LIP DETAILED 2017 REPORT

and plan for 2018

LABORATÓRIO DE INSTRUMENTAÇÃO
E FÍSICA EXPERIMENTAL DE PARTÍCULAS
partículas e tecnologia

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Foreword

Mário Pimenta
President

Over the past two years, LIP has been very successful in maintaining its activities of research, innovation and outreach at the highest standards. At the same time, LIP gained a new associate and underwent an important renewal of its internal procedures, which were clarified and optimized. The Faculty of Science of the University of Lisbon has formally become an associate of LIP, finally formalizing a close collaboration of many years. New by-laws were approved by LIP's associates. Internal regulations were defined and approved by secret ballot amongst LIP members. New regulations of LIP's Scientific Council were established and approved by its members. In this new framework the Board of Directors is elected by LIP's associates after consulting the LIP members. The Scientific Council has a new, better-defined and more effective structure, and new responsibilities. It is chaired by a President, assisted by two Vice-Presidents, and there is a Coordination Committee composed both by elected and appointed members, representing all LIP's lines of research.

The scientific activity is now organized in research areas, lines and groups. The scientific infrastructures were consolidated, and the first competence centres were created – aiming to be light and flexible transversal structures joining all LIP members sharing common technical expertise and tools. The Phenomenology activities will be, from now on, developed in the frame of a single group, and the groups working in low energy reactions with hadrons and ions now have closer ties. LIP's communication, education and outreach activities were organized in the new Education, Communication and Outreach Office (LIP-ECO). Advanced training activities are now coordinated and boosted by an Advanced Training Office.

LIP's premises were substantially improved. In Lisbon, new premises were contracted with the University of Lisbon, doubling the previous total area and allowing, for the first time, appropriated conditions for research and teaching laboratories. In Coimbra, the University doubled the working area of LIP's Mechanical Workshop and Detectors Laboratory. In Braga the University doubled the area given to LIP. Finally, at IST in Lisbon, LIP was assigned a small room, located at the entrance of the Physics Department, to be used as a "Control Room" for Auger and CMS remote operations and, at the same time, as a good environment to introduce students to experimental particle and astroparticle physics.

Scientific employment was, and still is, a major worry: too many LIP researchers have short-term contracts. In 2017, and already in 2018, some clear but still insufficient progress was achieved: calls for 6-year contracts were opened for the research positions that have been filled for more than three years through postdoc grants, and FCT is launching new calls for researcher positions at the scientific institutions. However, neither universities nor FCT have yet established a clear medium-term plan, which would be capable of providing a reasonable number of university positions to the best present and future researchers. Without this crucial step there will be, in our opinion, no balanced development and the system will continue to be dominated by perverse short-term cycles.

The collaboration protocol between Portugal and CERN for the next 10 years was renewed in December 2017. This protocol, first established in 1986 when Portugal joined CERN, has been and continues to be essential for the development of high-energy physics in Portugal. In the same occasion, Portugal declared its commitment to support the high-luminosity LHC upgrade program. LIP's responsibility is, as in the past, to fully exploit all the scientific, technological, educational, and advanced training opportunities that the collaboration with CERN provides, involving as much as possible of the Portuguese scientific, academic and industrial communities.

The Portuguese government has recently announced its decision to establish a Portuguese Space Agency and a National Hadron Therapy Centre for cancer treatment. These two new entities should support strong R&D activities, aiming to make Portugal a relevant international player in these challenging scientific and technological domains. LIP's collaboration with ESA has been actively pursued for many years. The challenge is now not only to maintain our successful participation in short-term contracts but also to participate in long-term missions. In medical physics, there is already a long tradition at LIP, focusing on medical imaging, radiotherapy instrumentation, and dosimetry. These activities, which were often sub-funded in the past, will have now the conditions for an ambitious development, in close collaboration with our strategic partners, namely the ICNAS and CTN research institutes. On the other hand, our activities in the study of the effects of radon, which have been pursued in partnership with the University of Beira Interior in Covilhã, may profit from the implementation by the Portuguese authorities of specific European public health regulations for the control of radon levels in the environment.

Computing is a fundamental area in LIP, both fullfilling the always growing needs of the other scientific groups, and developing novel technologies and methods. LIP is part of several international projects on distributed computing technologies, including Grid, Cloud, high throughput and high performance computing, and its participation has been always

very well acknowledged. In 2017 several projects have been successfully completed, and new ones have started. The INCD (Infraestrutura Nacional de Computação Distribuída) joining FCCN, LNEC and LIP, is now a well consolidated reality.

Detector research and development is part of LIP's DNA. LIP is a world reference in RPCs and has a solid expertise in noble gas/liquid detectors, as well as in optical fibres. However, to focus our activities in specific lines of research, where critical mass in human and financial resources can be achieved, has not been an easy task, and remains a priority.

The particle and astroparticle physics programme ahead of us is ambitious and challenging. We will be involved, in the next five years, in the LHC high luminosity upgrade and in fixed target experiments; in high energy cosmic and gamma rays experiments; in the search for neutrinoless double beta decay and in long baseline neutrino experiments; and in direct and indirect searches for dark matter. At the same time our commitments with the outside world (universities, research units, companies, schools, society in general) have to be strongly pursued and increased. New ideas and approaches are already in our mind and have to be tested in pilot projects. A global evaluation of the Portuguese scientific units is under way. It is a highly demanding process where we have to review our past activities and to present our plans for the next five years, including a rigid framework of questionnaires and a short visit of the evaluation committee to the laboratory. With the engagement of all of us, we are confident on a positive outcome, which will help us to build a better and even more ambitious LIP.

Before concluding, we celebrate the awarding of the Medal of Scientific Merit by the Minister of Science to two of our founder, Armando Policarpo and Gaspar Barreira, for their outstanding contribution to science in Portugal. A final word to remember Peter Sonderegger, passed away last July, a very good friend who played a fundamental role in the birth and consolidation of LIP.

// RESEARCH Areas an

Development of new instruments and methods

- Detectors for particle and nuclear physics
- Health and biomedical applications
- Space applications

Experimental particle and astroparticle physics

- LHC experiments and phenomenology
- Structure of matter
- Cosmic rays
- Dark matter and neutrinos

Computing

d Lines

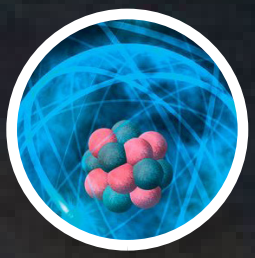
LHC experiments and phenomenology

- ATLAS
- CMS
- Phenomenology

Cosmic rays

- AMS
- Auger
- LATTES

// Experimental particle a



Structure of matter

- PARTONS AND QCD
- LERHI
  - HADES
  - NUC-RIA

Dark matter and neutrinos

- LUX/LZ
- SNO+
- NEXT

and astroparticle physics

LHC Experiments and phenomenology

COLLABORATION IN THE ATLAS EXPERIMENT AT CERN

ATLAS

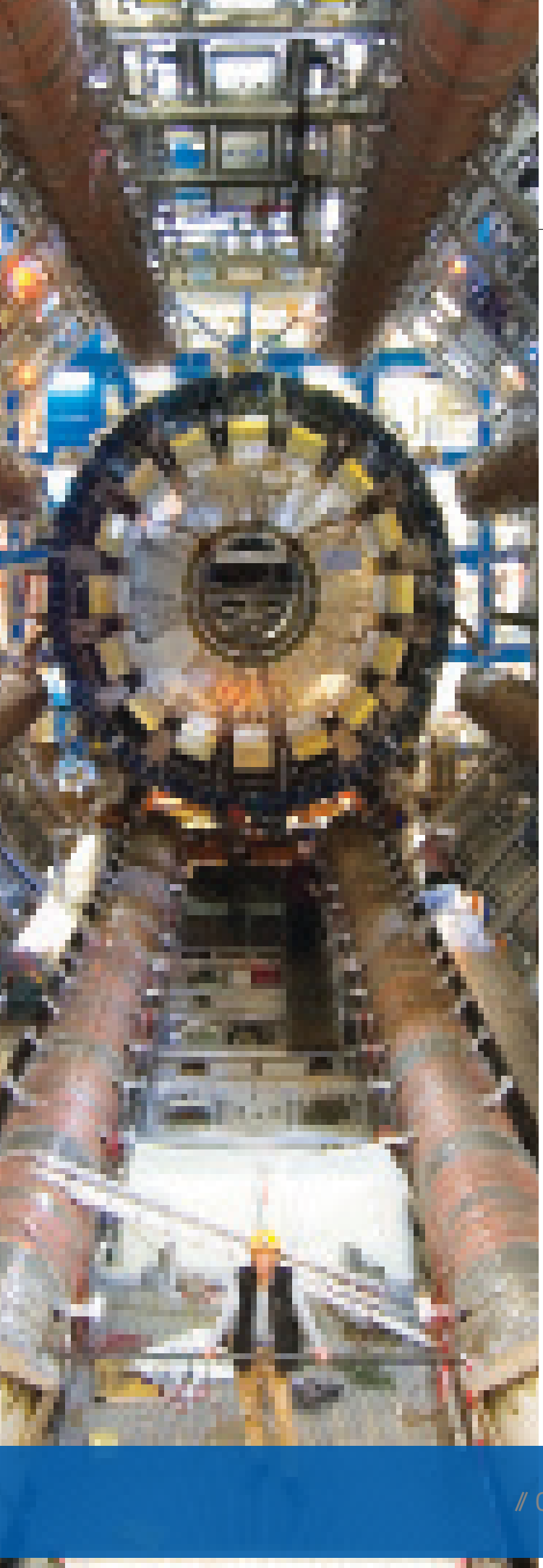
Overview

The LIP Portuguese group was a founding member of the ATLAS Collaboration and has made important contributions to the detector and Trigger/DAQ design, construction and commissioning. The most important of these were in the TileCal hadronic calorimeter, the forward detectors and the jet trigger software. Since the beginning of LHC operations we have contributed to detector operation, performance studies, and to physics analysis. We contributed to the Higgs boson discovery and are now measuring its properties. We are a reference in top quark physics studies and have exploited this expertise to lead several searches for new physics. We have made important contributions to the ATLAS heavy ion physics programme with the study of jets as probes of the quark-gluon plasma (QGP). In addition, we are contributing to the detector upgrade with responsibilities in the TileCal and trigger systems. Our members have occupied a number of coordination positions in the collaboration in most activities where the group is involved, from detector maintenance and operations to physics analysis and collaboration committees.

Last year the LHC was in production mode, running steadily and delivering a total integrated luminosity of 50 fb^{-1}, surpassing all expectations. The efforts of the collaboration went into ensuring a stable detector operation and data taking, resulting in around 94% efficiency for good quality data. In parallel, the detector upgrade developments continued in full swing with the preparation of the Technical Design Reports for the Phase II Upgrade and the continuation of the Phase I projects.

Summary of performance indicators

Articles in international journals:	7 With direct contribution from team 81 With indirect contribution
Internal notes:	12 Collaboration notes
International conferences:	4 Oral presentations 6 Posters 6 Proceedings
International meetings:	4 Oral presentations
National conferences:	6 Oral presentations
Collaboration meetings:	157 Oral presentations
Seminars:	9 Seminars 21 Outreach seminars
Completed theses:	3 PhD and 4 Master
Proposals:	2



Team

Principal Investigator Patricia Conde (85)

Researchers
Agostinho Gomes (85), Albano Alves (10), Amélia Maio (30), António Onofre (15), António Pina (30), Bruno Galhardo (100), Filipe Veloso (75), Gianpaolo Benincasa (15), Helena Santos (85), Helmut Wolters (75), José Maneira (20), José Rufino (17), João Gentil (70), Juan P. Araque (48), Liliana Apolinário (15), Marcin Stolarski (10), Miguel Fiolhais (30), Nuno Castro (70), Ricardo Gonçalo (62), Rui Faísca Pereira (100)

Technicians
Filipe Martins (100), José Manuel da Silva (10), Luís Gurriana (75), Luís Seabra (100)

PhD students
Ademar Delgado (25), Ana Peixoto (85), André Pereira (50), Duarte Azevedo (50), Emanuel Gouveia (100), Maria Ramos (10)(*), Mário Sargedas Sousa (92), Rute Pedro (100), Susana Santos (75), Tiago Vale (85)

Master students
Aidan Kelly (50), Ana Carvalho (33), André Reigoto (75), António Costa (33), Christopher Pease (30), David Fernandes (33), José Luís Silva (50), João Almendra Sabino (50), Lia Moreira (22), Ricardo Barrué (50), Rui Martins (75)

Undergraduate students
Ana Patrícia Afonso, Bruno Rodrigues, Maura Teixeira, Pedro Lagarelhos

External/Additional scientific collaborators
André Wemans, Artur Amorim de Sousa, Guiomar Evans, José Soares Augusto, Manuel Maneira, Pedro Martins Ferreira, Rui Santos, Susana Sério

Total FTE
24.8

(*) starting in 2018

// GROUPS: ATLAS / CMS / Phenomenology

Lines of work and team organization

The LIP Portuguese team is structured in subgroups lead by senior physicists (in brackets below), following the organization structure of the ATLAS activities:

Physics Analysis

- Higgs physics (P. Conde, R. Gonçalo). Our goal is to study the couplings of the Higgs boson to quarks, which are accessible at the LHC (top and bottom Yukawa couplings), including spin and CP properties in the coupling vertices. We are searching for the Higgs decaying to b-quark pairs in associated production with a W or Z boson, or in association with top quark pairs.

- Top Quark physics (A. Onofre, F. Veloso). We are currently focused on the search for Flavour Changing Neutral Currents (FCNC) in top quark decays and the study of the Vts vertex through the measurement of the top decays to Ws.

- Searches for exotic particles and interactions (N. Castro). We are searching for vector-like quarks, predicted by some of the extensions of the SM as a way to regulate the Higgs mass. We also lead the search for tZ production via FCNC and the search for dark matter production in association with top quarks.

- Heavy ion physics (H. Santos). Our long term goal is to understand the mechanism of the jet energy loss in the QGP using jets as probes. For the Run 2 we are concentrated on the study of heavy flavour jet production.

M&O and performance of the ATLAS detector and trigger system

- TileCal (A. Gomes). We are leading the development, maintenance and continuous upgrade of the DCS system, contributing to the calibration and to ageing studies of the scintillators and WLS fibres.

- Jet Trigger (R. Gonçalo). We have long expertise in jet reconstruction, hadronic calibration and real time algorithms. We are currently improving the jet trigger algorithms to reduce the huge rate of triggers in the TileCal cap/crack regions.

- Forward Detectors (A. Maio, P. Conde). We are responsible for the maintenance and continuous upgrade of the ALFA DCS system. In addition, we are contributing to the AFP with responsibilities in the DCS (vacuum and movement controls) and the implementation of the high-level trigger software.

- Grid and Distributed Computing (H. Wolters). We contribute to the development and support of global ATLAS Distributed Computing operations, such as monitoring software and shift organization.

Detector Upgrades

- TileCal Upgrade (A.Gomes, A. Maio). We are responsible for replacing gap fibres with more radiation-hard ones (Phase I) and for the production of the new TileCal high-voltage distribution system for Phase II, in collaboration with Portuguese industry. In addition, we are conducting radiation hardness tests of scintillators for the gap/crack regions.

- Jets high level trigger system (P. Conde). We are developing parallell trigger algorithms using Graphical Processing Units (GPUs) as accelerators and were responsible for the calorimeter module of the ATLAS GPU trigger prototype.

The portuguese team is represented as follows in ATLAS collaboration bodies:

- ATLAS National Physicist Board (P. Conde)
- ATLAS Collaboration Board (P. Conde)
- TileCal Institutes Board (A. Maio, A. Gomes)
- Trigger/DAQ Institutes Board (P. Conde)
- Forward Detectors Board (A. Maio, P. Conde)
- TileCal Phase II Upgrade Steering Committee (A. Gomes)

Stated objectives for past year

Physics studies

Higgs physics:

- Study angular variables to separate different spin and CP components in the WH (with H->bb) channel, both in the HWW and Hbb vertex.

- Contribute to the 13 TeV ATLAS searches for the SM Higgs decays to bb in the associated production channel with a W or a Z boson and in associated production with a top-quark pairs.

Top quark properties:

- Continue the t→qZ FCNC analysis
- Study of the Vts vertex with the 13 TeV dataset.

Exotic searches:

- Finish the analysis of the search for vector-like quarks in the Zt/b+X channel using the 2015+2016 dataset, extending it to additional signatures such as trilepton and dilepton plus large radius jets.
- Contribute to the combination of all the ATLAS analyses sensitive to the pair production of vector-like quarks.

Heavy Ions physics:

- Focus on the study of heavy flavour jet production.
- Develop b-tagging techniques for Heavy Ion collisions.

Sources of Funding

Code	Amount	Dates	Description
IF/00955/2013/CP1172/CT0004	50.000 €	2013-12-01 / 2018-11-30	FCT Exploratory research project (PI: P. Conde)
IF/00050/2013/CP1172/CT0002	50.000 €	2014-01-01 / 2018-12-31	FCT Exploratory research project - new physics(PI: N. Castro)
IF/01586/2014/CP1248/CT0003	42.000 €	2015-01-01 / 2019-12-31	FCT Exploratory research project - heavy ions (PI: H.Santos)
CERN/FIS-NUC/0005/2015	400.000 €	2015-03-01 / 2017-02-28	FCT - CERN related projects - Participation in ATLAS
CERN/FIS-PAR/0008/2017	340.000 €	2017-07-01 / 2019-06-30	FCT - CERN related projects - Participation in ATLAS

Detector maintenance, operation and upgrade

Forward Detectors:

- ALFA DCS: lab system development, maintenance of the production system and preparation for the end of the year migration.
- AFP DCS: integration and commissioning of the second detector arm for the cooling, movement and vacuum systems.
- AFP trigger:

  - Design, implementation and validation of the first trigger chains to select di-jet events in central exclusive production.

  - Measurement of the AFP L1 trigger efficiency in 2016 and 2017.

TileCal:

- With respect to the LOMAC lab, the removal and reinstallation of the lab in the new LIP premises was expected in the second half of 2017.
- Continue the linearity and stability monitoring studies of the TileCal's PMTs using the Laser II system.
- DCS: keep the same level of involvement in the operation and maintenance of the DCS and calorimeter, to consolidate the testbeam system and to prepare the system migration in early 2018.

TileCal upgrade:

- Produce and test the first prototype of the HV distribution board (HVRemote board), its control system, and a crate.
- Re-design and production of a new board (prototype 2) in case of problems in the first one.
- Finish the scintillator-WLS fibres couplings tests.
- Irradiation and tests of scintillators and fibres at CTN (Lisbon).

Jet trigger:

- Investigate ways to correct the large rates of jets in the gap/ crack TileCal regions.
- Finish the performance studies of the cluster splitter and the full GPU demonstrator prototype.

Our group is also responsible for the jet data quality monitoring during the Heavy Ion data acquisition and is committed with studies on jet quality, jet constituents and validation of underlying event subtraction.

Outreach and advanced training

We planned to contribute to the organization and support of several activities including Masterclasses, seminars and hands on tutorials. We also wanted to contribute to the organization of the LIP Summer Student Internship Program.

Achievements and responsibilities during the past year

Physics

Higgs:

- Contributed to the first evidence, published by the ATLAS collaboration, of:

  - Higgs decaying to b-quark pairs, with responsibility on the global fits in the di-lepton channel.

  - ttH associated production (with H→bb), mainly with a data-driven study to determine the Z+jets background to the di-lepton channel.

- Started developing analysis techniques, at generator level, to measure anomalous CP components in the HWW and Hbb vertices.

Top quark properties:

- Finished the search for top quark decays (t→qZ) via FCNC in top pair production at 13 TeV with 2015 and 2016 data sets. The publication is being finalized.

- The search for tZ production via FCNC using the 2015+2016 data set is close to unblinding, with the paper preparation ongoing.

- Preliminary results of the study of the Vts vertex through the measurement of the top decays to Ws were presented in collaboration meetings.

- Leading role in the effective field theory interpretation of the ATLAS top quark analysis, with a team member (N. Castro) appointed as contact person.

Exotics searches:

- Two analysis using the 2015+2016 data set are finished and papers are close to completion, under internal review:

  - Search for vector-like quarks in the Zt/b+X channel.

  - Search for the production of top quarks accompanied by missing transverse energy.

- Contribution to the first efforts of combination of the ATLAS searches for vector-like quarks.

- Contribution, with the monotop channel, to the global combination of the ATLAS searches for dark matter.

Heavy Ions:

- Developed b-tagging techniques for Heavy Ion collisions.

- Prepared the b-jets trigger menu for the p+p @ 5 TeV reference run.

- Monitoring control and performance studies on the p+p @ 5 TeV reference run.

Detector-related activities:

We contributed to detector operation and data quality control with on-call and data quality shifts in all detector areas where we participate.

TileCal detector maintenance, operation and upgrade

DCS:

- Maintained the DCS software and hardware for the TileCal and the demonstrator test beam.

- Assistance for detector maintenance teams during shutdowns.

- Consolidation of the DCS components for the upgrade of TileCal electronics.

- Preparation/validation of the migration of the DCS software to the new operating system and WinCC version.

TileCal calibration:

- Continued the linearity and stability monitoring studies of the TileCal's PMTs using the Laser II system.

- Studied the light loss of TileCal scintillators using pp collisions data. Our first results and further discussions with the LHCC lead to the creation of a task force to carefully evaluate the ageing of scintillators and fibres for Phase II.

With respect to our Upgrade activities:

- Optimized the LOMAC infrastructures for fibres aluminization and quality control, reaching a reflectivity of 80% on average. A set of 6000 fibres for the WA104/ICARUS muon tagger were aluminized in collaboration with SNO+.

- Production of the first prototype of HVRemote. The design of a second prototype with double number of channels per board is ongoing.

- Production of a board to test communications and the control system for the HVRemote board.

- Preparation and edition of the TileCal Phase II Upgrade TDR, in what corresponds to the HV and DCS systems.

Forward Detectors:

- Development, integration and commissioning of the DCS system of the second AFP arm, with focus on the cooling, movement and vacuum systems.
- Maintenance and development of the ALFA DCS.
- Designed specific triggers to select di-jet events in central exclusive production. The implementation and validation of these chains is still ongoing.
- First efficiency studies of the 2016 L1 AFP triggers. Alignment and more studies of the L1 AFP trigger efficiencies are still ongoing.

Jet trigger maintenance, operation and upgrade:

- Definition of new methods to improve the jets energy measurement in the region of the TileCal gap/crack.
- Performance studies of the GPU calorimeter cluster growing and splitting algorithms. A maximum of a factor of five time reduction was obtained when running together both algorithms.

Distributed Computing

- Excellent operation of the Iberian region and Portuguese Tier2.
- Improvement of the distributed computing monitoring infrastructure.

Education and outreach

The group participated in several outreach activities including the International Masterclasses in Particle Physics in many different locations in Portugal, presentations and seminars for general public and high school students/teachers. In addition, we contributed to the following activities for university students:

- The hands-on workshops organized by LIP in Sesimbra (February) and in FCUL/IST in July.
- Organization, lectures and hosting of six students in the LIP summer students programme. The programme was organized following the successful scheme of our 2016 ATLAS summer internship.
- Summer University of University of Coimbra, where high school students searched for Higgs boson production at the LHC during a one-week programme.
- Commemoration of the 25th anniversary of the ATLAS Collaboration in outreach events organized in Lisbon, Braga and Coimbra.

Coordination positions within the ATLAS Collaboration (in 2017):

- H. Wolters, coordinator of the Iberian Cloud.
- H. Wolters, responsible for the Portuguese Federated Tier2 in the Iberian Cloud Squad.
- N. Castro, theory hot-spot contact for the vector-like quark searches within the Exotics Working Group (since October 2014).
- N. Castro, contact person for the effective field theory interpretations of the Top Quark Working Group (since September 2017).
- J. P. Araque, contact editor for the search for vector-like quarks in the Zt/b+X channel.
- N. Castro, contact editor for the search for monotop events plus missing energy.
- N. Castro, analysis contact for the search for tZ production via FCNC.
- J. P. Araque, Monte Carlo manager for the Exotics Working Group.
- N. Castro, J.P. Araque, members of the ATLAS Physics Office.
- F. Martins, TileCal DCS coordinator.
- L. Seabra, AFD DCS co-convener.
- L. Seabra, Responsible for the ALFA DCS System.
- P. Conde, member of the Panel for Operation Task Sharing.
- F. Veloso, contact editor for the search for the t to qZ decay.

Editorial Boards

Members of our group participated in 12 ATLAS Editorial Boards: H. Santos (4), N. Castro (2, one as chair) F. Veloso (2), A. Onofre (1), P. Conde (2), J. P. Araque (1, as chair).

Lines of work and objectives for next year

Physics studies

Higgs physics:

- Finish the study of the ATLAS sensitivity to anomalous CP components in the H→bbγ vertex.
- Contribute to the updated searches for the SM H → bb in the associated production channel with a W or a Z boson, or with top-quark pairs.
- Study the feasibility of a bump-hunting type search for ttH(bb) at the HL-LHC.

Top quark properties:

- Continue the t→qZ FCNC analysis with the full 13 TeV data set, also taking into accound the contribution of the tZ production channel.
- Continue the study of the Vts vertex with the full 13 TeV data set.
- Lead and actively contribute to the effective field theory interpretation of different precision measurements in the top quark sector.

Exotics searches:

- Publish the two following searches using the 2015+2016 data sets and prepare the upgrade of the analysis of the full run-2 dataset on those channels:

  - Search for vector-like quarks in the Zt/b+X channel.

  - Search for events with a top quark and missing energy.

- Continue the contribution to the combination of all the ATLAS analyses sensitive to the pair production of vector-like quarks.
- Contribute to the general strategy of the Exotics Group in terms of searches for alternative production and decay mechanisms of vector-like quarks and the search for dark matter in the top quark sector using the full run-2 data set and beyond.

Heavy Ions physics:

- Focus on the study of heavy flavour jet production, benefiting from the b-tagging techniques developed in our group.
- Contribute to the preparation of the b-jet trigger menu in Pb+Pb data acquisition in the Fall 2018.

Detector maintenance, operation and upgrade

Forward Detectors:

- ALFA DCS: lab system development, maintenance of the production system and software migration.
- AFP DCS: maintenance of the production system for the cooling, movement and vacuum systems and software migration.
- AFP trigger:

  - Finish and validate the first trigger chains to select di-jet events in central exclusive production.

  - Measure the AFP trigger efficiency with 2017/18 data.

TileCal:

- Study the ageing of the TileCal scintillators using the calibration systems and pp collisions data, to determine the expected light loss at the end of the High-Lumi LHC phase.

With respect to the TileCal DCS, the objectives for 2018 are:

- Maintain the same reliability level in the operation of the TileCal DCS.
- Finish the migration of the DCS software to the new operating system and new WinCC version.
- Improve the functionality of the DCS with new procedures/ interfaces for the users.
- Develop, test and implement a DCS component for the Cesium Calibration System.
- Improve the DCS system for the Upgrade HVRemote boards and the monitoring of temperatures and voltages of the upgrade electronics.

In what corresponds to the TileCal upgrade:

- Develop a test bench for the quality control of the high voltage regulation systems of the upgrade of the TileCal.
- Test the first HVRemote board in Lisbon and in test beams at CERN.
- Design a crate to house the HVRemote boards and the primary HV boards.
- Finish the re-design and production the second prototype of HVRemote, with 48 channels per board.
- Test the new cable prototypes and connectors to ensure qualification of the cabling system.
- Aluminization of WLS fibres for the scintillators replacement and addition of E4' new scintillators.

- Irradiation and tests of scintillators and fibres at CTN (Lisbon).

Jet trigger:

- Write an internal ATLAS note documenting our proposed method to correct the jet rate increase due to ageing of the crack scintillators.

- With respect to the upgrade, study new possibilities to further improve the performance of the GPU calorimeter trigger prototype and reduce the data transfer overheads.

Our group is also responsible for the jet data quality monitoring during the Heavy Ion data acquisition and is committed with studies on jet quality, jet constituents and validation of underlying event subtraction.

Outreach and advanced training

We will maintain the same level of involvement in the organization and support of outreach and education activities such as the Masterclasses, seminars and internship programmes.

SWOT Analysis

Strengths

The LIP group is a well-established member of the ATLAS Collaboration, with many years' worth of important contributions to the experiment and with collective know-how in several important areas. Our main strengths are in the domains of calorimetry, DCS, software triggers and physics analysis. The group has experimental labs in Lisbon (LOMAC), dedicated to calorimetry and instrumentation for processing and characterization of optical wavelength shifting and scintillating fibres, plastic scintillators and photomultipliers. There is also expertise on electronics and advanced computing.

In the area of physics analysis we have made important contributions to the Higgs discovery and physics studies, to jet suppression in heavy ion collisions and our long expertise in top quark physics has put us in a leading role in many measurements of the top quark properties and searches for new physics. Our accumulated experience in both Higgs and top quark sectors is being exploited in the search for ttH associated Higgs production.

Weaknesses

Currently the group has very few PhD students in Lisbon or Coimbra. Our efforts in outreach in the universities and the summer internship attracted new master students but we need to ensure their continuation for PhD and maintain the rate of new master students.

Opportunities

We are a national team with connections to many of the universities in the country. This places us in an optimal situation to strengthen our outreach activities and attract new students. The new challenges of the LHC upgrade are an opportunity for a sustainable growth of the group.

Threats

The funding structure in Portugal continues to be unstable and poorly adjusted to large continuing projects. The reduction of funding in the last call and the lack of other sources of funding threaten the continuation of the group's activities with the same level of quality as before.

The unstable contractual situation of many key members of the group (senior physicists, post-docs, engineers) is becoming critical. The reduced budget is not sufficient to ensure direct hiring of post-docs or even grants for all the students.

Publications

7 Articles in international journals
(with direct contribution from team)

ATLAS Collaboration (2852 authors): "A measurement of the calorimeter response to single hadrons and determination of the jet energy scale uncertainty using LHC Run-1 pp-collision data with the ATLAS detector", Eur. Phys. J. C 77 (2017) 26

ATLAS Collaboration (2873 authors): "Measurements of top quark spin observables in tt events using dilepton final states in sqrt(s) = 8 TeV pp collisions with the ATLAS detector", JHEP 03 (2017) 113

ATLAS Collaboration: "Measurement of the W polarization in tt events from pp collisions at sqrt(s)=8 TeV in the lepton+jets channel with ATLAS", Eur. Phys. J. C 77 (2017) 4 264.

ATLAS Collaboration (2856 authors): "Performance of the ATLAS Trigger System in 2015", Eur. Phys. J. C 77 (2017) 317.

S. Amor dos Santos et al. (12 authors): "Probing the CP nature of the Higgs coupling in tth events at the LHC", Phys. Rev. D 96 (2017) 013004

ATLAS Collaboration (2835 authors): "Measurement of jet p(T) correlations in Pb+Pb and pp collisions at root s(NN)=2.76 TeV with the ATLAS detector", Phys. Lett. B 774 (2017) 379-402

ATLAS Collaboration (2856 authors): "Evidence for the H to bb decay with the ATLAS detector", JHEP 12 (2017) 024

81 Articles in international journals
(with indirect contribution from team)

ATLAS Collaboration (2863 authors): "Search for heavy resonances decaying to a Z boson and a photon in pp collisions at root s=13 TeV with the ATLAS detector", Phys. Lett. B 764 (2017) 11-30

ATLAS Collaboration (2861 authors): "Measurement of the t(t)over-barZ and t(t)over-barW production cross sections in multilepton final states using 3.2 fb(-1) of pp collisions at root s=13 TeV with the ATLAS detector", Eur. Phys. J. C 77 (2017) 40

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ATLAS collaboration (2860 authors): "Measurements of psi(2S) and X(3872) -> J/psi pi (+) pi (-) production in pp collisions at root s=8 Tev with the ATLAS detector", J. High Energy Phys. 1 (2017) 117

ATLAS Collaboration (2846 authors): "Search for lepton-flavour-violating decays of the Higgs and Z bosons with the ATLAS detector", Eur. Phys. J. C 77 (2017) 70

ATLAS Collaboration (2843 authors): "Measurement of the prompt J/psi pair production cross-section in pp collisions at root s=8 TeV with the ATLAS detector", Eur. Phys. J. C 77 (2017) 76

ATLAS Collaboration (2849 authors): "Search for anomalous electroweak production of WW/WZ in association with a high-mass dijet system in pp collisions at root S=8 TeV with the ATLAS detector", Phys. Rev. D 95 (2017) 032001

ATLAS Collaboration (2855 authors): "Search for new resonances decaying to a W or Z boson and a Higgs boson in the l(+)l(-)b(b)over-bar, l nu b(b)over-bar, and nu(nu) over-barb(b)over-bar channels with pp collisions at root s=13 TeV with the ATLAS detector", Phys. Lett. B 765 (2017) 32-52

ATLAS Collaboration (2857 authors): "Measurement of W boson angular distributions in events with high transverse momentum jets at root s=8 TeV using the ATLAS detector", Phys. Lett. B 765 (2017) 132-153

ATLAS Collaboration (2856 authors): "Measurements of charge and CP asymmetries in b-hadron decays using top-quark events collected by the ATLAS detector in pp collisions at root s=8 TeV", J. High Energy Phys. 2 (2017) 071

ATLAS Collaboration (2862 authors): "Search for triboson (WWW -/+)-W-+/--W-+/- production in pp collisions at root s=8 TeV with the ATLAS detector", Eur. Phys. J. C 77 (2017) 141

ATLAS Collaboration (2842 authors): "Search for new phenomena in events containing a same-flavour opposite-sign dilepton pair, jets, and large missing transverse momentum in root s=13 TeV pp collisions with the ATLAS detector", Eur. Phys. J. C 77 (2017) 144

ATLAS Collaboration (2849 authors): "Electron efficiency measurements with the ATLAS detector using 2012 LHC proton-proton collision data", Eur. Phys. J. C 77 (2017) 195

Collaboration, A (2847 authors): "Measurement of jet activity produced in top-quark events with an electron, a muon and two b-tagged jets in the final state in pp collisions root s=13TeV with the ATLAS detector", Eur. Phys. J. C 77 (2017) 220

ATLAS Collaboration (2854 authors): "Measurement of the t(t)over-bar production cross section in the tau plus jets final state in pp collisions at root s=8 TeV using the ATLAS detector", Phys. Rev. D 95 (2017) 072003

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ATLAS Collaboration (2824 authors): "Performance of algorithms that reconstruct missing transverse momentum in root s=8 TeV proton-proton collisions in the ATLAS detector", Eur. Phys. J. C 77 (2017) 241

ATLAS collaboration (2851 authors): "Measurement of the inclusive cross-sections of single top-quark and top-antiquark t-channel production in pp collisions at root s=13 TeV with the ATLAS detector", J. High Energy Phys. 4 (2017) 086

ATLAS Collaboration (2852 authors): "Probing the W tb vertex structure in t-channel single-top-quark production and decay in pp collisions at root s=8 TeV with the ATLAS detector", J. High Energy Phys. 4 (2017) 124

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M. Aaboud et al. (2840 authors): "Performance of the ATLAS Transition Radiation Tracker in Run 1 of the LHC: tracker properties", J. Instrum. 12 (2017) P05002

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ATLAS Collaboration (2859 authors): "Measurement of jet fragmentation in Pb plus Pb and pp collisions at root s(NN)=2.76 TeV with the ATLAS detector at the LHC", Eur. Phys. J. C 77 (2017) 379

ATLAS Collaboration (2864 authors): "Search for dark matter at root s=13 TeV in final states containing an energetic photon and large missing transverse momentum with the ATLAS detector", Eur. Phys. J. C 77 (2017) 393

ATLAS Collaboration (2827 authors): "Measurement of multi-particle azimuthal correlations in pp, p plus Pb and low-multiplicity Pb plus Pb collisions with the ATLAS detector", Eur. Phys. J. C 77 (2017) 428

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M. Aaboud et al. (2858 authors): "Measurement of forward-backward multiplicity correlations in lead-lead, proton-lead, and proton-proton collisions with the ATLAS detector", Phys. Rev. C 95 (2017) 064914

ATLAS Collaboration (2837 authors): "Measurement of

the cross section for inclusive isolated-photon production in pp collisions at root s=13 TeV using the ATLAS detector", Phys. Lett. B 770 (2017) 473-493

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ATLAS Collaboration (2837 authors): "Measurements of electroweak W j j production and constraints on anomalous gauge couplings with the ATLAS detector", Eur. Phys. J. C 77 (2017) 474

S. Amor dos Santos et al. (12 authors): "Probing the CP nature of the Higgs coupling in tth events at the LHC", Phys. Rev. D 96 (2017) 013004

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Atlas Collaboration (2873 authors): "Topological cell clustering in the ATLAS calorimeters and its performance in LHC Run 1", Eur. Phys. J. C 77 (2017) 490

ATLAS Collaboration (2855 authors): "Measurement of (WW +/-)-W-+/- vector-boson scattering and limits on anomalous quartic gauge couplings with the ATLAS detector", Phys. Rev. D 96 (2017) 012007

M. Aaboud et al. (2876 authors): "Search for direct top squark pair production in events with a Higgs or Z boson, and missing transverse momentum in root s=13 TeV pp collisions with the ATLAS detector", J. High Energy Phys. 8 (2017) 006

ATLAS Collaboration (2872 authors): "Search for the Dimuon Decay of the Higgs Boson in pp Collisions at root s=13 TeV with the ATLAS Detector", Phys. Rev. Lett. 119 (2017) 051802

ATLAS Collaboration (2843 authors): "Fiducial, total and differential cross-section measurements of t-channel single top-quark production in pp collisions at 8TeV using data collected by the ATLAS detector", Eur. Phys. J. C 77 (2017) 531

ATLAS Collaboration (2858 authors): "Search for pair production of vector-like top quarks in events with one lepton, jets, and missing transverse momentum in root S=13 TeV pp collisions with the ATLAS detector", J. High Energy Phys. 8 (2017) 1-40

ATLAS Collaboration (2877 authors): "Measurement of WW/WZ -> lvqq ' production with the hadronically decaying boson reconstructed as one or two jets in pp collisions at root s=8 TeV with ATLAS, and constraints on anomalous gauge couplings", Eur. Phys. J. C 77 (2017) 563

Atlas Collaboration (2849 authors): "Measurement of the charge asymmetry in top-quark pair production in the lepton-plus-jets final state in pp collision data at root s = 8 TeV with the ATLAS detector", Eur. Phys. J. C 77 (2017)

ATLAS Collaboration (2826 authors): "Measurements of long-range azimuthal anisotropies and associated Fourier coefficients for pp collisions at root s=5.02 and 13 TeV and p plus Pb collisions at root(NN)-N-s=5.02 TeV with the ATLAS detector", Phys. Rev. C 96 (2017) 024908

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ATLAS Collaboration (2852 authors): "Measurement of the inclusive jet cross-sections in proton-proton collisions at root s=8 TeV with the ATLAS detector", J. High Energy Phys. 9 (2017) 020

ATLAS collaboration (2877 authors): "Search for supersymmetry in final states with two same-sign or three leptons and jets using 36 fb(-1) of root&ITs&IT = 13 TeV &ITpp&IT collision data with the ATLAS detector", J. High Energy Phys. 9 (2017) 084

M. Aaboud et al. (2861 authors): "Search for new phenomena in a lepton plus high jet multiplicity final state the ATLAS experiment using root S=13 TeV proton-proton collision data", J. High Energy Phys. 9 (2017) 088

ATLAS Collaboration (2873 authors): "Study of WW gamma and WZ gamma production in pp collisions at root s=8 TeV and search for anomalous quartic gauge couplings with the ATLAS experiment", Eur. Phys. J. C 77 (2017) 646

M. Aaboud et al. (2863 authors): "Search for new phenomena in dijet events using 37 fb(-1) of pp collision data collected at root s=13 TeV with the ATLAS detector", Phys. Rev. D 96 (2017) 052004

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ATLAS Collaboration (2838 authors): "Jet energy scale measurements and their systematic uncertainties in proton-proton collisions at root s=13 TeV with the ATLAS detector", Phys. Rev. D 96 (2017) 072002

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ATLAS Collaboration (2862 authors): "Search for top quark decays t -> qH,with H -> gamma gamma, in root s=13 TeV pp collisions using the ATLAS detector", J. High Energy Phys. 10 (2017) 129

ATLAS Collaboration (2876 authors): "Measurement of inclusive and differential cross sections in the H -> ZZ* -> 4l decay channel in pp collisions at root s=13 TeV with the ATLAS detector", J. High Energy Phys. 10 (2017) 132

ATLAS Collaboration (2856 authors): "Search for pair production of heavy vector-like quarks decaying to high-p(T) W bosons and b quarks in the lepton-plus-jets final state in pp collisions at root s=13 TeV with the ATLAS detector", J. High Energy Phys. 10 (2017) 141

ATLAS Collaboration (2868 authors): "Search for new high-mass phenomena in the dilepton final state using 36 fb(-1) of proton-proton collision data at root s=13 TeV with the ATLAS detector", J. High Energy Phys. 10 (2017) 182

ATLAS Collaboration (2863 authors): "Identification and rejection of pile-up jets at high pseudorapidity with the ATLAS detector (vol 77, 580, 2017)", Eur. Phys. J. C 77 (2017) 712

ATLAS Collaboration (2853 authors): "Heavy Ion Results from ATLAS", Nucl. Phys. A 967 (2017) 51-58

ATLAS Collaboration (2849 authors): "Measurements of photo-nuclear jet production in Pb plus Pb collisions with ATLAS", Nucl. Phys. A 967 (2017) 277-280

ATLAS Collaboration (2879 authors): "Search for Dark Matter Produced in Association with a Higgs Boson Decaying to b(b)over-bar Using 36 fb(-1) of pp Collisions at root s=13 TeV with the ATLAS Detector", Phys. Rev. Lett. 119 (2017) 181804

ATLAS Collaboration (2863 authors): "Search for Heavy Higgs Bosons A/H Decaying to a Top Quark Pair in pp Collisions at root s=8 TeV with the ATLAS Detector", Phys. Rev. Lett. 119 (2017) 191803

Atlas Collaboration (2873 authors): "Search for heavy resonances decaying to a W or Z boson and a Higgs boson in the q(q)over-bar((')b(b)over-bar final state in pp collisions at root s =13 TeV with the ATLAS detector", Phys. Lett. B 774 (2017) 494-515

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ATLAS Collaboration (2873 authors): "Measurement of the t(t)over-bar gamma production cross section in proton-proton collisions at root s=8 TeV with the ATLAS detector", J. High Energy Phys. 11 (2017) 086

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ATLAS Collaboration (2840 authors): "Measurements of top-quark pair differential cross-sections in the lepton plus jets channel in pp collisions at root s=13 TeV using the ATLAS detector", J. High Energy Phys. 11 (2017) 191

ATLAS Collaboration (2882 authors): "Search for super symmetry inevents with b-tagged jets and missing transverse momentum in pp collisions at root s=13 TeV with the ATLAS detector", J. High Energy Phys. 11 (2017) 195

ATLAS Collaboration (2872 authors): "Study of ordered hadron chains with the ATLAS detector", Phys. Rev. D 96 (2017) 092008

ATLAS Collaboration (2868 authors): "Study of the material of the ATLAS inner detector for Run 2 of the LHC", J. Instrum. 12 (2017) P12009

ATLAS Collaboration (2870 authors): "Analysis of the Wtb vertex from the measurement of triple-differential angular decay rates of single top quarks produced in the t-channel at root s=8 TeV with the ATLAS detector", J. High Energy Phys. 12 (2017) 017

ATLAS Collaboration (2878 authors): "Search for new phenomena with large jet multiplicities and missing transverse momentum using large-radius jets and flavour-tagging at ATLAS in 13 TeV pp collisions", J. High Energy Phys. 12 (2017) 034

ATLAS Collaboration (2874 authors): "Search for dark matter in association with a Higgs boson decaying to two photons at root s=13 TeV with the ATLAS detector", Phys. Rev. D 96 (2017) 112004

ATLAS Collaboration (2894 authors): "Search for new phenomena in high-mass diphoton final states using 37 fb(-1) of proton-proton collisions collected at root s=13 TeV with the ATLAS detector", Phys. Lett. B 775 (2017) 105-125

ATLAS Collaboration (2874 authors): "Measurement of

the cross-section for electroweak production of dijets in association with a Z boson in pp collisions at root s=13 TeV with the ATLAS detector", Phys. Lett. B 775 (2017) 206-228

ATLAS Collaboration (2891 authors): "Measurement of the Drell-Yan triple-differential cross section in pp collisions at root s=8 TeV", J. High Energy Phys. 12 (2017) 059

ATLAS Collaboration (2874 authors): "Determination of the strong coupling constant alpha(s) from transverse energy-energy correlations in multijet events at root s=8 TeV using the ATLAS detector", Eur. Phys. J. C 77 (2017) 872

Atlas Collaboration (2864 authors): "Search for a scalar partner of the top quark in the jets plus missing transverse momentum final state at root s=13 TeV with the ATLAS detector", J. High Energy Phys. 12 (2017) 085

ATLAS Collaboration (2876 authors): "Search for direct top squark pair production in final states with two leptons in root s=13 TeV pp collisions with the ATLAS detector", Eur. Phys. J. C 77 (2017) 898

ATLAS Collaboration (2875 authors): "Search for squarks and gluinos in events with an isolated lepton, jets, and missing transverse momentum at root s=13 TeV with the ATLAS detector", Phys. Rev. D 96 (2017) 112010

ATLAS Collaboration (2847 authors): "Femtoscopy with identified charged pions in proton-lead collisions at root s(NN)=5.02 TeV with ATLAS", Phys. Rev. C 96 (2017) 064908

6 International Conference Proceedings

L. Seabra, E. Banaś, S. Czekierda, Z. Hajduk, J. Olszowska, B. Zabinski, D. Caforio, P. Sicho: "The AFP Detector Control System", accepted for publication in ATL-FWD-SLIDE-2017-934

Emanuel Gouveia et al.: "Probing the CP nature of the Higgs coupling in ttH events at the LHC", accepted for publication

F. Martins, L. Gurriana, L. Seabra, G. Evans, A. Gomes, A. Maio, C. Rato , J. Sabino, J. Soares Augusto: "Control System For ATLAS TileCal HVRemote Boards", accepted for publication in Journal of Physics: Conference Series, Volume 898, Track 1: Online Computing

E. Banaś, D. Caforio, S. Czekierda, Z. Hajduk, J. Olszowska, L. Seabra and P. Sícho: "Detector Control System for the AFP detector in ATLAS experiment at CERN", J.Phys.Conf. Ser. 898 (2017) no.3, 032022

C. Adam, D. Barberis, S. Crépé-Renaudin, K. De, F. Fassi, A. Stradling, M. Svatos, A. Vartapetian and H. Wolters: "Computing shifts to monitor ATLAS distributed computing infrastructure and operations", IOP Conf. Series: Journal of Physics: Conf. Series 1829384(526071879)092004

P. Conde Muíño, on behalf of the ATLAS Collaboration : "Multi-Threaded Algorithms for GPGPU in the ATLAS High Level Trigger", J.Phys.Conf.Ser. 898 (2017) no.3, 032003

7 Collaboration notes with internal referee

ATLAS Collaboration: "Trigger Menu in 2016", ATL-DAQ-PUB-2017-001

ATLAS Collaboration: "Z boson production in Pb+Pb collisions at √sNN=5.02 TeV with the ATLAS detector at the LHC ", ATLAS-CONF-2017-010

ATLAS Collaboration: "Measurement of the nuclear modification factor RAA in Pb+Pb collisions at √sNN=5.02TeV with the ATLAS detector at the LHC ", ATLAS-CONF-2017-012

ATLAS Collaboration: "Evidence for the H→bb decay with the ATLAS detector ", ATLAS-CONF-2017-041

ATLAS Collaboration: "Search for flavour-changing neutral current top quark decays t$\rightarrow$qZ in proton-proton collisions at $\sqrt{s}$=13 TeV with the ATLAS Detector", ATLAS-CONF-2017-070

ATLAS Collaboration: "Search for the Standard Model Higgs boson produced in association with top quarks and decaying into a $b\bar{b}$ pair in pp collisions at $\sqrt{s}$ = 13 TeV with the ATLAS detector", arXiv:1712.08895

ATLAS Collaboration: "Evidence for the associated production of the Higgs boson and a top quark pair with the ATLAS detector ", arXiv:1712.08891, ATLAS-HIGG-2017-02

5 Internal Notes

Araque Juan Pedro and Castro Nuno Filipe and Djobava Tamar and Durglishvili Archil and Galhardo Bruno and Hellman Sten and Molander Simon and Mosidze Maia and Veloso Filipe: "Search for flavour-changing neutral current top quark decays $t\to qZ$ in proton-proton collisions at $\sqrt{s}=13$ TeV with the ATLAS Detector", ATL-COM-PHYS-2017-1115

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Alhroob Muhammad et al.: "Top-quark physics with 100~fb^{-1}: Summary of the 2017 ATLAS top-quark workshop", ATL-COM-PHYS-2017-1055

Blanco Castro Alberto et al: "Performance of the upgraded Laser calibration system of the ATLAS Tile Calorimeter", ATL-COM-TILECAL-2017-061

D. Calvet, ..., L. Seabra, F. Martins: "The High Voltage distribution system of the ATLAS Tile Calorimeter and its performance during data taking", ATL-COM-TILECAL-2017-066

2 Proposals

A. Gomes, F. Martins et. al.: "Technical Design Report for the Phase-II Upgrade of the ATLAS Tile Calorimeter", accepted for publication in CERN-LHCC-2017-019; ATLAS-TDR-028

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Presentations

4 Oral presentations in international conferences

Helena Santos: "Jets and charged hadrons in heavy ion collisions with the ATLAS detector", 2017-05-12, Exited QCD 2017, Sintra, Portugal

Nuno Castro: "Searches for top-quark anomalous couplings", 2017-09-21, TOP2017: 10th International Workshop on Top Quark Physics, Braga, Portugal

Helena Santos: "Jets in heavy-ion collisions with the ATLAS detector", 2017-10-03, PANIC 2017, Beijing, China

Luís Seabra: "The AFP Detector Control System", 2017-10-12, ICALEPCS2017, Barcelona, Spain

6 Poster presentation in international conference

Ana Peixoto: "Search for tZ production via Flavour Changing Neutral Currents with the ATLAS Experiment at 13 TeV", 2017-09-10, ESHEP 2017, Évora, Portugal

Tiago Vale: "Search for heavy fermions with LHC data", 2017-09-10, ESHEP 2017, Évora, Portugal

Emanuel Gouveia: "Probing the CP nature of the Higgs coupling in ttH events at the LHC", 2017-09-10, 2017 European School of High-Energy Physics, Évora, Portugal

Emanuel Gouveia: "Probing the CP nature of the Higgs coupling in ttH events at the LHC", 2017-09-19, 10th International Workshop on Top Quark Physics, Braga, Portugal

Luís Seabra: "The AFP Detector Control System", 2017-10-12, ICALEPCS2017, Barcelona, Spain

Filipe Martins: "Control System For ATLAS TileCal HVRemote Boards", 2017-10-13, ICALEPCS 2017, Barcelona, Spain

6 Oral presentations in national conferences

Ana Peixoto: "Search for new interactions in the top quark sector at the Large Hadron Collider", 2017-03-24, LIP PhD Student Workshop, Coimbra (Portugal)

Tiago Vale: "Search for heavy fermions with LHC data", 2017-03-24, LIP PhD Student Workshop, Coimbra (Portugal)

Bruno Galhardo: "Search for FCNC top-quark decays to qZ", 2017-03-24, LIP PhD Students Workshop, Coimbra

Susana Santos: "Search for the Standard Model Higgs boson in H produc on with the ATLAS detector", 2017-03-24, LIP PhD Students Workshop, Coimbra

Emanuel Gouveia: "Probing the CP nature of top quark couplings in ttH production at the ATLAS experiment", 2017-03-24, LIP PhD Students Workshop. 24-25 March 2017, Coimbra, Portugal

Emanuel Gouveia: "Probing the CP nature of the Higgs coupling to top quarks during Run 2 of the LHC", 2017-05-26, 3rd IDPASC Students Workshop. 26-27 May2017, Braga, Portugal

4 Oral presentation in international meeting

Ana Peixoto: "Search for new interactions in the top quark sector at the Large Hadron Collider", 2017-03-24, 7th IDPASC School, Asiago (Itália)

Tiago Vale: "Search for heavy fermions with the ATLAS experiment", 2017-03-24, 7th IDPASC School, Asiago (Itália)

Ana Peixoto: "Search for new interactions in the top quark sector at the Large Hadron Collider", 2017-05-26, 3rd IDPASC Workshop, Braga (Portugal)

Tiago Vale: "Search for heavy fermions with the ATLAS experiment", 2017-05-26, 3rd IDPASC Workshop, Braga (Portugal)

9 Seminars

José Maneira: "Higgs boson: why it matters and how it was observed at the LHC", 2017-02-07, Invited Seminar at Laurentian University, Sudbury, Canada

Helena Santos: "Little bangs at LHC ", 2017-03-08, Departamento de Física, Faculdade de Ciências, Universidade de Lisboa

Helena Santos: "Little Bangs at LHC", 2017-03-22, Seminar, Faculdade de Ciências da Universidade de Lisboa, 22 de Março 2017

João Gentil: "Exploring the full potential of the TileCalorimeter", 2017-03-23, TileCal Meeting, Lisboa, Portugal

Ricardo Gonçalo: "Higgs Physics", 2017-04-03, Course on Physics at the LHC of the IDPASC Doctoral Programme, LIP

Patricia Conde: "Higgs Physics. Case-study of the H to WW search at ATLAS", 2017-04-05, IDPASC Course on Physics at the LHC, LIP

Nuno Castro: "Searches for new physics in the top quark sector at the LHC", 2017-05-11, Seminario del Departamento de Fisica Teorica y del Cosmos, Universidad de Granada, Granada, Spain

Patricia Conde: "A Física do LHC", 2017-07-11, IDPASC Workshop on Particles and Light, Departamento de Física, Faculdade de Ciências, Universidade de Lisboa

Patricia Conde: "What can the Higgs boson tell us about the Standard Model and beyond?", 2017-10-04, Departamento de Física/FCUL

21 Outreach seminars

Nuno Castro: "O que é a matéria?", 2017-01-20, Faculdade de Filosofia e Ciências Sociais, Universidade Católica

Nuno Castro: "A Física de Partículas e o CERN", 2017-01-31, Escola Secundária de Paredes

Nuno Castro: "O método científico: ponto de vista de um físico experimental de partículas", 2017-02-20, Escola de Ciências da Universidade do Minho

Bruno Galhardo: "Acelerar a Ciencia", 2017-02-21, Escola de Penafiel, Penafiel

Rui Faísca Pereira: "Iões pesados no LHC-ATLAS", 2017-03-02, Inside views das IV Jornadas de Engenharia Física do IST, LIP, Lisboa, Portugal

Ricardo Gonçalo: "Fotografando a passagem de partículas elementares", 2017-03-08, International Particle Physics Masterclasses, Universidade de Trás-Os-Montes e Alto Douro

Patricia Conde: "O bosão de Higgs", 2017-03-08, Planetário Calouste Gulbenkian

Ricardo Gonçalo: "Fotografando a passagem de partículas elementares", 2017-03-09, International Particle Physics Masterclasses, Bragança

Patricia Conde: "A Física do LHC", 2017-03-18, MasterClasses on Particle Physics, Departamento de Física, Faculdade de Ciências, Universidade de Lisboa

Ricardo Gonçalo: "Partículas", 2017-03-18, Masterclasses Internacionais de Física de Partículas, FCUL

Ricardo Gonçalo: "Física de Partículas e Detetores", 2017-03-25, Masterclasses Internacionais de Física de Partículas, Universidade de Aveiro

Filipe Veloso: "Caminho do W", 2017-03-25, 13.ª Edição das Masterclasses Internacionais em Física de Partículas, Coimbra

Bruno Galhardo: "Acelerar a Ciencia", 2017-03-25, 13.ª Edição das Masterclasses Internacionais em Física de Partículas, Coimbra

Susana Santos: "De que são feitas as coisas?", 2017-03-25, 13.ª Edição das Masterclasses Internacionais em Física de Partículas, Coimbra

Helena Santos: "Física no LHC", 2017-04-01, Masterclasses 2017, Instituto Superior Técnico, Lisbon, Portugal

Nuno Castro: "A Física de Partículas e o CERN", 2017-04-03, Escola Secundária de Águas Santas

Ricardo Gonçalo: "O bosao de Higgs ou A materia e o vazio", 2017-05-13, Encontros com a Ciencia no Montijo, Galeria Municipal do Montijo

Ricardo Gonçalo: "A Experiencia ATLAS", 2017-09-08, CERN Portuguese Language Teachers Programme, CERN

Tiago Vale: "À procura de matéria escura no LHC", 2017-11-22

Nuno Castro: "A Física das Partículas Elementares", 2017-11-23, Escola Secundária Henrique Medina, Esposende

Nuno Castro: "A Física das Partículas Elementares", 2017-11-23, Escola Básica e Secundária de Vila Cova (Barcelos)

Theses

9 PhD Theses

Bruno Galhardo: "Search for flavour-changing neutral current top-quark decays with the ATLAS detector" (finished on 2017-06-30)

Mário Sargedas Sousa: "Search for the Higgs boson at ATLAS/LHC, in associated production with a Z boson" (finished on 2017-07-17)

Rute Pedro: "Search for the Higgs boson at ATLAS/LHC in WH associated production and decay to b quark pairs using MVA methods" (finished on 2017-11-09)

Susana Santos: "Study of the ttH production and Higgs couplings to Top quarks in the ATLAS experiment" (ongoing)

Ademar Delgado: "Development of parallel jet triggers for Higgs searches at the ATLAS experiment at the LHC/CERN" (ongoing)

André Pereira: "An efficient particle physics data analysis framework for homogeneous and heterogeneous platforms" (ongoing)

Artur Amorim de Sousa: "Gauge/gravity duality and LHC forward physics" (ongoing)

Ana Peixoto: "Search for FCNC in tZ trilepton events at the ATLAS experiment" (ongoing)

Tiago Vale: "Search for vector-like quarks in Zt/b+X events at ATLAS" (ongoing)

11 Master Theses

Duarte Azevedo: "Probing the CP nature of the Higgs couplings in ttH events at the LHC" (finished on 2017-06-26)

José Luís Silva: "Optimization of clustering algorithms for the ATLAS Experiment at the LHC (CERN)" (finished on 2017-05-26)

Cátia Rato: "Development of a control board for the HV distribution system" (finished on 2017-06-25)

João Almendra Sabino: "Detector Control System of the HV distribution boards for the ATLAS Tile Calorimeter Phase II Upgrade" (finished on 2017-03-30)

Rui Martins: "Background studies for the ttH searches" (ongoing)

Christopher Pease: "Background studies for the ttH searches (Z+jets)" (ongoing)

David Fernandes: "Pesquisa de decaimentos raros do quark top na experiência ATLAS do LHC" (ongoing)

Ricardo Barrué: "Study of the ATLAS sensibility to anomalous Spin/CP components in the HWW vertex" (ongoing)

Aidan Kelly: "Study of the ATLAS sensibility to new physics contributions in the Hbb and Hbbγ vertices" (ongoing)

Ana Carvalho: "Search for highly boosted Higgs bosons decaying to b quarks in ATLAS" (ongoing)

António Costa: "Produção associada do bosão de Higgs com quarks top em ATLAS no LHC" (ongoing)

COLLABORATION IN THE CMS EXPERIMENT AT CERN

CMS

LIP is member of the Compact Muon Solenoid (CMS) Collaboration at the Large Hadron Collider (LHC) since its creation in 1992 [CERN-LHCC-92-003]. The research at the LHC is central to the quest for the fundamental physics laws of nature.

LIP had a leading role in the design and construction of important components of the CMS detector, namely the Data Acquisition System of the ECAL sub-detector used for the measurement of electrons and photons and the CMS Trigger System that performs the online selection of the interesting collisions. After the LHC start-up in 2010 LIP made major contributions to the CMS physics program in particular: the discovery of a Higgs boson; the measurement of the top quark properties; the first observation of rare Bs meson decays; the measurement of the psi and upsilon polarizations; and the searches for a charged Higgs and a top squark. A LIP group member has served as Deputy Spokesperson of the Collaboration in 2012-13.

After a two-year shutdown the LHC resumed operation in 2015 with the energy increased to 13 TeV. In preparation for the new beam conditions, the LIP group contributed to the upgrade of the experiment by building and installing a new full set of High-Speed Optical Links (oSLB-oRM) that interface the ECAL electronics to the trigger system.

The LIP group is leading the development of the new CTPPS forward proton spectrometer,

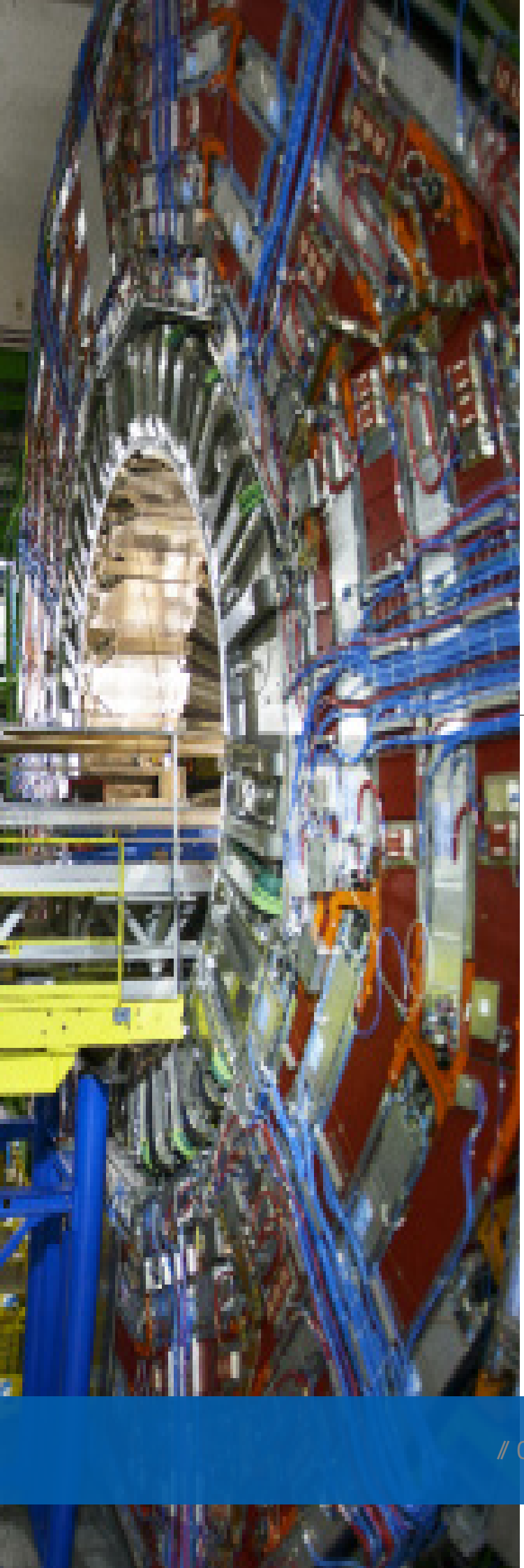
Overview

which took physics data integrated in CMS already in 2016 and 2017. CTPPS has proven for the first time the feasibility of operating a near-beam proton spectrometer at high luminosity on a regular basis. Members of the group are presently serving as CTPPS Project Coordinator and coordinators of the CTPPS sub-projects Timing Detectors and Data Acquisition System.

The group is actively involved and contributing to the physics analysis of the new data in the areas of top physics, Higgs physics, B physics, SUSY physics, and CTPPS physics. A member of the LIP group has coordinated the CMS B Physics group in 2014-2016. Two former members of the group, now with CERN, have

Summary of performance indicators

Articles in international journals:	3 With direct contribution from team 101 With indirect contribution
Internal notes:	9 Collaboration notes
International conferences:	2 Oral presentations 5 Proceedings 1 Poster presentation
International meetings:	9 Oral presentations
National conferences:	13 Oral presentations 2 Posters
Collaboration meetings:	77 Oral presentations
Seminars:	26 Seminars 4 Outreach Seminars



also coordinated in 2015-16 the CMS Higgs and Top physics groups.

The group is preparing the LIP participation in the CMS Phase 2 Upgrade in view of the High-Luminosity LHC. R&D in collaboration with Portuguese industry will be pursued in view of the development of microelectronics blocks for the frontend readout systems of the Electromagnetic Calorimeter (ECAL), High Granularity Calorimeter (HGCAL) and MIP Timing Detector (MTD).

Team

Principal Investigator João Varela (70)

Researchers
Betty Calpas (25), Cristóvão Silva (100), Jonathan Hollar (100), João Seixas (25), Michele Gallinaro (100), Nuno Leonardo (100), Pedrame Bargassa (100), Pietro Faccioli (22)

Technicians
César Carpinteiro (41), José Carlos Silva (50), Rui Pereira da Silva (30)

PhD students
Agostino di Francesco (100), Bruno Galinhas (100), Giles Strong (100), Oleksii Toldaiev (100)

Master students
Bruno Alves (100)

External/Additional scientific collaborators
Alessia Saggio, André David, Júlia Silva, Lara Lloret, Mathias Ajami, Pedro Ferreira da Silva, Pietro Vischia

Total FTE

13.1

Lines of work and team organization

Lines of work

The LIP/CMS group structure follows the main lines of activity:

- Proton-proton physics analysis:

The objective is to exploit fully the discovery opportunities offered by the LHC high energy and luminosity. The activity is organized in five main physics domains, namely Higgs Physics, Top Quark Physics, B Physics, SUSY Physics and physics in central exclusive production (CT-PPS). Each domain is led by a senior physicist and integrates researchers and students.

- Heavy-ion physics analysis:

The ultimate objective is the study of the quark-gluon plasma and of the strong interaction, taking benefit of the collisions of lead beams at LHC. The activity is led by a senior physicist and integrates other researchers and students.

- New detector developments for the CMS Upgrade program:

The objective of this sub-group is to contribute with R&D of new detector technologies for the Upgrade of the CMS experiment in view of its future operation at High Luminosity. Synergies with the LIP group in medical applications (TagusLIP) are exploited.

- Operation and maintenance of the ECAL trigger and data acquisition system:

The LIP/CMS group has people based at CERN that are required for the normal maintenance and operation of the ECAL detector. The group has a dedicated electronics lab installed in the CERN campus used for R&D and maintenance work.

Team organization

The PI of the group is João Varela. He has 30 years of research experience in Particle Physics collaborations at CERN. The senior researchers of the LIP-CMS group are the following João Seixas, Michele Gallinaro, Nuno Leonardo, Pedrame Bargassa, Jonathan Hollar.

The present coordination positions in the LIP/CMS group are listed below:

- LIP/CMS group coordinator - J. Varela
- LIP/CMS deputy group coordinator - J. Seixas
- Physics Analysis Coordinators - M. Gallinaro, N. Leonardo, P. Bargassa, J. Hollar, J. Seixas
- Upgrade coordinators:
  - CT-PPS (M. Gallinaro)
  - HL-LHC Upgrades (J. Varela)
- ECAL Electronics coordinator - J. C. Silva
- Computing link person - C. Cruz e Silva

The CMS Collaboration has about 3500 members from 200 institutes in 41 nations. The LIP group members have presently the following coordination positions in the CMS Collaboration structure:

- CT-PPS Project Manager (Level 1), since 2014 (J. Varela)
- CT-PPS Timing Detector Coordinator (Level-2), since 2014 (M. Gallinaro)
- CT-PPS DAQ Coordinator (Level-2), since 2015 (J. Hollar)
- ECAL Electronics Coordinator (Level-2), since 2011 (J. C. Silva)

LIP group members participate in the following CMS structures:

- CMS Executive, Management and Finance Boards (J. Varela)
- CMS Collaboration Board (J. Varela and J. Seixas)
- ECAL Executive Board (J.C. Silva)
- CTPPS Steering Committee (J.Varela, M. Gallinaro, J. Hollar)
- ECAL and CTPPS Institution Boards (J. Varela)
- Publication Board, Top and B physics (N.Leonardo)

Members of the LIP group are regularly selected to participate in Analysis Review Committees (ARC).

Sources of Funding

Code	Amount	Dates	Description
IF/01454/2013/CP1172/CT0003	50.000 €	2014-01-01 / 2018-12-31	FCT Exploratory research project - B physics (PI: N.Leonardo)
IF/00772/2014/CP1248/CT0002	50.000 €	2015-01-01 / 2019-12-31	FCT Exploratory research project - SUSY (PI: P.Bargassa)
CERN/FIS-NUC/0029/2015	400.000 €	2015-04-01 / 2017-03-31	FCT - CERN related projects - Participation in CMS
AMVA4NewPhysics - 675440	238.356 €	2015-09-01 / 2017-08-31	EU MSCA-ITN - Multi-Variate Analysis for New Physics@LHC
CERN/FIS-PAR/0006/2017	345.000 €	2017-06-01 / 2019-05-31	FCT - CERN related projects - Participation in CMS

Stated objectives for past year

The LIP group has planned to participate in the following areas of physics analysis and detectors activities in 2017:

1. Proton-proton physics:

1.1 measurement of the top cross-section in dilepton final states with one tau at 13 TeV and search for charged Higgs;
1.2 search for the top squark at 13 TeV in stop four-body decays.
1.3 search for di-Higgs events in resonant or non-resonant modes in di-tau and bbar final states (in the frame of the EU Marie-Curie network AMVA4NewPhysics).
1.4 study of Higgs bosons in the di-tau decay mode.
1.5 search for rare decays and measurement of heavy flavour production and properties with Run 2 data.
1.6 measurement of central exclusive di-photon production in proton collisions using the CT-PPS spectrometer.

2. Heavy-ions and QCD physics:

Pursue measurements of quarkonia polarization, including the polarization of chi states (χc and χb).

3. Physics objects development

Participation in the activities of development and validation of the tau lepton in the frame of the corresponding Physics Object Group (POG).

4. CT-PPS installation and operation

Installation, commissioning and operation at LHC of the new pixel and timing detectors and DAQ system of the CT-PPS project.

5. CMS Phase II Upgrade (HL-LHC)

5.1 Submission of the proposal for LIP participation in the CMS Phase II Upgrade.
5.2 R&D in collaboration with Portuguese industry provider of microelectronics IP blocks, of the frontend readout systems of ECAL, High Granularity Calorimeter (HGCAL) and Barrel Timing layer (BTL).

6. Operation and maintenance of the ECAL trigger and data acquisition system

7. Computing

LIP/CMS interface with the LIP's Tier2 group

8. General

The LIP group will provide in 2017 central shifts and EPR work according to the rules of the CMS collaboration. A fraction of this contribution is expected to correspond to CT-PPS data quality shifts performed at the new LIP Control Room being installed at IST.

Achievements and responsibilities during the past year

The LIP/CMS group made major scientific contributions in the following areas:

1. Physics

1.1 Top physics:

The analysis of top events with taus in the final state at 13 TeV (Run 2 data) is progressing (PhD student A. Toldayev, M. Gallinaro). The LIP/CMS group is pursuing the measurement of the cross section in the dilepton final state including a tau lepton by using a profile likelihood fit to better constrain the background composition. Preliminary results indicate an improved precision with respect to the Run1 measurements. Work is in progress to finalize the measurement and proceed to approval.

1.2 Search for SUSY:

The analysis of the data of 2016 was pursued by LIP/CMS in collaboration with HEPHY Vienna. The results of the search for the lightest scalar top (stop) were recently presented at the EPS HEP conference (CMS-SUS-16-031). The LIP/CMS group developed a unique search of the stop based on multivariate (MVA) approach, which bases the prediction of the background on the output of the MVA. The result (CMS-SUS-17-005) has been pre-approved in 2017 (Post-doctoral fellow C. da Silva e Cruz, P. Bargassa).

1.3 Search for di-Higgs events in di-tau and bbar final states:

Regression and classification studies in di-Higgs production were performed in 2017 with simulated CMS samples to validate the algorithms previously developed with DELPHES data. Di-Higgs production in the $\tau\tau$bb final state, with subsequent leptonic and hadronic decays of the tau leptons, is scrutinized. The studies are performed on CMS data using advanced machine learning analysis techniques with the goal of improving the separation of signal and background. Work is developed in the context of the Tau Id POG, and Higgs HH working group. This activity is carried in the frame of the EU Marie-Curie network AMVA4NewPhysics (PhD student G. Strong, M. Gallinaro).

1.4 Search for rare decays and measurement of heavy flavour:

The group has implemented several analyses of B-hadron production at 13 TeV (N. Leonardo, B. Galinhas, B. Alves). The search B$\rightarrow\mu\mu$ has remained a main priority analysis for CMS and LIP. The group developed the study to address the dominant systematics source. The group implemented the first CMS analysis of quark fragmentation fractions; the measurement has been carried out entirely by the LIP team (PhD student B.Galinhas, MSc student B.Alves, N.Leonardo) and is in internal review stage.

1.5 Search for exclusive two-photon production using the CTPPS spectrometer:

Members of the LIP group (L. Llorett, J. Hollar) led the analysis PPS-17-001 of dilepton production with tagged forward protons using the CTPPS spectrometer. The paper has now completed Collaboration Wide Review and is in the final stages before submission to a journal.

1.6 Studies on quarkonium production:

The activity of the group (P. Faccioli, J. Seixas) is centered in two connected lines of research. On one hand the group is involved in phenomenological studies aimed at interpreting quarkonium measurements towards an understanding of the mechanisms of hadron formation in QCD. From such studies stemmed important results that provide guidelines for experimental studies. More recently [Phys. Lett. B 773, 476 (2017)], we have brought to light a previously unnoticed observation: the existing LHC quarkonium production measurements reveal that all quarkonium states tend to follow one universal momentum scaling pattern. This lead to a complete program of measurements. On the other hand, the group is experimentally pursuing the measurement of the polarization of the χ_{c1} and χ_{c2} states with CMS data, in collaboration with the Austrian HEPHY group and the Mexican group of CIEA/IP.

1.7 B mesons as novel probes of the QGP

The CMS detector offers the unprecedented capability of exclusively reconstructing open heavy flavour states. The group (undergraduate student J.Silva, N.Leonardo) has delivered a first measurement of B_s production at 5TeV pp collisions, and explored first B_s signals in PbPb collisions. The work was pursued within and in collaboration with the CMS Heavy Ion working group.

2. Physics objects development

2.1 LIP members pursued the participation in the activities of POGs (Physics Object Groups), namely in the validation of the tau lepton reconstruction and identification (A. Toldaiev, G. Strong) and forward proton alignment (G. Strong) and CTPPS high-level trigger (C. Cruz e Silva)

3. CT-PPS installation, operation and physics

3.1 Under the leadership of a LIP member serving as overall CTPPS Project Manager (J. Varela), CTPPS collected about 40 fb^{-1} of data in the 2017 LHC run. The LIP group is leading the CTPPS DAQ system (J. Hollar) and the Timing detectors (M. Gallinaro) One member of the group (J. Hollar) served as overall detector operations manager for CTPPS. One student (B. Galinhas) started the collaboration in the online software. Members of the LIP group (L. Lloret, J. Hollar) were the main analysts of the paper "Observation of proton-tagged, central semi-exclusive production of high-mass lepton pairs at 13 TeV with the CMS-TOTEM Precision Proton Spectrometer" (CMS PPS-17-001) submitted for publication.

4. CMS Phase 2 Upgrade (HL-LHC)

In 2017 the activities of the LIP-CMS group towards the CMS Phase 2 Upgrade for operation at HL-LHC were strongly boosted. The participation of LIP in the CMS Phase 2 Upgrade was approved by FCT and the Minister of Science and Technology. The LIP group increased the involvement in the MIP Timing Detector (MTD) assuming responsibilities in the front-end readout system, in particular in the development of the TOFHiR ASIC (first submission foreseen in March 2018). LIP has also been leading the negotiation for the supply by Portuguese industry of the design of the new ADC (12-bit 160 Ms/s) for the ECAL Upgrade.

5. Outreach

5.1 Members of the group participated in several outreach and training activities, including: the International Masterclasses in Particle Physics in Évora and Faro, guidance of high school students in visits to CERN; CERN teachers program in Portuguese Language; organisation of Careers and Technology days at IST and FCUL, participation in workshops, lectures, and tutorials directed at university students; organisation of the LIP summer students program, where 9 students have been hosted by the group.

Lines of work and objectives for next year

The LIP/CMS group plans to participate in the following areas of physics analysis and detectors activities:

Task 1. Physics analysis

1.1 Higgs physics

1.1.1 Search for di-Higgs events in resonant or non-resonant modes in di-tau and bbar final states (in the frame of the EU Marie-Curie network AMVA4NewPhysics).

1.1.2 Study of Higgs bosons in the di-tau decay mode.

1.1.3 Search for rare decays of the Higgs boson into quarkonium.

1.2 Electroweak physics

1.2.1 Measurement of the quartic gauge coupling ggWW using the CTPPS spectrometer.

1.3 B physics

1.3.1 Search for rare decays and measurement of heavy flavour production.

1.4 New physics in top like events

1.4.1 Search for charged Higgs and for Dark Matter associated to Higgs boson

1.5 SUSY physics

1.5.1 Search for SUSY top squark in stop four-body decays.

1.6 Heavy-ion physics and QCD:

1.6.1 When more statistics is available in the CMS Heavy Ion program, there are interesting applications of the measurement of the polarization of the χ_{c1} and χ_{c2} states to the study of the sequential suppression of quarkonia in nucleus-nucleus collisions which we aim to pursue.

Task 2. R&D Phase 2 Upgrade

2.1 R&D in the Barrel Timing Layer (BTL)

2.1.1 Development and production of the BTL ASIC TOFHiR in CMOS 110 nm technology (LIP), integration with detector modules based on LYSO crystals and SiPMs and beam tests (in collaboration with INFN Milan, CERN, Caltech, Princeton).

2.2 R&D in the ECAL frontend readout system

2.2.1 Development of the new readout system of the PbWO4 crystals and APDs of the ECAL, based on a fast trans-impedance amplifier and a new 160MS/s low power ADC, in collaboration with INFN Torino and CEA Saclay.

2.3 R&D on the High Granularity Calorimeter (HGCAL)

2.3.1 Negotiation of the supply by Portuguese industry of low voltage regulator (LVR) resistant to radiation.

2.3.2 Development of algorithms for the HGCAL L1 trigger.

Task 3: Experiment operation and maintenance

3.1 ECAL

3.1.1 Maintenance of the ECAL trigger and data acquisition system.

3.2 CTPPS

3.2.1 Operation and maintenance of the DAQ system of the CTPPS project.

3.3 Physics objects development

3.3.1 Participation in the development and validation of the tau lepton reconstruction (Tau POG), forward proton alignment and high-level trigger in CTPPS.

3.4 Computing

3.4.1 LIP/CMS interface with the LIP's Tier2 group.

3.5 General

3.5.1 The LIP group will provide central shifts and EPR work according to the rules of the CMS collaboration.

SWOT Analysis

Strengths

Group well integrated in the Collaboration. Several senior physicists with long experience in CMS and strong impact. Several coordination positions, including the leadership of the CTPPS sub-detector and the leading role in several physics analysis. Emerging leadership in different areas of the front readout systems of the Phase II Upgrade.

Weaknesses

Difficulty in attracting foreign postdocs to Portugal.

Oportunities

Opportunity of strong participation of Portuguese industry world leader in segments of microelectronics IP market in the CMS Phase II Upgrade for HL-LHC.

Threats

Unclear career prospects for a large fraction of the senior physicists of the group.

Publications

3 Articles in international journals
(with direct contribution from team)

CMS Collaboration: "Measurement of B+ production cross section at 13 TeV", Physics Letters B 771 (2017) 435–456

M. Gallinaro et al.: "PICOSEC: Charged particle timing at sub-25 picosecond precision with a Micromegas based detector", arXiv:1712.05256

P. Faccioli, C. Lourenço, M. Araújo, V. Knünz, I. Krätschmer, J. Seixas: "Quarkonium production at the LHC: A data-driven analysis of remarkably simple experimental patterns", Phys. Lett. B773 (2017) 476-486

101 Articles in international journals
(with indirect contribution from team)

CMS Collaboration (2263 authors): "Inclusive search for supersymmetry using razor variables in pp collisions at root s=13 TeV", Phys. Rev. D 95 (2017) 012003

CMS Collaboration (2309 authors): "Measurements of the t(t)over-bar production cross section in lepton plus jets final states in pp collisions at 8 and ratio of 8 to 7 cross sections", Eur. Phys. J. C 77 (2017) 1-27

CMS Collaboration (2267 authors): "Observation of the decay B+ -> psi(2S)phi(1020)K+ in pp collisions at root s=8 TeV", Phys. Lett. B 764 (2017) 66-86

CMS Collaboration (2261 authors): "Search for Dark Matter and Supersymmetry with a Compressed Mass Spectrum in the Vector Boson Fusion Topology in Proton-Proton Collisions at root s=8 TeV", Phys. Rev. Lett. 118 (2017) 021802

CMS Collaboration (2269 authors): "Search for high-mass Z gamma resonances in e(+)e(-)gamma and mu(+)mu(-)gamma final states in proton-proton collisions at root s=8 and 13 TeV", J. High Energy Phys. 1 (2017) 076

CMS Collaboration (2269 authors): "Search for R-parity violating supersymmetry with displaced vertices in proton-proton collisions at root s=8 TeV", Phys. Rev. D 95 (2017) 012009

CMS Collaboration (2265 authors): "Search for supersymmetry in events with one lepton and multiple jets in proton-proton collisions at root s=13 TeV", Phys. Rev. D 95 (2017) 012011

CMS Collaboration (2305 authors): " Jet energy scale and resolution in the CMS experiment in pp collisions at 8 TeV", J. Instrum. 12 (2017) P02014

CMS Collaboration (2259 authors): "Search for anomalous Wtb couplings and flavour-changing neutral currents in t-channel single top quark production in pp collisions at root s=7 and 8 TeV", J. High Energy Phys. 2 (2017) 028

CMS Collaboration (2259 authors): "Evidence for collectivity in pp collisions at the LHC", Phys. Lett. B 765 (2017) 193-220

CMS Collaboration (2263 authors): "Measurement of the production cross section of a W boson in association with two b jets in pp collisions at root s=8TeV", Eur. Phys. J. C 77 (2017) 92

CMC Collaboration (2257 authors): "Search for top quark decays via Higgs-boson-mediated flavor-changing neutral currents in pp collisions at root s=8 TeV", J. High Energy Phys. 2 (2017) 079

Burns, D / CMS Collaboration (2299 authors): "Measurement of the transverse momentum spectra of weak vector bosons produced in proton-proton collisions at root s=8TeV", J. High Energy Phys. 2 (2017) 096

CMS Collaboration (2244 authors): "Search for dark matter and unparticles in events with a Z boson and missing transverse momentum in proton-proton collisions at root s=13 TeV", J. High Energy Phys. 3 (2017) 061

CMS Collaboration (2262 authors): "Measurements of differential cross sections for associated production of a W boson and jets in proton-proton collisions at root s=8 TeV", Phys. Rev. D 95 (2017) 052002

CMS Collaboration (2278 authors): "Search for heavy neutrinos or third-generation leptoquarks in final states with two hadronically decaying tau leptons and two jets in proton-proton collisions at root s=13 TeV", J. High Energy Phys. 3 (2017) 077

CMS Collaboration (2277 authors): "Measurement of the t(t)over-bar production cross section using events in the e mu final state in pp collisions at root s=13 TeV", Eur. Phys. J. C 77 (2017) 172

CMS Collaboration (2274 authors): "Search for CP violation in t(t)over-bar production and decay in proton-proton collisions at root s=8 TeV", J. High Energy Phys. 3 (2017) 101

CMS Collaboration (2272 authors): "Observation of Charge-Dependent Azimuthal Correlations in p-Pb Collisions and Its Implication for the Search for the Chiral Magnetic Effect", Phys. Rev. Lett. 118 (2017) 122301

CMS collaboration (2257 authors): "Measurement and QCD analysis of double-differential inclusive jet cross sections in pp collisions at root s=8 TeV and cross section ratios to 2.76 and 7 TeV", J. High Energy Phys. 3 (2017) 156

CMS Collaboration (2263 authors): "Search for electroweak production of charginos in final states with two T leptons in pp collisions at root s=8 TeV", J. High Energy Phys. 4 (2017) 018

CMS Collaboration (2257 authors): "Measurements of differential production cross sections for a Z boson in association with jets in pp collisions at root s=8 TeV", J. High Energy Phys. 4 (2017) 022

CMS Collaboration (2271 authors): "Charged-particle nuclear modification factors in PbPb and pPb collisions at root s(NN)=5.02 TeV", J. High Energy Phys. 4 (2017) 039

CMS Collaboration (2278 authors): "Search for high-mass diphoton resonances in proton-proton collisions at 13 TeV and combination with 8 TeV search", Phys. Lett. B 767 (2017) 147-170

CMS Collaboration (2296 authors): "Search for top squark pair production in compressed-mass-spectrum scenarios in proton-proton collisions at root s=8 TeV using the alpha(T) variable", Phys. Lett. B 767 (2017) 403-430

CMS Collaboration (2268 authors): "Measurement of the WZ production cross section in pp collisions at root s=7 and 8 TeV and search for anomalous triple gauge couplings at root s=8 TeV", Eur. Phys. J. C 77 (2017) 236

CMS Collaboration (2267 authors): "Suppression and azimuthal anisotropy of prompt and nonprompt J/psi production in PbPb collisions at root S-NN=2.76 TeV", Eur. Phys. J. C 77 (2017) 252

CMS Collabaration (2246 authors): "Search for electroweak production of a vector-like quark decaying to a top quark and a Higgs boson using boosted topologies in fully hadronic final states", J. High Energy Phys. 4 (2017) 136

CMS Collaboration (2236 authors): "Measurement of prompt and nonprompt J/psi production in pp and pPb collisions at root s(NN)=5.02 TeV", Eur. Phys. J. C 77 (2017) 269

CMS Collaboration (2276 authors): "Measurement of differential cross sections for top quark pair production using the lepton plus jets final state in proton-proton collisions at 13 TeV", Phys. Rev. D 95 (2017) 092001

CMS Collaboration (2277 authors): "Observation of gamma(1S) pair production in proton-proton collisions at root s=8 TeV", J. High Energy Phys. 5 (2017) 013

CMS collaboration (2230 authors): "Search for single productio no vector-like quarks decaying to a Z boson and a top or a bottom quark in proton-proton collisions at root s=13 TeV", J. High Energy Phys. 5 (2017) 029

CMS Collaboration (2285 authors): "A search for new phenomena in pp collisions at root s=13TeV in final states with missing transverse momentum and at least one jet using the alpha(T) variable", Eur. Phys. J. C 77 (2017) 294

CMS Collaboration (2263 authors): "Search for narrow resonances in dilepton mass spectra in proton-proton collisions at root s=13 TeV and combination with 8 TeV data", Phys. Lett. B 768 (2017) 57-80

CMS Collaboration (2295 authors): "Multiplicity and rapidity dependence of strange hadron production in pp, pPb, and PbPb collisions at the LHC", Phys. Lett. B 768 (2017) 103-129

CMS Collaboration (2235 authors): "Search for heavy resonances decaying into a vector boson and a Higgs boson in final states with charged leptons, neutrinos, and b quarks", Phys. Lett. B 768 (2017) 137-162

CMS Collaboration (2241 authors): "Searches for pair production of third-generation squarks in root s=13 TeV pp collisions", Eur. Phys. J. C 77 (2017) 327

CMS Collaboration (2223 authors): "Measurement of the top quark mass using single top quark events in proton-proton collisions at root s=8 TeV", Eur. Phys. J. C 77 (2017) 354

CMS Collaboration (2264 authors): "Search for supersymmetry in events with photons and missing transverse energy in pp collisions at 13 TeV", Phys. Lett. B 769 (2017) 391-412

CMS Collaboration (2266 authors): "Measurement of electroweak-induced production of W gamma with two jets in pp collisions at root s=8TeV and constraints on anomalous quartic gauge couplings", J. High Energy Phys. 6 (2017) 106

CMS Collaboration (2197 authors): "Search for t(t)over-bar resonances in highly boosted lepton plus jets and fully hadronic final states in proton-proton collisions at root s=13 TeV", J. High Energy Phys. 7 (2017) 001

CMS Collaboration (2231 authors): "Search for associated production of a Z boson with a single top quark and for tZ flavour-changing interactions in pp collisions at root s=8 TeV", J. High Energy Phys. 7 (2017) 003

CMS Collaboration (2203 authors): "Measurement of the mass difference between top quark and antiquark in pp collisions at root s=8 TeV", Phys. Lett. B 770 (2017) 50-71

CMS Collaboration (2282 authors): "Search for heavy gauge W ' bosons in events with an energetic lepton and large missing transverse momentum at root s=13TeV", Phys. Lett. B 770 (2017) 278-301

CMS Collaboration (2273 authors): "Suppression of gamma(1S), gamma(2S), and gamma(3S) quarkonium states in PbPb collisions at root S-NN=2.76TeV", Phys. Lett. B 770 (2017) 357-379

CMS Collaboration (2260 authors): "Measurement of the cross section for electroweak production of Z gamma in association with two jets and constraints on anomalous quartic gauge couplings in proton-proton collisions at root s=8 TeV", Phys. Lett. B 770 (2017) 380-402

CMS Collaboration (2230 authors): "Measurement of the jet mass in highly boosted t(t)over-bar events from pp collisions at root s=8TeV", Eur. Phys. J. C 77 (2017) 467

CMS Collaboration (2264 authors): "Measurement of inclusive jet cross sections in pp and PbPb collisions at root s(NN)=2.76 TeV", Phys. Rev. C 96 (2017) 015202

CMS Collaboration (2281 authors): "Search for supersymmetry in the all-hadronic final state using top quark tagging in pp collisions at root s=13 TeV", Phys. Rev. D 96 (2017) 012004

A. M. Sirunyan et al. (2232 authors): "Search for third-generation scalar leptoquarks and heavy right-handed neutrinos in final states with two tau leptons and two jets in proton-proton collisions at root s=13 TeV", J. High Energy Phys. 7 (2017) 121

V. Khachatryan et al. (2273 authors): "Pseudorapidity dependence of long-range two-particle correlations in pPb collisions at root sNN=5.02 TeV", Phys. Rev. C 96 (2017) 014915

CMS Collaboration (2205 authors): "Searches for W ' bosons decaying to a top quark and a bottom quark in proton-proton collisions at 13TeV", J. High Energy Phys. 8 (2017) 1-42

CMS Collaboration (2266 authors): "search for dark matter in proton-proton collisions at 8 TeV with missing transverse momentum and vector boson tagged jet (vol 12, 083, 2016)", J. High Energy Phys. 8 (2017) 035

CMS Collaboration (2286 authors): "Search for single production of a heavy vector-like T quark decaying to a Higgs boson and a top quark with a lepton and jets in the final state", Phys. Lett. B 771 (2017) 80-105

CMS Collaboration (2235 authors): "Measurement of the inclusive energy spectrum in the very forward direction in proton-proton collisions at root s=13 TeV", J. High Energy Phys. 8 (2017) 046

CMS Collaboration (2192 authors): "Search for top quark partners with charge 5/3 in proton-proton collisions at root s=13 TeV", J. High Energy Phys. 8 (2017) 073

CMS Collaboration (2232 authors): "Measurement of the top quark mass in the dileptonic t(t)over-bar decay channel using the mass observables M-bl, M-T2, and M-blv in pp collisions at root=8 TeV", Phys. Rev. D 96 (2017) 032002

A. M. Sirunyan et al. (2239 authors): "Study of Jet Quenching with Z plus jet Correlations in Pb-Pb and pp Collisions at root s(NN)=5.02 TeV", Phys. Rev. Lett. 119 (2017) 082301

CMS Collaboration (2227 authors): "Search for supersymmetry in multijet events with missing transverse momentum in proton-proton collisions at 13 TeV", Phys. Rev. D 96 (2017) 032003

CMS Collaboration (2227 authors): "Search for physics beyond the standard model in events with two leptons of same sign, missing transverse momentum, and jets in proton-proton collisions at root s=13TeV", Eur. Phys. J. C 77 (2017) 578

CMS Collaboration (2233 authors): "Search for standard model production of four top quarks in proton-proton collisions at root s=13TeV", Phys. Lett. B 772 (2017) 336-358

CMS Collaboration (2228 authors): "Search for high-mass Z gamma resonances in proton-proton collisions at root s=8 and 13 TeV using jet substructure techniques", Phys. Lett. B 772 (2017) 363-387

CMS Collaboration (2298 authors): "Coherent J/psi photoproduction in ultra-peripheral PbPb collisions at root s(NN)=2.76 TeV with the CMS experiment", Phys. Lett. B 772 (2017) 489-511

CMS Collaboration (2235 authors): "Search for single production of vector-like quarks decaying into a b quark and a W boson in proton-proton collisions at root s=13 TeV", Phys. Lett. B 772 (2017) 634-656

CMS Collaboration (2268 authors): "Cross section measurement of t-channel single top quark production in pp collisions at root s=13 TeV", Phys. Lett. B 772 (2017) 752-776

CMS Collaboration (2230 authors): "Search for a heavy resonance decaying to a top quark and a vector-like top quark at root s=13 TeV", J. High Energy Phys. 9 (2017) 053

CMS Collaboration (2245 authors): "Measurement of the t(t)over-bar production cross section using events with one lepton and at least one jet in pp collisions at root s=13 TeV", J. High Energy Phys. 9 (2017) 051

CMS Collaboration (2231 authors): "Search for Low Mass Vector Resonances Decaying to Quark-Antiquark Pairs in Proton-Proton Collisions at root s=13 TeV", Phys. Rev. Lett. 119 (2017) 111802

CMS Collaboration (2282 authors): "Search for new phenomena with multiple charged leptons in proton-proton collisions at root s=13TeV", Eur. Phys. J. C 77 (2017) 635

CMS Collaboration (2231 authors): "Search for heavy resonances that decay into a vector boson and a Higgs boson in hadronic final states at root s=13TeV", Eur. Phys. J. C 77 (2017) 636

CMS Collaboration (2244 authors): "Search for dark matter and unparticles in events with a Z boson and missing transverse momentum in proton-proton collisions at root s = 13 TeV (vol 3, 061, 2017)", J. High Energy Phys. 9 (2017) 106

CMS collaboration (2228 authors): "Particle-flow reconstruction and global event description with the CMS detector", J. Instrum. 12 (2017) P10003

CMS Collaboration (2230 authors): "Measurement of the semileptonic t(t)over-bar + gamma production cross section in pp collisions at root s=8 TeV", J. High Energy Phys. 10 (2017) 006

CMS Collaboration (2233 authors): "Search for direct production of super symmetric partners of the top quark in the all-jets final state in proton-proton collisions at root s=13 TeV", J. High Energy Phys. 10 (2017) 005

CMS Collaboration (2231 authors): "Search for top squark pair production in pp collisions at root s=13 TeV using single lepton events", J. High Energy Phys. 10 (2017) 019

CMS Collaboration / Ferri, F / Berger, J / Rabbertz, K / Shvetsov, I / Evangelou, I / CMS Collaboration (2222 authors): "Search for Charged Higgs Bosons Produced via Vector Boson Fusion and Decaying into a Pair of W and Z Bosons Using pp Collisions at root s=13 TeV", Phys. Rev. Lett. 119 (2017) 141802

Pietro Faccioli, Carlos Lourenco, Mariana Araujo, Valentin Knunz, Ilse Kraetschmer, Joao Seixas: "Quarkonium production at the LHC: Adata-driven analysis of remarkably simple experimental patterns", Phys. Lett. B 773 (2017) 476-486

CMS Collaboration (2255 authors): "Search for leptophobic Z ' bosons decaying into four-lepton final states in proton-proton collisions at root s=8 TeV", Phys. Lett. B 773 (2017) 563-584

CMS Collaboration (2270 authors): "Search for light bosons in decays of the 125 GeV Higgs boson in proton-proton collisions at root s=8 TeV", J. High Energy Phys. 10 (2017) 076

CMS Collaboration (2226 authors): "Search for new physics in the monophoton final state in proton-proton collisions at root s=13 TeV", J. High Energy Phys. 10 (2017) 073

CMS Collaboration (2196 authors): "Measurement of the B-+/- Meson Nuclear Modification Factor in Pb-Pb Collisions at root s(NN)=5.02 TeV", Phys. Rev. Lett. 119 (2017) 152301

CMS Collaboration (2235 authors): "Search for Supersymmetry in pp Collisions at root s=13 TeV in the Single-Lepton Final State Using the Sum of Masses of Large-Radius Jets", Phys. Rev. Lett. 119 (2017) 151802

CMS Collaboration (2228 authors): "Measurements of jet charge with dijet events in pp collisions at root s=8 TeV", J. High Energy Phys. 10 (2017) 131

CMS Collaboration (2257 authors): "Search for Higgs boson pair production in the bb tau state in proton-proton collisions at root(s)=8 TeV", Phys. Rev. D 96 (2017) 072004

CMS Collaboration (2233 authors): "Search for associated production of dark matter with a Higgs boson decaying to b(b)over-bar or gamma gamma at root s=13 TeV", J. High Energy Phys. 10 (2017) 180

CMS Collaboration (2234 authors): "Search for new phenomena with the M-T2 variable in the all-hadronic final state produced in proton-proton collisions at root s=13TeV", Eur. Phys. J. C 77 (2017) 710

CMS Collaboration (2234 authors): "Measurement of the differential cross sections for the associated production of a W boson and jets in proton-proton collisions at root s=13 TeV", Phys. Rev. D 96 (2017) 072005

CMS collaboration (2235 authors): "Search for a light pseudoscalar Higgs boson produced in association with bottom quarks in pp collisions at root s=8 TeV", J. High Energy Phys. 11 (2017) 010

CMS Collaboration (2229 authors): "Measurement of the triple-differential dijet cross section in proton-proton collisions at root s=8 TeV and constraints on parton distribution functions", Eur. Phys. J. C 77 (2017) 746

CMS Collaboration (2295 authors): "Measurements of the associated production of a Z boson and b jets in pp collisions at root s=8 TeV", Eur. Phys. J. C 77 (2017) 751

A. M. Sirunyan et al. (2239 authors): "Measurements of properties of the Higgs boson decaying into the four-lepton final state in pp collisions at root s=13 TeV", J. High Energy Phys. 11 (2017) 047

A. M. Sirunyan et al. (2228 authors): "Search for black holes and other new phenomena in high-multiplicity final states in proton-proton collisions at root s=13 TeV", Phys. Lett. B 774 (2017) 279-307

CMS Collaboration (2190 authors): "Combination of searches for heavy resonances decaying to WW, WZ, ZZ, WH, and ZH boson pairs in proton-proton collisions at root s=8 and 13 TeV", Phys. Lett. B 774 (2017) 533-558

CMS Collaboration (2237 authors): "Measurement of vector boson scattering and constraints on anomalous quartic couplings from events with four leptons and two jets in proton-proton collisions at root s=13 TeV", Phys. Lett. B 774 (2017) 682-705

CMS Collabration (2226 authors): "Search for pair production of vector-like T and B quarks in single-lepton final

states using boosted jet substructure in proton-proton collisions at root s=13 TeV", J. High Energy Phys. 11 (2017) 085

CMS Collaboration (2228 authors): "Measurement of charged pion, kaon, and proton production in proton-proton collisions at root s=13 TeV", Phys. Rev. D 96 (2017) 112003

CMS Collaboration (2193 authors): "Search for dark matter produced in association with heavy-flavor quark pairs in proton-proton collisions at root s=13 TeV", Eur. Phys. J. C 77 (2017) 845

A. M. Sirunyan et al. (2230 authors): "Constraints on anomalous Higgs boson couplings using production and decay information in the four-lepton final state", Phys. Lett. B 775 (2017) 1-24

CMS Collaboration (2217 authors): "Search for a heavy composite Majorana neutrino in the final state with two leptons and two quarks at root s=13 TeV", Phys. Lett. B 775 (2017) 315-337

CMS Collaboration (2249 authors): "Observation of Top Quark Production in Proton-Nucleus Collisions", Phys. Rev. Lett. 119 (2017) 242001

CMS collaboration (2231 authors): "Search for supersymmetry in events with at least one photon, missing transverse momentum, and large transverse event activity in proton-proton collisions at root s=13TeV", J. High Energy Phys. 12 (2017) 142

5 **International Conference Proceedings**

M. Gallinaro (for the CMS and Totem Collaborations): "Upgrades for the Precision Proton Spectrometer at the LHC: Precision Timing and Tracking Detectors", AIP Conf. Proc. 1819 (2017) no.1, 040021

M. Gallinaro et al.: "Characterization of irradiated APDs for picosecond time measurements", 11th Int. Conf. on Position Sensitive Detectors (PDS11)

M. Gallinaro (for the CMS Collaboration): "Latest Results on Top Quark Properties: Deciphering the DNA of the heaviest quark", arXiv:1711.10425

J.Seixas, CMS Collaboration: "Quarkonium polarization in pp collisions with CMS", QCD@LHC 2016

P.Faccioli: "A data-driven interpretation of heavy quarkonium measurements at the LHC", QCD@LHC 2016

9 Collaboration notes with internal referee

M. Gallinaro, D. Vadruccio, J. Varela et al.: "A Level 1 pixel-based track trigger for HL-LHC", CMS DN-2017/003

CMS Collaboration: "Evidence for proton-tagged, central semi-exclusive production of high-mass muon pairs at 13 TeV with the CMS-TOTEM Precision Proton Spectrometer", CMS PAS PPS-17-001

N.Leonardo, B.Galinhas, B.Alves: "Measurement of b-quark fragmentation fractions", CMS AN-2017/168

O. Toldayev, M. Gallinaro, P. Silva, J. Varela: "Measurement of ttbar production xsection in the dilepton channel including a tau lepton at 13TeV", CMS AN-2017/054

M. Gallinaro, J. Goncalves, G. Strong, et al.: "Search for Dark Matter produced in association with a Higgs boson in the four-lepton final state at 13 TeV", CMS AN-2016/328

M. Gallinaro, G. Strong, J. Varela et al.: "Multivariate analysis methods for Higgs boson searches at the Compact Muon Solenoid", CMS AN-2016/407

O. Toldayev, M. Gallinaro, P. Silva, J. Varela: "Measurement of ttbar production xsection in the dilepton channel including a tau lepton at 13TeV using a profile likelihood fit", CMS AN-2017/289

P. Bargassa, C. da Cruz e Silva: "Search for 4-body decays of stop in 1l final states at 13 TeV with a multivariate approach", CMS AN-2017-035

P. Bargassa, C. da Cruz e Silva & HEPHY group: "Search for top squarks decaying via four-body or chargino-mediated modes in the single-lepton final state at $sqrt{s} =$ 13 TeV", CMS SUS-2017-005

Presentations

2 Oral presentations in international conferences

Nuno Leonardo: "Properties of heavy flavor decays at CMS", 2017-05-18, 5th Annual Large Hadron Collider Physics Conference, Jiao Tong University, Shanghai

Michele Gallinaro: "Latest Results on Top Quark Properties", 2017-09-20, 10th International Workshop on Top Quark Physics, Braga, Sept 17-22, Braga, Portugal

1 Poster presentation in international conference

Bruno Galinhas: "Heavy Flavor Production at 13 TeV", 2017-09-10, 2017 European School High-Energy Physics, Évora

13 Presentations in national conferences

Pedrame Bargassa: "SUSY: What is it, How do we search for it, ...how do we work", 2017-02-01, IDPASC jornadas, Sesimbra

Nuno Leonardo: "Needles in the haystack", 2017-02-06, 2nd Lisbon mini-school on Particle and Astroparticle Physics, Sesimbra

Nuno Leonardo: "Rare and not-so-rare events: precision measurements and searches", 2017-02-08, 2nd Lisbon mini-school on Particle and Astroparticle Physics, Sesimbra

Giles Strong: "Machine Learning in Higgs Physics", 2017-02-08, Lisbon mini-school on Particle and Astro-particle Physics, Sesimbra, Portugal

Nuno Leonardo: "Quarks, Mesoes, Barioes, Bosoes, Ioes ...", 2017-03-02, 4th Jornadas Engenharia Fisica, IST, Lisboa

Pedrame Bargassa: "Looking for Susy: A well motivated search beyong the SM", 2017-03-02, Jornadas de Engenharia Física IV, IST Lisbon

Michele Gallinaro: "The Higgs or not the Higgs...and beyond", 2017-03-02, A desafiar os limites da ciencia e tecnologia, IST, Lisbon

Bruno Galinhas: "First Measurements of Heavy Flavor Production at 13 TeV", 2017-03-25, LIP PhD students workshop, Coimbra University

Bruno Galinhas: "First Measurements of Heavy Flavor Production at 13 TeV", 2017-05-25, 3rd IDPASC Students Workshop, Braga

Nuno Leonardo: "Hadron production and suppression in LHC collisions", 2017-07-14, 1º Encontro Nacional da Associação de Física de Interacções Fortes, Coimbra University

Pedrame Bargassa: "Introduction to statistics", 2017-07-19, Estagio de verao 2017, LIP Lisbon

Júlia Silva: "b hadrons as probes of the QGP", 2017-09-14, 1st LIP Summer Student Program, Final Workshop, LIP

Bruno Alves: "Measurement of b quark production at 13 TeV with 2016 data", 2017-09-14, 1st LIP Summer Student Program, Final Workshop, LIP

2 Poster presentations in national conferences

Júlia Silva: "Measurement of the B0 and B0s cross sections at 13 TeV", 2017-03-01, 4th Jornadas Engenharia Fisica, IST, Poster competition, IST

Bruno Alves: "Search for a rare decay at the LHC: Bs->mumu", 2017-03-01, 4th Jornadas Engenharia Fisica, IST, Poster competition, IST

9 Oral presentations in international meetings

Michele Gallinaro: "PPS Timing detectors: Status report", 2017-01-21, LHCC referee meeting, CERN, Switzerland

João Varela: "General CT-PPS status and plans", 2017-02-21, LHCC referees meeting, CERN, Switzerland

Giles Strong: "Feature optimisation through regression", 2017-05-18, 4th AMVA4NewPhysics Workshop, Oviedo University, Spain

Jonathan Hollar: "gamma-gamma and gamma-p measurements with forward proton taggers in CMS/TOTEM", 2017-05-22, Photon 2017: 2017 International Conference on the Structure and the Interactions of the Photon, CERN

João Varela: "CT-PPS detector and physics status", 2017-09-12, LHCC referees meeting, CERN, Switzerland

Giles Strong: "Regression & classification of di-Higgs events", 2017-10-05, AMVA4NewPhysics Mid-term review, UCL, Belguim

Giles Strong: "Contributed slides to "WP1 Status", 2017-10-05, AMVA4NewPhysics Mid-term review, UCL, Belguim

João Varela: "Completion of the CT-PPS MoU and future prospects", 2017-11-29, LHCC referees meeting, CERN, Switzerland

Giles Strong: "Contributed slides to ", 2017-12-14, HTT Workshop, CERN, Switzerland

26 Seminars

João Varela: "Course introduction", 2017-03-06, Course on Physics at the LHC, LIP, Lisbon

João Varela: "Experimental program at the LHC", 2017-03-07, Course on Physics at the LHC, LIP, Lisbon

João Varela: "Standard Model at the LHC", 2017-03-08, Course on Physics at the LHC, LIP, Lisbon

Michele Gallinaro: "Particle interactions and detectors", 2017-03-13, Course on Physics at the LHC, LIP, Lisbon

Giles Strong: "Understanding Neural Networks", 2017-03-15, AEMPP evaluation & LIP seminar seires, LIP, Lisbon

Michele Gallinaro: "Top quark: Introduction", 2017-03-22, Course on Physics at the LHC, LIP, Lisbon

Giles Strong: "Machine Learning in Higgs Physics", 2017-03-25, LIP PhD-Students' Workshop, Coimbra University, Portugal

Michele Gallinaro: "Top quark: Properties and beyond", 2017-03-27, Course on Physics at the LHC, LIP, Lisbon

Michele Gallinaro: "Higgs boson: Beyond the SM searches", 2017-04-12, Course on Physics at the LHC, LIP, Lisbon

Pedrame Bargassa: "Physics at the LHC: Supersymmetry", 2017-04-19, Physics at the LHC: Courses for students, LIP Lisbon

Michele Gallinaro: "Looking Forward: The Precision Proton Spectrometer at the LHC", 2017-04-20, Seminar, INFN Frascati, Italy

Pedrame Bargassa: "Physics at the LHC: Supersymmetry", 2017-04-26, Physics at the LHC: Courses for students, LIP Lisbon

Michele Gallinaro: "Exotic processes and Dark Matter", 2017-05-03, Course on Physics at the LHC, LIP, Lisbon

Nuno Leonardo: "Heavy flavor physics and rare decays searches", 2017-05-08, Course on Physics at the LHC, LIP, Lisbon

Michele Gallinaro: "The Standard Model and the LHC Experimental Program", 2017-05-16, Doctorate Course at "Bari Politecnico" (XXXII ciclo), Bari, Italy

Michele Gallinaro: "Top quark and beyond", 2017-05-17, Doctorate Course at "Bari Politecnico" (XXXII ciclo), Bari, Italy

Michele Gallinaro: "SM Higgs and Beyond", 2017-05-18, Doctorate Course at "Bari Politecnico" (XXXII ciclo), Bari, Italy

Michele Gallinaro: "Latest Results on BSM Physics in the Higgs sector at the LHC", 2017-05-18, Seminar at "Bari Politecnico, Bari, Italy

Nuno Leonardo: "Rare decays at the LHC", 2017-05-26, Chinese Academy of Sciences, IHEP, Beijing

Giles Strong: "Machine Learning in di-Higgs Physics", 2017-05-31, Physics Seminar evaluation, IST, Lisbon

Giles Strong: "Keras Tutorial", 2017-07-14, LIP Big-Data Competency Centre Meeting, Online

Nuno Leonardo: "Tutorial: event displays", 2017-07-18, 1st LIP Summer Student Program, Lectures session, LIP, Lisbon

Michele Gallinaro: "Probing the SM at the LHC", 2017-07-18, Summer student program, LIP, Lisbon

Nuno Leonardo: "Tutorial: data analysis", 2017-07-21, 1st LIP Summer Student Program, Lectures session, LIP, Lisbon

Nuno Leonardo: "Procura de processos raros no LHC", 2017-10-05, Universidade do Estado do Rio de Janeiro, UERJ, Rio de Janeiro

Oleksii Toldaiev: "Measurement of tt->bbltau and Lepton Universality test on LHC", 2017-11-15, Meeting with CMS Strasbourg group, Strasbourg

4 **Outreach seminars**

Giles Strong: "Self-introduction", 2017-02-02, Outreach at two schools in Venice, Venice, Italy

Nuno Leonardo: "Welcome to CERN, introducing the LHC", 2017-02-13, CERN guide, Geneva

Nuno Leonardo: "Detectando particulas no LHC", 2017-03-04, International MasterClasses 2017, Évora

Bruno Alves: "Search for a rare decay at the LHC", 2017-06-15, MEFT, IST

Theses

4 PhD Theses

Agostino di Francesco: "Development of high-performance timing detectors for the CMS forward proton spectrometer" (ongoing)

Oleksii Toldaiev: "Search for new physics processes with leptons in the final state at the Large Hadron Collider with the CMS detector" (ongoing)

Bruno Galinhas: "Search for new physics in rare processes at LHC" (ongoing)

Giles Strong: "Search for double Higgs production new physics processes using Advanced Multi-Variate Analysis tools in the CMS experiment at the Large Hadron Collider" (ongoing)

1 Master Theses

Bruno Alves: "Search for the B0_s->mumu rare decay at the LHC" (ongoing)

PHENOMENOLOGY / PHENOMENOLOGICAL STUDIES AT THE LHC

LHC Phenomenology

During 2017, the LHC Phenomenology Group had a very significant productivity, despite the lack of funding from FCT. At the same time, this was the last year of activity as a separate group. The creation of a new Phenomenology Group at LIP means the achievement of a milestone that was a long-term goal of this group since its inception, building a common effort between the experimental and theoretical communities. The importance of this effort has been widely recognized within the LIP community, with the official approval by the Scientific Council of the newly created Phenomenology Group, under the scientific leadership of a theoretical physicist. The LHC Phenomenology activity will be continued within the framework of the new group.

Over the years, the LHC Phenomenology group developed several tools (TopFit, ScannerS) which allow global fits to top quark and Higgs boson properties, which are widely used by the scientific community. We developed new Monte Carlo generators, such as MeTop (a NLO FCNC generator dedicated to single top quark production at the LHC), and the automatic analysis tool HepFrame (which allows to automatically identify the structure of a database and automatically build a complete structured analysis code with most of the required user interfaces).

Since 2010, when the PI of the group was hired by University of Minho, the project has been crucial to develop a research group at the University of Minho and build the LIP-Minho node. The smooth transition from a small group to a structured and mature research group was achieved in the most natural way, with a new leadership, and a promising and sustainable future ahead, giving freedom to members of the group to address new challenges in open questions at the leading edge of LHC physics. In 2017 the work of the group was structured in several tasks, whose status is summarized below.

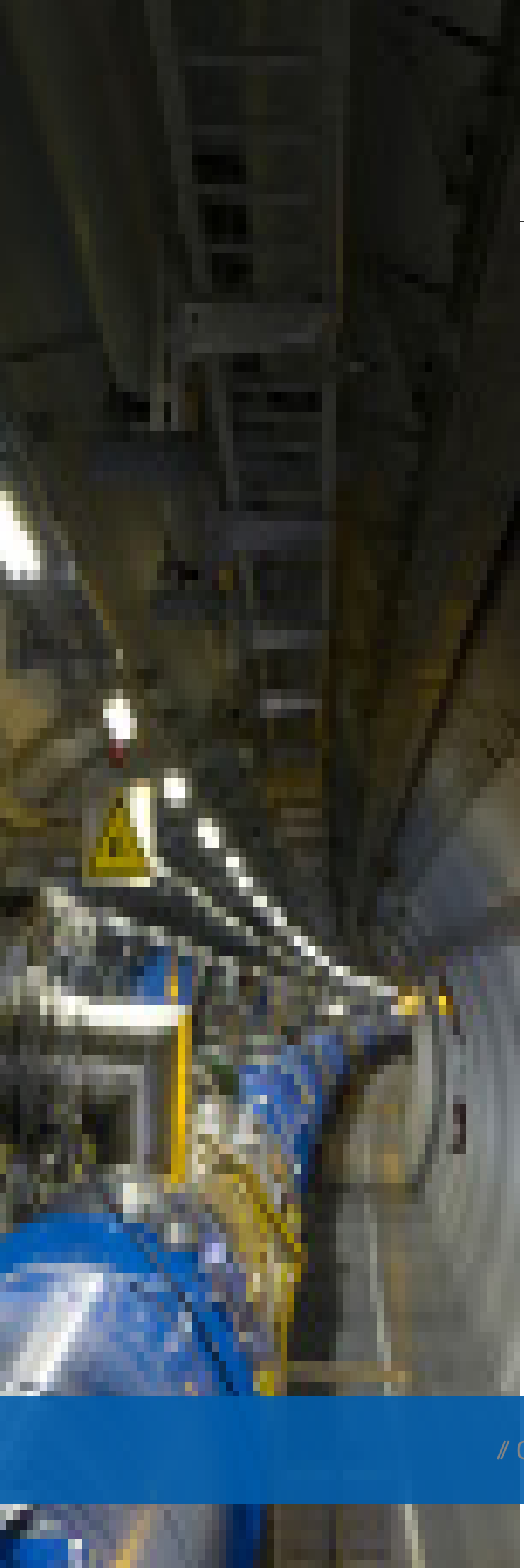
Overview

Summary of performance indicators

Articles in international journals:	4 With direct contribution from the team 5 With indirect contribution from the team
International Conferences:	1 Proceedings

EXPERIMENTAL PARTICLE AND ASTROPARTICLE PHYSICS

LHC experiments and phenomenology



Team

Principal Investigator António Onofre (64)

Researchers
Miguel Fiolhais (70), Rita Coimbra (100)

Undergraduate student
Pedro Lagarelhos

External/Additional scientific collaborators
Augusto Barroso, Francisco del Aguila Giménez, José Santiago Perez, Juan Aguilar-Saavedra, Pedro Martins Ferreira, Renato Guedes Júnior, Roberto Pittau, Rui Santos

Total FTE
2.3

// GROUPS: ATLAS / CMS / Phenomenology

Lines of work and team organization

1. Top Quark Production at the LHC: The main goal of the task was to study signals of physics beyond the SM in top quark FCNC processes at the LHC. The search for anomalous production of Zt and tγ at the high luminosity phase of the LHC and at a future collider FCC-hh, with 100TeV centre--of-mass energy, were studied. Using ultra-boosted topologies, limits on branching fractions were studied, showing that the level of 10^{-6} can be achieved (publications at the end of this report).

2. Study of Top quark Couplings in ttbar Events: The main goal of this task was to measure the Wtb vertex structure and the couplings of the top quark. The global fitter TopFit, developed by the team, was used to perform a global fit of the top quark observables (or related to top) in order to extract the best limits on the anomalous couplings or EFT parameters. Using the recent measurements of top quark properties at ATLAS, CMS, at the LHC, and D0 and CDF at the Tevatron, new combined limits on anomalous couplings at the Wtb vertex were set and published in 2 and 3 dimensional projections (publications at the end of this report). Limits showed that still 20-30% of the available phase space can be excluded in the future ahead.

3. Study of Higgs Production and Couplings: The main goal of this task was related to the pp–>tth process at the LHC. The CP-violating tth vertex can be written as "α+i $\beta\gamma_5$", containing thus a scalar and a pseudo-scalar component. The case where the Higgs is considered to be a mixture of scalar and pseudoscalar components was analysed with no assumptions regarding the size of each component and estimating the contribution from non-SM background. Two different topologies were studied: semileptonic and dileptonic decays of the ttbar system, together with the Higgs decaying to two b-quarks. Limits, in the background only hypothesis were studied and new angular distributions are proposed. The observables proposed are currently being studied by ATLAS in a new attempt for a global fit of the Higgs couplings to the top quarks in the fermionic sector (publications at the end of this report).

4. Theoretical Models and Monte Carlo Generators: One of the required tasks in this project was the development of theoretically consistent frameworks for the different topics under study, particularly relevant for the global fitters. These have been achieved and new observables have been introduced in the global fitters.

5. Smart Computing in Platforms with Accelerator Devices: Robust and accurate simulations require heavy and high performance computations (HPC). This resulted in the development of the HepFrame (a framework for High Energy Physics analysis at the LHC, which allows an automatic build of an analysis skeleton program for data analysis at the LHC that can be used by any user). This framework is being used, in particular in the studies for future accelerators.

Stated objectives for past year

The main objective of the group was to strengthen and develop a strong group with experimental and theoretical physicists for phenomenological studies with a special impact on the LHC physics. This goal has been achieved with the recently created Phenomenology Group within LIP. The discussion was intended to be concentrated in:

1. the production of top quarks at the LHC via FCNC;

2. the study of top quark couplings in ttbar and single top events;

3. the study of Higgs production and top quark to Higgs couplings at the LHC, via ttH;

4. theoretical improvements related to models under development;

5. efficient processing in homogeneous and heterogeneous platforms with accelerator devices and the development of the HepFrame;

Achievements and responsibilities during the past year

The main achievements of the project, which reflect the team's work over the last few years, can be summarized in the following:

- A research group involving experimentalists and theoretical physicists was developed within LIP, approved by the Scientific Council, an important milestone of this project.

- The sustained development of the LIP-Minho research group has been very successful, including University Professors, undergraduate, master and PhD students, as well as researchers and Pos-Docs, from different University departments. The group is considered mature enough with a sustained future ahead.

- In what concerns the scientific program of the project, for the single top quark production via FCNC at the LHC, new contributions have been studied in particular in what concerns the ultra-boosted regime of tZ and tγ single top quark production via FCNC at the LHC.

- For the Study of Top Quark Anomalous Couplings, new 95% CL limits were published by the team considering the most recent data from LHC and Tevatron. An improvement of, at least, 20-30% on the available phase space for new physics can be achieved by combining all the new experimental observables.

- In what concerns the study of the Higgs boson to top

quark couplings, the team has proposed several new angular distributions to study the CP nature of the couplings, which will be studied in the future in the global analysis of ttH within ATLAS.

- For the development of Theoretical Models, several studies were performed and the inclusion of the obtained cross sections in Monte Carlo generators and global fitters was accomplished.

- As has been a reality since many years already, the project has been very successful in motivating young students (license, Master and PhD) due to the strong collaboration between experimentalists and theoretical physicists.

SWOT Analysis

Strengths and Oportunities

The project has been very successful in attracting students (from Portuguese and foreign universities) and provided the correct framework for the development of several MSc and PhD thesis, both in experimental and theoretical physics. The project allowed bringing together the experimental and theoretical communities under a common research goal, with the long-term objective of efficiently exploring the data that will be collected at the LHC and future colliders. Particularly relevant was the fact that a new branch of LIP (LIP-Minho) was developed at the University of Minho, bringing the field of High Energy Particle Physics and Astroparticle Physics to the northern universities of Portugal. The development of the HepFrame framework for automatically building analysis skeleton software, was also a very interesting achievement in terms of the clear synergies that can be build among two different fields of science: computing and physics.

Weaknesses and Threats

The weakest points of the project is the very limited budget, for a long time already, for the activities planned and the internal institutional little relevance given to the project outcomes. While this doesn't seem aligned with the recognition the team has gathered internationally, it is also true that pursuing activities with no significant budget, as a team, probably doesn't make much sense. The PI has decided to terminate the project following the completion of the 2018 objectives, allowing team members to contribute to other projects, judged of more relevance.

Publications

3 Articles in international journals (with direct contribution from team)

F. Déliot, R. Faria, M. Fiolhais, P. Lagarelhos, A. Onofre, C. Pease, A. Vasconcelos: "Global Constraints on Top Quark Anomalous Couplings", Phys.Rev. D97 (2018) no.1, 013007

Alessandro Broggio, Andrea Ferroglia, Miguel C. N. Fiolhais, Antonio Onofre: "Pseudoscalar couplings in t(t)over-barH production at NLO plus NLL accuracy", Phys. Rev. D 96 (2017) 073005

S. Amor Dos Santos et al, Probing the CP nature of the Higgs coupling in $t{\bar t}h$ events at the LHC, arXiv:1704.03565 [hep-ph]., 10.1103/PhysRevD.96.013004, Phys.Rev. D96 (2017) no.1, 013004.

D. Azevedo, A. Onofre, F. Filthaut, R. Gonçalo, CP tests of Higgs couplings in $t\bar{t}h$ semileptonic events at the LHC arXiv:1711.05292 [hep-ph], submitted to PRD.

2 Articles in international journals (with indirect contribution from team)

Margarete Mühlleitner, Marco O.P. Sampaio, Rui Santos, Jonas Wittbrodt, Phenomenological Comparison of Models with Extended Higgs Sectors, arXiv:1703.07750 [hep-ph], 10.1007/JHEP08(2017)132,JHEP 1708 (2017) 132.

Marcel Krause, David Lopez-Val, Margarete Muhlleitner, Rui S antos, Gauge-independent Renormalization of the N2HDM, J. High Energ. Phys. (2017) 2017: 77, arXiv:1708.01578 [hep-ph]

Raul Costa, Marco O. P. Sampaio, Rui Santos, NLO electroweak corrections in general scalar singlet models, J. High Energ. Phys. (2017) 2017: 81, JHEP 1707 (2017) 081, arXiv:1704.02327 [hep-ph]

Abdesslam Arhrib, Rachid Benbrik, Stefano Moretti, Rui Santos, Pankaj Sharma, Signal to background interference in $pp\to t H^-\to t W^- b\bar b$ at the LHC Run-II, accepted by PRD, arXiv:1712.05018 [hep-ph]

Phillipp Basler, Pedro M. Ferreira, Margarete Mühlleitner, Rui Santos, High scale impact in alignment and decoupling in two-Higgs doublet models, arXiv:1710.10410 [hep-ph], submitted to PRD

1 International Conference Proceedings

E. Gouveia et al, Probing the CP nature of the Higgs coupling in $t\bar{t}h$ events at the LHC, arXiv:1801.04954 [hep-ph] accepted for publication.

PHENOMENOLOGY / HEAVY ION PHENOMENOLOGY

HIP

The Heavy Ion Phenomenology Group (HIP@ LIP) focused its activities on the exploration of the Quark Gluon Plasma (QGP) produced in ultra-relativistic heavy ion collisions at RHIC and the LHC with the aim of elucidating the dynamical mechanism underlying the transition between the perturbative and non-perturbative regimes of Quantum Chromodynamics (QCD). Our research revolved around the use of the unique potential of jets as multi-scale probes of the QGP both in currently available data and in opportunities afforded by future experimental runs and facilities under consideration. Activities in heavy ion Phenomenology will, in 2018, be carried out in the framework of the new wider-scope LIP Phenomenology Group.

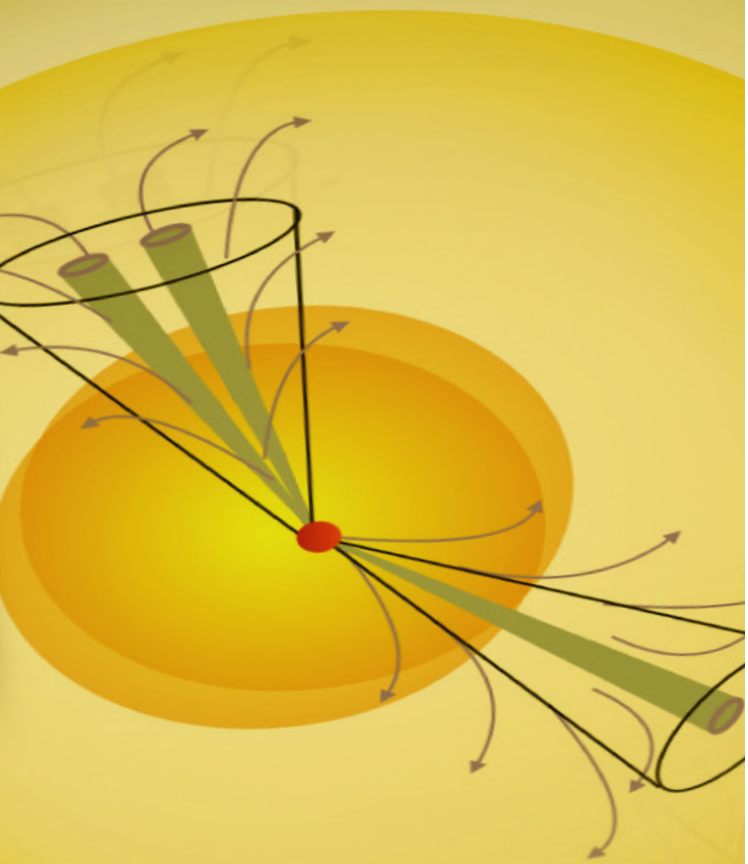
Framework and status for past and current year

Summary of performance indicators

Articles in international journals:	10 With direct contribution from team
International conferences:	8 Oral presentations 2 Proceedings
National conferences:	2 Oral presentations
International meetings:	1 Oral presentation
Seminars:	3 Seminars
Events organized:	1 Workshop

EXPERIMENTAL PARTICLE AND ASTROPARTICLE PHYSICS

LHC experiments and phenomenology



Team

Principal Investigator Guilherme Milhano (100)

Researchers
Korinna Zapp (100), Liliana Apolinário (70), Tolga Altinoluk (16)

Total FTE
2.9

// GROUPS: ATLAS / CMS / Phenomenology

Lines of work and team organization

All research previously carried out by the group will now be part of the new Phenomenology Group.

Stated objectives for past year

The group will focus on jets as QGP probes, with the following main objectives:

1. implementation of colour coherence effects in JEWEL through an antenna shower and in Q-PYTHIA via modification of the Sudakov.

2. release of test analyses compliant with the Lisbon Accord

3. assessment of the potential of top quarks as time-resolved QGP probes

4. further development of the strong/weak coupling hybrid model including resolution scale effects and realistic back-reaction

5. design of novel jet and sub-jet observables with controlled sensitivity to QGP properties and to the pattern of lost energy

6. initial exploration of Machine Learning techniques for feature identification of QGP-modified jets

Achievements and responsibilities during the past year

The stated objectives 2, 3, 4 and 5 where fully acomplished and resulted in publications. Work towards objectives 1 and 6 remains in progress. The exploration of Machine learning techniques (objective 6) has been supported by the Big Data and Simulation Compentence Centre at LIP. In this context, two funding requests were made: one to FCT and one as part of a H2020 call.

During 2017 the group co-organized a two-week CERN-TH Institute on 'Novel tools and observables for jet physics in heavy-ion collisions ' and the accompaning 5th Heavy Ion Jet Workshop and played a leading role in the preparation of the CERN Yellow Report 'Physics at the FCC-hh, a 100 TeV pp collider'. The high visibility of the group's work was guaranteed by several invited and contributed talks at international conferences of which we highlight an invited plenary talk at Quark Matter 2017. A funding request to FCT (in the CERN fund call) was submitted and approved guaranteing the continued funding of activities in heavy ion phenomenology at LIP.

The group's full and successful integration within LIP was a major contributing factor to initiate, go through and conclude the process that led to the creation of the new Phenomenology Group.

Lines of work and objectives for next year

All research previously carried out by the group will now be part of the new Phenomenology Group.

Publications

10 Articles in international journals
(with direct contribution from team)

Liliana Apolinário: "Recent progress on the understanding of the medium-induced jet evolution and energy loss in pQCD", EPJ Web Conf. 137 (2017) 07002

Liliana Apolinário: "In-medium parton branching beyond eikonal approximation", Few Body Syst. 58 (2017) 69

Jorge Casalderrey-Solana, Doga Gulhan, Guilherme Milhano, Daniel Pablos, Krishna Rajagopal: "Angular Structure of Jet Quenching Within a Hybrid Strong/Weak Coupling Model", JHEP 1703 (2017) 135

A. Dainese et al.: "Heavy ions at the Future Circular Collider", CERN Yellow Report (2017) 635-692

Raghav Kunnawalkam Elayavalli, Korinna Christine Zapp: "Medium response in JEWEL and its impact on jet shape observables in heavy ion collisions", JHEP 1707 (2017) 141

Raghav Kunnawalkam Elayavalli, Korinna Christine Zapp: "Medium Recoils and background subtraction in JEWEL", Nucl.Part.Phys.Proc. 289-290 (2017) 368-371

Jorge Casalderrey-Solana, Doga Can Gulhan, José Guilherme Milhano, Daniel Pablos, Krishna Rajagopal: "The angular structure of jet quenching within a hybrid strong/weak coupling model", Nucl.Part.Phys.Proc. 289-290 (2017) 359-362

Liliana Apolinário, Néstor Armesto, José Guilherme Milhano, Carlos A. Salgado: "Factorization of in-medium parton branching beyond the eikonal approximation", Nucl. Part.Phys.Proc. 289-290 (2017) 117-120

David d'Enterria, L. Apolinario, N. Armesto, A. Dainese, J. Jowett, J.P. Lansberg, S. Masciocchi, G. Milhano, C. Roland, C.A. Salgado, M. Schaumann, M. van Leeuwen, U.A. Wiedemann: "Physics with ions at the Future Circular Collider", Nucl.Phys. A967 (2017) 888-891

Korinna C. Zapp: "Jet energy loss and equilibration", Nucl.Phys. A967 (2017) 81-88

2 International conference proceedings

Jorge Casalderrey-Solana, Doga Can Gulhan, José Guilherme Milhano, Daniel Pablos, Krishna Rajagopal: "A Comprehensive Analysis of Jet Quenching via a Hybrid Strong/Weak Coupling Model for Jet-Medium Interactions", Nucl.Phys. A956 (2016) 613-616

Xiaoming Zhang, Liliana Apolinário, José Guilherme Milhano, Mateusz Płoskoń: "Sub-jet structure as a discriminating quenching probe", Nucl.Phys. A956 (2016) 597-600

Presentations

8 Oral presentations in international conferences

Guilherme Milhano: "The origin of the modification of the z_g distribution in AA collisions", 2017-01-07, XXVI international conference on ultrarelativistic heavy-ion collisions (Quark Matter 2017), Chicago, USA

Liliana Apolinário: "QGP studies with FCC-Heavy Ions", 2017-01-16, 1st FCC Physics Workshop, CERN

Korinna Zapp: "Jet energy loss and equilibration (plenary talk)", 2017-02-06, XXVI international conference on ultrarelativistic heavy-ion collisions (Quark Matter 2017), Chicago, USA

Guilherme Milhano: "J. G. Milhano, The origin of the modification of the z_g distribution in AA collisions, , Feb 2017, ", 2017-02-07, XXVI international conference on ultrarelativistic heavy-ion collisions (Quark Matter 2017), Chicago, USA

Liliana Apolinário: "QGP tomography through boosted objects", 2017-05-09, Precision Spectroscopy of QGP Properties with Jets and Heavy Quarks, Seattle USA

Guilherme Milhano: "International Europhysics Conference on High Energy Physics(EPS-HEP 2017)", 2017-07-07, International Europhysics Conference on High Energy Physics(EPS-HEP 2017), Venice, Italy

Liliana Apolinário: "Sub-jet observables in Heavy-Ion collisions", 2017-08-22, Novel tools and observables for jet physics in heavy-ion collisions / 5th Heavy Ion Jet Workshop, CERN

Liliana Apolinário: "Update on boosted tops", 2017-09-29, Ions at the Future Circular Collider, CERN

2 Presentations in national conferences

Liliana Apolinário: "Probing the most perfect liquid", 2017-02-08, Second Lisbon mini-school on Particle and Astroparticle Physics, Sesimbra

Liliana Apolinário: "Geradores Monte Carlo", 2017-07-19, Estágios de Verão 2017: Tutorials, LIP

1 Oral presentations in international meetings

Guilherme Milhano: "High density and eA physics", 2017-06-01, FCC week 2017, Berlin, Germany

3 Seminars

Liliana Apolinário: "Probing the most perfect liquid", 2017-02-08, Second Lisbon mini-school on Particle and Astroparticle Physics, Hotel do Mar, Sesimbra, Portugal

Liliana Apolinário: "QGP tomography with boosted objects", 2017-10-27, Universidade de Santiago de Compostela

Liliana Apolinário: "Exploring the early universe in the laboratory", 2017-11-29, FCUL

Events

1 Workshop

Novel tools and observables for jet physics in heavy-ion collisions / 5th Heavy Ion Jet Workshop, CERN, 2017-08-21 to 2017-09-01

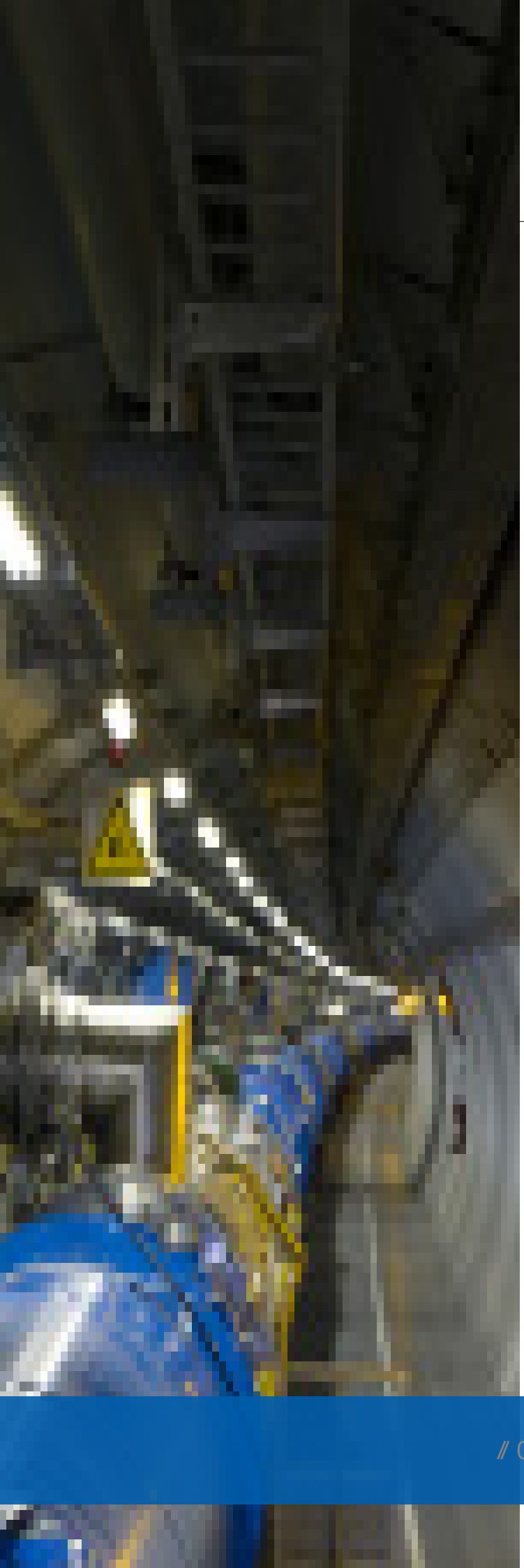
LIP PHENOMENOLOGY GROUP (LIP-Pheno)

Phenomenology

LIP's Phenomenology group, LIP-Pheno, conducts research bridging theory and experiment in particle and astroparticle physics. Its research, while independent, is centred around areas in which LIP has active experimental activities and aims to identify areas in which LIP's broader programme may evolve in the future. Its founding purpose is to strengthen the impact of the overall LIP programme through the provision of excellent directed phenomenological research

The group results from the aggregation of two previously existing LIP groups, Phenomenological Studies at the LHC (LHC Phenomenology) and Heavy Ion Phenomenology (HIP), whose members form the founding core of LIP-Pheno. The members of the group have an excellent publication record and high international visibility. The group was created in January 2018 following an extensive discussion process within LIP.

Framework and status for past and current year



Team (*)

Principal Investigator Guilherme Milhano (100)

Researchers
António Onofre (64), Juan P. Araque (20), Korinna Zapp (100), Liliana Apolinário (70), Miguel Fiolhais (20), Nuno Castro (40), Pietro Faccioli (50), Ricardo Gonçalo (20), Ruben Conceição (20), Tolga Altinoluk (16)

PhD students
Artur Amorim de Sousa (10), Maria Ramos (90)

Master students
André Reigoto (50), Duarte Azevedo (20), João Pedro Gonçalves (100), João Lourenço Barata (100), Rui Martins (50)

Undergraduate students
João Moreira, Pedro Lagarelhos

External/Additional scientific collaborators
José Santiago Perez, Juan Aguilar-Saavedra, Pedro Martins Ferreira, Rui Santos

Total FTE
9.4

(*) Starting in 2018

// GROUPS: ATLAS / CMS / Phenomenology

Lines of work and team organization

At present the group has internationally recognized consolidated research activities in top-quark, Higgs, quarkonia, and heavy-ion phenomenology with a strong expertise in the development of event-generators. In addition, the group encompasses phenomenological research previously undertaken within, but independently of, the various LIP experimental groups. Currently, steps are being taken to consolidate these existing research activities (simulation of cosmic ray air showers, and dark matter searches).

The activities of the group are distributed over all the three (Lisboa, Coimbra, Braga) nodes of LIP. Regular remote and periodic (typically four times a year) meetings of the group will be held in addition to an on-going effort to jointly host seminars via video--link. This gatherings are aimed at increasing crosstalk within the group and at providing a community for the many students being trained in the group.

Lines of work and objectives for next year

The main objective of the group for 2018 is to effectively bring the various activities carried out within the group into a coherent, yet diverse, phenomenologial research programme.

The group will grow around its excellent consolidated lines of work in:

1. Heavy-ion Phenomenology

- parton shower in the presence of a QGP based on first principles evolution equation ressuming both vacuum-like and medium induced radiation
- identification of observables unmodified by the QGP that can serve as bona-fide binning variables to study QGP induced modifications on other sensitive observables
- exploration of jet sub-structure properties to track temporal-spatial structure of jet modifications

2. Heavy Quarkonium

- explore implications of the simple scaling patterns, identified by our group in available data, for the validation of NRQCD and for the understanding of quarkonium production in hadronic collisions, and its applications to the study of the sequential suppression of quarkonia in nucleus-nucleus collisions

3. Top-quark and Higgs

- explore the potential of top-quark Higgs associated production, in particular of the angular distributions previously identified by the group, in future collider environments (HL-LHC, HE-LHC, FCC-hh)
- explore top-quark anomalous couplings in future collider environments (HL-LHC, HE-LHC, FCC-hh)
- effective Field Theory based searches for BSM Physics, in particular in the top-quark sector, to be conducted in articulation with the LHCtopWG

4. Exotics

- exploration of alternative production and decay mechanics for vector-like quarks in Composite Higgs models with particular emphasis on the definition of novel experimental analisys strategies
- specific efforts will be made towards consolidation of existing phenomenological activies in dark matter searches and cosmic ray phenomenology. These involve attempts to use existing complementary expertise to increase actvities in these lines of research.

To ensure continued competitiveness and responsiveness to new developments in areas of strategic importance, the group will work towards widening its scope through strategic recruitment and the establishment of new partnerships and collaborations to complement existing expertise.

SWOT Analysis

Strenghts:

Internationally recognized research of high impact; demonstrated ability to attract young researchers.

Weaknesses:

Insufficient critical mass to cover phenomenoligically the wealth of physics addressed by experimental groups at LIP; significicant part of workforce shared with experimental groups; group geographically spread

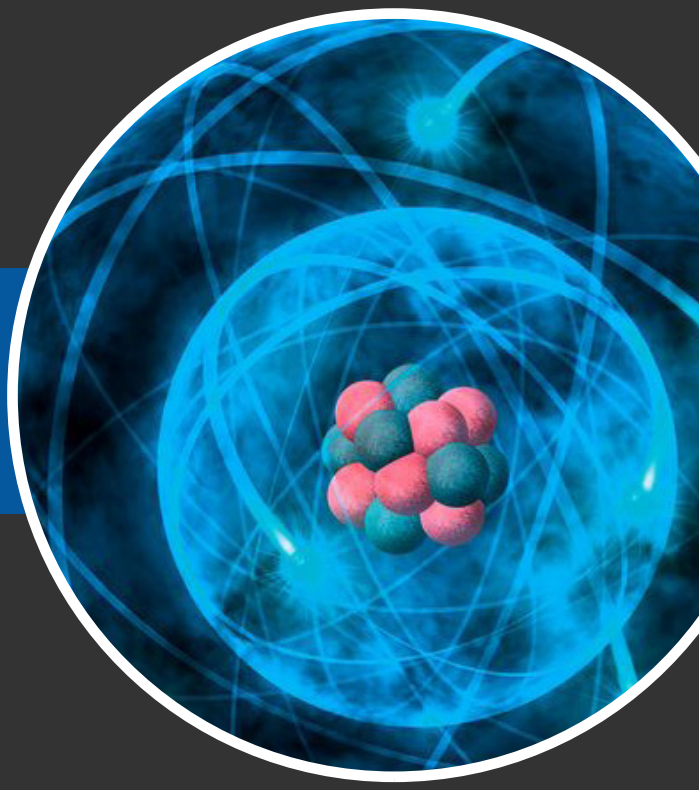
Opportunities:

increase of critical mass relative to pre-existing groups can boost ability to train young researchers; diversity and complementary expertise in the group increases ability to attract excelent new researchers to be hired through national and international external funding calls ; increased coherence of Phenomenology work at LIP.

Threats:

modest funding and distributed heterogeneously amongst different activities — no core group funding; most researchers in the group do not hold permanent positions

Structure of matter



PARTONS AND QCD: COLLABORATION IN THE COMPASS EXPERIMENT AT CERN

COMPASS

Overview

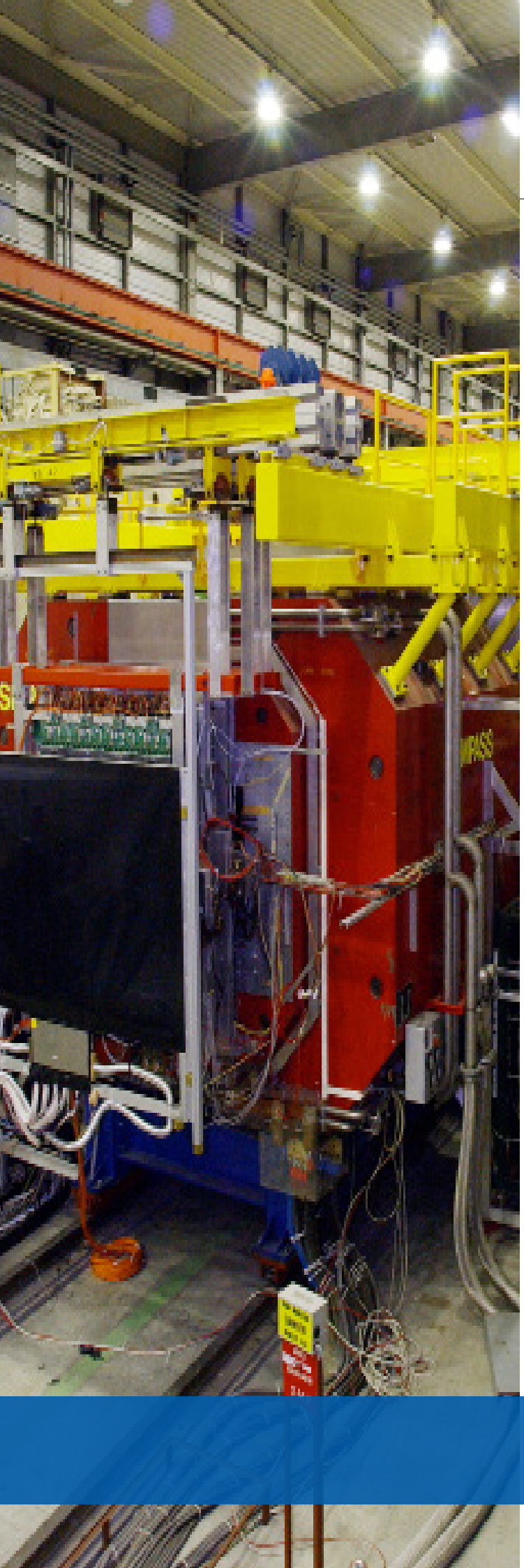
COMPASS is a fixed target experiment at CERN using high energy muon and hadron beams to study the nucleon spin structure and hadron spectroscopy. During its first phase COMPASS achieved the world most direct and precise measurement of the gluon contribution to the nucleon spin. A second research programme started in 2012 and is now close to completion, devoted to the 3-dimensional characterization of the nucleon structure. An addendum to the COMPASS-II proposal was submitted in October 2017, for additional deep inelastic scattering measurements using a transversely polarized deuteron target.

The LIP-Lisbon group joined COMPASS in 2003 and has been involved since then in the main analyses of the Collaboration. The group has the sole responsibility for the Detector Control System, an area where it has a recognized unique expertise.

The 2016 and 2017 data-taking was devoted to the study of exclusive DIS processes. In parallel, semi-inclusive studies of hadron multiplicities are being performed by members of the LIP group, an important ingredient for fragmentation functions extraction. The analysis of the COMPASS 2015 polarized Drell-Yan data was completed in 2017, by the LIP and Torino groups. It gave a first hint on the importance of parton transverse momentum dependent effects for the nucleon dynamics. More conclusive results shall be obtained with the increased statistics from the 2018 Drell-Yan Run, to which the LIP group is deeply committed.

Summary of performance indicators

Articles in international journals:	9 With direct contribution
International conferences:	3 Oral presentations 1 Proceedings
National conferences:	3 Oral presentations
Collaboration meetings:	9 Oral presentations
Outreach:	1 Seminar 3 Outreach seminars
Completed theses:	1 PhD



Team

Principal Investigator Catarina Quintans (100)

Researchers
Celso Franco (78), Luis Silva (48), Márcia Quaresma (67), Marcin Stolarski (88), Paula Bordalo (60), Sérgio Ramos (60)

Technicians
Christophe Pires (100)

PhD students
Ana Sofia Nunes (100) (*)

Total FTE

7.0 (4.7 for 2018)

(*) PhD finished in December 2017. Team researcher from 2018.

Lines of work and team organization

The LIP group in COMPASS follows presently 3 main lines of work:

- Detector Control System.
- Deep inelastic scattering studies.
- Polarized Drell-Yan studies.

The DCS team is responsible for the development and implementation of controls and monitoring for new detectors and systems included in each year's setup. It also maintains the system permanently working (including during the winter shutdown periods). The group provides the on-call service during the approximately 5 months/year of data-taking. The team is coordinated by Ana Sofia Nunes and Christophe Pires.

A multidimensional analysis of the helicity structure function of the proton at low-x, in the phase space region complementary to deep inelastic scattering, was completed by Ana Sofia Nunes during 2017. She proceeds as a project post-doc in 2018. An analysis of charged kaon (and pion) multiplicity ratios from deep inelastic scattering in deuteron target was performed in 2017 by Marcin Stolarski, and will be continued in 2018 by analysing the 2016/2017 collected data samples, on proton target.

The polarized Drell-Yan data taken in 2015 was analysed during 2017 by Márcia Quaresma, LIP COMPASS post-doc until September. Several LIP members were involved in this analysis and writing the corresponding paper, which was already published. An improved data re-processing is being prepared, with coordination of Catarina Quintans. Celso Franco coordinates the studies for the implementation of machine learning techniques to process separation in Drell-Yan data. Catarina Quintans coordinates the COMPASS Drell-Yan sub-group, and leads the group involved in writing the Drell-Yan part of a future experiment proposal.

In 2017 the LIP group was re-organized with Catarina Quintans taking over as principal investigator of the group.

Sources of Funding

Code	Amount	Dates	Description
CERN/FIS-NUC/0017/2015	200.000 €	2015-04-01 / 2017-03-31	FCT - CERN related projects - Participation in COMPASS
CERN/FIS-PAR/0007/2017	165.000 €	2017-09-01 / 2019-08-31	FCT - CERN related projects - Participation in COMPASS

Stated objectives for past year

As objectives for 2017, the LIP COMPASS group stated the following:

- proceed the studies of the azimuthal spin asymmetries in the Drell-Yan data;
- study possible improvements for the 2018 polarized Drell-Yan data taking;
- start the study of J/Psi production in hadron collisions;
- conclude the spin asymmetries study at low-x and low Q^2, in order to extract the proton longitudinally polarised structure function g_1(x);
- continue studies on hadron, pion and kaon multiplicities;
- implement the Detector Control System (DCS) developments for the 2017 Run and guarantee the maintenance and on-call support during the whole data-taking period;
- participate in the discussion of physics challenges beyond 2020 and the corresponding COMPASS spectrometer upgrade.

Achievements and responsibilities during the past year

In 2015 COMPASS performed the first-ever dedicated polarized Drell-Yan experiment, with the aim of accessing the transverse momentum dependent PDFs of proton and pion. Two main analysis groups started working in the extraction of transverse spin dependent azimuthal asymmetries from Drell-Yan events, the LIP and the Torino groups. The results, obtained in record time, were shown for the first time at the IWHSS workshop in Cortona, Italy, by Márcia Quaresma, post-doc of the Lisbon group. The group participated in the writing of the paper, published in Phys.Rev.Lett. in September 2017. Although with limited statistics, this result hints at a confirmation that the

Sivers TMD PDF of the u-quark in the proton changes sign when accessed from semi-inclusive DIS (also measured in COMPASS), or from Drell-Yan. This sign change is considered a fundamental proof of the TMD approach of QCD.

Together with Drell-Yan, a large sample of J/psi events was collected in 2015. Charmonium production mechanisms are a long-standing topic of research, as well as the understanding of the J/psi polarization. The most well-known models of J/psi production, the color evaporation model (CEM) and the non-relativistic QCD model (NRQCD), are not successful at describing the observed distributions for both LHC energies and the typical energies of fixed-target experiments. The COMPASS J/psi data allow differential cross-section studies and comparison with models. Such studies, done with the participation of the LIP group, were pursued in 2017 and have shown the need for a dedicated generator tuning, adequate to the sqrt{s}=19 GeV of COMPASS.

The multidimensional analysis of the spin asymmetries produced in the muon scattering off a longitudinally polarized proton target, in the region of low-x and low Q^2, was completed by a member of the group (A. S. Nunes), as the topic of her PhD thesis. The results have shown for the first time a clearly positive asymmetry at low-x, without strong dependences in any of the studied variables, contrary to what was suggested by some phenomenological models. A paper was written with the participation of LIP members and is already submitted for publication.

The analysis of the charged kaon multiplicity ratio in the region of high-z (large energy transfer to the produced hadron), performed by Marcin Stolarski, surprisingly evidenced a violation of the QCD limit, which might be a sign of QCD factorization breaking. This result was presented for the first time by this researcher at the DIS conference in 2017. A paper is presently being prepared.

In what concerns the DCS system, several modifications were introduced in the course of 2017, to integrate additional monitoring parameters of the beam optics and cope with several hardware upgrades done at the frontend level. The team managed to guarantee extreme stability and reliability of the system during the whole 2017 Run.

Finally, the Lisbon group was deeply involved in the physics discussions that lead to the submission of an addendum to the COMPASS-II proposal in October 2017, requesting additional data-taking in 2021, to perform a DIS measurement with transversely polarized deuteron target. In the same addendum, a novel measurement of the proton radius from elastic muon-proton scattering is proposed. In parallel, a Letter of Intent for a future follow-up experiment is being prepared. Drell-Yan measurements devoted to a precise determination of the pion and kaon structure, and transversely polarized Drell-Yan using antiproton radio-frequency separated beam, are an important part of the physics topics covered. The preparation of this physics programme is co-responsability of Catarina Quintans.

Lines of work and objectives for next year

The LIP group plans to collaborate in the quasi-online analysis during the 2018 data-taking and in all the data quality tests needed. This requires permanent monitoring, either locally or remotely, and developing automatized methods for data quality control. Once the data-taking is completed, by mid-November, the main priority is going to be the data processing and analysis. This requires a critical selection of the periods presenting good and stable enough conditions for physics analysis. As already done for the 2015 data sample, the group will participate in this process, now with added experience. The analysis will follow, having as final goal the publication of TSAs from the combined 2015+2018 data sets.

Several team members are experienced and deeply involved in the Monte-Carlo (MC) simulations. Their skills will be used in the optimization of different tools, from the tuning of the physics generators PYTHIA and MadGraph5, to the Geant4 spectrometer simulation and to the reconstruction of events. A multivariate analysis for separately selecting the processes that accompany the DY is one of the main goals of the group. Unsupervised and supervised machine learning algorithms will be developed with the goal of attributing DY and J/psi probabilities to each dimuon event. The total dimuon sample is composed by the following processes: dimuons from semi-leptonic decays of open-charm mesons, dimuons from uncorrelated sources (combinatorial background from pn and kaon decays), dimuons from charmonia decays and dimuons from the DY process. Once the multidimensional parameterisation is built, concerning the classification of dimuon events according to the processes, one can envisage to significantly improve the statistical precision of the DY asymmetries using a weighted analysis. The DY mass range of 4.3 to 8.5 GeV, free from background contamination, was the one used up to now for the asymmetries extraction. The goal of the DY parameteterisation is to extend the lower limit to 2.5 GeV which, in an ideal scenario of perfect multidimensional separation of processes, would improve the statistical gain by a factor of 3. The multidimensional separation of DY events is an idea being developed by one of the LIP team members. The team working on multivariate analysis works in close contact with the recently established LIP Big Data Competence Center.

The data collected in 2016 and 2017 by COMPASS using muon beams of both charges is also planned to be studied by LIP team members who focus on the hadron multiplicities and fragmentation functions (FFs). The fact that free quarks cannot be observed in Nature but always fragment to hadrons in the final state, is expressed by the FFs, which can be extracted from measurements performed in the proposed program. Several existing measurements, including some earlier COMPASS ones in which the LIP team participated, cannot be fully used before the uncertainties of FFs are reduced, and this constitutes a strong motivation for the proposed analysis. COMPASS has recently published a set of unidentified hadron, pion and kaon multiplicities extracted in a wide kinematic range from SIDIS using a LiD target. These data are crucial input for any analysis of FFs. But larger impact can be achieved by adding the analysis

of the 2016 and 2017 data collected on a liquid hydrogen target. These data are much easier to analyse from the theoretical point of view. Moreover, the COMPASS spectrometer includes now a recoil proton detector and the upgraded RICH detector, essential for multiplicity studies. COMPASS is presently the only DIS experiment in the world with beam energy above 20 GeV, thus it is a world unique facility to perform this kind of measurement. The LIP team has been playing an important role in this context, by leading the study of the charged kaon multiplicity ratio at high momentum fraction of the virtual photon carried by the hadron, a world pioneering measurement. During 2018, these works are planned to be continued, with the support from one additional post-doc partly dedicated to this topic.

Concerning the DCS, the project itself is a permanently evolving task, both from the hardware and the software points of view. In 2018 it has to be adapted to the Drell-Yan setup needs, with specific detectors being re-installed, and several front-end equipments updated. The COMPASS DCS adopts the most up-to-date solutions used at CERN, such as the supervision program WinCC OA running in Linux since its beginning; the fast, light-weight and flexible DIM server-client communication system, now used for many customised control and monitoring situations; the radiation-tolerant ELMBs used for monitoring and control of power supplies and sensors; OPC servers and the WinCC OA Siemens client to connect to high and low voltage power supplies and PLCs; as well as other customised solutions for non-standard devices. The LIP team intends to continue the strategy followed so far. With the foreseen obsolescence of several frontend solutions used up to now, the group plans to start testing new options, in close cooperation with dedicated teams from CERN and with the LIP monitoring and control Competence Center.

SWOT Analysis

Strengths

The LIP group is fully integrated in the COMPASS Collaboration, taking part in the technical tasks and in many analyses. It is also deeply involved in the scientific strategy discussions involving the preparation of a future experiment on COMPASS physics and beyond. The many years of expertise in the DCS of the Experiment and the excellent performance and reliability of the system are well recognised by the Collaboration and also by CERN. Leading roles in coordination of physics analyses and in drafting of papers and proposals are taken by team members. The team is motivated and committed to the completion of the ongoing analyses. The knowledge within the group opens new possibilities for future studies. The 2018 data-taking provides the opportunity to improve the data-taking methodology. The LIP group is very well positioned to have a leading role in this respect.

Weaknesses and Threats

The group was restrutured during 2017. While the physics analyses and the responsabilities taken by team members are to be continued, the team is now reduced and up to now was not able to attract new master or PhD students to the project. In spite of the efforts of the group, by engaging in LIP outreach and training activities, these were not yet successful. The funding obtained via the 2017/2018 CERN Fund is not enough to pay a post-doc for more than 12 months, a clear problem the group has to solve until the end of 2018.

Opportunities

In 2017 the LIP group started a cooperation with the Aveiro University group which also participates in COMPASS. This synergy benefits both: the Aveiro group being focused on detectors and instrumentation, and the LIP group on detector controls and physics analyses, the cooperation opens new opportunities for the ongoing preparation of a new physics programme.

Cooperation with other groups in the COMPASS Collaboration will bring in 2018 two undergraduate students from the Torino University for an internship at LIP, in the context of the Erasmus+ program. The continuation and further exploring of this possibility is a clear opportunity to attract students and dynamize the LIP group.

The creation of the new LIP monitoring and control Competence Center also offers an opportunity of cooperation for our group, since the COMPASS DCS team members have valuable expertise in the field. The possibility for a future project involving this competence center and horizontal to the different LIP groups with DCS responsibilities, for R&D in this field, could be beneficial to all the parties involved.

Publications

9 Articles in international journals
(with direct contribution from team)

C. Adolph et al. (233 authors): "Multiplicities of charged pions and charged hadrons from deep-inelastic scattering of muons off an isoscalar target", Phys. Lett. B 764 (2017) 1-10

C. Adolph et al. (228 authors): "Exclusive omega meson muoproduction on transversely polarised protons", Nucl. Phys. B 915 (2017) 454-475

COMPASS Collaboration (210 authors): "Resonance production and pi pi S-wave in pi(-) + p -> pi(-) pi(-) pi(+) + p(recoil) at 190 GeV/c", Phys. Rev. D 95 (2017) 032004

COMPASS Collaboration (221 authors): "Leading-order determination of the gluon polarisation from semi-inclusive deep inelastic scattering data", Eur. Phys. J. C 77 (2017) 209

C. Adolph et al. (227 authors): "Multiplicities of charged kaons from deep-inelastic muon scattering off an isoscalar target", Phys. Lett. B 767 (2017) 133-141

C. Adolph et al. (228 authors): "Final COMPASS results on the deuteron spin-dependent structure function g(1)(d) and the Bjorken sum rule", Phys. Lett. B 769 (2017) 34-41

C. Adolph et al. (225 authors): "Sivers asymmetry extracted in SIDIS at the hard scales of the Drell-Yan process at COMPASS", Phys. Lett. B 770 (2017) 138-145

COMPASS Collaboration (228 authors): "First measurement of the Sivers asymmetry for gluons using SIDIS data", Phys. Lett. B 772 (2017) 854-864

M. Aghasyan et al. (219 authors): "First Measurement of Transverse-Spin-Dependent Azimuthal Asymmetries in the Drell-Yan Process", Phys. Rev. Lett. 119 (2017) 112002

1 International Conference Proceedings

Marcin Stolarski on behalf of the COMPASS Coll.: "Final COMPASS results on hadrons, pions and kaons multiplicities in SIDIS", PoS(DIS2017)235

Presentations

3 Oral presentations in international conferences

Márcia Quaresma: "DY at COMPASS: recent results on TSAs", 2017-04-04, IWHSS 2017, Cortona, Italy

Marcin Stolarski: "Final COMPASS results on hadron, pion and kaon multiplicities", 2017-04-04, DIS 2017 -- 25th Int. Workshop on Deep Inelastic Scattering, Birmingham, UK

Catarina Quintans: "Physics with pion induced Drell-Yan at COMPASS and future experiment", 2017-11-07, ECT* workshop – Dilepton Productions with Meson and Antiproton Beams, ECT*, Trento, Italy

3 Presentations in national conferences

Christophe Pires: "COMPASS Detector Control System", 2016-02-20, Jornadas LIP 2016, Braga, Portugal

Márcia Quaresma: "COMPASS and the Transverse Momentum Dependent Parton Distributions Functions", 2016-02-20, Jornadas LIP 2016, Braga, Portugal

Sofia Nunes: "Results on COMPASS longitudinally polarized data from LIP", 2016-02-20, Jornadas LIP 2016, Braga, Portugal

1 Seminar

Márcia Quaresma: "First worldwide results on Polarised Drell-Yan measured at COMPASS", 2017-05-05, LIP, Lisbon, Portugal

3 Outreach seminars

Marcin Stolarski: "Three quarks for Muster Mark", 2017-02-06, 2nd Lisbon Mini-school on Particle and Astroparticle Physics, Sesimbra, Portugal

Sofia Nunes: "COMPASS - Espreitando a Estrutura do Nucleão", 2017-03-02, Jornadas de Engenharia Física 2017, NFIST, IST, Lisboa, Portugal

Catarina Quintans: "The physics of the nucleon", 2017-07-18, Palestras dos Estágios de Verão LIP 2017, LIP, Lisboa, Portugal

Theses

1 PhD Theses

Sofia Nunes: "Study of asymmetries with polarised proton target at low xBj and Q2" (finished on 2017-12-07)

LERHI: LOW ENERGY REACTIONS WITH HADRONS AND IONS / COLLABORATION IN HADES AT GSI

HADES

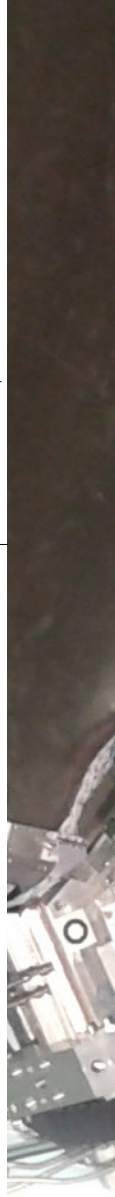
Overview

The LIP HADES group was originally created for the design and construction of a Time of Flight (TOF) detector based on Resistive Plate Chambers (RPCs), RPC-TOF-Wall (RPC-TOF-W), for he HADES spectrometer, operated at GSI, Darmstad, Germany. In recent years, the group was complemented with the incorporation of people from the LIP-COMPASS group who assumed tasks on the physics analysis.

Currently the group has assumed new commitments with the construction of a new TOF detector for the HADES forward region. With this, we continue developing this low cost, low gas consumption, high performance timing RPC technology in view of its possible utilization in other High Energy Physics Experiments.

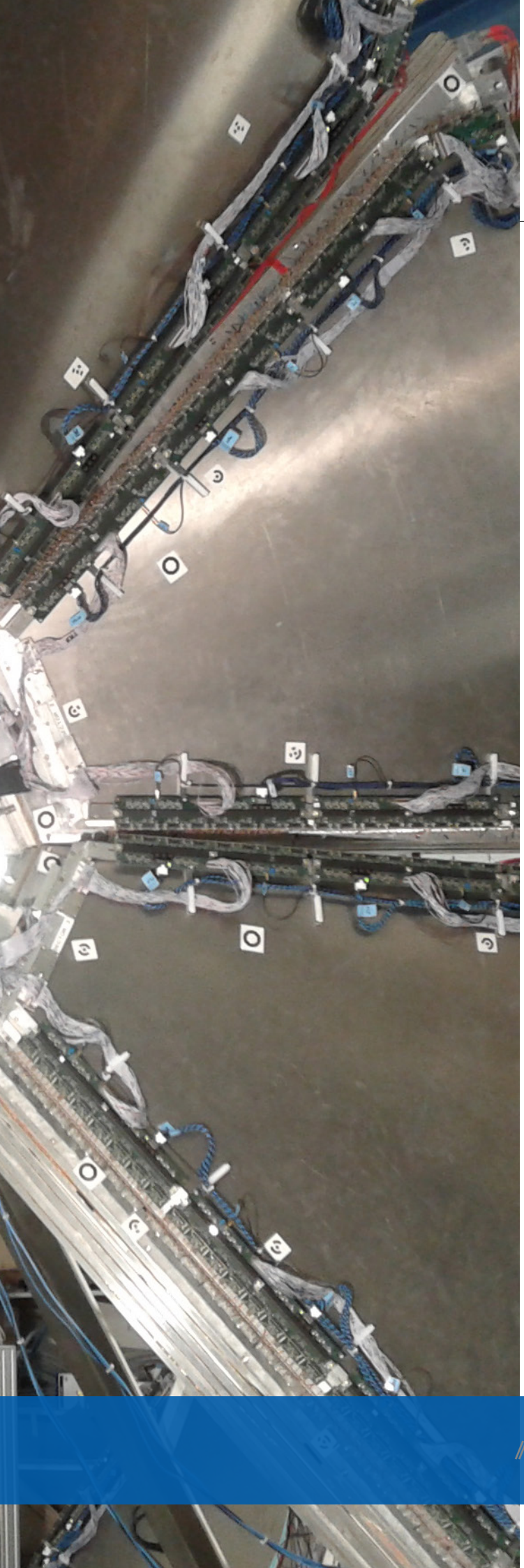
The accelerator infrastructure at GSI has been shutdown during the last three years and will resume its operation in middle of 2018. The performed upgrades will put into operation the future SIS100 synchrotron at the new FAIR facility, providing higher beam energies and intensities. HADES will be one of the first experiments to be operational at FAIR with the mission of providing high-quality dilepton data at baryon densities and temperatures not accessible by other detectors, neither in the past nor in the foreseeable future.

The group activities are financially supported only by a modest quantity in the framework of a MoU. Any opportunity of funding is pursued. In the last year a new project has been submitted to the national PTDC call. This time the project includes the contribution of a strong group from IST Lisbon, whose theoretical work is of special interest for HADES. With this joint effort we want to impulse, reinforce and complement the LIP-HADES group, which currently have competences in hardware and physics analysis, with a task within theory.



Summary of performance indicators

Articles in international journals:	4 With indirect contribution
International conferences:	1 Oral presentation
Collaboration meetings:	?



Team

Principal Investigator Alberto Blanco (30)

Researchers
Celso Franco (20), Luis Silva (10)(*), Paulo Fonte (10)

Technicians
João Saraiva (9), Luís Lopes (10),

PhD Student
Luís Pereira (17)

Total FTE

1.0

(*) Left in August 2017

// GROUPS: COMPASS / HADES / NUC-RIA

Lines of work and team organization

There are two main lines of work, one related to hardware and the other related to physics analysis:

Hardware:

- RPC-TOF-W operation. Operation of the RPC-TOF-W within the data taking periods and collaboration on general duties related with the data taking periods as HADES DAQ operator and shift leader. Responsibility: A. Blanco, C. Franco, P. Fonte, L. Lopes.
- Design and construction of the RPC-TOF-FD. In order to increase the acceptance of the spectrometer, a new detector, to cover the very low polar angles in the forward region, is being constructed. This new detector, Forward Detector (FD), is composed by a tracking detector and a TOF detector. The LIP group is in charge of the simulation, design and construction of the TOF detector of the FD, RPC-TOF-FD. Responsibility: A. Blanco, P. Fonte, L. Lopes, L. Pereira.
- Preparing the HADES Tracking System for High-Rate Experiments at SIS100. The future physics program of HADES at FAIR demands high detection standards and stability of the tracking system due to the expected increase of the beam energies and intensities. The LIP-HADES group collaborates in this task with the HADES-MDC group. Responsibility: L. Lopes.

Analysis:

Dilepton analysis: One of the major goals of HADES is the investigation of hadron properties inside a baryon-rich medium. According to the Chiral Mean Field model the baryonic densities achieved at HADES, with low energy heavy ion collisions (1-2 AGeV), are high enough to reproduce the state of matter resulting from the collision of two neutron stars. Besides the astrophysical relevance, this investigation is a unique contribution to the study of phase transitions in QCD matter: HADES is the only running experiment exploring the phase space at high densities (3 times the normal density) and moderate temperatures (70-80 MeV). The temperature achieved in a heavy-ion collision at HADES is enough to partially melt the quark-antiquark condensate responsible for the chiral-symmetry breaking in hadrons. Since this condensate is thought to be the main contributor to the hadronic masses, a detailed investigation of the "fireball" (dense medium created by the heavy-ion collision) can provide a clearer picture about the mechanism responsible for the mass generation in hadrons. The fireball of HADES is long-lived (up to a factor of 3 longer than the pion-rich fireballs produced at higher energy collisions) and is cleanly investigated by using dileptons coming from the decays of short-lived hadrons. Since these dileptons do not interact strongly within the fireball, they can be used as clean probes of the hadronic properties inside the dense medium. The LIP group collaborates in all the investigations of the HADES dilepton group.
Responsibility: C. Franco.

The LIP team is represented by the PI of the group (A. Blanco) in the HADES Technical Board and in the HADES Collaboration Board.

Stated objectives for past year

- Resume the HADES data taking after the upgrades of in the accelerator infrastructure.
- Finalize the implementation into the simulation software of the new detector, RPC-TOF-FD, and fine tuning the design. Assembly the first prototype of a RPC-TOF-FD module in order to evaluate the response to MIPs, namely efficiency and timing resolution.
- Possible re-installation of the RPC-TOF-W into the ECAL frame, depending on the construction delay of the ECAL frame.
- Collaborate in the construction at GSI of a new prototype of MDC.
- Investigation of the hadron properties within the dense medium produced by the Au+Au collisions. The dilepton thermal spectrum will be used in a multi-differential analysis to determine the lifetime and the temperature of the fireball. The in-medium modification of the $\rho 0$ properties will also be investigated. In parallel, the preparation of the next runs (2018 and 2019) will proceed with dedicated simulations.

Achievements and responsibilities during the past year

Detector

Due to the accumulated delay on the start-up of the new accelerator infrastructure, there was no beam available during 2017 and therefore no data taking for HADES.

The implementation of the RPC-TOF-FD into the simulation software has accumulated a considerable delay mainly due to the leaving of L. Silva from the group, who was in charge of this task. No significant progresses have beam made. The task was resumed at the end of 2017, by a new student L. Pereira, who will finalize the implementation during 2018. The prototyping of the RPC-TOF-FD accumulated some delay due to other commitments of the group members. The assembling of the first module started at the end of the year, and its finalization and evaluation is currently ongoing. The dismantling of the RPC-TOF-W from the HADES main frame (due to its reallocation into the ECAL mainframe) was accomplished with success at the middle of the year.

The MDC prototype (Lenav1) was constructed and tested at COSY.

Analysis

All physics goals for the year of 2017 were fully achieved. First, the experimental Au+Au dilepton mass spectrum (corrected for the efficiency, subtracted from combinatorial background and from the γ-conversion in the spectrometer) was subtracted from the contribution of first chance collisions by using the following HADES mass spectrum: 1/2(np + pp). Contributions from long-lived hadrons (hadronic cocktail), decaying outside of the fireball, were also suppressed. The main contributors from the hadronic cocktail are the π^0's, η's and ϕ's. Their contributions were determined by measurements of the charged pion multiplicities (π^0), double photon conversion (η) and from the K+K- channel (ϕ). After the subtraction of the first chance collisions and the hadronic cocktail, the dilepton mass spectrum revealed a strong excess yield with an almost exponential shape (above 150 MeV). By fitting this excess of thermal radiation it was found that the dense medium is radiating as a black body with a temperature of 72 MeV. This temperature is consistent with a significant drop of the quark condensate which is an order parameter of chiral symmetry restoration. By investigating the excess of thermal radiation as a function of the multiplicity of the collision it became clear that the medium does not result from simple nucleon-nucleon superpositions: it implies the existence of a regeneration of baryonic resonances. An interpretation for the dilepton excess yield comes from the additional contributions of the ρ self-energy inside a dense medium (namely by its coupling to the N*-hole loop). According to this interpretation the main contributor to the thermal dilepton spectrum is the N* resonance. Since the virtual photon mediating the N* decay fluctuates (mainly) into a ρ, due to the vector meson dominance, the observed excess yield of dileptons (below the ρ mass pole) is interpreted as resulting from a large broadening of the ρ inside the dense medium. In order to support this interpretation a preliminary comparison between the experimental results and simulation was already performed. The Au+Au collisions were simulated by using the Ultra Relativistic Quantum Molecular Dynamics model. The microscopic discription of the system was then combined with a coarse graining evolution of the fireball. A Preliminary Au+Au simulation using the coarse graining UrQMD embedded with a strongly broadened ρ meson shows a reasonable agreement with the experimental dilepton excess yield above 150 MeV.

From this simulation it was also extracted the lifetime of the fireball: 13 fm (it is long enough to allow for the in-medium decay of the ρ).

A paper was written concerning the dilepton analysis of the Au+Au data at 1.23 AGeV. It will be submitted to PLB in January or February 2018.

Lines of work and objectives for next year

The re-installation of the RPC-TOF-W in the new ECAL main frame will take place in the first trimester of the year. The RPC together with all subsystems and cabling will be reinstalled, which is a mayor operation.

The new accelerator infrastructure will resume its operation in 2018 and HADES will be one of the first experiments to have access to beam time. It is foreseen to take data with lighter nuclei systems, at a slightly higher energy, compared with Au+Au at 1.25 AGeV, in order to investigate the in-medium properties of hadrons in a more systematic way. Therefore, the RPC-TOF-W should be completely operative for this data.

The implementation of the RPC-TOF-FD will be finalized in the first semester of the year. With this, we will able to study the behaviour of the detector within the spectrometer and fine tune the design of the detector e.g., number of readout channels, exact geometry and position, parameters needed for the final production of the detector. In addition, the construction of the first prototype will be finalized early in 2018 and evaluated in order to measure the response to MIPs, namely efficiency and timing resolution. It is foreseen to test the prototype in beam or under a strong irradiation (Co or Cs source) to test the count rate performance of the module, a key parameter of the design. After validation of the prototype a total of four modules will be constructed and integrated into the HADES spectrometer by the end of the year.

The MDC prototype Lenav2 will be assembled trying to explore the lower limits of its drift cell sizes. The prototype will be tested in beam (HADES or COSY). Run aged chambers with water over four weeks at highest beam intensity; approve stability of old and aged chambers for future higher beam intensities at FAIR(we will try to go with spare chamber up to 5-6 times previous loads); most importantly, prepare the rebuild of Plane 2 within a collaboration of labs, namely LIP, GSI, HZDR and JINR Dubna.

In 2018 HADES has an approved Ag+Ag run using a beam energy of 1.65 AGeV. A member of the LIP group (C. Franco) will be one of the major driving forces concerning the analysis of these data using the dilepton channel. Currently HADES is the only running experiment investigating baryon-rich fireballs (3 times the normal density) of moderate temperatures (~70-80 MeV). Therefore, a systematic investigation of different collision systems using different beam energies is extremely important to improve our current understanding about the properties of QCD matter at high densities. The dilepton analysis of the Ag+Ag data is foreseen to start in the second half of 2018. Until then, besides the preparation and participation in the data taking, the group will also be involved in the preparation of the HADES Physics program for FAIR. One of the HADES goals will be the J/ψ studies in p+p and p+Au systems. The Lisbon group is planning to start developing a NLO J/ψ simulation for these systems. In 2019 HADES will take data with a pion (and maybe proton) beam. This data will be important for a better understanding of the vector meson-resonance couplings and their impact on the transition form-factors using the dilepton channel together with several others consisting on hadron pairs. These couplings are essential for the calculations of in-medium spectral functions and, consequently, they are crucial for the interpretation of the dilepton data from heavy ion collisions. In case the project submitted to the last national PTDC call is funded, there is the possibility to start this work still in 2018 in close collaboration with the group of Teresa Pena from IST.

SWOT Analysis

Strengths

- The skills and accumulated know-how on the construction of RPCs allowed us to build a detector able to run within specifications and flawlessly during all campaigns. Which is, most probably, the detector, of this kind, with best performance in the world.
- One of the team members has acquired, throughout his professional career, multidisciplinary competences, which will certainly add value to the scientific projects of HADES at FAIR. At the moment the group has strong competences in machine learning algorithms and in simulations. On the physics side, the group has competences in both particle and nuclear physics (studying processes involving leptonic, hadronic or heavy-ion collisions).

Opportunities

- The excellent work developed during the years leads now with the opportunity to build a new detector for the collaboration, the new TOF-FD.
- The performance and reliability demonstrated by the RPC-TOF-W is a good presentation letter for other experiments.
- One of the team members was responsible for one of the independent analysis of the main physics goal of HADES (using the Au+Au data). The acquired know-how will facilitate a possible integration of a student in the analysis activities. The experiment is about to start its first phase-0 run at FAIR and, therefore, it is the ideal time to integrate a student in the analysis group.

Weaknesses

The reduced number of team members and their commitments with other projects.

Threats

The lack of funding may strongly compromise all the group activities.

Publications

4 Articles in international journals
(with indirect contribution from team)

HADES Collaboration (109 authors): "Inclusive Lambda production in proton-proton collisions at 3.5 GeV", Phys. Rev. C 95 (2017) 015207

HADES Collaboration: "Delta (1232) Dalitz decay in proton-proton collisions at T=1.25 GeV measured with HADES at GSI", Phys. Rev. C 95, 065205

HADES Collaboration (117 authors): "Analysis of the exclusive final state npe(+)e(-) in the quasi-free np reaction", Eur. Phys. J. A 53 (2017) 149

HADES Collaboration (113 authors): "A facility for pion-induced nuclear reaction studies with HADES", Eur. Phys. J. A 53 (2017) 188

Presentations

1 Oral presentation in international conference

Celso Franco: "Exploring dense matter with Au+Au collisions at HADES", 2017-09-25, ISPUN17, Halong City, Vietnam

LERHI: LOW ENERGY REACTIONS WITH HADRONS AND IONS / EXPERIMENTAL NUCLEAR ASTROPHYSICS

NUC-RIA

Overview

In 2017 the main focus remained the participation in the R3B collaboration at FAIR. Following the CALIFA benchmark experiment, the conclusion of the analysis of previous experiments covered most of the year's activity. The Thesis defense of Ana Henriques and the submission of Paulo Velho's highlight this point. Complementarly, the group is involved in experimental proposals for the Phase-0 of FAIR in 2018-19, keeping the focus on the study of knockout reactions on halo nuclei at relativistic energies.

Regarding the participation at ISOLDE/CERN, a Letter of Intent to the execution of nuclear astrophysics experiments was submitted, specific targets were developed in Lisbon for experiment IS619, and grouped a consortium to continue the participation at ISOLDE for the upcoming 2 years which was approved for funding.

The transfer of technology aspect is awaiting for the resolution of a project, in consortium with a company, devoted to study the effects of radiation on fresh fruits.

Summary of performance indicators

Articles in international journals:	4 With direct contribution from team
Completed theses:	1 PhD Thesis

Team

Principal Investigator Daniel Galaviz (100)

Researcher
Ana Isabel Henriques (100)

PhD students
Pamela Teubig (80), Paulo Velho (100)

Undergraduated students
André Baptista, Frederico Arez, Nuno Soares, Patricia Marques

Additional Collaborators
David Ferreira, Miguel Marques, Ricardo Honório

Total FTE
3.8

// GROUPS: COMPASS / HADES / NUC-RIA

Lines of work and team organization

The group basicaly maintains last's years structure, with Daniel Galaviz as main researcher and without presently additional researchers with a PhD. The four topics which define the lines of work carried out by the group are still:

- High-energy reactions and data analysis on exotic nuclei at GSI/FAIR.
- Instrumentation for upcoming experiments at R3B/FAIR
- Low-energy reactions on stable and unstable nuclei for nuclear astrophysics.
- Technology transfer, namely contributions to the study of electron beam food irradiation.

After the PhD defense of Ana Henriques, two PhD candidates (Pamela Teubig and Paulo Velho) at their final stages remain in the structure. Collaborations with students at bachelor and master level occur, without effectively integrating the core of the research group. During 2018, Elisabet Galiana (a PhD student at the University of Santiago de Compostela) will join the group. The will remains to incorporate additional postdoctoral researchers and PhD candidates in the group, in order to better distribute and execute the various tasks associated to each line.

Stated objectives for past year

- Analysis of CALIFA experimental data: Advance with the analysis of the data measured in the Lisbon experiment in November 2016.
- R3B Day-Zero experiments in 2018: Preparation for the participation of the group in the first line of experiments devoted to detector benchmarking of the R3B collaboration starting towards the end of 2018. Contribution as well to the submission of experimental proposals on the study of neutron knock-out reactions on halo nuclei using the upgraded experimental setup.
- Experimental activity at ISOLDE: Involvement in the experimental campaign of ISOLDE experiment IS619, devoted to the study of the elastic scattering and the breakup probability of the halo nucleus 15C on a 208Pb target.
- ENSAR2 work within the “SaTNURSE” JRA: In collaboration with the University of Santiago de Compostela.
- Contribution to the IAEA CRP “Development of Electron Beam and X-Ray Applications for Food Irradiation”

Achievements and responsibilities during the past year

The following aspects during 2017 are worth mentioning:

- Analysis of knock-out reaction data: The conclusion of the analysis of the knock-out reaction data from the GSI experiment S393 was one of the main achievements of the past year. Ana Isabel Henriques defended her PhD-Thesis on July 21st, and Paulo Velho already submitted the PhD-Thesis work (defense expected during this year). The results were presented in collaboration meetings and their publication is expected over the upcoming months.
- Analysis of CALIFA experimental data: A first glimps of the data measured during the benchmark experiment of the future CALIFA calorimeter, performed in Lisbon, was obtained. The measurement of photons with energies beyond 12 MeV was confirmed and presented as well in collaboration meetings.
- Experimental proposal for R3B Day-Zero experiments: In addition to the measurements devoted to the benchmark of detectors of the upgraded R3B setup, the group also joined a consortium of groups proposing a physics program containing the study of neutron knock-out reactions on neutron--rich unstable nuclei. The proposal was recommended to get beam time, and presently is scheduled for 2019. The group will get responsibility on the study of the neutron knock-out reactions on 17C and 14B, two neutron halo systems closer to the dripline that the previously studied 11Be and 15C.
- Contribution to IS619: After joining the experimental proposal IS619 at the ISOLDE/CERN laboratory, the group provided a direct contribution to the execution of this experiment during August 2017. Using the Ultra-High Vacuum Evaporator available in Lisbon, the group produced isotopically enhanced 208Pb thin targets and brought them to the ISOLDE laboratory prior to the start of the measurement. The targets were succesfully used during the run. Four members of the group also took part in the preparation and execution works of the experiment at the ISOLDE lab.
- Connected to the previous activity, the group joined the proposal to obtain funds for the continuation of the participation at the ISOLDE lab. The proposal was recommended for funding, seccuring this line of research for the upcoming two years. The activity at the ISOLDE laboratory was complemented with the submission of a letter of intent for the realization of experiments focused on nuclear astrophysics using the post-accelerated line HIE-ISOLDE.

Lines of work and objectives for next year

The group has been integrated into the LERHI (Low Energy Reactions with Hadrons and Ions) research line, together with the group working at the HADES experiment at GSI. The interaction with the HADES group should not only result in an increase of the collaboration between LIP groups at the GSI laboratory, but also opens new perspectives for the future participation in the FAIR experiments to which the groups already belong. Following this topic, the main lines of work and goals for the present year are:

- R3B Day-Zero experiments in 2018: The Phase-0 of experiments at FAIR will start during the second half of 2018. The group intends to join the various benchmark runs that are already scheduled for this year. This should provide the solid basis for the execution and analysis of the data expected to be measured during 2019, with strong focus from the group study of knock-out reactions on halo nuclei at the R3B setup.

- Conclusion of the analysis of CALIFA benchmark experiment at Lisbon: The benchmark of existing photon-energy reconstruction algorithms and the search for angular correlations obtained during the experiment performed with units of the future CALIFA calorimeter will be concluded during the present year. This data will have a positive impact in the contribution of the group to the characterization of the detectors during the Phase-0 experiments expected for this year as well.

- One of the listed achievements was the continuation of the participation of the group within the existing consortium of Portuguese groups working at the ISOLDE/CERN laboratory, this time having LIP as institution. Along this line, the participation of the group at the ISOLDE laboratory should be reinforced during 2018, with the participation of the group in additional experimental runs and the proposal of a new line of research devoted to the study of nuclear reactions devoted to the field of nuclear astrophysics.

- Following the participation of the group in the ENSAR2 consortium, Elisabet Galiana will join the group during 2018. Her participation will reinforce the research line devoted to R3B, and open a line of work at the same time devoted to the development of applications to material analysis using GEANT4. Her contribution will be present within the Simulation and Big Data Competence Center created at LIP that the group has already joined.

- Contribution to the IAEA CRP "Development of Electron Beam and X-Ray Applications for Food Irradiation": Based on the weak contribution during 2018, and still waiting for the resolution of a research project submitted to the Portugal2020 Programme, the work on this topic should be reinforced during 2018, with more studies devoted to the modelling of the dose distribution in fresh fruits when treated with electron and photon beams from accelerators.

SWOT Analysis

Strengths

involvement in international collaborations. Knowledge in nuclear instrumentation, data analysis, particle transport simulations, and nuclear astrophysics. Participation over the years in experiments performed in various radioactive and stable beam accelerator institutes.

Weaknesses

The reduction of senior members and the lack of funding to attract and retain new members. This lack of funds also affects the possibility to effectively contribute to the construction of new detection systems in the international collaborations the group is involved in.

Opportunities

The participation in the consortium ENSAR2 of Horizon2020 allows the participation and active involvement in nuclear reaction experiments performed in radioactive and stable ion beam facilities in Europe until 2020. The ChETEC COST activity also opens a spectrum of opportunities in the field of Nuclear Astrophysics.

Threats

The possibility to effectively contribute to the next generation facilities like FAIR is presently real. If the group does not manage to execute such contribution, future participations in this facility and the frontier physics that will be performed is under threat.

Publications

4 Articles in international journals
(with direct contribution from team)

M. Heine, S. Typel, M. R. Wu, et al. (R3B Collaboration): "Determination of the neutron-capture rate of C-17 for r-process nucleosynthesis", Phys. Rev. C 95, 014613 (2017)

C. Rodriguez-Tajes, F. Farget, L. Acosta, H. Alvarez-Pol, M. Babo, F. Boulay, M. Caamano, S. Damoy, B. Fernandez-Dominguez, D. Galaviz, G. F. Grinyer, J. Grinyer, M. N. Harakeh, P. Konczykowski, I. Martel, J. Pancin, G. Randisi, R. Renzi, T. Roger, A. M. Sanchez-Benitez, P. Teubig,M. Vandebrouck: "First inverse-kinematics fission measurements in a gaseous active target", Nucl. Phys. A 958, 246 (2017)

R. Caballero-Folch, C. Domingo-Pardo, J. Agramunt, ..., D. Galaviz, et al.: "beta-decay half-lives and beta-delayed neutron emission probabilities for several isotopes of Au, Hg, Tl, Pb, and Bi, beyond N=126", Phys. Rev. C 95, 064322 (2017)

M. Vanderbrouck, A. Lepailleur, O. Sorlin, ..., A. Henriques, ... , D. Galaviz, ..., P. Velho, et al.: "Effective proton-neutron interaction near the drip line from unbound states in F-25,F-26", Phys. Rev. C 96, 054305 (2017)

Theses

3 PhD Theses

Paulo Velho: “Study of ground state properties of halo nuclei via quasi- free scattering reactions at the R3B setup at GSI” (ongoing)

Pamela Teubig: “Advanced simulation and particle reconstruction in the CALIFA calorimeter and data analysis treatment for the R3B experiment at FAIR” (ongoing)

Ana Isabel Henriques: "Study of ground state properties of the halo nucleus 11Be via scattering on a proton target at quasi-free scattering conditions performed at the R3B setup at GSI" (finished on 2017-07-21)

Cosmic rays

COLLABORATION IN THE AMS EXPERIMENT

AMS

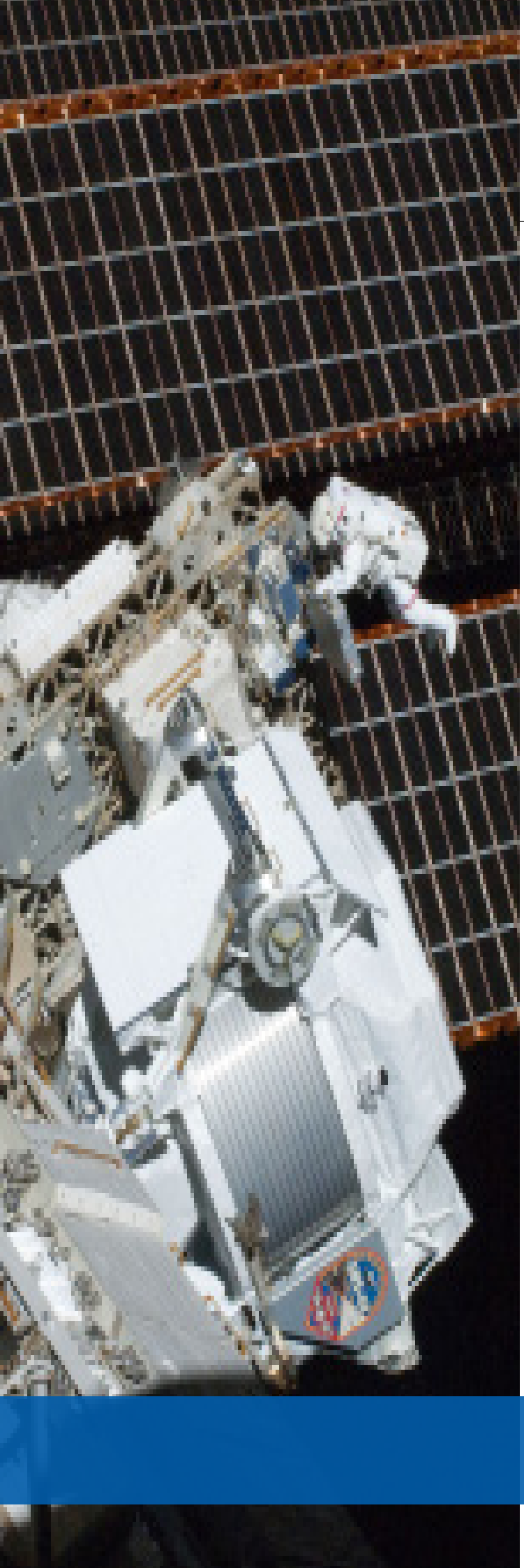
LIP is part of a broad international collaboration since 1998, that designed and operates the Alpha Magnetic Spectrometer (AMS). The project had two distinct phases: first a prototype was built and flewn aboard the space shuttle in 1998 and, later, a final detector was installed in the international space station (ISS), in May 2011. The experiment is expected to be carried out at least up to 2024.

Since May 2011, a large set of data has been gathered at a continuous rate of ~40 million events/day, corresponding now to around 112 billion events recorded. Before the launch of AMS, the LIP group took a leading role in the design, study, simulation and reconstruction activities of the RICH subdetector, aiming at measuring particle's velocity very precisely. On that context, the group is responsible for the development, implementation and maintenance of a set of algorithms for reconstructing the particle's electric charge and velocity in the RICH detector. Following the launch of AMS on 2011, the group got involved on data analysis, with particular emphasis on variability studies of particle fluxes related to solar activity.

Overview

Summary of performance indicators

Articles in international journals:	1 With direct contribution 2 With indirect contribution
National conferences:	1 Oral presentation 2 Poster presentation
Seminars:	2 Outreach seminars



Team

Principal Investigator Fernando Barão (60)

Researchers
Luísa Arruda (20), Paula Bordalo (25)(*), Sérgio Ramos (25)(*)

PhD students
Miguel Orcinha (100)

Master students
Pedro Nunes (67)

Total FTE
3.0

(*) Starting in September 2017

// GROUPS: AMS / Auger / LATTES

Lines of work and team organization

The main activities where the group is involved are the following:

1. RICH subdetector data reconstruction

The LIP group was responsible for one of the two sets of reconstruction algorithms implemented in the RICH subdetector of AMS. The algorithms provide measurements of particle velocity and electric charge based on Cherenkov ring patterns.

2. AMS data variability studies

Solar activity, varying in a periodic way, affects cosmic ray fluxes arriving at Earth, particularly up to rigidity cutoff values around 20 GV. Such variations are expected to depend on the particles charge sign. Since 2011 the LIP group is involved in the study of the solar modulation of cosmic rays and in it interpretation under Solar modulation models.

3. Particle identification and isotopic measurements

The group has also been involved in data analysis with particle identification, based on BDT or PDF techniques. Such tools can be used on anti-proton/electron separation and on isotopes identification.

Observations of light isotopes provides information on the origin of cosmic rays and propagation in the Galaxy. The study of unstable isotopes, like ^{10}Be, is essential to disentangle the size of the galaxy halo from the diffusion coefficient, reflecting the strength of the diffusion process cosmic rays undergo. These are two key parameters of cosmic rays propagation. Some isotopes are of primary origin while others are produced by collisions of cosmic primaries with the interstellar matter.

4. AMS POCC activities

The AMS detector monitoring and operation is carried out 24h/24h in the POCC (Payload Operations and Control Center) head-quartered at CERN. LIP team members participate regularly in the activities, performing shifts and acting as on-call experts for the RICH detector.

Sources of Funding

Code	Amount	Dates	Description
CERN/FIS-PAR/0020/2017	35.000 €	2017-09-01 / 2019-09-01	FCT - CERN related projects - Participation in AMS

Stated objectives for past year

The main objectives of the group for 2017 were:

- to fulfill our engagement in the monitoring operations at CERN
- the performance monitoring of the reconstruction tools developed by the group
- to participate on the data analysis effort of AMS:

  - variability studies of cosmic-ray fluxes (protons, electrons, ...)

  - nuclei selection and isotopic studies

Achievements and responsibilities during the past year

The group (FB, MO) participated in the monitoring operation at CERN.

During the first three months of the year the group received, as an invited scientist, Nicola Tomassetti, a fellow of the Marie-Curie program at Peruggia (INFN), Italy, and a cosmic ray expert bridging phenomelogical aspects related to cosmic ray propagation and data analysis interpretation.

Together with Nicola the team developed a propagation model to interpret cosmic ray flux time variations under solar modulation using solar parameters such as solar magnetic field axial inclination and number of sunspots. Using this model, the team was able to show evidence of a time-delay of ~8 months between solar parameter observations and their effect on the cosmic ray flux. The measurement of this time-delay also enables predictability of the cosmic ray flux since it allows for the connection of current solar parameters with future cosmic ray flux intensity. This study resulted in an article featured as a highlight by the AAS-NOVA editors.

MO continued his analysis on the time variability of the low-energy proton flux of AMS. A proton selection was developed and a study on the different selection efficiencies involved was performed. A time-dependent proton flux was estimated and is now under study. Flux unfolding is still a point of interest for this analysis and the inclusion of Monte-Carlo reweighting and reselection is still in development. Understanding the folding effect introduced by the detector is a key factor in flux estimation.

LA was responsible for the RICH reconstruction performance monitoring. The RICH detector response presents no particular variations with time.

FB spent two months as invited scientist at the LPSC/CNRS laboratory in France, in Grenoble. During that time he started working on isotope analysis.

Lines of work and objectives for next year

Monitoring and operation of the RICH detector in the POCC control room at CERN

The LIP team members will participate in the AMS mission control activities, performing shifts and acting as on-call experts for the RICH subdetector. LIP shifters are also responsible for monitoring the RICH, TOF and ECAL subdetectors and reporting any anomalies to shift leaders and on-call experts assigned to each specific subdetector. When acting as on-call experts, they are responsible for reporting the RICH detector's behaviour to the collaboration in daily briefings and performing contingency procedures if any issues occur with the RICH. These tasks have been undertaken by all AMS LIP members since the beginning of AMS operations in Space in order to guarantee the detector's performance and the good quality of the measurements. LIP is responsible for guaranteeing a "shifter" at CERN for 6-10 days every 2 months.

Variability studies of proton and electron fluxes at low energy and their interpretation under Solar modulation models

By making use of AMS' large exposure time and measurement precision, several studies will be performed in order to fully characterize the solar modulation phenomenon. The different temporal structures in solar modulation will also be studied by making use of the high temporal resolution available in AMS-02 data. Solar modulation also presents a charge sign dependency that should be studied as it is essential towards the comprehension of most of its different aspects.

This topic will involve the following steps:

- Estimation of electron fluxes
- Charge signal effect on cosmic ray flux
- Temporal variability study of cosmic ray fluxes (frequency analysis, time correlation with solar events)
- Usage of the propagation platform developed for the time-delay analysis on MO's time dependent proton flux
- Development and improvement of data analysis platform focused on systematic estimation, flux unfolding techniques and inclusion of additional particle selections (positron, anti-proton, helium and electrons)

Light isotope nuclei identification

Light isotopes like H and ^{4}He (and CNO) are believed to be of primary origin. Rarer CR elements such as ^{2}H, ^{3}He (and Li-Be-B) are believed to be of secondary origin, i.e. produced by collisions of primary cosmic rays with the gas nuclei of the interstellar medium (ISM). The secondary cosmic ray flux depend on the

abundance of their progenitors nuclei, their production rate and their diffusive transport in the ISM. Thus, secondary to primary ratios are used to discriminate among propagation models. The comparison between radioactive and stable nuclei (e.g., ^{10}Be/^{9}Be) will allow to estimate the halo size and the cosmic ray Galactic confinement time (diffusion).

The AMS isotope analysis aims at measuring the fraction of isotopes that can be found on cosmic rays for different elements like Helium (^{3}He, ^{4}He) – primordial, and Lithium (^{7}Li, ^{6}Li) and Beryllium (^{10}Be, ^{9}Be) – of secondary origin. Isotope identification requires a detector that can provide a good mass separation. The ability to separate masses relies on a good measurement of both velocity and momentum. In AMS, particle momentum is measured with a resolution of ~10 % up to ~ 20 GV, degrading a bit at very low momenta due to multiple scattering. While particle velocity is measured (RICH) with a 0.1 % precision for Z=1 particles. Given such resolutions, in order to explore a domain of energy as large as possible in isotopes identification, it is necessary to develop mass template fit methods.

RICH performance

The knowledge of heavy nuclei fluxes provides valuable information on the primary sources of cosmic rays and propagation parameters. For instance, the diffusive halo height is a key ingredient in the prediction of dark matter induced fluxes. As AMS gathers more events, these lower fluxes are now able to be estimated with meaningful statistics and accuracy.

The main challenge with selecting heavier nuclei comes from their non-negligible probability of fragmentation inside the detector, creating a very particular pattern of events which are characterised by lower charge particles and often disregarded. Including these events would generate a more appreciable accuracy.

The group intends to develop a selection framework for heavier nuclei in order to estimate their rates and study their interactions with the detector. These events will also be used to study the RICH detector.

Following the work the group has done on the RICH subdetector, and the extensive knowledge collected over the years, the group will continue it involvement by studying performance as a function of time, both on velocity and charge reconstruction. The RICH was built to provide AMS with the most precise velocity measurement and, concerning the LIP algorithm, it is the team's responsibility to guarantee this.

SWOT Analysis

Strengths

It is a highly experienced team in both experimental physics and astroparticle physics topics.

It keeps international relationships with several research laboratories in the field of study of the group. It has extensive computational skills spread throughout several platforms, OS's and programming/scripting languages. It has experience in numerical resolution of physical problems.

It developed, in collaboration with another laboratory, a very well sedimented analysis framework with large potential for expansion and adaptation, already in use on an international level by other members of the AMS collaboration.

Weaknesses and Threats

The main weakness, which is also a major threat, is the low funding attributed, combined with the small size of the group.

Oportunities

AMS keeps being a unique observatory in space. The increased interest by the scientific community in topics such as dark matter origin and cosmic anti-matter brings AMS to the spotlight as being an extraordinary source of knowledge. Due to AMS' high exposure time, nucleon and anti-matter fluxes are now able to be studied with sufficient accuracy due to the sheer amount of data. Another emerging topic in the international scientific community is time-variability of cosmic ray fluxes.

Publications

1 Article in international journals
(with direct contribution from team)

Nicola Tomassetti, Miguel Orcinha, Fernando Barão, and Bruna Bertucci: "Evidence for a Time Lag in Solar Modulation of Galactic Cosmic Rays", 2017 ApJL 849 L32

2 Articles in international journals
(with indirect contribution from team)

A. Ghelfi, F. Barao, L. Derome, D. Maurin: "Non-parametric determination of H and He interstellar fluxes from cosmic-ray data (vol 591, A94, 2016)", Astron. Astrophys. 605 (2017) C2

AMS Collaboration (257 authors): "Observation of the Identical Rigidity Dependence of He, C, and O Cosmic Rays at High Rigidities by the Alpha Magnetic Spectrometer on the International Space Station", Phys. Rev. Lett. 119 (2017) 251101

Presentations

1 Oral presentation in national conferences

Miguel Orcinha: "Solar modulation of the galactic cosmic-ray flux", 2017-03-24, LIP PhD Student's workshop, Coimbra

2 Posters presentations in national conferences

Miguel Orcinha: "Solar Modulation of Galactic Cosmic-Rays", 2017-04-05, IST PhD OpenDays, Instituto Superior Técnico

Miguel Orcinha: "Solar Modulation of Galactic Cosmic-Rays", 2017-10-12, Research Activity during the Top Industrial Managers Europe General Assembly, Instituto Superior Técnico

2 Outreach seminars

Miguel Orcinha: "A experiência AMS - Efeito do vento Solar", 2017-07-12, IDPASC Workshop "Hands on Particles and Light", Instituto Superior Técnico

Miguel Orcinha: "A Escuridão do Espaço - Matéria Escura e AMS", 2017-11-22, A Semana da Ciência e Tecnologia no LIP, Laboratório de Instrumentação e Física Experimental de Partículas

Theses

1 PhD Thesis

Miguel Orcinha: "Estudo da modulação Solar no fluxo de raios cósmicos com dados da experiência AMS" (ongoing)

1 Master Thesis

Pedro Nunes: "Análise de elementos isótopos presentes nos raios cósmicos com a experiência AMS" (ongoing)

HIGH ENERGY COSMIC RAYS

Auger

After more than a decade, the Pierre Auger Observatory is upgrading its detectors to operate at least to 2025.

The Observatory brought new fundamental insights into the origin and nature of highest-energy cosmic rays while raising further questions about their nature, origin and about the physics governing interactions at the highest energies.

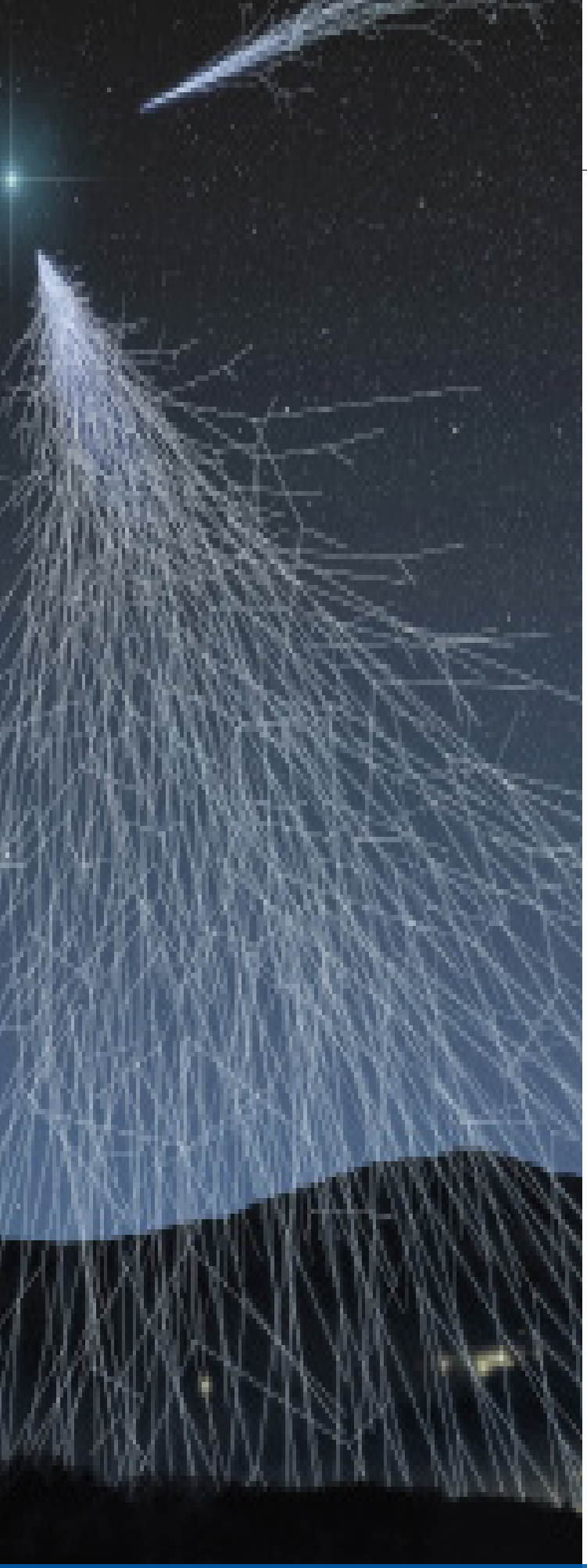
One of the most exciting results is the experimental confirmation that at the highest energies (7 orders of magnitude above what can be achieved at the LHC) the cosmic-ray flux is strongly suppressed. However the mechanism responsible for such suppression is still a subject of debate between a cosmic scenario, where sources exhaust, and the GZK scenario, where the energy of individual cosmic rays is degraded by their interaction with CMB photons in their voyage to Earth. Extensive Air Shower (EAS) parameters seem to favor a heavy composition scenario whereas the existence of anisotropies favors a light primary scenario. However, the mass of the primary Cosmic Rays can only be estimated if the shower development is clearly known. The interactions of the Ultra High Energy Cosmic Rays (UHECR) with the Earth's atmosphere are still poorly understood and the measurements of the EAS produced aren't able to shed light in a myriad of aspects of these interactions.

The Auger full detector upgrade, consisting on the installation of scintillators on top of the existing water tanks and on the electronics upgrade, aims at providing a better knowledge of the different components of EAS. A great effort is being done in next-generation analyses and in the development of hadronic models to attain a good description of the EAS observables and thus understand their development. The muonic component plays a big role, as it can probe directly the hadronic component of the shower in the early stages. This component is indirectly accessible with the new upgrade using refined analyses to estimate the muon content. A small part of the array will be equipped with extra detectors to understand and calibrate, at a lower energy, the full array measurements.

Overview

The LIP team has been deeply involved in the last years in the development of the MARTA project to measure directly the muon content at the shower front. An engineering array was funded in a very competitive joint FCT/FAPESP call for the installation at Malargüe of 8 surface stations (36 MARTA detectors). The project uses autonomous low gas flux, low cost, large surface (2 m^2) RPC detectors. More than 20 such detectors were produced at LIP-Coimbra and presently there are 6 such detectors at Malargue, some of them working continuously and successfully since almost three years, under extreme environmental conditions. MARTA detectors will be used for a deeper understanding of the Auger surface detectors, for the validation and test in situ of the scintillation detectors and for detailed shower studies at lower energies (10^{18} eV). This project is a close collaboration between Portugal and Brazil. MARTA detectors are also being installed at the CBPF in Rio de Janeiro. Their possible use in a future large field of view gamma-ray observatory at very high altitude in South America (LATTES) is a spin-off.

The LIP team has acquired a deep knowledge in shower physics and has developed innovative detailed analyses methods and tools that will allow us to give relevant contributions in the analysis of the new Auger data.



Team

Principal Investigator Pedro Assis (75)

Researchers
Alberto Blanco (26), Bernardo Tomé (60), Catarina Espírito Santo (25), Felix Riehn (100), Francisco Diogo (100), Helmut Wolters (20), João Espadanal (40), Liliana Apolinário (15), Lorenzo Cazon (100), Mário Pimenta (60),
Patrícia Gonçalves (15), Paulo Fonte (15), Pedro Abreu (60),
Pedro Brogueira (5), Raul Sarmento (100),
Ruben Conceição (60), Sofia Andringa (50)

Technicians
Américo Pereira (15), José Carlos Nogueira (96), Luís Lopes (35), Luís Mendes (85), Miguel Ferreira (85), Nuno Carolino (15), Orlando Cunha (15)

PhD students
Ricardo Luz (100)

Master students
David Christian Soares (41), Miguel Matos Ferreira (50), Paulo Ferreira (25), Steven Silva (100)

Undergraduate student
José Alves

External Collaborators
Alessandro de Angelis, Alexandra Fernandes, Rafaela Saraiva, Rui Figueiredo

Total FTE

15.9

Summary of performance indicators

Articles in international journals:	1 With direct contribution from team 10 With indirect contribution
Internal notes:	1 Collaboration note
International conferences:	4 Oral presentations 1 Poster 1 Proceedings
National conferences:	1 Oral presentation 2 Posters
Collaboration meetings:	8 Oral presentations
Seminars:	9 Seminars 3 Outreach seminars
Completed Theses:	1 PhD 2 Master

// GROUPS: AMS / Auger / LATTES

Lines of work and team organization

The Portuguese group in Auger has grown steadily. Its role and recognition in the collaboration are consolidated and its activities diversified.

The group is mainly focused on the full exploitation of the particle physics potential of the Observatory, namely in the efforts to understand hadronic interactions at high energies through a window that is largely complementary to the LHC.

On the detector development side the group has strong competences in Geant4 simulation and RPC development, in addition it has facilities for RPC development and production and a fast electronics laboratory.

The group pursues an ambitious program organized in the following tasks:

- Detector performance and calibration; Coordinator: Pedro Assis, Raul Sarmento
- MARTA RPCs R&D; Coordinator: L. Lopes, P. Fonte
- MARTA Engineering Array; Coordinator: P. Assis, M. Pimenta
- Shower Physics and Data Analysis; Coordinator: Lorenzo Cazon, Sofia Andringa
- Hadronic Models and interface with accelerator measurements; Coordinator: Ruben Conceição, Felix Riehn
- Auger Prime upgrade; Coordinator: Pedro Assis, Bernardo Tomé
- Education and Public Outreach; Coordinator: Pedro Abreu, Catarina E. Santo

Currently, L.Cazón is leader of the Shower Physics Task of Auger and P. Assis is leader of the Long Term performance task.

Sources of Funding

Code	Amount	Dates	Description
IF/00820/2014/CP1248/CT0001	50.000 €	2015-01-01 / 2019-12-31	FCT Exploratory research project (PI: L.Cazon)
CERN/FIS-NUC/0038/2015	150.000 €	2015-03-01 / 2017-02-28	FCT - CERN related projects - Participation in Auger
FAPESP/19946/2014	200.000 €	2015-09-01 / 2018-08-31	FAPESP (S. Paulo, Brazil) - FCT joint call for all domains
RPCs AUGER	30.000 €	2017-01-01 / 2017-12-31	RPCs AUGER
CERN/FIS-PAR/0023/2017	150.000 €	2017-06-01 / 2019-05-31	FCT - CERN related projects - Participation in Auger

Stated objectives for past year

The 2017 stated objectives for the different tasks were:

1. Use the hodoscope setup at a test tank in the Observatory central campus to measure conversion factors for VEM and study ageing effects. Also the response of the tank to very inclined muons would be pursued.

2. Pursue RPC R&D towards the production optimization and technology transfer to Brazil assuring the detector performance is maintained.

3. Start the production of the first engineering prototypes in São Carlos, Brazil, and have the first station taking data.

4. Study the muonic component for the understanding of Extensive Air Showers. Namely finish the measurement on the fluctuation on the number of muons and to study the shower driving quantities. Develop dedicated Monte-Carlo code for the study of the relation between shower observables and hadronic reactions

5. Increase the sensitivity and reduce the systematic uncertainty of the average longitudinal profile shape measurement. Try to disentangle the electromagnetic and muonic contributions by measuring the average lateral profile shape at intermediate zenith angle and test of the reconstruction model predictions.

6. Study the muon spectra and the proton-air cross section and their impact on the shower development, and their relation with high-energy interaction models. Pursue the development of analysis and strategies capable of discriminating between a change in composition and change of the proton-air cross-section.

7. Continuation of the activities based on the Auger public data set. Development of hardware for cosmic ray demonstrations and experiments in schools or with graduate students at the LIP and University labs

Achievements and responsibilities during the past year

The main achievements during the past year can be summarized as follows:

The MARTA hodoscope was used to measure the conversion constants to great accuracy. No ageing in these parameters, in this tank, was found, reaffirming the soundness of the Water Cherenkov Detector (WCD).

RPC R&D was finalized and technology transferred to São Carlos, Brazil. Two engineering prototypes were built in accordance with local available standard raw materials. The first 10 production enclosures were built and the assembly of the MARTA modules is ready to start at São Carlos.

Started a phenomenology study to understand the relationship between the first interactions properties and the muon content at ground.

The group is coordinating the publication of the Muon Production Depth full author paper.

The study on "Sensitivity of EAS measurements to the energy spectrum of muons" was published.

The RMS of the number of muons was studied and an editorial board for the publication was formed

The analysis developed by the group for the shower profile reconstruction has proven to be stable and is considered to become an official Auger reconstruction. The systematics uncertainties of the method are being studied prior to the publication of the method.

Benchmark scenarios were used to try to distinguish a scenario where hadronic interactions change rapidly at ultra-high energies from a scenario where the primary mass composition evolves with energy.

A Remote Operation Center was installed at IST with the capability to perform remote Auger Shifts. Last year the Portuguese Shift quota was fulfilled doing remote shifts from Lisboa.

Several events were organized for graduation students. This includes Cosmic Ray experimental setups and experiments. The idea is to get students in contact with Cosmic Rays at an early stage. Summer internships were organized fpr 3rd year students at LIP in which the use of Auger Public data was included.

Lines of work and objectives for next year

Next year will be crucial for the MARTA project as it is expected to have the installation of the first stations and first data. In early 2018 the supporting structures will be produced at the Auger site. They will be installed in the 2nd trimester, avoiding collision with the SSD deployment. Detectors are expected to be available at Malargue in the 3rd trimester. The final deployment is expected to be performed within a couple of weeks. We will focus on the production of all the necessary parts for the deployment. During this first phase we will prepare to explore the physics potential of the detector. We plan to start by defining the data formats and synchronization, which should be incorporated in the Auger main software, whilst starting a simulation campaign and develop the first specific analysis. First data is expected in the last trimester.

The SD detailed characterization will continue to be studied. We will focus on the Calibration of the tanks, and its inter-calibration with MARTA and AMIGA, a buried scintillator detector. We will also study the response of the WCD to very inclined muons. First data of the extended measurement range point to some inconsistencies in data that must be studied and understood.

A strong cooperation with the LATTES and RPC group will continue with the R&D of gaseous detectors. The slow control data of the detectors installed in Auger will be of extreme importance for the RPC study and to understand possible upgrades to the detectors. An effort to implement a systematic monitoring program is ongoing.

It is expected in next year to bring the study on the shower profile shape to publication state.

The Monte-Carlo developed will be further explored to put in evidence the correlation between fundamental properties of the initial interactions with the different observables at ground. The success of this work will be ground-breaking in the understanding of the process governing the cascade and its measurement.

The Phenomenology related with the muon energy distribution will be pursued to understand its importance and its relation with other shower parameters. We will also pursue a study for the measurement of the distribution using the new detectors installed at Auger.

The study on the measurement of the RMS of the number of muons will be finalized and subject of publication.

The outreach effort will be continued. Namely we will put great effort in lectures and activities directed to 3rd year master students as a mean to boost the recruitment of master students. We will also develop experimental setups for demonstrations and classes.

SWOT Analysis

Strengths

The LIP team is relatively large both in number of members and in competences. While the bulk of the team is in Lisbon, it relies on a close collaboration between the three LIP poles, with the involvement of the Coimbra RPC team and of the Minho analysis team.

In 2015 FCT renewed its commitment to the Portuguese participation in the Pierre Auger Observatory until 2025 providing a steady framework.

MARTA detectors have proved already their capabilities for running in harsh environments showing RPCs are suitable to be used in CR environment.

The group has a strong competence in the phenomenology of High energy Cosmic rays, namely in muon analyses and modelation.

Weaknesses

The team has a rather small number of master and PhD students which sometimes represent a lack of manpower for certain tasks.

The level of financing of the group is low for the number of team and for the responsibilities within the collaboration and the MARTA project. Meetings and field work in the latin America must wisely chosen.

Opportunities

The group will be in a privileged position for performing detailed and precise measurements of the muon component with the MARTA engineering array.

Visibility within the university is increasing (also with the installation of the Remote Control Room at IST) and this is an opportunity to attract new students.

R&D opportunities or potential applications for RPC in future astroparticle physics projects should be pursued and a great synergy with the Lattes group is established.

Threats

The funding level of the group might threaten the implementation of all of its research plan. Namely the installation of the MARTA engineering array will require a great financial effort.

The group must attract new students for its diversified activities. Funding of PhD students also composes a threat to the group.

Publications

1 Articles in international journals
(with direct contribution from team)

J. Espadanal, L. Cazon, R. Conceição: "Sensitivity of EAS measurements to the energy spectrum of muons", Astropart.Phys. 86 (2017) 32-40

10 Articles in international journals
(with indirect contribution from team)

A. Aab et al. (399 authors): "A Targeted Search for Point Sources of EeV Photons with the Pierre Auger Observatory", Astrophys. J. Lett. 837 (2017) L25

Pierre Auger Collaboration (399 authors): "Search for photons with energies above 10(18) eV using the hybrid detector of the Pierre Auger Observatory", J. Cosmol. Astropart. Phys. 4 (2017) 009

The Pierre Auger Collaboration: "Combined fit of spectrum and composition data as measured by the Pierre Auger Observatory", The Pierre Auger Collaboration, JCAP04(2017) 038

Pierre Auger Collaboration (402 authors): "Multi-resolution anisotropy studies of ultrahigh-energy cosmic rays detected at the Pierre Auger Observatory", J. Cosmol. Astropart. Phys. 6 (2017) 026

Pierre Auger Collaboration (406 authors): "Observation of a large-scale anisotropy in the arrival directions of cosmic rays above 8 x 10(18) eV", Science 357 (2017) 1266-1270

Pierre Auger Collaboration (404 authors): "Spectral calibration of the fluorescence telescopes of the Pierre Auger Observatory", Astropart Phys. 95 (2017) 44-56

Pierre Auger Collaboration (402 authors): "Calibration of the logarithmic-periodic dipole antenna (LPDA) radio stations at the Pierre Auger Observatory using an octocopter", J. Instrum. 12 (2017) T10005

LIGO Sci Collaboration & Virgo / Fermi GBM / INTERGRAL / IceCube Collaboration / AstroSat Cadmium Zinc Telluride / IPN Collaboration / Insight-Hxmt Collaboration / ANTARES Collaboration / Swift Collaboration / AGILE Team / The 1M2H Team / Dark Energy Camera GW-EM / DLT40 Collaboration / GRAWITA GRAvitational Wave / Fermi Large Area Telescope / ATCA Australia Telescope / ASKAP Australian SKA Pathfinder / Las Cumbres Observatory Grp / OzGrav DWF Deeper Wider Faster / VINROUGE Collaboration / MASTER Collaborat: "Multi-messenger Observations of a Binary Neutron Star Merger", Astrophys. J. Lett. 848 (2017) L12

ANTARES Collaboration / IceCube Collaboration / Pierre Auger Collaboration / LIGO Sci Collaboration & Virgo (1940 authors): "Search for High-energy Neutrinos from Binary Neutron Star Merger GW170817 with ANTARES, IceCube, and the Pierre Auger Observatory", Astrophys. J. Lett. 850 (2017) L35

The Pierre Auger Collaboration: "Inferences on Mass Composition and Tests of Hadronic Interactions from 0.3 to 100 EeV using the water-Cherenkov Detectors of the Pierre Auger Observatory", Phys. Rev. D 96, 122003 (2017)

1 International Conference Proceedings

Pedro Assis, Alberto Blanco, Nuno Carolino, Ruben Conceição, Orlando Cunha, Carola Dobrigkeit, Miguel Ferreira, Paulo Fonte, Luis Lopes, Ricardo Luz, Victor Barbosa Martins, Luis Mendes, Américo Pereira, Mário Pimenta, Raul Sarmento, Ronald Shellard, Vitor de Souza, Bernardo Tomé: "Autonomous RPCs for a Cosmic Ray ground array", PoS ICRC2017 (2017) 379

1 Collaboration notes with internal referee

P. Assis, A. Blanco, M. Cerda, R. Conceição, M. Ferreira, P. Ferreira, P. Fonte, L. Lopes, L. Mendes, M. Pimenta, R. Sarmento, R. Sato, R. Shellard, B. Tomé, H. Wolters: "Results on the Gianni Navarra tank VEM calibration using a RPC muon hodoscope ", GAP2017_027

Presentations

4 Oral presentations in international conferences

Raul Sarmento: "Muon measurements and hadronic interactions at the Pierre Auger Observatory ", 2017-03-22, 52nd Rencontres de Moriond, , La Thuile, France

Lorenzo Cazon: "The Pierre Auger Observatory: recent results and prospects", 2017-05-31, Blois 2017: 29th Rencontres de Blois on "Particle Physics and Cosmology", Blois, Loire Valley, France

Sofia Andringa: "Hadronic Interactions at Ultra High Energies – tests with the Pierre Auger Observatory", 2017-06-30, EDS Blois 2017, Prague, Check Republic

Felix Riehn: "Hadronic interactions at ultra-high energy", 2017-09-27, Workshop on forward physics and high-energy scattering at zero degrees 2017, Nagoya University, Japan

1 Poster presentations in international conferences

Ruben Conceição: "Autonomous RPCs for a Cosmic Ray ground array", 2017-07-15, 35th International Cosmic Ray Conference (ICRC2017), Busan, South Korea PoS ICRC2017 (2017) 379, arXiv:1709.09619 [astro-ph.IM]

1 Presentations in national conferences

Ricardo Luz: "MARTA front-end electronic and readout system", 2017-03-25, LIP PhD students workshop, LIP, Coimbra, Portugal

2 Poster presentations in national conferences

Ricardo Luz: "MARTA front-end electronic and readout system", 2017-04-05, PhD Open Days, IST, U. Lisboa, Portugal

Ricardo Luz: "MARTA front-end electronic and readout system", 2017-10-12, Técnico Lisboa Research Activity -, IST, U. Lisboa, Portugal

1 Oral presentations in international meetings

Ricardo Luz: "MARTA front-end electronic and readout system", 2017-05-26, 3rd IDPASC students workshop, U. Minho, Braga, Portugal

9 Seminars

Pedro Assis: "Ultra High Energy Cosmic Ray Puzzles", 2017-02-08, Second Lisbon mini-school on Particle and Astroparticle Physics, Hotel do Mar, Sesimbra, Portugal

Lorenzo Cazon: "The Pierre Auger Observatory: reaching beyond the 100 TeV frontier", 2017-02-08, Second Lisbon mini-school on Particle and Astroparticle Physics, Hotel do Mar, Sesimbra, Portugal

Ruben Conceição: "A road towards the highest energy interactions", 2017-03-07, , LIP

Sofia Andringa: "The Highest Energy Cosmic Rays at the Pierre Auger Observatory", 2017-03-29, Café com Física - seminários do DF da UC, Coimbra

Mário Pimenta: "MARTA and LATTES : R&D projects for a new generation of high energy cosmic rays and gamma ray experiments", 2017-06-20, , Prague, Czech Republic

Lorenzo Cazon: "Observation of a Large-scale Anisotropy in the Arrival Directions of Cosmic Rays above 8E18 eV", 2017-09-28, , LIP

Pedro Assis: "Showers from the far away Universe", 2017-11-08, , Instituto Superior Técnico, Universidade de Lisboa

Lorenzo Cazon: "Cosmic Rays with the Pierre Auger Observatory: messengers from the Ultra High Energy frontier", 2017-11-15, , Faculdade de Ciências, Universidade de Lisboa

Ricardo Luz: "Development of the instrumentation and readout schemes of MARTA ", 2017-12-04, Comissão de Acompanhamento de Tese, IST, Lisboa, Portugal

3 Outreach seminars

Mário Pimenta: "A aventura da Física de Partículas e Astropartículas no sec. XXI", 2017-05-03, , Planetário Calouste Gulbenkian, Lisboa, Portugal

Mário Pimenta: "A massa: Uma viagem pela Física do sec. XVII ao sec. XXI", 2017-05-13, , Montijo, Portugal

Raul Sarmento: "Cosmic rays and the Pierre Auger Observatory", 2017-07-15, Pecha Kucha Night Braga, Braga, Portugal

Theses

2 PhD Theses

Francisco Diogo: “Measurement of the longitudinal profile of cosmic ray air-showers at the Pierre Auger Observatory” (finished on 2017-05-04)

Ricardo Luz: “Development of the instrumentation and readout schemes of MARTA, an upgrade to the Pierre Auger Observatory” (ongoing)

4 Master Theses

Steven Silva: "Probing hadronic interactions at ultra-high energies" (finished on 2017-12-10)

Paulo Ferreira: "Response of a water-Cherenkov detector to inclined muons at the Pierre Auger Observatory" (finished on 2017-11-22)

David Christian Soares: "Muon energy spectrum in extensive air showers" (ongoing)

Miguel Matos Ferreira: "Average lateral distribution function of muons in 10^{17} eV extensive air showers" (ongoing)

HIGH ENERGY GAMMA RAYS

LATTES

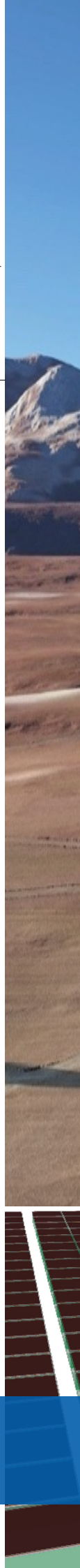
Present and planned large field-of-view (FoV) gamma-ray observatories are installed in the Northern Hemisphere, missing in particular the galactic center and have energy thresholds above 0.5 TeV.

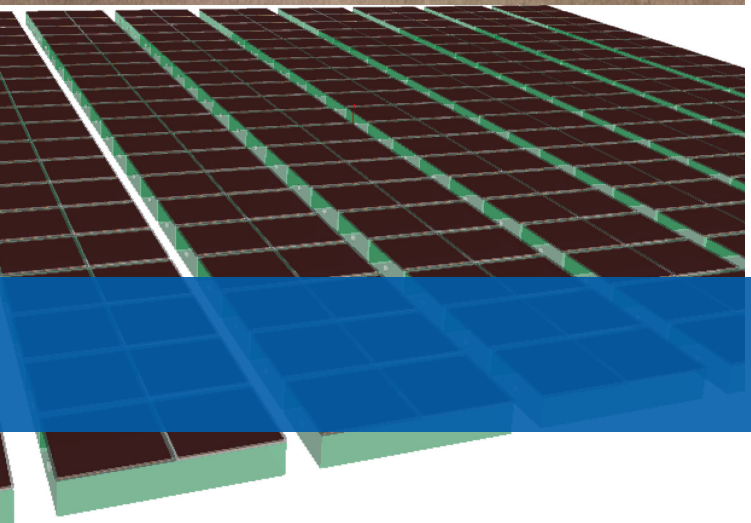
The goal of LATTES is to design, prototype and construct a ground array able to monitor the Southern gamma-ray sky above 50 GeV, bringing to ground the wide field-of-view and large duty cycle observations characteristic of satellites, with comparable sensitivity and a cost one order of magnitude lower. Such an instrument will be a powerful time-variance explorer covering a missing space in the global multi-messenger network of gravitational, electromagnetic and neutrino observatories. It will be able to issue pointing alerts to IACTs (Imaging Atmospheric Cherenkov Telescopes) and thus fully complementary to CTA. It will collect abundant and highly relevant data and play a fundamental role in the search for emissions from extended regions, as the Fermi bubbles or dark matter annihilation regions.

LATTES proposes an innovative concept: a compact EAS array of hybrid detector units, covering an area of at least 20,000 m2, to be placed at high altitude (about 5,000 m above sea level, a.s.l.) in the Southern hemisphere. Each detector unit combines two autonomous Resistive Plate Chambers (RPCs), with good space and time resolution with a Water Cherenkov Detector (WCD), ensuring trigger efficiency and efficient background rejection. The combination of the information collected by the two detectors allows a good sensitivity all the way down to 50 GeV.

Overview

The proposed solution relies on well-grounded R&D in which LIP has had a leading role. The LATTES concept has been proposed by scientists from Portugal (LIP), Brazil (CBPF) and Italy (INFN-Padova and Roma). To pursue such an ambitious goal, a sound international collaboration has to be formed.





Team

Principal Investigator Mário Pimenta (40)

Researchers
Bernardo Tomé (30), Catarina Espírito Santo (25), Fernando Barão (15), Paulo Fonte (15), Pedro Abreu (15), Pedro Assis (15), Pedro Brogueira (15), Ruben Conceição (40)

Technicians
Luís Mendes (15), Miguel Ferreira (15)

Undergraduate students
Gonçalo Raposo

External/Additional scientific collaborators
Adriano Henriques, Afonso do Vale, Alberto Blanco, Alessandro de Angelis, Inês Vieira, Luís Filipe Mendes, Luis Lopes

Total FTE

2.5

Summary of performance indicators

Articles in international journals:	2 with direct contribution from the team
International conferences:	1 Oral presentation 1 Poster presentation 1 Proceedings
National conferences:	1 Presentation
Seminars:	3 Seminars
Collaboration meetings:	14 Oral presentations
Organization:	2 Collaboration Meetings co-organized

// GROUPS: AMS / Auger / LATTES

Lines of work and team organization

Currently, the priority of the LATTES international team is to develop the concept in its different dimensions, bringing it to the point in which it is mature for the construction of a full scale experiment. For that, the following roadmap has been outlined:

- Completion of the detector R&D required prior to the construction of a detector unit, developing adequate technological solutions and demonstrating its feasibility.
- Construction of two full-size prototype detector units and demonstration of their functioning about 5,000 m a.s.l.
- Design optimization of a full array based on the developed units, with an area of the order of 20,000 m^2, assessing in detail its expected performance. The development of performant simulation and reconstruction tools is a crucial aspect.
- Construction of a 100 m^2 engineering array (EA) and its operation for extended periods at 5,000 m a.s.l. proving the feasibility, scalability and low cost of this innovative solution. While having a much reduced collection area, the EA exhibits already the low energy threshold of the full scale experiment and would be sensitive to transient phenomena with sufficiently high fluxes.

Naturally, the timescale and the successful completion of each of the steps in this roadmap depend upon external conditions. Efforts to build a strong collaboration, gain support within the community and attract funding are thus crucial. Nevertheless, each of these steps is in itself a sound R&D project, with high scientific interest for high-energy gamma-ray physics, and very promising scientific return in terms of results and of scientific production.

The Portuguese LATTES team is deeply involved in the project and currently has central responsibilities in the development of the simulation framework and evaluation of the expected performances, as well as in detector R&D, namely RPC R&D.

Stated objectives for past year

With the funding available last year, the main goals of the LATTES project resided in two major lines of work:

- continuing to work on the R&D of RPCs to operate outdoor with low flux and low maintenance, while performing long-term stability tests.
- consolidate the simulation used to extract LATTES preliminary performance results. Develop more sophisticated reconstruction analyses that allow to further explore LATTES capabilities.

Main Achievements

The 2017 achievements of the LIP LATTES team correspond to two lines of work and can be summarized as follows:

1. Detector R&D: The RPCs proposed for LATTES have been developed in the last four years at LIP-Coimbra, and tested under harsh conditions at the Pierre Auger Observatory site in Malargue, Argentina, at an altitude of 1,400 m a.s.l, with a low gas flux (1 to 4 cc/min). The tests done in outdoor conditions and with low maintenance continued during the year of 2017. The long-term stability is now demonstrated down to 4 cc/min. These results have been presented at the largest cosmic ray conference.
2. Simulation and analysis: The LATTES concept was developed and the baseline design was established. An end-to-end simulation was built in order to evaluate the performance of this detector concept under realistic conditions. Extensive air shower libraries were produced using CORSIKA while the detector simulation was done through the GEANT4 toolkit. Simulated shower events were then reconstructed allowing to evaluate the detector performance. Particular emphasis was given to: shower core reconstruction, shower geometry reconstruction (employing a conic model for the shower front), and gamma/hadron discrimination using only the WCD stations. This work led to a realistic estimation of the LATTES sensitivity to a steady source (Crab nebula). Obtained results were accepted for publication in the Astroparticle Physics Journal.

The LATTES concept and the results achieved so far were also presented in international meetings and conferences (see list below). General LATTES meetings were held in Rio de Janeiro, Brazil, and Padova, Italy.

Lines of work and objectives for next year

The level of activity in 2018 will depend on the available funding, but the main objectives in the different lines of work are:

1. Detector R&D

1.1 Adapt the RPC design to operate at a much reduced atmospheric pressure, to achieve a gas flux of 1 cc/min, and to make sure the required standards for remote, high-altitude locations are met. An small hypobaric chamber will be built in the LIP-Coimbra mechanichal workshop allowing the test of prototypes.

1.2 Develop a detailed thermal simulation of the detector in colaboration with IST experts. The goal is to predict the operation temperature of each detector component as a function of time (daily and seasonal variations). Particularly relevant is the study of water freezing in the WCDs. A grant for a master thesis on this subject will be offered.

1.3 Study the evolution of the freezing point and of the optical properties of sterilized water samples as a function different solvent concentrations. Experts from ITQB will collaborate in the project. The irradiation facilities at CTN may be used.

2. Simulation and analysis

A baseline design, able to reach, with good sensitivity, energies around 100 GeV has been established both for the detector unit and for the full array. Each unit (3 x1.5 m^2 surface, 0.5 m height) has three layers:

- a thin lead plate;
- a layer of glass RPC, sensitive to charged particles with very good space and time resolution;
- a shallow WCD readout by two photomultiplier tubes.

The full detector is an almost continuous carpet of individual stations placed along rows, each touching the other in their largest dimension, covering a total area of about 20,000 m^2.

Fundamental aspects for 2018 are:

2.1 Design optimization, considering in particular the possibility to add an external sparse array of detector units. This sparse array should not only allow to reach energy of 100 TeV, but also, as shown in preliminary studies, could greatly improve the sensitivity at lower energies, by removing high-energy showers that have the core outside the core-array.

2.2 Development of improved analyses methods for shower reconstruction and background rejection, combining the measurement of different detector components, in particular for low energy showers.

2.3 Evaluate the main background sources for operation of LATTES and explore the detector hybrid nature to develop strategies to mitigate these uncertainties.

3. Phenomenology

The LATTES science team is presently led by the Padova group, which has a long standing experience in gamma-ray astrophysics and a strong involvement in MAGIC, Fermi and CTA. The LIP team will increase its involvement in 2018. The complementarity with CTA and with other observatories will be explored.

4. Outreach

LATTES has a large potential to engage society with science. Target audiences will be schools, but also the general public. While the level of activity in 2017 and the timescale will depend on the available resources, medium-term targets, in collaboration with other astroparticle physics groups LIP groups, include:

4.1 Development and maintenance of a web site with outreach and educational purposes dedicated to the messengers of the most mysterious and energetic phenomena in the Universe (charged cosmic rays, gamma rays and neutrinos from astrophysics sources).

4.2 Development of portable, cheap and easy to operate detector units which can be used for demonstrations or installed in schools or science centers.

SWOT Analysis

Strengths

The team holds high-level expertise in cosmic-ray research and extreme energy phenomena, detector R&D, data analysis, simulation, air shower physics and phenomenology. In addition, the team has world-recognized expertise in RPC development and is involved in R&D for the construction of autonomous RPC for outdoor operation at very low gas flux;

The team has close links with other groups, in particular the CBPF group in the Pierre Auger Observatory and the INFN Padova group in high energy gamma rays. More recently, the Czech group (involved in the Pierre Auger Observatory and the Cherenkov Telescope Array) joined the efforts to further optimize the LATTES detector concept. As a consequence, the next LATTES meeting will be held in Prague.

Weaknesses

The team is a new-comer in the high-energy gamma-ray community.

Reasonably, Portugal will cover only a small fraction of the total cost of such an Observatory.

Opportunities

The energy threshold of the EAS experiments presently in operation or in construction remains very large and unable to bridge with data from satellite-borne experiments.

All the EAS experiments presently in operation or under construction are in the Northern hemisphere.

The recent observation of the first multi-messenger event combining the detection of gravitational and electromagnetic waves triggered a growing international interest in building such an Observatory in the South America.

The proposed detector concept has a large physics potential.

Threats

The resistance to a new concept of a community that is engaged in this domain since many years, and built and operates successfully the present experiments.

The technical, scientific and political problems that such an ambitious project will face.

Publications

2 Articles in international journals (with direct contribution from team)

P. Assis et al. (13 authors): "LATTES: a new gamma-ray detector concept for South America", EPJ WEB CONF 136 (2017) UNSP 03013

P. Assis et al. (13 authors): "LATTES: A new gamma-ray detector concept for South America", Nuovo Cim. C-Colloq. Commun. Phys. 40 (2017) 116

1 International Conference Proceedings

R. Conceição, P. Assis, U. Barres de Almeida, A. Blanco, B. D'Ettore Piazoli, A. De Angelis, M. Doro, P. Fonte, L. Lopes, G. Matthiae, M. Pimenta, R. Shellard, B. Tomé: "LATTES: a novel detector concept for a gamma-ray experiment in the Southern hemisphere", PoS ICRC2017 784 - Proceedings of the 35th International Cosmic Ray Conference (ICRC2017)

Presentations

1 Oral presentation in international conferences

Ruben Conceição: "LATTES: a novel detector concept for a gamma-ray experiment in the Southern hemisphere", 2017-07-17, ICRC 2017, 35th International Cosmic Ray Conference, Busan, Coreia do Sul

1 Poster presentation in international conferences

Alessandro de Angelis: "LATTES, a novel detector concept for a gamma-ray experiment in the Southern hemisphere", 2017-12-05, 29th International Texas Symposium on Relativistic Astrophysics, Cape Town, South Africa

1 Presentation in national conferences

Bernardo Tomé: "LATTES: a new gamma-ray detector concept for South America", 2017-07-21, XXVII Encontro Nacional de Astronomia e Astrofísica (ENAA), Lisboa, Portugal

3 Seminars

Bernardo Tomé: "Gamma ray physics at high altitude in the southern hemisphere.", 2017-02-08, Second Lisbon mini-school on Particle and Astroparticle Physics, Hotel do Mar, Sesimbra, Portugal

Ruben Conceição: "LATTES: a next generation gamma-ray detector concept", 2017-03-09, LIP seminar, Lisbon, Portugal

Mário Pimenta: "MARTA and LATTES : R&D projects for a new generation of high energy cosmic rays and gamma ray experiments", 2017-06-20, , Prague, Czech Republic

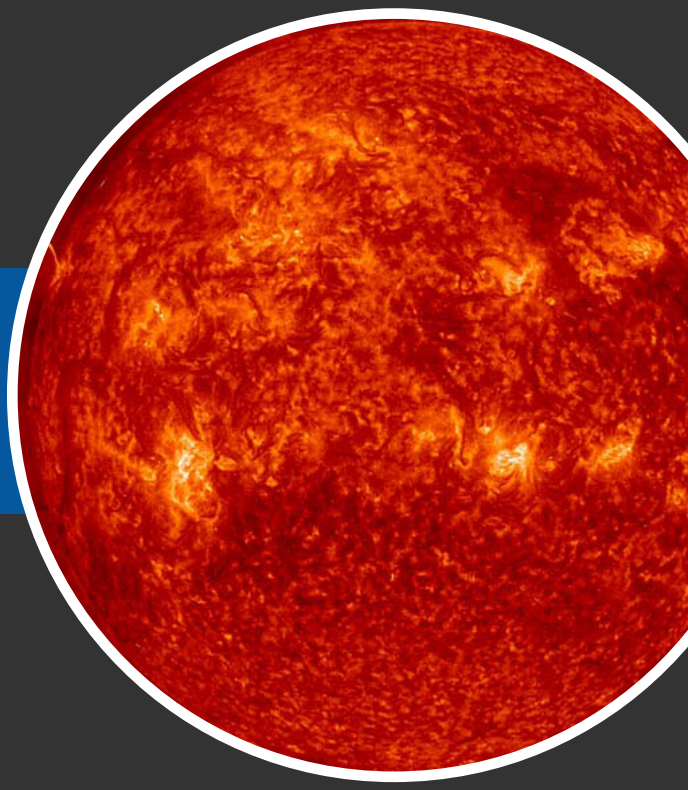
Events

2 Collaboration Meetings

4th LATTES Meeting, CBPF - Centro Brasileiro de Pesquisas Físicas, Rio de Janeiro, Brasil, 2017-05-19 to 2017-05-20

5th LATTES Meeting, Department of Physics and Astronomy, Padova, Italy, 2017-10-16 to 2017-10-17

Dark matter and neutrinos



PARTICIPATION IN DARK MATTER EXPERIMENTS LUX AND LZ

LUX/LZ

The LIP Dark Matter group joined the LUX experiment in 2010 and it is a founding member of the LUX-ZEPLIN (LZ) international collaboration. These two experiments search for dark matter in the form of Weakly Interacting Massive Particles (WIMPs), aiming at their direct detection with two-phase xenon Time Projection Chambers (TPCs).

LUX (Large Underground Xenon) has been the most sensitive direct detection experiment from 2013 until summer 2017, when the results from XENON-1T and PANDAX-II have marginally surpassed those of LUX. In total, LUX have acquired 427 live-days of science data that allowed to set a new limit on the WIMP-nucleon spin-independent cross-section with a minimum of 1.1 ×10−46 cm^2 at 50 GeV c^{-2}. This allowed to test some of the most favored WIMP parameter space, including models consistent with the SUSY CMSSM, and gave rise to a seminal paper (that already sums up 500 citations). Furthermore, from the analysis of the science and calibration data accumulated by LUX, resulted 8 papers already published (or accepted for publication) and 11 more being prepared. These papers cover a large variety of topics including the search of axions and Xe isotopes rare decays, several aspects of the microphysics of xenon as detector medium and the detector performance. In 2017, the decommission of LUX was completed.

Overview

The LZ experiment is a large step forward towards the direct detection of WIMPs. Although largely based on LUX, LZ has important enhancements apart from the large increase of active mass (which will be 7 tons of xenon), such as a 4π scintillator veto and the instrumentation of the xenon layer adjacent to the active region for use as additional veto. LZ will probe WIMP-nucleon cross sections down to 2.3x10-48 cm^2, ~50 times better than the current best limit, in a 1,000-day run. After having produced its Technical Design Report (arXiv:1703.09144) and successfully passed the CD3 DOE Review, (Jan 2017), LZ has started the procurement and fabrication phase. LZ parts are expected to start to arrive at Sanford Underground Research Facility (SURF) during the first quarter of 2018. The underground deployment of LZ is scheduled for 2019 and commissioning is expected to start in the beginning of 2020. Meanwhile, in parallel with the construction and deployment, there will be an intense activity of simulation, R&D of analysis tools, their implementation and validation.

Team

Principal Investigator Isabel Lopes (80)

Researchers
Alexandre Lindote (100), Andrey Morozov (15), Cláudio Silva (100), Francisco Neves (70), Guilherme Pereira (84), José Pinto da Cunha (50), João Pedro Martins Rodrigues (41), Sumanta Pal (52), Vladimir Solovov (50)

Technicians
Américo Pereira (20), Nuno Carolino (35)

PhD students
Paulo Brás (100)

Master students
Andrey Solovov (33), Cédric Pereira (100)

Undergraduate students
Fátima Alcaso, Guilherme Catumba

External collaborators
Natalija Novak

Total FTE

9.3

Summary of performance indicators

Articles in international journals:	4 With direct contribution from team 6 With indirect contribution from team
Internal notes:	3 Collaboration notes
International conferences:	4 Oral presentations
International meetings:	1 Oral presentation
Collaboration meetings:	13 Oral presentations
Seminars:	3 Seminars 2 Outreach seminars

// GROUPS: LUX/LZ / SNO+ / NEXT

Lines of work and team organization

The LIP team in LUX and LZ almost doubled in 2017. Its role and recognition in these collaborations are consolidated and its activities diversified. The main pillars of our intervention have been the leadership of the design and R&D of the LZ overall instrument control system (with over 10000 channels), the high precision measurement of the reflectivity of the detector light reflectors and the development of innovative analysis tools that have allowed the team to give very relevant contributions to the LZ and LUX data analysis.

The main lines of work (and respective group members involved) are the following:

- Data analysis tools for LUX and LZ, encompassing algorithms and techniques for pulse identification & characterization, detector related corrections and high-level analysis from the definition of the datasets, the development of quality cuts, up to the production of the final plots with the surviving events in the discrimination space used to produce the final limit curve after comparison with the background model of the detector (Alexandre Lindote, Francisco Neves, Paulo Brás and Andrey Solovov);
- Physics Beyond dark matter search with LZ detector: neutrino physics studies, search for neutrinoless beta decay in ^{136}Xe and ^{134}Xe and other Xe rare decays such as double capture in ^{124}Xe and ^{126}Xe, with a strong focus on the use of machine learning algorithms for improving the signal to background discrimination (Francisco Neves, Alexandre Lindote, Cláudio Silva, Paulo Brás, Sumanta Pal, Cédric Pereira, Andrey Solovov)
- Position reconstruction methods (Claudio Silva, and Guilherme Pereira, Cédric Pereira, Vladimir Solovov);
- Control systems (Vladimir Solovov, Cédric Pereira and Guilherme Pereira);
- Modeling, Monte Carlo Simulation and measurement of the reflectivity of rough and diffuse surfaces (Cláudio Silva, Francisco Neves and Sumanta Pal).
- Modelling and GEANT4 based simulation of the background in LZ (Alexandre Lindote)

The LIP team is represented by the PI of the project (I. Lopes) in the LUX Executive Board and LZ Institution Board. Francisco Neves is co-PI of the project.

Stated objectives for past year

- To continue the development of LZAP (the LZ data analysis platform) software modules for the pulse identification and pulse pairing.
- To investigate the feasibility of doing neutrino physics studies and search for rare decays of xenon isotopes in LZ.
- Design and implementation of the Data Quality Manager for LZ (DQM: the online data analysis system to monitor the quality of the data);
- Construction of a database for keeping track of the backgrounds in LZ with an advanced front-end which will allow the owners of the various subsystems to easily access information about the impact of their particular part or material in the overall background of the experiment, and test candidate materials and design strategies.
- Implementation of the LZ control system based on Ignition and its interface with the PLCs;
- To develop a detector temperature readout (4-wire RTD, ~100 channels, 0.1K precision) for LZ;
- To maintain the Control system of the Test System at SLAC.

Main Achievements

LZ

- We made several key contributions to the LZ Analysis Package (LZap), namely the development, implementation and benchmarking of the algorithms responsible for: i) matching of pulses belonging to different channels (each PMT has two readout channels) and/or acquired using different gains; ii) identification of the interaction type (e.g. single scatter, K83r-like event, single electron, etc); iii) assigning a classification to each pulse registered by the detector based on its geometrical properties (pulse classifier); improvement of the previous classification algorithm using simulated pulses to generate high statistical 2-dimensional probability density functions of pulse parameters, in order to extract relative probabilities of a given pulse being of a given class. iv) Integration and update of the event position reconstruction module with low gain (LG) and high gain (HG) evaluation. Neves is the coordinator of LZ offline Analysis and Reconstruction Working Package.

- We started to work on the determination of the sensitivity of LZ to ^{136}Xe $0\nu\beta\beta$ decay and possible ways to enhance it by improving the background discrimination. We completed: i) the analysis of the relevant radiogenic backgrounds for this process using the most recent simulations of radioactivity in the LZ detector components; ii) the identification of the components and materials of the detector with the highest impact on the sensitivity of LZ to this process. Silva is co-coordinator of the working group on this process (the second most important physics goal of LZ, after the WIMP detection).

- The development of a background model to be used for the study of the sensitivity of LZ to rare Xe decays (2vßß and 0vßß in ^{134}Xe, 2EC in ^{124}Xe) has started. Simulation data generated using the LZ MC simulation software (BACCARAT) for all the detector components and Rn (222 and 220) was already processed and included in the model using the contamination levels and masses from the Backgrounds Control Table for normalisation.

- We took full responsibility for the development and implementation of the real time Detector Quality Monitor (DQM) infrastructure for LZ. We implemented a full version of the software (multi-CPU only) and tested its performance using mock data sources/nodes (a multi-CPU version was chosen by the collaboration instead of a GPU based one).

- The precise measurements of the reflectivity, for xenon scintillation light, of different samples of the LZ detector reflector material (PTFE) immersed in liquid xenon at ~ -100°C were continued. More specifically, the work developed was

focused in characterizing differences in the reflectivity of the PTFE (previously) chosen for LZ but manufactured with different resin batches.We started to access the feasibility of using the existing setup, optimized for measuring reflectivities closed to 100% (e.g PTFE), for other materials with lower reflectivities and also used in LZ (e.g Titanium).

- Concerning our responsibilities on the LZ control systems, our main achievements were the following: i) Development of an Human-Machine Interface with Ignition SCADA to control and monitor approximately 10000 channels of the TPC subsystems. ii) Development of a Modbus simulator with a Web-based GUI to simulate the behaviour of sensors and controllers. iii) Development of several addon tools to facilitate the deployment of Ignition into LZ. iv) Integration of a dual-PLC (Programmable logic controller) system into the Ignition SCADA software. Solovov continued as coordinator of the LZ control system.

- Since 2016, the LIP group (A. Lindote) is responsible for keeping the repository of the experiment backgrounds (presently in the form of an Excel spreadsheet). It includes the compilation of the component materials, their respective masses and specific activity (coming from radio-assays), and the characterization of their impact on the backgrounds (coming from simulation). To ensure the accuracy and completeness of this repository is obviously of outmost importance for the experiment. Furthermore, in order to improve the versatility and cross-check of this essential tool, work of the LIP group with a software consultant from the Software Sustainability Institute (from the UK) resulted in a prototype application for the migration of the Backgrounds Table to a database format. This prototype is currently being expanded to a full fledged database with a web-based user interface.

- Numerous educational and outreach activities were promoted by the group:

1. construction of a cloud chamber for public demonstration and several public presentations on this type of device and applications (F. Neves and V Solovov);

2. Proposal and coordination of a month-long Summer Internship program for university-level students with the project “The mistery of dark matter”, Physics Department of the University of Coimbra, July 2017 (F. Neves, P. Brás and A. Lindote);

3. Participation in the Summer University project, with an intensive week-long scientific program for high-school students with the projects “Dark matter: looking for a needle in a haystack”, Coimbra, July 2017 (A. Lindote, F. Neves) and “Simulation of Gravitational Systems" (C. Silva).

LUX

- Claudio Silva was nominated coordinator of the LUX Analysis Working Group for 6 months. After this period, he was invited by the LUX-exec to serve for 6 months more in this position.

- We completed the writing of the paper on the position reconstruction method in LUX; it was accepted for publication in JINST (Claudio Silva was the main author and the corresponding author).

- Analysis of LUX Run04 data to search for 2EC in ^{124}Xe has started. The signature of this rare decay comes from the relaxation of the ^{124}Te atom via a cascade of X-rays and Auger electrons with a total of ~64 keV. A population of unexpected events in the energy region of interest for this decay was observed in several periods of this run, and identified as the result of the decay of the isotope ^{125}I (produced by neutron activation during DD-generator calibrations). Work is currently in progress to determine the required exclusion periods to remove this background from the affected datasets.

- Processing of Run03 and Run04 data continued, with specific settings for particular studies (DD calibration, post-Run04 ER calibrations, ^{83}Kr, search for Lightly Ionising Particles)

Coordination positions

In 2017, the LIP group members had the following coordination positions in the LZ and LUX Collaboration structures:

- Vladimir Solovov: coordinator of the LZ slow control system (L3 in the LZ management hierarchy).
- Alexandre Lindote: Coordinator of the LZ WBS 1.10.4 working group, responsible for background impact evaluation from all sources, and the development of the experiment background model;
- Francisco Neves: coordinator of the LZ offline Analysis and Reconstruction working group (WBS (1.11.5.2)).
- Claudio Silva: co-coordinator of the working group on neutrinoless beta decay of ^{136}Xe (the second most important physics goal of LZ, after the WIMP detection);
- Claudio Silva, coordinator of the LUX data analysis working group (since June 2017)

Members of the LIP group are regularly selected to participate in LUX Paper Review Committees.

Lines of work and objectives for next year

In 2018 the work will be focused mostly in LZ, particularly on:

- Regarding LIP work on LZap, the plan of the DM LIP group includes i) improvement of the pulse matching and interaction identification algorithms; ii) development of the benchmarking of new pulse and interaction identifiers based on machine learning techniques, iii) Development of advanced filters for pulse finding and benchmark them using LZ (simulated) data; iv) Improvement of the current pulse classification algorithm: development of methods for estimating absolute probabilities from a set of bivariant PDF representations; using LUX real data to benchmark the algorithm efficiency; v) Development and testing of more efficient pulse classification algorithms using machine learning methods.

- As for the search of ^{136}Xe $0\nu\beta\beta$ decay with LZ, we will explore several ways to improve the sensitivity of LZ to this

process, e.g. i) use of advanced filters for the discrimination of $0\nu\beta\beta$ interactions; ii) optimization of the analysis cuts; iii) exploitation of double vertex position reconstruction algorithms and Cherenkov light for the discrimination of $0\nu\beta\beta$ interactions.

- Concerning the study of other Xe rare decays, we plan: i) finish the analysis of LUX Run04 data for the 2EC in ^{124}Xe and combine it with the Run03 analysis to set a global lower limit for the half-life of this rare decay from the LUX experiment. ii) Perform sensitivity studies of LZ to $2\nu\beta\beta$ and $0\nu\beta\beta$ decays in ^{134}Xe. iii) Perform a sensitivity study of LZ to 2EC in ^{124}Xe, including different levels of Rn contamination and study the possibility of using the topological characteristics of the 2EC signal for additional discrimination power.

- As for the DQM, we plan: i) Integrate the DQM with the other elements of the LZ Data Pipeline (e.g. Run Control and Event Builder) and benchmark its performance in a more realistic environment; ii) Integrate LZap (the offline Data Analysis Framework - WBS 1.11) into the DQM. Although aiming for a solution based on GPUs for the online data processing, LZap was defined as the base solution for the DQM and it integration prioritized. iii) Continue the development of the analysis framework based on GPUs for integration into the DQM.

- Regarding the optical measurements on PTFE and other LZ materials, we plan: i) measure the reflectivity of PTFE samples cut from the panels used in LUX. The objective is investigate any possible degradation of the PTFE reflectivity after a being immersed in LXe for long periods of time and exposed to large fluxes of VUV, namely, during the detector conditioning stages; ii) Access the feasibility of using the existing setup, optimized for measuring reflectivities closed to 100% (e.g PTFE), for other materials with lower reflectivities and also used in LZ (e.g Titanium); If feasible, measure the reflectivity for the titanium used in the LZ vessel; iii) Development of a method to access and if possible to eliminate the fluorescence of PTFE.

- Concerning the LZ control system, the main objectives are the development of Machine Learning software to optimize several nonlinear parameters of the TCP using, as training data, 4 years of acquired data during the LUX experiment.

- Continue the responsability of keeping the background repository, finish the migration of the repository from the Excel format to the full database, add additional functionality to the database implementation (e.g. automatic generation of reports and summary tables, test "what-if" scenarios, automatic interface to the PLR code used to estimate the WIMP search sensitivity of the experiment).

- We will organize in Coimbra the LZ Spring 2018 Collaboration Meeting (April 17-19), the LZ Mock Data Challenge (April 19-20) and the LUX Workshop (April 22-24).

SWOT Analysis

Strengths

The group is a well-established and highly considered member of the LUX and LZ Collaborations. Besides the long experience in DM experiments, as well as a worldwide acknowledged expertise in liquid xenon detectors and their physics aspects, the group also has strong scientific and technical expertise in control and automation, position reconstruction methods, Monte-Carlo simulation of detectors and associated physical processes, background analysis and simulation in rare event particle experiments, analysis techniques of very low amplitude signals, data analysis of WIMP search experiments, optical measurements and photodetectors, data processing frameworks. With such wide range of solid competences, the group can have a strong participation with relevant impact in dark matter experiments of large scale such as LZ.

The group has a laboratory in Coimbra equipped to purify and liquefy xenon, to operate liquid xenon detectors, to perform optical measurements in the VUV and visible range and to test photodetectors.

Weaknesses

Currently we have only one PhD student (but a second one is applying to a scholarship) and 2 Master Students. We have taken important steps (outreach, internships, etc) to attract more students but it takes time.

There is shortage of several pieces of equipment and others are obsolete.

Opportunities

LZ is the most competitive dark matter experiment in the world, with a high potential of detecting WIMPs. To participate in such experiment is by itself a huge opportunity with several components from which we highlight two: 1) to use and extend our areas of expertise; 2) to hire postdocs and attract PhD students. In 2017, we have hired two more Master students that will make the Master thesis in the framework of the LZ project and two Bachelor students (to motivate them for joining the project).

Sources of Funding

Code	Amount	Dates	Description
PTDC/FIS-NUC/1525/2014	199.280 €	2016-01-01 to 2017-12-31	Direct Detection of Dark Matter: Participation in the LUX-ZEPLIN and LUX Experiments

Threats

The last funding was up to December 2017. In May 2017, we have put forward a project proposal for continuing the participation in LZ but we do not know the results of that FCT Funding Call yet. The funding structure in Portugal continues to be unstable and poorly adjusted to large continuing projects. The discontinuation of funding or the frequent time gaps between consecutive calls for proposals are a permanent threat and they are very disturbing for the project, both for taking responsibilities within the experiments and in keeping and attracting human resources.

Publications

4 Articles in international journals (with direct contribution from team)

D. S. Akerib et al. : "Results from a search for dark matter in the complete LUX exposure", Phys. Rev. Lett. 118, 021303

F. Neves, A. Lindote, A. Morozov, V. Solovov, C. Silva, P. Bras, J.P. Rodrigues and M.I. Lopes: "Measurement of the absolute reflectance of polytetrafluoroethylene (PTFE) immersed in liquid xenon", Journal of instrumentation, Vol.12 P01017

D. S. Akerib et al.: "Limits on spin-dependent WIMP-nucleon cross section obtained from the complete LUX exposure", Phys. Rev. Lett. 118, 251302 (2017)

D.S. Akerib et al.: "3D Modeling of Electric Fields in the LUX Detector", JINST 12 P11022 (2017)

6 Articles in international journals (with indirect contribution from team)

D.S. Akerib et al.: "Signal yields, energy resolution, and recombination fluctuations in liquid xenon", Physical Review D 95, 012008

D.S. Akerib et al.: "First Searches for Axions and Axionlike Particles with the LUX Experiment", Phys. Rev. Lett. 118, 261301 (2017)

D.S. Akerib et al.: "Identification of Radiopure Titanium for the LZ Dark Matter Experiment and Future Rare Event Searches", Astroparticle Physics, 96, 1 (2017)

D.S. Akerib et al.: "Chromatographic separation of radioactive noble gases from xenon", Astropart. Phys. 97, 80-87 (2018)

LUX Collaboration (93 authors): "Kr-83m calibration of the 2013 LUX dark matter search", Phys. Rev. D 96 (2017) 112009

D. S. Akerib et al. (94 authors): "Ultralow energy calibration of LUX detector using Xe-127 electron capture", Phys. Rev. D 96 (2017) 112011

3 Internal Notes

Claudio Silva: "Study of the Top/Bottom Asymmetry Along the WS2014—16 ", LuxDB00000520

A. Lindote: "Background from Pb210 in the bulk TPC PTFE", LZ Internal Note -(LZDB121)

A. Lindote and M.F. Mazioni: "Double Electron Capture Analysis in Run04 - A First Look", internal LUX note (LUXDB518)

Presentations

4 Oral presentations in international conferences

Cláudio Silva: "Dark Matter Searches with LUX", 2017-03-20, 52th Recontres de Moriond, 18-25 March 2017, La Thuile, Italy

Alexandre Lindote: "Direct Dark Matter Searches with LUX and LZ", 2017-05-17, 13th Axion-WIMP conference (Patras workshop), Thessaloniki, Greece

Alexandre Lindote: "New Results from LUX", 2017-07-06, EPS conference on High Energy Physics (HEP2017), 5-12 July , Venice, Italy

Isabel Lopes: "Searching for Dark Matter with LUX and LUX-ZEPLIN", 2017-09-07, 21st Particle & Nuclear Internacional Conference (PANIC 2017), Sept 1-5 2017, Beijing China

1 Oral presentations in international meetings

Isabel Lopes: "Current Status of Direct Dark Matter Searches", 2017-11-15, Fundamental and Applied Aspects of Radiation Physics, 15-17 November, 2017, Moscow, Russia

3 Seminars

Cláudio Silva: "Dark Matter Searches in LUX", 2017-01-06, Café com Física, Departamento de Física, Universidade de Coimbra

Isabel Lopes: "Dark Matter search with LUX and LUX-ZEPLIN", 2017-05-31, , University of Naples, Italy

Isabel Lopes: "Searching for dark matter with LUX and LUX-ZEPLIN", 2017-06-20, , University of Vilnius, Lituânia

2 Outreach seminars

Isabel Lopes: "Mistérios do Universo: á procura da matéria escura", 2017-01-18, Encontros com o cientista, Planetário Gulbenkian

Paulo Brás: "DM@LUX: dark matter direct detection", 2017-11-22, Matéria escura na Semana da Ciência e Tecnologia, LIP-Lisboa

Theses

1 PhD Theses

Paulo Brás: "New physics phenomenology and data processing tools for the LZ experiment" (ongoing)

3 Master Theses

Natalija Novak: "Study of neutrino interactions in the LZ Dark Matter detector" (ongoing)

Cédric Pereira: "Optimization of a liquid xenon TPC to search for 0v2ß decay in Xe136" (ongoing)

Andrey Solovov: "Development of analysis techniques for the identification of 0v2ß event topologies and their characterisation" (ongoing)

COLLABORATION IN THE SNO+ EXPERIMENT

SNO+

Overview

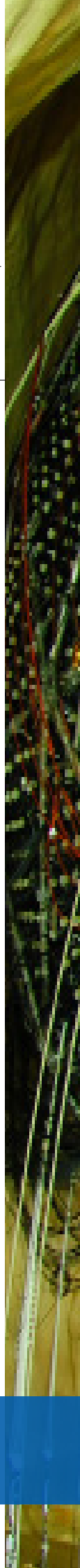
The LIP Neutrino Physics group joined the Sudbury Neutrino Observatory (SNO) experiment in 2005 and is a founding member of the SNO+ collaboration. The main goal of SNO+, that reuses the SNO detector, replacing the heavy water by liquid scintillator, is the search for neutrino-less double-beta decay ($0\nu\beta\beta$) by loading the scintillator with large quantities of Tellurium, but several other low-energy, low-background, physics topics are part of its program: antineutrinos from nuclear reactors and the Earth's natural radioactivity, solar and supernova neutrinos, and searches for new physics.

The initial data-taking phase, with the detector filled with water, started in 2017. The group has been very active in data analysis and software development, leading several aspects of the physics data quality studies, detector calibrations, backgrounds measurements, as well as preparation for anti-neutrino physics measurements.

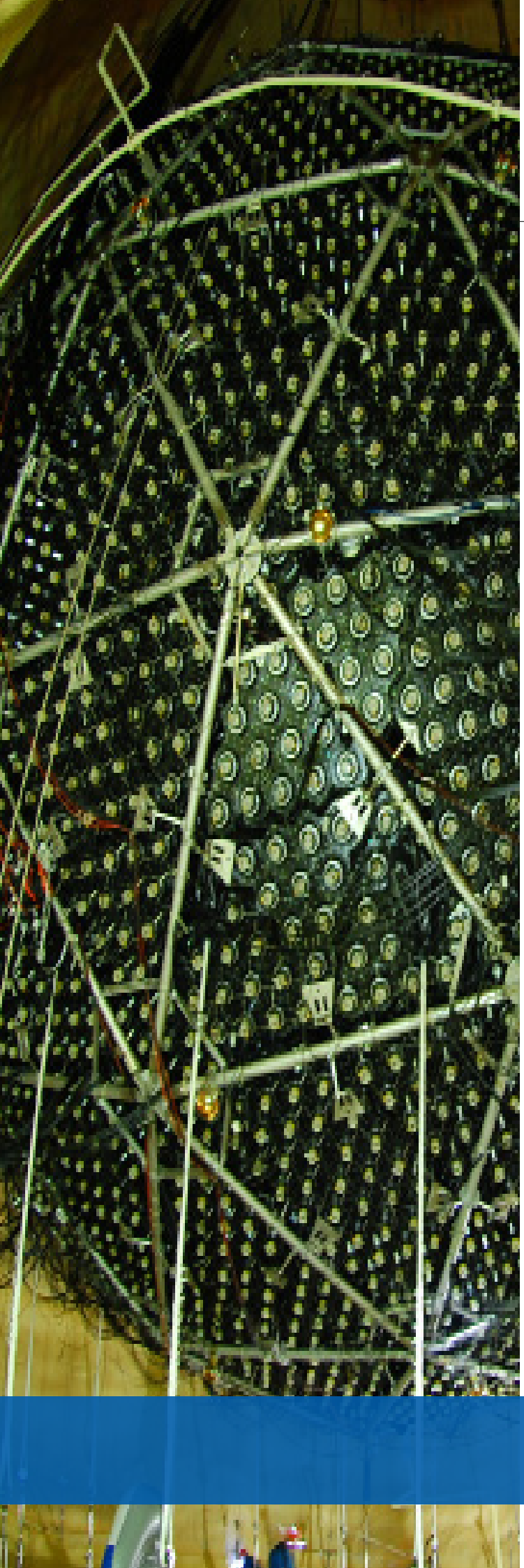
The scintillator fill is expected in 2018, and so the group's efforts will gradually shift from water phase to scintillator phase data analysis.

Summary of performance indicators

Articles in international journals:	1 With indirect contribution from team
International conferences:	4 Oral presentations 3 Posters 2 Proceedings
National conferences:	2 Oral presentations
Seminars:	2 Seminars 2 Outreach seminar
Completed Thesis:	1 Master thesis



EXPERIMENTAL PARTICLE AND ASTROPARTICLE PHYSICS
Dark matter and neutrinos



Team

Principal Investigator José Maneira (60)

Researchers
Amélia Maio (15), Fernando Barão (25), Gersende Prior (100), Nuno Barros (10), Sofia Andringa (50), Valentina Lozza (100)

Technicians
Américo Pereira (20), Nuno Filipe Silva Dias (20), Rui Alves (20)

PhD students
Ana Sofia Inácio (100)(*), Pedro Jorge (10), Stefan Nae (100)

External/Additional scientific collaborator
Margarida Moreira

Total FTE
6.3

(*) Concluded the Master in September 2017. PhD student in 2018.

// GROUPS: LUX/LZ / SNO+ / NEXT

Lines of work and team organization

The group's activities are organized according to three main lines of work, each one in turn divided into specific tasks.

Detector calibration

- Internal source deployment. After completing the first (of 2) calibration source deployment systems (undergoing tests at SNOLAB), production of the second system is ongoing at Coimbra. We are also responsible for the software tools providing calibration source information for use in the data analysis and simulation.
- Analysis of laserball calibration data. The main current task is the analysis of the water phase data and the preparation of software tools for the upcoming scintillator phase data.
- Radioactive sources. The work started at the TU Dresden is continuing, with the fabrication and tests of the radioactive sources' encapsulation for use in the scintillator phase.

Detector and data-taking performance

- Data quality and run selection. We contribute to and coordinate the review of the quality of the data for all physics runs, and are developing ways to further automatize the process.
- Backgrounds. The current focus is on the stability and spatial distribution of the backgrounds in the water phase, testing the effects of water recirculation, calibrations, and other detector conditions. The coordination of studies for the $0\nu\beta\beta$ phase is ongoing.

Analysis of physics data

- Anti-neutrinos. We are involved in the preparation of the general analyses tools for the different SNO+ phases, as well as on specific calibrations for anti-neutrino signals, with an AmBe source.
- Reconstruction. We coordinate the review of the SNO+ Reconstruction performance for the water phase.
- Detector modeling algorithms. We are developing numerical integration algorithms describing light production/ propagation/detection, to improve event reconstruction and particle identification.

List of internal SNO+ leadership responsibilities taken by group members: Antineutrino Physics Group (SA), Backgrounds Working Group (VL), Calibration Source Review Committee (JM), Optical Calibration Working Group (JM, GP), Reconstruction Review Committee (GP), Run Selection Committee (GP). In addition, we are responsible for software documentation, within the software validation group (ASI), and for overseeing the SNO+ database infrastructure (SN).

In addition, the group also contributes to Particle Physics Outreach activities. SA is the group's contact person in this area. GP is the admin for the SNO+ software and group's contact for computing at LIP.

Stated objectives for past year

Main objectives that we had planned for 2017, listed by activity area:

Calibrations:

- Finalize the preparation of the source insertion system for the scintillator phase;
- Implement and test software tools to: provide source deployment information to the data analysis and simulation; carry out the quality control of the laserball data; perform the analysis of the optical calibration data taken outside the AV
- Finalize, together with the TU Dresden, the development of two new gamma sources ^{57}Co and ^{48}Sc, to be used in the pure scintillator fill.

Data quality and Run Selection:

- Adapt the scripts to comply with changes in the DAQ and database systems
- Implement the slow-control and water level information
- Development and implementation of automatic tools for run selection developed in the SNO+ run processing framework

Data analysis and its preparation:

1. in the water phase:
   - Use the data, including a calibration with an AmBe neutron source, to evaluate the possibility of observing coincidences signals, and thus the sensitivity of an unloaded water Cherenkov detector to reactor anti-neutrinos.
   - Analysis of the external backgrounds, crucial for the future SNO+ phases. Review the reconstruction in water, comparing the performance of the energy and position/direction fitters with SNO.

2. in the scintillator phases:
   - Analysis of the first pure scintillator data, focusing on the internal backgrounds.
   - Analysis of the ^{222}Rn related backgrounds embedded in the acrylic vessel.

In addition, continue the development of detector modeling algorithms for light emission, propagation and detection, focusing on its application for optical calibration strategy and later for the reconstruction algorithms.

Finally, GP chairs the review committee for two SNO analysis topics: neutrino lifetime and Lorentz symmetry violations.

Main Achievements

Concerning the execution of the planned SNO+ activities for 2017, they were mostly achieved, only the plans related to scintillator fill are still pending.

Calibrations
The second unit of the Umbilical Retrieval Mechanism (URM) for the SNO+ calibration source insertion system is being produced at the LIP Coimbra workshop. The first unit arrived at SNOLAB, and was brought to the surface clean laboratory, but the main functionality tests are still awaiting the end of the water phase calibration campaign.

Our group also participated in the preparation of the Deck Clean Room and of the N2 calibration laser, as well as in the data-taking for the week-long, laserball optical calibration scan in December. We implemented a set of scripts that read the calibration hardware database and provide the necessary summary tables for data anaysis and simulation.

The first laserball calibration data runs were analysed, and we provided feed-back about the stability of the laser and the trigger. We developed a new method to measure in-situ the group velocity of light, which cross-checked the values inserted in the SNO+ database.

Data-quality and Run Selection (RS)
The code in charge of saving all the detector related information (run type, duration, high-voltage status, slow-control...) in a so-called low-level data-quality (DQLL) table is implemented in the nearline system since 2016 and numerous improvements have been implemented in 2017. The RS committee is performing on a daily basis the selection of the runs, using automated scripts (such as database query browsers and display tools) and offline tools. The first months of data-taking were essential to fully test the RS tools. This led to many more data quality checks on the hardware and analysis sides and, in order to optimize live-time, to relaxing some of the more stringent cuts.

Software tools for fully automated database queries and RS members shift sign-up were designed.

Water Phase Analysis
We analyzed the water phase data and coordinated the activities to identify the internal/external backgrounds. We provided weekly updates on the stability and spatial evolution of the signals from various sources of radioactivity in the internal and external water. This allowed the identification of localized contamination due to work in the detector, a leak in the purification system, and also changes due to trigger conditions.

We studied the effects of trigger thresholds, reconstruction cuts (energy, position, direction) in the various periods of the water phase. The analysis has led to the identification of the data periods in which it seems feasible to carry out an an anti-neutrino search, by identifying delayed coincidences with a second signal below the usual energy threshold. The full review of the Reconstruction in the water phase could not be finished in 2017 because documentation and guidelines were not completed.

Scintillator Phase developments
In preparation for the $0\nu\beta\beta$ phase, we estimated the required radio-purity (intrinsic and cosmogenic-induced) of the various cocktail components, including the purification factors. We started to study the required precision on the scintillator optical parameters and their effect on the sensitivity studies.

SNO analyses reviews
The review of the search for Lorentz Symmetry violations with SNO data has been completed, and publication is expected at the beginning of 2018 (GP is the chair of the editorial committee).

Lines of work and objectives for next year

We expect 2018 to be dedicated to the water phase data analysis and calibration, to the hardware activities related to the scintillator fill, and to the start of the scintillator data taking phase.

The specific planned activities are the following.

Calibrations

- Conclude the construction of the source insertion systems, and prepare both for use in the scintillator phase;
- Include the scripts that handle the calibration hardware information in the database, in the automated nearline framework of SNO+;
- Analyze the December 2017 laserball internal scan, in order to measure the water attenuation length and the PMT angular response. Analyze the upcoming external laserball scan in order to measure the acrylic attenuation and the PMT response at a high angles. The PMT angular response and acrylic attenuation will be harder to measure in the scintillator phase, so it's important to obtain those results with the water phase calibration campaigns.
- Participate in the deployment and analysis of the AmBe neutron source, in order to directly calibrate the efficiency of observing neutral capture signals following a higher energy signal, crucial for the antineutrino analysis in the SNO+ water phase;
- Finalize, in collaboration with the TU Dresden, the development of two new gamma sources ^{57}Co and ^{48}Sc, for deployment during the pure scintillator fill. These will be used to calibrate the energy scale and to study the detector response at energies close to the threshold.
- Finalize a note about the development of a design for a collimated neutron source for calibration of directional anti-neutrino signals.

- We'll continue to coordinate the Source Review Committee, that will review the sources and main components of the deployment hardware planned for use in the scintillator phase.

Data Quality and Run Selection

- Complete the content of the low-level data-quality tables with the insertion messages related to data-packing issues (loss of trigger trace, buffer corruption...);
- Deploy the fully automated run selection framework to be tested during the scintillation fill
- Install a remote control room at LIP. Material has been ordered and first testing of the network connection stability, VoIP phones and monitoring will be performed at the beginning of this year before our application for full benchmarking tests during a shadowing shifts campaign.

Water Phase Analysis

- Conclude the review of the reconstruction in the Water Phase.
- Continue to perform a background stability and uniformity analysis of the water phase data, checking for changes due to activities in the detector (calibrations, purification campaigns, changes in trigger settings).
- Resume the external background study of ^{208}Tl from the PMTs started in previous years but left on the side due to the demanding task of Run Selection.
- Start an analysis of muons in SNO/SNO+ using the SNO complete muon data set and SNO+ water phase data and Monte-Carlo.
- The data gathered in the water phase is expected to lead to publications in different time scales: a first one dedicated to a nucleon decay search, and later ones with more detailed analysis of internal and external backgrounds.

Scintillator Phase Preparation

- We will be involved in the scintillator filling activities and the analyses aiming to determine the purity level of the first scintillator batches in the detector, as well as measuring the background level throughout the entire scintillator phase.
- Double-beta decay: We will continue the preparatory work for the double-beta decay phase (cocktail purity and mitigation strategies). We will continue the sensitivities study as a function of the optics effects (PMT response, scintillator attenuation, ...).
- MonteCarlo simulation: we will write a code to allow a faster and more efficient production of MC of the various background components. This is specially in view of the larger statistics that will be needed to perform the background and sensitivities study in the scintillator phases.

SNO Analyses

The review of the neutrino lifetime analysis with the SNO data will be completed in the first half of 2018.

SWOT Analysis

Strengths

The main strength of the group resides in the diverse range of competences and experience of its members, from low and high energy neutrino physics to nuclear, collider and cosmic ray physics. From the technical standpoint, the group has experience in optical instrumentation, mechanical systems, PMTs, DAQ systems and programming.

Weaknesses

One weakness of the group is the absence of students at undergraduate and Master's level. The group is presently composed of six researchers, two PhD students and a graduated fellow, still a very “top-heavy” structure. This is a common situation at LIP, and our group is engaging with coordinated efforts to attract students at the undergrad and Masters level.

Threats

SNO+ is a high-risk, high-gain experiment: loading large quantities of very pure Tellurium in the liquid scintillator is a major technical challenge. Difficulties met while designing and installing the loading and purification plant can induce further delays to the schedule and compromise the impact of the scientific output in a competitive community.

Sources of Funding

Code	Amount	Dates	Description
IF/00863/2013/CP1172/CT0006	50.000 €	2014-01-01 / 2018-12-31	FCT Exploratory research project (PI: G.Prior)
PTDC/FIS-NUC/0640/2014	184.276 €	2016-02-01 / 2018-01-31	Portuguese Participation in the SNO+ neutrino experiment
IF/00248/2015/CP1311/CT0001	50.000 €	2017-01-01 / 2021-12-31	FCT Exploratory research project (PI: V. Lozza)

Opportunities
The recent start of the SNO+ water phase can potentially attract new students, since data analysis provides excellent opportunities for Master's theses. With the start of the scintillator phase, in addition to double-beta-decay physics, new topics will be explored.

Recently, the group has started contacts towards a possible future participation in the long baseline neutrino oscillation experiment DUNE. This would balance the current participation in the analysis of SNO+ with a focus on design and construction of future detectors that will have a very strong role in neutrino physics in the next decade

Publications

1 Articles in international journals (with indirect contribution from team)

B. Aharmin (SNO Collaboration) (incl. J. Maneira, G. Prior): "Search for neutron-antineutron oscillations at the Sudbury Neutrino Observatory", Phys. Rev. D 96, 092005

2 International Conference Proceedings

J. Maneira, E. Falk, E. Leming, S. Peeters on behalf of the SNO+ Collaboration: "Calibration of the SNO+ experiment", J. Phys.: Conf. Ser. 888 012247

G. Prior (on behalf of the SNO+ collaboration): "The SNO+ experiment physics goals and background mitigations", NuPhys2016 Conference Proceedings – SLAC eConf C16-12-12.1 (2017)

Presentations

4 Oral presentations in international conferences

José Maneira: "SNO", 2017-03-13, XVII International Workshop on Neutrino Telescopes, Venice, Italy

Sofia Andringa: "Introduction to neutrino experiments: neutrinos and neutrino observatories", 2017-07-17, 17th International Baikal Summer School on HEP and Astrophysics, Bol'shie Koty, Russia

Sofia Andringa: "Introduction to neutrino experiments: establishing oscillations and mixing", 2017-07-18, 17th International Baikal Summer School on HEP and Astrophysics, Bol'shie Koty, Russia

Sofia Andringa: "Introduction to neutrino experiments: present questions and experiments", 2017-07-19, 17th International Baikal Summer School on HEP and Astrophysics, Bol'shie Koty, Russia

3 Poster presentations in international conferences

Gersende Prior: "Data Quality and Run Selection for the SNO+experiment", 2017-07-25, TAUP 2017— XV International Conference on Topics in Astroparticle and Underground Physics, Sudbury, Canada

Ana Sofia Inácio: "Optical Calibration of the SNO+ Detector", 2017-08-31, VII International Pontecorvo Neutrino Physics School, Prague, Czech Republic

Stefan Nae: "Reactor Antineutrinos in SNO+", 2017-08-31, VII Pontecorvo Neutrino Physics School, Prague, Czech Republic

2 Presentations in national conferences

Stefan Nae: "Modelling antineutrino oscillations from reactor sources in SNO+", 2017-01-11, Jornadas dos Doutoramentos do Departamento de Fisica da FCUL, Lisboa

José Maneira: "LIP Activities on the interface of Particle and Nuclear Physics", 2017-06-16, 89th Nuclear Physics European Collaboration Committee (NuPECC) Meeting, Lisbon, Portugal

2 Seminars

José Maneira: "From SNO to SNO+ and the search for neutrino masses", 2017-11-06, Invited Seminar at CFTP, IST, Lisbon, Portugal

Ana Sofia Inácio: "Searching for Dark Matter at LSC", 2017-12-04, Journal Club presentation at SNOLAB, Sudbury, Canada

2 Outreach seminars

José Maneira: "O que os neutrinos nos podem dizer sobre o Universo", 2017-11-02, Palestra convidada no Ciclo de Conferências da E. S. António Damásio, Escola Secundária António Damásio, Lisboa, Portugal

José Maneira: "O que os neutrinos nos podem dizer sobre o Universo", 2017-11-03, Palestra no ciclo "O Espaço vai à Escola", org. Ciência Viva, Escola Secundária da Póvoa de Santa Iria, Portugal

Theses

1 PhD Thesis

Stefan Nae: "Anti-Neutrino physics in SNO+" (ongoing)

1 Master Thesis

Ana Sofia Inácio: "Optical calibration of the SNO+ experiment and sensitivity studies for neutrino-less double beta decay" (finished on 2017-09-19)

HIGH PRESSURE XENON DOPED MIXTURES FOR THE NEXT COLLABORATION

NEXT

Overview

NEXT (Neutrino Experiment with a Xenon TPC) is a neutrinoless double-beta decay experiment that operates at the Canfranc Underground Laboratory (LSC). It is based on a novel detection concept for neutrinoless double-beta decay searches consisting in a Time Projection Chamber (TPC) filled with high-pressure gaseous xenon and with separated-function capabilities for calorimetry and tracking. For a successful result the requirements are energy resolution and background suppression, given the large half-life of the searched decay. NEXT offers excellent performance in both aspects: an energy resolution of at least 1% FWHM at $Q_{\beta\beta}$ and a topological signature highly efficient in background rejection. Xenon has an isotope that decays $\beta\beta$ (^{136}Xe), with a quite high natural abundance (9%) and easily enriched, with $Q_{\beta\beta}$ value acceptably high (~ 2458 keV), which makes it an obvious choice.

The energy resolution optimization is granted by the use of proportional electroluminescent amplification (EL). Consecutive prototypes have shown excellent performance as well as the robustness. The LSC Scientific Committee has recommended that a first-phase of the NEXT detector, with a smaller dimension apparatus at the LSC, to measure the two neutrino mode double beta decay, which will allow a clear demonstration of the unique NEXT topological signal. As a consequence, a first stage of the NEXT detector, the NEW (NEXT-WHITE) apparatus was assembled at Canfranc. NEW is now fully operational and results are currently being obtained. Our team is going to collaborate in the shifts at Canfranc. The next generation detector is currently being planed, will start assembly in 2018, and is expected to be fully operating in 2020.

In spite of the fact that xenon is the perfect candidate as detection medium in this particular experiment, it has some drawbacks mostly related to electron diffusion parameters. However, these are known to respond favorably to the addition of trace amounts of molecular gases. Thus, a search for the ideal additive, which besides improving the necessary parameters does not compromise significantly the scintillation yield (both primary and secondary), has been requested to our group.

The first candidate was trimethylamine (TMA) which, besides the required advantages, might also act as a wavelength shifter to the Xe scintillation wavelength.

However, TMA has been ruled out as it degraded the energy resolution and was not effective as wavelength shifter for the xenon VUV scintillation. Additionally, it is very cumbersome to work with TMA, especially under the very strict

underground conditions at LSC in Canfranc. During the course of this extensive study with TMA, Monte Carlo simulations were also developed in order to understand/justify the results obtained. Our goals have been attained.

Our next study will be on CH_4, another possible candidate, and mainly on its effect on primary scintillation. Another following study may be on CO_2, as it has some known advantages. Subsequent candidates are still being discussed within the collaboration.

Team

Principal Investigator Filomena Santos (50)

Researchers
Carlos Conde (25), Filipa Borges (50), José Escada (25), Rui Marques (15)

PhD students
Alexandre Fonseca Trindade (30)

Total FTE
1.9

Summary of performance indicators

Articles in international journals:	1 with direct contribution from the team 4 with indirect contribution from the team
Collaboration meeting:	1 oral presentation

// GROUPS: LUX/LZ / SNO+ / NEXT

Lines of work and team organization

Our team in NEXT has been in charge of studying the performance of candidate additives. Measurements have already been performed on Xe-TMA and Xe-CF_4, which have been ruled out as solutions for the present problem. In the immediate future, other candidates will be assessed, starting with CH_4 and CO_2, namely regarding the primary scintillation yields. A new candidate, helium is also being considered. The group will be studying this mixture by Monte Carlo and possibly experimentally.

Alexandre Trindade, Carlos Conde and Filipa Borges have been responsible for the experimental project design and work, whereas José Escada and Filomena Santos carried out the simulation studies.

Stated objectives for past year

Along the past year, the team was to continue the study of several aspects of the performance of Xe-TMA mixtures, namely complementing and clarifying previous results. The measurements were to be performed in several modular devices specially built and high pressure enabled, allowing to detect and measure primary and secondary scintillations yields, charge gain and ion mobility in Xe-TMA mixtures. The absorption of xenon scintillation by TMA thought to be followed by re-emission, and this was the subject of complementary studies through both experimental measurements and Monte Carlo simulation.

Main Achievements

The use of TMA as an additive to Xe in the NEXT TPC detector was ruled out since we could observe that it degraded the energy resolution and also was not effective as wavelength shifter for the xenon VUV scintillation. During the course of this extensive study with TMA, Monte Carlo simulations were also developed in order to understand/justify the results obtained, our goals have been achieved concerning this task.

The results of this work have originated so far 1 paper published at JINST concerning the ion mobility in these mixtures and the another was recently submitted to publication at NIM A. Some more data will be analysed soon, eventually allowing the publication of 2 or 3 additional papers on the subject.

The attendance to the biannual NEXT collaboration meetings that took place in Valencia IFIC, allowed a constructive discussion with the collaboration partners on the obtained results and possible alternatives as additives.

Lines of work and objectives for next year

Experimental results on xenon-TMA mixtures, namely concerning charge gain, primary and secondary scintillation yields, Penning effect probability, that have already been obtained will be analyzed and published.

Upon finishing the analysis and publication of the results for Xe-TMA, our work plan for 2018 involves studying other Xe based mixtures of interest for the NEXT Collaboration, which are still under discussion, possibly with CH_4, CO_2 and possibly He.

These studies will be carried out experimentally in the available systems and also by Monte Carlo simulation, adapting the existing codes to the new additives.

A new experimental device to measure electron drift parameters, namely their drift velocity and diffusion, is being built, since this information is also very important to the Collaboration. The comparison between the obtained experimental results with Monte Carlo predictions will allow to assess the validity of the measurements.

In the national project submission call on May 2017, a new project with the other portuguese groups working in NEXT was submitted, which involved the LIP NEXT members.

SWOT Analysis

Strenghts

The expertise in the study of electroluminescence in gas detectors and drift parameters both experimentally and by Monte Carlo simulation is one of the biggest assets of the group, and the reason for our participation in the NEXT collaboration.

Also, the systems already assembled and working in our group are versatile tools that can be used for a variety of studies, namely of the gases used in the large volume detectors. A new device that will allow the measurement of electron drift parameters is under construction and will expand our scope of capabilities.

Weaknesses

The approved and financed projects in the recent years are few and shared with other groups (Aveiro and LIBphys, Coimbra) and limits both the investment in equipment and the attendance of scientific meetings by the team members.

Opportunities

From the expertise acquired and equipment developed, there is a serious possibility of expanding the scope of applications of our work since noble gas based mixtures are increasingly being sought in many research fields. Some properties of these

mixtures are known and motivate their choice, but side effects are not always clear. Although at the moment NEXT is still using pure Xe as the filling of the TPC, the search for additives is always considered and in this area the input of our group can be important for the collaboration goals.

Threats

Again, the limitations in funding that also limit the recruitment of manpower, which is important since some of the team members are also teachers at the Physcis Department of UC and the time to develop research work is limited. Also these budget restrictions have prevented the team members to participate in international scientific meetings, being a serious threat in the divulging of our work, and on the possibility of establishing new contacts. The funding for travelling expenses has been mainly used to attend to meetings of the collaboration that happen in Spain twice a year.

Publications

1 Article in international journals (with direct contribution from team)

A. Simon et al. (69 authors): "Application and performance of an ML-EM algorithm in NEXT", J. Instrum. 12 (2017) P08009

4 Articles in international journals (with indirect contribution from team)

The NEXT Collaboration: "Background rejection in NEXT using deep neural networks", JOURNAL OF INSTRUMENTATION Volume: 12 Article Number: T01004 DOI: 10.1088/1748-0221/12/01/T01004 Published: JAN 2017

A. Simon et al. (69 authors): "Application and performance of an ML-EM algorithm in NEXT", J. Instrum. 12 (2017) P08009

S. Cebrian et al. (70 authors): "Radiopurity assessment of the energy readout for the NEXT double beta decay experiment", J. Instrum. 12 (2017) T08003

The NEXT Collaboration: " Secondary scintillation yield of xenon with sub-percent levels of CO2 additive for rare-event detection", Source: PHYSICS LETTERS B Volume: 773 Pages: 663-671 DOI: 10.1016/j.physletb.2017.09.017 Published: OCT 10 2017

Sources of Funding

Code	Amount	Dates	Description
PTDC/FIS-NUC/2525/2014	60.000 €	2016-05-01 / 2018-05-31	Detection of the Neutinoless Double Beta Decay in Xe-136: the NEXT Experiment

Detectors for **particle** and **nuclear physics**

- Neutron detectors
- RPC R&D
- Gaseous Detectors R&D
- Liquid Xenon R&D

// Development of new in

Health and biomedical applications

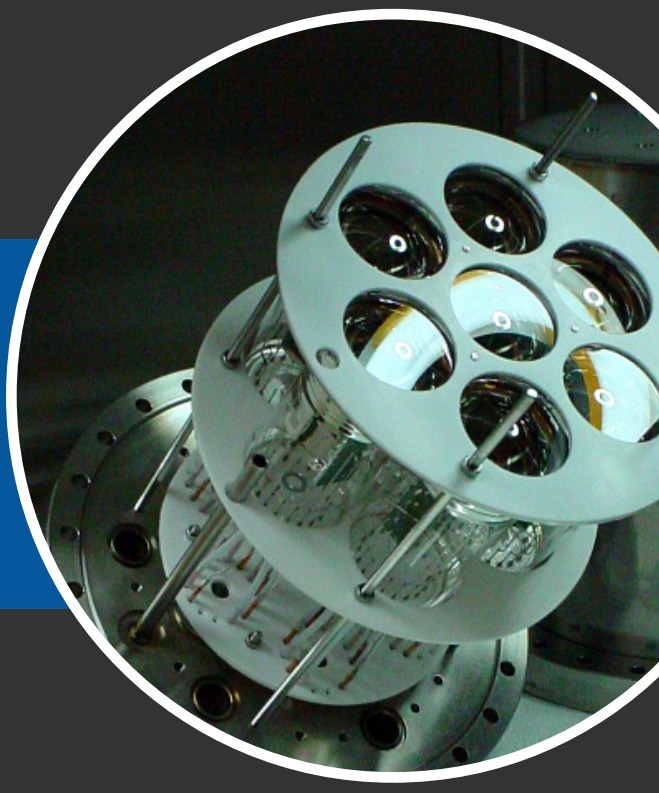
- RPC-PET
- OR Imaging
- Gamma cameras
- Dosimetry

Space applications

- Space Rad
- i-Astro

nstruments and methods

Detectors for particle and nuclear physics



Neutron Detectors

For over a decade that we are involved in detector development programmes in partnership with world leading detector groups from large-scale neutron facilities in Europe such as e.g. ILL (FR), ISIS (UK) and TUM-FRMII (IN). A continuous and fruitful effort has been pursued throughout successive European projects (NMI3-FP6, NMI3-FP7), which is currently being continued thanks to the participation of LIP-Coimbra in the SINE2020 consortium, funded by the European Union through the H2020 programme.

On previous research programmes we contributed with fundamental work for the development of high counting rate neutron detectors based on the optical readout of gaseous active scintillators with micropattern devices (such as, e.g. MSGCs and GEMs), bringing a high degree of recognition to the LIP-Coimbra team.

Pursuing our core mission, a strong commitment to innovation, we are developing ^{10}B lined RPCs as a novel thermal neutron detector technology alternative to ^{3}He based detectors. We are particularly focused on detector development for neutron scattering applications that meet the requirements of the upcoming European Spallation Source (ESS).

Currently, the group activity is being developed in the framework of SINE2020 EU,

Overview

Science and Innovation with Neutrons in Europe in 2020, is a consortium of 18 partner institutions from 12 countries, with a global budget of 12 M€ and EU contribution committed to LIP of 116 kEur and reinforced last year with further 30 kEur.

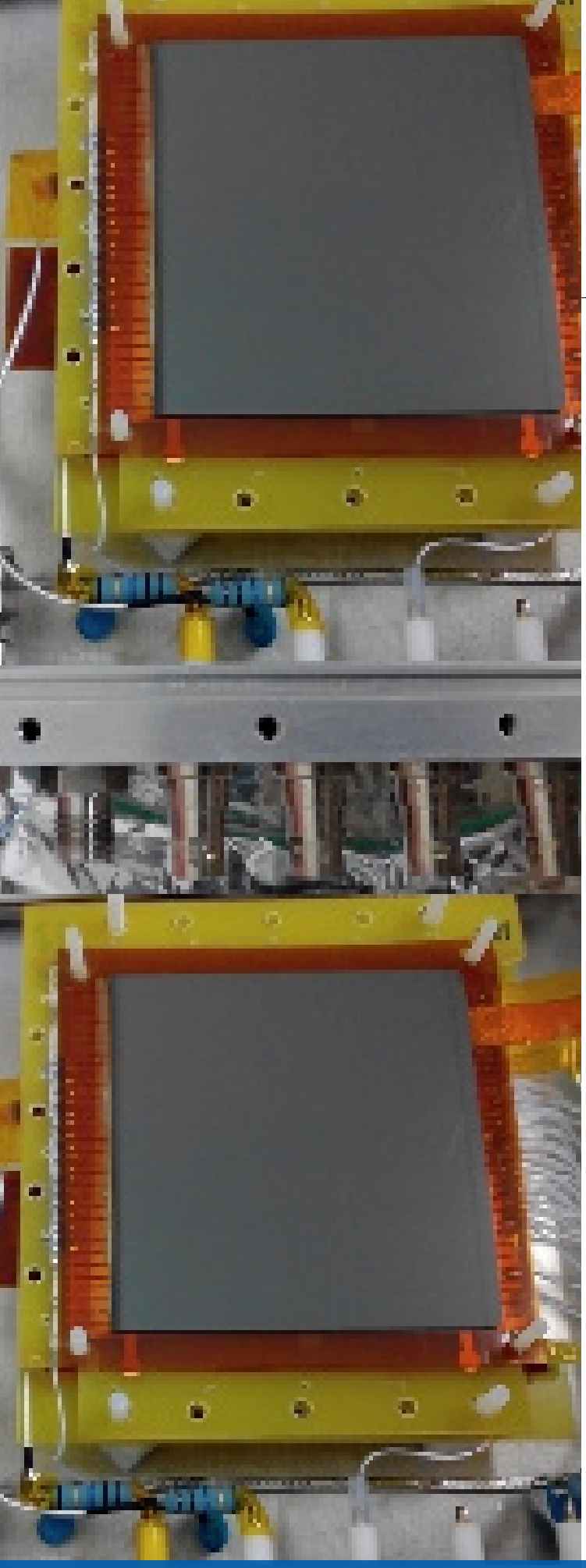
The LIP team has responsibilities on the research activity WP9/ Detectors/ Emergent Detector Technologies for Neutron Scattering and Muon Spectroscopy in which LIP coordinates the task 9.4.1 Resistive plate chambers development for thermal neutron detectors.

Summary of performance indicators

International meetings:	2 Oral presentation

DEVELOPMENT OF NEW INSTRUMENTS AND METHODS

Detectors for particle and nuclear physics



Team

Principal Investigator Luís Margato (85)

Researchers
Alberto Blanco (15), Andrey Morozov (25), Paulo Fonte (10)

External/Additional scientific collaborators
Alessio Mangiarotti (20)

Total FTE
1.4

// GROUPS: Neutron Detectors / RPC R&D / Gas Detectors R&D / Liquid Xenon R&D

Lines of work and team organization

The research being conducted is mainly framed by the SINE2020 objectives. A strong effort is being put on the development of instrumentation with performances beyond the present state-of-the-art, such as, e.g. the development of new thermal neutron detector technologies for the next generation of neutron scattering instruments. Successful advances in detector performance will be crucial to enhance the full scientific and technological output of the upcoming European Spallation Source (ESS) and of the other leading neutron sources in Europe.

Our activities are focused on the development of ^{10}B lined RPCs for high precision thermal neutron detectors and are organized as follows:

- Detector's modelling and simulation with GEANT and ANTS2 toolkits;
- Detector's design and prototyping;
- Experimental studies with thermal neutrons (e.g. at TUM-FRMII or at ILL);
- Basic Studies, e.g.:
  - Investigation of the performance of ^{10}B RPCs with different gas mixtures (e.g. background and plateau shift toward lower voltages);
  - Investigation of the induced signals time structure for MIPs and HIPs in ^{10}B RPCs (about three orders of magnitude of difference in the specific energy loss) to ascertain the possibility of pulse shape discrimination techniques (PSD) for background and gamma's rejection.

Locally, most of the activities are ensured by the group coordinator, with the contribution from the other members on specific competences. Andrey Morozov is giving is main contribution in MC simulations with ANTS2 and GEANT respectively; Paulo Fonte and Alberto Blanco are contributing mainly on the readout electronics (FEE and DAQ system).

The European Spallation Source (ESS) Detector Coatings team is highly committed in contributing on the development and manufacturing of $^{10}B_4C$ coatings for RPCs electrodes.

The experimental studies with thermal neutrons are performed in collaboration with the ESS and TUM-FRM II neutron detector groups (our partners in SINE2020). The TUM-FRMII group is in charge of organizing the tests with thermal neutrons on a neutron beamline at FRMII reactor.

Stated objectives for past year

For the past year, we have stated as one of the main goals addressing the low thermal neutron detection efficiency issues shown by single-gap ^{10}B RPCs (~12% for 4.7 Å neutrons).

To meet this challenge we have proposed a novel conceptual design consisting of a multilayer architecture with a stack of ten ^{10}B double-gap RPCs.

In view of the realization and evaluation of a prototype implementing such a design, the following tasks were settled:

- Optimization by MC simulations of the $^{10}B_4C$ coatings thickness (the optimum thickness that maximizes the detection efficiency will depends on both, neutron wavelength and number of $^{10}B_4C$ layers);
- Manufacture of the $^{10}B_4C$ coatings at ESS;
- Design and construction of a prototype with a stack of ten ^{10}B double-gap RPCs;
- Experimental study of the detector prototype on a neutron beamline at TUM-FRM II (conducted in collaboration with SINE2020 partners).

Main Achievements

MC-Simulation

A Neutron scattering module has been added to the ANTS2 simulation package (already in the debug phase). With this new feature ANTS2 takes into account the neutrons scattering in the materials and the transport of thermal neutrons through ^{10}B RPCs, e.g. the neutron capture in ^{10}B, ^{10}B(n, α)^{7}Li reaction and the stopping of fission fragments in the $^{10}B_4C$ layers and gas gap.

This will allow predicting the influence of the materials on the detector performance (e.g., spatial resolution, efficiency and lost events by scattered neutrons) during the detector design phase and to adopt the optimal choices for the detector construction.

For the ANTS2 first validation tests (cross-sections from IAEA site https://www-nds.iaea.org/exfor/endf.htm) we performed a series of cross-checks by implementing several basic models and comparing the results with the same simulations with GEANT4 (GEANT4 version 4.9.6.p02). Both results show to be in good agreement, apart from minor discrepancies, which are being

Sources of Funding

Code	Amount	Dates	Description
654000 SINE2020	116.250 €	2015-10-01 / 2019-09-30	World class Science and Innovation with Neutrons in Europe 2020 – SINE2020

debugged. The simulation in GEANT4 was performed in close collaboration with Irina Stefanescu (ESS).

Design and construction of a B-10 RPC detector prototype with a multilayer architecture

A prototype with a stack of 10 double-gap RPCs lined with ^{10}B (20 layers of $^{10}B_4C$ in total) was designed and build.

A set of aluminum plates, needed for the assembly of the 10 double-gap RPCs, were coated on both sides with a layer of $^{10}B_4C$ taken into account the thickness computed with ANTS2. The deposition of the $^{10}B_4C$ layers on the Al plates were carried out by the ESS Detector Coatings team. A special structure of signal pickup electrodes, allowing to read out both X- and Y-coordinates on the anode side, was designed. By sharing such electrodes structure, inserted between each RPC, with two adjacent double-gap RPCs in the stack we managed to reduce its number to almost half. This results in a lower material thickness in the neutron beam path.

The detector was instrumented with 96 readout channels in total: 43 channels per each X- and Y-coordinate, with the remaining 10 used for the cathodes readout. As DAQ system it was used the new TRB3 platform developed at GSI, Germany.

In such detector configuration, we also succeed in using the cathode signals for select the RPC in which a neutron event occurred. This provides the information of the third coordinate. The cathode signals can also be used to measure the time of flight (TOF) of the neutrons with very high precision.

Experimental tests on the TREFF neutron beamline at TUM-FRM II

The detector prototype was taken to TUM-FRM II (Germany) for the experimental tests with neutrons and was successful operated on the TREFF neutron beamline (λ = 4.7Å).

The studies of the detection efficiency revealed the behaviour expected from the simulation, but showing a lower value (measured detection efficiency ~55%).

It should be noted that one of the RPCs in the stack showed a detection efficiency well below the expected value. This may be explained by a non-uniformity of the gas-gap width due to a non-planarity of the Al-cathode plates. A distorted charge spectrum for this RPC also points in this direction.

We measured a spatial resolution of ~0.25 mm (FWHM) and ~0.30 mm (FWHM), respectively for the X- and Y-coordinates. These results preserve the outstanding benchmark achieved with the single-gap B-10 RPCs prototypes tested in the previous campaign (< 0.25 mm FWHM) and already reported.

Here it should be noted that we observed an offset between the histograms of the reconstructed positions for each individual RPC, suggesting random misalignments of about 0.05 mm for the strips from RPC to RPC, which is quite realistic. We also observed a small systematic shift between the histograms for the X-direction, suggesting non-orthogonality of the beam to the RPCs of ~0.4 degrees (0.2 mm over 30 mm of the thickness of the stack). Both effects are affecting the measured spatial resolution.

The experimental results show that it is feasible the design of position sensitive neutron detectors (PSNDs) based on the principle of ^{10}B RPCs, capable to achieve sub-millimeter spatial resolution (in 2D) and a detection efficiency above 50% (for 4.7 Å neutrons).

Moreover, it was also demonstrated the capability of this novel type of neutron detector to measure the third coordinate with a high timing resolution (RPCs are intrinsically fast detectors). The main uncertainty in time arises from the neutron flight in the converter layer (~1-2 micron thick), which for the ^{10}B RPCs case will corresponds to ~ 0.5 ns, for thermal neutrons (25 meV). For instance for a Micro Channel Plate (MCP), typically with 1mm thickness, the uncertainty in timing will be about 500 ns, which is three orders of magnitude worse than for ^{10}B RPCs.

This makes this Multilayer architecture very promising, e.g. for Timing-Resolved Neutron Imaging (to follow fast dynamics processes) or in Energy-Resolved Neutron Imaging applications at pulsed neutron spallation sources such as the ESS (neutron energy selected by a time-of-flight technique). Its modularity, robustness and low price per area, are other unbeatable arguments in relation to other detector technologies.

Lines of work and objectives for next year

Following the main objectives stated in the SINE2020 proposal our work plan is focused on the evaluation of the potential of ^{10}B lined RPCs based PSNDs for neutron scattering applications at ESS. The planned objectives for the next year are embodied in the following activities:

- Detector's modelling and simulation (GEANT and ANTS2 toolkits);
- Detector's design and prototyping;
- Gamma sensitivity and background studies with gamma sources and cosmic rays;
- Prototypes evaluation with thermal neutrons (e.g. at TUM-FRMII or at ILL);
- Basic Studies, e.g.:
  - Investigation the performance of ^{10}B RPCs with different gas mixtures;
  - Investigation of the induced signals time structure for MIPs and HIPs in ^{10}B RPCs (about three orders of magnitude of difference in the specific energy loss) to ascertain the possibility of pulse shape discrimination techniques (PSD) for background and gamma's rejection.

Low noise level and low sensitivity to gamma rays are part of the detector requirements puzzle. A major challenge is to exploit how low we will be able to reduce both, the background and the gamma sensitivity in ^{10}B RPCs. A dedicated setup is being designed for study the ^{10}B RPCs sensitivity to gamma radiation with ^{60}Co and ^{22}Na gamma sources. Here it should be noted that the RPCs plateau for the detection of thermal neutrons is considerably shifted towards the lower voltages relatively to the plateau for MIPs detection.

We should also proceed with the investigations of the Multigap RPCs configuration. We continue facing challenging issues related with the surface resistivity of the $^{10}B_4C$ coatings (not high enough to avoid a large spread of the induced signals).

In view of the optimization of the counting rate with multilayer configurations it will also be performed simulations with ANTS2 to set the optimal combinations of the $^{10}B_4C$ layers thicknesses allowing to equalizes the counting rate in all ^{10}B RPCs in the stack.

SWOT Analysis

Strengths
More than one decade of intensive international cooperation with the world-recognized leaders in the neutron detectors development community (e.g. ILL, TUM, ISIS and more recently ESS).

Participation in a H2020 EU-funded Project (No 654000): SINE2020 - Science & Innovation with Neutrons in Europe (http://sine2020.eu/) brings a great International visibility for LIP, increasing the likelihood of new EU funding opportunities.

Weaknesses
The funds from the SINE2020 budget for HR committed to LIP are being used to support the PI and not to hire additional HR as planned.

Opportunities
The research activities are part of a more general effort led by our partners in SINE2020/WP9-Detectors, aiming at developing very demanding neutron detectors, capable of performances not yet possible with present state-of-the-art. Being inside such an international collaboration is an asset to positioning the LIP at what will be the center of neutron detectors development needs in the coming decades.

Threats
Concerning the high level of difficulty and responsibility of the project the lacks of manpower, with the group leader to have to take in charge simultaneously the management tasks and almost all of the experimental work, results in a very exhaustive effort with negative consequences in other important activities such as the dissemination.

The precarious employment condition of the group leader persists.

Presentations:

2 Oral presentations in international meetings

Luís Margato: "Development of Resistive Plate Chambers (RPCs) at LIP-Coimbra", 2017-06-14, SINE 2020 Detector RTD Meeting, Paul Scherrer Institute (PSI), 5232 Villigen PSI Switzerland

Luís Margato: "Resistive Plate Chambers (RPCs) at LIP-Coimbra", 2017-06-13, SINE 2020 Industry Day Meeting, Paul Scherrer Institute, 5232 Villigen PSI Switzerland

R&D ON RESISTIVE PLATE CHAMBERS (RPC)

RPC R&D

The LIP RPC group has its roots in previous work on Parallel Plate Avalanche Chambers done in collaboration with the former Charpak group at CERN.

In 1998/9 we participated in the R&D effort for the time-of-flight (TOF) detector of the ALICE (CERN) experiment, within which we co-invented the timing Resistive Plate Chamber (tRPC) technology. These devices revolutionized the TOF detection technique, opening way for very large area TOF detectors, which were, are and will be present in many HEP experiments (ALICE, BESIII, BGO-EGG, CBM, FOPI, HADES, HARP, STAR).

Besides the original work in ALICE, along with numerous international and local collaborators, we contributed to the field with some developments that expanded the RPC applications range, continuing the work presently on some of these lines:

- Very large area/channel tRPCs
- Shielded tRPCs for robust multihit capability in dense arrays
- The use of ceramic materials and warm glass for enhanced count-rate capability
- Application of RPCs to animal and human Positron Emission Tomography (RPC-PET)
- Simultaneous high-resolution measurement of positions and times (TOFtracker)
- Very low maintenance, environmentally robust, RPCs for deployment in remote locations
- Large area fast-neutron TOF detectors
- Epi-thermal neutron detectors with ^{10}B converters

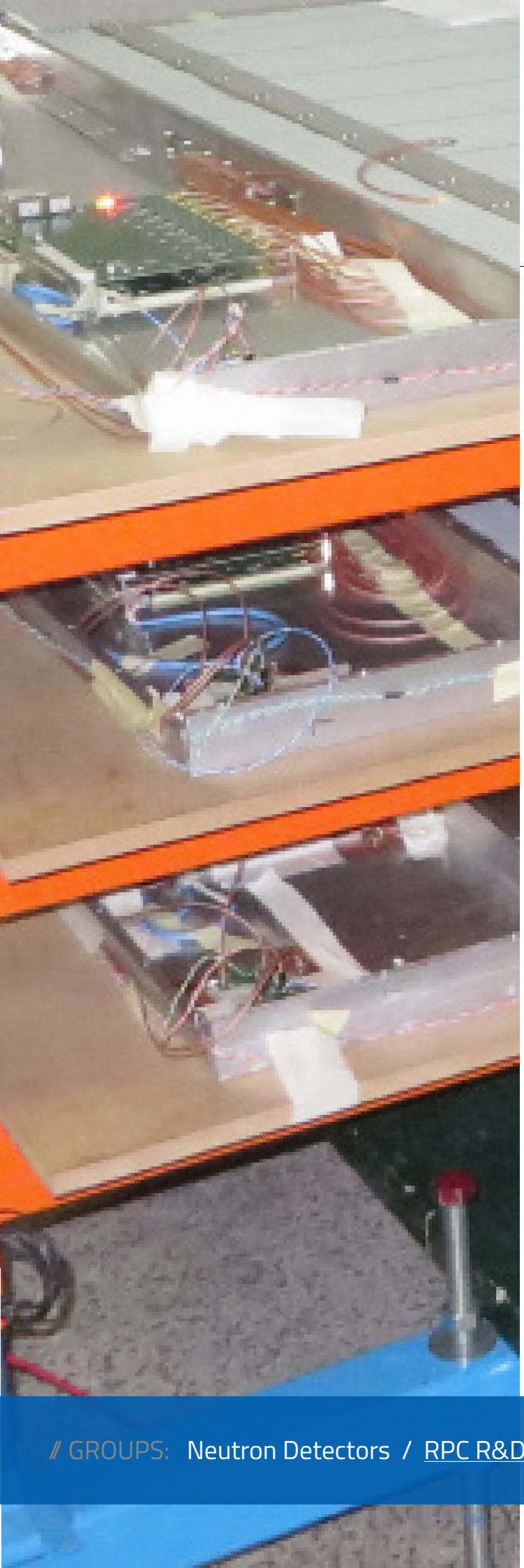
Overview

Our group designed and built the HADES TOF Wall detectors and we are now solely in charge for its operation, which has shown so far flawless performance. This work will be carried out into the future FAIR facility (Germany), as HADES is a FAIR experiment.

Besides the development of technology-expanding devices, we keep an interest in RPCs physical modelling and other fundamental issues, such as gas mixture properties and aging. In close collaboration with the detector lab we also design and produce detector-support electronics, such as front-end amplifiers and high-voltage power supplies.

We participated briefly in the ALICE and CBM experiments, in the FP6 EU projects I3-Hadron-Physics and DIRAC-PHASE-I, and, currently, in AIDA2020 (http://aida2020.web.cern.ch/) and SINE 2020. We are members of CERN's RD51 and SHiP collaborations.

The RPC group cooperates with several other LIP groups (Neutron Detectors, Auger, LATTES, HADES, RPC-PET), supporting their RPC-related activities. See the specific reports for further details.



Team

Principal Investigator Paulo Fonte (25)

Researchers
Alberto Blanco (20), Luís Margato (15)

Technicians
Américo Pereira (10), Carlos Silva (90), Douglas Lima (100), João Saraiva (9), Luís Lopes (70), Nuno Carolino (50), Nuno Filipe Silva Dias (70), Orlando Cunha (80), Rui Alves (69)

Total FTE

6.1

// GROUPS: Neutron Detectors / RPC R&D / Gas Detectors R&D / Liquid Xenon R&D

Lines of work and team organization

The core RPC group is rather small, with 3 part-time researchers and 1 part-time physicist (J. Saraiva), supported by the LIP's Detector Lab and Mechanical Workshop staff. Moreover, even if we list here a main responsible for each task, there is not a strong separation of responsibilities within the group.

TOFtracker (A. Blanco)

We are developing RPC detectors that simultaneously deliver accurate positions and times, having demonstrated a position resolution of 37 μ along with a time resolution of 80 ps in small areas. Work is ongoing in a large area (~2 m^2) detector with a readout of only 21 charge-readout channels and 32 time-readout channels, resulting therefore in an extremely economical detector. These detectors are intended, among others, for applications in Human RPC-PET, muon tomography (absorption or diffusion) and HEP tracking.

Sealed and environmentally robust RPCs (L. Lopes)

We ultimately aim at developing large-area sealed RPCs, which would constitute a major breakthrough in detector technology: environmentally friendly and large-area detectors, with excellent time and position capabilities (see previous task), freed from a permanent gas supply. Such detectors would easily replace the scintillator technology in many application fields and comply with gas distribution/purification requirements in HEP experiments. See also the report of the Auger and LATTES groups.

Our detectors are being used by the TRAGALDABAS (https://dx.doi.org/10.1088/1742-6596/632/1/012010) collaboration and will be used in the Antarctic Cosmic Ray Observatory (ORCA), interested in cosmic-ray probes for atmospheric physics research.

High-rate (L. Lopes)

We have a long-standing interest in this subject with some work already published. Currently we are responsible for a work-package of the project AIDA2020 that aims at identifying and testing a range of suitable materials.

Detectors for RPC-PET (P. Fonte)

We develop the detectors, front-end electronics and provide systems integration for the RPC-PET group. Please see the specific group report for details. This line of work is developed within the framework of our participation in the RD51 collaboration.

Physical modelling (P. Fonte)

Analytical and numeric models of RPC's physical behaviour. This line of work is developed within the framework of our participation in the RD51 collaboration.

Epi-thermal neutron detectors (L. Margato)

The present shortage of ^{3}He opens a window of opportunity for detectors with ^{10}B converter layers. We believe that RPCs are specially adapted for this application. Please see the specific group report.

HADES collaboration (A. Blanco)

Our group is now the sole responsible for the operation of the HADES TOF Wall and is currently prototyping a new TOF detector to be installed in the forward region of the HADES spectrometer. Please see the specific group report.

Stated objectives for past year

TOFtracker

4-layer of TOFtracker devices, for muon tomography of cargo containers, for the HYDRONAV S.A company to be delivered.

2/3-layers of TOFtracker devices, for the muon tomography of volcanoes, in the framework of the TOMOVOL project, to be delivered and deployed. It is foreseeing also to participate in the Stromboli muon tomography campaign.

The MASTER telescope in Rio to be commissioned.

Sources of Funding

Code	Amount	Dates	Description
AIDA-2020	45.000 €	2015-06-01 / 2019-05-31	Advanced European Infrastructure for Detectors at Accelera-tors

Sealed and environmentally robust RPCs

Initiate production of 30 to 40 sensitive volumes for the MARTA FCT/FAPESP project, along with HV power supplies and gas systems. A long stay in São Paulo is foreseen for the integration of the sensitive volumes, etc., with the locally-produced mechanics and wiring.

Identically, will support the integration of gaseous volumes on the Rio-produced mechanics and wiring.

We will continue the study of the reasons so far preventing us to achieve fully sealed operation.

Small tests of low-temperature, low-pressure RPC operation in view of the LATTES project will be carried out.

We will further pursue the contacts for a possible Antarctic Cosmic Ray Observatory (ORCA).

High-rate

Construction and test of small but super-quality single-gap, spacerless, stainless-steel cathode chambers to beam-test promising high-rate RPC electrode materials at the GIF facility at CERN.

Detectors for RPC-PET

Development of a "v2" pre-commercial small-animal scanner including improvements in electronics will be pursued. Please see the specific report.

Physical modelling

P.Fonte is writing a book on "Resistive gaseous detectors" with Vladimir Peskov and Marcello Abbrescia.

Epi-thermal neutron detectors

Construction and test of a new prototype of Epi-thermal neutron sensitive RPC with the aim of demonstrating the feasibility of a device with around 50% detection efficiency and sub-millimetre 2D-spatial resolution. Please see the specific group report.

HADES

It is expected to finish the implementation of the new RPC-TOF-FD into the software of the experiment. The first prototype of a module of the RPC-TOF-FD will be constructed and evaluated.

Main Achievements

Funding

The AIDA2020 EU project was continued from 2016, covering the development of high-rate RPCs. The SINE2020 EU project was continued as well. The group is also involved in the FAPESP/19946/2014 project.

Six projects have been submitted in the frame work of our activities:

KARMA- Development of magnetic storm risk map in the South Europe region. In the Interreg Sudoe EU call. (Recommended to be not funded, but very well classified. Three positions under the cut line)

Development of multi gap RPC with simultaneous time and bi-dimensional position capability for accurate particle identification. Within the Hadron Physics 2020 call. Recommended to be not integrated in the final call.

DET-APPs – Advanced Gaseous Detectors for Frontier Scientific and Societal Applications. National PTDC call. No decision yet.

MuTOM - Muon tomography of geological structures with tRPCs and its applications. National PTDC call. No decision yet.

HADES – Participation on the HADES collaboration. National PTDC call. No decision yet.

RPC-PET National PTDC call. No decision yet.

The new member of the RPC group (J. Saraiva) started functions in February 2017, since then he has revealed to be a very fruitful incorporation, contributing in several fronts within the group but specially within the RPC-PET group.

TOFtracker

A 4-layer of TOFtracker devices, for muon tomography of cargo containers at harbours, for the HYDRONAV S.A company has been constructed, integrated and deployed (http://macroescaner.com). The device is currently in operation delivering around 2-3 mm² and 200 ps spatial and time resolutions respectively, suitable for the detection of high Z material in cargo containers. The calibration of the device has to be completed and a significant improvement is expected . The collaboration with the aforementioned company will continue.

The construction of the 2/3-layers of TOFtracker devices, for the muon tomography of volcanoes, in the frame work of the TOMOVOL project (http://wwwobs.univ-bpclermont.fr/tomuvol/) has been postponed due to lack of resources within the group and due to an accumulated delay in the Stromboli muon tomography campaign.

The commissioning of the MASTER telescope in Rio has been started but it is still not concluded due to the current lack of resources.

Sealed and environmentally robust RPCs

20 RPC sensitive volumes (of a total of 40) have been constructed and tested for the MARTA FCT/FAPESP project along with the gas systems, environmental monitoring and HV Power Supplies. After a long campaign devoted to technology transfer, 10 of them are already in São Carlos for the integration of sensitive volumes, with the locally-produced mechanics and wiring.

In the R&D field (with the aim of developing large-area sealed RPC), some components used in the construction of sensitive volumes have been exchanged, but no major changes were observed. The internal inspection of "used" gaps suggests a non perfect fresh gas distribution over all the gaps area. For that reason, a second gas inlet has been introduced and will be tested in 2018.

No R&D on the frame work of LATTES has been done due to lack of resources.

The construction of the cosmic ray telescope for Antarctica has already been initiated.

We continue providing operational support to the TRAGALDABAS cosmic ray observatory, which is being upgraded after two years of data taking.

High-rate

The construction and test of eight small high-quality single-gap, spacerless, stainless-steel cathode chambers to beam-test promising high-rate RPC electrode materials at CERN was done at rates above few kHz/cm2. The data analysis is ongoing.

Detectors for RPC-PET

The upgrade of the existing RPC-PET to a pre-commercial small-animal scanner has been started. This includes a new DAQ system, FEE electronics and a friendly user interface. Please see the specific group report for details.

Physical modelling

The book on "Resistive gaseous detectors" written by P. Fonte with Vladimir Peskov and Marcello Abbrescia has been finished and is now in the edition phase.

Epi-thermal neutron detectors

The construction and test in beam of a new prototype of Epi-thermal neutron sensitive RPC has been done. A detection efficiency of more than 50% together with a 2D-spatial resolution of the order of 300 μ has been demonstrated. Please see the specific group report.

HADES

The implementation of the new RPC-TOF-FD into the software of the experiment and the first prototype of a module of the RPC-TOF-FD has accumulated some delay due to lack of resources. The RPC-TOF-W has been removed from the HADES main frame to proceed to the installation of the new ECAL calorimeter. Please see the specific group report.

Lines of work and objectives for next year

Funding

Any opportunity of funding on the framework of our activities will be pursued.

TOFtracker

The calibration of the 4-layer muon telescope for the HYDRONAV S.A company should be done as well as the commissioning of the MARTA RIO telescope.

It is not clear if the construction of the 2/3-layers of TOFtracker devices, for the muon tomography of volcanoes, in the frame work of the TOMOVOL project will continue. For the time being, due to lack of manpower, it is very unlikely that we proceed with this project.

Sealed and environmentally robust RPCs

The MARTA FCT/FAPESP production (40 RPC detectors in total) will be finished and the integration at São Carlos and installation at Auger site will be started.

Some R&D on the frame work of LATTES will be done, mainly in the operation of RPC at low pressure (high altitude).

The construction, test and deployment of the cosmic ray telescope for Antarctica project will be done.

The upgrade of the TRAGALDABAS cosmic ray observatory will be finished, resuming the data taking.

High-rate

Finish the data analysis of the gathered data during the test bean at CERN. This will be the outcome of the AIDA2020 EU project.

Detectors for RPC-PET

The upgrade of the existing RPC-PET to a pre-commercial small-animal scanner will be finished. Please see the specific group report for details.

Physical modelling

No specific work will be developed in this area.

Epi-thermal neutron detectors

The next challenge is to exploit how low we will be able to reduce the background and the sensitivity to the gamma rays; A dedicated setup will be implemented at LIP facilities for the studies of the gamma sensitivity of ^{10}B lined RPCs, by using the ^{60}Co and ^{22}Na gamma sources. It should be noted that the RPCs plateau for the detection of thermal neutrons is considerably shifted towards the lower voltages relatively to the plateau for the detection of MIPs.

We should proceed with the investigations of the Multigap RPCs configuration; we continue to face challenging issues related with the surface resistivity of the $^{10}B_4C$ coatings (not high enough to avoid the spreading of the induced signals).

In view of the optimization of the counting rate in a detector with a multilayer configuration, we will performe simulations with ANTS2 to set the optimal combinations of $^{10}B_4C$ layers thicknesses allowing to equalizes the counting rate in all ^{10}B lined RPCs forming the stack.

HADES

The implementation of the new RPC-TOF-FD into the software of the experiment should be done in the first semester of the year. The first prototype of a module of the RPC-TOF-FD will be constructed and tested. After validation the construction of four modules will be done.

The RPC-TOF-W will be mounted in the new ECAL mainframe. The detector should be prepared for the resume of the HADES data taking by the mid of the year. Please see the specific group report.

SWOT Analysis

Strenghts

The team has proven repeatedly to be competent, inventive, productive and reliable. It was reinforced recently with the arrival of a new physicist under a technical contract.

Have access to LIP's technical infrastructures, which include some very good and experienced technicians and a well equipped mechanical workshop.

Enjoy the confidence of some RPC-enthusiastic colleagues that help to overcome the reduced number of elements of our core team, presenting our work abroad and collaborating with us.

Weaknesses

Structurally, there is a limited capability to cope with variable demands on detector production, which in an optimistic scenario may limit our throughput capacity.

Opportunities

We believe to have or being about to have very competitive detectors for the application "markets": animal RPC-PET, muon tomography, cosmic ray physics and thermal neutrons.

The human RPC-PET application requires a longer and more demanding development, along with financing on the order of millions, but it is potentially hugely interesting.

We are proposing to the new SHIP collaboration at CERN to contribute to the experiment with RPC timing detectors.

Threats

Hostile funding environment.

In the long term, aging of the team members will become a determinant factor.

GASEOUS DETECTORS R&D

Gaseous Detectors R&D

The group has three main lines of work:

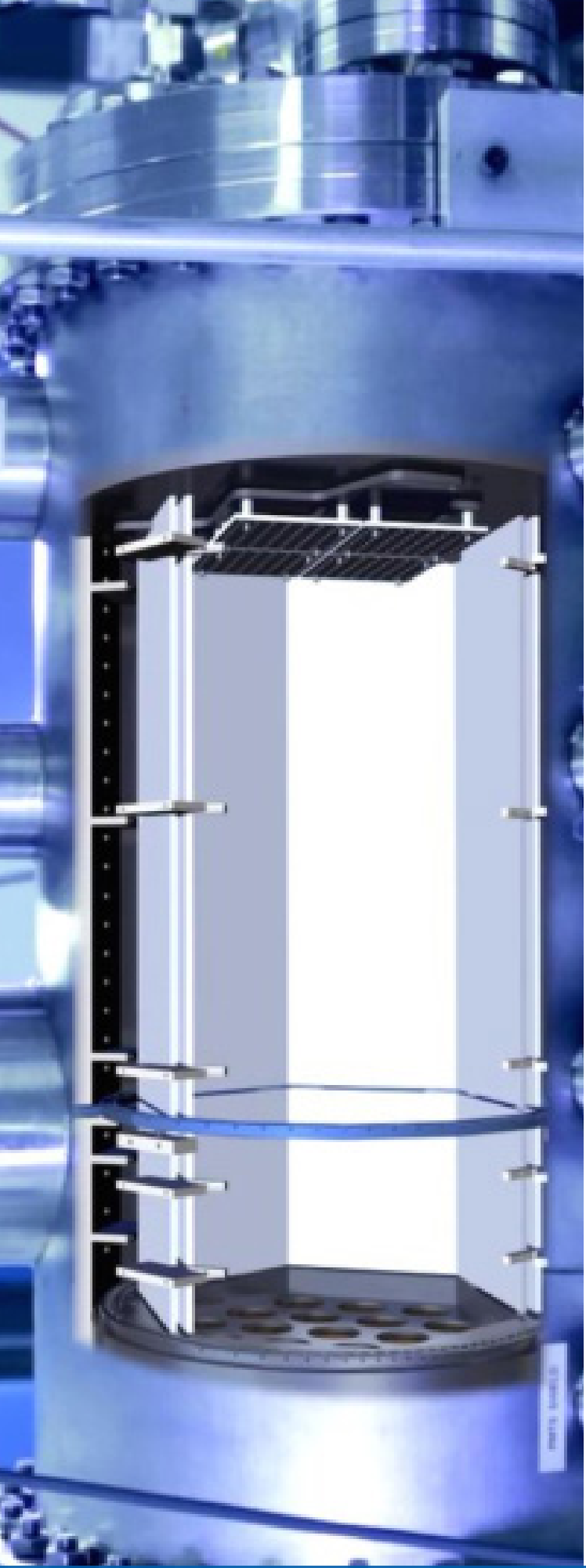
Development of HP-Xe detector: Development of a ruggedized high pressure Xe filled detector, optimized for field applications, namely for homeland security applications and geological boreholes prospection. We intend to build a prototype of a detector conceived within the team: the MultiGrid High Pressure Gas Proportional Scintillation Counter (MGHP-GPSC), that we hope will surpass the most common room temperature gaseous detectors described in the literature for gamma and hard X-ray spectrometry, namely with an efficiency above 5%, large size (of the order of the hundreds of cm^2) and an energy resolution better than 3% at 662 keV. It has the advantage of featuring a photocathode deposit integrated in the gas volume, which avoids the need for optical windows and microstructures or photodiodes, also rendering it more ruggedized than the standard GPSCs. Additionally, it provides improved energy resolution, as the gain of this device is scintillation mediated, not involving any charge multiplication.
The detector has been tested for its performance with alpha particles, namely by measuring its gain and achievable energy resolution. The performance dependence on the different adjustable parameters of the detector, like the voltage applied to the anode and collecting grid and gas pressure (up to 3 bar) were also made. Some tests with gamma rays for higher pressures (8-15 bar) were be performed, although limited due to problems with the available high voltage sources.

Ion mobility measurements: Measurement of the mobility of ions in gases is relevant in several areas such as the understanding of pulse shape in gaseous detectors, in IMS (Ion Mobility Spectrometry), a technique used for example for narcotics and explosives detection and recently in Negative Ion Time Projection Chambers(NITPCs), that use negative ions as charge carriers instead of electrons. In fact, data on ion mobility is especially important for improving the performance of large volume gaseous detectors, such as the ALICE and NEXT TPCs or NITPCs and in Transition Radiation Detectors. This has created an increasing interest among the CERN community, and several requests to study ion mobilities for specific gas mixtures have been made to our group. Ion mobility measurements have been made in several gaseous mixtures of interest for large volume gaseous detectors with a dedicated system, specially developed for this purpose that features unique characteristics. Monte Carlo simulation concerning ion mobility is also performed whenever considered adequate for the interpretation of the experimental results.

Overview

Summary of performance indicators

International journals:	3 Articles with direct contribution from the team
Completed Theses:	1 Master thesis



Low pressure application: In the XIPE mission (one of the three pre-selected missions seeking for approval from ESA for launching in the next decade) our group has the task of optimizing the GPD gas mixture. Our homemade Monte Carlo code is being adapted to identify the gas mixture that gives the lowest electron diffusion coefficients and higher drift velocity, while maintaining a good detection efficiency for the energy range under study (up to 15 keV). The combination of these characteristics will ensure a better reconstruction of the photoelectrons emission direction, improving the accuracy of the determination of the degree of polarization of the radiation. Results have already been obtained for Xe, Ne, Ar and He and the extension of the simulation code to their mixtures with quenching additive gases such as DME and isobutene is ongoing. Also an experimental system that will allow the measurement of the electron drift parameters in these gas mixtures is being projected and will be constructed soon.

Team

Principal Investigator Filomena Santos (30)

Researchers
Carlos Conde (50), Filipa Borges (50), Jorge Maia (15), José Escada (50), João Barata (40), Rui Marques (15), Teresa Dias (10)

Technician
Rui Pereira da Silva (15)

PhD Students
Alexandre Fonseca Trindade (40), André Cortez (100)

Master Students
José Perdigoto (66), Miguel Santos (33)

External/Additional Collaborator
Sérgio Carmo

Total FTE

5.1

// GROUPS: Neutron Detectors / RPC R&D / Gas Detectors R&D / Liquid Xenon R&D

Lines of work and team organization

a) Development of HP-Xe detector

This task has been a central part of the PhD work of André Cortez, supervised by Filipa Borges and Sergio do Carmo, counting with the support of Prof. Carlos Conde and the experimental expertise of Alexandre Trindade. The PhD thesis will be finished during 2018.

b) Measurement of the mobility of ions in gases

This task is also part of the work by PhD student André Cortez, who is also co-supervising with Filipa Borges the work of the MSc thesis of Miguel Santos on the subject. A chamber that will allow the measurement of negative ions of interest for Negative Ion Time Projection Chambers was already projected and constructed as part of this MSc thesis and is expected to allow the first experimental measurements in 2018.

Mobility of positive ions in several noble gas mixtures with molecular gases have been the subject of ongoing research work developed in the framework of RD51 Collaboration. The members of the team responsible for the task are André Cortez, Filipa Borges, Carlos Conde and João Barata.

c) Low pressure application

The Monte Carlo code to obtain the results for this task is being upgraded by José Escada, with the supervision of Rui Silva and Filomena Santos.

The experimental setup to measure the drift parameters of electrons in these gases is being performed by Alexandre Trindade as part of his PhD programme, co-supervised by Filomena Santos and Rui Silva, trusting on the experimental expertise of Jorge Maia.

Stated objectives for past year

a) HPXe detector

The objectives for the HPXe detector were the tests with alpha particles and gamma rays, these last ones expected to be more challenging, namely in the detector electronics associated and due to the need of solid angle correction.

b) Ion mobility

Extend the positive ion mobility measurements to other mixtures of interest for large volume detectors, like Xe-C2H6, Xe-CH4, Ar-N2 and, following requests received from the Univ. of Bonn (Germany) to study the ion mobility in Ar-CF4-IsoButhane (T2K mixture) for the LCTPC collaboration, the measurement of ion mobility in Ar-CF4, and CF4- IsoButhane were performed.

c) Low pressure application

Within the XIPE mission, adapt a Monte Carlo simulation code previously developed to the rare gases Ar and He. The purpose is to identify a suitable mixture of these light gases with quenching additives (DME and isobutene), in terms of electron drift parameters.

Main Achievements

a) HP xenon

The tests with alpha particles were made, allowing to assess the gain and energy resolution dependence with the adjustable detector parameters (gas pressure and high voltage at the anode and collecting grid). The tests with gamma rays have still given few results, due to some problems with the high voltage needed to bias the anode. In fact, since the gas pressure is higher for gamma ray detection, so is the biasing needed for the same reduced electric fields in the different detector regions. Limitations of the voltage sources available constrained the results obtained so far for gamma rays. The solid angle correction possibilities were studied, but not implemented yet, due to the delay in the gamma ray tests.

ThePhD work of André Cortez is now finished and just waiting for minor revisions of the supervisors, Filipa Borges and Sergio do Carmo, before being submitted for evaluation.

Concerning the system to study the photocathode extraction efficiency dependence with angle of incidence of light, a study of the lamp intensity effect on the instabilities problems of this experimental system were performed without significant results obtained.

b) ion mobility

In the ion mobility measurements we extended the positive ion mobility measurements to other mixtures of interest for large volume detectors, like Xe-C2H6, Xe-CH4, Ar-N2 and, following requests received from the Univ. of Bonn (Germany) to study mobility in Ar-CF4-IsoButhane (T2K mixture) for the LCTPC collaboration, also the measurement of ion mobility in Ar-CF4, and CF4- IsoButhane.

The collaboration with JINR (Joint Institute for Nuclear Research) is now established and with good perspectives for future work, since the negative ion mobility system already being assembled. This collaboration has originated a couple of visits to the LIP Coimbra Lab by Dr. Grzegorz Kaminski from JINR and also a 2-month stay by a MSc student in the scope of this collaboration.

Also, a MSc thesis was completed by MSc student José Perdigoto in 2017 under the supervision of André Cortez and Filipa Borges.

The approval of a national project funding (CERN/FIS-INS/0025/2017) that involves this task, will allow to develop the

systems and eventually the manpower needed.

Monte Carlo simulation codes were used in some mixtures to complement information obtained from the experimental measurements, although the Monte Carlo simulation study on the drift of Xe negative ion clusters in pure xenon, encountered some difficulties, namely on integral and differential collisional cross sections data available. For this reason no significant results were achieved in this item yet.

c) Low pressure application

Concerning the work related with the XIPE mission Collaboration our group has adapted a Monte Carlo simulation code to identify the gas mixture that has the lowest diffusion and highest drift velocity of electrons. The studied gases were Ar and He and the study of their mixtures with quenching additive gases, such as DME and isobutene, is on progress.

Outreach

Participation of 3 students from High School in the "Ciência Viva" program that gives the opportunity to students of high school to participate in scientific investigation teams as a first contact with the scientific community. Participation of 2 MSc students from the Master Science in Physical Engineering of the Physics Dep. of the UC in "Estágios de Verão da UC" which gives the opportunity to University students to participate in the work being developed in the investigation group.

Lines of work and objectives for next year

The team of Gas Detectors R&D group at LIP Coimbra has the expertise of more than 3 decades and, at the moment, several experimental systems assembled that allow the measurement of physical properties of most of the gases used in gaseous detectors, namely electron and ion drift parameters, electroluminescence yield and charge gain. Depending on the manpower availability, most of the times from students finishing their MSc degree at the Physics Dept. of UC, we propose to exploit the following areas in the coming years:

a) Development of gas detectors

We intend to continue the study of the performance of the HP-Xe detector, now for gamma rays, understanding the parameters that may improve its performance, namely in energy resolution, eventually through the compensation of solid angle effects and the use of digital signal processing. A contact recently established with Dr.Mohammad Nakhostin from Surrey University in England, may help in this last issue.

The possibility of changing the geometry of the HPXe detector to make it more adequate for other applications (e.g., Radon detection in consumable water) and eventually more efficient in the light collection will also be evaluated.

b) Study of mixtures for gas detectors

The experimental systems to measure positive ion mobility will continue working following the collaboration with the Univ. of Bonn (Germany), namely in the current study of the ion mobility in Ar-CF4-IsoButhane mixture (T2K mixture) for the LCTPC collaboration, and other mixtures considered interesting for large volume detectors. The negative ion mobility system is being assembled at the moment and will allow the continuity of the collaboration started with JINR (Joint Institute for Nuclear Research) for the coming years. Part of this work will be performed by MSc student Miguel Santos under the supervision of André Cortez and Filipa Borges.

The measurement of electroluminescence yield and charge gain of noble gas mixtures doped with electronegative gases, like SF6, is also a possibility, since the use of electronegative dopants, namely in large volume detectors that require accurate track reconstruction, is a subject that has received recent attention in the scientific community. The experimental systems to do such measurements are accessible, and this work is only depending on the availability of manpower.

Also, experimental systems to measure electron diffusion and drift velocity are being projected and will soon be implemented by PhD student Alexandre Trindade, allowing to obtain these parameters for the any needed mixture. The tests will start with noble gases and their mixtures, to cross-check the results obtained by Monte Carlo simulation in the scope of XIPE collaboration. The possibility of combining noble gases with quenching additives like DME and isobutane gases.

We also intend to evaluate the possibility of constructing an experimental system to measure ion diffusion, eventually using a TimePix device (developed at CERN) to obtain the XY position of the ion cloud. The interest of the scientific community, namely of groups from RD51 collaboration, in this issue is being assessed, with some interest already shown from CEA Saclay (France) and Uludag Univ. (Turkey) groups.

Monte Carlo simulation homemade codes to allow a better clarification of any of these issues is always a possibility that can be explored, since the group has a long expertise in this kind of computation skills.

c) Low pressure application

In XIPE mission collaboration our group has the task of optimizing the GPD gas mixture. Our custom made FORTRAN Monte Carlo code is being adapted to find the gas mixture which displays the lowest electron diffusion in the gas and the highest electron drift velocity. This optimal gaseous mixture will allow better reconstruction of photoelectrons emission direction and therefore degree of polarization of the incident radiation.. So far results were obtained for several noble gases (Xe, Ar, Ne and He), alone and mixtures between them, such as Xe and Ne, but the simulation code will be adapted to include quenching additive gases like DME and isobutane. Furthermore, an experimental system is being developed to measure electron cloud diffusion, in order to cross check with simulation results.

Outreach

Participation in Ciência Viva programs that give high school students the opportunity to participate in scientific research teams as a first contact with the scientific community; “Estágios de Verão da UC” directed towards University students of the scientific area, giving them the opportunity to participate in the work developed in the research group; Collaboration in visits from high school students to the Physics Department of the University of Coimbra, is also intended to continue.

SWOT Analysis

Strenghts

The expertise on both experimental gaseous detectors handling and on Monte-Carlo simulation involving electrons and ions in gases and gaseous admixtures, is one of the strengths of this group. We also have both the know-how and the equipment necessary to carry out measurements of electron and ion mobilities in gaseous mixtures, electroluminescence and gain yields. The systems developed are very versatile tools that can be used for a variety of studies, helping to improve the gaseous detectors, namely the large volume detectors now being used in several areas of fundamental research and field applications.

Weaknesses

Lack of financed projects / low budget granted in recent years has limited both the investment in equipment and/or the attendance of scientific meetings by the team members.

Opportunities

Ion mobility measurements eagerly needed by the community have recently been carried out with success. The NEXT and ALICE Collaborations, as well as the invitations from other collaborations are good examples of such lack of information and of the recognition by the scientific community.

The development of gas detectors that can be used in field applications, like the HPXe detector, with better performance than their competitors can allow to establish contacts with the industry on this area (mainly international), hoping that financial support for further developments can be obtained.

There is a serious possibility of expanding our work to the Astrophysics domain, where new gas mixtures for polarimetric studies are being sought.

Threats

The lack of financing that brings also the lack of dedicated manpower is a threat to the group, since the senior members are also teachers at universities (Coimbra and Covilhã) and so the available time to research is limited by the teaching constraints. These budgets constraints, limiting also the attendance to international conferences/scientific meetings on the research area, also make collaborations with other foreign groups of the area more difficult to be achieved.

Publications

3 Articles in international journals (with direct contribution from team)

Cortez, AFV (Cortez, A. F. V.); Santos, MAG (Santos, M. A. G.); Veenhof, R (Veenhof, R.); Patra, RN (Patra, R. N.); Neves, PNB (Neves, P. N. B.); Santos, FP (Santos, F. P.); Borges, FIGM (Borges, F. I. G. M.); Conde, CAN (Conde, C. A. N.): "Experimental ion mobility measurements in Xe-CO2", JOURNAL OF INSTRUMENTATION Volume: 12 Article Number: P06012 DOI: 10.1088/1748-0221/12/06/P06012 Published: JUN 2017

Perdigoto, JMC (Perdigoto, J. M. C.); Cortez, AFV (Cortez, A. F. V.); Veenhof, R (Veenhof, R.); Neves, PNB (Neves, P. N. B.); Santos, FP (Santos, F. P.); Borges, FIGM (Borges, F. I. G. M.); Conde, CAN (Conde, C. A. N.): "Experimental ion mobility measurements in Xe-CH4", JOURNAL OF INSTRUMENTATION Volume: 12 Article Number: P09003 DOI: 10.1088/1748-0221/12/09/P09003 Published: SEP 2017

Perdigoto, JMC; Cortez, AFV; Veenhof, R ; Neves, PNB; Santos, FP; Borges, FIGM; Conde, CAN: "Experimental ion mobility measurements in Xe-C2H6", JOURNAL OF INSTRUMENTATION Volume: 12 Article Number: P10011 DOI: 10.1088/1748-0221/12/10/P10011 Published: OCT 2017

Theses

1 PhD Thesis

André Cortez: "Novel Techniques for High Pressure Noble Gas Radiation Detectors" (ongoing)

2 Master Theses

José Perdigoto: "Measurement of ion mobility in relevant mixtures used in gas detectors" (finished on 2017-09-29)

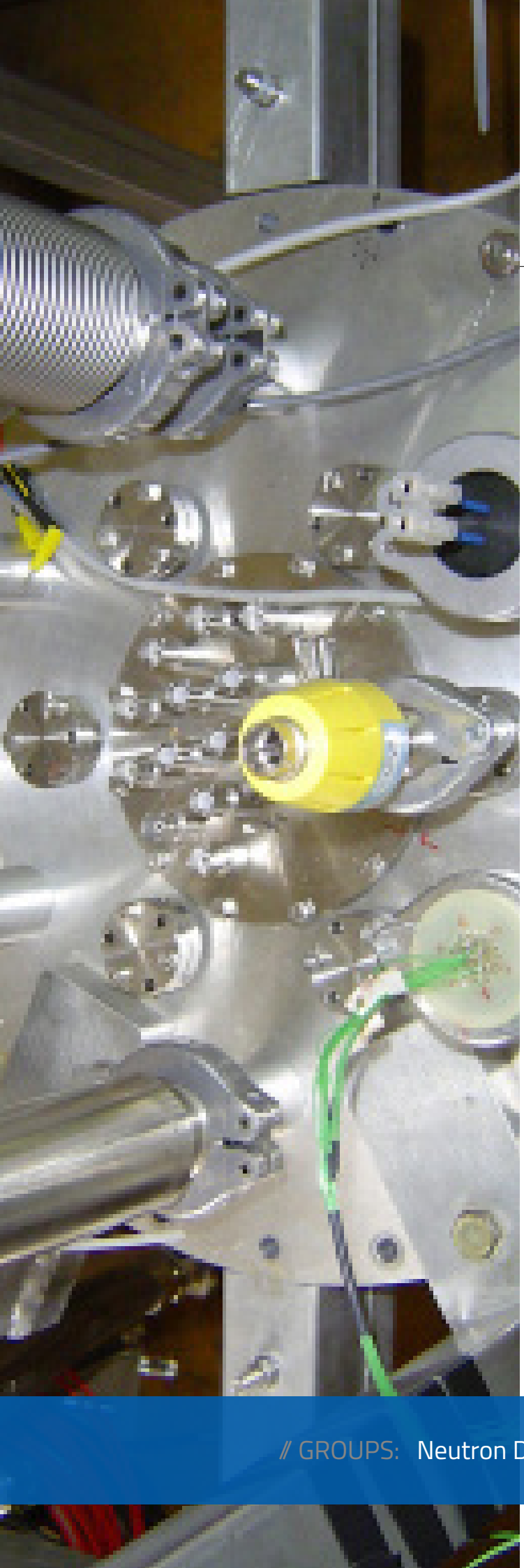
Miguel Santos: "Development of a Negative Ion Drift Chamber and Study of negative ion transport properties in gaseous mixtures of interest" (ongoing)

LIQUID XENON R&D

Liquid Xenon R&D

Overview

There is a number of experiments around the world using liquid xenon as detector medium. These include search for lepton number violating muon decay, dark matter searches and neutrino physics. Although the energy ranges of interest of these experiment are different, they have very much in common from the detection point of view. The general idea of this group is to carry out research on the processes triggered by particle interaction with liquid xenon as well as on the associated technologies, not being directly involved in any of those experiments. This would provide the opportunity for studying fundamental processes in liquid xenon and advanced detection technologies that are not immediate goals of large collaborations, whose work is usually highly focused and tightly scheduled. Such studies may become of significance for the future generation of liquid xenon detectors.



Team

Principal Investigator Vitaly Chepel(70)

Researchers
Andrey Morozov (10), Francisco Neves (15), Vladimir Solovov (15)

Technicians
Américo Pereira (15)

External/Additional scientific collaborator
Filipa Balau

Total FTE
1.4

// GROUPS: Neutron Detectors / RPC R&D / Gas Detectors R&D

Lines of work and team organization

R&D on liquid xenon as detector medium and associated technologies. All electronic, optical and molecular processes, that develop in a single or double phase liquid xenon detector in consequence of particle interaction with the liquid, are in the scope of the activity of this group. More specifically, propagation of scintillation photons in the liquid and their detection can be pointed out as the immediate objects of the study.

Stated objectives for past year

Study response of Hamamatsu silicon photomultipliers to liquid xenon and liquid argon scintillations without using wavelength shifting materials. Develop a concept of an experiment for measuring Rayleigh scattering length in liquid xenon at xenon scintillation wavelength. If possible, advance with construction of the setup. Apply for funding in the next FCT call. Search for other funding opportunities. We foresee a closer collaboration with other detector development groups including the possibility of a common funding application.

Main Achievements

A funding application has been submitted to FCT together with other detector development groups. The decision is expected soon. Another common application to CERN Fund has also been submitted in the frame of the RD51 Collaboration together with ADDF and University of Aveiro. A small funding has been recommended by the panel and is expected to start in spring.

Lines of work and objectives for next year

Start working in the framework of the RD51 project (assuming its approval in due time) where experimental studies of density effects on secondary scintillation signal formation in xenon time projection chambers are foreseen. The setup is planned to be designed and possibly manufactured, in part.

SWOT Analysis

Strenghts

Highly qualified team with many years of experience in the field.

Weaknesses

Systematic underfunding leading to degradation of the experimental base.

Opportunities

Overcome W and T, there would be a good opportunity of understanding fundamental physics of particle detectors and provide a valuable input for future large scale detector development.

Threats

Lack of support for R&D projects. Lack of long and medium term scientific policy. Heavy involvement of the team members in other projects and activities. Limited avalability of mechanical workshop for R&D projects.

Sources of Funding

Code	Amount	Dates	Description
CERN/FIS-INS/0025/2017	70.000 €	2018-05-01 / 2020-04-30	Participation in the RD51 Colaboration

Health and biomedical applications

PET WITH RESISTIVE PLATE CHAMBERS (RPC-PET)

RPC-PET

This Group is devoted to the application of the Resistive Plate Chamber (RPC) detector technology to Positron Emission Tomography (PET).

The activities started in 2000, with the first public presentation in 2001 and the first (simulation-based) publication "Perspectives for Positron Emission Tomography with Resistive Plate Chambers" appearing in 2003. Already two avenues of development were identified: high-sensitivity whole-body human PET and high-resolution animal PET.

Over the years there were three PhD theses and several other publications on the subject. We believe to have demonstrated:

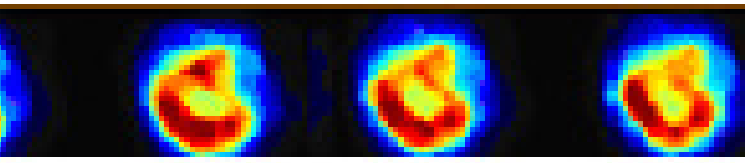
- the simulated quantum efficiency of RPCs for 511 keV photons corresponds to the reality
- a reconstructed source resolution of 0.4 mm FWHM
- practical high-resolution imaging of mice and rats
- the intrinsic time resolution of RPCs for 511keV photons is 300 ps FWHM for the time difference between the two photons
- the expected NEMA 2001-based NECR sensitivity of a human RPC-PET tomograph is 8-fold higher than the most sensitive current commercial scanner, excluding any TOF advantage
- anthropomorphic simulations confirmed the potential interest of this approach

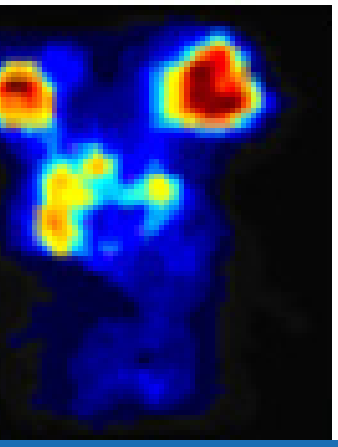
Overview

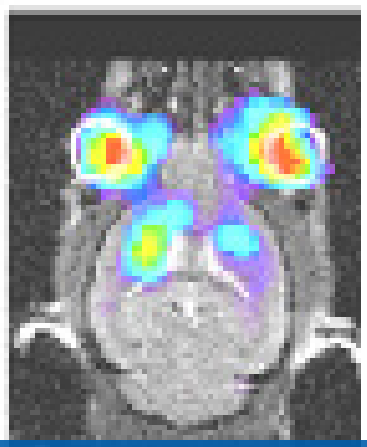
- image reconstruction of the huge whole-body dataset is possible in a practical time span
- the expected TOF capability provides strong advantages for trigger accuracy and scatter rejection, improving lesion contrast
- three years of routine use of the small animal scanner prototype in bio-research, operated by a non-specialized technician, without any major problems.

The first RPC-PET scanner for mice has been installed at the site of our collaborators at ICNAS (an institute of the University of Coimbra dedicated to Nuclear Medicine). Since August 2014 more than 200 examinations of mice and rats have been performed. The ICNAS team has used the prototype scanner for the study of the molecular mechanisms subjacent to the neurodegenerative diseases Alzheimer, Parkinson and Huntington in animal (mice) models. The radiopharceuticals used include FDG (metabolism), PK11195 (inflamation), PiB (beta-amiloid deposition), Cu-ASTM (oxidative stress).

On the human PET front, the basic structure of the scanner was long ago







designed and simulated, the readout method was patented (expired), and a general test of the readout system was performed.

It is specially important to mention that the DAQ group(*) of the HADES experiment at GSI, Germany (of which LIP is a member) is our partner in this project, providing a very modern and powerful data acquisition system.

The animal RPC-PET work fits the framework of our participation in the RD51 collaboration.

(*) Institutions: GSI, U.Frankfurt, U.J.Kracow

Team

Principal Investigator Paulo Fonte (25)

Researchers
Miguel Couceiro (10), Paulo Crespo (25), Rui Marques (30), Susete Fetal (20)

Technicians
Américo Pereira (5), João Saraiva (73), Orlando Cunha (5), Rui Alves (5)

PhD Student

Ana Lopes (25)

Total FTE

2.4

Lines of work and team organization

The team is broadly separated in two areas: hardware and software.

The hardware and data acquisition/processing is supported by the LIP RPC group/Detector Lab (see the specific reports) and HADES DAQ groups, while the remaining members concentrate on simulation and image reconstruction software.

Stated objectives for past year

Complete, test and deploy the pre-commercial version described above. Take steps towards an evaluation of the scanner in accordance with the relevant NEMA standard. Unfortunately the workload foreseen for the next year excludes the possibility to consider also improvements on the detectors (larger, as allowed by the new DAQ).

It is however a very positive development that LIP will hire in the next year a new physicist for the RPC group, which will remarkably increase the work capability of the group, with impact also on the RPC-PET project.

Apply for national funding, if possible.

Try to attract PhD students to work with us.

Main Achievements

Continuous support was provided to the routine bio-research activities at ICNAS using our prototype animal PET. Up to 2017 more than 200 PET examinations of mice were performed. The detectors performed flawlessly, but some need for improvement on the auxiliary instrumentation was identified. We believe it may be said that the small animal RPC-PET approach has been sufficiently tested and it is safe enough for pre-commercial deployment.

We initiated years ago the construction of a second, pre-commercial, animal PET, incorporating the following developments:

1. New front-end electronics with improved isolation with respect to external digital noise pickup, to improve the scanner's sensitivity by allowing to lower the trigger threshold.

2. New DAQ system (TRB3 - http://trb.gsi.de/), allowing to readout more charge channels for using fully the detector area (presently some channels are used for depth determination, reducing the active area)

3. Much smarter trigger electronics, allowing more timing/trigger channels for improved sensitivity (better signal transmission)

4. Integrated gas control and environmental monitorization system

5. More HV channels for tuning each head separately

6. New, friendly, operator and data-user interface software, with multi-user capability and browser-server architecture

7. Improved remote debugging/system recovery capability

8. Good-looking mechanics

As there were no manpower resources for the construction of a full new prototype we opted for upgrading the existing scanner. Therefore this activity becomes conditioned by the availability of a sufficiently wide time window on which the scanner will not be used for biology purposes.

The main development of the year was that items 1-3 were installed and are already operational. Evaluation is under way. In this, it must be emphasized the important role of the new (and the only one full-time) member of the RPC group.

Items 4 and 5 are fully developed and just await an opportunity for installation.

Items 6 to 8 remain about 50% developed. Some modest progress was made on #6.

Applied for national funding for this project.

Lines of work and objectives for next year

Continue the development of the pre-commercial RPC-PET scanner, as outlined in the previous section. Besides the items mentioned there, in 2018 there may be a chance to also upgrade the detectors and mechanics to cover the solid angle for the actual “rat-sized” tunnel (the detectors now installed were for the “mice-sized” tunnel). This is an important practical feature because it allows examination of rats and also full-body examination of mice.

Apply for regional funds to develop a brain+organs high-resolution RPC-PET. Important medical research questions require such development, an area in which our partners at ICNAS are active and successful.

SWOT Analysis

Strengths
The proposed technologies seem to be advantageous relatively to the standard solutions.

The group, in conjunction with its partners (ICNAS, GSI, U.Frankfurt), has the necessary competences and motivation to develop all elements of the RPC-PET scanners, including evaluation.

Weaknesses
Lack of insertion in the industry, affecting IP protection and eventual commercial operations.

While for the animal scanner the funding needs are small and within our reach, the development of the human scanner will require funding on the order of millions, probably inaccessible by small players like us. Let alone an eventual marketing phase.

In practice, lack of skilled manpower for hardware/software development, thinly spread over many projects. However, the recent addition of a physicist to the group has considerably improved this aspect.

Opportunities
The animal PET shows so far encouraging performance and, being also quite inexpensive, may be successfully marketable.

A high-resolution brain scanner seems to be also an interesting application niche, where the excellent resolution of RPC-PET may be very advantageous.

Threaths
Technical insuccess.
Inability to market the technology.

Theses:

1 PhD Theses

Ana Lopes: "Study by simulation and reconstruction of a brain-dedicated positron emission tomograph based on resistive plate chambers" (ongoing)

ORTHOGONAL RAY IMAGING FOR RADIOTHERAPY IMPROVEMENT

OR Imaging

Overview

The framework of the collaboration involves four main parties: the University of Coimbra (UC), LIP, the Department of Radiotherapy of Coimbra University Hospital Center (CHUC E.P.E.) and the Portuguese Institute of Oncology of Porto (IPO-Porto). For the past and current year two main tasks were accomplished:

1) the simulation of a complete OR imaging system acquiring data for the first time under several background conditions, and

2) data taking with a multi-sliced detector in realistic, therapeutic-like conditions.

Task 1 above was necessary in order to understand under what circumstances the technique may operate without degradation of the information provided by thin beams such as those to be used in OR imaging: 5 mm x 5 mm.

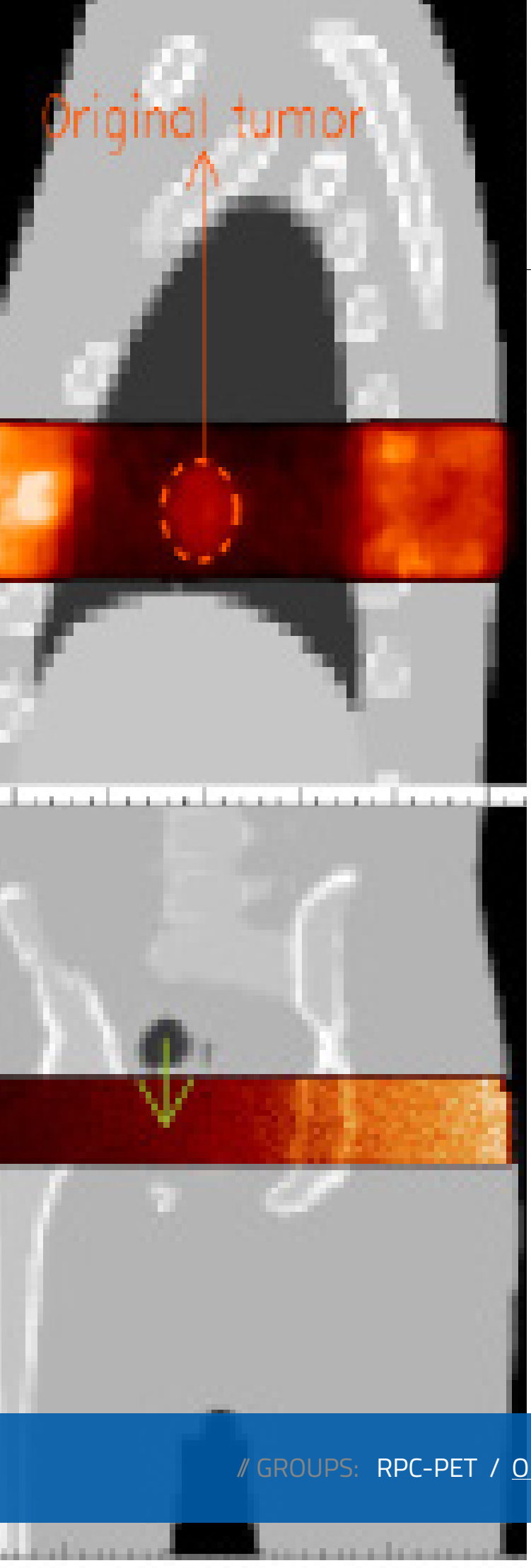
With respect to Task 2, data taking with a multi-sliced detector, this involved many hours of detector construction by the high-precision Mechanical Workshop of LIP together with the Detector Laboratory. For data taking the Truebeam linac recently installed at CHUC E.P.E. was utilized, with two main beam features alternatively activated: a 6 megavoltage beam with flattening filter, and a 6 megavoltage beam being flattening-filter free. Only the latter produced the expected results, showing excellent agreement with expectations.

Summary of performance indicators

Articles in international journals:	2 with direct contribution from the team
Completed theses:	1 PhD

DEVELOPMENT OF NEW INSTRUMENTS AND METHODS

Health and biomedical applications



Team

Principal Investigator Paulo Crespo (65)

Researcher
Carolina Travassos (41)

PhD students
Ana Lopes (41), Hugo Simões (100),
Patrícia Cambraia Lopes (79)

External scientific collaborators
Joana Lencart, João A. M. Santos, Maria do Carmo Lopes,
Paulo Rachinhas

Total FTE
3.3

// GROUPS: RPC-PET / OR Imaging / Gamma Cameras / Dosimetry

Lines of work and team organization

The lines of work are mainly divided between simulation and experimental work. Our colleagues from two hospitals providing high-energy X-ray-based radiotherapy treatments (Coimbra University Hospital Center and the Portuguese Oncology Institute of Porto) are (1) helping in carrying out the experimental work, and (2) giving their expert opinion on what simulations are of foremost importance.

At LIP and University of Coimbra we have so far engaged one assistant professor (project PI), and one PhD student putting forward efforts both in simulations and in the OrthoCT experiment that was carried out in the past half year.

Simulationwise, the main effort was put in mimicking the experiment carried out at CHUC EPE, where an acrylic phantom with cylindrical shape was irradiated. The phantom contains an air cavity at its center in order to provide a test of the capability of an OR imaging system to detect such cavity.

On the experimental side, the high-precision, mechanical workshop of LIP together with its detector laboratory have finalized the construction of a small-scale OrthoCT system that we have planned in collaboration. As predicted last year, that data taking at a therapeutic linac did already take place within the past half year, with very encouraging results obtained for irradiation in FFF mode (flattening-filter free). For the irradiation in the presence of a flattening filter (older treatment modalities), both simulation and experimental results have shown that the background arising from the linac compromises the imaging capability of the OR imaging system, making it not possible to visualize the air cavity in the center of the acrylic phantom.

Stated objectives for past year

Lines of work based on simulation:

- Adaptation of the simulation code in GEANT4 to the DICOM medical imaging data format, thus (later) enabling the computation of real treatment plans. This includes inputting into GEANT4 3D and 4D computed tomograms with patient data containing a tumor positioned in different locations in accordance with the respiratory cycle and/or patient dislocation and/or other physiologic movements such as bowel movements. Beam directions as indicated by the treatment planning should also be provided so that simulations take that variable into account if and when necessary.

- Adaptation of the simulation code in order to include the possibility of simulating the latest fiducial markers (usually gold-made small rods) imparted onto the bladder of a prostatic cancer patient.

Experimental lines of work:

- Achieving 1% 2D beam homogeinity at a therapeutic linac obtained via scanned, adjacent beamlets conformed by means of the jaws of the MLC (multi-leaf collimator). These homogeneous scans serve as the base for the next step

- Obtaining an image of a heterogeneous phantom with the small-scale OrthoCT system which is about to be complete in the next one-to-two months. These imaging experiments will allow hopefully to obtain an image of the interior of a muscle-like, heterogeneous phantom for the first time without the rotation of the X-ray source, which may lead to vary-fast OrthoCT imaging if the experiment arrives to provide useful 3D images of said phantom.

Main Achievements

The last objective stated in the past year was fully accomplished: we have obtained an image of the center of the acrylic phantom where the air cavity is clearly observed with a good confidence level (work is ongoing in this matter). The background of the linac has shown to be a major problem to be tackled, which was done with the help of lead walls amounting to over 300 kg of shielding positioned around the whole detector (except off course on the X-ray entrance window). The small-scale OR imaging device was utilized in order to obtain this result. Seven days of data-taking were necessary in order to cope and understand the source of the background flux of photons arising from several locations within the linac. The results show a clear correlation with the position of the air cavity in the case where the linac was operated in FFF mode (flattening filter free). The older mode of operation, FF (with flattening filter), did not reveal the necessary resolution in order to discriminate the presence of the air cavity within the acrylic phantom. These results are nevertheless encouraging since more and more modern irradiation techniques are using the FFF mode to treat patients.

Lines of work and objectives for next year

Analysis of the results obtained with FFF (flattening-filter free) and FF (with flattening filter) under the irradiation with a therapeutic-like beam at CHUC E.P.E. is now ongoing. This constitutes the most important objective for the next year.

Nevertheless, the so far very motivating results (correlation of the experimental small-scale OR images with the dose and the clear spatial correlation with the embedded air cavity) can be complemented by further simulations that could not be undertaken during the past year, namely:

- Adaptation of the simulation code in GEANT4 to the DICOM medical imaging data format, thus (later) enabling the computation of real treatment plans. This includes inputting into GEANT4 3D and 4D computed tomograms

with patient data containing a tumor positioned in different locations in accordance with the respiratory cycle and/or patient dislocation and/or other physiologic movements such as bowel movements. Beam directions as indicated by the treatment planning should also be provided so that simulations take that variable into account if and when necessary.

- Adaptation of the simulation code in order to include the possibility of simulating the latest fiducial markers (usually gold-made small rods) imparted onto the bladder of a prostatic cancer patient.

SWOT Analysis

Strengths

The rotation-free, low-dose imaging capability of OrthoCT are two of its great strengths. The imaging capability of OrthoCT has just recently been proven by experiment, although based on the FFF mode of irradiation (most modern irradiation technique). The on-board patient imaging capability is another potential strength of OrthoCT, together with its real-time imaging making use of the therapeutic beam, possible in some scenarios (irradiation angles) only.

Weaknesses

The high out-of-field photon flux existing in a clinical linac force OrthoCT to be surrounded by heavy shielding. This weakness can be overcome by proper robotic solutions to position the whole detector assembly; nevertheless, they come at non-negligible pricing.

Opportunities

The higher the degree of conformality achievable by means of external beam radiotherapy, the equally higher is the demand for patient imaging just prior (on-board) or during the therapy session, in order to ensure that the high conformal capability of the treatment is reaching its goals (tumor irradiation, sparing of organ(s) at risk or healthy tissue). OrthoCT represents an added value in both scenarios: on-board and/or real-time patient imaging.

Threats

The investment of clinical sites in other IGRT (image-guided radiation therapy) techniques makes investment in the OrthoCT technique questionable for such sites, at least before the return on investment is achieved.

Publications

2 Articles in international journals (with direct contribution from team)

A.L. Lopes, H. Simões, C. Travassos, P. Crespo: "Patient Compton scattered radiation for monitoring prostate radiotherapy with gold fiducial markers: A simulation study", Int. J. Pharma Med. Biol. Sci. 6:3 (2017) 77-82

H. Simões, A.L. Lopes, C. Travassos, P. Crespo, M. Alves Barros, J. Lencart, P.J.B.M. Rachinhas: "Monitoring tumor lung irradiation with megavoltage patient-scattered radiation: A full system simulation study", IEEE Trans. Radiat. Plasma Med. Sci. 1:5 (2017) 452-459

Theses

2 PhD Theses

Patrícia Cambraia Lopes: "Demonstration of a time-of-flight device for particle therapy monitoring" (finished on 2017-10-16)

Hugo Simões: "Demonstração de um dispositivo de imagiologia por raios ortogonais para apoio à radioterapia externa de fotões" (ongoing)

ADAPTIVE METHODS FOR MEDICAL IMAGING WITH GAMMA CAMERAS

Gamma Cameras

Overview

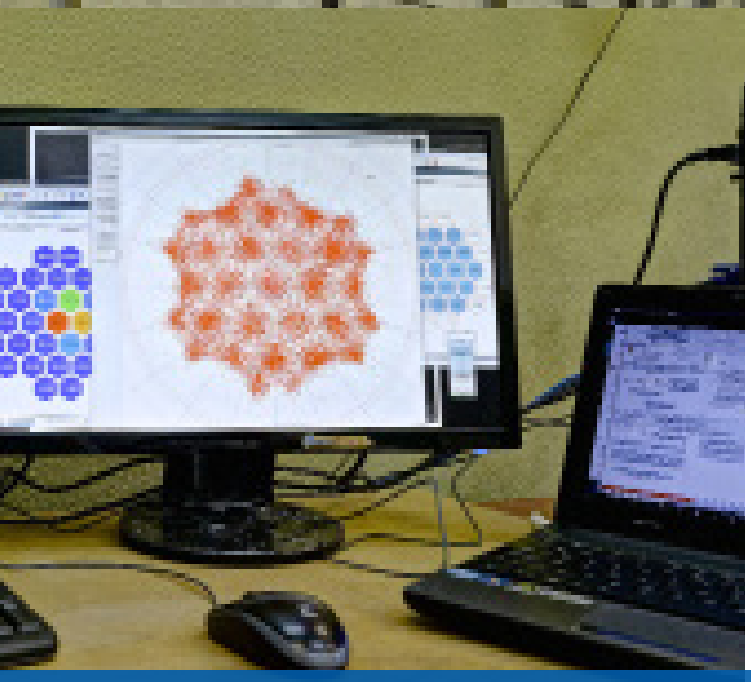
The group was formed in 2013 to apply the know-how accumulated at LIP in the course of the previous work on position-sensitive scintillation detectors (PSSD) to the areas of medical imaging and imaging techniques used in drug discovery. In the past years we confirmed, both by Monte Carlo simulation and experimentally, the applicability of our auto-calibration and position reconstruction techniques to both clinical gamma cameras of classical design and a compact high-resolution cameras with silicon photomultiplier (SiPM) readout. We also created an integrated software tool that incorporates the whole development workflow for PSSD: interactive design and simulation via a computer model as well as experimental data processing and event reconstruction. We collaborate with medical imaging units of Coimbra University (ICNAS and AIBILI) and Coimbra University Hospital (HUC). We continue collaboration with the Radiation Detectors and Applications Group at Politecnico di Milano.

Summary of performance indicators

Articles in international journals:	1 With direct contribution from team
International conferences:	1 Poster presentation
National conferences:	3 Oral presentations
National conferences:	1 Seminar

DEVELOPMENT OF NEW INSTRUMENTS AND METHODS

Health and biomedical applications



Team

Principal Investigator Vladimir Solovov (40)

Researchers
Andrey Morozov (50), Francisco Neves (10), Isabel Lopes (20), Vitaly Chepel (30)

Technicians
Américo Pereira (5), Nuno Carolino (5), Rui Alves (5)

PhD students
João Marcos (100), Luís Pereira (30)

External collaborators
Filipa Balau, M. Carminati

Total FTE
3.0

// GROUPS: RPC-PET / OR Imaging / Gamma Cameras / Dosimetry

Lines of work and team organization

- Autocalibration and fast calibration algorithms for PSSD. In this line of research, we work for expanding the range of detector configurations for which the self-calibrating techniques can be applied. Of particular interest here is the calibration of detectors with sensitivity in all three coordinates. We also look at possibilities to apply our expertise in areas beyond medical imaging, e.g. astrophysics and neutron detection.

- Development of simulation and data processing/ reconstruction software for PSSD. An open source ANTS2 software package, developed by the group, provides a set of easy-to-use tools for simulation and reconstruction of scintillation events in PSSD of configurable geometry. To our knowledge, it's the only publicly available software package that performs both event and detector response reconstruction for detectors of arbitrary geometry. Currently we are working on promoting the ANTS2 for use by other groups: creating better documentation and tutorials as well as integrating it with a third party open source package for SPECT and PET reconstruction.

- High resolution multi-isotope SPECT and PET. These are two fields of research for which fast calibration of scintillation crystal response in 3D can be highly beneficial. Our work in this direction is in collaboration with the Radiation Detectors and Applications Group at Politecnico di Milano that develops INSERT - multi-isotope SPECT brain imaging system. We also believe that our calibration techniques applied to small-animal PET can result in the development of a compact low-cost high resolution system. Here we are currently in the phase of feasibility study with Monte Carlo simulation.

- Experimental work required for the validation of our calibration and reconstruction techniques. This includes work with a clinical gamma camera upgraded for statistical event reconstruction and development of high resolution compact PSSD that can be eventually used in devices for prostate and intra-operative imaging. The experiments provide essential feedback for development of viable reconstruction algorithms and software.

Stated objectives for past year

The following lines of work were envisioned in the framework of this project for the past year:

- Development of algorithms for 3D position reconstruction in thick scintillation crystals and their experimental validation.

- Enhance event reconstruction in order to improve energy resolution.

- Promoting the ANTS2 software and increasing its user base.

- Feasibility study for freehand SPECT.

- Commercialization of the concept of self-calibrating clinical gamma camera.

Main Achievements

3D position reconstruction in thick scintillation crystals.

This work was carried out in collaboration with the Radiation Detectors and Applications Group at Politecnico di Milano. The Monte Carlo simulation with the ANTS2 package demonstrated that position sensitivity can be achieved in an off-the-shelf commercial cylindrical LaBr3:Ce crystal read out from only one side by an array of SiPMs. The predicted spatial resolution for 662 keV gamma rays in a 3"x3" crystal is better than 10 mm (FWHM) in transaxial plane and 15 mm in axial direction. The results of this work were presented at IEEE NSS-MIC 2017 conference. The experimental validation of this new technique is currently ongoing.

Enhance event reconstruction in order to improve energy resolution.

This research was also performed in collaboration with Politecnico di Milano from where we have hosted a master student working on implementation and optimization of the reconstruction technique (based on our adaptive method) for clinical and preclinical MRI/multi-energy SPECT systems (FP7 project INSERT). The objective was to use adaptive

Sources of Funding

Code	Amount	Dates	Description
IF/00378/2013/CP1172/CT001	50.000 €	2014-01-01 / 2018-12-31	FCT Exploratory research project (AM)

reconstruction in a thick scintillation camera without a lightguide in order to improve position and especially energy resolution. The developed solution was to apply kNN-based technique to filter out the events too close to the sensor array, effectively converting part of the crystal into a lightguide which permitted to use LRFs with axial symmetry in a reconstruction procedure similar to the one developed by us for standard scintillation cameras.

Development of the ANTS2 software and effort of increasing its user base.

The development repositories of the ANTS2 package were completely moved to Github. Github facilities are also used to host the documentation and support files. The task of maintaining software for constantly evolving platforms has proved to be particularly challenging. In response, we are exploring a modern virtualization/containerization approach: a test version of full ANTS2 system as a Docker image was made available from DockerHub.

The promotion effort resulted in adoption of the ANTS2 package for simulation and data processing by our collaborators both in LIP and other institutions. In particular, in LIP it is extensively used by Dark Matter group (determination of PTFE reflectivity, tuning of position reconstruction module for LZ mock data challenge and System Test) and Detectors group (neutron detector optimization; position reconstruction for RPC-based neutron detectors).

Additionally, the development effort was focused on improving usability of the system, in particular:

- Refactoring and streamlining material management system
- Upgrading of the LRF fitting module for improved stability, flexibility and ease of use.
- Interfacing with open source SPECT/PET reconstruction package (NiftyRec)

Also, full support for neutron elastic scattering and absorption was added to the simulation module.

Concept of a hand-held clinical gamma camera

After studying feasibility of developing a freehand SPECT scanner in collaboration with HUC, we reached the conclusion that its realisation would require a very significant effort, perhaps not fully justifiable by the expected benefit. However, based on this research and discussions with our colleagues from the hospital, we envisioned a simpler and more cost-effective system: a hand-held gamma imager for assisting the sentinel node biopsy surgery. This idea was taken with considerable interest by the hospital specialists, so we have developed a joint project in collaboration with the nuclear medicine department of HUC and submitted it to the last PTDC call in May 2017. The initial work on the detector head design, including Monte Carlo simulations and research on the collimator and shielding design, was performed by Joao Marcos as part of his PhD program.

Lines of work and objectives for next year

The objectives for the next year are:

- Work on 3D position sensitivity in thick monolithic scintillation crystals. This includes development of reliable calibration technique and experimental validation.
- Further push for expansion of the user base of the ANTS2 package
- Development of hand-held camera for sentinel node surgery.
- Work towards commercialization of the concept of self-calibrating clinical gamma camera.

The work will be organized along the following lines:

3D position sensitivity in thick monolithic scintillation crystals.

The problem of identifying the depth of interaction in a scintillation crystal existed for quite some time in PET imaging. The current solutions are expensive and/or time-consuming, for example, multiple high-resolution scans with pencil-beam source. There is also interest in measuring interaction position of high-energy gamma rays in large LaBr3:Ce scintillators for high-resolution gamma-spectroscopy of radioisotopes at relativistic velocities and for Compton camera for radiotherapy monitoring.

The main objective of the last year's work was to assess the feasibility of reconstructing all three coordinates of high energy gamma ray scatter positions in an off-the-shelf encapsulated scintillation detector. Our Monte Carlo study showed that it is possible and preliminary measurements made at Politecnico di Milano confirmed these findings. Based on this success, we are planning to advance to creating reliable 3D calibration technique based on machine learning methods (k Nearest Neighbour - kNN) and electronic collimation. This task will be performed in collaboration with Radiation Detectors and Applications Group from Politecnico di Milano and our partners from ICNAS. If successful, our method will be also beneficial to both multi-isotope SPECT and PET detectors.

Development of the ANTS2 software and increasing its user base.

The ANTS2 package is one of the core tools used in the research work conducted in the frame of this project. It is still under active development in order to meet the new challenges which rise during the work. We will continue to use GitHub to host the development files and support material. We plan to continue the work on making the ANTS2 package more attractive for the community by

- Providing powerful scripting capabilities through deeper integration of the scripting engine into the package
- Creating library of commonly used materials

- Creating web interface
- Creating a framework for distributed computing

Hand-held camera for sentinel node surgery.

The aim of this project is to develop an intraoperative gamma camera based on the state of the art technology, focusing the design on a low-cost, truly portable, ergonomic and simple-maintenance solution, that can be seamlessly integrated into the hospital environment. Moreover, the camera characteristics will permit to use it also for thyroid imaging, thus making it even a more cost-efficient solution. The project will be developed by an interdisciplinary team including physicists, nuclear medicine experts and surgeons to tailor the camera properties to the needs of the Portuguese nuclear medicine community.

Given the requirements (field of view of 60x60 mm2, energy resolution of 16% and intrinsic spatial resolution of 2mm, both at 140 keV), the task is challenging but realistic taking into account our level of expertise:

- We have acquired a lot of experience designing and operating compact cameras
- We will have constant feedback from hospital staff
- We count on help from LIP experts in electronics and mechanical design

The work to be performed in the first year will include studies on:

- Detector head: Crystal, SiPM, Collimator and Shielding
- Front-end electronics and data acquisition system
- Mechanical design

Commercialization of the concept of self-calibrating clinical gamma camera.

Our plan is to build a working prototype of self-calibrating gamma-camera that can be demonstrated and compared in performance with commercially available models. This year we completed the development of the data acquisition system based on TRB3 board from GSI. The system integrates TRB3 board, two ADC add-ons with total of 96 inputs, low-noise transimpedance front-end allowing readout of both SiPM and PMT arrays and trigger system. The read-out system was installed in an enclosure designed to provide good shielding and can now be taken outside the lab for experiments in clinical environment. We are currently running a set of tests to compare performance of this new acquisition system in respect to that of the MAROC3-based system, previously used by the group. After this we plan to collaborate with Nuclear Medicine department of HUC to run performance comparisons with currently available clinical models.

SWOT Analysis

Strengths

- The core members of the team have a proven track record of developing high-performance position sensitive scintillation detectors for several applications including medical imaging.
- The key technology of auto-calibrating scintillation camera was originally proposed and is currently developed by team members. The team maintains close ties with the dark matter research group at LIP, lead developer of position reconstruction and auto-calibration algorithms for LUX and LZ experiments.
- One of our key assets is the ANTS2 software package, the unique tool that permits to do both statistical event reconstruction and reconstruction of the detector response for a detector of practically arbitrary geometry.

Weaknesses

- Limited experience in dealing with business and industry. We are currently trying to close this gap by more actively seeking partners at the local “enterprise accelerator”

Opportunities

- Proximity of a large University Hospital (HUC). Doctors are interested in trying out compact gamma cameras as a guiding aid during chirurgical interventions
- The methods and tools developed in the group are of interest for a large community which leads to high potential to form new collaborations
- We expect that our advance to SPECT/PET reconstruction will attract new students to the team
- We must leverage current interest in machine learing both to develop new reconstruction/calibration methods and to promote our work

Threats

- One of the core team members and lead software developer is on a limited-duration contract
- The idea of self-calibration threatens large manufacturers’ revenue stream from periodic calibration services; we can hardly expect collaboration from this side.

Publications

1 Articles in international journals (with direct contribution from team)

A. Morozov, F. Alves, J. Marcos, R. Martins, L. Pereira, V. Solovov, V. Chepel: "Iterative reconstruction of SiPM light response functions in a square-shaped compact gamma camera", Phys. Med. Biol. 62 (2017) 3619-3638

Presentations

1 Poster presentations in international conferences

M. Carminati: "Study of Position Sensitivity of Large LaBr3:Ce Scintillators Readout by SiPMs", 2017-10-25, 2017 Nuclear Science Symposium and Medical Imaging Conference (NSS-MIC), Atlanta, Georgia, USA

3 Presentations in national conferences

João Marcos: "Characterization of silicon photomultiplier array for position sensitive scintillation detectors", 2017-06-08, 2nd Portuguese Doctoral Symposium on Engineering Physics, FEUP, Porto

João Marcos: "Characterization of silicon photomultiplier array for position sensitive scintillation detectors", 2017-07-20, Workshop of DAEPHYS Summer School,

João Marcos: "Câmaras gama com capacidade de auto-calibração", 2017-11-06, Encontro Nacional de Física Médica, Universidade de Coimbra

1 Seminars

Andrey Morozov: "ANTS2 toolkit: simulation and experimental data processing for Anger camera type detectors", 2017-04-20, , Politecnico di Milano, Dipartimento di Elettronica, Informazione e Bioingegneria

Theses

1 PhD Theses

João Marcos: "Real-time statistical event reconstruction for medical scintillation cameras" (ongoing)

RADIATION, HEALTH AND ENVIRONMENT

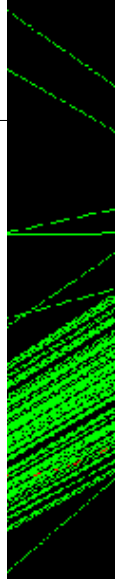
Dosimetry

Overview

The team is devoted to the development of detectors for dosimetry and Monte Carlo simulations of radiation effects in medical applications and radiation protection.

The group has been studying for the last year plastic scintillators in the context of clinical dosimetry. Light yield temperature dependency of four plastic scintillators (BCF-10, BCF-60, BC-404 and RP-200A) and two clear fibbers (BCF-98 and SK-80) have been studied. Except for BC-404 scintillator, all other scintillator's light yields showed small temperature dependence.

Another project started recently aims at obtaining accurate Auger electron spectra in selected radionuclides that can be incorporated in biomolecules for target cancer therapy. Currently we are updating the databases of Auger spectra of medical radionuclides for future dosimetry studies at the DNA scale (microdosimetry).

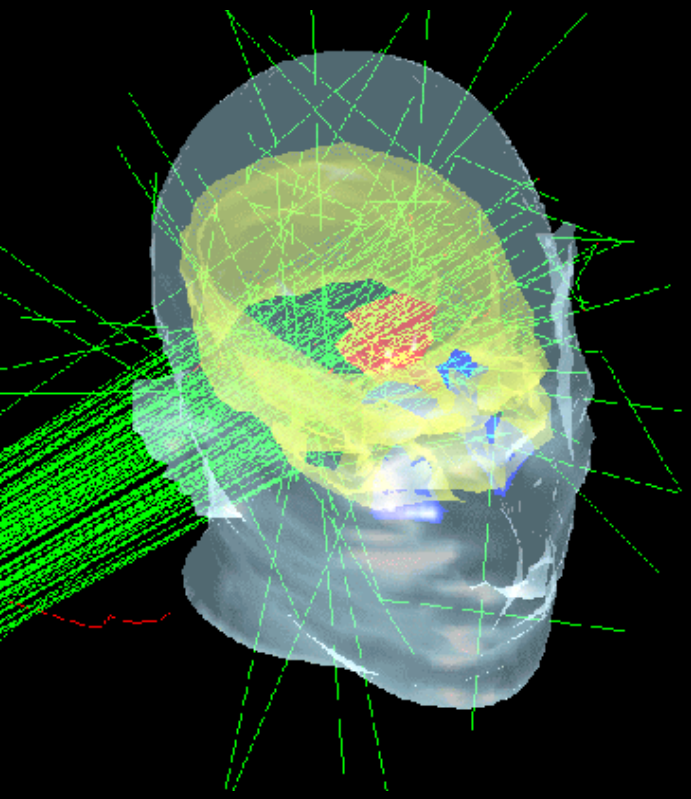


Summary of performance indicators

International journals:	2 Papers with direct contribution from team 1 Proceedings
Internal notes:	2 Internal notes
National meetings:	1 Oral presentation

DEVELOPMENT OF NEW INSTRUMENTS AND METHODS

Health and biomedical applications



Team

Principal Investigator Luis Peralta (25)

Researchers
Jorge Sampaio (30), Patrícia Gonçalves (10)

PhD students
Pamela Teubig (20)

Master students
José Miguel Venâncio (22)

External collaborators
Maria Daniela Pires

Total FTE
1.1

Lines of work and team organization

The group is divided into two thematic lines:

1. Clinical dosimetry

2. High-LET radiation microdosimetry

The first line focuses on the application of plastic scintillators and optical fibers in the context of clinical dosimetry. The responsible for this line is Luis Peralta.

The second line focuses on studies of radiation effects at cellular level aiming at determining the biological efficiency and induced damage of high LET radiation. Jorge Sampaio is responsible for this line of research.

Main Achievements

Plastic scintillator detectors have been studied as dosimeters, since they provide a cost- effective alternative to conventional ionization chambers. On the other hand, several articles have reported undesired response dependencies on beam energy and temperature, which enhances the necessity to determine appropriate correction factors. We studied the light yield temperature dependency of four plastic scintillators (BCF-10, BCF-60, BC-404 and RP-200A) and two clear fibers (BCF-98 and SK-80). Measurements were made using a 50 kVp X-ray beam to produce the scintillation and/or radioluminescence signal. The 0 to 40ºC temperature range was scanned for each scintillator, and temperature coefficients obtained. Except for BC-404 scintillator, all other scintillator's light yields showed small temperature dependence. This work was accepted for publishing in NIM A.

Tools for large-scale calculations of atomic transitions were developed in the past years (by one of the team members) that now can be applied to the determination of Auger electron spectra (including the very low-energy component that corresponds to very high-LET electrons). Calculations have now been completed for the electron captures descendants of ^{40}K, ^{111}In and ^{125}I, which are common radionuclides used in nuclear medicine and have potential for targeted cancer therapy. A project between the BioISI (FCUL) and LIP was proposed for funding to the FCT – "Auger Inputs for Targeted Cancer Therapy (AUGITTe)".

Lines of work and objectives for next year

In what concerns clinical dosimetry we expect that a collaboration with the Nu-Rise company from Aveiro will be under way. Dosimeters based on scintillating optical fibers will be tested in clinical environment.

We intend to initiate the design of a microdosimeter, that is, a dosimeter that allows determining the tracks and the energy deposited at the cell scale (which are stochastic in nature). For this we will explore the potential of using technology based on plastic scintillators as well as Si detectors that are known to have the high spatial resolution required for microdosimetry. This line of work will be developed in a partnership with INESC.

We will continue to update the Auger electron spectra database that will be used to study the energy deposited at the DNA scale. For these studies we intend to use the new extension GEANT4-DNA of the GEANT4 toolkit that allows implementing complex structures of the cell and infer radiation damage from the simulated energy deposition tracks. This line of work will be done in collaboration with the dosimetry and radiobiology group of CTN.

SWOT Analysis

Strengths

The team has a solid background in Nuclear and Atomic Physics, Radiation Physics and Dosimetry. Together the team encompasses competences in the development of detectors and applications of Monte Carlo simulations in detector characterization and dosimetry. The vast majority of the team members teach at faculties, which facilitates the recruitment of students for the project activities. In addition they have good contacts with the medical physics community.

Weaknesses

The group's activities have been dependent on highly competitive national funding programs and were therefore subject to bottlenecks due to research financial cuts in past years and delays in opening calls. There is a lack of a higher level of international networking that could promote the formation of consortia for applications to European funds.

Opportunities

The project will pursue the commercial development of dosimeters for clinical applications through partnership with the Nu-Rise company. Collaborations at national level with INESC in the development of a microdosimeter and in microdosimetry studies with CTN will be established. The (micro)dosimetry activities are in line with the strategic plan of LIP regarding future research in the projected installation of a hadron therapy unit in Portugal. These activities also open to international collaborations with the upcoming FAIR/GSI facility through the BIOMAT experiment regarding radiation effects of high-LET ions in biological systems.

Threats

Lack of funding that could hamper the development of the proposed new activities (mainly those related with the development of detectors).

Publications

2 Articles in international journals (with direct contribution from team)

J. Antunes, J. Machado, L. Peralta, N. Matela: "Plastic scintillation detectors for dose monitoring in digital breast tomosynthesis", Nucl. Instrum. Methods Phys. Res. Sect. A-Accel. Spectrom. Dect. Assoc. Equip. 877 (2018) 346-348

Luis Peralta: "Temperature dependence of plastic scintillators", Nucl. Instrum. Methods Phys. Res. Sect. A-Accel. Spectrom. Dect. Assoc. Equip. 883 (2018) 20-23

1 International Conference Proceedings

L.M. Moutinho, I.F. Castro, H. Freitas, J. Melo, P. Silva, A. Gonçalves, L. Peralta, P.J. Rachinhas, P.C.P.S. Simões, S. Pinto, A. Pereira, J.A.M. Santos, M. Costa , and J.F.C.A. Veloso: "Scintillating fiber optic dosimeters for breast and prostate brachytherapy", Optical Fibers and Sensors for Medical Diagnostics and Treatment Applications XVII, Proc. of SPIE Vol. 10058, 100580C, 2017

2 Internal Notes

J. Antunes, J. Machado, L. Peralta, N. Matela: "Plastic scintillation detectors for dose monitoring in digital breast tomosynthesis", arXiv:1707.01305v1 (2017)

Luis Peralta: "Temperature dependence of plastic scintillators", arXiv:1709.06458v1

Presentations

1 Oral presentation in National meeting

Jorge Sampaio: "Targeted Radiotherapy with Auger Electrons - An Atomic Physics Perspective", 2017-04-12, 2nd NOVA Biomedical Engineering Workshop, Faculdade de Ciências e Tecnologia da Universidade Nova de Lisboa, Caparica, Portugal

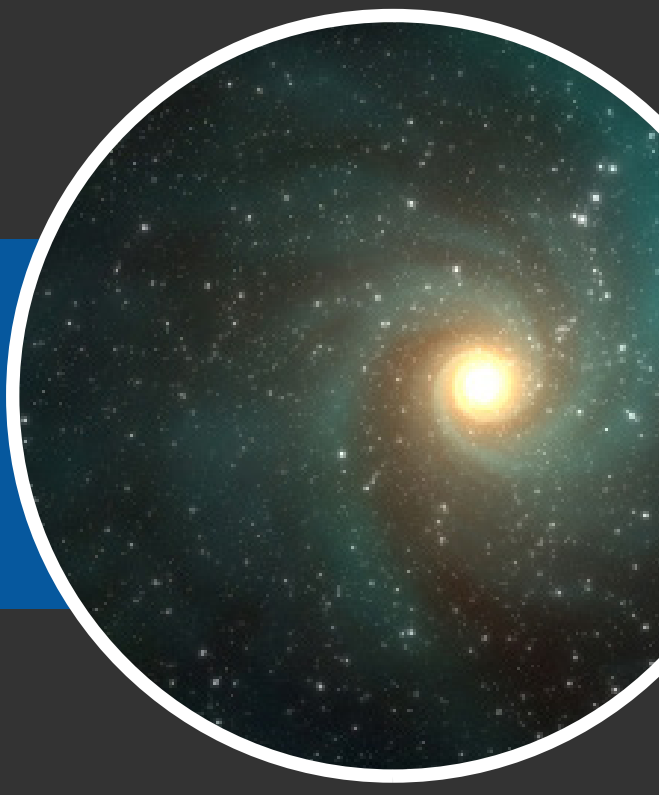
Theses

1 Master thesis

Maria Daniela Pires, "Simulation of Auger electron spectra from nuclides of medical interest", (Ongoing).

José Miguel Venâncio, "Study of fiber dosimetry in interventional cardiology", (Ongoing).

Space applications

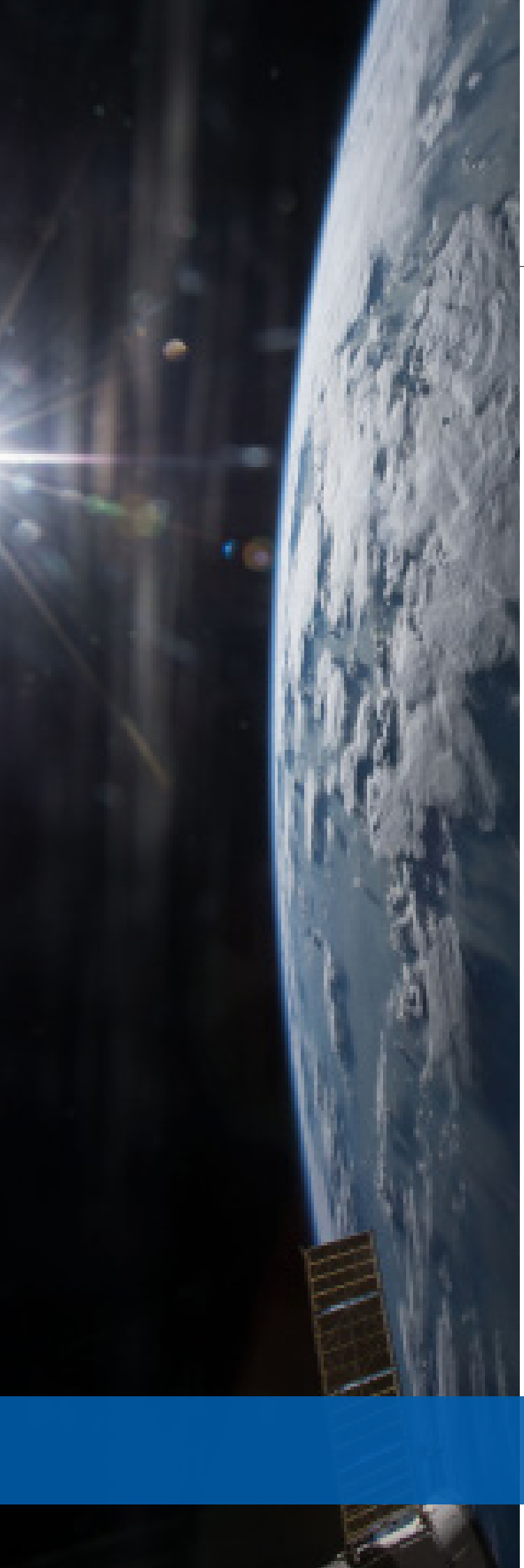


SPACE RADIATION ENVIRONMENT AND EFFECTS

Space Rad

Overview

Space exploration is one of the applications of particle physics technologies, particularly in what concerns radiation detection instrumentation and the modeling of complex interaction of radiation with matter processes. In the last ten years an R&D line focused on the study of Space radiation environments and their effects was created and consolidated at LIP. The competences developed include all the technologies identified on ESA's roadmap for this domain: radiation environment measurement technologies; radiation environment modeling; radiation effects analysis tools; test characterization and Radiation Hardness Assurance (RHA) of EEE components. In the past years various activities were developed, mainly in the framework of contracts with ESA, involving different institutions both in academia and in national industry, and LIP is today an international reference in the GEANT4 simulation of Space radiation monitors and also in the modeling of the radiation environment in Mars.



Team

Principal Investigator Patrícia Gonçalves (80)

Researchers
Bernardo Tomé (10), Jorge Sampaio (70), Luisa Arruda (80), Pedro Assis (10)

PhD students
Ana Luisa Casimiro (100), Marco Alves Pinto (90)

Master students
Filipe Maximo (100), Pedro Alves (86)

External/Additional scientific collaborators
Alessandro de Angelis, Ana Marques, Elsa Susana Fonseca

Total FTE
6.3

Summary of performance indicators

Articles in international journals:	2 With direct contribution from team
Collaboration notes:	1 Collaboration note
International conferences:	2 Poster 2 Proceedings
International meetings:	2 Oral presentations
National conferences:	2 Oral presentations 1 Posters
Collaboration meetings:	1 Oral presentation
Seminars:	2 Seminars 10 Outreach seminars
Completed Theses:	1 Master

Lines of work and team organization

Current LIP activities in the field of Space Radiation Environment and Effects are the following:

- **RADEM:** Development of the RADiation hard Electron Monitor for the JUICE ESA mission to the Jovian system, with launch foreseen to 2022. RADEM is developed by a consortium of institutes and industry including LIP and Paul Scherrer Institute in Switzerland, EFACEC SA in Portugal and IDEAS from Norway.
- **ECo60-JUICE:** Verification of Co-60 testing representativeness for EEE components flown in the Jupiter electron environment: radiation tests on EEE components for the ESA JUICE mission, exposing them to electron beams to validate standard Co-60 testing for components to be flown in the Jovian harsh electron environment.
- **AlphaSAT radiation Environment and Effects Facility (AEEF):** AlphaSAT is the largest ESA telecom satellite, in GEO since July 2013. LIP has been collaborating with EFACEC SA and EVOLEO SA in three different contracts regarding this facility: LIP is responsible for the analysis of the in-flight MFS data, the AEEF particle spectrometer and radiation monitor and also of the CTTB, the AEEF Component Technology Test Bed, where EEE components are being tested in GEO radiation environment. LIP was also involved in the ground testing and preparation of the CTTB data analysis prior to the AlphaSat launch.
- **Mars Energetic Radiation Environment Models:** In 2008-2009 LIP has developed a model for the radiation Environment in Mars, dMEREM (detailed Martian Energetic Radiation Environment Model) in the framework of the MarsREM, the Martian Radiation Environment Models contract between ESA and an international consortium. dMEREM was interfaced with SPENVIS, the Space Environment Information System, where it is available to the community (http://www.spenvis.oma.be). Since then the capabilities of dMEREM have been exploited at LIP. The ongoing work in this subject consists on the upgrade of dMEREM, its validation with data from Mars Curiosity Rover radiation detector (RAD), and on its use in assessing radiation hazards in future manned missions to Mars and also for astrobiology studies.

The team is organized so that most senior members supervise the work of PhD and Master students. Luisa Arruda is in charge of the MFS data analysis and co-supervises the Master Thesis of Filipe Maximo. Jorge Sampaio co-supervises the work of Ana Luisa Casimiro, in particular in what concerns the effects of radiation on crews and dosimetry and is in charge of the CTTB data analysis. Pedro Assis supports the team in the activities requiring the collaboration with the e-CRlab. Patrícia Gonçalves coordinates the Group and supervises the work of Marco Pinto on RADEM and ECO-60 and co-supervises the remaining theses.

Stated objectives for past year

Contracts

- **MFS data analysis:** Development of the MFS data spectra reconstruction algorithms for protons and electrons and publication of the results obtained in the analysis of MFS data.
- **ECO-60:** Contract closure in the first semester of 2017 and presentation of the results obtained in the analysis of the response of the EEE components to different particle fields at the the ESA TEC-QC section final presentation days at ESTEC and at NSREC 2017 Conference, followed by their publication in an international journal.
- **RADEM:** Simulation and science analysis of the Directionality Detector (DD), production of DD response functions, EM DD in-beam calibration; functional test and Calibration and Geant4 simulation of the RADEM Engineering Qualification Model; RADEM ASIC TID test plan definition and participation in the ASIC TID test campaigns. Presentation of RADEM performance at RADECS 2017, in Geneva and participation in the JUICE mission science working team meetings. Additionaly, it was planned that a flight opportunity for RADEM in a satellite such as PROBA-3 should be identified, for in-flight testing prior to integration in the JUICE mission.
- **CTTB Data Analysis:** Continuation of the analysis of the in-flight CTTB data.

Sources of Funding

Code	Amount	Dates	Description
ESA: 1-7560/13/NL/HB	300.000 €	2014-02-18 / 2018-12-31	RADEM proto-flight model
ESA: 3-13975/13/NL/PA	200.000 €	2014-03-10 / 2017-12-31	ECO-60: Verification of Co-60 testing representativeness for EEE components flown in the Jupiter electron environment
ESA: 3-14025/13/NL/AK	60.000 €	2014-03-17 / 2018-12-31	MFS Data Analysis
ESA/4000115004/15/NL/RA/ZK	80.116 €	2015-11-13 / 2018-11-12	Flight Data Analysis of TDP8 Radiation Experiments On-board AlphaSat

Other projects and research activities

Study of interplanetary mission hazards and surface stays for manned missions to Mars and/or the Moon. Start of a PhD thesis on this subject, using dMEREM and data taken with the RAD Curiosity/MSL detector on cruise to Mars and on its surface.

Exploitation of the predictions of Mars radiation environment models developed at LIP in the search for microbiological life in Mars sub-surface, extending dMEREM to subsurface configurations.

Main Achievements

Projects and contracts

The MFS data analysis contract has now entered a maintenance phase. The algorithms for proton and electron spectra reconstruction were implemented and are being tested and improved, based on the series of SEP events collected since the AlphaSat launch in 2013. A spectra reconstruction algorithm, developed in the framework of the Master Thesis of Filipe Maximo, was tested for the SEP event of January 2014, and this analysis was submitted to RADECS 2017, that took place in Geneva, as a poster presentation and published in the conference proceedings. It awaits publication in the IEEE TNS.

The ECO-60 contract was closed in 2017. The results obtained were presented in the ESA TEC-QC section final presentation days at ESTEC and at published in the NSREC 2017 conference proceedings, where they were presented at the Data Workshop. This contract was fundamental for LIP in order to acquire know-how in the area of radiation-hardness assurance testing.

In 2017 LIP activities in the RADEM contract 2017 were the full radiation analysis of RADEM, which included the development of an iterative RADEM shielding optimization process based in RADEM Geant4 simulation and the analysis of the performance of the Directionality Detector. The Radiation analysis was finished resulting on a RADEM model expected TID and Displacement Damage effects below EEE component TID sensitivity. These results we submitted to the NSREC 2018 conference, for a poster presentation. LIP is also participating in the JUICE mission science working team.

Theses

LIP applied successfully to the Lisbon University 2016 programme for the co-funding of a PhD grant in the field of studies of the "Radiation environment in the Solar System". The selected candidate was Ana Luisa Casimiro, whose PhD programme at Instituto Superior Técnico started in February 2017. The work program is centered in the study of radiation hazards for the crews in missions to Mars and in the development of corresponding mitigation strategies and thesis follows the work presented at the RAD conference in June 2017, in Montenegro, to be published in “Radiation and Applications” Journal (RAD Journal) in March 2018.

The work of Marco Pinto was successfully presented to its IST PhD CAT in July 2017.

Lines of work and objectives for next year

The critical issues for next years are the participation in the instrument development and science teams for planetary missions (to Mars, Jupiter or the Moon) extending the duration of the projects in which LIP is involved; the exploitation and development of installations for radiation tests in Portugal and the fostering of an interdisciplinary network to further develop applications and projects in the field of Space Radiation Environment and Effects and related areas. To contribute to ESA’s strategy in guaranteeing independence of the European Space sector in critical technologies and to promote innovation and technical excellence in industry are important guidelines for these efforts.

As for the group R&D activities, the key issues identified for the next years are:

1. The study of the interplanetary radiation environment, in orbit, and in the superficial layers of the planets of the solar system, participating in future exploration missions by exploitation of scientific data and development of technologies and dedicated sensors.

2. Assess the effects of radiation on electronics and satellite systems and in specific space missions, in particular using Commercial Off-The-Shelf components, both through testing and modeling of radiation effects.

3. Evaluate the effects of space radiation on crews, study dosimetry systems for manned space missions. Study and design shielding solutions for spacecraft and habitats for radiation protection of astronauts and radiation systems in space.

4. The effect of ionizing radiation on cell structure is one of the main factors limiting the survival of life forms in potential astrobiological habitats. The modeling and data analysis of radiation environments are fundamental to predict the survival possibilities of life forms in different planetary environments in the Solar System.

5. Extreme solar events, such as super storms, can seriously affect modern technological infrastructure (power distribution networks, telecommunications), especially given the dependence of this infrastructure on applications located in orbit (satellites). The knowledge and study of Spaceweather, and especially the enhancement of the predictive capacity of extreme events is fundamental to protect the terrestrial infrastructure, along with the development of mitigation strategies of this type of occurrence.

As an example, the work developed by the group in the area of Mars Radiation Environment covers several of the key issues, with the study of interplanetary and Martian radiation environments associated to hazards for manned missions to Mars, also applicable to Lunar missions and to the search for microbiological life in Mars sub-surface, for which dMEREM is being used. Additionally, the project "MarsSEP - SEP propagation model and radiological risk of human exploration of Mars" was subject for the global FCT call for projects during 2017 and the result of the project evaluation is expected soon.

The foreseen lines of work also encompass the contractual responsibilities of the group for 2018. For the MFS data analysis contracts these consist on the consolidation of the particle spectra reconstruction methodologies using the MFS and the publication of the MFS SEP reconstructed data. The data analysis of the CTTB data will be continued and a dedicated simulation of the test bed will be implemented with the objective of better understanding the in-flight response of the EEE components. On the follow up of the RADEM contract, the analysis of the Directional Detector performance, the data analysis of the RADEM calibration campaigns and the coordination of the RADEM ASIC TID test campaigns will take place in 2018. Additonally the group will continue participating in the JUICE Science Working Team and actively pursue a flight opportunity for in-flight testing prior to integration in the JUICE mission. The PhD thesis of Marco Pinto will cover most aspects of the Directional Detector data analysis and of the RADEM detector performance and it is expected to be finished in spring 2019.

SWOT Analysis

Strengths

- Expertise in GEANT4 for Space Applications is well developed and LIP is the only Portuguese institution with background in this area in the context of contracts with ESA.
- It is an applied area, not a fundamental science activity, and it can be seen as an interface area to several fields. This can be an advantage for the collaboration with industry and in the attraction of engineering students.
- The group holds a very solid physics background
- The team senior members have a wide experience in participating in international scientific collaborations since the beginning of their scientific careers.

Opportunities

- Collaboration with industry, Contracts with European Space Agency
- Participation in consortia (LIP is member of the EUROPLANET consortium http://www.europlanet-eu.org) for H2020 calls
- Participation in scientific consortia or teams for future space missions can enhance the scientific component of the activity

Weaknesses

- The group heavily depends on contracts with the European Space Agency which a typical duration between 1 year to 3 years
- The learning curve of students is difficult to articulate with the average duration of the contracts, in the case where they are developing academic work in the framework of a contract subject.
- This activity at LIP is not very well known to Physics university students: more outreach and dissemination is needed.

Threats

- Timing and duration of the contracts: since the average duration of the contracts with ESA is under 2 years, there can be several of these contracts overlapping in time
- Constant networking effort and attention to ESA intended and published invitation to tender calls is required
- Work from different and simultaneous contracts can have convergent delivery dates, making it difficult to comply with contract planning
- There can be periods of time between contracts in which the baseline and more scientific activities may lack funding
- To plan for this activity as a service oriented activity only, when scientific components can be exploited

Publications

2 Articles in international journals (with direct contribution from team)

A. L. Casimiro, J. M. Sampaio, P. Gonçalves, M. Pinto: "Assessment of radiation exposure in manned missions to Mars for three mission profiles", accepted for publication in Radiation and Applications Journal (RAD Journal), Volume 3, Issue 1, March 2018

Luisa Arruda, Patrícia Gonçalves, Ingmar Sandberg, Sigiava Giamini, Ioannis Daglis, Arlindo Marques, Joao Pinto, Adolfo Aguilar, Pedro Marinho, Tiago Sousa, Hugh Evans, Piers Jiggens, Alessandra Menicucci, Petteri Nieminen: "SEP Protons in GEO measured with the ESA MultiFunctional Spectrometer", IEEE Trans. Nucl. Sci. 64 (2017) 2333-2339

2 International Conference Proceedings

L. Arruda, P. Gonçalves, A. Marques, J. Costa-Pinto, A. Aguilar, P. Marinho, T. Sousa, P. Nieminen: "SEP Electrons in GEO measured with ESA MultiFunctional Spectrometer", accepted for publication in Proceedings of RADECS 2017

M. Pinto, P. Assis, M. Ferreira, P. Gonçalves, M. Muschitiello, and C. Poivey: "Representativeness of 60Co testing for EEE components to be flown in JUICE", accepted for publication in Proceedings of NSREC 2017

1 Collaboration notes with internal referee
Jorge Sampaio, Patricia Gonçalves: "Alphasat Dose Calculations From The CTTB RADFETS Response", accepted for publication in CTTBDA-LIP-TN-002.1

Presentations

2 Poster presentations in international conferences

Marco Alves Pinto: "Representativeness of 60Co testing for EEE components to be flown in JUICE", 2017-07-19, 2017 IEEE Radiation Effects Data Workshop (REDW), NSREC,, New Orleans, USA

Luisa Arruda: "SEP Electrons in GEO measured with ESA Multi Functional Spectrometer", 2017-10-05, RADECS 2017, Geneva, Switzerland

2 Presentations in national conferences

Marco Pinto: "Development of a Directionality Detector and RADEM Radiation Analysis for the JUICE mission", 2017-07-09, 2nd Doctoral Congress in Engineering – Symposium on Engineering Physics, Porto

Ana Marques: "Degradation of components with radiation", 2017-09-14, Estágios de Verão 2017 Final Workshop, LIP - Lisboa

1 Poster presentations in national conferences

Marco Alves Pinto: "Development of a Directionality Detector and RADEM Radiation Analysis for the JUICE mission", 2017-04-05, PhD Open Days, IST

2 Oral presentations in international meetings

Marco Alves Pinto: "From CAD geometries to Geant4 via CADMesh", 2017-04-11, 12th Geant4 Space Users Workshop, Guildford (UK)
Ana Luisa Casimiro : "Assessment of radiation exposure in manned missions to Mars for three mission profiles", 2017-06-13, RAD 2017, Budva, Montenegro

2 Seminars

Patrícia Gonçalves: "Space Radiation Environment & Effects", 2017-02-15, Café com Física, Universidade de Coimbra - Departamento de Física

Patrícia Gonçalves: "Particle Physics Technologies applied to Space and Biomedical Applications", 2017-07-19, Estágios de Verão do LIP , LIP - Lisboa

10 Outreach seminars
Jorge Sampaio: "Mulheres no Espaço - a discriminação radiológica", 2017-09-08, IGNITE Portugal, Faculdade de Ciências e Tecnologia da Universidade Nova de Lisboa, Caparica, Portugal

Jorge Sampaio: "Da Terra ao Espaço - o desafio radiológico", 2017-10-04, ESERO Portugal, Escola Secundária Dr. António Carvalho Figueired, Loures, Portugal

Patrícia Gonçalves: "Do Sol à Terra, da Terra à Lua", 2017-10-06, O Espaço vai à Escola - Ciência Viva, Escola Básica António Gedeão - Odivelas , 8ºano 3ºciclo ensino básico

Patrícia Gonçalves: "Do Sol à Terra, da Terra à Lua", 2017-10-11, O Espaço vai à Escola - Ciência Viva, Casa Pia de Lisboa, CED Nossa Senhora da Conceição - 5ºano, 2ºciclo ensino básico

Jorge Sampaio: "Da Terra ao Espaço - o desafio radiológico", 2017-10-11, ESERO Portugal, Escola Secundária, José Gomes Ferreira, Lisboa, Portugal

Patrícia Gonçalves: "Do Sol à Terra, da Terra à Lua", 2017-10-12, O Espaço vai à Escola - Ciência Viva, EB 2,3 Castanheiros, Caneças, 7º ano, 3º ciclo ensino básico

Patrícia Gonçalves: "O Sol e a Terra ", 2017-10-18, O Espaço vai à Escola - Ciência Viva, Jardim Infância Santo Condestável

Patrícia Gonçalves: "Do Sol à Terra, da Terra à Lua", 2017-10-28, O Espaço vai à Escola - Ciência Viva, Escola Secundária D. Filipa de Lencastre, 10ºano ensino secundário

Patrícia Gonçalves: "Participação do Grupo do Espaço e do eCR-Lab no Physics Technology Day", 2017-11-17, Physics Technology Day, Instituto Superior Técnico

Patrícia Gonçalves: "Do Sol à Terra, da Terra à Lua", 2017-11-29, Escola Ciência Viva, Planetário Calouste Gulbenkian

Theses

2 PhD Theses

Marco Alves Pinto: "Development of a Directionality Detector and Radiation analysis for RADEM, a RADiation hard Electron Monitor for the JUICE mission" (ongoing)

Ana Luisa Casimiro : "Radiation Hazard Assessment and Mitigation in Manned Missions in the Solar System" (ongoing)

2 Master Theses

Filipe Maximo: "Analysis of in-flight data on the AlphaSat radiation Environment Effects Facility" (ongoing)

Pedro Alves: "Development and Radiation Hardness Assessment of MR sensors for Space Applications" (finished on 2017-11-09)

SPACE INSTRUMENTATION FOR ASTROPHYSICS

i-Astro

Overview

The Space Instrumentation for Astrophysics Group kept developing its research activities in the framework of telescope mission proposals to ESA in the X- and gamma-ray domain. The group is part of H2020 AHEAD (Activities in the High Energy Astrophysics Domain) project as well as of e-ASTROGAM (enhanced-ASTROGAM) and XIPE (X-ray Imaging Polarimetry Explorer) space missions consortia. Our group kept developing focal plane instruments based in CdTe and in gas filled detectors, with polarimetric capabilities. Polarimetry in high-energy astrophysics is still little explored, however it has a great potential to open a new scientific observational window.

In 2017, in the framework of AHEAD WP9 (Work Package 9), named "Assessment of gamma-ray experiments", e-ASTROGAM instrument was simulated and its polarimetric performances were calculated and analyzed. Results were compared with a double layer CdTe detector under a polarized beam at the ESRF (European Synchrotron Radiation Facility).

We kept contributing to the development of the main instrument of XIPE mission, by simulating the potential polarimetric performances of different noble gases: Xe, Ar, Ne and He. In March 2018, ESA will decide if XIPE will be launched in 2026, among the 3 pre-selected missions.

Research activities underline the project BioMeXRay-Bio-Measurements by X-Ray Fluorescence, were carried on. This project aims to characterize the elemental constitution of brain tissues by X-rays fluorescence, in order to develop in the future new putative biological markers for neurological disorders. In the last year, a new approach was followed based on analytical electron microscopy, combining scanning electron microscopy with energy dispersive X-ray fluorescence spectrometry, allowing the detection and quantification of several low-Z elements (matrix + trace) in the samples, including the 2D spatial distribution.

Summary of performance indicators

Articles in international journals:	1 With direct contribution from team 1 With indirect contribution from the team
Books:	1 Book chapter
International conferences:	2 Oral presentation 2 Posters 2 Proceedings
National conferences:	6 Oral presentations
International meetings:	2 Oral presentation
Completed theses:	1 Master Thesis
Seminars:	1 Outreach seminar

DEVELOPMENT OF NEW INSTRUMENTS AND METHODS
Space applications

Team

Principal Investigator Rui Curado Silva (85)

Researchers
Filipa Borges (15), Filipe Moura (100), Filomena Santos (20), Jorge Maia (45), José Escada (20), Teresa Dias (15)

Technician
Carlos Patacas (20)

PhD students
Alexandre Fonseca Trindade (30), Marco Alves Pinto (10), Miguel Moita (100)

Master students
Joana Baptista (83), Marcela Páscoa (100)

External/Additional scientific collaborators
Alessandro de Angelis

Total FTE
6.4

// GROUPS: Space Rad / i-Astro

Lines of work and team organization

Development of focal plane instruments for high-energy astrophysics based in CdTe and in gas filled detectors has been progressing. These instruments are spectro-imagers with polarimetric capabilities. Indeed, polarimetry has been the focus of our instrument development for more than a decade. Our expertise in this field was decisive to take part in several mission proposals submitted to ESA, regardless of the detector material or design adopted in each proposal. These research activities are divided in three lines of work: 1) AHEAD/e-ASTROGAM; 2) XIPE mission; 3) BioMeXRay activities.

1. The main task of our group in AHEAD WP9 is to contribute to e-ASTROGAM focal plane instrument mass model simulations. Dr. Rui Curado da Silva coordinates the group participation in AHEAD.

1.1 High-energy astrophysical sources polarimetric analysis and modeling tasks are performed by researcher by PhD student Miguel Moita, under the supervision of Rui Curado da Silva.

1.2 Focal plane detector development and polarimetric analysis tasks are part of Miguel Moita PhD thesis, Marcela Páscoa master thesis and AHEAD funded Post-Doc, under the supervision of Prof. Jorge Maia.

1.3 e-ASTROGAM mass model simulations will be performed by André Cortez (AHEAD fellowship) and by researcher Marco Pinto, under the supervision of Dr. Rui Curado da Silva and Prof. Filomena Santos.

2. The XIPE scientific payload is composed by a mirror assembly and a focal plane instrument based on GPD (Gas Pixel Detector) X-ray polarimeter. GPD gas mixture optimization tasks are part of Dr. José Escada and Alexandre Trindade PhD thesis, under the supervision of Dr. Rui Curado da Silva and Prof. Jorge Maia.

2.1 GPD gas mixture simulation is performed by Post-Doc José Escada, under the supervision of Prof. Jorge Maia and of Dr. Rui Curado da Silva.

2.2 GPD gas mixture testing will be performed by PhD student Alexandre Trindade under the supervision of Prof. Filomena Santos and Prof. Jorge Maia.

3. The BioMeXRay-Bio-Measurements by X-Ray Fluorescence is a collaborative project leaded by our group integrating national patterns, where our group has the tasks of optimization and development of measurement/analysis methods by electron scanning microscopy and energy dispersive X-ray fluorescence spectrometry in brain tissues. Prof. Jorge Maia coordinates the group participation in BioMeXRay.

Stated objectives for past year

The objectives for the past year are again divided by: 1) AHEAD/ e-ASTROGAM; 2) XIPE mission; 3) BioMeXRay activities:

1. Contribute to AHEAD WP9 focal plane mass model simulation efforts in order to determine the best instrument configuration for the future gamma-ray telescopes.

1.1 Simulate e-ASTROGAM main instrument mass model. Simulate and compare (sensitivity, minimum detectable polarization, field of view, etc.) different instrument configurations;

1.2 Collaborate on polarimetry science of further AHEAD proposals: ASTENA (Advanced Surveyor of Transient Events and Nuclear Astrophysics) and HE Gamma-ray Polarization proposal.;

1.3 Analyze INTEGRAL IBIS polarimetric data of several strong gamma-ray emitters.;

1.4 Test double layer CdTe polarimeter prototype during an experiment scheduled for the ESRF in October 2017;

1.5 Study and analyze orbital proton radiation effects on CdTe prototypes performing a test campaign at ICNAS (Instituto de Ciências Nucleares Aplicadas à Saúde) proton beamline, by extending the beam energy range (more realistic) with respect to previous experiments.

2. Develop FORTRAN Monte Carlo code for XIPE mission GPD gas mixture. Contribute to find the best trade-off gas mixture, simulating noble gases (Xe, Ne, Ar and He) as well as quenching additive gases like DME and isobutane gases.

3. Conclude the development of measurement/analysis methods by electron scanning microscopy and energy dispersive X-ray fluorescence spectrometry in brain tissues in the framework of BioMeXRay project.

3.1 Study of the elemental composition of the brain

Sources of Funding

Code	Amount	Dates	Description
654215 - AHEAD	61.225 €	2015-09-02 / 2019-02-28	H2020 Integrated Activities for the High Energy Astrophysics Domain

tissues, including elements mass concentration (matrix + trace) in % weight (or atomic);

3.2 Study of the trace elements detection limits (in % weight (or atomic)) in brain tissues with the electron beam energy;

3.3 Statistical validation of differences in elemental composition in control and treated brain tissue samples.

Main Achievements

- In the framework of AHEAD WP9, e-ASTROGAM instrument mass model was simulated and its polarimetric performances were calculated and analyzed. Results were compared with a double-plane CdTe detector under a 278keV polarized beam at the ESRF;
- ASTENA mass model was simulated and compared with experimental results from innovative Laue lens. Two communications are being prepared for 2018 SPIE Astronomical Telescopes + Instrumentation Symposium;
- Double layer CdTe detector prototype was tested under a polarized beam at the ESRF. The polarimetric performance results obtained confirmed the potential of multilayer focal plane design for Laue lens and 3D position sensitive detectors;
- CdTe EuroRad prototypes tested under a composed 3 MeV up to 14 MeV ICNAS proton beam, simulating partial orbital environment, showed moderate degradation of detector performances (energy resolution, leakage current, $\mu\tau$, etc.);
- The polarimetric performances of several noble gases (Xe, Ar, Ne and He), alone and combined mixtures, were simulated for XIPE GPD instrument. A publication is being prepared on the pros and cons of each gas filling solution.
- In BioMeXRay project the development of measurement/analysis methods by electron scanning microscopy and energy dispersive X-ray fluorescence spectrometry in brain tissues were almost concluded.

Lines of work and objectives for next year

The main lines of work and tasks are divided in activities in the framework of 1) AHEAD/e-ASTROGAM; 2) XIPE mission; and 3) BioMeXRay activities:

1. The main task of our group in AHEAD WP9 is to contribute to focal plane mass model simulation efforts in order to determine the best instrument configuration for the future gamma-ray telescopes.

1.1 André Cortez (AHEAD fellowship) will keep simulating e-ASTROGAM mission (M5 ESA candidate), for different configurations and detector materials with MEGAlib toolkit, in order to obtain the best performances (sensitivity, minimum detectable polarization, field of view, etc.). Its results will be integrated with the other simulations performed within WP9. By the end of 2018, final instrument configuration will be adopted and its performances compared with other WP9 configurations;

1.2 R.M. Curado da Silva will keep its advisory and consulting tasks on ASTENA polarimetry science. The objective is maximizing the polarimetric performance of instrument configuration. By the end of 2018, final ASTENA configuration will be adopted and its performances compared with other WP9 configurations;

1.3 INTEGRAL IBIS polarimetric data of several strong gamma-ray emitters will be analyzed. The conclusions of this study will be used later on as input for AHEAD instrument polarimetric design optimization;

1.4 Double layer CdTe polarimeter prototype will be further tested through a wider beam energy band (150 keV up to 300 keV) and through finer step range of distances between layers, in order to improve 3D emulation. An experimental prototype test campaign at the ESRF will be requested for the 2nd semester of 2018;

2. In XIPE mission collaboration our group has the task of optimizing the GPD gas mixture. Our home FORTRAN Monte Carlo code is being developed to find the best trade-off gas mixture, between lowest electron diffusion in the gas and the highest possible electron drift speed. The best gaseous mixture solution will allow better reconstruction of photoelectrons emission direction and therefore a better degree and angle of polarization determination. So far results were obtained for several noble gases (Xe, Ar, Ne and He), alone and combined mixtures like Xe and Ne, but the simulation code will be improved to include quenching additive gases like DME and isobutane gases. Furthermore, an experimental system is being developed to measure electron cloud diffusion, in order to cross check with simulation results.

3. In BioMeXRay project our group will conclude the development of measurement/analysis methods by electron scanning microscopy and energy dispersive X-ray fluorescence spectrometry in brain tissues. And start the study of the 2D spatial distribution of the low-Z elements (matrix + trace) in the brain tissue samples.

SWOT Analysis

Strengths and Opportunities

The group is a partner of three major international projects in high-energy astrophysics: H2020 AHEAD, e-ASTROGAM mission candidate (ESA M5 call) and the ESA pre-selected XIPE mission. Our participation in these consortia results from our expertise on high-energy astrophysics polarimetry for more than one decade, both by simulation and experimental testing. AHEAD activities provide institutional and technical links (simulation tools, detector technology and scientific facilities) that improve our research potential. In case XIPE will be selected by March 2018 for launch in 2026, beyond the potential scientific breakthrough provided by the first X-ray space polarimeter, it would be the first time that a portuguese research team takes part in the main instrument development of a scientific mission launched by ESA. The same prestigious launch opportunity might profit e-ASTROGAM mission in the M5 call. However in 2018, we expect that e-ASTROGAM will be one of the three missions select for Phase A.

Spin-off project BioMeXRay provides an opportunity to apply the same methods and techniques of space instrumentation development to biomedical sciences and contribute to the impact of our scientific work in society.

Weaknesses and Threats

The level of collaboration with industry is still weak, however there is an agreement with space related companies to collaborate in the next call for projects, specially PRODEX space oriented call. Collaboration in the framework of student training in collaboration with company has been already established with Active Space company and further future student thesis will include collaboration with this and other companies.

Last decade lack of funding has compromised seriously equipment acquisition, as well as the number of grants and contracts available for young researchers as well as senior researchers as the group responsible.

Publications

1 Articles in international journals (with direct contribution from team)

N. Simões, J. M. Maia, R. M. Curado da Silva, S. Ghithan, P. Crespo, S.J.C. do Carmo, Francisco Alves, M. Moita, N. Auricchio, E. Caroli: "Inflight Proton Activation and Damage on a CdTe Detection Plane", Nucl. Instrum. Methods Phys. Res. Sect. A-Accel. Spectrom. Dect. Assoc. Equip. 877 (2018) 183-191

1 Articles in international journals (with indirect contribution from team)

De Angelis, A.; Tatischeff, V.; Tavani, M.; Oberlack, U.; Grenier, I.; Hanlon, L.; Walter, R.; Argan, A.; von Ballmoos, P.; Bulgarelli, A.; Donnarumma, I.; Hernanz, M.; Kuvvetli, I.; Pearce, M.; Zdziarski, A.; Aboudan, A.; Ajello, M.; Ambrosi, G.; Bernard, D.; Bernardini, E.; Bonvicini, V.; Brogna, A.; Branchesi, M.; Budtz-Jorgensen, C.; Bykov, A.; Campana, R.; Cardillo, M.; Coppi, P.; De Martino, D.; Diehl, R.; Doro, M.; Fioretti, V.; Funk, S.; Ghisellini, G.; Grove, E.; Hamadache, C.; Silva R.: "The e-ASTROGAM mission. Exploring the extreme Universe with gamma rays in the MeV - GeV range", Exp. Astron., Volume 44, Issue 1, pp.25-82

2 International Conference Proceedings

E. Caroli, G. De Cesare, R. M. Curado da Silva, N. Auricchio, C. Budtz-Jørgensen, S. Del Sordo, J. L. Galvèz, M. Hernanz, I. Kuvvetli, P. Laurent, O. Limousin, J. M. Maia, A. Meuris, M. Moita, and J. B. Stephen: "Monte Carlo Evaluation of a CZT 3D Spectrometer Suitable for a Hard X- and Soft-γ Rays Polarimetry", accepted for publication in 2017 Nuclear Science Symposium and Medical Imaging Conference Atlanta, Georgia, from October 21st to October 28th

E. Caroli, R. M. Curado da Silva, M. Moita, N. Auricchio, J. M. Maia, J.B. Stephen, M. Páscoa: "Hard X-ray and Soft Gamma Ray Polarimetry with CdTe/CZT Spectro-imager", accepted for publication in Alsatian Workshop on X-ray Polarimetry, 13-15 November 2017, University of Strasbourg, Strasbourg, France

1 Book Chapter

Rui M. Curado da Silva, Ezio Caroli, Stefano del Sordo, and Jorge Manuel Maia: "Chapter 10: Cadmium (Zinc) Telluride 2D/3D Spectrometers for Scattering Polarimetry", Semiconductor Radiation Detectors: Technology and Applications, 2017 by CRC Press, pp 241-282

Presentations

2 Oral presentations in international conferences

M. Moita: "Multilayer polarimetric analysis of a CdTe focal plane prototype", 2017-10-24, IEEE NSS MIC RTSD 2017 Conference, Atlanta, EUA R-05-4

Miguel Moita: "Hard X-ray and Soft Gamma Ray Polarimetry with CdTe/CZT Spectro-imager", 2017-11-13, Alsatian Workshop on X-ray Polarimetry, 13-15 November 2017, University of Strasbourg, Strasbourg, France http://awoxpol.u-strasbg.fr/#Program

2 Poster presentations in international conferences

E. Caroli: "Monte Carlo Evaluation of a CZT 3D Spectrometer Suitable for a Hard X- and Soft-Gamma Rays Polarimetry", 2017-10-24, IEEE NSS MIC RTSD 2017 Conference, Atlanta, EUA R-07-041

M. P. Páscoa: "Orbital Protons' Radiation Damage Analysis on a CdTe Detection Plane", 2017-10-24, IEEE NSS MIC RTSD 2017 Conference, Atlanta, EUA R-07-046

6 Presentations in national conferences

Miguel Moita: "CdTe Polarimetric Analysis For Future High-Energy Space Missions", 2017-03-24, LIP PhD Students Workshop, University of Coimbra

Miguel Moita: "Development of a Dual Plane Polarimeter for Future Gamma-ray Space Telescopes", 2017-06-08, DCE17 - Doctoral Congress in Engineering, FEUP, Porto

Rui Curado Silva: "Astronomia e Tecnologia Espacial no Quotidiano", 2017-07-13, Coimbra Space Summer School, Observatório Astronómico da UC

Rui Curado Silva: "XIPE mission LIP contribution", 2017-07-21, XXVII National Meeting of Astronomy and Astrophysics, Faculdade de Ciências da Universidade de Lisboa

Filipe Moura: "LIP contribution to eASTROGAM mission", 2017-07-21, XXVII National Meeting of Astronomy and Astrophysics, Faculdade de Ciências da Universidade de Lisboa

Miguel Moita: "Development of a Dual Plane Polarimeter for Future Gamma-ray Space Telescopes", 2017-07-21, XXVII National Meeting of Astronomy and Astrophysics, Faculdade de Ciências da Universidade de Lisboa

2 Oral presentations in international meetings

Filipe Moura: "LIP WP9 Team 1 e-ASTROGAM Simulation", 2017-04-25, AHEAD WP9 meeting: SWG kick-off meeting & MEGAlib school, ICE, CSIC-IEEC, Barcelona, Espanha
Filipe Moura: "eASTROGAM Compton Polarization", 2017-11-14, AHEAD WP9 Progress meeting, INFN and University of Roma Tor Vergata, Italy

1 Outreach seminars

Rui Curado Silva: "Astronomia e Tecnologia Espacial no Quotidiano", 2017-03-30, Agrupamento de Escolas de Mortágua, Mortágua

Theses

2 PhD Theses

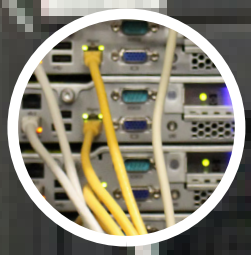
Miguel Moita: "ASTROGAM Space Gamma-ray Telescope Main Instrument Development" (ongoing)

Alexandre Fonseca Trindade: "Study of noble gases mixtures characteristics as a detection medium" (ongoing)

2 Master Theses

Joana Baptista : "Análise de Biometais em Tecido Cerebral por Microscopia Eletrónica Analítica" (finished on 2017-10-30)

Marcela Páscoa: "Análise da deterioração das características de um protótipo de CdTe para um Telescópio Espacial de Raios Gama em ambiente de radiação orbital" (ongoing)



Computing

- Distributed computing and digital infrastructures
- Advanced computing

// Computing

DISTRIBUTED COMPUTING AND DIGITAL INFRASTRUCTURES

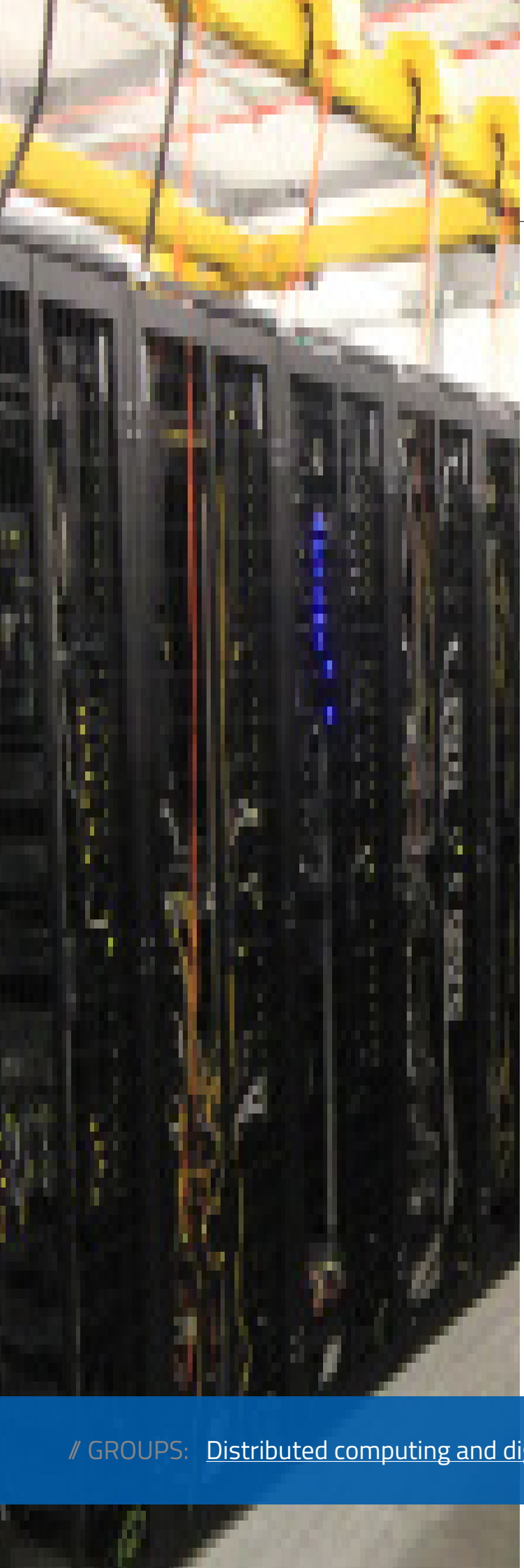
GRID

Overview

The LIP distributed computing and digital infrastructures group provides information technology (IT) services to LIP and its research groups. The group operates institutional IT services, including compute and data services for simulation and analysis that support the LIP research. These services include the Portuguese Tier-2, a compute and data intensive facility integrated in the Worldwide LHC Computing Grid (WLCG). WLCG is a global collaboration of more than 170 computing centres in 42 countries, linking up national and international grid infrastructures. In parallel the group is now delivering scientific computing services to the wider Portuguese scientific and academic community in the context of the Portuguese National Distributed Computing Infrastructure (INCD). These activities bridge at international level with the European Grid Infrastructure (EGI) and European Open Science Cloud (EOSC). Also in this context the group collaborates with several research communities beyond High Energy Physics. The development of the group competences and capabilities is also backed by participation in R&D projects at national and international level.

Summary of performance indicators

International journals:	2 With direct contribution from team
International conferences:	3 Oral presentations 1 Poster 1 Proceedings
National conferences:	4 Oral presentations
International meetings:	2 Oral presentations
National meetings:	1 Oral presentation
Collaboration meetings:	4 Oral presentations
Organization:	1 Collaboration meeting organized



Team

Principal Investigator Jorge Gomes (100)

Researchers
Dinis Monteiro (*), Gaspar Barreira (90), João Paulo Martins (100), João Pina (100), Luís Alves (100), Mário David (100)

Technicians
Carlos Manuel (100), Hugo Gomes (100), José Aparício (100), Nuno Ribeiro Dias (100)

Total FTE
9.9

(*) Starting in 2018

// GROUPS: Distributed computing and digital infrastructures / Advanced computing

Lines of work and team organization

The team is organized in three main lines of work.

- Implementation and operation of production IT services and related user support. This includes institutional services, data storage, computing, wide and local area networks, desktops, security and the management of datacenter infrastructures, including the operation of the Portuguese Worldwide LHC Computing Grid Tier-2. The group also delivers services to external research organizations and projects in the context of the Portuguese National Distributed Computing Infrastructure (INCD), whose activities have been pioneered by LIP. These services are integrated in international digital infrastructures and initiatives such as the European Grid Infrastructure (EGI), Iberian Grid Infrastructure (IBERGRID) and European Open Science Cloud (EOSC).

- Participation in ICT R&D projects. Enables the development of advanced competences and services that back the production services delivered to researchers. The group participates in projects addressing several aspects of scientific data processing including: federation of compute and storage resources, massive data management and processing, network related technologies, authentication and authorization, virtualization, digital preservation, and software quality assurance, among others. The group has extensive experience in high throughput computing, high performance computing, grid computing and cloud computing.

- Provisioning of web development and multimedia services, supporting outreach, dissemination, exploitation, management and research activities. This activity also supports the production services and the ICT R&D activities with additional skills and competences.

These lines of work are organized in a virtuous cycle. R&D pushes the evolution of the services and infrastructures delivered by the group, while the services themselves support and enable the R&D activities. This approach requires a very flexible infrastructure in constant evolution.

Stated objectives for past year

LIP computing Services

- Moving the LIP Lisbon center to a new building including the migration of IT infrastructure.
- Migration of the LIP Lisbon IT services to the University of Lisbon and INCD/NCD datacenters.
- Pursue adoption of cloud computing and containers technology at the datacenter level.

WLCG and Tier-2

- Follow the evolution of the LHC computing model and consider new approaches and technologies.
- Improve the Tier-2 by piloting the integration with the INCD IaaS cloud.
- Experimentation with containers technology.
- Begin the implementation of IPv6 at the Tier-2.

INCD

- Establish the INCD management structure.
- Operated the INCD IaaS cloud as a beta service.
- Operation of the INCD production services including HTC and HTC farms.
- Participation in thematic activities and networks.

EGI and IBERGRID

- Liaise the INCD infrastructure with the European Grid Infrastructure (EGI).
- Collaboration to support community and thematic services over the EGI fedcloud.
- Participation in the EGI security and AAI activities.
- Common IBERGRID participation in EGI and Iberian

Sources of Funding

Code	Amount	Dates	Description
EGI-ENGAGE	108.500 €	2015-04-01 / 2017-09-30	EGI-ENGAGE
INDIGO	503.625 €	2015-05-01 / 2017-10-31	INDIGO-DATACLOUD
INCD 01/SAICT/2016 - nº 022153	223.000 €	2017-07-18 / 2019-12-31	Portuguese National Distributed Computing Infrastructure
DEEP-HybridDataCloud Grant 777435	362.500 €	2017-11-01 / 2020-04-30	Designing and Enabling E-Infrastrctures for intensive Processing in a Hybrid DataCloud

infrastructure coordination.

- Deliver of middleware coordination services to EGI in partnership with IBERGRID partners.

INDIGO-DataCloud

- Coordination of the INDIGO-DataCloud software life-cycle and pilot services Work Package.
- Participation in the development of network capabilities for the OCCI cloud computing standard.
- Research Linux containers and application support in batch scheduling systems
- Testing of INDIGO-DataCloud middleware in partnership with T-Systems.
- Contribute to the 2nd INDIGO-DataCloud major software release and its maintenance.

H2020

- Pursue participation in future projects in the context of EGI, INDIGO, INCD and other collaborations.
- Participate in the editorial board of the joint EGI - INDIGO – EUDAT towards the delivery of services in the European Open Science Cloud.

Main Achievements

In 2017 the Tier-2 executed 2,084,407 jobs delivering 65,634,475 normalized (HEPSPEC06) processing hours to ATLAS and CMS. Although the group faced major difficulties in maintaining the now very old hardware infrastructure, this value still represents a slightly increase in comparison with 2016.

LIP Lisbon moved into a new building. The IT services were successfully migrated to the University of Lisbon and INCD datacenters. The LIP Lisbon IT infrastructure was transferred to the new building and deployed from scratch within schedule.

The INCD project submitted in 2016 was approved and initial funding received in December 2017. The management structure and regular operation of INCD was established. The collaboration in thematic activities was increased, examples are: cooperation with BioData in a genome sequencing data pilot, housing of the national GBIF biodiversity data repository, and the collaboration with IMM in life sciences.

Also in INCD, the Linux containers technology was applied to the HPC and HTC computing farms and to the IaaS cloud service enabling higher efficiency and flexibility. The HTC farm was extended into a tenant of the INCD cloud to exploit available capacity. The core network switching infrastructure was prepared to deploy IPv6.

LIP participated in the EGI governance and technical activities liaising Portugal with this international infrastructure. In the EGI-ENGAGE project, LIP worked in the LifeWatch competence center, and in AAI and security aspects of the infrastructure. The project finished successfully.

The IBERGRID collaboration continued providing an umbrella for a common Iberian participation in EGI. The EGI middleware coordination was again performed by LIP, IFCA and CESGA in the IBERGRID context.

The INDIGO-DataCloud project finished in September with an evaluation of outstanding. LIP was in the project management board and coordinated the work on software management, quality assurance, pilot services and exploitation. This work was praised for its innovation and results. The group also developed: a novel virtualization tool (udocker), a system to integrate Docker in batch systems (bdocker) and extended the OCCI implementation in Openstack. The group also collaborated with T-Systems the largest cloud provider in Europe to tests the INDIGO-DataCloud software. The project worked with major communities: BBMRI, ELIXIR, INSTRUCT, DARIAH, DCH-RP, LBT, CTA, LifeWatch, EMSO, ENES, and WLCG.

The group worked in the preparation of EOSC-hub project that joins EGI, INDIGO-DataCloud and EUDAT to provide the core infrastructure for the EC European Open Science Cloud (EOSC). Together with LNEC, proposed an EOSC thematic service to deliver wave and ocean circulation forecasts for the European Atlantic coast (OPENCoastS). The OPENCoastS bid was selected among more than 60 international proposals. Also in EOSC-hub, LIP will lead the software management for all cloud, grid and data services in EOSC. The project was approved to start in January 2018.

The INDIGO-DataCloud collaboration submitted the DEEP-HybridDataCloud project which aims to develop technologies for large scale deep learning using cloud, HPC and hardware accelerators. The project was approved and started in November 2017. LIP will coordinate the software management and pilot infrastructure activities, and will contribute to several activities including virtualization, accelerators and layered networks.

Lines of work and objectives for next year

LIP computing services

Continue the adoption of cloud computing and containers technology by exploiting the INCD IaaS cloud to support the LIP services and applications. This activity aims at improving the IT services flexibility and management.

Complete the deployment of the supporting IT services and local datacenter at the new LIP facilities in Lisbon. Adapt the LIP services to the new European General Data Protection Regulation (GDPR).

WLCG and Tier-2

After 8 years of continuous operation the Tier-2 hardware is now near obsolescence. The computing capacity will be improved by sharing capacity with the INCD cloud infrastructure to profit from the INCD cloud upgrade foreseen for 2018. However this is insufficient. The group will work with the LIP management and the LHC groups to seek a solution to renew and maintain the LIP Tier-2.

Meanwhile the IPv6 deployment and connection to the LHC one network will proceed once new INCD network equipment becomes available. New job scheduling technologies aiming at improving the Tier-2 setup will be evaluated.

INCD

Continue executing the first year of the INCD P2020 project. LIP will continue operating the cloud, HPC and HTC and storage services provided by INCD. In this context the existing IaaS cloud service will be upgraded and a first purchase of hardware will be performed to increase the currently saturated capacity. New high level SaaS and PaaS cloud services will be implemented to extend the current cloud capabilities. The INCD computing farm which is also supporting the Tier-2 will benefit from the improved cloud. After the INCD capacity upgrade the dissemination and training activities near the user community will be increased.

Continue the collaboration with other national thematic infrastructures such as BioData, PORBIOTA, GBIF and their international counterparts Elixir, LifeWatch and others, new collaborations will be pursued. Collaboration with other computing related initiatives such as the national HPC network and the Minho Advanced Computer Center (MACC) will be pursued.

EGI, IBERGRID and EOSC

The group will continue to liaise Portugal with the European Grid Infrastructure (EGI) both at the governance and operational levels enabling the integration of cloud and grid resources in this international infrastructure and their joint exploitation.

The IBERGRID collaboration will continue providing an umbrella for Iberian participation in EGI. The middleware coordination in EGI will be ensured by IBERGRID via LIP, IFCA, UPV and CESGA.

The EOSC-hub project will provide the core infrastructure to implement the European Open Science Cloud (EOSC). The project joins EGI, EUDAT and INDIGO-DataCloud. The group participates in EGI and in the INDIGO consortium, and will coordinated the software Configuration, Change, Release and Deployment management activities in EOSC-hub for all cloud, grid and data oriented services. The EUDAT data management solutions will be evaluated. The container technologies developed by LIP in INDIGO will be supported in EOSC-hub.

LIP and LNEC will implement and operate the OPENCoastS thematic service in EOSC to provide forecasts for the European Atlantic coast. The service is targeted at researchers, port authorities, municipalities, river authorities, civil protection, engineering companies, water treatment plants and all entities participating in activities related to planning and management of estuaries and coastal regions.

INDIGO-DataCloud

The INDIGO-DataCloud collaboration is establishing an agreement towards the development and maintenance of the software developed in the H2020 project finished in 2017, whose results have been adopted by EOSC-hub and by several research communities. Furthermore the INDIGO collaboration is executing the new DEEP-HybridDataCloud project that will developed solutions for large scale deep learning and post-processing in cloud and HPC environments exploiting specialized hardware accelerators and low latency. Use cases in security, biodiversity, physics and other areas will exploit and validated the solutions. LIP coordinates the software quality assurance, release management and infrastructure. LIP will also participate in R&D to further explore Linux containers and full virtualization in cloud and HPC environments facilitating application encapsulation and abstraction across infrastructures. LIP will also collaborate in the development of network overlay solutions across private and public clouds.

SWOT Analysis

Strenghts

- Extensive knowledge and experience in scientific computing.
- Excellent international relations and integration in scientific e-infrastructures.
- Operating the Portuguese WLCG Tier-2 under the CERN LHC computing MoU.
- Strong partnership with FCCN and LNEC via INCD.
- Participation in the FCT infrastructures roadmap.
- Users from multiple disciplines and organizations.
- Participation in major e-infrastructure European projects.

Weaknesses

- Hardware obsolescence and lack of processing and storage capacity
- Lack of human and hardware resources to address opportunities.

Opportunities

- Maintain and improve the LIP computing infrastructure in partnership with FCCN and LNEC.
- Consolidate and optimize scientific computing resources distributed across several organizations.
- Enable future policies for scientific computing and open access.
- Potential for industrial and e-government applications.
- Possibility of engagement with other communities.

Threats

- Lack of investment is destroying the WLCG Tier-2 and the existing infrastructure.
- Lack of coherent national policies for scientific computing and digital infrastructures.
- Lack of funding for operational costs may prevent resource sharing and exploitation of available capacity.

Publications

2 Articles in international journals (with direct contribution from team)

D. Salomoni, I. Campos, L. Gaido, G. Donvito, P. Fuhrman, J. Marco, A. Lopez-Garcia, P. Orviz, I. Blanquer, G. Molto, M. Plociennik, M. Owsiak, M. Urbaniak, M. Hardt, A. Ceccanti, B. Wegh, J. Gomes, M. David, L. Alves, J. Pina, J. Martins, C. Aiftimiei, L. Dutka, S. Fiore, G. Aloisio, R. Barbera, R. Bruno, M. Fargetta, E. Giorgio, D. Spiga, S. Reynaud, L. Schwarz, T. Bell, R. Rocha, M. Viljoen: "INDIGO-DataCloud:A data and computing platform to facilitate seamless access to e-infrastructures", arXiv:1711.01981

Jorge Gomes, Isabel Campos, Emanuele Bagnaschi, Mario David, Luis Alves, Joao Martins, Joao Pina, Alvaro Lopez-Garcia, Pablo Orviz: "Enabling rootless Linux Containers in multi-user environments: the udocker tool", Enabling rootless Linux Containers in multi-user environments: the udocker tool Jorge Gomes, Isabel Campos, Emanuele Bagnaschi, Mario David, Luis Alves, Joao Martins, Joao Pina, Alvaro Lopez-Garcia, Pablo Orviz. Nov 6, 2017. e-Print: arXiv:1711.01758 [cs.SE]

1 International Conference Proceedings

D. Salomoni, L. Gaido, I. Campos Plasencia, J. Marco de Lucas, P. Solagna, J. Gomes, L. Matyska, P. Fuhrmann, M. Hardt, G. Donvito, L. Dutka, M. Plociennik, R. Barbera: "The INDIGO-DataCloud project: enabling software technologies for efficient and effective use of Cloud computing and storage for science", accepted for publication in 2017 Nuclear Science Symposium and Medical Imaging Conference, together with the 24th Symposium on Room-Temperature X- and Gamma-Ray Detectors. Atlanta, Georgia, October 21st to October 28th 2017.

Presentations

3 Oral presentations in international conferences

D. C. Duma: "Software reliability: experiences in European scientific research projects and new trends", 2017-10-22, 2017 IEEE Nuclear Science Symposium and Medical Imaging Conference (NSS/MIC), Atlanta, USA

D. Salomoni: "The INDIGO-DataCloud project: enabling software technologies for efficient and effective use of Cloud computing and storage for science", 2017-10-24, 2017 Nuclear Science Symposium and Medical Imaging Conference, together with the 24th Symposium on Room-Temperature X- and Gamma-Ray Detectors., Atlanta, Georgia,

Jorge Gomes: "Advanced Virtualization in Computing", 2017-12-13, XXIII Christmas workshop at the IFT, Institute for Theoretical Physics (IFT) UAM-CSIC, Madrid, Spain

1 Poster presentations in international conferences

Luís Alves: "bdocker and udocker - two complementary approaches for execution of containers in batch systems", 2017-05-09, EGI Conference 2017, Catania, Italy

4 Presentations in national conferences

Jorge Gomes: "Serviços para acesso aberto e repositórios de dados", 2017-02-08, Encontro sobre repositórios de dados em acesso aberto, Centro Ciência Viva de Lisboa

Jorge Gomes: "Serviços de computação e processamento de dados para a comunidade científica e académica", 2017-04-20, Jornadas FCCN 2017, Universidade de Trás-os-montes e Alto Douro (UTAD)

Jorge Gomes: "INCD - Serviços de Computação", 2017-07-04, Ciência 2017, Encontro com a Ciência e Tecnologia em Portugal, Centro de Congressos de Lisboa

Nuno Ribeiro Dias: "EGI-CSIRT", 2017-11-28, 2ª Reunião da Rede Académica CSIRTs (RAC), Coimbra

2 Oral presentations in international meetings

Jorge Gomes: "UDOCKER running containers everywhere", 2017-05-09, EGI Conference 2017, Catania, Italy

Jorge Gomes: "Software Management and Pilot Services", 2017-11-15, INDIGO-DataCloud Final Review, EC Head Quarters, Brussels, Belgium

1 Oral presentation in national meeting

Jorge Gomes: "INCD Serviços de Computação", 2017-09-25, Portuguese Biological Data Network (BioData) Kick-off meeting, Fundação Calouste Gulbenkian, Lisboa

Events

1 Collaboration Meetings

INDIGO-DataCloud all hands meeting, Lisbon, 2017-02-06 to 2017-02-09

ADVANCED COMPUTING

Advanced Computing

Members of advanced computing group have previous work in Grid, HPC, computing models, high performance communication libraries and distributed data structures. Research also encompass R&D on the combination of traditional multicore CPUs with acceleration devices.

The group, part of the LIP-Minho, since the beginning of 2014, has been directing its activity to the fields of Computer Science and Engineering more closely related to the principal areas of interests of LIP investigation.

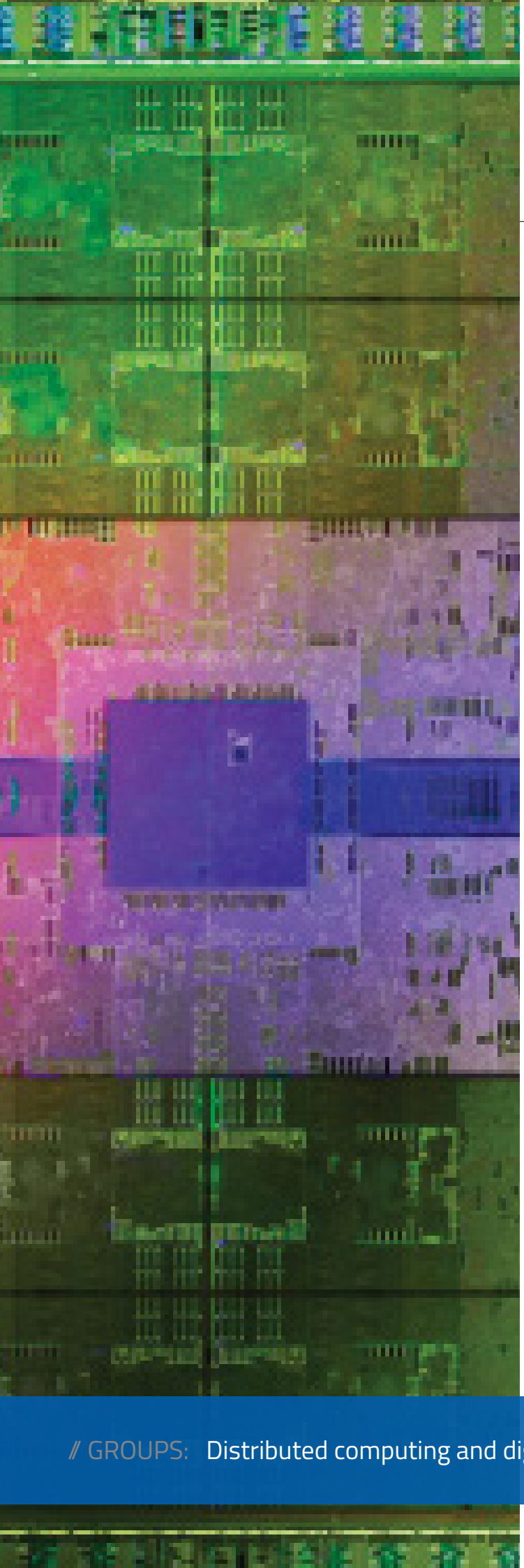
In particular, it is noteworthy the support for the development and optimization of code applications related to HEP and the search of explicit distribution strategies for access to large volumes of data, in order to improve efficiency and execution times. More recently the group embrace new topics related to the areas of big data and machine learning.

Another important dimension of activity is the support for advanced training in Scientific Computing. The group is also responsible for the administration of a local HPC cluster that supports the running of the data analysis applications developed by other groups in LIP.

Overview

Summary of performance indicators

International journals:	1 With direct contribution from team
International conferences:	2 Proceedings
Theses:	1 Master thesis



Team

Principal Investigator António Pina (65)

Researchers
Albano Alves (75), José Rufino (75), Vítor Oliveira (30)

Master Students
Bruno Ribeiro (25)

External Collaborators
António Esteves, José Luís Silva

Total FTE

2.4

// GROUPS: Distributed computing and digital infrastructures / Advanced computing

Lines of work and team organization

It is a small group whose work is currently focused in the following directions:

- application performance analysis;
- dynamic tracing;
- parallelization strategies for GPU based algorithms;
- hpc: support to computer cluster infra-structures;
- machine learning;
- advanced training: Linux, Concurrent C++.

Stated objectives for past year

The work developed closely followed the objectives set for the year 2107, without being able to overcome the limitations underlying the current non-exercise of scientific activity by a significant part of the group members, which in practice reduces the possibility to cover larger projects dimension.

In this context, the emphasis was placed on the following activities:

- To continue the process of enriching the pedagogical projects of which we are responsible, to include the research / development on areas more directly related to HEP software in order to encourage the incorporation of young researchers in the work of the LIP.
- Launching of new computer training activity for young researchers
- Involvement in the ATLAS collaboration.

Main Achievements

The activities developed by the group resulted in:

- some articles published in international conference/journals;
- the conclusion of one MSc thesis directly related with "Parallelization and Optimization of the TopoCluster Splitting Algorithm using GPUs "
- start of a new MSc thesis project to develop a computer platform to support the development of shared/distributed concurrent applications.
- second edition of the course, “The Basics of the LINUX Command Line” held in February 2017 in UMinho;
- maintenance and administration of the local computer cluster infrastructure.

Lines of work and objectives for next year

In 2018, the work will continue focused on the research of the themes already identified such as: application performance analysis, dynamic tracing, parallelization strategies for GPU based algorithms, cluster distributed file systems, along with the support to the local cluster infrastructure. Meanwhile, as a team group of a PTDC2017 proposal led us to embrace new scientific domains that combine big data with machine learning.

We also expected that the planned work of the current ongoing dissertation could attract new students for R/D in the group main scientific areas, in particular: i) performance analyse of HEP data analysis applications ii) evaluation of alternatives to developing hybrid shared/distributed memory applications iii) development of a platform intended to allow the efficient processing of data integration to “Understanding Big Data in High Energy Physics”

In another dimension, we also continue the training activities for young researchers, on themes related to the use of computer systems. It is also foreseen, in conjunction with other LIP groups, new courses in other themes, such as: “C++ Concurrency” and “Data Analysis”.

SWOT Analysis

Strenghts

- A group with solid foundation in the parallel and distributed computing scientific domains;
- International R/D collaboration experience as a result of the active participation in several EU FP6/FP7 projects;
- Experience in the promotion of advanced learning and knowledge exchange in scientific computing among young scientists and engineers;
- Expertise in combining traditional multicore CPUs with acceleration devices.

Weaknesses

- We are currently a small group with only one full active research member which is clearly insufficient to take advantage of the scientific and industrial potential of one of the youngest regions in Europe.

Opportunities

- Collaboration with other groups that need to optimize their HEP data analysis code applications;
- Expertise in combining traditional multicore CPUs with acceleration devices already proved to be and asset in the ATLAS TopoCluster algorithm parallelization;
- Administration of the local Tier 3 HPC cluster for the exploitation of new system architectures to allow efficiency increase of resource usage to support the increase in the complexity of current applications;
- Use of the Advanced Computing Center (MAAC) that will be hosted at UMinho may significantly extend the potential for processing large amounts of scientific data.

Threats

- Local HPC infrastructure, has no guarantee of continuity of service by the lacking of financial support for equipment maintenance/upgrade and system administration;
- In Portugal, there is no unemployed graduates in Computer Engineering. In this context, it is very difficult to attract to scientific work young people, without the availability of funds, to support new scholarships for MSc or PhD

Publications

1 Articles in international journals (with direct contribution from team)

Duarte Pousa, José Rufino: "Evaluation of Type-1 Hypervisors on Desktop-class Virtualization Hosts", IADIS International Journal on Computer Science and Information Systems (ISSN 1646-3692), vol. 12, num. 2, pp. 86-101

2 International Conference Proceedings

Laercio Minozzo, José Rufino, José Lima: "Experiences on Object Tracking Using a Many-Core Embedded System", Proceedings of the 14th International Conference on Applied Computing (AC 2017), pp. 195-204, IADIS. 18-20 October, 2017. Vilamoura, Portugal

Duarte Pousa, José Rufino: "Benchmarking of Bare Metal Virtualization Platforms on Commodity Hardware", Proceedings of the 14th International Conference on Applied Computing (AC 2017), pp. 205- 212, IADIS. 18-20 October, 2017. Vilamoura, Portugal. (best paper award)

Theses

2 Master Theses

José Luís Silva: "Optimization of clustering algorithms for the ATLAS Experiment at the LHC (CERN)" (finished on 2017-05-26)

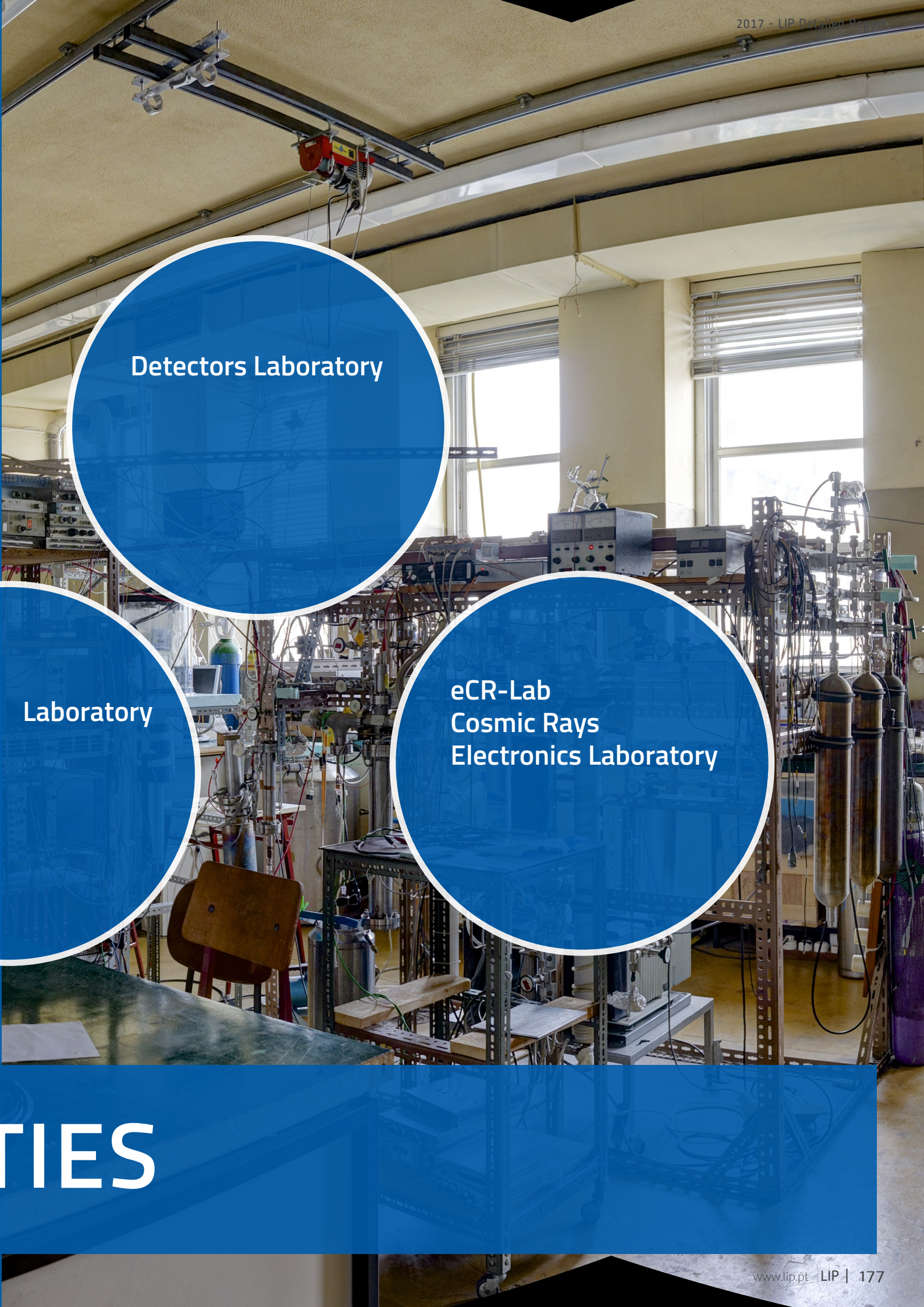
Bruno Ribeiro: "PlaCor: Plataforma para a Computação Orientada ao Recurso" (ongoing)

Mechanical Workshop

LOMAC
Laboratory of Optics and Scintillating Materials

TagusLIP

// RESEARCH FACILIT


Detectors Laboratory
Laboratory
eCR-Lab
Cosmic Rays
Electronics Laboratory

TIES

PRECISION MECHANICAL WORKSHOP

Workshop

Brief description of the facilities

The Mechanical Workshop (MW) of LIP was established in 1986 to support the experimental activities to be performed in collaboration with CERN. At present, the equipment available and the staff (two technicians and two Engineers) allow the MW to perform a large spectrum of mechanical services, from the project to the production and testing. Today, the MW provides services not only to the CERN projects but also to research groups inside and outside LIP and to external companies.

The work developed by the MW is especially complemented (or the other way round) with the Detector Lab (DL). This is of maximum importance since many of the works developed by LIP need the competences from both facilities, which complement each other.

Three decades of experience assures us that, in the absence of the LIP MW (+DL) it would not have been possible to perform with the same high level of quality the R&D in gaseous detectors performed in the framework of autonomous projects or small collaborations, or the responsibilities undertaken within medium and large international collaborations (CP-LEAR, DELPHI, HERA-B, ATLAS, HADES, AUGER). Equally evident are the benefits to the national R&D community of the intervention of the MW (+DL) in its projects, at the local and national level.

Coordinator **Alberto Blanco**

Team

Carlos Silva, Douglas Lima, Nuno Silva Dias

Research Facilities

Workshop / Detector Lab / e-CRLab / LOMaC / TagusLIP

Activities and achievements in the past year

2017 has been a year in which many projects (around 30) have been carried out, without any of them standing out in the use of available resources. Here, a list of main projects is presented.

- Construction of pieces for the RPC detectors for the LIP-Auger group in the frame work of the project "A new generation of RPC muon detectors for high-precision high-energy cosmic-shower", namely: gas bubblers, gas connectors, electronic supports, HV PS boxes and auxiliary mechanical pieces. 18% of total time with a total of 989 H/man (Hours/man) and 801 H/Machine. (Hours/M). Not finished yet.
- Construction, assembling and test of a second unit of the Umbilical Retrieval Mechanism (URM) (mechanics for the PMT calibration system) for the SNO+ experiment. 13% (736 H/m and 243 H/M). Not finished yet.
- Construction of aluminium boxes for the project "A muon telescope based on RPCs for muon scatter tomography", (MuTT), for the Hydronav company. 10% (551 H/m and 259 H/M).
- Construction of four SPARK chambers for the Outreach Project. 9% (509 H/m and 249 H/M). Not finished yet.
- Construction of two prototypes of camera supports for the BOSCH company. 7% (374H/m and 157 H/M).
- Construction of mechanical pieces of a test setup for the project "Orthogonal Ray Imaging for Radiotherapy Improvement, Orto-CT".5% (303 H/m and 161 H/M).
- Construction of a Stainless steel vessel for detector testing in the frame work of the RD51collaboration. 5% (298 H/m and 150 H/M).
- Reallocation of the infrastructures 5%
- Construction and annealing of two ultra clean PMMA vessels for the LIP-SNO group. 4% (199 H/m and 113 H/M).
- Construction of a cryostat for the Chemistry Department. 4% (196 H/m and 101 H/M).
- Construction of a prototype of Cloud Chamber for the Outreach Project. 3% (194 H/m and 88 H/M).
- Other projects. Support and construction of mechanical pieces for LIP-LZ, RPC-PET, LIP-HADES, AIDA2020, SINE 2020, Physics Department, AHEAD, and other small works 10 % (690 H/m and 200 H/M).

Plan for next year

The main project, which will require an important portion of the available resources (around 20%) during 2018, will be the finalization of the construction of a second unit of the URM for SNO+ experiment. Beside this, other projects are already allocated.

- Construction of the mechanics for a second RPC Preclinical-PET scanner.
- Finalization of four SPARK chambers and four Cloud chamber for the Outreach Project.
- Construction of pieces for the RPC detectors for the LIP-Auger group in the frame work of the project "A new generation of RPC muon detectors for high-precision high-energy cosmic-shower", namely: gas bubblers, gas connectors and auxiliary mechanical pieces.
- Construction of the mechanics for the new RPC detector for the LIP-HADES group.
- Construction of a test chamber for the Physics Department.
- Construction of Mechanical Supports for the LIP-LZ group.

The resources devoted to these projects already occupy a large fraction of the manpower available for 2018. There are still two other activities that will take some resources.

Finalization of the reallocation of the MW to the new infrastructures that started by the end of 2016. Due to the working load during 2017, this activity was relegated to a second plane to give priority to the running projects.

Installation and start-up of a new CNC machine. The MW will be equipped with a new CNC machine of large area (3x2m) especially devoted to the construction of large area detectors

SWOT Analysis

Strengths and Opportunities

- Valuable know-how, experience and skills of the technical staff.
- Valuable partnership (Detector Lab).
- The reallocation of the MW in the new space will improve the working conditions, eventually improving the efficiency.
- The incorporation of a new member staff has opened the opportunity to explore new capabilities of the CNC machines.
- Opportunity to extend services to other research groups / companies.
- New capabilities with a new large area CNC machine.

Weaknesses and Threats

- Difficulty in working simultaneously in many projects.
- Obsolescence of some of the equipment.

DETECTOR LABORATORY

Detector Lab

The Detectors Lab (DL) are currently split into two different facilities:

F1 is where the research groups develop their work and all electronics projects are developed. Situated in the fourth floor of the Physics Department, it is equipped most of the instrumentation and tools needed in a detector research laboratory. Each group has an independent work area to assemble their setups and develop their activities. The work related to R&D and production of electronics for all groups is performed here. Two secure rooms are available, one for gas bottles and another for radiation sources.

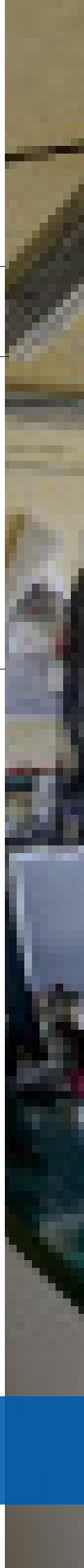
F2 is where the main research, development and production of large area radiation detectors takes place. Situated in the ground floor of the Physics Department, this area has been set up during the last year. At present, only about 50% of the foreseen area is available for our activities. The installation should be finalized in 2018. Currently available are a medium clean room for the assembly of sensitive parts of the detectors, a room for painting and another with an simple cutting machine used to prepare all the non metallic parts used in the production. Most of the mandatory instruments and tools are available in adequate quantity and quality.

Brief description of the facilities

Coordinator **Luis Lopes**

Team

Américo Pereira, Nuno Carolino, Orlando Cunha



Workshop / Detector Lab / e-CRLab / LOMaC / TagusLIP

Activities and achievements in the past year

The main activities were related to the R&D and production of three different types of large area Resistive Plate Chambers (RPCs) used in Collaborations (MARTA - FCT/FAPESP, muTT, Tomuvol, Antartida, HADES-FD) where LIP is involved. Our contribution is multidisciplinary once we almost fulfil all the needed branches: from the project design to the installation and maintenance of the detectors, developing tools and/or instruments to control/monitor the detector performance. Adapting the detector to the individual requirements of each application, following more or less the same procedure done in the industry. In total during 2017 were build more than 60 m2 including timing and trigger (counting) detectors. This activity spends around 50 % of our total manpower. For a more detailed description of our contribution to these projects, should be consider that we develop from zero the detector sensitive volume, the gas control and monitoring system and the monitoring of all the environmental properties that could affect the detector performance. All other parts used in these detectors were developed with the contribution of the researchers related to these projects.

Probably the more important activity is the capability to assist all the groups in their R&D activities. In total consumes around 30 % of our manpower. We contribute with technical work and added value in the following projects: APET, SNO+, MASTER-Rio, Spark Chamber, CriostatoLaserlab-DQUC, LZ (system upgrade), HADES, AIDA2020, SINE2020, Cloud Chamber, GSPC.LIP, OrthoCT.LIP and muTT/Tomuvol. Layout, loading and testing PCBs of home made electronic boards.

Other contributions more technical and related to management were done updating infrastructures of the LIP Mechanical Workshop and Detector Lab.

Organization and purchase of materials and instruments for LIP-Coimbra and Physics Department is also one of the tasks were DL has a relevant contribution.

Plan for next year

Continue to push with the improvement of new facilities (F2) is of major importance in order to achieve the established production targets.

The expect production of large area RPCs is the following: eight timing to the HADES-FD Collaborations; four timing to the SHiP test performance; four trigger to the Columbia project; twenty five sensitive volumes to the MARTA-FCT/FAPESP Collaboration. Fifty small area timing detectors for Animal-PET. Within detectors production is also scheduled the production of two Spark Chambers. Still with regard to production: fouty HV power supplies; twenty gas monitoring and/or control systems; many boards for charge and time measurements.

Regarding other projects is expected our contribution in the constructing, assembly and test of the following projects and/or setups: the version 2 of the APET; RPCs for neutrons, SINE2020; RPCs for high rate applications, AIDA2020; second unity of SNO+; finalization of the CriostatoLaserlab-DQUC; Cloud Chamber; GSPC.LIP; HADES and SHiP.

R&D contributions for projects as HADES-MDC, LATTES RPC detector and sealed RPCs will be very important to the continuous grown and establishment of our Detector Laboratory in the Science Community.

In a generalized way we look up to contribute in an organized and efficient way with all the collaborators.

Within the frame of the call for project submission, recently open by FCT in all areas, the group intends to submit a project probably together with other LIP teams. Also, when RD51 project calls opens, it is our plan to submit another project.

SWOT Analysis

Strengths

We have a multidisciplinary team that allows us to give a satisfactory answer to most of the requests. For this it is also important to note that we are well equipped. The ease with which we move to the places where Lip has its hardware, thus allowing a continuous monitoring from the R & D phase to the installation, operation and maintenance of most of the systems developed and built. This close monitoring allows a constant learning and improvement of our knowledge and abilities.

Weaknesses

Our current facilities are far from being indicated for the development of our activities. Space is limited and the time needed to change something in this situation is huge, sometimes unacceptable. Our production capacity and consequently our efficiency are greatly diminished for this reason. This stays more less as it was in 2016. Is very complicated to achieve significant improvements in that point...

Another important cause of inefficiency comes from not requesting the work in advance. Approximately 30 to 40% of jobs with more than 5 days of execution are requested less than a month in advance, or the information needed to execute them is only available within the same time frames. In this way it is impossible to make an efficient programming. Other issue is the non consulting of our expertise in many issues here we are "experts" leading many times to large time losses due to bad work preparation! We systematic alert all the collaborators to be sensitive to this issue but in some cases we were not well succeed.

Opportunities

The establishment of the ruggedness and performance of some of our detectors has been opening novel markets. Projects such as muTT and Antartida will allow these products to be based on a "market segment" that can have a very significant return to the Organization. As result of this we already are include in new Collaborations.

In the area of medical instrumentation, the quality of our work is also recognized, thus opening up another field to be explored.

Products more aimed at the disclosure of science such as the Spark Chamber and the Cloud Chamber are also products that may play an important role in spreading our name/brand. New instruments should be consider.

In the Collaborations where we are inserted, some updates and construction of new detectors are opportunities that we must consider, in a medium and long term.

New Collaboration opportunities are also being developed with international Organizations in order to extend our lines of action and/or implementation of the "products" already developed.

Threats

The uncertainty in some of our funding sources in medium and long term. The successive failure of the deliver times from our suppliers.

COSMIC RAYS ELECTRONICS LABORATORY

e-CRLab

The e-CRLab (electronics for Cosmic Ray Laboratory) is dedicated mainly to the development of electronics for Cosmic Ray experiments. The main focus is given to fast digital electronics implemented in FPGAs. The laboratory has the capability to design complex printed circuit boards and to produce simple PCB prototypes. The production of complex PCB and its assembly is outsourced. There is the capability to do rework in PCB boards. A small set of mechanical tools allows for the production of simple detector prototypes mainly for a proof of concept. The laboratory facilities are located at LIP-Lisboa and are composed by an office room, one instrumentation room installed with state-of-the-art equipment and a separate instrumentation room. A small mechanical workshop for detector prototypes development and a dark room will also be available in the short term. The capability to produce PCBs is installed at LIP premises in a separate room. The laboratory counts with two researchers, two PhD students and three electronics technicians.

Brief description of the facilities

Coordinator **Pedro Assis**

Team

José Carlos Nogueira, Luis Mendes, Marco Pinto, Miguel Ferreira, Pedro Brogueira, Ricardo Luz

Research Facilities

Workshop / Detector Lab / e-CRLab / LOMaC / TagusLIP

Activities and achievements in the past year

In 2017 the e-CRLab had two main activities: the development of MARTA instrumentation and the testing of radiation damage of components for ESA. MARTA is a project within the context of Auger to operate RPCs in the Argentine Pampa, under the Auger Water Cherenkov Tank. The electronics were developed at e-CRLab that has the responsibility of its operation within the project of the Portuguese participation in the Pierre Auger Observatory. It was developed and tested the engineering prototype of MARTA front-end electronics based in the MAROC ASIC. The system performed as expected and only minor problems were found and corrected in the project. In the context of ECO-60: Verification of Co-60 testing representativeness for EEE components flown in the Jupiter electron environment of the group Space Radiation Environment and Effects, the e-CRLab has developed the test procedure and test system for the irradiation in different conditions of several components. During 2017 the annealing phase was finished and the data analyzed. This work was done within the context of the Space Rad group. The e-CRLab has also been involved in outreach and teaching. In the outreach context it has been involved in the development of AMU – A ver MUões, a small Cosmic Ray Telescope to be deployed in high schools. The e-CRLab has been involved to the installation of experimental setups at IST for the Advanced Experimental Physics Laboratory and other education activities. These setups focus mainly in the detection of CR and on the study of scintillator detectors.

Plan for next year

For 2018 it is planned the consolidation of the activities in the e-CRLab and the beginning of the development of the electronics systems for LATTES. During 2017 the electronics for MARTA engineering array will be produced and tested at LIP and integrated in the RPC modules at Brasil. This activity will be done in close cooperation with the RPC R&D group and with Brasil that has the responsibility of the production and assembly of detector modules. We will also develop and produce support systems of RPC modules such as the LV power supply and control units. The e-CRLab will also participate in the deployment of the MARTA Engineering Array, performing the installation, testing the systems and developing monitoring tools.

A similar concept of the MARTA DAQ will be used in LATTES, a future large field of view gamma-ray observatory at very high altitude in South America. LATTES will count with RPCs coupled to Water Cherenkov tanks. The RPC readout can be very similar to the solution adopted but it must be included the tank readout in the system. On the other hand it is desirable to have a good time resolution (~1ns) which will probably pose some questions on the time distribution system that can probably be addressed by using copper or fiber clock distribution. The e-CRlab will have an important role on the development and support of advanced teaching laboratories at LIP. Part of the developments are expected to constitute outreach objects that can be installed in Universities and even High Schools.

SWOT Analysis

Strengths

The competences acquired in digital logic design as well as the competence in the design of complex electronic systems. Competence in handling several types of detectors such as RPCs, scintillators coupled to photomultipliers and Silicon Photomultipliers. Activities developed in the context of research projects. Capability to develop characterization systems. Possibility to plan and perform irradiation campaigns.

Weaknesses

Up to now it was not possible to attract direct financing for the development of detectors. The level of financing is incompatible with the full development of detectors that need an intense level of financing. Some equipment need to be upgraded to face growing time resolution demands. The lack of portable equipment limits the activity in off-premises experimental setups. Publishing of the work developed must be pursued as independent as possible.

Opportunities

The MARTA Engineering array will give the opportunity to lead the development of a medium size project from end-to-end. LATTES poses a mid-term opportunity to consolidate activities. The successful conclusion of the e-Co60 paves the way for future projects in radiation damage. Training activities, courses lectured in e-CRLab and Master thesis developed in e-CRLab can allow to increase manpower in the laboratory and allow to pursue different projects.

Threats

Financing is always a key issue when developing hardware that needs to spend in service acquisition and materials. Lack of man power could also be an issue in the mid-term.

LABORATORY OF OPTICS AND SCINTILLATING MATERIALS

LOMaC

Brief description of the facilities

LOMAC, the laboratory of optics of scintillating materials, has a long history as part of the ATLAS experiment project that created it.
LOMAC expertise is centered in the preparation and test of plastic WLS and scintillating optical fibres, scintillator plates and related devices to be used in high energy and nuclear physics detectors. The LOMAC facilities and setups are the following:

- Facility to cut/polish bundles of optical fibres.
- Aluminization facility – a facility to mirror fibres at one of their extremities. The aluminium mirror is deposited by magnetron sputtering.
- Fibrometer - a device for the semi-automatic characterisation of sets of up to 32 optical fibres.
- Mono-fibrometer – a device for the characterization of optical fibres (one by one).
- Tilemeter – a device for the characterization of scintillators.
- PMT test device – a setup to test PMTs.
- Equipment to measure absolute light yield

LOMAC was created for the tests and preparation of WLS fibres for the ATLAS Tilecal project in the 1990 decade, with human resources and expertise from CFNUL, LIP, FCUL, and UNL and it was based at CFNUL, where an external building was made to host the aluminization facility, near the ATLAS laboratories. The entire WLS fibres of ATLAS has been polished and aluminized and quality controlled at LOMAC.
LOMAC selected and/or prepared the following optical fibres by chronological order:

- R&D of scintillating and WLS fibres and scintillators for ATLAS.
- WLS optical fibres for STIC luminosity detector of Delphi.
- WLS optical fibres for the Tilecal hadronic calorimeter of ATLAS.
- Scintillating fibres for the ALFA luminosity detector of ATLAS.
- R&D for future calorimetry (DREAM project).
- Clear fibres for SNO+ calibration system.

LOMAC also studied the light output and uniformity of scintillators for Tilecal, having designed the optical masks to improve their uniformity, and tested a set of PMTs also for Tilecal. It also gave a decisive support to the development of the plastic profiles that house the WLS fibres in the Tilecal calorimeter.

LOMAC has contributed to several courses and events at FCUL and to outreach with the participation in many events and hosting yearly a summer activity for secondary school students in the framework of “Ciência Viva”.

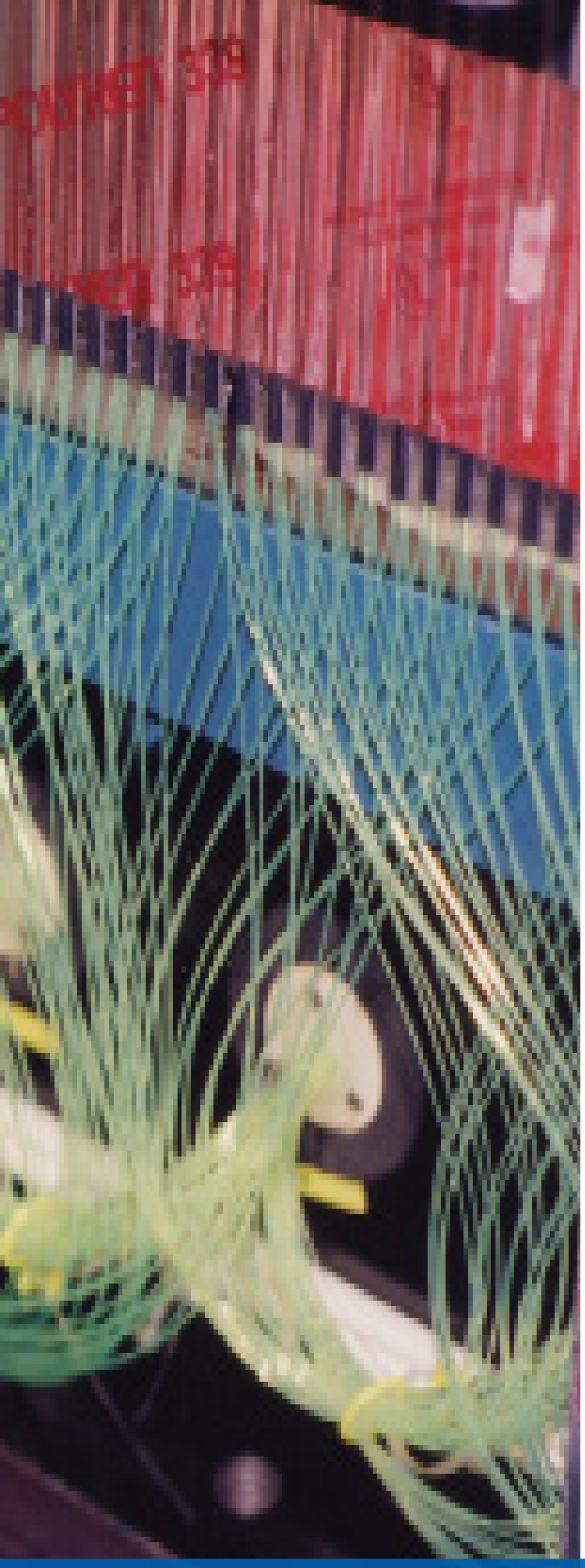
With the end of CFNUL, LOMAC was forced to abandon the laboratories where it was hosted, and was set up again at its current location at FCUL in 2016. Since LIP moved to the University of Lisbon building III, LOMAC is expected to move in part once again in the near future to concentrate its main facilities that now are disperse in the UL campus.

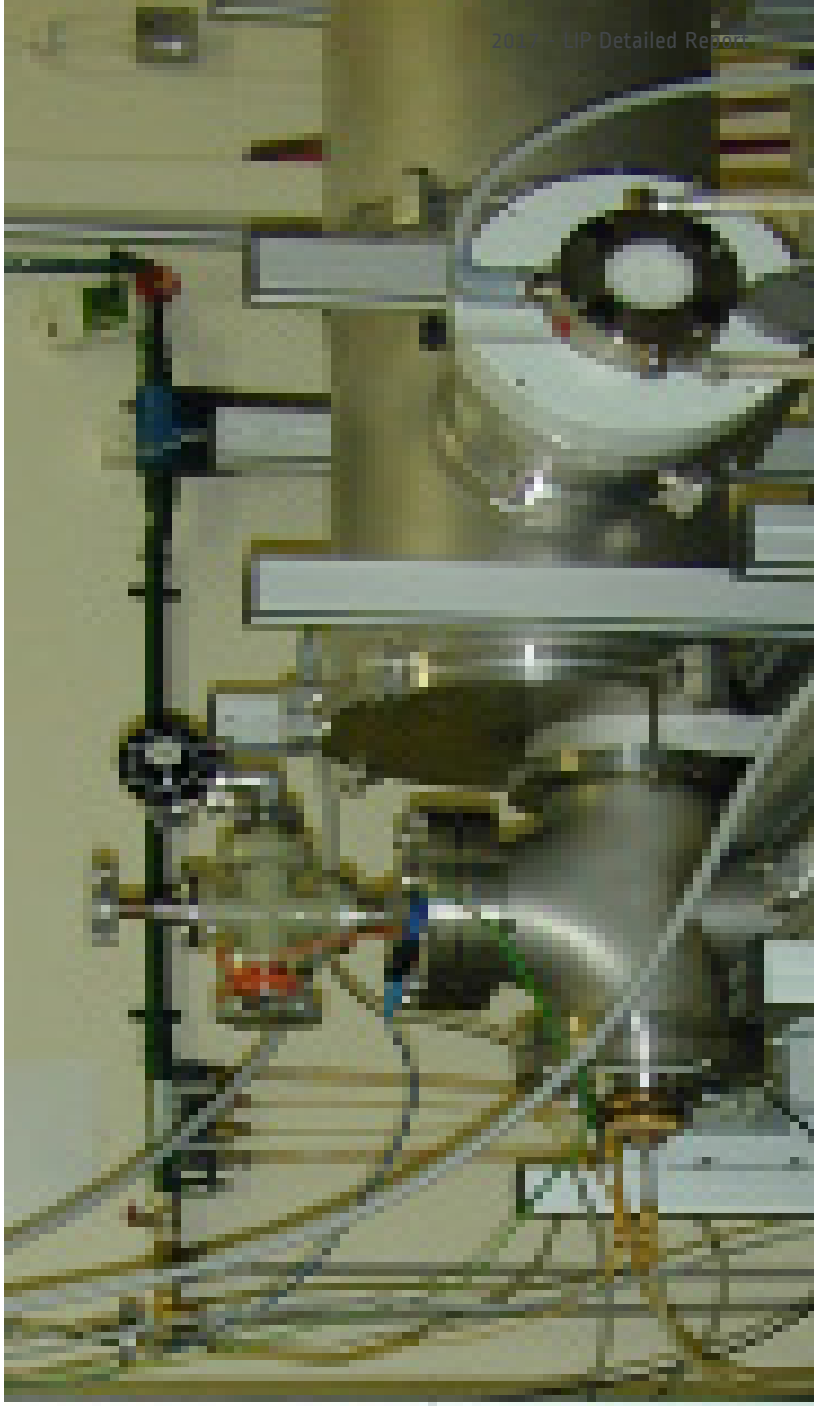
LOMAC activity will continue centered in the ATLAS experiment with contributions for R&D of scintillators and fibres and for the preparation of fibres needed for the upgrades of the gap/crack scintillators of Tilecal.

LOMAC is exploring also the possibilities to work in other future experiments and applications.

Coordinator **Agostinho Gomes**

Team Amélia Maio, João Gentil, Luís Gurriana, Luís Seabra, Ricardo Gonçalo





Workshop / Detector Lab / e-CRLab / LOMaC / TagusLIP

Activities and achievements in the past year

The fibrometer installed at the FCUL facilities was re-commissioned after the maintenance and repair that were done in the previous year.

Together with the setup to cut/polish the bundles of fibres using a lathe that belongs to the DEGGE department from FCUL and located at FCUL workshop, several sets of fibres were prepared for aluminization. The aluminization setup was used to put aluminium on the top of the fibres obtaining good quality mirrors.

After the re-commissioning of the systems, a set of almost 6000 Kuraray Y11 WLS fibres was aluminized for the W104/Icarus muon tagger.

Along the year, the mono-fibrometer setup had the mechanics and control improved.

Setups like the tilemeter and the mono-fibrometer have been used in several educational and outreach activities.

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Plan for next year

Most of the planned activities are related with the upgrade of the Tilecal calorimeter of ATLAS and they include:

- Preparation of sets of WLS fibres to be used with new scintillators E4' that extend coverage in eta in the gap/crack region, and in the reorganization of the existing scintillators E1-E4.
- Radiation damage of scintillators and fibres for the future replacements of scintillators E1-E4'.
- Scintillator-WLS fibres couplings tests.

There is work in progress to improve performance of the fibrometer and decrease systematic effects. If resources are available, the design of a new flexible system for the characterization of scintillators and fibres will be done.

Additionally there is work in progress to characterize scintillators with sizes and shapes that are foreseen for a tile calorimeter for the FCC in a first contribution for this long term R&D. The scintillators and WLS fibres used are the ones of the ATLAS Tilecal and the scintillators are cut to size and polished at the Coimbra LIP workshop.

The expected schedule for this year may prevent the transfer of the aluminization equipments for the new laboratories that will require a lot of effort and careful planning to avoid disruption of the current activities.

SWOT Analysis

Strengths

Long expertise in the test, preparation and aluminization of plastic optical fibres for detectors. Only a few facilities of this kind in the world. Fundamental for the ATLAS Tilecal upgrades.

Weaknesses

Ageing equipment needing replacements and upgrades.

Opportunities

Opportunity to participate in new detectors in HEP or related fields.

Threats

Lack of financial resources. Up to now we had more requests than we could handle. In the future we do not know. Lack of sustained operations in future is possible.

LABORATORY

TagusLIP Lab

The TagusLIP Laboratory is a LIP research infrastructure installed in 2004 at the Lisbon Science and Technology Park (Taguspark). The campus is home to a University (IST), several research centres as well as a large spectrum of startup's and PME's.

TagusLIP was conceived as a generic infrastructure for the development of radiation detectors in the areas of PET imaging and experimental particle physics. TagusLIP includes detector and electronics laboratories, electronics workshop, a hot laboratory for work with radioactive sources, offices space, and meeting rooms.

The TagusLIP laboratory is equipped with the necessary instrumentation for R&D on radiation detectors and associated electronics and data acquisition, including electronics lab equipment, computing and networking systems. The laboratory offers software tools for developing analog and digital electronic integrated circuits (Cadence), for firmware development (Xilinx and Altera), and for the design of printed circuit boards (Altium). The TagusLIP has a computing and data storage infrastructure, suitable to software projects in various areas, such as data acquisition, equipment control, data analysis and image processing. The TagusLIP is licensed for the use of radiation sources needed to develop and test new instruments in nuclear medicine.

The research team at TagusLIP has large experience in the development, commissioning and operation of large electronics and data acquisition systems in Particle Physics experiments and medical instruments. The group has developed and installed the Data Acquisition System of the Electromagnetic Calorimeter of the CMS experiment reading-out the data of 80'000 scintillating crystals. TagusLIP was home to the integration and commissioning of two PET scanners dedicated to mammography in the frame of the Crystal Clear Collaboration. The group has a long experience in the design and implementation of detector readout ASICs, in particular the ClearPEM ASIC for APD readout, the series of TOFPET ASICs for Time-of-Flight applications with SiPMs and the TOFEE chip for the readout of LGAD fast silicon sensors for the CT-PPS proton spectrometer.

Brief description of the facilities

Coordinator **João Varela**

Team Luís Ferramacho, Miguel Silveira, Rui Silva, Stefaan Tavernier, Tahereh Niknejad

Research Facilities

Workshop / Detector Lab / e-CRLab / LOMaC / TagusLIP

Activities and achievements in the past year

In 2017 the main user of the TagusLIP Laboratory was the start-up company PETsys that performed the following developments:

1. Extensive characterization of new ASIC TOFPET2 for Time-of-Flight applications together with SiPMs devices from all established producers. The measured timing performance was excellent. Associated to small LYSO crystals, a Coincidence Time Resolution of 127 ps FWHM was achieved for PET events.

2. Development of a PET detector module with DoI and Timing capability for large PET scanners. This work involved a LIP PhD student (T. Niknejad).

3. Design of a new ASIC (TOFHiR) for the CMS MIP Timing Detector, in the frame of the Phase II Upgrade of the CMS experiment for HL-LHC. The chip is derived from TOFPET2 and introduces new features in particular the possibility of operation at very high signal rate (1 MHz/channel).

The results obtained were presented at several international conferences, including SCINT2017, NDIP2017, PSMR2017 and IEEE/NSS/MIC 2017. An Award for the Best Poster at SCINT 2017 was given to the work on a new PET Detector Module presented by Tahereh Niknejad.

A preclinical PET/MR based on PETsys TOFPET1 ASIC presented at IEEE/MIC 2017 by Sibylle I. Ziegler's team from Technische Universität München Nuklearmedizinische Klinik und Poliklinik, showed excellent performance results. The results were also submitted to Physics in Medicine & Biology: PET Performance Evaluation of MADPET4: A Small Animal PET Insert for a 7-T MRI Scanner, S. I. Ziegler et al.

Plan for next year

The start-up PETsys will be the main user of the TagusLIP Laboratory in 2018. The activities planned in 2018 are the following:

1. Full validation of the new frontend and data acquisition system based on the TOFPET2 ASIC. New capabilities are being introduced in the system, in particular a distributed Coincidence Trigger, high-speed optical links (6 Gb/s), and new options for SiPM bias voltage generation.

2. Large scale production tests of components and systems supplied by PETsys Electronics. The company sold over 1 M€ of PET scanner components since 2014, of which about 0.4 M€ in 2017.

3. Development and test of the TOFHiR ASIC for the CMS experiment. The first MPW submission is foreseen in the Spring 2018.

SWOT Analysis

Strengths

Strong technical team and long expertise in radiation detectors. Excellent integration at international level. Complementarity with PETsys.

Weaknesses

Very limited research funding channelled by LIP. Presently the infrastructure is dependent on the funding attracted by PETsys.

Opportunities

Possible growth of PETsys, opening the possibility of research contracts between LIP and the company.

Threats

Lack of funding.

Theses

1 PhD Thesis

Tahereh Niknejad, "Development of new high-performance Positron Emission Mammography based on new photosensor technology", (2018-02-28)

// COMPETENCE CEN


Simulation and
Big Data Competence
Center
Monitoring and Control
Competence Center

ITERS

Simulation and Big Data Competence Center

Coordinators: Bernardo Tomé and Nuno Castro

The purpose of the Competence Center on Simulation and Big Data is the fostering of an effective collaboration between the different LIP groups working on these areas and to boost the capability to exploit the existing expertise both internally and externally, towards the university and the industry. The different LIP groups have a vast range of competences in data analysis and simulation tools, including physics models, Monte Carlo generators, detector simulation tools, big-data handling techniques and data mining. The ability to fully benefit from such competences requires achieving critical mass, a coordinated training program, the exploitation of synergies between groups and a clear identification of the key areas where we can contribute in a competitive way.

The competence center started its activities last year and the first priorities were the identification of the technical competences mastered by the LIP members in these two areas, establishing communication and discussion forums, starting a training program and establishing an action plan for the next few years.

2017 activities

The Simulation branch of the competence center developed the following activities:

- A survey of the GEANT4 competences at LIP was undertaken with the following relevant items identified:

  - LIP is a member of the GEANT4 collaboration for more than 10 years, accumulating an important expertise, both from the user and developer points of view, with an important know-how beyond applications development;
  - LIP members hold expertise in several GEANT4 kernel categories;
  - a potential to increase LIP's contribution to the GEANT4 toolkit was identified;
  - LIP members undertake teaching activities in MSc and PhD level courses with some emphasis in GEANT4.

- Start of regular informal meetings involving all the interested LIP members.

The Big-Data branch of the competence center developed the following activities:

- A survey of the big-data and machine learning competences at LIP was undertaken and the following relevant items were identified:

  - development of multivariate data analysis using advanced techniques (e.g. boosted decision trees, shallow and deep neural networks and principal component analysis);
  - expertise in modern tools used in HEP and beyond it (e.g. TMVA, Octave, Keras, SK-learn, Pandas, Theano, Tensorflow);
  - expertise in advanced methods for training and validation of multivariate analysis (e.g. use of accelerators such as GPUs, distributed training and cross-validation);
  - expertise in complex file systems and tools to deal with large volumes of data.

- Participation in different funding calls in the big-data area (FCT, COST action and a H2020 proposal).

- Successful application to a NVIDIA GPU grant, which allowed us to receive a modern GPU board to be used in the training of advanced multivariate analysis.

- Regular informal meetings with all the interested LIP members, which include topical discussions and tutorials.

- Participation in the iSci-ECUM-Bosch project, devoted to the improvement of the data quality in specific industrial contexts, which has a strong data analysis component.

Prospects for 2018

The Simulation branch of the competence center plans to continue the coordination of the existing expertise in order to foster the interaction with the community. It will be crucial to identify the strategies to create external links with the university and industry. In particular, the identification of projects and activities with the potential of capturing external fundings will be a concern. A training program will be developed aiming to establish regular workshops and tutorials. The contribution to the GEANT4 collaboration will be continued and strengthened.

On the Big Data side, a data science school at LIP and an associated symposium with students, researchers, private companies and industries will be organized in March 2018. Depending on the outcome of the fundings we applied to, dedicated computing infrastructures will be installed. An ongoing survey of the competences in data sciences by other portuguese groups will be continued, aiming to identify potential collaborations and the key areas were we can be competitive in providing external services.

SWOT analysis

Strengths

- Long date expertise in simulation and big data at LIP.
- Expertise in modern data mining techniques used in HEP and beyond.
- Integration in international collaborations (HEP experiments, GEANT4 collaboration).

Weaknesses

- The different ongoing efforts at LIP on this field are not yet fully integrated.
- Lack of critical mass in some areas.
- The contacts with industry on this area are still scarce.

Opportunities

- Huge interest and demand for expertise in simulation, big data and data mining.
- Interest in modern techniques by many LIP members.
- Large interest in the areas of the competence center by different funding agencies.

Threats

- These areas are extremely competitive, involving a community much larger than the HEP community.
- Dispersion of efforts in areas where we cannot be competitive.

Monitoring and Control Competence Center

Coordinator: Francisco Neves

The Competence Center in Monitoring and Control (CCMC) is intended to:

1. Gather the accumulated expertise in sensors, electronics and software used in Monitoring and Control by several experiments where LIP participate and have direct responsibilities;

2. Facilitate the sharing of know how, solutions in electronic and software design among LIP persons/groups with the potential benefit of:
   - Reduce development and delivery times;
   - Better debugging and quality control;

3. Establish partnerships/contracts with third parties (e.g. other laboratories, industry) where our scientific deliverables can be re-used.
   - Avoid time/costs associated of development of new products.

2017 activities

The activities of the CCMC developed in the framework of other LIP members/infrastructures were:

- Precision monitoring and control of an oven for annealing of PMMA containers for radioactive sources in the framework of SNO+ activities. This activity were developed also in collaboration with the mechanical workshop and the detector laboratory.

Concerning external entities, the activities were:

- Initiated negotiations with the CNC (Centro de Neurociências, Coimbra) towards the installations of an Environmental Monitoring System for their laboratory rooms. The system will be based in hardware and software tools developed/used by the LUX-LZ group. As a 1st stage, the CNC will just pay the equipment (~400€) and LIP would test/tune the system for free. After this trial period, we would re-negotiate the terms of the contract and eventually extend the system for other rooms (that would also include measuring pressures in virus rooms, etc). Currently LIP is waiting on their decision.

Prospects for 2018

For the next year, the activities of the CCMC developed in the framework of other LIP members/infrastructures will be:

1. Continue the work of monitoring and control an oven for the annealing of plastic pieces (e.g.PMMA) and assess the feasibility of working with higher temperatures (~200C).

2. During CERN 2019 Long Shutdown (LS2), COMPASS will be updating its Monitoring and Control system. In that process, COMPASS will study the possibility of replacing their Embedded Local Monitor Board boards (ELMB) by Raspberry/Beaglebone-based boards for measuring of temperatures, pressures, humidities, etc. COMPASS shown interest in collaborating with the CCMC to take advantage of the existent accumulated experience within this Competence Center and access the feasibilty of using those boards in their experimental environment. The extent and details of the collaboration between COMPASS and the CCMC is yet to be defined

Concerning external entities, the CCMC intends to:

1. Finalize the negotiations with CNC for the installation and maintenance of an Environmental Monitoring System and upon success proceed with its installation.

2. Further explore the possibility of develop and build a setup for the characterization of hydrocarbon (crude) reservoirs for the Universidade Fernando Pessoa (UFP). This project stems from previous contacts between LIP and UFP involving the maintenance of similar systems and, given its complexity and costs, still needs accurate and detailed evaluation before proceeding.

In General and with the help of LIP members, continue the search for potential new projects and help mediating the interaction between the various LIP structures when relevant in the context of each project

SWOT analysis

Strengths

A large body of knowledge accumulated from the participation of LIP members in several experiences, often with direct responsibilities in the development, constructions and maintenance of monitoring and control subsystems.

Weaknesses

- Do not have (explicitly) allocated FTEs or resources for the procurement and project development and integration with the other LIP infrastructures.
- The current inability to certificate LIP product or services

Opportunities

The ability to deploy very high quality products and services developed within scientific projects and meeting very high quality and reliability standards at competitive prices.

Threats

The ability to meet deadlines and ensure the man power required for the assistance to services/products contracted with third party entities and it potential impact in the LIP image.

// SCIENCE AND SOC


Knowledge transfer, industry and spin-offs
LIP-ECO
Education, communication, outreach
Advanced training
Radiation, health and environment

IETY

LIP EDUCATION, COMMUNICATION AND OUTREACH

LIP-ECO

Core team: Catarina Espírito Santo (coordinator LIP-ECO1), Pedro Abreu (coordinator LIP-ECO2), Aidan Kelly, Carlos Manuel, Conceição Abreu, Francisco Neves, Henrique Carvalho, Hugo Gomes, Leonor Coimbra, Nuno Castro, Ricardo Gonçalo, Sofia Andringa

Education, Communication and Outreach (ECO) are today a fundamental aspect of the activities of a research and development institution. This results from the recognition that ECO activities:

- **are part of our social role**
- **are essential for the recognition of our work's relevance**
- **help attracting funds, partnerships, opportunities**
- **help attracting students and researchers**

LIP-ECO was created in 2016 with the aim of better organizing and extending the ECO-related activities carried on at LIP. The celebration of LIP's 30th anniversary has played a crucial role in boosting LIP-ECO. Still in 2016, LIP's communication strategy document was written, and priority target audiences were defined: our peers (universities, research centres and funding agencies); the LIP community (internal communications); undergraduate students in Physics and Engineering; the school community. A core team with weekly editorial meetings and a clear and ambitious activity plan has been established.

The LIP Education, Communication, Outreach (LIP-ECO) office has two (interrelated) pillars:

1. corporate communications (LIP-ECO1);
2. education and outreach (LIP-ECO2).

A third fundamental pillar, advanced training, is treated separately in this report.

Overview

While ECO activities are transversal and involve all LIP members, to an extent that depends on their role in the lab, time availability and personal interests, coordinators and core teams have been assigned to each of the LIP-ECO pillars, in order to guarantee an adequate level of commitment and resources. LIP-ECO involves all three LIP nodes, which are represented in the core teams. The activities of LIP-ECO are developed in close collaboration with the LIP Computing group, namely in what concerns the sharing of human resources and technical means.

LIP has as main partners in outreach Agência Ciência Viva and the Portuguese Physics Society. LIP is part of several communication and outreach groups and networks at CERN and beyond:

- IPPOG — International Particle Physics Outreach Group, which formally became an international collaboration in 2017.
- EPPCN – European Particle Physics Communication Network, which aims at fostering particle physics communication by maximizing information exchange between CERN and the Member States
- CERN forum for high-school students and teacher programmes.

Support to the European HEP school:

The European School of High Energy Physics (ESHEP 2017) took place in Évora, Portugal, from 6 to 19 September. This school is organized yearly in a joint effort by CERN and JINR. This year it was coorganized by LIP with the support of the University of Évora. The ESHEP is attended typically by 100 highly selected PhD students. The local organizing committee included members from different LIP groups.

LIP-ECO members further participated in the jury of the school outreach presentations session and were instrumental in establishing contacts and conditions for an interview with Fabiola Gianotti to Visão, a national Portuguese reference magazine.

2017 activities

The main achievements in each of the LIP-ECO pillars are summarized below.

1. Communications

In 2017, the organization work was pursued in the wide set of tasks concerning LIP-ECO1, progressively widening the addressed challenges and thus the responsibilities:

Preparation of institutional LIP documentation and publications

- LIP early Reports and plans: LIP-ECO is responsible for the edition of LIP's early reports and plans. Since 2015, two different reports are prepared. The detailed activity report and plan is meant to give a complete, in detail view of the laboratory's work and achievements, aimed at LIP's associates, our international advisory commitee, and LIP members, and is a legal requirement. The public report gives an overview of the laboratory's activity aimed at partner institutions and the general public.

- FCT Evaluation: In 2017, LIP-ECO has coordinated the edition of the documents presented by LIP for the evaluation of all R&D units promoted by the Portuguese Foundation for Science and Technology (FCT), which will define the lab's level of public funding for the next five years.

- The LIP-news bulletin: for the first time, the goal of publishing three issues of the Bulletin per year was achieved in 2017. Guaranteeing a strong a regular collaboration of the LIP research groups in the Bulletin remains a goal for the future.

LIP web and social media

- LIP web site: In the last few years, a new LIP public web site has been developed from scratch. While the site has been released in 2016, further developments and updates were performed during 2017.

- New LIP intranet: we initiated the development of the new LIP intranet, which will play an enhanced role in internal communications. A first version is now ready for testing (web.lip.pt/new).

- Event management system: the team carried out the operation and upgrade of the event management system, where all events organized by LIP are handled (programmes, logistics, participation, registration, accounting, etc.)

- News reader system: we developed a news reader (raspberry Pi based), allowing for the news posted on the LIP web site to be displayed in screens located at IST (already there), at the LIP premises in Lisbon (ready for deployment) and possibly in other locations.

- Social networks: LIP is present in the social networks Facebook, Twitter and linkedin. For the first time this year, we had a person with some time allocated to social media. The number of followers on facebook more than doubled during this period. The efforts on Twitter and linkedin are more recent and will be pursued, based mainly on the collaboration of LIP members that are social media users.

This work was performed in a close collaboration with the LIP Computing group.

Branding

In order to foster the impact of our communication, we are developing a set of graphic rules and branding products. The goal is to improve the way in which we present LIP, communicate a coherent image of the lab, make useful materials available to the LIP community (logos, templates, image sets). The production of a limited set of merchandising products is a goal for 2018. These will serve several goals, such as to enhance the attractiveness of LIP event to young students, provide prizes for competitions, etc.

Other internal communication actions

- Internal communication survey: a survey on the status of internal communications was conducted in 2017. About 40% of the LIP community (75 people) answered the questionnaire, and the results have been presented at LIP's bi-annual meeting in February 2018. Among other outcomes, a digital internal newsletter will be issued monthly in 2018; a considerable amount of new information will be made available in the new intranet (namely practical and administrative information); and the strengthening of the communication between LIP groups emerged as a priority for 2018. Improving the sharing of news and the communication of the groups with LIP-ECO is a first step towards this goal.

- SciCom training: for the first time, a one-day workshop on speaking in public with a recognized expert in the field was offered to the LIP community. Twelve people coming from the three LIP notes attended the workshop, and the results of the satisfaction survey were rather positive.

Contacts with the Media and other institutions

- Press/Media: although this is not chosen as a priority, a number of press releases have been issued and some nice successes attained — in particular the publication in

Público, a reference national daily newspaper, of the news concerning the confirmation of the extragalactic origin of the highest energy cosmic rays, including a conversation with three members of LIP.

- Event advertising: LIP-ECO gives support to the advertising of events organized by LIP. During 2017, we succeeded in tightening our links with other communication offices, especially at our partner universities.

- SciCom conferences: we were present in the national science communication conference SciCom.pt with a communication on the cloud chamber developed at LIP-Coimbra, and another one on the organization of the LIP-ECO office itself.

2. Education and outreach

IPPOG's International Masterclasses in Particle Physics

Under the coordination of LIP, more than 1700 participants gathered in 16 sessions all over the country: Aveiro, Beja, Braga (2 sessions), Bragança, Coimbra, Covilhã, Évora, Faro, Funchal (Madeira), Lisboa (2 places, 3 sessions), Ponta Delgada (Azores), Porto, Vila Real, and with our remote support in São Tomé and Príncipe. In addition, a study on gender balance among Masterclass participants has been initiated, using data from different sites and evolution with time.

Summer internships for high school students

In the framework of Ciência Viva's programme "Science in the Summer", LIP has proposed several internships in Lisboa and Coimbra and hosted 17 students for two weeks to learn about experimental particle physics and directly experience the work of scientist's in the field. Within the internship's progamme of the University of Coimbra, LIP further hosted 13 students for one week in internships devoted to the ATLAS experiment at the LHC and to dark matter searches.

CERN Portuguese Language Teachers Programme

Under the responsibility of LIP and with strong support from CERN and Ciência Viva, the 11th edition of the school was held in the beginning of September, attended by 20 Portuguese teachers and 20 Brazilian teachers. In this edition, it was not possible to obtain support to bring teachers from Portuguese-speaking African countries. An effort to re-establish this participation will be made for the next edition. During the last ten years, 639 teachers have attended the school, which is considered one of the best teacher training programmes at CERN.

Instrumentation for education purposes

The construction at LIP-Coimbra of a cloud chamber for demonstration purposes has been completed, and the chamber has been shown in several events — in particular, in LIP's anniversary open day, in the national science forum Ciência 2017 and in the European researcher's night in Braga. Further developments were made in order to make the electronics more compact and the full system easier to transport and to operate.

Seminars in schools and special outreach sessions

More than 50 outreach talks were given by LIP scientists in Braga, Coimbra and Lisboa, at schools and in other settings, on particle physics, space and related technologies. Some special events are list below.

- 7 Public Sessions @ Planetário

  The exhibition "Particles: from the Higgs boson to dark matter", shown in Braga, Coimbra and Lisboa in 2016, was hosted by the Lisbon Planetarium for six months. Once per month, a "meeting with the scientist" event was held: a seminar given by a LIP researchers was followed by a discussion session, with guided visits o the exhibition. Subjects were: Antimatter/Fernando Barão; Quarks&Gluons/Helena Santos; Neutrinos/Sofia Andringa; Dark Matter/Isabel Lopes; Detectors/Alberto Blanco; Higgs boson/Patrícia Conde-Muíño; Particle and Astroparticle physics in the 21st century/Mário Pimenta

- Public session at the University of Évora

  In 15 September 2017, Fabiola Gianotti , Director General of CERN, and Victor Matveev, Director of JINR, were speakers at a public session organized by LIP and the University of Évora in the context of the European School in Heigh-Energy Phsyics. The Portuguese Minister of Science, Technology and Higher Education, Manuel Heitor, was an honoured guest at this session, which also counted an address by the Rector of the University of Évora, Ana Costa Freitas, and Gaspar Barreira, Director of LIP. The session was very successful, with an audience of 250 people and lively and interesting discussions.

- European Researchers Night

  - In Braga, integrated in the celebrations prepared by Escola de Ciências da U.Minho: the LIP stand displayed LIP's interactive screen, a spark chamber and a cloud

chamber; the workshop on "How to build a particle detector" was held.

- In Lisboa, in the Lisbon Planetarium, the movie "Particle Fever" was shown, followed by a lively discussion and a Virtual Visits to the CMS experiment.

- Dark Matter session during the national S&T week, featuring LIP PhD students
  - Miguel Orcinha (from LIP-Lisboa), DM@AMS (annihilation)
  - Paulo Brás (from LIP-Coimbra), DM@LUX (interaction)
  - Tiago Vale (from LIP-Minho) ,DM@LHC (production)

  Full house (more participants than chairs) and very positive feedback.

- School "How to become an astronaut": Organized by the Astronomical observatory of the University of Coimbra, with the collaboration of LIP, the school hosted 40 students for one week.

Other activities

- LIP gave logistic support to Portuguese schools organizing visits to CERN or participating in the CERN Beamline for Schools competition.

- Students visits to the LIP-Coimbra labs (300 students per year)

Prospects for 2018

The first goal of LIP-ECO for 2018 is to consolidate the activities and services already provided to the LIP community, as many new tasks have been recently initiated and human and material resources are limited. Consolidation of the nation-wide nature of the LIP-ECO office, by strengthening the collaboration between the three LIP notes, is certainly a priority.

1. Communications

In 2018, the organization work in the wide set of tasks concerning LIP-ECO1 will be pursued, progressively widening the addressed challenges and thus the responsibilities. Some flagship priorities are:

- A digital newsletter (cLIP) will be issued monthly, starting in February 2018

- The LIP science news issuing will be improved, which requires a stronger collaboration with the research groups and the scientific council.

- We will seek to boost the production of contents and materials to promote LIP's work and research in particle physics and related technologies (physics dossiers, videos, flyers, booklets, merchandising), provided the human and financial means are available.

- In what concerns the LIP website, the already existing tools must be improved: the intranet content will be completed; newly designed group pages and personal pages will be included; the upgrade of the event management system will be concluded.

- LIP-ECO also aims at having a role in the procurement and preparation of funding projects, which we believe could be very useful for LIP, but which is dependent on the availability of human resources.

2. Education and outreach

2017 was a year of continuation of the well-established education outreach programmes, putting emphasis on a better coordination between the activities developed at the different LIP nodes. Some

steps were taken in the direction of the development of equipment for outreach purposes, which we expect to boost in 2018, again depending on the available means. Some ideas are:

- Development of equipment for education and outreach purposes based on new technologies (virtual reality, DIY accelerators, arduinos, sensors, science kits). The scientific infrastructures and competence centres of LIP also play an important role in the project, as well as the specific expertise existing at LIP-Minho.

- An ambitious project is the establishment of the pilot phase of a teaching laboratory devoted to the experimental teaching of physics to school students (all age groups). Data acquisition, sensors, measurement setups adapted to the curricula, raspberry pi, simple python programming exercises, data analysis and, in general, the methodologies and tools of experimental physics are the aspects to be addressed. These possibilities are open by the new premises of LIP-Lisboa, which for the first time provide the adequate conditions for such a project.

It is worth stressing that the mission of LIP-ECO can only be fulfilled with close connection with LIP's management, with LIP's scientific and technical groups, and with our peers in partner institutions.

SWOT analysis

Strengths

The strong motivation of the team and the wide range of expertise covered — from particle physics to science communication, from computing to graphical design. The recognition of the work developed in the last few years, which considerably increased awareness on the importance of ECO activities at LIP

Weaknesses

The lack of dedicated human and material resources. Most team members are highly committed to other tasks and devote only a small fraction of their time to ECO. After dealing with all current and mandatory tasks, there is little time left to expand our activities or to implement new ideias.

Opportunities

The support of the LIP management and of a good fraction of the LIP community. The many suggestions received during LIP's internal communications survey and also by other means.

Threats

The lack of prospects of an increase of material or human resources. The fact that many people in the community still believe ECO activities are a minor issue and should only consume minimal resources.

ADVANCED TRAINING GROUP

ADVANCED TRAINING

Coordinators: Nuno Leonardo, Nuno Castro

Overview

The capability to attract the best undergraduate and graduate students is central for LIP. The advanced training office was created to coordinate and promote actions dedicated to university students at the several levels (undergraduate, master, PhD). Its goals are:

- Engage undergraduate students: attract university students to learn about HEP and engage in research at LIP, imparting the excitement of doing research in fundamental particle physics or advancing associated technologies in frontier experiments and in the context of international collaborations; ensure high quality underlying training in HEP.

- Ensure high-quality graduate training: support baseline core training and adequate guidance of LIP graduate students; Support national and international PhD programmes and networks in our fields of activity.

2017 activities

In 2017, a wide set of activities for undergraduate and graduate students was carried on, and are briefly described below:

1. Undergraduate students

LIP Summer Student programme

For the first time in 2017, the efforts by individual groups were joined and summer internships for undergraduate students were held as an integrated LIP programme. Over the summer period, students became actual scientific collaborators within the LIP groups. 29 students completed the program in Lisbon. The format of the programme was as follows:

- tutorials: 1 week of lectures (morning) and hands-on tutorials (afternoon)
- research project: participation in a project (from 2 weeks to 2 months)
- final workshop: 1 day where each student shows his/her work

The programme counted on a broad participation of LIP researchers, who served as project supervisors, delivered tutorials and lectures, attended and contributed to discussion of results at the final workshop.

In Coimbra, 12 students took part in 1-month long projects in topics such as top quark, dark matter, instrumentation & radiation.

The summer program was very successful, with a quite positive global evaluation by students, a large number of students engaged, and a good level on the research work and presentations.

Schools & workshops

LIP is involved in several regular school and workshop series directed at undergraduate students, involving general physics presentations, hands-on exercises, and an overview of ongoing research activity at LIP. Namely:

Lisbon (LIP-CFTP) mini-school in particle and astroparticle physics: the 2017 edition, held in Sesimbra in February, gathered 20 graduate students.
Hands on Particles and Light: the 2017 edition, held in July at FCUL and IST, counted on the participation of 14 students.

Outreach for undergraduates

Besides training events (internships, schools and workshops), LIP conducts a number of initiatives with the goal of making LIP and particle physics known and attractive among undergraduate students. Some highlights are listed:

- The LIP Remote Operations Center (LIP-ROC) at IST: in 2017, LIP inaugurated the LIP-ROC, a room at IST from which Auger and CMS control and monitoring shifts take place. The LIP-ROC creates additional opportunities to make contact with students and to involve and train students on detector status, control, data quality monitoring in real experiments for running experiments. Sessions for introducing detectors and physics topics have been held, and a display with LIP related news and announcements has been installed.
- Careers & Technology day: a two-day event on career prospects, technology and links to industry in particle physics was held at our partner universities in Lisbon: LIP Careers Day, at IST, 1.3.2017, and CERN Technology Day at FCUL, 2.3.2017. In each of the two places, around 30 students attended the event.
- Participation in events organized by Physics student associations and groups at the different universities. For example, LIP regularly participes in the “Inside Views” of research laboratories during the Physics Engineering Days at IST. In 2017, 54 students visited LIP for one morning, attending one of the 6 proposed sessions.

Graduate students

LIP permanently hosts tens of PhD, Master and Bachelor students, who actively work within LIP's research groups, and has a long standing experience in advanced training. In each of its three nodes, the Laboratory works in close relation and cooperation with the local universities.

Furthermore, LIP coordinates two FCT doctoral programs, IDPASC (Particle Physics, Astrophysics and Cosmology) and DAEPHYS (Doctorate in Applied Physics and Physics Engineering), and the IDPASC international network. LIP is a member of MV4NewPhys, a EU funded International training Network, and host a PhD student in this context.

A wide set of schools, workshops and courses were held in 2017, namely:

- 2017 IDPASC international school: held in Asiago during two weeks, the school included lectures, discussion sessions and a final exam. 13 students participated.
- First LIP PhD student workshops: for two days, all LIP PhD students presented the status of their work to an audience of graduate students and researchers, in Coimbra. Keynote lectures on topics selected by the students themselves started the session in each day.
- IDPASC student workshop: a similar meeting for all IDPASC students was held in Braga.
- LHC Physics Course: about 18 lectures covering introduction to the standard model, detectors, statistics, and overall research were proposed, from March through May. In 2017, 3 students made a final presentation on a chosen topic. Better coordination with university graduate courses, and covering a wider range (non-LHC) of topics are some of the ideas for the future.
- Computing tutorials on Linux (Braga, 20 hours of theory and practice, 15 participants), Git & GitLab (Lisbon, 20 attendees), Keras, Docker, etc.
- LIP Seminars, regularly held

Prospects for 2018

The first goal of LIP's advanced training office for 2018 is to consolidate the existing engagement events, training activities and support actions towards undergraduate students in Physics and Engineering, graduate students at LIP, and graduate students engaged in PhD programmes and networks coordinated by LIP. In fact, many new tasks have been recently initiated and human and material resources are limited.

Some of the foreseen key initiatives for 2018 are listed below:

- LIP Summer Student programme: to pursue this integrated LIP programme is a priority for 2018, building on the experience acquired in 2017 to further improve the programme.
- Schools & workshops for undergraduates, namely within the LIP-CFTP and Particles and Light series.
- 2017 IDPASC international school: will be held in Valencia in May, and maintain the usual format.
- Data science and big data: this flagship 2018 event emphasizes connection to and partnership with industry. It will take place at LIP-Lisbon for four days and includes a school and a symposium. A large attendance expected, and 26 companies will participate.

Plus a long list of events, seminars and tutorials.

SWOT analysis

Strengths

The motivation of the team and of the entire LIP community for the need to attract students and to provide excellent training and guidance to those already hosted at LIP. The long experience and high reputation of LIP as a host institution and of LIP researchers as highly committed supervisors.

Weaknesses

The fact that many LIP researchers have no link, or have only a weak link, to the universities and thus no direct contact with students on a regular basis and in classroom environment. The lack of manpower for event organization, as researchers are usually highly committed.

Opportunities

The success of the activities developed in the last couple of years has already resulted in a greater visibility of LIP among students. The fact that a few positions are opening at universities may strengthen their links with LIP.

Threats

The risk that the multiplication of the activities, together with the lack of manpower, result in poorly organized events that damage LIP's reputation or in internal conflicts.

Knowledge transfer, industry and spin-offs

Coordinator: Gaspar Barreira

Particle physics technologies have a wide range of applications, and the potential to respond to societal changes. LIP aims at boosting our shorter term societal impact through specific research lines dedicated to applications to health care and space exploration. Scientific computing is certainly one of the areas placing particle physics at the forefront of innovation. LIP co-leads the National Infrastructure for Distributed Computing, serving the Portuguese scientific community at large.

2017 Activities

Direct transfer

Knowledge transfer to companies occurs across the whole spectrum of LIP's activities. Highlights on knowledge transfer opportunities in 2017 are listed below:

- LIP had contracts or was in consortia with EFACEC SA, EVOLEO SA, HIDRONAV SA and BOSCH;
- LIP's spin-off company PETsys, created to commercialize the innovative electronics developed at LIP for PET systems, was the main user of the TagusLIP facilities in 2017. A LIP PhD student completed her thesis in the context of this close collaboration.
- A 4-layer TOFtracker device has been constructed, integrated and deployed, for muon tomography of cargo containers at harbours, for the HYDRONAV S.A company (http://macroescaner.com). The collaboration with the company will continue.
- LIP's RPC-based small animal PET scanner currently operating at ICNAS with a world-record resolution, and is at pre-commercial development stage; a human-brain scanner is a priority for the next years.
- We will pursue the commercial development of dosimeters for clinical applications through partnership with Nu-Rise company. Collaborations at national level with INESC in the development of a microdosimeter and in microdosimetry studies with CTN will be established. This is in line with the strategic plan of LIP regarding future research in the projected installation of a hadron therapy unit in Portugal.
- LIP's space activities are based upon collaboration with industry, contracts with European Space Agency, participation in consortia (LIP is member of the EUROPLANET consortium http://www.europlanet-eu.org) for H2020 calls (currently EFACEC and EVOLEO)
- The purpose of the recently created LIP Competence Centers is to exploit the existing expertise both internally and externally, towards the university and the industry. LIP's laboratories and workshops also provide services to external entities.
- LIP is committed to the Open Science paradigm and present in the Portuguese scientific open access platform.
- The work on IAEA CRP "Development of Electron Beam and X-Ray Applications for Food Irradiation" within the NUC-RIA group will be reinforced during 2018.
- The LIP computing group has extensive knowledge and experience in scientific computing, excellent international relations and integration in scientific e-infrastructures, with users from multiple disciplines and organizations, participates in the FCT infrastructures, and in the enabling of future policies for scientific computing and open access. This creates the potential for industrial and e-government applications, and the possibility of engagement with other communities.

Industrial liaisons

Indirectly, LIP's involvement with CERN has triggered technological transfer to Portuguese industry through contracts awarded to Portuguese firms by CERN, in the context of its industrial procurement rules. In this respect, LIP has been operative in the coaching and in some cases in the technical support to Portuguese firms in their networking with CERN. The Portuguese Industrial Liaison Officer (ILO) is a member of LIP's staff and his activities are developed under the framework of FCT, by agreement with LIP. The ILO that is mandated to support and actively promote national industry and R&D institutions to CERN, ESO, ESRF and contribute to their success in the procurement process, thus ensuring a positive industrial return to Portugal.

- The ILO continued in supporting company presentations to technical departments and/or groups from CERN, ESO and ESRF by establishing different formats of discussion forums (ex: dedicated meetings or industry days). Further, the ILO was selected by the Big Science Business Forum (BSBF)

organization committee, to be a speaker and moderator, to the upcoming 1st ever Big Science Industry Event that will be held in Copenhagen in 2018 expected to join around 1´000 participants (from industry, academia and government);
- The ILO ensured that several Portuguese companies could be considered as potential suppliers to a European Prime contractor, for the construction of the large and most advanced Telescope in the world - ESO ELT project;
- The ILO ensured that the contact details of Portuguese companies registered at CERN, ESO and ESRF are up to date. The number of companies registered amounts to more than 400.

Portuguese traineeship programme at CERN, ESA and ESO

The involvement of LIP at CERN and its role in has been instrumental in FCT's engineers training programme. In 2017, LIP was directly involved in the evaluation and selection process of the trainee engineers for the Technology Internships programme at CERN, ESA and ESO. Gaspar Barreira, Director of LIP and Portuguese representative in the CERN Council, was the president of the board, which included also Pedro Abreu (LIP/ IST). Eight new internships started in 2017.

HEPTech network

LIP is a member of HEPTech, a unique high energy physics technology transfer network (TTN) that aims to become "the innovation access point for accelerator and detector driven research infrastructures". The network bringing together leading European high energy physics research institutions: CEA, CERN, CNRS, CIEMAT, DEMOKRITOS, DESY, ELI-ALPS, ELI BEAMLINES, EPFL, ESS, GSI, IJS, IFIN-HH, INFN, INOVACENTRUM, KTN, LIP, NTUA, SOFIA University, STFC, TU of Kosice, University of Belgrade, WEIZMANN Institute and WIGNER; which work across a range of world-leading scientific areas in the field of Particle Physics, Astrophysics and Nuclear Physics.

To push back scientific frontiers in these fields requires innovation. It is challenging and costly to carry further research and development focused in applications, products and processes and turn them into commercial opportunities. HEPTech, as a source of technology excellence and innovation, tries to bridge the gap between researchers and industry by organizing a set of activities, namely:
- Academia Industry Matching Events (AIME);
- Workshops about Technology Transfer and commercialization of research;
- Show and Tell - showcase about activities and tools related to knowledge transfer;
- Heptech Symposium - unique opportunity for early stage researchers to learn how science can impact society;

LIP, as an HEPTech node member, follows the various activities and maintains updated its awareness about knowledge and technology transfer and the paths for commercialization from fundamental.
- The HEPTech network (http://heptech.web.cern.ch/) has been promoted among the LIP community, particularly the initiative HEPTech Symposium where early stage researchers can be selected to learn how science can impact society;
- LIP as a node member of the HEPTech network, is promoted at their yearbook 2017. The yearbook is disseminated among the European HEP community.

Prospects for 2018

LIP will continue to stimulate technology transfer by reinforcing its links with industry, in particular in the areas of health and space applications, but also in the development of detector systems for other application, and in computing. LIP's competence centres on Monitoring and Control and on Simulation and Big Data will boost the collaboration with external partners. The hadron therapy unit to be installed at CTN is of strategic importance, and we started a collaboration with ICNAS and CTN in instrumentation, image reconstruction and detector R&D. LIP's RPCs are well suited for a wide range of applications from security to geology and, most prominently, to health. In what concerns space applications, the goal is to move from short-term ESA contracts to long participations in ESA mission, in consortia with Portuguese and European companies, which will boost inter-sectorial technology and knowledge transfer. LIP will be instrumental in creating opportunities for Portuguese industry at CERN and in other scientific infrastructures. In particular, the LHC upgrade constitutes a unique opportunity for collaboration between LIP and industry.

HEPTech network - TTN

- As a node member in the HEPTech network, promote among the LIP community and participate, as deemed possible about: AIME - Academia Industry Matching Events, Knowledge and Technology Transfer workshops and the HEPTech Symposium.
- Organize and stimulate, per request, bilateral meetings with LIP researchers (in Lisbon, Coimbra and Braga) about Intellectual Property and Technology Transfer, leveraging the experience of participating in the HEPTech network and try to organize in 2018, an event or workshop in Portugal.

Industrial Liaison Officer - ILO

- Establish as much as possible, company presentations to technical departments and/or groups at CERN, ESO, ESRF. Always involve, as deemed possible, Portuguese staff at these venues. And, along with the FCT Space programme have an integrated approach towards the companies operating in the space sector, mainly for ESA.

- Organize and/or participate at industrial events to promote companies at CERN, ESO and/or ESRF, such as: Visit of firms @ CERN, Industry day @ ESO and Industry day @ ESRF.

- Attend, when possible, industry trade-shows and/or targeted events (nationally and internationally) to carry through targeted assessments about the different industrial sectors in Portugal that can contribute to the ILO activities.

RADIATION, HEALTH AND ENVIRONMENT

Radiation, Health and Environment

Overview

Development of Radon detectors

A radon detector based in a low-cost Si-PIN photodiode working in counter mode has been developed. Radon detectors sensitive to both beta and alpha particles have been under study.

Radon in the air

An expedition was made to the Angola city of Lubango make a survey of radon in dwellings.

Radon in the water

Evaluation of the bioaccumulation of direct descendants of radon in a plant species (watercress) was done in a controlled environment.

An expedition was made to the Angola province of Namibe to collect water samples for radon analysis.

Team

Principal Investigator Luis Peralta (50)

Researchers
Alina Louro (10), Conceição Abreu (30), Florbela Rego (10), Sandra Soares (80)

PhD students
Joaquim Pedro Kessongo (100), Margarida Isabel Inácio (100), Yoenls Bahu (100)

Master students
Ana Campos (10), Soraia Elísio (84)

External/Additional scientific collaborators
Pedro Gabriel Almeida

Total FTE
5.8

Science and Society

2017 activities

Development of Radon detectors

During this year we carried on the construction of radon detector based on a low-cost windowless Si-PIN photodiode. The detector works in counting mode (no energy discrimination) and the acquisition is based on the Arduino platform.

Tests on the suitability of scintillating optical fibers for radon detection have been carried out. The test setup consists on a natural radon generator (radon exhaled from uranium ore) connected through a gas hose to a box where scintillator and PMT sit. The signal from the PMT is amplified by a NIM amplifier and analyzed by a multichannel system. This type of detector is mostly sensitive to beta particles emitted from Pb-214 and Bi-214 radon progeny.

Radon in the air

An expedition was made to the Angola city of Lubango make a survey of radon in dwellings. In order to evaluate the potential of radon exposure, 68 houses were selected: 9 public establishments; and 59 single-family homes, in which 100 CR-39 passive detectors were placed for a period of 90 days. Radon concentration values between 30 and 415 Bq/m3 were found.

Radon in the water

Radon accumulation in plants:

Evaluation of the bioaccumulation of direct descendants of radon in a plant species (watercress) was done in a controlled environment.The antioxidant activity of watercress extract, caused by the presence of radioisotopes in the water was measured. The values already obtained show that when watercress is subjected to the effects of radiation emmited by radon progeny present in aerosols, present alterations of the bioactive compounds present in the leaves. The content of phenols and flavonoids and the index of antioxidant activity increases with increasing radon concentration.

Radon in water for human consumption:

An expedition was made to the Angola province of Namibe to collect water samples for radon analysis. The region of Bibala in the Namibe province has geological caracteristics that raise concern about the radon concentration in water for human consumption. To determine the radon concentration in the water samples, the RAD7 equipment, from Durridge, was used following the RAD7 H2O technique. A total of 39 samples were analised with values of radon concentration ranging from 39 to 207 Bq/L.

Prospects for 2018

Radon measurements

The European Council Directive 2013/59/EURATOM (EU-BSS) evokes new challenges for the metrology of radon measurements and calibrations in Europe. For the first time, the exposure of the public caused by radon will be part of legal metrology in Europe. Since the EU member states' levels of relevant activity concentration that are laid down in the EU-BSS shall not exceed 300 Bq/m3, new calibration procedures for existing commercial radon monitors with their limited counting statistics have to be developed.

Development of Radon detectors

The effort to develop and test low-cost radon detectors with particle identification and energy resolution that can be deployd in great numbers will continue to carried on. These detectors will be used in the Angola campains.

Radon in the air

Another campain to deploy CR-39 passive detectors for radon in air monitoring in Angola is foreseen.

Radon in the water

The program for the study of radon effects on watercress plant will continue. Another campain to collect water in the province of Namibe, Angola, for radon in monitoring is also foreseen.

SWOT Analysis

Strengths

Development of instrumentation with application outside academic environment, well equiped laboratory.

Weaknesses

small team.

Opportunities

Collaboration with other national and international institutions and laboratories.

Threats

Lack of financing.

Publications

3 Articles in international journals (with direct contribution from team)

Margarida Inácio, Sandra Soares, Pedro Almeida: "Radon concentration assessment in water sources of public drinking of Covilhã's county, Portugal", Journal of Radiation Research and Applied Sciences, Volume 10, Number 2, 2017, 135-139 (5)

Pessanha, S. and Alves, M. and Sampaio, J.M. and Santos, J.P. and Carvalho, M.L. and Guerra, M.: "A novel portable energy dispersive X-ray fluorescence spectrometer with triaxial geometry",

Luis Peralta: "An environmental dose experiment", European Journal of Physics,38 (2017) 065801

4 International Conference Proceedings

Luis Peralta, Joana Machado, Esmeralda Poli: "Dosimetry of kV Cone Beam CT with scintillation dosimeter", PRS2017- Proteção Radiológica na Saúde, 27 a 29 de Setembro, IST, Lisboa

P. Almeida, S. Soares, M. Inácio: "From Particle Physics to Civil Engineering for a better health", 13th Workshop on European Collaboration for Higher education and Research in Radiological and Nuclear Engineering and Radiation Protection,Covilhã - Portugal 24-29 May 2017

Luis Peralta: "Measurement of annual dose due to background gamma radiation", 13th Workshop on European Collaboration for Higher Education and Research in Radiological and Nuclear Engineering and radiation protection, Univ. Beira Interior, Covilhã, 22-25 May 2017

M. Inácio, S. Soares, E. Amaral: "Analysis of radiation from radon on bioactive compounds present on Nasturtium officinale Leaves", 13th Workshop on European

Collaboration for Higher education and Research in Radiological and Nuclear Engineering and Radiation Protection,Covilhã - Portugal 24-29 May 2017

1 National Conference Proceedings

S. Soares, A. Louro, L. Peralta: "O Radão – Projeto SOS radão Guarda", accepted for publication in 1º Seminário Construção Saudável na Saúde – A Saúde no Ambiente Construído, Universidade do Minho, 04 October 2017

Presentations

5 Oral presentations in international conferences

Luis Peralta: "Measurement of annual dose due to background gamma radiation", 2017-05-25, 13th Workshop on European Collaboration for Higher Education and Research in Radiological and Nuclear Engineering and radiation protection,, Univ. Beira Interior, Covilhã

Margarida Isabel Inácio: "Analysis of radiation from radon on bioactive compounds present on Nastur- tium officinale R. Br leaves", 2017-05-25, 13th Workshop on European Collaboration for Higher Education and Research in Radiological and Nuclear Engineering and radiation protection, Univ. Beira Interior, Covilhã

Margarida Isabel Inácio: "Radon Concentration Assessment in Water Sources of Public Drinking of Covilhã's County, Portugal", 2017-09-27, PRS2017- Proteção Radiológica na Saúde, 27 a 29 de Setembro, IST, Lisboa , IST, Lisboa, Portugal

Sandra Soares: "Radon concentration assessment in water sources of public drinking water system", 2017-09-28, PRS 2017 Conference: Proteção Radiológica na Saúde, IST – Lisboa

Luis Peralta: "Dosimetry of kV Cone Beam CT with scintillation dosimeter", 2017-09-29, PRS2017- Proteção Radiológica na Saúde, 27 a 29 de Setembro, IST, Lisboa , Lisboa, Portugal

1 Poster presentations in international conferences

Margarida Isabel Inácio: "Analysis of radiation from radon rich spray on bioactive compounds present in Nasturtium officinale R. Br leaves", 2017-09-27, PRS2017- Proteção Radiológica na Saúde, 27 a 29 de Setembro, IST, Lisboa, Portugal

1 Presentations in national conferences

Sandra Soares: "O Radão – Projeto SOS radão Guarda", 2017-10-04, 1o Seminário Construção Saudável – A Saúde no Ambiente Construído, Universidade do Minho, Guimarães

Theses

3 PhD Theses

Margarida Isabel Inácio: "Bioacumulação dos descendentes diretos do radão nas folhas de Nasturtium officinale" (ongoing)

Yoenls Bahu: "Avaliação do Potencial de Exposição ao Radão em Edifícios Públicos no Município do Lubango" (ongoing)

Joaquim Pedro Kessongo: "O Potencial da Concentração de Radão na Água do Município da Humpata-Angola: Implicações no Consumo Público" (ongoing)

1 Master Thesis

Ana Campos: "Simulação Monte Carlo de um sistema de tratamento de braquiterapia vaginal" (ongoing)

Events

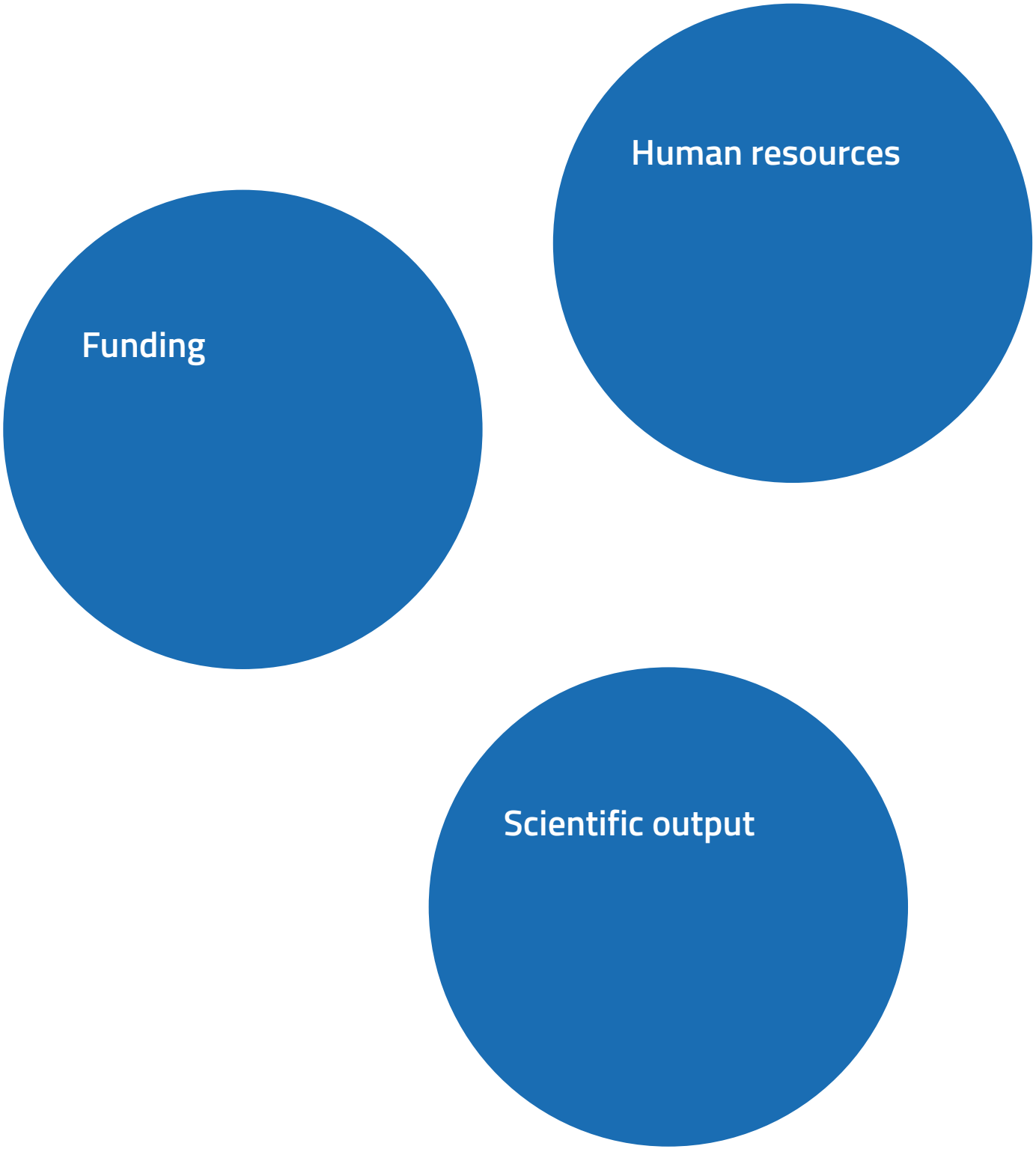
3 Workshops

13th Workshop on European Collaboration for Higher Education and Research in Radiological and Nuclear Engineering and Radiation Protection, Univ. Beira Interior, Covilhã, 2017-05-22 to 2017-05-25

CHERNE 2017 - 13th Workshop on European Collaboration for Higher Education and Research in Radiological and Nuclear Engineering and radiation protection, Univ. Beira Interior, Covilhã, 2017-05-22 to 2017-05-25

3º Workshop IDPASC Hands-on Particles and Light, Universidade de Lisboa, 2017-07-10 to 2017-07-13

// SUMMARY TABLES



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Funding

Group	Code	Funding	Entity	Start	End	LIP node
ATLAS	IF/00955/2013/CP1172/CT0004	50000	FCT	2013-12-01	2018-11-30	L
	IF/00050/2013/CP1172/CT0002	50000	FCT	2014-01-01	2018-12-31	M
	IF/01586/2014/CP1248/CT0003	42000	FCT	2015-01-01	2019-12-31	L
	CERN/FIS-NUC/0005/2015	400000	FCT	2015-03-01	2017-05-31	L, C, M
	CERN/FIS-PAR/0008/2017	340000	FCT	2017-07-01	2019-06-30	L, C, M
CMS	IF/01454/2013/CP1172/CT0003	50000	FCT	2014-01-01	2018-12-31	L
	IF/00772/2014/CP1248/CT0002	50000	FCT	2015-01-01	2019-12-31	L
	CERN/FIS-NUC/0029/2015	400000	FCT	2015-04-01	2017-04-30	L
	AMVA4NewPhysics - 675440	238356	EU	2015-09-01	2017-08-31	L
	CERN/FIS-PAR/0006/2017	345000	FCT	2017-06-01	2019-05-31	L
COMPASS	CERN/FIS-NUC/0017/2015	200000	FCT	2015-04-01	2017-05-31	L
	CERN/FIS-PAR/0007/2017	165000	FCT	2017-09-01	2019-08-31	L
AMS	CERN/FIS-PAR/0020/2017	35000	FCT	2017-09-01	2019-09-01	L
Auger	IF/00820/2014/CP1248/CT0001	50000	FCT	2015-01-01	2019-12-31	L
	CERN/FIS-NUC/0038/2015	150000	FCT	2015-03-01	2017-02-28	L, C, M
	FAPESP/19946/2014	200000	FCT	2015-09-01	2018-08-31	L, C, M
	RPCs AUGER	30000	FCT	2017-01-01	2017-12-31	L, C, M
	CERN/FIS-PAR/0023/2017	150000	FCT	2017-06-01	2019-05-31	L, C, M
Dark matter LUX/LZ	PTDC/FIS-NUC/1525/2014	199280	FCT	2016-01-01	2017-12-31	C
SNO+	IF/00863/2013/CP1172/CT0006	50000	FCT	2014-01-01	2018-12-31	L
	PTDC/FIS-NUC/0640/2014	184276	FCT	2016-02-01	2018-01-31	L
	IF/00248/2015/CP1311/CT0001	50000	FCT	2017-01-01	2021-12-31	L
NEXT	PTDC/FIS-NUC/2525/2014	60000	FCT	2016-05-01	2018-04-30	C

Summary Tables

Group	Code	Funding	Entity	Start	End	LIP node
Neutron Detectors	654000 SINE2020	116250	FCT	2016-05-01	2019-09-30	C
RPC R&D	AIDA-2020	45000	EU	2015-06-01	2019-05-31	C
Liquid Xenon	CERN/FIS-INS/0025/2017	70000	FCT	2018-05-01	2020-04-30	C
Gamma Cameras	IF/00378/2013/CP1172 /CT001	50000	FCT	2014-01-01	2018-12-31	C
Space Rad	ESA: 3-14025/13/NL/A K	60000	ESA	2014-03-17	2018-12-31	L
	ESA: 3-13975/13/NL/P A	200000	ESA	2014-03-10	2017-12-31	L
	ESA: 1-7560/13/NL/HB	300000	ESA	2014-02-18	2018-12-31	L
	ESA/4000115004/15/NL /RA/ZK	80116	ESA	2015-11-13	2018-11-12	L
I-Astro	654215 - AHEAD	61225	EU	2015-09-02	2019-02-28	C
Distributed Computing and Digital Infrastruc-tures	EGI-ENGAGE	108500	EU	2015-04-01	2017-09-30	L
	INDIGO	503625	EU	2015-05-01	2017-10-31	L
	INCD 01/SAICT/2016 - nº 022153	223000	EU	2017-07-18	2019-12-31	L
	DEEP-HybridDataCloud Grant 777435	362500	EU	2017-11-01	2020-04-30	L
	EOSC-hub grant 777536	273887	EU	2018-01-01	2020-12-31	L
IDPASC	IDPASC-Portugal	100000	FCT	2015-01-01	2018-12-31	L
INFIERI	INFIERI - 317446	211981	EU	2013-02-01	2017-01-31	L
Outreach	EPPCN - KE2826	23500	EPPCN	2016-01-01	2020-12-31	L
	CVIVA - PLTP2017-CV95	5000	CV	2017-05-01	2017-11-30	L
	CVIVA - MC2017-CV96	2400	CV	2017-03-01	2017-07-31	LCM
	UC - MC2017	500	UC	2017-03-25	2017-03-25	C

LIP Node: L - Lisboa, C - Coimbra, M - Minho

Human Resources on research (2017)

Group	FTE	Heads (*)	Researchers	Technicians	PhD	Master	Undergrad	External
ATLAS	24.8	55	21	4	9	11	2	8
CMS	13.6	26	9	3	4	1		7
Phenomenology	5.2	16	7				1	8
COMPASS	7.0	9	7	1	1			
HADES	1.0	7	4	2	1			
NUC-RIA	5.7	11	3		2	1	4	1
AMS	3.0	6	4		1	1		
Auger	15.9	36	19	7	1	4	1	4
LATTES	2.5	18	10	3				5
Dark Matter Search	9.3	18	10	2	1	2	2	1
SNO+	6.2	13	7	3	1	1		1
NEXT	1.9	6	5		1			
Neutron Detectors	1.4	5	4					1
RPC R&D	6.1	12	3	9				
Gaseous Detectors R&D	5.1	14	8	1	2	2		1
Liquid Xenon R&D	1.4	6	4	1	1			
RPC-PET	2.2	10	5	4	1			
OR Imaging	3.3	9	2		3			4
Gamma Cameras	3.4	12	5	3	3			
TagusLIP	1.4	7	1	1	1			2
Dosimetry	1.1	5	3		1	1		
Space	6.3	12	5		2	2		3
I-Astro	7.4	15	7	1	4	2		1
Distributed Computing	9.9	10	6	4				
Advanced Computing	2.7	7	4			2		1
Radiation, health and environment	5.8	13	6		3	2		1
total	**156.9**	**269**	**106**	**28**	**36**	**31**	**9**	**44**

Summary Tables

(*) Please note that the total heads number is not the sum of the column, as one person often participates in several groups.

Scientific output

Group	Jrn-I	Jrn-II	Other	Int.o	Int.p	Nat.	Int. meet.	Seminars	Outreach	D	M	Events
ATLAS	81	7	20	4	6	6	4	9	21	3	4	
CMS	101	3	14	2	1	15	9	26	4			
Phenomenology	5	14	3	8		2	1	3				1
COMPASS	9		2	3				1	3	1		
HADES	4						1					
NUC-RIA	4									1		
AMS	2	1				3			2			
Auger	10	1	2	4	1	3	1	9	3	1	2	
LATTES		2	1	1	1	1		3				2
Dark Matter LUX/LZ	6	4	3	4		2	1	3	2			
SNO+	1		2	4	3	2		2	2		1	
NEXT	5	1										
Neutron Detectors												
RPC R&D												
Gaseous Detectors		3									1	
Liquid Xenon R&D												
RPC-PET												
OR Imaging		2								1		
Gamma Cameras		1			1	3		1				
Dosimetry		2	3			1						
Tagus LIP										1		
Space Rad		2	3		2	3	2	2	10		1	1
I-Astro	1	1	3	2	2	6	2		1		1	1
Distributed Computing		2	1	3	1	4	2					1
Advanced Computing		1	2								1	
Radiation Health and Environment		3	5	5	1	1						3
Total	229	50	63	40	19	52	23	58	48	8	11	9

Summary Tables

Publications:
Jrn-I: Publications in international journals with scientific peer review co-authored by LIP members.
Jrn-II: Subset of publications Jrn-I in which LIP members had a major responsability.
Other: Internal notes, conference proceedings, etc, with direct involvement of LIP members.

Conferences:
Int.o: Oral presentations by LIP members in international conferences.
Int.p: Poster presentations by LIP members in international conferences.

Nat. Presentations by LIP members in national conferences.
International meet.:

Seminars:
Invited seminars in institutes or universities.

Outreach:
Seminars for students or general public.

Theses:
Theses concluded during this year (G - Graduation, M - Master, D - PhD).

Events:
Organization of conferences, workshops, collaboration meetings, etc.

LABORATÓRIO DE INSTRUMENTAÇÃO
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// ANNEXES

LIP Communications Strategy

LIP ECO - COMMUNICATION STRATEGY

Communication Strategy

Scope of this document:
This document is the roadmap for LIP's communications activities and public profile. It sets the communication objectives, defines the messaging architecture, maps out target audiences, and formulates key messages. It further defines the communication tools and channels. Evaluation methods are also addressed. This is meant to be a living document, periodically revised.
This communication strategy is defined in the perspective of the creation of a LIP brand, in order to boost communications and convey messages more effectively. Branding is thus present throughout the full strategy definition but is also developed in a specific section, where branding strategy is summarized and design and application issues are detailed.

LIP-ECO contact: outreach@lip.pt

Communication objectives

The role of communications is to plan strategically, manage and sustain the laboratory's relationship with key audiences, helping the leadership to achieve its strategic and operational goals. In line with the goals of LIP as defined in the statutes of the Laboratory (item 3 of article 2), LIP communications have the following objectives:

Obj. 1 / Promote LIP's image and build awareness of LIP as:

- the reference institution for experimental particle physics and related technologies in Portugal;
- the institution defining, under the supervision of FCT, the national policy and involvement in the area of experimental particle physics and related instrumentation;
- the reference partner of CERN in Portugal;
- a solid, top-quality, international research and advanced training organization;
- a reference institution for scientific computing in Portugal;
- a relevant partner in the national participation in Space research;
- an institution committed to technology transfer and fostering the links between the academia and industry, particularly in what concerns radiation technologies in health.

Obj. 2 / Encourage the participation of LIP members in the life of the laboratory and as its ambassadors.

Obj. 3 / Contribute to securing the commitment and support of policy makers, partner organizations and funding agents to LIP, CERN, particle physics, and the Portuguese participation in major international projects and infrastructures.

Obj. 4 / Increase LIP's capability to attract the best students and researchers in Portugal and abroad.

Obj. 5 / Promote scientific culture and inspire the younger generations to pursue careers in S&T.

Foundations: mission, positioning, vision and values

At the foundation of an effective communications strategy are a mission statement (describing the organization's reason for being in a concise way), a positioning statement (explaining in one sentence exactly what the organization is and stands for) and a vision statement (what the institution aims to become or is moving towards).
These statements are based on the terms of the statutes and supported by the directorate. Also strategic is the enunciation of the Lab's values (principles and attitudes guiding its behavior and interactions).
The following mission, positioning and vision statements, are proposed for LIP:

Annexes

Mission: LIP exists for the discovery of the fundamental laws of the Universe, ensuring the full participation of the National scientific community in this endeavor, and to share this knowledge with society in different ways.

Positioning: LIP is the reference institution for experimental particle physics and associated technologies in Portugal. LIP is nation-wide and, under the supervision of FCT, defines the national policy in this area and the participation at CERN and in other international scientific infrastructures.

Vision: LIP will be present in the next great scientific discoveries of humanity, and lead science and innovation in Portugal in close connection with the academic and business communities.

This mission, positioning and vision lead to a tagline we propose adopting for LIP's logo/visual identity whenever it is used: LIP — Particles and Technology

Finally, the key values of LIP can be summarized in the following words: discovery; vision; collaboration; commitment.

Key Messages

The following key messages have been identified. They are based on the mission and positioning statements, as well as on the three areas of activity of LIP:

- Discovery through science;
- Innovation through technology;
- Sharing with people.

What is LIP

LIP is the reference centre in Portugal for research in experimental particle physics and related technologies. LIP has a national dimension. Presently it has nodes in Lisboa, Coimbra and Minho, in association with the local Universities.

Discovery through science

Particle physics deals with some of the most compelling questions in science today.
LIP's program of experimental particle and astroparticle physics is international, has world class quality and addresses some of the most topical questions.

Innovation through technology

Basic science drives innovation in the long term and particle physics has been at the forefront of technology development many areas.

LIP gives key contributions in the development of new Instruments and methods for particle detection and in scientific computing and seeks for their application in society.

Sharing with people

Science has an impact in everyday life, is a key driver for individual and collective development, and an exciting career.

Advanced training, support to education in science and technology and public engagement with science are crucial to society development and central to LIP's program.

Audiences

Key audiences for LIP communications are those with whom we need to communicate to achieve the organizational objectives. It is important to direct communication resources towards key stakeholders, in order to maximize our impact.

The following target groups have been identified:

1. The LIP community (LIP members, collaborators, visitors and alumni)

2. Policy and funding partners (LIP associates, funding agencies, decision makers, referee and evaluation committees)

3. National academic, research and innovation system, including industry

4. International particle physics community (CERN and other infrastructures, research labs, including job seekers)

5. University physics and engineering students

6. School community (students and teachers, namely in high-school, but also at younger ages)

7. Portuguese media (particularly press / written media)

8. General public

The communication objectives, messages and performance indicators per target group are listed in the table:

Stakeholder group	Definition	Objective
1. The LIP Community	Members, collaborators, visitors, alumni	• To develop motivation and to foster a sense of belonging. • To develop ambassadors. • To foster an appreciation of the importance of strategic communications.
2. Policy and funding partners	LIP associates, funding agencies, political decision makers, referee and evaluation committees	Maintain support for LIP by providing timely, open and accurate information
3. Academic, research and innovation system	National academic, research and innovation system	• Generate understanding of LIP's position and competences, of the range of opportunities available at LIP. • Promote contacts and interchange between scientists and institutes. • Generate awareness of LIP as an organization with added value in innovation.
4. International particle physics community	International physicists and institutes that have an interest in LIP research, our partners at CERN and in other international settings. Job seekers.	• Promote contacts and interchange between scientists and institutes. • Foster understanding of LIP's position and competences. • Generate awareness of the range of opportunities available at LIP and position LIP as a great place to work. • Attract the best researchers and students.
5. Physics and engineering students	Students in Physics, Engineering and related areas, mainly in Portuguese Universities but also abroad.	• Generate understanding of LIP's position and competences, of the range of opportunities available at LIP • Position LIP as a great place to work and to do a truly international PhD. • Generate awareness of LIP as an organization with added value in innovation. • Create awareness of experimental particle physics as an exciting field.

Annexes - Communication Strategy

Messages	Key performance indicators
• LIP is your laboratory. CERN is LIP's flagship, but there is more to LIP than CERN. • You are LIP's face at CERN, ESA and other scientific infrastructures. • LIP is about people as well as research • LIP members are expected to keep learning and up to date, maintaining the high standards of the lab	• Measurable staff, user and contractor satisfaction trough feedback mechanisms (online, forms, direct communications, meetings, etc.) • Participation of LIP members in communication activities
• LIP is the reference centre in Portugal for research in experimental particle physics and related technologies, and the reference link to CERN. • LIP has a national dimension and is a reliable and fundamental partner in the definition of national policies in this area, in particular for the national participation in large international projects and infrastructures. • The LIP nodes have an important role in the local/regional scientific and technology development • "LIP gets the job done"	• Positive opinion expressed in regular surveys. • Reports and public statements; • Feedback from decision makers on an individual level • Budget decisions
• LIP is a reliable partner, • LIP is the reference partner of CERN in Portugal, • LIP is a world class participant in research in particle and astroparticle physics and related technologies (namely detector instrumentation, space exploration and scientific computing).	• Demonstrable knowledge of LIP and its role through participation in social media and reading of LIP dissemination material. • Number of positive comments/mentions, • Response to job postings, • Level of interest and participation in calls for tender.
• LIP is the reference partner of CERN in Portugal and a world class participant in research in particle and astroparticle physics and related technologies, namely detector instrumentation, space exploration and scientific computing. • LIP has great opportunities for young people in science.	• Demonstrable knowledge of LIP and its role through participation in social media and reading of LIP dissemination material. • Number of positive comments/mentions, • Response to job postings, • Contacts for collaboration
• LIP is the reference partner of CERN in Portugal and a world class participant in research and training in particle and astroparticle physics and related technologies (namely detector instrumentation, space exploration and scientific computing). • LIP is a great place to make a truly international PhD, which opens excellent possibilities in a wide range of careers. • Experimental particle physics is an exciting field with a great future and Portugal fully participates in this endeavor.	• Demonstrable knowledge of LIP and its role through participation in social media and reading of LIP dissemination material. • Number of positive comments/mentions. • Participation in advanced schools, workshops and other dedicated events organized by LIP. • Early report on the performed activities.

Stakeholder group	Definition	Objective
6. School community	Teachers and students, with emphasis on highschool level, ages 15-18 (but also younger ages)	• Develop knowledge of particle physics, CERN and LIP research - both fundamental science and • technology. • Develop understanding of benefits of fundamental research to society. • Promote physics and science as a career choice. (for younger ages) • Generate basic awareness of LIP's research and its broad purpose; • Foster interest in science, learning and discovery
7. Media	Media professionals from all sectors of the national and local media, including influential bloggers.	To be an authoritative, timely, accurate and open source of information about LIP, CERN, particle physics and related technologies.
8. The general public	Public at all levels with a focus on the science aware.	To generate trust and develop advocacy for science, particle physic and LIP, in collaboration with our partners — internacional (namely IPPOG) and national (namely Agência Ciência Viva)

Annexes - Communication Strategy

Messages	Key performance indicators
• Particle physics addresses some of the most compelling questions in science today. • LIP is the national leader in the field and the reference partner of CERN in Portugal. • Fundamental science satisfies the basic human instinct to explore. • Fundamental science is a driving force for technical innovation. • Wonders of the Universe. (Science is important to humankind's wellbeing. We are seeking to understand how the Universe works. • You can explore your world using the same approach that physicists use to explore the Universe)	• Long-term growth of student and teacher activities and programmes. • Direct approach (via website and social media) from schools/classes/students. • Requests of visits to/from schools. • Early report on the performed activities.
• Fundamental science satisfies the basic human instinct to explore. • Fundamental science is a driving force for technical innovation. • Particle physics addresses some of the most compelling questions in science today. • LIP is the national leader in the field • LIP is the reference partner of CERN in Portugal.	• Positive reporting of LIP, • Participation in media events, • Pro-active approach with information/interview requests • Registration on website/mailing lists
• Fundamental science satisfies the basic human instinct to explore. • Wonders of the Universe. • Fundamental science is a driving force for technical innovation. • Particle physics addresses some of the most compelling questions in science today. • LIP is the national leader in the field and the reference partner of CERN in Portugal.	• Sustained positive opinion in surveys • Sentiment in social media groups • Create communication channel in which people can ask questions to the scientists

Communication channels, tools and activities

LIP's communications can be divided into a number of channels and activities targeting our various audiences. Each channel can reach different target audiences and has its own characteristics and needs. The table below summarizes the current situation.

LIP is linked to other organizations which participate in the joint organization of events and contribute to communicating LIP activities: particularly LIP's associates FCT, the Universities of Lisboa, Coimbra, and Minho, IST, FCUL and ANIMEE, but also SPF - Sociedade Portuguesa de Física, and Physics students associations at the different Universities.

In what concerns public engagement with science and support to education, the main partner of LIP is Agência Ciência Viva. Internationally, LIP is involved in two networks, which promote particle physics and science in general:

1. The European Particle Physic Communications Network (EPPCN) consists of people whose job is to communicate science, though not exclusively particle physics. It is limited to the CERN member states. Its institutional role is to harmonize particle physics communications in the Member States.

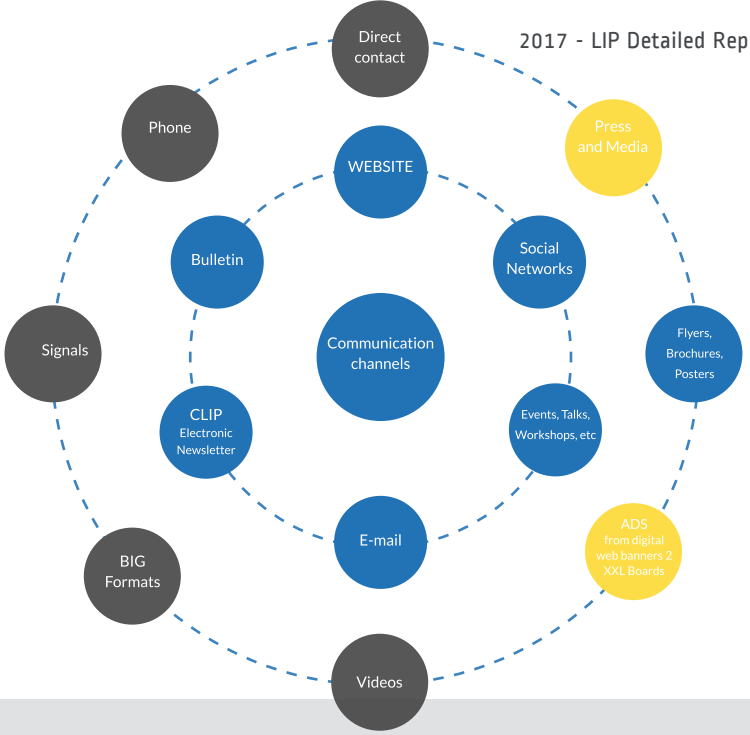
Main communication channel and their target audiences:

Channel	Comments	Audiences
Website	www.lip.pt Formal News section (+ IDPASC website)	All
Social media	Facebook Twitter YouTube Wikipedia Linkedin (professional) (+ IDPASC facebook and linkedin)	1, 5, 6, 7, 8 2, 3, 4, 7 1, 3, 4, 5
Platforms such as indico, moodle...	LIP indico LIP wiki LIP moodle	1, 4, 5 1 6
Press Communications	Press releases, press visits	7
LIP-news Bulletin	paper version + online version on the website 3 issues per year	1, 2, 3, 5, 6
CLIP newsletter	www.lip.pt Formal News section (+ IDPASC website)	1
e-mail	Internal communications To specific mailing lists to announce our events and activities	1 3, 5, 6, 7

Annexes - Communication Strategy

2. The International Particle Physics Outreach Group (IPPOG) is a global network of particle physicists, researchers and informal science communicators and educators.
Its activities are mainly in the educational arena, through Masterclasses and sharing of best practice through the IPPOG database.

LIP-ECO contact: outreach@lip.pt



Channel	Comments	Audiences
Annual reports	Public	All
	Technical + management and accounting	1, 2
Additional printed material	Brochures, leaflets	All
Image repository	For internal use in the preparation of different communication tools and activities	1
Exhibitions	General exhibitions (for example the 30 years celebration exhibition, Thematic exhibitions)	3, 5, 6, 8, 2, 7
Videos	Institutional videos (short, topical, engaging), didactic Animations	3, 5, 6, 7, 8
Activities and events for teachers and schools	Regular activities such as seminars in schools, IPPOG's international masterclasses in particle physics, activities/experiments in schools, the school for teachers in Portuguese language at CERN.	6
Activities and events for undergraduate students	Regular activities such as advanced schools, student workshops, hands-on sessions, information sessions on careers or other subjects, soft skill training, ...	3, 5
Other events	Various. May include open days, media events, inaugurations, political events	All
Graphic design	Branding. Determines a strong, coherent visual identity for LIP (see dedicated section below)	All

Branding

The brand is what people feel about the institution — its values and what it has to offer. It will help us create memory, an image of credibility, a relationship of trust with our audience. And it will help us communicate better. The brand must: transmit our mission and values; create a positive experience for our audience; be original, taking in the differentiating aspects.

The following aspects are crucial in the definition of the brand:

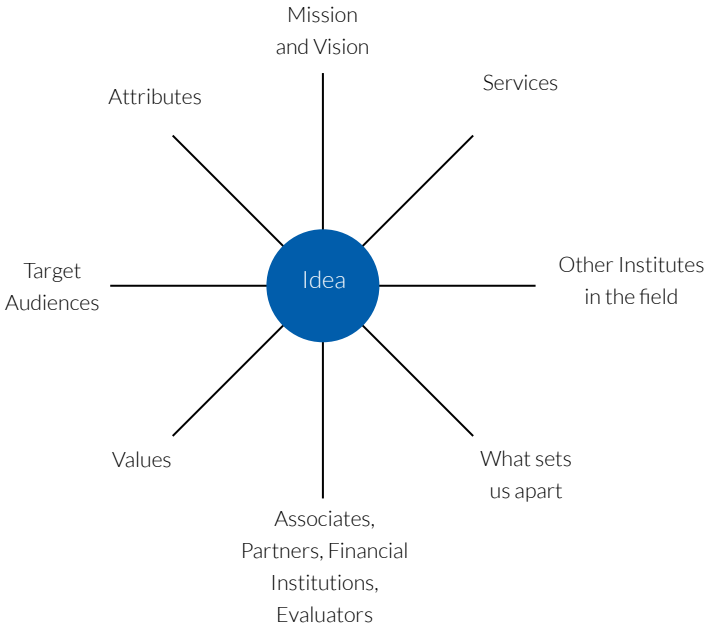
1. Strategy — The aspects discussed above will lead to an image summary that clarifies the strategy and position of the LIP as a brand. The essence of the brand is created by defining taglines and a tone of voice (that varies with the audience and purpose). This summary is to be added here. It must include, for each of the four key message defined above, the taglines and buzzwords to be used.

2. Design — The design will help to communicate clearly the values and culture of the laboratory. It must include all the elements as part of the brand, namely:

- Logo (improved, in different versions for different applications) and signature (with the chosen tagline)
- Color system
  (palette: primary - ready, secondary - To close)
- Fonts
  (main: Titillium Web; Secondary: Open sans Serif Condensed)
- Prepare the design of materials such as stationery, envelopes, business cards, notepads, letterhead, digital signature, office supplies, slides and any other form the laboratory uses to advertise the brand.

3. Consistency — Using and promoting the brand consistently involves:

- Create the guide of graphic standards, a tool that has as main objective to define the rules of use of the brand and to help in the application of the concept and image of the laboratory.
- Integrate the brand image consistently in the way of communicating and in the experience it provides in its different applications (workspace, site, social networks, printed and digital materials)



Evaluating success

Evaluation offers an opportunity to demonstrate how well an activity worked and also to identify areas that could be developed or enhanced. There are a variety of ways to evaluate: quantitative metrics (like press monitoring, the number of website hits or facebook followers, number of participants in events, request for funding success) and qualitative measures (such as event feedback, free quotes from people). Evaluation methods for each activity or channel should be thought beforehand. Surveys (such as the existing PhD student survey and masterclass participant survey) are useful but must be well planned and not overdone.

Annexes - Communication Strategy

Lines of work and team organization

Currently, the priority of the LATTES international team is to develop the concept in its different dimensions, bringing it in the next five years to the point in which it is mature for the construction of a full scale experiment. For that, the following roadmap has been outlined:

Completion of the detector R&D required prior to the construction of a detector unit, developing adequate technological solutions and demonstrating feasibility.

Construction of two full-size prototype detector units and demonstration of their functioning about 5,000 m a.s.l.

Design optimization of a full array based on the developed units, with an area of the order of 20,000 m2, assessing in detail its expected performance. The development of performant simulation and reconstruction tools is a crucial aspect.

Construction of a 100 m2 engineering array (EA) and its operatation for extended periods at 5,000 m a.s.l. proving the feasibility, scalability and low cost of this innovative solution. While having a much reduced collection area, the EA exhibits already the low energy threshold of the full scale experiment and would be sensitive to transient phenomena with sufficiently high fluxes.

Obviously, the timescale and the successful completion of each of the steps in this roadmap depend upon external conditions. Efforts to build a strong collaboration, gain support within the community and attract funding are thus crucial. Nevertheless, each of these steps is in itself a sound R&D project, with high scientific interest for high-energy gamma ray physics, and very promising scientific return in terms of results and of scientific production.

The Portuguese LATTES team is deeply involved in the project and currently central responsibilities in the development of the simulation framework and evaluation of the expected performances, as well as in detector R&D, namely RPC R&D.

Achievements and responsibilities during the past year

The 2016 achievements of the LIP LATTES team correspond to two lines of work and can be summarized as follows:

1. Detector R&D: The RPCS proposed for LATTES have been developed in the last four years at LIP-Coimbra, and tested under harsh conditions at the Pierre Auger Observatory site in Malargue, Argentina, at an altitude of 1,400 m a.s.l. These RPCs were designed to work with low gas flux (1 to 4 cc/min), in harsh outdoor conditions, and demanding very low maintenance services. Their intrinsic time resolution was measured to be better than 1 ns. In 2016, outdoor operation tests at the Observatory continued, and long-term stability is now demonstrated down to 4 cc/min (see the Auger group report for further details).

2. Simulation and analysis: The LATTES concept was developed, the baseline design was established and the first performance evaluations were obtained using detailed simulation based on Corsika for air shower simulation and on Geant4 for the detector simulation. The LATTES concept and the results achieved so far were presented in several international meetings and conferences (see list below). General LATTES meetings were held in Rio de Janeiro, Brazil, and Lisbon, Portugal.

Lines of work and objectives for next year

The level of activity in 2017 will depend on the available funding, but the main objectives in the different lines of work are:

1. Detector R&D

1.1 Adapt the RPC design to operate at a much reduced atmospheric pressure, to achieve a gas flux of 1 cc/min, and to make sure the required standards for remote, high-altitude locations are met. A revised design will be produced. We expect to built a small prototype, depending on the project status and resources.

1.2 Develop a detailed thermal simulation of the detector. The goal is to predict the operation temperature of each detector component as a function of time (daily and seasonal variations). Particularly relevant is the study of water freezing in the WCDs.

1.3 Study the evolution of the freezing point and of the optical proprieties of sterilized water samples as a function different solvent concentrations. Experts from ITQB will collaborate in the project. The possibility to use the irradiation facilities at CTN will be investigated.

2. Simulation and analysis

A baseline design has been established in 2016 both for the detector unit and for the full array. Each unit (3 x1.5 m2 surface, 0.5 m height) has three layers (see figure 1):

- a thin lead plate;
- a layer of glass RPC, sensitive to charged particles with very good space and time resolution;
- a shallow WCD readout by two photomultiplier tubes

The full detector is a set of individual stations placed along rows, each touching the other in their largest dimension, covering a total area of about 20,000 m2 (see figure 2). Fundamental aspects for 2017 are:

2.1 Design optimization, considering in particular the possibility to add an external sparse array of detector units.

2.2 Development of improved analyses methods for shower reconstruction and background rejection, combining the measurement of different detector components, in particular for low energy showers.

3. Phenomenology

The LATTES science team is presently led by the Padova team, which has a long standing experience in gamma-ray astrophysics and a strong involvement in MAGIC, Fermi and CTA. The LIP team will increase its involvement in 2017.

4. Outreach

LATTES has a large potential to engage society with science. Target audiences will be schools, but also the general public. While the level of activity in 2017 and the timescale will depend on the available resources, medium-term targets, in collaboration with other astroparticle physics groups LIP groups, include the development of portable, cheap and easy to operate detector units which can be used for demonstrations or installed in schools or science centers.

SWOT Analysis

Strengths

- The team holds high-level expertise in cosmic-ray research and extreme energy phenomena, detector R&D, data analysis, simulation, air shower physics and phenomenology. In addition, the team has world-recognized expertise in RPC development and is involved in R&D for the construction of autonomous RPC for outdoor operation at very low gas flux;
- The team has close links with other groups in particular the CBPF group in the Pierre Auger Observatory and the INFN Padova group in high energy gamma rays.

Weakness

- The team is a new-comer in the high-energy gamma-ray community,
- Reasonably, a limited amount of funding is to be expected from Portuguese authorities.

Opportunities

- The energy threshold of the EAS experiments presently in operation or in construction remains very large and unable to bridge with data from satellite-borne experiments,
- All the EAS experiments presently in operation or under construction are in the Northern hemisphere;
- The proposed detector concept has a large physics potential.

Threats

- The resistance to a new concept of a community that is engaged in this domain since many years, and built and operates successfully the present experiments;
- The technical, scientific and political problems that such an ambitious project will face.

Presentations

8 Oral presentations in international conferences

Bernardo Tomé: "Simulation framework for LATTES", 2016-01-14, Towards a Large Field-of-View TeV Experiment in the Southern Observatory, University of Tor Vergara, Rome, Italy

Ruben Conceição: "Studies on LATTES Performance at Low Energies", 2016-01-14, Towards a Large Field-of-View TeV Experiment in the Southern Observatory, University of Tor Vergara, Rome, Italy

Pedro Assis: "Electronics for LATTES Prototypes", 2016-01-14, Towards a Large Field-of-View TeV Experiment in the Southern Observatory, University of Tor Vergara, Rome, Italy

Ruben Conceição: "LATTES: a new gamma-ray detector concept for South America", 2016-06-23, RICAP16, 6th Roma International Conference on AstroParticle Physics, Rome, Italy

U. Barres: "Design and expected performance of a novel hybrid detector for very-high-energy gamma astrophysics", 2016-09-01, The Lake Baikal Three Messenger Conference, Listvyanka at Lake Baikal, Russia

Bernardo Tomé: "LATTES: a new window into very high energy gamma rays ", 2016-10-18, 11th Workshop on Science with the New generation of High Energy Gamma-ray Experiments, Pisa, Italy

Ruben Conceição: "LATTES: a next generation gamma-ray detector concept", 2016-11-10, Workshop on wide FoV Southern hemisphere TeV gamma-ray observatory, Puebla, Mexico

M. Doro : "LATTES: a proposal for a novel EAS gamma-ray detector concept", 2016-12-02, 7th Workshop on Air Shower Detection at High Altitude, Torino, Italy

1 Presentations in national conferences

Ruben Conceição: "LATTES: a next generation detector for γ-ray astrophysics in South America ", 2016-02-20, Jornadas Científicas do LIP 2016,
Campus de Gualtar, Braga

Events

1 Collaboration Meeting

9th MARTA Progress Meeting/3rd LATTES Meeting, Biblioteca Nacional, Lisboa, 2016-10-10 to 2016-10-11

SPIN-OFF TECHNOLOGIES FOR CANCER DIAGNOSTICS

STCD TagusLIP

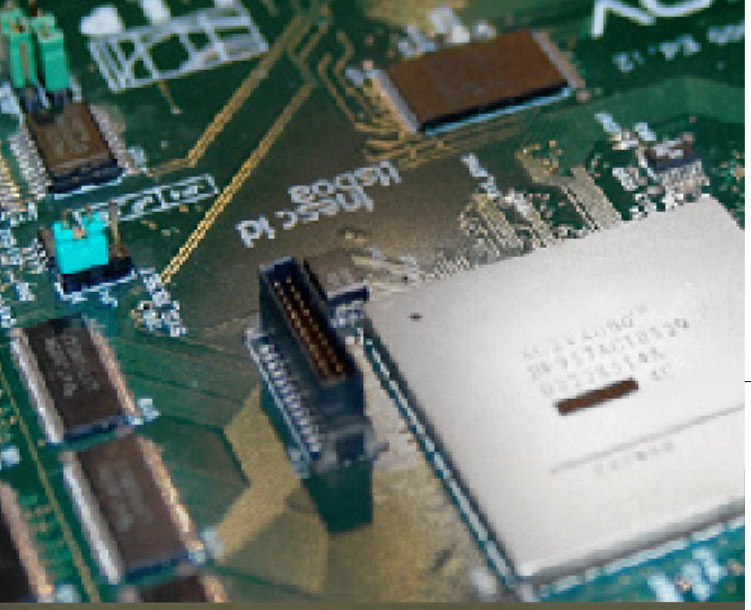
Framework and status for past and current year

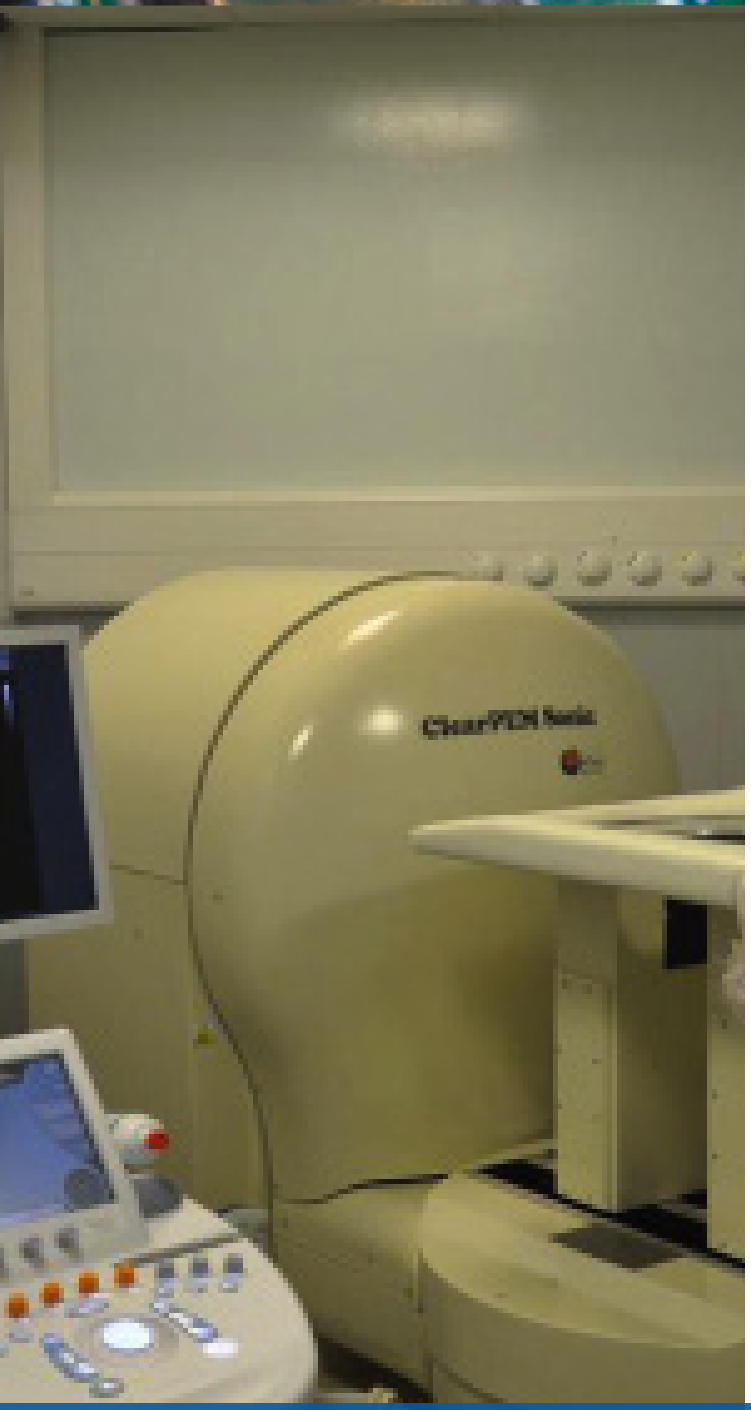
The PET/TagusLIP was created in 2004 around the development of a new Positron Emission Tomography scanner (ClearPEM) for breast cancer diagnosis, exploiting technologies developed at LIP for the CMS experiment at LHC. Scientific research, technological development and laboratory testing of new PET scanners is pursued at the laboratory infrastructure TagusLIP.

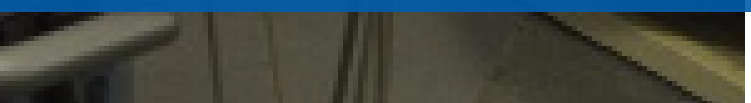
The ClearPEM project was developed by a national consortium of research institutes and clinical centers under the LIP leadership. The consortium collaborated with institutes of the international Crystal Clear Collaboration, namely CERN Switzerland, INFN-Milano Italy, Univ. Hospital Nord Marseille France, Hospital San Gerardo Monza Italy.

In 2011-15 the TagusLIP group was part of the EndoTOFPET project and the associated Marie Curie Training Network PICOSEC funded by the European Union. This project developed a PET detector for detection of prostate and pancreatic cancer. LIP coordinated the Work Package 4, responsible for the electronics and data acquisition systems. In this context LIP developed innovative electronics with good time resolution for Time-of-Flight PET. The technology was licensed to the spin-off PETsys.

The activities of the group are done in coordination with the start-up PETsys. The laboratory infrastructure TagusLIP at the science park Taguspark is shared by the two entities.







Team

Principal Investigator João Varela (25)

Technicians
José Carlos Silva (10)

PhD students
Tahereh Niknejad (100)

External/Additional scientific collaborators
Catarina Ortigão, Cláudia Sofia Ferreira, Stefaan Tavernier

Total FTE
1.4

Summary of performance indicators

Articles in international journals:	3 With direct contribution from team 1 With indirect contribution from team
International conferences:	8 Oral presentations 4 Posters
National conferences:	1 Oral presentation
International meetings:	2 Oral presentations
Collboration meetings:	1 Oral presentation
Seminars:	1 Seminar

// GROUPS: RPC-PET / OR Imaging / Gamma Cameras / STCD TagusLIP

Lines of work and team organization

The research lines pursued by the group at the following:

- development of new gamma ray detectors with improved performance for PET Time-of-Flight.
- development of new front-end and data acquisition systems, including electronics, firmware and software.
- construction and exploitation of demonstration PET scanners based on the above technologies, and associated calibration and image reconstruction software.
- development of detectors for other medical imaging applications.

The group continues to give technical support to the operation of two ClearPEM scanners (installed at ICNAS Coimbra and Hospital S. Gerardo Monza), and two EndoTOFPET detectors (installed in Cerimed Marseille and TUM Munich).

Achievements and responsibilities during the past year

The PET/TagusLIP group developed the following activities in 2016:

1. The new TOFPET2 ASIC was tested between March and July 2016. The expected performance was confirmed. A chip layout problem was identified that motivated a new MPW submission in September 2016. The chips were received in January 2017 and is under test.

2. A new frontend system based on TOFPET2 aiming at improved time resolution, energy resolution and rate performance was developed. It includes a complete chain of hardware, firmware and software, based on the new FEB/Av2 and FEB/Dv2 sets of boards, that allow implementing complete SiPM readout systems with several tens of thousand channels. A paper on the performance of the system was published in JINST (2016 JINST 11 P12003, doi:10.1088/1748-0221/11/12/P12003).

3. In collaboration with PETsys, firmware implementing extended triggering capabilities of the present SiPM readout system was developed.

4. The project submitted to the EU SME Instruments program for the development of new medical imaging applications based on SiPMs was not funded, despite approval in the Phase I and the award of a Seal of Excellence.

The obtained results were presented at several international conferences, including TWEPP 2016 and IEEE/NSS/MIC 2016.

Stated objectives for past year

The PET/TagusLIP group has planned the following activities in 2016:

1. Test of the new TOFPET2 ASIC.

2. Development of a new frontend system based on TOFPET2 aiming at improved time resolution, energy resolution and rate performance.

3. In collaboration with PETsys, upgrade of the available SiPM readout system to achieve extended triggering capabilities.

4. In collaboration with PETsys, and dependent on the approval of two projects submitted to EU, development of new medical imaging applications based on SiPMs.

A proposal for funding of the project ASIC-TOFPET2 submitted to the program Portugal 2020 (Sistema de Incentivo à Investigação e Desenvolvimento Tecnológico (SI I&DT) was approved.

A new proposal for EU funding was submitted in collaboration with several partners (URANUS - Total Body PET Nano-Imaging for In vivo Sphinteric, Bladder and Kidney Cell and Tissue Transplantation).

Lines of work and objectives for next year

The PET/TagusLIP group plans to develop the following activities in 2017:

1. Test of the revision 2 of the new TOFPET2 ASIC.

2. Full validation of the new frontend and data acquisition system based on TOFPET2, including the upgrade of the PET demonstrator installed at TagusLIP.

3. In collaboration with PETsys, development of new PET devices in the frame of projects submitted to EU.

SWOT Analysis

Strengths

Strong technical team and long expertise in medical imaging systems. Excellent integration at international level. Complementarity with PETsys.

Weaknesses

Very limited national funding available. The dedicated funding in the program Portugal-CERN does not cover medical applications. The FCT funding (physics, life sciences, engineering) does not appear suitable for cross-disciplinary projects. The only available funding is the one attracted by PETsys.

Opportunities

Possible but difficult growth of PETsys, opening the possibility of research contracts between LIP and the company.

Threats

PETsys bankruptcy leading to the extinction of the group and of the instrumentation lab at TagusLIP.

Publications

3 Articles in international journals
(with direct contribution from team)

Tahereh Niknejad, Marco Pizzichemi, Gianluca Stringhini, Etiennette Auffray, Ricardo Bugalho, Jose Carlos Da Silva, Agostino Di Francesco, Luis Ferramacho, Paul Lecoq, Carlos Leong, Marco Paganoni, Manuel Rolo, Rui Silva, Miguel Silveira, Stefaan Tavernier, Joao Varela, Carlos Zorraquino, Development of high-resolution detector module with depth of interaction identification for positron emission tomography, Nucl. Instrum. Meth. A, 845 (2017), 684–688, http://dx.doi.org/10.1016/j.nima.2016.04.080

Marco Pizzichemi, Gianluca Stringhini, Tahereh Niknejad, Zheng Liu, Paul Lecoq, Stefaan Tavernier, Joao Varela, Marco Paganoni, Etiennette Auffray: "A new method for depth of interaction determination in PET detectors", Phys. Med. Biol. 61 (2016) 4679–4698, doi:10.1088/0031-9155/61/12/4679

Tahereh Niknejad, Saeed Setayeshi, Stefaan Tavernier, Ricardo Bugalho, Jose Carlos Rasteiro Da Silva, Agostino Di Francesco, Luis Ferramacho, Carlos Leong, Manuel Rolo, Mahnaz Shamshirsaz, Rui Silva, Miguel Silveira, Carlos Zorraquino, Joao Varela: "Validation of a highly integrated SiPM readout system with a TOF-PET demonstrator", 2016 JINST 11 P12003, doi:10.1088/1748-0221/11/12/P12003

1 Articles in international journals
(with indirect contribution from team)

Carlos Zorraquino et al. (12 authors): "Asymmetric Data Acquisition System for an Endoscopic PET-US Detector", IEEE Trans. Nucl. Sci. 63 (2016) 213-221

Presentations

8 Oral presentations in international conferences

Tahereh Niknejad: "Development of High-Resolution Detector Module with Depth of Interaction Identification for Positron Emission Tomography", 2016-02-15, The 14th Vienna Conference on Instrumentation 2016, Vienna, Austria

Gianluca Stringhini: "Development of a High Resolution Module for PET scanners", 2016-02-15, International Conference on Translational Research in Radio-Oncology | Physics for Health in Europe (ICTR-PHE) 2016, Geneva, Switzerland

Stefaan Tavernier: "Development of a highly integrated PET readout system scalable to several 10'000 channels", 2016-05-01, IV Mediterranean Thematic Workshop in Advanced Molecular Imaging (MEDAMI), Corsica, France

Agostino di Francesco: "First Experimental Results with TOFPET2 ASIC", 2016-09-28, Topical Workshop on Electronics for Particle Physics TWEPP2016, Karlsruhe

F. Cenna: "TOFFEE: a fully custom amplifier-comparator chip for timing applications with silicon detectors.", 2016-09-30, Topical Workshop on Electronics for Particle Physics TWEPP2016, Karlsruhe

João Varela: "Recent progress in instrumentation for PEM imaging", 2016-10-15, Cofgress of the European Association of Nuclear Medicine EANM'16, Barcelona, Spain

H.V. Wachter: "Study on Coincidence Time Resolution with SiPM and TOFPET-ASIC utilizing LYSO, GAGG and GFAG", 2016-10-29, IEEE conference on Nuclear science and medical imaging (IEEE NSS/MIC) 2016, Strasbourg, France

F. Cenna: "TOFFEE: A Fully Custom Amplifier-Comparator Chip for Silicon Detectors with Internal Gain", 2016-11-02, IEEE conference on Nuclear science and medical imaging (IEEE NSS/MIC) 2016, Strasbourg, France

4 Poster presentations in international conferences

Stefaan Tavernier: "Validation of a highly integrated PET readout system scalable to several 10'000 channel", 2016-02-15, The 14th Vienna Conference on Instrumentation 2016, Vienna, Austria

Tahereh Niknejad: "Validation of 3D Model-Based Maximum-Likelihood Estimation of Normalisation Factors for Partial Ring Positron Emission Tomography", 2016-10-29, IEEE conference on Nuclear science and medical imaging (IEEE NSS/MIC) 2016, Strasbourg, France

Agostino di Francesco: "Experimental results with TOFPET2 ASIC", 2016-10-31, IEEE conference on Nuclear science and medical imaging (IEEE NSS/MIC) 2016, Strasbourg, France

C. Leng: "A 64 Channel Mixed-Signal ASIC for the Readout of GEM Detectors in the BESIII Experiment", 2016-10-31, IEEE conference on Nuclear science and medical imaging (IEEE NSS/MIC) 2016, Strasbourg, France

1 Presentation in national conference

Tahereh Niknejad: "Results with SiPM based PET detectors", 2016-02-21, Jornadas Científicas do LIP, Braga, Portugal

2 Oral presentation in international meetings

Stefaan Tavernier: "Report of Work group 5 Applications", 2016-03-16, Meeting of the EU COST Action FAST, Tento, Italy

Stefaan Tavernier: "PET developments at LIP/Lisbon & PETsys", 2016-04-12, 7th INFIERI Workshop, Lisbon, Portugal

1 Oral presentation in collaboration meeting

Tahereh Niknejad: "Improvements in 3D Model-Based Maximum-Likelihood Estimation of Normalisation Factors: Implementation of 3D geometric factors estimation in STIR", 2016-11-03, STIR User's and Developer's Meeting, at IEEE conference on Nuclear science and medical imaging 2016, Strasbourg, France

1 Seminar

Tahereh Niknejad: "Development of Time-of-Flight high performance Positron Emission Mammography system based on silicon photomultipliers", 2016-03-03, University College London, London, United Kingdom

Theses

2 PhD Theses

Carlos Gaston: "Development of a new PET detector for pancreatic and prostate cancer detection" (ongoing)

Tahereh Niknejad: "Development of new high-performance Positron Emission Mammography based on new photosensor technology" (ongoing)