LIP DETAILED 2016 REPORT and plan for 2017

LABORATÓRIO DE INSTRUMENTAÇÃO
E FÍSICA EXPERIMENTAL DE PARTÍCULAS
partículas e tecnologia

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Foreword

Mário Pimenta

President

2016 was a year of progress and transition for LIP and for the scientific projects where LIP is engaged.

At CERN, Switzerland, the LHC surpassed all the expectations and delivered an impressive number of events and new detectors were installed at COMPASS. The road for the high Luminosity LHC is now well established and the way has already started. The challenges and the opportunities for research centers and for the industry are enormous, from apparently "minor" problems, as the resistance of cables to the aggressive LHC environment, to the need of processing huge quantities of data. The secrets of the Higgs sector, of the top physics, of the hot and/or the dark matter may be on reach in a few years.

At the GSI, Germany, the accelerator was shut down in the beginning of 2015 for a complete upgrade in view of the future Facility for Antiproton and Ion Research (FAIR) implying also an intense activity on the detectors side.

At the Pierre Auger Observatory, Argentina, the international agreement has been renewed for the next 10 years and an upgrade plan was approved. The puzzling results observed so far may get a new look.

At the International Space Station, the AMS experiment is going on collecting billions of cosmic rays events and new exciting results on the positron spectrum were announced, giving rise to renewed speculations on the existence of a several hundred GeV WIMP particle.

At the Sanford Underground Research Facility (SURF), USA, LUX experiment completed its last run establishing a world leading result on (unfortunately!) direct dark matter exclusion limits. The next step, the LZ detector, is already under construction and should be deployed in 2019.

At the Sudbury Neutrino Observatory, Canada, the water filling of SNO+ detector was almost completed and a five-year program on the search for the neutrino double beta decay will start soon after a brief calibration period.

At Canfranc, Spain, a prototype of NEXT (Neutrino Experiment with Xenon TPC) is taking data paving the way to the construction of the full detector by 2018.

At LIP, it was possible to keep up our standard level of scientific and technical activity, as it is well documented in the present report, but a reference is due to the existence of a new group that joined LIP recently, the "Heavy Ion Phenomenology" group that is focused in the exploration of the Quark-Gluon plasma produced in heavy ion collisions at the LHC.

On the other hand, several internal reforms were launched:

The LIP By-laws were reviewed ensuring: the strengthening both of LIP national mission and of its regional delegations; the precise balance between the LIP scientific and management bodies; the involvement of all LIP members in the process leading to the appointment of LIP direction; a new framework for the adhesion of new associates to LIP, that allowed, finally, the Faculty of Sciences of the Lisbon University to become a LIP associate.

The management and the working conditions of the LIP scientific infra-structures were reviewed to improve their answers to internal and external requests.

New premises for LIP in Lisbon, doubling the present area and allowing for the first-time to have appropriated conditions for research and teaching laboratories, were contracted with the Lisbon University and will be available soon. At the same time, in Coimbra, the University made available a new area for the expansion of the mechanical workshop and of the detectors laboratory and, in Braga, the University announced that a new area for LIP-Minho will be available soon.

An ECO (Education, Communication, Outreach) office was created and its action has already made the difference for instance, on the organization of the LIP public report and of the exhibition commemorating the LIP 30th anniversary.

An advanced education group was created to coordinate and promote specific actions dedicated to university students at the several levels (undergraduate, master, PhD).

The idea of "Competences Centers" at LIP is making its way. They should be light and flexible horizontal structures joining all the LIP members that share the same technological background. Such centers should have a positive impact both internally, increasing the synergies between groups, and externally, either on advanced education or boosting LIP collaboration with other research centers and with industry. The first one, on "Simulation and Big Data", is in preparation and should become effective during 2017.

Scientific employment is the major issue for the development, even the survival at a competitive level, of Portuguese science and LIP is not an isolated island. The number of permanent positions for the scientists with an age below the 50th is rather scarce while the mean age at the Universities Physics Departments is unusually high (for instances at IST this mean is 55.6 years!). The good news is that the new Portuguese authorities have not only recognized this critical problem but are promoting an aggressive program to replace the endless post-doc grants by contracts. Most of these new contracts will however be at fix-term; an increase of the long-term positions, namely at the Universities, must happen to guarantee the future. LIP will try, by all the possible ways, to be part of the solution.

Funding is always smaller than the needs. In 2016 and probably in 2017 the public (FCT) funding for science was basically kept at a constant level. We hope that an increase should happen in the next years but clearly the challenge to find complementary National or European funding is on the top of the LIP priorities.

In 2016 LIP has commemorate its 30th anniversary. We have been exposed to many different political and economic environments but we were able always to develop our mission in terms of fundamental science, R&D in detectors and instrumentation and in education and public outreach. We are confident that we will be able to face the next 30 years with ambition and competence.

// RESEARCH Areas an

Experimental particle and astroparticle physics

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

Development of new instruments and methods

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

Computing

d Lines

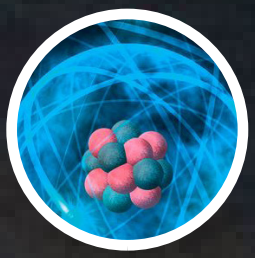
LHC experiments and phenomenology

- ATLAS
- CMS
- LHC phenomenology
- HIP

Cosmic rays

- AMS
- Auger
- LATTES

// Experimental particle a



Structure of matter

- COMPASS
- HADES

Dark matter and neutrinos

- LUX/LZ
- SNO+
- NEXT

and astroparticle physics

LHC Experiments and phenomenology

COLLABORATION IN THE ATLAS EXPERIMENT AT CERN

ATLAS

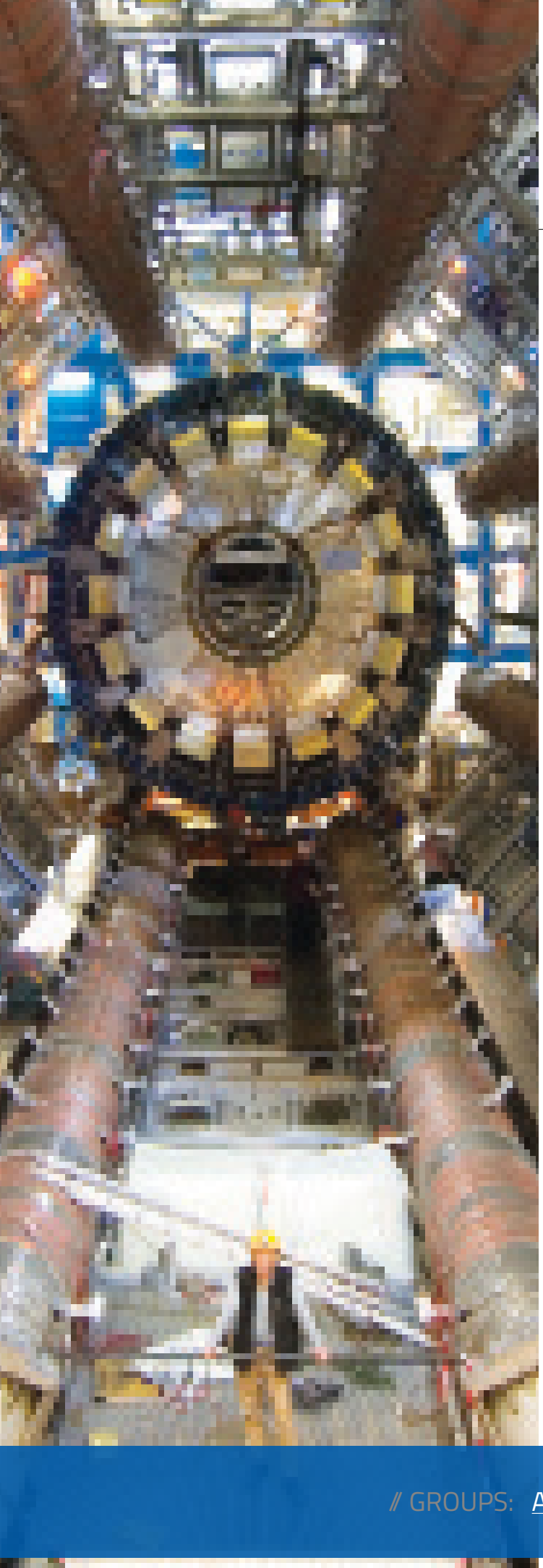
ATLAS is one of the experiments operating at CERN's LHC, where proton-proton and heavy ion collisions take place at unprecedented high energies and luminosities. After three years of very successful data taking, followed by a two year-long shutdown, the ATLAS experiment re-started data taking in 2015 with an improved detector, with the aim of studying a large variety of physics topics, ranging from the precise measurements of the Standard Model (SM) predictions, including the Higgs boson and the top quark properties, to the searches for new physics beyond SM, such as new particles and interactions. In the last year, 2016, the LHC surpassed all expectations delivering 38.6 fb-1 of pp collisions. The efforts of the collaboration were focused on the detector operation and data analysis, including performance and calibration, of these data as well as on the preparation of future upgrades.

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 the detector operation and performance studies, and to physics analysis, in the areas of Higgs boson discovery and properties measurements, top quark precision measurements, exotic quark searches and Heavy Ion physics, as well as to maintenance and upgrade work. We are a medium-size group within ATLAS. Our members have occupied a number of roles of responsibility in the collaboration in most activities where the group is involved, from detector maintenance and operations to physics analysis and collaboration committees.

Framework and status for past and current year

Summary of performance indicators

Articles in international journals:	6 With direct contribution from team 91 With indirect contribution
Internal notes:	8 Collaboration notes
International conferences:	11 Oral presentations 1 Poster 5 Proceedings
International meetings:	1 Oral presentation
National conferences:	8 Oral presentations 2 Poster
Collaboration meetings:	83 Oral presentations
Seminars:	6 Seminars 14 Outreach seminars
Completed theses:	1 PhD and 4 Master



Team

Principal Investigator Patricia Conde (85)

Researchers
Agostinho Gomes (85), Albano Alves (20), Amélia Maio (30), António Onofre (15), António Pina (20), Filipe Veloso (70), Helena Santos (85), Helmut Wolters (80), José Maneira (40), José Rufino (20), João Gentil (70), Juan P. Araque (15), Liliana Apolinário (15), Miguel Fiolhais (30), Nuno Castro (100), Ricardo Gonçalo (75), Rui Faísca Pereira (28)

Technicians
Filipe Martins (100), Luís Gurriana (75), Luís Seabra (100)

PhD students
Ademar Delgado (100), Ana Peixoto (100), André Pereira (50), Artur Amorim de Sousa (20), Bruno Galhardo (100), Emanuel Gouveia (100), José Correia (100), Mário Sargedas Sousa (100), Pedro Jorge (8), Rute Pedro (100), Susana Santos (75), Tiago Vale (100)

Master students
André Reigoto (100), Christopher Pease (30), Duarte Azevedo (100), José Luís Silva (100), João Almendra Sabino (67), Lia Moreira (45), Rui Martins (100)

Undergraduate students
Ricardo Barrué

External/Additional scientific collaborators
Alberto Palma, Cátia Rato, Gianpaolo Benincasa, Guiomar Evans, José Manuel da Silva, José Soares Augusto

Total FTE
26.5

// GROUPS: ATLAS / CMS / LHC phenomenology / HIP

Lines of work and team organization

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

Physics Analysis

- Higgs physics (P. Conde, R. Gonçalo). After contributing to the discovery of the Higgs boson in 2012, 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.
- Top Quark physics (A. Onofre, F. Veloso). We have a long--standing expertise in top quark physics studies. For the LHC Run 1 we had a leading role in several analyses. For Run 2, our focus is on the search for Flavour Changing Neutral Currents (FCNC) in the 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 complement the precision measurements of the Higgs and top quark properties with direct searches for new physics, in particular the search for vector-like quarks, predicted by some of the extensions of the SM. A spin-off of these studies is the search for tZ production via FCNC, allowing to probe the tqg and tqZ couplings in a final state topologically very similar to the one explored for the vector-like quark searches. The tZ final state in fully hadronic topologies is also searched for, in the context of searches for vector-like quarks and direct production of dark matter.
- Heavy ions physics (H. Santos). Our long term goal is to understand the mechanism of the jet energy loss in the quark-gluon plasma using jets as probes. After a strong contribution to Run 1 publications on the di-jet asymmetries in Pb-Pb collisions, we are concentrated now on the study of heavy flavour jets in the Run 2.

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

- TileCal (A. Gomes). Our group has contributed to the TileCal calorimeter detector from the early days of ATLAS. Currently, our main responsibility is on the development, maintenance and continuous upgrade of the DCS system. We contribute in addition to the study of the linearity of TileCal cells response with the Laser II system, and to the Tile-Muon trigger (use of the last layer of the TileCal calorimeter to tag muons at trigger level).
- Jet Trigger (R. Gonçalo). Our group has made very important contributions to the jet high-level trigger, ranging from algorithms development, to operations, maintenance, and group coordination, during the last ten years.
- Forward Detectors (A. Maio, P. Conde). The Portuguese group has contributed for several years to the ALFA luminosity detector, with responsibility on the construction (fibres preparation) and to the DCS implementation, maintenance and continuous upgrade. In addition, we are contributing to the AFP (ATLAS Forward Proton tagging detectors) with responsibilities in the DCS and the implementation of the high-level trigger software.
- GRID 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). Our main responsibilities in this area are the preparation and quality control of fibres and scintillators for the gap regions; radiation hardness tests of scintillators for the Upgrade Phase I and II; and the development of a high voltage distribution system for the Phase II.
- Jets high level trigger system (P. Conde). We are developing parallell trigger algorithms to run on Graphical Processing Units (GPUs). We are responsible for the design, implementation and tests of the calorimeter reconstruction algorithms for the ATLAS GPU demonstrator 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)

Stated objectives for past year

Physics studies

In what corresponds to the Higgs boson physics, for 2016, our objectives were:

- Contribute to the search for the SM Higgs decays to bb in the associated production channel with a W or a Z boson, using the discriminating variables studied the previous year.
- Start the study of angular variables to separate different spin and CP components in the WH (with H->bb) channel, both in the HWW and Hbb vertex.
- Exploit the angular observables studied the previous year as a mean to suppress the main backgrounds of the ttH production and extend previous studies to investigate the possible pseudo scalar component of the Higgs boson.

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

- Contribute to the analysis of the first 13 TeV pp collisions in the ttH and continue that analysis with new data collected in 2016.

Concerning the top quark physics:

- Continue the search for Flavour Changing Neutral Currents (FCNC) both in the top quark decays and tZ production with the 13 TeV data
- Start the study of the Vts vertex through the measurement of the top decays to Ws.

Exotic physics searches:

- Continue to lead the effort in the Zt/b+X topology and extend the studies done up to now to the run-2 data.
- Search for tZ production via FCNC.
- Contribute to the study of single T production, which can originate a fully hadronic topology with a boosted top and missing transverse energy if the T decays to tZ and the Z decays to neutrinos.

In what corresponds to heavy ion physics, for 2016 the focus was to be:

- Assess the jet data quality concerning the data acquisition in the fall of 2015.
- Start the study of heavy flavour jet production.

Detector maintenance, operation and upgrade

In TileCal our effort was on the following activities:

- Maintain our strong involvement in the DCS. The DCS of the phase 2 demonstrators was to be improved in the test-beam setup with emphasis on robustness of the monitoring of the HV system.
- Continue the linearity and stability monitoring studies of the TileCal's PMTs using the Laser II system.
- Perform the electronics noise survey at the new energy and pile-up conditions of the LHC.
- Maintenance and further developments of the Tile-Muon offline software and get involved in the L1 muon trigger performance studies as preparation for the HL-LHC.

For the TileCal Upgrade, we were to:

- Set up the lab, procure radiation hard WLS optical fibres and scintillators to be testes as replacement of TileCal gap and crack scintillators by 2018.
- Test alternative scintillator-WLS fibres couplings to improve light collection in the gap/crack scintillators.
- Produce a new prototype of the Phase 2 High Voltage Distributor System to be tested in a test beam at CERN.

On the high-level jet trigger side our plans were to concentrate on performance studies with the 13TeV data.

Our Upgrade activities in the trigger were to continue. The implementation of the parallel version of the TopoCluster algorithm (the Topo Automaton Clustering or TAC) was expected to be finished and its performance optimized. The results were to contribute to the decision of which kind of processors architecture will be used for the Phase I ATLAS trigger.

Continue our effort on the jet data quality monitoring during the Heavy Ion data acquisition and the studies on jet reconstruction, namely jet quality, jet constituents and validation of underlying event subtraction were to be continued.

In addition, our involvement in the ATLAS forward detectors was to continue with the validation of the AFP cooling and movement control systems in the lab and the transfer to production system.

Our contribution to outreach in these exciting years of LHC physics was expected to continue.

Achievements and responsibilities during the past year

Prizes

- 2016 ATLAS Outstanding Achievement Award: a member of our group, Filipe Martins, and a former member, Joana Miguéns, were distinguished by the ATLAS Collaboration for their outstanding contributions to the operations and upgrade of the Tile DCS and Trigger system.
- Joana Machado Miguens received one of the 2016 ATLAS Thesis Awards, for her PhD thesis Observation and measurement of the Higgs boson in the WW decay channel with ATLAS at the LHC, developed at LIP and defended at the Faculdade de Ciências, Universidade de Lisboa in December 2015.
- Best poster Award for the paper entitled The Interface and Control System of the Upgraded HVOpto/HVRemote card of the TileCal, presented at CETC 2016 (Conference on Electronics, Telecommunications and Computers, Lisbon, 6-7th December 2016) by C. Rato, J. Sabino, G. Evans, J. Augusto, A. Gomes, A. Maio and L. Gurriana.

Physics

In what corresponds to the physics, our main achievements during 2016 were:

Higgs:

- Identification of new variables that were added to the multi-variate analysis techniques to improve the selection of the Higgs decaying to b-quark pairs in the associated production with a W and a Z boson. These variables were studied in the context of the 13 TeV pp collisions data and found to increase sensitivity by around 7%. With this result we contributed to the first public note on this topic using the 13 TeV pp collisions this summer.
- In collaboration with the LIP LHC-Phenomenology group, we made important progress in the study of the experimental sensitivity for probing the CP nature of the top-Higgs coupling, through the use of angular variables. This study allowed us to identify optimal observables to obtain experimental sensitivity to the CP structure of this coupling after full event reconstruction in a realistic detector. The conclusions will be documented in a paper currently in preparation;
- Contributed to the ATLAS ttH analysis with H->bb decay through a study of the di-boson background to this channel. This study is documented in an internal ATLAS note.

Top quark properties:

- An article describing the search for top quark decays (t→qZ) via FCNC in top pair production at 8 TeV was published in the beginning of the year.
- The t→qZ FCNC analysis was updated to the 13 TeV dataset. The analysis aims at a publication in mid 2017.
- The study of the Vts vertex through the measurement of the top decays to Ws was started.

Exotics searches:

- Coordination of the search for pair production of vector-like quarks in the Z/t+X channel and main analysis team in the dilepton channel. We produced the first internal results with the 13 TeV dataset.
- Coordination of the search for the production of top quarks accompanied by missing transverse energy, where we also had a primary analysis role in the fully hadronic channel. First internal results were produced with the 13 TeV dataset.
- Coordination of the search for tZ production via flavour changing neutral currents. We led the analysis and produced first internal results on the trilepton channel with the 13 TeV dataset.
- Definition of the strategy for the combination of the ATLAS searches for vector-like quarks.

Heavy Ions:

- An analysis tool to clean jets from instrumental background using multivariate analysis has been developed.
- Initiated the activities related to heavy flavour jets. A new member, Rui Pereira, has joined the group and is working on the commissioning of the b-tagging algorithms in heavy ion environment. This project should open up several interesting physics studies related to the interaction of light and heavy-quark initiated jets with the quark gluon plasma.

TileCal detector maintenance, operation and upgrade

The main contributions for the TileCal DCS and operations were:

- The operation of the detector by performing 24h DCS on-call shifts (and backup) during the data taking.
- Assistance to the maintenance teams when repairs in the detector were performed (usually during LHC technical stops).
- Maintaining the DCS software and hardware, by fixing bugs in the code or including additional features or control/monitoring parameters.
- Development, implementation and maintenance of new prototype DCS component for the upgrade of TileCal electronics. In particular the implementation of a OPC (Ipbus based) for the control of the High voltage in the internal regulation option.

- Maintenance and support of the DCS system for the demonstrator test beam.

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

With respect to our Upgrade activities, we dedicated an important effort to setting up the LOMAC scintillator and optical fibre laboratory, now located at Faculdade de Ciências da Universidade de Lisboa, an essential infrastructure to support our contributions to the TileCal upgrade programme. The main milestones here were:

- The re-installation of the fibrometer, device for the semi-automatic characterisation of sets of up to 32 optical fibres. The re-installation included a deep repair and general maintenance, followed by re-commissioning;
- The automation of the mono-fibrometer, used for small-scale tests and for teaching/outreach purposes;
- The repair and commissioning of the aluminization equipment, including a new setup to cut/polish the bundles of fibres based on an external facility.

In addition, we:

- Designed a new HV distribution board (HVremote) for the Phase II Upgrade, to be tested in test beams at CERN. The PCB was produced and the production of this board is ongoing.
- Designed a board to test communications and the control system for the HVremote board.
- Started the study of alternative scintillator-WLS fibres couplings to improve light collection in the gap/crack scintillators.

Forward Detectors:

- Development, integration and commissioning of the AFP DCS system, with focus on the cooling, movement and vacuum systems.
- Maintenance and development of the ALFA DCS for the data taking
- Started the design and implementation of specific triggers to select di-jet events in central exclusive production.
- Started an analysis to measure the performance of the L1 AFP triggers during the 2016 data taking, in terms of efficiency and fake triggers.

Jet trigger maintenance, operation and upgrade:

- Contributed to the operations activities with on-call experts, dedicated to ensuring the validation of the jet trigger prior to data taking and the quality of the collected data.
- Started the study of the performance of alternative calibrations used during the 2016 data taking period, such as the Global Sequential Calibration (very important for the b-jet triggers).

In what corresponds to the Phase I Upgrade, our main achievements last year were:

- The optimization and performance studies of the TAC algorithm (parallel version of the cluster growing step of the TopoCluster algorithm). A gain of a factor of two in processing time was obtained, with a very similar physics performance. We demonstrated also that the total processing time is stable when the complexity of the events (occupancy) increases.
- The implementation of the first version of the cluster splitting step. The first evaluation of the performance of this algorithm indicates potential gains of a factor 5 in processing time of very complex events and a flat dependency on the complexity of the events. The validation of the physics performance of the new algorithm is still ongoing.

Distributed Computing

The Iberian region and the Portuguese Tier2 have shown excellent results in the operation during the last year. The Portuguese Tier2 has been well integrated as a satellite into the new world cloud and exhibited very good reliability and availability metrics, thus contributing to allow the ATLAS distributed computing (ADC) system to respond to the increased demand of data processing during Run2 during which the ATLAS detector produces significantly more data than had been expected. The daily resume information to all computing site managers has been improved and adapted to the new Jira ticketing system that is used now for handling issues between computing shifters, ADC experts and site managers. The daily overview monotoring dashboard has been extended and improved in collaboration with the Computing Run Coordinator shifters and ADC experts.

Education and outreach

Besides research, the group participated in several outreach activities including secondary school MasterClasses in many different locations in Portugal; contributed to the design, organization and support to the exposition Partículas, organized by LIP last year; presentations and seminars for general public and secondary school students/teachers.

With respect to advanced training, we contributed to the hands-on workshops organized by LIP in Costa da Caparica (February) and in FCUL/IST in July.

In addition, we organized a 1-month summer students internship in Lisbon, aimed at University students between the first and third year of the Physics or Engineering Physics degrees. The internship consisted on one week of introductory lectures about ATLAS and our research activities, complemented by hands-on tutorials on the software tools needed for the research projects

they developed during the following three weeks. The internship was very successful, with twenty two students participating and a very positive overall feedback received (average mark of 4.4/5). A similar scheme will be adopted in the LIP-Lisbon-wide Summer Student Program this year.

Coordination positions within the ATLAS Collaboration (in 2016):

- Helmut Wolters, coordinator of the Iberian Cloud.
- Helmut Wolters, responsible for the Portuguese Federated Tier2 in the Iberian Cloud Squad.
- Nuno Castro, theory hot-spot contact for the vector-like quark searches within the Exotics Working Group (since October 2014).
- Nuno Castro, convener of the Heavy Quarks, Top and Composite Higgs subgroup, integrated in the Exotics Working Group (since March 2015 to March 2016).
- Juan Pedro Araque, analysis contact for the search for vector-like quarks in the Zt/b+X channel.
- Nuno Castro, analysis contact for the search for monotop events plus missing energy.
- Nuno Castro, analysis contact for the search for tZ production via FCNC.
- Juan Pedro Araque, Monte Carlo manager for the Exotics Working Group.
- Nuno Castro, member of the ATLAS Physics Office.
- Filipe Martíns, TileCal DCS coordinator.

Editorial Boards

Members of our group participated in 12 Editorial Boards of ATLAS public notes or papers in the areas of new physics searches, heavy ions physics, Higgs and top quark physics: H. Santos (4), N. Castro (3), two of them as chair of the board, F. Veloso (2), Ricardo Gonçalo (1), A. Onofre (1). N. Castro acted as final sign-off responsible for two public notes and R. Gonçalo and H. Santos for one public note each.

A. Gomes and F. Martins were editors of the TileCal Initial Design Report for the Phase-II Upgrade.

Our group was requested by the ATLAS Publiccation Committee to formally review 4 papers.

Lines of work and objectives for next year

Physics studies

Higgs physics:

- Study of angular variables to separate different spin and CP components in the WH (with H->bb) channel, both in the HWW and Hbb vertex. The study will start on generator-level simulation before moving to full simulation.
- Contribute to the ATLAS search for the SM Higgs decays to bb in the associated production channel with a W or a Z boson using the 13 TeV pp collisions. Our focus will be the incorporation of the boosted Higgs boson tagging into the standard multi-variate analysis techniques.
- Contribute to the ATLAS search for the SM Higgs decays to bb in the associated production channel with a top-quark pair using 13 TeV pp collisions. This ongoing analysis should converge in mid 2017 in an ATLAS paper documenting the search results using the 2015 and 2016 datasets.
- A related, longer-term goal, will be to incorporate the angular observables explored in the previous years to suppress the ttbb irreducible background affecting Higgs searches in the ttH channel.

Top quark properties:

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

Exotic searches:

- Extend the search for vector-like quarks in the Zt/b+X channel, where the LIP team has a leading role since run-1. During 2017 the team will finish the analysis of the 2015+2016 dataset, exploring additional signatures such as trilepton and dilepton plus large radius jets. The corresponding paper is foreseen to be ready during 2017.
- Contribute to the common effort for a combination of the ATLAS analysis sensitive to the pair production of vector-like quarks.
- Coordinate and continue to contribute to the search for tZ production via FCNC in the trilepton topology and interpret the obtained results in terms of effective operators. The analysis of the 2015+2016 dataset is expected to be finished during 2017. In a longer timescale the combination with the search for t→qZ decays will be performed, including the study of the interference effects between the two channels.
- Coordinate and contribute at the analysis level to the search for events with a top quark and missing energy, which can be sensitive to dark matter and vector-like quarks.
- Contribute the common effort for the combination of the ATLAS analysis sensitive to the dark matter production.

In what corresponds to heavy ion physics, the focus will be the study of heavy flavour jet production.

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 system migration.
- Concerning the AFP DCS, integration and commissioning of the second detector arm for the cooling, movement and vacuum systems.
- With respect to the AFP trigger:

- Finish the design and implementation of the first trigger chains to select di-jet events in central exclusive production. This work will also contribute to the improvement of the offline AFP reconstruction software in terms of organization, re-usability and robustness.

- Validation and performance evaluation of these trigger chains with 2017 data.

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

TileCal:

- With respect to the LOMAC lab, the LIP-Lisbon pole will soon be moving to new installations at the University of Lisbon. The removal and reinstallation of the equipment for fibre preparation and quality control, PMT test bench and quality control of the scintillators will most likely be done only in the second half of 2017, to avoid disturbing ongoing experimental work. The removal will be carefully planned to avoid disruption of the current activities;
- We will continue the linearity and stability monitoring studies of the TileCal's PMTs using the Laser II system.

With respect to the TileCal DCS, the objectives for 2017 will be:

- To keep the same level of involvement in the operation and maintenance of the DCS and the TileCal.
- To prepare the migration of the DCS system which will take place in the next technical stop (beginning of 2018)
- To consolidate the control components of the DCS at the test beam for the TileCal Upgrade.
- To develop a test bench for the quality control of the high voltage regulation systems of the upgrade of the TileCal

In what corresponds to the TileCal upgrade:

- Finish the assembly of the first HVremote board and its control system, including the integration into the ATLAS DCS system.
- Purchase crate components and assembly of a crate to house the HVremote boards and the primary HV boards.
- Test the HVremote board, first in the laboratory and then at the test beam at CERN.
- Re-design and production of a new board (prototype 2) in case that problems are identified in the first one.
- Finish the scintillator-WLS fibres couplings tests.
- Irradiation and tests of scintillators and fibres at CTN (Lisbon).

Jet trigger:

- Besides our involvement in trigger operations, we will focus on studies with a potential to reduce the fake jet trigger rate and improve the jet trigger robustness against the expected higher pileup noise, two of the most pressing problems affecting this trigger. A first study should investigate ways to correct the rate increase caused by the ageing of the crack scintillators, placed near the TileCal layer 3.
- Finish the performance studies of the cluster splitter and the full GPU demonstrator prototype.
- If GPUs are chosen as hardware accelerators for Phase I upgrade High Level Trigger, the development of the TAC algorithm will have to continue in order to ensure it readiness for data taking in 2020. The most important task in 2017 will be the study the effects in the physics channels of the small algorithmic differences.
- The development of parallel trigger algorithms will also continue towards Phase II.

A proposal describing the Portuguese contribution to the ATLAS Phase II Upgrade will be prepared this year.

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

Outreach and advanced training:

Our strong effort on outreach and advanced training will continue. We will contribute to the organization and support of several activities including Masterclasses, seminars and hands on tutorials. We will also contribute to the organization of the LIP Summer Student Internship Program.

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 wave length shifting and scintillating fibres, plastic scintillators and photomultipliers. There is also expertise on electronics and advanced computing.

Our past investments in the TileCal design, construction and commissioning placed us in a good position to contribute to several related activities, such as the development of the DCS, detector operation, data quality, the Alfa luminosity monitor (which uses a similar technology), detector upgrades and the new AFP spectrometer. In the jet trigger area we have been involved in the High-Level Trigger development, operation and upgrade. Synergies are actively exploited, as in the case of the use of the TileCal outer cells to suppress problematic spurious signals in the Level-1 muon trigger (Tile-Muon), and the AFP trigger, combining the detection of diffracted protons in coincidence with di-jet events recorded in the central detector.

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 exotic new physics. Here, again, 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 few students starting in Lisbon or Coimbra, with a large number of PhD students in the concluding or writing phase of their PhD. We have taken important steps (outreach, internships, etc) to alleviate this situation and attract more students, but it will take time to restore the group's human resources.

Opportunities

Last year brought a large increase in accumulated luminosity, enough to improve the precision in many Higgs physics studies and the sensitivity in new physics searches. This will lead to several opportunities in all our physics analysis areas, which should be used to further our group's impact and build up our know-how for subsequent years.

On a slightly longer time scale, the replacement of the TileCal HV distribution boards and the gap and crack scintillators constitutes an important opportunity to invest the group's expertise and contribute in kind to the detector Upgrade. In addition, the development of the HV distribution boards opens the opportunity to extend and diversify the group's areas of expertise.

The investment in the ATLAS upgrade and the enlargement of our expertise has the importance of creating new opportunities to attract students.

Our long experience with optical WLS and scintillating fibres and scintillating materials place us in a privileged position to invest in the development and R&D on new detectors for the future accelerators and experiments. We were already invited to contribute on several projects that range from R&D on future calorimeters to the application of scintillating fibres to hadron-therapy.

The new LIP premises in Lisbon will provide the opportunity for our group to to concentrate again all the equipment for fibres preparation and quality control in the same place and have the laboratory and the research team in the same place. This will have potentially a very positive impact on the group's activity in the next few years, facilitating the interaction between group members and the development of the activities.

The promise of new installations in LIP-Minho will provide also an opportunity to consolidate and establish the group there.

As a consequence of the new computing technologies and the market tendency towards a wider use of many-core-processors, the use of GPGPUs is currently being considered not only as a solution to speed up the high level trigger (HLT) software in Phase I but also as a possibility for the first level trigger or HLT in Phase II. Our investment in GPGPU programming and our collaboration with the Lisbon and Minho computing centres has strengthened our group and leaves us in a good position to contribute to the trigger upgrade.

The preparation of the ATLAS Phase II TDR documents this year will provide an opportunity to consolidate and possibly expand the group responsibilities in the ATLAS Upgrade and to explore the involvement of the Portuguese industry in this effort.

The effort made last year in Lisbon to offer summer research projects for young university students has contributed to divulge the group activities and attracted new students in Lisbon, who are potential future Master and PhD students. This effort should continue, enforcing outreach activities in the universities and maintaining the interest of the students on our field.

Threats

The removal of the LOMAC laboratory from Faculdade de Ciências in Lisbon to the LIP's new facilities, which will happen this year, will imply dismantling, installing and recommissioning the laboratory's infrastructure in the new facilities. This will disrupt the activities of the LOMAC laboratory and has the potential of introducing delays in the execution of the current work plan. A careful planning of the activities, removal and re-installation of the lab will be fundamental to ensure a smooth transition.

The funding structure in Portugal continues to be unstable and poorly adjusted to large continuing projects. In the last few years, the group has suffered a reduction of 30% in yearly funding precisely at the time when new upgrade activities were starting and more funding was necessary. In addition, no new funding was received for the R&D and Upgrade activities we have started. Direct hiring of Post-docs or even maintaining grants for our current students is very difficult in this context.

A large fraction of the members of the group is currently in an unstable contractual situation. This affects not only students and young postdocs that are dependent on the research grants, but also senior members whose contracts will be finishing in the next two-three years. If the situation is not improved, the human-power situation may become critical.

Publications

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

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ATLAS Collaboration (2855 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 (2017) 77:26

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

ATLAS Collaboration (2828 authors): "Study of the B-c(+) -> J/psi D-s(+) and Bc(+) -> J/psi D-s*(+) decays with the ATLAS detector", Eur. Phys. J. C 76 (2016) 4

ATLAS Collaboration (2827 authors): "Measurements of the Higgs boson production and decay rates and coupling strengths using pp collision data at root s=7 and 8 TeV in the ATLAS experiment", Eur. Phys. J. C 76 (2016) 6

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ATLAS Collaboration (2871 authors): "Measurement of the production cross-section of a single top quark in association with a W boson at 8 TeV with the ATLAS experiment", J. High Energy Phys. 1 (2016) 064

ATLAS Collaboration (2874 authors): "Measurement of the correlation between the polar angles of leptons from top quark decays in the helicity basis at root s=7 TeV using the ATLAS detector", Phys. Rev. D 93 (2016) 012002

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ATLAS Collaboration (2859 authors): "Search for invisible decays of a Higgs boson using vector-boson fusion in pp collisions at root s=8 TeV with the ATLAS detector", J. High Energy Phys. 1 (2016) 172

ATLAS Collaboration (2857 authors): "Search for single top-quark production via flavour-changing neutral currents at 8TeV with the ATLAS detector", Eur. Phys. J. C 76 (2016) 55

ATLAS Collaboration (2869 authors): "A search for prompt lepton-jets in pp collisions at root s=8 TeV with the ATLAS detector", J. High Energy Phys. 2 (2016) 062

ATLAS Collaboration (2865 authors): "Constraints on non-Standard Model Higgs boson interactions in an effective Lagrangian using differential cross sections measured in the H ->gamma gamma decay channel at root s=8 TeV with the ATLAS detector", Phys. Lett. B 753 (2016) 69-85

ATLAS Collaboration (2864 authors): "Measurements of four-lepton production in pp collisions at root s=8 TeV with the ATLAS detector", Phys. Lett. B 753 (2016) 552-572

ATLAS Collaboration (2857 authors): "Search for direct top squark pair production in final states with two tau leptons in pp collisions at root s=8 TeV with the ATLAS detector", Eur. Phys. J. C 76 (2016) 81

ATLAS Collaboration (2870 authors): "Search for the production of single vector-like and excited quarks in the Wt final state in pp collisions at root s=8 TeV with the ATLAS detector", J. High Energy Phys. 2 (2016) 10

ATLAS Collaboration (2865 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 76 (2016) 87

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Atlas Collaboration (2841 authors): "Search for new phenomena in dijet mass and angular distributions from pp collisions at root s=13 TeV with the ATLAS detector", Phys. Lett. B 754 (2016) 302-322

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ATLAS Collaboration (2867 authors): "Search for magnetic monopoles and stable particles with high electric charges in 8 TeV pp collisions with the ATLAS detector", Phys. Rev. D 93 (2016) 052009

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11 (2016) P04008

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ATLAS Collaboration (2873 authors): "Search for new phenomena in events with at least three photons collected in pp collisions at root s=8 TeV with the ATLAS detector", Eur. Phys. J. C 76 (2016) 210

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ATLAS Collaboration (2853 authors): "Measurement of the charge asymmetry in highly boosted top-quark pair production in root s=8 TeV pp collision data collected by the ATLAS experiment", Phys. Lett. B 756 (2016) 52-71

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ATLAS Collaboration (2862 authors): "Measurements of W(+/-)Z production cross sections in pp collisions at root s=8 TeV with the ATLAS detector and limits on anomalous gauge boson self-couplings", Phys. Rev. D 93 (2016) 092004

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Collaboration, AT (659 authors): "The ATLAS Data Acquisition and High Level Trigger system", J. Instrum. 11 (2016) P06008

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ATLAS Collaboration (2860 authors): "Measurements of Z gamma and Z gamma gamma production in pp collisions at root s=8 TeV with the ATLAS detector", Phys. Rev. D 93 (2016) 112002

ATLAS Collaboration (2855 authors): "Search for new phenomena in events with a photon and missing transverse momentum in pp collisions at root s=13 TeV with the ATLAS detector", J. High Energy Phys. 6 (2016) 059

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Atlas Collaboration (2856 authors): "Measurement of the relative width difference of the B-0-(B)over-bar(0) system with the ATLAS detector", J. High Energy Phys. 6 (2016) 081

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ATLAS Collaboration (2823 authors): "A search for an excited muon decaying to a muon and two jets in pp collisions at root s=8 TeV with the ATLAS detector", New J. Phys. 18 (2016) 073021

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ATLAS Collaboration (2862 authors): "Measurement of the inclusive isolated prompt photon cross section in pp collisions at root s=8 TeV with the ATLAS detector", J. High Energy Phys. 8 (2016) 1-42

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ATLAS Collaboration (2861 authors): "Measurements of the charge asymmetry in top-quark pair production in the dilepton final state at root s=8 TeV with the ATLAS detector", Phys. Rev. D 94 (2016) 032006

ATLAS Collaboration (2833 authors): "Measurement of the angular coefficients in Z-boson events using electron and muon pairs from data taken at root s=8 TeV with the ATLAS detector", J. High Energy Phys. 8 (2016) 159

ATLAS Collaboration (2860 authors): "Measurement of exclusive gamma gamma -> W+W- production and

search for exclusive Higgs boson production in pp collisions at root s=8 TeV using the ATLAS detector", Phys. Rev. D 94 (2016) 032011

ATLAS Collaboration (2861 authors): "Search for resonances in diphoton events at root s=13TeV with the ATLAS detector", J. High Energy Phys. 9 (2016) 001

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M. Aaboud et al. (2859 authors): "Search for Higgs and Z Boson Decays to phi gamma with the ATLAS Detector", Phys. Rev. Lett. 117 (2016) 111802

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ATLAS Collaboration (2862 authors): "Searches for heavy diboson resonances in pp collisions at root S=13 TeV with the ATLAS detector", J. High Energy Phys. 9 (2016) 173

ATLAS Tile Calorimeter System (238 authors): "The Laser calibration of the ATLAS Tile Calorimeter during the LHC run 1", J. Instrum. 11 (2016) T10005

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ATLAS Collaboration (2861 authors): "Search for new phenomena in different-flavour high-mass dilepton final states in pp collisions at root s=13Tev with the ATLAS detector", Eur. Phys. J. C 76 (2016) 541

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5 International Conference Proceedings

P. Conde Muino, on behalf of the ATLAS Collaboration: "Multi-threaded algorithms for GPGPUs in the ATLAS Trigger System", Proceedings of the CHEP 2016 conference, ATL-DAQ-PROC-2016-045

P. Conde Muino on behalf of the ATLAS Collaboration: "ATLAS Search for the SM Higgs boson decay to b-quark pairs", Proceedings of the ICHEP 2016 conference ATL-PHYS-PROC-2016-201

Ademar Tavares Delgado, Dmitry Emeliyanov, on behalf of ATLAS Collaboration: "The ATLAS Trigger Algorithms for General Purpose Graphics Processor Units", accepted for publication

F. Martins on behalf of the ATLAS Tile Calorimeter System: "The ATLAS Tile Calorimeter DCS for Run 2", accepted for publication in Proceedings of the IEEE Nuclear Science Symposium and Medical Imaging Conference, Strasbourg/France, ATL-TILECAL-PROC-2016-011

A. Gomes (for the ATLAS Tile Calorimeter Syst): "The new front-end electronics for the ATLAS Tile Calorimeter Phase 2 Upgrade", J. Instrum. 11 (2016) C02015

5 Collaboration notes with internal referee

ATLAS Collaboration: "Measurement of the tt¯Z and tt¯W production cross-sections in the same-sign dimuon, three and four lepton final states using 3.2 fb−1 of pp collisions at s√=13 TeV", ATLAS-CONF-2016-003

ATLAS Collaboration: "Performance plots from pp and Pb+Pb collisions at sNN = 5.02 TeV based on full statistics data from the HI reprocessing", ATLAS-CONF-2016-109

ATLAS Collaboration: "Search for the Standard Model Higgs boson produced in association with a vector boson and decaying to a $b\bar{b}$ pair in pp collisions at 13 TeV using the ATLAS detector", ATLAS-CONF-2016-091

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3 Internal Notes

A. Blanco, R. Bonnefoy, D. Calvet, M. Calvetti, R. Chadelas, M. Crouau, C. Crozatier, F. Daudon, B. Galhardo, Ph. Gris, P. Lafarguette, D. Lambert, S. Leone, A. Maio, F. Martins, C. Santoni, F. Scuri, D. Simon, M. Van Woerden, F. Veloso, H. Wilkens: "Upgrade of the Laser calibration system of the ATLAS Tile Calorimeter", ATL-TILECAL-INT-2016-004

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A. Gomes, F. Martins et al.: "Initial Design for the Phase-II Upgrade of the ATLAS Tile Calorimeter System", ATL-COM-TILECAL-2016-054

Presentations

11 Oral presentations in international conferences

Juan P. Araque: "Pair VLQ - inc. Higgs interpretations", 2016-04-13, ATLAS Beyond the Standard Model Higgs and Exotics Joint Workshop, Grenoble Grenoble

Ricardo Gonçalo: "04/07/2016 Search for the 125GeV Higgs boson in ttH production with ATLAS", 2016-07-04, SUSY 2016, Melbourne

Patricia Conde: "ATLAS Search for the SM Higgs boson decay to b-quark pairs", 2016-08-04, ICHEP 2016 (International Conference on High Energy Physics), Chicago USA

Nuno Castro: "Top quark results from LHC", 2016-08-24, QCD@LHC 2016, Zurich, Switzerland

Patricia Conde: "Overview of recent ATLAS results", 2016-09-08, International Workshop on Multi-Higgs Models, Lisbon

Juan P. Araque: "Searches for FCNC", 2016-09-22, Top2106, Olomouch (Czech Republic) TOP2016

Patricia Conde: "Multi-threaded algorithms for GPGPUs in the ATLAS Trigger System", 2016-10-13, CHEP 2016 (22nd International Conference on Computing in High Energy Physics 2016), San Francisco USA

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Ademar Delgado: "The ATLAS Trigger Algorithms for General Purpose Graphics Processor Units", 2016-11-04, IEEE Nuclear Science Symposium and Medical Imaging Conference - NSS/MIC 2016, Strasbourg - France

Juan P. Araque: "Searches for vector-like top quarks and other HQT analyses", 2016-12-12, Valencia single-top workshop, Valencia Singletop workshop

Helena Santos: "Jet measurements in p+Pb and Pb+Pb with the ATLAS Experiment at the LHC", 2016-04-11, DIS 2016-24th International Workshop on Deep-Inelastic Scattering and Related Subjects, Hamburg, Germany,

1 Poster presentation in international conference

Juan P. Araque: "Overview of the vector-like quark searches with the LHC data collected by the ATLAS detector", 2016-09-18, Top2106, Olomouch (Czech Republic) TOP2016

8 Oral presentations in national conferences

Ademar Delgado: "Desenvolvimento de algoritmos de seleção em tempo real§ utilizando GPUs como aceleradores§ para o trigger de ATLAS do LHC/CERN", 2016-01-14, Jornadas FCUL, Lisboa Portugal

Ademar Delgado: "Jet trigger algorithms with GPUs for the ATLAS Upgrade", 2016-02-19, Jornadas do LIP, Braga Portugal

Mário Sargedas Sousa: "GSC calibration applied to the ZH ($H ightarrow b ar b$) analysis", 2016-02-19, Braga, Jornadas do LIP https://indico.lip.pt/indico/conferenceDisplay.py?confId=216

Rute Pedro: "WH->lvbb searches using a BDT", 2016-02-19, Jornadas do LIP, Braga Portugal

Ademar Delgado: "Development of parallel jet trigger algorithms for the ATLAS experiment at the LHC", 2016-06-16, Jornadas FCUL, Lisboa Portugal

Mário Sargedas Sousa: "Search for the Higgs boson at ATLAS/LHC§ in associated production with a Z boson", 2016-06-16, Lisboa, Jornadas de Doutoramento em Física e Engenharia Física

Rute Pedro: "WH->lvbb searches using a BDT", 2016-06-16, Jornadas FCUL, Lisboa Portugal https://ciencias.ulisboa.pt/sites/default/files/1ª%20Jornadas%20de%20PhD%20do%20DF%20%2816-6-2016%29%20-%20v2.pdf

Nuno Castro: "A Física experimental no CERN: desafios e oportunidades na próxima década", 2016-07-05, Ciência 2016, Lisboa

2 Poster presentations in national conference

Ana Peixoto: "Search for tZ production via Flavour Changing Neutral Currents at the ATLAS Experiment", 2016-09-08, 20th National Conference of Physics, Braga (Portugal) Reference

João Almendra Sabino: "The Interface and Control System of the Upgraded HVOpto/HVRemote card of the TileCal", 2016-12-05, CETC 2016 (Conference on Electronics, Telecommunications and Computers), ISEL, Lisbon, Portugal

5 Oral presentation in international meeting

Juan P. Araque: "Pair VLQ - inc. Higgs interpretations", 2016-04-13, ATLAS Beyond the Standard Model Higgs and Exotics Joint Workshop, Grenoble Grenoble

Filipe Veloso: "t?cH/FCNC & rare decays", 2016-04-21, ATLAS Beyond the Standard Model Higgs and Exotics Joint Workshop, França Grenoble

Filipe Veloso: "FCNC & rare decays", 2016-04-21, Beyond the first 13 TeV top measurement, Suiça CERN

Nuno Castro: "Tools for interpreting measurements in the context of EFT", 2016-12-12, 5th ATLAS single top-quark workshop, Valencia

Juan P. Araque: "Searches for vector-like top quarks and other HQT analyses", 2016-12-12, Valencia single-top workshop, Valencia Singletop workshop

6 Seminars

Bruno Galhardo: "Search for FCNC top-quark decays to qZ", 2016-02-19, Jornadas do LIP 2016, Braga

Patricia Conde: "Results from the Higgs searches at the LHC", 2016-05-10, IDPASC Course on Physics at the LHC, LIP-Lisboa http://www.idpasc.lip.pt/LIP/events/2016_lhc_physics/index.php?option=3

Juan P. Araque: "Vector-like quarks: why and how to look for them", 2016-05-20, Seminar at TU Dortmund, Dortmund (Germany) TU Dortmund

Ademar Delgado: "The ATLAS trigger system", 2016-09-06, Estágio ATLAS/LIP 2016, Lisboa Portugal

Rute Pedro: "Física do Bosão de Higgs", 2016-09-06, Estágio ATLAS/LIP 2016, Lisboa Portugal https://indico.lip.pt/indico/getFile.py/access?contribId=9&sessionId=11&resId=0&materialId=slides&confId=239

Bruno Galhardo: "Search for rare top quark decays", 2016-12-07, Café com Física, Coimbra

15 Outreach seminars

João Gentil: "Palestra sobre detectores e aceleradores", 2016-02-17, 12a MasterClasses Internacionais de Fisica de Particulas, Vila Real

João Gentil: "Palestra sobre detectores e aceleradores", 2016-02-18, 12a MasterClasses Internacionais de Fisica de Particulas, Bragança

João Gentil: "Palestra sobre detectores e aceleradores", 2016-02-27, 12a MasterClasses Internacionais de Fisica de Particulas, Beja

Filipe Veloso: "Detectores e Aceleradores", 2016-03-01, 12.ª Masterclasses Internacionais em Física de Partículas, Coimbra

Bruno Galhardo: "Acelerar a Ciência", 2016-03-05, 12.ª Masterclasses Internacionais em Física de Partículas, Aveiro

Rute Pedro: "Física de Altas Energias na Experiência ATLAS/LHC no CERN", 2016-03-19, CERN Masterclasses, Lisboa Portugal http://www.lip.pt/~rute/PublicTalks/2016/Masterclasses_2016.pdf

Bruno Galhardo: "Acelerar a Ciência", 2016-04-22, Partículas - do bosão de Higgs a matéria escura, Coimbra

Nuno Castro: "A Física de Partículas e o CERN", 2016-04-27, , Escola Secundária de Rio Tinto

Nuno Castro: "O Universo e a Fisica de Particulas", 2016-05-11, Festa da Ciência 2016, Escola de Ciências da Universidade do Minho, Braga, Portugal

Bruno Galhardo: "Acelerar a Ciência", 2016-05-17, SELECC?ÃO SUB30 investigadores, Escola Secundária de Cantanhede

Patricia Conde: "O bosão de Higgs", 2016-05-27, Noites de Ciências, Faculdade de Ciências (Universidade de Lisboa) Lisboa

Rute Pedro: "Introdução às Partículas", 2016-07-12, IDPASC Workshop Hands on Particles and Light, Lisboa Portugal

Patricia Conde: "A experiência ATLAS", 2016-08-30, CERN Portuguese Language Teachers Programme, CERN

Ana Peixoto: "Do átomo às partículas elementares", 2016-11-23, Conference, Escola Secundária de Paredes de Coura Reference

F. Veloso, "Partículas elementares e forças fundamentais: o LHC", 2016-01-15, EBS de São Martinho do Porto

Theses

11 PhD Theses

Duarte Azevedo: "Probing the CP nature of the Higgs couplings in ttH events at the LHC" (ongoing)

Bruno Galhardo: "Search for flavour-changing neutral current top-quark decays with the ATLAS detector" (delivered in October 2016, waiting for the defense)

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

Mário Sargedas Sousa: "Search for the Higgs boson at ATLAS/LHC, in associated production with a Z boson" (delivered in March 2017, waiting for the defense)

Juan P. Araque: "Search for heavy fermions with the ATLAS experiment at the LHC collider" (finished on 2016-04-20)

Rute Pedro: "Search for the Higgs boson at ATLAS/LHC in WH associated production and decay to b quark pairs using MVA methods" (writing up)

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)

9 Master Theses

Emanuel Gouveia: "Search for ttH production with the ATLAS experiment at the LHC" (finished on 2016-06-29)

Ana Peixoto: "Search for tZ production via FCNC at the ATLAS experiment" (finished on 2016-12-16)

Tiago Vale: "Search for Vector Like Quarks in a multilepton topology at the ATLAS experiment" (finished on 2016-09-12)

José Correia: "Search for Vector Like Quarks in a fully hadronic topology at the ATLAS experiment" (finished on 2016-09-16)

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

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

José Luís Silva: "Paralellization and Optimization of the TopoCluster Splitting Algorithm using GPUs" (ongoing)

Cátia Rato: "Development of a control board for the HV distribution system" (ongoing)

João Almendra Sabino: "Detector Control System of the HV distribution boards for the ATLAS Tile Calorimeter Phase II Upgrade" (ongoing)

1 Graduation Thesis

Lia Moreira: "Determinação da carga elétrica de jatos hadrónicos incluindo o decaimento semileptónico de quarks pesados" (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. 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 to 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 building and installing a new plant 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 forward proton spectrometer (CT-PPS), which took physics data integrated in

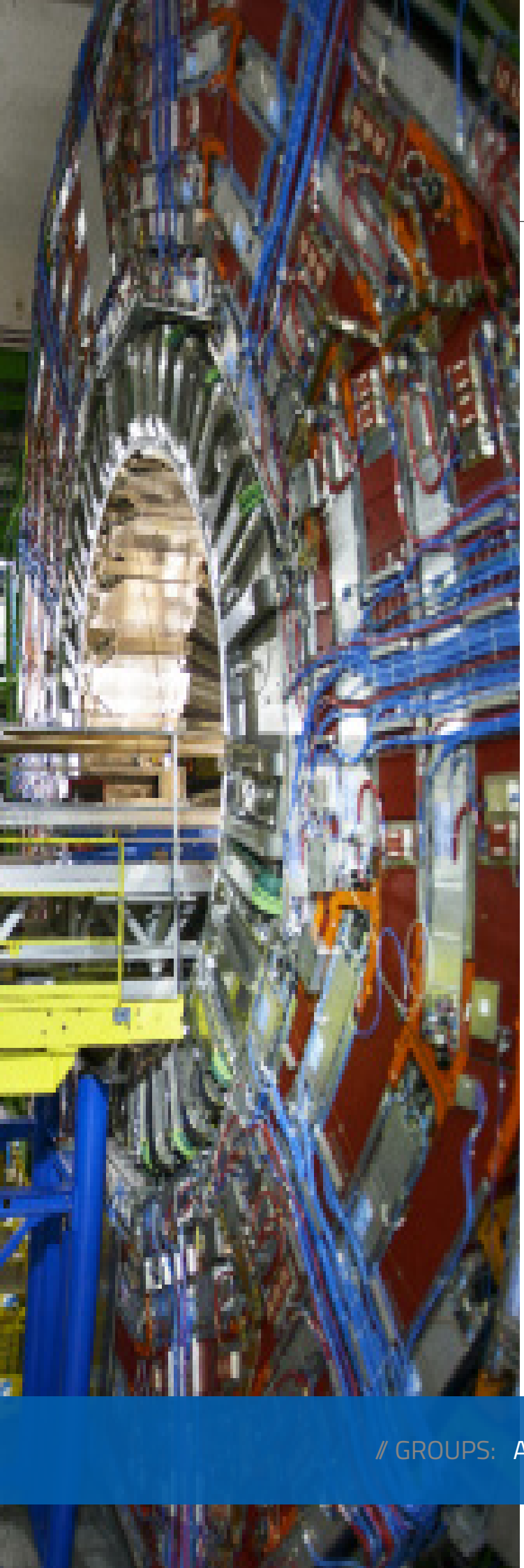
Framework and status for past and current year

CMS already in 2016. CT-PPS 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 CT-PPS Project Coordinator and coordinators of the CT-PPS 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 CT-PPS 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 also coordinated in 2015-16 the CMS Higgs and Top physics groups.

Summary of performance indicators

Articles in international journals:	5 With direct contribution from team 77 With indirect contribution
Internal notes:	4 Collaboration notes
International conferences:	10 Oral presentations 2 Proceedings 1 Poster presentation
International meetings:	14 Oral presentations
National conferences:	3 Oral presentation
Collaboration meetings:	122 Oral presentations
Seminars:	12 Seminars
Organization:	1 Collaboration meeting organized
Completed theses:	1 PhD



Team

Principal Investigator João Varela (70)

Researchers
Betty Calpas (42), Jonathan Hollar (100), João Seixas (25), Lara Lloret (100), Michele Gallinaro (100), Nuno Leonardo (100), Pedrame Bargassa (100), Pietro Faccioli (25), Pietro Vischia (100)

Technicians
Cesar Carpinteiro (100), José Carlos Silva (50), Rui Pereira da Silva (30)

PhD students
Agostino di Francesco (100), Bruno Galinhas (100), Cristóvão Silva (100), Daniele Vadruccio (100), Giles Strong (78), Oleksii Toldaiev (100)

Master students
Bruno Alves (25)

External/Additional scientific collaborators
André David, Manuel Rolo, Pedro Ferreira da Silva, Viesturs Veckalns

Total FTE
15.5

// GROUPS: ATLAS / CMS / LHC phenomenology / HIP

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 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 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 Joao Varela. He has 30 years of research experience in Particle Physics collaborations at CERN. The other senior researchers of the LIP-CMS group are Joao 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)
- Co-convener (Level-2) of the CMS B Physics and Quarkonia Analysis Group (B PAG), since 2014 (N. Leonardo)

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)
- CMS Physics Coordination (N.Leonardo)
- ECAL Executive Board (J.C. Silva)
- ECAL and CTPPS Institution Boards (J. Varela)

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 to 2017-08-31	EU MSCA-ITN - Multi-Variate Analysis for New Physics@LHC

Stated objectives for past year

The LIP group has planned to participate in the following areas of physics analysis and detectors activities in 2016:

1. Proton-proton physics:

1.1 Search for charged Higgs and other new physics in top events at 13 TeV;
1.2 Search for the top squark at 13 TeV; completion of the tau slepton analysis at 8 Tev;
1.3 Search for di-Higgs events in resonant or non-resonant modes in di-tau and bbar final states; study of Higgs bosons in the di-tau decay mode.
1.4 Search for rare decays and measurement of heavy flavour production and properties with Run 2 data;
1.5 Search for exclusive di-photon production events in proton collisions using the CT-PPS spectrometer.

2. Heavy-ions and related pp physics:

2.1 Quarkonia polarization as a function of charged multiplicity in proton-pronton and in heavy-ion collisions;
2.2 Heavy-flavour production in heavy-ion collisions (in coordination with pp studies);
2.3 Polarization of chi states (χc and χb).

3. Physics objects development

3.1 Participation in the activities of development and validation of the "physics objects" TAU (tau lepton) and MET (missing ET) in the frame of the corresponding Physics Object Groups (POGs).

4. CT-PPS installation and operation

4.1 Commissioning and operation at LHC of the CT-PPS detectors.
4.2 Development of the CT-PPS DAQ system.

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

5.1 Commissioning and operation of the optical Serial Links interfacing the ECAL electronics to the stage-2 Upgrade Trigger System.

6. Computing

6.1 LIP/CMS interface with the LIP's Tier2 group

7. General

7.1 Central shifts for data taking and EPR work according to the rules of the CMS collaboration.

Achievements and responsibilities during the past year

The LIP group developed the following activities in 2016 (CMS AN refers to internal Analysis Notes):

1. Proton-proton physics

1.1 Search for charged Higgs and other new physics in top events at 13 TeV:

Members of the LIP/CMS group (M. Gallinaro, P. Vischia) had a leading role in the data analysis and preparation of the publication of the Run 1 "legacy" paper on the search for a charged Higgs boson. The paper was published in 2015, JHEP 11(2015)018. Supporting documentation is detailed in CMS AN-2012/489. This work was the subject of the PhD Thesis of P. Vischia, defended in July 2016. Continuation of the analysis with the 13 TeV data with the higher collision energy and larger data samples is advancing in steps. The first step towards this goal is to study top quark pair production events, including electrons, muons, and taus. This first mandatory step is to re-establish the understanding of top quark pair production, a dominant background to charged Higgs boson searches. The final states are similar, and the studies performed to develop the analysis can be trained with known physics processes. 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).

1.2 Search for the top squark at 13 TeV; completion of the tau slepton analysis at 8 Tev:

The analysis CMS-SUS-14-015 "Search for direct stop pair production in the single and double lepton channel at sqrt(s)=8 TeV" was concluded and published in 2016, JHEP 07 (2016) 027. Supporting documentation is detailed in CMS-AN-2014-067. Members of the LIP/CMS group (P. Bargassa, L. Lloret) defined the selection of the signal, contributed to the combination of the two final results, and had a leading role in the data analysis and in the preparation of the "legacy" Run1 publication.

The analysis CMS-SUS-14-021 "Search for supersymmetry in events with soft leptons, low jet multiplicity, and missing transverse momentum in proton-proton collisions at sqrt(s) = 8 TeV" was concluded and published in 2016, PLB 759 (2016) 9-35. Supporting documentation is detailed in CMS-AN-2014-230. One member of the LIP group (P. Bargassa) contributed to the definition of the signal selection. Studies with the Run2 data started and members of the LIP/CMS group (P. Bargassa, L. Lloret) are contributing to the preparation of the analysis. One undergraduate student was integrated over summer 2016.

The analysis CMS-SUS-14-022 "Search for stau and chargino pair production in di-tau final states" was concluded, internally approved by the Analysis Review Committee, and submitted to JHEP for publication. LIP contributed to this analysis with the work of the PhD student C. Cruz e Silva on a new background

estimation method (CMS-AN-2015-038). An independent analysis of stau pair production was concluded and defended as doctoral thesis at IST (C. Cruz e Silva).

1.3 Search for di-Higgs events in resonant or non-resonant modes in di-tau and bbar final states; study of Higgs bosons in the di-tau decay mode:

Regression studies in di-Higgs production were performed during 2016 with simulated DELPHES samples as a preliminary step to validate the algorithm developed. This activity is carried in the frame of the EU Marie-Curie network AMVA4NewPhysics. Studies including CMS data and reconstruction software are progressing (PhD student G. Strong, M. Gallinaro). One undergraduate student was integrated over summer 2016.

1.4 search for rare decays and measurement of heavy flavour production and properties with Run 2 data:

A group member (N.Leonardo) has served as the CMS wide coordinator of the B physics area. Organized the Run2 B workshop in Lisbon: http://www.lip.pt/cms_bphysics_workshop2016

The group has actively explored initial Run2 data. The analysis of b-hadron cross sections at 13TeV has been established (N.Leonardo, B.Galinhas). Two undergraduate students (J.Melo, J.Silva) were integrated over summer 2016.

The search B→μμ remains a main priority analysis for CMS and LIP. The group develop the study to address the dominant systematics source.

The exploration by CMS in Run2 of the LFV decay of the tau lepton to 3 muons has been proposed and facilitated (N.Leonardo). An INFIERI student (D.Vadruccio) has explored the decay kinematics, contributed to development of a dedicated trigger algorithm for Run2 and studies for the HL-LHC phase.

1.5 search for exclusive two-photon production events in proton collisions using the CT-PPS spectrometer in Run 2 data; completion of two-photon production analyses with Run 1 data:

Two members of the LIP group (L. Llorett, J. Hollar) have led an ongoing analysis of 13 TeV data, PPS-17-001, studying γγ->ll production with tagged forward protons using the CT-PPS spectrometer.

The analysis FSQ-13-008 "Evidence for γγ->WW production and constraints on anomalous quartic gauge couplings in pp collisions at sqrt(s)=7 and 8 TeV" was concluded and published in the Journal of High Energy Physics. One member of the LIP group (J. Hollar) contributed to the analysis and served as co-editor of the paper.

2. Heavy-ions and related pp physics:

2.1 quarkonia polarization as a function of charged multiplicity in proton-pronton collisions;

The analysis HIN-2015-003 "Υ(nS) polarizations versus particle multiplicity in pp collisions at sqrt(s)=7 TeV" was concluded and published in Physics Letters B761, 2016, 31. Two members of the group (P. Faccioli, J. Seixas) had a leading role in the development of the polarization measurement methods (AN-2015/024, AN-2012/140, AN-2011/535, AN-2012/088, AN-2013/016).

2.2 heavy-flavour production in heavy-ion collisions (in coordination with pp studies):

One of the goals of the study of heavy flavour production in pp collisions that is carried out by the group is for application to collisions involving heavy ions. The pp results serve as reference to corresponding studies in PbPb collisions. The developed analysis strategy and tools may be applied to collisions involving heavy ions.

2.3 polarization of chi states (χc and χb).

The study of the polarization of chi states is on-going. This is a much more involved analysis than the previous ones for the Υ(nS) and y(nS) states but largely simplified by the methodology stemming from the study done by the Lisbon Group (published in "Determination of chi_c and chi_b polarizations from dilepton angular distributions in radiative decays", P. Faccioli, C. Lourenco, J. Seixas, H. K. Wohri, Phys.Rev. D83 (2011) 096001).

3. Physics objects development

3.1 Participation in the activities of development and validation of the "physics objects" TAU (tau lepton) and MET (missing ET) in the frame of the corresponding Physics Object Groups (POGs):

LIP members pursued the participation in the activities of two POGs (Physics Object Groups), namely on the validation of the tau lepton reconstruction (P. Vischia) and of the missing ET reconstruction (L. Lloret). Studies in the Tau POG are performed in connection with those developed for the top quark studies including tau leptons.

4. CT-PPS installation and operation

4.1 Commissioning and operation at LHC of the CT-PPS detectors.

Possible hints of an excess in diphoton events at 750GeV from CMS & ATLAS in 2015 data motivated to advance the CT-PPS installation using non-final detectors in view of taking data in 2016. Under the leadership of a LIP member serving as overall CT-PPS Project Manager (J. Varela) CT-PPS was able to collect about 16 fb-1 of data integrated in the CMS experiment (~40% of total 2016 luminosity). CT-PPS has proven for the first time the feasibility of operating a near-beam proton spectrometer at high luminosity on a regular basis.

The LIP group is also leading the developments of the CT-PPS Timing detectors (CMS Level-2 co-coordinator M. Gallinaro). Following the work done in 2015 in the development of the Digitizer Board (J. C. Silva), the LIP group had a leading role

in the timing firmware development (C. Carpinteiro) that operated successfully in the experiment in the data taking after September 2016. In collaboration with INFN-Torino, one doctoral student of the group (A. Di Francesco) developed a new frontend chip (TOFFEE) in CMOS 110nm technology for this detector.

Several group members (C. Carpinteiro, L. Lloret, J. Hollar) served as 24-hour detector on-call experts (DOC's) throughout the first year of operation of the CT-PPS detectors during 2016. One member of the group (J. Hollar) also served as overall detector operations manager for CT-PPS.

4.2 Development of the CT-PPS DAQ system:

The LIP group is leading the developments of the CT-PPS DAQ system (CMS Level-2 co-coordinator J. Hollar).

The CT-PPS DAQ system foreseen for operation in the 2017 run, based on the standard microTCA, is being assembled at CERN by the LIP group. The system uses hardware and firmware previously developed for the CMS Pixel Upgrade and that are being adapted for the CT-PPS needs. Software developments have also been started. Three members of the group are heavily involved now (J. Hollar, L. Lloret, C. Carpinteiro).

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

5.1 The new optical links plant was in operation already during Run 2 in 2015, connecting the ECAL both to the legacy L1 Trigger System and to the stage-1 upgrade system. The connection to the stage-2 upgrade trigger system was commissioned in 2015 and has successfully started operation in May 2016.

One member of the LIP group (J. C. Silva) is ECAL Electronics Coordinator. He has been responsible in particular for the maintenance of the hardware and firmware provided by LIP.

6. Computing

6.1 LIP operates the CMS Tier2 GRID computing center installed in Lisbon. This center is part of a world-wide computing infrastructure (GRID) used in the processing and analysis of the CMS data. One member of the group (P. Vischia) was in charge of establishing the interface to the LIP Tier2 Computing Team.

7. General

7.1 In 2016 the LIP group provided 52.50 person-months of EPR (Experimental Physics Responsibilities) work (including Shifts), corresponding to 1.01 of the amount expected.

Lines of work and objectives for next year

The LIP group plans 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 related pp physics:

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

3. Physics objects development

3.1 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

4.1 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 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

7.1 LIP/CMS interface with the LIP's Tier2 group

8. General

8.1 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.

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 new CTPPS detector, coordination of the B physics PAG and leading role in several physics analysis. Emerging leadership in different areas of the front readout systems of the Phase II Upgrade of ECAL, HGCAL and BTL.

Weaknesses

Not enough students, in particular Portuguese, showing insufficient penetration in the local Universities. A concerted effort at LIP level has been initiated to solve this problem. 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 the majority of the senior physicists of the group.

Publications

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

P. Bargassa et al [CMS Collaboration]: "Search for supersymmetry in events with soft leptons, low jet multiplicity, and missing transverse momentum in proton-proton collisions at sqrt(s) = 8 TeV", CMS-SUS-14-021, CERN-PH-EP-2015-307, PLB759 (2016) 9-35

Z.Hu, N.Leonardo [CMS Collaboration]: "Selected heavy flavor distributions from CMS with 2016 data at 13 TeV", CMS DP-2016/016

P. Bargassa, L. Lloret et al [CMS Collaboration]: "Search for direct pair production of scalar top quarks in the single- and dilepton channels in proton-proton collisions at s?=s= 8 TeV", JHEP 07 (2016) 027

S. Chatrchyan et al. [CMS Collaboration]: "Evidence for exclusive $\gamma\gamma \rightarrow$ W+W- production and constraints on anomalous quartic gauge couplings in pp collisions at sqrt(s) = 7 and 8 TeV", JHEP 1608 (2016) 119

K. Akiba et al. [LHC Forward Physics Working Group]: "LHC forward physics", J.Phys. G43 (2016) 110201

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

CMS Collaboration (2302 authors): "Measurement of transverse momentum relative to dijet systems in PbPb and pp collisions at root s(NN)=2.76 TeV", J. High Energy Phys. 1 (2016) 006

CMS Collaboration (2308 authors): "Search for resonant t(t)over-bar production in proton-proton collisions at root s=8 TeV", Phys. Rev. D 93 (2016) 012001

CMS Collaboration (2311 authors): "A search for pair production of new light bosons decaying into muons", Phys. Lett. B 752 (2016) 146-168

CMS Collaboration (2310 authors): "Search for neutral MSSM Higgs bosons decaying to mu(+) mu(-) in pp collisions at root s=7 and 8 TeV", Phys. Lett. B 752 (2016) 221-246

CMS Collaboration (2313 authors): "Measurement of differential cross sections for Higgs boson production in the diphoton decay channel in pp collisions at root s=8TeV", Eur. Phys. J. C 76 (2016) 13

V. Khachatryan et al. (2304 authors): "Observation of top quark pairs produced in association with a vector boson in pp collisions at root s=8 TeV", J. High Energy Phys. 1 (2016) 096

CMS Collaboration (2310 authors): "Search for vectorlike charge 2/3 T quarks in proton-proton collisions at root(s)=8 TeV", Phys. Rev. D 93 (2016) 012003

CMS Collaboration (2311 authors): "Study of B Meson Production in p plus Pb Collisions at root s(NN)=5.02 TeV Using Exclusive Hadronic Decays", Phys. Rev. Lett. 116 (2016) 032301

Cms Collaboration (2318 authors): "Search for the production of an excited bottom quark decaying to tW in proton-proton collisions at root s=8 TeV", J. High Energy Phys. 1 (2016) 166

CMS Collaboration (2297 authors): "Measurement of the Top Quark Pair Production Cross Section in Proton-Proton Collisions at root s=13 TeV", Phys. Rev. Lett. 116 (2016) 052002

CMS Collaboration (2305 authors): "Search for a Higgs boson decaying into gamma*gamma -> ll gamma with low dilepton mass in pp collisions at root s=8 TeV", Phys. Lett. B 753 (2016) 341-362

CMS Collaboration (2314 authors): "Search for exotic decays of a Higgs boson into undetectable particles and one or more photons", Phys. Lett. B 753 (2016) 363-388

CMS Collaboration (2310 authors): "Angular analysis of the decay B-0 -> K*(0)mu(+)mu(-) from pp collisions at root s=8 TeV", Phys. Lett. B 753 (2016) 424-448

CMS Collaboration (2283 authors): "Search for W ' -> tb in proton-proton collisions at root s=8 TeV", J. High Energy Phys. 2 (2016) 122

CMS Collaboration (2318 authors): "Measurement of the charge asymmetry in top quark pair production in pp collisions at root s=8 TeV using a template method", Phys. Rev. D 93 (2016) 034014

CMS Collaboration (2271 authors): "Search for Narrow Resonances Decaying to Dijets in Proton-Proton Collisions at root s=13 TeV", Phys. Rev. Lett. 116 (2016)

CMS Collaboration (2275 authors): "Search for a massive resonance decaying into a Higgs boson and a W or Z boson in hadronic final states in proton-proton collisions at root s=8 TeV", J. High Energy Phys. 2 (2016) 145

CMS Collaboration (2272 authors): "Correlations between jets and charged particles in PbPb and pp collisions at root s(NN)=2.76 TeV", J. High Energy Phys. 2 (2016) 156

CMS Collaboration / Harkonen, J (2308 authors): "Search for pair production of first and second generation leptoquarks in proton-proton collisions at root s=8 TeV", Phys. Rev. D 93 (2016) 032004

Butz, E / CMS Collaboration (2310 authors): "Search for single production of scalar leptoquarks in proton-proton collisions at root s=8 TeV", Phys. Rev. D 93 (2016) 032005

CMS Collaboration (2305 authors): "Measurement of the t(t)over-bar production cross section in the all-jets final state in pp collisions at root s=8TeV", Eur. Phys. J. C 76 (2016) 128

CMS Collaboration (2287 authors): "Measurements of t(t)over-bar spin correlations and top quark polarization using dilepton final states in pp collisions at root s=8 TeV", Phys. Rev. D 93 (2016) 052007

CMS Collaboration (2311 authors): "Transverse momentum spectra of inclusive b jets in pPb collisions atv root s(NN)=5.02 TeV", Phys. Lett. B 754 (2016) 59-80

CMS Collaboration (2306 authors): "Search for excited leptons in proton-proton collisions at root s=8 TeV", J. High Energy Phys. 3 (2016) 125

CMS Collaboration (2303 authors): "Event generator tunes obtained from underlying event and multiparton scattering measurements", Eur. Phys. J. C 76 (2016) 155

CMS Collaboration (2300 authors): "Search for dark matter and unparticles produced in association with a Z boson in proton-proton collisions at root s=8 TeV", Phys. Rev. D 93 (2016) 052011

CMS Collaboration (2302 authors): "Measurement of differential and integrated fiducial cross sections for Higgs boson production in the four-lepton decay channel in pp collisions at root s=7 and 8 TeV", J. High Energy Phys. 4 (2016) 005

CMS Collaboration (2288 authors): "Comparison of the Z/gamma* + jets to gamma + jets cross sections in pp collisions at root s = 8 (vol 10, 128, 2015)", J. High Energy Phys. 4 (2016) 010

CMS Collaboration (2307 authors): "Search for anomalous single top quark production in association with a photon in pp collisions at root s=8 TeV", J. High Energy Phys. 4 (2016) 035

CMS Collaboration (2309 authors): "Measurement of the top quark mass using proton-proton data at root(s)=7", Phys. Rev. D 93 (2016) 072004

CMS Collaboration (2140 authors): "Search for new phenomena in monophoton final states in proton-proton collisions at root s=8 TeV", Phys. Lett. B 755 (2016) 102-124

CMS Collaboration (2318 authors): "Search for W ' decaying to tau lepton and neutrino in proton-proton collisions at root s=8 TeV", Phys. Lett. B 755 (2016) 196-216

CMS Collaboration (2308 authors): "Searches for a heavy scalar boson H decaying to a pair of 125 GeV Higgs bosons hh or for a heavy pseudoscalar boson A decaying to Zh, in the final states with h -> tau tau", Phys. Lett. B 755 (2016) 217-244

CMS Collaboration (2299 authors): "Measurement of top quark polarisation in t-channel single top quark production", J. High Energy Phys. 4 (2016) 073

CMS Collaboration (2285 authors): "Measurement of Long-Range Near-Side Two-Particle Angular Correlations in pp Collisions at root s=13 TeV", Phys. Rev. Lett. 116 (2016) 172302

CMS Collaboration (2304 authors): "Search for massive WH resonances decaying into the l nu b(b)over-bar final state at root s=8 TeV", Eur. Phys. J. C 76 (2016) 237

CMS Collaboration (2143 authors): "Measurement of the ratio B(B-s(0) -> J/psi f(0)(980))/B(B-s(0) -> J/psi phi(1020))

in pp collisions at root s=7 TeV", Phys. Lett. B 756 (2016) 84-102

CMS Collaboration (2296 authors): "Measurement of the top quark mass using charged particles in pp collisions at root s=8 TeV", Phys. Rev. D 93 (2016) 092006

CMS Collaboration (2283 authors): "Search for supersymmetry in pp collisions at root s=8 TeV in final states with boosted W bosons and b jets using razor variables", Phys. Rev. D 93 (2016) 092009

Malgorzata Kazana (for the CMS Collaboration): "SEARCHES FOR SUPERSYMMETRY WITH THE CMS DETECTOR AT THE LHC", Acta Phys. Pol. B 47 (2016) 1489-1503

CMS Collaboration (2284 authors): "Search for lepton flavour violating decays of heavy resonances and quantum black holes to an e mu pair in proton-proton collisions at root s=8 TeV", Eur. Phys. J. C 76 (2016) 317

CMS Collaboration (2312 authors): "Search for supersymmetry in events with a photon, a lepton, and missing transverse momentum in pp collisions at root s=8 TeV", Phys. Lett. B 757 (2016) 6-31

CMS Collaboration (2311 authors): "Measurement of the CP-violating weak phase phi(s) and the decay width difference Delta Gamma(s) using the B-s(0) -> J/psi phi (1020) decay channel in pp collisions at root s=8 TeV", Phys. Lett. B 757 (2016) 97-120

CMS Collaboration (2316 authors): "Inclusive and differential measurements of the t(t)over-bar charge asymmetry in pp collisions at root s=8 TeV", Phys. Lett. B 757 (2016) 154-179

CMS Collaboration (2307 authors): "Forward-backward asymmetry of Drell-Yan lepton pairs in pp collisions at root s=8 TeV", Eur. Phys. J. C 76 (2016) 325

CMS Collaboration (2329 authors): "Search for pair-produced vectorlike B quarks in proton-proton collisions at root s=8 TeV", Phys. Rev. D 93 (2016) 112009

CMS Collaboration (2306 authors): "Search for the associated production of a Higgs boson with a single top quark in proton-proton collisions at root s=8 TeV", J. High Energy Phys. 6 (2016) 177

CMS Collaboration (2283 authors): "Measurement of inclusive jet production and nuclear modifications in pPb collisions at root s(NN)=5.02 TeV", Eur. Phys. J. C 76 (2016) 372

CMS Collaboration (2302 authors): "Measurement of t(t)over-bar production with additional jet activity, including b quark jets, in the dilepton decay channel using pp collisions at root s=8TeV", Eur. Phys. J. C 76 (2016) 379

CMS Collaboration (2275 authors): "Search for supersymmetry in the multijet and missing transverse momentum final state in pp collisions at 13 TeV", Phys. Lett. B 758 (2016) 152-180

CMS Collaboration (2308 authors): "Search for a low-mass pseudoscalar Higgs boson produced in association with a b(b)over-bar pair in pp collisions at root s=8 TeV", Phys. Lett. B 758 (2016) 296-320

CMS Collaboration (2307 authors): "Measurement of spin correlations in tf production using the matrix element method in the muon plus jets final state in pp collisions at root S=8 TeV", Phys. Lett. B 758 (2016) 321-346

CMS Collaboration (2268 authors): "Search for Narrow Resonances in Dijet Final States at root s=8 TeV with the Novel CMS Technique of Data Scouting", Phys. Rev. Lett. 117 (2016) 031802

CMS Collaboration (2263 authors): "Search for Resonant Production of High-Mass Photon Pairs in Proton-Proton Collisions at root s=8 and 13 TeV", Phys. Rev. Lett. 117 (2016) 051802

CMS Collaboration (2258 authors): "Search for new physics in same-sign dilepton events in proton-proton collisions at", Eur. Phys. J. C 76 (2016) 439

Cms Collaboration (2306 authors): "Search for supersymmetry in events with soft leptons, low jet multiplicity, and missing transverse energy in proton-proton collisions at root s=8 TeV", Phys. Lett. B 759 (2016) 9-35

Cms Collaboration (2331 authors): "Study of Z boson production in pPb collisions at root S-NN=5.02 TeV", Phys. Lett. B 759 (2016) 36-57

CMS Collaboration (2293 authors): "Search for neutral resonances decaying into a Z boson and a pair of b jets or tau leptons", Phys. Lett. B 759 (2016) 369-394

CMS Collaboration (2280 authors): "Search for supersymmetry in electroweak production with photons and large missing transverse energy in pp collisions at root s=8TeV", Phys. Lett. B 759 (2016) 479-500

CMS Collabordtion (2316 authors): "Measurement of the inelastic cross section in proton-lead collisions at root s(NN)=5.02 TeV", Phys. Lett. B 759 (2016) 641-662

CMS Collaboration (2274 authors): "Combined search for anomalous pseudoscalar HW couplings in VH(H -> b(b)over-bar) production and H -> VV decay", Phys. Lett. B 759 (2016) 672-696

CMS Collaboration (2309 authors): "ABC of multi-fractal spacetimes and fractional sea turtles (vol 76, 181, 2016)", Eur. Phys. J. C 76 (2016) 45

CMS Collaboration (2266 authors): "Evidence for exclusive gamma gamma -> W (+) W (-) production and constraints on anomalous quartic gauge couplings in pp collisions at and 8 TeV", J. High Energy Phys. 8 (2016) 119

Collaboration, C (2285 authors): "Search for s channel single top quark production in pp collisions at root s=7 and 8 TeV", J. High Energy Phys. 9 (2016) 027

Cms Collaboration (2311 authors): "Measurement of the differential cross sections for top quark pair production as a function of kinematic event variables in pp collisions at root s=7 and 8 TeV", Phys. Rev. D 94 (2016) 052006

CMS Collaboration (2294 authors): "Search for Higgs boson off-shell production in proton-proton collisions at 7 and 8 TeV and derivation of constraints on its total decay width", J. High Energy Phys. 9 (2016) 051

CMS Collaboration (2284 authors): "Search for R-parity violating decays of a top squark in proton-proton collisions at root s=8TeV", Phys. Lett. B 760 (2016) 178-201

CMS Collaboration (2292 authors): "Measurements of t(t)over-bar charge asymmetry using dilepton final states in pp collisions at root s=8 TeV", Phys. Lett. B 760 (2016) 365-386

CMS Collaboration (2273 authors): "Measurement of the Z gamma -> nu(nu)over-bar gamma production cross section in pp collisions at root s=8 TeV and limits on anomalous ZZ gamma and Z gamma gamma trilinear gauge boson couplings", Phys. Lett. B 760 (2016) 448-468

CMS Collaboration (2284 authors): "Search for direct pair production of scalar top quarks in the single- and dilepton channels in proton-proton collisions at root S = 8 TeV (vol 07, 027, 2016)", J. High Energy Phys. 9 (2016)

CMS Collaboration (2299 authors): "Search for two Higgs bosons in final states containing two photons and two bottom quarks in proton-proton collisions at 8 TeV", Phys. Rev. D 94 (2016) 052012

CMS Collaboration (2265 authors): "Search for new physics with the M-T2 variable in all-jets final states produced in pp collisions at root s=13 Tev", J. High Energy Phys. 10 (2016) 006

CMS Collaboration (2293 authors): "Measurement of the integrated and differential t(t)over-bar production cross sections for high-p(T) top quarks in pp collisions at root s=8 TeV", Phys. Rev. D 94 (2016) 072002

CMS Collaboration (2289 authors): "Phenomenological MSSM interpretation of CMS searches in pp collisions at root s=7 and 8 TeV", J. High Energy Phys. 10 (2016) 129

CMS Collaboration (2288 authors): "Search for third-generation scalar leptoquarks in the t tau channel in proton-proton collisions at root s = 8 TeV (vol 7, 042, 2015)", J. High Energy Phys. 11 (2016) 056

CMS Collaboration (1477 authors): "Decomposing transverse momentum balance contributions for quenched jets in PbPb collisions at root s(NN)=2.76 TeV", J. High Energy Phys. 11 (2016) 055

CMS Collaboration (2262 authors): "Search for long-lived charged particles in proton-proton collisions at root s=13 TeV", Phys. Rev. D 94 (2016) 112004

2 International Conference Proceedings

Pietro Vischia: "Searches for Charged Higgs Bosons in pp collisions with the ATLAS and CMS detectors", accepted for publication in CMS CR-2015/385

M. Gallinaro (for the CMS and Totem Collaborations): "Upgrades for the Precision Proton Spectrometer at the LHC: Precision Timing and Tracking Detectors", arXiv:1611.07431

4 Collaboration notes with internal referee

Pedrame Bargassa et al.: "Search for four-body decays of the top squark in the single lepton channel at 13 TeV", accepted

D. Christian et al.: "A Level 1 pixel-based track trgger for CMS", CMS DN-2015/008

A. Andreas et al.: "Search for dark matter, unparticle, and extra dimension in events with a Z boson and missing transverse momentum in pp collisions at 13 TeV", CMS AN-2015/285

M. Gallinaro, G. Strong, et al.: "Regression studies in di-Higgs events", CMS AN-2016/407

Presentations

10 Oral presentations in international conferences

Michele Gallinaro: "BSM Higgs boson search results at CMS", 2016-02-07, Lake Louise Winter Institute, Lake Louise, Canada

Nuno Leonardo: "QCD, heavy flavor, and soft physics", 2016-03-09, International conference La Thuile 2016, La Thuile

João Varela: "Highlights of CMS results at 13 TeV with first Run II data", 2016-05-23, PLANCK 2016 19th International Conference From the Planck Scale to Electroweak Scale, Valencia, Spain

João Varela: "The CMS-TOTEM Proton Precision Spectrometer", 2016-05-30, 3rd Elba Workshop on Forward Physics @ LHC Energy, Elba, Italy

Michele Gallinaro: "Upgrades for the CMS-Totem Precision Proton Spectrometer", 2016-05-31, 3rd Elba Workshop on Forward Physics, Biodola, Italy

Lara Lloret: "Di-boson production at the LHC", 2016-06-15, International conference LHCP 2016, Lund, Sweden

Michele Gallinaro: "Upgrades for the Precision Proton Spectrometer at the LHC: Precision Timing and Tracking Detectors", 2016-09-07, Diffraction 2016, International Workshop on Diffraction in High-Energy Physics, Acireale, Italy

Michele Gallinaro: "The standard model Higgs and beyond", 2016-12-03, The 6th Egyptian school of High Energy Physics, BUE, Cairo, Egypt

Michele Gallinaro: "Probing the SM: Top quark and Higgs", 2016-12-03, The 6th Egyptian school of High Energy Physics, BUE, Cairo, Egypt

Michele Gallinaro: "Regression Studies in di-Higgs Events", 2016-12-20, 3rd AMVA4NewPhysics all-network workshop, Oxford, England

1 Poster presentation in international conference

Bruno Galinhas: "B production at 13TeV", 2016-06-14, International conference LHCP 2016, Lund

3 Presentations in national conferences

Michele Gallinaro: "Looking forward: The Precision Proton Spectrometer at the LHC", 2016-02-05, Lisbon mini-school on Particle and Astroparticle Physics, Caparica, Portugal

Jonathan Hollar: "The CT-PPS Project and prospects for ?? exclusive production", 2016-02-19, Jornadas do LIP 2016,

Nuno Leonardo: "B physics: measurements, searches, coordination, prospects", 2016-02-19, Jornadas Cientificas do LIP 2016, Braga

14 Oral presentations in international meetings

Lara Lloret: "TOTEM and CTPPS DAQ integration", 2016-03-01, Meeting with LHCC Referees, CERN, Switzerland

Jonathan Hollar: "Update on physics simulations: resonances in ??->?? with CT-PPS", 2016-03-01, LHCC referees meeting, CERN, Switzerland

João Varela: "Advancing the CT-PPS program", 2016-03-01, Meeting with LHCC referees-LHCC125, CERN, Switzerland

João Varela: "CT-PPS Status, Concept and strategy for 2016", 2016-03-15, LHC Working Group on Forward Physics and Diffraction, CERN, Switzerland

Jonathan Hollar: "Simulation of a possible resonance at 750 GeV in CT-PPS", 2016-03-16, LHC Working Group on Forward Physics and Diffraction, CERN, Switzerland

Nuno Leonardo: "workshop co-organizer and session convener", 2016-04-01, INFIERI 7th workshop, Lisbon

Jonathan Hollar: "Timing Readout Chain and DAQ", 2016-05-24, LHCC referees meeting, CERN, Switzerland

João Varela: "Introduction to CTPPS project status and plans", 2016-05-24, LHCC referees meeting, CERN, Switzerland

Nuno Leonardo: "Heavy Flavor Sessions convener", 2016-06-01, International conference LHCP 2016, Lund

Jonathan Hollar: "Calibration studies using ??->?? events", 2016-09-20, LHCC referees meeting, CERN, Switzerland

João Varela: "CTPPS detector status and plans", 2016-09-20, LHCC referees meeting, CERN, Switzerland

Giles Strong: "hh->tau tau b b studies", 2016-10-06, University of Padova secondment AMVA4NewPhysics project, Padova, Italy

Nuno Leonardo: "Intensity frontier, cosmics frontier, sessions convener", 2016-10-19, INFIERI 8th workshop, Chicago

João Varela: "General CT-PPS status and plans", 2016-11-29, LHCC referees meeting, CERN, Switzerland

12 Seminars

João Varela: "Introduction to LHC Physics", 2016-02-22, Course on Physics at the LHC, LIP, Lisbon

João Varela: "Experimental program at the LHC", 2016-02-24, Course on Physics at the LHC, LIP, Lisbon

João Varela: "Standard Model at the LHC", 2016-02-26, Course on Physics at the LHC, LIP, Lisbon

Michele Gallinaro: "Particle interactions and detectors", 2016-02-29, Course on Physics at the LHC, LIP, Lisbon

Michele Gallinaro: "Top quark: Introduction", 2016-03-21, Course on Physics at the LHC, LIP, Lisbon

Michele Gallinaro: "Top quark: Properties and beyond", 2016-04-04, Course on Physics at the LHC, LIP, Lisbon

Michele Gallinaro: "Higgs boson: Beyond the SM searches", 2016-05-16, Course on Physics at the LHC, LIP, Lisbon

Nuno Leonardo: "Lecture on Heavy Flavor Physics and Rare Decay Searches", 2016-06-06, Course on Physics at the LHC, Lisbon

Pedrame Bargassa: "Course on Supersymmetry I", 2016-06-08, ,

Pedrame Bargassa: "Course on Supersymmetry II", 2016-06-14, ,

Oleksii Toldaiev: "Study of ttbar->leptontau final state at 13TeV CMS", 2016-06-23, IDPASC Workshop in Porto, Porto

Nuno Leonardo: "Lecture on Search for New Resonances and New Physics at the LHC", 2016-07-25, Helmholtz International Summer School (HISS & DIAS TH), Dubna

Theses

4 PhD Theses

Cristóvão Silva: "Search for staus in the CMS experiment at the Large Hadron Collider" (ongoing)

Pietro Vischia: "Study of top quark properties and tests of the Standard Model at the LHC with the CMS detector" (finished on 2016-07-27)

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)

Daniele Vadruccio: "Search for the lepton violating decay tau to 3mu and trigger upgrade for LHC phase 2"

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

Events

1 Collaboration meeting

CMS B Physics Workshop 2016, Biblioteca Nacional, Lisboa, 2016-04-11 to 2016-04-11

PHENOMENOLOGICAL STUDIES AT THE LHC

LHC Phenomenology

The activities of the LHC Phenomenology Group within LIP are focused on building a significant collaboration of the experimental and theoretical particle physics community to better explore the data collected by the experiments where LIP is involved at the LHC. This effort is very much driven by the LHC top quark and Higgs physics, as well as searches for new phenomena beyond the Standard Model (SM). The project has been running for quite some time already, and several tools have been developed and made available to the LHC community. Examples like TopFit (a fitter of top quark properties and search for anomalous couplings beyond the SM), ScannerS (a global fitter for the Higgs physics) or, new Monte Carlo generators like MeTop (a NLO FCNC generator for single top quark production at the LHC), or even the develoment of the automatic analysis tool HepFrame (which allows to automatically identify the structure of a database which could be Root based and automatically build a complete analysis structured code with most of the required user interfaces for a full data analysis program), are good examples of the type of tools developed by the team which are in use at the LHC. The goals of the project involve not only searching for new observables to perform precise tests of the Standard Model (SM) of Elementary Particle Physics at LHC, but also to develop new ideas that may probe physics beyond the SM. Particularly successful has been the series of Top Quark Workshops that were initiated by the team and is running now for 11 years already (since 2006). In 2017, the 10th Edition of the workshop will be commemorated once again in Portugal, in Braga. The project has been crucial to develop a research group for the LHC physics in the University of Minho. The project itself is structured in several tasks which status is summarized in what follows.

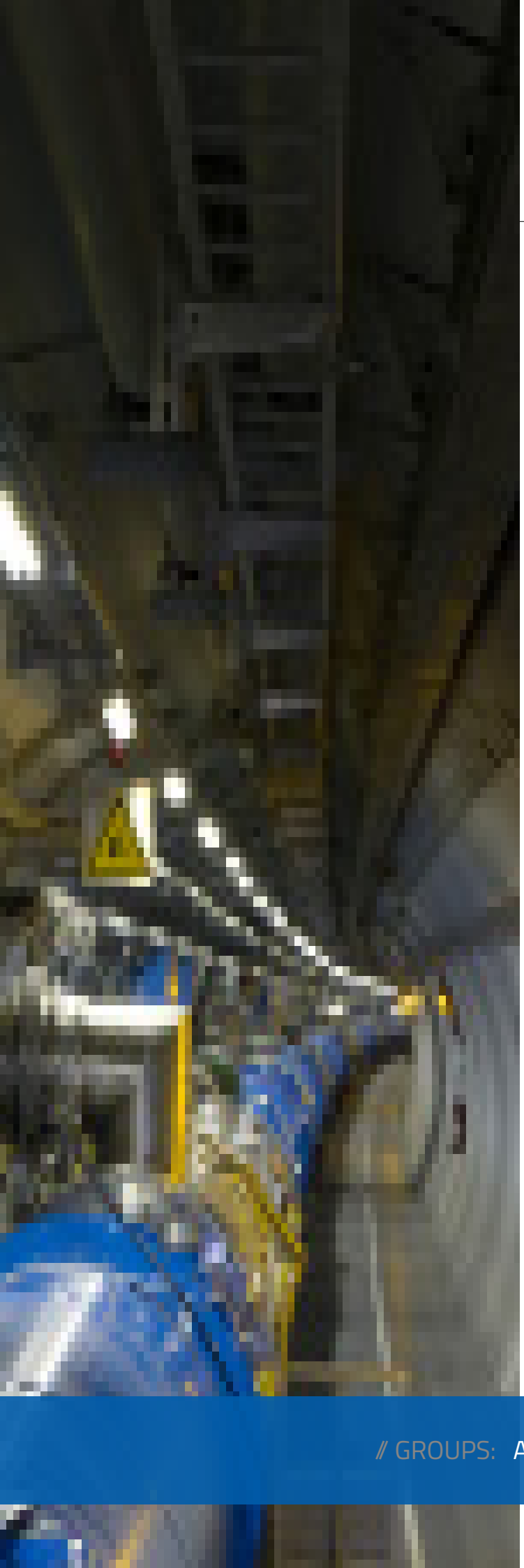
Framework and status for past and current year

Summary of performance indicators

Completed Theses: 1 Master

EXPERIMENTAL PARTICLE AND ASTROPARTICLE PHYSICS

LHC experiments and phenomenology



Team

Principal Investigator António Onofre (64)

Researchers
Miguel Fiolhais (75), Rita Coimbra (100)

Technicians
Henrique Carvalho (33)

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

Total FTE

2.7

// GROUPS: ATLAS / CMS / LHC phenomenology / HIP

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 LHC. Following the development of a model independent analysis for single top production via FCNC (where dimension 5 and 6 effective flavour changing and flavour conserving quark-gluon vertices were considered), the impact of these new couplings on the physical observables at LHC have been studied. Several contributions of this team (gg->tq, gq->tg, qq->tq) were in the past included in a general purpose generator like TopRex and a new NLO generator for single top production via FCNC (METop - MontE-Carlo generator for Top quark events) was developed. In METop the full NLO strong sector is included while the electroweak weak sector is included at approximately NLO. The LHC collaborations have used METop.

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. Although the double top production is insensitive to the Vtb CKM matrix element, the angular asymmetries between the top quark decay products can nevertheless give valuable information on the structure of the Wtb vertex. New vector and tensor like couplings were introduced within an effective Lagrangian approach, which can be probed at the LHC. A new software package, called TopFit, was made available to the physics community, which performs a global fit to the top quark observables (or related to top) in order to extract the best limits on the anomalous couplings. Using the recent measurements of top quark properties at ATLAS, CMS, at the LHC, and D0 and CDF at the Tevatron, combined limits on anomalous couplings at the Wtb vertex were set and published in 2 dimensional projections.

3. Study of Higgs Production and Couplings: The main goal of this task was related to the pp->tth process. The CP-violating tth vertex can be written as "a + i b gamma5", containing thus a scalar and a pseudo-scalar component. The team finished a work where we have explored a very large number of angular variables to facilitate the discrimination between signal and background in the final state pp -> tth -> 4b 2l ME. These studies have been performed assuming that the Higgs is a pure scalar particle once the goal was here to optimize the signal over background ratio. 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.

4. Probing the seesaw mechanism: The main goal of this task was to explore the clean signals of multilepton final states to probe the seesaw mechanism at LHC. This study has great interest because a positive answer would unveil the neutrino mass generation mechanism, which is an important step towards a theory of flavour, which is one of the standing problems in particle physics. On the other hand, final states with several leptons appear in other new physics models like models of extra dimensions with custodial symmetry.

5. Theoretical Models and Monte Carlo Generators: One of the required tasks in this project was the development of theoretical models for the different topics under study and the implementation of dedicated Monte Carlo generators. Most of the work was concentrated on the Higgs physics and models to search for new physics.

6. Smart Computing in Platforms with Accelerating Devices: Robust and accurate simulations require heavy and high performance computations (HPC). To be sustainable, and in particular to best explore and process the huge data collected at the LHC, HPC requires tools optimized for computational efficiency, developed by experts with deep knowledge on the computing platforms where the code is executed, within a multidisciplinary team work. In the current task the team proposed to modify and develop efficient tools and frameworks for data analysis at the LHC, in complementary tasks (Monte Carlo generators, global fitters, reconstruction tools). 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).

Stated objectives for past year

The main objective of the project was to strengthen the collaboration between experimental and theoretical physicists for phenomenological studies with a special impact on the LHC physics. 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 couplings at the LHC, via ttH;

4. the seesaw mechanism and the problem of neutrino masses;

5. theoretical improvements related to models under development;

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

One objective particularly relevant was the development of a new research group and new branch of LIP (LIP-Minho) at the University of Minho, North of Portugal, bringing the field of High Energy Particle Physics and Astroparticle Physics to the Northern Universities of Portugal. This initiative started February 2010.

Achievements and responsibilities during the past year

The main achievements of the project, which reflect the tem work over some time already, can be summarised in the following:

- A strong collaboration between experimentalists and theoretical physicists was developed for the LHC.
- For the single top production via FCNC at the LHC, the cross sections were included in a new version of Monte Carlo Generator TopRex (ver 4.20) and a new NLO generator (METop) has been developed and is available to the LHC community for testing.
- For the Study of Top Quark Anomalous Couplings, new asymmetries were found and published by the team (the A+ and A-) apart from the Forward-Backward asymmetry, which proved to be more sensitive to the structure of the Wtb vertex. Considering the most recent data from LHC and Tevatron the first results on the Wtb vertex structure were established.
- For the development of Theoretical Models, several studies were performed and the inclusion of the obtained cross sections in Monte Carlo generators under development was acomplished.
- The project has been very successful in motivating young students (license, Master and PhD) due to the strong collaboration between experimentalists and theoretical physicists.
- A strong collaboration between the Particle Physicists and Engineers from the Informatic Engineer Department of the University of Minho has been accomplished.
- The development of the LIP-Minho group has been very successful, including University Professors, undergraduate, master and PhD students.
- The list of students directly involved in activities of the project involves undergraduate, master and PhD students, as well as postdocs.

Lines of work and objectives for next year

The lines of work of the project for next year depend very much on the expertise acquired, and are concentrated in:

1. **Top Quark Production at the LHC**

   The main goal of this task is to develop a global fitter for FCNC vertices (tqZ, tqg, tqgamma and tqH) which will allow to set consistent limits on the possibility of new physics in top quark production (in ttbar and single top processes at the LHC) and decay. New contributions associated to top quark production and decay through the Higgs channel will also be considered

2. **Study of Top Quark Couplings in ttbar events**

   The LHC at 13 and 14TeV is expected to be a top factory. This fact allows for the improvement on the measurement of the Wtb vertex and the couplings of the top quark. A combination of several measurements, using also the results from the Tevatron collider (CDF and D0) will be performed to simultaneously set limits on all anomalous couplings parameters with TopFit. Given the expected measurements of the ATLAS, CMS and Tevatron experiments, a combination of the results is expected to be explored using TopFit. Results on the real and imaginary parts of the couplings are expected to be obtained at the new energy regimes of the LHC, 13 and 14TeV. This task complements well the first one i.e., while the first one is dedicated to the development of a global fitter for the neutral currents interactions of top quarks, the current task is dedicated to the study of the charge current interactions of top quarks. The results previously presented by the team i.e., the limits on the anomalous couplings in 2 dimensional planes, are to be complemented by 3 dimensional distributions. Part of the 3-dimensional distributions were already studied and published. The latest measurements at the LHC will be included as well as new observables to study their impact.

3. **Study of Higgs Production and Couplings**

   This task is related to the associated production of top quarks together with higgs boson (ttH) at the LHC and the study of the tth vertex CP nature which can be written as “a + i b gamma5”, containing thus a scalar and a pseudo-scalar component. The plan is to build all possible angular asymmetries that could probe the scalar to pseudoscalar ratio. The team is planning to use several angular distributions measured at detector level. The team plans to use some versions of the 2HDM and 3HDM as benchmark models to the extra background contribution. In both cases our proposal is different from the previous ones in that we will always release detector level studies. The team have just shown that many angular distributions that looked very promising at parton level become useless when a complete detector level study is performed (paper published). The

sensitivity to a possible new pseudoscalar component of the top-Higgs coupling will be explored as a function of luminosity.

4. Probing the seesaw mechanism

In this project the team proposes to continue exploring the clean signals of multilepton final states to probe the seesaw mechanism at LHC. This task is a continuation of a previous one, on the same subject.

5. Theoretical Models and MC Generators

One of the required tasks in this project is the development of theoretical models for the different topics under study and the implementation of dedicated Monte Carlo generators and global fitters. The strong collaboration with the theoreticians is expected to be extended to the New York university group on the interpretation of the top quark-Higgs couplings distributions.

6. Smart computing in platforms with accelerating devices

In this current project the team proposes to modify and/or develop efficient tools and frameworks for data analysis at the LHC, in complementary tasks (Monte Carlo generators, global fitters, reconstruction tools). These tools and frameworks will automatically adapt to the current and new emerging heterogeneous computing platforms, in a completely transparent way to the physics users. The HepFrame is to be adapated to several analysis developped by the team.

SWOT Analysis

In the present project, specific topics of the physics program of the LHC are addressed from both the experimental and theoretical points of view. Following the work previously developed by the experimental team at the LHC, the inclusion of new members from the field of theoretical particle physics allow us to develop a High Energy Physics group specifically dedicated to the physics at the LHC. The aim of this project is to support this group giving special emphasis to the training of MSc and PhD students and motivation to new undergraduate students.

The strongest points:

The project has been very successful, and continues to be so in attracting students (from Portuguese and foreign Universities) and provided the correct framework for the development of several MSc and PhD thesis already, both in experimental and theoretical physics. The project allowed to bring together the experimental and theoretical communities under a common goal of research, with the long term objective of exploring in an efficient way the data that will be collected at the LHC. Particularly relevant was the fact that a new branch of LIP (LIP-Minho) was developed at the University of Minho, North of Portugal, bringing the field of High Energy Particle Physics and Astroparticle Physics to the Northern Universities of Portugal (already discussed in the introduction of the present report). 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 is available to users) was also a very interesting achievement in terms of the clear sinergies that can be build among two different fields of science: Computing and Physics.

The weakest points:

The weakest point of the project is the very limited budget for the activities planned. In the last couple of years, the group simply did not have any financial support. The driving force of the team is essentially the motivation and skills of its members and the will to overcome all difficulties.

Theses

1 Master Thesis

Emanuel Gouveia: “Search for ttH production with the ATLAS experiment at the LHC” (finished on 2016-06-29)

HEAVY ION PHENOMENOLOGY

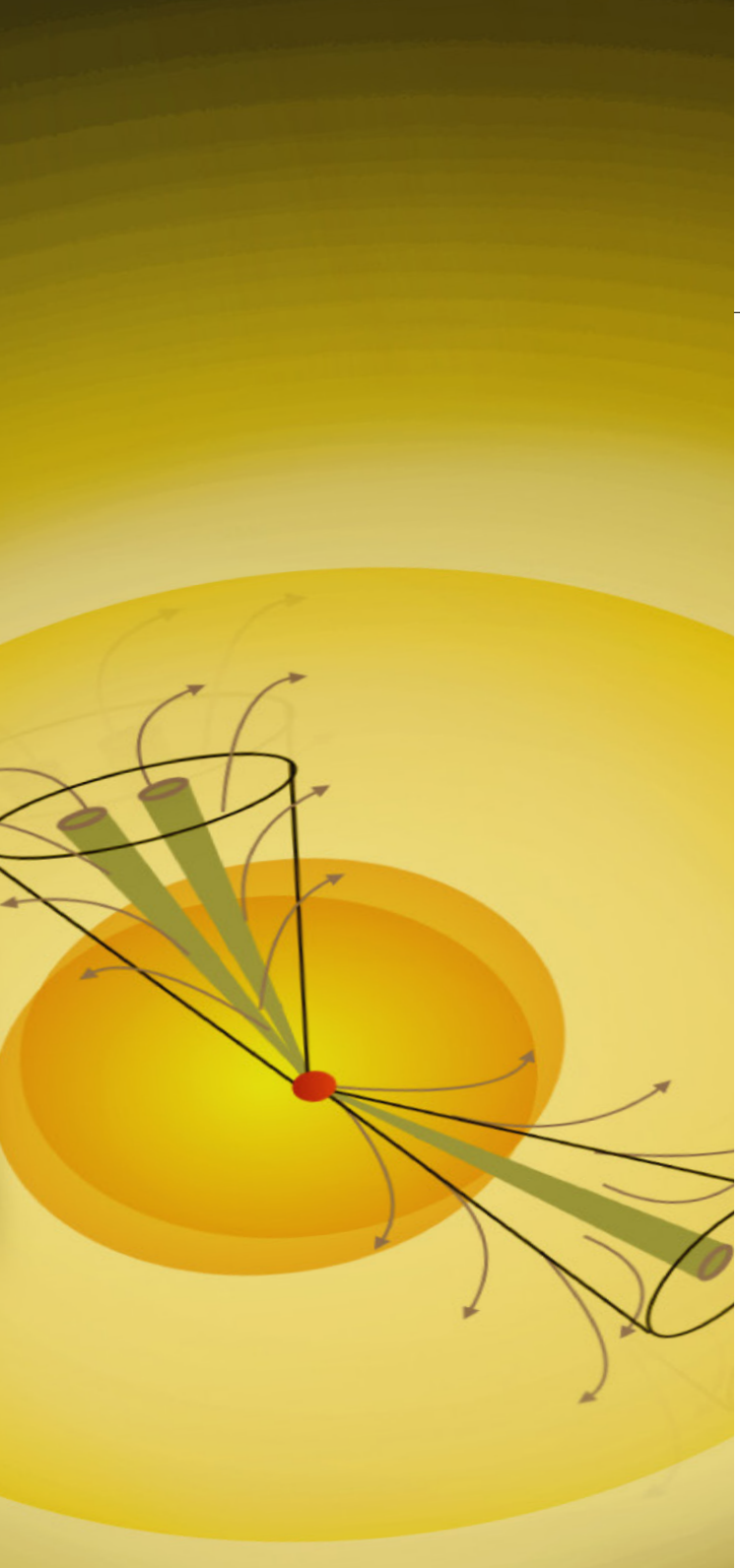
HIP

The Heavy Ion Phenomenology Group (HIP@ LIP) focuses 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. Our research revolves around two complementary lines: the use of unique potential of jets as multi-scale probes of the QGP, and the determination of the initial conditions in hadronic and nuclear collisions as a tool to distinguish, in existing and future experimental data, bona-fide QGP effects from those arising from intrinsic initial state complexity. The group offers a complementary phenomenological approach to experimental activities of the LIP groups working on LHC experiments. The activities reported here refer to the period since the group formally joined LIP in August 2016.

Framework and status for past and current year

Summary of performance indicators

Articles in international journals:	8 With direct contribution from team
International conferences:	7 Oral presentations 7 Proceedings



Team (*)

Principal Investigator Guilherme Milhano (100)

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

Total FTE
3.7

(*) Starting in August 2016.
Counts 1.5 FTE in 2016

// GROUPS: ATLAS / CMS / LHC phenomenology / HIP

Lines of work and team organization

The group develops its research along the following lines:

1. jets as QGP probes:
1.1 Development of Monte Carlo event generators for jets in heavy ion collisions (Q-PYTHIA, JEWEL, stron/weak coupling hybrid) and general-purpose (SHERPA).

1.2 Jet phenomenology focused on determination of sensitivity of observables to specific QGP properties

1.3 Computation of first-principle rules for jet dynamics in QGP

2. Initial conditions:
1.1 Proton and nuclei structure determination via global fits using non-linear (Colour Glass Condensate) evolution.

1.2 Computation of observables sensitive to initial conditions in proton-nucleus and nucleus-nucleus collisions

Besides collaborations within the group, all researchers in the group are involved in external collaborations, chiefly with the heavy ion phenomenology groups of Santiago de Compostela (Spain), CERN and MIT (USA) and experimental groups within and outside LIP.

The group spearheaded and presently leads the implementation of the Lisbon Accord (an agreement between the experimental and phenomenological communities for the adoption of standards fair theory-experiment comparisons and data legacy) and participates in the US-based JETSCAPE collaboration.

Stated objectives for past year

At the organizational level, the key group objective was to integrate smoothly in LIP. At the scientific level:

1. inclusion of QGP back-reaction effects in the strong/weak coupling hybrid model

2. implementation of background subtraction in JEWEL

3. implementation of boson-jet processes in JEWEL

4. assessment of sensitivity of sub-structure jet observables to QGP effects

5. first-principle computation of radiation spectrum for non-eikonal antenna

6. participation in the development of the case for a nucleus-nucleus option in a future circular collider (FCC)

Achievements and responsibilities during the past year

The stated objectives were accomplished. The group has successfully integrated in LIP. Objectives 1, 2, and 3 resulted each in a publication; objective 4 has led to two articles, both in final drafting stages. Two members of the group (Guilherme Milhano and Liliana Apolinário) played a pivotal role in the heavy ion FCC write-up with Guilherme Milhano acting as co-editor of its hard probes section. During the moving process to LIP, the group organized the 3rd International Conference on the Initial Stages in High-Energy Nuclear Collisions (InitialStages2016) at IST. The conference had an attendance of 120.

The group output was presented at 5 international conference (2 of which invited talks).

Lines of work and objectives for next 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

SWOT Analysis

Strenghts

Wide and consolidated network of international collaborators; high international visibility; solid and complementary competences in the group.

Weaknesses

Lack of students; small group

Opportunities

Integration in LIP potentiates attraction of students; application for European funding allowing for substantial group growth

Threats

Possible reduction of funding following changes in FCT schemes; employment precariousness (none of the group members has a permanent work contract) leading to group members seeking stable employment elsewhere (one group postdoc will leave in early 2017 to take permanent contract in Poland)

Publications

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

Tolga Altinoluk, Néstor Armesto, Guillaume Beuf, Alex Kovner, Michael Lublinsky: "Hanbury–Brown–Twiss measurements at large rapidity separations, or can we measure the proton radius in p-A collisions?", Phys.Lett. B752 (2016) 113-121

Tolga Altinoluk, Néstor Armesto, Guillaume Beuf, Alexis Moscoso: "Next-to-next-to-eikonal corrections in the CGC", JHEP 1601 (2016) 114

Jorge Casalderrey-Solana, Doga Can Gulhan, José Guilherme Milhano, Daniel Pablos, Krishna Rajagopal: "Predictions for Boson-Jet Observables and Fragmentation Function Ratios from a Hybrid Strong/Weak Coupling Model for Jet Quenching", JHEP 1603 (2016) 053

Tolga Altinoluk, Néstor Armesto, Guillaume Beuf, Alex Kovner, Michael Lublinsky: "Heavy quarks in proton-nucleus collisions - the hybrid formalism", Phys.Rev. D93 (2016) 054049

José Guilherme Milhano, Korinna Christine Zapp: "Origins of the di-jet asymmetry in heavy ion collisions", Eur.Phys.J. C76 (2016) 288

Tolga Altinoluk, Néstor Armesto, Guillaume Beuf, Amir H. Rezaeian: "Diffractive Dijet Production in Deep Inelastic Scattering and Photon-Hadron Collisions in the Color Glass Condensate", Phys.Lett. B758 (2016) 373-383

Tolga Altinoluk, Adrian Dumitru: "Particle production in high-energy collisions beyond the shockwave limit", Phys.Rev. D94 (2016) 074032

Raghav Kunnawalkam Elayavalli, Korinna Christine Zapp: "Simulating V+jet processes in heavy ion collisions with JEWEL", Eur.Phys.J. C76 (2016) 695

7 International conference proceesdings

Tolga Altinoluk, Nestor Armesto, Guillaume Beuf, Alexis Moscoso: "CGC beyond eikonal accuracy: finite width target effects", EPJ Web Conf. 112 (2016) 02001

Jorge Casalderrey-Solana, Doga Can Gulhan, Jose Guilherme Milhano, Daniel Pablos, Krishna Rajagopal: "Boson-Jet Correlations in a Hybrid Strong/Weak Coupling Model for Jet Quenching in Heavy Ion Collisions", C15-06-29.7

Liliana Apolinário, Néstor Armesto, Guilherme Milhano, Carlos A. Salgado: "In-medium jet evolution: interplay between broadening and decoherence effects", Nucl.Phys. A956 (2016) 681-684

T. Altinoluk, N. Armesto, G. Beuf, A. Kovner, M. Lublinsky: "Initial State Correlations and the Ridge", Acta Phys.Polon.Supp. 9 (2016) 479-485

Korinna Christina Zapp, Guilherme Milhano, Urs Achim Wiedemann: "The sensitivity of R_{pA} to colour recombination effects", Nucl.Phys. A956 (2016) 609-612

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

7 Oral presentations in international conferences

Liliana Apolinário: "Recent progress in understanding medium-induced jet evolution and energy loss in perturbative QCD", 2016-08-01, XII Quark Confinement and Hadron Spectrum Conference, Thessaloniki (Greece)

Tolga Altinoluk: "Initial State Correlations", 2016-09-01, QCD at LHC: forward physics and UPC collisions of heavy ions, ECT* Trento (Italy)

Liliana Apolinário: "In-medium parton branching beyond eikonal approximation", 2016-09-01, Light Cone 2016, Lisbon (Portugal)

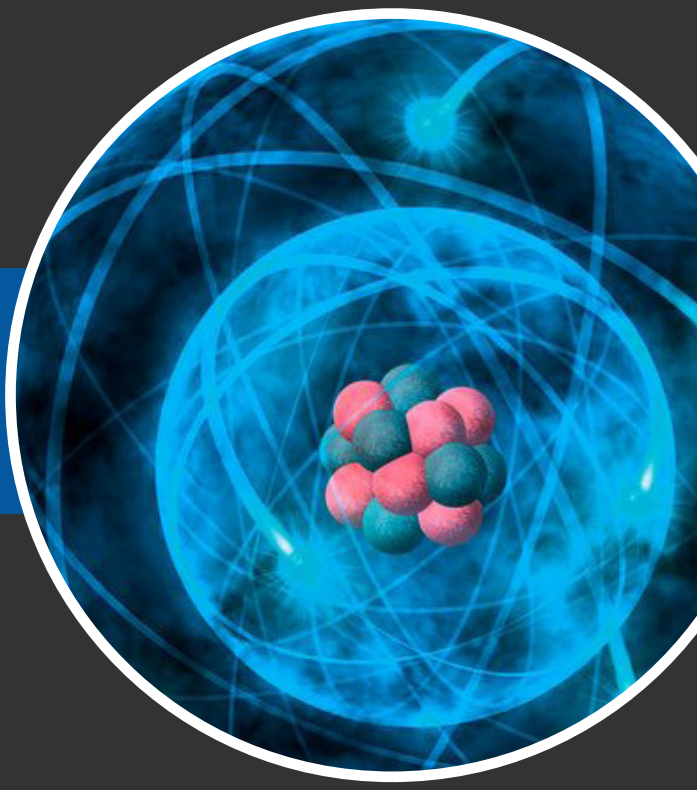
Liliana Apolinário: "Factorization of in-medium parton branching beyond the eikonal approximation", 2016-09-01, Hard Probes 2016, Wuhan (China)

Liliana Apolinário: " Status report: QPYTHIA", 2016-09-01, Hard Probes 2016, Wuhan (China)

Tolga Altinoluk: "Quark correlations in the CGC: Pauli Blocking and the Ridge", 2016-10-01, Various Faces of QCD 2, Swierk (Poland)

Guilherme Milhano: "How will recent and future jet measurements help us understand QGP?", 2016-10-01, Recent RHIC and LHC results and their implications for heavy ion physics in the 2020's, MIT, Boston (USA)

Structure of matter



COLLABORATION IN THE COMPASS EXPERIMENT AT CERN

COMPASS

COMPASS experiment is dedicated to the study of the structure of the nucleon. The previous COMPASS programme, which lasted till 2011, focused on the measurement of the gluon polarisation Delta_g/g (via two different approaches, the open charm photoproduction and the high p_T physics), of the longitudinal and the transverse quark spin structure and of the fragmentation functions. With a hadron beam, COMPASS studied the pion polarisabilities and some spectroscopy issues, as the production of new mesons and baryons, namely exotics or hybrids.

COMPASS uses high intensity beams, that is, a polarised muon (or hadron) beam impinging on a longitudinally or transversely polarised target (or a liquid hidrogen target) followed by a two stage spectrometer: a first one with a large angular acceptance, followed downstream by a second one with a reduced acceptance, designed to detect particles up to more than 100 GeV/c. In its original design, as stated in the first Proposal, each spectrometer is equipped with a magnet sorrounded by trackers, a set of electromagnetic and hadronic calorimeters, muon filters and a Cerenkov detector (RICH) for particle identification. The data acquisition system is based on a parallel read-out of the front-end electronics plus a distributed set of event-builders, specially designed to cope with huge data volumes.

Since our LIP-Lisbon group took in COMPASS the full responsibility of the Detector Control System (DCS), it has been continuously evolved, in order to introduce flexibility, reliability and speed. As a major change, one should point out the development of a new system's architecture: the introduction of important changes, both in the supervision (top) layer and in the front-ends layer (detectors interfaces), transforming a hardware oriented architecture into a detector oriented one. In fact, the DCS can not be a static system or a finalised product, because it is formed by a set of several packages, disposed in layers but strongly interacting. This means that the packages versions must be compatible among them.

On the other hand, the continuous COMPASS upgrade, in what concerns new detectors, namely new detectors for specific data takings, also imposes successive changes in the DCS, both concerning the software and the hardware interfaces. In view of this, the DCS is always increasing in complexity (new types and number of hardware interfaces with the detectors, new drivers), namely due to the non uniformity of the COMPASS detectors hardware.

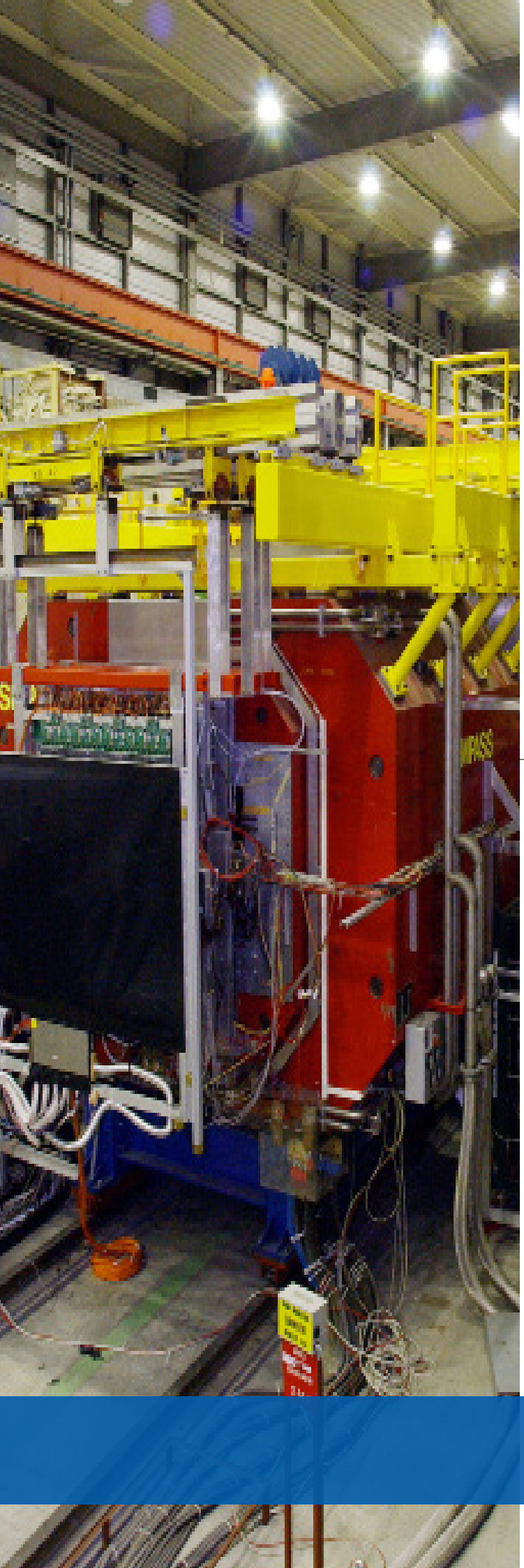
Framework and status for past and current year

In what concerns the analysis of the data already acquired, the group has been strongly contributing to key subjects of the COMPASS Collaboration, namely studies on the gluon polarisation from hard scale produced events originating from different processes, as the open charm meson production and high transverse momentum hadron production, on the longitudinal and transverse components of the nucleon polarised structure function, and on the hadron multiplicities and fragmentation functions extraction. Results concerning these matters have been published in international reviews, and have already plenty of citations.New analysis methods were also developed, in order to increase the results precision. Studies concerning the spectrometer simulation in relation with different physics channels were also developed, in view of contributing to the analyses results.

In the context of the present COMPASS Programme, the members of this Project have been playing an important role in the part concerning studies on transversity, namely TMD PDFs (Transverse Momentum Dependent Parton Distribution Functions), through the polarised Drell-Yan process (DY), which 2015 several months data taking was a first dedicated world measurement. In this respect, the group has developed studies concerning the preparation of the DY experiment, namely the study of physics generators and their simulation in the spectrometer, as well as the detector optimisation and the data reconstruction programme development.

In what concerns the new setup, adapted to the DY experiment, our group developed studies related to the design of new spectrometer components, as well as to its global simulation, including the dimuon trigger optimisation. Its instalation and test took place during the fall of 2014.

Presently, our group coordinates in COMPASS the data reconstruction and the data analysis relative to the long 2015 DY physics run, as well as of the 2014 pilot run.In this context, our group assumed a crucial role on the checks of the data stability and quality, and on the optimisation of data



reconstruction. The full data sample of the 2015 polarised DY run could be reconstructed in record time, and the analyses are now ongoing. The results are expected to provide a crucial check of non-perturbative QCD: the sign change of the Sivers transverse momentum dependent parton distribution function of the nucleon, when accessed from DY or from semi-inclusive deep inelastic scattering (SIDIS). The LIP group is leading this analysis effort.

In 2016, COMPASS devoted its data-taking to the study of exclusive processes in deep inelastic scattering: the Deeply Virtual Compton Scattering (DVCS) and the Deeply Virtual Meson Production (DVMP). These measurements were done with a polarized muon beam impinging on an unpolarised liquid hydrogen target. Two fundamental detectors were newly built, installed and commissioned: a recoil proton detector (CAMERA), and a large angle electromagnetic calorimeter (ECAL0). The implementation of the slow control of these new detectors was a responsibility of the LIP group.

In parallel with the exclusive measurements, also the SIDIS with unpolarised target was measured, with the goal of multidimensional extraction of unidentified hadron multiplicities, as well as the charged pion and kaon multiplicities. These provide crucial input for the determination of the quark fragmentation functions, in a not yet explored kinematic range. The group is directly involved in these studies.

Team

Principal Investigator Paula Bordalo (90)

Researchers
Catarina Quintans (100), Celso Franco (80), Luis Silva (80), Márcia Quaresma (100), Marcin Stolarski (100), Sérgio Ramos (90)

Technicians
Christophe Pires (100)

PhD students
Sofia Nunes (100)

Total FTE

8.5

Summary of performance indicators

Articles in international journals:	3 With direct contribution
International conferences:	8 Oral presentations 6 Proceedings
National conferences:	3 Oral presentations
Collaboration meetings:	1 Oral presentation
Collaboration notes:	1 Collaboration note
Outreach:	1 Seminar
Completed theses:	1 PhD

Lines of work and team organization

The COMPASS LIP group has both technical and analysis/offline lines of work.

Data Analysis / Offline Studies

The research follows two main lines of work: the Drell-Yan and the deep inelastic scattering programmes. Technical aspects important for data analysis, like detector performance studies and reconstruction codes development, are also lines of work. The team members involved in these tasks are listed bellow.

Paula Bordalo
Celso Franco
Sofia Nunes
Márcia Quaresma
Catarina Quintans
Sérgio Ramos
Luís Silva
Marcin Stolarski

Detector Control System

Development and maintenance of high and low level interfaces with all COMPASS detectors is the sole responsibility of the COMPASS LIP group.

Paula Bordalo
Christophe Pires
Sofia Nunes
Sérgio Ramos

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

Stated objectives for past year

One of the main current COMPASS physics goals is the polarised Drell-Yan experimental programme, which has been developed by LIP together with the Torino group, these two being the leading groups on this subject.

Also, a major activity of LIP is data analysis in view of the physics results extraction, together with technical developments for the present COMPASS physics programme. With respect to data analysis, the subjects carried on by LIP members are among the most important analysis channels of the experiment.

Moreover, LIP has the full responsibility of the Detector Control System (DCS) of the experiment, since it joined the COMPASS Collaboration, in September 2002.

The LIP group of the COMPASS experiment carried on the matters related with the working activities, namely data analysis and offline studies; full responsibility of the Detector Control System (DCS); and general activities. These subjects are developed hereafter.

Achievements and responsibilities during the past year

Data Analysis and Offline Studies

The analysis and offline studies task has always been a major concern of our group. The analysis subjects carried on by LIP members are among the most important analysis channels of the experiment.

As a consequence, our members have presented their results in several International Conferences, on behalf of COMPASS.

In 2016 the following subjects were addressed:

- Studies of alignment quality, trigger, reconstruction and pseudo-efficiencies relative to the 2015 DY data.
- Preparation of the full 2015 DY data production and control studies of the production quality.
- Studies of event selection and optimisations cuts for the 2015 DY data.
- Studies of target polarisation concerning the 2015 long DY polarised data taking.
- Studies of uncorrelated background in the dimuon mass spectra.
- Extraction of first results on one dimension and on a multi-dimensional analysis of the azimuthal spin asymmetries from the DY process in a transversely polarised target, in order to access several TMD functions.
- Multi-dimensional analysis of the transverse spin asymmetries from hadrons produced by muon scattering in a transversely polarised proton in the same kinematical region as DY analysis.
- Study of the gluon contribution to the nucleon Sivers effect from high p_T hadron pairs and high Q^2 .
- Spin asymmetries analysis in the low x_Bj and low Q^2 region, in order to extract the polarised structure function g_1^p(x).
- Studies of radiative corrections in semi-inclusive deep inelastic scattering.
- Study of the RICH quality particle identification in order to better identify pions and kaons.
- Measurement of hadron, pion, K- and K+ multiplicities as functions of z and p_T, in view of the fragmentation functions extraction.

Detector Control System

In 2016, the DCS proceeded with the tasks of continuing the integration of new or refurbished COMPASS detectors, in view of the Deep Virtual Compton Scattering long data taking.

In this context, the DCS monitoring developments concerned: the liquid hydrogen target (via several protocols: DIM, DIP and PLCs); the low and high voltages for the silicon detectors and monitoring of its cryogenic system (through ModBus); the high voltages for the new recoil proton detector - CAMERA, the Beam Momentum Spectrometer, the scifis stations, as well as veto and trigger hodoscopes (through OPC and SLiC).

Also, some major integrations took place: the new ECAL0 and monitoring of its cooling and ventilation system (via PLC); the RICH new modules, CsI Thick GEM; the ECAL1 and ECAL2 new laser system monitoring; the MWPCs new low voltage control (via ELMB/CANOpen).

One should stress that the DCS has to deal with a vast variety of COMPASS equipments that are being or will be controlled or monitored. While for some devices commercial supervision solutions exist (like OPC servers), for many others these solutions do not. That is why case-by-case solutions must be applied, namely by writing the drivers to control/monitor such devices, and integrate them in PVSS/WinCC OA, whenever necessary.

It is worth noting that the DCS system works practically 12 months per year. In fact, during the no-beam part of the year, several DCS sub-systems run, in order to control some devices, as it is the case of detectors gas systems. This implies the permanent presence of a group member at CERN, insuring also on-call activities during the long data taking period..

General Activities

COMPASS LIP-Lisbon members participated in the following general activities:

- Participation in the data taking periods and in their preparation.
- Participation in the Collaboration meetings.
- Member of the COMPASS Collaboration Board (P. Bordalo , S.Ramos).
- Coordination of the Drell-Yan analysis COMPASS subgroup (C.Quintans).
- Member of the COMPASS Publications Committee (M. Stolarski).
- Participation in the monthly offline and analysis meetings.
- Participation in several weekly subgroups on analysis and offline meetings.
- Participation in the technical friday meetings during the data takings.
- Week coordinations of the data taking (S. Nunes, C. Quintans, M. Stolarski).
- Participation in several paper's drafting committees.

Lines of work and objectives for next year

Concerning our commitments in COMPASS, besides the general tasks, attributed to each member of the Collaboration, our group will continue to contribute with an important role in the analysis effort as well as in offline studies.

Thus, in 2017 our tasks will be the following:

- to continue the studies of the azimuthal spin asymmetries in the Drell-Yan data;
- to prepare the new 2018 long Drell-Yan polarised data taking;
- to start the study of Psi production in hadron collisions;
- to conclude the spin asymmetries study concerning low x_Bj and low Q^2 physics, in order to extract the proton longitudinally polarised structure function g_1(x);
- to continue studies on hadron, pion and kaon multiplicities;
- to participate in the preparation of the 2017 DVCS run and in its long data taking;
- to participate in the discussion of physics issues beyond 2020 and the corresponding COMPASS spectrometer upgrade;
- to participate in the Collaboration and several other COMPASS meetings;
- to participate in several paper's drafting committees;
- to participate in several International Conferences/ Workshops.

In what concerns our technical commitment in COMPASS, some Detector Control System (DCS) developments and maintenance will take place for the 2017 data taking on the DVCS programme.

SWOT Analysis

Strengths

The group is well integrated in COMPASS, accomplishing both its technical duties, namely the global Detector Control System full responsibility since it joined the Collaboration in 2003, as well important physical aspects, in which it participated and leaded several physics channel analyses, some of them being the most important COMPASS ones.

The team is very motivated and committed to the completion of the ongoing analyses. The knowledge within the group opens new possibilities for future, novel studies. The approval during 2016 by the CERN SPS Committee of another year of polarized Drell-Yan data-taking in 2018 provides the opportunity to improve some elements of the setup and revise the data-taking methodology. The LIP group is very well positioned to have a leading role in this respect.

Weaknesses and Threats

The number of students interested in Particle Physics is clearly declining in the last few years, perhaps due to wrong policy of courses restructuration in our universities. The present national policy on grants attribution together with the precarious situation of the majority of team members is delicate to guarantee the conditions for the continuation of the group.

Opportunities

The present and the future polarised Drell-Yan physics programme, which will allow to deepen the understanding on the spin structure of the nucleon, namely the study its of transverse components, by accessing different TMD PDFs. Concerning the non-polarised programme, the understanding of the quark fragmentation into hadrons can be accessed.

Publications

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

P. Bordalo. C. Franco, M. Quaresma, C. Quintans, A.S. Nunes, S. Ramos, M. Stolarski, L. Silva et al: "The spin structure function g1 p of the proton and a test of the Bjorken sum rule", Phys Lett B 753 (2016) 18

P. Bordalo. C. Franco, M. Quaresma, C. Quintans, A.S. Nunes, S. Ramos, M. Stolarski, L. Silva et al: "Interplay among transversity induced asymmetries in hadron leptoproduction", Phys Lett B 753 (2016) 406

P. Bordalo. C. Franco, M. Quaresma, C. Quintans, A.S. Nunes, S. Ramos, M. Stolarski, L. Silva et al: "Longitudinal double spin asymmetries in single hadron quasi-real photoproduction at high pT", Phys Lett B 753 (2016) 573

6 International Conference Proceedings

M. Quaresma, for COMPASS Collaboration: "Polarised Drell-Yan process in the COMPASS experiment", PoS DIS2016 (2016) 218

A.S. Nunes, for COMPASS Collaboration: "The spin structure of the proton at low x and low Q2 in two-dimensional bins from COMPASS", PoS DIS2016 (2016) 229

M. Quaresma, for COMPASS Collaboration: "Study of the hadron structure using the polarised Drell-Yan process at COMPASS", Proceedings of MENU16 Conference

L. Silva, for COMPASS Collaboration: "Azimuthal angular distributions using unpolarized Drell-Yan data from COMPASS at CERN", Proceedings of SPIN16 Conference

C. Quintans: "Nucleon Spin Structure from experiments using the Drell-Yan Process", Proceedings of SPIN16 Conference

L. Silva, for COMPASS Collaboration: "The measurement of the gluon Sivers asymmetries in COMPASS at CERN", Proceedings of SPIN16 Conference

3 Internal notes

E. Seder, D. Hahne, Y. Bedfer, N. du Fresne, E. Kabuss, F. Kunne, N. Makke, N. Pierre, M. Stolarski: "Publication update for charged kaon multiplicities from muon DIS on 6LiD 2006 data",

B. Parsamyan, M. Quaresma, M. Vit: "COMPASS Drell-Yan 2015 data with NH3 and W targets: ongoing analysis Kinematic distributions and projected uncertainties for the asymmetries",

A. Szabelski and L. Silva on behalf of the Compass Transversity group: "Determination of the Collins asymmetry for gluons for Q2 > 1(GeV/c)2",

Presentations

8 Oral presentations in international conferences

Márcia Quaresma: "Polarised Drell-Yan process in the COMPASS experiment", 2016-04-12, XXIV International Workshop on Deep-Inelastic Scattering and Related Subjects - DIS2016, Hamburg, Germany

Sofia Nunes: "The spin structure of the proton at low x and low Q2 from COMPASS", 2016-04-13, XXIV International Workshop on Deep-Inelastic Scattering and Related Subjects - DIS2016, Hamburg, Germany

Márcia Quaresma: "Study of the hadron structure using the polarized Drell-Yan process at COMPASS", 2016-07-27, 14th International Conference on Meson-Nucleon Physics and the Structure of the Nucleon, Kyoto, Japan

Luís Silva: "The measurement of the gluon Sivers asymmetries in COMPASS at CERN", 2016-09-26, 22nd International Spin Symposium, Champaign, Illinois, USA

Catarina Quintans: "Nucleon Spin Structure from experiments using the Drell-Yan Process", 2016-09-27, 22nd International Spin Symposium, Champaign, Illinois, USA

Luís Silva: "Azimuthal angular distributions using unpolarized Drell-Yan data from COMPASS at CERN", 2016-09-28, 22nd International Spin Symposium, Champaign, Illinois, USA

Catarina Quintans: "Drell-Yan measurements at COMPASS", 2016-12-02, International Workshop 3D Parton Distributions: Path to the LHC, Frascati, Italy

Celso Franco: "COMPASS results on the nucleon spin structure", 2016-12-10, International Conference on Astrophysics and Particle Physics, Dalllas, USA

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 Outreach seminars

Paula Bordalo: "Desvendar os mistérios do nucleão - A Experiência COMPASS @ CERN", 2016-02-24, Interview published in the magazine Pulsar of the IST physics students group – NFIST, Lisbon, Portugal Pulsar, Edição 37, 2016

Theses

2 PhD Theses

Sofia Nunes: "Study of asymmetries with polarised proton target at low xBj and Q2" (ongoing)

Márcia Quaresma: "Transverse momentum dependent parton distributions functions through SIDIS and Drell-Yan at COMPASS" (finished on 2016-07-08)

Events

1 Conference

member of the Scientific International Advisory Committee of the Light Cone 2016 Conference, Lisbon, Portugal, 2016-09-05 to 2016-09-08

1 Workshop

member of the Scientific International Advisory Committee of the IWHSS 2016 Workshop, Seeon, Germany, 2016-09-05 to 2016-09-07

COLLABORATION IN THE HADES EXPERIMENT AT GSI

HADES

The LIP HADES group was originally created for the design and construction of a Time of Flight (TOF) detector based on Resistive Plate Cambers (RPCs) technology, RPC-TOF wall (RPC-TOF-W), for the HADES spectrometer, operated at GSI, Darmstadt, Germany (https://www-hades.gsi.de/). In recent years, the group was complemented with the incorporation of people from the LIP-COMPASS group at Lisbon who assumed tasks on the analysis.

After initial design, prototyping, construction, commissioning and several data taking campaigns, including the successful heavy system Au + Au in 2012 and pion induced reactions in 2014, the accelerator infrastructure has been shut down for a complete upgrade, in the beginning of 2015. This upgrade will put into operation the future SIS100 in the framework of the FAIR facilities (http://www.fair-center.eu/) providing higher beam energies and intensities. HADES will be one of the first experiments to be operative in the new infrastructure with the mission of providing high-quality di-lepton data at baryon densities and temperatures not accessible by other detectors, neither in the past nor in the foreseeable future.

At the same time, since the end of 2014, the project is not funded for research activities. In the last national PTDC call 2014 (at the beginning of 2015) the project "Participation in the HADES experiment, PTDC/FIS-NUC/3731/2014" was recommended to be

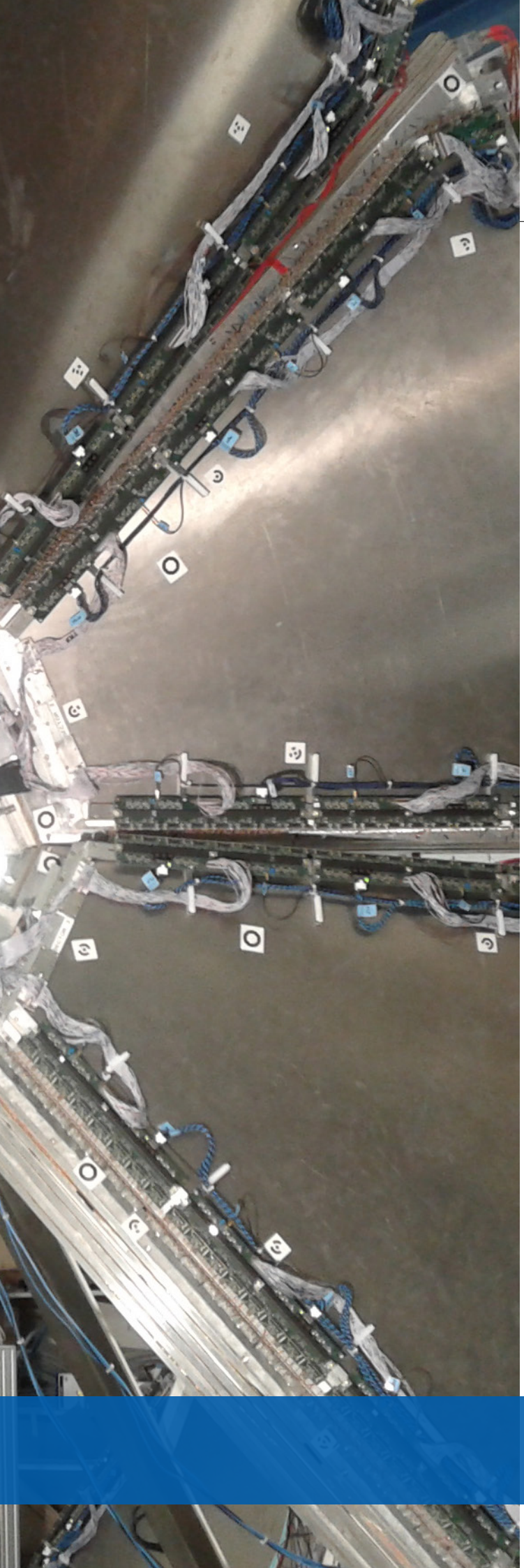
Framework and status for past and current year

not funded. The unique funding support of the project is within the framework of the FCT-HADES MOU, which provides 10 k€/year for operation and maintenance.

The conjugation of these two circumstances led the research activity of the group to be at minimum levels, since beginning of 2015. Nevertheless, collaboration with ECAL group (towards the final installation of the RPC-TOF-W on the new ECAL frame), simulation of a new RPC-TOF detector (to cover the very low polar angels of the spectrometer in the forward region RPC-TOF Forward wall (RPC-TOF-FW)), collaboration with the HADES Multiwire Drift Chambers (HADES-MDC) group, the ongoing analysis (focused on the mass properties of short lived mesons in the di-lepton channel) and attendance to the Collaboration Meetings were maintained during 2016.

Summary of performance indicators

Articles in international journals:	2 With indirect contribution
International conferences:	1 Oral presentation
National conferences:	1 Oral presentation
Collaboration meetings:	9 Oral presentations



Team

Principal Investigator Alberto Blanco (30)

Researchers
Celso Franco (20), Luis Silva (20), Paula Bordalo (10), Paulo Fonte (10), Sérgio Ramos (10)

Technicians
Luís Lopes (10)

Total FTE
1.1

// GROUPS: COMPASS / HADES

Lines of work and team organization

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

Hardware:

- RPC-TOF-W operation. Besides the continuous operation of the RPC-TOF-W and operation within the data taking periods, the LIP group collaborates on general duties related with the data taking periods as DAQ operator and shift leader. Responsibility: A. Blanco, P. Fonte, L. Lopes, C. Franco and L. Silva.

- RPC-TOF-W optimization. Developing and conclusion of monitoring tools. Implementation of efficient and fast tools to prepare the calibration parameters for each data taking period. Implementation of tools for the fast detection of anomalies on the performance of the RPC-TOF-W during the data taking. Responsibility: A. Blanco, P. Fonte, L. Lopes.

- Design and construction of the new RPC-TOF-FW. 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 Wall (FW), 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 FW, RPC-TOF-FW.Responsibility: A. Blanco, P. Fonte, L. Lopes and L. Silva.

- 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. This is of maximum importance in order to operate HADES in the future FAIR facility [http://dx.doi.org/10.15120/GR-2015-1-MU-NQM-HADES-31]. The LIP-HADES group collaborates in this task with the HADES-MDC group. Responsibility: L. Lopes, L. Silva and C. Franco

Analysis:

- Di-lepton analysis. Determination of the e+e- mass spectrum corresponding to all leptons coming from the fireball and identification and removal of the combinatorial background of e+e- pairs from the decay of “long-lived” hadrons and, above all, e+e- pairs coming from the conversion of photons in the spectrometer. The group is contributing with a new method of lepton identification based on a dynamic neural network. Responsibility: P. Bordalo, C. Franco, S. Ramos.

The line of work related to the analysis is basically developed by the Lisbon branch, while the line of work related to hardware is developed mainly by the Coimbra branch, although there are common tasks within the operation of the RPC-TOF-W and the simulation of the RPC-TOF-FW. Specially for this last task, regular on-line meetings are scheduled

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

Stated objectives for past year

During 2016 the accelerator infrastructure was inoperative, therefore no activities concerning data taking or operation were foreseen.

The initial work concerning the implementation of the new RPC-TOF-FW in the simulation and the modification of the software of the experiment, in order to handle this new detector, together with the initial evaluation / prototyping of the detector was expected.

Collaboration with the ECAL group towards the final installation of the RPC on the new ECAL frame.

Collaboration with the HADES-MDC group preparing the HADES Tracking System for High-Rate Experiments at SIS100.

From the lepton analysis, the goals were to correct the di-lepton mass spectrum for the slightly different acceptances that exist between tracks of opposite polarities and correct also for the efficiency of the lepton selection.

Achievements and responsibilities during the past year

The implementation of the new RPC-TOF-FW into the simulation framework of the experiment has been started in the last trimester of the year. The geometry of the system is already implemented and the modification of the analysis software, in order to handle the new detector, has been started. The initial evaluation of the detector, i.e., the evaluation of the RPC technology to be used, has been decided and presented to the HADES collaboration into the last CM. The main idea is to reuse a design previously developed in a former project of the RPC group*, the RPC sensitive volume, but here optimized to the specific requirements of HADES-TOF-FW, namely, high detection efficiency and timing resolution for Minimum Ionizing Particles (MIPs). 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. This technology has also been chosen because is currently produced for other outgoing projects of the RPC group.

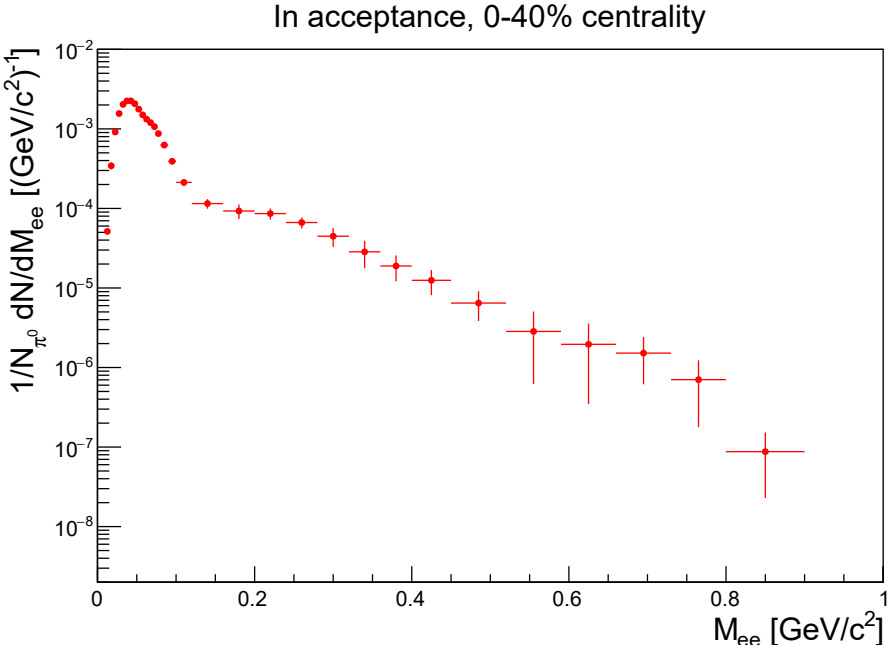
The expected activities related with the installation of the RPC-TOF-W into the new ECAl frame did not take place due to a delay in the construction of the ECAL frame.

Activities, with respect to the collaboration with the MDC group, were related with the verification of the stability of the tracking systems with a new gas mixture, reparation/ inspection of the current chambers and construction of a new spare chambers. In addition, the design of a prototype chamber together with some simulation work, with the aim of investigating new designs (e.g. different cell sizes) for the eventual possibility of rebuilding the tracking system was also done.

Within the analysis task, a preliminary di-lepton mass spectrum [see plot] was extracted from the Au+Au data taking at 1.25 GeV/nucleon. The selection of leptons from a hadronic environment of up to 300 tracks/event was efficiently performed with a dynamic Neural Network. The event mixing technique was used to compensate the small asymmetries on the detection of charge particles of different signs within the spectrometer. The goal was to correct the mass distribution of like-sign combinations, from the same event, in order for this sample to be used as a reliable model of the combinatorial background in the di-lepton mass spectrum. To this end the ratio between opposite-sign and like-sign pairs, with the pairs formed by leptons from different events of similar multiplicities and similar target positions, was used to correct for the charge asymmetries in the background model. Then the corrected background was subtracted from the opposite-sign mass spectrum, leaving only di-leptons coming from the dense medium (fireball of the Au+Au collision) and also from "long-lived" hadronic sources.

The di-lepton mass spectrum was also multidimensionally corrected with the efficiency of the analysis. The efficiency was determined from a simulation of thermal leptons which were embedded in real data and reconstructed using the standard cuts of analysis. A correction on the RICH detector (which is "hadron blind") performance was also implemented in order to account for the differences between data and simulation. This results has been present in the international MENU conference.

*NeuLAND - An innovative high-energy neutron time-of-flight detector for experiments at GSI and FAIR



Preliminary di-lepton mass spectrum from the Au+Au data taking at 1.25 GeV/nucleon. The selection of leptons from a hadronic environment of up to 300 tracks/ event was efficiently performed with a dynamic Neural Network.

Lines of work and objectives for next year

Presently, it is expected that the new accelerator infrastructure enters into operation in the second semester of 2017, but there are strong evidences that this schedule is already delayed. In this moment there is no time beam allocated for HADES experiments, but it could be the case that some time will be devoted to that.

During the first semester of 2017, the implementation of the new RPC-TOF-FW into the software of the experiment is expected to be finish. With this, we will able to study the behaviour of the detector within the spectrometer and fine tuning 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, during 2017, the first prototype of a module of the RPC-TOF-FW will be constructed and evaluated in order to measure the response to MIPs, namely efficiency and timing resolution.

It is expected that the activities related with the installation of the RPC-TOF-W into the ECAL frame take place during 2017 although in this moment there is no clear statement about this. This depends on the delay on the construction of the ECAL frame and the delay on the start-up of the new accelerator infrastructure.

During 2017 the activities related to the collaboration with the MDC group will concern the construction at GSI of a new prototype of MDC.

The main goal, for 2017, is to investigate the hadron properties within the dense medium produced by the Au+Au collisions. To accomplish this goal, all di-lepton contributions from elementary nucleon-nucleon collisions and also from long-lived hadrons (decaying outside of the fireball) must be subtracted. The resulting 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 rho0 properties will also be investigated by comparing the thermal spectrum with model predictions. This information is important towards a better understanding about the mechanism responsible for the generation of mass in hadrons. In parallel, the preparation of the next runs (2018 and 2019) will proceed with dedicated simulations. HADES will take data with lighter nuclei systems, at a slightly higher energy, in order to investigate the in-medium properties of hadrons in a more systematic way.

Recently, we had the approach from a theory group led by Teresa Pena from Instituto Superior Técnico (IST) in Lisbon with the proposal of joining efforts with respect to HADES. This already makes sense since this group has already collaborated with some members of the HADES collaboration in the past. Therefore, we expect to submit a project, together with this group, which will integrate some theoretical task of interest for HADES, in the next funding opportunity. With this joint effort, we want to impulse, reinforce and complete the LIP-HADES group, which currently have competences in hardware and analysis, with a task within theory.

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.
- The LIP-HADES group is a close collaboration between two groups sited in Coimbra and Lisbon poles. One of them, the Coimbra RPC group contributes with the hardware know-how while the Lisbon group provides the expertise on analysis. The synergy of these two skills has unique conditions to be a case of success.

Opportunities

- The excellent work developed during the years leads now with the opportunity to build a new detector for the collaboration, the new TOF-FW.
- The performance and reliability demonstrated by the RPC-TOF-W is a good presentation letter for other experiments / collaborations.

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

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

HADES Collaboration (112 authors): "Statistical hadronization model analysis of hadron yields in p plus Nb and Ar plus KCl at SIS18 energies", Eur. Phys. J. A 52 (2016) 178

Hades Collaboration (108 authors): "Lambda p interaction studied via femtoscopy in p plus Nb reactions at root s(NN)=3.18 GeV", Phys. Rev. C 94 (2016) 025201

Presentations

1 Oral presentation in international conference

Celso Franco: "Dilepton results from HADES using Au+Au data at 1.23 AGeV", 2016-06-25, MENU 2016, 25-30 July 2016 Clock Tower Centennial Hall, Kyoto University

1 Oral presentation in national conference

Luís Silva: "HADES Exploring dense and cold matter", 2016-02-20, Jornadas LIP 2016, Braga

Cosmic rays

COLLABORATION IN THE AMS EXPERIMENT

AMS

LIP is part of a broad international collaboration that, since 1998, 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 92 billion events recorded. Until the launch of AMS, the LIP group took part in the design, study, simulation and reconstruction activities of the RICH subdetector. In particular, the group is responsible for the development, implementation and maintenance of a set of algorithms for reconstructing the electric charge and velocity in the RICH detector. The group is involved on data analysis and participates on the AMS/RICH monitoring in the POCC room at CERN.

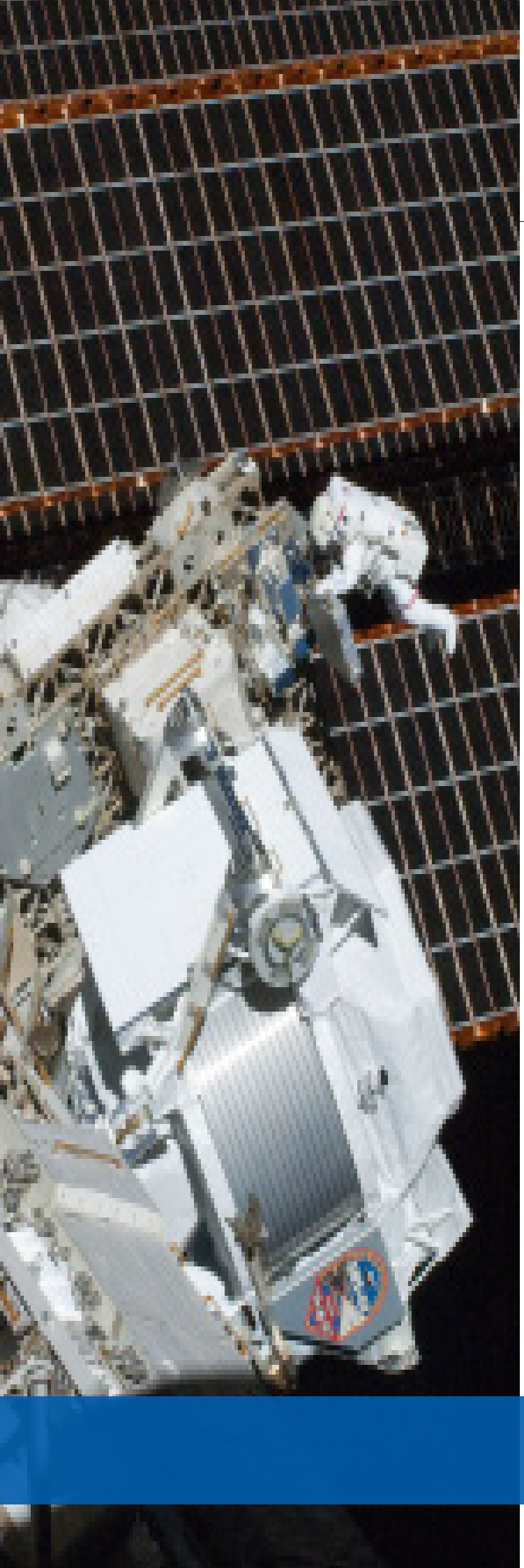
Framework and status for past and current year

Summary of performance indicators

Articles in international journals:	1 With direct contribution 2 With indirect contribution
National conferences:	1 Oral presentation 1 Poster presentation
Seminars:	1 Seminar 4 Outreach seminars

EXPERIMENTAL PARTICLE AND ASTROPARTICLE PHYSICS

Cosmic rays



Team

Principal Investigator Fernando Barão (75)

Researchers
Luisa Arruda (20)

PhD students
Miguel Orcinha (100)

Master students
Pedro Nunes (100)

Undergraduate students
Gonçalo Castro

Total FTE
3.0

// GROUPS: AMS / Auger / LATTES

Lines of work and team organization

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

- 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.
- 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 that the LIP group is involved in the study of the solar modulation of the cosmic rays and in their interpretation under Solar modulation models.
- Particle identification and isotopic measurements. The group is also involved in the development of statistical estimators for particle identification, based on BDT or PDF techniques. Such tools can be used on anti-proton/electron separation and on isotopes identification.
- 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.

Stated objectives for past year

The main objectives of the group for 2016 were:

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

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

  - isotopic studies

  - antiproton selection

Achievements and responsibilities during the past year

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

MO spent three months at the CNRS laboratory LPSC in Grenoble. In collaboration with LPSC's AMS group a software scheme was developed in order to streamline time-based data analysis. The event selection software platform used was one developed by LPSC AMS group.

The data so selected is analyzed using the newly developed analysis framework. In it particle selection cuts are split so they can be individualy analyzed and efficiencies estimated, as a function of time. Detector efficiency has a time-dependent component which needs to be parametrized in order to achieve proper flux estimation.

Flux unfolding was also a point of interest for this platform and the inclusion of Monte-Carlo reweighting and reselection is still in development. Understanding the folding effect introduced by the detector is also a key factor in flux estimation. This framework is still undergoing development and improvement.

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.

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

FB spent six months as invited scientist at the CNRS laboratories in France, LAPP in Annecy and LPSC in Grenoble. On anti-proton analysis, the major background comes from electrons that have the same charge sign and are ~100 times more abundant. An additional and severe background comes from wrong sign reconstructed protons that are more abundant than anti-protons ~10 000 times. FB worked on the optimization of the anti-proton selection based on electromagnetic calorimeter layer signals, using a BDT technique. FB was co-supervisor of a student master thesis (Sandy Aupetit) with the title "Optimization de l'identification d'antiprotons a haute energie (100-500 GeV/c)" at the Grenoble-Alpes University.

FB started also the development of statistical estimators for deuteron/proton separation based on the response of the different AMS detectors. The work included a toy model simulation for the estimators testing. For the moment, the detectors included are the Time-of-Flight and Tracker.

The work is aiming to obtain a set of probability density functions for every measured observable and combine them in order to have a statistical estimator able to distinguish different isotopes.

Along 2016 Fernando Barao was also involved in the following projects:

- Rapporteur of the PhD thesis "Timing Studies On Scintillator - Sillicon Photomultiplier Based Photon Detection System", presented by Mythra Varun Nemallapudi, in "Instituto Superior Técnico" (October, 2016).

- Jury member of MSc thesis: "Development of a Cosmic Ray telescope", presented by Bernardo Rosário, in "Instituto Superior Técnico" (May 2016).

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 its 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.

RICH detector reconstruction: monitoring of velocity and charge reconstruction algorithms performance and development of particle separation tools

The group will continue these studies and will keep on using the LIP analysis tools developed for monitoring detector performance and develop more for data quality control. The

monitoring and correction of the RICH velocity and charge measurements are fundamental for isotopic separation and charge selection, topics crucial to the AMS physics. Systematic effects become dominant at higher charge so a sharp control has to be ensured.

This topic will involve the following steps:

- Check stability of the RICH velocity reconstructed value and resolution over time (stability is checked with high rigidity events)
- Study resolution as a function of particle momentum
- Improve on the existing particle separation likelihood model (i.e. positron/proton, electron/anti-proton, ...). This model is highly dependent on a good understanding of RICH velocity resolution as a function of particle momentum

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

By making use 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 helium and electron fluxes
- Charge signal effect on cosmic ray flux
- Temporal variability study of cosmic ray fluxes (frequency analysis, time correlation with solar events)
- Implementation and improvement of Solar Modulation computational models
- 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)

Particles and Light isotopes identification

Anti-protons are secondary particles and its study can provide us with information from dark matter annihilation in the galaxy. The studies concerning the use of the electromagnetic calorimeter for anti-proton selection are to be continued. The goal is to improve the purity on the selection of the anti-proton data sample.

Light isotopes like H and 4He (and CNO) are believed to be of primary origin. Rarer CR elements such as 2H, 3He (and Li-Be-B) are believed to be of secondary origin, i.e. produced by collisions primary of 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., Be-10/Be-9) will allow to estimate the halo size and the cosmic ray Galactic confinement time (diffusion).

This goal is to develop isotope selection tools.

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 one other laboratory a very well sedimented analysis framework with high capacity 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 current absence of funding and the small size of the group.

Oportunities

AMS remains 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.

Publications

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

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

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

AMS Collaboration (269 authors): "Antiproton Flux, Antiproton-to-Proton Flux Ratio, and Properties of Elementary Particle Fluxes in Primary Cosmic Rays Measured with the Alpha Magnetic Spectrometer on the International Space Station", Phys. Rev. Lett. 117 (2016) 091103

AMS Collaboration (268 authors): "Precision Measurement of the Boron to Carbon Flux Ratio in Cosmic Rays from 1.9 GV to 2.6 TV with the Alpha Magnetic Spectrometer on the International Space Station", Phys. Rev. Lett. 117 (2016) 231102

Presentations

1 Oral presentation in national conferences

Luisa Arruda: "Introdução aos Raios cósmicos", 2016-07-14, Hands on Particles and Light Workshop, IST

1 Poster presentations in national conferences

Gonçalo Castro: "The tracing back of cosmic rays trajectories impinging near earth", 2016-03-02, Jornadas de Engenharia Física, Instituto Superior Técnico

1 Seminar

Miguel Orcinha: "Overview of the Solar Modulation Phenomenon", 2016-03-29, , Laboratoire de Physique Subatomique et de Cosmologie - CNRS, Grenoble, France

4 Outreach seminars

Fernando Barão: "AMS - the design and build of a flying detector", 2016-02-03, First Lisbon mini-school on Particle and Astroparticle Physics, Costa da Caparica

Miguel Orcinha: "Introdução a ROOT", 2016-07-14, IDPASC Workshop "Hands on Particles and Light", Instituto Superior Técnico

Fernando Barão: "A luz na detecção de partículas", 2016-07-14, IDPASC Workshop "Hands on Particles and Light", Instituto Superior Técnico

Miguel Orcinha: "A experiência AMS - Efeito do vento Solar", 2016-07-15, IDPASC Workshop "Hands on Particles and Light", Instituto Superior Técnico

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

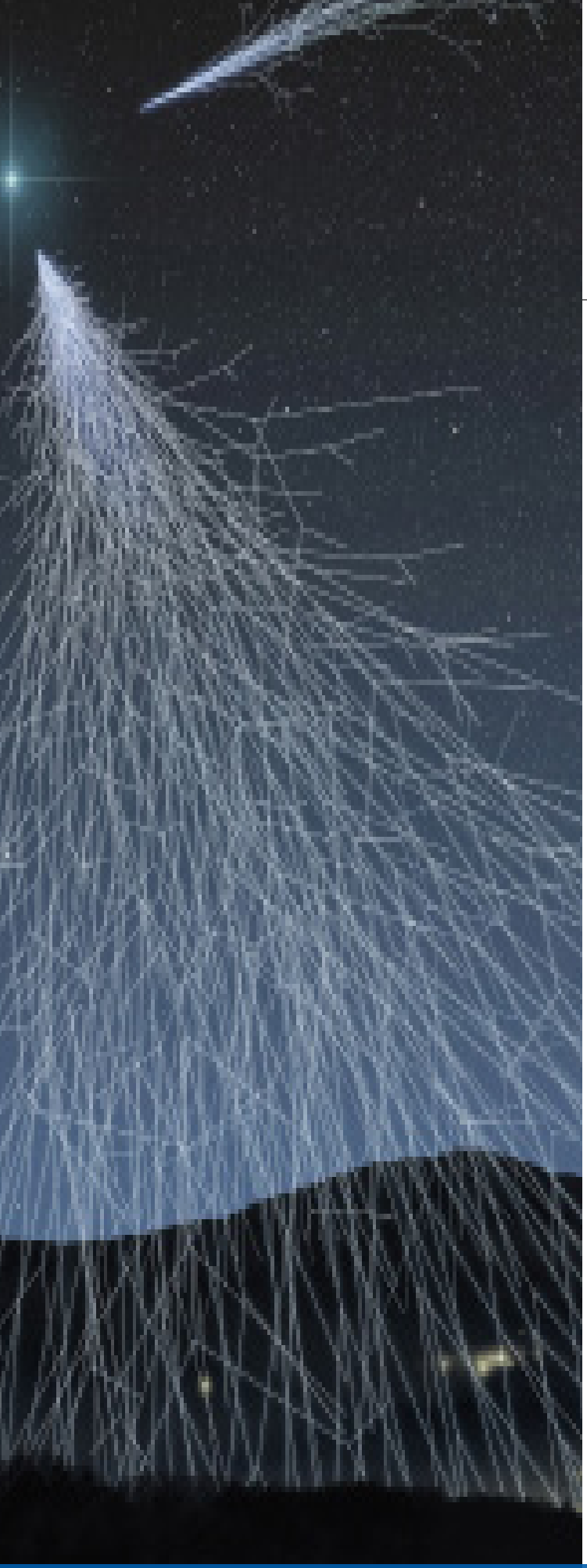
Following the signing of a renewal of the international agreement the Pierre Auger Observatory will operate an upgraded detector up to 2025. Ten years of data taking by the Pierre Auger Observatory have brought new fundamental insights into the origin and nature of highest-energy cosmic rays while raising 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 proof that at the highest energies (7 orders of magnitude above what can be achieved at the LHC) the cosmic-ray flux decreases much faster than at low energies. However the mechanism responsible for such decrease 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. The nature of Cosmic Rays play an important role as it may favor one of the scenarios. However, the nature of nuclear primaries can only be estimated if the shower development is clearly known.

The interactions of the Ultra High Energy Cosmic Rays with the Earth's atmosphere are still poorly understood and the measurements of the Extensive air Showers 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 analysis an in the development of hadronic models to attain a good description of the Air Shower Observables and thus understand its development. The muonic component play a big role as it can probe directly the hadronic component of the shower in the early stages. This component is not directly accessible with the new upgrade but refined analysis can be used 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.

Framework and status for past and current year

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 two 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 will run for three years in 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 (the LATTES project) 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 the team to give relevant contributions in the analysis of the Auger new data.



Team

Principal Investigator Pedro Assis (85)

Researchers
Alberto Blanco (30), Alessandro de Angelis (15), Bernardo Tomé (85), Catarina Espírito Santo (55), Helmut Wolters (20), João Espadanal (100), Liliana Apolinário (15), Lorenzo Cazon (100), Mário Pimenta (85), Patrícia Gonçalves (10), Paulo Fonte (15), Pedro Abreu (70), Pedro Brogueira (15), Raul Sarmento (100), Ruben Conceição (100), Sofia Andringa (50)

Technicians
Américo Pereira (15), José Carlos Nogueira (30), Luís Lopes (20), Luís Mendes (85), Miguel Ferreira (85), Nuno Carolino (10), Orlando Cunha (10)

PhD students
Francisco Diogo (100), Ricardo Luz (85)

Master students
Bernardo Rosario (34), David Christian Soares (92), Miguel Matos Ferreira(starting in 2017), Paulo Ferreira (100), Rui Figueiredo (11)

Total FTE

16.6

Summary of performance indicators

Articles in international journals:	7 With direct contribution from team 8 With indirect contribution
Internal notes:	4 Collaboration notes
International conferences:	5 Oral presentations
National conferences:	5 Presentations
Collaboration meetings:	22 Oral presentations
Seminars:	6 Seminars 5 Outreach seminars
Organization:	2 Collaboration meetings organized
Completed Theses:	1 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:

1. Detailed Study of the SD detectors; Coordinator: P. Assis
2. MARTA RPCs R&D; Coordinator: L. Lopes
3. MARTA Engineering Array; Coordinator: P. Assis
4. Measurement of the muonic component of Extreme Energy Cosmic Rays showers; Coordinator: L. Cazón
5. Measurement of the electromagnetic component of Extreme Energy Cosmic Rays showers; Coordinator: S. Andringa
6. Theory and Models for High Energy Interactions; Coordinator: R. Conceição
7. Education and Public Outreach in high energy cosmic rays; Coordinator: C. Espírito Santo

Currently, L.Cazon is co-leader of the Shower Physics Task of Auger and P. Assis is co-leader of the Long Term performance task.

Sources of Funding

Code	Amount	Dates	Description
EPLANET 246806	25.000 €	2011-01-01 / 2016-01-31	European Particle physics Latin America NETwork
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

Stated objectives for past year

The 2016 stated objectives for the different tasks were:

1. Stabilize the setups in Malargüe and to conduct data acquisitions. The collected data would allow estimating the tank response at large angles. We would also use the Tierra del Fuego Setup as a prototype installation of MARTA.
2. Test the first prototypes with embedded electronics in outdoor conditions. Several tests were expected to be conducted to test different aspects of the response of the RPC chambers. Production and test (both indoor and outdoor) of low-consumption HV power supplies was also foreseen during 2016.
3. Finish the technology transfer to Brazil and the production of the first detectors was planned for the end of the year.
4. a) enlarge the range of applicability of the algorithms to reconstruct the MPD distribution and coordinate an update of the published results, including dependency of the maximum with the zenith angle and its fluctuations;
   b) lead and develop methods to reconstruct the number of muons in the vertical range and its fluctuations;
   c) develop the phenomenological models within the air shower to interpret the MPD results and the muon content and fluctuations.
5. The objectives were centred on the analysis of the mean lateral density function as seen by the present SD, to disentangle the electromagnetic and muonic components and to work towards a journal publication of the average longitudinal profile shape measurements.
6. This period was mainly dedicated to the study, in close collaboration with task 4, of the phenomenology of muon production in air showers and its relation with multi-particle production in hadronic interactions. Two major lines of work were foreseen: investigate the impact of changes on the muon energy spectrum (at production) on the measurements at ground; explore the sensitivity of the fluctuations of the muon content in air showers to hadronic interaction models parameters.
7. Activities based on the Auger public data set and on our work guide for its exploitation were to be conducted also in this school year, as well as Summer internships and seminars in schools. In the 30 years of LIP, our team was to actively contribute to the celebrations.

Achievements and responsibilities during the past year

The main achievements during the past year can be summarized as follows (numbers are task numbers, as defined above):

1. The Gianna Navarra Water Cherenkov Detector response to isolated muons was studied. The hodoscope setup was configured to study vertical muons and campaigns were run dedicated to the study of the calibration of its response. First data suggest no ageing of the tank for ~10 years.

2 & 3. Engineering prototypes of both HV and MARTA DAQ were produced with minor corrections identified and corrected at project level. A close cooperation with Brazilian partners allowed to "translate" the RPC mechanics to Brazilian standards. Suppliers and technical solutions were identified for the production of the enclosures at São Carlos. Tests in the field showed a correct operation of the RPC detectors with stable efficiencies.

4. For the first time it was possible to assess the maximum of the MPD as a function of zenith angle and the fluctuations of the muonic shower maximum, which contain information about the mass of the primaries and hadronic physics on the shower. For such, in collaboration with other groups, the MPD algorithm was combined with a smoothing method to increase the range of applicability of the MPD. A publication is already in advanced state in the internal Auger process.
The measurement of the fluctuations on the number of muons in inclined showers was performed applying the techniques developed during the previous years to assess the physical fluctuations of the number of muons. It is the first time that this quantity is ever measured, and it drastically enhances the capabilities to discern mass composition from hadronic new physics scenarios.
It has been observed that the muonic and electromagnetic observables which are linear with lnA (logarithm of the mass number of the primary) display a significant different evolution with energy. This has been internally reported within the collaboration.

5. The average longitudinal profile shape measurement in the FD was fully reviewed, and an internal editorial board was set up. The main systematic uncertainty in the analysis comes from the description of the atmosphere, which is under detailed study by the collaboration.
The framework for the measurement of the average lateral shape was set up, including the comparison with different models used by the collaboration, to reconstruct data at different zenith angles with the SD.

6. The method to interpret the number of muon measurements in extensive air showers was improved and published. This method is stable under systematic changes of the absolute number of muons from model predictions and on the scale of the reconstructed energy, making an important tool to further assess and constrain hadronic interaction models. This work was developed in collaboration with Brazilian groups.
The impact of changes on the muon energy spectrum (at production) on the measurements at ground were investigated and published. This work demonstrated that there is an evolution of the number of muons with the zenith angle that could be exploited to test the muon energy spectrum and, as a consequence, hadronic interaction models. It was also shown that the maximum of the reconstructed muon production profile is very sensitive to the muon energy spectrum exhibiting opposite behaviour for showers above and below 60 degrees in zenith angle.

7) Several education and outreach activities took place, namely using the activity guide for the exploitation of the Auger public data set developed by our team and available in Portuguese, English and Spanish. The guide was used both at schools and at in internships at LIP. The team participated in the preparation of the LIP 30 years exhbition "Particles: from the Higgs boson to dark matter", both in the contents concerning high energy cosmic rays and in general development.

Lines of work and objectives for next year

1. The detailed characterization of SD tanks will focus on the study of calibration constants. The conversion factors for VEM will be measured in the Gianni Navarra tank and possible ageing effects will be further studied. The studies developed with this tank will be consolidated and subject of publications. The response of the tank to very inclined muons will be studied taking advantage of the upgrade of the Gianni Navarra setup. Methods to study and identify the ageing processes in the tanks will be pursued.

2. RPC R&D will be closely linked with the MARTA Engineering Array and focus will be put in the technology transfer, design and production optimization. It is, however, necessary to assure there is no negative impact on the performance of the detectors. As such, all proposed optimizations will be tested in the Detector Laboratory at Coimbra.

3. In 2017 we will start the production of the first engineering prototypes in São Carlos, Brazil, followed by their transport and installation in Argentina. We foresee by the end of the year to have at least one full MARTA station installed and taking data.

4. The study of the muonic component is paramount for the understanding of Extensive Air Showers. We plan to finish the measurement of the fluctuations of the number of muons in inclined showers that will be subject of publication.

   We plan to investigate the main drivers of the number of muons, extracting the main drivers of the fluctuations in relation with the reactions at the highest energies within the showers. For this we will develop modelization tools, tested with full Monte-Carlo, to expose the relation between shower observables and the fundamental quantities at the multiparticle hadronic reactions.

   The participation on a study on the invisible energy, carried by muons and neutrinos to be published by the collaboration will also be part of this task.

5. In terms of the electromagnetic component we will update the average longitudinal profile shape measurement with new atmospheric data leading to a reduction on the systematic uncertainty and an increase on sensitivity.

   We will also dedicate, in collaboration with the other tasks, to trying to disentangle the electromagnetic and muonic contributions. For this we will measure the average lateral profile shape at intermediate zenith angle and test of the reconstruction model predictions.

6. Regarding the high-energy interaction models we will study the muon spectra and the proton-air cross section and their impact on the shower development.

   The muon energy spectrum is very sensitive to the hadronic interaction properties. Therefore, its accurate measurement is highly desirable to constrain models with shower data. Strategies to obtain information about the muon energy spectrum from measurements at ground will be developed, taking particular attention to the sensitivity of the footprint at ground of inclined showers to the muon energy spectrum.

   The Xmax data can be explained through the evolution of mass composition or by a scenario where the proton-air cross-section has a sudden rise. We will pursue the development of analysis and strategies to distinguish between both scenarios.

7. Ongoing activities based on the Auger public data set will be continued. Further effort will be put on the development of hardware, based on the tehcnologies used by the group, for cosmic ray demonstrations and experiments in schools or with graduate students at the LIP and University labs

SWOT Analysis

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. It has unique conditions to play a world leading role in cosmic rays physics which has been however limited by the small number of master and PhD students that joined the team in the last few years. The increase of our capability to attract new students and our visibility at the university is therefore a challenge.

MARTA detectors have proved already their capabilities for running in harsh environments and the installation of an engineer array at Malargue is clearly a challenge and an opportunity but it will demand a close and fruitful collaboration with Brazilian Auger teams and industry. Furthermore, R&D opportunities or potential applications for RPC in future astroparticle physics projects should be pursued.

Finally in 2015 FCT renewed its commitment to the Portuguese participation in the Pierre Auger Observatory until 2025 which was obviously extremely positive but, the group funding from "Fundo CERN" for 2015/2016 was reduced by a factor around 40%. The adequate funding of the group might be thus a problem.

Publications

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

P. Assis, P. Brogueira, M. Ferreira, R. Luz and L. Mendes: "Design and characterization of the PREC (Prototype Readout Electronics for Counting particles)", Journal of Instrumentation, Volume 11, August 2016

L. Lopes et al. (15 authors): "Outdoor field experience with autonomous RPC based stations", J. Instrum. 11 (2016) C09011

P. Assis et al. (18 authors): "A large area TOF-tracker device based on multi-gap Resistive Plate Chambers", J. Instrum. 11 (2016) C10002

Raul R. Prado, Ruben Conceicao, Mario Pimenta, Vitor de Souza: "Interpretation of measurements of the number of muons in extensive air shower experiments", Astropart Phys. 83 (2016) 40-52

The Pierre Auger Collaboration: "Testing hadronic interactions at ultrahigh energies with air showers measured by the Pierre Auger Observatory", PRL 117, 192001 (2016)

J. Espadanal, L. Cazon, R. Conceição: "Sensitivity of EAS measurements to the energy spectrum of muons", Astroparticle Physics 86 (2017) 32–40

The Pierre Auger Collaboration: "Ultrahigh energy neutrino follow-up of Gravitational Wave events GW150914 and GW151226 with the Pierre Auger Observatory", Phys. Rev. D 94, 122007 (2016)

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

The Pierre Auger Collaboration: "Nanosecond-level time synchronization of autonomous radio detector stations using a reference beacon and commercial airplanes.", JINST 11 (2016) P01018

Pierre Auger Collaboration (452 authors): “Prototype muon detectors for the AMIGA component of the Pierre Auger Observatory”, J. Instrum. 11 (2016) P02012

Pierre Auger Collaboration (434 authors): “Azimuthal asymmetry in the risetime of the surface detector signals of the Pierre Auger Observatory”, Phys. Rev. D 93 (2016) 072006

Pierre Auger Collaboration (449 authors): “Energy estimation of cosmic rays with the Engineering Radio Array of the Pierre Auger Observatory”, Phys. Rev. D 93 (2016) 122005

Pierre Auger Collaboration (449 authors): “Measurement of the Radiation Energy in the Radio Signal of Extensive Air Showers as a Universal Estimator of Cosmic-Ray Energy”, Phys. Rev. Lett. 116 (2016) 241101

The Pierre Auger Collaboration: “Evidence for a mixed mass composition at the ‘ankle’ in the cosmic-ray spectrum”, Phys.Lett. B762 (2016) 288-295

Pierre Auger Collaboration (413 authors): “Search for ultrarelativistic magnetic monopoles with the Pierre Auger observatory”, Phys. Rev. D 94 (2016) 082002

The GEANT4 Collaboration: “Recent developments in Geant4”, Nuclear Instruments and Methods in Physics Research, A 835 (2016) 186-225.

4 Collaboration notes with internal referee

J. Espadanal, S. Andringa, P. Gonçalves, M. Pimenta: “Average slope of SD LDFs for the QGSJet-II model “, GAP2016_003

J. Espadanal, S. Andringa, P. Gonçalves, M. Pimenta: “Electromagnetic Xmax from SD signals with an upgraded SD”, GAP2016_002

L. Cazon, F. Diogo, R. Conceicao, S. Andringa, J. Espadanal, M. Pimenta: “dlnA/dlogE from hadronic-type and EM-type cascade observables”, GAP2016_022

R. M. de Almeida, R. Conceição, U. Giaccari, J. S. de Oliveira, B. Tomé: “Reconstruction of atmospheric muons by MARTA as a tool to assess the SD performance”, GAP2016_028

Presentations

5 Oral presentations in international conferences

Alberto Blanco: "A large area TOF-tracker", 2016-02-23, RPC 2016, XIII WORKSHOP ON RESISTIVE PLATE CHAMBERS AND RELATED DETECTORS, Ghent University, Belgium

Luís Lopes: "Outdoor Field experience with Autonomous Stations Luis Lopes", 2016-02-23, XIII Workshop on Resistive Plate Chambers and Related Detectors, Ghent University, Belgium

João Espadanal: "Constraints of hadronic interactions in extensive air showers with the Pierre Auger Observatory", 2016-06-02, MESON 2016 – 14th International Workshop on Meson Production, Properties and Interaction, Kraków, Poland

Francisco Diogo: "Testing hadronic interactions with the Pierre Auger Observatory", 2016-07-08, CRIS2016 - Cosmic Ray International Seminar 2016, Ischia, Italy

Ruben Conceição: "The Pierre Auger Observatory: results and prospects", 2016-09-23, LHC days in Split 2016, Split, Croatia

5 Presentations in national conferences

Ricardo Luz: “MARTA: Muons at the pampa”, 2016-02-20, Jornadas Científicas do LIP 2016, Campus de Gualtar, Braga

Francisco Diogo: “Auger: Showers and Physics”, 2016-02-20, Jornadas Científicas do LIP 2016, Campus de Gualtar, Braga

Raul Sarmento: “Ao encontro de medidas precisas de muões em chuveiros atmosféricos extensos”, 2016-09-08, 20a Conferência Nacional de Física, Universidade do Minho, Braga, Portugal

Francisco Diogo: “Física de altas energias no Observatório Pierre Auger”, 2016-09-08, 20a Conferência Nacional de Física, Universidade do Minho, Braga, Portugal

Pedro Abreu: “Oficina - Os dados públicos do Observatório Pierre Auger”, 2016-09-08, 20ª Conferência Nacional de Física e 26º Encontro Ibérico de Ensino da Física, Universidade do Minho, Braga, Portugal fisica2016

6 Seminars

Lorenzo Cazon: "Ultra High Energy Cosmic Rays a 100 years puzzle", 2016-06-04, First Lisbon mini-school on Particle and Astroparticle Physics, Costa da Caparica, Portugal

Sofia Andringa: "Hunting for Ultra-High Energy Cosmic Ray", 2016-06-17, Summer School in Nuclear Physics and Technologies, Università di Ferrara

Lorenzo Cazon: "Os Raios Cósmicos de Energia extrema e a sua interacção na atmosfera", 2016-07-14, Hands on Particles and Light Workshop, Lisboa

Ruben Conceição: "O observatório Pierre Auger ", 2016-07-15, Hands on Particles and Light Workshop, Lisboa

Sofia Andringa: "The Highest Energy Cosmic Rays at the Pierre Auger Observatory", 2016-11-30, Seminários do Departamento de Física da FCUL, Lisboa

Lorenzo Cazon: "Testing hadronic interactions beyond 100 TeV with the Pierre Auger Observatory", 2016-12-15, , LIP, Lisboa, Portugal

5 Outreach seminars

Sofia Andringa: “Raios Cósmicos, partículas extraterrestres”, 2016-03-20, Centro Ciência Viva de Constância, Constância, Portugal

Pedro Abreu: "Partículas e raios cósmicos", 2016-11-15, , Escola Sá da Bandeira, Santarém

Raul Sarmento: "Raios cósmicos: as partículas mais energéticas do Universo", on three school visits to the LIP Exhibition, Braga, March 2016

Theses

2 PhD Theses

Francisco Diogo: “Measurement of the longitudinal profile of cosmic ray air-showers at the Pierre Auger Observatory” (ongoing)

Ricardo Luz: “Development of the instrumentation and readout schemes of MARTA, an upgrade to the Pierre Auger Observatory” (ongoing)

4 Master Theses

Bernardo Rosario: "Desenvolvimento de um telescópio de Raios Cósmicos" (finished on 2016-05-04)

David Christian Soares: “Muon energy spectrum in extensive air showers” (ongoing)

Paulo Ferreira: “Response of a water-Cherenkov detector to inclined muons at the Pierre Auger Observatory” (ongoing)

Miguel Matos Ferreira: “Average lateral distribution function of muons in 10^{17} eV extensive air showers” (ongoing)

Events

2 Collaboration Meetings

8th MARTA Progress Meeting, CBPF - Centro Brasileiro de Pesquisas Físicas, Rio de Janeiro, Brasil, 2016-03-14 to 2016-03-15

9th MARTA Progress Meeting/3rd LATTES Meeting, Biblioteca Nacional, Lisboa, 2016-10-10 to 2016-10-11

HIGH ENERGY GAMMA RAYS

LATTES

The observations of gamma-ray telescopes in the last decade changed radically our perception of the Universe and raised new puzzles on the mechanisms powering the most energetic phenomena: gamma-ray bursts and relativistic outflows such as jets from black hole accretion disks or pulsar winds. High-intensity flares with an energy spectrum extending beyond the GeV have been observed. This phenomenon was not foreseen by the laboriously built models and its experimental study has just begun. The next step will be led by instruments able to survey continuously large portions of the sky, and sensitive to the energy gap between satellites and ground arrays (50 GeV to 0.5 TeV).

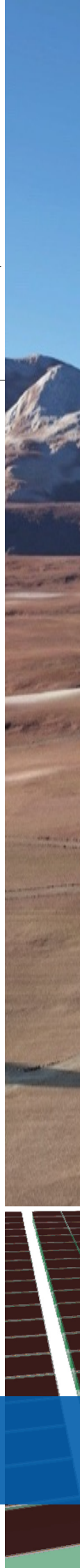
Present and planned large field-of-view (FoV) gamma-ray observatories are installed in the Northern Hemisphere, missing in particular the galactic center. While a wide FoV Southern Hemisphere observatory will surely be proposed and built, the question is whether it will be similar to the existing extensive air shower (EAS) arrays, or an innovative solution able to cover the energy gap between satellites and ground in wide FoV observations. The technological challenges of lowering the energy threshold of air shower arrays have been considered nearly impossible to overcome, as they stem directly from the physics of air showers.

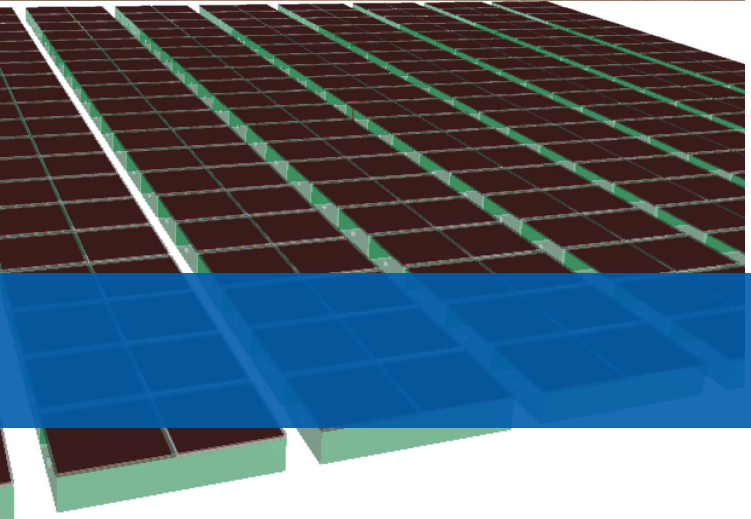
The goal of LATTES is to design, prototype and construct a a ground array able to monitor the Southern gamma-ray sky above 50 GeV, bringing to ground the wide field-of-view and large duty cycle observations characteristic of satellites, with comparable sensitivity and a cost one order of magnitude lower. Such an instrument will be a powerful time-variance explorer, able to issue pointing alerts to IACTs (Imaging Atmospheric Cherenkov Telescopes), boosting the efficiency of these powerful instruments, 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.

Framework and status for past and current year

To overcome the huge technology issues involved, 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 RPCs (Resistive Plate Chambers), with good space and time resolution) with a WCD (Water Cerenkov Detector), ensuring trigger efficiency and efficient background rejection, and thus good sensitivity all the way down to 50 GeV.

The proposed solution is conceptually and technologically innovative but relies on well-grounded R&D in which LIP had a leading role. In fact, the detector concept was originally developed at LIP and the LIP-Coimbra team members have a recognized world-leader expertise in RPCs. The LATTES concept has been proposed during 2016 by scientists from Portugal (LIP), Brazil (CBPF) and Italy (INFN-Padova and Roma). Scientists from other countries, namely from Spain and Check Republic, have attended the LATTES meetings in 2016 as observers. To pursue such an ambitious goal, a sound international collaboration has to be formed. The collaboration is taking form and should get the first dedicated fundings during 2017.





Team (*)

Principal Investigator Mário Pimenta (40)

Researchers
Alessandro de Angelis (20), Bernardo Tomé (35), Catarina Espírito Santo (30), 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 (17)

External/Additional scientific collaborators
Adriano Henriques, Alberto Blanco, Luís Filipe Mendes, Luís Lopes

Total FTE

3.0

Summary of performance indicators

International conferences:	8 Oral presentations
National conferences:	1 Presentation
Collaboration meetings:	7 Oral presentations
Organization:	1 Collaboration Meetings organized

(*) FTE and % valid for 2017

// 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 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

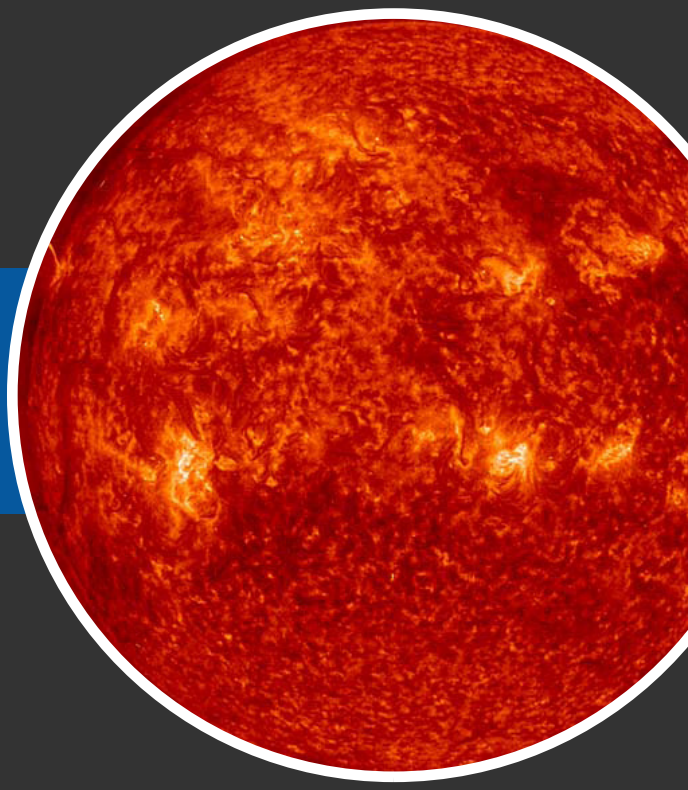
Ruben Conceição: "LATTES: a next generation detector for γ-ray astrophysics in South America ", 2016-02-20, Jornadas Científicas do LIP 2016,
Campus de Gualtar, Braga

Events

1 Collaboration Meeting

9th MARTA Progress Meeting/3rd LATTES Meeting, Biblioteca Nacional, Lisboa, 2016-10-10 to 2016-10-11

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 the direct detection of dark matter in the form of Weakly Interacting Massive Particles (WIMPs).

In 2016, LUX completed the 332 live-days second science run, corresponding to an exposure of 3.35×10^4 kg.day. With roughly fourfold improvement in sensitivity for high WIMP masses relative to the LUX previous results (from 2015), this search yielded no evidence of WIMP nuclear recoils and the WIMP-nucleon spin-independent cross sections above 2.2×10^{-46} cm^2 at a WIMP mass of 50 GeV c^{-2} were excluded at the 90% confidence level. This is the current word leading result. In September 2016, the decommissioning of LUX was started and it is planed to be completed by April 2017.

The LZ project proposes a 7-ton xenon detector using the same TPC technology as LUX. Its Concept Design was approved by DOE (DOE CD1 review). After having successfully passed the DOE CD-2/3b Review (April 2016) and the DOE CD3 Review, (Jan 2017), LZ has started the fabrication phase. The underground deployment of LZ is scheduled for 2019 and commissioning is expected to start in Spring 2020.

Framework and status for past and current year

Summary of performance indicators

Articles in international journals:	6 With direct contribution from team
Internal notes:	9 Collaboration notes
International conferences:	3 Oral presentations
National conferences:	2 Oral presentations
Collaboration meetings:	18 Oral presentations
Report:	1 Institute report
Seminars:	4 Seminars 6 Outreach seminars

Team

Principal Investigator Isabel Lopes (80)

Researchers
Alexandre Lindote (100), Andrey Morozov (15), Cláudio Silva (100), Francisco Neves (70), José Pinto da Cunha (50), João Pedro Rodrigues (100), Vladimir Solovov (50)

Technicians
Américo Pereira (20), Nuno Carolino (35)

PhD students
Paulo Brás (100)

Master students
Cédric Pereira (*45*), Natalija Novak (25)

Total FTE
7.9

// GROUPS: LUX/LZ / SNO+ / NEXT

Lines of work and team organization

The main lines of work (and respective group members involved) are centered on the development and implementation of:

- Vertex reconstruction methods in two-phase Time Projection Chambers like LZ and LUX (Claudio Silva and Vladimir Solovov);
- Data analysis tools for LUX and LZ, encompassing algorithms and techniques for low amplitude signal 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 and Paulo Brás);
- Physics Beyond Dark Matter search with LZ detector: neutrino physics studies, search for neutrinoless beta decay and Xe rare decays (Alexandre Lindote, Cláudio Silva e Paulo Brás)
- Modeling and GEANT4 based simulation of the background in LZ (Alexandre Lindote and Paulo Brás);
- Control systems for LUX and LZ (Vladimir Solovov and João Rodrigues);
- Data processing system of LUX (Alexandre Lindote);
- Modeling and Monte Carlo Simulation of reflectance processes in rough and diffuse surfaces (Cláudio Silva).
- Measurements of the reflectance and the transmittance of materials LZ (Francisco Neves)

The LIP team is represented by the PI of the project (I. Lopes) in the LUX Executive Board, the LZ Executive Board (till Sept 2016) and LZ Institution Board.

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

Stated objectives for past year

LZ

- To complete and to maintain the control system (CS) for the LZ System-Test operating at SLAC;
- To finalize the architecture of the CS system for LZ;
- To start the development of a vertex and energy reconstruction software tool for LZ.
- Completion of the reflectivity measurements of PTFE samples from different manufacturers and of thicknesses ranging from 10 mm down to 1 mm to guide the choice of the PTFE to be used in LZ. Refinement of the simulation and Monte Carlo modeling of reflectance processes in rough and diffuse surfaces.
- Participation and coordination of the development of software modules for the pulse classification and pulse pairing in LZ.

LUX

- Participation in the analysis of the data taken by LUX during the 300 live-day run that is expected to be completed by May 2016.
- Tuning of the vertex reconstruction tool for the analysis of LUX data.
- Responsibility for the data processing framework: besides keeping the coordination of the framework development and managing the collaboration cluster, to lead a major overhaul of the backbone of the data processing framework to allow for partial reprocessing of datasets — i.e. reapply only selected upgraded modules to a previously processed dataset (in its current state the framework only allows for a full reprocessing, starting with the raw data).
- Further improvement of the modeling of the background coming out from the walls and leaking into the fiducial volume. These improvements can allow the enlargement of the fiducial volume.
- M&O of the two LUX systems for which the group has sole responsibility (i.e., LN2 and SC systems).
- Participation onsite (about 100 days onsite in total) in the LUX operations and decommission of LUX.

Achievements and responsibilities during the past year

LZ

- Implementation of the control system (CS) for the System-Test at SLAC that also works as a prototype of the LZ control system, allowing to test the key components of the future LZ implementation: alarms, scripting, redundancy, etc.
- Implementation and validation of a second generation (using Ignition) of drivers for communication with the sensors, integration of the PLCs, alarm management, scripting and the GUI (system for the visualization and graphical temporal analysis of the behavior of the parameters of CS system) for the System-Test. This new generation was focused on increasing the performance and stability of the system.
- Complete design of the CS for LZ : architecture, infrastructure, devices interfaces, channels count.
- Final Review of the LZ CS Design: the CS technical design successfully passed two directors reviews and two DOE reviews, having proceeded to the implementation phase.
- Production of technical and interface documentation for the LZ CS.
- Lindote was appointed coordinator (L3) of the 1.10.4 group (Background Simulations) in July 2016. Ever since, he implemented crucial improvements to the way nuclear recoil backgrounds from detector materials are calculated.
- The reflectivity measurements of PTFE from three different manufacturers were carried out with the required accuracy and the results published. This was crucial to guide the choice of PTFE for LZ detector.
- Development of a position reconstruction module for LZAP. This module was developed to validate the LZAP standard data analysis chain and implements a simplified version of the Mercury Algorithm (the vertex reconstruction algoritm developed by us for LUX).
- Beta version of a module for pulse classification for LZAP is ready.
- We started to develop a LZ Data Processing Environment (DPE) with view to use GPUs (Graphical Processing Units) to implement a real time Detector Quality Manager (DQM). The DPE can combine analysis using n x CPUs with m x GPUs. Preliminary benchmarking of the DPE with only 2 GPUs (GeForce GTX 970, 1664 CUDA cores) shows that we can process up to ~5K events/s, while the process rate with only CPUs (Intel I7-6700 @ 3:4 GHz) is ~16 events/s/CPU. Based on these results, we have presented a proposal for taking the responsibility to develop and implement the DQM, which is under discussion.

LUX

- We coordinated the data processing effort for the entire run 4 data, in a total of ~1 Petabyte of raw data. Given the extension and amount of data collected during run 4, we modified the (in-house developed) LUX Data Processing Framework to allow partial reprocessing of data, applying only the relevant software modules.
- Development of an original method to describe the spatial distribution of the background events generated by the decays of 210Pb and 210Po plated-out on the PTFE walls.
- Comprehensive comparison of the discrimination of electron and nuclear recoils in simulation and calibration data.
- Writing of a collaboration paper on the position reconstruction in LUX (C. Silva is the person in charge of writing it and he will be the corresponding author).
- M&O of the two LUX systems for which the group has sole responsibility (i.e., LN2 and SC systems).
- Participation onsite (about days 58 onsite in total) in LUX operations and decommission.

Coordination positions within LZ

- Vladimir Solovov: coordinator of the LZ slow control system.
- Alex Lindote: coordinator of the background simulation group
- Alex Lindote e Francisco Neves: coordinators of the group responsible for the offline analysis tools for the vertex reconstruction and pulse identification.

Coordination positions in LUX

- Cláudio Silva, coordinator of the LUX position reconstruction analysis subgroup
- Francisco Neves, responsible for the M&O of LUX Liquid Nitrogen System
- Vladimir Solovov, responsible for the M&O of LUX control system

Editorial and Review Boards within LUX and LZ (in 2016):

- Cláudio Silva, corresponding author and chair of the writing committee of the collaboration paper “Position Reconstruction in LUX” to be submitted soon.
- Alex Lindote, member of the review committee of the

collaboration paper "Signal yields, energy resolution, and recombination fluctuations in liquid xenon", already published (Phys. Rev. D 95, 012008).

- Alex Lindote, member of the review committee of the collaboration paper "Tritium calibration of the LUX dark matter experiment", already published (Phys. Rev. D 93, 07200).
- Isabel Lopes, member of the review committee of the collaboration paper "Low-energy (0.7-74 keV) nuclear recoil calibration of the LUX dark matter experiment using D-D neutron scattering kinematics" submitted to Phys. Rev. C
- Alex Lindote, member of the writing committee of the paper "Calibration, event reconstruction, data analysis and limits calculation for the LUX dark matter experiment", to be submitted soon to PRD.

Lines of work and objectives for next year

In 2017 the work will be focused mostly in LZ, particularly in:

- 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.
- Design and implementation of the Data Quality Manager for LZ (DQM: the online data analysis system to monitor the quality of the data);
- Creation 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.
- 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.

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 and 1 Master Student. 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 or set the ultimate limit before reaching the irreducible neutrino background. 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.

Threats

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

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

D.S. Akerib et al.: "Signal yields, energy resolution, and recombination fluctuations in liquid xenon", accepted for publication in to be published in PRD arXiv:1610.02076

D. Akerib et al: "Improved WIMP scattering limits from the LUX experiment", Phys. Rev. Lett. 116, 161301

D. S. Akerib et al.: "First spin-dependent WIMP-nucleon cross section limits from the LUX experiment", Phys. Rev. Lett. 116, 161302

D. Akerib et al: "Tritium calibration of the LUX dark matter experiment", Phys. Rev. D 93, 072009

D. Akerib et al.: "FPGA-based Trigger System for the LUX Dark Matter Experiment", Nucl. Instrum. Meth. A Vol. 818 (2016) Pages 57–67

D. S. Akerib et al. : "Results from a search for dark matter in the complete LUX exposure", Phys. Rev. Lett. 118, 021303

1 Institute Report

A. Lindote: "Backgrounds Control Table Summary", LZ Controlled Document LZ-CTD-10-0001

9 Internal Notes

A. Lindote: "Contributions of the cryostat seals components to the estimated Rn, ER and NR backgrounds", LZ Internal Report

J. Rodrigues: "Ignition for System Test", LZ Technical Report

Eric Dahl, Vladimir Solovov: "Interfaces between Slow Control and critical (PLC-controlled) systems", LZ Internal note LZ-ICD-04-0001

A. Lindote: "Snapshot of WS datasets and final CP numbers for the Run04 analysis", LUX Internal Note LuxDB00000491

H. Araujo, E. Druszkiewicz, H. Lippincott, J. Rodrigues, F. Wolfs: "Vladimir Solovov, Joao Rodrigues, Jim Buckley", LzIcdDB0061

Vladimir Solovov, Joao Rodrigues, Jim Buckley: "Interface between Slow Control and Online software + Run control", LzIcdDB0064

Vladimir Solovov, Frank Wolfs: "Hardware protection", LzIcdDB0072

S.Burdin, V.Solovov, S.Powell, A.Greenall: "OD OCS electronics monitoring", LzIcdDB0080

Seth Hillbrand, Vladimir Solovov: "Analog electronics monitoring", LzIcdDB0065

Presentations

3 Oral presentations in international conferences

Isabel Lopes: "The LUX-ZEPLIN Dark Matter Experiment", 2016-06-21, 12th Patras Workshop on Axions, WIMPs and WISPs, Jeju Island, South Korea

Francisco Neves: "Measurement of the absolute reflectance of PTFE immersed in liquid xenon", 2016-07-19, 11th International Conference on Identification of Dark Matter, Sheffield, UK

Cláudio Silva: "Dark matter searches in LUX", 2016-11-28, 13th International Symposium on Cosmology and Particle Astrophysics (CosPA 2016), Sidney, Australia

2 Oral presentations in national conferences

Francisco Neves: "The next generation dark matter detector: LZ", 2016-02-20, Jornadas LIP, Braga, Portugal

Paulo Brás: "LUX: The world's most sensitive WIMP detector", 2016-02-20, Jornadas do LIP, Braga, Portugal

4 Seminars

Paulo Brás: "60 years of neutrinos in 60 minutes", 2016-02-05, Departamento de Física, Universidade de Coimbra

Isabel Lopes: "Searching for Dark Matter with LUX and LUX-ZEPLIN", 2016-06-01, University of Malta, Valetta, Malta

Isabel Lopes: "The hunt for dark matter", 2016-06-02, G.F. Abela Junior College, University of Malta, malta

Paulo Brás: "Effective Field Theories for Weakly Interacting Particles", 2016-07-08, , Departamento de Física, Universidade de Coimbra

6 Outreach seminars

Alexandre Lindote: "Dancing in the dark: the end of physics", 2016-01-29, Projecto Quark, Centro Ciência Viva Rómulo de Carvalho

Francisco Neves: "O Enigma da Matéria Escura", 2016-04-20, Partículas - do bosão de Higgs à matéria escura" - comemorações dos 30 anos do LIP, Museu de Ciência, Coimbra

Isabel Lopes: "The Mystery of Dark Matter", 2016-06-02, , Aula Magna, University Valletta, Malta

Isabel Lopes: "Mistérios do Universo: À procura da Matéria Escura", 2016-10-10, Escola Secúndaria Rainha D. Leonor

Isabel Lopes: "Mistérios do Universo: À procura da Matéria Escura", 2016-10-13, Secundária de Azambuja

Isabel Lopes: "Mistérios do Universo: À procura da Matéria Escura", 2016-10-14, Colégio Ramalhão, Sintra

Theses

1 PhD Thesis

Paulo Brás: "New physics phenomenology and data processing tools for the LZ experiment" (ongoing)

1 Master Thesis

Natalija Novak: "Study of neutrino interactions in the LZ Dark Matter detector" (ongoing)

COLLABORATION IN THE SNO+ EXPERIMENT

SNO+

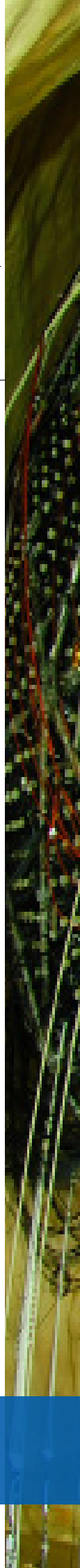
The LIP Neutrino Physics group joined the Sudbury Neutrino Observatory (SNO) experiment in 2005 and is a founding member of the SNO+ international collaboration. SNO+ reuses the SNO detector, replacing the heavy water by liquid scintillator. The main goal of the experiment is the search for neutrino-less double-beta decay (0NDBD) 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.

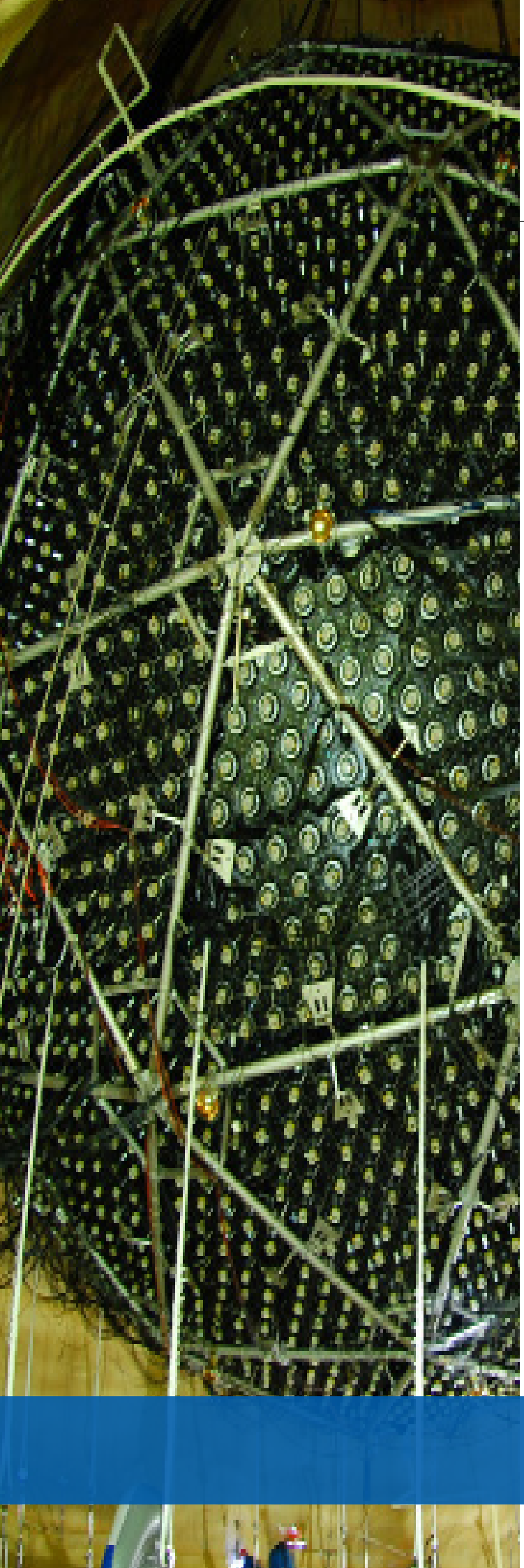
As of January 2017, the detector water fill is almost complete and commissioning data taking has started. The liquid scintillator phase is planned to start after a brief water phase with detector calibrations and physics data taking.

Framework and status for past and current year

Summary of performance indicators

Articles in international journals:	1 With direct contribution from team
International conferences:	2 Poster 2 Proceedings
National conferences:	7 Oral presentations 1 Poster
Collaboration meetings:	17 Oral presentations
Seminars:	3 Seminars 1 Outreach seminar
Completed Thesis:	1 Graduation thesis





Team

Principal Investigator José Maneira (60)

Researchers
Amélia Maio (15), Fernando Barão (25), Gersende Prior (100), Sofia Andringa (50)

Technicians
Américo Pereira (20), Nuno Filipe Silva Dias (20), Rui Alves (20)

PhD students
Pedro Jorge (55), Stefan Nae (100)

Master students
Ana Sofia Inácio (100), Evangelia Samara (20), Xavier Rodrigues (5)

External/Additional scientific collaborator
Nuno Barros

Total FTE
5.9

// GROUPS: LUX/LZ / SNO+ / NEXT

Lines of work and team organization

The group's activities are organized in three main lines, each divided into specific tasks. All the group members working on each subtask are listed below, the first one(s) having the main responsibility. 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 computation at LIP.

Detector calibration

- Optical Fiber-based system for PMT calibration. The installation of all the fibers at SNOLAB is now complete (JM). The database with the full information on installed positions is being updated after the final checks (SA).
- Internal source deployment system. The design (RA, JM) is finished, as well as the production (ND) of the first (of 2) system. Testing for leaks (AP) will continue at SNOLAB.
- Analysis of laserball optical calibration data (JM, GP, AI). The SNO+ optical calibration group is chaired by JM and GP. The main current task is the preparation of Monte Carlo and analysis tools for the upcoming water phase data.

Detector and data-taking performance

- Data quality. GP chairs the SNO+ Run Selection Committee and is responsible for the Data Quality "Low-Level" checks (i.e., detector electronics and slow control checks), and the flow of that information into the SNO+ database, through dedicated nearline software tools.
- Detector modeling algorithms (FB, GP). This is an effort to develop non-MC algorithms for the description of light production/propagation/detection, to improve event reconstruction and particle identification.

Analysis of physics data

- Backgrounds for double-beta decay. Current studies are on the performance of timing-based algorithms for tagging Bi-Po decay sequences (GP, ES), the main internal background to the 0NDBD signal, and on external backgrounds from the PMTs (GP). VL, who has recently joined our group, is the co-chair of the SNO+ Backgrounds group.
- Anti-neutrinos. SA is co-leading the SNO+ anti-neutrino physics group. We are involved in the preparation of the general analyses tools for the different SNO+ phases (SA, SN), as well as on specific calibrations for anti-neutrinos, including the development of a new directional neutron source (AM, PJ).
- Reconstruction performance in the water phase. GP is chair of the reconstruction review committee for the water phase since September 2016.

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

Stated objectives for past year

Main objectives that we had planned for 2016, listed by activity area:

Calibrations:

- conclude the installation of the fiber-based PMT calibration system;
- develop and test the nearline scripts that insert the laserball hardware information in the database;
- develop and test the framework for a fast quality control analysis for laserball data;
- develop methods to improve the optical calibration with laserball date taken outside the AV;
- finalize the construction of the source insertion system for the scintillator phase, and ship it to SNOLAB.

Data quality:

- complete the code in charge of recording the detector state on a run-per-run basis;

- test these scripts during detector commissioning.

Data analysis:

- continue the analysis of external backgrounds from 208Tl;
- test the lowering of thresholds in order to optimize neutron capture delayed coincidence signals in the beginning of the water phase data taking;
- continue the optimization of a directional neutron source and corresponding calibration plans;
- continue to optimize the cuts defined by the coincidence algorithms;
- explore the potential to use SNO+ to perform searches on dark-matter signals from the Sun.

Achievements and responsibilities during the past year

Concerning the execution of the planned SNO+ activities for 2016, they were still affected by delays in the detector fill. Even if the leaks were all identified and fixed, the detector was still not completely full by the end of the year, and so the activities that required data were affected.

Calibration and detector-related

A strong effort by the LIP Mechanical Workshop and Detector Lab was undertaken, in order to complete and test the Umbilical Retrieval Mechanism (URM) for the SNO+ calibration source insertion system. Mechanical parts production was finished in August, followed by installation of electrical parts and then mechanical and leak testing. A quite good He leak rate (< 10 -5 mbar.l/s) was reached on all parts and on the full assembly. URM #1 was shipped to SNOLAB in December. The second one will be built in 2017.

Installation at SNOLAB of the optical-fiber based system for PMT calibration was finished. Our group did not participate directly in the installation shifts at SNOLAB (that were highly dependent on the water-fill schedule), but provided detailed instructions for the personnel, and maintained responsibility for the book-keeping of the database of installed fiber positions.

Also, a group member (JM) started to chair the SNO+ source review committee, with the task of reviewing all the details of the construction and analysis of calibration sources, in order to prioritize physics gains versus contamination risks.

We continued to prepare the water phase optical calibration analysis. The development of a fast calibration analysis validation algorithm with a limited data set was concluded. The laserball light distribution in now analysed in a dedicated code, reducing the number of free parameters in the full optical fit. The software processing was updated, to line it up with requirements for real data. In terms of management tasks for the SNO+ optics group, we prepared a large set of documentation to be reviewed by an appointed review committee, and replies to several of the raised issues.

With respect to data-quality (DQ) low-level (LL) checks, GP is responsible for the scripts for the insertion of the DQ LL information on a run-per-run basis in the database. The scripts have been inserted in the nearline system and successfully tested during the May 2016 Mock Data Challenge.

Analysis and simulation studies

Among the tasks related to the background studies, GP has supervised student ES (6 months internship) on the study of the reconstruction in the water phase of external background events from 208Tl in the PMT glass. This was ES Bachelor thesis topic which was submitted to the University of Athens (Greece) in September 2016.

In the antineutrino task, the simulation study of a shielded neutron source with a collimator hole was finished, demonstrating its feasibility to calibrate the detector response to the direction asymmetry of antineutrino fluxes in the scintillator phases of SNO+. In addition, all the tools used to describe the reactor antineutrino signals in all phases were cross-checked and improved. The calibration and analysis plan for the water phase were outlined, but their finalization is still dependent on the detector conditions being established in early 2017.

Outreach

Neutrinos were one of the special topics of the national Física 2016 conference, which took place in Braga, with several contributions from our group and an invited lecture by the Nobel Prize winner Arthur McDonald (who also gave a public lecture in Pavilhão do Conhecimento in Lisbon).

Lines of work and objectives for next year

We expect 2017 to be mostly dedicated to the data taking, calibration and data analysis in the water phase, and to the preparation for the start of the next scintillator phases.

On the calibration side, we plan to:

- participate in the preparation of the calibration hardware to be used in the water phase, re-using much of the original equipment used in SNO;
- finalize and test the nearline scripts that insert the laserball hardware information in the database, to make it available for subsequent analysis;

- test the framework for a fast quality control/analysis of the laserball data shortly after data is taken;
- continue to develop and test analysis methods aimed at improving the optical calibration with the use of laserball data taken in the region outside the AV;
- finalize the preparation of the source insertion system for the scintillator phase (the one built at LIP) at SNOLAB, by checking and repairing any leaks that could have developed during transportation, and checking the mechanical performance;
- finalize, in collaboration with the TU Dresden (Germany), the development of two new gamma sources 57Co and 48Sc, 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.

On the data quality side:

- the scripts will be adapted to comply with recent changes in the data-acquisition and database systems
- the slow-control and detector water level information will be implemented
- automatic tools for run selection will be developped, tested and inserted in the SNO+ run processing framework

With respect to data analysis and its preparation:

in the water phase:

- first water data will tell if it is possible to lower the thresholds for delayed coincidence events, making possible a first reactor anti-neutrino measurement in a pure water cherenkov detector. A calibration with a AmBe neutron source is foreseen, in that case, to measure in-situ the efficiency for both coincident events and separate low energy gammas, and useful also for the background studies.
- analysis of the first water data of SNO+ will focus particularly on the external backgrounds: 214Bi and 208Tl from the acrylic vessel, external water and hold-down ropes. The analysis of Tl208 from the PMTs will be redone with new MC and water data when available. The information on the external backgrounds obtained from these analysis are crucial for the future SNO+ phases. The reconstruction in water will be reviewed with a focus on performance of the energy and position/direction fitters with respect to the SNO fitter performance.

in the scintillator phases:

- analysis of the first pure scintillator data will focus particularly on the internal backgrounds. Coincidence backgrounds (214Bi-Po and 212Bi-Po) algorithms will be fully tested with first scintillator data to evaluate their event tagging efficiency. Together with other sources, like 210Po and 7Be, these can be used to cross-check the energy scale and to monitor any drift in the detector's energy response.

On the other hand, LAB is the major component of the Te-loaded cocktail and therefore it is important to verify that all the background sources are within expectation. The development of the Te-cocktail will continue, with particular attention to other background sources, including the cosmogenic-induced ones.

- analysis of the 222Rn related backgrounds embedded in the acrylic vessel (210Pb, 210Bi, and 210Po) is another priority. Namely, the verification of the model used to calculate the leaching off these isotopes from the acrylic vessel surface and their diffusion in the scintillator.

The associated alpha-neutron reactions are expected to be the most important source of background for anti-neutrino analysis. A direct monitoring of the neutron delayed coincidences will be done in parallel, and the anti-neutrino selection strategies will be adapted accordingly.

In addition, we will continue the development of detector modeling algorithms for light emission, propagation and detection, including the different contributions to the time response. The focus will be on its application for the optimization of the optical calibration strategy for the scintillator phases, and later for the reconstruction and particle identification algorithms.

Finally, GP chairs the review committee for two SNO analysis topics: neutrino lifetime and Lorentz violations, which started in September 2016 and will continue their work in 2017.

SWOT Analysis

Strengths

The group members have a large variety of competences and experience, from low and high energy neutrino physics to nuclear, collider and cosmic ray physics and, from the technical standpoint, optical instrumentation, mechanical systems, PMTs and DAQ. Our strong role within the SNO+ collaboration surely contributed to the award of funding in the latest FCT call.

Weaknesses

After a few years with practically no students at all, in 2015 the situation started to change, but the group is still stronger in PhD level researchers (6) than in students (3). This is a common situation at LIP, and we are engaged with coordinated efforts to attract students at the undergrad level.

Opportunities

The recent addition of senior members (FB, VL) allows us to expand the group activities and strengthen our role in calibration and backgrounds / physics analyses, and also to contribute to the event reconstruction. The group now also

includes three students, that help consolidating our contributions in calibration and antineutrino physics.

Last but not least, commissioning data taking has started in late 2016. The water phase of SNO+ will be a great opportunity to use and commission the hardware and software tools we have developed, to attempt some physics measurements, and further prepare the upcoming scintillator phases.

Threats

The technique for loading Tellurium in the SNO+ scintillator has been demonstrated at the small scale level. The technique for large scale loading while maintaining a low background and a reasonable cost is still being developed by the SNO+ collaboration. If the goals are not met, this can result in a threat to the Te-loaded phase schedule.

Publications

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

S. Andringa et al. (SNO+ Collaboration): "Current Status and Future Prospects of the SNO+ Experiment", Advances in High Energy Physics, vol. 2016, Article ID 6194250, 21 pages, 2016

2 International Conference Proceedings

S. Andringa on behalf of the SNO+ Collaboration: "SNO+ status and plans for double beta decay search and other neutrino studies", Proc. of Nuclear Physics in Astrophysics VI (NPA6), May 2013, Lisbon, Portugal

J. Maneira on behalf of the SNO+ Collaboration: "Status and prospects of the SNO+ experiment", Proceedings of TAUP2015, Journal of Physics: Conference Series 718 (2016)

Presentations

2 Poster presentations in international conferences

José Maneira: "Calibration of the SNO+ experiment", 2016-07-08, XXVII international Conference on Neutrino Physics and Astrophysics, London, United Kingdom

Gersende Prior: "The SNO+ experiment physics goals and background mitigation", 2016-12-12, NUPHYS 2016 - Prospects in Neutrino Physics, London, UK

7 Oral presentations in national conferences

Gersende Prior: "Updates on the SNO+ experiment", 2016-02-20, Jornadas do LIP 2016, Braga, Portugal

Stefan Nae: "Antineutrino physics with SNO+", 2016-06-12, Jornadas de Doutoramento do Departamento de Física da FCUL, Lisboa

Stefan Nae: "Antineutrino detection and direction with SNO+", 2016-06-22, IDPASC Students Workshop, Porto, Portugal

José Maneira: "From SNO to SNO+ and the search for neutrino masses", 2016-09-08, 20a Conferência Nacional de Física, Braga, Portugal

Ana Sofia Inácio: "Optical calibration of the SNO+ experiment", 2016-09-08, 20a Conferência Nacional de Física, Braga, Portugal

Stefan Nae: "Reactor neutrino oscillations with the SNO+ detector", 2016-09-08, 20a Conferência Nacional de Física, Braga, Portugal

Sofia Andringa: "Measuring oscillations with different neutrino sources", 2016-09-08, 20a Conferência Nacional de Física, Braga, Portugal

1 Poster presentation in national conferences

Evangelia Samara: "SNO+ photomultiplier's background study", 2016-03-02, Jornadas de Engenharia Física, IST, Lisboa

3 Seminars

Sofia Andringa: "Geoneutrinos, probes of the Earth's interior", 2016-04-13, Seminários do IDL - Instituto D. Luiz, Lisboa

Ana Sofia Inácio: "Calibração Óptica da experiência SNO+", 2016-05-18, Seminário do 1º ano de Mestrado, FCUL, Lisboa

Sofia Andringa: "Medição de oscilação com diferentes fontes de neutrinos", 2016-09-19, Seminários de Física da UTAD, Vila Real

1 Outreach seminar

José Maneira: "As oscilações de neutrinos", 2016-10-25, , Escola Secundária António Damásio

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" (ongoing)

1 Graduation Thesis

Evangelia Samara: "The SNO+ Photo-multipliers Background" (finished on 2016-09-30)

HIGH PRESSURE XENON DOPED MIXTURES FOR THE NEXT COLLABORATION

NEXT

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 (to exclude events with close energies) and background suppression (to reject false events whose energy falls inside the energy window), 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 $\beta\beta$ (Xe136), 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 (the name honours the memory of Professor James White, recently deceased and one of the key scientists of the NEXT Collaboration). In the recent NEXT Collaboration Meeting the first successful results from NEW have been presented.

Framework and status for past and current year

In spite of the fact that xenon is the perfect candidate as detection medium in this particular experience, it has some drawbacks mostly related with 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, has been requested to our group.

The first candidate was trimethylamine 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.The work was recognized by our partners and publications have been /are being issued on this subject.

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:	2 with indirect contribution from team
International conferences:	1 oral presentation
Completed Theses:	2 Master theses

// 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-CF4, which have been ruled out as solutions for the present problem. In the immediate future, other candidates will be assessed, starting with CH4.

Alexandre Trindade has been responsible for the experimental work, whereas José Escada and Filomena Santos carried out the simulation studies.

Filipa Borges and Carlos Conde together with the rest of the team collaborate in the analysis and discussion of the experimental results.

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

Achievements and responsibilities during the past year

Along the past year, the team has continued the study of several aspects of the performance of Xe/TMA mixtures, namely charge multiplication and scintillation yields. The measurements were performed in several modular devices specially built and high pressure enabled.

As it was a matter of disagreement in the scientific community, the absorption of xenon scintillation by TMA, reportedly followed by re-emission, was the subject of complementary studies through both experimental measurements and Monte Carlo simulation. Our results, contradict what had been published and was believed.

Outreach

Participation of 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 in “Estágios de Verão da UC” which gives the opportunity to University students of the scientific area to participate in the work being developed in the investigation group. Collaboration in visits from high school students to the Physics Department of the University of Coimbra, presenting and explaining them kind of research work done in an investigation group in the Physics area.

Lines of work and objectives for next year

Upon finishing the analysis and publication of the results for Xe-TMA, our work plan for 2017 involves studying other Xe based mixtures of interest for the NEXT Collaboration, which are still under discussion.

Our next study will be on CH4, another possible candidate, and mainly on its effect on primary scintillation. Another following study may be on CO2, as it has some known advantages. Subsequent candidates are still being discussed within the collaboration.

These studies will be carried out in the systems custom built and, if needed, some new devices may have to be developed. Whenever necessary, Monte Carlo simulation studies will be carried out.

SWOT Analysis

Strengths

The concurrence of expertise and long experience both in experimental work and specially developed Monte Carlo simulations is one of the biggest assets of the group.

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.

Weaknesses

Lack of approved and financed projects in the recent years limit both the investment in equipment and the attendance of scientific meetings by the team members.

Opportunities

Measurements recently carried out with success proved to be eagerly needed by the community.

From the expertise acquired and equipment developed, there is a serious possibility of expanding our work to the Astrophysics domain, where new gas mixtures for polarimetric studies are being sought.

Threats

During 2016 F.S. has received at least two invitations to act as invited speaker in two international conferences which she couldn't attend, because financing these missions could jeopardize other commitments or the necessary acquisition of equipment and components.

Publications

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

NEXT Collaboration, "Sensitivity of NEXT-100 to neutrinoless double beta decay", JHEP05(2016)159

NEXT Collaboration, "First proof of topological signature in the high pressure xenon gas TPC with electroluminescence amplification for the NEXT experiment", JHEP01(2016)104

Presentations

1 Oral presentation in international conference

Filomena Santos: "VUV xenon scintillation wavelength shift by trimethylamine", 2016-01-01, IEEE trans.Nucl. Sci. 2016, France

Theses

2 Master theses

Bruno Rasteiro: "Estudo de parâmetros que afectam a tensão de descarga num detector gasoso" (finished on 2016-02-28)

Daniel Cavaleiro: "Projecto, desenho e desenvolvimento de um sistema para a medida da velocidade de deriva de electrões" (finished on 2016-02-28)

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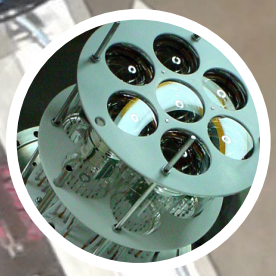


Detectors for **particle** and **nuclear physics**

- Neutron detectors
- RPC R&D
- Gaseous Detectors R&D
- Liquid Xenon R&D
- NUC-RIA

// Development of new in

Health and biomedical applications

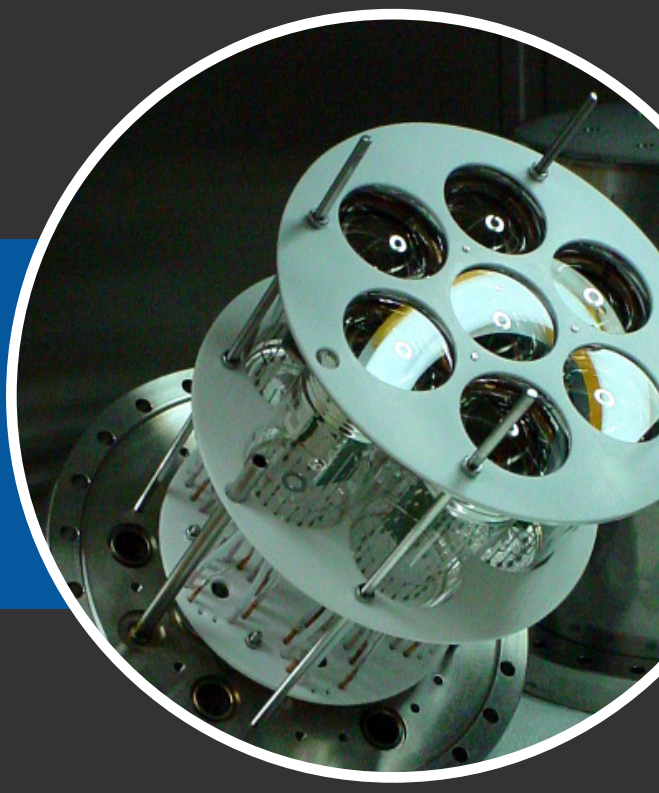
- RPC-PET
- OR Imaging
- Gamma cameras
- STCD TagusLIP

Space applications

- Space Rad
- i-Astro

nstruments and methods

Detectors for particle and nuclear physics



Neutron Detectors

Neutron scattering facilities have been drastically affected by the He-3 supply crisis since most of its instruments were equipped with neutron detectors based on He-3. Given the seriousness of the threat, the leading neutron facilities worldwide have been prioritizing the development of possible alternatives to He-3 detectors for neutron scattering applications.

LIP soon recognized the need to join this international effort in order to maintain the collaboration with its partners from previous European projects (FP6 and FP7). With this aim in mind the LIP team proposed the development of a new He-3 free detector concept based on 10B4C coated RPCs, with potential for improved performance, e.g. sub-millimetric spatial resolution and sub-microsecond timing, which could be competitive with the different approaches taken by other groups. The promising outcomes achieved in the framework of the FCT funded project (EXPL/FIS-NUC/2522/2013) led to the integration of LIP in a H2020 EU project, with partners from the ESS (European Spallation Source) and former partners from ILL, ISIS and TUM-FRMII in the previous FP6 and FP7 programmes.

Currently, the group activity is being developed in the framework of SINE2020 EU Project (No.: 654000) started October 2015 ending September 2019. Science and

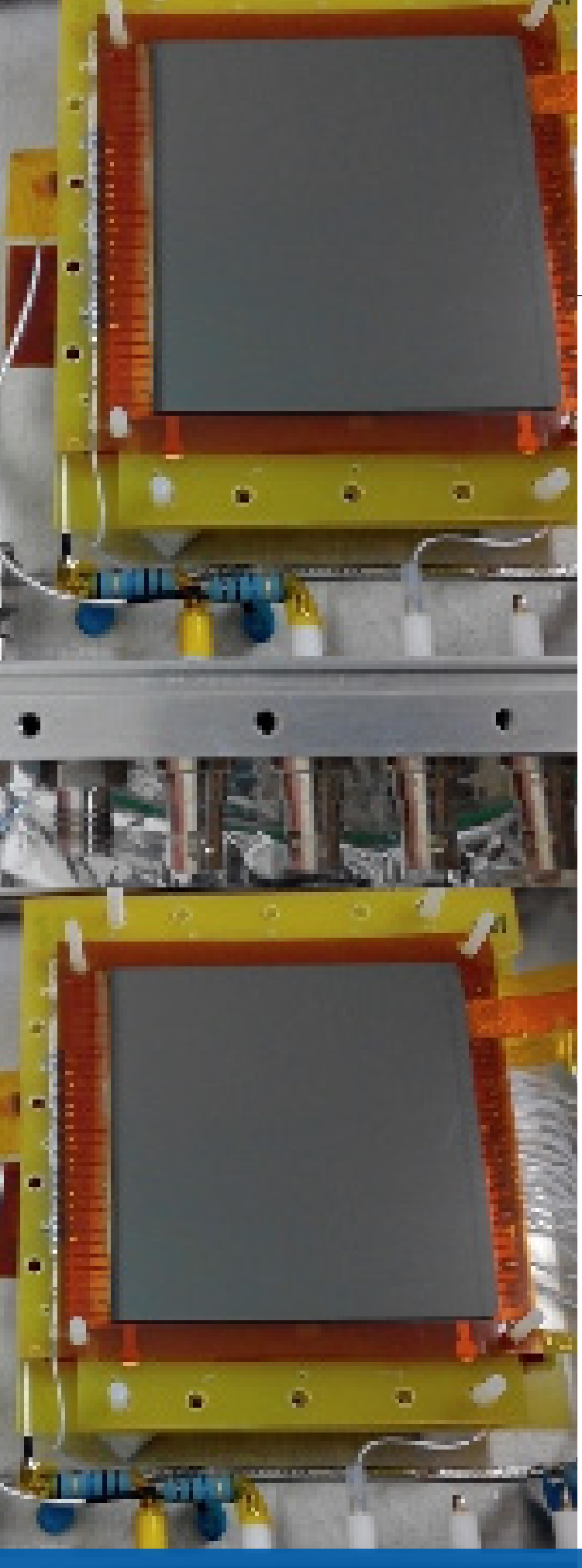
Framework and status for past and current year

Innovation with Neutrons in Europe in 2020 (SINE2020) is a consortium of 18 partner institutions from 12 countries, funded by the European Union through the H2020 programme, with a global budget of 12 M€ and EU contribution committed to LIP of 116 kEur.

LIP team have 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 conference:	1 Oral presentation
International meetings:	1 Oral presentation
National conferences:	1 Oral presentation
Collaboration meetings:	3 Oral presentations
Events:	1 Collaboration meeting organized



Team

Principal Investigator Luís Margato (85)

Researchers
Alberto Blanco (15), Andrey Morozov (25), Paulo Fonte (15)

External/Additional scientific collaborators
Alessio Mangiarotti (20)

Total FTE
1.6

UPS: Neutron Detectors / RPC R&D / Gas Detectors R&D / Liquid Xenon R&D / NUC-RIA

Lines of work and team organization

Aligned with the WP9 objectives, our activities involve the development of the $^{10}B_4C$-coated RPCs for thermal neutron detection and the evaluation of its potential for NSS instruments and other potential applications (e.g. neutron imaging and homeland security).

The research activities are organized as follows:

- Detector modelling and parameters optimization - MC simulations (GEANT and ANTS2 package)
- Detector prototyping :
  - Design, fabrication and assembly of different $^{10}B_4C$--coated RPCs prototypes.
  - Implementation of $^{10}B_4C$-coated RPCs in Multilayer configurations (Toward High Detection Efficiency).
- Detector evaluation and performance studies in a monochromatic thermal neutron beamline (e.g. efficiency, spatial resolution, count rate and gamma sensitivity).
- Basic studies (RPCs are well known in the literature for its operation with MIPs which is not the case for HIPs e.g. He-4 and Li-7 fission fragments):
  - Working gas composition influence on the detector performance and operation parameters (e.g. lower operation HV, dark counts and gamma sensitivity minimization).
  - There will be different pulses signatures for gamma's and for thermal neutrons events (Pulse Shape Discrimination techniques)?

It is a small team with most of the activities being ensured by the group coordinator. As far as possible, all members of the team (also with responsibilities in other projects) give their contribution both in addressing practical issues and in the discussion of scientific questions. Therefore it's hard to establish a segmentation of their involvement. Andrey Morozov and Allessio Mangiaroti are giving their 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 $^{10}B_4C$ coatings are produced in the European Spallation Source (ESS) Detector Coatings Workshop in the frame of an already established collaboration.

The evaluation tests of the detector prototypes with thermal neutrons are being conducted in a neutron beamline at TUM--FRM II, Garching, Munich, in collaboration with our SINE2020 partners.

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

Stated objectives for past year

The stated main objectives for the past year were:

- Further the investigations of the $^{10}B_4C$ coatings onto float glass and the modification of its surface resistivity to values above 1E6 ohm/sqr (task undertaken by the Detector Coatings Group at ESS, Sweden); this is one of the key requirements for the implementation of a $^{10}B_4C$-coated Multigap RPC (one of the possible RPCs configurations to be studied).

- Detector parameters optimization by MC Simulations (e.g. converter layer thickness, number of converter layers and the gas-gap width that optimizes the detection efficiency).

- Design and assembly of $^{10}B_4C$-coated RPCs prototypes with different configurations and their evaluation in a thermal neutron beam at a neutron facility.

Achievements and responsibilities during the past year

Investigations of the surface resistivity of $^{10}B_4C$ coatings were continued with specially focused in tuning the sheet resistance for the $^{10}B_4C$-coated Multigap RPCs configuration. It was obtained a surface resistivity difference of several orders of magnitude by varying the deposition temperature, various surface treatments and different coating thicknesses. It has also been observed that the impurity level in the films plays a significant role. This results were the subject of an oral presentation in the 2016 NSS/MIC Conference, Strasbourg, France (Tailoring the boron coating properties for use in neutron detector applications, C. Höglund, S. Schmidt, J. Birch, L. Hultman, M. Imam, L. Margato, H. Pedersen, R. Hall-Wilton)

Detector optimization can now be fully automatized in ANTS2: the script engine is capable to perform multi-variable optimization of the detector geometry (for example, to maximize the detection efficiency).

ANTS2 geometry manager and configuration tools were upgraded to provide the users a simple and effective way to configure any type of detector geometry which has to be considered during RPC detector design and optimization phases (scripting tools were added which are especially important for the multilayer RPCs configurations) .

MC simulations were performed for two $^{10}B_4C$-coated RPCs configurations. The values computed for the detection efficiency (~11%) shows to be in good agreement with the experimental results (shown later).

Two 10B4C-coated RPCs with different gas-gap widths were designed and assembled in LIP. The $^{10}B_4C$ coatings were produced at the ESS Detector Coatings Workshop. The Front End Electronics (designed by P. Fonte) consisted of charge sensitive amplifiers housed in a board equipped with 48 channels. As DAQ system it was used the new TRB3 platform developed at GSI, Germany.

In July 2016 the two prototypes were taken to TUM-FRM II in Garching (DE) for the experimental tests with neutrons:

- The plateau and detection efficiency measurements performed in the TREFF neutron beamline (λ= 4.7Å) revealed similar behaviour for both RPCs (0.35 mm and 1 mm gas-gap widths).

- It was observed a wide plateau (> 500 V) and in a HV region where RPCs show low sensitivity to minimum ionizing particles (MIPs).

- A detection efficiency of ~ 12 % was measured, which is as high as expected for a Single-gap RPC (~11% from MC simulations).

From the evaluation tests it seems that thinner gas-gap's are more suitable for multilayer RPCs configurations when compared with wide gas-gap.

The spatial resolution was also investigated:

- It was measured a spatial resolution of FWHM ~ 236 microns for both x and y-directions (well below 1mm) which for a neutron gaseous detector is a remarkable result.

In a $^{10}B_4C$-coated RPC the fission fragments start ionizing the gas in the vicinity of the cathode surface (neutron converter on the cathode). Thus, in principle, the centroid of the induced charge will be shrunk to the true neutron interaction position (due to an anti-parallax virtue resulting from an exponential dependence of the avalanches size with their starting position). Therefore, in principle, it will be possible to achieve even a better resolution (our measurement were limited by the width of the Cd slits and by the divergence of the neutron beam).

A high spatial resolution combined with a timing capability easily in the nanosecond range opens the possibility of applying the $^{10}B_4C$-coated RPCs being developed by the LIP team e.g. for Timing-Resolved Neutron Imaging (to follow fast dynamics processes) or in Energy-Resolved Neutron Imaging at pulsed neutron spallation sources (neutron energy selected by a time-of-flight technique) such as the ESS.

The LIP team results were also object of scientific highlights in the sites of the SINE2020 project, Phys.org and Neutrons source.org (http://neutronsources.org/news/scientific-highlights/what-if-neutron-scattering-uses-the-same-type-of-detectors-used-to-look-into-space.html).

Lastly, a non-minus valuable fulfilment was the organisation by LIP of the SINE2020 General Assembly at the University of Coimbra, September 7-8, 2016.

Lines of work and objectives for next year

Over the next year, the team will continue to investigate and develop the $^{10}B_4C$-coated RPCs for PSNDs for NSS applications.

Demonstrated experimentally that the $^{10}B_4C$coated RPCs can achieve sub-millimeter resolution (one of the main WP9 requirements), as the next challenge it was established to investigate the possibility of reach high detection efficiency by using RPCs in multilayer architectures.

The planned activities are:

- Optimization by MC simulations of the $^{10}B_4C$ coatings thickness (the optimum thickness that maximizes the detection efficiency will depend on both: neutron wavelength and number of $^{10}B_4C$ layers).
- Design and construction of a prototype comprising a stack of $^{10}B_4C$-coated Double gap RPCs at LIP.
- Manufacture of the $^{10}B_4C$ coatings at ESS by the Detector Coatings group. Experimental study of the detector prototype in a neutron beamline at FRM II, to be conducted in collaboration with SINE2020 partners.

SWOT Analysis

Strengths

- Consolidated knowledge in the field of gaseous radiation detectors and in particular with thermal neutron detectors; LIP is also one of the world leader's developers in RPCs technology.
- 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 and Portugal, increasing the likelihood of new EU funding opportunities in the future.

Weaknesses

- All team members have their time shared with other busy activities which combined with the lacks of funding to contract students or a researcher for the team leads to a critical deficit of manpower, much needed to fulfil the demands of an international collaboration.

Opportunities

- Opportunity of exchanging knowledge and experiences with the neutron detector expert community of the European-leading neutron facilities.
- The research activities are part of a more general effort led by our partners in SINE2020/WP9-Detectors, aiming to develop very demanding neutron detectors, capable of performances not yet possible with present state of the art, in particular for the instruments to be installed at the ESS. Being inside in such 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

- Precarious employment condition of the group leader: self-financing by a grant using funds from SINE2020 project in which he is the LIP representative; the available funds are not sufficient to maintain his grant during the 4-year duration of the project.
- Concerning the high level of difficulty and responsibility of the project, the lacks of manpower, with the group leader to have to take 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.

Presentations

1 Oral presentation in international conference

C. Höglund: "Tailoring the boron coating properties for use in neutron detector applications", 2016-10-31, IEEE, Nuclear Science Symposium and Medical Imaging Conference (NSS/MIC), Strasbourg, France

1 Oral presentations in international meeting

Luís Margato: "Boron-10 based thin-gap Hybrid RPCs for sub-millimeter resolution thermal neutron detectors", 2016-02-23, RPC 2016 - THE XIII WORKSHOP ON RESISTIVE PLATE CHAMBERS AND RELATED DETECTORS, Ghent University, Belgium

1 Presentation in national conferences

Luís Margato: "Neutron Detectors", 2016-02-20, Jornadas do LIP 2016, Braga, Campus de Gualtar

Events

1 Collaboration meeting

SINE2020 General Assembly 2016, University of Coimbra Department of Physics, Rua Larga, P-3004 516 Coimbra, 2016-09-07 to 2016-09-08

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 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 or 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 a number of 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 fast-neutron TOF detectors
- epi-thermal neutron detectors with ^{10}B converters

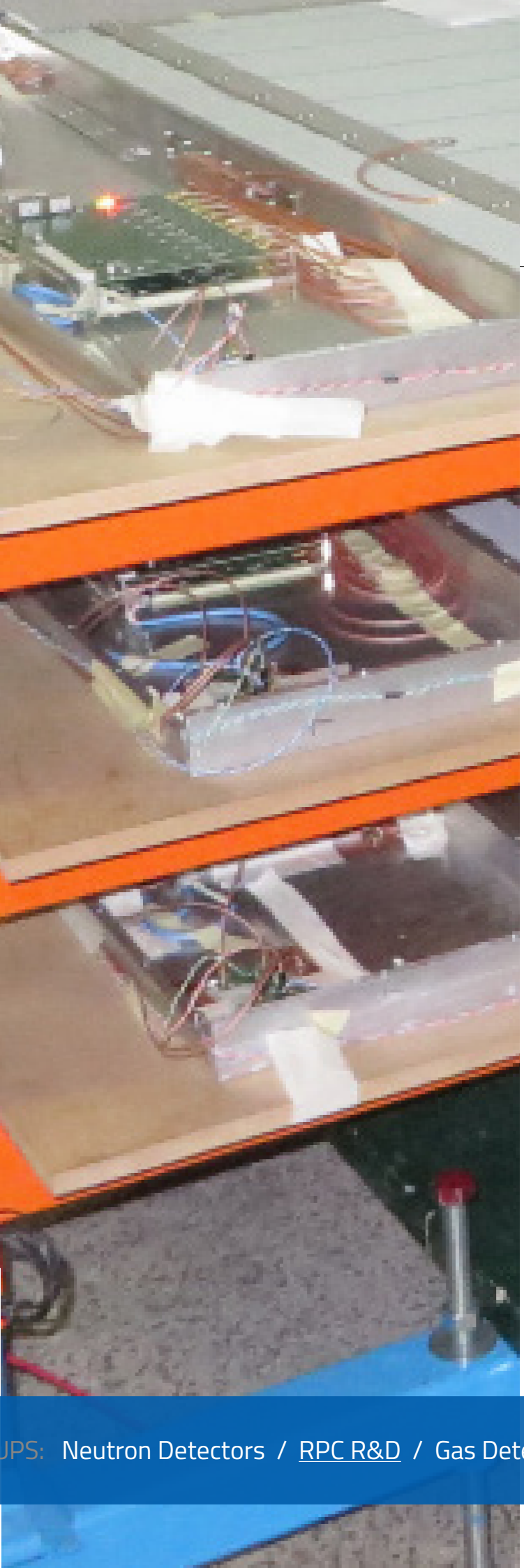
Our group designed and built the HADES TOF Wall detectors and it is now the sole responsible for the operation of the system, which has shown so far flawless performance. This work will be carried into the future FAIR facility (Germany), as HADES is a FAIR experiment.

Framework and status for past and current year

Besides the development of technology-expanding devices, we keep an interest in RPC's 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/). We are members of CERN's RD51 and SHiP collaborations.

The RPC group cooperates with several other LIP groups (neutron detectors, AUGER, LATTES, HADES, PET with RPCs and RD51), 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
Afonso Bernardino (2), Américo Pereira (10), Carlos Silva (90), Douglas Lima (100), Luís Lopes (70), Nuno Carolino (50), Nuno Filipe Silva Dias (70), Orlando Cunha (80), Rui Alves (69)

Total FTE
6.0

Summary of performance indicators

Articles in international journals:	2 With direct contribution from team
International conferences:	2 Oral presentations
International meetings:	3 Oral presentations
Collaboration meetings:	7 Oral presentations

UPS: Neutron Detectors / RPC R&D / Gas Detectors R&D / Liquid Xenon R&D / NUC-RIA

Lines of work and team organization

The core RPC group is rather small, with 3 part-time researchers, supported by LIP's Detector Lab and Mechanical Workshop staff. Therefore, even if we list here a main responsible for each task, there is not a strong segregation of responsibilities within our group.

TOFtracker (A.Blanco)

We are developing RPC detectors that simultaneously deliver accurate positions and times, having demonstrated a position resolution of 37 um along with a time resolution of 80 ps in small areas. Work is ongoing in a large area (~2 m2) detector readout only by 21 charge-readout channels and 32 time-readout channels, therefore extremely economical. These detectors are intended for applications in 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 robust large area detectors, with excellent time and position capabilities (see prev. task), free from a permanent gas supply. Such detectors would easily replace the scintillator technology in many field applications and ease the 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 collaboration, interested in cosmic-ray probes of atmospheric physics.

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 (see below) 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 fits 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 fits 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. We may contribute to the experiment with further detectors, under discussion. Please see the specific group report.

Sources of Funding

Code	Amount	Dates	Description
AIDA-2020	45.000 €	2015-06-01 / 2019-05-31	Advanced European Infrastructure for Detectors at Accelerators

Stated objectives for past year

Funding

No new opportunities have been announced so far. Naturally we will be attentive.

TOFtracker

We hope to finish successfully the ongoing commissioning of the 3-layer telescope, which will be later installed at CBPF, and present the results at the RPC2016 workshop.

We hope to produce and deliver a TOFtracker telescope system for diffusion muon tomography to HYDRONAV S.A company.

Sealed and environmentally robust RPCs

We will continue the study of the reasons so far preventing us to achieve fully sealed operation.

A large production of about 20 chambers is foreseen in the framework of a funded project. See the report of the Auger group.

High-rate

We will test systematically most of the currently available materials for high-rate RPCs.

Will participate in the many AIDA2020 meetings.

Detectors for RPC-PET

We hope to install the new front-end electronics in the current animal PET scanner, achieving considerable sensitivity gains. Steps towards the characterization of the scanner according to the NEMA standard will be taken. Please see the specific group report for details.

Physical modelling

P.Fonte will continue writing a book on "Resistive gaseous detectors" with Vladimir Peskov and Marcello Abbrescia.

Epi-thermal neutron detectors

Several prototypes, exploring different configurations, will be built and tested. Please see the specific group report.

HADES

There are ongoing studies of a forward detector that may include a TOF Wall. The LIP HADES group is active in the simulations (see specific report), but in principle in 2016 likely there will be no hardware activities.

Achievements and responsibilities during the past year

Funding

The AIDA2020 EU project (http://aida2020.web.cern.ch/) was continued from 2015, covering the development of high-rate RPCs. The group is also involved in the FAPESP/19946/2014 project (see below).

Funding opportunities for the RPC-PET line were investigated. Please see the specific report.

There were no funding opportunities at national programs.

Very importantly, LIP has decided, as a strategic decision, to reinforce the RPC group with one physicist on a technical contract. The selection procedure yielded a very interesting candidate, with several years of experience at CERN, which will start functions in February 2017.

TOFtracker

A large area (~2 m^2) TOFtracker 3-layer cosmic-ray telescope (MASTER) was concluded and shipped to its commissioner: CBPF, Rio de Janeiro, Brasil. The performance reached was somewhat below expectations (1.3x3.4 mm^2 in position and 150 ps in time), but it is our conviction that the calibration was severely incomplete (mostly owing to a subtle technical problem on the new front-end electronics that took a long time to solve) and much improvement will be possible in the next version (see below). Anyhow, it is a unique concept worldwide and a contribution on this subject was presented at the RPC2016 workshop and published in JINST.

A contract was signed with the company HIDRONAV, S.A. for supplying in 2017 a 4-layer TOFtracker telescope system for container inspection by muon tomography at sea ports (http://macroescaner.com). Our commitment is to produce the telescope system and the construction has started.

A scientific partnership was initiated with the TOMUVOL project (http://wwwobs.univ-bpclermont.fr/tomuvol/) for supplying a 2 layer TOFtracker to complement the project's detectors at a measuring campaign on the Stromboli volcano in 2017. Joint development was started on DAQ matters and construction was also started.

Sealed and environmentally robust RPCs

This activity benefits from strong collaboration/support of the AUGER and LATTES groups and the detector lab. Further details may be found on the specific reports.

The bulk of the activity in the year was the preparation (detector design, production infrastructure, coordination with other partners) for the construction of 40 MARTA-type sensitive volumes for the FAPESP/19946/2014 "A new generation of RPC muon detectors for high-precision high-energy cosmic-shower" project. Two volumes were delivered to the Brasilian partner in São Paulo. An integrated gas control and environmental monitoring system was developed.

The production of sensitive volumes for the MARTA-Rio activity was finalized, along with gas bubblers and HV power supplies. Support for the existing installation was provided.

The operation of several chambers in the field at the AUGER experiment site in Argentina was continued and a report on this subject was presented at the RPC2016 workshop and published in JINST.

We continued to support the operation of the TRAGALDABAS cosmic ray observatory (https://dx.doi.org/10.1088/1742-6596/632/1/012010).

The development of a low-power, low-cost, high-voltage supply suitable for field deployment was finalized and it is being deployed in all our systems.

A Spanish group manifested interest in a MARTA-type telescope for cosmic-ray studies in Antarctica.

Long term studies aimed at a sealed large-area RPC detector were continued, but without any significant breakthrough.

High-rate

Work was continued on the AIDA2020 project, with acquisition and test of several candidate high-rate RPC electrode materials. A beam-going chamber was designed for next year campaign.

Detectors for RPC-PET

The TOFtracker developments are directly relevant for human RPC-PET. The new front-end electronics is also relevant for animal RPC-PET. Please see the specific group report for details.

Physical modelling

P. Fonte is writing a book on "Resistive gaseous detectors" with Vladimir Peskov and Marcello Abbrescia.

Epi-thermal neutron detectors

Please see the specific group report.

HADES

The expected activities related with the installation of the RPC-TOF-W into the new ECAL frame did not take place due to a delay in the construction of the ECAL frame, but all the arrangements are already prepared. Please see the specific group report.

Lines of work and objectives for next year

Funding

No new opportunities have been announced so far. Naturally we will be attentive.

TOFtracker

In 2017 the 4-layer TOFtracker for the HYDRONAV S.A company must be delivered.

We must build the chambers, integrate them in the TOMUVOL detector, deploy and participate in the Stromboli muon tomography campaign.

The MASTER telescope in Rio must be commissioned.

Sealed and environmentally robust RPCs

Initiate production of 30 to 40 sensitive volumes for the 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 the eventual cosmic ray telescope in Antarctica.

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 will continue writing a book on "Resistive gaseous detectors" with Vladimir Peskov and Marcello Abbrescia.

Epi-thermal neutron detectors

Please see the specific group report.

HADES

It is expected to finish the implementation of the new RPC-TOF-FW into the software of the experiment. The first prototype of a module of the RPC-TOF-FW will be constructed and evaluated.

SWOT Analysis

Strenghts

The team has proven repeatedly to be competent, inventive, productive and reliable. It will be reinforced with a new physicist on a technical contract.

Have access to LIP's technical infrastructure, which includes some very good and experienced technicians, a well equipped mechanical workshop, and it is funded for the next year.

Enjoy the confidence of some RPC-enthusiastic colleagues that supplement the smallness of our core team by 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 throughtput.

Opportunities

We believe to have or being about to have very competitive detectors for the application "markets": animal RPC-PET, muon tomography and cosmic ray physics.

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 a tRPC timing detector.

Threats

Hostile funding environment.

In the long term, the excessive maturation of the team members will become a determinant factor.

Publications

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

L. Lopes et al. (15 authors): "Outdoor field experience with autonomous RPC based stations", J. Instrum. 11 (2016) C09011

P. Assis et al. (18 authors): "A large area TOF-tracker device based on multi-gap Resistive Plate Chambers", J. Instrum. 11 (2016) C10002

Presentations

4 Oral presentations in international conferences

Paulo Fonte: "Summary Talk", 2016-02-22, XIII workshop on Resistive Plate Chambers and Related Detectors (RPC2016), Ghent, Belgium

Alberto Blanco: "A large area TOF-tracker", 2016-02-23, RPC 2016, XIII WORKSHOP ON RESISTIVE PLATE CHAMBERS AND RELATED DETECTORS, Ghent University, Belgium

Luís Lopes: "Outdoor Field experience with Autonomous Stations", 2016-02-23, XIII Workshop on Resistive Plate Chambers and Related Detectors, Ghent University, Belgium

TRAGALDABAS Collaboration: "TRAGALDABAS. First results on cosmic ray studies and their relation with the solar activity, the Earth's magnetic field, and the atmospheric properties", 2016-09-04, XXV European Cosmic Ray Symposium, Turin, Sept. 4-9 2016

2 Oral presentations in international meetings

Paulo Fonte: "Marta RPCs", 2016-01-14, Towards a Large Field-of-View TeV Experiment in the Southern Observatory, University of Tor Vergara, Rome, Italy

Paulo Fonte: "Overview of Resistive Plate Chambers", 2016-09-07, SINE2020 General Assembly 2016, Coimbra, Portugal

GASEOUS DETECTORS R&D

Gaseous Detectors R&D

The group has two main lines of work:

1. HP xenon: Development and production of a prototype of a ruggedized Xe based high pressure detector optimized for field applications, whose performance surpasses 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 cm2) and an energy resolution better than 3% at 662 keV.

2. Ion mobility measurements: Ion mobility measurements and Monte Carlo simulation in several gaseous mixtures with a dedicated system, specially developed for this purpose that features unique characteristics.

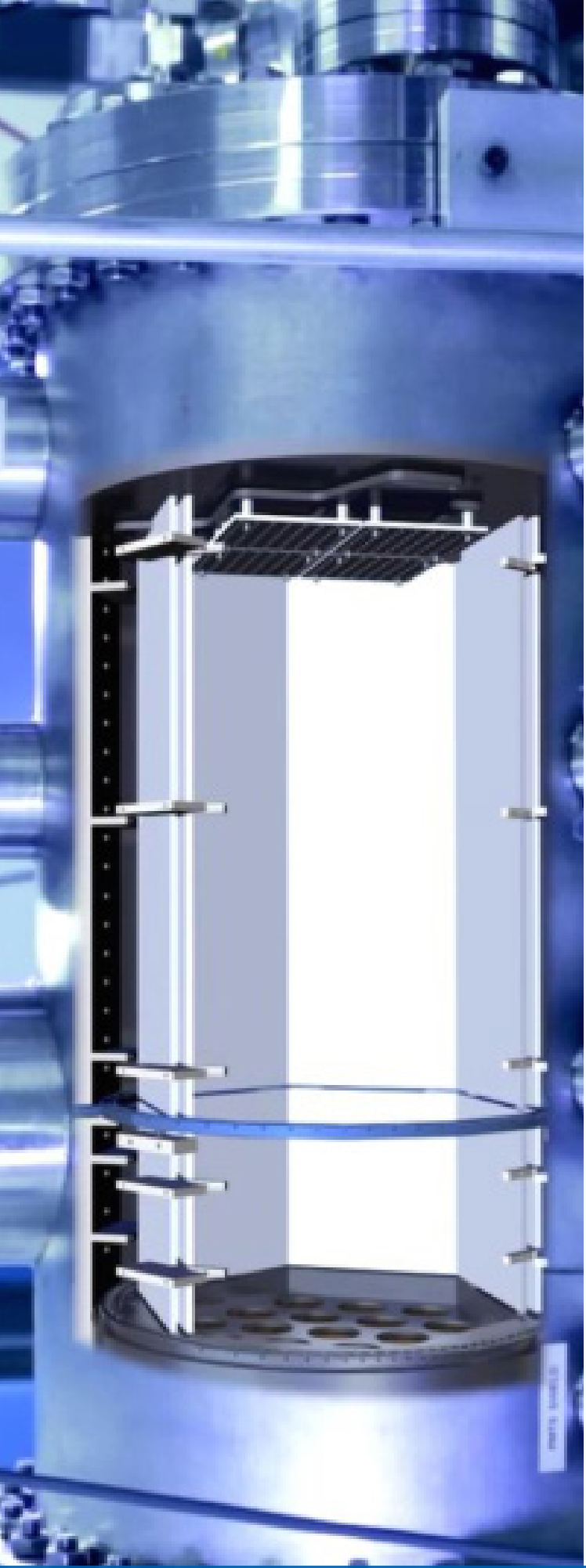
Concerning the first line of work, the rising interest of High Pressure Xe (HPXe) gas radiation detectors for hard x-ray and gamma radiation has triggered this study. The interest in these detectors grew in the last decade as the competing devices (e.g. Na(Tl) scintillation counters and CdZnTe(CZT) detectors for gamma-rays and liquid Xe detectors in rare event experiments) failed to comply with increasingly demanding requirements. In fact, HP-Xe detectors can work at room temperature, presenting good efficiency and adequate energy resolution, particularly for large areas, and have a much lower cost than CZT. These are important characteristics, especially for their possible application in Advanced Radiation Portals with spectroscopic capabilities. Indeed, the existing alternatives based on NaI(Tl) or high purity Ge, are

Framework and status for past and current year

not satisfactory for either primary radiation screening or geological prospection. HP-Xe detectors can be promising in this area, especially the GPSC which is less sensitive to microphonic noise than ionization chamber type detectors and presents a comparatively better energy resolution. Nevertheless, for High Pressure applications GPSCs have a disadvantage which limits their use: they require either vibration proof photomultipliers with thick optical windows, expensive and limited to small areas, or have to be equipped with photodiodes or microstructured elements integrated in the gas volume, both costly and with critical behaviour for large areas and at high pressures. The aim of the project is to develop and characterize a new type of GPSC, conceived within the team: the MultiGrid High Pressure Gas Proportional Scintillation Counter (MGHP-GPSC). This detector has the advantage of featuring a photocathode deposit integrated in the gas volume, which avoids the need for optical

Summary of performance indicators

Articles in international journals:	2 With direct contribution from team
International conferences:	1 Oral presentation 3 Posters 1 Proceeding
International meetings:	2 Oral presentations
Completed Theses:	2 Master theses



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 built and assembled during this year and is now
under tests.

Concerning thwe second line of work, measurement of the mobility of ions in gases is relevant in several areas, such as modeling of gaseous radiation detectors, the understanding of pulse shape, and also in IMS (Ion Mobility Spectrometry), a technique used even far from the common applications, for detecting narcotics and explosives. Data on ion mobility is especially important for improving the performance of large volume gaseous detectors, such as the ALICE and NEXT TPCs or Transition Radiation Detectors. This has created an increasing interest among the CERN community, and several requests to study ion mobilities for specific gas mixtures.

Team

Principal Investigator Filomena Santos (30)

Researchers
Carlos Conde (50), Filipa Borges (35), Jorge Maia(15), José Escada (50), João Barata (40), Rui Marques(15), Teresa Dias (10)

PhD Students
Alexandre Fonseca Trindade (40), André Cortez (100)

External/Additional Collaborator
Sérgio Carmo

Total FTE

3.9

Lines of work and team organization

1. Development of HP-Xe detector

This task is 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.

2. Measurement of the mobility of ions in gases

This task is also part of the work by PhD student André Cortez, who co-supervised himself an MSc thesis with Filipa Borges on the subject. Mobility of ions in Xe-TMA mixtures is the subject of past and ongoing academic work developed in the framework of the NEXT Collaboration and supervised by Filomena Santos. Monte Carlo simulation on drift of ions in gases is also planned and will be carried out by João Barata, Carlos Conde and Teresa Dias.provides an important insight on the needs and requirements of those experiments. The team also benefits from the previous experience of one of the members in the field of atomic spectroscopy.

Stated objectives for the past year

The objectives for the HPXe detector were the assembling of the detector prototype and the associated gas handling system, signal processing and detector biasing electronics, as well as the first tests for its performance with alpha particles. Also, different ways of compensating the solid angle effects for events detected at different positions along the detector were to be thought and implemented. The study of the photocathode quantum efficiency dependence on incidence angle of light and on gas pressure is important for the solid angle correction in the HPXe detector and the experimental system for these measurements was to be used to obtain results for Xe at pressures from the atmospheric one to 5 atm for a CsI photocathode. All the objectives were achieved with the exception of the solid angle correction which is still under evaluation. These works are part of a PhD thesis to be finished by the end of 2017 and of a MSc thesis that finished in July 2016.

Concerning the ion mobility measurements the objectives stated for the past year were studies for mixtures of Ne, N2, CO2 and Xe-TMA and these were performed, originating a MSc thesis on the subject, that was finished on July 2016.

Achievements and responsibilities during the past year

1. HP xenon

The HP-Xe detector with the new geometry, previously designed, constructed at LIP Coimbra workshop and recently assembled, is now being tested. The necessary custom-made electronics required is also ready. The high pressure gas handling and purification system, adapted for this project from a previous version, is operational and the capability of recovering the Xe gas, a recent addition, has been successfully tested. With this new geometry we expect to achieve for 662 keV and a filling pressure of 5 atm, an increased efficiency (up to 25%), and a five times increase of both photocathode solid angle and detector active volume. As a result, we expect to at least double the detector gain, attaining an energy resolution closer to the intrinsic value.

As the dependence of the photocathode extraction efficiency on gas pressure and on the angle of incidence of light is an important issue for solid angle correction, studies have been made with a specially dedicated set-up. Results allowed to correlate the efficiency of extraction of electrons with the angle of incidence of the photon, with an increase observed for higher angles of incidence.

The work developed so far is the subject of the ongoing PhD thesis under the supervision of Filipa Borges and Sergio do Carmo, whereas the photocathode study system was the subject of an MSc thesis by MSc student Francisco Rolo, entitled "Study of the relative extraction efficiency of photocathodes in gaseous atmosphere", finished in July 2016, under the supervision of Filipa Borges. The preliminary results obtained so far have been presented at several international meetings.

2. Ion mobility

Concerning the ion mobility measurement system, a common project with GSI (Germany), VECC (India) and Uludag Univ. (Turkey) was approved in the scope of the RD51 Collaboration (CERN) and is currently underway. Mobility of ions in several mixtures were studied last year, namely, Ar-CO2, Ne-CO2, CO2-N2, Ne-CO2-N2, Xe-CO2. The results obtained for Ne-CO2, CO2-N2 and Xe-CO2 mixtures have been published in peer reviewed journals and presented at several conferences. An MSc thesis was also finished on this subject by Pedro Encarnação in July 2016 entitled "Ion Mobility Studies in Mixtures used in gas detectors" supervised by Filipa Borges and André Cortez.

Outreach

Participation of 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 in "Estágios de Verão da UC" which gives the opportunity to University students of the scientific area to participate in the work being developed in the investigation group. Collaboration in visits from high

school students to the Physics Department of the University of Coimbra, presenting and explaining them kind of research work done in an investigation group in the Physics area.

Lines of work and objectives for next year

1. HP xenon detector

Concerning the HP-Xe detector, tests with alfa particles are now under way which will be followed by the assessment of the performance for gamma-rays. The PhD work of André Cortez, under the supervision of Filipa Borges and Sérgio do Carmo, is expected to be concluded by the end of 2017. Nevertheless, work concerning the improvement of its performance, namely in energy resolution, will certainly continue, namely the improvement of the energy resolution through the compensation of solid angle effects.

Concerning the system to study the photocathode extraction efficiency dependence with angle of incidence of light, there are still some issues to be improved, in particular the stability of the system for measuring the angular dependence of extraction efficiency, to be addressed in the framework of an ongoing MSc thesis (2016-2017) by MSc student João Araújo, supervised by Filipa Borges.

2. Ion mobility

In the ion mobility measurements, requests have been received from different institutes to extend our previous studies. The Univ. of Bonn (Germany) contacted us to study mobility in Ar-CF4-IsoButhane (T2K mixture) for the LCTPC collaboration, to improve the design of a TPC for the future ILC/ILD. More recently, a new collaboration started with JINR (Joint Institute for Nuclear Research) with the aim of developing a negative ion mobility system, opening new perspectives for future work. It is our intention to extend the work on positive ion mobility to other mixtures of known interest, such as Xe-C2H6, Xe-CH4, Ar-N2 and Ar-CF4-IsoButhane. Part of this work will be performed by an MSc student José Perdigoto under the supervision of André Cortez and Filipa Borges.

Furthermore, in order to fully model new detectors it is of primary importance to have detailed information on the ions transport properties. A Monte Carlo simulation code has therefore been developed in the past to study the drift of positive monoatomic noble gas ions in their parent gas and in noble gas mixtures, under the influence of low uniform reduced electric field, E/N. In order to complement the ongoing experimental ion mobility measurements, it is our plan for the coming year to further develop Monte Carlo simulation of the transport parameters of positive monoatomic noble gases ions in noble gas based admixtures of interest for particle physics gaseous detectors.
On the other hand, according to the literature (see Phys. Rev. Lett., 107, 133401 (2011)), negatively charged Xe clusters are stable for more than 5 or 6 Xe atoms. These might affect both the electron's drift time and their longitudinal diffusion for low electric drift fields, large pressures or long drift distances. To our knowledge, the attachment of electrons to such clusters, possibly followed by detachment, is a process which has never been addressed. These effects are more likely to occur in the High Pressure Cold Gas Xe, the detection medium in several Time Projection Chamber applications to Dark Matter or particle physics experiments. We plan to develop a Monte Carlo simulation study on the drift of Xe negative ion clusters in pure xenon (where data on integral and differential collisional cross sections are available) and to calculate cluster collision cross sections whenever the interaction potentials and structure of the cluster are known. This simulation work will be performed by João Barata and Carlos Conde.

3. Low pressure application

In the XIPE mission Collaboration (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 FORTRAN Monte Carlo code is being adapted to identify the best trade-off gas mixture between lowest diffusion and highest drift velocity of electrons. The combination of these characteristics will ensure a better reconstruction of the photoelectrons emission direction, improving the accuracy of the determination of the angle of polarization. Preliminary results have already been obtained for Xe and Ne, and the simulation code will be extended to He and Ar, as well as their mixtures with quenching additive gases such as DME and isobutane.

Outreach
Participation in programs like "Ciência Viva" that gives the opportunity to students of high school to participate in scientific investigation 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 being developed in the investigation group. Collaboration in visits from high school students to the Physics Department of the University of Coimbra, is also intended to continue.

SWOT Analysis

Strengths

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. 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.

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.

There is a serious possibility of expanding our work to the Astrophysics domain, where new gas mixtures for polarimetric studies are being sought.

Once the HPXe detector is working, a collaboration with industry will be sought for, hoping that financial support for further developments is obtained.

Threats

During 2016 one senior team member received invitations to act as invited speaker in two international conferences which she couldn't attend, because financing these missions could jeopardize other commitments..

Publications

2 Articles in international journals

(with direct contribution from team)

A.F.V. Cortez, P.M.C.C. Encarnação R. Veenhof, P.N.B. Neves, F.P. Santos, F.I.G.M. Borges and C.A.N. Conde,: "Experimental ion mobility measurements in Ne-N2", accepted for publication in 2016, JINST 11P 11019

P.M.C.C. Encarnação, A.F.V. Cortez, R. Veenhof, P.N.B. Neves, F.P. Santos, A.M.F. Trindade, F.I.G.M. Borges and C.A.N. Conde: "Experimental Ion Mobility measurements in Ne-CO2 and CO2-N2 mixtures", accepted for publication in Journal of Instrumentation 2016, JINST 072P 0316.

1 International conference proceeding

André F.V. Cortez, K. Saito, C.A.N. Conde, S.J.C. do Carmo, F.I.G.M. Borges: "New Developments in Gas Detectors - The Multi-Grid High-Pressure Gas Proportional Scintillation Counter", in JPS Conference Proceedings on July 2016.

Presentations

1 Oral presentation in international conferences

André Cortez: "Ion mobility measurements in gas mixtures", 2016-06-16, XIth International Conference on Ion Implantation and Other Applications of Ions and Electrons, 13-16 June 2016 – ION 2016, Kazimierz Dolny, Poland

3 Poster presentations in international conferences

André Cortez: "New Developments in Gas Detectors - The Multi-Grid High-Pressure Gas Proportional Scintillation Counter", 2016-01-31, International Symposium on Radiation Detectors and Their Uses (ISRD2016), Tsukuba (Japan)

Francisco Rolo: "Quantum Efficiency Dependence of a CsI Photocathode with Photon Incidence Angle", 2016-11-06, IEEE Nuclear Science Symposium, 29 October - 6 November 2016 - 2016, NSS, Strasbourg, France

Pedro Encarnação: "Experimental Ion Mobility Measurements in Nitrogen Based Mixtures", 2016-11-06, IEEE Nuclear Science Symposium, 29 October - 6 November 2016 - 2016, NSS, Strasbourg, France

2 Oral presentations in international meetings

P.M.C.C. Encarnação, André F.V. Cortez, R. Veenhof, F.I.G.M. Borges, F.P. Santos, C.A.N. Conde: "Ion transport in in Nitrogen based mixtures", 8th to 11th of March 2016, RD51 Collaboration Mini-week, CERN, Switzerland.

F.C. Rolo, F.I.G.M. Borges, K. Saito, André F.V. Cortez, C.A.N. Conde: "Dependence on the incident angle and pressure of the Relative Extraction Efficiency of photoelectrons from CsI photocathode", 8th to 11th of March 2016, RD51 Collaboration Mini-week, CERN, Switzerland.

Theses

1 PhD Thesis

André Cortez: "Novel Techniques for High Pressure Noble Gas Radiation Detectors" (ongoing)

2 Master Theses

Pedro Encarnação: "Ion Mobility Studies in Mixtures used in gas detectors", (finished in July 2016).

Francisco Rolo, "Study of the relative extraction efficiency of photocathodes in gaseous atmosphere", (finished in July 2016).

LIQUID XENON R&D

Liquid Xenon R&D

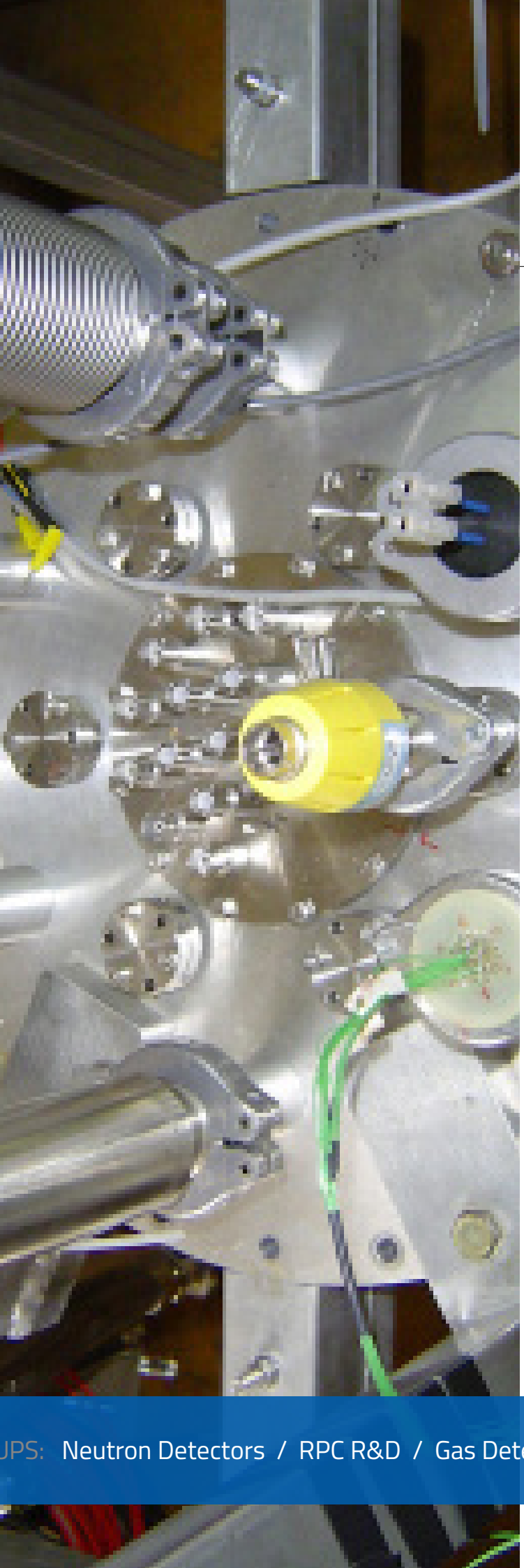
There is a number of experiments around the world using liquid xenon as detector medium. These include search for lepton number violating muon decay, dark matter searches, neutrino physics and double beta decay. Although the energy ranges of interest of these experiment are different, they have very 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 position would provide us with the freedom of studying physical processes in liquid xenon and advanced detection technologies that are not in the mainstream of the highly focused and tightly scheduled work of large collaborations but which can become of significance for future generation of liquid xenon detectors.

Framework and status for past and current year

Summary of performance indicators

Articles in international journals:	1 With direct contribution from team



Team

Principal Investigator Vitaly Chepel(70)

Researchers
Francisco Neves (15), Pedro Sanguino (58), Vladimir Solovov (15)

Technicians
Américo Pereira (15)

External/Additional scientific collaborator
Filipa Balau

Total FTE
1.7

UPS: Neutron Detectors / RPC R&D / Gas Detectors R&D / Liquid Xenon R&D / NUC-RIA

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 more immediate objects of the study.

The group is composed by highly qualified specialists in the field of particle detection and detector development, liquid xenon detectors, in particular. The involvement of some of them in the LUX experiment and the LZ direct dark matter search project provides an important insight on the needs and requirements of those experiments. The team also benefits from the previous experience of one of the members in the field of atomic spectroscopy.

Stated objectives for past year

Continuation of the previously started work on stability of wavelength shifters in liquid xenon. Characterization of new VUV sensitive silicon photomultipliers for detection of liquid xenon and liquid argon scintillations.

Achievements and responsibilities during the past year

The study of stabilrty of thin TPB films (wavelength shifter) in liquid xenon has been finalized and the results published. The setup for testing new models of silicon photomultipliers in liquid xenon and liquid argon has been developed and is currently under assembling.

Lines of work and objectives for next 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.

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

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 national support for R&D projects. Lack of long and medium term scientific policy.

Publications

1 Articles in international journals

(with direct contribution from team)

P. Sanguino, F. Balau, A.M. Botelho de Rego, A. Pereira, V. Chepel: "Stability of tetraphenyl butadiene thin films in liquid xenon. ", Thin Solid Films 600 (2016) 65-70.

EXPERIMENTAL NUCLEAR ASTROPHYSICS

NUC-RIA

During 2016 the group established itself within LIP, implementing the existing research lines while simultaneously looking for synergies and exploring collaborating possibilities with other LIP groups.

- The participation and involvement within the R3B collaboration at FAIR has increase substantially, highlighting the execution of a high-energy photon experiment in Lisbon with modules of the future CALIFA calorimeter, and the presentation of final results of the analysis of knockout reaction data measured on halo nuclei at GSI.

- The increase of the collaboration at ISOLDE/CERN has become clearer during the past year, participating in one beta-decay experiment on neutron rich nuclei and getting officially involved in experimental runs planned for 2017.

- The transfer of technology aspect is inserted in the IAEA-CRP devoted to the study of the effects of radiation on fresh fruits. The group is in charge of the simulation and modelling of the radiation transport.

Framework and status for past and current year

Summary of performance indicators

Articles in international journals:	2 With direct contribution from team 6 With indirect contribution from team
International conferences:	5 proceedings
National conferences:	2 Poster presentations
Completed theses:	1 Master Thesis

Team

Principal Investigator Daniel Galaviz (100)

PhD students
Ana Isabel Henriques (100), Pamela Teubig (100), Paulo Velho (100)

Master students
David Ferreira (100)

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

Total FTE
5.0

UPS: Neutron Detectors / RPC R&D / Gas Detectors R&D / Liquid Xenon R&D / NUC-RIA

Lines of work and team organization

At this stage the team has a single structure, with Daniel Galaviz as main researcher and without presently additional researchers with a PhD. There are four topics which define the lines of work carried out by the group, namely:

- 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.

The rest of the group was composed by three PhD candidates (Ana Henriques, Pamela Teubig, and Paulo Velho) at their final stages, one master student in physics engineering (who concluded his thesis in November 2016), and 4 bachelor students in physics. The structure of a single researcher coordinating the various research lines will continue, although it is desirable that additional postdoctoral researchers, PhD candidates, master and bachelor students join the group to better distribute and execute the various tasks associated to each line.

Stated objectives for past year

- Conclusion of S393 data analysis: The analysis of the neutron break-up reaction measured at relativistic energies on the nuclei 11Be and 15C should be concluded.
- Implementation of analysis tools for FAIR: Development of new analysis tools of the CALIFA calorimeter will be executed as well during 2016.
- Participation in nuclear physics activities at ISOLDE/CERN.
- Continue the low-energy program for nuclear structure and nuclear astrophysics.
- Start work in ENSAR2, namely the Joint Research Action "SATNuRSE", devoted to the development of particle transport simulation tools for basic and applied nuclear science.
- Participation in IAEA's Coordinated Research Project: The CRP "Development of Electron Beam and X-Ray Applications for Food Irradiation", was approved for 2016. The group is responsible for the modelling of the dose irradiation in food products. First tests and validations of the model using GEANT4 should be performed.

Achievements and responsibilities during the past year

During 2016, we highlight the following topics:

- Preparation and execution of high-energy gamma ray experiment for CALIFA: During 2016, the group was responsible for the preparation, execution and furthermore analysis of the data measured from an experiment producing mono-energetic, high-energy (Eg > 10 MeV) photons to benchmark the response of the future R3B calorimeter CALIFA. A total of 128 individual CsI(Tl) crystals with their corresponding readout electronics were mounted for the measurement of the high-energy photon decay from the reaction 27Al(p,g)28Si at the Tandem laboratory of the LATR/CTN facility in Lisbon. The experiment was performed during November 2016, in strong collaboration with groups from the University of Santiago de Compostela (Spain) and Technical University of Munich (Germany). The data successfully recorded will be extremely valuable to benchmark and improve the existing photon reconstruction algorithms for upcoming experiments at FAIR.
- Conclusion of breakup analysis data from S393: The analysis of the neutron breakup reaction data measured at the GSI facility on the halo nuclei 15C and 11Be was concluded and the results were presented at the R3B collaboration meeting in Gatchina/St. Petersburg in September 2016. The PhD thesis' of Ana Henriques and Paulo Velho are in their final phase with defence expected over the first half of 2017.
- Participation at ISOLDE/CERN experiment: During June 2016, the group participated in an ISOLDE experiment performing gamma and fast-timing spectroscopy of neutron--rich nuclei around 132Sn. The participation at that facility has improved since then, with the participation in upcoming approved experiments and the preparation of future experimental proposals to be executed in that laboratory.
- Preparation and execution of low-energy nuclear astrophysics experiments: In collaboration with A. Palumbo, the group prepared and executed the measurement of the 118Sn(p,g)119Sb reaction at low energies, looking for the impact of the measured data in nuclear astrophysics reaction network codes.
- Nuclear Astrophysics (NA) activity and COST participation: The group member Nuno Soares participated at the "Astrophysical Nuclear Reaction Network" School, advancing in the use of reaction networks for NA. In addition, D. Galaviz was elected as member of the Management Committee of the approved COST action ChETEC (Chemical Elements as Tracers of the Evolution of the Cosmos). He was also selected member of the writing committee of the NA section of the next Long Range Plan of the NuPECC, and member of the Program Committee of the upcoming "Nuclear Physics in Astrophysics" conference in Catania, Italy, during 2017.

- Participation at IAEA's CRP. The group initiated the simulation and particle transport activities needed to benchmark and define the use of electron and X-ray radiation in food products. The participation in this CRP was extended by the IAEA until 2019.

Lines of work and objectives for next year

During 2017, the line of work of the research group intends to consolidate the various aspects initiated during the past year and strengthen them:

- Analysis of CALIFA experimental data: 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 one of the priorities of the group during 2017. The presentation and discussion of the results at the meetings of the R3B collaboration is foreseen during the year, with publication of the results towards the end of 2017. This work will close the PhD Thesis of Pamela Teubig, who should defend her degree before the end of the year.

- R3B Day-Zero experiments in 2018: It is expected during spring 2017 the opening of a call for proposals for the first series of measurements that will be performed using the updated equipment of the future FAIR experiments. The R3B collaboration, of which the group is part, will present various proposals covering several of the physics aspects originally proposed by the collaboration. Considering the experience gained over the past years in the analysis of breakup data and the contributions to the CALIFA detector, the NUC-RIA group will propose for the first time the measurement of the neutron breakup on a proton target on halo nuclei with extreme neutron-to-proton ratio like 19C and 17B.

- Experimental activity at ISOLDE: During 2016 the group got involved in an experimental proposal aimed at studying the elastic scattering and the breakup probability of the halo nucleus 15C on a 208Pb target. The experiment was approved by the INTC-Committee at ISOLDE, and it is scheduled to run during Summer 2017. Members of the NUC-RIA group will participate, depending on the access to funds from own and other sources, in either the preparation or the execution of the measurement.

- Nuclear Astrophysics: The conclusion of the analysis of the data measured during 2016 and the involvement in the collaborative activities within the ChETEC COST action will concentrate the efforts of the group in the field of Nuclear Astrophysics.

- ENSAR2 work within the "SaTNURSE" JRA: In collaboration with the University of Santiago de Compostela, the group will work on the proposed activities within the SaT-NURSE Joint Research Action of the ENSAR2 consortium. Participation in activities of the network devoted the development of analysis and applications tools will concentrate the work during 2017.

- Contribution to the IAEA CRP "Development of Electron Beam and X-Ray Applications for Food Irradiation": Considering the main responsibility of simulating the transport and dose deposition in food products, the group will join the efforts for searching funds at the H2020 level to support the effective continuation and growth of this activity, promoting the connection with companies that will benefit from the development and application of this technologies. The transfer of knowledge to the technology sector is a goal that the group aims at implementing in the years to come.

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 an 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

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

P. Cabanelas, J. Cruz, M. Fonseca, A. Henriques, F. Lourenço, H. Luis, J. Machado, J. Pires Ribeiro, A.M. Sanchez-Benitez, P. Teubig, P. Velho, M. Zarza-Moreno, D. Galaviz and A.P. Jesus: "Cross sections for proton induced high energy gamma-ray emission (PIGE) in reaction F-19(p,alpha gamma)O-16 at incident proton energies between 1.5 and 4 MeV", Nucl. Instr. and Meth. B 381, 110 (2016)

A. Ornelas, P. Mohr, Gy. Gyürky, Z. Elekes, Zs. Fülöp, Z. Halász, G. G. Kiss, E. Somorjai, T. Szücs, M. P. Takács, D. Galaviz, R. T. Güray, Z. Korkulu, N. Özkan, and C. Yalçın: "alpha scattering and alpha-induced reaction cross sections of Zn-64 at low energies", Phys. Rev. C 94 (2016) 055807

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

B. Pietras, M. Winkel, H. Alvarez-Pol, M. Bendel, E. Casarejos, J. Cederkäll, D. Cortina-Gil, G. Fernandez, R. Gernhäuser, P. Golubev, D. González, A. Hartig, P. Izquierdo, P. Klenze, T. Le Bleis, E. Nácher, A. Perea, P. R: "First testing of the CALIFA Barrel Demonstrator", Nucl. Instr. and Meth. A 814, 56 (2016)

J. Marganiec, et al. R3B Collaboration (44 authors): "Coulomb dissociation of P-27 at 500 MeV/u", Phys. Rev. C 93, 045811 (2016)

R. Thies, et al., R3B Collaboration (122 authors): "Systematic investigation of projectile fragmentation using beams of unstable B and C isotopes", Physical Review C 93, 054601 (2016)

R. Caballero-Folch, C. Domingo-Pardo, J. Agramunt, et al. (65 authors): "First Measurement of Several beta-Delayed Neutron Emitting Isotopes Beyond N=126", Physical Review Letters 117, 012501 (2016)

M. Roder, et al. R3B Collaboration (123 authors): "Coulomb dissociation of N-20,N-21", Phys. Rev. C 93, 065807 (2016)

J. Marganiec, F. Wamers, F. Aksouh, et al. (60 authors): "Coulomb and nuclear excitations of narrow resonances in Ne-17", Phys. Lett. B 759, 200 (2016)

5 International conference proceedings

G. G. Kiss, T Szucs, P Mohr, Zs Fulop, Gy Gyurky, Z Halasz, R F Soha, E Somorjai, A Ornelas, D Galaviz, C Yalcin, R T Guray and N O–zkan: "High precision elastic α scattering on the even-odd 115In nucleus at low energies", J. Phys.: Conf. Ser. 665, 012035 (2016)

R. Reifahrt, et al. (320 authors): "Nuclear astrophysics with radioactive ions at FAIR", J. Phys.: Conf. Ser. 665, 012044 (2016)

C. Domingo-Pardo, et al. (64 authors): "Approaching the precursor nuclei of the third r-process peak with RIBs", J. Phys.: Conf. Ser. 665, 012045 (2016)

J. Marganiec, F. Wamers, F. Aksouh, et al. (60 authors): "Experimental study of the 15O(2p, γ)17Ne cross section by Coulomb Dissociation for the rp process", J. Phys.: Conf. Ser. 665, 012046 (2016)

H Luís, A P Jesus, M Fonseca, J Cruz, D Galaviz, N Franco, and E Alves: "Study of nuclear reactions producing 36Cl by micro-AMS", J. Phys.: Conf. Ser. 665, 012077 (2016)

Presentations

2 Poster presentions in national conferences

V. Corregidor: "Heavy elements in chestnuts", 2016-03-21, Heavy Metals: from the environment to the man, Univ. Nova de Lisboa, Caparica

A. L. Antonio: "A Física aplicada à qualidade alimentar: identificação de metais por "PIXE" em castanhas", 2016-09-08, FISICA 2016, Univ. do Minho, Braga

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)

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" (ongoing)

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

1 Master Thesis

David Ferreira: "Desenvolvimento do sistema de deteção de partículas carregadas Si-Ball no CMAM" (finished on 2016-11-21)

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:

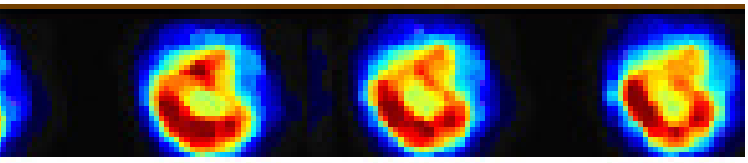
- the simulated quantum efficiency of RPCs for 511 keV photons corresponds to the reality
- a reconstructed source resolution of 0.4 mm FWHM
- practical high-resolution imaging of mice and rats
- the intrinsic time resolution of RPCs for 511keV photons is 300 ps FWHM for the time difference between both 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

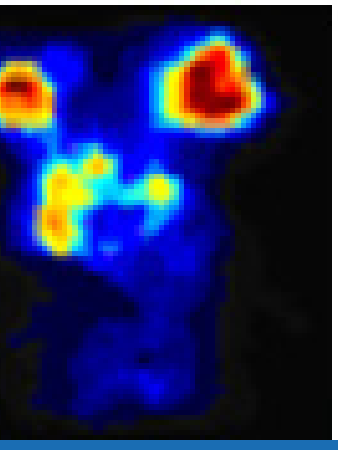
Framework and status for past and current year

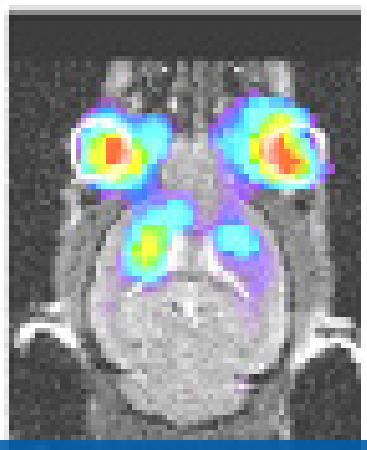
- image reconstruction of the huge whole-body dataset is possible in a practical time span
- the expected TOF capability provides strong advantages for trigger accuracy and scatter rejection, improving lesion contrast
- two years of routine use of the small animal scanner prototype in bio-research operated 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), Paulo Martins (58), Rui Marques (30), Susete Fetal (20)

Technicians
Américo Pereira (5), Orlando Cunha (5), Rui Alves (5)

Total FTE
1.8

Summary of performance indicators

Presentation in international meeting:	1 Oral presentation

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

Mice scanner:

- completion of the software modifications corresponding to the hardware upgrade
- installation of the improved front-end electronics and evaluation
- eventually, installation of an updated DAQ system (the current one was discontinued by the GSI team)
- take steps towards an evaluation of the scanner in accordance with the relevant NEMA standard

Complete the current development/test of the envisaged readout system for the human scanner (see the report of the RPC group).

Achievements and responsibilities during the past year

Continuous support was provided to the routine bio-research activities at ICNAS using our prototype animal PET. In 2016 more than 150 PET examinations 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 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. Integrated gas control and environmental monitorization system

4. Much smarter trigger electronics, allowing more timing/trigger channels for improved sensitivity (better signal transmission)

5. More HV channels for tuning each head separatelly

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

Items 1 to 5 were developed for other activities (see the RPC and detector lab reports) and are already operational. Items 6 to 8 are at about 50% developed.

The readout system envisaged for the human scanner was successfully tested in the MASTER detector (see the report of the RPC group).

It was explored the regional implementation of H2020 (called C2020) for funding opportunities in RPC-PET. After a detailed study it was concluded that, owing to the very specific rules of this program and other circumstances, it is not possible for LIP to apply.

Lines of work and objectives for next 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 very markedly 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.

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.

Opportunities

The animal PET shows so far encouraging performance and, being also quite inexpensive, may be successfully marketable.

Threats

- Technical insuccess
- Inability to market the technology.

Presentations

1 Presentation in international meeting

Paulo Fonte: "Towards the application of patterned RPCs to very high resolution PET for small animals", 2016-09-16, MPGD Applications Beyond Fundamental Science Workshop, Aveiro, Portugal

ORTHOGONAL RAY IMAGING FOR RADIOTHERAPY IMPROVEMENT

OR Imaging

The group has put forward simulation and experimental work in several fronts.

The accomplished status is that OrthoCT seems to be very useful in assisting lung treatments, providing important on-board patient morphological images and/or equally potentiating the real-time monitoring of an irradiation field (conclusions based on realistic, Geant4 simulations). Similar simulation results indicate usefulness in head-and-neck irradiation where the beam crosses theoretically empty sinuses. For prostate cancer it was observed that even when a contrast agent is incorporated, the visualization of the organ, either in its normal condition on in tumoral state, is not possible. However, visualizing very-small, implanted gold fiducial markers is possible with a very large reduction of the dose imparted onto adjacent organs like the bladder or the intestine.

Experimental work is also ongoing, with a single-line, very-long detector having proven its feasibility to read gamma rays.

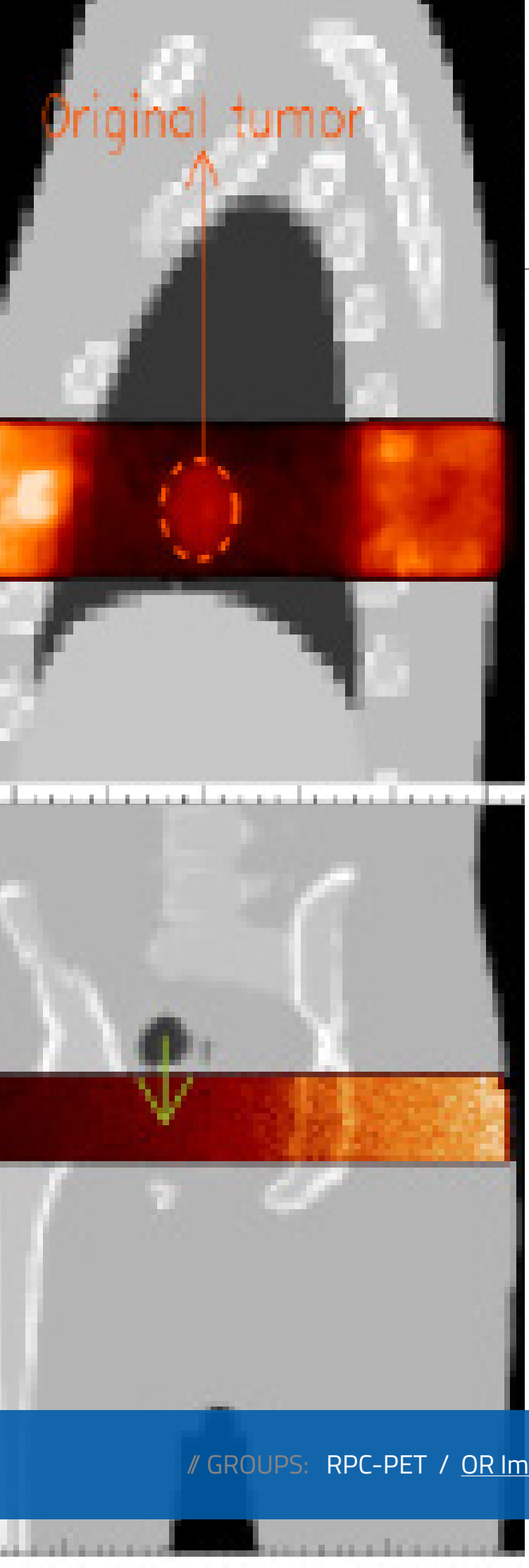
Framework and status for past and current year

Summary of performance indicators

International conferences:	4 Poster presentations 4 Proceedings
National conferences:	1 Poster presentation 1 Proceedings
Completed theses:	3 Master

DEVELOPMENT OF NEW INSTRUMENTS AND METHODS

Health and biomedical applications



Team

Principal Investigator Paulo Crespo (65)

PhD students
Hugo Simões (100), Patrícia Cambraia Lopes (100)

Master students
Ana Lopes (100), Carolina Travassos (100), Mariana Barros (75)

External scientific collaborators
Joana Lencart, João A. M. Santos,
Maria do Carmo Lopes, Paulo Rachinhas

Total FTE
5.5

// GROUPS: RPC-PET / OR Imaging / Gamma Cameras / STCD TagusLIP

Lines of work and team organization

The lines of work are mainly divided upon simulation and experimental work. Our colleagues from three hospitals providing high-energy X-ray-based radiotherapy treatments (Coimbra University Hospital Center and the Portuguese Oncology Institutes of Coimbra and Porto) are (1) helping in devising the experimental work, (2) helping carrying it out at their centers, and (3) giving their expertised opinion on what simulations are of foremost importance.

At LIP and University of Coimbra we have so far engaged one assistant professor (project PI), one PhD student putting forward efforts both in simulations and in the OrthoCT experiment to be carried during the present academic year at a therapeutic linac, and two researchers who finished their master theses in the course of the past academic year.

Simulationwise, several lines of work are being undertaken: lung irradiation, head irradiation, and irradiation of the prostate. In all the aforementioned study cases a full OrthoCT system has already been optimized although only in the lung and head irradiation such completeness has been finally fully carried out during this past year. This was done by adapting a software--based anthropomorphic phantom into Geant4. The team intends to move now to non-trivial realistic treatments in order to increase the statistical significance providing evidence of the usefulness of OrthoCT for both on-board imaging and real time treatment monitoring.

On the experimental side, the mechanical workshop of LIP together with its detector laboratory are putting forward a small-scale OrthoCT system that we have planned in collaboration. The system is expected to be ready within the next couple of months so that data taking at a therapeutic linac can occur within the next half year, as correctly estimated in the report of last year.

Stated objectives for past year

The objectives proposed for the past year included the simulation of selected real treatment plans, allowing to compute the correlation of the real patient morphological information (including tumor) with the images obtained by an OrthoCT system. Also planned was the study by simulation of the impact of utilizing tumor imaging contrast in order to enhance OrthoCT imaging in more difficult imaging scenarios such as, for example, the partial irradiation of the prostate gland. The study of the different thin-beam scanning possibilities (MLC-driven or jaw-driven) was also envisaged, yielding input information to a more complete simulation of a full OrthoCT system. Finally, the study by simulation of the capability of a CsI-based flat panel to provide OrthoCT images (provided a sliced collimator is positioned between the patient and the flat panel detector) was also planned.

Achievements and responsibilities during the past year

We presented for the first time work results related to:

- The full optimization of a system comprising a sliced collimator dedicated to imaging patient-scattered radiation;
- The consideration of real scintillating crystals and light readout performing the conversion of high-energy X-rays into an electronic readable signal;
- The conversion of the aforementioned readable signal into a charge signal collected by a proper transducer;
- The conversion of the resulting 3D image (with its characteristic exponential decay form along the beam axis) into an image weighted by a linear decay thus strongly enhancing the image contrast achievable with OrthoCT
- The support of the whole detection system on the axis of rotation of a clinical X-ray linac, hence allowing full space for other imaging modalities (a strong added value to the clinical implementation of OrthoCT).

With the aforementioned premises completed, it was possible to make a full study by simulation of an irradiation of the lung, of the head, and of a prostatic cancer. In the lung and in the head scenarios it was possible to verify the usefulness of OrthoCT to monitor onboard or in real time such irradiations. In the prostate case it was not possible to distinguish the prostate tissue, neither in its normal condition nor in a tumoral state. For this reasosn we are now investigatingt he possible usefulness of utilizing gold fiducial markers typical utilized in such prostate hard X-ray irradiations.

Lines of work and objectives for next 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.

SWOT Analysis

Strengths

The rotation-free, low-dose imaging capability of OrthoCT are two of its great strengths. The imaging capability of OrthoCT is so far proven only by simulation, although based on a software (Geant4) that is highly reliable in terms of handling electromagnetic interactions, which finally means that the positive results already obtained in the imaging of a lung tumor may be a possibility in the mid to long-term future. 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

It is expected that the high out-of-field photon flux existing in a clinical linac will force OrthoCT to be surrounded by heavy shielding. This weakness can be surpassed 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

4 International Conference Proceedings

H. Simões, M. Alves Barros, P. Crespo: "OrthoCT for Tumor Lung Irradiation: a Simulation Study", accepted for publication in in Conf. Records 2016 IEEE Nucl. Sci. Symp. & Med. Image. Conf

H. Simões, A. L. Lopes, P. Crespo: "OrthoCT for Tumor Head Irradiation: a Simulation Study", accepted for publication in in Conf. Records 2016 IEEE Nucl. Sci. Symp. & Med. Image. Conf

A.L. Lopes, H. Simões, P. Crespo, J.A.S. Barata, J. Lencart, J.A.M. Santos: "Impact of Tumor Contrast in Orthogonal Ray Imaging: a Prostate Irradiation Study", accepted for publication in in Conf. Records 2016 IEEE Nucl. Sci. Symp. & Med. Image. Conf

C. Travassos, H. Simões, P. Crespo, M. Alves Barros, J. Lencart, P.J. B. M. Rachinas, J.A. M. Santos: "Experimental Characterization of Megavoltage Beams for Orthogonal Ray Imaging", accepted for publication in in Conf. Records 2016 IEEE Nucl. Sci. Symp. & Med. Image. Conf

1 National Conference Proceeding

A. L. Lopes, H. Simões, P. Crespo, J. A. S. Barata, J. Lencart, J. A. M. Santos: "Impact of Prostatic Fiducial Markers in Orthogonal Ray Imaging - OrthoCT: A Simulation Study", accepted for publication in Conf. Records of FISICA2016 of SPF

Presentations

4 Poster presentations in international conferences

Ana Lopes: "Impact of Tumor Contrast in Orthogonal Ray Imaging: a Prostate Irradiation Study", 2016-11-03, 2016 IEEE Nucl. Sci. Symp. & Med. Imag. Conf., Strasbourg, France

Carolina Travassos: "Experimental Characterization of Megavoltage Beams for Orthogonal Ray Imaging", 2016-11-04, 2016 IEEE Nucl. Sci. Symp. & Med. Imag. Conf., Strasbourg, France

Hugo Simões: "Monitoring Tumor Lung Irradiation with OrthoCT (Orthogonal Ray Imaging): a Full System Simulation Study", 2016-11-05, 2016 IEEE Nucl. Sci. Samp. & Med. Imag. Conf., Strasbourg, France

Hugo Simões: "Monitoring Tumor Head Irradiation with OrthoCT(Orthogonal Ray Imaging): a Full System Simulation Study", 2016-11-06, 2016 IEEE Nucl. Sci. Symp. & Med. Imag. Conf., Strasbourg, France

1 Poster presentation in national conference

Ana Lopes: "Impacto dos Marcadores Fiduciais Prostáticos em Imagiologia por Raios Ortogonais – OrthoCT", 2016-09-09, SPF - Física2016, Universidade do Minho

Theses

2 PhD Theses

Patrícia Cambraia Lopes: "Demonstration of a time-of-flight device for particle therapy monitoring" (ongoing)

Hugo Simões: "Demonstração de um dispositivo de imagiologia por raios ortogonais para apoio à radioterapia externa de fotões" (ongoing)

3 Master Theses

Carolina Travassos: "Caracterização experimental de feixes de megavoltagem para imagiologia de raios ortogonais" (finished on 2016-09-30)

Ana Lopes: "O impacto do contraste tumoral em imagiologia de raios ortogonais" (finished on 2016-10-30)

Mariana Barros: "Medida da dose em fantomas submetidos a radiação de megavoltagem para imagiologia de raios ortogonais" (finished on 2016-09-30)

ADAPTIVE METHODS FOR MEDICAL IMAGING WITH GAMMA CAMERAS

Gamma Cameras

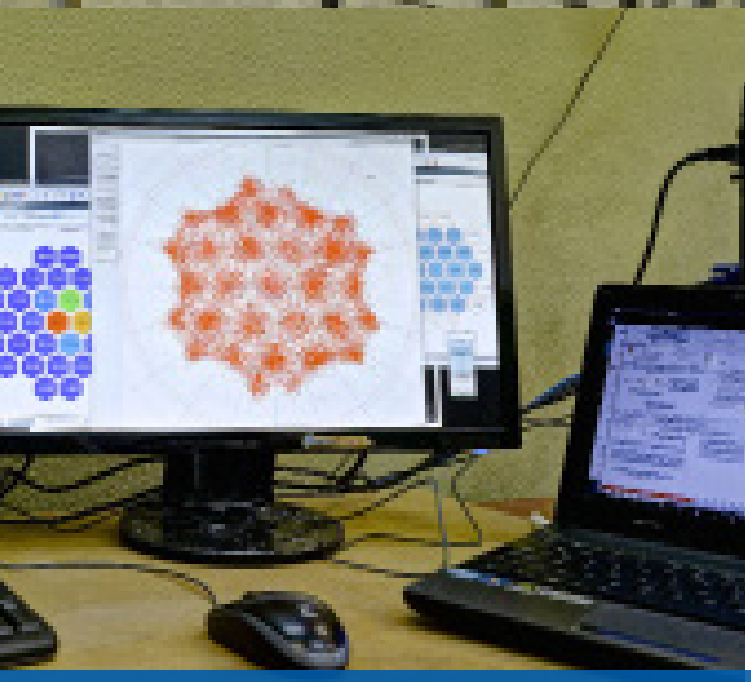
The group was formed in 2013 to apply the know-how accumulated in LIP in the course of the previous work on position-sensitive scintillation detectors (PSSD) to the areas of medical imaging and imaging techniques used in drug discovery. In the past years we confirmed, both by Monte Carlo simulation and experimentally, applicability of our auto-calibration and position reconstruction techniques to both clinical gamma cameras of classical design and a compact high-resolution cameras with 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. Recently, a collaboration was established with the Radiation Detectors and Applications Group at Politecnico di Milano.

Framework and status for past and current year

Summary of performance indicators

Articles in international journals:	2 With direct contribution from team
International conferences:	1 Poster presentation
Completed theses:	1 Master thesis

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), Raimundo Martins (100), Rui Alves (5)

PhD students
João Marcos (100), Luís Pereira (30)

External/Additional scientific collaborators
Filipa Balau

Total FTE
4.0

// GROUPS: RPC-PET / OR Imaging / Gamma Cameras / STCD TagusLIP

Lines of work and team organization

- Autocalibration and fast calibration algorithms for PSSD. In this line of research, we look for expanding the range of detector configuration for which the self-calibrating techniques can be applied. Of particular interest here is calibration of detectors with depth-of-interaction (DOI) sensitivity in all three coordinates. We also looking for 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. Currently we 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 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 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 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 the feedback, essential for correct development of reconstruction algorithms and software. Besides, it allows us to compare our results with those of other groups working on the subject.

Sources of Funding

Code	Amount	Dates	Description
IF/00378/2013/CP1172/CT001	20.000 €	2014-01-01 / 2018-12-31	FCT Exploratory research project (AM)

Stated objectives for past year

Four main objectives were envisioned in the framework of this project for the past year:

- Complete the feasibility study of the adaptive response reconstruction technique for compact gamma cameras of different configurations.

- Improve performance of the compact gamma camera prototype by optimizing its design and employing higher quality components.

- Complete research on using machine learning algorithms for position and response reconstruction.

- Continue the work towards commercialization of the concept of self-calibrating clinical gamma camera.

Achievements and responsibilities during the past year

Compact gamma camera.

The work on the optimization of the compact gamma camera geometry was performed by means of Monte Carlo simulation and then confirmed experimentally in the framework of R. Martins' MSc project. For the optimized compact camera design, the possibility of adaptive calibration form flood irradiation data was confirmed. The images, reconstructed with the maximum likelihood method, exhibit only minor distortions: <0.2 mm in the central area of 22 x 22 mm 2 and <0.4 mm for the whole crystal. Similar level of image distortions was demonstrated experimentally with the camera prototype. Sub-millimeter spatial resolution of the camera was confirmed. The paper based on this work has been recently published in Physics in Medicine and Biology.

Machine learning

The investigation on the perspectives of applying modern machine learning techniques to the event reconstruction in position-sensitive scintillation detectors constitutes a part of J. Marcos' PhD plan. He prepared an overview of the state-of-the-art in the field that was included in his thesis project.

Upgrade of the data acquisition system

Several options were investigated. Turn-key solutions offered by AiT and Vertillon were found too expensive and too closed to be useful. ASIC2 by PETSys is a viable solution, however, it will be commercially available no sooner than Q2 of 2017. TRIROC (MAROC3 successor marketed by WeeRoc) is a 64-channel DAQ system-on-a-chip in a compact 12x12 mm^2 BGA package. We selected this chip as a base for compact gamma-camera DAQ system. TRB3 acquisition board developed by GSI was selected as a base for research acquisition system. We purchased a TRIROC evaluation board from WeeROC and TRB3 board from GSI to use in experimental work in 2017

Upgrade of the front-end electronics

Two versions of the front-end electronics were developed, both based on transimpedance input stage to match the high-impedance output of PMT/SiPM with low-impedance input of the DAQ systems. The first one is targeted for the integrated multi-channel DAQ solutions (MAROC3, TRIROC) and the second for waveform digitizing acquisition system (TRB3). In both cases, the level of electronics noise was reduced to approximately 10^5 electrons or approximately 0.1 photoelectron. This allowed us to observe a SiPM spectra with the peaks corresponding to multiple photoelectrons well resolved, which, in turn, permits precise calibration of the optical readout.

Development of ANTS2 package

The main objective of the work on ANTS2 package was to extend the range of its possible applications in the area of scintillation detection. In particular:

- The detector geometry module was significantly upgraded to increase the flexibility and shorten the simulation model development time.
- More realistic models for several elements of detector design (diffuse scattering walls, grids, etc.) were implemented
- Photosensor group concept was introduced in order to process data from multi-head detector systems, such as, for example, PET.
- Versatile scripting system now allows to fully automatize complex detector simulation and optimization routines.

The simulation module of the ANTS2 package was validated with the compact camera prototype. Namely, it was confirmed that the simulated light response functions can be used to correctly reconstruct the event positions and energy from the experimental data.

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 did the groundwork by developing and purchasing two indispensable components: the front end electronics and the data acquisition system.

Lines of work and objectives for next year

The objectives for the next year are:

- Develop the method for rapid measurement/ reconstruction of 3D photosensor response in thick monolithic scintillation crystals.
- Optimize the event reconstruction in order to achieve the best possible energy resolution.
- Expand the user base of the ANTS2 package
- Complete feasibility study for high-resolution, high-sensitivity compact PET scanner for small animals
- Complete feasibility study for freehand SPECT for augmented reality intraoperative assistance
- Continue the work towards commercialization of the concept of self-calibrating clinical gamma camera.

The work will be organized along the following lines:

Development of algorithms for calibrating 3D response of thick crystals

This task will be performed in collaboration with Radiation Detectors and Applications Group from Politecnico di Milano and our partners from ICNAS. While feasibility study on 3D calibration of thick crystals were already reported in literature, the method employed there is extremely time-consuming, as it requires multiple high-resolution scans with pencil-beam source. We plan to speed up the method to make it practical by combining electronic collimation technique with iterative reconstruction. If successful, our method will be beneficial to both multi-isotope SPECT and PET detectors.

Enhanced ML event reconstruction

Good energy resolution is crucial for multi-isotope SPECT. If the energies of gamma rays emitted by isotopes are close, even small (1-2%) improvement in energy resolution can result in much better performance. For this reason, we plan to enhance ML event reconstruction by taking into account the shape of single photoelectron distribution.

Promoting the ANTS2 software in order to enhance its user base.

We already reached the point where ANTS2 package is sufficiently feature rich to handle wide range of PSSD applications. What we currently need is wider user base that can provide us feedback on its performance and usability for different problems and configurations. We plan to attract more users by:

- creating better documentation and tutorials;
- creating a library of ready-to-use detector configurations;
- integration with third party packages (e.g. for SPECT and PET reconstruction);
- using modern frameworks for collaborative development (GitHub);
- streamlining installation process;
- creating cloud version.

Experimental validation

In order to validate the algorithms for 3D calibration and ML event reconstruction, experimental work will be performed in partnership with Politecnico di Milano and ICNAS.

Feasibility study for freehand SPECT. This work will include studies on:

- Methods to reliably determine the camera position and orientation with precision of 1 mm and 1 degree, respectively. We are looking for a partnership with one of the Portuguese enterprises specializing in real-time position/orientation tracking.
- Reconstruction of SPECT image from incomplete projections
- Use of augmented reality to incorporate the reconstructed 3D activity distribution into the live video stream
- Commercialization of the concept of self-calibrating clinical gamma camera. With the electronics and DAQ systems available, we plan to focus on software development and have the prototype ready for comprehensive testing by the end of the year.

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 the 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 camera 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.

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

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

A. Morozov, V. Solovov, R. Martins, F. Neves, V. Domingos and V. Chepel: "ANTS2 package: simulation and experimental data processing for Anger camera type detectors", J. Instrum. 11 (2016) P04022

V. Solovov, A. Morozov, V. Chepel, V. Domingos, R. Martins: "B-spline parameterization of spatial response in a monolithic scintillation camera", J. Instrum. 11 (2016) P09014

Presentations

1 Poster presentation in international conference

Andrey Morozov: "Reconstruction of Spatial Response of Compact Gamma Camera from Flood Field Irradiation Data", 2016-11-04, IEEE NSS-MIC 2016, Strasbourg, France MIC-2016, M13B-13

Theses

1 PhD Thesis

João Marcos: "Real-time statistical event reconstruction for medical scintillation cameras" (ongoing)

1 Master Thesis

Raimundo Martins: "Optimization of compact gamma camera for medical imaging" (finished on 2016-07-29)

SPIN-OFF TECHNOLOGIES FOR CANCER DIAGNOSTICS

STCD TagusLIP

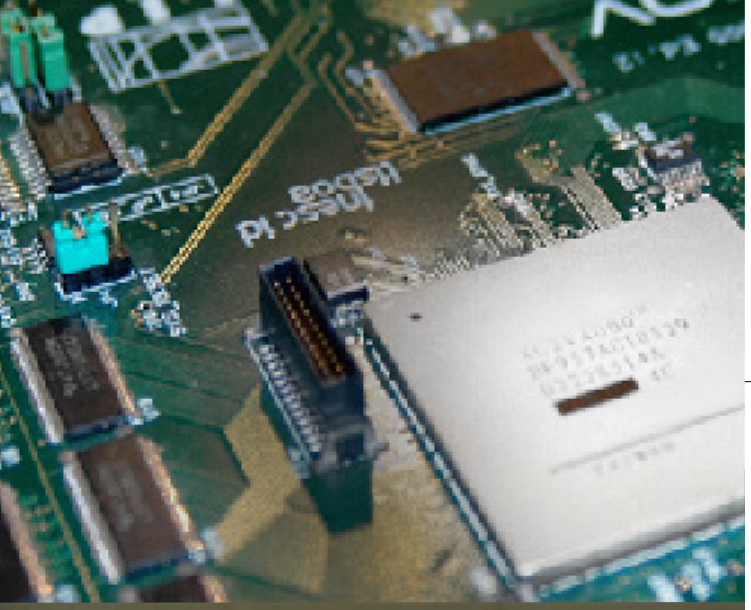
Framework and status for past and current year

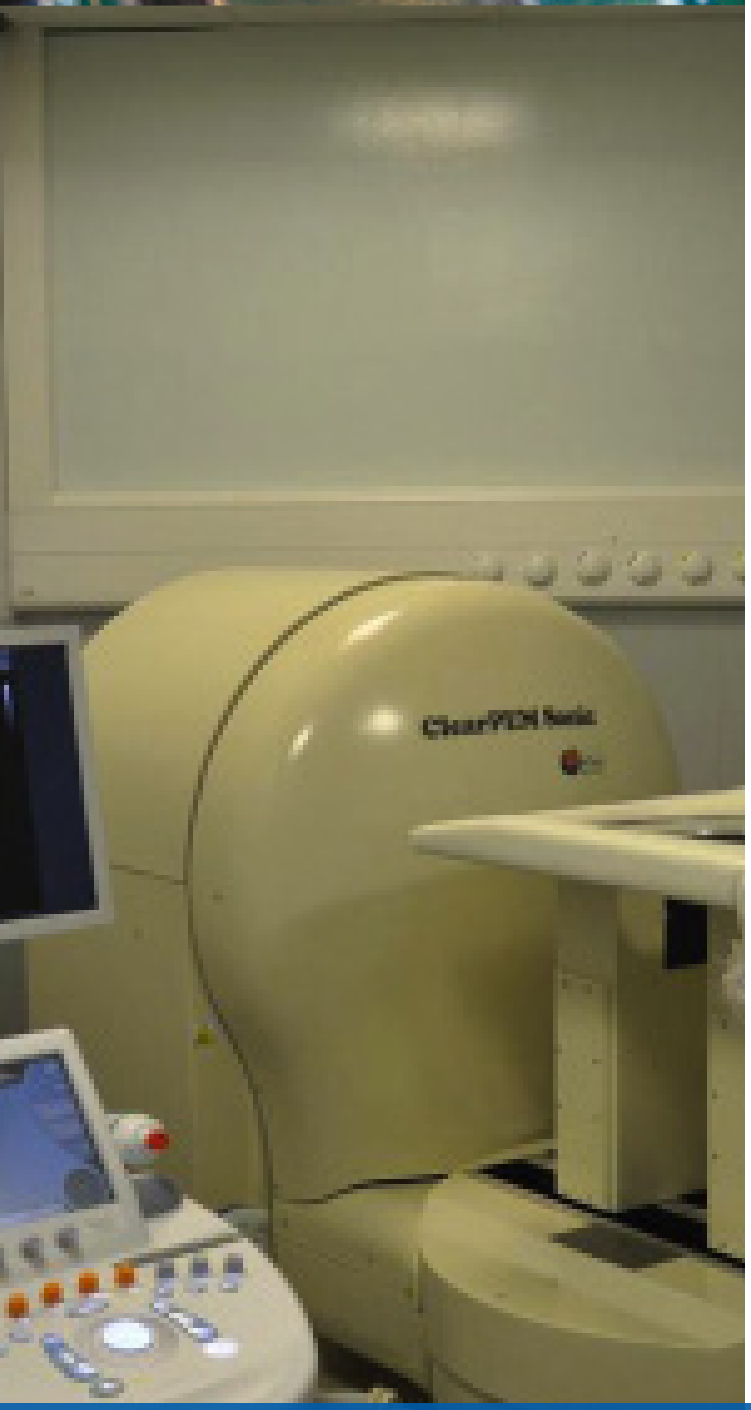
The PET/TagusLIP was created in 2004 around the development of a new Positron Emission Tomography scanner (ClearPEM) for breast cancer diagnosis, exploiting technologies developed at LIP for the CMS experiment at LHC. Scientific research, technological development and laboratory testing of new PET scanners 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

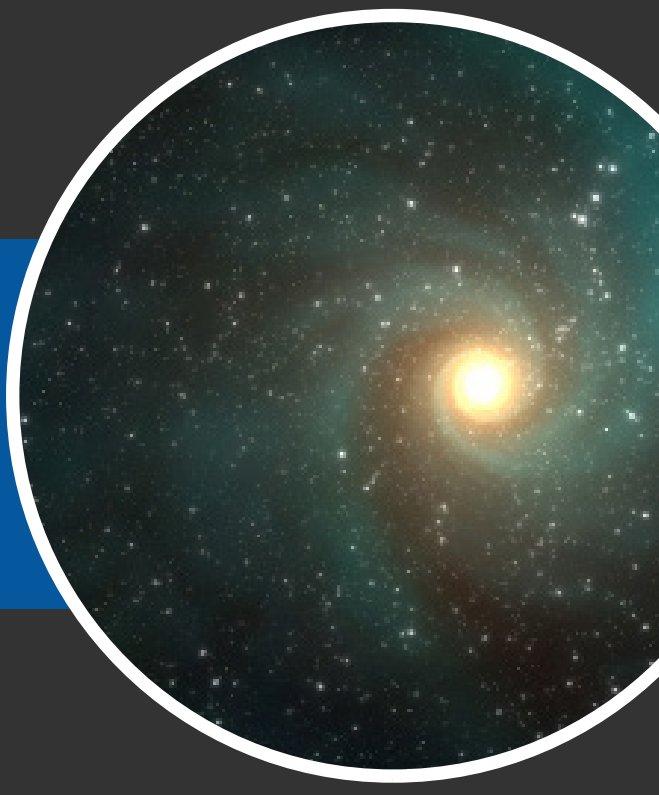
Theses

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)

Space applications



SPACE RADIATION ENVIRONMENT AND EFFECTS

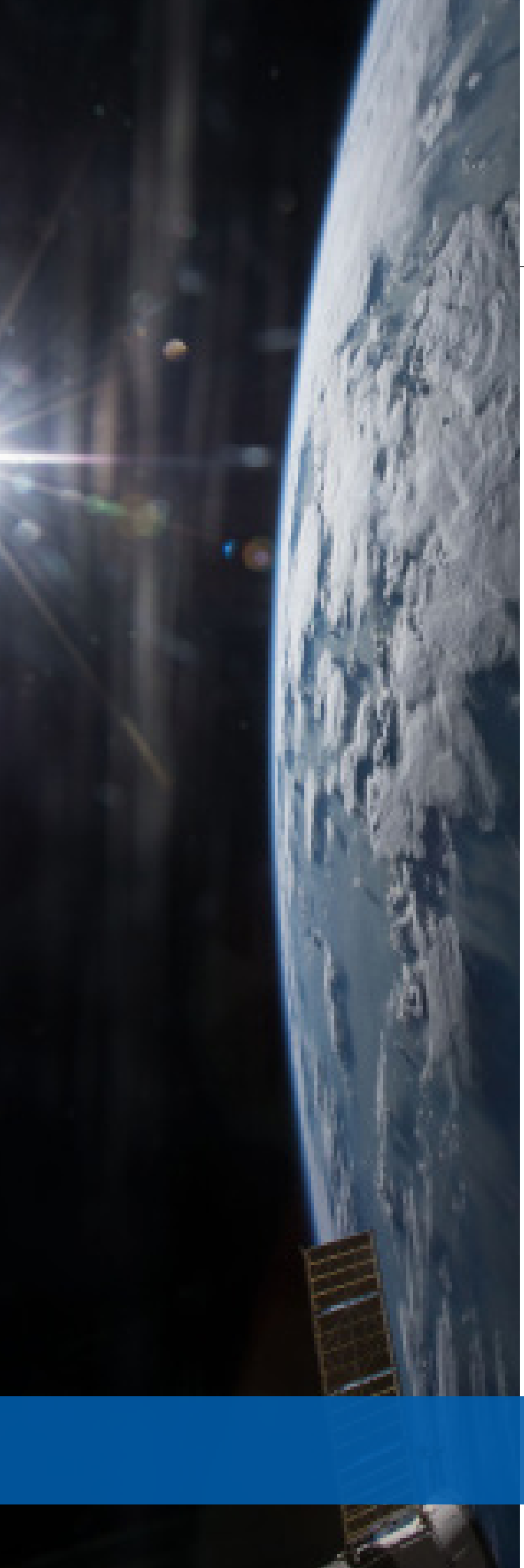
Space Rad

The Space Radiation Environment and Effects group at LIP has now more than 10 years of expertise in the development of applications dedicated to the study and measurement of the radiation environment in Space and of its effects. The group has been developing its activities mostly in the framework of contracts with the European Space Agency (ESA), LIP being either fully responsible for the projects or for parts of the projects. These activities have been a source of collaboration between LIP and other institutes, companies and the industry, and also of collaboration with external scientists. LIP is recognized by ESA as a Portuguese reference for Space Radiation and Environment Studies. The group holds unique competences in its activity domains with very strong competences in Geant4 for the simulation of radiation transport and interaction with matter and data analysis, with application to the study and measurement of the radiation environment in space and of its effects, which have been strategic for LIP activities in this domain.

The research themes within the scope of this group are:

- Study and model the radiation environment in Space, including planetary radiation environments, namely the Moon, Mars, Europa, Ganymede and asteroids radiation environments.
- Improvement and validation of the models with real data, starting from dMEREM model concept, the Geant4 based model developed for the Martian radiation environment;
- Analysis of Space mission energetic particle/ radiation data;
- Study of SEP Solar Energetic Particle events and model testing with radiation monitor data, initiated with the project “Portuguese Participation in the Heliospheric Network”;
- Study and development of detector design concepts for radiation monitors (based on Si sensors and/or in scintillators) and exploitation of these designs in different planetary and interplanetary environments, both for platform support and scientific data analysis;
- Study, model and ground testing of the effects of radiation in EEE components;
- Study biological effects of the radiation environment in space, in planetary atmospheres and surfaces;
- Study and develop mitigation strategies for radiation hazards, both for spaceship systems and components and for human spaceflight.

Framework and status for past and current year



Team

Principal Investigator Patrícia Gonçalves (90)

Researchers
Alessandro de Angelis (10), Bernardo Tomé (15), Jorge Sampaio (100), Luisa Arruda (80), Pedro Assis (10)

PhD students
Ana Luisa Casimiro (100), Marco Alves Pinto (90)

Master students
Filipe Máximo (33), Pedro Miguel Magalhães (43)

External/Additional scientific collaborators
Bruno Morgado, Elsa Susana Fonseca

Total FTE
6.0

Summary of performance indicators

Articles in international journals:	1 With direct contribution from team
International conferences:	2 Poster 3 Proceedings
International meetings:	2 Oral presentations
National conferences:	2 Oral presentations 3 Posters
Outreach:	5 Outreach seminars
Completed Theses:	1 PhD and 2 Master

// GROUPS: Space Rad / i-Astro

Lines of work and team organization

Lines of work

LIP activities in the field of Space Radiation Environment and Effects during 2016 and 2017 are listed below:

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: LIP and Paul Scherrer Institute in Switzerland, EFACEC SA 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.

CODES: Integrated Radiation Environment, Effects and Component Degradation Simulation tool developed at LIP, which is top level web based engineering framework based on GEANT4 to predict Single Event Effects in EEE devices.

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.

Team organization

The team is organized in smaller groups as a function of the the ongoing and foreseen contracts. Each group has at least one senior researcher or post-doc and Master and/or PhD students. The teams working on each subject:

- RADEM: Marco Pinto, Pedro Assis and Patrícia Gonçalves
- ECo60-JUICE : Marco Pinto, Pedro Assis, Miguel Ferreira and Patrícia Gonçalves
- MFS data analysis: Filipe Máximo, Luisa Arruda and Patrícia Gonçalves
- CTTB Data Analysis: Filipe Máximo, Jorge Sampaio and Patrícia Gonçalves
- CODES: Patrícia Gonçalves with João Conceição(*) and Carlos Manuel(*)
- Mars Radiation Environment: Ana Luisa Casimiro, Pedro Magalhães, Luisa Arruda, Jorge Sampaio and Patrícia Gonçalves
- Heliospheric particle propagation models and data analysis: Bruno Morgado and Patrícia Gonçalves

(*) LIP Computing group

Sources of Funding

Code	Amount	Dates	Description
ESA:22381/09/NL/PA/CCN04	20.000 €	2013-10-01 / 2016-02-28	CODES IV- CODES Framework Implementation
ESA: 1-7560/13/NL/HB	300.000 €	2014-02-18 / 2017-11-30	RADEM proto-flight model
ESA: 3-13975/13/NL/PA	200.000 €	2014-03-10 / 2016-12-31	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 / 2017-06-30	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

Stated objectives for past year

- Contract CODES, MFS data analysis, and ECo60-JUICE should be finished in 2016.

- RADEM

- Study and tradeoffs for the best location of RADEM in the JUICE spacecraft.

- For the RADEM Engineering Model (EM): Simulation and science analysis of the DD, production of DD response functions, EM DD in-beam calibration.

- For the RADEM Engineering Qualification Model: 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.

- Participation in the JUICE Science Working Team along with PSI, both being "scientific" partners of the RADEM consortium.

• CTTB Data Analysis:

- The CTTB data analysis contract started in November 2015 to be continued during 2016. In this project the data of the CTTB EEE components flying in GEO, aboard the AlphaSat, will be analyzed and the results of the analysis will be published.

Achievements and responsibilities during the past year

CODES

The CODES contract was closed in te begining of 2016 with the release of the CODES web based engineering framework based on GEANT4 to predict Single Event Effects in EEE devices.

MFS data analysis

The MFS data analysis contract was not closed in 2016. The proton energy spectra reconstruction method for MFS data was developed, in collaboration with Ingmar Sandberg from the National Observatory of Athens, Greece, and results of spectral proton measurements for SEP events measured with MFS were presented in the RADECS 2016 conference in Bremen (as a poster and for Publication), but the electron energy spectra reconstruction algorithms are still being developed. The presults obtained were presented at the ESTEC/TEC-EES Final Presentation Days in ESTEC, the Netherlands, in November 2016.

ECo60-JUICE

During 2016 four irradiation campaigns were conduced, two with Co-60 gammas - at Low Dose Rate and at High Dose Rate - and two with electron beams at energies above 10 MeV. The test facilities used included the CO-60 Radiosterilisation Unit at the Centro Tecnológico Nuclear in Sacavém and a LINAC at the Santa Maria Hospital in Lisbon. The analysis of the response to different particle fields of the EEE components tested is being finalized and will be submited to the NSREC 2017 conference hat will take place in the US for presentation and publication.

RADEM

The RADEM radiation analysis was performed during 2016, and was centred mostly on finding the minimum mass needed in order to shield the EEE components and RADEM sensors from the harsh Jovian radiation environment given the chosen location of RADEM in the JUICE Spacecraft. Several studies concering the performance of the Directional Detector Head and the degradation aand total Ionising Dose expected for all the relevant components were performed and were reported in three Project Technical Notes delivered.

During 2016 the RADEM consortium scientific partners - LIP and PSI - team have participated in the meetings of the he JUICE mission science working team due to the scientific interest on using RADEM data to complement JUICE mission scientific payload data.

CTTB Data Analysis

The first in-flight dose measurements performed by the RADFETS on the CTTB boards were computed from data and reported in the corresponding Project Technical Note. Preliminary results of these measurements were presented at the RADECS 2016 conference in Bremen, as a poster in the Data Workshop section.

Other developments

A method for exporting CAD mechanical models into a format readable by Geant4 - from CAD to gdml - was developed and is described in an internal note.

Lines of work and objectives for next year

Activities

MFS data analysis

The MFS data analysis contract energy spectra reconstruction algorithms development will be closed in 2017. Electron energy spectra reconstruction algorithms are still being developed and its results will be published and compared with other missions at simular location (in GEO).

ECo60-JUICE

The ECO-60 contract will be closed during the first semester of 2017. The results obtained will be presented in the ESA TEC-QC section final presentation days at ESTEC in the Netherlands in March 2017. The analysis of the response to different particle fields of the EEE components tested will be finalized and submited to the NSREC 2017 conference that will take place in the US in June It is foreseen that the analysis will be published in an international journal.

RADEM

The activities of the RADEM contract wil continue during 2017 with the following tasks:

- For the RADEM Engineering Model (EM): Simulation and science analysis of the DD, production of DD response functions, EM DD in-beam calibration.
- For the RADEM Engineering Qualification Model: 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

Results of RADEM performance are expected to be presented ar RADECS 2017 which will take place in October 2017 in Genebra. LIP also will participate in the JUICE mission science working team meetings and expects to continue this participation.

The consortium will pursue efforts to find a flight opportinity for RADEM in a satellite such as PROBA-3 in order to be able to test it in-flight prior to integration in the JUICE mission.

CTTB Data Analysis

The analysis of the in-flight CTTB data will be continued and the results obtained will be published.

Mars Radiation Environment

Work will continue to be developed in the exploration of the Mars radiation environment models. One line is the study of interplanetaly mission hazards and surface stays for manned missions to Mars and/or the Moon . A PhD thesis is expected to be initiated in this subject, in the study of the radiation hazards for the crews and in the development of mitigation strategies.

The work started by Ana Luisa Casimiro in her Master thesis, Assessment of radiation exposure in manned missions to Mars for three mission profiles" was accepted as an oral presentation at the RAD 2017 conference that will take place in June 2017 in Montenegro.

The exploitation of the Mars radiation environment models developed at LIP from the point of view of the search for microbiological life in Mars sub-surface will be continued. The validation of dMEREM surface results with the corresponding measurements of the RAD Curiosity data along with dMEREM predictions for subsurface radiation levels, will be submitted to publication in 2017.

Theses

The Master Thesis of Filipe Máximo with the title "Analysis of in-flight data on the AlphaSat radiation Environment Effects Facility" will be finished and presented in 2017. In this thesis an alternative method to reconstruct particle energy spectra using the MFS data will be developed and correlations between the CTTB components response and MFS reconstructed energy spectra are expected.

The Master thesis of Pedro Lança Alves, with the title "Development and Test of EEE devices for Space Applications", with the objective of testing magnetoresistive sensors for space applications, which is being supervised by Patrícia Gonçalves at LIP and Susana Freitas at INESC, will be finished and presented in 2017.

The PhD thesis of Marco Gui Pinto, with the preliminary title "A Directionality Detector for the JUICE mission Radiation Hard Electron Monitor" will enter its third year.

LIP has 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 candidate selection should be performed in the 1st semester of 2017, so that the PhD programme should start in 2017, as required.

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.

Weaknesses

- The group heavily depends on contracts with the European Space Agency which a typical duration between 1 year to 3 years
- Physics Students learning curve -> 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.

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

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

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

Luisa Arruda, Patricia Goncalves, Ingmar Sandberg et al.: "SEP Protons in GEO with the ESA MultiFunctional Spectrometer", accepted for publication in IEEE TNS

3 International Conference Proceedings

Alankrita Mrigakshi, Wojtek Hajdas, Radoslaw Marcinkowski, Hualin Xiao, Patricia Gonçalves, Marco Pinto, Costa Pinto, Arlindo Marques, and Dirk Meier : "Bread-Board Testing of the Radiation Hard Electron Monitor (RADEM) being developed for the ESA JUICE Mission", accepted for publication in EGU General Assembly 2016, Vol. 18, EGU2016-13998-2, 2016

Luisa Arruda, Patricia Goncalves, Ingmar Sandberg et al.: "SEP Protons in GEO with the ESA MultiFunctional Spectrometer", accepted for publication in RADECS 2016 Proceedings, Bremen, Germany,

J. M. Sampaio, P. Gonçalves, C. Pinto, T. Sousa, A. Marques, P. Ribeiro, S. Sobreiro, R. Martins, M. Muschitiello, and C. Povey: "Dose calculations from RADFETS response onboard the ALPHASAT CTTB experiment", accepted for publication in RADECS 2016 Proceedings, Bremen, Germany,

5 Collaboration notes with internal referee

Marco Pinto, Patricia Goncalves: "RADEM Geant4 Model Radiation Analysis", accepted for publication in JUI-LIP-RDM-TN-002.7

Luisa Arruda, Patricia Goncalves: "Comparison of MFS data with radiation environment models and available radiation monitor data", accepted for publication in MFSDA-LIP-TN-0013.1

Marco Pinto, Patricia Goncalves: "RADEM EEE Component Radiation Analysis Total Ionising Dose", accepted for publication in JUI-LIP-RDM-TN-004.3

Marco Pinto, Patricia Goncalves: "RADEM Directionality Detector Head Displacement Damage Simulations", JUI-LIP-RDM-TN-003.1

Jorge Sampaio, Patricia Goncalves: "Alphasat Dose Calculations From The CTTB RADFETS Response", accepted for publication in CTTBDA-LIP-TN-002.1

Presentations

2 Poster presentations in international conferences

Luisa Arruda: "SEP Protons in GEO with the ESA MultiFuntional Spectrometer", 2016-09-21, RADECS 2016, Bremen, Germany

Jorge Sampaio: "Dose calculations from RADFETS response onboard the ALPHASAT CTTB experiment", 2016-09-22, RADECS 2016, Bremen, Germany

2 Oral presentations in international meetings

Luisa Arruda: "AlphaSat/TDP-8/MFS Particle Spectrometer data analysis", 2016-10-05, Space Radiation Modelling and Data Analysis Workshop 2016, Sykia, Peloponnese, Greece

Patrícia Gonçalves: "Final Presentation: AlphaSat TDP–8 MFS Particle Spectrometer Data Analysis", 2016-10-24, ESA days: Final presentations, ESTEC, ESA, The Netherlands

2 Oral presentations in national conferences

Marco Alves Pinto: "Space Radiation Environment & Effects", 2016-02-20, Jornadas do LIP 2016, Universidade do Minho – Braga

Patrícia Gonçalves: "Overview & Prospects for the research line "SREE and Applications to Space Missions"", 2016-02-20, Jornadas LIP 2016, Braga, Portugal

3 Poster presentations in national conferences

Pedro Miguel Magalhães: "Martian radiation environment and effects on its surface and underground ", 2016-03-02, Jornadas de Engenharia Física 2016, Instituto Superior Técnico, Lisboa

Ana Luisa Casimiro : "Effects of the space radiation environment in manned missions to Mars", 2016-03-02, Jornadas de Engenharia Física 2016, Instituto Superior Técnico, Lisboa

Ana Luisa Casimiro : "Effects of the space radiation environment in manned missions to Mars", 2016-11-25, Apresentação para Comissão de avaliação do Departamento de Física IST, Instituto Superior Técnico, Lisboa

5 Outreach seminars

Patrícia Gonçalves: "Do Sol à Terra, da Terra à Lua", O Espaço vai à Escola - Ciência Viva, 2016-10-6, Escola EB 2,3 de Santa Iria de Azóia; 2016-10-7 Escola EB 2,3 António Gedeão , Arroja; 201610-20 Escola EB 2,3 de Santa Iria de Azóia.

Jorge Sampaio: " Dosimetry on Earth and Space", 2016-11-16, Seminário Departamento de Física, FCT-UNL

Patrícia Gonçalves: "Do Sol à Terra, da Terra à Lua", 2016-11-24, Sessão para o 7º ano no Planetário de Lisboa, Planetário de Lisboa

Theses

2 PhD Theses

Bruno Morgado: "Analysis of Near Relativistic Protons and Electrons im solar Events" (finished on 2016-07-25)

Marco Alves Pinto: "A Directionality Detector for the JUICE mission Radiation Hard Electron Monitor" (ongoing)

2 Master Theses

Pedro Miguel Magalhães: "Radiation Environment Effects on the Martian Surface and Underground" (finished on 2016-06-07)

Ana Luisa Casimiro : "Efeitos da Radiação Espacial Ambiente em Missões Tripuladas a Marte" (finished on 2016-06-08)

SPACE INSTRUMENTATION FOR ASTROPHYSICS

i-Astro

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 mission 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 little explored, with great potential to open a new scientific observational window.

In 2016 were chosen the priority science objectives of AHEAD WP9 (Work Package 9), entitled "Assessment of gamma-ray experiments", and the instrument configurations to be simulated. E-ASTROGAM mass model simulation was assigned to our group.

We kept contributing to the development of the main instrument of XIPE mission. In June 2017, ESA will decide if XIPE will be launched in 2026, among the 3 pre-selected missions.

BioMeXRay (Biometals Detection by X-Ray Fluorescence) biomedical application spin-off research activities were carried on.

Framework and status for past and current year

Summary of performance indicators

Articles in international journals:	1 With direct contribution from team
International conferences:	1 Oral presentation 2 Posters 2 Proceedings
National conferences:	2 Oral presentation 1 Poster
International meetings:	1 Oral presentation
Completed theses:	1 Master Thesis

DEVELOPMENT OF NEW INSTRUMENTS AND METHODS

Space applications

Team

Principal Investigator Rui Curado Silva (85)

Researchers
Filipa Borges (15), Filipe Moura(*), Filomena Santos (20), Jorge Maia (45), José Escada (20),
Teresa Dias (15)

PhD students
Alexandre Fonseca Trindade (30), Marco Alves Pinto (10), Miguel Moita (100)

Master students
Joana Baptista (100), Marcela Páscoa (100), Mariana Martins (17)

External/Additional scientific collaborators
Carlos Patacas, José Marques

Total FTE
5.6

(*) Started December 2016

// 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. 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 Carlos Patacas and by 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 Jorge Maia.

1.3 e-ASTROGAM mass model simulations will be performed by AHEAD funded Post-Doc and by Marco Pinto, under the supervision of Rui Curado da Silva and 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 José Escada and Alexandre Trindade PhD thesis, under the supervision of Rui Curado da Silva and Jorge Maia.

2.1 GPD gas mixture simulation is performed by José Escada, under the supervision of Jorge Maia and of Rui Curado da Silva.

2.2 GPD gas mixture testing will be performed by Alexandre Trindade under the supervision of Filomena Santos.

3. The BioMeXRay (Biometals Detection 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 X-ray fluorescence in brain and eyes tissues. Jorge Maia coordinates the group participation in BioMeXRay.

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

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. Start of AHEAD WP9 main activities and consortium networking.

1.1 Hiring an AHEAD financed postdoc and start the mass model simulation of a gamma-ray focal plane equipped with Laue lens.;

1.2 Conclude a white paper on the priority scientific objectives of high-energy astrophysics;

1.3 INTEGRAL IBIS polarimetric data analysis of stronger gamma-ray emitters, such as the Crab pulsar;

1.4 Start the development of double layer CdTe polarimeter prototype.

2. XIPE mission optimization of the GPD gas mixture, develop the first version of a FORTRAN Monte Carlo code allowing the study the best trade-off gas mixture, between lowest electron diffusion in the gas and the highest possible electron drift speed.

3. In BioMeXRay project: conclude the development of measurement/analysis methods by X-ray fluorescence in brain and eyes tissues.

Achievements and responsibilities during the past year

- Science Advisory Group of AHEAD WP9 concluded the White Paper on the Gamma-ray Astrophysics priority science objectives;
- AHEAD WP9 Instrument Working Group evaluated the proposals that have been submitted to the call for instrument concepts issued June 15th, 2016. 5 proposals were selected, including ASTENA (Advanced Surveyor of Transient Events and Nuclear Astrophysics) that was co-proposed by our group as well as e-ASTROGAM proposal;
- Double layer CdTe polarimeter prototype and its front end electronic readout were designed, developed and mounted in the laboratory precision table;
- We observed significant performances' recovery (energy resolution, leakage current, etc.) of a CdTe ACRORAD detector matrix for orbital environment, one year after proton irradiation at ICNAS (Instituto de Ciências Nucleares Aplicadas à Saúde);
- Obtained the first results for XIPE mission gas electron production and transport simulations for Xe and Ne gas filled GPD;
- In BioMeXRay project the optimization of the X-ray fluorescence spectrometer parameters were almost concluded. The development of measurement/analysis methods by X-ray fluorescence in brain and eyes tissues is under way.
- R.M. Curado da Silva was H2020 project evaluator for the Research Executive Agency, European Commission, Brussels, Belgium, for the call "Leadership in Enabling and Industrial Technologies – Space", topic Scientific Instrumentation (COMPET-5-2016).

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 The AHEAD financed postdoc will simulate e-ASTROGAM mission (M5 ESA candidate) configuration. Instrument mass model simulation will be performed with GEANT4 and MEGAlib toollkits. Later on, up to 2018, the different simulated instrument configuration will be compared (sensitivity, minimum detectable polarization, field of view, etc.) and a future gamma-ray instrument configuration will be adopted for the next ESA call for missions;

1.2 Due to our expertise in gamma-ray polarimetry, R.M. Curado da Silva will be advisor on polarimetry science of further proposals: ASTENA and HE Gamma-ray Polarization proposal. The objective is maximize the polarimetric performance of the selected instrument configuration;

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 a precious input for AHEAD instrument polarimetric design optimization;

1.4 The double layer CdTe polarimeter prototype will be tested that will allow to access the performances of polarimeters based on stack/multi-planar configuration such as e-ASTROGAM baseline configuration. An experimental prototype test campaign is scheduled for the European Synchrotron Radiation Facillity by October 2017;

1.5 Orbital proton radiation effects on a CdTe focal plane prototype performance study will be further improved in ICNAS proton beamline, extending the beam energy range (more realistic), studying in deeper the activation background noise, energy resolution, leakage current dependence with time.

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 preliminary results were already obtained for noble gases like Xe and Ne, but the simulation code will be extended to include He, Ar as well as quenching additive gases like DME and isobutane gases.

These tasks will be developed in a larger scale effort on gaseous and Xenon research and development project, in particular in charged particle mobility in different detection gas.

3. In BioMeXRay project our group will conclude the development of measurement/analysis methods by X-ray fluorescence in brain and eyes tissues. And start the study of the sensitivity (integral and differential) of the X-ray fluorescence spectrometer for the several biometals that we intend to measure.

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 June 2017 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 opportunity might occur in the gamma-ray domain, in case e-ASTROGAM mission will be selected in the M5 call.

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)

M. Pinto, R.M. Curado da Silva, J.M. Maia, N. Simões, J. Marques, L. Pereira, A.M.F. Trindade, E. Caroli, N. Auricchio, J.B. Stephen, P. Gonçalves: "Polarimetric analysis of a CdZnTe spectro-imager under multi-pixel irradiation conditions", Nuclear Inst. and Methods in Physics Research, A (2016), pp. 69-76

2 International Conference Proceedings

E. Caroli, N. Auricchio, C. Budtz-Jørgensen, G. De Cesare, R. M. Curado da Silva, S. Del Sordo, P. Ferrando, P. Laurent, O. Limousin, J. L. Galvèz, M. Hernanz, J. Isern, I. Kuvvetli, J. M. Maia, A. Meuris: "A Small 3D CZT Payload for Hard X Ray Polarimetry and Spectroscopic Imaging", A Small 3D CZT Payload for Hard X Ray Polarimetry and Spectroscopic Imaging, E. Caroli1, N. Auricchio1, C. Budtz-Jørgensen2, G. De Cesare1, R. M. Curado da Silva3, S. Del Sordo4, P. Ferrando5, P. Laurent5, O. Limousin5, J.

E. Caroli, G. De Cesare, R. M. Curado da Silva, L. Abbene, N. Auricchio, C. Budtz-Jørgensen, S. Del Sordo, P. Ferrando, J. L. Galvèz, M. Hernanz, J. Isern, I. Kuvvetli, P. Laurent, O. Limousin, J. M. Maia, M. Moita, N. Pro: "Monte Carlo evaluation of a CZT 3D spectrometer suitable for a Hard X- and soft-? rays polarimetry balloon borne experiment", International Symposium on Room-Temperature Semiconductor X-Ray and Gamma-ray Detectors, 31 Oct. – 7 Nov.San Diego, USA, 2015.

Presentations

1 Oral presentation in international conferences

Rui Curado Silva: "XIPE Mission Focal Plane Optimization", 2016-10-16, International Workshop on Soft X-ray Single-order Diffraction Grating Development and Application, Chengdu na China

2 Poster presentations in international conferences

José Escada: "Gas mixture optimization for the GPD focal plane of the XIPE mission", 2016-05-24, First Science Meeting on XIPE Mission, Valência, Espanha

José Escada: "XIPE Mission Focal Plane Gas Mixture Optimization", 2016-11-02, IEEE Nuclear Science Symposium, Estrasburgo, França

2 Oral presentation in national conferences

Miguel Moita: "Development of a Polarimeter for Future Gamma-Ray Space Telescopes", 2016-07-15, School DAEPHYS 2016 on Atomic and Nuclear Analytical Methods and their Applications and 2nd DAEPHYS PhD student Workshop, LIP de Coimbra

Rui Curado Silva: "XIPE space telescope proposal", 2016-09-08, XXVI Encontro Nacional de Astronomia e Astrofísica , Departemento de Física da Universidade de Aveiro e Centro de Investigação e Desenvolvimento em Matemática e Aplicações

1 Poster presentation in national conferences

Miguel Moita: "Development of a Polarimeter for Future Gamma-Ray Space Telescopes", 2016-09-08, XXVI Encontro Nacional de Astronomia e Astrofísica , Departemento de Física da Universidade de Aveiro e Centro de Investigação e Desenvolvimento em Matemática e Aplicações

1 Oral presentation in international meeting

Rui Curado Silva: "Space Instrumentation for High-Energy Astrophysics", 2016-03-23, Erasmus+ Meeting, Department of Physics, Czech Technical University in Prague, Czech Republic

Theses

1 PhD Thesis

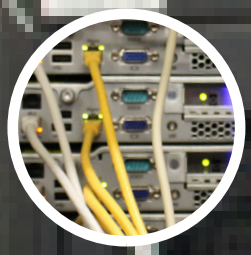
Miguel Moita: "ASTROGAM Space Gamma-ray Telescope Main Instrument Development" (ongoing)

3 Master Theses

Mariana Martins: "Deteção por fluorescência de raios X de biometais em tecido cerebral e olhos de ratos" (finished on 2016-02-26)

Joana Baptista : "Análise de Biometais em Tecido Cerebral por Microscopia Eletrónica Analítica" (ongoing)

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

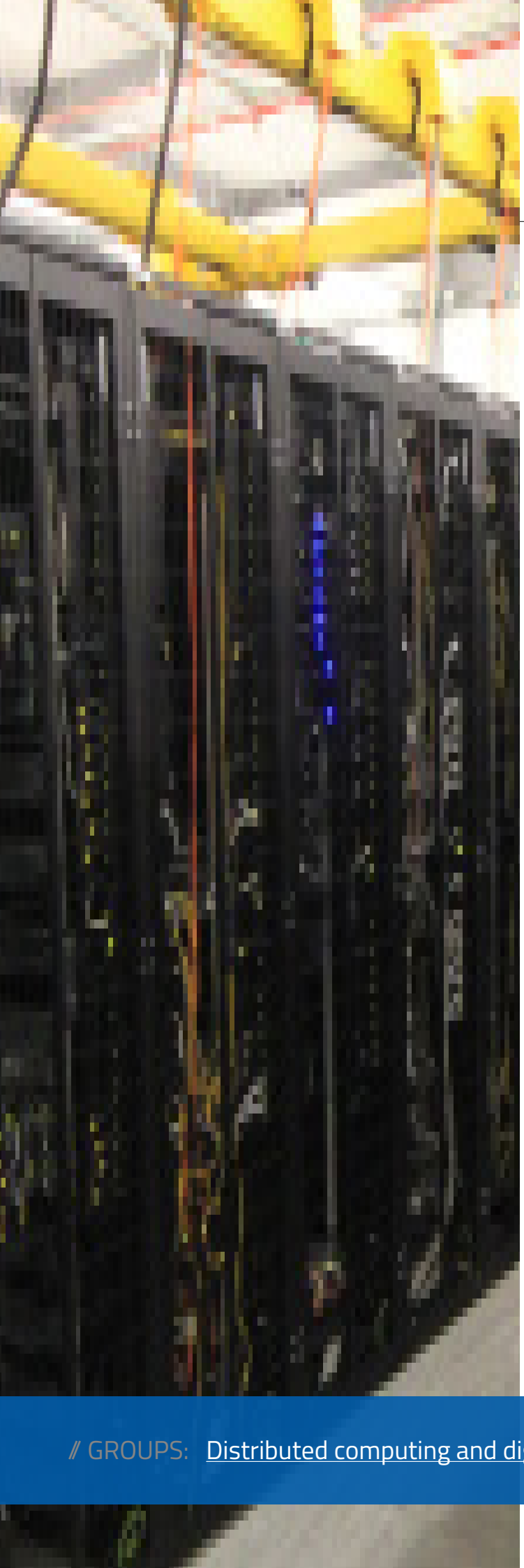
Scientific research requires increasingly higher data storage and processing capacities that stress the limits of information systems and related technologies. Large scientific endeavors such as the CERN Large Hadron Collider (LHC) are a good example. The LHC distributed data simulation, processing and analysis lead to the creation of the Worldwide LHC Computing Grid (WLCG), the largest distributed computing infrastructure ever built for a single scientific problem.

The LIP distributed computing and digital infrastructures group, provides information technology (IT) services to LIP and to its research groups. The group operates most LIP core IT services, including compute and data services for simulation and data analysis that support the LIP research including the participation in the LHC. The development of the IT services and competences is backed by participation in ICT R&D projects and e-infrastructures at national and international level.

Framework and status for past and current year

Summary of performance indicators

International journals:	2 Papers (with direct contribution from team)
Reports:	1 Institute report
International conferences:	4 Presentations 1 Proceedings
National conferences:	3 Presentations
International meetings:	2 Oral presentations
Collaboration notes:	4 Notes with internal referee
Collaboration meetings:	4 Oral presentations
Seminars:	3 Seminars
Proposals:	2 Proposals
Organization:	2 Workshops organized



Team

Principal Investigator Jorge Gomes (100)

Researchers
Gaspar Barreira (90), Jorge Cedillo (100), João Paulo Martins (100), João Pina (100), Mário David (100), Nuno Ribeiro Dias (100)

Technicians
Carlos Manuel (100), Hugo Gomes (100), José Aparício (100)

Total FTE
9.9

// 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. The operation of the Portuguese Worldwide LHC Computing Grid Tier-2 is one of the services delivered by the group. In addition the group is delivering 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 such as the European Grid Infrastructure (EGI) and the Iberian Grid Infrastructure (IBERGRID).
- Participation in ICT R&D projects. Enables the development of advanced competences and services that back the production services delivered to the researchers. The group participates in projects addressing several aspects of scientific data processing including: federation of compute and storage resources, technologies for 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. Currently the group participates in the H2020 projects EGI-ENGAGE and INDIGO-DataCloud.
- Provisioning of web development and multimedia services, supporting outreach, dissemination, exploitation, management and research activities. These services are provisioned on top of the IT services platform. 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.

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

Stated objectives for past year

LIP computing Services

- Consolidation of compute and data services at the NCG datacenter.
- Preparation of the migration of the LIP Lisbon office to a new building.
- Improvement of the network connectivity.
- Pursue opportunities to improve the data and compute services in the INCD context.

WLCG and Tier-2

- Follow the evolution of the LHC computing model and consider new approaches and technologies.
- Organization of the 2016 WLCG Collaboration Workshop.

INCD

- Open the INCD cloud as a beta service to the national research community.
- Evaluate cloud bursting approaches with commercial providers.
- Implementation of a Ceph storage system integrated in the INCD cloud service.
- Continue supporting the academic and research community by sharing the HTC and HPC production services.

EGI and IBERGRID

- Represent Portugal and liaise with the European Grid Infrastructure (EGI) and Iberian Grid Infrastructure (IBERGRID).
- Participation in the H2020 EGI-ENGAGE in the areas of authentication and authorization, and in the EGI LifeWatch competence centre in collaboration with national biodiversity researchers.
- Provide middleware coordination for the EGI global infrastructure.

INDIGO-DataCloud

- Coordination of the INDIGO-DataCloud software life-cycle and pilot services.
- Participation in the development of network capabilities for the OCCI cloud computing standard.
- Research Linux containers and application support in batch scheduling systems

Achievements and responsibilities during the past year

In 2016 the Tier-2 executed 1,809,210 jobs amounting to 65,485,165 normalized (HEPSPEC06) processing hours to ATLAS and CMS. This is an increase of ~ 21% in comparison to 2015. The gain was obtained with multicore jobs and cloud technologies. LIP has been one of the WLCG centres pioneering higher efficiency with multicore jobs.

The LIP Lisbon computing farm has been moved and merged with the NCG computing farm. This consolidation enabled lower operational costs and higher efficiency. This was a mandatory step to enable the migration of the LIP Lisbon office to a new building. The commercial and academic network bandwidth for the NCG services has been improved.

At the FCCN workshop 2016, the INCD cloud was announced as a beta service open to the community. The service has been reinforced with a Ceph storage system providing scalable block and object storage. Lightweight virtualization with containers was added to the cloud providing higher performance with less overheads.

A transparent cloud bursting approach for OpenStack was implemented based on remote virtual cloud compute nodes. Nested virtualization is implemented with containers minimizing overheads . The approach was successfully tested enlarging the INCD cloud with computing resources provided by the Portugal Telecom cloud in a joint collaboration.

INCD, through LIP, continued to support national researchers and projects. Adherence has increased with new users, organizations and projects especially from the biomedical domain, exploiting the HPC, HTC and cloud resources. The INCD pilot GPGPU service and the large memory systems have been heavily used for genome research.

A project proposal for the development and enlargement of the INCD infrastructure was submitted in July under the umbrella of the FCT roadmap of research infrastructures. The project partners are FCCN, LIP and LNEC.

The group continued to coordinate IBERGRID operations enabling sharing of computing and data resources at pan-European level for the benefit of research experiments and projects. LIP contributed to the LifeWatch competence centre in EGI and together with CIBIO established the Portuguese GBIF portal delivering access to Portuguese biodiversity data. The service is hosted at the INCD cloud.

The group has participated in the testing and commissioning of the new EGI global federated authentication and authorization (AAI) system. LIP and its Iberian partners (CSIC and CESGA) delivered middleware testing and coordination services to EGI. LIP also participated in the EGI security coordination. The group PI participated in the EGI council and executive board.

In the INDIGO-DataCloud project, the group successfully coordinated the “Pilot Services and Release Management” supervising the software quality assurance, release management, pilot services and exploitation activities of this large software R&D project. During the project review in November this work was praised for the innovation and excellence.

Also in INDIGO, the OCCI cloud computing standard was enlarged to include network support, the extension was added to the OCCI reference implementation for OpenStack. Ansible modules for OpenStack configuration management were further extended. For contributions to OpenStack, group members have been invited to attend the OpenStack summit 2016 in Barcelona.

The udocker software developed by the group in INDIGO is already being used to support multiple applications. The MasterCode collaboration is using udocker to run in supercomputers in Europe and US and presented udocker at the SUSY 2016 conference. udocker provides a novel approach to run Linux containers in any Linux system transparently and efficiently without root privileges.

EGI, INDIGO and EUDAT were pushed by the EC as the base building blocks for the European Open Science Cloud (EOSC). The group participates in EGI and INDIGO, the PI participated in the negotiations to join these three entities in the upcoming H2020 EINFRA-12 2017 call in a unified large project.

The group organized the 2016 WLCG Collaboration Workshop in Lisbon, followed by a data preservation DPHEP Workshop. The events had more than 130 participants.

Lines of work and objectives for next year

LIP computing services

LIP Lisbon will move to a new building, consequently the IT infrastructure and services will be migrated and reorganized. The equipment still remaining at the LIP Lisbon datacenter will be moved to NCG and/or to the Lisbon University datacenter. Having the core computing and storage equipment at NCG will enable further service improvements.

The adoption of cloud computing and containers technology to support the LIP services and applications will be pursued, aiming at improving the flexibility, resilience and management. More LIP services will take advantage of the INCD cloud. Automation of installation and configuration management will be enhanced using technologies such as Ansible, Experience and technologies from ongoing projects will be applied to improve the services.

WLCG and Tier-2

The LHC computing model is evolving and middleware components are likely to continue being replaced. Following the activity started in 2016, the Tier-2 compute nodes will be migrated to virtual instances supported by the INCD cloud. This major farm reorganization will enable the exploitation of future capacity to be delivered via INCD. In addition will enable to exploit idle cloud resources and provide higher flexibility for software configurations and maintenance.

The provisioning of IPv6 connectivity for Internet facing services will become mandatory in WLCG. Currently the Tier-2 does not offer IPv6 connectivity and this requirement will trigger a major network overhauling with impact on many site services. Experimentation with containers based technology for lightweight virtualization of compute nodes will be conducted.

INCD

A proposal to fund the Portuguese National Distributed Computing Infrastrcture (INCD) was submitted in mid 2016 to a restricted call aimed at funding infrastructures in the FCT roadmap of scientific infrastructures. It is expected that funding for the INCD activities may become available in 2017. The INCD activities described in the proposal cover a three years period. In the first year the operational and management structure will be established. The technical focus will be put in the improvement of the INCD IaaS cloud housed at INCD. The IaaS cloud now being delivered as a beta service will continue to support the current user base. R&D for new services to be provisioned on top of the IaaS layer is also foreseen.

The HTC and HPC services currently delivered via the NCG farm will continue being provided to a growing set of users. The farm nodes (including the Tier-2) will be virtualized taking advantage of the INCD cloud.

Participation in thematic activities and networks will be considered through the INCD partnership and also in collaboration with other organizations. These activities may include the participation in projects aimed to deliver thematic services to the scientific community. Biodiversity, earth observation and bio-medicine are possible domains of collaboration.

EGI and IBERGRID

The group will continue to liaise the Portuguese grid and cloud resources within the European Grid Infrastructure (EGI). The EGI federated cloud is growing and is now supporting a diversified set of international research communities including many ESFRIs. The EGI related activities will become more focused on cloud and support to user communities. Collaboration to support services over the EGI fedcloud already include: CIBIO with LifeWatch services, and IPMA with EMSO services. The commissioning of the EGI federated AAI and its evolution will continue together with participation in the EGI security activities.

The IBERGRID collaboration will continue providing an umbrella for Iberian participation in EGI and other common activities. The middleware coordination for EGI will be delivered by IBERGRID via LIP, IFCA and CESGA. The middleware coordination will grow to encompass cloud and other services.

INDIGO-DataCloud

The coordination of the “Pilot Services and Release Management” work package will continue. The focus will be the 2nd INDIGO-DataCloud software release featuring enhanced PaaS capabilities. The deployment of use-cases in collaboration with the user communities in the project (BBMRI, ELIXIR, INSTRUCT, DARIAH, DCH-RP, LBT, CTA, LifeWatch, EMSO, ENES, and WLCG) will be performed aimed at validating the software completeness, readiness and scalability.

Similarly exploitation activities to push the software into infrastructure providers such as EGI and others will be reinforced, in this context agreements are also being established with commercial and non-commercial entities. Currently, a joint trial of the INDIGO-DataCloud solutions with T-Systems (one of the largest European commercial cloud providers) is being conducted by the group.

H2020

Participation in future projects both in the context of EGI, INDIGO, INCD and other collaborations will be pursued. The group will participate in the editorial board of the joint EGI-INDIGO-EUDAT proposal to the upcoming EINFRA-12 2017 call aimed at services delivery towards the European Open Science Cloud (EOSC)..

SWOT Analysis

Strengths

- Highly skilled staff with unique experience and competences.
- Excellent international relations and integration in international scientific e-infrastructures.
- Cost effective, infrastructure with advanced software technologies.
- Fulfilling the CERN LHC computing MoU, and exploiting synergies with other research and academic areas.
- 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

- Lack of resources to reach researchers in other organizations.
- Lack of personnel and equipment 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 to publicly funded capacity.
- Potential for industrial and e-government applications.
- Overcome the obsolescence of critical infrastructure components.
- Well positioned to participate in upcoming projects and initiatives.

Threats

- Lack of funding, funding gaps and delays menace sustainability,
- Lack of investment is deeming the existing infrastructure obsolete. Continuous investment is needed to address research requirements.
- 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 INFN CNAF; G.Donvito INFN-Bari; I.Plasencia CSIC; J.Marco (Univ Cantabria); J.Gomes (LIP); L.Gaido (INFN); L.Dutka (Cyfronet); M.Plociennik (PSNC); M.Hardt KIT; P.Fuhrmann, DESY; R.Barbera INFN Catania: "INDIGO-Datacloud: a Cloud-based Platform as a Service oriented to scientific computing for the exploitation of heterogeneous resources", accepted for publication in Journal of Physics Conference Series (JPCS) papers from CHEP 2016 Conference, San Francisco, October 8-14, 2016

G.C.P. van Zundert, M. Trellet, J. Schaarschmidt, Z. Kurkcuoglu, M. David, M. Verlato, A. Rosato, A.M.J.J. Bonvin: "The DisVis and PowerFit web servers: Explorative and Integrative Modeling of Biomolecular Complexes", J. Mol. Biol. (2016)

1 Institute report

J.Gomes, J.Pina, M.David, J.P.Martins, N.Dias, H.Gomes: "Support for the ATLAS and CMS Portuguese Tier-2 in the Context of the WLCG MoU Final Report"

1 International Conference Proceedings

S. Fiore, M. Płóciennik, C. Doutriaux, C. Palazzo, J. Boutte, T. Żok, D. Elia, M. Owsiak, A. D'Anca, Z. Shaheen, R. Bruno, M Fargetta, M. Caballer, G. Moltó, I. Blanquer, R. Barbera, M. David, G. Donvito: "Distributed and cloud-based multi-model analytics experiments on large volumes of climate change data in the Earth System Grid Federation eco-system", accepted for publication in Distributed and cloud-based multi-model analytics experiments on large volumes of climate change data in the Earth System Grid Federation eco-system, S.Fiore et al., 2016 IEEE International Conference on Big Data, pp 2911-

4 Collaboration notes with internal referee

J.Gomes, J.Pina, M.David, J.P.Martins, N.Dias, H.Gomes, C.Manuel, J.Aparicio, J.Cedillo: "Piloto Cloud Relatório E1 sistema técnico funcional de Cloud IaaS híbrida baseado em openstack", accepted for publication !!! missing reference journal !!!

J.Gomes, J.Pina, M.David, J.P.Martins, N.Dias, H.Gomes, C.Manuel, J.Aparicio, J.Cedillo: "Piloto Cloud Relatório E3 testes de integração de sistemas comerciais", accepted for publication !!! missing reference journal !!!

J.Gomes, J.Pina, M.David, J.P.Martins, N.Dias, H.Gomes, C.Manuel, J.Aparicio, J.Cedillo: "Piloto Cloud Relatório E5 linhas estratégicas futuras", accepted for publication !!! missing reference journal !!!

J.Gomes, M.David, C.Aiftimiei, M.Viljoen, P.Orviz, M.Orzechowski, I.Neilson: "INDIGO-DataCloud Status report and updated plan of WP3 activities", INDIGO-WP3-D3.2-v1.0

2 Proposals

J.Gomes, J.Pina, M.David, J.P.Martins: "Suporte para o tier-2 de ATLAS e CMS no contexto do memorando de entendimento do WLCG II", Proposal of extension of the Portuguese Tier-2 project RECI-II/FIS-NUC/0115/2012

J.Gomes (LIP), M.David (LIP), J.Pina (LIP), J.Ferreira (FCCN), A.Oliveira (LNEC), M.A.Santos (LNEC), J.Pagaime (FCCN): "Portuguese National Distributed Computing Infraestruture",

Presentations

4 Oral presentations in international conferences

Mário David: "NoSQL working group - Use case: Network of Life", 2016-04-06, EGI Conference 2016 - LifeWatch Competence Center, Krakow, Poland

Isabel Campos: "Container Technology for Phenomenology Tools", 2016-07-10, SUSY 2016, Melbourne, Australia

João Pina: "Handling time-critical service applications with EGI e-Infrastructure", 2016-11-29, 2nd International Workshop on Interoperable infrastructures for interdisciplinary big data sciences (IT4RIs 16), Porto, Portugal

Mário David: "Tutorial: EGI A&A Demo", 2016-12-12, 1st ASTERICS – OBELICS Workshop, Rome, Italy

3 presentations in national conferences

Jorge Gomes: "LIP Computing Report and Plans", 2016-02-18, LIP Workshop 2016, Braga, Portugal

Jorge Gomes: "Piloto Cloud : infraestrutura implementação e resultados", 2016-04-07, Jornadas FCCN 2016, University of Algarve, Portugal

Jorge Gomes: "INCD e os Desafios da computação científica", 2016-07-06, Ciência 2016, Academia de Ciências, Lisbon

2 Oral presentations in international meetings

Mário David: "The EGI AAI CheckIn Service", 2016-10-17, OSO F2F Meet Up on Openstack-Federated Identity integration, Rome, Italy

Jorge Gomes: "Software Management and Pilot Services (WP3)", 2016-11-05, INDIGO-DataCloud 1st project review, CNAF, Bologna, Italy

4 Oral presentations in collaboration meetings

Jorge Gomes: "Piloto Cloud implementação e resultados", 2016-03-16, , FCCN, Lisbon, Portugal

Jorge Gomes: "WP3 status of the pilot testbeds and release management", 2016-04-05, INDIGO-DataCloud face-to-face, CWI, Amsterdam, Netherlands

Jorge Gomes: "Computing Research", 2016-04-07, LIP Advisory Board 2016, Braga, Portugal

Jorge Gomes: "UDOCKER demonstration", 2016-11-05, INDIGO-DataCloud 1st project review, CNAF, Bologna, Italy

3 Seminars

Mário David: "e-Infrastructure for Open Science", 2016-02-23, Seminar Computer Engineering MSc students, University of Minho, Portugal

Mário David: "Parallel computing, data and storage", 2016-02-23, Seminar Computer Engineering MSc students, University of Minho

Jorge Gomes: "INCD Serviços de computação para a comunidade científica e académica", 2016-11-25, Seminar for ISCTE researchers, FCCN, Lisbon, Portugal

Events

2 Workshops

2016 WLCG Collaboration Workshop, ISCTE-IUL, 2016-02-01 to 2016-02-02

DPHEP workshop 2016, ISCTE-IUL, 2016-02-03 to 2016-02-03

ADVANCED COMPUTING

Advanced Computing

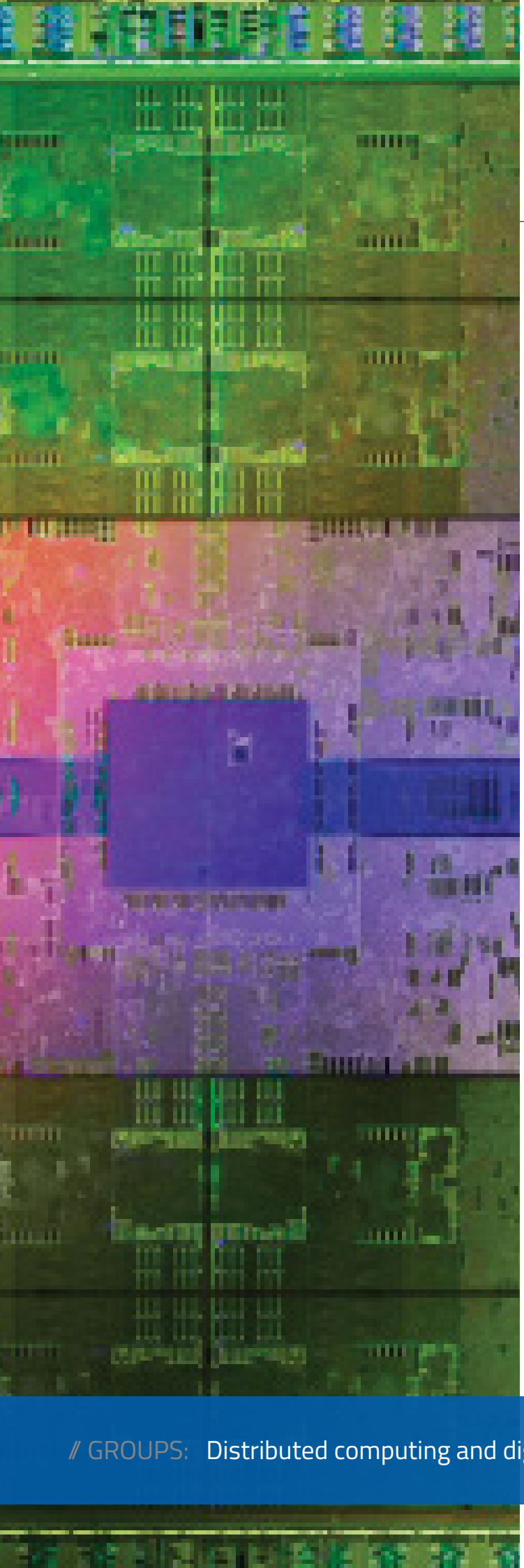
Members of advanced computing group have previous work in Grid, HPC, computing models, high performance communication libraries and distributed data structures. Research also encompass R&D on the combination of traditional multicore CPUs with acceleration devices.

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. 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.

Framework and status for past and current year



Team

Principal Investigator António Pina (65)

Researchers
Albano Alves (75), José Rufino (75), Vítor Oliveira (30)

Additional Collaborator
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;
- support to the local cluster infra-structure;
- advanced training.

Stated objectives for past year

- The work developed closely followed the objectives set for the year 2106, 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 critical mass required 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. In particular, during the course of this year, we supervised several master's theses one of which has already been completed

- Launching of new computer training activity for young researchers

- Involvement in the ATLAS collaboration, particularly in the upgrade of the software triggers, namely with a presentation on the Trigger Demonstrator week, held in CERN, March 2016.

Achievements and responsibilities during the past year

The activities developed by the group resulted in:

- The supervision of three ongoing MSc thesis

- Scientific orientation of three Research Scholarships, one ongoing

- A presentation on the Trigger Demonstrator week, held in CERN, March 2016, by a MSc student that integrates the LIP team in charge of the " Parallelization and Optimization of the TopoCluster Splitting Algorithm using GPUs ".

- Upgrade and maintenance of the local cluster infrastructure

- Start of the training activities with the course, "The Basics of the LINUX Command Line" held in February 2016 in LIP-Minho

Lines of work and objectives for next year

In 2017, 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.

We also expected that the conclusion of the dissertations of the current postgraduate students might produce not only publications but also attract new students for R/D in the group main scientific areas, in particular i) in the parallelization of algorithms on GPUs, ii) the performance analyse of HEP data analysis applications iii) the use of support tools to parallelize applications and iv) evaluation of alternatives for scalable distributed filesystems.

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++ Programming" and "Data Analysis".

SWOT Analysis

Strengths

- 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 involved in particle physics and other sciences;
- Expertise in combining traditional multicore CPUs with acceleration devices.

Weaknesses

- We are currently a small group with only two full active research members which is clearly insufficient to take advantage of the scientific and industrial potential of a region that a few years ago was considered the youngest of Europe.

Opportunities

- Collaboration with other groups at LIP-Minho that need to optimize their HEP data analysis code applications;
- Administration of a small flexible Tier 3 HPC cluster allows for the exploitation of new local system architectures to increase resource usage efficiency and take advantages of new facilities and improved performance, of modern parallel file systems, such as glusterFs, to support the increase in the complexity of current and future applications;
- Expertise in combining traditional multicore CPUs with acceleration devices has proved to be and asset in the ATLAS TopoCluster algorithm parallelization.

Threats

- Local HPC infrastructure hosted in the Department of Informatics, of UMinho, has no guarantee of continuity of service by the lacking of financial support;
- It is known that at present, in Portugal, there are virtually no unemployed graduates in Computer Engineering. In this context, it is very difficult to attract to scientific work, young people who leave the higher education institutions in the north, without the availability of funds, to support scholarships for MSc or PhD, and conditions of work that guaranty the continuity of employment of the researchers.

Theses

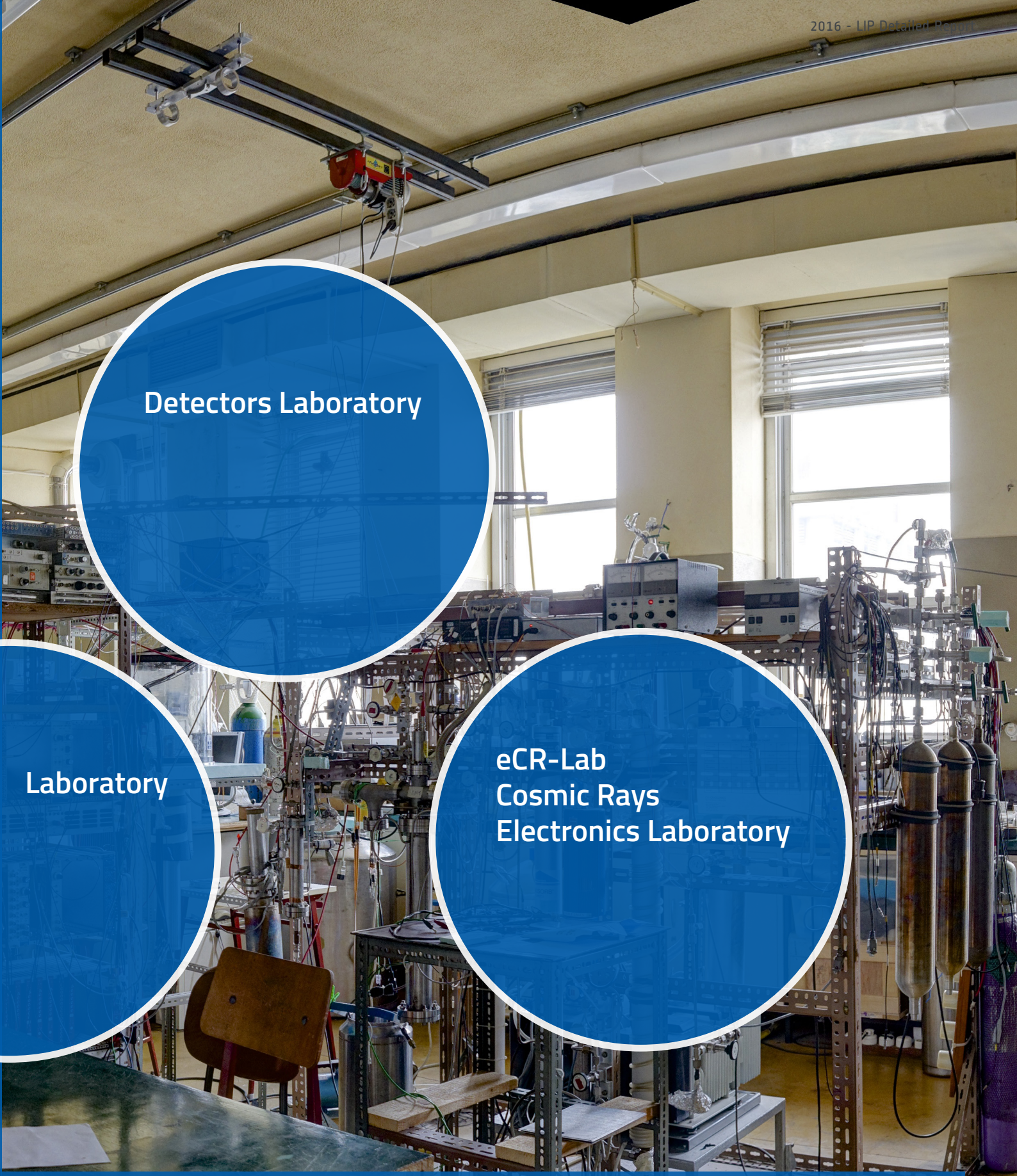
3 Master Theses

José Luís Silva: "Paralellization and Optimization of the TopoCluster Splitting Algorithm using GPUs" (finished 2016-07-01)

José Marcos Carvalho: " VIPe - Visualização Integrada de Perfis de Execução" (ongoing)

Luís Caseiro: "Otimização do código utilizado na pesquisa de novos quarks pesados, na experiência ATLAS" (ongoing)

// RESEARCH FACILIT


Detectors Laboratory
Laboratory
eCR-Lab
Cosmic Rays
Electronics Laboratory

TIES

PRECISION MECHANICAL WORKSHOP

Workshop

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 available equipment (http://coimbra.lip.pt/index.php?id=7&option=2) and 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 complemented by the Detectors Lab (DL), and vice-versa. Indeed, many of the projects developed at LIP clearly require the competences from both facilities.

Three decades of experience clearly show that the LIP MW (and DL) were fundamental for the high quality of the work performed in R&D in gaseous detectors, both in the framework of autonomous projects or small collaborations and in the framework of LIP's responsibilities within medium and large international collaborations (CP-LEAR, DELPHI, HERA-B, ATLAS, HADES, AUGER). Equally evident are the benefits for the national R&D community of the intervention of the MW (+DL) in its projects, at local and national levels.

Brief description of the facilities

2016 has been a year of deep changes in many aspects:

- Installation of the MW facilities in the space of the former Physics Department MW: As a consequence of the considerable increase in activity in recent years, both in the MW and DL, the MW is being installed in more appropriate location, while valuable space is being released for the DL activities. This had a strong impact on the activities of the MW during 2016.

- Retirement of the technician J. Oliveira: After almost 30 years of exemplary work at the LIP MW, J. Oliveira retired. This position has been occupied by a new technician, D. Lima. This also a strong impact on the MW activities, because, for some time, the position was not occupied and, as expected, the full integration of D. Lima took some time. Fortunately, D. Lima has already shown to be an essential element of the MW.

- New coordinator assigned: Starting from mid 2016, the MW has a new coordinator, A. Blanco.

Coordinator **Alberto Blanco**

Team

Nuno Dias, Carlos Silva, Douglas Lima

Research Facilities

Workshop / Detector Lab / e-CRLab / LOMaC / TagusLIP

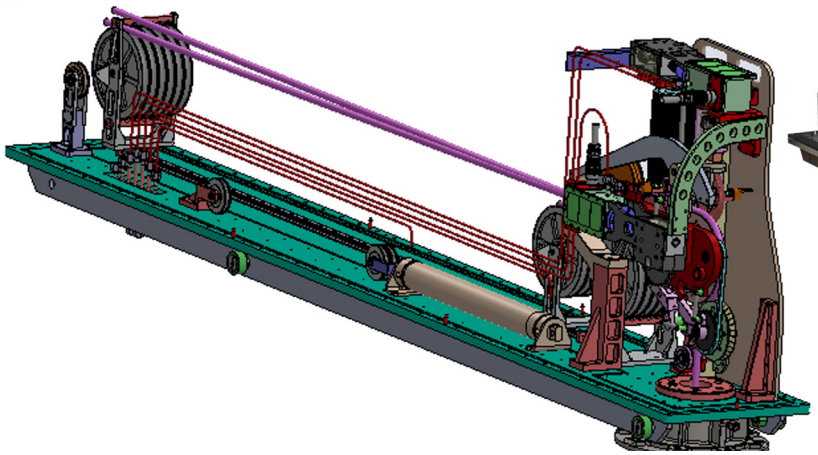
Activities and achievements in the past year

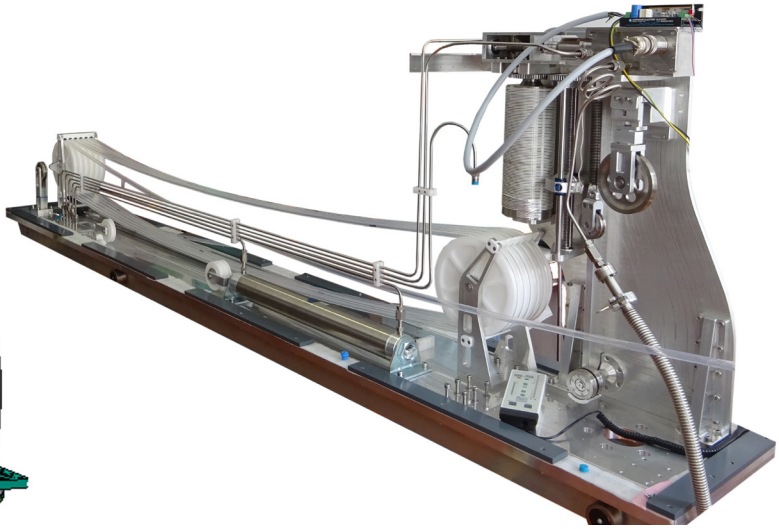
During 2016, the project that required most of the available resources (around 60%) was the final construction, assembling and test of the Umbilical Retrieval Mechanism (URM) (mechanics for the calibration system) for the SNO+ experiment, see picture.

In addition to this main activity, others are summarized in the following topics ,ordered by the assigned resources:

- Construction of a cryostat for the Chemistry Department.
- Construction of aluminium boxes for the project "A muon telescope based on RPCs for muon scatter tomography", (MuTT), for the hydronav company.
- Construction of mechanical pieces for LIP-LUX/LZ activities in the Detector Lab.
- Construction of mechanical pieces of a test setup for the project "Orthogonal Ray Imaging for Radiotherapy Improvement, Orto-CT".
- Construction of auxiliary mechanical pieces for assembling RPC detectors for the project MUTT and the project "A muon telescope based on RPCs for volcano tomography", (TomuVol).
- Construction of a wheel system to transport and hold the HADES-RPC sectors.
- Construction of mechanics for a prototype of Cloud Chamber.
- Construction of a aluminium tight gas box to host a RPC type detector for the detection of thermal neutrons for the project "Research and Development of Multi-Gap RPCs with B4C coatings for Position Sensitive Thermal Neutron Detectors", (n-RPCs).
- Preparation of scintillators for the Radiation, health and environment project.
- Final works related to the construction of high pressure chambers for detector testing in the framework of the RAD4Life project.
- Construction of mechanical pieces for elements of the exposition commemorative of the 30th anniversary of LIP.
- Some other small works for the Coimbra Physics department.

The Umbilical Retrieval Mechanism (URM) built at LIP Workshop for the SNO+ experiment





Plan for next year

The main project, which will require an important portion of the available resources (around 40%) during 2017, will be the construction of a second unit of the URM for the SNO+ experiment, which is expected to be finished around the end of the year. Beside this, two other projects will consume significant resources.

- Construction of aluminium boxes for the MuTT and TomuVol projects
- 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 and auxiliary mechanical pieces.

In addition, other projects that are already planed and will use resources of the MW are:

- Construction of mechanics for a second prototype of Cloud Chamber and for four Spark Chambers in the frame work of the Outreach Project.
- Construction of the mechanics for a second RPC Pre-clinical PET scanner.
- Construction of mechanics for RPCs based detectors for the detection of Thermal neutrons, n-RPCs project.
- Construction of mechanics for High rate RPCs for the AIDA-2020 project.
- Conclusion of the construction of a cryostat for the Chemistry Department.

The resources devoted to these projects basically occupy the entire manpower for 2017. In any case, the MW will try to respond,as far as possible, to other projects that request services.

SWOT Analysis

Strengths and Opportunities

- Valuable know-how, experience and skills of the technical staff.
- Valuable partnership (Detectors Lab).
- The installation of the MW in the new space will improve the working conditions, eventually improving the efficiency.
- The incorporation of a new staff member has opened the opportunity to explore new capabilities of the CNC machines.
- Opportunity to extend services to other research groups / companies.

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 25% of the foreseen area is available for our activities. The installation should be finalized in 2017. 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 developed in 2016 were related to the R&D and production of three different types of large area Resistive Plate Chambers (RPCs) used in collaborations where LIP is involved: MASTER-Rio, MARTA-Rio, MARTA - FCT/FAPESP, MTT, Tomuvol. Our contribution is multidisciplinary, as we are able to develop most of the required tasks: from the project design to the installation and maintenance of the detectors, including the development of tools and/or instruments to control/monitor the detector performance. The detector is adapted to the individual requirements of each application, following more or less the same procedure done in the industry. In total, during 2016, we build more than 40 m2 of detectors, including timing and trigger (counting) detectors. This activity consumed around 40 % of our total manpower. It is worth noting that the DL developed from scratch 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.

One of the most important activities of the DL is the support to the different groups in their R&D activities. In total, this consumes around 35 % 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.

Contributions related to management were given in the framework of the preparation of the exhibition celebrating the 30 years of LIP, and within the upgrade of the Mechanical Workshop and Detectors Lab infrastructures.

Organization and purchase of materials and instruments for LIP-Coimbra and for the Physics Department is also one of the tasks where the DL has a relevant contribution.

Plan for next year

The rapid completion of the new facilities (F2) and the acquisition of a new CNC cutting machine for large areas are of major importance in order to achieve the established production targets. Without these two breakthroughs will not be possible to keep the foreseen schedules.

Expectations for large area RPCs production are the following: eight timing for the muTT and Tomuvol Collaborations; four trigger for the Antartida project; forty five sensitive volumes for the MARTA-FCT/FAPESP collaboration. The total number of sensitive volumes for MARTA might be achieved only in the beginning of 2018, but for the moment we keep it as goal for 2017. The production of two Spark Chambers is also scheduled. Still concerning production, we expect to deliver: fifty HV power supplies; forty gas monitoring and/or control systems; many boards for charge and time measurements.

Regarding other projects our contribution is expected in the constructing, assembly and test of the following projects and/or setups: the version 2 of the APET; the OrthoCT; 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.

In general, we look forward to contribute in an organized and efficient way to the different groups and projects.

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 suitable 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.

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.

Opportunities

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.

In the area of medical instrumentation, the quality of our work is also recognized, thus opening up another field to be explored.

Products more targeted to science outreach such as the Spark Chamber and the Cloud Chamber may also play an important role in spreading our name/brand.

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 delivery 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 two office rooms, one instrumentation room for up to 4 persons that acts as a mechanical and PCB workshop, one instrumentation room for up to 4 persons installed with state-of-the-art equipment. There is also a separate instrumentation room and a dark room, both with restricted access. Setups that require either larger space, continuous unperturbed measurements or low light levels are installed in these rooms.

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

Workshop / Detector Lab / e-CRLab / LOMaC / TagusLIP

Activities and achievements in the past year

In 2016 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 prototype 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. The prototype system was characterized and the results were published in JINST. PREC has already been adopted in other RPC detectors. It was developed the engineering prototype of MARTA front-end electronics based in the MAROC ASIC. The system was designed and built. First tests indicate that the system is performing as expected and only minor problems were found that will be corrected in the next version.

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 been developing the test procedure and test system for the irradiation in different conditions of several components. In 2016 several irradiation campaigns were performed with Co-60 sources at IST-CTN (Campus Tecnológico e Nuclear) and ESA-ESTEC and with electron beams at Hospital Santa Maria and at RADEF, Finland. The components were tested during the irradiation campaign and were afterwards brought to LIP to be tested during the annealing phase.

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. These setups focus mainly in the detection of CR and on the study of scintillator detectors.

Plan for next year

For 2017 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 main developments for the MARTA engineering array will be concluded. The e-CRLab will produce the engineering prototypes and, after successfully tested, it will develop the production version of the Front-End electronics for MARTA. 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. We expect to have in the beginning of the year the integration in Brasil of the first MARTA RPC module engineering prototypes.

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.

In the beginning of 2017 the e-CRLab will be installed in the new facilities of LIP at 3IS. We will reinforce the capabilities of the laboratory in the production of PCB prototypes and on the production of small detectors mainly for Cosmic Rays. 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.

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. 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 project will pave 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 fibers, 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 fibers.
- Aluminization facility – a facility to mirror 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 fibers (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 fibers 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 fibers of ATLAS has been polished and aluminized and quality controlled at LOMAC. The Lab selected and/or prepared the following optical fibers by chonological order:

- R&D of scintillating and WLS fibers and scintillators for ATLAS.
- WLS optical fibers for STIC luminosity detector of DELPHI.
- WLS optical fibers for the Tilecal hadronic calorimeter of ATLAS.
- Scintillating fibers for the ALPHA luminosity detector of ATLAS.
- R&D for future calorimetry (DREAM project).
- Clear fibers 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 fibers 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”.

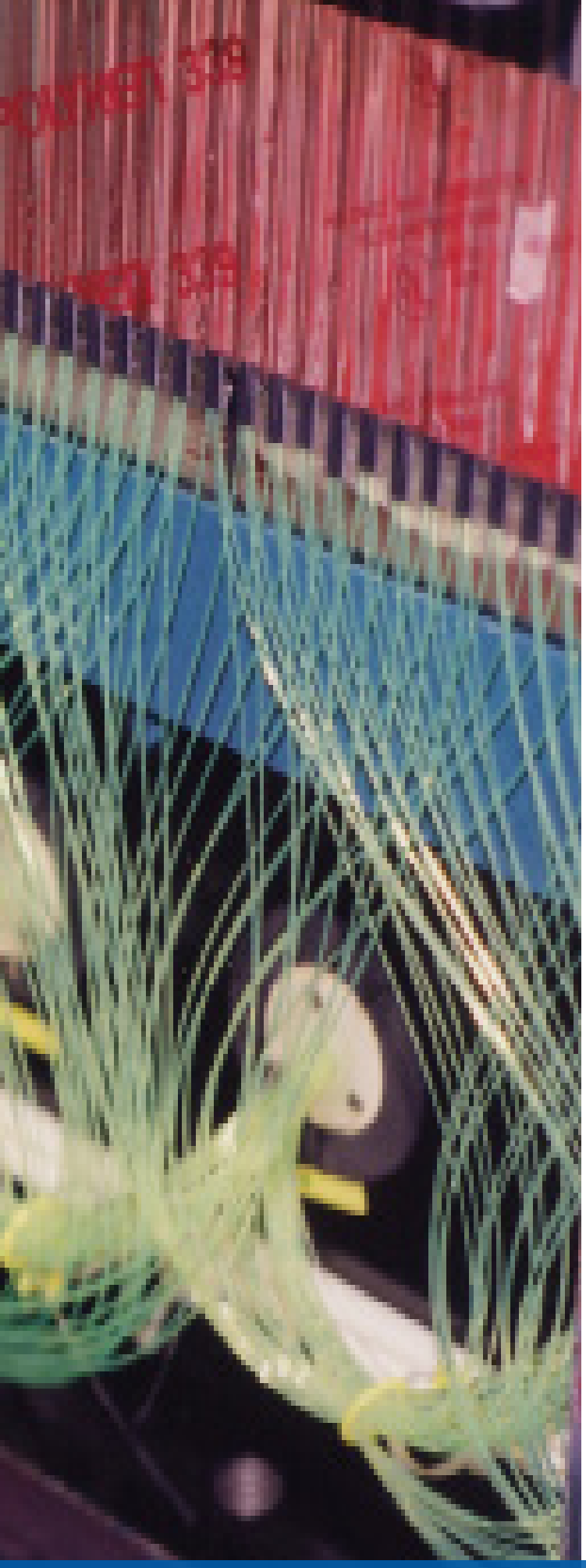
With the end of CFNUL, LOMAC was forced to abandon the laboratories where it was hosted with the exception of the aluminization facility, and most of the year of 2016 was dedicated to set it up again in laboratories at its current location at FCUL. With LIP moving to the University of Lisbon building III in 2017, LOMAC will move in part once again to concentrate its main facilities that now are disperse in the UL campus.

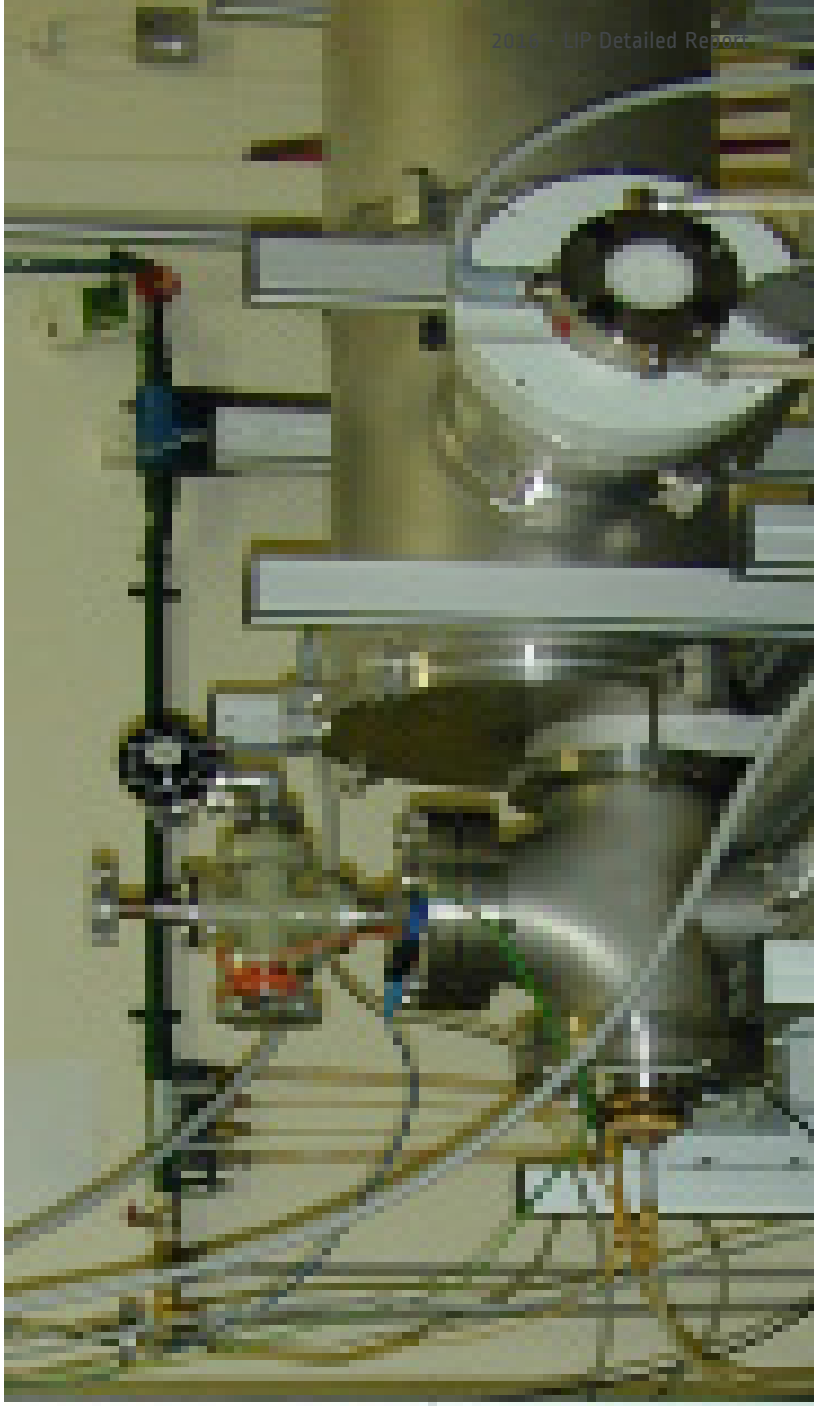
LOMAC activity will continue centered in the ATLAS experiment where it will contribute for R&D of scintillators and fibers and for the preparation of fibers needed for the upgrades of the gap/crack scintillators of Tilecal. LOMAC will explore the possibilities to work for other future experiments, as it is doing currently with the preparation of fibers for a neutrino experiment.

Coordinator **Agostinho Gomes**

Team Amélia Maio, João Gentil, Luís Gurriana, Luís Seabra

Research Facilities





Workshop / Detector Lab / e-CRLab / LOMaC / TagusLIP

Activities and achievements in the past year

Most of the work was dedicated to put the laboratory operational at FCUL.

With the tilemeter operational we participated in several educational/outreach activities and started the study of alternative scintillator-WLS fibers couplings to improve light collection in the Tilecal gap/crack scintillators.

By June 2016 the fibrometer started to be re-installed and was submitted to a deep repair and general maintenance. Re-commissioning is ongoing and the quality of aluminium mirror reached before was almost achieved.

A new setup to cut/polish the bundles of fibers was prepared to use a lathe belonging to the DEGGE department from the FCUL and located at FCUL workshop. The essential maintenance of the aluminization setup at III was done to start aluminization in early 2017.

Plan for next year

The LIP-Lisbon pole will soon be moving to new installations at the University of Lisbon III building. It is foreseen that part of LOMAC will move from Faculty of Sciences to III, and that the equipment for fiber aluminization will also change place. These movements will require a lot of effort and even if they will be carefully planned to avoid disruption of the current activities, they will affect the activities.

Apart the relocation, our planned activities are:

- Finish the fiber preparation for neutrino experiment that is ongoing
- Pursue the scintillator-WLS fibres couplings tests
- Preparation of WLS fibers as necessary.
- Radiation damage of scintillators and fibers. The irradiations will be done at CTN.

SWOT Analysis

Strengths

Long expertise in the test, preparation and aluminization of plastic optical fibers for detectors. Only a few facilities of this kind in the world. Needed to be kept alive for the ATLAS Tilecal upgrades.

Weaknesses

Lack of funding to be kept fully operational.

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 with emphasis on nuclear medicine imaging technologies opened to external entities. TagusLIP includes detector and electronics laboratories, electronics workshop, a hot laboratory for work with high activity 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.

Brief description of the facilities

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 ClearPEM machines in the frame of the Crystal Clear Collaboration and of the ClearPEM-Sonic project. The machine is a PET scanner dedicated to mammography based on LYSO crystals and double readout by Avalanche Photodiodes (APDs). The readout and data acquisition system is based on a dedicated front-end ASIC, and a large electronics and computing system.

Coordinator **João Varela**

Team Stefaan Tavernier, Miguel Silveira, Luís Ferramacho, Rui Silva

Research Facilities

Workshop / Detector Lab / e-CRLab / LOMaC / TagusLIP

Activities and achievements in the past year

In 2016 the main activities at the TagusLIP Laboratory were the following:

1. Development and test of a new ASIC for Time-of-Flight applications (TOFPET2).

2. Activities of the startup PETsys in the development of readout and data acquisition systems for PET-TOF scanners. The company has assembled a TOF-PET demonstrator ring and performed the validation of the system using radiation sources.

3. Development and test of a new frontend ASIC (TOFFEE) for the readout of Ultra Fast Silicon Detectors (UFSD) developed for time measurements in the proton spectrometer CTPPS of the CMS experiment.

The TagusLIP Laboratory is member of the ERAMMIT European consortium that submitted the proposal "Enabling Research Access for Multi-parametric Molecular Imaging Technologies" to the EU Infrastructures call INFRAIA-02-2017. The aim of the ERAMMIT Starting Community is to enhance the access to Europe's best research infrastructures (RIs) to solve key technical challenges restricting the wider adoption of MMIT for personalised medicine. In this context the TagusLIP Laboratory will provide access to the necessary instrumentation for R&D on radiation detectors and associated electronics and data acquisition.

Plan for next year

The activities planned at the TagusLIP Laboratory in 2017 are the following:

1. Test of the revision 2 of the new TOFPET2 ASIC.

2. Activities in collaboration with PETsys:

- Full validation of the new frontend and data acquisition system based on TOFPET2, including the upgrade of the PET demonstrator installed at TagusLIP.

- Development of new PET devices in the frame of projects submitted to EU.

3. Development of prototypes of frontend systems for the Phase II Upgrade of the CMS experiment.

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. Integration in a EU Distributed Infrastructure in case of approval of the ERAMMIT proposal.

Threats

Lack of funding.

// COMPETENCE CEN

ITERS

Simulation and Big Data Competence Center

Coordinators: Bernardo Tomé and Nuno Castro

In the past years a wealth of competences in data analysis software and simulation tools has been accumulated among the various LIP groups. These include physics models and Monte Carlo generators, detector simulation tools and big-data handling techniques.

Implementing a competence centre in this area aims primarily at fostering an effective collaboration/ coordination among the various groups that can boost the capability to exploit the existing expertise, both internally and, externally, towards the university and the industry.

At present two of the areas of competence have already emerged as having the span and the potential to fulfil this purpose.

Geant4

The Geant4 simulation toolkit has long been used at LIP, in a variety of fields from biomedical applications to detector performance studies or space radiation effects. LIP is a member of the Geant4 collaboration for more than ten years. Important expertise has been accumulated from the point of view of the user as well as at the developer level, with a particular in depth knowledge of some of the physics processes of the Geant4 kernel.

Notably, Geant4 based applications were developed by the LIP collaborators, in the context of their participation in international collaborations, with recognised impact in the better understanding of the performance of the detectors.

Also, LIP members are responsible for teaching advanced detector-simulation techniques, as part of the curricula of specific pre-graduate courses and doctoral programs, where the Geant4 toolkit is extensively used.

During 2017 one of the main concerns should be to intensify the communication among the LIP Geant4 experts. Coordinating the available skills and expertise should foster the capacity of LIP to offer courses in the curricula of the universities, namely those where LIP has effective teaching activities, as well as in advanced training schools and workshops.
A kick-off should also be undertaken in identifying the potential of our competences useful to the industry.
LIP activity in the context of the participation in the Geant4 collaboration will be continued, including the identification of possible new areas of intervention in this context.

Big Data

LIP has been involved in the analysis of the extremely large amounts of data produced by the experimental collaborations in High Energy Physics, for a long time. Many of the LIP members have actively contributed to the implementation and development of elaborate multivariate techniques aiming at a vast range of applications: from the reconstruction and identification of physics objects in the detectors to the search for rare events. Methods such as likelihood analyses, neural networks and boosted decision trees, for instance, were successfully used by different LIP groups in the context of their scientific activities.

In a complementary way, the efficient processing of the available data has also been a concern and LIP has developed some expertise in the optimization of the available resources. It should be noted that the analysis of the typical amount of data produced by the experiments integrated by LIP is extremely demanding on the underlying computing, storage and networking infrastructures. As it is typical of big-data applications, large volumes of data must be written, stored read and processed over time, with the added difficulty that data must often be revisited and re-analysed, both at the GRID and locally. The complexity and hardware requirements of analyses using machine-learning techniques is even bigger and, therefore, using the computing resources efficiently is an imperative.

Some of the methods used and developed by LIP in the context of big-data and machine learning are currently being used in an industrial context, aiming at significantly improving the quality control in production lines.

During 2017 it is planned to increase the collaboration between the different groups in this context, aiming at exploring synergies and fostering the expertise in the efficient analysis of Big Data, exploring recent advances in the field, such as anomaly detection, cross-validation, multidimentional reweighting and imaging, and deep learning. The application of such techniques and competences to contexts beyond High Energy Physics will also be pursued.

// SCIENCE AND SOC


Technology transfer, industry and spin-offs
LIP-ECO
Education, communication, outreach and advanced training
Radiation, health and environment

IETY

LIP EDUCATION, COMMUNICATION, OUTREACH AND ADVANCED TRAINING GROUP

LIP-ECO

Coordinators: Catarina Espírito Santo (Corporate Communications), Pedro Abreu (Education and Outreach), João Varela and Mário Pimenta (Advanced Training)

The LIP Education, Communication, Outreach and Training (ECO) office aims at fostering and coordinating the ECO-related activities carried on at LIP. It has three main (interrelated) pillars:

1. Corporate communications
2. Education and Outreach
3. Advanced training

These activities have been developed at LIP since long, and many successes have been attained, particularly in what concerns the work with schools (teachers and students). However, the dimension of LIP and the importance of ECO are today such that a more structured effort and additional commitment and resources are required. For this reason, the LIP-ECO office has been created. 2016 was clearly a transition year, dominated by the celebration of the 30th anniversary of LIP and by the creation of the LIP-ECO office. Its priorities for 2016-2017 have been set and include:

1. Structure corporate communications, better defining goals, strategies and responsibilities, in order to achieve a more efficient communication of LIP's image, activity and impact.
2. Consolidate the existing outreach and education activity program, maintaining the established partnerships and collaborations, in particular with Ciência Viva, CERN and IPPOG.
3. Increase LIP's capability to attract new post-graduation students, and to provide post-graduation students at LIP adequate integration and excellent training.

Overview

The following audiences have been selected as immediate priorities:

1. The LIP community and our direct partners — LIP associates, funding agencies, the academy, research centers in Portugal and abroad.
2. The school community (teachers and students)
3. University students in Physics and Engineering

While ECO activities are traversal and involve all LIP members, to an extend 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.

2016 activities

The main achievements in each of the three LIP-ECO pillars are summarized below:

1. Corporate communications

The Exhibition and LIP's anniversary

The exhibition "Partículas, do bosão de Higgs à matéria escura" (Particles: from the Higgs boson to dark matter) was the key element of the celebration of LIP's 30th anniversary. From February to May 2016, the exhibition has been shown in the three towns where LIP is present (Braga, Coimbra and Lisboa) at the premises of the Universities that are LIP associates. It gave LIP remarkable institutional visibility and had more than five thousand visitors. On the 9th of May, LIP's anniversary was celebrated in a public session with an invited talk by Rolf

Heuer and the presence of the Minister of Science,Technology and Higher Education.

The exhibition is focused on the big challenges of particle physics for the next decades. After an introduction about LIP, particles and detectors, the visitor was "accelerated" to the different modules: quarks and gluons, the Higgs boson, antimatter, neutrinos and dark matter. In each module, what we know and what we don't know yet was highlighted together with LIP's contributions and the relations to technology and innovation. The exhibition was produced by LIP in partnership with a professional company and had the support of Agência Ciência Viva. CERN Media Lab's LHC interactive tunnel was shown.

Since September 30th 2016 (European researcher's night) and until May 2017, the exhibition can be visited at Planetário Calouste Gulbenkian in Lisboa. In the three towns, public talks were regularly given by LIP's scientists on topics related to the exhibition. An oral communication on the exhibition was presented at the national science communication conference SciCom.pt.

LIP's annual reports
In the first quarter of 2016, LIP's 2015 reports were issued in a newly defined format - better structured, easier to read and graphically more attractive. A public report serving as visiting card of the institution was issued, together with a more detailed technical report with complementary information for our associates and for the International Advisory Board. The necessary modification in the information collection and edition procedures were implemented in order to make the process more straightforward for the coming years (including a reshuffling of LIP's database).

Renewal of the LIP web site
The ongoing full renewal of the LIP public web site was an important activity during the year. A final test version was released to the LIP community in December 2016. Making it public is a priority for the first quarter of 2017.

Other activities

- Issuing of the LIP-news bulletin, an instrument for internal communication which also plays a role in the links with the school community and our partners institutions, namely universities.

- Support to public events, in particular, in the framework of the visit to Portugal of Arthur MacDonald, Nobel Prize of Physics 2015, in September 2016, invited by LIP and the Portuguese Physic's Society;

- Participation to EPPCN meetings and activities;

- Issuing of CERN and LIP press releases and revision/ reshuffle of the contact list and procedures for communication with the media and the media offices of our main partners.

The LIP interactive panel
An interactive touch panel is currently under development at LIP-Minho. It can be used to introduce LIP, particle physics, or a variety of subjects. The flexible structure can accommodate a variety of contents and media supports, namely 3D representations of detectors and other structures. The emphasis of this communicational approach is put on the interactivity of the presented contents. The panels will be permanently on display at the Braga and Lisbon LIP premises and can also be used in different events and locations.

2. Education and outreach

IPPOG's International Masterclasses in Particle Physics
Under the coordination of LIP, more than 1500 participants gathered in 15 sessions all over the country: Aveiro, Beja, Braga, 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.

Participation in Ciência Viva's programme "Science in the Summer"
LIP proposed several internships in Lisboa and Coimbra and hosted 20 students for 10 days to learn about experimental particle physics and directly experience the work of scientist's in the field.

CERN Portuguese Language Teachers Programme
Under the responsibility of LIP and with strong support from CERN and Ciência Viva, the school was held in the beginning of September and attended by 22 Portuguese teachers, 20 teachers from Brazil, 1 from Mozambique and 1 from São Tomé and Príncipe.

Instrumentation for education purposes
The construction of a cloud chamber for demonstration purposes (an order from Ciência Viva) made good progress and should be finalized soon; the development of a small, portable muon telescope for experiments at school is ongoing. In 2017,

the activity will be boosted by additional resources and international cooperation within IPPOG.

Other activities
- More than 50 outreach talks were given by LIP scientists at schools and in other settings, on particle physics, space and related technologies.
- LIP gave logistic support to Portuguese schools organizing visits to CERN or participating in the CERN Beamline for schools competition.

3. Advanced training

LIP needs to reinforce its capability to attract the best undergraduate and graduate students. This requires both a consolidation of the training program and additional investment in the communication of the lab's activity, image and impact.

Doctoral programs
LIP coordinates the IDPASC-Portugal (Particles, astrophysics and Cosmology) and DAEPHYS (applied physics and engineering) doctoral programs, as well as the IDPASC international network. Currently about 20 students are engaged in each of the programs.

The following events were held in 2016

- IDPASC: the annual international IDPASC school was held in Slovenia and hosted about 30 students for two weeks, with a program covering all PASC fields; the IDPASC-Portugal student workshop happened in Porto, Portugal; the LHC physics course had its 5th edition.

- DAEPHYS: the DAEPHYS summer school.

Summer internships for undergraduate students
During the summer of 2016, LIP hosted about 40 students from IST and FCUL in internships within the ATLAS and CMS groups, and in the cosmic rays laboratory. The internships, which were diverse in model and duration, included formal training (seminars and tutorials) and the development of research projects in electronics, detector construction, computing and data analysis. In 2017, this efforts will be coordinated and a LIP summer student program will be offered.

Opinion survey to LIP's PhD students
LIP must guarantee excellent training and adequate supervision to its graduate students and assessment instruments are fundamental. In 2016, a survey was prepared and distributed to current and former PhD students at LIP. It is meant as a follow-up instrument and a tool to identify problems and propose solutions.

Prospects for 2017

The LIP-ECO strategy for 2017 follows the priority goals and audiences defined above for each of the pillars:

1. Corporate communication
The priority is to conclude the restructuring of corporate communications and achieve a more efficient communication of LIP's image, activity and impact. The LIP community and our direct partners — LIP associates, funding agencies, the academy, research centers in Portugal and abroad — are our priority target audiences.
LIP communication's strategy and branding
The document defining LIP's communication strategy and the creation of the LIP brand will be drafted and used as a guideline for all communication actions and materials. Graphic and style guidelines, as well as presentation templates and standard slides for introducing LIP will be made available to the LIP community.

The following communication tools will be developed during the year
- The LIP Bulletin will be issued on a more regular basis, hopefully 3 times per year;
- An e-mail internal newsletter LIP communications, cLIP, will be created - to start with, on a monthly basis;
- The presence of LIP in the social media is re-designed; human resources and expertise have recently been reinforced;
- Short videos: a small set of corporative videos will be created;
- An interactive pannel introducing LIP to be used at different settings, is being developed by LIP-ECO at LIP-Minho.

Support to all ECO activities: LIP-ECO gives support to the organization and communication of LIP outreach, education and advanced training events. Key aspects are to reinforce planning (timeline definition and resource allocation); to foster the participation of LIP researchers and the integration of the activities carried out by different groups.

Science and Society

2. Education and outreach

The priority is to consolidate the existing outreach and education activity program, maintaining the established partnerships and collaborations, in particular with Ciência Viva, CERN and IPPOG. This includes the 2017 edition of:

- IPPOG's International Masterclasses in Particle Physics in Portugal: under the coordination of LIP, is expected to keep its dimension, and to grow in some recently added locations. Training of monitors and technical conditions in some sites will be reinforced.
- Participation in Ciência Viva's programme "Science in the Summer": will be maintained. The participation of the different groups at LIP will be encouraged and a larger integration of the proposals of the different teams will be encouraged.
- CERN's Portuguese Language Teachers Programme: The 10th edition of this successful school will take place early in September.

Instrumentation for education purposes:

- In 2017, the activity will be boosted by additional resources and the possibility of an international cooperation framework within IPPOG.

Other activities:

- LIP will continue to encourage schools to request talks on particle physics and related subjects, to visit CERN and to participate in LIP and CERN outreach activities. A wider participation of LIP researchers should be fostered.

3. Advanced training

Undergraduate students

University students in Physics and Engineering are a priority target of LIP's communications.

The main activities are:

- **Summer internships for undergraduate students**
  In 2017, this efforts will be coordinated and a LIP summer student program will be offered.
- Careers and technology in particle physics - March 1st and 2nd, at IST and FCUL.
- Particle physics mini-school, Sesimbra, Feb 2017 - co-organized by LIP and CFTP.

Graduate students

LIP will continue coordinating the IDPASC and DAEPHYS doctoral programs, reinforcing soft skills training. The following events targeted at graduate students are foreseen:

- IDPASC international school: Asiago, Italy, June 2017;
- IDPASC student workshop, Braga, May 2017;
- LHC physics course, LIP-Lisboa, March to May 2017;
- IDPASC hands on particles and light workshop, IST and FCUL, Lisboa, July 2017;

LIP's PhD students

We will reinforce the follow-up of LIP's post-grad students, including a program of common activities for all students and regular survey mechanisms. The results of the 2016 surveys will be analyzed and made public to the community; the 2017 survey will be conducted. The first LIP students workshop will take place in Coimbra in March.

SWOT analysis

Strengths

The strong motivation of the group; its well established flagship projects targeted at the high school community, which endow LIP with the capability to attract a large number of participants and over the years generated a wide contact list.

Opportunities

The boost given to LIP-ECO, which increased the dedicated human resources; the celebration of the 30 years was an opportunity to re-think and upgrade the communication strategies of the lab and in general to increase the visibility of LIP particularly in the academia - the results of this should be visible in the next few years.

Weaknesses

The structuring of the LIP-ECO team is still ongoing and its success yet to be demonstrated; while the know-how exists, the capability to built kits and demonstrators on particle detection must be reinforced in what concerns technical, human and financial resources.

Threats

Funding is limited and a clear definition of our priorities is crucial; some of the projects have the support of Agência Ciência Viva, and the decrease of their funding in the last few years had already a negative effect.

Technology transfer, industry and spin-offs

Overview

Coordinator: Gaspar Barreira

LIP is a key player in the application of particle physics technologies to Health, Space exploration and scientific computing. The Lab's activities provide various sets of opportunities for knowledge transfer to the economy

Direct transfer

Direct knowledge transfer opportunities are expected across the whole spectrum of LIP's activities. In particular, applications to the health and space sectors are potential sources for the generation of new industrial property rights to be transferred to existing or new companies. In several of the medical applications groups, steps in this direction are expected in the near future. Examples of direct knowledge transfer in the 2016 activities are highlighted:

- Industrial contracts with ESA shared by LIP and Portuguese companies, namely EFACEC SA and EVOLEO SA.
- In the context of the STCD – Spin-off technology for cancer diagnosis group, LIP developed innovative electronics with good time resolution for Time-of-Flight PET. This technology was licensed to the spin-off PETsys. The activities of the group are done in coordination with PETsys. The laboratory infrastructure TagusLIP at the science park Taguspark is shared by the two entities
- In the context of the RPC R&D group, a contract was signed with the company HIDRONAV, S.A. for supplying in 2017 a 4-layer TOFtracker telescope system for container inspection by muon tomography at sea ports.
- The LIP NUC-RIA group develops technology transfer activities, namely contributions to the study of electron beam food irradiation in the framework of the International Atomic Energy Agency (IAEA) Coordinated Research Project (CRP) devoted to the study of the effects of radiation on fresh fruits.

Finally, the LHC Phase II upgrade offers great opportunities for the participation of Portuguese industry. In 2017, the planning of the ATLAS and CMS upgrades will allow a clear definition of such opportunities. The main areas sought at present include segments of the microelectronics market, in the context of frontend readout systems for CMS subdetectors, and the replacement of the ATLAS TileCal HV distribution boards and gap/crack scintillators.

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.

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 2016, 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). Five new internships started in 2016.

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 research in high energy physics.

Main achievements

- 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 2016. The yearbook is disseminated among the European HEP community.

- The ILO ensured a pro-active communication with the industry presented in the catalogue called "Portugal in Large Scale Research Facilities - https://www.fct.pt/apoios/tecnologia/docs/catalogo_tecnologia_web.pdf". This communication entails raising awareness and promoting technical meetings regarding the upcoming large science projects such as: CERN (HiLumi HL-LHC Project - https://hilumilhc.web.cern.ch/), ESO (E-ELT - http://www.eso.org/public/teles-instr/e-elt/), ESRF (Upgrade programme - http://www.esrf.eu/Apache_files/Upgrade/ESRF-orange-book.pdf)

- The ILO, with the support of LIP and FCT, organized the 2nd High Luminosity LHC (HL-LHC) industry day at IST in Lisbon (October 2016). This was an event that gathered many important European and Portuguese companies (more than 150 participants) with interests to become CERN suppliers for products and services.

- 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). It is important to underline that for the 1st time of Portuguese industry participation at CERN, a software and services company called DoDoc started a pilot with several researchers to test and potentially adopt a new software platform to accelerate publications writing contributing to a new paradigm beyond LaTeX.

- 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.

Lines of work for next year

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, per request, bilateral meetings with LIP researchers (in Lisbon and Coimbra) about Intellectual Property and Technology Transfer, leveraging the experience of participating in the HEPTech network.

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 Office 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

Clinical dosimetry

Radiotherapy image guided (IGRT) arose from the need for greater precision in patient positioning. The IGRT uses the kV-CBCT imaging technique which allows a complete three-dimensional representation of the bone structure of the patient and other target tissue interfaces. It allows to check and correct the patient's position on the treatment couch. However, to obtain kV-CBCT images it is used ionizing radiation which is not recorded correctly in the current days. In clinical environment, various types of dosimeters are used to make dose measurements. According to the literature the plastic scintillator dosimeter has several advantages, such as good linearity and sensitivity in the range of energies to be used (100-120 keV) and is (almost) transparent in radiographic images. The plastic scintillator dosimeter could be an asset to quantify the kV-CBCT dose.

Environmental dosimetry

Extensive natural radioactive sources

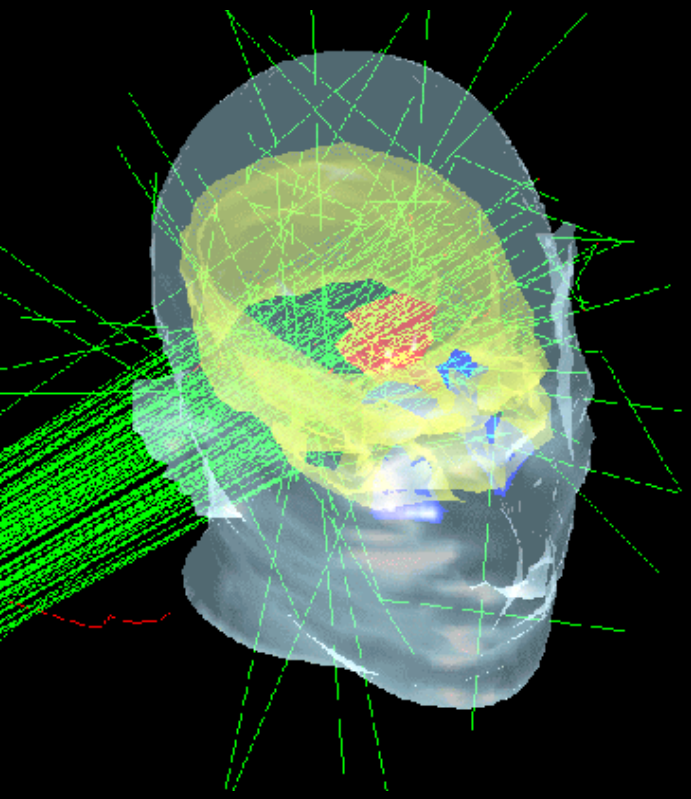
There are several situations in which we are confronted with extensive natural radioactive sources, such as uranium or thorium deposits. The activity determination of these sources appears complicated in many cases and results are presented as count-rate. This makes it difficult to make an intercomparison between different studies. In this work we proceeded to assemble a NaI(Tl) scintillation detector of 7.6x7.6 cm2. The activity of an extensive

Overview

7.5 kg potassium chloride mixed with sand (in a 1:5 ratio) was then made with this detector. The value of the activity per unit volume was compared with the value obtained by Monte Carlo simulation.

Radon in the air

Radon monitoring is a concern in public health. Most popular radon monitoring systems are based on passive detectors that can not give a real-time value of radon concentration. In this work we develop a radon progeny detector based on a windowless photodiode that can give real-time information on radon gas concentration.



Radon in the water

The presence of natural radionuclides in water is associated with the geological features of the sampling region. The slow dissolution of these elements steadily increases its concentration in ground water. In some circumstances, exposure to natural radionuclides, through drinking water, could exceed acceptable levels. The main goal of this work is to present an evaluation of radon concentration on samples of water used for human consumption, collected on uranium-rich granitic rock areas.

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 (33)

Master students
Ana Campos (10), Joana Machado (100), João Antunes (5), Pedro Brasil (50)

External/Additional scientific collaborators
Patrick Sousa, Pedro Gabriel Almeida

Total FTE
5.8

2016 activities

Clinical Dosimetry

Plastic scintillation dosimeters provide a low cost alternative to dose monitoring, and can be manufactured with several shapes and sizes. The main aim of this work was to build a replica of the plastic scintillator dosimeter and get its validation in kV-CBCT beams. It was proved with the present work, carried out in the Radiotherapy Service of Hospital de Santa Maria in Lisbon, that this type of dosimeter can be competitive with other systems for beam qualities between 100 and 120 kV. In this study, the dose index of Cone Beam CT (CBDI) was measured. Tests performed for CBDI measurement showed that the result obtained with the Plastic Dosimeter Scintillator presents a coherent response with the result obtained with a Farmer ionization chamber of 0.6 cm3.

Environmental dosimetry

Extensive natural radioactive sources

In this work the measurement of the activity of an extensive source consisting of a mixture of sand and potassium chloride was carried out. The measured activity due to decay of the 40K isotope was (117 ± 5) kBq. The setup was simulated by Monte Carlo, and a value of 121 kBq was obtained with the used parameters. In this work it was shown that it is possible to use Monte Carlo simulations to obtain the activity of an extensive and homogeneous source with uncertainties less than 5% from the measurement performed with a scintillation detector. It has also been shown that in the case of a large and homogeneous source, the product of the efficiency by the volume of the source tends to a limit value, being possible to calculate its specific activity.

Radon in the air

A detector prototype based on a windowless PIN-photodiode was built and tested. The test setup consists on a natural radon generator (radon exhaled from uranium ore) connected through a gas pipe to a box where the detector and two Geiger counters (one sensitive to beta and gamma radiation and other only sensitive to gamma radiation) were enclosed. The signal from the detector was analyzed by a multichannel system and the alpha particle spectrum from radon progeny obtained. The results obtained with the detector are well correlated with the ones obtained by both Geiger counters, indicating the system fitness to monitor radon.

Radon in the water

Radon in ground water can be released into the air during household activities such as showering, dishwashing and laundry. When radon accumulates on indoor air, it can pose an increased health risk, primarily lung cancer. Radon concentrations were measured with the radon gas analyzer DURRIDGE RAD7. Radon concentration measurements were performed on thirty three samples collected from water wells at different depths and types of aquifers, at Covilhã's county, Portugal. Radon concentration measurements, in twenty three, of the total water sample collected, give, values over 100 Bq/L. Taking into account public health it is recommended that the measured water is not safe for drinking purposes, accordingly to those international limits, and will be advantageous boiling it if it were used for drinking purpose.

During 2016 the past years intervention in the community continue with radon analysis made for two companies:

- Air and water measurements for Casa de Pedra, Águas Radium - Sortelha, September 2015 / January de 2016.

- Air and water measurements requested by Engº João Paulo Patrício - Covilhã May/July 2016.

Prospects for 2017

Clinical dosimetry

In 2017 we foresee the collaboration with the group of Aveiro University for the commercial development of scintillator based dosimeters. A number of applications are envisaged, ranging from dose control in brachytherapy to radioprotection monitoring of clinical staff.

Environmental dosimetry

Extensive natural radioactive sources

The concept of specific activity measurement of extensive sources is going to be exploited in connection to radon in the air.

Radon in the air

The construction of a counter prototype based on a windowless PIN-photodiode for radon detection is envisaged. The data from the counter is to be acquired with a system based on Arduino connected to a personal computer or tablet. The aim is to develop a low-cost system for radon detection that can be easily replicated.

Radon in the water

Our aim is to extend the present study to other locations in the nearby counties.

Publications

1 Article in national journals

M. Conceição Abreu e Luis Peralta: "No ano da Luz-medir a constante de Planck com díodos LED", Gazeta da Física Vol. 39 no.1/2 (2016) pp. 82-85

5 International Conference Proceedings

J. Antunes, J. Machado e L. Peralta: "Plastic Scintillator Detectors For Real-Time Patient Dose Control", accepted for publication in Congresso de Proteção Contra Radiações da Comunidade dos Países de Língua Portuguesa, 10 a 12 de Março de 2016, Coimbra

P. Brasil e L. Peralta: "Construção e Estudo de Um Detetor de Cintilação para Medidas de Atividade de Fontes Naturais Extensas", accepted for publication in V Congresso de Proteção Contra Radiações da Comunidade dos Países de Língua Portuguesa, 10 a 12 de Março de 2016, Coimbra

M. Inácio, S. Soares, P. Almeida: "Radon concentration assessment in water sources of public drinking of Covilhã' s county, Portugal", V Congresso Proteção Contra Radiações na Comunidade de Países de Língua Portuguesa

Luis Peralta, Florbela Rego: "Deteção da radiação térmica emitida por um filamento de tungsténio aquecido", accepted for publication in Revista Brasileira de Ensino de Física, vol. 38, no 1, xxxx (2016)

M. Inácio, S. Soares: "Estimation of the indoor radon and the effective dose in public building in the Covilhã County, Portugal", IV ERA Radon workshop, Ciudad Rodrigo, Espanha

1 National Conference Proceedings

M. Inácio, S. Soares, P. Almeida: "Radon concentration assessment in water sources of public drinking of Covilhã 's county, Portugal", 20.a Conferência de Nacional de Física e 26.o Encontro Ibérico para o Ensino da Física

1 Book

Sandra Soares, Albino Pinto, Carlos Saraiva: "Exercícios de Física 11", Raiz Editora, ISBN 978-972-680-812-1

Presentations

3 Oral presentations in international conferences

Luis Peralta: "Plastic Scintillator Detectors For Real-Time Patient Dose Control", 2016-03-10, V Congresso de Proteção Contra Radiações da Comunidade dos Países de Língua Portuguesa, Coimbra

Luis Peralta: "Construção e Estudo de Um Detetor de Cintilação para Medidas de Atividade de Fontes Naturais Extensas", 2016-03-10, V Congresso de Proteção Contra Radiações da Comunidade dos Países de Língua Portuguesa, Coimbra

Sandra Soares: "From Particle Physics to Medicine for a better health", 2016-05-30, 12th Workshop on European Collaboration for Higher Education and Research in Nuclear Engineering and Radiological Protection (CHERNE), Cervia – Itália

1 Poster presentation in international conferences

Sandra Soares: "Estimation of the indoor radon and the effective dose in public building in the Covilhã County, Portugal", 2016-04-28, V ERA Radon workshop, Ciudad Rodrigo, Espanha

1 Presentation in national conferences

Sandra Soares: "Hidroterapia e o Radão", 2016-09-09, 20.a Conferência de Nacional de Física e 26.o Encontro Ibérico para o Ensino da Física, Braga

1 Poster presentation in national conferences

Sandra Soares: "Avaliação da Concentração de Radão nas fontes de água de abastecimento público da Covilhã, Portugal", 2016-09-08, 20.a Conferência de Nacional de Física e 26.o Encontro Ibérico para o Ensino da Física, Braga

2 Seminars

Sandra Soares: "Da Física de Partículas à Medicina para uma melhor saúde", 2016-05-02, Centro de Ótica da Universidade da Beira Interior, Covilhã

Sandra Soares: "Marie Curie e o Radão", 2016-11-04, Biblioteca Municipal Eduardo Lourenço, Guarda

1 Outreach seminar

Sandra Soares: "Da Escola à prática – reflexão curricular", 2016-09-22, Agrupamento de Escolas de Almeida, Almeida

Theses

1 PhD Thesis

Margarida Isabel Inácio: "Bioacumulação dos descendentes diretos do radão nas folhas de Nasturtium officinale" (ongoing)

4 Master Theses

Ana Campos: "Simulação Monte Carlo de um sistema de tratamento de braquiterapia vaginal" (ongoing)

João Antunes: "Desenvolvimento de Dosímetros de Cintilador de Plástico para Dosimetria em Tomossíntese " (finished on 2016-10-26)

Joana Machado: "Dosimetria de Feixes de kV Cone Beam CT com Dosímetro Cintilador e Câmara de Ionização" (finished on 2016-12-16)

Pedro Brasil: "Construção e Caraterização de um detector de cintilação para detecção de radão" (ongoing)

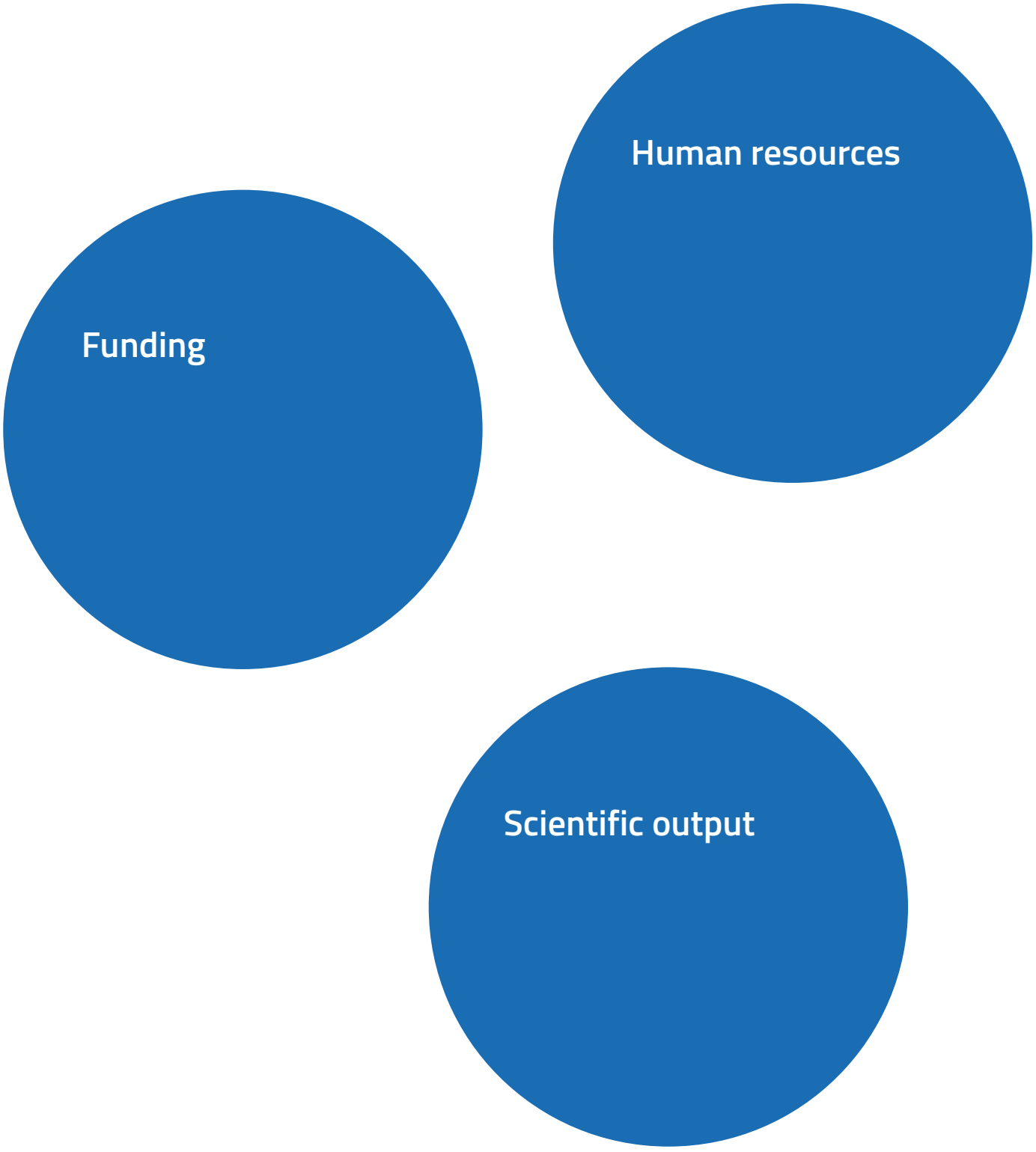
Events

2 Outreach Events

12ª Edição das Masterclasses em Física de Partículas - Hands on Particle Physics, UBI- Covilhã, 2016-02-27 to 2016-02-27

Masterclasses 2016, Faculdade de Ciências da Universidade de Lisboa, 2016-03-19 to 2016-03-19

// 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
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
COMPASS	CERN/FIS-NUC/0017/2015	200000	FCT	2015-04-01	2017-05-31	L
Auger	EPLANET 246806	10800	EU	2011-01-01	2016-01-31	L, C, M
	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
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
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
Gamma Cameras	IF/00378/2013/CP1172 /CT001	50000	FCT	2014-01-01	2018-12-31	C
Space Rad	ESA:22381/09/NL/PA/C CN04	20000	ESA	2013-10-01	2016-02-28	L
	ESA: 3-14025/13/NL/A K	60000	ESA	2014-03-17	2017-06-30	L
	ESA: 3-13975/13/NL/P A	200000	ESA	2014-03-10	2016-12-31	L
	ESA: 1-7560/13/NL/HB	300000	ESA	2014-02-18	2017-11-30	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
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	2016-8/763 MASTERCLASSES	4000	CVIVA	2016-01-01	2016-07-31	L, C, M
	MASTERCLASSES	500	FCTUC	2016-01-01	2016-07-31	C
	EPPCN - KE2826	23500	EPPCN	2016-01-01	2020-12-31	L
	PLTP2015 - CV731	14000	CVIVA	2016-05-01	2016-11-30	L
	2015-77/753	15000	CVIVA	2015-12-16	2016-06-30	L

LIP Node: L - Lisboa, C - Coimbra, M - Minho

Human Resources on research (2016)

Group	FTE	Heads (*)	Researchers	Technicians	PhD	Master	Undergrad	External
ATLAS	26.5	47	18	3	12	7	1	6
CMS	15.4	27	10	3	6	1		4
LHC Phenomenology	2.7	12	3	1				8
HIP	1.5	4	4					
COMPASS	8.5	9	7	1	1			
HADES	1.1	7	6	1				
AMS	3.0	5	2		1	1	1	
Auger	16.6	31	17	7	2	4		
Dark Matter Search	7.9	13	8	2	1	2		
SNO+	5.9	14	5	3	2	3		1
NEXT	1.9	6	5		1			
Neutron Detectors	1.4	5	4					1
RPC R&D	6.0	12	3	9				
Gaseous Detectors R&D	3.9	12	8	1	2			1
Liquid Xenon R&D	1.7	7	5	1				1
NUC-RIA	5.0	9	1		3	1	4	
RPC-PET	1.8	9	6	3				
OR Imaging	5.4	10	3		2	1		4
Gamma Cameras	3.9	12	5	4	2			1
STCD TagusLIP	1.4	7	1	1	1			3
Space	6.0	12	6		2	2		2
I-Astro	5.6	15	7		3	2		3
Distributed Computing	9.9	10	7	3				
Advanced Computing	2.4	4	4					
total	**146**	**299**	**145**	**43**	**41**	**24**	**6**	**35**

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	91	7	13	8	1	10	5	6	14	1	5	
CMS	77	5	6	10	1	3	14	12		2		1
LHC Phenomenology											1	
HIP		8	7	7								
COMPASS		3	9	8		3			1	1		
HADES	2			1		1						
AMS	2	1				2		1	4			
Auger	8	7	6	5		5		6	5		1	2
LATTES				8		1						1
Dark Matter LUX/LZ		6	10	3		2		4	6			
SNO+		1	2		2	8		3	1			
NEXT	2			1							2	
Neutron Detectors				1		1	1					1
RPC R&D		2		4			2					
Gaseous Detectors		2	1	1	3		2				2	
Liquid Xenon R&D		1										
NUC-RIA	6	2	5			2					1	
RPC-PET							1					
OR Imaging			5		4	1					3	
Gamma Cameras		2			1						1	
STCD Tagus LIP	1	3		8	4	1	2	1				
Space Rad		1	8		2	5	2		5	1	2	
I-Astro		1	2	1	2	3	1				1	
Distributed Computing		2	8	4		3	2	3				2
Advanced Computing												
Total	189	54	82	70	20	51	32	36	36	5	19	7

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.

// 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.

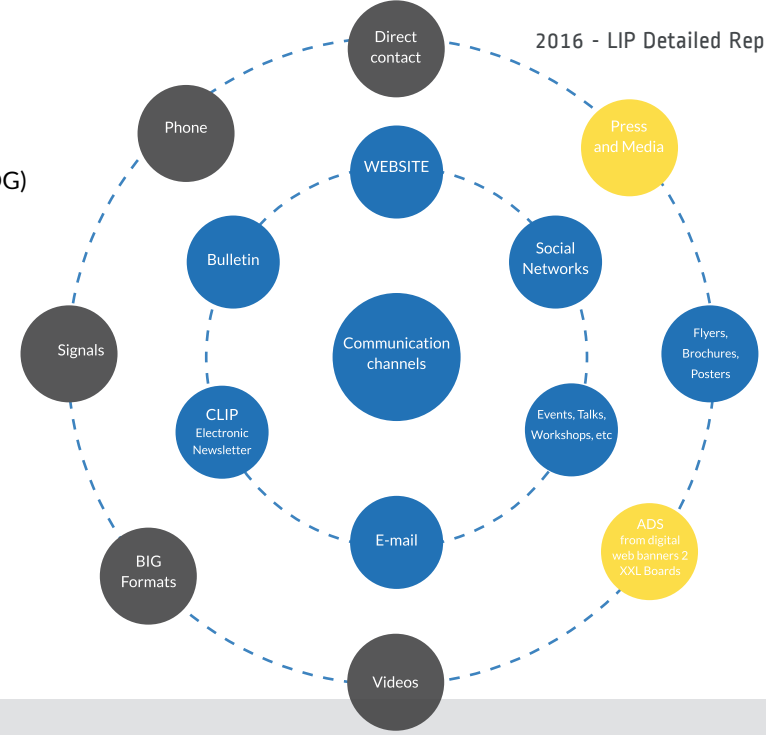
Main communication channel and their target audiences:

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:

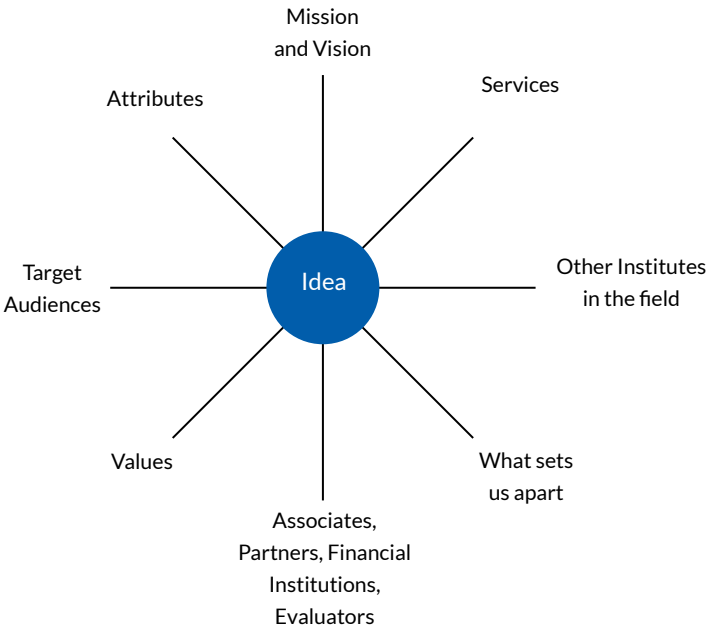
1. Strategy — The aspects discussed above will lead to an image summary that clarifies the strategy and position of the LIP as a brand. The essence of the brand is created by defining taglines and a tone of voice (that varies with the audience and purpose). This summary is to be added here. It must include, 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

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