LIP DETAILED 2015 REPORT

and plan for 2016

30 anos LIP

LIP

LABORATÓRIO DE INSTRUMENTAÇÃO E FÍSICA EXPERIMENTAL DE PARTÍCULAS

CONTENTS

Foreword

This year, LIP's annual report comes in a new format. It is now divided into a general and a detailed report. The big picture, global statistics, the description of our research lines, our main achievements and the challenges we face, are presented in the general, public report. The detailed report – this report – provides specific information on the past and future objectives, last year's achievements, and a brief strategic analysis of each research group. It also includes reports on our research facilities, as well as on activities in advanced training, education, outreach and technology transfer. We hope that this new format will give the adequate level of information for each audience it is aimed for, and in particular for our External Advisory Committee.

2015 was a very difficult and challenging year for LIP. It started sadly with the unexpected and dramatic illness soon followed by the death of José Mariano Gago, which was for all of us an enormous loss. It was also one more year of severe financial cuts in science funding. This led to enormous difficulties to maintain normal research activities and, worst of all, made the new generation of young students loose confidence in the possibility of finding their future in scientific careers in Portugal. In Coimbra, the Rad4life project funded by the regional structural funds was instrumental to keep the human resources and expertise in the instrumentation and medical physics domain. Moreover, LIP's classification in the 2014 Portuguese research assessment exercise was not the one we expected. LIP obtained the mention "Very good", the third highest. This assessment, widely contested by the Portuguese scientific community, was carried out by an external committee whose members, nominated by the previous government, demonstrated both in the visit and in written reports, a profound ignorance of our scientific area.

The above difficulties obliged us to give a renewed and special attention to the way LIP is internally organized, to LIP's premises, and to how LIP interacts with the outside world – in particular with students, the Universities, and the scientific community. To this end, we undertook several initiatives:

- A review of LIP's by-laws is being carried out, and should be finalized until summer. In the reviewed by-laws, the national character of LIP, with sections at Braga, Coimbra and Lisbon will be explicitly acknowledged. The composition, competences and duties of LIP's management bodies: General Assembly, Board of Directors, Scientific Council and External Advisory Committee, will be acknowledged and clearly stated.
- The composition of the External Advisory Committee was reinforced with the entry of three new members.
- A strong effort to move LIP to better premises was carried out. In Minho, there are good perspectives to obtain new premises, within one or two years, in a new University of Minho building. A new space to install our mechanical workshop was made available by the University of Coimbra. In Lisbon, an agreement was established to relocate LIP to a University of Lisbon central building. This should happen in the first semester of 2017, and will provide us with very good conditions to install laboratories and with approximately twice our current available office area.
- The possibility to open a few university professorships in experimental particle and astroparticle physics, in cooperation with LIP, is presently under discussion in Minho University and in IST management bodies. We hope that such type of agreement will be established soon and may be extended to other Universities and/or Faculties.
- Persistent work was pursued to establish a framework able to ensure the renewal and the management of the Portuguese computing infrastructure. A national association, the National Distributed Computing Infrastructure (INCD) was created in a partnership with the Portuguese funding agency (FCT) and with the National Laboratory of Civil Engineering (LNEC). The main Portuguese Universities will become members of such association in a near future.
- Profiting from the fact that LIP celebrates 30 years in 2016, an exhibition on the future challenges in our field was organized with the title "Particles: from the Higgs boson to Dark Matter". The exhibition was held in Braga in February/March and will be held in April in Coimbra and in May in Lisbon. The main intended audiences are undergraduate university students from the first years, and the last year high school student and teachers.
- The communication strategy of LIP with the general public, media and other stakeholders is under revision. One example outcome is the new format of this annual report.

The Portuguese government changed recently and, even though overall economic and budgetary constraints will certainly continue to exist in the next few years, a deep revision of science policy is now under way. Subjects such as scientific careers, support for new and better partnerships between Universities and the research centres, the definition of criteria and methods for the evaluation of the research

centres, the number and the attribution process of PhD grants, and in particular the role of inter-university PhD programs are, in our opinion, critical to the future of scientific development in Portugal. Regardless of this, LIP has to pursue its way; improving its internal methods of work; increasing synergies between its research groups; being ready to select, exploit and construct new opportunities; increase its interaction with society; in summary to be able to fully accomplish its scientific, technical and public role.

Mário Pimenta
March 2016

// RESEARCH Areas an

Experimental particle and astroparticle physics

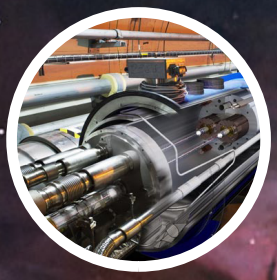
- LHC experiments and phenomenology
- Structure of matter
- Cosmic rays
- Dark matter and neutrinos

Development of new instruments and methods

- Detector development for particle and nuclear physics
- Instruments and methods for biomedical applications
- Radiation environment studies and applications for space missions

Computing

d Lines



LHC experiments and phenomenology

- ATLAS
- CMS
- LHC phenomenology

Cosmic rays

- AMS
- Auger

// Experimental particle a

Structure of matter

- COMPASS
- HADES

Dark matter and neutrinos

- LUX/LZ
- SNO+

and astroparticle physics

LHC Experiments and phenomenology

COLLABORATION IN THE ATLAS EXPERIMENT AT CERN

ATLAS

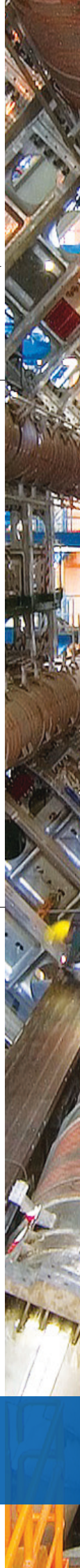
ATLAS is one of the experiments operating at CERN's LHC, where proton-proton and heavy ion collisions take place at unprecedented high energies and luminosities. After three years of very successful data taking, followed by a two year-long shutdown, the ATLAS experiment re-started data taking in 2015 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.

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 system, the forward detectors and the jet trigger software. Since the beginning of LHC operations we contribute to the detector operation and performance studies, physics analysis of the Higgs boson properties, top quark precision measurements, exotic quark searches and heavy ion physics, and on maintenance and upgrade work. We are a medium-size group within ATLAS. Our members have occupied a number of responsibility roles 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

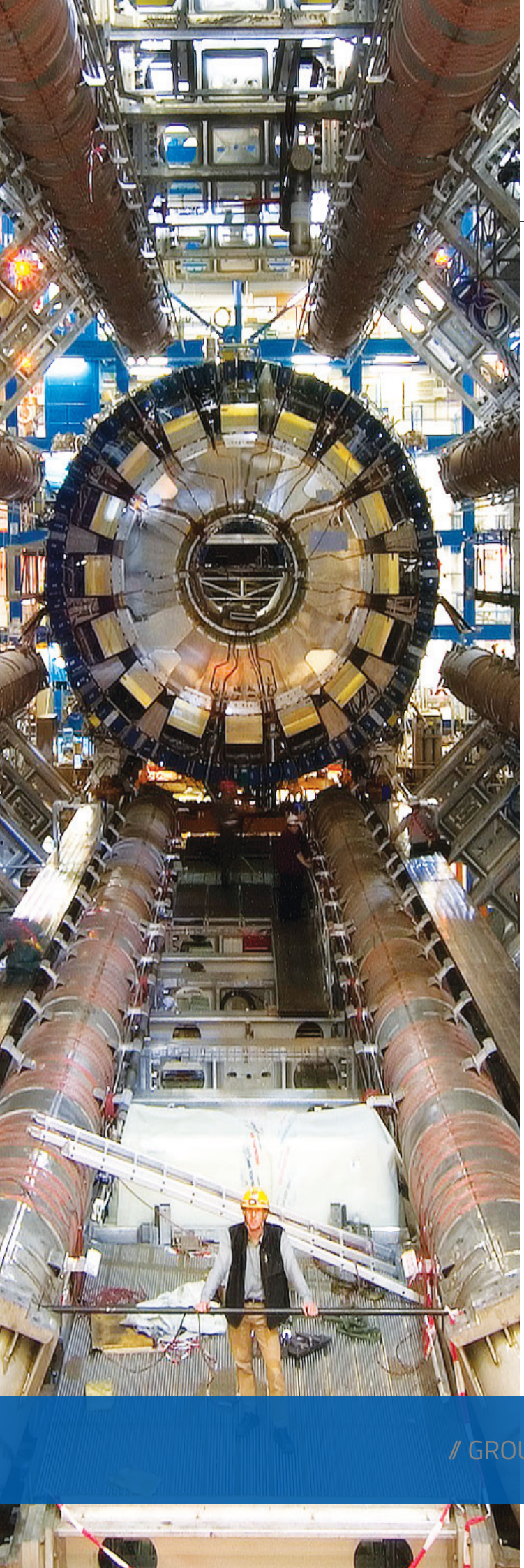
Summary of performance indicators

Articles in international journals:	10 With direct contribution from team 99 With indirect contribution
Internal notes:	6 Collaboration notes
International conferences:	12 Oral presentations 6 Posters 8 Proceedings
National conferences:	3 proceedings
Collaboration meetings:	52 Oral presentations
Proposals:	1 Technical proposal for detector upgrade
Seminars:	5 Seminars
Outreach:	7 Outreach seminars
Completed theses:	1 PhD and 1 Master Thesis
Organization:	2 Workshops organized



EXPERIMENTAL PARTICLE AND ASTROPARTICLE PHYSICS

LHC experiments and phenomenology



Team

Principal Investigator Patricia Conde (85)

Researchers
Agostinho Gomes (85), Albano Alves (17), Alberto Blanco (2), Amélia Maio (34), António Onofre (36), António Pina (17), Filipe Veloso (100), Gianpaolo Benincasa (13), Helena Santos (87), Helmut Wolters (80), José Maneira (40), José Rufino (17), José Santiago Perez (18), João Gentil (75), Miguel Fiolhais (25), Nuno Castro (72), Ricardo Gonçalo (98), Robert Cantrill (8), Rui Santos (9)

Technicians
Filipe Martins (100), José Manuel da Silva (21), Luís Gurriana (71), Luís Seabra (100), Paulo Marques (24),

PhD students
Ademar Delgado (100), Alberto Palma (100), André Pereira (42), Artur Amorim de Sousa (93), Bruno Galhardo (100), Ester Simões (29), Joana Miguéns (16), Juan Espinosa (29), Lourenço Lopes (16), Mário Sargedas Sousa (100), Pedro Jorge (30), Rute Pedro (100), Susana Santos (99)

Master students
Ana Peixoto (84), Christopher Pease (3), Duarte Azevedo (25), Emanuel Gouveia (100), José Correia (25), José Luís Silva (8), João Tiago Silva (25), Renato Dantas (41), Rui Martins (25), Tiago Vale (84)

Undergraduate students
André Reigoto (25), Henrique Carvalho (16), Lia Moreira (100)

External/Additional scientific collaborators
Guiomar Evans (24), José Soares Augusto(26), Liliana Apolinário (13)

Total FTE
27.1

// GROUPS: ATLAS / CMS / LHC phenomenology

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
- Top Quark physics (A. Onofre, F. Veloso)
- Searches for exotic particles and interactions (N. Castro)
- Higgs physics (P. Conde, R. Gonçalo)
- Heavy ions physics (H. Santos)

M&O and performance of the ATLAS detector and trigger system
- TileCal (A. Gomes)
- Jet Trigger (R. Gonçalo)
- Forward Detectors (A. Maio, P. Conde)
- GRID Distributed Computing (H. Wolters)

Detector Upgrades
- TileCal Upgrade (A.Gomes, A. Maio)
- Jets high level trigger system (P. Conde)

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)

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)
EXPL/FIS-NUC/1705/2013	49.485 €	2014-04-07 / 2015-08-06	FCT Exploratory research project - Htt (PI: R.Gonçalo)
FCG	10.000 €	2015-01-01 / 2015-12-31	Fundação Calouste Gulbenkian - Prize (A.Amorim)
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

Stated objectives for past year

Physics studies

In what corresponds to the Higgs boson physics, our goal is to study the couplings of the Higgs to the quarks accessible at the LHC (top and bottom), including spin and CP properties in the coupling vertex, and the HWW vertex in the associated production channel with a W. For 2015, our focus was to be the preparation and analysis of the first 13 TeV pp collisions in the ttH and VH (H->bb) channels, building up on our expertise from Run 1. In addition, we wanted to explore angular variables to disentangle the different spin and CP components in the ttH and HWW vertex (WH production).

Concerning the top quark physics, we wanted to continue the search for Flavour Changing Neutral Currents (FCNC) in the top quark decays with the 13 TeV and start the study of the Vts vertex through the measurement of the top decays to Ws.

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 as a way to regulate the quadratic mass-squared divergence of the Higgs boson. We intended to continue leading the effort in the Zt/b+X topology and to extend the studies done before to the new data acquired in 2015. 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.

Sensitivity studies of top quark physics and related new physics in the context of the High Luminosity phase were to be updated with new incoming information about the expected conditions of the ATLAS detector.

Concerning heavy ion physics, our long term goal is to understand the mechanism of the jet energy loss in the quark-gluon plasma. For 2015, we wanted to conclude the study of dijet asymmetries in Pb+Pb collisions, concentrating afterwards on the analysis preparation of heavy-flavour jet production in Pb+Pb collisions in Run2.

Detector maintenance, operation and upgrade

Our commitments in the ATLAS hadronic calorimetry, both in the Trigger system and in the TileCal detector, were to be continued.

In TileCal our effort was to be concentrated on the following activities:

- Maintain our strong involvement in the DCS. A custom-made generic OPC server was in development for the high voltage system, and the DCS had to be adapted to be compatible with the demonstrators: prototypes of electronics designed for upgrade phase 2, to be tested in ATLAS detector and in a test beam.
- Commission the Laser II system for the Run 2 and use it to keep track of the linearity of the PMTs and associated electronics and to monitor the gain drift of the PMTs, that need particular attention to spot possible troubles in the near or far future.
- Perform the electronics noise survey at the new energy and pile-up conditions of the LHC.

For the TileCal Upgrade:

- Procurement and test radiation hard WLS optical fibers and scintillators for replacement of TileCal gap and crack scintillators by 2018.
- Design and production of a new prototype of the Phase 2 High Voltage Distributor System to be tested in a test beam at CERN.

In what concerns the Tile-Muon trigger, a task that links our TileCal and trigger expertise, we pursued our responsibilities with focus on software and performance. The Tile-Muon trigger was expected to be ready for data taking from the start of physics collisions in Run 2. We aimed to participate in the fast validation of this trigger making use of the byte stream converters being developed by us. For the future, we also want to study the possible gain that can be obtained by an extension of the Tile-Muon trigger to the full TileCal barrel region for the Phase 2 upgrade.

On the high level jet trigger side, that was completely re-structured for the Run 2, we wanted to concentrate on performance studies with the 2015 data. This is extremely important for validation, optimization of the trigger menu and for physics analyses relying on jet triggers.

Our Upgrade activities on the trigger side were to be continued with the development of parallelizable trigger algorithms to run on Graphical Processing Units (GPUs). We wanted to implement a full prototype of a jet trigger chain for the end of 2015 to evaluate the possible gain in the use of these technologies and collaborate with the LIP's Computing group to test different hardware technologies.

In addition, our involvement in the ATLAS forward detectors was to continue with the migration of the ALFA detector DCS and the design and implementation of the AFP trigger.

With respect to ATLAS GRID, the main objective of the Portuguese group was the operation and monitoring of the local Tier-2 and Tier-3 clusters with respect to the ATLAS production activities, and the collaboration in the central organization of operation and monitoring of the world-wide GRID.

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

Achievements and responsibilities during the past year

The LIP group has done major or leading contribution to the following achievements during 2015:

Physics studies

- We contributed to the preparation of the 13 TeV Higgs to bb searches with the identification of new discriminating event shape variables to be added to the multi-variate analysis Boosted Decision Tree aiming to the improvement of the signal separation. The variables identified may contribute up to 10% improvement. One PhD thesis is being finalized on this topic.
- Developed a novel method to separate ttH and the main irreducible background, ttbb, based on the use of angular observables connected with the spin of the Higgs boson. One paper was published.
- The analysis of the top quark decays via FCNC at 8 TeV were finished and published. One PhD thesis that presents these results is in writing phase.
- The searches for new heavy quarks production were updated to the full 8 TeV dataset with several publications. One PhD thesis was finished and is about to be defended. The phenomenological consequences of the obtained results were interpreted in terms of alternative production mechanisms such as new heavy gluons.
- Conclusion of the Run-1 di-jet asymmetry studies in Pb+Pb collisions. The results are summarized in a publication in preparation.
- Development of the jet data quality and validation monitoring tools for the Heavy Ion data acquisition.

Detector maintenance, operation and upgrade

The LHC Run 2 commissioning in mid 2015 marked the culmination of a major overhaul of detectors and trigger system during the long shutdown, with strong/leading contributions from our group, as described in what follows.

TileCal:

- The migrations and upgrades of TileCal DCS detector and test systems were finished, so that they were operational for data taking at the restart of the LHC. They included the integration of Laser II control, a custom-made generic OPC server for HV and the set up of a complete DCS system for the TileCal testbeam, ready to work with the demonstrator prototypes for upgrade phase 2. A member of our group is leading the TileCal DCS since spring 2015.

- The linearity and stability survey of the TileCal's PMTs using the Laser II system was initiated.

- We contributed to the data-taking operations of ATLAS during the proton-proton and heavy ion 2015 runs with control room and on-call shifts (calorimeter, trigger, DCS, data quality). In addition, one member of our group was Data Quality leader for TileCal. This role includes the checking and signing-off of all runs, as well as the coordination of the DB updates/corrections for the fast processing.

- Designed the basic blocks for a High Voltage distributor board and the respective control system for one of the HV options that are being evaluated to replace the current system in the Phase II Upgrade, the off-detector option (in the alternative solution the boards remain inside the detector and need to be radiation hard as the existing ones).

- We were responsible for the production of 28 electronic boards in order for the TileCal to be used as interface with the central trigger processor (TTCdec) for the Tile-Muon trigger. The TTCdec boards were successfully tested at CERN. The installation of this hardware was finalized in the spring/summer of 2015.

- Developed and validated the necessary software (bytestream converters) for the reconstruction of Tile-Muon trigger raw data for the online monitoring and offline analysis.

In what concerns the **Forward Detectors**, our main contributions were to the DCS and test beam activities:

- Finalized the migration of the ALFA DCS for the production detector and lab systems to linux. Maintenance and development of new functionalities for the ALFA DCS for data taking.

- Contributed to the test beam of the ATLAS Forward Proton tagging detector (AFP) in September 2015. Using the test beam data we studied the cross-talk of the timing detector channels for different conditions.

- The control and monitoring of the secondary vacuum system, cooling and detector movement of AFP were developed.

Jet trigger maintenance, operation and upgrade:

A member of our team led the ATLAS Jet Trigger Group during the preparation and commissioning phase of the 13 TeV data taking period. The main achievements were:

- The new jet trigger reconstruction software, much closer to offline reconstruction, was developed and commissioned, leading to less bias and better performance when compared with the previous system;

- A new method to use partial calorimeter data, and therefore less DAQ network bandwidth, was put in place at LIP and commissioned as a backup plan in case of high online rates;

- The jet trigger operations team was reorganised, and the monitoring infrastructure rewritten and commissioned with cosmics data, well before beam operations took place, leading to a well debugged and reliable system;

- The jet trigger menu was planned for physics exploitation during run 2, and the jet fraction of the express stream menu was rationalised to provide the needed support for online and offline data quality assessment;

- A note was written and internally reviewed in the collaboration, to document the new software, menu, organization and commissioning.

With respect to the upgrade of the software triggers, a strong effort was invested this year on the development and implementation of a demonstrator trigger prototype that uses GPGPUs (General Purpose Graphical Processing Unit) as hardware accelerators for the Phase I upgrade. Our group has the responsibility of the calorimeter trigger prototype. Our achievements in this area were:

- Implementation of the first version of a parallel TopoClustering algorithm for the calorimeter, using a cellular automaton. The cluster splitting is currently under implementation and the evaluation of the performance of the new algorithm under evaluation.

- Contributed to the implementation of a client-server architecture to outsource specific code from the standard trigger algorithms to the GPGPUs.

Distributed Computing

The Iberian cloud and the Portuguese Tier2 have shown excellent results in the operation during the last year. The Portuguese Tier2 delivered a capacity that exceeded the WLCG pledges for ATLAS and exhibited very good reliability and availability metrics. The Site Status Board of the global ATLAS GRID monitoring system has been adapted successfully to the new data distribution system RUCIO and the new distributed job monitoring system, bigpanda.

Outreach

The group participated in several outreach activities including secondary school MasterClasses in many different locations in Portugal, presentations, seminars and hands-on workshops for young undergraduate university students.

Coordination positions within the ATLAS Collaboration (in 2015):

- Ricardo Gonçalo, Jet Trigger coordinator.
- 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)
- Nuno Castro, contact person for the run-2 searches for vector-like quarks (since October 2014 to December 2015).
- Filipe Martíns, TileCal DCS coordinator.
- TileCal DQ leader, José Maneira (1 month shift November-December 2015)

Editorial Boards:

Members of our group participated in 13 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 (5), N. Castro (4), one of them as chair of the board), F. Veloso (2), Ricardo Gonçalo (1), A. Onofre (1).

Lines of work and objectives for next year

Physics studies

In what corresponds to the Higgs boson physics, for 2016, our focus will be:

- 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 this 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 this 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. We will also contribute to the analysis of the first 13 TeV pp collisions in the ttH and continue that analysis with new data to be 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.

We will complement the precision measurements of the Higgs and top quark properties with direct searches for new physics:

- 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, a spin-off of the previous studies 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.
- 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, the long term goal of the group is to understand the mechanism of jet energy loss in the quark gluon plasma. For 2016, the focus will 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, operations and upgrades

In TileCal our effort will be concentrated on the following activities:

- Maintain our strong involvement in the DCS, leading the maintenance and continous upgrade of the system. The DCS of the phase 2 demonstrators will be improved in the testbeam 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.
- For the first trimester of 2016 the Tile-Muon trigger at the end-cap will finish its commissioning. The L1 Muon Trigger is foreseen to include the D-layer of the TileCal for the restart of LHC Run 2 in April 2016. Also during 2016 an extension of the Tile-Muon to one octant of L1 Muon Trigger barrel coverage is being prepared. We keep the responsibility of maintenance and further developments of the Tile-Muon offline software. We plan to get involved in the Tile-Muon trigger performance studies for the current setup and its future extensions for Run 3 or HL-LHC.

For the TileCal Upgrade, we will:

- Set up the lab, procure radiation hard WLS optical fibers and scintillators to be tested as replacement of TileCal gap and crack scintillators by 2018.
- Investigate alternative scintillator-WLS fibers 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 we will concentrate on performance studies with the 13 TeV data. This is extremely important for the validation and continuous optimisation of the trigger menu in view of ongoing ATLAS physics analyses.

Our Upgrade activities in the trigger will continue. The performance of the parallel version of the TopoCluster algorithm (the Topo Automaton Clustering or TAC) will be evaluated and the algorithm optimized. The results will contribute to the decision of which kind of processors architecture will be used for the Phase I ATLAS trigger. In a longer time scale the development of GPGPU trigger algorithms will also continue towards Phase II (either at the High Level Trigger or at Level one).

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.

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

The main objective of the Portuguese group in the ATLAS Grid continues to be the operation and monitoring of the local Tier-2 and Tier-3 clusters with respect to the ATLAS production activities, and the collaboration in the central organization of operation and monitoring of the world-wide GRID, which includes the development and maintainance of software for the Site Status Board. The current coordinator of the Iberian Cloud (ATLAS GRID infrastructures in Spain, Portugal and Latin America) is a member of the Portuguese group.

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

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 can be viewed as centering around calorimetry, DCS, software triggers and several physics areas. The group has experimental labs in Lisbon, dedicated to calorimetry and instrumentation for processing and characterization of optical wave length shifting and scintillating fibers, 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 of related activities, such as the development of the DCS, detector operation, data quality, the ALFA luminosity monitor (which uses a similar technology), use of the TileCal in the muon trigger, detector upgrade, etc. In the jet trigger area we have been involved in the High-Level Trigger trigger development, operation and upgrade. In the area of physics analysis we have made important contributions to the Higgs discovery and physics studies, jet suppression in heavy ion collisions and our long expertise in top quark physics has lead us to a leading role in many measurements of the top quark properties and searches for new physics.

Weaknesses

A reorganization within the University of Lisbon, has forced to a removal and substantial reduction of lab space, so many equipments are currently out-of-use. This situation is expected to be temporary.

Currently the group has no new students starting in Lisbon or Coimbra, with a large number of PhD students in the concluding or writing phase of their PhD. The number of Post-docs (2) is also small, relative to the size of the group. The current level of funding is insufficient to hire directly more post-docs.

Oportunities

After a successful data taking at 13 TeV in 2015, this year will bring a considerable 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. In fact, 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.

With respect to the lab, LIP has requested the use of installations at the University of Lisbon, for the Lisbon pole. If and when this change happens, it will be fundamental to stabilize and speed up the experimental activities in the groups's labs. Given that the whole of LIP-Lisbon will move there, this can be very beneficial for those 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 centers has strengthened our group and leaves us in a good position to contribute to the trigger upgrade.

Threats

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. If the severe financial constraints continue, the human-power situation will become critical.

Publications

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

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S. P. Amor dos Santos, J. P. Araque, R. Cantrill, N. F. Castro, M. C. N. Fiolhais, R. Frederix, R. Gonçalo, R. Martins, R. Santos, J. Silva, A. Onofre, H. Peixoto, A. Reigoto: "Angular distributions in $t{\bar t}H (H\ rightarrow b\bar{b})$ reconstructed events at the LHC", Phys.Rev. D92 (2015) 3, 034021

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G. Aad et al. (2898 authors): "Search for the X-b and other hidden-beauty states in the pi(+)pi(-)gamma(1S) channel at ATLAS", Phys. Lett. B 740 (2015) 199-217

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ATLAS Collaboration (2882 authors): "Measurement of the t(t)over-bar production cross-section as a function of jet multiplicity and jet transverse momentum in 7 TeV proton-proton collisions with the ATLAS detector", J. High Energy Phys. 1 (2015) 1-67

ATLAS Collaboration (2882 authors): "Measurement of the $WW+WZ$ cross section and limits on anomalous triple gauge couplings using final states with one lepton, missing transverse momentum, and two jets with the ATLAS detector at $sqrt{ m{s}} = 7$ TeV", JHEP 1501 (2015) 049

ATLAS Collaboration (2891 authors): "Searches for heavy long-lived charged particles with the ATLAS detector in proton-proton collisions at $ sqrt{s}=8 $ TeV", JHEP 1501 (2015) 068

ATLAS Collaboration (2898 authors): "Measurements of Higgs boson production and couplings in the four-lepton channel in pp collisions at center-of-mass energies of 7 and 8 TeV with the ATLAS detector", Phys.Rev. D91 (2015) 012006

ATLAS Collaboration (2891 authors): "Measurement of the production and lepton charge asymmetry of W bosons in Pb+Pb collisions at $mathbf {sqrt{mathbf {s}_{mathrm {mathbf {NN}}}}=2.76;TeV}$ with the ATLAS detector", Eur.Phys.J. C75 (2015) 23

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ATLAS Collaboration (2897 authors): "Measurements of the W production cross sections in association with jets with the ATLAS detector", Eur.Phys.J. C75 (2015) 82

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ATLAS Collaboration (2883 authors): "Performance of the ATLAS muon trigger in pp collisions at $sqrt{s}=8$ TeV", Eur.Phys.J. C75 (2015) 120

ATLAS collaboration (2881 authors): "Search for charged Higgs bosons decaying via H-+/- -> tau(+/-) nu in fully hadronic final states using pp collision data at root s=8 TeV with the ATLAS detector", J. High Energy Phys. 3 (2015) 088

ATLAS Collaboration (2825 authors): "Search for Higgs and Z Boson Decays to J/psi gamma and Upsilon(nS) gamma with the ATLAS Detector", Phys. Rev. Lett. 114 (2015) 121801

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G. Aad et al. (2889 authors): "Identification and energy calibration of hadronically decaying tau leptons with the ATLAS experiment in pp collisions at root s=8 TeV", Eur. Phys. J. C 75 (2015) 303

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ATLAS Collaboration (2835 authors): "Search for type-III seesaw heavy leptons in pp collisions at root s=8 TeV with the ATLAS detector", Phys. Rev. D 92 (2015) 032001

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ATLAS Collaboration (2829 authors): "Search for high-mass diphoton resonances in pp collisions at root s=8 TeV with the ATLAS detector", Phys. Rev. D 92 (2015) 032004

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ATLAS Collaboration (2878 authors): "Search for new phenomena in events with three or more charged leptons in pp collisions at TeV with the ATLAS detector", J. High Energy Phys. 8 (2015) 138

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ATLAS Collaboration (2826 authors): "A search for t(t) over-bar resonances using lepton-plus-jets events in proton-proton collisions at root s=8 TeV with the ATLAS detector", J. High Energy Phys. 8 (2015) 148

ATLAS Collaboration (2850 authors): "Modelling Z -> tau tau processes in ATLAS with tau-embedded Z -> mu mu data", J. Instrum. 10 (2015) P09018

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Collaboration, A (2850 authors): "Search for metastable heavy charged particles with large ionisation energy loss in pp collisions at root s=8 TeV using the ATLAS experiment", Eur. Phys. J. C 75 (2015) 407

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ATLAS Collaboration (2825 authors): "Search for massive, long-lived particles using multitrack displaced vertices or displaced lepton pairs in pp collisions at root s=8 TeV with the ATLAS detector", Phys. Rev. D 92 (2015) 072004

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ATLAS Collaboration (2840 authors): "Measurements of the top quark branching ratios into channels with leptons and quarks with the ATLAS detector", Phys. Rev. D 92 (2015) 072005

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8 International Conference Proceedings

B. Galhardo: "Search for rare top quark decays", C13-09-14 37-42, 2014

J.P. Araque: "Noise dependency with pile-up in the ATLAS Tile Calorimeter", ANIMMA 2015, Lisbon

S. Kama, A. Delgado, P. Conde, J. Augusto Soares et al.: "Triggering events with GPUs at ATLAS", J.Phys.Conf.Ser. 664 (2015) 9, 092014

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Helena Santos: "Jet Path Length Dependence in Pb+Pb Collisions with the ATLAS Detector", HardProbes 2015 - Montreal - Jun. 29 - Jul. 3

3 National Conference Proceedings

J. Alves, A. Gomes, G. Evans, J. Soares Augusto: "Three Channel G-Link Transmitter Emulation in FPGA for the ATLAS Tile Muon Digitizer Board", 11th Portuguese Meeting on Reconfigurable Systems, Instituto Superior de Engenharia do Porto, 5-6 february 2015 pp 47-52

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3 Collaboration notes with internal referee

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Atlas Collaboration: "Internal structure of jets measured in Pb+Pb collisions with the ATLAS detector at the LHC", ATLAS-CONF-2015-055

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3 Internal Notes

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1 Proposal

ATLAS Collaboration: "ATLAS Forward Proton Phase I Upgrade Technical Design Report (TDR)", ATLAS-TDR-024

Presentations

12 Oral presentations in international conferences

Filipe Veloso: "Searches for Flavour Changing Neutral Currents in the top sector at the LHC", 2015-03-05, Workshop on New Physics Searches in the Top Quark Sector at the LHC. Braga, Portugal

Juan Espinosa: "Discussion about prelimiary sensitivy studies for heavy gluons and vector-like quarks", 2015-03-05, Workshop on New Physics Searches in the Top Quark Sector at the LHC, Braga (Portugal)

Nuno Castro: "Experimental wrap-up of the Workshop", 2015-03-05, Workshop on New Physics Searches in the Top Quark Sector at the LHC, Braga (Portugal)

Luís Seabra: "ALFA Detector Control System", 2015-03-18, ICIT 2015, Sevilha

Bruno Galhardo: "Search for flavour changing neutral currents in top-quark decays t->qZ at 8 TeV in 20.3 fb-1 of proton-proton collision data collected with the ATLAS detector", 2015-03-30, IDPASC workshop on foundations of particle physics, Porto, Portugal

Nuno Castro: "Search for new physics in the top quark sector at the LHC", 2015-03-31, IDPASC workshop on foundations of particle physics, Porto (Portugal)

Ademar Delgado: "ATLAS Jet Trigger Update for the LHC Run II", 2015-04-20, Advancements in Nuclear Instrumentation Measurement Methods and their Applications (ANIMMA 2015), Lisbon

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Bruno Galhardo: "Top quark pair properties using the ATLAS detector at the LHC", 2015-05-05, Phenomenology 2015, Pittsburgh, USA

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Helena Santos: "Jet Path Length Dependence in Pb+Pb Collisions with the ATLAS Detector", 2015-06-29, HardProbes 2015, Montreal

Nuno Castro: "Ideas for combinations of measurements constraining the Wtb vertex", 2015-11-18, LHC TOP WG meeting, CERN

6 Poster presentations in international conferences

Juan Espinosa: "Search for vector-like quarks decaying to a Z boson with the ATLAS experiment", 2015-09-02, The 2015 European School of High-Energy Physics, Bansko (Bulgary)

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Ademar Delgado: "An evaluation of GPUs for use in an upgraded ATLAS High Level Trigger", 2015-10-31, IEEE-NSS, San Diego

6 Seminars

José Maneira: "Properties of the Higgs boson: recent results from ATLAS at the LHC", 2015-02-11, Universdidade de Coimbra

Nuno Castro: "Search for new heavy quarks with the ATLAS experiment at the LHC", 2015-02-18, CFP Journal Club, Porto (Portugal)

Patricia Conde: "Pesquisas do Higgs e estrutura do protão em ATLAS", 2015-04-07, IDPASC Hands on Particles and Light Workshop,

Patricia Conde: "Results from the Higgs searches at the LHC", 2015-05-04, IDPASC Course on Physics at the LHC,

Ricardo Gonçalo: "Future directions in Higgs Physics at the LHC", 2015-05-04, IDPASC Course on Physics at the LHC,

Nuno Castro: "Search for new heavy quarks with the ATLAS experiment at the LHC", 2015-10-25, City College of New York seminar, New York (USA)

7 Outreach seminars

João Gentil: "Aceleradores e Detectores", 2015-02-25, MasterClasses Internacionais em Física de Partículas, UTAD, Vila Real

João Gentil: "Aceleradores e Detectores", 2015-02-26, MasterClasses Internacionais em Física de Partículas, IPB, Bragança

Filipe Veloso: "Detectores e aceleradores de partículas", 2015-03-07, Masterclasses Internacionais em Física de Partículas, Coimbra, Portugal

Filipe Veloso: "Física das Altas Energias", 2015-03-21, 11. Masterclasses Internacionais em Física de Partículas, Aveiro, Portugal

Patricia Conde: "O CERN, o LHC, ATLAS", 2015-03-21, MasterClasses Internacionais em Física de Partículas, IST, Lisbon

João Gentil: "Introdução ao programa de análise de eventos Minerva", 2015-03-21, IMasterClasses Internacionais em Física de Partículas, IST, Lisboa

Patricia Conde: "A experiência ATLAS", 2015-09-04, CERN Portuguese Language Teachers Programme

Theses

9 PhD Theses

Bruno Galhardo: "Search for flavour-changing neutral current top-quark decays with the ATLAS detector" (writing up)

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

Joana Miguéns: "Observation and measurement of Higgs boson decays to WW* with ATLAS at the LHC" (finished on 2015-12-17)

Mário Sargedas Sousa: "Search for the Higgs boson at ATLAS/LHC, in associated production with a Z boson" (writing up)

Juan Espinosa: "Search for heavy fermions with the ATLAS experiment at the LHC collider" (writing up)

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)

9 Master Theses

Emanuel Gouveia: "Search for ttH production with the ATLAS experiment at the LHC" (ongoing)

Artur Amorim de Sousa: "Search for tZ events produced via flavour changing neutral currents at the LHC" (finished on 2015-12-02)

Ana Peixoto: "Search for tZ production via FCNC at the ATLAS experiment" (ongoing)

Tiago Vale: "Search for Vector Like Quarks in a multilepton topology at the ATLAS experiment" (ongoing)

José Correia: "Search for Vector Like Quarks in a fully hadronic topology at the ATLAS experiment" (ongoing)

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

João Tiago Silva: "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)

1 Graduation Thesis

Lia Moreira: "Determinação da carga elétrica de jatos hadrónicos incluindo o decaimento semileptónico de quarks pesados" (ongoing)

Events

2 Workshops

ATLAS Trigger GPU Demonstrator Sprint, Lisbon, 2015-04-28 to 2015-04-29

Workshop on New Physics Searches in the Top Quark Sector at the LHC, Universidade do Minho, Braga, 2015-05-05 to 2015-05-07

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 the data acquisition system of the ECAL sub-detector used for the measurement of electrons and photons and contributed to the CMS Trigger System which performs online selection of the interesting collisions. A LIP member led the construction of the latter system, and served as Deputy Spokesperson of the Collaboration in 2012-13. 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 measurement of the psi and upsilon polarizations; and the searches for a charged Higgs and a top squark.

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 that interface the ECAL electronics to the trigger system. The LIP group is currently contributing to the physics analysis of the new data and is leading the development of the new forward proton sub-detector (CT-PPS).

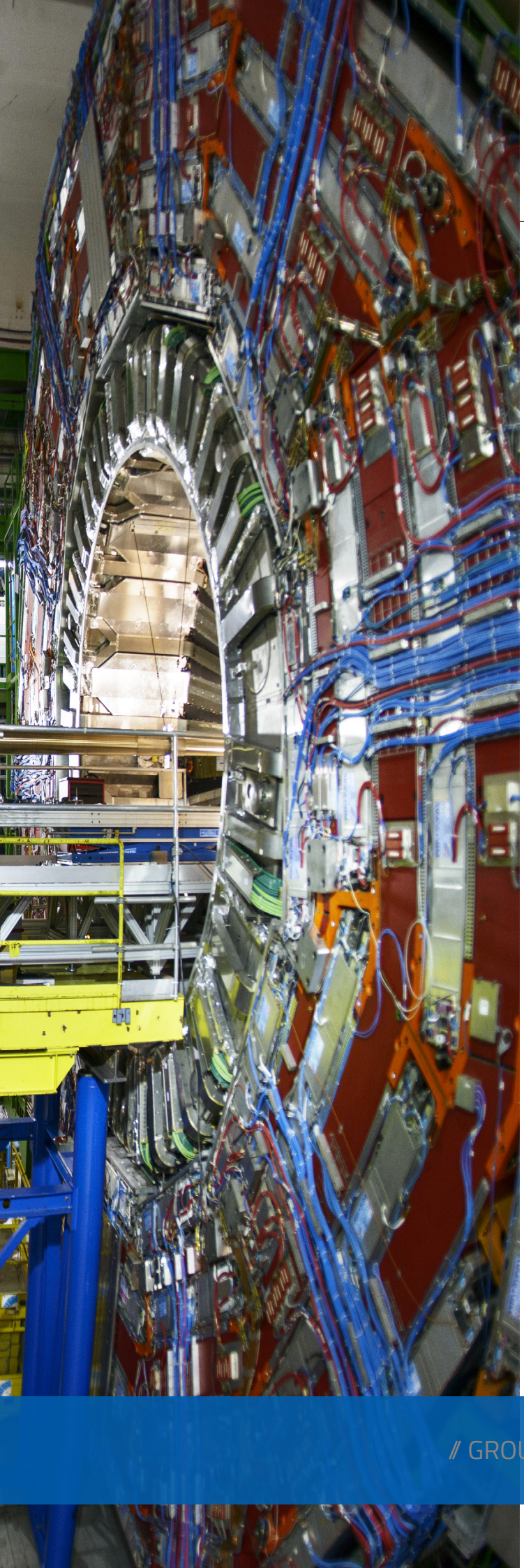
Framework and status for past and current year

Summary of performance indicators

Articles in international journals:	4 With direct contribution from team 72 With indirect contribution
Internal notes:	7 Collaboration notes
International conferences:	8 Oral presentations 4 Proceedings
International meetings:	7 Oral presentations
National conferences:	1 Oral presentation
Collaboration meetings:	73 Oral presentations
Proposals:	1 Technical proposal for detector upgrade
Seminars:	20 Seminars
Organization:	1 Conference organized

EXPERIMENTAL PARTICLE AND ASTROPARTICLE PHYSICS

LHC experiments and phenomenology



Team

Principal Investigator João Varela (71)

Researchers
André Tinoco Mendes (62), Jonathan Hollar (42), João Seixas (31), Lara Lloret (100), Manuel Rolo (43), Michele Gallinaro (100), Nuno Leonardo (100), Pedrame Bargassa (100), Pedro Ferreira da Silva (50), Pedro Parracho (25), Pietro Faccioli (43)

Technicians
José Carlos Silva (61), Rui Pereira da Silva (23)

PhD students
Agostino di Francesco (100), Bruno Galinhas (24), Cristóvão Silva (100), Daniele Vadruccio (100), Oleksii Toldaiev (100), Pietro Vischia (100), Viesturs Veckalns (17)

Undergraduate students
César Carpinteiro (16), João Rodrigues Antunes (25), Marcelo Vicente (62)

External/Additional scientific collaborators
Federico Nguyen (25)

Total FTE
14.8

// GROUPS: ATLAS / CMS / LHC phenomenology

Lines of work and team organization

The activities of the LIP/CMS group are organized along four main lines:

1. Proton-proton physics analysis exploiting the discovery opportunities offered by the new LHC energy and luminosity

2. Heavy-ions physics and the study of the quark-gluon plasma

3. New detector developments for the CMS Upgrade program

4. Operation and maintenance of the trigger and data acquisition system of the CMS Electromagnetic Calorimeter

The coordination positions in the LIP/CMS group are listed below (in parenthesis are indicated the names of the current coordinators):

- LIP/CMS group coordinator (J. Varela)
- LIP/CMS deputy group coordinator (J. Seixas)
- Proton-proton physics coordinator (M. Gallinaro)
- Heavy-ion physics coordinator (J. Seixas)
- Upgrade coordinators:
  - Optical links project (J. C. Silva)
  - Precision proton spectrometer (J. Varela)
- ECAL detector:
  - Electronics coordinator (J. C. Silva)
  - Computing coordinator (P. Vischia)

The CMS Collaboration has about 3500 members from 179 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 (BPH 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)
- CMS Statistics Committee (P. Vischia)
- ECAL Executive Board (J.C. Silva)
- ECAL, Trigger 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
CERN/FP/123601/2011	550.000 €	2012-04-01 / 2015-03-31	FCT - CERN related projects - Participation in CMS
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 2015:

1. Proton-proton physics:

1.1 search for charged Higgs and other new physics in top events;

1.2 search for 3rd generation supersymmetric particles (stop, stau);

1.3 search for rare decays and measurement of heavy flavour production and properties

1.4 central exclusive production in proton collisions

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;

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. New detector developments for the CMS Upgrade program

4.1 installation and commissioning of the new optical Serial Links that interface the ECAL electronics to the Trigger System

4.2 development of the timing detectors of the CT-PPS project.

5. Operation and maintenance of the ECAL trigger and data acquisition 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. In 2015 the LIP group was expected to provide 120 shifts (8h each) and 50 months of EPR work (EPR – Experimental Physics Responsibilities).

Achievements and responsibilities during the past year

The LIP group developed the following activities in 2015 (same numbering is used in the previous section; CMS AN refers to internal Analysis Notes):

1. Proton-proton physics

1.1 Search for charged Higgs and other new physics in top events.

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 is the subject of the PhD Thesis of P. Vischia, to be submitted in March 2016.

The analysis of top events with taus in the final state at 13 TeV (Run 2 data) is proceeding (PhD student A. Toldayev, M. Gallinaro).

1.2 Search for 3rd generation supersymmetric particles (stop, stau)

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 submitted to publication in JHEP. Members of the LIP/CMS group participated in the analysis and had a leading role in the preparation of the "legacy" Run1 publication (P.Bargassa, L. LLoret). The paper was published in 2016, JHEP, arXiv:1602.03169.

The analysis CMS-SUS-14-022 "Search for stau and chargino pair production in di-tau final states" was concluded and internally approved by the Analysis Review Committee but not yet made public. LIP contributed to this analysis with the work of the PhD student (C. Cruz e Silva) on new background estimation methods (CMS AN-2015/038).

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 submitted to publication. One member of the LIP group (P. Bargassa) contributed to the early stages of analysis. Studies with the Run2 data started and members of the LIP/CMS group are contributing to the preparation of the analysis (P. Bargassa, L. Lloret).

1.3 Search for rare decays and measurement of heavy flavour production and properties

The analysis CMS- BPH-13-007 "Observation of the rare B0s→μ+μ− decay from the combined analysis of CMS and LHCb data" was concluded and published in Nature. One member of the group (N. Leonardo) was the main author of one of two CMS parallel analysis (CMS AN-2013/216).

In the frame of the European INFIERI network, a ESR student (D. Vadruccio) developed simulation studies of a dedicated pixel trigger sensitive to secondary vertices. These studies are now being applied to triggering on muons from tau decays in order to increase the sensitivity to the rare decay of the tau in 3 muons.

1.4 Central exclusive production in proton collisions

One member of the LIP group (J. Hollar) made the simulation study of the exclusive production of photon pairs, complementing the TDR studies done in 2014, in order to evaluate the SM background to a possible diphoton resonance at 750 GeV. These simulations are at the basis of the CMS decision to accelerate the CT-PPS program (see plans for 2016).

1.5 WW production cross-section at 8 TeV (not foreseen in the plan)

Given the discrepancy relative to the SM observed in the measurement with 5 fb-1, CMS decided to review the analysis and to use the full data set at 8TeV. The analysis CMS-SMP-14-016 "Measurement of the W+ W- cross section in pp collisions at sqrt(s) = 8 TeV and limits on anomalous gauge couplings" was concluded and submitted to publication. One member of the group (L. Lloret) was asked to contribute (CMS AN-2014/064, CMS AN-2014/081, CMS AN-2014/077) given her previous expertise in this measurement.

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 submitted for publication (PRL). 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 the framework of the CMS B-Physics Group, co-coordinated by a member of the LIP group (N.Leonardo) several activities have been pursued ("Dimuon spectrum 2015 (CERN-CMS-DP-2015-055), "Selected Heavy Flavor distributions from CMS with first 13 TeV data" (CERN-CMS-DP-2015-018), "B Physics analyses for the Phase-II Upgrade Technical Proposal" (CMS-PAS-FTR-14-015). A PhD student (B. Galinhas) is pursuing the analysis of B hadron production with pp 13 TeV data.

2.3 polarization of chi states (χc and χb).

The study of the polarization of chi states in pp collisions is on-going.

3. Physics objects development

LIP members participated 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).

4. New detector developments for the CMS Upgrade program

4.1 Installation and commissioning of the new optical Serial Links that interface the ECAL electronics to the Trigger System.

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 will enter in operation in April 2016.

4.2 Development of the timing detectors of the CT-PPS project.

The LIP group is leading the developments of the CT-PPS Timing detectors (CMS Level-2 co-coordinator M. Gallinaro).

One PhD student (A. Toldayev) performed the GEANT simulation study of the light collection in the CT-PPS Quartic timing detector.

The LIP group had a leading role in the specification and design of the CT-PPS Timing Detectors front-end electronics (J. C. Silva, C. Carpinteiro, M. Gallinaro). Three boards have been designed and produced (NINO board, HPTDC mezzanine and Digitizer motherboard), the first two under LIP responsibility. Several group members had a leading role in the Test Beam activities in the SPS H8 line aiming at the characterization of CT-PPS Timing detector options (M. Gallinaro, J. Hollar, L. Lloret, A. Toldayev, J.C. Silva, C. Carpinteiro, M. Alves).

4.3 Development of the CT-PPS DAQ system (not foreseen)

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 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

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/CMS interface with the LIP's Tier2

One member of the group (P. Vischia) was in charge of establishing the interface to the LIP Computing Team.

7. General

In 2015 the LIP group provided 97 shift credits and 46 man-months of EPR work (POGs, CT-PPS, ECAL).

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 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. This activities are carried in the frame of the EU Marie-Curie network AMVA4NewPhysics.

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 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 heavy-ion collisions;

2.2 heavy-flavour production in pp and heavy-ion collisions;

2.3 polarization of chi states (χc and χb) in pp collisions.

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 timing detectors and DAQ system of the CT-PPS project.

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. In 2016 the LIP group is expected to provide 130 shifts credits and 60 months of EPR work (EPR – Experimental Physics Responsibilities).

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, leading role in several physics analysis and the coordination of the B physics PAG.

Weaknesses

Not enough students, in particular Portuguese, revealing insufficient penetration in the local Universities.

Oportunities

Study of the exclusive diphoton production at invariant mass ~750 GeV using CTPPS.

Threats

Unclear career prospects for the majority of the senior physicists of the group.

Publications

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

CMS Collaboration (2132 authors): "Search for long-lived particles that decay into final states containing two electrons or two muons in proton-proton collisions at root s=8Tev", Phys. Rev. D 91 (2015) 052012

CMS/LHCb Collaboration (2828 authors): "Observation of the rare B-s(0)->mu(+)mu(-) decay from the combined analysis of CMS and LHCb data", Nature 522, 68–72 (04 June 2015)

CMS Collaboration (2154 authors): "Measurement of J/psi and psi(2S) Prompt Double-Differential Cross Sections in pp Collisions at root s=7 TeV", Phys. Rev. Lett. 114 (2015) 191802

CMS Collaboration (2307 authors): "Search for a charged Higgs boson in pp collisions at root s=8 TeV", J. High Energy Phys. 11 (2015) 018

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

CMS Collabordtion (2132 authors): "Search for new resonances decaying via WZ to leptons in proton-proton collisions at root s=8 TeV", Phys. Lett. B 740 (2015) 83-104

Collaboration, CMS (2135 authors): "Measurement of the pp -> ZZ production cross section and constraints on anomalous triple gauge couplings in four-lepton final states at root s=8 TeV", Phys. Lett. B 740 (2015) 250-272

CMS Collaboration (2210 authors): "Search for new physics in events with same-sign dileptons and jets in pp collisions at root s = 8 TeV (vol 01, pg 163, 2014)", J. High Energy Phys. 1 (2015)

CMS Collaboration (2142 authors): "Measurement of the W boson helicity in events with a single reconstructed top quark in pp collisions at $ sqrt{s}=8 $ TeV", JHEP 1501 (2015) 053

CMS Collaboration (2143 authors): "Measurement of the ratio of the production cross sections times branching fractions of Bc+/- to J/psi pi+/- and B+/- to J/psi K+/- and B(Bc+/- to J/psi pi+/- pi+/- pi-/+)/B(Bc+/- to J/psi pi+/-) in pp collisions at sqrt(s)", JHEP 1501 (2015) 063

V. Khachatryan et al. (2127 authors): "Search for disappearing tracks in proton-proton collisions at root s=8 TeV", J. High Energy Phys. 1 (2015) 096

CMS Collaboration (2146 authors): "Search for long-lived neutral particles decaying to quark-antiquark pairs in proton-proton collisions at root s=8 TeV", Phys. Rev. D 91 (2015)

CMS Collaboration (2143 authors): "Long-range two-particle correlations of strange hadrons with charged particles in pPb and PbPb collisions at LHC energies", Phys.Lett. B742 (2015) 200-224

CMS Collaboration (2137 authors): "Study of vector boson scattering and search for new physics in events with two same-sign leptons and two jets", Phys.Rev.Lett. 114 (2015) 051801

CMS Collaboration (2146 authors): "Measurement of electroweak production of two jets in association with a Z boson in proton-proton collisions at $sqrt{s}=8, ext {TeV}$", Eur.Phys.J. C75 (2015) 66

CMS Collaboration (2143 authors): "Performance of the CMS missing transverse momentum reconstruction in pp data at $sqrt_s$ = 8 TeV", JINST 10 (2015) P02006

CMS Collaboration (2141 authors): "Search for Displaced Supersymmetry in events with an electron and a muon with large impact parameters", Phys.Rev.Lett. 114 (2015) 061801

CMS Collaboration (2131 authors): "Study of Z production in PbPb and pp collisions at $ sqrt{s_ {mathrm{NN}}}=2.76 $ TeV in the dimuon and dielectron decay channels", JHEP 1503 (2015) 022

CMS Collaboration (2147 authors): "Search for monotop signatures in proton-proton collisions at $sqrt{s}$ = 8 TeV", Phys.Rev.Lett. 114 (2015) 101801

CMS Collaboration (2143 authors): "Measurements of jet multiplicity and differential production cross sections of $Z +$ jets events in proton-proton collisions at $sqrt{s} =$ 7 TeV", Phys.Rev. D91 (2015) 052008

CMS Collaboration (2142 authors): "Search for resonances and quantum black holes using dijet mass spectra in proton-proton collisions at $sqrt{s} =$ 8 TeV", Phys.Rev. D91 (2015) 052009

CMS Collaboration (2129 authors): "Search for supersymmetry using razor variables in events with b-tagged jets in pp collisions at root s=8 TeV", Phys. Rev. D 91 (2015) 052018

CMS Collaboration (2145 authors): "Search for physics beyond the standard model in dilepton mass spectra in proton-proton collisions at root s=8 TeV", J. High Energy Phys. 4 (2015) 025

CMS Collaboration (2154 authors): "Measurements of differential and double-differential Drell-Yan cross sections in proton-proton collisions at root s=8 TeV", Eur. Phys. J. C 75 (2015) 147

V. Khachatryan et al. (2148 authors): "Measurement of the production cross section ratio sigma(chi b2(1P))/ sigma(chi b1(1P)) in pp collisions at root s=8TeV", Phys. Lett. B 743 (2015) 383-402

V. Khachatryan et al. (2132 authors): "Search for stealth supersymmetry in events with jets, either photons or leptons, and low missing transverse momentum in pp collisions at 8 TeV", Phys. Lett. B 743 (2015) 503-525

CMS Collaboration (2127 authors): "Search for decays of stopped long-lived particles produced in proton-proton collisions at root s=8TeV", Eur. Phys. J. C 75 (2015) 151

CMS Collaboration (2155 authors): "Search for physics beyond the standard model in events with two leptons, jets, and missing transverse momentum in pp collisions at root s=8 TeV", J. High Energy Phys. 4 (2015) 124

CMS Collaboration (2127 authors): "Measurement of the Z gamma production cross section in pp collisions at 8 TeV and search for anomalous triple gauge boson couplings", J. High Energy Phys. 4 (2015) 164

CMS Collaboration (2146 authors): "Measurement of the inclusive 3-jet production differential cross section in proton-proton collisions at 7 TeV and determination of the strong coupling constant in the TeV range", Eur. Phys. J. C 75 (2015) 186

CMS Collaboration (2145 authors): "Search for a standard model-like Higgs boson in the mu(+)mu(-) and e(+)e(-) decay channels at the LHC", Phys. Lett. B 744 (2015) 184-207

CMS Collaboration (2150 authors): "Precise determination of the mass of the Higgs boson and tests of compatibility of its couplings with the standard model predictions using proton collisions at 7 and 8 TeV", Eur. Phys. J. C 75 (2015) UNSP 212

CMS Collaboration (2124 authors): "Searches for supersymmetry using the M-T2 variable in hadronic events produced in pp collisions at 8 TeV", J. High Energy Phys. 5 (2015) 078

CMS Collaboration (2134 authors): "Searches for supersymmetry based on events with b jets and four W bosons in pp collisions at 8 TeV", Phys. Lett. B 745 (2015) 5-28

CMS Collaboration (2118 authors): "Search for physics beyond the standard model in final states with a lepton and missing transverse energy in proton-proton collisions at root s = 8 TeV", Phys. Rev. D 91 (2015) UNSP 092005

CMS Collaboration (2134 authors): "Search for dark matter, extra dimensions, and unparticles in monojet events in proton-proton collisions at root s=8TeV", Eur. Phys. J. C 75 (2015) UNSP 235

CMS Collaboration (2116 authors): "Nuclear effects on the transverse momentum spectra of charged particles in pPb collisions at root s(NN)=5.02 TeV", Eur. Phys. J. C 75 (2015) UNSP 237

CMS Collaboration / CMS Collaboration (2141 authors): "Study of final-state radiation in decays of Z bosons produced in pp collisions at 7 TeV", Phys. Rev. D 91 (2015)

CMS Collaboration (2143 authors): "Performance of electron reconstruction and selection with the CMS detector in proton-proton collisions at root s=8 TeV", J. Instrum. 10 (2015) P06005

CMS Collaboration (2161 authors): "Search for a standard model Higgs boson produced in association with a top-quark pair and decaying to bottom quarks

using a matrix element method", Eur. Phys. J. C 75 (2015) UNSP 251

CMS Collaboration (2140 authors): "Search for vector-like T quarks decaying to top quarks and Higgs bosons in the all-hadronic channel using jet substructure", J. High Energy Phys. 6 (2015) UNSP 80

CMS Collaboration (2157 authors): "Search for the production of dark matter in association with top-quark pairs in the single-lepton final state in proton-proton collisions at root s=8 TeV", J. High Energy Phys. 6 (2015) 121

CMS Collaboration (2278 authors): "Searches for third-generation squark production in fully hadronic final states in proton-proton collisions at root s=8 TeV", J. High Energy Phys. 6 (2015) 116

CMS Collaboration (2137 authors): "Constraints on parton distribution functions and extraction of the strong coupling constant from the inclusive jet cross section in pp collisions at root s=7TeV", Eur. Phys. J. C 75 (2015) 288

CMS Collaboration (2151 authors): "Evidence for Collective Multiparticle Correlations in p-Pb Collisions", Phys. Rev. Lett. 115 (2015) 012301

CMS Collaboration (2142 authors): "Search for quark contact interactions and extra spatial dimensions using dijet angular distributions in proton-proton collisions at root s=8 TeV", Phys. Lett. B 746 (2015) 79-99

V. Khachatryan et al. (2146 authors): "Measurement of the cross section ratio sigma(t(t)over-barb(b)over-bar)/ sigma(t(t)over-barjj) in pp collisions at root s=8 TeV", Phys. Lett. B 746 (2015) 132-153

CMS Collaboration (2118 authors): "Distributions of topological observables in inclusive three- and four-jet events in pp collisions at root s=7 TeV", Eur. Phys. J. C 75 (2015) 302

CMS Collaboration (2145 authors): "Measurement of diffractive dissociation cross sections in pp collisions at root s=7 TeV", Phys. Rev. D 92 (2015) 012003

CMS Collaboration (2282 authors): "Search for third-generation scalar leptoquarks in the t tau channel in proton-proton collisions at root s=8 TeV", J. High Energy Phys. 7 (2015) 042

CMS Collaboration (2131 authors): "Constraints on the spin-parity and anomalous HVV couplings of the Higgs boson in proton collisions at 7 and 8 TeV", Phys. Rev. D 92 (2015) 012004

CMS Collaboration (2140 authors): "Constraints on the pMSSM, AMSB model and on other models from the search for long-lived charged particles in proton-proton collisions at root s=8TeV", Eur. Phys. J. C 75 (2015) 325

CMS Collaboration (2132 authors): "Search for pair-produced resonances decaying to jet pairs in proton-proton collisions at root s=8 TeV", Phys. Lett. B 747 (2015) 98-119

CMS Collaboration (2144 authors): "Performance of photon reconstruction and identification with the CMS detector in proton-proton collisions at root s=8TeV", J. Instrum. 10 (2015) P08010

CMS Collaboration (2307 authors): "Search for the standard model Higgs boson produced through vector boson fusion and decaying to b(b)over-bar", Phys. Rev. D 92 (2015) 032008

CMS Collaboration (2151 authors): "Search for heavy Majorana neutrinos in mu(+/-)mu(+/-) + jets events inproton-proton collisions at root s=8TeV", Phys. Lett. B 748 (2015) 144-166

CMS Collaboration (2296 authors): "Search for a pseudoscalar boson decaying into a Z boson and the 125 GeV Higgs boson in l(+)l(-)b(b)over-bar final states", Phys. Lett. B 748 (2015) 221-243

CMS Collaboration (2150 authors): "Search for narrow high-mass resonances in proton-proton collisions at root s=8 TeV decaying to a Z and a Higgs boson", Phys. Lett. B 748 (2015) 255-277

CMS Collaboration (2310 authors): "Measurement of the underlying event activity using charged-particle jets in proton-proton collisions at root s=2.76 TeV", J. High Energy Phys. 9 (2015) 137

CMS Collaboration (2301 authors): "Search for neutral color-octet weak-triplet scalar particles in proton-proton collisions at root s=8TeV", J. High Energy Phys. 9 (2015) 201

CMS Collaboration (2139 authors): "Measurements of the Upsilon(1S), Upsilon(2S), and Upsilon(3S) differential cross sections in pp collisions at root s=7 TeV", Phys. Lett. B 749 (2015) 14-34

CMS Collaboration (2172 authors): "Measurement of the Z boson differential cross section in transverse momentum and rapidity in proton-proton collisions at 8 TeV", Phys. Lett. B 749 (2015) 187-209

CMS Collaboration (2147 authors): "Search for lepton-flavour-violating decays of the Higgs boson", Phys. Lett. B 749 (2015) 337-362

CMS Collaboration (2146 authors): "Search for resonant pair production of Higgs bosons decaying to two bottom quark-antiquark pairs in proton-proton collisions at 8TeV", Phys. Lett. B 749 (2015) 560-582

CMS Collaboration (2335 authors): "Search for supersymmetry with photons in pp collisions at root s=8 TeV", Phys. Rev. D 92 (2015) 072006

CMS Collaboration (2289 authors): "Comparison of the Z/gamma* plus jets to gamma plus jets cross sections in pp collisions at root s=8 TeV", J. High Energy Phys. 10 (2015) 128

CMS Collaboration (2297 authors): "Search for a Higgs boson in the mass range from 145 to 1000 GeV decaying to a pair of W or Z bosons", J. High Energy Phys. 10 (2015) 144

CMS Collaboration (2319 authors): "Limits on the Higgs boson lifetime and width from its decay to four charged leptons", Phys. Rev. D 92 (2015) 072010

CMS Collaboration (2308 authors): "Search for neutral MSSM Higgs bosons decaying into a pair of bottom quarks", J. High Energy Phys. 11 (2015) 1-43

CMS Collaboration (2178 authors): "Angular coefficients of Z bosons produced in pp collisions at root S=8 TeV and decaying to mu(+)mu(-) as a function of transverse momentum and rapidity", Phys. Lett. B 750 (2015) 154-175

CMS Collaboration (2307 authors): "Search for diphoton resonances in the mass range from 150 to 850 GeV in pp collisions at root s=8 TeV", Phys. Lett. B 750 (2015) 494-519

CMS Collaboration (2132 authors): "Study of W boson production in pPb collisions at root(NN)-N-S=5.02 TeV", Phys. Lett. B 750 (2015) 565-586

CMS Collaboration (2140 authors): "Measurement of the differential cross section for top quark pair production in pp collisions at root s=8TeV", Eur. Phys. J. C 75 (2015) 542

CMS Collaboration (2322 authors): "Search for supersymmetry in the vector-boson fusion topology in proton-proton collisions at root s=8TeV", J. High Energy Phys. 11 (2015) 189

CMS Collaboration (2150 authors): "Production of leading charged particles and leading charged-particle jets at small transverse momenta in pp collisions at root s=8 TeV", Phys. Rev. D 92 (2015) 112001

CMS Collaboration (659 authors): "Impact of low-dose electron irradiation on n(+) p silicon strip sensors", Nucl. Instrum. Methods Phys. Res. Sect. A-Accel. Spectrom. Dect. Assoc. Equip. 803 (2015) 100-112

CMS Collaboration (2306 authors): "Pseudorapidity distribution of charged hadrons in proton-proton collisions at root s=13TeV", Phys. Lett. B 751 (2015) 143-163

4 International Conference Proceedings

N. Leonardo: "Search and measurement of the B to mumu rare processes with LHC Run I data", Nuclear and Particle Physics Proceedings, NPPP456 (CMS CR-2014/318)

M. Gallinaro: "Tau (or no) leptons in top quark decays at hadron colliders", Proc. 6th International Workshop on Top Quark Physics (TOP2013)

M. Gallinaro: "Top quark physics experimental results at the LHC: Cross section and mass measurements with the CMS experiment", CMS-CR-2015/047

Pietro Vischia: "Search for MSSM H+ bosons decaying into H+ ? taunu and H+ ? tb with l+tau(->had) and dilepton final states", CMS CR-2015/099

7 Collaboration notes with internal referee

Pedrame Bargassa, et al.: "Search for four-body decays of the top squark in the single muon channel at 8 TeV", CMS AN-14-230

M. Gallinaro, F. Nguyen, P. Silva, A. Toldayev, J. Varela, P. Vischia, et al.: "Combination of charged Higgs boson searches with 20/fb of sqrt(s)=8 TeV data", CMS AN-2014/259

Pedrame Bargassa, Lara Lloret, et al.: "Search for direct stop pair production in the semi-leptonic channel at 8 TeV", CMS AN-14-067

S. Chatrchyan et al. [CMS Collaboration]: "Selected Heavy Flavor distributions from CMS with first 13 TeV data", CERN-CMS-DP-2015-018

S. Chatrchyan et al. [CMS Collaboration]: "B Physics analyses for the Phase-II Upgrade Technical Proposal", CMS-PAS-FTR-14-015

P. Bargassa, J.Varela, Cristóvão Beirão da Cruz e Silva, et al.: "Search for Direct Stau Pair Production at 8 TeV", CMS AN-15-038

S. Chatrchyan et al. [CMS Collaboration]: "Dimuon spectrum 2015", CERN-CMS-DP-2015-055

1 Proposal

CMS Collaboration: "Technical Proposal for the Phase-II Upgrade of the CMS Detector", CERN-LHCC-2015-010

Presentations

8 Oral presentations in international conferences

Michele Gallinaro: "Top quark physics: Cross section and mass", 2015-03-01, 29th Rencontres de Physique de La Thuile, La Thuile, Italy

João Varela: "The CT-PPS project and timing detectors", 2015-06-08, WORKSHOP ON PICOSECOND PHOTON SENSORS, Prague

João Varela: "Highlights of three years of LHC physics", 2015-06-30, FLASY2015, Manzanillo, Mexico

João Varela: "Physics Prospects with the CT-PPS Forward Proton Spectrometer", 2015-08-02, LISHEP2015, Manaus, Brazil

Lara Lloret: "CMS: Searches for third generation squarks", 2015-09-01, LHCP, S. Peterburg

Pietro Vischia: "Searches for charged Higgs bosons in pp collisions with the CMS and ATLAS detector", 2015-09-05, LHCP 2015, St. Petersburg, Russia

Michele Gallinaro: "Experimental results on diffraction at the Tevatron", 2015-09-10, Workshop on Forward Physics and High-Energy Scattering at Zero Degrees, HESZ 2015, Nagoya, Japan

Michele Gallinaro: "CMS-Totem Precision Proton Spectrometer: Status and Physics Prospects", 2015-09-10, Workshop on Forward Physics and High-Energy Scattering at Zero Degrees, HESZ 2015, Nagoya, Japan

1 Presentations in national conferences

Michele Gallinaro: "The Higgs or not the Higgs...and beyond", 2015-06-26, A desafiar os limites da ciencia e tecnologia, IST, Lisbon

7 Oral presentations in international meetings

João Varela: "CT-PPS Status Report ", 2015-03-03, LHCC referees meeting, CERN

João Varela: "CT-PPS Status Report ", 2015-06-02, LHCC referees meeting, CERN

Michele Gallinaro: "The CMS-Totem Precision Proton Spectrometer", 2015-10-28, LHC Working group on Forward Physics and Diffraction, CERN, Switzerland

João Varela: "Instrumentation for Particle Detection in Accelerators", 2015-11-11, ESS Partner and Industrial Day , IST Lisbon

Michele Gallinaro: "The standard model Higgs and beyond", 2015-11-15, 5th Egyptian School on High Energy Physics, ESHEP2015, Zewail City, Egypt

Michele Gallinaro: "Probing the SM: Top quark and Higgs", 2015-11-17, 5th Egyptian School on High Energy Physics, ESHEP2015, Zewail City, Egypt

João Varela: "CT-PPS Status Report ", 2015-12-01, LHCC referees meeting, CERN

20 Seminars

Pietro Vischia: "Search for charged Higgs bosons in taunu and tb decays in pp collisions at 7 and 8 TeV with the CMS detector", 2015-01-22, Commission for evaluation the status of the PhD thesis work, Instituto Superior Técnico, Instituto Superior Técnico, Lisboa

Pedrame Bargassa: "Course on Statistics", 2015-02-03, , LIP

Pietro Vischia: "Searching for a charged Higgs boson in pp collisions with the CMS detector", 2015-02-05, LIP Seminar, LIP, Lisboa

João Varela: "Experimental program at the LHC", 2015-02-26, Course on Physics at the LHC, LIP

Michele Gallinaro: "Particle interactions and detectors", 2015-03-09, Course on Physics at the LHC, LIP, Lisbon

João Varela: "Standard Model at the LHC", 2015-03-18, Course on Physics at the LHC, LIP

Michele Gallinaro: "The Top quark: Introuction", 2015-03-23, Course on Physics at the LHC, LIP, Lisbon

Michele Gallinaro: "The Top quark: Properties and beyond", 2015-03-30, Course on Physics at the LHC, LIP, Lisbon

Michele Gallinaro: "LHC Restart at 13 TeV: Achievement Highlights", 2015-04-01, LHC Restart at 13 TeV, IST, Lisbon

Pietro Vischia: "GRID and cloud computing at the LHC", 2015-04-01, LHC 13 TeV program startup – Information to IST students, Instituto Superior Técnico, Lisboa

Lara Lloret: "Working in big collaborations", 2015-04-01, Instituto Superior Tecnico, Lisboa

João Varela: "What is happening at the LHC? ", 2015-04-01, LHC Restart at 13 TeV: Information to the students, IST Lisbon

Michele Gallinaro: "The Top quark: Properties and beyond (part 2)", 2015-04-13, Course on Physics at the LHC, LIP, Lisbon

Michele Gallinaro: "The role of top quark physics in the Higgs era", 2015-04-17, Lecce University, Lecce, Italy

Pedrame Bargassa: "Course on Supersymmetry I", 2015-05-18, , LIP

Pedrame Bargassa: "Course on Supersymmetry II", 2015-05-25, , LIP

Pietro Vischia: "Searching for a charged Higgs boson in pp collisions with the CMS detector", 2015-05-28, IST Seminar (Seminários de Fisica), Instituto Superior Técnico, Lisboa

Nuno Leonardo: "Heavy flavor physics and rare decays", 2015-06-01, Course on physics at the LHC, LIP, Lisbon

João Varela: "Highlights of three years of LHC physics", 2015-07-13, , IST Lisbon

Pietro Vischia: "Reconstruction of taus at CMS", 2015-10-29, LIP Seminar, LIP, Lisboa

Theses

5 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" (ongoing)

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"

Events

1 Conference

TWEPP 2105 - Topical Workshop on Electronics for Particle Physics, IST Centro de Congressos, 2015-09-28 to 2015-10-02

PHENOMENOLOGICAL STUDIES AT THE LHC

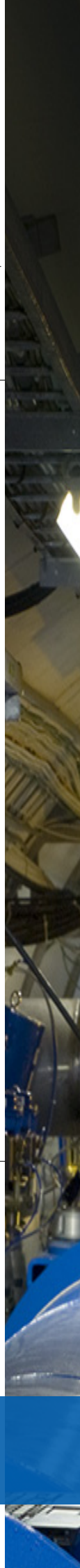
LHC Phenomenology

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), 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 10 years already (since 2006). The project has been crucial to develop research groups for the LHC physics, first in the University of Coimbra and more recently 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

Articles in international journals:	1 With direct contribution from team



EXPERIMENTAL PARTICLE AND ASTROPARTICLE PHYSICS

LHC experiments and phenomenology

Team

Principal Investigator António Onofre (64)

Researchers
José Santiago Perez (20), Juan Aguilar-Saavedra (40), Marco Oliveira Pena Sampaio (15), Miguel Fiolhais (75), Miguel Won (50), Nuno Castro (20), Pedro Martins Ferreira (15), Renato Guedes Júnior (15), Rita Coimbra (100), Rui Santos (15)

PhD students
João Marques de Carvalho (100)

Master students
Mikael Chala (20)

Undergraduate students
Henrique Carvalho (50)

External/Additional scientific collaborators
Augusto Barroso (15), Francisco del Aguila Giménez (20), João Carvalho (35), Roberto Pittau (20)

Total FTE
6.9

// GROUPS: ATLAS / CMS / LHC phenomenology

Lines of work and team organization

1. Top Quark Production at the LHC: The main goal of this task is 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 is 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 is 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 is to be 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 is 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 is the development of theoretical models for the different topics under study and the implementation of dedicated Monte Carlo generators.

6. Smart Computing in Platforms with Accelerator 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).

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;

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

5. theoretical improvements related to models under development and

6. efficient processing in homogeneous and heterogeneous platforms with accelerator devices.

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 can be summarised in the following:

A) A strong collaboration between experimentalists and theoretical physicists was developed for the LHC.

B) 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.

C) 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.

D) 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.

E) The project has been very successful in motivating young students (license, Master and PhD) due to the strong collaboration between experimentalists and theoretical physicists.

F) A strong collaboration between the Particle Physicists and Engineers from the Informatic Engineer Department of the University of Minho has been accomplished.

G) The development of the LIP-Minho group has been very successful, including University Professors, undergraduate, master and PhD students.

H) The list of students directly involved in activities of the project is the following: (undergraduate) Lia Moreira, André Reigoto, Pedro Lagarelhos, José Gomes, Chris Pease, Beatriz Ferreira; (master) Emanuel Gouveia, Rui Martins, Eduardo Dias; (PhD) André Pereira, Susana Santos.

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 (Figure 1), are to be complemented by 3 dimensional distributions as Figure 2 is one example.

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 (example in Figure 3) 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 to be submitted).

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.

6. Smart computing in platforms with accelerator 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.

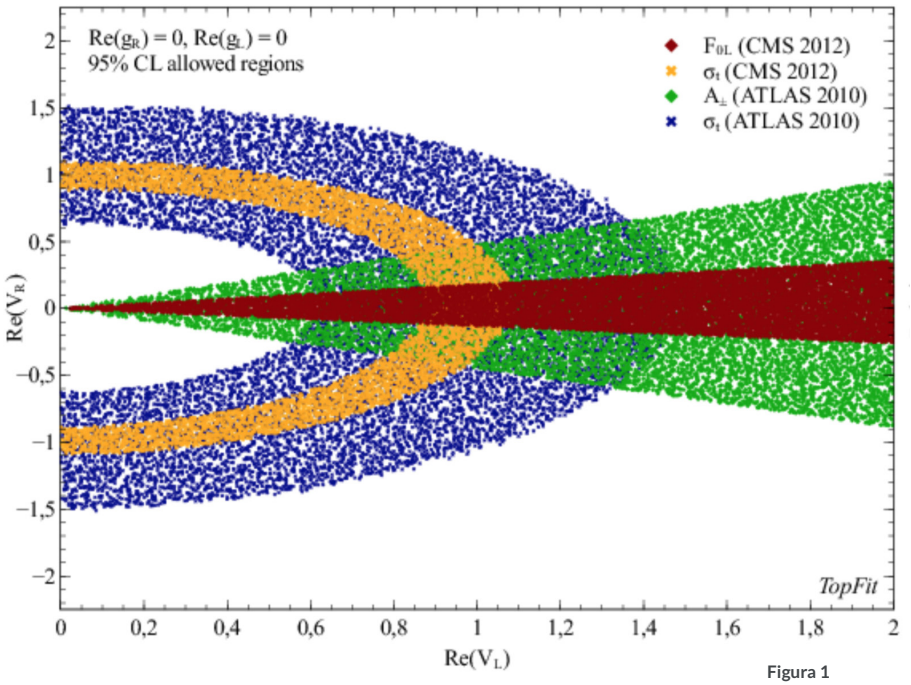


Figura 1

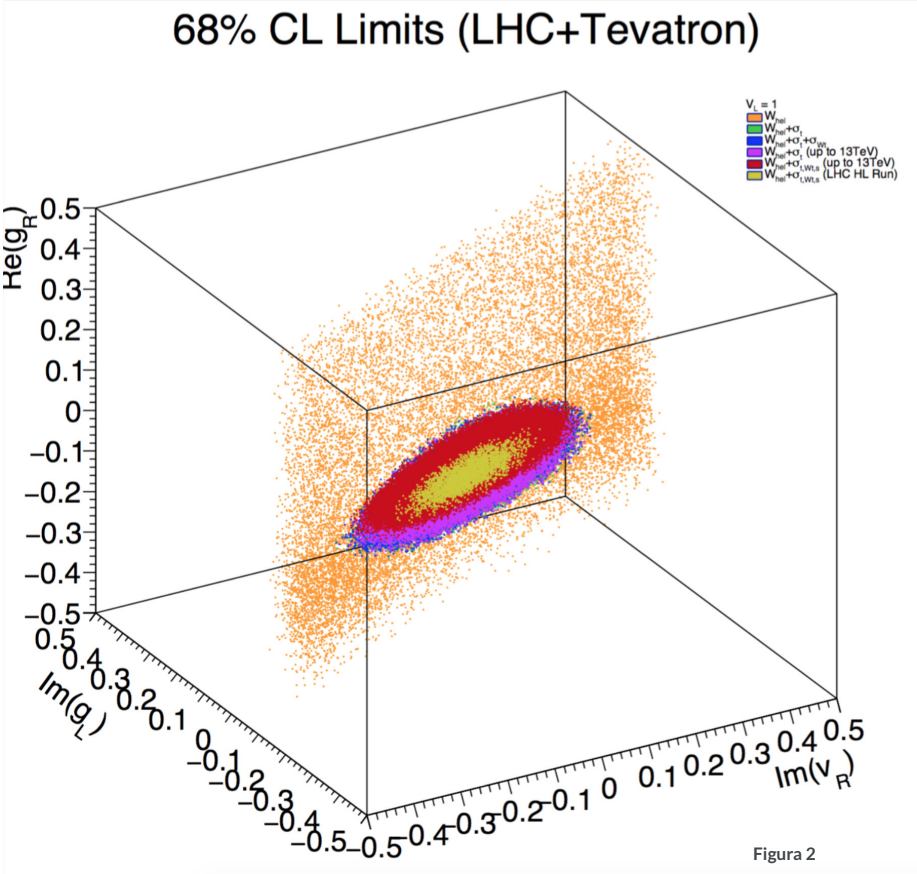
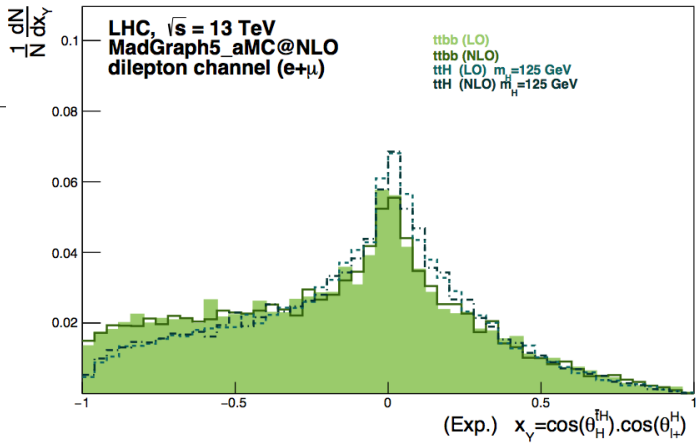


Figura 2



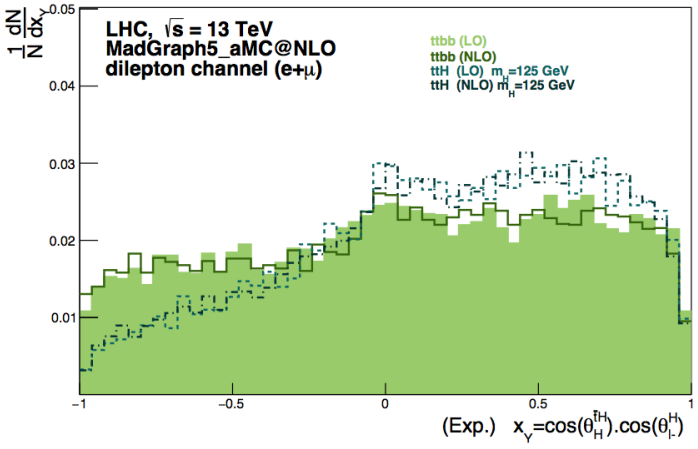


Figura 3

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.

1. The strongest points:

The project was very successful in the past 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).

2. The weakest points:

The weakest point of the project is the very limited budget for the activities planned.

Publications

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

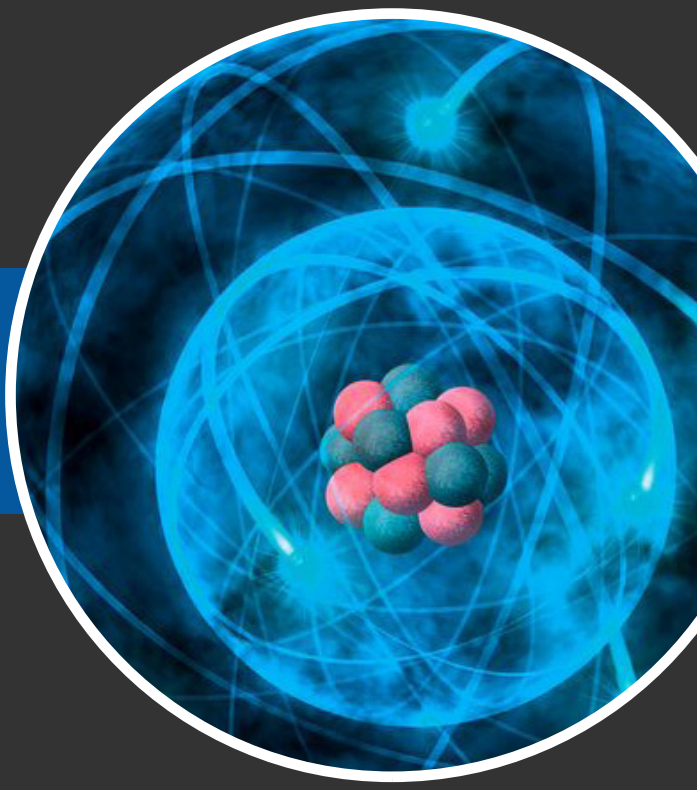
S. P. Amor dos Santos, J. P. Araque, R. Cantrill, N. F. Castro, M. C. N. Fiolhais, R. Frederix, R. Gonçalo, R. Martins, R. Santos, J. Silva, A. Onofre, H. Peixoto, A. Reigoto: "Angular distributions in $t{\bar t}H (H\rightarrow b\bar{b})$ reconstructed events at the LHC", Phys.Rev. D92 (2015) 3, 034021

Theses

1 PhD Thesis

João Marques de Carvalho: (ongoing)

Structure of matter



COLLABORATION IN THE ATLAS EXPERIMENT AT CERN

COMPASS

COMPASS experiment is dedicated to the study of the structure of 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.

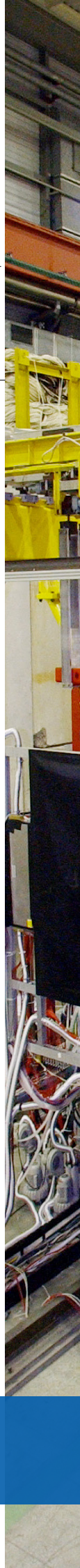
The data acquisition system is based in a parallel read-out of the front-end electronics plus a distributed set of event-builders, specially designed to cope with huge data volumes.Since our LIP-Lisbon group took in COMPASS the full responsibility of the Detector Control System (DCS), it has been continuously 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

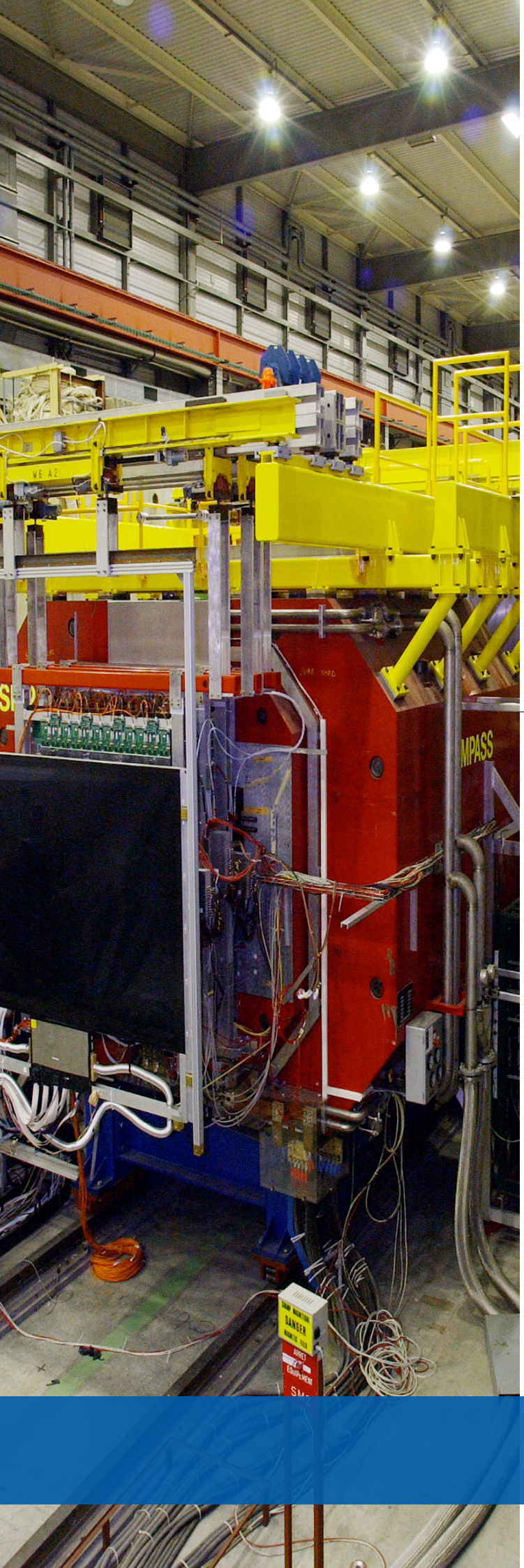
Framework and status for past and current year

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.

In parallel, the group is focusing more and more on offline studies concerning the polarised Drell-Yan physics, such as studies of physical generators and their simulation in the spectrometer, as well as the optimisation of the detector and of the data reconstruction programme.

In what concerns the analysis of the data already acquired, the group is strongly contributing to key subjects of the COMPASS Collaboration, namely studies on the gluon polarisation from high Q^2 events originating from different processes, as the open charm and 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.
In the context of the present COMPASS Program, the members of this Project team 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, which 2015 several months data taking was a first world measurement.In this respect, the group has developed studies concerning the preparation of the DY experiment, namely the design of new spectrometer components, including the dimuon trigger. Its instalation and test has taken 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.

Team

Principal Investigator Paula Bordalo (92)

Researchers
Catarina Quintans (100), Celso Franco (80), Luis Silva (80), Marcin Stolarski (100), Sérgio Ramos (92)

Technicians
Christophe Pires (100)

PhD students
Márcia Quaresma (100), Sofia Nunes (100)

Master students
Miguel Vasco (100)

Total FTE

9.4

Summary of performance indicators

Articles in international journals:	3 With direct contribution from team 6 With indirect contribution
Internal notes:	3 Collaboration notes
International conferences:	2 Oral presentations 1 Proceedings
Outreach:	5 Seminars 1 Outreach event

Lines of work and team organization

Data Analysis / Offline Studies

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

Detector Control System

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 concerning the muon programme, that is, deep inelastic muon scattering.

Moreover, LIP has the full responsibility of the Detector Control System (DCS) of the experiment, since it has been accepted as a member of 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.

In 2015 the following subjects were addressed:

• Study of the gluon contribution to the nucleon Sivers effect from high p_T hadron pairs and high Q^2 .

• Development of a multi-dimensional analysis of the azymuthal spin asymmetries from hadrons produced by muon scattering in a transversely polarised proton (NH_3) target, in order to access the TMD functions, namely Sivers, Collins, pretzelosity and transversity.

• Optimisation of the COMPASS reconstruction programme, namely hit to track association, in view of increasing the track matching efficiency in spectrometer specific parts crucial to the Drell-Yan experiment.

•Insertion of the vertex detector in new reconstruction algorithm, and optimisation of the procedure.

• Preparation of the data production and the data analysis of the 2014 Drell-Yan pilot run.

• Trigger optimisation, performance and timing studies concerning the 2015 long Drell-Yan run.

• Alignment studies and detector calibrations of the new setup spectrometer during the first part of the 2015 DY data taking.

• Estimation of the expected experimental accuracy of polarised Drell-Yan azymuthal asymmetries, as a function of x_F for the 2015 DY run.

• Differential detector efficiencies studies with Monte Carlo.

• 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).

• Measurement of hadron multiplicities in view of the fragmentation functions extraction, namely strangeness to kaon D_s^K(z).

• Development of a new all-p_T method concerning the gluon polarisation extraction, from high Q^2 events (concluded).

Detector Control System

In 2015, the DCS proceeded with the tasks of continuing the integration of new or refurbished COMPASS detectors, in view of the polarised Drell-Yan long data taking.

In this context, the DCS monitoring developments concerned: the new polarised ammonia target, namely the dilution refrigerator, the magnet, the microwave cavities, the NMR probe and the pumps (via several protocols: DIM, DIP and PLCs); the low and high voltages for the new large drift chamber DC5, as well as its temperature monitoring (through DIM); the low and high voltages for the new vertex detector (through OPC).

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.

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 and C.Quintans).

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 2016 our tasks will be the following:

- to continue the optimisation of the COMPASS reconstruction programme due to the major setup changes imposed by the Drell-Yan programme;
- to start the analysis of the 2015 Drell-Yan long data taking;
- to start the extraction of the azymuthal spin asymmetries in the Drell-Yan data;
- to continue the SIDIS study concerning the nucleon Sivers effect with a transversely polarised target and initiate the study on the nucleon Collins effect;
- 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 participate in the preparation of the 2016 DVCS and in its long data taking;
- to participate in the Collaboration and several other COMPASS meetings.

In what concerns our technical commitment in COMPASS, important Detector Control System (DCS) developments will take place during the first period of 2016 to prepare the data taking for the DVCS programme. In fact, due to the very different physics programmes, major changes from the polarised DY setup to the DVCS setup will take place. Specifically, for the DVCS run, new huge detectors are foreseen to be installed and fully controlled by DCS, namely the proton recoil detector and a new electromagnetic calorimeter (for the backward region).

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.

Weaknesses and Threats

The number of students interested in Particle Physics is clearly declining in the last few years, perhaps due to wrong politics of courses reestructurations in our universities. The present national politics on grants attribution together with the absence of a medium term employement strategy is also another cause of refraining the incoming students in our field, in view of the lack of perspectives.

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.

Publications

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

P. Bordalo, C. Franco, C. Pires, A. S. Nunes, M. Quaresma, C. Quintans, S. Ramos, L. Silva, M. Stolarski, et al.: "The COMPASS setup for physics with hadron beams", NIMA 779 (2015) 69-115.

P. Bordalo. C. Franco, M. Quaresma, C. Quintans, A.S. Nunes, S. Ramos, M. Stolarski, L. Silva et al: "Collins and Sivers asymmetries in muonproduction of pions and kaons off transversely polarised protons", Phys. Lett. B 744 (2015) 250-259

M. Stolarski: "Comment on Reevaluation of the parton distribution of strange quarks in the nucleon", Phys. Rev. D92 (2015) 098101

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

P. Bordalo. C. Franco, M. Quaresma, C. Quintans, A.S. Nunes, S. Ramos, M. Stolarski, L. Silva et al: "Odd and even partial waves of ηπ− and η'π− in π−p→η(')π−p at 191 GeV/c", Phys. Lett. B740 (2015) 303

P. Bordalo, C. Franco, M. Quaresma, C. Quintans, A.S. Nunes, S. Ramos, M. Stolarski, L. Silva et al: "Measurement of the charged-pion polarisability", Phys. Rev. D 114, 062002 (2015)

P. Bordalo, C. Franco, M. Quaresma, C. Quintans, A.S. Nunes, S. Ramos, M. Stolarski, L. Silva et al: "Search for exclusive photoproduction of Z±c (3900) at COMPASS", Phys Lett B 742 (2015) 330

C. Adolph et al. (210 authors): "Hadron transverse momentum distributions in muon deep inelastic scattering at 160 GeV/c (vol 73, pg 2531, 2013)", Eur. Phys. J. C 75 (2015) UNSP 94

P. Bordalo, C. Franco, M. Quaresma, C. Quintans, A.S. Nunes, S. Ramos, M. Stolarski, L. Silva et al: "Observation of a new narrow axial-vector meson a1(1420)", Phys. Rev. D 115, 082001 (2015)

M. Stolarski: "Comment on "Reevaluation of the parton distribution of strange quarks in the nucleon"", Phys. Rev. D 92 (2015) 098101

1 International Conference Proceedings

M. Stolarski et al. for COMPASS Collaboration: "COMPASS hadron multiplicity measurements and fragmentation functions", Proceedings of the VI Conference on Physics Opportunities at an ElecTron-Ion Collider, Palaiseau, France

3 Collaboration notes with internal referee

M. Stolarski et al.: "Transverse momentum dependent multiplicities of charged hadrons from 2006 data", 2015-02

A.S. Nunes et al.: "Extraction of Ap1 and g1p for Q2 < 1 (GeV/c)2 in two-dimensional bins from the 2007 and 2011 longitudinal data", release_note_2015-11_1

A.S. Nunes et al.: "systematic error of g1p", release_note_2015-11_2

Presentations

2 Oral presentations in international conferences

Paula Bordalo: "Portuguese Collaboration in the COMPASS Experiment at SPS/CERN", R-ECFA Meeting 2015, Coimbra, Portugal

Marcin Stolarski: "COMPASS hadron multiplicity measurements and fragmentation functions", POETIC6, Palaiseau, France

5 Outreach seminars

Sofia Nunes: "Experiência COMPASS @ CERN", À Caça das Partículas, LIP-Lisbon

Paula Bordalo: "Hands-on @ COMPASS: Introduction & Motivation", Internship: Hands-On @ COMPASS, LIP-Lisbon Hands-On @ COMPASS

Sérgio Ramos: "Introdução às Partículas, Ressonâncias e Massa Invariante", Internship Hands-On @ COMPASS, LIP-Lisbon Hands-On @ COMPASS

Marcin Stolarski: "Alinhamento do Espectrómetro", Internship Hands-On @ COMPASS, LIP-Lisbon Hands-On @ COMPASS

Sofia Nunes: "Sistema de Controlo de Detectores na Experiência COMPASS", Internship Hands-On @ COMPASS, LIP-Lisbon Hands-On @ COMPASS

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" (ongoing)

2 Master Theses

Miguel Vasco: "Study of Drell-Yan in the COMPASS experiment at CERN" (ongoing)

Gonçalo Terça: "AdI TECHNICAL TRAINING: Development of tools for the COMPASS DCS " (ongoing)

Events

1 Outreach Event

Estágio Hands-on @ COMPASS, LIP-Lisbon, 2015-09-17 to 2015-10-16

COLLABORATION IN THE ATLAS EXPERIMENT AT CERN

HADES

In the beginning of 2015, considering the present situation and the tasks still to be carried on in the near future, an extension of the in force Memorandum of Understanding (MOU) was approved by FCT for the next two years, until the end of 2016.

After 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. 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-electron data at baryon densities and temperatures not accessible by other detectors, neither in the past nor in the foreseeable future.

One important handicap is the fact that since the end of 2014, the project is not funded for research activities. In the recent 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 not funded. On the other hand the CERN program, which was a fundamental support on the beginning of this endeavor, is not anymore an option for the project after the policy change towards a much more CERN-centered approach in 2009.

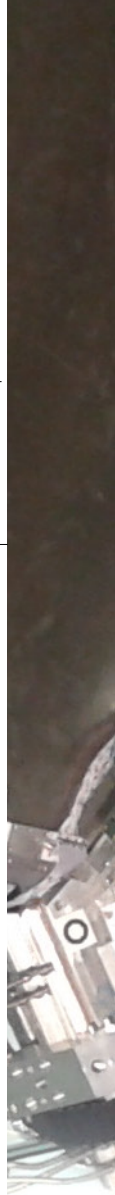
Framework and status for past and current year

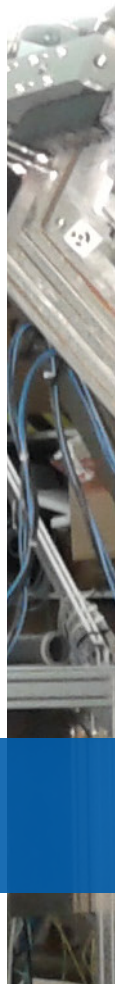
The unique funding support is within the framework of the recently extended MOU, which provides 10k€/year for operation and maintenance.

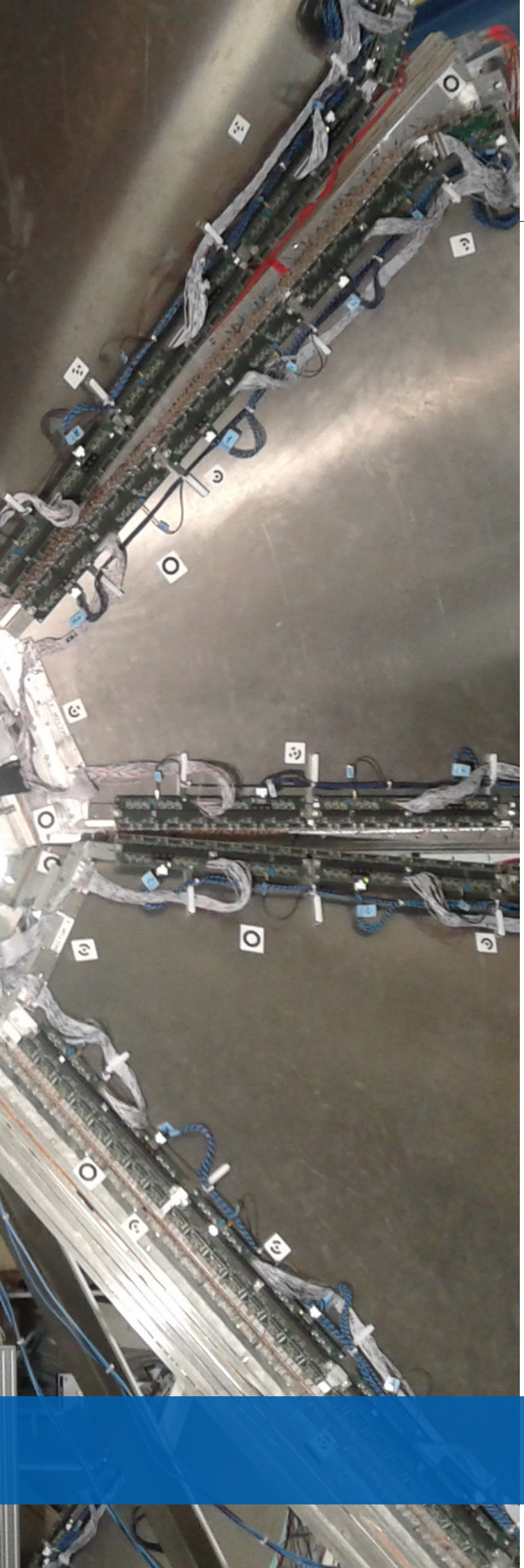
The conjugation of these two circumstances led the research activity of the group to be at minimum levels.

Summary of performance indicators

Articles in international journals:	6 With indirect contribution
Collaboration meetings:	2 Oral presentations
Organization:	1 Collaboration meeting organized







Team

Principal Investigator Alberto Blanco (29)

Researchers
Celso Franco (20), Luis Silva (20), Paula Bordalo (8), Paulo Fonte (12), Sérgio Ramos (8)

Technicians
Luís Lopes (13), Ricardo Caeiro (1)

Total FTE
1.1

Lines of work and team organization

The activities of the group can be summarized in three categories:

- Analysis. The analysis part is focused in two main topics:

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-life" resonances 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.

Strangeness studies. The focus is on the production rate of strange particles in Au+Au collisions (at 1.25 GeV/c2). Special attention will be given to the production of strange particles below the production threshold in N+N collisions.

Responsibility of P. Bordalo, C. Franco, S. Ramos and L. Silva.

- RPC operation. From the point of view of operation, besides the continuous operation of the RPC TOF Wall and operation within the data taking periods, the LIP group will continue collaborating on general duties related with the data taking periods as DAQ operator and shift leader.

Responsibility of A. Blanco, P. Fonte, L. Lopes, C. Franco and L. Silva.

- RPC optimization. Concerning the optimization of the RPC--Wall we will concentrate on developing and completing the monitoring tools. There are still a couple of necessary tools, that were foreseen in the beginning, have not been implemented yet due to lack of time and manpower. Although the calibration strategies of the RPC-TOF are already implemented, efficient and fast tools to prepare the calibration parameters for each data taking period are not available. In addition, tools for the fast detection of anomalies on the performance of the RPC-TOF wall during the data taking period are also missing.

Responsibility of A. Blanco, P. Fonte, L. Lopes.

Sources of Funding

Code	Amount	Dates	Description
PTDC/FIS/113339/2009	91.742 €	2011-04-01 / 2015-01-31	FCT- R&D projects in all domains - Participation in HADES

Stated objectives for past year

1. Physics analysis, focused on the mass properties of short lived mesons in the dilepton channel, the study of the non-resonant mass spectrum of dileptons and the study of the momentum and multiplicity distributions of particles with strangeness.

2. RPC operation. Collaboration on general duties related with the data taking periods as DAQ operator and shift leader besides the continuous operation of the RPC.

3. RPC optimization. Development and finalization of the monitoring tools. This includes the implementation of monitor tools to check the quality of the gas and the health of the detectors using the reference chambers and trigger signal monitoring.

Achievements and responsibilities during the past year

The accelerator infrastructure has been shut down for a complete upgrade in 2015. Consequently, there were no activities concerning data taking or operation. In addition, since the end of 2014 the project is not funded for research activities. The conjugation of these two circumstances led the research activity of the group to be at minimum levels.

Nevertheless, the continuous operation and maintenance of the detector (It should be noted that due to the intrinsic characteristics of the detector it is kept powered and running all the time) and the ongoing physics analysis were maintained during 2015.

With respect to the physics analysis, a lepton purity of 97% was achieved in the dilepton analysis. The group contributed to this result by using a dynamic Neural Network for the PID of leptons. Furthermore, detailed studies of the efficiency and acceptance corrections were performed. These corrections will be applied to the dilepton mass spectrum. Concerning the physical background, several simulation studies were performed with the purpose of removing the dilepton contamination resulting from photon conversion in the spectrometer.

The group is also collaborating actively with the ECAL group on the installation of the new electromagnetic calorimeter of HADES, which will have a huge impact on the RPC detector since it will be supported on the ECAL frame. Therefore, the mechanics and all the cabling should be revisited to meet the new requirements.

Concerning management and organization, the group organized in Oct 2015 one of the collaboration meeting of the year, held in Estoril.

Lines of work and objectives for next year

The research activities continue to be unfunded at this moment, but the group is actively looking for other opportunities of funding.

During 2016 the accelerator infrastructure will be inoperative, therefore no activities concerning data taking or operation are foreseen, but as usual we will guarantee the continuous operation and maintenance of the RPC.

On the physics analysis side, strangeness studies are proposed namely the multiplicity distribution of strange particles, momentum distributions, which may provide information regarding the production rates of the different strange hadrons. For these studies it becomes important to optimize the efficiency of the particle identification so as to obtain a set of events with a higher purity and better statistics. To this end, we intend to optimize the Kaon identification using the RPC detectors (in particular K- particles). From the lepton analysis, the goal is to correct for the slightly different acceptances that exist between tracks of opposite polarities. Such correction is crucial to remove the combinatorial background (from the dilepton mass spectrum) using the geometric mean of like-sign combinations. Another goal is to use simulated events embedded in real data in order to correct for the efficiency of the lepton selection in a more realistic way. Several systematic studies concerning the PID of leptons will also be performed. Here a new approach for the selection of leptons will be attempted: a neural network parametrization of tracks including the information about their back-propagation towards the RICH detector (Cherenkov ring-finding).

The group has recently got involved on the simulation of a new Time of Flight detector to cover the very low polar angles on the forward region call TOF-FD where the use of RPC technology is been evaluated. It is expected that this activity will gain importance.

The group will continue collaborating with the ECAL group towards the final installation of the RPC on the new ECAL frame.

SWOT Analysis

Strengths

The skills and accumulated know-how in 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 HADES-LIP 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 physics 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.

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

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

HADES Collaboration (96 authors) : "Partial wave analysis of the reaction p(3.5 GeV)+p→pK+Λp(3.5 GeV)+p→pK+Λ to search for the "ppK−ppK−" bound state", Physics Letters B 742 6, 242–248

HADES Collaboration (99 authors): "Subthreshold Xi(-) Production in Collisions of p(3.5 GeV) + Nb", Phys. Rev. Lett. 114 (2015) 212301

HADES Collaboration (105 authors): "Highlights of Resonance Measurements With HADES", EPJ WEB CONF 97 (2015) 00015

HADES Collaboration (105 authors): "Investigating hadronic resonances in pp interactions with HADES", EPJ WEB CONF 97 (2015) 00024

HADES Collaboration (98 authors): "K*(892)(+) production in proton-proton collisions at E-beam=3.5 GeV", Phys. Rev. C 92 (2015) 024903

HADES Collaboration (105 authors): "Study of the quasi-free np→npπ+π−np→npπ+π− reaction with a deuterium beam at 1.25 GeV/nucleon", Physics Letters B Volume 750, 12 November 2015, Pages 184–193

Presentations

2 Oral presentations in collaboration meetings

Celso Franco: "Latest results on the Au+Au dilepton mass spectrum using gen7", HADES Collaboration Meeting XXIX, Darmstadt, Germany

Celso Franco: "Determination of the dilepton mass spectrum using gen8", HADES Collaboration Meeting XXX, Estoril, Portugal

Events

1 Collaboration meeting

HADES Collaboration Meeting XXX, Hotel Estoril Eden, Estoril, Portugal, 2015-10-07 to 2015-10-10

Cosmic rays

COLLABORATION IN THE ATLAS EXPERIMENT AT CERN

AMS

LIP is since 1998 part of a broad international collaboration that designed and operates the Alpha Magnetic Spectrometer (AMS). The project had two distinct phases: first a prototype was built and flew aboard the space shuttle in 1998 and a after a final detector was installed in the international space station (ISS), in May 2011. The experiment is expected to be carried out up to at least 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 60 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.

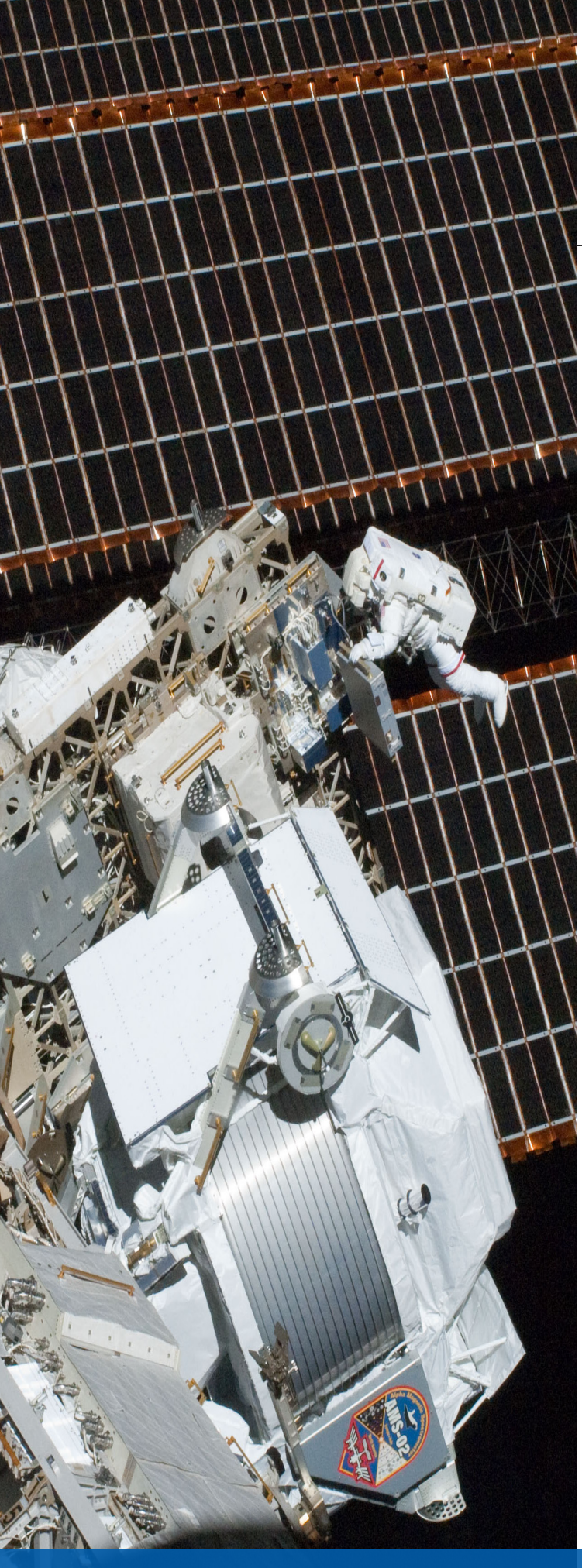
Framework and status for past and current year

Summary of performance indicators

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

EXPERIMENTAL PARTICLE AND ASTROPARTICLE PHYSICS

Cosmic rays



Team

Principal Investigator Fernando Barão (85)

Researchers
Luisa Arruda (20)

PhD students
Miguel Orcinha (100)

Master students
Pedro Nunes (100)

Total FTE
3.0

// GROUPS: AMS / Auger

Lines of work and team organization

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

- The LIP group is responsible for the development and ongoing improvement of one of the two sets of reconstruction algorithms implemented for the RICH subdetector. The algorithms provide measurements of particle velocity and electric charge based on Cherenkov ring patterns. The group studies include the evaluation and monitoring of the reconstruction accuracy up to the highest possible nuclear charges.
- The AMS detector monitoring and operation is carried out 24h/24h in the POCC (Payload Operations and Control Center) 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.
- 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.

Stated objectives for past year

The main objectives of the group for 2015 were:

- to fulfill our engagement in the monitoring operations at CERN
- to monitor the reconstruction tools perfomance developed by the group
- to optimize the solution solar modulation equation in two dimensions and start to prepare a set of criteria for data analysis selection of different species, to be used on variability studies
- to participate in the optimization of the anti-proton selection based on the electromagnetic calorimeter
- start the development of a statistical estimator for the isotopic separation data analysis

Achievements and responsibilities during the past year

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

MO continued his work on the RICH velocity resolution studies. Previously, a model for RICH velocity was developed with the aim of extracting the effect of Tracker resolution from the velocity analysis. This model was explored further and applied to both Data and Monte-Carlo. Extensive studies were performed on different variables in order to estimate sources for RICH resolution and determine RICH's single-photon resolution. These studies are still undergoing.

MO began his analysis on the time variability of the low-energy proton flux of AMS. A selection and corresponding NTuple were developed taking into account the time dependency of the analysis but keeping its modularity so it could be split into jobs (and later fully parallelized). It requires preservation of event order, in order to study time dependency, event splitting in order to study trigger and Tracker efficiency and an organization into different time scale bins in order to estimate correct time exposure. These constraints required improvements to the selection platform and allowed for the initiation of a parallelization scheme based on OpenMPI to be applied not only to this data analysis but to the group's selection platform.

LA was responsible for the RICH reconstruction performance monitoring. The RICH detector response presents no particular variations with the 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 2015 Fernando Barão took part on the following thesis defence panels:

- Rapporteur of PhD thesis, "Étude du rayonnement de vestiges de supernova en interaction avec des nuages moléculaires et optimisation de l'analyse des données de H.E.S.S." presented by Cyril Trichard in Université Grenoble Alpes, (Sep, 2015)
- Member of the PhD thesis jury: "Measurement of the cosmic lepton and electron fluxes with the AMS detector on board of the International Space Station. Monitoring of the energy measurement in the calorimeter", presented by Li Tao, in "Université Grenoble Alpes" (July, 2015).
- Advisor of the MSc thesis "Optimization de l'identification d'antiprotons a haute energie (100-500 GeV/c)", presented by Sandy Aupetit in "Université Grenoble Alpes" (July, 2015).
- Reviewer of the MSc Thesis "Search for photons in the ultra-high cosmic rays", presented by Vincent Schipperges in "Université Grenoble Alpes" (July, 2015).

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

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 the 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.
- Evaluation of aerogel velocity resolution tile by tile
- Study of systematic effects on velocity with particle direction and radial impact position
- Evaluation of the RICH reconstructed charge stability over time Gain factors and pedestal values used in the calibrations and their correlated with temperature, in order to ensure the stability of detected signal, for the different nuclei
- Evaluation of the charge resolution obtained for different nuclei

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 proton, helium and electron fluxes
- Charge signal effect on cosmic ray flux
- Temporal variability study of cosmic ray fluxes
- Implementation and improvement of Solar Modulation computational models

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 leaving of post-docs on 2015. In this context it becomes hard to host and support long term students. Moreover and as a genereal reflexion, LIP as laboratory could have a long term scientific strategy able to afford the financial fluctuations arriving to smaller groups and that can be very dramatic to their existence. Although most of LIP scientific staff is concentrated in major projects, it should be envisaged a more balanced distribution of the scientific resources. In addition and sporadically, specific recruitment able to strengthen smaller projects should be devised (off course, much less power demanding), in order to guarantee at LIP an enriched set of scientific options.

Oportunities

AMS keeps going to be 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

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

AMS Collaboration (296 authors): "Precision Measurement of the Proton Flux in Primary Cosmic Rays from Rigidity 1 GV to 1.8 TV with the Alpha Magnetic Spectrometer on the International Space Station", Phys. Rev. Lett. 114, 171103

AMS Collaboration (296 authors): "Precision Measurement of the Helium Flux in Primary Cosmic Rays of Rigidities 1.9 GV to 3 TV with the Alpha Magnetic Spectrometer on the International Space Station", Phys. Rev. Lett. 115, 211101

Presentations

1 Oral presentation in international conferences

Fernando Barão: "AMS: a cosmic ray experiment in space - status and results", 2015-07-01, , Institute de Physique Nucléare ORSAY - IPNO

1 Poster presentations in international conferences

Fernando Barão: "Non-parametric determination of H and He IS fluxes from TOA cosmic-ray data", 2015-10-18, Solar Energetic Particles (SEP), Solar Modulation and Space Radiation: New Opportunities in the AMS-02 Era (workshop), Honolulu, Hawaii

2 Presentations in national conferences

Miguel Orcinha: "Short-term structures in the AMS-02 proton flux", IDPASC Workshop on "Space Particles and Earth", Évora, Portugal

Fernando Barão: "AMS, a cosmic ray observatory in space", IDPASC Workshop on "Space Particles and Earth", Évora, Portugal

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

In November 2015 the science funding agencies and the main laboratories signed, at Malargue, the renewal of the international agreement of the Pierre Auger Observatory assuring its continuous operation until 2025. For Portugal both FCT and LIP signed the agreement and the Portuguese ambassador in Argentina was present at the signing ceremony. In fact, after ten years of data taking the results from the Pierre Auger Observatory have brought new fundamental insights into the origin and nature of highest-energy cosmic rays. 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, even more detailed measurement of the nature of cosmic particles at the highest energies, as well as a better understanding of the hadronic interaction at such energies, is crucial to understand the mechanisms responsible for this decrease. A minimal upgrade plan was approved, with the goal of enabling a better understanding of the electromagnetic and muonic shower components. It foresees the installation of scintillators at the top of the present surface detectors and the replacement of their readout electronics.

The LIP team has been deeply involved in the last years in the development of autonomous low gas flux, low cost, large surface (2 m^2) RPC detectors, the MARTA project. More than 20 such detectors were produced at

Framework and status for past and current year

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. The MARTA upgrade proposal was not finally selected by the collaboration. Nevertheless 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). In this context the installation at Malargue of a MARTA engineering array of 8 surface detectors (36 MARTA detectors) was recently approved in a very competitive joint FCT/FAPESP call. This project will run for three years in a close collaboration between Portugal and Brazil. MARTA detectors are also being installed at CBPF in Rio de Janeiro and their possible use in a possible future large field of view gamma-ray observatory at very high altitude in South America (the LATTES project) is under study.

On the other hand, 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 Mário Pimenta (85)

Researchers
Alberto Blanco (33), Alessandro de Angelis (28), Bernardo Tomé (85), Catarina Espírito Santo (45), Helmut Wolters (33), João Espadanal (50), Lorenzo Cazon (83), Patrícia Gonçalves (10), Paulo Fonte (5), Pedro Abreu (70), Pedro Assis (85), Pedro Brogueira (15), Raul Sarmento (100), Ruben Conceição (100), Sofia Andringa (50)

Technicians
Américo Pereira (15), Luís Lopes (30), Luís Mendes (88), Miguel Ferreira (91), Nuno Carolino (5), Orlando Cunha (5)

PhD students
Francisco Diogo (100), João Espadanal (50), Ricardo Luz (75)

Master students
Bernardo Rosário (95), David Soares (starting in 2016), Paulo Ferreira (83)

External/Additional scientific collaborators
Liliana Apolinário (15), Nikolas Kemmerich (75), Thomas Schweizer (10)

Total FTE

16.1

Summary of performance indicators

Articles in international journals:	2 With direct contribution from team 8 With indirect contribution
Internal notes:	6 Collaboration notes
Books:	2 Books published
International conferences:	3 Oral presentations 4 Posters 7 Proceedings
National conferences:	1 Presentation
Collaboration meetings:	31 Oral presentations
Seminars:	1 Seminar
Outreach:	3 Outreach seminars
Completed theses:	1 PhD Thesis
Organization:	2 Collaboration meetings organized

// GROUPS: AMS / Auger

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, with more than 100 scientists collaborating. He has also been part of 3 editorial boards and internal referees in Auger Journal Publications in several papers of which one has been already published and the other two are to be published this year.

Sources of Funding

Code	Amount	Dates	Description
EPLANET 246806	25.000 €	2011-01-01 / 2016-01-31	European Particle physics Latin America NETwork
ASPERA/0001/2010	150.000 €	2012-09-01 / 2015-08-31	AStroParticle ERAnet - AugerNext - New experiments
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 stated objectives for the different tasks were as follows:

1. Systematic studies on the characterization of the response of the water Cerenkov tanks to the passage of muons (charged particles).

2. and 3. Development of a HV Power Supply Unit; Development of MARTA DAQ; Development of an RPC module with HV and DAQ embedded.

4. Determination of the mean and the RMS of the distribution of the number of muons reaching ground.

5. Determination of independent shape variables sensitive to composition and hadronic interactions from the full electromagnetic longitudinal profiles.

6. The development of analyses methods to disentangle in an upgraded detector the mass of the primaries and the details of hadronic physics at energies beyond those reached by LHC.

7. The development of education and public outreach activities and tools, namely using the Auger public data set.

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. Several data acquisitions campaigns, using different configurations, were performed to study the Gianni Navarra tank response. The results show, at this point, that the mean behavior of the acquired data is compatible with simulations to the percent level.

2. and 3. Prototypes of both HV and MARTA DAQ were produced. An engineering prototype of an RPC with embedded electronics was produced.

4. 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 and to subtract those fluctuations coming from the SD detector resolution as well as those inherited from the energy reconstruction from FD. 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.

4. and 5 The analysis of the mean shape of the lateral density function of the high energy cosmic ray data as seen by the present SD was performed and compared to the model predictions for which the muonic and electromagnetic components can be separated, as in the spirit of the Auger upgrade. From this study, there is new independent evidence that the muon production in the models must be changed, not only in total numbers, to describe the high energy data.

5. The first measurement of the average longitudinal profile shapes of the showers measured by the FD, described by two new independent parameters that are sensitive to primary composition was presented at the ICRC. The present accuracy is limited by systematic uncertainties and the data is compatible with models, although with some stress at the highest available energies.

6. A method to interpret the number of muons measurements in extensive air shower experiments was developed. The method is able to verify/falsify mass composition scenarios almost independently of the absolute energy scale and standard high-energy hadronic interaction models.

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 now available in Portuguese, English and Spanish. The guide was used both at schools (in activities developed along the year by the teachers with our support) and at LIP (in summer internships for high school students).

Lines of work and objectives for next year

The group will continue to pursue an ambitious program which will be organized in tasks each led by a team member:

Task 1 - "Detailed characterization of the SD detectors" - Coordinator: Pedro Assis

In 2016 we expect to stabilize the setups in Malargüe and to conduct data acquisitions. The collected data will allow estimating the tank response at large angles. We will also use the Tierra del Fuego Setup as a prototype installation of MARTA.

Task 2 - "MARTA RPCs R&D" - Coordinator: Luis Lopes

In the year 2016 we intend to test the first prototypes with embedded electronics in outdoor conditions. Indoor tests have shown that flushing the aluminum case with the gas exhaust from the sensitive volume improves chamber stability. We need to confirm these observations in an outdoor environment. A set of sensors to monitor the gas flow rate and quality/humidity contamination is near the end of the R&D phase and will be installed in all indoor and outdoor setups. Indoor tests will continue, stressing a couple of chambers to large amounts of integrated charge to evaluate the chambers life time. Production and test (both indoor and outdoor) of low-consumption HV power supplies developed at LIP will take place during 2016.

Task 3 - "MARTA Engineering Array" - Coordinator: Pedro Assis

2016 will be a crucial year for the production of MARTA Hardware. The technology transfer to Brazilian companies will be completed. Prototypes of the detectors hardware will be produced in preparation for production. By the end of the year the production should start.

Task 4 - "Measurement of the muonic component of Extreme Energy Cosmic Rays showers" - Coordinator: Lorenzo Cazon

The goals are:

1. 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;

2. lead and develop methods to reconstruct the number of muons in the vertical range and its fluctuations;

3. develop the phenomenological models within the air shower to interpret the MPD results and the muon content and fluctuations.

Task 5 - "Measurement of the electromagnetic component of Extreme Energy Cosmic Rays showers" - Coordinator: Sofia Andringa

In 2016 the analysis of the mean lateral particle density function of the high energy cosmic ray data as seen by the present SD will be pursued, now focusing on constraining the electromagnetic component and relating it to the longitudinal profiles, in order to more directly extract the characteristics of the muonic component from data. We will work towards a journal publication of the average longitudinal profile shape measurements.

Task 6 - "Theory and Models for High Energy Interactions" - Coordinator: Ruben Conceição

2016 shall be dedicated to understand, in close collaboration with task 4, the phenomenology of muon production in air showers and its relation with multi-particle production in hadronic interactions. Two major lines of work are 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.

Task 7 - "Education and Public Outreach in the area of high energy cosmic rays" - Coordinator: Catarina Espirito Santo

Activities based on the Auger public data set and on our work guide for its exploitation are being conducted also in this school year and we will follow the process. Summer internships will be carried on once more, as well as many seminars in schools. In the 30 years of LIP, our team will actively contribute to the celebrations, with the goal of increasing the visibility of the lab and of the field.

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

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

Pierre Auger Collaboration (487 authors): "Muons in air showers at the Pierre Auger Observatory: Measurement of atmospheric production depth (vol 90, 012012, 2014)", Phys. Rev. D 92 (2015) 019903

The Pierre Auger Collaboration: "The Pierre Auger Cosmic Ray Observatory", NIM A 798 (2015) 172-213

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

The Pierre Auger Collaboration: "Muons in air showers at the Pierre Auger Observatory: mean number in highly inclined events", Physical Review D 91, 032003 (2015)

The Pierre Auger Collaboration: "Large scale distribution of ultra high energy cosmic rays detected at the Pierre Auger Observatory with zenith angles up to 80 degrees", Accepted for publication in Astrophysical Journal

Pierre Auger Collaboration (481 authors): "SEARCHES FOR ANISOTROPIES IN THE ARRIVAL DIRECTIONS OF THE HIGHEST ENERGY COSMIC RAYS DETECTED BY THE PIERRE AUGER OBSERVATORY", Astrophys. J. 804 (2015) 15

Pierre Auger Collaboration (464 authors): "Improved limit to the diffuse flux of ultrahigh energy neutrinos from the Pierre Auger Observatory", Phys. Rev. D 91 (2015) 092008

Pierre Auger Collaboration (486 authors): "Search for patterns by combining cosmic-ray energy and arrival directions at the Pierre Auger Observatory", Eur. Phys. J. C 75 (2015) 269

Pierre Auger Collaboration (463 authors): "Measurement of the cosmic ray spectrum above 4 x 10(18) eV using inclined events detected with the Pierre Auger Observatory", J. Cosmol. Astropart. Phys. 8 (2015) 049

The Pierre Auger Collaboration, Telescope Array Collaboration, IceCube Collaboration : "Correlation between the UHECRs measured by the Pierre Auger Observatory and the Telescope Array and the neutrino candidate events from IceCube.", JCAP 01 (2016) 037

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

7 International Conference Proceedings

A. De Angelis, M. Pimenta, R. Conceicao: "Messengers of the High Energy Universe", Springer Proc.Phys. 161 (2015) 283-335

João Espadanal for the Pierre Auger Collaboration: "Measurement of the Muon content of EAS with the Pierre Auger Observatory", Particle and Astroparticle Physics, Gravitation and Cosmology: Predictions, Observations and New Projects, 2015, pp. 287-292. Proceedings of the XXX-th International Workshop on High Energy Physics, Protvino 2014, Russia.

R. Conceicao, S. Andringa, F. Diogo, M. Pimenta: "The average longitudinal air shower profile: exploring the shape information", J PHYS CONF SER 632 (2015) 012087

R. Conceição for the Pierre Auger Collaboration: "High-energy interactions at the Pierre Auger Observatory", Proceedings of the EPS-HEP, Vienna, 2015. arXiv:1510.06898[astro-ph.HE]

R. Sarmento, P. Abreu, S. Andringa Dias, P. Assis, A. Blanco Castro, P. Brogueira, N. Carolino, L. Cazon, M. Cerda, G. Cernicchiaro, R. Colalillo, R. Conceição, O. Cunha, F. Diogo, J. Espadanal, M. Ferreira, P. Fonte, U. G: "Muon Array with RPCs for Tagging Air showers (MARTA)", Proceedings of the 34th International Cosmic Ray Conference PoS(ICRC2015)629

Francisco Diogo for the Pierre Auger Collaboration: "Measurement of the average electromagnetic longitudinal shower profile at the Pierre Auger Observatory", Proceedings of the 34th International Cosmic Ray Conference

Pedro Assis for the Pierre Auger Collaboration: "Measurement of the water-Cherenkov detector response to inclined muons using an RPC hodoscope", Proceedings of the 34th International Cosmic Ray Conference PoS(ICRC2015)620

6 Collaboration notes with internal referee

Lorenzo Cazon, Catarina Espirito Santo, Alan Watson: "A new approach to probing the upper reaches of air-showers ", GAP2015_015

Raul R. Prado, Ruben Conceição, Mario Pimenta, Vitor de Souza: "Predictions of the Moments of the Number of Muons Distributions", GAP2015_025

P. Assis, A. Blanco, M. Cerda, R. Conceicao, F. Diogo, M. Ferreira, P. Fonte, L. Lopes, L. Mendes, M. Pimenta, R. Sarmento, R. Sato, C. Scarso, R. Shellard, B. Tome, H. Wolters: "Measurements with the RPC Muon Hodoscope Installed at the Gianni Navarra Tank: First Results", GAP2015_033

L. Cazon, M. Pimenta, G. Torralba Elipe, I. Valiño and E. Zas: "Measurement of the N_mu fluctuations using inclined showers", GAP2015_056

João Espadanal: "Study of the longitudinal and transverse cosmic ray shower pro files at the Pierre Auger Observatory.", GAP2015_079

Ruben Conceição, Bernardo Tomé: "Some comments on the Offline coordinate system and its relation with the GEANT4 simulation of the WCD.", GAP2015_084

2 Books

M. Pimenta al. (Editor): "Proceedings of the 24th European Cosmic Ray Symposium", J.Phys.Conf.Ser. 632 (2015) 1.

Alessandro De Angelis, Mário Pimenta: "Introduction to Particle and Astroparticle Physics", Undergraduate Lecture Notes in Physics, Springer. ISBN: 978-88-470-2687-2 (Print) 978-88-470-2688-9 (Online)

Presentations

3 Oral presentations in international conferences

Mário Pimenta: "Particle Physics at sqrt(s) =100 TeV with high energy cosmic rays", Fourteenth Marcel Grossmann Meeting, University of Rome

Ruben Conceição: "High-energy interactions at the Pierre Auger Observatory", EPS-HEP, European Physical Society Conference on High Energy Physics, 2015, Vienna, Austria

Lorenzo Cazon: "Hadronic physics with the Pierre Auger Observatory", CRIS 2015, Cosmic Ray International Seminar, Gallipoli, Italy

4 Poster presentations in international conferences

Raul Sarmento: "Muon Array with RPCs for Tagging Air showers (MARTA)", 34th International Cosmic Ray Conference, The Hague, The Netherlands

Pedro Assis: "Measurement of the water-Cherenkov detector response to inclined muons using an RPC hodoscope", 34th International Cosmic Ray Conference, The Hague, The Netherlands

Francisco Diogo: "Measurement of the average electromagnetic longitudinal shower profile at the Pierre Auger Observatory", 34th International Cosmic Ray Conference, The Hague, The Netherlands

Ricardo Jorge Barreira Luz: "DAQ of MARTA RPCs", EDIT2015, Excellence in Detectors and Instrumentation Technologies, 2015, INFN, Frascati, Italy

1 Presentation in national conferences

João Espadanal: "Cosmic Rays Anisotropies and Point Sources at Pierre Auger Observatory", XXV ENAA 2015, Encontro Nacional de Astronomia e Astrofísica, Lisboa, Portugal

1 Seminar

Mário Pimenta: "MARTA and Lattes", Santiago de Compostela, Spain

3 Outreach seminars

Mário Pimenta: "Olhares sobre o Universo", Escola secundaria Mouzinho da Silveira, Portalegre

Sofia Andringa: "Astropartículas no LIP", 2015-06-29, Ocupação Científica de Jovens em Férias 2015, LIP, Lisboa

Pedro Abreu: "Partículas e Raios Cósmicos", 2015-10-29, Escola Secundária Ginestal Machado, Santarém

Theses

3 PhD Theses

João Espadanal: "Study of hadronic interactions with the hybrid detector of the Pierre Auger Observatory" (finished on 2015-07-15)

Francisco Diogo: "Medição da secção eficaz de raios cósmicos de alta energia no Observatório Pierre Auger" (ongoing)

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

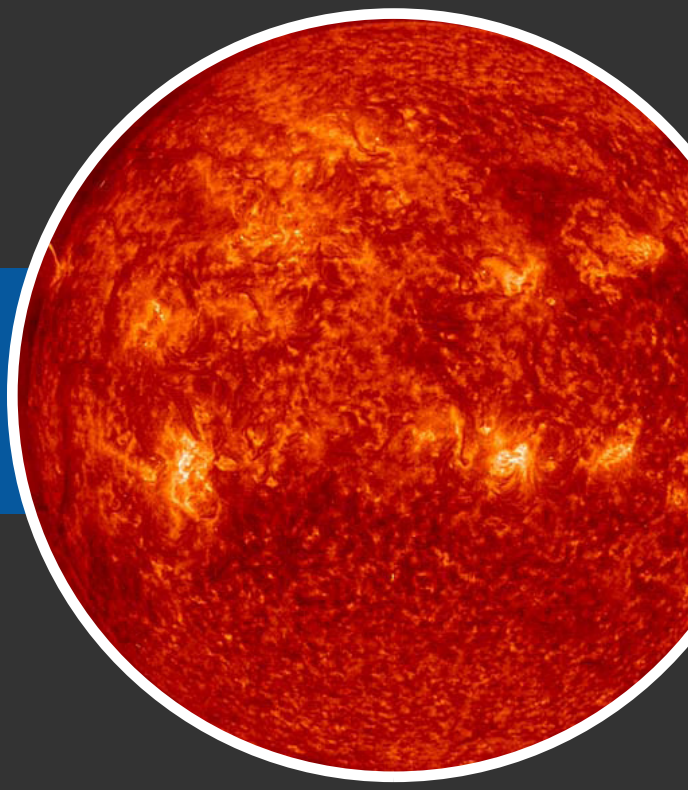
Events

2 Collaboration Meetings

6th MARTA Progress Meeting, CBPF - Centro Brasileiro de Pesquisas Físicas, Rio de Janeiro, Brasil, 2015-03-02 to 2015-03-03

7th MARTA Progress Meeting, Lisboa, 2015-10-05 to 2015-10-06

Dark matter and neutrinos



PARTICIPATION IN DARK MATTER EXPERIMENTS AND R&D ON LIQUID XENON DETECTORS FOR DARK MATTER SEARCH

LUX/LZ

The activity of this LIP group has been carried out in the framework of the direct detection dark matter experiments "Large Underground Xenon" (LUX) and LUX-ZEPLIN (LZ).

After having obtained in 2013 a world-leading limit for the spin-independent WIMP-nucleon elastic scattering cross-section (see figure) that has received enormous interest from the scientific community (the paper has more than 1130 citations on InspireHEP), LUX started a new science-data acquisition period in Sept 2014. Ever since, LUX has been collecting science data, with periodic calibrations. An improvement of the sensitivity by a 2 to 3 factor is expected from this run. Meanwhile, several improvements in the calibration of the photomultipliers and the detector, as well as various advances in modelling the background, have motivated a re-analysis of the data from the previous run. The result is plotted in fig.1, having been submitted for publication on PRL.

The LZ project proposes a 7-ton xenon detector using the same TPC technology as LUX. After having been selected for funding by DOE (USA) and STFC (UK) in 2014, LZ reached another major milestone in April 2015: the LZ Concept Design (CD1) was approved by DOE. This triggered the procurement of xenon, PMTs and titanium for the detector and the preparation of the Technical Design Report that is expected to be approved by DOE in April 2016. After that, the fabrication of the detector and auxiliary

Framework and status for past and current year

systems will be start off. The underground deployment of LZ is scheduled to begin in September 2018 and operations are expected to start in Spring 2020.

Summary of performance indicators

Articles in international journals:	1 With direct contribution from team
Internal notes:	4 Collaboration notes
International conferences:	3 Oral presentations 1 Proceedings
International meetings:	1 Presentation
National conferences:	1 Presentation
Collaboration meetings:	11 Oral presentations
Proposal:	1 Detector Conceptual Design Report
Completed theses:	1 Master Thesis
Organization:	1 Collaboration meeting organized

Team

Principal Investigator Isabel Lopes (65)

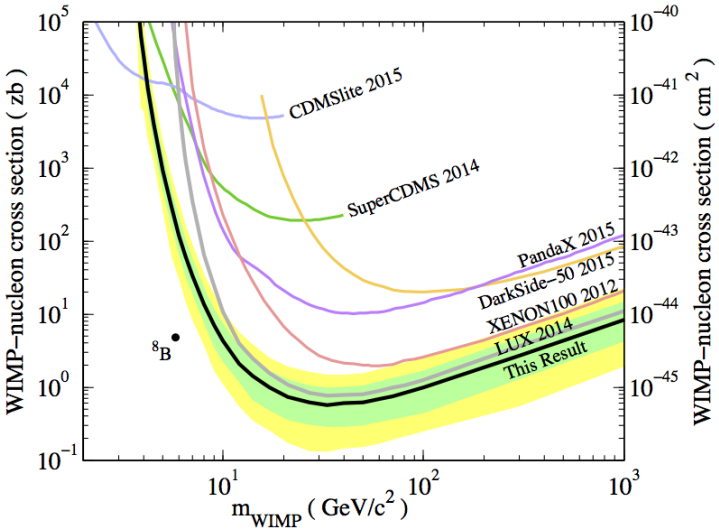
Researchers
Alexandre Lindote (85), Cláudio Silva (100), Francisco Neves (75), José Pinto da Cunha (35), João Pedro Rodrigues (100), Vladimir Solovov (50)

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

PhD students
Paulo Brás (100)

Total FTE

6.6



// GROUPS: LUX/LZ / SNO+

Lines of work and team organization

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

- Vertex reconstruction methods in LUX and LZ detectors (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 and Francisco Neves);
- Modelling and GEANT4 based simulation of the background in LZ (Alexandre Lindote and Paulo Brás);
- Slow-control systems for LUX and LZ (Vladimir Solovov and João Rodrigues);
- Data processing framework in LUX (Alexandre Lindote);
- M&O and performance of LN2 system of LUX (Francisco Neves).

Other lines of work are:

- Measurements of the reflectance and the transmittance of materials with interest for LZ (Francisco Neves)
- Simulation and Monte Carlo modeling of reflectance processes in rough and diffuse surfaces (Claudio Silva).

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

Stated objectives for past year

- To maintain the leadership in the development of the LZ control and monitoring system (also referred to as Slow Control - SC) and widen the responsibilities of the group in this system.

- To contribute to the viability study of searching for physics beyond dark-matter with LZ, namely regarding neutrino scattering and neutrinoless beta decay.

- To perform reflectivity measurements of PTFE samples of different thicknesses and from various manufacturers to help select the optical reflector materials for LZ.

- To continue our participation in LUX, including further develop of the vertex reconstruction tool, several topics of data analysis, the maintenance of the two LUX subsystems for which the group has sole responsibility (Slow control and LN2 distribution system) and the participation onsite in LUX operations.

Achievements and responsibilities during the past year

LZ

- The LZ SC system is comprised of two components: software platform Ignition from Inductive Automation and Siemens SIMATIC PLC with associated I/O modules. The Ignition server works as the main hub of the SC. The sensors belonging to the critical subsystems will be controlled by PLCs. LIP coordinates the LZ SC system (L3-level responsibility in LZ management hierarchy) and is responsible for the software development for the Ignition platform and its interface with PLCs. In 2015, the following milestones were reached regarding our responsibilities in the LZ SC:
  - Choice of the architecture of the SC system for LZ.
  - Design of the architecture of the SC for the System-Test (ST) installed at SLAC, in which several options adopted for LZ are tested.
  - Implementation (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 SC system) for the System-Test.
- Participation in the task force dedicated to study the sensitivity of LZ to detect neutrinoless double-beta decays. We contributed to the study of the viability and the required resolution of the position reconstruction of these events and the discrimination of the double scatter events for the energy range of interest.
- The chamber for the improved measurements of the reflectivity of PTFE immersed in liquid xenon for its scintillation light was completed and tested. The reflectivity of the PTFE from one producer was measured with the required precision of the order of 1% (96.5 ± 1.5 %). PTFE will be used in LZ detector as reflector of the VUV (175 nm) xenon scintillation light. It is known that PTFE reflectivity is strongly dependent on the manufacturing process and the ultimate sensitivity of LZ detector critically depends on its value.

LUX

- Position reconstruction of the events from the second-science run data using the vertex reconstruction tool that we have developed and maintained.
- Key contribution to the modeling of the background events from the recoils of the Pb-206 after a Po-210 alpha decay and the discrimination of double scatter events from single scatter events using the position reconstruction software. This was a crucial contribution to achieve the improved limit on the WIMP-nucleon cross-section mentioned above.
- Coordination of the WIMP and Low Energy Backgrounds group during the reanalysis of the data from the previous run. This group was responsible for the high level analysis of the WIMP search data, from the definition of the datasets to use in the analysis, the development of quality cuts to remove spurious events, 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.
- Coordination of the Data Processing team of LUX, being responsible for coordinating the upgrades of the various modules for processing data of the ongoing run and the processing of the full 300 live days of WS data and calibration datasets in the collaboration computer cluster in a total of ~1 million CPU hours.
- Maintenance of the LUX SC and LN2 distribution systems.
- 85 days onsite (underground shifts at SURF, SD, USA, where LUX is running).

Coordination positions within LUX

- A. Lindote, Coordinator of the LUX WIMP and Low Energy Background Investigation group (2014/15)
- A. Lindote, Co-coordinator of the LUX Data Quality Group (since Sep 2015)
- C. Silva, coordinator of the LUX position reconstruction analysis subgroup (2015)
- A. Lindote, Coordinator of the LUX Data Processing Framework (2015)
- F. Neves, responsible for the M&O of LUX Liquid Nitrogen System (2015)
- V. Solovov, responsible for the M&O of LUX SC (2015).
- A. Lindote LUX Detector Operations Manager (23 Feb - 1 Mar 2015)
- A.Lindote, LUX Shift Manager (16-29 Nov 2015).

Coordination positions in LZ

- V. Solovov, coordinator of the LZ slow control system.
- A. Lindote, coordinator of the LZ subgroup responsible for the event reconstruction & identification.

Editorial and Review Boards within LUX and LZ (in 2015):

- A. Lindote, member of the writing committee of the paper "Calibration, event reconstruction, data analysis and limits calculation for the LUX dark matter experiment", in preparation.
- A. Lindote, member of the review committee of the collaboration paper "Tritium calibration of the LUX dark matter experiment", submitted to PRD.
- F. Neves and V. Solovov, members of the Review Committee for the TPC monitoring sensors in LZ.
- V. Solovov, Member of the Review Committee for calibration source delivery system & isotope sources in LZ.

Lines of work and objectives for next year

In 2016 the work will continue focused on the participation in LUX and LZ.

LZ

- Regarding the LZ slow control, the three main objectives are: to complete and to maintain the SC for the System-Test, finalize the architecture of the SC system for LZ and to develop the detector temperature readout (4-wire RTD, ~100 channels, 0.1K precision).
- Start the development of a vertex and energy reconstruction 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. Refinement of the simulation and Monte Carlo modelling of reflectance processes in rough and diffuse surfaces.
- Participation and coordination of the development of software modules for the pulse identification and pulse pairing, which will categorise each acquired pulse as primary or secondary scintillation (or one of the various possibilities of "noise" pulses) based on their characteristics and group them in events for further analysis. Although there will be no real data to analyse in the near future, the detailed GEANT4 simulation of the detector, together with data samples from the test DAQ and electronics systems, can be used to develop and benchmark these modules, ensuring that the framework will be ready and optimised once data taking begins.

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. This includes the coordination of the high level WIMP data analysis group.
- Tuning of the vertex reconstruction tool for the analysis of the ongoing LUX run.
- Responsibility for the data processing framework: besides keeping the coordination of the framework development and managing the collaboration cluster, we will 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). This is a critical need, considering that the processing modules will continue to evolve as our understanding of the detector improves, and it is not feasible to fully reprocess the entire (300 live days) run.
- 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.

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

The group lacks fresh Post-Docs (it counts with 2 Post-Docs that have got the PhD about 6 years ago) and it has shortage of PhD students (it has 1 PhD student that started in Oct 2015). The level of funding in recent years has been insufficient to directly hire Post-Docs and/or give grants to PhD students.

There is shortage of several pieces of equipment (e.g. we do not have a residual gas analyzer to monitor the impurities in xenon in the reflectivity measurements that we have been carrying out; there is shortage of basic pieces like vacuum valves, vacuum connections, pressure sensors to make modifications in the xenon handling system or replace any faulty piece). The level of funding in recent years has been insufficient to buy new equipment or spare pieces.

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

- In the past 5 years, the funding in Portugal has been extremely unstable, very limited and not adjusted to large continuing projects, especially those taking place outside CERN. The only calls to which we can apply are those integrated in the “Funding Program for all the Scientific Domains”. The last but one of those calls was in 2011 and we were awarded 80kEuros for 2 years (the maximum project duration allowed in that call). There were no open calls until Dec 2014. We applied for funding of the LIP participation in LUX and LZ and in Aug 2015 we were informed that the project had been recommended to be funded but up to now the contract was not signed yet. This situation is incompatible with the participation in a demanding, schedule tight and long-term project as LZ.

- In the last 5 years, the group has suffered a reduction of about 50% in yearly funding, which corresponds to receive 40kEuros/year, precisely when we have shifted from ZEPLIN-III to LUX and LZ. These are much larger and expensive projects but in which we can make use of the extensive know-how that has been accumulated by the group. If the funding scenario is maintained like this, it will be unmanageable to continue to participate in LZ.

- We may also loose key personnel due to the absence of career development. To avoid that, competitive permanent contracts are essential.

- In Coimbra Lab, there are very old key pieces of equipment, in risk of stopping to work at every moment (e.g. the vacuum pumps and the circulation pump of the xenon purification and handling system) compromising the continuation of the reflectivity measurements that are crucial for the LZ collaboration.

Publications

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

D.S. Akerib et al.: "Radiogenic and muon-induced backgrounds in the LUX dark matter detector", Astroparticle Physics, 62 (2015) 33-46

1 International Conference Proceedings

Markus Horn et al. : "Results from the LUX dark matter experiment", Nucl. Instrum. Methods Phys. Res. Sect. A-Accel. Spectrom. Dect. Assoc. Equip. 784 (2015) 504-507

4 Internal Notes

Francisco Neves: "Measurement of the PTFE Reflectivity in LXe", DocDB384

Claudio Silva: "Fiducial Mass for the Reanalysis of Run III", LuxDB00000404

Alexandre Lindote: "Final WIMP Search Plots for the Run03 Reanalysis", LUX DocDB352

Claudio Silva: "SE single electrons studies", LuxDB00000439

1 Proposal

D. S. Akerib et al (The LZ Collaboration): "LUX-ZEPLIN (LZ) Conceptual Design Report", arXiv:1509.02910v2

Presentations

3 Oral presentations in international conferences

Vladimir Solovov: "The LUX direct dark matter search experiment ", 2015-08-24, 17th Lomonosov Conference on Elementary Particle Physics, Moscow, Russia

Vladimir Solovov: "LUX experiment status and reconstruction of low-photon signals", 2015-10-23, 3rd International Workshop on Low Energy Particle Physics, Moscow, Russia

Isabel Lopes: "LUX and LZ present status", 2015-12-15, Dark Matter – Cairo Workshop, Cairo, Egypt

1 Presentation in national conference

Francisco Neves: "Underground Experiments: LUX/LZ/SNO+", 2015-04-27, Jornadas do LIP 2015, Lisboa

1 Oral presentation in international meeting

Francisco Neves: "Dark matter search (LUX/LZ and XENON)", 2015-05-15, R-ECFA meeting, Coimbra, Portugal

Theses

1 PhD Thesis

Paulo Brás: "Development of data processing and online monitoring tools for the LZ Dark Matter direct search experiment" (ongoing)

1 Master Thesis

Paulo Brás: "Finding a needle in a haystack: Background studies & WIMP detection efficiency in LUX" (finished on 2015-09-30)

Events

1 Collaboration Meeting

LZ Collaboration Meeting, Coimbra, Portugal, 2015-09-21 to 2015-09-24

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 2016, the detector water fill is ongoing. Installation activities will continue in the spring and the commissioning data taking phase is expected in in the Summer/Autumn. The liquid scintillator phase is planned for 2017. Therefore, during this year the group's activities will correspondingly change focus, from construction and preparation of calibration systems and analysis software to the deployment of sources, and commissioning data analysis.

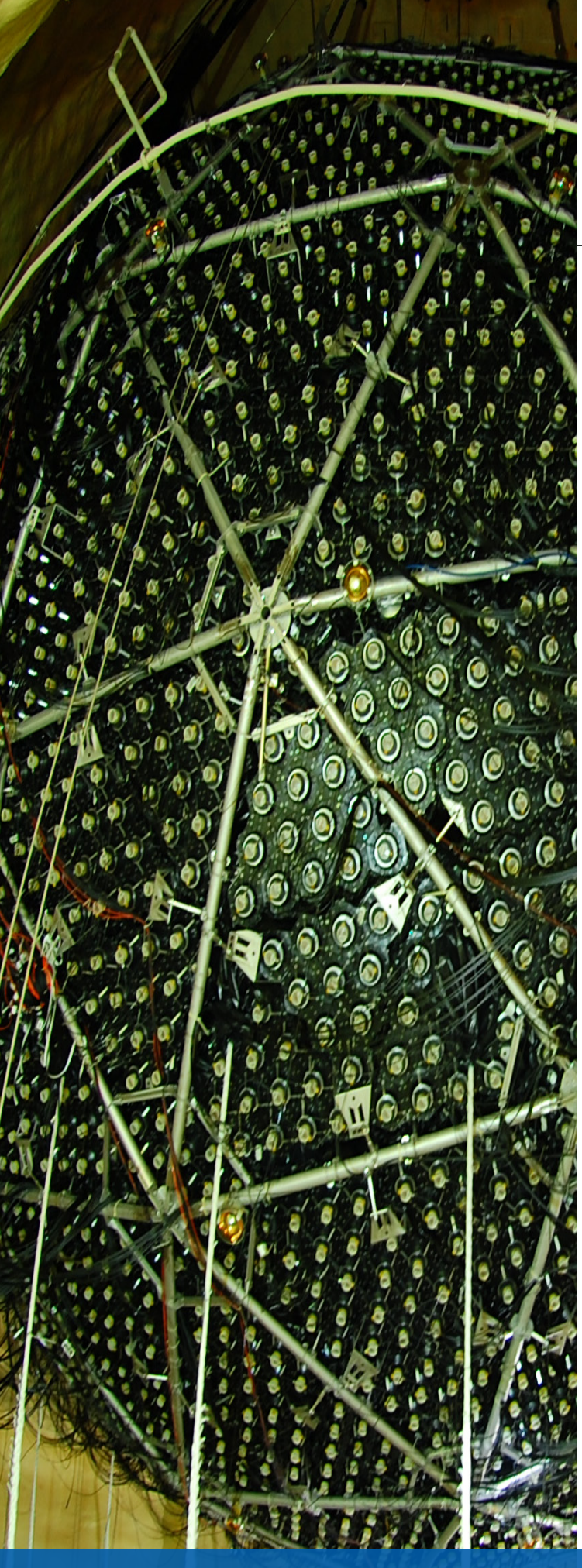
Framework and status for past and current year

Summary of performance indicators

Articles in international journals:	2 With direct contribution from team
Internal notes:	10 Collaboration notes
International conferences:	3 Oral presentations 1 Poster 3 Proceedings
Collaboration meetings:	13 Oral presentations
Seminars:	7 Seminars
Outreach:	2 Outreach seminars

EXPERIMENTAL PARTICLE AND ASTROPARTICLE PHYSICS

Dark matter and neutrinos



Team

Principal Investigator José Maneira (60)

Researchers
Amélia Maio (26), Fernando Barão (10), Gersende Prior (100), Naima Zahar (39), Sofia Andringa (60)

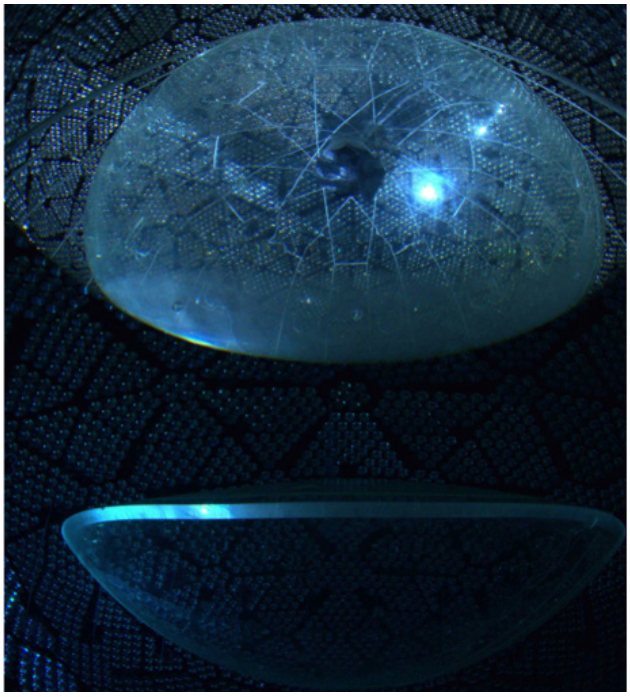
Technicians
Américo Pereira (20), Nuno Filipe Silva Dias (20), Rui Alves (16)

PhD students
Pedro Jorge (33), Stefan Nae (starting in 2016)

Master students
Ana Sofia Inácio (20), Evangelia Samara (30), Xavier Rodrigues (20)

Undergraduate students
Gonçalo Lemos (10)

Total FTE
4.6



// GROUPS: LUX/LZ / SNO+

Lines of work and team organization

The group's activities are organized according to three main lines of work, each one in turn divided into specific tasks. In each subtask all the group members currently working on that item are listed as well, the first one (or two) having the main responsibility.

- Detector calibration
  - Fiber-based system for PMT calibration. Currently the main activity is the ongoing installation at SNOLAB (JM).
  - Internal source deployment system. The design (RA, JM) is finished, production and tests (ND, AP) are ongoing at Coimbra.
  - Analysis of laserball optical calibration data (JM, GP, AI). The SNO+ optical calibration group is led 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 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, XR). This is a new area, for the development of non-MC algorithms for the modelling of light production/propagation/detection, that could be used in 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), the main internal background to the 0NDBD signal.
  - External background. Our group has had a relevant role in this area in the past, and we have recently re-started the activity (GP, ES), aiming at the water phase data analysis.
  - Anti-neutrinos. SA is co-leading the SNO+ anti-neutrino physics group, and in the last few years this activity was funded through a dedicated exploratory project that concluded in 2015. This activity comprises studies of the sensitivity of SNO+ to the directionality of antineutrino signals (SA), and the development of a directional neutron calibration source (SA, AM, PJ, SN).

In addition, the group also contributes to Particle Physics Outreach activities. SA is the group's contact person in this area.

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)
EXPL/FIS-NUC/1557/2013	28.119 €	2014-04-01 / 2015-09-30	FCT Exploratory research project - Geoneutrinos (PI: S.Andringa)

Stated objectives for past year

Our main objectives for 2015 were centered in the activities for the water commissioning phase:

- Completing the installation of the optical fibers system and using it with a full detector, for PMT time and charge calibration, stability monitoring, and high-intensity/high-frequency tests of the DAQ and trigger systems;
- Development of on-line and off-line data monitoring tools, especially the so-called "low-level" checks (i.e., on detector electronics and slow control);
- Development of on-line and analysis tools for anti-neutrino identification in the water data;
- Data-taking campaigns using the laserball source, and its analysis for a calibration of the PMTs and media attenuation parameters, including an extension to the external water shielding region;
- Analysis of events occurring in the external water region, leading to an improved external background model.

Non-water phase related goals were:

- Analysis of the sensitivity to anti-neutrino directionality in liquid scintillator detectors; design and optimization of a dedicated neutron direction calibration source.
- Development of the coincidence tagging of the Bi-Po alpha-beta backgrounds affecting the neutrinoless double beta decay signal region;
- Finalization of the design and production of the source insertion mechanism, being built in Coimbra.

Achievements and responsibilities during the past year

Awards

2015 was a remarkable year for Neutrino Physics. The Nobel prize in Physics was awarded to Arthur McDonald and Takaaki Kajita, for the discovery of neutrino oscillations. LIP is proud to have been collaborating with Arthur McDonald since 2005, through the participation in the SNO and SNO+ experiments. The Nobel prize was followed soon after by the 2016 Breakthrough Prize in Fundamental Physics, that was shared by all members of several collaborations, again for the discovery of neutrino oscillations. Current members of the LIP group SA, JM and GP, and a former member (Nuno Barros, now at the University of Pennsylvania), were among the recipients. These awards are of course very important in raising the awareness of Particle Physics in the general public: a dedicated web page was prepared, members of LIP gave interviews to several mass media – TV, radio, newspapers, websites – and gave 8 seminars in different Universities in the whole country.

2015 Activities

Concerning the execution of the planned SNO+ activities for 2015, it was strongly affected by a severe water leak in the SNO+ cavity, found in November 2014. A large-scale search campaign for the location of the leak was undertaken by the collaboration, and our group participated in that effort in August. By the end of 2015 the leak was identified and repaired, and water fill has resumed.

Calibration and detector-related

The design for the source insertion system (RA, JM) was finalized in 2015, following additional requirements asked by the collaboration in 2014. The bulk aluminum for production was procured and testd at SNOLAB. Production of the large parts started (ND). One important milestone reached in 2015 was the validation of the welding procedure, with purposefully-built boxes checked with vacuum and helium tests (AP).

Among the tasks related to the optical calibration, work proceeded in the preparation of the water phase data taking (JM, GP): optimization of the run-per-run laserball information database tables, improvements to the MC simulation of the source data, a major laserball MC production (~200 run settings), preparation of the run plan, and the development of a fast calibration analysis validation algorithm with a limited data set ("diagonal analysis"), with Master's student AI.

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. She tested the scripts and benchmarked the process during a Mock Data Challenge.

Analysis and simulation studies

Among the tasks related to the background studies, GP tested the rejection power of an algorithm aimed at tagging 214BiPo and 212BiPo via delayed coincidences, using a mixed MC data-set (including signal and different backgrounds), compared with three other algorithms. A study of the reconstruction of external background events from 208Tl in the PMT glass in the water phase was also performed (ES, GP).

A new activity was started (FB, GP and XR): the development of a tool for the description of the generation of scintillation and Cherenkov photons, optical propagation and detection, with the aim of contributing to possible new event reconstruction and particle identification tools.

The SNO+ antineutrino group (co-led by SA) concentrated on preparation for the water phase. At LIP, we focused on the calibrations needed to ensure that delayed coincidence with neutrons can be seem in water, by improving the simulation of the existing AmBe neutron source and establishing the corresponding calibration plan. In what concerns antineutrino directionality studies (SA), we concluded that the expected asymmetries in anti-neutrino fluxes can be experimentally observed at a one standard deviation in the present SNO+ configuration. By loading the liquid scintillator with elements with a high neutron capture cross-section, the sensitivity to direction is highly enhanced. We started the simulation study of a shielded AmBe source (SA, AM, PJ, NZ), which could be used to establish in-situ the neutron direction reconstruction in the different scintillator mixtures.

Lines of work and objectives for next year

Now that the detector water-fill has restarted, we expect to be able to work towards some of our goals for 2015 that had been left pending. We expect 2016 to still be heavily dedicated to technical work geared towards the water and scintillator commissioning phases.

On the calibration side, we plan to:

- conclude the installation of the fiber-based PMT calibration system, that started in 2012;
- develop and test the nearline scripts that insert the laserball hardware information in the database, to make it available for subsequent analysis;
- develop and test the framework for a fast quality control/ analysis of the laserball data shortly after data is taken;

- develop and test analysis methods aimed at improving the optical calibration with the use of laserball data taken in the region outside the AV;
- in parallel to the water phase preparation, we plan to finalize the construction of the source insertion system for the scintillator phase, and ship it to SNOLAB.

On the data quality side, we plan to:

- complete the code in charge of recording the detector state on a run-per-run basis, adding mainly the access to the slow control database and water level information;
- test these scripts within the nearline framework during detector commissioning.

With respect to data analysis and its preparation:

- regarding external backgrounds from 208Tl, we will continue the analysis external backgrounds from 208Tlstarted in 2015, with goal to measure the background levels from the partial air-water fill data taken in 2014;
- on the anti-neutrino side, we will test the lowering of thresholds in order to optimize neutron capture delayed coincidence signals versus low energy fake coincidence rate in the beginning of the water phase data taking. The first months will tell if the anti-neutrino analysis is possible or not;
- we will continue the optimization of the directional neutron source and develop the calibration plans in that aspect for the future scintillator phases;
- regarding internal backgrounds, we will continue to optimize the cuts defined by the coincidence algorithms, with both a pure 214/212BiPo and a mixed data-set as new production data will come (with different scintillator optics);
- we also plan to explore the potential to use SNO+ water and scintillator phases to perform searches on dark-matter signals from the Sun.

SWOT Analysis

Strengths

The main strength of the group resides in the diverse range of competences and experience of its members, from low and high energy neutrino physics to nuclear, collider and cosmic ray physics. From the technical standpoint, the group has experience in optical instrumentation, mechanical systems, PMTs and DAQ. Our strong role within the SNO+ collaboration surely contributed to our award of funding in the latest FCT call.

Weaknesses

One weakness of the group is the current absence of mid-level researchers, such as advanced PhD students and Post-Docs. After a few years with practically no students, in 2015 the situation changed, but the current students are all starting. Similarly to other groups, stability of funding and the lag time of FCT calls are a very significant problem. No formal approval for spending of project funding awarded in August 2015 has yet been given. This is a threat to our responsibilities in the collaboration, and for student support.

Opportunities

Several opportunities can have the potential to expand the group's activities. The recent addition of a senior member (FB) can allow us to contribute to the SNO+ event reconstruction, important in the data analysis phases, and strengthen our role in calibration and physics analyses. Moreover, new students have recently joined the group, allowing a consolidation of the activities in reactor antineutrino physics (SN, IDPASC PhD), optical calibration (AI, Master's) and background analyses (ES, undergrad internship). Last but not least, after a few years of preparation, and a delay due to a water leak, water phase data should arrive in 2016. This 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 phase.

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

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

R. Alves, S. Andringa, J. Carvalho, D. Chauhan, L. Gurriana, A. Maio, J. Maneira (corresponding), L. Seabra, et al (24 authors) : "The calibration system for the photomultiplier array of the SNO+ experiment", JINST Vol. 10 (2015) P03002

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

3 International Conference Proceedings

L. Seabra, on behalf of the SNO+ Collaboration: "The LED and fiber based calibration system for the photomultiplier array of SNO+", J.Phys.Conf.Ser. 587 (2015) 012031

S. Andringa, for the SNO+ Collaboration: "Anti-neutrino measurements in SNO+", Proceedings of European Physical Society Conference on High Energy Physics, Vienna, Austria, July 2015

G. Prior, on behalf of the SNO+ Collaboration: "Status of the SNO+ Experiment", Proceedings of European Physical Society Conference on High Energy Physics, Vienna, Austria, July 2015

10 Internal Notes

J. Maneira, G. Prior, R. Stainforth: "Proposal for new angular distribution reference for the laserball in SNO+", SNO+ DocDB 3141

J. Maneira, M. Mottram, S. Peeters, J. Sinclair, J. Waterfield: "Characterisation Procedure for TELLIE LED Drivers", SNO+ DocDB 3148

J. Maneira: "Estimation of Radon emanation from Aluminum in the SNO+ URM", SNO+ DocDB 3174

G. Prior et al.: "March 2015 DAQ summary", SNO+ DocDB 3386

G. Prior et al.: "Mock Data Challenge Summary Document", SNO+ DocDB 3436

G. Prior: "laserball ratdb new format", SNO+ DocDB 3439

J. Maneira: "Water Phase Laserball Deployment Plan", SNO+ DocDB 3447

J. Maneira: "SNO+ In-situ Optics plan for the water and scintillator commissioning phases", SNO+ DocDB 3498

G. Prior: "Laserball production RAT-5.2.2", SNO+ DocDB 3502

I. Coulter, S. Langrock, V. Lozza, G. Prior, J. Wilson: "Month Mixed Data Set Analysis Summary", SNO+ DocDB 3504

Presentations

3 Oral presentations in international conferences

Gersende Prior: "Status of the SNO+ Experiment", EPS-HEP, European Physical Society Conference on High Energy Physics, Vienna, Austria

José Maneira: "Status and prospects of the SNO+ experiment", TAUP2015 - XIV International Conference on Topics in Astroparticle and Underground Physics, Torino, Italy

Sofia Andringa: "Geoneutrinos as probes of the Earth's internal heat budget and composition", X Congresso Ibérico de Geoquímica, LNEG, Lisboa, Portugal

1 Poster presentations in international conferences

Sofia Andringa: "Anti-neutrino measurements in SNO+", EPS-HEP, European Physical Society Conference on High Energy Physics, Vienna, Austria

7 Seminars

José Maneira: "The 2015 Nobel Prize in Physics", Seminar at Physics Dept. IST, Lisboa, Portugal

José Maneira: "The 2015 Nobel Prize in Physics", Seminar at Physics Dept. FCUL, Lisboa, Portugal

José Maneira: "The 2015 Nobel Prize in Physics", Seminar at Physics Dept. ISEL, Lisboa, Portugal

José Maneira: "The 2015 Nobel Prize in Physics", Seminar at Physics Dept. University of Aveiro, Aveiro, Portugal

José Maneira: "The 2015 Nobel Prize in Physics", Seminar at Physics Dept. University of Coimbra, Coimbra, Portugal

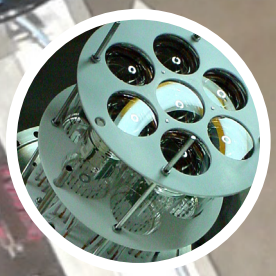
José Maneira: "The 2015 Nobel Prize in Physics", Seminar at Physics Dept. University of Minho, Braga, Portugal

José Maneira: "The 2015 Nobel Prize in Physics", Seminar at Physics Dept. University of Porto, Porto, Portugal

2 Outreach seminars

José Maneira: "O Prémio Nobel da Física 2015", and Sofia Andringa at IDPASC Workshop on "Space Particles and Earth", Évora, Portugal

Sofia Andringa: "O Prémio Nobel da Física 2015", Noites de ciências, noites de luz, FCUL, Lisboa, Portugal



Detector development for **particle** and **nuclear physics**

- Neutron detectors
- RPC R&D
- NEXT
- Liquid Xenon R&D
- NUC-RIA

// Development of new in

Instruments and methods for biomedical applications

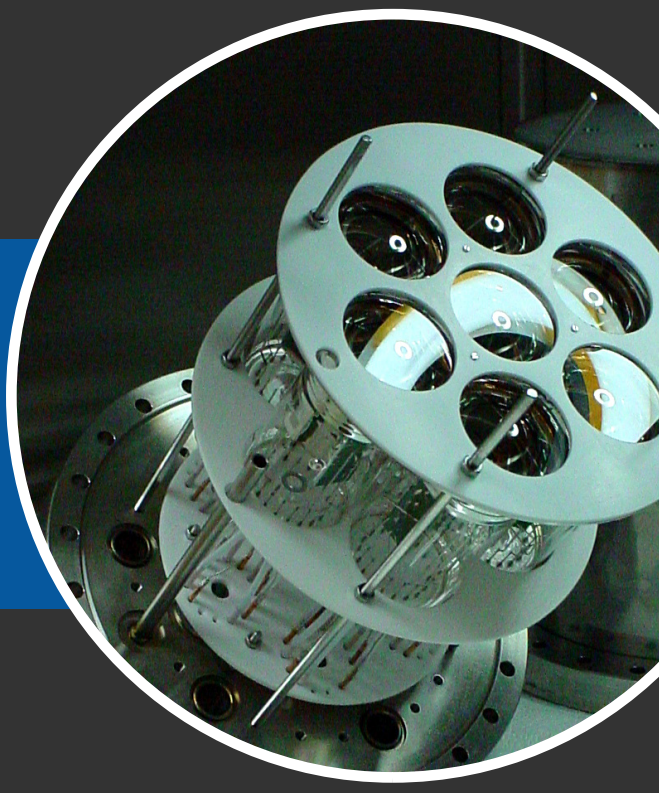
- RPC-PET
- OR Imaging
- Gamma cameras
- Dosimetry
- STCD TagusLIP

Radiation environment studies and applications for space missions

- Space
- A-HEAD

nstruments and methods

Detector development for particle and nuclear physics



Neutron Detectors

At LIP, we are developing a 3He free thermal neutron detector concept, based on 10B4C-Coated RPCs, for high position resolution Position Sensitive Neutron Detectors (PSNDs). This novel approach was introduced in an exploratory project led by L. Margato and funded by FCT (EXPL/FIS-NUC/2522/2013).

PSNDs play a critical role in many fields, such as neutron scattering science (NSS), homeland security and well logging. During the last decades these detectors were mainly based on the 3He isotope, the golden standard for thermal neutron detection. Nowadays, however, the 3He crisis resulted in a change of paradigm which poses demanding challenges to develop new types of neutron detectors, capable to satisfy high performance standards. For instance, the future European Spallation Source (ESS) will produce first neutrons in 2019-2020. Detectors with enhanced performance are urgently needed to full explore all the potential of these sources.

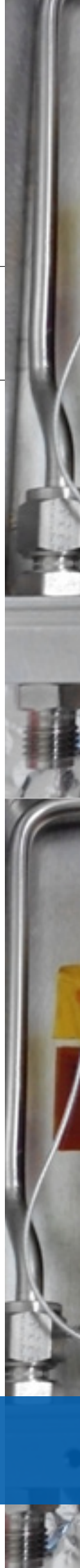
To prepare Europe for the unique opportunities at the European Spallation Source, a Consortium of 18 partner institutions, including LIP, from 12 countries (Science & Innovation with Neutrons in Europe in 2020 – SINE2020) submitted a proposal to the call H2020-INFRADEV-4, which was funded by the European Union through the H2020 programme (EU contribution committed to LIP: 116,250 €).

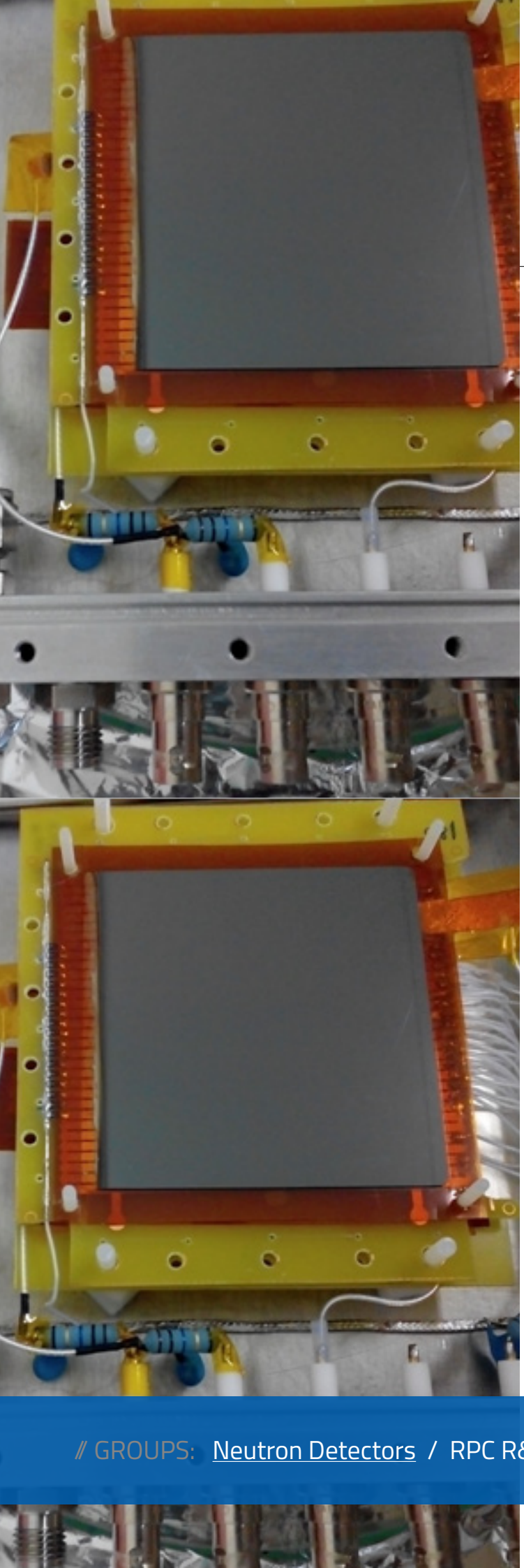
Framework and status for past and current year

The research activities will be developed in the framework of the SINE2020 project (EU project 654000) within Work Package 9. We have responsibilities on the research activity Emergent Detector Technologies for Neutron Scattering and Muon Spectroscopy and in which LIP coordinates the task 9.4.1 Resistive plate chambers development for thermal neutron detectors.

Summary of performance indicators

International meetings:	1 Oral presentation





Team

Principal Investigator Luís Margato (78)

Researchers
Alberto Blanco (14), Andrey Morozov (23), Paulo Fonte (4)

External/Additional scientific collaborators
Alessio Mangiarotti (18), Francisco Fraga (20)

Total FTE
1.6

// GROUPS: Neutron Detectors / RPC R&D / NEXT / Liquid Xenon R&D / NUC-RIA

Lines of work and team organization

The group is dedicated to the development of high resolution PSNDs for neutron scattering science (NSS) and other potential applications (e.g. neutron imaging applications and homeland security).

In line with the SINE2020 WP9 (Detectors) objectives, we will explore the potential of 10B4C coated RPCs for PSNDs. We are focused on the accomplishment of the following tasks:

- Design, Fabrication and Building of 10B4C coated RPCs prototypes.
- Detector prototypes chracterization and optimization.
- Study of 10B4C coated RPCs operation in avalanche mode.
- 2D position reconstruction.
- MC simulations and detector prototypes development is to be carried out at LIP.
- The 10B4C coatings will be produced at the European Spallation Source (ESS) Detector Coatings Workshop in Linköping in the frame of already established cooperation.
- The tests of the detector prototypes with thermal neutrons will be conducted at a neutron facility of the LIP partners, (e.g., at ILL, Grenoble or in TUM-FRM II, Munich) and in collaboration with partners from SINE2020/WP9 (Detectors).

Sources of Funding

Code	Amount	Dates	Description
EXPL/FIS-NUC/2522/2013	31.200 €	2014-03-01 / 2015-08-31	FCT Exploratory research project (PI: L.Margato)
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

Demonstrate experimentally the feasibility of a high position resolution thermal neutron detector with B4C coated RPCs.

Proceed with the optimization of the detector using MC simulations: optimization of parameters such as, the B4C coatings thickness, the number of B4C layers and the gas gap width (e.g. optimization of the detection efficiency and spatial resolution).

Design, fabrication and assembling of a B4C coated RPC detector prototype.

Conduct the evaluation of the detector prototype, together with the DAQ system, in a monochromatic thermal neutron beam at a neutron facility (ILL, Grenoble, France).

Focus and give full support to the LIP integration in the International Consortium SINE2020 (Call: H2020-INFRADEV-1-2014-1, Proposal No.: 654000) led by the European (ESFRI) facilities, ILL and ESS.

Achievements and responsibilities during the past year

A MC simulation for the 10B4C coatings thickness optimization was implemented.

Through simulation we proceeded to the optimization of the 10B4C coatings thickness as a function of the neutron wavelength and the number of 10B4C layers that maximizes the detection efficiency. This information was used in the manufacture of 10B4C coatings.

A portable 64 channels Data Acquisition System (based on a test board with a MAROC3 ASIC from Omega) was developed for the electronic readout of the detector prototype.

High quality B4C coatings enriched in 10B were manufactured at the European Spallation Source (ESS) Detector Coatings Workshop in Linköping.

A detector prototype with RPCs (single gap and Multi-gap) made of electrodes coated with 10B4C (enriched in B-10) was designed and assembled at LIP Coimbra Facilities.

In July-August 2015, the prototypes together with the DAQ system were taken to ILL, Grenoble, where they were tested in the monochromatic thermal neutron beam CT2 (2.5 Angstroms).

The feasibility of thermal neutron detectors based on the 10B4C coated RPCs concept was successfully demonstrated.

Detector response to thermal neutrons shows a long and very stable plateau and a strong evidence for the ability of this thermal neutron detector concept for sub-millimetre position resolution.

It was measured a position resolution of ~0.8 mm FWHM without introducing the corrections for the ~0.5 mm width of the slit collimator, demonstrating its viability for high resolution Position Sensitive Thermal Neutron Detector's.

Lastly, a non-minus significant achievement and as a results of the promising outcomes, achieved in the framework of the exploratory project funded by FCT (EXPL/FIS-NUC/2522/2013), was the integration of our team in the European-funded 4-years research project SINE2020 (EU project 654000 under the Horizon 2020 EU Framework Programme), which started in October 2015.

Lines of work and objectives for next year

Our attention will be focused on achieving the goals set by the SINE2020 collaboration.

In order to disseminate the most significant results, showing the feasibility of the 10B4C coated RPCs concept for thermal neutrons detection we are writing a paper to be submitted for publication in an International journal with independent peer-review.

The research work on the B4C Coated Multi-Gap RPC concept should be continued.

A Multi-Gap RPC with three gas gaps and with the cathodes (0.35mm soda lime glass) coated with 10B4C (~1.3 microns thick) showed that the efficiency to thermal neutrons was enhanced according to the number of layers of 10B4C (evidencing the advantages of this architecture for higher detection efficiencies).

However, during the experimental tests with a thermal neutron beam it was observed a continuous growth of the plateau with the high voltage (HV), accompanied by a significant increase of the background. More detailed studies on this issue are needed.

It was found that the 10B4C coatings, deposited onto soda lime glass plates, of the last batch provided by the European Spallation Source (ESS) Detector Coatings Workshop and to be used in the Multi-Gap RPCs assembly, show a surface resistivity of about 2 orders of magnitude lower than previous samples (~ 2M ohm/sqr).

In order that a Multi-Gap RPC, made with electrodes coated

with 10B4C, preserves its spatial resolution capability, is required that the 10B4C coatings show a surface resistivity above 1E6 ohm/sqr.

A number of studies to investigate what is causing this change on the surface resistivity in 10B4C coatings produced in seemingly similar experimental conditions (to the present date it has not yet been found an explanation) will be undertaken by the European Spallation Source (ESS) Detector Coatings Workshop in Linköping.

In line with the SINE2020/ WP9 (Detectors) requirements for high performance detectors, we will pursue the investigation of 10B4C coated RPCs for high resolution PSNDs. During the year 2016 the main objectives are:

- Prototypes optimization by MC Simulations (e.g. number of converter layers, converter layers thickness, gas-gap width).
- Manufacture and evaluation of 10B4C coatings, enriched in 10B, for the Multi-Gap RPC detector configuration; this task will be undertaken by the European Spallation Source (ESS) Detector Coatings Workshop in Linköping, Sweden.
- Selective choice of materials to be used in the design of the detector prototypes, particularly those that will be on the path of neutrons (e.g. avoid materials with power to cause attenuation and scattering of thermal neutrons and susceptible of being activated).
- Detector prototype designing, fabrication and assembly (will be carried out at LIP, Coimbra). Different RPCs configurations are considered e.g. Stack of Single-gap RPCs, Double-gap RPCs (two anodes sharing the same cathode), or Multi-gap RPCs (leads to very modular and compact designs but the 10B4C coatings have to display a surface resistivity > 1E6 Ω/sqr).
- Experimental tests with the detector prototypes in a thermal neutron beam at a neutron facility of the LIP partners, (e.g., at ILL, Grenoble or in TUM - FRM II, Munich) are foreseen in collaboration with SINE2020 / WP9 (Detectors) partners.

SWOT Analysis

Strengths

- Team with accumulated extensive knowledge in the field of gaseous radiation detectors and in particular with thermal neutron detectors.
- LIP is 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 from the leading neutron facilities of the world (e.g. ILL, TUM, ISIS and recently ESS).
- Participation on a H2020 European-funded 4-years (2015-2019) research project (EU project 654000): Science & Innovation with Neutrons in Europe – SINE2020 (http://sine2020.eu/).
- Collaboration with a group which is one of the world leaders in thin film research (Thin Film Physics Division of Linkoping University, Sweden), which is crucial in thin film solid neutron converters-based neutron detector development.

Weaknesses

- PSNDs based on the 10B4C coated RPCs concept, in principle, could satisfy spatial resolution (sub-millimetre) and the detection efficiencies requirements established for PSNDs for ESS. For detectors with high counting rates requirements (1MHz/mm2) the RPCs will be in disadvantage relatively to other technologies (e.g. MSGCs and 6Li doped glass scintillators). Nevertheless, recent efforts were undertaken by RPC community to develop the RPCs technology for high rate applications, e.g. in the framework of the AIDA-2020 project in which LIP participates. Synergies with this LIP-team can bring major improvements for B4C coated RPCs with respect to the counting rate capability.
- Precarious employment condition of the group leader. He has to be self-financing by a grant using funds from its SINE2020 project, otherwise it would not be possible for LIP to secure the SINE2020 EU project funding. Almost certainly, breaking the connections with this international community would have in the future severe implications in the access to future EU funding opportunities.
- Lacks of man power (concerning the high level of project difficulty and responsibility), with the project leader to have to take simultaneously the project management and almost all of the experimental execution, hindering the development of other important tasks such as

dissemination, creative thinking and apply for potential funding opportunities.

- Condition for training new students needs to be concretized; it is imperative engage postgraduate and master students, preferably a PhD student, in the research team.

- Dissemination of research activities must be more effective; this will be boosted releasing the project leader of certain tasks that can be undertaken e.g. by postgraduate students.

Opportunities

- We are working on a topical issue.

- The outcome of the research activities will be the development and characterization of a new class of detectors: 10B4C-coated RPCs PSNDs.

- Proved, the 10B-coated RPCs concept could allow designing PSNDs with lower costs, easily scalable and very modular. Therefore, a major impact on the related scientific community could be expected. The 3He crisis makes this technology extremely attractive and gives a basis for high industrialization potential.

- LIP participation in the SINE2020 project will allow solidifying and expanding its international contacts; it brings a great International visibility for LIP and Portugal, increasing the likelihood of new EU funding opportunities in the future.

Threats

- Shifting of focus to speedy investigations.

- Intellectual property is not protected.

- Money for Human Resources is uncertain.

Presentations

1 Oral presentations in international meeting

Luís Margato: "10B4C coated RPCs for Position Sensitive Neutron Detectors", Kick-off meeting SINE2020, Neils Bohr Institute, University of Copenhagen, Copenhagen, Denmark

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 old 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, CBM, FOPI, HADES, HARP, STAR).

Besides the original work in ALICE, along with numerous international 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 expanding the count-rate capability
- application of RPCs to animal and human Positron Emission Tomography
- 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

Framework and status for past and current year

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.

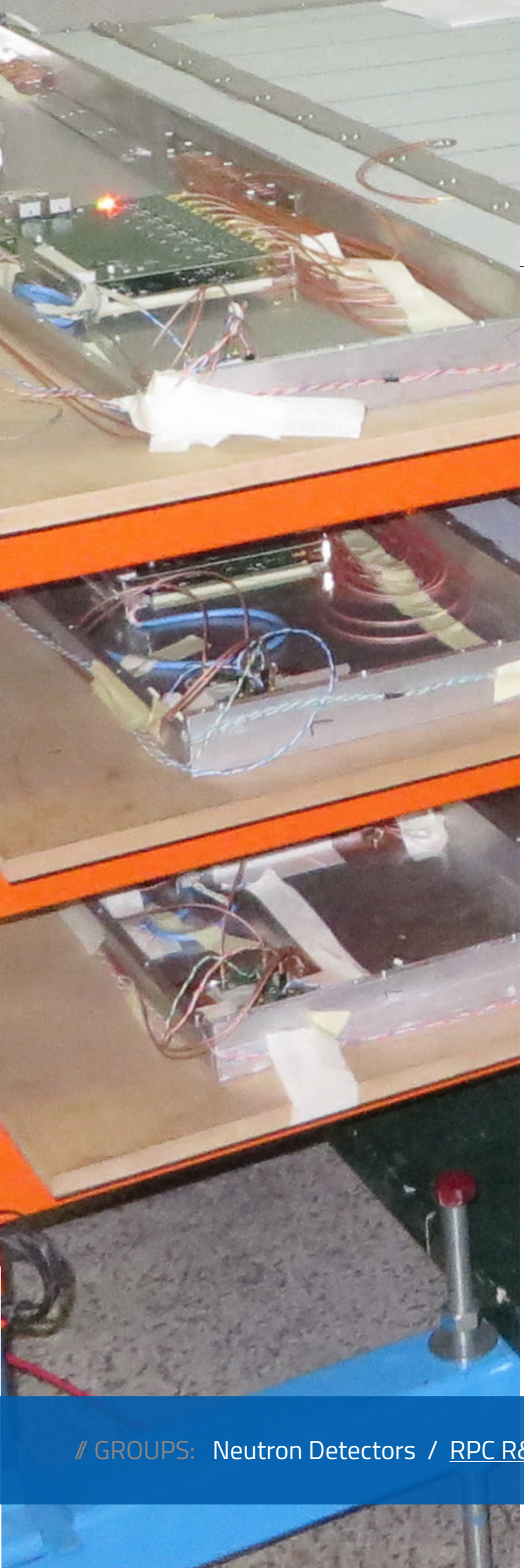
Besides the development of technology-expanding devices, we keep an interest in RPC's physical modelling and other fundamental issues, such as gas mixture properties and aging. We also design and produce detector-support electronics, such as front-end amplifiers and high-voltage power supplies.

A new line of work concerns the development of epi-thermal neutron detectors with ^{10}B converters.

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 collaboration.

The RPC group cooperates with several other LIP groups (neutron detectors, HECR, HADES, PET with RPCs and RD51), supporting their RPC-related activities. See the specific reports for further details.

DEVELOPMENT OF NEW INSTRUMENTS AND METHODS
Detector development for particle and nuclear physics



Team

Principal Investigator Paulo Fonte (25)

Researchers
Alberto Blanco (20), Luís Margato (15)

Technicians
Afonso Bernardino (100), Américo Pereira (10), Carlos Silva (90), Joaquim Oliveira (85), Luís Lopes (68), Nuno Carolino (50), Nuno Filipe Silva Dias (70), Orlando Cunha (80), Rui Alves (69)

External/Additional scientific collaborators
Douglas Lima (100)

Total FTE
7.8

Summary of performance indicators

Articles in international journals:	3 With direct contribution from team
Internal notes:	1 Collaboration note
International meetings:	3 Oral presentations
Collaboration meetings:	6 Oral presentations
Seminars:	2 Seminars

// GROUPS: Neutron Detectors / RPC R&D / NEXT / Liquid Xenon R&D / NUC-RIA

Lines of work and team organization

The core RPC group is rather small, with 1 full-time physicist and 2 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 (~2m^2) 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 HECR group.

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.

These activities were partially funded this year by the Rad4Life project of the COMPETE/MAISCENTRO program. 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

Achievements and responsibilities during the past year

Funding

A funding proposal entitled "Resistive Plate Chambers for next-generation cosmic-ray and neutron detectors" was submitted to the general "PTDC" call in January 2015 and was classified with 7/9, therefore rejected for funding. It was stated by the jury "… letters of support from those working in this area of research would have been helpful.".

The funding request for participation in the RD51 collaboration submitted to the CERN-related projects call was not financed because there were too many RD51-related projects in the call (also from other institutes). Therefore, none of them was financed…

The AIDA2020 EU project (http://aida2020.web.cern.ch/) started in June. This is the only active funding of the group, covering only the study of high-rate RPCs.

TOFtracker

A large area (~2m^2) TOFtracker 3-layer cosmic-ray telescope was built and preliminarily tested, showing encouraging initial performance. A contribution on this subject was submitted and accepted for the RPC2016 workshop.

A new generation of front-end electronics specially suited for the TOFtracker (providing strong insulation from external digital pickup) was developed.

We were contacted by a company interested in muon tomography for container inspection at sea ports for supplying one TOFtracker telescope system.

Sealed and environmentally robust RPCs

We have achieved stable operation in the lab of large chambers at gas flows as low as 1 cc/min. A contribution on this subject was submitted and accepted for the RPC2016 workshop.

The operation of several chambers in very harsh field conditions at the site of the AUGER experiment in Argentina was continued, as well as the operation of the TRAGALDABAS cosmic ray observatory (http://pos.sissa.it/archive/conferences/236/598/ICRC2015_598.pdf).

A 3-layer cosmic-ray telescope was installed at CBPF, Rio de Janeiro, Brasil, to support the HECR group.

We continued the development of a low-power, low-cost, high-voltage supply suitable for field deployment. See also the report of the HECR group.

High-rate

Work was started on the AIDA2020 project, with participation in the kickoff meeting (CERN, June) and re-commissioning of our old test setup. This allows to take coincidence data between 2 chambers using cosmic rays or correlated gammas from a ^{22}Na source, under strong X-ray background irradiation, yielding time resolution and efficiency vs. rate.

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

This was a dormant year from the point of view of our group, as no experiment took place. 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

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 the above-mentioned 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 HECR 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.

SWOT Analysis

Strenghts

The team has proven repeatedly to be competent, inventive, productive and reliable.

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 two years.

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

Lack of young members:

The standard fellowship-based system seems to be not sufficiently attractive.

It takes a long time and attention to train a skilled detector physicist. The usual cycle of fellowship-funded renewable PhD students/Post-docs is too taxing on the senior members and globally a net waste of their time.

LIP’s technical infrastructure may prevent us to cope with the demand for detectors.

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 a few millions, but it is potentially hugely interesting.

Threats

Hostile funding environment.

In the long term, the excessive maturation of the team members will become a determinant factor.

Publications

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

J. Machado, J. Adamczewski-Musch, A. Blanco, R. Ferreira Marques, P. Fonte, A. Henriques, L. Lopes, A. Pereira, et al.: "Performance of timing Resistive Plate Chambers with protons from 100 MeV to 800 MeV", Journal of Instrumentation 10 (2015) C01043

A. Blanco, J Machado, J. Adamczewski-Musch, K. Boretzky, L Cartegni , R. Ferreira Marques, P. Fonte, J. Fruehauf, D. Galaviz, M. Heil, A. Henriques, G. Ickert, D. Koerper, L. Lopes, M. Palka, A. Pereira, D. Rossi, H. Simon: "Performance of timing Resistive Plate Chambers with relativistic neutrons from 200Mev to 1500MeV", Journal of Instrumentation 10 (2015) C02034

A. Blanco, P.Fonte, L.Lopes et al. (19 authors): "TRAGALDABAS: A new high resolution detector for the regular study of cosmic rays", J PHYS CONF SER 632 (2015) 012010

1 Collaboration notes with internal referee

P. Assis, A. Blanco, M. Cerda, R. Conceicao, F. Diogo, M. Ferreira, P. Fonte, L. Lopes, L. Mendes, M. Pimenta, R. Sarmento, R. Sato, C. Scarso, R. Shellard, B. Tome, H. Wolters: "Measurements with the RPC Muon Hodoscope Installed at the Gianni Navarra Tank: First Results", GAP2015_033

Presentations

3 Oral presentations in international meetings

Luís Lopes: "RPCs @ Coimbra and Malargue", 2015-03-02, 6th Marta Progress Meeting, Rio de Janeiro

Luís Lopes: "Production and tests of Rio RPCs @ Coimbra", 2015-03-03, 6th Marta Progress Meeting, Rio de Janeiro

Luís Margato: "10B4C coated RPCs for Position Sensitive Neutron Detectors", 2015-10-16, Kick-off meeting SINE2020, Neils Bohr Institute, University of Copenhagen, Copenhagen, Denmark

2 Seminars

Paulo Fonte: "On the physics and simulation of Resistive Plate Chambers", 2015-03-28, Second National Symposium on Particles, Detectors and Instrumentation, 27-31 March 2015, Madurai, India

Paulo Fonte: "Expanding the RPC technology and applications", 2015-04-01, Second National Symposium on Particles, Detectors and Instrumentation, 27-31 March 2015, Indian Institute of Technology, Cheenai, India

HIGH PRESSURE XENON DOPED MIXTURES FOR THE NEXT COLLABORATION

NEXT

This team is involved in the development of gaseous detectors and in the study of the properties of gaseous mixtures that can enhance their performance. In the last years some effort has been dedicated to high pressure gaseous detectors.

One of the goals consists in the study of Xe mixtures with molecular gases for filling high pressure gaseous detectors and it comes in the scope of the NEXT international collaboration in which some members of the team are involved. Other of the team goals is the development of a prototype of a ruggedized high pressure Xe based detector optimized for field applications and whose performance surpasses the most common room temperature gaseous detectors described in the literature for hard X- and gamma-ray spectrometry.

The experimental measurement of the mobility of ions in gaseous mixtures has also been one of the areas of investigation of the team and in 2014 the RD51 CERN collaboration revealed interest in these measurements for some gaseous mixtures. A proposal for a RD51 Common Project with some of the team members was approved in 2015.

Framework and status for past and current year

Summary of performance indicators

Articles in international journals:	1 With direct contribution from team 5 With indirect contribution from team
International conferences:	1 oral presentation 2 posters 1 proceedings

DEVELOPMENT OF NEW INSTRUMENTS AND METHODS

Detector development for particle and nuclear physics

Team

Principal Investigator Filomena Santos (50)

Researchers
Carlos Conde (30), Filipa Borges (30), Jorge Maia (15), José Escada (60), João Barata (15), Rui Marques (5), Teresa Dias (15)

PhD students
André Cortez(100)

MsC students
Daniel Cavaleiro (50), Bruno Rasteiro (50), Pedro Encarnação (50), Francisco Rolo (30)

External/Additional scientific collaborators
K. Saito (100), Paulo Rachinhas (10), Sérgio Carmo (10)

Total FTE
6.2

// GROUPS: Neutron Detectors / RPC R&D / NEXT / Liquid Xenon R&D / NUC-RIA

Lines of work and team organization

The main areas are coordinated by the senior members.

The study of some properties of the Xe-TMA mixtures are being coordinated by Filomena Santos and the charge multiplication and scintillation light measurements were performed by MSc Alexandre Trindade. The design, assembly and test of new devices, namely to measure the electron drift velocity in gases and the disrupter field in high pressure gas detectors were in charge of MsC students Bruno Rasteiro and Daniel Cavaleiro.

The development of the ruggedized high pressure detector (MGHP-GPSC) is coordinated by Filipa Borges with the collaboration of Carlos Conde and Sergio do Carmo. The lines of work are divided for each of the main goals as follows:

- The design, construction supervision, detector simulation and first tests are part of a PhD thesis of PhD student André Cortez. This PhD thesis is supervised by Filipa Borges and Sergio do Carmo.
- The experimental system to measure the photocathode quantum efficiency at high pressure and its dependence with photon angle incidence is the subject of a MsC thesis being performed by the MsC student Francisco Rolo. Dr. Kiwamu Saito in sabbatical from KEK, Japan and MSc Alexandre Trindade collaborated in the development and some initial measurements with this experimental system.
- The measurement of ion mobility in gaseous mixtures used as filling gases of detectors are performed by MsC student Pedro Encarnação with the supervision of PhD student André Cortez and MSc Alexandre Trindade. In the scope of this work a RD51 Common project started in June 2015.

The problems that arise during the assembly and test of the experimental systems and the results of the experimental measurements are discussed whenever necessary between the younger researchers and the supervisors and senior researchers involved in the different tasks.

Stated objectives for past year

- Study the behavior of Xe-TMA mixtures, as filling gas of proportional counters and gas proportional scintillation counters.
- Project and construction of an experimental system to study gas discharges at high pressures in pure gases and in mixtures.
- Project and construction of an experimental system to study electron drift parameters in gases.
- Design, construction and test for vacuum and high pressure of a new MGHP-GPSC prototype (10 to 20 litre volume) with a different geometry.
- Study of the electronic system and electric shielding to solve the problems of the previous prototype are amongst the issues to be addressed.
- A high pressure gas handling and purification system with Xe recovering capability will also be designed and built.
- Techniques will be studied to optimize the detector performance for large area radiation entrance windows.
- Measure of the mobility of ions in gases suitable for the current CERN experiments.

Achievements and responsibilities during the past year

Along the past year, the team has studied several aspects of the behavior of Xe/TMA mixtures, namely charge multiplication, scintillation yields and mobility of the ions in the parent gas.

These studies were performed in an experimental system that hosts both a proportional counter and a gas proportional scintillation counter. We developed devices to study electron drift parameters in gases, gas discharges at high pressure and to observe if xenon scintillation light is eventually re-emitted by TMA molecules in another wavelength. These devices are now under test and first results are being obtained. From the studies performed we believe it will be concluded that TMA is not the additive sought for Xe detectors so other candidate additives will be explored soon.

The study on xenon/TMA mixtures properties has been made, the main challenges overcome and quite successful results have been obtained. For the success of theses studies it was fundamental the collaboration of MSc Alexandre Trindade that acknowledged a grant from project Rad4life.

During these last 2 years, a new geometry for the MGHP-GPSC detector was considered to solve the most problematic issues of the first prototype. A new detector with cylindrical geometry was designed and built at LIP Coimbra workshop and is now at the assembly stage. The high pressure gas handling and purification system is also already assembled and the capability of recovering the gas was added. With the new geometry we expect for 662 keV and at a pressure of 5 atm an increased efficiency (from1% to 25%), and a solid angle subtended by the photocathode and detector active volume both 5 times larger. This will allow doubling the detector gain and attaining an energy resolution closer to the intrinsic value.

Simulation studies of the detector gain, efficiency and energy resolution were made using GEANT4 and Maxwell codes and the results of this simulation were used to optimize the design of the prototype. Different ways of compensating the solid angle effects for events detected at different positions along the detector were also addressed and a good compromise was attained, considering two different corrections.

An experimental system was also projected, designed and constructed to study the dependence of the photocathode quantum efficiency on gas pressure and on the angle of incidence of light, since this is an important issue for the above mentioned solid angle correction and little information on this subject is found in the literature. This system is already assembled and the first results for Xe at atmospheric pressure and for the CsI photocathode were recently obtained. Studies for higher pressures and for different photocathodes will soon follow.

The electronics for the data acquisition of the HPXe detector was also simulated with Orcad Cadence software and the possibility of using optical coupling was also considered. The components needed to assemble the electronic system are already identified.

We believe that the first tests of the complete set-up for the HPXe detector, in the next few months, will be made with the alpha particle source. Some delay was essentially due to the acquisition of raw materials.

In parallel, ion mobility studies have also been performed in a separate system and we were able to identify ions produced in TMA as a function of the electron energy and to assess their relative abundance. This type of measurements is of great interest for TPC devices (e.g., ALICE). Also the measure of ion mobility in gases of interest for the CERN RD51 collaboration were performed and for this reason an RD51 Common project was submitted with success in the scope of this work and started in June 2015.

Preliminary results obtained in these experiments have been presented at several meetings and two papers have been published in international scientific journals with peered review.

Lines of work and objectives for next year

Our work plan for 2016 involves assessing further mixtures of interest for the NEXT collaboration, eventually with TEA with the Xe additive to be studied. We also expect to have our electron drift velocity device fully tested and operational as the measurement of this parameter is important in several gases and their mixtures currently used in important international experiments. The improvement of this device will also be considered if deemed necessary.

Studies of drift parameters with rare gases and their mixtures, namely for neon, which is of interest for polarimetry studies of interest for Astrophysics are on the agenda, both experimentally and by Monte Carlo simulation. Dr. Rui Silva and Jorge Maia will collaborate with the team members in this research.

The studies concerning the gas discharges in high pressure noble gases with molecular admixtures will also continue for different gas pressures, and for different additives, eventually an upgrade of the system to allow the change in the distance between the electrodes will be considered.

The tests of the new MGHP-GPSC will continue during this year, starting with the alpha particle source in a first stage and with a gas pressure of 5 atm and progressing for the gamma-rays and X-rays at higher pressures (up to 15-20 atm). The use of curved grid, a masked photocathode or other techniques will be considered to optimize the detector performance, minimizing the energy resolution dependence on the solid angle subtended by the interaction point.

The experiments of the dependence of the quantum efficiency with the light incidence angle will proceed for higher pressures and for other rare gases and their mixtures with molecular gases. Study of different photocathodes will also be considered. The results obtained will be used to estimate the quantum efficiency of the photocathode in the MGHP-GPSC, depending on the point of interaction of the detected event, which may be an important issue in the optimization of the detector performance concerning solid angle effects.

Ion mobility measurements will continue for mixtures of 2 and 3 gases in accordance with the requests of RD51 collaboration. Some changes in the experimental system, namely to allow to change the ion drift distance and to allow to measure the mobility of negative ions will be projected and built. We expect this will allow to solve some of the limitations of the system that were identified during the last years.

SWOT Analysis

Strengths

The team has a long experience in the development of gaseous detectors together with a long standing experience in Monte Carlo simulation of several processes in gas detectors namely in electron and ion transport parameters in several different gases. This allows us to interpret the experimental results in a more organized way.

Weaknesses

The experimental character of the work being developed since it involves the project and construction of experimental apparatus is many times a difficulty, both due to the lack of budget to buy the raw materials needed and due to the time that is needed to construct, assemble and test the systems.

Opportunities

The measurements recently carried out with Xe-TMA, Ar-CO2 and Ne-CO2-N2 mixtures proved to be useful for the NEXT collaboration and for other collaborations like the ALICE TPC (in the scope of RD51).

Concerning the ion mobility measurements a lot of interest has arisen within the CERN RD51 collaboration with a common project approved and a lot of contacts established with groups interested in this area of research.

There is a possibility of expanding our collaboration to Astrophysics where new gas mixtures for polarimetric studies are being sought.

Collaboration with industry within the scope of the high pressure detector that is being developed is a possibility to be looked after as soon as the prototype yields positive results.

Threats

Financing is obviously a problem that endangers the possibility of being present at conferences, to make further contacts and attract other collaborations. The possibility of losing some researchers of the team that have non-permanent positions is also a threat to the team.

Ion mobility measurements will continue for mixtures of 2 and 3 gases in accordance with the requests of RD51 collaboration. Some changes in the experimental system, namely to allow to change the ion drift distance and to allow to measure the mobility of negative ions will be projected and built. We expect this will allow to solve some of the limitations of the system that were identified during the last years.

Publications

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

Encarnacao, P. M. C. C.; Cortez, A. F. V.; Pinto, M. G. A.; Neves, P. N. B.; Trindade, A. M. F; Escada, J. Santos, F. P ; Borges, F. I. G. M.; Barata, J. A. S.; Conde, C. A. N., "Experimental ion mobility measurements in Ar-CO2 mixtures", JOURNAL OF INSTRUMENTATION 10 (2015) P01010

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

NEXT Collaboration (66 authors): "An improved measurement of electron-ion recombination in high-pressure xenon gas", J. Instrum. 10 (2015) P03025

NEXT Collaboration , "Accurate gamma and MeV-electron track reconstruction with an ultra-low diffusion Xenon/TMA TPC at 10 atm", NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH SECTION A-ACCELERATORS SPECTROMETERS DETECTORS AND ASSOCIATED EQUIPMENT, Vol 804 , p. 8-24, 21 DEC 2015.

NEXT Collaboration, "Ionization and scintillation of nuclear recoils in gaseous xenon", NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH SECTION A-ACCELERATORS SPECTROMETERS DETECTORS AND ASSOCIATED EQUIPMENT Vol. 793, p. 62-74 ; 1 SEP 2015

NEXT Collaboration, "Radiopurity assessment of the tracking readout for the NEXT double beta decay experiment", JOURNAL OF INSTRUMENTATION 10 (2015) P05006

NEXT Collaboration , "PMT calibration of a scintillation detector using primary scintillation" , JOURNAL OF INSTRUMENTATION 10 (2015) C02039

1 International conference proceedings

Next Collaboration, "Radon and material radiopurity assessment for the NEXT double beta decay experiment ", LOW RADIOACTIVITY TECHNIQUES 2015 (LRT 2015) Book Series: AIP Conference Proceedings Volume: 1672 Article Number: 060002 Published: 2015

1 Oral presentation in international conference

"Novel Techniques for Gaseous Radiation Detectors", A.F.V. Cortez, C.A.N. Conde, S.J.C do Carmo, F.I.G.M. Borges - oral presentation at 1st Doctoral Congress in Engineering - Symposium on Physics Engineering - DCE 2015, Porto (Portugal) - 11 a 12 de Junho de 2015.

2 Poster presentations in international conferences

"Multi-Grid High-Pressure Gas Proportional Scintillation Counter - A New Approach", A.F.V. Cortez, C.A.N. Conde, S.J.C do Carmo, F.I.G.M. Borges - poster presented at 3rd International Summer School on Intelligent Signal Processing for FrontIEr Research and Industry - INFIERI 2015, Hamburgo (Alemanha) - 14 a 25 de Setembro de 2015

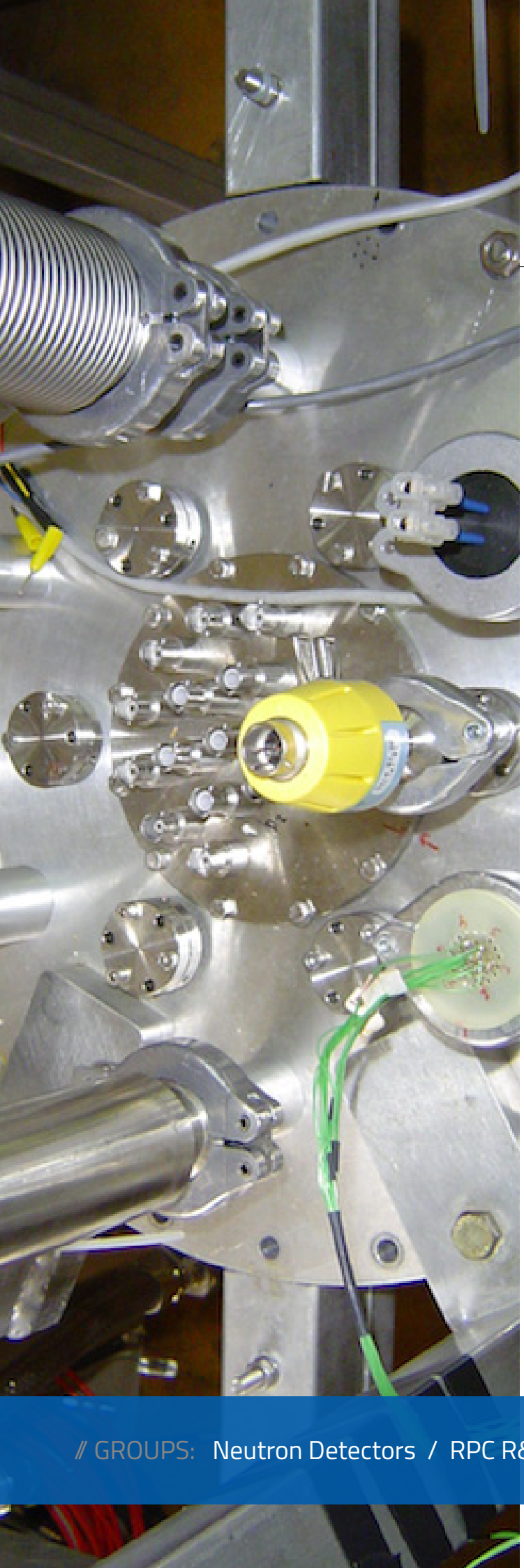
"High-Pressure Xenon based Detectors for Gamma-ray Spectrometry - A New Approach", A.F.V. Cortez, C.A.N. Conde, S.J.C do Carmo, F.I.G.M. Borges - poster presented at Exellence in Detectors and Instrumentation Technologies - EDIT 2015, Frascati (Itália) - 20 a 29 de Outubro de 2015;

LIQUID XENON R&D

Liquid Xenon R&D

There is a number of experiments around the world, with different physics goals. 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 range of interest of these experiment are different, from the detection point of view they have very much in common. The general idea of this group is to carry out research on the processes triggered by interaction of ionizing radiation 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 the effects which are potentially important but are not in the mainstream of the tightly scheduled work of big collaborations.

Framework and status for past and current year



Team

Principal Investigator Vitaly Chepel(50)

Researchers
Francisco Neves (10), Pedro Sanguino (100), Vladimir Solovov (10)

Technicians
Américo Pereira (15), Carlos Silva (5), Joaquim Oliveira (5), Nuno Carolino (5), Nuno Filipe Silva Dias (5), Orlando Cunha (5), Rui Alves (5)

PhD students
Filipa Balau (50)

Total FTE
2.6

// GROUPS: Neutron Detectors / RPC R&D / NEXT / Liquid Xenon R&D / NUC-RIA

Lines of work and team organization

The general objective of this group is R&D on liquid xenon as detector medium and associated technologies, in particular, detection of VUV scintillation photons emitted by liquid xenon. It is intended to test and characterize new photon detectors, in particular silicon photodiodes, in the VUV wavelength region and at the conditions they should operate in a liquid xenon detector. Additionally, wavelength shifting materials are planned to be studied as an alternative. Possible contamination of liquid xenon with the molecules of the wavelength shifter should be of primary concern. More generally, all electronic, optical and molecular processes, that develop in a single or double phase liquid xenon detector as a sequence of particle interaction, are in the scope of activity of this group.

Stated objectives for past year

In the past year we were planning to study the possibility of using wavelength shifting materials in contact with liquid xenon, tetraphenylbutadien (TPB), in particular. Although xenon scintillation light can be detected with photomultiplier tubes with quartz windows, the use of wavelength shifters would widen the possible choice of photon detectors (for example, silicon photomultipliers, which can be especially attractive due to their lower intrinsic background). However, stability of organic wavelength shifters in contact with liquid xenon has long been questioned. This was precisely our objective for the past year - study stability of TPB thin films in liquid xenon via direct measurements and using advanced material analysis methods.

Achievements and responsibilities during the past year

Stability of TPB thin films in liquid xenon has been studied. A number of samples of TPB on quartz substrates has been prepared and exposed to liquid xenon for up to 40 hours. Three main methods have been used to characterize the exposed samples and compare them with the control ones: electron microscopy (for possible structural changes), XPS (for chemical degradation) and UV-visible light transmission measurements (to detect possible layer by layer removal of the material). The first two methods gave negative results but the increase of transmission in the exposed samples allowed to conclude that there is indeed dissolution of TPB molecules in liquid xenon. These were the first direct proves of degradation of organic films in contact with liquid xenon.

The conclusion from this work is that the use of TPB in direct contact with liquid xenon must be avoided in xenon detectors.

Lines of work and objectives for next year

Although the continuation of this work strongly depends on the available funding, one can envisage attempts to decrease the solubility of wavelength shifter in liquid xenon by using heavier molecules (eventually metallorganic).

Another line of planned work is characterization of new silicon photomultipliers developed by Hamamatsu for liquid xenon.

EXPERIMENTAL NUCLEAR ASTROPHYSICS

NUC-RIA

The Nuclear Reactions, Instrumentation and Astrophysics group joined LIP at the end of 2015. Over this last year, as part of the continuation of the group activity during the past 5 years, the focus has been on:

- Analysis of Quasi-Free Breakup experiment S393 performed at the GSI laboratory in Darmstadt, Germany.
- Participation in the Working Group activity of future detectors of the R3B collaboration at FAIR, Darmstadt, Germany.
- Participation in the FCT/CERN project CERN/FIS-NUC/0004/2015, with the scope of the participation at the ISOLDE/CERN facility.
- Preparation and planning of nuclear astrophysics reaction experiments at low-energy facilities.

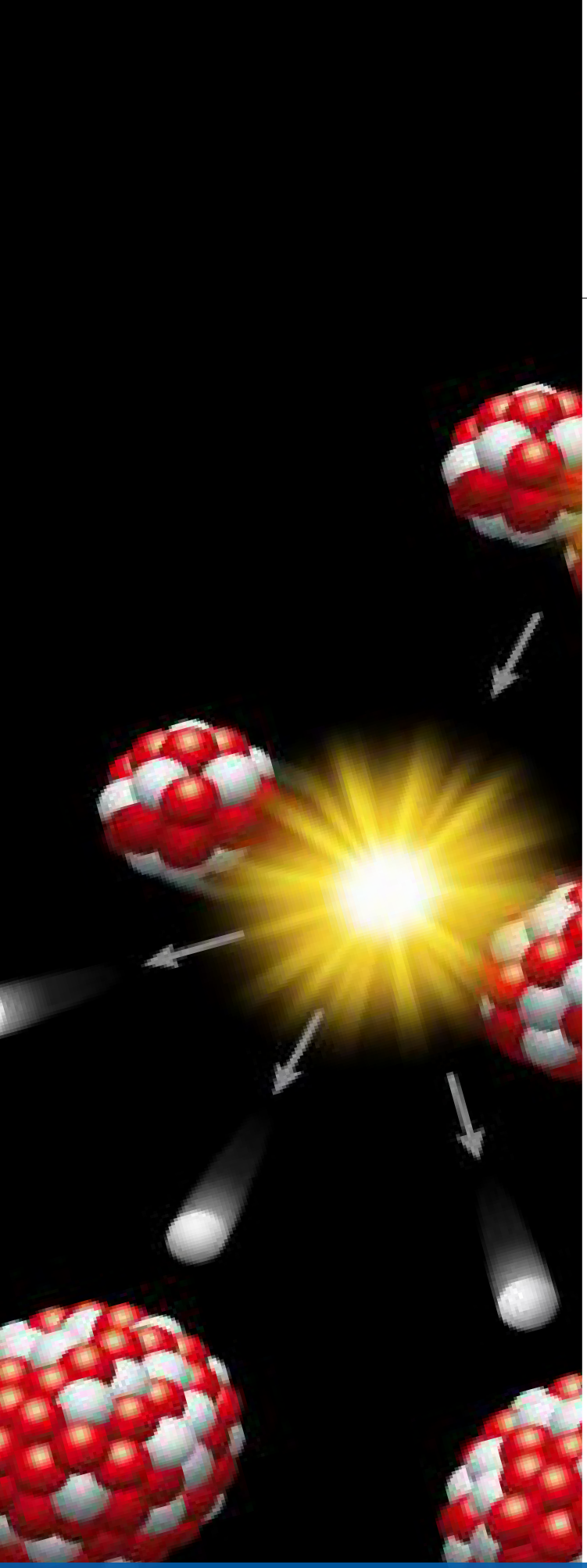
Framework and status for past and current year

Summary of performance indicators

Completed theses: 1 PhD Thesis

DEVELOPMENT OF NEW INSTRUMENTS AND METHODS

Detector development for particle and nuclear physics



Team (starting in 2016)

Principal Investigator Daniel Galaviz

PhD students
Ana Isabel Henriques, Pamela Teubig, Paulo Velho

Master students
David Ferreira

External/Additional scientific collaborators
André Baptista, Frederico Arez, Patricia Marques

Total FTE
8 (for 2016)

// GROUPS: Neutron Detectors / RPC R&D / NEXT / Liquid Xenon R&D / NUC-RIA

Lines of work for next year

The research lines to which the group will devote its activity during 2016 are the following:

- 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. This experiment, S393, performed at the GSI laboratory, was proposed and executed by the R3B (Reactions with Relativistic Radioactive Beams) collaboration of the future FAIR facility. The analysis and interpretation of the measured data is the main part of the PhD Thesis of Ana Henriques and Paulo Velho, which should be finished and defended during this year.

- Implementation of analysis tools for FAIR: While in the preparation phase prior to the first experiments to be performed by the R3B collaboration using the upgraded detection systems, the development of new analysis tools of the CALIFA calorimeter will be executed as well during 2016. This work is part of the PhD Thesis of Pamela Teubig.

- Participation in nuclear physics activities at ISOLDE/CERN: The group was part of the research project CERN/FIS-NUC/0004/2015, which was recommended for funding during the past FCT-CERN call. The main aspects of the research project will be executed during 2016. Responsibilities of the group will be the construction of new HV-sources for scintillation detectors and the simulation of the anisotropy of photon detection in scintillator materials.

- Continue the low-energy program for nuclear structure and nuclear astrophysics: During 2016, the group will perform low-energy proton-induced reactions to deepen in the understanding of the level structure of light nuclei below the neutron emission threshold, and to characterise the reaction cross section induced by protons for nuclear astrophysics purposes.

- Start work in ENSAR2: The group is part of the applicants of the consortium ENSAR2 (European Nuclear Science and Application Research) of the Horizon 2020 program. In addition to the Transnational Access Network considered within the consortium, which allows the participation of members of the group in experiments at radioactive ion beam facilities in Europe, the group is directly involved in the Joint Research Action "SATNuRSE", devoted to the development of particle transport simulation tools for basic and applied nuclear science. The activities related to this JRA will start as well during 2016.

- Participation in IAEA's Coordinated Research Project: The group applied during 2015 as participant to the IAEA's Coordinated Research Project "Development of Electron Beam and X-Ray Applications for Food Irradiation", with the proposed project "Fostering E-beam Food Irradiation: Modelling and Validation" being approved for 2016. The group is responsible for the modelling of the dose irradiation in food products. During 2016, first tests and validations of the model simulated using GEANT4 will be performed.

SWOT Analysis

Strengths

Involvement in international collaborations. Knowledge in nuclear instrumentation, data analysis, and particle transport simulations. 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 provides the hiring of a postdoctoral researcher and allows the participation and active involvement in nuclear reaction experiments performed in radioactive and stable ion beam facilities in Europe for the upcoming 4 years.

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.

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" (ongoing)

Instruments and methods for biomedical applications

In addition to other sources of funding mentioned in this section, several groups benefited from the Rad4Life project, in execution until September 2015: RPC-PET imaging, improved photon localization in gamma cameras, fiber-based scintillation dosimeters, radiotherapy monitoring techniques, and high pressure xenon detectors. This project was run by LIP in association with the University of Coimbra and covered personnel costs: fellowships and contracts, including an Assistant Professorship, for a period of 28 months. In 2015 the budget was 97 k€. Besides the indirect support to research and its outcomes, the real success of "Rad for Life" was in maintaining LIP's human resources: it was possible to keep a top team of detector experts, carrying the accumulated experience of many years, throug the funding difficulties of recent years.

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:

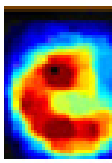
- the simulated quantum efficiency of RPCs for 511 keV photons corresponds to the reality.
- a reconstructed source resolution of 0.4 mm FWHM.
- practical high-resolution imaging of mice and rats.
- the intrinsic time resolution of RPCs for 511keV photons is 300 ps FWHM for the time difference between 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.
- 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.

Framework and status for past and current year

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 and dozens of examinations of mice and rats have been performed by the ICNAS team.

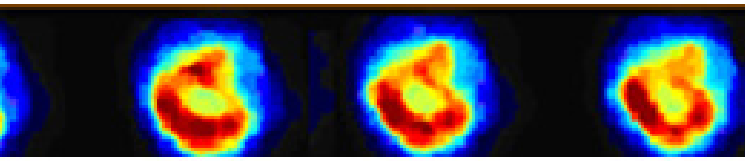
On the human PET front, the basic structure of the scanner was long ago designed and simulated, the readout method was patented (expired), and a general test of the readout system is now under way.

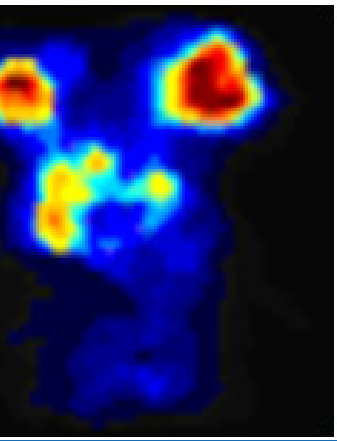
It is specially important to mention that the DAQ group (*) of the HADES experiment at GSI, Germany (of which LIP is a member) is our partner in this project, providing a very modern and powerful data acquisition system.

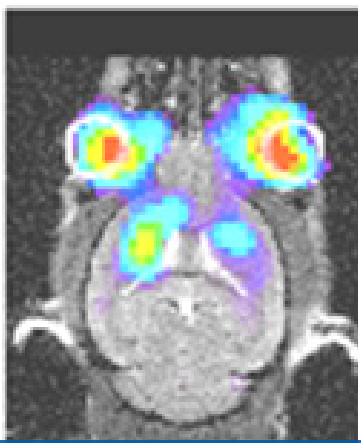


DEVELOPMENT OF NEW INSTRUMENTS AND METHODS

Instruments and methods for biomedical applications







These activities were partially funded this year by the Rad4Life project of the COMPETE/ MAISCENTRO program.

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 (100), Rui Marques (30), Susete Fetal (20)

Technicians
Américo Pereira (5), Joaquim Oliveira (5), Orlando Cunha (5), Rui Alves (5)

Total FTE

2.3

Summary of performance indicators

Articles in international journals:	1 With direct contribution from team
National conferences:	1 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 (see the specific report) and HADES DAQ groups, while the remaining members concentrate on simulation and image reconstruction software.

Achievements and responsibilities during the past year

The scanner installed at ICNAS was continuously upgraded, driven by the user demands:

- graphical user interface (GUI) for image reconstruction and visualization, with exportation to a standard image interchange format
- new mice "bed" with improved marker for MRI co-registration and other improvements
- mechanical structure enlarged to accommodate both rats and mice (at the expense of lower sensitivity)
- number of RPCs per head increased from 3 to 7 (10 nominal) and initiated the corresponding adaptation of the data-processing software
- improved monitorization and remote control systems
- automatization of the data acquisition and processing to allow operation by non-experts

A new front-end electronics with improved isolation with respect to external digital noise pickup was developed and it is now being tested. This is expected to strongly improve the scanner's sensitivity by allowing to lower the trigger thresholds.

It is worth noting that, on what concerns the animal scanner, we are concentrated on achieving its full development and abstaining for the moment from publications or presentations in conferences.

A funding proposal entitled "A radically new instrument for PET imaging in humans" was submitted to the call H2020-FETOPEN-2014-2015-RIA with partners: LIP, ICNAS/ University of Coimbra, GSI, University of Frankfurt, Hopital Universitaire de Tours. To this call were submitted 822 projects for a total funding of 154M€ and indicative budget per project of 2M€ (up to 4M€). Not unexpectedly, our project was not financed, with a classification of 3/5, showing the four referees strong disagreement in their evaluations.

A project entitled "An extremely high spatial resolution Positron Emission Tomography scanner for small animals" was submitted in January to the general "PTDC" call, achieving a classification of 8/9. In contrast with many projects with the same classification, it was not financed.

Lines of work and objectives for next year

Group Activities

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).

SWOT Analysis

Strengths

The proposed technologies seem to be advantageous relativelly 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 a few millions, probably inaccessible by small players like us. Let alone an eventual marketing phase.

In practice, lack of skilled manpower for hardware 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.

Publications

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

M. Couceiro, P. Crespo, A. Blanco, N. C. Ferreira, L. Mendes, R. Ferreira Marques, P. Fonte: "Time-of-Flight Positron Emission Tomography with Resistive Plate Chamber Detectors: An Unlikely but Promising Approach", Acta Phys. Pol. A 127 (2015) 1453-1461

Presentations

1 presentation in national conferences

Miguel Couceiro: "An ultra-high resolution preclinical positron emission tomography scanner", 2015 IEEE 4th Portuguese Meeting on Bioengineering (ENBENG), Atmosfera m, Porto, Portugal

ORTHOGONAL RAY IMAGING FOR RADIOTHERAPY IMPROVEMENT

OR Imaging

LIP has proposed a new very-low-dose imaging technology in the field of external beam photon radiotherapy. The purpose of such imaging is twofold:

1. to image the tumor region when the patient is already immobilized on the patient couch, just prior to the onset of one irradiation plan (so-called on-board imaging)

2. to image the region of the patient being irradiated with a multi-sliced detector positioned at 90 degrees in respect to the direction of the incoming beam.

Both cases are illustrated in the image.
This type of imaging, which we have termed OrthoCT (orthogonal computed tomography), relies on the fact that photon scattering in the patient occurs with higher intensity in tissues of higher density. The same will hold for photons emitted at 90 degrees in respect to the beam direction. By applying a beam that is scanned in 2 directions (with these directions known), the 3rd point where the interaction occurred is given by the detector slice, which yields a signal proportional to the photon that escaped the patient.

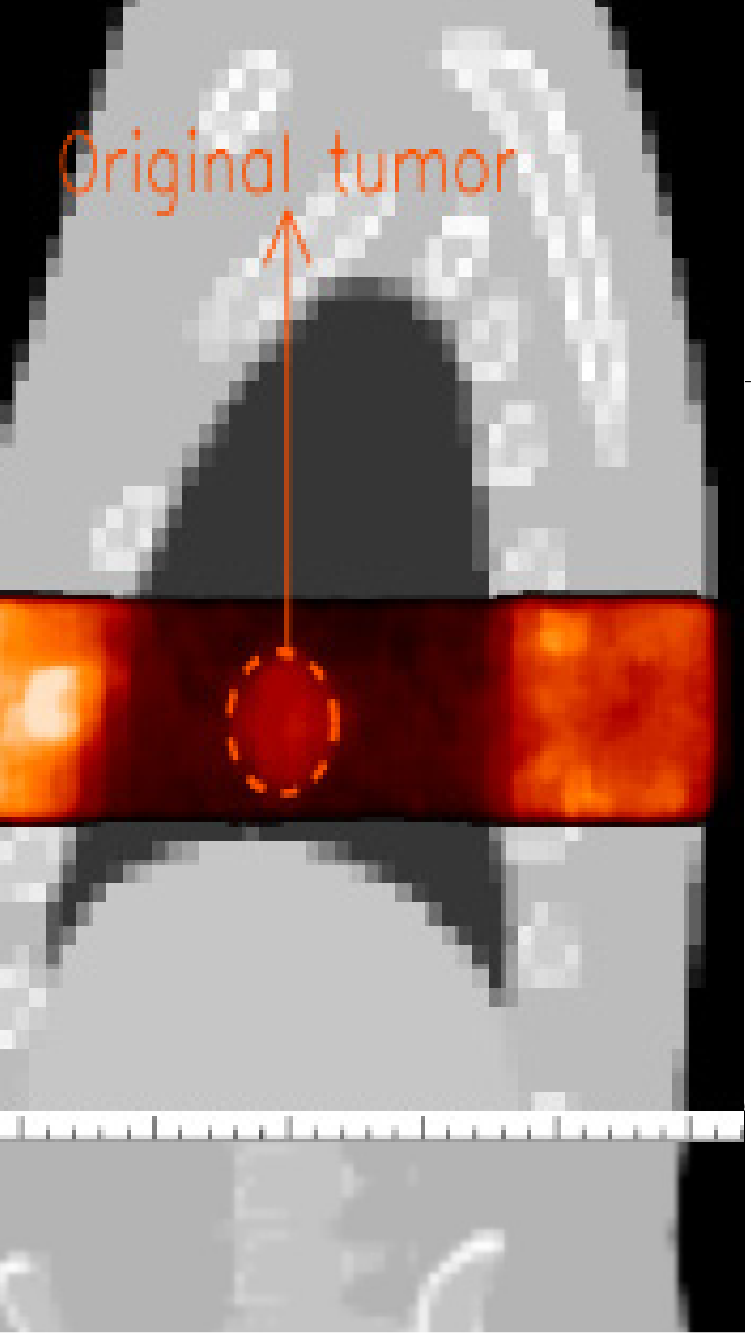
Framework and status for past and current year

Summary of performance indicators

Articles in international journals:	1 With direct contribution from team

DEVELOPMENT OF NEW INSTRUMENTS AND METHODS

Instruments and methods for biomedical applications



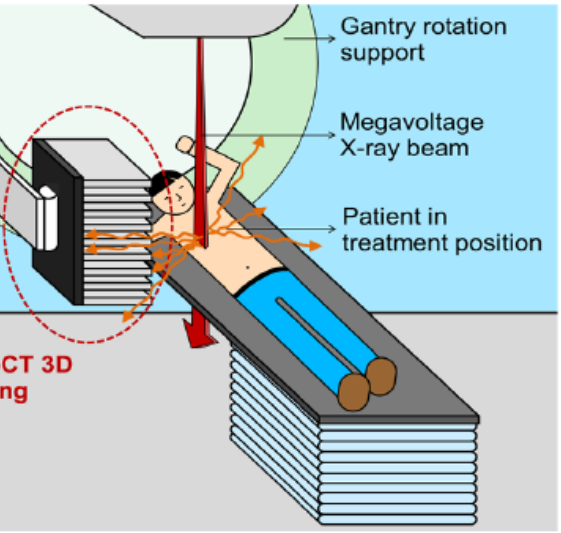
Team

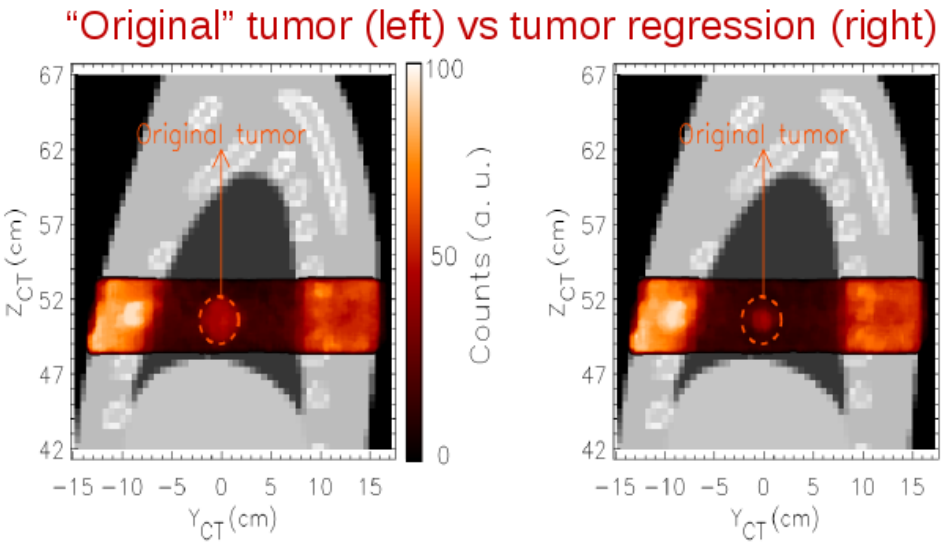
Principal Investigator Paulo Crespo (65)

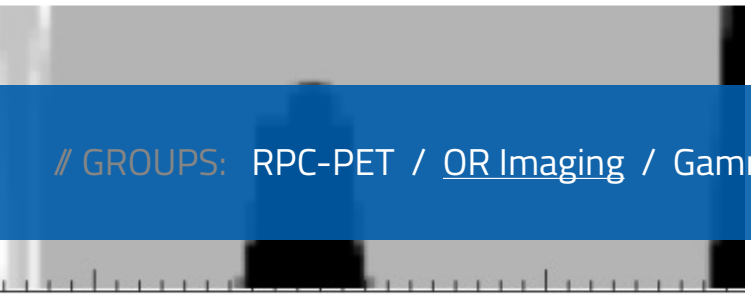
PhD students
Hugo Simões (100), Patrícia Cambraia Lopes (100)

Master students
Ana Lopes (33), Carolina Travassos (33), Mariana Barros (33)

Total FTE
3.7







Lines of work and team organization

The team is so far based at LIP Coimbra, with occasional meetings occurring with medical physicists from the Portuguese Institutes of Oncology of Coimbra and Porto (IPOCFG, EPE and IPOPFG, EPE) and from the Radiotherapy Department of Coimbra University Hospital Center (CHUC, EPE). The lines of research and associated investigators are described in the next paragraphs.

The project is moving forward in two fronts at LIP Coimbra, substantiated by the work of one assistant professor (coordinator), one PhD student, and three master students. Medical physicists at the Portuguese Institutes of Oncology of Coimbra and Porto (IPOCFG, EPE and IPOPFG, EPE), together with medical physicists from the Radiotherapy Department of Coimbra University Hospital Center (CHUC, EPE) are also assisting the experimental work, together with providing feedback to the orthogonal ray imaging concept per se.

The two aforementioned fronts are:
1. adaptation of the simulation code in Geant4 to the DICOM medical imaging data format, thus (later) enabling the computation of real treatment plans
2. measurements of dose values and distributions obtained so far with gafchromic EBT (external beam radiotherapy) films. These measurements have the purpose of subtantiatingt he capability of a linac to deliver homogeneous dose distributions even when scanning thin beams. It has been seen so far that the minimum beam size deliverable with the jaws of the Varian TrueBeam linac is of the order of 6 mm x 6 mm, with fairly good homogeneity obtained in an EBT film positioned inside a cylindrical, PMMA (polymethyl methacrylate) phantom. This allows OrthoCT (i.e. orthogonal ray imaging based on a multislice imaging device) imaging in principle to be carried on, although better imaging variables are expected to be obtained if thin films delivered by an MLC (multileaf collimator) are collected. The latter is already under planning.

Finally, one third working front that is temporarily waiting feedback from the high-precision mechanical workshop of LIP is the construction of an OrthoCT prototype made of 200 GSO crystals, already purchased, so that imaging of an already existing heterogenous phantom can take place. This imaging experiment should occur in the next 1 to 1.5 years.

Stated objectives for past year

The objectives proposed for the past year were connected with (1) the further development of the simulation software, so that a full OrthoCT system could be characterized, including optimum crystal size, optimum septa width, thickness and length, and viability of current integration electronics readout (also validated by simulation); (2) the design of an experimental OrthoCT prototype system for later data readout under irradiation with a clinical beam.

Achievements and responsibilities during the past year

The group achievements over the past year included the optimization by software of a full blown OrthoCT system. For that, the irradiation of a lung tumor positioned in an anthropomorphic phantom was mimicked. The comparison of OrthoCT images obtained with different septa thicknesses, lengths, and widths was accomplished by means of computing the correlation of such obtained images with the initial image containing the patient morphological information together with the dose distribution. Missing in these simulations is the real thin-beam transverse profile which is being measured this year. Nevertheless, regions with correlation stability could already be identified in maps representing the sliced collimator septa variables, which allowed a small prototype system to be designed with the help of the high-precision mechanical workshop of LIP. Work is now being carried out in order to find out experimentally the best thin-beam profile that yields the highest possible (scanned) on-target dose homogeneity.

Another group achievement was the implementation into Geant4 of the capability of reading medical images in the DICOM format. This will allow in the near future the simulation of real treatment plans, including the capability of an OrthoCT system to retrieve patient morphological information in so-called on-board imaging, i.e., imaging a location of the patient just prior to the onset of the irradiation treatment. It must be stated for completion that such OrthoCT images are obtained with quite low dose and without rotation of the X-ray source, hence improving dramatically image speed and highly reducing dosage in out-of-field organs and normal tissue.

Lines of work and objectives for next year

The lines of work and objectives proposed for the coming year include the simulation of selected real treatment plans, which will allow to compute the correlation of the real patient morphological information (including tumor) with the images obtained by an OrthoCT system. Also planned is 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) is 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) is also planned.

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 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 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

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

Patricia Cambraia Lopes et al. (12 authors): "Time-resolved imaging of prompt-gamma rays for proton range verification using a knife-edge slit camera based on digital photon counters", Phys. Med. Biol. 60 (2015) 6063-6085

Theses

2 PhD Theses

Patrícia Cambraia Lopes: "Demonstration of a time-of-flight device for particle therapy monitoring" (ongoing)

Hugo Simões: "Demonstration of an orthogonal ray imaging device for assisting external photon beam radiotherapy" (ongoing)

3 Master Theses

Carolina Travassos: "Caracterização experimental de feixes de megavoltagem para imagiologia de raios ortogonais" (ongoing)

Ana Lopes: "O impacto do contraste tumoral em imagiologia de raios ortogonais" (ongoing)

Mariana Barros: "Medida da dose em fantomas submetidos a radiação de megavoltagem para imagiologia de raios ortogonais" (ongoing)

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 to the areas of medical imaging and imaging techniques used in drug discovery. In the past two years we performed the proof-of-the-concept work in which it was confirmed, using both simulated and experimental data, that auto-calibration and position reconstruction techniques developed in LIP can be successfully applied to a clinical gamma camera of classical design. The next step will be developing of the working prototype with the characteristics comparable with the industrial standards. In the parallel line of work, we are performing R&D in a view of developing a compact high-resolution gamma camera for small animal imaging. We collaborate with medical imaging units of Coimbra University (ICNAS and AIBILI) and Coimbra University Hospital.

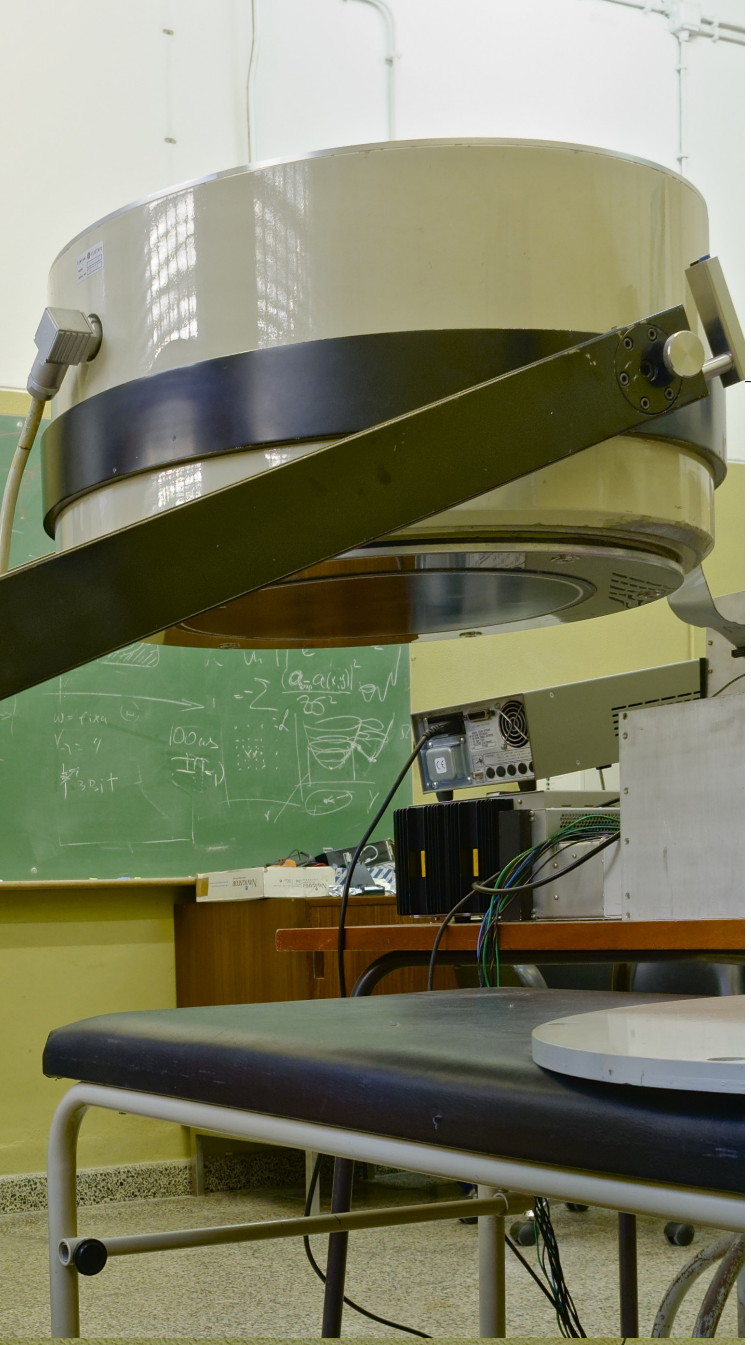
Framework and status for past and current year

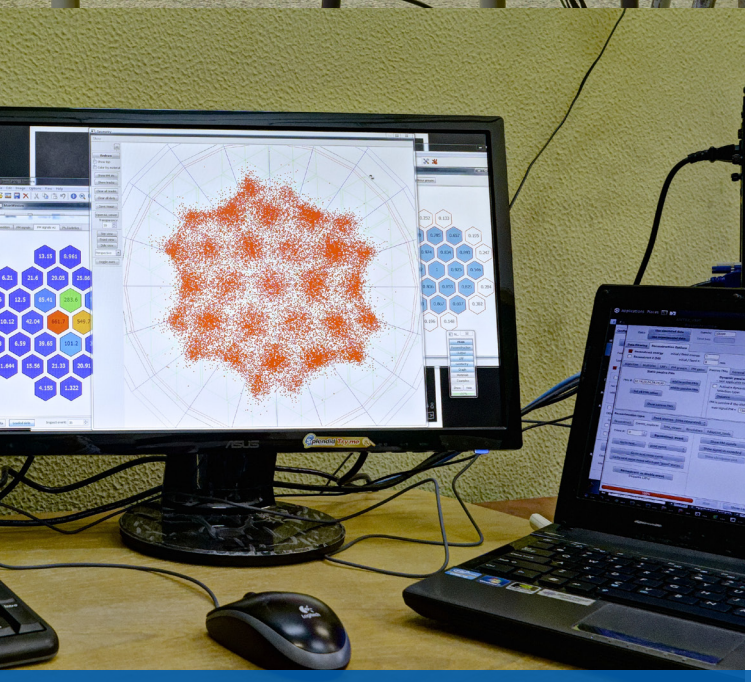
Summary of performance indicators

Articles in international journals:	1 With direct contribution from team
National conferences:	1 Presentation

DEVELOPMENT OF NEW INSTRUMENTS AND METHODS

Instruments and methods for 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), Carlos Silva (5), Joaquim Oliveira (5), Nuno Carolino (5), Nuno Filipe Silva Dias (5), Orlando Cunha (5), Rui Alves (5), Valdemar Domingos (100)

PhD students
Filipa Balau (50), João Marcos (100), Luís Pereira (30)

External/Additional scientific collaborators
Alessio Mangiarotti (20)

Total FTE
4.8

// GROUPS: RPC-PET / OR Imaging / Gamma Cameras / Dosimetry / STCD TagusLIP

Lines of work and team organization

The main lines of work are:

- Development of the simulation and data processing software for position-sensitive scintillation detectors. The main focus is on the integrated software package ANTS2 specifically targeting scintillation cameras and providing a set of easy-to-use tools for simulation and reconstruction of scintillation events in cameras of configurable geometry. This ANTS2 package is extensively used in other lines of work.
- Development of a prototype of a clinical gamma camera with statistical event reconstruction and auto-calibration capability. This involves both simulations and experimental work. The simulations are used to find the algorithmic approach that provides the best performance, both in terms of image quality and convergence rate. The prototype used for experimental verification of the developed algorithms is being built on the chassis of a decommissioned commercial gamma camera upgraded for list-mode data acquisition.
- Development of compact gamma cameras for prostate and intra-operative imaging and high-resolution SPECT detector module for small animal imaging. The use of statistical position reconstruction methods permits to achieve sub-millimeter intrinsic spatial resolution for 140 keV gamma rays over almost the whole crystal area. Additionally, it is possible to efficiently filter out multiple scattering events - a feature important for the crystals with high intrinsic radioactivity, e.g. LSO.

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

Three main objectives were envisioned in the framework of this project for the past year:

- Build a working prototype of a high-resolution compact camera with self-calibration capabilities
- Explore possibility of using machine learning algorithms for position and response reconstruction. The list of techniques to consider included artificial neural networks (ANN), k-nearest neighbour (k-NN), gaussian mixture models (GMM) and self-organizing maps (SOM)
- Prepare to commercialize the concept of self-calibrating clinical gamma camera

Achievements and responsibilities during the past year

Compact gamma camera. The prototype of a compact gamma camera with SiPM readout was built, featuring a 30x30x2 mm^3 LYSO crystal coupled to an 8x8 SiPM array by SensL (composed of four ArraySB-4-30035-CER elements). The mechanical design was made adjustable to facilitate testing of different optical configurations. In order to use statistical methods for event reconstruction, all 64 SiPMs were read individually with a custom-made data acquisition system based on a 64-channel MAROC3 ASIC. With the SiPM outputs AC coupled to MAROC3 inputs and optimized signal and ground layout, the electronic noise and interference were brought to the level below a single photoelectron.

Performance of the compact gamma camera was studied with 140 keV gamma rays from a Tc-99m source installed on a precision computer-controlled XY positioning table. This allowed scanning the camera with line and point sources to emulate expensive bar and hole phantoms. Also, direct measurement of the response profiles of individual photosensors were performed. A comparative study of position reconstruction techniques with respect to the linearity of the reconstructed image and the area of useful field of view was performed for:

- centroid
- statistical reconstruction with iteratively reconstructed SiPM response profiles
- statistical reconstruction with measured SiPM response profiles.

Predictably, the statistical reconstruction demonstrated significantly better performance than the centroid. The useful field of view was estimated to be 26x26 mm^2 for both statistical reconstruction methods, with somewhat better linearity demonstrated by using measured response profiles. In the latter case, the spatial resolution was found to be better that 1.0 mm across the useful field of view and energy resolution of 25% FWHM was measured for flood irradiation data. With this study the possibility of response reconstruction from flood field data was fully confirmed for the compact gamma camera design used in the experiments.

Machine learning. The study of the machine learning algorithms for position and response reconstruction was focused on two methods: artificial neural networks (ANN) and k-nearest neighbour (k-NN). In both cases the performance was compared with the standard statistical methods as least squares and maximum likelihood. The advantage of ANN is very fast reconstruction even on single-processor systems. k-NN has proved itself invaluable for the purposes of fast camera calibration and background filtering. Both methods were incorporated into the ANTS2 software package.

Self-calibrating clinical gamma camera. The preparation work was done including research on available options for a fast multichannel data acquisition system. The data acquisition software was upgraded with new features like support for multiple hardware (via plugins) and script-driven acquisition. The ANTS2 package was also augmented with advanced scripting system and a versatile module for import of experimental data.

Lines of work and objectives for next year

The objectives for the next year are:

- 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.

The work will be organized along the following lines:

Software development. We will continue to work on the ANTS2 package. The main focus will be:

- Development of the techniques for adequate representation of the SiPM spatial response for the compact gamma camera;
- Optimization of the photosensor response reconstruction algorithms for the case of the presence of a significantly non-axially-symmetric component;
- Integration with the data acquisition software.

Simulations. We will continue to work on optimization of the camera parameters, such as the lightguide thickness and the properties of the optical interface between the scintillation crystal and the materials on the crystal back and side surfaces. The event data generated in simulations will be used to develop and optimize the adaptive response reconstruction technique for this detector.

Upgrade of the front-end electronics and data acquisition system. The upgrade is planned in order to increase the acquisition rate, increase the range of signal integration time, introduce a flexible triggering system and reduce the electronic noise. This is especially important for improving the performance of the clinical gamma camera prototype to the level comparable with that the modern commercial models. The work on the compact gamma camera will also benefit from this upgrade.

Experimental validation. The optimal configuration found by simulation will be implemented in the compact gamma camera prototype. The prototype will be characterized in terms of the image linearity, intrinsic spatial resolution and energy resolution for 140 keV gamma-rays. The work will be performed on fine-tuning the camera and the reconstruction algorithms to the best performance. Additional simulation study might be required during this optimization phase in order to match the simulated and the experimental performances.

Finally, if the progress of the both lines indicated above will be fast, we intend to test the performance of the compact gamma camera as an element of a SPECT system. For this purpose we will equip the camera with a pinhole collimator (will be supplied by our medical partners) and investigate the limit of the spatial resolution of the system. The experimental work will be performed in parallel with simulations using ANTS2 package.

SWOT Analysis

Strengths

- Expertise of the team in the research area
- Ongoing collaboration with national medical research groups and hospitals
- Support infrastructure and engineering expertise provided by LIP mechanical and electronics workshops

Weaknesses

- Aging experimental base and limited funding for its upgrade
- Limited experience in the area of protection of intellectual property

Opportunities

- The technology under development is attractive for industry
- The methods and tools developed in the group are of interest for a large community which leads to high potential to form new collaborations
- The research area is attractive for students
- Access to Instituto Pedro Nunes (the local “enterprise accelerator”): can get support in creating links with industry and in search for investment

Threats

- Failure to hire sufficiently qualified human resources due to recent “brain drain” from Portugal
- Inability to obtain funding for equipment and materials required for completion of the experimental part of the project
- Threat to lose key member(s) of the group (the majority of the group members are on non-permanent work contracts)

Publications

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

A. Morozov, V. Solovov, F. Alves, V. Domingos, R. Martins, F. Neves, V. Chepel: "Iterative reconstruction of detector response of an Anger gamma camera", Phys. Med. Biol. 60 (2015) 4169-4184

Presentations

1 Presentation in national conference

João Marcos: "Compact medical gamma camera", 2015-06-11, 1st Doctoral Congress in Engineering, FEUP, Porto, Portugal

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" (ongoing)

DOSIMETRY IN HEALTH AND ENVIRONMENT

Dosimetry

During 2015 the project had two main tasks:

1. Development of scintillation detectors for medical applications.

2. Development of radon detection techniques and environmental radon survey

In task 1, a plastic scintillation detector (PSD) was developed for personal dosimetry in radiology. The PSD is constituted by a small (10 to 20 mm long, 3 mm in diameter) plastic scintillator connected to a PMMA optical fiber, read by a PMT. The device was tested in a PMMA phantom in under the X-ray beam produced by a Siemens Mammomat tomograph (Hospital da Luz, Lisbon) used for Tomosynthesis. The device showed a linear response with dose in for beams of 26 and 36 kV and no relevant energy dependence.

In task 2 the radon concentration in water sources of public drinking of Covilhã's County was assessed. In this study 30/33 assessed samples had radon concentration levels above the safe limit of 11.1 Bq/L recommended by the United States Environmental Protection Agency.

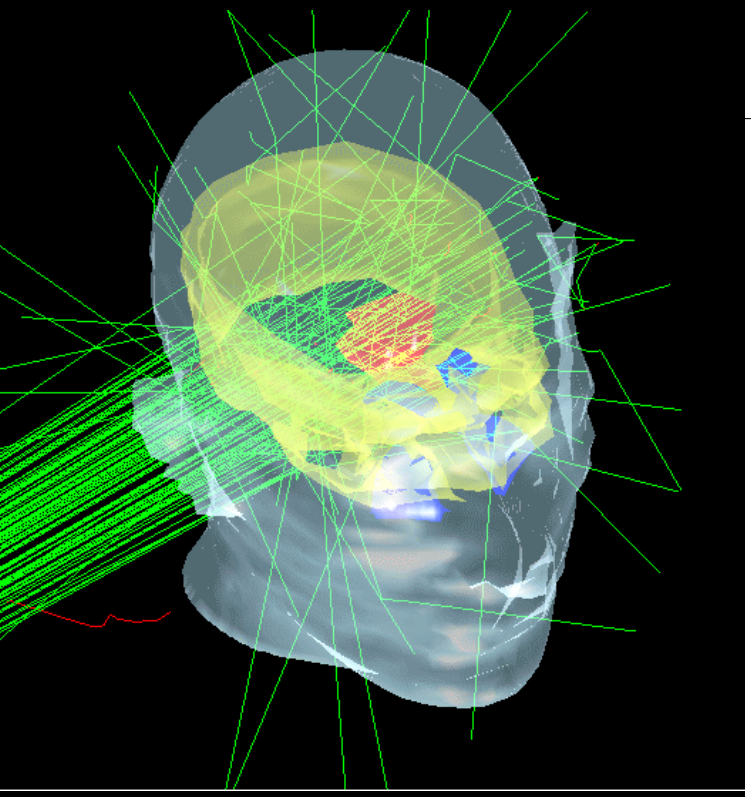
Framework and status for past and current year

Summary of performance indicators

Articles in international journals:	1 With direct contribution from team
International conferences:	2 Oral presentations 2 Posters 1 Proceedings
National conferences:	2 Oral presentations 1 Proceedings
Outreach:	1 Outreach seminar
Organization:	2 Workshops organized

DEVELOPMENT OF NEW INSTRUMENTS AND METHODS

Instruments and methods for biomedical applications



Team

Principal Investigator Luis Peralta (80)

Researchers
Alina Louro (30), Conceição Abreu (30), Florbela Rego (60), Patrick Sousa(20), Sandra Soares (80)

PhD students
Margarida Isabel Inácio (100)

Master students
Ana Campos (30), Joana Machado (33), João Antunes (70)

External/Additional scientific collaborators
Jorge Sampaio (20), Pedro Gabriel Almeida (20)

Total FTE
5.7

Lines of work and team organization

Presently the project is divided in two tasks

1. Development and test of plastic scintillator detectors for dosimetry application in radiology.

This task is developed in Lisbon and is coordinated by Luis Peralta. The team is also composed by João Antunes and Joana Machado (Master Students) and Florbela Rego.

2. Radon survey in water in Beira Interior

This activity is developed in Covilhã and is coordinated by Sandra Soares. The main goal is to assess the influence of radon dissolved in the water in life quality. The team is also composed by Margarida Inácio and Pedro Gabriel Almeida.

Sources of Funding

Code	Amount	Dates	Description
PTDC/BBB-IMG/3310/2012	25.920 €	2013-07-01 to 2015-12-31	FCT - R&D projects in all domains

Stated objectives for past year

Last year goals were:

1. Breast CT: New tools for Dosimetry and Image quality in breast cancer diagnostics

2. Novel approaches to RADiation Physics simulation and modelling at the NANOmetric scale

3. Radon in water: what ecological benefits?

Due to lack of founding objective one was adapted to further development of the plastic scintillator detector to Tomosynthesis and to Cone-Beam CT, objective 3 (Radon in water) could be pursued with some differences to the original plan, but object 2 was not initiated.

Achievements and responsibilities during the past year

1. Development of plastic scintillation detectors for medical dosimetry

Breast cancer diagnose techniques, such as mammography and tomosynthesis, make use of x-ray beams with kilovoltage peaks ranging from 25 kV to 36 kV to obtain digital images of the organ. Dose monitoring is necessary to avoid patients' over exposure, due to patient repetitive examination or machine malfunction. Plastic scintillators detectors (PSDs) have been studied as field dosimeters, since they provide a cost-effective alternative to conventional ionization chambers. In this study, we exploit the energy and temperature dependencies of a polyvinyltoluene plastic scintillator, the BC-404 from Saint-Gobain. The scintillator is connected to a photomultiplier tube (R647P from Hamamatsu) by a PMMA optical cable, and the readout is made with a charge amplifier connected to a voltmeter. Measurement and analysis of energy dependency were performed with a Siemens Mammomat tomograph (Hospital da Luz, Lisbon) for two different peak kilovoltages: 26 kV and 35 kV. Tests were conducted placing the dosimeter inside a PMMA phantom. The BC-404 PSD displayed good linearity for each energy considered and almost no energy dependence. This allows the use of the dosimeter in tomosynthesis after an appropriate calibration. Measurements were made at 50 kVp to study the temperature dependence of the BC-404 response. In the 0 to 40 ºC range a small relative signal variation of +- 0,40% / ºC was measured, confirming a reliable low-cost alternative of PSD to current state-of-the-art expensive dosimeters.

2. 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. While the most importante contribution of natural radiation is from inhaled radon progeny, in certain circumstances exposure to radon through drinking water can exceed safety levels. Radon concentration measurements were performed on 33 samples collected from water wells at different depths and types of aquifers at Covilhã. Of these, 30 had radon concentration levels above the safe limit of 11.1 Bq/L recommended by the United States Environmental Protection Agency, a value adopted in this work because Portugal has no standards for radon in drinking water.

Lines of work and objectives for next year

The foreseen activities are:

1.Test a new prototype with an optical cable 10 m long in a 100 - 120 kV CT Cone-beam CT in Hospital de Santa Maria, Lisboa.

2. Continue the radon in water survey and study its influence in cell grow, namely the study of the sensitivity of the daphnia and microalgae to ionizing radiation.

3. Build a prototype of a autonomous low cost measurement of airborne alpha particle for radon monitoring.

SWOT Analysis

Strengths

- Good contacts with other groups
- Large experience in the field of medical applications
- Part of the team is located in a high radon region

Weaknesses

- Small budget
- Small team

Opportunities

- A number of radiological exams can use the plastic scintillator dosimeter.
- Radon policies in need to be more developed in the country.

Threats

- Fluctuations in team composition (master students stay one year)

Publications

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

L. M. Moutinho, I. F. C. Castro, L. Peralta, M. C. Abreu, J. F. C. A. Veloso: "Brachytherapy dosimeter with silicon photomultipliers", Nucl. Instrum. Methods Phys. Res. Sect. A-Accel. Spectrom. Dect. Assoc. Equip. 787 (2015) 358-360

1 International Conference Proceedings

Maria Conceição Abreu, Jorge Miguel Sampaio,Luis Peralta, Patrick Sousa, Patricia Enes de Lima: "Should we reasses strutural shielding design of mammographic instalations?", Current Issues of Physics and Scientific Diving, 1ªs Jornadas da Macronésia, Universidade dos Açores, pg.91-96, Oct 2015

1 National Conference Proceedings

S. Soares, M. Inácio, P. Almeida: "Determinação da concentração de radão na água da serra da Pena", Física 2014 - 19a Conferência Nacional de Física - IST – Lisboa, Setembro de 2014

Presentations

2 Oral presentations in international meetings

Sandra Soares: "Microdosimetric prespective of human lung acinus cancer prevalence", 2015-04-16, Workshop LOWDOSE-PT-2015 Biological effects and risks of low dose and protracted exposures to ionizing radiation, CTN-Campus Bobadela

Luis Peralta: "Dosimetros de plástico para avaliação em tempo real do risco de exposições em radiologia", 2015-09-10, Justificação e Optimização das Exposições Médicas a Radiações Ionizantes, Lisboa, Auditório do IPOLFG

2 Poster presentations in international conferences

João Antunes: "Plastic Scintillators Dosimeters for Tomosynthesis", 2015-04-16, Workshop LOWDOSE-PT-2015 Biological effects and risks of low dose and protracted exposures to ionizing radiation , CTN-Campus Bobadela, 2015

João Antunes: "Plastic Scintillator Dosimeters for Tomosynthesis", 2015-04-18, 7th Workshop on Biomedical Engineering, Faculdade Ciências Universidade Lisboa

2 Presentations in national conferences

Alina Louro: "Acino pulmonar: a incidência de neoplasias radioinduzidas numa perspetiva micrododimétrica", 2015-01-17, 4º Ciclo de Conferências da Faculdade de Ciências "Ciência: Fazer, Comunicar e Ensinar", UBI, Covilhã

Luis Peralta: "Hands-on Monte Carlo Simulation of Alpha Particle Transport", 2015-02-09, Workshop Hands-on Monte Carlo Simulation of Alpha Particle Transport, , Universidade da Beira Interior, Covilhã

1 Outreach seminar

Sandra Soares: "Radiações Ionizantes - Riscos e Aplicações", 2015-11-25, Semana da Ciência e Tecnologia, Universidade Beira Interior, Covilhã

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 " (ongoing)

Joana Machado: "Dosimetria de Feixes de kV Cone Beam CT com Dosímetro Cintilador e Câmara de Ionização" (ongoing)

Pedro Brasil: "Construção e Caraterização de um detector de cintilação para detecção de radão" (ongoing)

Events

2 Workshops

Workshop Hands-on Monte Carlo Simulation of Alpha Particle Transport, Universidade da Beira Interior, Covilhã, 2015-02-09 to 2015-02-11

Workshop UBIMedical - Em busca do Radão no concelho da Covilhã, Universidade Beira Interior, Covilhã, 2015-07-09 to 2015-07-09

SPIN-OFF TECHNOLOGIES FOR CANCER DIAGNOSTICS

STCD TagusLIP

The group Spin-off Technologies for Cancer Diagnosis (STCD) 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 LIP/STCD group was part of the EndoTOFPET project and the associated Marie Curie Training Network PICOSEC funded by the European Union. This project developed a 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.

Framework and status for past and current year

Summary of performance indicators

Articles in international journals:	2 With direct contribution from team
International conferences:	2 Posters
International meetings:	1 Oral presentation

DEVELOPMENT OF NEW INSTRUMENTS AND METHODS

Instruments and methods for biomedical applications

Team

Principal Investigator João Varela (5)

Researchers
Luis Ferramacho (16), Manuel Rolo (40), Miguel Silveira (16), Ricardo Bugalho (50), Stefaan Tavernier (25)

Technicians
José Carlos Silva (2), Rui Pereira da Silva (50)

PhD students
Carlos Gaston (25), Tahereh Niknejad (100), Viesturs Veckalns (67)

Master students
Leonor Frazão (50)

External/Additional scientific collaborators
Catarina Ortigão (50), Cláudia Sofia Ferreira (50), Jorge Neves (50)

Total FTE

5.9

// GROUPS: RPC-PET / OR Imaging / Gamma Cameras / Dosimetry / STCD TagusLIP

Lines of work and team organization

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.

The research lines pursued by the LIP/STCD 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) which are being used in clinical research.

Sources of Funding

Code	Amount	Dates	Description
Endo TOFPET-US256984	509.400 €	2011-01-01 / 2015-06-30	Endo TOFPET-US
PicoSEC-MCNet (289355)	423.082 €	2012-01-01 / 2015-12-31	Pico-second Silicon photomultiplier-Electronics - & Crystal research-Marie-Curie-Network
...	...	...	...
...	...	...	...
...	...	...	...

Stated objectives for past year

The LIP/STCD group has planned the following activities in 2015:

1. To exploit the research directions in PET Time-of-Flight (ToF) aiming to reach better than 200 ps time resolution.

2. To apply the new SiPM-based technology to the design of a second generation ClearPEM system with optimized cost/performance. A proposal to pursue this effort in framework of an international collaboration was submitted to FCT in February 2015.

3. In collaboration with CERN to develop a high resolution variant of the PET detector module using crystals of 1.5x1.5 mm and a new method to extract DoI information.

4. In collaboration with PETsys and INFN Torino, to develop a second version of the TOFPET ASIC aiming at better time resolution and increased rate performance. The first prototype MPW submission was foreseen in June 2015.

5. In collaboration with PETsys to pursue the development of an u pgrade version of the PCIe-based DAQ board using optical data links at 8 Gb/s. A first prototype was expected in July 2015.

Achievements and responsibilities during the past year

The LIP/STCD group developed the following activities in 2015 (same numbering as used in the previous section):

1. A PET scanner demonstrator with about 2000 SiPM channels was built and tested. The methods for time calibration and alignment where developed. The Coincidence Time Resolution (CTR) in the full scanner was measured at 375 ps FWHM, which is better than available commercial PET TOF scanners. An improvement of this results is expected with the second version of the TOFPET ASIC.

2. The funding application to FCT to the design of a second generation ClearPEM system was not approved. This line of research was not pursued.

3. A new high-resolution PET detector module with DoI capability based on SiPMs and the TOFPET1 ASIC was built and evaluated experimentally. Excellent crystal identification and a DoI resolution of 5 mm FWHM was achieved. A patent application was submitted.

4. The second version of the TOFPET ASIC (TOFPET2) was designed and extensively simulated . The submission to fabrication in a MPW run took place in end October 2015. The chips where received in March 2016.

5. The development of an upgrade version of the PCIe-based DAQ board using data links at 8 Gb/s was concluded. The new DAQ system was validated using the PET scanner demonstrator.

The obtained results were presented at several international conferences.

The LIP group is member of the COST network FAST led by CERN dedicated to fast timing. Members of the group are coordinating WG4 and 5.

A project led by PETsys was submitted to the EU SME Instruments program. The proposal was approved in phase I. The corresponding phase II proposal is now in preparation.

No funding from national sources was available in 2015.

Lines of work and objectives for next year

The LIP/STCD group plans to develop 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.

SWOT Analysis

Strengths

Strong technical team and long expertise in medical imaging systems. Excellent integration at international level. Complementarity with PETsys.

Weaknesses

No 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.

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 TagusLIP.

Publications

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

Agostino Di Francesco, Ricardo Bugalho, Luis Oliveira, Luca Pacher, Angelo Rivetti, Manuel Rolo, Jose C. Silva, Rui Silva, Joao Varela: "TOFPET2: a high-performance ASIC for time and amplitude measurements of SiPM signals in time-of-flight applications", accepted for publication in JINST Conference Proceedings TWEPP 2015

Agostino Di Francesco, Ricardo Bugalho, Luis Oliveira, Angelo Rivetti, Manuel Rolo, Jose C. Silva, Joao Varela: "TOFPET 2: A High-Performance Circuit for PET Time-of-Flight", accepted for publication in NIM A Conferece Proceedings 13th Pisa Meeting

Theses

3 PhD Theses

Viesturs Veckalns: "New technologies and algorithms for high-performance local processing of large scale sensor data in high energy and medical physics" (ongoing)

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)

Presentations

2 Poster presentations in international conferences

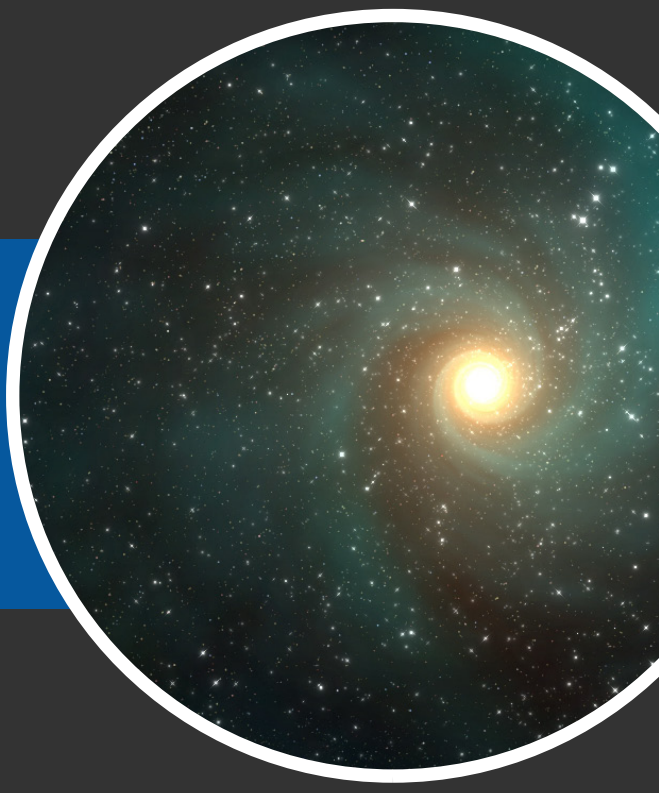
"A new method for Depth of Interaction determination in PET detectors", 2015-11-01, 2015 IEEE Nuclear Science Symposium and Medical Imaging Conference, San Diego, CA

Miguel Silveira: "A SiPM-based PET-TOF demonstrator featuring a highly integrated readout and DAQ system", 2015-11-01, 2015 IEEE Nuclear Science Symposium and Medical Imaging Conference, San Diego, CA

1 Oral presentation in international meetings

Tahereh Niknejad: "Simulation of the new high resolution TOF positron emission mammography (new Clear-PEM)", 2015-04-16, First FAST Annual General Meeting and 63rd Crystal Clear Collaboration meeting, Prague, Czech

Radiation environment studies and applications for space missions



SPACE RADIATION ENVIRONMENT AND EFFECTS

Space

The LIP Space Radiation Environment and Effects group has now more than 10 years of expertise in the development of applications dedicated to the Radiation environment in Space in the framework contracts with the European Space Agency and it 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, whose application to the radiation environment in space has been strategic for LIP's activities.

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 Poster 1 Proceedings
International meetings:	5 Oral Presentations
National conferences:	1 Presentation
Collaboration meetings:	7 Oral presentations
Outreach:	3 Outreach seminars

DEVELOPMENT OF NEW INSTRUMENTS AND METHODS

Radiation environment studies and applications for space missions

Team

Principal Investigator Patrícia Gonçalves (80)

Researchers
Alessandro de Angelis (10), Bernardo Tomé (20), Catarina Espírito Santo (10), Jorge Sampaio (starting in 2016), Luisa Arruda (80), Pedro Assis (10)

PhD students
Bruno Morgado (100), Marco Alves Pinto (90)

Master students
Ana Luisa Casimiro (33), Pedro Miguel Magalhães (100)

External/Additional scientific collaborators
Elsa Susana Fonseca (15)

Total FTE
5.5

Lines of work and team organization

The research themes that are 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;
- Follow up of the evolution on SEP (Solar Energetic Particle events) models and their test 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 in Si sensors and/or in scintillators) and exploitation of these designs in different planetary and interplanetary environments, both for platform support and for 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 and in planetary atmospheres and surfaces;
- Study and develop mitigation strategies for radiation hazards, both for spaceship systems and components and for human spaceflight.

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 / 2016-12-31	RADEM proto-flight model
ESA: 3-13975/13/NL/PA	200.000 €	2014-03-10 / 2016-08-31	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 / 2016-05-31	MFS Data Analysis
ESA/4000115004/15/NL/RA/ZK	80.116 €	2015-11-13 / 2018-11-12	Flight Data Analysis of TDP8 Radiation Experiments On-board AlphaSat

Stated objectives for past year

The objectives of this activity for 2015 were to continue with the ongoing contracts in which LIP is involved with ESA and with its contractual partners and to search for other opportunities in the framework of ESA ITTs or within the H2020 programme. Among the four ongoing contracts, the RADEM contract will continue to 2016, but the remaining three (the ECo-60, MFS data Analysis and the CODES Framework implementation) were foreseen to be completed in 2015.

RADEM is a radiation monitor for the JUICE ESA mission to the Jovian system, whose lauch is foreseen to 2022. The RADEM (RADiation hard Electron Monitor for the JUICE mission) contract started in May 2014 with a duration of 30 months. It involves a consortium of scientific institutes, LIP an dPSI (Paul Scherrer Institute in Switzerland) and the industry (EFACEC, SA, and IDEAS, a Portuguese and a Norwegian Company, respectively). LIP is responsible for the development of the design concept the RADEM electron Directional Detector (DD), one of the three RADEM sensor heads, and for its calibration and data analysis. For 2015 it was foreseen that LIP would be involved in the development and optimization of the RADEM Directional Detector, in its simulation, calibration and calibration data analysis and also on the radiation analysis of the RADEM.

LIP is the prime contractor for the ECo-60 contract, for the verification of the representativeness of Co-60 Total Ionizing Dose tests for selected EEE components to be flown in the Jovian electron environment (in the ESA JUICE mission to Jupiter). LIP will perform the radiation tests of the EEE components with Co-60 gammas and electrons of energy>10 MeV. During 2015 the component tests with electrons and Co-60 sources should have been performed and the corresponding data analyzed, closing the activity.

LIP is in charge of performing the analysis of the data of the MFS (MultiFunctional Spectrometer) orbiting the Earth in GEO

since 2013. In the MFS data analysis contract LIP collaborates with EFACEC. In 2015 LIP should finish the development of the algorithm for particle energy spectra reconstruction and performed the analysis of MFS in-flight data and cross-comparison with radiation environment models and other in-flight radiation monitors data, closing the contract.

CODES, the Component Degradation Simulation tool is a GEANT4 based top level engineering tool, to predict Single Event Effects in EEE devices. In 2015 LIP was due to release the web based CODES framework and oversee its maintenance and user management. The contract was due to finish in 2015.

An important objective for 2015 was to consolidate the group with one more senior researcher and to increase the numbers of MsC and PhD Students, reinforcing the Group connection to university.

Achievements and responsibilities during the past year

The 2015 objectives for 2015 were fulfilled for the RADEM contract: LIP performed the RADEM radiation analysis, completed the design of the RADEM electron Directional Detector (DD) along with the analysis of its performance using the full RADEM Geant4 model and participated in the radiation tests of the RADEM bread-board Model at PSI, in particular in the evaluation of the performance of the DD.

The objectives for the ECo-60 contract in 2015 were not fully completed and the activity will continue during 2016. Although the EEE component carrier boards and the control system for the irradiation tests were developed at LIP during 2015, the workflow was delayed due to several draw backs in the development of the system, which have finally been resolved. Therefore, the irradiation tests and test data analysis will take place in 2016.

The MFS data analysis activity will be closed in the first semester of 2016. A preliminary analysis of MFS SEP proton data was presented to the International Cosmic Ray Conference 2015 in The Hague.

A new contract, the CTTB Data analysis started in November 2015. The CTTB (Component Technology Test Bed) is flying in AlphaSat, in GEO, since 2013, in the AEEF (AlphaSat Environment and Effects Facility), which includes the MFS. In this contract with ESA, LIP will be collaborating with EFACEC and EVOLEO, two Portuguese companies, in the validation, data analysis and production of level 2 data sets of the CTTB in-flight data. This contract is a follow up of the "CTTB in-fligh preparation data analysis" contract between ESA, LIP, EFACEC and EVOLEO that took place in 2010 in which LIP was responsible for the RADFET calibration and for the analysis of ground test data for the EEE components to be flown in the CTTB.

Master and PhD thesis subjects were made available for Physics and Physics Engineering Students at "Instituto Superior Técnico". A PhD student started had started his work in November 2014 in the development of the DD detector for the RADEM and there are currently two students working on their MsCs in the following subjects: "Space Radiation Environment Effects in Human Space Flight" and "Radiation Environment and its effects on the Martian surface and underground". In the case of the latter subject, it is being explored in the continuation of LIP activity in the development of the dMEREM, the detailed Martian Energetic Radiation Environment Model and LIP is collaborating with its former partners in the MarsREM project and with the Space Research Centre Dept. Physics & Astronomy of the University of Leicester, with the aim of evaluating the radiation environment in the Martian subsoil from the astrobiology point of view.

The team was reinforced with a senior Physicist, Jorge Sampaio, whose expertise in the field of low energy radiation interactions and dosimetry, and experience in the supervision of students are fundamental to the objectives of the group.

Lines of work and objectives for next year

Group Activities

During 2016 three contracts CODES, MFS data analysis, and ECO-60 will be finished: the ECO-60 contract will continue in 2016 and be closed as soon as the irradiation tests and irradiation test data analysis are completed and the MFS contract will be closed in the 1st semester of 2016. However LIP will continue to analyse MFS data. The final results of the MFS data analysis and of the ECO-60 irradiation data analysis will be presented in international conferences and published.

The RADEM contract will continue during 2016, with the following tasks:

- 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.

The JUICE mission science working team has demonstrated a strong interest in the use of RADEM data to complement the data of JUICE scientific payload and therefore, LIP expects to participate in the JUICE Science Working Team along with PSI, both being “scientific” partners of the RADEM consortium.

A new contract, the CTTB data analysis started in November 2015 will 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.

Theses

Two master thesis shall be completed during the first semester of 2016, and at least one master thesis is expected to start in the second semester of 2016.

The PhD thesis of Bruno Morgado, “Analysis of Near Relativistic Protons and Electrons in Solar Events” will be finished during 2016.

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 i 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 exploitedo the Te-loaded phase schedule.

Publications

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

Bruno Morgado, Dalmiro Jorge Filipe Maia, Louis Lanzerotti, Patrícia Gonçalves, J. Douglas Patterson: "The low energy magnetic spectrometer on Ulysses and ACE response to near relativistic protons", Astron. Astrophys. 577 (2015) A61

1 International Conference Proceedings

L. Arruda, P. Goncalves, I. Sandberg, A. Marques, J. Costa-Pinto, A. Aguilar, P. Marinho, T. Sousa, A. Menicucci, P. Nieminen: "Protons in GEO with the ESA Multifunctional Spectrometer", PoS (ICRC2015) 137, Proceedings of Science, SISSA, for the the 34th International Cosmic Ray Conference, 30 July- 6 August, 2015 The Hague, The Netherlands

Presentations

5 Oral presentations in international meetings

Patrícia Gonçalves: "CODES - Simulation of Single Event Effects and Rate Prediction", CNES/ESA Radiation Effects Final Presentation Days, Centre Nationale d´Études Spatiales, Toulouse

Patrícia Gonçalves: "Space Radiation Environment & Effects", LIP 2014-2015 Activities Overview with the LIP International Advisory Committee, Pavilhão do Conhecimento, Lisboa https://indico.lip.pt/indico/conferenceDisplay.py?confId=174

Marco Alves Pinto: "A Directionality Detector for the JUICE mission Radiation Hard Electron Monitor", IDPASC Workshop on "Space Particles and Earth", Évora

Patrícia Gonçalves: "Radiation Monitors in Space", IDPASC Workshop on "Space Particles and Earth", Évora, Portugal

Patrícia Gonçalves: "LIP & Space Applications ", Portugal Space Day 2015 , PORTUGUESE PERMANENT REPRESENTATION TO THE EU AVENUE DE CORTENBERGH 12, BRUSSELS

1 presentation in national conferences

Patrícia Gonçalves: "O LIP no Espaço", Encontro Nacional de Estudantes de Física, Instituto Superior Técnico, Lisboa

1 Poster presentations in international conferences

Luisa Arruda: "SEP Protons in GEO with the ESA MultiFuntional Spectrometer ", 34th International Cosmic Ray Conference, The Hague, Netherlands https://indico.cern.ch/event/344485/session/132/contribution/1230/attachments/1138857/1630687/icrc2015-1230.pdf

3 Outreach seminars

Patrícia Gonçalves: "Do Sol à Terra, Da Terra à Lua (7º ano)", "O Espaço vai à Escola" -Semana do Espaço organizada pelo programa ESERO - Ciência Viva, Agrupamento de Escolas de Catujal

Patrícia Gonçalves: "Do Sol à Terra, Da Terra à Lua (5º, 6º,7º anos)", "O Espaço vai à Escola" -Semana do Espaço organizada pelo programa ESERO - Ciência Viva, Agrupamento de Escolas de Caneças - Escola Básica dos Castanheiros

Patrícia Gonçalves: "Do Sol à Terra, Da Terra à Lua (10º ano)", "O Espaço vai à Escola" -Semana do Espaço organizada pelo programa ESERO - Ciência Viva, Escola Secundária Alfredo da Silva - Barreiro

Theses

2 PhD Theses

Bruno Morgado: "Analysis of Near Relativistic Protons and Electrons im solar Events" (ongoing)

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" (ongoing)

Ana Luisa Casimiro : "Efeitos da Radiação Espacial Ambiente em Missões Tripuladas a Marte" (ongoing)

INTEGRATED ACTIVITIES FOR THE HIGH ENERGY ASTROPHYSICS DOMAIN

A-HEAD

LIP Coimbra Astrophysics Instrumentation Group research activities are developed in the framework of H2020 AHEAD (Activities in the High Energy Astrophysics Domain) project (ref. 654215) started September 1st, 2015 for 42 months, with a global budget of 4,982,477€, where 61,225€ were granted to LIP. The overall objective of AHEAD is to integrate national efforts in high-energy astrophysics and to promote the domain at the European level, to keep its community at the cutting edge of science and technology in this competitive research area and ensure that space observatories for high-energy astrophysics will be solid proposals to future ESA call for missions.

Our group will contribute to WP9 (Work Package 9) of AHEAD, entitled "Development and characterization of optics for next generation X-ray telescopes".

Furthermore we are in XIPE (X-ray Imaging Polarimetry Explorer) mission, selected in 2015 M4 call for phase A&B1 by ESA. After phase A&B1 period, aimed at studying technical and scientific aspects of the three concepts, one mission will be selected in June 2017 to be launched by 2026.

Additionally we are involved in a parallel project designed BioMeXRay (Biometals Detection by X-Ray Fluorescence) which has started in September 2014.

Framework and status for past and current year

Summary of performance indicators

Articles in international journals:	2 With direct contribution from team
International conferences:	2 Posters 1 Proceedings
Outreach:	3 Outreach seminars 1 Outreach event organized
Completed theses:	2 Master Theses

DEVELOPMENT OF NEW INSTRUMENTS AND METHODS

Radiation environment studies and applications for space missions

Team

Principal Investigator Rui Curado Silva (85)

Researchers
Filipa Borges (15), Filomena Santos (20), Jorge Maia (45), José Escada (40), Teresa Dias (15)

Technicians
Alexandre Fonseca Trindade (30), Carlos Patacas (20), Patrícia d' Amil (100)

PhD students
José Marques (60), Marco Alves Pinto (10), Miguel Moita (100)

Master students
Mariana Martins (100), Nelson Simões (80)

Total FTE
7.2

// GROUPS: Space / A-HEAD

Lines of work and team organization

1. The main task of our group in AHEAD WP9 is to contribute to focal plane instrument mass model simulations in order to determine the optimal future high-energy space telescope instrument configuration. Rui Curado da Silva coordinates the group participation in AHEAD.

1.1 Astrophysical sources analysis and modeling tasks are performed by Carlos Patacas and by PhD student Miguel Moita, under the supervision of Rui Curado da Silva.

1.2 Detector Physics analysis tasks are part of Miguel Moita PhD thesis, of José Marques PhD thesis and of a new AHEAD funded Post-Doc that will join our group in 2016, under the supervision of Jorge Maia.

1.3 Monte Carlo simulations will be performed by AHEAD funded Post-Doc and by researcher 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) photoelectric X-ray polarimeter. Our group has the task of optimize the GPD gas mixture. Rui Curado da Silva and Jorge Maia coordinate the group participation in XIPE consortium.

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 Fonseca Trindade under the supervision of Filomena Santos.

3. The BioMeXRay (Biometals Detection by X-Ray Fluorescence) is a collaborative project, proposed by us, with national patterns were we are responsible for the optimization and development of measurement/analysis methods by X-ray fluorescence in brain and eyes tissues. Jorge Maia coordinates the group participation in BioMeXRay.

3.1. The optimization of the X-ray fluorescence spectrometer parameters are performed by the MSc students Mariana Martins e Patricia d'Amil under the supervision of Jorge Maia.

3.2. The development of measurement/analysis methods are performed by Jorge Maia and Rui Curado Silva.

Sources of Funding

Code	Amount	Dates	Description
654215 - AHEAD	61.225 €	2015-09-02 (ongoing)	H2020 Integrated Activities for the High Energy Astrophysics Domain

Stated objectives for past year

- Selection of ASTROGAM and/or XIPE missions in the 2015 ESA M4 call for missions;
- start AHEAD H2020 project activities;
- start of AHEAD scientific objectives white paper;
- Evaluate the effects of high-energy proton irradiation on CdTe prototype detectors for focal plane high-energy space telescopes;
- Conclude multi-pixel polarimetric analysis on a CdZnTe detection plane prototype for space applications;
- Start INTEGRAL IBIS polarimetric data analysis.
- Start the work in BioMeXRay project.

Achievements and responsibilities during the past year

- XIPE was one of the three 2015 M4 call selected missions for phase A&B1 by ESA;
- We analyzed proton effects on a pixelated CdTe ACRORAD detector matrix under a ICNAS (Instituto de Ciências Nucleares Aplicadas à Saúde) proton beam. Main activation products were identified and radiation damage did not affect detector performances for a satellite life-time dose equivalent;
- Multi-pixel polarimetric analysis methods and techniques were implemented for a CdZnTe prototype and were validated both by simulation and experimental methods;
- Science Advisory Group of AHEAD WP9 was selected including Prof. Constança Providência of the University of Coimbra, appointed by LIP.
- In BioMeXRay project the optimization of the X-ray fluorescence spectrometer parameters were almost carried out and the development of measurement/analysis methods by X-ray fluorescence in brain and eyes tissues is under way.

Lines of work and objectives for next year

The main lines of work and tasks are divided in activities in the framework of AHEAD and of XIPE ESA mission, and in BioMeXRay project:

1. The main task of our group in AHEAD WP9 is to contribute to focal plane mass model simulations in order to determine the best configuration.

1.1 An AHEAD financed postdoc will join our team by the end of 2016 in order to start the simulation of a multilayer semiconductor based (CdTe and Si) focal plane equipped with Laue lens. Focal plane mass model will be performed with LIP GEANT4 code. Lens photon input will be delivered by Laue Lens Library of our Ferrara University partners. Later on, up to 2018, in order to evaluate lens sensitivity advantage, a simulation comparative study will be performed between a Laue lens focal plane and a highly segmented detection plane – allow better photon reconstruction – without lens;

1.2 Furthermore, a white paper on the main scientific objectives of high-energy astronomy will be release before the end of the year;

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 design;

1.4 It will be started the development of two planes CdTe polarimeter prototype that will allow to access the performances of polarimeters based on stack/multi-planar configuration.

2. In XIPE mission collaboration our group has the task of optimizing the GPD gas mixture. In 2016, we will start the development of a LIP FORTRAN Monte Carlo code in order to study 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. Noble gases like He or Ne as well as quenching additive gases like DME and isobutane gases will be studied.

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. Study and tradeoffs for the best location of RADEM in the JUICE spacecraft.

SWOT Analysis

Strengths and Opportunities

The group is involved in two major international projects in high-energy astrophysics: the H2020 funded AHEAD and the ESA pre-selected XIPE mission. This is mainly due to the high expertise and vast level of high-energy astrophysics polarimetry research that our group acquired in the last decade, both by extensive simulation and experimental research.

AHEAD activities will provide new institutional and technical links (simulation software and detector technology) that will reinforce significantly our research potential.

XIPE mission ESA pre-selection is a prestigious event that will enable our group to work at the top level in the domain of X-ray photoelectric polarimetry. In case XIPE will be down-selected in June 2017 for launch in 2026, beyond the excellent scientific perspectives, it would be an unprecedented space instrumentation major achievement to Portugal, since the country joined ESA.

The project BioMeXRay is an excellent opportunity to extend methods and techniques, already used by us in nuclear and astrophysics instrumentation, to the biomedical sciences. Allowing the work in a multidisciplinary environment with partners of Physics and Biomedical Sciences.

Weaknesses and Threats

The level of collaboration with industry is very weak, even if there have been great efforts by our group and Portuguese space related companies to engage in common projects. Often collaborative academic and private companies' funding schemes and calls bureaucracy are inadequate for common technical and scientific goals and for institution's legal restrictions. Group responsible and other researchers' future is uncertain, depending on funding and on number of grants and research contracts available on future calls.

Last decade lack of funding has compromised seriously equipment acquisition, mainly nuclear electronics devices and data analysis software, as well as the number of grants available for young researchers, although that many candidates have been attracted by astrophysics and nuclear instrumentation subject.

Publications

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

S. Antier, P. Ferrando, O. Limousin, E. Caroli, R. M. Curado da Silva, C. Blondel, R. Chipaux, V. Honkimaki, B. Horeau, P. Laurent, J.M. Maia, A. Meuris, S. Del Sordo, J.B. Stephen: "Hard X-ray polarimetry with Caliste, a high performance CdTe based imaging spectrometer"

J. M. Maia, R. M. Curado da Silva, Yoon-Seong Kim: "Prospects on Low-Z elements K fluorescence and actinide-radionuclides L fluorescence X-ray detection with cooled CZT", IEEE Trans. Nucl. Sci. 62 (2), April 20

1 International Conference Proceedings

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-γ 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

2 Poster presentations in international conferences

"Monte Carlo Evaluation of a Czt 3d Spectrometer Suitable for a Hard X- and Soft-Gamma Rays Polarimetry Balloon Borne Experiment", International Symposium on Room-Temperature Semiconductor X-Ray and Gamma-ray Detectors, San Diego, USA International Symposium on Room-Temperature Semiconductor X-Ray and Gamma-ray Detectors, 31 Oct. – 7 Nov.San Diego, USA, 2015.

"Inflight Proton Activation and Damage on a CdTe Matrix Detection Plane", International Symposium on Room-Temperature Semiconductor X-Ray and Gamma-ray Detectors, San Diego, USA International Symposium on Room-Temperature Semiconductor X-Ray and Gamma-ray Detectors, 31 Oct. – 7 Nov.San Diego, USA, 2015.

3 Outreach seminars

Rui Curado Silva: "Como ser Astronauta?", , Colégio da Imaculada Conceição, Cernache

Rui Curado Silva: "Astronomia & Tecnologia Espacial no Quotidiano", Escola Secundária Emídio Navarro, Viseu

Rui Curado Silva: "Astronomia & Tecnologia Espacial no Quotidiano", Space Summer School, Observatório Geofísico e Astronómico da UC, 13 de julho de 2015, Observatório Astronómico da Universidade de Coimbra

Theses

2 PhD Theses

José Marques: "Experimental CdTe Polarimeter development " (ongoing)

Miguel Moita: "ASTROGAM Space Gamma-ray Telescope Main Instrument Development" (ongoing)

2 Master Theses

Nelson Simões: "CdTe focal plane radiation environment experimental analysis" (finished on 2015-09-11)

Patrícia d' Amil: "Detection of biometals signature of brain tissues by X-ray fluorescence" (finished on 2015-11-15)

Events

1 Outreach Events

Escola de Verão - 'Como ser Astronauta', Laboratório de Instrumentação e Física Experimental de Partículas and UC Observatório Astronómico, 2015-07-20 to 2015-07-24

Computing

- Distributed computing and digital infrastructures
- Advanced computing

// Computing


SEC06.M18
SEC06.N22

DISTRIBUTED COMPUTING AND DIGITAL INFRASTRUCTURES

GRID

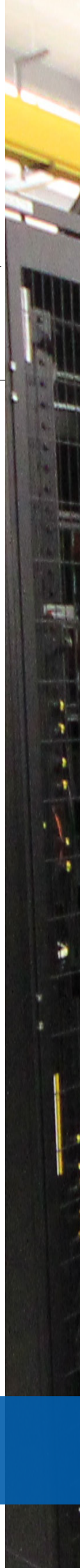
The LIP distributed computing and digital infrastructure activities encompass the support to scientific research through the provisioning of computing and support services, complemented by a component of innovation, aimed at staying in the forefront of computing technologies.

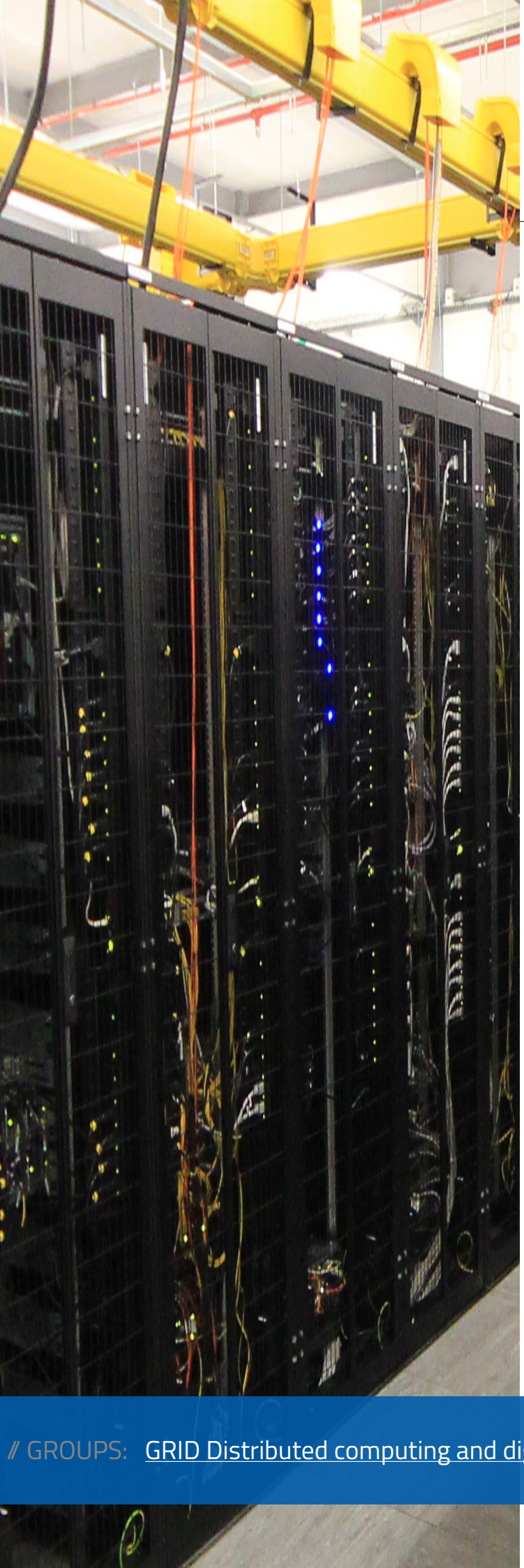
The activities are developed in the context of national and international projects. At national level the activities are now focused on ramp-up of the National Distributed Computing Infrastructure (INCD) in the context of the FCT infrastructures roadmap, and in the LIP Tier-2 facility in the Worldwide LHC Computing Grid (WLCG). At international level the activities are shaped by the participation in European ICT projects which currently include the H2020 projects EGI-ENGAGE and INDIGO-DATACLOUD, and by the participation in international e-infrastructures such as the European Grid Infrastructure (EGI) and Iberian Grid Infrastructure (IBERGRID).

Framework and status for past and current year

Summary of performance indicators

Reports:	1 Institute report
National conferences:	2 Presentation 1 Proceedings
Collaboration meetings:	4 Oral presentations
Seminars:	6 Seminars
Completed theses:	1 Master Thesis
Organization:	1 Conference organized 1 Workshop organized 1 Collaboration meeting organized 1 Seminar organized





Team

Principal Investigator Jorge Gomes (100)

Researchers
Gaspar Barreira (90), Jorge Cedillo (16), João Paulo Martins (100), João Pina (100), Mário David (100), Nuno Ribeiro Dias (100)

Technicians
Carlos Manuel (100), Hugo Gomes (100), José Aparício (100)

External/Additional scientific collaborators
Pedro Miranda (100)

Total FTE
10.1

// GROUPS: GRID Distributed computing and digital infrastructures / Advanced computing

Lines of work and team organization

The group main line of work is the research, development and provisioning of services and infrastructures for scientific computing. The group is especially focused in distributed computing technologies including:

- grid computing
- cloud computing
- high throughput computing
- high performance computing

The activities encompass a wide range of areas including:

- Federation of computing and storage resources across networks and organizations
- Technologies for massive data processing and analysis
- Databases and information systems
- Computing, storage and networking technologies
- Systems and network design, implementation and management
- Systems and network security
- Authentication and authorization
- Virtualization technologies
- Datacenter design and operation
- Resilient systems
- IT management

The group also operates many core IT services for LIP.

Sources of Funding

Code	Amount	Dates	Description
RECI/FIS-NUC/0115/2012	500.000 €	2013-01-01 / 2015-12-31	Support for the ATLAS and CMS Portuguese Tier-2 in the context of the WLCG MoU
Cloud - Piloto	83.000 €	2014-08-14 / 2015-12-31	Cloud - Piloto
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

- Operate, consolidate and improve the LIP IT infrastructure.
- Operate the Portuguese WLCG Tier-2 and Tier-3 services for ATLAS and CMS.
- Further improve the WLCG Tier-2 services.
- Establish the National Distributed Computing Infrastructure (INCD) foundations.
- Develop the new INCD services with a strong focus on cloud computing.
- Manage the national computing centre (NCG) in partnership with FCCN and LNEC already in the context of the INCD program of work.
- Through INCD engage with new research projects, communities and organizations with a focus on the national infrastructures and ESFRI roadmap.
- Continue and reinforce the IBERGRID collaboration through the participation in common projects such as EGI-ENGAGE and Lifewatch.
- Participate in EGI at the operational and strategic level.
- Provisioning of EGI global services namely: middleware rollout, middleware acceptance, and user support.
- Participate in the development and shaping of future e-infrastructure services through the INDIGO-DATACLOUD project.

Achievements and responsibilities during the past year

The LIP Tier-2 has delivered 51,646,727 normalized hours to ATLAS and CMS corresponding to 104% of the pledged capacity. The distribution among the two experiments was 43% for ATLAS and 57% for CMS. The response time of the LIP computing support team continued to be significantly better than the WLCG average, and the reliability and availability continue within the SLA.

Significant IT improvements were performed. The Tier-2 storage hardware purchased in the end of 2014 was put into production. The new hardware allowed a full renewal of the Tier-2 storage capacity. The Lustre storage system at NCG was fully reorganized. The Tier-3 component hosted at the Coimbra datacenter was migrated to NCG. The LIP-Lisbon tape library was upgraded enabling larger capacity and faster access for data backups.

The network switching at NCG was reinforced. A network topology for connection to LHCONE was agreed with FCCN and Geant. The topology of the layer 2 network that interconnects NCG, LIP-Lisbon and LIP-Coimbra is being improved aiming at better connectivity.

The contract with FCT for the creation of a pilot cloud service finished in December 2015 with very good results. LIP deployed cloud services based on Openstack which were tested by several user communities and demonstrated good potential. This work was complemented by an evaluation of storage systems both for the cloud and also for the Tier-2. A master thesis in cooperation with FCT/UNL took place addressing this topic and was successfully defended in December 2015.

The pilot cloud activities included several research projects and organizations such as: INESC-ID, IGC, IPMA, LNEC, ISCTE, FCCN and roadmap infrastructures such as PORBIOTA and BIODATA. The cloud pilot constitutes the basis for a future service to be delivered by the National Distributed Computing Infrastructure (INCD). As a result of these activities, FCT via FCCN made available to the group new computing equipment to support the cloud activities.

Regarding the National Distributed Computing Infrastructure (INCD), a prioritization of the infrastructures was performed by FCT during 2015, and the INCD evaluation was positive. The INCD association was formaly established in December 2015 having as members LIP, FCT and LNEC. It is expected that funding will be made available through the Portugal 2020 funding line.

The participation in two new H2020 projects has started in the first quarter. The EGI-ENGAGE project is a follow up of EGI-INSPIRE with a larger focus on user communities namely ESFRIs. LIP participates in the authentication and authorization (AAI), and in the competence centre for the Lifewatch (ESFRI).

The INDIGO-DATACLOUD project, aims to develop a PaaS system that will enable easier execution across multiple infrastructures and hardware. LIP coordinates the infrastructure and pilot services work-package which manages the whole software life-cycle for the project and provides the infrastructures for development and testing. In addition LIP participates in the development of software for INDIGO namely the implementation of an OCCI network layer, and the implementation of containers support for conventional compute clusters.

LIP continued to participate in the European Grid Infrastructure (EGI) and in IBERGRID. LIP won the bid to deliver middleware QA coordination in EGI for 2016/2017. The EGI Conference 2015 was organized by LIP in Lisbon and joined about 300 participants from Europe and elsewhere.

Lines of work and objectives for next year

In 2016 the work will continue focused on the operation and improvement of the LIP computing services, participation in the Worldwide LHC Computing Grid (WLCG), European H2020 projects, and in the national and international initiatives: National Distributed Computing Infrastructure (INCD), European Grid Infrastructure (EGI) and Iberian Grid Infrastructure (IBERGRID).

LIP computing services

The datacenter services consolidation will continue. The Tier-3 consolidation at NCG will be finalized. The LIP-Lisbon computing farm will be migrated to NCG. Better integration between the NCG services with the LIP environment will be pursued. These measures will allow easier management and optimization of the computing resources, and are essential to reduce the energy costs and facilitate the moving of LIP Lisbon to a new building.

Moving to a new building at the University of Lisbon, will constitute a major challenge, as the LIP Lisbon datacenter in the current building will have to be discontinued. A more cost effective solution will be pursued by housing most of the heavy computing and storage equipment at NCG and at University facilities. Furthermore the new building requires major improvements. This will be an opportunity to renew and improve the LIP Lisbon IT infrastructure.

The network will suffer major changes which will be performed in several steps. The Géant connectivity for the layer two network cloud that interconnects the LIP datacenters will be upgraded from 3Gbps to 10 Gbps. The commercial connectivity will be also improved. LIP Lisbon itself will get a separate Internet connection which in the new building will be implemented via the University network. The separation of connectivity will improve the Internet bandwidth for LIP general users by preventing the mix of traffic with the Tier-2/3. The connectivity to LHCONE has been designed and will be implemented afterwards.

WLCG and Tier-2

The temporary cut to the Tier-2 pledges agreed with CERN has finished and the original processing and storage capacity will be delivered. The Tier-2 is now fully housed at NCG in Lisbon and the other sites LIP Lisbon and LIP Coimbra which are no longer active will be removed from the Tier-2. Opportunities to improve the Tier-2 and Tier-3 will be followed namely in the context of INCD.

The evolution of the LHC computing model will be followed and the introduction of new approaches and technologies will be pursued. The group is organizing the WLCG workshop 2016 in Lisbon, the workshop is devoted to in-depth discussions of the current issues and how to solve them in the medium term, and to have a common brainstorming on the long term future of WLCG over the next 10 years. The DHEP digital preservation workshop will be co-located with this event.

The current activities that already encompass the successful participation in the joint experimentation of multicore jobs, and experimentation with cloud computing, virtual compute nodes, storage systems and GPGPUs computing will continue. As previously stated the Tier-2/3 connectivity will be improved both in terms of bandwidth and topology.

INCD

The INCD association was formally created and its activities are expected to increase along the year. The current pilot cloud infrastructure will move towards a beta service opened to the academic and scientific community. Some of the pilot cloud activities will continue in 2016 namely, cloud bursting tests with commercial providers, development of a Ceph storage system for the cloud, development of the monitoring and accounting infrastructure, evolution towards IPv6, and several others. A better integration between the cloud and other services such as the High Throughput Computing and High Performance Computing services will be addressed. In this context the possibility of expanding the capacity of the computing farm via INCD cloud resources will be considered. In the context of INCD, the group will continue supporting academic and scientific organizations and projects in exploiting the current production and pilot services. As defined in the INCD proposal the WLCG Tier-2 renewal and development will be performed through INCD.

EGI and IBERGRID

Through INCD, the group will continue to represent Portugal in the European Grid Infrastructure (EGI) and in the Iberian Grid Infrastructure (IBERGRID). The activities towards federated cloud computing will assume increased importance. The group will continue coordinating and supporting the participation of Portuguese grid and cloud sites in the EGI pan-European infrastructure. LIP is partner in the EGI-ENGAGE project and will work in the areas of authentication, authorization and community support. The participation in the LifeWatch (ERIC) Competence Centre in EGI and the collaboration with CIBIO in supporting biodiversity applications will continue.

The IBERGRID collaboration will continue providing an umbrella for the Portuguese and Spanish joint participation in EGI. IBERGRID has again won the bid to provide middleware coordination services to the global EGI infrastructure in 2016/2017.

INDIGO-DATACLOUD

The group will continue its participation in the INDIGO-DataCloud H2020 project, where it coordinates the software life-cycle activities and the pilot infrastructure services. In addition LIP will continue working in the development of an OCCI network interface, and in supporting the execution of Linux containers in batch scheduling systems.

SWOT Analysis

Strengths

- Highly skilled staff with unique extensive experience.
- Excellent international relationship and integration in international multidisciplinary infrastructures (EGI, WLCG, IBERGRID).
- Cost effective, robust well performing infrastructure.
- Fulfilling the CERN LHC computing MoU, and exploiting synergies to provide capacity for other research and academic purposes.
- Successful running production infrastructure.
- Strong partnership with FCCN and LNEC in the INCD infrastructure.
- Participation in the FCT infrastructures roadmap via INCD.

Weaknesses

- Grid computing has been very successful in many scientific areas but it does not fit well the needs of most users that work in smaller research groups. A wider portfolio of more generic and simpler to use services needs to be provided in a consolidated way (e.g: cloud computing, direct access to clusters, and other technologies based on real requirements) in parallel with grid.
- Lack of dissemination resources to reach researchers in other organizations.
- Lack of personnel 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 under a single well defined infrastructure.
- Optimize present and future computing investments to provide an open national computing service.
- Enable future policies for scientific computing by creating a structure for the sharing and open access to publicly funded computing capacity.
- Keep building strategic know-how accumulated over the last 10 years.
- Potential for industrial and e-government applications.
- Avoid non-effective proliferation of computing resources.
- Maintain the current production infrastructure supporting flagship communities.
- Overcome the obsolescence of critical infrastructure components.

Threats

- Loosing key personnel is possibly the biggest threat. Competitive permanent contracts are essential.
- Lack of investment may deem the existing infrastructure obsolete in terms of capacity, characteristics and performance. Continuous investment is needed to keep the infrastructure at the state of the art and capable of answering the researcher's challenges.
- Lack of computing funding policies may continue to allow research projects to acquire and own their own computing clusters which are frequently: badly managed, hosted under bad conditions, insufficient for the needs, cost inefficient and not shared.
- Lack of funding for the infrastructure operational costs may prevent resource sharing and the full exploitation of available capacity.

Publications

1 Institute reports

Jorge Gomes: "Support for the Portuguese tier-2 in the context of the WLCG MoU 2014 report"

1 National Conference Proceedings

Anabela Oliveira; João Rogeiro; Alberto Azevedo; André B. Fortunato; Ricardo Tavares da Costa; Marta Rodrigues; Kai Li; João Paulo Martins; Mário David; João Pina; Jorge Gomes: "Sistemas multi-escala de previsão em tempo real da dinâmica estuarina e costeira: desafios para a sua operacionalização em ambiente cloud e de elevada performance", Sistemas multi-escala de previsão em tempo real da dinâmica estuarina e costeira: desafios para a sua operacionalização em ambiente cloud e de elevada performance;

Presentations

2 presentation in national conferences

Jorge Gomes: "INCD e o Acesso Aberto", 2015-02-04, Infraestruturas de Investigação: desafios do acesso aberto, LNEC

Jorge Gomes: "Atividades cloud computing e piloto de experimentação", 2015-02-11, Jornadas FCCN 2015, ISCTE, Lisboa

4 Oral presentations in collaboration meetings

Jorge Gomes: "Piloto Cloud - Implementação e Conclusões", Piloto Cloud Final Meeting, FCCN

João Pina: "UMD 3.11 update", EGI Operations Management Board,

Jorge Gomes: "WP3 plans and feedback to the JRA WPs", INDIGO Technical Architecture Meeting, UPV, Valencia, Spain

Jorge Gomes: "Software Management and Pilot Services - status", INDIGO Architecture Meeting, CSIC, Madrid, Spain

6 Seminars

Jorge Gomes: "Openstack CLI tutorial", , FCCN, Lisbon

Mário David: "Distributed Computing Infrastructure for Scientific Research in Portugal", , Champalimaud Foundation

Jorge Gomes: "INCD - Análise de Maturidade", National Infrastructures Roadmap Maturity Analysis, FCT

Mário David: "Openstack Web Frontend and Dashboard", INCD - Openstack Workshop, LNEC, Lisboa

Jorge Gomes: "Openstack Command Line Interface", INCD - Openstack Workshop, LNEC, Lisboa

Jorge Gomes: "INCD - Infraestrutura Nacional de Computação Distribuida", Public Presentation of National Infrastructures, CCDR Centro, Coimbra

Theses

1 Master Theses

Pedro Miranda: "Enabling and Sharing Storage Space Under a Federated Cloud Environment" (finished on 2015-12-22)

Events

1 Conferences

EGI Conference 2015, Centro de congressos do ISCTE, Lisboa, 2015-05-18 to 2015-05-22

1 Workshops

INCD - Workshop OpenStack, FCCN, Lisboa, 2015-07-02 to 2015-07-02

1 Collaboration Meetings

INDIGO WP3 , ISCTE, Lisboa, 2015-05-21 to 2015-05-21

1 Seminar organizations

Openstack CLI tutorial, LNEC, 2015-01-08 to 2015-01-08

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. More recently it has developed R&D on the combination of traditional multicore CPUs with acceleration devices.

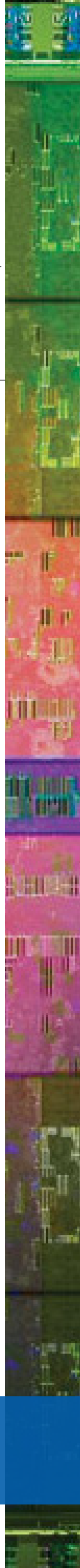
The group, part of the LIP-Minho, since the beginning of 2014, without abandoning research in fields close related with the Computer Science and Engineering has been directing its activity to areas more related to the general interests of LIP investigation. In particular, is noteworthy support for the 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 support for advanced training in Scientific Computing.

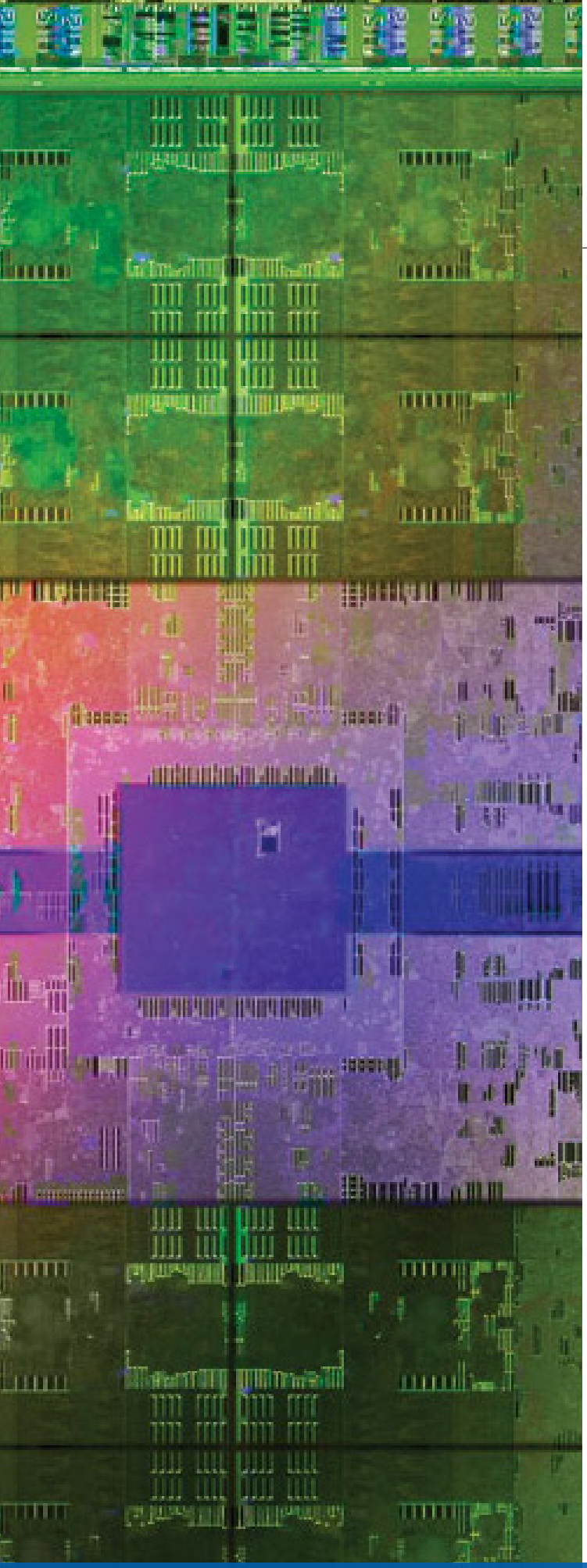
Finally, the group is also responsible for the administration of a local HPC cluster that supports the running of the data analysis applications developed by other groups in LIP.

Framework and status for past and current year

Summary of performance indicators

Books: 4 Book chapters





Team

Principal Investigator António Pina (65)

Researchers
Albano Alves (75), José Rufino (75), Vítor Oliveira (30)

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

Stated objectives for past year

It is important to emphasize that 2015 was an atypical year, since the activities carried out by the group, were very conditioned by the need to continue the work on projects of various natures, existent prior to the joining of its members to LIP.

In particular, the scientific objectives pursued were limited by a strong involvement of its members in educational projects (A. Pina), higher education management (A. Alves) and external professional activities (V. Oliveira). In this context, during 2015, we focused in the following objectives:

- Targeting of pedagogic projects for which we are responsible, for scientific areas more directly related to R/D in software for HEP;
- Upgrade and maintenance of the local cluster computing infrastructure (LIP-Minho);
- Planning of training activities and training in scientific computing;
- Involvement in the ATLAS collaboration, particularly in the upgrade of the software triggers;
- Continuation of the collaboration in the parallelization of algorithms in Simulated Annealing.

Achievements and responsibilities during the past year

The activities developed by the group resulted in the following main contributions: the publication of 4 articles in international journals, the start of 3 new master dissertations and the upgrade of the local cluster infrastructure.

It should also be pointed out the start of participation in the ATLAS collaboration. In this context, members of the group attended the Trigger GPU Demonstrator Sprint, in Lisbon 2015, and later assumed responsibilities on the "Parallelization and Optimization of the TopoCluster Splitting Algorithm using GPUs"

Lines of work and objectives for next year

In 2016, 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, along with the support to the local cluster infra-structure.

It is also expected that the conclusion of the dissertations of the current postgraduate students might produce not only publications but also attract new students for research and development 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 the applications

In another dimension, we also anticipate the launching of new computer training activities for young researchers, like the "O essencial da linha de comandos em LINUX " course held in February 2016 in LIP-Minho.

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;
- Local Organising Committee Chair of the CERN School of Computing 2014, Braga, Portugal, aiming to promote advanced learning and knowledge exchange in scientific computing among young scientists and engineers involved in particle physics and other sciences.

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 to provide a gradual upgrade route from current systems, to support the increase in the complexity of current and future applications;
- Expertise in combining traditional multicore CPUs with acceleration devices provides the opportunity to participate 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.

Publications

4 Book Chapters

J. Rufino, A.I. Pereira, J Pidanic : "coPSSA - constrained parallel stretched simulated annealing", In Proceedings of the 25th International Conference Radioeletronika. p. 435-439. Pardubice, Czech Republic, 2015;

Ana I. Pereira, José Rufino: "Solving Constrained Multilocal Optimization Problems with Parallel Stretched Simulated Annealing", Volume 9156 of the series Lecture Notes in Computer Science pp 534-548

A. Pereira, A. Onofre, A. Proença: "HEP-Frame: A Software Engineered Framework to Aid the Development and Efficient Multicore Execution of Scientific Code", International Conference on Computational Science and Computational Intelligence (CSCI) 2015, Las Vegas USA, IEEE Proceedings, pp. 615–620, 2015

J. Rufino, A.I.Pereira: "Solving Multilocal Optimization Problems with Parallel Stretched Simulated Annealing", Volume 8580 of the series Lecture Notes in Computer Science pp 154-168

Theses

3 Master Theses

José Marcos Carvalho: " VIPe - Visualização Integrada de Perfis de Execução" (ongoing)

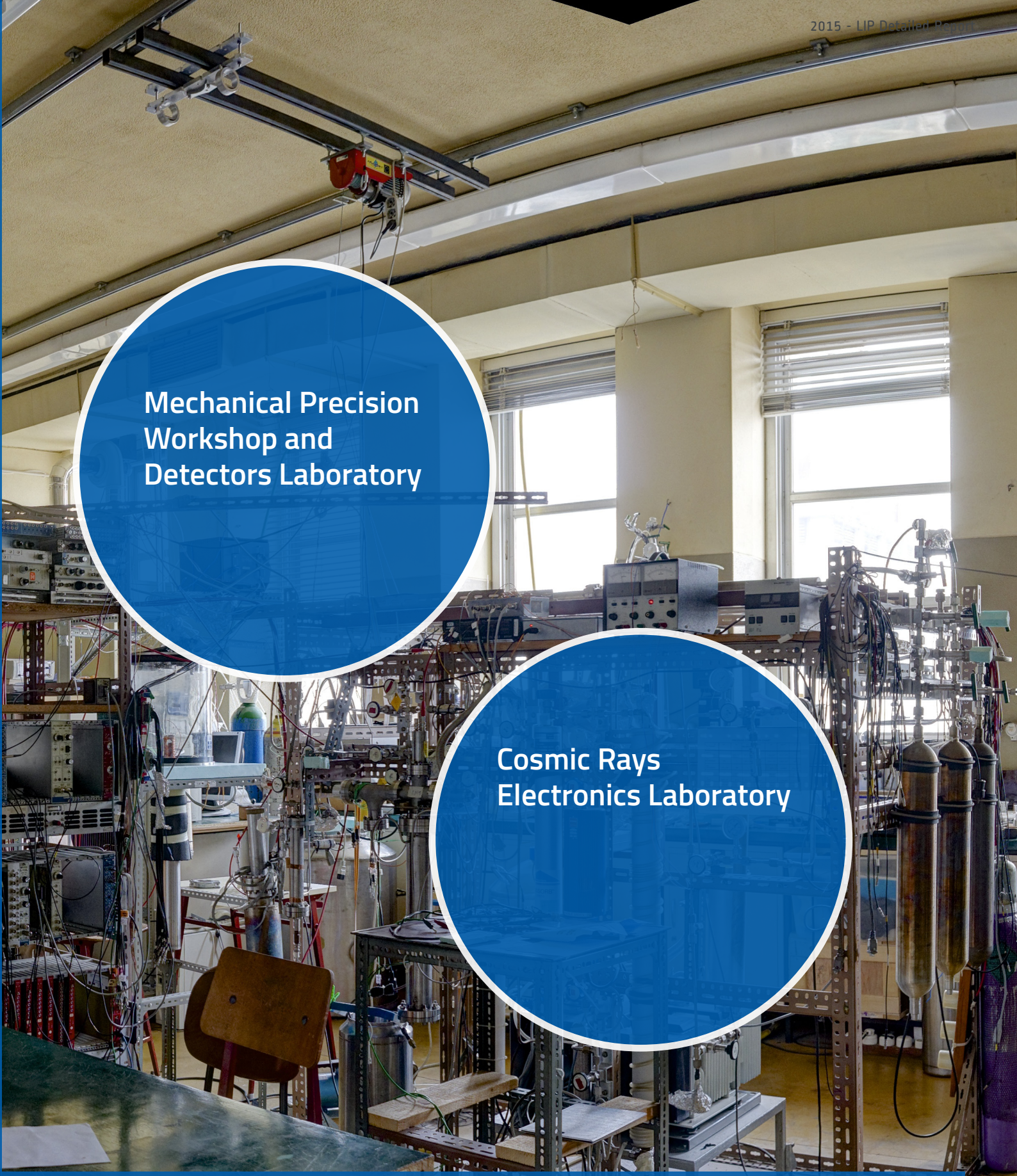
Luís Caseiro: "Otimização do código utilizado na pesquisa de novos quarks pesados, na experiência ATLAS" (ongoing)

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

TagusLIP Laboratory

Laboratory of Optics and Scintillating Materials

// RESEARCH FACILIT



Mechanical Precision Workshop and Detectors Laboratory

Cosmic Rays Electronics Laboratory

TIES

DETECTOR LAB / MECHANICAL WORKSHOP

Workshops

The Mechanical Workshop (MW) of LIP was established in 1986 to support the experimental activities to be performed in collaboration with CERN. At present, the equipment available, recently improved with high performing machine tools and CAD--CAM software, and the highly qualified staff allow the MW to perform a large spectrum of mechanical services, from the design project to the production and testing. Nowadays, the MW provides services not only to the CERN projects but also to research groups inside and outside LIP and to external companies.

In parallel, the detector laboratory (DL) was also created at the beginning of the LIP foundation with the main aim of supporting the experimental activities developed at LIP. The laboratory has been continuously updated according to general and specific needs of the research groups. The available equipment and technical staff, allow a variety of services: design, construction and reparation of electronic circuits and vacuum systems, design, construction and test of particle detectors.

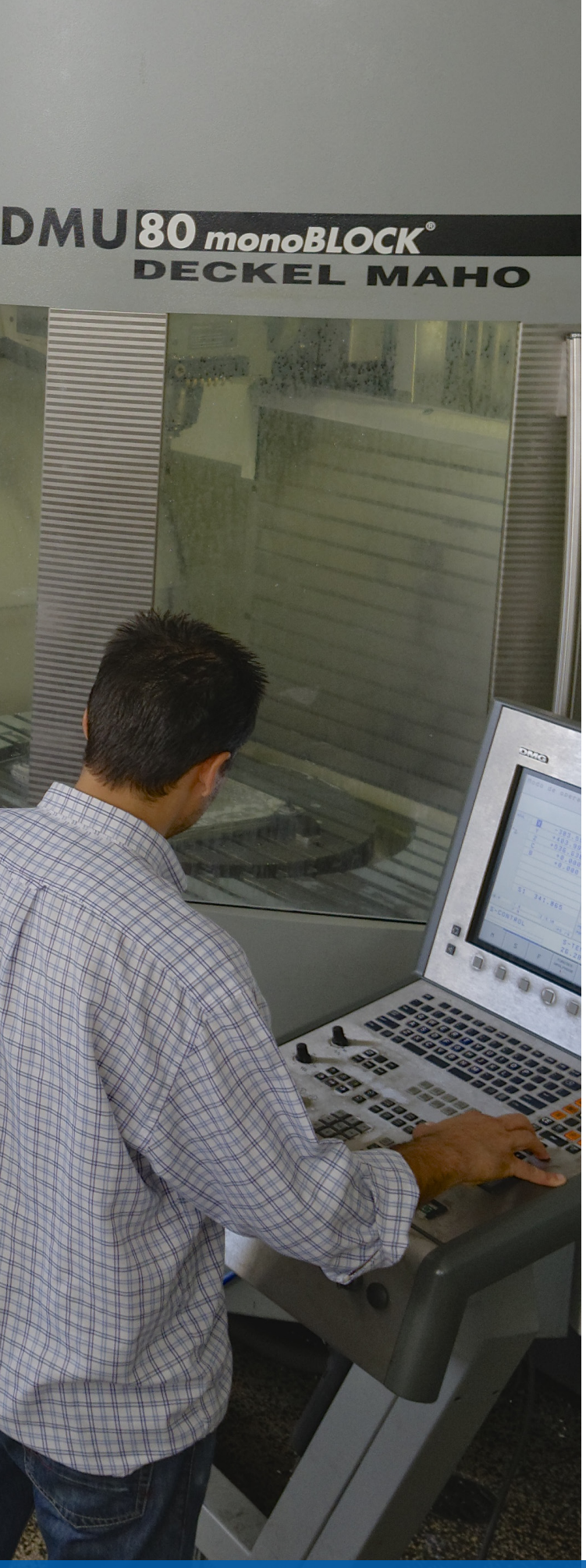
Three decades of experience assures us that, in the absence of the LIP MW/DL, it would not have been possible to perform with the same high level of quality the R&D in gaseous detectors performed in the framework of autonomous projects or small collaborations, or the responsibilities undertaken within medium and large international collaborations

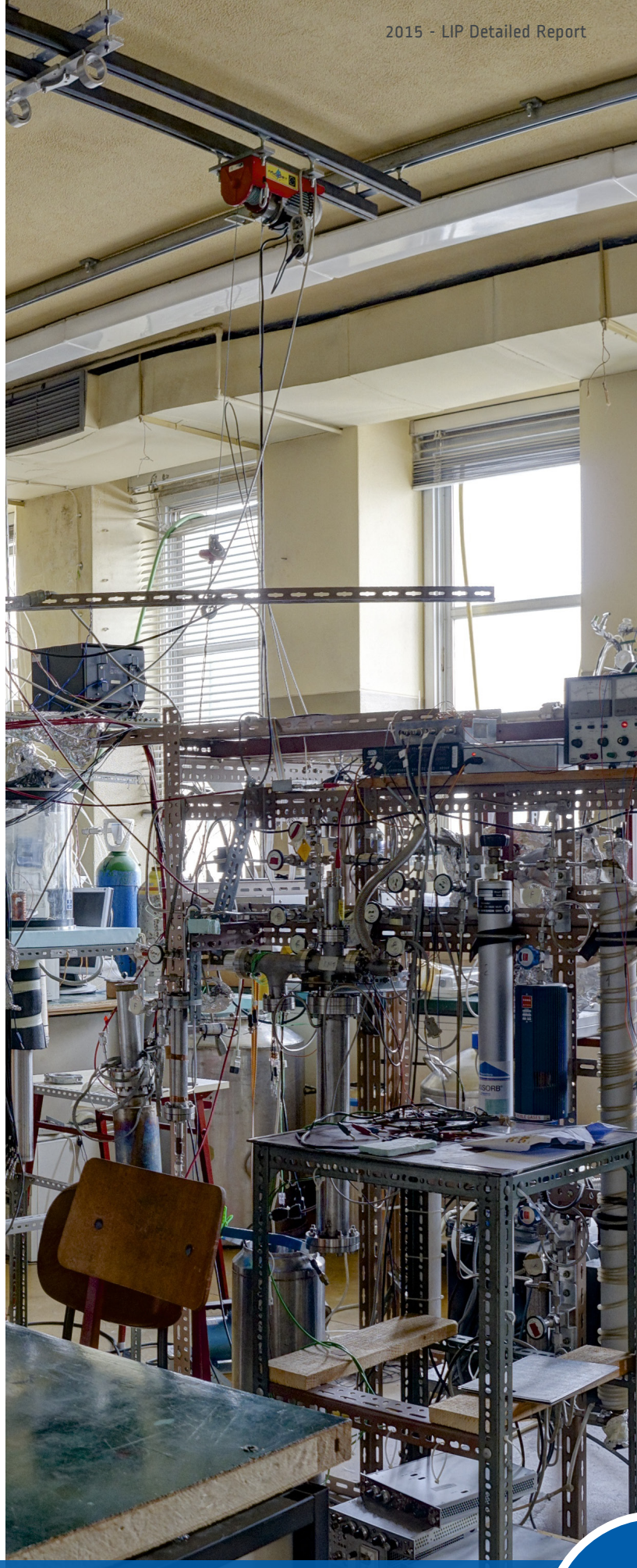
Brief description of the facilities

(CP-LEAR, DELPHI, HERA-B, ATLAS, HADES, AUGER). Equally evident are the benefits to the national R&D community of the intervention of the MW/DL in its projects, at the local and national level.

Coordinator **Alberto Blanco**

Research Facilities





Workshops / e-CRLab / LOMaC / TagusLIP

Activities and achievements in the past year

During 2015 there were two main projects that required an important quantity of the available resources.

- Construction, assembling and test of Resistive Plate Chambers (RPC) detectors and related instrumentation (high voltage power supply, gas system and monitoring system) for the LIP-Auger group.

- Construction, assembling and test of the Umbilical Retrieval Mechanism (URM) (mechanics for the PMT calibration system) for the SNO+ experiment.

In addition to these two main activities, other activities are summarized within the following topics:

- Construction, assembling and test of three layers of RPC detectors equipped with a prototype of Human-PET readout. This system is at the same time a high performance muon telescope (MASTER) to be shipped to Brazil, in the frame work of a collaboration with Centro Brasileiro de Pesquisas Físicas (CBPF).

- Support to the LIP-LUX/LZ activities in the Detector Laboratory.

- Support to the RPC Preclinical-PET activities focused on the construction of a new front-end electronics, modification of the mechanics to accommodate rats and upgrade on the detectors and monitoring system. In addition, different beds has been constructed to accommodate different animal sizes and allow the co-registration with MRI.

- Construction of a spark chamber for CBPF, Brazil.

- Development of a cryostat for Chemistry Department.

- Construction of several particle collimators for the radiation monitor (RADEM) for the ESA JUICE mission.

- Construction of four high pressure chambers for detector testing in the framework of the RAD4Life project.

- Development and construction of 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".

Within external research groups / companies, the most relevant activities are related with: Active Space Technologies (AST), Centro Neuro Ciencias (CNC), Physics and Chemistry Departments and Institute of Systems and Robotics (ISR).

In recent years, the activities related with research projects, both in the MW and in the DL, have increased considerably. As a consequence, the physical space available to develop these activities has been getting smaller. This is a problem that has been especially intensified at the end of 2015 with the construction in parallel of the URM for SNO+ and the RPC detectors for the LIP-Auger group. The ultimate solution found to this problem was to reallocate the MW on a new location, the old Physics Department workshop. Thus, the MW will be installed in better and appropriate location, while, at the same time, valuable space is released for the Detector Laboratory activities.

Plan for next year

It is expected that in the first semester of 2016, the change of the MW to the new installations (and the consequent release of space) will be finished allowing the parallelization of more works due to the extra space available.

Again, as in 2015, the two main projects, which will require an important portion of the available resources during 2016, will be the construction of the URM for SNO+ experiment, which is expected to be finish by the end of July and the construction of RPC detectors for the LIP-Auger group in the frame work "A new generation of RPC muon detectors for high-precision high-energy cosmic-shower", which extends throughout the year. Besides this, the construction, assembling and test of a four layer muon telescope based on RPC detectors, for the Hydronav company, will also need considerable resources.

Other projects that are expected to request resources from the MW and DL are:

- Support the RPC Preclinical-PET activities with the construction of a second scanner, equipped with new FEE and DAQ.
- Support to the LIP-LUX/LZ activities in the Detector Laboratory.
- Support to the development of RPCs based detectors for the detection of Thermal neutrons.
- General support to different research groups.

SWOT Analysis

Strengths and Opportunities

- Valuable know-how, experience and skills of the technical staff.
- The degree of commitment of a part of the staff.
- Opportunity to extend services to other research groups / companies.

Weaknesses and Threats

- Difficulty in combining production and research work.
- Difficulty in working simultaneously in many projects.
- Obsolescence of some of the equipment.
- Lack of resources both technical and human.

COSMIC RAYS ELECTRONICS LABORATORY

e-CRLab

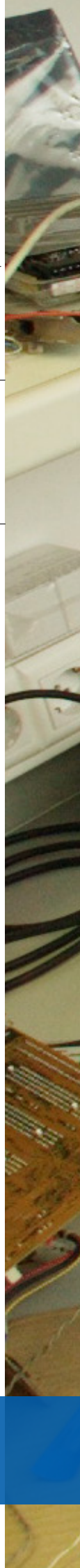
The e-CRLab (electronics for Cosmic Ray Laboratory) is dedicated mainly to the development of electronics for Cosmic Ray experiments. The main focus is given to fast digital electronics implemented in FPGAs. The laboratory has the capability to design complex printed circuit boards and to produce simple 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 a PhD, two PhD student, three Master students and three electronics technicians.

Brief description of the facilities

Coordinator	**Pedro Assis**



Research Facilities

Workshops / e-CRLab / LOMaC / TagusLIP

Activities and achievements in the past year

In 2015 the e-CRLab had two main activities: the development of MARTA-DAQ 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. During 2015 it was started the development of the engineering prototype of MARTA front-end electronics based in the MAROC ASIC.

In the context 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.

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 2016 is planned the consolidation of the activities in the e-CRLab and the beginning of the development of the electronics systems for LATTES.

During 2016 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 tha has the responsibility of the production and assembly of detector modules.

A similar concept of the MARTA DAQ will be used in LATTES, a future large field of view gamma-ray observatory at very high altitude in South America. LATTES will count with RPCs coupled to Water Cherenkov tanks. The RPC readout can be very similar to the solution adopted but it must be included the tank readout in the system. On the other hand it is desirable to have a good time resolution (~1ns) which will probably pose some questions on the time distribution system that can probably be addressed by using copper or fiber clock distribution.

The test setups for e-Co60 will be finalized and measurements of pre-irradiation tests will be done in the first quarter of the year. The setups will be prepared for irradiation phase which include irradiations at several facilities forcing the shipment of the setup to several locations. The e-CRLab will be responsible for the operation of the test-setups during irradiation and annealing phases.

It is expected that the experimental setups at IST will be concluded during the first semester. These setups will also be used in workshops organized in the context of the IDPASC network and probably in summer activities for high-school students.

It is also expected to have by the end of the year the first functional prototype of the AMU.

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-te

LABORATORY OF OPTICS AND SCINTILLATING MATERIALS

LOMaC

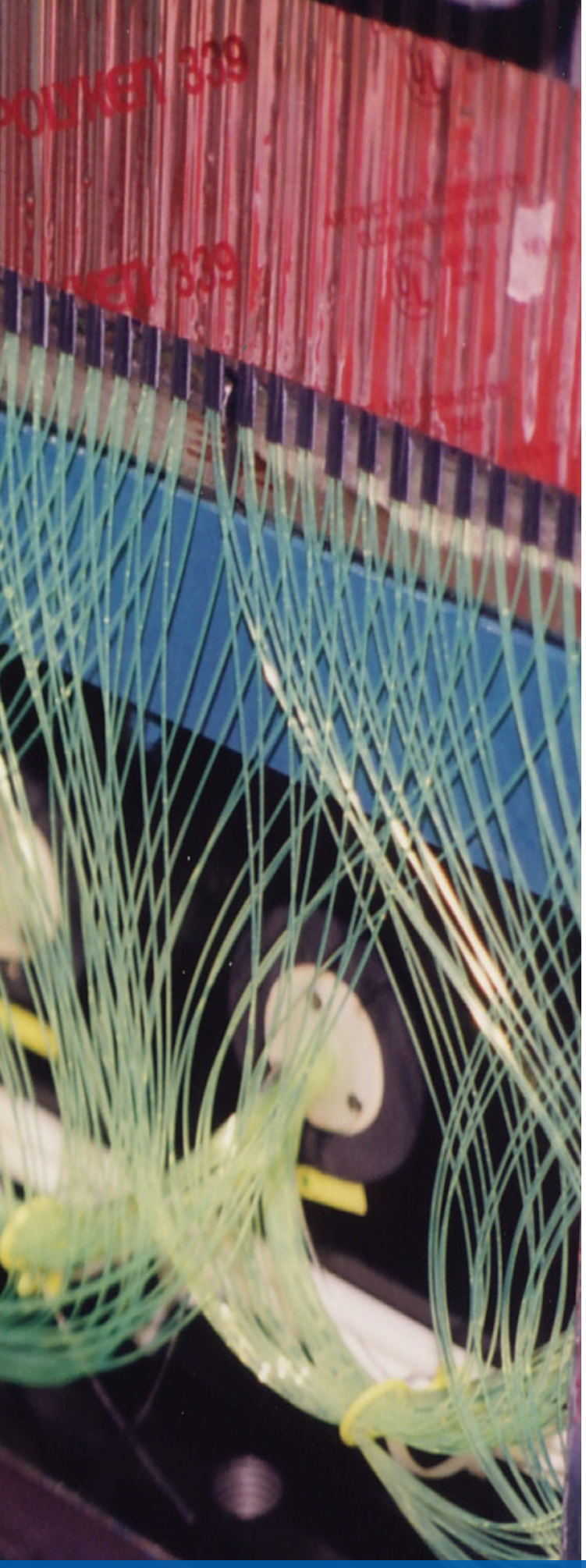
The laboratory of scintillating materials was established in the framework of the ATLAS experiment, to provide support for detector R&D and construction. It focuses on the characterization of plastic scintillators and clear, scintillating and wavelength shifting (WLS) optical fibres. The laboratory was set up in collaboration with CFNUL, where it was located until 2015. It was used to select radiation hard scintillators and WLS fibres for the ATLAS Tilecal calorimeter, and for the massive preparation and quality control of the WLS fibre sets used in the calorimeter. By the time of the selection of the WLS fibres for Tilecal, the laboratory contributed also for the construction of the DELPHI luminosity monitor, STIC, with the selection, aluminization and quality control of the respective WLS fibres. The team was later requested to contribute to the ATLAS Luminosity detector ALFA with the preparation of scintillating fibres with a square cross-section at a smaller scale and to the RD52/DREAM fibre calorimeter project, including also clear/non-scintillating optical fibres. Clear fibres for the calibration systems of Tilecal and SNO+ were also tested in this laboratory.

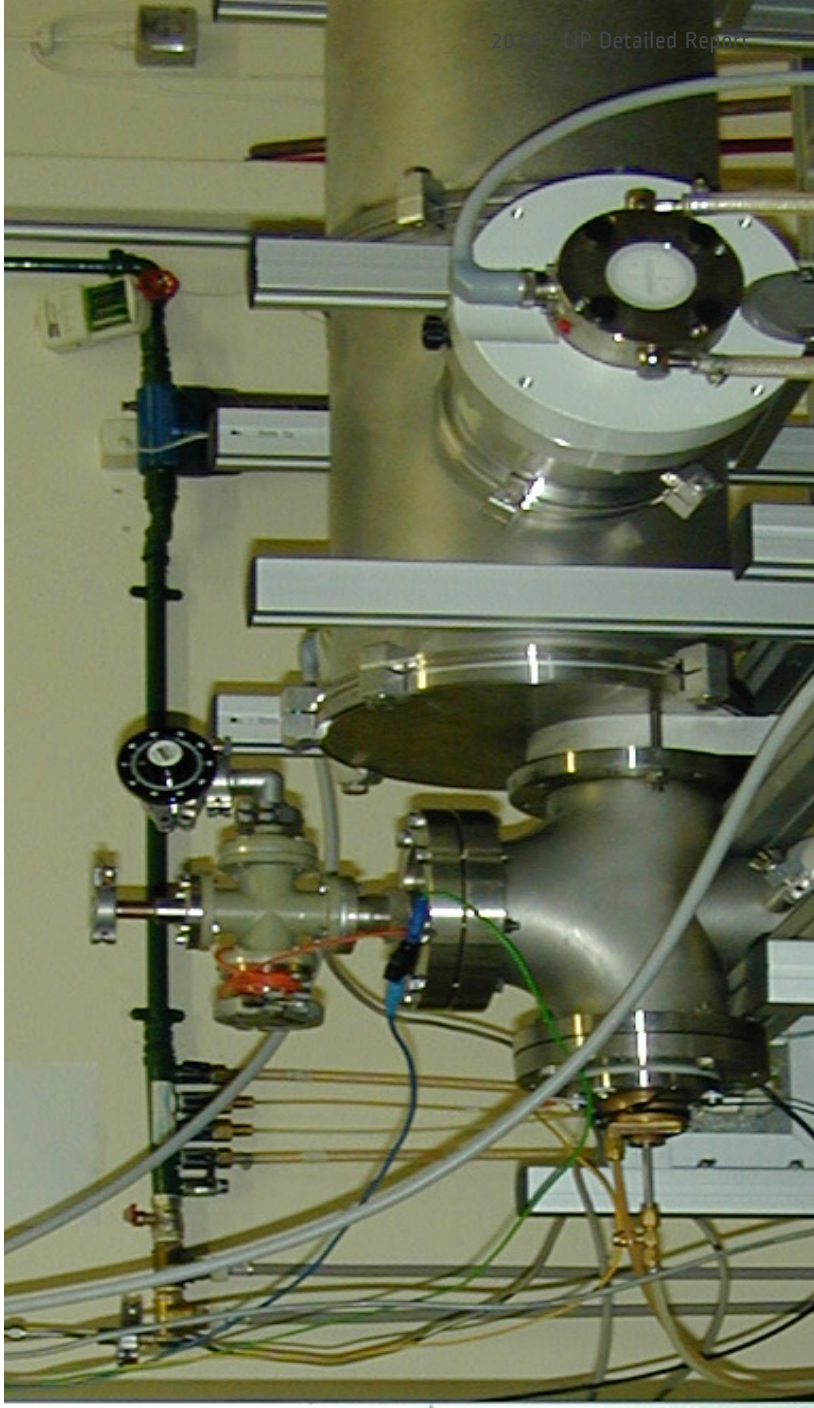
The laboratory is equipped for testing and preparation of scintillators, optical fibres, photomultipliers (PMTs) and related electronics. The main test setup is used for the characterization of plastic WLS or scintillating optical fibres in large numbers, using holders for the scan of up to 32 fibres at a time. It can use both direct radiation from a 90Sr radioactive source to produce light in the fibres or use an additional scintillator as light source. There are additional setups to test scintillators and PMTs. There are facilities for the preparation and aluminization of plastic optical fibres. The cutting and polishing of the fibres is done with a diamond blade tool using a lathe or a milling machine. The aluminization is done by magnetron sputtering technique and the facility allows the deposition of aluminium mirrors in the top of fibres with variable length up to 3 m.

Brief description of the facilities

Coordinator **Agostinho Gomes**

Research Facilities





LABORATORY

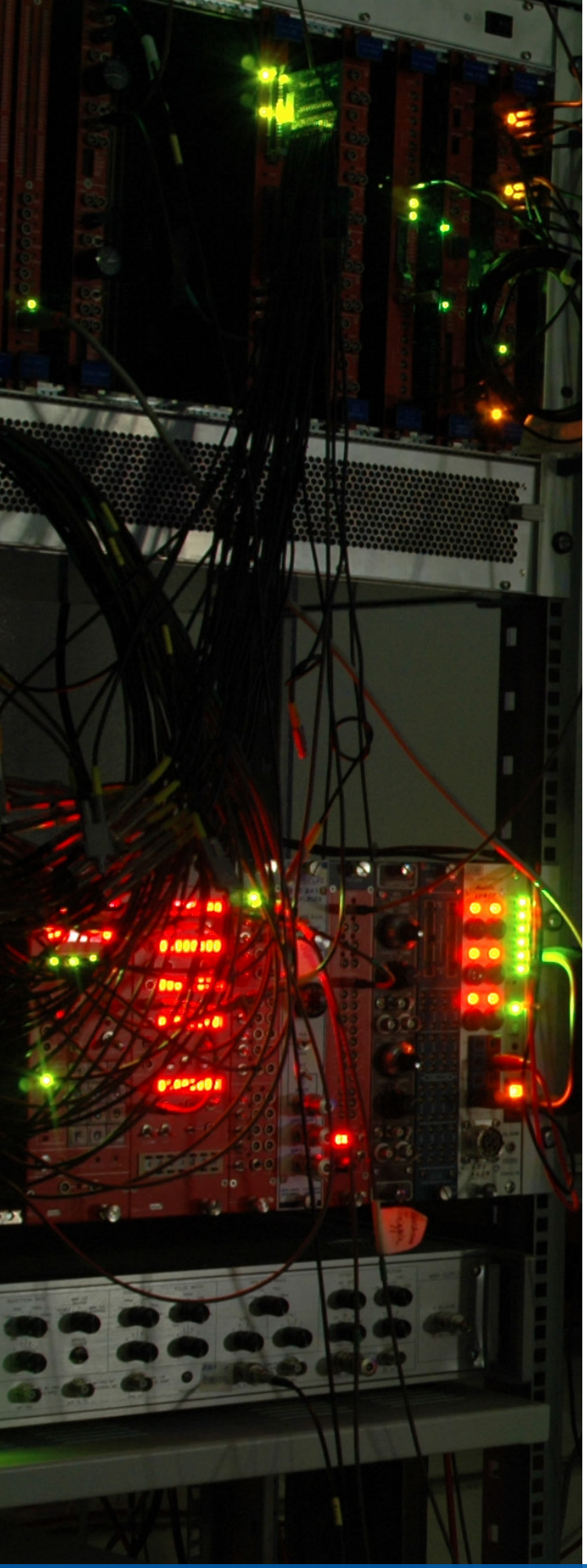
TagusLIP

TagusLIP was created in 2004 at the Lisbon Science and Technology Park (Taguspark) as a generic infrastructure for the development of nuclear medicine imaging technologies. It is installed in the modular building with a total of 400 m2 which includes office space for about 15 people, a meeting room for 20 people, two large laboratory spaces, electronics workshop, and a bunker for work with high activity sources. The TagusLIP laboratories are well equipped with general purpose equipment needed in the development and validation of large electronics and data acquisition systems. The PETsys start-up company has recently been using the TagusLIP infrastructure for the development and validation of Time-of-Flight PET technology. The company has assembled a TOF-PET demonstrator ring and performed the validation of the system using radiation sources.

More details on the 2015 activities can be found in the STCD TagusLIP Group Report (page 136)

Brief description of the facilities

Coordinator **João Varela**



// SCIENCE AND SOC


Technology transfer, industry and spin--offs
Advanced training
Education, outreach and engagement

IETY

Outreach and communication

Coordinators: Pedro Abreu and Catarina Espírito Santo

All LIP members contribute at a variable fraction of their time to the Comm & Outreach activities. Research groups usually assign a contact person to this tasks. The people listed below gave core contributions in 2015: C. Abreu, S. Andringa, A. Blanco, N. Castro, H. Gomes, R. Gonçalo, C. Manuel, A. Onofre, L. Peralta, F. Rego, S. Soares, F. Veloso.

To engage society with particle physics and related technologies, and to give support to education in science and technology, are key aspects of LIP's mission. The LIP Communication & Outreach team cares both for communication (internal and external) and for science outreach and public educations. LIP is part of international communication and outreach groups, namely the International Particle Physics International Group (IPPOG) and the European Particle Physics Communication Network (EPPCN).

Communication

This activity encompasses both internal and external communication tasks. Different audiences are considered, with specific goals and approaches for the different cases. Internally, goals are to improve the information flow, the communication and collaboration between the different groups within the lab, and to potentiate the role of our researchers as LIP ambassadors. Externally, we aim to increase the public awareness of its role and achievements. For the more specific university-related public, the visibility of LIP plays an important role in our ability to attract graduate students and partnerships with other institutions. An effort to better organize communication at LIP is ongoing, endowing it with a more efficient structure and adequate human resources.

Outreach and Education

While outreach concerns every group and every researcher in the lab, the Comm & Outreach team fosters such efforts and leads its own activity lines. Flagship projects are IPPOG's International Masterclasses in particle physics and the CERN Portuguese language teachers programme. These and other projects and events developed in 2015 are detailed below.

While schools are a privileged target of the LIP outreach and education activities, public sessions for other audiences are also undertaken. LIP is an associate of the Ciência Viva Agency for the promotion of scientific and technological culture, our partners in several education and outreach projects.

2015 Activities

2015 was a special year, with the prizes given to neutrino physics, which attracted much attention to our filed, and with preparation for the 30 years of LIP celebrated in 2016. This celebration is also an opportunity to re-think and upgrade the communication and outreach strategies of the lab. The main achievements can be summarized as follows:

Communication

- The 30 years of Portugal's accession to CERN were celebrated. In a public session at the Pavilion of Knowledge (Lisbon's science centre of Agência Ciência Viva) the documentary "Particle Fever" was presented and followed by an open discussion with scientists at the auditorium, which was at the ceremony renamed as "Auditorium José Mariano Gago".

- The Nobel Prize in Physics 2015 given to neutrino physics, and the Breakthrough Prize for Fundamental Physics awarded to three colleagues working at LIP brought much media attention and requests for seminars. Timely and complete information for journalists and for the public was provided at the LIP web site.

- In the context of EPPCN, LIP works in close contact with the CERN press office, locally spreading, translating and adding the national angle to the CERN press releases. In addition, LIP increasingly spreads its own news, via press releases send to our media contacts but also via the lab's web site and social media.

- To celebrate the 30 years of LIP, a large exhibition on the big challenges of particle physics for the next decades will be presented in university venues in Braga, Coimbra and Lisboa, and public sessions will be organized. The preparation of this exhibition was an important activity line in the second half of 2015.

- For the 30th anniversary, a new LIP web site will be launched. The planning, development and implementation work took place in 2015.

- A proposal for the new format of the LIP early reports was prepared and presented, better structured, easier to read and graphically more attractive. A public report serving as a visiting card of the institution will be issued. Complementary information for our associates and for the International Advisory Board will be provided in a more detailed technical report.

- The LIP-News Bulletin was regularly issued. The Bulletin is a relevant internal communication instrument. It also plays a role in

the links with the school community and our partners institutions, namely universities.

Outreach and education

- The International Masterclasses in Particle Physics occurred in 14 sessions at Aveiro, Beja, Braga, Bragança, Coimbra, Covilhã, Évora, Faro, Lisboa (2 places and 3 sessions), Ponta Delgada (Azores Islands), Porto, Vila Real, and with our remote support in São Tomé and Príncipe. The total number of participants was of the order of 2000, constituting the largest participating country in the activity.

- In the scope of the Ciência Viva's programme "Summer in the Science", LIP proposed 3 internships in Lisboa and 3 internships in Coimbra, that received 18 and 6 students, respectively, for 10 days to learn about modern physics and work with detectors. The internships in Lisboa were concentrated in the area of data analysis of public data from the ATLAS and the Auger experiments, and in Coimbra in the area of detectors and associated technologies.

- The CERN Portuguese Language Teachers Programme happened in the first week of September with an important support from CERN and Ciência Viva for 24 portuguese teachers, 20 teachers from Brazil, 2 from Mozambique, 2 from East Timor, 1 from Cape Verde and 1 from São Tomé and Príncipe.

- The involvement of the schools in the Environmental Radiation project was very low in 2015 and the scheduled national meeting was cancelled. Nevertheless, the LabLEDs project pursues the goal of bringing to the classroom simple experiments on particles, radiation and their detection, keeping the contact with a consolidated network of teachers built over the years.

- About 25 schools organized visits to CERN and Portugal had 18 teams (in a total of 212) participating in the 2015 edition of the "CERN Beamline for schools" contest. A Portuguese team made it to the shortlist final of only 13 teams.

- More than 30 outreach talks where given at the schools by LIP scientists in 2015, on particle and astroparticle physics, Space, and related technologies.

Prospects for 2016

In 2016 LIP celebrates its 30th anniversary. The main objectives for this year are:

- To keep the lines of work described in the previous sections, in particular in the regular event series such as the teacher's programme, the masterclasses, OCJF, LabLEDs and seminars in schools.

- To pursue detector developments projects for demonstration and for school experiments, in particular a cloud chamber and a small muon telescope. This will follow the good example of the LIP spark chamber, that exists now in Austria, Argentina, Brazil, Italy, Spain, at CERN, and in several locations in Portugal.

- To ensure the success of the exhibition, and of the celebration of the 30 years of LIP in general. This will be a major effort for the first semester of the year.

- To improve the contact with the media, and to foster internal communication and to the coordination of the different outreach efforts in the lab.

SWOT Analysis

Strengths

The strong motivation of the group and its well established and recognized flagship projects are clear strengths. Over the years, this endowed LIP with the capability to attract a large number of participants to the events it organizes and generated a wide contact list, particularly in high schools.

Opportunities

The celebration of the 30 years of LIP an opportunity to re-think and upgrade the communication strategies of the lab. In particular, the exhibition produced for the occasion and present at university premises is a project of unusual size for the lab and an opportunity to attract university students to particle physics and related technologies, and in general to increase the visibility of LIP. The increase in the human resources dedicated to the project is also an opportunity to enlarge our set of activities and better structure the group.

Weaknesses

The capability to built kits and demonstrators on particle detection should be reinforced in what concerns technical, human and financial means.
There is also the need to improve communication - internally, in order to foster and integrate the outreach activities developed by the different groups, and to more efficiently gather news and information concerning the work of the different research groups; and externally, in particular in looking for a more efficient communication with the media.
Threats
An threat to some of these activities is the lack of funding. In particular, some of the projects have the support of Agência Ciência Viva, and the decrease of the funding of the Agency had in the last few years had already a negative effect.

Threats

The decrease of the its capability to attract students is a threat for the lab, as well as the reasons behind it: lack of connection of researchers to the universities, funding difficulties, lack of physical space or adequate premises.
The disregard of the role of fundamental research in innovation in the long term in favor of immediate-result oriented policies is another threat.

References:

- "The international Masterclasses in particle physics: the Portuguese experience", SciCom.pt, Lagos, 2015.
- "The role of networks in the local communication of big science organizations: the example of Portugal at CERN". SciCom.pt, 2015
- Chapter on the beginning of outreach activities in Portugal in the book "Histórias da física do século XX", by Conceição Abreu and Jorge Dias de Deus.

Advanced training

Coordinators: Mário Pimenta and Isabel Lopes

The advanced training of new researchers is one of the priorities of LIP. The laboratory permanently hosts some tens of Bachelor, Master and PhD students, which actively work within its research groups. The Universities of Lisboa, Coimbra and Minho are LIP associates. In each of its three nodes, LIP works in close relation and cooperation with the local University, and the strengthening of these bounds is a clear goal.

LIP coordinates two national doctorate programmes (FCT PhD programmes): DAEPHYS - Applied Physics and Physical Engineering, at the Universities of Coimbra, Aveiro and Lisbon (both ULisboa and UNL); and IDPASC-Portugal: Particle Physics, Astrophysics and Cosmology, involving the Universities of Minho, Porto, Coimbra, Lisboa and Évora. We are also a partners in two others programme: MAP-FIS, with the Universities of Minho, Porto and Aveiro; and DP-MPI, Physics and Mathematics for future information technologies, involving IST and several research centers.

LIP belongs to international doctorate networks that bring together universities and research centres, including the IDPASC international network, coordinated by LIP, and several International Training Network (ITN) sponsored by the European Commission.

The importance of training events targeting university students from the first years (1st Bologna cycle) has been recognized in recent years.

The role of LIP in the training of teachers and engineers, via schools and internships at CERN, is also widely recognized.

2015 Activities

Graduate students at LIP

In 2015, LIP hosted 41 PhD students, 29 Master students and 7 bachelor students.

The number of students per research line and information on grants is given in the performance chapter of the report.

IDPASC

The national IDPASC was approved by FCT in 2014 with 24 grants for 4 years. In 2015 the second call was open and 6 grants were given. The start of the program suffered from considerable bureaucratic delays.

In 2015, the IDPASC network organized the following events:

- 5th IDPASC school, Paris, February 2015
- 4th LHC Physics
- Workshop "The foundations of particle physics", Univ. Porto, March 2015
- Workshop "Hands on particles and light", FCUL, Univ. Lisbon, April 2015
- Workshop "Space, particles and Earth", Univ. Évora, October 2015

DAEPHYS

DAEPHYS was approved by FCT in 2013 with 24 grants for 4 years. The Program results from the association of four Universities - Universidade de Aveiro, Universidade de Coimbra, Universidade de Lisboa and Universidade Nova de Lisboa – two Associated Laboratories - Instituto de Nanoestruturas, Nanomodelação e Nanofabricação (I3N) and Laboratório de Instrumentação e Física Experimental de Partículas (LIP) - and a Research Centre - Centro de Instrumentação (CI).

ITNs

During 2015, LIP participated in several active International Training Network (ITN) sponsored by the European Commission:

- The PicoSEC-MCNet network, "Pico-second Silicon photomultiplier-Electronics - & Crystal research-Marie Curie-Network" had two Early Stage Researchers (ESR) with 36 month contracts at LIP, both of which ended during 2015. The project finished at the end of 2015.
- The network INFIERI, "INtelligent Fast Interconnected and Efficient Devices for Frontier Exploitation in Research and Industry" is ongoing, with one ESR at LIP.
- The AMVA4NewPhysics network, "Advanced Multi-Variate Analysis for New Physics Searches at LHC" started last September.

Training for 1st cycle university students

A variety of short duration training events were proposed to 1st cycle students by LIP in collaboration with the local Universities:

- At LIP/Minho, the so-called "particle physics analysis tasks"

Science and Society

(3 hours per week during one semester) and offered to students since 2010. 20 students have participated until now.

- Summer internships for university students were proposed in Lisbon by several groups:
  - 7 afternoons for an immersion in the analysis, data taking, detector control system of COMPASS (9 students)
  - 2 weeks analysis internships in CMS (2 students)
  - 2 days course on relativity with Cosmic Rays at LIP (3 students)
  - 2 days course on electronics at the LIP Electronics Laboratory (4 students)
- Training events for 1st cycle students were also held within the IDPASC programme, in particular the "Hands on particles and light" workshop.

Prospects for 2016

For 2016, the reinforcement of the training events and activities for 1sr cycle students will be pursued. Teaching links of the researchers to the universities will be strengthened, in formal and informal ways.

In the first month of 2016 two such events took place:
- 2-day course on linux, at Univ. Minho, Jan 2016
- LIP-CFTP IDPASC mini-school on particle and astroparticle physics, Costa da Caparica, Feb 2016

With the same goal of increasing the visibility of LIP at universities, the exhibition celebrating the 30 years of LIP and featuring the challenges of particle physics for the next decades will be in University premises, in Braga, Coimbra and Lisboa, during the first half of 2016. A team of students will, in each location, help in monitoring the exhibition and guiding visitors. Physics students organisation are being invited to participate.

Concerning, IDPASC-PT, the third call will take place during this year. The number of grants insufficient for the wideness of the subject and the size of the network. A reinforcement of the programme will be attempted. Meanwhile, several events will be carried on:
- 6th IDPASC school, Slovenia
- 5th LHC Physics
- 2nd IDPASC student Workshop
- Workshop "Hands on particles and light", FCUL, Univ. Lisbon,

Now that the number of students in the programme in finally increasing, aspects such as complementary training and career plan development should be reinforced.

LIP is a partner in several applications for Marie Curie International Training Networks. In particular, it coordinated the DM@IDPASC proposal, which stems from the IDPASC international network, adding a focus on a cutting edge, stronger mobility and links to non-academic sector and innovation.

The AMVA4NewPhysics network will have its first contracted fellow at LIP starting in March 2016.

SWOT Analysis

Strengths

LIP has long standing experience in offering advanced training opportunities and hosting post-graduate students. It offers, scientific excellence, appropriate infrastructures, careful guidance, a stimulating atmosphere, and the integration in its local research groups and in the framework of international conferences.

LIP can offer research subjects in a broad range of areas, covering broadly the subject of experimental particle and astroparticle physics, but also related technologies and computing. LIP has Specific Laboratories for detector developments, electronics and for Nuclear Medical Physics, in cooperation with hospitals and other entities, has a high precision mechanical workshop and distributed computing infrastructures used by many other research institutions.

Weaknesses

Today, most LIP researchers have no contractual link to the universities, opposite to what happened some years ago. The lack of direct and regular contact with students explains, at least in part, the decrease in our ability to attract post-graduation students. Funding difficulties, and in particular the difficulty to offer grants to young researchers, also play a role. Due to the issues mentioned above but also to the lack of a communication strategy targeted at science and technology university students, the visibility of LIP for this group needs to be reinforced.

Opportunities

Following the recognized outreach work developed with high school students, to engage university students in experimental particle physics and related technologies is a challenge and an opportunity.

The participation in international networks offers opportunities to increase our capabilities to attract students, reinforcing the quality and diversity of our offer.

Externally, a new science policy committed to strengthen the ties between scientific researchers and the universities, with new contracts at public universities, may be an opportunity.

Events such as the prizes given to neutrino physics in 2015 or the celebration of the 30 years of LIP are opportunities to increase the visibility of the lab and of our research subject, for the general public and in particular for the potential future LIP students.

Threats

The decrease of the its capability to attract students is a threat for the lab, as well as the reasons behind it: lack of connection of researchers to the universities, funding difficulties, lack of physical space or adequate premises.

The disregard of the role of fundamental research in innovation in the long term in favor of immediate-result oriented policies is another threat.

Technology transfer, industry and spin-offs

Coordinator: Gaspar Barreira

LIP's activities provide various sets of opportunities for knowledge transfer to the economy.

Directly, the areas of application, namely in the biomedical field and in the space sector, are potential sources for the generation of new industrial property rights to be transferred to existing or new companies. Knowledge transfer opportunities may also be expected across the whole spectrum of LIP experimental activities, especially by research leading to new instruments and methods, or in advances in computing applied to other fields. Two examples of direct technology transfer in the 2015 activities are highlighted below.

Indirectly, LIP's involvement with CERN has triggered technological transfer to Portuguese industry through the training of Portuguese engineers at CERN and through industrial 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. Industrial contracts with ESA shared by LIP and by Portuguese industry are also important sources of technology transfer induced or facilitated by LIP in specific areas.

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.

STCD – Spin-off technology for cancer diagnosis

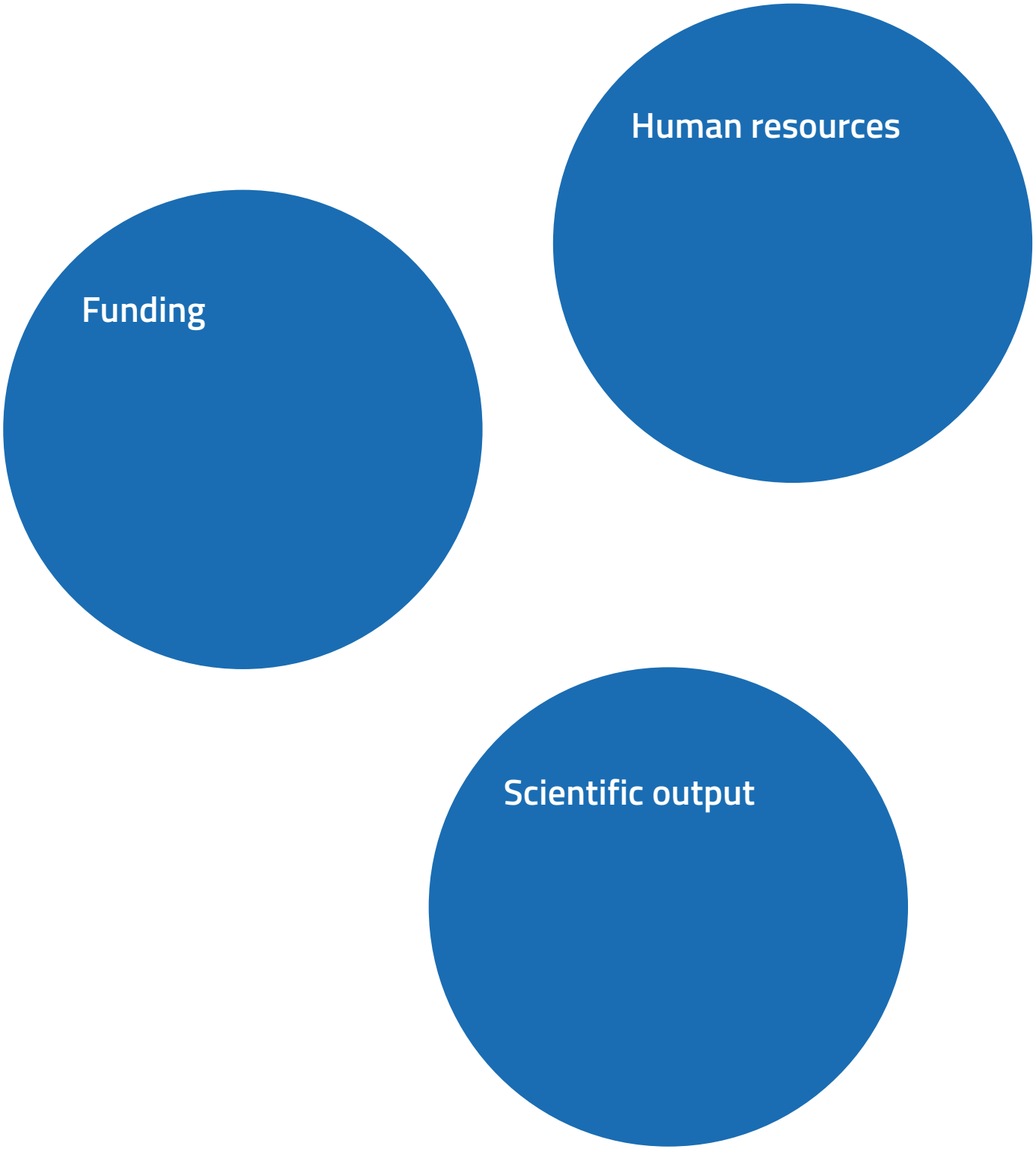
The STCD group was created in 2004 around the development of a new Positron Emission Tomography scanner (ClearPEM) for breast cancer diagnosis, exploiting technologies developed at LIP for the CMS experiment at LHC. Scientific research, technological development and laboratory testing of new PET scanners 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 LIP/STCD group was part of the EndoTOFPET project and the associated Marie Curie Training Network PICOSEC funded by the European Union. This project developed a 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.

RPC production in the Brazilian industry

LIP is a recognized world leader in RPC (Resistive Plate Chamber) detectors. MARTA is an RPC-based cosmic ray detector thought for an upgrade of the Pierre Auger Observatory but with many other possible applications. The installation at the Observatory of an engineering array of MARTA was recently approved in a very competitive joint FCT/FAPESP. This project will run for three years in a close collaboration between Portugal and Brazil, and foresees the transfer of the RPC production technology to the Brazilian industry. In November 2015 the science funding agencies and the main laboratories signed, at Malargue, the renewal of the international agreement of the Pierre Auger Observatory assuring its continuous operation until 2025. For Portugal both FCT and LIP signed the agreement and the Portuguese ambassador in Argentina was present at the signing ceremony.

// SUMMARY TABLES



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Funding

Project	Code	Funding	Entity	Start	End	LIP node
ATLAS	EXPL/FIS-NUC/1705/20 13	49485	FCT	2014-04-07	2015-08-06	L, C, M
	FCG	10000	LIP Lisboa	2015-01-01	2015-12-31	L, C, M
	CERN/FIS-NUC/0005/20 15	400000	FCT	2015-03-01	2017-02-28	L, C, M
	IF/00955/2013/CP1172 /CT0004	50000	FCT	2013-12-01	2018-11-30	L, C, M
	IF/00050/2013/CP1172 /CT0002	50000	FCT	2014-01-01	2018-12-31	L, C, M
	IF/01586/2014/CP1248 /CT0003	42000	FCT	2015-01-01	2019-12-31	L, C, M
CMS	CERN/FP/123601/2011	550000	FCT	2012-04-01	2015-03-31	L
	CERN/FIS-NUC/0029/20 15	400000	FCT	2015-04-01	2017-03-31	L
	AMVA4NewPhysics - 67 5440	238356	EU	2015-09-01	2017-08-31	L
	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
COMPASS	CERN/FIS-NUC/0017/20 15	200000	FCT	2015-04-01	2017-03-31	L
Dosimetry	PTDC/BBB-IMG/3310/20 12	25920	FCT	2013-07-01	2015-12-31	L
GRID	Cloud - Piloto	83000	FCT	2014-08-14	2015-12-31	L
	RECI/FIS-NUC/0115/20 12	500000	FCT	2013-01-01	2015-12-31	L
	EGI-ENGAGE	108500	EU	2015-04-01	2017-09-30	L
	INDIGO	503625	EU	2015-05-01	2017-10-31	L
HECR	ASPERA/0001/2010	150000	FCT	2012-09-01	2015-08-31	L, C, M
	EPLANET 246806	10800	EU	2011-01-01	2016-01-31	L, C, M
	CERN/FIS-NUC/0038/20 15	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
	IF/00820/2014/CP1248 /CT0001	50000	FCT	2015-01-01	2019-12-31	L, C, M
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	MC2015 - RadAmb	4000	CVIVA	2015-02-01	2015-07-31	L
	OCJF2015	650	CVIVA	2015-06-22	2015-08-22	L
	PLTP2015 - CV731	14000	CVIVA	2015-04-01	2015-11-30	L
	2015-77/753	15000	CVIVA	2015-12-16	2016-06-30	L

Summary Tables

Project	Code	Funding	Entity	Start	End	LIP node
PET/TagusLIP	Endo TOFPET-US256984	509400	EU	2011-01-01	2015-06-30	L
	PicoSEC-MCNet (28935 5)	423082	EU	2012-01-01	2015-12-31	L
SNO+	EXPL/FIS-NUC/1557/20 13	28119	FCT	2014-04-01	2015-09-30	L
	IF/00863/2013/CP1172 /CT0006	50000	FCT	2014-01-01	2018-12-31	L
Space	ESA:22381/09/NL/PA/C CN04	20000	ESA	2013-10-01	2016-02-28	L, C
	ESA: 3-14025/13/NL/A K	60000	ESA	2014-03-17	2016-05-31	L, C
	ESA: 3-13975/13/NL/P A	200000	ESA	2014-03-10	2016-08-31	L, C
	ESA: 1-7560/13/NL/HB	300000	ESA	2014-02-18	2016-12-31	L, C
	ESA/4000115004/15/NL /RA/ZK	80116	ESA	2015-11-13	2018-11-12	L, C
AHEAD	654215 - AHEAD	61225	EU	2015-09-02	9999-12-31	C
Gamma Cameras	IF/00378/2013/CP1172 /CT001	50000	FCT	2014-01-01	2018-12-31	C
HADES	PTDC/FIS/113339/2009	91742	FCT	2011-04-01	2015-01-31	C
Neutron Detectors	EXPL/FIS-NUC/2522/20 13	31200	FCT	2014-03-01	2015-08-31	C
	654000 SINE2020	116250	EU	2015-10-01	2019-09-30	C
RAD4LIFE	QREN CENTRO-07-ST24- FEDER-002007	495773	EU	2013-06-01	2015-06-30	C
RPC R&D	AIDA-2020	45000	EU	2015-06-01	2019-05-31	C

LIP Node: L - Lisboa, C - Coimbra, M - Minho

Human Resources

Group	FTE	Heads (*)	Researchers	Technicians	PhD	Master	Undergrad	External
ATLAS	27.1	54	20	5	13	10	3	3
CMS	14.8	25	12	2	7		3	1
LHC Phenomenology	6.9	18	11		1	1	1	4
COMPASS	9.4	10	6	1	2	1		
HADES	1.1	8	6	2				
AMS	3.0	4	2		1	1		
HECR	16.1	30	16	6	3	2		3
Dark Matter Search	6.6	10	7	2	1			
SNO+	4.6	14	6	3	1	3	1	
Neutron Detectors	1.6	6	4					2
RPC R&D	7.8	13	3	9				1
NEXT	6.2	17	9		1	4		3
Liquid Xenon R&D	2.6	12	4	7	1			
RPC-PET	2.3	10	6	4				
OR Imaging	3.7	6	1		2	3		
Gamma Cameras	4.8	17	5	8	3			1
Dosimetry	5.7	12	6		1	3		2
STCD/TagusLIP	5.9	15	6	2	3	1		3
Space	5.5	11	6		2	2		1
AHEAD	7.2	14	6	3	3	2		
GRID	10.1	11	7	3		1		
Advanced Computing	2.4	4	4					
total	**154.4**	**250**	**153**	**57**	**45**	**34**	**8**	**24**

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	99	10	18	12	6			5	7	1	1	2
CMS	72	4	12	8		1	7	20				1
LHC Phenomenology		1										
COMPASS	6	3	4	2					5			1
HADES	6											1
AMS	2			1	1	2						
HECR	8	2	15	3	4	1		1	3	1		2
Dark Matter Search		1	6	3		1	1				1	1
SNO+		2	13	3	1			7	2			
Neutron Detectors							1					
RPC R&D		3	1	2			1	2				
NEXT	5	1	1	1	2							
Liquid Xenon R&D												
RPC-PET		1				1						
OR Imaging		1										
Gamma Cameras		1				1						
Dosimetry	1		2	2	2	2			1			2
STCD/TagusLIP		2			2		1					
Space		1	1		1	1	5		3			
AHEAD		2	1		2				3		2	1
GRID			2			2		6			1	4
Advanced Computing			4									
Total	199	35	80	37	21	12	16	41	24	2	5	15

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.

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