ANNUAL REPORT

2017/2018

LABORATÓRIO DE INSTRUMENTAÇÃO
E FÍSICA EXPERIMENTAL DE PARTÍCULAS
partículas e tecnologia

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ABOUT LIP

LIP is the reference laboratory for experimental particle physics and associated technologies in Portugal

LIP exists for the discovery of the fundamental laws of the Universe, ensuring the full participation of the Portuguese scientific community in this endeavor, and to share this knowledge with society. The laboratory is nation-wide, with nodes in Lisboa, Coimbra and Braga, working in close collaboration with the local universities. It has close to 200 members, including over 80 PhD researchers and 70 graduate students.

Under the supervision of FCT, LIP defines the national research agenda for experiental particle physics and the Portuguese participation at CERN and in other international scientific infrastructures. LIP is the Portuguese reference partner of CERN, and also a partner of ESA, the GSI research centre in Germany, SNOLAB in Canada, the Pierre Auger Observatory in Argentina and the Sanford Underground Research Facility (SURF) in the USA. The associates of LIP are FCT, the Universities of Lisboa, Coimbra and Minho, Instituto Superior Técnico (IST), the Faculty of Science of the University of Lisbon (FCUL) and the Electrical and Electronics Business Association.

The three pillars of activity at LIP are:

- **Discovery through science:** LIP's program of experimental particle and astroparticle physics is international, has world-class quality and addresses some of the most topical questions of our time.
- **Innovation through technology:** basic science drives innovation in the long term. LIP is a key player in the application of particle physics technologies to health care and space exploration, and in scientific computing.
- **Sharing with people:** LIP works to engage society in science, to inspire the younger generations to pursue careers in science and technology, and to address societal challenges through science.

LIP is committed to R&D in three main areas:

- **Experimental particle and astroparticle physics;**
- **Development of new instruments and methods;**
- **Scientific computing.**

LIP is deeply involved in the CERN Large Hadron Collider (LHC) programme, contributing from the very beginning to the two largest LHC experiments, ATLAS and CMS, and exploring new physics phenomenology. LIP is also involved in the fixed target programmes at CERN and GSI, probing the strong nuclear force and dense nuclear matter. The quest for dark matter, a deeper understanding of the elusive neutrinos, or the study of hadronic interactions at the highest energies in cosmic rays are among the great challenges of particle physics for the next decades, and part of our agenda.

The development of new instruments and methods for particle physics has been from its inception one of the main strengths of LIP. Current activities include research in fundamental detection processes and applications of particle detectors. LIP is a world leader in Resistive Plate Chambers (RPC) and liquid xenon detectors, with

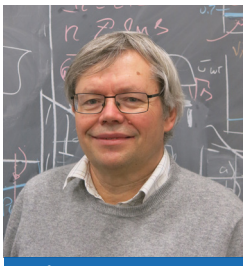
strong expertise in other gaseous detectors and scintillator/fibres calorimetry. Specific R&D lines are dedicated to health care and space exploration applications.

LIP develops novel information technologies and operates advanced services to support demanding scientific applications, focusing on Grid and Cloud computing technologies. LIP participates in some of the largest R&D projects in this field, operates the largest scientific computing facility in Portugal, and delivers services to the scientific community at large. LIP co-leads the National Distributed Computing Infrastructure.

Our vision for the future is to make sure that LIP will be present in the next great scientific discoveries of humankind, and lead science and innovation in Portugal in close connection with the academic and business communities.

DIRECTORATES REPORT

It´s moving...



prof.
Mário Pimenta
President

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

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

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

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

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

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

Computing is a fundamental area at LIP, both fullfilling the always growing needs of the other scientific groups, and developing novel technologies and methods. LIP is part of several international projects on distributed computing technologies, including Grid, Cloud, high throughput and high performance computing, and its participation has been always very well acknowledged. In 2017 several projects have been successfully completed, and new ones have started. The INCD (Infraestrutura Nacional de Computação Distribuída) joining FCCN, LNEC and LIP, is now a well consolidated reality.

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

The particle and astroparticle physics programme ahead of us is ambitious and challenging. We will be involved, in the next five years, in the LHC high luminosity upgrade and in fixed target experiments; in high energy cosmic and gamma rays experiments; in the search for neutrinoless double beta decay and in long baseline

neutrino experiments; and in direct and indirect searches for dark matter. At the same time our commitments with the outside world (universities, research units, companies, schools, society in general) have to be strongly pursued and increased. New ideas and approaches are already in our mind and have to be tested in pilot projects. A global evaluation of the Portuguese scientific units is under way. It is a highly demanding process where we have to review our past activities and to present our plans for the next five years, including a rigid framework of questionnaires and a short visit of the evaluation committee to the laboratory. With the engagement of all of us, we are confident on a positive outcome, which will help us to build a better and even more ambitious LIP.

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

(Mário Pimenta)

Report from the International Advisory Board

L. Rolandi, S. Bertolucci, K. Parodi, C.W. Fabjan, P.G. Innocenti, M. Teshima

The LIP International Advisory Committee met at the new LIP premises in Lisbon on April 27 and 28, 2018. Prior to the meeting the Committee had received extensive and well-prepared documentation about the LIP activities. Oral presentations and discussions during the meeting provided further relevant information.

One mission of LIP is the study of the fundamental laws of particle physics. This research is carried out at the CERN LHC (ATLAS and CMS experiments) and at the CERN SPS (COMPASS). The origin of cosmic rays and the astrophysics implications are studied in ambitious programmes, with a large array of earth-based detectors (Auger in Argentina) and on the International Space Station (AMS). The search for the possible constituents of Dark Matter in our Universe is pursued with the LUX and LUX-ZEPLIN experiments (in USA) and the nature of neutrinos is investigated with SNO+ in Canada. These research programmes address some of the most fundamental and topical issues at the forefront of particle and astroparticle physics. They are conducted in large international scientific collaborations in which LIP frequently has leading positions and makes major scientific contributions of world-class quality. Recently, the two LIP theory groups merged, forming the productive Phenomenology Group, contributing to the forefront of theoretical research in particle and nuclear physics.

The Committee was pleased to learn that the upgrade programmes of ATLAS and CMS have received financial support. The extension of the neutrino programme, toward a possible involvement in the frontier experiment DUNE and the possible enlargement of the astroparticle programme with LATTES, are very valid initiatives.
In another mission LIP researchers and technical staff apply particle physics technologies to areas of benefit to Society. One example is LIP's ambitious development of advanced medical imaging instrumentation, which would make a major impact if brought to clinical use. LIP contributes also in significant ways to important programs in terrestrial and space radiation monitoring. These activities profit from the synergy with LIP's broad detector R&D programme on gaseous detector and liquid argon and xenon instrumentation. A small number of R&D projects should sharpen its focus, and clarify its medium- and long-term goals and applications. The Committee encourages the Management in its plans to request for applied R&D projects concise descriptions providing this needed information.

LIP has been one of the driving forces in the recent decision to establish in Portugal in the near future a centre for tumour therapy with high-energy proton beams. This facility will also provide a proton beam for research, which will be heavily used by the LIP researchers and which will federate a number of activities related to medical technology.

LIP continues to be at the forefront of scientific computing for its own research and for the large Portuguese scientific community. It continues to assume leading roles in several European computing initiatives.

LIP's exemplary outreach program has been further enriched with the introduction of an undergraduate training initiative, including summer student programmes at the three LIP sites.

LIP concluded successfully the process of reviewing and adapting the governance of the Laboratory to present needs. The structure of the Scientific Council has been strengthened to provide better guidance for the research strategies.

One further positive development is the long-awaited move of LIP Lisbon to new premises on the University Campus. It is providing more favourable working conditions for its staff, fostering collaboration, consolidation of the technical infrastructure and closer ties to the University. LIP Coimbra is now responsible for the management of the former mechanical workshops of the Physics Department, whose large space became part of the LIP technical infrastructures. At Minho, the University doubled the total space allocated to LIP researchers.

The employment conditions at LIP have been improved with the establishment of four professorships and the prolongation of a number of fixed contracts for six years. This is an important achievement and in the view of the Committee a significant step towards stabilizing employment conditions and providing career prospects to the young researchers. However, there are still too many key LIP researchers with short-term contracts.

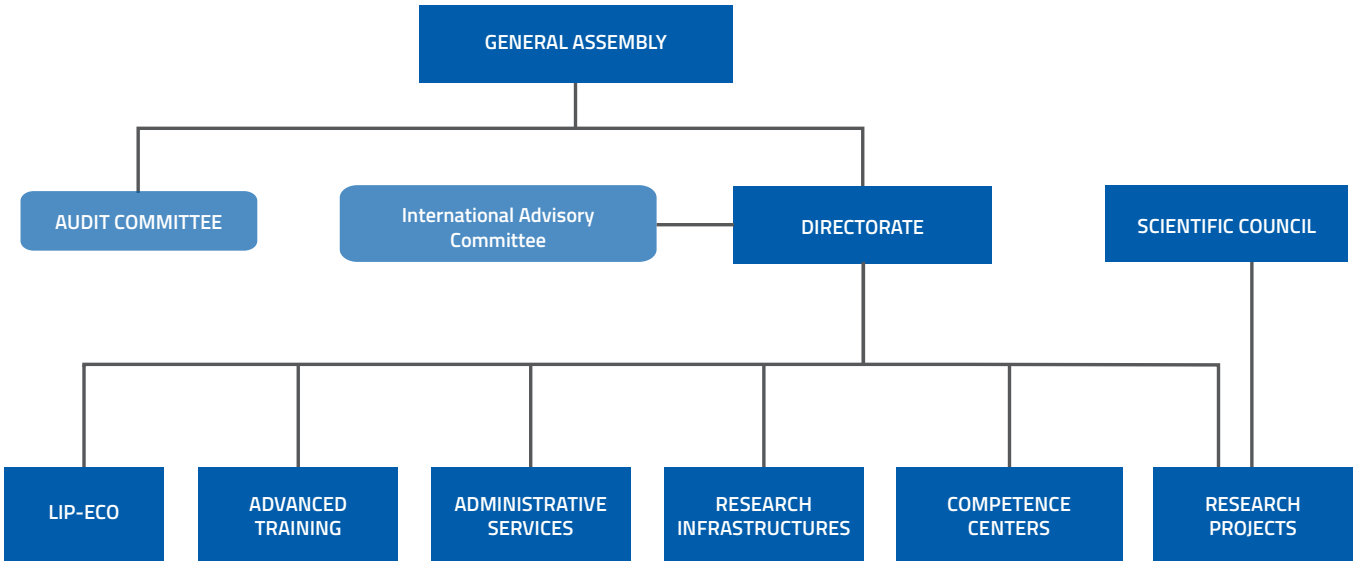
In line with the governance and the improved working conditions some group activities have been successfully consolidated, including certain technical activities (e.g. workshops) improving efficiency. LIP has established two Competence Centres, which already allow the full community to profit from knowledge sharing.

LIP employs its limited financial and personnel resources with great care, which is one important factor for its remarkably successful and multi-faceted programme. Unsurprisingly, these restrictions are clearly limiting a number important of LIP activities.

In the view of the Committee these funds could be used even more effectively if the Portuguese medium-term funding strategy would be more closely aligned with the long-term scientific research plans of the Laboratory, a step the Committee recommends again FCT to consider.

The Committee congratulates the LIP directorate and the LIP staff for another exceptionally productive year and thanks the Laboratory for the efficient organization of the review and its hospitality.

Structure and governance



Research in experimental particle physics and associated technologies is often conducted within large international collaborations or using large scientific infrastructures. This requires research teams large enough to have the required critical mass and adequate support infrastructures. The organizational structure of LIP ensures a coordinated strategy at national level and is designed to be efficient and flexible.

The governing bodies of LIP are the following:

General Assembly

LIP is an Associated Laboratory of the Ministry of Science, Technology and Higher Education. The associates of LIP are the Portuguese Foundation for Science and Technology (FCT, president), the Universities of Lisbon, Coimbra and Minho, Instituto Superior Técnico (IST), the Faculty of Sciences of the University of Lisbon (FCUL) and ANIMEE (Electrical and Electronics Business Association).

Directorate

LIP is governed by a Board of Directors nominated by its General Assembly, after consultation of LIP members. The different nodes of LIP are represented in the Board of Directors, which meets on a monthly basis and issues brief reports of its deliberations to the scientific council. At present the national directorate is formed by Mário Pimenta (president), Isabel Lopes, Nuno Castro, Patrícia Gonçalves and Rui Ferreira Marques.

Scientific Council

LIP's Scientific Council is the laboratory's scientific management body. Its members include all PhD holders, a representative of the technical staff and a representative of the students from each LIP node. The Scientific Council participates in the definition of the scientific strategy of the laboratory, namely in the creation of new research groups and in the decision to participate in international collaborations, as well as in the evaluation of LIP's researchers. The Scientific Council delegates some of its authority to a committee where all research groups are represented. Presently, the Scientific Council board is formed by José Maneira (president), Helmut Wolters and Raúl Sarmento.

International Advisory Committee

An External Advisory Committee provides strategic advice to the Laboratory. The Committee is formed by six worldwide recognized experts in the areas of activity of LIP and holds regular meetings with the directors and the group leaders. Presently, the members of the International Advisory Committee are: Christian W. Fabjan, Katia Parodi, Luigi Rolandi, Masahiro Teshima, Pier Giorgio Innocenti, Sergio Bertollucci

Audit Committee

LIP administrative and financial operations are systematically audited by external auditors and reviewed by a top level independent finances council and auditing authority. Members are: João Ferreira do Amaral (president), António Morão Dias, Vera Martins , José Martins Correia, Maria Salete Leite

The main elements of the working structure of LIP are:

Research Areas and Research Groups

Research Groups are the fundamental organizational units of LIP. The research groups are organized in eight Research Lines gathered in three Research Areas: particle and astroparticle physics; development of new instruments and methods; scientific computing.

Research Infrastructures

Research infrastructures are central in the laboratory's activities. They provide support to R&D activities at LIP and services to external entities. The existing infrastructures are: the precision mechanical workshop and the detector laboratory in Coimbra, the scintillating materials laboratory and the electronics laboratories in Lisbon.

Competence Centres

The Competence Centres cluster related expertise from the different research groups and infrastructures of LIP to create a pool of knowledge that eases R&D and can provide services to external entities and foster knowledge transfer into the non-academic sector. They are designed to be light and flexible horizontal structures joining all the LIP members that share the same tools and technologies. For the moment, two competence centres have been created: the Simulation and Big Data Competence Centre, and the Monitoring and Control Competence Centre.

Administrative services

The LIP community has the support of a small but effective group of administrative staff (five elements in Lisboa and two in Coimbra).

Advanced training office

The advanced training office organizes schools, workshops and internships for undergraduate and graduate students; oversees the hosting and training condition of PhD and master students at LIP.

Education, Communications and Outreach office (ECO)

The LIP-ECO office coordinates the ECO related activities carried out at LIP, including corporate communications (internal and external), outreach and support to education.

Highlights of the year

Feb-March 2017,
IPPOG International Masterclasses in Particle Physics in Portugal

March 2017,
SNO+ becomes a recognized CERN experiment

March 2017,
ESA Juice mission enters construction phase

March 2017,
LIP / CERN Careers and Technology Days at IST and FCUL

April 2017,
International Particle Physics Outreach Group

May 2017,
SNO+ starts taking data with the detector filled with water, after several months of commisioning

May 2017,
Inauguration of the new LIP premises in Lisbon

May 2017,
New LIP website launched

June 2017,
CMS Young Researchers Prize to Pedro Silva

July 2017,
LIP was present at the European Physics Society High Energy Physics Conference in Venice, with oral presentations and in the organizing committee

July 2017,
For the first time the LIP control center at IST performed the control of the Auger Fluorescence Detectors

July 2017,
Scientific Merit Medals awarded by the Minister of Science to Armando Policarpo and Gaspar Barreira, founders of LIP

July 2017,
INCD official launch

July-September 2017,
LIP Summer Student Programme

August 2017,
ATLAS presents the first evidence for Higgs decay to b quarks and also for light-by-light scattering at high energy

September 2017,
Portuguese language teachers programme held at CERN

September 2017,
10th Edition of the International Workshop on top quark physics, Top2017, held in Braga

September 2017,
Auger confirms extra-galactic origin of the highest energy cosmic rays, in a paper published in the Science Magazine

September 2017,
European Particle Physics School 2017 held in Évora, and included a public session with Fabiola Gianotti and Victor Matveev, directors of CERN and JINR

October 2017,
Xenon collisions at the LHC

October 2017,
Creation, by the Ministry of Science, of a working group for the installation of a hadron therapy unit in Portugal

October 2017,
Milestone achieved in the Project Optical Bonding Bosch: LIP designed system put into the continuous production chains

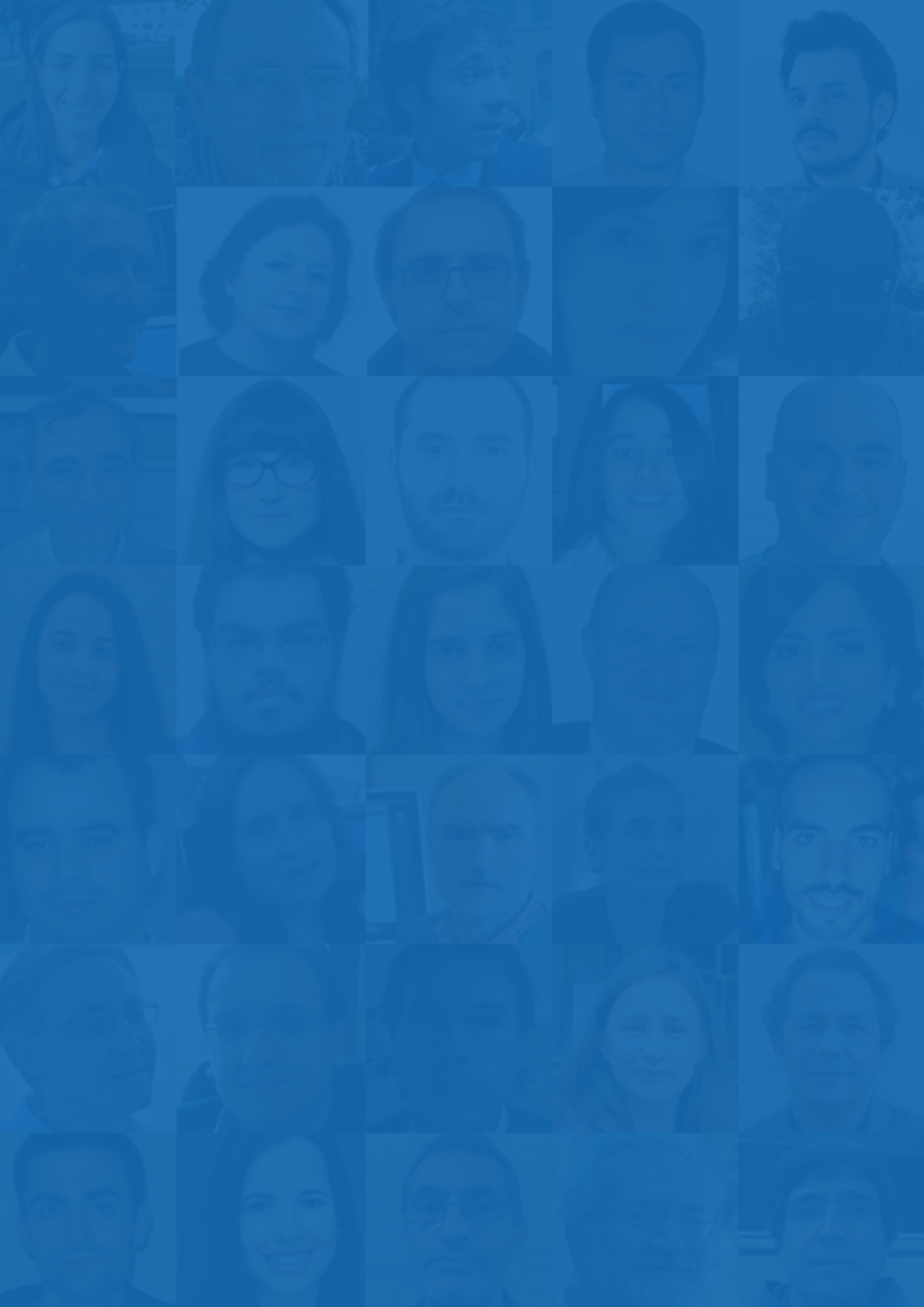
October 2017,
25th Anniversary of the ATLAS and CMS experiments and Amelia's Maio Fest

October 2017,
Multi-messenger observations, on the origin of gravitational wave GW170817 presented and including Pierre Auger Observatory

November 2017,
National Science and Technology Week celebrated at LIP

December 2017,
Protocol for the collaboration between Portugal and CERN for the next 10 years signed

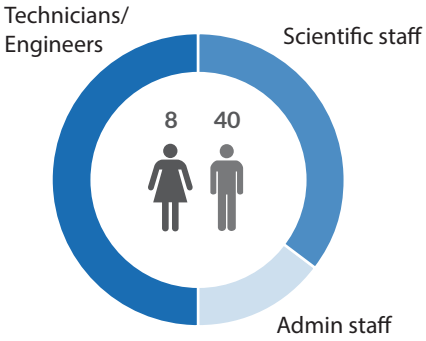
December 2017,
INDIGO-DataCloud classified has Outstanding in the final review



LIP IN NUMBERS

HUMAN RESOURCES

STAFF



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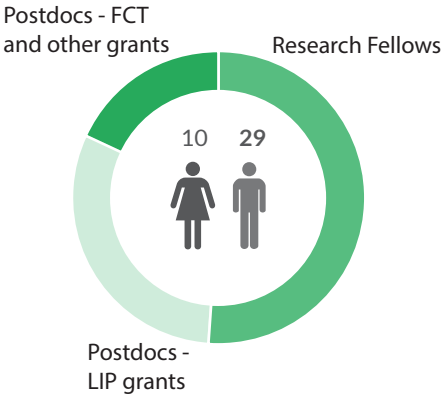
48
TOTAL

Technicians/ Engineers	0	24
Scientific staff	3	14
Admin staff	5	2

FIXED-TERM RESEARCHERS



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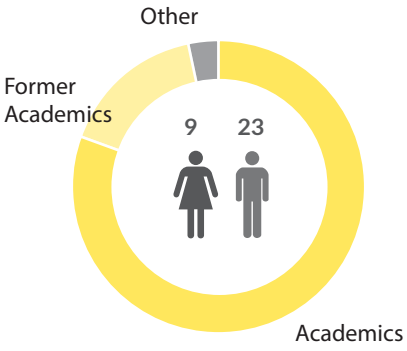
39
TOTAL

Postdocs FCT and other grants	2	5
Research Fellows	6	14
Postdocs LIP grants	2	10

UNPAID



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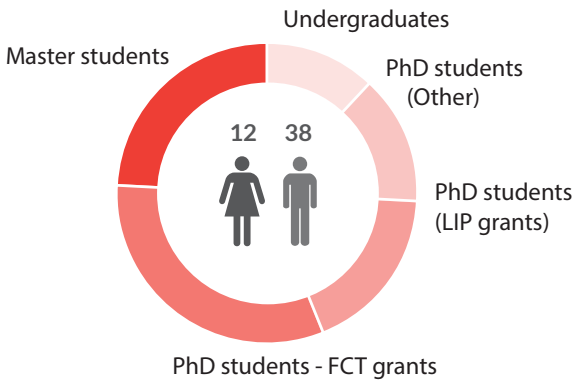
31
TOTAL

Academics	5	20
Former Academics	4	1
Other	0	1

TOTAL 186

44 142

STUDENTS



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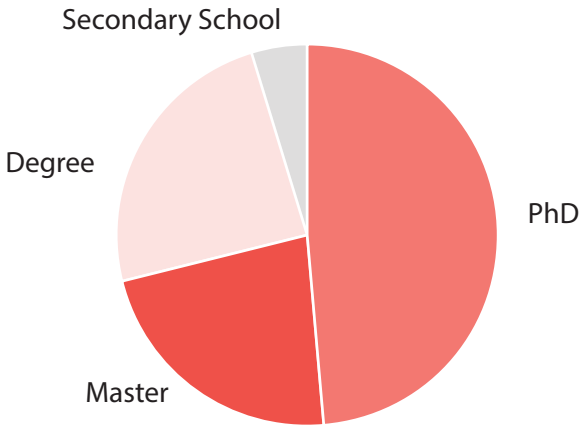
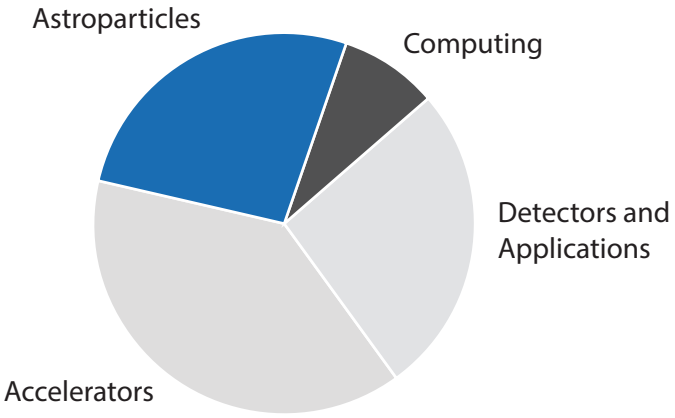
50
TOTAL

Master students	2	10
PhD students FCT grants	2	14
PhD students LIP grants	3	6
PhD students Other	2	5
Undergraduates	3	3

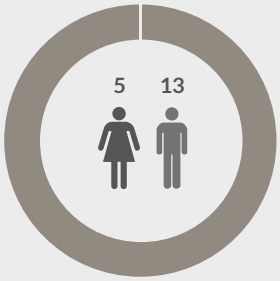
DISTRIBUTION BY ACADEMIC DEGREE



DISTRIBUTION BY RESEARCH AREA



EXTERNAL COLLABORATORS



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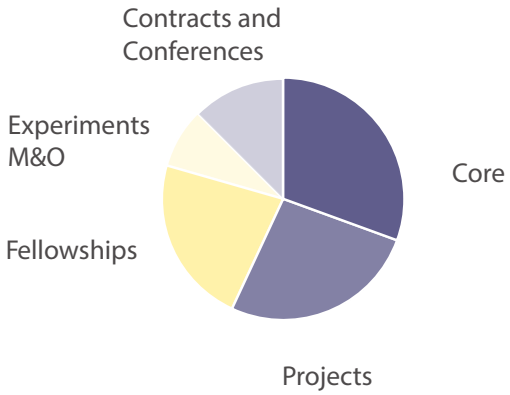
18

TOTAL

GENERAL FUNDING



1.5M
CORE FUNDING

1.3M
PROJECT-BASED

1.1M
FELLOWSHIPS

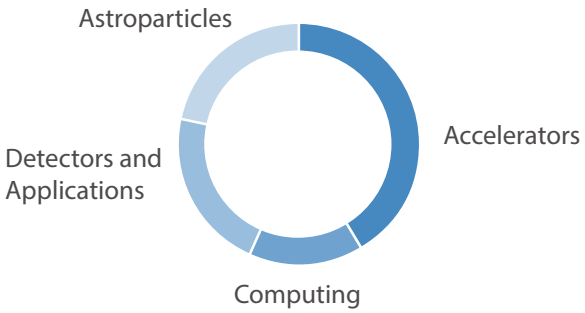
0.4M
EXPERIMENTS M&O

0.6M
CONTRACTS AND CONFERENCES

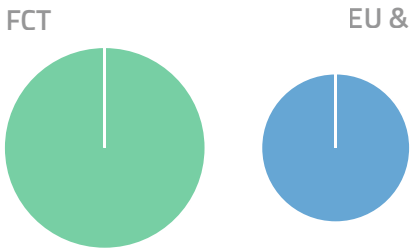
TOTAL
4.9M €

PROJECT AND CONTRACT-BASED FUNDING

BY RESEARCH AREA



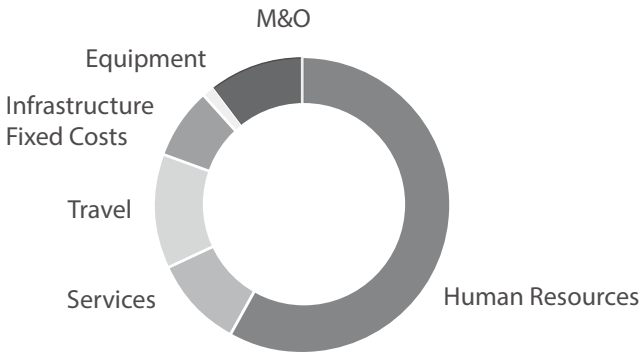
BY ORIGIN



TOTAL
1.6M €

FINANCES

COSTS



HUMAN RESOURCES

STAFF 1.6M

FIXED-TERM RESEARCHERS 1.7M

SERVICES AND OTHER EXPENSES

0.4M

TRAVEL

0.5M

EXPERIMENTS M&O

0.4M

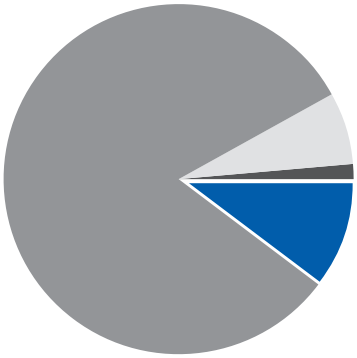
INFRASTRUCTURE FIXED COSTS

0.3M

EQUIPMENT

0.06M

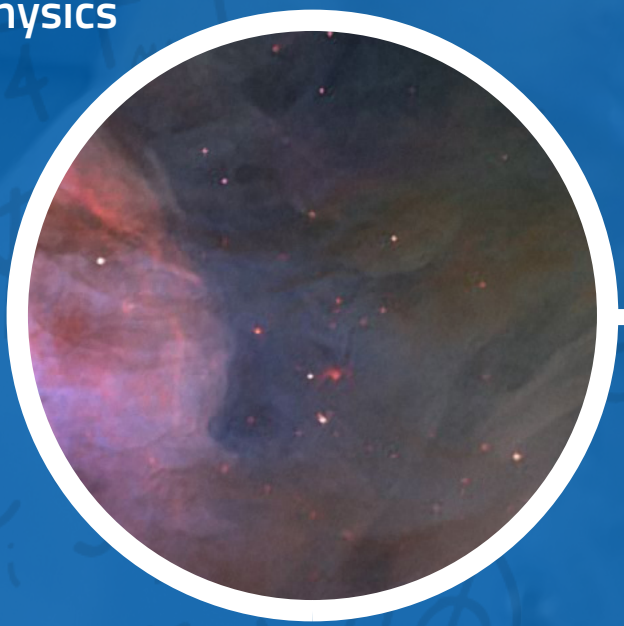
SCIENTIFIC OUTPUT

		Astroparticles	Accelerators
Books, Reports and Proposals		0	3
PhD Theses		1	5
Master Theses		3	4
Proceedings		4	15
Notes		4	21
Presentations		48	101
Papers in refereed journals		27	221

Detectors and Applications	Computing	TOTAL
1	0	**4**
2	0	**8**
3	1	**11**
14	3	**36**
3	0	**28**
34	10	**193**
18	3	**269**

Astroparticles Accelerators Detectors and Applications Computing

Experimental particle and astroparticle physics



RESEARCH AT LIP

Development of **new instruments** and **methods**

Computing

RESE

Experimental particle and astroparticle physics

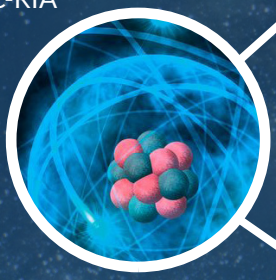
Development of new instruments and methods

LHC experiments and phenomenology

- ATLAS
- CMS
- Phenomenology

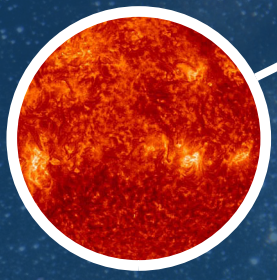
Structure of matter

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



Cosmic rays

- AMS
- Auger
- LATTES



Dark matter and neutrinos

- LUX/LZ
- SNO+
- NEXT

ARCH

Computing

- GRID
- Advanced Computing

Detectors for particle and nuclear physics

- Neutron detectors
- RPC R&D
- Liquid Xenon R&D
- Gaseous Detectors R&D

Health and biomedical applications

- RPC-PET
- OR Imaging
- Gamma Cameras
- Dosimetry

Space applications

- Space Rad
- i-Astro

Experimental particle and astroparticle physics

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

Experimental particle physics seeks always deeper into the universe – its constituents and workings at the most elementary level, its origin and evolution.

LIP is deeply involved in the CERN LHC endeavor, contributing from the very beginning to the two largest LHC experiments, ATLAS and CMS. With these fantastic scientific instruments we are studying Nature in many ways, from deepening our understanding of the Higgs boson, to searching for new physics or recreating the conditions that existed just after the Big Bang. To do this in an optimal way LIP's Phenomenology group creates strong links between experimental and theoretical particle physics. At the same time, we are very actively improving our experiments, to respond to future challenges of running at higher LHC luminosities.

We still have a lot to discover about the ways in which elementary quarks and gluons work together to form the particles we observe, and that's the focus of LIP's Structure of Matter line of research. Our Partons and QCD group is currently involved in the COMPASS experiment, designed to study hadron structure, as well as in the preparation of the next steps in CERN's fixed target experimental programme; LIP's Low Energy Reactions with Hadrons and Ions group is the only Portuguese experimental team preparing to explore the frontier between nuclear and particle physics at the new FAIR facility at the GSI.

Experimental particle physics is conducted in ever more powerful accelerators, but also in astroparticle physics experiments, detecting particles that come to us from the cosmos. The quest for dark matter, a deeper understanding of the elusive neutrinos, or the origin and nature of cosmic rays are among the great challenges of particle physics for the next decades. LIP is part of these challenges through its engagement in some of the main international collaborations, including SNO+ at the Sudbury Neutrino Laboratory in Canada, LZ at the Sandford Underground Research Laboratory in the USA, the Pierre Auger Observatory in Argentina and the Alpha Magnetic Spectrometer in the International Space Station.

EXPERIMENTAL PARTICLE AND ASTROPARTICLE PHYSICS

LHC experiments and phenomenology

Physics at the energy frontier

In 2017 the LHC continued to break its own records, allowing its experiments to record a huge amount of proton-proton collision data, around 50 fb-1 per experiment. The ATLAS and CMS groups at LIP made good use of the recorded data to push back the experimental boundaries of particle physics. LIP members were deeply involved in analyzing these data to extract exciting new physics results. But also in operating the detectors, developing their trigger, data acquisition, event reconstruction algorithms, detector control tools, and in various R&D efforts to prepare for the future upgrade of the LHC and its experiments. The first phase of this upgrade will start in 2019 with a long LHC shutdown, to resume data taking in 2021 and finally enter the High-Luminosity LHC (HL-LHC) phase in 2026.

The 25th Anniversary of the ATLAS and CMS experiments was celebrated in 2017. The approval of the experiments in 1992 was an important milestone in the history of particle physics, and the first step in a long journey in which LIP participated from the start. At LIP, the 25th anniversary was also an opportunity to celebrate the crucial and long contribution of Amélia Maio as PI of the Portuguese team in ATLAS.

Within particle physics phenomenology, a new group has been proposed at the end of 2017 and approved by LIP's Scientific Council early in 2018. It consolidates the expertise from the former LHC Phenomenology and Heavy Ion Phenomenology groups into a strong and dynamic community dedicated to bridging the gap between theoretical studies and the experimental activity at LIP. It has a focus on LHC physics, but also ambitious plans to touch upon several other scientific areas at LIP.

Experimental Particle Physics

Studies of the Higgs boson, first seen at the LHC in 2012, have kept researchers from both ATLAS and CMS quite busy. The ATLAS team focuses on the study of the Higgs coupling to the heavy top and b quarks. The team contributed to the first direct evidence for both couplings, seen in 2017. This evidence was achieved in challenging analyses searching for the Higgs boson produced together with a vector boson or with a top quark pair. These open the way to future measurements of properties crucial to our understanding of electroweak symmetry breaking, such as Yukawa couplings and the Higgs CP quantum numbers. Already in 2018, the CMS Collaboration has achieved a full observation of ttH production at the "5-sigma level", in an analysis tour-de-force combining several channels. The LIP CMS team is focusing on double-Higgs production channels, with decays to tau leptons and b quarks. The team has developed and tested advanced machine learning techniques, in the framework of an European training network. Such techniques will be essential to make feasible this very challenging analysis. In the longer term it will give us access to the triple-Higgs coupling, a fundamental property that is related to the shape of the Higgs potential. In the coming years, the CMS team also plans to invest in channels where the Higgs boson decays to hadrons, important to clarify the properties of this very special particle. It also plans to search for charged Higgs bosons and dark matter particles.

The top quark is heavier than any other known fundamental particle, and a likely window to observe subtle effects of new physics, not described by the Standard Model of particle physics. It has also long been a particular specialty of LIP's ATLAS and CMS groups, which have for long been deeply involved in important top-quark analysis. The CMS team is currently dedicated to the LHC run-2 measurement of the top-quark pair production cross section with top decays to tau leptons. In the future, it plans to search for dark matter in top-like events. In 2017, the ATLAS team has completed a search for top quark decays to a Z and a quark, through a forbidden Flavor-Changing Neutral Current process (FCNC). A positive signal would indicate the presence of new physics. Another FCNC analysis, of tZ production is ongoing, and an analysis searching for the decay of a top quark to a W boson and an s quark has achieved first internal results. The team is also contributing to interpretation of top-quark measurements through advanced Effective Field Theory techniques.

Supersymmetric theories are a very popular way to circumvent certain shortcomings of the Standard Model. The weakly interacting and stable lightest supersymmetric partner of our familiar particles would also be a perfect candidate to explain the mysterious dark matter, which is known to exist in abundance in the Universe around us. The CMS group has for long invested in this area, and in 2017 has completed the a search for a very light stop, the super-partner of the top quark, using LHC run-2 collision data. No signal of the stop was found, but a lower limit

of up to 560 GeV was determined for its mass. In the future, the team will continue to search for the stop in other channels.

Besides supersymmetric extensions of the Standard Model, many theories predict the existence of exotic new particles. These would be powerful clues to what currently lies beyond our experimental grasp, and could be the answer to profound questions emerging from our current understanding of Nature. The ATLAS team has been developing a strong expertise in searches for new, heavy vector-like quarks, T and B, whose existence would account for the unexpectedly low value of the Higgs mass, one of the lingering mysteries in this area. In 2017 the team has focused on two analyses of LHC run-2 data, which are currently under review by the collaboration. The first is the search for vector-like quarks decaying to a b or a top quark and a Z boson. In a second analysis, the ATLAS team has been searching for events containing top quarks together with a large imbalance in transverse momentum originating from a new, weakly interacting particle, which could be a candidate for the elusive dark matter. Another important focus of the team has been the statistical combination of different vector-like quark search channels.

After being deeply involved in the observation of the extremely rare $B_s^0 \to \mu^+\mu^-$ and $B^0 \to \mu^+\mu^-$ decays, one of the physics highlights in 2015/16, the CMS team has continued to pursue this channel as one of its main priorities. In particular, in 2017, team members studied the dominant systematic uncertainties affecting this measurement, aiming towards future improved analyses. The group has also produced the first CMS analysis of quark fragmentation fractions. The measurement has been carried out entirely by the LIP team and is currently in internal review by the collaboration.

The CMS team has a long history of studies of quarkonium production. Group members were involved in phenomenological studies of quarkonium measurements, to better understand the mechanisms of hadron formation in QCD. In an article from 2017, they uncovered a previously unnoticed scaling behavior followed by quarkonium states, which will lead to a complete program of measurements. On the experimental side, the group is pursuing the measurement of the polarization of the χ_{c1} and χ_{c2} states with CMS data, which they plan to apply to the study of sequential quarkonia suppression in nucleus-nucleus collisions.

Apart from its proton-proton programme, the LHC is a unique place to study heavy-ion collisions and observe the Quark Gluon Plasma (QGP), which existed in the hot and dense medium of the very early Universe. Hadronic jets in very energetic heavy ion collisions are invaluable probes for the study of the QGP. The ATLAS team is deeply involved in studies using jets initiated by heavy b quarks to probe the dense quark-gluon plasma. In 2017, the group developed and optimized b-tagging algorithms for the dense heavy ion collisions environment. They have also contributed to defining the trigger selection that allows selecting in real time and keeping such interesting collisions for later analysis. The CMS team has followed a parallel path, employing well-identified B hadrons, containing b quarks, instead of the b-initiated jets employed by ATLAS. The team has produced a first measurement of B_s production during a lower-energy proton-proton run, and explored first B_s signals in lead-lead collisions.

Detector operation and upgrade

In addition to the physics analysis activity, during 2017 the ATLAS and CMS teams at LIP were very actively involved in running their experiments. Both groups are also heavily involved in R&D for the experiment upgrade. The LHC will be upgraded in two phases, one to start operation in 2021 with around twice the current luminosity, or rate of interesting collisions. A second phase, known as High-Luminosity LHC (HL-LHC), will start around 2026 with even higher luminosity, with the goal of collecting around 50 times more data than has been accumulated so far.

CMS and ATLAS have both installed forward proton spectrometers, located a few hundred meters from their main detectors, very near to the beam-line. The LIP group is leading the CMS-Totem Proton Spectrometer (CT-PPS) project as well as several of its crucial parts, such as the data acquisition and timing systems. The past year was very successful for the project. The detector, which had already collected a sizeable amount of data in 2016, was operated during much of the 2017 LHC run. An article, led by LIP members, was submitted for publication, documenting the first observation of di-lepton pairs observed in the CMS detector accompanied by protons detected in the CT-PPS spectrometer, a process known as central exclusive production.

The ATLAS Forward Proton spectrometer (AFP) had been operating with a single spectrometer arm in 2016, and its second arm was completed in 2017. The ATLAS team at LIP is committed to the development of the AFP detector control and trigger systems. In the past year, LIP members were responsible for the AFP control system development, have studied the performance of the hardware trigger and developed the software trigger selections dedicated to selecting di-jet central exclusion production events. The ATLAS team is also responsible for the control of the ALFA luminosity detector.

Both the ATLAS and CMS teams at LIP have made crucial contributions to the calorimeters of each experiment. The CMS team is a long-standing contributor to the electromagnetic calorimeter (ECAL) data acquisition system and the trigger. The ATLAS team was from the start responsible for the optical readout system of the hadronic calorimeter (TileCal). This is one of the main ATLAS subdetectors, where the group holds important responsibilities in its operation and upgrade, including the detector control system and the monitoring of its response. The LHC upgrade creates important opportunities for collaborating with Portuguese industry, which are being pursued both by the ATLAS and CMS teams.

The ATLAS team is involved in the upgrade of the TileCal calorimeter. In 2017, the team has produced a first prototype of a new electronics board for the High-Voltage distribution system of the TileCal, which will be fully replaced under the team's responsibility and was strongly involved in the preparation of the Technical Design Report. They are involved in the R&D effort to select scintillators and wavelength-shifting optical fibres, to replace the ones most exposed to radiation-induced ageing. Studies by LIP members triggered the creation of a taskforce to study this subject, where LIP members are strong contributors. Another group responsibility is on the hadronic jet High-Level trigger algorithms. We have produced a study of possible improvements to the jet reconstruction in a gap region where ageing scintillators were

producing a high rate of wrongly accepted events. The group has also developed a parallelized version of the more time-consuming trigger algorithm, to run in general-purpose graphical processors. Performance studies of the algorithms indicated that a maximum CPU-time reduction factor of five times was obtained with respect to standard reconstruction.

The CMS team is deeply involved in R&D of new detector technologies for the upgrade of the CMS experiment, and in 2017 the activities towards the CMS Phase 2 upgrade for operation at the HL-LHC were strongly boosted. Namely, The LIP group increased its involvement in the Minimum Ionizing Particle Timing Detector assuming responsibilities in the front-end readout system. For this, the team is developing a custom integrated circuit. It will be integrated with scintillating detector modules and tested in beam tests, in collaboration with other institutes. The team also plans to make a strong contribution to the development of the new ECAL readout system, based on a fast amplifier and a new, fast and low power analog to digital converter. These contributions will involve Portuguese industry in this new high-end technological development activity. Portuguese industry will also be involved in the development and supply of a new low voltage regulator resistant to radiation for the CMS upgrade. Finally, the team is dedicated to the development of trigger algorithms for the new CMS High-Granularity CALorimeter.

Phenomenology

The new LIP Phenomenology group, created at the end of 2017, inherited very valuable expertise from the previous LHC Phenomenology and Heavy Ion Phenomenology groups. This group presents great added value to the research at LIP, bridging theory and experimental work that, while independent, is centered on areas in which LIP has active experimental activities. At present the group has internationally recognized consolidated research activities in top-quark, Higgs, quarkonia, and heavy-ion phenomenology, with a strong expertise in the development of event generators. In the past year, this community was very active, studying a wide range of subjects, from ultra-boosted top-quarks produced with a Z or a photon in flavor-changing neutral current analyses, to anomalous couplings of the top quark, the implementation of new features in the Monte Carlo generators, proposing new experimental probes to study quark-gluon plasma or the tensor structure of top-Higgs interactions, to studying Machine Learning techniques for extracting information from experimental data.

In the near future, the combined Phenomenology group will grow around consolidated lines of work in: heavy-ion phenomenology, exploring sub-structure properties of jets and their temporal-spatial modifications by the quark-gluon plasma; heavy quarkonium, exploring implications of simple scaling patterns or the sequential suppression of quarkonia in nucleus-nucleus collisions; top-quark and Higgs, exploring the top-Higgs associated production as a probe of the Higgs sector or top-quark anomalous couplings in future colliders; effective field theory based searches for new physics; and exotic physics, exploring vector-like quarks in composite Higgs models. Efforts will be made to consolidate existing activies in dark matter searches and cosmic ray phenomenology.

SELECTED
References

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

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

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

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

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

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

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

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

ATLAS Collaboration: “Evidence for the H to bb decay with the ATLAS detector”, JHEP 12 (2017) 024

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

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

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

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

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

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

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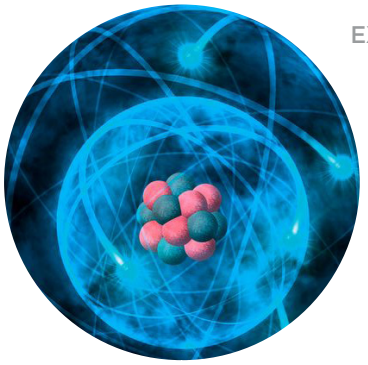

EXPERIMENTAL PARTICLE AND ASTROPARTICLE PHYSICS

Structure of matter

Looking inside hadronic matter

We still have a lot to discover about the ways in which elementary quarks and gluons work together to form the particles we observe, and that's the focus of LIP's structure of matter research line. LIP's Partons and QCD (PQCD) group is currently involved in the COMPASS experiment, designed to study hadron structure, as well as in the preparation of the next steps in CERN's fixed target experimental programme; LIP's Low Energy Reactions with Hadrons and Ions group (LERHI) is the only Portuguese experimental team preparing to explore the frontier between nuclear and particle physics at the new FAIR facility at the GSI, and is deeply involved in the HADES and R3B experiments.

COMPASS – the workings of nucleons

The LIP PQCD group is heir to a long tradition in CERN's fixed target experimental programme, starting in the 1980s with the heavy ion experiments NA38 and later NA50. The group now concentrates on the COMPASS experiment. Major aims of the experiment are to discover how quarks and gluons contribute to the spin of the proton and to investigate the spectrum of particles that quarks and gluons can form. To do so, they collide high intensity muon or hadron beams with a polarized target at a temperature of -273 °C. The experiment uses beams from the SPS accelerator (super proton synchrotron). The target is followed by a two stage spectrometer observing the particles that result from the collision.

The LIP group is the sole responsible for the complex detector control system, known at CERN for its outstanding reliability. The group is also responsible for a number of key analyses and is a reference in the measurements using the Drell-Yan (DY) process, the production of lepton pairs in hadron collisions. The LIP group was co-responsible for the DY run in 2015, in which the first world measurement of the polarized DY process was achieved, and currently coordinates de DY group in COMPASS.

The 2016 and 2017 data-taking run was devoted to the study of exclusive Deep Inelastic Scattering (DIS) processes. In parallel, semi-inclusive studies of hadron multiplicities are being performed by members of the LIP group, an important ingredient for fragmentation functions extraction. The analysis of the COMPASS 2015 polarized Drell-Yan data was completed in 2017. The COMPASS J/psi data allow differential cross-section studies and comparison with models. The multidimensional analysis of the spin asymmetries produced in muon scattering off a longitudinally polarized proton target, in the region of low-x and low Q^2, was completed. In what concerns the DCS system, several modifications were introduced in 2017, to integrate additional monitoring parameters of the beam optics and cope with several hardware upgrades. The team managed to guarantee extreme stability and reliability of the system during the whole 2017 Run.

The 2018 data-taking period will be devoted again to the polarized DY measurement. The development of machine learning analysis techniques adapted to polarized DY, lead by LIP group members, is a strong commitment for the coming years. In October 2017, the COMPASS collaboration submitted a request to the CERN-SPSC for an extension of its scientific programme for additional DIS measurements with a polarized deuteron target, to be performed in 2021. The DY group coordinator is also among the proponents of a Letter of Intent for a new fixed-target experiment at CERN. It will be devoted to the study of meson structure and of the role of gluons in the hadron mass hierarchy, which includes also a pioneering measurement of the proton radius in elastic muon-proton collisions. A proposal will be submitted by the end of 2018.

LERHI – At the frontier between nuclear and particle physics

The group is built around a solid expertise in instrumentation for particle detection and the study of nuclear reactions and hadronic processes at medium energies (a few MeV to a few GeV per nucleon). Our activity is centered on experiments based at GSI/FAIR-Facility for Antiproton and Ion Research, the next generation facility at GSI, and at CERN. LIP is a member of two of the four pillars of GSI/FAIR: HADES and R3B, contributing both in R&D, construction and operation of detectors and in physics studies. After several successful data taking campaigns, the accelerator infrastructure has been shut down for a complete upgrade, and is expected to initiate its Phase-0 operations already in 2018.

HADES – the secrets of high densities

HADES is currently the only experiment studying the region of the QCD phase diagram of very high net-baryon densities and low temperatures. Di-electrons originating from in-medium hadron decays, and rare strange hadrons (kaons, hyperons), are the main probes measured in the experiment. The LIP group plays a leading role in this area, having developed one of the independent analyses of the HADES golden channel, where a di-lepton system is observed in Au+Au collisions at 1.23 GeV per nucleon.

The dismantling of the RPC-TOF-W from the HADES main frame (due to its reallocation into the ECAL mainframe) was accomplished with success at the middle of the year. The re-installation of the RPC-TOF-W in the new ECAL main frame will take place in the first trimester of the year. The RPCs, together with all subsystems and cabling, will be reinstalled, and this is a major operation.

In order to increase the acceptance of the spectrometer, a new detector is being built to cover the very low polar angles in the forward region. This new Forward Detector (FD), is composed by a tracking detector and a TOF detector. The LIP group is in charge of the simulation, design and construction of the TOF detector of the FD, the RPC-TOF-FD. The assembling of the first prototype module started at the end of the year, and its finalization and evaluation is currently ongoing.

HADES will be one of the first experiments to have access to beam time in FAIR. It is foreseen to take data with lighter nuclei systems, at a slightly higher energy, compared with Au+Au at 1.25 AGeV (HADES has an approved Ag+Ag run using a beam energy of 1.65 AGeV) in order to investigate the in-medium properties of hadrons in a more systematic way. Therefore, the RPC-TOF-W should be completely operative for this data. The implementation of the RPC-TOF-FD will be finalized in the first semester of the year.

R3B and beyond

In the R3B experiment, the LIP group has a very active role in the study of break-up reactions of nuclear halo systems on a proton target. Two well-established cases, ^{11}Be and ^{15}C, were studied over the past few years. In addition, the group is involved in low-energy reaction experiments of interest for nuclear astrophysics at the HiE-ISOLDE/CERN facility.

The conclusion of the analysis of the knock-out reaction data from the GSI experiment S393 was one of the main achievements of the past year. A first glimps of the data measured during the benchmark experiment of the future CALIFA calorimeter, performed in Lisbon, confirms the measurement of photons with energies beyond 12 MeV. Complementary, the group is involved in experimental proposals for the Phase-0 of FAIR in 2018-19, keeping the focus on the study of knockout reactions on halo nuclei at relativistic energies. The group will get responsibility on the study of the neutron knock-out reactions on ^{17}C and ^{14}B, two neutron halo systems closer to the dripline that the previously studied 11Be and 15C.

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

SELECTED
References

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

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

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

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

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

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

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

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

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EXPERIMENTAL PARTICLE AND ASTROPARTICLE PHYSICS

Cosmic rays

Messenger from outer space

Planet Earth is constantly being struck by cosmic rays — particles expelled by distant stars and galaxies. These messengers from outer space bring much information about the history and composition of the Universe. Cosmic ray physics is an active field of research, with many ongoing experiments addressing questions on their origin, nature, acceleration and propagation. The very wide range of energies of cosmic rays implies that different detection methods are used, from space-based experiments in the GeV/TeV, range to ground-based giant air shower detectors in the EeV range. The LIP cosmic ray group covers much of this range, as it is committed to the Alpha Magnetic Spectrometer (AMS) and to the Pierre Auger Observatory. The group has also unique conditions to play a leading role in R&D of future detectors, and is involved in the LATTES project for a future high-energy gamma-ray observatory.

AMS – a particle detector in Space

The AMS Spectrometer is installed in the International Space Station. Since May 2011, a large set of data has been gathered at a continuous rate of ~40 million events/day, corresponding now to around 112 billion events recorded. This detector can identify cosmic ray particles before they interact with Earth's atmosphere. AMS studies cosmic ray fluxes in detail, but it also searches for antimatter nuclei and dark matter in the Universe.

LIP is involved in AMS from the beginning and had an important role in the design and construction of the Ring-Imaging Cherenkov (RICH) detector. Today, the group holds responsibilities on the RICH operations, monitoring and reconstruction algorithm optimization. It is also strongly involved in solar modulation analyses, and in analyses related to particle identification. AMS remains a unique observatory in Space and is expected to continue taking data up to at least 2024.

In 2017, the LIP group maintained the responsibility for the development, implementation and maintenance of a set of algorithms for reconstructing the particle's electric charge and velocity in the RICH detector. In addition, the group continued the studies on the variability of particle fluxes related to solar activity. A proton selection was developed and a study on the different selection efficiencies involved was performed. A time-dependent proton flux was estimated and is now under study. Understanding the folding effect introduced by the detector is a key factor in flux estimation. Finally, the group was also involved, with cosmic ray phenomenology experts, in the development of a propagation model to interpret cosmic ray flux time variations under solar modulation using solar parameters such as solar magnetic field axial inclination and number of sunspots. Using this model, the team was able to show evidence of a time-delay of ~8 months between solar parameter observations and their effect on the cosmic ray flux.

Auger – the most energetic particles in the Universe

The Pierre Auger Observatory covers are area of 3000 km^2 in the pampa Amarilla, Argentina. It consists of 1600 detectors separated by 1.5 km that sample the shower of millions of particles produced when the highest energy cosmic rays hit the atmosphere. In dark nights, 27 telescopes detect the ultraviolet light emitted by the showers. The Observatory is taking data since 2004, and a number of breakthroughs have been achieved. Nevertheless, several open questions remain concerning the nature and origin of the highest energy cosmic rays. The observatory will continue operations until 2025 and is currently being upgraded, to enable a better understanding of the electromagnetic and muonic shower components. R&D for future cosmic ray detectors also takes place at the Observatory site.

In the last few years, LIP has been deeply involved in the development of autonomous, low gas flux, large surface RPCs for outdoor operation. More than 20 such detectors were produced at LIP-Coimbra and 6 are working successfully in Malargue. The MARTA concept combines the Auger surface detectors with an RPC. A MARTA engineering array of 8 surface detectors (and 36 plane RPC) is under construction, in a close collaboration between LIP and Brazilian colleagues. It will be used to obtained a deeper understanding of the surface detectors, for the validation and in situ test of the scintillation

detectors and for detailed shower studies at lower energies (10^{18} eV). In 2017, we continue using a MARTA hodoscope to study possible aging effects in Auger's Water Cherenkov Detector (WCD). All tests reaffirmed the soundness of these detectors. RPC R&D was finalized and technology transferred to São Carlos, Brazil. Two engineering prototypes were built in accordance with local available standard raw materials. The first 10 production enclosures were built and the assembly of the MARTA modules is ready to start at São Carlos.

Concerning data analysis, the LIP group is mainly focused on the full exploitation of the particle physics potential of the Observatory, namely on the efforts to understand hadron interactions at high energies through a window that is largely complementary to the LHC. The observation of more muons in Auger than is expected in current models is one of the most intriguing questions raised by Auger data. Furthermore, the detailed study of both the electromagnetic and muonic shower components is crucial for the determination of the nature of the primary particle and to disentangle it from hadron interaction modeling. The LIP group is directly involved in this quest.

In 2017, the LIP group started a phenomenology study to understand the relationship between the first interactions properties and the muon content at ground. The group is coordinating the publication of the Muon Production Depth results. The analysis developed by the group for the shower profile reconstruction has proven to be stable and is considered to become an official Auger reconstruction. Benchmark scenarios were used to try to distinguish a scenario where hadronic interactions change rapidly at ultra-high energies from a scenario where the primary mass composition evolves with energy.

LATTES – at the top of the mountains

The LIP cosmic ray group has proposed an innovative detector combining traditional air-shower detector units with autonomous RPCs, able to operate outdoors with minimal maintenance, and providing a direct measurement of muons with very good space and time resolution. Particularly interesting is the possible application of the new detector concept to lower the energy threshold of gamma air-shower detectors. The LATTES project, initiated by LIP and CBPF in Brazil, has the goal to design, prototype and construct a ground array able to monitor the Southern gamma-ray sky above 50 GeV.

The energy threshold of the air shower experiments presently in operation or in construction remains very large and unable to bridge with data from satellite-borne experiments. All the EAS experiments presently in operation or under construction are in the Northern hemisphere. The recent observation of the first multi-messenger event combining the detection of gravitational and electromagnetic waves triggered a growing international interest in building such an Observatory in the South America. The proposed detector concept has a large physics potential.

The RPCs proposed for LATTES have been developed in the last four years at LIP-Coimbra, and tested under harsh conditions at the Pierre Auger Observatory site in Argentina, at an altitude of 1,400 m a.s.l, with a low gas flux (1 to 4 cc/min). The tests done in outdoor conditions and with low maintenance continued during 2017. The long-term stability is now demonstrated down to 4 cc/min. In parallel, the LATTES concept was further developed and the baseline design was established. An end-to-end simulation was built in order to evaluate the performance of this detector concept. This work led to a realistic estimation of the LATTES sensitivity to a steady source (Crab nebula).

SELECTED
References

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

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

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

Pierre Auger Collaboration: "Observation of a large-scale anisotropy in the arrival directions of cosmic rays above 8 x 10(18) eV", Science 357 (2017) 1266-1270

ANTARES Collaboration / IceCube Collaboration / Pierre Auger Collaboration / LIGO Sci Collaboration & Virgo: "Search for High-energy Neutrinos from Binary Neutron Star Merger GW170817 with ANTARES, IceCube, and the Pierre Auger Observatory", Astrophys. J. Lett. 850 (2017) L35

P. Assis et al.: "LATTES: a new gamma-ray detector concept for South America", EPJ WEB CONF 136 (2017) UNSP 03013

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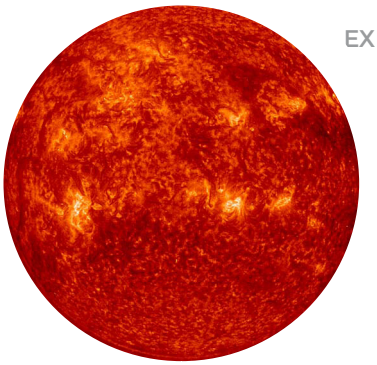

EXPERIMENTAL PARTICLE AND ASTROPARTICLE PHYSICS

Dark matter and neutrinos

Hunting for the most elusive particles

What do neutrinos and dark matter have in common? They are searched for in deep underground detectors that other particles can't reach. Only in such clean, background-free environments one can try to better understand the properties of the elusive neutrinos, which interact only through the weak force, or look for direct hints of the still undetected dark matter particles. In the coming generation of highly sensitive detectors, neutrinos also become a relevant background for dark matter searches. Through its engagement in the LUX, LZ, SNO+ and NEXT collaborations, LIP is deeply involved in the quest for dark matter and for a deeper understanding of neutrinos, two of the great challenges in particle physics for the next decades.

Searching for the dark side

According to the most recent experimental evidence, dark matter makes up 27% of the total density of the Universe. We have strong clues that dark matter is made of particles that interact very weakly. One of the ways to search for it is to use super-sensitive underground detectors to identify very rare interactions between dark matter particles that cross the Earth and normal matter particles. LIP is part of the LUX collaboration, and a founding member of LUX-ZEPLIN (LZ).

LUX (Large Underground Xenon) has been the most sensitive direct detection experiment from 2013 until summer 2017, when the results from XENON-1T and PANDAX-II have marginally surpassed those of LUX. In total, LUX have acquired 427 live-days of science data that allowed to set a new limit on the WIMP-nucleon spin-independent cross-section with a minimum of 1.1×10^{-46} cm^2 at 50 GeV c^{-2}. This allowed to test some of the most favored WIMP parameter space, and gave rise to a seminal paper. In 2017, the decommission of LUX was completed.

The LZ project proposes a 7-ton xenon detector based on the same time projection chamber (TPC) technology as LUX. It uses simultaneously liquid and gaseous xenon to obtain two different signals, so that dark matter can be distinguished from background noise. LZ will probe WIMP-nucleon cross sections down to 2.3×10^{-48} cm^2, ~50 times better than the current best limit, in a 1,000-day run. LZ has started the procurement and fabrication phase in 2017. LZ parts are expected to start to arrive at Sanford Underground Research Facility (SURF) during the first quarter of 2018. The underground deployment of LZ is scheduled for 2019 and commissioning is expected to start in the beginning of 2020. Meanwhile, in parallel with the construction and deployment, there will be an intense activity of simulation, R&D of analysis tools, their implementation and validation.

In 2017, the main pillars of the LIP team's intervention have been the leadership of the design and R&D of the LZ overall instrument control system (with over 10,000 channels), the high precision measurement of the reflectivity of the detector light reflectors and the development of innovative analysis tools that have allowed the team to give very relevant contributions to the LZ and LUX data analysis. In particular, we started to work on the determination of the sensitivity of LZ to ^{136}Xe neutrinoless double beta decay ($0\nu\beta\beta$) and on the development of a background model to be used for the study of the sensitivity of LZ to rare Xe decays. We took full responsibility for the development and implementation of the real time Detector Quality Monitor. A member of the LIP group was coordinator of the LUX Analysis Working Group. In 2018 the work will be focused mostly in LZ.

Are neutrinos their own antiparticle?

After photons, neutrinos are the second most abundant particle in the Universe. The main goal of the SNO+ and NEXT experiments is the search for neutrino-less double-beta decay. The observation of this process would show that neutrinos are Majorana particles, i.e., that neutrinos are their own antiparticle.

SNO+

The Sudbury Neutrino Observatory (SNO) measured the oscillations of solar neutrinos, i.e., their transformations from one type to another (Nobel prize in Physics 2015). The detector is located 2 km deep underground, in SNOLAB, Canada. An acrylic sphere with 12 m diameter and 5 cm thickness, that contained 1000 tons of heavy water, is surrounded

by 9500 light sensors. The SNO+ experiment follows from SNO, replacing the heavy water with liquid scintillator to increase the sensitivity to other neutrino physics signals. The LIP Neutrino Physics group joined the SNO experiment in 2005, and is a founding member of the SNO+ international collaboration. The main goal of the experiment is the search for neutrino-less double-beta decay, by loading the scintillator with large quantities of Tellurium. Several other low-energy, low-background, physics topics are also part of its program: antineutrinos from nuclear reactors and the Earth's natural radioactivity, solar and supernova neutrinos, and searches for new physics.

The initial data-taking phase, with the detector filled with water, started in 2017. The group has been very active in data analysis and software development, leading several aspects of the physics data quality studies, detector calibrations, backgrounds measurements, as well as preparation for anti-neutrino physics measurements. The second unit of the Umbilical Retrieval Mechanism (URM) for the SNO+ calibration source insertion system is being produced at the LIP Coimbra workshop. The first unit arrived at SNOLAB, and was brought to the surface clean laboratory, but the main functionality tests are still awaiting the end of the water phase calibration campaign.

The scintillator fill is expected in 2018, and so the group's efforts will gradually shift from water phase to scintillator phase data analysis. We expect 2018 to be dedicated to the water phase data analysis and calibration, to the hardware activities related to the scintillator fill, and to the start of the scintillator data taking phase. Recently, the group has started contacts towards a possible future participation in the long baseline neutrino oscillation experiment DUNE. This would balance the current participation in the analysis of SNO+ with a focus on design and construction of future detectors that will have a very strong role in neutrino physics in the next decade

NEXT

NEXT (Neutrino Experiment with a Xenon TPC) is a neutrinoless double-beta decay experiment at the Canfranc Underground Laboratory (LSC), in the Spanish Pyrenees. It is based on a novel detection concept for neutrinoless double-beta decay searches consisting in a TPC filled with high-pressure gaseous xenon and with capabilities for calorimetry and tracking. The LIP team is dedicated to study the optimal gas mixture for use in the NEXT detector. A search for the ideal additive, which improves the necessary parameters without significantly compromising the scintillation yield, is being conducted.

The use of TMA as an additive to Xe in the NEXT TPC detector was ruled out since we could observe that it degraded the energy resolution and also was not effective as wavelength shifter for the xenon VUV scintillation. Monte Carlo simulations were also developed. Experimental results on xenon-TMA mixtures, namely concerning charge gain, primary and secondary scintillation yields, Penning effect probability, will be analyzed and published.

Our work plan for 2018 involves studying other Xe based mixtures of interest for the NEXT Collaboration, which are still under discussion, possibly with CH_4, CO_2 and possibly He. A new experimental device to measure electron drift parameters, namely their drift velocity and diffusion, is being built. The comparison between the obtained experimental results with Monte Carlo predictions will allow to assess the validity of the measurements.

In the national project submission call on May 2017, a joint project with the other Portuguese groups working in NEXT was submitted.

SELECTED
References

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

F. Neves, A. Lindote, A. Morozov, V. Solovov, C. Silva, P. Bras, J.P. Rodrigues and M.I. Lopes: "Measurement of the absolute reflectance of polytetrafluoroethylene (PTFE) immersed in liquid xenon", Journal of instrumentation, Vol.12 P01017

D. S. Akerib et al.: "Limits on spin-dependent WIMP-nucleon cross section obtained from the complete LUX exposure", Phys. Rev. Lett. 118, 251302 (2017)

B. Aharmin (SNO Collaboration): "Search for neutron-antineutron oscillations at the Sudbury Neutrino Observatory", Phys. Rev. D 96, 92005

J. Maneira, E. Falk, E. Leming, S. Peeters on behalf of the SNO+ Collaboration: "Calibration of the SNO+ experiment", J. Phys.: Conf. Ser. 888 012247

G. Prior (on behalf of the SNO+ collaboration): "The SNO+ experiment physics goals and background mitigations", NuPhys2016 Conference Proceedings – SLAC eConf C16-12-12.1 (2017

A. Simon et al.: "Application and performance of an ML-EM algorithm in NEXT", J. Instrum. 12 (2017) P08009

The NEXT Collaboration: " Secondary scintillation yield of xenon with sub-percent levels of CO2 additive for rare-event detection", Source: PHYSICS LETTERS B Volume: 773 Pages: 663-671 DOI: 10.1016/j.physletb.2017.09.017 Published: OCT 10 2017

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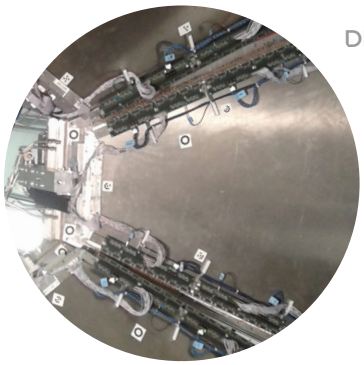
Development of new instruments and methods

Radiation detectors are sensitive to the passage of particles and able to measure some of their characteristics. Throughout the history of particle physics, the development of ever more powerful detection technologies has played a crucial role in fostering new discoveries. Detector development involves not only the detecting device itself but the associated data acquisition and readout electronic system, as well as trigger and data processing tools.

The development of new instruments and methods related to experimental particle physics has been from its inception one of the main pillars of activity at LIP. Over the years, LIP has built a high level of expertise in key radiation detection technologies, supported by research on the fundamental processes involved. Our current activities include research on fundamental detection processes and applications of radiation detectors. Our specialities include Resistive Plate Chambers (RPC), gaseous and Xenon-based detectors and optical fiber calorimeters.

LIP's expertise in planning, building and operating detectors for particle physics finds natural application in the fields of radiation therapy instrumentation, medical imaging and dosimetry. These are the areas covered by this group in multidisciplinary projects developed in collaboration with partners such as the ICNAS institute for nuclear health applications, the CTN/IST centre for nuclear technology, and several hospitals and medical research centres.



DEVELOPMENT OF NEW INSTRUMENTS AND METHODS

Detectors for particle and nuclear physics

Technologies to see the invisible

The development of particle detectors and related instrumentation has been, from the start, one of the pillars of activity at LIP. Over the years LIP has built a high level of expertise in key radiation detection technologies, supported by research on the fundamental processes involved.

RPC R&D

Resistive Plate Chambers (RPC) are versatile detectors with a fast response, intrinsically radiation hard, and with relative low cost. Over the last years, LIP's Detector R&D group developed a coherent and ambitious R&D line of work that took the performance and the flexibility of RPCs to a new level. This expanded the range of RPC applications to several areas widely recognized as addressing societal challenges, from nuclear and particle physics to medical physics, from rugged outdoor muon detection to systems to helium-free neutron detectors, confirming LIP as a world leader in the development, design and construction of RPCs.

The group presently works in a number of R&D lines. One of these lines is the simultaneous high-resolution measurement of position and time (TOFtracker). These detectors are intended, among others, for applications in Human RPC-PET, muon tomography (absorption or diffusion) and HEP tracking. A 4-layer TOFtracker device for muon tomography of cargo containers at harbours, for the HYDRONAV S.A company, has been constructed, integrated and deployed. The device is currently in operation delivering around 2-3 mm^2 and 200 ps spatial and time resolutions respectively. The calibration of the device has to be completed and a significant improvement is expected. The collaboration with the company will continue.

Another activity line concerns the development of low flux, autonomous and environmentally robust RPCs for deployment in remote locations, possibly with multihit capability in dense arrays. 20 RPC sensitive volumes (of a total of 40) have been constructed and tested for the MARTA array. After a long technology transfer campaign, 10 of them are already in São Carlos, Brazil, for the integration of sensitive volumes with the locally-produced mechanics and wiring. The construction of a cosmic ray telescope for Antarctica has already been initiated.

The construction and test of eight small high-quality single-gap, spacerless, stainless-steel cathode chambers to beam-test promising high-rate RPC electrode materials at CERN was done at rates above few kHz/ cm^2. The data analysis is ongoing.

Neutron Detectors

There is a widespread need for ^{3}He free Position Sensitive Neutron Detectors (PSNDs) with enhanced performance for applications ranging from neutron scattering science (NSS) to homeland security and well logging. The European Spallation Source (ESS), currently under construction, is a prime example and a driver of such need for high performance PSNDs to fully explore all its potential. Neutrons as a non-ionizing radiation cannot be detected directly, but only through the reaction products in converter materials. Only a few isotopes can be used for this purpose, with ^{3}He being the most commonly used. Nowadays, however, the ^{3}He shortage resulted in a change of paradigm which poses demanding challenges to develop new types of ^{3}He free neutron detectors, capable of satisfying high performance standards. ^{10}B is one of the most promising alternative candidates to ^{3}He. However the maximum detection efficiency achieved with a single layer of a solid neutron converter such as $^{10}B_4C$, is only ~5%. As a solution to face this challenge the LIP team proposed a new detector concept based on $^{10}B_4C$ coated RPCs, which takes advantage of the naturally layered configuration of RPCs. The feasibility of the proposed concept was successfully demonstrated, and the work developed at LIP is now integrated into the Horizon-2020 EU research project Science & Innovation with Neutrons in Europe in 2020 (SINE2020).

In 2017, a detector prototype with a stack of 10 double-gap RPCs lined with ^{10}B (20 layers of $^{10}B_4C$ in total) was designed and build. The detector was taken to TUM-FRM II (Germany) for the experimental tests with neutrons and was successful operated on the TREFF neutron beamline (λ = 4.7Å). A detection efficiency of more than 50% together

with a 2D-spatial resolution of the order of 300 μ has been demonstrated. We measured ~0.25 mm (FWHM) and ~0.30 mm (FWHM), respectively for the X- and Y-coordinates. These results confirmed the outstanding benchmark achieved with the single-gap ^{10}B RPCs prototypes tested in the previous campaign (< 0.25 mm FWHM). These results show that the design of PSNDs based on the principle of ^{10}B RPCs with sub-millimeter spatial resolution (in 2D) detection efficiency above 50% is feasible. They also demonstrate the capability of this novel type of neutron detector to measure the third coordinate with a high timing resolution, making this multilayer architecture very promising. Its modularity, robustness and low price per unit surface, are other unbeatable arguments when compared to other detector technologies.

R&D on gaseous and liquid Xenon detectors

Another speciality of LIP are detectors based on the use of Xenon as the active material. The high density and high interaction cross sections with ionizing radiation make it an ideal detection medium for many applications, such as gamma radiation and dark matter searches. Although the energy ranges of interest of these experiments are different, from the detection point of view they have very much in common.

High-pressure Xenon

High pressure Xe detectors can work at room temperature with good efficiency and adequate energy resolution, particularly for large areas, and have a much lower cost than competitors. The aim of the project is to develop and characterize a new type of high pressure gas proportional scintillation counter, conceived within the team: the MultiGrid High Pressure Gas Proportional Scintillation Counter (MGHP-GPSC). A previously built detector has been tested with alpha particles, allowing to assess the gain and energy resolution dependence with the adjustable detector parameters (gas pressure and high voltage at the anode and collecting grid). Tests with gamma rays are ongoing.

Ion mobility measurements

The group also has unique expertise in the measurement and modelling of fundamental processes in gaseous and liquefied noble gas detectors. This is relevant in several areas, such as modeling of gaseous radiation detectors, the understanding of pulse shape, and also in IMS (Ion Mobility Spectrometry), a technique used in a wide variety of applications, even for detecting narcotics and explosives. Data on ion mobility is especially important for improving the performance of large volume gaseous detectors, such as the ALICE and NEXT TPCs or Transition Radiation Detectors. This has created an increasing interest among the CERN community, and several requests to study ion mobilities for specific gas mixtures. We have extended the positive ion mobility measurements to other mixtures of interest for large volume detectors, like Xe-C_2H_6, Xe-CH_4, Ar-N_2 and, following requests received from the Univ. of Bonn (Germany) to study mobility in Ar-CF_4-IsoButhane (T2K mixture) for the LCTPC collaboration, also the measurement of ion mobility in Ar-CF_4, and CF_4- IsoButhane.

Liquid Xenon detectors

There is a number of experiments around the world using liquid xenon as detector medium. These include search for lepton number violating muon decay, dark matter searches, neutrino physics and double beta decay. Although the energy ranges of interest of these experiment are different, they have very much in common from the detection point of view. The general idea of this group is to carry out research on the processes triggered by particle interaction with liquid xenon as well as on the associated technologies, focusing on giving significant contributions for the future generation of liquid xenon detectors. A setup for testing new models of silicon photomultipliers in liquid xenon and liquid argon has been developed.

Still concerning liquid Xenon, and in the framework of the LZ collaboration, the LIP group is involved in the measurement, simulation and modeling of reflectance and transmittance of materials for LZ. The reflectivity measurements of PTFE from three different manufacturers were carried out with the required accuracy.

Scintillating Detectors and Optical Fibres

LIP has expertise in detectors based on radiation hard scintillators and scintillating or wavelength-shifting (WLS) optical fibres and decisively contributed to the ATLAS Tilecal calorimeter and to a number of other projects. The group has experimental labs in Lisbon (LOMAC), dedicated to calorimetry and instrumentation for processing and characterization of optical wavelength shifting and scintillating fibres, plastic scintillators and photomultipliers.

The group is now involved in R&D for the TILECAL upgrade, in which a set of special scintillators located in the calorimeter gap and crack areas, and the respective WLS fibres, will be replaced. LOMAC is exploring also the possibilities to work in other future experiments and applications. After the re-commissioning of the systems, a set of almost 6000 Kuraray Y11 WLS fibres was aluminized for the W104/Icarus muon tagger.

SELECTED
References

Luís Margato: "Development of Resistive Plate Chambers (RPCs) at LIP-Coimbra", 2017-06-14, SINE 2020 Detector RTD Meeting, Paul Scherrer Institute (PSI), 5232 Villigen PSI Switzerland

Pedro Assis, Alberto Blanco, Nuno Carolino, Ruben Conceição, Orlando Cunha, Carola Dobrigkeit, Miguel Ferreira, Paulo Fonte, Luis Lopes, Ricardo Luz, Victor Barbosa Martins, Luis Mendes, Américo Pereira, Mário Pimenta, Raul Sarmento, Ronald Shellard, Vitor de Souza, Bernardo Tomé: "Autonomous RPCs for a Cosmic Ray ground array", PoS ICRC2017 (2017) 379

Cortez, AFV (Cortez, A. F. V.); Santos, MAG (Santos, M. A. G.); Veenhof, R (Veenhof, R.); Patra, RN (Patra, R. N.); Neves, PNB (Neves, P. N. B.); Santos, FP (Santos, F. P.); Borges, FIGM (Borges, F. I. G. M.); Conde, CAN (Conde, C. A. N.): "Experimental ion mobility measurements in Xe-CO2", JOURNAL OF INSTRUMENTATION Volume: 12 Article Number: P06012 DOI: 10.1088/1748-0221/12/06/P06012 Published: JUN 2017

Perdigoto, JMC (Perdigoto, J. M. C.); Cortez, AFV (Cortez, A. F. V.); Veenhof, R (Veenhof, R.); Neves, PNB (Neves, P. N. B.); Santos, FP (Santos, F. P.); Borges, FIGM (Borges, F. I. G. M.); Conde, CAN (Conde, C. A. N.): "Experimental ion mobility measurements in Xe-CH4", JOURNAL OF INSTRUMENTATION Volume: 12 Article Number: P09003 DOI: 10.1088/1748-0221/12/09/P09003 Published: SEP 2017

Perdigoto, JMC; Cortez, AFV; Veenhof, R ; Neves, PNB; Santos, FP; Borges, FIGM; Conde, CAN: "Experimental ion mobility measurements in Xe-C2H6", JOURNAL OF INSTRUMENTATION Volume: 12 Article Number: P10011 DOI: 10.1088/1748-0221/12/10/P10011 Published: OCT 2017

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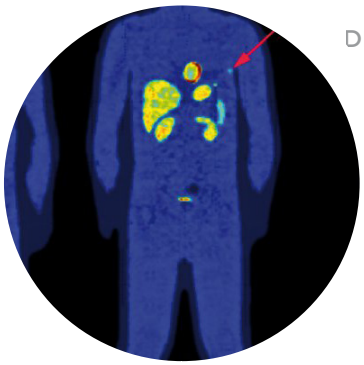

DEVELOPMENT OF NEW INSTRUMENTS AND METHODS

Health and biomedical applications

From physics labs to the hospital

LIP's expertise in planning, building and operating detectors for particle physics finds natural application in the fields of radiation therapy instrumentation, medical imaging and dosimetry. These are the areas covered by this group in multidisciplinary projects developed in collaboration with partners such as the ICNAS institute for nuclear health applications, the CTN/IST centre for nuclear technology, and several hospitals and medical research centres.

In the next five years our partnership with ICNAS will be fundamental for our projects, especially RPC-PET and Ortho-CT. The installation at CTN/IST of a hadron therapy unit, recently announced as a priority in science policy, will be of strategic importance and a perfect fit with our radiation therapy instrumentation activities.

RPC-PET

Positron emission tomography, or PET, is an extremely sensitive technique of medical diagnosis. A marker containing a radioactive substance is injected in the patient's body, releasing positrons by radioactive decay in the zone to study. When the positrons encounter electrons from neighboring molecules, they annihilate, producing two very energetic gamma photons travelling in opposite directions. These photons are identified by a ring of detectors, to create detailed images of the organism and to monitor dynamic processes. The detectors, electronics and algorithms for image reconstruction used in PET are similar to those developed by particle physicists for their experiments.

RPCs, with their good uniformity, excellent spatial and time resolution and low cost per unit area, offer a radically different alternative to the usual crystal-based gamma detection systems, and a dramatic increase in the field of view. Already two avenues of development have been identified: high-resolution animal PET and high-sensitivity, whole body human PET.

A small-animal functional PET scanner based on RPCs, with the best position reconstruction resolution ever achieved, has been developed and is being exploited at the ICNAS nuclear medicine research centre in Coimbra. Steps towards prototyping a human full-body RPC-PET, an invaluable medical imaging tool, are in progress. Since August 2014 more than 200 examinations of mice and rats have been performed. The ICNAS team has used the prototype scanner for the study of the molecular mechanisms subjacent to the neurodegenerative diseases Alzheimer, Parkinson and Huntington in animal (mice) models. The radiopharceuticals used include FDG (metabolism), PK11195 (inflamation), PiB (beta-amiloid deposition), Cu-ASTM (oxidative stress). In fact, the animal PET shows so far encouraging performance and, being also quite inexpensive, may be successfully marketable.

A second, pre-commercial, animal PET, is under construction. In 2017 the main developments concerned the front-end electronics, DAQ and trigger systems, which have been completed, as well as the gas and environmental monitoring systems. A new, user friendly user interface, the possibility of remote debugging and an improved mechanical system remain in progress.

In 2018, the development of the pre-commercial RPC-PET scanner will be continued. The detectors and mechanics will also be updated to cover a wider solid angle, allowing for the examination of rats and the full-body examination of mice. In addition a high-resolution brain scanner seems to be also an interesting application niche, where the excellent resolution of RPC-PET may be very advantageous. In fact, such a development seems to be a requirement to answer important medical research questions in areas in which our partners at ICNAS are active and successful, and a common application for funding has been presented.

Orthogonal ray imaging

The development of an orthogonal computed tomography system (OrthoCT), LIP's core project in instrumentation for radiation therapy is developed in partnership with two Portuguese Oncology Institutes, the Hospital of the University of Coimbra and several medical research centers. The aim is to improve traditional radiotherapy by optimizing the treatment in near real time, so that the irradiation can better accommodate the tumor and spare surrounding healthy tissue. To do this, we make use of X-rays emitted orthogonally to the treatment beam and detected by a multi-slice scintillating detector. The project is moving forward in several fronts at LIP Coimbra, in both simulation and experimental work. In 2017, two main

tasks were accomplished: simulation of a complete OrthoCT imaging system, acquiring data for the first time under several background conditions; and data taking with a multi-sliced detector in realistic, therapeutic-like conditions.

The simulation work was necessary to understand under what circumstances the technique may operate without degradation of the information provided by thin beams such as those to be used in OrthoCT imaging: 5 mm x 5 mm. Data taking with a multi-sliced detector involved many hours of detector construction in LIP's Mechanical Workshop and Detector Laboratory. For data taking, the Truebeam linac recently installed at CHUC E.P.E. was utilized, with two main beam features alternatively activated: a 6 megavoltage beam with flattening filter, and a 6 megavoltage beam being flattening-filter free. Only the latter produced the expected results, showing excellent agreement with expectations.

The rotation-free, low-dose imaging capability of OrthoCT are two of its great strengths. The imaging capability of OrthoCT has just recently been proven by experiment, although based on the FFF mode of irradiation (most modern irradiation technique). The on-board patient imaging capability is another potential strength of OrthoCT, together with its real-time imaging making use of the therapeutic beam, possible in some scenarios (irradiation angles) only.

Gamma cameras and position reconstruction in medical imaging

The group was formed in 2013 to apply the know-how accumulated at LIP in the course of the previous work on position-sensitive scintillation detectors (PSSD) to the areas of medical imaging and imaging techniques used in drug discovery. In the past years we confirmed, both by Monte Carlo simulation and experimentally, the applicability of our auto-calibration and position reconstruction techniques to clinical gamma cameras of classical design, and also to high-resolution cameras with silicon photomultiplier (SiPM) readout. We also created an integrated software tool that incorporates the whole development workflow for PSSD. The research on the use of machine learning algorithms for position and response reconstruction has been focused on two methods: artificial neural networks (ANN) and k-nearest neighbour (k-NN). Both methods were incorporated into the LIP ANTS2 software package. We collaborate with medical imaging units of Coimbra University (ICNAS and AIBILI) and Coimbra University Hospital (HUC). We continue our collaboration with the Radiation Detectors and Applications Group at Politecnico di Milano (RDAP-PdM).

2017 development included work on the 3D position reconstruction in thick scintillation crystals, in collaboration with RDAP-PdM. Monte Carlo simulations with ANTS2 demonstrated that position sensitivity can be achieved in an off-the-shelf commercial cylindrical $LaBr_3:C_e$ crystal read out from only one side by an array of SiPMs. The predicted spatial resolution for 662 keV gamma rays in a 3"x3" crystal is better than 10 mm (FWHM) in transaxial plane and 15 mm in axial direction. The experimental validation of this new technique is currently ongoing. Another line of work initiated in 2017 is the concept of a hand-held clinical gamma camera. From previous work with HUC on the feasibility of developing a free-hand SPECT scanner, the conclusion arised that a simpler and more cost-effective project would be the development of a hand-held gamma imager for assisting sentinel node biopsy surgery. A joint funding proposal has been submitted.

Dosimetry

LIP has a long standing expertise in dosimetry. R&D lines of work are combined with the provision of services to society in areas related to environmental radiation and public health. The team is devoted to the development of detectors for dosimetry and Monte Carlo simulations of radiation effects in medical applications and radiation protection.

In 2017, in the context of clinical dosimetry, the light yield temperature dependency of four plastic scintillators (BCF- 10, BCF-60, BC-404 and RP-200A) and two clear fibres (BCF-98 and SK-80) have been studied. Another recently started project aims at obtaining accurate Auger electron spectra in selected radionuclides that can be incorporated in biomolecules to target cancer therapy. Currently we are updating the databases of Auger spectra of medical radionuclides for future dosimetry studies at the DNA scale (microdosimetry).

SELECTED
References

A.L. Lopes, H. Simões, C. Travassos, P. Crespo: "Patient Compton scattered radiation for monitoring prostate radiotherapy with gold fiducial markers: A simulation study", Int. J. Pharma Med. Biol. Sci. 6:3 (2017) 77-82

H. Simões, A.L. Lopes, C. Travassos, P. Crespo, M. Alves Barros, J. Lencart, P.J.B.M. Rachinhas: "Monitoring tumor lung irradiation with megavoltage patient-scattered radiation: A full system simulation study", IEEE Trans. Radiat. Plasma Med. Sci. 1:5 (2017) 452-459

A. Morozov, F. Alves, J. Marcos, R. Martins, L. Pereira, V. Solovov, V. Chepel: "Iterative reconstruction of SiPM light response functions in a square-shaped compact gamma camera", Phys. Med. Biol. 62 (2017) 3619-3638

M. Carminati: "Study of Position Sensitivity of Large LaBr3:Ce Scintillators Readout by SiPMs", 2017-10-25, 2017 Nuclear Science Symposium and Medical Imaging Conference (NSS-MIC), Atlanta, Georgia, USA

J. Antunes, J. Machado, L. Peralta, N. Matela: "Plastic scintillation detectors for dose monitoring in digital breast tomosynthesis", Nucl. Instrum. Methods Phys. Res. Sect. A-Accel. Spectrom. Dect. Assoc. Equip. 877 (2018) 346-348

Luis Peralta: "Temperature dependence of plastic scintillators", Nucl. Instrum. Methods Phys. Res. Sect. A-Accel. Spectrom. Dect. Assoc. Equip. 883 (2018) 20-23

Jorge Sampaio: "Targeted Radiotherapy with Auger Electrons - An Atomic Physics Perspective", 2017-04-12, 2nd NOVA Biomedical Engineering Workshop, Faculdade de Ciências e Tecnologia da Universidade Nova de Lisboa, Caparica, Portugal

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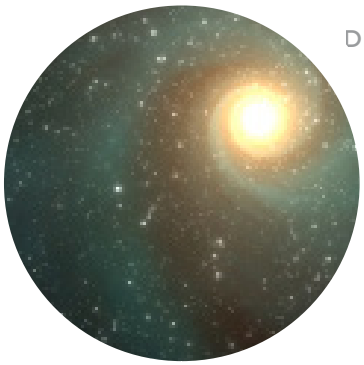

DEVELOPMENT OF NEW INSTRUMENTS AND METHODS

Space applications

Into outer space

Space exploration is one of the natural applications of particle physics technologies, particularly in what concerns radiation detection instrumentation and the modelling of complex processes involving the interaction of radiation with matter. Over the last decade, LIP became a recognized partner in the Space community, and particularly in the Portuguese participation in the European Space Agency (ESA).

Space Rad: Radiation environments and more

In the last ten years an R&D line focused on the study of space radiation environments and their effects was created and consolidated at LIP. The competences developed include all the technologies identified on ESA's roadmap for this domain: radiation environment measurement technologies; radiation environment modeling; radiation effects analysis tools; test characterization and radiation hardness assurance of Electrical, Electronic and Electro-mechanical components (EEE). In the last five years, a wide range of activities was developed, mainly in the framework of contracts with ESA, and involving different institutions both in the academia and in national industry. LIP is today an international reference in the GEANT4 simulation of space radiation monitors, and in the modeling of the radiation environment in Mars.

In 2017, the group was involved in the development of the RADiation hard Electron Monitor (RADEM) and EEE component testing (ECo60-JUICE) for the JUICE ESA mission to the Jovian system, with launch foreseen in 2022, is developed by a consortium of institutes and industry: LIP and the Paul Scherrer Institute in Switzerland, EFACEC SA and IDEAS from Norway. LIP was also involved in the data analysis of the radiation Environment and Effects Facility of AlphaSAT, the largest ESA telecom satellite. In 2008-2009 LIP has developed a model for the radiation Environment in Mars, dMEREM (detailed Martian Energetic Radiation Environment Model). Since then the capabilities of dMEREM have been exploited at LIP. The ongoing work in this subject consists on the upgrade of dMEREM, its validation with data from Mars Curiosity Rover radiation detector (RAD), and on its use in assessing radiation hazards in future manned missions to Mars and also for astrobiology studies.

Strategic lines for the next few years include the participation in the instrument development and science teams for planetary missions; the exploration and development of facilities for radiation tests in Portugal; and the creation of a multidisciplinary network for Space Physics in Portugal. ESA's strategy to guarantee the independence of the European space sector in critical technologies and to promote innovation and technical excellence in industry are guidelines to these efforts.

i-Astro: astrophysics instrumentation in Space

The i-Astro group holds high-level competences in instrumentation for astrophysics, particularly in x- and gamma-ray polarimetry. Recent activity has focused on the participation on the working group for XIPE, the first Space mission devoted to x-ray polarimetry, selected by ESA for Phase A on the M4 call. The group is also involved in the eASTROGAM mission, a gamma-ray observatory selected by ESA for the restricted list of the M5 call. The group is part of H2020 AHEAD (Activities in the High Energy Astrophysics Domain). Our group kept developing focal plane instruments based in CdTe and in gas filled detectors, with polarimetric capabilities. Polarimetry in high-energy astrophysics is still little explored, however it has a great potential to open a new scientific observational window.

In 2017, in the framework of AHEAD WP9 (Work Package 9), named "Assessment of gamma-ray experiments", the e-ASTROGAM instrument was simulated and its polarimetric performances calculated and analyzed. Results were compared with a double layer CdTe detector under a polarized beam at the ESRF (European Synchrotron Radiation Facility). We kept contributing to the development of the main instrument of the XIPE mission, by simulating the potential polarimetric performances of different noble gases: Xe, Ar, Ne and He.

SELECTED
References

A. L. Casimiro, J. M. Sampaio, P. Gonçalves, M. Pinto: "Assessment of radiation exposure in manned missions to Mars for three mission profiles", accepted for publication in Radiation and Applications Journal (RAD Journal), Volume 3, Issue 1, March 2018

Luisa Arruda, Patrícia Gonçalves, Ingmar Sandberg, Sigiava Giamini, Ioannis Daglis, Arlindo Marques, Joao Pinto, Adolfo Aguilar, Pedro Marinho, Tiago Sousa, Hugh Evans, Piers Jiggens, Alessandra Menicucci, Petteri Nieminen: "SEP Protons in GEO measured with the ESA MultiFunctional Spectrometer", IEEE Trans. Nucl. Sci. 64 (2017) 2333-2339

Marco Alves Pinto: "Representativeness of 60Co testing for EEE components to be flown in JUICE", 2017-07-19, 2017 IEEE Radiation Effects Data Workshop (REDW), NSREC,, New Orleans, USA

N. Simões, J. M. Maia, R. M. Curado da Silva, S. Ghithan, P. Crespo, S.J.C. do Carmo, Francisco Alves, M. Moita, N. Auricchio, E. Caroli: "Inflight Proton Activation and Damage on a CdTe Detection Plane", Nucl. Instrum. Methods Phys. Res. Sect. A-Accel. Spectrom. Dect. Assoc. Equip. 877 (2018) 183-191

De Angelis, A.; Tatischeff, V.; Tavani, M.; Oberlack, U.; Grenier, I.; Hanlon, L.; Walter, R.; Argan, A.; von Ballmoos, P.; Bulgarelli, A.; Donnarumma, I.; Hernanz, M.; Kuvvetli, I.; Pearce, M.; Zdziarski, A.; Aboudan, A.; Ajello, M.; Ambrosi, G.; Bernard, D.; Bernardini, E.; Bonvicini, V.; Brogna, A.; Branchesi, M.; Budtz-Jorgensen, C.; Bykov, A.; Campana, R.; Cardillo, M.; Coppi, P.; De Martino, D.; Diehl, R.; Doro, M.; Fioretti, V.; Funk, S.; Ghisellini, G.; Grove, E.; Hamadache, C.; Silva R.: "The e-ASTROGAM mission. Exploring the extreme Universe with gamma rays in the MeV - GeV range", Exp. Astron., Volume 44, Issue 1, pp.25-82

Rui M. Curado da Silva, Ezio Caroli, Stefano del Sordo, and Jorge Manuel Maia: "Chapter 10: Cadmium (Zinc) Telluride 2D/3D Spectrometers for Scattering Polarimetry", Semiconductor Radiation Detectors: Technology and Applications, 2017 by CRC Press, pp 241-282

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Computing

Computer science is a fundamental tool in modern research. LIP develops novel information technologies and operates advanced services to support demanding scientific applications. As an example the LHC experiments have to process about 8000 Terabytes of data per year that must be analyzed by researchers in many different locations. A worldwide distributed computing infrastructure was developed to overcome this challenge. LIP has been participating in several projects for the development, deployment and operation of the computing infrastructure for the LHC experiments, and also for generic use. These activities are mainly focused on grid computing and cloud computing technologies.

LIP participates in some of the largest European R&D projects in this field and operates the largest scientific computing facility in Portugal. The facility is part of the Worldwide LHC Computing Grid (WLCG) and delivers computing and storage capacity to high energy physics experiments and to the research community in a large ensemble of scientific domains. In partnership with FCCN and LNEC, LIP leads the National Distributed computing Infrastructure (INCD), which is part of the Portuguese Science Foundation Roadmap of Research Infrastructures of strategic relevance.

Computing

Enabling Compute Intensive and Data Intensive Science

Scientific research requires increasingly higher data storage and processing capacities that stress the limits of information systems and related technologies. Large scientific endeavors such as the LHC are perfect examples of this. The LHC distributed data simulation, processing and analysis led to the creation of the Worldwide LHC Computing Grid (WLCG), the largest distributed computing infrastructure ever built for a single scientific problem. The LIP distributed computing and digital infrastructure activities encompass the support for scientific research, through the provisioning of computing services, complemented by a component of innovation aimed at staying at the forefront of computing technologies, namely through a strong participation in some of the main European R&D projects in the field.

Distributed computing and digital infrastructures

The LIP distributed computing and digital infrastructures group, provides information technology (IT) services to LIP and its research groups. The group operates institutional IT services, including compute and data services for simulation and analysis that support the LIP research. These services include the Portuguese Tier-2, a compute and data intensive facility integrated in the Worldwide LHC Computing Grid (WLCG). WLCG is a global collaboration of more than 170 computing centres in 42 countries, linking up national and international grid infrastructures. In parallel the group is now delivering scientific computing services to the wider Portuguese scientific and academic community in the context of the Portuguese National Distributed Computing Infrastructure (INCD). These activities bridge at international level with the European Grid Infrastructure (EGI) and European Open Science Cloud (EOSC). Also in this context the group collaborates with several research communities beyond High Energy Physics. The development of the group's competences and capabilities is also backed by participation in R&D projects at national and international level.

In 2017 the Tier-2 executed 2,084,407 jobs delivering 65,634,475 normalized (HEPSPEC06) processing hours to ATLAS and CMS. LIP Lisbon moved into a new building. The LIP Lisbon IT infrastructure was transferred to the new building and deployed from scratch within schedule. The management structure and regular operation of INCD was established. The collaboration in thematic activities was increased, examples are: cooperation with BioData in a genome sequencing data pilot, housing of the national GBIF biodiversity data repository, and the collaboration with IMM in life sciences.

Also in INCD, the Linux containers technology was applied to the High Performance and High Throughput Computing (HPC and HTC) farms and to the IaaS cloud service enabling higher efficiency and flexibility. The HTC farm was extended into a tenant of the INCD cloud to exploit available capacity. The core network switching infrastructure was prepared to deploy IPv6.

LIP participated in the EGI governance and technical activities liaising Portugal with this international infrastructure. In the EGI-ENGAGE project, LIP worked in the LifeWatch competence centre, and in AAI and security aspects of the infrastructure. The project finished successfully.

The IBERGRID collaboration continued providing an umbrella for a common Iberian participation in EGI. The EGI middleware coordination was again performed by LIP, IFCA and CESGA in the IBERGRID context.

The INDIGO-DataCloud project finished in September with an evaluation of outstanding. LIP was in the project management board and coordinated the work on software management, quality assurance, pilot services and exploitation. This work was praised for its innovation and results. The group also developed: a novel virtualization tool (udocker), a system to integrate Docker in batch systems (bdocker) and extended the OCCI implementation in Openstack. The group also collaborated with T-Systems the largest cloud provider in Europe to tests the INDIGO-DataCloud software. The project worked with major communities: BBMRI, ELIXIR, INSTRUCT, DARIAH, DCH-RP, LBT, CTA, LifeWatch, EMSO, ENES, and WLCG.

The group worked in the preparation of EOSC-hub project that joins EGI, INDIGO-DataCloud and EUDAT to provide the core infrastructure for the EC European Open Science Cloud (EOSC). Together with LNEC, proposed an EOSC thematic service to deliver wave and ocean circulation forecasts for the European Atlantic coast (OPENCoastS). The OPENCoastS bid was selected among more than 60 international proposals. Also in EOSC-hub, LIP will lead the software management for all cloud, grid and data services in EOSC. The project was approved to start in January 2018.

The INDIGO-DataCloud collaboration submitted the DEEP-HybridDataCloud project which aims to develop technologies for large scale deep learning using cloud, HPC and hardware accelerators. The project was approved and started in November 2017. LIP will coordinate the software management and pilot infrastructure activities, and will contribute to several activities including virtualization, accelerators and layered networks.

Advanced Computing

The group, part of the LIP-Minho, since the beginning of 2014, has been directing its activity to the fields of Computer Science and Engineering more closely related to the principal areas of interests of LIP investigation.

In particular, it is noteworthy the support for the development and optimization of code applications related to HEP and the search of explicit distribution strategies for access to large volumes of data, in order to improve efficiency and execution times. More recently the group embrace new topics related to the areas of big data and machine learning.

Another important dimension of activity is the support for advanced training in Scientific Computing. The group is also responsible for the administration of a local HPC cluster that supports the running of the data analysis applications developed by other groups in LIP.

SELECTED
References

D. Salomoni, I. Campos, L. Gaido, G. Donvito, P. Fuhrman, J. Marco, A. Lopez-Garcia, P. Orviz, I. Blanquer, G. Molto, M. Plociennik, M. Owsiak, M. Urbaniak, M. Hardt, A. Ceccanti, B. Wegh, J. Gomes, M. David, L. Alves, J. Pina, J. Martins, C. Aiftimiei, L. Dutka, S. Fiore, G. Aloisio, R. Barbera, R. Bruno, M. Fargetta, E. Giorgio, D. Spiga, S. Reynaud, L. Schwarz, T.Bell, R. Rocha, M. Viljoen: "INDIGO-DataCloud:A data and computing platform to facilitate seamless access to e-infrastructures", arXiv:1711.01981

Jorge Gomes, Isabel Campos, Emanuele Bagnaschi, Mario David, Luis Alves, Joao Martins, Joao Pina, Alvaro Lopez-Garcia, Pablo Orviz: "Enabling rootless Linux Containers in multiuser environments: the udocker tool", Enabling rootless Linux Containers in multi-user environments: the udocker tool Jorge Gomes, Isabel Campos, Emanuele Bagnaschi, Mario David, Luis Alves, Joao Martins, Joao Pina, Alvaro Lopez-Garcia, Pablo Orviz. Nov 6, 2017. e-Print: arXiv:1711.01758 [cs.SE]

D. Salomoni, L. Gaido, I. Campos Plasencia, J. Marco de Lucas, P. Solagna, J. Gomes, L.Matyska, P. Fuhrmann, M. Hardt, G. Donvito, L. Dutka, M. Plociennik, R. Barbera: "The INDIGO-DataCloud project: enabling software technologies for efficient and effective use of Cloud computing and storage for science", accepted for publication in 2017 Nuclear Science Symposium and Medical Imaging Conference, together with the 24th Symposium on Room-Temperature X- and Gamma-Ray Detectors. Atlanta, Georgia, October 21st to October 28th 2017.

Duarte Pousa, José Rufino: "Evaluation of Type-1 Hypervisors on Desktop-class Virtualization Hosts", IADIS International Journal on Computer Science and Information Systems (ISSN 1646-3692), vol. 12, num. 2, pp. 86-101

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Research facilities

- Mechanical workshop
- Detectors laboratory
- e-CRLab
- LOMaC
- TagusLIP laboratory

Mechanical workshop

The Mechanical Workshop (MW) of LIP was established in 1986, to support the experimental activities performed in collaboration with CERN. At present, the available equipment and the highly qualified staff allow us to perform a large spectrum of mechanical services, from project to production and testing. Today, the MW provides services not only to the CERN projects but also to research groups inside and outside LIP and to external companies. The work developed by the MW is complemented by the Detectors Lab, as many of the projects developed by LIP need the competences of both facilities. Over three decades, the two infrastructures assured excellent quality support to gaseous detector R&D both at LIP and National level, as well as to the participation and responsibilities of LIP in large collaborations, namely CP-LEAR, DELPHI, HERA-B, ATLAS, HADES, Auger, LUX and SNO+.

During 2017 over 30 projects were carried out by LIP's mechanical workshop, none of them standing out in the use of available resources. These included the construction of parts for the RPC detectors for the Auger group, namely gas bubblers, gas connectors, electronic supports, HV PS boxes and auxiliary mechanical pieces; the construction, assembling and test of a second unit of the Umbilical Retrieval Mechanism (URM) for the PMT calibration system of the SNO+ experiment; the construction of aluminium boxes for the project the muon tomography project with the Hydronav company; and the construction of two prototypes of camera supports for BOSCH. Several of these works are still ongoing. Parts and pieces for many other LIP groups were produced, namely Ortho-CT, RD51, SNO, LZ, HADES, RPC-R&D and i-Astro, and also for the Physics and Chemistry departments of the University of Coimbra. Further work was developed for LIP outreach projects, with the construction of four SPARK chambers and of a prototype cloud chamber.

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Detectors laboratory

The Detectors Laboratory (DL) was created at LIP's foundation with the main aim of supporting the experimental activities developed at LIP. The laboratory has been continuously updated according to the general and specific needs of the research groups. The available equipment and technical staff allow a variety of services, including the design, construction and repair of electronic circuits and vacuum systems, and the design, construction and testing of particle detectors.

During 2017, the main activities were related to the R&D and production of three different types of large area Resistive Plate Chambers (RPCs) used in international projects in which LIP is involved: MARTA, in a collaboration with Brazil in the framework of Auger, muTT, with Hiydronav, Tomuvol, Antartida and HADES-FD. Our contribution is multidisciplinary and spans from project design to the installation and maintenance of the detectors, development of tools and/or instruments to control/monitor the detector performance. Adapting the detector to the individual requirements of each application follows more procedures that are similar to industry's. In total, during 2017 we build more than 60 m^2 of RPC detectors, including timing and trigger (counting) detectors. This activity corresponds to around 50 % of our total manpower. We develop from zero the detector sensitive volume, the gas control and monitoring system and the monitoring of all the environmental properties that could affect the detector performance. All other parts used in these detectors were developed with the contribution of the researchers related to these projects. A fundamental activity of the DL is the capability to assist all the groups in their R&D activities. In total this consumes around 30 % of our manpower. We contribute with technical work and added value in the following projects: APET, SNO+, MASTER-Rio, Spark Chamber, CriostatoLaserlab-DQUC, LZ (system upgrade), HADES, AIDA2020, SINE2020, Cloud Chamber, GSPC.LIP, OrthoCT.LIP and muTT/Tomuvol.

TagusLIP laboratory

The TagusLIP Laboratory is a LIP research infrastructure installed in 2004 at the Lisbon Science and Technology Park (Taguspark). The campus is home to a University (IST), several research centres, as well as a large spectrum of startups and small companies. TagusLIP was conceived as a generic infrastructure for the development of radiation detectors with emphasis on nuclear medicine imaging technologies opened to external entities. The TagusLIP laboratory is equipped with the necessary instrumentation for R&D on radiation detectors and associated electronics, and data acquisition, including electronics lab equipment, computing and networking systems. The laboratory offers software tools for developing analog and digital electronic integrated circuits (Cadence), for firmware development (Xilinx and Altera), and for the design of printed circuit boards (Altium). TagusLIP has a computing and data storage infrastructure, suitable for software projects in various areas, such as data acquisition, equipment control, data analysis and image processing. TagusLIP is licensed for the use of radiation sources needed to develop and test new instruments in nuclear medicine.

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.

In 2017 the main user of the TagusLIP Laboratory was the start-up company PETsys that performed the following developments: Extensive characterization of new ASIC TOFPET2 for Time-of-Flight applications together with SiPM devices from all established producers. The measured timing performance was excellent. Associated to small LYSO crystals, a Coincidence Time Resolution of 127 ps FWHM was achieved for PET events; development of a PET detector module with depth of interaction information and timing capability for large PET scanners. This work involved a LIP PhD student; design of a new ASIC (TOFHiR) for the CMS MIP Timing Detector, in the frame of the Phase II Upgrade of the CMS experiment for HL-LHC. The chip is derived from TOFPET2 and introduces new features in particular the possibility of operation at very high signal rate (1 MHz/channel).

e-CRLab
(Cosmic rays electronics laboratory)

The e-CRLab is mainly dedicated to the development of electronics for Cosmic Ray experiments. The focus is put on fast digital electronics implemented in FPGAs. The laboratory has the capability to design complex printed circuit boards and to produce simple printed circuit board (PCB) prototypes. The production of complex PCB and its assembly is outsourced. There is capability to do rework in PCB boards. A small set of mechanical tools allows the production of simple detector prototypes mainly for proofs of concept.

In 2017 the e-CRLab had two main activities: the development of MARTA instrumentation and the testing of radiation damage of components for ESA. MARTA is a project within the context of Auger to operate RPCs in the Argentine Pampa, under the Auger Water Cherenkov Tank. The electronics were developed at e-CRLab that has the responsibility of its operation within the project of the Portuguese participation in the Pierre Auger Observatory. The engineering prototype of MARTA front-end electronics based in the MAROC ASIC was developed and tested. The system performed as expected and only minor problems were found and corrected in the project. In the context of ECO-60: Verification of ^{60}Co testing representativeness for EEE components flown in the Jupiter electron environment of the group Space Radiation Environment and Effects, the e-CRLab has developed the test procedure and test system for the irradiation in different conditions of several components. During 2017 the annealing phase was finished and the data analyzed. This work was done within the context of the Space Rad group. The e-CRLab has also been involved in outreach and teaching. In the outreach context it has been involved in the development of AMU – A ver MUões, a small Cosmic Ray Telescope to be deployed in high schools. The e-CRLab has been involved to the installation of experimental setups at IST for the Advanced Experimental Physics Laboratory and other education activities. These setups focus mainly in the detection of CR and on the study of scintillator detectors.

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LOMaC
(Laboratory of Optics and Scintillating Materials)

The laboratory 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 (Centro de Física Nuclear da Universidade de Lisboa), where it was located. The laboratory 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. It was also used for several detector R&D projects: DELPHI, ALFA, RD52/DREAM, and SNO+. The laboratory is equipped for testing and preparation of scintillators, optical fibres, photomultipliers 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 ^{90}Sr 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 by magnetron sputtering, and the facility allows the deposition of aluminium mirrors in the top of fibres with variable length up to 3 m.

In 2017, the fibrometer installed at the FCUL facilities was re-commissioned after the maintenance and repair that were done in the previous year. Together with the setup to cut/polish the bundles of fibres using a lathe that belongs to the DEGGE department from FCUL and located at FCUL workshop, several sets of fibres were prepared for aluminization. The aluminization setup was used to put aluminium on the top of the fibres obtaining good quality mirrors. After the re-commissioning of the systems, a set of almost 6000 Kuraray Y11 WLS fibres was aluminized for the W104/Icarus muon tagger. Along the year, the mono-fibrometer setup had the mechanics and control improved. Setups like the tilemeter and the mono-fibrometer have been used in several educational and outreach activities.

Competence Centres

Competence Centres at LIP are designed to be light and flexible horizontal structures joining all the LIP members that share the same tools and technologies. Such centers should have a positive impact both internally, increasing the synergies between groups, and externally, in advanced training and boosting LIP's collaboration with other research centers and with industry.

COMPETENCE CENTRES

Simulation and Big Data

The purpose of the Competence Centre on Simulation and Big Data is the fostering of an effective collaboration between the different LIP groups working on these areas and to boost the capability to exploit the existing expertise both internally and externally, towards the university and the industry. The different LIP groups have a vast range of competences in data analysis and simulation tools, including physics models, Monte Carlo generators, detector simulation tools, big-data handling techniques and data mining. The ability to fully benefit from such competences requires achieving critical mass, a coordinated training program, the exploitation of synergies between groups and a clear identification of the key areas where we can contribute in a competitive way.

The competence centre started its activities in 2017 and the first priorities were the identification of the technical competences mastered by the LIP members in these two areas, establishing communication and discussion forums, starting a training program and establishing an action plan for the next few years.

Simulation

In 2017, the Simulation branch of the competence centre undertook a survey of the GEANT4 competences at LIP. The following items were identified:

- LIP is a member of the GEANT4 collaboration for more than 10 years, accumulating an important expertise, both from the user and developer points of view, with an important know-how beyond applications development;
- LIP members hold expertise in several GEANT4 kernel categories;
- There is a potential to increase LIP's contribution to the GEANT4 toolkit;
- LIP members undertake teaching activities in MSc and PhD level courses with some emphasis in GEANT4.

In addition we started regular informal meetings involving all the interested LIP members.

Big Data

The Big Data branch of the competence centre developed a survey of the big-data and machine learning competences at LIP, and the following items were identified:

- Development of multivariate data analysis using advanced techniques (e.g. boosted decision trees, shallow and deep neural networks and principal component analysis);
- Expertise in modern tools used in HEP and beyond it (e.g. TMVA, Octave, Keras, SK-learn, Pandas, Theano, Tensorflow);
- Expertise in advanced methods for training and validation of multivariate analysis (e.g. use of accelerators such as GPUs, distributed training and cross-validation);
- Expertise in complex file systems and tools to deal with large volumes of data.

Regular informal meetings with all the interested LIP members have also been started, which include topical discussions and tutorials. A successful application to a NVIDIA GPU grant allowed us to receive a modern GPU board to be used in the training of advanced multivariate analysis. We are also participating in the iSci-ECUM-Bosch project, devoted to the improvement of the data quality in specific industrial contexts, which has a strong data analysis component.

In 2018, it will be crucial to identify the strategies to create external links with the university and industry. In particular, the identification of projects and activities with the potential of capturing external fundings will be a concern. A training program will be developed aiming to establish regular workshops and tutorials. The contribution to the GEANT4 collaboration will be continued and strengthened. On the Big Data side, a data science school at LIP and an associated symposium with students, researchers, private companies and industries took place in March 2018. An ongoing survey of the competences in data sciences by other portuguese groups will be continued, aiming to identify potential collaborations and the key areas were we can be competitive in providing external services.

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COMPETENCE CENTRES

Monitoring and Control

The Competence Centre in Monitoring and Control (CCMC) is intended to:

- *Gather the accumulated expertise in sensors, electronics and software used in Monitoring and Control by several experiments where LIP participate and have direct responsibilities;*
- *Facilitate the sharing of know how, solutions in electronic and software design among LIP persons/groups*
- *Establish partnerships/contracts with third parties (e.g. other laboratories, industry) where our scientific deliverables can be re-used.*
- *Avoid time/costs associated of development of new products.*

In 2017, the main activities of the CCMC developed in the framework of other LIP members/infrastructures were:

- Precision monitoring and control of an oven for annealing of PMMA containers for radioactive sources in the framework of SNO+ activities. This activity were developed also in collaboration with the mechanical workshop and the detector laboratory.

Concerning external partners, we initiated negotiations with the CNC (Centro de Neurociências, Coimbra) towards the installations of an Environmental Monitoring System for their laboratory rooms. The system will be based in hardware and software tools developed/used by the LUX-LZ group. As a first stage, the CNC will only pay the equipment and LIP will test/tune the system. After this trial period, we would re-negotiate the terms of the contract and eventually extend the system for other rooms (that would also include measuring pressures in virus rooms, etc). Currently LIP is waiting on their decision.

For the next year, the activities of the CCMC developed in the framework of other LIP members/infrastructures will include the continuation of the work of monitoring and control an oven for the annealing of plastic pieces (e.g.PMMA) and assess the feasibility of working with higher temperatures (~200C). During CERN"s 2019 Long Shutdown (LS2), COMPASS will be updating its Monitoring and Control system. In that process, COMPASS will study the possibility of replacing their Embedded Local Monitor Board boards (ELMB) by Raspberry/Beaglebone-based boards for measuring of temperatures, pressures, humidities, etc. COMPASS shown interest in collaborating with the CCMC to take advantage of the existent accumulated experience within this Competence Centre and access the feasibilty of using those boards in their experimental environment. The extent and details of the collaboration between COMPASS and the CCMC is yet to be defined.

Concerning external entities, the CCMC intends to:

- Finalize the negotiations with CNC for the installation and maintenance of an Environmental Monitoring System and upon success proceed with its installation.
- Further explore the possibility of develop and build a setup for the characterization of hydrocarbon (crude) reservoirs for the Universidade Fernando Pessoa (UFP). This project stems from previous contacts between LIP and UFP involving the maintenance of similar systems and, given its complexity and costs, still needs accurate and detailed evaluation before proceeding.

In general and with the collaboration of LIP members, we will continue the search for potential new projects and help mediating the interaction between the various LIP structures when relevant in the context of each project.

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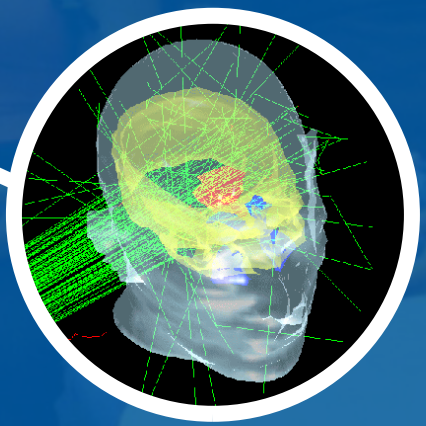
Communication, Outreach and Education

Advanced training

SCIENCE AND SOCIETY

Knowledge transfer, industry, spin-offs and **societal impact**

Radiation, health and **environment**



Communication, outreach and education

Education, Communication and Outreach (ECO) are today a fundamental aspect of the activities of any research and development institution. This results from the recognition that ECO activities: are part of our social role; are essential for the recognition of our work's relevance; help attracting funds, partnerships, opportunities; help attracting students and researchers.

The LIP-ECO office, Education, Communication, Outreach and Advanced training

LIP-ECO was created in 2016 with the aim of better organizing and extending the ECO-related activities carried on at LIP. The celebration of LIP's 30th anniversary has played a crucial role in boosting LIP-ECO. Still in 2016, LIP's communication strategy document was written, and priority target audiences were defined: our peers (universities, research centres and funding agencies); the LIP community (internal communications); undergraduate students in Physics and Engineering; the school community.

A core team with weekly editorial meetings and a clear and ambitious activity plan has been established.

The LIP Education, Communication, Outreach (LIP-ECO) office has two (interrelated) pillars:

- corporate communications (LIP-ECO1);
- education and outreach (LIP-ECO2).

LIP has as main partners in outreach Agência Ciência Viva and the Portuguese Physics Society. LIP is part of several communication and outreach groups and networks at CERN and beyond:

- IPPOG — International Particle Physics Outreach Group, which formally became an international collaboration in 2017.
- EPPCN – European Particle Physics Communication Network.
- CERN forum for high-school students and teacher programmes.

2017 highlights

European HEP school in Évora

The European School of High Energy Physics (ESHEP 2017) took place in Évora, Portugal, from 6 to 19 September. This school is organized yearly in a joint effort by CERN and JINR. This year it was coorganized by LIP with the support of the University of Évora. The ESHEP is attended typically by 100 highly selected PhD students. The local organizing committee included members from different LIP groups.

In 15 September 2017, Fabiola Gianotti , Director General of CERN, and Victor Matveev, Director of JINR, were speakers at a public session organized by LIP and the University of Évora in the context of the European School in Heigh-Energy Phsyics. The Portuguese Minister of Science, Technology and Higher Education, Manuel Heitor, was an honoured guest at this session, which also counted an address by the Rector of the University of Évora, Ana Costa Freitas, and Gaspar Barreira, Director of LIP. The session was very successful, with an audience of 250 people and lively and interesting discussions.

LIP-ECO members further participated in the jury of the school outreach presentations session and were instrumental in establishing contacts and conditions for an interview with Fabiola Gianotti to Visão, a national Portuguese reference magazine.

Local Committee

N. Antunes (LIP), G. Barreira (LIP) M. Bezzeghoud, U. Évora, R. Conceição (LIP) P. Conde Muíño (LIP), M. Gallinaro (LIP), R. Gonçalo (LIP and FCUL), I. Lopes (U. Coimbra and LIP), J. Maneira (LIP and FCUL), A. Onofre (U. Minho and LIP) J. Romão (CFTP and IST), J. Varela (LIP and IST)

LIP flagship initiatives for the school community

IPPOG's International Masterclasses in Particle Physics
Under the coordination of LIP, more than 1700 participants gathered in 16 sessions all over the country: Aveiro, Beja, Braga (2 sessions), Bragança, Coimbra, Covilhã, Évora, Faro, Funchal (Madeira), Lisboa (2 places, 3 sessions), Ponta Delgada (Azores), Porto, Vila Real, and with our remote support in São Tomé and Príncipe.

CERN Portuguese Language Teachers Programme
Under the responsibility of LIP and with strong support from CERN and Ciência Viva, the 11th edition of the school was held in the beginning of September, attended by 20 Portuguese teachers and 20 Brazilian teachers. During the last ten years, 639 teachers have attended the school, which is considered one of the best teacher training programmes at CERN.

Summer internships for high school students
In the framework of Ciência Viva's programme "Science in the Summer", LIP hosted 17 students for two weeks to learn about experimental particle physics. Within the internship's progamme of the University of Coimbra, LIP further hosted 13 students for one week in internships devoted to the ATLAS experiment at the LHC and to dark matter searches.

Seminars in schools and special outreach sessions
More than 50 outreach talks were given by LIP scientists in Braga, Coimbra and Lisboa, at schools and in other settings, on particle physics, space and related technologies.

References:
P. Abreu. S. Andringa, L. Coimbra, C, Espírito Santo, H. Gomes, R. Gonçalo, C. Manuel, "A construção do gabinete de comunicação do LIP", Scicom.pt, Coimbra, Portugal, November 2017

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European Researchers Night

In Braga, integrated in the celebrations prepared by Escola de Ciências da U.Minho: the LIP stand displayed LIP's interactive screen, a spark chamber and a cloud chamber; the workshop on "How to build a particle detector" was held. In Lisboa, in the Lisbon Planetarium, the movie "Particle Fever" was shown, followed by a lively discussion and a Virtual Visits to the CMS experiment.

In the media

the news concerning the publication, in the Science magazine, of the confirmation of the extragalactic origin of the highest energy cosmic rays by the Pierre Auger Observatory appeared in Público, a reference national daily newspaper, including a conversation with three members of LIP.

Advanced training

At LIP, we train the scientists of tomorrow. PhD and master students at LIP go through a truly international training, in the framework of international collaborations. LIP hosts undergraduate students in schools, workshops and summer internships.

The capability to attract the best undergraduate and graduate students is central for LIP. The advanced training office was created to coordinate and promote actions dedicated to university students at the several levels (undergraduate, master, PhD).
Its goals are:

- Engage undergraduate students: attract university students to learn about HEP and engage in research at LIP, imparting the excitement of doing research in fundamental particle physics or advancing associated technologies in frontier experiments and in the context of international collaborations; ensure high quality underlying training in HEP.
- Ensure high-quality graduate training: support baseline core training and adequate guidance of LIP graduate students; Support national and international PhD programmes and networks in our fields of activity.

Graduate students

LIP permanently hosts tens of PhD, Master and Bachelor students, who actively work within LIP's research groups, and has a long standing experience in advanced training. In each of its three nodes, the Laboratory works in close relation and cooperation with the local universities. Furthermore, LIP coordinates two FCT doctoral programs, IDPASC (Particle Physics, Astrophysics and Cosmology) and DAEPHYS (Doctorate in Applied Physics and Physics Engineering), and the IDPASC international network. LIP is a member of MV4NewPhys, a EU funded International training Network, and host a PhD student in this context. A wide set of schools, workshops and courses were held in 2017. The IDPASC international school was held in Asiago during two weeks, the school included lectures, discussion sessions and a final exam. 13 students participated.

In the 1st LIP PhD student workshop, held in Coimbra, all LIP PhD students presented the status of their work to an audience of graduate students and researchers. Keynote lectures on topics selected by the students themselves started the session in each of the two days. A similar meeting for all IDPASC students was held in Braga. The xth edition of the LHC Physics Course was held. About 18 lectures covering introduction to the standard model, detectors, statistics, and overall research were proposed, from March through May.

The following events targeted at graduate and undergraduate students are foreseen in 2018:

Particle physics mini-school, Oeiras, Feb 2018 - co-organized by LIP and CFTP

Data science school and symposium, LIP Lisbon, March 2018 - A flagship event emphasizing the connection to and partnership with industry.

LHC physics course, LIP-Lisboa, March to May 2018;

IDPASC student workshop, Coimbra, June 2018;

IDPASC international school, Valencia, Spain, May 2018;

LIP Summer Student Programme,
July-September 2018

Undergraduate students

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LIP Summer Student programme

For the first time in 2017, the efforts by individual groups were joined and summer internships for undergraduate students were held as an integrated LIP programme. Over the summer period, students became actual scientific collaborators within the LIP groups. 29 students completed the program in Lisbon.

The programme included one week of lectures (morning) and hands-on tutorials (afternoon), the participation in a research project (from 2 weeks to 2 months), and a final workshop where each student shows his/her work. The programme counted on a broad participation of LIP researchers, who served as project supervisors, delivered tutorials and lectures, attended and contributed to discussion of results at the final workshop. In Coimbra, 12 students took part in 1-month long projects in topics such as top quark, dark matter, instrumentation & radiation. The summer program had a very positive global evaluation by students, a large number of students engaged, and a good level on the research work and presentations.

Schools & workshops

LIP is involved in several regular school and workshop series directed at undergraduate students, involving general physics presentations, hands-on exercises, and an overview of ongoing research activity at LIP. In 2017, the LIP-CFTP mini-school in particle and astroparticle physics was held in Sesimbra in February and gathered 20 students; the Hands on Particles and Light workshop was held in July at FCUL and IST and counted on the participation of 14 students.

Outreach for undergraduates

Besides training events (internships, schools and workshops), LIP conducts a number of initiatives with the goal of making LIP and particle physics known and attractive among undergraduate students. In 2017, LIP inaugurated the LIP Control Centre at IST, from which Auger and CMS control and monitoring shifts take place. The Control Centre creates additional opportunities to make contact with students and to involve and train students on detector status, control, data quality monitoring in real experiments for running experiments. Sessions for introducing detectors and physics topics have been held, and a display with LIP related news and announcements has been installed. The Careers & Technology day, an event on career prospects, technology and links to industry in particle physics was held at our partner universities in Lisbon: LIP Careers Day, at IST, 1.3.2017, and CERN Technology Day at FCUL, 2.3.2017. In each of the two places, around 30 students attended the event. LIP further participates in events organized by Physics student associations and groups at the different universities. For example, LIP regularly participes in the “Inside Views” of research laboratories during the Physics Engineering Days at IST. In 2017, 54 students visited LIP for one morning, attending one of the 6 proposed sessions.

Knowledge transfer, industry, spin-offs and societal impact

Fundamental science drives innovation in the long term. Particle physics technologies have a wide range of applications, and the potential to respond to societal changes. We aim at boosting our shorter term societal impact through specific research lines dedicated to applications to health care and space exploration.

Direct transfer

Knowledge-transfer to companies occurs across the whole spectrum of LIP's activities. Recently, a spin-off company, PETsys was created to commercialize the innovative electronics developed at LIP for Time-of- Flight PET systems. In the last year, LIP had contracts or was in consortia with EFACEC SA (under ESA contracts), EVOLEO SA, HIDRONAV S.A. and BOSCH.
Scientific computing is certainly one of the areas placing particle physics at the forefront of innovation. LIP co-leads the National Infrastructure for Distributed Computing, serving the Portuguese scientific community at large.
The hadron therapy unit to be installed at CTN is of strategic importance, and we started a collaboration with ICNAS and CTN in instrumentation, image reconstruction and detector R&D. In addition, LIP's RPCs are well suited for a wide range of applications from security to geology and, most prominently, to health. LIP's RPC-based small animal PET scanner currently operating at ICNAS with a world-record resolution, and is at pre-commercial development stage; a human-brain scanner is a priority for the next years. In what concerns space applications, the goal is to move from short-term ESA contracts to long participations in ESA mission, in consortia with Portuguese and European companies, which will boost inter-sectorial technology and knowledge transfer.
LIP's laboratories and workshops provide support to our activities and services to external entities. Competence Centres on Big Data and Simulation and on Monitoring and Control have recently been created to increase the synergies between groups and boost LIP's collaboration with other research centres and the industry. LIP is committed to the Open Science paradigm and present in the Portuguese scientific open access platform.

Industrial liaisons

LIP's involvement with CERN has triggered technological transfer to Portuguese industry through contracts awarded by CERN. The Portuguese Industrial Liaison Officer is a member of LIP's staff developing activity within FCT. The ILO that is mandated to support and actively promote national industry and R&D institutions to CERN, ESO, ESRF and contribute to their success in the procurement process, thus ensuring a positive industrial return to Portugal.
The recently renewed protocol between Portugal and CERN recognizes LIP as CERN's reference laboratory in Portugal. While CERN remains our main partner, LIP is now a partner of ESA and belongs to international collaborations at GSI, SNOLAB, Auger and SURF. In the next few year, LIP will remain instrumental in creating opportunities for Portuguese industry at CERN and in other scientific infrastructures, in the context of its industrial procurement rules. In particular, the LHC upgrade constitutes a unique opportunity for collaboration between LIP and industry.

Portuguese traineeship programme at CERN, ESA and ESO

The involvement of LIP at CERN and its role in has been instrumental in FCT's engineers training programme. In 2017, LIP was directly involved in the evaluation and selection process of the trainee engineers for the Technology Internships programme at CERN, ESA and ESO. Gaspar Barreira, Director of LIP and Portuguese representative in the CERN Council, was the president of the board, which included also Pedro Abreu (LIP/IST). Eight new internships started in 2017.

HEPTech network

LIP is a member of HEPTech, a unique high energy physics technology transfer network (TTN) that aims to become "the innovation access point for accelerator and detector driven research infrastructures". The network bringing together leading European high energy physics research institutions: CEA, CERN, CNRS, CIEMAT, DEMOKRITOS, DESY, ELI-ALPS, ELI BEAMLINES, EPFL, ESS, GSI, IJS, IFIN-HH, INFN, INOVACENTRUM, KTN, LIP, NTUA, SOFIA University, STFC, TU of Kosice, University of Belgrade, WEIZMANN Institute and WIGNER; which work across a range of world-leading scientific areas in the field of Particle Physics, Astrophysics and Nuclear Physics.
To push back scientific frontiers in these fields requires innovation. It is challenging and costly to carry further research and development focused in applications, products and processes and turn them into commercial opportunities. HEPTech, as a source of technology excellence and innovation, tries to bridge the gap between researchers and industry by organizing a set of activities: academia industry matching events; workshops on technology transfer and commercialization of research; show and tell sessions; the Heptech Symposium. LIP, as an HEPTech node member, follows the various activities and maintains updated its awareness about knowledge and technology transfer and the paths for commercialization from fundamental.

http://heptech.web.cern.ch

Radiation, Health and Environment

LIP has a long standing expertise in dosimetry. The team is devoted to the development of detectors for dosimetry and Monte Carlo simulations of radiation effects in medical applications and radiation protection. R&D lines of work are combined with the provision of services to society in areas related to environmental radiation and public health.

The group has previously conducted a survey assessing the radon concentration in water sources of public drinking of Covilhã's County. In 2017, A radon detector based in a low-cost Si-PIN photodiode working in counter mode has been developed. A survey of radon in dwellings in the city of Lubango, Angola, was conducted. Bioaccumulation of direct descendants of radon in a plant species (watercress) was evaluated in a controlled environment, and an expedition was made to the Angola province of Namibe to collect water samples for radon analysis.

The LIP dosimetry group manages the LabExpoRad laboratory in Beira Interior University, one of the three laboratories in the country dedicated to radon analysis. The laboratory will play a key role providing technical support to companies and public services in transposing the 2013/59/Euratom directive, which sets more restrictive radon levels and the need for a national action plan addressing long-term risks from radon exposure.

During the next year, the effort to develop and test low-cost radon detectors with particle identification and energy resolution that can be deployed in great numbers will continue to carried on. These detectors will be used in the Angola campaign, where further campaigns for radon monitoring in air and water are foreseen.

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LOOKING FORWARD

Looking forward

In the next few years, LIP will strengthen its role as a nation-wide laboratory defining, under the supervision of FCT, the national research agenda in experimental particle physics and associated technologies, and the participation at CERN and other international scientific infrastructures.

LIP's strategy aims at creating the required organization, processes and tools to ensure: a high degree of collaboration, internally and externally, optimizing the use of resources and potentiating the impact of our research; the promoting of the integrated development of the different LIP nodes; the capability to attract and secure top level researchers and students, as well as funding from diversified sources; the transfer of knowledge from R&D to society, through enhanced collaboration with Portuguese universities, research centres, companies and schools.

LIP was created for the internationalization of science, as Portugal joined CERN. The recently renewed protocol between Portugal and CERN recognizes LIP as CERN's reference partner in Portugal. Today LIP is also a partner of ESA and belongs to international collaborations at GSI, SNOLAB, Auger and SURF. LIP will be instrumental in creating opportunities for Portuguese industry at CERN and in other scientific infrastructures. In particular, the LHC upgrade constitutes a unique opportunity for collaboration between LIP and industry. LIP is strongly committed with the internationalization of advanced training, through programmes for young scientists and engineers at CERN, and participating in international PhD networks. LIP has privileged research cooperation with Brazil.

The work developed at LIP confirms the laboratory as an international reference in several areas, namely physics data analysis (heavy quarks, Higgs and Drell-Yan physics), detectors and instrumentation (liquid xenon and RPC detectors, control systems, calibration in low background experiments) and distributed computing (Cloud, Grid). LIP further opens new promising R&D avenues.

In the next few years LIP will be at the forefront of LHC data analysis in topical channels such as the Higgs, top, B mesons, and quark-gluon plasma, while preparing the LHC upgrade. The ATLAS and CMS groups at LIP will be participating in the R&D and construction of new sub-detector systems in collaboration with Portuguese industry, maintaining the high level of quality and leadership in physics analyses. LIP will remain involved in the fixed target program at CERN, leading a proposal for a new experiment to address fundamental questions in QCD; and at GSI/FAIR, starting in 2018, with the only Portuguese experimental team exploring the frontier between nuclear and particle physics. The LIP Phenomenology group will strengthen the impact of the overall LIP programme through excellent directed phenomenological research, in collaboration with the experimental groups.

LIP will contribute to leading astroparticle physics experiments in: dark matter searches, with LZ, the most sensitive upcoming experiment, to collect data from 2020 to 2025, and in the world R&D effort for a third generation, ultra-low background, 30-70 ton liquid Xe experiment; neutrino physics, with the SNO+ scintillator phase starting in 2018 to search for neutrinoless double-beta decay, and preparing for the future large scale project DUNE, to study neutrino mass hierarchy and leptonic CP violation; cosmic rays, with AMS taking data until 2024, and with the Auger upgrade and the construction and operation of the MARTA engineering array, also paving the way for LIP's involvement in LATTES, a novel type of gamma ray detector, in collaboration with Brazil.

LIP will continue to contribute strongly to R&D for future detectors. In the next years, a detector R&D strategy towards the success of RPC and noble gas and liquid based detectors will be pushed forward. With unique expertise in the development of RPCs, we keep considerably widening their range of application. Besides further progress in helium-free slow neutron detectors, greatly needed in many areas, large TOF detectors with very good time and space resolution and a wide range of applications; and the development of sealed RPCs will surely constitute a revolution in gaseous detectors. Noble gas and liquid detectors are in increasing demand around the world (e.g. DUNE). We will pursue R&D in this area in the framework of international R&D collaborations, in particular RD51 at CERN.

In the field of health applications, LIP will conduct projects in the areas of: beam control, developing supporting instrumentation and beam diagnostics and adjustment techniques, and dosimetry; imagiology, developing image reconstruction algorithms and detectors for pre-clinical rehearsals, such as LIP's RPC-based PET scanner, with a world-record resolution, and a human-brain scanner. LIP favours the creation of partnerships and consortia with medical research institutes and companies. The hadron therapy unit at CTN/IST is of strategic importance, and we favour a collaboration with ICNAS and CTN/IST in instrumentation, image reconstruction and detector development.

LIP's strategy for space application is centered in the collaboration with ESA, and the main challenge is the participation in long-term missions, namely eAstrogam, shortlisted for the next ESA M5 mission, and the full lifecycle of the Jupiter JUICE mission. We will also reinforce the capabilities of LIP in the area of radiation hardness assurance.The recently announced decision to create a Portuguese Space Agency will be crucial to support R&D in this domain.

The LIP Computing group will continue to be a backbone not only of LIP's scientific activities, but also of the national scientific computing infrastructures. It will focus on ramping-up the National Distributed Computing Infrastructure, while operating the LIP Tier-2 Worldwide LHC Computing Grid facility and collaborating with thematic e-infrastructures and user communities from different organizations and domains. At international level, the group is starting the European Open Science Cloud hub project, with 74 major research organizations, establishing its technological

basis. LIP computing R&D activities will continue to be shaped by the participation in European projects such as DEEP-Hybrid-DataCloud (H2020) and in e-infrastructures like EGI.

LIP will continue to stimulate technology transfer by reinforcing its links with industry. LIP's competence centres on Monitoring and Control and on Simulation and Big Data will boost the collaboration with external partners. LIP aims at increasing its return to society, responding to societal challenges within our field of technological expertise. LIP will continue its mission in advanced training, contributing to the qualification of Portuguese science and innovation sectors. LIP reaffirms its long term commitment with scientific literacy, providing support to education and promoting science among the young, in collaboration with Ciência Viva, SPF, CERN and the IPPOG outreach network.

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