

## **LIP International Advisory Committee**

Meeting of 27 and 28 April 2018 in Lisbon

### **Executive Summary**

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 program 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 center for tumor 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 Centers, 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.



## Introduction

The LIP International Advisory Committee met in Lisbon on 27 and 28 April 2018 to review the 2017 results and to discuss the 2018 and long-range programme of work.

The meeting took place on the new LIP Lisbon premises on the campus of the University of Lisbon.

Committee Members S. Bertolucci (remotely connected), C. W. Fabjan, P. G. Innocenti, K. Parodi (remotely connected), L. Rolandi and M. Teshima participated in the meeting.

Prior to the meeting, Committee Members had received written reports on the work carried out in 2017 and an outline of the activities planned for 2018. The reports consisted of a general description of the individual programmes and of a detailed account of each research project, covering scope, past achievements and plans for 2018 and beyond. Funding and personnel for each project were described in detail. A Strength Weakness Opportunities Threats (SWOT) analysis was presented for each project.

Committee Members had an introductory meeting with members of the LIP Management: M. Pimenta (President), N. Castro, P. Gonçalves and I. Lopes. J. Maneira, President of the LIP Scientific Council Board, attended this meeting.

M. Pimenta welcomed the Committee members and emphasized the importance of the Committee's recommendations.

He reported that the management structure of the Laboratory had been aligned to the new legal frame, which became effective in 2017. He described the new organization of the Scientific Council, of which the membership is unchanged, but now has a President seconded by two Vice-Presidents (the Board) and a Coordination Committee where all the research groups are represented.

He also announced some changes in the appointments of the local directors in the three LIP poles.

He then provided an overview of the Portuguese and international LIP activities.

Detailed presentations on the progress of each project were given by the project leaders, followed by questions and answers. The Committee appreciated the careful preparation of the meeting and the high quality of the presentations.

In the closing session after all presentations, Committee Members had the opportunity of expressing comments of a general nature to the LIP Management and to the representatives of each project.

## Particle and Astroparticle Physics

The renewal in 2017 of the agreement between Portugal and CERN (for 10 years) and the commitment by Portugal to support the high-luminosity LHC upgrade set the frame for particle physics research for the medium and long term.

The LIP groups are indeed very present and visible in the LHC program. The experimental groups of ATLAS and CMS contribute to the upgrade of the experiments with important responsibilities in parallel with standard operation and maintenance of the apparatus. The ATLAS group has the full responsibility for the production of the new High Voltage distribution system of the TileCal hadronic calorimeter and the CMS group has the full responsibility for the readout of the barrel timing layer. In addition, they contribute to the ATLAS forward detector systems (AFP, ALPHA) in various aspects of the project and especially DCS and to the ATLAS jet trigger software. The CMS group has central responsibility in the CMS-Totem Precision Proton Spectrometer in commissioning, operation and management. More than 50 fb<sup>-1</sup> have been already collected and the first physics paper ( $\gamma\gamma \rightarrow l^+l^-$ ) has been published while several analyses are ongoing. In addition, the CMS group contributes to the ECAL data acquisition system and to the trigger system.

Both groups are very active in analyzing the data already collected. The ATLAS group is involved in analyses contributing to the measurement of the Higgs couplings (VH with  $H \rightarrow b\bar{b}$  and  $t\bar{t}H$  production),

to top quark physics (search for flavour changing neutral currents and  $V_{ts}$  coupling) and searches (new vector-like quarks). The ATLAS group participates also to heavy ion data analysis in the study of quark gluon plasma using di-jet and b-jet events. The CMS group contributes to measurements of the Higgs decay to tau tau, top decays to taus, studies for double Higgs production, search for dark matter and for scalar top, B production cross section and B rare decays, Higgs and Z rare decays to quarkonia. They have a leading role in measurements and phenomenology of quarkonium production.

A new theory group has been recently founded aggregating the former LHC-phenomenology group, the Heavy Ions Phenomenology @ LIP group and few researchers of the experimental groups. The start-up team comprises 10 researchers, located at all the three nodes of LIP, with a commitment of 5 FTEs and several students. The new group has the challenging goal to become the theory and phenomenology counterpart of the LIP experimental activity by covering all LIP related phenomenological activities including LHC proton-proton and heavy ions collisions, quarkonia, cosmic rays, dark matter and other BSM topics. During 2017 HIP focused on novel tools and observables for jet physics in heavy-ion collisions. This activity has been recognized with the award of a plenary talk at Quark Matter. In the same period the LHC phenomenology group developed several tools for global fits to top quark and Higgs boson properties, documented in three publications.

Since 2017 a new, young and motivated PI is leading the COMPASS group, which continues actively the participation to the experiment. The LIP group coordinates the full analysis of the Drell-Yan data, which gave a first hint of parton transverse momentum dependent effects. New Drell-Yan data are being collected in 2018 with a central contribution by LIP. In 2017 the LIP group contributed also to the analysis of spin dependent structure functions and the measurement of  $K^- K^+$  multiplicity ratio in deep inelastic scattering. The group continues with the full responsibility of the DCS of the experiment, which is running smoothly. They also started a very welcome collaboration with the COMPASS group in Aveiro, organizing jointly the 2019 International Workshop on Hadron Structure and Spectroscopy (IWHSS). The LIP group is involved in the preparation of a new LOI soon to be submitted.

The HADES LIP group continues the participation to the experiment in the recurrent situation of lack of funding and uncertainties due to the schedule of the FAIR project at GSI. In 2017 the group has been strengthened by the contributions of a group from IST Lisbon, whose theoretical work is of special interest to the Collaboration. The LIP group maintains and operates the present RPC wall and is involved in the design the RPC-TOF-FD, planning to start its construction in 2018. In addition, the group contributes in preparing the HADES tracking system for high-rate data taking. They continue the analysis work of the  $e^+e^-$  mass spectrum from the Au+Au collisions at 1.25 GeV/nucleon, already presented last year, aiming now at a PLB publication.

LIP participates to the spectacularly successful AMS experiment on the ISS. Due to the very high quality and statistics of the data, significant measurements of the electron and positron fluxes, flux and nuclear composition of cosmic radiation are being pursued. These results will contribute, and may even revolutionize our understanding of cosmic radiation and, possibly, Dark Matter. The LIP group concentrates on the development, implementation and maintenance of algorithms for reconstructing the electric charge and velocity of particles measured in the RICH detector. LIP also contributes to the analysis of the striking solar modulation of cosmic rays and its interpretation in terms of the Solar model. The LIP team participates to the shifts for the detector monitoring and operation at CERN.

LIP continues the successful participation to the AUGER Collaboration studying cosmic ray collisions at the highest accessible energies. The detector is being upgraded with the installation of scintillators on top of the existing water tanks and more modern electronics with the goal of increasing the sensitivity to the composition of Extended Air Showers (EASs). The LIP team had proposed the use of the RPC technology (MARTA project) to measure the muon content of the EAS. All detectors for an Engineering Array, consisting of seven modules, have been produced and the technology transferred to Brazilian Universities. The array is presently being commissioned. The LIP group is active in the analysis of the muon content of EASs with new algorithms to extract the Muon Production Depth (MPD) distribution that carries information about the mass of the primaries and of the hadronic physics of the



initial interaction. Contributing to the understanding of hadronic physics at energies significantly above LHC energies would represent a major breakthrough. The Committee encourages the Auger group to vigorously pursue this research line.

LIP has started a novel project, LATTES. The plan is to measure the Southern gamma ray sky above 50 GeV with a large field-of-view and large duty cycle array of hybrid detector units comprising two autonomous RPCs and a water Cherenkov detector. These modules provide trigger capability, background rejection and good space and time resolution. LATTES would consist of an array of these detector units covering an area of about 20,000 square meters at high altitude. The detector concept, based on the successful RPC technology developed for MARTA in AUGER, is presently being tested with several prototypes. In the near term, LATTES plans to complete the R&D phase constructing two prototype detector units and demonstrating their operation at 5000 m a.s.l. While LIP has the technology to build such detector units, the scale of the project needs a large international collaboration and commensurate funding for the large detector array. LIP has taken first steps towards forming an international collaboration. The Committee was pleased to see the development of innovative ideas in synergy with the expertise present in LIP. If the new project will advance to a real proposal with LIP taking the leading role, the involvement of resources from LIP will be large. In the view of the Committee this would imply shifting of resources presently devoted to other projects.

LIP is involved in the direct dark matter search with the LUX and LZ experiments. LUX has completed its science programme. It has published one of the world's most stringent limit on the WIMP-nucleon spin-independent cross sections at the level of  $2.2 \times 10^{-46} \text{ cm}^2$  at a WIMP mass of 50 GeV. The LZ detector is based on a 7 ton xenon TPC designed to reach a sensitivity 50 times higher compared to LUX. LZ will also search for neutrino-less double-beta decay. The construction phase has started and commissioning is scheduled to start in spring 2020. The LIP team provides four coordination positions, has full responsibility for the control system, and makes important contributions to the analysis. LZ is one of the most competitive dark matter experiments with a high potential of detecting WIMPs or setting the ultimate limit, reaching the irreducible neutrino background. The Committee is pleased to see that the LIP group is a well established and a highly appreciated member of this collaboration.

The SNO+ collaboration searches for neutrino-less double-beta decay in liquid scintillator loaded with large quantities of tellurium. The LIP group has completed the installation of the optical fiber system for the PMT calibration. The first of the two "Umbilical Retrieval Mechanism" for the calibration source insertion system has been built at LIP and shipped to SNOLAB. The LIP team has central responsibility in the calibration and data quality. Data have been taken with the initial water-filled detector for the last year. The LIP team contributes to this data analysis, searching for nucleon decay and the detection of antineutrinos. The detector will be filled with scintillator in the course of 2018. The LIP SNO+ team is considering the collaboration with DUNE, one of the major neutrino experiments of the coming decade and has established first contacts. The Committee welcomes this, being a plausible and logical next step in the growing LIP involvement in neutrino physics.

The NEXT collaboration also has the goal to search for neutrino-less double-beta decay using a TPC filled with gaseous xenon at high pressure. The LIP group of NEXT has considerable experience in the study of gas mixtures and contributes with studies of xenon doped with additives to reduce the electron diffusion without compromising the scintillation yield. This is presently the only contribution of the LIP group to NEXT, besides planning to take shifts. The Committee reiterates its concern on the long-term involvement of LIP in NEXT beyond the R&D phase, which should be clarified.

#### **Detector Developments and Medical Physics**

One of the major developments during the past year was the decision to establish in the near future a Portuguese center for tumour therapy with high-energy proton beams. LIP was one of the driving forces behind this development. This facility will provide a proton beam for research, which LIP researchers will use and which will federate a number of activities related to medical technology.

LIP contributes with several R&D projects to Medical Imaging. One group developed successfully, in collaboration with TagusPetsys, the TOFPET2 ASIC for TOF PET instrumentation. A coincidence time resolution of 127 ps FWHM has been achieved. A TOFPET with such an outstanding time resolution would represent a significant improvement in PET sensitivity. A variant of this chip will also be used for the upgrade of the CMS for its new timing layer. The use of RPCs for PET instrumentation has been extensively evaluated. An animal PET is presently being evaluated at ICNAS and operates with world-record resolution. It is in a pre-commercial stage. A human brain scanner, based on this technology, is the group's priority for the coming years. Whether this technology will be applied to a full-body human PET remains an open issue. The Committee urges LIP to complete its evaluation so that priorities can be decided between the many RPC-based projects of this inventive group. Besides PET imaging, Ortho Computer Tomography (Ortho CT) is another promising imaging method for real-time verification of the more widely used photon therapy. After extensive simulations, encouraging results were obtained with a first prototype detecting scattered photons from a phantom irradiated with energetic X-rays at a collaborating hospital. A natural extension of the system could be conceived for range verification of proton beams. Here, very promising results on the simulation and experimental detection of so called prompt gamma emitted as a by-product of proton irradiation have been obtained in the framework of an international collaboration. The Committee encourages the group to develop a work plan towards phantom studies with these imaging modalities in view of a future possible clinical translation.

LIP applies its world-class competence on RPCs also to other areas, besides medical imaging. One promising application, and of potentially great impact, is the use of RPCs, coated with Boron10 for the detection of neutrons. LIP is involved in an international collaboration to develop such detectors. Another high-priority activity is R&D towards sealed RPCs. This would be a real breakthrough and would open many novel applications.

It is clear that the RPC group is very innovative and follows a very large number of diverse projects. In the view of the Committee the group and LIP management should evaluate whether personnel and financial resources are adequate for pursuing all these efforts at a satisfactory pace.

LIP has a long-standing program in ion mobility measurements. This is a useful facility for a diverse user community needing such information on novel gas mixtures.

### Space Applications

Methods and techniques of high energy physics find applications in space missions, both to simulate and measure the effects radiation and to design and test detectors to be used in scientific space missions. LIP's expertise in simulation and detector technology give a valuable contribution to the ESA programmes, which provide most of the funding for these activities. A sizable part of the work is either in relation with specific problems of future approved (e.g. JUICE) and of proposed space missions, or in assessing the feasibility and performance of detectors for space research, as for different types of X-ray polarimeters.

### Computing

LIP has been a user of high performance computing for three decades and has promoted and supported the advancement of this technology in Portugal. The National Computing Network Infrastructure (INCD), proposed in 2016, had LIP as a major partner in its setting up, operation and evolution. LIP participates in many European projects and collaborations on high performance, grid and cloud computing, with LIP staff having leading managerial and/or technical positions.

A number of significant software developments in High Performance Computing (HPC) and High Throughput Computing (HTC) have been successfully completed.



During the past year, the performance of the computing facilities operated by LIP has again been excellent. The move of the computing infrastructure to the new premises in Lisbon has taken place without disruption; the collaboration and load sharing with the INCN has been efficient.

A point of concern is obsolescence of the installed hardware, which at the same time has to cope with an increasing demand: the challenges of the ever-increasing LHC data volume, novel, more sophisticated and CPU intensive analysis techniques, not to mention special processors, have to be addressed.

### **Competence Centers**

**Simulation and Big Data** - This competence center has been active with success for more than a year. Simulation at LIP covers primarily physics models and detector performance in the frame of Geant4, but other packages such as FLUKA and ANTS2 could be part of the portfolio. The developments of GeantV should also be monitored, in view of an efficient use of available and future computer hardware.

In the LHC context data analysis is increasingly relying on Machine Learning tools, such as deep neural networks and boosted decision trees, to extract information from the large data set. Such tools have also entered with success the trigger and on-line selection areas. On account of the power and complexity of the methods, it is mandatory to maintain the highest level of proficiency and to facilitate exchange of knowledge (and criticism).

**Monitoring and Control** - The decision to establish a Competence Center for Monitoring and Controls is viewed by the Committee as a desirable move to make available to the entire Laboratory the experience acquired by some groups in many successful and well established projects, as for instance ATLAS, COMPASS and LUX/LZ. In addition, the Competence Center represents a point of convergence for possible new collaborations.

### **Opening to Society**

The LIP ECO (Education, Communication, Outreach and Advanced Training) team has worked in the best Laboratory tradition of presenting research at LIP to the scientific community and to Society.

The highlight of the year was the organization of the CERN-JINR European HEP School in Évora with 250 participants.

The training activities, which ranges from Portuguese speaking physics teachers and industrial trainees at CERN, summer training of University students on ATLAS and CMS, Master Classes in Particle Physics and many more events, recorded an ever increasing participation.

Knowledge transfer and translating research results into industry spin-offs were also given particular attention with encouraging results.

### **Remarks and Suggestions by the Committee**

LIP is widening its base in the Portuguese scientific community. Notable developments in the past year were the Faculty of Science of the University of Lisbon (FCUL) becoming an associate of LIP, the Heavy Ion Phenomenology (HIP) group of IST joining the LIP program and LIP's leading role in establishing and operating the National Computing Network Infrastructure (INCN). In the opinion of the Committee, these events signal the consolidation of the prominent role of the Laboratory in Portuguese science.

LIP has succeeded in improving internal knowledge transfer and collaboration by setting up laboratory-wide projects and competence centers in outreach, computing services, computational methods and instrument control and monitoring. The Committee values these steps as very positive for the future development of the Laboratory. Other areas could benefit from an improved horizontal communication and collaboration, as for instance detector R&D and electronic design. The Committee strongly encourages the LIP Management to pursue its efforts along these lines.

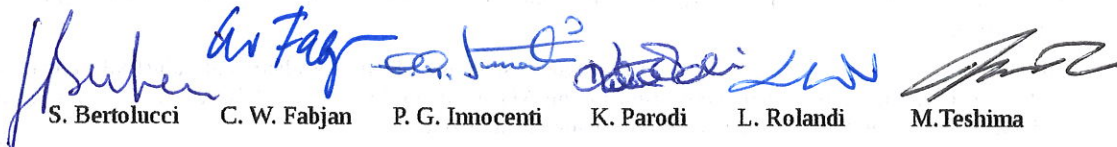
The Committee has repeatedly expressed its concerns about the fragile employment policy, which provides most researchers only with short-term contracts or grants, with unknown career prospects. The recent success of joint appointments between Universities and LIP is definitely an appreciable move in mitigating the problem of securing more stable career prospects, with the added benefit of improving collaborations in some areas of research. However, more remains to be done, especially for the senior researchers who are the core asset of the Laboratory, but have little chance of obtaining one of the very few stable appointments, which are expected to be offered by the Universities in the near future. Considering the size of LIP, its national importance and standing in Portuguese science the Committee encourages LIP's Management to advance this process for the benefit of all of science in Portugal.

LIP carries out a very significant part of the research programmes in large international collaborations, which are active for ten to twenty years or longer, from proposal, to experiment design and construction, data taking, analyses and results. This requires a perspective for a relative stability of the funding profiles for construction and operation. ATLAS and CMS have recently produced documents describing their plans for detector improvements for Phase 2 (high luminosity) of the LHC: these long range plans have met with support by the Portuguese authorities. The Committee, which has repeatedly stressed the need for a road-map for long range funding profiles, acknowledges this decision as crucial for the future of the Laboratory and hopes that this practice will be extended to other areas of LIP research.

The Committee was again impressed by the careful use of the limited financial and personnel resources with which a very broad and multi-faceted program is carried out with remarkable success. This success is one more strong motivation for collaborating with the National Agencies to further improve the alignment of the medium term funding strategy with LIP's medium and long range scientific program. This is one effective way to increase even further the efficiency of the available resources.

The Committee once again warmly congratulates LIP for its outstanding achievements:

- maintaining and enhancing its prominent position at the scientific forefront, with its researchers as leading members in international Collaborations.
- transmitting a positive and well received message to Society, through the training and outreach programmes.

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