

LIP International Advisory Committee

Meeting of 28 and 29 April 2017 in Braga

Executive Summary

The LIP International Advisory Committee met at the University of Minho in Braga on 28 and 29 April 2017. 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 with ambitious programs, 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 LUX and the follow-up experiment LZ (in USA) and the nature of neutrinos is investigated with SNO+ in Canada. This research, addressing some of the most fundamental and topical issues in particle and astroparticle physics, is conducted in large international scientific collaborations to which LIP makes essential contributions of world-class quality.

LIP has a long tradition of world-class developments of new instruments and methods for particle physics, for example, in the area of Resistive Plate Chambers. These competences are very effectively directed to another mission of LIP, applying these particle physics technologies to areas of benefit to Society. One example is LIP's ambitious program of advanced medical imaging instrumentation for diagnostics and therapy, which is very promising and could make a major impact if the prototypes under development would eventually reach clinical use. LIP contributes also in significant ways to important programs in terrestrial and space radiation monitoring.

LIP has been spearheading the employment of large computing resources needed for particle physics. This program has been very successful, leading most recently to the establishment of the National Infrastructure for Distributed Computing (INCD), which serves and benefits not only LIP but also all of the Portuguese scientific community.

LIP has always been a champion in communicating its research activities to the public. During the past year, it has reached a new level of professionalism by developing a broad communication strategy and establishing the "LIP-ECO" program (Education, Communication, Outreach).

One further positive development is the long awaited move of LIP Lisbon to new premises on the University Campus. It will provide better working conditions for the scientists, closer ties with the University and consolidation of the technical infrastructure.

Given LIP's growth and evolution over the past thirty years, it became important to review and to adapt the governance structure of the Laboratory. This process has been successfully concluded during the past year.

The Committee was very pleased to learn that new positions were established in the form of joint appointments between Universities and LIP. The Committee considers this a most effective way to foster research and education with mutual benefit to both parties.

20 June 2017

The Committee was again impressed by the careful use of the rather limited financial and personnel resources with which a very broad and multi-faceted program is carried out with remarkable success. LIP is in the process of establishing "Competence Centers", an important move to further increase efficiency and impact of the Laboratory. Aligning the funding strategy more closely to the scientific research plans of the Laboratory will arguably also result in more effective usage of the funds, a step the Committee recommends 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 for its hospitality.

Introduction

The LIP International Advisory Committee met at the University of Minho in Braga on 28 and 29 April 2017 to review the 2016 results and to discuss the 2017 and long-range programme of work.

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

Prior to the meeting, Committee Members received written reports on the work carried out in 2016 and an outline of the activities planned for 2017. 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 2017 and beyond. Funding and personnel for each project were described in detail. A Strength Weakness Opportunities Threats (SWOT) analyses was presented for each project.

Committee Members had an introductory meeting with members of the LIP Management: M. Pimenta (President), G. Barreira, N. Castro, R. Marques and A. Onofre. The secretaries of the LIP Scientific Council, P. Gonçalves and F. Veloso also attended this meeting.

M. Pimenta welcomed the Committee members, recalled the terms of reference of the Committee and emphasized the importance of its advice.

He reported that the legal frame regulating the internal structure of LIP had been updated to account for the significant developments, which had occurred over the 30 years of existence of the Laboratory. The new frame would become effective in the coming months.

He informed the Committee that the Faculty of Science of the University of Lisbon had become a member of LIP and that the long awaited move of LIP Lisbon to new premises on the campus of the University of Lisbon was imminent.

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 a wrap-up session after the 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 LIP groups involved in ATLAS and CMS contribute with high visibility and effectiveness to various stages of the LHC program. During 2016, the focus on the upgrade phase of the experiments has increased without reducing the attention on the analysis of the collected data and on the detector operation and maintenance.

In the past year, 2016, the LHC exceeded all expectations delivering 38 fb^{-1} of pp collisions. The ATLAS team is involved in the analyses of the top and bottom couplings to the Higgs boson, the search for flavour changing neutral currents in the decay of the top quark and in the search for vector-like quarks. The CMS team is involved in the search for charged Higgs and new physics in top decays, in the search for various supersymmetric particles and in the search for events with two Higgs bosons. It participates in the search for rare decays and measurement of heavy flavour production and properties, and in the search for exclusive two-photon production events in proton collisions using the CT-PPS spectrometer. Both LIP groups are also involved in analyses of Heavy Ion data and will profit of the collaboration with the new group on Heavy Ion Phenomenology, which recently joined LIP.

The excellent performance of the accelerator requires major efforts for the operation and maintenance of the two detectors. The ATLAS team contributes to the Tile Calorimeter, especially to the DCS system, the jet trigger, the maintenance and operation of the ALFA luminosity detector and to the DCS and trigger software of the ATLAS forward proton tagging detectors. The CMS team contributes to the commissioning and operation of the CT-PPS detectors, for which the LIP group has the central responsibility, also developing the new DAQ system and on the operation and maintenance of the ECAL trigger and data acquisition system.

The involvement in the upgrade is now increasing with the responsibilities for the construction being defined in the coming years. In ATLAS, the LIP group concentrates on the quality control of fibers and scintillators for the gap regions of the tile calorimeter, the new high voltage distribution system of the calorimeter and studies for the use of GPUs for use of parallel trigger algorithms in the “Jet high level trigger” system. Given their broad or leading experience in several instrumentation areas, the Committee would expect that the group take leadership in one significant upgrade project. The CMS team leads the developments of the CT-PPS Timing detectors and is involved in R&D, in collaboration with Portuguese industry provider of microelectronics IP blocks, on front-end readout systems of ECAL, High Granularity Calorimeter (HGCAL) and Barrel Timing layer (BTL). The LHC Phenomenology group has continued the studies of top and Higgs boson physics developing tools for the analysis, identifying new observables to perform tests of the Standard Model and developing new ideas to probe physics beyond the Standard Model. It is important that in the near future these new ideas converge toward physics publications in high impact journals. This group has been and continues to be very (pro)active in consolidating its role inside the Physics Department of the University of Minho.

The HIP@LIP (Heavy Ions Phenomenology @ LIP) group joined LIP in August 2016. Its field of research is the exploration of the Quark Gluon Plasma produced in ultra-relativistic heavy ion collisions at RHIC and at the LHC, with emphasis on the dynamical mechanism underlying the transition between the perturbative and non-perturbative regimes of Quantum Chromodynamics. There is ample room for collaboration with the experimental groups of ATLAS and CMS and the Committee looks forward to the exploitation of these synergies.

In 2016 COMPASS focused on the study of Deeply Virtual Compton Scattering and Deeply Virtual Meson Production. The data taking involved new detectors whose control system is the responsibility of the LIP group. These data are also relevant for the study of the semi-inclusive deep inelastic scattering on an unpolarized target, in which the LIP group is directly involved. This analysis

is important for the determination of the quark fragmentation functions. In parallel, the LIP group has led data quality monitoring and reconstruction of the 2015 Drell-Yan physics run and is now involved in the analysis of these data that is expected to be an important check of non-perturbative QCD. The LIP group continues to maintain the COMPASS DCS and adapting it to the evolving experimental and apparatus requirements.

The HADES LIP group has performed an analysis of the e^+e^- mass spectrum from the Au+Au collisions at 1.25 GeV/nucleon. Preliminary results have been shown in the open session. The LIP group is also maintaining the present RPC wall implementing tools for its calibration. They are involved in the design and construction of a new forward RPC system to cover the very low polar angles. The Committee re-iterates its concern on the long-term involvement of LIP in this experiment that suffers from lack of funding and uncertainties due to the schedule of the FAIR project at GSI.

The participation to the very successful AMS experiment on the ISS concentrates on the development, implementation and maintenance of algorithms for reconstructing the electric charge and velocity of particles measured in the RICH detector. The LIP group is also involved in the analysis of the 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: twenty detectors have been produced, six of which are installed in Auger. They will be used for the validation and in situ test of the scintillation detectors and for studies of the shower composition at lower energies. 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 in the shower. The study of the MPD helps in separating the effect of mass composition of cosmic rays from new physics effects in the collisions of cosmic rays at energies that are several orders of magnitude above the LHC energy.

LIP has started a project, LATTES, proposing a new concept to monitor the Southern gamma ray sky above 50 GeV. The innovative concept of LATTES is to build a hybrid detector unit comprising two autonomous RPCs and a water Cherenkov detector providing trigger capability, background rejection, good space and time resolution. An array of these detector units covering an area of about 20,000 square meters at high altitude could provide a detection threshold as low as 50 GeV and operate with a large duty cycle. The detector concept, based on the successful RPC technology developed for MARTA in AUGER, is presently being tested with several prototypes. Its performance is under evaluation with simulation and data. 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. 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 of an international collaboration 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 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. The construction phase has started and

commissioning is expected to begin in spring 2020. LIP makes major contributions to these experiments with the full responsibility of the control system, and important contributions to the analysis, especially in the background simulation and in the vertex reconstruction and pulse identification. 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 a 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 and is preparing the analysis of the water data that will be collected before the detector is filled with scintillator.

The search for neutrino-less double beta decay is also the goal of the NEXT experiment that exploits a TPC filled with gaseous xenon at high pressure. The LIP group of NEXT has large experience in the study of gas mixtures. They are contributing to the project evaluating the performance of charge multiplication and scintillation yields of xenon doped with additives to reduce the electron diffusion without compromising the scintillation yield. The Committee has expressed concerns on the long-term involvement of LIP in NEXT beyond the R&D phase, which is presently the only contribution of the LIP group to the experiment.

Detector Developments and Medical Physics

In a wide-ranging programme, LIP implements particle physics detector technologies in a range of applications outside particle physics.

Medical Imaging: the successful development of an ASIC in collaboration with TagusPetsyS aims at TOF PET instrumentation with sub-100 ps time resolution with the promise of a significant improvement in PET sensitivity. This chip will also be used for the upgrade of CMS of its new timing layer. The use of RPCs for PET instrumentation has been extensively evaluated. It has led to the construction of a prototype animal PET, which has been used for a series of animal studies. Whether this technology will be applied to the promising use for a full-body human PET is a major issue and the Laboratory should make a final evaluation. The Ortho Computer Tomography (Ortho CT) shows promise, based on extensive simulations. A demonstrator should be constructed to allow clinical evaluation. This would be one requirement towards commercialization, provided industrial collaborators can be found. Gamma radiation imaging also shows promise, again based on simulation. The effort should now focus on developing a hand-held camera, ready for use in a clinical environment.

LIP directs 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.

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.

Radiation Effects

LIP has a very successful program on radiation studies for space applications, covering both simulation and measurements. This work extends also to preparatory measurements for space instrumentation to be flown on possible future ESA missions. All these activities are essentially funded with contracts from ESA. In the view of the Committee a modest level of additional Portuguese funding would significantly further increase the productivity and impact of this group. LIP contributes also to national programs in terrestrial radiation surveys and monitoring.

Computing

Since its beginnings, LIP has been a driver of high performance computing. The computing group continues to be very successful: It has been the main driver of, and holds a key position in the recently established National Computing Network Infrastructure (INCD), which benefits not only LIP but also the whole of the Portuguese science community.

Performance of the computing facilities operated by LIP has been excellent, surpassing by an significant factor the good performance of the previous year. This is partly due to software improvements pioneered by LIP to exploit more efficiently the computer architectures available both locally and on the Grid.

Simulation and Big Data Competence Center

Over the years, LIP groups have acquired competence in simulation tools and in advanced data analysis software. Simulation covers primarily physics models and detector performance in the frame of Geant4, while data analysis is most demanding in the LHC context, where Machine Learning tools, such as deep neural networks and boosted decision trees, are used to extract information from the large data set.

An additional challenge comes from the efficient use of available computer hardware, where the market offers innovating architectures requiring ingenious programming techniques to enhance performance.

In these areas, an active exchange of information between groups and early tutoring of newcomers is essential. The recent establishment of a Competence Center, offering all staff access to the best information available in the Laboratory, is an efficient means of employing the intellectual and infrastructure resources and of increasing the impact and visibility of the Laboratory.

Outreach

Communicating research at LIP to the scientific community and to Society has always been a strong commitment of LIP. This culminated recently in defining a professional communication strategy and the establishment of LIP ECO (Education, Communication, Outreach) programme.

The exhibition “Particles: from the Higgs boson to dark matter”, presented subsequently in Braga, Coimbra and Lisbon in 2016 to mark the LIP 30th anniversary, had a large success, as measured by the number of visitors and by their interest.

It has become by now a LIP tradition to organize Master Classes for high school students, training for Portuguese speaking physics teachers at CERN and summer training of University students on ATLAS and CMS, with an ever-larger number of participants. The LIP Annual Report, which has undergone a major improvement of the layout in the previous edition, has been further enhanced with respect to content, readability and presentation.

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 (INCD). 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 centres in outreach, computing services and computational methods. The Committee values these steps as very positive for the future development of the Laboratory. Other areas could benefit from an improved horizontal communication, as for instance detector R&D and electronic design. The Committee strongly encourages the LIP Management to continue along these lines.

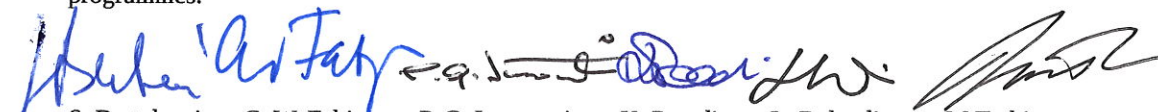
The Committee has repeatedly expressed its concerns about the fragile contract policy, which provides researchers only with short-term contracts or grants, with unknown career prospects. The recent success of joint appointments between Universities and LIP is definitely an appreciable move in mitigating the problem of securing more stable career prospects, with the added bonus of improving collaboration in some areas of research. The Committee feels that more remains to be done, especially for the mature 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.

A very significant part of the research programmes of LIP is carried out 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 needed for construction and operation. ATLAS and CMS have recently produced two documents outlining the planned participation in the detector improvement programme for Phase 2 (high luminosity) of the LHC. This prompts the Committee to reiterate their concern about the lack of a mechanism to provide a road-map for long range funding profiles.

The Committee was again impressed by the careful use of the rather limited financial and personnel resources with which a very broad and multi-faceted program is carried out with remarkable success. Aligning more closely the medium term funding strategy for LIP with its medium and long range scientific program is one effective way to increase even further the efficiency of the available resources.

The Committee warmly congratulates LIP for its achievements:

- maintaining and enhancing its prominent position at the forefront of the scientific scene, 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