7th July 2019

LIP International Advisory Committee

Meeting of 3rd and 4th May 2019 in Coimbra

Executive summary

The LIP International Advisory Committee met in Coimbra on 3rd and 4th May 2019. 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.

LIP's primary mission is the study of the fundamental laws of particle physics. The accelerator-based programme of this research is carried out at CERN, principally with the two flagship experiments ATLAS and CMS at the LHC. Cosmic rays and their astrophysics implications are studied with the world's largest array of earth-based detectors (Auger in Argentina) and on the International Space Station (AMS). Search for Dark Matter in our Universe is pursued with the LUX-ZEPLIN (LZ) experiment (in USA) and neutrino properties are investigated with SNO+ in Canada. These research programmes are conducted in large international scientific collaborations in which LIP has many leading positions, shares major responsibilities and makes first-class scientific contributions.

In parallel, LIP prepares for the future. In 2018, LIP teams continued to make significant progress with R&D and design towards the upgrade of ATLAS and CMS in preparation for the High-Luminosity LHC. The LIP teams also continue to make world-class contributions to the physics research based on LHC data. LIP has joined the DUNE collaboration on neutrino physics as a logic continuation of their SNO+ efforts and has already been entrusted with significant responsibilities. LIP is among the proponents of the new SHiP facility at CERN, proposing its RPC technology for precision time-of-flight measurements, in a programme searching for weakly interacting long-lived particles and studying neutrino physics. Noteworthy and very productive is the close involvement of LIP theorists in the interpretation of the results obtained by the experimental groups.

A second major pillar of LIPS's activities is the development of applications which have a direct and beneficial impact on society. This line profits from the competence of individuals and teams, notably particle detector R&D and construction techniques, electronics and computing. LIP's development of novel medical imaging instrumentation is one promising example. LIP also makes significant contributions to important programs in terrestrial and space radiation simulation and environmental monitoring.

LIP is maintaining its outstanding leadership in scientific computing, both internationally and within Portugal. Software developments, advanced algorithms and techniques and an excellent record of system management, performance and availability have made LIP a most welcome partner in several international projects as well as the leader in the deployment and operation of the Portuguese scientific computing infrastructure. The LIP computing teams are engaged in many important international collaborations and have again remarkably progressed in 2018.

LIP is aware of the importance of communicating science to the Public. Its staff is fully engaged in an innovative outreach programme, with an emphasis on attracting students to STEM and to particle physics, through seminars, masterclasses, internships and summer courses. The Committee considers this activity exceptional at a European level.

As noted previously, the remarkably diverse and multi-faceted research and R&D activities carry a certain

risk of fragmentation. The LIP Leadership is fully aware of this risk and during 2018 has continued their efforts in sharpening the focus. As a consequence, several activities will be brought to a logical conclusion during 2019. R&D in the medical field will concentrate on the development of a brain scanner using LIP RPC technology and on another novel imaging technique. These efforts should get a boost in view of the planned construction of a center for tumor therapy with proton beams.

Streamlining of efforts has also taken place in the study of detector properties and performance. All these actions aim at increasing efficiency in the use of the limited resources. The Committee applauds and encourages the LIP Management to pursue these lines of convergence.

The Committee was pleased to learn that the employment conditions at LIP continue to improve with the establishment of several professorships and the award of indefinite contracts. It is essential that these improvements continue, that ways are found to increase the ratio of permanent to fixed-term contracts to an international level and to provide a career perspective for young researchers.
The Committee encourages the LIP management to continue their constructive efforts in this direction.

The new management structure established in 2018 has proven to be effective. Notable achievements are the improved coordination among groups active in neighboring fields of research. The recently established Competence Centers is another fine example of improved use of human resources and competence.

LIP employs its limited financial and personnel resources with great care, which is one important factor for its remarkably successful and multi-faceted programme. The Committee is impressed by the scientific output of many research groups, despite sometimes extremely limited resources. Unsurprisingly, these restrictions are clearly limiting a number important of LIP activities.

The Committee feels appropriate to repeat its suggestion that the available 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 and engagements of the Laboratory.

The Committee congratulates the LIP directorate and the LIP staff for another exceptionally productive year with an impressive range of world-class activities. It thanks the Laboratory for the efficient organization of the review and for its hospitality.

7th July 2019

Introduction

The LIP International Advisory Committee met in Coimbra on 3rd and 4th May 2019 to review the 2018 results and to discuss the 2019 and long-range programme of work.
The meeting took place on the campus of the University of Coimbra.

Committee Members S. Bertolucci, E. Daly, C. W. Fabjan, P. G. Innocenti, K. Parodi , 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 2018 and an outline of the activities planned for 2019. The two 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 2019. Funding and personnel for each project were described in detail. Each project presented also a "Strength Weakness Opportunities Threats (SWOT)" analysis. A "Strategic Plan for the LIP groups 2018/2019" was also presented to the Committee, describing goals for the next five years and beyond. This document was a welcome answer to a former request by the Committee.

Committee Members had an introductory meeting with members of the LIP Management: M. Pimenta (President) and the LIP Directorate, N. Castro, P. Gonçalves, I. Lopes and R. Marques.

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

He reported on the governance structure of the Laboratory introduced at the end of 2017, organizing the operation of the Scientific Council with a Board, consisting of the President and two Vice-Presidents, and with a Coordination Committee where all the research groups are represented.

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

The project leaders gave detailed presentations on the progress of each of their projects, 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, 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 LHC experiments ATLAS and CMS will analyse the recently collected data. The long shutdown LS2 will be used by both accelerator and experiments for a first campaign of improvements in preparation of the high luminosity upgrade scheduled for 2026.

Both LIP groups in ATLAS and CMS achieved an impeccable record for maintenance and operation of the detectors under their responsibility during the 2018 run. They have been very productive in data analyses, which is expected to continue all along LS2. The ATLAS group contributes to crucial measurements of the Higgs properties, such as couplings (VH with H-->bb and ttH production), to top quark physics (search for flavour changing neutral currents and Vts coupling) and searches (new vector-like quarks). The ATLAS group participates also to heavy ion physics with the study of the 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. The CMS group participates also to heavy ion physics with the study of the sequential suppression of quarkonia and has a leading role in the CTPPS project, which collected more than 100/fb of data.

The LIP groups in ATLAS and CMS have major responsibilities in the upgrade programme of the experiments. The ATLAS group has the full responsibility for the production of the new High Voltage distribution system of the TileCal hadronic calorimeter. In addition, they contribute to the ATLAS forward detector systems (AFP, ALPHA) and to the ATLAS jet trigger software. The CMS

group has the full responsibility for the readout of the barrel timing layer. It also contributes to the ECAL data acquisition system and to the trigger system: it has initiated and brought to success the design and production of an advanced ASIC in collaboration with Portuguese industry.

The PHENO group, established in 2017 by aggregating the former LHC-phenomenology group, the Heavy Ions Phenomenology @ LIP group and several researchers of the experimental teams, has been very productive. Its research achievements are in line with the stated goal of being a collaborating partner to all LIP experiments, by addressing all LIP related research activities, namely LHC proton-proton and heavy ions collisions, quarkonia, cosmic rays, dark matter and certain other BSM topics.

The LIP group in COMPASS coordinates the full analysis of the Drell-Yan data, which gave a first hint of parton transverse momentum dependent effects with further information expected from the new data collected in 2018. The group continues with the full responsibility of the DCS of the experiment, which is running smoothly. They closely collaborate with the COMPASS group in Aveiro, organizing jointly the upcoming International Workshop on Hadron Structure and Spectroscopy (IWHSS) which will take place in June 2019 in Aveiro. The LIP group participates in proposals for widening the present research programme (COMPASS++) in 2021 and for a new experiment (AMBER).

SHiP (Search for Hidden Particles), a proposal for fixed target physics at the CERN SPS has been submitted and is proceeding to the technical design, It aims at detecting heavy neutrinos, dark photons and other long lived very weakly interacting particles and at studying neutrino properties with high precision, in particular ν_τ and anti-ν_τ. LIP proposes to use RPCs for precise timing in two of the detectors.

The re-installation and an engineering run of the RPC timing wall (RPC-TOF) in HADES was carried out successfully. Unfortunately, the Ag-Ag run was delayed and new data for the di-lepton analysis did not become available. The test, in a pion beam at CERN, of the prototype RPC for the forward spectrometer (RPC-TOF-FD) confirmed the design specifications, for both timing precision and efficiency. Preparation for moving HADES to FAIR is progressing.

LIP has been a member of the AMS experiment on the ISS from the beginning, contributing to the success of a range of activities: hardware, data analysis and daily operation. The very high data quality and unprecedented statistics allow significant measurements of the electron and positron fluxes and their ratio as well as flux and nuclear composition of cosmic radiation. 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 in the AMS control room at CERN.

LIP continues to assume an important role in the AUGER experiment, studying cosmic ray collisions at the highest accessible energies. The upgrade of the detectors, with the installation of scintillators on top of the existing water tanks and more performing electronics, is in progress with the goal of increasing the sensitivity to the composition of Extended Air Showers (EASs). The LIP team is also pursuing a pilot project (MARTA) using low gas flux RPCs to measure the muon content of the EAS directly. RPC modules will be installed under the water tanks to detect muons. The Engineering Array of seven RPC modules is ready for installation and tests in Malargue in 2019. Their installation will be coordinated with the AMIGA project (buried muon detectors) for logistic reasons, allowing also correlating the recorded muon signals. In the future, the MARTA engineering array will operate as a sub-detector for the study of low energy cosmic rays. The LIP group focuses on 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 represents a major challenge and an exceptional physics opportunity. Once again, the Committee strongly encourages the Auger group to pursue this research line.

LIP has been active for some time on a project, LATTES, 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. RPCs developed for MARTA in AUGER are one of the building blocks of the design. Water Cherenkov detectors have also been tested successfully at low pressure and low temperature, corresponding to high altitude conditions. Alternative projects for a large field of view telescope in the southern hemisphere are being evaluated by other scientific communities. The scale of any of these projects calls for a large international collaboration and for substantial funding. At the time of editing this report, a meeting has taken place in Lisbon, establishing the ground for a collaboration between these project proponents for R&D for such an observatory. These groups were already involved in R&D in this field, coming both from currently running experiments and from new R&D projects. This is the case of LATTES, which brings its long term and specific detector experience and of the SGSO (Southern Gamma-ray Survey Observatory) Alliance, established to discuss and to prepare a white paper with ideas and recommendations for the future of this field. The Committee encourages this development.

LIP is involved in the direct dark matter searches with the LUX and LZ experiments. LUX has been dismantled, but the collaboration continues to analyse data obtaining world-class results. The LZ detector will employ a 7 ton dual phase xenon TPC, designed to reach a 50 times higher sensitivity compared to LUX. LZ will also search for neutrino-less double-beta decay. Construction is proceeding according to schedule with commissioning scheduled for spring 2020. The LIP group holds important positions in the management of the experiment, is responsible for the control system and is heavily involved in the analysis. LZ is world-wide one of the most competitive dark matter experiments with a high potential of detecting WIMPs or setting very significant limits. LZ is also competitive in the observation of the neutrino-less double beta decay of ^{136}Xe; the LIP group has been instrumental in assessing the discovery potential of this topic. The Committee is pleased to see that the LIP group is a highly appreciated and very productive member of this collaboration despite its relatively limited resources.

The SNO+ collaboration searches for neutrino-less double-beta decay of ^{130}Te, in liquid scintillator loaded with large quantities of tellurium. The LIP group was responsible for the installation of the optical fiber system for the PMT calibration. The second and last "Umbilical Retrieval Mechanism" for the calibration source insertion system, built at LIP, was completed and sent to SNOLAB. The LIP team has central responsibility in the calibration and data quality. Data have been taken with the initial water-filled detector. The LIP team uses this data analysis, searching for nucleon decay and the detection of antineutrinos. The detector has been partially filled with scintillator in the course of 2018. In a logical move, the LIP SNO+ team has joined the DUNE collaboration in 2018, initially designing the detector calibration systems. It also participates in design and tests of prototypes.

Detector Developments

RPCs for precise timing have been in use for the last twenty years, thanks to the ingenuity and efforts of the LIP team. They have been deployed in large projects e.g. HADES and MARTA.

Due to the potential of the RPC technology, numerous new applications have been considered, studied and prototyped at LIP. R&D had to be and was consolidated in 2018 in four main areas:

- Large area timing RPCs, where the excellent record of the LIP team has paved the way to a promising participation in SHiP;

- Human brain PET, which, building on the success of the small animal PET, is considered a very significant project within reach in terms of timescale and resources;

- Autonomous sealed RPCs, which would boost the range of applications in and outside research;

- Neutron detectors, where finding an affordable substitute for ^{3}He detectors is urgent.

The Committee congratulates the LIP Management for defining priorities in this important area.

LIP has continued its programme of ion mobility measurements. This is a useful and reliable service rendered to the community, which needs such information on novel gas mixtures used in detectors.

Medical Physics

Ortho Computer Tomography (Ortho CT), detecting radiation emitted orthogonally to the incoming beam, allows real-time verification in photon therapy. Data obtained with a first prototype built at LIP, detecting scattered photons from a phantom irradiated with energetic X-rays, confirmed the performance expected by simulation.

A similar layout O-PGI (Orthogonal Prompt Gamma Imaging) can be used for range verification of proton beams in proton therapy. Promising results on the simulation and experimental detection of prompt gammas emitted as a by-product of proton irradiation (carrying information on the Bragg peak) have been obtained. Work is in progress to optimise the crystal granularity of the detectors for achieving the required spatial resolution.

The TOFPET2 ASIC for a time-of flight PET instrumentation, developed by a collaboration between the LIP CMS group and the Portuguese firm PETsys is now commercially available. As many as seven PET systems are currently being designed and built by commercial firms using this chip. PETsys is also preparing to offer a complete data acquisition for a PET setup with 500 channels.

The self-calibration of the Gamma Camera by adaptive software has been enhanced by Machine Learning techniques to remove background. A toolkit has been prepared for the software package ANTS2 to make it available on different platforms. Having successfully achieved the originally set goals the project will be terminated during 2019.

The Dosimetry group is now focusing on two objectives. In "Clinical Dosimetry", R&D on small diameter scintillating fibres dosimeters aims at Clinical Certification. The second focus, "Microdosimetry", measures the energy deposit of energetic particle beams in biological tissue at the microscopic cell level. This work is most relevant in view of the proposed Proton Therapy Facility in Portugal. The Committee supports the clear focus and both activities.

Space Applications

LIP's know-how and experience in simulation and detector technology are valuable assets for predicting and measuring radiation effects in space and for designing and testing scientific instruments for space missions.

Under contracts with ESA, the Space Application group contributes very successfully to a wide range of topics related to approved space missions. It also participates to the design of equipment for proposed future missions.

The i-Astro group contributes to the design and performance assessment of gamma ray polarimeters, for use in planned experiments such as e-ASTROGRAM, AMEGO and IXPE. Once operational, these experiments will open a new window in the electromagnetic spectrum.

Computing

LIP has continued to be a reliable partner and centre for computing, providing a complete range of computing resources to its own staff and the HEP community. It was instrumental in advancing computing technology for science in Portugal: it propelled the National Computing Network Infrastructure (INCD) to reality and is ensuring its continued operation and development. LIP is a leading participant in many European projects and collaborations on high performance, grid and cloud computing, with LIP staff having top-level managerial and/or technical positions.

Significant software developments in High Performance Computing (HPC) and High Throughput Computing (HTC) have been made, with particular attention to the efficient use of the new commercial products, e.g. GPUs. Major and appropriate attention is given to Machine Learning.

During the past year, the performance of the LIP-operated computing facilities has been excellent, delivering the full performance to the LHC users, notwithstanding the increasing failure rate of aging hardware. In this task the collaboration and load sharing with the INCD has been of great help, thanks to their newly acquired equipment. The concern about obsolescence of the installed hardware persists and requires adequate investment.

Competence Centers, Research Facilities, Training and Outreach

The idea of Competence Centres has proven to be a success, by the range of topics covered and by the number of people who have taken advantage of the expertise available at LIP.

In addition to providing technical guidance to people, the Simulation and Big Data Competence Centres has implemented specific developments of use to a wider community, as for instance software to transfer CAD files in STEP format to Geant4 or the installation of computer servers equipped with GPU co-processors. The fast deployment of Machine Learning techniques in HEP is a particular challenge, in training people on methods, their merits and limitations.

The Monitoring and Control Competence Centre has designed and implemented a software framework with a user friendly interface, which can be used by all LIP groups. It has also started new collaborations with groups external to LIP.

The Detector Lab and Mechanical Workshop produced and tested large pieces of equipment, such as MARTA chambers, but also a large number of different devices, mostly for LIP groups, but also for external customers.

The training programmes offered by LIP have targeted a large population; special attention has been given to programmes for students with the aim of raising interest in science career. In addition the by now traditional initiatives on knowledge transfer and translating research results into industry spin-offs have been pursued with success.

It should be stressed that all LIP staff carry a significant load on these "horizontal" activities on top of their primary duties in experiments. The Committee strongly supports and encourages this engagement.

Remarks and Suggestions by the Committee

LIP has consolidated its position in Portuguese science and technology by its role in establishing and operating the National Computing Network Infrastructure (INCD). Another opportunity is about to start with the imminent launch of the Proton Therapy Center, approved in 2018 by the Portuguese Authorities following a LIP initiative/proposal.

The success of the competence centers and other Laboratory-wide collaborative projects shows that this is the right way to go. The Committee feels that other areas could benefit from an improved horizontal communication and collaboration, as for instance detector R&D and electronic design and encourages the LIP Management to pursue its efforts along these lines.

The Committee continues to be concerned about the fragile employment policy, which provides most researchers only with short-term contracts or grants, with unknown career prospects. The Committee acknowledges the good progress being made with joint appointments with universities and strongly encourages pursuit of this approach. One specific concern is the status of more senior researchers who, in general, have large responsibilities in international collaborations lasting decades. Considering the size of LIP, its national and international standing, the Committee encourages LIP's Management to explore multiple routes in advancing this process. LIP ought to be one of the spearheads, ultimately for the benefit of a science and knowledge-based society in Portugal.

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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. The Committee appreciates the timely approval by the Portuguese Authorities of the detector improvements for Phase 2 (high luminosity, starting 2026) of the LHC for ATLAS and CMS as a major step in this direction. The Committee acknowledges this decision as very important for the Laboratory and for the two experiments and encourage extension of this practice to other areas of LIP research.

The Committee praises the LIP Management for the judicious use of the limited financial and personnel resources with which a very broad and multi-faceted program is carried out with remarkable success.

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

- maintaining and enhancing its prominent position at the scientific forefront by the richness of the results produced, with its researchers as leading members in international Collaborations;

- applying its expertise in research and instrumentation to areas of great societal importance together with the involvement of Portuguese industry;

- providing support and services to the community at large, as for instance in computing.

- transmitting to Society a positive and well-received message on the role and importance of science, through the training and outreach programmes.

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