ISSUE N.16, JULY 2019

LIP NEWS

DATA SCIENCE IN (ASTRO)PARTICLE PHYSICS and COSMOLOGY

When CP goes off beaten tracks

AMBER and the misteries of Quantum Chromodynamics

SHiP: search for hidden particles

Future colliders and the EPPS upgrade

HiRezBrainPET: high resolution medical imaging with RPCs

page 4

LABORATÓRIO DE INSTRUMENTAÇÃO
E FÍSICA EXPERIMENTAL DE PARTÍCULAS
partículas e tecnologia

LIP NEWS
issue n.16 July 2019

O boletim do LIP é uma edição da C4 - Comissão Coordenadora do Conselho Científico do LIP. Tem como equipa editorial Carlos Manuel, Catarina Espírito Santo, Conceição Abreu, Leonor Coimbra, Ricardo Gonçalo e Sofia Andringa.

Authors/Contributions Agostinho Gomes, Alberto Blanco, Ana Sofia Inácio, Catarina Espírito Santo, Catarina Quintans, Celso Franco, Daniel Galaviz, Fernando Barão, Grigorios Chachamis, Guilherme Milhano, Henrique Carvalho, Igor Ivanov, João Carmelino, João Varela, Jorge Gomes, José Maneira, Liliana Apolinário, Lorenzo Cazón, Luís Afonso, Luís Lopes, Luís Peralta, Mário Pimenta, Nuno Barros, Nuno Castro, Nuno Leonardo, Paula Bordalo, Paulo Fonte, Patrícia Gonçalves, Pedro Abreu, Pedro Assis, Rita Lima, Ricardo Gonçalo, Ruben Conceição, Rui Silva, Rute Pedro, Sofia Andringa, Valentina Lozza.

Design Carlos Manuel

Contacts outreach@lip.pt
www.lip.pt/boletim

EDITORIAL

Much has happened at LIP and in the world of particles in the last few month, and it was not all good, or easy.

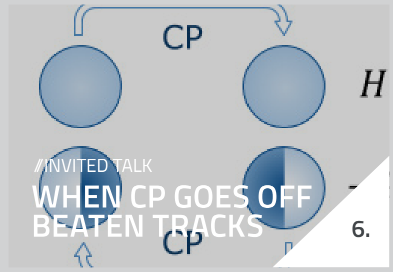
We said goodbye to Gaspar Barreira, one of the founder of LIP, who devoted to this laboratory much of his immense energy in the last 30 years. Gaspar was also the Portuguese representative in the CERN Council and in the SESAME Council, and a widely known and highly respected person in the world of particle physics and much beyond. LIP will never be the same without Gaspar — without his energy, intelligence, vision, generosity and humanity. But his legacy remains, and it is our duty to honour it and to develop it as best we can.

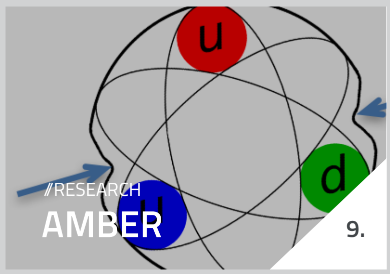
Just a few days later, the FCT evaluation of the R&D units in Portugal was concluded, and LIP was considered Excellent. In the report, the evaluation panel stated that "LIP is truly a Center of Excellence and should continue to lead particle physics research and innovation in Portugal". Let' do what Gaspar would have done with this: first, celebrate, and then take it as an incentive to always do more and better. In this Bulletin, we set our eyes on the future and dare to imagine it big and bright. We open the door and reach out and further to society, to other research centers, to industry, to universities and schools, to future experiments, to application in other areas of science and of life, aiming to create wider collaborative efforts able to help building this future. We discuss new projects and opportunities that can help us work in this direction and succeed.

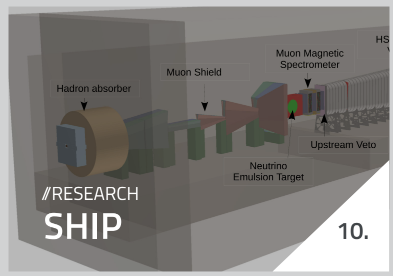
A tribute session to Gaspar with the title “Particle physics: from fundamental science to society” will be held on September 11 at LIP, in Lisbon. Registration is now open at www.lip.pt/homenagem/gaspar. It will be a full-day event guided by Gaspar’s life and vision. As such, science, technology, politics and friendship will be key ingredients.

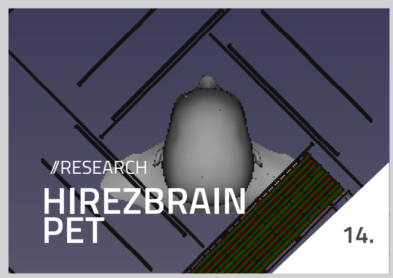
FCT Fundação para a Ciência e a Tecnologia
PORTUGAL 2020
COMPETE 2020
UNIÃO EUROPEIA
Fundo Europeu de Desenvolvimento Regional

4. DATA SCIENCE SCHOOL AND SYMPOSIUM
6. WHEN CP GOES OFF BEATEN TRACKS
8. A NEW FLAVOUR OF CP VIOLATION AT THE LHC
9. AMBER AND THE MISTERIES OF QCD
10. SHiP SEARCH FOR HIDDEN PARTICLES
11. 40 YEARS OF PHYSICS AT SPS NA
12. FUTURE COLLIDERS
14. THE HIREZBRAINPET PROJECT
16. THE NEW OBSERVATORY SWGO
17. EDDINGTON 100
18. IN BRIEF
22. EVENTS AND OUTREACH
24. ADVANCED TRAINING
26. LIPIANOS
TOP-12 FACEBOOK
AGENDA









As an outcome of the tribute session, a special edition of the Bulletin dedicated to Gaspar will be prepared later this year, putting together some of the memories (texts, photos, documents) brought to us by his friends and colleagues. Gaspar's last big project and enthusiasm, the installation in Portugal of a treatment and research center for cancer therapy with protons, is not yet accomplished. A part of the tribute session will be devoted to this — and thus to the future. At LIP, for this we will strive.

Data Science School and Symposium in Braga

Rute Pedro and Valentina Lozza

The second edition of the Data Science School and Symposium, organised by LIP, University of Minho (UM) and COST action g2net, was held in Braga, between 25 and 29 March 2019. The event has the objective to show the potential of data science in modern society and to stimulate synergies between fundamental research and industry.

The school

The first three days of the event were dedicated to the school, attended by over 80 students with a variety of backgrounds. The programme combined lectures on statistics and machine learning, in the mornings, with tutorials and a data challenge in the afternoons. It all started with the vibrating lectures of Glen Cowan (Royal Holloway, University of London), author of the book "Statistical Data Analysis", who covered the basics of statistics, the definition of confidence intervals and the various approaches such as the Bayesian and Frequentist. It was a wide subject to cover in a limited time, but the lectures were clear and highly appreciated. The challenge to present machine learning in just three lectures was given to Tommaso Dorigo (INFN and University of Padova). Despite the complexity of this fast evolving subject, the lecturer gave a satisfying overview of the various methods used and their applications. Lecture's material is available on: https://indico.lip.pt/event/557/timetable/?view=standard

The data challenge

The school ended with a data challenge, jointly organised by LIP and COST Action g2net. This year the subject were the Nobel prize winning gravitational waves. From the talk of Elena Cuoco (professor at Scuola Normale Superiore, Pisa, head of the Data Science Office at the European Gravitational Observatory, EGO and coordinator of g2net) we learned that LIGO and Virgo experiments expect very few signal events (one per week), while noise signal have a much higher frequency (up to one per second). Therefore, noise identification and classification should happen very fast in order to clean up data (and save disk space!). This is why gravitational wave's researchers have started to use machine leaning to clean the collected data in a fast and reliable way. Under the supervision of Roberto Corizzo (University of Bari), Massimiliano Razzano (Univerisity of Pisa and member of LIGO/VIRGO), and Tiago Vale (LIP), participants looked at the gravitation wave's data trying to find a predictive model for noise classification. The participants enjoyed the challenge and interesting discussions arised, but more time should probably be devoted to this in future editions.

The symposium

The last two days were, instead, focused on the connection with industry. The data science symposium gathered 114 professionals from the academia and from around 20 companies active in the data science field, ranging from technology companies to banks: IBM, Siemens, Nielsen, Bial, Altice Labs, Vodafone, Novo Banco, just to name a few. The participants spoke about the role and challenges of data science in their domain of activity and debated with the audience. Ruben Conceição opened the session with a talk presenting LIP, the experiments in which LIP collaborates, and explaining the data analysis methods involved in our research, exemplifying our

usage of machine learning. LIP was also represented by João Pina, who introduced LIP's computing infrastructures and projects, such as the Worldwide LHC Computing Grid and IBERGRID. From the academia side, we also learned from António Cunha (President of CoLab DTX and former rector of the University of Minho) about the opening of the Minho Advanced Computing Centre dedicated to high performance computing, data science and cloud computing. The Engineering and Economy and Management Schools of UM also joined the School of Sciences in this event. We learned from Nuno Palma (Bial) how data science helps in the discovery of new molecules with potential pharmaceutical properties. Rita Lima (Nielsen) and Ruben Conceição (LIP) presented the joint project, born on last year's edition of the Symposium, in which LIP researchers explore data from Nielsen's operations seeking an increased efficiency. Willem Hendricks (IBM) captured everyone's attention by showing machine learning in action: he guided us in a step-by-step machine learning application that scanned a telescope image of the night sky looking for anomalies in the stars' pattern. At the end, he even found one "alien"!

- **Roberto Corizzo,** one of the data challenge organisers, highly appreciated the opportunity to join the event and visit Braga. Roberto has already worked in partnership with a company during his university studies, for the development of solar panels, and considers that nowadays the connection with industry is very important.

- **Filipa Peleja,** Vodafone, started working in topic classification for her master degree in Computing Engineering at FCT-UNL. For her PhD she deepened her expertise and integrated a team of computer scientists at Yahoo!. Now she is a Senior Data Scientist at Vodafone, also lecturing at Universidade Nova and giving training in the field of data science in other companies as free-lancer. On her varied path, she observes that the academic training and research experience are being more and more valued by the industry, leading to a tendency of migration of professionals from academia to industry.

Many of the School participants were present and past students from the universities of Lisbon, Braga, Coimbra. Others came from abroad, some of them supported by the g2net COST action. They had the common goal of expanding their knowledge on the data science field. We collected some opinions of the event.

- **João Silva** learned about data science during his master degree at UMinho, under the supervision of Nuno Castro and António Onofre. Today he works for a company in a different sector, but decided to join the school in order to expand his knowledge on data science and widen his work prospectives.
- **Srija Chakraborty** is an Indian student doing her PhD at Scuola Normale Superiore di Pisa, Italy. Working on observational astrophysics, she is interested in learning more about machine learning and later use it in her data analysis. From the Data Science school, she highlights the hands-on sessions and the Statistics lectures: "very helpful to newcomers to the field".
- **Filipa Peres** comes from UMinho and is doing her master degree at LIP supervised by Nuno Castro and Guilherme Milhano. She is investigating Pb+Pb collisions and the dynamics by which jets of particles are affected by the quark gluon plasma, the so-called

LIP-Nielsen partnership
(Rita Lima)

I have a degree in Mathematics, with specialization in Statistics from FCT-UNL and a post-graduation in Business Administration from INDEG-ISCTE. For 16 years I was a Data Scientist at Nielsen supporting clients understanding of Nielsen methodologies. I have experience in project management, client engagement, consumer analytics and market research for retail and media clients in Europe. In the last year and a half I've been working in a Global Data Intelligence role with special focus to leverage predictive analytics capabilities to deploy proactive quality management tools. In all my roles I've used data science skills to ensure the best solutions to our clients, delivering quality, accuracy and innovation. I had the pleasure to work with data scientists from fundamental sciences. LIP has talented researchers that apply data science techniques in the day to day, that have experience in big data technologies and use computer science languages to manipulate, analyse, interpret large data sources. I find one of the biggest advantages of working with them is their critical thinking skills necessary to evaluate results in order to make decisions.

The birth of the Data Science School and Symposium series
(Lorenzo Cazón)

The idea was born in the summer 2016. At the time, I felt a kind of "motivation crisis" of students for fundamental science. On the other hand, several of my friends and former colleagues were moving out of physics to start working as Data Scientists in different companies. Not long before, our PhD student Michael Oliveira (together with another former LIP student, Luís Batalha) left physics to found his own company, in the field of data science, which later moved to Sillicon Valley). Putting all this together, I thought it would be good to show young students how fundamental physics trains you to deal with any data, complex and noisy data, in such a way that you become proficient in searching for information and finding some order in the chaos. The idea evolved to an event including a school followed by a symposium with companies, exploring the similarity of the work of a physicist and a data scientist in a company. With Ruben Conceição and Bernardo Tomé, we started contacting companies and detailing the plan. By mid 2017 we presented the proposal to Mário Pimenta, who was enthusiastic about it, underlined the opportunities this would create for joint projects with industry, and suggested it would be organized within the framework of the IDPASC PhD network - Particles, Astrophysics and Cosmology. We then contacted Nuno Castro and LIP's Data Science and Simulation Competence Center, and formed an organizing committee to start preparing the first edition of the event, held in March 2018 in Lisbon.

The 2019 edition of the school and symposium
(Nuno Castro)

After the first edition organized in Lisbon in 2018, moving to Braga and proposing to the UM to be partner of the 2019 edition was a natural choice. After all, the northern part of Portugal is well known for its strong industry and the UM to have in its DNA the relation to the productive system. Nonetheless, the second edition of a successful event is always a challenge, which was overcome in close collaboration with the Rectorate team of the University. The Rector, Professor Rui Vieira de Castro, and the Pro-rectors for Research and Projects, and Institutional Assessment and Special Projects, Professors Filipe Vaz and Guilherme Pereira, were enthusiastic supporters of the event and introduced us to several companies which accepted the invitation to participate in the Symposium. Another aspect of this year's edition was the extension of the school topics to also cover cosmology and gravitational waves. Not only this goes in the direction of IDPASC but also it gave us an excellent topic for the data challenge. From the students feedback, it's clear that this was a tough challenge but I'm very proud of how far they manage to get in solving it. In my opinion, both the School and the Symposium were very successful and from the many chats over the coffee-breaks and lunches I was convinced that the participants found it useful — I certainly enjoyed it and look forward to the 2020 edition!

When CP goes off beaten tracks

Igor Ivanov, CFTP

How does a theoretical idea beyond the Standard Model transform into a well-developed, experimentally viable model?

Igor Ivanov, FCT Researcher at Centro de Fisica Teorica de Particulas (CFTP), offers a glimpse into the model-building kitchen, telling us the story of CP4 3HDM, a multi-Higgs model he is developing with colleagues.

Who breaks CP?

The central role in this story is played by the theoretical phenomenon enigmatically labeled as CP4. This is a novel form of CP symmetry hypothesized to exist in our world. And before the story becomes too complicated, let us get back to basics and recall what the experiment tells and the Standard Model (SM) knows about CP symmetry.

Violation of CP symmetry is the fact that particle and antiparticle interactions do differ in essential ways. Although it is now a part of the standard particle physics curriculum, it remains a surprising, still unexplained feature of our Universe. It is also absolutely fundamental for our own existence. All CP-violating phenomena we have firmly discovered can be tracked down to the weak interactions among quarks, and this is the only form of CP violation which the Standard Model can accommodate. But we also know that the amount of CP violation contained in the SM is insufficient for the matter-antimatter asymmetry of the universe. A diverse experimental program across the particle physics community is being pursued to discover yet more forms of CP violation.
The quest for the origin of CP violation is a recurrent theme in many public lectures on particle physics. But here I want to put it in a slightly different perspective, emphasizing its theoretical richness. We, particle theorists, too, are baffled by CP violation. We are trying to grasp its origin and, on the way, we keep discovering novel forms of this phenomenon.

Back in 1950's, the observation of parity violation threw the particle physics community out of the comfort zone. Before that, the prevailing feeling was that any good quantum theory must be at least as symmetric as the vacuum. We insisted that the laws of any microscopic theory respect Lorentz invariance, and it seemed natural to extend this requirement to spacial reflections. But in 1957, we learned that the subatomic world does not comply with this requirement: weak interactions do distinguish left from right. We accepted the fact and, later on, incorporated parity violation in the fabric of the Standard Model. Not that we gained any profound insight why left-handed and right-handed fermions interact so differently, but at least we got used to it.

The drastic violation of parity (P) comes along with the equally dramatic violation of charge conjugation symmetry (C). The two nicely merge into the combined CP symmetry of the gauge interactions of the SM. In 1964, we learned, once again, that weak interaction violate this combined symmetry too, albeit at a much smaller level. Now theorists felt more humble than before: there was no way to nicely incorporate this observation into the structure of the SM. It was introduced in the Yukawa sector just as a numerical coefficient, without any explanation, without a hint of possible origin. The Standard Model simply gives up at this point: it can fit the fermion properties but it is completely agnostic about the origin of all these structures.

This somewhat awkward situation has not changed much since then. On the one hand, theorists are convinced that such a fundamental feature of our universe as CP violation must originate from an underlying phenomenon rather than from a play of numbers. On the other hand, in the absence of convincing experimental hints of a deeper theory, we still do not know what this phenomenon is. What theorists can do in this atmosphere of suspense is to explore all mathematically consistent sources of CP violation and develop methods to test them experimentally. This goal drives many researchers around the globe, including many members of CFTP, to construct models beyond the SM with novel forms of CP violation. One may even want to rethink what the CP symmetry actually is — and it is here that the story goes off the beaten track.

A hidden gem

One evening we were sitting with João P. Silva in a cafeteria near Técnico, enjoying some pastries and discussing mathematical intricacies of multi-Higgs models. João was always fascinated by CP and its breaking, while I had just completed the full classification of CP-symmetric models with three generations of Higgs doublets (3HDMs). João asked a seemingly simple question: what happens if one applies a CP transformation twice? Do we always get back to where we started? Particles go to antiparticles and then back to particles; so the conclusion looks inevitable. This is what we almost always assumed before, in a huge variety of models with CP symmetries. If the model has additional neutral Higgses, they can always be classified as CP-even or CP-odd (Fig. 1). This is what we encounter in the famous two-Higgs-doublet model (2HDM), and there seems to exist no other possibility.

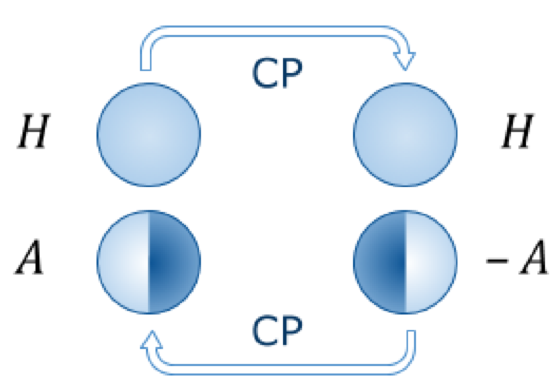


Figure 1

// INVITED TALK

But is it always true?

I had the 3HDM classification at my fingertips and immediately answered: "Well, I have an example where it does not hold." In this example, you would need to act with CP transformation four times, not two, to return to the beginning. A particle first turns into "something else", which then turns into minus particle, then to minus "something else", and finally, at the fourth step, back to the initial particle (Fig. 2). You are back to where you started, but in four steps, not two.
To be fair, theorists already knew about this mathematical peculiarity since long ago. But there was no specific example of a model in which this CP symmetry of order 4 (hence CP4) would play a central, constructive role. It was even mentioned in the classical textbook on quantum field theory by Steven Weinberg, only to conclude that "No examples are known of particles that furnish unconventional representations of inversion, so these possibilities will not be pursued further here."

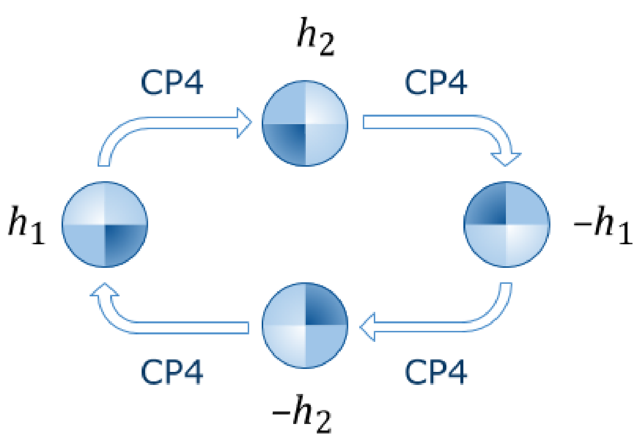


Figure 2

The life of a model

Now we had such a model with three Higgs generations, and we decided to sit down and explore it in some detail. The new Higgs particles emerging in this model were quite unusual: they were neither CP-even nor CP-odd but CP-half-odd, in the sense that you need a pair of them to build a CP-odd object. We also saw that these Higgses come in pairs which are degenerate in mass and that the lightest pair must be stable. We automatically get a pair of dark matter candidates stabilized by an unconventional CP. Very peculiar, but nothing which would contradict experiment. In fact, as we understood later, the dark matter evolution was in many aspects similar to a duplicated version of the inert doublet model, a famous 2HDM example with scalar dark matter candidates studied in hundreds of papers. But in the asymmetric regime, the dark matter evolution looks rather non-standard, with extra features originating from CP4.

We had a nice model based on the exotic CP symmetry, but only within the scalar sector. Can one extend CP4 to fermions? This is a necessary step if one wants to build a full model based on this symmetry feature. In several papers coauthored with colleagues from Sweden, Mexico, and Portugal, we showed that it can be done, both for quarks and for neutrinos. However, CP4 must be spontaneously broken in this case — otherwise, we would get mass-degenerate quarks. But spontaneous breaking of a symmetry is nothing new, it can be easily triggered by the Higgs potential. A scan in the parameter space revealed many points with the correct quark masses, mixing angles, amount of CP violation, as well as the meson mixing parameters. Later on, others picked up the topic and demonstrated, for example, that CP4 can help resolve the so-called strong CP problem.

This sounds like a success story: a predictive and phenomenologically rich multi-Higgs model emerged from the single CP4 symmetry requirement. It differs in a specific way not only from the SM but also from other multi-Higgs models. What's more important is that these differences are correlated because they originate from the same phenomenon. One can now explore them in many ways trying to verify in experiment whether the CP violation in our world indeed comes from CP4 rather than the usual CP.

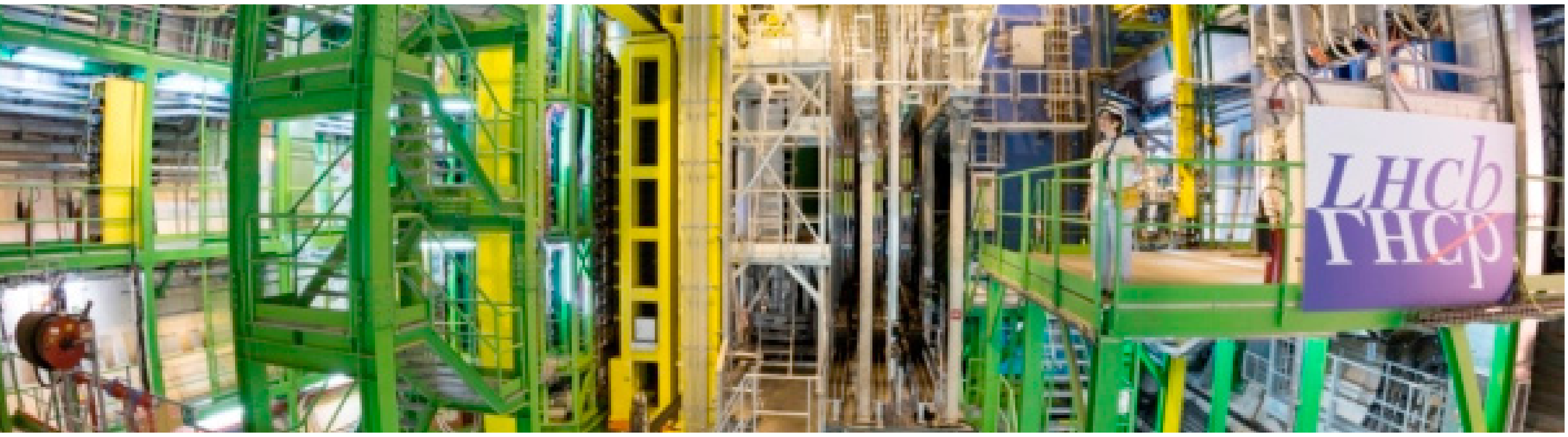
However, the life of a model-builder is not that easy. There are many dozens of experimental constraints which any new model must pass. Our first scan agreed with the quark properties but, as we found later, it predicted rather light charged Higgses, which can be copiously produced in top-quark decays. The predicted signals were incompatible with the recent LHC constraints, which means that those parameter space points do not really lead to an acceptable model. Thus, the scan must be repeated, and one needs to cleverly select a regime which avoids light charged Higgses — not an easy task when several sectors of your model are correlated! Fortunately, the exploration has just begun, and there remains large room for acceptable versions of this model.

Igor Ivanov graduated from Novosibirsk State University, Russia, and got his PhD in Bonn in 2002. At present, he is an FCT Investigator at CFTP. He explores New Physics models with extended Higgs sectors, studying their mathematical aspects and phenomenological consequences.

A new flavour of matter-antimatter asymmetry at the LHC

// RESEARCH

Based on the CERN presss released issued March 21 2019



Matter-antimatter asymmetry in the Universe is one of the grand open questions in particle physics, and the experimental searches for CP violation are many and varied. In this article we highlight a recent result from the LHC: the LHCb collaboration presented the observation of CP violation in D^0 mesons. This result establishes for the first time the observation of CP-violation involving the charm quark.

A CP-symmetry transformation swaps a particle with its mirror image, or antiparticle. CP violation means that particle and antiparticle interactions are different, creating an asymmetry between matter and antimatter. This is a still puzzling but essential feature of our Universe, necessary to explain the fact that today we live in a matter-dominated world.

The invited talk in this Bulletin, by Igor Ivanov, tells us about CP violation from the model-builder's perspective. Before going into that, the author provides a nice summary of what experiment tells us and the Standard Model (SM) knows about CP symmetry. The author reminds us that the amount of CP violation contained in the SM is insufficient for the matter-antimatter asymmetry of the universe, and that a diverse experimental program is being pursued to discover yet more forms of CP violation.

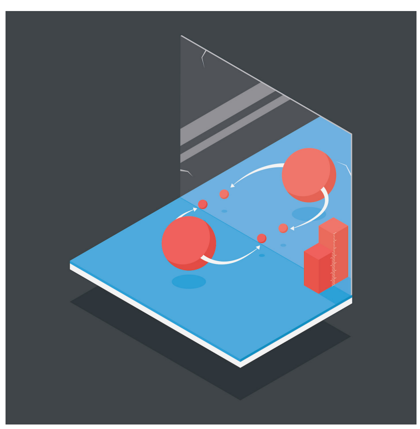
So far, CP violation has only been seen in the quark sector. More specifically, in particles containing a strange or a bottom quark. These observations have confirmed the pattern of CP violation described in the SM by the so-called Cabbibo-Kobayashi-Maskawa (CKM) mixing matrix, which describes how quarks of different types can transform into each other via weak interaction. However, the deep origin of the CKM matrix remains unknown. And, again, additional sources of CP violation are required to explain the asymmetry.

The D^0 meson is made of a charm quark and an up antiquark. The LHCb collaboration recently presented the observation of matter-antimatter asymmetry in D^0 mesons. This result, which comes after decades of experimental search, establishes for the first time the observation of CP-violation involving the charm quark, and the first one involving an up-type quark (charge +2/3), as both s and b are down-type quarks (charge -1/3). It thus adds new elements to the exploration of these questions.

The LHCb result is based on the full dataset delivered by the LHC between 2011 and 2018. Decays of the D^0 and of its anti-particle into a pair of kaons or pions have been identified and counted. But how can we take perfectly identical pairs of light mesons and tell whether they come from the decay of a D^0 or an anti-D^0? For that, LHCb physicists had to considerar particular D^0 (and anti-D^0) production modes: a D^0 can be produced together with a positively charged pion from the decay of an D^{*+} meson. On the other hand, an anti-D^0 can be produced together with a negatively charged pion from the decay of a D^{*-} meson. Spotting the charge sign of the accompanying pi meson thus tells us whether we are "looking" at a D^0 or anti-D^0 decay. In a similar way, the decay of a B^+ meson can produce D^0 together with a positive muon and a neutrino; while the decay of a B^- can produce and anti-D^0 together with a negative muon and an anti-neutrino.

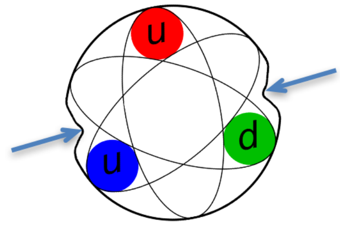
The unprecedented amount of data provided the required sensitivity to spot the tiny amount of CP violation expected for such decays, which translates into a tiny difference between the number of D^0 and anti-D^0 decays: ΔA_{CP} = (-0.154 +/- 0.029) %. The result has a statistical significance of 5.3 standard deviations, exceeding the threshold of 5 standard deviations generally used by particle physicists to claim a discovery.

This represents the first observation of CP-violation with charm quarks, inaugurating the study of CP violation in the sector of up-type quarks, and and searches for new physics effects using charm CP asymmetry measurements. It will stimulate theoretical work to assess its impact on the CKM description of CP violation built into the SM, and will open a new window to search for possible sources of CP violation using charmed particles.

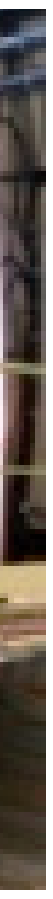


The LHCb collaboration has observed a breakdown of CP symmetry in the decays of the D^0 meson and its antimatter counterpart, the anti-D^0 (represented by the big spheres), into other particles (smaller spheres). The extent of the breakdown was deduced from the difference in the number of decays in each case (vertical bars, for illustration only (Image: CERN)

AMBER and the mysteries of Quantum Chromodynamics



Catarina Quintans



AMBER, Apparatus for Meson and Baryon Experimental Research, is a new CERN project. More than an Experiment, it is a multipurpose facility for QCD studies, a platform for experimental studies related to Quantum Chromodynamics.

The project resulted from the versatility of the M2 beam line, its unique high energy muon beam (160-200 GeV), as well as charged hadron beams with energies that can range from 20 to 280 GeV. The AMBER philosophy is identical to the one followed by its predecessor experiment, COMPASS: a modular detector that can adapt to a large variety of physics topics, each with specific requisites.

But AMBER is not COMPASS. It emerged from the need to answer newly formulated questions on hadron structure and spectroscopy. For that, several new detectors, based on recently available technologies or that constitute themselves research and development projects. With a supporting community of 270 physicists, AMBER puts together COMPASS groups as well as new ones that are simultaneously preparing other far future projects like the Electron Ion Collider in the USA, and groups finishing other experiments like SeaQuest at FermiLab.

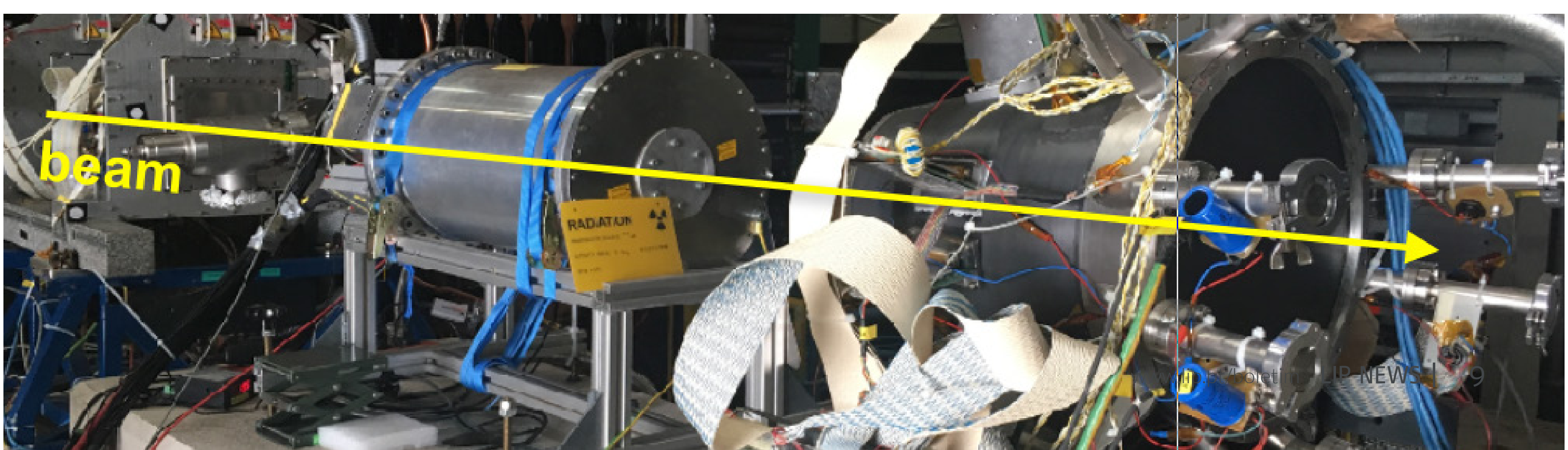
The physics programme shall progress in consecutive phases, starting immediately after the completion of the approved COMPASS-II measurements (end of 2021). The highest priority is the high energy muon elastic scattering on a proton target, a precise measurement that aims at answering the proton charge radius puzzle using a new technique. The proton radius is roughly 1 fermi, a fact described in any basic physics course. The crisis arose in 2010, when muonic hydrogen measurements performed with unprecedented precision revealed a stricking disagreement with the previous measurements obtained from atomic spectroscopy techniques. The discrepancy still remains at the level of 5 sigma. Although the expected statistics from the AMBER measurement will not be enough to answer the question per se, the systematic uncertainties anticipated are very different from those affecting previous measurements, which is clearly advantageous.

Very precise measurements of well-known and understood processes, like the antiproton hadro-poduction cross section, may be decisive in the new physics searches. The so-called Dark Matter, that constitutes one quarter of the contents in the Universe, is one of the components that still remains unknown. It should manifest itself via the extremely rare weak interactions of the Dark Matter particles, that decay or annihilate into other well-known ones. Dark Matter searches look for evidence of an excessive production of antimatter, like positrons or antiprotons, that may be observed at the largest scale available laboratory, Space itself. But definig an excess depends on the precise measurement of the reference process - in the case of antiprotons, their hadro-production. AMBER proposes an energy scan, complementary to another that will be done at LHCb but at much lower energies.

Another main topic in the AMBER physics programme is meson structure. The hadron mass hierarchy is an essential aspect in the understanding of Quantum Chromodynamics. The dynamics of quarks and gluons inside the pion or the kaon is forcely very different from that of those inside the proton, and from this difference results their extremely different masses: from the almost-null mass of the pion to the extremely massive proton. Our poor knowledge of the pion structure comes from pion-induced Drell-Yan measurements (a quark-antiquark annihilation process, with production of a lepton pair in the final state) done more than 30 years ago. AMBER proposes new very precise measurements of pion-induced Drell-Yan.

In the longer term, a modification of the M2 beam line (using unique techniques being developed at CERN) will allow for high intensity and energy separated charged kaon and antiproton beams. The kaon-induced Drell-Yan process will provide a first ever experimental access to the kaon structure. Additionally, these kaon beams will open a new opportunity window to do hadron spectroscopy in the strange sector, and unique searches for exotic and hybrid hadrons (variants of the well known quark-antiquark or three-quark bound states). The Drell-Yan events produced from antiproton beam, on the other hand, will provide an access to the dynamics of partons in the nucleon with minimized systematic error.

AMBER results from a synergy of diverse physics interests that use a single fixed-target detector, with a modular and versatile concept. It proposes to explore unique aspects of Quantum Chromodynamics, in a phase space complementary to that accessible by collider experiments. AMBER offers the opportunity, nowadays rare in experimental particle physics, to design and implement a detector concept, perform the measurement and analyse results in a humanly reasonable time scale - and that is one of the reasons that motivates us to pursue this physics.



SHiP: Search for Hidden Particles

Celso Franco

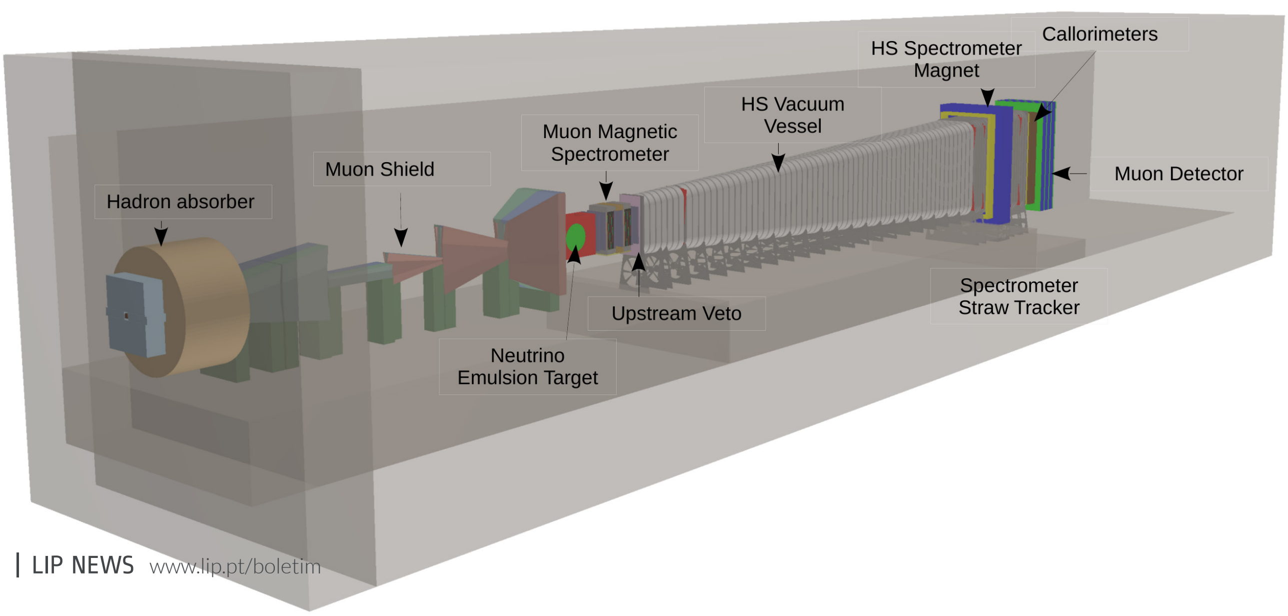
The SHiP experiment is being designed to search for extremely feebly interacting, relatively light and long-lived particles, at the intensity frontier. The experiment will be located in a new beam dump facility at CERN where it will use the high-intensity beam of 400 GeV/c protons from the SPS accelerator.

An expression of interest was submitted to the SPS Committee in 2013, the subsequently formed collaboration submitted the Technical Proposal and the Physics Proposal in 2015, with the latter accumulating more than 350 citations. Presently SHiP is a CERN recognized collaboration of about 300 Physicists from 54 institutes and 18 countries. The experiment is expected to be approved by middle of 2020 to start taking data in 2027. The main goal of SHiP is to explore the so-called Hidden Sector of Particle Physics in a region of phase space that is not accessible to LHC experiments.

The discovery of the Higgs boson at the LHC in 2012 made the Standard Model (SM) of elementary particles complete. For the particular value of the Higgs mass revealed by the LHC, the SM remains mathematically consistent and valid as an effective field theory up to a very high energy scale, possibly all the way up to the Planck scale. Nevertheless we are certain that the SM does not represent the full picture of the quantum world. For instance, it cannot explain some well established observational phenomena: neutrino masses and oscillations, dark matter, baryon asymmetry of the Universe and inflation. The fact that no convincing signs of new particles have been found so far suggests that they are either heavier than the reach of present day accelerators or that they interact very weakly. SHiP will address these topics by searching for new particles with masses much lighter than the electroweak scale that may couple feebly to the SM fields. These so called "portals" can mediate interactions between the SM and Hidden Sectors. Depending on the spin of the mediator, there are three classes of portals mixing with the SM particles: scalar portal, neutrino and vector portal. The SHiP experiment is sensitive to all these portals.

The golden portal of SHiP is the neutrino portal. The experiment will be a neutrino factory as a result of its huge Open Charm production: a total annual yield of 4×10^{19} protons on target will produce more than 10^{18} Open Charm mesons. The left-handed neutrinos of the SM, resulting from the decays of Open Charm and Open Beauty mesons, can mix with hypothetical right-handed neutrinos via Yukawa interactions made possible by the Higgs field. The existence of these right-handed neutrinos, called Heavy Neutral Leptons (HNLs) or "sterile" neutrinos (no electric, strong or weak charges), could simultaneously explain the origin of neutrino masses, the baryonic asymmetry of the Universe and the nature of dark matter. The addition of 3 HNLs to the SM list of elementary matter particles is in fact the simplest extension of the SM model capable of explaining a wide range of phenomena beyond the SM. This SM extension is called the Neutrino Minimal Standard Model (νMSM). According to the model the neutrino masses are generated by their mixing with two HNLs via the so-called seesaw mechanism (meaning that the HNL masses must be significantly bigger than the neutrino ones). If the two HNLs have a degenerate mass of the order of 1 GeV/c^2, their oscillations can generate enough leptonic asymmetry to explain the observed baryonic asymmetry of the Universe. The model then predicts the existence of a third HNL, with a mass of the order of 10 KeV/c^2, with a mean lifetime much longer than the age of the Universe. Its predicted abundance makes this particle an ideal dark matter candidate. The radiative decay of this last HNL implies the emission of a photon with an energy of about half the HNL mass. In 2014 unidentified lines in the X-ray spectra of the Andromeda galaxy and Perseus galaxy cluster were reported. The energy of these lines is about 3.5 keV and they provide a strong support to the νMSM hypothesis.

At SHiP, the heavier HNLs can be cleanly reconstructed by detecting their decays into SM particles. These particles are long-lived and travel many tens of meters before decaying. Therefore, the spectrometer is being designed to maximise their production and subsequent detection in a zero background environment. This is accomplished as follows: all hadrons produced in a titanium-zirconium doped molybdenum target are absorbed by a 5-meter magnetised absorber; the muons are deflected by a 35-meter muon shield located after the absorber and, after a neutrino emulsion detector, the spectrometer includes a 50-meter vacuum vessel located in a region where the Hidden Particles are expected to decay. The vacuum is required to minimise possible contaminations resulting from neutrino interactions. The products of the Hidden Particle decays are reconstructed and identified in the Hidden Sector spectrometer following the vacuum vessel. An important component of this spectrometer is a 50 m^2 timing detector, crucial to reject the residual combinatorial background. Currently the LIP group is providing the best solution: an RPC-based detector with an efficiency of 98% and a time resolution of 50 ps over the whole detector size. At the entrance of the vacuum vessel a veto detector is also needed to reject events originating in neutrino or muon deep



inelastic scattering in the preceding muon detector. The LIP group is presently the only candidate to build a 300 ps RPC covering an area of 10 m^2.

The LIP group is also contributing to the development of Physics simulations, with a particular focus on the ALP (axion-like particle) decay in two photons, ALP $\rightarrow \gamma\gamma$. The detection of such a channel, for ALP masses of about 1 GeV/c^2 would mean that SHiP would be recreating part of the reheating phase of the early Universe and providing insights into its inflationary period. The LIP group is involved in both the implementation of the generator in the official software and in the reconstruction of the photons direction in the electromagnetic calorimeter (essential for a precise reconstruction of the ALP mass).

SHiP will also search for other important possible Hidden Particles. Considering the vector portal, the experiment will make use of its huge photon production (over 10^{20} photons in 5 years) to search for its dark counterpart: the dark photon. This massive particle is predicted to mix with the SM photons and it can decay either to dark matter particles or to SM ones. Using the neutrino detector SHiP is able to detect interations between light dark matter particles, resulting from dark photon decays, and electrons. Due to its micrometric precision the detector is capable of providing a clear distinction between light dark matter and neutrino interactions. In the region from a few MeV/c^2 to 200 MeV/c^2 the SHiP sensitivity reaches below the limit which gives the correct relic abundance of dark matter. The decays of the dark photon into SM particles could also be detected by the Hidden Sector spectrometer. Concerning the scalar portal, a wide variety of light scalars will also be searched for at SHiP in rare decays of Open Beauty mesons. Finally, SHiP will also search for light suppersymmetric particles such as the neutralino and the sgoldstino. The latter is regarded as the longitudinal component of the gravitino, the superpartner of the gravitron, and its detection would unambiguously probe the supersymmetry breaking scale up to 10^7 GeV.

While SHiP is being designed as a discovery experiment, it also includes a rich tau neutrino physics program, neutrino-induced charm-charm production and the study of the proton structure with neutrino beams. The ν_τ result from the D_s decays: more than 10^{16} ν_τ are expected to be produced over a period of 5 years. SHiP will be able to detect for the first time interactions involving anti-ν_τ. Several thousands of ν_τ / anti-ν_τ interactions are expected to be detected, allowing for the first measurement ever of the F_4 and F_5 structure functions of the proton. The Lepton Flavour Universality will also be tested by exploring the anomalous magnetic moment of ν_τ down to 1.3 X 10^7 μB. Moreover, no charm candidate from ν_e and ν_τ interactions has ever been reported. Therefore all the studies on charm physics performed with neutrino interactions will be updated with improved accuracy, and some channels inaccessible in the past will be explored. This includes the double charm production cross-section and the search for pentaquarks with charm quark content. Charmed hadrons produced in neutrino interactions are also important to investigate the strange quark content of the nucleon. The statistics available at SHiP will improve on the knowledge about the nucleon strangeness by at least a factor of two. New physics will also be explored with ν_τ: the third generation of leptons may be more sensitive to new physics effects because of their larger masses. In particular, SHiP will search for evidence of charged higgs, W' and leptoquark contributions to the ν_τ scatterings. Due to a combination of an emulsion detector with muon magnetic spectrometer SHiP will be capable of separating all six neutrino/anti-neutrino interactions.

The LIP group is growing quite fast but there is still room to accommodate enthusiasts wanting to enter the SHiP.

CERN celebrated the 40 years of Physics in the SPS NA

Fixed-target experiments have a long history at CERN. Notable among them are those fed by the Super Proton Synchrotron (SPS), which has provided high-energy proton beams to the North Area (NA), at the CERN Prévessin site, for over 40 years, feeding a wide variety of experiments. The first physics paper from an experiment in the North Area – a measurement of the production rate of muon pairs by quark–antiquark annihilation – was published in 1979 by the NA3 experiment. As the North Area marks 40 years since its first physics result, CERN celebrated with a symposium on April 3 2019.

The SPS NA was the scene of many important activities for Portugal. Three of the future founders of LIP did their PhD in the NA10 and NA14 experiments (João Varela, Paula Bordalo and Sérgio Ramos). During the period from 1986 to 2002, LIP had a significant participation in the experiments NA38, NA50 and NA51. Already in the 21st century, since 2004, LIP participates in NA58 (COMPASS). During the 1990s, tests for detectors of future LHC experiments were performed in some dedicated North Area beam lines.

On the conference link (https://indico.cern.ch/event/800748) one can access the (historical) slides presented by the various speakers, among them Daniel Treille, Dietrich Von Harrack and Cristina Lazzeroni, collaborators of some LIP researchers. The conference ended with a round table where questions on the future program were raised, followed by a party.

Photo: Paula Bordalo was present at the 40 years of the SPS symposium at CERN

Eyes set on the future

Update of the European Strategy for Particle Physics

Ricardo Gonçalo

As the CERN LHC collider reaches cruising speed, the European Strategy Group is preparing a new update of the European Strategy for Particle Physics. This will define the landscape of this field of research for years to come, setting the scene for the next major advances in our understanding of particle physics.

Forefront particle physics experiments have reached a size and complexity that was simply unthinkable a few generations ago. These go from giant accelerators, of which the LHC is the current exponent, to detectors occupying huge areas in remote locations in the Argentinian Pampa or the South Pole, to experiments buried in deep, background-free mines, or installed at the edge of the Earth's atmosphere, in the International Space Station.

Building such experiments pushes the edge of human technological ability and demands a huge investment of effort and money, and, of course, careful planning. It is not easy to guess where the next significant discovery is going to emerge, what investment is more worthwhile, what technology will have more far-reaching impact. Vision and inspiration also don't come from the vacuum, but are instead fed by knowledge and much debate. This is why the CERN Council has set up a Strategy Group in 2005, with a mandate to review and address the main lines of Particle Physics in Europe; accelerator-based and non-accelerator based, including R&D for novel accelerator and detector technologies.

The first document outlining the European strategy for particle physics was unanimously approved in a special Council meeting, held in Lisbon on the 14th of July 2006. Gaspar Barreira, director of LIP, was the Portuguese representative in the Strategy Group, led by Thorsten Åkesson and Ken Peach. The document touches on all areas of particle physics, the interface with nuclear physics, R&D on enabling technologies and the connection with industry, as well as the visibility of this research and its outreach to society. Its first update, in 2013, was developed in coordination with similar debates throughout the world, to guarantee the optimal use of resources in the global particle physics endeavour.

The second update of the European Strategy is now approaching, and the stakes are high. The particle physics world community must decide on what are the right priorities and projects, that will allow the field to flourish, to continue to benefit society, to train future scientists, and to continue to uncover the fantastic world of the infinitely small. To achieve this, there has been a lot of R&D for ambitious post-LHC accelerator facilities, including fixed-target experiments. Europe is also fully engaged, through CERN, in a global neutrino programme, with next-generation experiments planned in the US and Japan. And a lot of other related studies are ongoing, ranging from dark matter physics, to computing, wakefield and other acceleration technologies, detector technologies, muon colliders, etc.

One of the crucial questions is which large facility will be the future flagship of collider-based particle physics. And there are many contenders! This choice is very much tied to the type of physics priorities that emerge from our current explorations. An e^+e^- machine, for example, could be operated as a Higgs factory for precision studies of this particle, or be aimed at di-Higgs production, a Holy Grail of this area of physics that the LHC will only be able to identify, but not study in detail. But even here there are many different choices: between different acceleration technologies, linear or circular colliders, where to build them and how to raise the necessary funds. Hadronic machines such as the FCC-hh, colliding protons and heavy ions, can be a more natural "discovery machine", since they naturally scan a wide range of new particle masses. But they currently seem a longer-term goal, requiring a greater investment and technological development. The main difficulty is in building the high-field magnets needed for such machines, an R&D project that has been evolving at CERN for several years and has already led to initial prototypes.

In the discussion of all these plans, there is a wide consensus that a large facility must succeed the LHC, allowing us to probe further into the secrets of Nature. But there are many other issues on the table, beyond what will be the next big collider: several choices exist for future fixed-target experiments, such as SHiP and AMBER at CERN, with different physics goals and a time scale similar to that of the LHC. These will study the strong force between quarks and gluons in matter at the huge densities present in the Big Bang, or search for new particles and connections with dark matter. Developing or planned long baseline neutrino experiments such as DUNE in the US and Hyper-Kamiokande in Japan will study neutrino physics in detail, searching for example for a much needed new source of CP symmetry violation, to explain why our current universe is made of matter and has no significant amount of antimatter.

The strategy of a global area such as particle physics must also be coordinated not only with plans in other continents but also paying close attention to interface areas. The FAIR facility in Germany will soon explore the interface between particle and nuclear physics; the global roadmap for astroparticle physics has recently been updated and touches issues from dark matter to neutrino and cosmic rays, gamma-rays, gravitational waves and dark energy. More and more, science is a global journey, and the cross-fertilization of different areas is more rapid and more productive.

And why is all this important? Because so many fundamental questions are before us and, perhaps, within our reach. As a species, we have a chance of understanding Nature at a level of detail never reached before. We can now use the Higgs boson as a tool for probing new physics, find what lies behind the small neutrino mass, understand the nature and physics of dark matter and dark energy, search for a new, deeper theory that must underlie the Standard Model, and so much more.

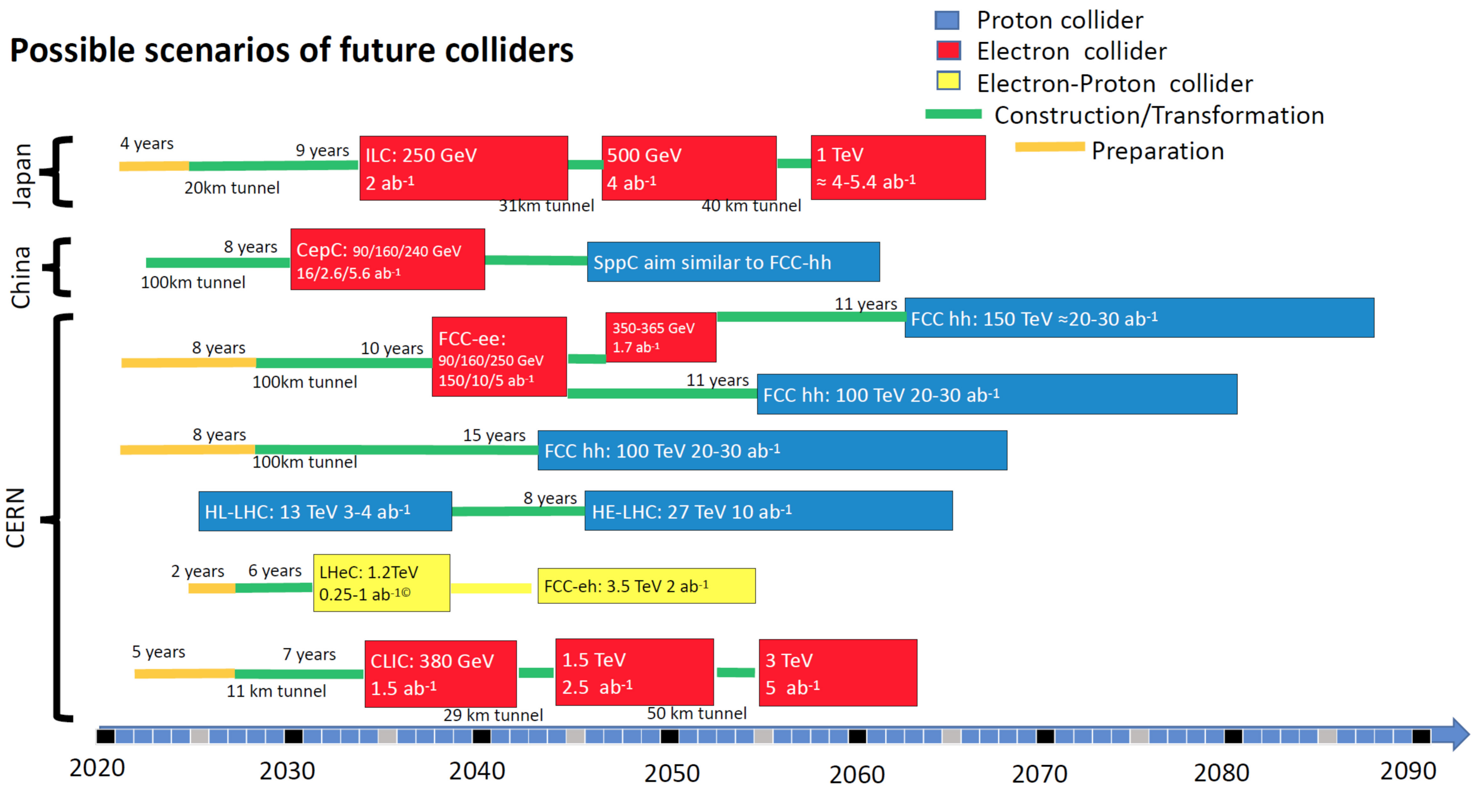
Most likely, not all of these goals will be achieved. But if we have a chance to do it, then for sure we must try! And this is the essence of the discussion: to find the optimal way for all this activity to result in future knowledge, to provide the right tools to future students and researchers, that will take us one step further in our understanding of our Universe at the infinitesimal scale.

References:

http://council-strategygroup.web.cern.ch/council-strategygroup

The Next Big Collider

There are many contenders in the race to succeed the High-Luminosity LHC (HL-LHC). One is known as the Future Circular Collider (FCC, see image). This is a 100 km long, 100 TeV circular collider to be built at CERN in a series of successive incarnations: the FCC-ee, FCC-ep, and FCC-hh, which will run with e^+e^-, then $e^{\pm}p$ and finally pp and ion collisions, respectively. A close competitor is the Circular Electron Positron Collider (CepC), a large e^+e^- collider, to be built in China, to be later followed by a hadronic collider. And there are different options for a linear e^+e^- collider: the International Linear Collider (ILC), to be built in Japan, with energies up to 1 TeV, and the Compact LInear Collider (CLIC, the name is slightly misleading) to be built at CERN, to run with energies up to 3 TeV. An intermediate solution also exists, the High-Energy LHC (HE-LHC), to use pre-production FCC-hh magnets to reach higher energy in the LHC tunnel. And there are other possibilities, such as the idea of accelerating muons, which is very challenging but avoids the important difficulty in circular e^+e^- colliders that beam energy is lost through synchrotron radiation; or an electron-ion collider (EIC) aimed at the detailed understanding of the mass and spin of nucleons.



The HiRezBrainPET project: high resolution medical imaging with RPCs

Paulo Fonte and Catarina Espírito Santo

The **HirezBrainPET** project, financed by the "Sistema de Incentivos à Investigação e Desenvolvimento Tecnológico (SI I&DT) – Portugal 2020" program, is a co-promotion between ICNAS-Produção Unipessoal, Lda. (ICNAS-P), a radiopharmaceutical production company wholly owned by the University of Coimbra and project leader, with LIP and Instituto Politécnico de Coimbra as scientific partners.

The project aims to develop an innovative PET scanner dedicated to the human brain with sub-millimeter spatial resolution using Resistive Plate Chambers as active medium (RPC-PET).

PET: what and what for?

Today, medical imaging plays a crucial role in early diagnosis, therapy planning and monitoring, as well as in medical research. Among the different imaging techniques, Positron Emission Tomography (PET) stands out as one of the most powerful. PET is based on the injection to the organism of a biologically-active tracer molecule containing a positron-emitting radioactive isotope (for example, fludeoxyglucose, an analogue of glucose, containing fluorine-18). In practice, these radioactive molecules take part in specific biological processes, accumulating in the location at which these processes occur. Their distribution thus maps quantitatively the intensity of such processes, revealing not the morphology but the physiology. The positron annihilates close to its emission point, originating most of the time two nearly-collinear photons with an energy of 511 keV. The PET scanner detects the pairs of gamma rays emitted when positrons annihilate. The detection of each photon pair defines a line, and from the millions of response lines one can infer the distribution of the activity, allowing to observe the metabolic processes in the body.

PET thus locates and quantifies, in vivo, physiological or pathophysiological functions. This has important applications in the diagnosis and investigation of some of the most important diseases of the central nervous system, including neurological diseases such as epilepsy, Alzheimer's, Parkinson's, Huntington; psychiatric disorders such as depression and schizophrenia; cerebrovascular accidents (strokes) and also on neuro-oncology.

PET has known important advances over the last decades, particularly with the development of ever more specific and selective radioactive tracers. These advances have however not been accompanied by the corresponding developments in what concerns the detection devices used to produce the images (tomographs). In particular, the use of this technique has been limited by poor spatial resolution (typically a few millimeters) when compared to other brain imaging techniques, such as magnetic resonance imaging (MRI) or computed tomography (CT), which reach spatial resolutions below 1 millimeter but lack the sensitivity and the specificity of PET.

From RPC to RPC-PET

Timing RPCs are gaseous detectors made of parallel resistive plates, inter-layered by a suitable gas or gas mixture. A uniform electric field is created in the gas gaps by applying a high voltage to the outer glasses, where a resistive layer is deposited. Whenever a charged particle crosses the detector it ionizes the gas, initiating an avalanche, and the charge is then collected by electrodes close to the resistive plates. The detection principle is illustrated in figure 1.

LIP has a long tradition in R&D in gaseous detectors in general and in RPCs in particular. Over the last decades we worked to expand the range of RPC applications to several new areas, from time-of-flight detectors for nuclear and particle physics to medical physics, from rugged outdoor muon detection systems to helium-free neutron detectors.

The RPC-PET technology was proposed in 2003 by the LIP RPC group. Photon detection in RPCs occurs after they generate electrons mostly by Compton interaction in the matter, acting the resistive plates as converters. In fact, the RPC's layered structure and a number of other characteristics make them particularly well-suited for high-resolution PET, when compared to traditional techniques, namely scintillating crystal detectors: excellent position resolution, due to the precise 3D reconstruction of the interaction point of the two photons; excellent time resolution, intrinsic to RPC detectors; direct production of an electric signal (not a light signal as in scintillators), lowering costs and improving resolution. They are also reliable and low-cost. The lower photon detection efficiency with respect to the traditional scintillator option can be offset by a better solid angle coverage and improved time and space resolution.

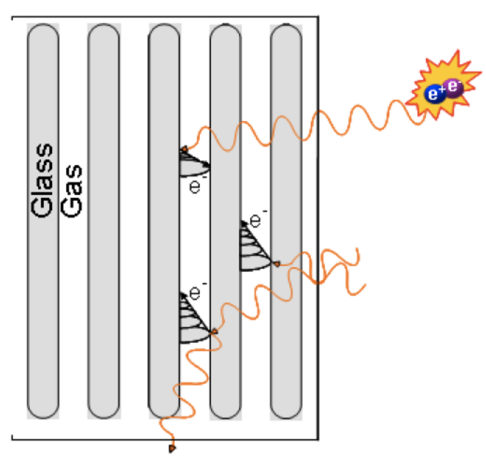


Figure 1: RPC-PET detection principle: gamma rays (wavy lines) originated in electron-positron annihilation interact with the thin glass plates. An electron is produced, mainly by Compton interaction, and makes it to the gas gap, originating an avalanche and a detectable electric signal.

The first RCP-PET tomograph was a small-animal PET scanner developed at LIP and installed at ICNAS in August 2014. Since then, more than 300 mice examinations have been performed. These allowed for the study in animals of the molecular processes underlying the Alzheimer, Parkinson and Huntington neurodegenerative diseases. The radioactive drugs used so far include FDG (metabolism studies) PK11195 (inflammation), PiB (amyloid-beta deposition), Cu-ASTM (oxidative stress). Example images are presented in figure 2. A linear spatial resolution of 0.39 mm has been demonstrated, which is about a factor of 2 (a factor of 8 in volume) better than what is achievable with other techniques.

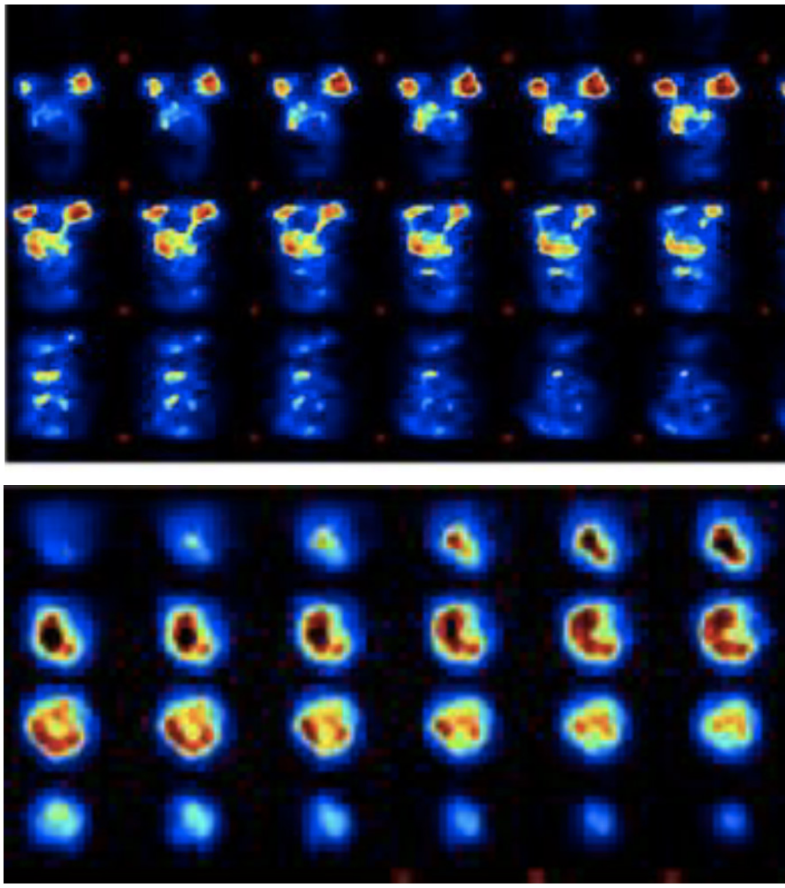


Figure 2: Images of high resolution PET scans of mice: head (top) and heart (botttom).

HirezBrainPET: a change of paradigm

The project HirezBrainPET (neurofunctional cerebral imaging by high resolution positron emission tomography) has the goal to develop and demonstrate a prototype of an RPC-based PET scanner with a space resolution below 1 millimeter for the diagnosis of human diseases centered in the brain. Other characteristics of the new device will be a time resolution of 300 ps, solid angle coverage above 50% and sensitivity better than 0.1%.

Such a device has the potential to change the paradigm in the diagnosis and investigation of diseases of the central nervous system by allowing, for instance, to resolve small brain structures involved in neuropsychiatric diseases, such as the striatum, amygdala and thalamic subnuclei. On the other hand, the high spatial resolution of the system may play an important role in the characterization of vascular injuries, improving diagnosis and guiding therapeutics, and in the detection and staging of central nervous system tumors, allowing a better planning of surgery and radiotherapy for cancer patients.

The system may also be adapted to high-resolution PET imaging of other organs, such as the heart or liver, also with high clinical and scientific interest. Last but not least, the reduced cost of RPC-PET technology could allow rapid expansion of this technology in the scientific and clinical market worldwide.

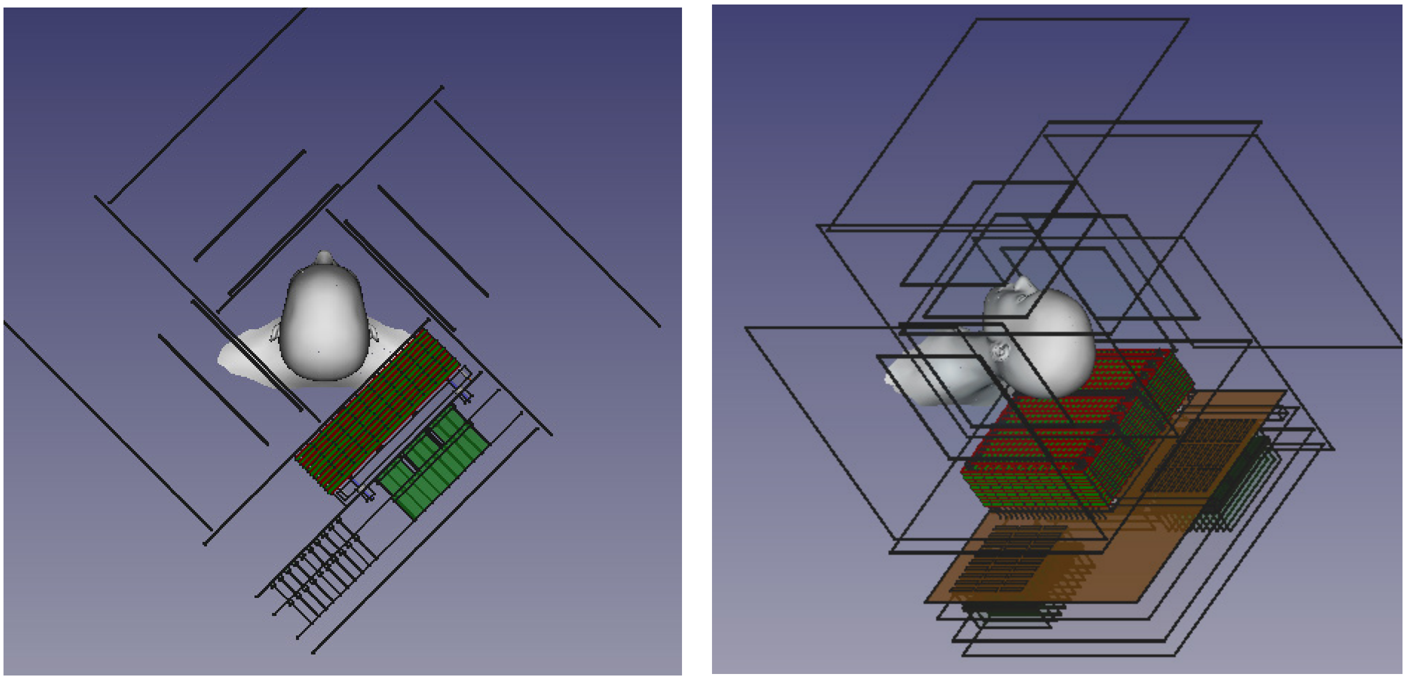


Figure 3: Schematic views of the HIRezBrainPET scanner.

SWGO: exploring the extreme Universe

An international collaboration was launched for a new gamma-ray observatory in the southern hemisphere

On July 1st 2019, almost 40 research institutions from nine countries officially signed the agreement for the creation of a new international R&D collaboration for a future wide field-of-view gamma ray observatory in the southern hemisphere. The founding countries of the newly created Southern Wide field-of-view Gamma-ray Observatory (SWGO) are Argentina, Brazil, Czech Republic, Germany, Italy, Mexico, Portugal, the United Kingdom and the United States of America, creating a worldwide community around the project. SWGO unifies different communities that were already involved in R&D in this field. The signature of the agreement comes after a successful meeting of the scientists from the different countries, held in Lisbon in May.

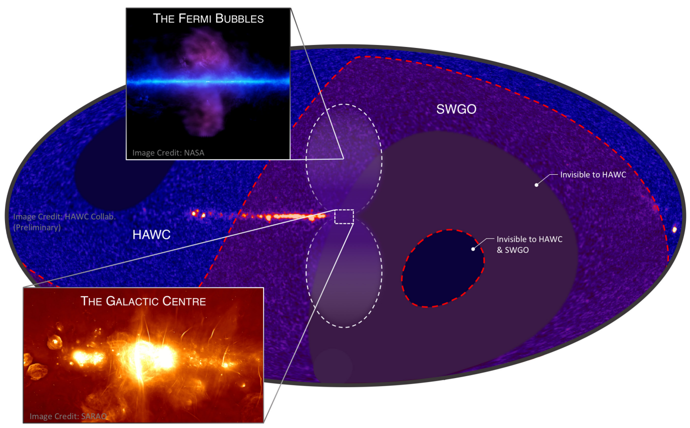
The new observatory is planned to be installed in the Andes, at an altitude above 4.4 km, to detect the highest energy gamma rays — particles of light billions or trillions of times more energetic than visible light. It will probe the most extreme phenomena and environments to address some of the most compelling questions about our Universe, such as the origin of high-energy cosmic rays and the search for dark matter particles and for deviations from Einstein's theory of relativity. Its location in the southern hemisphere will allow the most interesting region of our galaxy to be observed directly, namely the Galactic Centre, hosting a black hole four million times the mass of the Sun. Wide field-of-view observations are ideal to search for transient sources but also to search for very extended emission regions, including the 'Fermi Bubbles' or annihilating dark matter, as well as to discover unexpected phenomena. "The new observatory will be a powerful time-variability explorer, filling an empty space in the global multi-messenger network of gravitational, electromagnetic and neutrino observatories. It will also be able to issue alerts and be fully complementary to the next generation imaging atmospheric Cherenkov telescope array, CTA", explains Mário Pimenta, president of LIP and coordinator of the Portuguese team in LATTES, an R&D project for a future gamma-ray observatory in which LIP has been deeply involved, together with partners from Brazil and Italy, and which now becomes part of SWGO.

Direct detection of primary gamma-rays is only possible with satellite-based detectors, such as Fermi. However, the cost of space technology limits the size of satellite-borne detectors, and thus their sensitivity, as fluxes become too small at higher energies. In the atmosphere, gammas interact creating a shower of particles. These showers can be studied in observatories of two complementary types: imaging atmospheric Cherenkov telescopes, pointing instruments such as CTA, and high altitude air shower arrays, such as SWGO. Cherenkov telescopes are highly sensitive pointing detectors, with high precision but limited duty cycle and narrow field-of-view, benefiting from pointing alerts provided by complementary observatories. Wide field-of-view observations from the ground have the highest energy reach, and are ideal to search for transient sources and for emissions from very extended regions of the sky.

The baseline for the new observatory will be the approach of the current ground-based gamma-ray detectors, which sample the particle showers produced by gamma rays in the atmosphere, namely HAWC in Mexico and LHAASO in China. New layouts and technologies will however be explored in order to increase the sensitivity and lower the energy threshold of the observatory. In particular, detectors based in resistive plate chambers (RPC), a technology in which LIP is world leader, can play a crucial role.

The first very-high-energy gamma-ray emission was observed only 30 years ago, from the Crab Nebula. Hundreds of sources have been discovered since then at these extreme energies. Many extragalactic and some galactic sources present variability, and the duration of flares and transients can be days, hours, minutes or even just a few seconds. The study of these phenomena requires instruments such as SWGO, able to monitor in a continuous way large portions of the sky, sensitive to energies above the reach of satellite-based experiments, and operating in a multi-messenger context: able to alert and to follow up on alerts from neutrino and gravitational wave detections as well as other photon observatories.

Figure 1: Gamma-ray sky image as seen by the (current) HAWC and (future) SWGO observatories. Credits: Richard White, MPIK (preliminary)



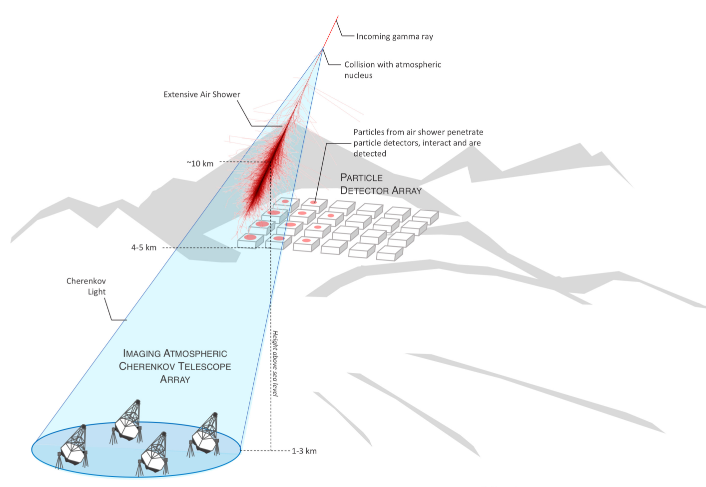


Figure 2: Illustration of the complementary detection techniques of high-energy gamma rays on ground. Credits: Richard White, MPIK.

// IN BRIEF

100 years of Eddington's observations in Príncipe

During the solar eclipse of May 29th, 1919, astronomer Arthur Eddington performed at Príncipe Island astronomical observations that were the first experimental confirmation of Einstein´s Theory of General Relativity. Eddington led a joint expedition of the Royal Astronomical Society and the Royal Society and sent another team to make observations in Sobral, Brazil. For the first time, the deflection of light by gravity was observed and measured, and this made newspaper headlines.

In 2009, LIP celebrated the 90th anniversary of Eddington´s observations with a scientific conference, a school and an exhibition in S. Tomé e Príncipe. Now, to celebrate the centenary, the exhibition, updated with the latest discoveries, became part of the Sundy Science Space, inaugurated on the day of the centenary at the place where the observations were made.

Images: the entrance to "Espaço Ciência" at Roça Sundy where the exhibition can be visited; different views of the exhibition; In the last photo, we see our colleagues Sofia Andringa (LIP/SPF) and Gonçalo Figueira (IPFN/SPF), who were deeply involved in the preparation of the exhibition, with a group of visitors.

On May 30th, just after the centenary celebrations in Príncipe, the 3rd Physics Conference of the Portuguese Speaking Countries (3rd CF-PLP) started in S. Tomé.

This conference brings back the series initiated in September 2010 in Maputo, Mozambique and September 2012 in Rio de Janeiro, Brazil. This happens in a time full of challenges, but also of opportunities, for the physicists in Portuguese speaking countries. This year, the conference theme was "Physics for Balanced Development", and the following topics were covered: physics and teaching; energy; nanotechnologies; environment and climate; physics for health.

During the conference, there was a strong interaction with the local school community, with activities such as e-learning and robotics at the university or in schools, and also with local institutions, such as the Nacional Meteorology Institute. Our colleague Sofia Andringa presented a contribution on the Portuguese Language Teachers Programme at CERN.

Also present at the conference was Dr. Sekazi K. Mtingwa, coordinator of the 13th commision — Physics for Development of the Internacional Union of Pure and Applied Physics (IUPAP) and leader of Light Source for Africa, the Americas, Asia and Middle East Project (LAAMP). Last but not least, at the 3rd FC-PLP, the Union of Physicists of the Portuguese Speaking Countries has been launched.

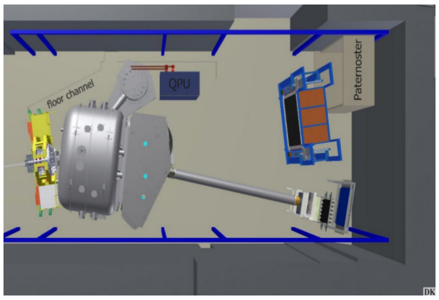
IN BRIEF

News from LIP and the world of particles

FAIR is taking off at GSI

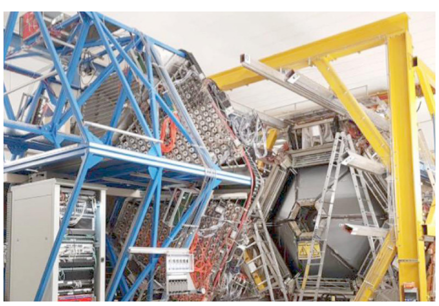
The accelerator infrastructure at GSI was shutdown for upgrades during the last five years and resumed in mid 2018. The upgrades will put into operation the future SIS100 synchrotron at the new FAIR — Facility for Antiproton and Ion Research, providing higher beam energies and intensities. Two LIP groups are involved in early phase experiments.

First R3B experiments



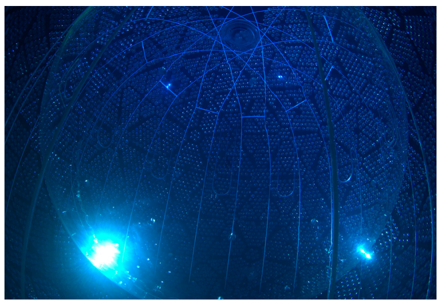
The R3B (Reactions with Relativistic Radioactive Beams) collaboration at FAIR recently executed the first series of experiments — the so-called Day-0 experiments at FAIR. The first run, under the acronym S444, consisted in the joint commissioning of the new detection systems that have been developed over the past ten years, and will give shape to the R3B experiment. Among them we could find a large portion of the future CALIFA (CALorimeter for In-Flight detection of gamma rays and high energy charged pArticles), a scintillation based detector that will act simultaneously as photon spectrometer and light charged particle identifier. Members of the NUC-RIA group from LIP joined the preparation and execution phases of the experiment, with a strong focus on the development of data analysis and calibration tools related to CALIFA.

HADES is taking data



The also renovated HADES spectrometer, with a new electromagnetic calorimeter (ECAL) and RICH detector, is now back in operation. This implied the full unmounting and remounting of the RPC-TOF-wall, the time of flight detector based on resistive plate chambers (RPCs) fully built, maintained and operated by the LIP-HADES group. The group has recently assumed new commitments with the construction of a new TOF detector for the HADES forward region, the RPC-TOF-FD. HADES will be one of the first experiments to be operational at FAIR with the mission of providing high-quality dilepton data at baryon densities and temperatures not accessible by other detectors, neither in the past nor in the foreseeable future.

SNO+ publishes first results



The SNO+ experiment at SNOLAB, Canada, started taking data in spring 2017. During 2018, SNO+ functioned as a Cherenkov detector using pure water as the active medium inside the detector. And the collaboration had a busy 2018 preparing the first publications. Solar neutrino measurement results and nucleon decay search results are now out. The LIP group in SNO+ was responsible for monitoring the detector operating conditions, basic quality selection and analysis of radioactive background evolution. Data quality selection and the very low background environment are key features of the analyses now published. Several other publications with the water phase data are expected in 2019. For the next phase of the experiment, the water inside the detector will be replaced with 780 tonnes of liquid scintillator with 3.9 tonnes of tellurium (0.5% by mass) added to allow a search for neutrino-less double beta decay.

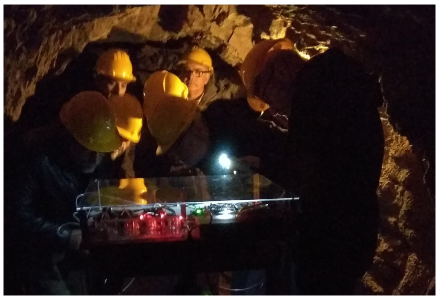
1st Biophysics Collaboration meeting at GSI

An International Biophysics Collaboration is now being created for the development of research programmes and common instrumentation in biomedical applications for existing and new accelerator facilities. One of these facilities is certainly FAIR, the new Facility for Antiproton and ion Research at GSI, but the International Biophysics Collaboration goes well beyond FAIR, including the many new particle accelerator facilities under construction all over the world where applied nuclear physics program are planned and biomedical research will be possible. A first meeting was held at GSI, Darmstadt, on May 20-22. Every scientist interested in biomedical applications at particle accelerators was invited to contribute with ideas and proposals. LIP will participate in this network that will create a community of applied nuclear physics at accelerators looking for new exciting research opportunities generated by the new facilities.

Excellent

LIP was considered 'Excellent' in FCTs evaluation of the R&D units in Portugal. In the report, the evaluation panel considered that "LIP is truly a Center of Excellence and should continue to lead particle physics research and innovation in Portugal".

Prototype installed at the Lousal mine



MuTom is an exploratory muon tomography project with RPC detectors. It combines particle physics and geophysics to map large geological structures using abundant natural radiation. LouMu will be a prototype telescope with several planes of resistive plate chambers (RPC) to detect muons at the Lousal Mine in Alentejo. The goal is to map the matter column crossed in each direction. The first step was now taken, with the installation in the Lousal mine of the first prototype, the MiniMu demonstrator. This is a pilot project, developed in a collaboration between LIP and the Institute of Earth Sciences of the University of Évora, which begins its activities at the Lousal Science Center.

Inauguration of MACC

The Minho Advanced Computing Centre (MACC) of the Foundation for Science and Technology (FCT) was Inaugurated on July 5 in Riba d'Ave. It increases the national computing capacity by about 10 times. The start of operations of this supercomputer, within the scope of the National Digital Competence Initiative - INCoDE.2030 and in the context of the National Advanced Computing Strategy, will boost the current participation of Portugal in the different European networks and consortia involved in the use and development of computing. It will also contribute to the reinforcement of the "Iberian Network of Advanced Computing - RICA" and to the start of the national participation in the European initiative "EuroHPC - European High performance Computing".

MADE in LIP

SNO + calibration equipment ready and shipped

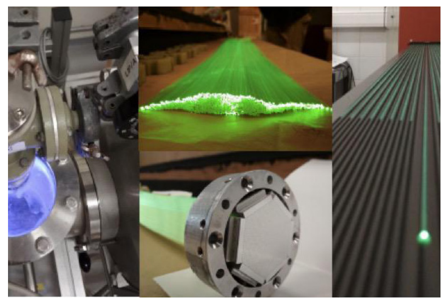
The second calibration equipment for the SNO+ neutrino experiment built at the LIP Mechanical Workshop and Detector Laboratory in Coimbra was sent to the SNOLAB laboratory in Canada. The next step is to install and run it in the experiment. The Umbilical Retrieval Mechanism (URM) now shipped is part of the system for insertion of calibration radioactive sources. The first URM, also built at LIP, is already at SNOLAB, being prepared for operation in the experiment. This milestone marks the conclusion of a complex and labor-intensive project in which the LIP technical infrastructures have been engaged for several years.

The LIP SNO+ group plays a key role in detector calibrations, as well as in the study of backgrounds and data quality control. These are absolutely fundamental issues in an experiment searching for rare events, in particular neutrinoless double beta decay. SNO+ is presently in the transition from the water phase to the scintillator phase as active medium inside the detector, which also means that the LIP group, having fulfilled its main detector-related tasks, can now focus on analyzing the data collected.

101 RPCs produced at the Detectors Lab

The Detectors Lab at LIP-Coimbra (DL) has recently concluded the production of the 42 sensitive volumes for the RPC detectors (Resistive Plate Chambers) of the MARTA R&D project, which is being installed at the Pierre Auger Observatory. In this project the DL collaborated with the LIP RPCs group, Mechanical Workshop and Auger group. In total, the DL has now surpassed the barrier of the 100 volumes produced: the last one is number 101! These 100 detectors, all with the same type of construction and an active area of 1.2 x 1.5 m^2, are operating in various experiments and geographic locations. RPCs are robust detectors, adaptable to a wide range of applications, and providing an excellent measure of the arrival time of particles. LIP-Coimbra is a world leader in this area.

Optical fibres for the ATLAS Upgrade



The heart of the hadronic calorimeter of the ATLAS experiment was born in the LOMaC laboratory at LIP. It is made of special wavelength-shifting optical fibres which read out the light produced by crossing particles. Just as the year 2019 started we were sending 2000 optical fibres newly prepared at LIP to the Michigan State University. There, special counters are being assembled to upgrade the ATLAS detector and improve its performance for the next LHC run. The counters will later travel to CERN, to be installed on the ATLAS detector during 2019/2020.

30 years of WWW

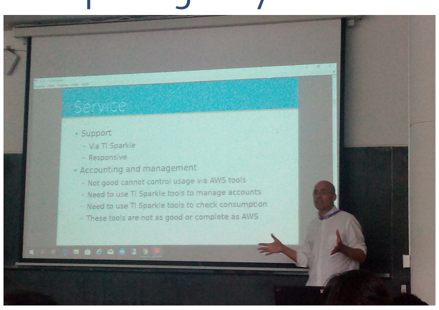
On March 12 2019 the world celebrated the 30 years since the birth of the World Wide Web at CERN. CERN celebrated with a full day event, with the presence of Tim Berners-Lee.

LIP at...

FCUL Open Day

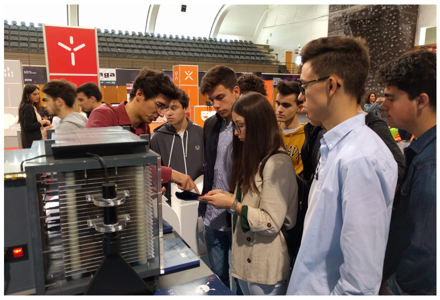
LIP was in the Open Day of the Faculty of Sciences of the University of Lisbon (FCUL), represented by its researchers who are lecturers at FCUL. In the activity "What neutrinos can tell us about the Universe", José Maneira told visitors about how these particles, which are among the most abundant in the Universe and motivated the Nobel Prize in Physics in 2015, may help us understand why there is more matter than anti-matter in the Universe. In "(Small) Big Bangs in the LHC", Helena Santos led visitors to discover the history of the first moments of the Universe, and how today, endowed with high technology, we can reproduce them in the laboratory. Luís Peralta led those interested in a visit to a laboratory where they could discover the relationship between "Radiation and Environment", that is, the various sources of ionizing radiation in nature, from cosmic rays to natural radioactivity. Ana Sofia Inácio and Daniel Galaviz participated in the "Speed Dating with Scientists", where they were available to talk about science, their academic paths, or the work they do.

Jornadas de Computação Científica / Scientific Computing Days 2019



As every year, the LIP Computing Group participated in the Scientific Computing Days, organized by the National Scientific Computing Unit of the Foundation for Science and Technology (FCCN / FCT). The "Jornadas" are the annual meeting point for the various communities of managers and users of advanced computing, communication and other digital service platforms offered by FCT. The 2019 edition took place in the Azores, at the University of the Azores (UAc), in Ponta Delgada, from May 6 to 8, 2019. In the photo we see Jorge Gomes, LIP Computing Coordinator, during his presentation entitled "Function-as-a-Service: Comparison Study". LIP and FCCN, along with LNEC, are partners in leading the National Distributed Computing Infrastructure (INCD).

UMinho open days



LIP was in the first edition of University of Minho Open Doors (UPA), taking place from May 2 to 4 at the University of Minho. These were three intense days with the aim of making known what is done at the University of Minho - in education, research and culture. With the spark chamber, a particle detector built at LIP, visitors were able to "see" cosmic rays, particles from space that constantly arrive at Earth, take a photo with "their" cosmic ray and take home a printed certificate. An interactive screen allowed to explore the Laboratory and the experiments scattered around the world in which LIP participates. Along the way, there were chats and sharing of ideas with LIP scientists and students.

ENEF Inside Views

LIP hosted about 30 students per day for the "Inside Views" organized within the National Physics Students Meeting(ENEF), which took place at IST this year. After a general introduction to LIP, the students were divided into groups that discusssed with members of several LIP research groups, according to their interests: ATLAS, CMS, Cosmic Rays, Neutrino Physics, Nuclear Astrophysics, Space Radiation and Phenomenology. The students who visited us were from the Physics and Physics Engineering courses of several Portuguese universities: Minho, Porto, Aveiro, Coimbra and Lisboa (UNL, IST and FCUL). The Inside Views are annually organized as part of the Physic Engineering Days of IST, organized by NFIST-Núcleo de Estudantes de Física do IST.

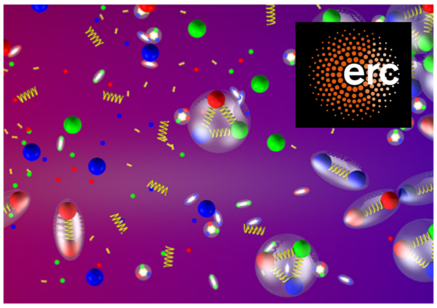
EPS-HEP 2019

The high energy physics conference of the European Physics Society was held in Ghent, Belgium, and LIP was well represented, with talks on the Higgs Physics, Heavy Ion Physics and Outreach, Education and Diversity sessions. LIP researchers also contributed as session conveners and in the international committees. One of the major conferences in the field, EPS-HEP is organized by the High Energy and Particle Physics Division of the European Physical Society every second year since 1971. It is always a conference full of new results and discussion opportunities, covering exhaustively particle and astroparticle physics.

Among many other topics, an impressive set of new results of the ATLAS and CMS Collaborations using the full Run II data sets were presented. The emphasis was naturally put on the most recent Higgs measurements, showing the enormous progress made by the two experiments since the Higgs discovery. Promising results on the couplings of the Higgs boson to quarks and leptons of the second generation are now available, even if more data will be needed to reach the sensitivity to test the SM couplings. Additionally, many other important results on a broad range of physics topics have been highlighted, including electroweak measurements involving vector bosons and the top quark, and searches for supersymmetry and exotica. It is also interesting to note that both experiments are now exploring innovative data analysis methods and techniques, including scouting, data parking and machine learning, to maximize their discovery potential.

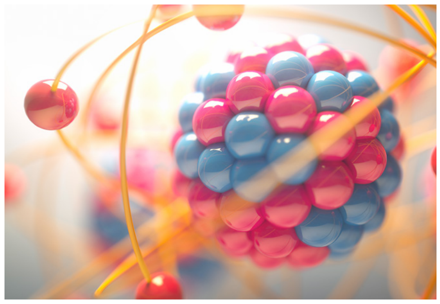
New Projects

YoctoLHC



The European Research Council awarded an Advanced Grant to the project Yoctosecond imaging of QCD collectivity using jet observables, led by Carlos Salgado (Univ Santiago de Compostela/IGFAE) and to be developed by a international team including researchers from LIP and Univ Jyväskylä (Finland). Light takes three yoctoseconds to cross a proton. In heavy ion collisions at CERN LHC, this tiny time is apparently enough for quarks and gluons to lose quantum coherence, interact among themselves and form the quark gluon plasma that permeated the entire universe microseconds after the Big Bang. The YoctoLHC project will study the fundamental aspects of the formation of this primordial plasma. Two decades of intense experimental study have identified many of the plasma properties: its viscosity is lower than that of any known material (it is the most perfect liquid ever observed) and its temperature is a hundred times higher than the Sun's core. In spite of such significant advances, the mechanism that allows the creation of this state of matter from the fundamental constituents of protons and neutrons in a very short time remains elusive. The YoctoLHC project proposes a novel use of specific probes, highly energetic particle jets, to build a time image of the first 10 yoctoseconds of the collision and unravel the process of emergence of complexity from the elementary building blocks of Nature. LIP's team will be responsible for the development of innovative techniques to identify jet properties sensitive to the early times of a collision.

STRONG-2020



LIP is part of STRONG-2020, a new European project devoted to the theoretical and experimental study of strong interactions. Strong interactions are a cornerstone of the Standard Model of particle physics. The list of open fundamental questions in this field is rich, and their theoretical and experimental study attracts an active community of about 2500 researchers in Europe. STRONG-2020 is a structured enterprise to address the open questions in the strong interaction studies in theory and experiment. The Consortium includes 44 participant institutions, among which LIP. LIP coordinates one of the project work packages, devoted to heavy ion physics, and participates in another two, on fixed target experiments and nucleon structure. STRONG-2020, strongly supported by NuPECC (the Nuclear Physics European Collaboration Committee), brings together many of the European leading research groups and infrastructures presently involved in the forefront research in strong interaction. It provides transnational access to world-class research infrastructures in Europe, and virtual access to open-source codes and tools. STRONG-2020 fosters the synergy between theoreticians and experimentalists.

EOSC-synergy

The LIP computing group will participate in the new H2020 project EOSC-synergy. The EOSC-synergy project will promote the development and adoption of the European Open Science Cloud (EOSC) services by scientific users in the participating countries. The project will be coordinated by CSIC and by LIP in the framework of IBERGRID, the Iberian scientific and technological cooperation on distributed computing. In addition, the consortium also includes computing research infrastructures, data providers, and research groups from Germany, Poland, Czech Republic, Slovakia, France, Netherlands, United Kingdom, Brazil and also the EGI foundation. The Portuguese participation includes LIP, INCD, LNEC and FCT-FCCN. The objective is to build EOSC as a coordinated effort, and as an open environment for scientific data and related processing promoting convergence of digital infrastructures and scientific thematic services at national or European level.

Ciência 2019

LIP was present in the 2019 edition of the yearly meeting point of researchers in Portugal. In the session dedicated to the UT Austin — Portugal Program, "Enhancing international collaboration in R&D to address major societal challenges", Nuno Castro (LIP/UM) presented to contribution "Big Data and Machine Learning in High Energy Physics". In the session devoted to Industry, Innovation and Infrastructures, he also discussed "The Portuguese participation in the Upgrade of CERN's LHC". In the session devoted to the 100 years of the International Astronomical Union, Patrícia Gonçalves (LIP/IST) highlighted the "Portuguese Scientific Participation in Future Space Missions". On a session devoted to Oncology, Paulo Crespo (LIP/UC) presented the contribution "Therapy with protons: clinical advantages and technological challenges". Finally, in the session devoted to InCoDe.2030 - Advan-ced Computing Portugal 2030 - High Performance Computing for Science & Economy, Jorge Gomes (LIP) discussed the "Lessons for effective use of HPC".

EVENTS AND OUTREACH

// EVENTS

IWHSS19

The 16th edition of the International Workshop on Hadron Structure and Spectroscopy - IWHSS 2019, was held this year in Aveiro, Portugal, from June 24th to 26th. This event was organized jointly by the groups from LIP and from the University of Aveiro that are part of the COMPASS experiment at CERN. This year, the workshop had 85 participants, motivated by the varied scientific agenda, the magnificent views of Ria de Aveiro and Costa Nova beaches, and the excellent local gastronomy. As usual, this event was followed by the COMPASS Collaboration meeting.

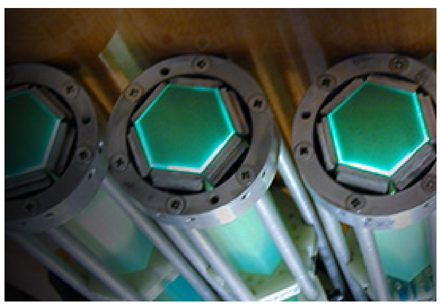
Lisbon mini-school on Particle and Astroparticle Physics

The Lisbon mini-school on Particle and Astroparticle Physics, a joint organization of LIP and CFTP, had its fourth edition. The school was held in Costa da Caparica between 11th and 13th February and was attended by two tens of students. On the first day, there were introductory lectures on particle and astroparticle physics, covering both theoretical and experimental aspects. The second day was dedicated to hands-on sessions. On the last day, research opportunities in this area in Portugal were highlighted. Along the school days, the presence of many LIP and CFTP researchers created opportunities for discussion on particle physics and research projects.

9th IDPASC School

The 9th edition of the IDPASC international school was held in Otranto, Italy, in the first week of June, jointly with the Francesco Romano international seminar in nuclear and sub-nuclear Physics. The LIP PhD students Tiago Vale and Ana Sofia Inácio were among the participants.

Workshop "Particles and Light for Life"



The 2019 edition was held at the LIP in Lisbon from 8th to 10th July. The objective was to give Physics, Physics Engineering and Biomedical Engineering students a vision on several nuclear and particle physics research topics, as well as on their applications to medicine. The workshop consisted mostly on hands-on laboratory and computational activities related to the different topics presented.

Masterclasses in Particle Physics

Masterclasses offer high-school students the opportunity to be particle physicists for a day, analyzing real data collected at CERN's LHC experiments. In 2019 they happened from March 7 to April 17 and had the participation of students from more than 50 countries around the world. Portugal participates since the first edition, with LIP as national promoter of the activity and the support of Agência Ciência Viva. This year, 13 institutions organized Masterclasses all around the country, from Funchal to Bragança and from Beja to Ponta Delgada, passing through Braga, Évora, Lisbon (FCUL and IST), Covilhã, Coimbra, Aveiro, Porto and Vila Real. LIP also provided support to the Masterclasses at the University of São Tomé and Príncipe.

International Day of Women and Girls in Science at LIP

On February 11th LIP celebrated the International Day of Women and Girls in Science with the public session «Partículas: Do Universo ao Laboratório», led by LIP PhD and master students. The session, attended by about 140 secondary school students and teachers, was conducted by six young people who studied Physics or Physics Engineering in several Portuguese universities and are now doing their PhD or master work within the LIP research groups: Luísa Carvalho and Ricardo Barrué work in the ATLAS experiment at the LHC; Júlia Silva and Diogo de Bastos in the LHC CMS experiment; Ana Sofia Inácio in the SNO+ neutrino experiment, and Ricardo Luz in the Pierre Auger Observatory. The goal was to convey some ideas about particle physics and the universe, in a somewhat more dynamic way than in a conventional lecture. But also, and most of all, to share the enthusiasm they have for the area in which they work! The International Day of Women and Girls in Science was established by the UN, considering that science and gender equality are two vital factors for the success of the 2030 Agenda for Sustainable Development.

Summer school: How to become an astronaut?

The 2019 edition of the summer school "Como ser Astronauta?" was held in Coimbra, organized jointly by the Physics Department of the University of Coimbra, the Geophysical and Astronomical Observatory of the University of Coimbra and LIP. The school counted on the participation of 35 secondary school students, who came to know everything it takes to be an astronaut!

LIP in Casa das Ciências

LIP was present in the VI Casa das Ciências Meeting, a meeting and training opportunity for teachers held on July 10-12 at FCUL, in Lisbon. LIP proposed three workshops related to particle physics, which attracted many participants: "CERN open data: educational resources for particle physics", "Experimentation with sensors, Raspberry Pis and Python programming" and "Cloud chambers - building a particle detector". These were supported by our colleagues Ricardo Gonçalo, Ana Luísa Carvalho, Fernando Barão, Miguel Orcinha, Pedro Abreu and also by Luís Afonso, Physics teacher at Escola Secundária José Gomes Ferreira and collaborator or LIP in several education and outreach projects.

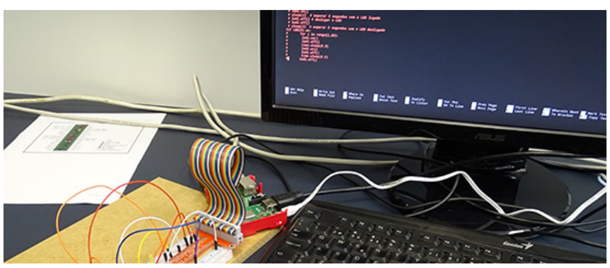
Ciência Viva Internships at LIP

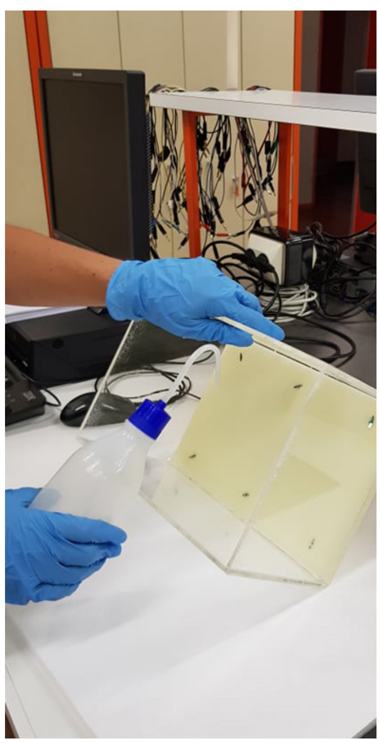
During the first week of July, LIP hosted the 14 participants in the 2019 edition of the Ciência Viva internships for high school students in research labs. The internship started with introductory talks and activities on particle physics and LIP research and ended with student presentations on their work. In between, there were three days full of activities and opportunities to talk about physics. One of them fell on the 4th of July, the anniversary of the announcement of the Higgs boson discovery at CERN. Besides the analysis of ATLAS open data and a virtual visit to CMS, there was even a (non-virtual) Higgs birthday cake!

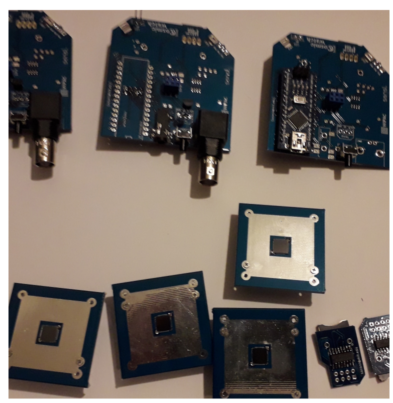
LIP-EduLab and other projects

During the school year 2018/19 LIP was engaged in projects with several school, helping to bring the world of particle physics closer to secondary school students. Our main partners this year included Escola Secundária Padre Benjamim Salgado, Joane, in Minho, and, in the Lisbon area, ES José Gomes Ferreira, ES D. Filipa de Lencastre, ES do Restelo and ES Sebastião e Silva. The work was in several cases developed within the framework of the projects "Cientificamente Provável" of Rede de Bibliotecas Escolas and "Clubes Ciência Viva nas Escolas", of Agência Ciência Viva. A large number of talks and seminars was also given by LIP researchers in these and many other schools. A list of proposed seminars in available in https://www.lip.pt/outreach/palestras

As example activities, we highlight: a series of hands on sessions on the tools of particle physics, based on the use of Raspberry Pis and Python programming to read sensors and control simple devices (top left image), attended by two groups of students from ES D. Filipa de Lencastre and ES Restelo; The students in ES Joane are preparing a balloon flight, and LIP is giving technical support to the project of including simple temperature, pressure and radiation monitoring instruments; the construction of CosmicWatch particle detectors autonomously by a group of students and their teacher, at ES José Gomes Ferreira, with a small amount of technical support from LIP researchers; students in the same school also developed cloud chamber construction kits, based on the CERN SCool Lab model, which have often been used at LIP during school visits and internships (see central and bottom images).







2019 LIP Student Workshop

The 2019 LIP student Workshop was held in Braga in July 1-3. This is a yearly meeting in which PhD students are invited to present and discuss their work with their peers and with supervisors and other senior researchers at LIP. This year, the workshop gathered LIP and IDPASC students in a joint meeting.

On this occasion, the LIP-News Bulletin flash-interviewed Ana Sofia Inácio (ASI), representative of the LIP-Lisboa students in the LIP Scientific Council, and one of the people currently active in pushing forward the newly created LIP Student Council.

Bulletin: Which aspects would you highlight as the two most positive ones of the workshop?

ASI: First, the quality of the student presentations. They covered a variety of topics in particle physics, nuclear physics, cosmology, astrophysics and were generally very good. There was a visible effort to capture the audience's attention with good slides and well structured presentations — covering the motivation of the PhD work, the work already developed and the steps necessary for conclusion. All this resulted not only in high quality presentations but, more generally, in a high quality workshop very much appreciated by all those who participated. In addition, the discussions after each presentation were very lively, in particular with the public asking many questions driven by curiosity about areas different from their own. In some cases, this lead to quite interesting discussions!

Another positive aspect of the workshop was that, from day one, there was a great group spirit and sharing among students. Part of this, in my opinion, was encouraged by the creation of the LIP Student Council, which has been trying hard to improve and promote fellowship among students at each LIP node, and among students at different nodes. In addition, the LIP student representatives did their best to include the IDPASC students from other research centers in this spirit, namely by organizing a dinner on the first day of the workshop. The result was that everybody was at ease, exchanging work and life experiences, in a relaxed and fun atmosphere.

Bulletin: And which were the two most negative, or less positive aspects?

ASI: During the workshop, there was some discussion about the fact that many LIP students take longer than expected to complete their theses, which leads to a number of problems, such as the payment of extra university fees or the end of the scholarships. But the positive part is that we started discussing it, and all students who participated in this discussion consider the LIP Student Workshop as a key point for a future LIP monitoring committee to evaluate students' progress and identify potential sources of delays of their PhD projects.

Another negative aspect was that unfortunately there was not much supervisor participation in the workshop. I think this was more visible than usual due to the good performance of the students — who would like to have more senior researchers watching their presentations and giving feedback. The presence of more researchers in the public, and in particular of the student supervisors, would contribute to increase even more the quality of the discussions. And, relating to the previous point, would be essential for the discussion of possible problems or delays in the projects that are being developed by the students and on how to address them.

Director-general of CERN awarded the European Prize Helena Vaz da Silva

The prize awarded to Fabiola Gianotti aims to highlight the contribution of the Italian scientist to the dissemination of scientific culture in an "attractive and accessible way". The award ceremony is scheduled for November 25th at the Calouste Gulbenkian Foundation in Lisbon. Fabiola Gianotti declared herself "very honored to receive the prestigious European Prize Helena Vaz da Silva", adding: "Scientific knowledge belongs to everyone. As scientists, we must make every effort to share with society in general our findings and to promote an open science, accessible to all."

The European Prize Helena Vaz da Silva for the Promotion of the Cultural Heritage was established in 2013 by Centro Nacional de Cultura and recalls the Portuguese journalist, writer, cultural activist and politician (1939-2002), and her notable contribution to the dissemination of cultural heritage and European ideals. It is awarded annually to a European citizen with a dinstinguished career in the diffusion, defense, and promotion of Europe's cultural heritage. The prize is supported by the Ministry of Culture, the Calouste Gulbenkian Foundation and Turismo de Portugal.

ATLAS PhD grant awarded to LIP-Minho student

Every year, the ATLAS Collaboration awards the ATLAS PhD grant to three PhD students. This year, among the winners is Ana Peixoto, PhD student at LIP-Minho and the University of Minho under the MAP-Fis Doctoral Program (a partnership between the universities of Minho, Porto and Aveiro). The names of the three winners were announced at a ceremony at the CERN Globe of Science and Innovation. Ana Peixoto is doing her PhD work at LIP-Minho, as member of the Portuguese group that participates in the ATLAS Collaboration. The theme of her thesis is the search for new phenomena associated to the top quark, namely the production of tZ events through flavour changing neutral currents. This research is done using the ATLAS data. As part of her thesis, Ana also studies the performance of the triggers dedicated to the ATLAS forward detector (AFP). The goal of ATLAS PhD Grants is to stimulate some of the most talented and motivated young people who are doing PhD in the realm of the ATLAS collaboration.

Mariana Araújo awarded the Maria de Lourdes Pintassilgo Prize of IST

The Maria de Lourdes Pintassilgo Award in the Young alumni category was awarded to Mariana Araújo "in recognition of her exemplary academic path, involvement in scientific activities within the IST community and remarkable academic progression", which culminated in her master dissertation in Technological Physics entitled "Phenomenology of a single right-handed neutrino seesaw model," with a final classification of 19/20. Mariana Araújo is currently a PhD student, developing her research work in the LIP group that participates in the CMS experiment at the CERN LHC.

Rute Pedro coordinates TileCal calibration

TileCal is the hadronic calorimeter of the ATLAS detector at the LHC. It is a crucial detector for the experiment, and has always been a great investment of the Portuguese group, which was involved in its design, construction, testing, calibration and operation.
Our colleague Rute Pedro was recently appointed co-coordinator of the TileCal calibration. Good luck to Rute in her new responsibilities!

NEW MEMBERS OF LIP

Nuno Barros

I graduated in Physics Engineering at FCUL, having subsequently worked at CERN in the ATLAS experiment for almost two years. Later, I decided to dedicate myself to the study of neutrinos, and so returned to Portugal to join the neutrino group at LIP, having obtained my PhD in Physics at the University of Lisbon, for my work on the optical calibration and solar neutrino oscillation analysis using the complete SNO dataset. Afterwards I spent three years at TU-Dresden as a postDoc on the GERDA experiment, followed by five years at the University of Pennsylvania where I have worked on the neutrino experiments DUNE and SNO+, having carried out activities in both data analysis and development of instrumentation. In May 2019 I rejoined the neutrino group at LIP, where I intend to continue to study neutrinos, their properties and their impact in the greater picture. I am currently involved in the SNO+ and DUNE experiments, two experiments that spearhead the effort to answer some of the open questions about these elusive particles. Additionally, as one of the last students graduating with the SNO experiment, I am also involved in some new analyses of their data.

Grigorios Chachamis

I studied Physics in Greece, I received my Master degree from the University of Durham in the UK and my PhD from the University of Hamburg in Germany. Since then, I held research positions at the University of Wuerzburg in Germany (three years), the Paul Scherrer Institut in Switzerland (four years), the IFIC CSIC-UV in Spain (two years) and the IFT UAM/CSIC in Spain (four years). I mainly work in two fields of particle physics theory and phenomenology: 1. radiative corrections, cross sections and precision physics and 2. formal and phenomenological studies on high energy scattering. I joined LIP in May 2019, I am very happy and excited with the new position and I look forward to contribute to the scientific production of the Institute.

Gaspar Barreira

1940-2019

Gaspar Barreira passed away on June 1st 2019. He was one of the founders of LIP and the Portuguese Delegate to the CERN Council and to the SESAME Council.

It is with great sadness and emotion that we speak of the passing away of Gaspar Barreira. He departed on June 1st, but leaves us an immense legacy of vision, endurance and resilience. He worked as few in the construction of a Portugal where Knowledge, Freedom and Rationality were decisive, before and after the Revolution of April 25th 1974.

He was one of the founders of LIP, and over the past 30 years devoted to it much of his immense energy. If today we have LIP, which is not just a group of physicists participating in experiments at CERN, but rather a diverse but coherent community of physicists, engineers, technicians, administrative staff and students, engaged in the challenges of particle physics but also of instrumentation, computing and technology, deeply embedded in international and national collaborations, we owe much of it to Gaspar. His last big project and enthusiasm, the installation in Portugal of a treatment and research center for cancer therapy with protons, is not yet accomplished. For this we will strive. Gaspar, the seed has fructified and the tree will stand!

LIP IN SOCIAL MEDIA

TOP POSTS on LIP FACEBOOK

Periodic table enigmas

675 engagements

Ana Peixoto, PhD student at LIP-Minho, wins ATLAS PhD Grant

457 engagements

Gaspar Barreira 1940-2019

425 engagements

Portuguese Language Teacher's programme at CERN

372 engagements

LIP Summer Student Programme

321 engagements

Article about the Future Circular Collider in Público

306 engagements

THESES

PHD

Development of a Directionality Detector and Radiation Hardness Assurance for RADEM, the ESA JUICE mission Radiation Monitor

Marco Alves Pinto, IST, July 25

MASTER

Analysis of in-flight data from ESA's AlphaSat Environment and Effects Facility Multi-Functional Spectrometer

Filipe Máximo Ribeiro Lopes de Carvalho, IST, June 27

follow us:

facebook.com/pt.lip

twitter.com/lipwebapps

linkedin.com/company/lip

agenda

Portuguese Teachers Language Programme at CERN / Escola para Professores no CERN em Língua Portuguesa

September 01-06, CERN, Switzerland

Tribute session / Sessão de Homenagem Gaspar Barreira

September 11, LIP Lisboa

Portugal Space Summer School – Exploring the World using Space

September 11-13, Coimbra

IBERGRID 2019
Delivering Innovative Computing and Data services to Researchers

September 23-26, Santiago de Compostela, Spain

The 10th Iberian Grid Conference will focus in topics related with fostering the development, integration and adoption of services to support cutting-edge research projects. The event will also host the Kick-off Meeting of the project EOSC-synergy. Tutorials and hands-on sessions dedicated to advanced tools to access Digital Infrastructures will also be organized. Topics covered will include Accessing Cloud infrastructures at the IaaS, SaaS and PaaS level; Orchestrating services on Cloud infrastructures; Everything you need to work with Containers; Machine Learning/Deep Learning tools for Data Processing; Integrating Quantum Computing applications via Cloud services.

web site: ibergrid.eu

European Researchers Night

September 27

"Do Universo ao Laboratório" - Public session by LIP graduate students

296 engagements

May 16, National Scientist Day

236 engagements

IPPOG's International Masterclasses in Particle Physics

205 engagements

Fabiola Gianotti awarded Helena Vaz da Silva Prize

202 engagements

LIP classified as Excellent in FCT evaluation

197 engagements

International Day of Women and Girls in Science

190 engagements

Particle Physics:
from fundamental science to society

Tribute to
Gaspar Barreira
1940-2019

11
September
2019

session 1 - **Physics**
session 2 - **Technology**
session 3 - **Proton-therapy**
session 4 - **Gaspar's life and vision**

www.lip.pt/homenagem/gaspar-barreira

LET'S INSPIRE PEOPLE

LIP | LABORATÓRIO DE INSTRUMENTAÇÃO E FÍSICA EXPERIMENTAL DE PARTÍCULAS
partículas e tecnologia