20. Overview

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Fundação para a Ciência e a Tecnologia
Evaluation Research Unit 2017/2018

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Part 1: Identification of the R&D Unit, the Management Institutions and the Participant Institutions

01. IDENTIFICATION OF THE R&D UNIT

1.0 Reference

50007

1.1 Name of the R&D Unit

Laboratório de Instrumentação e Física Experimental de Partículas

1.2 Acronym

LIP

1.3 Coordinator

Mário João Martins Pimenta

1.4 Scientific areas

Exact and Natural Sciences - Physics

Exact and Natural Sciences - Computation and information sciences

Medical and Health Sciences - Health sciences

Engineering and Technology Sciences - Other engineering and technology sciences

1.5 Keywords

Experimental Particle Physics

Astroparticle Physics

Scientific Computing

Particle and radiation detector systems

Development of new instruments and methods

Applications to Health and Space Exploration

1.6 R&D Unit Contacts and Address

Postal Address:
Universidade de Coimbra, Departamento de Física, Rua Larga
3004 - 516 Coimbra

Delegadas pela Instituição:

LIP

210493611

Endereço e-mail: natalia@lip.pt

1.7 Link to the R&D Unit's page on the Internet

http://www.lip.pt

02. EVALUATION PANEL TO WHOM THE R&D UNIT SUBMITS THE CURRENT APPLICATION

2.1 Evaluation Panel to whom the R&D Unit submits the current application

EXACT SCIENCES - Physics

03. INVOLVED INSTITUTIONS

3.1 Main Management Institution

Laboratório de Instrumentação e Física Experimental de Partículas (LIP)

3.2 Other(s) Management Institution(s)

3.3 Partnership agreements with Management Institution(s)

3.4 Participating Institution(s)

3.5 Partnership agreements with Participant Institution(s)

Institution Name

Instituto Politécnico de Coimbra (IPC)

Universidade do Minho (UM)

Universidade da Beira Interior (UBI)

Universidade de Coimbra (UC)

Faculdade de Ciências da Universidade de Lisboa (FC/ULisboa)

Instituto Superior Técnico (IST/ULisboa)

04. DESCRIPTION OF THE MAIN CONTRIBUTIONS OF THE TEAM OF INTEGRATED RESEARCHERS IN THE CURRENT APPLICATION

4.1 General description of the R&D Unit

LIP is the reference laboratory for experimental particle physics and associated technologies in Portugal, and the Portuguese reference partner of CERN. It exists for the discovery of the fundamental laws of the Universe, ensuring the full participation of the Portuguese scientific community in this endeavour, and to share this knowledge with society. The laboratory is nation-wide, with nodes in Lisboa, Coimbra and Braga, working in close collaboration with the local universities. Under the supervision of FCT, LIP defines the national research agenda in this area and the participation at CERN and in other international scientific infrastructures. LIP is also a partner of ESA, the GSI research centre in Germany, SNOLAB in Canada, the Pierre Auger Observatory in Argentina and the Sanford Underground Research Facility (SURF) in the USA. The associates of LIP are FCT, the Universities of Lisboa, Coimbra and Minho, Instituto Superior Técnico (IST), the Faculty of Science of the University of Lisbon (FCUL) and the Electrical and Electronics Business Association.

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

LIP is committed to R&D in three main areas:
- Experimental particle and astroparticle physics: LIP is deeply involved in the CERN Large Hadron Collider (LHC) programme, contributing from the very beginning to the two largest LHC experiments, ATLAS and CMS, and exploring new physics phenomenology (Groups 1-3). LIP is also involved in the fixed target programmes at CERN and GSI, probing the strong nuclear force and dense nuclear matter (Groups 4-5). The quest for dark matter, a deeper understanding of the elusive neutrinos, or the study of hadronic interaction at the highest energies in cosmic rays are among the great challenges of particle physics for the next decades (Groups 6-8).
- New instruments and methods: The development of new instruments and methods for particle physics

has been from its inception one of the main strengths of LIP. Current activities include research in fundamental detection processes and applications of particle detectors. LIP is a world leader in Resistive Plate Chambers (RPC) and liquid xenon detectors, with strong expertise in other gaseous detectors and scintillator/fibres calorimetry. Specific R&D lines are dedicated to health care and space exploration applications (Groups 9-11).
- Scientific computing: LIP develops novel information technologies and operates advanced services to support demanding scientific applications, focusing on Grid and Cloud computing technologies. LIP participates in some of the largest R&D projects in this field, operates the largest scientific computing facility in Portugal, and delivers services to the scientific community at large. LIP co-leads the National Distributed Computing Infrastructure, INCD (Group 12).

LIP has a number of technical infrastructures that give support to its R&D activities and provide services to external entities: the precision mechanical workshop and the detector laboratory in Coimbra, the scintillating materials and the electronics laboratories in Lisboa, and the computing infrastructures.

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

4.2 Identification and brief description of up to 5 contributions the R&D Unit considers most important of those provided in period 2013-2017 by Integrated Researchers registered in the current application, independently of the R&D Unit having existed or not

Heavy quark physics
LIP made world-class contributions to heavy quark physics and is an international reference in the field. Our activity encompasses a large body of experimental and phenomenological studies over the last five years. The study of the top and bottom quarks, the heaviest fermions, is a privileged opportunity to perform high precision tests of the Standard Model, and a promising route to gain insights into the new physics beyond it. We have led or collaborated in many heavy-quark analyses, in both ATLAS and CMS, such as measurements of the top quark mass, width, production cross-section and couplings to the Higgs and W bosons. We had a leading role in the measurements of bottomonium production in both pp and PbPb collisions, and the discovery of the Bs rare decay into dimuons, a long-sought flagship process highly sensitive to new physics. These efforts are complemented by new physics searches, such as for vector-like quarks in different topologies. Our leading role in the above contributions was reflected in coordinating positions in working groups, namely the "CMS B physics group", and also the "Top Quark Mass" (CMS), "Top Properties" (ATLAS), "B rare decays and quarkonium" (CMS) and "Heavy Quarks, Top and Composite Higgs" (ATLAS). A LIP member was Deputy Spokesperson of the whole CMS collaboration in 2012-2013. Experimental studies were backed by phenomenological investigations, where LIP members have proposed new observables and techniques, namely using heavy quarks to probe new physics and the quark gluon plasma. LIP has also initiated the annual International Workshop on Top Quark Physics conference series, which became the main conference in this area.

CMS-Totem Precision Proton Spectrometer (CTPPS)
The LIP CMS group led the development of the new CTPPS forward proton spectrometer. CTPPS was proposed in 2013 as an additional CMS sub-detector, allowing the study of collisions of quasi-real photons at the TeV scale. In 2016 the detector was integrated with the CMS experiment, demonstrating for the first time the feasibility of operating a near-beam proton spectrometer at high luminosity on a regular basis in a proton collider. Members of the group are presently serving as CTPPS Project Manager and coordinators of the CTPPS sub-projects Timing Detectors and Data Acquisition System. The forward proton tagging permitted by the new CTPPS spectrometer enhances the ability of the CMS detector to carry out the primary physics program of the LHC in various sectors and the search for extensions of the Standard Model of particle physics. This includes electroweak physics in two-photon interactions and the unique ability to measure the quartic neutral gauge couplings. With 2016 data we already proved the sensitivity to gamma-gamma interactions at the electroweak scale. Two members of the LIP group led the first analysis using data from the CTPPS spectrometer, namely the measurement of dimuon production with tagged forward protons.

Hadronic Physics at Ultra High energies
The LIP Cosmic Rays group developed a consistent, independent and productive research activity in hadronic interactions and air-shower physics, and has obtained worldwide recognition. Cosmic rays at ultra-high energies, observed at the Pierre Auger Observatory, are an unique opportunity to study particle physics well above LHC energies. In this context, we proposed new sensitive observables for the parameterisation of longitudinal electromagnetic profiles, which are now commonly used to constrain the reconstruction of individual shower profiles, for both the electromagnetic and muonic components. The physics of muon production in air showers, a largely unexplored field in the past, was addressed at LIP with innovative analyses and is now one of the hot topics in air-shower physics. The discrepancy between the observed and expected number of muons is presently one of the most interesting puzzles presented by Auger data. A member LIP coordinates the muon analysis group in Auger. The application of RPC detectors for the precise measurement of the muon content of air showers at ground was proposed by the LIP group; prototypes were built and successfully operated at the Pierre Auger Observatory site, where an engineering array of such detectors is presently being constructed.

Resistive Plate Chambers (RPC)
Over the last years, LIP's Detector R&D group developed a coherent and ambitious R&D line of work that took the performance and the flexibility of RPCs to a new level. This expanded the range of RPC applications to several areas widely recognized as addressing societal challenges, and confirmed LIP as a world leader in the development, design and construction of RPC detectors. Examples are:
- RPC-based epi-thermal neutron detectors: LIP pioneered the concept of an imaging thermal neutron detector based on Boron-10 lined RPCs with sub-millimetre spatial resolution (FWHM<0.25 mm, a world record) and sub-nanosecond timing. This detector technology is most attractive for world-leading neutron facilities and very promising for transfer to industry. There is a widespread need for helium-3 free position-sensitive neutron detectors with enhanced performance for applications ranging from neutron scattering science to homeland security and geological applications;
- RPC-based Positron Emission Tomography (RPC-PET) for medical applications: A small animal functional PET scanner based on RPCs, with the best position reconstruction resolution ever achieved, has been

developed and is being exploited at a medical research centre in Coimbra, ICNAS. Steps towards prototyping a human full-body RPC-PET, an invaluable medical imaging tool, are in progress.

Distributed computing infrastructures
The LIP computing group pioneered the Portuguese participation in large distributed computing R&D projects and had a major role in projects related to digital infrastructures (Grid and Cloud) at European level. LIP represents Portugal in the EGI-European Grid Infrastructure governing council, was a member of the EGI Executive Board in 2013-2016, and coordinates the EGI regional Iberian operations and all EGI software quality assurance. In 2013, we submitted a proposal for the enlargement of the Portuguese Grid infrastructure. The National Distributed Computing Infrastructure (INCD) was approved in 2014 and funded in 2017. Meanwhile, in partnership with LNEC and FCT-FCCN, LIP provided high performance computing, high-throughput computing and cloud services to a wide range of scientific users, delivering 45 million hours of processing time. In 2013, LIP was first in introducing a Cloud computing service for the Portuguese research community. This service has been incorporated in INCD, and since 2016 has delivered 6 million CPU-hours. The portfolio of services and the available capacity are being enlarged. New synergies with research organizations and thematic e-infrastructures are also being established.

4.3 Main publications in 2013-2017 authored by Integrated Researchers registered in the current application

REFERENCE	URL
"Combined analysis of all three phases of solar neutrino data from the Sudbury Neutrino Observatory", B. Aharmim et al. (SNO Collaboration), Phys. Rev. C 88 (2013) 025501	http://www.lip.pt/outreach/publicacoes/article01.pdf
"Liquid noble gas detectors for low energy particle physics" V. Chepel and H. Araujo, Journal of Instrumentation, 8 (2013) R04001	http://www.lip.pt/outreach/publicacoes/article02.pdf
"Resistive plate chambers in positron emission tomography", P. Crespo, A. Blanco, M. Couceiro et al., European Physics Journal Plus 128 (2013) 73	http://www.lip.pt/outreach/publicacoes/article03.pdf
"Search for pair and single production of new heavy quarks that decay to a Z boson and a third-generation quark in pp collisions at \sqrt{s} = 8 TeV with the ATLAS detector", ATLAS Collaboration, J. High Energy Phys. 11 (2014) 104	http://www.lip.pt/outreach/publicacoes/article04.pdf
"Measurement of the tt production cross section in pp collisions at \sqrt{s} = 8 TeV in dilepton final states containing one \tau lepton", CMS Collaboration, Physics Letters B 739 (2014) 23	http://www.lip.pt/outreach/publicacoes/article05.pdf
"Performance analysis for the CALIFA Barrel calorimeter of the R3B experiment", H. Alvarez-Pol et al, Nuclear Instruments and Methods A 767 (2014) 453	http://www.lip.pt/outreach/publicacoes/article06.pdf
"First Results from the LUX Dark Matter Experiment at the Sanford Underground Research Facility", DS Akerib et al, Physical Review Letters 112 (2014) 091303	http://www.lip.pt/outreach/publicacoes/article07.pdf
"Validation of Grid Middleware for the European Grid Infrastructure", M. David, G. Borges, J. Gomes et al, Journal of Grid Computing 12 issue 3 (2014) 543	http://www.lip.pt/outreach/publicacoes/article08.pdf
"Observation and measurement of Higgs boson decays to WW* with the ATLAS detector", ATLAS Collaboration, Physical Review D 92 (2015) 012006	http://www.lip.pt/outreach/publicacoes/article09.pdf
"Observation of the rare B^0_s -> mu+mu- decay from the combined analysis of CMS and LHCb data", CMS and LHCb Collaborations, Nature 522 (2015) 68	http://www.lip.pt/outreach/publicacoes/article10.pdf
"The low energy magnetic spectrometer on Ulysses and ACE response to near relativistic protons", B. Morgado et al, Astronomy and Astrophysics 577 (2015) A61	http://www.lip.pt/outreach/publicacoes/article11.pdf
"Measurements of the Higgs boson production and decay rates and constraints on its couplings from a combined ATLAS and CMS analysis of the LHC pp collision data at \sqrt{s} = 7 13. and 8 TeV", ATLAS and CMS Collaborations, Journal of High Energy Physics 08 (2016) 45	http://www.lip.pt/outreach/publicacoes/article12.pdf
"Testing Hadronic Interactions at Ultrahigh Energies with Air Showers Measured by the Pierre Auger Observatory", A. Aab, P. Abreu, M.	http://www.lip.pt/outreach/publicacoes/article13.pdf

REFERENCE	URL
Aglietta et al, Physical Review Letters 117 (2016) 19	
"Angular structure of jet quenching within a hybrid strong/weak coupling model", J. Casalderrey-Solana, D. Gulhan, G. Milhano, D. Pablos, Daniel and K. Rajagopal, Journal of High Energy Physics 03 (2017) 135	http://www.lip.pt/outreach/publicacoes/article14.pdf
"First measurement of transverse-spin-dependent azimuthal asymmetries in the Drell-Yan process", COMPASS Collaboration, Physical Review Letters 119 (2017) 112002	http://www.lip.pt/outreach/publicacoes/article15.pdf

4.4 Description of other relevant contributions resulting from the activities in 2013-2017 of Integrated Researchers registered in the current application

Advanced training
- LIP hosts about 70 PhD and master students enrolled at our partner universities working within our research groups, benefiting from a truly international training in the framework of international collaborations.
- LIP coordinates 2 FCT doctoral programmes involving about 40 students, IDPASC-Particles, Astrophysics and Cosmology and DAEPHYS-Applied physics and Physics Engineering, and the IDPASC international network.
- LIP hosts undergraduate students in schools, workshops and internships. LIP Summer Student Programme hosts about 30 students per year and includes formal training and research projects. LIP organizes about 4 schools for graduate and undergraduate students per year. In the last 5 years, LIP participated in 5 International Training Networks and COST actions sponsored by the European Commission.

Outreach/Initiatives for schools
- Under the coordination of LIP, over 1500 secondary school students from all over the country participate every year in IPPOG's International Masterclasses in Particle Physics.
- Every year since 2005, around 40 teachers from Portugal, Brazil and other Portuguese speaking countries attend CERN's Portuguese Language Teachers Programme, organized by LIP with the support of CERN and Agência Ciência Viva (CV).
- Every year, over 50 outreach talks are given by LIP scientists at schools and other settings; LIP hosts a few tens of secondary school students within programs organized by CV and by our partner universities.
- LIP is a close partner of the Portuguese Physics Society in many outreach and support to education initiatives.
- The exhibition "Particles: from the Higgs boson to dark matter", celebrating LIP's 30th anniversary, has been shown at our partner universities and at the Lisbon planetarium and had more than 40 000 visitors.

Knowledge transfer, spin-offs
- Knowledge-transfer to companies occurs across the whole spectrum of LIP's activities. A spin-off company, PETsys was created to commercialise the innovative electronics developed at LIP for Time-of-Flight PET systems. In the last 5 years, LIP also had contracts or was in consortia with EFACEC SA (under ESA contracts), EVOLEO SA, HIDRONAV S.A. and BOSCH.
- LIP's involvement with CERN has triggered technological transfer to Portuguese industry through contracts awarded by CERN. The Portuguese Industrial Liaison Officer is a member of LIP's staff developing activity within FCT. The LHC Phase II upgrade offers great opportunities for the participation of Portuguese industry.
- LIP is directly involved in the selection process of FCT's Technology Internships programme for young engineers at CERN, ESA and ESO.
- In collaboration with FCT-FCCN and LNEC, LIP leads INCD, the National Infrastructure for Distributed Computing, serving all the Portuguese scientific community.

Internationalisation
LIP was created over 30 year ago, at the time of Portugal's accession to CERN. The recently renewed protocol between Portugal and CERN for the next 10 years recognizes LIP as CERN's reference laboratory in Portugal. While CERN remains our main partner, LIP now belongs to international collaborations at ESA, GSI, SNOLAB, Auger and SURF, and our activities are intrinsically related to international infrastructures, collaborations and networks. International meetings, schools, workshops and conferences are periodically organized by LIP in Portugal.

Open Science
LIP is committed to the Open Science paradigm and is present in RCAAP, the Portuguese scientific open access platform, where published papers, contributions to conferences and theses are available. Several international collaborations to which LIP belongs follow a strict open access publication policy. LIP makes intensive use of platforms such as arXiv. In addition, LIP is committed to the FAIR (Findability, Accessibility, Interoperability, Reusability) data principles, performs R&D and delivers services oriented to support data lifecycle.

Part 2: Description of the R&D Unit, main contributions of the team of integrated researchers in the application and funding in 2013-17

05. REPORTS AND MEMBERSHIP OF EXTERNAL ADVISORY BOARD

5.1 External Advisory Board reports in 2013-2017

R&D Unit	File
LIP	LIP Advisory Committee_ Report 2015.pdf
LIP	LIP Advisory Committee_Report 2017.PDF
LIP	LIP Advisory Committee_Report 2013.PDF
LIP	LIP Advisory Committee_Report 2016.pdf
LIP	LIP Advisory Committee_Report 2014.pdf

5.2 Current External Advisory Board membership

R&D Unit	Member Name	Institution
LIP	Pier Giorgio Innocenti	CERN - Switzerland
LIP	Christian Fabjan	CERN - Switzerland
LIP	Luigi Rolandi	CERN - Switzerland
LIP	Sergio Bertolucci	University of Bologna - Italy
LIP	Katia Parodi	Ludwig-Maximilians, Universität München - Germany
LIP	Masahiro Teshima	Max Planck Institute for Physics - Germany

5.3 External Advisory Board membership

Member Name	Institution
Pier Giorgio Innocenti	CERN - Switzerland
Christian Fabjan	CERN - Switzerland
Luigi Rolandi	CERN - Switzerland
Sergio Bertolucci	University of Bologna - Italy
Katia Parodi	Ludwig-Maximilians, Universität München - Germany
Masahiro Teshima	Max Planck Institute for Physics - Germany

06. FUNDING IN 2013-2017

6.1 Annual funding in 2013-2017

FUNDING SOURCES (TOTAL FUNDING)	2013	2014	2015	2016	2017	TOTAL (K€)
Fundação para a Ciência e a Tecnologia, I.P. - FCT	3.934	3.875	4.521	4.370	4.369	21.069
R&D Unit Pluriannual funding	1.075	1.166	1.696	1.452	1.298	6.687
Project funding	1.357	876	860	958	934	4.985
Funding for contracts of researchers with PhD (1)	346	614	647	728	1.075	3.410
Funding for PhD, PostDoc or other fellowships (2)	513	483	583	497	368	2.444
Other funding	643	736	735	735	694	3.543
Other national sources	60	101	107	75	179	522
Funding received from Participant or Management Institutions	0	0	0	0	7	7
Public sources (3)	0	0	0	0	0	0
Companies, industry and other private sources based in Portugal (3)	12	51	88	62	160	373
Any other funding source (3)	48	50	19	13	12	142
International sources	660	810	780	681	818	3.749
European Commission (3)	501	540	450	511	390	2.392
Companies, industry and other private sources not based in Portugal (3)	75	119	159	100	273	726
Other funding sources (3)	84	151	171	70	155	631
Total (K€)	**4.654**	**4.786**	**5.408**	**5.126**	**5.366**	**25.340**

(1) Payed through an institution or directly to researchers with PhD integrated in the R&D Unit

(2) Payed directly to fellows, researchers or students integrated in the R&D Unit

(3) Grants, projects, fellowships, prizes received, etc

07. INTEGRATED RESEARCHERS, PHD STUDENTS AND RESEARCH CONTRACTS IN 2013-2017

7.1 Total numbers of Integrated Researchers, PhD students and research contracts in 2013-2017

RESEARCHERS AND STUDENTS	2013	2014	2015	2016	2017
No. of integrated researchers	158	163	168	164	161
No. of Integrated researchers with PhD	77	81	81	81	85
No. of PhD students advised by integrated members of the R&D Unit	38	36	42	41	35
No. of research contracts with national public or private entities	19	26	23	17	19
No. of research contracts with international bodies	8	11	16	14	12

Part 3: Research team with links to CVs and ORCID record

08. LISTS OF RESEARCHERS IN THE CURRENT APPLICATION

8.1 List of the Integrated Researchers of the R&D Unit who hold a PhD degree

NAME	NUCLEAR CV	ORCID ID
Mário João Martins Pimenta	Yes	0000-0002-2590-0908
Agostinho da Silva Gomes	No	0000-0002-5940-9893
Alberto Blanco Castro	No	0000-0001-9827-8294
Alexandre Miguel Ferreira Lindote	No	0000-0002-7965-807X
Amelia Arminda Teixeira Maio	No	0000-0001-9099-0009
Ana Sofia da Silva Nunes	No	0000-0001-8361-622X
Andrey Morozov	No	0000-0002-7922-970X
Antonio Joaquim Onofre de Abreu Ribeiro Goncalves	Yes	0000-0003-3471-2703
António Manuel da Silva Pina	No	0000-0001-6548-6396
Bernardo António Neto Gomes Baptista Tomé	No	0000-0002-7564-8392
Bruno Miguel Leonardo Galhardo	No	0000-0003-0641-301X
Carlos Alberto Nabais Conde	No	0000-0002-1387-2161
Catarina Marques Quintans	No	0000-0002-9345-716X
Celso Filipe Correia Franco	No	0000-0003-2729-4064
Claudio Frederico Pascoal da Silva	No	0000-0002-1771-1517
Cristóvão Beirão da Cruz e Silva	No	0000-0002-1231-3819
Daniel Galaviz Redondo	No	0000-0003-2992-4496
Felix Riehn	No	0000-0001-8434-7500
Fernando José de Carvalho Barão	No	0000-0002-8346-9941
Filipa Isabel Gouveia de Melo Borges Belo Soares	No	0000-0001-5790-173X
Filipe Alexandre Pedra Aguiar de Moura	No	0000-0003-0050-6805
Filipe Manuel Almeida Veloso	No	0000-0002-5956-4244
Francisco Filipe Bento Neves	No	0000-0003-3635-1083

NAME	NUCLEAR CV	ORCID ID
Francisco Gonçalves Dias Cardoso Diogo	No	0000-0002-6378-4741
Gaspar Pereira de Morais Barreira	No	0000-0001-6373-9441
Gersende Prior	No	0000-0002-6058-1420
Helena de Fatima Nunes Casimiro dos Santos	No	0000-0003-1710-9291
Helmut Wolters	No	0000-0002-9588-1773
João António da Silva Barata	No	0000-0001-7415-4705
Joao Antonio Tomasio Pina	No	0000-0001-8959-5044
João Carlos Carvalho Sa Seixas	No	0000-0002-7531-0842
João Gentil Mendes Saraiva	No	0000-0002-7006-0864
João Manuel Coelho Varela	Yes	0000-0003-2613-3146
Jonathan Hollar	No	0000-0002-8664-0134
Jorge Humberto Lúcio Oliveira Gomes	Yes	0000-0002-9142-2596
Jorge Manuel Maia Pereira	No	0000-0002-9314-1763
Jorge Miguel de Brito Almeida Sampaio	No	0000-0003-4359-493X
Jorge Miguel Tavares Couceiro de Sousa	No	0000-0002-6800-8653
José Carvalho Maneira	Yes	0000-0002-3222-2738
José Guilherme Teixeira de Almeida Milhano	No	0000-0001-8154-3688
José Lopes Pinto da Cunha	No	0000-0002-9049-0693
José Manuel Dias Escada	No	0000-0002-4497-2931
José Ricardo Morais Silva Gonçalo	No	0000-0002-3826-3442
Juan Pedro Araque Espinosa	No	0000-0003-2927-9378
Korinna Christine Zapp	No	0000-0003-3046-6453
Liliana Marisa Cunha Apolinário	No	0000-0003-3500-9681
Lorenzo Cazon Boado	No	0000-0001-6748-8395
Lozza Valentina	No	0000-0002-9521-8517
Luis Filipe dos Santos Garcia Peralta	No	0000-0002-3834-1762
Luis Manuel Silva Margato	No	0000-0001-5849-1410
MARCIN STOLARSKI	No	0000-0003-0276-8059
Maria Catarina Ferreira do Espírito Santo	No	0000-0003-1286-7288
Maria da Conceicao Abreu e Silva	No	0000-0003-0093-7496
Maria Filomena de Osorio Pinto dos Santos	No	0000-0002-0214-4185
Maria Isabel Silva Ferreira Lopes	Yes	0000-0003-0419-903X
Maria Luísa Ferreira da Gama Velho Arruda	No	0000-0001-6720-6933
Maria Paula Frazão Bordalo e Sá	No	0000-0002-3651-6370
Mário Jorge Moura David	No	0000-0003-1802-5356
Michele Gallinaro	No	0000-0003-1261-2277
Miguel Castro Nunes Fiolhais	No	0000-0001-9035-0335
Nuno Filipe da Silva Fernandes de Castro	No	0000-0001-8491-4376
Nuno Teotonio Viegas Guerreiro Leonardo	No	0000-0002-9746-4594
Patricia Carla Serrano Gonçalves	Yes	0000-0003-2042-3759
Patricia Conde Muino	Yes	0000-0002-9187-7478
Paulo Alexandre Vieira Crespo	No	0000-0002-0891-032X
Paulo Jorge Baeta Mendes	No	0000-0002-8964-3330

NAME	NUCLEAR CV	ORCID ID
Paulo Jorge Ribeiro da Fonte	Yes	0000-0002-2275-9099
Pedrame Bargassa	No	0000-0001-8612-3332
Pedro Jorge dos Santos de Assis	No	0000-0001-7765-3606
Pedro Moraes Salgueiro Teixeira de Abreu	No	0000-0002-9973-7314
Pietro Faccioli	No	0000-0003-1849-6692
Raul Cambraia Lopes Sarmento Pereira	No	0000-0002-5018-5467
Ruben Maurício da Silva Conceição	No	0000-0003-4945-5340
Rui Ferreira Marques	Yes	0000-0003-3549-8198
Rui Miguel Curado da Silva	No	0000-0002-9961-965X
Rui Miguel Faisca Rodrigues Pereira	No	0000-0003-1411-5354
Rute Costa Batalha Pedro	No	0000-0002-7139-9587
Sandra da Costa Henriques Soares	No	0000-0002-6401-5290
Sérgio Eduardo Campos Costa Ramos	No	0000-0001-8946-2268
Sofia Andringa Dias	No	0000-0002-6397-9207
SUMANTA PAL	No	0000-0002-5717-7750
Susete Teresa Gaspar do Fetal	No	0000-0002-7970-1082
Teresa Maria da Mota Horta e Vale Teixeira Dias	No	0000-0001-5101-4902
Vitali Iourievitch Tchepel	No	0000-0003-0675-4586
Vladimir Solovov	No	0000-0002-0659-7034

8.2 **List of the Integrated Researchers of the R&D Unit who do not hold a PhD degree**

NAME	IS PHD STUDENT?	ORCID ID
Agostino Di Francesco	Yes	0000-0002-7846-1726
Alexandre Manuel da Fonseca Trindade	Yes	0000-0003-2240-8544
Americo Manuel de Almeida Pereira	No	0000-0001-6457-1441
Ana Luísa Martins de Carvalho Casimiro	Yes	0000-0002-4176-3755
Ana Luisa Moreira de Carvalho	No	0000-0002-1986-5720
Ana Luísa Rodrigues Lopes	Yes	0000-0001-9196-3125
Ana Paula Pereira Peixoto	Yes	0000-0003-3424-7338
Ana Sofia Carpinteiro Inácio	Yes	0000-0002-3684-5908
André Filipe Ventura Cortez	Yes	0000-0003-0067-3128
André Reigoto da Costa	No	0000-0001-5544-677X
António Manuel Mendes Jacques da Costa	No	0000-0001-6305-8400
Bruno Afonso Fontana Santos Alves	No	0000-0002-4299-1071
Bruno Emanuel Martins Galinhas	Yes	0000-0001-8110-2743
Carlos Alberto Nunes Manuel	No	0000-0003-0560-7365
Carlos Manuel Martins da Silva	No	0000-0002-1127-714X
Cédric Pedroso Pereira	No	0000-0002-2839-6479
Christophe Menezes Pires	No	0000-0003-4270-0008
David Lopes Fernandes	No	0000-0001-5145-4641
Diogo Carlos Chasqueira de Bastos	Yes	0000-0002-4615-1141
Douglas Alves de Lima	No	0000-0002-5928-7072
Duarte Rocha Peixoto Azevedo	Yes	0000-0002-2647-1893
Emanuel Demétrio Mendes Gouveia	Yes	0000-0002-7785-2047

NAME	IS PHD STUDENT?	ORCID ID
EMIR KADIR SIRAGE	No	0000-0001-9725-2383
Filipe Manuel Pedro Martins	No	0000-0003-2965-7746
Giles Chatham Strong	Yes	0000-0002-4640-6108
Guilherme Pinheiro Pereira	Yes	0000-0001-9156-4239
Henrique Manuel Peixoto Carvalho	No	0000-0003-0081-4648
Hugo Joel de Jesus Simões	Yes	0000-0003-4336-6080
Hugo Miguel da Silva Gomes	No	0000-0002-9074-3179
Joao Carlos Sousa Rodrigues Silva	No	0000-0002-4741-1478
João de Sena Baptista Pimentel Marcos	Yes	0000-0001-8288-9509
Joao Paulo Martins Conceicao	No	0000-0003-4308-266X
João Pedro de Carvalho Saraiva	No	0000-0002-8757-4570
Joaquim Pedro Kessongo	Yes	0000-0003-4315-0634
José Carlos Fernandes Nogueira	No	0000-0001-5396-7379
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Jose Carlos Rasteiro da Silva	No	0000-0001-7504-4225
José Miguel Patuleia Venâncio	No	0000-0003-4708-1242
José Pedro Ferreira Alves	No	0000-0003-0200-3208
Luis Alberto Vieira Lopes	No	0000-0001-8571-0033
Luis António Rodrigues de Figueiredo Ferreira Pereira	Yes	0000-0002-8381-1081
Luis Filipe Oleiro Vivaldo Seabra	No	0000-0002-9320-8825
Luís Filipe Sequeira Alves	No	0000-0003-1271-9904
Luís Miguel da Silva Gurriana	No	0000-0002-6413-4425
Luis Miguel Domingues Mendes	No	0000-0003-0651-9404
Marco Gui Alves Pinto	Yes	0000-0002-5712-9396
Margarida Isabel de Matos Inácio	Yes	0000-0001-5921-5418
Maria Alexandra Lima Fernandes	No	0000-0002-9187-4007
Maria Pestana da Luz Pereira Ramos	Yes	0000-0001-7743-7364
Maura Gabriela Barros Teixeira	No	0000-0003-0914-8178
Miguel Antonio Freitas Ferreira	No	0000-0002-5662-9030
Miguel Fernandes Moita	Yes	0000-0002-8240-509X
Miguel Matos Ferreira	No	0000-0002-0194-827X
Miguel Reis Orcinha	Yes	0000-0003-1874-2144
Nuno Filipe Silva Dias	No	0000-0002-5736-6594
Nuno Manuel Ribeiro Dias	No	0000-0001-8687-1277
Nuno Miguel Vasconcelos Costa Carolino	No	0000-0001-9039-1559
Oleksii Toldaiev	Yes	0000-0002-8286-8780
Orlando Lopes Cunha	No	0000-0002-5674-4346
Pamela Teubig	Yes	0000-0002-9177-7522
Paulo Alexandre Brinca Costa Brás	Yes	0000-0001-7012-9932
Paulo Jorge Fernandes Velho	Yes	0000-0002-7578-6189
Pedro Mendes Jorge	Yes	0000-0002-3849-4814
Ricardo Filipe Coelho Barrué	No	0000-0001-8985-5379
Ricardo Jorge Barreira Luz	Yes	0000-0001-6467-9866

NAME	IS PHD STUDENT?	ORCID ID
Rui Fernando Alves	No	0000-0002-0163-8968
Rui Jorge de Carvalho Martins	No	0000-0002-9426-8897
Rui Manuel Pereira da Silva	No	0000-0002-4477-0467
Soraia Sofia Clareu Elísio	No	0000-0002-7108-135X
Stefan-Alexandru Nae	Yes	0000-0002-2771-5095
Susana Patrícia Amor dos Santos	Yes	0000-0001-7566-6067
Tahereh Sadat Niknejad	Yes	0000-0003-3276-9482
Tiago Dias do Vale	Yes	0000-0001-8855-3520
Viorel Dubceac	No	0000-0002-6375-4331
Vítor Serafim Pereira de Oliveira	No	0000-0001-5783-8902
Yoenls Prata Alicerces Bahu	Yes	0000-0002-9353-468X

8.3 List of the Collaborator Researchers of the R&D Unit

NAME	ORCID ID
Alessandro De Angelis	
Alina Rosa Coelho Louro	
Ana Isabel Martinho Henriques	0000-0002-1417-8518
André Martins Pereira	0000-0002-2110-914X
António Joaquim André Esteves	0000-0003-3694-820X
Artur Jorge Carvalho Amorim de Sousa	0000-0002-1659-2202
Elisabet Galiana Baldó	
Elsa Susana dos Reis da Fonseca	0000-0002-1531-8789
Fátima Sofia Monteiro Alcaso	
Florbela Martins Rêgo	0000-0002-7217-3037
Guilherme Telo Rodrigues Catumba	
Guiomar Gaspar de Andrade Evans	0000-0003-0434-6925
José António Soares Augusto	0000-0002-5869-7950
José Carlos Rufino Amaro	0000-0002-1344-8264
Juan Antonio Aguilar Saavedra	0000-0002-5475-8920
Luis Filipe Dores Ferramacho	0000-0002-8481-1163
Miguel Patricio da Silveira	0000-0002-6595-8741
Pedro Manuel Vieira de Castro Ferreira da Silva	0000-0002-5725-041X
Pedro Miguel Félix Brogueira	0000-0001-6069-4073
Pedro Miguel Martins Ferreira	0000-0002-9351-1074
Ricardo Alexandre Marques Bugalho	
Rui Alberto Serra Ribeiro dos Santos	0000-0002-7948-0355
Stefaan Paul K TAVERNIER	

09. PROPOSED RESEARCH GROUPS

Reference	Name	Principal Investigator
RG-50007-5095	1. ATLAS - Portuguese participation in the ATLAS experiment	Patricia Conde Muino
RG-50007-5101	2. CMS - Portuguese participation in the CMS experiment	João Manuel Coelho Varela
RG-50007-388457	3.Phenomenology	José Guilherme Teixeira de Almeida Milhano

RG-50007-388458	4. PQCD - Partons and QCD	Catarina Marques Quintans
RG-50007-388459	5. LERHI - Low Energy Reactions with Hadrons and Ions	Daniel Galaviz Redondo
RG-50007-388460	6. Cosmic rays	Mário João Martins Pimenta
RG-50007-388462	7. Neutrino physics	José Carvalho Maneira
RG-50007-388463	8. Dark matter	Maria Isabel Silva Ferreira Lopes
RG-50007-388478	9. Detector development for particle and nuclear physics	Rui Ferreira Marques
RG-50007-388486	10. Health and biomedical applications	Paulo Jorge Ribeiro da Fonte
RG-50007-388487	11. Applications for space exploration	Patricia Carla Serrano Gonçalves
RG-50007-388488	12. Computing	Jorge Humberto Lúcio Oliveira Gomes

(RG-50007-5095) 1. ATLAS - Portuguese participation in the ATLAS experiment

09.1. IDENTIFICATION OF THE RESEARCH GROUP

9.1.1 Reference of the research group

RG-50007-5095

9.1.2 Name of the Research Group in portuguese

1. ATLAS - Participação portuguesa na experiência ATLAS

9.1.3 Name of the Research Group in English

1. ATLAS - Portuguese participation in the ATLAS experiment

9.1.4 Keyword(s)

Higgs

Top quark

Heavy ions

Calorimetry

9.1.5 Existed in 2008/2012

Yes

09.2. RESEARCHERS OF THE RESEARCH GROUP

9.2.1 List of Integrated Researchers of the R&D Unit who hold a PhD degree and belong to the Research Group

NAME	PRINCIPAL INVESTIGATOR
Patricia Conde Muino	Yes
Agostinho da Silva Gomes	No
Amelia Arminda Teixeira Maio	No
Antonio Joaquim Onofre de Abreu Ribeiro Goncalves	No
António Manuel da Silva Pina	No
Bruno Miguel Leonardo Galhardo	No
Filipe Manuel Almeida Veloso	No
Helena de Fatima Nunes Casimiro dos Santos	No
Helmut Wolters	No
João Gentil Mendes Saraiva	No
José Ricardo Morais Silva Gonçalo	No
Juan Pedro Araque Espinosa	No
Liliana Marisa Cunha Apolinário	No
MARCIN STOLARSKI	No
Miguel Castro Nunes Fiolhais	No

NAME	PRINCIPAL INVESTIGATOR
Nuno Filipe da Silva Fernandes de Castro	No
Rui Miguel Faisca Rodrigues Pereira	No
Rute Costa Batalha Pedro	No

9.2.2 List of Integrated Researchers of the R&D Unit who do not hold a PhD degree and belong to the Research Group

NAME
Ana Paula Pereira Peixoto
André Reigoto da Costa
António Manuel Mendes Jacques da Costa
Duarte Rocha Peixoto Azevedo
Emanuel Demétrio Mendes Gouveia
Filipe Manuel Pedro Martins
Luis Filipe Oleiro Vivaldo Seabra
Luís Miguel da Silva Gurriana
Maria Pestana da Luz Pereira Ramos
Maura Gabriela Barros Teixeira
Ricardo Filipe Coelho Barrué
Rui Jorge de Carvalho Martins
Susana Patrícia Amor dos Santos
Tiago Dias do Vale
David Lopes Fernandes
Ana Luisa Moreira de Carvalho

09.3. DESCRIPTION OF THE MAIN CONTRIBUTIONS OF THE RESEARCH GROUP IN 2013-2017

9.3.1 General description of the Research Group

LIP is a founding member of the ATLAS collaboration and made crucial contributions to all the phases of the experiment, from R&D and construction to physics analysis and discovery. Our members have occupied a number of leading roles in the collaboration in most activities in which the group is involved. After contributing to the discovery of the Higgs boson in 2012, in the last five years we have continued to measure its properties. We are a reference in top quark physics studies, with a leading role in several measurements of the top quark properties, and have proposed innovative analysis techniques. This expertise allowed us to initiate, and soon lead analyses to search for new physics, namely vector-like quarks. We have made important contributions to the ATLAS heavy ion physics programme with the study of jets as probes of the quark-gluon plasma (QGP), a state of matter prevalent immediately after the Big Bang.
Our group was responsible for the design and construction of the optical readout of the hadronic calorimeter TileCal, one of the main ATLAS sub-detectors; the design and implementation of the TileCal Detector Control System (DCS); and contributed to the Trigger and Data Acquisition system (Trigger/DAQ) as well as the forward detector systems. Today, the group has a leading responsibility in the DCS of several sub-detectors: the TileCal, the Forward Proton tagging detector (AFP) and the ALFA luminosity detector. For the next five years, the team will continue to give high-level contributions to the exploration of particle physics at the high-energy frontier with ATLAS, in the physics channels we are engaged on. We are also engaged in upgrading the detector to prepare for the future High-Luminosity LHC: we are responsible for the production of the new TileCal high-voltage distribution system, in collaboration with Portuguese industry, for replacing gap scintillators and fibres with more radiation-hard ones, and improving trigger selection algorithms.

9.3.2 Identification and summary description of up to 3 contributions deemed most important of those provided in 2013-2017 by researchers who belong to the Research Group in the current R&D Unit application

1. LHC data analysis and interpretation: Since the Higgs discovery in 2012, where we had a leading role in the VH and WW search analyses, we gave a crucial contribution to the first observation and measurement of the Higgs decays to WW, recognized with an ATLAS PhD thesis award in 2016. We then concentrated on channels where the Higgs boson couples to heavy b and top quarks. Both channels have yielded fruits recently, with the first observation of 3-sigma evidence in each case, and will soon provide crucial measurements of the Higgs boson properties. We are an international reference in top-quark physics, with group members occupying leading roles in ATLAS analysis groups. We have explored the physics of this unique quark in many ways, by searching for rare decays, anomalous couplings, and forbidden flavour-changing neutral currents. In searches for new physics, we are leading three different searches for top quark production in association with hypothetical vector-like quarks (coordination of the ATLAS teams and

main analysis). We have contributed to the first observation and to the study of the quark-gluon plasma in heavy-ion collisions at the LHC, through the asymmetry created in di-jet collisions when a jet crosses this strongly interacting medium.

2. Detector calibration and control: We have contributed to the design and implementation of the TileCal DCS. Since 2013 our group has been fundamental in the maintenance and continuous upgrade of the TileCal DCS, a contribution that has resulted in an ATLAS Outstanding Achievement Award in 2016 for a group member who is also the current coordinator of this system. We are also responsible for the ALFA DCS, and contributed to the design and implementation of the AFP DCS. We have built the optics of the new Laser-II calibration system, essential to guarantee the good operation and uniform response of the TileCal. We have created and implemented a method to automatically detect unstable photomultipliers. We have also produced an important survey of the calorimeter electronic noise.

3. Trigger: this is one of our main commitments in ATLAS. We coordinated the ATLAS jet trigger group, and had a leading role in the upgrade of the jet High Level Trigger during the long shutdown before Run-2, starting in 2015. This included the difficult migration to a new two-level trigger scheme, a new partial-scan readout scheme to cope with high trigger rates, a new trigger selection menu for physics exploitation, and the re-organization of jet trigger operations. The group implemented a parallel reconstruction algorithm for calorimeter energy clusters to run on GPUs intended for the high luminosity upgrade. In other trigger areas, we have contributed to the new Tile-muon trigger, and had a major role in the design and commissioning of the AFP jet trigger. The Tile-muon trigger uses the outermost TileCal cells to reject fake muons in the Level-1 trigger in a poorly instrumented region of the muon spectrometer.

(RG-50007-5101) 2. CMS - Portuguese participation in the CMS experiment

09.1. IDENTIFICATION OF THE RESEARCH GROUP

9.1.1 Reference of the research group

RG-50007-5101

9.1.2 Name of the Research Group in portuguese

2. CMS - Participação portuguesa na experiência CMS

9.1.3 Name of the Research Group in English

2. CMS - Portuguese participation in the CMS experiment

9.1.4 Keyword(s)

LHC

CMS

Higgs

Heavy quarks

9.1.5 Existed in 2008/2012

Yes

09.2. RESEARCHERS OF THE RESEARCH GROUP

9.2.1 List of Integrated Researchers of the R&D Unit who hold a PhD degree and belong to the Research Group

NAME	PRINCIPAL INVESTIGATOR
João Manuel Coelho Varela	Yes
Cristóvão Beirão da Cruz e Silva	No
João Carlos Carvalho Sa Seixas	No
Jonathan Hollar	No
Michele Gallinaro	No
Nuno Teotonio Viegas Guerreiro Leonardo	No
Pedrame Bargassa	No
Pietro Faccioli	No

9.2.2 List of Integrated Researchers of the R&D Unit who do not hold a PhD degree and belong to the Research Group

NAME
Agostino Di Francesco

NAME

Bruno Afonso Fontana Santos Alves

Bruno Emanuel Martins Galinhas

Diogo Carlos Chasqueira de Bastos

Giles Chatham Strong

Jose Carlos Rasteiro da Silva

Oleksii Toldaiev

Rui Manuel Pereira da Silva

Tahereh Sadat Niknejad

Viorel Dubceac

09.3. DESCRIPTION OF THE MAIN CONTRIBUTIONS OF THE RESEARCH GROUP IN 2013-2017

9.3.1 General description of the Research Group

LIP is member of the Compact Muon Solenoid (CMS) Collaboration at the LHC since its creation in 1992. The LIP group maintains an important and visible participation in CMS, reflected in various coordinating positions at the highest level, in the responsibility for the development and construction of major CMS components, and in the leadership in the physics analysis of some of the most important topics in the LHC programme. In particular, a LIP member has served as Deputy Spokesperson of the CMS Collaboration in 2012-13 and other members have recently coordinated the Top, Higgs, and B-physics working groups.
LIP had a leading role in the design and construction of important components of the CMS detector, namely the data acquisition system of the Electromagnetic Calorimeter (ECAL) and the CMS trigger system. The LIP group is leading the development of the new CTPPS forward proton spectrometer, which took physics data already in 2016, proving for the first time the feasibility of operating near-beam at high luminosity on a regular basis.
LIP made major contributions to the CMS physics programme. In particular, to the discovery of a Higgs boson, the measurement of the top quark properties, the first observation of rare Bs meson decays, the measurement of the psi and upsilon polarizations, and to searches for supersymmetric particles. Our group has been playing a leading role in the development of advanced analysis techniques using deep neural networks and machine learning tools.
In 2018-22 the LIP group will keep the participation in CMS at the same high level of quality, responsibility and visibility. In addition to continuing its involvement in physics exploitation, the group will participate in the CMS upgrade in view of the High-Luminosity LHC. R&D in collaboration with Portuguese industry is being pursued for the development of microelectronics blocks for the frontend readout systems of the ECAL, the High Granularity Calorimeter and the MIP Timing Detector.

9.3.2 Identification and summary description of up to 3 contributions deemed most important of those provided in 2013-2017 by researchers who belong to the Research Group in the current R&D Unit application

1. Higgs, top quark and heavy flavour Physics: The LIP group had a leading role in the discovery of the Higgs boson in the two-photons decay channel. Two members of the group had a major role in the analysis and in the publication of the results, and one co-convened the whole CMS Higgs Physics analysis group. LIP had a leading role in the development of innovative techniques to measure the most fundamental properties of the top quark. Among those, measurements of tau lepton and dilepton production in top quark decays, the Vtb matrix-element, and top quark width provide among the most accurate so far. A member of the group was co-convener of the CMS Top Quark Mass analysis group, and is currently the co-convener of the whole CMS Top Quark Physics Analysis Group. LIP-CMS group members are recognised world leaders in heavy flavor physics in hadron collisions, including b-hadron and heavy quarkonium measurements and in the search for rare physics processes at the LHC. The first observation of the Bs->mumu channel was a flagship discovery of LHC Run1, in which we were actively involved. One member of the group served recently as co-convener of the CMS B and Quarkonium Physics group. A group member has served as Deputy Spokesperson of the whole CMS Collaboration in 2012-13. This leadership position at the highest level of the CMS Collaboration, associated to the coordination positions in three of the main CMS Physics Analysis Groups, provide clear evidence of the excellence of the LIP-CMS contributions to the science produced by CMS.

2. High luminosity forward proton spectrometer at LHC: LIP-CMS has a leading role in the new forward proton spectrometer (CTPPS) proposed in 2013 as an additional CMS sub-detector allowing the study of collisions of quasi-real photons at the TeV scale. This detector permits proton tagging in central exclusive events allowing the measurement of electroweak vector boson quartic couplings with unprecedented sensitivity. The detector was integrated in 2016 demonstrating for the first time the feasibility of operating a near-beam proton spectrometer at high luminosity in a proton collider. Group members serve has CTPPS Project Manager, CTPPS Timing Detector Coordinator and CTPPS DAQ Coordinator.

3. CMS Detector Upgrades for High Luminosity: LIP-CMS made major contributions for the high-luminosity upgrades of the CMS detector. The group has developed and operated a new plant of High-Speed Optical Links that interface the Electromagnetic Calorimeter electronics to the Trigger System as part of the CMS Phase 1 Upgrade of the Trigger System. The LIP-CMS group participates in the new MIP Timing Detector (MTD) for the CMS Phase 2 Upgrade. The LIP group had a leading role in the design and construction of the readout system. The ASIC developed for TOF-PET applications by LIP and the Portuguese start-up PETsys was selected by the Collaboration for use in the MTD. A group member belongs to the MTD Steering Committee.

09.1. IDENTIFICATION OF THE RESEARCH GROUP

9.1.1 Reference of the research group

RG-50007-388457

9.1.2 Name of the Research Group in portuguese

3. Fenomenologia

9.1.3 Name of the Research Group in English

3.Phenomenology

9.1.4 Keyword(s)

heavy-ion phenomenology

Standard Model phenomenology

Monte Carlo event simulation

New Physics searches

9.1.5 Existed in 2008/2012

Yes

09.2. RESEARCHERS OF THE RESEARCH GROUP

9.2.1 List of Integrated Researchers of the R&D Unit who hold a PhD degree and belong to the Research Group

NAME	PRINCIPAL INVESTIGATOR
José Guilherme Teixeira de Almeida Milhano	Yes
Antonio Joaquim Onofre de Abreu Ribeiro Goncalves	No
Juan Pedro Araque Espinosa	No
Korinna Christine Zapp	No
Liliana Marisa Cunha Apolinário	No
Miguel Castro Nunes Fiolhais	No
Nuno Filipe da Silva Fernandes de Castro	No
José Ricardo Morais Silva Gonçalo	No
Ruben Maurício da Silva Conceição	No

9.2.2 List of Integrated Researchers of the R&D Unit who do not hold a PhD degree and belong to the Research Group

NAME
André Reigoto da Costa
Duarte Rocha Peixoto Azevedo
Maria Pestana da Luz Pereira Ramos
Rui Jorge de Carvalho Martins

09.3. DESCRIPTION OF THE MAIN CONTRIBUTIONS OF THE RESEARCH GROUP IN 2013-2017

9.3.1 General description of the Research Group

The LIP Phenomenology group conducts research bridging theory and experiment in particle and astroparticle physics. Its research, while independent, is centred on areas in which LIP has active experimental activities and aims to identify areas in which LIP's broader programme may evolve in the future. Its founding purpose is to strengthen the impact of the overall LIP programme through the provision of excellent directed phenomenological research. At present the group has internationally recognized and consolidated research activities in top quark, Higgs, and heavy-ion phenomenology, with a strong expertise in the development of event generators. The group also encompasses phenomenological research previously undertaken within various LIP groups.
Past activity has included the development of Monte-Carlo generators, including the Hybrid Strong/Weak Coupling Model, dedicated to the detailed simulation of hadronic jets in heavy-ion collisions, and METop, which allows for modified top-quark couplings and properties. Other contributions have included the study of top-pair production at the LHC, proton and nuclei structure determination using non-linear (Colour Glass

Condensate) evolution, the computation of observables sensitive to initial conditions in proton-nucleus and nucleus-nucleus collisions, the development of fitting packages for the global fit of top quark properties including the possibility of anomalous couplings, and the identification of new observables sensitivite to top-Higgs couplings.
Currently, steps are being taken to consolidate existing research activities and expand our activity, namely to cosmic ray air showers physics and dark matter searches. To ensure continued competitiveness and responsiveness to new developments in areas of strategic importance, the group will work towards widening its scope, and to establish new partnerships and collaborations to complement the existing expertise.

9.3.2 Identification and summary description of up to 3 contributions deemed most important of those provided in 2013-2017 by researchers who belong to the Research Group in the current R&D Unit application

1. New tools and methods for top-quark physics at the LHC: Since 2013, the group has proposed innovative tools to solve some of the most difficult problems in top-quark physics at the LHC. We proposed novel angular observables to suppress the irreducible ttbb background in searches for Higgs production in association with top quarks. This poorly understood background is the main stumbling block to this crucial search. An extension of the proposed method also provides experimental sensitivity to the CP nature of the ttH vertex, allowing the study of a non-standard pseudoscalar component of the top Yukawa coupling. We have produced, detailed analyses of the anomalous couplings of top quarks, through a combined fit of its measured properties. Finally, we started in 2006 the International Workshop on Top Quark Physics, which became the leading conference in top-quark physics.

2. Heavy-ion physics at the LHC: The group is a world reference on the interpretation of LHC heavy ion jet data. Our contributions have consistently brought novel insights to augment the scope of use of jets as probes of quark-gluon plasma (QGP). We identified, for the first time, fluctuations in jet development as the driving mechanism for the modification of jet properties by the QGP. We pioneered the use of jet substructure properties to isolate the QGP's hydrodynamical response to the passage of jets, and as a robust tool to distinguish quenched and unquenched jets. The Hybrid Weak/Strong Coupling Model, based on holographic methods, provides the first overwhelmingly successful description of heavy ion jet data assuming non-perturbative dynamics between jet and the QGP. These contributions have played a crucial role to motivate new experimental analyses. The group's strong activity in development of state-of-art Monte-Carlo event-generators (Q-PYTHIA, JEWEL, Hybrid Weak/Strong) has contributed decisively to the above achievements. The group's prominence is further illustrated by invitations for plenary (most recently for Quark Matter 2017 and 2018) talks at the leading conferences.

3. Future Heavy-Ion Programme and the Lisbon Accord: We have identified as a priority the definition of the short and long term heavy-ion experimental programmes. We have been the driving force behind a community effort (Lisbon Accord) to standardise theory/data comparisons and guarantee legacy of experimental analyses. Further, we have been key players in providing a physics case for heavy-ion runs during the LHC high-luminosity era and in future collider facilities, such as the Large Hadron-electron Collider (LHeC) and a Future Circular Collider (FCC) at CERN. We contributed substantially to the FCC CERN Yellow Report and have been nominated often to represent the working groups at workshops and conferences. Substantially, we have established the basis for experimental studies of top-quark production in heavy-ion collisions aimed as a direct probe of the time evolution of QGP properties.

(RG-50007-388458) 4. PQCD - Partons and QCD

09.1. IDENTIFICATION OF THE RESEARCH GROUP

9.1.1 Reference of the research group

RG-50007-388458

9.1.2 Name of the Research Group in portuguese

4. PQCD - Partões e QCD

9.1.3 Name of the Research Group in English

4. PQCD - Partons and QCD

9.1.4 Keyword(s)

Hadron structure

Fragmentation functions

Drell-Yan process

Detector control systems

9.1.5 Existed in 2008/2012

Yes

09.2. RESEARCHERS OF THE RESEARCH GROUP

9.2.1 List of Integrated Researchers of the R&D Unit who hold a PhD degree and belong to the Research Group

NAME	PRINCIPAL INVESTIGATOR
Catarina Marques Quintans	Yes
Ana Sofia da Silva Nunes	No
Celso Filipe Correia Franco	No
MARCIN STOLARSKI	No

9.2.2 List of Integrated Researchers of the R&D Unit who do not hold a PhD degree and belong to the Research Group

NAME
Christophe Menezes Pires

09.3. DESCRIPTION OF THE MAIN CONTRIBUTIONS OF THE RESEARCH GROUP IN 2013-2017

9.3.1 General description of the Research Group

The LIP PQCD group is heir to a long tradition in CERN's fixed target experimental programme, starting in the 1980s with the heavy ion experiments NA38 and later NA50. The group now concentrates on the COMPASS experiment, devoted to hadron spectroscopy and to measurements fundamental for the detailed understanding of nucleon structure. COMPASS collides high intensity muon and hadron beams with a polarized nuclear target. The LIP group is the sole responsible for the complex detector control system, known at CERN for its outstanding reliability. The group is also responsible for a number of key analyses and is a reference in the measurements using the Drell-Yan (DY) process, the production of lepton pairs in hadron collisions. The group was co-responsible for the DY run in 2015, in which the first world measurement of the polarized DY process was achieved. The DY team is today the largest one in COMPASS, and is coordinated by the PI of the LIP PQCD group. The 2018 data-taking period will be devoted again to the polarized DY measurement. The development of machine learning analysis techniques adapted to polarized DY, lead by LIP group members, is a strong commitment for the coming years.
In October 2017, the COMPASS collaboration submitted a request to the CERN-SPSC for an extension of its scientific programme for additional Deep Inelastic Scattering (DIS) measurements with polarized deuteron target, to be performed in 2021. The DY group coordinator is also part of an informal team of researchers from institutions in several countries that is at the origin of a Letter of Intent (LoI) for a new fixed-target experiment at CERN devoted to the study of meson structure and of the role of gluons in the hadron mass hierarchy. This LoI includes also a pioneering measurement of the proton radius in elastic muon-proton collisions, a high-precision measurement aiming to solve one of the most intriguing puzzles in proton physics. A proposal will be submitted by the end of 2018.

9.3.2 Identification and summary description of up to 3 contributions deemed most important of those provided in 2013-2017 by researchers who belong to the Research Group in the current R&D Unit application

1. Nucleon spin: The measurement of the gluon contribution to the spin of the nucleon was one of the main goals of the first phase of COMPASS. These are complex and demanding measurements, which are often object of successively refined analyses. The most direct and cleanest gluon polarization measurement was performed by the LIP group using D and D* meson production. These results were the subject of a LIP PhD thesis. The most precise world results on gluon polarization were obtained from the measurement of semi-inclusive deep inelastic scattering (SIDIS) data using a longitudinally polarized target. The analysis, using a new neural network based method, was developed by a LIP group member. The contribution of quarks to the nucleon spin is also measured at COMPASS. Namely, the longitudinal spin asymmetry A1 at low quark momentum fraction was measured to be clearly positive for the first time, with a huge significance. This analysis was the subject of a LIP PhD thesis.

2. Transverse Momentum Parton Density Functions (TMD PDFs): The first world measurement of the DY process with a transversely polarized target was performed in 2015 by the COMPASS experiment. The LIP group was at the origin of this measurement. The corresponding analysis of spin asymmetries was performed by the Lisbon and Turin groups in COMPASS and presented for the first time by a LIP member. The measured quark Sivers asymmetry favors the predicted sign change of this TMD PDF of the nucleon, when measured in SIDIS or in DY. The Sivers sign change is considered one of the fundamental tests of non-perturbative QCD. In order to increase the statistical significance of the measurement, COMPASS will collect further polarized DY data in 2018, under the coordination of the LIP group. Also the gluon TMDs of the nucleon are accessible in COMPASS SIDIS measurements with transversely polarized targets. The gluon Sivers TMD PDF asymmetry results from the correlation between the proton spin and the transverse momentum of the struck gluon. The spin asymmetry measured from a sample of high transverse momentum hadron pairs is related to this TMD PDF and its measurement, another world first, was performed by LIP members.

3. Fragmentation functions and perturbative QCD: One of the possible ways to study fragmentation functions is via the hadron multiplicities from the SIDIS processes. This measurement is performed from pion and kaon multiplicities at COMPASS and other experiments, and the comparative analysis of world results was published by a LIP member. Recently, a COMPASS analysis of the kaon multiplicity ratio in the region of high z (fraction of energy of the kaon with respect to that of the virtual photon) was seen to strongly violate the perturbative QCD limit, both at LO and at NLO, thus suggesting the perturbative QCD factorization breaks in this region. These results were shown for the first time at the DIS 2017 conference, by the LIP member responsible for the analysis.

(RG-50007-388459) 5. LERHI - Low Energy Reactions with Hadrons and Ions

09.1. IDENTIFICATION OF THE RESEARCH GROUP

9.1.1 Reference of the research group

RG-50007-388459

9.1.2 Name of the Research Group in portuguese

5. LERHI - Reacções de baixa energia com hadrões e iões

9.1.3 Name of the Research Group in English

5. LERHI - Low Energy Reactions with Hadrons and Ions

9.1.4 Keyword(s)

GSI/FAIR

HADES

R3B

Low energy reactions

9.1.5 Existed in 2008/2012

Yes

09.2. RESEARCHERS OF THE RESEARCH GROUP

9.2.1 List of Integrated Researchers of the R&D Unit who hold a PhD degree and belong to the Research Group

NAME	PRINCIPAL INVESTIGATOR
Daniel Galaviz Redondo	Yes
Alberto Blanco Castro	No
Celso Filipe Correia Franco	No
Paulo Jorge Ribeiro da Fonte	No

9.2.2 List of Integrated Researchers of the R&D Unit who do not hold a PhD degree and belong to the Research Group

NAME
Americo Manuel de Almeida Pereira
João Pedro de Carvalho Saraiva
Luis Alberto Vieira Lopes
Nuno Miguel Vasconcelos Costa Carolino
Orlando Lopes Cunha
Pamela Teubig
Paulo Jorge Fernandes Velho

09.3. DESCRIPTION OF THE MAIN CONTRIBUTIONS OF THE RESEARCH GROUP IN 2013-2017

9.3.1 General description of the Research Group

The LERHI group is built around a solid expertise in instrumentation for particle detection and the study of nuclear reactions and hadronic processes at medium energies (a few MeV to a few GeV per nucleon). Our activity is centred on experiments based at GSI/FAIR-Facility for Antiproton and Ion Research, the 1.3 billion next generation facility at GSI, and at CERN. LIP is a member of two of the four pillars of GSI/FAIR: HADES and R3B. Our contribution to these experiments is both in R&D, construction and operation of detectors and in physics studies.
The group has recognized expertise in Resistive Plate Chamber (RPC) detectors for particle identification and on scintillator detectors for calorimetry. HADES is currently the only running experiment that studies the region of the QCD phase diagram of very high net-baryon densities and low temperatures. The group plays a leading role in this area, having developed one of the independent analyses of the HADES golden channel, where a di-lepton system is observed in Au+Au collisions at 1.23 GeV per nucleon. In the R3B experiment, the group has a very active role in the study of break-up reactions of nuclear halo systems on a proton target. Two well-established cases, Be-11 and C-15, were studied over the past few years. In addition, the group is involved in low-energy reaction experiments of interest for nuclear astrophysics at the HiE-ISOLDE/CERN facility.
In the next five years the LERHI group will focus on the Portuguese participation in FAIR that should initiate its Phase-0 operations already in 2018. Collaboration in the R3B and HADES experiments will continue. The LIP group has strong instrumentation responsibilities in both experiments, namely in the new forward

RPC-TOF wall for HADES and in the CALIFA calorimeter for R3B (both under construction), and will continue to make strong contributions to data analysis.

9.3.2 Identification and summary description of up to 3 contributions deemed most important of those provided in 2013-2017 by researchers who belong to the Research Group in the current R&D Unit application

1. The HADES RPC-TOF wall: One of the main contributions of the group has been the design and construction of a high granularity (1200 channels in 8 m2), high resolution, RPC-based TOF wall for the HADES spectrometer, for which we were fully responsible. The TOF wall was operated at GSI and will be operated in FAIR in the near future. This detector has produced a large improvement in the HADES experiment, reducing the limitations imposed by the old scintillator-based TOF wall. The experiment is now able to analyse heavy nuclear systems, which is a fundamental aspect in the HADES physics program. The HADES RPC-TOF is a unique detector within the timing-RPC technology. The innovative design, with highly segmented, electrically shielded RPC cells, allows the measurement of the crossing time of particles with high precision in environments of high multiplicity, up to 300 tracks per event in 8 m2. The detector has operated flawlessly since 2012 until now. Its exceptional performance, with a 70 ps timing resolution and an efficiency higher than 92%, make the HADES RPC-TOF a world reference.

2. The CALIFA calorimeter: The group has made important contributions to the R&D for the future CALIFA calorimeter for R3B at FAIR. The main part of the detector, the so-called barrel, consist of 1952 CsI(Tl) crystals optically coupled to avalanche photodiodes. The detector, presently under construction, will be challenged with the simultaneous measurement of high energy photons (up to 30 MeV) and high energy protons (up to 300 MeV) emerging from the reactions induced on radioactive nuclei at R3B. During the construction phase of the detector, the group has prepared and executed a beam test at the CTN/IST Tandem facility in Lisbon where high-energy photons (E>10 MeV) were used to test 128 CALIFA units. The group is working in the development of reconstruction algorithms for CALIFA based on the data from this experimental campaign in Portugal, helping to better understand the response and performance of the detector. This will be an important benchmark prior to its installation at the R3B setup in the second half of 2018.

3. Data analysis in HADES: The group plays a leading role in the study of dense cold nuclear matter and in-medium hadron properties. The group has developed one of the independent analyses of the HADES golden channel, where a di-lepton system is observed in Au+Au collision data at 1.23 AGeV (di-leptons are ideal probes of the dense medium because they do not interact strongly with hadrons). The analysis uses an innovative application of a dynamic neural network that allows an efficient selection of di-leptons in a highly contaminated environment. In the last two years, the results were presented in relevant international conferences (MENU16 and ISPUN17) and is currently in the publication phase.

(RG-50007-388460) 6. Cosmic rays

09.1. IDENTIFICATION OF THE RESEARCH GROUP

9.1.1 Reference of the research group

RG-50007-388460

9.1.2 Name of the Research Group in portuguese

6. Raios cósmicos

9.1.3 Name of the Research Group in English

6. Cosmic rays

9.1.4 Keyword(s)

Cosmic rays

Very High Energy Gamma-rays

Hadronic Models

New Physics

9.1.5 Existed in 2008/2012

Yes

09.2. RESEARCHERS OF THE RESEARCH GROUP

9.2.1 List of Integrated Researchers of the R&D Unit who hold a PhD degree and belong to the Research Group

NAME	PRINCIPAL INVESTIGATOR
Mário João Martins Pimenta	Yes
Alberto Blanco Castro	No
Bernardo António Neto Gomes Baptista Tomé	No
Felix Riehn	No

NAME	PRINCIPAL INVESTIGATOR
Fernando José de Carvalho Barão	No
Francisco Gonçalves Dias Cardoso Diogo	No
Helmut Wolters	No
Liliana Marisa Cunha Apolinário	No
Lorenzo Cazon Boado	No
Maria Catarina Ferreira do Espírito Santo	No
Maria Luísa Ferreira da Gama Velho Arruda	No
Maria Paula Frazão Bordalo e Sá	No
Paulo Jorge Ribeiro da Fonte	No
Pedro Jorge dos Santos de Assis	No
Pedro Moraes Salgueiro Teixeira de Abreu	No
Raul Cambraia Lopes Sarmento Pereira	No
Ruben Maurício da Silva Conceição	No
Sofia Andringa Dias	No
Sérgio Eduardo Campos Costa Ramos	No
Patricia Carla Serrano Gonçalves	No

9.2.2 List of Integrated Researchers of the R&D Unit who do not hold a PhD degree and belong to the Research Group

NAME
Americo Manuel de Almeida Pereira
José Pedro Ferreira Alves
José Carlos Fernandes Nogueira
Luis Alberto Vieira Lopes
Luis Miguel Domingues Mendes
Maria Alexandra Lima Fernandes
Miguel Antonio Freitas Ferreira
Miguel Matos Ferreira
Miguel Reis Orcinha
Nuno Miguel Vasconcelos Costa Carolino
Orlando Lopes Cunha
Ricardo Jorge Barreira Luz

09.3. DESCRIPTION OF THE MAIN CONTRIBUTIONS OF THE RESEARCH GROUP IN 2013-2017

9.3.1 General description of the Research Group

Cosmic rays are a window to the Universe and to particle physics. The LIP Cosmic Rays group is involved in AMS, the only particle physics experiment at the International Space Station, and in the Pierre Auger Observatory, the largest cosmic ray observatory in the world. In both cases, the group combines a strong participation in detector R&D and operations with a solid contribution to data analysis. We are involved in AMS from the beginning and had an important role in the design and construction of the Ring-Imaging Cherenkov (RICH) detector. Today, the group holds responsibilities on the RICH operations, monitoring and reconstruction algorithm optimization. It is also strongly involved in solar modulation analyses, and in analyses related to particle identification.
The group is a member of Auger since 2006. In the last five years, we concentrated on hadronic shower physics, profiting from the interactions initiated by the highest energy protons ever measured. The group's main impact is on the study of the electromagnetic and muonic shower profiles. We proposed an innovative detector combining traditional air-shower detector units with autonomous RPCs, able to operate outdoors with minimal maintenance, and providing a direct measurement of muons with very good space and time resolution.
In the next five year, LIP will continue strongly involved in both AMS and Auger while preparing the next generation of experiments. AMS remains a unique detector in space, collecting until 2024 a wealth of high quality data. Auger will take data until 2025, allowing us to deepen and extend the analyses and to take further the R&D program for future detectors. Particularly interesting is the possible application of the new detector concept to lower the energy threshold of gamma air-shower detectors. The LATTES project,

initiated by LIP and CBPF in Brazil, has the goal to design, prototype and construct a ground array able to monitor the Southern gamma-ray sky above 50 GeV.

9.3.2 Identification and summary description of up to 3 contributions deemed most important of those provided in 2013-2017 by researchers who belong to the Research Group in the current R&D Unit application

1. Detailed studies of the muon component of air showers: Shower observables are sensitive to the composition of the highest energy cosmic rays, but also to the details of hadronic interactions. To understand them we rely on shower models that are tuned using LHC data and extrapolated well beyond that regime. Muons are a direct probe of the hadronic shower development. The LIP CR group had a crucial participation in these studies, with a group member coordinating the Hadronic Interaction Analysis working group. The Pierre Auger Observatory has confirmed a significant muon deficit, in the order of 30% to 50%, within the air shower simulations when compared to data. Moreover, the best model to predict the number of muons in showers dramatically fails to predict their production depth in the atmosphere. The group built a muon telescope to calibrate the response of the detector units to muons. A later analysis, benefiting directly from the better calibration, confirmed the muon problem by measuring it in vertical showers. This was of extreme importance since it also confirmed that there is no mismatch on the overall energy scale of the shower. These results might indicate the presence of new phenomena at the highest energies that can only be tested in cosmic rays.

2. Novel observables for electromagnetic shower profiles: The LIP CR group has completed the last measurements needed for a full description of the average longitudinal profile of the electromagnetic component of very high energy showers. This was the subject of a PhD thesis at LIP and the results are expressed in terms of new sensitive observables identified by earlier work at LIP for the parameterization of the profile shapes. Our parameterizations are now used as a standard to constrain the reconstruction of individual shower profiles, for both the electromagnetic and muonic components. The placement of these constraints allows to improve the efficiency of the reconstruction for a higher number of events, namely at lower energies. Joint analysis of the two components is key to isolate hadronic interaction properties.

3. A new detector concept for air shower measurements: LIP has played a leading role in developing a new detector concept, able to separate the electromagnetic and muonic contributions in air showers. This combines water Cherenkov detectors (WCD), commonly used in cosmic-ray observatories such as Auger, with autonomous, low-gas flux and large-surface RPCs for outdoor operation, which were developed at LIP. Several RPCs were installed for test in the Auger observatory in Malargue since 2014. An Engineering Array of 8 combined WCD-RPC units is under construction, in a project jointly funded by FCT and FAPESP, Brazil. A similar concept was adapted for a gamma-ray observatory to monitor the Southern sky, in the LATTES project, which is led by LIP together with Brazilian and Italian colleagues.

(RG-50007-388462) 7. Neutrino physics

09.1. IDENTIFICATION OF THE RESEARCH GROUP

9.1.1 Reference of the research group

RG-50007-388462

9.1.2 Name of the Research Group in portuguese

7. Física de neutrinos

9.1.3 Name of the Research Group in English

7. Neutrino physics

9.1.4 Keyword(s)

Neutrino physics

Neutrinoless double beta decay

Calibration and data quality

Radioactivity backgrounds

9.1.5 Existed in 2008/2012

Yes

09.2. RESEARCHERS OF THE RESEARCH GROUP

9.2.1 List of Integrated Researchers of the R&D Unit who hold a PhD degree and belong to the Research Group

NAME	PRINCIPAL INVESTIGATOR
José Carvalho Maneira	Yes
Amelia Arminda Teixeira Maio	No
Carlos Alberto Nabais Conde	No
Fernando José de Carvalho Barão	No

NAME	PRINCIPAL INVESTIGATOR
Filipa Isabel Gouveia de Melo Borges Belo Soares	No
Gersende Prior	No
José Manuel Dias Escada	No
Maria Filomena de Osorio Pinto dos Santos	No
Rui Ferreira Marques	No
Sofia Andringa Dias	No
Lozza Valentina	No

9.2.2 List of Integrated Researchers of the R&D Unit who do not hold a PhD degree and belong to the Research Group

NAME
Alexandre Manuel da Fonseca Trindade
Americo Manuel de Almeida Pereira
Ana Sofia Carpinteiro Inácio
Nuno Filipe Silva Dias
Pedro Mendes Jorge
Rui Fernando Alves
Stefan-Alexandru Nae

09.3. DESCRIPTION OF THE MAIN CONTRIBUTIONS OF THE RESEARCH GROUP IN 2013-2017

9.3.1 General description of the Research Group

The LIP Neutrinos group was created in 2005, focused on the participation in the SNO experiment. Ten years later the Nobel Prize in Physics was awarded to Art McDonald for the work on neutrino oscillations at SNO. Meanwhile, the LIP neutrino group has grown steadily in size, competences and commitments, and remarkably increased its capability to attract highly qualified new members.
The team is now centred in the SNO+ experiment, searching for neutrinoless double beta decay, which may elucidate the nature of neutrinos as Majorana particles and give an indication of their absolute mass. Our responsibilities range from detector and software-related activities to physics analyses. LIP leads the SNO+ working groups in data quality and run selection, backgrounds and optical calibration. We are also leading the preparation of the reactor and geo-neutrinos analyses, and participating in the Te-130 double-beta decay studies. After years of preparation, in the next five years we expect to exploit the physics potential of the experiment.
In a parallel effort, sharing the double-beta decay goal, LIP is involved in the NEXT experiment at the Canfranc laboratory. This involvement was motivated by LIP's extensive know-how in electroluminescence and charge transport in gaseous detectors, but constitutes an opportunity to further contribute to the experiment.
As a medium-sized group involved in long-term projects, our strategy is to combine data analysis in the ongoing experiments with R&D or preparation work for future projects. The future long-baseline neutrino experiments are our natural long-term focus. Together with neutrinoless double-beta decay, the precise determinations of the leptonic CP violation phase and the neutrino mass hierarchy are priorities in the European Strategy for Particle Physics. To pursue these goals we are mainly focusing on DUNE, one of the future leading experiments, and have initiated contacts in view of planning the participation of LIP.

9.3.2 Identification and summary description of up to 3 contributions deemed most important of those provided in 2013-2017 by researchers who belong to the Research Group in the current R&D Unit application

1. Final SNO results on solar neutrino oscillations: The LIP neutrino group gave important contributions to the analysis of the combined data set from the three phases of the SNO experiment, leading to the final results of the experiment on neutrino oscillation, published in 2013. We also had responsibilities on the detector optical calibration of the third and last phase. More recently, a group member is active as Review Committee chair for new upcoming analyses. In 2015, the Nobel Prize in Physics was awarded to Art McDonald for the work on neutrino oscillations at SNO, and the Breakthrough Prize in Fundamental Physics distinguished several neutrino collaborations, including three current and one former members of the LIP neutrinos group.

2. The SNO+ calibration system: The LIP group had a leading role in the proposal of a novel type of calibration system for large arrays of PMTs that can calibrate over 9000 PMTs with only about 100 LED/fiber channels, and in which the LEDs are outside the detector, for ease of replacement in case of failure. The system was partly built and tested at LIP (Lisbon and Coimbra) and its installation at SNOLAB (supervised by LIP) was concluded in 2016. Its good performance has been verified with SNO+ data in the current water-fill phase. Similar systems are being proposed for both the JUNO and Hyper-Kamiokande experiments. In addition, our group was asked to take responsibility over the re-design and production of the calibration source insertion system for SNO+, adapting the existing SNO design to the much more stringent requirements of SNO+ in terms of material selection and gas tightness. This work was funded primarily by SNO+ Canadian funds. This is a complex mechanical system that started production in 2014 at

the LIP Mechanical Workshop in Coimbra. It was shipped to SNOLAB in early 2017, where it is currently undergoing performance tests. LIP will still produce a second, identical, system, to be shipped in 2018. The LIP neutrino group has other coordination tasks in the area of calibrations within SNO+: chairs of the Optical Calibration working group, chair of the Source Review Committee.

3. Commissioning of the SNO+ experiment: The LIP neutrino group gave a crucial contribution to the successful preparation of the SNO+ experiment, which is now taking commissioning data. Since 2013, LIP group members have coordinated several essential tasks, namely the Background Analysis task, which will be the main ingredient to achieve an optimal neutrinoless double-beta decay sensitivity, and the Anti-neutrino Analysis, which extends the goals of the experiment to oscillations and geo-neutrino measurements. LIP is coordinating the Data Quality and Run Selection tasks of the present data taking, as well as the detector's Optical Calibration, and is leading the analysis of the first commissioning data, in view of background estimation and monitoring.

(RG-50007-388463) 8. Dark matter

09.1. IDENTIFICATION OF THE RESEARCH GROUP

9.1.1 Reference of the research group

RG-50007-388463

9.1.2 Name of the Research Group in portuguese

8. Matéria escura

9.1.3 Name of the Research Group in English

8. Dark matter

9.1.4 Keyword(s)

Dark matter

Rare event searches

Liquid xenon detectors

Low-bakground experiments

9.1.5 Existed in 2008/2012

Yes

09.2. RESEARCHERS OF THE RESEARCH GROUP

9.2.1 List of Integrated Researchers of the R&D Unit who hold a PhD degree and belong to the Research Group

NAME	PRINCIPAL INVESTIGATOR
Maria Isabel Silva Ferreira Lopes	Yes
Alexandre Miguel Ferreira Lindote	No
Andrey Morozov	No
Claudio Frederico Pascoal da Silva	No
Francisco Filipe Bento Neves	No
José Lopes Pinto da Cunha	No
Paulo Jorge Baeta Mendes	No
SUMANTA PAL	No
Vladimir Solovov	No

9.2.2 List of Integrated Researchers of the R&D Unit who do not hold a PhD degree and belong to the Research Group

NAME
Americo Manuel de Almeida Pereira
Cédric Pedroso Pereira
Guilherme Pinheiro Pereira
Nuno Miguel Vasconcelos Costa Carolino
Paulo Alexandre Brinca Costa Brás

09.3. DESCRIPTION OF THE MAIN CONTRIBUTIONS OF THE RESEARCH GROUP IN 2013-2017

9.3.1 General description of the Research Group

After participating in the ZEPLIN III experiment (2002-2012), the LIP Dark Matter (DM) group had a strong participation in LUX since 2010 and was one of the proponents of LUX-ZEPLIN (LZ) in 2012. All these experiments use a xenon dual-phase (liquid/gas) detector to search for DM. LUX is a world-leading experiment in the race for DM detection and LZ is the most sensitive Weakly-Interacting Massive Particles (WIMP, the leading candidate for DM particle) search experiment under construction. LIP has a very strong participation both in hardware (namely control systems and detailed performance studies) and data analysis, and is an international reference in this area. In the last five years, the group more than doubled size, attracting international researchers and PhD students.
In the next five years, the following lines of work will be pursued: Participation in LZ, maintaining the control system and data analysis responsibilities throughout preparation, commissioning (completed by 2020) and operation (until 2025); Investigation of rare decays of xenon isotopes and neutrinoless double-beta decay, benefiting from LZ's large mass and sensitivity, and pioneering the use of machine learning algorithms for pattern recognition and anomaly detection; Participation in the R&D world effort towards an ultra-low background 30-70 ton liquid xenon experiment, a 3rd generation DM experiment covering the parameter space down to the ultimate limitation imposed by MeV neutrinos scattering, or study the WIMP properties in case of detection. Such a detector will also be able to study solar and supernova neutrinos via coherent neutrino-nucleus scattering and to search for neutrinoless double-beta decay. This is the natural way to extend our expertise in both DM search and liquid xenon detectors. These R&D activities will be carried out in collaboration with LZ groups from the UK that submitted a proposal to their funding agency (STFC) in which we are included as international partners.

9.3.2 Identification and summary description of up to 3 contributions deemed most important of those provided in 2013-2017 by researchers who belong to the Research Group in the current R&D Unit application

1. LUX results on dark matter direct searches: In the absence of a WIMP signal, exclusion limits are the final results of a DM experiment. LUX tested some of the most favored WIMP parameter space and had the leading result in the DM search from 2013 to 2017. The LIP group made a series of key contributions to these seminal results: 1) development of algorithms for pulse characterization and identification (the first step of the data analysis chain); 2) proposition and implementation of the position reconstruction method adopted by LUX (its key role is transversal to the whole analysis chain); 3) modeling the background from the detector walls (essential to the definition of the fiducial volume, background spatial description and thus to the sensitivity of the experiment); 4) calculation of the exclusion limits. The extension and relevance of LIP's participation in the LUX data analysis was recognized in several ways, one of them by the appointment of two LIP members as Data Analysis Coordinator. The position reconstruction method has also been used with some modifications in the DarkSide-50 and Panda-X DM experiments, and proven to work well also for gamma cameras for medical imaging.

2. Control systems: LIP has been responsible for the full control system of both LUX and LZ. In the case of LZ, we have the leadership in the design and R&D of the LZ overall instrument control system, which includes nearly 10000 channels, as well as in its implementation that is currently underway. A LIP group member is the coordinator of the working group responsible for this system, and belongs to the LZ project management organization as manager of the control system. Our expertise in control systems has significantly contributed to the creation of a LIP Competence Center in this area.

3. Reflectivity measurements for LZ: The LIP team has carried out very precise measurements of the reflectivity, for xenon scintillation light, of different samples of the LZ detector reflector material (PTFE) immersed in liquid xenon at around -100ºC. These measurements, the first of their kind, confirmed an increase of the reflectivity of PTFE from 70% to 97% when immersed in liquid xenon, compared to its value in air at room temperature. The experimental method designed by the group proved to be sensitive to small differences, O(0.1%), in the absolute reflectance of the material and allowed LZ to choose the best PTFE from the point of view of light collection. The sensitivity of LZ to WIMPs is a steep function of the energy threshold obtained in the scintillation channel, which in turn strongly depends on the reflectivity of the material covering the inner walls of the detector. Small variations in the reflectivity translate into large changes in sensitivity. The results obtained show that reflectivity values near 97% can be achieved, enabling very low energy thresholds in liquid xenon scintillator-based detectors.

(RG-50007-388478) 9. Detector development for particle and nuclear physics

09.1. IDENTIFICATION OF THE RESEARCH GROUP

9.1.1 Reference of the research group

RG-50007-388478

9.1.2 Name of the Research Group in portuguese

9. Desenvolvimento de detectores para física nuclear e de partículas

9.1.3 Name of the Research Group in English

9. Detector development for particle and nuclear physics

9.1.4 Keyword(s)

Instrumentation

RPC

Liquified noble gases

Gaseous detectors

9.1.5 Existed in 2008/2012

Yes

09.2. RESEARCHERS OF THE RESEARCH GROUP

9.2.1 List of Integrated Researchers of the R&D Unit who hold a PhD degree and belong to the Research Group

NAME	PRINCIPAL INVESTIGATOR
Rui Ferreira Marques	Yes
Alberto Blanco Castro	No
Andrey Morozov	No
Carlos Alberto Nabais Conde	No
Filipa Isabel Gouveia de Melo Borges Belo Soares	No
Francisco Filipe Bento Neves	No
João António da Silva Barata	No
Jorge Manuel Maia Pereira	No
José Manuel Dias Escada	No
Luis Manuel Silva Margato	No
Maria Filomena de Osorio Pinto dos Santos	No
Paulo Jorge Ribeiro da Fonte	No
Teresa Maria da Mota Horta e Vale Teixeira Dias	No
Vitali Iourievitch Tchepel	No
Vladimir Solovov	No

9.2.2 List of Integrated Researchers of the R&D Unit who do not hold a PhD degree and belong to the Research Group

NAME
Alexandre Manuel da Fonseca Trindade
André Filipe Ventura Cortez
Americo Manuel de Almeida Pereira
Carlos Manuel Martins da Silva
Douglas Alves de Lima
Luis Alberto Vieira Lopes
Nuno Miguel Vasconcelos Costa Carolino
Nuno Filipe Silva Dias
Orlando Lopes Cunha
Rui Fernando Alves

09.3. DESCRIPTION OF THE MAIN CONTRIBUTIONS OF THE RESEARCH GROUP IN 2013-2017

9.3.1 General description of the Research Group

The development of particle detectors and related instrumentation has been, from the start, one of the pillars of activity at LIP. There are two main aspects: construction of detection systems, and research in fundamental detector processes.
LIP is a world reference in the design and construction of Resistive Plate Chamber (RPC) detectors. These are versatile detectors with a fast response, intrinsically radiation hard, and with relative low cost. The group has expanded their application range to several new areas, from nuclear and particle physics to medical imaging applications, from rugged outdoor muon detection systems to helium-free slow neutron detectors.
The group also has unique expertise in the measurement and modelling of fundamental processes in gaseous and liquefied noble gas detectors. We are concentrating on studying ion mobility in gas mixtures for time projection chambers crucial for LHC and neutrino experiments (e.g. ALICE, NEXT). Our group is

known for pioneering work towards a liquid xenon based positron emission tomograph (PET). This is now gaining a new momentum due to the prospects of achieving very high time resolution.
The group will remain involved in developing detectors for various sites, like GSI/FAIR or Auger. In addition we maintain our involvement in international collaborations such as CERN's RD51, the world-leading detector R&D collaboration, the SINE2020 EU project associated with the European Spallation Source, and the PETALO R&D project at the University of Valencia. In the next few years we plan to pursue an ambitious R&D programme with several strands, such as developing RPC-based epi-thermal neutrons detectors, developing upon our RPC-based PET systems, or improving the performance of a TOFtracker concept, applicable from particle physics to muon tomography of buildings or volcanoes. An ambitious goal is to produce a proof-of-concept sealed RPC, reliable and with large area, which would be a revolution is gas detectors.

9.3.2 Identification and summary description of up to 3 contributions deemed most important of those provided in 2013-2017 by researchers who belong to the Research Group in the current R&D Unit application

1. RPC-based neutron detectors: LIP has recently pioneered the concept of an imaging thermal neutron detector based on Boron-10 lined RPCs. Detector simulations and the operation of an early prototype confirm the excellent potential of this technology for high precision position sensitive thermal neutron detectors: sub-millimetre spatial resolution (FWHM<0.25 mm, world´s best) and fast timing (sub-nanosecond range). Helium-3 scarceness is posing a serious threat to the development of slow neutron detectors. This enhances the attractiveness of the Boron-10 alternative pioneered at LIP. Due to modularity, robustness and low price per area, this detector technology is most attractive for the world leading neutron facilities and applications in, for example homeland security, and thus very promising for transfer to industry. The potential of this emergent detector technology is currently being evaluated at LIP in the framework of the H2020 project Science & Innovation with Neutrons in Europe in 2020, in close collaboration with the European Spallation Source.

2. RPC-based detector systems: Over the past five years, the LIP group designed, built and operated large RPC systems installed in particle physics experiments, namely the RPC TOF Wall of the HADES experiment (see group 5); prototype RPC-based detectors for long-term operation in harsh outdoor conditions, with no maintenance and very low gas flow in the MARTA R&D experiment (see group 6); large-area RPC-based detectors for muon tomography, with nanosecond-level timing and fine localization capabilities, etc. Several of these systems are at pre-industrial level, and our R&D in this technology has considerably extended its range of applicability, now going from particle physics experiments into national security, geology or medicine.

3. Fundamental studies in gaseous and liquefied gas detector physics: In the framework of the RD51 Collaboration, we run since 2014 a project for the measurement and calculation of ion mobility in gas mixtures of interest for current and future particle physics experiments. We have made detailed studies of mixtures such as Ar-CO2, Ne-CO2, Xe-CO2, and Ar-CF4, of particular interest for time-projection chambers (TPC). These studies were conducted in the framework of the ALICE LHC experiment, and of R&D projects for the future International Linear Collider and for NEXT (see group 7). We collaborate with the GSI, JINR, in Russia, the University of Bursa, Turkey, and VECC, India. As for liquefied xenon detectors, the long-standing expertise at LIP, permits the development of setups and methods for unique measurements, such as the recent measurement of wavelength shifter stability in liquid xenon. A sign of the international recognition of our work is a review paper on liquified noble gas detectors for low energy particle physics in Journal of Instrumentation written on request from the journal and which has the highest citation index in the field.

(RG-50007-388486) 10. Health and biomedical applications

09.1. IDENTIFICATION OF THE RESEARCH GROUP

9.1.1 Reference of the research group

RG-50007-388486

9.1.2 Name of the Research Group in portuguese

10. Aplicações biomédicas e para a saúde

9.1.3 Name of the Research Group in English

10. Health and biomedical applications

9.1.4 Keyword(s)

Radiation therapy instrumentation

Medical imaging

Positron emmission tomography

Dosimetry

9.1.5 Existed in 2008/2012

Yes

09.2. RESEARCHERS OF THE RESEARCH GROUP

9.2.1 List of Integrated Researchers of the R&D Unit who hold a PhD degree and belong to the

Research Group

NAME	PRINCIPAL INVESTIGATOR
Paulo Jorge Ribeiro da Fonte	Yes
Andrey Morozov	No
Francisco Filipe Bento Neves	No
João Manuel Coelho Varela	No
Jorge Miguel Tavares Couceiro de Sousa	No
Luis Filipe dos Santos Garcia Peralta	No
Maria da Conceicao Abreu e Silva	No
Maria Isabel Silva Ferreira Lopes	No
Paulo Alexandre Vieira Crespo	No
Rui Ferreira Marques	No
Sandra da Costa Henriques Soares	No
Susete Teresa Gaspar do Fetal	No
Vitali Iourievitch Tchepel	No
Vladimir Solovov	No

9.2.2 List of Integrated Researchers of the R&D Unit who do not hold a PhD degree and belong to the Research Group

NAME
Americo Manuel de Almeida Pereira
Ana Luísa Rodrigues Lopes
Hugo Joel de Jesus Simões
João de Sena Baptista Pimentel Marcos
Joaquim Pedro Kessongo
João Pedro de Carvalho Saraiva
Jose Carlos Rasteiro da Silva
José Miguel Patuleia Venâncio
Luis António Rodrigues de Figueiredo Ferreira Pereira
Margarida Isabel de Matos Inácio
Nuno Miguel Vasconcelos Costa Carolino
Orlando Lopes Cunha
Rui Fernando Alves
Soraia Sofia Clareu Elísio
Tahereh Sadat Niknejad
Yoenls Prata Alicerces Bahu

09.3. DESCRIPTION OF THE MAIN CONTRIBUTIONS OF THE RESEARCH GROUP IN 2013-2017

9.3.1 General description of the Research Group

LIP's expertise in planning, building and operating detectors for particle physics finds natural application in the fields of radiation therapy instrumentation, medical imaging and dosimetry. These are the areas covered by this group in multidisciplinary projects developed in collaboration with partners such as the ICNAS institute for nuclear health applications, the CTN/IST centre for nuclear technology, and several hospitals and medical research centres.
Our core project in instrumentation for radiation therapy is the development of an orthogonal computed tomography system (Ortho-CT), which optimizes radiation therapy treatments in near real time. In medical imaging, the group focuses on developing innovative, high performance positron emission tomography (PET) scanners. We have two PET projects with different technologies: an RPC-based scanner, showing unprecedented position resolution, and a scintillator-based scanner using technology developed for CMS/LHC. An adaptive algorithm for position reconstruction developed at LIP for dark matter detectors has been adapted for medical imaging, for example to improve the auto-calibration of gamma cameras. LIP has also a line of activity in medical and environmental dosimetry, and manages the LabExpoRad laboratory in

Beira Interior University, one of the three laboratories in the country dedicated to radon analysis. The laboratory will play a key role providing technical support to companies and public services in transposing the 2013/59/Euratom directive, which sets more restrictive radon levels and the need for a national action plan addressing long-term risks from radon exposure.
In the next five years our partnership with ICNAS will be fundamental for our projects, especially RPC-PET and Ortho-CT. The installation at CTN/IST of a hadron therapy unit, recently announced as a priority in science policy, will be of strategic importance and a perfect fit with our radiation therapy instrumentation activities.

9.3.2 Identification and summary description of up to 3 contributions deemed most important of those provided in 2013-2017 by researchers who belong to the Research Group in the current R&D Unit application

1. Orthogonal computed tomography: In the last five years we have made great progress in proving the viability and usefulness of the Ortho-CT technique. Ortho-CT makes use of radiation that scatters in the patient in order to visualize the tumour and its surrounding healthy tissues, including organs at risk. With this technique, the irradiation field can better match the tumour while sparing surrounding healthy tissue. We make use of x-rays emitted orthogonally to the treatment beam and detected by a multi-slice scintillating detector. We have made detailed Monte-Carlo simulation studies showing the usefulness of this technique for head and neck irradiation and lung treatments, although not prostate. In addition, for in vivo imaging in proton therapy, the simulations were complemented by experimental measurements with dedicated phantoms, carried out in Germany. These have shown very promising results, namely by verifying the position of the Bragg peak. The Ortho-CT project, is developed in partnership with two Portuguese Oncology Institutes, the Hospital of the University of Coimbra, ICNAS, AIBILI and other medical research centers. The rotation-free and low-dose imaging capability of Ortho-CT are two of its most promising strengths.

2. RPC-based Positron Emission Tomography (RPC-PET) for medical applications: A functional small animal positron emission tomography scanner based on RPCs, with the best position reconstruction resolution ever achieved, has been developed and is being exploited at ICNAS. Our low-cost and super high resolution small animal PET prototype will be developed towards a pre-commercial status, to be transferred to industry.
The animal RPC-PET and TOFtracker developments pave the way towards prototyping a human brain or full-body RPC-PET. Simulation studies concerning the viability for humans have been performed, with most encouraging results.

3. Readout and data acquisition for PET-TOF scanners: The TagusLIP facility was conceived as a generic infrastructure for the development of radiation detectors for medical applications and data acquisition systems, including electronics, firmware and software. In the last few years, the TagusLIP team developed a readout and data acquisition system for PET-TOF scanners and other time-of-flight applications. A new front-end ASIC (TOFFEE) for the readout of Ultra Fast Silicon Detectors (UFSD) was also developed for time measurements in the proton spectrometer CTPPS of the CMS experiment. The PETsys start-up company emerged from the developments at TagusLIP and has been using the infrastructure for the development and validation of Time-of-Flight PET technology. The company has assembled a TOF-PET demonstrator ring and performed the validation of the system using radiation sources.

(RG-50007-388487) 11. Applications for space exploration

09.1. IDENTIFICATION OF THE RESEARCH GROUP

9.1.1 Reference of the research group

RG-50007-388487

9.1.2 Name of the Research Group in portuguese

11. Aplicações para a exploração espacial

9.1.3 Name of the Research Group in English

11. Applications for space exploration

9.1.4 Keyword(s)

Space radiation environment

Radiation effects on crews and systems

Detector design and simulation

x- and gamma-ray polarimetry

9.1.5 Existed in 2008/2012

Yes

09.2. RESEARCHERS OF THE RESEARCH GROUP

9.2.1 List of Integrated Researchers of the R&D Unit who hold a PhD degree and belong to the Research Group

NAME	PRINCIPAL INVESTIGATOR
Patricia Carla Serrano Gonçalves	Yes
Bernardo António Neto Gomes Baptista Tomé	No
Filipa Isabel Gouveia de Melo Borges Belo Soares	No
Filipe Alexandre Pedra Aguiar de Moura	No
Jorge Manuel Maia Pereira	No
Jorge Miguel de Brito Almeida Sampaio	No
José Manuel Dias Escada	No
Maria Luísa Ferreira da Gama Velho Arruda	No
Maria Filomena de Osorio Pinto dos Santos	No
Pedro Jorge dos Santos de Assis	No
Rui Miguel Curado da Silva	No
Teresa Maria da Mota Horta e Vale Teixeira Dias	No

9.2.2 List of Integrated Researchers of the R&D Unit who do not hold a PhD degree and belong to the Research Group

NAME
Alexandre Manuel da Fonseca Trindade
Ana Luísa Martins de Carvalho Casimiro
Marco Gui Alves Pinto
Miguel Fernandes Moita

09.3. DESCRIPTION OF THE MAIN CONTRIBUTIONS OF THE RESEARCH GROUP IN 2013-2017

9.3.1 General description of the Research Group

Space exploration is one of the natural applications of particle physics technologies, particularly in what concerns radiation detection instrumentation and the modelling of complex processes involving the interaction of radiation with matter. In the last ten years an R&D line focused on the study of space radiation environments and their effects was created and consolidated at LIP. The laboratory became a recognized partner of ESA. The competences developed include all the technologies identified on ESA's roadmap for this domain: radiation environment measurement technologies; radiation environment modelling; radiation effects analysis tools; test characterization and radiation hardness assurance EEE components. In the last five years, a wide range of activities was developed, mainly in the framework of contracts with ESA, and involving different institutions both in the academia and in national industry. LIP is today an international reference in the GEANT4 simulation of space radiation monitors, and in the modelling of the radiation environment in Mars.
Strategic lines for the next five years include: participation in the instrument development and science teams for planetary missions; exploration and development of facilities for radiation tests in Portugal; creation of a multidisciplinary network for Space Physics in Portugal. ESA's strategy to guarantee the independence of the European space sector in critical technologies and to promote innovation and technical excellence in industry are guidelines to these efforts.
The LIP Space group further holds high-level competences in instrumentation for astrophysics, specifically x- and gamma-ray polarimetry. Recent activity has focused on the participation on the working group for XIPE, the first Space mission devoted to x-ray polarimetry, selected by ESA for Phase A on the M4 call. The group is also involved in the eASTROGAM mission, a gamma-ray observatory selected by ESA for the restricted list of the M5 call.

9.3.2 Identification and summary description of up to 3 contributions deemed most important of those provided in 2013-2017 by researchers who belong to the Research Group in the current R&D Unit application

1. Detailed Martian Energetic Radiation Environment Model (dMEREM): The LIP Space group developed for ESA a model of the radiation environment in Mars, dMEREM, based on the GEANT4 toolkit, which became an international reference. The development was made within the MarsREM international consortium, and new developments and updates are continuously performed at LIP. The model continues to be an object of collaboration between LIP and its former consortium partners. The model is currently being adapted to study astrobiological implications of the radiation environment on Mars and on its moons, and to further explore the radiation effects on manned missions to Mars.

2. Radiation monitors: In the last few years, the LIP Space group developed tools for the analysis of radiation effects, as well as radiation detection technologies. This was done in the context of the development of radiation monitors for missions Bepi-Colombo to Mercury and JUICE to Jupiter, and of the development and exploitation of the AlphaSAT Environment and Effects Facility (AEEF). The AEEF is installed on ESA's geosynchronous orbit satellite AlphaSAT, launched in 2013, and has both a radiation monitor (MFS) and an EEE component test facility (CTTB). This in-flight test facility allows for the study of the radiation environment in geostationary orbit, including solar energetic particles (SEP). In what concerns SEP events, data analysis methods were developed for the now concluded ULYSSES mission and for

EPAM at L1, and there is an on-going dedicated SEP analysis of MFS data, which are being collected since 2013. The LIP Space group is a member of the consortium responsible for the development of the Radiation hard Electron Monitor (RADEM) for JUICE, the next class-L ESA mission, which will study the Jovian Icy Moons. RADEM is not only a radiation monitor providing house-keeping data to the mission, but also a full proton and electron spectrometer. It is capable of both measuring electron, proton and ion spectra, and of discriminating electron directionally spectra inside the complex Jovian magnetosphere.

3. Radiation-hardness assurance of Electrical, Electronic and Electromechanical (EEE) components: The LIP Space group developed a project on radiation testing of EEE components for the JUICE mission to the Jovian Icy Moons, in which their response to electron beams with energies above 10 MeV, as expected in the Jovian magnetosphere, was compared with their response to the standard tests performed with Co-60 gamma sources. These tests made use of Portuguese irradiation facilities, namely of the Technological Radiosterilization Unit at CTN and of a Clinical LINAC at Hospital de Santa Maria. CTTB in-flight data on EEE component response to radiation in GEO are also being analysed by the LIP Space group, including the response of GaN sensors developed in IT, at Universidade de Aveiro. The group thus has now established competences in the sector of radiation hardness assurance.

(RG-50007-388488) 12. Computing

09.1. IDENTIFICATION OF THE RESEARCH GROUP

9.1.1 Reference of the research group

RG-50007-388488

9.1.2 Name of the Research Group in portuguese

12. Computação

9.1.3 Name of the Research Group in English

12. Computing

9.1.4 Keyword(s)

Scientific computing

Digital infrastructures

Big data

Software quality control

9.1.5 Existed in 2008/2012

Yes

09.2. RESEARCHERS OF THE RESEARCH GROUP

9.2.1 List of Integrated Researchers of the R&D Unit who hold a PhD degree and belong to the Research Group

NAME	PRINCIPAL INVESTIGATOR
Jorge Humberto Lúcio Oliveira Gomes	Yes
António Manuel da Silva Pina	No
Gaspar Pereira de Morais Barreira	No
Joao Antonio Tomasio Pina	No
Mário Jorge Moura David	No

9.2.2 List of Integrated Researchers of the R&D Unit who do not hold a PhD degree and belong to the Research Group

NAME
Carlos Alberto Nunes Manuel
Hugo Miguel da Silva Gomes
Joao Paulo Martins Conceicao
Jose Carlos Pereira Aparicio
Luís Filipe Sequeira Alves
Nuno Manuel Ribeiro Dias
Vítor Serafim Pereira de Oliveira

NAME

Henrique Manuel Peixoto Carvalho

09.3. DESCRIPTION OF THE MAIN CONTRIBUTIONS OF THE RESEARCH GROUP IN 2013-2017

9.3.1 General description of the Research Group

The LIP computing group provides services and infrastructures for scientific computing and performs related R&D. We are focused on distributed computing (Grid and Cloud), high throughput computing (HTC), high performance computing (HPC) and data intensive processing. We develop and provide IT services for LIP and the Portuguese scientific community at large, from life sciences
to marine sciences, engineering and social sciences among others. The development of services and competences is performed in R&D projects and e-infrastructures.
We are ramping-up the National Distributed Computing Infrastructure (INCD), part of FCT's infrastructures roadmap. We operate the LIP Tier-2 facility, part of the Worldwide LHC Computing Grid (WLCG) and collaborate with thematic e-infrastructures and user communities from different organizations and domains. At international level, we participate in e-infrastructures such as the European Grid Infrastructure (EGI) and Iberian Grid Infrastructure (IBERGRID). We represent Portugal in the EGI governing council and were a member of the executive board. Together with 74 major research organizations, we are starting the EOSC-hub project, to establish the technological basis for the European Open Science Cloud (EOSC). Since 2010 we coordinate all EGI software quality assurance.
The group pioneered the Portuguese participation in distributed computing R&D projects and had a major role in digital infrastructure projects. We participated in the H2020 R&D projects EGI-INSPIRE, EGI-ENGAGE, TIMBUS and INDIGO-DATACLOUD, and are starting DEEP-Hybrid-DataCloud on deep learning. LIP is member of EUgridPMA, the international charter
defining the computing security and accreditation policies for interoperable authentication in scientific Grid, HPC and Cloud infrastructures. We periodically assume the security coordination of the EGI international infrastructure.

9.3.2 Identification and summary description of up to 3 contributions deemed most important of those provided in 2013-2017 by researchers who belong to the Research Group in the current R&D Unit application

1. Worldwide LHC Computing Grid Tier-2: Established in 2009, the Portuguese WLCG Tier-2 is operated by LIP and, since then, provides simulation and massive data processing for the ATLAS and CMS experiments. This infrastructure is essential to the Portuguese participation in the LHC. The Tier-2 has successfully enabled the data analysis by Portuguese teams and fulfilled the obligations assumed by the Portuguese authorities in the Worldwide LHC Computing Grid Memorandum of Understanding established with CERN. The infrastructure has been continuously improved and respects strict service level agreements imposed by CERN and the LHC experiments.

2. Establishment of the National Distributed Computing Infrastructure: In 2013, we submitted the INCD proposal for the enlargement of the infrastructure previously established in the national grid initiative. INCD was approved in 2014 and funded in 2017. Meanwhile, in partnership with LNEC and FCT-FCCN we provided HPC, HTC and cloud services to a wide range of scientific users executing 16 million jobs and delivering 45 million hours of processing time. The infrastructure was fully integrated in the EGI international infrastructure. We also coordinate the EGI regional Iberian operations (IBERGRID) collaboration between Portugal and Spain. We were pioneers in introducing in 2013 a cloud computing service for the Portuguese research community. This service has been incorporated in INCD, and since 2016 has delivered 6 million hours. The portfolio of services and the available capacity are being enlarged. New synergies with research organizations and thematic e-infrastructures are being established. A legal INCD entity was created with LIP, LNEC and FCT-FCCN as main partners. INCD is included in the national initiative for digital competences, and is a potential collaborator in the Azores international research center (AIR Center). INCD is member of the national HPC network.

3. Cloud computing for science: In 2015-2017, we coordinated the software quality assurance and pilot infrastructures of the INDIGO-DataCloud project that developed middleware to enable execution of data and compute intensive scientific applications across heterogeneous environments. We also developed network extensions for the Open Cloud Computing Interface cloud standard and a new tool (udocker) to execute Linux containers in HPC and HTC environments. In the final review the INDIGO-DataCloud project achievements were evaluated by the European Commission as outstanding. udocker has been selected for support in the EOSC-hub project as part of the European software catalogue. Also in the EOSC context we submitted a proposal for an European Atlantic coastal wave simulation service (OpenCOASTS) that has been approved and is currently being integrated to become a EOSC production services in 2018. This service will exploit INDIGO-DataCloud developments.

Part 4: Plan of Activities for 2018-2022

10. SUMMARIES OF THE PLAN OF ACTIVITIES FOR 2018-2022

10.1 Summary in Portuguese for general dissemination purposes

Nos próximos cinco anos, o LIP reforçará o seu papel como o laboratório de âmbito nacional que, sob a supervisão da FCT, define a agenda para a física experimental de partículas e tecnologias associadas em Portugal, bem com a participação portuguesa no CERN e noutras infraestruturas científicas internacionais. Os três pilares de actividade do LIP são: Ciência e descoberta, com um programa de excelência em física de partículas; Tecnologia e inovação, como parceiro chave nas aplicações dos instrumentos e métodos da física de partículas e na computação distribuída; Partilha com a sociedade, abordando desafios societais, promovendo a formação avançada e implicando a sociedade na ciência,

O trabalho desenvolvido no LIP confirma o laboratório como referência internacional em diversas áreas da

análise de dados, detectores, instrumentação, e computação distribuída. O LIP assegura a presença de Portugal na linha da frente de grandes desafios científicos. Nos próximos anos, o LIP estará na preparação do LHC para a alta luminosidade, enquanto explora os dados já recolhidos; abordará questões fundamentais de QCD no programa de alvo fixo do CERN; explorará a fronteira entre a física nuclear e de partículas no GSI/FAIR; e estudará os mensageiros do Universo em experiências de astropartículas dedicadas à procura de matéria escura, física dos neutrinos e raios cósmicos. Em todas estas áreas, o trabalho experimental continuará a ser apoiado por sólidos estudos fenomenológicos. O LIP é fundamental na I&D rumo aos detectores do futuro. Como especialistas internacionais no desenvolvimento de RPC, alargámos consideravelmente o campo de aplicação destes detectores. Particularmente promissores são os detectores de neutrões lentos sem hélio e as RPC seladas, uma revolução nos detectores gasosos. O tomógrafo RPC-PET construído no LIP e em funcionamento no ICNAS detém o recorde mundial de resolução. O PET humano para corpo inteiro é uma prioridade para os próximos anos.

O LIP potenciará o seu retorno para a sociedade, respondendo a desafios societais nas nossas áreas de competência técnica. A unidade de terapia com hadrões a instalar no CTN/IST é de importância estratégica, e foi iniciada uma colaboração com o ICNAS e o CTN/IST em instrumentação, reconstrução de imagem e detectores. As RPC desenvolvidas no LIP têm aplicações que vão da segurança à geologia, com destaque para a saúde. O grupo de computação do LIP é uma peça fundamental da infrestrutura nacional de computação científica. Opera a componente portuguesa do Worldwide LHC Computing Grid e co-lidera a Infraestrutura Nacional de Computação Distribuída, que fornece serviços a toda a comunidade científica nacional. O LIP dará continuidade à sua missão de formação avançada e qualificação do sector da ciência e da inovação. Reafirmamos o nosso compromisso com a literacia científica, apoio à educação e implicação da sociedade na ciência, em colaboração com a Agência Ciência Viva e a Sociedade Portuguesa de Física.

10.2 Summary in English for general dissemination purposes

In the next five years, LIP will strengthen its role as a nation-wide laboratory defining, under the supervision of FCT, the national research agenda in experimental particle physics and associated technologies as well as the Portuguese participation at CERN and other international scientific infrastructures. The three pillars of activity at LIP are: Discovery through science, with a world-class research programme in particle physics; Innovation through technology, as a key player in application of particle physics instruments and methods, and in scientific computing; Sharing with people, addressing societal challenges, promoting advanced training, and engaging society with science.

The work developed at LIP confirms the laboratory as an international reference in several areas of data analysis, detectors and instrumentation, and distributed computing. LIP ensures the presence of Portugal at the forefront of the next big scientific challenges. In the next few years we will be preparing the LHC upgrade while exploring the data already collected; will address fundamental QCD questions in fixed target experiments at CERN; will explore the frontier between nuclear and particle physics at GSI/FAIR; and will continue to study messengers from the Universe in astroparticle physics experiments on dark matter, neutrinos and cosmic rays. Our experimental work will continue to be backed by solid phenomenology studies. LIP strongly contributes to R&D for future detectors. Our leading expertise in the development of RPC detectors has considerably widened their range of application. Promising new applications include helium-free slow neutron detectors and sealed RPCs, a potential revolution in gaseous detectors.
LIP's RPC-based PET scanner, currently operating at ICNAS, has a world-record resolution. A full-body human scanner is a priority for the next years.

LIP aims at enhancing its return to society, responding to societal challenges within our field of technological expertise. The hadron therapy unit to be installed at CTN/IST is of strategic importance, and we started a collaboration with ICNAS and CTN/IST in instrumentation, image reconstruction and detector development. In addition, LIP's RPCs are well suited for a wide range of applications from security to geology and, most prominently, to health. The LIP computing team is a backbone of the national scientific computing infrastructure. It operates the Portuguese component of the Worldwide LHC Computing Grid and co-leads the National Distributed Computing Infrastructure, providing services to the entire Portuguese scientific community. LIP will continue its mission in advanced training, contributing to the qualification of the Portuguese science and innovation sectors. We reaffirm our long term commitment to scientific literacy, providing support to education and engaging society with science, in collaboration with Ciência Viva, the Portuguese Physics Society, CERN and the IPPOG outreach network.

10.3 Summary in English for evaluation

In the next five years, LIP will strengthen its role as a nation-wide laboratory defining, under the supervision of FCT, the national research agenda in experimental particle physics and associated technologies, and the participation at CERN and other international scientific infrastructures. The three pillars of activity at LIP will remain: Discovery through science, with a world-class research programme in particle physics; Innovation through technology, as a key player in the application of particle physics instruments and methods, and in scientific computing; Sharing with people, addressing societal challenges, promoting advanced training, and engaging society with science.
LIP has the required organization, processes and tools for the implementation of its strategy, ensuring: a high degree of collaboration, internally and externally, optimizing the use of resources and potentiating the impact of our research; the promoting of the integrated development of the different LIP nodes; the capability to attract and secure top level researchers and students, as well as funding from diversified sources; the transfer of knowledge from R&D to society, through enhanced collaboration with Portuguese universities, research centres, companies and schools.
LIP was created for the internationalization of science, as Portugal joined CERN. The recently renewed protocol between Portugal and CERN recognizes LIP as CERN's reference laboratory in Portugal. While CERN remains our main partner, LIP is now a partner of ESA and belongs to international collaborations at GSI, SNOLAB, Auger and SURF. LIP will be instrumental in creating opportunities for Portuguese industry at CERN and in other scientific infrastructures. In particular, the LHC upgrade constitutes a unique opportunity for collaboration between LIP and industry. LIP is strongly committed with the internationalization of advanced training, through programmes for young scientists and engineers at CERN, and participating in international PhD networks. LIP has privileged research cooperation with Brazil. In scientific computing, LIP is a key player in R&D activities developed in the framework of European projects and international e-infrastructures.

The work developed at LIP confirms the laboratory as an international reference in several areas, namely physics data analysis (heavy quarks, Higgs and Drell-Yan physics), detectors and instrumentation (liquid xenon and RPC detectors, control systems, calibration in low background experiments) and distributed computing (Cloud, Grid). LIP further opens new promising R&D avenues. In the next few years LIP will be at the forefront of LHC data analysis in topical channels, while preparing the upgrade. LIP will remain involved in the fixed target program at CERN, leading a proposal for a new experiment to address fundamental questions in QCD, and at GSI/FAIR, starting in 2018, with the single Portuguese experimental team exploring the frontier between nuclear and particle physics. LIP contributes to leading astroparticle physics experiments in: dark matter searches, with LZ and R&D for a third generation liquid xenon detector; neutrino physics, with the SNO+ scintillator phase starting in 2018 to search for neutrinoless double-beta decay, and preparing for DUNE, to study neutrino mass hierarchy and leptonic CP violation; cosmic rays, particularly with the Auger upgrade. Our experimental work is backed by solid phenomenology studies, which will be widened in the next few years. LIP strongly contributes to R&D for future detectors. With unique expertise in the development of RPCs, we have considerably widened their range of application. Particularly promising are helium-free slow neutron detectors and sealed RPCs, a potential revolution in gaseous detectors. The RPC-based PET scanner developed at LIP, currently operating at ICNAS, has a world-record resolution. The full-body human scanner is a priority for the next few years.

Presently, LIP attracts funding from the EU mainly in computing, detectors and health projects. It is our goal to enhanced LIP's capability to secure EU funding in other areas, namely via projects motivated by societal challenges and applications. It is also our goal to enhance the funding from ESA, evolving from contracts for the delivery of services to participating in missions. Other strategies aiming at attracting resources are the creation of partnerships and consortia with medical research institutes and companies. LIP will continue to stimulate technology transfer by reinforcing its links with industry. LIP's competence centres on Monitoring and Control and on Simulation and Big Data will boost the collaboration with external partners. LIP aims at increasing its return to society, responding to societal challenges within our field of technological expertise. The hadron therapy unit at CTN/IST is of strategic importance, and we favour a collaboration with ICNAS and CTN/IST in instrumentation, image reconstruction and detector development. In addition, RPC detectors developed at LIP are well suited for a wide range of applications of societal interest, from security to geological studies, and most prominently health applications. The LIP Computing team is a backbone of the national scientific computing infrastructures. It operates the Portuguese component of the Worldwide LHC Computing Grid and co-leads the National Distributed Computing Infrastructure, providing services to the entire Portuguese scientific community. In the next few years both the portfolio of services and the installed capacity will be enlarged. LIP will continue its mission in advanced training, contributing to the qualification of Portuguese science and innovation sectors. LIP reaffirms its long term commitment with scientific literacy, providing support to education and promoting science among the young, in collaboration withCiência Viva, SPF, CERN and the IPPOG outreach network.

11. DESCRIPTION OF THE PLAN OF ACTIVITIES FOR 2018-2022

11.1 Objectives and strategy of the R&D Unit for 2018-2022

LIP will remain the reference laboratory for experimental particle physics and associated technologies in Portugal. We will continue to ensure the full participation of the Portuguese scientific community in this international endeavour, and to share its benefits with society. Under the supervision of FCT, LIP will continue to define the national policy in this area and the Portuguese participation at CERN and in other international scientific infrastructures by:

- Maintaining and reinforcing its positioning as international key player, through a strong participation in the main projects, experiments and discoveries in its areas of activity;
- Boosting knowledge and technology transfer, by reinforcing its links with Portuguese industry, in particular in the areas of health and space applications. And by exploring the potential of its competence centers on Monitoring and Control and on Simulation and Big Data;
- Continuing its mission in the advanced training of young researchers, through its Advanced Training office, contributing to the qualification of Portuguese science, technology and innovation sectors, and by strengthening its collaboration with national and international research centers;
- Promoting the engagement of science with society, through its Education, Communication and Outreach office, in collaboration with Agência Ciência Viva, CERN and the International Particle Physics Outreach Group (IPPOG), providing support to education, science and scientific careers among the young.

In experimental particle physics, projects and experiments frequently have a long development cycle. In five years, several of the ongoing experiments will still be running, in parallel with the preparation of the next long-term projects. Our strategic planning for this period is coherent with the European Strategy for Particle Physics, whose highest priority is the "exploitation of the full potential of the LHC, including the high-luminosity upgrade of the machine and detectors with a view to collecting ten times more data than in the initial design, by around 2030". The ATLAS and CMS groups at LIP will be part of this effort, participating in the R&D and construction of new sub-detector systems in collaboration with Portuguese industry. They will maintain a high level of quality and leadership in physics analyses, using LHC data to address the most topical questions in the physics of Higgs, top, B mesons, and quark-gluon plasma, and to search for new phenomena. LIP will also continue to take part in the fixed target experimental programme at CERN. Its Partons and QCD group will remain committed to the COMPASS experiment and is leading a proposal for a new experiment to address fundamental questions in QCD, such as a high-precision pioneering measurement of the proton radius in elastic muon-proton collisions.

LIP is aligned with the 2017-2026 strategy of the Astroparticle Physics European Consortium to explore all possible multi-messenger channels, addressing open questions such as the phenomena behind the very high energy gamma rays, neutrinos and cosmic rays, the nature of dark matter and dark energy, the properties of neutrinos, and the physics of the early Universe. In the next few years LIP will be involved in the analysis of the Auger data and in the construction and operation of the MARTA engineering array. MARTA is the result of an intensive R&D effort for outdoor operation of RPCs, which is also paving the way for LIP's involvement in LATTES, a novel type of gamma ray detector. These projects are developed in collaboration with Brazil. In Space, the AMS experiment, operating until 2024, is a unique cosmic ray detector in space that our group will

continue to explore. Back on Earth, the LIP Dark Matter group participates in LZ, the most sensitive upcoming WIMP search experiment, to collect data from 2020 to 2025, and in the world R&D effort for a third generation, ultra-low background, 30-70 ton liquid Xe experiment. Our Neutrinos group will explore the potential of the SNO+ scintillator phase starting in 2018. Its physics goals include the study of reactor neutrino oscillations, geo-neutrinos, and mainly the search for neutrinoless double beta decay, a common goal with the NEXT experiment. In the longer run the group is planning to explore leptonic CP violation and the neutrino mass hierarchy with DUNE.

The Low Energy Reactions with Hadrons and Ions group at LIP is currently the single Portuguese experimental group exploring the frontier of nuclear and particle physics. Its work at GSI has paved the way for an effective contribution to the experiments of the Facility for Antiprotons and Ion Research (FAIR). The group has strong responsibilities in the CALIFA calorimeter for the R3B experiment and in the forward RPC-TOF wall for HADES, one of the first experiments to start running in FAIR.

The LIP Phenomenology group aims at strengthening the impact of the overall LIP programme through the provision of excellent directed phenomenological research, bridging theory and experiment in particle and astroparticle physics. Its work is symbiotic with the experimental activities developed at LIP. The group is internationally recognized for research in top quark, Higgs, and heavy-ion phenomenology. In the next five years it will continue to invest in these areas, while consolidating the expertise in the simulation of cosmic ray air showers, new physics, and dark matter searches, in collaboration with experimental groups at LIP and theoretical groups in Portugal and elsewhere.

The LIP Computing group will continue to be a backbone not only of LIP's scientific activities, but also of the national scientific computing infrastructures. It will focus on ramping-up the National Distributed Computing Infrastructure (INCD), while operating in parallel the LIP Tier-2 Worldwide LHC Computing Grid facility (WLCG) and collaborating with thematic e-infrastructures and user communities from different organizations and domains. At the international level, in 2018 the group will start the European Open Science Cloud hub project, establishing its technological basis, together with 74 major research organisations. LIP computing R&D activities will continue to be shaped by the participation in European projects such as DEEP-Hybrid-DataCloud (H2020) and in e-infrastructures like EGI.

Since its inception, LIP relies on strong competences in the development of detectors and associated instrumentation. In the next years, a detector R&D strategy towards the success of RPC and noble gas, and liquid, based detectors will strongly be pushed forward. RPC applications such as neutron detectors, greatly needed in many areas, from neutron scattering studies to security; large TOF detectors with very good time and space resolution and a wide range of applications; and the development of sealed RPCs, will surely constitute a revolution in gaseous detectors. Noble gas and liquid detectors are in increasing demand around the world (e.g. DUNE). We will pursue R&D in this area in the framework of international R&D collaborations, in particular RD51 at CERN.

LIP's background in instrumentation, data analysis and detector design and simulation, has been applied to areas such as Health and Space. In the field of medical applications LIP has a clear strategic goal to establish strong partnerships with research centres and companies. In particular, in the next five years, LIP favours the collaboration with ICNAS and CTN/IST. LIP can contribute mainly in two areas. In the area of beam control, by supporting associated instrumentation and by developing beam diagnostics and adjustment techniques, such as the OrthoCT technique; and, in the area of imagiology, in the development of image reconstruction algorithms and of detectors for pre-clinical rehearsals, such as the very high resolution small animal PET scanner, based on state of the art miniaturized RPCs, currently used at ICNAS. The hadron therapy unit at CTN/IST, a recently announced science policy priority in Portugal, is of strategic importance, and a key element in our five-year plan. LIP foresees a collaboration with ICNAS and CTN, based on the areas of expertise already developed in the collaboration with ICNAS, which can be a common ground for the collaboration between the three institutes.
In the area of space, LIP's strategy is centered in the collaboration with ESA, and the main challenge is to move the bulk of the activity from short-term contracts to long-term missions, participating in the full lifecycle of instruments. This is the case of the eAstrogam mission, shortlisted for the next ESA M5 mission, with approval decision due in March 2018. In the field of space radiation environment and effects, our objectives are to participate in the full life cycle of the Jupiter JUICE mission, and of future exploration missions, and to reinforce the capabilities of LIP in the area of radiation hardness assurance and in the study of the biological effects of radiation in Space, towards manned missions and astrobiology.

We will continue to collaborate with local universities to guarantee the availability of long-term positions capable of attracting motivated and qualified scientists, which is essential to guarantee that Portuguese science is kept at an internationally competitive level. In this context the program of scientific employment plan foreseen in this evaluation process, as well as other partnership programmes with Universities, are essential to the future of LIP.

11.2 Organization of the R&D Unit for 2018-2022

Research in experimental particle physics and associated technologies is often conducted within large international collaborations or using large scientific infrastructures. This requires research teams large enough to have the required critical mass and adequate support infrastructures. The organizational structure of LIP ensures a coordinated strategy at national level. It is designed to be efficient and flexible. The laboratory is nation wide, with nodes in Lisboa, Coimbra and Braga, working in close collaboration with the local Universities, and has close to 200 members, including more than 80 PhD researchers and 70 post-graduate students.

The governing bodies of LIP are:

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

Directorate

LIP is governed by a Board of Directors nominated by its General Assembly, after consultation of the LIP members. The different nodes of LIP are represented in the Board of Directors, which meets on a monthly basis and issues brief reports of its deliberations to the scientific council.

Scientific Council
LIP's Scientific Council is the laboratory's scientific management body. Its members include all PhD holders, the heads of LIP's research facilities and a representative of the students from each LIP node. The Scientific Council participates in the definition of the scientific strategy of the laboratory, namely in the creation of new research groups and in the decision to participate in international collaborations, as well as in the evaluation of LIP's researchers. The Scientific Council delegates some of its authority to a committee where all research groups are represented.

International Advisory Committee
An External Advisory Committee provides strategic advice to the Laboratory. The Committee is formed by six worldwide recognized experts in the areas of activity of LIP and holds regular meetings with the directors and the group leaders.

Audit Committee
LIP administrative and financial operations are systematically audited by external auditors and reviewed by a top level independent finances council and auditing authority.

The main elements of the working structure of LIP are:

Research Areas and Research Groups
Research Groups are the fundamental organizational units of LIP. The 12 research groups described above are organized in three thematic Research Areas, namely: Particle and astroparticle physics - Groups 1 to 8; Development of new instruments and methods - Groups 9 to 11; Scientific computing - Group 12.

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

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

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

Advanced training office
The advanced training office organizes schools, workshops and internships for undergraduate and graduate students; oversees the hosting and training condition of PhD and master students at LIP, and participates in the coordination of the PhD networks (FCT doctoral programmes) IDPASC and DAEPHYS.

Education, communications and outreach office (ECO)
The LIP-ECO office coordinates the ECO related activities carried out at LIP. Recently, LIP's Communications Strategy for the next five years has been established. The LIP-ECO office coordinates the preparation of LIP's annual report and the (quarterly) LIP-news bulletin, manages LIP social media and web site news, issues press releases, interacts with our partner communication offices and gives support to the preparation and advertising of public events organized by LIP. LIP researches widely participate in education and outreach events, an opportunity to acquire new competences and tools.

LIP thus has the required organization, and the required processes and tools in order to ensure the implementation of the strategy and the achievement of the objectives outlined above.

The present structure and organization ensures:
- A high degree of collaboration and sharing of resources and information among the LIP groups, and between the research groups and the scientific infrastructures, in order to optimize the use of the resources and potentiate the impact of our research.
- The affirmation of LIP as a nation-wide institution, promoting the integrated development of the different LIP nodes.
- The capability to attract the best students, and to attract and secure top level national and international researchers.
- The application and transfer of knowledge and technology from the performed R&D in benefit of society.

LIP works in close collaboration with universities and other higher education institutions. The universities of Lisboa, Coimbra and Minho are LIP associates, and LIP hosts tens of PhD students from these Universities. Many university professors are LIP researchers, under protocols between LIP and the higher education institutions. LIP permanently host about 70 PhD and Master students enrolled at our partner universities who develop their research work at LIP.
LIP coordinates national and international PhD networks in our field of activity: DAEPHYS - applied physics and physics engineering, and IDPASC - particle physics, astrophysics and cosmology, and the International IDPASC Network.

LIP has recently received new premises at the university campus in Lisboa and also in Minho. In Coimbra, the space assigned to the mechanical workshop have been doubled. These improvements will guarantee better working conditions, closer ties with the universities and the consolidation of the technical

infrastructure.

12. THEMATIC LINES

The minimum number of confirmed integrated researchers in order to fill thematic lines information is 100 and you have only 85.

13. ETHICAL ISSUES

13.1 Ethical issues

Direct relation of LIP R&D activities with ethical issues in the process of research or in the use of R&D results are to be expected mainly in the field of health applications. LIP R&D activities in this field only reach the stage of ethical assessment of choices and methods within the institutional context of partner biomedical research centres and hospitals, in Portugal or abroad. LIP naturally complies with the legal and ethical framework defined by those biomedical institutions, namely by their internal ethical committees. LIP per se does not develop R&D activities using cells or living organisms, nor R&D activities involving the collection and processing of personal data.

LIP will not perform research aiming at contributing to war, or anyhow affecting human integrity or causing harm to the environment, to animals or plants. LIP will however follow closely the unexpected outcomes of its scientific and technical research, in order to prevent, whenever possible, the exploitation of its research results for unethical uses, or for any harmful application, namely in war.

LIP is part of several international collaborations involving non-EU countries, and is a member of international scientific infrastructures located in non-EU countries, namely in the USA, Canada, Argentina and Brazil. The research performed in this context does not however raise any ethics issues, and does not involve risks to humans, the use of local resources or the importing of any material or personal data into the EU. Furthermore, it is a policy of international scientific collaborations to contribute for local community development whenever appropriate, as is for example the case of the Pierre Auger Observatory in Argentina.

Indirect ethical issues may arise in outreach and education activities, namely through the need of assessing the limits of reliability in the transmission of research results and their interpretation to the general public and to schools. This may become an important issue in the communication to the media of research namely in health applications. LIP strives to learn and to follow the best international practice.

LIP management will enforce those ethical guidelines and keep a constant internal and external dialogue among researchers on these or other ethical issues related to its activities. It will also strive to meet at all times the highest levels of health laboratory security.

14. ASPECTS OF THE PLAN OF ACTIVITIES INVOLVING REQUESTS OF PROGRAMMATIC FUNDING

14.1 Pluriannual plan for PhD fellowships to be awarded in 2019-2022

NAME OF THE PHD PROGRAM	INSTITUTION	DATE OF ACCREDITATION	PRESENTLY FUNTIONING	R&D UNIT INVOLVEMENT/CONTRIBUTION OF PHD RESEARCHERS/SCOPE OF THE WORK
PhD in Physics at IST	Instituto Superior Técnico, ULisboa	2011	Yes	In the period 2019-2022, LIP expects to host 8 students from the Physics PhD Programme at IST. This number is based on the number of LIP researchers with a link to IST and on the experience of the last few years. Given the profile of the student's training, they can develop crucial work in the exploration of the data of experiments in which the LIP groups are engaged. The research areas envisaged are: - Particle physics at accelerators, both at LHC and in CERN's fixed target programme, including phenomenology (groups 1 to 5): the students will address the challenges of LHC physics, including the preparation for the high-luminosity run, and explore the secrets of QCD at CERN and GSI experiments, both from an experimental and phenomenological point of view. - Astroparticle physics, namely cosmic rays and neutrino physics

NAME OF THE PHD PROGRAM	INSTITUTION	DATE OF ACCREDITATION	PRESENTLY FUNTIONING	R&D UNIT INVOLVEMENT/CONTRIBUTION OF PHD RESEARCHERS/SCOPE OF THE WORK
				(groups 6 and 7): the students will address the challenges and opportunities created by the data collected in SNO+, AMS and by the exploration of the highest energy frontier in Auger. The hosted PhD students will develop their research work within the LIP-Lisboa research groups, fully integrated in the international collaboration in which the group's activities are developed. Their supervision will be ensured by a LIP researcher that is a professor at IST and, whenever useful, by another LIP researcher with crucial expertise within the student's research field. LIP coordinates the IDPASC and DAEPHYS doctoral networks, which regularly hold schools and workshops, and promote the sharing of expertise and resources. This is a clear added value for the quality and international scope of the training of PhD students hosted at LIP. IST is part of the IDPASC network. In the period 2019-2022, LIP expects to host 4 students from the Physics Engineering PhD Programme at IST. This number is based on the number of LIP researchers with a link to IST and on the experience of the last few years. They will develop work in the following areas: - Particle physics at accelerators: in the context of the LHC high-luminosity upgrade and of the next steps in CERN's fixed target programme and FAIR, the students will be part of the teams addressing great experimental challenges namely in electronics, data acquisition and control systems, and calorimetry (groups 1-2, 4-5). - Astroparticle physics: the students will be part of the teams preparing future experiments, namely with the construction and running of the MARTA engineering array in Auger, and research and development for DUNE and LATTES (groups 6-7), including the construction of prototypes. - Health care and space exploration: the students will participate in the challenges of applying particle detection technologies, as well as simulation and reconstruction methodologies, to health and space (groups 10-11). - Computing: the students would develop research projects within the LIP research group activities and projects, namely Grid and Cloud technologies (group 12). The students will develop their research work within the LIP-Lisboa research groups, fully integrated in the international collaborations. Their supervision will be ensured by a LIP
PhD in Physics Engineering at IST	Instituto Superior Técnico, ULisboa	2011	Yes	

NAME OF THE PHD PROGRAM	INSTITUTION	DATE OF ACCREDITATION	PRESENTLY FUNTIONING	R&D UNIT INVOLVEMENT/CONTRIBUTION OF PHD RESEARCHERS/SCOPE OF THE WORK
				researcher that is a professor at IST and, whenever useful, by another LIP researcher with crucial expertise in the student's research field. LIP coordinates the IDPASC and DAEPHYS PhD networks, and this is a clear added value for the quality and international scope of the training of PhD students hosted at LIP. IST is an IDPASC member. In the period 2019-2022, LIP expects to host 6 students from the Physics PhD Programme at FCUL. This number is based on the number of LIP researchers with a link to FCUL and on the experience of the last few years. Given the profile of the students, the research areas envisaged are: - Particle physics at accelerators, both at LHC and in CERN's fixed target programme, including phenomenology (groups 1 to 5): the students will address the challenges of LHC physics, including the preparation for the high-luminosity run, and explore the secrets of QCD at CERN and GSI experiments, both from an experimental and phenomenological point of view. - Astroparticle physics, namely cosmic rays and neutrino physics (groups 6 and 7): the students will address the challenges and opportunities brought by the data collected in SNO+, AMS and by the exploration of the highest energy frontier in Auger. The hosted PhD students will develop their research work within the LIP-Lisboa research groups, fully integrated in the international collaboration in which the group's activities are developed. They will be-supervised by a LIP researcher that is a professor at FCUL and, whenever useful, by another LIP researcher with crucial expertise within the student's research field. LIP coordinates the IDPASC and DAEPHYS PhD networks, and this is a clear added value for the quality and international scope of the training of PhD students hosted at LIP. FCUL is part of the DAEPHYS and IDPASC networks.
PhD in Physics at FCUL	Faculty of Sciences of the University of Lisboa	2011	Yes	
PhD in Physics Engineering at FCUL	Faculty of Sciences of the University of Lisboa	2011	Yes	In the period 2019-2022, LIP expects to host 4 students from the Physics Engineering PhD Programme at FCUL. This number is based on the number of LIP researchers with a link to FCUL and on the experience of the last few years. They can develop important work in the following research areas: - Particle physics at accelerators: in the context of the LHC high-luminosity upgrade and of the next steps in CERN's fixed target programme and FAIR, the students will be part of the teams addressing great experimental challenges namely in electronics,

NAME OF THE PHD PROGRAM	INSTITUTION	DATE OF ACCREDITATION	PRESENTLY FUNTIONING	R&D UNIT INVOLVEMENT/CONTRIBUTION OF PHD RESEARCHERS/SCOPE OF THE WORK
				data acquisition and control systems, and calorimetry (groups 1-2, 4-5). - Astroparticle physics: the students will be part of the teams preparing future experiments, namely with the construction and running of the MARTA engineering array in Auger, and research and development for DUNE and LATTES (groups 6-7), including the construction of prototypes. - Health care and space exploration: the students will participate in the challenges of applying particle detection technologies, as well as simulation and reconstruction methodologies, to health and space (groups 10-11). - Computing: the students would develop research projects within the LIP research group activities and projects, namely Grid and Cloud technologies (group 12). The students will develop their research work within the LIP-Lisboa research groups, fully integrated in the international collaborations. They will be supervised by a LIP researcher that is professors at FCUL and, if useful, by another LIP researcher with crucial expertise in the student's research field. LIP coordinates the IDPASC and DAEPHYS PhD networks, and this is a clear added value for the quality and international scope of students training. FCUL is part of DAEPHYS and IDPASC.
PhD in Physics at UC	University of Coimbra	2016	Yes	In the period 2019-2022, LIP expects to host 4 students from the Physics PhD Programme at UC. This number is based on the number of LIP researchers with a link to UC and on the experience of the last few years. Given the profile of the student's training, they can develop crucial work in the exploration of the data of experiments in which the LIP groups are engaged. The research areas envisaged are: - Particle physics at accelerators: the students will address the challenges of LHC physics, including the preparation for the high-luminosity run, integrated in the ATLAS-LIP group, which is present in all LIP nodes. - Astroparticle physics: the students will be part of the quest for dark matter, addressing the big challenges and opportunities brought by the data collected by the LZ detector, in which LIP-Coimbra has great responsibilities. The hosted PhD students will develop their research work within the LIP-Coimbra research groups. They will be supervised by a LIP researcher that is a professor at UC and, whenever useful, by another LIP researcher with

NAME OF THE PHD PROGRAM	INSTITUTION	DATE OF ACCREDITATION	PRESENTLY FUNTIONING	R&D UNIT INVOLVEMENT/CONTRIBUTION OF PHD RESEARCHERS/SCOPE OF THE WORK
				crucial expertise within the student's research field. LIP coordinates the IDPASC and DAEPHYS PhD networks, and this is a clear added value for the quality and international scope of the training of PhD students hosted at LIP. UC is part of both IDPASC and DAEPHYS.
PhD in Physics Engineering at UC	University of Coimbra	2016	Yes	In the period 2019-2022, LIP expects to host 8 students from the Physics Engineering PhD Programme at UC. This number is based on the number of LIP researchers with a link to UC and on the experience of the last few years. Given the student's profile, they can develop crucial instrumentation work for experimental upgrades, future experiments, and health care and space exploration application. They will profit from the support of LIP's research infrastructures and competence centres. The research areas envisaged are: - Particle and astroparticle physics: the students will address the technology challenges of developments for future detectors. This includes both the research and development projects in RPC and noble gas detectors and the preparation for the high-luminosity LHC and for the next generation of dark matter detectors. - Health care and space exploration: the students will participate in the challenges of applying particle detection technologies, as well as simulation and reconstruction methodologies, to the areas of health care and space exploration, in the framework of the projects developed by groups 10 and 11and based at LIP-Coimbra. The students will develop their research work within the LIP-Coimbra research groups. They will be supervised by a LIP researcher that is a professor at UC and, whenever useful, by a LIP researcher with crucial expertise within the student's research field. LIP coordinates the IDPASC and DAEPHYS PhD networks, and this is a clear added value for the quality and international scope of the training of PhD students hosted at LIP. UC is part of both IDPASC and DAEPHYS.
MAPfis	Universities of Minho, Aveiro and Porto	2011	Yes	LIP expects to host 8 students from MAPfis, the joint PhD Programme of the universities of Minho (UM), Porto (UP) and Aveiro (UA). This number is based on the number of LIP researchers with a link to these universities or to MAPfis and on the experience of the last few years. The students will develop their research work within the LIP-Minho research groups, fully integrated in the international collaborations in which the group activities are

NAME OF THE PHD PROGRAM	INSTITUTION	DATE OF ACCREDITATION	PRESENTLY FUNTIONING	R&D UNIT INVOLVEMENT/CONTRIBUTION OF PHD RESEARCHERS/SCOPE OF THE WORK
				developed. Given the student's profile, they can develop crucial work in the exploration of the data of ongoing experiments in which LIP-Minho is engaged, namely ATLAS and Auger; and also phenomenology work in particle and astroparticle physics. The research areas envisaged are thus: - Particle physics at accelerators, namely analysis and interpretation of the data collected by the ATLAS experiment at the LHC and related phenomenology work (groups 1 and 3). - Astroparticle physics, namely analysis and interpretation of the high-energy cosmic ray data collected by the Pierre Auger Observatory and related phenomenology work (groups 6 and 3). In addition, more technology-oriented students can be accommodated either in the framework of ongoing technology transfer projects (e.g. with BOSCH) and within the LIP-Minho computing group. The students will be supervised by a LIP researcher that is a professor at University of Minho and, whenever useful, by another LIP researcher with crucial expertise within the student's research field. LIP coordinates the IDPASC and DAEPHYS PhD networks, and this is a clear added value for the quality and international scope of the training of PhD students hosted at LIP. UM and UP are part of the PhD network IDPASC, and UA is part of DAEPHYS.
PhD in Physics at UBI	University of Beira Interior	2016	Yes	In the period 2019-2022, LIP expects to host 2 students from the Physics PhD Programme at UBI. This number is based on the number of LIP researchers with a link to UBI and on the experience of the last few years. The hosted PhD students will develop their research work in the framework of the LabExpoRad, managed by LIP at UBI. The students will be supervised by a LIP member that is a professor at UBI and by other LIP researchers, namely from LIP-Lisboa, with crucial expertise within the student's research field. The focus of the work will be on medical and environmental dosimetry, namely radon analysis. LIP coordinates the IDPASC and DAEPHYS PhD networks, and this is a clear added value for the quality and international scope of the training of PhD students hosted at LIP.

14.2 Pluriannual plan for hiring new researchers holding a PhD in 2019-2022

NEW RESEARCHERS TO HIRE	2019	2020	2021	2022	TOTAL
No. researchers	**8**	**5**	**3**	**2**	**18**

Short description of the type of researchers to hire, their expected added-value to the R&D Unit activities, expect contract duration, conditions of co-responsability of higher education or research institutions through which the contracts will be awarded, and of the finantial and material conditions that still need to be fulfilled.

This hiring plan is a fundamental piece in the implementation of LIP's strategy for the next 5 years. It will allow us to:
- Guarantee LIP remains able to fulfill its core mission at the top level, keeping our high quality engagement in international collaborations and R&D projects throughout the future challenges.
- Potentiate the return to society, increasing our capability to invest in R&D for applications in health and space, knowledge transfer, collaboration with universities and research centres.

This hiring plan will allow us to address the following issues:
- The Portuguese science community had an impressive growth in the last decades. It is now crucial to consolidate the scientific employment scheme, retaining the highly qualified scientists as part of our research and advanced training institutions. In the last few year LIP was very successful in attracting top quality researchers under "FCT researcher" 5-year contracts. As a result, key expertise and responsibilities, including in some cases group leadership, are today held by researchers without a stable link to LIP. Given the outstanding CV of these researchers, their level of seniority and the responsibilities they hold in the scientific commitments of LIP, it is of great importance to consolidate their link to LIP.
- LIP has developed great capability to attract top-level researchers worldwide. This is important to guarantee we maintain this capability, remaining at the highest scientific level and able to address the new challenges brought in by the next steps in international experimental programs, and by news ideas in technology applications. This is particularly important since some of the founding group leaders at LIP are approaching retirement.

A reasonable number of 6-year researcher contracts in the next few years will thus provide LIP the appropriate means and autonomy to address these issues. A rapidly decreasing number of contracts is requested: from 2019 to 2022, the number of contracts is 8, 5, 3 and 2, in a total of 18. This tends to a sustainable situation in which LIP offers one or two research positions per year, to accommodate researcher's mobility (retirements, internationalization, etc.) as well as a slow growth. Depending upon an absolute merit evaluation and the existence of the required financial means, the contracts may become permanent after 5 years.

Of the 18 contracts, 4 are meant to be for auxiliar researchers in partnership with the universities of Lisboa (2 position at IST and 1 at FCUL) and Coimbra (1 position). These expectations are based on agreements established in the last few years that have already resulted in 2 places at IST (one filled in 2016 and another one to start in 2018) and 1 at UC (to be assigned in 2018). In addition, 3 positions are fully supported by LIP: 1 principal researcher per year starting in 2020. For the remaining 11 positions we request full FCT support for 7 auxiliar and 4 principal researchers.

The hired researchers will reinforce the scientific and technical capabilities of LIP in all 3 nodes. According to the dimension and commitments, we plan to hire, until 2022, 10 researchers in Lisbon (5 researchers in 2019, 3 in 2020 and 1 per year in the following 2 years), 6 researchers in Coimbra (2 per year in 2019 and 2020, and 1 per year in the last 2 years), and 2 researchers in Minho (1 in 2019 and 1 in 2021).

2 basic researcher profiles are considered: one physics analysis or phenomenology oriented, and one instrumentation and technology oriented. This will cover the needs for the exploitation of the data of running experiments and the participation in upgrades, preparation of future projects and R&D activities. Of the 18 positions, 10 correspond to the physics profile and 8 to the instrumentation and technology profile.

In Lisbon, 6 physics positions and 4 instrumentation and technology positions are considered. The 6 physics researchers will contribute to maintain and consolidate our role in data analysis and phenomenology in particle physics at accelerators, namely at the LHC but also beyond, in the fixed target programmes at CERN and GSI, and also in astroparticle physics, namely in cosmic rays and neutrinos. The 4 instrumentation and technology researchers will have a crucial role in the LHC upgrade for high luminosity, namely in our responsibilities in electronics and calorimetry, but also in R&D for the preparation of future astroparticle physics and space projects.

In Coimbra, given the importance of the instrumentation and technology research line in this LIP node, 2 researchers for physics will be considered, for LHC data analysis and dark matter; and 4 in instrumentation and technology, to reinforce the detector development, medical and space applications groups. According to our strategic plan, a boost is to be expected in these areas: in health applications with the synergy projects with ICNAS and CTN; in space application with the participation in ESA missions.

LIP-Minho, founded in 2010, is a relatively recent LIP node. Given the fast growth in number of students and areas of activity, it is essential in the next few years to increase the number of research staff. Hiring two researchers with the physics profile would thus reinforce LIP-Minho's capability in LHC physics and cosmic rays.

In conclusion, this hiring plan aims at ensuring that LIP has the means and the autonomy to solve the scientific employment problem we are now facing, guaranteeing that the laboratory's s commitments are maintained at the highest standards, that the existing know-how and responsibilities are kept and enhanced. The strategic development plan now presented, of which this hiring plan is a crucial part, is expected to result in the consolidation of LIP, increasing its activity and its capability to attract funding from diversified sources, for example EU-funded projects and partnerships with industry and other institutions.

14.3 Support for participation in infrastructures or international networks in 2019-2022

The participation in international infrastructures is at the core of LIP's activities. The participation at CERN was the reason of existence of LIP and remains a central aspect. With the diversification of our research activities, other partners came to play a role: GSI, SNOLAB, SURF, the Pierre Auger Observatory, and ESA. The participation in such infrastructures in supported by the resources allocated to LIP's research projects, and within the National agreements with the involved organisations via contracts, Memoranda of Understanding, etc.

There are however opportunities that could benefit from dedicated funding:

- LIP has particularly strong scientific connections with countries like Spain, Italy, Brazil and other latin-american countries. Even a modest budget for bilateral agreements would be instrumental in fostering these relations, allowing in particular for student and researcher mobility, as well as joint training efforts and the submission of proposals for common projects.

- At LIP, we very much value advance training, in particular the internationalisation of the training. In the last few years, the international PhD network coordinated by LIP benefited from the support of FCT. As a result, an international school was organized every year since 2010, and a level of mobility of students within the network was achieved. It would be an important step forward to formalize now this support, guaranteeing it now for the next few years.

- Another aspect of advanced training and internationalization that is very important for LIP is the effective participation o post-graduate students in the international collaborations where LIP participates. This includes not only the analysis of the data collected by the collaborations and the participation in related R&D, but also the participation and presentation of their work in collaboration meetings, the attendance of scientific conferences and schools, the participation in experimental runs, prototype construction and test beam, etc. This implies travel expenses, which are often difficult to cover with limited resources in large groups often with many students.

For these reasons, complementary budgets dedicated to bilateral agreements (50 kEuros) and to student mobility (100 kEuros) are requested for the period 2019-2022.

14.4 Other types of support for which the R&D Unit requests Programmatic Funding in 2019-2022

As discussed above, one of the goals of this strategic plan is to potentiate the return of our research to society. In particular, advanced training and support to education are areas in which LIP aims to have a greater impact. LIP has been considered by its international board a "champion" in science outreach, with some widely recognized events such as the CERN school for teachers in Portuguese language, IPPOG's International Masterclasses in Particle Physics and a large number of talks in schools and other settings. While this program is to be pursued and consolidated, it is our intention to develop lines of work more related to the development of equipment and setups that can be used to support education both in formal and informal settings.

- Teaching laboratories for high school students: We will set up a teaching laboratory devoted to the experimental teaching of physics. Our aim is to explore data acquisition, sensors, measurement setups adapted to the curricula, raspberry pi, simple python programming exercises, data analysis and, in general, the methodologies and tools of experimental physics. In a first phase, a pilot project will be developed with a couple of schools. In a second phase, the project will be extended to more schools and to all LIP nodes. The requested budget includes both equipment and human resources - one person, who would contribute not only to this project but also to reinforce the LIP-ECO office in its general activities.

- Development of demonstration and pedagogical equipment - LIP has developed a spark chamber particle detector to be used for demonstration in science events or museums. Several chambers have been sold to institutions worldwide (price is 15 kEuros). We would now like to work in the development of a lighter and cheaper version which we could offer to schools as a prize in an outreach competition. In addition, a prototype cloud chamber has been developed and already used in several outreach events. The completion of this project, turning the apparatus into an easily portable and usable device, is now a priority. We would like to follow this line of work, having some dedicated funding.

These possibilities are created by the new premises of LIP-Lisboa, which for the first time provide the space and conditions for the development of teaching laboratories. The scientific infrastructures and competence centres of LIP also play an important role in the project. The teaching laboratories' project will greatly benefit from solid network of schools that LIP has built over the years in its three poles. In Minho there is in addition a protocol between LIP and an association of municipalities from the region which reinforces the links with schools and could provide an adequate framework for the development of these projects.
These projects will be developed in partnership with the Portuguese Physics Society, SPF, and Agência Ciência Viva.

While LIP keeps strong partnerships in the area of Science and Society, namely with Agência Ciência Viva, the possibilities of financial support have decreased considerably in the last few years. For this reason, and within the strategy of potentiating our contribution to society, and specifically our involvement in support to education, a budget of 200 kEuros is requested for the period until 2022 with the purpose of developing teaching laboratories devoted to projects with high school students. It will be dedicated to the experimental teaching of physics and to the development of educational equipment related to particle physics.

15. EXPECTED FUNDING AND BUDGET FOR 2018-2022 FOR EVALUATION PURPOSES

15.1 Expected funding of the R&D Research Unit for 2018-2022

FUNDING SOURCES (TOTAL FUNDING)	2018	2019	2020	2021	2022	TOTAL (K€)
Fundação para a Ciência e a Tecnologia, I.P. - FCT	5.062	3.496	3.757	3.909	3.957	20.181
R&D Unit Pluriannual funding awarded for 2018	1.482	0	0	0	0	1.482
Total (K€)	**6.019**	**4.520**	**4.971**	**5.193**	**5.421**	**26.124**

FUNDING SOURCES (TOTAL FUNDING)	2018	2019	2020	2021	2022	TOTAL (K€)
Project funding expected to be received	1.000	1.000	1.200	1.200	1.300	5.700
Expected funding for contracts of researcherswith PhD (1)	1.425	1.220	1.281	1.465	1.465	6.856
Expected funding for PhD, PostDoc or other fellowships (2)	355	376	376	344	292	1.743
Other funding	800	900	900	900	900	4.400
Other national sources	207	244	264	284	314	1.313
Funding expected to be received from Participant or Management Institutions	7	14	14	14	14	63
Public sources (3)	0	0	0	0	0	0
Companies, industry and other private sources based in Portugal (3)	150	180	200	220	250	1.000
Any otherfunding source (3)	50	50	50	50	50	250
International sources	750	780	950	1.000	1.150	4.630
European Commission (3)	500	500	600	600	700	2.900
Companies, industry and other private sources not based in Portugal (3)	150	180	200	250	300	1.080
Other fundingsources (3)	100	100	150	150	150	650
Total (K€)	**6.019**	**4.520**	**4.971**	**5.193**	**5.421**	**26.124**

(1) Payed through an institution or directly to researchers with PhD integrated in the R&D Unit

(2) Payed directly to fellows, researchers or students integrated in the R&D Unit

(3) Grants, projects, fellowships, prizes received, etc.

15.2 Expense budget of the R&D Research Unit in the Main Management Institution for 2018-2022

Laboratório de Instrumentação e Física Experimental de Partículas (LIP)

EXPENSE BUDGET ITEMS	2018	2019	2020	2021	2022	TOTAL (K€)
Human Resources	3.271	1.714	1.855	2.032	2.116	10.988
Contracts of researchers with PhD	2.457	1.276	1.390	1.574	1.574	8.271
PhD, PostDoc or other fellowships	264	183	129	122	122	820
Contracts of technical or secretarial staff	550	255	336	336	420	1.897
Researchers external missions	445	448	541	560	625	2.619
Temporary visiting researchers or consultants	20	60	80	60	97	317
Patents registration and maintenance	0	10	10	20	20	60
Service or product procurement and acquisition	330	498	576	660	687	2.751
Equipment	80	110	150	120	130	590
Adaptation of facilities and buildings	30	0	0	0	0	30
Other expenses	1.488	1.305	1.382	1.397	1.453	7.025
Total (K€)	**5.664**	**4.145**	**4.594**	**4.849**	**5.128**	**24.380**

15.3 Expense budget of the R&D Research Unit in the other Management Institutions for 2018-2022

15.4 Estimated percentages of application by general expense budget items of Base Funding in case it will be awarded by FCT, I.P. for 2018-2022 following the evaluation

EXPENSE BUDGET ITEMS	%
	78 %
Total	**100 %**

EXPENSE BUDGET ITEMS	%
Human Resources	
Contracts of researchers with PhD	60 %
PhD, PostDoc or other fellowships	0 %
Contracts of technical or secretarial staff	18 %
Total	**100 %**

EXPENSE BUDGET ITEMS	%
Researchers external missions	0 %
Temporary visiting researchers or consultants	0 %
Patents registration and maintenance	0 %
Service or product procurement and acquisition	0 %
Total	**100 %**

EXPENSE BUDGET ITEMS	%
Equipment	0 %
Adaptation of facilities and buildings	2 %
Other expenses	20 %
Total	**100 %**

16. JUSTIFICATION OF THE BUDGET FOR 2018-2022

16.1 Justification of the total proposed budget

In the year 2018, the total proposed budget amounts to 5.7 million Euros. The 2018 base funding is considered, since it does not depend on the ongoing evaluation and has already been attributed. Other funding sources considered in Table 15.1 are:
- FCT funds for scientific projects secured in competitive calls (CERN fund and PTDC, R&D projects in all scientific domains), research contracts and grants, and contributions related to international commitment such as Memoranda of Understanding for the Portuguese participation in international collaborations.
- Funds from international sources, namely EU funds for research projects and advanced training, and contracts with ESA and with industrial companies, as well as the financial results from the organisation of conferences;
- Funds from other national sources, in particular universities (shared grants) and companies (products and services from the mechanical workshop and several LIP groups), and also from our outreach partners.

These are redistributed by the different items in Table 15.2 in the way detailed below.

In 2018, 58% of the total budget is allocated to human resources. This includes the contracts of PhD researchers, technicians and administrative staff, as well as PhD and post-doc grants, and is shared between the base funding and the scientific project funding. More details are given in 16.2. External missions represent 8% of the total budget. They are of extreme importance to ensure a regular presence at the experimental sites (for reasons that evolve with the project phases), attendance of conferences and working visits to collaborators. Missions are supported by the funding attracted for research projects. Service or product procurement and acquisition amounts to 6% of the 2018 budget. Under this item are included most of the running costs of the research groups, including prototype construction and material and components acquisition, additional contributions to the construction and operation of experiments, and any external services to be procured. Such costs are to be supported by research project funds. A budget fraction of 1% is allocated to equipment (see justification below), adaptation of facilities and buildings (from the 2018 base funding) and temporary visiting researchers or consultants (from research project funds). Under the item "Other expenses" we are including general LIP running expenses, paid with project funding overheads (25% of the direct costs), and also fees related to the Portuguese participation in international experiments (600 kEuros in 2018).

In the year 2019, the decrease of the total budget to 4.1 million Euros is explained by the absence of the expendes related to the base funding. Human resources are in this case 41% of the total. It is however worth noting that the base funding attributed by FCT is essencial for the functioning of LIP, in particular for the laboratory's human resources responsibilities (see 16.2).

In the following years (2020-22), a moderate but consistent growth is expected, taking into account, among other aspects, the natural growth of the groups' size and responsibility. It is backed by the increase in funding foreseen in the new protocol between Portugal and CERN, by our reasonable expectation to increase the EU funding for research projects attracted by LIP, and by the income from contracts and service and equipment delivery to industry. LIP currently has several R&D products and ideas at pre-industrial level. Our strategy for the next five years reinforces the investment in R&D in health and space application, as well as in innovative detectors for nuclear and particle physics. For this reason, a modest but increasing budget for patents is considered. As for the adaptation of facilities and buildings, although moderate expenses with building adaptation are expected, they can only be supported by the laboratory's base funding and are thus not included in 15.2.

16.2 Justification of the Human Resources component in total proposed budget

Human resources are an important fraction of the expenses of LIP. They include contracts of PhD researchers, grants (namely post-doc and PhD grants), and contracts of technicians and administrative staff. These are covered in a shared way by the laboratory's base funding and by research project funds secured by LIP groups in competitive calls (direct FCT contracts and grants are not included). In 2018, the base funding of LIP (already attributed) is included in table 15.2, and 58% of the total budget is allocated to human resources. In the following years, no base funding is considered and human resources corresponds to 41% of the budget. Details for each of the three discriminated items are given below:

- Contracts of PhD researchers: Under this item we include researchers under contracts with FCT paid to LIP or with LIP. In 2018, there are 16 active researchers at LIP with ongoing "FCT researcher" contracts. Two more are expected as a result of the currently open call. In addition, we include 13 researchers (4 who started already in 2017 and 9 to start in 2018) with 6-year contracts funded by FCT, under Decree 57/2016. Still in 2018, we include the salaries of 16 LIP research staff members, covered by the already secured 2018 base funding. For the following years, these salaries are not included, as no base funding is considered. As for the remaining researchers, the end dates of the different contracts are taken into account in the proposed budget for each year, plus a reasonable expectation of two or three "FCT researcher" contracts per year.
- Grants: Post-doc, PhD and short duration grants are considered under this item. We are assuming that post-doc grants will no longer be awarded by FCT (as they are to be replaced by research contracts), although some post-doc grants may be awarded by the research projects. On the contrary, PhD grants will be awarded in national FCT competitive calls, and only exceptionally within research projects. A small but increasing number of post-doc grants for young PhD researchers supported by project's funds in thus included. For PhD grants, we take into account the end dates of ongoing grants supported by projects, and no additional grants are foreseen (as these should be secured in national call and via programatic funding).
- Contracts of technical and administrative staff: The fraction of the technical and administrative staff salaries payed by the base funding of LIP is included only in 2018. While most of the secretariat and mechanical workshop staff salaries is covered by the base funding, technical staff is often partially payed by research projects funds, particularly in EU projects, namely within the computing group.

Finally, It is worth emphasizing that the base funding attributed by FCT is essencial for the functioning of LIP. In particular, the laboratory has substancial human resources responsibilities (16 researchers and several technician are staff members) which must be covered by these funds. Also, and as detailed in section 14, the programatic funding will allow to address critical issues related to scientific employment, ensuring that LIP fulfills all its responsibilities at the highest level, enhances its contribution to society and evolves into a more stable and sustainable mode of operation.

16.3 Justification of the Equipment component in total proposed budget

In this budget, only equipment necessary for maintaining the general activities of research groups and current working conditions was considered. This includes IT and other general-purpose equipment for the different laboratories
of LIP and to support the research group's activities. Nevertheless, an appropriate re-equipment of the LIP scientific infrastructures will be considered whenever funds are available or a specific call is open for that purpose. In that case, priorities would be as follows, for each of LIP's scientific infrastructures:
- Mechanical workshop in LIP-Coimbra: renewal and upgrade of some of the equipment (bought 30 years ago), mainly a new milling CNC machine and a new profile cutting machine for fast and accurate mass productions, with a cost of 250 kEuros.
- Detectors Laboratory in LIP-Coimbra: Preparation of a clean room with forced air flow and dust particle contamination monitoring; acquisition of an oven for welding SMD components, one production unit for

prototype printed circuit boards (PCBs), one production unit of flexible flats/PCBs for large area signal readout and standardized workstations for production and test electronics. Total cost 250 kEuros.
- Electronics laboratory in LIP-Lisboa: acquisition of state-of-the art oscilloscopes and portable equipment for field operations to enhance the capability for tests and measurements; and of electronics fabrication equipment for the reworking and production of prototypes using components with fine pitch, reducing outsourcing and development time (100 kEuros).
- Laboratory of Optics and Scintillating Materials in LIP-Lisboa: construction of a detector test stand with sub-nanoseconds resolution using muons; acquisition of a silicon photomultiplier array system and a lathe for machining plastic scintillators; replacing obsolete equipment (photomultipliers, electronics and crates, vacuum pump). Total cost 100 kEuros.

17. REVIEWERS PROPOSED BY THE R&D UNIT(S)

17.1 Proposed experts for consideration of FCT, I.P. for eventual request of opinion about applications submitted by R&D Units for evaluation

Name	Institution	Email	Scientific Areas