Laboratório de Instrumentação e Física Experimental de Partículas

Work Plan

2015

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Chapter 1

Introduction

1.1 Introdução

1.2 Introduction

LIP activities are fully integrated in the European Strategy for Particle Physics adopted by CERN member states, as well in the EU e-infrastructures, e-IRG and EGI European roadmaps, fulfilling the already assumed international commitments and developing its own innovative contributions, both in large international collaborations and in specific application fields.
Particle and Astroparticle Physics are at a turning point: the Standard Models of Particle Physics and of Cosmology were in the last years firmly established but, as usual, they opened new burning questions in the understanding of the Universe. LIP is present in several leading experiments at CERN and in Astroparticle Physics that may contribute to important discoveries, clarifying, for instance, the nature of the Higgs field or of Dark Matter.
We expect that the adequate level of funding of LIP scientific projects will be restored, at least during the second semester of 2015, enabling the full development of LIP scientific, technological and training programmes at short and medium term and, in particular, the full exploitation of LHC data in the upcoming new 13 TeV energy regime. The development of the strategic areas of space applications, advanced computing, detectors and instrumentation and medical applications will be pursued. Outreach and advanced training programmes will continue to be an important component of our activities.
The detailed plan for each experiment/activity in which LIP will be involved in 2015 can be found in the following sections, but the highlights for the different groups can be found below.

Experimental Particle Physics with accelerators

The Run 2 of LHC, with an increased luminosity and a centre-of-mass energy of 13TeV, starts in mid-2015. The physics data taking will be performed with upgraded detectors (ATLAS and CMS) with the aim testing the structure of the SM with larger statistical data samples acquired at a new energy scale. A large variety of physics topics, ranging from the precise measurements of the Standard Model (SM) theory, including the Higgs boson and top quark properties, the searches for new physics beyond the SM (like supersymmetry) as well as the production of new particles will be studied. The joint effort between the experimental and theoretical communities in the search for new observables to better probe the physics case at the LHC will be continued. COMPASS in 2015 will prepare and then start the polarised Drell-Yan long physics run, which will take place from April to November, and continue the ongoing data analyses and physics studies. In HADES the activities will be centred in the operation and optimization of the RPC TOF wall and in physics analysis of the dilepton channels and strangeness.

Computing

LIP has strong responsibilities in the operation and development of Portuguese scientific computing infrastructures namely the WLCG Tier-2 and Tier-3 services for ATLAS and CMS, and the National Distributed Computing Infrastructure (INCD). LIP is deeply involved in major
international infrastructures such as the European Grid Infrastructure (EGI), IBERGRID, and Lifewatch. Furthermore it will participate in relevant Horizon 2020 R&D projects (EGI-ENGAGE, INDIGO-DATACLOUD).

Focus on advanced computing research related to HEP and on bridging the advanced training available in Computer Science and Engineering with the LIP research interests will be pursued.

Astroparticle Physics

The activity in the field of Astroparticle physics will be centred in the full exploitation of the data, on the fulfilment of LIP technical and scientific commitments and in the preparation of the future upgrades of the experiments. In particular, AMS, LUX and Auger are taking data and SNO+ and LZ are in the final phases of preparation and/or construction of the experimental setups, and Auger is undergoing a preliminary design phase for the upgrade of the Surface Detector array. This field is strongly focused on the search for new physics, through the search for Dark Matter in space or underground, in the quest for the Majorana nature of neutrinos, or in trying to solve the puzzles presented by cosmic rays.

Detector development for particle and nuclear physics

The expertise acquired in the development and production of RPC detectors enables the group to have a determinant role in different LIP projects. In particular innovative applications will continue to be developed on the areas of neutron detection (TOFtrackers and multi-gap RPCs), in the development of arrays of standalone low gas flux RPCs for Astroparticle experiments and in the construction of RPC-PET scanners. Detailed studies of the transport of ions in gases as well the optimization of Xenon based gaseous mixtures, both of interest for application to gaseous radiation detectors, including detectors for high energy physics will be pursued.

Instruments and methods for biomedical applications

LIP will continue to be a player in the field of development of innovative PET detectors, with a strong participation in the ClearPEM project, and in the application of RPCs to human and animal PET. The development and applications in the area of dosimetry will be continued as well as the proton radiotherapy studies in collaboration with the medical community (ICNAS) and the construction and preparation for commercialisation of compact gamma cameras for medical imaging.

Radiation Environment Studies and Applications for Space Missions

In 2015 the ongoing contracts between LIP, its contractual partners and the European Space Agency (RADEM; ECO-60, MFS data analysis and CODES) will be continued and new opportunities in the framework of ESA ITTs or within the H2020 programme will be pursued, also with the aim of establishing new collaborative international and national activities. The participation of LIP in the AHEAD project, for integrating key research infrastructures for on-ground test and calibration of space-based sensors and electronics and promoting their coordinated use will start by mid-2015.

Higher Education and Advanced Training, Technological Transfer and Outreach Activities

The engagement of LIP in the higher education and Outreach activities will be continued. In particular LIP is responsible for the coordination of the joint PhD programs DAEPHYS and IDPASC involving several Portuguese Universities; for the organization of the CERN Portuguese Language Teachers Programmes; and for the organization and participation in many activities involving primary and high-school students, such as the participation in the International Masterclasses in Particle Physics.

1.3 Human resources (head counts)

Project	Researchers	Technicians	Post-Docs	Students			
				D	M	G	O
ATLAS	15	1	3	10	4		2
CMS	7	1	3	7			1
LHC Phenomenology	13		2	1	1		1
COMPASS	3	1	3	2			
HADES	2	2	2				
GRID	5	3	1				
Advanced Computing	4						
AMS	1		1		1		1
SNO+	5	3	1				
Dark Matter Search	4	2	3	1	1		
HECR	14	3	5	2	1	1	1
RD51	5	10		1			
Neutron Detectors	3		1				
NEXT	7		1				
Ion Transport Processes	5		1	1			
ICNAS	2			2			
PET - Mammography	5	2	1	6	1		
Human PET	5	7					
MC in Medical Physics	7		1		1	1	
OrthogonalRayImaging	1			2	1		
Gamma Cameras	5		2	2			
Space	4		2	1			
AHEAD	6		1	1	1		
Education							
TTN-ILO		1					
OUTREACH	10	2	1				
Totals:	89	19	27	36	12	2	5

Legend:

Students: D - PhD, M - Master, G - Graduation, O - Other

FTE: Full Time Equivalent

1.4 Human resources (FTE)

Project	Researchers	Technicians	Post-Docs	Students				total
				D	M	G	O	
ATLAS	7	1	2	8	3		1	25
CMS	6	1	3	6			1	20
LHC Phenomenology	4		1	1			1	7
COMPASS	3	1	2	2				9
HADES	1	1	1					2
GRID	5	3	1					9
Advanced Computing	4							4
AMS	1				1		1	3
SNO+	3	1	1					4
Dark Matter Search	2	1	3	1				6
HECR	6	1	4	2	1			14
RD51	1	2		1				3
Neutron Detectors	1		1					2
NEXT	2		1					2
Ion Transport Processes	1			1				3
ICNAS				1				2
PET - Mammography	1	1	1	3	1			5
Human PET	1	1						2
MC in Medical Physics	3		1		1			6
OrthogonalRayImaging	1			2	1			3
Gamma Cameras	1			1				3
Space	1		1	1				4
AHEAD	2			1	1			5
Education								
TTN-ILO		1						1
OUTREACH								
Totals:	57	15	23	31	9		4	144

Legend:

Students: D - PhD, M - Master, G - Graduation, O - Other

FTE: Full Time Equivalent

1.5 Organisational Structure

Directors

José Mariano Gago, Gaspar Barreira, Mário Pimenta, Paulo Fonte, Rui Marques

Secretaries of the Scientific Council

Patrícia Gonçalves, Filipe Veloso

Administrative Staff

Cláudia Delgado, Elisabete Neves, Isabel Melo, João Pedro Santos, Leonor Coimbra, Lina Barata, Maria José Miguel (IST), Natália Antunes, Ricardo Caeiro, Sandra Dias, Teresa Marques

Technical Staff

Alexandre Moita, Américo Pereira, Carlos Manuel, Carlos Silva, Christophe Pires, Emir Sirage, Hugo Gomes, João Silva, Joaquim Oliveira, José Aparício, José Carlos Nogueira, José Carlos Silva, Luís Gurriana, Luís Lopes, Luís Mendes, Miguel Ferreira, Nuno Carolino, Nuno Filipe Silva Dias, Orlando Cunha, Pedro Parracho, Rui Alves, Rui Pereira da Silva

Chapter 2

Experimental Particle Physics with accelerators

2.1 Collaboration in the ATLAS experiment at CERN

2.1.1 Resumo

A experiência ATLAS opera no acelerador LHC do CERN, onde se produzem colisões de protões e iões pesados a energias e luminosidades sem precedentes, abrindo uma nova fronteira no limiar do conhecimento em física de partículas.
Em 2015 a experiência ATLAS inicia um novo ciclo de recolha de dados com capacidades de detecção melhoradas e um amplo programa de física que abarca medidas de parâmetros previstos no Modelo Padrão (MP), incluindo as propriedades do bosão de Higgs e do quark top, por exemplo, até buscas por nova física para além do MP.
O grupo do LIP contribui para análises de física e estudos do desempenho do detector com dados de colisões do LHC, operação e manutenção e upgrade do detector. A equipa é estruturada em sub-grupos liderados por um investigador sénior (nomes entre parêntesis), seguindo a estrutura das actividades dentro de ATLAS:
Análises de Física

- Física do Quark Top (A. Onofre, F. Veloso)
- Buscas de novas partículas pesadas (N. Castro)
- Física do sector de Higgs (P. Conde, R. Gonçalo)
- Física de Iões Pesados (H. Santos)

Operação e Desempenho do Detector ATLAS e do Trigger

- TileCal (A. Gomes)
- Trigger de Jatos (R. Goncalo, P. Conde)
- Detetor ALFA (A. Maio)

Upgrade do Detetor

- Upgrade do TileCal (A.Gomes)
- Trigger de Jatos (P. Conde)
- Detetores de Forward proton tagging, AFP (P.Conde)

Computação Distribuída na GRID (H. Wolters).
Dentro de ATLAS, a equipa portuguesa é representada segundo:

- ATLAS National Physicist Board (P. Conde)
- ATLAS Collaboration Board (P. Conde)
- TileCal Institutes Board (A. Maio, A. Gomes)

- Trigger/DAQ Institutes Board (P. Conde)
- Forward Detectors Board (A. Maio)
- AFP Board (P. Conde)

2.1.2 Abstract

ATLAS is one of the experiments that operates at the CERN Large Hadron Collider (LHC) where proton-proton and heavy ion collisions take place at unprecedented high energies and luminosities, opening a new frontier in particle physics.
In 2015 ATLAS is re-starting physics data taking with an improved detector, with the aim of studying a large variety of physics topics, ranging from the precise measurements of the Standard Model (SM) predictions, including the Higgs boson and the top quark properties, to the searches for new physics beyond SM, such as supersymmetry, new heavy quarks, ...
The LIP Portuguese team contributes to physics analysis and performance studies with data from LHC collision events, detector operation and maintenance, and upgrades. The team is structured in subgroups lead by a senior physicist (in brackets below), following the organization structure of the ATLAS activities:
Physics Analysis

- Top Quark physics (A. Onofre, F. Veloso)
- Search for new heavy particles (N. Castro)
- Higgs physics (P. Conde, R. Gonçalo)
- Heavy ions physics (H. Santos)

M&O and performance of the ATLAS detector and trigger system

- TileCal (A. Gomes)
- Jet Trigger (R. Goncalo, P. Conde)
- ALFA detector (A. Maio)

Detector Upgrades

- TileCal Upgrade (A.Gomes)
- Jets high level trigger system (P. Conde)
- ATLAS Forward proton tagging detectors, AFP (P.Conde)

GRID Distributed Computing (H. Wolters).
In ATLAS the portuguese team is represented as follows:

- ATLAS National Physicist Board (P. Conde)
- ATLAS Collaboration Board (P. Conde)
- TileCal Institutes Board (A. Maio, A. Gomes)
- Trigger/DAQ Institutes Board (P. Conde)
- Forward Detectors Board (A. Maio)
- AFP Board (P. Conde)

2.1.3 Objectives

The detailed description of the different group objectives for 2015 will be described in what follows.

Physics studies

In what corresponds to the Higgs boson physics, our long term goal is to study the couplings of the Higgs to the quarks accessible at the LHC (top and bottom), including spin and CP properties in the coupling vertex, and the HWW vertex in the associated production channel with a W. For 2015, our focus will be the preparation and analysis of the first 13 TeV pp collisions in the ttH and VH (H->bb) channels, building up on our expertise from Run 1. In addition, we will explore angular variables to disentangle the different spin and CP components in the ttH and HWW vertex (WH production).
Concerning the top quark physics, we will continue the search for Flavour Changing Neutral Currents (FCNC) in the top quark decays with the 13 TeV data to be collected and we will start the study of the Vts vertex through the measurement of the top decays to Ws.
We will complement the precision measurements of the Higgs and top quark properties with direct searches for new physics, in particular the search for vector-like quarks, predicted by some of the extensions of the SM as a way to regulate the quadratic mass-squared divergence of the Higgs boson. We will continue to lead the effort in the Zt/b+X topology and will extend the studies done up to now to the new data acquired in 2015. A spin-off of these studies will be the search for tZ production via FCNC, allowing to probe the tqg and tqZ couplings in a final state topologically very similar to the one explored for the vector-like quark searches.
Sensitivity studies of top quark physics and related new physics in the context of the High Luminosity phase will be updated with new incoming information about the expected conditions of the ATLAS detector.
Concerning heavy ion physics, the main goal of the group for 2015 is to conclude the study of dijet asymmetries in Pb+Pb collisions, concentrating afterwards on the analysis preparation of heavy-flavour jet production in Pb+Pb collisions in Run2. Our long term goal is to understand the mechanism of jet energy loss in the quark gluon plasma.

Detector maintenance, operation and upgrade

Our commitments in the ATLAS hadronic calorimetry, both in the Trigger system and in the TileCal detector, will continue.
In TileCal our effort will be concentrated on the following activities:

- Maintain our strong involvement in the DCS. A new generic OPC is in development for the high voltage system, and the DCS will become compatible with the demonstrators: prototypes of electronics designed for upgrade phase 2, to be tested in ATLAS detector and in a test beam.
- Commission the Laser II system for the Run 2 and use it to keep track of the linearity of the PMTs and associated electronics and to monitor the gain drift of the PMTs, that need particular attention to spot possible troubles in the near or far future.
- Perform the electronics noise survey at the new energy and pile-up conditions of the LHC.

For the TileCal Upgrade, we will

- Test radiation hard WLS optical fibers and scintillators for replacement of TileCal gap and crack scintillators by 2018.
- Design and produce of a new prototype of the Phase 2 High Voltage Distributor System to be tested in a test beam at CERN.

In what concerns the Tile-muon trigger, a task that links our TileCal and trigger expertise, we will continue our responsibilities with focus on software and performance. The Tile-Mu trigger will be ready for data taking from the start of Run 2. We will participate in the fast validation of this trigger, with 50 ns and 25 ns data, making use of the byte stream converters developed by us. For the future, we will study the possible gain that can be obtained by an extension of the Tile-Muon trigger to the full TileCal barrel region for the Phase 2 upgrade.
On the high level jet trigger side, that has been completely re-structured for the Run 2, we will concentrate on performance studies with the 2015 data. This is extremely important for validation, optimization of the trigger menu and for physics analyses relying on jet triggers.
Our Upgrade activities on the trigger side will continue with the development of parallelizable trigger algorithms to run on Graphical Processing Units (GPUs). We will implement a full prototype of a jet trigger chain for the end of 2015 to evaluate the possible gain in the use of these technologies. We collaborate with the LIP´s Computing group to test different hardware technologies.
In addition, our involvement in the ATLAS forward detectors will continue with the migration of the ALFA detector DCS and the design and implementation of the AFP trigger.

With respect to ATLAS GRID, the main objective of the Portuguese group is the operation and monitoring of the local Tier-2 and Tier-3 clusters with respect to the ATLAS production activities, and the collaboration in the central organization of operation and monitoring of the world-wide GRID.
Our contribution to outreach in these exciting years of LHC physics will continue.

2.1.4 Team

Project coordinator: Patricia Conde

Name	Status	FTE %
Ademar Delgado	PhD student (LIP/FCT)	100
Agostinho Gomes	Researcher (LIP)	85
Alberto Blanco	Researcher (LIP)	15
Alberto Palma	PhD student (LIP)	100
Amélia Maio	Researcher (LIP/FCUL)	55
André Pereira	(LIP)	100
António Onofre	Researcher (LIP/UMinho)	18
Artur Amorim de Sousa	Master student (LIP)	41
Bruno Galhardo	PhD student (LIP/FCT)	100
Emanuel Gouveia	Master student (LIP)	100
Ester Simões	Master student (LIP)	100
Filipe Martins	Master (LIP)	100
Filipe Veloso	Post-Doc (LIP/FCT/FCTUC)	90
Guiomar Evans	Researcher (FCUL)	15
Helena Santos	Researcher (LIP)	100
Helmut Wolters	Researcher (LIP/FCTUC)	70
Henrique Carvalho	Student (LIP)	50
Joana Miguéns	PhD student (LIP/FCT)	100
João Gentil	Post-Doc (LIP/FCT)	100
José Maneira	Researcher (LIP)	40
José Manuel da Silva	Master (LIP)	50
José Santiago Perez	Researcher (LIP/UGR)	18
José Soares Augusto	Researcher (IST/INESC/FCUL)	30
Juan Espinosa	PhD student (LIP/FCT)	100
Lia Moreira	Student (LIP)	60
Lourenço Lopes	PhD student (LIP/FCUL)	16
Luís Gurriana	Technician (LIP)	50
Luís Seabra	Master (LIP)	100
Manuel Maneira	Researcher (LIP/FCTUNL)	15
Mário Sargedas Sousa	PhD student (LIP/FCT)	100
Nuno Castro	Researcher (LIP/UP/UMinho)	40
Patricia Conde	Researcher (LIP)	85
Paulo Marques	Master (LIP)	24
Pedro Jorge	PhD student (LIP/FCT)	80
Renato Dantas	Master student (LIP/UMinho)	41
Ricardo Gonçalo	Researcher (LIP)	80
Robert Cantrill	Post-Doc (LIP)	8
Rui Santos	Researcher (LIP/FCUL)	9
Rute Pedro	PhD student (LIP/FCT)	100
Susana Santos	PhD student (LIP/FCT)	36

2.1.5 Academic Training

PhD Theses

- **Measurement of the W -> mu nu production cross section with the ATLAS detector**
  Pedro Jorge, (on-going)
- **Search for the WH associated production with the Higgs decaying to b-quark pairs at ATLAS/LHC**
  Alberto Palma, (on-going)
- **Medida da taxa de decaimentos raros do quark top, na experiência ATLAS no LHC**
  Bruno Galhardo, (on-going)
- **Study of the ttH production and Higgs couplings to Top quarks in the ATLAS experiment**
  Susana Santos, (on-going)
- **Observation and measurement of Higgs boson decays to WW* with ATLAS at the LHC**
  Joana Miguéns, (on-going)
- **Search for the Higgs boson at ATLAS/LHC, in associated production with a Z boson**
  Mário Sargedas Sousa, (on-going)

- **Search for new vector-like quarks at the LHC (provisional)**
  Juan Espinosa, (on-going)
- **Search for the Higgs boson at ATLAS/LHC in WH associated production and decay to b quark pairs using MVA methods**
  Rute Pedro, (on-going)
- **Development of boosted jet triggers for Higgs searches at the ATLAS experiment at the LHC/CERN**
  Ademar Delgado, (on-going)

Master Theses

- **Search for ttH production with the ATLAS experiment at the LHC**
  Emanuel Gouveia, (on-going)
- **Search for tZ events produced via flavour changing neutral currents at the LHC (provisional)**
  Artur Amorim de Sousa, (on-going)

Graduation Theses

- **Determinação da carga elétrica de jatos hadrónicos incluindo o decaimento semileptónico de quarks pesados**
  Lia Moreira, (on-going)
- **Melhoramentos na determinação da carga de jatos hadrónicos e estudo de variáveis angulares em produção de ttH**
  Eduardo Dias, (on-going)

2.2 Collaboration in the CMS experiment at CERN

2.2.1 Resumo

O Laboratório de Instrumentação e Física Experimental de Partículas é membro da Colaboração Compact Muon Solenoid (CMS) no Large Hadron Collider (LHC) do CERN desde 1992. O objectivo científico da investigação no programa do LHC é compreender as leis da Física ao nível mais fundamental.
Em 2015-16 as atividades do grupo LIP/CMS serão organizadas em quatro eixos principais:
1) análise da física em protão-protão, explorando as possibilidades de descoberta oferecidas pela nova energia e luminosidade do LHC, incluindo:

- busca de Higgs carregado e outra nova física em estados finais com quarks top;
- busca de parceiros supersimétricos do quark top e do leptão tau;
- busca de decaimentos raros de quarks e leptões da 3ª geração.

2) física de iões pesados e o estudo do plasma de quarks-gluões, incluindo:

- produção de estados quarkonia em colisões com iões de chumbo (p-Pb e Pb-Pb), incluindo medida da polarização;
- produção de sabores pesados em colisões com iões de chumbo (e também em pp como referência).

3) Novos desenvolvimentos do detector para a Fase 1 do programa de Upgrade de CMS incluindo:

- contribuição para o novo Sistema de Trigger desenvolvendo e explorando ligações ópticas de alta velocidade entre o sistema electrónico do ECAL e o sistema de Trigger;
- contribuição para o novo Precision Proton Spectrometer, desenvolvendo o sistema electrónico "front-end"dos detectores de tempo;

4) A operação e manutenção do Trigger e do Sistema de Aquisição de Dados do Calorímetro Electromagnético.

2.2.2 Abstract

LIP is member of the Compact Muon Solenoid (CMS) Collaboration at the Large Hadron Collider (LHC) at CERN since 1992. The scientific motivations of the research at the LHC are at the heart of our quest for understanding the fundamental physics laws of the universe.
In 2015-16 the activities of the LIP/CMS group will be organized along four main lines:
1) Proton-proton physics analysis, exploiting the discovery opportunities offered by the new LHC energy and luminosity, including:

- search for a charged Higgs and other new physics in final states with top quarks;
- search for the supersymmetric partners of the top quark and tau lepton;
- search for rare decays of 3rd generation quark and leptons.

2) Heavy-ion physics and the study of the quark-gluon plasma, including:

- quarkonium production in collisions involving lead ions (p-Pb and Pb-Pb), including polarization measurements
- heavy flavour production in collisions with lead ions (and also pp as reference)

3) New detector developments for the CMS Phase 1 Upgrade program, including:

- contribution to the new Trigger System developing and operating the high-speed optical links that interface the ECAL electronics to the Trigger System;
- contribution to the new forward Precision Proton Spectrometer, developing and operating the front-end electronic system of the timing detectors;

4) Operation and maintenance of the trigger and data acquisition system of the CMS Electromagnetic Calorimeter.

2.2.3 Objectives

Physics analyses

The top quark is the heaviest of all known elementary particles. The large top quark mass implies a large coupling to the Higgs boson, thus establishing a privileged link to the Higgs sector. Measurements of top quark final states may provide constraints for new physics processes. The LIP/CMS group plans to maintain a leading role in several top quark studies, using the increased statistics in Run 2, including the measurement of the top pair cross section with taus at 13 TeV, and the studies of the heavy flavor content of top events.
Supersymmetry (SUSY) is an attractive and elegant theory of physics beyond the SM. It naturally solves the hierarchy problem. Furthermore, in the case the lightest SUSY particle is stable, SUSY predicts weakly interacting particles which are natural candidates for the observed Cold Dark Matter. In the case SUSY is a symmetry of nature the lightest stop quark is the lightest squark, thus, the most easily observable at the LHC. Researchers of the LIP/CMS group have been searching for the stop quark in the "lepton plus jets"final state. We plan to pursue these searches with increased sensitivity allowed by the higher energy and luminosity of LHC in Run 2.
In the Minimal Supersymmetric extension of the SM (MSSM), the Higgs sector contains five particles. Whereas the neutral Higgs boson is compatible with both the SM and the MSSM, the detection of a charged Higgs boson would unequivocally point to new physics beyond the SM. Researchers of the LIP/CMS group have a leading role in the search for the charged Higgs. In Runs 2, the search will be focused on heavy charged Higgs decaying to top quarks.
Since the discovery of the J/psi meson, quarkonia, bound states of heavy quark-antiquark pairs, have played a crucial role in understanding some of the basic properties of quantum chromodynamics (QCD). Researchers in the LIP/CMS group played a leading role in measuring the polarization of the J/psi and Y states. We plan to pursue these studies with increased statistic and to apply the techniques developed to other polarization measurements, in particular the direct measurement of the Higgs spin-parity.
The search for processes that are highly suppressed in the SM is a promising means to detect effects of new-physics (NP) contributions. The combined observation by CMS and LHCb of the long-sought Bs→μμ rare decay is a significant LHC milestone. It illustrates the capability of the CMS detector to lead searches and measurements of rare processes. We plan to further the exploration of very rare decays with Run 2 data, building up on the experience we have acquired during Run 1. With very first Run 2 data, we plan in addition to carry out production measurements of heavy flavour, initially in pp, and also in collisions involving heavy ions.
A joint effort of the CMS and TOTEM collaborations culminated in the preparation of a Report (CERN-LHCC-2014-021) on the technical design and expected performance of the CMS-TOTEM Precision Proton Spectrometer (CT-PPS). The PPS adds precision proton tracking and timing detectors in the very forward region on both sides of CMS at about 200m from the Interaction Point, which together with the CMS central detector will enable the study of final states produced in association with leading protons pp→p+X+p. Central exclusive production (CEP) provides a unique method to access a variety of physics topics at high luminosity LHC, such as new physics via anomalous production of W and Z boson pairs, high-pT jet production, and possibly the production of new resonances. LIP/CMS researchers are planning to contribute to these physics studies.

Detector Upgrades

The original design goal of the LHC was to operate at 1034 cm2 s-1. With the LHC upgrades, the instantaneous luminosity will more than double. One important part of the CMS Phase 1 upgrade program is to improve the performance of the Level-1 Trigger by installing a new system. The LIP/CMS group has developed the new optical Serial Links that interface the ECAL electronics to the Trigger System. The new system was built and is being installed.
In the Phase 1 Upgrade CMS will add a new forward proton spectrometer (PPS). The PPS detector consists of a silicon tracking system and a set of timing counters to measure their arrival time with a precision of the order of 10 ps. This allows the reconstruction of the mass and momentum as well as of the z-coordinate of the primary vertex of the centrally produced system. Timing detectors in both arms will measure the time difference of the protons providing an effective way to reduce the background from pileup events, thus enhancing the sensitivity and physics performance. The LIP/CMS group is directly involved in the preparation of the detector electronics (data readout, monitoring, integration with the central detector, test beam) and simulation of the detector performance. The detectors will operate at a few mm from the beam during data-taking, and will be moved away from the beam during beam injection, acceleration, and luminosity tuning. Each station

will be instrumented with radiation-hard detector components. The baseline design of the PPS timing detectors is the quartz-based timing detector, the Quartic. Members of the LIP/CMS group will be involved in studying alternative options; among other options, timing detectors based on Avalanche PhotoDiodes (APDs) will be explored for their fast response and superior/finer segmentation capability.
The current program has two phases: an exploratory phase (2015-2016) and a production phase (2016-2017). The exploratory phase aims at proving the ability to operate detectors close to the beam-line at high luminosity, start tests of the tracking and timing detectors, demonstrate the timing performance and pileup rejection capability, integrate the CT-PPS detectors into the CMS trigger/DAQ system. The production phase aims at finalizing detector commissioning and taking data for physics studies. The LIP/CMS group will intensively participate on the activities of both phases, in the preparation, commissioning, and operation of the detectors.
The main LIP responsibilities in new detector developments for the CMS Upgrade program are:
1) Contribution to the new Trigger System (Phase 1), with full responsibility for the optical links interfacing ECAL to the Trigger System.
Coordination positions :

- Chief engineer of the oSLB/oRM link project (J. C. Silva).

2) Contribution to the new forward CT-PPS detector [1], with full responsibility in developing the readout of the timing detectors.
Coordination positions :

- CT-PPS Project Manager (J. Varela).
- CT-PPS Physics Performance Coordinator (M. Gallinaro).
- CT-PPS Timing Detector Co-Coodinator (M. Gallinaro).

References:
[1] Technical Design Report of the CMS-TOTEM Precision Proton Spectrometer, CERN-LHCC-2014-021, https://cds.cern.ch/record/1753795

Project objectives

The objectives of the project are:

1) Proton-proton physics:
The objective is to exploit fully the discovery opportunities offered by the LHC high energy and luminosity. The activity is organized in three main physics domains, namely Top Quark Physics, SUSY Physics and Heavy Flavors. Each domain is led by a senior physicist and integrates researchers and students. The coordinator is responsible to supervise the analyses and to establish the interface to the corresponding Physics Analysis Group (PAG) guaranteeing that the effort is well integrated in CMS and that the LIP group has adequate visibility and impact.
The LIP group is planning to participate in the following areas of physics analysis:

- search for charged Higgs and other new physics in top events;
- search for 3rd generation supersymmetric particles (stop, stau);
- search for rare decays and measurement of heavy flavour production and properties
- central exclusive production in proton collisions

2) Heavy-ion physics:
The ultimate objective is the study of the quark-gluon plasma and the strong interaction, exploring the collisions of lead beams at the LHC.
The LIP group is planning to participate in the following analyses:

- quarkonia polarization as a function of charged multiplicity in proton-pronton and in heavy-ion collisions;
- heavy-flavour production in heavy-ion collisions (in coordination with pp studies);
- polarization of chi states (χc and χb).

3) Physics objects development:
As part of the Experimental Physics Responsibilities (EPR) with the collaboration, the LIP group plans to participate in the activities of development and validation of the "physics objects"TAU (tau lepton) and MET (missing ET) in the frame of the corresponding Physics Object Groups (POGs). This choice is motivated by the impact that these objects have in key analyses lead by LIP, namely the search for charged Higgs and the SUSY searches.

4) New detector developments for the CMS Upgrade program:
The objective of this sub-group is to contribute with R&D of new detector technologies for the Upgrade of the CMS experiment. In the next two years we concentrate these efforts in two areas:

- installation and commissioning of the new optical Serial Links that interface the ECAL electronics to the Trigger System.
- development of the timing detectors of the CT-PPS project.

Each of the R&D programs (Trigger, PPS) is led by a coordinator. The activity is integrated in the corresponding CMS structure, respectively the L1 Trigger Project and the PPS Sub-detector. Synergies with the LIP group in medical applications (PET) are exploited.

5) Operation and maintenance of the ECAL trigger and data acquisition system:
The LIP/CMS group has a small team of people based at CERN which is required for the normal maintenance and operation of the ECAL detector. The LIP/CMS group has a dedicated electronics lab installed in the CERN campus used for R&D and maintenance work.

6) Computing:
LIP operates the CMS Tier2 GRID computing center installed in Lisbon. This center is part of a world-wide computing infrastructure (GRID) used in the processing and analysis of the CMS data. One member of the LIP/CMS group coordinates the interface with the LIP´s Tier2 group.

7) General:
The LIP group is responsible to provide central shifts for data taking and EPR work according to the rules of the CMS collaboration. In 2015 the LIP group shall guarantee about 120 shifts (8h each) and about 50 months of EPR work.

2.2.4 Team

Project coordinator: João Varela

Name	Status	FTE %
Agostino di Francesco	PhD student (LIP)	100
André Tinoco Mendes	Researcher (LIP)	100
Andrea Barisone		100
Cristóvão Silva	PhD student (LIP/FCT)	100
Daniele Vadruccio	Researcher (LIP)	100
Federico Nguyen		100
João Pela	PhD student (LIP/Imperial)	100
João Rodrigues Antunes	PhD student (LIP)	100
João Seixas	Researcher (LIP/IST)	50
João Varela	Researcher (LIP/IST)	75
José Carlos Silva	Technician (LIP)	98
Lara Lloret	Post-Doc (LIP/FCT)	100
Manuel Rolo	PhD student (LIP)	5
Marcelo Vicente		100
Michele Gallinaro	Researcher (LIP)	100
Nuno Leonardo	Researcher (LIP)	100
Oleksii Toldaiev	PhD student (LIP)	100
Pedrame Bargassa	Researcher (LIP)	100
Pedro Ferreira da Silva	Post-Doc (LIP/FCT)	50
Pedro Parracho	Collaborator (LIP/AdI)	100
Pietro Faccioli	Post-Doc (LIP/FCT)	100
Pietro Vischia	PhD student (LIP/FCT)	100
Rogério Jorge	Student (LIP)	50

2.2.5 Academic Training

PhD Theses

- **Search for staus in the CMS experiment at the Large Hadron Collider**
  Cristóvão Silva, (on-going)
- **Study of top quark properties and tests of the Standard Model at the LHC with the CMS detector**
  Pietro Vischia, (on-going)
- **Development of high-performance timing detectors for the CMS forward proton spectrometer**
  Agostino di Francesco, (on-going)
- **Search for new physics processes with leptons in the final state at the Large Hadron Collider with the CMS detector**
  Oleksii Toldaiev, (on-going)
- **Search for the lepton violating decay tau to 3mu and trigger upgrade for LHC phase 2**
  Daniele Vadruccio, (on-going)

2.3 Phenomenological Studies at the LHC

2.3.1 Resumo

Por forma a cobrir o campo de física aberto pelo programa do LHC, é fundamental um importante esforço conjunto da comunidade experimental e teórica. Este esforço deve ser concentrado não apenas no estudo dos melhores observáveis físicos disponíveis no LHC, para realizar testes de precisão do Modelo Padrão (SM) da Física das Partículas Fundamentais, mas também no desenvolvimento de novas ideias para a física para além do SM. Neste projecto serão tratados alguns aspectos específicos do programa de física do LHC, tanto do ponto de vista experimental como teórico.
No seguimento do trabalho previamente desenvolvido pelo grupo experimental, a inclusão de novos membros da área da física teórica de altas energias permite o desenvolvimento em Coimbra e na Universidade do Minho, de um grupo de Física de Partículas especialmente dedicado à física do LHC. Uma ênfase especial será colocada na formação de estudantes de doutoramento e na motivação de estudantes de licenciatura.
O projecto em si tem tido o mérito de atrair vários estudantes (quer de universidades portuguesas quer estrangeiras) e proporcionou um ambiente favorável que deu origem à elaboracao de várias teses de mestrado e doutoramento quer na área da fisica experimental quer teórica. O projecto tem o mérito de juntar as comunidades experimental e teórica sob um tema comum de investigação, com o objectivo, a longo prazo, de explorar de uma forma eficiente os dados adquiridos no LHC. Tal como foi feito no passado, estão previstos encontros regulares durante a execução do projecto, e serão realizados seminários para motivação da comunidade científica para o potencial da física de LHC.
Particularmente relevante e´ o desenvolvimento de um grupo de Fisica de Particulas e Astroparticulas na Universidade do Minho, um dos principais objectivos deste projecto, no recem criado Polo do LIP na Universidade do Minho, LIP-Minho. Esta iniciativa, que se iniciou em Fevereiro de 2010 conta já com a colaboracao de 23 membros, 6 Investigadores Doutorados, 5 estudantes de Doutoramento, 8 estudantes de Mestrado, 3 estudantes de licenciatura e 1 engenheiro informático.

2.3.2 Abstract

In order to address the physics potential of the LHC program, a significant joint effort of the experimental and theoretical community is required. This effort must consider not only the study of the best physical observables to perform a precise test of the Standard Model (SM) of Elementary Particle Physics at LHC, but also to develop new ideas for physics beyond the SM. In the present project, specific topics of the physics program of the LHC are addressed from both the experimental and theoretical points of view.
Following the work previously developed by the experimental team at the LHC, the inclusion of new members from the field of theoretical particle physics allow us to develop a High Energy Physics group specifically dedicated to the physics at the LHC. The aim of this project is to support this group giving special emphasis to the training of MSc and PhD students and motivation to new undergraduate students.
The project was very successful in the past in attracting students (from Portuguese and foreign universities) and provided the correct framework for the development of several MSc and PhD thesis already, both in experimental and theoretical physics. The project in itself is very valuable once it brings together the experimental and theoretical communities under a common goal of research, with the long term objective of exploring in an efficient way the data that will be collected at the LHC. As was done in the past, regular meetings are foreseen in the course of the project, and seminars are expected to be held in order to motivate the scientific community to the physics potential of the LHC.
Particularly relevant is the fact that a new branch of LIP (LIP-Minho) is under development at the University of Minho, North of Portugal, bringing the field of High Energy Particle Physics and Astroparticle Physics to the Northern Universities of Portugal. This initiative started February 2010 and counts with the collaboration of 23 researchers: 6 senior PhD members, 5 PhD students, 8 Master students, 3 undergraduate students and 1 computer sciences engineer.
Several tasks are expected to be developed during the course of the project:
1. Top Quark Production at the LHC
The main goal is to study top quark production at the LHC and signals of physics beyond the SM in top quark FCNC processes. Following the development of a model independent analysis for single top production via FCNC (where dimension 5 and 6 effective flavour changing and flavour conserving quark-gluon vertices were considered), the impact of these new couplings on the physical observables at LHC will be studied at centre-of-mass energies of 13 and 14TeV. Several contributions of this team were already included (gg->tq, gq->tg, qq->tq) in general purpose generators like MeTop (a NLO Monte Carlo generator developed by the team). Results show that these new contributions cannot be neglected when compared with the direct single top production process. The combination of the different results for the top quark production (double and single),

the FCNC decays of top quarks and the production through FCNC processes need to be carefully performed. The main goal of this task is to develop a global fitter for FCNC vertices (tqZ, tqg, tqgamma and tqH) which will allow to set consistent limits on the possibility of new physics in top quark production (in ttbar and single top processes at the LHC) and decay. New contributions associated to top quark production and decay through the Higgs channel will be calculated and included in the generators.

2. Study of Top Quark Couplings

The LHC at 13 and 14TeV is expected to be a top factory. This fact allows for the measurement of the Wtb vertex and the couplings of the top quark. Although the double top production is insensitive to the V_tb CKM matrix element, the angular asymmetries between the top quark decay products can nevertheless give valuable information on the structure of the Wtb vertex. New vector and tensor like couplings can be introduced within an effective lagrangian approach, which can be probed at the LHC. A new software package, called TopFit, was made available to the physics community, which performs a global fit to the top quark observables (or related to top) in order to extract the best limits on the anomalous couplings (assuming the SM). During the execution of the task two different issues will be adressed. The first is related to the limits from indirect measurements (e.g. the radiative b decay, b->s gamma) which set very stringent limits on VR and gL (but not on gR). The second issue is related to the measurement of asymetries in top quark decays which set very stringent limits on gR (but not on VR or gL). A combination of all measurements, using also the results from the Tevatron collider (CDF and D0) will be performed to simultaneously set limits on all parameters with TopFit. Given the expected measurements of the ATLAS, CMS and Tevatron experiments, a combination of the results is expected to be explored using TopFit. Results on the real and imaginary parts of the couplings are expected to be obtained at the new energy regimes of the LHC, 13 and 14TeV. This task complements well the first one i.e., while the first one is dedicated to the development of a global fitter for the neutral currents interactions of top quarks, the current task is dedicated to the study of the charge current interactions of top quarks.

3. Study of Higgs Production and Couplings

This task is related to the pp-> tth process. The CP-violating tth vertex can be written as "a + i b gamma5", containing thus a scalar and a pseudo-scalar component. The team is about to finish a work where we have explored a very large number of angular variables to facilitate the discrimination between signal and background in the final state pp -> tth -> 4b 2l ME. These studies have been performed assuming that the Higgs is a pure scalar particle once the goal was here to optimize the signal over background ratio. The case where the Higgs is considered to be a mixture of scalar and pseudoscalar components is to be analysed with no assumptions regarding the size of each component and estimating the contribution from non-SM background. It was shown in previous papers in the literature that there are some chances of discriminating scalar and pseudo-scalar components. The team approach is similar but more systematic. As was recently done for the SM Higgs (to tackle the huge background problem), the plan is to build all possible asymmetries that could probe the scalar to pseudoscalar ratio. However, until these and other angular variables are tested at detector level it is not possible to understand the level of precision in discriminating scalar and pseudo-scalar components. The team plans to use some versions of the 2HDM and 3HDM as benchmark models to the extra background contribution. In both cases our proposal is different from the previous ones in that we will always release detector level studies. The team have just shown that many angular distributions that looked very promising at parton level become useless when a complete detector level study is performed (paper to be submitted).

4. Probing the see-saw mechanism

In this project the team proposes to explore the clean signals of multilepton final states to probe the seesaw mechanism at LHC. This study has great interest because a positive answer would unveil the neutrino mass generation mechanism, which is an important step towards a theory of flavour, which is one of the standing problems in particle physics. On the other hand, final states with several leptons appear in other new physics models like models of extra dimensions with custodial symmetry. Studying multilepton signals will also allow the team to probe these models.

5. Theoretical Models and Monte Carlo Generators

One of the required tasks in this project is the development of theoretical models for the different topics under study and the implementation of dedicated Monte Carlo generators and global fitters. For the single top production via FCNC, a complete calculation of cross-sections and branching ratios (eletroweak+strong and t->qX,X=gluon,gamma,Z and H) was provided by the theoretical physicists in order to be implemented in the global fitters planned. This is the natural continuation of the previous project were it was shown that, apart from the direct single top production via FCNC at the LHC, there are other contributions that must be considered, if a complete view of the FCNC processes in the single top production is wanted. For the study of the Wtb vertex structure and angular asymmetries in top quark decays, the correct parametrization of the phase space should be provided by the theoreticians, together with the dependence on the new vector and tensor like couplings that could exist at the vertex. The dependence of the NNLO corrections to the b->s gamma branching ratio must also be provided (and calculated) by the theoreticians as a function of the new anomalous

couplings. Both the real and imaginary parts of the couplings must be considered. For the Higgs task, new observables are expected to be proposed and the correct theoretical framework need to be explored in order to relate these new observables with tests of the CP-nature of ttH vertex.

2.3.3 Objectives

In order to address the physics potential of the LHC program, a significant joint effort of the experimental and theoretical community is required. This effort must consider not only the study of the best physical observables to perform a precise test of the Standard Model (SM) of Elementary Particle Physics at LHC, but also to develop new ideas for physics beyond the SM. In the present project, specific topics of the physics program of the LHC are addressed from both the experimental and theoretical points of view.
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2.3.4 Team

Project coordinator: António Onofre

Name	Status	FTE %
António Onofre	Researcher (LIP/UMinho)	72
Augusto Barroso	Researcher (FCUL)	15
Francisco del Aguila Giménez	Researcher (UGR)	20
Henrique Carvalho	Student (LIP)	50
João Carvalho	Researcher (FCTUC)	35
João Marques de Carvalho	PhD student (LIP)	100
José Santiago Perez	Researcher (LIP/UGR)	20
Juan Aguilar-Saavedra	Researcher (LIP/UGR)	40
Marco Oliveira Pena Sampaio	Post-Doc (LIP/UA)	15
Miguel Fiolhais	Researcher (LIP)	100
Miguel Won	Researcher (LIP)	50
Mikael Chala	Master student (LIP)	20
Nuno Castro	Researcher (LIP/UP/UMinho)	20
Pedro Martins Ferreira	Researcher (LIP/FCUL)	15
Renato Guedes Júnior	Researcher (LIP/FCUL)	15
Rita Coimbra	Post-Doc (LIP)	100
Roberto Pittau	Researcher (UGR)	20
Rui Santos	Researcher (LIP/FCUL)	15

2.4 Collaboration in the COMPASS experiment at CERN

2.4.1 Resumo

O objectivo principal da experiência COMPASS é o estudo da estrutura do nucleão. O programa anterior de COMPASS, que decorreu até 2011, dedicou-se à medida da polarização do gluão Delta_g/g, através de dois métodos, a fotoprodução de charme e a física de elevado p_T, ao estudo das funções de estrutura relativas às componentes transversas e longitudinais do spin do nucleão, e ainda às funções de fragmentação.
Com um feixe de hadrões, estuda a polarização do pião, e ainda algumas questões espectroscópicas de actualidade, como a produção de novos mesões e bariões, nomeadamente exóticos e híbridos.
COMPASS usa feixes de alta intensidade, de muões polarizados (ou de hadrões) interagindo com um alvo polarizado longitudinalmente e transversalmente (ou um alvo de hidrogénio líquido) ao qual se segue um espectrómetro duplo: a primeira parte tem uma grande aceitância angular, e é seguida a jusante por outra de aceitância reduzida, concebida para a detecção de partículas ultrapassando os 100 GeV/c. Na sua concepção original, formulada na Proposta então aprovada, cada espectrómetro é formado por um magnete rodeado por detectores de posição, um conjunto de calorímetros electromagnético e hadrónico, filtros de muões e um detector de Cherenkov do tipo RICH para identificação de partículas. O sistema de aquisição de dados baseia-se na leitura em paralelo da electrónica de front-end e num sistema distribuído de event-builders, especialmente concebidos para tratar grandes volumes de dados.
Com a tomada de responsabilidade do Sistema de Controlo de Detectores (DCS) de COMPASS, o grupo do LIP-Lisboa tem vindo a desenvolver o sistema de forma continuada, de modo a torná-lo mais fiável, versátil e rápido. É ainda de salientar a alteração profunda de arquitectura efectuada, tanto a nível do software de topo, como a nível das interfaces com os detectores, tendo passado de uma arquitectura orientada para o hardware para uma orientada para os detectores.
Na verdade, o DCS não pode ser um sistema estático ou um produto finalizado pois é constituído por várias camadas de packages cujas versões têm de ser compatíveis entre si. Por outro lado, devido à contínua instalação de novos detectores específicos de determinadas tomada de dados, o software do DCS (e o seu hardware de interface) tem de aumentar constantemente o seu grau de complexidade (interfaces de novo tipo, novos drivers), devido à não uniformidade dos detectores e do seu hardware.
Paralelamente, o grupo tem-se ocupado crescentemente de tarefas offline com vista ao estudo física do Drell-Yan polarizado, nomeadamente o estudo de geradores físicos e da sua simulação no espectrómetro, da optimização do detector e do programa de reconstrução de dados.
Em relação à análise dos dados já adquiridos, o grupo tem contribuído com um peso relevante na Colaboração COMPASS, nomeadamente estudos de polarização do gluão através de eventos de grande Q^2 em diversos processos, como a produção de charme aberto ou de hadrões, sobre as componentes da função de estrutura do nucleão sensíveis às polarizações longitudinal e transversa, e ainda sobre multiplicidades de hadrões e a extracção das funções de fragmentação, assuntos chave na experiência COMPASS. Artigos sobre estes temas têm vindo a ser publicados em revistas internacionais, apresentando já dezenas, ou mesmo algumas centenas, de citações. Novos métodos de análise estão a ser desenvolvidos, de modo a serem obtidos resultados com maior precisão.
No programa actual de COMPASS, o grupo tem um papel destacado na parte que pretende estudar a transversidade, nomeadamente as TMD PDFs (funções de distribuição partónicas dependentes do momento transverso), através do processo de Drell-Yan (DY) polarizado, cuja primeira tomada de dados a nível mundial se realizará este ano de 2015.
Neste contexto, o grupo desenvolveu os estudos preparativos para a realização dessa experiência de DY, quer na sua simulação, quer na concepção de novos componentes para o espectrómetro, incluindo a selecção de eventos em linha. A sua instalação e teste teve lugar no final de 2014.
Presentemente, o grupo coordena, no seio de COMPASS, a reconstrução destes dados, e prepara, em simultâneo, a tomada de dados que terá lugar de Abril a Novembro de 2015.

2.4.2 Abstract

COMPASS experiment is dedicated to the study of the structure of nucleon. The previous COMPASS programme, which lasted till 2011, focused on the measurement of the gluon polarisation Delta_g/g (via two different approaches, the open charm photoproduction and the high p_T physics), of the longitudinal and the transverse quark spin structure and of the fragmentation functions. With a hadron beam, COMPASS studies the pion polarisabilities and some spectroscopy issues, as the production of new mesons and baryons, namely exotics or hybrids.
COMPASS uses high intensity beams, that is, a polarised muon (or hadron) beam impinging on a longitudinally or transversely polarised target (or a liquid hidrogen target) followed by a two stage spectrometer: a first one with a large angular acceptance, followed downstream by a second one with a reduced acceptance, designed to detect

particles up to more than 100 GeV/c. In its original design, as stated in the first Proposal, each spectrometer is equipped with a magnet surrounded by trackers, a set of electromagnetic and hadronic calorimeters, muon filters and a Cerenkov detector (RICH) for particle identification. The data acquisition system is based in a parallel read-out of the front-end electronics plus a distributed set of event-builders, specially designed to cope with huge data volumes.
Since our LIP-Lisbon group took in COMPASS the full responsibility of the Detector Control System (DCS), it has been continuously evolved, in order to introduce flexibility, reliability and speed. As a major change, one should point out the development of a new system´s architecture: the introduction of important changes, both in the supervision (top) layer and in the front-ends layer (detectors interfaces), transforming a hardware oriented architecture into a detector oriented one.
In fact, the DCS can not be a static system or a finalised product, because it is formed by a set of several packages, disposed in layers but strongly interacting. This means that the packages versions must be compatible among them. On the other hand, the continuous COMPASS upgrade, in what concerns new detectors, namely new detectors for specific data takings, also imposes successive changes in the DCS, both concerning the software and the hardware interfaces. In view of this, the DCS is always increasing in complexity (new types and number of hardware interfaces with the detectors, new drivers), namely due to the non uniformity of the COMPASS detectors hardware.
In parallel, the group is focusing more and more on offline studies concerning the polarised Drell-Yan physics, such as studies of physical generators and their simulation in the spectrometer, as well as the optimisation of the detector and of the data reconstruction programme.
In what concerns the analysis of the data already acquired, the group is strongly contributing to key subjects of the COMPASS Collaboration, namely studies on the gluon polarisation from high Q^2 events originating from different processes, as the open charm and hadron production, on the longitudinal and transverse components of the nucleon polarised structure function, and on the hadron multiplicities and fragmentation functions extraction. Results concerning these matters have been published in international reviews, and have already plenty of citations. New analysis methods are also being developed, in order to increase the results precision.
In the context of the present COMPASS Program, the members of this Project team have been playing an important role in the part concerning studies on transversity, namely TMD PDFs (Transverse Momentum Dependent Parton Distribution Functions), through the polarised Drell-Yan process, which 2015 several months data taking will be a first world measurement.
In this respect, the group has developed studies concerning the preparation of the DY experiment, namely the design of new spectrometer components, including the dimuon trigger. Its installation and test has taken place during the fall of 2014.
Presently, our group coordinates in COMPASS the data reconstruction of the fall 2014 DY test data, and simultaneously prepares the 2015 DY long physics run, which will take place from April to November.

2.4.3 Objectives

Concerning our commitments in COMPASS, besides the general tasks, attributed to each member of the Collaboration, our group will continue to contribute with an important role in the analysis effort as well as in offline studies.
Thus, in 2015 our tasks will be the following:

- to continue the optimisation of the COMPASS reconstruction programme due to the major setup changes imposed by the Drell-Yan programme;
- to continue the spin asymmetries study concerning low x_Bj and low Q^2 physics, in order to extract the proton longitudinally polarised structure function g_1(x);
- to continue the development of the simultaneous method of extraction the spin asymmetries and the gluon polarisation in order to improve precision on the Delta_g/g measurement;
- to continue the studies on hadron multiplicities in view of the fragmentation functions extraction, namely strangeness to kaon function D_s^k(z);
- to continue the study of the nucleon Sivers effect with a transversely polarised target;
- to continue studies on the Drell-Yan signal and its background components;
- to participate in the preparation of the 2015 polarised Drell-Yan run and in its long data taking;
- to start the analysis of the 2014 Drell-Yan pilot run data;

- to participate in the Collaboration and several other COMPASS meetings;
- to continue as a member of the COMPASS Boards: Collaboration Board (P.Bordalo, S.Ramos); Publications Committee (M. Stolarski).

In what concerns our technical commitment in COMPASS, important Detector Control System (DCS) developments will take place during 2015, in parallel with the DY long data taking, to prepare the 2016 data taking for the DVCS programme. In fact, due to the very different physics programmes, major changes from the polarised DY setup to the DVCS setup will take place. Specifically, for the DVCS run, new huge detectors are foreseen to be installed and fully controlled by DCS, namely the proton recoil detector and a new electromagnetic calorimeter (for the backward region).

2.4.4 Team

Project coordinator: Paula Bordalo

Name	Status	FTE %
Catarina Quintans	Researcher (LIP)	100
Celso Franco	Post-Doc (LIP/FCT)	50
Christophe Pires	Technician (LIP)	100
Gonçalo Terça	Master (LIP/AdI)	100
Luis Silva	Post-Doc (LIP/FCT)	50
Márcia Quaresma	PhD student (LIP/FCT)	100
Marcin Stolarski	Post-Doc (LIP/FCT)	100
Paula Bordalo	Researcher (LIP/IST)	100
Sérgio Ramos	Researcher (LIP/IST)	100
Sofia Nunes	PhD student (LIP/FCT)	100

2.4.5 Academic Training

PhD Theses

- **Study of asymmetries with polarised proton target at low xBj and Q2**
  Sofia Nunes, (on-going)
- **Polarised Drell-Yan studies in COMPASS**
  Márcia Quaresma, (on-going)

Master Theses

- **Study of Drell-Yan in the COMPASS experiment at CERN**
  Miguel Vasco, (on-going)
- **AdI TECHNICAL TRAINING: Development of tools for the COMPASS DCS**
  Gonçalo Terça, (on-going)

2.5 Collaboration in the HADES experiment at GSI

2.5.1 Resumo

O "High Acceptance Di Electron Spectrometer (HADES)"(http://www-hades.gsi.de) é um sistema versátil de detetores para a espectroscopia de pares de e+e- (dielectrões) e hadrões carregados produzidos em reações induzidas por piões e iões pesados em feixes de 1 - 3.5GeV de energia. O detetor foi construído entre 1996 e 2002 no GSI (https://www.gsi.de) por uma colaboração europeia envolvendo grupos de 19 institutos de 10 países. O seu principal objetivo e investigar as propriedades da matéria nuclear densa criada durante a colisão de iões pesados e em última análise aprender sobre as propriedades dos hadrões neste meio. Por exemplo, as propriedades que são responsáveis pela maioria da massa da matéria ordinária ou o mecanismo responsável pela termalização dos hadrões à temperatura universal de 170MeV. A matéria criada neste tipo de colisões é diferente da matéria estudada no SPS, RHIC ou LHC porque consiste basicamente em bariões e poucos mesões, podendo ser comprimida ate três vezes a densidade da matéria nuclear, ate 10-12 fm/c. Pares de dielectrões originados em decaimentos hadronicos neste meio e hadrões com estranheza são as principais provas de medida desta experiência. Uma vez que as conclusões retiradas dos efeitos acontecidos neste meio dependem fortemente da compreensão das propriedades dos hadrões no vácuo e os seus mecanismos de produção nas colisões núcleo – núcleo, foi também iniciado um programa complementar focado em produção de e+e-, kaões e hiperões em colisões elementares. Apresentações com uma visão geral da física de HADES podem ser encontradas em http://www-hades.gsi.de /?q=node/10
Nos próximos anos, HADES vai operar no novo acelerador SIS100 no laboratório FAIR (http://www.fair-center.eu/) com o objetivo de obter dados de alta qualidade relativos a dielectrões a densidades barionicas e a temperaturas não acessíveis por outros detetores, nem agora nem no futuro previsível. De salientar que nesta faixa de energia, 2-40AGeV, não existem para já dados disponíveis para dieletrões, esta área é "terra incógnita"para medidas de dielectrões. As medidas com dielectrões na experiência "Compressed Baryon Matter"(CBM) no SIS300 (o novo acelerador atualizado) continuarão com o estudo da emissão de dielectrões pela matéria nuclear comprimida a maiores energias de feixe fazendo a ponte com as energias do CERN. Nos últimos anos HADES produziu uma serie de resultados de física relevantes, a maioria com partículas elementares o iões leves devido a uma limitação imposta pelo antigo detetor de tempo de voo. Uma lista de publicações com os resultados mais relevantes encontra-se em: http://www-hades.gsi.de/?q=node/204
A principal contribuição do nosso grupo para a colaboração HADES foi o desenho e construção de um novo detetor de tempo de voo baseado em RPCs (câmaras de planos resistivos) para medida de tempos com uma alta segmentação (1200 canais em 8m2) e prestações (resolução temporal de 70 ps, o tempo que demora a luz a percorrer uma distância de 3 cm). O novo sistema reduz as limitações impostas pelo antigo detetor de tempo de voo ao espectrómetro HADES, que o impedia de medir em sistemas pesados, uma parte fundamental do programa de física. Em 2012, o novo detetor RPC-TOF participou pela primeira vez numa tomada de dados com iões pesados, Au-Au a 1.25AGeV, durante 5 semanas (um dos principais objetivos do programa de física). Após uma precisa calibração, o RPC-TOF apresentou um excelente desempenho.
O grupo RPC-TOF de HADES foi inicialmente constituído por três instituições, das quais só o grupo do LIP permanece ativo dentro da colaboração. Isto significa que a operação continua e otimização do RPC-TOF, juntamente com todos os seus sistemas, está agora sob a responsabilidade única do nosso grupo.

2.5.2 Abstract

The High Acceptance Di Electron Spectrometer (HADES) (http://www-hades.gsi.de) is a versatile detector for a precise spectroscopy of e+e- pairs (dielectrons) and charged hadrons produced in proton, pion and heavy ion induced reactions in a 1 - 3.5 GeV kinetic beam energy region. The detector has been set-up in 1996 - 2002 at GSI (https://www.gsi.de) by an international collaboration of 19 institutions from 10 European countries. The main experimental goal is to investigate the properties of dense nuclear matter created in the course of heavy ion collisions and ultimately learn about in-medium hadron properties. For instance, the properties that are responsible for most of the mass of the ordinary matter or the mechanism responsible for the thermalization of hadrons to a universal temperature of 170 MeV. The matter created in such collisions differs from the one studied at SPS, RHIC or LHC because it consists mainly of baryons (nucleons and its excited states - baryon resonances) and few mesons and can be compressed up to 3 times nuclear matter density for about 10-12 fm/c. Dielectron pairs originating from in-medium hadron decays and rare strange hadrons (kaons, hyperons) are the main probes measured in the experiment. Since conclusions on in-medium effects rely strongly on the understanding of hadron properties in vacuum and their production mechanism in nucleon-nucleon collisions a complementary program focusing on e+e-, kaon and hyperon (sigma, lambda) production in elementary collisions is also in progress. Overview talks with presentation of HADES physics can be found in http://www-hades.gsi.de/?q=node/10.

In the following years, HADES will operate in the new accelerator SIS100 at the future FAIR facility (http://www.faircenter.eu/) with the mission of providing high-quality dielectron data at baryon densities and temperatures not accessible by other detectors, neither in the past nor in the foreseeable future. One should note that, in this energy range, 2-40 AGeV no dilepton data exist so far, this is complete "terra incognita"for dielectron measurements. The dilepton opportunities of the Compressed Baryon Matter (CBM) experiment at SIS300 (the upgraded new accelerator) will later on continue the study of the dilepton emissivity of compressed nuclear matter at higher beam energies and bridges over to CERN energies. In recent years HADES has produced a series of relevant physics results, mostly with elementary particles or light ions owing to granularity limitations in the forward time-of-flight (TOF) detector. A list of publication summarizing this results can be found in http://www-hades.gsi.de/?q=node/204.
The main contribution of LIP team to the collaboration was the design and construction of a high granularity (1200 channels in 8 m2), high resolution (70 ps, the time that it takes the light to cross a distance of 3cm) timing RPC (Resistive Plate Chambers) based TOF wall. This new system reduced the limitations imposed to the spectrometer by the old scintillator based TOF that prevent it to measure with heavy systems, a fundamental part of the physics program. In 2012, the RPC-TOF wall took part for the first time in a very successful heavy-ion production run with Au-Au collisions at 1.25AGeV during 5 weeks (one of the main objectives of the physics program). After accurate calibration, the RPC-TOF wall showed an excellent performance.
The HADES-RPC group was initially composed by three institutions, from which only the LIP team remains active within the collaboration. This means that the continuous operation and optimization of the RPC-TOF wall together with all subsystems fall now entirely on our group.

2.5.3 Objectives

Recently (in the last PTDC call, Jan 2015), financial support for the next three year was requested. The achievement of the objectives described below depends strongly on the financial support attributed to the project.
Our research plan for 2015 will be focused in three major tasks:

- Physics analysis, focused on the mass properties of short lived mesons in the dilepton channel, the study of the non-resonant mass spectrum of dileptons and the study of the momentum and multiplicity distributions of particles with strangeness,
- Operation of the RPC-TOF wall
- Optimization of the RPC-TOF wall.

PHYSICS ANALYSIS
The analysis part of the project is dedicated to the study of hadron properties inside a heavily dense state of matter. This high density is created in HADES by colliding Au ions at 1.25 GeV. In a dense medium, changes in the nuclear properties are expected with respect to ordinary matter. Since HADES is focused on the phase space region covered by high densities and low temperatures, it recreates similar conditions to those existing inside neutron stars. This region was not yet covered by previous experiments of heavy ion collisions.
One of the major physics goals is the study of the mass property of hadrons inside the cold dense medium of HADES. Emphasis will be put on the rho0 meson (mass shift, increase in width of the resonance, etc.). Although rare, the leptonic decay to an electron-positron pair is a clean signature of the rho0 properties inside the dense medium (the so-called fireball of the collision), since leptons are much less likely to interact with the in-medium hadrons. A possible observation of a rho0 mass shift may indicate the quark - antiquark condensate as the responsible for most part of the hadronic masses. Since part of this condensate is destroyed in heavily dense media, we expect to measure a smaller rho0 mass. In addition to the study of short-lived resonances, also the non-resonant e+e- mass spectrum is of great interest to the study of hadronic masses. Here the main contributions from our group can be summarized as follows:

1. determination of the e+e- mass spectrum corresponding to all leptons coming from the fireball.
2. identification and removal of the following contributions: combinatorial background, e+e- pairs from the decay of long-lived resonances and, above all, e+e- pairs coming from the conversions of photons in the spectrometer.

The total cross section that encompasses all contributions to the mass spectrum referred in 1) is of great interest for the theoreticians: they need this experimental information to explain the process of mass generation

in hadrons. The LIP group will contribute with a new method of lepton identification based on a dynamic neural network.
Concerning our contribution to the strangeness studies, the focus will be on the production rate of strange particles in Au+Au collisions (at 1.25 GeV). Special attention will be given to the production of strange particles below the production threshold in N+N collisions. In this way, it is ensured that such production comes from secondary collisions in the dense medium. In particular, it is possible to study the compressibility, thereby establishing a relationship between the probability of production of strange hadrons and the compressibility of the medium. This information is very relevant to the equation of state of neutron stars, which governs the balance of forces between the pressure produced by the density of the medium and gravity. In addition to the multiplicity distribution of strange particles, momentum distributions may also provide information regarding the production rates of the different strange hadrons. For these studies it becomes important to optimize the efficiency of the particle identification so as to obtain a set of events with a higher purity and better statistics. To this end, we intend to optimize the Kaon identification using the RPC detectors (in particular K- particles).

OPERATION
From the point of view of operation, for 2015, it is foreseen only the continuous operation of the RPC (it should be noted that owing to its intrinsic characteristics, it is a detector that is kept powered on and running all the time) since there are no plans of data taken for this period due to the programed shutdown of the accelerator. This comprise the continuous monitoring of the RPC operating parameters and auxiliary systems and devise and implement corrective actions if needed.

OPTIMIZATION OF THE RPC TOF WALL
Although the detector is fully operational and performing as expected, the RPC-TOF is a recent detector (it has only taken part in two physics runs), and it is expected to participate in many physics runs and contribute to the excellence of the HADES spectrometer. A continuous optimization of the RPC-TOF wall will contribute to this goal. We will mainly concentrate on developing and completing the monitoring tools, calibration issues and preparation of tools for the fast detection of anomalies.
There are still a couple of necessary monitoring tools, that were foreseen in the beginning, but have not been implemented yet due to lack of time and manpower. These monitoring tools do not use information from the DAQ data stream (which is normally not available outside the data taken periods) but information from other subsystems, which are always available, making these tools very convenient. They will use the information from the reference chambers (small RPC chambers installed inside of each sector to measure the quality of the gas) and the RPC-TOF wall trigger signal monitor (a monitor device that is "sniffing"the trigger signals from the RPC-TOF wall cells and allows to monitor the health of the detector). Both tools were already installed but never used or tested. With this, we will incorporate to the system two important tools that will allow to improve the monitoring of the RPC. Although the calibration strategies of the RPC-TOF are already implemented, (charge, walk, 2D-position corrections) efficient and fast tools in order to prepare the calibration parameters for each data taken period and study its evolution with time, pressure and temperature are not available. In addition, tools for the fast detection of anomalies on the performance of the RPC-TOF wall during the data taken period are still missing (Pulse Height Spectra characterization, intrinsic time resolution verification,...). As a consequence, these important tolls will be prepared. With this we will expect to decrease the preparation time for the data taken periods and the reaction time in case of malfunctions.

2.5.4 Team

Project coordinator: Alberto Blanco

Name	Status	FTE %
Alberto Blanco	Researcher (LIP)	15
Celso Franco	Post-Doc (LIP/FCT)	50
Luís Lopes	Technician (LIP)	50
Luis Silva	Post-Doc (LIP/FCT)	50
Paulo Fonte	Researcher (LIP/ISEC)	35
Ricardo Caeiro	Technician (LIP)	15

Chapter 3

Computing

3.1 Distributed Computing and Digital Infrastructures

3.1.1 Resumo

As actividades do LIP no domínio da computação distribuída e infraestruturas digitais, englobam o suporte à investigação cientifica através do fornecimento de serviços de computação e suporte, e a participação em actividades de I&D destinadas a manter o LIP na linha da frente das tecnologias de informação.
Em 2015 estas actividades serão moldadas pelo arranque da Infraestrutura Nacional de Computação Distribuída (INCD) no âmbito do roteiro de infraestruturas da FCT, e pelo inicio dos projectos EGI-ENGAGE e INDIGO-DATACLOUD no âmbito do horizonte 2020. Desta forma a equipa reforçará as relações com infraestruturas cientificas relevantes, e participará na definição e desenvolvimento de novos serviços para processamento intensivo de dados.

Worldwide LHC Computing Grid (WLCG)
Entrarão em produção novos sistemas de armazenamento recentemente adquiridos. Estes sistemas substituirão os sistemas actuais mais obsoletos, mas ainda em uso intensivo. As novas matrizes de armazenamento serão integradas numa nova instalação de Lustre, o que permitirá melhor desempenho no acesso aos meta-dados.
A viabilidade de usar no Tier-2 o sistema *Ceph* para armazenamento de ficheiros e/ou objectos será analisada. O sistema de armazenamento *Ceph* poderá facilitar a evolução para tecnologias cloud. Esta actividade terá por base uma tese de mestrado actualmente em curso e que também deverá terminar durante o primeiro semestre do ano.
Prevê-se a realização de mais alguns melhoramentos aproveitando o financiamento restante do projecto FCT de suporte ao Tier-2.

Infraestrutura Nacional de Computação Distribuída (INCD)
Será estabelecido o modelo formal de gestão e operação da infraestrutura. O plano de desenvolvimento será estabelecido. O foco inicial será a evolução dos serviços e a melhoria da capacidade instalada no NCG.
No âmbito do actual contrato FCT-FCCN, continuar-se-á o desenvolvimento da *Cloud* (IaaS) e sistema de armazenamento de objectos do INCD. A avaliação das tecnologias de computação *cloud* e GPUs será efectuada em colaboração com o LNEC e com ATLAS. O actual piloto *cloud* será alargado com vista ao lançamento de um serviço de produção no final de 2015.
Novos requisitos da infraestrutura INCD serão estabelecidos em cooperação com outras infraestruturas do roteiro e grandes comunidades de utilizadores.

IBERGRID e EGI
As actividades de inovação e suporte aos utilizadores anteriormente realizadas no âmbito do projecto EGI-INSPIRE, passarão a ser executadas no âmbito do projecto EGI-ENGAGE. Este projecto suportado pelo horizonte 2020 terá inicio no segundo trimestre. Neste projecto o LIP participará nos centros de competência de AAI e Lifewatch. As actividades de AAI são criticas para o EGI e têm por objectivo evoluir a atual infraestrutura de autenticação X.509 para um modelo mais flexível de autenticação federada, possivelmente baseado no serviço EDUGAIN. O centro de competência Lifewatch adaptará aplicações e serviços que permitirão o uso da *cloud* e *grid* do EGI por este ESFRI. A *cloud* de produção do INCD será integrada no serviço federado de *cloud* do EGI permitindo o acesso por parte de comunidades internacionais.

No contexto do IBERGRID, o LIP continuará a fornecer serviços de suporte e coordenação do *middleware* para toda a infraestrutura internacional do EGI. A infraestrutura IBERGRID terá um papel relevante no suporte aos ESFRIs na península Ibérica através do EGI e dos roteiros nacionais. No contexto do EGI e do IBERGRID procurar-se-á novas oportunidades para projectos comuns, nomeadamente em colaboração com as comunidades de utilizadores. As actividades nacionais no IBERGRID passarão a ser desenvolvidas no contexto do INCD.
O IBERGRID fornecerá os serviços que suportarão a participação Ibérica no Lifewatch (ESFRI). A capacidade de processamento a fornecer fará parte da contribuição a este ERIC no domínio da biodiversidade.
O LIP será o anfitrião da conferencia EGI 2015 que terá lugar em Maio no centro de congressos do ISCTE, e que reunirá investigadores e especialistas em infraestruturas digitais internacionais.
O LIP através da equipa deste projecto continuará assegurar a ligação ao EGI, a representar Portugal no conselho do EGI, e a participar na direcção desta organização.

INDIGO-DATACLOUD
O projecto INDIGO-DATACLOUD apoiado pelo horizonte 2020 terá inicio no segundo trimestre de 2015. O LIP coordenará o *Software Management and Pilot Services*, uma das cinco *workpackages* técnicas. O LIP contribuirá também nas actividades de desenvolvimento das infraestruturas *cloud*. O consorcio é composto por 26 organizações, que incluem: INFN, CSIC, DESY, LIP, KIT, CERN, CNRS, EGI, INAF, CNR, STFC e o CEA, entre outras. O projecto também inclui uma forte participação de comunidades de utilizadores principalmente de ESFRIs.
O projecto contribuirá para a evolução das actuais infraestruturas digitais e criará serviços adicionais que permitirão uma mais fácil utilização combinada dos recursos *cloud*, *grid* e HPC. A participação no INDIGO encontra-se alinhada com os objectivos da INCD, e será extremamente importante para o alargar do portefólio de serviços, permitindo responder as necessidades de um conjunto mais abrangente de comunidades de utilizadores.

ESA CODES
O LIP continuará a operar serviços de simulação da degradação de componentes no âmbito de um contracto com a ESA, explorando assim os desenvolvimentos efectuados em 2014.

Serviços de Computação
Os restantes serviços Tier-3 do LHC ainda alojados em instalações do LIP serão consolidados no NCG. Adicionalmente procurar-se-á consolidar no NCG outros serviços de IT alojados no LIP de Lisboa, com vista a melhorar a eficiência e reduzir custos.
As actividades com vista à renovação das páginas web do LIP continuarão.
O LIP aderirá ao sistema de autenticação federada da RCTS permitindo o acesso a novos serviços da FCCN.

3.1.2 Abstract

The LIP distributed computing and digital infrastructure activities encompass the support to scientific research through the provisioning of computing and support services, complemented by a component of innovation, aimed at staying in the forefront of computing technologies.
The 2015 activities will be shaped by the ramp-up of the National Distributed Computing Infrastructure (INCD) in the context of the FCT infrastructures roadmap, and by the start of two new H2020 projects EGI-ENGAGE and INDIGO-DATACLOUD. Through them the team will reinforce its relations with major infrastructure initiatives, and will play a role in the definition and development of novel services for data intensive computing.

Worldwide LHC Computing Grid (WLCG)
The recently acquired storage systems will be commissioned replacing the most obsolete yet heavily used Tier-2 storage arrays. The new systems will be incorporated in a new Lustre installation featuring faster access to metadata.
The feasibility of using Ceph object storage and/or filesystem capabilities as backend for grid storage will be evaluated, opening the path towards the use of cloud like technology in the Tier-2. This activity will build on top of the master thesis initiated in 2014.
Some additional improvements are foreseen profiting from the remaining funding of the FCT Tier-2 support project.

National Distributed Computing Infrastructure (INCD)
The formal INCD governance and operational structure will be established. A development plan will be defined aiming in a first phase at evolving the services and capacity of the existing infrastructure centered at NCG.

The INCD (IaaS) cloud and object storage services will be further developed within the current FCT-FCCN contract. The cloud and GPU technologies will be evaluated in collaboration with LNEC and the ATLAS team. The current cloud pilot
will be enlarged to other academic and scientific communities aiming at launching a production service by the end of 2015.
Additional requirements for the INCD services evolution will be established in cooperation with other roadmap infrastructures and major user communities.

IBERGRID and EGI
The EGI-ENGAGE project will replace the innovation and user support activities previously performed within the EGI-INSPIRE project. This H2020 project will start in the second quarter. LIP will contribute to the AAI and Lifewatch competence centres. AAI is a critical EGI activity aiming at evolving the current X.509 based authentication towards a more flexible identity federation mechanism possibly leveraging the EDUGAIN service. The Lifewatch CC will adapt applications and services to the EGI cloud and grid infrastructures, enabling their usage by this ESFRI. The upcoming INCD cloud will be further integrated in the EGI federated cloud allowing access from international user communities.
In the IBERGRID context, LIP will continue to deliver user support and middleware coordination services to the whole EGI international infrastructure. IBERGRID will play an important role in supporting ESFRIs in the Iberian region both through EGI and via the national roadmaps. Within IBERGRID and EGI, new opportunities for joint projects will be pursued, namely with user communities. The national activities in IBERGRID will start being performed under the INCD context.
IBERGRID will provide the ICT services for the Iberian participation in the Lifewatch ESFRI ensuring in-kind computing contributions to this European biodiversity ERIC.
LIP will host the EGI Conference 2015 which will take place in May joining researchers and e-infrastructure experts from Europe and elsewhere.
LIP, through this computing team, will continue representing Portugal in the EGI council and playing a major role in the EGI management.

INDIGO-DATACLOUD
The H2020 project INDIGO-DATACLOUD will start in the second quarter. LIP will coordinate the Software Management and Pilot Services workpackage (one of the five technical WPs). LIP will also contribute to the cloud infrastructure developments. The consortium has 26 partners, including: INFN, CSIC, DESY, LIP, KIT, CERN, CNRS, EGI, INAF, CNR, STFC and CEA among others. The project also includes a strong user community presence mainly from ESFRIs.
The project results will contribute to evolve current e-infrastructures and provide additional services that will allow a user-friendlier combined exploitation of the cloud, grid and HPC ecosystem. The participation in INDIGO is fully align with the INCD goals, and will be of utmost importance to enlarge the INCD portfolio of services addressing the needs of a wider range of user communities.

ESA CODES
LIP will continue delivering component degradation simulation services under a contract with ESA exploring the developments performed in 2014.

Computing Services
The remaining LHC Tier-3 services still in LIP premises will be consolidated at NCG. In addition further consolidation of the LIP Lisbon computing services at NCG will be pursued aiming at improving efficiency and reducing costs.
The work to improve and renew the LIP web presence will continue.
LIP will join the RCTS AAI domain enabling access to new FCCN services.

3.1.3 Objectives

- Operate, consolidate and improve the LIP IT infrastructure.
- Operate the Portuguese WLCG Tier-2 and Tier-3 services for ATLAS and CMS.
- Further improve the WLCG Tier-2 services.
- Establish the National Distributed Computing Infrastructure (INCD) foundations.

- Develop the new INCD services with a strong focus on cloud computing.
- Manage the national computing centre (NCG) in partnership with FCCN and LNEC already in the context of the INCD program of work.
- Through INCD engage with new research projects, communities and organizations with a focus on the national infrastructures and ESFRI roadmap.
- Continue and reinforce the IBERGRID collaboration through the participation in common projects such as EGI-ENGAGE and Lifewatch.
- Participate in EGI at the operational and strategic level.
- Provisioning of EGI global services namely: middleware rollout, middleware acceptance, and user support.
- Participate in the development and shaping of future e-infrastructure services through the INDIGO-DATACLOUD project.

3.1.4 Team

Project coordinator: Jorge Gomes

Name	Status	FTE %
Carlos Manuel	Technician (LIP)	100
Gaspar Barreira	Researcher (LIP)	90
Hugo Gomes	Technician (LIP)	100
João Paulo Martins	Researcher (LIP)	100
João Pina	Post-Doc (LIP/FCT)	100
Jorge Gomes	Researcher (LIP)	100
José Aparício	Technician (LIP)	100
Mário David	Researcher (LIP)	100
Nuno Ribeiro Dias	Researcher (LIP)	100
Pedro Miranda		41

3.2 Advanced Computing

3.2.1 Resumo

Na maioria das ciências, a quantidade de dados provenientes quer de experiências reais quer de simulações tem vindo a aumentar substancialmente porque os instrumentos são cada vez melhores cada e mais económicos enquanto os custos de armazenamento têm vindo a diminuir drasticamente. O grupo de computação avançada tem trabalho anterior de R&D em computação Grid, computação de alto desempenho, modelos de computação, bibliotecas de comunicação de alto desempenho e estruturas de dados distribuídos. Mais, recentemente o grupo tem vindo a explorar a combinação de CPUs multicores tradicionais com dispositivos de aceleração, tendo desenvolvido uma implementação de OpenCL distribuído e também participado no desenvolvimento e otimização de códigos de aplicações, relacionadas com HEP.

O grupo de Computação Avançada, integrado no LIP-Minho desde 2014, pretende concentrar-se a sua atividade na investigação de computação avançada relacionada com HEP e em fazer a ponte entre a formação avançada em Ciências e Engenharia da Computação e os interesses de pesquisa do LIP.

3.2.2 Abstract

In most sciences the amount of both experimental and simulated data has been increasing because instruments are getting much better and cheaper and storage costs have been decreasing dramatically. The advanced computing group joins previous R&D work on Grid computing, high-performance computing, computing models, high-performance communication libraries and distributed data structures. Recently the team explored combining traditional multi-core CPUs with accelerator devices, implemented a distributed OpenCL implementation and participated on the development and optimization of applications code related to HEP.

The Advanced Computing group, integrated in LIP-Minho since 2014, intends to focus on advanced computing research related to HEP and on bridging the advanced training available in Computer Science and Engineering with the LIP research interests.

3.2.3 Objectives

The main issues on scientific computing are no longer confined to homogeneous parallelism and conventional job task scheduling/allocation. Nodes on emerging clusters include several multicore CPUs, accelerator devices with their own disjoint memory, several levels of hierarchy both in memory and in storage, with several types of networks connecting those highly heterogeneous components.

Computing capacity is, however, a very precious resource, with the on-going costs of electricity, support and maintenance exceeding the already high acquisition cost of computers and other equipment. But using computing resources efficiently becomes an imperative when the societal costs are also very high, as data-centres are already responsible for a large portion of the greenhouse environmental emissions.

Previous work by team members has demonstrated that CPU and IO execution profiles can be useful to highlight the main optimization opportunities on the applications, developed by the ATLAS team at LIP-Minho. But it also showed that large active datasets restrict the effectiveness techniques such as caching and make it ineffective to optimize the applications without taking into account the complete execution environment.

To extend beyond what can be achieved on the application side alone requires tight cooperation between computer scientists and physicists to produce efficient analysis systems that can also adjust the underlying execution system to varying requirements of the applications.

To amplify the capacity of the computing resources requested we propose an analysis platform that maximizes the amount of work that can be performed per event read from storage using modular analysis functions and that entices the reuse of previously computed results whenever possible. With the separation of the definition of the workloads from their execution scripts, it will also allow the construction of advanced heuristics to more effectively guide the scheduling systems, while the user just need to define their workloads.

In another direction of research, in 2015 the team we will also contribute to the Upgrade of the ATLAS Trigger system in the implementation of a parallel version of the TopoClustering algorithm to be run on GPUs.

3.2.4 Team

Project coordinator: António Pina

Name	Status	FTE %
Albano Alves	Researcher (LIP)	100
António Pina	Researcher (LIP)	100
José Rufino	Researcher (LIP)	100
Vítor Oliveira	Researcher (LIP)	100

Chapter 4

Astroparticle Physics

4.1 Collaboration in AMS - Alpha Magnetic Spectrometer

4.1.1 Resumo

O modelo standard da cosmologia (modelo do Big Bang) baseia-se na expansão do Universo a partir de um estado inicial muito quente e denso e tem como suporte experimental a descoberta do movimento de recessão das galáxias por Hubble em 1929 bem como a descoberta da radiação cósmica de fundo por Penzias e Wilson em 1964. No estado inicial do Universo, iguais quantidades de matéria e antimatéria terão sido produzidas, no entanto, actualmente observa-se nos raios cósmicos que são detectados na Terra uma clara assimetria na sua composição no que respeita a matéria e antimatéria. A procura de eventuais aglomerados de antimatéria no Universo e o entendimento do mecanismo que produziu esta assimetria são questões essenciais na astrofísica actual. Outra questão fundamental é a compreensão da natureza da matéria que compõe o Universo. Mais de 90% da matéria existente é não-luminosa, isto é, matéria escura, mas a sua composição permanece um mistério. Os raios cósmicos são compostos por partículas neutras e carregadas que atravessam a Galáxia em todas as direcções. Um melhor entendimento dos mecanismos da sua aceleração e propagação requer uma medida dos fluxos tão precisa quanto possível e abrangendo o maior intervalo de energias. O detector AMS, instalado na Estação Espacial Internacional (ISS) desde 19 de Maio de 2011, permitirá inspecionar a existência de antimatéria e matéria escura com uma precisão nunca antes alcançada dada a elevada estatística recolhida e a exactidão das medidas que o instrumento está apto a fazer.
O grupo LIP participa desde 1997 de forma activa e continuada na experiência AMS e em particular nas actividades do subdetector RICH. Desde então, o grupo tomou parte em actividades de construção do detector, da sua simulação, de desenvolvimento de métodos de reconstrução dos anéis de Cherenkov e de análise de dados recolhidos durante os testes de um protótipo. Em particular, o grupo é responsável por um dos algoritmos de reconstrução de carga eléctrica e velocidade do subdetector RICH. Desde a instalação de AMS na ISS o grupo tem estado envolvido em actividades de monitorização do desempenho do detector, em especial do RICH, e também em actividades de análise de dados. Na actividade de reconstrução de carga eléctrica e velocidade com dados da ISS, o grupo tem desenvolvido trabalho com o objectivo de corrigir efeitos ditos sistemáticos e que resultam de variações de temperatura, de variações da reflectividade do espelho cónico e de variações na eficiência de detecção à escala do pixel do fotomultiplicador. Na actividade de análise de física, o grupo está envolvido em:

- modulação solar 2D e estudos de modulação dos fluxos de raios cósmicos primários (teses de mestrado em Física, IST Julho 2012 e Novembro de 2014).
- estudos de separação isotópica de núcleos leves (tese de mestrado a decorrer).
- estudos de avaliação do impacto da polarização da radiação de Cherenkov na reconstrução da carga eléctrica (tese de mestrado em Física, IST Novembro 2013).
- estudos da fracção de positrões com grande aceitância geométrica (detectores RICH e TRD) feitos a baixa energia (< 10 GeV).
- construção de um estimador usando as medidas de velocidade e sinal medidos no RICH para ser usado na identificação de partículas com massas distintas.

O grande fluxo de dados gerados na experiência tem permitido a integração no grupo de novos estudantes com o objectivo de realizar tese de mestrado e dinamizar novos tópicos de estudo.

Os membros do grupo têm participado ainda nas actividades de monitorização contínua da experiência no Payload Operation Control Center localizado no CERN.

4.1.2 Abstract

The standard model of cosmology (Big Bang model) is based on the Universe expansion from an extremely hot and dense initial state and has as experimental support the discoveries of the recession movement of the galaxies by Hubble in 1929 and of the cosmic microwave background radiation by Penzias and Wilson in 1964. In the initial state of the Universe, equal amounts of matter and antimatter would have been produced. However, what is now observed in cosmic rays detected at Earth is a clear asymmetry in their composition in what concerns matter and antimatter. The search for possible clusters of antimatter in the Universe and the understanding of the mechanism that produced such asymmetry are essential issues for present astrophysics. Another fundamental question is the understanding of the origin of matter of which the Universe is composed. More than 90% of existing matter is non-luminous, i.e, dark matter, but its composition remains a mystery. Cosmic rays are composed of neutral and charged particles that cross the Galaxy along all directions. A better understanding of acceleration mechanisms and propagation requires a measure of cosmic-ray fluxes as accurate as possible and over a wider range of energies. The AMS detector, installed on the International Space Station (ISS) on 19th May 2011, will allow to search for the existence of antimatter and dark matter with an unprecedented accuracy. Since 1997, the AMS/LIP group has been actively taking part in the AMS experiment, and in particular in the subdetector RICH activities. During this time, the group took part in the subdetector construction and simulation as well as in the development of reconstruction methods for Cherenkov rings and data analysis with data collected with a RICH prototype. In particular, the group is responsible for the development of one of the algorithms aiming charge and velocity reconstruction. Since the installation of AMS on the ISS, the group has been involved in activities of detector performance monitoring, in particular with the RICH, as well as in data analysis activities. The activities in the charge and velocity reconstruction with the AMS data include the study of corrections for the so-called systematic effects, due to namely temperature variations, mirror reflectivity variations and photon detection efficiency variations at the scale of the photomultiplier pixel. In physics analysis the group is involved in the following topics:

- solar modulation 2D and particle fluxes modulation studies of primary cosmic rays and their correlation with the solar activity (master thesis, IST July 2012 and November 2014).
- isotopic separation of light nuclei (ongoing master thesis).
- evaluation of the impact of Cherenkov radiation polarization in the reconstruction of the electric charge (master thesis, IST November 2013).
- measurement of the positron fraction at low energies (<10 GeV) and with a large detector acceptance by using both the RICH and TRD detectors.
- study of a statistical estimator that uses velocity and signal measured by the RICH detector and allows separation of different mass particles.

The large amount of AMS data allowed to integrate new students in the group aiming to perform master thesis and promoting the study of new physics topics.
The group members took also part in the task common to all collaboration, of continuously monitoring the experiment from the Payload Operation Control Center located at CERN.

4.1.3 Objectives

Monitoring and operation of the RICH detector in the POCC at CERN
LIP team members will participate regularly in the activities taking place at the AMS mission control room, performing shifts and acting as on-call experts for the RICH detector. AMS detector´s perfect operation in Space and data quality control implies continuous monitoring (24 hours over 24 hours). AMS´ operations taking place at POCC (Payload Operations and Control Center) include storage and analysis of house keeping data and partial science data analysis for rapid quality control and feedback.

RICH detector monitoring and optimization of velocity and charge reconstruction algorithms
The precision of RICH´s measurement is highly dependent on several parameters: mirror reflectivity, refractive index uniformity, aerogel clarity and detection cells calibration. The group has been involved in these studies and will keep on using the LIP analysis tools developed for monitoring detector performance, while developing

more for data quality control. The monitoring and correction of the RICH velocity and charge measurements is fundamental for the isotopic separation and charge selection topics crucial to the AMS physics. Systematic effects become dominant at higher charge so a sharp control has to be ensured.

Variability studies of proton, helium and electron fluxes at low energy and their interpretation under Solar modulation models
By making use AMS´ large exposure time and measurement precision, studies will be performed in order to fully characterize the Solar modulation phenomenon. Using computational tools already developed, Parker´s equation resolution will be extended to higher dimensions and temporal evolution, allowing for a more complete understanding of the complex magnetic structure surrounding the Solar system and Solar modulation´s charge sign dependency. It will also enable three-dimensional parametrization and propagation of Solar events. The different temporal structures in Solar modulation will also be studied.

Light isotope nuclei identification
Light isotopes like H and 4He (and CNO) are believed to be of primary origin. Rarer CR elements such as 2H, 3He (and Li-Be-B) are believed to be of secondary origin. Secondary to primary ratios are used to discriminate among propagation models. The comparison between radioactive and stable nuclei will allow the estimation of the halo size and the cosmic-ray Galactic confinement time (diffusion).
We propose to explore a new mass separation method using the geomagnetic cutoff and RICH´s precise velocity measurement. This identification method can be applied to the light nuclei isotopes like 1H, 2H, 6Li, 7Li, 9Be and 10Be and involves selecting primary cosmic rays using the geomagnetic cutoff and the evaluation of isotope probability using RICH´s measurements. Since threshold velocity varies with geomagnetic latitude and AMS is orbiting around Earth, we will scan the isotope regions at different energies.

4.1.4 Team

Project coordinator: Fernando Barão

Name	Status	FTE %
Fernando Barão	Researcher (LIP/IST)	85
Luisa Arruda	Post-Doc (LIP)	20
Miguel Orcinha	Student (LIP)	100
Pedro Nunes	Master student (LIP)	100

4.1.5 Academic Training

Master Theses

- **Análise de elementos isótopos presentes nos raios cósmicos com a experiência AMS**
  Pedro Nunes, (on-going)

4.2 Collaboration in the SNO+ experiment

4.2.1 Resumo

Introdução

O grupo de Física de Neutrinos do LIP foi formado em 2005 para participar na experiência de Neutrinos Solares, SNO (Sudbury Neutrino Observatory), e integrou desde 2006 a proposta da experiência sucessora, SNO+.
Os resultados de SNO resolveram o chamado Problema dos Neutrinos Solares, ao provar a mudança de sabor dos neutrinos emitidos e confirmando as previsões do fluxo em todos os sabores. O grupo do LIP teve um papel importante na calibração ótica do detector e na medida de precisão dos parâmetros de oscilação dos neutrinos.
O detector SNO consistia numa esfera central de 12 m de diâmetro preenchida por água pesada, rodeada por cerca de 9500 PMTs. Uma camada de água (leve) ultra-pura fazia a blindagem da radiação proveniente dos PMTs e da rocha, enquanto que o fluxo de muões cósmicos é fortemente suprimido pela localização subterrânea, a uma profundidade de 2km no SNOLAB, Canadá. SNO+ adapta o detetor de SNO, substituindo o meio ativo por cintilador líquido dopado e tem múltiplos objetivos científicos, sendo o principal a pesquisa com elevada sensibilidade do sinal de duplo declínio beta sem neutrinos (Neutrinoless Double Beta Decay – 0NDBD). A confirmar-se, a descoberta deste processo assinalaria o carácter de Majorana dos neutrinos massivos, e permitiria estimar o valor da sua massa. A medição de neutrinos solares, geo-neutrinos e anti-neutrinos produzidos em reactores nucleares, bem como neutrinos de supernovas são objetivos adicionais.
A instalação do detetor está em curso, e em 2015 esperamos completar o enchimento com água e iniciar a fase de tomada de dados de commissioning. Será iniciado em 2016 o enchimento com cintilador líquido, seguido pela dopagem com Telúrio. A dopagem inicial a 0.3%, deverá atingir uma sensibilidade para a vida média do declínio 0NDBD do Te130 (a 90% C.L.) de 10ˆ26 anos, depois de 5 anos de dados. Os estudos de I&D dedicados a aumentar a dopagem são promissores: 3% de Telúrio pode ser o modo de cobrir toda a região de "hierarquia invertida"da massa dos neutrinos.

Atividades do grupo

O grupo SNO+ do LIP está fortemente envolvido em vários aspetos da construção do detetor e da preparação da análise dos dados de física.

Construção de equipamento de calibração
Em colaboração com a Univ. de Sussex (UK), desenvolvemos um método de calibração não invasivo, baseado em cabos de fibra ótica ligados a um conjunto de LEDs. Para o desenvolvimento e testes das fibras foram utilizadas as instalações do grupo ATLAS no CFNUL. Todas as partes mecânicas relacionadas com as fibras foram construídas nas oficinas do LIP em Coimbra. A instalação do sistema é coordenada pelo nosso grupo e já foi completada a 2/3.
Tomámos também a responsabilidade pelo desenho e construção do sistema de inserção de fontes de calibração em SNO+. É um sistema complexo que requer estanquicidade (para evitar a contaminação do cintilador com radão) e uma mecânica robusta e precisa.

Análise de calibração e qualidade dos dados
Devido à experiência adquirida em SNO, uma das nossas responsabilidades é a calibração ótica de SNO+ , assumindo a coordenação do correspondente grupo. Estamos a finalizar grande parte do software necessário, em preparação para a tomada de dados na fase da água.
O grupo iniciou recentemente o desenvolvimento de ferramentas de software para a monitorização da performance do detetor e da qualidade dos dados. Ferramentas de análise automatizadas e de resposta rápida são essenciais para a tomada de dados de longo curso e são uma das nossas prioridades para a fase da água.

Preparação das análises de física
Estamos ativos também no contexto dos grupos de análise de física dedicados a antineutrinos (onde assumimos a coordenação) e declínio beta duplo.
SNO+ irá detetar antineutrinos vindos de reatores nucleares e da radioatividade natural da Terra. O nosso grupo contibui para o software de simulação, para estudos de sensibilidade a oscilações e de direcionalidade, bem como a preparação da análise na fase da água.
No grupo do declínio beta duplo, a nossa contribuição principal é nos algoritmos de rejeição de fundos, em especial a identificação de coincidências para os fundos internos, mas também a rejeição por volume fiducial dos fundos externos.

Aspetos organizativos

Membros do grupo do LIP asseguram a coordenação dos subgrupos de calibração ótica (JM, GP) e de física de antineutrinos (SA). JM foi eleito para a presidência da "Collaboration Board"no mandato 2011/2012, e pertence também a diversas comissões: coordenação da análise, oradores/conferências, revisão de fontes de calibração. Em 2010 organizámos a reunião de colaboração em Lisboa. Um Memorando de Entendimento entre a FCT, o LIP, SNO+ e SNOLAB foi assinado em 2009 e renovado em 2014. A participação do LIP em SNO+ foi apoiada financeiramente por um projeto FCT/PTDC que terminou em 2014, e por projetos exploratórios em curso; o primeiro (IR: SA) suporta o desenvolvimento de novas ideias para as medições de anti-neutrinos e o segundo está associado à posição de Investigadora FCT de GP. O desenho e construção do equipamento de inserção de fontes é suportado por financiamento canadiano.

4.2.2 Abstract

Introduction

The LIP group on Neutrino Physics was created in 2005 to participate in the solar neutrino experiment SNO (Sudbury Neutrino Observatory), and integrated since 2006 the proposal for its successor experiment SNO+.
The SNO results simultaneously confirmed the predicted total flux of 8B solar neutrinos and demonstrated neutrino oscillations, solving the so-called Solar Neutrino Problem. The LIP group had a strong role in the optical calibration of the detector and in the precision measurement of the neutrino oscillation parameters.
The SNO detector consisted of a 12m diameter spherical vessel filled with heavy water, surrounded by about 9500 PMTs. Shielding of radiation from the PMTs and the rock is achieved by an ultra-pure water layer around the vessel, and the cosmic muon flux is strongly suppressed by the underground location at a depth of 2 km in SNOLAB, Canada. The SNO+ experiment is adapting the detector, in order to use isotope-loaded liquid scintillator as the active medium. SNO+ has multiple scientific goals, the main one being the search for neutrinoless double beta decay, the most promising signature for the possible Majorana character of neutrinos and for the absolute neutrino mass.
Measurements of neutrinos from the Sun, the Earth, Supernovae and nuclear reactors are additional goals of the the experiment. The installation of the detector components is in progress and in 2015 we expect to complete the filling with ultra-pure water, and start the water commissioning phase. After completion of the scintillator purification systems, scintillator fill starts in 2016, followed by the loading of Tellurium. The initial loading at 0.3% is expected to reach a 90% C.L. sensitivity for the Te130 DBD half-life of 10ˆ26 y, after 5 years of data. R&D aimed at higher loadings is promising: 3% of Tellurium could be the way to probe the full inverted neutrino mass hierarchy region.

Group´s activities

The SNO+ LIP group is strongly involved in several aspects of the detector construction and preparation of the physics data analysis.

Construction of calibration hardware
In collaboration with the University of Sussex (UK), we have developed a new system for PMT calibration based on a set of optical fibers transmitting light from external LEDs. Initial design tests and the final quality control of all the fiber cables were carried out at the ATLAS group lab at CFNUL. All the mechanical parts for feeding the fiber cables into the detector and attaching them in their mount points were designed and built at the LIP-Coimbra workshop. The installation of the system is led by our group and is now 2/3 complete.
We have also taken the responsibility of redesigning and building the source deployment system for SNO+. This is a complex system, requiring gas tightness (to avoid Radon contamination) and accurate and reliable mechanics.

Analysis of calibration data and data quality
The SNO+ optical calibration constitutes one of the group´s tasks, building on the experience acquired with SNO. We chair the optical calibration analysis subgroup, for which we are finalizing a large part of the software, in preparation for data-taking in the water phase.
The group started recently the development of software tools for the monitoring of the detector performance and data quality. Automated, near-line analysis tools are essential for long-term data taking and are one of our priorities for the upcoming water run, both for Physics and calibration data.

Preparation of physics anayses
We are also active in the context of the physics analysis groups dedicated to antineutrinos (which we chair) and double-beta-decay.
SNO+ is expected to detect antineutrinos coming from nuclear reactors and from the Earth´s natural radioactivity. We contribute to the simulation software, sensitivity studies on oscillations and directionality, and preparation of the water phase analysis.
In the double-beta-decay group, our main contribution is in the evaluation of the backgrounds, and optimization of the performance of their rejection algorithms, mainly the coincidence tagging for internal backgrounds, but also the fiducial volume rejection of external ones.

Organizational aspects

Members of the group chair the analysis subgroups of optical calibration (JM, GP) and anti-neutrino physics (SA). JM served the 2011/2012 term as elected chair of the collaboration board and is also a member of several committees: analysis coordination, speaker´s, source review. In 2010, the LIP group organized the collaboration meeting in Lisbon. A Memorandum of Understanding for scientific cooperation was signed between FCT, LIP, the SNO+ Collaboration and SNOLAB in 2009, and renewed in 2014. The LIP participation in SNO+ was funded by FCT/PTDC project that finished in 2014, and two exploratory projects; the first one (PI: SA) focuses on developing new ideas for the anti-neutrino measurements, the second is associated to the FCT grant of GP. The design and construction of the source insertion equipment is supported by Canadian funding.

4.2.3 Objectives

A commissioning data taking phase, with the detector filled with water, is expected to start in 2015 and possibly extend to 2016. Our main objectives are centered in the activities for the water data, and their use for preparing the next phases of the experiment:

- The optical fibers system will be fully installed as the detector is filled, before data taking starts.
  - This system will give first charge and timing calibration of the full array of the PMTs.
  - It will provide high-intensity and high-frequency data for testing DAQ and trigger systems.
  - Its permanent 1Hz firing mode, will lead to fast monitoring tools for the PMT response.
- Automated versions of the on-line and off-line monitoring tools – for fast problem identification and fixing, and effective data selection – will also need to be ready before data taking starts.
- Test versions of a L2 trigger will be used for anti-neutrino identification, in an attempt to tag delayed coincidences with neutron capture signals below the normal analysis threshold.
  - If successful, it will be the first reactor anti-neutrino selection in water Cherenkov detectors.
- Dedicated data-taking campaigns using the laserball diffuser system for a comprehensive calibration of PMTs and media attenuation parameters.
  - The existing calibration plans will be extended to include the external water shielding region of the detector, in order to have a more complete description of the detector details.
  - The full optical detector model (including its up-down asymmetries and high incidence angle response of the PMTs) is needed for accurate event reconstruction in all analysis.
- Events occurring in the external water region will be available in this phase only. Their measurement will lead to an improved external background model to be extrapolated to the internal detector regions. The analysis will make use of the improved external region calibration and of dedicated simulation and reconstruction methods.

At the same time, non-water phase related activities will continue, namely with:

- Analysis of the sensitivity to anti-neutrino directionality in liquid scintillator detectors, including but not limited to SNO+, through the reconstruction of the produced neutron; and design and optimization of a dedicated neutron direction calibration source.
- Development of the coincidence tagging and pile-up classification methods of the Bi-Po alpha-beta backgrounds affecting the neutrinoless double beta decay signal region; this will be later included as a L2 trigger fast selection in the scintillator phase.

The design of the source insertion mechanism, being built in Coimbra, will be finalized according to changes requested by SNOLAB, all pieces will be produced and mounted, mechanical and gas-tightness tests will be performed. The goal is for the full system to be delivered to SNOLAB before 2016.

4.2.4 Team

Project coordinator: José Maneira

Name	Status	FTE %
Amélia Maio	Researcher (LIP/FCUL)	26
Américo Pereira	Technician (LIP)	20
Fernando Barão	Researcher (LIP/IST)	10
Gersende Prior	Researcher (LIP)	100
José Maneira	Researcher (LIP)	60
Naima Zahar	Post-Doc (LIP)	75
Nuno Filipe Silva Dias	Technician (LIP)	20
Rui Alves	Technician (LIP) *	16
Sofia Andringa	Researcher (LIP)	60

4.3 Participation in Dark Matter experiments and R&D on Liquid Xenon Detectors for Dark Matter Search

4.3.1 Resumo

A natureza da matéria escura é uma das questões de física fundamental mais intrigantes. Uma ampla gama de observações cosmológicas e de astrofísica aponta para que 84% da massa do universo é constituída por uma forma de matéria desconhecida que não emite nem absorbe luz (i.e. matéria escura). Vários modelos sugerem que a matéria escura seja constituída por partículas nunca observadas (WIMPs).

O esclarecimento deste problema passa necessariamente pela detecção direta dos WIMPs que hipoteticamente constituem a matéria escura da nossa galáxia. A detecção indireta de WIMPs através da observação dos produtos da sua aniquilação e a procura de novas partículas em aceleradores, como por exemplo o LHC, são complementares, não substituindo de modo algum as experiências de detecção direta.

Entre as mais de 20 experiências de detecção direta existentes no mundo, LUX é a que tem maior sensibilidade a WIMPs. Instalada a 1478 metros de profundidade em "Sanford Underground Research Facility"(SURF, SD, USA) em Julho de 2012, obteve um resultado superior a todas as outras experiências em apenas cerca de um ano. Com apenas 85.3 dias de aquisição de dados, ultrapassou os limites superiores para a secção eficaz de WIMPs com massas superiores a 10 GeV estabelecidos pelas outras experiências, incluindo o anterior limite mais baixo que tinha sido determinado pela experiência XENON100 para o qual necessitou de 225 dias de aquisição de dados.

Este resultado de LUX foi acolhido com muito interesse pela comunidade científica, contando a sua publicação na Phys. Rev. Lett. já com mais de 630 citações no Inspire-HEP. Após um período de testes, pequenas intervenções e calibrações, LUX iniciou uma tomada de dados de 300 dias em Novembro de 2014 com a qual espera melhorar a sensibilidade a WIMPs de um factor de 3.

Qualquer que seja o resultado desta tomada de dados–a detecção de WIMPs ou uma melhoria do limite da secção eficaz – serão sempre necessárias experiências capazes de obter uma sensibilidade pelo menos 10 vezes melhor (referidas na literatura como as experiências de segunda geração).

A experiência LZ foi uma das três experiências de segunda geração selecionadas em 2014 pelo DOE e pela NSF para receberem financiamento. LZ tem como objectivo descobrir e estudar a matéria escura na forma de WIMPs e espera obter uma sensibilidade cerca de 300 vezes melhor do que a obtida por LUX, superando o resultado esperado por XENON1T que está em construção.

LZ é uma câmara de duas fases de projeção temporal (DPXe-TPC) com 7 toneladas de xénon. Este tipo de detector constitui uma tecnologia bem comprovada, cuja adequação à detecção de WIMPs está comprovada pelos excelentes resultados obtidos pelas experiências que a utilizaram (i.e. ZEPLIN-II, ZEPLIN-III, XENON10, XENON100 e LUX). LUX foi especialmente concebida para servir de balão de ensaio de tecnologias necessárias para as DPXe-TPC com várias toneladas de xénon e o excelente resultado obtido comprova o excelência das soluções desenvolvidas. LZ é muito semelhante a LUX mas com alguns importantes melhoramentos tais como o veto cintilador de 4π e a instrumentação da camada exterior de xénon de modo a funcionar como um veto adicional.

Após um período de I&D que se iniciou em 2009, LZ completou o projeto de concepção que já foi avaliado positivamente pelo DOE. A construção está prevista decorrer em 2016 e 2017. A tomada de dados espera-se que ocorra de 2019 a 2021.

O grupo do LIP envolvido nestes projetos tem uma sólida e longa experiência em todos os aspectos relacionados com a detecção de WIMPs com DPXe-TPCs. Integrou a colaboração LUX em 2010 e desde então o grupo tem dado contribuições fundamentais nas áreas do processamento e análise de dados, tem sido responsável por dois subsistemas de LUX desde a sua instalação no laboratório subterrâneo. Vários elementos da equipa tiveram cargos de liderança durante períodos de 3 a 6 meses. Isto demonstra a competência, o envolvimento e a capacidade de liderança do grupo. Em LZ, o grupo coordena a concepção e o programa de I&D do sistema de controlo e monitorização da experiência e tem sido responsável pelo programa de I&D com vista à seleção dos refletores de luz de cintilação a utilizar em LZ.

4.3.2 Abstract

The nature of dark matter is one of the most intriguing open questions in fundamental physics. There is unambiguous evidence based on a broad range of astrophysical and cosmological observations indicating that about 84% of the mass of the universe is in a new form which does not emit or absorb light (i.e. dark matter), and whose nature is unknown. Many models of new physics suggest that dark matter is composed by one or more previously unobserved types of WIMPs.

The route to solving this mystery must include the direct detection of the WIMPs composing our galactic dark matter. Indirect detection of WIMPs by observing products of their annihilation and searches for new particles in accelerators such as the LHC can complement but cannot replace the direct detection experiments.
Amongst more than 20 experiments around the world, LUX (Large Underground Xenon) is the most sensitive WIMP search experiment. Deployed at the 1478 m deep level of the Sanford Underground Research Facility (SURF, SD, USA) in July 2012, it attained a world-leading result in just over one year. With only 85.3 live-days of data taking, it surpassed all existing dark matter limits for WIMP masses above 10 GeV, including the previous best result by XENON100, which had required 225 live-days of exposure. The LUX result allowed to probe WIMP theoretical models and excluded the low-mass WIMP regions where hints of signal have been published.
This result from LUX has received enormous interest, from astrophysicists to particle physicists, its publication in Phys. Rev. Lett. having so far over 630 citations in Inspire-HEP. After a period for several tests, some upgrades and calibrations, LUX started a 300 live-day run in November 2014, expecting to boost its sensitivity by a factor of 3.
Regardless of the outcome of the next run of LUX - either a discovery or a lowering of the cross-section limit - experiments able to reach sensitivities at least 10 times better than current detectors (the so-called second-generation dark matter experiments) are mandatory.
In 2014, the LZ experiment was one of only three second-generation dark matter experiments selected by DOE for being funded. LZ aims to discover and to study dark matter in the form of WIMPs, and will improve the current LUX world-leading sensitivity by a factor of ≈300. LZ will reach further and faster in sensitivity than any competing experiment being proposed on a similar timescale, including XENON1T (presently under construction).
LZ is a dual-phase xenon time projection chamber (DPXe-TPC) using 7 ton of xenon. This is an extensively proven detection technology, and its leading role in dark matter search was demonstrated by several prominent experiments in the field (ZEPLIN-II, ZEPLIN-III, XENON10, XENON100 and finally LUX). LUX was explicitly designed to be the test-bed for the development of the technologies required to operate a multi-ton DPXe-TPC deployed inside a water tank, and its breakthrough result demonstrates the merits of this concept. LZ is largely based on LUX but with important enhancements such as a 4π scintillator veto and the instrumentation of the outer xenon layer for use as additional veto.
Following an extensive R&D program dating back to 2009, LZ has already completed its concept design. After a period for procurement, the construction phase is expected to occur in 2016 and 2017. The underground deployment and commissioning is planned for 2018 and the science run is projected for 2019-2021.
The LIP group has a long-standing experience in all aspects of the dark matter search with DPXe-TPCs. It participated in the ZEPLIN program (pioneer in the use of DPXe-TPCs for WIMP search) from 2002 to 2012 and joined LUX in 2010. In LUX, the group has made key contributions to data processing and analysis. Furthermore the group has had full responsibility for two systems (the slow control and the liquid nitrogen distribution and control systems) since LUX was deployed underground. Several members of the team served for periods of 6 or 3 months in key coordination positions, such as Analysis Group Coordinator, Deputy Science Coordination Manager, Data Processing Manager and Detector Working Group Coordinator. This demonstrates the expertise, involvement and leadership of the LIP group in the experiment. In LZ, we have had the leadership in the design and R&D of the overall instrument control system, and full responsibility for the R&D towards the selection of the light reflectors.

4.3.3 Objectives

For 2015, the group has a program composed by several tasks/objectives, as follows:
Task 1 - LZ monitoring and control system (Coordinator: Vladimir Solovov)
The objective of this task is to maintain the leadership in the development of the LZ control and monitoring system (also referred to as Slow Control - SC) and widen the scope of our involvement in this LZ subsystem.
In the case of LZ, the SC has to monitor and/or control ≈1000 channels simultaneously (e.g. level sensors, thermometers position sensors, electromagnetic signal antennae, acoustic bubble sensors, light detectors, etc.). It also provides a user interface for various subsystems.
We are committed to maintain the leadership of the LZ working package related with the SC during the LZ construction and commissioning phase. We are also committed to supply a set of multi-channel analog monitoring hardware modules, that will be used for readout of detector temperature as well as monitoring the condition (temperature, current consumption etc.) of the signal processing and data acquisition electronics.
Task 2 - Physics beyond DM search in LZ (Coordinator: Alexandre Lindote)
Due to the protection offered by the outer layers of xenon, the 5 tons of the inner region of LZ will be an extremely low background place, allowing the study of important rare physics processes other than WIMP-

nucleon recoils. In this task we propose to perform detailed studies of the expected response of LZ to some of these processes, namely: i) Elastic $\nu e \rightarrow \nu e$ scattering; ii) coherent neutrino-nucleus scattering; iii) double beta (2ß) of 134Xe; iv) Two neutrinos double electron capture (2ν2EC) for 124Xe.
This task includes a phenomenological study to estimate the rates and energy spectra expected for each of these interactions as well as those of all the relevant backgrounds, followed by detailed Monte Carlo simulations to obtain the expected detector response and the preparation of analysis tools to apply to real data once LZ starts taking data.
The neutrino studies will be carried out in collaboration with José Maneira and Sofia Andringa from LIP-Lisboa.
Task 3 - Light reflector of LZ detector (Coordinator: Francisco Neves)
This task deals with aspects relevant to the choice of the light reflector for LZ detector, namely, the measurement of the reflectivity and transmittance of samples of polytetrafluoroethylene (PTFE) of different thicknesses and producers.
Task 4 - Participation in LUX experiment (Coordinator: Cláudio Silva)
This task includes further develop the vertex reconstruction tool, several topics of data analysis, the maintenance of the two LUX subsystems for which the group has sole responsibility and the participation onsite in LUX operations.

4.3.4 Team

Project coordinator: Isabel Lopes

Name	Status	FTE %
Alexandre Lindote	Post-Doc (LIP)	80
Américo Pereira	Technician (LIP)	35
Cláudio Silva	Post-Doc (LIP/FCT)	100
Filipa Balau	PhD student (LIP)	50
Francisco Neves	Post-Doc (LIP)	80
Isabel Lopes	Researcher (LIP/FCTUC)	65
José Pinto da Cunha	Researcher (LIP/FCTUC)	20
Nuno Carolino	Technician (LIP)	25
Paulo Brás	Master student (LIP)	25
Vitaly Chepel	Researcher (LIP/FCTUC)	30
Vladimir Solovov	Researcher (LIP)	50

4.3.5 Academic Training

PhD Theses

- **Estudo de métodos de leitura de sinais de baixa amplitude em detectores de xenon líquido**
  Filipa Balau, (on-going)

Master Theses

- **Dark Matter Data Analysis in LUX**
  Paulo Brás, (on-going)

4.4 High Energy Cosmic Rays

4.4.1 Resumo

O Observatório Pierre Auger foi construído com o objetivo de dar um contributo essencial no estudo de Raios Cósmicos de muito alta energia, na compreensão da sua origem e natureza e também para estudar as interações das partículas a essas altas energias. Atualmente, a colaboração é constituída por cerca de 500 físicos de mais de 90 instituições em 16 países. O Observatório, situado na Argentina, iniciou a sua tomada de dados em 2004 e a sua construção foi finalizada em 2008. É um detetor híbrido que combina um array de detetores de superfície (SD) com telescópios de fluorescência (FD) que observam a atmosfera por cima do array. O SD cobre uma área efetiva de 3000 km^2 com tanques de água de efeito Cherenkov. Entre 2008 e 2014, a Colaboração publicou 50 artigos que tiveram mais de 5800 citações, incluindo 6 artigos classificados entre os mais citados nas revistas Physics Review Letters, Astroparticle Physics Journal e Nuclear Instruments and Methods.
Os dados adquiridos por Auger contribuíram para importantes descobertas na física de raios cósmicos de energias extremas. A supressão no fluxo de raios cósmicos para energias superiores a 5,5x10^19 eV foi inequivocamente estabelecida e foram encontradas evidências de anisotropia na distribuição das direções de chegada das partículas com energias mais elevadas. A natureza (composição) dos raios cósmicos de muito alta energia foi estimada e é interpretada usualmente como uma transição inesperada de elementos leves a pesados para energias superiores a 3x10^18 eV. No entanto, os resultados são igualmente compatíveis com misturas de diferentes tipos de primários bem como com uma mudança drástica da física das interações hadrónicas a muito altas energias. A secção eficaz protão-ar a uma energia no centro de massa de 57 TeV foi medida. Os fortes limites impostos nas magnitudes do fluxo de fotões e neutrinos permitiram excluir a maioria dos modelos de produção de raios cósmicos a partir da desintegração de partículas super-massivas presentes nas primeiras fases do Universo.
Atualmente, Auger é o maior detetor de raios cósmicos do mundo e tem originado importantes avanços. No entanto, ainda existem várias questões em aberto. Para os próximos anos, os principais objetivos são:
1) Averiguar a origem da supressão do fluxo e a composição dos primários às energias mais altas;
2) Procurar isolar a componente de protões primários até às energias mais altas, procurando uma sensibilidade que permita separar uma componente tão pequena quanto 10%;
3) Estudar os chuveiros atmosféricos e a física das interações hadrónica, tentando explorar a física de partículas a energias muito além das que podem ser obtidas em aceleradores terrestres.
Para responder a estas perguntas científicas, a Colaboração Auger tem por objetivo um programa de upgrade do Observatório. Auger propõe, nomeadamente, um reforço das capacidades de deteção de muões no detetor de superfície.
O grupo possui um vasto conhecimento na física dos chuveiros atmosféricos e tem uma visão clara e ideias próprias quanto ao desenvolvimento de futuros detetores. O grupo do LIP está focado principalmente na exploração do potencial para o estudo da física de partículas no Observatório, nomeadamente nos estudos que visam entender as interações a altas energias, através de uma janela que é complementar ao LHC. Com efeito, o grupo detém, competências em domínios específicos reconhecidas mundialmente. No que diz respeito ao desenvolvimento do detetor, o grupo possui: fortes competências na simulação, em particular GEANT4, estando preparado para participar nos seus desenvolvimentos futuros; Instalações de desenvolvimento RPC e produção de RPCs no LIP-Coimbra, com uma equipa que é referência mundial em RPCs, e com um vasto conhecimento sobre as suas aplicações em experiências de raios cósmicos; um laboratório de eletrónica rápida no LIP-Lisboa, dedicado ao desenvolvimento de sistemas digitais de aquisição de dados e à construção de protótipos de deteção de raios cósmicos.
A equipa do LIP é relativamente grande, tanto em número de membros, como em competências. Apesar da maioria da equipa se encontrar em Lisboa, os 3 polos do LIP trabalham em estreita parceria, sendo que equipa de Coimbra é especialista em RPCs e a equipa do Minho está especializada na análise de dados. Finalmente, o grupo de raios cósmicos do LIP possui condições únicas para desempenhar um papel preponderante a nível mundial nas atividades de I&D na área da análise da física de raios cósmicos em Auger. O grupo também atua como uma excelente plataforma de treino académico e de difusão do conhecimento.

4.4.2 Abstract

The Pierre Auger Observatory was built to give a major contribution to the understanding of ultra-high energy cosmic rays, their origin and nature, as well as to study particle interactions at such high energies. Today, nearly 500 physicists from more than 90 institutions in 16 countries are part of the Collaboration. The Observatory, located in Argentina, is taking data since 2004 and construction was completed in 2008. It is a hybrid detector combining a surface detector array (SD) with a set of fluorescence detector telescopes (FD) watching the atmosphere above it. The SD covers an effective area of 3000 km2 with water Cherenkov tanks. In 2008-2014, the Collaboration published 50 papers which had already more than 5800 citations, including 6 papers ranked

among the most cited in Physics Review Letters, Astroparticle Physics journal and Nuclear Instruments and Methods

The data taken by Auger have led to a number of breakthroughs in ultra-high energy cosmic ray physics. A suppression of the cosmic ray flux above 5.5x10ˆ19 eV is firmly established, and there are indications for an anisotropic distribution of the arrival direction of the highest energy particles. The cosmic ray composition at very high energies has been addressed and is usually interpreted as an unexpected transition from proton to heavier elements above 3x10ˆ18 eV. The results are however compatible both with the presence of different primary particle types and with a drastic change in hadronic interactions at very high energies. The proton-air cross-section at a center-of-mass energy of 57 TeV has been measured. Strong limits on photon and neutrino fluxes rule out most models for cosmic ray production from relic particle decay.

Auger is presently the world´s largest cosmic ray detector and provided impressive results. Nevertheless, puzzles and open questions remain. The main objectives for the next years can be summarized as:

1) Elucidate the origin of the flux suppression and mass composition at the highest energies;

2) Search for a flux contribution of protons up to the highest energies, aiming to reach sensitivity to a contribution as small as 10%;

3) Study extensive air showers and hadronic multi-particle production, aiming at the exploration of fundamental particle physics at energies well beyond those accessible at terrestrial accelerators.

The physics implications are profound and the Observatory will remain for many years a unique place to explore them.

In order to fully answer these scientific questions, the Auger Collaboration aims at an upgrade of the Observatory. This is cost and schedule effective, and will provide key knowledge on cosmic rays, as well as important know-how for the planning of future experiments. Auger proposes, namely, an enhancement of the muon identification capabilities in the surface array.

The LIP Auger group owns a deep know-how in air shower physics and has a clear and unique view on the possible developments for future detectors. The group is mainly focused on the full exploitation of the particle physics potential of the Observatory, namely in the efforts to understand hadronic interactions at high energies through a window that is largely complementary to the LHC. In fact, the group holds unique, world reference competences in specific domains. On the detector development side the group has: strong competences in simulation, in particular GEANT4, being ready to participate in its future developments; RPC development and production facilities at LIP-Coimbra, with a team that is a world reference on RPCs, and a strong know-how on their application to cosmic ray experiments; A fast electronics lab at LIP-Lisbon, devoted to the development of digital data acquisition systems and to the setting up of prototype cosmic ray detection setups.

The LIP team is relatively large both in number of members and in competences. While the bulk of the team is in Lisbon, it relies on a close collaboration between the three LIP poles, with the involvement of the Coimbra RPC team and of the Minho analysis team. In conclusion, the LIP cosmic ray group has unique conditions to play a world leading role in R&D in cosmic rays physics analysis in Auger. The group is also an excellent platform for academic training and knowledge dissemination.

4.4.3 Objectives

The group will continue to pursue an ambitious program which will be organized in tasks each led by a team member.

Task 1- "Detailed Study of the SD detectors"

Coordinator: Pedro Assis

A full program is being carried out by the LIP group for systematic studies on the characterization of the response of the water Cerenkov tanks as a function of the direction and impact point of the incoming particles as well as of the tank age and the atmospheric conditions namely the temperature. A hodoscope using two MARTA RPCS was recently installed in a surface tank in the Observatory campus. These studies, which will be pursued and extended, are of the utmost relevance for the control and correction of the systematics errors on the disentangling of the electromagnetic and muonic shower components which is central to achieve the Auger physics goal for the next years.

Task 2- "Measurement of the muonic component of Extreme Energy Cosmic Rays showers"

Coordinator: Lorenzo Cazon

The Surface Detector is sensitive to the particles that reach the ground namely muons coming directly from the decay of charged pions and other mesons. The LIP group leads the effort for the reconstruction of the production depth of the muons along the shower axis (the so called MPD method). This method is nowadays used in many analyses by several groups that resulted in several publications and has an enormous potential for the study of the hadronic interactions at the extreme energies. The determination of the mean and the

RMS of the distribution of the number of muons reaching ground will also be pursued and will be crucial to the understanding of the hadronic development of the shower.
Task 3 – "Measurement of the electromagnetic component of Extreme Energy Cosmic Rays showers"
Coordinator: Sofia Dias
The Fluorescence Detector images the development of the electromagnetic component in the atmosphere while the Surface Detector is sensitive to the particles that reach the ground. The LIP group pioneered the use of the full electromagnetic longitudinal profiles to extract independent shape variables sensitive to composition and hadronic interactions. First results should be made public in the next months. The relation between the lateral and longitudinal electromagnetic shower shapes will be now also explored to search for new observables which can be used in the analysis of ground-only data.
Task 4 – "Theory and Models for High Energy Interactions"
Coordinator: Ruben Conceição
High energy cosmic rays are a unique, but difficult, window to explore Particle Physics at an energy scale well beyond the LHC. The development of models for air shower phenomenology, and their application to experimentally assess the mass of the primaries and the details of high energy physics at energies beyond those reached by LHC will be pursued. The challenge is to build a coherent picture able to accommodate both recent Auger and LHC data, as well as to explore possible "New Physics"scenarios.
Task 5 – "Education and Public Outreach in the area of high energy cosmic rays"
Coordinator: Catarina Espirito Santo
Education and public outreach is developed within the double framework of the Pierre Auger Observatory outreach group, where the Portuguese team in Auger is one of the most active teams, and of the LIP communication and outreach plan, where it is articulated with other groups and infrastructures in the laboratory.

4.4.4 Team

Project coordinator: Mário Pimenta

Name	Status	FTE %
Alberto Blanco	Researcher (LIP)	13
Alessandro de Angelis	Researcher (LIP)	28
Américo Pereira	Technician (LIP)	10
Bernardo Tomé	Researcher (LIP)	75
Catarina Espírito Santo	Researcher (LIP)	80
Eva Santos	Post-Doc	100
Francisco Diogo	PhD student (LIP/FCT)	100
Helmut Wolters	Researcher (LIP/FCTUC)	20
João Espadanal	PhD student (LIP/FCT)	100
Jorge Dias de Deus	Researcher (LIP/IST)	15
José Milhano	Researcher (LIP/IST)	15
Liliana Apolinário	Post-Doc (LIP)	15
Lorenzo Cazon	Researcher (LIP)	93
Luís Lopes	Technician (LIP)	10
Luís Mendes	Student (LIP)	43
Mário Pimenta	Researcher (LIP/IST)	73
Miguel Ferreira	Technician (LIP)	80
Patrícia Gonçalves	Researcher (LIP)	20
Paulo Ferreira	Graduate student (LIP)	33
Pedro Abreu	Researcher (LIP/IST)	65
Pedro Assis	Post-Doc (LIP/FCT/IST)	73
Pedro Brogueira	Researcher (LIP/IST)	15
Raul Sarmento	Post-Doc (LIP/FCT)	100
Ricardo Jorge Barreira Luz	Master student (LIP)	50
Ruben Conceição	Post-Doc (LIP/FCT)	99
Sofia Andringa	Researcher (LIP)	40
Thomas Schweizer	Researcher (MPP)	10

4.4.5 Academic Training

PhD Theses

- **Study of hadronic interactions with the hybrid detector of the Pierre Auger Observatory**
  João Espadanal, (on-going)
- **Medição da secção eficaz de raios cósmicos de alta energia no Observatório Pierre Auger**
  Francisco Diogo, (on-going)
- **Particle Physics at 100 TeV with the Pierre Auger Observatory**
  José Micael Oliveira, (on-going)

Chapter 5

Detector development for particle and nuclear physics

5.1 Participation in the RD51 Collaboration

5.1.1 Resumo

A colaboração RD51 [RD51] tem como objectivo facilitar o desenvolvimento de tecnologias avançadas de detectores gasosos de partículas e dos sistemas de leitura associados para aplicação na investigação básica e aplicada. O principal objectivo do programa de I&D é o avanço da tecnologia de Detectores Gasosos de Microestruturas. A invenção de Detectores Gasosos de Microestruturas (MPGD), em particular o Multiplicador Gasoso de Electrões (GEM), da Estrutura Gasosa de Micro-grelhas (MICROMEGAS), e mais recentemente outros esquemas de microestruturas, oferece o potencial para desenvolver novos detectores gasosos com resolução espacial sem precedentes, elevada taxa de contagem, grande área sensível, estabilidade operacional e resistência à radiação. Nalgumas aplicações, requerendo a cobertura de áreas muito elevadas com resolução espacial moderada, detectores macroestruturados, por exemplo o GEM espesso (THGEM) ou câmaras de placas resistivas estruturadas poderão oferecer uma solução interessante e económica.
A constituição dos novos detectores microestruturados parece adequada à sua produção industrial. Adicionalmente, a disponibilidade de sistemas electrónicos altamente integrados de amplificação e leitura permite o desenvolvimento de sistemas de detectores gasosos com densidade de canais comparável à dos detectores de silício modernos. O pós-processamento moderno de bolachas de silício permite a integração de estruturas de amplificação gasosa directamente em cima de uma pastilha de silício pixelizada. Graças a estes desenvolvimentos recentes, a detecção de partículas através da ionização do gás tem largos campos de aplicação em futuras experiências de física das partículas, nuclear a de astro-partículas, com e sem aceleradores.
A colaboração RD51 envolve ≈450 autores, 75 Universidades e Laboratórios de 25 países na Europa, América, Ásia e África. Todos os parceiros perseguem activamente quer investigação básica, quer aplicada envolvendo uma variedade de conceitos de MPGD. A colaboração estabeleceu objectivos comuns, tais como ferramentas experimentais e de simulação comuns, métodos e conceitos de caracterização, infra-estruturas comuns em feixes de teste e instalações de irradiação, e métodos e infraestruturas para a produção de MPGD.
[RD51] RD51 proposal (http://rd51-public.web.cern.ch/RD51-Public/Documents/RD51Proposal_21082008.pdf)

5.1.2 Abstract

The RD51 collaboration [RD51] aims at facilitating the development of advanced gas-avalanche detector technologies and associated electronic-readout systems, for applications in basic and applied research. The main objective of the R&D programme is to advance technological development and application of Micropattern Gas Detectors.
The invention of Micro-Pattern Gas Detectors (MPGD), in particular the Gas Electron Multiplier (GEM), the Micro-Mesh Gaseous Structure (MICROMEGAS), and more recently other micro pattern detector schemes, offers the potential to develop new gaseous detectors with unprecedented spatial resolution, high rate capability, large sensitive area, operational stability and radiation hardness. In some applications, requiring very large-area coverage with moderate spatial resolutions, more coarse Macro-patterned detectors, e.g. Thick-GEMs (THGEM) or patterned resistive-plate devices could offer an interesting and economic solution.
The design of the new micro-pattern devices appears suitable for industrial production. In addition, the availability of highly integrated amplification and readout electronics allows for the design of gas-detector systems

with channel densities comparable to that of modern silicon detectors. Modern wafer post-processing allows for the integration of gas-amplification structures directly on top of a pixelized readout chip. Thanks to these recent developments, particle detection through the ionization of gas has large fields of application in future particle, nuclear and astro-particle physics experiments with and without accelerators.
The RD51 collaboration involves ≈ 450 authors, 75 Universities and Research Laboratories from 25 countries in Europe, America, Asia and Africa. All partners are already actively pursuing either basic- or application-oriented R&D involving a variety of MPGD concepts. The collaboration established common goals, like experimental and simulation tools, characterization concepts and methods, common infrastructures at test beams and irradiation facilities, and methods and infrastructures for MPGD production.
[RD51] RD51 proposal (http://rd51-public.web.cern.ch/RD51-Public/Documents/RD51Proposal_21082008.pdf)

5.1.3 Objectives

As the currently approved RD51 funding (CERN/FP/123605/2011) terminated in July 2014 the animal RPC-PET activity will continue in the framework of the "RAD4LIFE"project in the framework of the EU QREN program approved to take place between July 2013 and December 2015.
The TOFtracker device currently under construction will be completed and fully characterized.
Concerning the ion mobility measurements, we will use an experimental system already available (Nev07), considering the possibility of upgrading this system to allow a longer drift length and higher pressure. The mixtures to be studied will be Ne, Xe, Ar doped with CO2, CF4, N2 and others considered of interest, for pressures up to 15 Torr and E/N from 5-45 Td.
If further fundings will be available (to be vigorously pursued), for WG3-T3 we will resume studies of liquid xenon double and single phase detectors with GEM (Gaseous Electron Multiplier) and THGEM (Thick GEM) readout, which have at present a leading position in high sensitivity searches for WIMP – weakly interacting massive particles – dark matter candidates.
Nev07 – "A new experimental technique for positive ion drift velocity measurements in noble gases: Results for xenon ions in xenon"P.N.B. Neves, C.A.N. Conde and L.M.N. Tavora, Nuclear Instruments and Methods in Physics Research A 580 (2007) 66-69.

5.1.4 Team

Project coordinator: Rui Marques

Name	Status	FTE %
Américo Pereira	Technician (LIP)	15
António Rocha Gonsalves	Researcher (FCTUC)	15
Carlos Silva	Technician (LIP)	15
Joaquim Oliveira	Technician (LIP)	15
Luís Lopes	Technician (LIP)	15
Marta Gomez	Researcher (FCTUC)	15
Nuno Carolino	Technician (LIP)	15
Nuno Filipe Silva Dias	Technician (LIP)	15
Orlando Cunha	Technician (LIP)	15
Paulo Fonte	Researcher (LIP/ISEC)	25
Paulo Martins	PhD student (LIP/FCT)	70
Ricardo Caeiro	Technician (LIP)	15
Rui Alves	Technician (LIP) *	15
Rui Marques	Researcher (LIP/FCTUC)	35
Sílvia Alexandre	Technician (FCTUC)	15
Susete Fetal	Researcher (LIP/ISEC)	20

5.2 Neutron detectors

5.2.1 Resumo

A necessidade de detetores de neutrões térmicos para uso em reatores nucleares e fontes de neutrões de espalhamento (Spallation Neutron Sources) bem como para aplicações ligadas à segurança interna e proteção radiológica continua a crescer. O detetor é um componente chave quer nos instrumentos dedicados ao estudo da matéria (por exemplo, em instrumentos de dispersão de neutrões tais como difractómetros, espectrómetros e reflectómetros) quer em sistemas de radiografia e tomografia com neutrões.
Os neutrões como radiação não-ionizante não podem ser detetados diretamente, podendo apenas a sua deteção ser realizada através dos produtos da reação da sua conversão em determinados materiais. Apenas alguns isótopos servem este propósito, como por exemplo: He-3, Li-6, B-10, Gd-157. Dada a escassez mundial de He-3, o seu preço atingiu atualmente valores proibitivos, por outro lado, à taxa atual de utilização as reservas de He-3 nos EUA serão esgotadas até 2024.
Apesar dos esforços na busca de alternativas para o He-3, atualmente não existem ainda detetores com a capacidade de taxa de contagem e resolução espacial, adequadas, para um número significativo de instrumentos, particularmente para as fontes de espalhamento com fluxos mais intensos e portanto são urgentes novos desenvolvimentos tecnológicos.
O B-10 com uma secção eficaz de captura para neutrões térmicos de $\approx$ 3840 barns ($\approx$ 72% da secção transversal de He-3) é uma das alternativas mais promissoras ao isótopo He-3. O B-10 tem uma ocorrência no boro natural de $\approx$ 20%, o qual se apresenta com uma abundância média na Terra.
Este projeto tem como objetivo o desenvolvimento de um novo conceito de detetor para neutrões térmicos, sensível à posição, tendo por base a tecnologia já bem estabelecida das RPCs (Câmaras de Placas Resistivas) como uma potencial alternativa futura aos detetores de He-3. A nossa ideia é usar uma RPC, com os elétrodos revestidos com um filme fino (1-2 mícron) de B4C enriquecido em B-10 (conversor de neutrões térmicos). Esta abordagem tira partido da configuração em multi-camada, característica das RPCs e que é indispensável para garantir uma eficiência de deteção elevada. Pretende-se demonstrar que este tipo de detetor pode ser aplicado com sucesso para a deteção 2D (bidimensional) de neutrões térmicos, com uma elevada resolução espacial (resolução sub-milimétrica). De salientar que para detetores de elevada resolução, no intervalo de 1-3 mm, uma previsão dos requisitos necessários aos detetores, para os intrumentos da ESS (European Spallation Source), mostra que há uma lacuna clara entre a performance desejada e a que é possível atingir atualmente.
Foram realizadas estudos preliminares, tendo sido dada prioridade à realização do ingrediente básico para a implementação do conceito, ou seja, os revestimentos de B4C. Recentemente, recebemos as primeiras amostras revestidas com B4C enriquecido em B-10, providenciadas pela Dra. Carina Höglund (Linkoping University, Sweden), responsável pela produção de revestimentos de B4C de grande área para os nossos parceiros (por exemplo, ILL: "Multi-Grid Project"; TUM: "Boron-10 based detetor with stacked macrostructured cathodes").
Na fase seguinte, segue-se o estudo de um protótipo, contendo uma RPC com cátodo revestido com um filme fino de B4C (enriquecido em B-10), com neutrões térmicos a fim de completar os testes de viabilidade do conceito.
O desenvolvimento da ideia aqui descrita, está a ser realizada no âmbito de um projeto exploratório financiado pela FCT (EXPL / FIS-NUC / 2522/2013) que termina em 31 de agosto de 2015.
Este projeto encontra-se a ser desenvolvido em estreita colaboração com parceiros internacionais (e.g. ILL, TUM-FRM II, ESS). Para além disso o LIP integra um consórcio internacional de 18 beneficiários, liderados pelas infraestruturas Europeias (ESFRI), ILL e ESS, que apresentou em setembro 2014 uma proposta ao Horizonte 2020 "World class Science and Innovation with Neutrons in Europe 2020 – SINE2020"(Call: H2020-INFRADEV-1-2014-1, Proposal No.: 654000). O LIP tem sob sua responsabilidade a tarefa "câmaras de placas resistivas (RPC)"parte da atividade de investigação "Tecnologias de detetores emergentes para a dispersão com neutrões e espectroscopia muónica"(recursos previstos para o LIP: € 116.250).
A continuidade dos trabalhos de investigação relativos ao assunto deste projeto está também prevista no âmbito de um projeto Nacional submetido à FCT em 29-01-2015: PTDC/FIS-NUC/6742/2014, Placas Resistivas para a nova geração de detetores de raios cósmicos e de neutrões, cujo o Investigador Responsável é o Prof. Paulo Fonte.

5.2.2 Abstract

The need of thermal neutron detectors for use at nuclear reactors and spallation sources as well as for applications related to homeland security and radiological protection continues to grow. The detector is a key component in instruments dedicated to materials research (e.g. neutron scattering instruments) and in neutron radiography and tomography.
Neutrons as a non-ionizing radiation cannot be detected directly; they can only be detected through the reaction products in converter materials. Only a few isotopes can be used for this purpose, e. g.: He-3, Li-6, B-10, Gd-

157. Until recently, the isotope most commonly used in position sensitive thermal neutron detectors was He-3. Unique properties of this isotope allowed to design detectors with excellent performance (detection efficiency ≈100%, position resolution ≈ 0.5 mm FWHM, low sensitivity to gamma radiation). Given the world shortage in H-3, his price is presently attaining a forbidding level, moreover at the current rate of usage the stock of He-3 in the USA will be exhausted by 2024.
Despite the efforts in the search for He-3 alternatives, adequate high spatial resolution, high count rate detectors do not exist today for a significant number of instruments, particularly at the highest flux sources, and the necessary technological developments are urgently needed.
Boron-10 with a thermal neutron capture cross section of ≈3840 barn (≈72% of the cross section for He-3) is one of the most promising alternatives to He-3 isotope. Boron-10 has an occurrence in natural boron of ≈20%, which has an average abundance on earth.
This project aims to develop a new position-sensitive neutron detector concept, based on the well established RPCs (Resistive Plate Chambers) technology as a potential future alternative to He-3 detectors. Our idea is to use resistive electrodes coated with a thin film (1-2 micron) of a B4C solid neutron converter in a multi-gap RPC configuration. This approach takes advantage of the naturally layered configuration of RPCs which is needed to ensure high neutron detection efficiency. We intend to demonstrate that this type of detector can be successfully applied for 2D positioning of thermal neutron events with high spatial resolution (sub-mm regime). For higher resolution detectors, in the range 1-3mm, estimates of detector requirements for ESS (European Spallation Source) instruments show that there is a clear requirement gap between desired detector performance and the best that is currently available.
Preliminary studies have been conducted and priority was given to the realization of the basic ingredient for the implementation of the concept, i.e., the B4C coatings. Recently, we received the first samples coated with B4C, enriched in B-10, provided by Dr. Carina Höglund (Linkoping University, Sweden), responsible for the large area B4C coatings production for our partners (e.g. ILL: "Multi-Grid Project"; TUM: "Boron-10 based detector with stacked macro-structured cathodes").
In a next phase, it follows up the study of a B4C coated RPC prototype (cathode coated with B4C, enriched in B-10) with thermal neutrons, in order to complete the concept´s feasibility tests.
The development of the idea herein described is being held in the framework of an exploratory project funded by FCT (EXPL/FIS-NUC/2522/2013) and which will end in August 31, 2015.
This project is being developed in close collaboration with international partners (e.g. ILL, TUM-FRM II, ESS). Furthermore LIP integrated an international consortium of 18 beneficiaries led by the European (ESFRI) facilities, ILL and ESS, which submitted in September 2014 a Horizon2020 proposal "World class Science and Innovation with Neutrons in Europe 2020 – SINE2020"(Call: H2020-INFRADEV-1-2014-1, Proposal No.: 654000). LIP has under his responsibility the task "Resistive plate chambers (RPCs)"part of the research activity "Emergent Detector Technologies for Neutron Scattering and Muon Spectroscopy", coordinated by ESS (resources committed to LIP: € 116,250).
The continuity of the research work of this project is also foreseen in the framework of a National project submitted to the FCT on 29/01/2015: PTDC / FIS-NUC / 6742/2014, Resistive Plate Chambers for next-generation of cosmic-ray and neutron detectors, wherein Prof. Paulo Fonte is the Principal Investigator.

5.2.3 Objectives

Demonstrate experimentally the feasibility of a high position resolution thermal neutron detector with B4C coated RPCs.
Proceed with the optimization of the detector using MC simulations implemented with GEANT: optimization of parameters such as, the B4C coatings thickness, the number of B4C layers and the gas gap width which can lead, simultaneously in the improvement of the detection efficiency and the position resolution.
Despite the operation of RPCs is very well studied for the detection of MIPs (Minimum Ionizing Particle), this is not the case for thermal neutron detection where neutron capture in boron-10 results in emission of HIPs - Highly Ionizing Particles (alpha and lithium). One major objective (not possible to be accomplished during 2014) is to study the operation of the RPC with HIPs, namely the effect of a high ionization density on the electron avalanche development and related phenomena.
To perform this study a convenient neutron source or a thermal neutron beam is needed. The possibility to emulate the HIPs by using an alpha particle emitter are already foreseen (as an extra option), e.g. adding Rd-220 emanations from Thorium-232 oxide (e.g. used in gas light mantles fabrication) to the gas flow (Radon-220 decays by alpha emission with a half life of ≈56 seconds). Moreover, this approach might lead to a very suitable method to characterize the response uniformity of the RPC with the detection system.
Assemble a B4C coated RPC detector, according to the optimized parameters. The detector prototype together with the DAQ system will be taken to a neutron facility e.g. ILL at Grenoble, France, where tests in a neutron

beam will be performed. It is foreseen to measure the overall detection efficiency, neutron scattering, gamma discrimination and spatial resolution available with this detector prototype.

5.2.4 Team

Project coordinator: Luís Margato

Name	Status	FTE %
Alberto Blanco	Researcher (LIP)	15
Alessio Mangiarotti	Researcher (USP)	20
Andrey Morozov	Researcher (LIP)	25
Francisco Fraga	(FCTUC)	20
Luís Margato	Post-Doc (LIP)	85

5.3 High Pressure Xenon Doped Mixtures for the NEXT Collaboration

5.3.1 Resumo

Os estudos relativos às misturas gasosas baseadas em xénon vão prosseguir, com aditivos acordados com a colaboração NEXT. O próximo candidato será TEA. Pretende-se também testar pressões mais elevadas (até 20 atmosferas). Será ainda realizado o estudo da cintilação primária, que até aqui não foi possível por dificuldades técnicas com o detector. As alterações necessárias estão a ser feitas e prosseguiremos com esse estudo em breve. Logo que os dispositivos projectados estejam prontos serão testados e far-se-ão medidas das velocidades de deriva e estudos das disrupções eléctricas a altas pressões.
No início de 2015 será submetido à FCT ao concurso PTDC (projectos em todos os domínios científicos, concurso anunciado no final de 2014) um projecto conjunto com os outros dois grupos portugueses participantes na colaboração NEXT (LIBPhys – Universidade de Coimbra e Universidade de Aveiro). Para além das actividades locais da responsabilidade de cada grupo, prevê-se a participação de investigadores do LIP nas actividades de montagem e de arranque da tomada de dados no laboratório de Canfranc.

5.3.2 Abstract

The studies regarding xenon based gaseous mixtures will proceed, with the additives agreed upon with the NEXT Collaboration. The following foreseeable candidate is TEA. We also intend to go to higher pressures (up to 20 atm). Study of the primary scintillation is also planned and has not been done yet due to technical difficulties, so changes in the detector to allow these measurements are under way. When the devices projected are ready, they will be tested and the measurements of drift velocities and gas electrical disruption at high pressure will begin.
In the beginning of 2015, a research proposal will be submitted to the FCT PTDC call. This is a proposal presented together with the other two Portuguese teams participating in NEXT collaboration (LIBPhys - University of Coimbra and University of Aveiro). Besides of the local responsibilities of each group, it is predicted that research and technicians will be involved in the assembly, commissioning of the detector and first data acquisition at the Canfranc Laboratory.

5.3.3 Objectives

- Investigation of other xenon based gaseous mixtures concerning primary and secondary scintillation yields, drift velocities, charge multiplication and energy resolution at various pressures, up to 20 atm.
- Characterization of the behavior of the gas concerning its electrical disruption with varying applied reduced electric fields at increasing pressures
- Participation in the NEXT set-up and commissioning at the Canfranc Lab.

5.3.4 Team

Project coordinator: Filomena Santos

Name	Status	FTE %
Carlos Conde	Researcher (LIP)	30
Filipa Borges	Researcher (LIP)	30
Filomena Santos	Researcher (LIP)	50
João Barata	Researcher (LIP/UBI)	15
Jorge Maia	Researcher (LIP/UBI)	15
José Escada	Post-Doc (LIP)	60
Paulo Rachinhas	Master (LIP)	10
Sérgio Carmo	Researcher (LIP/IBILI)	10
Teresa Dias	Researcher (LIP)	15

5.4 Ion Transport Processes in Gaseous Detectors for Particle Physics

5.4.1 Resumo

O estudo do transporte de iões em gases continua a ser um tema de muito interesse não só devido aos problemas de física atómica e molecular que levanta e que procura resolver, mas também devido à sua aplicação em áreas diversas, como a área dos detectores gasosos de radiação, nomeadamente os detectores para física das altas energias. Nos detectores gasosos de radiação baseados em processos de avalanche, a amplitude do impulso do sinal de saída tem duas componentes, uma devida à deriva dos electrões, e outra devida à deriva dos iões. Embora a velocidade de deriva dos iões seja muito menor do que a dos electrões, a sua contribuição para a formação do impulso induzido é frequentemente predominante. Para misturas gasosas do tipo gás nobre/gás molecular utilizadas em detectores para física das altas energias, mais do que um tipo de ião tem que ser considerado no processo de deriva.

Na sequência dos trabalhos teóricos anteriormente realizados por investigadores da equipa, um dos objectivos deste projecto é o cálculo teórico de secções eficazes integrais e diferenciais de colisão elástica ião-átomo/molécula e a simulação do transporte de iões no próprio gás. Serão consideradas misturas gasosas com base em gases nobres com interesse para detectores de física de partículas. Serão utilizadas técnicas de Monte Carlo para calcular parâmetros de transporte dos iões (velocidades de deriva e coeficientes de difusão longitudinal e transversal) para campos eléctricos reduzidos até ao limiar para ionização por electrões.

Este projecto tem como objectivo principal a medida experimental da mobilidade de iões no próprio gás para diferentes pressões e campos eléctricos reduzidos, E/N, utilizando um sistema experimental, anteriormente concebido e implementado pela equipa de investigação. O sistema experimental é baseado em técnicas originais desenvolvidas por investigadores da equipa. Uma lâmpada VUV de Xe pulsada liberta electrões da superfície de um filme de CsI que cobre um GEM. Estes electrões disparam uma avalanche onde são produzidos os iões positivos a estudar. Os iões derivam sob a influência de um campo eléctrico uniforme e são recolhidos numa grelha colectora, blindada electrostaticamente por uma grelha de Frisch, dando origem a um impulso que permite medir os tempos de deriva dos diversos iões formados e assim obter as velocidades de deriva. Este sistema experimental será utilizado para medir as velocidades de deriva dos iões positivos resultantes da ionização de gases puros ou de misturas de gases e quando possível para identificar esses iões.

5.4.2 Abstract

The study of the transport of ions in gases continues to be a subject of great interest not only due to the fundamental atomic and molecular physics problems involved but also due to its applications in many fields of interest such as the area of gaseous radiation detectors, including detectors for high energy physics. In gaseous detectors based on electron avalanches, the output pulse amplitude has two components: one due to the drift of electrons and another due the drift of the ions. Although the drift velocity of the ions is much slower than that for electrons, their contribution to the induced pulse is often predominant. In gaseous mixtures like noble gas / organic gas mixtures used in high energy physics detectors, more than one type of ion contributes to the drifting processes.

Following the theoretical studies carried out before by the team researchers, this project aims to calculate differential and integral ion-atom/molecule elastic collision cross sections and the simulation of the transport of ions in gases. Will be considered noble gas based mixtures with interest for particle physics detectors. Detailed Monte Carlo techniques will be used to calculate ion transport parameters (drift velocities, longitudinal and transversal diffusion coefficients), for reduced electric fields up to about the threshold for electron ionization.

This project has as main objective the experimental measurement of ion mobility in their parent gases. An experimental system designed and constructed before by the research team, will be used for measure the mobilities of ions in their parent gases under different pressures and reduced electric yields, E/N, and for the identification of the different ions present. The experimental system is based on the original techniques developed before by researchers of the team. A pulsed Xe UV lamp releases electrons from a CsI covered GEM. These electrons trigger an avalanche where positive ions are produced. Under the influence of an uniform electric field these ions drift towards a collecting grid shielded by a Frisch grid. A time-of-flight spectrum generally allows positive ion identification and the determination of their drift velocities. This experimental system will be used to measure the drift velocities of positive ions resulting from the ionization of pure gases or gas mixtures, and whenever possible to identify these ions.

5.4.3 Objectives

Following the work done until now, the research team intends to continue the experimental and theoretical studies of the transport of ions in other gases or noble gas based mixtures with interest for gaseous radiation detectors for high energy physics (HEP).
It is our aim to continue the research works using other mixtures of noble gases with carbon dioxide, such as Ne-CO2 and Ne-CO2-N2, and of Xe with trimethylamine (TMA) since these mixtures are important for different experiments.
The main properties of interest are the identification of the different ion species presented and the calculation and/or experimental measurement of their reduced mobilities.

5.4.4 Team

Project coordinator: João Barata

Name	Status	FTE %
Alexandre Fonseca Trindade	Master (LIP)	40
André Cortez	PhD student (LIP)	100
Carlos Conde	Researcher (LIP)	20
Filipa Borges	Researcher (LIP)	20
Filomena Santos	Researcher (LIP)	15
João Barata	Researcher (LIP/UBI)	40
Pedro Neves	Post-Doc (ATP-Group)	15
Teresa Dias	Researcher (LIP)	20

5.5 Beam Monitoring System for Cyclotron Proton Beams at ICNAS

5.5.1 Resumo

Neste projeto o grupo do LIP colabora com o ICNAS, centro da Universidade de Coimbra que alberga o ciclotrão acelerador de protões para aplicações em medicina nuclear. A colaboração já alcançoiu bastantes objetivos previamente propostos, nomeadamente (1) no desenvolvimento e aplicação de instrumentação para medida do feixe de protões, e (2) na irradiação controlada automaticamente de doses compreeendidas entre as dezenas de Gy e a centena de mGy. O objetivo último do projeto é providenciar ao utilizador final uma instalação onde se possam efectuar estudos de dosimetria com protões bem como estudos no âmbito da radioterapia com pequenos animais. As doses deverão por isso estar compreendidas entre alguns cGy a vários Gy. Estudos também envisionados no âmbito da radioproteção deverão compreender doses entre algumas centenas até às dezenas de mGy.
No ano de 2014 vários dos objetivos acima mencionados foram atingidos. Tornou-se possível irradiar de forma homogénea e controlada uma região com um diâmetro de 18 mm. Este passo era necessário por forma a possibilitar a irradiação de culturas celulares dispostas em placas de multi orifícios apropriadas da biologia, com um diâmetro de 16 mm por orifício. Verificou-se que o controlo do campo magnético no interior do ciclotrão desempenha um papel fundamental para se lograr a homogeneidade da irradiação. Um varrimento do mesmo antes da irradiação de qualquer amostra evidencia um comportamento quasi-gaussiano na taxa de dose resultante, sendo apenas a região central do campo magnético apropriada para irradiações homogéneas. A quantificação da não-homogeneidade obtida está em curso, com primeiros resultados a apontar para valores inferiores a +/- 2%. Uma instalação para irradiação de culturas celulares foi também construída. Pensa-se ser possível a médio prazo realizar as primeiras curvas de relação dose-sobrevivência de culturas celulares.

5.5.2 Abstract

The group at LIP develops this project in collaboration with ICNAS, the center from the University of Coimbra that hosts a proton cyclotron for applications in nuclear medicine. The collaboration has already moved forward in its goals in several aspects related with (1) instrumentation for proton beam measurements, and (2) automatic irradiation and quantification of doses of several Gy down to one hundred mGy. The final goal of the project is to provide the end user with a setup offering the possibility of carrying out proton dosimetric experiments together with small-animal radiotherapy studies. One of the goals of the project is to allow studies in the field of radiotherapy comprising total doses between a few cGy to a few Gy, as well as studies in the field of radiation protection, hence comprising doses of the order of a few hundreds down to tens of mGy.
In 2014 several developments were accomplished within the aforementioned objectives. We are now able to control a homogeneous beam spot on target with a diameter of 18 mm, and excluding the (computed) outer skirts of the beam where non-homogeneity occurs. This was intended in order to allow the controlled irradiation of cell cultures located in typical biological multi-well dishes with diameters of 16 mm. The control of the magnetic field applied inside the cyclotron plays a major role for achieving said homogeneity. A scan revealing a quasi-gaussian shape must be performed before any irradiation, with the final shutter closed, so that the optimum magnetic field can be applied hence producing a homogeneous target dose. Inhomogeneity quantification is ongoing, with first results pointing to values inferior to +/- 2%. A setup for cell-culture irradiation has also been constructed. Plans are to perform first dose-survival curves on the mid-term.

5.5.3 Objectives

The objectives for 2015 comprise:
- The implementation of a multi-hole irradiation setup specially adapted for radiobiology studies with existing cell-culture multi-hole plates. This requires adapating a 2D automatica positioning system controlled from outside the bunker in order to avoid the slow opening of the bulky bunker door.

5.5.4 Team

Project coordinator: Paulo Crespo

Name	Status	FTE %
Hugo Simões	PhD student (LIP/FCTUC)	25
Paulo Crespo	Researcher (LIP/FCTUC)	30
Rui Marques	Researcher (LIP/FCTUC)	10
Sharif Ghithan	PhD student (LIP/FCT)	100

5.6 Detector Lab / Mechanical Workshop

5.6.1 Resumo

O laboratório de detetores tem vindo a ser equipado para atender quer as necessidades gerais, quer às exigências específicas dos diferentes grupos de investigação.
O equipamento disponível e a especialização do pessoal técnico permitem atualmente prestar una larga gama de serviços.

5.6.2 Abstract

The detector laboratory has been continuously updated according to both general demands and specific needs of the research groups.
The available equipment and the technical staff expertise allow a variety of services to the research teams.

5.6.3 Objectives

In 2015, we foresee continuing the support to the research teams, in particular through:

- Design, construction and repair / maintenance of electronic equipment,
- Construction and test of detectors,
- Design, construction and maintenance of gas and vacuum systems.

Chapter 6

Instruments and methods for biomedical applications

6.1 Spin-off technologies for Cancer Diagnostics

6.1.1 Resumo

O grupo Spin-off Technologies for Cancer Diagnosis (STDC) foi criado há dez anos em torno do desenvolvimento de um novo tomógrafo por emissão de positrões (ClearPEM) para diagnóstico de cancro da mama, explorando tecnologias desenvolvidas no LIP para a experiência CMS no Large Hadron Collider.
A pesquisa científica, o desenvolvimento tecnológico e o teste em laboratório de novos equipamentos PET são realizados na infraestrutura laboratorial TagusLIP, dedicada ao desenvolvimento de novas tecnologias em medicina nuclear. O laboratório TagusLIP está instalado no Taguspark.
O projecto ClearPEM foi desenvolvido por um consórcio nacional de institutos de investigação e centros clínicos sob a liderança do LIP. O consórcio é formado por institutos especializados nas áreas de física, medicina nuclear, detectores de radiação, biofísica, engenharia biomédica, electrónica, computação, engenharia mecânica e robótica, e pela empresa PETsys, os quais colaboraram no desenvolvimento de novas tecnologias aplicadas à detecção de cancro.
O consórcio ClearPEM colaborou no desenvolvimento de sistemas de imagem multimodal PET e Ultrasom com institutos da colaboração internacional Crystal Clear, nomeadamente CERN Switzerland, INFN-Milano Italy, Univ. Hospital Nord Marseille France, Hospital San Gerardo Monza Italy.
Desde 2011 o grupo LIP/STDC faz parte do consórcio EndoTOFPET financiado pelo programa FP7 da União Europeia. O projecto prossegue até Julho 2015 com o objectivo de desenvolver uma sonda endoscópica PET/ultrassom, associada a um detector PET externo para detecção de cancro do pâncreas e da próstata. O LIP coordena o Work Package 4, responsável pelos sistemas electrónicos de aquisição de dados.
O grupo LIP/STDC faz parte da FP7 Marie Curie Training Network (ITN) PICOSEC, dedicada ao desenvolvimento de sensores com boa resolução temporal para PET Tempo-de-Voo.

6.1.2 Abstract

The group on Spin-off Technologies for Cancer Diagnosis (STDC) was created ten years ago around the development of a new Positron Emission Tomography scanner (ClearPEM) for breast cancer diagnosis, exploiting technologies developed at LIP for the CMS experiment at the Large Hadron Collider.
Scientific research, technological development and laboratory testing of new PET scanners is pursued at the laboratory infrastructure TagusLIP, dedicated to the development of new nuclear medicine technologies. The TagusLIP infrastructure is installed at Taguspark.
The ClearPEM project was developed by a national consortium of research institutes and clinical centers under the LIP leadership. The consortium is formed by institutions specialized in the areas of physics, nuclear medicine, radiation detectors, biophysics, medical engineering, electronics, computing, mechanical engineering and robotics, and by the start-up company PETsys, which collaborated to develop new technologies applied to cancer detection.
The ClearPEM consortium collaborated in the development of multi-modality imaging systems integrating PET and Ultra-Sound with institutes of the international Crystal Clear Collaboration, namely CERN Switzerland, INFN-Milano Italy, Univ. Hospital Nord Marseille France, Hospital San Gerardo Monza Italy.

Since 2011 the LIP/STCD group is part of the consortium EndoTOFPET funded by the FP7 framework program of the European Union. This project is being developed until July 2015 with the aim of developing an endoscopic PET and ultrasound probe, associated with an external PET detector for detection of prostate and pancreatic cancer. LIP coordinates the Work Package 4, responsible for the electronics and data acquisition systems.
The LIP/STCD group is part of the FP7 Marie Curie Training Network (ITN) PICOSEC, focused in the development of sensors with very good time resolution for Time-of-Flight PET.

6.1.3 Objectives

The main objective of the LIP/STCD research group is the investigation of new nuclear imaging technologies. In the next few years the group will be exploiting the research directions we have already initiated in PET Time-of-Flight (ToF). The time resolution of about 300-350 ps FWHM that we have already achieved at system level translates in a precision in the measurement of the point of electron-positron annihilation of about 5 cm. This time-of-flight performance allows a gain in equivalent sensitivity of a factor of about 6 relative to PET systems without ToF capability. We aim at improving this performance to reach better than 200 ps time resolution.
The start-up company PETsys, promoted by LIP and established in Portugal, aims at the development and commercialization of these new technologies. LIP has licensed to PETsys the technologies developed by the LIP/STCD group with the aim of commercializing PET detector modules and electronics for high-end PET applications. PETsys has been awarded venture capital funds to pursue this goal.
The LIP/STCD group plans to apply the new SiPM-based technology to the design of a second generation ClearPEM system with optimized cost/performance. We have on-going discussions involving PETsys and other companies in the PET and MRI markets, as well as a major clinical centers in breast cancer diagnosis and treatment, in view of developing a PET-MR system for breast cancer diagnosis. A proposal to pursue this effort in framework of an international collaboration was submitted to FCT in February 2015. This project would also build-up on the new PET detector modules and electronics we have developed.
In 2015 the group will pursue the development of a high resolution variant of the PET detector module with two LYSO arrays with 256 crystals measuring 1.53x1.53x12mm and a glass light guide between the LYSO array and the MPPC array. The crystal where the interaction occurred can be identified using light sharing. A new method to extract DoI information was patented in 2014 and will be fully validated in 2015.
In collaboration with PETsys and INFN Torino, the group will develop a second version of the TOFPET ASIC aiming at better time resolution and increased rate performance. The first prototype MPW submission is foreseen in June 2015.
We will also pursue the development of an upgrade version of the PCIe-based DAQ board using optical data links at 8 Gb/s. A first prototype is expected in July 2015.

6.1.4 Team

Project coordinator: João Varela

Name	Status	FTE %
Carlos Gaston	Researcher (LIP)	25
Catarina Ortigão	Post-Doc (LIP/FCT)	50
Cláudia Sofia Ferreira	PhD student (LIP/FCT)	50
João Varela	Researcher (LIP/IST)	5
Jorge Neves	PhD student (FCT)	50
José Carlos Silva	Technician (LIP)	2
Leonor Frazão	Master student (LIP)	50
Luis Ferramacho	Researcher (LIP)	16
Manuel Rolo	PhD student (LIP)	40
Miguel Silveira	Researcher (LIP)	16
Ricardo Bugalho	PhD student (LIP)	50
Rui Pereira da Silva	Technician (LIP)	50
Stefaan Tavernier	Researcher (LIP)	25
Tahereh Niknejad	PhD student (LIP)	50
Viesturs Veckalns	PhD student (LIP)	67

6.1.5 Academic Training

PhD Theses

- **Estudo do tomógrafo Clear-PEM no diagnóstico do cancro da mama**
  Cláudia Sofia Ferreira, (on-going)

- **New technologies and algorithms for high-performance local processing of large scale sensor data in high energy and medical physics**
  Viesturs Veckalns, (on-going)
- **Development of a new PET detector for pancreatic and prostate cancer detection**
  Carlos Gaston, (on-going)
- **Development of new high-performance Positron Emission Mammography based on new photosensor technology**
  Tahereh Niknejad, (on-going)

Master Theses

- **Development of an innovative LSO-SiPM detector module for high-performance Positron Emission Tomography**
  Leonor Frazão, (on-going)

6.2 PET with Resistive Plate Chambers (RPC-PET)

6.2.1 Resumo

Objectivo
A Tomografia de Emissão de Positrões (PET) é uma técnica poderosa de imagiologia molecular funcional. O nosso objectivo é o desenvolvimento um tomógrafo baseado numa tecnologia radicalmente nova de TOF-PET, que envolve todo o corpo do paciente, com resolução espacial a atingir os limites físico da técnica PET e sensibilidade uma ordem de grandeza superior à dos sistemas comerciais correntes, sem aumento de custo. Uma tal inovação fornecerá aos clínicos capacidades superiores de diagnosticar e detectar doenças oncológicas e de outros tipos, bem como de estudar mecanismos de doença, constituindo uma mudança de paradigma no uso clínico de PET. Realizados já os estudos básicos de viabilidade, neste projecto pretende especificamente desenhar, construir, testar e desenvolver um primeiro protótipo de dimensão real de um tomógrafo para corpo inteiro, com um campo de visão axial (AFOV) de 2m e uma abertura de 90 cm.
A demonstração desta tecnologia, radicalmente diferente da dos cristais tradicionalmente usados na detecção de raios gama, pode, aliás, abrir perspectivas totalmente novas na detecção de raios gama em áreas extensas, para lá das aplicações médicas.

Ideia fundamental
A sensibilidade é um parâmetro fundamental dos sistemas PET, determinando a quantidade de traçador radioactivo a administrar ao paciente, o tempo de observação e o nível de ruído para uma dada granularidade da imagem. Qualquer melhoria na sensibilidade permite o correspondente melhoramento num destes parâmetros ou numa combinação deles. Deve contudo garantir-se que qualquer nova tecnologia forneça os melhoramentos esperados sem contudo conduzir a um aumento significativo de custos relativamente aos sistemas disponíveis no mercado. Ora tal não é o que se passa com muitas das soluções que estão actualmente em estudo, podendo ser necessários compromissos [ERI06].
A nossa proposta para PET de alta sensibilidade a custo moderado envolve a técnica TOF-PET e o aumento dramático do AFOV [BLA03, ERI08] até uma dimensão de corpo inteiro (2 m) graças a um detector de radiação com custo por unidade de área moderado, capaz de fornecer excelente resolução espacial, uniforme ao longo do FOV, sensível à profundidade de interacção e com uma resolução de 300 ps para tempo de vôo.
Um campo de visão muito extenso, capaz de abranger todo o corpo dum paciente ("single bed"), tem ainda outras vantagens sobre os sistemas com AFOV reduzido. Entre elas, está a possibilidade de, obtendo imagens simultâneas de todo o corpo, permitir o estudo completo de processos dinâmicos graças a uma segmentação temporal melhorada. Outra vantagem está na possibilidade de obter uma melhor quantificação da actividade através duma melhor correcção de difusão ("scatter"), dado não haver actividade fora do FOV.

Aproximação inovadora
A nossa aproximação baseia-se numa tecnologia de detecção já em uso na Física de Partículas para a medida de tempo de vôo de partículas elementares carregadas: as "timing Resistive Plate Chambers"(tRPCs). Esses detectores gasosos foram desenvolvidos para cobrir áreas de mais de uma centena de metros quadrados a preços moderados, fornecendo ao mesmo tempo excelente resolução temporal, abaixo dos 100 ps rms.
Há alguns anos este grupo propôs a aplicação destes detectores à tecnologia TOF-PET, tanto para tomógrafos de corpo inteiro para humanos, como para pequenos animais [BLA03]. Tal aplicação baseia-se no princípio das "placas conversoras"e tira partido da estrutura natural "em camadas"das tRPCs e de a sua construção em áreas grandes ser económica. A baixa eficiência naturalmente esperada para os fotões de 511 keV é mais que compensada [COU07a, ERI08, CRE09] pela possibilidade de alcançar campos de visão extensos, que poderão ir até 2 m.
O conceito foi também revisto independentemente [ERI08], embora assumindo condições diferentes, confirmando-se que poderá para corpo inteiro substituir com vantagem os tomógrafos de cristais que constituem o "state-of-the-art".

6.2.2 Abstract

Aim of the project

Positron Emission Tomography (PET) is a powerful diagnostic technique employed in functional medical imaging (molecular imaging). Our overall objective is to develop a radically new technology for TOF PET systems targeted at human whole-body scanning, with resolution down to the physical limit of the PET technique and with a sensitivity improved by over one order of magnitude with respect to current commercial systems, without

increase in cost. Such breakthrough would provide physicians with superior capabilities for diagnosing and detecting oncological and other diseases and investigating disease mechanisms, potentially allowing a paradigm shift in PET clinical use.
As the basic feasibility studies have been already carried out, this project specifically aims at designing building, testing and developing a first prototype of a full-size human whole body TOF-PET scanner with a field-of-view of 2 m and a borehole of 90 cm (Fig. 1).
The demonstration of this technology, offering a radically different alternative to crystal-based gamma detection systems, may open totally new avenues for future research in large-area gamma detection, even beyond medical applications.

Fundamental idea

Sensitivity is a fundamental parameter of PET systems. It determines the amount of radioactive tracer to be administered to the patient, the observation time and the noise level in the image for a given image granularity. Any improvement in system sensitivity will allow a corresponding improvement in one of these parameters or in a combination of them.
However, a practical view should be kept in that a successful new technology should provide the expected benefits without any significant increase in cost over the presently available commercial systems. This is by far not evident with many of the currently researched approaches and some compromise may be necessary [ERI06].
Our proposal for high-sensitivity PET at reasonable cost involves the TOF-PET technique along with a dramatic extension of the FOV [BLA03, ERI08], up to whole-body size (2 m), using a low-cost per unit area particle detector, with excellent spatial resolution, uniform in the Field-of-View owing to its Depth-of-Interaction capability and time-of-flight resolution of 300 ps.
Furthermore, a very large field-of-view, taking the whole image simultaneously (single-bed), has supplementary potential advantages over narrow-FOV PET. These include the possibility of imaging simultaneously the whole body, allowing a more complete study of dynamic processes, covering the whole subject at any given instant with a better temporal segmentation. Other advantages include the possibility of achieving better quantitation through improved scatter correction, since there is no activity outside the FOV.

Innovative approach

Our approach is based on a detector technology already used in High Energy Physics Experiments for time-of-flight measurements on charged elementary particles: timing Resistive Plate Chambers (tRPCs). Such gaseous detectors have been deployed in areas over one hundred square meters at reasonable cost, while generally providing an excellent time resolution below 100 ps rms.
Several years ago our group proposed that such detectors might find useful application in TOF-PET technology, both for whole-body human scanning and small animal imaging [BLA03]. The application is based on the "converter plate"principle and takes decisive advantage of the naturally layered structure of tRPCs and of its economic construction in large areas. The expectable low efficiency for 511 keV photons is more than offset [COU07a, ERI08, CRE09] by the possibility to afford a very large field of view (FOV), on the order of 2 m.
The concept has also been independently reviewed [ERI08], although on a different set of assumptions, confirming that it may replace with advantage the present state-of-the-art crystal-based scanners for whole-body scanning.
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[ERI06] Future instrumentation in positron emission tomography, L. Eriksson et al., 2006 IEEE Nuclear Science Symposium Conference Record, Volume 4, Oct. 29 2006-Nov. 1 2006 Page(s): 2542 - 2545.
[ERI08] Potentials for large axial field of view positron camera systems, L. Eriksson et al., 2008 IEEE MIC Conference, published in the Conference Record.

6.2.3 Objectives

This work was continued in the framework of the RAD4LIFE project. Please see the corresponding report and plan.

Further funding opportunities will be vigorously pursued.

6.2.4 Team

Project coordinator: Paulo Fonte

Name	Status	FTE %
Alberto Blanco	Researcher (LIP)	20
Américo Pereira	Technician (LIP)	10
Carlos Silva	Technician (LIP)	10
Joaquim Oliveira	Technician (LIP)	10
Miguel Couceiro	Researcher (LIP/ISEC)	20
Nuno Carolino	Technician (LIP)	10
Orlando Cunha	Technician (LIP)	10
Paulo Crespo	Researcher (LIP/FCTUC)	20
Paulo Fonte	Researcher (LIP/ISEC)	25
Ricardo Caeiro	Technician (LIP)	10
Rui Alves	Technician (LIP) *	10
Rui Marques	Researcher (LIP/FCTUC)	10

6.3 Detectors and Monte Carlo in Medical Physics

6.3.1 Resumo

O projecto prevê as seguintes componentes:
1.Tomografia Computerizada com Raios-X para o diagnostico do cancro da mama: novas ferramentas Dosimetricas e de Qualidade de Imagem (Breast CT)
2.Estudos inovadores de simulação e modelação em Fisica das Radiações à escala nanométrica (RADNANO)
3. Radão na água: que vantagens ecológicas? (RAVE)
Breast CT
A técnica imagiológica que contribuiu para diminuir em cerca de 30% o cancro da mama é a mamografia, sendo amplamente utilizada em programas de rastreio. Porém, o rastreio mamográfico é actualmente um tema controverso relativamente à sua eficácia, debatendo-se se novas técnicas de diagnóstico 3D, como tomossíntese digital mamária (DBT) e a tomografia computorizada dedicada da mama (bCT) poderão substituir DM em programas de rastreio. A DBT é uma modalidade 3D promissora que envolve a aquisição de um reduzido número de projecções a baixas doses, em torno da mama comprimida e estacionária . Porém, a aplicabilidade da DBT em ambiente clínico encontra-se em investigação. Alguns estudos prospectivos [3] demostram que nos rastreios é benéfico utilizarem esta técnica, juntamente com aquisições de DM. A bCT apresenta potencial para se tornar a técnica ideal na detecção precoce das microcalcificações, com uma resolução elevada (na ordem dos 100 um).
RADNANO
Em anos recentes, verificou-se a utilização de um número crescente de novos radionuclidos nas aplicações médicas, para efeitos de diagnóstico e terapêutica. Terapias direccionadas utilizando emissores alfa e de Auger exploram o facto de a energia depositada por tais partículas ser fortemente localizada reforçando a eficácia biológica no tratamento do cancro. Entre os emissores alfa com maior potencial para utilizações clínicas contam-se 149Tb, 211At, 212Bi, 213Bi, 225Ac e 223Ra. A utilização de 223Ra para o tratamento de metástases ósseas em doentes com cancro da próstata resistente após a remoção da próstata foi já aprovada em mais de 40 países, incluindo os Estados Unidos e a União Europeia. E um estudo recente, envolvendo 921 pacientes, revelou uma redução de 30% na mortalidade dos pacientes a quem foi administrado 223Ra. Para além dos emissores alfa, isótopos tais
como 64Cu, 99mTc, 111In, 123I, 125I e 161Tb, a maioria dos quais amplamente utilizados em Medicina Nuclear para efeitos de diagnóstico, são emissores de electrões de Auger de baixa energia com alcance muito curto em tecidos biológicos, sendo também de relevância para este estudo.
Este projecto visa o desenvolvimento de metodologias inovadoras de simulação para determinar as características físicas dos emissores alfa e Auger e as características da estrutura dos seus percursos, ao nível da densidade de ionização (entre outros), e correlacioná-los com efeitos biológicos ao nível sub-celular.
RAVE
Na utilização doméstica, o radão presente na água constitui, em muitas habitações, uma segunda fonte de libertação, podendo inclusivamente exceder a proveniente do solo, contribuindo assim para o aumento da sua concentração, bem como dos seus descendentes directos, no ar interior. Uma vez que o risco proveniente do radão pode ocorrer por inalação ou por ingestão, tornase por isso pertinente estudar o efeito da exposição ao radão, por estas vias na população. De modo a compreender esta relação recorreuse ao estudo "Sistema Integrado Georreferenciado sobre Saúde, Doença e Ambiente da Beira Interior: Estudo Comunitário Longitudinal"que decorre desde 2014 na região da Beira Interior Norte. Neste estudo pretende se descrever o perfil sociodemográfico, estilo de vida, saúde, doença e eventuais factores de risco incluindo os de carácter ambiental da população.

6.3.2 Abstract

The following project components are foressen
1. Breast CT: New tools for Dosimetry and Image quality in breast cancer diagnostics
2. Novel approaches to RADiation Physics simulation and modelling at the NANOmetric scale (RADNANO)
3. Radon in water: what ecological benefits? (RAVE)
Breast CT
Mammography is the technique that contributes for a decreasing of about 30% in breast cancer, being widely used in screening programs. However, mammography screening is still subject of ongoing controversy regarding its effectiveness and more in specific, if relatively new 3D diagnostic techniques such as Digital Breast Tomosynthesis (DBT) and breast CT (bCT) could replace DM in screening programs. DBT shows promise as a 3D modality for breast imaging. DBT involves the acquisition of small number of low dose projections around a

stationary compressed breast. However, the applicability of DBT in the clinical setting is still under investigation. Despite this, some studies show that a real benefit in screening practices is only reached when DBT is
associated to standard DM acquisitions. In the other hand, bCT shows potential to become optimal for the early detection of micro calcifications with a very high resolution (of the order of 100 um). Considering that breast tissues are radiation-sensitive, a major drawback for this technique is the
high Mean Glandular Dose (MGD) involved in this examination. If bCT aims to be used as screening tool, this dose should lower than 5 mGy, as suggested by European guidelines [6]. Moreover, keeping low MGD values in a bCT exam, it means that the total exposure level should be distributed over a large number of projection views, making the image reconstruction process a challenging task, since each single view will have low signal-to-noise ratio .
RADNANO
In recent years, an increasing number of new radionuclides appeared in medical diagnostic and therapeutic procedures. Targeted therapies using alpha-, beta- and Auger emitters exploit the highly localized energy deposition of these particles, therefore enhancing the biological effectiveness of these radiations to treat cancer. Among the most important alpha-emitters with potential for clinical use are 149Tb, 211At, 212Bi, 213Bi, 225Ac and 223Ra. The use of 223Ra was already approved for the treatment of bone metastases in patients with castrate-resistant prostate cancer in more than 40 countries, including the United States and the European Union. Furthermore, a recent study, involving 921 patients, showed a reduction of 30% in the risk of death in patients receiving injections of 223Ra. Besides alpha emitters, isotopes such as 64Cu, 99mTc, 111In, 123I, 125I and 161Tb, most of
them widely used in diagnostic nuclear medicine, emit low-energy Auger electrons with very short ranges in biological tissues, becoming relevant to this study. The aim of this project is to develop novel simulation techniques, methodologies and approaches for determining the physical features of alpha and Auger electron emitters and correlate them with sub-cellular biological effects.
RAVE
Currently radiation protection protocols, for low doses effects are based on the extrapolations obtained, linearly, from effects observed at high doses and there is no safe threshold for radiation since even small doses produce biological effects. Nevertheless, we may consider the effects of radiation as "beneficial"or "harmful"depending on the biological context in which they occur. In domestic use, the radon present in water constitutes, in many homes, a second source of radon liberation, and may even exceed that from the soil, thus contributing to the increase of its concentration, as well as their direct descendants, in indoor air. Since de radon associated risks may occur through inhalation or ingestion becomes pertinent to study the effects of radon exposure through these routes on the population.

6.3.3 Objectives

Breast CT
An optimized dosimetric protocol will be necessary in order to routinely assess doses in clinical bCT examinations since this is a 3D imaging procedure, as such significantly different from their 2D counterparts. We intend to develop new physical phantoms that together with plastic scintillator detectors will be able to assess MGD with less uncertainties with respect to the ones involved for example in the Dance et al. MGD methodology estimation. These authors reported the total uncertainty in the MGD estimation of the order of 15%. Since a more uniform dose distribution was observed in CT irradiation of the breast, we intend to propose a new dosimetric protocol able to reduce uncertainties in dose assessments, first through Monte Carlo (MC) simulation optimization studies and then by developing specific physical phantoms that, together with suitable detector configurations, will able to precisely asses absorbed doses. Moreover, we will have the opportunity to perform measurements in one of the few bCT prototype systems existing in the world, which will allow realistic dose measurements using phantoms. Finally, the different imaging choices possible with bCT will be evaluated via MC in order to assess the organ doses in a bCT examination.
RADNANO
The project encompasses four main components: computational, experimental, radiobiological and clinical. The objectives are:
i) to develop novel approaches to Radiation Physics Modeling and Simulation at the micrometric (cellular) and nanodosimetric (DNA) scales
ii) to study radiation track structure and energy deposition patterns for alpha- and beta-emitters
iii) to assess the validity of dosimetric quantities at the micrometric and nanometric level
iv) to perform uncertainty analysis on state-of-the-art Monte Carlo computer programs (AlfaMC, GEANT4-DNA, PARTRAC, etc.)

v) to validate and benchmark the aforementioned computer programs with experimental results and
vi) to correlate the computational results with biological and clinical outcomes.
RAVE
In order to understand this relationship we used the study "Georeferenced System on Health, Disease and Environment of Beira Interior: Community Longitudinal Study"taking place in the North Beira Interior region since 2014. This study aims to describe the population demographic profile, lifestyle, health, illness and possible risk factors including the environmental ones. Variables selected from the survey applied to the inhabitants of the region in study and from the collection of biological material
(nails, hair, blood, urine, feces, saliva) will be studied. The results obtained will be mapped through the Integrated Geographical Monitoring System, enabling the risk factors georreferenciacion of the population, including those of environmental character. This project consists of two unique approaches: 1) a communitybased population study in a georeferenced cohort home by home 2) evaluation of the effects of different concentrations of radon in water in "in vivo"and "in vitro"environment.

6.3.4 Team

Project coordinator: Luis Peralta

Name	Status	FTE %
Alina Louro	Post-Doc (LIP)	80
Ana Campos	Master student (FCUL)	50
Conceição Abreu	Researcher (LIP)	50
Florbela Rego	Researcher (LIP)	90
João Antunes		67
Jorge Sampaio	Researcher (CFA/FCUL)	20
Luis Peralta	Researcher (LIP/FCUL)	57
Patrick Sousa	Researcher	20
Pedro Gabriel Almeida	Researcher (UBI)	20
Rui Carvalhal	Graduate student (LIP)	30
Sandra Soares	Researcher (LIP/UBI)	80

6.3.5 Academic Training

Master Theses

- **Estudo da atenuação da radiação ionizante em materiais heterogéneos usados na construção de barreiras de proteção radiológica**
  Sónia Dias, (on-going)

- **Simulação Monte Carlo de um sistema de tratamento de braquiterapia intra-uterina**
  Ana Campos, (on-going)

6.4 Orthogonal Ray Imaging for Radiotherapy Improvement

6.4.1 Resumo

Nas sociedades modernas o papel da radioterapia (RT) tem vindo a estebelecer-se como fundamental, verificando-se atualmente que o número de casos tratados por RT tem vindo a aumentar. No entanto, é também sabido que mesmo com as mais modernas técnicas de RT, tanto a taxa de cura efectiva como a toxicidade derivada de tratamentos de RT apresentam ainda margens para melhoria. O LIP, com o intuito de aumentar dentro do possível a eficácia dos tratamentos de RT, tem vindo a trabalhar numa linha de investigação denomindada de imagiologia de raios ortogonais. Esta divide-se fundamentalmente em dois conceitos: o sistema RTmonitor e o sistema OrthoCT. O sistema RTmonitor usa a imagiologia de raios ortogonais para monitorizar de certa forma a dose a ser efectivamente depositada no paciente. O sistema OrthoCT por sua vez adquire imagens do campo a ser irradiado momentos antes do tratamento, permitindo verificar se a morfologia do paciente e tumor se encontram de forma idêntica ao planeado. Simulações e primeiros resultados experimentais têm mostrado que, através destes conceitos de imagiologia, alterações morfológicas e ou fisiológicas pertinentes podem ser detetadas, providenciando assim importantes informações que potencialmente podem vir a melhorar os tratamentos de RT.
No âmbito da RT com fotões, o LIP colabora muito proximamente com a Universidade de Coimbra, o Instituto Português de Oncologia de Coimbra (IPOCFG,EPE), o Serviço de Radioterapia do Centro Hospitalar Universitário de Coimbra e com o Instituto Português de Oncologia do Porto (IPOPFG,EPE). Acrescente-se ainda que vários membros desta equipa de investigação viram a sua participação garantida financeiramente através de bolsas de mestre e de pósdoc atribuídas no âmbito do projecto "Radiation for Life". Este projecto, financiado em ca 1.2 milhões de Euro, resulta de uma candidatura em parceria entre o LIP e a Universidade de Coimbra. O seu financiamento foi aprovado em 2013 e no verão do mesmo ano tiveram início as suas atividades de investigação. A linha de investigação em imagiologia de raios ortogonais é parte integrante deste projeto.
No que concerne à terapia com partículas (protões e iões de carbono), a imagiologia de raios ortogonais pode também ser denominada de, em Inglês, "prompt gamma imaging". Tal advém do fato de os fotões que escapam o paciente terem origem em desexcitações nucleares após a interação entre os projéteis penetrantes e os núcleso no tecido do paciente. Neste contexto o LIP colabora ativamenmte com a Universidade Técnica de Delft, na Holanda, com o Centro de Terapia com Iões de Heidelberg, na Alemanha, e com a Universidade de Munique, também na Alemanha.

6.4.2 Abstract

Radiotherapy (RT) plays a growing, well established role in the management of cancer disease in modern societies. Nevertheless, it is also well known that even with newer, state-of-the-art machinery delivering highly conformal RT, effective cure rates or minimization of toxicity still present today margins for improvement. With the aim of further improving the efficacy of external photon beam RT, LIP has been exploring within this line of research the capability of using orthogonal ray imaging systems to monitor to some extent both the dose that is being delivered to the patient (RTmonitor) as well as its morphology within the irradiated field (OrthoCT). In this way, simulations and experimental work have shown (see Fig.) that pertinent dose-changing morphological or physiological alterations may be detected, which results in important information for assisting and potentially improving RT treatments.
In the photon RT field, LIP collaborates tightly with the University of Coimbra, the Oncology Institute of Coimbra (IPOCFG,EPE), the Department of Radiotherapy of Coimbra University Hospital Center, and with the Oncology Institute of Porto (IPOPFG,EPE). Several expert members are now fully supported with master and postdoc fellowships granted by the Radiation for Life project. This 1.2-million-Euro funded project was proposed within a tight collaboration between LIP and the University of Coimbra. Upon successful approval for funding, the project deployed in the Summer of 2013. One of its research lines is this orthogonal ray imaging initiative.
In the context of particle therapy (protons and carbon ions), orthogonal ray imaging may also be called prompt-gamma imaging since here escaping photons are gamma rays created in excited nuclei during the interactions of the incoming projectiles with the atomic nuclei of the patient. Here LIP is actively collaborating with the Delft University of Technology, The Netherlands, with the Heidelberg Ion Beam Therapy Center, in Germany, and with the University of Munich, also in Germany.

6.4.3 Objectives

The objectives of the research line on orthogonal ray imaging (RTmonitor and OrthoCT) can be divided mainly twofold, namely in the simulation and experimental fields.

In respect to simulations, a full system has been analyzed. A small prototype is under construction. In OrthoCT, for example, multi-parameter optimizations include septa and air-slice thicknesses, system length and total area, choice of heavy scintillator for stopping X-rays produced in bunches of 3 microsecond duration, choice of readout mode for the electronics and choice of digital signal processing filters so that pertinent morphological and dose alterations are detected with high sensitivity and specificity. Results obtained so far are very encouraging (vide Fig.).
Regarding experimental work, funding obtained in contest from the University of Coimbra has already allowed to purchase 200 heavy scintillators of gadolinium silicate (GSO). A multi-slice prototype detector should now be constructed and its operation under several modern irradiation techniques should also be tested, namely under clinical linear accelerators operating with beam flattening filter (more classic approach) and in more modern flattening-filter-free mode.

6.4.4 Team

Project coordinator: Paulo Crespo

Name	Status	FTE %
Hugo Simões	PhD student (LIP/FCTUC)	75
Patrícia Cambraia Lopes	PhD student (LIP/TU-Delft/FCT)	100
Paulo Crespo	Researcher (LIP/FCTUC)	50
Sónia Sousa	Master student (LIP)	100

6.4.5 Academic Training

PhD Theses

- **Demonstration of a time-of-flight device for particle therapy monitoring**
  Patrícia Cambraia Lopes, (on-going)
- **Demonstration of an orthogonal ray imaging device for assisting external photon beam radiotherapy**
  Hugo Simões, (on-going)

6.5 Adaptive methods for medical imaging with gamma cameras

6.5.1 Resumo

A nossa equipa desenvolveu recentemente um novo método de calibração no qual as funcões de resposta dos fotosensores num detector de cintilação são calculadas iterativamente a partir de irradiações ditas de campo uniforme (quando o detector é uniformemente irradiado por uma fonte radioativa sem colimador). De facto, o método desenvolvido não apresenta exigencias intrinsecas quanto à uniformidade da irradiação ou ao espectro de energia, fazendo com que o processo de calibração seja simples e rápido. Verificou-se igualmente, usando tanto dados simulados como os obtidos experimentalmente, que este método pode ser aplicado com sucesso a uma câmara gama clínica.

Durante o projeto anterior, desenvolvemos um pacote de software integrado para simulação e reconstrução de eventos de cintilação em câmaras de geometria configurável. Usando dados simulados demostramos que, para uma câmara gama médica com geometria típica, o método iterativo produz funcões de resposta muito parecidas com a resposta do foto-sensor utilizada para simular os dados de campo uniforme. Para confirmação experimental destes resultados, foi utilizada uma câmara gama clinica descomissionada e uma máscara contendo riscas com diversas orientações. Os resultados obtidos mostram imagens sem distorções relevantes ao longo de todo o campo de visão. É de salientar que o método desenvolvido permitiu monitorizar continuamente e em tempo real as variações do ganho dos PMTs e consequentemente auto-recalibar a câmara.

Neste projeto pretendemos actualizar o sistema de aquisição do protótipo construído no projecto anterior a partir de uma câmara gama clínica. Pretende-se com esta actualização melhorar a taxa de aquisição e tempo de integração de fotões. Estas melhorias permitirão alcançar características equivalentes às esperadas de um modelo comercial de modo a tornar esta tecnologia mais atraente para os potenciais investidores.

Numa linha de trabalho paralela pretendemos igualmente aplicar esta técnica de calibração a câmaras gama compactas usando reconstrução estatística em tempo real. Para isso, vamos combinar a nossa abordagem iterativa com métodos de aprendizagem automatica para desenvolver técnicas híbridas de reconstrução das funções de resposta em cristais retangulares e integrá-los no nosso pacote de software. Pretendemos igualmente desenvolver a câmara gama compacta no que diz respeito à optimização do seu campo de visão, aumento da resolução em posição e obtenção de informação da profundidade da interacção no cristal. Estão previstos dois protótipos: a câmara de cristal fino para uso com colimador paralelo e uma câmara com a espessura maior, com um colimador "pinhole"para SPECT para pequenas animais.

6.5.2 Abstract

Recently, our team has developed a novel calibration method by which the light response functions (LRFs) of the photosensors in a position sensitive scintillation detector can be iteratively calculated from the standard flood field calibration (the detector is uniformly irradiated by an uncollimated radioactive source). There is no strict requirement on the irradiation uniformity or the energy spectrum, making the calibration process straightforward and quick. We have also confirmed, using both simulated and experimental data, that this method can be successfully applied to a clinical gamma camera of classical design.

In the course of the previous FCT project, we have developed an integrated software package specifically targeting scintillation cameras and providing a set of easy-to-use tools for simulation and reconstruction of scintillation events in cameras of configurable geometry. Using simulated data we have shown that for a typical medical gamma camera geometry, the iterative method produces the LRFs that are very close to the photosensor response used to simulate the flood field data. To obtain experimental confirmation, we upgraded a decommissioned clinical gamma for list mode data acquisition with which images of a bar phantom were obtained showing little to no distortion over the whole field of view. We were also able to continuously monitor variations of the PMT gain from acquired data in real time.

In this project we plan to upgrade the acquisition system of the prototype of the self-calibrating clinical camera, constructed during the previous project, in order to improve acquisition rate and photon integration time. This will allow to reach characteristics expected from a commercial model and help to attract potential investors.

As a parallel line of work we intend to apply a similar calibration technique and implement real-time statistical position reconstruction to compact gamma cameras. For this, we plan to combine our iterative approach with machine learning methods to develop hybrid technique(s) for reliable LRF reconstruction in rectangular crystals and integrate it into our software package. We will develop and optimize design of compact gamma camera in order to maximize the undistorted field of view, achieve highest possible spatial resolution and to attempt accurate depth of interaction reconstruction. Two prototypes are envisaged: a thin crystal camera for use with a parallel hole collimator and a thicker camera with a pinhole collimator for small animal SPECT.

6.5.3 Objectives

Three tasks will be executed in the framework of this project:

1. Build a working prototype of a high-resolution compact camera with self-calibration capabilities
2. Explore possibility of using machine learning algorithms for position and response reconstruction:
   - artificial neural networks (ANN)
   - k-nearest neighbour (k-NN)
   - gaussian mixture models (GMM)
   - self-organizing map (SOM)
3. Prepare to commercialize the concept of self-calibrating clinical gamma camera
   - build an operational prototype of self-calibrating clinical camera with upgraded front-end and acquisition electronics.
   - achieve spatial and energy resolution, as well as acquisition rate comparable to those of commercial systems.
   - characterize long term stability of the camera

The expected outcome:

- novel reconstruction techniques developed, integrated in our software package and validated using simulated and experimental data;
- compact camera prototype built and tested;
- ready to look for investors with the self-calibrating gamma camera prototype.

6.5.4 Team

Project coordinator: Vladimir Solovov

Name	Status	FTE %
Alessio Mangiarotti	Researcher (USP)	20
Alexandre Lindote	Post-Doc (LIP)	12
Andrey Morozov	Researcher (LIP)	19
Filipa Balau	PhD student (LIP)	50
Francisco Neves	Post-Doc (LIP)	13
Isabel Lopes	Researcher (LIP/FCTUC)	20
Luís Pereira	PhD student (LIP)	30
Valdemar Domingos	Master (LIP)	100
Vitaly Chepel	Researcher (LIP/FCTUC)	30
Vladimir Solovov	Researcher (LIP)	32

6.5.5 Academic Training

PhD Theses

- **Real-time statistical event reconstruction for medical scintillation cameras**
  João Marcos, (on-going)

Master Theses

- **Optimization of compact gamma camera for medical imaging**
  Raimundo Martins, (on-going)

6.6 Rad for Life

6.6.1 Resumo

Rad4Life ou "Rad for Life"(Radiação para a Vida), é um projecto submetido pela Universidade de Coimbra em parceria com o LIP. Financiado com cerca de 1 milhão de Euros pelo QREN Mais Centro, este projecto com uma extensão de até 30 meses e iniciado em 1 de Julho de 2013, visa explorar aplicações à área da saúde - nomeadamente na imagiologia e na monitorização e controlo de radioterapia - de tecnologias de detecção de radiação surgidas na Física de Partículas.
De facto, nas experiências de Física de Partículas e no longo trabalho de I&D levado a cabo pelas equipas do LIP, tem-se desenvolvido uma série de tecnologias e arquitecturas que provaram ter amplo potencial de aplicação em áreas de interesse para a sociedade, nomeadamente na saúde e na segurança.
Visando inicialmente a contratação de seis doutorados, um deles como Professor Auxiliar da FCTUC, o projecto permite, neste período de grandes constrangimentos, manter uma equipa capaz de potenciar algumas das linhas de trabalho científico que têm vindo a ser seguidas pelo LIP, criando condições para progredir em diversas frentes:
i) Aplicação à PET (Tomografia por Aniquilação de Positrões) de detectores de placas resistivas (RPC), com o desenvolvimento e teste de protótipos de scanners de PET‑Animal e de PET‑Humano;
ii) Exploração em SPECT (Single Photon Emission Computed Tomography) dos avanços conseguidos nas técnicas de localização da interacção de fotões em meios cintiladores;
iii) Desenvolvimento de técnicas inovadoras de monitorização (e melhoria de eficácia) da radioterapia e estudo de novos dosímetros à base de fibras de cintilantes;
iv) Aplicações de detectores gasosos de xénon a alta pressão e com grande área de detecção aos campos da saúde e da segurança.

6.6.2 Abstract

Rad4Life or "Rad for Life"(Radiation for Life), is a project submitted by the University of Coimbra in partnership with LIP. Funded by QREN Mais Centro in about 1 M€, this project with an initial duration of up to 30 months, started on July 1st, 2013, aims at exploring applications to the biomedical area of new techniques of imaging and radiotherapy control and monitoring as well as radiation detection technologies emerging from Particle Physics.
Indeed, in the work carried on by the LIP-Coimbra teams either in Particle Physics experiments or in the renown R&D of detecors, a series of detection technologies and architectures have been developed which are potentially beneficial in areas of general interest for society, particularly in health and in homeland security. In a period of great financial constraints "Rad for Life"was initially designed to allow the contract of six PhDs, one of them in a position of Assistant Professor at the University of Coimbra, thus maintaining a team capable of pursuing some lines of work that have been successfully followed by LIP and creating conditions for progressing in various fields:

- Application to PET (Positron Emission Tomography) of resistive plate detectors (PRC), through the development and test of prototype scanners for animal and human PET;
- Exploring in SPECT (Single Photon Emission Computed Tomography) progresses made in techniques for localization of the interaction point of photons in scintillators;
- Developing innovative techniques for monitoring (and improving the effectiveness) of radiotherapy and for studying new dosimeters based on scintillating fibers;
- Applications of high pressure and large area gaseous xenon detectors to homeland security.

6.6.3 Objectives

The deadline for the project execution was recently postponed till end of September 2015, with no budget change.New opportunities for applying to regional funds will be open (probably by mid 2015), probably with especial focus on applications to medicine and health sciences. In order to qualify for those applications, it is important that, besides of the full financial execution of present project (perfectly achievable in our case), several publications from Rad4Life appear in the meantime.
Although the requirements for such calls are not clear yet, they may give preference to projects carried out in collaboration with industries. Anyway, these and any further funding opportunities to maintain our work in applications to health sciences will be vigorously pursued.

Main Goals for 2015
Animal RPC-PET
- Number of RPCs/head will be extended from 3 to 7 (out of a maximum of 10), in principle quadrupling the sensitivity.
- A new version of the front-end electronics will be developed, trying to minimize the digital noise induced by the ADCs into the trigger system, which considerabl reduces the sensitivity of the scanner.
Human RPC-PET
- Test of the readout system started in 2014 will be completed
- Development of a realistic RPCs and (very thin) electrodes, aiming at a first full-body scanner prototype.
SPECT
- Finalize characterization of the adaptive reconstruction method applied to a round shaped full size gamma camera.
- Finalize data analysis on wavelength shifter stability in liquid xenon and submit a paper.
- Test SiPM arrays at low temperature.
- Extend adaptive reconstruction method to rectangular geometry.
Radiotherapy
- Assembly and bench test of the small prototype OrthoCT detector consisting 200 finger-like crystals of GSO (gadolinium oxyorthosilicate).
- Tests of that prototype under therapy-like conditions (at IPOCFG-EPE, Chuc-EPE, in Coimbra, and/or IPOPFG-EPE, Porto); the necessary readout electronics has been kindly made available by German laboratories (HZDR in Dresden and GSI in Darmstadt).
HIGH PRESSURE Xe
- Publications of results is an immediate task to carry out.
- Other additives, presently under scrutiny, shall be tested.
- High pressure detector tests will start, as soon as construction and assembly are finished.

Chapter 7

Radiation Environment Studies and Applications for Space Missions

7.1 Space Radiation Environment and Effects

7.1.1 Resumo

O LIP iniciou a actividade de desenvolvimento de aplicações para o estudo do ambiente de radiação no espaço e seus efeitos há mais de 10 anos e é reconhecido pela Agência Espacial Europeia como uma referência em Portugal nesta área. Esta actividade baseia-se na aplicação de ferramentas e tecnologias utilizadas no desenvolvimento de experiências e na análise de dados nas áreas da física experimental de altas energia, física nuclear e astropartículas, aos problemas colocados pelo ambiente de radiação no espaço e noutras superfícies planetárias. Os desafios para os próximos anos centram-se na expansão da actividade e o aumento de sinergias com parceiros nacionais e internacionais, incluindo-se neste espectro a universidades e a indústria. Os temas de cobertos nesta actividade são:

- Estudo e modelização do ambiente de radiação no espaço, incluindo ambientes de radiação planetários, nomeadamente a Lua, Marte, Europa, Ganimedes e asteroides.
- Análise de dados de detectores de partículas /radiação energética em missão espaciais;
- Estudo dos modelos de propagação de SEP - eventos de partículas energéticas solares e teste destes modelos com dados reais, na continuação da actividade inicida com o projeto "Participação Portuguêsa na Rede Heliosférica";
- Estudo e desenvolvimento de conceitos para monitores de radiação (com base em sensores de Si e/ou em cintiladores) e exploração destes conceitos para utilização em diferentes ambientes planetários e interplanetários, tanto no suporte das missões como na análise de dados científicos;
- Estudo, modelização e testes em feixe dos efeitos da radiação em componentes EEE utilizados em missões no espaço;
- Estudo dos efeitos biológicos do ambiente de radiação no espaço, nas atmosferas e superfícies planetárias;
- Estudo e desenvolvimento de estratégias de mitigação para os riscos da exposição à radiação no espaço, tanto para os sistemas e componentes das missões como e para as tripulações.

7.1.2 Abstract

The Space Radiation Environment and Effects group activities started more than 10 years ago at LIP and the Group is now recognized by the European Space Agency as a national reference in this field. The activity is based in the application of technologies and tools used in the development of high energy physics experiments, in nuclear instrumentation and astroparticle physics to the problems posed by the radiation environment in Space and planetary surfaces and atmospheres. The challenge for the coming years is to expand the group activity and resources and to establish additional synergies with national and international partners, both academic and industrial, in the group area of activity and related areas. The research themes within the scope of the activity are:

- Study and model the radiation environment in Space, including planetary radiation environments, namely the Moon, Mars, Europa, Ganymede and asteroids radiation environments. Improvement and validation of the models with real data, starting from dMEREM model concept, the Geant4 based model developed for the Martian radiation environment;
- Analysis of Space mission energetic particle/radiation data;
- Follow up of the evolution on SEP (Solar Energetic Particle events) models and their test with radiation monitor data, initiated with the project "Portuguese Participation in the Heliospheric Network";
- Study and development of detector design concepts for radiation monitors (based in Si sensors and/or in scintillators) and exploitation of these designs in different planetary and interplanetary environments, both for platform support and for scientific data analysis;
- Study, model and ground testing of the effects of radiation in EEE components;
- Study biological effects of the radiation environment in space and in planetary atmospheres and surfaces;
- Study and develop mitigation strategies for radiation hazards, both for spaceship systems and components and for human spaceflight.

7.1.3 Objectives

The objectives of this activity for 2015 are to continue with the ongoing contracts in which LIP is involved with ESA and with its contractual partners and to search for other opportunities in the framework of ESA ITTs or within the H2020 programme. Among the ongoing contracts, the RADEM contract will continue to 2016, but the remaining three are foreseen to be completed in 2015.
The RADEM (RADiation hard Electron Monitor for the JUICE mission) contract started in May 2014 with a duration of 30 months. The aim of the project is to develop the RADEM proto-flight model. LIP is responsible for the development of the design concept the RADEM electron Directional Detector, one of the three RADEM sensor heads, and for its calibration and data analysis. Therefore concerning the RADEM contract, in 2015 the group will be involved in the development and optimization of the RADEM Directional Detector, in its simulation, calibration and calibration data analysis and also on the radiation analysis of the RADEM.
The contract "ECo-60"between LIP and ESA started in February 2014, with a duration of 15 months. In this project, the representativeness of Co-60 Total Ionizing Dose tests for EEE components to be flown in the Jovian electron environment is being verified by performing radiation tests in EEE components with both types of source particles: Co-60 gammas and electrons with energies above 10 MeV. During 2015 the component tests with electrons and Co-60 sources will be performed and the corresponding data will be analyzed, closing the activity.
The MFS data analysis contract with ESA, in which LIP collaborates with EFACEC will started in March 2014, with a duration of 12 months. In 2015 LIP will finish the development of an algorithm for particle energy spectra reconstruction and will perform MFS in-flight data analysis and cross-comparison with radiation environment models and other in-flight radiation monitors data, closing the contract.
CODES, the Component Degradation Simulation tool is a GEANT4 based top level engineering tool, to predict Single Event Effects in EEE devices. CODES was developed at LIP and it consists of different GEANT4 modules with a user friendly web-based interface. In 2015 LIP will release the wed based CODES framework, for whose management and maintenance LIP will be responsible until the present CODES contract extension is closed.
An important objective for 2015 is to consolidate the group with one more senior researcher and to increase the numbers of MsC and PhD Students, reinforcing the Group connection to university. MsC and PhD thesis subjects in this area are available to Physics and Physics Engineering Students at Instituto Superior Técnico. A PhD student started his work in November 2104 in the development of the DD detector for the RADEM and there are currently two students working on their MsCs in the following subjects: "Space Radiation Environment Effects in Human Space Flight"and "Radiation Environment and its effects on the Martian surface and underground". In the case of the latter subject, it is being explored in the continuation of LIP activity in the development of the dMEREM, the detailed Martian Energetic Radiation Environment Model and LIP is collaborating with its former partners in the MarsREM project and with the Space Research Centre Dept. Physics & Astronomy of the University of Leicester, with the aim of evaluating the radiation environment in the Martian subsoil from the astrobiology point of view.

7.1.4 Team

Project coordinator: Patrícia Gonçalves

Name	Status	FTE %
Alessandro de Angelis	Researcher (LIP)	10
Bernardo Tomé	Researcher (LIP)	20
Bruno Morgado	PhD student (LIP)	100
Catarina Espírito Santo	Researcher (LIP)	10
Luisa Arruda	Post-Doc (LIP)	80
Marco Alves Pinto	(LIP)	90
Patrícia Gonçalves	Researcher (LIP)	69
Pedro Assis	Post-Doc (LIP/FCT/IST)	10

7.1.5 Academic Training

PhD Theses

- **Participation in the Heliospheric Network: Analysis of Solar Particle Events Measured with the EPAM and HISCALE Detectors**
  Bruno Morgado, (on-going)
- **A Directionality Detector for the JUICE mission Radiation Hard Electron Monitor**
  Marco Alves Pinto, (on-going)

7.2 Integrated Activities for the High Energy Astrophysics Domain

7.2.1 Resumo

AHEAD (Activities in the High Energy Astrophysics Domain) project was submitted to the INFRAIA-2014-2015 call Research Infrastructures for High EnergyAstrophysics and was approved for two year funding starting by mid-2015. The overall objective of AHEAD is to integrate national efforts in high-energy Astrophysics and to promote the domain at the European level, to keep its community at the cutting edge of science and technology in this competitive research area and ensure that space observatories for high-energy astrophysics are at the state of the art. AHEAD will integrate key research infrastructures for on-ground test and calibration of space-based sensors and electronics and promote their coordinated use. In parallel, the best facilities for data analysis of high-energy astrophysical observatories will be made available to the European community. This initiative will provide new tools to our group to prepare stronger and solid proposals to future ESA call for missions.
Our group will contribute do WP8 of AHEAD. The WP8 title is "Development and characterization of optics for next generation X-ray telescopes". The goal of this work package is to further develop and characterize key X-ray optics technologies for the next generation X-ray missions. In the framework of AHEAD consortium effort, together with our partners of the Istituto di Astrofisica Spaziale e Fisica Cósmica, Bologna, Italy, novel focal planes will be developed, simulated and tested. A 3D position sensitive CdZnTe prototype will be developed, that will operate in PTF (Planar Transverse Field) configuration with drift microstrip readout of each sensitive units and the three dimensional spatial resolution. In order to increase the photon absorption thickness up to 20 mm without increasing the charge collection distance, the charge collecting field is perpendicular with respect to the optical axis of the crystal. Furthermore multiplanar CdTe focal planes will be studied and the effects of space radiation on the instruments´ performance will be tested and analyzed under an experimental beam. Development and optimization of GPD will be performed, in particular by studying gaseous mixtures optimization (Xenon, Argon, etc.) for photoelectric based polarimetry, both through experimental and simulation work.
ASTROGAM (http://astrogam.iaps.inaf.it/) and the XIPE (X-ray Imaging Polarimetry Explorer) mission proposals submitted last January, 15th, 2015 to ESA Cosmic Vision Call for M class missions will be evaluated during 2015. If one of these missions will be approved, the focal plane development efforts will be oriented to space qualified solutions in order to address the requirements of second phase mission selection and evaluation process. In case neither of these missions will be approved the respective consortia will continue their efforts for next ESA call for missions supported by AHEAD activities.

7.2.2 Abstract

AHEAD (Activities in the High Energy Astrophysics Domain) project was submitted to the INFRAIA-2014-2015 call Research Infrastructures for High EnergyAstrophysics and was approved for two year funding starting by mid-2015. The overall objective of AHEAD is to integrate national efforts in high-energy Astrophysics and to promote the domain at the European level, to keep its community at the cutting edge of science and technology in this competitive research area and ensure that space observatories for high-energy astrophysics are at the state of the art. AHEAD will integrate key research infrastructures for on-ground test and calibration of space-based sensors and electronics and promote their coordinated use. In parallel, the best facilities for data analysis of high-energy astrophysical observatories will be made available to the European community. This initiative will provide new tools to our group to prepare stronger and solid proposals to future ESA call for missions.
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process. In case neither of these missions will be approved the respective consortia will continue their efforts for next ESA call for missions supported by AHEAD activities.

7.2.3 Objectives

AHEAD overall objective of AHEAD is to integrate national efforts in high-energy Astrophysics and to promote the domain at the European level, to keep its community at the cutting edge of science and technology in this competitive research area and ensure that space observatories for high-energy astrophysics are at the state of the art. By participating in AHEAD we expect to acquire new tools to prepare stronger and solid proposals to future ESA call for missions. Through our participation in the WP8 ("Development and characterization of optics for next generation X-ray telescopes") we expect to improve our focal plane development capacity, that will provide a precious help to prepare future X- and gamma-ray mission proposals and that will provide better tools and increased expertise in case of ASTROGAM or XIPE will be approved by the ESA.

7.2.4 Team

Project coordinator: Rui Curado Silva

Name	Status	FTE %
Alexandre Fonseca Trindade	Master (LIP)	30
Carlos Conde	Researcher (LIP)	20
Carlos Patacas	Master (LIP)	20
Filipa Borges	Researcher (LIP)	15
Filomena Santos	Researcher (LIP)	20
Jorge Maia	Researcher (LIP/UBI)	45
José Escada	Post-Doc (LIP)	20
José Marques	PhD student (LIP)	60
Marco Alves Pinto	(LIP)	10
Miguel Moita		100
Nelson Simões	Master student (LIP)	80
Rui Curado Silva	Researcher (LIP)	85
Teresa Dias	Researcher (LIP)	15

7.2.5 Academic Training

PhD Theses

- **Experimental CdTe Polarimeter development**
  José Marques, (on-going)
- **ASTROGAM Space Gamma-ray Telescope Main Instrument Development**
  Miguel Moita, (on-going)

Master Theses

- **Development and Analysis of inflight performance of a CZT Prototype for Gamma-Ray Astronomy**
  Nelson Simões, (on-going)

Chapter 8

Higher Education and Advanced Training, Technological Transfer and Outreach Activities

8.1 Higher Education and Advanced Training

8.1.1 Objectives

LIP will continue to contribute to physics and engineering education at Portuguese high-education institutions thanks to the direct intervention of senior LIP researchers as invited Professors in higher education institutions. LIP coordinates joint PhD programs involving several Portuguese Universities, namely:

- DAEPHYS for applied and Engineering Physics, with Aveiro, Coimbra, Lisboa and Nova de Lisboa Universities;
- IDPASC-Portugal for Particle and Astroparticle Physics, Astrophysics and cosmology with Coimbra, Évora, Lisboa, Minho and Porto Universities. This Program is part of an international network of Universities and research institutions, counting with the participation of universities and research institutions in Portugal, Spain, France, Italy, Slovenia, and Brazil as well as with CERN and EGO.

Both DAEPHYS and IDPASC-Portugal PhD programs will open in 2015 new calls for PhD grants. LIP will also go on actively collaborating with MAP-fis (joint Physics PhD program of Minho, Aveiro and Porto Universities) and DP-PMI (Physics and Mathematics for future Information Technologies PhD program of IST).

8.2 Technology Transfer

8.2.1 Resumo

Rede HEPTech - TTN
A HEPTech é uma rede de transferência de tecnologia da área da física de alta energias (TTN) que ambiciona ser reconhecida como "o ponto de acesso para a inovação de infraestruturas de investigação em aceleradores e detectores". Reúne as principais instituições Europeias de pesquisa fundamental em física de altas energias (CEA, CERN, CNRS, CPAN, DEMOKRITOS, DESY, ELI-ALPS, ELI BEAMLINES, EPFL, ESS, GSI, IJS, IFIN-HH, INFN, INOVACENTRUM, KTN, NTUA, LIP, NTUA, Universidade de Sofia, STFC, Universidade de Belgrado, Instituto Weizmann, Wigner RCP). Neste domínio é complexo e dispendioso transferir a investigação e desenvolvimento para aplicações, produtos e processos e transformá-los em oportunidades comerciais. A HEPTech, como uma fonte de excelência em tecnologia e inovação, tenta preencher a lacuna entre os investigadores e a indústria, através da organização de um conjunto de actividades: 1) AIME - Academia Industry Matching Events, 2) Workshops sobre Transferência de Tecnologia, 3) Show and Tell - showcase de actividades e ferramentas relacionadas com a transferência do conhecimento. O LIP, sendo nó membro da HEPTech, segue as diversas iniciativas da rede e mantém-se actualizado sobre o conhecimento da transferência de tecnologia e os processos de comercialização no domínio da investigação fundamental em física de altas energias.
Industrial Liaison Officer - ILO
O mandato da ILO é apoiar e promover activamente a indústria nacional e instituições de I&D no CERN, ESO, ESRF e contribuir para o seu sucesso no processo de aquisição de bens e serviços. Neste âmbito, o ILO pode garantir um retorno industrial positivo para Portugal potenciando impacto na economia e facilitando a internacionalização de know-how industrial, produtos e serviços inteiramente nacionais.

8.2.2 Abstract

HEPTech network - TTN
The HEPTech is a unique high energy physics technology transfer network (TTN) that aims to become "the innovation access point for accelerator and detector driven research infrastructures". Bringing together leading European high energy physics research institutions (CEA, CERN, CNRS, CPAN, DEMOKRITOS, DESY, ELI-ALPS, ELI BEAMLINES, EPFL, ESS, GSI, IJS, IFIN-HH, INFN, INOVACENTRUM, KTN, NTUA, LIP, NTUA, SOFIA University, STFC, University of Belgrade, WEIZMANN Institute, WIGNER RCP) which work across a range of world-leading scientific areas in the field of Particle Physics, Astrophysics and Nuclear Physics. It is challenging and costly to carry further research and development focused in applications, products and processes and turn them into commercial opportunities. HEPTech, as a source of technology excellence and innovation, tries to bridge the gap between researchers and industry by organizing a set of activities: AIME - Academia Industry Matching Events, 2) Workshops about Technology Transfer, 3) Show and Tell - showcase about activities and tools related to knowledge transfer. LIP, as a HEPTech node member, follows the various initiatives of HEPTech and maintains updated its knowledge about technology transfer and the paths of commercialization from fundamental research in high energy physics.
Industrial Liaison Officer - ILO
The ILO mandate is to support and actively promote national industry and R&D institutions to CERN, ESO, ESRF and contribute to their success in the procurement process. By doing this, the ILO may ensure a positive industrial return to Portugal impacting the national economy and the internationalization of Portugal´s industry know-how, products and services.

8.2.3 Objectives

HEPTech network - TTN
- Ensure a link to the HEPTech webpage: http://www.heptech.eu/ to be included at LIP Outreach web platform.
- As a node member in the HEPTech network, promote among the LIP community and participate, as deemed possible on AIME - Academia Industry Matching Events, Workshops about Technology Transfer, Show and Tell initiatives and the HEPTech Symposium.
- Organize, per request, bilateral meetings with LIP researchers (in Lisbon and Coimbra) about Intellectual Property and Technology Transfer, leveraging the experience of participating in the HEPTech network.
Industrial Liaison Officer - ILO
- Support in organizing the 15 years celebration of the traineeship programme established between Portugal and the International organizations CERN, ESO and ESA.
- Support in organizing the 15 years celebration of the Portugal´s accession to ESO and at the same occasion the realization of ESO Council meeting in Lisbon.

- Establish as much as possible, company presentations to technical departments and/or groups at CERN, ESO, ESRF. Always involve, as deemed possible, Portuguese staff at these venues. And, along with the FCT Space Office have an integrated approach towards the companies operating in the space sector, mainly for ESA.
- Organize and/or participate at industrial events to promote companies at CERN, ESO and/or ESRF, such as: Visit of firms @ CERN, Industry day @ ESO and Industry day @ ESRF.
- Attend, when possible, industry trade-shows and/or targeted events (nationally and internationally) to carry through targeted assessments about the different industrial sectors in Portugal that can contribute to the ILO activities.

8.2.4 Team

Project coordinator: Emir Sirage

Name	Status	FTE %
Emir Sirage	Technician (LIP)	100

8.3 Outreach Activities

8.3.1 Resumo

O LIP promove o avanço do conhecimento científico para o público em geral, estudantes e professores do ensino secundário, além do treino avançado nas suas áreas de actividade específicas. O grupo de Divulgação Científica é constituído por investigadores do LIP que sentem a necessidade de promover a literacia científica na sociedade e de procurar, motivar e treinar os cientistas de amanhã. Este grupo trabalha de perto com todos os projectos de investigação do LIP, ajudando a explorar as possibilidades de divulgação e promovendo novas actividades, organizando também acções regulares que vão além do trabalho específico de cada projecto.

As suas actividades abrangem diferentes áreas e diferentes públicos alvo, embora se foque principalmente nas comunidades escolares (alunos, professores e famílias), principalmente ao nível das escolas secundárias. As actividades regulares podem ser agrupadas em:

1) Seminários de divulgação e sessões públicas, por convite das escolas ou à margem de eventos científicos promovidos pelo LIP; em particular, realizar palestras nas escolas que visitam o CERN, para que possam rentabilizar a visita que irão fazer.

2) Actividades ao longo do ano escolar, nomeadamente as enquadradas no projecto de Radiação Ambiente, que funciona há vários anos num número crescente de escolas.

3) Participação no Programa de Ocupação Científica de Jovens em Férias, em que diferentes projectos no LIP recebem alguns estudantes para estágios de uma ou duas semanas;

4) As "Masterclasses"Internacionais em Física de Partículas, uma actividade de um dia inteiro em que os estudantes seguem as tarefas de um cientista, com palestras, análise de dados e discussão dos seus resultados. As "Masterclasses"envolvem anualmente milhares de estudantes em todo o país e em coordenação internacional pelo IPPOG;

5) O Programa do CERN para Professores em Língua Portuguesa, em que professores dos países de língua oficial portuguesa passam uma semana no CERN, com aulas de actualização sobre Física de Partículas e o Universo, sessões práticas experimentais e visitas ao complexo de aceleradores e experiências do CERN, acompanhados por investigadores portugueses;

6) A participação na "Noite Europeia dos Investigadores", em parceria com o Planetário Calouste Gulbenkian, já se tornou uma prática regular do laboratório;

7) Participação em grupos internacionais dedicados à Divulgação e Comunicação, nomeadamente o IPPOG - Grupo Internacional de Divulgação da Física de Partículas - e o EPPCN - Rede Europeia de Comunicação em Física de Partículas - dedicado à divulgação das actividades do CERN nos seus países membros;

8) Criação e adaptação de conteúdos relacionados com Física de Partículas e Astropartículas para a web, para exibições, para as escolas, etc.

9) Criação e adaptação de Comunicados de Imprensa, editados pelo CERN ou outros relacionados com a Física de Partículas e Astropartículas para os meios de comunicação social portugueses.

Em conjunto, o Programa de professores do CERN e o Projecto de radiação ambiente já colocaram em contacto próximo com a investigação recente, várias centenas de professores. Permitiram-nos assim criar uma rede de escolas, espalhada pelo país, em contacto ou com facilidade de acesso aos investigadores e vice-versa, o que consideramos fundamental para a generalização e o impacto das outras acções de divulgação.

O Programa de Professores em língua portuguesa é um exemplo para o próprio CERN, já que foi estendido a todos os outros países de língua portuguesa, dando também a possibilidade aos professores participantes de partilhar experiências com colegas de outras realidades.

Nas masterclasses participam anualmente cerca de dois milhares de estudantes, e várias dezenas de professores. É uma das acções de maior impacto directo e tem sido alargada a todo o país, contando com a colaboração de investigadores do LIP e também de outros investigadores nas instituições locais de Ensino Superior.

É já uma prática corrente que todos os grandes eventos organizados pelo LIP sejam acompanhados por uma sessão pública ou uma pequena exposição dedicada às escolas e ao público em geral. A comunicação com os parceiros internacionais, no sentido de procurar as melhores práticas, e com a comunicação social portuguesa, complementam as actividades do grupo de Divulgação.

Depois de termos adaptado para português o poster "The Particles Chart"do grupo CPEP ("Contemporary Physics Education Project") que também criou o website "The Particle Adventure", propomo-nos adaptar para português o poster "Constituints elémentaires de la matiére", elaborado pelo IN2P3 de França, para ser também disponibilizado

gratuitamente às escolas (em versão PDF para ser impresso e afixado na parede do Laboratório de Física da Escola).

8.3.2 Abstract

The LIP outreach group is an autonomous team with the role of enhancing the science communication and scientific knowledge dissemination efforts of the laboratory. While working closely with the different research groups of the laboratory, making sure that all the scientific activity lines are adequately represented, the Outreach group has its own lines of activity. The group includes researchers from different LIP groups, participating at different fractions of their time.
The LIP outreach team will still be concerned both with the promotion of scientific literacy in the society at large and with educational activities directed to school communities, which will remain as the main target. The LIP outreach group will keep in addition the role of institutional science communication, dealing with the media and with several national institutions. The close collaboration with the Ciência Viva agency, CERN and the Portuguese research centers and universities will be pursued.
The LIP outreach group will continue playing an active role in IPPOG - International Particle Physics Outreach Group, dedicated to the dissemination of science, and of particle physics in particular, in EPPCN - European Particle Physics Communication Network, committed with the effective communication to the public of the mission of CERN and other laboratories, as well as in other international communication and outreach forums.
LIP considers very important to continue the successful activities carried out so far, in particular the CERN Portuguese Language Teachers Programmes, the IPPOG International Masterclasses in Particle Physics and the outreach public sessions and seminars at school. The group expects also to widen its objectives and expand its set of proposals. In particular, the development of educational materials, demonstration setups and kits for use in other institutions and contexts; the expansion of the dissemination activities to other Portuguese speaking countries; and the publication of the developments made and results achieved in dedicated international journals are essential aspects of the activity plan.
We also will provide support to the school teams participating in the competition organized by CERN entitled "A Beamline for Schools". In 2015 we expect the participation of 18 portuguese schools, a number much larger than in the previous year (7 official participating schools, for which only a few asked for our support).

8.3.3 Objectives

LIP considers very important to continue the successful activities carried out so far, in particular:
i) The CERN Portuguese Language Teachers Programmes, which became our flagship programme for teachers and includes participants from all Portuguese speaking countries, and that is allowing to spread particle and astroparticle physics over large geographical areas and different social contexts;
ii) The IPPOG International Masterclasses in Particle Physics, LIP´s most participated activity, engaging students in a scientific quest;
iii) Outreach public sessions, seminars at schools and small exhibitions;
iv) Support to the school teams participating in the CERN Beamline-for-schools international competition;
v) Participation in the "Science in the Summer"programme from Ciência Viva;
vi) Participation in the European Researcher´s Night, in partnership with the Planetarium
Calouste Gulbenkian - Centro Ciência Viva;
vii) The Environmental Radiation Project, which is renewing the set of experiments proposed to high school students and teachers to include cosmic radiation detection, UV, visible and infrared light detection. Some of the experiments will require the assembly of detectors by the students. A constant project goal is to improve the awareness in environmental radiation related issues, and we are committed to a better information of the general public through the participating schools.
vIIi) The LIP outreach group will remain engaged in its communication roles, in particular with the Portuguese media and institutions, preparing press releases and providing specific information and clarifications;
ix) The group plans to put a new effort in the development of educational contents and materials, demonstration setups, kits to build or use in the schools, brochures, booklets, and activity guides. Of particular interest is the development of kits and setups that can be used in schools but also interesting to other Institutions such as museums and science centers. Some of the existing ideas are related to the demonstration of particle detection, in particular cosmic rays, and atmospheric phenomena. The existing know-how, and the LIP mechanical workshop and electronics labs, give us all the conditions to be successful in this task;
x) The group will encourage and promote links with specific sectors of the society for which the LIP expertise areas are of particular interest (for example, associations of flight professionals have shown interest in seminars or workshops on cosmic radiation);
xi) The participation in international forums is a reality and will be pursued;
xii) the publication of the group achievements in dedicated international journals should be enlarged, and this is an important goal for the next few years;

xiii) and finally, LIP is now particularly concerned with outreach and communication in the Portuguese speaking countries, proposing to enlarge the IPPOG to include representatives from such countries, specially Brazil.

8.3.4 Team

Project coordinator: Pedro Abreu

Name	Status	FTE %
Agostinho Gomes	Researcher (LIP)	
Amélia Maio	Researcher (LIP/FCUL)	
Américo Pereira	Technician (LIP)	
Ana Fernandes	Collaborator	
Ana Maria Pinto	Collaborator (FCUL)	
António Onofre	Researcher (LIP/UMinho)	
Carlos Bernardino	Collaborator	
Carmen Oliveira	Collaborator (LIP)	
Catarina Espírito Santo	Researcher (LIP)	
Conceição Abreu	Researcher (LIP)	
Fernando Barão	Researcher (LIP/IST)	
Florbela Rego	Researcher (LIP)	
Luis Peralta	Researcher (LIP/FCUL)	
Miguel Ferreira	Technician (LIP)	
Paula Pinho	Collaborator	
Pedro Abreu	Researcher (LIP/IST)	
Pedro Assis	Post-Doc (LIP/FCT/IST)	
Sandra Soares	Researcher (LIP/UBI)	