Laboratório de Instrumentação e Física Experimental de Partículas

Work Plan

2014

Contents

Chapter 1

Introduction

1.1 Introdução

O programa científico do LIP para o ano de 2014 integra uma lista exaustiva e equilibrada de temas de investigação, abrangendo algumas das questões em aberto mais relevantes na vanguarda da física de partículas e de astropartículas, com base nas competências existentes e nos resultados obtidos no passado. O LIP está empenhado em explorar plenamente o potencial do LHC, que será aumentado com o aumento de luminosidade da máquina e com o upgrade dos detetores para medir as propriedades da partícula de Higgs com o maior rigor possível e assim testar a validade do Modelo Padrão e procurar mais indícios de nova física.
Durante o ano de 2014, os grupos ATLAS e CMS do LIP preparar-se-ão para a recolha e análise dos novos dados, explorando o potencial físico oferecido pelo aumento de energia do LHC no Run 2 (2015-2018) e contribuindo igualmente para o upgrade dos detetores. Medir as propriedades de Higgs e investir na procura de nova física em acontecimentos com quarks top e leptões tau no estado final constituem duas áreas promissoras de especialização no LIP. Os estudos da física do B e medidas de polarização, bem como o estudo de jatos em colisões de iões pesados, continuarão a ser desenvolvidos no LIP pelos grupos CMS e ATLAS, respetivamente.
Situada na fronteira da física de partículas e da física nuclear, a experiência COMPASS estuda as funções da estrutura de spin do nucleão. O LIP assumiu a liderança de partes relevantes do programa de upgrade de física da experiência COMPASS, bem como na implementação de detetores RPCs inovadores, desenvolvidos e construídos no LIP para a experiência HADES.
A observação das oscilações dos neutrinos abriu uma nova janela na física para além do modelo padrão. A experiência SNO+, encontra-se na fase de instalação, na qual o LIP colabora activamente, estando o detetor SNO a ser adaptado de forma a utilizar um cintilador liquido com dopagem de telúrio para permitir uma pesquisa meticulosa do declínio beta duplo sem neutrinos, que pode vir a trazer nova luz sobre a assimetria observada entre matéria e anti-matéria no Universo. Em SNO+ as atividades do LIP irão centrar-se na compreensão das fontes de ativação, bem como na construção do sistema de calibração baseado em fibra ótica. Na procura da matéria escura as atividades de I&D ,no que respeita às misturas gasosas de Xe para a câmara de projeção de grandes dimensões da experiência NEXT, vão continuar.
Para além das experiências com aceleradores, o LIP participa num conjunto abrangente de experiências sem aceleradores em que se sobrepõem as áreas da física de partículas e de astropartículas, tais como a procura de matéria escura e o estudo de raios cósmicos, em que se abordam questões fundamentais para além do Modelo Padrão da física de partículas. Os Grupos do LIP participam em experiências de referência nas pesquisas de matéria escura (LUX) e de raios cósmicos de alta energia (Auger e AMS), respetivamente. As experiências AMS e Auger abordam questões sobre a origem, a natureza, a aceleração e propagação de raios cósmicos, cobrindo uma vasta gama de energias que vão do GeV ao EeV. O grupo do LIP, responsável pela física de raios cósmicos, participa igualmente na exploração do potencial de Auger na aplicação à física de partículas, desenvolvendo esforços para entender as interações hadrónicas a energias superiores às que se podem atingir com o LHC.
Quanto às aplicações e instrumentação, o LIP tem objetivos precisos de I&D para o upgrade das experiências do LHC (fibras cintilantes, detetores de tempo de voo precisos, circuitos microeletrónicos, conexões óticas de alta velocidade), para o upgrade dos detetores Auger (detetores de muões baseados em RPCs), bem como para o LZ (o detetor de xénon liquido que irá suceder à experiência LUX na procura de matéria escura). Atividades gerais de I&D no que respeita a aplicação de técnicas de deteção inovadoras estão igualmente a ser prosseguidas com determinação.
No domínio da computação avançada, o LIP tem a missão estratégica de participar em infraestruturas de computação científica. Neste contexto, os planos para 2014 são a gestão da participação portuguesa no Worldwide LHC Computing Grid, além do desempenho de um papel central na nova estrutura nacional de GRID e em

EGI, participando também ativamente no Programa-Quadro de I&D da UE nesta área.
A transferência de tecnologias para outros domínios será acelerada em 2014, em particular no que diz respeito às aplicações médicas (nomeadamente os progressos desenvolvidos na imagiologia para diagnóstico do cancro, ou nos tratamentos contra o cancro, usando feixes de partículas), bem como às aplicações para o sector espacial e à instrumentação. A descoberta de novos instrumentos e métodos relacionados com a física experimental de partículas são os principais pilares de atuação do LIP, com uma maior ênfase nas atividades de I&D relacionadas com os Detetores para a Física Nuclear e de Partículas, na área Biomédica (Detetores e Métodos para Aplicações Biomédicas) e no setor do Espaço com a ESA (Estudos do Ambiente de Radiação e Aplicações para Missões no Espaço).
Um exemplo de um spin-off das actividades de I&D do LIP, que resultou de um esforço em I&D inicialmente bem sucedido, na aplicação da mais moderna tecnologia de detetores no projeto PET-Mamografia, foi a criação de empresa com parceiros privados e públicos que o LIP irá continuar a seguir de perto. O LIP irá estimular a transferência de tecnologia para a indústria portuguesa e explorar as oportunidades para a criação de novas empresas spin-off. O LIP está empenhado em facilitar o acesso da indústria portuguesa ao CERN e em estimular com sucesso a transferência de tecnologia do CERN para as empresas portuguesas, bem como da ESA em áreas específicas.
O LIP continuará a contribuir para o ensino da Física e das Engenharias em Portugal, atraindo jovens para as carreiras de I&D, e informando e promovendo o interesse na Ciência e no diálogo com o público em geral, através dos seus programas de divulgação. O LIP está igualmente empenhado em atrair jovens cientistas com talento, oriundos de outros países para participar no seu programa de investigação. Em 2014, o LIP vai continuar a trabalhar num programa de divulgação mais vasto, dirigido às escolas, aos museus e centros de ciência, não só em Portugal como no estrangeiro, nomeadamente nos países de língua portuguesa, incluindo o desenvolvimento e implementação de novos recursos experimentais e ferramentas de comunicação.

1.2 Introduction

LIP scientific programme for 2014 integrates a comprehensive and balanced list of research topics covering some of the most relevant open questions at the forefront of particle physics and astroparticle physics, building upon existing competences and past achievements.
LIP is committed to the exploitation of the full potential of the LHC, including the high-luminosity upgrade of the machine and detectors to measure this Higgs particle´s properties with the highest possible precision for testing the validity of the Standard Model and to search for further new physics at the energy frontier, including the search for dark matter candidates.
During 2014, the ATLAS and CMS groups at LIP will be preparing for the new data, exploiting the physics potential offered by the increased LHC energy in Run 2 (2015-2018) and beyond, and have precise plans to contribute to the upgrade of the detectors. Measuring Higgs properties, and investing in the search for new physics in events with top quarks and tau leptons in the final state, are both promising areas of expertise at LIP. Studies of b-physics and polarization measurements, and jets in heavy-on collisions, will be pursued by the CMS and ATLAS groups respectively.
At the boundary of particle and nuclear physics, COMPASS aims at the measurement of the spin structure functions of nucleons. LIP is taking the lead in relevant parts of the COMPASS physics upgrade program as well as in the operation of novel RPC detectors developed and built at LIP for the HADES experiment.
The observation of neutrino oscillations has opened a new window to physics beyond the standard model. LIP is contributing to the preparation of the neutrino-less double beta decay experiment SNO+, which may bring new light into the matter-antimatter asymmetry of the Universe. The SNO+ experiment is in its installation phase, adapting the SNO detector in order to use Tellurium-loaded liquid scintillator for a high sensitivity search for neutrino-less double-beta decay. LIP will focus on the understanding of activation backgrounds, as well as the construction of optical-fibre based calibration system. R&D on xenon-based mixtures for the large time projection chamber of the NEXT experiment will also be pursued.
We recognize the importance of a range of non-accelerator experiments taking place at the overlap of particle and astroparticle physics, such as searches for dark matter and the study of cosmic-rays, as they address fundamental questions beyond the Standard Model of particle physics. LIP groups are contributing to leading experiments in dark matter searches (LUX) and in high energy cosmic rays (Auger and AMS), respectively. The AMS and Auger experiments address questions about the origin, nature, acceleration and propagation of cosmic rays covering a wide range of energies from GeV to EeV. The LIP group on cosmic rays physics is also focused on the exploitation of the particle physics potential of Auger, namely in the efforts to understand hadronic interactions at energies above the LHC.
LIP has precise R&D plans for the upgrade of the LHC experiments (scintillating fibres, precise timing detectors,

microelectronic circuits, high speed optical links), for the upgrade of the Auger detectors (RPC muon detectors) as well as for LZ (the Liquid Xenon detector that will follow LUX in the search for Dark Matter). Generic R&D in novel detection techniques is also being vigorously pursued.
In advanced computing LIP has the strategic mission of operating the Portuguese component of the Worldwide LHC Computing Grid. LIP will play a central role in the new national GRID structure and in EGI and is also committed to be an active participant of the EU Framework Programme for R&D in this area.
The transfer of technologies to other fields will be accelerated in 2014, in particular to medical applications (namely related to progress in imaging for cancer diagnostics, or to cancer therapies using particle beams), as well as to space studies and instrumentation. New instruments and methods related to experimental particle physics are main pillars of LIP activities, focused on R&D for Detectors for Nuclear and Particle Physics, in the Biomedical field (Detectors and Methods for Biomedical Applications) and in the Space sector with ESA (Radiation Environment Studies and Applications for Space Missions). As a R&D Spin-off Group has been established to explore the initially successful R&D efforts leading to the application of state of the art electronics and crystal detectors to PET mammography, and a spin-off company was launched with private and public partners, LIP will closely support the deployment of its R&D activities.
LIP will stimulate technological transfer to the Portuguese Industry, and to explore opportunities for the creation of new spin-off companies. LIP is committed to facilitate access of the Portuguese industry to CERN, and in successfully stimulating technological transfer to Portuguese companies from CERN, and, in specific areas, from ESA.
LIP will continue to contribute to Physics and Engineering Higher Education in Portugal, to the attraction of youth to R&D careers, and to inform and promote the interest in science and the dialogue with the general public through its outreach programmes. LIP is also committed to attract talented young scientists from other countries to join its research programme.
In 2014 LIP will continue to work on an expanded outreach programme, addressed to schools, science museums and science centres, both in Portugal and abroad, namely in other Portuguese-speaking countries, will include the development and deployment of new experimental resources and communication tools.

1.3 Human resources (head counts)

Project	Researchers	Technicians	Post-Docs	Students			
				D	M	G	O
ATLAS	18	1	4	9	5		1
CMS	7	2	4	7			2
LHC Phenomenology	13		2	1	2		1
COMPASS	3	1	3	2	1		
HADES	2	2	2				
GRID	5	3	1				
Advanced Computing	4						
AMS	1		1		2		1
SNO+	5	5					
Dark Matter Search	5	2	3	1	2		
HECR	14	3	5	3	1		1
RD51	5	10		1			
Neutron Detectors	4		1				
NEXT	7		1				
Ion Transport Processes	5		1	1			
ICNAS	3			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	6		2	2			
RAD4LIFE							
Space	4		1	1			
DUAL	7			1	1		
Education							
TTN-ILO		1					
OUTREACH	10	2	1				
Totals:	95	20	28	36	17	1	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	9	1	4	9	5		1	33
CMS	6	2	4	6			2	20
LHC Phenomenology	5		1	1	1		1	9
COMPASS	3	1	2	2	1			10
HADES	1	1	1					2
GRID	5	3	1					9
Advanced Computing	4							4
AMS	1		1		2		1	5
SNO+	2	1						3
Dark Matter Search	2	1	3	1	1			6
HECR	7	1	4	3	1		1	17
RD51	1	2		1				3
Neutron Detectors	1		1					1
NEXT	2		1					2
Ion Transport Processes	1			1				3
ICNAS	1			1				2
PET - Mammography	2	1	1	6	1			11
Human PET	1	1						2
MC in Medical Physics	4		1		1			5
OrthogonalRayImaging	1			2	1			3
Gamma Cameras	2			1				3
RAD4LIFE								1
Space	1			1				2
DUAL	2			1				3
Education								
TTN-ILO		1						1
OUTREACH								
Totals:	64	16	25	36	14		6	160

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, 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

ATLAS é uma das experiências do Grande Colisionador de Hadrões (LHC) do CERN, onde se dão colisões protão-protão e entre iões pesados a altas energias e luminosidades, abrindo uma nova fronteira na Física de Partículas. O objectivo principal para os próximos anos, após a paragem em curso para aumentar a energia dos feixes, é a medição das propriedades do bosão de Higgs que foi descoberto em 2012 pelas experiências ATLAS e CMS. A estrutura do detector permite também medidas de precisão no âmbito do Modelo Padrão (SM) e pesquisas de nova Física que pode surgir a altas energias como, por exemplo, o modelo da Supersimetria que pode explicar a abundância de Matéria Escura no Universo.
As nossas actividades estão concentradas em estudos de Física e desempenho do detector com análise dos acontecimentos do LHC, mantendo as nossas responsabilidades a nível de operação e especialmente melhoramento do detector, área esta que conta com várias actividades em curso durante a paragem prolongada do LHC em 2013-14.
A descoberta do bosão de Higgs foi um acontecimento de extrema importância. Presentemente estão em progresso os estudos dos canais de decaimento em que o grupo está envolvido, H->b-bbar e H->WW, com vista a terminar e publicar as análises do run I e preparar as do run II (determinação dos acoplamentos da nova partícula aos fermiões e bosões vectoriais). Está em curso uma nova actividade na fronteira entre o Higgs e o quark top, que é a pesquisa do bosão de Higgs em associação com um par de quarks top e anti-top.
Prosseguiremos com os estudos do quark top, no contexto do SM e para além do SM. As análises do grupo relativas à procura de decaimentos do quark top através de correntes neutras com troca de sabor (FCNC) e às medidas de assimetrias angulares no decaimento mais comum serão finalizadas utilizando o conjunto completo de dados a 8 TeV e os resultados serão publicados. O mesmo será feito relativamente à análise da pesquisa de nova Física associada à produção de quarks vectoriais pesados no LHC. Serão actualizados os estudos de sensibilidade da Física do quark top no contexto do LHC a luminosidade elevada (HL-LHC), utilizando informação adicional relativa às condições esperadas para o detector.
Relativamente ao programa de Iões Pesados, o objectivo é concluir o estudo das assimetrias de bi-jactos em colisões Pb+Pb e investir nas actividades relacionadas com a análise da produção de jactos pesados em colisões Pb+Pb.
As responsabilidades na calorimetria hadrónica, tanto no sistema de Trigger como no detector TileCal serão mantidas.
No sistema de Trigger, concentraremo-nos no desempenho e melhoria do trigger de jactos de alto nível, explorando a nova estrutura do HLT para proporcionar algoritmos mais eficientes e mais rápidos. Prosseguiremos o projecto da estratégia de trigger para seleccionar processos de Física difractiva com interesse no "run"II recorrendo aos novos detectores de protões a baixos ângulos (AFP). Estamos também a fazer a validação de algoritmos para o trigger de muões de nível 1, que incluem as células D do TileCal, e planeamos participar também no desenvolvimento de firmware, testes de electrónica e montagem de cartas de electrónica para este trigger.
No TileCal, o sistema de calibração com laser será montado e instalado na caverna de ATLAS. Está prevista a construção de um segundo expansor de feixe e caixa de óptica, para serem usados no laboratório de superfície, onde estará operacional uma réplica do sistema da caverna.

O estudo do ruído electrónico associado ao empilhamento de sinais a 8 TeV será concluído, e continuará o trabalho para identificar e corrigir energias medidas incorrectamente devido a saturação.
Continuamos o nosso forte envolvimento no DCS do TileCal. A migração do hardware e software será concluída durante a paragem em curso, e o sistema será actualizado para ser compatível com os protótipos demonstradores da electrónica prevista para a fase 2 e que começará a ser testada a partir de 2014. Faremos irradiações de componentes para o futuro sistema distribuidor de alta tensão (HVDS) e projectaremos um novo protótipo. Faremos também desenvolvimento do sistema de controlo do HVDS, que se baseia em comunicações através da carta sROD e utilizando ligações ópticas.
Mantemos ainda uma pequena participação nos detectores "forward"de ATLAS, onde será concluída a migração do DCS do detector ALFA, e continuará o desenho do trigger do detector AFP.
Continuaremos também a contribuir para a divulgação.

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. The main goal of the ATLAS experiment for the next few years, after the ongoing shutdown of the LHC to increase the beam energy, is to measure the properties of the Higgs boson, which was discovered in 2012 by the ATLAS and CMS experiments. The general-purpose detector structure will also allow the precise measurements of several Standard Model (SM) predictions, such as the top quark properties, and to search for New Physics, such as Supersymmetry, which could explain the abundance of Dark Matter in the Universe.
Our activities are centered in Physics analysis and Performance studies with data from LHC collision events, but keeping our commitments and responsibilities in detector operation, maintenance and development/upgrade activities, which will be intense in 2014 during the LHC shutdown.
The discovery of a Higgs boson candidate was a major achievement. Now, the study of the decay channels H->b-bbar and H->WW, in which the team is involved, is in progress to conclude and publish the full run I data analysis and to prepare for the run II determination of the Higgs couplings to fermions and vector bosons. The search for the Higgs boson production in association with a top-quark pair, an activity that has recently started, will continue, bridging our Higgs and top-quark studies. Our investment in W bosons, jet physics and performance will continue.
The top quark studies will continue, in the context of the SM and beyond. The group analyses on the search for top quark decays via Flavor Changing Neutral Currents and the measurements of asymmetries of its standard decay with the full 8 TeV data set will be finalised and the results will be published. The same will be done with the analysis of the search for new physics searches associated to heavy quark production at the LHC.
Sensitivity studies of top quark 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 is to conclude the study of dijet asymmetries in Pb+Pb collisions and to increase the activities related to the analysis of heavy-flavour jet production in Pb+Pb collisions.
Our commitments in the ATLAS hadronic calorimetry, both in the Trigger system and in the TileCal detector, where the team is responsible for continuous support, maintenance and upgrade of the TileCal Detector Control System (DCS) will continue.
On the Trigger side, we will focus on the performance and improvements of the high level jet trigger, exploiting the new HLT structure and providing faster/more efficient selection. We will start the development of parallelizable trigger algorithms to run on Graphical Processing Units (GPUs) in view of the Phase I Upgrade of the trigger system. The design of a trigger strategy for the new Forward Proton tagging detectors (AFP) to select diffractive physics processes of interest for Run II will proceed. We are also validating the algorithms for the level 1 muon trigger that will include the TileCal D cells. We intend to participate also in development of firmware, tests of electronics and assembly of boards for this trigger.
In TileCal, the laser system will be assembled and installed in the ATLAS cavern. It is foreseen to build a second beam expander and optics box, to be used as a spare at surface, where a replica of the cavern system will be operative.
The Tilecal electronic noise survey associated to pile-up at 8 TeV will also be finished. The work for identification and correction of wrongly measured channel energies due to overflow will continue.
We maintain our strong involvement in the TileCal DCS. The migration of hardware and software will be finished during the shutdown, and the system will become compatible with the demonstrators: prototypes of electronics designed for upgrade phase 2, to be tested in ATLAS from 2014. We will do irradiations of electronics components for the future High Voltage Distributor System (HVDS) and will design and produce a new

prototype. We will do also developments of the control system of the HVDS, which will rely on communications via the sROD and optical links.
In addition, our involvement in the ATLAS forward detectors will continue with the migration of the ALFA detector DCS and in the design of the AFP trigger.
Our contribution to outreach in these exciting years of LHC physics will continue.

2.1.3 Objectives

Although the ATLAS detector will remain switched off for most of this year, in order to be upgraded at the same time as the LHC upgrade, data analysis will continue.
The objectives relative to Physics are the study of the Higgs boson properties using the H->WW and H->b bbar channels, the search for the top-quark pair associated production of a Higgs boson, searches for top quark decays via FCNC, measurements of asymmetries in top quark decays, and search for heavy quarks. Also the conclusion of the study of dijet asymmetries and the preparation of the analysis of heavy flavour jet production in Pb+Pb collisions are in the objectives.
The Physics is complemented with performance studies and in this field the main objectives are the conclusion of the TileCal electronic noise survey associated to pile-up at 8 TeV, the improvement of the identification and correction of wrongly measured channel energies due to overflow and the study of dedicated jet calibrations to improve the b-jet energy scale.
Relative to operation and maintenance there is a big load in the shutdown. The main objectives are to keep TileCal (and ALFA) DCS operational along the shutdown with full support to consolidation and upgrade activities and have it fully migrated and compatible with demonstrators before the end of the shutdown, and have the new laser system operational in the cavern.
Relative to upgrades, the main activities are focused on the improvements of the jet trigger algorithms, in the implementation of the Tile D trigger and in the TileCal high voltage system, in this last case the goal is to select radiation hard components and project a new prototype of the high voltage distributor system.
Participation in several outreach activities, such as International Masterclasses Hands on Particle Physics, seminars and the School for Portuguese language teachers at CERN are also objectives.

Coordination

The Portuguese ATLAS group has been coordinated by Amélia Maio since the beginning, and this year, for the next project Patricia Conde Muiño will become the new coordinator. The group is structured in areas similar to the ATLAS organization. The main activities are the following (coordinators in brackets):
1-Physics Analysis and MC simulation studies
a) Top Quark physics (A. Onofre, F. Veloso)
b) Search for new heavy particles (N. Castro)
c) Higgs physics (P. Conde, R. Gonçalo)
d) Heavy ions physics (H. Santos)
2- M&O and performance of the ATLAS detector and trigger system
a) TileCal (A. Gomes)
b) Calorimetry Performance and Calibration (J. Maneira)
c) Jet Trigger (R. Goncalo, P. Conde)
d) ALFA detector (A. Maio)
3- Detector Upgrades
a) TileCal Upgrade (A.Gomes)
b) R&D on new technologies for the High Level Trigger (P. Conde)
c) ATLAS Forward proton tagging detectors, AFP (P.Conde)
4- GRID Distributed Computing (H. Wolters).
In ATLAS the portuguese team is represented as follows:
ATLAS National Physicist Board (A. Maio)
ATLAS Collaboration Board (A. Maio)
TileCal Institutes Board (A. Maio, A. Gomes)
Trigger Institutes Board (P. Conde)
Forward Detectors Board (A. Maio)
AFP Board (P. Conde)
Convenor of Top Properties (N. Castro)

2.1.4 Team

Project coordinator: Amélia Maio

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
Alexandre Lopes	Master student (LIP)	100
Amélia Maio	Researcher (LIP/FCUL)	55
André Pereira	Master (LIP)	67
António Amorim	Researcher (FCUL)	10
António Onofre	Researcher (LIP/UMinho)	57
Artur Amorim de Sousa	Master student (LIP)	84
Belmiro Pinto	Researcher (LIP)	67
Bruno Galhardo	PhD student (LIP/FCT)	100
Carlos Marques	Researcher (LIP)	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)	60
Henrique Carvalho	Student (LIP)	100
Joana Miguéns	PhD student (LIP/FCT)	100
João Gentil	Post-Doc (LIP/FCT)	100
José Domingos Alves	Master (LIP)	100
José Maneira	Researcher (LIP)	70
José Manuel da Silva	Master (LIP)	50
José Santiago Perez	Researcher (LIP/UGR)	22
José Soares Augusto	Researcher (IST/INESC/FCUL)	30
Juan Espinosa	PhD student (LIP/FCT)	100
Lourenço Lopes	Master (LIP/FCUL)	100
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 Anjos	Post-Doc (LIP/FCT)	100
Nuno Castro	Researcher (LIP)	30
Patricia Conde	Researcher (LIP)	85
Pedro Jorge	PhD student (LIP/FCT)	80
Ricardo Gonçalo	Researcher (LIP)	87
Robert Cantrill	Post-Doc (LIP)	67
Rui Santos	Researcher (LIP/FCUL)	11
Rute Pedro	PhD student (LIP/FCT)	100
Samuel Almeida	Master student (LIP)	100
Susana Santos	PhD student (LIP/FCT)	100

2.1.5 Academic Training

PhD Theses

- *Measurement of the W -> mu nu production cross section with the ATLAS detector*
  Pedro Jorge, (on-going)
- *Non-standard Higgs and top-quark production and decay at the Large Hadron Collider: a collaboration between theory and experiment*
  Miguel Won, 2014-05-23

- *Medição da secção eficaz de produção do bosão W em ATLAS/LHC/CERN*
  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)
- *Measurement of the WW Production in 7TeV pp Collisions at the LHC with the ATLAS Detector*
  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 the Higgs boson at ATLAS/LHC in WH associated production and decay to b quark pairs*
  Rute Pedro, (on-going)
- *Development of boosted jet triggers for Higgs searches at the ATLAS experiment at the LHC/CERN*
  Ademar Delgado, (on-going)
- João Marques de Carvalho, (on-going)

Master Theses

- Ester Simões, (on-going)
- *Search for ttH production with the ATLAS experiment at the LHC*
  Emanuel Gouveia, (on-going)
- Artur Amorim de Sousa, (on-going)

Graduation Theses

- Lia Moreira, (on-going)
- Eduardo Dias, (on-going)

2.2 Collaboration in the CMS experiment at CERN

2.2.1 Resumo

LIP é membro da colaboração Compact Muon Solenoide (CMS) no Large Hadron Collider do CERN desde a sua origem em 1992 (www.lip.pt/cms/). As motivações científicas da pesquisa no LHC encontram-se na investigação das leis físicas fundamentais do Universo. A experiência CMS estuda colisões de protões e núcleos a alta energia com o objectivo de compreender as propriedades básicas da matéria.
A comunidade no LHC realizou em 2012 uma descoberta de grande relevo com consequências profundas na física de partículas. As experiências ATLAS e CMS observaram um novo bosão com uma massa de aproximadamente 125 GeV compatível com um bosão de Higgs (cms.web.cern.ch/org/cms-public). O grupo LIP/CMS orgulha-se de ter sido parceiro nesta descoberta através de trabalho científico realizado consistentemente nos últimos vinte anos.
O grupo LIP/CMS teve actividade em várias áreas da experiência CMS e contribuiu significativamente em todas as fases do seu longo percurso. As responsabilidade principais do LIP nas contrução da experiência CMS foram as seguintes:

1. Responsabilidade total pelo projecto e construção do Sistema de Aquisição de Dados de um dos cinco Sub-Detectores de CMS, nomeadamente o Calorímetro Electromagnético (ECAL) usado na detecção de electrões e fotões.

2. Contribuições importantes no projecto e construção do Sistema de Trigger de CMS, o qual realiza o primeiro nível de selecção de eventos.

Presentemente as actividades do grupo LIP/CMS estão organizadas em quarto linhas:

- Análise de física em colisões protão-protão, explorando o potencial de descoberta proporcionado pela energia disponível no LHC, incluindo:
  - medidas das propriedades do bosão de Higgs no canal de decaimento em dois fotões;
  - medidas da secção eficaz de produção e das propriedades do quark top;
  - pesquisa de bosões de Higgs com carga eléctrica;
  - pesquisa do parceiro supersimétrico do quark top.
- Análise de física em colisões de iões pesados e física dos estados quarkonium, incluindo:
  - o estudo do plasma de quarks e gluões;
  - medidas da polarização das ressonâncias J/Psi e Upsilon nas colisões pp.
- Desenvolvimentos de novos detectores para o programa de melhoramentos de CMS (Upgrades), incluindo:
  - contribuição para o novo Sistema de Trigger (Fase 1), tendo responsabilidade total pelo desenvolvimento de ligações ópticas de alta velocidade entre o detector ECAL e o Sistema de Trigger;
  - contribuição para o novo Espectrómetro de Precisão de Protões (Fase 1), tendo responsabilidade no desenvolvimento da electrónica de leitura dos detectores de medida de tempo.
  - I&D com vista ao Pixel Trigger para a Fase2 do programa de Upgrade.
- Operação e manutenção do sistema de trigger e 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 its origin in 1992 (www.lip.pt/cms/). 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. The CMS experiment studies very high energy collisions of proton and nuclear beams to investigate the most fundamental properties of matter.
The LHC community achieved in 2012 a major discovery with profound consequences in particle physics. The ATLAS and CMS experiments observed a new heavy boson with mass of approximately 125 GeV, compatible with a Higgs boson (cms.web.cern.ch/org/cms-public). The LIP/CMS group is proud to have been a full partner of this achievement through the scientific work developed consistently in the past twenty years.
The LIP/CMS group has been active in many areas of the CMS experiment having contributed significantly to all phases of its long trajectory. The main LIP responsibilities in the construction of the CMS Experiment were the following:

1. Full responsibility in the design and construction of the Data Acquisition System of one of the five major CMS Sub-Detectors, namely the Electromagnetic Calorimeter (ECAL) used for the measurement of electrons and photons;

2. Important contributions to the design, construction and commissioning of the CMS Trigger System responsible for the first level of event selection.

Presently the activities of the LIP/CMS group are organized in four main lines:

- Proton-proton physics analysis, exploiting the discovery opportunities offered by the new LHC energy, including:
  - measurement of Higgs boson properties in the di-photon decay channel;
  - measurements of the production cross-section and properties of the top quark;
  - search for a charged Higgs;
  - search for the supersymmetric partner of the top quark.
- Heavy-ion and quarkonium physics analysis, including:
  - the study of the quark-gluon plasma;
  - the measurement of the J/Psi and Upsilon polarizations in pp collisions.
- New detector developments for the CMS Upgrade program, including:
  - contribution to the new Trigger System (Phase 1), with full responsibility in developing the high-speed optical links that interface the ECAL electronics to the Trigger System;
  - contribution to the new forward Precision Proton Spectrometer (Phase 1), with full responsibility in developing the front-end electronic system of the timing detectors;
  - R&D in view of the Pixel Trigger of the Phase 2 Upgrade.
- Operation and maintenance of the trigger and data acquisition system of the CMS Electromagnetic Calorimeter.

2.2.3 Objectives

Physics analysis
The Higgs boson has a special role in the SM. It is the only scalar particle, and via the Higgs mechanism it is responsible for the mass of all elementary particles. Researchers at LIP/CMS played a leading role in the search for SM Higgs decays into a pair of photons, and are studying some of its properties. The LIP/CMS group will pursue the Higgs studies aiming a precise determination of the Higss couplings and spin-parity with the increased statistics accumulated in LHC Run 2 (2015-18).
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. The expertise of the LIP/CMS group in this area is particularly appropriate to carry the analysis of the associate production ttH, with the Higgs decaying in b-quarks.
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 in 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 of 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 this studies with increased statistic and to apply the techniques developed to other polarization measurements, in particular the direct measurement of the Higgs spin-parity.

Detector Upgrades
The original design goal of the LHC was to operate at 10^34 cm-2s-1. With LHC upgrades, the 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 installing a new system. The importance of the trigger upgrade increased with the discovery of a relatively light Higgs boson, since high trigger efficiency for Higgs studies requires low trigger thresholds. The LIP/CMS group is presently developing the new optical Serial Links that interface the ECAL electronics to the Trigger System. The new system will be built and installed in the period 2013-2018.
CMS will add in Phase 1 Upgrade a forward proton spectrometer (PPS) which together with the CMS central detector will enable the study of final states produced in association with leading protons pp→p+X+p. The LIP/CMS group is participating in PPS with the development of the timing detectors aiming at a time resolution of 10 ps.
The LIP/CMS group is studying the design and implementation of a L1 Pixel Trigger in the frame of FP7 project INFIERI.

Summary of objectives

The objectives of the project are:

- Proton-proton physics analysis: 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 Higgs Physics, Top Quark Physics and SUSY Physics. Each domain is led by a senior physicist and integrates researchers and students. The coordinator is responsible to supervise the analysis 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.

- Heavy-ion and quarkonium physics analysis: The ultimate objective is the study of the quark-gluon plasma and the strong interaction, taking benefit of the collisions of lead beams at LHC. The activity is led by a senior physicist and integrates other researchers and students, with responsibilities as above. The activity is integrated in the B-Physics and Heavy-Ion Physics Analysis Groups.

- 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 view of its future operation at High Luminosity. Synergies with the LIP group in medical applications (PET) are exploited. Each of the three R&D programs (Phase 1 Trigger, PPS and Phase 2 Pixel Trigger) is led by a coordinator. The activity is integrated in the corresponding CMS structure, respectively the L1 Trigger Project, PPS Sub-detector, and Upgrade Trigger Strategy Group.

- Operation and maintenance of the ECAL trigger and data acquisition system: The LIP/CMS group has a team of four 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.

- 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.

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	Technician (LIP)	100
Cristóvão Silva	PhD student (LIP/FCT)	100
Daniele Vadruccio	Researcher (LIP)	100
Federico Nguyen	Post-Doc (LIP/FCT)	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)	100
Lara Lloret	Post-Doc (LIP)	100
Manuel Rolo	PhD student (LIP)	10
Marcelo Vicente	Student (LIP)	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)
- *Search for new physics processes with leptons in the final state at the Large Hadron Collider with the CMS detector*
  Oleksii Toldaiev, (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, 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 20 membros (6 investigadores doutorados, 4 estudantes de licenciatura, 6 estudantes de mestrado e 4 estudantes de doutoramento)

2.3.2 Abstract

Several tasks are expected to be developed during the course of the project:
1. Top quark FCNC Processes
The main goal is to study signals of physics beyond the SM in top quark FCNC processes at LHC. 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. Several contributions of this team were already included (gg->tq, gq->tg, qq->tq) in a general purpose generator like TopRex. Results show that these new contributions cannot be neglected when compared with the direct single top production process. Following this experience, a new dedicated Monte Carlo based on CalcHep and interfaced with the LHC experiment simulations will continue to be developed. Pythia will be used to perform the parton level particles hadronization. This new Monte Carlo will include the new contributions already calculated from the strong and electroweak sectors (and their interferences). New contributions associated to top quark production and decay through the Higgs channel will be calculated and included in the generator.
2. Non Standard Higgs Production
All Higgs sectors have self-interactions between Higgs states, and these are notably different from model to model. The simplest self-interaction is the SM triple-coupling. To look for trilinear self-interactions at the LHC one ought to search for final states with two Higgs bosons (chiefly, involving the lightest Higgs state available in the model). This analysis was done not only for the SM by several groups but also for some parameter regions of the MSSM and THDM in the decoupling limit, for Little Higgs Models, Extra Dimension Models, Fermiophobic Models, etc. It was shown that searches for pair-produced Higgs boson at the LHC in the framework of the SM and MSSM can be very challenging in the accessible mass regions. In contrast, the results are very promising for some regions of general THDM. However, until a thorough experimental analysis is performed it will be very hard to distinguish between the different models proposed. The main goal is to be able to say, for a chosen set of luminosities (from the first year of data taken at the LHC to the full Super-LHC sample), which models can be tested and for which regions of the parameter space of each specific model. Together with the theoretical group at NExT (University of Southampton), cross sections and branching ratios will be calculated for those models where this is not already done. All tools readily available (for some models, like for instance the MSSM, there are already a lot of tools, like FeynHiggs or HDECAY which are ready to be used) will be used and similar ones will be created for the remaining models. The next step will be to incorporate the missing channels to standard Monte Carlo (MC) event generators (such as PYTHIA and/or HERWIG) as additional core processes or through suitable interfaces (like SLHA and/or MadGraph/MadEvent and/or CompHep/CalcHep). Then, identify the channels that cover as many models as possible and together with the LHC groups at the University of Coimbra

and University of Minho, and Rutherford Appleton Laboratory, discuss the feasibility of a possible analysis (production modes, decay channels, signatures, triggers, cuts, etc.) and identify the backgrounds generated by the SM in the different extended models.

3. Top Quark Couplings

The LHC will 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, will be 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.

4. Tri-leptons and the see-saw mechanism

In this project we propose to explore the clean tri-lepton signals 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, trilepton final states appear in other new physics models. They are produced in the decay of new heavy vector-like quarks with charges 2/3, -1/3 or 5/3, which are predicted in several models of extra dimensions with custodial symmetry. Studying trilepton signals will also allow us to probe these models, and to establish the identity of the new particles, if discovered.

5. New physics in models of strong EWSB.

In the presence of fermion custodians, new vector resonances of the
strong sector become very broad and have large branching fractions into the custodians. Thus, a good knowledge of the properties of the custodians is crucial as they are the ideal probe to search for the vector resonances that characterise the strong sector responsible for EWSB. Current studies use tops as a final state in the search of new vector resonances, neglecting a large fraction of events that decay in the fermion custodians. The goal is to implement a simplified model that incorporates the main features of models of strong EWSB but has enough freedom to
parametrize a large class of models. The model will be based on
deconstruction of models with warped extra dimensions, which are dual to quasi conformal models of strong EWSB. Then we will study the potential at the LHC to use top and/or light quark custodians to search for new vector resonances of the strong sector.

6. 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. 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) must be provided by the theoretical physicists in order to be implemented in the Monte Carlo generator under development (based on CalcHep and interfaced with Pythia and LHC detector simulations). 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. A new Monte Carlo generator (which is already under test within the members of the group) called PROTOS will be made available to the community. This generator has implemented the correct parameterization of the anomalous couplings for ttbar and single top production. All couplings are on-mass shell. A new Monte Carlo generator (based on CalcHep and interfaced with Pythia and the LHC experiments simulations) is under development for the study of top quark electroweak couplings (ttgamma and ttZ) for the LHC.

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.
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 already 20 members (6 senior PhD researchers, 4 undergraduate students, 6 master students and 4 PhD students).

2.3.4 Team

Project coordinator: António Onofre

Name	Status	FTE %
António Onofre	Researcher (LIP/UMinho)	50
Augusto Barroso	Researcher (FCUL)	15
Francisco del Aguila Giménez	Researcher (UGR)	20
Henrique Carvalho	Student (LIP)	100
João Alves	Master student (LIP/UMinho)	100
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/FCT)	100
Miguel Won	Researcher (LIP) *	50
Mikael Chala	Master student	20
Nuno Castro	Researcher (LIP)	60
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

2.3.5 Academic Training

PhD Theses

- *Non-standard Higgs and top-quark production and decay at the Large Hadron Collider: a collaboration between theory and experiment*
  Miguel Won, 2014-05-23

2.4 Collaboration in the COMPASS experiment at CERN

2.4.1 Resumo

A experiência COMPASS dedica-se essencialmente ao estudo da estrutura do nucleão, nomeadamente das contribuições de gluões e quarks para o seu spin total.
Na primeira fase, cujas tomadas de dados decorreram até 2011, COMPASS dedicou-se, através da difusão inelástica profunda de muões na matéria, ao estudo da polarização do gluão (usando 2 canais independentes: a produção de charme e a física de elevado p_T), bem como a medida das funções de estrutura dependentes do spin, nos modos longitudinal e transverso, de modo a separar as contribuições das componentes de sabor para o spin total do nucleão.
Têm ainda vindo a ser estudadas as funções de fragmentação, através das multiplicidades no estado final dos hadrões carregados.
Actualmente, na sua segunda fase, COMPASS dedica-se principalmente ao estudo das funções de estrutura dependentes do momento transverso (TMD PDFs), através do processo de Drell-Yan polarizado, bem como das funções de estrutura tridimensionais (GPDs), a tomografia do nucleão, através do processo DVCS (Deep Virtual Compton Scattering).
Por outro lado, COMPASS tem ainda por objectivo o estudo de algumas questões de actualidade relativas à espectroscopia hadrónica, como a produção de novos hadrões, bem como de mesões, nomeadamente exóticos ou híbridos.
Em 2012 efectuou-se a tomada de dados para o estudo experimental das polarizabilidades de piões e kaões, usando o processo de Primakoff.
Neste contexto, COMPASS usa feixes de alta intensidade, de muões polarizados (ou de hadrões) interagindo com um alvo polarizado longitudinalmente ou 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. Cada espectrómetro é formado por um magnete e, a montante e a jusante, 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. De facto, o programa de muões com alvo de 6LiD que decorreu de 2002 a 2007 perfez um total de 1700 TB. E no programa de hadrões, levado a cabo em 2008 e 2009, os dados adquiridos totalizaram 1300 TB.
Em 2010 e 2011 decorreram as últimas tomadas de dados com feixe de muões e com alvo de amónia (polarizado transversalmente e também longitudinalmente), o que permitiu concluir este programa polarizado de Difusão Inelástica Profunda Semi-Inclusiva (SIDIS).
Em 2012 a segunda fase do programa de COMPASS iniciou-se com uma tomada de dados com feixe de hadrões para estudo das polarizabilidades do pião e do kaão.
A farm de processamento de dados de COMPASS, devido ao seu grande volume de dados adquiridos (∼5 PB), tem um desempenho do nível requerido em LHC, pelo que a experência foi usada pelos grupos técnicos de apoio do CERN em vários domínios relativos à aquisição e ao controlo dos dados como um ambiente de teste em grande escala.
Neste contexto, a aposta do grupo do LIP-Lisboa de, ao ingressar em COMPASS em finais de 2002, tomar a total responsabilidade do Sistema de Controlo de Detectores (DCS), revelou-se muito importante para a estratégia de evolução do grupo no plano tecnológico. Daí o notável esforço de recursos humanos que foi necessário.
Na sua vertente técnica, objectivo do grupo do LIP, atingido em anos anteriores, era o desenvolvimento de uma nova arquitectura para o DCS de COMPASS. Mas continuadas evoluções e adaptações têm sido necessárias.
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, pelo que a alteração de um deles, muitas vezes com aspectos incompatíveis em relação à sua versão precedente, implica em geral a adaptação de todos os outros, o que é uma tarefa muito pesada.
Por outro lado, devido à contínua instalação de novos detectores específicos dos diferentes programas com feixes de muões e hadrõ̃es, o software do DCS (bem como o seu hardware de interface) tem vindo a aumentar constantemente o seu grau de complexidade (interfaces de novo tipo, novos drivers), devido à não uniformidade dos detectores e do seu hardware.
O objectivo principal do grupo do LIP diz respeito à análise de dados e à extracção dos seus resultados físicos. Neste contexto, o grupo tem levado a cabo um conjunto de tarefas de grande importância para a Colaboração COMPASS e para o próprio grupo.
No que respeita ao offline, desenvolveram-se estudos de geradores físicos e sua simulação no detector, com

vista à sua concordância com os dados experimentais. Em relação à análise de dados propriamente dita, foram desenvolvidos estudos nos canais físicos mais importantes do programa de Difusão Inelástica Profunda de COMPASS. Foram, nomeadamente, feitos estudos independentes sobre a polarização do gluão, Δg(x), tanto através do processo de charme aberto (o "Golden Channel"de COMPASS), como através de eventos de grande pT. Estudaram-se também as assimetrias de sabor do mar do nucleão, nomeadamente Δs(x), e ainda as multiplicidades dos hadrõ̃es π e K, com vista à extracção das funções de fragmentação.
As assimetrias de spin do nucleão, tanto a grande Q2, como a pequenos Q2 e xBj, foram estudadas em detalhe, permitindo a extracção com grande precisão e até valores muito baixos de x da função de estrutura dependente de spin, g(x).
A partir do início de 2010, o grupo do LIP-Lisboa assumiu um papel de destaque na preparação do próximo Programa experimental de COMPASS, no que concerne aos estudos de transversidade através do processo de Drell-Yan polarizado.
Neste contexto, o grupo tem vindo a participar activamente nos estudos de adaptação e optimização do espectrómetro, nomeadamente sobre o absorvedor de hadrões e sobre o trigger de dimuão, bem como sobre os algoritmos de reconstrução de dimuões e sua eficiência.

2.4.2 Abstract

The COMPASS experiment is dedicated to the study of the structure of the nucleon, namely of the contributions of gluons and quarks to its total spin.
In its first phase, which data taking periods last till 2011, COMPASS was devoted, through the deep inelastic scattering of muons, to the gluon polarization (using 2 independent channels: open charm photoproduction and high pT physics), as well as to the measurement of spin dependent structure functions, both in the longitudinal and the transverse modes, in order to disentangle their flavour components.
The study of fragmentation functions, through the charged hadron multiplicities, has also been addressed.
In the present phase, COMPASS aims mainly to the study of the transverse momentum dependent structure functions (TMD PDFs) through the polarised Drell-Yan process, as well as the three dimensional structure functions (GPDs), the so-called nucleon tomography, through the DVCS process (Deep Virtual Compton Scattering).
On the other hand, COMPASS studies also some important hadron spectroscopy issues, such as the production of new hadrons, as well of mesons, namely exotics or hybrids.
In 2012, the polarisability of pions and kaons, using the Primakoff process, was addressed, by means of a dedicated data taking.
In this context, COMPASS uses high intensity beams, that is, a polarized muon (or hadron) beam impinging on a longitudinally or transversely polarized target (or a liquid hydrogen 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. Each spectrometer is equipped with a magnet and, upstream and downstream, by trackers, a set of electromagnetic and hadronic calorimeters, muon filters and a Cherenkov detector (RICH) for particle identification.
The data acquisition system is based on a parallel read-out of the front-end electronics, followed by a distributed set of event-builders, specially designed to cope with huge data volumes. In fact, during the muon programme with a 6LiD target, from 2002 to 2007, COMPASS collected a total of 1700 TeraByte of data. And, in the hadron programme, from 2008 to 2009, the data taken totalised 1300 TB.
The years 2010 and 2011 were dedicated to the two last data takings with a muon beam and an ammonia target, polarised in the transverse as well as in the longitudinal mode, allowing to finalise this polarised programme of Semi-Inclusive Deep Inelastic Scattering (SIDIS).
In 2012 the COMPASS second phase was initiated, with a data taking using a hadron beam, aiming to the study of pion and kaon polarisabilities.
The COMPASS data processing farm, due to the huge data volume to handle, requires a LHC-like performance. That is why the experiment was used as large scale test envi- ronment by some CERN support technical groups in several data acquisition and data control domains.
In this context, the full responsibility of the Detector Control System (DCS) taken by the LIP-Lisbon group at the time of its ingress in COMPASS, in the late 2002, was very important to the evolving strategy of the group on a technological ground. In that view, a big effort in human resources was undertaken.
Concerning the technical tasks, the main purpose of our group was the development a new DCS architecture, which has been previously achieved. But a constant evolution of the system is needed. In fact, the COMPASS 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. Thus, changing one package version, which may even be not backward compatible with its previous one, may imply the change of all other packages versions. This is a very heavy task.
On the other hand, COMPASS continues its hardware upgrade, namely in what concerns new detectors specific to muon or hadron programmes. 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.
The main objective of our LIP group concerns the data analysis and the physical results extraction. In this context, our group gives a major contribution in several important COMPASS physics channels.
Regarding offline, the development of new physics generators and their simulation through the detector, as well as their overall compatibility studies with the experimental data were performed. In what concerns the analysis, the most important physics channel in the COMPASS Deep Inelastic Scattering programme, the gluon polarisation measurement, Δg(x), was performed by means of two independent studies, one from the open charm process (the COMPASS "Golden Channel"), the other through high pT events. Also addressed were the studies of flavour asymmetries of the nucleon sea, namely Δs(x), as well as of hadrons´ multiplicities of π and K, in view of the fragmentation functions extraction.
The nucleon spin asymmetries, at high Q2, as well as at low Q2 and low xBj, were studied in detail, allowing a high precision extraction of the spin dependent structure function , g(x), till very low x values.
From the begining of 2010 on, our group has taken an important role in the preparation of the next COMPASS experimental physics programme, in what concerns transversity studies through the polarised Drell-Yan process. In this view, our group has actively participated, since then, in the spectrometer upgrade design, namely of the hadron absorber and of the dimuon trigger, as well as on the optimisation of the dimuon data reconstruction algorithms and their efficiency.

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 offline and in the analysis effort.
Thus, in 2014 our tasks will be the following:

- study of fragmentation functions in view of the strange quark polarised parton distribution measurement;
- to continue the development of the new method based on all pT hadron pairs, aiming to the gluon polarisation extraction;
- to continue the studies on the COMPASS setup upgrade, namely the new dimuon trigger requirements and its optimisation, in view of the polarised Drell-Yan process experiment;
- 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 xBj and low Q2 physics;
- to continue the reanalysis of the 2009 data taking test run with absorber, in view of the data reconstruction programme optimisation for the polarised Drell-Yan experiment;
- studies on the Drell-Yan signal and its background components;
- study of the nucleon Sivers effect with a transversely polarised target;
- to participate in the preparation of the 2014 Drell-Yan run and in its data taking;
- to participate in the Collaboration and in the monthly analysis meetings;
- to continue as a member of the COMPASS Publications Committee (M. Stolarski).

With respect to the technical commitments, the Detector Control System activities, in view of the next COMPASS experimental physics Programme will pursue, profiting from the CERN long shutdown, LS1.
Our main DCS task will be to finalise the major change of the supervisor level software, concerning the replacement of the old PVSS 3.8 version by the new WinCC OA 3.11. In this view, extensive large scale tests have to be performed, as this change has implied major compatibility developments of the new JCOP and the COMPASS Framework packages, as well as of the front-end software, namely OPC servers.

From the DCS hardware point of view, the change to 64 bit machines will also continue to take place, together with the installation of the new Linux SLC6 and Windows 7 operating systems.
As a consequence of these major changes, deep studies concerning the stability and performance of the new DCS system will be performed.
Also, a higher level of monitorisation of the polarised target will be developed.

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	(LIP/AdI)	100
Luis Silva	Post-Doc (LIP)	50
Márcia Quaresma	PhD student (LIP/FCT)	100
Marcin Stolarski	Post-Doc (LIP/FCT)	100
Miguel Vasco	Master student (LIP)	84
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

- *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

A colaboração HADES (www-hades.gsi.de), acrónimo de "High Acceptance Di-Electron Spectrometer", é uma experiência internacional de Física das Partículas, onde participam 17 instituições de 9 países europeus entre os quais Portugal, através do Laboratório Associado LIP (www.lip.pt). Esta experiência está instalada no laboratório GSI (www.gsi.de), situado em Darmstadt, na Alemanha.
Fazendo colidir núcleos atómicos pesados acelerados no acelerador SIS18 do GSI, a experiência pretende criar um estado nuclear muito mais denso que o habitual. Essa densidade acrescida, ao provocar alterações mensuráveis nas propriedades das forças nucleares, permitirá estudar algumas propriedades destas forças que são responsáveis pela maior parte da massa da matéria comum.
A participação portuguesa nesta experiência, assegurada por equipas do LIP, consiste no projecto, construção e operação de um detector de partículas de concepção original que ajudará a identificar com mais rigor o tipo de partículas que emergem das referidas colisões nucleares. Este novo detector será capaz de medir o tempo de voo das partículas (desde o ponto da colisão até ao detector) com uma precisão equivalente ao tempo que demora a luz a percorrer uma distância de 3 cm (100 picosegundos, isto é 0,0000000001 s). Esta informação permite por sua vez determinar a velocidade das partículas, o que é um passo importante para identificar o tipo de partícula de que se trata.
O objectivo fundamental da experiência, a medida de colisões entre núcleos de ouro, teve lugar em Abril-Maio de 2012. Outras experiências complementares seguir-se-ão. Nesta experiência o detector RPC teve um desempenho sem falhas e foi demonstrada uma excelente performance. O LIP participa agora na análise dos dados de física resultantes da experiência.

2.5.2 Abstract

The HADES collaboration (www-hades.gsi.de), "High Acceptance Di-Electron Spectrometer", is an international Particle Physics experiment in which participate 17 institutions from 9 European countries, including Portugal via the "Associated Laboratory"LIP (www.lip.pt). The experiment is installed in the laboratory GSI (www.gsi.de), located in Darmstadt, Germany.
By colliding heavy atomic nucleus accelerated by GSI´s SIS18 accelerator the experiment aims at creating a nuclear state much denser than usually. This increased density, causing changes in the measurable properties of the nuclear forces, will allow the study of some properties of these forces that are responsible for most of the mass of ordinary matter.
The Portuguese participation in the experiment, assured by LIP teams, includes the design, construction and operation of an original particle detector that will help to identify more accurately the kind of particles that emerge from the nuclear collisions. This new detector will be able to measure the time of flight of the particles (from the collision point to the detector) with a precision equivalent to the time that it takes the light to cross a distance of 3cm (100 picoseconds, or 0.0000000001 s). This information allows the determination of the velocity of the particles, which is an important step to identify the particle.
The fundamental goal of the experiment, the measurement of the collisions between gold nuclei, was achieved in April-May 2012. Other complementary experiments will follow. The RPC detector has shown flawless operation and excellent performance. LIP participates now in the analysis of the physics data thus produced.

2.5.3 Objectives

HADES RPC TOF WALL

In 2014 there will be a test run with pion beam in Spring and a production beamtime in Summer either (depending on the results from the test run) with pion beam or with the Ag-Ag system (covering the ground between the light systems and last year´s Au-Au). Our group is now the sole responsible for the maintenance and operation of the RPC TOF Wall and will be heavily involved in all operations.
Besides, it is likely that our involvement will be increased on other aspects of HADES hardware, owing to the lack of experienced manpower in the experiment.

PARTICIPATION IN THE PHYSICS PROGRAM

The production of particles in a highly dense medium is currently a important topic. In this context, the physics analysis will pursue on the two following subjects:

- The study of the non-resonant mass spectrum of dileptons, which come from the fireball in the high density environment, as well as the mass properties of short lived mesons in the dilepton channel.
- The study of the momentum and multiplicity distributions of particles with strangeness, namely kaons, which have to be produced through in-medium mechanisms.

The LIP-HADES group will also participate in the next physics run with a pion beam, starting in 2014.

2.5.4 Team

Project coordinator: Paulo Fonte

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)	50
Paulo Fonte	Researcher (LIP/ISEC)	35
Ricardo Caeiro	Technician (LIP)	15

Chapter 3

Computing

3.1 Grid Computing

3.1.1 Resumo

As actividades de computação englobam o suporte à investigação cientifica, a participação em actividades de I&D com o objectivo de manter o LIP na linha da frente das tecnologias de informação, e a participação em infraestruturas de computação científica. Neste contexto os planos para 2014 são:

Worldwide LHC Computing Grid (WLCG)
Gerir os recursos dos Tier-2 e Tier-3 Portugueses que servem ATLAS e CMS. Fornecer a capacidade Tier-2 acordada com o CERN e com as autoridades Portuguesas. Através do projecto de suporte ao Tier-2 financiado pela FCT, garantir a inovação e integração dos serviços de computação no WLCG, e efectuar um concurso para renovação dos equipamentos de armazenamento mais críticos do Tier-2.
Continuar a consolidação dos serviços de Tier-2 e Tier-3 unificando a capacidade no nó central GRID (NCG). As excelentes instalações do centro de processamento de dados do NCG foram recentemente melhoradas em termos de redundância e fiabilidade. A consolidação no NCG simplificará a topologia e permitirá uma melhor optimização dos recursos, melhor desempenho, gestão mais simples, maior fiabilidade, e redução dos custos de operação. A consolidação criará oportunidades para melhorar os serviços de análise do Tier-3.

Infraestrutura Nacional de Computação Distribuída (INCD)
A proposta de evolução da GRID nacional submetida ao roteiro de infraestruturas da FCT foi avaliada em 2014 tendo recebido a pontuação máxima. A proposta para uma Infraestrutura Nacional de Computação Distribuída (INCD) demonstrou "potencial científico elevado e relevância estratégica". O consórcio inicial composto pelo LIP, FCCN e LNEC será alargado às universidades do Minho, Porto e Aveiro.
O programa de trabalho inclui a criação de centros de competência nas organizações parceiras. Estes centros disponibilizarão suporte, treino, adaptação de aplicações, disseminação, desenvolvimento tecnológico e serviços de valor acrescentado. Alguns centros disponibilizarão capacidade e serviços que complementarão o nó central de computação (NCG) cujos equipamentos deverão ser renovados ao longo dos próximos anos. O consórcio está empenhado em manter e suportar os serviços GRID actuais, e desenvolver novos serviços em áreas como: computação em nuvem, computação com processadores gráficos, e "big data".
A infraestrutura será aberta à comunidade científica e académica e suportará projectos de investigação nacionais e internacionais. O consórcio procurará participar em projectos do Horizonte 2020.

Infraestrutura Ibérica de Computação Grid (IBERGRID)
A participação nacional na infraestrutura Ibérica IBERGRID é uma componente fundamental do programa de trabalhos da INCD. Esta bem sucedida colaboração será continuada e reforçada através do suporte dos correspondentes roteiros nacionais. O suporte e desenvolvimento de novos serviços será efectuado em estreita colaboração com os centros Espanhóis.
O IBERGRID está a empreender contactos com novas comunidades e neste contexto uma potencial colaboração com o ESFRI LifeWatch será explorada. A comunidade IBERGRID seguirá de perto as oportunidades para colaboração no Horizonte 2020.
A conferência IBERGRID 2014 terá lugar em Portugal na Universidade de Aveiro, e será organizada conjuntamente com o LIP. Este será o primeiro grande encontro no contexto das novas estruturas nacionais.

European Grid Initiative (EGI)
O IBERGRID continuará a suportar a participação comum no EGI, permitindo a partilha de recursos, serviços, esforço e conhecimentos entre ambos os países, e uma participação mais forte e competitiva na infraestrutura EGI.
Durante 2014 o portfolio de serviços do EGI será alargado com um novo serviço federado de computação em nuvem. Este serviço encontra-se actualmente em fase piloto. Os serviços de computação em nuvem Portugueses (INCD) e Espanhóis serão integrados no serviço federado do EGI.
O LIP no contexto do IBERGRID continuará a ser responsável por diversas tarefas globais do EGI. O IBERGRID venceu o concurso internacional para o fornecimento dos serviços de coordenação de middleware, e de suporte para os próximos dois anos.
O projecto EGI-Inspire que actualmente financia a infraestrutura EGI e que deveria terminar em Maio de 2014 foi estendido até ao final do ano. Entretanto o EGI e os seus parceiros irão preparar novos projectos de acordo com a visão estratégica para o Horizonte 2020. Os novos projectos terão por objectivo desenvolver e suportar novos serviços e plataformas de investigação virtuais, que explorarão o potencial da computação em nuvem e a experiência do EGI na federação de recursos distribuídos.
O LIP continuará a representar Portugal no conselho do EGI, e participará na gestão da organização através do Executive Board.

LIP Serviços de Computação
A consolidação e simplificação dos serviços de tecnologias de informação e fundamental para uma maior eficiência, escalabilidade e sustentabilidade. Será procurada uma maior integração e racionalização dos recursos do LIP.
Nos últimos dois anos diversos membros da equipa de computação abandonaram o LIP criando uma situação muito difícil em termos de recursos humanos e de conhecimento que se está a perder. Manter a equipa e o seu conhecimento (construído ao longo dos últimos doze anos) é o maior desafio que o LIP enfrenta no domínio da computação.

3.1.2 Abstract

The computing activities encompass the support to scientific research, the participation in R&D activities aimed at staying in the forefront of IT technologies, and the participation in scientific computing infrastructures. In this context the plans for 2014 are:

Worldwide LHC Computing Grid (WLCG)
Manage the Portuguese Tier-2 and Tier-3 computing resources for ATLAS and CMS. Deliver the pledged Tier-2 capacity agreed with CERN and the Portuguese authorities. Through the Tier-2 support project funded by FCT, ensure the innovation and integration of the computing services in WLCG, and perform a procurement to renew the most critical Tier-2 storage components.
Continue the consolidation of the Tier-2 and Tier-3 services by unifying the capacity at the national GRID computing centre (NCG). The excellent NCG datacenter facilities have been recently enhanced in terms of redundancy and reliability. The consolidation at NCG will simplify the Tier-2 topology and will enable better resource optimization, higher performance, easier management, increased reliability and reduced operational costs. The consolidation will also open opportunities to improve the Tier-3 data analysis services.

National Distributed Computing Infrastructure (INCD)
The application to support and evolve the national GRID submitted to the Portuguese Science Foundation infrastructures roadmap was successfully evaluated in 2014 obtaining the maximum score. The proposed National Distributed Computing Infrastructure (INCD) was considered to demonstrate "high scientific potential and strategic relevance". The initial consortium composed of LIP, FCCN and LNEC will be enlarged to the universities of Minho, Porto and Aveiro.
The work program includes the creation of competence centres in the partner organizations, which will provide support, training, porting of applications, dissemination, technology development and added value services. Some competence centres will also complement the computing capacity and services provided by the core computing centre (NCG) whose equipments will be renewed along the coming years. The consortium is committed to maintain and support the GRID legacy services and develop of new services in areas such as: cloud computing, GPU computing and big data.
The infrastructure will be open to the scientific and academic communities supporting national and international research projects. The consortium will also seek participation in Horizon 2020 projects.

Iberian GRID Infrastructure (IBERGRID)
The national participation in the Iberian Grid Infrastructure is a fundamental component of the INCD work program. This very successful collaboration will be further pursued and strengthened through the support of the corresponding national infrastructures roadmaps. The development of new INCD services and the support to well established ones will be performed in close collaboration with the Spanish centres.
IBERGRID is engaging with new user communities and in this context a potential collaboration with the LifeWatch ESFRI will be explored. The IBERGRID community is also closely following opportunities for participation in Horizon 2020.
The IBERGRID 2014 conference will take place in Portugal at the University of Aveiro and will be jointly organized with LIP. This will be the first large face-to-face meeting under the new national structures.

European Grid Initiative (EGI)
IBERGRID will continue supporting a common Iberian participation in the European Grid Initiative, enabling the sharing of computing resources, services, effort and knowledge between both countries, and a stronger and more competitive participation in the EGI infrastructure.
During 2014 the portfolio of EGI services will be enlarged with the federated cloud computing service that is currently in pilot phase. The Portuguese INCD and Spanish cloud services under IBERGRID will be integrated in the EGI cloud.
LIP under the IBERGRID umbrella will continue to provide global tasks to the EGI infrastructure. IBERGRID won the EGI international bid for the provisioning of middleware coordination and user support services to the global EGI community for the next two years.
The EGI-Inspire project that is currently funding the EGI infrastructure was scheduled to finish in May 2014 but it will be extended until the end of the year. Meanwhile EGI and its members will be working towards new projects following the EGI vision for Horizon 2020. The new projects will aim at developing and supporting new services and virtual research platforms that will exploit cloud potential and the EGI experience in federating distributed resources.
LIP will continue representing Portugal at the EGI council and also in the EGI upper management through the executive board membership.

LIP Computing Services
The consolidation and streamlining of the IT services is fundamental for higher efficiency, scalability and sustainability. A deeper integration of services across the organization will be pursued.
Over the last two years several computing team members have left LIP creating a very difficult situation in terms of human resources and expertise that is being lost. Provide conditions to retain the team and its unique expertise (built over the last twelve years) is the biggest challenge faced by LIP in the computing domain.

3.1.3 Objectives

- Operate and further consolidate the LIP IT infrastructure.
- Operate the Portuguese WLCG Tier-2 and Tier-3 services for ATLAS and CMS.
- Renew the storage systems of the WLCG Tier-2.
- Coordinate and evolve the Portuguese GRID infrastructure into a wider National Distributed Computing Infrastructure (INCD) following the program of work approved in the FCT infrastructures roadmap.
- Participate in the development of new INCD services and bridge these services with opportunities in Horizon 2020.
- Manage the national computing centre (NCG) in partnership with FCCN and LNEC and in the context of the INCD program of work.
- Continue and reinforce the IBERGRID collaboration.
- Participate in EGI at the operational and strategic level.
- Provisioning of EGI global services namely: middleware rollout, middleware acceptance, and user support.

3.1.4 Team

Project coordinator: Jorge Gomes

Name	Status	FTE %
Carlos Manuel	Technician (LIP)	100
Gaspar Barreira	Researcher (LIP)	78
Gonçalo Borges	Researcher (LIP)	100
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
Nuno Ribeiro Dias	Researcher (LIP)	100

3.2 Advanced Computing

3.2.1 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, integrated in LIP-Minho, since 2013, intends to focus on advanced computing research on HEP related applications and on bridging the Computer Science academic courses available there with the LIP research interests. The research team joins previous R&D work on Grid computing, high-performance computing, computing models, high-performance communication libraries and distributed data structures. Its researchers participated in Grid related projects such as FP6-CYCLOPS, FP7-EELA2/ GISELA, FCT-CROSS-Fire and FCT-Aspect Grid. Recently they explored combining traditional multi-core CPUs with accelerator devices and provide distributed OpenCL in projects FCT-IGIDE and FCT-PERFORM, building HPC virtualization solutions that run user provided VMs in batch-oriented clusters and optimizing systems behaviour using application profiling information.

3.2.2 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 multi-core 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.
The Advanced Computing team has already explored application behaviour analysis, particularly using IO profiling, to optimized execution time of the analysis programs developed by the ATLAS team at LIP-Minho. This provided significant performance gains to the ATLAS research group at LIP-Minho, and even suggested a more economic system architecture based on nodes that can both compute and store data to be used when increasing the computing power and in data storage capacity of the tier 3 analysis facilities .
Further research will be directed towards data-location aware scientific computing, which adaptively improve execution efficiency by reducing highly expensive data migrations and contentions on their scheduler strategies, both across primary memory modules and storage units.
The size of data sets delivered by the LHC is expected to grow one order of magnitude following the LHC upgrade that will be performed during the shutdown in 2013-14, starting at present in the multi-petabyte range. The processing time currently required by the data analysis applications is already limiting the scientific results, so research must now focus on how to deal with a 10-fold increase in the data volume, while supporting the increase in the complexity of the analysis applications and reducing the turnover time of the results.
Further research must now be directed to making systematic analysis of a range of HEP applications, resorting of complete execution profiles, both in terms of CPU and IO, to evaluate the optimization opportunities from the computational points of view. These profiles may be used to optimize the underlying execution system or to build new systems more adapted to the applications that are most widely used. A central technique is placing applications near the resources they effectively require by using adapted file systems or by using virtualization as mechanism by which VMs are migrated to the nodes where data is being sourced.
A tighter cooperation between Computer Scientists and Physicists, with training and know-how transfer, seems fundamental for the development of better models, techniques and tools that lead to faster advancement of science by promoting an effective use of scarse human and computing resources.
The organization of the 2014 edition of the CERN School of Computing, which will be hosted by the University of Minho and LIP at Braga, is a major achievement that may be further expanded with related activities in the following years. This summer school is a major venture of the CERN IT Department and has become a highly regarded reference, training physicists, computer scientists and engineers from all over the world in HEP applications.

3.2.3 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

AMS é uma larga colaboração envolvendo cerca de 500 insvestigadores de 56 institutos oriundos de 16 países distintos que ambiciona operar um observatório na Estação Espacial Internacional pelo menos por um período de 10 anos. AMS-02 é um inovador detector de partículas desenhado para a detecção directa de partículas cósmicas que chegam à Terra vindas do Universo. Os principais objectivos de AMS são a medida detalhada do espectro de raios cósmicos, a pesquisa de antimatéria cosmológica e a procura de matéria escura. A identificação de núcleos será possível até à região do elemento ferro. O seu longo tempo de exposição conjugado com a sua grande aceitância (≈0.5 m^2 sr) irão permitir colectar uma estatística sem precedentes, até à presente data mais de 45 000 milhões de eventos foram adquiridos o que conduz a um espectro detalhado das diferentes partículas. O grupo do LIP tem participado activamente na experiência quer pelo desenho do detector de Imagiamento de Cherenkov (RICH), quer pela sua construção, testes e validação. As principais tarefas onde o grupo continuará envolvido serão a de monitorização do detector AMS, control do desempenho do RICH, reconstrução de dados, estudos de modulação solar nos raios cósmicos primários, separação de isótopos leves bem como medição da fracção de positrões a baixas energias.

4.1.2 Abstract

AMS is a broad international collaboration involving around 500 researchers from 56 institutes in 16 countries aiming to operate a cosmic-ray observatory in the international space station for at least 10 years. AMS-02 is a state-of-the-art particle detector designed to directly detect the cosmic-ray particles arriving at earth from the universe. The main goals of AMS are to perform a detailed measurement of the cosmic-ray spectrum, to search for cosmological antimatter and to search for dark matter. Nuclei identification will be possible up to the iron region. The long exposure time and large acceptance (≈0.5 m^2 sr) of AMS will enable to collect an unprecedented statistics, so far more than 45 000 million events were acquired, leading to detailed energy spectra of different particles. The LIP group has been actively taking part in the AMS experiment, by participating in the design and construction of the Ring Imaging Cerenkov detector (RICH) and on its exploitation. The main tasks where the group will keep on being involved are AMS detector monitoring, RICH performance and data reconstruction, solar modulation of primary cosmic rays, light isotopic separation and measurement of positron ratio at low energies.

4.1.3 Objectives

The AMS detector assembly was finished in 2010 at CERN. The detector was subsequently transported to NASA´s Kennedy Space Center (KSC) where it underwent the final testing procedures before its launch aboard Space Shuttle Endeavour in mission STS-134 and instalation aboard the ISS in May 2011. The minimum expected data acquisition time is three years, but the detector´s robustness may allow it to operate for a significantly longer period which might exceed a decade.
Since installation a large amount of data have been collected, at a rate of approximately 40 million events per day. Until now more than 45×10^9 events have been collected.
For the year 2014 the following activities are foreseen:

AMS detector monitoring
The mission´s POCC (Payload Operations and Control Center) operations are headquartered at CERN since June 2011, another dedicated facility (CNA) also operates in Tawain for the GMT night shift. LIP team members will continue their activity in AMS mission control, performing shifts and acting as on-call experts for the RICH, TOF and ECAL subdetectors.

RICH performance and data reconstruction
The LIP group is responsible for the development and ongoing improvement of one of the two sets of reconstruction algorithms for the RICH subdetector (LIP algorithms). The LIP algorithms provide measurements of particle velocity and electric charge based on Cherenkov ring patterns observed in the RICH. Typical velocity resolutions for single-charged particles such as protons with velocity ≈1 are 1.2x10ˆ-3 for aerogel events and 4.5x10ˆ-3 for NaF events. The aimed accuracy on the velocity and charge reconstruction implies the control of several parameters such as: mirror reflectivity, refractive index uniformity, aerogel clarity, calibration of detection cells. The group has been involved in these studies and will keep on using the LIP analysis tools developed for monitoring the performance of the detector and develop even more to control data quality. Recent work at LIP has focused on improving charge reconstruction to allow the identification of nuclear charges up to the highest possible values of Z. The RICH detector´s intrinsic limit on the visible number of photoelectrons per ring sets charge resolution for low Z at approximately 0.3 charge units. Systematic effects become dominant at higher charges, since they appear as a fixed relative error in the reconstructed charge value. During the last year, charge systematics for aerogel events have already been reduced from 5.1% to 2.6% through several optimizations, leading to an improvement in resolution of e.g. 0.6 to 0.4 charge units for Z=10 and 1.4 to 0.7 units for the iron region (Z≈26). The monitoring and correction of the velocity and charge measurements made by the RICH are fundamental for the isotopic separation and charge selection topics. RICH was built to provide AMS with the most precise particle velocity measurement (1 per mil for singly charged particles) and concerning LIp algorithm it is our responsability to garantee this target.

Solar Modulation of primary cosmic rays
The AMS launch took place during a minimum of solar activity (beginning of 24th cycle) and now we have approched a maximum of activity. Phenomenological studies on cosmic-ray propagation are being explored as well. Since there is no full analytical solution to the Parker Equation several different approaches have been tried, from numerical solutions to analytical approximations. Different ways of solving the transport equation are being studied and numerical methods (2D) are being explored. Solar modulation affects the low energy region of the cosmic-ray (CR) spectrum (<2 GeV) and a high efficient particle selection method is desired. Solar modulation of CR spectrum is a topic being currently explored with a MSc thesis is on-going and will be observed its effect on proton, helium and electron fluxes in a detailed time scale.

Light isotopic separation

A new mass separation method based on the geomagnetic cutoff was developed and will be applied to the deuterium flux measurement. The study of secondary particles coming from the interaction of primary particles with the interstellar medium is of major importance to validate the available cosmic-ray propagation models in our Galaxy. Deuterons, which are formed from helium nuclei collisions with the interstellar medium matter or from p-p collisions, are one of the most interesting particle species since they are rare in astrophysical terms but relatively abundant in cosmic rays. The major difficulty arises from proton background separation. The separation method developed takes into account the natural separation in different velocity regions for protons and deuterons provided by the geomagnetic field. The same method wil be exploited for helium and beryllium isotopes separation.

Statistical estimator for mass separation
A statististical estimator for mass sepation was developed at LIP and has being improved: it is based on the definition of velocity and RICH signal probability density functions (PDFs) for every particle kind and for every event with a given rigidity measured by the Silicon Tracker. The measured velocity and RICH signal of every event can therefore be used to estimate the probability defining the degree of compatibility of the measurement with what is expected for every particle type (e+/e-, protons, He,...). It was successfully apllied to electron/proton separation in the low energy regime (<10 GeV) for positron ratio measurement (results published last April) and is foreseen to be applied to other mass separation issues in other physical analysis with the advantage of performing a large acceptance selection.

Sub-Iron elements measurements
The group expertise on RICH charge measurement and on its systematic errors pinpoints them to explore the highest charge area of the cosmic-ray spectrum and perform the measurement of the abundances of sub-iron (Sc to Cr) compared to the iron nuclei abundances in cosmic rays. Most of the sub-iron elements are not present in the vicinity of the sources and are generated by fragmentation of the iron nuclei during their path in the interstellar medium. AMS-02 with its capability of charge measurement up to iron element due to its good resolution and high statistics will give a precise measurement of this ratio. Within one or two more years of data acquisition we will be able to perform those measurements. A continuous understanding of the charge systematic errors is desired for a good quality measurement as well as a deep understanding of particle´s interactions inside the AMS detector.

Post-graduated trainning
Two master thesis are ongoing and more are expected to be devoloped within the framework of the group activities.

4.1.4 Team

Project coordinator: Fernando Barão

Name	Status	FTE %
Bruno Santos	Master student (LIP)	60
Fernando Barão	Researcher (LIP/IST)	85
Luisa Arruda	Post-Doc (LIP/FCT)	80
Miguel Orcinha	Student (LIP)	100
Pedro Nunes	Master student (LIP)	100
Rui Faísca Pereira		60

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

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+. O detector SNO consistia numa esfera central de 12 m de diâmetro, rodeada por cerca de 9500 PMTs montados numa estrutura geodésica, instalada a uma profundidade de 2km no SNOLAB, Canadá. Os resultados de SNO comprovaram o fluxo total previsto de neutrinos solares de Boro-8, medido por interacção de correntes neutras (sensível a todos os sabores de neutrinos), e simultaneamente a diminuição da taxa de neutrinos do eletrão, medida por correntes carregadas - confirmando a oscilação de neutrinos e resolvendo o chamado Problema dos Neutrinos Solares.
O grupo do LIP teve um papel importante na calibração ótica do detector e na medida de precisão dos parâmetros de oscilação dos neutrinos - que resulta na mais precisa medida do ângulo de mistura θ_{12}. Este trabalho originou uma tese de doutoramento na Universidade de Lisboa (2012).
SNO+ adapta o detetor de SNO, substituindo o alvo e meio ativo de água pesada por cerca de 800 ton de cintilador líquido, com múltiplos objetivos científicos, sendo o principal a pesquisa com elevada sensibilidade do sinal de duplo declíneo 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 utilização de cintilador líquido permitirá baixar significativamente o limiar de energia, de modo a medir neutrinos solares pep e CNO, geo-neutrinos e anti-neutrinos produzidos em reactores nucleares, aumentar a sensibilidade a neutrinos de supernovas; para estas medidas estão previstas diferentes fases de tomada de dados primeiro com e depois sem dopagem de Telúrio para 0NDBD.
A instalação do detetor está em progresso, sendo o sistema de purificação do cintilador e alguns componentes dos sistemas de calibração os principais items ainda a finalizar. Em 2014 está previsto completar o enchimento com água ultra-pura para primeiros testes antes do enchimento com cintilador líquido, em 2015.
No entanto, algumas fases de tomada de dados de testes em ar já foram realizadas desde 2012.
A calibração em tempo e carga dos fotomultiplicadores (PMTs) é fundamental para a reconstrução de posição e energia dos eventos detetados. Em colaboração com a Universidade de Sussex (UK), desenvolvemos um novo método de calibração não invasivo, baseado em vários cabos longos de fibra ótica, com ligação sequencial a um conjunto de LEDs externo ao detetor. As fibras são instaladas em posições fixas no detetor, reduzindo a necessidade de introdução de fontes dentro do volume interno de cintilador. Para o desenvolvimento e testes dos 110 cabos de fibras duplas do novo sistema foram utilizadas as instalações do grupo ATLAS no Centro de Física Nuclear da Universidade de Lisboa. Todas as partes mecânicas para inserção das fibras no detetor e a sua colocação nos pontos requeridos foram construídas nas oficinas do LIP em Coimbra. Um terço das fibras foram já instaladas em 2012, as restantes serão instaladas por barco durante o enchimento do detetor com água em 2014.
Recentemente, o LIP tornou-se também responsável pelo desenho e construção dum novo sistema de colocação de fontes de calibração em SNO+. Este é um sistema complexo que requere estanquicidade (para evitar a contaminação do cintilador com radão externo) e um controlo preciso das tensões sobre as cordas de suporte e os cabos de ligação à fonte.
Devido à experiência adquirida em SNO, a calibração óptica de SNO+ irá ser uma das nossas responsabilidades principais no futuro. O nosso grupo é desde já responsável por este subgrupo de trabalho, em que estamos a atualizar o software e desenvolver o plano de análise.
Assim, nos próximos dois anos, as nossas atividades serão centradas nos sistemas de calibração, com a preparação das análises de física para os anos seguintes.
A recente associação ao grupo de G. Prior irá permitir não só consolidar as atividades já em curso, mas contribuir também numa das suas áreas de especialização, os sistemas de aquisição de dados.
Em termos organizativos, o responsável pelo grupo do LIP assegurou (por eleição) a presidência da "Collaboration Board", entre Setembro de 2011 e Agosto de 2012, depois de um ano com a vice-presidência. Membros do grupo do LIP asseguram a coordenação dos subgrupos de Calibração Ótica (JM) e de Física de Antineutrinos (SA). JM pertence também ao Analysis Coordination Committee e Speaker´s Committe. Em 2010 organizámos a reunião de colaboração em Lisboa. Em 2009 foi assinado o Memorando de Entendimento entre a FCT, o LIP, SNO+ e SNOLAB. A participação do LIP em SNO+ é apoiada financeiramente pela FCT, com projecto PTDC que termina em 2014, e com um novo projeto exploratório (IR: Sofia Andringa), que suporta o desenvolvimento de novas ideias para as medições de anti-neutrinos.
O desenho e construção do equipamento de inserção de fontes é suportado por financiamento canadiano.

4.2.2 Abstract

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 detector consisted of a 12m diameter spherical vessel, surrounded by about 9500 PMTs mounted on a 17m diameter geodesic structure, installed at a depth of 2 km in SNOLAB, Canada. The SNO results simultaneously confirmed the predicted total flux of 8B solar neutrinos flux 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. These results provide the world´s best precision on the neutrino mixing angle θ_{12}. In 2012, a PhD thesis containing this work was defended at the University of Lisbon.
The SNO+ experiment is adapting the SNO 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, for which further data-taking phases with unloaded scintillator are planned. The installation of the detector components is in progress. The scintillator purification systems and some parts of the calibration systems are the main components still being finalized. After some delays, in 2014 we expect to complete the filling with ultra-pure water, and start the water commissioning phase, before starting the scintillator fill in 2015. However, several "air run"test data-taking periods were already carried out since 2012.
Timing and charge calibration of the PMTs is fundamental for the position and energy reconstruction of any detected events. In collaboration with the University of Sussex (UK), we have developed a new method for PMT calibration that does not require the insertion of sources in the detector, since it is based on a set of optical fibers transmitting light from external LEDs. Initial design tests and the final quality control of the full 110 double-fiber cables was carried out at the ATLAS group lab at Centro de Física Nuclear da Universidade de Lisboa. 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 first one-third of the system was carried out in 2012, and the remaining fibers will be installed in 2014 during the water fill.
The LIP group has also recently 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 an accurate control over the tensions on the source umbilical and support rope.
Building on the experience acquired in SNO, the SNO+ optical calibration will soon become one of our main tasks. Our group is already responsible for this analysis subgroup, for which we are upgrading the analysis software.
During the next two years, these activities, focused on the commissioning of the calibration systems and analysis software, will be the main goal of the LIP group. The recent association of G. Prior to the group will allow not only to consolidate the ongoing activities, but also to contribute in one of her expertise areas, data acquisition. Physics data analysis, focused on reconstruction and background reduction, will be the strategic goals for the years to follow.
Focusing on the organizational aspects, JM served the 2011/2012 term as elected chair of the Collaboration Board and members of the group chair the analysis subgroups of Optical calibration (JM) and Anti-neutrino Physics (SA). JM is also a member of the Analysis Coordination Committee and the Speakers Comittee. In 2010, the LIP group organized the collaboration meeting in Lisbon. In December 2009, a Memorandum of Understanding for scientific cooperation was signed between FCT, LIP, the SNO+ Collaboration and SNOLAB. The LIP participation in SNO+ is funded by FCT through a PTDC project that is finishing in 2014, and an Exploratory Project (PI: Sofia Andringa), that focuses on developing new ideas for the anti-neutrino measurements.
The design and construction of the source insertion equipment is supported by Canadian funding.

4.2.3 Objectives

As we are expecting the water fill of SNO+ to be done in 2014, our objectives will include:
1) The installation of the remaining 2/3 of the fibers of the PMT calibration system, to be done by boat during the filling.
2) Commissioning of the calibration systems with the water data, including both the LED/fibers PMT calibration system, and the laserball. In the latter case, we will test the analysis code currently being developed (parts of it adapted from SNO), and measure the angular response of the PMTs, in order to determine if there was a continuing degradation of the performance of the reflectors associated to the PMTs.

3) DAQ/Data-quality control tests: The LIP group will be responsible for low-level checks of the data-quality such as verifying that events where recorded and built correctly as well as cross-checking the hardware configuration with the run-recorded configuration. These can be performed even with the detector only partially filled.
In addition, we will also pursue the following calibration-related goals:
3) Submission of a publication about the PMT calibration system;
4) Initiate the production of the mechanism for source manipulation (URM) at the mechanical workshops of LIP- Coimbra. Prior to shipping to SNOLAB, mechanical and leak-checking tests will be performed on the complete URM.
In terms of Physics analyses preparation, the following tasks will be prioritary:
5) Double-beta decay: Background events in the ROI can be removed using event tagging techniques to achieve maximum rejection efficiencies. The LIP group will join the background analysis group with focus on investigating α-β tagging techniques (events coming from the natural U/Th chains).
6) Anti-neutrinos: The group will explore the possible directional information for anti-neutrino analyses. The accuracy of direction reconstruction from the separation between the positron annihilation and neutron capture signals, for the SNO+ run conditions or future detector, will be assessed with simulated data. Existing isotropic neutron sources will be used to assess the SNO+ sensitivity, but the necessity for a new directional source will be also considered. The quantitative impact of this new variable will be evaluated in terms of reactor anti-neutrino oscillations and geo-neutrino studies.

4.2.4 Team

Project coordinator: José Maneira

Name	Status	FTE %
Amélia Maio	Researcher (LIP/FCUL)	26
Carlos Silva	Technician (LIP)	15
Gersende Prior	Researcher (LIP)	100
Joaquim Oliveira	Technician (LIP)	15
José Maneira	Researcher (LIP)	37
Luís Gurriana	Technician (LIP)	15
Nuno Barros	Researcher (LIP/FCT)	50
Orlando Cunha	Technician (LIP)	15
Rui Alves	Technician (LIP) *	26
Sofia Andringa	Researcher (LIP)	36

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

4.3.1 Resumo

Em 2014, as actividades do LIP na área da detecção directa de matéria escura continuarão centradas na participação na experiência Large Underground Xenon (LUX). Incluirão também actividades de I&D com vista à concepção e construção do detector LZ, assim como a participação na elaboração do "Conceptual Design"da experiência LZ.
A experiência LUX constitui um passo decisivo na procura da matéria escura na forma de "Weakly Interacting Massive Particles"(WIMPs). LUX utiliza um detector de xénon de duas fases, técnica bem comprovada pelas experiências ZEPLIN e XENON, introduzindo, no entanto, avanços cruciais relativamente a estas duas experiências, como por exemplo, um aumento muito significativo da massa de xénon (350 kg comparada com 6,5kg e 100 kg em ZEPLIN-III e XENON, respectivamente), avanços nas técnicas de blindagem e de criogenia, redução do fundo de radiação, o que permite melhorar a sensibilidade da experiência.
Para além da sua elevada sensibilidade e do seu consequente potencial para detectar WIMPs, LUX serve também de "balão-de-ensaio"de tecnologias necessárias à próxima geração de detectores de WIMPs: 1) Utilização de fotomultiplicadores maiores e com menor radioatividade; 2) Um sistema criogénico que utiliza termosifões que permite arrefecer o detector de forma compacta e muito eficiente; 3) crióstato e detector em titânio de baixa radioatividade; 4) imersão do crióstato num tanque de água ultra-pura, equipado com fotomultiplicadores, em vez das blindagens de chumbo e de polietileno habitualmente utilizadas; 5) Fontes de calibração gasosas (Kr-83m e H-3) introduzidas diretamente no xénon.
A Colaboração LUX é constituída por 14 instituições de 3 países (EUA, Portugal e UK), num total de cerca de 86 indivíduos. O LIP é membro da Colaboração LUX desde Dezembro de 2010.
No final de 2013, após 3 meses de aquisição de dados, LUX anunciou e publicou os seus primeiros resultados respeitantes à procura da matéria escura que mostram que LUX é a experiência em funcionamento com maior sensibilidade para a detecção de WIMPs usando a dispersão elástica WIMP-nucleões mediada pela interação independente de spin. Essa sensibilidade tem um máximo para mWIMP=33 GeV/c2 e é cerca de 3 vezes maior do que a sensibilidade máxima de qualquer outra experiência em funcionamento. Para baixos valores de mWIMP, esse factor passa para cerca de 20 e os resultados de LUX não concordam com os de outras experiências que sugerem terem observado WIMPs a baixas massas.
LUX fará uma aquisição de dados de cerca de 300 dias efetivos em 2014/2015. Antes disso, decorrerão alguns estudos de engenharia e calibrações para estabelecer os parâmetros ideais com que o detector deve operar durante a tomada de dados e que podem conduzir ao acréscimo adicional da sensibilidade do detector. Entre os aspectos que vão merecer atenção nesta fase contam-se o possível aumento dos campos eléctricos aplicados, o aumento da estatística nas calibrações, o decréscimo da radiação de fundo e o funcionamento do tanque como veto ativo.
Em 2014, o grupo do LIP continuará com as responsabilidade que tem assumido até agora, nomeadamente o sistema de controlo do detector e subsistemas associados (SCD), o sistema automático de distribuição de azoto líquido e a reconstrução em posição das interações no detector. O SCD e o sistema de distribuição de azoto sofrerão intervenções no sentido de aumentar a sua flexibilidade e minimizar a necessidade de intervenção local de pessoal. O algoritmo/software de reconstrução das coordenadas das interações no detector será optimizado no sentido de conseguir reconstruir as coordenadas de interações que depositam muito baixa energia até ao limite daquelas que dão origem a um único electrão livre. O grupo planeia também aumentar o envolvimento na análise de dados e continuar a participar nas operações locais em SURF.
Paralelamente ao envolvimento em LUX, o grupo planeia também participar na preparação da próxima geração de detetores de matéria escura. Qualquer que seja o resultado da próxima tomada de dados de LUX - a detecção de WIMPs ou a melhoria substancial do limite superior da secção eficaz da interação WIMP-nucleão - vai ser necessário construir um novo detector com uma massa substancialmente superior, i.e., da ordem das várias toneladas, de modo a aumentar a estatística para permitir estudar as propriedades dos WIMPs (no caso da descoberta) ou levar a sensibilidade até ao valor para além do qual esta técnica deixa de ser útil por causa do fundo devido às interações dos neutrinos solares.
Nesse sentido fazemos já parte da Colaboração LUX_ZEPLIN (LZ) que propõe a construção de um detector de 7 toneladas, que utiliza a mesma tecnologia que LUX, a ser instalado em SURF, Lead, Dakota do Sul. A experiência LZ tirará proveito da infraestrutura existente e de algumas componentes de LUX, como é o caso do tanque de água. A Colaboração conta com 17 instituições dos EUA, 7 do Reino Unido, 1 da Rússia e o LIP de Portugal. O LIP foi convidado a participar em LZ quando do estabelecimento da colaboração em 2009. LZ está presentemente a terminar o seu "Conceptual Design"financiado pelo DOE, EUA.
Em LZ, o LIP coordenada o Grupo responsável pela sistema de controlo da experiência que constitui a principal responsabilidade assumida pelo grupo até ao momento. Planeamos no futuro próximo desenvolver o software

para a reconstrução em posição no detector de LZ baseados na larga experiência que temos nesta matéria.
LZ constitui um excelente projeto para o treino de engenheiros físicos, ao nível do Mestrado e do Doutoramento, numa grande variedade de técnicas e tecnologias. Será também muito atraente para estudantes de doutoramento em Física dado o interesse e actualidade do tópico (a detecção da matéria escura) e o desafio que a análise de dados comporta. LZ constituirá para todos um ambiente de investigação muito competitivo e estimulante.

4.3.2 Abstract

The group aims to continue, in the framework of LUX and LUX-ZEPLIN (LZ) Collaborations, to participate in the dark matter search towards a possible discovery or to lead the direct detection of WIMPs with scattering experiments down to its ultimate limit.
LUX experiment constitutes a large step forward in the search for dark mater in the form of Weakly Interacting Massive Particles (WIMPs). Based on the well-proven dual-phase xenon detector technology in the ZEPLIN and XENON detectors, it adds improvements in key areas, such as a much larger xenon mass (350 kg compared with 6.5 kg of ZEPLIN-III and 100 kg of XENON100), improvement in shielding and cryogenics and reduction of backgrounds.
Apart from its potential of WIMP discovery, LUX is also very important because it introduces technological innovations required to major scale-up to the ton-scale detectors and beyond: 1) Larger, low activity photomultipliers. 2) A cryogenic system using liquid nitrogen thermosyphons that compactly and economically provides high capacity cooling heads. 3) A low-background titanium cryostat. 4) Immersion of the cryostat in an ultra pure water shield instead of Pb/polyethylene shields more suitable for small experiments. 5) Use of internal calibration sources (Kr-83m and H-3) introduced directly into the liquid xenon.
LUX Collaboration comprises 14 institutions from 3 countries (USA, Portugal and UK) and 86 individuals. LIP is member of LUX collaboration since December 2010.
At the end of 2013, after just less three months of data taking, LUX announced and published its first dark matter results, proving to be the most sensitive dark matter detector in operation. LUX has peak sensitivity at WIMP mass of 33 GeV/c2 (see fig.1), with a sensitivity limit three times better than any previous experiment. LUX also has a sensitivity that is more than 20 times better than previous experiments for low-mass WIMPs, whose possible detection has been suggested by other experiments and is not supported by LUX results.
LUX will continue operations at Sanford Underground Research Facility (SURF) during 2014 and 2015. Further engineering and calibration studies will establish the optimal parameters for detector operations, with potential improvements in applied electric fields, increased calibration statistics, decaying backgrounds and an instrumented water tank veto further enhancing the sensitivity of the experiment. Subsequently, LUX will complete the ultimate goal of conducting a blinded 300 live-day WIMP search further improving sensitivity to explore significant new regions of WIMP parameter space.
During the preparation of this run, the data taking period and the data analysis effort, the LIP group will continue with the full responsibilities taken so far, namely the Detector Control System (DCS), the liquid nitrogen distribution system and the position reconstruction algorithm. The DCS and the liquid nitrogen distribution systems will be upgraded towards the increase of flexibility and the minimization of the personnel onsite. The vertex reconstruction algorithm will be optimized trying to lower the limit of the position reconstruction down to single primary electrons. We also aim to increase our participation in the data analysis. Finally, the group will participate in the LUX operations.
In parallel with being deeply involved in LUX, the group plans to participate in the second generation of dark matter detectors. Whatever is the result of the LUX one year run, the WIMP discovery or a much lower exclusion limit, a ton-scale detector has to be built for obtaining better statistics (in the case LUX makes a discovery) or improving the sensitivity up to the ultimate limit of the direct detection of WIMPS by looking for their scattering off the detector nuclei.
In fact, we have already been participating in the LUX-ZEPLIN (LZ) Collaboration that proposes the construction of a 7-ton xenon detector using the same TPC technology as LUX and to be installed at SURF, Lead, South Dakota. The experiment will take advantage of existing infrastructure and some detector components from the LUX experiment. The collaboration counts with 17 Institutions from USA, 7 from UK, 1 from Russia and LIP from Portugal). We were invited to join LZ since the beginning in 2009. LZ is just finishing the Conceptual Design, which is being funded by DOE, USA.
At LZ, LIP coordinates the Slow Control Subsystem Working Group, which is our main responsibility so far. We also aim to develop a position reconstruction algorithm suitable for LZ based on our large experience on this topic. A good 3-D position resolution is crucial to exploit the self-shielding of the liquid xenon, removal of surface artifacts, and calibration of position-dependent response functions.
LZ will be an excellent playground to train physical engineers at Master and PhD level in a variety of techniques and technologies. It will also be very attractive for Physics PhD students because of the challenging data

analysis and the interest of the topic. For all involved, LZ will provide a very competitive and stimulating research environment.

4.3.3 Objectives

In the framework of our participation in LUX, our main goals are:
* Complete the update of the slow control and the liquid nitrogen systems for the long science run. They will be upgraded towards the increase of flexibility and the minimization of the personnel onsite. Maintain these two systems during the 300 days data-taking period.
* To optimize the vertex reconstruction method aiming: i) to lower the limit of the position reconstruction down to single primary electrons; ii) to be able to identify multiple interaction events in which the interactions are not separable in z (i.e in the drift direction); in this case the identification of the two interactions has to be achieved by the separation of their xy coordinates. For that, the resolution in xy has to be improved for small energy depositions.
* Increase the involvement in the data analysis, in particular regarding the pulse analysis algorithms and the improvement of the electron/nuclear recoils discrimination.
* To participate in the LUX engineering phase and operations which is expected to involve about 220 days*person per year for the LIP team.
* To train two master students already involved in the group. One of them will finish his master thesis in 2014.
* Francisco Neves will be the LUX Detector Working Group Coordinator from 1/1/2014 to 30/6/2014. In this period there will a lot of activity centred in the detector to prepare it for the long science run.
* Alexandre Lindote will be LUX Data Processing Manager from 1/1/2014 to 31/3/2014.
* Isabel Lopes will continue to serve as member of the LUX Executive Board.
Regarding our participation in LZ, our present objectives:
* To continue to coordinate and participate in the design (and R&D yet required) of the slow control system for LZ.
* To develop a position reconstruction algorithm suitable for LZ based on our large experience on this issue.
* To progress with the measurements of PTFE immersed in liquid xenon. To conclude about the sensitivity of the experimental method that has been used.
* To study the sensitivity of the LZ detector as function of isotopic composition of the target mass. Several stable isotopes with significative abundances compose natural Xenon and they have both a high ratio of neutron-odd nuclei (mainly 129Xe and 131Xe) and neutron-even nuclei. For this reason the xenon is one of the few WIMP targets that can do "target exchange": find a signal at natural abundance, then use exactly the same experiment (same systematics) with depleted/enriched isotopes. The first objective will be to study the sensitivity of the spin-dependent interactions using only odd (spin-dependent sensitive) or even nuclei. We will also study the influence of the number of neutrons and protons in the sensitivity of the detector.
* Isabel Lopes will continue to serve as member of the Executive Board (and in the Institutional Board) of the LZ Collaboration

4.3.4 Team

Project coordinator: Isabel Lopes

Name	Status	FTE %
Afonso Bernardino	Master student (LIP)	50
Alessio Mangiarotti	Researcher (USP)	15
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)	22
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

- *Control and monitoring platform for LZ experiment*
  Afonso Bernardino, (on-going)

4.4 High Energy Cosmic Rays

4.4.1 Resumo

Em 2014, as actividades do LIP na área dos raios cósmicos de alta energia vão continuar centradas na participação no Observatório Pierre Auger (AUGER). Nomeadamente, na análise de dados focada na determinação da composição dos raios cósmicos e na física hadrónica de alta energia, incluindo a procura de eventos exóticos e na preparação de MARTA – "Muon Auger RPC for the Tank Array- um projecto para a instalação de RPCs no detector de superfície de Auger.
O Observatório Pierre Auger foi construído com o objectivo de compreender a origem e natureza dos raios cósmicos de ultra-altas energias e também para estudar as interações das partículas nessas energias. Hoje, cerca de 500 físicos de mais de 90 instituições em 19 países fazem parte da Colaboração. O Observatório, localizado na Argentina, está a tomar dados desde 2004 e foi terminado em 2008. Combina um detector de superfície, (um array que cobre uma área de 3000 km^2 com tanques de água de efeito Cherenkov para detectar as partículas secundárias no chão) com um conjunto de telescópios de fluorescência que recolhem a luz emitida pela passagem da cascata pela atmosfera. Cerca de 10% dos eventos são observados pelos dois detectores, (eventos híbridos), permitindo assim fazer calibrações cruzadas e, em particular, assignar uma energia calorimétrica medida pelo FD da componente electromagnética (EM) a uma amostra muito maior de eventos de SD, constituída principalmente por partículas EM e muões.
Actualmente, Auger é o maior detector de raios cósmicos do mundo e tem originado importantes avanços: estabeleceu inequivocamente a supressão do fluxo de raios cósmicos às energias mais altas. Graças aos limites de fotões, foram excluídos cenários cosmológicos para a origem dos raios cósmicos de altas energias e foram favorecidos os cenários de aceleração em objectos astrofísicos. Finalmente, foram observados indícios de anisotropia às energias mais altas. No entanto, ainda há várias questões em aberto. Em particular, é crucial:
1) Averiguar a origem da supressão do fluxo e composição dos primários às energias mais altas.
2) Separar, evento-a-evento, as composições mais leves das mais pesadas atingindo uma sensibilidade de, no mínimo, de 10% da contribuição de protões. Esta conquista abriria a possibilidade de trabalhar com feixes mais puros em análises de anisotropia e de espectro energético, e que se pode tornar no nascimento da Astronomia de Partículas Carregadas de Alta Energia.
3) Estudar os chuveiros atmosféricos e a física hadrónica, apontando na exploração da física fundamental de partículas a energias que superam aquelas acessíveis pelos aceleradores terrestres.
O grupo do LIP está focado principalmente na exploração da física de partículas do Observatório, nomeadamente nos estudos que visam entender a composição dos raios cósmicos e as interações a altas energias, através de uma janela que vai para além das energias atingidas pelo LHC. Os modelos de interações hadrónicas não podem ser derivados de primeiros princípios. Os seus parâmetros fenomenológicos têm que ser ajustados dos dados dos aceleradores e depois serem extrapolados até às energias dos raios cósmicos. A procura de eventos exóticos nos dados de Auger poderia também desvendar nova física para além do Modelo Padrão, representando assim um importante complemento.
No que respeita ao programa de upgrade, o grupo do LIP lidera MARTA que consiste na detecção de muões através da instalação de RPCs por baixo dos tanques do SD. MARTA permitirá ao Observatório medir o conteúdo muónico dos chuveiros evento-a-evento. A decisão final da proposta será escolhida em 2014. Se MARTA for selecionada, o grupo estará a liderar um enorme projecto com a responsabilidade de produzir 3600 RPCs. Se outra proposta for escolhida, a prova de conceito do protótipo MARTA servirá de base para projectos futuros neste campo com a construção de RPCs seladas e autónomas.
O grupo do LIP está também substancialmente envolvido na difusão do conhecimento, com vários membros do grupo com um papel muito activo na dinamização de actividades de divulgação, (um deles é Coordenador para a Divulgação no LIP). Em particular o grupo propôs a 3 escolas a análise dos dados públicos do Observatório Pierre Auger ao longo este ano lectivo, às quais prestamos apoio, e esperamos alargar o âmbito do nosso guia para escolas em Espanha, México e Uruguai.
A equipa do LIP é relativamente grande, tanto em número de membros, como em competências, sendo também uma excelente plataforma de treino académico e de difusão do conhecimento. Apesar da maioria da equipa se encontrar em Lisboa, trabalham em estreita parceria os 3 polos do LIP. Sendo que a equipa de Coimbra é especialista em RPCs e a equipa do Minho está especializada na análise de dados. O grupo está dividido em 7 tarefas que correspondem aproximadamente a estas competências, cada uma liderada por um membro da equipa.

4.4.2 Abstract

The LIP activities in the area of high energy cosmic rays will continue, in 2014, centred in the Participation in the Pierre Auger Observatory (Auger). Namely, data analysis focussed in the determination of the mass

composition and high energy hadronic physics, including the search of exotic events, and the preparation of MARTA – "Muon Auger RPC for the Tank Array- a project for the installation of RPCs in the Auger surface detector.
The Pierre Auger Observatory was built to give a major contribution to the understanding of the origin and nature of ultra-high energy cosmic rays, as well as to study particle interactions at such high energies. Today, nearly 500 physicists from more than 90 institutions in 19 countries are part of the Collaboration. The Observatory, located in Argentina, is taking data since 2004 and its construction was completed in 2008. It combines a surface detector array (SD) covering an effective area of 3000 km^2 with water Cherenkov tanks to detect the secondary particles at ground, with a set of fluorescence detector telescopes (FD) watching the fluorescence light emitted after the passage of the shower particles through the atmosphere. Around 10% of the events are recorded by both detectors (Hybrid events) allowing for cross-calibration, in particular to assign a calorimetric energy measurement of the electromagnetic (EM) component (recorded by FD) to the larger sample of events of SD, mainly made of EM particles and muons.
Auger is presently the world´s largest cosmic ray detector and has provided important breakthroughs: it has established the suppression of the flux and provided hints of anisotropy at the highest energies. Thanks to photon limits, it has been ruled out top-down scenarios as the origin of the UHECR, favouring astrophysical acceleration scenarios. Nevertheless, puzzles and open questions remain. In particular, it is crucial to:
1) Elucidate the origin of the flux suppression and mass composition at the highest energies.
2) Provide a separation of heavy and light particles in an event-by-event basis, aiming to reach a sensitivity to a proton contribution as small as 10%; This would open the possibility of working with a purer composition beam for anisotropy and energy spectrum analysis, which can turn out to be the dawn of high energy charged particle astronomy.
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.
In order to 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 group is mainly focused on the full exploitation of the particle physics potential of the Observatory and, in particular, in the efforts to understand mass composition and hadronic interactions through a window that reaches well above the LHC energies. Hadronic interactions models cannot be derived from first principles. Their phenomenological parameters have to be fitted from the available accelerator data and extrapolated to the UHECR energies. In addition, the search for exotic events in the Auger data might also unveil physics beyond the standard model.
Concerning the upgrade program, LIP group led the MARTA to detect muons by deploying RPCs under the tanks of the SD array. MARTA will allow Auger to measure the muon content of showers on an event-by-event basis. A decision on the choice of the upgrade is expected in 2014. If MARTA is the selected upgrade, the group will lead a major effort in the Collaboration, with the responsibility of the production of 3600 RPCs. If another solution is selected, the proof-of-concept already made with the MARTA full scale prototypes will be the basis for future R&D towards the construction of autonomous sealed RPCs.
The LIP team is strongly committed to knowledge dissemination and outreach, with several members playing an very active role, and being one of its members general LIP Outreach Coordinator. In particular, during 2014 three schools will have students analysing the Auger public data with LIP support, an activity that is expected to expand, with our guide translated into Spanish, to schools in Spain, Mexico and Uruguay.
The LIP team is relatively large both in number of members and competences, being also an excellent platform for academic training and knowledge dissemination. While the bulk of the team is in Lisbon, it relies on a close collaboration between the 3 LIP poles, with the involvement of the Coimbra RPC team and of the Minho analysis team. The group is organized in 7 tasks corresponding to these competences, each lead by a team member.

4.4.3 Objectives

Task 1 - EM component and energy determination
Coordinator: Sofia Andringa
a) Separation of the EM and muonic components in an upgraded detector, using MARTA simulation as test-bench.
b) Calibration of the EM signals at ground with the calorimetric FD energy to set an independent energy scale, unaffected by muons.
c) Study of the relation of the average lateral distributions (SD) with the average profile (FD).

Task 2 – Muon component and hadronic cascade
Coordinator: Lorenzo Cazon
a) Relate the muon distributions with the hadronic cascade for real data (systematics limited) and MARTA simulations. Study the consistency of LHC-tuned models with data.
b) Integration of the Muon Production Depth and Transport Model into the "Universality"description of the shower.
c) As leader of the Auger "Hadronic Interactions Task", coordinate the different Collaboration contributions, in particular those related to muons.
Task 3 – High energy hadronic interaction phenomenology
Coordinator: Ruben Conceição
a) Identify the mechanisms of hadronic interactions at energies up to sqrt(s) $\approx$ 400 TeV that have a measurable impact on showers.
b) Assess the sensitivity of the EM and muonic longitudinal profiles to constrain the hadronic parameter space (multiplicity, elasticity and cross section), with mutual feedback from the new LHC data.
c) Interface with other tasks to interpret results in terms of high energy physics phenomena.
Task 4 – Search for exotic and rare events
Coordinator: Catarina Espírito Santo
a) Explore the curvature of the shower front as variable to identify rare or exotic showers, as it carries information of the shower development stage and of the primary.
b) Assess the sensitivity of muons in exotics search, and make the bridge with the muon and MARTA tasks.
Task 5 – MARTA simulation and performance
Coordinator: Bernardo Tomé
a) Interface with other tasks to produce simulations and reconstruction tools to optimize the MARTA design.
b) Integration and maintenance of packages within the official Auger software.
c) Participation in the Auger Simulation Challenge to assess the performance of the various upgrade proposals.
Task 6 – MARTA electronics, data acquisition and calibration
Coordinator: Pedro Assis
a) Development of the MARTA readout board based on the MAROC3 ASIC;
b) Commissioning and running of the data acquisition of the MARTA units deployed in the Auger site;
c) Development of MARTA calibration methods based in atmospheric muons and calibration of the first MARTA units deployed in the Auger site.
Task 7 – Outreach
Coordinator: Pedro Abreu
a) Analysis of Auger public data at portuguese schools and at LIP internships for high-school students.
b) Translation of the Public Data Guide into spanish.
c) Display of LIP Spark Chamber in exhibitions, together to tabletop cloud chamber. Production and distribution of new units worldwide.
The development and production of the RPCs will be made at the LIP Coimbra facilities by the team coordinated by Paulo Fonte. This team is a world reference on RPCs.

4.4.4 Team

Project coordinator: Mário Pimenta

Name	Status	FTE %
Alberto Blanco	Researcher (LIP)	20
Alessandro de Angelis	Researcher (LIP)	35
Américo Pereira	Technician (LIP)	15
Bernardo Tomé	Researcher (LIP)	80
Catarina Espírito Santo	Researcher (LIP)	80
Eva Santos	Post-Doc (LIP) *	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 Micael Oliveira	PhD student (LIP)	100
José Milhano	Researcher (LIP/IST)	15
Liliana Apolinário	Post-Doc	15
Lorenzo Cazon	Researcher (LIP)	98
Luís Lopes	Technician (LIP)	15
Luís Mendes	Student (LIP)	66
Mário Pimenta	Researcher (LIP/IST)	85
Miguel Ferreira	Technician (LIP)	100
Patrícia Gonçalves	Researcher (LIP)	20
Pedro Abreu	Researcher (LIP/IST)	65
Pedro Assis	Post-Doc (LIP/FCT/IST)	85
Pedro Brogueira	Researcher (LIP/IST)	30
Pedro Cardoso	Master student (LIP)	100
Raul Sarmento	Post-Doc (LIP/FCT)	100
Ruben Conceição	Post-Doc (LIP/FCT)	100
Sofia Andringa	Researcher (LIP)	86
Thomas Schweizer	Researcher	15

4.4.5 Academic Training

PhD Theses

- *Cosmic Rays at the Ankle: Auger South Enhancements*
  Eva Santos, 2014-02-07
- *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 project (CERN/FP/123605/2011) will terminate in July 2014 the activity will continue in the framework of the "RAD4LIFE"project, a QREN program (UE funded) approved to take place between 1st June 2013 and 30th June 2015.
For WG3 the construction of the first complete prototype of the animal RPC-PET scanner will be terminated and tested.
A large area (≈2 m2) TOFtracker device will also be developed and tested.

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

5.1.5 Academic Training

PhD Theses

- *Demonstration of a Positron Emission Tomography small-animal scanner based on Resistive Plate Chambers*
  Paulo Martins, (on-going)

5.2 Neutron detectors

5.2.1 Resumo

The aim of this research project is to develop and build a prototype of a thermal neutron detector, combining resistive plate chamber (RPC) technology with solid neutron converters based on boron-10.
The main objective of this project is to demonstrate that the proposed concept is a promising alternative to detectors based on He-3 and can be expanded to large area low-cost neutron detectors.
Detection of a low-energy neutron requires a neutron capture followed by a nuclear reaction that results in emission of charged particles. 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 neutron imaging was He-3 (e.g. thermal neutron scattering, radiography and tomography).
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). The unforeseen decline of He-3 stock after the September 11 attacks, boosted its price to a forbidding level.
In this project we intend to develop a different detector concept. Our idea is to use resistive electrodes coated with a thin film (1-2 microns) of a B4C solid neutron converter in a multi-gap RPC configuration . RPCs are well suited to operate in the multi-layer configuration which is needed to ensure high neutron detection efficiency. Moreover, the RPCs allow modular detector design and good scalability maintaining low number of readout channels.
This project was unsuccessfully submitted to the FCT general call for funding in 2012.Resubmitted to the 2013 call for Exploratory Projects, it has been financed with 32k euros, starting in March 2014.

5.2.2 Abstract

O objetivo deste projeto de investigação é desenvolver e construir o protótipo de um detetor de neutrões térmicos conjugando
a tecnologia das câmaras de placas resistivas (RPCs), com um conversor de neutrões sólido de boro-10.
Pretendemos demonstrar que o conceito proposto é uma alternativa promissora aos detetores baseados no He-3 e que pode ser
expandido a detetores de neutrões térmicos de grande área e baixo custo.
A deteção de neutrões de baixa energia requer a captura do neutrão por intermédio de uma reação nuclear (Fig.1), que resulte
na emissão de partículas carregadas. O tipo de isótopos adequados é muito limitado: He-3, Li-6, B-10, Gd-157. Até à bem
pouco tempo, o isótopo mais utilizado na imagiologia de neutrões era o He-3 (e.g. neutron scattering, neutron radiography,
neutron tomography). As propriedades únicas do He-3 permitem o design de detetores de elevado desempenho (eficiência de
deteção ≈100%, resolução em posição ≈0.5mm FWHM, baixa sensibilidade à radiação gama).
O declínio abrupto dos stocks de He-3, após os ataques de 11 de setembro, fez disparar o seu preço (Fig.2) para valores
proibitivos.
Neste projeto pretendemos desenvolver um conceito de detetor diferente. A nossa ideia consiste em utilizar elétrodos resistivos
revestidos com um filme fino (1-2 mícron) de B4C numa configuração da RPC em multi-camadas.
As RPCs são apropriadas para operar numa configuração em multi-camada, necessária para assegurar uma elevada eficiência
de deteção para neutrões térmicos. Além disso as RPCs permitem um design modelar, com boa escalabilidade mantendo um
número de canais de eletrónica baixo.

5.2.3 Objectives

One of the objectives of this project is to characterize the detection of thermal neutrons with RPCs, both with MC (Monte Carlo) simulations and experimentally. 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 highly ionizing particles (alpha and lithium).

In this project a prototype will be assembled and measurements will be carried out using gamma and neutron sources available at our laboratory. At the next phase, the prototype will be operated in a neutron beam at the ILL in Grenoble, which is our partner who is also involved in the search for He-3 alternative in neutron detection.
We have already established fruitful contacts with the Engineering Surfaces Group at University of Coimbra Mechanical Engineering Research Center, where small area B4C coatings can be manufactured. It is also planned to establish collaboration with the Linköping University in Sweden where large area coatings are currently produced for our partners.
The detector assembly will be carried out in the LIP-Coimbra, which has all the required facilities.
In the framework of an international collaboration with ICMA, HZG, BNC, ILL, TUM, ESS, LLB, CNR Milano, ISIS, Julich, PSI, TUD, CNR Perugia an EoI for a Joint Research Activity on neutron detectors is being prepared during 2014 and will be submitted to Horizons 2020. LIP integrated this collaboration with a proposal on the B4C coated Multi-Gap RPCs.

5.2.4 Team

Project coordinator: Francisco Fraga

Name	Status	FTE %
Alberto Blanco	Researcher (LIP)	13
Alessio Mangiarotti	Researcher (USP)	4
Francisco Fraga	Researcher (LIP/FCTUC)	25
Luís Margato	Post-Doc (LIP)	71
Margarida Fraga	Researcher (LIP/FCTUC)	21

5.3 High Pressure Xenon Doped Mixtures for the NEXT Collaboration

5.3.1 Resumo

Em 2014 os trabalhos relativos à colaboração Internacional NEXT vão continuar embora o projecto FCT em que se enquadravam tenha terminado), concretamente no que respeita às misturas gasosas de Xe com aditivos moleculares a alta pressão para saber as características de cintilação (primária e secundária), multiplicação de carga, etc. Outro tópico em estudo é o desenho e construção de um detector gasoso de cintilação proporcional de alta pressão baseado em fotocátodo. Estes tópicos estão também enquadrados no projecto QREN Rad4life.

5.3.2 Abstract

In 2014 investigation work within NEXT collaboration will be continued (although FCT project which funded this work has ended), namely with high pressure xenon based gas mixtures with molecular additives in order to measure primary and secondary scintillation as well as gas multiplication, etc. Another current investigation topic is the design and construction of a high pressure gas proportional scintillation counter based on a photocathode. These topics are also supported by QREN project RAD4life.

5.3.3 Objectives

The objectives for 2014 are
- To investigate primary and secondary scintillation characteristics of xenon based mixtures in high pressure gas proportional scintillation counters as well as multiplication factors.
- To design and build a good energy resolution photocathode-based high pressure gas proportional scintillation counter.

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. As secções eficazes, integrais e diferenciais, de colisão elástica serão calculadas para energias, no centro de massa, aproximadamente entre 0.001 e 10 eV pelo método das ondas parciais, com desvios de fase calculados pelo método de JWKB e potenciais de interacção teóricos ou derivados de resultados de pesquisa bibliográfica. Estas secções eficazes serão utilizadas para calcular, utilizando técnicas de Monte Carlo, os 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 também tem como objectivo 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. The differential and integral elastic collision cross sections for centre-of-mass energies at least in the 0.001 eV to 10 eV range will be calculated by the partial waves method, with phase-shifts calculated using the JWKB approximation and theoretical interaction potentials or derived from literature searches. These cross-sections will be used to calculate, by detailed Monte Carlo techniques, ion transport parameters (drift velocities, longitudinal and transversal diffusion coefficients), for reduced electric fields up to about the threshold for electron ionization.
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 proceed the research works using mixtures of noble gases with carbon dioxide, such as Ar-CO2 and Xe-CO2, since these mixtures are important in gas detectors 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 o 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 2013 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 +/- 3%. Uma instalação para irradiação de culturas celulares foi também construída. Pensa-se ser possível em breve realizar as primeiras curvas de relação dose-sobrevivência de células.

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 2013 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 +/- 3%. A setup for cell-culture irradiation has also been constructed. Plans are to perform first dose-survival curves soon.

5.5.3 Objectives

The objectives for 2014 comprise:
- The (ongoing) independent validation of the dosimetry system implemented at ICNAS, which relies mainly on the measurement of the secondary electron current resulting from the protons trespassing a micrometer-thin aluminum foil. A megavoltage photon-based dosimetry system managed by the Department of Radiotherapy of Coimbra University Hospital Center is being utilized to implement this dosimetric cross-calibration.
- The implementation of a multi-hole irradiation setup specially adapted for radiobiology studies with existing cell-culture multi-hole plates.
- The investigation of alternative current-measuring systems allowing for lower current readouts.
- The substitution of the bulky CAMAC-based shutter control, which provides an utmost important separate ground between the sensitive current measurements and the larger-power shutter driver system.

5.5.4 Team

Project coordinator: Paulo Crespo

Name	Status	FTE %
Francisco Fraga	Researcher (LIP/FCTUC)	10
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

5.5.5 Academic Training

PhD Theses

- *Research and development of a beam monitor for high-current particle accelerators*
  Sharif Ghithan, (on-going)

5.6 Detector Lab / Mechanical Workshop

5.6.1 Resumo

A oficina mecânica (OM) do LIP foi estabelecida em 1986 para apoiar as atividades experimentais a realizar em colaboração com o CERN. O equipamento inical de maquinação CNC, foi depois complementado com máquinas-ferramentas de alto desempenho e CAD-CAM. As condições técnicas e o pessoal técnico altamente qualificado, permitem atualmente assegurar uma larga gama de serviços mecânicos, desde a conceção e desenho, à maquinação, montagem e testes.
Paralelamente o laboratório de detetores (LD) foi também criado logo na fundação do LIP para apoiar as atividades experimentais da delegação de Coimbra. Ao longo do tempo 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, nomeadamente: concepção, desenho, construção e reparação de equipamentos electrónicos; concepção, desenho, construção e teste de detetores; concepção, desenho, construção e reparação de sistemas de gases e de vácuo.
A experiência de duas décadas, garante-nos que na ausência da OM/LD não teria sido possível realizar com a elevada qualidade atingida, nem o trabalho de I&D em detetores gasosos (centrado em projetos autónomos ou em pequenas colaborações), nem os compromissos assumidos no âmbito de médias e grandes colaborações internacionais (nomeadamente CP-LEAR, DELPHI, HERA-B, ATLAS, HADES, AUGER ou SNO+). São igualmente incontestáveis os benefícios para a comunidade nacional de I&D que a intervenção da OM/LD do LIP trouxe aos seus projetos, tanto no plano local e nacional, como em colaborações internacionais.

5.6.2 Abstract

The mechanical workshop (OM) LIP was established in 1986 to support the experimental activities to be undertaken in CERN collaboration. The inical CNC machining equipment was in the meantime complemented with new and performant machine tools and CAD-CAM software. The technical conditions and highly qualified personnel are currently enabling a wide range of mechanical services, from conception and design to machining, assembly and testing.
The detector lab (LD) was also created to support the experimental activities of the LIP-Coimbra branch. Over time, it has been equipped to meet both the general support requirements or the specific requirements of different research groups. Thanks to the available equipment and the expertise of its technical staff, the LD can currently provide un wide range of services including: design, construction and repair of electronic equipment; conception, design, construction and testing of detectors; design, construction and repair of systems gas and vacuum.
The experience of two decades, ensures us that in the absence of both the OM and the LD, it wouldn´t have been possible to attain the high quality of services achieved, neither perform the R&D work on gaseous detectors (centered on either autonomous projects or small collaborations), nor take significant technical commitments within medium and large size international collaborations (including CP-LEAR, DELPHI, HERA-B, ATLAS, HADES, AUGER or SNO+). The benefits of the OM and the LD for projects of the national community of R&D, both at local and national level, but also in international collaborations, are equally indisputable.

5.6.3 Objectives

Detector Lab
-Upgrade of instrumentation for the future cosmic ray stations (HV and front end included within the RPC box) and deployment at the AUGER´s Batata site.
- Construction and delivery of the RPC telescope for the Brazilian AUGER team.
Assembly of the complete animal RPC-PET tomograph (at present, just two heads are operating).
- Study and test of the new front end electronics for the human RPC-PET
Production of new Spark Chamber units (already two foreseen) and contributions to the cloud chamber full size prototype.
Mechanial workshop
- Besides of tasks foreseen to be carried out by the workshop for several ongoing projects, one of the main activities for 2014 will be the construction of the source deployment system of SNO+, under contract with the Collaboration.

Chapter 6

Instruments and methods for biomedical applications

6.1 Development of Positron Emission Mammography

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 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 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 that will allow maintaining a competitive advance in the field.
In the next few years the group will be exploiting the research directions we have already initiated in PET Time-of-Flight. The time resolution of 250 ps FWHM that we have already achieved at prototype level translates in a precision in the measurement of the point of electron-positron annihilation of about 4 cm. This time-of-flight performance allows a gain in sensitivity of a factor 5 to 8 in whole-body PET systems.
The start-up company PETsys, promoted by LIP and other institutes of the consortium 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 recently 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. Presently there are on-going negotiations with Brazil at ministerial level (Science and Health) involving Brazilian research groups and clinical centers, aiming at a join program in this direction.
Another direction that is attracting much attention in the medical imaging research community is imaging multimodality. It aims to combine in a single instrument different imaging modalities providing in the same image information from different sources. The combination of PET with Magnetic Resonance Imaging (MRI) is in this respect very attractive. MRI is a powerful technique that provides anatomical information with very high resolution. The PET technologies based on solid-state photo-sensors (APD and SiPM) that the group has developed are immune to the presence of magnetic fields making them suitable for association with MRI.
In collaboration with the Center for Biomedical Imaging (CIBM) at EPFL Lausanne Switzerland, we have carried an evaluation of the combined PET-MT operation of ClearPEM detector modules in a 7 Tesla MR scanner. This work, developed in the frame of the Joint Doctoral Program IST-EPFL, was quite successful and motivated a new project in 2014 funded by EPFL and aiming at a similar evaluation of our new SiPM PET modules.
Complementary we have initiated discussions involving PETsys and other companies in the PET and MRI markets, as well as two major clinical centers in breast cancer diagnosis and treatment, in view of setting-up a funding proposal to Horizon2020 in 2015 for the development of a PET-MR system for breast cancer diagnosis. This project would also build-up on the new PET detector modules we have developed.

6.1.4 Team

Project coordinator: João Varela

Name	Status	FTE %
Carlos Gaston	Researcher (LIP)	100
Catarina Ortigão	Post-Doc (LIP/FCT)	100
Cláudia Sofia Ferreira	PhD student (LIP/FCT)	100
João Varela	Researcher (LIP/IST)	10
Jorge Neves	PhD student (FCT)	100
José Carlos Silva	Technician (LIP)	5
Leonor Frazão	Master student (LIP)	95
Luis Ferramacho	Researcher (LIP)	34
Manuel Rolo	PhD student (LIP)	80
Miguel Silveira	Researcher (LIP)	34
Ricardo Bugalho	PhD student (LIP)	100
Rui Pereira da Silva	Technician (LIP)	100
Stefaan Tavernier	Researcher (LIP)	50
Tahereh Niknejad	PhD student (LIP)	100
Viesturs Veckalns	PhD student (LIP)	100

6.1.5 Academic Training

PhD Theses

- *Estudo do tomógrafo Clear-PEM no diagnóstico do cancro da mama*
  Cláudia Sofia Ferreira, (on-going)
- *Development of advanced data acquisition technologies for PET applications*
  Ricardo Bugalho, 2014-01-10
- *Integrated Circuit Design for Picosecond Timing measurements on Radiation Detectors*
  Manuel Rolo, 2014-03-15
- *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

We have initiated and in 2014 will finish a 4-head full-body system, simplified from the detectors point of view, but complete from the electrical point of view. This will allow us to measure all the important quantities and

perform full tests of the readout electronics.
In view of the pressures on the lab by the AUGER/MARTA project it is unclear whether we can develop the large-area thin RPC needed for PET in 2014.
The extension of the scanner to 3 layers is one of the research lines of the "RAD4LIFE"project in the framework of the EU QREN (Regional Funds) program approved to take place during 25 months, started on June 1st 2013.

6.2.4 Team

Project coordinator: João Pedroso Lima

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

6.2.5 Academic Training

PhD Theses

- *Study of PET systems of very wide field of view*
  Miguel Couceiro, 2014-05-09

6.3 Detectors and Monte Carlo in Medical Physics

6.3.1 Resumo

1. Microdosimetria com feixes de partículas alfa emitidas pelo gás radão e seus descendentes :
Relativamente à microdosimetria iremos proceder à realização, de estudos in vitro com células pulmonares radiosensíveis sujeitas a partículas alfa oriundas de fontes particulares, contribuindo para a determinação da sensibilidade dessas células às partículas alfa. Iremos igualmente colaborar num estudo epidemiológico, na área da saúde pública, levado a cabo pelo Hospital de Sousa Martins da Guarda e pela Associação Portuguesa de Doenças Respiratórias. Esse estudo, deverá ter como objetivo principal o conhecimento da taxa de incidência de tumores radioinduzidos na região da Guarda a figurar no Registo Oncológico Regional (ROR). Procederemos ainda à simulação Monte Carlo de modelos de dose-resposta no acino pulmonar humano com o objetivo de estimar o risco de desenvolvimento de tumores linfáticos originados nesta região do pulmão.
Propomos ainda estudar a contribuição da radiação gama para o cálculo da dose efectiva anual média na região da Beira Interior, através do reconhecimento geológico e georeferenciação da distribuição da dosimetria gama no território com produção de cartografia, bem como do estudo dos materiais que são mais usualmente utilizados na construção.
2. Desenvolvimento de dosimetros de cintiladores plásticos para o estudo de doses dadas a pacientes sujeitos a exames de tomossintese:
Realização de testes dos dosimetros de cintiladores plásticos em ambiente clínico em exames radiológicos de radiografia dental panorâmica e tomossintese. Melhoramento dos protótipos já desenvolvidos.

6.3.2 Abstract

1. On what concerns microdosimetry we will proceed with in-vitro studies with radio-sensitive lung cells subject to alpha particles originating from radon sources and their progeny, contributing to the determination of the sensitivity of these cells to alpha particles. We will also collaborate on an epidemiological study in the area of public health, conducted by the Hospital de Sousa Martins at the city of Guarda. The main goal of this study is the knowledge of the incidence of tumors in the region induced by exposition to radon. We will proceed with the Monte Carlo simulation dose-response models in the human lung cell in order to estimate the risk of developing lymphatic tumors in the lung area. We also propose to study the contribution of gamma radiation to the average annual effective dose in the region of Beira Interior, through the geology of the area and the most commonly used construction materials.
2. A new dosimetry system based on plastic scintillator was developed for the mammographic scans. The system is constituted by a set of small plastic scintillators coupled to optical fibers allowing for a real-time dose measurement simultaneously in several points. The dosimeters have a minimum impact in the image quality due to their size (a few milimeters) and building material (plastic). Clinical trials of the dosimetric system are foreseen for 2014.

6.3.3 Objectives

The team main goal is to successfully translate the knowledge, skills and technology arising from the research on ionizing radiation into practical applications that will benefit the Portuguese economy and society as a whole. It is a well established fact that Life Sciences in general and particularly Medicine have benefit from applied research in Physics and Bioengineering. A huge number of health equipments use ionizing radiation both for diagnostic and therapeutics. Patient protection is more now than ever a concern and international recommendations advise for a need in dose radiation reduction and control. Our team has a solid background in dosimetry and radioprotection research acquired in collaboration with national and international institutions.
The team will pursue the research and development of dosimetric systems, particularly the ones capable of assessing the dose delivered to patients in radiological exams or therapeutic procedures. These devices might prove fundamental in further reducing dose in conventional and in new radiological devices like tomosynthesis mammography. They constitute an important technology transfer from particle physics to life sciences. The team has collaborations with national institutes and hospitals where prototyping and field tests will be carried on.
Cell response to radiation is a problem of paramount importance, specially in the case of heavy charge particles (alpha particles and light elements nuclei) . The understanding of energy deposition at the cell level and the mechanisms leading to cell destruction are still not completely known. In future years we will continue to study the detailed alpha particle interactions will cells, namely cells of respiratory system and contribute to a better understanding of cell killing and tumor development. A part of this work will be on the development of simulation codes dedicated to photon and charged particle tracking and interaction.

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
Jorge Sampaio	Researcher (CFA/FCUL)	32
Luis Peralta	Researcher (LIP/FCUL)	64
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 largas margens de 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, explanados nos relatórios dos anos anteriores: 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, desde 2013, com o Instituto Português de Oncologia do Porto (IPOPFG,EPE). De entre os colaboradores salienta-se as duas médicas oncologistas que aceitaram juntar-se a esta linha de investigação na qualidade de consultoras. 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 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, e com o Centro de Terapia com Iões de Heidelberg, 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 large margins for improvement. With the aim of further improving the efficacy of external photon beam RT, LIP has been exploring within this research line 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, since 2013, with the Oncology Institute of Porto (IPOPFG,EPE). Among other staff, two medical doctors responsible for radiation oncology treatments at their hospitals have become consultants of the orthogonal ray imaging project. In addition, 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, and with the Heidelberg Ion Beam Therapy Center, 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 is being analyzed. 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 20 heavy scintillators of gadolinium silicate (GSO). A multi-slice 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 Abstract

The main scientific objective to be addressed is the systematic characterization and the study of the applicability range of the adaptive reconstruction method for medical applications. The tolerance to the initial guess of the detector response on the performance of the adaptive algorithms will be investigated. The bulk of the study will be performed using the Monte Carlo simulations in ANTS2, which provides a very versatile tool. At the next step, tests at the emulation workbench of Anger camera-type detector (a PMT array and an isotropic light source mounted at a precision XYZ table) will be performed. Finally, processing of experimental data, recorded at gamma cameras operated in-house or obtained from our partners, will be conducted.
We are planning a public release of ANTS2 software package with the event reconstruction and the experimental data processing modules included. We´ll continue development of adaptive algorithms for gain reconstruction and 3D light response evaluation from flood field data. Both available gamma cameras (recently built compact 64-channel one and the commercial gamma camera after upgrading it to list mode acquisition) will be used for cross validation of different gain reconstruction methods as well as characterized for performance in terms of spatial and energy resolution.

6.5.2 Objectives

- ANTS2 software package
  - Finalize the event reconstruction module
  - Finalize the experimental data processing module
  - Public release
- Adaptive algorithms
  - gain reconstruction
  - 3D light response reconstruction
- Anger camera emulation system
  - Comparison between the simulated and measured PMT response
  - Analysis of performance of adaptive algorithms in a completely controlled environment
- Compact gamma-camera
  - Design and construction of a dedicated calibration system
  - Cross validation of different gain reconstruction methods
  - Performance characterization: spatial and energy resolution
- Upgrade of commercial gamma camera
  - Cross validation of different gain reconstruction methods
  - Performance characterization: spatial and energy resolution

6.5.3 Team

Project coordinator: Vladimir Solovov

Name	Status	FTE %
Alessio Mangiarotti	Researcher (USP)	20
Alexandre Lindote	Post-Doc (LIP)	20
Andrey Morozov	Researcher (LIP)	50
Filipa Balau	PhD student (LIP)	50
Francisco Fraga	Researcher (LIP/FCTUC)	15
Francisco Neves	Post-Doc (LIP)	20
Isabel Lopes	Researcher (LIP/FCTUC)	20
Luís Pereira	PhD student (LIP)	30
Vitaly Chepel	Researcher (LIP/FCTUC)	30
Vladimir Solovov	Researcher (LIP)	50

6.5.4 Academic Training

Master Theses

- *Compact calibration system for silicon photomultiplier arrays*
  Raimundo Martins, (on-going)

6.6 Rad for Life

6.6.1 Resumo

O projecto "Radiação para a Vida"código CENTRO -07- ST24 -FEDER - 002007), também mencionado como "Rad for Life"ou RAD4LIFE, apoiado por fundos regionais do programa QREN, arrancou a 2 de junho de 2013. Este projeto, apresentado pela Universidade de Coimbra com a colaboração do LIP, será executado pela Delegação de Coimbra e as suas actividades estão voltadas para a aplicação de tecnologias desenvolvidos na Física de Partículas à área Biomédica.
Com um financiamento para o LIP de 496 k€ (de um total de cerca de 1.1 M€, incluindo a Universidade de Coimbra), é um apoio muito importante para a manutenção dos recursos humanos do nosso laboratório, capaz de garantir a continuação da actividade de investigação actual ou de projectos futuro que doutro modo, no período difícil que atravessamos, seriam seriamente dificultadas senão mesmo inviabilizadas. O contrato prevê a contratação por um período de 25 meses de um equivalente a 6 doutorados e alguns mestres. Além de um Professor Auxiliar para a UC, e de bolsas de pós-doc e uma de cientista convidado, o projecto financiará ainda algumas bolsas de mestre e parte dos salários dos quatro investigadores já contratados pelo LIP .

6.6.2 Abstract

The project "Radiation for Life"(code CENTRO-07-ST24-FEDER-002007), also mentioned as Rad for Life or RAD4LIFE, supported by regional funds of the QREN program started on June 1st 2013. This project was submitted by the University of Coimbra with the collaboration of LIP and will be executed by our Coimbra branch and the activities are focused on the application of thechnologies developed for Particle Physics to the Biomedical area.
With a foreseen financing for LIP of 496 k€ (from a total 1.1 M€, including UC), it a very substantial help for maintaining the human resources of our laboratory in order to allow for the efficient running of current and future research activities that would otherwise be seriously slowed down, if not hindered, in the present difficult period. Thus, it foresees contraction an equivalent of 6 PhDs for a period of 25 months plus a few Masters. Besides of grants for Post-Docs and one for Invited Scientist (better paid) the project also supports some grants for Marter´s and part of the salaries of four researchers already under LIP contract.

6.6.3 Objectives

In order to explore applications to the biomedical area of radiation detection technologies emerging from Particle Physics, activities will continue to be supported along several ongoing lines of work or projects, namely i)Human and Animal RPC-PET; ii) Monitoring of Radiotherapy; iii) Improvement of SPECT imaging and iv) High pressure and large area xenon detectors.
During 2014 the project is foreseen to support a total of 71 months of PhDs personnel (fellowships, LIP Researchers amd UC staff) and 48 months of Masters.

6.6.4 Team

Project coordinator: Rui Marques

Name	Status	FTE %
Valdemar Domingos	Master (LIP)	100

Chapter 7

Radiation Environment Studies and Applications for Space Missions

7.1 Space Radiation Environment and Effects

7.1.1 Resumo

O grupo do LIP que desenvolve actividades relativas ao estudo do ambiente de radiação no espaço e dos seus efeitos prepara-se para 2014 e para os anos seguintes, partindo de 10 anos de experiência no desenvolvimento de aplicações no âmbito de projectos da ESA.
O grupo tem três projectos aprovados pela ESA, com início em 2014. Estes projectos irão exigir que a equipa seja reforçada com pós-doutorandos e estudantes de doutoramento e mestrado. Em particular, está a ser preparado um anúncio de bolsa de pós-doutoramento nesta área e têm sido disponibilizados temas para dissertações de doutoramento e mestrado nesta área aos estudantes de Física e Engenharia do Instituto Superior Técnico.
As actividades do grupo estão agora consolidadas deverão entrar numa fase de expansão durante os próximos anos. O LIP é reconhecido pela ESA como uma referência em Portugal na área do estudo do ambiente de radiação no Espaço, detendo competências exclusivas nos seus domínios de actividade, reforçadas pela experiência na utilização da ferramenta de simulação Geant4, que permite simular de forma realista o transporte e interacção da radiação com a matéria
Os temas de cobertos por esta actividade são

- O estudo e modelização do ambiente de radiação no espaço, incluindo ambientes de radiação planetários, nomeadamente a Lua, Marte, Europa, Ganimedes e asteróides.
- A análise de dados de detectores de partículas energéticas/radiação em missão espaciais;
- O estudo dos modelos de propagação de SEP - eventos de partículas energéticas solares e teste destes modelos com dados reais , na continuação da actividade iniciada com o projecto "Participação Portuguesa na Rede Heliosférica";
- O Estudo e o desenvolvimento de conceitos para monitores de radiação (com base em sensores de Si e/ou em cintiladores) e a 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 interplanetário, 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 para as tripulações;

7.1.2 Abstract

The Space Radiation Environment and Effects group prepares for 2014 and for the next years, starting from 10 years of expertise in the development of applications dedicated to the Radiation environment in Space in the framework of ESA projects.

The group has 3 ESA projects approved to start in 2014. These will require the reinforcement of the team with Post-Doc researchers and with for PhD and MsC students. In particular, an international call for post-doc researchers in the framework of these projects is currently being prepared and MsC and PhD thesis subjects in this area are available to Physics and Physics Engineering Students at Instituto Superior Técnico. The group activities are now well consolidated, and the group is entering a phase of expansion, which is foreseen to continue during the next years. Our group is recognized by ESA as a Portuguese reference for Space Radiation and Environment Studies. The group holds unique competences in its activity domains with very strong competences in Geant4 for the simulation of radiation transport and interaction with matter and data analysis. The research themes that are within the scope of this project are:

- Study and model the 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 ands surfaces;
- Study and develop mitigation strategies for radiation hazards, both for spaceship systems and components and for human spaceflight.

7.1.3 Objectives

The group starts 2014 after having closed all past contracts with ESA and prepares for initiating three new projects. The objectives of the group for 2014 and beyond are on the one hand to follow and comply with the planning for each of the approved activities with ESA and with its partners, and, on the other hand, to continue the preparation of other collaborative activities.

Aproved activities starting in 2014

The RADEM (radiation hard electron monitor for the JUICE mission) ESA contract will start in February 2014 with a duration of 30 months. The aim of the project is to develop the RADEM proto-flight model. During 2014 LIP will be involved in the critical review of detector requirements, on its design iteration and consolidation and in the simulation and science analysis of the instrument.
The contract "Eco-60"between LIP and ESA will start 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 will be 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 2014, the selection of test candidates and their procurement will take place, followed by preparation and performance of the radiation tests and radiation data analysis.
The MFS data analysis contract with ESA, in which LIP collaborates with EFACEC will start in March 2014 with a duration of 12 months. LIP is responsible for the consolidation of the analysis of available radiation ground test data and MC simulation, for the development of an algorithm for particle energy spectra reconstruction and for the MFS in-flight data analysis and cross-comparison with radiation environment models and other in-flight radiation monitors data.

Activities in preparation during 2014

The CODES web interface will be made available to the community and the study of single event effects will be continued.

dMEREM, the Geant4 based Mars radiation environment model developed by LIP for ESA, will be validated with Curiosity mission data from Mars surface and the results of the validation will be published. Additionally, a collaboration is envisaged with the Exomars mission particle instruments team with the aim of participating in the radiation data analysis.
A proposal to the Horizon 2020 program call "COMPET-5-2015 Scientific exploitation of astrophysics, comets, and planetary data"(November 2014) will be prepared in collaboration with UNINOVA (a portuguese R&D institute) and other international partners. The project "Multispectral Data Analytics for Planetary Missions"has the objective providing added value to archive spectrometer data covering a wide range of wavelengths (from infrared to gamma-rays) from past missions and applicability to future missions, by retrieval of heterogeneous data (data integration), their processing (data fusion) and analysis (data analytics) with the subsequent generation of scientific return (knowledge discovery) that can lead to the improvement of current models and better focus on future mission requirements.

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
Patrícia Gonçalves	Researcher (LIP)	80
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)

7.2 Gamma-Ray Polarimetry with Fermi and DUAL Space Missions

7.2.1 Resumo

Desenvolvimento do Instrumento Principal do Telescópio Espacial DUAL

Em colaboração com o Istituto di Astrofisica Spaziale e Fisica Cósmica, Bolonha, Itália continuará a ser desenvolvido e testado um novo conceito de detectores de CZT com informação tridimensional. O protótipo a desenvolver funcionará no modo Campo Plano Transverso com a recolha de sinal a ser efectuada por um sistema de micro-fitas, permitindo a leitura tridimensional da trajectória das partículas. De forma a tornar possível a absorção de fotões em cristais de CZT até 20 mm sem aumentar a distância de recolha de carga, aplica-se um campo perpendicular ao eixo óptico do cristal. No último trimestre de 2014 será muito provavelmente lançado um novo concurso da ESA para missões da classe M. Conjuntamente com um novo consórcio internacional, o nosso grupo tem estado a preparar uma nova proposta de missão para este futuro concurso que foi iniciada no workshop Instrumental concepts in the MeV domain decorrido de 6 a 8 de Novembro de 2013 em Paris.

Desenvolvimento do plano focal do polarímetro XIPE

Integrando o grupo de trabalho de instrumentação, o nosso contributo para a missão centra-se no desenvolvimento do instrumento principal, constituído por GPD, em particular na optimização das misturas gasosas (Xénon, Árgon, etc.) tendo em vista a realização de medidas polarimétricas baseadas no efeito fotoeléctrico. Uma versão atualizada da missão XIPE será submetida ao concurso para uma missão conjunta entre a ESA e a Academia das Ciências da China, que ocorrerá no último trimestre deste ano e/ou ao próximo concurso de missões da classe S da ESA em 2015.

7.2.2 Abstract

Polarimeter development for DUAL Space Mission

Together with our partner of the Istituto di Astrofisica Spaziale e Fisica Cósmica, Bologna, Italy, a novel 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. In second semester of 2014, a new call for M class mission proposals will be announced by ESA. Together with a new international consortium, our group is preparing a new mission proposal for the referred call, that was launched during the Workshop on Instrumental concepts in the MeV, November 6th to 8th 2013 in Paris.

XIPE mission main instrument development

We are in XIPE instrumentation working group, with the objective of developing its main instrument composed by GPD, in particular by studying gaseous mixtures optimization (Xenon, Argon, etc.) for photoelectric based polarimetry, both through experimental and simulation work. An updated version of XIPE mission will be submitted to ESA-Chinese Academy Sciences Joint Mission Call that will be announced by the fourth quarter of 2014.

7.2.3 Objectives

Even though XIPE mission was not selected by ESA in the 2012 S class call, it was a top three ranked mission. Therefore, the development of a GPD instrument to study the X-ray polarization of celestial objects will be pursued by our group in the framework of XIPE consortium since the next ESA call for S (small) missions´ proposals will occur by 2015.
The driving idea of developing a 3D position prototype is the use of CZT crystals in PTF (Planar Transverse Field) configuration to increase the photon absorption thickness up to 20 mm without increasing the charge collection distance. In the PTF configuration the charge collecting field is perpendicular to the optical axis of the crystal, improving the spectroscopic performance of CZT. In its final configuration it will be composed of 64x64 cubic voxel. A miniaturised ASIC electronics integrating a pre-amplifying stage, an amplifying and signal shaping stage will be developed in order to fit to the pixelisation level of each detection plane, as well as a coincidence electronic subsystem suitable to detect double events produced by polarized Compton photons inside the semiconductor material. The 3D CZT prototype will be tested at the European Synchrotron Radiation Facillity, Grenoble, France under a ≈100% polarized beam, monitored by a Monte Carlo simulations to better

understand the results of each test. Complementary and longer experimental tests will be performed on CZT prototypes with LIP laboratorial polarization precision table.
A new mission proposal based on DUAL proposal will be developed and submitted to the next ESA cal for M class missions that will open in the second semester of 2014.

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
João Barata	Researcher (LIP/UBI)	20
Jorge Maia	Researcher (LIP/UBI)	45
José Marques	PhD student (LIP)	60
Marco Alves Pinto	Master student (LIP)	
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)

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 further 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 and also by continuing to provide real contact with frontier research and frontier experimental methods under expert supervision by expert scientists.
Concerning the cooperation with Portuguese Universities and other research institutions, LIP continues to collaborate with DAEPHYS (doctoral network for applied and Engineering Physics) where it has especial co-ordination responsibilities, with MAP-fis (with Minho, Aveiro and Porto Universities) and DP-PMI (for Physics and Mathematics for future Information Technologies). Another such program in Biomedical Engineering (with the Universities of Lisbon and Coimbra, research centres IBEB, ISR-Coimbra and LIP, as well as the multinational companies Philips and Siemens, and several UK universities) will be submitted in March 2014 to the FCT call.
IDPASC will go on with the current high quality training program and, probably, with increasing participating Universities and research centres, namely from South America. At national level a proposal is being joitly prepared by the participating institutions to be submitted to FCT in early 2014.
LIP and Minho University will co-organise and host the 2014 CERN Computing School (25 Aug to 5 Sep 2014).
LIP will also assess the added value and the possibilities of setting up in Portugal a new international annual summer school devoted to selected issues of experimental particle physics, including instrumentation, biomedical and space applications.

8.2 Technology Transfer

8.2.1 Resumo

Rede HEPTech
A rede HEPTech que integra as matérias da transferência de tecnologia no domínio da física das altas energias, é única. A rede incluí a participação das principais instituições e universidades na Europa (CEA/DSM, CPAN, CERN, Chalmers, Universidade de Copenhaga, CNRS/IN2P3, DESY, EPFL, GSI, INFN, JSI, PSI, STFC, Universidade de Sofia, INFN, CTU, ILL, WIS e ESS), que actuam na área da Física de Partículas, Astrofísica e Física Nuclear. Diversas atividades serão desenvolvidas através da rede HEPTech em 2014, nomeadamente: 1) o simpósio PhD onde investigadores orientados ao empreendedorismo poderão explorar projectos em áreas específicas como Detectores, Aceleradores e as TIC com possíveis impactos para a sociedade; 2) uma apresentação mensal designada de "HEPTech report on European Funding Calls"será promovida a todos os nodos da rede; 3) a organização de eventos AIME "Academia Industry Matching Events"onde a ciência encontra a indústria será um pilar recorrente. O LIP acompanhará estas várias iniciativas e contribuirá, sempre que possível.
Actividades do ILO
O mandato do ILO mantém a mesma estratégia para 2014, que visa em apoiar e promover activamente a indústria nacional e instituições de I&D, para o CERN, ESO, ESRF e contribuir para o seu sucesso no processo de aquisições, e na divulgação de novas oportunidades de projectos e tecnologias disponíveis*, por forma a garantir um retorno industrial sustentável para Portugal. O ILO prosseguirá a estreita colaboração com o Gabinete de Tecnologia e do Espaço da FCT na representação da delegação Portuguesa na Agência Espacial Europeia (ESA) para os assuntos industriais.
(oportunidades de projectos e tecnologias disponíveis* significa: anúncio de documentos técnicos sobre oportunidades de concursos para o fornecimento de bens e serviços, tecnologias disponíveis que incluem patentes, know-how, software, projectos de I&D ou colaborações)

8.2.2 Abstract

HEPTech network
The HEPTech is a unique high energy physics technology transfer network. The network is made up of leading institutions and universities in Europe (CEA / DSM, CPAN, CERN, Chalmers University of Copenhagen, CNRS/IN2P3, DESY, EPFL, GSI, INFN, JSI, PSI, STFC, University of Sofia, INFN, CTU, ILL, WIS and ESS), which work across a range of world-leading scientific areas in the field of Particle Physics, Astrophysics and Nuclear Physics. Several activities will be developed through HEPTech in 2014, namely: 1) the PhD symposium where entrepreneurial researchers can explore projects in the Detectors, Accelerators and ICT technological fields with potential impacts for society; 2) a monthly presentation of a HEPTech report on European Funding Calls will be promoted to all nodes; 3) the organization of Academia Industry Matching Events (AIME) where science meets industry will be a recurrent pilar. LIP will follow these various initiatives being a network node and contributing as deemed possible.
ILO activities
The mandate of the ILO will maintain the same strategy for 2014, aiming to support and actively promote national industry and R&D institutions to CERN, ESO, ESRF and contribute to their success in the procurement process, and disseminate new project opportunities and technologies available*, to ensure a sustainable industrial return for Portugal. The ILO will continue working closely with the FCT Technology and Space Office and the Portuguese delegation at the European Space Agency (ESA) for industrial matters.
(project opportunities and technologies available* means: announcement of technical documents on procurement opportunities for the supply of goods and services, available technologies that include patents, know-how, software, R&D projects or collaborations)

8.2.3 Objectives

HEPTech network
- Ensure the publication of the HEPTech Intellectual Property charter at the LIP Outreach main page.
- As a node member in the HEPTech network, promote among the LIP community and participate, as deemed possible, on AIME "Academia Industry Matching Events"in the following areas: 1) Technology for Accelerators, 2) Control Systems, 3) ICT, 4) Detectors, 5) and 6) Good practices and Specialization support to Technology Transfer Offices.
- Organize, per request, bilateral meetings with LIP researchers (in Lisbon and Coimbra) about Intellectual Property and Technology Transfer matters, leveraging the experience of the participation in the HEPTech network.

ILO activities
- Orient the current database of national firms at FCT to a CRM information system helping the ILO with matters related to project opportunities and available technologies* at CERN, ESO, ESRF and ESA.
- 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.
(project opportunities and available technologies* means: announcement of technical documents on procurement opportunities for the supply of goods and services, available technologies that include patents, know-how, software, R&D projects or collaborations)

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) Em 2014 o CERN celebra o seu 60º aniversário, e portanto o LIP irá organizar sessões públicas e Seminários de divulgação, por convite das escolas ou à margem de eventos científicos promovidos pelo LIP, bem como aproveitar as acções do LIP relacionadas com o CERN para promover a comemoração desta importante ocasião;
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 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 ainvestigação 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.

8.3.2 Abstract

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 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.
In 2014 CERN celebrates its 60th anniversary, and LIP will participate in the celebrations by organizing specific public sessions, and profiting of its CERN-related activities to celebrate this occasion. A highlight of these celebrations will be the anniversary event at CERN on the 29th of September, 2014, as well as a a competition organized by CERN entitled "A Beamline for Schools",
in which we expect the participation of several portuguese schools with our support.

8.3.3 Objectives

LIP considers very important to continue the successful activities carried out so far, in particular:
i) The CERN programme for Portuguese Speaking Teachers from CPLP countries, 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) Celebration in Portugal of the CERN 60th Anniversary;
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 Rodrigues		
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)	
Maria do Anjo Albuquerque	(LIP)	
Miguel Ferreira	Technician (LIP)	
Paula Pinho	Collaborator	
Pedro Abreu	Researcher (LIP/IST)	
Pedro Assis	Post-Doc (LIP/FCT/IST)	
Sandra Soares	Researcher (LIP/UBI)	