Laboratório de Instrumentação e Física Experimental de Partículas

Activity Report

2013

Contents

Chapter 1

Overview

1.1 Introdução

Os últimos anos foram marcados pelos primeiros resultados do LHC que levaram à observação de uma nova partícula com uma massa de cerca de 125 GeV, identificada, em 2013, como sendo um bosão de Higgs. O LIP tem estado fortemente envolvido em todas as fases das experiências de LHC - ATLAS e CMS - em que os grupos do LIP têm assumido responsabilidades importantes no desenvolvimento de calorímetros, nos sistemas de aquisição de dados e de trigger e na análise de resultados. Estes grupos contribuíram significativamente para o estudo do bosão de Higgs (o grupo de ATLAS em H -> WW e H -> bb, e o grupo de CMS com H -> gamma gamma, nos estudos dos acoplamentos do bosão de Higgs e na pesquisa do bosão de Higgs carregado), bem como, para os estudos do quark top (o grupo de ATLAS na medida da polarização do bosão W, na estrutura do vértice Wtb e na pesquisa de decaimentos raros do quark top e o grupo de CMS na determinação da massa do quark top, nas medidas da secção eficaz e Vtb). O grupo ATLAS do LIP tem igualmente contribuído para a física de iões pesados, nomeadamente, nos estudos de assimetrias em di-jets, enquanto o grupo CMS do LIP tem vindo a estudar a produção de quarkonia em colisões protão-chumbo.
O grupo da Estrutura da Matéria (hadrónica) do LIP estuda o nucleão na matéria nuclear normal no âmbito da experiência COMPASS do CERN, e na matéria nuclear fria de alta densidade, no âmbito da experiência HADES em GSI. Os estudos das funções de distribuição partónicas desenvolvidos por COMPASS tiveram um forte impacto nesta área impulsionando a segunda fase da experiência COMPASS, na qual o LIP desempenha um papel de liderança no programa Drell–Yan. O grupo contribuíu também para o upgrade do HADES ao projetar, construir, instalar e colocar em funcionamento uma parede RPC TOF de 8 metros quadrados, que tem apresentado um excelente desempenho.
O LIP teve uma contribuição significativa na conceção do detetor RICH da experiência AMS e na sua calibração, bem como no desenvolvimento de algoritmos para a reconstrução da massa e da velocidade das partículas aí detectadas, participando actualmente na análise dos dados de voo de AMS, na estação espacial internacional desde 2011. Os primeiros resultados de AMS, na medição da componente de eletrões e positrões presente nos raios cósmicos primários, com energias até 350 GeV, foram publicados em 2013. Estes resultados são baseados em mais 400.000 positrões detetados e confirmam claramente que uma fração destas partículas tem origem em fontes primárias clássicas, ou noutras fontes, tais como a Matéria Escura.
Os resultados da experiência Auger apresentados na conferência ICRC2013, no Rio de Janeiro, são compatíveis não só com a existÊncia de raios cósmicos primários com energias acima de 1 EeV mais pesadas do que os protões, uma indicação de cenários inesperados em astrofísica, mas que também pode indicar uma mudança drástica nas interações hadrónicas a estas altas energias. Em 2013, o grupo Auger do LIP tornou-se o líder de uma proposta de upgrade do detetor Pierre Auger, MARTA, que tem por objetivo dotar o observatório com novos detetores basedos em Câmaras Resistivas (RPC) para medições precisas do conteúdo muónico dos chuveiros atmosféricos originados pelos raios cósmicos de alta energia, que permitrão não só compreender melhor as interacções hadrónicas a estas energias, como também contribuir para a determinação da composição dos raios cósmicos de alta energia.
O LIP foi responsável pela análise de oscilação de neutrinos puiblicada em 2013 e que utilizou todo o conjunto de dados de SNO. Em 2013, o LIP assegurou a presidência da colaboração SNO+ e foi responsável pelo desenho do sistema de colocação de fontes de calibração em SNO+, que será produzido na oficina de mecânica do LIP. Nas experiências de deteção da matéria escura ZEPLIN -III e LUX, o LIP foi responsável pelo desenvolvimento do algoritmo de reconstrução de posição e por ferramentas de análise, bem pelo sistema de controlo do detetor e pelo sistema automático de distribuição de N2 líquido. A primeira pesquisa de WIMPs desenvolvida na experiência LUX em 2013, já modificou os constrangimentos na secção eficaz de interações entre WIMPs e nucleões escalares,

à qual a experiência LUX é três vezes mais sensível do que qualquer outra experiência concorrente.
Na área da instrumentação e aplicações, o grupo do LIP responsável pelo desenvolvimento de detetores concebeu a parede RPC-TOF da experiência HADES e, mais recentemente, o "TOF tracker", um novo dispositivo que combina excelente resuloção em posição e em tempo com a facilidade de funcionamento típico das RPCs em vidro. Em 2013, um conjunto de ferramentas de software desenvolvido pelo LIP, utilizando um algoritmo de reconstrução de eventos adaptável e inovador, foi explorado com sucesso na experiência LUX, e foram obtidos resultados excelentes na deteção de electrões num detetor de xénon de fase dupla. Foram também desenvolvidos no LIP protótipos de uma nova tecnologia de scanner RPC- PET, com uma resolução de imagem de 0,4 mil e de um dosímetro de fibra ótica cintilante. Com vista à obtenção de baixas exposições à dose em radioterapia, foram obtidos perfis de correlação de dose, para o caso de um LINAC clínico irradiando um famtoma heterogéneo e foram propostos e demonstrados dois métodos inovadores para a quantificação da dose alvo na dosimetria de feixes.
O LIP liderou o consórcio nacional que desenvolveu e construiu um scanner PET para o diagnóstico do cancro da mama (ClearPEM). Trata-se de uma aplicação das tecnologias desenvolvidas para o calorímetro EM de CMS. ClearPEM é o primeiro scanner PET ao nível mundial, associando cristais cintilantes a fotossensores de estado sólido. Esta tecnologia (licenciada pela empresa tecnológica PETsys) permitiu a primeira implementação da dupla leitura do cristal num scanner PET, impedindo o efeito de paralaxe nas imagens.
Os projetos do LIP com a ESA, no âmbito do estudo do ambiente de radiação no espaço e dos seus efeitos e o desenvolvimento de instrumentos para missões científicas no espaço, têm constituído oportunidades de colaboração com outros institutos de I&D e com a indústria. Ao longo de 2013, o LIP apresentou três propostas na sequência de concursos lançados pela ESA, uma na qualidade de contratante principal e duas em consórcios. Estas propostas foram aceites pela ESA e iniciar-se-ão no primeiro trimestre de 2014.
O grupo de computação do LIP coordena a Iniciativa National Grid (NGI). A capacidade do nó central da NGI encontra-se instalada no maior centro de computação científica construído pelo LIP, em parceria com a FCCN e o LNEC. Em 2013, o LIP venceu a licitação internacional EGI para a coordenação global de middleware e suporte ao utilizador nos próximos 2 anos e o líder da equipa de computação do LIP foi eleito pelo conselho EGI ao Conselho Executivo EGI e é agora um dos diretores da Iniciativa Europeia Grid. O LIP preparou, conjuntamente com o LNEC e a FCCN, uma proposta de consórcio para a Infraestrutura Nacional de Computação Distribuída no âmbito do Concurso para criação de um Roteiro Nacional de Infraestruturas de Investigação, lançado pela FCT. Além disso, a proposta de projeto do LIP para a manutenção e o upgrade dos serviços de armazenamento Tier-2 do LIP apresentada num concurso público nacional foi aprovada pela FCT, tendo obtido financiamento máximo.

1.2 Introduction

The last years were marked by LHC first results leading to the observation of a new particle at a mass near 125 GeV, which, in 2013 was confirmed to be a Higgs boson. LIP has been strongly committed to all phases of the ATLAS and CMS LHC experiments. The ATLAS and CMS LIP groups hold important responsibilities in the development of calorimeters, data acquisition and trigger systems, and in the analysis of results. They contributed significantly to the study of the Higgs (ATLAS in H->WW and H->bb, and CMS with H->gamma gamma and Higgs couplings studies, and the search for charged Higgs) and to the studies of the top quark (ATLAS in the measurement of W polarisation, Wtb vertex structure and rare top decays search, and CMS in the top quark mass, cross-section and Vtb measurements). The ATLAS LIP group has also contributed to heavy ion physics, namely to the di-jet asymmetry studies, whereas the CMS LIP group studied quarkonia production in proton and in lead collisions.
The LIP Structure of (Hadronic) Matter group participates in the COMPASS at CERN and in HADES at GSI. The group measured the gluon polarization in the nucleon, one of the main COMPASS results and had a leading role in the Drell-Yan programme for the second COMPASS phase in preparation during 2013.
LIP had a relevant contribution in the AMS RICH detector design and calibration and in the development of algorithms for the reconstruction of particle mass and velocity and it actively participates in the analyses of ight data. The first results of AMS, in the measurement of the electron and positron component in primary cosmic rays up to 350 GeV were published in 2013. The results, based in more than 400.000 detected positron events, give a clear indication that a fraction of these particles is originated in primary classical sources, or in other sources, such as Dark Matter.
The Auger results presented at ICRC2013 in Rio de Janeiro, are compatible both with the presence of primary particles heavier than protons at the highest energies, a signal for unexpected astrophysics scenarios, and with a drastic change of hadronic interactions at very high energies. In 2013 the Auger LIP group became the leader of the MARTA upgrade proposal aiming to provide the observatory with new RPC detectors for accurate

measurements of the muonic component of Extensive Air Showers, in order to understand hadronic physics and mass composition of cosmic rays at ultra-high energies.
LIP was responsible for the neutrino oscillation analysis of the full dataset of SNO, published in 2013. In 2013 LIP was also responsible for the design project of SNO+ calibration source insertion system, which will be produced in LIP Mechanical Workshop during 2014. In the ZEPLIN-III and LUX dark matter experiments, LIP was responsible for the development of the position reconstruction algorithm and pulse analysis tools, as well as the Detector Control System and the automatic liquid N2 distribution system.The first WIMP search run with LUX in 2013, has already changed the constraints on the scalar WIMP-nucleon interactions cross-section, to which LUX is three three times more sensitive that any competing experiment.
The LIP group devoted to the development of detectors has produced the HADES RPC-TOF wall, which features flawless operation and excellent performance and, more recently, the "TOF tracker", a new device combining excellent time and position resolutions with the ease of operation typical of glass RPCs. In 2013 a LIP software toolkit with an innovative adaptive statistical event reconstruction algorithm was successfully exploited in the LUX experiment and outstanding detectability of single electrons, in a double phase xenon detector, has been demonstrated. Prototypes of a new RPC-PET scanner technology, with a world-leading image resolution of 0.4mm and of an image-invisible scintillating optical fibre dosimeter were demonstrated at LIP. Pursuing dose-free radiotherapy monitoring, unprecedented dose-correlated profiles for a clinical linac beam impinging onto a heterogeneous phantom have been measured, while two innovative methods for quantification of target dose in beam dosimetry were proposed and validated. LIP led the national consortium that developed and built a PET scanner for breast cancer diagnosis (ClearPEM), which is an application of the technologies developed for the CMS EM calorimeter. ClearPEM is the first PET scanner worldwide associating scintillating crystals to solid-state photo-sensors. This techology (licensed to the spin-off company PETsys) permitted the first implementation of crystal double-readout in a PET scanner, eliminating parallax blurring in the images.
LIP projects with ESA e.g. the study of the radiation environment in Space and of its effects and the development of instruments for scientific missions in space, have been opportunities for collaborating with other R&D institutes and with industry. During 2013, three proposals to ESA calls prepared by LIP, one as prime contractor and two within consortia, were accepted by ESA to be initiated in the first trimester of 2014. LIP Computing Group coordinates the National Grid Initiative (NGI). NGI´s core capacity is installed in the largest national scientific computing data centre built by LIP in partnership with FCCN and LNEC. In 2013 LIP won the EGI international bid for delivering the global middleware coordination and user support for the next 2 years and the LIP computing team leader was elected by the EGI council to the EGI Executive Board and is now a director at the European Grid Initiative. LIP prepared, with LNEC and FCCN, a consortium proposal for the National Infrastructure of Distributed Computing in the framework of the FCT Roadmap for Instractructures. LIP project proposal for the maintenance and upgrade of the LIP Tier-2 storage services submitted to a FCT national competitive call in 2013 was approved with maximum funding.

1.3 Sources of Funding for LIP Lisboa

Project	Code	Funding	Entity	Start	End
AMS	PTDC/FIS/122567/2010	40.000 €	FCT	2011-12-07	2014-08-06
ATLAS	CERN/FP/123595/2011	530.000 €	FCT	2012-04-01	2014-04-30
CMS	CERN/FP/123601/2011	550.000 €	FCT	2012-04-01	2014-09-30
COMPASS	CERN/FP/123600/2011	300.000 €	FCT	2012-01-01	2014-09-30
GRID	EGI InSPIRE	485.000 €	EU	2010-05-01	2014-12-31
	RECI/FIS-NUC/0115/20 12	500.000 €	FCT	2013-01-01	2015-12-31
HECR	CERN/FP/123611/2011	280.000 €	FCT	2012-02-01	2014-04-30
	EPLANET 246806	10.800 €	EU	2011-01-01	2014-12-31
	ASPERA/0001/2010	150.000 €	FCT	2012-09-01	2015-08-31
	Particle Physics at 100 TeV AFR PhD Gran	114.660 €	AFR	2012-09-01	2015-08-31
INFIERI	INFIERI - 317446	211.981 €	EU	2013-02-01	2016-01-31
MC in Medical Physics	EXPL/FIS-ATO/0776/20 12	2.400 €	FCT	2013-04-01	2014-03-31
	PTDC/BBB-IMG/3310/20 12	25.920 €	FCT	2013-07-01	2015-06-30
OUTREACH	PEC37	20.000 €	CVIVA	2013-01-01	2014-07-01
	PEC258	30.000 €	CVIVA	2013-01-01	2014-08-31
PET - Mammography	Endo TOFPET-US256984	509.400 €	EU	2011-01-01	2014-12-31
	PicoSEC-MCNet (28935 5)	423.082 €	EU	2012-01-01	2015-12-31
SNO+	PTDC/FIS/115281/2009	108.971 €	FCT	2011-01-01	2014-06-30
Space	ESA:223981/09/NL/PA/ CCN03	20.000 €	ESA	2012-11-01	2013-09-30
Laboratório Associado	PEst	655.677 €	FCT	2013-01-01	2013-12-31
Quotas	2013	157.120 €	FCT	2013-01-01	2013-12-31
Incentivo FCT	2013	22.706 €	FCT	2013-01-01	2013-12-31

1.4 Sources of Funding for LIP Coimbra

Project	Code	Funding	Entity	Start	End
Dark Matter Search	CERN/FP/123610/2011	80.000 €	FCT	2012-04-01	2013-03-31
Gamma Cameras	PTDC/BBB-BMD/2395/20 12	48.202 €	FCT	2013-05-01	2014-04-30
HADES	PTDC/FIS/113339/2009	91.742 €	FCT	2011-04-01	2015-01-31
Human PET	PTDC/SAU-BEB/104630/ 2008	120.856 €	FCT	2010-04-01	2013-09-30
Ion Transport Processes	CERN/FP/123613/2011	10.000 €	FCT	2012-03-12	2013-12-31
LHC Phenomenology	CERN/FP/123619/2011	70.000 €	FCT	2012-03-01	2014-02-28
NeuLand - R3B	PTDC/FIS/114876/2009	99.589 €	FCT	2011-01-01	2014-06-30
OrthogonalRayImaging	INOV.C - OrthoCT	10.000 €	UC	2013-01-01	2014-03-06
	INOV.C - DeepbrainTM S	10.000 €	UC	2013-01-01	2014-03-06
RAD4LIFE	QREN CENTRO-07-ST24-FEDER-002007	495.773 €	EU	2013-06-01	2015-06-30
RD51	CERN/FP/123605/2011	50.000 €	FCT	2012-07-01	2014-06-30
Laboratório Associado	PEst	419.204 €	FCT	2013-01-01	2013-12-31
Quotas	2013	87.280 €	FCT	2013-01-01	2013-12-31
Workshops	2013	33.255 €		2013-01-01	2013-12-31

1.5 Scientific Statistical data

Project	Publications			Conferences			Semi-	Outr.	Theses			Evts.
	Jrn-I	Jrn-II	other	int.o	int.p	nat.	nars	Sem.	G	M	D	
ATLAS	91	7	10	6			4	13				
CMS	92	14	16	15			12	8				2
LHC Phenomenology	3	3									1	
COMPASS	6	6	11	7			4					
HADES	9	1										
GRID	1	1	5	7	1	3	1					2
AMS	1		9	2	1					1		
SNO+	3	2	1	2	1		1	1				
Dark Matter Search	5	3	7	3			4					
HECR	7	1	8	3			2					4
RD51	5	4										
NeuLand - R3B	1	1										
GEMs	3	1										
NEXT	3	3		1								2
Ion Transport Processes	2	2										
ICNAS	1	1	1		1	1						
PET - Mammography	5	5	4	4	5		1				1	
Human PET	2	2		1								
MC in Medical Physics	2	2		2	1						1	
OrthogonalRayImaging	2	2	7	2	3	1						
Gamma Cameras				1						1		
RAD4LIFE												
Space	1	1	1	5	1	1	1					
DUAL	1	1						3				
Education												
TTN-ILO												
OUTREACH				1				1				
Totals:	245	62	80	62	14	6	30	26		2	3	10

Legend:

Publications:

Jrn-I: Publications in international journals with scientific peer review co-authored by LIP members

Jrn-II: Subset of publications Jrn-I in which LIP members had a major responsibility

Other: Internal notes, conference proceedings, etc. with direct involvement of LIP members

Conferences:

Int.o: Oral presentations by LIP members in international conferences

Int.p: Poster presentations by LIP members in international conferences

Nat.: Presentations by LIP members in national conferences

Seminars: Invited seminars in Institutes or Universities

Outr. Sem.: Seminars for students or general public

Theses: Theses concluded during this year (G - Graduation, M - Master, D - PhD)

Evts: Organisation of events (conferences, workshops, collaboration meetings, etc.)

1.6 Human resources (head counts)

Project	Researchers	Technicians	Post-Docs	Students			
				D	M	G	O
ATLAS	13	1	4	10	4		
CMS	6	2	4	5			2
LHC Phenomenology	11		3	2	2		1
COMPASS	3	1	3	2			
HADES	3	2	2				
GRID	6	3	1				
AMS	1		2		2		1
SNO+	5	5					
Dark Matter Search	5	2	4	1	1		
HECR	15	3	3	5	2		1
RD51	5	10		1			
NeuLand - R3B	3	8					
GEMs	5			1			
NEXT	7		1				
Ion Transport Processes	6		1				
ICNAS	3			2			
PET - Mammography	3	2	1	6			
Human PET	4	7		1			
MC in Medical Physics	7		1		4	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	2				
Totals:	86	20	28	38	17	1	5

Legend:

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

FTE: Full Time Equivalent

1.7 Human resources (FTE)

Project	Researchers	Technicians	Post-Docs	Students				total
				D	M	G	O	
ATLAS	7	1	3	9	3			27
CMS	5	2	3	4			1	16
LHC Phenomenology	3		2	1	1		1	9
COMPASS	3	1	2	2				9
HADES	1	1	1					3
GRID	4	3	1					8
AMS	1		2		2			5
SNO+	2	1						4
Dark Matter Search	2	1	4	1				7
HECR	6	1	3	4	1		1	16
RD51	1	2		1				3
NeuLand - R3B	1	1						2
GEMs	1			1				2
NEXT	2		1					2
Ion Transport Processes	1							2
ICNAS	1			1				2
PET - Mammography	1	1	1	5				8
Human PET	1	1						2
MC in Medical Physics	4		1		2			7
OrthogonalRayImaging	1			2				3
Gamma Cameras	1			1				2
RAD4LIFE								
Space	1		1	1				3
DUAL	2			1				4
Education								
TTN-ILO		1						1
OUTREACH								
Totals:	52	17	25	34	9		3	147

Legend:

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

FTE: Full Time Equivalent

1.8 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. Um dos objectivos principais para os próximos anos é o estudo das propriedades do bosão de Higgs. A estrutura do detector permite também medidas de precisão no âmbito do Modelo Padrão e pesquisas de nova Física.
O grupo português contribui para os estudos de Física e para as actividades de manutenção, funcionamento e actualização do detector.
Na pesquisa do bosão de Higgs, no canal H->WW, estudámos o caso em que os leptões no estado final são do mesmo sabor. Desenvolvemos um método alternativo baseado em dados para reduzir e medir o fundo de Drell-Yan remanescente. Optimizámos o método de selecção de acontecimentos e estudámos diferentes definições de energia transversa em falta (Etmiss) para uma melhor separação do sinal face ao fundo, obtendo uma melhoria significativa da sensibilidade.
Para a pesquisa do Higgs no canal H->bb e para produção associada VH, com o bosão vectorial V a decair em leptões, desenvolvemos um sistema de análise que nos permitiu fornecer parâmetros independentes para a análise global. Com vista a melhorar a resposta e resolução de jactos que se repercute na massa invariante do par de jactos b, estudámos efeitos da radiação do estado final e uma calibração global sequencial para jactos b. Foi também feito um estudo preliminar recorrendo a análise multi-variável no canal WH.
Nas análises relacionadas com o quark top, a procura de ttH, decaimentos do quark top através de correntes neutras com troca de sabor (FCNC) e de novos quarks vectoriais pesados, foram actualizadas para o conjunto completo dos dados a 8 TeV. Um membro da equipa é responsável pelo sub-grupo das propriedades do quark top. No âmbito dos estudos para o LHC a 14TeV e alta luminosidade foi estudada a sensibilidade do detector para os processos FCNC t->qZ e t->qgama recorrendo a amostras de Monte Carlo, e os resultados são compatíveis com os obtidos anteriormente por extrapolação a partir de 7 TeV.
Relativamente aos estudos com Iões Pesados, no último "run"com colisões p+Pb preparámos o menu do trigger de jactos e fizemos ajustes contínuos de forma a obter uma alocação eficiente aos sinais mais relevantes. Durante a aquisição de dados supervisionámos o sistema de monitorização de jactos offline. O grupo estudou a escala de energia dos jactos, a resolução e as eficiências de reconstrução para colisões p+Pb e continuou a análise das assimetrias em bi-jactos em colisões Pb+Pb. Recentemente começámos o estudo da produção de jactos pesados em colisões Pb+Pb.
Participámos na validação da reconstrução de Etmiss num ambiente com elevado empilhamento de acontecimentos. Foram usados decaimentos leptónicos de bosões W para avaliar os diferentes métodos de reconstrução do Etmiss e o seu impacto na massa transversa do W.
O desempenho do sistema de trigger de jactos foi estudado em detalhe e resumido numa publicação. Para isso foi necessário estender as funcionalidades do pacote de software desenvolvido e mantido pelo grupo. O algoritmo de formação de clusters no calorímetro foi melhorado para ficar mais rápido com o objectivo de o implementar no segundo nível (L2). Foi implementado um varrimento parcial sobre as regiões de interesse no L2.
Prosseguiu também a actividade no calorímetro TileCal. No sistema de calibração com laser foi desenvolvido um novo expansor de feixe que aumenta a transmissão de luz e melhora a uniformidade e reprodutibilidade. Foi desenvolvido um método para detectar fotomultiplicadores instáveis recorrendo ao laser. Continuou o trabalho

para identificar e corrigir medições erradas de energia devidas a saturação. Foi estudado o ruído electrónico do calorímetro associado ao empilhamento de sinais tanto a 7 como a 8 TeV. O Sistema de Controlo (DCS) está em migração de Windows para Linux e também de PVSS para WinCC OA, sendo necessário substituir placas e redesenhar o software para compatibilidade. Foram produzidos módulos de software para ser usados na consolidação da electrónica e para permitir o uso do hardware novo e velho em paralelo. Um elemento do grupo tornou-se responsável pelo DCS do detector ALFA, que também está em migração e actualização.
Iniciámos novas actividades de actualização do TileCal e do sistema de Trigger, que se descrevem a seguir.
O trigger de muões de nível 1 vai passar a combinar o TileCal com o espectrómetro de muões na região 1.0<‖eta‖<1.3 para reduzir o número de sinais falsos que degradam o desempenho. Foram preparados algoritmos para validar o novo trigger.
O TileCal vai precisar de um novo sistema de distribuição de alta tensão, devido a danificação por radiação e obsolescência do sistema actual. Iniciámos a nossa contribuição com o desenho de placas para a irradiação de componentes em Portugal.
Iniciámos também o projecto da estratégia de trigger para os novos detectores AFP capazes de identificar protões a baixos ângulos, e seleccionar processos difractivos com interesse para o "run"2.
O projecto inclui também uma componente de divulgação, com vários membros a participarem nas Master-Classes em várias universidades, na escola para professores de língua portuguesa no CERN, em actividades do programa Ciência Viva para jovens estudantes e em outras actividades destinadas ao público em geral.

2.1.2 Abstract

ATLAS is one of the experiments that operates at CERN´s LHC, where proton-proton and heavy ion collisions take place at unprecedented high energies and luminosities. One of the main goals for the next years is the measurement of the properties of the Higgs boson. The general purpose detector will also allow precise measurements of SM predictions and searches for new Physics.
The Portuguese group contributes to Physics studies, detector performance, operation and upgrade.
In the H->WW->lvlv channel, we have mainly contributed to the same flavour channels. We have developed a data-driven method to reduce and measure the remaining yield of the Drell-Yan background, one of the most important ones. We have also optimized the selection in that channel and studied how different missing transverse energy (Etmiss) definitions could be used to better separate signal from background, leading to a significant improvement in the overall sensitivity.
For the H->bb search in the VH associated production, where the vector boson V decays into leptons, we have developed an analysis code that allows us to give independent inputs for the global analysis. Additionally, a Global Sequential Calibration for b-jets and the effects of the final-state radiation were studied to improve the response and resolution of jets and therefore invariant mass of the pair of b-jets. A preliminar Multi-Variate Analysis study in the WH channel was also performed.
Related to top quark analysis, the measurement of the ttH cross-section and the searches for top quark decays via Flavor Changing Neutral Currents and new heavy quarks production done previously were updated to the full 8 TeV dataset and several notes were prepared. One member of the team served as co-convener of the top quark properties sub group. The sensitivity for the search of the FCNC processes t->qZ and t->qgamma at the high-luminosity phase of the 14 TeV LHC was studied using Monte Carlo samples and the results are compatible with previous ones obtained from 7 TeV extrapolations.
Concerning Heavy Ions, in the last p+Pb run we prepared the jet trigger menu and did fine tuning in order to obtain efficient allocation of the signals of interest. During data taking we supervised the offline jet reconstruction monitoring. After this stage the group studied the jet energy scale, resolution and reconstruction efficiencies in p+Pb collisions and continued with the analysis of dijet asymmetries in Pb+Pb collisions. Recently we started the study of heavy flavour jet production in Pb+Pb collisions.
We participated in the validation of the Etmiss reconstruction in a challenging pileup environment. W boson´s leptonic decays were used to evaluate the impact of different methodologies on Etmiss reconstruction and its impact on the W boson transverse mass reconstruction.
The performance of the jet trigger system has been studied in detail and was summarized in a publication. For this purpose the software package developed and maintained by the group was extended. The TopoCluster algorithm was speeded up with the aim of its implemention at L2. A Partial Scan joining all L2 Regions of Interest was implemented.
The work in TileCal proceeded. In the laser calibration system a new beam expander was developed to increase light transmission and improve uniformity and reproducibility. A new laser box was produced. A method that allows automatic detection of unstable PMTs was developed using laser data. The work for identification and correction of wrongly measured channel energies due to overflow continued. A survey of Tilecal electronic noise associated to pile-up was performed with data collected at 7-8 TeV.

The TileCal DCS is migrating from Windows to Linux, and also from PVSS to WinCC OA. New cards were needed and the software was redesigned for compatibility. Software modules were produced to help in the activity of electronics consolidation and to allow the usage of old and new hardware in parallel. We became responsible for the DCS of the ALFA detector and the respective migration and upgrade is underway.
We started new TileCal and Trigger upgrade activities, described below.
Fake triggers degrade the L1 muon trigger performance limiting the effective rate available. To reduce these fake triggers, TileCal will be combined with the Muon Spectrometer in the region 1.0<‖eta‖<1.3. Simulation algorithms to validate this new trigger were written.
TileCal will need a new High Voltage Distributor due to radiation damage and obsolescence of the current system. Work in a new system was started, with the design of boards for irradiation of components in Portugal.
We have also started to design a trigger strategy for the new Forward Proton tagging detectors (AFP) to select diffractive physics processes of interest for Run II.
We had a strong outreach participation, with Physics Masterclass in several universities, school for portuguese speaking teachers at CERN, Ciência Viva program for young students and many other activities.

2.1.3 Achievements

The ATLAS detector took collisions data smoothly and eficiently until the first months of 2013 and then was shutdown for maintenance, consolidation and upgrade. The main tasks carried out have been Physics and Performance studies, Operation and Maintenance of the detector and preparation of the future Upgrades. A summary of the main achievements follows:

- In the H->WW the data-driven method to reduce/measure Drell-Yan background was finished in the beginning of the year and used for the first 8 TeV full data set analysis for the Rencontres de Moriond and for a publication.
- Update of the H-> bb analysis, in associated production with a W boson, with the full 7 and 8 TeV analysis. Contribution with independent inputs for the global analysis and improvements in the mass resolution using Global Sequential Calibration.
- Searches for ttH, top quark decays via FCNC and new heavy quarks production updated to the full 8 TeV dataset with several publications.
- The performance of the jet trigger system was summarized in a publication (in preparation).
- The Tilecal laser system optics was significantly improved with new beam expander and it was possible to start migration of Tilecal DCS while keeping operationality for maintenance and consolidation work in the detector.
- Upgrade work started in faster algorithms for level 2 jet trigger, level 1 muon trigger with combination of Tilecal D cells, AFP trigger strategy, and high voltage distributor system for Tilecal.
- In the context of the work done, several PhD thesis progressed substantially and will be finished in 2014.

2.1.4 Sources of Funding

Code	Funding	Start	End
CERN/FP/123595/2011	530.000 €	2012-04-01	2014-04-30

2.1.5 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/FCT)	100
Alexandre Lopes	Master student (LIP)	100
Amélia Maio	Researcher (LIP/FCUL)	55
António Onofre	Researcher (LIP/UMinho)	35
Bruno Galhardo	PhD student (LIP/FCT)	100
Carlos Marques	Researcher (LIP)	100
Emanuel Gouveia	Master student (LIP)	100
Emiliano Pinto	Master student (LIP)	50
Ester Simões	Master student (LIP)	84
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)	40
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 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
Miguel Won	PhD student (LIP)	13
Nuno Anjos	Post-Doc (LIP/FCT)	100
Nuno Castro	Post-Doc (LIP/FCT)	30
Patricia Conde	Researcher (LIP)	85
Pedro Jorge	PhD student (LIP/FCT)	80
Ricardo Gonçalo	Researcher (LIP)	13
Rute Pedro	PhD student (LIP/FCT)	100
Susana Santos	PhD student (LIP/FCT)	100

2.1.6 Publications

Articles in international journals (with direct contribution from LIP members)

- *Higgs Boson Searches at ATLAS*
  R. Goncalo (for the ATLAS Collaboration)
  J.Phys.Conf.Ser. 447 (2013) 012044

- *The optical instrumentation of the ATLAS tile calorimeter*
  ATLAS Tile Calorimeter Community (221 authors)
  JINST 8 (2013) P01005

- *A new portable test bench for the ATLAS Tile calorimeter front-end electronics*
  P. Moreno et al. (13 authors)
  JINST 8 (2013) C02046

- *Measurement of the jet radius and transverse momentum dependence of inclusive jet suppression in lead-lead collisions at $\sqrt{s_{NN}}$= 2.76 TeV with the ATLAS detector*
  ATLAS Collaboration (2864 authors)
  Phys.Lett. B719 (2013) 220-241

- *Measurements of Higgs boson production and couplings in diboson final states with the ATLAS detector at the LHC*
  ATLAS Collaboration (2923 authors)
  Phys.Lett. B726 (2013) 88-119

- *Particle identification in the longitudinally unsegmented RD52 calorimeter*
  N. Akchurin, J.G. Saraiva et al
  Nucl. Instr. and Meth. in Phys. Res. A 735 (2014)

- *The electromagnetic performance of the RD52 fiber calorimeter*
  N. Akchurin, J.G. Saraiva et al
  Nucl. Instr. and Meth. in Phys. Res. A 735 (2014) 130

Articles in international journals (with indirect contribution from LIP members)

- *Measurements of top quark pair relative differential cross-sections with ATLAS in pp collisions at $\sqrt{s} = 7$ TeV*
  ATLAS Collaboration (2875 authors)
  Eur.Phys.J. C73 (2013) 2261

- *Search for dark matter candidates and large extra dimensions in events with a photon and missing transverse momentum in pp collision data at $\sqrt{s} = 7$ TeV with the ATLAS detector*
  ATLAS Collaboration (2904 authors)
  Phys.Rev.Lett. 110 (2013) 011802

- *Search for contact interactions and large extra dimensions in dilepton events from pp collisions at $\sqrt{s} = 7$ TeV with the ATLAS detector*
  Atlas Collaboration (2906 authors)
  Phys.Rev. D87 (2013) 015010

- *Search for direct production of charginos and neutralinos in events with three leptons and missing transverse momentum in $\sqrt{s} = 7$ TeV pp collisions with the ATLAS detector*
  ATLAS Collaboration (2890 authors)
  Phys.Lett. B718 (2013) 841-859

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  ATLAS Collaboration (2891 authors)
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  ATLAS Collaboration (2905 authors)
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- *Measurement of Z boson Production in Pb+Pb Collisions at $\sqrt{s_{NN}} = 2.76$ TeV with the ATLAS Detector*
  ATLAS Collaboration (2905 authors)
  Phys.Rev.Lett. 110 (2013) 022301

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  ATLAS Collaboration (2890 authors)
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- *Search for pair production of heavy top-like quarks decaying to a high-pT W boson and a b quark in the lepton plus jets final state at $\sqrt{s}$=7 TeV with the ATLAS detector*
  ATLAS Collaboration (2905 authors)
  Phys.Lett. B718 (2013) 1284-1302

- *Search for resonances decaying into top-quark pairs using fully hadronic decays in pp collisions with ATLAS at $\sqrt{s} = 7$ TeV*
  ATLAS Collaboration (2916 authors)
  JHEP 1301 (2013) 116

- *ATLAS search for new phenomena in dijet mass and angular distributions using pp collisions at $\sqrt{s} = 7$ TeV*
  ATLAS Collaboration (2903 authors)
  JHEP 1301 (2013) 029

- *Measurement of the flavour composition of dijet events in pp collisions at $\sqrt{s} = 7$ TeV with the ATLAS detector*
  ATLAS Collaboration (2905 authors)
  Eur.Phys.J. C73 (2013) 2301

- *Search for the neutral Higgs bosons of the Minimal Supersymmetric Standard Model in pp collisions at $\sqrt{s} = 7$ TeV with the ATLAS detector*
  ATLAS Collaboration (2894 authors)
  JHEP 1302 (2013) 095

- *Measurement of the Λ_b lifetime and mass in the ATLAS experiment*
  ATLAS Collaboration (2873 authors)
  Phys.Rev. D87 (2013) 3, 032002

- *A search for high-mass resonances decaying to $\tau^+\tau^-$ in pp collisions at $\sqrt{s} = 7$ TeV with the ATLAS detector*
  Atlas Collaboration (2911 authors)
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- *Search for supersymmetry in events with photons, bottom quarks, and missing transverse momentum in proton-proton collisions at a centre-of-mass energy of 7 TeV with the ATLAS detector*
  Atlas Collaboration (2897 authors)
  Phys.Lett. B719 (2013) 261-279

- *Search for long-lived, heavy particles in final states with a muon and multi-track displaced vertex in proton-proton collisions at $\sqrt{s} = 7$ TeV with the ATLAS detector*
  ATLAS Collaboration (2915 authors)
  Phys.Lett. B719 (2013) 280-298

- *A search for prompt lepton-jets in pp collisions at $\sqrt{s} = 7$ TeV with the ATLAS detector*
  ATLAS Collaboration (2886 authors)
  Phys.Lett. B719 (2013) 299-317

- *Multi-channel search for squarks and gluinos in $\sqrt{s} = 7$ TeV pp collisions with the ATLAS detector*
  ATLAS Collaboration (2894 authors)
  Eur.Phys.J. C73 (2013) 2362

- *Single hadron response measurement and calorimeter jet energy scale uncertainty with the ATLAS detector at the LHC*
  ATLAS Collaboration (3054 authors)
  Eur.Phys.J. C73 (2013) 2305

- *Measurement of the ttbar production cross section in the tau+jets channel using the ATLAS detector*
  ATLAS Collaboration (2896 authors)
  Eur.Phys.J. C73 (2013) 2328

- *Jet energy measurement with the ATLAS detector in proton-proton collisions at $\sqrt{s} = 7$ TeV*
  ATLAS Collaboration (3066 authors)
  Eur.Phys.J. C73 (2013) 2304

- *Jet energy resolution in proton-proton collisions at $\sqrt{s} = 7$ TeV recorded in 2010 with the ATLAS detector*
  ATLAS Collaboration (2877 authors)
  Eur.Phys.J. C73 (2013) 2306

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  ATLAS Collaboration (2900 authors)
  JHEP 1303 (2013) 128

- *Search for charged Higgs bosons through the violation of lepton universality in $t\bar{t}$ events using pp collision data at $\sqrt{s} = 7$ TeV with the ATLAS experiment*
  ATLAS Collaboration (2900 authors)
  JHEP 1303 (2013) 076

- *Search for new phenomena in events with three charged leptons at /sqrts = 7 TeV with the ATLAS detector*
  ATLAS Collaboration / ATLAS Collaboration (2901 authors)
  Phys.Rev. D87 (2013) 5, 052002

- *Measurement of Upsilon production in 7 TeV pp collisions at ATLAS*
  ATLAS Collaboration (2898 authors)
  Phys.Rev. D87 (2013) 5, 052004

- *Search for light top squark pair production in final states with leptons and b^- jets with the ATLAS detector in $\sqrt{s} = 7$ TeV proton-proton collisions*
  ATLAS Collaboration (2910 authors)
  Phys.Lett. B720 (2013) 13-31

- *Measurement of angular correlations in Drell-Yan lepton pairs to probe Z/gamma* boson transverse momentum at sqrt(s)=7 TeV with the ATLAS detector*
  ATLAS Collaboration (2892 authors)
  Phys.Lett. B720 (2013) 32-51

- *Measurement of isolated-photon pair production in pp collisions at $\sqrt{s} = 7$ TeV with the ATLAS detector*
  ATLAS Collaboration (2899 authors)
  JHEP 1301 (2013) 086

- *Measurement of hard double-parton interactions in $W(\rightarrow l\nu)$+ 2 jet events at $\sqrt{s}$=7 TeV with the ATLAS detector*
  ATLAS Collaboration (2917 authors)
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- *Searches for heavy long-lived sleptons and R-Hadrons with the ATLAS detector in pp collisions at $\sqrt{s} = 7$ TeV*
  ATLAS Collaboration (2904 authors)
  Phys.Lett. B720 (2013) 277-308

- *Search for pair-produced massive coloured scalars in four-jet final states with the ATLAS detector in proton-proton collisions at $\sqrt{s} = 7$ TeV*
  ATLAS Collaboration (2912 authors)
  Eur.Phys.J. C73 (2013) 2263

- *Search for direct chargino production in anomaly-mediated supersymmetry breaking models based on a disappearing-track signature in pp collisions at $\sqrt{s} = 7$ TeV with the ATLAS detector*
  ATLAS Collaboration (2911 authors)
  JHEP 1301 (2013) 131

- *Search for dark matter candidates and large extra dimensions in events with a jet and missing transverse momentum with the ATLAS detector*
  G. Aad et al. (2869 authors)
  JHEP 1304 (2013) 075

- *Search for Extra Dimensions in diphoton events using proton-proton collisions recorded at $\sqrt{s} = 7$ TeV with the ATLAS detector at the LHC*
  ATLAS Collaboration (2905 authors)
  New J.Phys. 15 (2013) 043007

- *Search for WH production with a light Higgs boson decaying to prompt electron-jets in proton-proton collisions at $\sqrt{s}$=7 TeV with the ATLAS detector*
  ATLAS Collaboration (2916 authors)
  New J.Phys. 15 (2013) 043009

- *Search for displaced muonic lepton jets from light Higgs boson decay in proton-proton collisions at $\sqrt{s} = 7$ TeV with the ATLAS detector*
  ATLAS Collaboration (2903 authors)
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- *A study of heavy flavor quarks produced in association with top quark pairs at sqrt(s) = 7 TeV using the ATLAS detector*
  ATLAS Collaboration (2923 authors)
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- *Search for single b^*-quark production with the ATLAS detector at $\sqrt{s} = 7$ TeV*
  ATLAS Collaboration (2905 authors)
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- *Observation of Associated Near-side and Away-side Long-range Correlations in $\sqrt{s_{NN}}$=5.02 TeV Proton-lead Collisions with the ATLAS Detector*
  ATLAS Collaboration (2925 authors)
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- *Measurement of kT splitting scales in W->lv events at sqrt(s)=7 TeV with the ATLAS detector*
  ATLAS Collaboration (2931 authors)
  Eur.Phys.J. C73 (2013) 2432

- *Search for long-lived, multi-charged particles in pp collisions at $\sqrt{s}$=7 TeV using the ATLAS detector*
  ATLAS Collaboration (2898 authors)
  Phys.Lett. B722 (2013) 305-323

- *Search for third generation scalar leptoquarks in pp collisions at $\sqrt{s}$ = 7 TeV with the ATLAS detector*
  ATLAS Collaboration (2896 authors)
  JHEP 1306 (2013) 033

- *Search for a light charged Higgs boson in the decay channel $H^+ \to c\bar{s}$ in $t\bar{t}$ events using pp collisions at $\sqrt{s}$ = 7 TeV with the ATLAS detector*
  ATLAS Collaboration (2894 authors)
  Eur.Phys.J. C73 (2013) 2465

- *Measurement of the cross-section for W boson production in association with b-jets in pp collisions at $\sqrt{s}$ = 7 TeV with the ATLAS detector*
  ATLAS Collaboration (2911 authors)
  JHEP 1306 (2013) 084

- *Measurement of W^+W^- production in pp collisions at $\sqrt{s} = 7$ TeV with the ATLAS detector and limits on anomalous WWZ and $WW\gamma$ couplings*
  ATLAS Collaboration (2912 authors)
  Phys.Rev. D87 (2013) 112001

- *Measurements of $W\gamma$ and $Z\gamma$ production in pp collisions at $\sqrt{s}$= 7 TeV with the ATLAS detector at the LHC*
  ATLAS Collaboration (2907 authors)
  Phys.Rev. D87 (2013) 112003

- *Search for a heavy narrow resonance decaying to $e\mu$, $e\tau$, or $\mu\tau$ with the ATLAS detector in $\sqrt{s} = 7$ TeV pp collisions at the LHC*
  ATLAS Collaboration (2896 authors)
  Phys.Lett. B723 (2013) 15-32

- *Search for resonant diboson production in the lvjj decay channels with the ATLAS detector at 7 TeV*
  ATLAS Collaboration (2906 authors)
  Phys.Rev. D87 (2013) 112006

- *Measurement of the production cross section of jets in association with a Z boson in pp collisions at $\sqrt{s}$ = 7 TeV with the ATLAS detector*
  ATLAS Collaboration (2920 authors)
  JHEP 1307 (2013) 032

- *Characterisation and mitigation of beam-induced backgrounds observed in the ATLAS detector during the 2011 proton-proton run*
  ATLAS Collaboration (2913 authors)
  JINST 8 (2013) P07004

- *Triggers for displaced decays of long-lived neutral particles in the ATLAS detector*
  ATLAS Collaboration (2917 authors)
  JINST 8 (2013) P07015

- *Search for non-pointing photons in the diphoton and E_T^miss final state in sqrt(s) = 7 TeV proton-proton collisions using the ATLAS detector*
  G. Aad et al. (2924 authors)
  Phys.Rev. D88 (2013) 012001

- *Evidence for the spin-0 nature of the Higgs boson using ATLAS data*
  ATLAS Collaboration (2923 authors)
  Phys.Lett. B726 (2013) 120-144

- *A search for $t\bar{t}$ resonances in the lepton plus jets final state with ATLAS using 4.7 fb^{-1} of pp collisions at $\sqrt{s} = 7$ TeV*
  ATLAS Collaboration (2929 authors)
  Phys.Rev. D88 (2013) 012004

- *Measurement of top quark polarization in top-antitop events from proton-proton collisions at sqrts = 7 TeV using the ATLAS detector*
  ATLAS Collaboration (2926 authors)
  Phys.Rev.Lett. 111 (2013) 232002

- *Measurement of the inclusive jet cross section in pp collisions at sqrt(s)=2.76 TeV and comparison to the inclusive jet cross section at sqrt(s)=7 TeV using the ATLAS detector*
  ATLAS Collaboration (2893 authors)
  Eur.Phys.J. C73 (2013) 2509

- *Improved luminosity determination in pp collisions at $\sqrt{s}$ = 7 TeV using the ATLAS detector at the LHC*
  ATLAS Collaboration (2912 authors)
  Eur.Phys.J. C73 (2013) 2518

- *Measurement of charged-particle event shape variables in $\sqrt{s} = 7$ TeV proton-proton interactions with the ATLAS detector*
  ATLAS Collaboration (2890 authors)
  Phys.Rev. D88 (2013) 032004

- *Measurement with the ATLAS detector of multi-particle azimuthal correlations in p+Pb collisions at $\sqrt{s_{NN}}$=5.02 TeV*
  ATLAS Collaboration (2922 authors)
  Phys.Lett. B725 (2013) 60-78

- *Search for excited electrons and muons in $\sqrt{s}$=8 TeV proton-proton collisions with the ATLAS detector*
  ATLAS Collaboration (2936 authors)
  New J.Phys. 15 (2013) 093011

- *Performance of jet substructure techniques for large-R jets in proton-proton collisions at $\sqrt{s}$ = 7 TeV using the ATLAS detector*
  ATLAS Collaboration (2910 authors)
  JHEP 1309 (2013) 076

- *Search for new phenomena in photon+jet events collected in proton–proton collisions at sqrt(s) = 8 TeV with the ATLAS detector*
  ATLAS Collaboration (2924 authors)
  Phys.Lett. B728 (2014) 562-578

- *Search for dark matter in events with a hadronically decaying W or Z boson and missing transverse momentum in pp collisions at sqrts=8 TeV with the ATLAS detector*
  ATLAS Collaboration (2937 authors)
  Phys.Rev.Lett. 112 (2014) 041802

- *Search for microscopic black holes in a like-sign dimuon final state using large track multiplicity with the ATLAS detector*
  ATLAS Collaboration (2941 authors)
  Phys.Rev. D88 (2013) 072001

- *Measurement of the high-mass Drell–Yan differential cross-section in pp collisions at $\sqrt{s}$=7 TeV with the ATLAS detector*
  ATLAS Collaboration (2916 authors)
  Phys.Lett. B725 (2013) 223-242

- *Measurement of the differential cross-section of B^+ meson production in pp collisions at $\sqrt{s}$ = 7 TeV at ATLAS*
  ATLAS Collaboration (2917 authors)
  JHEP 1310 (2013) 042

- *Measurement of the Azimuthal Angle Dependence of Inclusive Jet Yields in Pb+Pb Collisions at $\sqrt{s_{NN}}$= 2.76 TeV with the ATLAS detector*
  ATLAS Collaboration (2916 authors)
  Phys.Rev.Lett. 111 (2013) 152301

- *Search for new phenomena in final states with large jet multiplicities and missing transverse momentum at $\sqrt{s} = 8$ TeV proton-proton collisions using the ATLAS experiment*
  ATLAS Collaboration (2919 authors)
  JHEP 1310 (2013) 130

- *Dynamics of isolated-photon plus jet production in pp collisions at $\sqrt{(s)}$ = 7 TeV with the ATLAS detector*
  ATLAS Collaboration (2916 authors)
  Nucl.Phys. B875 (2013) 483-535

- *Measurement of the mass difference between top and anti-top quarks in pp collisions at sqrt(s) = 7 TeV using the ATLAS detector*
  ATLAS Collaboration (2935 authors)
  Phys.Lett. B728 (2013) 363-379

- *Search for long-lived stopped R-hadrons decaying out-of-time with pp collisions using the ATLAS detector*
  ATLAS Collaboration (2934 authors)
  Phys.Rev. D88 (2013) 112003

- *Search for direct third-generation squark pair production in final states with missing transverse momentum and two b-jets in $\sqrt{s}$ = 8 TeV pp collisions with the ATLAS detector*
  ATLAS Collaboration (2917 authors)
  JHEP 1310 (2013) 189

- *Measurement of the top quark charge in pp collisions at $\sqrt{s}$ = 7 TeV with the ATLAS detector*
  ATLAS Collaboration (2914 authors)
  JHEP 1311 (2013) 031

- *Measurement of the inclusive isolated prompt photon cross section in pp collisions at sqrts = 7 TeV with the ATLAS detector using 4.6 fb-1*
  ATLAS Collaboration (2916 authors)
  Phys.Rev. D89 (2014) 052004

- *Search for Quantum Black-Hole Production in High-Invariant-Mass Lepton+Jet Final States Using Proton-Proton Collisions at sqrts = 8 TeV and the ATLAS Detector*
  ATLAS Collaboration (2909 authors)
  Phys.Rev.Lett. 112 (2014) 091804

- *Measurement of the distributions of event-by-event flow harmonics in lead-lead collisions at = 2.76 TeV with the ATLAS detector at the LHC*
  ATLAS Collaboration (2917 authors)
  JHEP 1311 (2013) 183

- *Measurement of the top quark pair production charge asymmetry in proton-proton collisions at sqrts = 7 TeV using the ATLAS detector*
  ATLAS Collaboration (2935 authors)
  JHEP 1402 (2014) 107

- *Standalone vertex finding in the ATLAS muon spectrometer*
  ATLAS Collaboration (2931 authors)
  JINST 9 (2014) P02001

- *Search for charginos nearly mass-degenerate with the lightest neutralino based on a disappearing-track signature in pp collisions at $\sqrt{s}$ = 8 TeV with the ATLAS detector*
  ATLAS Collaboration (2934 authors)
  Phys.Rev. D88 (2013) 112006

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  ATLAS Collaboration (1 authors)
  EPJ Web Conf. 60 (2013) 14007

- *Search for a Multi-Higgs Boson Cascade in $W^+W^-b\bar{b}$ events with the ATLAS detector in pp collisions at root s = 8 TeV*
  ATLAS Collaboration (2935 authors)
  Phys.Rev. D89 (2014) 032002

- *Measurement of jet shapes in top pair events at sqrt(s) = 7 TeV using the ATLAS detector*
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International Conference Proceedings

- *SM Top properties at LHC: top charge, Branching Ratio and top pair production associated with gauge bosons*
  Mara Senghi Soares (for the CMS Collaboration / ATLAS Collaboration)
  J PHYS CONF SER 452 (2013) 012038

- *Overview of Recent ATLAS Physics Results*
  Patricia Conde Muino (for the ATLAS Collaborations)
  J PHYS CONF SER 447 (2013)

- *Study of Jet Quenching in Pb+Pb Collisions with the ATLAS Detector*
  H. Santos
  ATL-PHYS-PROC-2013-095

- *Single hadron response measurements in ATLAS and evaluation of the uncertainty on the jet energy measurement*
  M.J.Sousa
  Nuclear Instruments and Methods in Physics Research A 718 (2013) 112-114

- *High Mass Higgs boson searches in ATLAS and CMS*
  J. Machado Miguéns, on behalf of the ATLAS and CMS Collaborations
  PoS (EPS-HEP 2013) 298

- *Jet and photon measurements from ATLAS*
  J. Gentil Saraiva et al.
  EPJ Web of Conferences, Volume 60, 2013

- *Lessons learned from the ATLAS performance studies of the Iberian Cloud for the first LHC running period*
  V Sánchez-Martínez, G Borges, C Borrego, J del Peso, M Delfino, J Gomes, S González de la Hoz, A Pacheco Pages, J Salt, A Sedov, M Villaplana and H Wolters
  J. Phys.: Conf. Ser. 513 032082

Collaboration notes with internal referee

- *Measurements of the properties of the Higgs-like boson in the WW(*) $\rightarrow l\nu l\nu$ deca*
  The ATLAS Collaboration
  ATLAS-CONF-2013-030

- *Measurement of the centrality-dependence of inclusive jet production in p+Pb data at sqrt(sNN)=5.02 TeV with the ATLAS detector*
  D. Perepelitsa, A. Lopes et al
  ATL-COM-PHYS-2013-1369

Internal Notes

- *Invariant Mass Studies for the H->bb Measurements for LHCP*
  P. Conde-Muíño, J. Maneira, A. Maio, E. Pinto et al.
  ATL-COM-PHYS-2013-449

2.1.7 Presentations

Oral presentations in international conferences

- *Study of Jet Quenching in Pb+Pb Collisions with the ATLAS Detector*
  presented by Helena Santos
  Excited QCD 2013 — Bjelasnica, Bosnia-Herzegovina.

- *Associated production (VH(bb)+ttH, all decays)*
  presented by José Maneira
  SM@LHC2013 — Freiburg, Germany.

- *Jet and photon measurements from ATLAS*
  presented by João Gentil
  LHCP 2013 — Barcelona, Spain.

- *High Mass Higgs Boson Searches in ATLAS and CMS*
  presented by Joana Miguéns
  EPS-HEP — Stockholm, Sweden.

- *Lessons learned from the ATLAS performance studies of the Iberian Cloud for the first LHC running period*
  presented by Helmut Wolters
  20th International Conference on Computing in High Energy and Nuclear Physics 2013 — Amsterdam, Netherlands, 14 - 18 Oct 2013.

- *Measurement of Properties of the Higgs boson in bosonic decay channels using the ATLAS detector*
  presented by Alberto Palma
  PASCOS 2013 — Taipei, Taiwan.

Oral presentations in collaboration meetings

- *2011 analysis unblinding status.*
  presented by Joana Miguéns
  HSG3 Weekly meeting — CERN.

- *Summary of Analysis*
  presented by Nuno Castro
  EB Meeting: 4GT VLQ to Zb / Zt pair at 8 TeV — .

- *Testing GSC validation with WH samples*
  presented by José Maneira
  VH->bb Moriond Analysis — .

- *Same Flavour analysis status*
  presented by Joana Miguéns
  HSG3 2011 lvlv reanalysis — CERN.

- *SF ee1j Update*
  presented by Joana Miguéns
  HSG3 Weekly meeting — CERN.

- *2011 Re-analysis: SF*
  presented by Joana Miguéns
  H to wW Editorial Board — CERN.

- *Update on the GSC in the VH samples*
  presented by Patricia Conde
  Topical Meeting on H->bb invariant mass Resolution — .

- *Same Flavour analysis status*
  presented by Joana Miguéns
  HSG3 2011 lvlv reanalysis — CERN.

- *ee+1 jet and first look at Moriond dataset.*
  presented by Joana Miguéns
  H to wW Editorial Board — CERN.
- *2011 SF: Answer to ed board questions and MET comparison between the HCP and the Moriond dataset*
  presented by Joana Miguéns
  H to wW Editorial Board — CERN.
- *Performance paper: EF resolutions*
  presented by Lourenço Lopes
  Jet Trigger Signature Group Meeting — CERN.
- *WW 2011+2012+VBF Combination Pre Approval*
  presented by Joana Miguéns
  WW Pre-approval meeting — CERN.
- *Updates to the HCP 0 1 jet results and first look at new data*
  presented by Joana Miguéns
  HSG3 Pre-approval rehearsals — CERN.
- *Pileup studies using 25 and 50 ns bs data*
  presented by
  Tilecal Calibration, Data Quality, Performance and Processing — .
- *Update on the GSC in the VH samples*
  presented by José Maneira
  Topical Meeting on H->bb invariant mass Resolution — .
- *Validation in W MC events with the p1344 D3PDs*
  presented by João Gentil
  ETmiss Subgroup Meeting — .
- *mbb Resolution*
  presented by Patricia Conde
  HSG5 Weekly Meeting — .
- *Status of the Same Flavour analysis*
  presented by Joana Miguéns
  HSG3 2011 lnln reanalysis — CERN.
- *Zb+X status report*
  presented by Juan Espinosa
  Extraordinary Top and Fourth Generation Subgroup Meeting — .
- *Cloud support and ADCoS*
  presented by Helmut Wolters
  Software & Computing Workshop — CERN.
- *Top fcnc decays studies*
  presented by Filipe Veloso
  Upgrade physics weekly meeting — Phone meeting.
- *Control distributions for the $t \to qZ$ analysis*
  presented by Filipe Veloso
  Top properties meeting — Phone meeting.
- *Searches for rare decays of the top quark*
  presented by Filipe Veloso
  ATLAS Week 2013 — Marrakech, Morocco.

Seminars

- *The challenge of EtMiss reconstruction at ATLAS*
  presented by João Gentil
  LIP seminar — LIP, Lisbon.
- *Study of Jet Quenching in Pb+Pb Collisions with the ATLAS Detector*
  presented by Helena Santos
  — Centro de Física Teórica de Partículas, Instituto Superior Técnico de Lisboa, Portugal.
- *Higgs Physics: Summary of results from the discovery in the different channels. Case-study of the H->WW search at ATLAS.*
  presented by Patricia Conde
  IDPASC course on Physics at the LHC — LIP, Lisbon.
- *O bosão de Higgs*
  presented by Patricia Conde
  — FCUL.

Outreach seminars

- *The Higgs Boson*
  presented by Filipe Veloso
  Encontro Nacional de Estudantes de Física 2013 — Coimbra, Portugal.
- *Aceleradores e Detetores: como se produzem e se vêem as partículas*
  presented by José Maneira
  Masterclasses de Física de Partículas — FCUL, Lisboa.
- *Detectores e Aceleradores*
  presented by Filipe Veloso
  9th International Masterclasses — Coimbra, Portugal.
- *Introdução à Física de Partículas*
  presented by José Maneira
  Masterclasses de Física de Partículas — Escola Secundária da Povoação, Ilha de São Miguel, Açores.
- *Introdução à Física de Partículas*
  presented by José Maneira
  Masterclasses de Física de Partículas — Escola Secundária Domingos Rebelo, Ponta Delgada, Ilha de São Miguel, Açores.
- *Aceleradores e Detectores*
  presented by João Gentil
  International Masterclasses — Vila Real, Portugal.
- *Aceleradores e Detectores*
  presented by João Gentil
  International Masterclasses — Bragança, Portugal.
- *Detectores e Aceleradores*
  presented by Filipe Veloso
  9th International Masterclasses — Aveiro, Portugal.
- *Temos bosao de Higgs*
  presented by Patricia Conde
  Exhibition Dos Ceus ao Universo — Biblioteca Nacinal, Lisboa.
- *A experiência ATLAS*
  presented by José Maneira
  Estágio no CERN para Professores em Língua Portuguesa — CERN.
- *Mas afinal o que é o bosão de Higgs?*
  presented by Filipe Veloso
  Semana da Ciência e da Tecnologia — Universidade de Coimbra, Portugal.

- *Partículas elementares e forças fundamentais: o LHC*
  presented by Filipe Veloso
  — Escola Secundária Dr. Júlio Martins, Chaves, Portugal.

- *Mas afinal o que é o bosão de Higgs?*
  presented by Filipe Veloso
  — Escola Secundária de São Pedro do Sul, Portugal.

2.1.8 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)

2.1.9 Project Summary

	number
Articles in international journals (with direct contribution from LIP members)	7
Articles in international journals (with indirect contribution from LIP members)	84
International Conference Proceedings	7
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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 125-126 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 Achievements

Physics
The CMS experiment at LHC is a major scientific endeavor. Within the CMS experiment physics program, the LIP/CMS group has made major scientific contributions in the following areas:

- The discovery of a Higgs boson in the two-photons decay channel, the most sensitive channel in the Higgs low mass region. Two members of the LIP/CMS group (A. David, P. Musella) had a major role in this analysis, and one (A.David) was main editor of the analysis documentation. A former member of the team (P. Musella) is presently co-coordinator of the CMS analysis group "Higgs in two-photons".

- The study of the Higgs properties. These studies are at the base of the recent statement that the new particle is a Higgs boson. A member of the group (A. David, on-leave at CERN) is co-convener of the CMS analysis group "Higgs properties".

- The measurement of the top quark mass. The LIP/CMS group (P. Silva, M. Gallinaro, et al.) performed the first measurement of the top quark mass at the LHC, and produced in collaboration with the Brown University the most precise measurement in the dilepton channel up-to date. A member of the group (P. Silva, on-leave at CERN) is co-convener of the CMS analysis group "Top quark mass".

- The measurement of the Vtb element of the CKM matrix, by studying the decays of the top quark. The LIP/CMS group (P. Silva, M. Gallinaro, et al.) provided the most precise measurement of this fundamental parameter of the SM available today. A paper is the final stage of revision by the collaboration.

- The measurement of the J/Psi and Upsilon polarizations in pp collisions. The LIP/CMS group (P. Faccioli, J. Seixas) led this important measurement which challenges the present QCD predictions. P. Faccioli is widely recognized as world expert in polarization measurements. The results are now published.

- The search for a light charged Higgs in decays of the top quark. The measurement of the LIP/CMS group (P. Vischia, M. Gallinaro, et al.) in collaboration with Helsinki provided the best limits in the branching ratio of top decay in charged Higgs, using events with one lepton and one hadronic decaying tau.

In addition, the LIP/CMS group has been recently actively involved and/or had a leading role in the following physics analysis:

- measurement performed by the LIP group of the cross section of production of top quark pair in the dilepton channel with one hadronically decaying tau (M. Jordao, F. Nguyen, M. Gallinaro, paper in final stage of review);
- search for the supersymmetric partner of the top quark following (M. Fernandes, P. Bargassa, L. Lloret, on-going).
- search for heavy charged Higgs decaying in top quark ((P. Vischia, M. Gallinaro, et al. – on-going)

Upgrades

The LIP/CMS group participates in 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.

In 2012-13 the LIP/ group did the R&D and built working prototypes of the new 4.8 Gb/s optical Serial Link Boards (oSLB) that interfaces the ECAL electronics to the Trigger System. The oSLB is a key element in the CMS strategy for commissioning the new trigger system in 2015 in parallel with normal data taking.

Coordination
The coordination positions in the LIP/CMS group are listed below (in parenthesis are indicated the names of the coordinators in 2013):

- LIP/CMS group coordinator (J. Varela)
- LIP/CMS deputy group coordinator (J. Seixas)
- Proton-proton physics coordinator (M. Gallinaro)
- Heavy-ion physics coordinator (J. Seixas)
- Upgrade coordinators:
  - Optical links project (J. C. Silva)
  - Precision proton spectrometer (J. Varela)
  - Pixel trigger (F. Nguyen)
- ECAL detector:
  - Run coordinator (A. David)
  - Electronics coordinator (J. C. Silva)
- Computing coordinator (P. Vischia)

Within the CMS Collaboration, LIP group members participated in 2013 in the following structures:

- CMS Executive Board (J. Varela, CMS Deputy Spokesperson)
- CMS Management Board (J. Varela, CMS Deputy Spokesperson)
- CMS Finance Board (J. Varela, country representative)

- CMS Collaboration Board (J. Varela and J. Seixas, group representative)
- ECAL Executive Board (A. David, J.C. Silva, ECAL L1 and L2 managers)
- ECAL Institution/Finance Board (J. Varela, A. David, group representative)
- Trigger/DAQ Institution/Finance Board (J. Varela, group representative)
- Physics Analysis Groups (Higgs, TOP, SUSY, B-physics, Heavy-Ions)
- ECAL, Trigger and Upgrade projects and its sub-structures.

Members of the LIP group have been selected to participate in many Analysis Review Committees (ARC). The LIP group members have the following coordination positions in the CMS Collaboration structure:

- CMS Deputy Spokesperson, 2012-13 (J. Varela): Top management position, second to the Spokesperson that leads the Collaboration.
- ECAL Run Coordinator, since 2010 (A. David): Level 2 management position, responsible for the Operation of the ECAL Detector.
- ECAL Electronics Coordinator, since 2010 (J. C. Silva): Level 2 management position, responsible for the Electronics of the ECAL Detector.
- ECAL Data Acquisition Coordinator, since 2011 (P. Parracho): Level 2 management position, responsible for the Data Acquisition of the ECAL Detector.
- Level 3 management position, responsible for top quark mass and properties measurements, since 2013 (P. Silva)
- Level 3 management position, responsible for Higgs combination and properties, since 2013 (A. David)

2.2.4 Sources of Funding

Code	Funding	Start	End
CERN/FP/123601/2011	550.000 €	2012-04-01	2014-09-30

2.2.5 Team

Project coordinator: João Varela

Name	Status	FTE %
Agostino di Francesco	PhD student (LIP)	33
André Tinoco Mendes	Researcher (LIP)	100
Andrea Barisone	Technician (LIP)	75
Cristóvão Silva	PhD student (LIP/FCT)	100
Daniele Vadruccio	Researcher (LIP)	42
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)	42
Marcelo Vicente	Student (LIP)	90
Michele Gallinaro	Researcher (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

2.2.6 Publications

Articles in international journals (with direct contribution from LIP members)

- *The optical synchronization and link board project, oSLB*
  J. C. Da Silva, J. Varela, P. Parracho
  JINST 8 (2013) C02036

- *Measurement of the Y1S, Y2S and Y3S polarizations in pp collisions at* $\sqrt{s} = 7$ *TeV*
  CMS Collaboration (2181 authors)
  Phys.Rev.Lett. 110 (2013) 081802

- *Measurement of differential top-quark pair production cross sections in pp colisions at* $\sqrt{s} = 7$ *TeV*
  CMS Collaboration (2200 authors)
  Eur.Phys.J. C73 (2013) 2339

- *Measurement of the* $t\bar{t}$ *production cross section in pp collisions at* $\sqrt{s} = 7$ *TeV with lepton + jets final states*
  CMS Collaboration (2196 authors)
  Phys.Lett. B720 (2013) 83-104

- *Measurement of the top-antitop production cross section in the tau+jets channel in pp collisions at sqrt(s) = 7 TeV*
  CMS Collaboration (2200 authors)
  Eur.Phys.J. C73 (2013) 2386

- *Identification of b-quark jets with the CMS experiment*
  CMS Collaboration (2202 authors)
  JINST 8 (2013) P04013

- *Search for supersymmetry in pp collisions at* $\sqrt{s} = 7$ *TeV in events with a single lepton, jets, and missing transverse momentum*
  CMS Collaboration (2195 authors)
  Eur.Phys.J. C73 (2013) 2404

- *Search for a standard-model-like Higgs boson with a mass in the range 145 to 1000 GeV at the LHC*
  CMS Collaboration (2189 authors)
  Eur.Phys.J. C73 (2013) 2469

- *Observation of a new boson with mass near 125 GeV in pp collisions at* $\sqrt{s} = 7$ *and 8 TeV*
  CMS Collaboration (2189 authors)
  JHEP 1306 (2013) 081

- *Energy calibration and resolution of the CMS electromagnetic calorimeter in pp collisions at root s = 7 TeV*
  CMS Collaboration (2203 authors)
  JINST 8 (2013) P09009

- *The return of quarkonia*
  P. Faccioli
  CERN Courier, Jul-Aug 2013

- *Minimal physical constraints on the angular distributions of two-body boson decays*
  P. Faccioli, C. Lourenço, J. Seixas and H. K. Wöhri
  Phys. Rev. D 88 (2013) 031901.

- *Search for top-squark pair production in the single-lepton final state in pp collisions at* $\sqrt{s}$ *= 8 TeV*
  CMS Collaboration (2222 authors)
  Eur.Phys.J. C73 (2013) 2677

- *Measurement of the prompt J/psi and psi(2S) polarizations in pp collisions at sqrt(s) = 7 TeV*
  CMS Collaboration (2220 authors)
  Phys.Lett. B727 (2013) 381-402

Articles in international journals (with indirect contribution from LIP members)

- *Measurement of the elliptic anisotropy of charged particles produced in PbPb collisions at nucleon-nucleon center-of-mass energy = 2.76 TeV*
  CMS Collaboration (2206 authors)
  Phys.Rev. C87 (2013) 014902

- *Forward-backward asymmetry of Drell-Yan lepton pairs in pp collisions at* $\sqrt{s} = 7$ *TeV*
  CMS Collaboration (2192 authors)
  Phys.Lett. B718 (2013) 752-772

- *Studies of jet quenching using isolated-photon+jet correlations in PbPb and pp collisions at* $\sqrt{s_{NN}} = 2.76$ *TeV*
  CMS Collaboration (2197 authors)
  Phys.Lett. B718 (2013) 773-794

- *Observation of long-range near-side angular correlations in proton-lead collisions at the LHC*
  CMS Collaboration (2193 authors)
  Phys.Lett. B718 (2013) 795-814

- *Search for new physics in events with opposite-sign leptons, jets, and missing transverse energy in pp collisions at* $\sqrt{s} = 7$ *TeV*
  S. Chatrchyan et al. (2213 authors)
  Phys.Lett. B718 (2013) 815-840

- *Observation of a diffractive contribution to dijet production in proton-proton collisions at* $\sqrt{s} = 7$ *TeV*
  CMS Collaboration (2199 authors)
  Phys.Rev. D87 (2013) 012006

- *Evidence for associated production of a single top quark and W boson in pp collisions at* $\sqrt{s}$ *= 7 TeV*
  CMS Collaboration (2197 authors)
  Phys.Rev.Lett. 110 (2013) 022003

- *Measurement of the azimuthal anisotropy of neutral pions in PbPb collisions at* $\sqrt{s_{NN}} = 2.76$ *TeV*
  CMS Collaboration (2198 authors)
  Phys.Rev.Lett. 110 (2013) 042301

- *Search for a narrow spin-2 resonance decaying to a pair of Z vector bosons in the semileptonic final state*
  CMS Collaboration (2203 authors)
  Phys.Lett. B718 (2013) 1208-1228

- *Search for a $W^{\prime}$ boson decaying to a bottom quark and a top quark in pp collisions at $\sqrt{s} = 7$ TeV*
  CMS Collaboration (2197 authors)
  Phys.Lett. B718 (2013) 1229-1251

- *Search for flavor changing neutral currents in top quark decays in pp collisions at 7 TeV*
  CMS Collaboration (1984 authors)
  Phys.Lett. B718 (2013) 1252-1272

- *Measurement of the sum of WW and WZ production with W+dijet events in pp collisions at $\sqrt{s} = 7$ TeV*
  CMS Collaboration (2190 authors)
  Eur.Phys.J. C73 (2013) 2283

- *Search for exotic resonances decaying into WZ/ZZ in pp collisions at $\sqrt{s} = 7$ TeV*
  CMS Collaboration (2206 authors)
  JHEP 1302 (2013) 036

- *Search in leptonic channels for heavy resonances decaying to long-lived neutral particles*
  CMS Collaboration (2211 authors)
  JHEP 1302 (2013) 085

- *Search for contact interactions in $\mu^+\mu^-$ events in pp collisions at $\sqrt{s} = 7$ TeV*
  CMS Collaboration (2202 authors)
  Phys.Rev. D87 (2013) 3, 032001

- *Search for supersymmetry in events with photons and low missing transverse energy in pp collisions at $\sqrt{s} = 7$ TeV*
  CMS Collaboration (2197 authors)
  Phys.Lett. B719 (2013) 42-61

- *Search for pair production of third-generation leptoquarks and top squarks in pp collisions at $\sqrt{s} = 7$ TeV*
  CMS Collaboration (2201 authors)
  Phys.Rev.Lett. 110 (2013) 081801

- *Study of the Mass and Spin-Parity of the Higgs Boson Candidate Via Its Decays to Z Boson Pairs*
  CMS Collaboration (2211 authors)
  Phys.Rev.Lett. 110 (2013) 081803

- *Search for new physics in events with photons, jets, and missing transverse energy in pp collisions at $\sqrt{s} = 7$ TeV*
  CMS Collaboration (2197 authors)
  JHEP 1303 (2013) 111

- *Search for supersymmetry in final states with a single lepton, b-quark jets, and missing transverse energy in proton-proton collisions at $\sqrt{s} = 7$ TeV*
  CMS Collaboration (2198 authors)
  Phys.Rev. D87 (2013) 5, 052006

- *Search for heavy narrow dilepton resonances in pp collisions at $\sqrt{s} = 7$ TeV and $\sqrt{s} = 8$ TeV*
  CMS Collaboration (2203 authors)
  Phys.Lett. B720 (2013) 63-82

- *Measurement of the $\Upsilon(1S), \Upsilon(2S)$, and $\Upsilon(3S)$ cross sections in pp collisions at $\sqrt{s}$ = 7 TeV*
  CMS Collaboration (2195 authors)
  Phys.Lett. B727 (2013) 101-125

- *Search for excited leptons in pp collisions at $\sqrt{s} = 7$ TeV*
  CMS Collaboration (2201 authors)
  Phys.Lett. B720 (2013) 309-329

- *Precision measurement of $\sigma(e^+e^- \to \pi^+\pi^-\gamma)/\sigma(e^+e^- \to \mu^+\mu^-\gamma)$ and determination of the $\pi^+\pi^-$ contribution to the muon anomaly with the KLOE detector*
  KLOE Collaboration / KLOE-2 Collaboration (74 authors)
  Phys.Lett. B720 (2013) 336-343

- *Search for contact interactions using the inclusive jet p_T spectrum in pp collisions at $\sqrt{s} = 7$ TeV*
  CMS Collaboration (2186 authors)
  Phys.Rev. D87 (2013) 052017

- *Measurement of the X(3872) production cross section via decays to J/psi pi pi in pp collisions at sqrt(s) = 7 TeV*
  CMS Collaboration (2208 authors)
  JHEP 1304 (2013) 154

- *Study of the underlying event at forward rapidity in pp collisions at $\sqrt{s}$ = 0.9, 2.76, and 7 TeV*
  CMS Collaboration (2214 authors)
  JHEP 1304 (2013) 072

- *Search for supersymmetry in events with opposite-sign dileptons and missing transverse energy using an artificial neural network*
  CMS Collaboration (2189 authors)
  Phys.Rev. D87 (2013) 072001

- *Search for Z ´ resonances decaying to $t\bar{t}$ in dilepton+jets final states in pp collisions at $\sqrt{s} = 7$ TeV*
  CMS Collaboration (2213 authors)
  Phys.Rev. D87 (2013) 072002

- *Search for pair-produced dijet resonances in four-jet final states in pp collisions at $\sqrt{s}$ = 7 TeV*
  CMS Collaboration (2207 authors)
  Phys.Rev.Lett. 110 (2013) 141802

- *Search for new physics in final states with a lepton and missing transverse energy in pp collisions at the LHC*
  CMS Collaboration (2220 authors)
  Phys.Rev. D87 (2013) 7, 072005

- *Measurement of associated production of vector bosons and top quark-antiquark pairs at sqrt(s) = 7 TeV*
  CMS Collaboration (2217 authors)
  Phys.Rev.Lett. 110 (2013) 172002

- *Measurement of W^+W^- and ZZ production cross sections in pp collisions at sqrts=8 TeV*
  CMS Collaboration (2211 authors)
  Phys.Lett. B721 (2013) 190-211

- *Measurement of the ratio of the inclusive 3-jet cross section to the inclusive 2-jet cross section in pp collisions at $\sqrt{s}$ = 7 TeV and first determination of the strong coupling constant in the TeV range*
  CMS Collaboration (2195 authors)
  Eur.Phys.J. C73 (2013) 2604

- *Measurement of the $t\bar{t}$ production cross section in the all-jet final state in pp collisions at $\sqrt{s}$ = 7 TeV*
  CMS Collaboration (2202 authors)
  JHEP 1305 (2013) 065

- *Search for the standard model Higgs boson produced in association with a top-quark pair in pp collisions at the LHC*
  CMS Collaboration (2184 authors)
  JHEP 1305 (2013) 145

- *Studies of jet mass in dijet and W/Z + jet events*
  CMS Collaboration (2215 authors)
  JHEP 1305 (2013) 090

- *Measurement of the inelastic proton-proton cross section at $\sqrt{s} = 7$ TeV*
  CMS Collaboration (2201 authors)
  Phys.Lett. B722 (2013) 5-27

- *Search for anomalous production of highly boosted Z bosons decaying to dimuons in pp collisions at $\sqrt{s} = 7$ TeV*
  CMS Collaboration (2200 authors)
  Phys.Lett. B722 (2013) 28-47

- *Search for fractionally charged particles in pp collisions at $\sqrt{s} = 7$ TeV*
  CMS Collaboration (2197 authors)
  Phys.Rev. D87 (2013) 092008

- *Search for a Higgs boson decaying into a b-quark pair and produced in association with b quarks in proton-proton collisions at 7 TeV*
  CMS Collaboration (2199 authors)
  Phys.Lett. B722 (2013) 207-232

- *Event shapes and azimuthal correlations in Z + jets events in pp collisions at $\sqrt{s} = 7$ TeV*
  CMS Collaboration (2201 authors)
  Phys.Lett. B722 (2013) 238-261

- *Search for long-lived particles decaying to photons and missing energy in proton-proton collisions at $\sqrt{s} = 7$ TeV*
  CMS Collaboration (2181 authors)
  Phys.Lett. B722 (2013) 273-294

- *Measurement of the hadronic activity in events with a Z and two jets and extraction of the cross section for the electroweak production of a Z with two jets in pp collisions at $\sqrt{s}$ = 7 TeV*
  CMS Collaboration (2191 authors)
  JHEP 1310 (2013) 101

- *Measurements of differential jet cross sections in proton-proton collisions at $\sqrt{s} = 7$ TeV with the CMS detector*

CMS Collaboration (2184 authors)
Phys.Rev. D87 (2013) 112002

- *Search for narrow resonances using the dijet mass spectrum in pp collisions at sqrt(s) = 8 TeV*
  CMS Collaboration (2213 authors)
  Phys.Rev. D87 (2013) 114015

- *Search for heavy resonances in the W/Z-tagged dijet mass spectrum in pp collisions at 7 TeV*
  CMS Collaboration (2198 authors)
  Phys.Lett. B723 (2013) 280-301

- *The performance of the CMS muon detector in proton-proton collisions at sqrt(s) = 7 TeV at the LHC*
  CMS Collaboration (2263 authors)
  JINST 8 (2013) P11002

- *Search for new physics in events with same-sign dileptons and b jets in pp collisions at* $\sqrt{s} = 8$ *TeV*
  S. Chatrchyan et al. (2188 authors)
  JHEP 1303 (2013) 037, Erratum-ibid. 1307 (2013) 041

- *Measurement of the* Λ_b^0 *lifetime in pp collisions at* $\sqrt{s} = 7$ *TeV*
  CMS Collaboration (2199 authors)
  JHEP 07 (2013) 163

- *Searches for long-lived charged particles in pp collisions at* $\sqrt{s}$*=7 and 8 TeV*
  CMS Collaboration (2203 authors)
  J. High Energy Phys., 7, 122 (2013)

- *Study of exclusive two-photon production of* W^+W^- *in pp collisions at* $\sqrt{s} = 7$ *TeV and constraints on anomalous quartic gauge couplings*
  CMS Collaboration (2209 authors)
  JHEP 1307 (2013) 116

- *Search for microscopic black holes in pp collisions at* $\sqrt{s} = 8$ *TeV*
  CMS Collaboration (2199 authors)
  JHEP 1307 (2013) 178

- *Searches for Supersymmetry with the CMS Detector at the LHC*
  Malgorzata Kazana (for the CMS Collaboration)
  Acta Phys.Polon. B44 (2013) 7, 1509-1526

- *Measurement of masses in the* $t\bar{t}$ *system by kinematic endpoints in pp collisions at* $\sqrt{s} = 7$ *TeV*
  CMS Collaboration (2192 authors)
  Eur.Phys.J. C73 (2013) 2494

- *Search for physics beyond the standard model in events with* τ *leptons, jets, and large transverse momentum imbalance in pp collisions at* $\sqrt{s} = 7$ *TeV*
  CMS Collaboration (2204 authors)
  Eur.Phys.J. C73 (2013) 2493

- *Determination of the top-quark pole mass and strong coupling constant from the* $t\bar{t}$ *production cross section in pp collisions at* $\sqrt{s} = 7$ *TeV*

CMS Collaboration (2211 authors)
Phys.Lett. B728 (2013) 496

- *Search for a Higgs boson decaying into a Z and a photon in pp collisions at $\sqrt{s}$ = 7 and 8 TeV*
  CMS Collaboration (2216 authors)
  Phys.Lett. B726 (2013) 587-609

- *Multiplicity and transverse momentum dependence of two- and four-particle correlations in pPb and PbPb collisions*
  CMS Collaboration (2200 authors)
  Phys.Lett. B724 (2013) 213-240

- *Searches for Higgs bosons in pp collisions at sqrt(s) = 7 and 8 TeV in the context of four-generation and fermiophobic models*
  CMS Collaboration (2198 authors)
  Phys.Lett. B725 (2013) 36-59

- *Angular analysis and branching fraction measurement of the decay $B^0 \to K^{*0}\mu^+\mu^-$*
  CMS Collaboration (2217 authors)
  Phys.Lett. B727 (2013) 77-100

- *Inclusive search for supersymmetry using the razor variables in pp collisions at $\sqrt{s} = 7$ TeV*
  CMS Collaboration (2195 authors)
  Phys.Rev.Lett. 111 (2013) 081802

- *Search for a new bottomonium state decaying to $\Upsilon(1S)\pi^+\pi^-$ in pp collisions at $\sqrt{s}$ = 8 TeV*
  CMS Collaboration (2224 authors)
  Phys.Lett. B727 (2013) 57-76

- *Measurement of neutral strange particle production in the underlying event in proton-proton collisions at sqrt(s) = 7 TeV*
  CMS Collaboration (2204 authors)
  Phys.Rev. D88 (2013) 052001

- *Measurement of the B(s) to mu+ mu- branching fraction and search for B0 to mu+ mu- with the CMS Experiment*
  S. Chatrchyan et al. (2217 authors)
  Phys.Rev.Lett. 111 (2013) 101804

- *Search for supersymmetry in hadronic final states with missing transverse energy using the variables AlphaT and b-quark multiplicity in pp collisions at 8 TeV*
  CMS Collaboration (2185 authors)
  Eur.Phys.J. C73 (2013) 2568

- *Interpretation of Searches for Supersymmetry with simplified Models*
  CMS Collaboration (2187 authors)
  Phys.Rev. D88 (2013) 052017

- *Search for gluino mediated bottom- and top-squark production in multijet final states in pp collisions at 8 TeV*
  CMS Collaboration (2204 authors)
  Phys.Lett. B725 (2013) 243-270

- *Rapidity distributions in exclusive Z + jet and γ + jet events in pp collisions at $\sqrt{s}$=7 TeV*
  CMS Collaboration (2211 authors)
  Phys.Rev. D88 (2013) 112009

- *Measurement of the production cross section for $Z\gamma \to \nu\bar{\nu}\gamma$ in pp collisions at $\sqrt{s} = 7$ TeV and limits on $ZZ\gamma$ and $Z\gamma\gamma$ triple gauge boson couplings*
  CMS Collaboration (2205 authors)
  JHEP 1310 (2013) 164

- *Measurement of the W-boson helicity in top-quark decays from $t\bar{t}$ production in lepton+jets events in pp collisions at $\sqrt{s} = 7$ TeV*
  CMS Collaboration (2220 authors)
  JHEP 1310 (2013) 167

- *Measurement of the W^+W^- Cross section in pp Collisions at $\sqrt{s} = 7$ TeV and Limits on Anomalous $WW\gamma$ and WWZ couplings*
  CMS Collaboration (2204 authors)
  Eur.Phys.J. C73 (2013) 2610

- *Search for a non-standard-model Higgs boson decaying to a pair of new light bosons in four-muon final states*
  CMS Collaboration (2197 authors)
  Phys. Lett. B 726 (2013) 564-586

- *Searches for anomalous ttbar production in pp collisions at sqrt(s)=8 TeV*
  CMS Collaboration (2224 authors)
  Phys.Rev.Lett. 111 (2013) 211804

- *Search for top squarks in R-parity-violating supersymmetry using three or more leptons and b-tagged jets*
  CMS Collaboration (2206 authors)
  Phys.Rev.Lett. 111 (2013) 221801

- *Measurement of the differential and double-differential Drell-Yan cross sections in proton-proton collisions at $\sqrt{s} = 7$ TeV*
  CMS Collaboration (2226 authors)
  JHEP 1312 (2013) 030

- *Measurement of the cross section and angular correlations for associated production of a Z boson with b hadrons in pp collisions at $\sqrt{s} = 7$ TeV*
  CMS Collaboration (2207 authors)
  JHEP 1312 (2013) 039

- *Jet and underlying event properties as a function of charged-particle multiplicity in proton-proton collisions at $\sqrt{s} = 7$ TeV*
  CMS Collaboration (2224 authors)
  Eur.Phys.J. C73 (2013) 2674

International Conference Proceedings

- *Highlights of recent results from the CMS experiment at the Large Hadron Collider*
  M. Gallinaro
  CMS CR-2013/005 PoS CHARGED 2012, 003 (2012)

- *Search for H+->taunu with l+(tau->had) and dilepton final states in CMS*
  P. Vischia
  CMS CR-2013/038

- *First measurement of B(t->Wb)/B(t->Wq) in the dilepton channel in pp collisions at sqrts=7TeV*
  S. Chatrchyan et al. [CMS Collaboration]
  CMS-PAS-TOP-12-035

- *Prospects for physics at high luminosity with CMS*
  J. Varela
  EPJ Web of Conferences, 23rd Hadron Collider Physics Symposium 2012, HCP 2012; Kyoto; Japan

- *Performance of b tagging at sqrt(s)=8 TeV in multijet, ttbar and boosted topology events*
  S. Chatrchyan et al. [CMS Collaboration]
  CMS-PAS-BTV-13-001

- *Tau (or no) leptons in top quark decays at hadron colliders*
  M. Gallinaro
  CMS CR-2013/423

- *Measurement of the properties of the 125 GeV Higgs boson with the CMS detector*
  J. Varela
  Journal of Physics: Conference Series, Volume 447, Issue 1, 2013, Article number 012010

Collaboration notes with internal referee

- *J/psi; and psi(2S) polarizations in pp collisions at sqrts=7TeV*
  P. Faccioli, V. Knunz, I. Kratschmer, C. Lourenco, J. Seixas, H.K. Wohri, L. Zhang, W. Adam, C. Fabjan, R Fruhwirth, L. Perrozzi, H. Rohringer, J. Strauss
  CMS AN-2013/016

- *Search of the lightest scalar top quark pair production in single lepton signature at sqrts=7TeV*
  P. Bargassa, Th. Caebergs, J. Chasserat, M. Fernandes, G. Hammad, A. Ocampo, N. Strobbe, M. Tytgat, C. v. Velde, J. Varela
  CMS AN-2012/131

- *Measurement of R=B(t->Wb)/B(t->Wq) using a ttbar dilepton sample selected in proton-proton collisions*
  P. Silva , M. Gallinaro , J. Varela
  CMS AN-2012/302

- *Determination of the width of the top quark*
  P. Silva, M. Gallinaro, J. Varela, etc.
  CMS AN-2013/041

- *Measurement of R=B(t->Wb)/B(t->Wq), ttbar cross section, Vtb, and top quark width with the 8 TeV proton-proton data*
  P. Silva, M. Gallinaro, J. Varela
  CMS AN-2013/074

- *Measurement of the performance of b jet identification algorithms using a ttbar sample in proton-proton collisions at sqrts=8TeV*
  P. Silva, M. Gallinaro, J. Varela
  CMS AN-2013/164

- *Search for a heavy charged Higgs boson in proton-proton collisions at sqrts=8TeV with the CMS detector*
  M. Gallinaro , F. Nguyen , P. Silva , J. Varela , P.Vischia
  CMS AN-2012/489

- *Search for heavy neutral Higgs bosons in tau+lepton and dilepton final states in pp collisions at 8 TeV*
  P. Vischia, M. Gallinaro, F. Nguyen, P. Silva, J. Varela
  CMS AN-2013/355

- *Measurement of the ttbar production cross section in the dilepton channel including a tau lepton in pp collisions at sqrts=8TeV*
  N. Almeida , M. Gallinaro , F. Nguyen , P. Silva , J. Varela , P.Vischia
  CMS AN-2012/250

2.2.7 Presentations

Oral presentations in international conferences

- *New probes for QGP: quarkonium polarisation at LHC and AFTER*
  presented by João Seixas
  Workshop AFTER@ECT — ECT, Trento.
- *Charged and other BSM Higgs searches*
  presented by Michele Gallinaro
  Higgs Quo Vadis? - International workshop on Higgs physics — Aspen, USA.
- *New probes for QGP: quarkonium polarisation at LHC*
  presented by João Seixas
  LISHEP 2013 — LISHEP , Rio de Janeiro.
- *Recent results of the CMS experiment*
  presented by João Varela
  HEP 2013 Conference on Recent Developments in High Energy Physics and Cosmology — Chios, Greece.
- *Measurement of Quarkonium polarization with the CMS detector*
  presented by João Seixas
  DIS2013 — DIS2013, Marseilles.
- *Top quark properties (ATLAS, CMS, CDF, D0, HERA)*
  presented by João Varela
  Lepton-Photon Conference 2013 — San Francisco, CA, USA.
- *Recent results of the CMS experiment*
  presented by João Varela
  Summer School and Workshop on the Standard Model and Beyond — Corfu, Greece.
- *Quarkonium polarization at the LHC*
  presented by
  QCD@LHC 2013 — DESY, Hamburg.
- *Tau (or no) leptons from top quark decays*
  presented by Michele Gallinaro
  TOP2013 - International workshop on Top quark physics — Durbach, Germany.
- *CMS upgrade plans and physics prospects at high luminosity*
  presented by João Varela
  IPMLHC2013: The 2nd IPM Meeting on LHC Physics — Tehran, Iran.

- *Towards the solution of the "quarkonium polarization puzzle"*
  presented by
  Hard Probes 2013 — Cape Town, South Africa.

- *Recent results of the CMS experiment*
  presented by João Varela
  Inter Academy Seoul Science Forum — Seoul, Korea.

- *Puzzles, achievements and perspectives in quarkonium production studies*
  presented by
  SaporeGravis Workshop — Nantes, France.

Oral presentations in international meetings

- *L1 CMS pixel trigger*
  presented by Federico Nguyen
  Infieri Paris Meeting — Paris.

- *CMS: First results and future perspectives*
  presented by João Varela
  HEP Workshop — Sao Paulo, Brazil.

Oral presentations in collaboration meetings

- *CMS News*
  presented by João Varela
  CMS Wednesday General Meeting: WGM139 — CERN.

- *oSLB development and Test status*
  presented by José Carlos Silva
  ECAL Procurement Readiness Review — CERN, Switzerland.

- *oRM development and Test status*
  presented by José Carlos Silva
  ECAL Procurement Readiness Review — CERN, Switzerland.

- *Offline DQM L1TRate Status*
  presented by Federico Nguyen
  L1 DQM Meeting — CERN/Vidyo.

- *Pixel Trigger Work*
  presented by Federico Nguyen
  TPSWG — CERN/Vidyo.

- *Offline DQM L1TRate Status*
  presented by Federico Nguyen
  L1 DQM Meeting — CERN/Vidyo.

- *ECAL electronics in view of the HL-LHC*
  presented by José Carlos Silva
  ECAL Upgrade Meeting — CERN, Switzerland.

- *CMS News*
  presented by João Varela
  CMS Wednesday General Meeting: WGM147 — CERN.

- *oSLB/oRM Status Report*
  presented by José Carlos Silva
  Trigger Upgrade Meeting — CERN, Switzerland.

- *Offline DQM L1TRate Status*
  presented by Federico Nguyen
  L1 DQM Meeting — CERN/Vidyo.

- *Critical Manpower Overview*
  presented by João Varela
  XC on CMS human resources — CERN.

- *ESP & manpower*
  presented by João Varela
  Meeting of the Management Board (MB168) — CERN.

- *Status of ESP and manpower*
  presented by João Varela
  88th Meeting of the CMS Collaboration Board (CB 88) — CERN.

- *tests on limit read-out rate and thoughts on new electronics design*
  presented by José Carlos Silva
  ECAL Upgrade Meeting — CERN, Switzerland.

- *Horizon 2020 and HL-LHC*
  presented by João Varela
  179th CMS Finance Board Meeting — CERN.

- *Incl. xsection in tau+lepton (TOP-12-026)*
  presented by Federico Nguyen
  Top cross sections — CERN/Vidyo.

- *Status and integration testing plans for oSLB/oRM*
  presented by José Carlos Silva
  Trigger Upgrade Meeting — CERN, Switzerland.

- *Towards a HL-LHC funding line in Horizon 2020*
  presented by João Varela
  Discussion on Horizon2020 — CERN.

- *ECAL/HCAL to RCT Architecture, TPG distribution*
  presented by José Carlos Silva
  CMS L1 Trigger Meeting — CERN, Switzerland.

- *First Report Forward Spectrometer Review*
  presented by João Varela
  Meeting of the Management Board (MB170) — CERN.

- *oSLB/oRM Status Report*
  presented by José Carlos Silva
  Trigger Upgrade Meeting, DESY — DESY, Hamburg, Germany.

- *New Electronics Design*
  presented by José Carlos Silva
  ECAL Upgrade Meeting — DESY, Hamburg, Germany.

- *Incl. cross section (tau+lepton, TOP-12-026)*
  presented by Federico Nguyen
  Top cross sections — CERN/Vidyo.

- *Status of meetings with the institutes*
  presented by João Varela
  89th Meeting of the CMS Collaboration Board (CB 89) — CERN.

- *Summary of additional review material*
  presented by João Varela
  PPS Review Committee meeting — CERN.

- *Offline DQM L1TRate Status*
  presented by Federico Nguyen
  L1 DQM Meeting — CERN/Vidyo.

- *oSLB/oRM Status Report*
  presented by José Carlos Silva
  CMS WEEK — CERN, Switzerland.

- *Status of meetings with the institutes*
  presented by João Varela
  90th Meeting of the CMS Collaboration Board (CB90) — CERN.

- *Offline DQM L1TRate Status*
  presented by Federico Nguyen
  L1 DQM Meeting — CERN/Vidyo.

- *CMS News*
  presented by João Varela
  CMS Wednesday General Meeting: WGM158 — CERN.

- *oSLB/oRM Status Report*
  presented by José Carlos Silva
  CMS Calorimeter trigger upgrade progress review — CERN, Switzerland.

- *Offline DQM L1TRate Status*
  presented by Federico Nguyen
  L1 DQM Meeting — CERN/Vidyo.

- *PPS approval*
  presented by João Varela
  91st Meeting of the CMS Collaboration Board (CB91) — CERN.

- *Status of meetings with the institutes*
  presented by João Varela
  91st Meeting of the CMS Collaboration Board (CB91) — CERN.

- *Perspectives for top mass measurement*
  presented by Michele Gallinaro
  Top quark mass analysis group — .

- *oSLB/oRM Status Report*
  presented by José Carlos Silva
  CMS L1 Trigger Meeting — CERN, Switzerland.

- *Timing Work at Lisbon*
  presented by João Varela
  PPS Weekly Meeting — CERN.

- *Offline DQM L1TRate Status*
  presented by Federico Nguyen
  L1 DQM Meeting — CERN/Vidyo.

- *Participation in ECAL/Trigger Upgrade*
  presented by José Carlos Silva
  LIP/CMS Workshop — Lisboa, Portugal.

- *CMS physics overview and future perspectives*
  presented by João Varela
  LIP/CMS Workshop — CERN.

- *Perspectives for the Precision Proton Spectrometer*
  presented by João Varela
  LIP/CMS Workshop — CERN.

- *oSLB/oRM Status Report*
  presented by José Carlos Silva
  CMS L1 Trigger Meeting — CERN, Switzerland.

- *Goals and status of the CMS-TOTEM common project*
  presented by João Varela
  CMS-TOTEM PPS General Meeting — CERN.
- *Option for readout of QUARTIC detectors*
  presented by João Varela
  CMS-TOTEM PPS General Meeting — CERN.
- *CMS-TOTEM agreement*
  presented by João Varela
  Meeting of PPS institutes — CERN.
- *Status report on tau+lepton cross section measurement*
  presented by Michele Gallinaro
  Top quark cross section analysis group — CERN.
- *Full status report on cross section in tau+lepton (TOP-12-026)*
  presented by Federico Nguyen
  Top cross sections — CERN/Vidyo.
- *oSLB/oRM Design and Status Report*
  presented by José Carlos Silva
  CMS EDR Phase I Level 1 Trigger Upgrade — CERN, Switzerland.
- *New Tau ID in top quark events*
  presented by Federico Nguyen
  Tau ID Meeting — CERN/Vidyo.
- *Status on TOTEM and PPS*
  presented by João Varela
  Meeting of the Management Board (MB176) — CERN.
- *CMS News*
  presented by João Varela
  CMS Wednesday General Meeting: WGM166 — CERN.
- *Round of the table discussion on electronics working groups plans*
  presented by José Carlos Silva
  ECAL Upgrade Meeting — CERN, Switzerland.
- *Offline DQM L1TRate Status*
  presented by Federico Nguyen
  L1 DQM Meeting — CERN/Vidyo.
- *CMS News*
  presented by João Varela
  CMS Wednesday General Meeting: WGM168 — CERN.
- *Status of the project in CMS*
  presented by João Varela
  CMS-TOTEM PPS General Meeting — CERN.
- *oSLB/oRM Status Report*
  presented by José Carlos Silva
  CMS L1 Trigger Meeting — CERN, Switzerland.
- *Proposal: CMS-TOTEM MOU for the Precision Proton Spectrometer*
  presented by João Varela
  93rd Meeting of the CMS Collaboration Board (CB93) — CERN.
- *Pre-Approval of TOP-12-026 "Measurement of ttbar cross section in the tau+lepton channel"*
  presented by Federico Nguyen
  Special TopQuark Meeting — CERN/Vidyo.

Seminars

- *Standard Model 1*
  presented by João Varela
  Course on Physics at the LHC — LIP, Lisbon.
- *Standard Model 2*
  presented by João Varela
  Course on Physics at the LHC — LIP, Lisbon.
- *Top quark physics: Lecture 1*
  presented by Michele Gallinaro
  Course on physics at the LHC — Lisbon, Portugal.
- *Angular momentum and decay distributions in high energy physics: an introduction and use cases for the LHC*
  presented by Pietro Faccioli
  HEPHY-SMI seminar on fundamental interactions and symmetries — HEPHY, Vienna.
- *Top quark physics: Lecture 2*
  presented by Michele Gallinaro
  Course on physics at the LHC — Lisbon, Portugal.
- *Angular momentum and decay distributions in high energy physics: an introduction and use cases for the LHC*
  presented by Pietro Faccioli
  CERN EP seminar — CERN.
- *Recent results of the CMS experiment*
  presented by João Varela
  Seminar Departamento Física IST — IST, Lisbon.
- *Highlights from recent CMS results*
  presented by Michele Gallinaro
  Tor Vergata University — Rome, Italy.
- *Heavy Ions at LHC*
  presented by João Seixas
  Course on Physics at the LHC — LIP, Lisbon.
- *Discovery of the Higgs boson*
  presented by Michele Gallinaro
  IST - Instituto Superior Tecnico — Lisbon, Portugal.
- *The Higgs boson as a technology catalyzer in the next decades*
  presented by João Varela
  Colóquios Departamento de Física IST — IST, Lisbon.
- *CMS upgrade plans and physics prospects at high luminosity*
  presented by João Varela
  LIP seminar — LIP, Lisbon.

Outreach seminars

- *From X-rays to the Higgs Boson: The World of Subatomic Particles*
  presented by João Varela
  Scientific American Travel, Bright Horizons 16 — South America.
- *The Big Bang Factory: Story of the World's Largest Machine*
  presented by João Varela
  Scientific American Travel, Bright Horizons 16 — South America.
- *The Higgs Boson and You: Why Society Should Invest in Big Science*
  presented by João Varela
  Scientific American Travel, Bright Horizons 16 — South America.

- *The Higgs Boson: What Is It and How Was It Discovered?*
  presented by João Varela
  Scientific American Travel, Bright Horizons 16 — South America.

- *Beyond the Higgs Boson: open questions in particle physics*
  presented by João Varela
  Scientific American Travel, Bright Horizons 16 — South America.

- *Introduction to CERN*
  presented by José Carlos Silva
  CERN Portuguese Language Teachers Programme 2013 — CERN, Switzerland.

- *A Física de CMS e a Participação Portuguesa em CMS*
  presented by João Varela
  CERN Portuguese Language Teachers Programme 2013 — CERN.

- *Portugal e o CERN*
  presented by José Carlos Silva
  — Escola Antonio Gedeao , Almada.

2.2.8 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)

2.2.9 Events

- *Course on Physics at the LHC*
  Workshop, LIP Lisbon, 2013-03-01

- *CMS - SUSY Workshop 2014*
  Collaboration Meeting, Biblioteca Nacional, Lisboa, 2013-03-12

2.2.10 Project Summary

	number
Articles in international journals (with direct contribution from LIP members)	14
Articles in international journals (with indirect contribution from LIP members)	78
International Conference Proceedings	7
Collaboration notes with internal referee	9
Oral presentations in international conferences	13
Oral presentations in international meetings	2
Oral presentations in collaboration meetings	58
Seminars	12
Outreach seminars	8
Workshops	1
Collaboration Meetings	1

2.3 Phenomenological Studies at the LHC

2.3.1 Resumo

Um importante esforço conjunto de preparação da comunidade experimental e teórica de Física de Partículas Elementares é necessário por forma a responder ao desafio do LHC. Este esforço foi concentrado não apenas no estudo dos melhores observáveis em LHC que permitam realizar testes de precisão do Modelo Padrão (SM) da Física Elementar de Partículas, mas também no desenvolvimento de novos modelos de Física para além do SM. Com o objectivo de concretizar uma estreita colaboração entre a comunidade de Físicos Experimentais e Teóricos de Partículas, foram propostas várias tarefas no âmbito do presente projecto, e cujo estado actual se passa a descrever.
A primeira tarefa envolveu o estudo de processos associados a correntes neutras com troca de sabor (FCNC) na produção simples de quarks top em LHC. Para o efeito foi desenvolvido um modelo teórico efectivo e desenvolvido um novo gerador (MeTop) que inclui processos FCNC para além do nível árvore (NLO). Quer o Pythia quer o Herwig podem ser usados na hadronização dos acontecimentos produzidos a nível partonico. Em colaboração com a Universidade de Goettingen, testes com dados reais adquiridos em LHC estão a ser desenvolvidos. Uma segunda tarefa envolveu o estudo da produção de bosões de Higgs para alem do Modelo Padrão. Todos os sectores do Higgs prevêm a possibilidade de interacções próprias que podem ser de facto distintas em função dos modelos considerados. Esta análise foi realizada quer para o Modelo Padrão quer em determinadas regiões do espaço de fase de alguns modelos teóricos como MSSM, dimensões extra, modelos fermiofóbicos, etc. Nesta tarefa foram considerados os últimos resultados obtidos em LHC na pesquisa do bosão de Higgs. Outra tarefa desenvolvida no âmbito deste projecto, envolveu o estudo de assimetrias angulares em decaimentos do quark top produzidos aos pares e de forma simples em LHC. No SM o vértice Wtb é considerado puramente esquerdo com uma intensidade proporcional ao elemento Vtb da matriz de Cabibbo-Kobayashi-Maskawa (CKM). Apesar da secção eficaz de produção dupla de quarks top em LHC não ser sensível ao valor de Vtb, as correlações angulares dos produtos de decaimento destes quarks podem dar informação valiosa sobre a estrutura do vértice Wtb. Novas assimetrias foram introduzidas (A+ e A-) bem como novas razões entre as polarizações dos bosões W (ρR e ρL). Foi possível verificar que os novos observáveis introduzidos são mais sensíveis aos acoplamentos anómalos vectoriais e tensoriais do que os previamente utilizados em LHC. Foram estudadas as correlações entre os vários observáveis e desenvolveu-se o programa (designado por TopFit) que permite fazer o ajuste global de todos os observáveis (quer associados à produção simples quer dupla de quarks top em LHC) em função dos novos acoplamentos anómalos. Foram obtidos limites preliminares nos acoplamentos anómalos em experiencias do LHC. No âmbito do presente projecto foram ainda estudados sinais de nova Física que produzem, em LHC, eventos com estados finais com 3 leptões (que permitem estudar o mecanismo que possibilita aos neutrinos adquirirem massa) e produção de novas ressonâncias vectoriais. Foram ainda explorados novos Modelos Teóricos implementados em geradores Monte Carlo.

2.3.2 Abstract

In order to address the physics potential of the LHC program, a significant joint effort of the experimental and theoretical particle physics 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. Several tasks were proposed in the present project to implement a strong collaboration between experimental and theoretical particle physicists. The status of such tasks is summarized in what follows.
Top Quark FCNC Processes: The main goal was 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 were studied. Several contributions of this team were already included (gg->tq, gq->tg, qq->tq) in a general purpose generator like TopRex and a new NLO generator for single top production via FCNC (METop - MontE-Carlo generator for Top quark events) was developed and is under test. In METop the full NLO strong sector is included while the electroweak weak sector is included at approximately NLO. The LHC collaborations are being contacted in order to further extend the test program of METop
Non-Standard Higgs Production: 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 are being calculated for those models where this is not already done. All tools readily available (like FeynHiggs or HDECAY) are being 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.
Top Quark Couplings: The main goal of this task is to measure the Wtb vertex and the couplings of the top quark. Although the double top production is insensitive to the Vtb 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 were introduced within an effective lagrangian approach, which can be probed at the LHC. A new software package, called TopFit, was made available to the physics community, which performs a global fit to the top quark observables (or related to top) in order to extract the best limits on the anomalous couplings (assuming the SM). Using the recent measurements of the top quark decay asymmetries in ATLAS and the tchannel single top cross section in CMS, the first combined LHC limits on the Wtb vertex, were set and published. This combination allows to obtain much better limits than the ones obtained by using only the individual measurements.
Tri-leptons and the seesaw mechanism: The main goal of this task is 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. Tri-lepton final states appear in many 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 allows us to probe these models, and to establish the identity of the new particles, if discovered.
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 top quarks 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 of this task 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.
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.

2.3.3 Objectives

The main objective of the project is to continue and strengthen the collaboration between experimental and theoretical physicists for phenomenological studies with a special impact on the LHC physics. The discussion is intended to be concentrated in: (1) the top quark physics and Flavour Changing Neutral Current processes associated with single top quark production at colliders; (2) the Wtb vertex structure and asymmetries in top quark decays which are related to possible anomalous couplings beyond the SM; (3) non standard Higgs boson production within several extensions of the Standard Model; (4) the seesaw mechanism and neutrino mass; (5) new vector like resonances related to fermions by custodial symmetry and (6) theoretical improvements related to models under development.

2.3.4 Achievements

A) A strong collaboration between experimentalists and theoretical physicists was developed for the LHC.
B) For the single top production via FCNC at the LHC, the cross sections were included in a new version of Monte Carlo Generator TopRex (ver 4.20) and a new NLO generator (METop) has been developed and is available to the LHC community for testing.
C) For the Study of Top Quark Anomalous Couplings, new asymmetries were found and published by the team (the A and A-) apart from the Forward-Backward asymmetry, which proved to be more sensitive to the structure of the Wtb vertex. Considering the most recent data from LHC and Tevatron the first results on the Wtb vertex structure were established.

D) For the development of Theoretical Models, several studies were performed and the inclusion of the obtained cross sections in Monte Carlo generators under development was acomplished.
E) The project has been very successful in motivating young students (license, Master and PhD) due to the strong collaboration between experimentalists and theoretical physicists.
F) The newly created pole of LIP at the University of Minho, LIP-Minho, is an important achievement of the project, which counts already with 20 members (6 PhD senior researchers, 4 undergraduate students, 6 master students and 4 PhD students)

2.3.5 Sources of Funding

Code	Funding	Start	End
CERN/FP/123619/2011	70.000 €	2012-03-01	2014-02-28

2.3.6 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)	65
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	PhD student (LIP)	50
Mikael Chala	Master student	20
Nuno Castro	Post-Doc (LIP/FCT)	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

2.3.7 Publications

Articles in international journals (with direct contribution from LIP members)

- *ScannerS: Constraining the phase diagram of a complex scalar singlet at the LHC*
  Rita Coimbra, Marco O.P. Sampaio, Rui Santos
  Eur.Phys.J. C73 (2013) 2428

- *MEtop - a top FCNC event generator*
  Rita Coimbra, Antonio Onofre, Rui Santos, Miguel Won
  J.Phys.Conf.Ser. 447 (2013) 012031

- *Limits on strong flavor changing neutral current top couplings at the LHC*
  Renato Guedes, Rui Santos, Miguel Won
  Phys. Rev. D 88 (2013) 114011

2.3.8 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
- *Study of the Wtb vertex structure in top quark decays*
  Miguel Fiolhais, 2013-03-07

2.3.9 Project Summary

	number
Articles in international journals (with direct contribution from LIP members)	3
PhD Theses	1

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

A major activity of LIP is data analysis in view of the physics results extraction, together with studies for the next COMPASS physics program. With respect to data analysis, the subjects carried on by LIP members are among the most important analysis channels of the experiment concerning the muon programme, that is, deep inelastic muon scattering. Also, the polarised Drell-Yan experimental programme is being developed by LIP together with the Torino group, these two being the leading groups on this subject.
Also, LIP has the full responsibility of the Detector Control System (DCS) of the experiment, since it has been accepted as a member of the COMPASS Collaboration, in September 2002.
The LIP group of the COMPASS experiment carried on the matters related with the working activities, namely data analysis and offline studies; full responsibility of the Detector Control System (DCS); and general activities. These subjects are developed hereafter.

2.4.4 Achievements

Data Analysis and Offline Studies

The offline and analysis task has always been a major concern of our group. The analysis subjects carried on by LIP members are among the most important analysis channels of the experiment. As a consequence, our members have presented their results in several International Conferences, on the behalf of COMPASS.
In 2013 the following subjects were addressed:

- Studies of hadron multiplicities in view of the fragmentation functions measurement, namely strangeness to kaon DsK(z).
- Spin asymmetries analysis in the low xBj and low Q2 region, in order to extract the polarised structure function g1p(x).
- Development of a new method of asymmetries evaluation concerning the gluon polarisation extraction, from hadron pairs with high Q2 .
- Studies on the setup optimization for the future polarised Drell-Yan process experiment, namely the dimuon trigger charge symmetrisation.
- Development of algorithms for the COMPASS reconstruction programme in view of increasing the track matching efficiency in specific parts of the spectrometer essential to the Drell-Yan experiment.
- Reproduction and reanalysis of the 2009 Drell-Yan data taking test run, in view of the optimisation of the reconstruction programme for dimuon production.

- Production and first analysis of the 2012 Drell-Yan data taking test run, in order to develop the dimuon trigger concept.

Detector Control System

In 2013, we profited from the CERN Long Shutdown (LS1) to adapt the high level part of the DCS, namely the PVSS programme, to the new one, WinCC OA , together with the required change of all computers running the different DCS package levels to 64 bits machines.
The tasks of continuing the integration of new or refurbished detectors for the new COMPASS physics programme also proceeded.
One should point out that, in spite of the fact that there was no beam in 2013, several DCS sub-systems have to work, in order to control the devices which run permanently, as it is the case of the gas systems of plenty of detectors.

General Activities

COMPASS LIP-Lisbon members participated in the following general activities:

- Member of the International Committee of the International Workshop on Hadron Structure and Spectroscopy, IWHSS2013, held in Erlangen, Germany (P.Bordalo).
- Convener in Spin Physics sessions of the 2013 International DIS Conference (M.Stolarski).
- Participation in the Collaboration meetings.
- Members of the COMPASS Collaboration Board (P. Bordalo , S.Ramos).
- Member of the COMPASS Publications Committee (M. Stolarski).
- Participation in the monthly offline and analysis meetings.
- Participation in several weekly subgroups on analysis and offline meetings.

2.4.5 Sources of Funding

Code	Funding	Start	End
CERN/FP/123600/2011	300.000 €	2012-01-01	2014-09-30

2.4.6 Team

Project coordinator: Paula Bordalo

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

2.4.7 Publications

Articles in international journals (with direct contribution from LIP members)

- *Leading order determination of the gluon polarisation from DIS events with high-pT hadron pairs*
  P. Bordalo. C. Franco, M. Quaresma, C. Quintans, A.S. Nunes, S. Ramos, M. Stolarski, L. Silva et al
  Phys. Lett. B, 718 (2013) 922.

- *Leading and Next-to-Leading Order Gluon Polarisation in the Nucleon and Longitudinal Double Spin Asymmetries from Open Charm Muoproduction*
  P. Bordalo. C. Franco, M. Quaresma, C. Quintans, A.S. Nunes, S. Ramos, M. Stolarski, L. Silva et al
  Phys. Rev. D 87, 052018 (2013)

- *Experimental Program of the future COMPASS-II experiment at CERN*
  L. Silva for the COMPASS Collaboration
  Few Body Syst. 54 (2013) 1075-1078

- *Study of Σ(1385) and Ξ(1321) hyperon and antihyperon production in deep inelastic scattering*
  P. Bordalo. C. Franco, M. Quaresma, C. Quintans, A.S. Nunes, S. Ramos, M. Stolarski, L. Silva et al
  Eur. Phys. J C 73 (2013), 2581

- *Hadron transverse momentum distributions in muon deep inelastic scattering at 160 GeV/c*
  P. Bordalo. C. Franco, M. Quaresma, C. Quintans, A.S. Nunes, S. Ramos, M. Stolarski, L. Silva et al
  Eur. Phys. J C 73 (2013), 2531

- *Measurement of the Cross Section for High-pT Hadron Production in Scattering of 160 GeV/c Muons off Nucleons*
  P. Bordalo. C. Franco, M. Quaresma, C. Quintans, A.S. Nunes, S. Ramos, M. Stolarski, L. Silva et al
  Phys. Rev. D 88, 091101 (2013)

International Conference Proceedings

- *A1p and g1p at low x and low Q2 from COMPASS*
  A.S. Nunes et al. for COMPASS Collaboration
  Proceedings of DSpin 2013 Conference

- *Study of transverse momentum dependent distributions from polarised Drell-Yan at COMPASS*
  M. Quaresma et al. for COMPASS Collaboration
  Proceedings of MENU2013 Conference

- *Polarised Drell-Yan physics at COMPASS*
  C. Franco et al. for COMPASS Collaboration
  Proceedings of ISMD 2013 Conference

- *Polarized Drell-Yan studies at COMPASS*
  C. Quintans et al. for COMPASS Collaboration
  Proceedings of INPC 2013 Conference

- *WG6 Highlights - Spin Physics*
  M. Stolarski et al.
  Proceedings of DIS2013 Conference

- *Gluon polarisation results from the COMPASS experiment*
  L. Silva et al. for COMPASS Collaboration
  Proceedings of DIS2013 Conference

- *Overview of the nucleon spin studies at COMPASS*
  C. Franco et al. for COMPASS Collaboration
  Proceedings of ICNFP2013 Conference

Collaboration notes with internal referee

- *Unpolarised, multiplicities, isoscalar/deuteron, 2004, 2006*
  M. Stolarski et al.
  COMPASS Release Note-Apr

- *Longitudinal, inclusive, low-x, A1, g1, proton, 2007, 2011*
  S. Nunes et al.
  COMPASS Release Note-Sep

- *2009 Drell-Yan beam test 2ˆnd production analysis*
  M. Quaresma, C. Quintans, P. Bordalo, S. Ramos
  COMPASS Note 2013_11

- *Efficiency study using flat NR simulations processed with DPF stable release version 1.3*
  Lea Reichhart and Alex Lindote
  Analysis Note, LuxDB00000172

2.4.8 Presentations

Oral presentations in international conferences

- *Gluon polarisation results from the COMPASS experiment*
  presented by Luis Silva
  21th International Workshop on Deep-Inelastic Scattering and Related Subjects — Marseille, France.

- *WG6 Highlights - Spin Physics*
  presented by Marcin Stolarski
  21th International Workshop on Deep-Inelastic Scattering and Related Subjects — Marseille, France.

- *Polarized Drell-Yan studies at COMPASS*
  presented by Catarina Quintans
  International Nuclear Physics Conference — Florence, Italy.

- *Overview of the nucleon spin studies at COMPASS*
  presented by Celso Franco
  2nd International Conference on New Frontiers in Physics — Kolymbari, Crete, Greece.

- *Polarised Drell-Yan physics at COMPASS*
  presented by Celso Franco
  43th International Symposium on Multiparticle Dynamics — Chicago, Illinois, USA.

- *Study of transverse momentum dependent distributions from polarised Drell-Yan at COMPASS*
  presented by Márcia Quaresma
  13th Int. Conf. on Meson-Nucleon Physics and the Structure of the Nucleon — Rome, Italy.

- *A1p and g1p at low x and low Q2 from COMPASS*
  presented by Sofia Nunes
  15th Workshop on High Energy Spin Physics — Dubna, Russia.

Seminars

- *Longitudinal spin structure of the nucleon at COMPASS*
  presented by Sofia Nunes
  — IST, Lisbon.

- *Drell-Yan program at the COMPASS experiment*
  presented by Márcia Quaresma
  — IST, Lisbon.

- *Strange Quark Polarisation Puzzle - Unfinished Quest*
  presented by Marcin Stolarski
  — LP, Lisbon.

- *Spin structure of the nucleon as seen by COMPASS experiment at CERN*
  presented by Catarina Quintans
  — FCUL, Lisbon.

2.4.9 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)

2.4.10 Project Summary

	number
Articles in international journals (with direct contribution from LIP members)	6
International Conference Proceedings	7
Collaboration notes with internal referee	4
Oral presentations in international conferences	7
Seminars	4

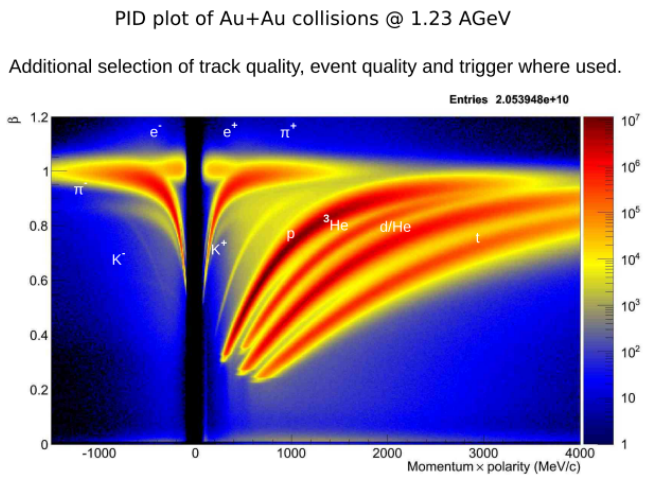
2.5 Collaboration in the HADES experiment at GSI

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 presence of kaons testifies a very good performance in high multiplicity environment

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

The HADES detector is dedicated to the study of heavy ion collisions at energies below 2 AGeV and elementary reactions below 4 GeV.
In recent years HADES has produced a series of relevant physics results, mostly with elementary particles or light ions owing to granularity limitations in the forward time-of-flight (TOF) detector. From 2010 onwards the work will be continued with heavy ions. Furthermore, the experimental program is expected to be continued at the higher beam energies (8-10 AGeV) available at the future FAIR facility.
Since several years LIP is contributing to the upgrade of HADES. The involvement of LIP has been mostly technical with the design, construction and commissioning of a large RPC wall (8 square meters), which will cover the most forward region of the spectrometer and provide time of flight information with a resolution of $\approx$70 ps.
Our group is now responsible for all detector hardware, auxiliary systems (slow control, monitoring) and specific software (simulation, calibration) of the RPC TOF Wall. This is under direct responsibility of the LIP staff member Alberto Blanco, who is now a member of the HADES Technical Board. The detector electronics, both front-end and digital acquisition, are the responsibility of GSI and of groups from the Universities of Santiago de Compostela and Valencia, Spain.
LIP is expected to take a major role in the exploration of the new system (2012 onwards), joining other international institutions in sharing the load of running the experimental setup, by taking part into beamtimes and by participating in the physics program. Indeed, the physics program is now in the hands of the LIP-HADES physics group (P.Bordalo, Sergio Ramos, Luís Silva, Celso Franco), based in the Lisbon branch.

2.5.4 Achievements

HADES RPC TOF WALL

After the very successful physics run which took place in April-May 2012 with a beam of Au-Au@1.25GeV/a the collaboration spent the year 2013 analyzing such data.
Calibration procedures have been optimized and improved substantially yielding a system time resolution for electrons of 113 ps (including start counter and tracking errors). The intrinsic performance of the RPC detector is: time resolution for minimum ionizing particles 76 ps ; average efficiency (all particles, full area) 97%.
The excellent multihit PID capability of the upgraded HADES system can be perceived by the clear identification of sub-threshold produced K- particles (only produced in very central events), as can be seen in the figure.
The event embedding code was implemented in the RPC software. This is an important piece of software responsible for merging real and simulated event and it is used for corrections in advanced phases of data analysis.
During this year our group got involved in the maintenance and recovery of the aged multidrift chambers (MDC), owing to a lack of detectors-skilled manpower in HADES.

PARTICIPATION IN THE PHYSICS PROGRAM

The LIP-HADES group developed a new method for the multidimensional identification of dileptons. This method makes use of a dynamic neural network and is being applied in HADES for the first time. In addition, new techniques using neural networks are currently being tested for the rejection of the combinatorial and physical backgrounds in the dilepton mass spectrum.

FUNDING

The participation in HADES is formalized via a Memorandum of Understanding (MOU) celebrated between the Collaboration, GSI and FCT. The MOU expired in 2012 and a proposal for its extension has been submitted to FCT and apparently accepted.
Funding of 91.742€ for these activities was granted by the project PTDC/FIS/113339/2009 which will extend up to January 2015.

2.5.5 Sources of Funding

Code	Funding	Start	End
PTDC/FIS/113339/2009	91.742 €	2011-04-01	2015-01-31

2.5.6 Team

Project coordinator: Paulo Fonte

Name	Status	FTE %
Alberto Blanco	Researcher (LIP)	15
Alessio Mangiarotti	Researcher (LIP/USP)	42
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

2.5.7 Publications

Articles in international journals (with direct contribution from LIP members)

- *Performance of the HADES-TOF RPC wall in a Au + Au beam at 1.25 AGeV*
  Blanco A., Fonte P., Garzon J.A., Koenig W., Kornakov G., Lopes L.
  Journal of Instrumentation 8, 1, P01004

Articles in international journals (with indirect contribution from LIP members)

- *Di-pion and di-electron production in NN reactions with HADES at 1.25GeV incident beam energy*
  Agakishiev G. et al. HADES collaboration
  Proceedings of Science 9 100843 (2013)

- *PK +Λ final state: Towards the extraction of the p pK - contribution*
  Fabbietti L., et al. HADES collaboration
  Nuclear Physics A 914 60-68 (2013)

- *Baryonic resonances close to the $\bar{K}N$ threshold: The case of Λ(1405) in pp collisions*
  Agakishiev G. et al. HADES collaboration
  Physical Review C - Nuclear Physics 87, 2, 25201

- *Deep sub-threshold K*(892)(0) production in collisions of Ar + KCl at 1.76A GeV*
  HADES Collaboration (111 authors)
  Eur. Phys. J. A 49 (2013) 34

- *Inclusive pion and η production in p+Nb collisions at 3.5 GeV beam energy*
  Agakishiev G. et al. HADES collaboration
  Physical Review C - Nuclear Physics 88, 2, 24904

- *An upper limit on hypertriton production in collisions of Ar(1.76 A GeV) + KCl*
  The HADES collaboration
  European Physical Journal A 49 (2013) 1-5

- *Proton induced dielectron radiation off Nb: Pt and y distributions*
  Lorenz M. et al. HADES Collaboration
  Journal of Physics: Conference Series 425, 12034

- *Hades experiments: Investigation of hadron in-medium properties*
  Salabura P. et al. HADES collaboration
  Journal of Physics: Conference Series 420, 1, 12013

2.5.8 Project Summary

	number
Articles in international journals (with direct contribution from LIP members)	1
Articles in international journals (with indirect contribution from LIP members)	8

Chapter 3

Computing

3.1 Grid Computing

3.1.1 Resumo

As actividades no domínio da computação distribuída avançada estão focadas no suporte à investigação cientifica através da disponibilização de serviços e apoio. Esta actividade é complementada por uma componente de inovação cujo objectivo é manter o LIP na linha da frente das tecnologias de computação.
A equipa (baseada em Lisboa) tem desenvolvido desde 2001 competências no processamento distribuído de dados,através da participação em projectos de I&D independentes. A equipa coordena e gere o Tier-2 Português integrado no Worldwide LHC Computing Grid, disponibiliza serviços a comunidade científica nacional, e participa em projectos e iniciativas nacionais e internacionais no domínio da computação científica.

Worldwide LHC Computing Grid (WLCG)
Em 2013, o Tier-2 Português forneceu 6,936,606 horas às experiências ATLAS e CMS. Durante este período o Tier-2 demonstrou uma fiabilidade superior a 96%, bem acima dos mínimos requeridos. Desde 2012 e devido à redução do pessoal, os três centros de processamento que compõem o Tier-2 e Tier-3 são geridos a partir de Lisboa. Estes centros são: LIP-Lisboa, LIP-Coimbra e NCG. O NCG é um serviço nacional operado pelo LIP em parceria com a FCCN.
Em 2013 foi iniciado um processo de consolidação do Tier-2 de forma a reduzir custos e melhorar a eficiência. Os serviços do Tier-2 e Tier3 de CMS alojados no LIP-Lisboa foram migrados para o NCG consolidando todos os Tiers de CMS numa única localização. Os serviços do Tier-2 de ATLAS alojados no LIP-Lisboa foram migrados para o NCG e LIP-Coimbra, ficando apenas no LIP-Lisboa parte do Tier-3.
O projecto para suporte da operação do Tier-2 foi avaliado como excelente, e obteve o financiamento máximo por parte da FCT. O projecto com uma duração de três anos teve início em Janeiro de 2013, e suporta parcialmente os custos do Tier-2 incluindo: um técnico, manutenção dos sistemas mais críticos, parte do consumo de energia, e a renovação parcial dos sistemas de armazenamento. No âmbito deste projecto foi efectuado um estudo dos padrões de acesso no armazenamento do Tier-2.

Iniciativa Nacional GRID

O LIP coordena tecnicamente a infraestrutura GRID nacional. A equipa opera os serviços GRID centrais e gere a rede de centros de recursos GRID localizados em universidades e centros de pesquisa. A equipa também gere o Nó Central de Computação GRID (NCG) que disponibiliza serviços de processamento à comunidade científica. O NCG suporta um leque variado de utilizadores e disciplinas.
Uma proposta para evolução da infraestrutura GRID nacional foi submetida ao roteiro de infra-estruturas da FCT, por um consórcio liderado pelo LIP e que inclui a FCCN e o LNEC. A proposta foi submetida com o suporte das universidades do Minho, Porto e Aveiro. Prevê-se o alargamento do portfolio de serviços, a criação de centros de competências, e a renovação de equipamentos obsoletos. Estas actividades serão efectuadas em colaboração com o IBERGRID e o EGI.

IBERGRID e EGI

A infraestrutura Ibérica de computação GRID (IBERGRID) é uma federação das iniciativas nacionais GRID de Portugal e Espanha. Através do IBERGRID ambas as infraestruturas estão integradas, e partilham recursos

e serviços a nível Ibérico, e na infraestrutura GRID Europeia (EGI). A equipa continuou a ter um papel de relevo na coordenação técnica do IBERGRID. Similarmente a equipa coordenou a participação e integração de recursos nacionais na GRID Europeia. Foram também fornecidos ao EGI serviços globais de coordenação do "middleware"GRID e de CRM.
Foram estabelecidos contactos entre o LIP, FCT, CSIC e o Ministério da Inovação e competitividade de Espanha no sentido do envolvimento do IBERGRID no projecto LifeWatch (ESFRI) na área dos serviços de computação.
O LIP e o CSIC organizaram em Setembro de 2013 o EGI Technical Forum e a conferência IBERGRID. Estes eventos foram realizados em conjunto em Madrid. O EGI Technical Forum é a maior conferência técnica da GRID Europeia.
O LIP no âmbito da colaboração IBERGRID ganhou novamente o concurso internacional para o fornecimento de serviços de coordenação de middleware para a infraestrutura GRID Europeia. Em adição, o LIP também ganhou o concurso para o suporte de primeira linha.
O coordenador da equipa está a cumprir um mandato de director na infraestrutura GRID Europeia (EGI), e é representante da FCT no conselho do EGI.

Serviços de Computação
Os serviços de computação e armazenamento do centro de processamento de Coimbra foram reestruturados para melhorar a sua gestão. Os serviços de virtualização de Coimbra e Lisboa foram redesenhados com vista a um melhor desempenho e redundância. A migração para o sistema operativo SL6 foi completada em todos os centros.
Mário David, um dos membros chave da equipa, deixou o LIP no inicio de 2013 para continuar a sua carreira em actividades semelhante no estrangeiro. Foi membro da equipa desde o primeiro projecto GRID.

3.1.2 Abstract

The LIP advanced distributed computing activities encompass the support to scientific research through the provisioning of services and assistance, complemented by a component of innovation, aimed at staying in the forefront of computing technologies.
Since 2001 the team, based in Lisbon, has been developing expertise in distributed data intensive processing through the participation in independent R&D activities . The team coordinates and manages the Portuguese Tier-2 computing infrastructure for the Worldwide LHC Computing Grid, provides services to the Portuguese research community, and participates in national and international research projects and initiatives related to e-Science.

Worldwide LHC Computing Grid (WLCG)

In 2013 the Portuguese Tier-2 has delivered 6,936,606 hours to the ATLAS and CMS experiments with an overall reliability higher than 96%, well above the Tier-2 requirements. Due to staff reduction, since 2012 all three computing centres that comprise the LIP Tier-2 and Tier-3 are managed remotely from Lisbon. These centres are LIP-Lisbon, LIP-Coimbra and NCG a national service operated in partnership with the Portuguese NREN (FCCN). In order to reduce costs and improve efficiency a consolidation process has been started. During 2013 the CMS Tier-2 and Tier-3 services housed at LIP-Lisbon were migrated to NCG thus consolidated the CMS Tiers at a single location. The ATLAS Tier-2 services housed at LIP-Lisbon were split between NCG and LIP-Coimbra. Only half of the ATLAS Tier-3 remains at LIP-Lisbon.
The project to support the LIP Tier-2 operational costs was evaluated as excellent and obtained the full funding from the Portuguese Science Foundation. The three years project started in January 2013 and aims to partially cover the operational costs of the Tier-2 including: one technician, maintenance costs for very critical equipment, some energy costs, and a partial replacement of the storage systems that are getting older and more unreliable.
A study of the Tier-2 storage access patterns was performed in the context of these activities.

Portuguese National Grid Initiative

LIP is the technical coordinator of the Portuguese GRID infrastructure. The team operates the national GRID core services, and manages a network of GRID resources at several universities and research centres. The team also manages the Portuguese Central GRID Computing Node (NCG) that provides high throughput and high performance services to the Portuguese scientific community. NCG supports a wide range of users and disciplines.
A proposal to evolve the national GRID infrastructure was submitted to the Portuguese Science Foundation infrastructures roadmap by LIP, in consortium with FCCN and the Portuguese Civil Engineering Laboratory

(LNEC). The proposal was submitted with the support of the universities of Minho, Porto and Aveiro. The program foresees the enlargement of the services portfolio, the creation of competence and support centres in partner organizations, and the renewal of obsolete computing equipment. These activities will be performed in collaboration with IBERGRID and EGI.

IBERGRID and EGI

The Iberian GRID infrastructure (IBERGRID) is a federation of the Portuguese and Spanish national GRID initiatives. Through IBERGRID, both infrastructures are seamlessly integrated to share resources and services at Iberian level, and in the European Grid Initiative (EGI). The team continued having a major role in the IBERGRID technical coordination. Similarly the team coordinated the participation and integration of Portuguese resource centres in the European Grid. In addition global task for the EGI middleware coordination and CRM were provided.
Contacts were established between LIP, FCT, CSIC and the Spanish Ministry of Innovation and Competitiveness towards the IBERGRID engagement in the LifeWatch ESFRI project as a core computing services provider.
LIP jointly with CSIC has organized the EGI Technical Forum collocated with the IBERGRID conference. The events took place in Madrid in September 2013. The EGI technical Forum is the largest European GRID technical conference.
LIP, in the IBERGRID context, won again the EGI international bid for the delivery of global middleware coordination services, and in addition also won the global user support for the next two years.
The team coordinator is serving in the EGI Executive Board and represents Portugal in the EGI council.

LIP Computing Services

The Coimbra computing centre storage and processing services were restructured to improve their management. The virtualization clusters in Coimbra and Lisbon were rebuilt for better performance and redundancy. The migration to Scientific Linux 6 was completed at all centres.
Mario David a key member has left LIP in the beginning of the year. He was with the computing team since the first GRID project.

3.1.3 Objectives

- Operation of the Portuguese WLCG Tier-2 and Tier-3 services for ATLAS and CMS.
- Consolidation of the LIP computing resources and downsize of the Tier-2 aiming at improving the sustainability.
- Start the Tier-2 support project, and execute the activities program for 2013 including the improvement of the Tier-2 services efficiency and perform a study for the replacement of the storage system.
- Coordinate the Portuguese GRID infrastructure in the context of IBERGRID and EGI.
- Manage the national GRID computing centre (NCG).
- Provisioning of global services for EGI namely: middleware rollout, middleware acceptance and CRM.
- Participation in the EGI management at the strategic level.
- Search and engage in proposals in its domain of competence.
- Manage the LIP IT infrastructure.

3.1.4 Achievements

- During 2013 the Portuguese Tier-2 delivered 6,936,606 hours to the ATLAS and CMS experiments with an overall reliability higher than 96%, well above the Tier-2 requirements.
- In parallel a complex migration of Tier-2 and Tier-3 resources from LIP-Lisbon to NCG and LIP-Coimbra was successfully performed.
- LIP won the EGI international bid for delivering the global middleware coordination and user support for the next two years.

- LIP together with FCCN and LNEC has prepared a proposal for the evolution of the national grid initiative towards a national distributed computing infrastructure. The proposal was supported by the Universities of Porto, Minho and Aveiro.
- The LIP computing team coordinator was elected by the EGI council to the EGI Executive Board, and is serving as director at the European Grid Initiative.
- The project proposal for the maintenance and upgrade of the LIP Tier-2 submitted in a national call for all scientific domains was approved by FCT, and got the maximum funding.
- LIP and CSIC have organized the EGI Technical Forum collocated with the IBERGRID conference. The EGI technical Forum is the largest EGI technical conference. Both events took place in Madrid in September 2014.

3.1.5 Sources of Funding

Code	Funding	Start	End
EGI InSPIRE	485.000 €	2010-05-01	2014-12-31
RECI/FIS-NUC/0115/2012	500.000 €	2013-01-01	2015-12-31

3.1.6 Team

Project coordinator: Jorge Gomes

Name	Status	FTE %
Carlos Manuel	Technician (LIP)	100
Gaspar Barreira	Researcher (LIP)	40
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
Mário David	Researcher (LIP)	8
Nuno Ribeiro Dias	Researcher (LIP)	100

3.1.7 Publications

Articles in international journals (with direct contribution from LIP members)

- *Phenomenology tools on cloud infrastructures using OpenStack*
  I.Campos, E.Fernández-del-Castillo, S.Heinemeyer, A.Lopez-Garcia, F.Pahlen, G.Borges
  The European Physical Journal C, vol 73 (4), pp:1-17, ISSN: 14346044

International Conference Proceedings

- *IBERGRID 2012 6th IBERIAN GRID INFRASTRUCTURE CONFERENCE PROCEEDINGS*
  Gonçalo Borges, Jorge Gomes, Isabel Campos
  ISBN: 978-989-98265-0-2

- *Analyzing File Access Patterns in Distributed File-systems*
  J.Gomes, J.Pina, G.Borges, J.Martins, N.Dias, H.Gomes, C.Manuel
  7th Iberian Grid Infrastructure Conference Proceedings pp:89-101, ISBN:978-84-9048-110-3

- *SPARKS, a dynamic power-aware approach for managing computing cluster resources*
  J.Martins, G.Borges, N.Dias, H.Gomes, J.Gomes, J.Pina, C.Manuel
  7th Iberian Grid Infrastructure Conference Proceedings pp:3-15, ISBN:978-84-9048-110-3

- *IBERGRID 2013 7th IBERIAN GRID INFRASTRUCTURE CONFERENCE PROCEEDINGS*
  Ignacio Blanquer, Isabel Campos, Gonçalo Borges, Jorge Gomes
  ISBN:978-84-9048-110-3

Proposals

- *Infraestrutura Nacional de Computacao Distribuida*
  Gonçalo Borges, Jorge Gomes, Gaspar Barreira
  ROTEIRO/0166/2013 (accepted)

3.1.8 Presentations

Oral presentations in international conferences

- *SPARKS, a dynamic power-aware approach for managing computing cluster resources*
  presented by Gonçalo Borges
  IBERGRID2013 — Madrid.
- *Analyzing File Access Patterns in Distributed File-systems*
  presented by Jorge Gomes
  IBERGRID2013 — Madrid.
- *7th IBERIAN GRID CONFERENCE OPENING*
  presented by
  IBERGRID2013 — Madrid.
- *IBERGRID INFRASTRUCTURE*
  presented by Jorge Gomes
  e-Infrastructures & Biodiversity Workshop — Madrid.

Poster presentations in international conferences

- *Integrating and testing SLURM in EMI-3 cream-CE*
  presented by
  EGI Technival Forum 2013 — Madrid.

Presentations in national conferences

- *Serviços de Computação Distribuída*
  presented by Jorge Gomes
  Jornadas FCCN 2013 — Aveiro.
- *Iniciativa Nacional Grid*
  presented by João Pina
  New Brain Technologies: A roadmap for Portuga — Fundação Champalimaud.
- *IBERIAN GRID INFRASTRUCTURE*
  presented by Jorge Gomes
  LifeWatch meeting — FCT - Fundação para a Ciência e a Tecnologia.

Oral presentations in international meetings

- *LIP Computing Activities*
  presented by Jorge Gomes
  — ESA - ESTEC.
- *UMD staged rollout testing*
  presented by João Pina
  New developments in WLCG for Run2 — Madrid.
- *EGI CRM demostration*
  presented by Hugo Gomes
  EFI Technical Forum 2013 — Madrid.

Seminars

- *Computação em HEP e no LIP*
  presented by Jorge Gomes
  Seminar for FCUL Parallel Computing master students — University of Lisbon.

3.1.9 Events

- *IBERGRID 2013 7th IBERIAN GRID INFRASTRUCTURE CONFERENCE*
  Conference, Madrid, 2013-09-19
- *EGI Technical Forum 2013*
  Conference, Madrid, 2013-09-19

3.1.10 Project Summary

	number
Articles in international journals (with direct contribution from LIP members)	1
International Conference Proceedings	4
Proposals	1
Oral presentations in international conferences	4
Poster presentations in international conferences	1
Presentations in national conferences	3
Oral presentations in international meetings	3
Seminars	1
Conferences	2

Chapter 4

Astroparticle Physics

4.1 Collaboration in AMS - Alpha Magnetic Spectrometer

4.1.1 Resumo

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

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

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

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

4.1.2 Abstract

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

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

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

4.1.3 Objectives

AMS-02 (Alpha Magnetic Spectrometer) detector is a state-of-the-art particle physics detector which is successfully operating as an external module on the ISS since May 2011. This large acceptance detector is foreseen to operate for the next decade and use the unique environment of space to study the Universe by searching for antimatter, dark matter while performing precision measurements of cosmic ray composition. The Portuguese group has been actively taking part in the experiment, and in particular in the RICH activities, since 1997.
Since installation a large amount of data have been collected, at a rate of approximately 40 million events per day. Until now more than 45×10ˆ9 events have been collected.

4.1.4 Achievements

The main tasks where the group was involved in 2013 were the following:

Measurement of e+/e- ratio and fluxes at low energies

The first AMS-02 physics results were published in PRL1110,141102 (2013) with an analysed statistics of 6.8×106 positron and electron events in the energy range from 0.5 to 350GeV. The positron fraction steadily increased from 10 to 250GeV, but from 20 to 250GeV the slope decreased by an order of magnitude. There was no fine structure in the positron fraction spectrum, and no anisotropies were observed in the positron to electron ratio (0.030 at the 95% confidence level). The first results confirm an unexplained excess of high-energy positrons in Earth-bound CR. These results are consistent with the positrons originating from the annihilation of DM particles in space, but not yet sufficiently conclusive to rule out other explanations. Over the next years, the measured spectrum will be accurately extended up to 1TeV and AMS will shed light on the origin of these observed features, either from exotic sources or other astrophysical sources as pulsars.
The main AMS analysis on positron identification relies on observables measured by the electromagnetic calorimeter (ECAL) and the Transition Radiation Detector (TRD). At low energies (E<10 GeV), positron identification can be done with a larger detector acceptance by using the RICH and the TRD. Therefore, a factor of 4 to 5 more events can be collected at these low energies when compared with an analysis purely done with ECAL and TRD. Positron separation with the RICH detector uses both the velocity and signal independent measurements.
The LIP positron identification method 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. This method was applied in LIP studies on e+/e- identification.

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. Recent work on algorithm improvements was mainly focused on addressing several sources of systematics due to non-uniformities in RICH detector components such as radiator tiles, the mirror and detection cells. Algorithm refinement and testing is expected to continue. In addition, photomultiplier gain drifts and temperature gain variations have to be monitored and its effects corrected, if needed. The quality of RICH measurements is fundamental for the AMS physics program success. A velocity resolution of 1.2×10ˆ-3 is obtained for single-charged particles with $\beta \approx 1$ crossing aerogel and 4.5×10ˆ-3 for NaF crossing events. The group has been involved in improving the charge measurement accuracy by applying corrections to the ring signal. The RICH charge resolution for low Z is around 0.3 charge units while systematic effects become dominant at higher charges. The charge systematic error for aerogel events was reduced from 5.1% to 2.5% through several optimizations, leading to a resolution of 0.4 charge units for Z=10 and 0.7 units for iron (Z=26).
Update on the LIP charge reconstruction for AMS RICH rings
A segment-based description for the charge reconstruction method was adopted in order to better deal with the different sources of systematics and a point smearing method was used. With this new approach a better evaluation of ring width effects and support of efficiency correction on a local scale (PMT or pixel) was achieved. The updated algorithm is available in the AMS code and is one of the two possible methods for obtain RICH reconstructed charge. In LIP charge reconstruction method a charge statistical error of 0.2864+-0.0013 is attained together with a systematic error of 2.503+-0.038 for aerogel events.
Impact of the Cherenkov radiation polarization on the electric charge reconstruction

The Cherenkov electromagnetic radiation is of polarized nature. The photon path from radiation point to detection includes two interfaces: the radiator-vacuum and the vacuum-light guide. The transmission efficiency depends on the photon polarization. Therefore, the effect of the polarization was evaluated for both radiator materials, aerogel and sodium fluoride and compared to the unpolarized case that is currently implemented in the charge reconstruction algorithms developed by the LIP group. The resulting correction was evaluated in the framework of a master thesis and prooved to improve the former charge resolution to value 4% lower.

Solar modulation of primary cosmic rays

AMS works as a continuous monitor of the cosmic ray fluxes up to one TeV, placed out of the atmosphere. The solar magnetic field, embedded in the solar wind, is responsible for cosmic-ray modulation at low energies (< 10GeV), affecting both their flux and their energy. It imposes a long term time modulation of $\approx$11 years (polarity inversion) and short time effects due to the solar rotation period ($\approx$27 days). The AMS launch took place during a minimum of solar activity (beginning of 24th cycle). The large acceptance of the AMS detector

will allow a precise knowledge of the primary fluxes with a fine granularity in time. The study and monitoring of the proton, electron and helium fluxes, is the subject of a master thesis currently going on in the group. The energy spectrum allows to derive the solar modulation effective parameter and therefore, characterize the solar activity. The measured fluxes can be compared with predictions from cosmic rays propagation in the heliosphere, described by the so-called Parker Equation. Different ways of solving the transport equation were already studied by the group and numerical methods (1D) were explored. This numerical solution was integrated in USINE code package developed by D. Maurin et al. from LPSC Grenoble for cosmic-ray propagation description.

Measurements with light nuclei isotopes

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 in their detection arises from proton background separation. A new mass separation method using the geomagnetic cutoff and the very precise determination of the velocity within AMS is currently being explored and applied to ams data. This topic is being explored and is the subject of an ongoing master thesis.

Participation in the AMS detector monitoring (shifts)

The mission´s POCC (Payload Operations and Control Center) operations are headquartered at CERN since June 2011. LIP team members have been participating in the AMS mission control activities, performing shifts and acting as on-call experts for the RICH subdetector. LIP shifters are responsible for monitoring the RICH, TOF and ECAL subdetectors and reporting any anomalies to shift leaders and on-call experts assigned to each specific subdetector. When acting as on-call experts, they are responsible for reporting the RICH detector´s behaviour to the collaboration in its daily briefings and performing contingency procedures if any issues occur with the RICH. These taks were undertaken by all AMS LIP members in order to garantee the detector´s performance and the good quality of the measurements.

4.1.5 Sources of Funding

Code	Funding	Start	End
PTDC/FIS/122567/2010	40.000 €	2011-12-07	2014-08-06

4.1.6 Team

Project coordinator: Fernando Barão

Name	Status	FTE %
Bruno Santos	Master student (LIP)	100
Fernando Barão	Researcher (LIP/IST)	85
Luisa Arruda	Post-Doc (LIP/FCT)	80
Miguel Orcinha	Student (LIP)	42
Pedro Nunes	Master student (LIP)	100
Rui Faísca Pereira	Post-Doc (LIP/FCT)	100

4.1.7 Publications

Articles in international journals (with indirect contribution from LIP members)

- *First Result from the Alpha Magnetic Spectrometer on the International Space Station: Precision Measurement of the Positron Fraction in Primary Cosmic Rays of 0.5-350 GeV*
  AMS Collaboration (348 authors)
  Phys. Rev. Lett. 110 (2013) 141102

International Conference Proceedings

- *Positron and proton separation with the AMS-RICH detector*
  L. Arruda, F. Barao, R. Pereira
  Proceedings International Cosmic Ray Conference 2 013 (Brazil) (accepted)

- *Precision measurement of the positron fraction in primary cosmic rays of 0.5-350 GeV*
  L. Arruda, F. Barao, R. Pereira, et al.
  Proceedings International Cosmic Ray Conference 2 013 (Brazil) (accepted)

- *Precision measurements of the electron spectrum and the positron spectrum with AMS, AMS collab.*
  L. Arruda, F. Barao, R. Pereira, et al.
  Proceedings International Cosmic Ray Conference 201 3 (Brazil) (accepted)

- *Precision measurement of the e+ + e- spectrum with AMS*
  L. Arruda, F. Barao, R. Pereira, et al.
  Proceedings International Cosmic Ray Conference 2013 (Brazil) (accepted)

- *Precision measurement of the proton flux with AMS*
  L. Arruda, F. Barao, R. Pereira, et al.
  Proceedings International Cosmic Ray Conference 2013 (Brazil) (accepted)

- *Precision Measurement of the Cosmic Ray Helium Flux with AMS Experiment*
  L. Arruda, F. Barao, R. Pereira, et al.
  Proceedings International Cosmic Ray Conference 2013 (Brazil) (accepted)

- *Precision Measurement of the Cosmic Ray Boron-to-Carbon Ratio with AMS*
  L. Arruda, F. Barao, R. Pereira, et al.
  Proceedings International Cosmic Ray Conference 2013 (Brazil) (accepted)

- *In-flight determination of the AMS-RICH photon yield*
  L. Arruda, F. Barao, R. Pereira, et al.
  Proceedings International Cosmic Ray Conference 2013 (Brazil) (accepted)

- *High precision measurement of the AMS-RICH aerogel refractive index with cosmic-ray*
  L. Arruda, F. Barao, R. Pereira, et al.
  Proceedings International Cosmic Ray Conference 2013 (Brazil) (accepted)

4.1.8 Presentations

Oral presentations in international conferences

- *Rayons Cosmiques: cent ans de mystères...et grandes découvertes*
  presented by Fernando Barão
  — Institut Franco-Portugais, Lisbonne.

- *AMS a cosmic-ray experiment in the ISS - from HESS discovery to AMS first data results*
  presented by Fernando Barão
  Modified Gravity Theories: Beyond Einstein´s Legacy - IDPASC School — FCUL, Lisbon.

Poster presentations in international conferences

- *Positron and proton separation with the AMS-RICH detector*
  presented by Luisa Arruda
  International Cosmic Ray Conference 2013 — Rio de Janeiro. Brazil.

Oral presentations in collaboration meetings

- *e/p separation with RICH: statistical estimators*
  presented by Luisa Arruda
  — CERN, Geneva, Switzerland.

- *e/p separation with RICH: statistical estimators*
  presented by Luisa Arruda
  — CERN, Geneva.

(unspecified Communications)

- *Cosmic rays observations near earth: detector principles and observations*
  presented by Fernando Barão
  IDPASC school - Graduate School of Particle and Astroparticle Physics of Annnecy-les-Vieux — Annecy.

4.1.9 Academic Training

Master Theses

- *Effect of Cerenkov Polarization in the Cosmic Rays charge reconstruction - Charge reconstruction with RICH/AMS-02 data*
  Bruno Santos, 2013-11-25

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

4.1.10 Project Summary

	number
Articles in international journals (with indirect contribution from LIP members)	1
International Conference Proceedings	9
Oral presentations in international conferences	2
Poster presentations in international conferences	1
Oral presentations in collaboration meetings	2
(unspecified Communications)	1
Master Theses	1

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

These were our goals (from the 2013 LIP Plans):
1) The analysis of the previous (air-filled) data taking is being used to prepare the common data structure for the PMT and optical calibration task and should lead to a publication describing the new system.
2) Before filling the radiopurity of the water must be assessed, and during the filling the remaining optical fibres of the new calibration system will be installed by boat.
3) With the water filled detector, both the PMT and optical calibrations should be performed. These data will allow first tests of the new data structure, hardware, software and calibration algorithms. The analysis will provide the first set of calibration constants for the liquid scintillator phase.

Additional goals were not connected to the water fill:
4) The fabrication of the new equipment for source insertion and removal in Coimbra should be completed also in 2013. The present schedule assumes its installation in SNOLAB in the second half of the year.
5) Anti-neutrino sensitivity studies will be continued, with full simulation analysis and including the expected signals from geo-neutrinos.

4.2.4 Achievements

At the beginning of 2013, a complete water fill and commissioning phase were planned for that year. Several of our objectives we based around that expectation, but the set-up of the water processing plant systems suffered many delays.
Nevertheless, the group was active in several aspects:
1) PMT calibration system
The production of the definitive LEDs and electronics drivers was completed by other groups (Sussex and Leeds). With a visit to the Univ. of Sussex, LIP collaborated in establishing the quality control procedure of the final components. At SNOLAB, D. Chauhan (holder of a fellowship) carried out several tasks for the completion of the installation of the fiber system: design and installation of a protection box for the fiber cables, between the deck feed-through and the LED rack; preparation of the book-keeping system to be used in the water-based installation.
2) Calibration sources insertion system
One of our main activities was the design of the SNO+ "Umbilical Retrieval Mechanism", for the insertion of calibration sources. A full 3D model was made by Rui Alves, and samples of different materials were procured and sent to SNOLAB and BNL for tests. The first phase of the internal design review, focused on the rope deployment mechanism, was passed in December.
3) Preparation of detector filling
Since the water plant was identified as affecting the experiment´s schedule, our group collaborated also in this area. D. Chauhan coordinated the water quality assay shifts and participated in their analysis.
4)
Preparation of the Double-Beta Decay phase
Our group participated in the task force dedicated to the evaluation of the Physics potential of Te130 instead of Nd150 as the isotope of choice. We raised the concern of external backgrounds and contributed to the simulation and analysis of several components of them.
5) Anti-neutrinos
The main focus was on the implementation of the antineutrino spectral features for each nuclear reactor, as well as for the geo-neutrinos, and estimating the detector performance for them in the water commissioning phase, for instance, by determining the trigger efficiency for the 2.2 MeV signal coming from the neutron.

4.2.5 Sources of Funding

Code	Funding	Start	End
PTDC/FIS/115281/2009	108.971 €	2011-01-01	2014-06-30

4.2.6 Team

Project coordinator: José Maneira

Name	Status	FTE %
Amélia Maio	Researcher (LIP/FCUL)	15
Carlos Silva	Technician (LIP)	15
Dimpal Chauhan	Master (LIP)	75
Gersende Prior	Researcher (LIP)	42
Joaquim Oliveira	Technician (LIP)	15
José Maneira	Researcher (LIP)	30
Luís Gurriana	Technician (LIP)	15
Nuno Barros	Researcher (LIP/FCT)	100
Orlando Cunha	Technician (LIP)	15
Rui Alves	Technician (LIP) *	15
Sofia Andringa	Researcher (LIP)	25

4.2.7 Publications

Articles in international journals (with direct contribution from LIP members)

- *Measurement of the ν_e and Total ^8B Solar Neutrino Fluxes with the Sudbury Neutrino Observatory Phase-III Data Set*
  SNO Collaboration (incl. N. Barros, J. Maneira and G. Prior)
  Phys. Rev. C 87, 015502 (2013)

- *Combined Analysis of all Three Phases of Solar Neutrino Data from the Sudbury Neutrino Observatory.*
  SNO Collaboration (incl. N. Barros, J. Maneira and G. Prior)
  Phys. Rev. C 88, 025501 (2013)

Articles in international journals (with indirect contribution from LIP members)

- *A Search for Astrophysical Burst Signals at the Sudbury Neutrino Observatory*
  SNO Collaboration includes, J. Maneira, N. Barros and G. Prior)
  Astroparticle Physics (accepted)

International Conference Proceedings

- *The SNO+ experiment: status and overview*
  J. Maneira (on behalf of the SNO+ Collaboration)
  Proc. of DISCRETE 2012 – Third Symposium on Prospects in the Physics of Discrete Symmetries 3–7 December 2012, Portugal

4.2.8 Presentations

Poster presentations in international conferences

- *Optical Calibration of SNO+*
  presented by José Maneira
  NuPhys2013, Topical Research Meeting on Prospects in Neutrino Physics — London, United Kingdom.

Oral presentations in international meetings

- *SNO+ status and plans for double beta decay search and other neutrino studies*
  presented by Sofia Andringa
  Nuclear Physics in Astrophysics VI — Lisboa, Portugal.

- *Neutrino Observations in Astrophysics*
  presented by José Maneira
  Modified Gravity Theories: Beyond Einstein´s Legacy — Univ. of Lisbon.

Oral presentations in collaboration meetings

- *Fiber installation during water fill*
  presented by José Maneira
  SNO+ Collaboration Meeting — SNOLAB, Sudbury, Canada (remotely).

- *Optics Group Report*
  presented by José Maneira
  SNO+ Collaboration Meeting — SNOLAB, Sudbury, Canada (remotely).

- *Fiber installation during water fill*
  presented by Dimpal Chauhan
  SNO+ Collaboration Meeting — Laurentian University, Sudbury, Canada.

- *Optics Workshop Summary*
  presented by José Maneira
  SNO+ Collaborarion Meeting — Laurentian University, Sudbury, Canada.

Seminars

- *Neutrinos: messengers from the centre of the Sun and the Earth*
  presented by Sofia Andringa
  — Centro de Geofísica de Évora.

Outreach seminars

- *O Mistério dos Neutrinos*
  presented by José Maneira
  Mini-Cursos do Dep. Física — FCUL, Lisbon.

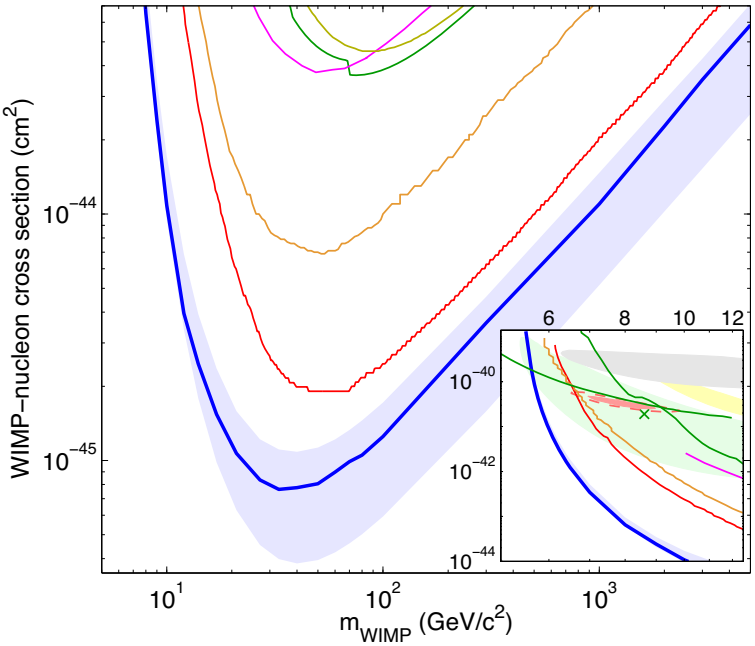
4.2.9 Project Summary

	number
Articles in international journals (with direct contribution from LIP members)	2
Articles in international journals (with indirect contribution from LIP members)	1
International Conference Proceedings	1
Poster presentations in international conferences	1
Oral presentations in international meetings	2
Oral presentations in collaboration meetings	4
Seminars	1
Outreach seminars	1

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

4.3.1 Resumo

Em 2013, as actividades do LIP na área da detecção directa de matéria escura continuaram centradas na participação na experiência Large Underground Xenon (LUX). Incluiram também trabalho 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 residual, o que permite melhorar a sensibilidade relativamente a detectores precedentes.
Para além da sua muito 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 radioactividade; 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 radioactividade; 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 directamente no xénon.
A Colaboração LUX é constituída por 14 instituições de 3 países (EUA, Portugal e UK), num total de cerca de 80 indivíduos.



The LUX 90% confidence limit on the spin-independent elastic WIMP-nucleon cross section (blue), together with the 1 variation from repeated trials, where trials fluctuating below the expected number of events for zero BG are forced to 2.3 (blue shaded). We also show Edelweiss II (dark yellow line), CDMS II (green line), ZEPLIN-III (magenta line), CDMSlite (dark green line), XENON10 S2-only [20] (brown line), SIMPLE (light blue line) and XENON100 100 live-day (orange line), and 225 live-day [(red line) results. The inset (same axis units) also shows the regions measured from annual modulation in CoGeNT [(light red, shaded), along with exclusion limits from low threshold re-analysis of CDMS II data [(upper green line), 95% allowed region from CDMS II silicon detectors (green shaded) and centroid (green x), 90% allowed region from CRESST II (yellow shaded) and DAMA/LIBRA allowed region (grey shaded). Results sourced from DMTools.

Em Julho de 2012, o detector e os seus sistemas auxiliares foram foi transportados para o laboratório subterrâneo "Sanford Underground Research Facility (SURF)"nos EUA. A instalação e integração de todos os subsistemas no laboratório subterrâneo foram concluídas em Dezembro de 2012.
Em 2013, após um período dedicado à purificação do xénon e à calibração do detector utilizando fontes internas de radiação gama e electrões (83mKr e 3H), assim como fontes externas de neutrões (AmBe and 252Cf), deu-se início à primeira tomada de dados da experiência com vista à detecção de WIMPs. A análise dos dados recolhidos durante 85.3 dias num volume útil no detector de 118kg manifestou-se consistente com a hipótese de que os sinais observados se deviam apenas ao fundo (ou seja não foram observados sinais que pudessem ser atribuídos a WIMPs), permitindo estabelecer em 7.6×10-46 cm2, com 90% de confiança, o mínimo do limite superior da secção eficaz da interação WIMP-nucleão independente do spin.
Com este resultado, LUX afirmou-se como a experiência de procura de WIMPs com maior sensibilidade que atinge um máximo para m_WIMP=33GeV/c2 , sendo cerca de 3 vezes melhor do que qualquer outra experiência de procura de WIMPs (ver figura 1). Esta melhoria passa para um factor de 20 para WIMPs de baixas massa cuja detecção tem vindo a ser sugerida por outras experiências. Assim, a experiência LUX deveria ter observado 1600 sinais devidos a interacções de matéria escura se os três sinais observados pela experiência CDMS fossem realmente devidos a WIMPs, tal como foi aventado.
Os resultados de LUX foram anunciados a 30 de Outubro de 2013 e estão já publicados em Rev. Lett. 112, 091303 (2014).
Em 2013, as principais responsabilidades do LIP no âmbito de LUX estiveram centradas (mas não restritas) no sistema de controlo da experiência, no sistema automático de distribuição de azoto líquido para o detector e outros subsistemas que dele necessitam, no desenvolvimento e implementação de um método de reconstrução do vertex das interacções no detector e no desenvolvimento de ferramentas de software para o processamento e análise de dados da experiência.
O LIP é membro da colaboração LUX desde Dezembro de 2010 na sequência da assinatura de um Memorando de Entendimento entre a FCT, o LIP e a colaboração LUX em Agosto de 2010. A participação do LIP em LUX é apoiada financeiramente pela FCT desde Janeiro de 2011. Presentemente, esse financiamento é feito através de um projecto a 2 anos que se iniciou em Abril de 2012 e que termina a 31 de Março de 2014.
Em paralelo, o LIP tem participado na Colaboração LUX-ZEPLIN (LZ) que propõe a construção de um detector de 7 toneladas de xénon, usando a mesma tecnologia que LUX. LZ será para instalar em SURF e irá utilizar a infraestrutura e algumas das componentes da experiência LUX. A Colaboração conta com 17 instituições de investigação dos EUA, 7 do Reino Unido, 1 da Rússia e o LIP de Portugal. LZ está a finalizar a proposta de "Conceptual Design". O programa de I&D de suporte a esta proposta está a ser financiado pelo DOE, USA. O LIP foi convidado a juntar-se à Colaboração LZ desde a sua formação em 2009.

4.3.2 Abstract

In 2013, the LIP activities in the area of dark matter search continued centred in the participation in LUX experiment. They also included R&D work towards the LZ experiment and the participation in the elaboration of the LZ conceptual design.
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 of shielding and cryogenics, reduction of backgrounds that boost its sensitivity.
Apart from its potential of 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 smaller detectors. 5) Gas calibration sources (Kr-83m and H-3) introduced directly into the liquid xenon.
LUX Collaboration comprises 16 institutions from 3 countries (USA, Portugal and UK) and 86 individuals.
LUX detector and its ancillary systems were moved underground at Sanford Underground Research Facility (SURF), Homestake, SD, US, in July 2012. Underground integration and commission of the LUX detector and all the subsystems started promptly and were completed in December 2012.
In 2013, after a xenon purification campaign and calibration of the detector with internal gamma and beta sources (83mKr and 3H), as well as external neutron sources (AmBe and 252Cf), the first WIMP search run was started. Data was taken for 3 months. The results from the analysis of 85.3 live-days of data with a fiducial volume of 118 kg proved to be consistent with the background-only hypothesis, allowing 90% confidence limits

to be set on spin-independent WIMP-nucleon elastic scattering with a minimum upper limit on the cross section of 7.6×10-46 cm2 at a WIMP mass of 33 GeV/c2 (see fig.1).
With this result, LUX proved to be the most sensitive dark matter detector in operation. LUX has a peak sensitivity at a 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. Three candidate low-mass WIMP events recently reported by CDMS would have produced more than 1,600 events in LUX run. These results were announced on 30 October 2013 and they are already published in Phys. Rev. Lett. 112, 091303 (2014).
In 2013, LIP main responsibilities were mainly centred in (but not limited to) the slow control system, the automated liquid nitrogen distribution system, the development and implementation of the method for 3D position reconstruction of events in LUX detector and in the development of software tools for LUX data processing and analysis.
LIP formally joined LUX in December 2010 after a Memorandum of Understanding was signed by FCT, LIP and the LUX Collaboration. The LIP participation in LUX has been funded by FCT since January 2011. Presently it is funded through a 2-year project that will end on 31 March 2014.
In parallel with being deeply involved in LUX, LIP has participated in the LUX-ZEPLIN (LZ) Collaboration that proposes the construction of a 7-ton xenon detector, using the same TPC technology as LUX, 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. LZ is just finishing the Conceptual Design. The R&D program associated to this conceptual design is being funded by DOE, USA. LIP was invited to join LZ Collaboration since its establishment in 2009.

4.3.3 Objectives

In the framework of LUX, the main LIP goals in 2013 were:
* Software development for LUX data processing and analysis. Apart from other smaller tasks, this included to develop; i) a standalone package for reconstruction of event energy and position, crucial for background rejection as it allows to select a low activity region in the centre of the detector and to reject multi-interaction events; ii) an event viewer.
* Participation in the analysis of the data from the purification campaign, calibration and first science run.
* Slow Control System upgrade and maintenance (LIP full responsibility).
* Construction and commission of the motorised system for automatic calibration of the detector with external radioactive sources (LIP full responsibility).
* Participation in the xenon purification campaign, calibrations and science run operations by maintaining always a person from LIP onsite.
Regarding our participation in the LUX-ZEPLIN (LZ) Collaboration:
* Measurement of the reflectivity of LUX reflector (PTFE) at low temperature and immersed in liquid xenon (LIP full responsibility).
* Leadership in the conceptual design of the Detector Control System.

4.3.4 Achievements

* Development and implementation of the algorithm for 3D position reconstruction of events in the LUX detector. It is presently the official position reconstruction tool used by LUX experiment for data analysis and it was integrated in the data analysis chain. It played a key role in the achievement of the world leading results obtained in the first science run. LIP has full responsibility for this task.
* An event viewer was developed and implemented. It became a tool widely used by the collaboration for a variety of data analysis and processing purposes.
* We strengthened our participation in both the data processing and data analysis in LUX. In the framework of the Analysis Working Group (AWG), the LIP team has carried out several tasks related with the development of data analysis tools and the analysis of the data taken during the science run, authoring (or co-authoring) 7 internal data analysis notes. Alexandre Lindote was appointed by the Collaboration for the positions of Deputy Data Processing Manager (from 10/1/2013 to 1/1/2014) followed by Data Processing Manager (starting 1/1/2014).
* Participation in the initial assessment of the underground data, comparing the internal background rates with Monte Carlo predictions.
* The Slow Control System was set operational for underground operation, in particular for the science run.

* Several features were added to the automated liquid nitrogen distribution system to optimise its efficiency and safety, as well as to minimise the losses of liquid nitrogen. This system is a full responsibility of LIP.
* LIP team participated in LUX purity and calibrations campaigns and in the science run data taking, having contributed, in total, with 280 days*person onsite. Luiz de Viveiros was appointed Deputy Science Coordination Manager (from 1/10/2013 to 30/11/2013).
* A dedicated test chamber was constructed for measuring the reflectance of PTFE immersed in liquid xenon. Preliminary results for the same PTFE as used in LUX are yielding 97% hemispherical reflectance when immersed in the liquid. This result is consistent with that derived by comparing LUX data with optical simulations (i.e. R >95%).
* The transmittance of the PTFE used in LUX was measured as function of thickness and for different wavelengths: xenon gas scintillation (178 nm) as well as 255, 340 and 470 nm. Results show a transmittance <0.1% for 1.5 mm for xenon scintillation light, but rising to as much as 10% for 5 mm in case of blue light (470 nm). Both the reflectivity and the reflectance of PTFE are critical parameters for the design and material procurement for LZ detector.
* Vladimir Solovov was appointed as coordinator of the Working Group in charge of making the conceptual design of the Slow Control System for LZ.
* Isabel Lopes was elected member of the LZ Executive Board.

4.3.5 Sources of Funding

Code	Funding	Start	End
CERN/FP/123610/2011	80.000 €	2012-04-01	2013-03-31

4.3.6 Team

Project coordinator: Isabel Lopes

Name	Status	FTE %
Afonso Bernardino	Master student (LIP)	13
Alessio Mangiarotti	Researcher (LIP/USP)	15
Alexandre Lindote	Post-Doc (LIP)	85
Américo Pereira	Technician (LIP)	35
Cláudio Silva	Post-Doc (LIP/FCT)	100
Filipa Balau	PhD student (LIP)	50
Francisco Neves	Post-Doc (LIP)	85
Isabel Lopes	Researcher (LIP/FCTUC)	65
José Pinto da Cunha	Researcher (LIP/FCTUC)	20
Luiz de Viveiros	Post-Doc (LIP)	100
Nuno Carolino	Technician (LIP)	25
Vitaly Chepel	Researcher (LIP/FCTUC)	30
Vladimir Solovov	Researcher (LIP)	62

4.3.7 Publications

Articles in international journals (with direct contribution from LIP members)

- *Technical Results from the Surface Run of the LUX Dark Matter Experiment*
  D.S. Akerib et al.
  Astroparticle Physics 45 (2013) 34-43

- *Liquid noble gas detectors for low energy particle physics*
  V. Chepel and H. Araujo
  JINST 8 (2013) R04001

- *Measurement and simulation of the muon-induced neutron yield in lead*
  L. Reichhart, A. Lindote, D. Yu Akimov et al.
  Astroparticle Physics 47 (2013) 67-76

Articles in international journals (with indirect contribution from LIP members)

- *Measurement of the neutron induced fission cross section of 241Am at the time-of-flight facility n_TOF*
  Belloni, F., Calviani, M., Colonna, N., Mastinu, P., Milazzo, P.M., et al.
  European Physical Journal A, 49 (1) 2013, pp. 1-6

- *The 93Zr(n,γ) reaction up to 8 keV neutron energy*
  Tagliente, G., Milazzo, P.M., Fujii, K., Abbondanno, U., Aerts, G., et al.
  Physical Review C Nuclear Physics, 87 (1), 2013, art. no. 014622

International Conference Proceedings

- *A measurement of the muon induced neutron yield in lead at a depth of 2850 m water equivalent*
  Reichhart, L., Lindote, A., Akimov, D.Yu., Araújo, H.M., Barnes, et al.
  AIP Conference Proceedings, 1549 (2013) pp. 219222

Collaboration notes with internal referee

- *Measurement of the Electron Extraction in Run3*
  Luiz de Viveiros
  LUX Internal Note

- *Summary of pulse finding and classifying efficiencies*
  Lea Reichhart and Alex Lindote
  Analysis Note, LuxDB00000173

- *Preselection, blinding and evt volume reduction for Run 4*
  Alastair Currie, Carlos Faham, Alex Lindote
  Technical Note, LuxDB00000222

Internal Notes

- *S2 tails, e-trains and super-trains: implications for the short WIMP Run*
  Luiz de Viveiros
  LUX Internal Note

- *Sweep of the S2 Threshold on the DDC Trigger*
  Luiz de Viveiros
  LUX Internal Note

- *Position Reconstruction - Mercury Algorithm*
  Cláudio Silva
  LUX Internal Note

4.3.8 Presentations

Oral presentations in international conferences

- *The LUX Dark Matter Search Experiment*
  presented by Vladimir Solovov
  DM, DE and their detection — Novosibirsk, Russia.

- *Searching for Dark Matter: The LUX Experiment*
  presented by Luiz de Viveiros
  21st International Conference on Supersymmetry and Unification of Fundamental Interactions - SUSY 2013 — Trieste, Italy.
- *Dark matter searches with the Large Underground Xenon (LUX) experiment*
  presented by Cláudio Silva
  14th ICATPP Conference on Astroparticle, Particle, Space Physics and Detectors for Physics Applications — Como, Italy.

Oral presentations in collaboration meetings

- *Study of the PTFE optical properties*
  presented by Francisco Neves
  LZ Collaboration Meeting — Texas A&M, College Station, TX, USA.
- *LUX Position Reconstruction : Present Status*
  presented by Cláudio Silva
  LUX Collaboration Meeting — Sanford Laboratory, Lead, USA.
- *S2 tails and trains - implications for the short WIMP run*
  presented by Luiz de Viveiros
  LUX Collaboration Meeting — Sanford Laboratory, Lead, USA.
- *S2 tails, trains and super trains*
  presented by Luiz de Viveiros
  LUX Collaboration Meeting — Sanford Laboratory, Lead, USA.
- *Slow control plans and performance*
  presented by Vladimir Solovov
  LZ Collaboration Meeting — Sanford Laboratory, Lead, USA.
- *LZ Calibration Status*
  presented by Luiz de Viveiros
  LZ Collaboration Meeting — Sanford Laboratory, Lead, USA.
- *LUX Position Reconstruction*
  presented by Cláudio Silva
  LUX Collaboration Meeting — University of California - Davis, Davis, USA.
- *Measuring PTFE reflectivity in LXe (status update*
  presented by Vladimir Solovov
  LZ Collaboration Meeting at LBNL — LBNL -Lawrence Berkeley National Laboratory, USA.
- *Measuring PTFE Reflectivity in Liquid Xenon*
  presented by Vladimir Solovov
  LZ Collaboration Meeting — Imperial College London, UK.

Seminars

- *First results from the LUX experiment*
  presented by Alexandre Lindote
  — LIP- Lisboa.
- *First Dark Matter Search Results from the LUX Detector*
  presented by Cláudio Silva
  — LNGS - Gran Sasso National Laboratory, Itália.
- *First results from the LUX dark matter experiment*
  presented by Isabel Lopes
  — DESY, Hamburgo, Alemanha.
- *First results from the LUX dark matter experiment*
  presented by Isabel Lopes
  — DESY, Berlin, Germany.

4.3.9 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)

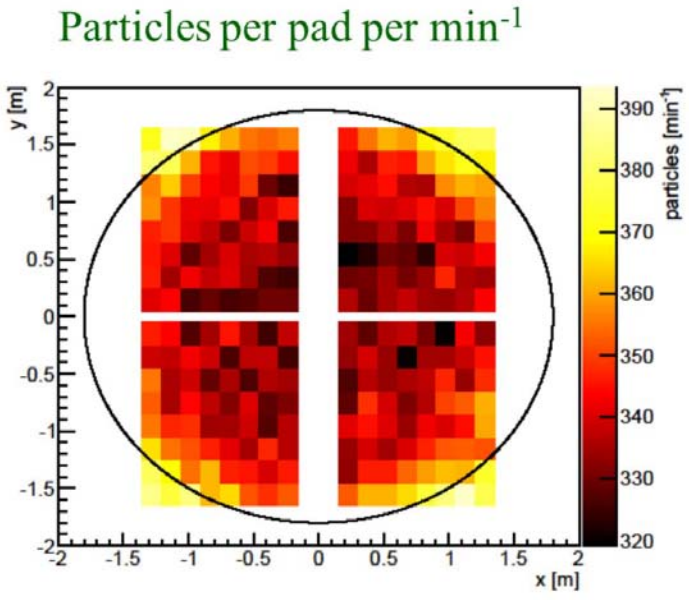
4.3.10 Project Summary

	number
Articles in international journals (with direct contribution from LIP members)	3
Articles in international journals (with indirect contribution from LIP members)	2
International Conference Proceedings	1
Collaboration notes with internal referee	3
Internal Notes	3
Oral presentations in international conferences	3
Oral presentations in collaboration meetings	9
Seminars	4

4.4 High Energy Cosmic Rays

4.4.1 Resumo

Em 2013, as actividades do LIP desenvolvidas na área dos raios cósmicos de ultra-altas energias continuaram centradas na participação no Observatório Pierre Auger (AUGER). As actividades de R&D no contexto de um futuro upgrade foram incrementadas na preparação de MARTA - "Muon Auger RPC for the Tank Array- um projecto que visa instalar RPCs no detector de superfície de Auger.
A física de raios cósmicos é um activo campo de investigação, com muitos projectos experimentais em curso que estudam algumas das mais importantes questões da ciência de hoje. A alargada região de energias dos raios cósmicos implica necessariamente o uso de diferentes métodos de detecção: desde os detectores no espaço nas energias dos GeV-TeV, até aos experimentos gigantes no chão que detectam chuveiros de partículas nas energias dos EeV. Nestas regiões persistem ainda perguntas sem resposta sobre a origem, aceleração e propagação destas partículas.
O Observatório Pierre Auger foi construído para determinar a origem e natureza dos raios cósmicos de ultra-altas energias, e também para estudar as interações nessas energias. Actualmente, a Colaboração é constituída por 500 cientistas de mais de 90 instituições em 19 países. O Observatório, situado na Argentina, iniciou a sua tomada de dados em 2004 e a sua construção foi finalizada em 2008. É um detector híbrido que combina um array de detectores de superfície (SD) com telescópios de fluorescência (FD) que observam a atmosfera por cima do array. O SD cobre um área efectiva de 3000 kmˆ2 com tanques de água de efeito Cherenkov.
Os dados de Auger contribuíram com importantes descobertas na física de raios cósmicos de ultra-altas energias: a supressão no fluxo de raios cósmicos para energias superiores a 5.5x10ˆ19 eV foi inequivocamente estabelecida e foram encontradas evidências de anisotropia na distribuição das direcções de chegada às energias mais elevadas. Os limites nas magnitudes do fluxo de fotões e neutrinos permitiram excluir a maioria dos modelos de produção de raios cósmicos a partir da desintegração de partículas super-massivas presentes nas primeiras fases do Universo. A secção eficaz protão-ar a uma energia no centro de massa de 57 TeV foi medida. Os dados de composição a muito altas energias são interpretados como uma transição inesperada de elementos leves a pesados para energias superiores a 3x10ˆ18 eV. No entanto, os resultados são igualmente compatíveis com misturas de diferentes tipos de primários em conjunto com uma mudança drástica da física das interações hadrónicas a muito altas energias.
Portugal tornou-se membro de pleno direito do Observatório em Março de 2006. A equipa do LIP é relativamente grande, tanto em número de pessoas, como em competências. Ainda que a maioria da equipa se encontre em Lisboa, trabalham em estreita parceria os 3 pólos do LIP, sendo a equipa de Coimbra especialista em RPCs e a equipa do Minho especializada na análise de dados.
O LIP tem tido um papel activo nos grupos de composição e modelos hadrónicos dentro da Colaboração, em particular na exploração do potencial do estudo da física de partículas que Auger pode revelar, uma janela às



Number of atmospheric particles in each MARTA RPC pad per minute

mais altas energias largamente complementar com o LHC. Um membro da equipa foi recentemente nomeado líder da Auger Hadronic Interactions Task e vários membros do LIP formam parte de vários painéis editoriais designados para coordenar publicações nestes tópicos.
Desde 2010, uma parte importante das actividades do grupo tem-se focado em MARTA, uma proposta para instalar RPCs (Resistive Plate Chambers) com vista à detecção de muões no detector de superfície de Auger. Foi estabelecida uma colaboração internacional liderada pelo LIP que conta já com a participação de instituições do Brasil, República Checa, Espanha e Itália.
Finalmente, o grupo também actua como excelente plataforma de treino académico e de difusão do conhecimento. No âmbito da difusão do conhecimento, o grupo organizou uma exposição e uma sessão pública no âmbito da reunião da colaboração Pierre Auger que organizou em Lisboa, na Biblioteca Nacional. A exposição "Dos Céus ao Universo"teve a duração de três meses e a originalidade de juntar documentos antigos e artefactos modernos na sala de exposições temporárias da Biblioteca. No verão, o grupo organizou um estágio de ocupação científica de jovens em férias, com 6 alunos do ensino secundário, para explorar os dados públicos do Observatório Pierre Auger. O sucesso destes estágios levou o grupo a propor esta actividade ao longo do ano lectivo a várias escolas portuguesas, dando apoio a 3 escolas que estão a trabalhar estes dados no Cacém, em Lisboa e Santarém.

4.4.2 Abstract

The LIP activities in the area of high energy cosmic rays continued, in 2013, centered in the Participation in the Pierre Auger Observatory (Auger). R&D activities in view of future Auger upgrades were increased. Namely, the preparation of MARTA – "Muon Auger RPC for the Tank Array- a project for the installation of RPCs in the Auger surface detector.
Cosmic ray physics is an active field of research, with many ongoing experimental projects addressing some of the most compelling questions in science today. The very wide range of energies of cosmic rays implies that different detection methods are used, from space-based experiments in the GeV-TeV to ground-based giant air shower detectors in the EeV range. Common to all regions, questions remain to be answered about the origin, nature, acceleration and propagation of these particles.
The Pierre Auger Observatory was built to give a major contribution to the understanding of ultra-high energy cosmic rays, namely to determine their origin and nature, as well as to study particle interactions at such high energies. Today, nearly 500 physicists from more than 90 institutions in 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 is a hybrid detector combining a surface detector array (SD) with a set of fluorescence detector telescopes (FD) watching the atmosphere above it. The SD covers an effective area of 3000 km^2 with water Cherenkov tanks.
The data taken by Auger have led to a number of breakthroughs in ultra-high energy cosmic ray physics. A suppression of the cosmic ray flux above 5.5x10^19 eV is firmly established, and there are indications for an anisotropic distribution of the arrival direction of the highest energy particles. Strong limits on photon and neutrino fluxes rule out most models for cosmic ray production from relic particle decay. The proton-air cross-section at a center-of-mass energy of 57 TeV has been measured. The cosmic ray composition at very high energies has been addressed and is usually interpreted as an unexpected transition from proton to heavier elements above 3x10^18 eV. The results are however compatible both with the presence of different primary particle types and with a drastic change in hadronic interactions at very high energies.
Portugal became a full member of the Observatory in March 2006. The LIP team is relatively large both in number of members and in competences. While the bulk of the team is in Lisbon, it relies on a close collaboration between the 3 LIP poles, with the involvement of the Coimbra RPC team and of the Minho analysis team.
LIP has been an active player in the composition and hadronic models groups within the Collaboration, specially in the exploitation of the particle physics that Auger can reveal, a window to the highest energies largely complementary to the LHC. A team member has recently become leader of the Auger Hadronic Interactions Task. Besides, LIP members are within several Editorial Boards designated to produce Full Collaboration publications on these topics.
Since 2010, the group activities have been partly focused on MARTA a proposal for the installation of RPCs (Resistive Plate Chambers) for muon detection in Auger. An international collaboration has been established, led by LIP and counting already with institutions from Brazil, Czech Republic, Spain and Italy.
The group is also an excellent platform for academic training and knowledge dissemination. A public session and a public exhibition, following the organization of the meeting in Lisboa of the Pierre Auger Collaboration at the National Library, were organized. The 3 months exhibition "From the skies to the Universe"put together in an original way old documents and modern artifacts at a room of the National Library. In the summer, the group has proposed an internship for 6 high-school students, to exploit the Auger public data. The success of these internships motivated the group to propose this activity to the schools as an activity for their school year,

now supporting 3 schools in Cacém, Lisboa, and Santarém.

4.4.3 Objectives

The main areas of activity in 2013 were:
Task 1- Tools and studies for light propagation and detection with the FD, crucial for calibrating the energy measurement. Determination of the systematic uncertainties
Task 2- Measurement of electromagnetic (EM) and muonic shower profiles for composition and hadronic interaction studies;
a) Measurement of the average EM shower profile and its interpretation.
b) Measurement of the average muon production depth (MPD) as a function of energy.
c) Measurement of the total number of muons and its fluctuations.
d) Study the impact of RPCs in the above muon measurements and on the energy estimation with the Auger surface detector.
Task 3 - Search for Exotic and Rare Events
Task 4 - Theory and Models for High Energy Interactions
Task 5 - R&D for the next generation of high energy cosmic ray experiments and Auger upgrade
Task 6 - Education and Public Outreach in the area of high energy cosmic rays.

4.4.4 Achievements

Task 1
The full program of systematic studies on light propagation/collection in the FD was completed, using laser data and Geant4 simulations.
Task 2
It has been demonstrated that fluctuations on the muon component introduce a smearing in the SD energy (calibrated by FD) which affects the interpretation of the muon observables. The group has started a new calibration strategy using the EM signals at ground with MARTA.
The average EM profile (FD) was obtained as a function of energy with very high precision, opening new ways to test composition and hadronic interaction models, and being proposed for a Full Collaboration publication.
The MPD was obtained from a fit of the SD time-distributions, increasing the statistics. Inconsistencies of data with some LHC-tuned models were unveiled.
Fluctuations of the muon number was shown to carry relevant information. Its RMS was reconstructed, being in disagreement with models. The case for an upgrade with muon capabilities was thus reinforced.
Task 3
The tools previously developed to search for exotic showers were applied on the new data set; Additional functions were added and explored, dealing with: i) the possible existence of a late arriving component of the shower front; ii) the number of muons in the shower.
Task 4
LIP group has developed new models that take into account Auger and LHC data, constraining certain hadronic physics parameters.
Task 5
R&D activities have been focused on silicon photo multipliers (SiPM) and, following an innovative and unique research line, RPCs able to operate autonomously, outdoors and with low gas flux were built. In the context of MARTA, full scale prototype chambers are now in production at LIP-Coimbra, while the data acquisition system is being developed and tested in LIP-Lisbon.
Task 6
An exhibition and a public session were held at the National Library of Lisbon. Auger public data was analyzed by several schools during the academic year, and by high-school groups at LIP during summer.

4.4.5 Sources of Funding

Code	Funding	Start	End
EPLANET 246806	10.800 €	2011-01-01	2014-12-31
CERN/FP/123611/2011	280.000 €	2012-02-01	2014-04-30
Particle Physics at 100 TeV AFR PhD Gran	114.660 €	2012-09-01	2015-08-31
ASPERA/0001/2010	150.000 €	2012-09-01	2015-08-31

4.4.6 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	PhD student (LIP/FCT)	100
Francisco Diogo	PhD student (LIP/FCT)	100
Helmut Wolters	Researcher (LIP/FCTUC)	4
João Espadanal	PhD student (LIP/FCT)	100
Jorge Dias de Deus	Researcher (LIP/IST)	15
Jorge Romão	Researcher (LIP/IST)	15
José Micael Oliveira	PhD student (LIP)	100
José Milhano	Researcher (LIP/IST)	15
Liliana Apolinário	PhD student (LIP)	15
Lorenzo Cazon	Researcher (LIP)	80
Luís Lopes	Technician (LIP)	6
Luís Mendes	Student (LIP)	100
Mário Pimenta	Researcher (LIP/IST)	85
Miguel Ferreira	Technician (LIP)	100
Patrícia Gonçalves	Researcher (LIP)	50
Pedro Abreu	Researcher (LIP/IST)	65
Pedro Assis	Post-Doc (LIP/FCT/IST)	85
Pedro Brogueira	Researcher (LIP/IST)	15
Pedro Cardoso	Master student (LIP)	33
Raul Sarmento	Post-Doc (LIP/FCT)	100
Ricardo Jorge Barreira Luz	Master student (LIP)	25
Ruben Conceição	Post-Doc (LIP/FCT)	100
Sofia Andringa	Researcher (LIP)	75
Thomas Schweizer	Researcher	15

4.4.7 Publications

Articles in international journals (with direct contribution from LIP members)

- *Study of standalone RPC detectors for cosmic ray experiments in outdoor environment*
  L.Lopes, P.Fonte, M.Pimenta
  Journal of Instrumentation 8 (2013) T03004

Articles in international journals (with indirect contribution from LIP members)

- *Constraints on the origin of cosmic rays above 10ˆ18 eV from large scale anisotropy searches in data of the Pierre Auger observatory*
  The Pierre Auger Collaboration
  ApJL, 762 (2012) L13

- *Interpretation of the depths of maximum of extensive air showers measured by the Pierre Auger Observatory*
  Pierre Auger Collaboration (508 authors)
  J. Cosmol. Astropart. Phys. 2 (2013) 026

- *Ultra-High Energy Neutrinos at the Pierre Auger Observatory*
  The Pierre Auger Collaboration
  Advances in High Energy Physics, 2013 (2013) 708680

- *Techniques for measuring aerosol attenuation using the Central Laser Facility at the Pierre Auger Observatory*
  Pierre Auger Collaborat (506 authors)
  J. Instrum. 8 (2013) P04009

- *Bounds on the density of sources of ultra-high energy cosmic rays from the Pierre Auger Observatory*
  Pierre Auger Collaboration (512 authors)
  J. Cosmol. Astropart. Phys. 5 (2013)

- *Identifying Clouds over the Pierre Auger Observatory using IR Satellite Data*
  The Pierre Auger Collaboration
  Astroparticle Physics, 50-52 (2013) 92-101

Collaboration notes with internal referee

- *Requirements on the measurements of the number of muons to validate mass composition scenarios*
  R. Conceição, M. Pimenta
  GAP2013-004

- *Thermal simulation of MARTA*
  P. Fonte
  GAP2013-015

- *Considerations on the choice of RPCs as charged particle detectors for MARTA*
  A. Blanco, N. Carolino, O. Cunha, P. Fonte, L. Lopes, A. Pereira
  GAP2013-016

- *Expected performance of MARTA in the measurement of muons*
  L. Cazon, M. Pimenta, R. Sarmento, B. Tomé. P. Travnicek, J. Vicha
  GAP2013-018

- *MARTA (Muon Auger RPC for the Tank Array) Design Report*
  The MARTA teams
  GAP2013-20

- *SD Energy Calibration based on the Electromagnetic Signal*
  J. Espadanal, M. Pimenta, P. Gonçalves, S. Andringa
  GAP-2013-054

- *MARTA (Muon Auger RPC for the Tank Array) 1st Progress Report*
  The MARTA teams
  GAP-2013-052

- *Number of muons, fluctuations and systematics at 60 degree*
  M. Oliveira, L. Cazon, M. Pimenta
  GAP-2013-053

4.4.8 Presentations

Oral presentations in international conferences

- *The Pierre Auger Observatory: results on the highest energy particles*
  presented by Ruben Conceição
  Time and Matter 2013 — Venice, Italy.

- *The nuclear mass composition of UHECR with the Pierre Auger Observatory*
  presented by Eva Santos
  Rencontres de Moriond - Very High Energy Phenomena in the Universe — La Thuile, Italy.

- *Particle physics measurements at the highest energies with the Pierre Auger Observatory*
  presented by Sofia Andringa
  EPS-HEP 2013 — Stockholm, Sweden.

Oral presentations in collaboration meetings

- *Air Shower Longitudinal Profiles*
  presented by Francisco Diogo
  MPD Meeting — IST, Lisboa.

- *Average and RMS of the number of muons at 60 degrees*
  presented by José Micael Oliveira
  MPD Meeting — IST, Lisboa.

- *Update on the MPD time-domain fit*
  presented by Eva Santos
  MPD Meeting — IST, Lisboa.

- *MPD General Status*
  presented by Lorenzo Cazon
  MPD Meeting — IST, Lisboa.

- *MARTA simulation and expected performance*
  presented by Bernardo Tomé
  MPD Meeting — IST, Lisboa.

- *MARTA hardware & prototypes & readout*
  presented by Pedro Assis
  MPD Meeting — IST, Lisboa.

- *Requirements on the measurement of Nmu to validate the mass composition scenarios*
  presented by Ruben Conceição
  MPD Meeting — IST, Lisboa.

- *Requirements for RPC interface*
  presented by Pedro Assis
  Auger SDE Upgrade Meeting — IPN-Orsay, Paris, France.

- *RPC Hardware and Prototypes*
  presented by Pedro Assis
  AugerNext Meeting — KIT-CN, Karlsruhe.

- *MARTA simulation and expected performance*
  presented by Bernardo Tomé
  AugerNext Meeting — KIT-CN, Karlsruhe.

- *Requirements for muon measurements*
  presented by Ruben Conceição
  Pierre Auger Collaboration Meeting — Malargüe, Argentina.

- *MARTA concept and performance*
  presented by Bernardo Tomé
  Pierre Auger Collaboration Meeting — Malargüe, Argentina.

- *MARTA Status of Development, Workplan and Schedule*
  presented by Pedro Assis
  Pierre Auger Collaboration Meeting — Malargüe, Argentina.
- *MARTA resources*
  presented by Mário Pimenta
  Pierre Auger Collaboration Meeting — Malargüe, Argentina.
- *MARTA R&D - 2013/2014*
  presented by Mário Pimenta
  Pierre Auger Collaboration Meeting — Malargüe, Argentina.
- *Update on the MPD Time-domain fit*
  presented by Eva Santos
  Pierre Auger Collaboration Meeting — Malargüe, Argentina.
- *MARTA Readout*
  presented by Pedro Assis
  3rd MARTA Progress Meeting — LIP, Lisboa, Portugal.
- *MARTA tests at Malargüe*
  presented by Pedro Assis
  3rd MARTA Progress Meeting — LIP, Lisboa, Portugal.
- *Background rejection in photon searches*
  presented by Raul Sarmento
  3rd MARTA Progress Meeting — LIP, Lisboa, Portugal.
- *N_mu and RMS N_mu*
  presented by Bernardo Tomé
  3rd MARTA Progress Meeting — LIP, Lisboa, Portugal.
- *SD Muon Signal Calibration with MARTA*
  presented by Ruben Conceição
  3rd MARTA Progress Meeting — LIP, Lisboa, Portugal.
- *SD Energy Calibration based on the electromagnetic Signal*
  presented by João Espadanal
  3rd MARTA Progress Meeting — LIP, Lisboa, Portugal.
- *Number of muons, fluctuations and systematics at 60 degree*
  presented by José Micael Oliveira
  3rd MARTA Progress Meeting — LIP, Lisboa, Portugal.
- *Sem and Smu fit with MARTA: finding two components in N stations and 3 sub-detectors*
  presented by Sofia Andringa
  3rd MARTA Progress Meeting — LIP, Lisboa, Portugal.
- *RPC for Auger - Production and Schedule*
  presented by Luís Lopes
  3rd MARTA Progress Meeting — LIP, Lisboa, Portugal.
- *MARTA Efficiency measurements*
  presented by Paulo Fonte
  3rd MARTA Progress Meeting — LIP, Lisboa, Portugal.
- *Progress on MARTA R&D*
  presented by Pedro Assis
  Pierre Auger Collaboration Meeting — Biblioteca Nacional, Lisboa, Portugal.
- *Progress on MARTA simulation and performance studies*
  presented by Bernardo Tomé
  Pierre Auger Collaboration Meeting — Biblioteca Nacional, Lisboa, Portugal.

- *MARTA schedule and costs*
  presented by Mário Pimenta
  Pierre Auger Collaboration Meeting — Biblioteca Nacional, Lisboa, Portugal.
- *Number of muons fluctuations and systematics at 60 deg*
  presented by José Micael Oliveira
  Pierre Auger Collaboration Meeting — Biblioteca Nacional, Lisboa, Portugal.
- *Update on double shell searches*
  presented by Catarina Espírito Santo
  Pierre Auger Collaboration Meeting — Biblioteca Nacional, Lisboa, Portugal.
- *An update on the MPD time-domain fit*
  presented by Eva Santos
  Pierre Auger Collaboration Meeting — Biblioteca Nacional, Lisboa, Portugal.
- *HEPP/APP Outreach in Portugal*
  presented by Pedro Abreu
  Pierre Auger Collaboration Meeting — Biblioteca Nacional, Lisboa, Portugal.
- *MARTA Electronics Readout*
  presented by Pedro Assis
  4th MARTA Progress Meeting — Biblioteca Nacional, Lisboa, Portugal.
- *MARTA front end using the MAROC*
  presented by Miguel Ferreira
  4th MARTA Progress Meeting — Biblioteca Nacional, Lisboa, Portugal.
- *MARTA simulation and reconstruction*
  presented by Bernardo Tomé
  4th MARTA Progress Meeting — Biblioteca Nacional, Lisboa, Portugal.
- *S1000em and N1000mu from MARTA and Tank*
  presented by Sofia Andringa
  4th MARTA Progress Meeting — Biblioteca Nacional, Lisboa, Portugal.
- *SD Energy Calibration based on the electromagnetic Signal*
  presented by João Espadanal
  4th MARTA Progress Meeting — Biblioteca Nacional, Lisboa, Portugal.
- *Array configuration optimization*
  presented by Ruben Conceição
  4th MARTA Progress Meeting — Biblioteca Nacional, Lisboa, Portugal.
- *Autonomous RPCs: a review*
  presented by Paulo Fonte
  4th MARTA Progress Meeting — Biblioteca Nacional, Lisboa, Portugal.
- *RPC prototypes and large scale production*
  presented by Luís Lopes
  4th MARTA Progress Meeting — Biblioteca Nacional, Lisboa, Portugal.
- *RPC modules testing infrastructure. Validation, efficiency measurements and testing*
  presented by Alberto Blanco
  4th MARTA Progress Meeting — Biblioteca Nacional, Lisboa, Portugal.
- *MARTA databases*
  presented by Helmut Wolters
  4th MARTA Progress Meeting — Biblioteca Nacional, Lisboa, Portugal.
- *MARTA near the core*
  presented by Pedro Abreu
  4th MARTA Progress Meeting — Biblioteca Nacional, Lisboa, Portugal.

- *Asymmetry and Nmu for photon discrimination*
  presented by Raul Sarmento
  4th MARTA Progress Meeting — Biblioteca Nacional, Lisboa, Portugal.
- *Monitoring and cross-calibration of MARTA and SD Tank*
  presented by Ruben Conceição
  4th MARTA Progress Meeting — Biblioteca Nacional, Lisboa, Portugal.
- *Impact of systematics on the muon measurements*
  presented by Lorenzo Cazon
  4th MARTA Progress Meeting — Biblioteca Nacional, Lisboa, Portugal.
- *MARTA Design Report*
  presented by Catarina Espírito Santo
  4th MARTA Progress Meeting — Biblioteca Nacional, Lisboa, Portugal.
- *MARTA Installation in the Gianni Navarra tank and in BATATA*
  presented by Pedro Assis
  4th MARTA Progress Meeting — Biblioteca Nacional, Lisboa, Portugal.
- *MARTA status and future plans*
  presented by Mário Pimenta
  4th MARTA Progress Meeting — Biblioteca Nacional, Lisboa, Portugal.
- *Muon detection in Auger with MARTA*
  presented by Bernardo Tomé
  Pierre Auger Collaboration Meeting — Malargüe, Argentina.
- *Muon trajectory reconstruction with MARTA and the SD tanks*
  presented by Ruben Conceição
  Pierre Auger Collaboration Meeting — Malargüe, Argentina.
- *Upgrade 2015: MARTA tests at Malargüe*
  presented by Bernardo Tomé
  Pierre Auger Collaboration Meeting — Malargüe, Argentina.
- *Status of R&D MARTA*
  presented by Bernardo Tomé
  Pierre Auger Collaboration Meeting — Malargüe, Argentina.
- *Measurement of the shape parameters of FD profiles*
  presented by Francisco Diogo
  Pierre Auger Collaboration Meeting — Malargüe, Argentina.

Seminars

- *Auger 2015 - My Vision*
  presented by Mário Pimenta
  — Physics Department, University of Santiago de Compostela .
- *Auger : Physics results and upgrade programme*
  presented by Mário Pimenta
  — LIP, Coimbra.

4.4.9 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)

4.4.10 Events

- *MPD Meeting*
  Collaboration Meeting, IST, Lisboa, 2013-01-17
- *3rd MARTA Progress Meeting*
  Collaboration Meeting, LIP, Lisboa, Portugal, 2013-06-01
- *Auger Analysis Meeting 2013*
  Collaboration Meeting, Biblioteca Nacional, Lisboa, Portugal, 2013-06-03
- *4th MARTA Progress Meeting*
  Collaboration Meeting, Biblioteca Nacional, Lisboa, Portugal, 2013-10-29

4.4.11 Project Summary

	number
Articles in international journals (with direct contribution from LIP members)	1
Articles in international journals (with indirect contribution from LIP members)	6
Collaboration notes with internal referee	8
Oral presentations in international conferences	3
Oral presentations in collaboration meetings	55
Seminars	2
Collaboration Meetings	4

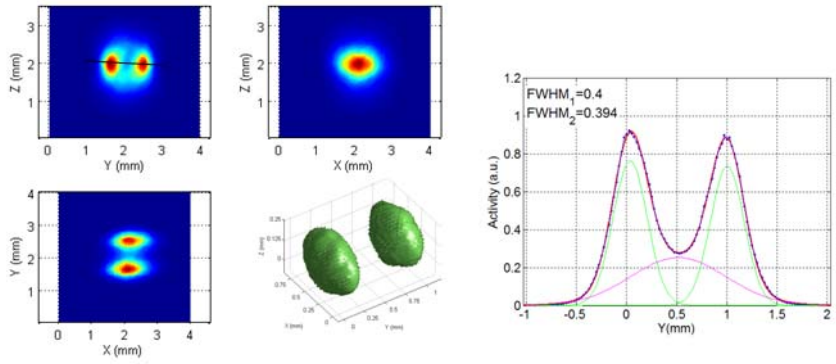
Chapter 5

Detector development for particle and nuclear physics

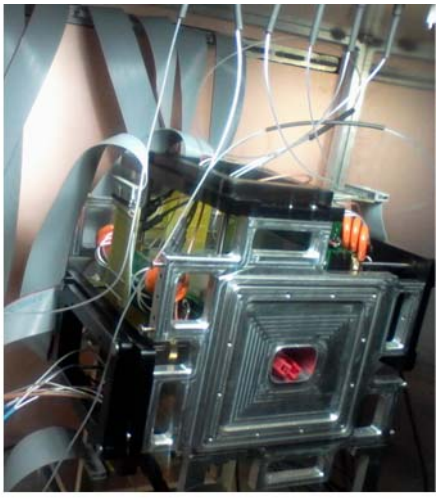
5.1 Participation in the RD51 Collaboration

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.



Left panel: joint MLEM reconstruction of the activity distribution of a quasi-puntual 22Na source in two positions separated by 1mm, along with the 50% relative activity isosurfaces.
Right panel: reconstructed activity profile along the line represented in the upper left figure, showing a 0.4 mm position resolution superimposed to a background.



Mice scanner in final geometry, almost finished

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

The responsibilities of LIP are in the following workgroups (WG) and tasks (T):

- Common Characterization and Physics Issues (WG2):
  - (T2) Discharge studies and spark-protection developments for MPGDs;
  - (T3) Generic aging and material radiation-hardness studies;
- Applications (WG3):
  - (T1) MPGD based detectors for tracking and triggering;
  - (T7) Medical imaging and diagnostics applications.

For WG2-T2 we will collaborate in the elaboration of a bibliographic review of the breakdown features of gaseous detectors, aiming at the publication of a CERN yellow report.
For WG2-T3, we will study the chemical properties of the polymerized material that is produced by the operation of detectors in fluorinated gases and will address the possibility of adding polymerization inhibitors to the gas mixture.
For WG3 we will develop patterned RPCs for two applications: TOFtracker (T1) and small-animal PET (T7). These detectors will be capable simultaneously of sub-millimetric localization accuracy and timing resolution below 100ps.
The TOFtracker device will be aimed at high-multiplicity tracking because it provides a 4th coordinate, time, which can be used to match the hits corresponding to the same track and its correlation with the beam hodoscope readings. This may be of use, for instance, for NA60-like experiments where the exquisite time resolution would help matching the pre-absorber to the post-absorber tracks, while reducing the combinatorial background.
The small animal RPC-PET will feature a world-leading image resolution of close to 0.5 mm FWHM (already demonstrated at small scale [BLA06]), largely dominated by physical limitations and not by instrumental effects. This will be achieved in a compact, low cost, instrument, benefitting from the simplicity of construction of RPCs.

[BLA06] A.Blanco, et al., "RPC-PET: A new very high resolution PET technology", IEEE Trans. Nucl. Sci.53 (2006) 2489-2494

5.1.4 Achievements

For WG-T1 we wrote a large review article, which was published in JINST plus two companion papers (see publications list).
For WG3-T3, strong progress was made in the implementation of the animal RPC-PET scanner.
Tests of a prototype comprising two detectors with X,Y information imaging a cylindrical 22Na source with 0.2 mm diameter yielded a MLEM-reconstructed position resolution of 0.4 mm FWHM without software enhancements. This is a world-class figure, a factor ≈2.5 times better than any known commercial scanner.
Similar tests with a planar source yielded a resolution of 0.5mm FWHM.
The construction of a full scanner is almost finished and it is expected for 2014 (see illustrating figure).
This work will be part of a PhD thesis to be submitted by Paulo Jorge Magalhães Martins to the University of Coimbra.

5.1.5 Sources of Funding

Code	Funding	Start	End
CERN/FP/123605/2011	50.000 €	2012-07-01	2014-06-30

5.1.6 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

5.1.7 Publications

Articles in international journals (with direct contribution from LIP members)

- *Liquid noble gas detectors for low energy particle physics*
  V. Chepel and H. Araujo
  JINST 8 (2013) R04001

- *Analytical calculation of the charge spectrum generated by ionizing particles in Resistive Plate Chambers at low gas gain*
  P.Fonte
  Journal of Instrumentation 8 (2013) P04017

- *Frequency-domain formulation of signal propagation in multistrip Resistive Plate Chambers and its low-loss, weak-coupling analytical approximation*
  P. Fonte

Journal Journal of Instrumentation 8 (2013) P08007

- *Survey of RPC simulation and modeling*
  P.Fonte
  Journal of Instrumentation 8 (2013) P11001

Articles in international journals (with indirect contribution from LIP members)

- *Development of a new generation of micropattern gaseous detectors for high energy physics, astrophysics and environmental applications*
  Peskov V., Di Mauro A., Fonte P., Martinengo P., Nappi E., Oliveira R., Pietropaolo P., Picchi P.
  Nucl. Instrum. and Meth. in Phys. Res. A 732 (2013) 255-259

5.1.8 Academic Training

PhD Theses

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

5.1.9 Project Summary

	number
Articles in international journals (with direct contribution from LIP members)	4
Articles in international journals (with indirect contribution from LIP members)	1

5.2 NeuLAND - An innovative high-energy neutron time-of-flight detector for experiments at GSI and FAIR

5.2.1 Resumo

O objectivo global deste projecto, desencadeado com vista ao futuro detector Neuland, para FAIR, é contribuir para o desenvolvimento de um novo conceito de sistema de detecção para neutrões com energia cinética da ordem de 1 GeV baseado em Câmaras do tipo RPC.
O conceito de design dos módulos RPC foi essencialmente criado durante o primeiro ano do projeto, através de estudos de simulação detalhados realizados por colaboradores da Universidade de Lisboa. Este estudo foi concluído na Primavera de 2012, permitindo a conclusão da construção do protótipo a tempo de ser testado no GSI, ainda no decorrer desse ano.
A partir daí decorreu, e prossegue ainda, a fase da análise dos dados e validação do novo conceito. Até agora comprovou-se uma resolução temporal de 140 ps (com uma precisão algo limitada pelo "jitter"no inal do neutrão) para energias entre 200 e 1500 MeV
A fase final da análise focar-se-á na avaliação da eficiência do detector, seguindo-se a comparação global dos resultados obtidos com as simulação anteriormente efectuadas.

5.2.2 Abstract

The global aim of this project, triggered by the future NeuLAND detector, is to contribute to the development of a new concept of detection system based on RPC for neutrons with kinetic energy of the order of 1 GeV.
The design concept of the RPC modules was essentially established during the first year of the project, through a detailed simulation study carried out by our Lisbon collaborators. This study was finished already in spring 2012, allowing for the completion of the prototype construction for the tests at GSI.
Indeed, the prototypes were built in Coimbra during 2012, in time for the test beam period at GSI (experiment S406 "Characterization of NeuLAND prototypes and the LAND detector using fast monoenergetic neutrons"), in which the performance of the constructed modules has been checked, in November.
The final evaluation of results, already under way, will be accomplished during the third year of the project which ends mid 2014.

5.2.3 Objectives

The prototypes were built in Coimbra in 2012, tested and sent to GSI in time for the test beam period (experiment S406 "Characterization of NeuLAND prototypes and the LAND detector using fast monoenergetic neutrons"), in November, during which the performance of the several different modules has been checked .
During 2013, the evaluation of data will be made and final assessment will be accomplished during the first semester of 2014.

5.2.4 Achievements

The data analysis was far from a simple exercise, requiring the compehesion of the full set-up.
The first results on time resolution were presented on a Collaboration Meeting at GSI, in spring 2013. It became clear that the data were not understood by different groups participating in this test experiment S406 (several detectors were under test) due to some problem in the data acquisition chain.
Some further efforts were made by our team, revealing that the problem did not actually affect te measurements with our prototype. The analysis was further refined by comparing data with protons and with neutrons, thus performing a full calibration of the detector and electronics.
As for results, we obtained 140 ps for the whole detector area, for neutrons of 200 to 1500 MeV. An abstract has been submitted in December 2013 to the RPC workshop 2014, to be held in Beijing in February 2014.

5.2.5 Sources of Funding

Code	Funding	Start	End
PTDC/FIS/114876/2009	99.589 €	2011-01-01	2014-06-30

5.2.6 Team

Project coordinator: Rui Marques

Name	Status	FTE %
Alberto Blanco	Researcher (LIP)	30
Carlos Silva	Technician (LIP)	15
Joaquim Oliveira	Technician (LIP)	20
Luís Lopes	Technician (LIP)	30
Nuno Carolino	Technician (LIP)	15
Nuno Filipe Silva Dias	Technician (LIP)	20
Orlando Cunha	Technician (LIP)	15
Paulo Fonte	Researcher (LIP/ISEC)	15
Ricardo Caeiro	Technician (LIP)	15
Rui Alves	Technician (LIP) *	15
Rui Marques	Researcher (LIP/FCTUC)	25

5.2.7 Publications

Articles in international journals (with direct contribution from LIP members)

- *Simulations of a new detection concept for high-energy neutrons based on timing RPCs* Machado J., Blanco A., Fonte P., Galaviz D., Lopes L., Ferreira Marques R., Teubig P. Journal of Instrumentation 8 (2013) P07020

5.2.8 Project Summary

	number
Articles in international journals (with direct contribution from LIP members)	1

5.3 Microstructure Gas Detectors

5.3.1 Resumo

Este relatório deveria cobrir três áreas de trabalho do grupo anteriormente envolvido nos projetos historicamente relacionados com detectores gasosos e de microestrutura no LIP - a câmara Anger gasosa, a detecção de neutrões e o desenvolvimento de detectores gasosos para aplicações específicas. Devido a alterações na organização do grupo o primeiro tópico é relatado no projecto Câmaras Anger.
As outras duas actividades incluem o desenvolvimento de detectores de neutrões alternativos ao 3He usando conversores sólidos e a tecnologia dos detectores de placa resistiva, bem como o desenvolvimento de uma câmara de ionização cilíndrica de fluxo de gás para uso em tomografia com microssonda nuclear com discriminação em profundidade (STIM-T).

5.3.2 Abstract

This report should cover three areas of work of the group involved in former projects historically related to gaseous and micropattern detectors in LIP - the gaseous Anger camera, the neutron detection and the development of specific gaseous detectors. Due to organizational changes the first subject is reported in the project Anger Cameras.
The other two activities include the development of 3He alternative neutron detectors using solid converters and resistive plate technology, as well as the development of a gas flow cylindrical ionization chamber for use with on-axis scanning transmission ion microscopy tomography (STIM-T).

5.3.3 Objectives

One of the main objectives was keeping alive the project we had unsuccessfully submitted to FCT "Boron coated RPCs for thermal neutron detectors"EXCL/FIS-NUC/0389/2012, advancing with the tasks that could be carried on with small funds, and preparing for a new call, in collaboration with teams formerly involved on FP6 and FP7.
In another area we want to develop a gas flow cylindrical ionization chamber for use with on-axis scanning transmission ion microscopy tomography (STIM-T)in close collaboration with the Campus Tecnologico Nuclear of Intituto Superior Técnico. Scanning transmission ion microscopy (STIM) is a non-destructive technique that relies on measuring the energy losses of MeV ions of a highly focused beam scanned across very thin samples in a microprobe. The entrance window is composed of a square silicon nitride membrane 100 nm thick and 1 mm2 in area. The use of this type of window combined with low noise electronics shows good energy resolution with the 2 MeV H+ and He+ particles used in STIM experiments, allowing to take full advantage of the insensitivity of these detectors to radiation damage. The concept of a gas ionization chamber has proven to be ideal for on-axis STIM due its radiation hardness, speed and suitable energy resolution.

5.3.4 Achievements

A reformulated project "Development of Novel Detector Technologies for Large Area Neutron Detectors "was presented to the 2013 FCT call and was awarded a FCT «exploratory project» contract in value of 32 keuros, starting in March 2014. We have been working on the deposit of B4C layers in close collaboration with Engineering Surfaces Group at University of Coimbra Mechanical Engineering Research Center the and two RPC prototype detectors, one coated with non enriched common 10B0 and one un-coated that are ready for tests with cosmic rays and neutrons. The acquisition system with localization capabilities, needed for this project was studied, and will be bought as soon as funds are available. The team is now applying foran EoI for neutron detector development in Horizons 2020, in cooperation with the leading European institutes having neutron facilities.
The first prototype of the gas flow cylindrical ionization chamber for use with on-axis scanning transmission ion microscopy tomography (STIM-T)was built for detecting protons and He+ ions in the 0.5-3 MeV range at counting rates of $\approx$ 104 Hz/mm2. Some gas fillings have already been tested (pure isobutane and He/iC4H10 mixtures) and as well as two different electric field configurations. Preliminary results have shown that is possible, under the right conditions, to obtain resolutions comparable to those obtained with the Si surface barrier (SSB) detector, revealing the usefulness of this prototype for future tomography experiments. Its ability to withstand direct beam hit without significant loss of resolution clearly outperforms the more standard use of Si diodes.

A drawback of the current prototype was the distance between the sample and the detector window. Thus, a new prototype was designed and built, the next tests being foreseen for early 2014. These tests also include the study of the performance of the detector with different wire diameters.

5.3.5 Team

Project coordinator: Francisco Fraga

Name	Status	FTE %
Andrey Morozov	Researcher (LIP)	50
Francisco Fraga	Researcher (LIP/FCTUC)	50
Luís Pereira	PhD student (LIP)	100
Margarida Fraga	Researcher (LIP/FCTUC)	10
Paulo Mendes	Researcher (LIP/FCTUC)	20
Rui Marques	Researcher (LIP/FCTUC)	10

5.3.6 Publications

Articles in international journals (with direct contribution from LIP members)

- *New gas detector setup for on-axis STIM tomography experiments*
  A.C. Marques, M.M.F.R. Fraga, P. Fonte, D.G. Beasley, L.C. Alves, R.C. Da Silva
  Nucl. Instrum. and Meth. in Phys. Res. B 306 (2013) 104-108

Articles in international journals (with indirect contribution from LIP members)

- *Adaptive algorithms of position and energy reconstruction in Anger-camera type detectors: experimental data processing in ANTS*
  A. Morozov et al. (23 authors)
  J. Instrum. 8 (2013) P05002

- *Effective decay time of CF4 secondary scintillation*
  L. M. S. Margato, A. Morozov, M. M. F. R. Fraga, L. Pereira, F. A. F. Fraga
  J. Instrum. 8 (2013) P07008

5.3.7 Academic Training

PhD Theses

- *Gaseous Anger Camera Emulation*
  Luís Pereira, (on-going)

5.3.8 Project Summary

	number
Articles in international journals (with direct contribution from LIP members)	1
Articles in international journals (with indirect contribution from LIP members)	2

5.4 High Pressure Xenon Doped Mixtures for the NEXT Collaboration

5.4.1 Resumo

O objectivo da experiência NEXT é a detecção do deacimento beta duplo sem neutrinos do Xe-136 (para determinar se o neutrino é uma partícula Majorana) através da identificação do pico no final do espectro de decaimento beta duplo e, simultaneamente, medir a vida média do decaimento.
Há um conjunto de assuntos ainda a esclarecer, alguns dos quais foram atribuídos à nossa equipa. Um deles é a questão de escolher entre Xe puro, para o qual o tracking dos electrões é limitado por baixas velocidades de deriva e elevados coeficientes de difusão, e Xe dopado com gases moleculares como TMAE, CH4, CF4, N2 ou outros gases cuja adição pode aumentar a velocidade de deriva e minimizar a difusão e eventualmente agir como conversor de corrente de comprimento de onda, sem, no entanto comprometer significativamente o rendimento de electroluminescência (EL) e suas flutuações, comparadas com xénon puro.
Coeficientes de difusão baixos e elevadas velocidades de deriva, são altamente desejáveis já que os electrões vão deslocar-se grandes distâncias de deriva (1m) até chegar á região de electroluminescência da TPC. Baixa taxa de recombinação e de "attachment"são também desejáveis e terão de ser avaliados. Foi projectado um sistema que albergará os dois detectores que trabalharão em paralelo permitindo confirmação independente dos fenómenos observados.

5.4.2 Abstract

The goal of the NEXT experiment is the detection of the neutrinoless double beta decay of Xe-136 (to find out whether the neutrino is a Majorana particle) by searching for a peak at the end of the double beta decay spectrum, and measure at the same time the half-life of the decay.
There are a number of still open issues, some of which have been assigned to this team. One of them is the question of choosing between pure Xe, where tracking of the electrons is limited by low drift velocities and large diffusion coefficients, and Xe doped with molecular gases like TMAE, CH4, CF4, N2 or other gases, whose addition may improve electron drift velocity and minimize electron diffusion, and eventually act as a wavelength shifter without jeopardizing electroluminescence (EL) yields and their fluctuations compared to pure Xe.
Low electron diffusion coefficients and high electron drift velocities are required, because electrons will travel long drift distances (about 1m) until reaching the EL region of the TPC. Low electron attachment by the admixture is an important additional requisite and needs also to be assessed. We have projected a system where two detectors will be connected. These detectors will work in parallel allowing for an independent cross checking of the phenomena observed.

5.4.3 Objectives

Having previously assembled and tested the gas system and test detectors,the objectives for this final period of the project were to finish all the experiments proposed, with the aim of assessing the influence of the very low concentration of molecular additive on the scintillation yield at different total gas pressures.
Molecular additives considered: CF4, CH4 and TMA.
In order to have a guideline, the first gas to be tested is CH4, whose behaviour at moderate concentrations is known; CF4 will follow and in the end TMA.

5.4.4 Achievements

During 2013 detector tests were finished and best possible working conditions established, namely reducing the noise levels.
Scintillation and charge multiplication data were acquired in xenon based mixtures with molecular gases (CF4 and CH4) at 1 and 2 atmospheres. As the mixtures had experimentally unknown characteristics, it took some time to optimize the best working voltages, i.e., those yielding the best possible energy resolution in each case. The behavior of these mixtures regarding energy resolution was investigated in the best working conditions, as a function of the additive concentration.
REached the end of the project, the work from Summer onwards had the support of the QREN project "Rad for Life"for technicians´ and student´s grants.

5.4.5 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

5.4.6 Publications

Articles in international journals (with direct contribution from LIP members)

- *Radiopurity control in the NEXT-100 double beta decay experiment: procedures and initial measurements*
  Next collaboration team
  JINST- J. of Instrumentation, vol. 8, T01002, 2013

- *Operation and first results of the NEXT-DEMO prototype using a silicon photomultiplier tracking array*
  Next Collaboration Team
  JINST 8 (2013) P09011

- *Near-Intrinsic Energy Resolution for 30 to 662 keV Gamma Rays in a High Pressure Xenon Electroluminescent TPC*
  Next Collaboration team
  Nucl. Instr. and Meth. in Physics Research A 708 (2013) 101–114

5.4.7 Presentations

Oral presentations in international conferences

- *Noble gas electroluminescence: work at Coimbra*
  presented by Filomena Santos
  Advances on neutrino technology — Tahoe City, Lake Tahoe, U.S.

5.4.8 Events

- *NEXT Collaboration Meeting*
  Collaboration Meeting, Canfranc, espanha, 2013-05-26

- *NEXT Collaboration Meeting*
  Collaboration Meeting, Valencia, Espanha, 2013-11-21

5.4.9 Project Summary

	number
Articles in international journals (with direct contribution from LIP members)	3
Oral presentations in international conferences	1
Collaboration Meetings	2

5.5 Ion Transport Processes in Gaseous Detectors for Particle Physics

5.5.1 Resumo

O estudo do transporte de iões em gases continua a ser um tema com muito interesse para diversas áreas, 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. Geralmente, é apenas considerado um único tipo de ião, mas muitas vezes, 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.
O presente projecto tem duas componentes principais:

1. Cálculo teórico de secções eficazes integrais e diferenciais de colisão elástica ião-átomo/molécula e cálculo dos parâmetros de transporte dos iões utilizando técnicas de Monte Carlo.

2. Medida experimental da mobilidade de iões positivos, resultantes da ionização de gases puros ou misturas de gases, para diferentes pressões e campos eléctricos reduzidos, E/N, utilizando um sistema experimental anteriormente concebido e construído por investigadores da equipa do projecto.

No que diz respeito aos cálculos teóricos, e na sequência do trabalho anteriormente realizado por investigadores da equipa para gases nobres, foram estendidos estes cálculos a moléculas orgânicas com interesse para detectores para física das altas energias tais como o CH4. As secções eficazes, integrais e diferenciais, de colisão elástica foram calculadas 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. As secções eficazes foram calculadas para energias, no centro de massa, entre 0.001 e 10 eV, para a colisão de iões CH4+ com átomos neutros de Ar e moléculas neutras de CH4. Estas secções eficazes foram 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.
O sistema experimental utilizado na medida de mobilidades iónicas de iões positivos no próprio gás é baseado em técnicas originais desenvolvidas por investigadores da equipa. Uma lâmpada VUV de Xe pulsada liberta electrões da superfície de um foto-cátodo de CsI depositado num GEM, electrões esses que ao colidir com os átomos do gás produzem os iões positivos a estudar. Os iões 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. O sistema experimental foi usado para medir as velocidades de deriva de iões positivos presentes em misturas gasosas do tipo gás nobre/ gás molecular utilizadas em detectores para física das altas energias (nomeadamente Ar/CH4 e Ar/C2H6) e quando possível para identificar esses iões.

5.5.2 Abstract

The study of the transport of ions in gases is subject of great interest in many fields, like the field of gaseous radiation detectors, namely high energy physics detectors. Indeed, for 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. Usually, only one type of drifting ion is considered, but often 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.
The present project consists of two main parts:

1. Theoretical calculations of low energy ion-atom/molecule elastic scattering cross sections and calculation of ion transport parameters using Monte Carlo techniques.

2. Experimental measurement of the mobility of positive ions resulting from the ionization of pure gases or gas mixtures, for different values of pressure and reduced electric field, E/N, using an experimental system previously designed and constructed by researchers of the team.

Concerning the theoretical calculations, we have continued the work carried out before by the researchers of the team for noble gases and extend it to organic molecules of interest for high energy physics detectors like

CH4. The differential and integral elastic collision cross sections were calculated by the partial waves method, with phase-shifts calculated using the JWKB approximation and interaction potentials derived from literature searches or theoretical models. The cross-sections were calculated for centre-of-mass energies in the 0.001 eV to 10 eV range, for the elastic collision of CH4+ ions with neutral Ar atoms and neutral molecules of CH4. These cross-sections were 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.
The experimental system used to measure the mobilities of positive ions in their parent gases is based on original techniques developed by researchers of the team. A pulsed Xe UV lamp releases photoelectrons from a CsI covered GEM which start an avalanche producing a variety of positive ions, in an amount and in a variety that depends on the GEM applied voltage, that 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. The experimental system were used to measure the drift velocities of the positive ions present in gaseous mixtures like noble gas/ organic gas mixtures used in high energy physics detectors (namely Ar/CH4 and Ar/C2H6) and whenever possible their identification.

5.5.3 Objectives

This project consists of two main parts:

1. Theoretical calculations of low energy ion-atom/molecule elastic scattering cross sections and Monte Carlo calculation of ion transport parameters.

2. Experimental ion mobility measurements in different noble gas/organic gas mixtures with interest for high energy physics detectors and, whenever possible, the identification of the different ions present.

5.5.4 Achievements

During the year of 2013 the following tasks were carried out:

- Theoretical calculations of low energy integral and differential cross-sections for elastic collisions of CH4+ ions with argon atoms.

- Experimental ion mobility measurements of the ions originated in Ar/C2H6 mixtures and in Ar/CH4 mixtures for different values of pressures and reduced electric yields. Data taking, analysis and interpretation.

The experimental study of the mobility of ions originated in ethane (C2H6) in their parent gas were made for pressures ranging from 6 to 10 Torr and for reduced electric fields varying from 6 to 42 Td. The time of arrival spectra revealed two peaks. Considering the corresponding reduced mobilities values extrapolated to zero-field (E/N=0) in C2H6 and the reaction rates of the ions initially formed in the GEM, the first peak of the spectra are likely to belong to a 3-carbon ions group which includes C3H5+, C3H7+, C3H8+ and C3H9+ and the second to a 4-carbon ions group which includes C4H9+/C4H10+ ions with similar mobility values. These works led to a paper published in Journal of Instrumentation.
The experimental study of the mobility of ions in Ar/C2H6 gaseous mixtures was completed. Measurements were made for pressures ranging from 6 to 10 Torr and for reduced electric fields in the 10 Td to 25 Td range, at room temperature. For Ar concentrations below 80% two peaks were observed in the time of arrival spectra which were attributed to ion species with 3-carbons (C3H7+, C3H8+ and C3H9+) and with 4-carbons (C4H7+, C4H9+, C4H10+ and C4H12+ ions). For Ar concentrations above 80% a third peak appears which may belong to C5H11+. These works led to a paper published in Journal of Instrumentation.
Experimental studies on the ionic mobility of positive ions formed in Ar/CH4 gaseous mixtures for pressures between 5 and 8 Torr and reduced electric fields between 17 Td and 43 Td at room temperature were performed. The time of arrival spectra of the several mixture ratios studied revealed that the number of peaks displayed depends on the mixture ratios. For CH4 concentrations in the 2.5-10.0% range three well defined peaks were observed which were attributed to single-carbon ions (CH5+), 2-carbon ions (C2H4+ and C2H5+) and 3-carbon ions (C3H7+). An article concerning these studies was already submitted for publication.

5.5.5 Sources of Funding

Code	Funding	Start	End
CERN/FP/123613/2011	10.000 €	2012-03-12	2013-12-31

5.5.6 Team

Project coordinator: João Barata

Name	Status	FTE %
Alessio Mangiarotti	Researcher (LIP/USP)	17
Alexandre Fonseca Trindade	Master (LIP)	40
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

5.5.7 Publications

Articles in international journals (with direct contribution from LIP members)

- *Experimental measurement of the mobility of ions originated in ethane in their parent gas*
  A. F. V. Cortez, A. N. C. Garcia, P. N. B. Neves, F. P. Santos, F. I. G. M. Borges, J. A. S. Barata and C. A. N. Conde
  Journal of Instrumentation 8 P07013

- *Experimental Ion Mobility measurements in Ar-C2H6 mixtures*
  A. F. V. Cortez, A. N. C. Garcia, P. N. B. Neves, F. P. Santos, F. I. G. M. Borges, J. A. S. Barata and C. A. N. Conde
  JINST 8 P12012

5.5.8 Project Summary

	number
Articles in international journals (with direct contribution from LIP members)	2

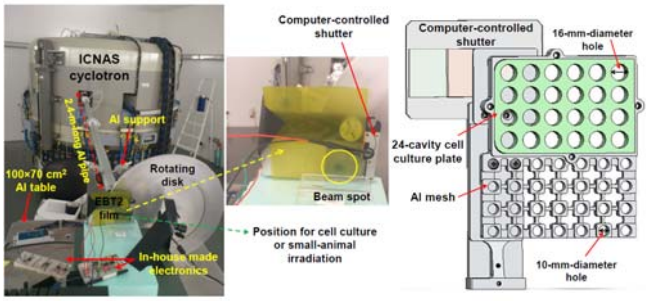
5.6 Beam Monitoring System for Cyclotron Proton Beams at ICNAS

5.6.1 Resumo

Neste projeto o grupo do LIP colabora com o ICNAS, instituto da Universidade de Coimbra que alberga o ciclotrão acelerador de protões para aplicações em medicina nuclear. A colaboração já alcançou bastantes dos 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 compreendidas entre o cGy 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 previstos 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.

5.6.2 Abstract

The group at LIP develops this project in collaboration with ICNAS, the structure belonging to 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



Photograph showing the out-of-yoke proton beam setup and the location for controlled irradiation of multi-well grown cell cultures.

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.

5.6.3 Objectives

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.

5.6.4 Achievements

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.

5.6.5 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

5.6.6 Publications

Articles in international journals (with direct contribution from LIP members)

- *On-line measurements of proton beam current from a PET cyclotron using a thin aluminum foil*
  S. Ghithan, S.J.C do Carmo, R. Ferreira Marques, F.A.F Fraga, H. Simões, F. Alves, P. Crespo
  JINST 8 P07010

International Conference Proceedings

- *Fast and precise verification of proton beam position, range, and dose by using a plastic scintillator at PET-dedicated cyclotrons*
  S. Ghithan, S.J.C. do Carmo, F. Alves, R. Ferreira Marques, F. Fraga, H. Simões, P. Crespo
  (accepted)

5.6.7 Presentations

Poster presentations in international conferences

- *Fast and precise verification of proton beam position, range, and dose by using a plastic scintillator at PET-dedicated cyclotrons*
  presented by Paulo Crespo
  2013 IEEE Nucl. Sci. Symp. & Med. Imag. Conf. — Seoul.

Presentations in national conferences

- *Study and development of a setup for proton radiobiology and radiophysiology with doses ranging from 100 Gy down to 100 mGy*
  presented by Sharif Ghithan
  I Encontro Nacional de Física Médica e Engenharia Biomédica — Lisbon (PIO-Lisboa).

5.6.8 Academic Training

PhD Theses

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

5.6.9 Project Summary

	number
Articles in international journals (with direct contribution from LIP members)	1
International Conference Proceedings	1
Poster presentations in international conferences	1
Presentations in national conferences	1

5.7 Detector Lab / Mechanical Workshop

5.7.1 Objectives

During this year the Mechanical Workshop and Detector Lab should stabilize their present capabilities, thus strengthening their recognition in the research community.
They should respond in an efficient way and in due time to the needs of the LIP research teams for technical support.
The Mechanical Workshop and Detector Lab should also collaborate with other Portuguese R&D units. Since they are installed in premises of the University of Coimbra, their close collaboration with units of the UC is not just natural but also recognized as very important by several such units, themselves, and by the University. This is particularly true for the Physics Department.
The international recognition should continue to be regarded as very important. Therefore, any orders coming from abroad, most probably from Collaborations in which LIP is involved, besides of any possible economical meaning (probably small), should be regarded as very important indicators of the technical quality achieved.

5.7.2 Achievements

Detector Lab
- Construction of RPC prototypes for the Auger upgrade, including gas system and high voltage supply, and their deployment at Malargue; project of the full RPC telescope for the Brazilian Auger team and a similar one for LABCAF, Universidade de Santiago de Compostela.
- Construction of prototype Animal RPC-PET (12 units of the sensitive module), already under test. Design of improved front-end electronics.
- Construction of first RPC prototype for thermal neutron detectors.
- Construction of a gaseous ionization chamber for on-axis Scanning Transmission Ion Microscopy (STIM) experiments, at ITN-IST.
- Transport and set-up of a gamma camera from ICNAS to LIP.

Construction of one Spark Chamber unit and one cloud chamber prototype (reduced size).
Mechanical Workshop
The numerous items and tasks carried out by the workshop during 2013 are listed in the next table. It is visible that it is an essential infrastructure for the current R&D activitis of LIP, but also a very important one for other units, mostly at the University of Coimbra (UC) and, very especially, for its Physics Department (DF - UC).

Institute	Project / Group	# orders
LIP-C	Animal RPC-PET	5
LIP	Auger	4
LIP-C	Cloud Ch.	1
LIP-C	Cycl.Beam	5
LIP-C	Det	6
LIP-C	Hades	1
LIP-C	Human RPC-PET	1
LIP-C	HP-Xe	8
LIP-C	LUX	5
LIP-C	Manut	6
LIP-C	RT-Mon	2
LIP-C	spark	2
LIP	ATLAS	5
LIP	Med	2
LIP	SNO+	3
Other institutions		
DF - UC	Aulas	5
DF - UC	Biofisica	2
DF - UC	CEMDRX	17
DF - UC	Olimpíadas	1
DEEC		1
DEM UC		1
DEQ - UC		3
DQ - UC		2
ICNAS - UC		2
IMAR		1
ISR		1
ISEC		2
IST		1
ITN		1
Palbit		1
ISICOM		2

Following the assignment of the design and construction of the new source deployment system of SNO+ to our workshop, under a contract with the Collaboration, the design phase took place during 2013.
Some tests have also been performed in our machine tools for outside companies.

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 Achievements

Technologies developed by LIP for the CMS experiment at LHC/CERN were used to develop a new PET scanner for the detection of breast cancer. PET is the medical imaging modality of reference for cancer diagnosis. However commercial whole-body PET scanners have insufficient image resolution ($>$ 5mm) and sensitivity ($\approx$1%) for the detection of breast cancer in the early stage of growth. The ClearPEM scanner fully developed in Portugal improves significantly these two parameters (image resolution of 1.5 mm), allowing the detection of small tumors with reduced radiation doses.
The technology has been demonstrated in clinical trials. A ClearPEM scanner was built and installed at ICNAS Faculty of Medicine Coimbra. A second scanner (ClearPEM-Sonic) was in operation at the Univ. Hospital Nord, Marseille. Several cases of cancerous tumors not detected by the whole-body PET were identified by the ClearPEM. The clinical evaluation program is now being pursued at Ospedale San Gerardo, Monza, Italy. The two scanners are now being used in the clinical study of new radiotracers: [18F] fluorothymidine (FLT), a novel biomarker for imaging cellular proliferation, at Ospedale San Gerardo; and [18F] fluoroestradiol (FES), a radio-ligand used to quantify estrogen receptors in breast carcinomas, at ICNAS, Coimbra. These new PET tracers have large potential for accurate tumor staging, follow up of therapies and early detection of breast cancer.
Relative to whole-body PET, dedicated Positron Emission Mammography is expected to improve significantly the sensitivity to breast cancer in particular to small tumors. The new equipment has an image resolution of the order of 1.5 mm and a very high data acquisition rate, improving the detectability of small tumors. The performance of the scanner allows to reduce the injected doses and to shorten considerably the examination time, when compared to the present PET exams.
The standard techniques widely used in breast cancer screening are X-rays mammography and ultra-sound imaging. Unfortunately, the sensitivity of the techniques is insufficient in many cases. The ClearPEM is expected to be complementary of these diagnosis tools. We foresee its application in routine breast cancer screening in risk populations, in the exam of patients with inconclusive results of other modalities, and in the post-surgery follow-up of patients for early detection of breast cancer recurrence.
The ClearPEM scanner is a unique medical instrument worldwide. It was the first clinical PET scanner exploiting solid-state photo-sensors (avalanche photodiodes-APD). A dedicated low-noise and low-power integrated circuit (ASIC) in CMOS 250 nm technology was developed to read the signals of LYSO crystals coupled to APD arrays. It allowed the highest integration density ever achieved in PET scanners permitting the use of the double-readout technique for Depth-of-Interaction (DoI) measurement and eliminating the parallax effect in the PET images.
These features make the ClearPEM scanner also suitable for high-resolution PET imaging of small animals. PET images of mice with implanted cancer tumors were successfully done at ICNAS Coimbra, as well as several other small animals studies in collaboration with bio-medical research groups, demonstrating the high performance of the ClearPEM scanner for this application. A plan to adapt and use the available scanner as a national infrastructure for small animal PET imaging is under discussion.
Strong of this experience, the LIP/STCD group was invited to join the EndoTOFPET European project aiming the diagnosis of pancreatic and prostate cancer, and to lead the development of the electronics and data acquisition systems. The experience of the group with APDs was instrumental in exploiting a new solid-state technology for photon detection (Silicon Photomultiplier) with the goal of achieving time resolution in Time-of-Flight PET of 200 ps FWHM. This excellent time resolution, allowing large gains in PET sensitivity, is obtained with Silicon Photomultipliers associated to high-precision integrated Time Digital Converts (TDC). In this context, the LIP/STCD group developed a new 64-channel ASIC in CMOS 130 nm technology integrating low-power TDCs with 25 ps r.m.s. intrinsic time resolution. This chip permits today the most advanced electronics for crystal-based PET Time-of-Flight.

6.1.4 Sources of Funding

Code	Funding	Start	End
Endo TOFPET-US256984	509.400 €	2011-01-01	2014-12-31
PicoSEC-MCNet (289355)	423.082 €	2012-01-01	2015-12-31

6.1.5 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
Manuel Rolo	PhD student (LIP)	80
Ricardo Bugalho	PhD student (LIP)	100
Rui Pereira da Silva	Technician (LIP)	100
Stefaan Tavernier	Researcher (LIP)	21
Tahereh Niknejad	PhD student (LIP)	17
Viesturs Veckalns	PhD student (LIP)	100

6.1.6 Publications

Articles in international journals (with direct contribution from LIP members)

- *Detection sensitivity and light collection studies of an APD-based high packing-fraction LYSO:Ce matrix for PET applications*
  V. Veckalns, R. Bugalho, R. Silva, J.A. Neves, S. Tavernier, C. Zorraquino, C. Ortigão, M. Rolo, J.C. Silva, J. Varela
  NIM A,Volume 732, 2013, Pages 607-610

- *EndoTOFPET-US: A novel multimodal tool for endoscopy and positron emission tomography*
  N. Aubry et al. (EndoTOFPET-US Collaboration)
  Journal of Instrumentation Volume 8, Issue 4, April 2013, Article number C04002

- *Feasibility and electromagnetic compatibility study of the ClearPEM frontend electronics for simultaneous PET-MR imaging*
  J.A. Neves, R. Bugalho, R. Gruetter, A.W. Magill, C. Ortigão, J.C. Silva, R. Silva, J. Varela
  10.1016/j.nima.2012.08.033

- *9.4-14.1 T small-animal PET-MR imaging: Feasibility analysis of LYSO APD readout via long signal lines*
  J.A. Neves, R. Bugalho, R. Gruetter, A.W. Magill, C. Ortigão, J.C. Silva, R. Silva, J. Varela
  10.1016/j.nima.2012.08.032

- *TOFPET ASIC for PET applications*
  M D Rolo, R Bugalho, F Gonçalves, G Mazza, A Rivetti, J C Silva, R Silva and J Varela
  M D Rolo et al 2013 JINST 8 C02050

International Conference Proceedings

- *A 64-channel ASIC for TOFPET applications*
  M D Rolo, R Bugalho, F Gonçalves, G Mazza, A Rivetti, J C Silva, R Silva and J Varela
  M D Rolo et al., NSSMIC 2012 Conf. Proc

- *EndoTOFPET-US data acquisition system*
  R Bugalho, C Gaston, M D Rolo,, J Carlos Silva, R Silva and J Varela
  Journal of Instrumentation Volume 8, Issue 2, February 2013, Article number C02049

- *EndoTOFPET-US DAQ, designing the Data Acquisition System of a High Resolution Endoscopic PET-US Detector*
  Carlos Zorraquino, Ricardo Bugalho, Manuel Rolo, Jose Carlos Silva, Viesturs Veckalns, Rui Silva, Catarina Ortigão, Jorge Neves, Stefaan Tavernier and João Varela
  NSSMIC 2013 Conf. Proc

- *EndoTOFPET-US a High Resolution Endoscopic PET-US Scanner used for Pancreatic and Prostatic Clinical Exams*
  C. Zorraquino on behalf of EndoTOFPET-US collaboration
  Mediterranean Conference on Medical and Biological Engineering and Computing, 2013, Sevilla SP

6.1.7 Presentations

Oral presentations in international conferences

- *Integrated Circuit Design for Time-of-Flight PET with Silicon Photomultiplier*
  presented by Manuel Rolo
  TREDI 2013: 8th "Trento"Workshop on Advanced Silicon Radiation Detectors (3D and p-type) — Trento, Italy.

- *Development and Performance Evaluation of a Simultaneous PET-MR Detector based on the ClearPEM Technology*
  presented by Jorge Neves
  13th Vienna Conference on Instrumentation — Vienna, Austria.

- *TOFPET ASIC: a low-power 64-channel mixed-mode IC for SiPM readout*
  presented by Manuel Rolo
  Fast Timing Workshop — Erice, Italy.

Poster presentations in international conferences

- *EndoTOFPET-US DAQ, designing the Data Acquisition System of an Endoscopic PET-US Detector*
  presented by
  3rd EIROforum School of Instrumentation — Geneve, Switzerland.

- *Development and Performance Evaluation of a Simultaneous PET-MR Detector based on the ClearPEM Technology*
  presented by Jorge Neves
  PSMR 2013 / 4th Jülich MR-PET Workshop — Aachen, Germany.

- *WP3 : Electronics & Data Acquisition*
  presented by
  PICOSEC Mid Term Review — Heidelberg, Germany.

- *EndoTOFPET-US a High Resolution Endoscopic PET-US Scanner used for Pancreatic and Prostatic Clinical Exams*
  presented by
  XIII Mediterranean Conference on Medical and Biological Engeneering and Computing — Sevilla, Spain.

- *EndoTOFPET-US DAQ, designing the Data Acquisition System of a Hi gh Resolution Endoscopic PET-US Detector*
  presented by
  2013 IEEE Nuclear Science Symposium and Medical Imaging Conference — Seoul, Korea.

Oral presentations in international meetings

- *Results from the TOFPET ASIC*
  presented by Manuel Rolo
  International Workshop on Real time, self triggered front end electronics for multichannel detectors — Torino, Italy.

Oral presentations in collaboration meetings

- *Data Acquisition System Overview & Development Status*
  presented by
  PicoSEC General Annual Meeting — Munich, Germany.
- *The TOFPET chip: a time based readout for radiation detectors*
  presented by Manuel Rolo
  Panda Front-End and DAQ Workshop — Alba, Italy.
- *TOFPET ASIC Status Report*
  presented by Manuel Rolo
  EndoTOFPET-US Collaboration Meeting — Geneve, Switzerland.
- *Data Acquisition System Overview & Development Status*
  presented by
  EndoTOFPET general meeting — Geneve, Switzerland.
- *Acquiring not only knowledge*
  presented by
  PICOSEC Mid Term Review — Heidelberg, Germany.

Seminars

- *Front-end electronics for Time-of-Flight applications*
  presented by Manuel Rolo
  DATA driven FEE for time and energy measurement with highly segmented detector — Torino, Italy.

6.1.8 Academic Training

PhD Theses

- *Estudo do tomógrafo Clear-PEM no diagnóstico do cancro da mama*
  Cláudia Sofia Ferreira, (on-going)
- *Development and evaluation of combined PET-MRI imaging*
  Jorge Neves, 2013-07-01
- *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)

6.1.9 Project Summary

	number
Articles in international journals (with direct contribution from LIP members)	5
International Conference Proceedings	4
Oral presentations in international conferences	3
Poster presentations in international conferences	5
Oral presentations in international meetings	1
Oral presentations in collaboration meetings	5
Seminars	1
PhD Theses	1

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.

New front-end board for timing measurements with 8 channels and allowing very low thresholds was successfully developed and tested in the electrical mockup.

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.
[BLA03] Perspectives for positron emission tomography with RPCs, Blanco, A; Chepel, V; Ferreira-Marques, R; Fonte, P; Lopes, M.I; Peskov, V; Policarpo, A., Nucl. Instrum. and Meth. A 508 (2003) 88-93.
[COU07a] RPC-PET status and perspectives, M.Couceiro, A.Blanco, Nuno C.Ferreira, R.Ferreira Marques, P.Fonte, L.Lopes., Nucl. Instrum. and Meth. A 580 (2007) 915-918.
[CRE09] Whole-body single-bed time-of-flight RPC-PET: simulation of axial and planar sensitivities with NEMA and anthropomorphic phantoms, P. Crespo et al., 2009 IEEE Nuclear Science Symposium Conference Record (NSS/MIC), Jan 2010, Page(s): 3420 - 3425
[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

To develop a full-size prototype that will demonstrate scientifically the RPC-PET concept. Translate this result into a useful clinical tool.

6.2.4 Achievements

The national project (PTDC/SAU-BEB/104630/2008 – "RPC-PET - A novel technology for single-bed whole-body human molecular imaging with higher sensitivity and resolution") terminated in September. The work will continue in the framework of the Rad4Life project.
Unfortunately, the activities in hardware are still mostly stopped, waiting for the large milling machine that was acquired in the framework of another project to become available (under much pressure from the AUGER/MARTA project). This is needed to produce a 2nd prototype of the thin-walled RPC detector.
However a full size demonstrator with a thicker (MARTA-style) RPC was initiated and will be finished in 2014.

Some progress was made in the front-end electronics
A first prototype of a "trigger0"hardware module was developed, allowing to test the fundamental functionality of a trigger system. A method for time calibration was devised capable of suppressing inhomogeneous delays due to electronics variability and cable connections among the different signals arriving from the RPCs. A hardware implementation was built showing sub-nanosecond coincidence window resolution. Several strategies to implement more sophisticated trigger algorithms owing to overall scanner simulation results are being thought of and are expected to be implemented in future developments.
A front-end board for timing measurements with 8 channels was successfully developed and tested in the electrical mockup (see figure). This board allows for extraordinarily low signal detection thresholds, potentially optimizing the scanner´s sensitivity.

A review paper on the subject was published in The European Physical Journal Plus and other papers were submitted or accepted (see list of publications).
A PhD thesis by the team member Luís Guilherme Arneiro Mendes, "POSITRON EMISSION TOMOGRAPHY: IMAGE RECONSTRUCTION BASED ON MULTISCALE AND RESOLUTION METHODS- Coimbra: [s.n.], 2013. (http://hdl.handle.net/10316/23349) was defended at the University of Coimbra.
A PhD thesis "STUDY OF PET SYSTEMS OF VERY WIDE FIELD OF VIEW"was submitted by the project team member Jorge Miguel Tavares Couceiro de Sousa to the University of Coimbra.
The work on PET image reconstruction will be part of a thesis to be submitted by Paulo Jorge Magalhães Martins to the same University.

6.2.5 Sources of Funding

Code	Funding	Start	End
PTDC/SAU-BEB/104630/2008	120.856 €	2010-04-01	2013-09-30

6.2.6 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	PhD student (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

6.2.7 Publications

Articles in international journals (with direct contribution from LIP members)

- *Resistive plate chambers in positron emission tomography*
  Paulo Crespo, Alberto Blanco, Miguel Couceiro, Nuno C. Ferreira, Luís Lopes, Paulo Martins, Rui Ferreira Marques, Paulo Fonte
  The European Physical Journal Plus (2013) 128:73

- *An all-digital coincidence-selection and coincidence-trigger generation for a small animal RPC-PET camera*
  F.M.C. Clemencio, C.F.M. Loureiro, P. Fonte, and J. Landeck
  IEEE Trans. Nucl. Sci.60:4 (2013) 2912-2917

6.2.8 Presentations

Oral presentations in international meetings

- *RPC-PET - Positron emission tomography with Resistive Plate Chambers*
  presented by Paulo Fonte
  Symposium on Positron Emission Tomography. September 19th - 22nd 2013 — Jagiellonian University, Kraków, Poland.

6.2.9 Academic Training

PhD Theses

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

6.2.10 Project Summary

	number
Articles in international journals (with direct contribution from LIP members)	2
Oral presentations in international meetings	1

6.3 Detectors and Monte Carlo in Medical Physics

6.3.1 Resumo

As actividades do projecto são realizadas em quatro áreas
1) Desenvolvimento de dosimetros de plásticos cintiladores para controlo de dose em tomossíntese
No ambito do projecto "Melhoria da qualidade de imagem e redução de dose em tomossíntese para mamografia com recurso a algoritmos estatíticos de reconstrução de imagem", construiram-se protótipos de dosimetro de plástico cintilador. Foram construídos dois sistemas de leitura dos dosimetros (um baseado em PMT e outro em fotodiodo Si-PIN). Foi igualmente desenvolvido um amplificador de carga que faz a aquisição do sinal do fotodetector. O sistema foi testado no laboratório, encontram-se operacional. Está previsto para o inicio de 2014 um teste em ambiente hospitalar.
2) Estudo e optimização de barreiras de protecção em radiologia mamária
Fez-se o estudo por simulação Monte Carlo das configurações experimentais que estão na base dos relatórios NCRP 49 e NCRP 147 e por sua vez foram incorporados na legislação de vários países incluindo Portugal.
3) Microdosimetria da interacção de partículas alfa em tecidos pulmonares. Estudo da indução de cancros pulmonares por partículas alfa.
Desenvolveu-se o código de simulação Monte Carlo AlfaMC que permite a simulação rápida do transporte de partículas alfa em geometrias complexas. O código AlfaMC usa o código Ulysses de simulação do transporte de partículas arbitrárias em geometrias e que inclui o pacote Ulhistos de contabilização e histogramação de resultados.
4) Desenvolvimento de técnicas de simulação Monte Carlo aplicadas às técnicas de determinação da composição elementar de amostras por fluorescência de raios-X.
As técnicas de dispersão de energia por fluorescência de raios-X para a análise da composição elementar de amostras são bem conhecidas. Contudo na maioria dos casos requerem a utilização de padrões físicos dispendiosos para a obtenção de resultados quantitativos. O projecto tem desenvolvido uma alternativa com base na simulação Monte Carlo de amostras irradiadas com uma fonte de radiação também ela descrita por uma simulação Monte Carlo.

6.3.2 Abstract

Project activities are developed in four distinct areas:
1) Development of a plastic scintillator dosimeter for radiation control in breast tomosynthesis.
We built a three plastic scintillator dosimeters in the framework of the project "Improvement of image quality and dose reduction in digital breast tomosynthesis using statistical image reconstruction algorithms. Two different light reading systems were built, one based om a PMT an other based on a Si-PIN photodiode. A charge amplification system was also developed to read the signal from the photodetectors. The system was successfully tested in laboratory. A clinical trial is foreseen for 2014.
2) Study and development of protection barriers in breast radiology
Shielding design of x-ray imaging installations requires the knowledge of reliable values of the primary beam transmission and of the scattered radiation fraction. Current values of the latter quantity are based on measurements obtained more than 40 years ago by Trout and Kelley with a simple homogeneous cylindrical phantom made of a non-standard radiological material - Masonite. Their values were later revised by Simpkin and Dixon, in 1998, based on data of scattered radiation measured at 90^{o} , using updated equipments, higher filtrations and a more realistic anthropomorphic phantom. In this work, we revisit the measurements of Trout and Kelley, and, Simpkin and Dixon, by means of Monte Carlo simulations. Starting with a simple cylindrical homogeneous phantom, we introduce a more realistic phantom and the effect of the bucky in the simulations. Our results indicate that the scatter by a patient can not be realistically modeled by a simple phantom. Furthermore, we argue that optimized shielding methodologies can no longer neglect the overall attenuation by the patient plus bucky on the primary beam and its effect on the scattered radiation distribution.
3) Microdosimetry with beams of alpha particles emitted by radon and its progeny.
We developed the AlfaMC, Monte Carlo simulation code for the transport of alpha particles. This code is based on the Continuous Slowing Down Approximation and uses the NIST/ASTAR stopping-power database. The code uses a powerful geometrical package, which allows coding of complex geometries. A flexible histogramming package is used as well, which greatly eases the scoring of results. The code is tailored for microdosimetric applications in which speed is a key factor. Comparison with the SRIM code is made for deposited energy in thin layers and range for air, mylar, aluminum and gold. The general agreement between the two codes is good for beam energies between 1 and 12 MeV.
4) The use of Monte Carlo simulation in X-ray fluorescence quantitative determinations.

X-ray fluorescence (XRF) is a relatively simple, inexpensive and non-destructive technique for analysing sample compositions. An important feature of EDXRF techniques is the possibility to predict concentrations from experimentally measured spectral intensities using well established mathematical relations. The Fundamental Parameter Method (FPM) has been, for many years, very useful in predicting concentrations of unknown samples. Another possibility is to use empirical methods, where a guess function is assumed to account for matrix effects and the concentrations are determined through an iterative algorithm [2-4]. Both methods yield good results when high quality standards are used to calibrate spectral intensities, since they have the advantage of canceling out unknown factors in the fundamental equations and eliminate, in first approach, dependencies on the experimental parameters. The need of standards is, however, a practical limitation for doing quantitative EDXRF analysis. Standards are expensive to produce and acquire, or simply they are not available with adequate compositions for the type of samples to be measured. In this project we use MC calculations to improve quantitative determination of elemental concentrations in unknown samples analyzed by X-ray fluorescence (XRF)techniques. A reliable MC simulation of a portable EDXRF spectrometer, was implemented to generate sample spectra iteratively. In the first step, the composition of the unknown sample is assumed, based on standard quantification methods. A simulation is made with this composition and the spectrum of the sample is generated as well as the individual spectra of each element. A fit to the measured spectrum is performed using the simulated spectra and new concentrations are determined. These concentration will feed a subsequent simulation and the process will be repeated until convergence is reached. To benchmark this method (QEXMC) we will apply it to reference standards of known composition. Combining EDXRF measurements with MC techniques and standard quantification methods, we expect to obtain reliable quantitative analysis of various kinds of samples. Although in this project we will implement this approach to a particular EDXRF spectrometer, the methodology can be extended to any other XRF system used for quantitative analysis. As first test we will apply the QEXMC to the analysis of samples of pigment on paper.

6.3.3 Objectives

1) Development of a plastic scintillator dosimeter for radiation control in breast tomosynthesis.
The objective is the construction and operation of a low-cost dosimetric system capable of controlling delivered dose in a tomosynthesis scan. The dosimeter should be small and transparent to x-rays so to not disturb the exam results.
2) Study and development of protection barriers in breast radiology
The object is to improve the construction of protection barriers lowering the inherent price to a heavy shield installation.
3) Microdosimetry with beams of alpha particles emitted by radon and its progeny.
The objective is to develop a fast and reliable MC code for alpha particle dosimetry.
4) Use of Monte Carlo simulation in X-ray fluorescence quantitative determinations.
The model samples will replicate the simple stratigraphy of a layer of pigment applied on paper, simulating artworks commonly studied in Cultural Heritage applications. Stratigraphic samples are a good example where MC methods might improve significantly the quantitative analysis when compared with current standard quantification methods.

6.3.4 Achievements

1) Prototypes of the plastic scintillator dosimeter were built and tested.
2) The simulation made corresponds to more than 1000 distinct measurements in a real radiolog room. Such amount of data would no be feasible to acquire in most of Hospital departments and clinics. MC simulations provide a very useful tool to obtain accurate results when such systematic studies are needed, allowing researchers to focus on a more limited number of relevant measurements.
The current methodology to design primary and secondary barriers in x-ray imaging installations rely on transmission and scatter fraction values established between 20 years and 40 ago, using more or less simplified anthropomorphic phantoms. Our simulations show that, despite the magnitude of these values are generally correct, further measurements with more realistic phantoms are needed. The proportionality between the scattering air kerma and the FOV is a valid assumption, as well as, that the scatter fraction increases with higher filtrations. This increase is not, however, uniform for all scattering angles. More striking is that our results show a significant increase of backscattering by the RAP relatively to the present values obtained with a cylindrical homogeneous phantom. In fact, we have suggested that the inner complexity of a Realistic Anthropomorphic Phantom might have a more important effect on the transmitted and scattered radiation than assumed so far. This clearly must be further investigated. Simulations, in the transmission region, support the idea that the effect of the patient can not be neglected in an optimized design of primary barriers. The overall attenuation

introduced by the patient plus bucky is between ∼ 10-5 at 50 kV and ∼ 2 x 10-3 at 150 kV in the forward direction, corresponding to ∼ 0.62 mm Pb and ∼ 1.76 mm Pb equivalent, respectively. Future methodologies could include this effect by introducing a new analytical fit of the scatter fraction describing the monotonic increase between 0º and 180º . This means that the shape of the scatter fraction must depart from the current convex profile (cubic dependence on the scattering angle) shown in the NCRP report No. 147.
3) AlfaMC is a fast MC for the transport of alpha particles in complex geometries. The program uses the ASTAR / NIST precomputed stopping power tables to get the alpha particles energy loss. The default energy straggling is assumed to be Gaussian, but a more comprehensive description using the Vavilov and Landau distributions is also available using modified routines from GEANT3. A simple model is adopted for the multiple Coulomb scattering, based on a Gaussian distribution. The need to use a fast, multiple scattering sampling distributions is a major cause for uncertainty in AlfaMC at low energies.
The comparison with the well established SRIM program shows that AlfaMC can deliver meaningful results in the 1 to 12 MeV range for the alpha particle´s energy. For energies lower than 1 MeV, differences greater than 10% can be found between the results of both programs.
The AlfaMC program speed was compared with SRIM and the general-purpose Monte Carlo code FLUKA running on the same CPU for a simple slab geometry. A 10 MeV alpha particle beam was set to irradiate a 10 um-thick Al foil. Under these conditions the particle losses about 1 MeV crossing the foil and eventual different cut-offs have little influence in program speed. This is important since SRIM does not allow any user cut-off control. It was found that, per event, the ratio of spent time between FLUKA and AlfaMC was 5, while the ratio of spent time between SRIM and AlfaMC was 63.
The AlfaMC code, as well as the ULYSSES and ULHISTOS packages are open-source codes released under the General Public Licence (GPL) and can be obtained from the site http://www.lip.pt/ulysses .
4) When characterizing a layered sample by Energy Dispersive X-Ray Fluorescence (EDXRF) one of the most important problems is to identify for each element the corresponding layer and determining the thickness of the different layers. Recently Cesareo et al. [1,2] proposed a method to reconstruct the structure and determine the thickness of multi-layered materials from measurements of X-ray intensities ratios. The method is based on attenuation expressions valid for well collimated beams and assuming that the incident beam is monochromatic. Moreover, accurate values of self-attenuation in the deeper layers are only obtained for infinitely thin or thick samples, and depend strongly on the accuracy of the measured peak areas. This method has been applied in the analysis of pre-colombian alloys, gilded lead, protective coating in ornamental limestones. Recently our group applied this method in the study of gold leaf thickness in renaissance illumination [3].
In our project we proposed to make the reassessment of this gold leaf thickness based on a realistic Monte Carlo (MC) simulation of the EDXRF spectrometer, using the code package PENELOPE. The simulation includes the generation of the incident beam spectrum (on Rh transmission tube with Be window (Amptek), beam aperture and pin-hole collimator), interaction of photons and secondary electrons in the multi-layered sample, and interaction of fluorescence photons in the detector (escape peaks, scattering and attenuation on the Be window and dead layer). A very good comparisons between the results obtained with empirical peak ratio formulas and MC simulations was achieved.
[1] - R. Cesareo et al. Nucl. Inst. Meth. Phys. Res. B 267, 2890 (2009).
[2] - R. Cesareo et al. Nucl. Inst. Meth. Phys. Res. B 312, 15 (2013).
[3] – S. Pessanha et al. X-ray Spectrom., doi:10.1002/xrs.2518 (2013).

6.3.5 Sources of Funding

Code	Funding	Start	End
EXPL/FIS-ATO/0776/2012	2.400 €	2013-04-01	2014-03-31
PTDC/BBB-IMG/3310/2012	25.920 €	2013-07-01	2015-06-30

6.3.6 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)	85
Jorge Sampaio	Researcher (CFA/FCUL)	58
Luis Peralta	Researcher (LIP/FCUL)	85
Marta Dias	Master student (FCUL)	20
Patrick Sousa	Researcher	20
Pedro Gabriel Almeida	Researcher (UBI)	20
Rui Carvalhal	Graduate student (LIP)	30
Sandra Soares	Researcher (LIP/UBI)	80
Sónia Dias	Master student (FCUL)	20
Yoenls Bahu	Master student (FCUL)	100

6.3.7 Publications

Articles in international journals (with direct contribution from LIP members)

- *Development of a scintillating optical fiber dosimeter with silicon photomultipliers,*
  L.M. Moutinho, I.F.Castro, L.Peralta, M.C.Abreu, J.F.C.A.Veloso,
  Nucl. Instr. and Meth. in Phys. Res. A 735 (2014) 640–643

- *AlfaMC: A fast alpha particle transport Monte Carlo code*
  L. Peralta, A. Louro
  Nucl. Instr. and Meth. in Phys. Res. A, Vol 737 (2014) 163-169,

6.3.8 Presentations

Oral presentations in international conferences

- *Developments in quantitative EDXRF analysis*
  presented by Jorge Sampaio
  Iberian Joint Meeting on Atomic and Molecular Physics (IBER2013) — Seville, Spain .

- *Efeito do paciente no dimensionamento das barreiras de proteção em instalações de mamografia*
  presented by Conceição Abreu
  3ª Conferência Nacional sobre Ciencia e Tecnologia — Luanda 11-13 de Setembro de 2013.

Poster presentations in international conferences

- *Quantification in X ray Fluorescence Spectrometry by Monte Carlo Methods*
  presented by Jorge Sampaio
  International Conference on Total Reflection X-Ray Fluorescence Analysis and Related Methods (TXRF2013) — Osaka City University, Osaka, Japan.

6.3.9 Academic Training

PhD Theses

- *Environmental Radon Exposure and Human Health Risk*
  Alina Louro, 2013-03-28

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)

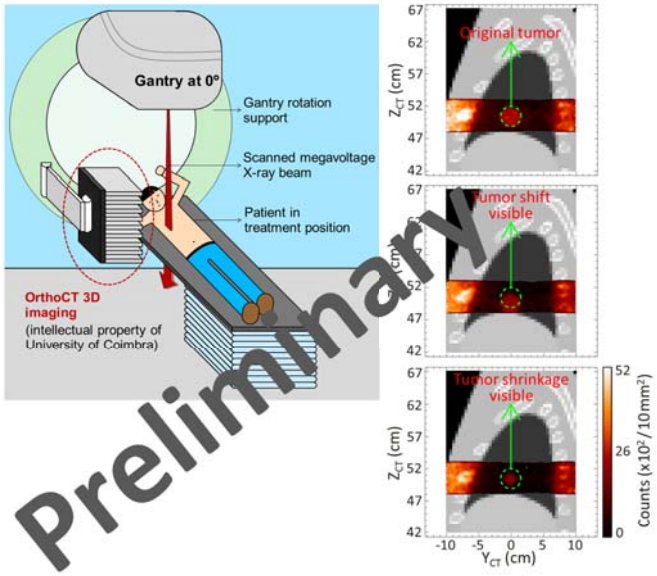
6.3.10 Project Summary

	number
Articles in international journals (with direct contribution from LIP members)	2
Oral presentations in international conferences	2
Poster presentations in international conferences	1
PhD Theses	1

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.



(Left) Scheme depicting the imaging of a patient just prior to the onset of a radiotherapy session with an OrthoCT orthogonal ray imaging system. A minimal amount of dose is deposited in the patient in a very non-invasive manner. (Right) The three images show that OrthoCT is capable of providing pertinent morphological information, allowing not only for image fusion with bony structures and lung tissue, together with tumor identification in normal (top) and abnormal scenarios (middle and bottom images).

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 an internal call 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 Achievements

The main achievements obtained in the year 2013 were connected with simulation work.
In regard to the RTmonitor orthogonal ray imaging technique, its was seen that an IMRT-like (intensity modulated RT) treatment of the head could provide a dose difference at the edges of the field of ca 10% if the nasal sinuses are filled with mucus or edema tissue, in contrast to a treatment where said cavities are normally empty. The images obtained with RTmonitor after a few milligray of dose only show that differentiating the two potentially clinically relevant scenarios is immediately possible. The same can be said during the irradiation of a lung tumor that has either increased volume, decreased volume, or changed position during the course of the irradiation. Here, an OrthoCT orthogonal ray imaging system could even provide such tumor changing evidence before the start of the irradiation, with a seemingly clinically non-relevant dose of the order of 2 milligrey, as shown in the appended figure.

6.4.5 Sources of Funding

Code	Funding	Start	End
INOV.C - OrthoCT	10.000 €	2013-01-01	2014-03-06
INOV.C - DeepbrainTMS	10.000 €	2013-01-01	2014-03-06

6.4.6 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)	33

6.4.7 Publications

Articles in international journals (with direct contribution from LIP members)

- *Dose-free monitoring of radiotherapy treatments with scattered photons: concept and simulation study*
  M. Cunha, M. Pinto, B. Ferreira, P. Fonte, M.C. Lopes, P. Crespo
  IEEE Trans. Nucl. Sci. 60:4 (2013) 3119-3126

- *Dose-free monitoring of radiotherapy treatments with scattered photons: first experimental results at a 6-MV linac*
  H. Simões, M. Cunha, M. Pinto, J. Gonçalves, L. Sampaio, R.J. Ferreira, H.M. Saraiva, A.R. Barbeiro, M. Capela, B. Ferreira, P. Fonte, S. Ghithan, A. Leal Plaza, M.C. Lopes, P. Martins, P. Crespo
  IEEE Trans. Nucl. Sci. 60:4 (2013) 3110-3118

International Conference Proceedings

- *Observation of tumor morphological changes in lung irradiation with orthogonal ray imaging: RTmonitoring - a simulation study*
  H. Simões, I. Bravo, M. Capela, A. Cavaco, R. Ferreira Marques, P. Fonte, J. Lencart, M.C. Lopes, H. Pereira, P.J.B.M. Rachinhas, J.A.M. Santos, P. Soares, P.C.P.S. Simões, P. Crespo
  2013 IEEE Nucl. Sci. Symp. & Med. Imag. Conf. (NSS/MIC) (accepted)

- *Characterization of GSO:Ce phosphorescence after low-dose-rate gamma-ray irradiation*
  H. Simões, S. Ghithan, M. Loureiro, P. Crespo
  Conf. Records 2013 IEEE Nucl. Sci. Symp. & Med. Imag. Conf. (NSS/MIC) (accepted)

- *Orthogonal ray imaging with megavoltage beams: simulated results with an anthropomorphic phantom*
  M.C. Battaglia, H. Simões, V. Bellini, E. Cisbani, M.C. Lopes, P. Crespo
  Conf. Records 2012 IEEE Nucl. Sci. Symp. & Med. Imag. Conf. (NSS/MIC)

- *Rotation-free computed tomography with orthogonal ray imaging: first millimetric experimental results*
  H. Simões, M.C. Battaglia, M. Capela, M.C. Lopes, P. Crespo
  Conf. Records 2012 IEEE Nucl. Sci. Symp. & Med. Imag. Conf. (NSS/MIC)

- *Optimization of collimator designs for real-time proton range verification by measuring prompt gamma rays*
  P. Cambraia Lopes, M. Pinto, H. Simões, A.K. Biegun, P. Dendooven, D.C. Oxley, K. Parodi, D.R. Schaart, P. Crespo
  Conf. Records 2012 IEEE Nucl. Sci. Symp. & Med. Imag. Conf. (NSS/MIC)

- *LYSO scintillators coupled to phototransistors for orthogonal ray imaging: experimental results at 4 and 6-MV linacs*
  H. Simões, M.C. Battaglia, M. Capela, A. Cavaco, M.C. Lopes, P.J.B.M. Rachinhas, P. Soares, P.C.P.S. Simões, P. Crespo
  Conf. Records 2012 IEEE Nucl. Sci. Symp. & Med. Imag. Conf. (NSS/MIC)

National Conference Proceedings

- *Experimental demonstration of induction by means of a transcranial magnetic stimulator coil immersed in a conducting liquid*
  H. Simões, M. Dias Silva , C. Vieira Ferreira, L. Jesus, H. Oliveira, P. Cavaleiro Miranda , R. Salvador, P. Crespo, J. Silvestre
  Conf. Records IEEE 3rd Portuguese Meeting in Bioengineering (ENBENG)

6.4.8 Presentations

Oral presentations in international conferences

- *First performance tests of digital SiPMs in prompt gamma imaging with a knife-edge slit camera for proton range verification*
  presented by Patrícia Cambraia Lopes
  2013 IEEE Nucl. Sci. Symp. & Med. Imag. Conf. — Seoul.

Poster presentations in international conferences

- *Observation of tumor morphological changes in lung irradiation with orthogonal ray imaging: a simulation study*
  presented by Paulo Crespo
  2013 IEEE Nucl. Sci. Symp. & Med. Imag. Conf. — Seoul.
- *Characterization of GSO:Ce phosphorescence after low-dose-rate gamma-ray irradiation*
  presented by Paulo Crespo
  2013 IEEE Nucl. Sci. Symp. & Med. Imag. Conf. — Seoul.
- *Insitu PET imaging with digital SiPMs for proton range verification: initial performance study*
  presented by Patrícia Cambraia Lopes
  2013 IEEE Nucl. Sci. Symp. & Med. Imag. Conf. — Seoul.

Presentations in national conferences

- *Experimental demonstration of induction by means of a transcranial magnetic stimulator coil immersed in a conducting liquid*
  presented by Hugo Simões
  IEEE 3rd Portuguese Meeting in Bioengineering (ENBENG) — Braga.

Oral presentations in international meetings

- *Monte- Carlo study on prompt-gamma imaging through multi-slat collimators: intrinsic performances with simple and anthropomorphic phantoms*
  presented by Patrícia Cambraia Lopes
  2013 IEEE Nucl. Sci. Symp. & Med. Imag. Conf. — Seoul.

6.4.9 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)

6.4.10 Project Summary

	number
Articles in international journals (with direct contribution from LIP members)	2
International Conference Proceedings	6
National Conference Proceedings	1
Oral presentations in international conferences	1
Poster presentations in international conferences	3
Presentations in national conferences	1
Oral presentations in international meetings	1

6.5 Adaptive methods for medical imaging with gamma cameras

6.5.1 Abstract

From the project start (May 2013) the main focus of the software development team was on the ANTS2 simulation and data processing package. This package is already capable of simulating virtually any type of position-sensitive scintillation detectors (PSSD) with the emphasis on the medical applications (gamma cameras). Simulations were also performed for neutron and dark matter scintillation-based detectors which are developed by our partners. Event position and energy reconstruction module is currently in the active development phase. An effective approach to parametrization of the light response functions (LRFs) for thick solid scintillators has been found. The LRFs generated with the simulation module of ANTS2 were successfully applied for 3D reconstruction of the data recorded at our SiPM-based detector prototype. The developed algorithms are currently being integrated in the experimental data processing module of ANTS2. These results provide an important input for our QREN project Rad4Life (task SPECT) and fulfill, in part, the objectives of that project.
A data acquisition system based on MAROC3 test board was developed. It features low noise, configurable filters and triggering options permitting simultaneous acquisition of up to 64 channels at rates of up to 3 kHz. The system was developed and characterized with the first compact gamma camera prototype in the frame of a master project at FCTUC. The prototype, based on a single 4x4 Hamamatsu SiPM array and multichannel Hamamatsu preamplifier, was built as a proof-of-concept design and a test bed for data acquisition. A similar DAQ is planned to be used in the RAD4LIFE project.
Based on the experience gained with the first prototype, the second prototype was built, featuring 30x30x5 mm LYSO crystal coupled to 8x8 SensL SiPM array. The mechanical design is adjustable to facilitate testing different optical configurations. This second prototype is currently being used for data taking with first images and energy spectra already obtained with Co-57 and Na-22 sources.
Also A 7 PMT Anger camera emulation system, based on a highly isotropic LED light source developed in LIP-Coimbra was built and ready for operation. The source is mounted on a XYZ coordinate table and allows to directly measure light response of phototubes to be compared later with the ones reconstructed using adaptive algorithms. In order to prepare for this work, a thorough calibration of the system was performed and single electron response of the PMTs was measured.
Last but not least, upgrade of commercial gamma camera is under way. The HV distribution chain was fixed and the work on integration with the DAQ system is ongoing. The camera is expected to be operational soon. This camera will also be used in the Rad4Life project.

6.5.2 Objectives

The main goal of this project is to extend applicability of adaptive algorithms for event position estimation, developed by the team during work on two-phase dark matter detectors with optical readout and anger camera neutron detectors to medical gamma cameras. The main objectives are:

- Development of a software package for detailed Monte Carlo simulations of position sensitive scintillation detectors. This multi-platform software is going to include an easy-to-use but realistic simulation module as well as a experimental data processing and event reconstruction modules in a self-contained package.

- Development and optimization of the adaptive position estimation algorithms for gamma cameras. This work will be performed with the help of the mentioned MC simulation package. The algorithms will be characterized by the difference between the estimated response of the photodetectors as well as the event locations compared to the actual response/locations used in the simulations.

- Experimental verification of adaptive algorithms performance by the Anger camera emulation system. The system allows direct measurement of light response of phototubes to be compared later with the ones reconstructed using adaptive algorithms.

- Development and characterization of a prototype of a small SiPM based gamma-camera.

- Upgrade of commercial gamma camera for list-mode event readout. This will allow to evaluate performance of statistical methods for event reconstruction and of adaptive algorithms for PMT response determination for a realistic device.

- Provide solid background for the RAD4LIFE project (task SPECT) which will take the developed concepts further.

6.5.3 Achievements

- ANTS2 simulation and data processing package
  - Capable of simulating virtually any type of position-sensitive scintillation detectors
  - Wavelength, time and angle resolved simulation possible
  - Several options for modelling PMT light response in 2D and 3D
  - Experimental data processing and event reconstruction are being applied for 3D reconstruction of the data recorded with the SiPM gamma camera prototype.
- Data acquisition system based on MAROC3 test board
  - 64-channel
  - Low noise
  - Configurable filters and triggering options
  - Acquisition rate up to 3 kHz
- First prototype of SiPM scintillation camera
  - 30x30x5 mm LYSO crystal
  - 4x4 Hamamatsu SiPM matrix
  - Hamamatsu preamplifiers
  - Proof-of-concept design and a test bed for data acquisition
- Second prototype of SiPM scintillation camera
  - 30x30x5 mm LYSO crystal
  - 8x8 SensL SiPM matrix
  - Direct coupling to MAROC3 inputs
  - Adjustable mechanical design allows to test different optical configurations
  - Working prototype
  - Currently used for data taking
  - First energy spectra and images already obtained
- Gamma camera emulation system
  - A 7 PMT system was built and ready for operation
  - Thorough calibration performed
  - Single electron response of PMTs measured
- Upgrade of commercial gamma camera
  - HV distribution fixed
  - Ongoing work on integration with the DAQ system
  - Expected to be operational soon

6.5.4 Sources of Funding

Code	Funding	Start	End
PTDC/BBB-BMD/2395/2012	48.202 €	2013-05-01	2014-04-30

6.5.5 Team

Project coordinator: Vladimir Solovov

Name	Status	FTE %
Alessio Mangiarotti	Researcher (LIP/USP)	13
Alexandre Lindote	Post-Doc (LIP)	13
Andrey Morozov	Researcher (LIP)	34
Filipa Balau	PhD student (LIP)	34
Francisco Fraga	Researcher (LIP/FCTUC)	10
Francisco Neves	Post-Doc (LIP)	13
Isabel Lopes	Researcher (LIP/FCTUC)	13
Luís Pereira	PhD student (LIP)	20
Vitaly Chepel	Researcher (LIP/FCTUC)	20
Vladimir Solovov	Researcher (LIP)	34

6.5.6 Presentations

Oral presentations in international conferences

- *ANTS / ANTS2 – simulation and experimental data processing packages for Anger camera-type detectors*
  presented by Andrey Morozov
  Workshop "Detecting Neutrons with MPGDs-– CERN.

Oral presentations in collaboration meetings

- *ANTS / ANTS2 – simulation and experimental data processing packages for Anger camera-type detectors*
  presented by Andrey Morozov
  NEXT collaboration meeting — Valencia, Spain.

6.5.7 Academic Training

Master Theses

- *Desenvolvimento do sistema de leitura e aquisição para uma câmara de Anger utilizando fotomultiplicadores de silício*
  João Pedro Martins Rodrigues, 2013-10-04
- *Compact calibration system for silicon photomultiplier arrays*
  Raimundo Martins, (on-going)

6.5.8 Project Summary

	number
Oral presentations in international conferences	1
Oral presentations in collaboration meetings	1
Master Theses	1

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 total previsto, 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

Goals of the Project:
- Exploring applications to the biomedical area of radiation detection technologies emerging from Particle Physics, particularly in imaging, radiotherapy control and monitoring and general purpose high-pressure large-area Xe detectors.
- Maintaining a team of experts capable of enhancing those lines of work which are being followed by LIP and, thus, creating conditions for futher progressing along several different lines of work; this involves in particular the support of six PhDs (one of them in a position of Assistant Professor at the University of Coimbra, already contracted in 2013), either under post-doc fellowships or as a partial payment of the salaries of LIP reasearchers.

6.6.4 Achievements

In 2013 the project supported a total of ≈35 months of PhDs (fellowships plus LIP researchers and University staff allocated to the project) and 16 months of Masters.
The activities carried out are split by 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. Consequently, the achievements appear disseminated in different sections of the present report.

6.6.5 Sources of Funding

Code	Funding	Start	End
QREN CENTRO-07-ST24-FEDER-002007	495.773 €	2013-06-01	2015-06-30

6.6.6 Team

Project coordinator: Rui Marques

Name	Status	FTE %
Valdemar Domingos	Master (LIP)	16

Chapter 7

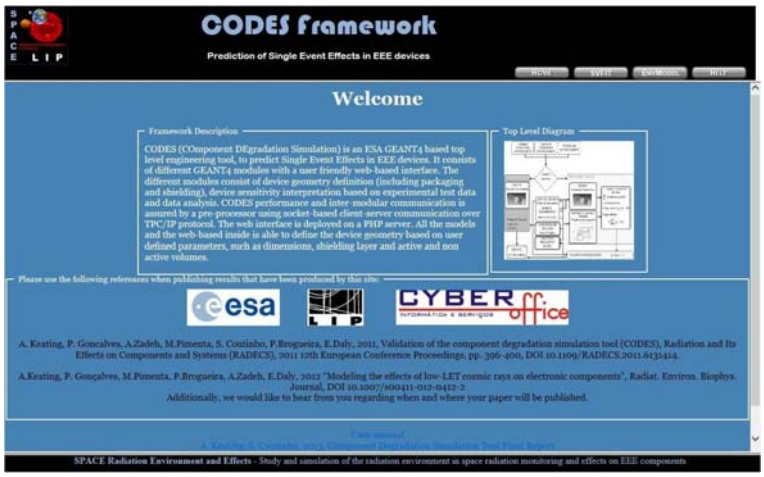
Radiation Environment Studies and Applications for Space Missions

7.1 Space Radiation Environment and Effects

7.1.1 Resumo

As actividades desenvolvidas no âmbito deste projecto são baseadas na experiência prévia do LIP nas áreas de simulações de interacção da radiação, de detecção de radiação e instrumentação para física experimental de partículas. As actividade desenvolvidas tiveram início com a aplicação da ferramenta de simulação Geant4 a experiências de astropartículas, num primeiro contrato celebrado entre LIP e da Agência Espacial Europeia (ESA) em 2003. Desde então, o trabalho desenvolvido tem sido apoiado principalmente por contratos entre o LIP e a ESA, sendo o LIP total ou parcialmente responsável pelos projectos. Estas actividades têm sido uma fonte de colaboração entre LIP e outros institutos, empresas e com a indústria e também com cientistas externos ao LIP e incluem:

- Estudo e modelização do ambiente de radiação no espaço , incluindo ambientes de radiação planetários, nomeadamente a Lua, Marte, Europa , Ganimedes e asteroides.
- Análise de dados de detectores de partículas energéticas/radiação em missões espaciais;
- 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";
- Estudo e desenvolvimento de conceitos para monitores de radiação (com base em sensores de Si e/ou em cintiladores) e exploração destes conceitos para utilização em diferentes ambientes planetários e interplanetários , tanto no suporte das missões como na análise de dados científicos;



CODES Web Interface home page

- Estudo, modelização e testes em feixe dos efeitos da radiação em componentes EEE utilizados em missões no espaço;
- Estudo dos efeitos biológicos do ambiente de radiação no espaço, nas atmosferas e superfícies planetárias.
- Estudo e desenvolvimento de estratégias de mitigação para os riscos da exposição à radiação no espaço, tanto para os sistemas e componentes das missões como e para as tripulações;

Durante 2013 foram terminadas actividades como o CODES e a modelização da resposta de RADFETs em função de taxa de dose e temperatura. Foram também preparadas propostas para diversas actividades que terão início em 2014.

Actividades terminadas em 2013

A ferramenta CODES é baseada em Geant4 e permite simular a degradação de componentes EEE devido a passagem de partículas energéticas, induzindo "Single Event Effects"nas componentes. Esta ferramenta foi objecto de três contratos entre o LIP e a sua validação terminou em Outubro de 2013, tendo encerrado o respectivo contrato com a ESA. O CODES está actualmente instalado no LIP, de onde virá a ser disponibilizado à comunidade utilizadora.
Durante 2011 e 2012, o LIP colaborou com a EFACEC SA e com EVOLEO Technologies no contrato com a ESA "Alphasat radiation Environment and Effects Facility (AEEF) Component Technology Test-Bed (CTTB), Preparation of In-Flight Data Analysis". Neste contrato o LIP foi responsável pela irradiação com Co-60 e "annealing"de dosímetros RADFET para a experiência CTTB, e pela análise de dados obtidos na irradiação em terra dos componentes EEE que serão testados no CTTB, em ambiente espacial. O LIP foi também responsável pela análise dos dados de calibração dos dosímetros RADFET. Estes dados foram obtidos em irradiação com Co-60, a diferentes taxas de dose e temperaturas. Com o objectivo de obter uma calibração consistente dos RADFETs, um modelo para a dependência da resposta dos RADFETs com a temperatura e a taxa de dose foi desenvolvido no LIP. Um artigo descrevendo este modelo e demonstrando o seu bom ajuste ao comportamento dos dosimetros foi submetido e aceite para publicação na revista "IEEE - Transactions on Nuclear Science", em 2013.

Atividades em preparação durante 2013

O satélite Alphasat foi lançado para GEO (Orbita Geoestacionária) em julho de 2013, levando a bordo o TDP-8, uma plataforma de testes dos efeitos da radiação no espaço, desenvolvida sob a liderança da EFACEC. Na sequência do projecto "Alphasat radiation Environment and Effects Facility (AEEF) Component Technology Test-Bed (CTTB), Preparation of In-Flight Data Analysis", o LIP e a EFACEC apresentaram uma proposta à ESA para o projecto AlphaSat TDP-8 MFS Particle Spectrometer Data Analysis"(MFS é o monitor de radiação da AEEF) que foi aceite pela ESA. O respectivo contrato terá início em março de 2014.
Durante 2013 o LIP preparou duas propostas no âmbito da futura missão JUICE da ESA às luas geladas de Júpiter: a proposta para o desenvolvimento e demonstração do "RADEM: Radiation-Hard Electron Monitor for the Jupiter Environment"(em que LIP participa de um consórcio internacional, liderado pela EFACEC(pt), com a RUAG (ch), PSI (ch) e a IDEIAS (no)) foi aceite pela ESA e o projecto, com a duração de 30 meses, terá início no começo de 2014. Foi também apresentada uma proposta em resposta ao Pedido de Cotação da ESA "Verification of 60Co TID testing representativeness for EEE components flown in the Jupiter electron environment", emitido no âmbito do Programa de TRP da ESA. A proposta do LIP (ECo-60) foi aceite pela ESA e respectivo o contrato, com a duração de 15 meses, terá início em fevereiro de 2014.

7.1.2 Abstract

The activity of the LIP group for "Radiation Environment Studies and Applications for Space Missions"is based on the LIP knowhow in the areas of radiation interaction simulations, radiation detection and instrumentation for experimental particle physics. The Space Radiation Environment and Effects activities were triggered by the application of the Geant4 simulation toolkit to astroparticle experiments in a first contract celebrated between LIP and the European Space Agency (ESA) in 2003. Since then, the work developed has been supported mainly by contracts between LIP and ESA, LIP being either fully responsible for the projects or for parts of the projects. These activities have been a source of collaboration between LIP and other institutes, companies and the industry, and also of collaboration with external scientists and include:

- Study and model the radiation environment in Space, including planetary radiation environments, namely the Moon, Mars, Europa, Ganymede and asteroids radiation environments.

- 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.

In 2013 activities such as CODES and RADFET response modeling were finished and several activities, which will start in 2014, were prepared.

Activities closed in 2013

CODES is an Integrated Radiation Environment, Effects and Component Degradation Simulation tool, which has been the object of three contracts between LIP and ESA. CODES is a Geant4 based framework for the prediction of radiation induced Single Event Effects in EEE components. Its validation ended in October 2013, when the CODES web based interface was delivered to ESA. CODES is currently installed at LIP from where it will be made available to the community.
During 2011 and 2012, LIP collaborated with, EFACEC, S.A. and with EVOLEO Technologies in the ESA contract "Alphasat radiation Environment and Effects Facility (AEEF) Component Technology Test-Bed (CTTB), Preparation of In-Flight Data Analysis". In this contract LIP was responsible for the Co-60 irradiation and annealing of RADFET dosimeters for the CTTB experiment in space, and for the analysis of ground data of the EEE components tested in the CTTB. LIP was also responsible for the analysis of RADFET calibration data. These data were taken at different dose rates and temperatures and, in order to obtain a consistent calibration of the RADFETs, a model for the RADFET temperature and dose rate dependent behaviour was developed at LIP. A paper describing the model and its good description of the RADFET response was submitted and accepted for publication in "IEEE – Transactions on Nuclear Science", in 2013.

Activities in preparation during 2013

The AlphaSat Satelite was launched to GEO (Geostationary Earth Orbit) in July 2013. Following the contract "Alphasat radiation Environment and Effects Facility (AEEF) Component Technology Test-Bed (CTTB)", LIP and EFACEC submitted a proposal to ESA for the "AlphaSat TDP-8 MFS Particle Spectrometer Data Analysis"(MFS is the radiation monitor included in the payload) which was accepted. The corresponding contract will start in March 2014.
During 2013 LIP prepared two proposals to ESA calls in the framework of the future JUICE mission to the Jovian Icy Moons. The proposal for the development and demonstration of the "RADEM: Radiation-Hard Electron Monitor for the Jupiter Environment"(in which LIP participates in an international consortium, lead by EFACEC(pt), with RUAG (ch), PSI(ch) and IDEAS(no)) was accepted by ESA and the project, with a duration of 30 months, will start in the begining of 2014.
LIP prepared a proposal in response to the ESA Request for Quotation "Verification of 60Co TID testing representativeness for EEE components flown in the Jupiter electron environment", issued in the framework of the ESA Technological Research Program. LIP´s proposal (ECo-60) was accepted by ESA and the corresponding project, with a duration of 15 months, will start in February 2014.

7.1.3 Objectives

The objective of the LIP Group for Radiation Environment Studies and Applications for Space Missions is to become a national reference in the area of space radiation environment applications and in the development related instrumentation for space. To achieve this, the collaboration with the national industry and the participation in international consortia for specific ESA calls has been pursued. This is the case of the project "MFS data analysis", in which LIP will collaborate with EFACEC and also of RADEM.

The connection with the University has also been sought, through the collaboration with groups from national Universities and institutes, and through the announcement of MsC and PhD theses subjects. Additionally, networking activities in the framework of H2020 program are also being explored with national and international institutes and with the university.
The team´s R&D themes follow the ESA cosmic vision programme 2015-2025 and long term plan 2013-2022, as well as the European Roadmap for Fundamental Physics in Space. During 2015-2020, ESA is heading for Mars (with the ExoMars mission) and preparing for Jupiter - with the Jupiter Icy Moons Explorer (JUICE) mission, the selected ESA L-Class launch slot in 2022. The Space Radiation Environment and Effects group is preparing for both. LIP is involved in two ESA technologic development plan activities for JUICE: the development of RADEM and the ECo-60 project. As for Mars, the publication of data from the RAD detector aboard the NASA Curiosity rover will soon enable the validation of the dMEREM model developed at LIP for ESA, with the first radiation data from Mars surface. Exomars payloads will be launched in 2016 and in 2018 carrying neutron spectrometers and our group is in contact with the instruments team with the aim of contributing to the ExoMars radiation data analysis.

7.1.4 Achievements

In 2013 the CODES activity was finished and several activities, which will start in 2014, were prepared. CODES validation ended in October 2013, when the CODES web based interface (CODES home page is shown in the figure) was delivered to ESA. CODES is installed at LIP from where it will be made available to the community. A model for the RADFET temperature and dose rate dependent behaviour was developed at LIP, following the project "AlphaSat radiation Environment and Effects Facility (AEEF) Component Technology Test-Bed (CTTB)". A paper describing the model developed and its good description of the RADFET data was accepted for publication in IEEE – Transations on Nuclear Science in 2013. The AlphaSat was launched to Geostationary orbit in July 2013 carrying the AEEF facility, in whose preparation LIP participated. LIP will participate with EFACEC in the analysis of the data collected with the AEEF, namely in project the "AlphaSat TDP-8 MFS Particle Spectrometer Data Analysis", which will start in 2014.
LIP prepared two proposals to the following ESA calls related to the JUICE mission to the Jovian system: "RADEM: Radiation-Hard Electron Monitor for the Jupiter Environment", with an international consortium lead by EFACEC ; "ECo- 60 : Verification of 60Co TID testing representativeness for EEE components flown in the Jupiter electron environment"in which LIP is the prime contractor. These proposals were accepted by ESA and the corresponing projects will start in 2014.

7.1.5 Sources of Funding

Code	Funding	Start	End
ESA:223981/09/NL/PA/CCN03	20.000 €	2012-11-01	2013-09-30

7.1.6 Team

Project coordinator: Patrícia Gonçalves

Name	Status	FTE %
Alessandro de Angelis	Researcher (LIP)	10
Ana Keating	Post-Doc (LIP/FCT)	68
Bernardo Tomé	Researcher (LIP)	20
Bruno Morgado	PhD student (LIP)	100
Catarina Espírito Santo	Researcher (LIP)	10
Patrícia Gonçalves	Researcher (LIP)	50

7.1.7 Publications

Articles in international journals (with direct contribution from LIP members)

- *Modeling the response of the ESAPMOS4 RADFETs for the ALPHASAT CTTB experiment*
  P. Gonçalves, A. Keating, A. Trindade, P. Rodrigues, M. Ferreira, P. Assis, M. Muschitiello, B. Nickson, C. Poivey
  IEEE - Trans. Nucl. Sci. (accepted)

International Conference Proceedings

- *Modeling the response of the ESAPMOS4 RADFETs for the ALPHASAT CTTB experiment*
  P. Gonçalves, A. Keating, A. Trindade, P. Rodrigues, M. Ferreira, P. Assis, M. Muschitiello, B. Nickson, C. Poivey
  IEEE - RADECS 2013

7.1.8 Presentations

Poster presentations in international conferences

- *Modeling the response of the ESAPMOS4 RADFETs for the ALPHASAT CTTB experiment*
  presented by Patrícia Gonçalves
  IEEE - RADECS 2013, 23-27 September 2013 — Oxford, UK.

Presentations in national conferences

- *Towards a Radiation Monitor for the Jovian System*
  presented by Patrícia Gonçalves
  XXIII ENAA- Encontro Nacional de Astronomia e Astrofísica, 18-19 July 2013 — FCUL, Lisboa.

Oral presentations in international meetings

- *LIP Planetary Environment Tools*
  presented by Patrícia Gonçalves
  9th Geant4 Space Users´ Workshop — Barcelona, Spain.
- *Component degradation simulation tool*
  presented by Ana Keating
  9th Geant4 Space Users´ Workshop — Barcelona, Spain.
- *Simulation of Single event effects in EEE components*
  presented by Ana Keating
  SPENVIS Space Users Workshop — Brussels, Belgium.
- *Modeling the response of the ESAPMOS4 RADFETs for the ALPHASAT CTTB experiment*
  presented by Patrícia Gonçalves
  "ESA -CNES Final Presentation Days 2013 — ESTEC, Noordwijk, The Netherlands.
- *"Final presentation of CODES: Component Degradation Simulation Tool"*
  presented by Ana Keating
  CNES and TEC-QEC Presentation Days — ESTEC, Noordwijk, The Netherlands.

Seminars

- *Modeling and Measuring Planetary Radiation Environments*
  presented by Patrícia Gonçalves
  CENTRA Seminars, IST — Instituto Superior Técnico, Lisboa.

7.1.9 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)

7.1.10 Project Summary

	number
Articles in international journals (with direct contribution from LIP members)	1
International Conference Proceedings	1
Poster presentations in international conferences	1
Presentations in national conferences	1
Oral presentations in international meetings	5
Seminars	1

7.2 Gamma-Ray Polarimetry with Fermi and DUAL Space Missions

7.2.1 Resumo

Otimização polarimétrica do plano focal da missão DUAL

Em 2013 o nosso grupo prosseguiu o desenvolvimento de um plano focal de CdZnTe (CZT) optimizado para a observar emissões polarizadas de raios gama no espaço que integrará uma proposta de um telescópio de raios gama a ser submetida ao próximo concurso para missões da classe M do programa Cosmic Vision da ESA. Em colaboração com o Istituto di Astrofisica Spaziale e Fisica Cósmica, Bolonha, Itália tem vindo a ser simuladas e testadas várias configurações bidimensionais de um plano focal baseado em detectores de CZT. Os resultados experimentais e resultantes de simulações indicam que as prestações deste instrumento são compatíveis com os requerimentos estabelecidos pelo antigo consórcio DUAL para o instrumento de plano focal: sensibilidade de 10ˆ-6 fotões/(cmˆ2.s.keV) entre 100 keV e 1 MeV, resolução de 1% e polarização mínima detectável $< 1\%$ para uma fonte equivalente à Nebulosa do Caranguejo durante 10ˆ-6 s.

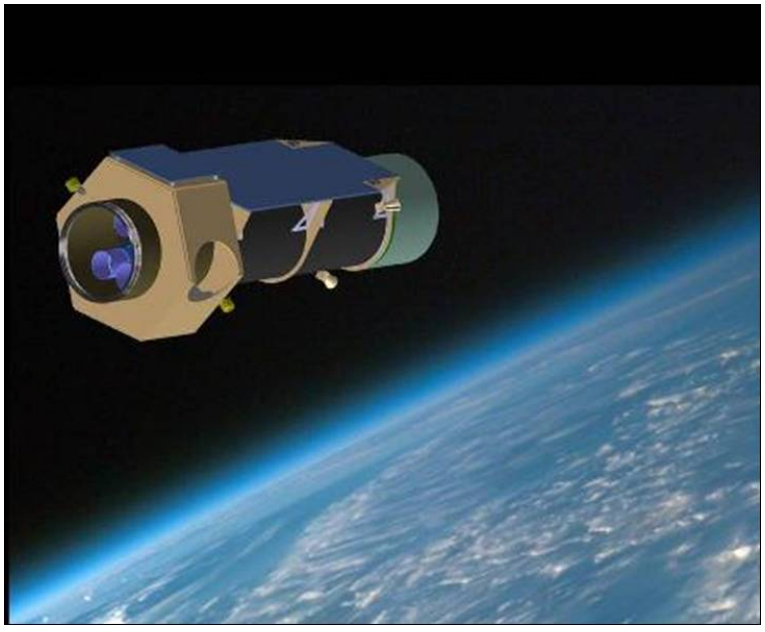
Desenvolvimento do plano focal do polarímetro XIPE

No domínio dos raios X, a missão XIPE (X-ray Imaging Polarimetry Explorer) pretende oferecer à comunidade científica o primeiro polarímetro a operar no espaço. Foram por nós estudadas através de um programa de simulação pelo Método de Monte Carlo baseado em Fortran as prestações polarimétricas em função da energia, até 20 keV, de um Contador Gasoso Pixelizado (GPD: Gas Pixel Detectors) contendo Xénon a uma atmosfera. Análise dos dados obtidos permitiu-nos concluir que as potenciais prestações polarimétricas deste tipo detectores são compatíveis com as exigências de sensibilidade de instrumento a ser enviado para o espaço. Do ponto de vista experimental, testámos um GPD com xénon a uma atmosfera irradiado por uma fonte de radiação polarizada entre os 5 e os 15 keV, tendo sido obtidos resultados que, dentro da margem de erro experimental, verificam os resultados obtidos nas simulações.

7.2.2 Abstract

Polarimetric optimization of DUAL Space Mission

In 2013 our group pursued the development of a Laue lens focal plane instrument based on CdZnTe for a space gamma-ray observatory proposal equipped with Laue lens, to be submitted to the next ESA Cosmic Vision Call for M class missions. In collaboration with the Istituto di Astrofisica Spaziale e Fisica Cósmica, Bologna, Italy, several CZT focal plane prototypes, in bi-dimensional configuration, where simulated and tested. So far, these prototype experimental and simulation results are compatible with the performances required for a gamma-ray



Artistic view of the XIPE (X-ray Imaging Polarimetry Explorer) mission proposal

telescope main instrument established by the old DUAL consortium: 10ˆ-6 photons/(cmˆ2.s.keV) detection sensitivity between 100 keV and 1 MeV, energy resolution of ≈1% and minimum detectable polarization < 1% for a Crab source equivalent and for 10ˆ-6s.

XIPE mission main instrument development

In the X-ray domain, XIPE (X-ray Imaging Polarimetry Explorer) is expected to be the first dedicated polarimeter instrument ever launched into space. Up to the present a Fortran Monte Carlo simulation program has been developed allowing polarimetric performances analysis up to 20 keV. The preliminary results show that the performances of this type of detectors are potentially compatible with XIPE mission requirements. Experimentally, a GPD (Gas Pixel Detectors) prototype was filled with xenon at one atmosphere and tested under a partially polarized X-ray beam in an energy range between 5 and 15 keV. The results obtained are in agreement with the results obtained by the performed simulations.

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 Achievements

Ongoing PhD Thesis:
José Marques, CAUP and LIP PhD student, started 01/10/2011
Ongoing Master Thesis:
Marco Pinto, LIP student, started 01/10/2013
Submitted exploratory projects:
"Raios-X Polarizados para Imagem Médica: uma nova abordagem", ref. EXPL/FIS-NUC/2145/2013. Not funded Project.
For more achievements, see publications and presentations sections.

7.2.5 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
Collin Gloucester	On leave (LIP)	100
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

7.2.6 Publications

Articles in international journals (with direct contribution from LIP members)

- *XIPE: the X-ray imaging polarimetry explorer*
  Paolo Soffitta, ..., Rui Miguel Curado da Silva, ..., Jorge Maia, ..., Teresa Teixeira Dias, et al.
  "XIPE: the X-ray Imaging Polarimetry Explorer", Paolo Soffitta et al., Experimental Astronomy 2013, DOI: 10.1007/s10686-013-9344-3

7.2.7 Presentations

Outreach seminars

- *Astronomia & Tecnologia Espacial no Quotidiano*
  presented by Rui Curado Silva
  — Escola Básica N.º 2 de Manteigas .
- *Telescópios para ver o Universo invisível*
  presented by Rui Curado Silva
  — Escola secundária/3º Amato Lusitano, Castelo Branco.
- *Aquecimento global: consequências e soluções*
  presented by Rui Curado Silva
  — Escola Secundária de Cantanhede, Cantanhede.

7.2.8 Academic Training

PhD Theses

- *Experimental CdTe Polarimeter development*
  José Marques, (on-going)

7.2.9 Project Summary

	number
Articles in international journals (with direct contribution from LIP members)	1
Outreach seminars	3

Chapter 8

Higher Education and Advanced Training, Technological Transfer and Outreach Activities

8.1 Higher Education and Advanced Training

8.1.1 Achievements

LIP has greatly contributed and will further contribute to physics and engineering education at high-education (Universities and Polytechnics) in Portugal. As part of a LIP strategy to help modernizing higher education (Physics and Engineering, Physical Engineering and Biomedical Engineering), such a contribution is no longer restricted to higher education Professors who are LIP members, but is expanding through the direct intervention of senior LIP researchers as invited Professors in higher education institutions, thus providing those students real contact with frontier research and frontier experimental methods and by insisting on the key role of experimental science education in science courses.

LIP will expand this strategy not only by pursuing its educational activities at its member Universities but also by stimulating joint programmes with other Universities, namely at masters and doctorate levels, either at national and at international levels. In addition, LIP will address interested Polytechnics in devising modern advanced technical courses or modules related to LIP activities.

LIP is also committed to stimulate cooperation among Portuguese Universities and other research institutions, namely by participating in several FCT supported post- graduation programmes, as DAEPHYS (for applied and Engineering Physics, with Aveiro, Coimbra, Lisboa and Nova de Lisboa Universities, I3N, LIP and CI), MAP-fis (for Physics, with Minho, Aveiro and Porto Universities) and DP-PMI (for Physics and Mathematics for future Information Technologies (IST and several multidisciplinary research centres, including LIP). 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) is also being prepared for the next call for proposals.

However, the specific backbone of LIP involvement in academic (doctoral) advanced training is IDPASC. Created by LIP and already based upon an international network of Universities and research institutions, counting already with the participation of three international research organizations (CERN, EGO and ICFA) and universities and research institutions in Portugal (Algarve, Coimbra, Évora, Lisbon and Porto, the educational network MAP-Fis and LIP), in Spain (Granada, Santiago Compostela and Valencia), in France (Paris VI, Paris VII and Savoie), in Italy (Padova, Bari, Genova, Siena, Trento and Udine), in Slovenia (Nova Gorica) and in Brazil (CBPF).

Aiming at progressive diversification, IDPASC strives to become a platform for joint doctoral degrees, nationally and internationally, competing for recognition and for student funding by international programmes like Erasmus Mundus. It will also support new academic platforms for the development of modern methods of distance learning, namely MOOCS, by some of its partner institutions, in its specific scientific field. At national level a proposal is being prepared to be jointly submitted to FCT in early 2014.

New opportunities are also to be exploited in the development of short specialised courses or advanced training modules devoted to the learning of new experimental techniques and methods, to the scientific update of physicists and engineers, but also to respond to the growing demand of further education by professionals from other fields, namely in areas of interface and application of particle physics methods and instruments

(e.g., biomedical, computing). As an example, LIP and Minho University are co-organising the 2014 CERN Computing School which will be held in Potugal from 25th August to 5th September 2014).

8.2 Technology Transfer

8.2.1 Resumo

Rede HEPTech
A rede HEPTech evoluiu para um conceito de uma rede ativa de nodos que se interligam numa área comum que é a transferência de tecnologia com origem da investigação fundamental. Esta rede continua a captar a atenção das principais instituições 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 operam nas áreas da Física de Partículas, Astrofísica e Física Nuclear. O estabelecimento de "Termos de Referência - ToR"para a rede HEPTech consolidou a sua orgânica e modo de operação e em 2013 várias iniciativas estiveram em curso de realização através de 6 grupos de trabalho, designadamente nas seguintes áreas: 1) Tecnologia para Aceleradores, 2) Sistemas de Controlo, 3) Tecnologias de Informação, 4) Detectores e duas áreas relacionadas com a Transferência do Conhecimento, nomeadamente: 5) e 6) Boas práticas e Suporte na especialização dos gabinetes de transferência de tecnologia. Estes grupos de trabalho, principalmente os de 1) a 4), tiveram um denominador comum que foi na organização de eventos AIME "Academia Industry Matching Events"onde a ciência encontra a indústria para explorarem colaborações para a comercialização de tecnologias com potencial de mercado. O LIP acompanhou estas várias iniciativas não só através da sua participação como nodo da rede mas também através da sua contribuição "in-kind"colaborando na coordenação da rede HEPTech.
Atividades do ILO
O mandato de ILO manteve a mesma estratégia para 2013 em apoiar e promover ativamente a indústria nacional e instituições de I&D no CERN, ESO, ESRF no processo de compras e na divulgação de novas oportunidades de projectos e tecnologias disponíveis*, por forma a garantir um retorno industrial sustentável para Portugal. O ILO prosseguiu a estreita colaboração com o Gabinete 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 network evolved from a concept to an active network of nodes that are connected in a common area that is technology transfer from fundamental research. This network continues to capture the attention of leading institutions 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 operate in the fields of Particle Physics, Astrophysics and Nuclear Physics. The establishment of "Terms of Reference - ToR"for the HEPTech network, consolidated the operating mode of the network for 2013 and several initiatives were implemented through six working groups, particularly in the following areas: 1) Technology for Accelerators, 2) Control Systems, 3) Information and Communication Technologies (ICT), 4) Detectors and two additional areas related to Knowledge Transfer, namely: 5) and 6) Good practices and Specialization support to Technology Transfer Offices. These working groups, mainly from 1) to 4) had a common goal being the organization of AIME "Academia Industry Matching Events"where science meets industry to explore collaborations for the commercialization of technologies with market potential. LIP followed these various initiatives not only through its participation as node member but also by its "in-kind"collaborating in the coordination of the HEPTech network.
ILO activities
The mandate of the ILO maintained the same strategy for 2013, 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 continued working closely with the FCT 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 establishment of a dedicated web-page about Technology Transfer at the LIP Outreach main page with the support of LIP "in-kind"contribution to the HEPTech project.
- As a node member in 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, at least, one forum with LIP researchers (in Lisbon and Coimbra) about Intellectual Property and Technology Transfer matters, leveraging on the experience of the HEPTech network.
ILO activities
- Ensure that the Industrial Liaison Officer function for CERN, ESO, ESRF is integrated as a formal operational unit in the Portuguese Science and Technology Foundation (FCT) internal structure.
- Ensure the creation of an industry database (a CRM information system helping the ILO with matters related to project opportunities and available technologies* at CERN, ESO, ESRF and ESA) can be considered as a FCT internal ICT project.
- 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.
- Continue with the national road-show initiative to present CERN, ESO, ESRF to Portuguese firms. And, along with the FCT Space Office have an integrated approach towards the firms operating in the space sector.
- 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 that may 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 Achievements

HEPTech network
- In order to disseminate matters on Technology and Knowledge Transfer throughout the LIP community, during 2013 a CERN report on Knowledge Transfer was shared. Further, the assurance for the creation of a dedicated web-page about Technology Transfer at LIP Outreach main-page required dedicated resources for its development thus being an on-going effort to be accomplished. However, it is expected that during the 1st semester of 2014 a document designated as Intellectual Property Charter (IP Charter) will be published for consultation. This IP Charter provides a set of principles facilitating the adoption of a sensible IP and Knowledge and Technology Transfer framework for institutions active in particle, astro-particle and nuclear physics, being fully compatible with open science models.
- Several AIME "Academia Industry Matching Events"and workshops were identified relevant to the LIP community during 2013, mainly, 1) AIME on Neutron Detection with MPGDs at the 12th RD51 Collaboration Meeting and Workshop on Neutron Detection with MPGDs; 2) The HEPTech Industry Open Innovation Forum; 3) HEPTech Workshop on Open Hardware; 4) HEPTech and ESS Innovation Procurement.
- LIP dedicated its efforts in responding and contributing to the 2013 HEPTech nodes survey about institutions that have relevant experience in technology transfer from particle physics. Further, LIP provided information for the HEPTech yearbook to be published during 2014.
ILO activities
- In 2013, the Technology office (http://www.fct.pt/apoios/tecnologia/), was created, integrating programmes, including the ILO unit, that connects Academia (universities, national laboratories and R&D units) with industry and its sectors. Further, this office ensured the transition of a training programme for young graduates traineeships at CERN, ESO and ESA from the national innovation agency (AdI) to be fully managed at FCT.
- A database composed of 361 firms from Portugal was created to support the ILO activities and ready for being exported to a more advanced information management system (IMS), such as a CRM (Customer Relationship Management) tool.
- The ILO continued in supporting company presentations to technical departments and/or groups from CERN, ESO and ESRF by establishing different formats of discussion forums (ex: dedicated meetings or industry days). It is reported for each organization, the company name and to whom it was presented, and also other activities that promote Portugal in these organizations, as follows:
CERN
- Company: Tuboplan – Boccard (Metalworking and piping products); To Whom: Senior Staff for Procurement – Finance Department.

- Company: Cubos & Polígonos Lda (High precision mechanics); To Whom: Mechanical and Materials Engineering Group.
- Company: EFACEC (Automation business unit); To Whom: Director of Engineering Department, Director of Finance, Procurement and Knowledge transfer, Head of Electrical Engineering Group.
- Company: FiberSensing (FBG monitoring solutions); To Whom: Physics Department/Detector Infrastructure Group.
- Company: UbiWhere (Software Engineering products and services); To Whom: Senior Staff for Procurement – Finance Department.
- Company: Godinho Luz (Consulting services in mechanical and electronics structures/simulations); To Whom: Engineering Department/Equipment controls and electronics/Industrial Controls and Engineering/Machines and Experimental Facilities Group.
- Company: Clarke, Modet & Cº (Patent Attorney services); To Whom: Senior Staff for Procurement – Finance Department.
- Company: ARSOPI (Metalworking Equipment); To Whom: Technology Department/Magnets, Superconductors and Cryostats.
- Participated in the CERN Special Day 2013 accompanied with the following companies: A.Silva Matos, EFACEC Engenharia e Sistemas, ISQ, Solidal Condutores SA, ActiveSpace Technologies.
- Provided a list of firms in the area of mechanical engineering and precision mechanics, as follows: SIROCO Sociedade Industrial de Robótica e Controlo S.A, Sirmaf, Incompol, EDAETECH, ActiveSpace Technologies, Inapal Metal SA, Azevedos Indústria – Máquinas e Equipamentos Industriais S.A.
- Provided to the Head of CERN Purchasing department an updated list of 164 Portuguese firms registered in CERN database.

ESO
- ISQ (Technical Consultancy Services); To Whom: Directorate of Programmes/E-ELT programme.
- Presentation of the Portuguese ILO activities at the ILO Forum on February 2013, held at ESO headquarters.
- Participated as ILO in a Ministerial visit to ESO facilities in Chile on March 2013, regarding the inauguration of ALMA (the Atacama Large Millimeter/submillimeter Array), one of the largest ground-based astronomy projects in the world.
- Participated in a Science Coffee event on April 2013 about the outcomes of participation of the Portuguese research community and firms at ESO and ESA at a Parliamentary Commission for Education, Science and Culture.
- Organized an event on June 2013, called: Public Session on ESO and the European Extremely Large Telescope (E-ELT). This event involved Portuguese top researchers in Astronomy and key supplier firms such as ISQ, Critical Software and Active Space Technologies that supplied technology and services to ESO.
- On June 2013, and following the visit of an European Prime contractor called Astrium Space Transportation, the ILO provided a list of companies that could be sub-contractors to the E-ELT project (Active Space Technologies, ASilva Matos, Critical Software, EFACEC, FiberSensing, INEGI, ISQ, Martifer, Metalúrgica Palmelense, Pinto&Cruz, Ply Engenharia, Sirmaf-Solien).
- Provided to the Head of ESO Contracts and Procurement an updated list of 44 Portuguese firms registered in ESO database.

ESRF
- Company: Assimagra (Portuguese Association of Granite producers); To Whom: Head of ESRF Purchasing Service.
- Organized an event coupled to the 2nd ENURS and ESRF Day in Portugal on February 2013, called: Industry Parallel Session. The event was attended by the following companies: Active Space Technologies, Godinho-Luz, LusoSpace, GMV Consulting, Deimos Engenharia, Sirmaf, Solidal Condutores Eléctricos SA, Cudell-Engenharia & Serviços Lda.
- Provided to the Head of ESRF Purchasing Service an updated list of 40 Portuguese firms to be registered in ESRF database.

8.2.5 Team

Project coordinator: Emir Sirage

Name	Status	FTE %
Emir Sirage	Technician (LIP)	100

8.3 Outreach Activities

8.3.1 Resumo

O LIP promove o avanço do conhecimento científico para o público em geral, estudantes e professores do ensino secundário, além do treino avançado nas suas áreas de actividade específicas. O grupo de Divulgação Científica é constituído por investigadores do LIP que sentem a necessidade de promover a literacia científica na sociedade e de procurar, motivar e treinar os cientistas de amanhã. Este grupo trabalha de perto com todos os projectos de investigação do LIP, ajudando a explorar as possibilidades de divulgação e promovendo novas actividades, organizando também acções regulares que vão além do trabalho específico de cada projecto.
As suas actividades abrangem diferentes áreas e diferentes públicos alvo, embora se foque principalmente nas comunidades escolares (alunos, professores e famílias), principalmente ao nível das escolas secundárias. As actividades regulares podem ser agrupadas em:
1) Seminários de divulgação por convite das escolas ou em sessões públicas organizadas à margem de eventos científicos promovidos pelo LIP;
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) 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;
7) Criação e adaptação de Comunicados de Imprensa, editados pelo CERN ou outros relacionados com a Física de Partículas e Astropartículas para os meios de comunicação social portugueses.
Em conjunto, o Programa de professores do CERN e o Projecto de radiação ambiente já colocaram em contacto próximo com a investigação recente, várias centenas de professores. Permitiram-nos assim criar uma rede de escolas, espalhada pelo país, em contacto ou com facilidade de acesso aos investigadores e vice-versa, o que consideramos fundamental para a generalização e o impacto das outras acções de divulgação.
O Programa de Professores em língua portuguesa é um exemplo para o próprio CERN, já que foi estendido a todos os outros países de língua portuguesa, dando também a possibilidade aos professores participantes de partilhar experiências com colegas de outras realidades.
Nas masterclasses participam anualmente cerca de dois milhares de estudantes, e várias dezenas de professores. É uma das acções de maior impacto directo e tem sido alargada a todo o país, contando com a colaboração de investigadores do LIP e também de outros investigadores nas instituições locais de Ensino Superior.
É já uma prática corrente que todos os grandes eventos organizados pelo LIP sejam acompanhados por uma sessão pública ou uma pequena exposição dedicada às escolas e ao público em geral. A comunicação com os parceiros internacionais, no sentido de procurar as melhores práticas, e com a comunicação social portuguesa, complementam as actividades do grupo de Divulgação.

8.3.2 Abstract

LIP promotes the advancement of scientific knowledge for the general public, high school students and teachers, and advanced training within its specific areas of activity. The LIP Outreach Group is constituted by LIP researchers engaged with the necessity to promote scientific literacy in the society, and to find, motivate and train the scientists of tomorrow. It works in close connection with all other groups in LIP to help exploring their outreach opportunities and promote new activities, and additionally organizes specific regular actions that are beyond the specific scientific projects.
Our activities spread over different areas and for different targets, although we mainly focus in the school communities (teachers, students and families). The regular activities can be grouped in:
1) Outreach seminars, either by invitation from schools, or in public sessions within scientific events organized by LIP;

2) Year long activities with schools, in particular with the Environmental Radiation Project, which exists already for several years with growing numbers of schools;
3) "Science in the Summer"Occupational Youth program from Ciência Viva, in which different LIP projects host a few students in one or two weeks internships;
4) International "Master classes"in Particle Physics, a one full day activity in which the students follow the path of the scientist with lectures, data analysis and discussion of the results. The masterclasses are done in coordination with other countries and CERN through IPPOG;
5) CERN Portuguese Language Teachers Program, in which teachers from Portuguese speaking countries spend a week at CERN, having update classes of particle physics and the Universe, experimental hands-on sessions, and visits to the CERN´s complex and experiments, accompanied by Portuguese researchers.
6) Participation in international groups about Outreach and Communication, namely IPPOG - International Particle Physics Outreach Group - dedicated to the outreach of particle physics worldwide, and EPPCN - European Particle Physics Communication Network - dedicated to the proper communication of Particle Physics and CERN within its member states;
7) Creation or adaptation of Press Releases issued by CERN or related to Particle and Astroparticle Physics for the Portuguese media.
Together, the CERN Portuguese Language Teachers Program and the Environmental Radiation Project have put by now several hundreds of teachers in close contact with present day research. They allowed us to create a network of schools spread all over the country, in close contact or easy access to researchers and vice-versa, which is fundamental for the generalization and impact of our other outreach actions.
The CERN Portuguese Language Teachers Program is an example at CERN, as it was extended to all other Portuguese speaking countries, which creates also the opportunity for teachers to share experiences with colleagues from different realities.
In the International Master classes two thousand students and dozens of teachers participate each year. It is one of the actions with largest direct impact and is being extended to all the country, counting not only on LIP researchers but also researchers in the local Universities.
It is common practice that all major events that LIP organizes are accompanied by a public lecture or small exhibition dedicated to the school and general public. The communication with international partners, in search for best practices, and with the Portuguese media complement the activities of the Outreach group.

8.3.3 Objectives

The objectives for the LIP Outreach group are always to increase the awareness of Particle and Astroparticle Physics in the Society, and to reach a larger sector of the population, both in number of persons and in geographical dispersion. Separated in the above topics, our objectives were:
1) To support schools wanting to visit CERN, and provide outreach seminars in schools and public places, in collaboration with Universities and Institutions.
2) To continue and expand the Environment Radiation Project in the school years of 2012/2013 and 2013/2014.
3) To provide summer occupation programs for high-school students, involving different scientific projects at LIP.
4) To organize the 9th edition of IPPOG´s International Masterclasses in Particle Physics, including two new venues - Évora and Ponta Delgada (Azores), crucial locations where the demand is high, and the transport to any of the other 12 venues is difficult.
5) To organize the 7th edition of the now CERN Portuguese Language Teachers Program, which has grown to become the largest CERN Teachers Program. Receiving, in addition to the normal quota of 40 portuguese teachers, a total of 30 Brazilian, 4 Mozambican, 4 Angolan, 1 Capeverdian, 1 Santomense teachers and 1 teacher from Guinea-Bissau and from East-Timor (in Asia).
6) To attend 2x2 meetings of the IPPOG - International Particle Physics Outreach Group and EPPCN - European Particle Physics Communication Network, and meetings of ASPERA Outreach Group;

8.3.4 Achievements

1) 20 seminars and public sessions.
In particular public seminars were co-organized with Planetário Calouste Gulbenkian and Centro de Ciência Viva; and several public seminars regarding the prospectives of the LHC, following the discovery of the Higgs boson, were requested and/or offered by LIP in 4 occasions, one of them in Brazil.
Another nice adventure were the presence of LIP Scientists at the basic school based on The Pavillion of Knowledge, in the activity "Meet a Scientist". The targets were 1st year, 6 years old, in one session, and 3rd year, 8 years old, in another session.

2) The 5th National Meeting of the Project ´Environment Radiation´ taok place in Cacém on the 4th of May, with about 200 participants presenting posters which reflect the work performed during the school-year.
3) 20 students were hosted by the following projects (ATLAS, AUGER, Detectors) in Lisbon and Coimbra.
4) Around 2000 students participated in the MasterClasses in 14 locations, including Évora and Ponta Delgada for the first time, and the support to São Tomé and Príncipe for the second time;
5) 72 teachers participated in the CERN Portuguese Language Teachers Programme: 34 portuguese, 30 brazilian, plus 4 from East-Timor and São Tomé and Príncipe. Unfortunately none could come from Angola, Mozambique, Cape-Verde, and Guinea-Bissau because of sudden difficulties in getting the adequate travel VISAs.
6) Both IPPOG and EPPCN meet twice a year. Now one of the meetings has a shared session, by suggestion of our group (that is, the autumn meetings of both groups occur at CERN at the same time, and have a shared session to discuss issues of common interest).
7) An exhibition entitled "From the skies to the universe", featuring old documents and artifacts versus modern detectors and technologies - including the LIP Spark Chamber, was prepared and open to the public from May 2nd to July 26th at the National Library, with free guided tours (upon appointment), in the scope of the Workshop "Auger Analysis Week"organized by LIP/Auger group.
8) The teacher view of the Masterclasses was an object of presentation in a international conference dedicated to the skills of Teaching and Education in Physics.

8.3.5 Sources of Funding

Code	Funding	Start	End
PEC37	20.000 €	2013-01-01	2014-07-01
PEC258	30.000 €	2013-01-01	2014-08-31

8.3.6 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 Keating	Post-Doc (LIP/FCT)	
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)	

8.3.7 Presentations

Oral presentations in international conferences

- *What motivates high school teachers to join the Masterclasses Day - Hands on Particle Physics?* presented by
  ICPE-EPEC 2013 — Prague, Czech Republic.

Outreach seminars

- *À procura do Bosão de Higgs*
  presented by José Maneira
  XVI Semana da Física IST — IST, Lisboa.

8.3.8 Project Summary

	number
Oral presentations in international conferences	1
Outreach seminars	1