Laboratório de Instrumentação e Física Experimental de Partículas

Activity Report

2014

Contents

Chapter 1

Overview

1.1 Introdução

1.2 Introduction

2014 was a difficult year for Particle Physics in Portugal in what concerns funding. Both the general call for funding projects in all scientific domains, and the specific call for funding CERN related projects did not open. The cut in funding at this level at LIP was around 400 k€. Nevertheless, LIP was able to maintain its scientific activity at high level, fulfilling its main international commitments, but most investments and the preparation of the upgrades of experiments, namely at LHC, were postponed. Scientific employment at LIP, both in the form of contracts and in the form of ongoing grants, was secured, but basically no new grants were given. If this tendency is not inverted, it will have an extremely negative impact on a whole generation of students, with mid and long term effects on the scientific performance of LIP. The call for projects in the framework of the Portuguese cooperation with CERN that was initially foreseen to open in last semester of 2013 was opened by FCT in January 2015

The strategy for the development and consolidation of LIP participation in EU and ESA projects was successfully pursued, and, in particular, new contracts were obtained in the areas of space applications, advanced computing and medical applications. The IDPASC-Portugal PhD programme coordinated by LIP was approved by FCT and the first call was launched. This programme involves the main Portuguese Universities with research activities in the fields of Particle and Astroparticle physics and Cosmology.

During 2014 the Portuguese Research Units underwent a process of evaluation by the FCT. In the outcome of this evaluation process, LIP was classified with "Very good"in contrast with all previous evaluations as "Excellent". LIP has strongly objected to the arguments used by the Evaluation Panel in the justification presented for LIP evaluation results. No further developments on the complaint process presented by LIP to the FCT are known to the present day.

LIP acknowledges and thanks the CERN directorate and the LIP International advisory committee for their constant support and help clarifying the specific scientific and technological aspects of experimental particle physics and the role that LIP has accomplished in this highly specialized domain.

The detailed report for each experiment/activity in which LIP was involved in 2014 can be found in the following sections, but the highlights for the different projects can be found below.

Experimental Particle Physics with accelerators

ATLAS – Observation and measurement of the H->WW decays with the full LHC Run 1 luminosity; Improved limits on the search for the H->bb in associated production with a W or a Z boson. Updates on searches for ttH, for new heavy quarks production and FCNC in top quark decays for the 8 TeV dataset. Update on the di-jet asymmetry analysis in Pb-Pb collisions. Remaking and reinstallation of the TileCal laser system (Laser II) and migration and upgrade of the TileCal DCS. Implementation of a new Partial Scan for improving the jet trigger allowing partial event reconstruction.

CMS - Consolidation of the analysis of the Higgs boson decay in the two-photons and study of the Higgs properties; update of the measurement of the top quark mass in di-lepton events; search for a light/heavy charged Higgs decaying from/to the top quark; search for the stop quark. Pursuing the leading role in the Data Acquisition System and Trigger of the Electromagnetic Calorimeter, the group developed, built and installed the new optical links that interface the ECAL electronics to the Trigger System. The group led the proposal of

the new CMS-TOTEM Precision Proton Spectrometer approved by the LHC Experiments Committee (LHCC).
Phenomenology at the LHC – Development of a strong collaboration between experimentalists and theoretical physicists for the LHC. Upgrades, improvements and new developments in the models for single top production via FCNC at the LHC and for the Top Quark Anomalous Couplings. Derivation of the first results on the Wtb vertex structure from LHC and Tevatron data.
COMPASS experiment at CERN – Co-leading role in the preparation and first tests of the Polarised Drell-Yan Programme, first world experiment. Study of spin asymmetries in order to extract the gluon polarisation as well as the polarised structure functions of the nucleon, namely the longitudinal g_1(x) and the transverse Sivers functions. Measurement of hadron multiplicities in view of the strangeness to kaon D_sˆK(z) fragmentation function extraction. Full responsibility of the COMPASS DCS.
HADES experiment at GSI – Demonstration of the excellent performance well above the requirements of the RPC-TOF wall, at the design multiplicity, after accurate calibration, from data of the 2012 Au-Au at 1.25A GeV physics run. Development of a new method based on a dynamic neural network for leptons selection.

Computing

Digital Computing and advanced infrastructures - Approval of the INCD proposal into the Portuguese Science Foundation strategic infrastructures roadmap following an international evaluation where it received the maximum score.
Advanced Computing - Local organization of the 2014 edition of the CERN School of Computing, a highly regarded reference for training physicists, computer scientists and engineers from all over the world in HEP applications.

Astroparticle Physics

Collaboration in AMS - Alpha Magnetic Spectrometer – Development and successful application of a preliminary likelihood estimator to electron/proton separation in the low energy regime for positron ratio measurement. Exploration of AMS data for studying solar activity effects in the cosmic rays arriving to earth.
Collaboration in the SNO+ experiment – Continued involvement in the SNO+ detector construction: installation during the water fill of the PMT calibration system fibers and related hardware; production started at the Coimbra workshop of the internal calibration source insertion system. Preparation of the physics data analyses: measurement of antineutrinos from nuclear reactors and the Earth; data quality and background rejection algorithms for the search for the neutrinoless double beta decay of Te130.
Participation in Dark Matter experiments and R&D on Liquid Xenon Detectors for Dark Matter Search – Completion of the upgrade of the slow control and the liquid nitrogen systems for the long science run. Both systems have been running with availability better than 99.5%. Completion of the measurements of the reflectivity of PTFE used by LUX immersed in liquid xenon. The group also gave key contributions to the data processing and in the data analysis. In particular, the group continues to have full responsibility for the development of the vertex reconstruction tool.
High Energy Cosmic Rays – Development of innovative methods for the characterization of electromagnetic and muonic shower profiles which are relevant for disentangling primary composition from hadronic models. Production of full scale prototype RPC chambers capable of operating autonomously, outdoors and with low gas flux (MARTA - Muon Array RPC for Tagging Air showers - project), which are operating in the Pierre Auger Observatory since several months.

Detector development for particle and nuclear physics

Participation in RD51 – Design and start of construction of a large area (≈2 m2) TOF tracker device with 3 layers, with preliminary, but full-size, tests suggesting position resolutions on the order of 0.3 mm FWHM.
NeuLAND - An innovative high-energy neutron time-of-flight detector for experiments at GSI and FAIR - The innovative concept for a TOF detection system based on RPCs for detecting relativistic neutrons was successfully tested and can be adopted for future experiments. An upper value of 150 ps timing resolution for neutrons in the energy range of 300 to 1500 MeV was determined.
Neutron Detectors – Development of B4C coated multi-gap RPCs for high resolution position sensitive thermal neutrons (PSNDs). Integration of a consortium led by the European (ESFRI) facilities, ILL and ESS, which submitted in September 2014 a proposal to Horizon2020 (SINE2020).
High Pressure Xenon Doped Mixtures for the NEXT Collaboration – Assessment of the influence of very small concentrations of molecular additives in the charge multiplication and electroluminescence yield of xenon based gaseous mixtures.

Ion Transport Processes in Gaseous Detectors for Particle Physics – Development of ion mobility studies at reduced electric field values typically used in gaseous detectors, in particular for 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 and for ions originated in argon-carbon dioxide gaseous mixtures (Ar/CO2) for pressures ranging from 6 to 10 Torr and for reduced electric fields in the 10 Td to 25 Td range, at room temperature.
Beam Monitoring System for Cyclotron Proton Beams at ICNAS – Construction of a 2D positioning system to allow irradiating automatically cells positioned in a multi well plate.
Detector Lab / Mechanical Workshop – Construction and test of several large Resistive Plate Chamber detectors (RPCs) for the Auger project together with the High Voltage Power Supply (HVPS), gas and monitoring systems.

Instruments and methods for biomedical applications

Spin-off technologies for Cancer Diagnostics - The LIP/STCD group concluded the development of a new PET Detector Module and SiPM Readout System for the EndoTOFPET-US prototype scanner, in close collaboration with the startup company PETsysElectronics. In 2014 the clinical exploitation of the ClearPEM scanner was strongly affected by the difficulty to assure technical support due to lack of funding.
PET with Resistive Plate Chambers (RPC-PET) - Deployment of the prototype scanner to ICNAS and first tests with mice using several radiopharmaceuticals. A FWHM of 0.4mm was confirmed. Full-scale tests of the readout system of the Human RPC-PET with preliminary results pointing to a transaxial position resolution of 0.8 mm FWHM.
Detectors and Monte Carlo in Medical Physics – Construction of a plastic scintillator dosimeter (PSD) prototype, which underwent successful clinical tests, showing a very good linearity of the PSD response with dose and no-energy dependence for the studied energy-range.
Orthogonal Ray Imaging for Radiotherapy Improvement – Confirmation that pertinent dose-changing morphological or physiological alterations may be detected through RTmonitor/OrthoCT, thus providing information for assisting and potentially improving RT treatments.
Adaptive methods for medical imaging with gamma cameras – Construction and test of a compact gamma camera with 64-channel SiPM readout. Successful application of adaptive algorithms for event reconstruction in position sensitive scintillation detectors to an upgraded commercial gamma camera refurbished and retrofitted with a modern data acquisition system.

Radiation Environment Studies and Applications for Space Missions

Space Radiation Environment and Effects – Kick-off of four contracts with the European Space Agency in the following subjects: development of RADEM, a radiation monitor for the JUICE mission to the Jovian System; testing EEE components to be used in the JUICE mission systems and sub-systems; data analysis of the MFS data, orbiting in GEO aboard AlphaSAT since 2013; and in the installation at LIP and support of CODES, a Single Event Effects modelling framework based on Geant4.
Integrated Activities for the High Energy Astrophysics Domain – Approval of AHEAD (Activities in the High Energy Astrophysics Domain), a H2020 project proposal in response to a call for Research Infrastructures for High Energy Astrophysics, which was elaborated and submitted in 2014, to start in 2015, with the duration of 24 months.

Higher Education and Advanced Training, Technological Transfer and Outreach Activities

Higher Education and Advanced Training – Coordination of joint PhD programs involving several Portuguese Universities DAEPHYS and IDPASC, both with PhD grant calls opening in 2014.
Technology Transfer – Participation of LIP as a node member in HEPTech, a high energy physics technology transfer network. Support to the Portuguese Industry in presentations to technical departments and/or groups from CERN, ESO and ESRF by establishing different formats of discussion such as dedicated meetings or industry days.
Outreach Activities - Organization of more than 30 seminars and public sessions for Primary and High School students, some of them in co-coordination with other institutes such as Planetário Calouste Gulbenkian and Ciência Viva. Organization of the 7th National Meeting of the Project "Environmental Radiation". Hosting of high school students for two week summer internships. Organization of the CERN Portuguese Language Teachers Programme with the participation of 72 teachers. Translation, adaptation and dissemination to the Portuguese media of all press releases from CERN and from other scientific entities.

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	2014-11-30
ATLAS	CERN/FP/123595/2011	530.000 €	FCT	2012-04-01	2014-04-30
	EXPL/FIS-NUC/1705/20 13	49.485 €	FCT	2014-04-07	2015-08-06
	IF/00955/2013/CP1172 /CT0004	50.000 €	FCT	2013-12-01	2018-11-30
	IF/00050/2013/CP1172 /CT0002	50.000 €	FCT	2014-01-01	2018-12-31
CMS	CERN/FP/123601/2011	550.000 €	FCT	2012-04-01	2015-03-31
	IF/01454/2013/CP1172 /CT0003	50.000 €	FCT	2014-01-01	2018-12-31
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
	Cloud - Piloto	100.000 €	FCT	2014-08-14	2015-12-31
HECR	CERN/FP/123611/2011	280.000 €	FCT	2012-02-01	2014-04-30
	RPCs Auger	66.000 €	CBPF	2014-01-01	2014-12-31
	ASPERA/0001/2010	150.000 €	FCT	2012-09-01	2015-08-31
	EPLANET 246806	10.800 €	EU	2011-01-01	2015-12-31
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	2015-12-31
OUTREACH	PEC258	30.000 €	CVIVA	2013-01-01	2014-08-31
	PEC37	20.000 €	CVIVA	2013-01-01	2014-12-31
PET - Mammography	Endo TOFPET-US256984	509.400 €	EU	2011-01-01	2015-06-30
	PicoSEC-MCNet (28935 5)	423.082 €	EU	2012-01-01	2015-12-31
SNO+	PTDC/FIS/115281/2009	108.971 €	FCT	2011-01-01	2014-10-30
	EXPL/FIS-NUC/1557/20 13	49.485 €	FCT	2014-04-01	2015-09-30
	IF/00863/2013/CP1172 /CT0006	50.000 €	FCT	2014-01-01	2018-12-31
Space	ESA: 3-14025/13/NL/A K	60.000 €	ESA	2014-03-17	2015-06-30
	ESA:22381/09/NL/PA/C CN04	20.000 €	ESA	2013-10-01	2015-06-30
	ESA: 3-13975/13/NL/P A	200.000 €	ESA	2014-03-10	2015-08-31
	ESA: 1-7560/13/NL/HB	300.000 €	ESA	2014-02-18	2016-07-28
Laboratório Associado	PEst	655.677 €	FCT	2014-01-01	2014-12-31
Quotas	2014	157.121 €	FCT	2014-01-01	2014-12-31
Incentivo FCT		91.342 €	FCT	2014-01-01	2014-12-31
Investigador FCT		533.935 €	FCT	2014-01-01	2014-12-31
Conferences		110.000 €		2014-01-01	2014-12-31

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	2014-03-31
Gamma Cameras	PTDC/BBB-BMD/2395/20 12	48.202 €	FCT	2013-05-01	2014-04-30
	IF/00378/2013/CP1172 /CT001	50.000 €	FCT	2014-01-01	2018-12-31
HADES	PTDC/FIS/113339/2009	91.742 €	FCT	2011-04-01	2015-01-31
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
Neutron Detectors	EXPL/FIS-NUC/2522/20 13	31.200 €	FCT	2014-03-01	2015-08-31
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	base e programático	419.204 €	FCT	2014-01-01	2014-12-31
Quotas	2014	87.080 €	FCT	2014-01-01	2014-12-31
Outros Nacionais	C. Viva, conferências	214.538 €		2014-01-01	2014-12-31
Investigador FCT		55.281,00 €	FCT	2014-01-01	2014-12-31

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	79	7	14	4	2	7	11	9		2	1	1
CMS	80	3	14	13	1	2	8					1
LHC Phenomenology	9	9	5								1	
COMPASS	8	6	12	10		2	1					
HADES	9	1										
GRID	1	1	10			2	1					2
Advanced Computing	4	4								2		3
AMS	3			1		1						
SNO+	2		4	4								
Dark Matter Search	3	2	13	4			1			1		
HECR	13	4	5	10				2			1	2
RD51	2	2		4	1		1				1	
NeuLand - R3B	1	1		1								
Neutron Detectors				1	1							
NEXT	3											
Ion Transport Processes	3	3										
ICNAS											1	
PET - Mammography	1		5	6	3						3	3
Human PET	1	1		1		2					1	
MC in Medical Physics	3	3	1	6	1	4						
OrthogonalRayImaging												
Gamma Cameras					2							
RAD4LIFE	2	2		2		2					2	
Space	1	1		1	2		1					
AHEAD			1		3	1		1				
Education												
TTN-ILO												
OUTREACH						2						17
Totals:	226	48	84	66	16	23	24	12		5	8	28

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	16	1	3	10	5		2
CMS	7	2	4	7			2
LHC Phenomenology	13		2	1	2		1
COMPASS	3	1	3	2	1		
HADES	2	2	2				
GRID	6	3	1				
Advanced Computing	4						
AMS	1		1		2		1
SNO+	5	5					
Dark Matter Search	4	2	3	1	2		
HECR	14	3	5	2	2		1
RD51	5	10		1			
NeuLand - R3B	3	8					
Neutron Detectors	5		1				
NEXT	7		1				
Ion Transport Processes	5		1	1			
ICNAS	3			2			
PET - Mammography	5	2	1	6	1		
Human PET	5	7					
MC in Medical Physics	7		1		1	1	
OrthogonalRayImaging	1			2	1		
Gamma Cameras	6		2	2			
Space	4		2	1	1		
AHEAD	6		1	1	2		
Education							
TTN-ILO		1					
OUTREACH	10	1	1				
Totals:	94	20	27	36	19	1	6

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	8	1	3	10	3		1	28
CMS	6	2	4	6			2	20
LHC Phenomenology	4		1	1				7
COMPASS	3	1	2	2	1			10
HADES	1	1	1					2
GRID	5	3	1					9
Advanced Computing	4							4
AMS	1		1		2		1	5
SNO+	3	1						4
Dark Matter Search	2	1	3	1				6
HECR	6	1	4	2	1		1	16
RD51	1	2		1				3
NeuLand - R3B		1						1
Neutron Detectors	1		1					2
NEXT	2		1					2
Ion Transport Processes	1			1				3
ICNAS	1			1				2
PET - Mammography	2	1	1	6	1			11
Human PET	1	1						2
MC in Medical Physics	4		1		1			5
OrthogonalRayImaging	1			2	1			3
Gamma Cameras	2			1				4
Space	1		1	1				3
AHEAD	2			1	1			5
Education								
TTN-ILO		1						1
OUTREACH								
Totals:	62	17	25	36	11		5	158

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, Leonor Coimbra, Lina Barata, Maria José Miguel (IST), Natália Antunes, Ricardo Caeiro, Sandra Dias, Teresa Marques

Technical Staff

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

Chapter 2

Experimental Particle Physics with accelerators

2.1 Collaboration in the ATLAS experiment at CERN

2.1.1 Resumo

A experiência ATLAS opera no acelerador LHC do CERN, onde se produzem colisões de protão-protão (p+p) e iões pesados (p+Pb e Pb+Pb) a energias e luminosidades sem precedentes. Depois de três anos de recolha de dados de 7 e 8TeV (Run 1) e de um interregno de dois anos para melhoramentos, ATLAS vai em breve retomar a recolha de dados a 13 e 14TeV com capacidades melhoradas (Run 2).

O grupo de ATLAS no LIP participa nos estudos de física bem como do desempenho do detector, na sua operação, manutenção, e melhoramentos com vista a exploração futura (Upgrade). Esta actividade é aqui resumida (designando-se os coordenadores de cada área).

Estudos de Física:

a) Bosão de Higgs (R. Gonçalo, P. Conde)

Desde a descoberta do bosão de Higgs em 2012, dedicámo-nos ao estudo das suas propriedades em três canais diferentes: H->WW, produção associada com um par de quarks top (ttH) e com um bosão W ou Z seguida do decaimento em quarks b. Em 2014 finalizámos a análise dos dados recolhidos no Run 1 nestes três canais, de onde resultou a publicação de vários artigos e notas. Iniciámos também a preparação das análises futuras no canal de decaimento em quarks b. Na análise de ttH estudamos a utilização de novas variáveis para melhorar a sensibilidade da análise.

b) Quark Top (A. Onofre, F. Veloso)

A procura do decaimento do quark top através de Flavour Changing Neutral Current (FCNC) foi actualizada com os dados de 8TeV, resultando em vários artigos e notas. Um membro do grupo co-liderou o sub-grupo dedicado ao estudo das propriedades do top. A sensibilidade para as buscas dos processos de FCNC t->qZ e t->qgamma durante a fase de alta luminosidade do LHC a 14TeV foi estudada em dados simulados e os resultados são compatíveis com a extrapolação das medidas feitas a 7TeV.

c) Procura de quarks pesados (N. Castro)

As buscas de novos quarks pesados foram atualizadas com os dados de 8TeV. O nosso grupo lidera a análise da topologia de Zt/b+X e contribui para a combinação estatística dos vários canais. Na ausência de sinais experimentais, obtiveram-se os melhores limites existentes para a massa dos quarks vectoriais T e B, tendo sido excluídos no intervalo de massas até 800GeV com nível de confiança de 95%.

d) Supressão de jatos em colisões de iões pesados (H. Santos)

No último período de recolha de dados de p+Pb, fomos responsáveis pela preparação das assinaturas do trigger de jatos, pela sua optimização e pela monitorização da reconstrução dos dados. Depois disto, estudámos a escala de energia de jatos e a sua resolução e eficiência de reconstrução em colisões de p+Pb e Pb+Pb, contribuindo para a análise da fragmentação de jatos. A análise de assimetrias em eventos de di-jatos progrediu notoriamente. Recentemente iniciámos o estudo de jatos de sabores pesados em colisões de Pb+Pb, em preparação para o Run 2.

Operação, manutenção e melhoramentos do detetor:

1) Trigger de jatos (R. Gonçalo, P. Conde)
Durante os últimos dois anos contribuímos para o desenvolvimento do trigger de jatos no nível High Level Trigger (HLT) que une os antigos L2 e Event Filter. Implementámos a leitura parcial do calorímetro que actua como supressor do ruído e aumenta a flexibilidade do trigger de jatos para se adaptar a diferentes condições de operação do LHC.
Iniciámos também a investigação da paralelização de algoritmos do trigger utilizando General Purpose Graphical Processing Units (GPGPU), destinada à fase 1 do Upgrade, onde estamos a implementar um protótipo paralelizado do algoritmo que reconstrói depósitos tridimensionais de energia no calorímetro. Colaboramos com o grupo e computação do LIP para testar o algoritmo em várias plataformas.
2) TileCal (A. Gomes)
As nossas contribuições para o calorímetro TileCal centraram-se nos sistemas de controlo do detector (DCS) e de calibração por laser, e nos melhoramentos para a fase.
O DCS foi migrado para Linux e também de PVSS para o WinCC OA. A substituição de fontes de alimentação pelas novas TDK levou à reorganização do software, facilitando a substituição de unidades defeituosas. Um servidor OPC UA foi implementado para o sistema de alta tensão. Simultaneamente, foi garantido o apoio às atividades de upgrade do detetor. O sistema DCS do detector ALFA foi também migrado e actualizado.
O novo laser II do sistema de calibração foi montado na caverna USA15 com ótica melhorada e uma nova caixa de laser produzida em Portugal. Depois da montagem, foi ajustada a equalização da luz transmitida às fibras óticas que a transportam até aos módulos do detector, tendo sido iniciado o seu comissionamento.
O ruído eletrónico imitando a presença muões cria limitações da taxa de contagem aceitável no trigger. Para reduzir estes falsos sinais na região de 1.0<‖eta‖<1.3, o TileCal e o espectrómetro de muões vão ser usados conjuntamente (Tile-Mu trigger). Algoritmos de simulação foram desenvolvidos para validar este novo trigger, tendo sido implementado um transmissor de G-link numa FPGA do Trigger Muon Digitizer Board (TMDB) assim como um conjunto de placas descodificadoras de TTC produzidas em Portugal. Estamos também a preparar os conversores de byte-stream de modo a testar em breve o desempenho do Tile-Mu com colisões a 50ns.
O TileCal vai precisar de um novo distribuidor de altas voltagens para o período de HL-LHC devido aos danos pela radiação acumulada que se espera afectem o actual sistema. O nosso grupo desenhou cartas para irradiação e testes de componentes resistentes á irradiação.
O TileCal vai precisar de um novo distribuidor de altas voltagens para o periodo de HL-LHC devido aos danos por radiação esperados no atual sistema para 2022. O nosso grupo desenhou cartas para irradiação e testes de componentes resistentes á irradiação.
3) AFP (ATLAS Forward Proton tagging detectors)
Iniciámos o desenho da estratégia de trigger para a seleção de processos de física difractiva a ser explorada no Run-2 do LHC, contribuindo assim para o TDR do AFP.
4) Computação distribuída (H. Wolters)
A Iberian cloud e o Tier2 português mostraram excelente desempenho na operação durante o ano passado. A capacidade do Tier2 português excedeu os compromissos de WLCG feitos a ATLAS, demonstrando também óptimas métricas de fiabilidade e disponibilidade.

Divulgação:

Tivemos uma excelente participação em atividades de divulgação, com Masterclasses em várias universidades, participação na escola de professores de língua portuguesa no CERN, programa Ciência Viva para estudantes e várias outras atividades.

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. After three years of very successful data taking, followed by a two year-long shutdown, the ATLAS experiment is about to re-start data taking with improved capabilities.
The LIP Portuguese group contributes to Physics and performance studies, detector operation and maintenance and upgrade. In what follows, our contributions to these activities will be summarized. The coordinators of the different activities appear in brackets.

Physics analysis

a) Higgs boson studies (R. Gonçalo, P. Conde)
After the discovery of the Higgs boson in 2012, the group´s efforts have been dedicated to the study of the its properties in three different channels: H->WW, associated production of the Higgs with the top-quark pairs and associated production with a W or Z boson when the Higgs decays to b-quark pairs. During 2014 we have finalized analysis of the full luminosity Run 1 data in these three channels, leading to several public notes and papers. In addition, we started the preparation of the 13 TeV data analysis for the bb channel. In the ttH analysis, we are studying new angular variables to further improve the sensitivity of the analysis.
b) Top quark studies (A. Onofre, F. Veloso)
The searches for top quark decays via Flavour Changing Neutral Currents were updated to the full 8 TeV dataset and several notes and papers were prepared. The expected resolutions of the reconstructed masses of the FCNC processes t->qZ and t->qgamma at the high-luminosity phase of the 14 TeV LHC were studied as a function of the mean number of events per beam crossing using Monte Carlo samples.
c) Heavy quark searches (N. Castro)
The searches for new heavy quarks production were updated to the full 8 TeV data set. Our team is leading the effort on the Zt/b+X topology and contributing to the global combination effort. In the absence of an evidence for signal in the run-1 dataset, the most stringent limits on the vector-like T and B quarks were obtained, excluding the masses of these quarks up to 800 GeV at 95% confidence level.
d) Jet suppression in Heavy Ions collisions (H. Santos)
In the last p+Pb run we prepared the jet trigger menu, fine tuned it in order to ensure enough statistics for the signals of interest, and supervised the offline jet reconstruction monitoring. After this stage we studied the jet energy scale, resolution and reconstruction efficiencies in p+Pb and Pb+Pb collisions, contributing to the published analysis on jet fragmentation. The analysis of dijet asymmetries gained significant progress. Recently we started the study of heavy flavour jet production in Pb+Pb collisions in preparation for the Run 2.

Detector operation, maintenance and upgrade:

1) Jet Trigger (R. Gonçalo, P. Conde)
During the long shutdown we contributed to the development of the new jets High Level Trigger (HLT) that now joins the L2 and the Event Filter. We implemented a partial scan that acts a zero suppressed event readout, and increases the flexibility of the jet trigger to adapt to different data taking conditions.
In addition, we have started R&D on parallelization of trigger algorithms to be run on General Purpose Processing Units (GPGPU) for the Phase I Upgrade. We are implementing a prototype parallel version of the topo-clustering algorithm and collaborating with the computing group of LIP to test it on different hardware technologies.
2) TileCal (A. Gomes)
Our contributions to the TileCal have focused mainly on the DCS, the new laser calibration system and the upgrade, described in more detail in what follows.
The TileCal DCS was migrated from Windows to Linux, and also from PVSS to WinCC OA. The replacement of the old 200V power supplies by the TDK lead to a new organization of the respective software, making easier in the future the replacement of faulty units by spares. An OPC UA server was implemented for the high voltage system. At the same time it was provided a large scale support to the upgrade activities. The ALFA DCS was also migrated and upgraded.
In the laser calibration system, the new Laser II was set up in the USA15 cavern, with improved optics and a new laser box made in Portugal. After the set up, the system was adjusted for equalization of the light in the several fibres that transmit it to the modules, and the commissioning started.
The team performed detailed studies of the pileup noise in the TileCal calorimeter for both 50 and 25 ns bunch spacing. The pileup noise dependency with pseudorapidity, studied for different towers and partitions, was evaluated.
To reduce fake L1 muon triggers, for the Run 2 TileCal will be combined with the Muon Spectrometer in the region 1.0<‖eta‖<1.3 (Tile-Mu trigger). Simulation algorithms to validate this new trigger were written, a G-link trasmitter was implemented in one FPGA of the ATLAS Trigger Muon Digitizer Board (TMDB) and a set of TTC decoder boards was produced in Portugal. We are implementing data bytestream converters for a fast test of the Tile-Mu trigger performance with the 50 ns collision and for monitoring/debugging during Run 2.
TileCal will need a new High Voltage Distributor System for the HL-LHC, due to radiation damage and obsolescence of the current system. Our team designed boards for irradiation and selection of the best radiation hard components.

In addition to these activities the group contributed to the TileCal operations and commissioning with cosmic muons with data quality and DCS shifts, remotely or at CERN.
3) AFP (ATLAS Forward Proton tagging detectors)
We have started to design a trigger strategy to select diffractive physics processes of interest for Run II, contributing to the AFP TDR.
4) Distributed Computing (H. Wolters)
The Iberian cloud and the Portuguese Tier2 have shown excellent results in the operation during the last year. The Portuguese Tier2 delivered a capacity that exceeded the WLCG pledges for ATLAS and exhibited very good reliability and availability metrics.
Outreach:
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 during holidays (Ocupação Científica para Jovens nas Férias, OCJF) and many other activities.

2.1.3 Achievements

The LIP group has done major or leading contribution to the following achievements during 2014:

- Observation and measurement of the H->WW decays with the full Run 1 luminosity. We contributed mainly to the same flavour channel with the determination of one of the main backgrounds and the optimization of the analysis. 1 PhD thesis was finished and is about to be defended.
- Validation of the Global Sequential Calibration to improve the b-jet energy scale.
- Improved limits on the search for the H->bb in associated production with a W or a Z boson. We contributed to the improvement of the di-bjet mass resolution, to the systematics studies and the global fits. On this topic, 2 PhD thesis are being finalized and one will be finished in 2015.
- Searches for ttH were updated for the 8 TeV dataset. One PhD thesis on this topic will be finished this year.
- Top quark decays via FCNC were updated to the full TeV datase.
- New heavy quarks production updated to the full 8 TeV dataset with several publications. One PhD thesis was finished and is about to be defended.
- Update of the analysis of dijet asymmetry in Pb+Pb collisions.
- The TileCal laser system was redone and installed in the detector (Laser II).
- The TileCal DCS was migrated and upgraded while keeping it, at the same time, operational for maintenance and consolidation work in the detector.
- Contributed to the Tile-Mu trigger hardware and software.
- Improved the jet trigger with the implementation of a new Partial Scan that allows partial event reconstruction, focusing on the regions with detector activity.
- Upgrade work started in faster algorithms for level 2 jet trigger, 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 2015.

Coordination positions within the ATLAS Collaboration (in 2014):

- Ricardo Gonçalo, Jet Trigger coordinator.
- Helmut Wolters, coordinator of the Iberian Cloud.
- Helmut Wolters, responsible for the Portuguese Federated Tier2 in the Iberian Cloud Squad.
- Nuno Castro, convenor of the top properties sub-group (until March 2014).
- Nuno Castro, theory hot-spot contact for the vector-like quark searches within the Exotics Working Group (since October 2014) .

- Nuno Castro, contact person for the run-2 searches for vector-like quarks (since October 2014).

Editorial Boards:
Members of our group participated in 9 Editorial Boards of ATLAS public notes or papers in the areas of new physics searches, heavy ions physics, Higgs and top quark physics: H. Santos (2), N. Castro (2), F. Veloso (1), Ricardo Gonçalo (2, one of them as chair of the board), A. Onofre (2, as chair of the board in both cases).

2.1.4 Sources of Funding

Code	Funding	Start	End
CERN/FP/123595/2011	530.000 €	2012-04-01	2014-04-30
IF/00955/2013/CP1172/CT0004	50.000 €	2013-12-01	2018-11-30
IF/00050/2013/CP1172/CT0002	50.000 €	2014-01-01	2018-12-31
EXPL/FIS-NUC/1705/2013	49.485 €	2014-04-07	2015-08-06

2.1.5 Team

Project coordinator: Patricia Conde

Name	**Status**	**FTE %**
Ademar Delgado	PhD student (LIP/FCT)	100
Agostinho Gomes	Researcher (LIP)	85
Alberto Blanco	Researcher (LIP)	15
Alberto Palma	PhD student (LIP)	100
Alexandre Lopes	Master student (LIP)	33
Amélia Maio	Researcher (LIP/FCUL)	55
André Pereira	Master (LIP)	67
António Onofre	Researcher (LIP/UMinho)	57
Artur Amorim de Sousa	Master student (LIP)	67
Bruno Galhardo	PhD student (LIP/FCT)	100
Carlos Marques	Researcher (LIP)	33
Emanuel Gouveia	Master student (LIP)	100
Ester Simões	Master student (LIP)	100
Filipe Martins	Master (LIP)	100
Filipe Veloso	Post-Doc (LIP/FCT/FCTUC)	90
Guiomar Evans	Researcher (FCUL)	15
Helena Santos	Researcher (LIP)	100
Helmut Wolters	Researcher (LIP/FCTUC)	60
Henrique Carvalho	Student (LIP)	56
Joana Miguéns	PhD student (LIP/FCT)	100
João Gentil	Post-Doc (LIP/FCT)	100
José Domingos Alves	Master (LIP)	84
José Maneira	Researcher (LIP)	52
José Manuel da Silva	Master (LIP)	50
José Santiago Perez	Researcher (LIP/UGR)	22
José Soares Augusto	Researcher (IST/INESC/FCUL)	30
Juan Espinosa	PhD student (LIP/FCT)	100
Lia Moreira	Student (LIP)	40
Lourenço Lopes	PhD student (LIP/FCUL)	100
Luís Gurriana	Technician (LIP)	50
Luís Seabra	Master (LIP)	66
Manuel Maneira	Researcher (LIP/FCTUNL)	15
Mário Sargedas Sousa	PhD student (LIP/FCT)	100
Nuno Castro	Researcher (LIP/UP)	64
Patricia Conde	Researcher (LIP)	85
Pedro Jorge	PhD student (LIP/FCT)	80
Renato Dantas	Master student (LIP/UMinho)	8
Ricardo Gonçalo	Researcher (LIP)	87
Robert Cantrill	Post-Doc (LIP)	67
Rui Santos	Researcher (LIP/FCUL)	11
Rute Pedro	PhD student (LIP/FCT)	100
Susana Santos	PhD student (LIP/FCT)	77

2.1.6 Publications

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

- **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) — DOI: 10.1016/j.nima.2013.09.024

- **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 — DOI: 10.1016/j.nima.2013.09.033

- **Measurement of the top quark pair production charge asymmetry in proton-proton collisions at 7 TeV using the ATLAS detector**
  ATLAS Collaboration
  JHEP02(2014)107

- **Measurements of spin correlation in top-antitop quark events from proton-proton collisions at $\sqrt{s} = 7$ TeV using the ATLAS detector**
  ATLAS Collaboration
  Phys. Rev. D. 90, 112016 (2014) — DOI: 10.1103/PhysRevD.90.112016

- **Search for the $b\bar{b}$ decay of the Standard Model Higgs boson in associated $(W/Z)H$ production with the ATLAS detector**
  ATLAS Collaboration
  JHEP01(2015)069 — DOI: 10.1007/JHEP01(2015)069

- **Search for pair and single production of new heavy quarks that decay to a Z boson and a third-generation quark in pp collisions at root s=8 TeV with the ATLAS detector**
  ATLAS Collaboration (2897 authors)
  J. High Energy Phys. 11 (2014) 104 — DOI: 10.1007/JHEP11(2014)104

- **Measurement of inclusive jet charged-particle fragmentation functions in Pb plus Pb collisions at root S-NN=2.76 TeV with the ATLAS detector**
  ATLAS Collaboration (2876 authors)
  Phys. Lett. B 739 (2014) 320-342 — DOI: 10.1016/j.physletb.2014.10.065

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

- **Measurement of the production cross section of prompt J/psi mesons in association with a W^pm boson in pp collisions at $sqrts$ = 7 TeV with the ATLAS detector**
  ATLAS Collaboration (2914 authors)
  JHEP 1404 (2014) 172 — DOI: 10.1007/JHEP04(2014)172

- **Search for new phenomena in final states with large jet multiplicities and missing transverse momentum at root s = 8 TeV proton-proton collisions using the ATLAS experiment (vol 10, pg 130, 2013)**
  ATLAS Collaboration (2908 authors)
  J. High Energy Phys. 1 (2014) 109 — DOI: 10.1007/JHEP01(2014)109

- **Measurement of the electroweak production of dijets in association with a Z-boson and distributions sensitive to vector boson fusion in proton-proton collisions at $sqrts$ = 8 TeV using the ATLAS detector**
  ATLAS Collaboration (2884 authors)
  JHEP 1404 (2014) 031 — DOI: 10.1007/JHEP04(2014)031

- **Search for Higgs boson decays to a photon and a Z boson in pp collisions at $sqrts$=7 and 8 TeV with the ATLAS detector**
  ATLAS Collaboration (2905 authors)
  Phys.Lett. B732 (2014) 8-27 — DOI: 10.1016/j.physletb.2014.03.015

- **Search for direct production of charginos and neutralinos in events with three leptons and missing transverse momentum in $sqrts$ = 8TeV pp collisions with the ATLAS detector**
  ATLAS Collaboration (2898 authors)
  JHEP 1404 (2014) 169 — DOI: 10.1007/JHEP04(2014)169

- **Measurement of dijet cross-sections in pp collisions at 7 TeV centre-of-mass energy using the ATLAS detector**
  ATLAS Collaboration (2951 authors)
  J. High Energy Phys. 5 (2014) 059 — DOI: 10.1007/JHEP05(2014)059

- **Search for direct production of charginos, neutralinos and sleptons in final states with two leptons and missing transverse momentum in pp collisions at root s=8TeV with the ATLAS detector**
  G. Aad et al. (2886 authors)
  J. High Energy Phys. 5 (2014) 1-52 — DOI: 10.1007/JHEP05(2014)071

- **Measurement of the production of a W boson in association with a charm quark in pp collisions at root s=7 TeV with the ATLAS detector**
  G. Aad et al. (2901 authors)
  J. High Energy Phys. 5 (2014) 1-67 — DOI: 10.1007/JHEP05(2014)068

- **Search for Invisible Decays of a Higgs Boson Produced in Association with a Z Boson in ATLAS**
  ATLAS Collaboration (2916 authors)
  Phys. Rev. Lett. 112 (2014) 201802 — DOI: 10.1103/PhysRevLett.112.201802

- **Measurement of the parity-violating asymmetry parameter ab and the helicity amplitudes for the decay Lambda(0)(b) -> J/psi Lambda(0) with the ATLAS detector**
  ATLAS Collaboration (2897 authors)
  Phys. Rev. D 89 (2014) 092009 — DOI: 10.1103/PhysRevD.89.092009

- **Search for direct top squark pair production in events with a boson, -jets and missing transverse momentum in TeV collisions with the ATLAS detector**
  ATLAS Collaboration (2886 authors)
  Eur. Phys. J. C 74 (2014) 2883 — DOI: 10.1140/epjc/s10052-014-2883-6

- **Search for top quark decays t -> q H with H -> gamma gamma using the ATLAS detector**
  ATLAS Collaborat (2891 authors)
  J. High Energy Phys. 6 (2014) 008 — DOI: 10.1007/JHEP06(2014)008

- **Search for supersymmetry at root 8=8 TeV in final states with jets and two same-sign leptons or three leptons with the ATLAS detector**
  G. Aad et al. (2873 authors)
  J. High Energy Phys. 6 (2014) 035 — DOI: 10.1007/JHEP06(2014)035

- **Measurements of Four-Lepton Production at the Z Resonance in pp Collisions at root s=7 and 8 TeV with ATLAS**
  ATLAS Collaboration (2898 authors)
  Phys. Rev. Lett. 112 (2014) 231806 — DOI: 10.1103/PhysRevLett.112.231806

- **Measurement of the low-mass Drell-Yan differential cross section at root s=7 TeV using the ATLAS detector**
  ATLAS Collaboration (2900 authors)
  J. High Energy Phys. 6 (2014) 112 — DOI: 10.1007/JHEP06(2014)112

- **Search for direct top-squark pair production in final states with two leptons in pp collisions at root s=8 TeV with the ATLAS detector**
  ATLAS Collaboration (2900 authors)
  J. High Energy Phys. 6 (2014) 124 — DOI: 10.1007/JHEP06(2014)124

- **Monitoring and data quality assessment of the ATLAS liquid argon calorimeter**
  ATLAS Collaboration (2872 authors)
  J. Instrum. 9 (2014) P07024 — DOI: 10.1088/1748-0221/9/07/P07024

- **The differential production cross section of the phi(1020) meson in root s=7 TeV pp collisions measured with the ATLAS detector**
  ATLAS Collaboration (2906 authors)
  Eur. Phys. J. C 74 (2014) 2895 — DOI: 10.1140/epjc/s10052-014-2895-2

- **Search for dark matter in events with a Z boson and missing transverse momentum in pp collisions at root s=8 TeV with the ATLAS detector**
  ATLAS Collaboration (2894 authors)
  Phys. Rev. D 90 (2014) 012004 — DOI: 10.1103/PhysRevD.90.012004

- **Electron reconstruction and identification efficiency measurements with the ATLAS detector using the 2011 LHC proton-proton collision data**
  ATLAS Collaboration (2898 authors)
  Eur. Phys. J. C 74 (2014) 2941 — DOI: 10.1140/epjc/s10052-014-2941-0

- **Measurement of chi(c1) and chi(c2) production with root s=7 TeV pp collisions at ATLAS**
  ATLAS Collaboration (2960 authors)
  J. High Energy Phys. 7 (2014) 154 — DOI: 10.1007/JHEP07(2014)154

- **Operation and performance of the ATLAS semiconductor tracker**
  ATLAS Collboration (2886 authors)
  J. Instrum. 9 (2014) — DOI: 10.1088/1748-0221/9/08/P08009

- **Measurement of event-plane correlations in root s(NN)=2.76 TeV lead-lead collisions with the ATLAS detector**
  ATLAS Collaboration (2884 authors)
  Phys. Rev. C 90 (2014) 024905 — DOI: 10.1103/PhysRevC.90.024905

- **Measurement of the underlying event in jet events from 7 proton-proton collisions with the ATLAS detector**
  ATLAS Collaboration (2875 authors)
  Eur. Phys. J. C 74 (2014) 2965 — DOI: 10.1140/epjc/s10052-014-2965-5

- **Measurement of the centrality and pseudorapidity dependence of the integrated elliptic flow in lead-lead collisions at root S-NN=2.76 TeV with the ATLAS detector**
  ATLAS Collaboration (2862 authors)
  Eur. Phys. J. C 74 (2014) 2982 — DOI: 10.1140/epjc/s10052-014-2982-4

- **Search for microscopic black holes and string balls in final states with leptons and jets with the ATLAS detector at root s=8 TeV**
  ATLAS Collaboration (2881 authors)
  J. High Energy Phys. 8 (2014) 103 — DOI: 10.1007/JHEP08(2014)103

- **Light-quark and gluon jet discrimination in collisions at root s=7 TeV with the ATLAS detector**
  ATLAS Collaboration (2879 authors)
  Eur. Phys. J. C 74 (2014) 3023 — DOI: 10.1140/epjc/s10052-014-3023-z

- **Search for direct pair production of the top squark in all-hadronic final states in proton-proton collisions at=8 TeV with the ATLAS detector**
  ATLAS Collaboration (2883 authors)
  J. High Energy Phys. 9 (2014) 015 — DOI: 10.1007/JHEP09(2014)015

- **Search for supersymmetry in events with four or more leptons in root s=8 TeV pp collisions with the ATLAS detector**
  ATLAS Collaboration (2876 authors)
  Phys. Rev. D 90 (2014) 052001 — DOI: 10.1103/PhysRevD.90.052001

- **Search for new particles in events with one lepton and missing transverse momentum in pp collisions at root s=8 TeV with the ATLAS detector**
  ATLAS Collaboration (2882 authors)
  J. High Energy Phys. 9 (2014) — DOI: 10.1007/JHEP09(2014)037

- **Measurement of the Higgs boson mass from the H -> gamma gamma and H -> ZZ* -> 4l channels in pp collisions at center-of-mass energies of 7 and 8 TeV with the ATLAS detector**
  ATLAS Collaboration (2900 authors)
  Phys. Rev. D 90 (2014) 052004 — DOI: 10.1103/PhysRevD.90.052004

- **Measurement of the production cross-section of psi(2S) -> J/psi(-> mu(+)mu(-))pi(+) pi(-) in pp collisions at root s=7 TeV at ATLAS**
  ATLAS Collaboration (2875 authors)
  J. High Energy Phys. 9 (2014) 1-49 — DOI: 10.1007/JHEP09(2014)079

- **A neural network clustering algorithm for the ATLAS silicon pixel detector**
  ATLAS Collaboration (2883 authors)
  JINST 9 (2014) P09009 — DOI: 10.1088/1748-0221/9/09/P09009

- **Muon reconstruction efficiency and momentum resolution of the ATLAS experiment in proton-proton collisions at *sqrts* = 7 TeV in 2010**
  ATLAS Collaboration (2917 authors)
  Eur.Phys.J. C74 (2014) 3034 — DOI: 10.1140/epjc/s10052-014-3034-9

- **Search for supersymmetry in events with large missing transverse momentum, jets, and at least one tau lepton in 20 fb(-1) of root s=8 TeV proton-proton collision data with the ATLAS detector**
  ATLAS Collaboration (2886 authors)
  J. High Energy Phys. 9 (2014) 103 — DOI: 10.1007/JHEP09(2014)103

- **Measurements of fiducial and differential cross sections for Higgs boson production in the diphoton decay channel at TeV with ATLAS**
  ATLAS Collaboration (2892 authors)
  J. High Energy Phys. 9 (2014) 1-61 — DOI: 10.1007/JHEP09(2014)112

- **Search for high-mass dilepton resonances in pp collisions at root s = 8 TeV with the ATLAS detector**
  ATLAS Collaboration (2881 authors)
  Phys. Rev. D 90 (2014) 052005 — DOI: 10.1103/PhysRevD.90.052005

- **Flavor tagged time-dependent angular analysis of the B-s(0) -> J/psi phi decay and extraction of Delta Gamma(s) and the weak phase phi(s) in ATLAS**
  ATLAS Collaboration (2898 authors)
  Phys. Rev. D 90 (2014) 052007 — DOI: 10.1103/PhysRevD.90.052007

- **Measurement of the Z/gamma* boson transverse momentum distribution in pp collisions at root s=7 TeV with the ATLAS detector**
  G. Aad et al. (2879 authors)
  J. High Energy Phys. 9 (2014) 145 — DOI: 10.1007/JHEP09(2014)145

- **Search for pair-produced third-generation squarks decaying via charm quarks or in compressed supersymmetric scenarios in pp collisions at root s = 8 TeV with the ATLAS detector**
  ATLAS Collaboration / ATLAS Collaboration (2887 authors)
  Phys. Rev. D 90 (2014) — DOI: 10.1103/PhysRevD.90.052008

- **Search for squarks and gluinos with the ATLAS detector in final states with jets and missing transverse momentum using root s=8 TeV proton-proton collision data**
  ATLAS Collaboration (2878 authors)
  J. High Energy Phys. 9 (2014) 176 — DOI: 10.1007/JHEP09(2014)176

- **Electron and photon energy calibration with the ATLAS detector using LHC Run 1 data**
  ATLAS Collaboration (2892 authors)
  Eur. Phys. J. C 74 (2014) 3071 — DOI: 10.1140/epjc/s10052-014-3071-4

- **Evidence for Electroweak Production of W(+/-)W(+/-)jj in pp Collisions at root s=8 TeV with the ATLAS Detector**
  ATLAS Collaboration (2880 authors)
  Phys. Rev. Lett. 113 (2014) 141803 — DOI: 10.1103/PhysRevLett.113.141803

- **Search for strong production of supersymmetric particles in final states with missing transverse momentum and at least three b-jets at root s=8 TeV proton-proton collisions with the ATLAS detector**
  G. Aad et al. (2881 authors)
  J. High Energy Phys. 10 (2014) — DOI: 10.1007/JHEP10(2014)024

- **Search for WZ resonances in the fully leptonic channel using pp collisions at root s=8 TeV with the ATLAS detector**
  ATLAS Collaboration (2881 authors)
  Phys. Lett. B 737 (2014) 223-243 — DOI: 10.1016/j.physletb.2014.08.039

- **Measurement of long-range pseudorapidity correlations and azimuthal harmonics in root s(NN)=5.02 TeV proton-lead collisions with the ATLAS detector**
  ATLAS Collaboration (2892 authors)
  Phys. Rev. C 90 (2014) 044906 — DOI: 10.1103/PhysRevC.90.044906

- **Measurements of normalized differential cross sections for t(t)over-bar production in pp collisions at root(s)=7 TeV using the ATLAS detector**
  ATLAS Collaboration (2882 authors)
  Phys. Rev. D 90 (2014) 072004 — DOI: 10.1103/PhysRevD.90.072004

- **Search for the direct production of charginos, neutralinos and staus in final states with at least two hadronically decaying taus and missing transverse momentum in pp collisions at root s=8 TeVwith the ATLAS detecto**
  ATLAS Collaboration (2886 authors)
  J. High Energy Phys. 10 (2014) 096 — DOI: 10.1007/JHEP10(2014)096

- **Search for Scalar Diphoton Resonances in the Mass Range 65-600 GeV with the ATLAS Detector in pp Collision Data at root s=8 TeV**
  ATLAS Collaboration (2890 authors)
  Phys. Rev. Lett. 113 (2014) — DOI: 10.1103/PhysRevLett.113.171801

- **Lessons from Monte Carlo simulations of the performance of a dual-readout fiber calorimeter**
  N. Akchurin et al. (23 authors, including J. G. Saraiva)
  Nucl. Instrum. Methods Phys. Res. Sect. A-Accel. Spectrom. Dect. Assoc. Equip. 762 (2014) 100-118 — DOI: 10.1016/j.nima.2014.05.121

- **Search for the lepton flavor violating decay Z -> e mu in pp collisions at root s=8 TeV with the ATLAS detector**
  ATLAS Collaboration (2902 authors)
  Phys. Rev. D 90 (2014) 072010 — DOI: 10.1103/PhysRevD.90.072010

- **Measurement of differential production cross-sections for a Z boson in association with b-jets in 7 TeV proton-proton collisions with the ATLAS detector**
  ATLAS Collaboration (2886 authors)
  J. High Energy Phys. 10 (2014) 141 — DOI: 10.1007/JHEP10(2014)141

- **Measurement of the t(t)over-bar production cross-section using e mu events with b-tagged jets in pp collisions at root s=7 and 8 TeV with the ATLAS detector**
  ATLAS Collaboration (2886 authors)
  Eur. Phys. J. C 74 (2014) 3109 — DOI: 10.1140/epjc/s10052-014-3109-7

- **Measurements of jet vetoes and azimuthal decorrelations in dijet events produced in pp collisions at root s=7 TeV using the ATLAS detector**
  ATLAS Collaboration (2889 authors)
  Eur. Phys. J. C 74 (2014) 3117 — DOI: 10.1140/epjc/s10052-014-3117-7

- **Measurement of the cross-section of high transverse momentum vector bosons reconstructed as single jets and studies of jet substructure in pp collisions at root s=7TeV with the ATLAS detector**
  ATLAS Collaboration (3146 authors)
  New J. Phys. 16 (2014) 113013 — DOI: 10.1088/1367-2630/16/11/113013

- **Measurement of the cross section of high transverse momentum Z -> b(b)over-bar production in proton-proton collisions at root s=8 TeV with the ATLAS detector**
  Atlas Collaboration (2877 authors)
  Phys. Lett. B 738 (2014) 25-43 — DOI: 10.1016/j.physletb.2014.09.020

- **Search for the Standard Model Higgs boson decay to mu(+)mu(-) with the ATLAS detector**
  ATLAS Collaboration (2886 authors)
  Phys. Lett. B 738 (2014) 68-86 — DOI: 10.1016/j.physletb.2014.09.008

- **Fiducial and differential cross sections of Higgs boson production measured in the four-lepton decay channel in pp collisions at root s=8 TeV with the ATLAS detector**
  ATLAS Collaboration (2901 authors)
  Phys. Lett. B 738 (2014) 234-253 — DOI: 10.1016/j.physletb.2014.09.054

- **Search for new resonances in W gamma and Z gamma final states in pp collisions at root s=8 TeV with the ATLAS detector**
  ATLAS Collaboration (2893 authors)
  Phys. Lett. B 738 (2014) 428-447 — DOI: 10.1016/j.physletb.2014.10.002

- **Search for neutral Higgs bosons of the minimal supersymmetric standard model in pp collisions at root s=8 TeV with the ATLAS detector**
  ATLAS Collaboration (2895 authors)
  J. High Energy Phys. 11 (2014) 056 — DOI: 10.1007/JHEP11(2014)056

- **Search for long-lived neutral particles decaying into lepton jets in proton-proton collisions at root s=8 Tev with the ATLAS detector**
  ATLAS collaboration (2903 authors)
  J. High Energy Phys. 11 (2014) 088 — DOI: 10.1007/JHEP11(2014)088

- **Observation of an Excited B-c(+/-) Meson State with the ATLAS Detector**
  ATLAS Collaboration (2884 authors)
  Phys. Rev. Lett. 113 (2014) 212004 — DOI: 10.1103/PhysRevLett.113.212004

- **Search for top squark pair production in final states with one isolated lepton, jets, and missing transverse momentum in *sqrts* =8 TeV *pp* collisions with the ATLAS detector**
  ATLAS Collaboration (2891 authors)
  JHEP 1411 (2014) 118 — DOI: 10.1007/JHEP11(2014)118

- **Measurement of the muon reconstruction performance of the ATLAS detector using 2011 and 2012 LHC proton-proton collision data**
  ATLAS Collaboration (2891 authors)
  Eur. Phys. J. C 74 (2014) 3130 — DOI: 10.1140/epjc/s10052-014-3130-x

- **Measurement of flow harmonics with multi-particle cumulants in Pb+Pb collisions at $sqrts_{mathrmNN} = 2.76$ TeV with the ATLAS detector**
  ATLAS Collaboration (2888 authors)
  Eur.Phys.J. C74 (2014) 3157 — DOI: 10.1140/epjc/s10052-014-3157-z

- **Measurement of the total cross section from elastic scattering in pp collisions at root s=7 TeV with the ATLAS detector**
  ATLAS Collaboration (2900 authors)
  Nucl. Phys. B 889 (2014) 486-548 — DOI: 10.1016/j.nuclphysb.2014.10.019

- **A measurement of the ratio of the production cross sections for W and Z bosons in association with jets with the ATLAS detector**
  ATLAS Collaboration (2883 authors)
  Eur. Phys. J. C 74 (2014) 3168 — DOI: 10.1140/epjc/s10052-014-3168-9

- **Measurement of distributions sensitive to the underlying event in inclusive Z-boson production in pp collisions at root s=7 TeV with the ATLAS detector**
  ATLAS Collaboration (2895 authors)
  Eur. Phys. J. C 74 (2014) 3195 — DOI: 10.1140/epjc/s10052-014-3195-6

- **Search for nonpointing and delayed photons in the diphoton and missing transverse momentum final state in 8 TeV pp collisions at the LHC using the ATLAS detector**
  ATLAS Collaboration (2891 authors)
  Phys. Rev. D 90 (2014) — DOI: 10.1103/PhysRevD.90.112005

- **Search for contact interactions and large extra dimensions in the dilepton channel using proton-proton collisions at root s=8 TeV with the ATLAS detector**
  ATLAS Collaboration (2891 authors)
  Eur. Phys. J. C 74 (2014) — DOI: 10.1140/epjc/s10052-014-3134-6

- **Comprehensive measurements of t-channel single top-quark production cross sections at root S=7 TeV with the ATLAS detector**
  ATLAS Collaboration (2888 authors)
  Phys. Rev. D 90 (2014) 112006 — DOI: 10.1103/PhysRevD.90.112006

- **Measurement of Higgs boson production in the diphoton decay channel in pp collisions at center-of-mass energies of 7 and 8 TeV with the ATLAS detector**
  ATLAS Collaboration (2901 authors)
  Phys.Rev. D90 (2014) 112015 — DOI: 10.1103/PhysRevD.90.112015

International Conference Proceedings

- **Emulation in FPGA of G-Link Chip-set of Tile Calorimeter Electronic System**
  José Alves, José Silva, Guiomar Evans, José Soares Augusto
  Procedia Technology Volume 17, 2014, Pages 319–326. — DOI: 10.1016/j.protcy.2014.10.242

- **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 — DOI: 10.1088/1742-6596/513/3/032082

- **Measurement of the top quark mass and properties at the LHC**
  N. Castro
  ATL-PHYS-PROC-2014-079

- **A new portable test bench for the ATLAS Tile Calorimeter front-end electronics certification**
  J. Alves et al. (12 authors)
  Proc. 3rd Int. Conf. on Advancements in Nuclear Instrumentation Measurement Methods and their Applications (ANIMMA 2013) — DOI: 10.1109/ANIMMA.2013.6728018

National Conference Proceedings

- **Serial Peripheral Interface (SPI) Master Evaluation in FPGA for ATLAS Tile Calorimeter High Voltage Control System**
  J. Alves, G. Evans, J. Soares Augusto, J. Silva, L. Gurriana, A. Gomes
  10th Portuguese Meeting on Reconfigurable Systems, Vilamoura, Algarve (Portugal) – 13 April 2014, pp. 53- 56, ISBN: 978-989-98875-1-0

Collaboration notes with internal referee

- **Jet Production in pPb collisions**
  ATLAS Collaboration
  ATLAS-CONF-2014-024
- **Search for pair and single production of new heavy quarks that decay to a Z boson and a third generation quark in pp collisions at √s=8 TeV with the ATLAS detector**
  ATLAS Collaboration
  ATLAS-CONF-2014-036
- **Search for pair and single production of new heavy quarks that decay to a Z boson and a third generation quark in pp collisions at sqrt(s) = 8 TeV with the ATLAS detector**
  ATLAS Collaboration
  ATLAS-CONF-2014-036
- **Observation and measurement of Higgs boson decays to WW* with the ATLAS detector**
  ATLAS Collaboration
  ATLAS-HIGG-2013-13
- **´Search for Scalar Charm Pair Production with the ATLAS Detector in pp Collisions at √s = 8 TeV**
  ATLAS Collaboration
  ATLAS-CONF-2014-063

Internal Notes

- **Jet energy scale determination for heavy ion jet reconstruction : JES for HI jets**
  H. Santos et al
  ATL-COM-PHYS-2014-329
- **Jet energy scale and its uncertainty for jets reconstructed using the ATLAS heavy ion jet algorithm**
  H. Santos et al
  ATL-COM-PHYS-2014-947
- **Search for the Production of a Standard Model Higgs Boson produced in association with a Vector Boson and decaying to a pair of b-quarks**
  F. Ahmadov, A. da Palma, P. Conde Muino, J. Gentil, R. Gonçalo, A. Maio, J. Maneira, R. Pedro, M. Sousa et al
  ATL-COM-2014-051
- **Numerical inversion for calibration of Heavy-ion jets**
  H. Santos et al
  ATL-COM-PHYS-2014-795

2.1.7 Presentations

Oral presentations in international conferences

- **Top FCNC @ ATLAS**
  presented by Nuno Castro
  The top-charm frontier at the LHC Workshop — CERN, Geneva, Switzerland.
- **Measurement of the top quark mass and properties at the LHC**
  presented by Nuno Castro
  Rencontres de Moriond, Electroweak Interactions and Unified Theories — La Thuile, France.
- **Study of FCNC in top quark production and decay with the ATLAS detector**
  presented by Juan Espinosa
  The 15th International Conference on B-Physics at Frontier Machines — Edinburgh, Scotland, Uk .
- **Higgs Physics at ATLAS**
  presented by Ricardo Gonçalo
  Workshop on Multi-Higgs Models — Lisbon.

Poster presentations in international conferences

- **Higgs Boson Searches with ATLAS in the WH->lvbb channel**
  presented by Rute Pedro
  European School of High-Energy Physics (ESHEP) — .
- **The global sequential jet calibration to improve VH(bb) invariant mass resolution**
  presented by Mário Sargedas Sousa
  European School of High-Energy Physics (ESHEP) — .

Presentations in national conferences

- **Search for vector-like quarks with the ATLAS detector.**
  presented by Juan Espinosa
  4th IDPASC School — Braga.
- **ATLAS H->WW and H->bb Results**
  presented by Patricia Conde
  New Worlds in Particle and Astroparticle Physics — Braga.
- **ttH Searches and Higgs Couplings at the LHC**
  presented by Ricardo Gonçalo
  New Worlds in Particle, Astroparticle and Cosmology — Braga.
- **Search for vector-like quarks with the ATLAS experiment**
  presented by Nuno Castro
  New Worlds in Particle, Astroparticle and Cosmology — Braga.
- **Search for vector-like quark pair production in the ATLAS experiment.**
  presented by Juan Espinosa
  Jornadas do LIP 2014, Lisbon. — Lisbon.
- **Overview of the Standard Model Higgs Boson Experimental Results**
  presented by Patricia Conde
  Física 2014 (Conferência Nacional de Física) — Lisboa.
- **Study of the Higgs boson decaying to b-quarks in the ZH channel with the ATLAS detector**
  presented by Mário Sargedas Sousa
  Física 2014 (Conferência Nacional de Física) — Lisboa.

Oral presentations in collaboration meetings

- **Vector-like quark searches**
  presented by Juan Espinosa
  Analysis meeting — CERN.
- **GSC results for AFII/FS, for QCD and ttbar, with inclusive di-jets and with flavor dependence**
  presented by Mário Sargedas Sousa
  — .
- **T2AllRoiCellUnpacking**
  presented by Ademar Delgado
  Jet Trigger Menu and Software — .
- **Quantiles studies presentation.**
  presented by Juan Espinosa
  TileCal meeting — CERN.
- **GSC with Atlfast-II**
  presented by Mário Sargedas Sousa
  — .
- **GSC results for AFII/FS, for QCD and ttbar, with inclusive di-jets**
  presented by Mário Sargedas Sousa
  — .
- **Tile DCS issues and migration status**
  presented by Filipe Martins
  TileCal Operation and Maintenance Weekly Meeting — CERN.
- **Tile DCS issues and migration status**
  presented by Filipe Martins
  TileCal Operation and Maintenance Weekly Meeting — CERN.
- **TMDB emulator (AI-03)**
  presented by João Gentil
  LVL1 Tile-Muon trigger meeting — CERN, Geneva.

- **Updates for the FullSim-AtlasFast II difference for the forward region**
  presented by Mário Sargedas Sousa
  — .
- **physics upgrade — top physics**
  presented by Filipe Veloso
  reunião do grupo ATLAS-PT — .
- **Forward GSC with Atlfast-II**
  presented by Mário Sargedas Sousa
  — .
- **Treatment of overflow channels**
  presented by José Maneira
  TileCal Week — CERN.
- **Tile DCS**
  presented by Filipe Martins
  TileCal Operation and Maintenance Weekly Meeting — CERN.
- **PIC Cloud support**
  presented by Helmut Wolters
  XV Face to Face Meeting of the Spanish ATLAS Tier-2 — Valencia, Spain.
- **AFP Trigger Status Open Questions**
  presented by Patricia Conde
  ATLAS Week — CERN.
- **AFP Trigger status: open questions**
  presented by Patricia Conde
  ATLAS Week — CERN, Geneva.
- **Monte Carlo corrections discussion and implementation**
  presented by Juan Espinosa
  Analysis meeting — CERN.
- **Ademar´s Report**
  presented by Ademar Delgado
  Jet Trigger Menu and Software — CERN, Geneva.
- **superRoI implementation**
  presented by Ademar Delgado
  Calorimeter Trigger — CERN, Geneva.
- **Single top systematic uncertainties**
  presented by Rute Pedro
  HSG5 Meeting — CERN, Geneva.
- **New input production and discussion**
  presented by Juan Espinosa
  Analysis meeting — CERN.
- **Partial scan news**
  presented by Ademar Delgado
  Jet Trigger Menu and Software — CERN, Geneva.
- **Cut-flow optimisation discussion.**
  presented by Juan Espinosa
  Analysis meeting — CERN.
- **partial scan**
  presented by Ademar Delgado
  Jet Trigger Signature Group Meeting — CERN, Geneva.
- **Cutflow optimisation.**
  presented by Juan Espinosa
  Analysis meeting — CERN.
- **Irradiation of ADCs and DACs for HV in Lisbon**
  presented by Agostinho Gomes
  Tilecal Demonstrator meeting — CERN.
- **Welcome by local organisers**
  presented by Ricardo Gonçalo
  ATLAS Trigger Workshop — CERN, Geneva.
- **Single top systematic uncertainties**
  presented by Rute Pedro
  VH(bb) Informal — CERN, Geneva.

- **Tile-d Simulation**
  presented by João Gentil
  LVL1 Tile-Muon trigger meeting — CERN, Geneva.
- **Status report in the HQT subgroup for the Zb/t+X analysis.**
  presented by Juan Espinosa
  Analysis meeting — CERN.
- **Data/MC comparison for quantiles studies.**
  presented by Juan Espinosa
  TileCal meeting — CERN.
- **Quantiles studies update in the TileCal group weekly meeting.**
  presented by Juan Espinosa
  TileCal meeting — CERN.
- **Single top systematic uncertainties**
  presented by Rute Pedro
  VH(bb) Informal — CERN, Geneva.
- **the 1 million dollar challenge**
  presented by Ademar Delgado
  Jet Trigger Signature Group Meeting — CERN, Geneva.
- **Simulation of Tile Muon trigger board - current status: algorithm status**
  presented by João Gentil
  Tilecal Calibration, Data Quality, Performance and Processing — CERN, Geneva.
- **Single top systematic uncertainties**
  presented by Rute Pedro
  VH(bb) Informal — CERN, Geneva.
- **Single top systematic uncertainties**
  presented by Rute Pedro
  VH, H to bb Editorial Board Meeting — CERN, Geneva.
- **Cutflow optimisation.**
  presented by Juan Espinosa
  Analysis meeting — CERN.
- **Tile-d trigger simulation and software status**
  presented by João Gentil
  LVL1 Tile-Muon trigger meeting — CERN, Geneva.
- **Study of the response different jet flavours and different MC samples using GSC**
  presented by João Gentil
  Jet Calibration and Resolution — CERN, Geneva.
- **Study of the response of different jet flavours and different MC samples using GSC**
  presented by Mário Sargedas Sousa
  — .
- **Error estimation discussion.**
  presented by Juan Espinosa
  Analysis meeting — CERN.
- **the 1 million dollar challenge**
  presented by Ademar Delgado
  Jet Trigger Signature Group Meeting — CERN, Geneva.
- **Update on search for FCNC in trilepton**
  presented by Bruno Galhardo
  Top properties meeting — .
- **Single top systematic uncertainties**
  presented by Rute Pedro
  VH, H to bb Editorial Board Meeting — CERN, Geneva.
- **Quantiles studies update.**
  presented by Juan Espinosa
  TileCal meeting — CERN.
- **the 1 million dollar challenge**
  presented by Ademar Delgado
  Jet Trigger Signature Group Meeting — CERN, Geneva.
- **Bayes vs Svd**
  presented by Helena Santos
  HIJet meeting — CERN, Geneva.

- **Single top systematic uncertainties**
  presented by Rute Pedro
  Higgs Working Group Workshop — .

- **Advantages of using topo-cluster full-scan for jet triggers**
  presented by Ademar Delgado
  Trigger General Meeting — CERN, Geneva.

- **Vector-like quark searches**
  presented by Juan Espinosa
  Analysis meeting, Editorial Board — CERN.

- **Single top systematic uncertainties**
  presented by Rute Pedro
  VH(bb) Informal — CERN, Geneva.

- **ADC Monitoring of the Site Status Board**
  presented by Helmut Wolters
  ADC monitoring meeting — CERN.

- **Systematics studies.**
  presented by Juan Espinosa
  Analysis meeting — CERN.

- **the 1 million dollar challenge**
  presented by Ademar Delgado
  Jet Trigger Signature Group Meeting — CERN, Geneva.

- **Single top systematic uncertainties**
  presented by Rute Pedro
  VH, H to bb Editorial Board Meeting — CERN, Geneva.

- **MC correction tool update and features discussion.**
  presented by Juan Espinosa
  Analysis meeting — CERN.

- **Status report on performance study of FS and PS jet triggers**
  presented by Ademar Delgado
  Calorimeter Trigger — CERN, Geneva.

- **Uncertainties studies and results discussion**
  presented by Juan Espinosa
  Analysis meeting — CERN.

- **status of trilepton FCNC**
  presented by Bruno Galhardo
  Top properties meeting — .

- **Status of the DCS system**
  presented by Filipe Martins
  Tilecal Demonstrator meeting — CERN.

- **Exotic group approval of the Zb/t+X analysis**
  presented by Juan Espinosa
  Analysis meeting — CERN.

- **Discussion of modifications after Exotic group approval.**
  presented by Juan Espinosa
  Analysis meeting — CERN.

- **status of FCNC t->Zq analysis**
  presented by Bruno Galhardo
  Top properties meeting — .

- **Update on full scan topoclustering for jet triggers**
  presented by Ademar Delgado
  Trigger General Meeting — CERN, Geneva.

- **Tile DCS**
  presented by Filipe Martins
  TileCal Week Operation/Maintenance — CERN.

- **Site Status Board Review Update**
  presented by Helmut Wolters
  ADC monitoring meeting — CERN.

- **Search for pair and single production of new heavy quarks that decay into a Z boson and a third generation quark at ATLAS**
  presented by Nuno Castro
  ATLAS Week — Sibiu, Romania.

- **superRoI update**
  presented by Ademar Delgado
  Calorimeter Trigger — CERN, Geneva.

- **G-Link connection test between TGC SectorLogic and TMDB in blg. 175**
  presented by José Domingos Alves
  Tile D meeting — CERN.

- **Ed Board meeting on the FCNC decay t->qZ**
  presented by Bruno Galhardo
  FCNC t->Zq 8 TeV TOPQ-2014-08 — .

- **Update on PS vs FS studies**
  presented by Ademar Delgado
  Jet Trigger Signature Group Meeting — CERN, Geneva.

- **timing measurement using 14TeV MC samples**
  presented by Ademar Delgado
  Calorimeter Trigger — CERN, Geneva.

- **FCNC t->Zq tri-lepton channel Update**
  presented by Bruno Galhardo
  Top properties meeting — .

- **Status of the TTCdec Mezzanine Production**
  presented by Agostinho Gomes
  Technical review: Tile-Muon Digitiser Board — CERN.

- **pre-approval: search for FCNC in trilepton events**
  presented by Bruno Galhardo
  Top properties meeting — .

- **DCS plan**
  presented by Filipe Martins
  TileCal Operation and Maintenance Weekly Meeting — CERN.

- **Update on partial scan vs. full scan**
  presented by Ademar Delgado
  Jet Trigger Signature Group Meeting — CERN, Geneva.

- **follow-up on trilepton FCNC pre-approval**
  presented by Bruno Galhardo
  Top properties meeting — .

- **Full Scan vs Partial Scan Update**
  presented by Ademar Delgado
  Jet Trigger Signature Group Meeting — CERN, Geneva.

- **Status and updates TMDB simulation**
  presented by João Gentil
  LVL1 Tile-Muon trigger meeting — CERN, Geneva.

- **Full-scan vs partial-scan update**
  presented by Ademar Delgado
  Jet Trigger Signature Group Meeting — CERN, Geneva.

- **Status Report from Analysis Team**
  presented by Bruno Galhardo
  FCNC t->Zq 8 TeV TOPQ-2014-08 — .

- **Update on Asymmetry Analysis**
  presented by Helena Santos
  HI meeting — CERN, Geneva.

- **Update on FS vs PS**
  presented by Ademar Delgado
  Jet Trigger Signature Group Meeting — CERN, Geneva.

- **Overview on searches for FCNC with top quarks**
  presented by Bruno Galhardo
  Top working group plenary during P&P week — .

- **DCS for M5**
  presented by Filipe Martins
  TileCal Operation and Maintenance Weekly Meeting — CERN.

- **Jet and ETmiss Trigger**
  presented by Ricardo Gonçalo
  ATLAS Hadronic Calibration Workshop — Munich.

- **Jet: Partial Scan vs. Full Scan jet triggers**
  presented by Ademar Delgado
  ATLAS Hadronic Calibration Workshop — Munich.

- **PS and FS timing**
  presented by Ademar Delgado
  Jet Trigger Signature Group Meeting — CERN, Geneva.

- **SCS migration**
  presented by Filipe Martins
  TileCal Operation and Maintenance Weekly Meeting — CERN.

- **LIP plans for the search of new heavy quarks in Run II**
  presented by Nuno Castro
  HQT meeting, — CERN, Geneva, Switzerland.

- **topo-clustering timing measurement**
  presented by Ademar Delgado
  Calorimeter Trigger — CERN, Geneva.

- **Reconstruction efficiencies**
  presented by Helena Santos
  HI meeting — CERN, Geneva.

- **Timing measurements update**
  presented by Ademar Delgado
  Jet Trigger Signature Group Meeting — CERN, Geneva.

- **topo-clustering timing measurement**
  presented by Ademar Delgado
  Calorimeter Trigger — CERN, Geneva.

- **Jet monitoring in Run 2**
  presented by Helena Santos
  HI meeting — CERN, Geneva.

- **update on trilepton FCNC**
  presented by Bruno Galhardo
  Top properties meeting — .

- **DCS operations**
  presented by Filipe Martins
  TileCal Operation and Maintenance Weekly Meeting — CERN.

- **Asymmetry - JES uncertainties**
  presented by Helena Santos
  HI meeting — CERN, Geneva.

- **DCS report**
  presented by Filipe Martins
  TileCal Operation and Maintenance Weekly Meeting — CERN.

- **Presentation of comments in CDS as Ed.Board chair**
  presented by Ricardo Gonçalo
  — .

- **DCS on call report**
  presented by Filipe Martins
  TileCal Operation and Maintenance Weekly Meeting — CERN.

- **Commissioning requirements from hadronic trigger signatures**
  presented by Ricardo Gonçalo
  ATLAS TDAQ Week — CERN, Geneva.

- **DQ status**
  presented by Rute Pedro
  TileCal Calibration, Data Quality, Performance and Processing — CERN, Geneva.

- **Run-1 performance summary and Run-2 plans for Jet triggers**
  presented by Ricardo Gonçalo
  ATLAS Weekly meeting — CERN, Geneva.

- **DQ status**
  presented by Rute Pedro
  TileCal Operation and Maintenance Weekly Meeting — CERN, Geneva.

- **DQ status**
  presented by Rute Pedro
  TileCal Calibration, Data Quality, Performance and Processing — CERN, Geneva.

- **PbPb dijet asymmetry update**
  presented by Helena Santos
  HI meeting — CERN, Geneva.

- **DQ status**
  presented by Rute Pedro
  TileCal Operation and Maintenance Weekly Meeting — CERN, Geneva.

- **p+p analysis**
  presented by Helena Santos
  HI meeting — CERN, Geneva.

- **FCNC t->Zq @ 8 TeV**
  presented by Bruno Galhardo
  Top working group approval — .

- **DQ status**
  presented by Rute Pedro
  TileCal Operation and Maintenance Weekly Meeting — CERN, Geneva.

- **Analysis of ln xJ for R = 0.2 and 0.3 jets**
  presented by Helena Santos
  HI meeting — CERN, Geneva.

Seminars

- **Git for dummies**
  presented by Juan Espinosa
  — Universidad de Granada, Granada, Spain.

- **ATLAS Physics Prospects for the High Luminosity LHC**
  presented by Patricia Conde
  — LIP.

- **Search for vector-like quark pair production with the ATLAS detector.**
  presented by Juan Espinosa
  Café com física — Universidade de Coimbra, Coimbra, Portugal.

- **Run I Heavy Ions Results from ATLAS**
  presented by Helena Santos
  LIP Seminar — LIP-Lisbon (Portugal).

- **Results from the Higgs searches at the LHC**
  presented by Patricia Conde
  IDPASC course on Physics at the LHC — LIP-Lisbon (Portugal).

- **The top quark and the search for new physics at the LHC**
  presented by Nuno Castro
  — CFUM seminar, Braga.

- **The top quark and the search for new physics at the LHC**
  presented by Nuno Castro
  — LIP, Lisbon.

- **ATLAS searches for single and pair production of new heavy quarks decaying to Zt/b+X**
  presented by Juan Espinosa
  — University of Glasgow, Glasgow, UK.

- **O Bosao de Higgs: descoberta e futuro**
  presented by Ricardo Gonçalo
  FCUL — Universidade de Lisboa.

- **Computer challenges from a high energy physicist point of view**
  presented by Juan Espinosa
  Dept. Informática — Universidade do Minho, Braga.

- **Properties of the Higgs boson: recent results from ATLAS at the LHC**
  presented by José Maneira
  — .

Outreach seminars

- **Detectores e Aceleradores**
  presented by Filipe Veloso
  10th International Masterclasses — Universidade de Coimbra.

- **A Detecção de Partículas Elementares**
  presented by Ricardo Gonçalo
  International Particle Physics Masterclass — Évora.

- **Introdução à Física das Partículas**
  presented by José Maneira
  Masterclasses de Física de Partículas — Esc. Sec. Domingos Rebelo, Ponta Delgada, Açores.

- **Detectores e Aceleradores**
  presented by Filipe Veloso
  10th International Masterclasses — Universidade de Aveiro.

- **Mas afinal o que é o bosão de Higgs?**
  presented by Filipe Veloso
  Universidade de Verão — Universidade de Coimbra.

- **The ATLAS Experiment and the Portuguese Participation in ATLAS**
  presented by Ricardo Gonçalo
  CERN Portuguese Teachers School — .

- **Como observar partículas? CERN 60 anos de Ciencia para a Paz**
  presented by Patricia Conde
  Noite Europeia dos Investigadores — Planetário Gulbenkian, Lisbon.

- **Um Universo de Particulas - o infinitamente grande e o infinitamente pequeno**
  presented by Ricardo Gonçalo
  European Researchers Night — Planetario Gulbenkian, Lisboa.

- **Ciência para a paz: os 60 anos do CERN e a descoberta do bosão de Higgs**
  presented by José Maneira
  — Associação de Residentes de Telheiras, Lisboa, 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

- **Search for the WH associated production with the Higgs decaying to b-quark pairs at ATLAS/LHC**
  Alberto Palma, (on-going)

- **Medida da taxa de decaimentos raros do quark top, na experiência ATLAS no LHC**
  Bruno Galhardo, (on-going)

- **Study of the ttH production and Higgs couplings to Top quarks in the ATLAS experiment**
  Susana Santos, (on-going)

- **Observation and measurement of Higgs boson decays to WW* with ATLAS at the LHC**
  Joana Miguéns, (on-going)

- **Search for the Higgs boson at ATLAS/LHC, in associated production with a Z boson**
  Mário Sargedas Sousa, (on-going)

- **Search for new vector-like quarks at the LHC (provisional)**
  Juan Espinosa, (on-going)

- **Search for the Higgs boson at ATLAS/LHC in WH associated production and decay to b quark pairs using MVA methods**
  Rute Pedro, (on-going)

- **Development of boosted jet triggers for Higgs searches at the ATLAS experiment at the LHC/CERN**
  Ademar Delgado, (on-going)

Master Theses

- **Use of a Multivariate Analysis in the Search for Vector-Like Quarks at the LHC**
  Ester Simões, 2014-11-18
- **Search for ttH production with the ATLAS experiment at the LHC**
  Emanuel Gouveia, (on-going)
- **Search for tZ events produced via flavour changing neutral currents at the LHC (provisional)**
  Artur Amorim de Sousa, (on-going)
- **Study of jet trigger signatures in p+Pb collisions with the ATLAS detector**
  Alexandre Lopes, 2014-05-19

Graduation Theses

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

2.1.9 Events

- **ATLAS Trigger Workshop**
  Collaboration Meeting, Sesimbra, Portugal, 2014-03-10

2.1.10 Project Summary

	number
Articles in international journals (with direct contribution from LIP members)	7
Articles in international journals (with indirect contribution from LIP members)	72
International Conference Proceedings	4
National Conference Proceedings	1
Collaboration notes with internal referee	5
Internal Notes	4
Oral presentations in international conferences	4
Poster presentations in international conferences	2
Presentations in national conferences	7
Oral presentations in collaboration meetings	115
Seminars	11
Outreach seminars	9
PhD Theses	1
Master Theses	2
Collaboration Meetings	1

2.2 Collaboration in the CMS experiment at CERN

2.2.1 Abstract

Activity report

Within the CMS experiment physics program, the LIP/CMS group 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 (2011-12).
- the study of the Higgs properties, including the measurement of the Higgs couplings (A. David). These studies lie at the basis of the recent confirmation that the new particle is a Higgs boson (2012-13)
- the measurement of the top quark mass, a fundamental parameter of the Standard Model. 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 Brown University the most precise measurement in the dilepton channel up-to date (2012-14).
- 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 yet of this fundamental parameter of the SM (under the assumptions of unitarity and three generations) (2013-14).
- the discovery of the Bs to mumu rare decay, with a definitive observation attained with the combination of the full Run I CMS and LHCb datasets (N. Leonardo – 2013-2014)
- the measurement of the CP violation phase phi_s and development of flavour tagging methods (N. Leonardo – 2012-14)
- the measurement of the Psi and Upsilon polarizations in pp collisions. The LIP/CMS group (P. Faccioli, J. Seixas) led these important measurements (2012-14).
- the discovery of sequential quarkonium suppression in heavy ion collisions (N. Leonardo – 2011-12)
- the measurement of Upsilon production cross sections at 7 TeV (N. Leonardo – 2010-2011)
- the search for a light/heavy charged Higgs decaying from/to 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 the top decay in charged Higgs, using events with one lepton and one hadronic decaying tau (2012-14).
- participation in the measurement of top-quark pair production cross section in the dilepton channel (P. Bargassa, M. Gallinaro, P. Ribeiro, P. Silva – 2011-12)
- measurement performed by the LIP group of the production cross section of top-quark pairs in the dilepton channel with one hadronically decaying tau (M. Jordao, F. Nguyen, M. Gallinaro – 2012-14)
- measurement led by the LIP group of the isolated prompt photon cross section (P. Musella, A. David – 2010-11);
- search for the supersymmetric partner of the top quark (M. Fernandes, P. Bargassa, L. Lloret – 2011-14);
- the search for heavy resonances decaying to long-lived neutral particles through the analysis of displaced leptonic vertices (N. Leonardo – 2011-2014)
- the development of b-tagging and tau reconstruction algorithms (M. Gallinaro, P. Silva, M. Jordao – 2011-13).

In detector development, the LIP/CMS group made major scientific and technological contributions in the following areas:

- leader in the R&D and construction of the Data Acquisition System of the Electromagnetic Calorimeter (ECAL). LIP/CMS group members are ECAL Electronics Coordinator since 2011 (J. C. Silva), and were ECAL Run Coordinator in 2010-13 (A. David), and ECAL Data Acquisition Coordinator in 2008-10 (A. David) and in 2010-14 (P. Parracho).

- leader in the R&D and construction of the Trigger System. A member of the LIP/CMS group was Trigger Project Manager in 2007-10 (J. Varela) , and members of the group were Trigger DQM coordinators (J. Pela, F. Nguyen – 2012-14).

The LIP group was directly involved in the ECAL and Trigger operation during the LHC runs. Several members of the group are "experts on-call"available during LHC runs to intervene in case of system faults. The group assures a number of data taking Shifts as required by the Collaboration. Members of the group also served as Run Field Manager, Shift Leader and Trigger Field Manager at several occasions during the data taking periods.
In the computing area, the LIP/CMS GRID activities are focused in the exploitation of the Portuguese LHC Tier-2 Federation for CMS physics analysis. The Tier-2 has been continuously monitored and proven to operate with high computing efficiencies and data transfer throughputs and quality on both download and upload streams.
In the CMS Upgrade Program the LIP group did the R&D, built and installed the new 4.8 Gb/s optical Serial Link Boards (oSLB) that interface 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.
The LIP group is participating in the development of the new CT-PPS detector and in 2014 contributed strongly to the document Technical Design Report of the CMS-TOTEM Precision Proton Spectrometer, CERN-LHCC-2014-021. The CT-PPS TDR was approved by the LHC Experiments Committee (LHCC).
The difficult situation in the past two years which led to the absence of dedicated funding in 2014 implied a strong reduction of our activities, the loss of collaborators and the impossibility to engage new students.

CMS Awards received by group members:

CMS Achievement Awards:

- P.Musella: important contributions to ECAL Data Acquisition (2008)

- A.David: key efforts on the ECAL DAQ and central CMS operations (2008)

- M. Gallinaro: key contributions to the TDR of the CT-PPS project (2014)

CMS Young Researcher Prize

- A. David: for sustained and critical contributions to the preparation and commissioning of the electromagnetic calorimeter, to the search of the Higgs boson in its decay to photons, and to the combination of results from its various decay modes (2013)

CMS Lifetime Achievement Award:

- J.C. Silva: outstanding contributions to the ECAL and HCAL Trigger/DAQ electronics (2011)

CMS Thesis Award:

- P. Musella: best PhD thesis in the CMS collaboration in the year 2011.

Management Structure

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

- 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)
- ECAL detector:
  - Electronics coordinator (J. C. Silva)
- Computing coordinator (P. Vischia)

The CMS Collaboration has about 3500 members from 179 institutes in 41 nations. The LIP group members have presently the following coordination positions in the CMS Collaboration structure:

- CT-PPS Project Manager, since 2014 (J. Varela): Level-1 management position.
- CT-PPS Timing Detector Coordinator (Level-2), since 2014 (M. Gallinaro)
- ECAL Electronics Coordinator (Level-2), since 2011 (J. C. Silva)
- Co-convener (Level-3) of top quark mass and properties measurements, since 2013 (P. Silva)
- Co-convener (Level-2) of the CMS B Physics and Quarkonia Analysis Group (B PAG), since 2014 (N. Leonardo)
- Co-convener (Level-3) of quarkonium analysis working group, 2013-2014 (P. Faccioli)
- Co-convener (Level-3) of CP violation and rare decays analysis working group, 2014 (N. Leonardo)

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

- CMS Executive, Management and Finance Boards (J. Varela)
- CMS Collaboration Board (J. Varela and J. Seixas, group representatives)
- CMS Physics Coordination (N.Leonardo)
- ECAL Executive Board (A. David, J.C. Silva)
- 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 and CT-PPS projects and its sub-structures.

Members of the LIP group have been selected to participate in many Analysis Review Committees (ARC).

2.2.2 Sources of Funding

Code	Funding	Start	End
CERN/FP/123601/2011	550.000 €	2012-04-01	2015-03-31
IF/01454/2013/CP1172/CT0003	50.000 €	2014-01-01	2018-12-31

2.2.3 Team

Project coordinator: João Varela

Name	Status	FTE %
Agostino di Francesco	PhD student (LIP)	100
André Tinoco Mendes	Researcher (LIP)	100
Andrea Barisone	Technician (LIP)	100
Cristóvão Silva	PhD student (LIP/FCT)	100
Daniele Vadruccio	Researcher (LIP)	100
Federico Nguyen	Post-Doc (LIP/FCT)	100
João Pela	PhD student (LIP/Imperial)	100
João Rodrigues Antunes	PhD student (LIP)	100
João Seixas	Researcher (LIP/IST)	50
João Varela	Researcher (LIP/IST)	75
José Carlos Silva	Technician (LIP)	95
Lara Lloret	Post-Doc (LIP)	100
Manuel Rolo	PhD student (LIP)	15
Marcelo Vicente	Student (LIP)	100
Michele Gallinaro	Researcher (LIP)	100
Nuno Leonardo	Researcher (LIP)	100
Oleksii Toldaiev	PhD student (LIP)	100
Pedrame Bargassa	Researcher (LIP)	100
Pedro Ferreira da Silva	Post-Doc (LIP/FCT)	50
Pedro Parracho	Collaborator (LIP/AdI)	100
Pietro Faccioli	Post-Doc (LIP/FCT)	100
Pietro Vischia	PhD student (LIP/FCT) *	100
Rogério Jorge	Student (LIP)	50

2.2.4 Publications

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

- **Measurement of the ratio B(t -> Wb)/B(t -> Wq) in pp collisions at root s=8 TeV**
  CMS Collaboration (2127 authors)
  Phys. Lett. B 736 (2014) 33-57 — DOI: 10.1016/j.physletb.2014.06.076

- **Observation of the diphoton decay of the Higgs boson and measurement of its properties**
  CMS Collaboration (2127 authors)
  Eur. Phys. J. C 74 (2014) 3076 — DOI: 10.1140/epjc/s10052-014-3076-z

- **Measurement of the t(t)over-bar production cross section in pp collisions at root s=8 TeV in dilepton final states containing one tau lepton**
  CMS Collabration (2154 authors)
  Phys. Lett. B 739 (2014) 23-43 — DOI: 10.1016/j.physletb.2014.10.032

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

- **Measurement of Higgs boson production and properties in the WW decay channel with leptonic final states**
  CMS Collaboration (2207 authors)
  J. High Energy Phys. 1 (2014) 096 — DOI: 10.1007/JHEP01(2014)096

- **Search for the standard model Higgs boson produced in association with a W or a Z boson and decaying to bottom quarks**
  CMS Collaboration (2218 authors)
  Phys. Rev. D 89 (2014) 012003 — DOI: 10.1103/PhysRevD.89.012003

- **Search for new physics in events with same-sign dileptons and jets in pp collisions at root s=8 TeV**
  CMS Collaboration (2210 authors)
  J. High Energy Phys. 1 (2014) 163 — DOI: 10.1007/JHEP01(2014)163

- **First look at the physics case of TLEP**
  TLEP Design Study Working Grp (131 authors)
  J. High Energy Phys. 1 (2014) 164 — DOI: 10.1007/JHEP01(2014)164

- **Measurement of associated W plus charm production in pp collisions at root s=7 TeV**
  CMS Collaboration (2224 authors)
  J. High Energy Phys. 2 (2014) 013 — DOI: 10.1007/JHEP02(2014)013

- **Measurement of the t(t)over-bar production cross section in the dilepton channel in pp collisions at root s=8 TeV**
  CMS Collaboration (2210 authors)
  J. High Energy Phys. 2 (2014) 024 — DOI: 10.1007/JHEP02(2014)024

- **Studies of azimuthal dihadron correlations in ultra-central PbPb collisions at=2.76 TeV**
  CMS Collaboration (2202 authors)
  J. High Energy Phys. 2 (2014) 088 — DOI: 10.1007/JHEP02(2014)088

- **Measurement of the t(t)over-bar production cross section in the dilepton channel in pp collisions at root s = 8 TeV (vol 2, 024, 2014)**
  CMS Collaboration (2199 authors)
  J. High Energy Phys. 2 (2014) 102 — DOI: 10.1007/JHEP02(2014)102

- **Study of double parton scattering using W+2-jet events in proton-proton collisions at root s=7 TeV**
  CMS Collaboration (2207 authors)
  J. High Energy Phys. 3 (2014) 032 — DOI: 10.1007/JHEP03(2014)032

- **Searches for light- and heavy-flavour three-jet resonances in pp collisions at root s=8 TeV**
  CMS Collaboration (2214 authors)
  Phys. Lett. B 730 (2014) 193-214 — DOI: 10.1016/j.physletb.2014.01.049

- **Modification of jet shapes in PbPb collisions at root s(NN)=2.76 TeV**
  CMS Collaboration (2222 authors)
  Phys. Lett. B 730 (2014) 243-263 — DOI: 10.1016/j.physletb.2014.01.042

- **Search for anomalous production in the highly-boosted all-hadronic final state (vol 09, 029, 2012)**
  CMS Collaboration (2212 authors)
  J. High Energy Phys. 3 (2014) — DOI: 10.1007/JHEP03(2014)132

- **Search for baryon number violation in top-quark decays**
  CMS Collaboration (2224 authors)
  Phys. Lett. B 731 (2014) 173-196 — DOI: 10.1016/j.physletb.2014.02.033

- **Measurement of the top-quark mass in all-jets $t\bar{t}$ events in pp collisions at $\sqrt{s}$=7 TeV**
  CMS Collaboration (2210 authors)
  Eur.Phys.J. C74 (2014) 2758 — DOI: 10.1140/epjc/s10052-014-2758-x

- **Measurement of higher-order harmonic azimuthal anisotropy in PbPb collisions at root s(NN)=2.76 TeV**
  CMS Collaboration (2202 authors)
  Phys. Rev. C 89 (2014) 044906 — DOI: 10.1103/PhysRevC.89.044906

- **Event activity dependence of (nS) production in=5.02 TeV pPb and=2.76 TeV pp collisions**
  CMS Collaboration (2209 authors)
  J. High Energy Phys. 4 (2014) 103 — DOI: 10.1007/JHEP04(2014)103

- **Search for Top Squark and Higgsino Production Using Diphoton Higgs Boson Decays**
  CMS Collaboration (2210 authors)
  Phys. Rev. Lett. 112 (2014) 161802 — DOI: 10.1103/PhysRevLett.112.161802

- **Search for Top-Quark Partners with Charge 5/3 in the Same-Sign Dilepton Final State**
  CMS Collaboration (2200 authors)
  Phys. Rev. Lett. 112 (2014) 171801 — DOI: 10.1103/PhysRevLett.112.171801

- **Measurements of the t(t)Overbar charge asymmetry using the dilepton decay channel in pp collisions at root s=7 TeV**
  CMS Collaboration (2224 authors)
  J. High Energy Phys. 4 (2014) 191 — DOI: 10.1007/JHEP04(2014)191

- **Search for Flavor-Changing Neutral Currents in Top-Quark Decays t -> Zq in pp Collisions at root s=8 TeV**
  CMS Collaboration (2200 authors)
  Phys. Rev. Lett. 112 (2014) 171802 — DOI: 10.1103/PhysRevLett.112.171802

- **Measurements of t(t)over-bar Spin Correlations and Top-Quark Polarization Using Dilepton Final States in pp Collisions at root s=7 TeV**
  CMS Collaboration (2202 authors)
  Phys. Rev. Lett. 112 (2014) 182001 — DOI: 10.1103/PhysRevLett.112.182001

- **Measurement of the W gamma and Z gamma inclusive cross sections in pp collisions at root s=7 TeV and limits on anomalous triple gauge boson couplings**
  CMS Collaboration (2192 authors)
  Phys. Rev. D 89 (2014) 092005 — DOI: 10.1103/PhysRevD.89.092005

- **Measurement of the properties of a Higgs boson in the four-lepton final state**
  CMS Collaboration (2207 authors)
  Phys. Rev. D 89 (2014) 092007 — DOI: 10.1103/PhysRevD.89.092007

- **Measurement of Inclusive W and Z Boson Production Cross Sections in pp Collisions at root s=8 TeV**
  S. Chatrchyan et al. (2209 authors)
  Phys. Rev. Lett. 112 (2014) 191802 — DOI: 10.1103/PhysRevLett.112.191802

- **Evidence for the 125 GeV Higgs boson decaying to a pair of tau leptons**
  S. Chatrchyan et al. (2231 authors)
  J. High Energy Phys. 5 (2014) 104 — DOI: 10.1007/JHEP05(2014)104

- **Search for W ´ -> tb decays in the lepton plus jets final state in pp collisions at root s=8 TeV**
  CMS Collaboration (2207 authors)
  J. High Energy Phys. 5 (2014) 108 — DOI: 10.1007/JHEP05(2014)108

- **Measurement of four-jet production in proton-proton collisions at root s=7 TeV**
  CMS Collaboration (2209 authors)
  Phys. Rev. D 89 (2014) 092010 — DOI: 10.1103/PhysRevD.89.092010

- **Alignment of the CMS tracker with LHC and cosmic ray data**
  CMS Collaboration (2402 authors)
  J. Instrum. 9 (2014) P06009 — DOI: 10.1088/1748-0221/9/06/P06009

- **Search for supersymmetry in pp collisions at root s=8 TeV in events with a single lepton, large jet multiplicity, and multiple b jets**
  CMS Collaboration (2210 authors)
  Phys. Lett. B 733 (2014) 328-353 — DOI: 10.1016/j.physletb.2014.04.023

- **Measurement of the triple-differential cross section for photon plus jets production in proton-proton collisions at=7 TeV**
  CMS Collaboration (2220 authors)
  J. High Energy Phys. 6 (2014) 009 — DOI: 10.1007/JHEP06(2014)009

- **Study of the production of charged pions, kaons, and protons in pPb collisions at root SNN=5.02 TeV**
  CMS Collaboration (2368 authors)
  Eur. Phys. J. C 74 (2014) 2847 — DOI: 10.1140/epjc/s10052-014-2847-x

- **Observation of the Associated Production of a Single Top Quark - and a W Boson in pp Collisions at root s=8 TeV**
  CMS Collaboration (2206 authors)
  Phys. Rev. Lett. 112 (2014) 231802 — DOI: 10.1103/PhysRevLett.112.231802

- **Search for new physics in the multijet and missing transverse momentum final state in proton-proton collisions at root s=8 Tev**
  CMS Collaboration (2214 authors)
  J. High Energy Phys. 6 (2014) 055 — DOI: 10.1007/JHEP06(2014)055

- **Probing color coherence effects in pp collisions at root s=7 TeV**
  CMS Collaboration (2367 authors)
  Eur. Phys. J. C 74 (2014) 2901 — DOI: 10.1140/epjc/s10052-014-2901-8

- **Measurement of the t-channel single-top-quark production cross section and of the ||V (tb)|| CKM matrix element in pp collisions at root s=8 TeV**
  CMS Collaboration (2128 authors)
  J. High Energy Phys. 6 (2014) 090 — DOI: 10.1007/JHEP06(2014)090

- **Search for pair production of excited top quarks in the lepton plus jets final state**
  CMS Collaboration (2221 authors)
  J. High Energy Phys. 6 (2014) 125 — DOI: 10.1007/JHEP06(2014)125

- **Measurement of the production cross sections for a Z boson and one or more b jets in pp collisions at root s=7 TeV**
  CMS Collaboration (2221 authors)
  J. High Energy Phys. 6 (2014) 120 — DOI: 10.1007/JHEP06(2014)120

- **Evidence for the direct decay of the 125 GeV Higgs boson to fermions**
  CMS Collaboration (2232 authors)
  Nature Phys. 10 (2014) 557-560 — DOI: 10.1038/nphys3005

- **Observation of a peaking structure in the J/psi phi mass spectrum from B-+/- -> J/psi phi K-+/- decays**
  CMS Collaboration (2210 authors)
  Phys. Lett. B 734 (2014) 261-281 — DOI: 10.1016/j.physletb.2014.05.055

- **Studies of dijet transverse momentum balance and pseudorapidity distributions in pPb collisions at root s(NN)=5.02 TeV**
  CMS Collaboration (2345 authors)
  Eur. Phys. J. C 74 (2014) 2951 — DOI: 10.1140/epjc/s10052-014-2951-y

- **Measurement of the production cross section for a W boson and two b jets in pp collisions at root s=7 TeV**
  CMS Collaboration (2215 authors)
  Phys. Lett. B 735 (2014) 204-225 — DOI: 10.1016/j.physletb.2014.06.041

- **Measurement of WZ and ZZ production in pp collisions at in final states with b-tagged jets**
  CMS Collaboration (2383 authors)
  Eur. Phys. J. C 74 (2014) 2973 — DOI: 10.1140/epjc/s10052-014-2973-5

- **Measurement of the muon charge asymmetry in inclusive pp -> W plus X production at root s=7 TeV and an improved determination of light parton distribution functions**
  CMS Collaboration (2213 authors)
  Phys. Rev. D 90 (2014) 032004 — DOI: 10.1103/PhysRevD.90.032004

- **Search for invisible decays of Higgs bosons in the vector boson fusion and associated ZH production modes**
  CMS Collaboration (2240 authors)
  Eur. Phys. J. C 74 (2014) 2980 — DOI: 10.1140/epjc/s10052-014-2980-6

- **Search for jet extinction in the inclusive jet-p(T) spectrum from proton-proton collisions at root s=8 TeV**
  CMS Collaboration (2133 authors)
  Phys. Rev. D 90 (2014) 032005 — DOI: 10.1103/PhysRevD.90.032005

- **Measurement of jet fragmentation in PbPb and pp collisions at root s(NN)=2.76 TeV**
  CMS Collaborat (2212 authors)
  Phys. Rev. C 90 (2014) 024908 — DOI: 10.1103/PhysRevC.90.024908

- **Measurement of jet multiplicity distributions in t(t)over-bar production in pp collisions at root s=7TeV**
  CMS Collaboration (2233 authors)
  Eur. Phys. J. C 74 (2014) 3014 — DOI: 10.1140/epjc/s10052-014-3014-0

- **Search for anomalous production of events with three or more leptons in pp collisions at $sqrt(s) =$ 8 TeV**
  CMS Collaboration (2230 authors)
  Phys.Rev. D90 (2014) 032006 — DOI: 10.1103/PhysRevD.90.032006

- **Search for WW gamma and WZ gamma production and constraints on anomalous quartic gauge couplings in pp collisions at root s=8 TeV**
  CMS Collaboration (2239 authors)
  Phys. Rev. D 90 (2014) 032008 — DOI: 10.1103/PhysRevD.90.032008

- **Search for massive resonances in dijet systems containing jets tagged as W or Z boson decays in pp collisions at root s=8 TeV**
  CMS Collaboration (2135 authors)
  J. High Energy Phys. 8 (2014) — DOI: 10.1007/JHEP08(2014)173

- **Search for massive resonances decaying into pairs of boosted bosons in semi-leptonic final states at root s=8 TeV**
  CMS Collaboration (2133 authors)
  J. High Energy Phys. 8 (2014) — DOI: 10.1007/JHEP08(2014)174

- **Constraints on the Higgs boson width from off-shell production and decay to Z-boson pairs**
  CMS Collaboration (2138 authors)
  Phys. Lett. B 736 (2014) 64-85 — DOI: 10.1016/j.physletb.2014.06.077

- **Search for top-squark pairs decaying into Higgs or Z bosons in pp collisions at root s=8 TeV**
  CMS Collaboration (2135 authors)
  Phys. Lett. B 736 (2014) 371-397 — DOI: 10.1016/j.physletb.2014.07.053

- **Quarkonium production in the LHC era: A polarized perspective**
  Pietro Faccioli, Valentin Knuenz, Carlos Lourenco, Joao Seixas, Hermine K. Woehri
  Phys. Lett. B 736 (2014) 98-109 — DOI: 10.1016/j.physletb.2014.07.006

- **Search for the associated production of the Higgs boson with a top-quark pair**
  CMS Collaboration (2136 authors)
  J. High Energy Phys. 9 (2014) 087 — DOI: 10.1007/JHEP09(2014)087

- **Measurement of prompt J/psi pair production in pp collisions at root s = 7 Tev**
  CMS Collaboration (2129 authors)
  J. High Energy Phys. 9 (2014) 094 — DOI: 10.1007/JHEP09(2014)094

- **Measurement of top quark-antiquark pair production in association with a W or Z boson in pp collisions at** $sqrts = 8\ , extTeV$
  CMS Collaboration (2143 authors)
  Eur.Phys.J. C74 (2014) 3060 — DOI: 10.1140/epjc/s10052-014-3060-7

- **Evidence of b-Jet Quenching in PbPb Collisions at root S-NN=2.76 TeV**
  CMS Collaboration (2205 authors)
  Phys. Rev. Lett. 113 (2014) 132301 — DOI: 10.1103/PhysRevLett.113.132301

- **Searches for electroweak production of charginos, neutralinos, and sleptons decaying to leptons and W, Z, and Higgs bosons in pp collisions at 8 TeV**
  CMS Collaboration (2131 authors)
  Eur.Phys.J. C74 (2014) 3036 — DOI: 10.1140/epjc/s10052-014-3036-7

- **Description and performance of track and primary-vertex reconstruction with the CMS tracker**
  CMS Collaboration (2411 authors)
  J. Instrum. 9 (2014) P10009 — DOI: 10.1088/1748-0221/9/10/P10009

- **Study of hadronic event-shape variables in multijet final states in pp collisions at root s=7 TeV**
  CMS Collaboration (2134 authors)
  J. High Energy Phys. 10 (2014) 087 — DOI: 10.1007/JHEP10(2014)087

- **Measurement of the ratio of inclusive jet cross sections using the anti-k(T) algorithm with radius parameters R=0.5 and 0.7 in pp collisions at root s=7 TeV**
  CMS Collaboration (2210 authors)
  Phys. Rev. D 90 (2014) 072006 — DOI: 10.1103/PhysRevD.90.072006

- **Search for the associated production of the Higgs boson with a top-quark pair (vol 9, 087, 2014)**
  CMS Collaboration (2137 authors)
  J. High Energy Phys. 10 (2014) 106 — DOI: 10.1007/JHEP10(2014)106

- **Search for neutral MSSM Higgs bosons decaying to a pair of tau leptons in pp collisions**
  CMS Collaboration (2145 authors)
  J. High Energy Phys. 10 (2014) 160 — DOI: 10.1007/JHEP10(2014)160

- **Measurement of pseudorapidity distributions of charged particles in proton-proton collisions at root s=8 TeV by the CMS and TOTEM experiments**
  CMS Collaboration / TOTEM Collaboration (2287 authors)
  Eur. Phys. J. C 74 (2014) 3053 — DOI: 10.1140/epjc/s10052-014-3053-6

- **Search for excited quarks in the gamma plus jet final state in proton-proton collisions at root s=8 TeV**
  CMS Collaboration (2064 authors)
  Phys. Lett. B 738 (2014) 274-293 — DOI: 10.1016/j.physletb.2014.09.048

- **Measurement of differential cross sections for the production of a pair of isolated photons in pp collisions at root s=7TeV**
  CMS Collaboration (2227 authors)
  Eur. Phys. J. C 74 (2014) 3129 — DOI: 10.1140/epjc/s10052-014-3129-3

- **Searches for electroweak neutralino and chargino production in channels with Higgs, Z, and W bosons in pp collisions at 8 TeV**
  CMS Collaboration (2149 authors)
  Phys. Rev. D 90 (2014) 092007 — DOI: 10.1103/PhysRevD.90.092007

- **Search for heavy neutrinos and W bosons with right-handed couplings in proton-proton collisions at root s=8TeV**
  CMS Collaboration (2134 authors)
  Eur. Phys. J. C 74 (2014) 3149 — DOI: 10.1140/epjc/s10052-014-3149-z

- **Search for standard model production of four top quarks in the lepton plus jets channel in pp collisions at root S=8 TeV**
  CMS Collaboration (2148 authors)
  J. High Energy Phys. 11 (2014) 154 — DOI: 10.1007/JHEP11(2014)154

- **A change of perspective in quarkonium production: All data are equal, but some are more equal than others**
  Carlos Lourenco, Pietro Faccioli, Valentin Knuenz, Joao Seixas, Hermine K. Woehri
  Nucl. Phys. A 932 (2014) 466-471 — DOI: 10.1016/j.nuclphysa.2014.09.079

- **Search for supersymmetry with razor variables in pp collisions at root s=7 TeV**
  CMS Collaboration (2239 authors)
  Phys. Rev. D 90 (2014) 112001 — DOI: 10.1103/PhysRevD.90.112001

- **Differential cross section measurements for the production of a W boson in association with jets in proton-proton collisions at** $sqrts = 7$ **TeV**
  CMS Collaboration (2134 authors)
  Phys.Lett. B741 (2015) 12-37 — DOI: 10.1016/j.physletb.2014.12.003

- **Identification techniques for highly boosted W bosons that decay into hadrons**
  CMS Collaboration (2145 authors)
  JHEP 1412 (2014) 017 — DOI: 10.1007/JHEP12(2014)017

- **Search for pair production of third-generation scalar leptoquarks and top squarks in proton-proton collisions at v root s=8 TeV**
  CMS Collaboration (2144 authors)
  Phys. Lett. B 739 (2014) 229-249 — DOI: 10.1016/j.physletb.2014.10.063

- **Searches for heavy Higgs bosons in two-Higgs-doublet models and for t -> ch decay using multilepton and diphoton final states in pp collisions at 8 TeV**
  CMS Collaboration (2146 authors)
  Phys. Rev. D 90 (2014) 112013 — DOI: 10.1103/PhysRevD.90.112013

- **Measurement of Prompt** $psi(2S)oJ/psi$ **Yield Ratios in Pb-Pb and** $p-p$ **Collisions at** $sqrts_{NN}$ **= 2.76??TeV**
  CMS Collaboration (2147 authors)
  Phys.Rev.Lett. 113 (2014) 262301 — DOI: 10.1103/PhysRevLett.113.262301

International Conference Proceedings

- **Electroweak production of Z bosons with forward-backward jets at CMS**
  Pedro Ferreira da Silva
  PoS EPS-HEP2013 (2013) 466

- **CMS data and workflow management system**
  CMS Collaboration (120 authors)
  C07-10-08.3 441-445, 2008 — DOI: 10.1142/9789812819093_0076

- **CMS-Totem Precision Proton Spectrometer**
  M. Gallinaro, J. Varela, et al.
  CERN-LHCC-2014-021
- **Scope and implementation plan of the CT-PPS baseline program**
  M. Gallinaro, J. Varela, et al.
  CERN-LHCC-2014-026

Collaboration notes with internal referee

- **Search for direct stop pair production in the semi-leptonic channel at 8 TeV**
  Pedrame Bargassa, Lara Lloret, et al.
  AN-14-067 (accepted)
- **Search for four-body decays of the top squark in the single muon channel at 8 TeV**
  Wolfgang Adam, Pedrame Bargassa, Vasile Ghete, Ivan Mikulec, Manfred Jeitler, Robert Schoefbeck, C.E. Wulz
  AN-14-230 (accepted)
- **Bs mu mu search**
  N.Leonardo, et al
  CMS AN-2013/216 (accepted)
- **Search for long-lived particles decaying to final states that include dimuons reconstructed using the muon chambers only**
  N.Leonardo, M.Mattia,Z.Hu, et al
  CMS AN-2014/176 (accepted)
- **Search for long-lived particles that decay into final states containing two electrons or two muons using the 2012 data sample**
  N.Leonardo, M.Mattia,Z.Hu, et al
  CMS AN-2012/474 (accepted)
- **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 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
- **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 a heavy charged Higgs boson in proton-proton collisions at sqrts=8 TeV with the CMS detector**
  S. Chatrchyan et al. [CMS Collaboration]
  CMS-PAS-HIG-13-026
- **Combination of charged Higgs boson searches with 20/fb of sqrt(s)=8 TeV data**
  M. Gallinaro, F. Nguyen, P. Silva, A. Toldayev, J. Varela, P. Vischia, et al.
  CMS AN-2014/259

2.2.5 Presentations

Oral presentations in international conferences

- **Probing new physics via rare decays**
  presented by Nuno Leonardo
  New Worlds in Particle, Astroparticle and Cosmology - 2014 — Universidade do Minho, Braga.
- **Top quark Physics after the Higgs boson discovery**
  presented by Michele Gallinaro
  New Worlds in Particle Physics — Braga, Portugal.
- **B Physics with ATLAS and CMS**
  presented by Nuno Leonardo
  DISCRETE 2014, Fourth Symposium on Prospects in the Physics of Discrete Symmetries — Kings College, London, UK.
- **Experimental results on diffraction at the Tevatron**
  presented by Michele Gallinaro
  2nd workshop on Detectors for Forward Physics at the LHC — La Biodola, Elba, Italy.
- **Observation of Bs ??? and search for B0 ??? at CMS**
  presented by Nuno Leonardo
  ICHEP 2014: 37th International Conference on High Energy Physics — Valencia, Spain.

- **Search for MSSM H+/- decaying into taunu and tb with l->tau(->had) and ll final states in CMS**
  presented by Pietro Vischia
  Prospects for Charged Higgs Discovery at Colliders (cHarged2014) — Uppsala, Sweden.

- **Physics with the CT-PPS project**
  presented by Michele Gallinaro
  LHC Forward working group — CERN, Geneva.

Poster presentations in international conferences

- **Development of a Pixel Tracking Trigger in the CMS experiment at LHC**
  presented by Daniele Vadruccio
  INFIERI Nikhef Workshop & Midterm Review — Amsterdam.

Presentations in national conferences

- **The Higgs or not the Higgs...and beyond**
  presented by Michele Gallinaro
  A desafiar os limites da ciencia e teconologia — IST, Lisbon.

- **Beyond the Higgs boson: Open questions in particle physics**
  presented by João Varela
  Conferência Nacional de Física 2014 — IST, Lisboa.

Oral presentations in international meetings

- **Pixel Trigger Feasibility studies for b-quarks**
  presented by Daniele Vadruccio
  INFIERI Madrid Workshop — Madrid.

- **BSM physics: Strong SuSy production searches at ATLAS & CMS**
  presented by Pedrame Bargassa
  Moriond EW — Moriond, Italy.

- **SuSy searches at CMS**
  presented by Pedrame Bargassa
  Protvino XXX — Protvino, Russia.

- **CT-PPS Technical Design Report**
  presented by João Varela
  LHCC referees meeting — CERN.

- **Answers to LHCC comments/questions on CT-PPS TDR**
  presented by João Varela
  LHCC referees meeting — CERN.

- **Status report : b-tagging with L1Pixel based trigger**
  presented by Daniele Vadruccio
  INFIERI Nikhef Workshop & Midterm Review — Amsterdam.

Oral presentations in collaboration meetings

- **TOP-12-035 "Measurement of the ratio R, ttbar cross section, and top quark width in pp collisions at 8 TeV"**
  presented by Pedro Ferreira da Silva
  Top Quark Physics Analysis Group: Paper talk — CERN, Geneva.

- **1 Lepton Stop Optimization: status**
  presented by Lara Lloret
  TBT meeting — CERN/Vidyo.

- **1 Lepton Stop Optimization: status**
  presented by Lara Lloret
  TBT meeting — CERN/Vidyo.

- **Pixel Trigger occupancy for b-quarks**
  presented by Daniele Vadruccio
  TTIWG — CERN/Vidyo.

- **1 Lepton Stop Optimization: status**
  presented by Lara Lloret
  TBT meeting — CERN/Vidyo.

- **Updates on heavy H+ searches**
  presented by Pietro Vischia
  CMS Higgs-Exo meeting — CERN.

- **1 Lepton Stop Optimization: status**
  presented by Lara Lloret
  TBT meeting — CERN/Vidyo.
- **1 Lepton Stop Optimization: status**
  presented by Lara Lloret
  TBT meeting — CERN/Vidyo.
- **Pixel occupancy studies for b-jets**
  presented by Daniele Vadruccio
  TTIWG — CERN/Vidyo.
- **1 Lepton Stop Optimization: status**
  presented by Lara Lloret
  TBT meeting — CERN/Vidyo.
- **1 Lepton Stop Optimization: status**
  presented by Lara Lloret
  TBT meeting — CERN/Vidyo.
- **1 Lepton Stop Optimization: status**
  presented by Lara Lloret
  TBT meeting — CERN/Vidyo.
- **1 Lepton Stop Optimization: status**
  presented by Lara Lloret
  TBT meeting — CERN/Vidyo.
- **PPS TDR: Detector and physics performance**
  presented by Michele Gallinaro
  PPS general meeting — CERN, Geneva.
- **1 Lepton Stop Optimization: status**
  presented by Lara Lloret
  TBT meeting — CERN/Vidyo.
- **1 Lepton Stop Optimization: status**
  presented by Lara Lloret
  TBT meeting — CERN/Vidyo.
- **Highlights from B physics and heavy ions**
  presented by Nuno Leonardo
  LIP Jornadas — LIP, Lisbon.
- **1 Lepton Stop Optimization: status**
  presented by Lara Lloret
  TBT meeting — CERN/Vidyo.
- **Pixel b-tagging**
  presented by Daniele Vadruccio
  TTIWG @ CMS Upgrade Week — Karlsruhe.
- **1 Lepton Stop Optimization: status**
  presented by Lara Lloret
  TBT meeting — CERN/Vidyo.
- **Progress on b-tagging with pixels**
  presented by Daniele Vadruccio
  TTIWG — CERN/Vidyo.
- **PPS TDR: Detector and physics performance**
  presented by Michele Gallinaro
  PPS general meeting — CERN, Geneva.
- **CP violation - experimental review**
  presented by Nuno Leonardo
  International Workshop on CMS B-Physics Run2 readiness — Venice, Italy.
- **1 Lepton Stop Optimization: status**
  presented by Lara Lloret
  TBT meeting — CERN/Vidyo.
- **Approval of TOP-12-026 "Measurement of ttbar cross section in the tau+lepton channel"**
  presented by Federico Nguyen
  Top Quark Physics Analysis Group — CERN, Geneva.
- **1 Lepton Stop Optimization: status**
  presented by Lara Lloret
  TBT meeting — CERN/Vidyo.

- **Updates on H+->tb since preapproval**
  presented by Pietro Vischia
  CMS Higgs-Exo meeting — CERN.
- **Report on CT-PPS project and TDR status**
  presented by João Varela
  CT-PPS IB meeting — CERN.
- **Status on b-tagging**
  presented by Daniele Vadruccio
  TTIWG — CERN/Vidyo.
- **Update on heavy H+->tb, tau nu analysis**
  presented by Pietro Vischia
  CMS Higgs-Exo meeting — CERN.
- **1 Lepton Stop Optimization: status**
  presented by Lara Lloret
  TBT meeting — CERN/Vidyo.
- **Update on heavy charged higgs HIG-13-026**
  presented by Pietro Vischia
  CMS Higgs-Exo meeting — CERN.
- **PPS TDR: Detector and physics performance**
  presented by Michele Gallinaro
  PPS general meeting — CERN, Geneva.
- **Readout of Cherenkov Timing Detectors**
  presented by João Varela
  CMS-TOTEM PPS General Meeting — CERN.
- **Update of HIG-13-026: high mass charged Higgs to tb**
  presented by Pietro Vischia
  CMS Higgs Physics Analysis Group — CERN.
- **HIG-13-026 ARC-Authors meeting**
  presented by Pietro Vischia
  CMS ARC-Authors meeting for HIG-13-026 — CERN.
- **HIG-13-026: last answers to ARC questions**
  presented by Pietro Vischia
  CMS Higgs-Exo meeting — CERN.
- **1 Lepton Stop Optimization: status**
  presented by Lara Lloret
  TBT meeting — CERN/Vidyo.
- **HIG-13-026 ARC-Authors meeting**
  presented by Pietro Vischia
  CMS ARC-Authors meeting for HIG-13-026 — CERN.
- **Full status report 1l stop analysis**
  presented by Lara Lloret
  Leptonic SUSY meeting — CERN/Vidyo.
- **1 Lepton Stop Optimization: status**
  presented by Lara Lloret
  TBT meeting — CERN/Vidyo.
- **PPS TDR: Detector and physics performance**
  presented by Michele Gallinaro
  pre-approval presentation — CERN, Geneva.
- **TDR chapter Organization, Cost, Schedule**
  presented by João Varela
  CT-PPS IB meeting — CERN.
- **1 Lepton Stop Optimization: status**
  presented by Lara Lloret
  TBT meeting — CERN/Vidyo.
- **1 Lepton Stop Optimization: status**
  presented by Lara Lloret
  TBT meeting — CERN/Vidyo.
- **Search for heavy charged Higgs: model independent and mH-tanb plane limits**
  presented by Pietro Vischia
  CMS Higgs-Exo meeting — CERN.

- **PPS TDR: Detector and physics performance**
  presented by Michele Gallinaro
  pre-approval presentation: update — CERN, Geneva.

- **1 Lepton Stop Optimization: status**
  presented by Lara Lloret
  TBT meeting — CERN/Vidyo.

- **CT-PPS Technical Design Report**
  presented by João Varela
  Approval of CT-PPS TDR — CERN.

- **1 Lepton Stop Optimization: status**
  presented by Lara Lloret
  TBT meeting — CERN/Vidyo.

- **Summary of the TDR of the CT-PPS project**
  presented by João Varela
  97th Meeting of the CMS Collaboration Board (CB97) — CERN.

- **Approval of HIG-13-026 "Search for a charged Higgs boson in the tau dileptona dn dilepton channels"**
  presented by Pietro Vischia
  Higgs Physics Analysis Group — CERN, Geneva.

- **Approval talks for HIG-13-026: "Search for a heavy charged Higgs in the tau dilepton and dilepton channels**
  presented by Pietro Vischia
  CMS Higgs Physics Analysis Group — CERN.

- **PPS: Timing detectors**
  presented by Michele Gallinaro
  PPS general meeting — CERN, Geneva.

- **1 Lepton Stop Optimization: status**
  presented by Lara Lloret
  TBT meeting — CERN/Vidyo.

- **1 Lepton Stop Optimization: status**
  presented by Lara Lloret
  TBT meeting — CERN/Vidyo.

- **Generation level matching for b-jets**
  presented by Daniele Vadruccio
  TTIWG — CERN/Vidyo.

- **Timing detectors for the CT-PPS experiment**
  presented by Michele Gallinaro
  Workshop on Timing detectors — CERN, Geneva.

Seminars

- **Standard Model 1**
  presented by João Varela
  Course on Physics at the LHC — LIP.

- **Standard Model 2**
  presented by João Varela
  Course on Physics at the LHC — LIP.

- **Particle interactions and detectors**
  presented by Michele Gallinaro
  Course on Physics at the LHC — LIP, Lisbon.

- **The Top quark: Introuction**
  presented by Michele Gallinaro
  Course on Physics at the LHC — LIP, Lisbon.

- **The Top quark: Properties and beyond**
  presented by Michele Gallinaro
  Course on Physics at the LHC — LIP, Lisbon.

- **Charged and other BSM Higgs searches**
  presented by Michele Gallinaro
  Bari University — Bari, Italy.

- **Heavy flavor physics and rare decays**
  presented by Nuno Leonardo
  Course on physics at the LHC — LIP, Lisbon.

- **The CMS-Totem Precision Proton Spectrometer**
  presented by Michele Gallinaro
  LIP seminar — LIP, Lisbon.

2.2.6 Academic Training

PhD Theses

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

2.2.7 Events

- **Course on Physics at the LHC**
  Workshop, LIP Lisbon, 2014-03-10

2.2.8 Project Summary

	number
Articles in international journals (with direct contribution from LIP members)	3
Articles in international journals (with indirect contribution from LIP members)	77
International Conference Proceedings	4
Collaboration notes with internal referee	10
Oral presentations in international conferences	7
Poster presentations in international conferences	1
Presentations in national conferences	2
Oral presentations in international meetings	6
Oral presentations in collaboration meetings	58
Seminars	8
Workshops	1

2.3 Phenomenological Studies at the LHC

2.3.1 Resumo

Por forma a cobrir o campo de física aberto pelo programa do LHC, é fundamental um importante esforço conjunto da comunidade experimental e teórica. Este esforço foi concentrado não apenas no estudo dos melhores observáveis físicos disponíveis no LHC, para realizar testes de precisão do Modelo Padrão (SM) da Física das Partículas Fundamentais, mas também no desenvolvimento de novas ideias para a física para além do SM. Neste projecto foram tratados alguns aspectos específicos do programa de física do LHC, tanto do ponto de vista experimental como teórico.
O projecto em si tem tido o mérito de atrair vários estudantes (quer de universidades portuguesas quer estrangeiras) e proporcionou um ambiente favorável que deu origem à elaboracao de várias teses de mestrado e doutoramento quer na área da fisica experimental quer teórica. O projecto tem tido o mérito de juntar as comunidades experimental e teórica sob um tema comum de investigação, com o objectivo, a longo prazo, de explorar de uma forma eficiente os dados adquiridos no LHC. Tal como foi feito no passado, foram realizados encontros regulares durante a execução do projecto, e realizados seminários para motivação da comunidade científica para o potencial da física de LHC.
Particularmente relevante é o desenvolvimento de um grupo de Fisica de Particulas e Astroparticulas na Universidade do Minho, um dos principais objectivos deste projecto, no recem criado Polo do LIP na Universidade do Minho, LIP-Minho. Esta iniciativa, que se iniciou em Fevereiro de 2010 conta já com a colaboracao de 23 membros, 6 Investigadores Doutorados, 5 estudantes de Doutoramento, 8 estudantes de Mestrado, 3 estudantes de licenciatura e 1 engenheiro informático.
A actividade do projecto incidiu sobre várias tarefas abaixo discriminadas.
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 foram 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 community is required. This effort considered 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 the development of new ideas for physics beyond the SM. In the present project, specific topics of the physics program of the LHC were addressed from both the experimental and theoretical points of view.
The project was very successful in the past in attracting students (from Portuguese and foreign universities) and provided the correct framework for the development of several MSc and PhD thesis already, both in experimental and theoretical physics. The project in itself is very valuable once it brings together the experimental and theoretical communities under a common goal of research, with the long term objective of exploring in an

efficient way the data that will be collected at the LHC. As was done in the past, regular meetings were performed in the course of the project, and seminars were given in order to motivate the scientific community to the physics potential of the LHC.
Particularly relevant is the fact that a new branch of LIP (LIP-Minho) is under development at the University of Minho, North of Portugal, bringing the field of High Energy Particle Physics and Astroparticle Physics to the Northern Universities of Portugal. This initiative started February 2010 and counts already with the collaboration of 23 researchers: 6 senior PhD members, 5 PhD students, 8 Master students, 3 undergraduate students and 1 computer sciences engineer.
The project activity was split in several tasks described below.
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 were contacted in order to further extend the test program of METop and one PhD thesis was developed, using MeTop as the main signal Monte Carlo generator, to set the best limits on the t->qgluon FCNC decay branching ratio at the LHC.
Non-Standard Higgs Production: The main goal of this task was to be able to say, for a chosen set of luminosities (from the first year of data taken at the LHC), which models could be tested and for which regions of the parameter space of each specific model. Together with the theoretical group of the team, cross sections and branching ratios were studied for those models where this was not already done. All tools readily available (for some models, like for instance the MSSM, there are already a lot of tools, like FeynHiggs or HDECAY which are ready to be used) were used and similar ones were created for the remaining models.
Top Quark Couplings: The main goal of this task was to measure the Wtb vertex structure 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 allowed to obtain much better limits than the ones obtained by using only the individual measurements. Several publications were performed that showed that still the Tevatron measurements on the top quark properties can still give an improvement in the overall limits on the anomalous couplings (better then 20%).
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.
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

was 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) Particularly important has been the development of a Particle Physics group at the Northern part of the country which counts already with the collaborations of 23 members.

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)	33
Augusto Barroso	Researcher (FCUL)	15
Francisco del Aguila Giménez	Researcher (UGR)	20
Henrique Carvalho	Student (LIP)	45
João Carvalho	Researcher (FCTUC)	35
João Marques de Carvalho	PhD student (LIP)	100
João Rodolfo Alves	Master student (UMinho)	16
José Santiago Perez	Researcher (LIP/UGR)	20
Juan Aguilar-Saavedra	Researcher (LIP/UGR)	40
Marco Oliveira Pena Sampaio	Post-Doc (LIP/UA)	15
Miguel Fiolhais	Researcher (LIP)	100
Miguel Won	Researcher (LIP) *	50
Mikael Chala	Master student (LIP)	20
Nuno Castro	Researcher (LIP/UP)	26
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)

- **Are there hidden scalars in LHC Higgs results?**
  A. Arhrib, P. M. Ferreira, Rui Santos
  J. High Energy Phys. 3 (2014) 053 — DOI: 10.1007/JHEP03(2014)053

- **Probing wrong-sign Yukawa couplings at the LHC and a future linear collider**
  P. M. Ferreira, Rui Santos, John F. Gunion, Howard E. Haber
  Phys. Rev. D 89 (2014) 115003 — DOI: 10.1103/PhysRevD.89.115003

- **New directions for top quark polarization in the t-channel process**
  J. A. Aguilar-Saavedra, S. Amor dos Santos
  Phys. Rev. D 89 (2014) 114009 — DOI: 10.1103/PhysRevD.89.114009

- **From Tevatron´s top and lepton-based asymmetries to the LHC**
  Adrian Carmona, Mikael Chala, Adam Falkowski, Sara Khatibi, Mojtaba Mohammadi Najafabadi, Gilad Perez, Jose Santiago
  J. High Energy Phys. 7 (2014) 005 — DOI: 10.1007/JHEP07(2014)005

- **Portrait of a colour octet**
  J. A. Aguilar-Saavedra
  J. High Energy Phys. 8 (2014) 172 — DOI: 10.1007/JHEP08(2014)172

- **Quantum coherence, top transverse polarisation and the Tevatron asymmetry A(FB)(l)**
  J. A. Aguilar-Saavedra
  Phys. Lett. B 736 (2014) 132-136 — DOI: 10.1016/j.physletb.2014.07.013

- **Collider limits on leptophilic interactions**
  Francisco del Aguila, Mikael Chala, Jose Santiago, Yasuhiro Yamamoto
  JHEP 1503 (2015) 059 — DOI: 10.1007/JHEP03(2015)059

- **Wrong sign and symmetric limits and non-decoupling in 2HDMs**
  P. M. Ferreira, Renato Guedes, Marco O. P. Sampaio, Rui Santos
  J. High Energy Phys. 12 (2014) 067 — DOI: 10.1007/JHEP12(2014)067

- **Studying the Wtb vertex structure using recent LHC results**
  Cesar Bernardo, Nuno F. Castro, Miguel C. N. Fiolhais, Hugo Goncalves, Andre G. C. Guerra, Miguel Oliveira, Antonio Onofre
  Phys. Rev. D 90 (2014) 113007 — DOI: 10.1103/PhysRevD.90.113007

International Conference Proceedings

- **The CP-conserving 2HDM after the 8 TeV run**
  P.M. Ferreira, Renato Guedes, John F. Gunion, Howard E. Haber, Marco O. P. Sampaio, Rui Santos
  Conference: C14-04-28.1 Proceedings

- **The Wrong Sign limit in the 2HDM**
  P.M. Ferreira, Renato Guedes, John F. Gunion, Howard E. Haber
  Conference: C14-06-02.2, e-Print: arXiv:1410.1926

- **Missing Top Properties**
  J.A. Aguilar-Saavedra
  Conference: C14-09-28.1 Proceedings

- **The CP-conserving 2HDM after the 8 TeV run**
  Rui Santos, P.M. Ferreira, Renato Guedes, John F. Gunion, Howard E. Haber, Marco O.P. Sampaio
  PoS DIS2014 (2014) 127

Collaboration notes with internal referee

- **Asymmetries in top quark pair production at hadron colliders**
  J.A. Aguilar-Saavedra, D. Amidei, A. Juste, M. Perez-Victoria
  CERN-PH-TH-2014-101

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

2.3.9 Project Summary

	number
Articles in international journals (with direct contribution from LIP members)	9
International Conference Proceedings	4
Collaboration notes with internal referee	1
PhD Theses	1

2.4 Collaboration in the COMPASS experiment at CERN

2.4.1 Resumo

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

2.4.2 Abstract

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

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

2.4.3 Objectives

A major activity of LIP is data analysis in view of the physics results extraction, together with studies for the present COMPASS physics programme. 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.
Moreover, 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 analysis and offline studies 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 2014 the following subjects were addressed:

- Study of the gluon contribution to the nucleon Sivers effect from high p_T hadron pairs and high Q^2 .

- Measurement of hadron multiplicities in view of the fragmentation functions extraction, namely strangeness to kaon D_sˆK(z).
- Spin asymmetries analysis in the low x_Bj and low Qˆ2 region, in order to extract the polarised structure function g_1ˆp(x).
- Development of a new all-p_T method concerning the gluon polarisation extraction, from high Qˆ2 events.
- Monte-Carlo studies for Drell-Yan dimuon background coming from open-charm and open-bottom events.
- Optimisation of the COMPASS reconstruction programme, namely hit to track association, in view of increasing the track matching efficiency in spectrometer specific parts crucial to the Drell-Yan experiment.
- New reproduction and reanalysis of the 2009 Drell-Yan data taking test runs, in view of the optimisation of the reconstruction programme and to experimentally validate the new Monte-Carlo parameters of the simulation programme.
- Monte-Carlo studies concerning the hodoscopes refurbishing in view of their geometrical coverage, as well as correlation matrices definition, in order to optimise the dimuon trigger.
- Alignment studies of the new setup spectrometer during the whole fall 2014 Drell-Yan test run.
- Development of a multi-dimensional analysis of the azymuthal spin asymmetries from hadrons produced by muon scattering in a transversely polarised proton (NH_3) target, in order to access the TMD functions, namely Sivers, Collins, pretzelosity and transversity.
- Estimation of the expected experimental accuracy of polarised Drell-Yan azymuthal asymmetries, as a function of x_F.

Detector Control System

In 2014, the DCS proceeded with the tasks of continuing the integration of new or refurbished COMPASS detectors, in order to prepare the spectrometer for the polarised Drell-Yan programme. In this view the Drell-Yan setup was installed in the fall 2014 and a data taking test took place.
In this context, the DCS monitornig developments concerned: the refurbishing of the H3 and H4 hodoscopes; the new polarised ammonia target (via DIM, DIP and PLCs); the low and high voltages for the new drift chamber DC5, as well as its temperature monitoring; the CEDARS detector parameters via DIP; the high voltages for the new trigger hodoscopes; the low and high voltages for the new vertex detector (through DIM and OPC, respectively).
One should stress that the DCS has to deal with a vast variety of COMPASS equipments that are being or will be controlled or monitored. While for some devices commercial supervision solutions exist (like OPC servers), for many others these solutions do not. That is why case-by-case solutions must be applied, namely by writing the drivers to control/monitor such devices, and integrate them in PVSS/WinCC OA, whenever necessary.
It is worth noting that the DCS system works practically 12 months per year. In fact, during the no-beam part of the year, several DCS sub-systems run, in order to control some devices, as it is the case of detectors gas systems.

General Activities

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

- Participation in the data taking periods and in their preparation.
- Participation in the Collaboration meetings.
- Member 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.
- Participation in the technical friday meetings during the data takings.

- Participation in the data taking periods.
- Week coordination of the data taking (S. Nunes).
- Stays at CERN for the run preparation.

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/FCT)	50
Márcia Quaresma	PhD student (LIP/FCT)	100
Marcin Stolarski	Post-Doc (LIP/FCT)	100
Miguel Vasco	Master student (LIP)	59
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)

- **Transverse target spin asymmetries in exclusive ρ0 muoproduction**
  P. Bordalo. C. Franco, M. Quaresma, C. Quintans, A.S. Nunes, S. Ramos, M. Stolarski, L. Silva et al
  Phys. Lett. B 731 (2014) 19-26 — DOI: 10.1016/j.physletb.2014.02.005

- **Long term experience and performance of COMPASS RICH-1**
  P. Bordalo, C. Franco et al.
  JINST 9 (2014) C09011 — DOI: 10.1088/1748-0221/9/09/C09011

- **A high-statistics measurement of transverse spin effects in dihadron production from muon-proton semi-inclusive deep-inelastic scattering**
  P. Bordalo. C. Franco, M. Quaresma, C. Quintans, A.S. Nunes, S. Ramos, M. Stolarski, L. Silva et al
  Phys. Lett. B 736 (2014) 124-131 — DOI: 10.1016/j.physletb.2014.06.080

- **Measurement of azimuthal hadron asymmetries in semi-inclusive deep inelastic scattering off unpolarised nucleons**
  P. Bordalo. C. Franco, M. Quaresma, C. Quintans, A.S. Nunes, S. Ramos, M. Stolarski, L. Silva et al
  Nucl. Phys. B 886 (2014) 1046-1077 — DOI: 10.1016/j.nuclphysb.2014.07.019

- **Spin alignment and violation of the OZI rule in exclusiveW and ϕ production in pp collisions**
  P. Bordalo. C. Franco, M. Quaresma, C. Quintans, A.S. Nunes, S. Ramos, M. Stolarski, L. Silva et al
  Nucl. Phys. B 886 (2014) 1078-1101 — DOI: 10.1016/j.nuclphysb.2014.07.020

- **Reevaluation of the parton distribution of strange quarks in the nucleon**
  M. Stolarski
  arXiv:1407.3721

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

- **Measurement of radiative widths of a2 (1320) and π2(1670)**
  P. Bordalo. C. Franco, M. Quaresma, C. Quintans, A.S. Nunes, S. Ramos, M. Stolarski, L. Silva et al
  Eur. Phys. J. A 50 (2014) 79 — DOI: 10.1140/epja/i2014-14079-8

- **Odd and even partial waves of ηπ- and η'π- in π-p$\rightarrow\eta(')$π-p at 191 GeV/c**
  P. Bordalo. C. Franco, M. Quaresma, C. Quintans, A.S. Nunes, S. Ramos, M. Stolarski, L. Silva et al
  Phys. Lett. B740 (2015) 303 — DOI: 10.1016/j.physletb.2014.11.058

International Conference Proceedings

- **Polarized Drell-Yan studies at COMPASS**
  Catarina Quintans (for the COMPASS Collaboration)
  EPJ WEB CONF 66 (2014) 06021 — DOI: 10.1051/epjconf/20146606021

- **Polarised Drell-Yan measurements at COMPASS-II**
  M. Quaresma et al., for COMPASS Collaboration
  Phys. Part. Nuclei 45 (2014) 333-335 — DOI: 10.1134/S1063779614010845

- **Overview of the nucleon spin studies at COMPASS**
  Celso Franco (for the COMPASS Collaboration)
  EPJ WEB CONF 71 (2014) 00046 — DOI: 10.1051/epjconf/20147100046

- **Drell-Yan physics at COMPASS**
  Catarina Quintans (for the COMPASS Collaboration)
  PoS DIS2014 (2014) 240

- **A new LO extraction of gluon polarisation from COMPASS DIS data**
  M. Stolarski (for the COMPASS Collaboration)
  Proceedings of DIS2014 Conference

- **First results on Ap1 and gp1 at low x and low Q2 from COMPASS**
  A.S. Nunes (for the COMPASS Collaboration)
  PoS DIS2014 (2014) 221

- **Measurement of the Polarised Drell-Yan process at COMPASS**
  M. Quaresma (for the COMPASS Collaboration)
  EPJ Web Conf. 81 (2014) 04011 — DOI: 10.1051/epjconf/20148104011

- **New COMPASS results on A1p and g1p and QCD fit**
  A.S. Nunes (for the COMPASS Collaboration)
  Proceedings of QCD14 Conference

- **The New Spin Physics Program of the COMPASS Experiment**
  L. Silva (COMPASS Collaboration)
  Proceedings of CNFP2014 Conference

- **Overview of the COMPASS results on the nucleon spin**
  C. Franco (for the COMPAS COllaboration)
  Proceedings of HEP2014 Conference

- **Polarised Drell-Yan measurement in the COMPASS experiment at CERN**
  M. Quaresma (for the COMPASS Collaboration)
  Proceedings of PANIC2014 Conference

- **Latest Results from the COMPASS Experiment**
  M. Stolarski (for the COMPASS Collaboration)
  Proceedings of SPIN2014 Conference

2.4.8 Presentations

Oral presentations in international conferences

- **Monte-Carlo simulations for Drell-Yan in COMPASS**
  presented by Catarina Quintans
  INT Workshop on Studies of 3D Structure of Nucleon — Seattle, USA.

- **"A New LO Extraction of Gluon Polarisation from DIS Data"**
  presented by Marcin Stolarski
  XXII International Workshop on Deep-Inelastic Scattering and Related Subjects - DIS2014 — Warsaw, Poland.

- **"First results on A1p and g1p at low x and low Q2 from COMPASS"**
  presented by Sofia Nunes
  XXII International Workshop on Deep-Inelastic Scattering and Related Subjects - DIS2014 — Warsaw, Poland.

- **"Drell-Yan Physics at COMPASS"**
  presented by Catarina Quintans
  XXII International Workshop on Deep-Inelastic Scattering and Related Subjects - DIS2014 — Warsaw, Poland.

- **"Measurement of the Polarised Drell-Yan process at COMPASS"**
  presented by Márcia Quaresma
  13th International Workshop on Meson Production, Properties and Interaction - MESON2014 — Krakow, Poland..

- **"Overview of the COMPASS results on the nucleon spin"**
  presented by Celso Franco
  37th International Conference on High Energy Physics - ICHEP14 — Valencia, Spain..

- **"New COMPASS results on A1p and g1p and QCD fit",**
  presented by Sofia Nunes
  17th International Conference on Quantum Chromodynamics — Montpellier, France.
- **"The New Spin Physics Program of the COMPASS Experiment"**
  presented by Luis Silva
  3rd International Conference on New Frontiers in Physics - CNFP2014 — Kolymbari, Crete, Greece..
- **"Polarised Drell-Yan measurement in the COMPASS experiment at CERN"**
  presented by Márcia Quaresma
  20th Particles and Nuclei International Conference - PANIC2014, — Hamburg, Germany..
- **"Latest results from the COMPASS Experiment"**
  presented by Marcin Stolarski
  21st International Symposium on Spin Physics - SPIN2014 — Beijing, China..

Presentations in national conferences

- **COMPASS experiment at CERN - Recent LIP contributions**
  presented by Marcin Stolarski
  Jornadas LIP 2014 — Lisbon, Portugal.
- **COMPASS II : 3D nucleons**
  presented by Catarina Quintans
  Jornadas LIP 2014 — Lisbon, Portugal.

Seminars

- **Spin Physics at COMPASS: Past, Present and Future**
  presented by Luis Silva
  — FCT, Univ. Coimbra.

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

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

2.4.10 Project Summary

	number
Articles in international journals (with direct contribution from LIP members)	6
Articles in international journals (with indirect contribution from LIP members)	2
International Conference Proceedings	12
Oral presentations in international conferences	10
Presentations in national conferences	2
Seminars	1

2.5 Collaboration in the HADES experiment at GSI

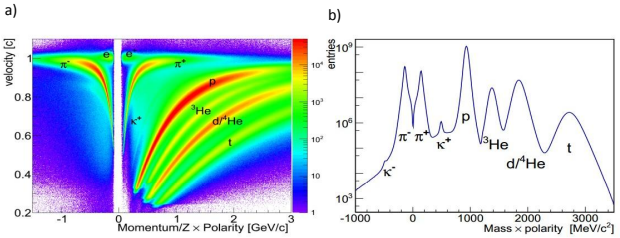
2.5.1 Resumo

O "High Acceptance Di Electron Spectrometer (HADES)"(http://www-hades.gsi.de) é um sistema versátil de detetores para a espectroscopia de pares de e+e- (dielectrões) e hadrões carregados produzidos em reações induzidas por piões e iões pesados em feixes de 1 - 3.5GeV de energia. O detetor foi construído entre 1996 e 2002 no GSI (https://www.gsi.de) por uma colaboração europeia envolvendo grupos de 19 institutos de 10 países. O seu principal objetivo e investigar as propriedades da matéria nuclear densa criada durante a colisão de iões pesados e em última análise aprender sobre as propriedades dos hadrões neste meio. Por exemplo, as propriedades que são responsáveis pela maioria da massa da matéria ordinária ou o mecanismo responsável pela termalização dos hadrões à temperatura universal de 170MeV. A matéria criada neste tipo de colisões é diferente da matéria estudada no SPS, RHIC ou LHC porque consiste basicamente em bariões e poucos mesões, podendo ser comprimida ate três vezes a densidade da matéria nuclear, ate 10-12 fm/c. Pares de dielectrões originados em decaimentos hadronicos neste meio e hadrões com estranheza são as principais provas de medida desta experiência. Uma vez que as conclusões retiradas dos efeitos acontecidos neste meio dependem fortemente da compreensão das propriedades dos hadrões no vácuo e os seus mecanismos de produção nas colisões núcleo – núcleo, foi também iniciado um programa complementar focado em produção de e+e-, kaões e hiperões em colisões elementares. Apresentações com uma visão geral da física de HADES podem ser encontradas em http://www-hades.gsi.de/?q=node/10

Nos próximos anos, HADES vai operar no novo acelerador SIS100 no laboratório FAIR (http://www.fair-center.eu/) com o objetivo de obter dados de alta qualidade relativos a dielectrões a densidades barionicas e a temperaturas não acessíveis por outros detetores, nem agora nem no futuro previsível. De salientar que nesta faixa de energia, 2-40AGeV, não existem para já dados disponíveis para dieletrões, esta área é "terra incógnita"para medidas de dielectrões. As medidas com dielectrões na experiência "Compressed Baryon Matter"(CBM) no SIS300 (o novo acelerador atualizado) continuarão com o estudo da emissão de dielectrões pela matéria nuclear comprimida a maiores energias de feixe fazendo a ponte com as energias do CERN. Nos últimos anos HADES produziu uma serie de resultados de física relevantes, a maioria com partículas elementares o iões leves devido a uma limitação imposta pelo antigo detetor de tempo de voo. Uma lista de publicações com os resultados mais relevantes encontra-se em: http://www-hades.gsi.de/?q=node/204

A principal contribuição do nosso grupo para a colaboração HADES foi o desenho e construção de um novo detetor de tempo de voo baseado em RPCs (câmaras de planos resistivos) para medida de tempos com uma alta segmentação (1200 canais em 8m2) e prestações (resolução temporal de 70 ps, o tempo que demora a luz a percorrer uma distância de 3 cm). O novo sistema reduz as limitações impostas pelo antigo detetor de tempo de voo ao espectrómetro HADES, que o impedia de medir em sistemas pesados, uma parte fundamental do programa de física. Em 2012, o novo detetor RPC-TOF participou pela primeira vez numa tomada de dados com iões pesados, Au-Au a 1.25AGeV, durante 5 semanas (um dos principais objetivos do programa de física). Após uma precisa calibração, o RPC-TOF apresentou um excelente desempenho.

O grupo RPC-TOF de HADES foi inicialmente constituído por três instituições, das quais só o grupo do LIP permanece ativo dentro da colaboração. Isto significa que a operação continua e otimização do RPC-TOF,



a)Velocity (β) as a function of the particle momentum times polarity. The different particle species are shown with labels. b) Mass reconstructed from time of flight shows a very low background contamination.

juntamente com todos os seus sistemas, está agora sob a responsabilidade única do nosso grupo.

2.5.2 Abstract

The High Acceptance Di Electron Spectrometer (HADES) (http://www-hades.gsi.de) is a versatile detector for a precise spectroscopy of e+ e- pairs (dielectrons) and charged hadrons produced in proton, pion and heavy ion induced reactions in a 1 - 3.5 GeV kinetic beam energy region. The detector has been set-up in 1996-2002 at GSI (https://www.gsi.de) by an international collaboration of 19 institutions from 10 European countries. The main experimental goal is to investigate the properties of dense nuclear matter created in the course of heavy ion collisions and ultimately learn about in-medium hadron properties. For instance, the properties that are responsible for most of the mass of the ordinary matter or the mechanism responsible for the thermalization of hadrons to a universal temperature of 170 MeV. The matter created in such collisions differs from the one studied at SPS, RHIC or LHC because it consists mainly of baryons (nucleons and its excited states - baryon resonances) and few mesons and can be compressed up to 3 times nuclear matter density for about 10-12 fm/c. Dielectron pairs originating from in-medium hadron decays and rare strange hadrons (kaons, hyperons) are the main probes measured in the experiment. Since conclusions on in-medium effects rely strongly on the understanding of hadron properties in vacuum and their production mechanism in nucleon-nucleon collisions a complementary program focusing on e+e-, kaon and hyperon (sigma, lambda) production in elementary collisions is also in progress. Overview talks with presentation of HADES physics can be found in http://www-hades.gsi.de/?q=node/10.
In the following years, HADES will operate in the new accelerator SIS100 at the future FAIR facility (http://www.faircenter.eu/) with the mission of providing high-quality dielectron data at baryon densities and temperatures not accessible by other detectors, neither in the past nor in the foreseeable future. One should note that, in this energy range, 2-40 AGeV no dilepton data exist so far, this is complete "terra incognita"for dielectron measurements. The dilepton opportunities of the Compressed Baryon Matter (CBM) experiment at SIS300 (the upgraded new accelerator) will later on continue the study of the dilepton emissivity of compressed nuclear matter at higher beam energies and bridges over to CERN energies. In recent years HADES has produced a series of relevant physics results, mostly with elementary particles or light ions owing to granularity limitations in the forward time-of-flight (TOF) detector. A list of publication summarizing this results can be found in http://www-hades.gsi.de/?q=node/204.
The main contribution of LIP team to the collaboration was the design and construction of a high granularity (1200 channels in 8 m2), high resolution (70 ps, the time that it takes the light to cross a distance of 3cm) timing RPC (Resistive Plate Chambers) based TOF wall. This new system reduced the limitations imposed to the spectrometer by the old scintillator based TOF that prevent it to measure with heavy systems, a fundamental part of the physics program. In 2012, the RPC-TOF wall took part for the first time in a very successful heavy-ion production run with Au-Au collisions at 1.25AGeV during 5 weeks (one of the main objectives of the physics program). After accurate calibration, the RPC-TOF wall showed an excellent performance.
The HADES-RPC group was initially composed by three institutions, from which only the LIP team remains active within the collaboration. This means that the continuous operation and optimization of the RPC-TOF wall together with all subsystems fall now entirely on our group.

2.5.3 Objectives

The main objectives for 2014 comprised:

- Final calibration of the RPC-TOF using the 2012 Au-Au at 1.25Gev data.
- Participation on the scheduled (4 weeks) pinon beam. The HADES-RPC group was initially composed by three institutions, from which only the LIP team remains active within the collaboration. This means that the operation of the RPC-TOF wall together with all subsystems fall now entirely on our group.
- Study of the non-resonant mass spectrum of dileptons, which come from the fireball in the high density environment, as well as the mass properties of short lived mesons in the dilepton channel and the
- Study of the momentum and multiplicity distributions of particles with strangeness, namely kaons, which have to be produced through in-medium mechanisms.

2.5.4 Achievements

After accurate calibration, using data of the 2012 Au-Au at 1.25AGeV physics run, the RPC-TOF wall shows, at the design multiplicity, an excellent performance well above the requirements [KOR14]. An overall intrinsic

efficiency of 97% together with a system time accuracy of 81 ps σ (intrinsic time accuracy of 64 ps σ) for electrons. The degradation in time accuracy due to this high multiplicity environment is only a few ps with respect to the low multiplicity situation, thanks to the innovative design adopted (individually shielded RPCs). Such performance allows a very good particle identification in a wide momentum range and a reconstructed mass distribution with very low background contamination. In the later, a K- peak is clearly visible, which is a very demanding test on the apparatus time response as well as granularity due to their extreme rarity (K- is produced at sub-threshold energy): about one per 10000 anti-pions (see plot annexed). When compare with other similar systems the HADES RPC-TOF wall can be considered as one of the most performing TOF systems.
In 2014, the RPC-TOF wall was used in a pion beam during 4 weeks, initiating the elementary collisions program. The RPC-TOF wall performed satisfactorily confirming its reliability.
A new selection method of leptons has been optimized. The method makes use of a dynamic neural network to isolate the leptons from the very dense hadronic medium. In addition, it was also conducted a detailed study of the combinatorial background underlying the dilepton mass spectrum. This study was performed with the help of simulated leptons embedded in real events. Concerning the strangeness studies, the group contributed with some work to improve the PID of K- particles.
[KOR14] 2014 Time of flight measurement in heavy-ion collisions with the HADES RPC TOF wall G. Kornokov et al., JINST 9 (2014), C11015.

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: Alberto Blanco

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

2.5.7 Publications

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

- **Time of flight measurement in heavy-ion collisions with the HADES RPC TOF wall**
  G. Kornakov et al.
  JOURNAL OF INSTRUMENTATION 9 — DOI: 10.1088/1748-0221/9/11/C11015

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

- **Low mass dielectrons radiated off cold nuclear matter measured with HADES**
  M. Lorenz et al.
  INPC 2013 - INTERNATIONAL NUCLEAR PHYSICS CONFERENCE, VOL. 2 66 09011 — DOI: 10.1051/epjconf/20146609011

- **In-medium hadron properties measured with HADES**
  J. Pietraszko et al.
  NPC 2013 - INTERNATIONAL NUCLEAR PHYSICS CONFERENCE, VOL. 2 66 04023 — DOI: 10.1051/epjconf/20146604023

- **Searching a dark photon with HADES**
  G. Agakishiev et al.
  PHYSICS LETTERS B 731 265-271 — DOI: 10.1016/j.physletb.2014.02.035

- **Baryon resonance production and dielectron decays in proton-proton collisions at 3.5 GeV**
  G. Agakishiev et al.
  EUROPEAN PHYSICAL JOURNAL A 50 5, 82 — DOI: 10.1140/epja/i2014-14082-1

- **Lambda hyperon production and polarization in collisions of p(3.5 GeV)+Nb**
  G. Agakishiev et al.
  EUROPEAN PHYSICAL JOURNAL A 50 5, 81 — DOI: 10.1140/epja/i2014-14081-2

- **Associate K-0 production in p plus p collisions at 3.5 GeV: The role of Delta(1232)(++)**
  G. Agakishiev et al.
  PHYSICAL REVIEW C 90 1 015202 — DOI: 10.1103/PhysRevC.90.015202
- **Medium effects in proton-induced K0 production at 3.5 GeV**
  Agakishiev, G. et al.
  Physical Review C 90 5 — DOI: 10.1103/PhysRevC.90.054906
- **Measurement of the quasi free $nponppi^+pi^-$ and $npopppi^-pi^0$ reactions at 1.25 GeV With HADES**
  HADES Collaboration (105 authors)
  EPJ Web Conf. 81 (2014) 02009 — DOI: 10.1051/epjconf/20148102009

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 Distributed Computing and Digital Infrastructures

3.1.1 Resumo

As actividades no domínio da computação distribuída e infraestruturas digitais estão focadas no suporte à investigação científica 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 infraestruturas nacionais e internacionais no domínio da computação científica.

Worldwide LHC Computing Grid (WLCG)
Em 2014, o Tier-2 Português forneceu 47,572,104 HEPSPEC06 horas de processamento normalizadas às experiências ATLAS e CMS, satisfazendo e excedendo os compromissos assumidos para 2014. A disponibilidade média do Tier-2 esteve acima dos requisitos operacionais, e o tempo de resposta para resolução de incidentes foi significativamente inferior à média do WLCG.
A consolidação do tier-2 foi finalizada estando agora todos os equipamentos alojados em melhores condições técnicas no NCG em Lisboa. Recentemente foram adquiridos novos equipamentos de armazenamento para substituição dos sistemas mais obsoletos e problemáticos.

Infraestrutura Nacional de Computação Distribuída (INCD)
Foram publicados os resultados finais da avaliação do roteiro de infraestruturas da FCT. A proposta para uma Infraestrutura Nacional de Computação Distribuída, submetida pelo LIP em parceria com o LNEC e a FCCN obteve a pontuação máxima. Pretende-se evoluir a actual infraestrutura baseada em tecnologia grid alargando o leque de serviços e a sua capacidade.
No Outono de 2014 deu-se inicio um projecto preliminar ao INCD para a criação de um piloto de computação em nuvem (cloud computing), financiado através de um contrato FCT-FCCN. Este projecto tem por objectivo fomentar o desenvolvimento de um serviço de computação em nuvem do tipo IaaS interoperável com federação EGI, e com o EDUGAIN do Géant. A avaliação de nuvens híbridas e HPC incluindo GPUs estão também incluídos.
Teve inicio uma tese de mestrado em parceria com a FCT/UNL focada na avaliação do sistema de armazenamento Ceph para o armazenamento de objectos em ambiente de computação em nuvem. Este trabalho tem por objectivo estabelecer as bases para o sistema de armazenamento de objectos do INCD que complementará o serviço de computação em nuvem IaaS.

IBERGRID e EGI
As infraestruturas grid e em nuvem Portuguesa e Espanhola continuaram a ser operadas no âmbito do IBERGRID. O LIP contribuiu para a coordenação e operações Ibéricas. O LIP também disponibilizou serviços de suporte aos utilizadores e coordenação do middleware para toda a infraestrutura EGI em parceria com outros centros IBERGRID.
A conferência IBERGRID 2014 teve lugar em Setembro na Universidade de Aveiro. Foi organizada pelo IEETA com o suporte do LIP. Incluiu a participação de membros da divisão de infraestruturas digitais da UE, Fundação de Ciência e Tecnologia, e do Ministério da Industria e Competitividade de Espanha. A conferência incluiu

uma jornada Ibérica do Lifewatch, e um tutorial de treino sobre computação em nuvem para especialistas de TI das universidades Portuguesas. O tutorial foi organizado pela FCCN e LIP em parceria com outros centros IBERGRID.
As actividades do EGI continuaram em 2014 com a execução do projecto EGI-INSPIRE que terminou em Dezembro. Um novo projecto (EGI-ENGAGE) foi submetido ao H2020 em Setembro 2014 e foi recentemente aprovado com pontuação máxima. O LIP contribuiu para a proposta coordenando a elaboração de um centro de competência em AAI que integrará esforços internacionais nesta área, e contribuindo activamente para a criação do centro de competência Lifewatch em parceria com o CIBIO e outros centros IBERGRID.
O LIP investiu no estabelecimento de colaborações com outros centros nacionais e infraestruturas, no âmbito do roteiro de infraestruturas da FCT, e da estratégia EGI 2020. Teve inicio uma colaboração com a fundação Champalimaud. Estão em curso contactos com organizações nacionais ligadas a diversos ESFRIs.
O coordenador da equipa de computação foi reeleito para a direcção do EGI, e continuou a representar a FCT do conselho do EGI.

INDIGO-DATACLOUD
A proposta INDIGO-DATACLOUD foi submetida ao H2020 em Setembro de 2014, tendo sido recentemente aprovada. A proposta é coordenada pelo INFN. O projecto pretende desenvolver componentes de software que permitirão a execução de aplicações em infraestruturas grid e nuvem, assim como em ambientes HPC. Pretende-se também melhorar soluções do tipo PaaS permitindo a exploração de infraestruturas privadas e públicas, incluindo as disponibilizadas pelo EGI, EUDAT, PRACE e Helix Nebula, integrando os seus serviços.
Ainda neste contexto tiveram inicio actividades de I&D com vista a futuros desenvolvimentos na área da computação em nuvem, nomeadamente através da exploração das tecnologias emergentes de *lightweight virtualization*.

ESA CODES
Em parceria com a equipa de *Space Radiation* do LIP, foram fornecidos serviços de simulação de degradação de componentes no âmbito de um contrato com a ESA. Neste contexto a equipa de computação também implementou melhoramentos significativos no software de forma a satisfazer os requisitos de produção.

Serviços de Computação
Teve inicio a renovação e melhoramento das páginas web do LIP num processo aberto em colaboração com a comunidade.
Gonçalo Borges, um investigador chave da equipa deixou o LIP para incorporar o *ARC Centre of Excellence in Particle Physics at the Tera-scale* parte da infraestrutura Australiana de computação NeCTAR. Mário David também investigador chave da equipa regressou ao LIP após dois anos de trabalho em infraestruturas de computação Ciências da Terra no IPGP/CNRS em Paris.

3.1.2 Abstract

The LIP distributed computing and digital infrastructure 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 infrastructures related to e-Science.

Worldwide LHC Computing Grid (WLCG)
In 2014, the Portuguese Tier-2 has delivered 47,572,104 HEPSPEC06 normalized processing hours to the ATLAS and CMS experiments fulfilling and exceeding the 2014 pledge. The average Tier-2 availability has been above the operational requirements, and the response time to fix issues was significantly better than the WLCG average.
The Tier-2 consolidation was completed. The computing and storage resources are now being housed under better technical conditions at NCG in Lisbon. New storage equipment has been recently purchased to replace the most obsolete and problematic Tier-2 storage systems.

National Distributed Computing Infrastructure (INCD)
The final evaluation results of the Portuguese Science Foundation (FCT) roadmap of strategic infrastructures were published. The proposal for a National Distributed Computing Infrastructure submitted by LIP in partnership with LNEC and FCCN, received the maximum score. The infrastructure aims to further evolve the existing grid based infrastructure enlarging its services portfolio and capacity.
In this context a preliminary project to create a pilot cloud service for the Portuguese academic and scientific community started in the fall of 2014, funded by an FCT-FCCN contract. The project aims to bring to speed the future INCD cloud service and is focused on provisioning of an IaaS cloud interoperable with the EGI cloud federation and Géant EDUGAIN. It also includes evaluation of hybrid cloud solutions, and HPC services in cloud environments including GPU computing.
A master student from FCT/UNL started a thesis at LIP focused on the evaluation of the Ceph storage system as a cloud object storage system. This work is aimed at establishing the foundations for the INCD object storage service that will complement the IaaS cloud.

IBERGRID and EGI
The Portuguese and Spanish cloud and grid infrastructures continued operating under the IBERGRID umbrella. LIP contributed to the Iberian coordination and operations. LIP also provided user support and software roll-out services to the global EGI community in partnership with other IBERGRID centres.
The IBERGRID 2014 conference took place in the University of Aveiro in September. It was organized by IEETA with support from LIP. It included the participation of EC officials and representatives from FCT and the Ministry of Industry and Competitiveness of Spain. The conference included an Iberian Lifewatch workshop and a cloud tutorial for IT staff from Portuguese universities, organized by FCCN and LIP in partnership with other IBERGRID centres.
The EGI activities continued in 2014 with the execution of the EGI-INSPIRE project which finished in December. A new EGI project (EGI-ENGAGE) was submitted to H2020 in September of 2014 and has been recently approved with maximum score by the evaluation panel. LIP contributed to the project coordinating the creation of the AAI competence center merging international developments in this area, and contributing to the creation of the Lifewatch competence centre within EGI-ENGAGE in partnership with CIBIO and the IBERGRID centres.
LIP worked towards establishing collaborations with national research centres and infrastructures in the scope of the FCT infrastructures roadmap and EGI 2020 strategy. A collaboration with the Champalimaud foundation started. Contacts with national organizations participating in ESFRIs are ongoing.
The LIP computing team leader was reelected to the EGI board of directors, and continued as FCT representative in the EGI council.

INDIGO-DATACLOUD
The INDIGO-DATACLOUD proposal was submitted to a H2020 call in September 2014 and has been recently approved. The proposal is coordinated by INFN. INDIGO will develop software components allowing execution of applications on Cloud and Grid based infrastructures, as well as on HPC clusters. The project will extend existing PaaS (Platform as a Service) solutions, allowing public and private e-infrastructures, including those provided by EGI, EUDAT, PRACE and Helix Nebula, to integrate their existing services.
In this context R&D towards future cloud developments started namely with the exploration of emerging lightweight virtualization technologies for scientific computing.

ESA CODES
In a partnership with the LIP Space Radiation team, the computing team is delivering component degradation simulation services under contract with ESA. Within the contract the team enhanced significantly the software to meet production quality requirements.

Computing Services
LIP web presence is being openly redesigned and improved with contributions from the community.
Gonçalo Borges, a key team member left LIP to joint the ARC Centre of Excellence in Particle Physics at the Tera-scale, part of the Australian NeCTAR national e-infrastructure. Mario David also a key team member returned to LIP after two years working in e-infrastructures for Earth Sciences at IPGP/CNRS in Paris.

3.1.3 Objectives

- Operate and further consolidate the LIP IT infrastructure.

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

3.1.4 Achievements

- Approval of the INCD proposal into the Portuguese Science Foundation strategic infrastructures roadmap following an international evaluation where it received the maximum score.
- Launching of a pilot to support the development of cloud services for INCD funded through a FCCN-FCT contract.
- Manage the national computing node (NCG) in partnership with FCCN and LNEC already in the context of the INCD program of work.
- Wining of the bid to host the EGI Conference for 2015.
- Wining of two proposals for EGI competence centres (AAI and Lifewatch) that have been incorporated in the EGI-ENGAGE proposal.
- Approval of two Horizon 2020 projects on e-Infrastructures (EGI-ENGAGE, INDIGO-DATACLOUD) with excellent evaluations.
- Public tender for Tier-2 storage capacity will allow an almost complete renewal.
- Consolidation of the Tier-2 services at a single location (NCG).
- Increase of the capacity to host computing equipment at NCG.
- Delivery of EGI user support services and middleware rollout coordination to the whole EGI international community.
- Reelection to the European Grid Initiative (EGI) board of directors (J.Gomes).
- Representation of the Portuguese Science Foundation in the EGI council (J.Gomes).
- Representation of IBERGRID at EGI Operations Management Board (J.Pina).

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
Cloud - Piloto	100.000 €	2014-08-14	2015-12-31

3.1.6 Team

Project coordinator: Jorge Gomes

Name	Status	FTE %
Carlos Manuel	Technician (LIP)	100
Gaspar Barreira	Researcher (LIP)	68
Gonçalo Borges	Researcher (LIP)	94
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)	25
Nuno Ribeiro Dias	Researcher (LIP)	100
Pedro Miranda		38

3.1.7 Publications

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

- **Validation of Grid Middleware for the European Grid Infrastructure**
  Mário David, Gonçalo Borges, Jorge Gomes, João Pina et al.
  Journal of Grid Computing, vol 12, 2014 — DOI: 10.1007/s10723-014-9301-z

Institute reports

- **Support for the Portuguese tier-2 in the context of the WLCG MoU 2013 report**
  Jorge Gomes

International Conference Proceedings

- **Exploring Containers for Scientific Computing**
  J.Gomes et al
  J.Gomes et al, Exploring Containers for Scientific Computing, IBERGRID 2014, ISBN: 978-84-9048-246-9, pp 27-38

- **Py4Grid, a user centred tool for the long tail of science**
  G.Borges et al
  G.Borges et al, Py4Grid, a user centred tool for the long tail of science, IBERGRID 2014, ISBN: 978-84-9048-246-9, pp 65-76

Proposals

- **EGI Authentication and Authorization Infrastructure Competence Centre**
  Jorge Gomes, David Groep, Daniel Kouril, David Kelsey, Christos Kanellopoulos, Leif Nixon, Jesus Marco de Lucas

- **EGI-LifeWatch Competence Centre**
  Jesus Marco, Ignacio Blanquer, Jorge Gomes, Gonçalo Borges, et al

- **INDIGO-DATACLOUD INtegrating Distributed data Infrastructures for Global ExplOitation**
  Jorge Gomes, Mario David, Gonçalo Borges and the INDIGO collaboration

- **EGI-ENGAGE**
  Jorge Gomes, Gonçalo Borges and the EGI-ENGAGE collaboration

Books

- **IBERGRID 2014 8th Iberian Grid Infrastructure Conference proceedings**
  Ilidío Oliveira, Jorge Gomes, Isabel Campos, Ignacio Blanquer
  - Ilidío Oliveira, Jorge Gomes, Isabel Campos, Ignacio Blanquer, IBERGRID 2014 8th Iberian Grid Infrastructure Conference proceedings

- **IBERGRID 2014 8th Iberian Grid Infrastructure Conference proceedings**
  Ilidío Oliveira, Jorge Gomes, Isabel Campos, Ignacio Blanquer
  Ilidío Oliveira, Jorge Gomes, Isabel Campos, Ignacio Blanquer, IBERGRID 2014 8th Iberian Grid Infrastructure Conference proceedings, ISBN: 978-84-9048-246-9

Book Chapters

- **Portuguese Roadmap of Research Infrastructures**
  FCT and the Infrastructure Coordinators

3.1.8 Presentations

Presentations in national conferences

- **Computação Distribuída em Nuvem**
  presented by Jorge Gomes
  Jornadas FCCN 2014 — University of Evora.

- **Computing @ LIP-Lisbon**
  presented by Jorge Gomes
  Jornadas do LIP 2014 — Lisbon.

Oral presentations in collaboration meetings

- **CA update IV: LIP CA**
  presented by Nuno Ribeiro Dias
  30th EUGridPMA meeting — Abingdon, Oxfordshire, UK.

- **WP3 kickoff**
  presented by Jorge Gomes
  INDIGO WP3 meeting — .

- **WP3 design**
  presented by Jorge Gomes
  INDIGO WP managers meeting — .

- **Software Management and Pilot services**
  presented by Gonçalo Borges
  DATACLOUD meeting — CERN.

- **News from UMD**
  presented by João Pina
  EGI Operations Management Board — EGI Amsterdam.

Seminars

- **Openstack User Tutorial**
  presented by Mário David
  — FCCN, Lisbon.

3.1.9 Events

- **IBERGRID 2014 8th Iberian Grid Infrastructure Conference**
  Conference, University of Aveiro, 2014-09-08

- **IBERGRID Cloud workshop**
  Workshop, University of Aveiro, 2014-09-10

3.1.10 Project Summary

	number
Articles in international journals (with direct contribution from LIP members)	1
Institute reports	1
International Conference Proceedings	2
Proposals	4
Books	2
Book Chapters	1
Presentations in national conferences	2
Oral presentations in collaboration meetings	5
Seminars	1
Conferences	1
Workshops	1

3.2 Advanced Computing

3.2.1 Resumo

Os membros do grupo de computação avançada têm trabalho anterior em Grid, HPC, modelos de computação, bibliotecas de comunicação de alto desempenho e estruturas de dados distribuídos. Mais recentemente tem desenvolvido R&D na combinação de CPUs multicore tradicionais com dispositivos de aceleração.
O grupo, integrado no LIP-Minho, desde o início de 2014, sem abandonar a investigação em domínios estritamente relacionados com as Ciências e Engenharia da Computação tem vindo a dirigir a sua atividade para áreas mais diretamente relacionadas com os interesses gerais de investigação do LIP. Em particular é de salientar o apoio ao desenvolvimento e otimização de códigos de aplicações, relacionadas com HEP e a pesquisa de estratégias explicitas de distribuição para acesso a grandes volumes de dados, de forma a melhorar a eficiência e os tempos de execução. Uma outra importante dimensão de atividade desenvolve-se em iniciativas de suporte à formação avançada em Computação Científica.

3.2.2 Abstract

Members of advanced computing group have previous work in Grid, HPC computing models, high performance communication libraries and distributed data structures. More recently it has developed R&D on the combination of traditional multicore CPUs with acceleration devices.
The group, part of the LIP-Minho, since the beginning of 2014, without abandoning research in fields close related with the Computer Science and Engineering has been directing its activity to areas more related to the general interests of LIP investigation. In particular is noteworthy support for the development and optimization of code applications related to HEP and the search of explicit distribution strategies for access to large volumes of data in order to improve efficiency and execution times. Another important dimension of activity is support for advanced training in Scientific Computing.

3.2.3 Achievements

In accordance with the planned activities for training and know-how transfer, the group was responsible for the local organization of the 2014 edition of the CERN School of Computing. This summer school has become a highly regarded reference, training physicists, computer scientists and engineers from all over the world in HEP applications.
The event hosted by the University of Minho and LIP at Braga, was a major achievement that we expect to be further expanded with related activities in the following years.
Among the 61 students from laboratories and universities coming from 26 countries, two of them were PhD student´s members LIP-Minho.
In this context, it is also worth noting the responsibility for the creation and coordination of the program in Advanced Training Course in Scientific Computing for High Energy Physics that supported the delivered by the University of Minho of a formal Certificate of 5 ECTS Credit Points (European Credit Transfer System) to the students who succeed in the final examination of the CSC2014 program.
Coinciding with the opening of CSC2014 the group was also responsible for the organization of the celebrations of the 60th anniversary of CERN, in Braga.
The event, which was attended by the director general of CERN, included a photographic exhibition allusive to the 60th anniversary of CERN and the Portuguese involvement.
In terms of scientific activity there is to consider the completion of two-master´s theses related to research in the areas of compression of scientific data and PROOF - The Parallel ROOT Facility.
Regarding publications, we can mention the publication in LNCS, Springer International Publishing, of four scientific articles written in collaboration with other research groups.
Also worthy of consideration, participation in scientific committees of the Conference: ICSC 2014 Workshop on High Performance Computing in Engineering and Science, Guimarães, 2014 and the 7th Iberian Infrastructure For Distributed Computing Conference, Aveiro, Portugal,
In mid-2012 began operating the compute cluster lip.di.uminho.pt that supports an important part of the analysis of the data acquired by the ATLAS experiment at LIP-Minho, since then, installation, configuration and maintenance has been fully supported by advanced computing group.
We may also mention the collaboration in the candidature: Search-ON2: Revitalization of HPC infrastructure of UMinho"(NORTE-07-0162-FEDER-000086) Minho, 2013. The project approved for funding in 2014, by the ON.2, under the NSRF through the European Regional Development Fund represents a significant enhancement of computing power in conventional multicore processors and accelerators search cluster consortium to which the administration infrastructure, including members of the advanced computing group.

3.2.4 Team

Project coordinator: António Pina

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

3.2.5 Publications

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

- **Two high-performance alternatives to ZLIB scientific-data compression**
  S. Almeida, V. Oliveira, A. Pina, M. Melle-Franco
  ICCSA 2014, Part IV, LNCS 8582, pp. 623-638,Springer International Publishing, 2014 — DOI: 10.1007/978-3-319-09147-1_45
- **Removing Inefficiencies from Scientific Code: The Study of the Higgs Boson Couplings to Top Quarks**
  A. Pereira, A. Onofre, A. Proença
  ICCSA 2014, Part IV, LNCS 8582, pp. 576–591, 2014 — DOI: 10.1007/978-3-319-09147-1_42
- **Solving Multilocal Optimization Problems with a Recursive Parallel Search of the Feasible Region**
  A. Pereira, J. Rufino
  ICCSA 2014, LNCS 8580, 2014, pp 154-168, Springer International Publishing, 2014 — DOI: 10.1007/978-3-319-09129-7_12
- **Towards a Comprehensive Evaluation of Ultrasound Speckle Reduction, Image Analysis and Recognition**
  F. Monteiro, J. Rufino, V. Cadavez
  ICIAR 2014, LNCS 8814, pp 141-149, Springer International Publishing, 2014 — DOI: 10.1007/978-3-319-11758-4_16

3.2.6 Academic Training

Master Theses

- **Estudo de viabilidade de paralelização de códigos de análise de dados em PROOF**
  Rafael Silva, 2014-12-18
- **Desempenho de compressores em dados científicos: um estudo comparativo**
  Samuel Almeida, 2014-04-07

3.2.7 Events

- **Curso de Formação Avançada em Computação Científica para Física das Altas Energias**
  Workshop, Escola Ciências e Escola de Engenharia Universade do Minho, 2014-01-01
- **CERN School of Computing 2014**
  Workshop, University of Minho, 2014-08-24
- **60 anos do CERN**
  Outreach Event, Largo do Paço, Universidade do Minho, 2014-01-01

3.2.8 Project Summary

	number
Articles in international journals (with direct contribution from LIP members)	4
Master Theses	2
Workshops	2
Outreach Events	1

Chapter 4

Astroparticle Physics

4.1 Collaboration in AMS - Alpha Magnetic Spectrometer

4.1.1 Resumo

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

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

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

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

4.1.2 Abstract

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

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

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

4.1.3 Objectives

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. AMS´ main goals reflect some the most fundamental quests in contemporary Physics and Astrophysics. Since this is the first scientific experiment dedicated to particle detection outside of Earth´s atmosphere, combining large geometrical acceptance and great exposure time, AMS is a pioneering experiment in approaching all the following scientific topics:

- antimatter searches in the Universe: the AMS detection of anti-helium nuclei, anti-carbon or even heavier nuclei would be undoubtedly a very strong evidence of the existence of antimatter regions somewhere in the Universe. The AMS long stay on the Space Station will allow reaching a high sensitivity level on the antinuclei detection.

- dark matter detection: there are evidences that more than 90% of Universe matter is non-luminous - dark matter. Its composition remains a mystery. The AMS identification capability of different particles that constitute cosmic rays in particular on the electron and positron detection up to high energies (up to around 1 TeV) allow the eventual anomaly detection on these particle spectra. The AMS collaboration published on April 2013 the first scientific article with the analysis on the positron over electron and positron ratio showing undoubtedly the existence of primary sources of positrons in Earth´s vicinity, not excluding the dark matter hypothesis (see publications list).

- cosmic ray fluxes: the study of cosmic rays origin and composition in order to characterize the interGalactic medium and to get deep knowledge on the secondary fluxes of particles coming from primary cosmic rays interaction with Earth´s atmosphere.

The Portuguese group has been actively taking part in the experiment, and in particular in the RICH activities, since 1997. Following the strong commitment in the RICH detector construction and in the development of data reconstruction tools, the group continued to explore the RICH data as well as monitoring both the detector and reconstruction algorithms performance.
On the other hand, the work developed in the framework of the low energy (GeV) particle identification with RICH is expected to be enlarged to include the RICH signal beyond the aperture angle of the Cerenkov cone and extended over the sodium fluoride (NaF) region.
A previous work on the numerical solution of the solar modulation equation was done in the group hence the Portuguese collaboration intends to focus its efforts on the study of proton, helium and electron fluxes at low energies (up to 100 GeV) and on the time variance study. Light Isotopic separation is also aimed to be done and the viability of a light isotopic separation method using the geomagnetic cut-off has being explored.

4.1.4 Achievements

The main tasks where the group was involved in 2014 were the following:

Participation in the AMS detector monitoring (shifts)
The mission´s POCC (Payload Operations and Control Center) operations are headquartered at CERN since June 2011, another dedicated facility (CNA) also operates in Tawain for the GMT night shift. During the last year, all assigned shifts to the LIP group (10 days every 2 months) were performed together with the on-call position for the RICH, TOF and ECAL subdetectors. 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.

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. In addition, photomultiplier gain drifts and temperature gain variations had to be monitored and some effects were corrected. The quality of RICH measurements is fundamental for the AMS physics program success. A velocity resolution of $1.2\times10\hat{}$-3 was obtained for single-charged particles with $\beta\approx1$ crossing aerogel and $4.5\times10\hat{}$-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).

Solar Modulation Studies
The AMS launch took place during a minimum of solar activity (beginning of 24th cycle) and now we have approched a maximum of activity. Phenomenological studies on cosmic-ray propagation were explored as well. Since there is no full analytical solution to the Parker Equation several different approaches have been tried, from numerical solutions to analytical approximations. Different ways of solving the transport equation were studied and numerical methods (2D) were explored. Solar modulation affects the low energy region of the cosmic-ray (CR) spectrum (<2 GeV). A MSc thesis on this topic was succesfully completed and presented to Instituto Superior Técnico in November 2014.

Light isotopic separation

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

Statistical estimator for mass separation: Electron-proton separation tool
A preliminary likelihood estimator for mass sepation was developed at LIP and is being improved: it is based on the definition of velocity and RICH signal probability density functions (PDFs) for every particle kind and for every event with a given rigidity measured by the Silicon Tracker. The measured velocity and RICH signal of every event can therefore be used to estimate the probability defining the degree of compatibility of the measurement with what is expected for every particle type (e+/e-, protons, He,...). It was successfully apllied to electron/proton separation in the low energy regime (<10 GeV) for positron ratio measurement (results published April 2013) and it is foreseen to be applied to other mass separation issues in other physical analysis with the advantage of performing a large acceptance selection.

4.1.5 Sources of Funding

Code	Funding	Start	End
PTDC/FIS/122567/2010	40.000 €	2011-12-07	2014-11-30

4.1.6 Team

Project coordinator: Fernando Barão

Name	**Status**	**FTE %**
Bruno Santos	Master student (LIP)	92
Fernando Barão	Researcher (LIP/IST)	85
Luisa Arruda	Post-Doc (LIP/FCT)	53
Miguel Orcinha	Student (LIP)	100
Pedro Nunes	Master student (LIP)	100
Rui Faísca Pereira		92

4.1.7 Publications

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

- **High Statistics Measurement of the Positron Fraction in Primary Cosmic Rays of 0.5-500 GeV with the Alpha Magnetic Spectrometer on the International Space Station**
  AMS Collaboration (300 authors)
  Phys. Rev. Lett. 113 (2014) 121101 — DOI: 10.1103/PhysRevLett.113.121101

- **Electron and Positron Fluxes in Primary Cosmic Rays Measured with the Alpha Magnetic Spectrometer on the International Space Station**
  AMS Collaboration (281 authors)
  Phys. Rev. Lett. 113, 121102 — DOI: 10.1103/PhysRevLett.113.121102

- **Precision Measurement of the ($e^+ + e^-$) Flux in Primary Cosmic Rays from 0.5 GeV to 1 TeV with the Alpha Magnetic Spectrometer on the International Space Station**
  AMS Collaboration (287 authors)
  Phys. Rev. Lett. 113, 221102 — DOI: 10.1103/PhysRevLett.113.221102

4.1.8 Presentations

Oral presentations in international conferences

- **Positron selection with the AMS-02 detector and at low energy with RICH**
  presented by Luisa Arruda
  New Worlds in Particle, Astroparticle and Cosmology — Braga.

Presentations in national conferences

- **Status and results of the AMS-02 experiment**
  presented by Luisa Arruda
  Jornadas científicas LIP — Pavilhão do Conhecimento, Lisboa.

4.1.9 Academic Training

Master Theses

- **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)	3
Oral presentations in international conferences	1
Presentations in national conferences	1

4.2 Collaboration in the SNO+ experiment

4.2.1 Resumo

Introdução

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

Atividades do grupo

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

Construção de equipamento de calibração
Em colaboração com a Univ. de Sussex (UK), desenvolvemos um método de calibração não invasivo, baseado em cabos de fibra ótica ligados a um conjunto de LEDs. Para o desenvolvimento e testes das fibras foram utilizadas as instalações do grupo ATLAS no CFNUL. Todas as partes mecânicas relacionadas com as fibras

SNO+ PMT calibration system: installation of optical fibers in the detector by boat. Oct/Nov 2014.

foram construídas nas oficinas do LIP em Coimbra. A instalação do sistema é coordenada pelo nosso grupo e já foi completada a 2/3.
Tomámos também a responsabilidade pelo desenho e construção do sistema de inserção de fontes de calibração em SNO+. É um sistema complexo que requer estanquicidade (para evitar a contaminação do cintilador com radão) e uma mecânica robusta e precisa.

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

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

Aspetos organizativos

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

4.2.2 Abstract

Introduction

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

Group´s activities

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

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

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

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

Organizational aspects

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

4.2.3 Objectives

The goals of our group for 2014 in terms of hardware/detector activities, were the following (adapted from the 2014 plans):

1. Installation of the remaining 2/3 of the fibers of the PMT calibration system, to be done by boat during the filling.

2. Commissioning of the calibration systems with the water data, including both the LED/fibers PMT calibration system, and the laserball. In the latter case, we intend to use it to measure the angular response of the PMTs.

3. DAQ/Data-quality control tests: The LIP group will be responsible for low-level checks of the data-quality such as verifying that events where recorded and built correctly as well as cross-checking the hardware configuration with the run-recorded configuration. These can be performed even with the detector only partially filled.

4. Submission of a publication about the PMT calibration system;

5. Initiate the production of the mechanism for source manipulation (URM) at the mechanical workshops of LIP- Coimbra. Prior to shipping to SNOLAB, mechanical and leak-checking tests will be performed on the complete URM.

In terms of Physics analyses preparation, the focus was on these tasks:

1. Double-beta decay: Background events in the ROI can be removed using event tagging techniques to achieve maximum rejection efficiencies. The LIP group will join the background analysis group with focus on investigating Bi-Po tagging techniques (events coming from the natural U/Th chains).

2. Anti-neutrinos: The group will explore the possible directional information for anti-neutrino analyses, both for studies of reactor anti-neutrino oscillations and geo-neutrinos. The accuracy of direction reconstruction from the separation between the positron annihilation and neutron capture signals, for the SNO+ run conditions or future detectors, will be assessed with simulated data. Isotropic neutron sources will be used to assess the SNO+ sensitivity, but the necessity for a new directional source will be also considered.

4.2.4 Achievements

Most of the proposed goals were reached, and they are listed below. Delays in the water purification and assay systems caused the fill to proceed above the acrylic vessel level only in the summer.

1. During water fill, two more fiber bundles were installed, so now only 1/3 remains.

2. The LED/fiber system was successfully tested during a partial water fill run in December, but no data with the full system or with the laserball diffusor source was possible.

3. DAQ/Data-quality control tests: Activities have started in this area, namely contributing to the DQ of the December partial fill run.

4. A publication about the PMT calibration system was submitted (and now published) by JINST.

5. Production of the mechanism for source manipulation (URM) at the mechanical workshops of LIP- Coimbra has started. One of the modules (for storage and drive of the central support rope) is now built and mechanically tested.

6. Neutrino-less Double-beta decay: Very high efficiencies will be required for the rejection of radioactivity backgrounds using the coincidence tagging and pile-up classification techniques. The group has started to study these, using Monte Carlo simulations, and has developed plans to use the L2 trigger to improve them.

7. Anti-neutrinos: In the framework of an exploratory FCT project, the group started to explore possible directional information for anti-neutrino analyses, both for studies of reactor anti-neutrino oscillations and geo-neutrinos. Work was done in checking and improving the SNO anti-neutrino simulations, leading to the factorization of the most relevant factors contributing to the directional resolution: neutron capture, gamma shower spread, gamma reconstruction.

4.2.5 Sources of Funding

Code	Funding	Start	End
PTDC/FIS/115281/2009	108.971 €	2011-01-01	2014-10-30
IF/00863/2013/CP1172/CT0006	50.000 €	2014-01-01	2018-12-31
EXPL/FIS-NUC/1557/2013	49.485 €	2014-04-01	2015-09-30

4.2.6 Team

Project coordinator: José Maneira

Name	Status	FTE %
Amélia Maio	Researcher (LIP/FCUL)	26
Carlos Silva	Technician (LIP)	12
Gersende Prior	Researcher (LIP)	100
Joaquim Oliveira	Technician (LIP)	12
José Maneira	Researcher (LIP)	48
Luís Gurriana	Technician (LIP)	12
Luís Seabra	Master (LIP)	33
Nuno Barros	Researcher (LIP)	83
Orlando Cunha	Technician (LIP)	15
Rui Alves	Technician (LIP) *	24
Sofia Andringa	Researcher (LIP)	36

4.2.7 Publications

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 vol. 55 (2014), pp1-7 — DOI: 10.1016/j.astropartphys.2013.12.004

- **The LED and fiber based calibration system for the photomultiplier array of SNO+**
  SNO+ Collaboration (22 authors)
  J.Phys.Conf.Ser. 587 (2015) 012031 — DOI: 10.1088/1742-6596/587/1/012031

International Conference Proceedings

- **Optical Calibration of SNO+.**
  J. Maneira, S. Peeters, J. Sinclair
  Proc. of the Topical Research Meeting: Prospects in Neutrino Physics, December 2013, London, UK (accepted)

- **The LED and fiber based calibration system for the photomultiplier array of SNO+**
  L. Seabra (for the SNO+ Collaboration)
  Proc. of the 16th In. Conf. on Calorimetry for High Energy Physics, April 2014, Giessen, Germany (accepted)

- **Search for Majorana neutrinos with the SNO+ detector at SNOLAB**
  A. Maio (for the SNO+ Collaboration)
  Proc. of the 16th In. Conf. on Calorimetry for High Energy Physics, April 2014, Giessen, Germany (accepted)

- **Combined Analysis of all Three Phases of Solar Neutrino Data from the Sudbury Neutrino Observatory**
  J. Maneira
  Proceedings ICATPP 2011, 360-366 — DOI: 10.1142/9789814405072_0052

4.2.8 Presentations

Oral presentations in international conferences

- **Neutrino Physics: present experiments status and future facilities**
  presented by Gersende Prior
  NWPAC2014 — Braga, Portugal.

- **Searches for Majorana neutrinos with large volume detectors**
  presented by José Maneira
  NWPAC2014 — Braga, Portugal.

- **Water Assay Using Hydrous Titanium Oxide Technique for the SNO+ Experiment**
  presented by Dimpal Chauhan
  Congress of the Canadian Association of Physics — Sudbury, Canada.

Oral presentations in international meetings

- **Neutrino Physics**
  presented by Sofia Andringa
  4th IDPASC School — Braga, Portugal.

4.2.9 Project Summary

	number
Articles in international journals (with indirect contribution from LIP members)	2
International Conference Proceedings	4
Oral presentations in international conferences	3
Oral presentations in international meetings	1

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

4.3.1 Resumo

Em 2014, as actividades do LIP na área da detecção directa de matéria escura estiveram centradas na participação na experiência Large Underground Xenon (LUX) e no projecto LUX-ZEPLIN Dark Matter Experiment (LZ).
LUX utiliza um detector de duas fases (líquida e gasosa) de xénon para detectar Weakly Interacting Massive Particles (WIMPs), partículas que hipoteticamente constituem a matéria escura. No final de 2013, após 3 meses de aquisição de dados, LUX anunciou e publicou os seus primeiros resultados respeitantes à procura da matéria escura que não evidenciaram a deteção de WIMPs dentro dos limites impostos pela sensibilidade do detector. Esses resultados mostraram também que LUX é a experiência em funcionamento com maior sensibilidade para a detecção de WIMPs. Essa sensibilidade tem um máximo para mWIMP=33 GeV/c2, excluindo WIMPs com seção eficaz de interação com nucleões superior a 7.6x10ˆ-46 cm2, que é cerca de 3 vezes maior do que a sensibilidade máxima de qualquer outra experiência em funcionamento (ver fig.1). Para baixos valores de mWIMP, esse factor passa para cerca de 20 e os resultados de LUX não concordam com os de outras experiências que sugerem terem observado WIMPs a baixas massas.
Para além da sua elevada sensibilidade e do seu consequente potencial para detectar WIMPs, LUX serviu também de "balão-de-ensaio"de tecnologias necessárias à próxima geração de detectores de WIMPs: 1) Utilização de fotomultiplicadores maiores e com menor radioatividade; 2) Um sistema criogénico que utiliza termosifões que permite arrefecer o detector de forma compacta e muito eficiente; 3) crióstato e detector em titânio de baixa radioatividade; 4) imersão do crióstato num tanque de água ultra-pura, equipado com fotomultipli-

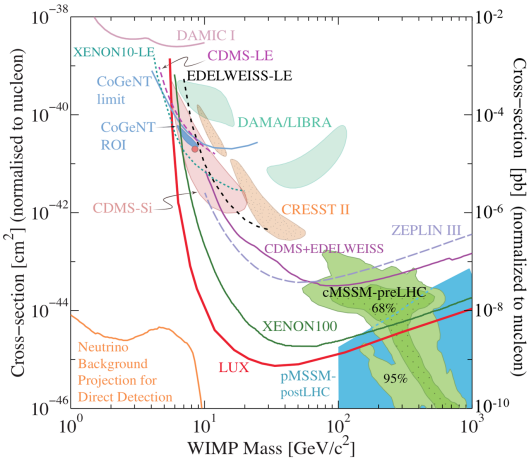


Fig.1 - A compilation of current WIMP- nucleon SI cross- section upper limits at 90% confidence level (solid and dashed curves, labeled by experiment names), and hints for WIMP signals (pale shaded closed contours, labeled by experiment names). The recent CDMSlite result is labeled CDMS- LE. Regions favored by supersymmetric models are the bold closed curves at the lower right. From Ref. [4]

cadores, em vez das blindagens de chumbo e de polietileno habitualmente utilizadas; 5) Fontes de calibração gasosas (Kr-83m e H-3) introduzidas diretamente no xénon.
A Colaboração LUX é constituída por 18 instituições de 3 países (EUA, Portugal e UK), num total de cerca de 85 investigadores. O LIP é membro da Colaboração LUX desde Dezembro de 2010.
Em 2014, LUX procedeu a intervenções de engenharia para preparar o detector para a tomada de dados de 300 dias que teve início em Novembro de 2014. Para além das calibrações com fontes de raios-gama internas ao detector e fontes de 242Cf e de AmBe externas, foram realizadas pela primeira vez calibrações com um gerador de neutrões monoenergéticos para fazer a calibração relativamente a recúos nucleares no intervalo de energia utilizado na deteção de matéria escura.
Em 2014, o grupo do LIP foi responsável pelas intervenções efectuadas no sistema de controlo do detector e subsistemas associados (SCD) e no sistema automático de distribuição de azoto líquido, subsistemas que são da sua inteira responsabilidade desde que a experiência foi instalada no laboratório subterrâneo SURF, Lead, USA. Essas intervenções tiveram como objectivo aumentar a flexibilidade e segurança dos sistemas e minimizar a necessidade de intervenção local de pessoal. Outra área de intervenção foi a do algoritmo/software de reconstrução das coordenadas das interações no detector que desde o início é da inteira responsabilidade do LIP. Trata-se do software oficialmente adoptado pela colaboração para a reconstrução dos vértices das interações e é uma peça fundamental da cadeia de análise de dados. Foram desenvolvidos novos módulos para essa ferramenta para vários fins, tais como a reconstrução das coordenadas de interações que depositam muito baixa energia até ao limite daquelas que dão origem a um único electrão livre e a reconstrução de eventos com mais do que um vértice. O grupo do LIP também reforçou muito o seu envolvimento no processamento e análise dos dados. Continuou também a participar regularmente nas operações locais em SURF.
Paralelamente ao envolvimento em LUX, o grupo participou também no projecto LZ que propõe a construção de um detector de 7 toneladas, que utiliza a mesma tecnologia que LUX e a ser instalado também em SURF, Lead, Dakota do Sul. A experiência LZ tirará proveito da infraestrutura existente e de algumas componentes de LUX, como é o caso do tanque de água.
A Colaboração conta com 20 instituições dos EUA, 7 do Reino Unido, 1 da Rússia e o LIP de Portugal, incluindo um total de 158 investigadores e engenheiros. O LIP foi convidado a participar em LZ quando do estabelecimento da colaboração em 2009.
Em 2014, LZ foi selecionada pelo "Department Of Energy (DOE)"dos EUA como uma das três experiências da próxima geração a ser financiada, o que foi um marco importantíssimo para a continuação deste projeto. No Reino Unido, o projecto foi igualmente financiado pela agência financiadora principal, a "Science and Tecnology Facilities Council", STFC.
Durante 2014, a colaboração LZ realizou R&D em vários aspectos de engenharia e concluiu a primeira fase do "Concept Design", tendo completado o CDR1 (Concept Design Report 1 na terminologia do DOE).
Em LZ, o LIP coordenou o grupo de trabalho responsável pela sistema de controlo da experiência que constitui a principal responsabilidade assumida pelo LIP até ao momento. A nível do R&D, tem a seu cargo as medidas de reflectividade do PTFE a utilizar no detector como refletor da luz de cintilação do xénon. Participou também nas simulações do detector. O LIP não assumiu mais responsabilidades em LZ devido ao projeto não estar a receber financiamento da FCT e nada se saber sobre o futuro financiamento.

4.3.2 Abstract

In 2014, the activity of this LIP group was carried out in the framework of the direct detection dark matter experiment "Large Underground Xenon"(LUX) and LUX-ZEPLIN Dark Matter Experiment (LZ).
LUX employs a 350 kg liquid/gas xenon detector to search for Weakly Interacting Massive Particles that may constitute the dark matter. At the end of 2013, after just less three months of data taking, LUX announced and published its first results. They were 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 x10ˆ-46 cm2 at a WIMP mass of 33 GeV/c2 (see fig.1). The results also demonstrate that LUX is the most sensitive dark matter detector in operation with a peak sensitivity at WIMP mass of 33 GeV/c2 three times better than any previous experiment. LUX has a sensitivity that is more than 20 times better than previous experiments for low-mass WIMPs, whose possible detection has been suggested by other experiments and is not supported by LUX results. These first results from LUX have received enormous interest, from astrophysicists to particle physicists, its publication having collected over 630 citations on InspireHEP. In the Nature 2013 review, they were considered as "one of the year´s most important cosmological results".
Apart from its potential of WIMP discovery, LUX was also very important because it introduced technological innovations required to major scale-up to the ton-scale detectors and beyond: 1) Larger, low activity photomultipliers. 2) A cryogenic system using liquid nitrogen thermosyphons that compactly and economically provides high capacity cooling heads. 3) A low-background titanium cryostat. 4) Immersion of the cryostat in an ultra

pure water shield instead of Pb/polyethylene shields more suitable for small experiments. 5) Use of internal calibration sources (Kr-83m and H-3) introduced directly into the liquid xenon.
LUX Collaboration comprises 18 institutions from 3 countries (USA, Portugal and UK) and about 85 researchers. LIP is member of LUX collaboration since December 2010.
In 2014, LUX carried out additional tests and several minor upgrades to prepare the detector for the 300 day run that is expected to boost its sensitivity by a factor of 3. Besides the calibrations with internal gamma-sources and with external 252Cf and AmBe neutron sources, the detector was calibrated by the first time with monoenergetic neutrons from a neutron generator.
In 2014, the LIP group was responsible for the upgrades of the slow control and the liquid nitrogen distribution systems aiming to increase their flexibility, safety and to minimize the need of personnel onsite. The vertex reconstruction algorithm was optimized and provided with additional features such as the capability to reconstruct the position of single primary electron events and of multiple scattered events. The group also increased substantially its participation in the data processing and in the data analysis. Finally, LIP has also participated in the LUX operations onsite throughout the year.
In parallel with being deeply involved in LUX, the group participated in the LUX-ZEPLIN (LZ) project. Whatever is the result of the LUX one year run, the WIMP discovery or a much lower exclusion limit, a ton-scale detector has to be built for obtaining better statistics (in the case LUX makes a discovery) or improving the sensitivity up to the ultimate limit of the direct detection of WIMPS by looking for their scattering off the detector nuclei.
The LZ project proposes 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 components from the LUX experiment. LZ aims to discover and to study dark matter in the form of WIMPs, and will improve the current LUX worldleading sensitivity by a factor of ≈300. LZ will reach further and faster in sensitivity than any competing experiment being proposed on a similar timescale, including XENON1T (presently under construction).
The LZ collaboration counts with 20 institutions from USA, 7 from UK, 1 from Russia and LIP from Portugal, including a total of 158 researchers and engineers. We were invited to join LZ since the beginning in 2009.
In 2014, LZ was selected by the DOE as one of only three next generation dark matter experiments to be funded. This is an extremely important milestone for the LZ project. LZ was also funded by the UK main funding agency, the STFC. During 2014, LZ was engaged in the R&D program that had also been funded and it concluded the first stage of its concept design (the CDR1 according to the terminology of DOE).
In LZ, LIP coordinated the Slow Control Subsystem Working Group, which is our main responsibility so far. Regarding the R&D program, LIP is responsible for the measurements of the reflectivity of PTFE immersed in liquid xenon. This material will be used in LZ detector as reflector of the VUV (175 nm) xenon scintillation light and its reflectivity is a key parameter for the performance and ultimate sensitivity of the detector. LIP has also participated in the LZ simulation effort. LIP did not assume more responsibilities in LZ due to the lack of funding during 2014 and because nothing is known about the future funding.

4.3.3 Objectives

In the framework of our participation in LUX, our main goals were:

- To complete the upgrade of the slow control and the liquid nitrogen systems for the long science run and maintain these two systems during the long science run.
- To optimize and add more features to the vertex reconstruction tool.
- To increase the involvement in the processing and data analysis.
- To participate in the LUX upgrade and operations onsite.
- To involve two master students already in the group.

Regarding our participation in LZ, our main objectives were:

- To continue to coordinate and participate in the design of the slow control system for LZ.
- To progress with the measurements of PTFE immersed in liquid xenon and to conclude about the sensitivity of the experimental method that has been used.
- To participate in the LZ simulation effort.

4.3.4 Achievements

- The vertex position reconstruction tool was upgraded and outfitted with new features, among which we highlight the reconstruction of double scatter events, the reconstruction using photon counting, the improvement to the position corrections module (for instance that due to deformation of the electric field lines) and the inclusion of saturated PMTs in the position reconstruction algorithm. Cláudio Silva has been responsible for the vertex position reconstruction tool.

- Coordination by Alexandre Lindote of the group responsible for the analysis of the dark matter search data (this includes, for instance, the definition of thresholds and cuts, determination of their efficiencies and of the fiducial volume, etc).

- Coordination by Alexandre Lindote of the assembly of the new data analysis chain including the updated versions of all data analysis modules (updates developed after the publication of the results of the 3 month run); reprocessing all the data with the new data analysis chain.

- Completion of the upgrade of the slow control and the liquid nitrogen systems for the long science run. Both systems have been running with availability better than 99.5%.

- Completion of the measurements of the reflectivity of PTFE used by LUX immersed in liquid xenon. A reflectivity of PTFE in liquid xenon of 97%(+2%; -10%) was obtained. The measurements were carried out in Coimbra.

- Participation and coordination of the development of the conceptual design of the slow control system for LZ. Vladimir Solovov was chosen as project´s Level 3 manager, responsible for design, material choice and cost estimate for the LZ slow control system. The developed design passed two internal reviews and has been included into the final LZ Conceptual Design document.

- Development of a multi-channel temperature readout system, comprised of a bespoke resistive temperature detector (RTD) readout board and a data concentrator based on inexpensive commercial hardware for LZ slow Control system (part of the R&D program for this system).

- Francisco Neves was Detector Working Group Coordinator from 1/1/2014 to 30/6/2014. In this period there was an intensive activity centred in the detector to prepare it for the long science run.

- Alexandre Lindote was Data Processing Manager from 1/1/2014 to 31/3/2014.

- Vladimir Solovov continued to be Manager of the LZ Slow Control System.

- Isabel Lopes was elected member of LZ Executive Board (Jan 2014 -).

4.3.5 Sources of Funding

Code	Funding	Start	End
CERN/FP/123610/2011	80.000 €	2012-04-01	2014-03-31

4.3.6 Team

Project coordinator: Isabel Lopes

Name	**Status**	**FTE %**
Afonso Bernardino	Master student (LIP)	29
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
Nuno Carolino	Technician (LIP)	25
Paulo Brás	Master student (LIP)	19
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)

- **First Results from the LUX Dark Matter Experiment at the Sanford Underground Research Facility**
  D. S. Akerib et al. (LUX Collaboration)
  Phys. Rev. Lett. 112 (2014) 091303 — DOI: 10.1103/PhysRevLett.112.091303

- **Radiogenic and muon-induced backgrounds in the LUX dark matter detector**
  D.S. Akerib et al.
  Astroparticle Physics, 62 (2015) 33-46 — DOI: 10.1016/j.astropartphys.2014.07.009

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

- **LUX Cryogenics and Circulation**
  A. Bradley et al. (67 authors)
  Phys.Procedia 37 (2012) 1122-1130 — DOI: 10.1016/j.phpro.2012.03.734

International Conference Proceedings

- **Results from the first underground run of the LUX experiment**
  C. Silva (for the LUX Collaboration)
  Proceedings, 49th Rencontres de Moriond on Electroweak Interactions and Unified Theories : La Thuile, Italy, March 15-22, 2014, Conference: C14-03-15.1, p.195-198 (accepted)

Internal Notes

- **Study of the evolution of the reconstruction with time**
  Claudio Silva

- **Calibration of the PMTS Arrays**
  Claudio Silva

- **Final analysis of the WS data from Run03 using DP2.0**
  Alex Lindote, Claudio Silva

- **Photon Counting in LUX**
  Cláudio Silva

- **S2 threshold and Fiducial Volume definition for the Run03 reanalysis**
  Alex Lindote, Claudio Silva

- **Position Correction**
  Claudio Silva

- **Position Correction (New Version)**
  Cláudio Silva

- **Upgrade to the Fast Sim in LUX**
  Cláudio Silva

- **Extending the Run 3 WS dataset**
  Alex Lindote, Paul Terman

- **S2 bottom only versus S2 total**
  Cláudio Silva

- **Analysis of the Po-210 for the Run III reanalysis**
  Cláudio Silva and Alexandre Lindote

- **Assessment of the Fiducial Volume for the Run IV**
  Claudio Silva, Adam Bailey

4.3.8 Presentations

Oral presentations in international meetings

- **Results from the first underground run of the LUX experiment**
  presented by Cláudio Silva
  Rencontres de Moriond: EW Interactions and Unified Theories, 2014 — La Thuile, Italy, March 15th - 22nd, 2014.

- **Large Underground Xenon (LUX) dark matter experiment**
  presented by Isabel Lopes
  2014 Shanghai Particle Physics and Cosmology Symposium, 28-31 May 2014 — Shangai, China.

- **Recent results from the LUX experiment**
  presented by Alexandre Lindote
  Astroparticle Physics 2014: TeVPA/IDM Conference — Amsterdam, The Netherlands.

- **First Results from LUX Dark matter Experiment**
  presented by Vladimir Solovov
  XXX-th International Workshop on High Energy Physics "Particle and Astroparticle Physics, Gravitation and Cosmology: Predictions, Observations and New Projects-– IHEP, Protvino, Russia.

Oral presentations in collaboration meetings

- **LUX Slow control**
  presented by Vladimir Solovov
  — University of Maryland, USA.

- **Measuring PTFE reflectivity in LXe (status update)**
  presented by Vladimir Solovov
  LUX-ZEPLIN Collaboration Meeting — University of Maryland, USA.

- **Hardware changes for Run 4**
  presented by Francisco Neves
  LUX Collaboration Meeting — SURF, Lead, USA.

- **S2 and vertex position reconstruction.**
  presented by Cláudio Silva
  LUX Collaboration Meeting — SURF, Lead, USA.

- **Leakage for 1kph events**
  presented by Vladimir Solovov
  LZ Collaboration Meeting — Edinburgh, UK.

- **PTFE Characterization**
  presented by Isabel Lopes
  LZ Collaboration Workshop — MEPHI, Moscow, Russia.

- **Position Reconstruction**
  presented by Vladimir Solovov
  LZ Collaboration Workshop — MEPHI, Moscow, Russia.

Seminars

- **First Dark Matter Search Results from the LUX Detector**
  presented by Cláudio Silva
  — Centre de Physique des Particules de Marseille (CPPM), France.

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, 2014-09-30

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

4.3.10 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
Internal Notes	12
Oral presentations in international meetings	4
Oral presentations in collaboration meetings	7
Seminars	1
Master Theses	1

4.4 High Energy Cosmic Rays

4.4.1 Resumo

O Observatório Pierre Auger foi construído com o objetivo de dar um contributo essencial no estudo de Raios Cósmicos de muito alta energia, na compreensão da sua origem e natureza e também para estudar as interações das partículas a essas altas energias. Atualmente, a colaboração é constituída por cerca de 500 físicos de mais de 90 instituições em 16 países. O Observatório, situado na Argentina, iniciou a sua tomada de dados em 2004 e a sua construção foi finalizada em 2008. É um detetor híbrido que combina um array de detetores de superfície (SD) com telescópios de fluorescência (FD) que observam a atmosfera por cima do array. O SD cobre uma área efetiva de 3000 km^2 com tanques de água de efeito Cherenkov. Entre 2008 e 2014, a Colaboração publicou 50 artigos que tiveram mais de 5800 citações, incluindo 6 artigos classificados entre os mais citados nas revistas Physics Review Letters, Astroparticle Physics Journal e Nuclear Instruments and Methods.

Os dados adquiridos por Auger contribuíram para importantes descobertas na física de raios cósmicos de energias extremas. A supressão no fluxo de raios cósmicos para energias superiores a 5,5x10^19 eV foi inequivocamente estabelecida e foram encontradas evidências de anisotropia na distribuição das direções de chegada das partículas com energias mais elevadas. A natureza (composição) dos raios cósmicos de muito alta energia foi estimada e é interpretada usualmente como uma transição inesperada de elementos leves a pesados para energias superiores a 3x10^18 eV. No entanto, os resultados são igualmente compatíveis com misturas de diferentes tipos de primários bem como com uma mudança drástica da física das interações hadrónicas a muito altas energias. A secção eficaz protão-ar a uma energia no centro de massa de 57 TeV foi medida. Os fortes limites impostos nas magnitudes do fluxo de fotões e neutrinos permitiram excluir a maioria dos modelos de produção de raios cósmicos a partir da desintegração de partículas super-massivas presentes nas primeiras fases do Universo.

O grupo de raios cósmicos do LIP representa a maior equipa portuguesa envolvida em experiências no domínio da física de astropartículas. O grupo adquiriu uma vasta experiência na pesquisa de raios cósmicos, um conhecimento sólido em física de partículas, e desenvolve uma atividade em I&D particularmente importante na área da deteção de raios cósmicos.

A equipa do LIP é relativamente grande, tanto em número de membros, como em competências. Apesar da maioria da equipa se encontrar em Lisboa, os 3 polos do LIP trabalham em estreita parceria, sendo que equipa de Coimbra é especialista em RPCs e a equipa do Minho está especializada na análise de dados. Finalmente, o grupo de raios cósmicos do LIP possui condições únicas para desempenhar um papel preponderante a nível mundial nas atividades de I&D na área da análise da física de raios cósmicos em Auger. O grupo também atua como uma excelente plataforma de treino académico e de difusão do conhecimento.

4.4.2 Abstract

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

The data taken by Auger have led to a number of breakthroughs in ultra-high energy cosmic ray physics. A suppression of the cosmic ray flux above 5.5x10^19 eV is firmly established, and there are indications for an anisotropic distribution of the arrival direction of the highest energy particles. The cosmic ray composition at very high energies has been addressed and is usually interpreted as an unexpected transition from proton to heavier elements above 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. The proton-air cross-section at a center-of-mass energy of 57 TeV has been measured. Strong limits on photon and neutrino fluxes rule out most models for cosmic ray production from relic particle decay.

The LIP cosmic ray group is the largest Portuguese team in astroparticle physics experiments. The group owns great expertise in cosmic ray research, a solid particle physics background, and is particularly active in R&D in cosmic ray detection.

The LIP team is relatively large both in number of members and in competences. While the bulk of the team is in Lisbon, it relies on a close collaboration between the three LIP poles, with the involvement of the Coimbra RPC team and of the Minho analysis team. In conclusion, the LIP cosmic ray group has unique conditions

to play a world leading role in R&D in cosmic rays physics analysis in Auger. The group is also an excellent platform for academic training and knowledge dissemination.

4.4.3 Objectives

The Portuguese group in Auger has grown steadily. Its role and recognition in the collaboration are consolidated and its activities diversified. The group owns a deep know-how in air shower physics and has a clear and unique view on the possible developments for future detectors. The group is mainly focused on the full exploitation of the particle physics potential of the Observatory, namely in the efforts to understand hadronic interactions at high energies through a window that is largely complementary to the LHC. On the detector development side the group has: strong competences in simulation, in particular GEANT4; RPC development and production facilities at LIP-Coimbra; A fast electronics lab at LIP-Lisbon. The group pursues an ambitious program organized in five main tasks: "Detailed Study of the SD detectors"; "Measurement of the muonic component of Extreme Energy Cosmic Rays showers"; "Measurement of the electromagnetic component of Extreme Energy Cosmic Rays showers"; "Theory and Models for High Energy Interactions"; "Education and Public Outreach in the area of high energy cosmic rays".

4.4.4 Achievements

The LIP cosmic ray group is involved since March 2006 in the Pierre Auger Observatory and its main activities were:

1. The development of a full program of systematic studies on light propagation/collection in the FD crucial for calibrating the energy measurement using laser data and Geant4 simulations;

2. The contribution in the composition vs. hadronic models discussions, publishing innovative methods for the characterization of electromagnetic and muonic shower profiles. One of the team members is presently hadronic physics task leader;

3. The development of a set of tools to search for exotic showers in the Auger data exploring a narrow but unique window to search for physics beyond the standard model;

4. The development of theoretical models that take into account both the Auger and the LHC data and allow to constrain the physics parameters;

5. The development of innovative R&D activities on RPCs able to operate autonomously, outdoors and with low gas flux (MARTA - Muon Array RPC for Tagging Air showers - project). Full scale prototype RPC chambers were produced at LIP-Coimbra and the data acquisition system was developed in LIP-Lisbon. An intense collaboration has been established with Auger teams of Brazil, Czech Republic and Spain. Since few months several RPCs are working at Malargue delivering already important data on the performance of the water tanks to single muons.

4.4.5 Sources of Funding

Code	Funding	Start	End
EPLANET 246806	10.800 €	2011-01-01	2015-12-31
CERN/FP/123611/2011	280.000 €	2012-02-01	2014-04-30
ASPERA/0001/2010	150.000 €	2012-09-01	2015-08-31
RPCs Auger	66.000 €	2014-01-01	2014-12-31

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	Post-Doc (LIP) *	100
Francisco Diogo	PhD student (LIP/FCT)	100
Helmut Wolters	Researcher (LIP/FCTUC)	20
João Espadanal	PhD student (LIP/FCT)	100
Jorge Dias de Deus	Researcher (LIP/IST)	15
José Milhano	Researcher (LIP/IST)	15
Liliana Apolinário	Post-Doc (LIP)	15
Lorenzo Cazon	Researcher (LIP)	98
Luís Lopes	Technician (LIP)	15
Luís Mendes	Student (LIP)	66
Mário Pimenta	Researcher (LIP/IST)	85
Miguel Ferreira	Technician (LIP)	100
Patrícia Gonçalves	Researcher (LIP)	20
Pedro Abreu	Researcher (LIP/IST)	65
Pedro Assis	Post-Doc (LIP/FCT/IST)	85
Pedro Brogueira	Researcher (LIP/IST)	15
Pedro Cardoso	Master student (LIP)	91
Raul Sarmento	Post-Doc (LIP/FCT)	100
Ricardo Jorge Barreira Luz	Master student (LIP)	58
Ruben Conceição	Post-Doc (LIP/FCT)	100
Sofia Andringa	Researcher (LIP)	63
Thomas Schweizer	Researcher (MPP)	15

4.4.7 Publications

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

- **Muons in air showers at the Pierre Auger Observatory: Measurement of atmospheric production depth**
  Pierre Auger Collaboration (487 authors)
  Phys. Rev. D 90 (2014) 012012 — DOI: 10.1103/PhysRevD.90.012012
- **Resistive Plate Chambers for the Pierre Auger array upgrade**
  L. Lopes, P. Assis, A. Blanco, M. A. Cerda, N. Carolino, O. Cunha, M. Ferreira, P. Fonte, L. Mendes, M. Palka, A. Pereira, M. Pimenta and B. Tomé
  Journal of Instrumentation 9 (2014) C10023 — DOI: 10.1088/1748-0221/9/10/C10023
- **Depth of maximum of air-shower profiles at the Auger Observatory. I. Measurements at Energies above 10^17.8 eV**
  The Pierre Auger Collaboration
  Physical Review D 90, 122005 (2014) — DOI: 10.1103/PhysRevD.90.122005
- **Depth of maximum of air-shower profiles at the Pierre Auger Observatory. II. Composition implications**
  Pierre Auger Collaboration (485 authors)
  Phys.Rev. D90 (2014) 122006 — DOI: 10.1103/PhysRevD.90.122006

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

- **Search for patterns by combining cosmic ray energy and arrival directions at the Pierre Auger Observatory**
  The Pierre Auger Collaboration
  Accepted for publication in European Physical Journal C (EPJ C) (accepted)
- **Probing the radio emission from air showers with polarization measurements**
  Pierre Auger Collaboration (496 authors)
  Phys. Rev. D 89 (2014) 052002 — DOI: 10.1103/PhysRevD.89.052002
- **Highlights from the Pierre Auger Observatory**
  Pierre Auger Collaboration (497 authors)
  Braz.J.Phys. 44 (2014) 560-570 — DOI: 10.1007/s13538-014-0218-6
- **A SEARCH FOR POINT SOURCES OF EeV PHOTONS**
  Pierre Auger Collaborat (485 authors)
  Astrophys. J. 789 (2014) 160 — DOI: 10.1088/0004-637X/789/2/160
- **A TARGETED SEARCH FOR POINT SOURCES OF EeV NEUTRONS**
  Pierre Auger Collaboration (484 authors)
  Astrophys. J. Lett. 789 (2014) L34 — DOI: 10.1088/2041-8205/789/2/L34

- **Reconstruction of inclined air showers detected with the pierre Auger Observatory**
  Pierre Auger Collaborat (487 authors)
  J. Cosmol. Astropart. Phys. 8 (2014) 019 — DOI: 10.1088/1475-7516/2014/08/019

- **SEARCHES FOR LARGE-SCALE ANISOTROPY IN THE ARRIVAL DIRECTIONS OF COSMIC RAYS DETECTED ABOVE ENERGY OF 10(19) eV AT THE PIERRE AUGER OBSERVATORY AND THE TELESCOPE ARRAY**
  Pierre Auger Collaboration / Telescope Array Collaboration (607 authors)
  Astrophys. J. 794 (2014) 172 — DOI: 10.1088/0004-637X/794/2/172

- **Origin of atmospheric aerosols at the Pierre Auger Observatory using studies of air mass trajectories in South America**
  Pierre Auger Collaborat (497 authors)
  Atmos. Res. 149 (2014) 120-135 — DOI: 10.1016/j.atmosres.2014.05.021

- **Muons in air showers at the Pierre Auger Observatory: mean number in highly inclined events**
  The Pierre Auger Collaboration
  Physical Review D 91, 032003 (2015) — DOI: 10.1103/PhysRevD.91.032003

International Conference Proceedings

- **Particle physics measurements at the highest energies with the Pierre Auger Observatory**
  S. Andringa
  PoS EPS-HEP2013 (2013) 391

- **Constraints and measurements of hadronic interactions in extensive air showers with the Pierre Auger Observatory**
  L. Cazon
  Proc. if TAUP2013, Phys.Dark Univ. 4 (2014) pp.1-97

Collaboration notes with internal referee

- **Measurement of the shape parameters of FD average profiles**
  S. Andringa, R. Conceição, F. Diogo, M. Pimenta
  GAP2014_004

- **Is it possible to discriminate mass composition scenario from new physics?**
  Ruben Conceição, Mário Pimenta, Raul R. Prado
  GAP2014_069

- **Measurement of the shape parameter of FD average profiles in age**
  S. Andringa, R. Conceicao, F. Diogo, M. Pimenta

4.4.8 Presentations

Oral presentations in international conferences

- **Resistive Plate Chambers for the Pierre Auger array upgrade**
  presented by Luís Lopes
  XII Workshop on Resistive Plate Chambers and Related Detectors,Tsinghua University, 23-28 February 2014 — Beijing, China.

- **Questions and answers on extreme energy cosmic rays: A guide to explore the public data set of the Pierre Auger Observatory**
  presented by Sofia Andringa
  ICHEP 2014 - 37th International Conference on High Energy Physics — Valencia, Spain.

- **Electromagnetic and muonic shower development: breaking degeneracy in mass composition/hadronic models interpretation**
  presented by Francisco Diogo
  International Symposium on Very High Energy Cosmic Ray Interactions, ISVHECRI 2014 — CERN, Geneva, Switzerland.

Oral presentations in international meetings

- **IDPASC- International Doctorate Network in Particle Physics, Astrophysics and Cosmology**
  presented by Mário Pimenta
  New Worlds in Particle and Astroparticle Physics — Universidade do Minho, Braga, Portugal.

- **Extensive Air Shower muons: the key of the UHECR puzzle**
  presented by Lorenzo Cazon
  New Worlds in Particle and Astroparticle Physics — Universidade do Minho, Braga, Portugal.

- **Understanding Ultra High Energy Interactions thr ough the study of Longitudinal Shower Profiles**
  presented by Ruben Conceição
  New Worlds in Particle and Astroparticle Physics — Universidade do Minho, Braga, Portugal.

- **Overview of MARTA – Muon Auger RPC for the Tank Array**
  presented by Catarina Espírito Santo
  New Worlds in Particle and Astroparticle Physics — Universidade do Minho, Braga, Portugal.

- **AUGER: Present results and possible futures**
  presented by Mário Pimenta
  SciNeGHE 2014 - 10th Workshop on Science with the New Generation of High-Energy Gamma-ray experiments — Universidade de Lisboa, Lisboa, Portugal.

- **Discrimination of gamma/proton primaries using the EAS muon content for IACTs**
  presented by Ruben Conceição
  SciNeGHE 2014 - 10th Workshop on Science with the New Generation of High-Energy Gamma-ray experiments — Universidade de Lisboa, Lisboa, Portugal.

- **Ultra high-energy cosmic rays: present and future**
  presented by Catarina Espírito Santo
  From Higgs to Dark Matter 2014 Second Topical Meeting on Consequences of the Higgs Discovery for Dark Matter Searches — Geilo, Norway.

Oral presentations in collaboration meetings

- **General discussion on the muon papers**
  presented by Lorenzo Cazon
  Pierre Auger Collaboration Meeting — Malargüe, Argentina.

- **An update of the measurement of the average longitudinal profiles: systematic studies**
  presented by Francisco Diogo
  Pierre Auger Collaboration Meeting — Malargüe, Argentina.

- **Update on the MPD time-domain fit**
  presented by Eva Santos
  Pierre Auger Collaboration Meeting — Malargüe, Argentina.

- **Systematics on the determination of the FD profile shape**
  presented by Francisco Diogo
  Pierre Auger Collaboration Meeting — Malargüe, Argentina.

- **Requests from MARTA for 2 more installations**
  presented by Mário Pimenta
  Pierre Auger Collaboration Meeting — Malargüe, Argentina.

- **Status of MARTA**
  presented by Pedro Assis
  Pierre Auger Collaboration Meeting — Malargüe, Argentina.

- **MARTA Physics**
  presented by Sofia Andringa
  Pierre Auger Collaboration Meeting — Malargüe, Argentina.

- **First measurement with the RPC telescope at the Gianni Navarra tank**
  presented by Ruben Conceição
  Pierre Auger Collaboration Meeting — Golden, Colorado, USA.

- **MARTA**
  presented by Mário Pimenta
  Pierre Auger Collaboration Meeting — Golden, Colorado, USA.

- **Thoughts on shower physics and hadronic interactions in a B2015 precision (sub)array**
  presented by Lorenzo Cazon
  — Golden, Colorado, USA.

- **Is it possible to discriminate mass composition scenarios from new physics?**
  presented by Ruben Conceição
  Pierre Auger Collaboration Meeting — Golden, Colorado, USA.

- **Update and discussion on the muon measurements comparisons**
  presented by Lorenzo Cazon
  Pierre Auger Collaboration Meeting — Golden, Colorado, USA.

- **MARTA DAQ Setups**
  presented by Pedro Assis
  5th MARTA Progress Meeting — LIP Coimbra.

- **MAROC Board**
  presented by Miguel Ferreira
  5th MARTA Progress Meeting — LIP Coimbra.

- **First tests with the MAROC DAQ**
  presented by Ricardo Jorge Barreira Luz
  5th MARTA Progress Meeting — LIP Coimbra.

- **MARTA, Auger and the UHECR World**
  presented by Mário Pimenta
  5th MARTA Progress Meeting — Biblioteca Nacional, Lisboa.

- **MARTA DAQ Setups @ Malargue**
  presented by Pedro Assis
  5th MARTA Progress Meeting — Biblioteca Nacional, Lisboa, Portugal.

- **Gianni data**
  presented by Raul Sarmento
  5th MARTA Progress Meeting — Biblioteca Nacional, Lisboa, Portugal.

- **Muon energy spectrum from UHECR showers**
  presented by Ruben Conceição
  5th MARTA Progress Meeting — Biblioteca Nacional, Lisboa.

- **Full Shower Reconstruction**
  presented by Sofia Andringa
  5th MARTA Progress Meeting — Biblioteca Nacional, Lisboa, Portugal.

- **Full Shower Reconstruction**
  presented by Lorenzo Cazon
  5th MARTA Progress Meeting — Biblioteca Nacional, Lisboa, Portugal.

- **Mean muon LDFs and Energy resolution with MARTA**
  presented by João Espadanal
  5th MARTA Progress Meeting — Biblioteca Nacional, Lisboa, Portugal.

- **Composition versus new physics scenarios**
  presented by Ruben Conceição
  5th MARTA Progress Meeting — Biblioteca Nacional, Lisboa, Portugal.

- **Shape parameters of FD average profiles**
  presented by Francisco Diogo
  5th MARTA Progress Meeting — Biblioteca Nacional, Lisboa, Portugal.

- **Physics with the High-Precision Array**
  presented by Lorenzo Cazon
  5th MARTA Progress Meeting — Biblioteca Nacional, Lisboa, Portugal.

- **First thoughts on the MARTA Engineering Array**
  presented by Bernardo Tomé
  5th MARTA Progress Meeting — Biblioteca Nacional, Lisboa, Portugal.

- **Data bases for MARTA**
  presented by Helmut Wolters
  5th MARTA Progress Meeting — Biblioteca Nacional, Lisboa, Portugal.

- **Measurements in the Gianni tank with the MARTA RPCs telescope**
  presented by Bernardo Tomé
  Pierre Auger Collaboration Meeting — Malargüe, Argentina.

- **Update on MARTA**
  presented by Mário Pimenta
  Pierre Auger Collaboration Meeting — Malargüe, Argentina.

- **Measurement of the mean longitudinal profile: depth and age**
  presented by Francisco Diogo
  Pierre Auger Collaboration Meeting — Malargüe, Argentina.

Outreach seminars

- **"Esmiuçar as coisas- Partículas e forças elementares**
  presented by Mário Pimenta
  Masterclasses Internacionais em Física de Partículas — IST, Lisboa, Portugal.

- **Os raios cósmicos de energia extrema e o observatório Pierre Auger**
  presented by Catarina Espírito Santo
  — Escola Sá da Bandeira, Santarém.

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

- **SciNeGHE2014 - 10th Workshop on Science with the New Generation of High Energy gamma-ray experiments**
  Workshop, Museu Nacional de Ciência e História Natural da Universidade de Lisboa, 2014-06-04
- **5th MARTA Progress Meeting**
  Collaboration Meeting, Biblioteca Nacional, Lisboa, 2014-09-23

4.4.11 Project Summary

	number
Articles in international journals (with direct contribution from LIP members)	4
Articles in international journals (with indirect contribution from LIP members)	9
International Conference Proceedings	2
Collaboration notes with internal referee	3
Oral presentations in international conferences	3
Oral presentations in international meetings	7
Oral presentations in collaboration meetings	30
Outreach seminars	2
PhD Theses	1
Workshops	1
Collaboration Meetings	1

Chapter 5

Detector development for particle and nuclear physics

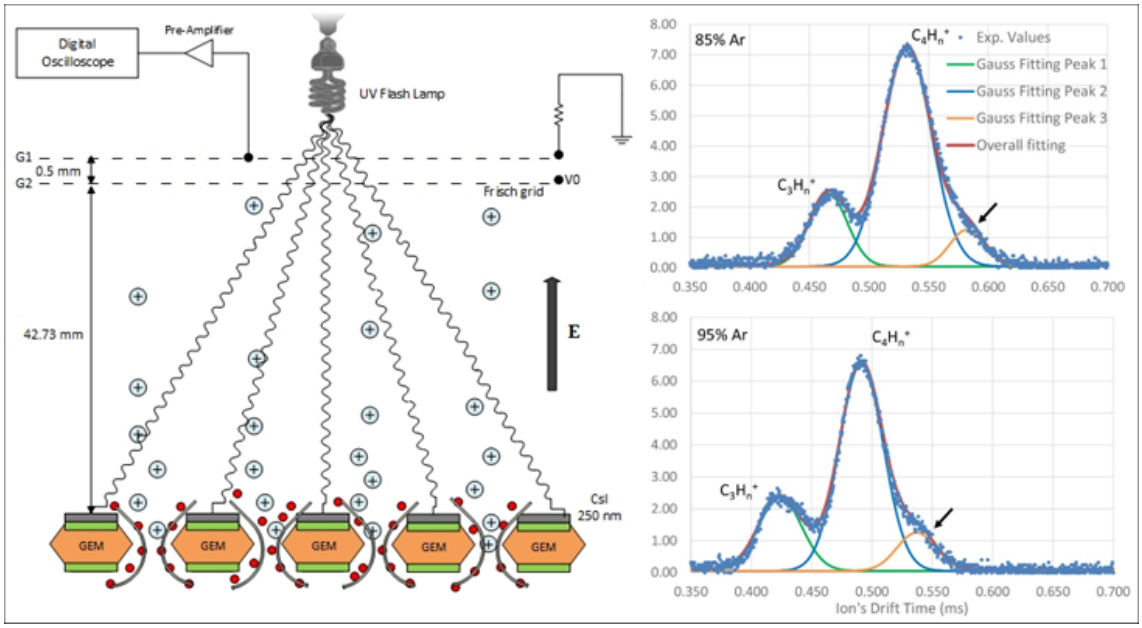
5.1 Participation in the RD51 Collaboration

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



The Ion Mobility Experimental Setup & sample results

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 e de astro-partículas, com e sem aceleradores.
A colaboração RD51 envolve ≈450 autores, 75 Universidades e Laboratórios de 25 países na Europa, América, Ásia e África. Todos os parceiros perseguem activamente quer investigação básica, quer aplicada envolvendo uma variedade de conceitos de MPGD. A colaboração estabeleceu objectivos comuns, tais como ferramentas experimentais e de simulação comuns, métodos e conceitos de caracterização, infra-estruturas comuns em feixes de teste e instalações de irradiação, e métodos e infraestruturas para a produção de MPGD.
[RD51] RD51 proposal (http://rd51-public.web.cern.ch/RD51-Public/Documents/RD51Proposal_21082008.pdf)

5.1.2 Abstract

The RD51 collaboration [RD51] aims at facilitating the development of advanced gas-avalanche detector technologies and associated electronic-readout systems, for applications in basic and applied research. The main objective of the R&D programme is to advance technological development and application of Micropattern Gas Detectors.
The invention of Micro-Pattern Gas Detectors (MPGD), in particular the Gas Electron Multiplier (GEM), the Micro-Mesh Gaseous Structure (MICROMEGAS), and more recently other micro pattern detector schemes, offers the potential to develop new gaseous detectors with unprecedented spatial resolution, high rate capability, large sensitive area, operational stability and radiation hardness. In some applications, requiring very large-area coverage with moderate spatial resolutions, more coarse Macro-patterned detectors, e.g. Thick-GEMs (THGEM) or patterned resistive-plate devices could offer an interesting and economic solution.
The design of the new micro-pattern devices appears suitable for industrial production. In addition, the availability of highly integrated amplification and readout electronics allows for the design of gas-detector systems with channel densities comparable to that of modern silicon detectors. Modern wafer post-processing allows for the integration of gas-amplification structures directly on top of a pixelized readout chip. Thanks to these recent developments, particle detection through the ionization of gas has large fields of application in future particle, nuclear and astro-particle physics experiments with and without accelerators.
The RD51 collaboration involves ≈ 450 authors, 75 Universities and Research Laboratories from 25 countries in Europe, America, Asia and Africa. All partners are already actively pursuing either basic- or application-oriented R&D involving a variety of MPGD concepts. The collaboration established common goals, like experimental and simulation tools, characterization concepts and methods, common infrastructures at test beams and irradiation facilities, and methods and infrastructures for MPGD production.
[RD51] RD51 proposal (http://rd51-public.web.cern.ch/RD51-Public/Documents/RD51Proposal_21082008.pdf)

5.1.3 Objectives

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;
  - (task undefined) Ion mobility measurements (NEW ACTIVITY);
- 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 WG2 we will make the ion mobility measurements, using an experimental system already available [Nev07]. The experimental technique has already provided good results for the ion mobility determination in their parent gases in earlier experiments[Trind14]. We will consider the possibility of upgrading this system to allow a longer drift length and higher pressure. The mixtures to be studied will be Ne, Xe, Ar doped with CO2, CF4, N2 and others considered of interest, for pressures up to 15 Torr and E/N from 5-45 Td.

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, benefiting 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

[Nev07] "A new experimental technique for positive ion drift velocity measurements in noble gases: Results for xenon ions in xenon"P.N.B. Neves, C.A.N. Conde and L.M.N. Tavora, Nuclear Instruments and Methods in Physics Research A 580 (2007) 66-69.

[Trind14]-"Experimental Ion Mobility measurements Ar-CH4 mixtures", A.M.F.Trindade, A.F.V.Cortez, P.N.B.Neves, A.N.C. Garcia, J.M.D.Escada, F.P.Santos, F.I.G.M.Borges, J.A.S.Barata and C.A.N.Conde, 2014 JINST 9 (2014) P06003

5.1.4 Achievements

Owing to a lack of any approved funding from the "projects in collaboration with CERN"program, the animal RPC-PET activities, formally in the framework of WG3-T3, were pursued in the framework of the Rad4Life project, as stated in the plan for 2014.

Paulo Jorge Magalhães Martins successfully obtained a PhD degree from the University of Coimbra with a thesis entitled "Imaging Techniques in RPC-PET", strongly based on work made within this project.

A large area (≈2 m2) TOFtracker device with 3 layers was designed and it is under construction. Preliminary, but full-size, tests suggest position resolutions on the order of 0.3 mm FWHM.

This year a new activity was started, on the transport properties of ions in the avalanche process in MPGDs. Since data of effective ion mobility for mixtures of two and three gases is scarce, in 2014 a presentation of the experimental system used for ion mobility measurement in rare gases and their mixtures was made to RD51 collaboration [Cortez2014]. In the sequence of this presentation, the Collaboration revealed interest in the experimental measurement of ion mobility for some gaseous mixtures and a proposal for a RD51 Common Project was approved on this subject ("Measurement and calculation of ion mobility of some gas mixtures of interest").

Cortez2014 – "Ion Mobility in Ar-CO2", presented at RD51 Collaboration Mini-week, June 2014 (http://indico.cern.ch/event/323839/session/3/contribution/25/material/slides/0.pdf)

Nev07 – "A new experimental technique for positive ion drift velocity measurements in noble gases: Results for xenon ions in xenon"P.N.B. Neves, C.A.N. Conde and L.M.N. Tavora, Nuclear Instruments and Methods in Physics Research A 580 (2007) 66-69.

5.1.5 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)

- **Towards very high resolution RPC-PET for small animals**
  Paulo Martins et al.
  Journal of Instrumentation 9 (2014) C10012 — DOI: 10.1088/1748-0221/9/10/C10012
- **Demonstration of new possibilities of multilayer technology on resistive microstrip/microdot detectors**
  V. Cairo, R. de Oliveira, P. Fonte, S. Franchino, V. Peskov, P. Picchi and F. Pietropaolo
  Journal of Instrumentation 9 (2014) C11022 — DOI: 10.1088/1748-0221/9/11/C11022

5.1.8 Presentations

Oral presentations in international conferences

- **Towards very high resolution RPC-PET for small animals**
  presented by Paulo Fonte
  XII Workshop on Resistive Plate Chambers and Related Detectors,Tsinghua University, 23-28 February 2014 — Beijing, China.
- **Summary talk**
  presented by Paulo Fonte
  XII workshop on Resistive Plate Chambers and Related Detectors (RPC2014), February 23-28, 2014 — Beijing, China.
- **Simulation of discharges in gaseous particle detectors for CERN´s RD51 collaboration**
  presented by Paulo Fonte
  Keynote presentation at Iberian COMSOL Multiphysics Conference 2014, 29/5/2014 — Málaga, Spain.
- **Phénomènes de streaming dans les gaz**
  presented by Paulo Fonte
  Conference Instrumentation days on gaseous detectors, 25-26 juin 2014, IPNO — Orsay, France.

Poster presentations in international conferences

- **Demonstration of new possibilities of multilayer technology on resistive microstrip/microdot detectors**
  presented by Paulo Fonte
  XII Workshop on Resistive Plate Chambers and Related Detectors,Tsinghua University, 23-28 February 2014 — Beijing, China.

Seminars

- **Gaseous detectors and applications**
  presented by Paulo Fonte
  Conference 4th School on High Energy Physics, 30 March 2014 — Cairo, Egypt.

5.1.9 Academic Training

PhD Theses

- **Imaging Techniques in RPC-PET**
  Paulo Martins, 2014-12-11

5.1.10 Project Summary

	number
Articles in international journals (with direct contribution from LIP members)	2
Oral presentations in international conferences	4
Poster presentations in international conferences	1
Seminars	1
PhD Theses	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, foi 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 final desse ano.
A partir daí decorreu a fase da análise dos dados e validação do novo conceito. Comprovou-se uma resolução temporal de 150 ps (com uma precisão algo limitada pelo "jitter"no sinal do neutrão) para energias entre 200 e 1500 MeV
A fase final da análise, até ao encerramento do projecto em 1 de Março de 2014) focou-se 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, was 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 phase of data analysis and validation of the new concept proved a time resolution of 150 ps (somewhat limited by the "jitter"in the neutron signal) for neutrons with energy between 200 and 1500 MeV
The final evaluation of results, accomplished during the remaining part of the project (which officially finished on the 1st March 2014), focussed on the determination of the detection efficiency and on the comparison with previous simulations.

5.2.3 Objectives

The overal plan is explained elsewhere in this report and the goal for the last two months of the project was to achieve the final analysis od the data from the prototype test, which took longer than anticipated in view of some technical issues related to the data taking system of the experiment.

5.2.4 Achievements

Reaching the end of the project we can summarize as follows the results obtained:
- The results of the analysis of the prototype tested prove the excellent performance of the detector for both neutral and charged particles at relativistic energies.
- The innovative concept proposed for detecting relativistic neutrons was successful and can be adopted for future experiments. Indeed, an upper value of 150 ps was determined for the time resolution of the prototype, which is the lowest value ever presented for relativistic neutrons.
- Although our prototype was not optimized for relativistic protons, a time resolution of 80 ps was obtained, in line with the current best RPC-based detectors.
- Overall, the joint work carried out by the LIP-Coimbra RPC team and the team of U. Lisboa showed a great coordination and resulted in a successful alternative approach. This extremely productive atmosphere created between the two teams may well motivate further collaboration in a possible implementation of this kind of detectors in other nuclear physics applications.

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)	15
Carlos Silva	Technician (LIP)	7
Joaquim Oliveira	Technician (LIP)	10
Luís Lopes	Technician (LIP)	15
Nuno Carolino	Technician (LIP)	7
Nuno Filipe Silva Dias	Technician (LIP)	10
Orlando Cunha	Technician (LIP)	7
Paulo Fonte	Researcher (LIP/ISEC)	7
Ricardo Caeiro	Technician (LIP)	7
Rui Alves	Technician (LIP) *	7
Rui Marques	Researcher (LIP/FCTUC)	12

5.2.7 Publications

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

- **Performance of timing Resistive Plate Chambers with protons from 100 MeV to 800 MeV**
  J. Machado, J. Adamczewski-Musch, A. Blanco, R. Ferreira Marques, P. Fonte, A. Henriques, L. Lopes, A. Pereira, et al.
  Journal of Instrumentation 10 (2015) C01043 — DOI: 10.1088/1748-0221/10/01/C01043

5.2.8 Presentations

Oral presentations in international meetings

- **Performance of timing Resistive Plate Chambers with relativistic neutrons from 300 to 1500MeV**
  presented by Alberto Blanco
  XII Workshop on Resistive Plate Chamber and Related Detectors — Beijing.

5.2.9 Project Summary

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

5.3 Neutron detectors

5.3.1 Resumo

A necessidade de detetores de neutrões térmicos para uso em reatores nucleares e fontes de neutrões de espalhamento (Spallation Neutron Sources) bem como para aplicações ligadas à segurança interna e protecção radiológica continua a crescer. O detetor é um componente chave quer nos instrumentos dedicados ao estudo da matéria (por exemplo, em instrumentos de dispersão de neutrões tais como difractómetros, espectrómetros e reflectómetros) quer em sistemas de radiografia e tomografia com neutrões.
Os neutrões como radiação não-ionizante não podem ser detetados diretamente, podendo apenas a sua detecção ser realisada através dos produtos da reação da sua conversão em determinados materiais. Apenas alguns isótopos servem este propósito, como por exemplo: He-3, Li-6, B-10, Gd-157. Dada a escassez mundial de He-3, o seu preço atingiu atualmente valores proibitivos, por outro lado, à taxa atual de utilização as reservas de He-3 nos EUA serão esgotadas até 2024.
Apesar dos esforços na busca de alternativas para o He-3, atualmente não existem ainda detetores com a capacidade de taxa de contagem e resolução espacial, adequadas, para um número significativo de instrumentos, particularmente para as fontes de espalhamento com fluxos mais intensos e portanto são urgentes novos desenvolvimentos tecnológicos.
O B-10 com uma secção eficaz de captura para neutrões térmicos de $\approx$ 3840 barns ($\approx$ 72% da secção transversal de He-3) é uma das alternativas mais promissoras ao isótopo He-3. O B-10 tem uma ocorrência no boro natural de $\approx$ 20%, o qual se apresenta com uma abundância média na Terra. O principal desafio de um detetor para neutrões térmicos baseado num conversor de neutrões sólido, contendo B-10, é superar a diminuta eficiência de deteção de uma única camada de conversor ($\approx$ 5%, o que é significativamente menor que a eficiência alcançada com contadores proporcionais de He-3 e que é de $\approx$ 100%).
Esta limitação pode ser ultrapassada usando uma série de camadas de conversor em cascata, tendo em consideração que a espessura de cada camada deve ser menor que o alcance das partículas He-4 e Li-7, resultantes da reação de captura no B-10. Caso contrário, as partículas He-4 e Li-7 serão travadas dentro do conversor sólido não produzindo ionização no gap de gás, sendo o evento perdido. A fim de maximizar a probabilidade de escape das partículas carregadas (Li-7 e He-4) para o gap de gás, a espessura do conversor sólido deverá ser apenas de alguns microns. Como consequência deste constrangimento é necessário um número considerável de camadas de conversor para obter uma eficiência de deteção aceitável ($\approx$50%).
Este projeto tem como objetivo o desenvolvimento de um novo conceito de detetor para neutrões térmicos, sensível à posição, tendo por base a tecnologia já bem estabelecida das RPCs (Câmaras de Placas Resistivas) como uma potencial alternativa futura aos detetores de He-3. A nossa ideia é usar uma RPC, com os elétrodos revestidos com um filme fino (1-2 microns) de B4C enriquecido em B-10 (conversor de neutrões térmicos).Esta abordagem tira partido da configuração em multi-camada, característica das RPCs e que é indispensável para garantir uma eficiência de deteção elevada. Para além disso, a tecnologia usada nas RPCs possibilita um design modular do detetor e uma boa escalabilidade a custos aceitáveis.
Tanto quanto se saiba, a ideia aqui proposta de usar uma RPC numa configuração em multi-camada, com elétrodos revestidos com um filme fino de B4C, enriquecido em B-10, para detetores de neutrões térmicos sensíveis à posição, não foi ainda considerada por outros autores.
Este projeto de investigação está a ser desenvolvido no âmbito de um projeto exploratório, financiado pela FCT (EXPL/FIS-NUC/2522/2013) e que teve início a 1 de Março de 2014.

5.3.2 Abstract

The need of thermal neutron detectors for use at nuclear reactors and spallation sources as well as for applications related to homeland security and radiological protection continues to grow. The detector is a key component in instruments dedicated to materials research (e.g. neutron scattering instruments) and in neutron radiography and tomography.
Neutrons as a non-ionizing radiation cannot be detected directly; they can only be detected through the reaction products in converter materials. Only a few isotopes can be used for this purpose, e. g.: He-3, Li-6, B-10, Gd-157. Until recently, the isotope most commonly used in position sensitive thermal neutron detectors was He-3. Unique properties of this isotope allowed to design detectors with excellent performance (detection efficiency $\approx$100%, position resolution $\approx$ 0.5 mm FWHM, low sensitivity to gamma radiation). Given the world shortage in H-3, his price is presently attaining a forbidding level, moreover at the current rate of usage the stock of He-3 in the USA will be exhausted by 2024.
Despite the efforts in the search for He-3 alternatives, adequate high spatial resolution, high count rate detectors do not exist today for a significant number of instruments, particularly at the highest flux sources, and the necessary technological developments are urgently needed.

Boron-10 with a thermal neutron capture cross section of ≈3840 barn (≈72% of the cross section for He-3) is one of the most promising alternatives to He-3 isotope. Boron-10 has an occurrence in natural boron of ≈20%, which has an average abundance on earth. The main challenge of a detector based on solid neutron converters, as B-10, is the low thermal neutron detection efficiency for a single layer (maximum detection efficiency ≈5%, which is very low when compared with the ≈100% efficiency of the He-3 counter tubes).
This limitation can be solved by cascading a series of conversion layers, taking into consideration that the layer thickness have to be lower than the range of the Li-7 and He-4 particles originated from the neutron capture reaction in B-10, otherwise they are not able to escape from the solid converter to the gas-gap and the event will be lost. The thickness of the solid converter should be only a few microns in order to maximize the escape probability of the Li-7 and He-4 particles. As a consequence of this constrain a considerable number of layers is required to achieve acceptable detection efficiency (≈50%).
This project aims to develop a new position-sensitive thermal neutron detector concept, based on the well established RPCs (Resistive Plate Chambers) technology as a potential future alternative to He-3 detectors. Our idea is to use resistive electrodes coated with a thin film (1-2 microns) of a B4C solid neutron converter (enriched in B-10) in a multi-gap RPC configuration. This approach takes advantage of the naturally layered configuration of RPCs which is needed to ensure high neutron detection efficiency. Moreover, the RPCs technology allows modular detector design and good scalability at affordable costs.
As far as we know, the idea of a multi-gap RPC configuration proposed here for position sensitive thermal neutron detectors was not yet considered by other authors.
The development of this research project is being held in the framework of an exploratory project funded by FCT (EXPL/FIS-NUC/2522/2013) and which started in March 2014.

5.3.3 Objectives

One of the objectives of this project was to characterize the detection of thermal neutrons with RPCs, both with MC (Monte Carlo) simulations and experimentally. Despite the operation of RPCs is very well studied for the detection of MIPs (Minimum Ionizing Particles), this is not the case for thermal neutron detection where neutron capture in B-10 results in emission of highly ionizing particles (alpha and lithium).
The project contemplated the assembling of a detector prototype and testing with gamma and neutron sources available at our laboratory.
At the next phase, the prototype will be operated in a neutron beam, e.g. at the ILL in Grenoble, which is our partner who is also involved in the search for He-3 alternative in neutron detection.
Fruitful contacts have been established with the Engineering Surfaces Group at University of Coimbra Mechanical Engineering Research Center, where small area B4C coatings (not enriched in B-10) were manufactured.
It was also planned to establish collaboration with the University of Linköping, Sweden, where large area B4C coatings, enriched in B-10, are currently produced for our partners.
The detector assembly was carried out in the LIP-Coimbra, which has all the required facilities.
In the framework of an international collaboration with e.g. ILL, TUM, ESS and ISIS, an EoI for a Joint Research Activity on neutron detectors was prepared during 2014 and was submitted to Horizon 2020, September 2014. LIP integrated this collaboration with a proposal on the B4C coated multi-gap RPCs.

5.3.4 Achievements

We have been working on the deposition of B4C thin films (crucial ingredient to implement the detector concept) by DC magnetron sputtering in close collaboration with Engineering Surfaces Group at University of Coimbra. After an intensive effort we managed to stabilize the adhesion of B4C onto glass substrates (B4C thin films deposited onto glass substrates revealed poor adhesion) by means of an interlayer of Cr. These results were presented as a poster at PSE 2014-14th International Conference on Plasma Surface Engineering, Garmisch-Partenkirchen, Germany.
Two RPCs prototypes were manufactured and assembled in LIP: one RPC with the cathode coated with B4C and the other with uncoated electrodes (to be used as a reference RPC).
Both prototypes were tested with cosmic rays and a Na-22 gamma source. Preliminary tests show that the background and the response of the B4C coated RPC to gammas are similar to those obtained with the reference RPC, showing that an adequate B4C coating can be introduced into a thin-gap RPC without negative effects (increased dark currents, for instance), indicating the basic feasibility of the concept.
We are about to start the first tests with a neutron source of Am/Be. The MC (Monte Carlo) simulation of the detector using GEANT is on the track.
A 64 channels Data Acquisition System (MAROC3 ASIC) has been assembled. The first tests of the DAQ system connected to the signal pick-up electrodes of the RPC were already started.

A successfully collaboration has been established with Dr. Carina Höglund from the Linkoping University, in Sweden. She is currently working on the feasibility of the transferring of her patented technique for the 10B4C coatings production to glass substrates.
LIP integrated an international consortium led by the European (ESFRI) facilities, ILL and ESS, which submitted in September 2014 a proposal to Horizon2020 (SINE2020, world-class Science and Innovation with Neutrons in Europe in 2020, Proposal No.:654000).

5.3.5 Sources of Funding

Code	Funding	Start	End
EXPL/FIS-NUC/2522/2013	31.200 €	2014-03-01	2015-08-31

5.3.6 Team

Project coordinator: Luís Margato

Name	**Status**	**FTE %**
Alberto Blanco	Researcher (LIP)	13
Alessio Mangiarotti	Researcher (USP)	17
Andrey Morozov	Researcher (LIP)	21
Francisco Fraga	Researcher (LIP/FCTUC)	25
Luís Margato	Post-Doc (LIP)	71
Margarida Fraga	Researcher (LIP/FCTUC)	21

5.3.7 Presentations

Poster presentations in international conferences

- **B4C Sputtered Coatings on Resistive Plate Chambers for Neutron Detection**
  presented by Luís Margato
  PSE 2014 - 14th International Conference on Plasma Surface Engineering — Garmisch-Partenkirchen, Germany.

Oral presentations in international meetings

- **10B4C Coated Multigap RPCs for Position Sensitive Neutron Detectors**
  presented by Luís Margato
  PSND 2014 -International Workshop on Position Sensitive Neutron Detectors — Forschungszentrum Jülich, Germany.

5.3.8 Project Summary

	number
Poster presentations in international conferences	1
Oral presentations in international meetings	1

5.4 High Pressure Xenon Doped Mixtures for the NEXT Collaboration

5.4.1 Resumo

Os desafios propostos no âmbito da colaboração NEXT para o nosso grupo, são a escolha de um meio gasoso em que o xénon seja o gás maioritário (já que ele contem também a fonte radioactiva para o decaimento beta duplo) mas que tenha mais baixos coeficientes de difusão e mais elevada velocidade de deriva, sem que, no entanto, a resolução em energia seja comprometida. Vários aditivos foram apontados como candidatos: CF4, CH4, TMA, TEA, etc. Assim durante este ano a equipa que participa na experiência NEXT esteve envolvida nos estudos previstos com as misturas gasosas de xénon. Concretamente foram investigadas misturas de xénon com CH4, CF4 e TMA em percentagens inferiores a 2%. Em particular a TMA é um gás muito difícil de manusear e controlar pelo que constituiu um grande desafio. Os estudos tiveram como objectivo a avaliação da multiplicação de carga (com um contador proporcional) e da electroluminescência (com um detector do tipo contador gasoso de cintilação proporcional) em função da concentração de aditivo e do campo eléctrico reduzido aplicado. Foi ainda medida a mobilidade dos iões produzidos nessas misturas. Em paralelo está a ser desenvolvido uma simulação pelo método de Monte Carlo, usando secções eficazes e informação relativa a processos que poderão ocorrer nas misturas, para entender – e portanto prever, o comportamento destas.
Embora a investigação tenha sido bem sucedida e os resultados coerentes e interessantes, concluiu-se que nenhum destes gases tem as propriedades que se pretendia para a experiência NEXT pelo que a procura vai continuar, possivelmente com TEA. Entretanto foi projectado um sistema para medir a velocidade de deriva (e posteriormente os coeficientes de difusão) das misturas gasosas que está em construção. Outro sistema que foi desenvolvido destina-se a estudar o comportamento das misturas sob a acção do campo eléctrico: é sabido que os gases a alta pressão tendem a sofrer ruptura eléctrica a campos mais baixos que os gases a pressão atmosférica. O sistema que foi projectado destina-se a confirmar esta observação e tentar explicá-la.

5.4.2 Abstract

The challenge for LIP group participating in NEXT was the choice of a xenon based gaseous detection medium that would have lower diffusion coefficients and higher drift velocities than the parent gas, while maintaining the very good energy resolution. Several additives were target (CF4,CH4,TMA,TEA) and the behavior of their mixtures with xenon were the focus of our work during this year. Mixtures of up to 2% of each additive were studied. In particular TMA is a very challenging component and it took some effort to deal correctly with it. The studies were mainly focused on charge multiplication (and were carried out with a proportional ionization counter) and on electroluminescence yield (with a gas proportional scintillation counter) as a function of the additive concentration and of the applied reduced electric field. The mobility of the ions formed in the mixtures was also measured. At the same time a Monte Carlo simulation study is under way. This study uses cross section data, and other information on processes which may occur in the mixtures, available in the literature to understand – and predict, their behavior.
Although the investigation has been successful and results coherent, they were not what was hoped for and none of the additives had the properties needed for the experiment so the quest for the ideal additive is still on, possibly with TEA. Also during this year two systems were projected: one to measure drift velocities (and further on diffusion coefficients) in gases, and another to assess how increasing pressure influences the tendency of a gas to suffer disruption at lower electric fields. They are both being built in the workshop.

5.4.3 Objectives

The objectives were the assessment of the influence of very small concentrations of molecular additives in the charge multiplication and electroluminescence yield of xenon based gaseous mixtures.

5.4.4 Achievements

The objectives proposed were fully accomplished (namely the successful study of the challenging xenon TMA mixtures) although they were not quite what was hoped for. In fact several groups had attempted working with TMA but none could implement a stable functional experimental system where reliable results could be obtained. In our group not only could we develop a stable, reliable, system but also we were able to achieve (and confirm) the very low percentages aimed at (0.025% TMA). TMA didn´t show the properties expected or better hoped for as it absorbs and doesn´t reemit xenon´s scintillation. This being the case the energy resolution in the mixture is worse than in pure xenon, in spite of the higher number of electrons produced.

As a consequence of the success obtained in dealing with TMA the Collaboration has asked the group to experiment with all challenging and unconventional molecular gases target as potential convenient molecular admixtures.

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 indirect contribution from LIP members)

- **Description and commissioning of NEXT-MM prototype: first results from operation in a Xenon-Trimethylamine gas mixture**
  V. Alvarez et al. (84 authors)
  J. Instrum. 9 (2014) P03010 — DOI: 10.1088/1748-0221/9/03/P03010
- **Characterization of a medium size Xe/TMA TPC instrumented with microbulk Micromegas, using low-energy gamma-rays**
  NEXT Collaboration (89 authors)
  J. Instrum. 9 (2014) C04015 — DOI: 10.1088/1748-0221/9/04/C04015
- **Characterisation of NEXT-DEMO using xenon K-alpha X-rays**
  D. Lorca et al. (65 authors)
  J. Instrum. 9 (2014) P10007 — DOI: 10.1088/1748-0221/9/10/P10007

5.4.7 Project Summary

	number
Articles in international journals (with indirect contribution from LIP members)	3

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:
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.
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.
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 CO2 puro e em misturas gasosas do tipo gás nobre/ gás molecular utilizadas em detectores para física das altas energias, nomeadamente Ar/CH4 e Ar/CO2, 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:
Theoretical calculations of low energy ion-atom/molecule elastic scattering cross sections and calculation of ion transport parameters using Monte Carlo techniques.
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.
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 pure CO2 and in gaseous mixtures like noble gas/ organic gas mixtures used in high energy physics detectors, namely Ar/CH4 and Ar/CO2, and whenever possible their identification.

5.5.3 Objectives

This project consists of two main parts:
Theoretical calculations of low energy ion-atom/molecule elastic scattering cross sections and Monte Carlo calculation of ion transport parameters.

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 2014 the following tasks were carried out:
Experimental ion mobility measurements of the ions originated in pure CO2 and in Ar/CO2 mixtures for different values of pressures and reduced electric yields. Data taking, analysis and interpretation.
Publication in the Journal of Instrumentation of the 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.
The experimental study of the mobility of ions originated in argon-carbon dioxide gaseous mixtures (Ar/CO2) for pressures ranging from 6 to 10 Torr and for reduced electric fields in the 10 Td to 25 Td range, at room temperature was performed. The time-of-arrival spectra of the several mixture ratios studied revealed that the relative abundance of the ions and their mobilities depend on the mixture ratio. For Ar concentrations below 80% only one peak was observed in the spectra which was attributed to CO2+ (the ion responsible for this peak is the same ion identified in pure CO2), while for Ar concentrations above 80% a second peak appears at the left side of the main peak, which may be due to impurities. The ion mobility study was performed at reduced electric field values typically used in gaseous detectors. These works led to a paper published in Journal of Instrumentation.

5.5.5 Team

Project coordinator: João Barata

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

5.5.6 Publications

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

- **Experimental study on ion mobility in Ar-CH4 mixtures**
  A. M. F. Trindade, A. F. V. Cortez, P. N. B. Neves, A. N. C. Garcia, J. Escada, F. P. Santos, F. I. G. M. Borges, J. A. S. Barata, C. A. N. Conde
  J. Instrum. 9 (2014) P06003 — DOI: 10.1088/1748-0221/9/06/P06003
- **Experimental ion mobility measurements in Xe-N-2 mixtures**
  A. N. C. Garcia, P. N. B. Neves, A. M. F. Trindade, A. F. V. Cortez, F. P. Santos, C. A. N. Conde
  J. Instrum. 9 (2014) P07008 — DOI: 10.1088/1748-0221/9/07/P07008
- **Experimental ion mobility measurements in Ar-CO2 mixtures**
  P.M.C.C. Encarnacao, A.F.V. Cortez, M.G.A. Pinto, P.N.B. Neves, A.M.F. Trindade, J. Escada, F.P. Santos, F.I.G.M. Borges, J.A.S. Barata and C.A.N. Conde
  JINST 10 P01010 — DOI: 10.1088/1748-0221/10/01/P01010

5.5.7 Project Summary

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

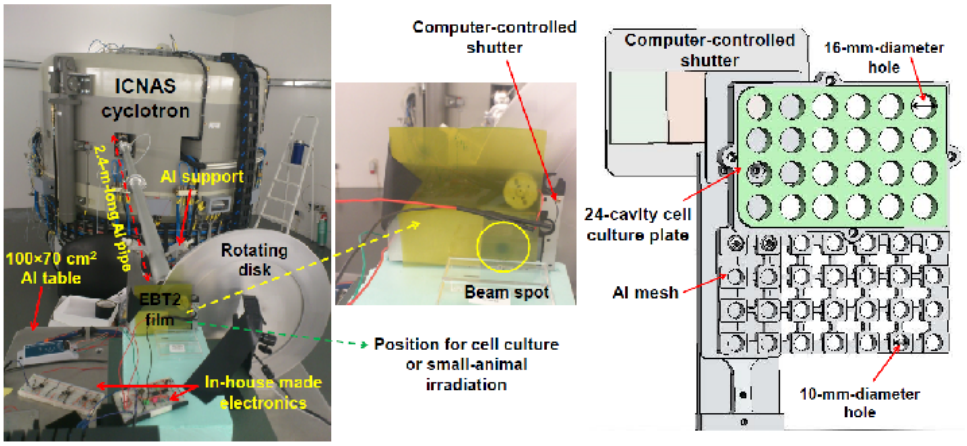
5.6 Beam Monitoring System for Cyclotron Proton Beams at ICNAS

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 objetivos previamente propostos, nomeadamente (1) no desenvolvimento e aplicação de instrumentação para medida do feixe de protões, e (2) na irradiação controlada automaticamente de doses compreeendidas entre as dezenas de Gy e as centenas de mGy. O objetivo último do projeto é providenciar ao utilizador final uma instalação onde se possam efectuar estudos de dosimetria com protões bem como estudos no âmbito da radioterapia com pequenos animais. As doses deverão por isso estar compreendidas entre alguns cGy a vários Gy. Estudos também envisionados no âmbito da radioproteção deverão compreender doses entre algumas centenas até às dezenas de mGy.

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 2014 several developments were accomplished within the aforementioned objectives. We are now able to control a homogeneous beam spot on target with a diameter of 16 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



Installation being assemebled at ICNAS for proton radiobiology and other dosimetric studies.

field applied inside the cyclotron plays a major role for achieving said homogeneity. A scan revealing a quasi-gaussian shape must be performed before any irradiation, with the final shutter closed, so that the optimum magnetic field can be applied hence producing a homogeneous target dose. Inhomogeneity quantification is ongoing, with first results pointing to values inferior to +/- 2%. A setup for cell-culture irradiation has also been constructed. Before first dose-survival curves are obtained a 2D positioning system is being constructed that will allow irradiating automatically cells positioned in a multi well plate.

5.6.3 Objectives

Before first dose-survival curves are obtained a 2D positioning system is being constructed that will allow irradiating automatically cells positioned in a multi well plate (without opening the slow bunker access door).

5.6.4 Achievements

In the past year of 2014 the bulky CAMAC system, together with the GPIB/LAN-100 ethernet converter were substituted by a SUB-20 Multi Interface USB Adapter. This compact and rugged device provides the necessary ground isolation that separates the sensitive current readout electronics from the actuator current driving the mechanical shutter that allows setting the beam on/beam off positions.

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 Academic Training

PhD Theses

- **Development of a PET cyclotron based irradiation setup for proton radiobiology**
  Sharif Ghithan, 2014-12-17

5.6.7 Project Summary

	number
PhD Theses	1

5.7 Detector Lab / Mechanical Workshop

5.7.1 Resumo

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

5.7.2 Abstract

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

Auger RPC unit (left) and Auger testing infrastructure (right)

HADES, AUGER or SNO+). The benefits of the OM and the LD for projects of the national community of R&D, both at local and national level, but also in international collaborations, are equally indisputable.

5.7.3 Objectives

The available equipment and technical staff, allow a variety of services, mainly:

- Mechanical design and production
- Construction and test of detectors
- Design, construction and reparation of electronic circuits.
- Design, construction and reparation of gas and vacuum systems.

5.7.4 Achievements

Detector lab

During 2014, the main activities were the construction and test of **several large** Resistive Plate Chamber detectors (RPCs) for the Auger project together with the High Voltage Power Supply (HVPS), gas and monitoring systems.
Other activities*, in parallel with the daily support to the research groups that deserve to be mentioned are listed here:

- Auger project. Production and testing of 9 RPC units (2 x 1mm gaps RPCs 1.5 x 1.2 m² with 8 x 8 readout plane), 10 HVPS, 10 sensors readout unit + 10 sensors buses . Technical Support in the development of a low power consumption HV PS. Development of an electronic gas bubble counter.
- Construction of one RPC unit (2 x 1 mm gaps RPCs 1.5 x 1.2 m² with 8 x 8 readout plane) + 2 HVPS, + 2 sensors readout unit + 4 sensors buses + low power consumption DAQ for a RPC remote location installation project.
- Development of a monitoring system for solar panels based on I2C sensors.
- Tragaldabas collaboration. Production and testing of two RPC units (2 x 1mm gaps RPCs 1.5 x 1.2 m² with 12 x 10, readout plane) + 2 HVPS, + 2 sensors readout unit + 2 sensors buses.
- Spark Chamber. Production of two new spark chambers and reparation of one chamber for the outreach project.
- Production of a RPC test setup for CSIC (Madrid).
- Small animal RPC-PET. Production of a new FEE structure, FEE timing channels and RPC modules.
- Human RPC-PET. Construction of three planes of Human RPC-PET, (4 x 0.3 mm gaps RPCs, 1.5 x 1.2 m² with strip readout).
- HADES. Test and reparation of the spare FEE, Mother Boards MBs and Low Voltage Power Supplies (LVPS) for the RPC-TOF of the HADES experiment.
- Production of acrylic mask for IPO.
- Reparation of electronic modules / devices, e.g., High Voltage (HV) modules, amplifiers, Analog to Digital Converter (ADC) modules, ...
- Different laboratory presentations to students in the framework of the physics department outreach program.

* Mind that these activities are frequently overlapped with the experimental activities of the projects themselves and are difficult to disentangle from these

Mechanical Workshop activity in 2014

This year the Mechanical Workshop activities were centred in the AUGER, Animal PET and SNO++ projects, while keeping the services for external entities as well.

Requerente	Projecto	nº de ordens
AST	Active Space Tech	1
CNC	CNC	1
DFUC	Diversos	4
DFUC	CEMDRX	3
DFUC	Biofisica	1
Escola D. Maria	F1 in School	1
IPO	IPO - Tratamento mamario	2
ISEC	Fstudent	1
ISICOM	ISICOM	1
ISR	Robos em calha	1
LIP	Auger	13
LIP-C	Petanimal	9
LIP-C	Rad4Life	7
LIP-C	Dual	5
LIP-C	Oficina	5
LIP-C	Spark Chamber	4
LIP-C	Aldeias sustentaveis	2
LIP-C	ITN	2
LIP-C	Ciclotrão	1
LIP-C	Maroc	1
LIP-C	PetHumano	1
LIP-C	Xenon	1
LIP-LX	Atlas	4
LIP-Lx	Detector Cintilador portatil	1
LIP-LX	Ebubble	1
LIP-LX	Peça Aluminio	1
LIP-LX	SNO++	1
Palbit	Palbit	3
UC	IBILI	2
UC	ICNAS	2
UC	DMUC	2

Chapter 6

Instruments and methods for biomedical applications

6.1 Spin-off technologies for Cancer Diagnostics

6.1.1 Resumo

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

6.1.2 Abstract

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

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

6.1.3 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 is being 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. In 2014 the clinical work was affected by the lack of technical support from LIP due to lack of funding.
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.
In 2014 the LIP/STCD group concluded the development of a new PET Detector Module and a SiPM Readout System in close collaboration with the startup company PETsysElectronics:

- The SiPM based PET detector module comprises two Hamamatsu 8x8 MPPC arrays, two 8x8 LYSO arrays with crystals measuring 3.13x3.13x20mm, and one fronted board (FEB/A) with two TOFPET ASICs. The crystals are in one-to one coupling with the MPPC pixels. The external dimensions of each module are 26.04x52.58 mm. The modules can be plugged directly in the motherboard (FEB/D) to form a planar detector unit measuring 105.7x105.7 mm as used in the EndoTOFPET project. The modules can also be arranged in a continuous ring. A demonstrator PET ring with 20 cm diameter in now being assembled.

- The SiPM Readout System comprises three types of readout and data acquisition boards - FEB/A, FEB/D and DAQ boards - which allow to assemble complete scalable data acquisition systems with tens of thousand SiPM channels for Time Of Flight applications. The Front End Board type A (FEB/A) is a low power, low noise SiPM readout board. The Front End Board type D (FEB/D) is a carrier of FEB/A readout boards. Each FEB/D collects data from 16 TOF ASICs (1024 channels) and transmits assembled data frames through an electrical serial link (1.6 Gb/s) or two high-speed optical links (up to 2x 8 Gb/s duplex). The DAQ Board is a PCIe data acquisition board that collects data from several FEB/D boards.

6.1.4 Sources of Funding

Code	Funding	Start	End
Endo TOFPET-US256984	509.400 €	2011-01-01	2015-06-30
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
Leonor Frazão	Master student (LIP)	95
Luis Ferramacho	Researcher (LIP)	34
Manuel Rolo	PhD student (LIP)	80
Miguel Silveira	Researcher (LIP)	34
Ricardo Bugalho	PhD student (LIP)	100
Rui Pereira da Silva	Technician (LIP)	100
Stefaan Tavernier	Researcher (LIP)	50
Tahereh Niknejad	PhD student (LIP)	100
Viesturs Veckalns	PhD student (LIP)	100

6.1.6 Publications

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

- **A free-running, time-based readout method for particle detectors**
  A. Goerres et al. (18 authors)
  J. Instrum. 9 (2014) C03025 — DOI: 10.1088/1748-0221/9/03/C03025

International Conference Proceedings

- **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

- **Performance evaluation of a PET/MR detector based on the ClearPEM technology**
  Jorge A. Neves, Ricardo Bugalho, Catarina Ortigão, Carlos Zorraquino, Rui Silva, José C. Silva, Arthur Magill, Stefaan Tavernier, Rold Gruetter, João Varela
  IEEE/NSS/MIC Conference Records 2014

- **A Compact Detector Module for Time of Flight PET and the Associated DAQ system**
  Ricardo Bugalho, Katayoun Doroud, Agostino Di Francesco, Jorge Neves, Tahereh Niknejad, Catarina Ortigão, Manuel Dionísio Rolo, José C. Silva, Rui Silva, Stefaan Tavernier, Viesturs Veckalns, Carlos Zorraquino, J. Varela
  IEEE/NSS/MIC Conference Records 2014

- **EndoTOFPET-US: a Multi-Modal Endoscope for Ultrasound and Time of Flight PET**
  Joao Varela, on behalf of the EndoTOFPET-US Collaboration
  IEEE/NSS/MIC Conference Records 2014

- **Calibration and Dead Time Correction for a PET Scanner with Variable Geometry**
  Isabel P. Almeida, Nuno C. Ferreira, Catarina Ortigão, Ricardo Bugalho and João Varela
  IEEE/NSS/MIC Conference Records 2014

6.1.7 Presentations

Oral presentations in international conferences

- **Asymmetric Data Acquisition System for an Endoscopic PET-US Detector**
  presented by Carlos Gaston
  19th IEEE Real-Time Conference — Nara, Japan.

- **TOFPET chip, present results and future developments.**
  presented by Agostino di Francesco
  2nd Workshop on Detectors for Forward Physics at LHC — La Biodola, Isola d´Elba, Italy.

- **TOFPET ASIC - status and perspectives**
  presented by Manuel Rolo
  MEDAMI 2014 — Alghero, Italy.

- **Electronics and Data Acquisition in Medical Imaging**
  presented by João Varela
  MEDAMI 2014 — Alghero, Italy.

- **EndoTOFPET-US: a Multi-Modal Endoscope for Ultrasound and Time of Flight PET**
  presented by João Varela
  2014 IEEE Nuclear Science Symposium and Medical Imaging Conference — Seattle, USA.

- **R&D on Time-of-Flight measurements**
  presented by Agostino di Francesco
  Workshop on ``Timing detectors for PPS´´ — CERN.

Poster presentations in international conferences

- **A Compact Detector Module for Time of Flight PET and the Associated DAQ system**
  presented by João Varela
  2014 IEEE Nuclear Science Symposium and Medical Imaging Conference — Seattle, USA.

- **Calibration and Dead Time Correction for a PET Scanner with Variable Geometry**
  presented by Nuno Ferreira
  2014 IEEE Nuclear Science Symposium and Medical Imaging Conference — Seattle, USA.

- **Performance evaluation of a PET/MR detector based on the ClearPEM technology**
  presented by Stefaan Tavernier
  2014 IEEE Nuclear Science Symposium and Medical Imaging Conference — Seattle, USA.

Oral presentations in collaboration meetings

- **Data Acquisition System Overview & Development Status**
  presented by Carlos Gaston
  PicoSEC General Annual Meeting — Lisbon, Portugal.

- **Data Acquisition System Overview & Development Status**
  presented by Carlos Gaston
  EndoTOFPET general meeting — Lisbon, Portugal.

6.1.8 Academic Training

PhD Theses

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

- **Development of advanced data acquisition technologies for PET applications**
  Ricardo Bugalho, 2014-01-10

- **Integrated Circuit Design for Picosecond Timing measurements on Radiation Detectors**
  Manuel Rolo, 2014-03-15

- **Integrated Circuit Design for Time-of-Flight PET**
  Manuel Rolo, 2014-04-14

- **New technologies and algorithms for high-performance local processing of large scale sensor data in high energy and medical physics**
  Viesturs Veckalns, (on-going)

- **Development of a new PET detector for pancreatic and prostate cancer detection**
  Carlos Gaston, (on-going)

- **Development of new high-performance Positron Emission Mammography based on new photosensor technology**
  Tahereh Niknejad, (on-going)

Master Theses

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

6.1.9 Events

- **PicoSEC-MCNet training on electronics and DAQ systems for radiation detectors**
  Workshop, Taguspark, Oeiras, 2014-01-27

- **PicoSEC-MCNet General Annual Meeting**
  Collaboration Meeting, Biblioteca Nacional, Lisboa, 2014-01-29

- **EndoTOFPET-US General Annual Meeting**
  Collaboration Meeting, Biblioteca Nacional, Lisboa, 2014-01-30

6.1.10 Project Summary

	number
Articles in international journals (with indirect contribution from LIP members)	1
International Conference Proceedings	5
Oral presentations in international conferences	6
Poster presentations in international conferences	3
Oral presentations in collaboration meetings	2
PhD Theses	3
Workshops	1
Collaboration Meetings	2

6.2 PET with Resistive Plate Chambers (RPC-PET)

6.2.1 Resumo

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

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

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

6.2.2 Abstract

Aim of the project

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

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

Fundamental idea

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

Innovative approach

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

This work was continued in the framework of the RAD4LIFE project. Please see the corresponding report and plan.
The project team member Jorge Miguel Tavares Couceiro de Sousa was awarded a PhD degree by the University of Coimbra, with a thesis entitled "STUDY OF PET SYSTEMS OF VERY WIDE FIELD OF VIEW".

6.2.5 Team

Project coordinator: Paulo Fonte

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

6.2.6 Publications

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

- **Scatter Fraction, Count Rates, and Noise Equivalent Count Rate of an RPC TOF-PET System: Simulation Study Following the NEMA NU2-2001 Standards**
  Couceiro, M.; Crespo, P. ; Marques, R.F. ; Fonte, P.
  IEEE Trans. Nucl. Sci.61 (2014) 1153-1163 — DOI: 10.1109/TNS.2014.2303654

6.2.7 Presentations

Oral presentations in international conferences

- **RPC-PET: An Unlikely but Promising Approach**
  presented by Miguel Couceiro
  II Symposium on Positron Emission Tomography — Jagiellonian University, Kraków, Poland.

Presentations in national conferences

- **Expected Performance of a Positron Emission Tomography System with Time-of-Flight Information, Based on Resistive Plate Chamber Detectors**
  presented by Miguel Couceiro
  Física 2014 – 19ª Conferência Nacional de Física e 24º Encontro Ibérico para o Ensino da Física — Instituto Superior Técnico, Lisboa, Portugal.
- **A High Resolution Rpc-Pet Prototype for Small Animals**
  presented by Miguel Couceiro
  Física 2014 – 19ª Conferência Nacional de Física e 24º Encontro Ibérico para o Ensino da Física — Instituto Superior Técnico, Lisboa, Portugal.

6.2.8 Academic Training

PhD Theses

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

6.2.9 Project Summary

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

6.3 Detectors and Monte Carlo in Medical Physics

6.3.1 Resumo

Técnicas de diagnóstico do cancro de mama como a mamografia ou a tomossintese, fazem uso de radiação X de potenciais aceleradores na gama de 25 a 36 kV para obterem as imagens digitais do órgão. A monitorização das pacientes é uma necessidade para evitar a sobre-exposição devido a exames repetidos ou a falhas no equipamento. Neste projecto estudámos a dependência em energia e temperatura do cintilador plástico (PVT BC-404 da Saint-Gobain) usado como dosimetro. As medidas experimentais foram realizadas no tomógrafo do Hospital da Luz em Lisboa e em laboratório na Faculdade de Ciências da Universidade de Lisboa.

6.3.2 Abstract

Breast cancer diagnose techniques, such as mammography and tomosynthesis, make use of x-ray beams with kilovoltage peaks ranging from 25 kV to 36 kV to obtain digital images of the organ. Dose monitoring is necessary to avoid patients´ over exposure, due to patient repetitive examination or machine malfunction. In this study, we exploit the energy and temperature dependencies of a polyvinyltoluene plastic scintillator (BC-404 from Saint-Gobain) used as dosimeter. Measurement were performed with a Siemens Mammomat tomograph at Hospital da Luz, Lisbon and in the laboratory of the Faculty of Sciences of the University of Lisbon.

6.3.3 Objectives

A new dosimetry system based on plastic scintillator was developed for the mammographic scans. The system is constituted by a set of small plastic scintillators coupled to optical fibers allowing for a real-time dose measurement simultaneously in several points. The dosimeters have a minimum impact in the image quality due to their size (a few milimeters) and building material (plastic).

6.3.4 Achievements

A plastic scintillator dosimeter (PSD) prototype was build, consisting of a 10 mm-long BC404 plastic scintillator, coupled to a 3 m-long PMMA Mitsubishi SK-80 optical cable, which was read by a R647 Hamamatsu PMT. The PMT was biased by a HV supply based on a Hamamatsu C4900 integrated circuit and build by the collaboration. The PMT signal is read by a charge amplifier, also developed by the collaboration. For the clinical tests a PMMA slice-phantom was build. The phantom allows for the use of Farmer ionizing chambers or the prototype PSD, so that a calibration of the PSD can be made. A slice with aluminum disks simulating lesions was also build.

Clinical testes were performed in Hospital da Luz in Lisbon, using a Siemens Mammomat Tomosynthesis machine. The results show a very good linearity of the PSD response with dose and no-energy dependence for the studied energy-range (26 - 35 kVp) and anode/filtration combination (W/Rh). Monte Carlo simulations of the acquisition setup were made using the PENELOPE code. Agreement with measurements are within 5% for most data points, but simulation results can still be improved with a better X-ray beam description.

PSD prototypes using different scintillating materials are ready to test as well as a different photodetector system using Si-PIN photodiodes.

The task has fulfilled the foreseen schedule for this year.

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	2015-12-31

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)	90
João Antunes		33
Jorge Sampaio	Researcher (CFA/FCUL)	32
Luis Peralta	Researcher (LIP/FCUL)	64
Patrick Sousa	Researcher	20
Pedro Gabriel Almeida	Researcher (UBI)	20
Rui Carvalhal	Graduate student (LIP)	30
Sandra Soares	Researcher (LIP/UBI)	80

6.3.7 Publications

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

- **AlfaMC: A fast alpha particle transport Monte Carlo code**
  Luis Peralta, Alina Louro
  Nucl. Instr. and Meth. in Phys. Res. A, Vol 737 (2014) 163-169, — DOI: 10.1016/j.nima.2013.11.026
- **SCATTER FRACTION WITH SIMULATIONS**
  J. M. Sampaio; M. C. Abreu; P. Sousa; L. Peralta; A. F. Ferreira; S. Rodrigues
  Radiat. Prot. Dosim. 162 (2014) 52-57 — DOI: 10.1093/rpd/ncu217
- **Response of plastic scintillators to low-energy photons**
  Luis Peralta, Florbela Rego
  Phys. Med. Biol. 59 (2014) 4621-4633 — DOI: 10.1088/0031-9155/59/16/4621

Articles in national journals

- **Estaremos a sobrestimar o dimensionamento das barreiras de proteção em mamografia?**
  J. M. Sampaio, Mª. C. Abreu, P. Sousa, L.Peralta, P. E. Lima, A. F. Ferreira, S. Rodrigues, R. Carvalhal
  Acta Radiológica Portuguesa (accepted)

6.3.8 Presentations

Oral presentations in international conferences

- **Determination of gold leaf thickness by realistic Monte Carlo /simulations of an EDXRF spectrometer: application to a renaissance illumination**
  presented by Jorge Sampaio
  Workshop on Monte Carlo simulation tools for X-ray imaging and fluorescence — Grenoble, França, 24-25 de fevereiro, 2014.
- **Determination of gold leaf thickness by realistic Monte Carlo simulations of an EDXRF spectrometer: application to a renaissance illumination**
  presented by Jorge Sampaio
  Workshop on Monte Carlo simulation tools for X-ray imaging and fluorescence — Grenoble, France.
- **Revisiting radiation scatter in x-ray imaging with simulations.**
  presented by Jorge Sampaio
  Radiation and Dosimetry in Various fields of Research (RAD2014) — Nís, Serbia.
- **Revisiting radiation scatter in x-ray imaging with simulations**
  presented by Jorge Sampaio
  Radiation and Dosimetry in Various fields of Research (RAD2014) — Nis, Servia, 27-30 maio.
- **Scatter Fraction with simulations – Revisiting radiation scatter in X-ray Imaging**
  presented by Jorge Sampaio
  RAD2014, May 27-30, 2014 — Nis, Sérvia.
- **Microdosimetric perspective of human lung acinus cancer prevalence**
  presented by Luis Peralta
  GeoRadon´14 — Lisboa 30 e 31 de Outubro, 2014.

Poster presentations in international conferences

- **AlfaMC: A fast alpha particle transport Monte Carlo code**
  presented by Luis Peralta
  GeoRadon´14 — Lisboa 30 e 31 de Outubro, 2014.

Presentations in national conferences

- **Simulação Monte Carlo e análise por fluorescência de raios-X**
  presented by Luis Peralta
  19ª Conferencia Nacional de Física e 24º Encontro Ibérico para o Ensino da Física — Lisboa 2 a 4 de Setembro, 2014.

- **Estudo Da Indução De Danos Provocados Por Partículas Alfa Em Células Do Pulmão**
  presented by Sandra Soares
  19ª Conferencia Nacional de Física e 24º Encontro Ibérico para o Ensino da Física — Lisboa 2 a 4 de Setembro, 2014.

- **Estudo da radiação dispersa e transmitida toráxica com um fantôma antropomórfico realista**
  presented by Jorge Sampaio
  19ª Conferência Nacional de Física e 24º Encontro Ibérico para o Ensino da Física — Lisboa.

- **Contributos da Física na previsão de tumores pulmonares radioinduzidas**
  presented by Alina Louro
  Sessão de Divulgação de Ciências (para alunos de Física do 12º Ano) — Agrupamento de Escolas do Concelho da Mêda.

6.3.9 Academic Training

Master Theses

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

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

6.3.10 Project Summary

	number
Articles in international journals (with direct contribution from LIP members)	3
Articles in national journals	1
Oral presentations in international conferences	6
Poster presentations in international conferences	1
Presentations in national conferences	4

6.4 Orthogonal Ray Imaging for Radiotherapy Improvement

6.4.1 Resumo

Nas sociedades modernas o papel da radioterapia (RT) tem vindo a estebelecer-se como fundamental, verificando-se atualmente que o número de casos tratados por RT tem vindo a aumentar. No entanto, é também sabido que mesmo com as mais modernas técnicas de RT, tanto a taxa de cura efectiva como a toxicidade derivada de tratamentos de RT apresentam ainda margens para melhoria. O LIP, com o intuito de aumentar dentro do possível a eficácia dos tratamentos de RT, tem vindo a trabalhar numa linha de investigação denomindada de imagiologia de raios ortogonais. Esta divide-se fundamentalmente em dois conceitos (ainda não existentes, mas em investigação e desenvolvimento): 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 (CHUC, EPE) e com o Instituto Português de Oncologia do Porto (IPOPFG,EPE). Acrescente-se ainda que vários membros da equipa de investigação do LIP/UC viram a sua participação garantida financeiramente através de bolsas de mestre e de pósdoc atribuídas no âmbito do projecto "Radiation for Life". Este projecto, financiado em 1.2 milhões de Euro, resulta de uma candidatura em parceria entre o LIP e a Universidade de Coimbra. O seu financiamento foi aprovado em 2013 e no verão do mesmo ano tiveram início as suas atividades de investigação. A linha de investigação em imagiologia de raios ortogonais é parte integrante deste projeto.

No que concerne à terapia com partículas (protões e iões de carbono), a imagiologia de raios ortogonais pode também ser denominada de, em Inglês, "prompt gamma imaging". tal advém do fato de os fotões que escapam o paciente terem origem em desexcitações nucleares após a interação entre os projéteis penetrantes e os núcleso no tecido do paciente. Neste contexto o LIP colabora ativamenmte com a Universidade Técnica de Delft, na Holanda, com o Centro de Terapia com Iões de Heidelberg, na Alemanha, e com a Universidade de Munique, também na Alemanha.

6.4.2 Abstract

Radiotherapy (RT) plays a growing, well established role in the management of cancer disease in modern societies. Nevertheless, it is also well known that even with newer, state-of-the-art machinery delivering highly conformal RT, effective cure rates or minimization of toxicity still present today margins for improvement. With the aim of improving further 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 (CHUC, EPE), and with the Oncology Institute of Porto (IPOPFG,EPE). Several expert members are now fully supported with master and postdoc fellowships granted by the Radiation for Life project. This 1.2-million-Euro funded project was proposed within a tight collaboration between LIP and the University of Coimbra. Upon successful approval for funding, the project deployed in the Summer of 2013. One of its research lines is this orthogonal ray imaging initiative.

In the context of particle therapy (protons and carbon ions), orthogonal ray imaging may also be called prompt-gamma imaging since here escaping photons are gamma rays created in excited nuclei during the interactions of the incoming projectiles with the atomic nuclei of the patient. In this context LIP is actively collaborating with the Delft University of Technology, The Netherlands, with the Heidelberg Ion Beam Therapy Center, in Germany, and with the University of Munich, also in Germany.

6.4.3 Objectives

The objectives of the research line on orthogonal ray imaging (RTmonitor and OrthoCT) can be divided mainly twofold, namely in the simulation and experimental fields.
In respect to simulations, a full system was 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 2014 were connected with simulation work.
We have shown by simulation 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 OrthoCT after only a few milligray of dose 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.
We have also optimized by simulation a full OrthoCT system. For that, a multipixel system of detectors oriented in rows was interleaved with lead sheets acting as a sliced collimator. Images of the lung tumor irradiation were utilized to dictate image optimum.

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)	100

6.4.7 Academic Training

PhD Theses

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

6.5 Adaptive methods for medical imaging with gamma cameras

6.5.1 Abstract

The main goal of this project is to apply the know-how acquired during our previous work on position-sensitive detectors to medical gamma cameras in order to develop self-calibrating systems performing statistical image reconstruction and capable of operating in real time. We intended to consider several types of cameras, including the classical ones used in medical practice as well as compact cameras for small animal SPECT. The work was integrated into QREN project Rad4Life (task SPECT).

From the project start, development of the simulation and data processing package for position-sensitive scintillation detectors (PSSD) was a high priority task, as it provided the foundation for the work on all other tasks in the project. In the first phase (covered in the previous report) the simulation module with the emphasis on the medical applications (gamma cameras) and the reconstruction module were developed. Also, several 2D and 3D parametrization options for the light response functions (LRFs) were introduced. At the second phase the ability to perform adaptive reconstruction of the LRFs was added to the reconstruction module. Also, data processing module was developed to take care of importing and processing of the experimental data. All the modules were integrated in a single package which provided data exchange between the modules as well as common graphical environment for interaction with the user and data visualization.

A model of a clinical gamma camera was created and simulated. The iterative PMT response reconstruction was proven to work with simulated data yielding reconstructed response profiles similar to those used in simulation. Due to lower signal to noise ratio, the convergence of LRF reconstruction proved to be more difficult and slower than it was originally expected. For this reason, a set of techniques was developed to facilitate convergence and speed it up. The reconstruction module was augmented with contracting grid search algorithm implemented on a graphical processing unit (GPU) which allowed to reconstruct up to 10^6 events per second on a typical high-end graphic card. With the use of GPU processing the PMT gains can be evaluated from flood field data in less that 5 minutes using a modern consumer-grade computer.

First confirmation of these simulation results was obtained using the 7 PMT Anger camera emulation system, comprised of a PMT array and an isotropic LED light source mounted on a coordinate table. The system was used to emulate flood irradiation with monoenergetic gamma rays and reconstruct the PMT LRFs using the adaptive method. The same LRFs were measured directly as well and the agreement between both LRF sets was confirmed. Additionally, single photoelectron response of the PMTs was measured and its effect on the spatial resolution was found to be in agreement with that predicted by the simulations.

For the experimental part of the project, the 64-channel data acquisition system based on MAROC3 front-end ASIC from LAL-Orsay was used. It features low noise, configurable filters and triggering options permitting simultaneous acquisition of up to 64 channels at rates of up to 3 kHz. We also developed (in the framework of the Rad4Life project) a data acquisition software package specifically tailored for PSSD.

A compact gamma camera prototype featuring 30x30x5 mm LYSO crystal coupled to 8x8 SiPM array, was built and extensively studied with Co-57 and Na-22 sources. Unfortunately, it was found that in this particular case due to (i) multiple light reflections from the crystal surfaces and (ii) strong dependence of the light collection on the depth of interaction inside the crystal, the shape of the LRFs is too complex to be reliably reconstructed using adaptive methods. As the follow-on study, several approaches to solve this problem are being explored including reducing thickness of the crystal and altering reflective properties of the side walls.

Following this setback, the experimental effort was focused on the decommissioned medical gamma camera provided by University of Coimbra and refurbished in order to make it operational. The signal pathways were altered so that the data from the camera could be read out in list mode by the data acquisition system described above. The LRFs were reconstructed by adaptive methods from flood field irradiation by Co-57 source. To verify the validity of the LRF reconstruction, the camera was irradiated with Co-57 source through a lead mask with parallel strip pattern. It was demonstrated that mask image obtained using the adaptively reconstructed LRFs reproduces the original mask image well with only fairly small distortions on the very edge of the field of view. It was also demonstrated that using adaptive techniques the PMT gain variations of single or even multiple PMTs can be rapidly assessed from flat field data.

6.5.2 Objectives

The main goal of this project was to demonstrate that adaptive algorithms for event reconstruction in position sensitive scintillation detectors can be successfully applied to medical imaging devices such as gamma camera and SPECT scanner. These adaptive algorithms, recently developed by the LIP-Coimbra researchers for position sensitive neutron and astroparticle detectors, allowed to achieve good spatial and energy resolution using very fast and simple calibration techniques. Use of these algorithms for event reconstruction in the medical imaging

devices can considerably simplify the calibration process for them as well, and provide the tool for monitoring and compensating for the drift of photomultiplier gains.
The project was comprised of four main tasks:

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

2. Development and optimization of the adaptive position estimation algorithms for gamma cameras. This work was performed on the simulated datasets generated by the above mentioned MC package.

3. Experimental verification of the developed adaptive algorithms by the Anger camera emulation system. The system allows to measure the light response functions of the phototubes directly and compare them with the reconstructed ones.

4. Further experimental verification with two gamma cameras:

   - a decommissioned commercial gamma camera retrofitted with a modern multi-channel acquisition system for list-mode event recording;
   - a compact (30x30 mm) prototype with LYSO crystal and SiPM readout.

Here the main objective was to obtain acceptable phantom image using nothing else than flood field for calibration of the camera.

6.5.3 Achievements

- A software package ANTS2 for Monte Carlo simulation of position sensitive scintillation detectors, integrated with event reconstruction and experimental data processing modules was developed.

- Adaptive algorithms suitable for automatic PMT gain monitoring and position reconstruction of PMT response in medical gamma cameras and SPECT scanners developed and integrated into the ANTS package.

- Scintillation camera emulation setup built and calibrated.

- Light response simulations and adaptive LRF reconstruction reproduced for 7-PMT hexagonal array using the emulation setup.

- A decommissioned commercial gamma camera was refurbished and retrofitted with a modern data acquisition system permitting list mode event acquisition.

- A compact gamma camera with 64-channel SiPM readout was built and tested.

- The applicability of the adaptive techniques to medical imaging was confirmed for the upgraded commercial gamma camera:

  – the image of the lead bar phantom was reconstructed with good fidelity using only flood field data for calibration;

  – the ability to monitor photomultiplier gain drift was demonstrated

6.5.4 Sources of Funding

Code	Funding	Start	End
PTDC/BBB-BMD/2395/2012	48.202 €	2013-05-01	2014-04-30
IF/00378/2013/CP1172/CT001	50.000 €	2014-01-01	2018-12-31

6.5.5 Team

Project coordinator: Vladimir Solovov

Name	Status	FTE %
Alessio Mangiarotti	Researcher (USP)	20
Alexandre Lindote	Post-Doc (LIP)	15
Andrey Morozov	Researcher (LIP)	29
Filipa Balau	PhD student (LIP)	50
Francisco Fraga	Researcher (LIP/FCTUC)	15
Francisco Neves	Post-Doc (LIP)	15
Isabel Lopes	Researcher (LIP/FCTUC)	20
Luís Pereira	PhD student (LIP)	30
Valdemar Domingos	Master (LIP)	100
Vitaly Chepel	Researcher (LIP/FCTUC)	30
Vladimir Solovov	Researcher (LIP)	38

6.5.6 Presentations

Poster presentations in international conferences

- **Position estimation in monolithic scintillation cameras using B-spline parametrization**
  presented by Vladimir Solovov
  PSD10 - 10th International Conference on Position Sensitive Detectors — University of Surrey, Guildford, UK.
- **Fast Calibration of SPECT Detector Response Using Adaptive Iterative Technique**
  presented by Vladimir Solovov
  IEEE NSS-MIC 2014: IEEE Nuclear Science Symposium and Medical Imaging Conference - 2014 — Seattle, WA, USA.

6.5.7 Academic Training

Master Theses

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

6.5.8 Project Summary

	number
Poster presentations in international conferences	2

6.6 Rad for Life

6.6.1 Resumo

RPC-PET

Neste ano houve um forte desenvolvimento no RPC-PET animal, com a implantação do scanner-protótipo no ICNAS (Instituto de Ciências Nucleares Aplicadas à Saúde, Universidade de Coimbra) e a realização duma série de 16 exames de ratos com diferentes radiofármacos (ver figura em anexo). Para além das imagens em si, a resolução parece ser muito bom. Num fantoma em forma de agulha, a observação feita com a gemometria completa (4 cabeças) confirmou a medição anterior de 0,4 mm de resolução FWHM.

O software do sistema foi sendo desenvolvido e progressivamente melhorado, dispondo-se já de um interface gráfico dde utilizador para a reconstrução da imagem (algoritmo OSEM).

No que diz respeito RPC-PET humano, iniciou-se um teste em larga escala do sistema de leitura, embora usando RPCs recicladas de outro projecto e que são inadequadas para PET. Os resultados preliminares sugerem uma resolução de posição transaxial de 0,8 milímetros FWHM, bastante satisfatória para PET humano.

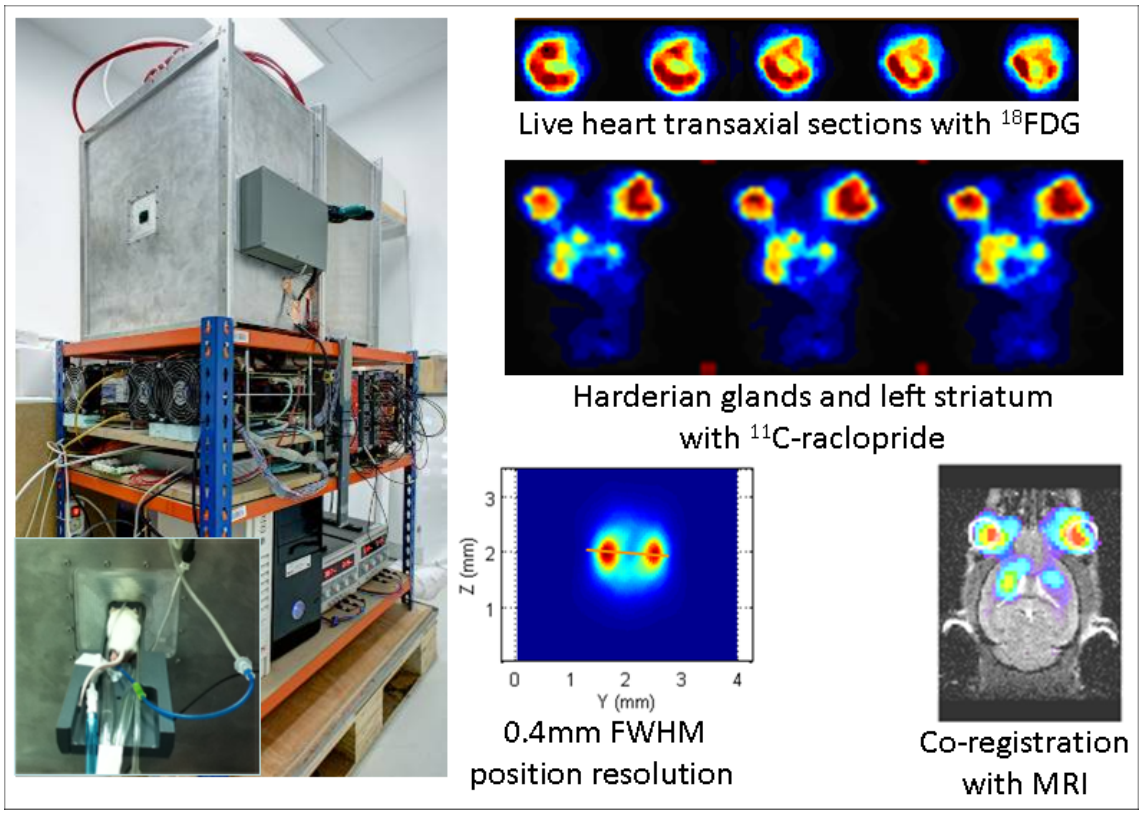
SPECT

Uma câmara gama obsoleta foi remodelada e equipada com um novo sistema de leitura. As funções de resposta à luz (LRF) de cada PMT foram reconstruídos por métodos adaptativos, a partir de irradiação uniforme com uma fonte de Co-57. Obteve-se uma imagem não distorcida duma máscara de chumbo colocada em frente do colimador, comprovando a validade das LRFs reconstruídas e a capacidade de o algoritmo corrigir não uniformidades e não-linearidade (por exemplo, variação de ganho por um factor de dois para alguns PMT). Dois artigos sobre este tema foram já submetidos para publicação .

Como se verificou que as LRFs radiais (utilizadas para câmaras grandes) não são suficientemente precisas para resolver nem problemas resultantes da forma quadrada, nem os resultantes duma razão espessura sobre tamanho do cristal acrescida, está actualmente em desenvolvimento um algoritmo capaz de lidar LRFs mais complexas.

Com recursos de outro projeto (ver Camara Gamma) foi construído um protótipo de uma gama-câmara compacta com leitura por SiPMs e iniciaram-se estudos com Co-57 e Na-22, a fim de clarificar a sua aplicação ao diagnóstico médico.

Dado que os SiPMs correntes não são sensíveis à luz ultravioleta de vácuo do xénon líquido, iniciaram-se trabalhos sobre o seu potencial uso com este cintilador. Os testes focaram-se em conversores de comprimento de onda (TPB, em particular) e sua estabilidade no xénon líquido (por exemplo, a degradação dos filmes em



contacto com a l-Xe foi verificada por várias técnicas de análise de materiais). Está em preparação um artigo sobre este tema.
Foi desenvolvido e integrado no software de processamento de sinal e reconstrução de posiçãoum pacote de Simulação de Monte Carlo de câmaras Anger, a fim de obter uma compreensão mais profunda sobre a natureza das observações experimentais e proporcionar uma forma inicial para as LRFs, a melhorar pelo procedimento iterativo.
Radioterapia
A fim de optimizar a eficácia da radioterapia com feixe externo de fotões (RT), explorámos a possibilidade de utilização de imagiologia de raios ortogonais para, em certa medida, monitorizar a dose administrada ao paciente (RTmonitor), bem como a sua morfologia dentro do campo irradiado (OrthoCT). As simulações e trabalho experimental realizados demonstraram que podem ser detectadas alterações morfológicas e fisiológicas causadores de alterações de dose pertinentes, o que constitui informação importante para ajudar e, potencialmente, melhorar os tratamentos de RT.
No campo RT con fotões, a equipa tem colaborado estreitamente com três hospitais (IPOCFG-EPE e Chuc-EPE, em Coimbra, e IPOPFG-EPE, no Porto). Vários membros da equipa tiveram bolsas de estudo deste projeto, o que permitiu um progresso substancial em diferentes áreas.
No que diz respeito ao desenvolvimento de detectores, a configuração do detector 2D ideal para sistemas OrthoCT é agora conhecido. Além disso, verificou-se que o possível uso de um sistema OrthoCT pode ir para além do seu âmbito de aplicação inicial (monitorização da aplicação de dose), parecendo que a monitorização da dose seja, em certa medida, alcançável.
Um membro da equipa estagiou no IPOPFG-EPE e no Chuc-EPE analisando várias posições de tratamento de pacientes, o que permitiu identificar o posicionamento ideal dum sistema de detecção OrthoCT / RTmonitor.
Os resultados acima referidos foram divulgados em conferências nacionais (Fisica2014 e ENBENG15 - organizado pelo Capítulo Português do IEEE Engineering in Medicine and Biology Society). Estão em fase de preparação artigos para publicação em revistas sujeitas a revisão.
Xe-Alta Pressão
Por se um meio de detecção preferido devido à sua alta eficiência de detecção, o xénon gasoso a alta pressão tornou-se um sério concorrente da fase líquida, uma vez que oferece melhor resolução de energia e permite um manuseamento mais simples.
No entanto, o xénon gasoso apresenta uma velocidade de deriva dos electrões baixa e altos coeficientes de difusão, limitações severas quando se exige rejeição de fundo ou reconstrução de traços. Por isso, têm sido apontados vários aditivos moleculares como soluções possíveis para esses problemas (CH4, CF4, TMA) e o uso destes aditivos nos detectores gasosos de alta pressão tem vondo a ser investigado.
Estes estudos, de longa duração e exigindo pessoal especializado, comuns que são a outras linhas de investigação em que a mesma equipa está envolvida (ver relatório de RD51 e NEXT), aproveitaram bem os recursos humanos disponibilizados pelo projecto. Os parâmetros avaliados incluem rendimento de electroluminescência, multiplicação de carga, "attachment"e recombinação de electrões, resolução em energia e mobilidade de iões na mistura. A TMA, em particular, é um composto pouco conhecido e por isso o estudo que realizámos de todos esses parâmetros, lançou luz sobre algumas das suas propriedades e contribuiu decisivamente para a compreensão do seu comportamento. Os resultados obtidos até o momento constituem material que se espera publicar em breve em pelo menos dois artigos em revistas internacionais

6.6.2 Abstract

RPC-PET
In this year there was a strong development of the animal RPC-PET activity, with deployment of the prototype scanner to ICNAS (Instituto de Ciências Nucleares Aplicadas à Saude, Universidade de Coimbra) and a series of 16 mice examinations using several radiopharmaceuticals. Some representative results can be seen in the attached figure. Besides the mice images, the resolution seems to be extremely good, with measurements with needle phantoms in final (4 heads) geometry confirming the previous measurement of 0.4 mm FWHM resolution. The system software has been continuously developed and strongly improved. A true graphical user interface for image reconstruction (custom OSEM algorithm) is already in use.
In what concerns human RPC-PET, we have started a full-scale test of the readout system, although using RPCs recycled from another project and unsuitable for PET. Preliminary results suggest a transaxial position resolution of 0.8 mm FWHM, which is quite satisfactory for human PET purposes.
SPECT
A decommissioned gamma-camera was refurbished and equipped with a new readout system. The light response functions (LRF) of every PMT were reconstructed by adaptive methods, starting from flood field irradiation by a Co-57 source. An undistorted image of a lead mask in front of the collimator was also obtained, showing

the validity of the reconstructed LRFs and the capability of the algorithm to correct for non-uniformities and non-linearity (e.g., gain variation by a factor of two for some PMTs). Two papers are submitted for publication on this subject.

As it was found that the radial LRFs (used for a full scale gamma-camera) are not sufficiently precise to account for either the square shape or much larger thickness-to-size ratio of the crystal, an algorithm capable of dealing with more complex LRFs in presently being developed.

With resources from another project (see Gamma Cameras) a prototype of a compact gamma-camera with SiPM readout has been built and studies with Co-57 and Na-22 begun, in order to clarify its application to medical diagnosis.

Standard SiPMs are not sensitive to the vacuum ultraviolet light from liquid xenon. Work on their potential use with this scintillator thus focussed on tests of wavelength shifters (TPB, in particular) and their stability in liquid xenon (e.g., degradation of the films in contact with l-Xe has been verified by various material analysis methods). A paper is in preparation.

Monte Carlo simulation of Anger cameras has been developed and integrated into the signal processing and position reconstruction software, in order to gain a deeper insight on the nature of the experimental observations and provide the initial LRF shape for the iteration procedure.

Radiotherapy

For further improving the efficacy of external photon beam radiotherapy (RT) we explore the possible use of orthogonal ray imaging to monitor to some extent the dose delivered to the patient (RTmonitor), as well as its morphology within the irradiated field (OrthoCT). In this way, simulations and experimental work carried out have shown 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, the team collaborated tightly with three different hospitals (IPOCFG-EPE and CHUC-EPE, in Coimbra, and IPOPFG-EPE, at Porto). Several team members had fellowships from the project, which allowed substantial progress in different areas.

In regard to detector development, the optimum 2D detector configuration for OrthoCT systems is now known. In addition, it has been found that the potential use of an OrthoCT system may be extended beyond its original scope of on-board target imaging, since dose monitoring is also, to some extent, within reach.

One team member has been working at IPOPFG-EPE and CHUC-EPE analysing several patient treatment positions, which allowed an optimum location for an OrthoCT/RTmonitor detection system to been identified.

The aforementioned results have been made public in local conferences (Fisica2014 and ENBENG15 - Portuguese Chapter of the IEEE Engineering in Medicine and Biology Society). The corresponding papers in peer reviewed journals are under preparation.

High-Pressure Xe

Being a preferred detection medium because of its high detection efficiency, high pressure xenon has become a serious competitor to the liquid phase as it offers better energy resolution and simpler handling features.

However, gaseous xenon offers low electron drift velocity and high diffusion coefficients which are serious caveats when background rejection or event tracking are required. Several molecular additives have been pointed out has potential solutions to these problems (CH4, CF4, TMA) and the use of these additives in high pressure gaseous detectors has been investigated.

These lengthy and rather specialized studies, common in scope to other lines of research carried out by the same research team (see RD51 and NEXT reports), profited appreciably from the human resources made available. The features addressed include electroluminescence yield, charge multiplication, electron attachment and recombination, energy resolution and the mobility of the ions produced in the mixture. TMA, in particular, is a poorly studied compound and its study, in all the aspects focused, has shed some light to some of its properties and contributed decisively to the understanding of its behavior. Results obtained so far constitute publishing material and will soon be converted into at least two publications in international journals.

6.6.3 Objectives

The human resources made available through this QREN project should contribute to a meaningful increase of activity along the various lines of the project, while permitting to maintain our Coimbra scientific staff during this very difficult period.

Indeed, during this year, Rad4Life supported 33 man.months (m.m) of LIP PhD contracted staff -Alberto Blanco, Francisco Neves, Helmut Wolters and Vladimir Solovov - as well as, under fellowships, 17 m.m of Post Docs (one of them as Invited Scientist, 10 m.m), 65 m.m of MSc and 30 m.m of Undergraduates.

Since contracting Post Docs turned out to be extremely difficult - possibly in view of the relatively short duration of the project, initially foreseen to be finished by the end of June 2015 – the number of MScs and Undergrads

increased significantly, which requested a lot more work of supervision for the senior researchers of the different lines.

6.6.4 Achievements

RPC-PET
- Successful test of the small animal SPC-PET scanner prototype with the final geometry (4 heads) Confirmed the fine reconstructed position resolution of 0.4 mm
- Progress also made in the full scale readout system for the human RPC-PET, already under test on a non-optimized RPC detector.
SPECT
- Validity of the technique developed for obtaining LRFs and the capability of the algorithm to correct for non-uniformities and non-linearity has been established.
- A prototype compact gamma-camera with SiPM readout is under test, in order to clarify its capacity for medical diagnosis.
- Preliminary results on stability of wavelength shifters (TPB) in contact with liquid Xenon
- Development of Monte Carlo simulation of Anger cameras, seeking for both a deeper insight on the nature of the experimental observations, and an initial LRF shape for the iterative procedure.
Radiotherapy
- It has been established that pertinent dose-changing morphological or physiological alterations may be detected through RTmonitor/OrthoCT, thus providing information for assisting and potentially improving RT treatments.
- The optimum 2D detector configuration for OrthoCT systems is now known, and dose monitoring, to some extent, seems within reach.
- The optimum location for an OrthoCT/RTmonitor detection system coupled to current RT gantries has been identified.
High-Pressure Xe
- Studies on TMA/Xe mixtures, have shed light to some of their properties (electroluminescence and charge multiplication yields, electron attachment and recombination, energy resolution and ion mobility) and contributed to the understanding of their behavior.

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 Publications

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

- **Scatter Fraction, Count Rates, and Noise Equivalent Count Rate of an RPC TOF-PET System: Simulation Study Following the NEMA NU2-2001 Standards**
  Couceiro, M.; Crespo, P. ; Marques, R.F. ; Fonte, P.
  IEEE Trans. Nucl. Sci.61 (2014) 1153-1163 — DOI: 10.1109/TNS.2014.2303654

- **Towards very high resolution RPC-PET for small animals**
  Paulo Martins et al.
  Journal of Instrumentation 9 (2014) C10012 — DOI: 10.1088/1748-0221/9/10/C10012

6.6.7 Presentations

Oral presentations in international conferences

- **Towards very high resolution RPC-PET for small animals**
  presented by Paulo Fonte
  XII Workshop on Resistive Plate Chambers and Related Detectors,Tsinghua University, 23-28 February 2014 — Beijing, China.

- **RPC-PET: An Unlikely but Promising Approach**
  presented by Miguel Couceiro
  II Symposium on Positron Emission Tomography — Jagiellonian University, Kraków, Poland.

Presentations in national conferences

- **Expected Performance of a Positron Emission Tomography System with Time-of-Flight Information, Based on Resistive Plate Chamber Detectors**
  presented by Miguel Couceiro
  Física 2014 – 19ª Conferência Nacional de Física e 24º Encontro Ibérico para o Ensino da Física — Instituto Superior Técnico, Lisboa, Portugal.

- **A High Resolution Rpc-Pet Prototype for Small Animals**
  presented by Miguel Couceiro
  Física 2014 – 19ª Conferência Nacional de Física e 24º Encontro Ibérico para o Ensino da Física — Instituto Superior Técnico, Lisboa, Portugal.

6.6.8 Academic Training

PhD Theses

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

- **Imaging Techniques in RPC-PET**
  Paulo Martins, 2014-12-11

6.6.9 Project Summary

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

Chapter 7

Radiation Environment Studies and Applications for Space Missions

7.1 Space Radiation Environment and Effects

7.1.1 Resumo

O grupo do LIP que desenvolve actividades relativas ao estudo do ambiente de radiação no espaço e dos seus efeitos parte de 10 anos de experiência no desenvolvimento de aplicações no âmbito de contratos com a Agência Espacial Europeia e é reconhecido por esta como a referência nacional para a área do estudo do ambiente de radiação no espaço e dos seus efeitos. Este grupo detém competências exclusivas nos seus domínios de actividade, reforçadas pela experiência na utilização da ferramenta de simulação Geant4, que permite simular de forma realista o transporte e interacção da radiação com a matéria, e cuja aplicação ao ambiente de radiação no espaço e aos seus efeitos tem sido uma mais valia para o LIP.
O grupo iniciou 2014 com a perspectiva de ter 3 contratos com a ESA com início previsto durante o primeiro trimestre 2014, o que se veio a verificar. Estes projetos exigiram que a equipa fosse reforçada com pós doutorados e com estudantes de doutoramento e mestrado. Durante 2014 as actividades deste grupo iniciaram uma fase de consolidação e espera-se que o grupo possa expandir as suas actividades nos próximos anos. Os temas de cobertos por esta actividade são:

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

7.1.2 Abstract

The LIP Space Radiation Environment and Effects group has now more than 10 years of expertise in the development of applications dedicated to the Radiation environment in Space in the framework contracts with the European Space Agency and it is recognized by ESA as a Portuguese reference for Space Radiation and

Environment Studies. The group holds unique competences in its activity domains with very strong competences in Geant4 for the simulation of radiation transport and interaction with matter and data analysis, whose application to the radiation environment in space has been strategic for LIP´s activities.
The group had 3 contracts with ESA foreseen to start in 2014. For these, during 2014 the team was reinforced with one Post-Doc researcher and PhD and MsC students. The group activities are now well consolidated, and the challenge for the coming years is to expand the group activity and resources and to establish additional synergies with national and international partners in the group area of activity and related areas. The research themes that are within the scope of this group are:

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

7.1.3 Objectives

The group started 2014 preparing of three new projects in the framework of contracts with the European Space Agency. The objectives of the group for 2014 were on the one hand to follow and comply with the planning for each of the approved activities with ESA and with its partners, and, on the other hand, to explore the possibilities of other collaborative activities in its area of activity.

7.1.4 Achievements

During 2014 the first work phases in these three foreseen contracts were accomplished and a fourth contract, an extension to CODES contract was started. In particular:

- The RADEM (RADiation hard Electron Monitor for the JUICE mission) contract started in May 2014 with a duration of 30 months. The aim of the project is to develop the RADEM proto-flight model. LIP is responsible for the development of the design concept the RADEM electron Directional Detector, one of the three RADEM sensor heads, and for its calibration and data analysis. During 2014 LIP was involved in the critical review of the RADEM requirements, on the design iteration and consolidation and in the simulation and science analysis of the instrument. The RADEM contract will be continued during 2016 and it is foreseen to be closed in 2016.
- The contract "Eco-60"between LIP and ESA started in February 2014, with a duration of 15 months. In this project, the representativeness of Co-60 Total Ionizing Dose tests for EEE components to be flown in the Jovian electron environment is being verified by performing radiation tests in EEE components with both types of source particles: Co-60 gammas and electrons with energies above 10 MeV. During 2014, the test candidates were selected and procured, followed by the selection and test of the radiation test facilities. The contract will be completed during 2015.
- The MFS data analysis contract with ESA, in which LIP collaborates with EFACEC will started in March 2014, with a duration of 12 months. LIP is responsible for the consolidation of the analysis of available radiation ground test data and MC simulation, for the development of an algorithm for particle energy spectra reconstruction and for the MFS in-flight data analysis and cross-comparison with radiation environment models and other in-flight radiation monitors data.

- CODES, the Component Degradation Simulation tool is a GEANT4 based top level engineering tool, to predict Single Event Effects in EEE devices. CODES was developed at LIP and it consists of different GEANT4 modules with a user friendly web-based interface. LIP initiated an extension to the CODES contract in July 2014, for the final phase of implementing the CODES web interface at LIP and of making it available to the community. LIP will be in charge of managing and maintaining the CODES web server and to provide support to CODES users for one year.

7.1.5 Sources of Funding

Code	Funding	Start	End
ESA:22381/09/NL/PA/CCN04	20.000 €	2013-10-01	2015-06-30
ESA: 1-7560/13/NL/HB	300.000 €	2014-02-18	2016-07-28
ESA: 3-13975/13/NL/PA	200.000 €	2014-03-10	2015-08-31
ESA: 3-14025/13/NL/AK	60.000 €	2014-03-17	2015-06-30

7.1.6 Team

Project coordinator: Patrícia Gonçalves

Name	**Status**	**FTE %**
Alessandro de Angelis	Researcher (LIP)	10
Bernardo Tomé	Researcher (LIP)	20
Bruno Morgado	PhD student (LIP)	100
Catarina Espírito Santo	Researcher (LIP)	10
Luisa Arruda	Post-Doc (LIP/FCT)	47
Marco Alves Pinto	Master student (LIP)	11
Patrícia Gonçalves	Researcher (LIP)	80
Pedro Assis	Post-Doc (LIP/FCT/IST)	10

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., Volume:61 , Issue: 3, pp 1439 - 1443 — DOI: 10.1109/TNS.2014.2321477

7.1.8 Presentations

Poster presentations in international conferences

- **Simulation of Single Event Effects and Rate Prediction: CODES an ESA Tool**
  presented by Patrícia Gonçalves
  2014 IEEE Nuclear and Space Radiation Effects Conference — Paris, France.

- **Radiation Environment Studies and Applications for Space Missions**
  presented by Patrícia Gonçalves
  5th Portuguese Space Forum — Pavilhão do Conhecimento, Lisboa.

Oral presentations in international meetings

- **Alphasat TDP-8 MFS Particle Spectrometer Data Analysis: Towards a MFS Geant4 Simulation of the Flight Model and Flight data analysis**
  presented by Luisa Arruda
  Advances on Radiation and Plasma Monitoring Workshop — ESTEC, Noordwijk, The Netherlands.

Seminars

- **The radiation Environment in Space and its Effects**
  presented by Patrícia Gonçalves
  — Faculdade de Ciências da Universidade de 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)
- **A Directionality Detector for the JUICE mission Radiation Hard Electron Monitor**
  Marco Alves Pinto, (on-going)

7.1.10 Project Summary

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

7.2 Integrated Activities for the High Energy Astrophysics Domain

7.2.1 Resumo

The group has been involved in the development of focal plane prototypes for the next generation of gamma-ray and x-ray telescopes, participating in the GRI (Gamma-Ray Imager) mission consortium up to 2007, afterwards integrating to date DUAL mission and XIPE (X-ray Imaging Polarimetry Explorer) mission consortia. In the framework of these consortia, our group was co-proponent of three mission proposals submitted to ESA Cosmic Vision S and M mission calls by the different consortia: GRI in 2007, DUAL in 2010 and XIPE in 2012.
In 2014 our group pursued the development of a focal plane instrument based on gaseous detectors and CdZnTe sensors for two space gamma-ray observatory proposals setup during 2014 and submitted to ESA Cosmic Vision Call for M class missions last January, 15th, 2015. Those proposals were the ASTROGAM (http://astrogam.iaps.inaf.it/) and the XIPE (X-ray Imaging Polarimetry Explorer) 2015 version proposals.
Furthermore our group integrated the AHEAD (Activities in the High Energy Astrophysics Domain) H2020 project proposal in response to the INFRAIA-2014-2015 call Research Infrastructures for High Energy Astrophysics which was elaborated and submitted in 2014 and will be funded starting in 2015, with the duration of 24 months. The overall objective of AHEAD is to integrate national efforts in high-energy Astrophysics and to promote the domain at the European level, to keep its community at the cutting edge of science and technology in this competitive research area and ensure that space observatories for high-energy astrophysics are at the state of the art. Our group will contribute to WP8 of AHEAD. The WP8 title is "Development and characterization of optics for next generation X-ray telescopes".
The focal planes under development in the framework of ASTROGAM and XIPE proposals are based in semiconductor detectors and in Gas Pixel Detectors (GPD), respectively. The instruments proposed have a significant potential to contribute for a scientific leap in the field of high-energy astrophysics in the next decade. They will be capable of improving the sensitivity of previous missions by a factor of ≈100, by applying state-of-the-art gamma-ray focusing techniques, and also of providing future missions with polarimetric capabilities. To probe the polarization state of emitting celestial sources such as pulsars, solar flares, active galactic nuclei, galactic black holes or gamma-ray bursts can provide important information about their geometries, magnetic fields, and composition and emission mechanisms.
ASTROGAM is a space mission dedicated to the observation of the Universe with unprecedented sensitivity

XIPE artistic view

in the mostly unexplored energy range 0.3 MeV - 100 MeV. ASTROGAM is designed to achieve: a) the best gamma-ray sensitivity (by a factor of 10-30) ever obtained in the range 0.3 MeV - 100 MeV; b) an exceptional angular resolution for gamma-rays in the range 50 MeV – 1 GeV (0.15° at 1 GeV); c) a very large field of view (2.5 sr); d) polarization capability for both steady and transient sources;
In collaboration with the Istituto di Astrofisica Spaziale e Fisica Cósmica, Bologna, Italy, several CZT focal plane prototypes are being developed and tested. Simulation studies and experimental tests are being carried out with bi-planar configuration and 3D position sensitive CdTe prototypes in the framework ASTROGAM consortium. Also, a planar (11×11 pixels) CdTe prototype polarimeter was tested under a partial polarized laboratorial beam generated by a plastic scintillator polarizer when irradiated by a radioactive source (137Cs 22Na, etc.). Full detector surface was irradiated, similarly to source radiation inflight conditions. So far, these prototype experimental and simulation results are compatible with the performances required for a gamma-ray telescope main instrument established by the old ASTROGAM 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.
In the X-ray domain, XIPE is expected to be the first dedicated polarimeter ever launched into space. The LIP group is part of the XIPE instrumentation working group participating in the development of its main instrument composed by GPD (Argon, Xenon, etc.) for photoelectric based polarimetry. Our group is studying the gaseous mixtures optimization both through experimental and simulation work. 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.

7.2.2 Abstract

The group has been involved in the development of focal plane prototypes for the next generation of gamma-ray and x-ray telescopes, participating in the GRI (Gamma-Ray Imager) mission consortium up to 2007, afterwards integrating to date DUAL mission and XIPE (X-ray Imaging Polarimetry Explorer) mission consortia. In the framework of these consortia, our group was co-proponent of three mission proposals submitted to ESA Cosmic Vision S and M mission calls by the different consortia: GRI in 2007, DUAL in 2010 and XIPE in 2012.
In 2014 our group pursued the development of a focal plane instrument based on gaseous detectors and CdZnTe sensors for two space gamma-ray observatory proposals setup during 2014 and submitted to ESA Cosmic Vision Call for M class missions last January, 15th, 2015. Those proposals were the ASTROGAM (http://astrogam.iaps.inaf.it/) and the XIPE (X-ray Imaging Polarimetry Explorer) 2015 version proposals.
Furthermore our group integrated the AHEAD (Activities in the High Energy Astrophysics Domain) H2020 project proposal in response to the INFRAIA-2014-2015 call Research Infrastructures for High Energy Astrophysics which was elaborated and submitted in 2014 and will be funded starting in 2015, with the duration of 24 months. The overall objective of AHEAD is to integrate national efforts in high-energy Astrophysics and to promote the domain at the European level, to keep its community at the cutting edge of science and technology in this competitive research area and ensure that space observatories for high-energy astrophysics are at the state of the art. Our group will contribute to WP8 of AHEAD. The WP8 title is "Development and characterization of optics for next generation X-ray telescopes".
The focal planes under development in the framework of ASTROGAM and XIPE proposals are based in semiconductor detectors and in Gas Pixel Detectors (GPD), respectively. The instruments proposed have a significant potential to contribute for a scientific leap in the field of high-energy astrophysics in the next decade. They will be capable of improving the sensitivity of previous missions by a factor of ≈100, by applying state-of-the-art gamma-ray focusing techniques, and also of providing future missions with polarimetric capabilities. To probe the polarization state of emitting celestial sources such as pulsars, solar flares, active galactic nuclei, galactic black holes or gamma-ray bursts can provide important information about their geometries, magnetic fields, and composition and emission mechanisms.
ASTROGAM is a space mission dedicated to the observation of the Universe with unprecedented sensitivity in the mostly unexplored energy range 0.3 MeV - 100 MeV. ASTROGAM is designed to achieve: a) the best gamma-ray sensitivity (by a factor of 10-30) ever obtained in the range 0.3 MeV - 100 MeV; b) an exceptional angular resolution for gamma-rays in the range 50 MeV – 1 GeV (0.15° at 1 GeV); c) a very large field of view (2.5 sr); d) polarization capability for both steady and transient sources;
In collaboration with the Istituto di Astrofisica Spaziale e Fisica Cósmica, Bologna, Italy, several CZT focal plane prototypes are being developed and tested. Simulation studies and experimental tests are being carried out with bi-planar configuration and 3D position sensitive CdTe prototypes in the framework ASTROGAM consortium. Also, a planar (11×11 pixels) CdTe prototype polarimeter was tested under a partial polarized laboratorial beam generated by a plastic scintillator polarizer when irradiated by a radioactive source (137Cs

22Na, etc.). Full detector surface was irradiated, similarly to source radiation inflight conditions. So far, these prototype experimental and simulation results are compatible with the performances required for a gamma-ray telescope main instrument established by the old ASTROGAM 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.

In the X-ray domain, XIPE is expected to be the first dedicated polarimeter ever launched into space. The LIP group is part of the XIPE instrumentation working group participating in the development of its main instrument composed by GPD (Argon, Xenon, etc.) for photoelectric based polarimetry. Our group is studying the gaseous mixtures optimization both through experimental and simulation work. 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.

7.2.3 Objectives

H2020 AHEAD project approval addresses to the objectives and efforts being carried out by this group. The overall objective of AHEAD is to integrate national efforts in high-energy Astrophysics and to promote the domain at the European level, to keep its community at the cutting edge of science and technology in this competitive research area and ensure that space observatories for high-energy astrophysics are at the state of the art. This initiative will provide new tools to our group to prepare stronger and solid proposals to future ESA call for missions.

The experimental and simulation analysis work performed on CZT prototypes with LIP laboratorial polarization precision table and with a 3D position and on gaseous detectors provided important conclusions for the configuration of the main instruments of XIPE and ASTROGAM proposals submitted last January 15th 2015.

7.2.4 Achievements

AHEAD (Activities in the High Energy Astrophysics Domain) H2020 project proposal in response to the INFRAIA-2014-2015 call Research Infrastructures for High EnergyAstrophysics which was elaborated and submitted in 2014 and will be funded starting in 2015, with the duration of 24 months.

September 29th 2014: Marco Gui Alves Pinto obtained his Master degree by presenting the thesis "CdTe matrix Polarimetric analysis with a crystal polarizer"at the Departamento de Física da Universidade de Coimbra, under the supervision of Rui Miguel Curado da Silva.

Ongoing PhD Thesis:

José Marques, CAUP and LIP PhD student, started 01/10/2011

Ongoing Master Thesis:

Nelson Simões, Master Thesis started 01/10/2014

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
Filipa Borges	Researcher (LIP)	15
Filomena Santos	Researcher (LIP)	20
Jorge Maia	Researcher (LIP/UBI)	45
José Escada	Post-Doc (LIP)	20
José Marques	PhD student (LIP)	60
Marco Alves Pinto	Master student (LIP)	10
Miguel Moita		100
Nelson Simões	Master student (LIP)	80
Rui Curado Silva	Researcher (LIP)	85
Teresa Dias	Researcher (LIP)	15

7.2.6 Publications

International Conference Proceedings

- **A Small 3D CZT Payload for Hard X Ray Polarimetry and Spectroscopic Imaging**
  E. Caroli, N. Auricchio, C. Budtz-Jørgensen, G. De Cesare, R. M. Curado da Silva, S. Del Sordo, P. Ferrando, P. Laurent, O. Limousin, J. L. Galvèz, M. Hernanz, J. Isern, I. Kuvvetli, J. M. Maia, A. Meuris
  A Small 3D CZT Payload for Hard X Ray Polarimetry and Spectroscopic Imaging, E. Caroli1, N. Auricchio1, C. Budtz-Jørgensen2, G. De Cesare1, R. M. Curado da Silva3, S. Del Sordo4, P. Ferrando5, P. Laurent5, O. Limousin5, J. (accepted)

7.2.7 Presentations

Poster presentations in international conferences

- **A Compact Solar Hard X-ray Polarimeter**
  presented by Rui Curado Silva
  Planning for a joint scientific space mission Chinese Academy of Sciences (CAS) - European Space Agency (ESA) — Chengdu, China.

- **A Small 3D CZT Payload for Hard X Ray Polarimetry and Spectroscopic Imaging**
  presented by Rui Curado Silva
  21st Symposium on Room-Temperature Semiconductor Detectors, 8 - 15 November 2014 — Seattle, USA.

- **Inflight Conditions Experimental Analysis of a Squared Pixel Matrix CdTe Polarimeter**
  presented by Rui Curado Silva
  21st Symposium on Room-Temperature Semiconductor Detectors, 8 - 15 November 2014 — Seattle, USA.

Presentations in national conferences

- **A Compact Solar Hard X-ray Polarimeter**
  presented by Marco Alves Pinto
  XXIV Encontro Nacional de Astronomia e Astrofísica (ENAA) — Faculdade de Engenharia, Universidade do Porto.

Outreach seminars

- **Aquecimento global: consequências e soluções**
  presented by Rui Curado Silva
  — Escola Básica da Gafanha da Encarnação.

7.2.8 Academic Training

PhD Theses

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

Master Theses

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

7.2.9 Project Summary

	number
International Conference Proceedings	1
Poster presentations in international conferences	3
Presentations in national conferences	1
Outreach seminars	1

Chapter 8

Higher Education and Advanced Training, Technological Transfer and Outreach Activities

8.1 Higher Education and Advanced Training

8.1.1 Achievements

LIP contributes to physics and engineering education at high-education (Universities and Polytechnics) in Portugal both by the direct intervention of its researchers as professors and invited professors, and promoting and coordinating joint PhD programs involving several Portuguese Universities, namely:

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

DAEPHYS and IDPASC-Portugal PhD programs were approved respectively in the 2013 and 2014. Both programs opened in 2014 PhD grants and a total of XX students were selected.

8.2 Technology Transfer

8.2.1 Resumo

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

8.2.2 Abstract

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

8.2.3 Objectives

HEPTech network - TTN
- Ensure the publication of the HEPTech Intellectual Property charter at the LIP Outreach main page.
- As a node member in the HEPTech network, promote among the LIP community and participate, as deemed possible, on AIME "Academia Industry Matching Events"in the following areas: 1) Technology for Accelerators, 2) Control Systems, 3) ICT, 4) Detectors, 5) and 6) Good practices and Specialization support to Technology Transfer Offices.
- Organize, per request, bilateral meetings with LIP researchers (in Lisbon and Coimbra) about Intellectual Property and Technology Transfer matters, leveraging the experience of the participation in the HEPTech network.
Industrial Liaison Officer - ILO
- Orient the current database of national firms at FCT to a CRM information system helping the ILO with matters related to project opportunities and available technologies* at CERN, ESO, ESRF and ESA.

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

(project opportunities and available technologies* means: announcement of technical documents on procurement opportunities for the supply of goods and services, available technologies that include patents, know-how, software, R&D projects or collaborations)

8.2.4 Achievements

HEPTech network - TTN

- In order to disseminate matters on Technology and Knowledge Transfer throughout the LIP community, during 2014 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.
- Several AIME "Academia Industry Matching Events", Workshops and Show and Tell initiatives were identified relevant to the LIP community during 2014, mainly: 1) In-Kind Contribution process in European Large Scale infrastructure, 2) AIDA AIME: Resistive Plate Chambers and Thin Gap Chambers, 3) Building an ELI Centric Ecosystem, 4) Show and Tell @ CTU, 5) Marketing of Science and Technology, 6) Hellenic Forum for Science Technology and Innovation, 7) HEPTech Symposium.
- The HEPTech nodes survey was presented during 2014 and LIP registers that awareness campaigns and visibility about technology transfer is further needed among the High Energy Physics community. This overall conclusion pushes further the HEPTech to foster communication and marketing activities towards the HEPTech members.

Industrial Liaison Officer – ILO

- An updated database composed of 430 companies from Portugal is supporting the ILO activities and ready for being exported to a more advanced information management system (IMS), such as a CRM (Customer Relationship Management) tool. This database with updated contacts was sent to the procurement department Directors of CERN, ESO, ESA and ESRF, in order to be distributed among the organizations technical departments.
- To show the most significant examples of the Portuguese scientific and industrial participation at CERN, ESO, ESRF and ITER, the ILO published a catalog called: Portugal in Large Scale Research Facilities - https://www.fct.pt/apoios/tecnologia/docs/catalogo_tecnologia_web.pdf
- The ILO followed closely the 2014 trainsheep programme for young Portuguese graduates at CERN, ESO and ESA with the goal of understanding their path during the training in the organizations and as deemed possible connect them with Portuguese companies.
- 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, as follows:

CERN

- Company: Innovayt (Innovation Consultancy); To Whom: Senior Staff for Procurement - Finance Department.
- Company: ActiveAerogels (Nano-structured materials for thermal insulation and absorption of pollutants); To Whom: Technology department/Cryogenic group/Materials Engineering
- Company: Meethub (Networking Platform); To Whom: Directorate General/Communication Group
- The ILO presented to CERN Director General Unit three industrial partners to be invited to CERN 60th Anniversary VIP ceremony: EFACEC, ISQ, Solidal Condutores SA.
- On October 2014, the ILO organized a road-show with CERN Mechanical workshop representative to Portuguese companies for the sectors – mechanical engineering and precision mechanics: 1) ACLmoldes, 2) Tsftrofa, 3) Falual, 4) Ruprec, 5) Durit, 6) Abrito, 7) Siroco, 8) RRMP, 9) Gosimac, 10) NCP, 11) Cunhol, 12) Cubospoligonos.
- The ILO organized a visit to CERN with 2 science managers from FCT to experience how the Portuguese financed projects are impacting experiments such as: ATLAS, CMS. Further, other experiments were visited: LHCb, AMS and the Computing Center that manages CERN GRID.

ESO

- On June 2014, the ILO organized a road-show with 2 ESO Directors (Procurement and the E-ELT project) to targeted Portuguese companies in the framework of the E-ELT programme: 1) ISQ, 2) Critical Software, 3) ActiveSpace Technologies.
- Following a contact from a Spanish Prime for the E-ELT DMS project – Empresarios Agrupados, the ILO provided a list of Portuguese companies that could be sub-contractors to the project regarding metallic structures: 1) Martifer, 2) Ply Engenharia, 3) Metalúrgica Palmelense.

ESRF

- Company: ActiveSpace Technologies (Space instrumentation and structural systems); To Whom: Senior Staff for Procurement and Insertion Device Group.
- Company: EFACEC (Group in the Energy sector); To Whom: Senior Staff for Procurement.

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, e no âmbito do "Encontro com o Cientista"na Escola Ciência Viva para alunos do primeiro ciclo do ensino básico.

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. Participação na "Noite Europeia dos Investigadores", em parceria com o Planetário Calouste Gulbenkian - Centro Ciência Viva (e nas suas instalações).

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

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

Em conjunto, o Programa de professores do CERN e o Projecto de radiação ambiente já colocaram em contacto próximo com a investigação recente, várias centenas de professores. Permitiram-nos assim criar uma rede de escolas, espalhada pelo país, em contacto ou com facilidade de acesso aos investigadores e vice-versa, o que consideramos fundamental para a generalização e o impacto das outras acções de divulgação.
O Programa de Professores em língua portuguesa é um exemplo para o próprio CERN, já que foi estendido a todos os outros países de língua portuguesa, dando também a possibilidade aos professores participantes de partilhar experiências com colegas de outras realidades.
Nas masterclasses participam anualmente cerca de dois milhares de estudantes, e várias dezenas de professores. É uma das acções de maior impacto directo e tem sido alargada a todo o país, contando com a colaboração de investigadores do LIP e também de outros investigadores nas instituições locais de Ensino Superior.
No final do ano foi adaptado para português o cartaz "The Particles Chart"do projecto "Contemporary Physics Education Project", que pode ser descarregado gratuitamente a partir de www.cpepweb.org/particles.html, e que já está afixado em algumas escolas portuguesas.
No ano de 2014 celebrou-se os 60 anos do CERN. Portugal contribuiu com várias ações, através do LIP, através de palestras em escolas, visitas ao LIP, e preparação de uma exposição fotográfica histórica associada à "CERN School of Computing", inaugurada pelo Director-Geral do CERN na Reitoria

da Universidade do Minho (local da escola).
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, or in the scope of the "Meet the Scientist"activity within the Ciência Viva School for the students aged 6-9 years old;

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. Participation in the "European Researchers Night", in cooperation with Planetário Calouste Gulbenkian - Ciência Viva Centre (and in their premises).

8. To adapt and develop contents related to particle and astroparticle physics, for the web, the use in exhibitions, display in the schools, etc.

9. 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.
Portugal participated strongly in the celebrations of the CERN 60th anniversary, through LIP, and in particular held the "CERN School of Computing"
to which was associated a photographic and historical exhibition that was prepared and inaugurated by the CERN Director-General and the Rector of the University of Minho.

The "Particles Chart"from the Contemporary Physics Education Project (www.cpepweb.org) that runs "The Particle Adventure"website, was adapted to Portuguese and made available at the CPEP website (http://www.cpepweb.org/particles.html). It can be downloaded (free of charge) and printed, and is already in display at the Physics laboratory/classroom in a few portuguese schools.
In 2014 Portugal, through LIP, has also celebrated the CERN 60th Anniversary in many places, in particular the "CERN School of Computing"
at the University of Minho, linked to a photographic historical exhibition inaugurated by the CERN Director-General and the Rector of
the University.
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 2013/2014 and 2014/2015.

3. To provide summer occupation programmes for high-school students, involving different scientific projects at LIP.

4. To organize the 10th edition of IPPOG´s International Masterclasses in Particle Physics, in 13 venues with 2 sessions in 2 venues, due to the high demand, and support to the masterclasses in São Tomé and Príncipe for the 3rd time.

5. To organize the 8th 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 35 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 2 meetings of the IPPOG - International Particle Physics Outreach Group and EPPCN - European Particle Physics Communication Network and a common meeting of the two groups (in autumn), as proposed by the LIP group.

7. To participate in the "European Researchers Night", in cooperation with Planetário Calouste Gulbenkian - Ciência Viva Centre.

8. To adapt and develop contents related to particle and astroparticle physics, for the web, the use in exhibitions, display in the schools, etc.

9. To celebrate the CERN 60th Anniversary in Portugal.

10. To adapt and disseminate the CERN Press Releases and a few from other institutions.

8.3.4 Achievements

1. 30 seminars and public sessions. In particular public seminars were co-organized with Planetário Calouste Gulbenkian and Ciência Viva, with two special sessions: a talk in the Ciência Viva Conference of Space Teachers, and a web-i-nar made at the ministry of education. LIP participated twice in the activity "Meet a Scientist"of the Ciência Viva School for 8 years future scientists.

2. The 7th National Meeting of the Project ´Environment Radiation´ took place in Oficinas de São José in Lisboa on the 10th of May, with about 100 participants presenting posters which reflect the work performed during the school-year.

3. 12 students were hosted by the projects ATLAS and Auger in Lisbon.

4. Around 2000 students participated in the MasterClasses in 13 locations (and 1 location with 2 sessions due to the very high demand), and the support to São Tomé and Príncipe for the third time;

5. 72 teachers participated in the CERN Portuguese Language Teachers Programme: 35 portuguese, 30 brazilian, 2 from Mozambique, 1 from Cape Verde, and 1 São Tomé and Príncipe.

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. LIP organized with Planetário Calouste Gulbenkian and in their premises a "European Researchers Night"with the attendance of about 200 people.

8. The "Particles Chart"from the CPEPweb.org was adapted to portuguese and made available for the schools.

9. The celebration of the CERN 60th Anniversary took place in many sites in Portugal, through LIP, of which an highlight was the inauguration of a photographic and historical exhibition by the CERN Director-General and the Rector of the University of Minho, coupled to the CERN School of Computing that took place in that University.

10. All CERN Press Releases and a few from other institutions were adapted and sent to the portuguese media.

8.3.5 Sources of Funding

Code	Funding	Start	End
PEC37	20.000 €	2013-01-01	2014-12-31
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 Fernandes	Collaborator	
Ana Maria Pinto	Collaborator (FCUL)	
António Onofre	Researcher (LIP/UMinho)	
Carlos Bernardino	Collaborator	
Carmen Oliveira	Collaborator (LIP)	
Catarina Espírito Santo	Researcher (LIP)	
Conceição Abreu	Researcher (LIP)	
Fernando Barão	Researcher (LIP/IST)	
Florbela Rego	Researcher (LIP)	
Luis Peralta	Researcher (LIP/FCUL)	
Paula Pinho	Collaborator	
Pedro Abreu	Researcher (LIP/IST)	
Pedro Assis	Post-Doc (LIP/FCT/IST)	
Sandra Soares	Researcher (LIP/UBI)	

8.3.7 Presentations

Presentations in national conferences

- **Experiências com radiação infravermelha**
  presented by Luis Peralta
  19ª Conferencia Nacional de Física e 24º Encontro Ibérico para o Ensino da Física — Lisboa 2 a 4 de Setembro, 2014 .

- **Feixes iónicos contra o cancro**
  presented by Luis Peralta
  Seminário — Oficinas de S. José, Colégio Salesiano de Lisboa.

(unspecified Communications)

- **Projeto Radiação Ambiente**
  presented by Florbela Rego
  19ª Conferencia Nacional de Física e 24º Encontro Ibérico para o Ensino da Física — Lisboa 2 a 4 de Setembro, 2014.

8.3.8 Events

- **60 anos do CERN**
  Outreach Event, Largo do Paço, Universidade do Minho, 2014-01-01
- **Masterclasses 2014 - 10th IPPOG Int´l Masterclasses in Particle Physics**
  Outreach Event, UTAD, Vila Real, 2014-03-12
- **Masterclasses 2014 - 10th IPPOG Int´l Masterclasses in Particle Physics**
  Outreach Event, IPB, Bragança, 2014-03-13
- **Masterclasses 2014 - 10th IPPOG Int´l Masterclasses in Particle Physics**
  Outreach Event, FCTUC and LIP, Coimbra, 2014-03-15
- **Masterclasses 2014 - 10th IPPOG Int´l Masterclasses in Particle Physics**
  Outreach Event, FCUL, Lisboa, 2014-03-15
- **Masterclasses 2014 - 10th IPPOG Int´l Masterclasses in Particle Physics**
  Outreach Event, FCUP, Porto, 2014-03-15
- **Masterclasses 2014 - 10th IPPOG Int´l Masterclasses in Particle Physics**
  Outreach Event, FCTUAlgarve, Faro, 2014-03-19
- **Masterclasses 2014 - 10th IPPOG Int´l Masterclasses in Particle Physics**
  Outreach Event, Univ.Évora, 2014-03-22
- **Masterclasses 2014 - 10th IPPOG Int´l Masterclasses in Particle Physics**
  Outreach Event, IPBeja, Beja, 2014-03-22
- **Masterclasses 2014 - 10th IPPOG Int´l Masterclasses in Particle Physics**
  Outreach Event, Univ. Açores, Ponta Delgada, 2014-03-25
- **Masterclasses 2014 - 10th IPPOG Int´l Masterclasses in Particle Physics**
  Outreach Event, Univ. Aveiro, 2014-03-29
- **Masterclasses 2014 - 10th IPPOG Int´l Masterclasses in Particle Physics**
  Outreach Event, FC-UBI, Covilhã, 2014-03-29
- **Masterclasses 2014 - 10th IPPOG Int´l Masterclasses in Particle Physics**
  Outreach Event, IST, Lisboa, 2014-03-29
- **Masterclasses 2014 - 10th IPPOG Int´l Masterclasses in Particle Physics**
  Outreach Event, ISP-STP, São Tomé, São Tomé e Príncipe, 2014-03-29
- **Masterclasses 2014 - 10th IPPOG Int´l Masterclasses in Particle Physics**
  Outreach Event, EC-UMinho, Braga, 2014-04-04
- **Masterclasses 2014 - 10th IPPOG Int´l Masterclasses in Particle Physics**
  Outreach Event, EC-UMinho, Braga, 2014-04-05
- **Masterclasses 2014 - 10th IPPOG Int´l Masterclasses in Particle Physics**
  Outreach Event, IST, Lisboa, 2014-04-05

8.3.9 Project Summary

	number
Presentations in national conferences	2
(unspecified Communications)	1
Outreach Events	17