Laboratório de Instrumentação e Física Experimental de Partículas

Relatório de Actividades

2006

Contents

Chapter 1

Overview

During 2006 LIP has pursued the execution of the last year of the first five years term of the Associated Laboratory Contract, finalizing the recruitment process for the selection of new researchers and technicians, both at Lisbon and Coimbra.
We summarize here the main areas of LIP activity in 2006.
The strong commitment with CERN has been pursued, still centered in the LHC experiments and technologies (ATLAS, CMS and LCG) and in the COMPASS Collaboration.
The involvement in space related activities continued, namely with the participation in the AMS as well as in the activities concerning ESA.
The GRID Computing activities have been enlarged. LIP will have soon a Tier-2 infrastructure, for support of ATLAS and CMS, with 180 CPUs, both in Lisbon and Coimbra.
Medical Physics research has continued to be a privileged area of research with a strong commitment to towards the Pet Mammography project.
In 2006, LIP has pursued a continuous activity in education and outreach.
LIP interests in astroparticle physics have been consolidated mainly through our participation in the Auger Observatory program.
As for the LIP Coimbra commitments with large collaborations, we should note three programs: the GSI contract under the European project "DIRAC-PHASE-1", the participation in the work of the ATLAS Collaboration and the intervention in the Zeplin programme of the UKDM Collaboration. Concerning the GSI project, the construction of the RPC detectors for the new TOF wall of the HADES experiment has started in summer, after a long and careful preparation, with important involvement of our technical staff. It is foreseen that this phase lasts until early 2008, and the following commissioning period extends up to the end of 2009. Along 2006, also the complementary activity covering the construction and assessment of an RPC PET prototype made important progresses, both in simulation and in the preparation of the elementary detector cells. Thus, it is now clear that the prototype head will be assembled in the first half of 2007, the foreseen validation tests taking place thereafter. In what regards the dark matter search with liquid xenon, this was a quite successful year, in view of the extremely positive assessment of the UK Dark Matter Collaboration program issued recently by the committee appointed by the UK funding agency. It should be stressed that this was a direct consequence of the progresses made in the ZEPLIN II and ZEPLIN III programmes, for which the contributions of the Coimbra team were essential. As for the ATLAS Collaboration, the Coimbra team is gaining a prominent role in the TOP quark physics. The responsibility attributed to the team members is a measure of the contribution given to the study and simulation of physics channels relevant for the analysis of the data to be collected from this year. The team is also developing the adequate analysis tools which will be used within the GRID framework.
The scintillation Anger camera for neutron detection was fully tested in the lab, achieving the localization of alpha particle tracks with unprecedented combined position and angular (2 degrees sigma) resolutions, results to be reported at the collaboration meeting of NMI3-JRA2 in early 2007. It is expected that such results establish a sound basis for the future submission of an FP7 proposal.
In the direction of Astroparticle Physics, analysis of experimental data for the dependence of the nitrogen UV fluorescence on pressure and temperature was performed.
Along 2006 the process of selection of the two machine tools for the LIP Mechanical workshop was accomplished.
We sould also refer to the main role of LIP in the organization of the 10th International Symposium on Radiation Physics (Coimbra, 17-22 September 2006) and the associated Workshop on Use of Monte Carlo Techniques for Design and Analysis of Radiation Detectors (15-17 September).
One quite rewarding event was the completion of the spark chamber for the visualization of cosmic ray tracks. This relatively simple instrument is a real success in attracting the attention of students for physics, particularly

efficient for the secondary schools' population.

1.1 Fundings for LIP Lisboa

Project	Code	Funding	Entity	Start	End
AMS	PDCTE/FNU/50364/2003	40.000 €	FCT	2004-11-01	2007-10-31
ATLAS	POCI/FP/63936/2005	220.000 €	FCT	2006-09-01	9999-12-31
	POCI/FP/63422/2005	225.000 €	FCT	2005-06-01	2006-09-30
CMS	POCI/FP/63922/2005	255.000 €	FCT	2006-09-01	9999-12-31
	POCI/FP/63434/2005	225.000 €	FCT	2005-08-01	2006-09-30
	RTN2-2001-00571	166.320 €	EU	2003-03-01	2006-09-30
COMPASS	POCI/FP/63939/2005	130.000 €	FCT	2006-09-01	2007-08-31
	POCI/FP/63431/2005	120.000 €	FCT	2005-05-01	2006-09-30
	010.6/B009/2005	252.000 €	EU	2004-01-01	2008-12-31
ESA	ESA:18121/04/NL/CH	80.000 €	ESA	2006-11-01	2008-10-31
	ESA: 18121/04/NL/ch	100.000 €	ESA	2004-04-01	2006-09-30
	ESA 19100/05/NL/HB	23.240 €	ESA	2005-09-11	2006-02-28
	ESA:19770/06/NL/JD	78.200 €	ESA	2006-07-01	2007-12-31
GRID	EGEE-complement (010 .6/B002/2005)	119.250 €	FCT	2005-04-01	2006-03-31
	EELA (026409)	78.000 €	EU	2006-01-01	2007-12-31
	int.eu.grid (IST-7-0 31857)	154.000 €	EU	2006-05-01	2008-04-30
	EGEE-II (RI-031688)	274.888 €	EU	2006-04-01	2008-03-31
	EGEE (INFSO 508833)	247.500 €	EU	2004-04-01	2006-03-31
	EGEE-additional (POC I/V.5/A016/2005)	100.000 €	FCT	2005-05-01	2006-04-30
HECR	POCI/FP/63917/2005	100.000 €	FCT	2006-09-01	9999-12-31
	POCTI/FIS/55759/2004	80.000 €	FCT	2005-03-01	2006-12-31
MC in Medical Physics	POCI/FP/63448/2005	36.000 €	FCT	1000-01-01	9999-12-31
	POCI/FP/63909/2005	30.000 €	FCT	2006-09-01	9999-12-31
	POCI/FP/63448/2005	36.000 €	FCT	1000-01-01	9999-12-31
	POCI/FP/63448/2005	36.000 €	FCT	2005-09-01	2006-08-31
NA60	POCI/FP/63919/2005	25.000 €	FCT	2006-09-01	9999-12-31
OUTREACH	POCTI/DIV/2005/00087	50.000 €	FCT	2005-06-01	2007-03-31
	000 CRESCERE	23.400 €	EU	2005-07-01	2006-02-28
	OCJF2006	1.100 €	Ciência Viva	2006-07-01	2006-09-30
PET - Mammography	POSI/DGDR-SIFEC/14/0 1/03/FDR/00134	569.000 €	AdI	2003-01-01	2006-12-31
RPCs	010.6/B009/2005	110.000 €	FCT	2004-01-01	2006-12-31
SNO	POCI/FIS/56691/2004	35.000 €	FCT	2005-01-01	2007-03-31

1.2 Fundings for LIP Coimbra

Project	Code	Funding	Entity	Start	End
Air Scintillation	POCI/FP/63913/2005	20.000 €	FCT	2006-11-01	9999-12-31
	POCI/FP/63440/2005	30.000 €	FCT	2005-07-04	2006-11-30
GEMs	POCTI/FP/FNU/50338/2003	25.000 €	FCT	2004-07-04	2006-04-30
	CERN/FNU/43735/2001	50.000 €	FCT	2002-03-11	2006-06-30
	RII3-CT-2003-505925	88.000 €	FCT / EU	2004-01-01	2007-12-31
HADES	EU Contract 515876 DIRAC-Phase-1	52.000 €	EU	2005-11-01	2009-10-31
	LIP-GSI contract	414.000 €	GSI	2005-11-01	2009-10-31
Human PET	POCI/SAU-OBS/61642/2 004	47.160 €	FCT	2005-01-01	2007-12-31
Oficina-Coimbra	REEQ/573/FIS/2005	441.000 €	FCT	2005-03-01	2006-12-31
Physics at LHC	POCI/FP/63420/2005	36.000 €	FCT	2005-06-01	2006-12-31
	POCI/ FP/63926/2005	20.000 €	FCT	2006-11-01	9999-12-31
RPCs	POCI/FP/63411/2005	34.540 €	FCT	2005-06-01	2006-11-09
	RII3-CT-2003-506078	55.000 €	EU	2004-01-01	2006-12-31
ZEPLIN and n-TOF	POCTI/FP/FNU/50208/2003	60.000 €	FCT	2004-10-01	2006-02-28
	POCI/FP/63446/2005	55.000 €	FCT	2005-09-01	2007-01-31
	POCI/FP/63925/2005	60.000 €	FCT	2006-11-01	9999-12-31

1.3 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	3	3	3	2	4							
CMS	3	2	9	2				1				
COMPASS	3	3	3	2		3						
HADES	1		1									
NA60	1	1	1									
Physics at LHC	2	2	3	7								1
DELPHI	9	2	4			1						
GRID			4	10			1					
AMS	1	1	3									
SNO	2	2	1	1	1							
ZEPLIN and n-TOF	7	5		1	3						1	2
HECR	6	5	8	3	1	1	1		1			1
Air Scintillation			2	1	2							
ESA			4	4	1							
PET - Mammography	4	4		3	2				1	1		
Human PET				1			2					
MC in Medical Physics	1		6		4	4				4	2	
RPCs	4	3	2	1			1					
GEMs												
OUTREACH				2				2				5
Totals:	46	33	51	39	18	9	4	3	2	5	3	9

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.)

1.4 Human resources

Project	Researchers	Technicians	Post-Docs	Students				FTE
				D	M	G	O	
ATLAS	8	5	3	5	1		5	14.91
CMS	10	5	3	7	1	3	1	15.29
COMPASS	3		2	2	1		1	8.36
HADES	6	2						0.66
NA60	4	1	2	2				6.83
Physics at LHC	9	1	1	2	1			2.63
DELPHI	3			3				1.48
GRID	3	6	1					7.85
AMS	3		1	2				2.95
SNO	1		1	1				1.02
ZEPLIN and n-TOF	7	7	1	3	1			5.99
HECR	8	1	2	1		4	1	9.04
Air Scintillation	8	6	1	2		1	1	3.56
ESA	4		1	3			1	2.08
PET - Mammography	7	2	1	5	1		1	8.66
Human PET	10	6						1.65
MC in Medical Physics	9		1	4	3	1	1	9.74
RPCs	10	10					2	4.29
GEMs	7	4		2	1			6.27
OUTREACH	7	4		2	1		2	2.70
Totals:	70	24	15	33	10	9	14	115.96

Legend:

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

FTE: Full Time Equivalent

Chapter 2

Accelerator physics

2.1 Collaboration in the ATLAS experiment at CERN

2.1.1 Activity Report

Resumo:

Ao longo do ano de 2006, o grupo Português envolvido no projecto ATLAS prosseguiu as suas actividades, centradas no desenvolvimento, construção e "commissioning" do Sistema de Controlo (DCS) do calorímetro Tilecal, no "commissioning" da performance do Tilecal com raios cósmicos e na simulação de Física do quark top e bosão W.

Na parte de construção de componentes ópticas, foram preparados os cabos de fibras ópticas que vão conduzir a luz do laser (sistema de monitorização) até aos barris laterais do Tilecal. Foram instalados conectores nas fibras que ligam ao barril central e o sistema foi testado no que diz respeito à intensidade e unformidade da distribuição de luz utilizando LEDs. No DCS do Tilecal tivemos que dedicar um esforço imprevisto a solucionar problemas de segurança no sistema de ligação das fontes de alimentação de baixa tensão. Iniciou-se o arquivamento dos dados lidos pelo DCS na base de dados Oracle e mais tarde foi estabelecida a ligação com a base de dados de condições (COOL) onde serão arquivados os parâmetros do DCS relevantes para a análise dos dados de física. Um primeiro protótipo da máquina de estados finitos (FSM), incluindo apenas as fontes de baixa tensão, foi testado durante a "Milestone 1" de integração do ATLAS em finais de 2006.

O grupo esteve fortemente envolvido nos testes de "commissioning" de ATLAS com muões cósmicos, tendo realizado a análise dos dados de Tilecal dos vários períodos de tomada de dados: Tilecal isolado, em conjunto com o calorímetro do rgonLíquido (LAr) e com o detector de muões. O algoritmo de reconstrução de muões cósmicos TileMuonFitter, actualmente muito usado nos estudos de performance do calorímetro combinado (Tilecal + LAr), foi inteiramente concebido, desenvolvido e testado pelo nosso grupo durante o ano de 2006. Foi também desenvolvido o algoritmo TileCosmicsTrigger, para a simulação da placa de trigger de muões cósmicos de Tilecal, que será usado centralmente para as próximas simulações do detector ATLAS combinado, a realizar em 2007. No que respeita aos estudos de desempenho de Tilecal com muões cósmicos, foi dado relevo: aos estudos de resolução em tempo, importantes para a reconstrução da energia no calorímetro com o método de filtro óptimo; aos estudos de uniformidade da resposta do detector; aos estudos de qualidade dos dados, como por exemplo a identificação de canais demasiado ruidosos.

Como preparação para o "commissioning" do detector e do sistema de trigger, começámos a trabalhar na calibração de jactos no segundo nível do trigger. As ferramentas usadas na calibração offline são aplicadas aos jactos do trigger, mas estes são reconstruídos com algoritmos mais simples e rápidos, como é exigido na selecção online. A avaliação destes métodos demonstrou que, depois da calibração, a escala de energia dos jactos está determinada com uma precisão de +/-2%.

A nossa participação na simulação de Física aumentou significativamente. Para além das tarefas anteriores de estudos da massa e largura do W e da Física do quark top, começámos a preparação do "commissioning" da Física, preparando a medida da secção eficaz de produção do W no canal de desintegração W$\rightarrow \mu\nu$. Os métodos de análise estão-se a desenhar e avaliar com dados Monte Carlo, para serem aplicados depois em dados.

Os decaimentos FCNC do quark top ($t \rightarrow q\gamma$, $t \rightarrow qZ$ and $t \rightarrow qg$) produzidos individualmente ou aos pares em LHC, foram estudados utilizando a simulação rápida do detector ATLAS. A radiação de estado inicial e final foi tida em conta no presente estudo bem como as contribuições dos vários erros sistemáticos. Os resultados obtidos foram apresentados de duas formas distintas: considerando um limiar de descoberta de 5 sigma na razão sinal-ruído na presença de sinal, ou sob a forma de limites a 95% de nível de confiança na ausência de

sinal. Foram ainda avaliadas várias contribuições para os erros sistemáticos como são por exemplo, a radiação de estado inicial e final, a variação na massa do quark top e a calibração de energia dos jatos.
As actividades de I&D no envelhecimento de fibras ópticas e cintiladores plásticos prosseguiram, tendo agora como motivação extra os cenários de Super-LHC com níveis de radiação até 10 vezes mais elevados do que os previstos em LHC, e um tempo de vida do detector mais extenso. Relativamente ao detector de luminosidade, ALFA, foi desenhado e construído um "carrossel" para aluminizar o corpo das fibras ópticas cintilantes. Foi utilizado já para aluminizar fibras pela técnica de evaporação e está a ser adaptado à câmara de vácuo existente em Lisboa para aluminizar as fibras finais pela técnica de "sputtering" com magnetrão. Participou-se na construção do protótipo e nos respectivos testes em feixe no CERN. O projecto inclui também uma componente de divulgação, que foi intensa ao longo de 2006, com vários dos membros deste projecto a participarem activamente no projecto "Crescere" experiências remotas com muões cósmicos feitas via internet e destinadas principalmente aos alunos das escolas secundárias, e no "Master Class" organizado pela EPOG.

Summary of Activities:

During 2006 the activities related with the construction and commissioning of the ATLAS detector and Physics studies proceeded. They were centred in the Tilecal DCS development, implementation and commissioning, in the Tilecal performance commissioning with cosmic muons and simulation of physics of quark top and W boson. The involvement in the construction of the ALFA luminosity detector and in optics ageing studies continued.

Construction and mounting of components for the Laser calibration system
The laser monitoring system for the Tilecal photomultipliers is in the final phase of installation at the ATLAS experimental area. The clear optical fibres for light transmission to the Tilecal modules of one of the extended barrel were cut to length, polished, labelled, and then optical connectors installed at their ends. Connectors were also installed in the optical fibres of the barrel modules and the system was tested with respect to performance and uniformity of light distribution using a LED source.

Scintillating fibres for the luminosity detector
Our participation in the construction of the luminosity detector for ATLAS started in 2005. This detector (ALFA - Absolute Luminosity For ATLAS) uses square 0.5x0.5 mm^2 scintillating fibres staggered in 20 layers. These fibres need to be aluminized both along their body and in one of the ends. The aluminization at the end aims to increase the light yield and the aluminization of the body is used to eliminate the cross talk between the optical fibres of that tracking system. For aluminization of the fibres body with magnetron sputtering technique, we designed and built a prototype of a moving support system (type "Carrosel") to be adapted to the vacuum chamber at CEFITEC in Lisbon, where the aluminization of the final fibres will be done. In the first testing phase (June 2006), due to timing matters, we used the Carrosel to aluminize the fibres at CERN but still using evaporation technique. The fibres have been previously polished and aluminized on the top opposite to the Photomultiplier in our lab in Lisbon, sent to CERN for the aluminization along the body and finally used in the prototype that was tested at CERN in October 2006. Besides that we contributed, at CERN, to the adaptation of one XY table to the set-up that supported the detector on beam. During 2006/2007 we continue to invest on the construction (adaptation) of the final sputtering machine (located at the CEFITEC/UNL) in order to aluminized the fibres along the body. Presently the tests are starting. Very soon we should aluminize a new set of 2000 scintillating fibres to be delivered to CERN. Those new fibres are 50 cm long, what implied a change in the mechanics of the sputtering machine. During that period we continue also with the characterization of the aluminized fibres in order to understand and optimize the quality of the polishing and aluminization. An ATLAS note is being prepared that summarises those works. We have participated in the test beam setup and data taking of the ALFA detector in October 2006, that had as main objective to validate the first electronics prototype and confirm the detector tracking resolution in a high energy proton/pion beam. We are now involved in the analysis of the data, and in particular in the evaluation of the cross talk, noise and fibre efficiency. This work is still going on.

Tilecal Detector Control System (DCS)
The development, installation and commissioning of the Tilecal Detector Control System (DCS) proceeded. In the beginning of the year a huge effort was dedicated to produce software able to make a safe switch on of the finger low voltage power supplies (fLVPS) of the calorimeter, that were designed and built with a feature that was setting the voltage to the maximum of the allowed range at switch on, creating a significative danger to the electronics located inside the drawers and powered by them. There was also a contribution in the review of the fLVPS, in such a way that the respective design becomes safe. Due to the number of fLVPS already produced, the DCS still has to cope with unsafe fLVPS when the LHC starts late in 2007. The Oracle databases used to

store the DCS data were set up late in the summer, and the conditions database (COOL) was set up slightly later, and has been in use for the storage of fLVPS date in test mode. The Finite State Machine (FSM) of the LVPS was designed and a first prototype was put to work in December, during ATLAS Milestone 1 (M1) week, when the Tilecal, the LArg calorimeter and the ATLAS central DCS were set up together for the first time in the cavern. Along the year, we also put effort to help our colleagues of Clermont-Ferrand in the design, implementation and debugging of the HV DCS system, that finally starts to converge to a stable software that is able to monitor the drawers.

Characterization of scintillators, WLS fibres and ageing
The ATLAS detector is planned to have an operational life of 10 years (LHC), with a possible extension of 5 years (SLHC). The period of detector construction and commissioning spanned about 8 years. From previous measurements, the expected light loss in the fibres and scintillators due to natural ageing, is about 1% per year. So, in this extended operation scenario, the natural and accelerated ageing studies play a central role in predicting the evolution of the detector performance throughout its operational life, at the end of which the optical components will be more than 20 years old. We followed the optical ageing performing the optical quality control of 338 fibres of several production batches: - "Reference fibres", a set of 32 fibres with 200 cm length, from the tendering phase of the optical fibre procurement for the Tilecal. - "Non-aluminized mass production fibres", a set of 176 fibres with 200 cm length, from 6 different batches of the production runs for Tilecal. - "Aluminized mass production fibres", a set of 128 fibres from batch #6. They are divided in 8 subsets of 16 fibres, each with a different length, from 114 cm to 207 cm. After following for 6 years (8 years for the reference fibres) the light output and transmission of these 336 Tilecal WLS fibres, we reached these conclusions: - The fibre-to-fibre light output in each group of 16 fibres is at the level of 5% or less, the typical precision level of this measurement setup, as requested for the Tilecal performance. - Degradation on the attenuation length due to natural ageing for 4 years is lower than 5%. - No degradation of the mirror reflectivity is observed, within the experimental accuracy of 5%. It is planned to conclude soon the data analysis for the most recent measurements of aluminized and irradiated fibres.

Commissioning of ATLAS with cosmic muons
Our group was strongly involved in the ATLAS cosmic muon commissioning tests, having carried out the Tilecal data analysis for the various data taking periods: Tilecal standalone, or combined with the Liquid Argon (LAr) calorimeter or muon detector. The tasks carried out were the following: - The TileMuonFitter algorithm was fully conceived, developed and tested by our group in 2006. This tool reconstructs the track and time of cosmic muons using Tilecal information only. The goal is to provide the optimal filter energy reconstruction in the Liquid Argon calorimeter with a time reference, and to calculate the path length travelled by the muon in the calorimeter, in order to improve the energy response uniformity. This algorithm has been already extensively used in several Liquid Argon and Tilecal commissioning analyses. We started an analysis of test beam data to evaluate the dependency of the cell PMT imbalance (assimetry in measured energy) on the incidence point in the cell. The first results showed that this will lead to the use of the imbalance to improve the resolution on the phi coordinate in the TileMuonFitter cosmics reconstruction. - We also developed the TileCosmicsTrigger tool for the simulation of the Tilecal cosmic muon trigger board, that will be centrally used for the upcoming ATLAS combined cosmics simulations, to be done in 2007. - In what regards the Tilecal performance studies with cosmic muons, our emphasis was on: - data quality studies, such as the identification of noisy channels; - timing resolution studies: In this task we introduced the timing offsets from the LED calibration (due to differences in cable lengths in the Tilecal electronics drawer) in the data reconstruction, and calculated the exact offsets due to the WLS fibre lengths. - detector response uniformity studies: we calculated the imbalance in each cell, and grouped it according to sampling and module. We verified that the mean imbalance was smaller than 5% for all the tested modules, and that the modules with smaller mean imbalance were the ones calibrated with Cesium during test beam, as expected.

Jet Calibration at the Second Level Trigger
The Second Level Trigger of ATLAS (LVL2) runs simple reconstruction algorithms with the aim of confirming the signals provided by the first hardware trigger, in about 10 ms processing time. Given the fact that the dominant background for jets are also jets, the main difficulty of the jet trigger consists on measuring correctly the jet energy scale, with the best possible resolution, allowing to reject low energetic jets while keeping high efficiency for the jets over threshold. Therefore, the calibration is the main problem for the LVL2 jet reconstruction. During the year 2006, our group started to work in the jet calibration for the LVL2. In the first few months of the project, we implemented the software tools that were necessary to apply to the offline available calibration procedures in the LVL2. We chose a simple calibration method that is very robust and adequate for the short processing times of the trigger. The performance of this method was evaluated using Monte Carlo data samples

generated at CERN. The calibration constants were produced running the calibration jobs in the GRID, allowing to process very large amounts of data in short time. Afterwards, the jet energy scale and resolution were studied. We reached an energy scale that is correct within +/-2%. The calibration procedure also improves the resolution by a few %, for all energies. The results obtained with this work were presented in several collaboration meetings, including two dedicated calibration workshops.

W $\rightarrow \mu\nu$ production cross section measurement
The physics commissioning of the detector will start at the end of the year 2007, when the first proton-proton collisions at the LHC will happen. During this period, the first physics studies will be done, at the same time that the detector performance (resolutions, trigger and reconstruction efficiencies) is evaluated with real data. One of the first expected measurements at ATLAS will be the production cross sections of the electroweak bosons W,Z. In 2006, the group started already the preparation for these first physics studies using Monte Carlo simulated data to develop a procedure to measure the W production cross section in the decay channel W $\rightarrow \mu\nu$. The work started with the optimization of the signal selection requirements and the implementation of the software tools that were necessary. It continued with the preparation of the methods to extract the reconstruction efficiencies (tracking, muon identification and trigger) with real data, that are needed for the calculation of the cross section.

Top quark physics
In the top quark physics, our work focus on angular asymmetries and Flavour Changing Neutral Currents (FCNC). The LHC will be a top factory with a total t-tbar production cross-section of around 800 pb and single top production of about 300 pb. This fact allows to measure with high precision the Wtb vertex and the couplings of the top quark. Although the double top production is insensitive to the Vtb CKM matrix element, the angular asymmetries between the top quark decay products can nevertheless give valuable information on the structure of the Wtb vertex. These studies were presented in several conferences and were published in ATLAS notes, and are waiting to be published in international scientific journals. For the top quark FCNC processes, the main goal is to study signals of physics beyond the Standard Model (SM) associated to top quark rare decays at the LHC. The FCNC decays $t \rightarrow q\gamma$, $t \rightarrow qZ$ and $t \rightarrow qg$ were studied in the double top production channel. The analysis software was developed for all the channels, optimizing the signal to background ratios, using a probabilistic approach. A careful study of the statistical and systematic errors allowed to estimate the limits on the branching ratios for the different channels in the five sigma discovery and in the 95% confidence level limits. The results were presented in international conferences and workshops and were published as ATLAS notes. A publication in an international scientific journal is in preparation.

2.1.2 Fundings

Code	Funding	Start	End
POCI/FP/63422/2005	225.000 €	2005-06-01	2006-09-30
POCI/FP/63936/2005	220.000 €	2006-09-01	

2.1.3 Team

Project coordinator: Amélia Maio

Name	Status	%of time in project
Agostinho Gomes	Researcher (LIP)	100
Alexandre Moita	Technician (LIP)	11
Amélia Maio	Researcher (LIP/FCUL)	67
André Wemans	Researcher (FCTUNL)	13
António Amorim	Researcher (FCUL)	6
António Onofre	Researcher (LIP/UCPFF)	55
Carlos Marques	Student (LIP/FCUL) *	100
Carlos Silva	Technician (LIP)	14
Fernando Moita Ribeiro		7
Filipe Veloso	PhD student (LIP/FCT)	80
João Bastos	Post-Doc (LIP)	18
João Carvalho	Researcher (LIP/FCTUC)	40
João Faustino	Technician (LIP)	67
João Gentil	PhD student (LIP/FCUL)	100
João Pina	PhD student (LIP/FCUL)	100
João Santos	Master student (LIP)	67
José Maneira	Post-Doc (LIP/FCT)	100
José Pinhão	Technician (LIP)	5
José Silva	PhD student (LIP/FCUL)	100
Juan Aguilar-Saavedra	Researcher (LIP)	15
Luís Gurriana	Technician (LIP)	33
Manuel Maneira	Researcher (FCTUNL)	13
Nuno Castro	PhD student (LIP/FCT)	80
Patricia Conde	Post-Doc (LIP/FCT)	100
Pedro Jorge	Student (LIP/FCT) *	100
Sandra Alexandra Soares	Student (LIP)	25
Sandra Alexandra Soares	Student (LIP/FCUL)	25
Zita Lopes	Student (LIP)	50

2.1.4 Publications

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

- *Luminosity Measurement at ATLAS : Development, Construction and Test of Scintillating Fibre Prototype Detectors*
  A. Maio, J.P. Santos, J.G. Saraiva et al.
  NIMA, Volume 568, Issue 2, Pages 588-600

- *Characterization of plastic optical fibres with pulsed LEDs*
  J. Santos, A. Maio, J. G. Saraiva, J. Silva , L. Gurriana
  Nuclear Instrumentation and Methods A (accepted)

- *Ageing studies of wavelenght shifter fibres for the TILECAL/ATLAS experiment*
  J. Silva, A. Maio, J. Pina, J. Santos, J. G. Saraiva
  Nuclear Instrumentation and Methods A (accepted)

International Conference Proceedings

- *LHC sensitivity to top properties beyond the SM*
  N. Castro
  PoS(TOP2006)028 (submitted)

- *The CRESCERE Muon´s Lifetime Experiment*
  J. Santos, J. Augusto, A. Gomes, L. Gurriana, N. Lourenço, A. Maio, C. Marques, J. Silv

Internal Notes

- *The ATLAS sensitivity to new angular asymmetres in the top quark*
  Aguilar-Saavedra, J A; Bastos, J; Carvalho, J; Castro, N;
  ATL-COM-PHYS-2006-008 (submitted)

2.1.5 Presentations

Oral presentations in international conferences

- *Top properties beyond the SM*
  presented by Nuno Castro
  at TOP 2006 International Workshop on Top Quark Physics in Coimbra, Portugal.
- *Calibration and Monitoring of the ATLAS Tile Calorimeter*
  presented by João Carvalho
  at CALOR2006 in Chicago.

Poster presentations in international conferences

- *Characterization of plastic optical fibres with pulsed LEDs*
  presented by João Santos
  at 10th International Symposium on Radiation Physics in Coimbra.
- *Ageing studies of wavelength shifter fibers for the TILECAL/ATLAS experiment*
  presented by José Silva
  at 10th International Symposium on Radiation Physics in Coimbra.
- *The TileCal DCS Detector control system*
  presented by João Pina
  at 9th International Computational Accelerator Physics Conference in Chamonix Mont-Blanc, France.
- *The CRESCERE Muon´s Lifetime Experiment*
  presented by João Santos
  at IV International Conference on Multimedia and Information Technologies in Education in Sevilla, Spain.

Oral presentations in collaboration meetings

- *Simulation of Custom LVL1 Trigger Boards for Cosmics*
  presented by José Maneira
  at ATLAS Calorimeter Trigger Software in CERN.
- *Simulation of cosmics trigger board*
  presented by José Maneira
  at TileCal Performance in CERN (remote).
- *Thoughts on Hadronic Calibration for Jets and MissingET in the Trigger*
  presented by Patricia Conde
  at ATLAS Trigger & Physics Week in CERN.
- *New algorithm for Tile commissioning trigger simulation*
  presented by José Maneira
  at ATLAS Software & Computing in CERN (remote).
- *LVL2 Jet Algorithm*
  presented by Patricia Conde
  at PESA algorithms @ ATLAS Software Week in CERN.

- *A ´First´ look at 1M vs. 2M1 : ATHENA 9.1.2*
  presented by João Gentil
  at ATLAS CBT LAr+Tile pion analysis meeting in CERN.

- *Jet Calibration at the HLT*
  presented by Patricia Conde
  at ATLAS Hadronic Calibration Workshop in Munique, Alemanha.

- *Jet calibration at LVL2*
  presented by Patricia Conde
  at ATLAS Trigger & Physics Week in CERN.

- *LVL1 Jet trigger studies*
  presented by Patricia Conde
  at ATLAS PESA Algorithms and Performance in CERN.

- *Aluminisation of fibers*
  presented by Amélia Maio
  at Luminosity & Forward detectors working group in Stockholm.

- *Update on the LVL2 Jet Calibration*
  presented by Patricia Conde
  at ATLAS Jet/Tau/ETmiss Performance meeting in CERN.

- *Conditions data-base*
  presented by Carlos Marques
  at TileCal DCS in CERN.

- *Update on the LVL2 Jet Calibration studies*
  presented by Patricia Conde
  at ATLAS PESA Performance and Validation in CERN.

- *First study of W -> mu nu*
  presented by Pedro Jorge
  at ATLAS Standard Model meeting in CERN.

- *Tau/Jet/Etmiss HLT calibration*
  presented by Patricia Conde
  at ATLAS Calorimeter Calibration Workshop in Costa Brava, Spain.

- *Calibration with cosmic muons in TileCal*
  presented by José Maneira
  at Calorimeter Calibration Workshop in Sant Feliu de Guixols, Costa Brava, Spain.

- *Cosmic muons reconstruction*
  presented by José Maneira
  at TileCal Performance Development in CERN.

- *Condition Database*
  presented by Carlos Marques
  at TileCal Week Online DAQ Tools in CERN.

- *Cosmics Analysis (run 8035): First impressions*
  presented by João Gentil
  at TileCal Team 5 in CERN.

- *Conditions data-base*
  presented by Carlos Marques
  at TileCal DCS Meeting call in .

- *Jet calibration in the LVL2*
  presented by Patricia Conde
  at ATLAS Trigger & Physics Week in CERN.

- *Timing analysis of cosmic muons*
  presented by José Maneira
  at TileCal Team 4+5+Performance in CERN.

- *Timing analysis of cosmic muons*
  presented by José Maneira
  at TileCal Commissioning in CERN.

- *Imbalance as a measure of phi*
  presented by José Maneira
  at TileCal Team 4+5+Performance in CERN.

- *Cosmics Analysis*
  presented by João Gentil
  at Tilecal Team-4,5 + Performanc in CERN.

- *Tiles: Tiles DCS system*
  presented by João Pina
  at Phase 2 Commissioning in CERN.

- *Wmunu signal selection - update*
  presented by Pedro Jorge
  at ATLAS SM CSC note : Inclusive W,Z in CERN.

2.1.6 Academic Training

PhD Theses

- *Study of top quark decays and the structure of the Wtb vertex"*
  Nuno Castro, (on-going)

- *Production and decay of top quarks via FCNC at the LHC"*
  Filipe Veloso, (on-going)

- *O sistema de controlo do detector TILECAL/ATLAS"*
  João Pina, (on-going)

- *Measurement of the W -> mu nu production cross section with the ATLAS detector"*
  Pedro Jorge, (on-going)

Master Theses

- *Systematic Uncertainties on the W mass measurement with the ATLAS Detector"*
  Carlos Marques, (on-going)

2.1.7 Project Summary

	number
Articles in international journals (with direct contribution from LIP members)	3
International Conference Proceedings	2
Internal Notes	1
Oral presentations in international conferences	2
Poster presentations in international conferences	4
Oral presentations in collaboration meetings	27

2.2 Collaboration in the CMS experiment at CERN

2.2.1 Activity Report

Collaboration in the CMS Experiment at CERN

Resumo:
O LIP é membro da experiência Compact Muon Solenoid (CMS) no acelerador Large Hadron Collider (LHC) actualmente em construção no CERN. O objectivo da experiência é o estudo de colisões de protões e núcleos pesados a muito alta energia. Pretende-se investigar as propriedades fundamentais da matéria e, em particular, estudar a natureza da quebra de simetria na interacção electrofraca e a origem da massa das partículas. A actividade do LIP tem três componentes principais: 1) O desenvolvimento de hardware e software para o trigger e para o sistema de leitura de dados do calorímetro electromagnético; 2) Física das colisões protão-protão, em particular a pesquisa de dimensões suplementares e física do quark top explorando as possibilidades de descoberta proporcionadas pela energia do LHC; 3) Física de iões pesados, em particular o estudo do plasma de quarks e gluões através da análise da produção de quarkonia.
O Calorímetro Electromagnético (ECAL) é um detector de electrões e fotões com uma granularidade extremamente fina e uma excelente resolução em energia, que tornam este instrumento particularmente bem adaptado para as condições do LHC. O sistema de leitura de dados é responsável pela recolha dos dados produzidos pelos oitenta mil cristais PbWO4.
O trigger da experiência CMS/LHC no CERN é um sistema electrónico e computacional de elevado desempenho que processa em-linha os dados do detector provenientes de cerca de cem mil canais, para seleccionar electrões, fotões, muões, taus e eventos com energia perdida, assim como amostras de jets. O sistema de trigger executa a primeira etapa do processo de selecção na pesquisa de novas reacções físicas.

Project Coordinator:
João Varela

Summary of Activities:

The ECAL trigger and readout electronics system is now entering the final underground installation and commissioning phase. The Portuguese group has important responsibilities in the project. The Synchronization and Link Boards (SLB, 1210 boards), which are required to synchronize the ECAL and HCAL trigger data, were produced and tested. The Data Concentrator Cards (DCC, 70 boards), used for the data acquisition of the ECAL detector (and also of the RPC detector), were produced and tested. One hundred thousand 12-bit ADC chips in 0.25-micron rad-hard technology, developed by the Portuguese company Chipidea under contract with LIP, were produced and integrated in the ECAL frontend boards. The LIP group has a major role in the development and coordination of the ECAL online software, and is taking the lead in the installation and commissioning of the ECAL Off-Detector electronics in the underground service cavern USC55.
The LIP group is responsible for the operation of the ECAL data acquisition hardware and software in several integration setups and test beams at CERN since 2004. In 2006, this included the final detector assembling in the ECAL Supermodule Integration Center, the integration tests of ECAL Off-Detector Crates in the CMS Electronics Integration Center, the calibration and test of ECAL SMs in the electron beam H4, the test of the SLB trigger synchronization capabilities in the H4 pulsed beam, the combined ECAL and HCAL test in the beam line H2, and finally the major CMS integration effort at the Magnet Test and Cosmic Challenge (MTCC), last fall. It was during the MTCC that, for the first time, the CMS detector was closed, the superconducting solenoid achieved stable 4T magnetic field and a significant slice of the full CMS detector, trigger and data acquisition was operated smoothly, as a complete system, taking cosmic data in stable conditions.
Analysis of beam data was also included in the LIP activities in 2006: a) the analysis of the trigger data and validation of the SLB synchronization methods: b) the analysis of the H2 beam data to study the efficiency and selectivity of the electron trigger algorithms; c) the study of the ECAL calibration using mip particles. LIP took the full responsibility in these studies.
The preparation for physics analysis is becoming a major area of activities in CMS. The LIP group is actively taking part in this effort. The analysis of Universal Extra-Dimensions models that we developed in the context of the SUSY and Beyond Standard Model group was formally approved by CMS and published as a CMS Note. This work was also presented in a poster at the conference "Physics at LHC", in Cracow. A member of the LIP group presented in a plenary session of the same conference an overview with the title "Beyond Standard Model Physics at the Large Hadron Collider at CERN".
The organization of the physics activity in the LIP/CMS group was strongly reinforced in 2006. A senior physicist (M. Gallinaro) with long experience at the Tevatron joined the group and is taking a leading role in

the preparation for proton-proton physics. On the other hand, the heavy-ions physics LIP group lead by J. Seixas that had a leading role in the NA60 experiment at CERN (study of charmonia and open charm production in heavy-ion collisions at the SPS) is now integrated in the CMS experiment, aiming at an active participation in the heavy-ions LHC program. Finally, the leader of the LIP/CMS group (J. Varela) was recently appointed CMS Trigger Project Manager.

2.2.2 Fundings

Code	Funding	Start	End
RTN2-2001-00571	166.320 €	2003-03-01	2006-09-30
POCI/FP/63434/2005	225.000 €	2005-08-01	2006-09-30
POCI/FP/63922/2005	255.000 €	2006-09-01	

2.2.3 Team

Project coordinator: João Varela

Name	Status	%of time in project
Adarsh Jain	Master student (LIP)	100
André Tinoco Mendes	Post-Doc (LIP/IST)	68
Carlos Almeida	Researcher (INESC/IST)	21
Carlos Leong	PhD student (INESC)	4
Isabel Parreira	(INESC)	2
Isabel Teixeira	Researcher (IST/INESC)	19
João Pela	Graduate student (LIP/IST)	29
João Seixas	Researcher (LIP/IST)	38
João Teixeira	Researcher (IST/INESC)	21
João Varela	Researcher (LIP/FCT)	78
Jorge Semião	Technician (INESC)	21
José Carlos Silva	Technician (LIP)	100
José Soares Augusto	Researcher (IST/INESC)	25
Malgorzata Kazana	Post-Doc (LIP)	100
Marcelino Santos	Researcher (INESC/IST)	21
Marcelo Jordão	Graduate student (LIP)	29
Michal Husejko	Student (LIP)	100
Michele Gallinaro	Researcher (LIP)	100
Miguel Ferreira	Technician (LIP)	63
Nuno Almeida	PhD student (LIP/FCT) *	100
Pasquale Musella	PhD student (LIP/FCT)	100
Paula Bordalo	Researcher (LIP)	10
Pedro Bento	PhD student (INESC)	17
Pedro Manuel Silva	PhD student (LIP/FCT)	100
Pedro Martins	PhD student (LIP/IST)	8
Pedro Parracho	Technician (LIP/AdI)	8
Pedro Ramalhete	Technician (LIP/AdI)	8
Pedro Ribeiro	PhD student (LIP/FCT)	100
Reyes Alemany	Post-Doc (LIP)	100
Rui Neto	Graduate student (LIP)	29
Sérgio Ramos	Researcher (LIP)	10

2.2.4 Publications

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

- *Reconstruction of the signal amplitude of the CMS electromagnetic calorimeter*
  The CMS Electromagnetic Calorimeter Group
  Submitted to Eur. Phys. J. (submitted)

- *Calorimeter trigger synchronization in the CMS experiment*
  N. Almeida, J.C. Da Silva, R. Alemany, C. Almeida, M. Santos, I. Teixeira, J.P. Teixeira, J. Varela

NIM A 568 (2006) 634641

- *Results of the first performance tests of the CMS electromagnetic calorimeter*
  The CMS Electromagnetic Calorimeter Group
  Eur Phys J C 44, s02, 110 (2006)

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

- *The CMS high level trigger*
  The CMS Collaboration
  Eur. Phys. J. C 46, 605667 (2006)

International Conference Proceedings

- *Hyperdaq Where Data Acquisition meets the Web*
  The CMS Data Acquisition Group
  ICALEPS 2005, Geneva

- *Installation and Commissioning of the CMS Timing, Trigger and Control Distribution System*
  Jan Troska, Tim Christiansen, Emlyn Corrin, Magnus Hansen, Daniel Martinho, Matthew Stettler, Joao Varela
  IEEE Nuclear Science Symposium, San Diego, California, 2006.

- *Beyond Standard Model Physics at the Large Hadron Collider at CERN*
  R. Alemany-Fernandez
  Conference Physics at LHC, Cracow, Poland, July 3-8, 2006, CMS CR 2006/057

- *Discovery potential for Universal Extra Dimensions signals with four leptons in the final state*
  M. Kazana
  Conference Physics at LHC, Cracow, Poland, July 3-8, 2006, CMS CR 2006/062

Collaboration notes with internal referee

- *Energy Resolution Performance of the CMS Electromagnetic Calorimeter*
  CMS Collaboration ECAL group
  CMS-NOTE-2006-140

- *Energy Resolution of the Barrel of the CMS Electromagnetic Calorimeter*
  CMS Collaboration ECAL group
  CMS-NOTE-2006-148

- *CMS DAQ Event Builder Based on Gigabit Ethernet*
  CMS Data Acquisition Group
  CMS CR-2006/033

- *The 2 Tbps Data to Surface System of the CMS Data Acquisition*
  The CMS Data Acquisition Group
  CMS CR-2006/034

Internal Notes

- *Discovery potential for Universal Extra Dimensions signals with four leptons in the final state*
  R. Alemany-Fernandez, M. Kazana, P. Ribeiro, J. Varela
  CMS AN-2006/008

2.2.5 Presentations

Oral presentations in international conferences

- *Discovery potential for Universal Extra Dimensions signals with four leptons in the final state*
  presented by Malgorzata Kazana
  at Conference Physics at LHC in Cracow, Poland.
- *Beyond Standard Model Physics at the Large Hadron Collider at CERN*
  presented by Reyes Alemany
  at Conference Physics at LHC in Cracow, Poland.

Oral presentations in collaboration meetings

- *SLB & TPG Integration*
  presented by José Carlos Silva
  at CMS Trigger Meeting in CERN.
- *DAQ interface to condition DB*
  presented by Pasquale Musella
  at Database meeting ECAL week in CERN.
- *Status of UED study (4 leptons final state)*
  presented by Malgorzata Kazana
  at CMS SUSY-BSM Meeting in CERN.
- *UED in 4-lepton final states*
  presented by Malgorzata Kazana
  at SUSY-BSM Meeting in CERN.
- *Trigger Tables: Tri-and tetra-lepton triggers for SUSY-BSM*
  presented by Malgorzata Kazana
  at Online Selection Group Meeting in CERN.
- *Status of DCS Integration*
  presented by João Varela
  at CMS Week DAQ General Meeting in CERN.
- *The ECAL Function Manager (RCMS)*
  presented by Reyes Alemany
  at ECAL DAQ meeting at the CMS WEEK in CERN.
- *Serial Link Boards*
  presented by José Carlos Silva
  at CMS Trigger Meeting in CERN.
- *The ecalBase package*
  presented by Pasquale Musella
  at ECAL DAQ meeting CMS WEEK in CERN.
- *DCS for MTCC*
  presented by João Varela
  at CMS week DAQ session in CERN.
- *Tri-and tetra-lepton triggers for SUSY-BSM*
  presented by Malgorzata Kazana
  at CMS Online Selection Group Meeting in CERN.

- *CMS Detector Control System*
  presented by João Varela
  at DCS Workshop in CERN.

- *Introduction to Trigger Software*
  presented by João Varela
  at Trigger Software Review in CERN.

- *Trigger databases*
  presented by João Varela
  at Trigger Software Review in CERN.

- *Search for Universal Extra Dimensions signals in 4 lepton + PTmiss final state*
  presented by Malgorzata Kazana
  at CMS AN approval meeting in CERN.

- *Status of the DAQ software development in view of the MTCC and Test Beam*
  presented by Reyes Alemany
  at ECAL TriDAS meeting at the ECAL Week in CERN.

- *904 Test System Software*
  presented by Pedro Manuel Silva
  at ECAL TriDAS meeting at the ECAL Week in CERN.

- *The L1 Trigger software: general introduction*
  presented by João Varela
  at ECAL trigger primitives workshop in CERN.

- *MTCC Synchronization & HLT: ECAL*
  presented by Reyes Alemany
  at Trigger Workshop in CERN.

- *SLB to RCT Cabling*
  presented by José Carlos Silva
  at CMS Trigger Meeting in CERN.

- *DCS : status and integration summary*
  presented by João Varela
  at Run meeting in CERN.

- *904 Test System Software, status report*
  presented by Pedro Manuel Silva
  at CMS ECAL TriDAS Software meeting in CERN.

- *UED wrap up*
  presented by Malgorzata Kazana
  at SUSY-BSM Meeting in CERN.

- *ECAL DAQ and Commissioning Software/Plans*
  presented by Reyes Alemany
  at CMS Annual Reviews (AR06) in CERN.

- *Off detector Electronics*
  presented by José Carlos Silva
  at CMS Annual Reviews (AR06) in CERN.

- *Trigger Software*
  presented by João Varela
  at CMS Annual Reviews (AR06) in CERN.

- *ECAL DAQ Status report*
  presented by Reyes Alemany
  at OPEN ECAL TCG in CERN.

- *SLB & Cal Trig cabling status*
  presented by José Carlos Silva
  at CMS Trigger Meeting in CERN.
- *Discovery potential for Universal Extra Dimensions signals with four leptons in the final state*
  presented by Malgorzata Kazana
  at CMS Physics Meeting in CERN.
- *ECAL DAQ status*
  presented by Reyes Alemany
  at LHCC Comprehensive Review (CR06) in CERN.
- *Trigger software*
  presented by João Varela
  at CMS LHCC Comprehensive Review (CR06) in CERN.
- *BSM at the LHC*
  presented by Reyes Alemany
  at CMS Pleanry Talks in CERN.
- *DCC/TCC Tester FW+SW*
  presented by Pedro Manuel Silva
  at ECAL Week Electronics Meeting in CERN.
- *DCC Production and Firmware Status*
  presented by João Varela
  at ECAL Week Electronics Meeting in CERN.
- *MTCC Trigger Integration Plan*
  presented by João Varela
  at CMS Trigger Meeting in CERN.
- *SLB & Cal Trig cabling*
  presented by José Carlos Silva
  at CMS Trigger Meeting in CERN.
- *Results from the muon scan*
  presented by Pasquale Musella
  at CMS ECAL cosmics IC WG in CERN.
- *Firmware and ECAL Off detector electronics*
  presented by José Carlos Silva
  at ECAL MTCC meeting in CERN.
- *MIP at H4: preliminary intercalibration*
  presented by Pasquale Musella
  at ECAL TB IC working group meeting in CERN.
- *MTCC Sub-system DCS*
  presented by João Varela
  at DAQ session CMS week in CERN.
- *ECAL TTC*
  presented by José Carlos Silva
  at TTC Trigger meeting in CERN.
- *Summary of TTC meeting with Subsystems*
  presented by João Varela
  at Electronics Systems Steering Committee in CERN.
- *Preliminary results on Intercalibration with MIPs at H4*
  presented by Pasquale Musella
  at ECAL Test Beam and Pre-calibration in CERN.

- *Trigger primitive generation at H4 test beam*
  presented by Pedro Manuel Silva
  at ECAL Test Beam and Pre-calibration in CERN.

- *L1 Trigger Electron Study*
  presented by Pedro Ribeiro
  at H2 ECAL Analysis Meeting in CERN.

- *Summary Status of L1 electron trigger study*
  presented by Pedro Ribeiro
  at Workshop Preparing for Physics in CMS in CERN.

- *Analysis of SLB data in H4 bunched beam*
  presented by André Tinoco Mendes
  at CMS Trigger Meeting in CERN.

- *SLB Status & Cabling*
  presented by José Carlos Silva
  at CMS Trigger Meeting in CERN.

- *Status and outlook of L1 Trigger commissioning*
  presented by João Varela
  at 2nd Workshop on CMS Startup in CERN.

Outreach seminars

- *Fisica para alem do Modelo Padrão e Dimensões Extra*
  presented by Pedro Ribeiro
  at Coloquio LIP, Experiencia CMS no Large Hadron Collider, IST in IST, Lisboa.

2.2.6 Academic Training

PhD Theses

- *Search for Universal Extra-Dimensions in proton-proton collisions at 14 TeV center-of-mass energy"*
  Pedro Ribeiro, (on-going)

- *Study of Universal Extra Dimensions signals with two photons and missing energy in the final state"*
  Pedro Manuel Silva, (on-going)

- *Physics Simulation and Reconstruction of Universal Extra Dimensions Processes in the CMS Experiment"*
  Pasquale Musella, (on-going)

2.2.7 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	4
Collaboration notes with internal referee	4
Internal Notes	1
Oral presentations in international conferences	2
Oral presentations in collaboration meetings	49
Outreach seminars	1

2.3 Collaboration in the COMPASS experiment at CERN

2.3.1 Activity Report

Sumário

A experiência COMPASS dedica-se ao estudo da estrutura da matéria, nomeadamente à polarização do gluão $\Delta G/G$ (através da fotoprodução de charme e da física de elevado p_T), às funções de estrutura relativas às componentes transversas e longitudinais do spin, e às funções de fragmentação. Com um feixe de hadrões, tem por objectivo o estudo de algumas questões espectroscópicas de actualidade, como a produção de novos mesões e bariões, nomeadamente exóticos, híbridos e partículas com charme duplo.
COMPASS usa feixes de alta intensidade, de muões polarizados (ou de hadrões) interagindo com um alvo polarizado longitudinalmente ou transversalmente (ou um alvo de microstrips de silício) 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 aquisiçã?o de dados baseia-se na leitura em paralelo da electrónica de front-end e num sistema distribuído de event-builders, especialmente concebidos para tratar grandes volumes de dados. De facto, durante o ano de 2006, a experiência COMPASS adquiriu 360 TeraByte de dados, perfazendo um total de 1400 TB desde 2002.
A farm de processamento de dados de COMPASS tem um desempenho do nível requerido em LHC e os primeiros resultados sobre medidas de assimetria começaram a ser publicados.
Desde a tomada de responsabilidade do Sistema de Controlo de Detectores (DCS) de COMPASS em fins de 2002, que o grupo do LIP-Lisboa tem vindo a desenvolver uma nova arquitectura, com notável esforço de recursos humanos, que não é ainda totalmente satisfatório.
Durante o shutdown do CERN em 2005 procedemos, tanto ao nível do software de topo, como ao nível das interfaces com os detectores, a novas e profundas alterações.
Na verdade, o DCS não pode ser um sistema estático ou um produto finalizado pois é constituído por várias camadas de packages cujas versões têm de ser compatíveis entre si, pelo que a alteração de um deles, muitas vezes com aspectos incompatíveis em relação à sua versão precedente, implica em geral a adaptação de todos os outros, o que é uma tarefa muito pesada.
Por outro lado, devido à contínua instalação de novos detectores, como sejam o novo magnete supracondutor de grande aceitância angular para a polarização do alvo da experiência, as novas câmaras que cobrirão essa nova aceitância angular, bem como os novos detectores específicos das próximas tomadas de dados com feixes de hadrões, o software do DCS (bem como 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 feito um grande reforço de recursos humanos em offline e análise de dados, nomeadamente na questão da eficiência para traços lentos do programa de reconstrução de COMPASS, na simulação das propriedades do detector RICH, equipado com novos detectores na região central, com vista ao cálculo da sua nova eficiência, e ainda em relação à análise de canais físicos, como sejam os estudos da polarização do gluão através do processo de charme aberto ou de eventos de grande pT, assim como as assimetrias de sabor do mar do nucleão.
Continuam em 2007 os longos períodos de 6 meses anuais de tomadas de dados de COMPASS, os quais, com a preparação técnica prévia e as longas estadas durante o run, pressupõem um nível de financiamento acrescido.

Summary

COMPASS experiment is dedicated to the study of the structure of matter, namely the gluon polarization DeltaG/G (from open charm photoproduction and high p_t physics), the longitudinal and the transverse spin structure and fragmentation functions. With a hadron beam, COMPASS aims to study some spectroscopy issues, as the production of new mesons and baryons, namely exotics, hybrids and double charmed particles.
COMPASS uses high intensity beams, that is, a polarized muon (or hadron) beam impinging on a longitudinally or transversely polarized target (or silicon microstrips 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 the original design, as stated in the accepted Proposal, each spectrometer is equipped with a magnet sorrounded 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. In fact, in 2006 COMPASS collected 360 TeraByte of data, totalizing 1400 TB since 2002.
COMPASS data processing farm also requires a LHC-like performance, and first results concerning asymmetries started to be published. Since late 2002, when our LIP-Lisbon group took in COMPASS the responsibility of the Detector Control System (DCS), a new system architecture has been developed. In that view, a big effort in human resources, nevertheless not sufficient, was undertaken.
Profiting from the 2005 CERN shutdown, new and major changes, both in the supervision (top) layer and in the front-ends layer (detectors interfaces), have been performed.
In fact, DCS can not be a static system or a finalised product, because it is formed by a set of several packages, disposed in layers but strongly interacting. This means that the packages versions must be compatible among them. Thus, changing one package version, which may even be not backward compatible with its previous one, may imply the change of all other packages versions. This is usually a heavy task.
On the other hand, the continuous COMPASS upgrade, in what concerns new detectors, also imposes successive changes in the DCS. Let us refer the installation of the new superconducting magnet for the target polarization, which new large acceptance imposed the installation of new tracking chambers to cope with, as well as several new detectors specific to the hadron beam runs, which are presently being installed for the 2007 data taking. 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, a great effort in human resources for offline and data analysis is being done. It includes the development of a new algorithm to cure the low efficiency of the COMPASS reconstruction program for slow tracks, the simulation of the new characteristics of the RICH detector, due to its new photon detectors in the central region, in view of the new efficiency calculation, and the analysis of physics channels, namely studies on the gluon polarisation from the open charm process or high p_T events, and flavour asymmetries of the nucleon sea.

Summary of the Activities

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.
Since 2006, the COMPASS experiment LIP group carried on the matters related with the working activities, namely:

- General activities
- Full responsibility of the Detector Control System (DCS)
- Offline and data analysis.

General Activities

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

- Participation in the Collaboration meetings
- Participation in the Steering Committee meetings (the Project Leader)
- Participation in the monthly offline and analysis meetings
- Participation in the technical friday meetings
- Participation in the data taking periods.

Detector Control System

In view of the preparation of the future hadron runs, new detectors were installed in the experimental area. These detectors are being included in the new DCS sheme. The DCS has also proceeded with the study of the issues for the integration of some already existing standalone detectors, as the LV systems for the RICH and Straw chambers.
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, whenever necessary.
In what concerns the analog variables, such as temperatures, humidities, etc., controled by the ELMB cards, a new line was installed in order to integrate in the DCS these types of parameters of some new detectors.
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 is the case of detectors gas systems. While this requires the permanent presence of one DCS expert, it also prevents the system to run in standalone mode (as everytime a sub-system is controling some detector).

Offline and Data Analysis

The study of the reconstruction efficiency for the low momentum tracks, based on a cellular automaton algorithm approach, has pursued. This is a problem for very complicated channels, e.g., multiple vertex events.
Simulation and reconstruction studies dealing with the geometrical description of photon trajectories in the new photon detection system of the RICH detector were performed. They led to new detector efficiency results, which were experimentally confirmed by the analysis of the 2006 RICH data.
Deep inelastic scattering inclusive asymmetries studies concerning all 2002, 2003 and 2004 statistics have been concluded, and a paper was submited.
Semi-inclusive asymmetries studies, in view of the separation of the spin flavour components, has started.
Data filtering for the subject of high p_T events in view of gluon polarisation studies, has been initiated.

Academic Training

- Luís Silva, Experimental Particle Physics PhD Thesis, pursuing
- Celso Franco, Experimental Particle Physics PhD Thesis, pursuing
- David Sora, Software Engineering Master Thesis, pursuing.

2.3.2 Fundings

Code	Funding	Start	End
010.6/B009/2005	252.000 €	2004-01-01	2008-12-31
POCI/FP/63431/2005	120.000 €	2005-05-01	2006-09-30
POCI/FP/63939/2005	130.000 €	2006-09-01	2007-08-31

2.3.3 Team

Project coordinator: Paula Bordalo

Name	Status	%of time in project
Catarina Quintans	Post-Doc (LIP/FCT) *	100
Celso Franco	PhD student (LIP/IST)	100
David Sora	Master student (LIP)	100
Francisco Pedro Mota	Student (LIP/CERN)	66
Helena Santos	Post-Doc (LIP/FCT)	100
João Cruz	Researcher (LIP/FCTUNL)	70
Luis Silva	PhD student (LIP/IST)	100
Paula Bordalo	Researcher (LIP)	100
Sérgio Ramos	Researcher (LIP)	100

2.3.4 Publications

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

- *Spin asymmetry A1d and the spin-dependent structure function g1d of the deuteron at low values of x and Q2*
  P. Bordalo, C. Quintans, S. Ramos, H. Santos, L. Silva et al.
  (accepted)

- *Spin asymmetry A1d and the spin-dependent structure function g1d of the deuteron at low values of x and Q2*
  P. Bordalo, C. Quintans, S. Ramos, H. Santos, L. Silva et al.
  CERN-PH-EP/2006-040 (accepted)

- *The Deuteron Spin-dependent Structure Function g1d and its First Moment*
  P. Bordalo, C. Quintans, S. Ramos, H. Santos, L. Silva et al.
  CERN-PH-EP/2006-029 hep-ex/0609038 (accepted)

International Conference Proceedings

- *New Results on the Spin-dependent Structure Function of the deuteron, g_1*
  H. Santos et al.
  Procs. of Symmetries and Spin (SPIN-Praha-2006)

- *Recent COMPASS Results on the Polarised Structure Function g1d of the*
  C. Quintans et al.
  Procs. of 17th International Spin Physics Symposium (SPIN06)

Collaboration notes with internal referee

- *RELEASE NOTE FOR INCLUSIVE ASYMMETRY A1d AND STRUCTURE FUNCTION g1d*
  H. Santos et al.

- *QCD ANALYSIS OF g1p,d,n INCLUDING THE COMPASS 02-03-04 g1d MEASUREMENTS*
  H. Santos et al.

2.3.5 Presentations

Oral presentations in international conferences

- *New Results on the Spin-dependent Structure Function of the deuteron, g_1*
  presented by Helena Santos
  at Advanced Studies Institute on Symmetries and Spin in Praha.

- *Recent COMPASS Results on the Polarised Structure Function g1d of the*
  presented by Catarina Quintans
  at 17th International Spin Physics Symposium (SPIN06) in Kyoto.

Presentations in national conferences

- *he spin-dependent structure function of the deuteron g1(x,Q^2)*
  presented by Helena Santos
  at V Encontro Nacional Física Hadrónica in Porto.

- *Longitudinal polarisation of lambda and anti-lambda in deep inelastic scattering at COMPASS*
  presented by Celso Franco
  at V Encontro Nacional Física Hadrónica in Porto.

- *Measurement of gluon polarisation from high transverse*
  presented by Luis Silva
  at V Encontro Nacional Física Hadrónica in Porto.

2.3.6 Academic Training

PhD Theses

- *COMPASS - Experimental Particle Physics Thesis"*
  Celso Franco, (on-going)
- *COMPASS - Experimental Particle Physics Thesis"*
  Luis Silva, (on-going)

Master Theses

- *COMPASS - Software Engineering Master Thesis"*
  David Sora, (on-going)

2.3.7 Project Summary

	number
Articles in international journals (with direct contribution from LIP members)	3
International Conference Proceedings	2
Collaboration notes with internal referee	1
Oral presentations in international conferences	2
Presentations in national conferences	3

2.4 Collaboration in the HADES experiment at GSI

2.4.1 Activity Report

Resumo:

A experiência HADES, no instituto alemão GSI, destina-se a investigar as propriedades dos mesões leves no seio da matéria nuclear. Esta investigação ajudará a esclarecer a origem física da maior parte da massa existente na matéria vulgar.
A participação do LIP nesta investigação, em associação com a Escola Superior de Tecnologia e Gestão de Leiria, consiste no projecto, teste, construção, instalação e exploração de um detector para identificação de partículas por tempo-de-voo.

Summary of the Activities:

The necessary semi-industrial infrastructure for the production of the HADES RPC TOF wall (1 prototype + 6 sextants, 1400 detectors) was put in place, mass production methods perfected and a the sextant (prototype) is now in production. The financing of the whole detector was already obtained via an EU FP6 project and GSI funds.
The possibility to extend the HADES physics goals to the measurement of K flow by an appropriate design of the RPC TOF system was investigated during the first part of 2006 by the new LIP researcher Alessio Mangiarotti. It is found that the RPC TOF wall has very good conditions for an accurate measurement of K-flow. A chapter on this subject was contributed to the HADES RPC TOF wall Techical Design Report.

2.4.2 Fundings

Code	Funding	Start	End
EU Contract 515876 DIRAC-Phase-1	52.000 €	2005-11-01	2009-10-31
LIP-GSI contract	414.000 €	2005-11-01	2009-10-31

2.4.3 Team

Project coordinator: Paulo Fonte

Name	Status	%of time in project
Alberto Blanco	Technician (LIP)	10
Alessio Mangiarotti	Researcher (LIP)	10
Carlos Capela	Researcher (ESTGL)	5
Carlos Neves	Researcher (ESTGL)	1
Carlos Sousa	Researcher (ESTGL)	10
Luís Lopes	Technician (LIP)	10
Milena Vieira	Researcher (ESTGL)	10
Paulo Fonte	Researcher (LIP/ISEC)	10

2.4.4 Publications

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

- *HADES experiment: Di-lepton spectroscopy in p+p (2.2 GeV) and C+C (1 and 2 A GeV) collisions*
  W.Przygoda and the HADES collaboration
  ACTA PHYSICA POLONICA B 37 (1): 139-151

Institute reports

- *Status of the HADES RPC Project*
  The HADES RPC Group
  GSI Scientific Report 2005

2.4.5 Presentations

Oral presentations in collaboration meetings

- *RPC: Beam and cosmic test results*
  presented by Luís Lopes
  at HADES Collaboration Meeting XVI in Dresden Germany.
- *RPC: K detection and wall design*
  presented by Alessio Mangiarotti
  at HADES Collaboration Meeting XVI in Dresden, Germany.
- *RPC: Construction status, summary and general outlook*
  presented by Paulo Fonte
  at HADES Collaboration Meeting XVI in Dresden, Germany.
- *Task HADES-1 status*
  presented by Paulo Fonte
  at CNI First Annual Reporting Meeting in GSI, Germany.
- *RPC status*
  presented by Paulo Fonte
  at HADES Collaboration Meeting XVII in GSI, Germany.

2.4.6 Project Summary

	number
Articles in international journals (with indirect contribution from LIP members)	1
Institute reports	1
Oral presentations in collaboration meetings	5

2.5 Participation in the NA60 experiment at CERN

2.5.1 Activity Report

The NA60 experiment is a fixed target experiment at the CERN/SPS accelerator which studies prompt dimuon and open charm production in collisions induced by high energy proton and heavy-ion beams.
During 2005-2006 the Portuguese group involved in NA60 participated in the two major tasks of the Collaboration: data analysis and maintenance of the experimental site. The latter is to a large extent finished, while the former is expected to continue during the next year, since the high quality proton-nucleus data is still to a large extent not analyzed.
We will now specify by task the work done.
Electronics Pool
The first detailed inventory of the Electronics Pool items in possession of NA60 was performed during this period. Given the large number of items NA60 is renting and the fact that many of them were unaccounted for, and had not been in use in NA60, it was not an easy task. A number of iterations between our group, the Electronics Pool and several labs in NA50 and NA60 were required to perform this task. An important fraction of the "lost" items were found.
In May it was decided to return all the Electronic pool modules to the Electronic pool, and we were in charge of this task.
A presentation about this subject was presented during the collaboration meeting on June 2006.
Data quality assurance
After the data collection (more than 3 terabytes) we need to start a number of checks over that data to make sure that the data available for analysis was collected during the correct operation of all the parts of the detectors and the DAQ systems.
DCS during data taking wrote in excess of 18 million entries in the original database. We went through the entries in the electronic logbook and checked whether the values in the fields of the database were correct. Furthermore a new database was created with a selection of the variables relevant for decisions related to the sampling of the initial data. After that we added two new fields to the database, viz. the raw size and number of segments that each run is occupying in tape.
Data selection
During the Proton run 2004, the NA60 apparatus suffered several changes, so after the run we tracked these changes and wrote setup files reflecting these changes in order that the reconstruction software could work correctly. This task also led to a division of the data sample in more manageable data sets.
The tasks performed in this context were
1. January - March 2005 Preliminary analysis of the 2004 proton data, performing the first data sampling
2. June - September 2005 Participation in the cataloging of the 2004 data and the creation of tools for detector alignment
3. October 2005 - January 2006 organization and selection of data samples in the 2004 data for a subsequent integration in the alignment and reconstruction processing
February - May 2006 Vertex Telescope (VT) alignment for the different experimental setups. Tool development for the second reconstruction phase of the data (prod2) (not yet finished) Preliminary alignment of the NA60 Vertex Tracker detectors in view of the 2004 pA data first reconstruction.
Coordination of efforts on the final realignment of the Vertex Tracked used in 2003 In-In run and reconstruction of the 2003 In-In data. Significant improvement of the tracking quality is achieved in still ongoing reconstruction.
4. Creation of an interface between the databases of the Detector Control System (DCS), the electronic logbook and na60root, the programming interface used for the NA60 physics analysis
5. Creation of a tool for data indexation(burst tagging tool).
6. June - July 2006 Second data reconstruction phase. Starting of the production study of J/psi and psi' in the 400 GeV p-A reconstructed data.
Resynchronization of the data
During the Indium run 2003 it was observed that sometimes the data recorded from the pixel detector was shifted by one to 3 events. During the data analysis of this run, a software tool was developed in NA60 that allowed the study of the correlation between the several pixel planes, the Zero Degree Calorimeter (ZDC) and the Interaction counter, and from these correlations he could get the number of events by which the data was shifted allowing thus the recovery of some of the data.
In the proton run 2004 the ZDC was not used and Microstrip modules were added to the vertex telescope. We changed the above mentioned code so that it could cope with the setup changes and to be able to run in the CERN Batch Services (lxbatch).

After thorough testing he did the resynchronization over ≈20% of the data collected in 2004 that is currently being processed in later stages.
This task was presented to the collaboration in the meeting of the 03-04 May 2006.
Work made on the Silicon Strip Detector
One of the detectors in the NA60 experiment is the Microstrip Telescope composed of several sensors of silicon microstrips. The purpose of this telescope is to track the secondary particles, including muons, produced as a result of an interaction in the target, before they enter in the hadron absorber. In conjunction with the Pixel Telescope it allows to:
1. Extract the coordinates of the interaction point
2. Measure the momentum and angles of the muons
3. Determine the muons offsets
4. Track the e+e- pair in the protons runs, coming from the converted gamma of the cbarc's radiative decay.
Charge Sharing
Whenever a silicon strip is hit by a particle, the adjacent strips share some of the deposited charge. If this information is used, we can obtain a better spatial resolution, deposited charge and maybe even improve the hit detection method.
After experimenting with many different methods, we tried using an algorithm named "Entropy Distance" and this one was able to identify with very good confidence the events where the charge sharing effect occurs.
This work is still in progress and will continue with the data from the 2004 run. Parallel to this, new more robust methods to detect hits in the Silicon Strip Detector are also being investigated and will be tested on the 2004 data.
Amplitude and Timing of Digits
We have devised several new methods to obtain the Amplitude and Time of a digit in the Silicon Strip detector (of NA60) and are currently fine-tuning them. The best of these methods seems to provide very accurate results with an error less than 7 ns for the time resolution which will allows eliminating digits that are out-of-time from the reconstruction process and in this way, have a more efficient reconstruction of events.
Basic software and hardware coordination activities
Our group has since the beginning of NA60 been responsible for a number of basic software and hardware activities in the Collaboration, namely:
1. System administration
2. Web page creation and NA60 site maintenance using Zope
3. Computer hardware maintenance
4. Setting up and constructing the PC farm used for Monte Carlo and data processing of NA60.
5. Disk server administration, where the reconstructed data and other relevant information is stored
Offline status and data analysis
The topic of my own physics studies was intermediate masses dimuons production in In-In collisions which is one of the main points in NA60 program: NA50 experiment has observed in Pb-Pb collisions an excess over expected dimuon sources in the range 1.2<M<2.7 GeV/c. The shape of the excess would favor en enhancement of open charm by factor ≈3 in central interactions which would be difficult to explain within pQCD framework. Thanks to its ability to measure the offset of the muons from the interaction point with precision of 40-50μm NA60 can solve this puzzle by distinguishing between the prompt dimuons and those originating in the open charm decays.
Within the responsibilities for the offline framework and data reconstruction of the group:
Development of methods and software for the subtraction of the:
i) combinatorial background from uncorrelated π,K → μ decays in
NA60 dimuon spectra.
ii) background from the "fake matches" between the muons from the
Muon Spectrometer and tracks in the Vertex Tracker of NA60.
Large samples of background dimuons were generated for further signal
extraction.
Preparation of summary ntuples with matched dimuons from first reconstruction of 2003 In-In data and corresponding artificial background samples.
They are used in the studies of all NA60 topics related to dimuon data. A major topic in the NA60 physics programme is intermediate masses dimuon production in In-In collisions: the NA50 experiment has observed in Pb-Pb collisions an excess over expected dimuon sources in the range 1.2<M<2.7 GeV/c. The shape of the excess would favor en enhancement of open charm by factor ≈3 in central interactions which would be difficult to explain within pQCD framework. Thanks to its ability to measure the offset of the muons from the interaction point with precision of 40-50μm NA60 can solve this puzzle by distinguishing between the prompt dimuons and those originating in the open charm decays.

The analysis confirmed the excess observed by NA50 and showed that it is caused by prompt (Drell-Yan and/or thermal) dimuons rather than open charm decays. Preliminary results of this study were presented at several conferences and will be published in the proceedings. These analysis continue using new reconstruction of In-In 2003 data.
Major results in the low mass region have also seen the light during 2005-2006. A first measurement of the ρ spectral function has been presented and a comparison with the available theoretical models has been made for the first time in heavy ion physics, which allowed ruling out some of these models and showing that in some cases no available models could accommodate part of the existing NA60 data.
More recently two other items have been subject to preliminary studies from the portuguese group, namely the channel D0->K-pi+ and ultra-peripheral collisions in In-In. Both are presently actively pursued, but it is still too soon to present any results on this report.

2.5.2 Fundings

Code	Funding	Start	End
POCI/FP/63919/2005	25.000 €	2006-09-01	

2.5.3 Team

Project coordinator: João Seixas

Name	Status	%of time in project
André Tinoco Mendes	Post-Doc (LIP/IST)	100
tila Neves	PhD student (LIP)	100
João Seixas	Researcher (LIP/IST)	100
Markus Keil	Researcher (CERN)	50
Pedro Martins	PhD student (LIP/IST)	100
Pedro Parracho	Technician (LIP/AdI)	23
Peter Sonderegger	Researcher (LIP)	10
Rob Veenhof	Researcher (CFTP)	100
Ruben Shahoyan	Post-Doc (LIP/CERN)	100

2.5.4 Publications

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

- *First Measurement of the rho Spectral Function in High-Energy Nuclear Collisions*
  NA60 Collaboration
  Phys. Rev. Lett. 96, 162302 (2006)

International Conference Proceedings

- *NA60 results on the rho spectral function in Indium-Indium collisions*
  J. Seixas (NA60 Collaboration)
  presented at Quark Matter ´06, Shanghai, China November 14-20, 2006 (submitted)

2.5.5 Project Summary

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

2.6 Physics at LHC

2.6.1 Activity Report

Resumo:

Por forma a cobrir o campo de física aberto pelo programa do Large Hadron Collider (LHC) que se encontra em fase de instalação no Centro Europeu de Pesquisa Nuclear (CERN) em Genebra, é fundamental um importante esforço conjunto de preparação da comunidade experimental e teórica de Física de Partículas Elementares. Este esforço deve ser concentrado não apenas no estudo dos melhores observáveis físicos disponíveis no LHC, para realizar testes de precisão do Modelo Padrão (SM) da Física Elementar de Partículas, mas também no desenvolvimento de novas ideias de Física para além do SM. Com o objectivo de concretizar uma estreita colaboração entre a comunidade de Físicos Experimentais e Teóricos de Partículas, foram propostas várias tarefas no âmbito do presente projecto, e cujo estado actual se passa a descrever.
A primeira tarefa envolveu o estudo de processos associados a correntes neutras com troca de sabor (FCNC) na produção simples de quarks top em LHC. Para o efeito foi desenvolvido um modelo teórico efectivo e estudado o impacto de novos acoplamentos em observáveis físicos em LHC. Os novos processos foram incluidos em geradores Monte Carlo de LHC (TopRex) e verificou-se que a sua importância não pode ser ignorada em LHC face aos canais normais de produção directa.
Outra tarefa desenvolvida no âmbito deste projecto, envolveu o estudo de assimetrias em decaimentos do quark top. 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 (rhoR e rhoL). Foi possível verificar que os novos observáveis introduzidos são mais sensíveis aos acoplamentos anómalos vectoriais e tensoriais do que os previamente utilizados em LHC.
No âmbito do presente projecto tem sido ainda estudada a radiação dos quarks tops (para gluões, fotões e Zs). Esta pesquisa incide numa primeira fase, no estudo da produção dupla de quarks top acompanhados de um fotão energético que vai permitir estudar os factores de forma do quark top em LHC.

Summary of the Activities:

In order to address the physics potential of the LHC program, a significant joint effort of the experimental and theoretical particle physics community is required. This effort must consider not only the study of the best physical observables to perform a precise test of the Standard Model (SM) of Elementary Particle Physics at LHC, but also to develop new ideas for physics beyond the SM. Several tasks were proposed in the present project to implement a strong collaboration between experimental and theoretical particle physicists. The status of such tasks is sumarized in what follows.

Single Top via FCNC
The main goal of this task is to study signals of physics beyond the SM in single top quark Flavour Changing Neutral Currents (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.
Current status of the present task: the theoretical model is well developed (with publications in international scientific journals and presentations in conferences) and its implementation within the framework of the TOPREX generator is done. Studies already performed show that these new contributions cannot be ignored at the LHC when compared to the direct process: they give the same order of magnitude contributions to the overall single top production cross-section via FCNC.

Forward-Backward Asymmetries
The LHC will be a top factory with a total t-tbar production cross-section of around 800pb and single-top production of around 300pb. This fact allows to measure with high precision the Wtb vertex and the couplings of the top quark. Although the double top production is insensitive to the Vtb CKM matrix element, the angular asymmetries between the top quark decay products can nevertheless give valuable information on the structure of the Wtb vertex. New right-handed couplings can be introduced within an effective lagrangian approach which can be probed at the LHC.

Current status of the present task: New asymmetries (A+ and A-) and new W polarization states ratios (rhoR and rhoL) were introduced and tested at the LHC. The studies performed with several Monte Carlo generators (TOPREX, ALPGEN, MC@NLO, etc.) have shown that the new observables are more sensitive to vector and tensor like (right and left) anomalous top couplings.

Study of Electroweak Top Quark Couplings
The study of the electroweak couplings of the top quark started with the pp->ttgamma process which is the more promising channel at the moment. This study will allow to probe the top quark charge and will lead to a better understanding of the form factors associated to the top quark.
Current status of the present task: this task is under way. A new Monte Carlo generator was developed to generate the ttgamma physics process. This generator will allow to perform a comparative study of the t-tbar production cross-sections (with and without energetic photons) at the LHC.

2.6.2 Fundings

Code	Funding	Start	End
POCI/FP/63420/2005	36.000 €	2005-06-01	2006-12-31
POCI/ FP/63926/2005	20.000 €	2006-11-01	

2.6.3 Team

Project coordinator: António Onofre

Name	Status	%of time in project
Amélia Maio	Researcher (LIP/FCUL)	5
António Onofre	Researcher (LIP/UCPFF)	30
Augusto Barroso	Researcher (FCUL)	5
Filipe Veloso	PhD student (LIP/FCT)	30
Helmut Wolters	Researcher (LIP/UCPFF)	7
João Bastos	Post-Doc (LIP)	69
João Carvalho	Researcher (LIP/FCTUC)	40
João Silva	Technician (LIP)	10
Matilde Castanheira	Master student (LIP)	17
Nuno Castro	PhD student (LIP/FCT)	30
Orlando Oliveira	Researcher (LIP/FCTUC)	5
Pedro Martins Ferreira	Researcher (LIP/FCUL)	5
Renato Guedes Júnior	Researcher (LIP/FCUL)	5
Rui Santos	Researcher (LIP/FCUL)	5

2.6.4 Publications

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

- *Probing anomalous Wtb couplings in top pair decays*
  J. A. Aguilar-Saavedra, J. Carvalho, N. Castro, A. Onofre, F. Veloso
  hep-ph/0605190 (submitted)

- *Strong flavour changing effective operator contributions to single top quark production (10)*
  P. M. Ferreira, R. Santos
  Phys.Rev. D73 (2006) 054025 (accepted)

- *Contributions from dimension six strong flavor changing operators to top anti-top, top plus gauge boson, and top plus Higgs boson production at the LHC*
  P. M. Ferreira, R. Santos
  Phys.Rev. D74 (2006) 014006 (accepted)

International Conference Proceedings

- *LHC sensitivity to top properties beyond the SM*
  N. Castro
  PoS(TOP2006)028 (submitted)

Internal Notes

- *The ATLAS sensitivity to new angular asymmetres in the top quark*
  Aguilar-Saavedra, J A; Bastos, J; Carvalho, J; Castro, N;
  ATL-COM-PHYS-2006-008 (submitted)

- *Study of the ATLAS sensitivity to angular asymmetries in top quark decays (09)*
  Aguilar-Saavedra, J A; Carvalho, J; Castro, N; Onofre, A; Veloso, F
  ATL-PHYS-PUB-2006-018 (accepted)

2.6.5 Presentations

Oral presentations in international conferences

- *Top properties beyond the SM*
  presented by Nuno Castro
  at TOP 2006 International Workshop on Top Quark Physics in Coimbra, Portugal.

- *Contributions from flavour changing effective operators to the physics of the top quark at LHC*
  presented by Pedro Martins Ferreira
  at International Workshop on Top Quark Physics, TOP2006 in Coimbra, Portugal.

- *Status report on the top FCNC studies at the LHC*
  presented by Nuno Castro
  at Flavour in the era of the LHC in CERN, Geneve, Suiça.

- *Studies of top quark decay asymmetries*
  presented by João Carvalho
  at Flavour in the era of the LHC in CERN, Geneve, Suiça.

- *Top physics at the LHC: testing SM in ttbar and single top production*
  presented by António Onofre
  at ICHEP 06 in ICHEP 06: XXXIII International Conference on High Energy Physics - Moscow.

- *Contributions from dimension five and six effective operators to flavour changing top physics*
  presented by Pedro Martins Ferreira
  at Flavour in the era of the LHC (4th meeting) in Flavour in the era of the LHC (4th meeting) - CERN.

- *Wtb Anomalous Top Quark Couplings*
  presented by António Onofre
  at Flavour in the era of the LHC (4th meeting) in Flavour in the era of the LHC (4th meeting) - CERN.

Oral presentations in collaboration meetings

- *Determining top couplings*
  presented by António Onofre
  at ATLAS Overview Week in ATLAS Overview Week - CERN.

2.6.6 Events

- *TOP2006-International Workshop on Top Quark Physics*
  Workshop, Coimbra, Portugal, 2006-01-12

2.6.7 Project Summary

	number
Articles in international journals (with direct contribution from LIP members)	2
International Conference Proceedings	1
Internal Notes	2
Oral presentations in international conferences	7
Oral presentations in collaboration meetings	1
Workshops	1

2.7 Collaboration in the DELPHI experiment at CERN

2.7.1 Activity Report

Resumo:

O grupo DELPHI do LIP tem desenvolvido as suas actividades segundo o plano anteriormente definido, e que consiste na obtenção dos melhores resultados possíveis a partir dos dados da experiência DELPHI, cujo detector funcionou no acelerador LEP do CERN entre 1989 e 2000. Na fase actual de conclusão de análises de dados e preparação de artigos finais, a participação dos membros de DELPHI do LIP teve lugar nos grupos de física "QCD/gamma-gamma"e "Exotica - Pesquisas de sinais de nova física", bem como na coordenação destes e das respectivas linhas de pesquisa.
No ano de 2006 foi aceite para publicação 1 artigo e submetido outro, ambos sob responsabilidade de membros do grupo LIP/DELPHI. Foram ainda publicados 3 artigos em Actas de Conferências Internacionais com Edição. Foram ainda enviadas, na forma de Notas DELPHI, três comunicações científicas a conferências internacionais (com revisão científica por membros da colaboração). Foram ainda preparados 2 artigos que foram submetidos à Colaboração e que estão neste momento em diferentes estados de discussão ou preparação avançada.

Summary of Activities:

In the year 2006, the LIP/DELPHI group carried on the program of finishing the analyses and preparation of papers and communications to international conferences, as detailed in the previous plan of activities. In 2006, one paper was accepted and another was submitted for publication, both under the responsibility of members of the LIP-DELPHI team.
In 2006 LIP members wrote also three contributions to the Proceedings of International Conferences, and three communications to international conferences. At this stage there are still 2 articles in advanced state of discussion in the Collaboration, to be submitted for publication, under the responsibility of the LIP-DELPHI team. The Ph. D. program of Nuno Anjos, with the title of "Hadronic final states at LEPII" has progressed and is expected to be concluded in 2007.

2.7.2 Fundings

Code	Funding	Start	End

2.7.3 Team

Project coordinator: Pedro Abreu

Name	Status	%of time in project
António Onofre	Researcher (LIP/UCPFF)	8
Catarina Espírito Santo	Researcher (LIP)	5
Filipe Veloso	PhD student (LIP/FCT)	10
Nuno Anjos	PhD student (LIP)	100
Nuno Castro	PhD student (LIP/FCT)	10
Pedro Abreu	Researcher (LIP/IST)	15

2.7.4 Publications

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

- *Search for excited leptons in e+e- collisions at sqrt(s)=189-209 GeV*
  J. Abdallah et al., The DELPHI Collaboration
  Eur. Phys. J. C46 (2006) 277 (accepted)

- *Search for a fourth generation b´ -quark at LEP-II at sqrt(s)=196-209 GeV*
  J. Abdallah et al. (The DELPHI Collaboration)
  PH-EP 2006-023 (accepted)

- *Investigation of Colour Reconnection in WW Events with the DELPHI detector at LEP-2*
  J. Abdallah et al. (The DELPHI Collaboration)
  PH-EP 2006-037 (submitted)

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

- *Measurement and Interpretation of Fermion-Pair Production at LEP energies above the Z0 Resonance*
  J. Abdallah et al., The DELPHI Collaboration
  Eur. Phys. J. C45 (2006) 589-632

- *Search for neutral MSSM Higgs bosons at LEP*
  S. Schael et al. (The ALEPH Collaboration and DELPHI Collaboration and L3 Collaboration and OPAL Collaborations and LEP Working Group for Higgs Boson Searches)
  Eur.Phys.J.C47:547-587,2006

- *Search for η_b in two-photon collisions at LEP II with the DELPHI detector*
  J. Abdallah et al., The DELPHI Collaboration
  Phys. Lett. B634 (2006) 340-346

- *Determination of the b quark mass at the M(Z) scale with the DELPHI detector at LEP*
  J. Abdallah et al. (The DELPHI Collaboration)
  Eur.Phys.J.C46:569-583,2006

- *Evidence for an excess of soft photons in hadronic decays of Z*
  J. Abdallah et al. (The DELPHI Collaboration)
  Eur.Phys.J.C47:273-294,2006

- *Masses, Lifetimes and Production Rates of Xi- and anti-Xi+ at LEP 1*
  J. Abdallah et al. (The DELPHI Collaboration)
  Phys.Lett.B639:179-191,2006

- *Study of Leading Hadrons in Gluon and Quark Fragmentation*
  J. Abdallah et al. (The DELPHI Collaboration)
  Phys.Lett.B643:147-157,2006

International Conference Proceedings

- *Bose-Einstein correlations in DELPHI W W events at LEP2*
  P. Abreu for The DELPHI Collaboration
  Nucl.Phys.Proc.Suppl.152:31-34,2006

- *Final state QCD studies at LEP: Part I*
  P. Abreu for The DELPHI Collaboration
  PoS HEP2005:038,2006

- *Final state QCD studies at LEP: Part II*
  N. Anjos for The DELPHI Collaboration
  PoS HEP2005:062,2006

- *Search for excited fermions*
  B. Tome for The DELPHI Collaboration
  PoS HEP2005:313,2006

2.7.5 Presentations

Presentations in national conferences

- *Search for Pentaquark states in Z decays at LEP*
  presented by Pedro Abreu
  at V Encontro Nacional de Física Hadrónica in F.E.U.P., Porto, Portugal.

2.7.6 Academic Training

PhD Theses

- *Hadronic Final States at LEP II"*
  Nuno Anjos, (on-going)

2.7.7 Project Summary

	number
Articles in international journals (with direct contribution from LIP members)	2
Articles in international journals (with indirect contribution from LIP members)	7
International Conference Proceedings	4
Presentations in national conferences	1

Chapter 3

Computing

3.1 Grid Computing

3.1.1 Activity Report

Resumo:

A computação Grid é um paradigma de computação que consiste na agregação de recursos computacionais autónomos, heterogéneos e distribuídos numa única infra-estrutura. Uma Grid esconde as especificidades dos recursos que a constituem possibilitando um acesso fácil e transparente a meios de cálculo poderosos.
O LIP encontra-se envolvido em vários projectos nacionais e internacionais que têm por objectivo o desenvolvimento e a aplicação de tecnologias Grid para cálculo científico e em especial para o LHC. Durante 2006 o LIP reforçou as suas infra-estruturas de computação, e participou nos projectos Worldwide LHC Computing Grid (WLCG), E-infrastructure shared between Europe and Latin América (EELA), Interactive European Grid (int.eu.grid) e ainda na fase final do projecto Europeu Enabling Grids for E-Science (EGEE), e no novo projecto Europeu Enabling Grids for E-Science - II (EGEE-II). O LIP teve ainda um papel importante no lançamento da iniciativa nacional grid.

Summary of Activities:

During 2006 the LIP computing team pursued its line of work in the area of grid computing. In this context LIP continued its participation in several international grid projects aimed at improving the international grid computing infrastructures and providing production quality grid computing services for scientific researchers. The activities were mostly driven by the participation in the CERN Worlwide LHC Computing Grid project (WLCG) in which the Portuguese contribution is now officially defined through the signature of the WLCG MoU by the Portuguese government. In addition LIP continued its participation in the European project EGEE phase-I that finished in March 2006.The activities were also deeply influenced by the participation in three new European projects: Enabling Grids for E-Science - II (EGEE-II), E-infrastructure shared between Europe and Latin America (EELA) and Interactive European Grid (int.eu.grid). All these projects plan to extend the existing generic grid production infrastructures for all scientific domains including High Energy Physics.

- WLCG is the CERN project that is responsible for deploying and maintaining the computing infrastructure for the LHC experiments. This infrastructure will integrate more than 100,000 computers distributed in high-energy physics laboratories worldwide and is already the largest problem oriented grid infrastructure ever attempted. The WLCG project is closely related with the European Union project EGEE that is currently providing the operations, user support and training for WLCG in Europe.

- EGEE and EGEE-II are the European Union flagship projects in the area of grid computing infrastructures for science. The EGEE project is coordinated by CERN and operates a production Grid infrastructure for scientific computing open to all scientific domains. EGEE provides middleware reengineering, support, integration, and coordination of computing resources. The EGEE infrastructure is the largest multidisciplinary Grid in the world. The WLCG resources are integrated and managed as part of the EGEE infrastructure. Similarly many of the LCG and EGEE services are being shared by both infrastructures. The EGEE phase-I was finished in March 2006 and was immediately followed by the EGEE-II project that started in April 2006 with duration of two more years. The EGEE-II project is still coordinated by CERN and has now 90 partners from 32 countries organized into 12 regional federations. LIP is the

only EGEE Portuguese partner and is a member of the EGEE Southwest federation jointly with several Spanish research institutes.

- EELA is a European Union funded project that aims to bring the e-Infrastructures of Latin American countries to the level of those of Europe. EELA benefits from the mature state of the ALICE project and of the RedCLARA network to focus on the dissemination and deployment of Grid technologies and related e-Science applications. The EELA project is coordinated by CIEMAT in Spain and has 21 partners from European and Latin American countries. EELA is building a grid infrastructure interoperable with EGEE and WLCG.

- The interactive European Grid project (int.eu.grid) is a European Union funded project that aims to provide a production quality grid infrastructure for demanding interactive and parallel (MPI) applications for all scientific domains. The int.eu.grid infrastructure is interoperable with EGEE and uses the gLite middleware building blocks to provide additional services targeted at supporting this class of applications. The int.eu.grid project is based on the developments of the CrossGrid project. Both CrossGrid and int.eu.grid included a strong Portuguese and Spanish contribution. The int.eu.grid project infrastructure is currently composed of 12 different computing sites across Europe, in Spain, Portugal, Germany, Poland, Austria, Slovakia, and Ireland. The project is coordinated by IFCA in Spain.

LIP Tier-2
Following the WLCG MoU agreement signed in 2006 LIP will operate a federated Tier-2 supporting both the ATLAS and CMS experiments. Sites in Lisbon and Coimbra will integrate the federated LIP Tier-2.
In order to accommodate the always-increasing computing requirements during 2006 the Lisbon computer centre suffered a major infrastructure improvement with a new data-centre facility that entered into operation during last summer. Thanks to this effort that started in 2005 it was possible to increase significantly the LIP computing capacity. New worker nodes have been added to the cluster, the resource management system was fully replaced, the storage capacity was increased and the network connectivity was upgraded. The LIP presence in the grid was much improved and the WLCG related activities are now operating in better conditions. In the same context the grid storage architecture at LIP was deeply modified with the introduction of a dcache storage manager and its SRM grid counterpart. The dcache storage system can also be used by non-grid applications and is now the recommended approach for data storage at LIP-Lisbon.
The Tier-2 component at Coimbra will be hosted at the "Centro de Física Computacional (CFC)" and will be initially based on a cluster of systems inherited from this research institute that is being improved with additional storage recently acquired. The conversion of the cluster for grid computing started in the summer of 2006.

National grid initiative
In addition to these LHC specific activities LIP was involved in the first steps of establishing a national grid initiative namely through the support for the organization of the first national grid initiative workshop (INGRID'06) that was held in Braga in November.

EGEE
The participation in the EGEE phase-I project ended successfully in March. The project review highlighted the importance of this project and its international dimension. The EGEE-II project started immediately after in April with a wider geographic coverage. The LIP responsibilities in EGEE-II remain basically unchanged however now the range of activities also includes dissemination and training. LIP is an active member of the EGEE SouthWest federation jointly with Spain and is a member of the EGEE SWE distributed regional operations centre (ROC) responsible for the management and coordination of grid computing resources and services in the region. In this context LIP is: operating two grid clusters integrated in the EGEE production and pre-production infrastructures, doing the trouble tickets management and first line support for the whole federation, performing the trouble tickets management for the whole EGEE infrastructure by participating in the TPM shifts, supporting users and site managers in the SWE region, coordinating the middleware deployment and site certification for Portugal, participating in the SGE integration team jointly with CESGA and UCL, finally is operating grid core services for the federation. In addition LIP is acting as SWE operations deputy (Mario David) and as SWE federation coordinator deputy with responsibilities in Portugal and Spain (Jorge Gomes).

EELA
The EELA project started in January of 2006. LIP is coordinating the EELA certification authorities and virtual

organizations task. Within this context LIP is responsible for the setup of grid authentication and authorization infrastructures supporting the secure and seamless access to computing resources between Europe and Latin America. During 2006 LIP has been responsible for coordinating the deployment of internationally accredited certification authorities in Latin America (CAs). The first result from this effort was the accreditation of the Brazilian BrGrid CA by the international Grid Trust Federation (IGTF) through the Americas Policy Management Authority (TAGPMA) in the summer of 2006. Currently the CAs from Argentina, Chile and EELA-LatinAmerica-catchall are at the final accreditation stage, and the CAs from Venezuela and Mexico are currently in the process of accreditation. A temporary authentication infrastructure based on a network of registration authorities subordinated to the EUgridPMA catchall operated by CNRS has been established also under the coordination of LIP. The authorization infrastructure has been established based on the Virtual Organizations Membership Service (VOMS), the infrastructure is based on two core authentication servers located at LIP and UFRJ (Rio de Janeiro) that support the EELA virtual organizations (VO) and are operated by LIP. A file replica catalogue for the EELA VOs has also been established at LIP.

int.eu.grid
The int.eu.grid project started in May 2006. LIP is playing an important role in the infrastructure operations and is also responsible by the authorization infrastructure and core services operation. LIP is also contributing to the helpdesk and to the test and validation activities. In this context LIP is: coordinating the production infrastructure operation and deployment, operating production grid core services, operating a VOMS authentication infrastructure with backup services at IFCA in Spain, developing components necessary for proper site operation, providing support to users and site managers, performing site validation, and coordinating the overall grid infrastructure operation. The infrastructure architecture was defined by LIP in collaboration with the project middleware developers. Still in 2006 the infrastructure from the CrossGrid project was migrated to int.eu.grid under the LIP coordination.

3.1.2 Fundings

Code	Funding	Start	End
EGEE (INFSO 508833)	247.500 €	2004-04-01	2006-03-31
EGEE-complement (010.6/B002/2005)	119.250 €	2005-04-01	2006-03-31
EGEE-additional (POCI/V.5/A016/2005)	100.000 €	2005-05-01	2006-04-30
EELA (026409)	78.000 €	2006-01-01	2007-12-31
EGEE-II (RI-031688)	274.888 €	2006-04-01	2008-03-31
int.eu.grid (IST-7-031857)	154.000 €	2006-05-01	2008-04-30

3.1.3 Team

Project coordinator: Jorge Gomes

Name	Status	%of time in project
Bruno Silva	Technician (LIP)	100
Gaspar Barreira	Researcher (LIP)	35
Gonçalo Borges	Technician (LIP)	100
Hugo Gomes	Technician (LIP)	25
João Martins	Researcher (LIP)	100
Jorge Gomes	Researcher (LIP)	100
José Aparício	Technician (LIP)	100
Manuel Montecelo	Technician (LIP)	25
Mário David	Post-Doc (LIP/FCT)	100
Nuno Dias	Technician (LIP)	100

3.1.4 Publications

International Conference Proceedings

- *Operation and support of a grid infrastructure*
  M. David, G. Barreira, G. Borges, N.Dias, J.Gomes, J. P. Martins
  CISTI 2006, Vol II pag: 405-421, ISBN: 978-989-20-0271-2

- *Operation and management issues in the EGEE SWE grid infrastructure*
  G. Borges, G. Barreira, M.David, J. Gomes, N. Dias, J. P. Martins
  (accepted)

Collaboration notes with internal referee

- *EELA project plan*
  Diego Carvalho, Jorge Gomes, Pedro Raush, Iara Machado, Eriko Porto, Marcio Faerman, Michael Stanton
  EELA-D2 1 1-v1 5

- *Int.eu.grid interactive grid infrastructure status report*
  Jorge Gomes
  i2g-DSA1.1-v1.0-LIP-InteractiveGridInfrastructureStatusReport

3.1.5 Presentations

Oral presentations in international conferences

- *Training for GGUS supporters*
  presented by Mário David
  at EGEE´06 in Geneva.

- *Operation and management issues in the EGEE SWE grid infrastructure*
  presented by Gonçalo Borges
  at Krakow grid workshop in Krakow.

Oral presentations in international meetings

- *The EELA project authentication infrastructure*
  presented by Jorge Gomes
  at 6th EUgridPMA in Vienna.

- *Certification authorities and Virtual organizations*
  presented by Jorge Gomes
  at EELA KoM workshop in Madrid.

- *CA DEPLOYMENT Considerations about certification authorities deployment*
  presented by Jorge Gomes
  at EELA KoM workshop in Madrid.

- *Certification Authorities in LA and links with TAGPMA*
  presented by
  at 1st Latin American EELA Workshop in Mérida - Venezuela.

- *The gLite EGEE middleware*
  presented by Jorge Gomes
  at int.eu.grid workshop in Santander.

- *Prospectives for the int.eu.grid infrastructure*
  presented by Jorge Gomes
  at int.eu.grid KoM Workshop in Santander.

- *Operation and support of a grid Infrastructure*
  presented by Mário David
  at Conferência Ibérica de Sistemas e Tecnologias de Informação in Esposende.

- *HEP grid computing in Portugal*
  presented by Jorge Gomes
  at international ICFA workshop HEP networking, grid and digital divide in Krakow.

Oral presentations in collaboration meetings

- *GGUS trainning*
  presented by Mário David
  at in CERN.
- *The int.eu.grid infrastructure status*
  presented by Jorge Gomes
  at i2g integration workshop in Krakow.
- *int.eu.grid SA1 workshop summary*
  presented by Jorge Gomes
  at i2g integration workshop in Krakow.

Seminars

- *Introduction to grid computing*
  presented by Gonçalo Borges
  at in University of Algarve.

3.1.6 Project Summary

	number
International Conference Proceedings	2
Collaboration notes with internal referee	2
Oral presentations in international conferences	2
Oral presentations in international meetings	8
Oral presentations in collaboration meetings	3
Seminars	1

Chapter 4

Astroparticle Physics

4.1 Collaboration in AMS - Alpha Magnetic Spectrometer

4.1.1 Activity Report

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, as descobertas do movimento de recessão das galáxias por Hubble em 1929 e 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, o que se observa actualmente nos raios cósmicos que são detectados na Terra é 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 de partículas neutras e carregadas que atravessam a galáxia em todas as direcções. Um melhor entendimento dos mecanismos de aceleração e propagação requer uma medida dos fluxos de raios cósmicos tão precisa quanto possível e abrangendo o maior intervalo de energias. O detector AMS, a ser instalado na Estação Espacial Internacional por um período de três anos em 2007, permitirá prospectar a existência de antimatéria e matéria escura com uma precisão nunca antes alcançada.

Summary of Activities:

AMS (Alpha Magnetic Spectrometer) is a particle physics experiment to be installed in the future International Space Station Facility (ISS). The main physics objectives will be the search for antimatter and dark matter. In addition, it will study the propagation and confinement of cosmic rays in the galaxy.
The capabilities of the AMS spectrometer, compared to the one which flew in the Discovery shuttle in 1998, were largely improved and extended through the inclusion of new detectors: a Ring Imaging Cerenkov Detector (RICH), an Electromagnetic Calorimeter (ECAL) and a Transition Radiation Detector (TRD).
The RICH will provide both independent measurement of the particle velocity and of electric charge.
A velocity goal resolution for singly charged particles of the order of 0.1% is envisaged.
Such a resolution together with an improved measurement of the particle rigidity due to a higher magnetic field (0.9T), will allow to obtain a very good isotopic separation on a large kinetic range (up to 10 GeV per nucleon).
The RICH is a conical shaped detector with a dual radiator index configuration on the top made of aerogel (n=1.050) and sodium fluoride (n=1.33), a matrix of 680 photodetectors on the bottom and an enveloping outer mirror of very large reflectivity.
The Portuguese team is involved in the RICH simulation and developed algorithms for velocity and charge reconstruction. In addition, the team started exploring isotopes identification physics analysis, relying in the AMS full simulation and on the RICH detector skills.
Preliminary results on the deuterium-proton separation show a rejection factor of 1 per 10000.
Particle identification studies envisage to clearly establish a set of criteria on the Rich reconstruction for data samples selection.

Reconstruction of particle velocity has to deal with an essentially flat background from photomultipliers noise and photon scattering on aerogel radiator. Additionally, complex photon patterns can be set at the detector plane due to the mirror. A least squares and a likelihood method were developed and cross-checked.
A method for charge reconstruction with the rich detector was also implemented. The existence of background photons, uncorrelated with the Cerenkov photon ring, which differ from event to event due to the ring geometrical acceptance and event kinematics implied a charge reconstruction method based on an overall efficiency estimation on a event by event basis. The efficiency estimation relies on a semi-analytical method. A typical charge resolution (DZ) of the order of 20% is obtained for protons.
A RICH prototype made of a radiator and 96 photomultipliers separated by an expansion volume similar to the final one, was assembled at the Institut de Sciences Nucléaires (Grenoble). Following previous tests with cosmic data (2001,2002) and a fragmented Lead ion beam of 20 GeV per nucleon (October 2002, Cern), a new prototype run was performed with a fragmented Indium beam of 158 GeV per nucleon (October 2003, Cern). New readout electronics and new readout settings (tuning of the signal peaking time) were tested. The physics program included the testing of different aerogel radiators, the testing of the mirror material and the reconstruction of inclined particles.
The group continued the analysis activities in the data gathered during the 2003 test beam. Studies aiming a better understanding of the NaF data/MC disagreement were performed. A slight signal excess was observed in data. A detailed simulation of the light guide geometry and housing was realized in order to include photon reflections from shielding walls with specular and non specular components.
The assembling of the RICH detector continued during 2006 at the CIEMAT institute (Madrid, Spain). All the readout grids were assembled involving a total of 680 cells and about half of them cabled. Vibration and vacuum tests were performed.
The knowledge of the cell overall efficiency (cathode quantum efficiency, optical couplings,...) is aimed in order to keep a good charge separation up to Iron.
A systematic measurement of the readout cells efficiency, at the CIEMAT institute (Madrid) was done on 2006 for few cell grids.
The Portuguese group participated in the measurements and in the data analysis effort.
In summary, the activities where the group was involved along the year 2006 were the following:
* Fine tuning of the velocity and charge reconstruction algorithms
* Simulation studies of the refractive index spread of the aerogel tiles and its implication to physics
* Geant3 implementation of the light guide detailed geometry
* Simulation studies of the light guide and comparison with data
* Particle identification studies for isotopic separation
* Measurement and analysis of the unit cells efficiency
* Data Analysis of the 2003 test beam data

4.1.2 Fundings

Code	Funding	Start	End
PDCTE/FNU/50364/2003	40.000 €	2004-11-01	2007-10-31

4.1.3 Team

Project coordinator: Fernando Barão

Name	Status	%of time in project
Fernando Barão	Researcher (LIP/IST)	75
Gaspar Barreira	Researcher (LIP)	10
Luisa Arruda	PhD student (LIP/FCT)	100
Mário Pimenta	Researcher (LIP/IST)	5
Patrícia Gonçalves	Post-Doc (LIP/FCT)	5
Rui Faísca Pereira	PhD student (LIP/FCT)	100

4.1.4 Publications

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

- *Prototype Study of the cherenkov imager of the AMS experiment*
  P. Aguayo et al.

Nuclear Instruments and Methods in Physics Research A 560 (2006) 291-302

International Conference Proceedings

- *Cosmic Ray velocity and electric charge measurements with the AMS/RICH detector: prototype results*
  L. ARRUDA, F. Barao, P. Goncalves, R. Pereira
  Proceedings of the 20th European Cosmic Ray Symposium (Lisboa 2006), electronic publication

- *Particle identification with the AMS-02 RICH detector: search for dark matter with antideuterons*
  L. Arruda, F. Barao, R. PEREIRA
  Proceedings of the 20th European Cosmic Ray Symposium (Lisboa 2006), electronic publication

- *The Ring Imaging Cherenkov detector of the AMS experiment: test beam results with a prototype*
  L. ARRUDA, F. Barao, P. Goncalves, R. Pereira
  Proceedings of the 10th Topical Seminar on Innovative Particle and Radiation Detectors (IPRD06) (submitted)

4.1.5 Academic Training

PhD Theses

- *Charge and velocity reconstruction with the RICH detector of the AMS experiment; performance studies of a rich prototype with test beam data"*
  Luisa Arruda, 2007-10-01

- *Deuterium and light isotopes measurements and Dark matter searches with the AMS experiment"*
  Rui Faísca Pereira, 2008-10-01

4.1.6 Project Summary

	number
Articles in international journals (with direct contribution from LIP members)	1
International Conference Proceedings	3

4.2 Data analysis and calibration of the solar neutrino detector Solar Neutrino Observatory (SNO)

4.2.1 Activity Report

Sumário

A Física das oscilações de neutrinos é um campo de investigação muito activo e actual, e os resultados da experiência SNO resolveram definitivamente o problema dos neutrinos solares, provando que há mistura de sabores no sector leptónico. Durante o ano de 2006, foram realizadas as últimas calibrações do detector e em Novembro encerrou a tomada de dados da experiência. A colaboração está agora empenhada na análise dos dados da terceira fase que apresenta mais dificuldades do que as anteriores devido à presença no volume de D_2O de um conjunto de 40 contadores proporcionais de ^3He ("Neutral Current Detectors", ou NCDs)(5 cm de diâmetro, $\approx$10 m de comprimento).
Durante o ano de 2006, as actividades levadas a cabo pelo grupo do LIP na experiência SNO foram as seguintes:

- Detector: Participámos em dois períodos de tomada de dados de calibração óptica, responsabilizando-nos pela operação do equipamento de calibração: uma semana de turnos de uma pessoa em Fevereiro e outra semana de turnos de duas pessoas em Agosto. Em Agosto, foram também efectuados 10 turnos de tomada de dados regular, cumprindo a quota anual do LIP. Além disso, foram efectuados os treinos de segurança necessários para o acesso ao laboratório subterrâneo.

- Reuniões: Participámos nas reuniões de colaboração de Inverno em Austin (Texas, USA) e na de Verão em Sudbury, nas quais apresentámos os resultados no nosso trabalho na calibração óptica. Participámos também em várias reuniões telefónicas regulares dos grupos de trabalho "Energy & Optics"e "Low Energy Threshold Analysis".

- Análise: O desenvolvimento de um novo método para o cálculo dos parâmetros ópticos, utilizável na fase 3, foi concluído e integrado no software oficial de SNO. Utilizando este método, as constantes de calibração para a primeira análise dos dados da fase 3 foram determinadas. Participámos na escrita da documentação associada, que está presentemente na fase de revisão interna. Tendo atingido esta meta, iniciámos actividades para melhorar a análise, com vista à redução do erro sistemático da escala de energia na medição do fluxo de neutrinos para a próxima análise da fase 3 de SNO (que será também uma análise combinada das três fases). Nomeadamente, começámos a estudar o método Monte-Carlo de correcção das reflexões da luz nos NCDs, e também a assimetria cima-baixo na resposta do detector:

  - Verifica-se com a fonte de calibração ^{16}N que a resposta em energia do detector apresenta uma assimetria ao longo do eixo dos zz (cima-baixo). Ao investigar as possíveis causas desta assimetria, desenvolvemos um método de selecção de dados para rejeitar PMTs para os quais a luz atravessa os suportes das NCDs (no fundo do volume de D_2O), até agora nunca considerados na análise. Além disso, desenvolvemos um método para obter simultaneamente a resposta angular média de dois grupos de PMTs (z>0 e z<0), em vez de uma média geral.
  - As reflexões da luz nos NCDs aumentam a quantidade de luz detectada nos PMTs sem sombras e isso falseia em 10-20% a medição da atenuação da água pesada. Em 2006, utilizando simulações Monte-Carlo dos dados de calibração, estudámos o efeito dessas reflexões nos parâmetros ópticos, com vista a uma futura correcção dos dados.

- SNO+: Começámos a desenvolver simulações de Monte-Carlo para o estudo dos ruídos de fundo externo de SNO+.

- Artigos: Participámos no comité editorial do artigo sobre neutrinos hep, e na redação de parte do artigo sobre os dados da primeira fase.

Summary

Neutrino oscillation Physics today is a very active field, and the results of the SNO experiment have definitely solved the soalr neutrino problem, proving the existence of lepton flavor mixing. During 2006, the last detector calibrations were performed and data taking was completed in November. The collaboration is now commited to the data analysis for Phase 3 which is more challenging than the previous ones due to the presence of 40

^3He proportional counters (Neutral Current Detectors, or NCDs)(5 cm diameter, ≈10 m length) in the D_2O volume.
During 2006, the activities carried out by the LIP group in the SNO experiment were the following:

- Detector: We participated in two optical calibration data taking shift weeks, taking responsibility for the operation of the calibration hardware: one person in February and two persons in August. In August, we also carried out 10 normal detector operation shifts, fulfilling the LIP annual quota. In addition, we carried out the safety training necessary to access the underground lab.
- Meetings: We participated in the Winter collaboration meeting in Austin (Texas, USA) and in the Summer meeting in Sudbury, where we presented the results of our optical calibration work. We also participated in several regular conference calls for the working groups "Energy & Optics"and "Low Energy Threshold Analysis".
- Analysis: The development of a new optical calibration method, usable in phase 3, was concluded and integrated in the official SNO software. Using this method, the calibration constants for the first analysis of phase 3 data were determined. We participated in the writing of the associated documentation, that is presently under internal review. Having achieved this milestone, we initiated activities to improve the analysis, aiming at a reduction of the energy scale systematics on the neutrino flux measuremente in the next analysis of the phase 3 of SNO (which will be as well a combined 3-phase analysis). Namely, we started to study Monte-Carlo method for correction of the effect of light reflections in the NCDs, and also the up-down assimetry in detector response.
  - The detector energy response, measured with the ^{16}N source, shows an assimetry along the z axis (up-down). To investigate the possible causes of this assimetry, we developed a data selection method to rekject PMTs for which the light crosses the NCD anchors in the bottom of the D_2O volume, that until now had never been considered in the analysis. in addition, we developed a method to obtain simultaneously the average angular response of two groups of PMTs (z>0 and z<0), instead of a single average.
  - The light reflections in the NCDs increase the amount of light detected in the non-shadowed PMTs and that fakely decreases by 10-20% the measurement of the heavy water attenuation. In 2006, using Monte-Carlo simulations of the calibration data, we studied the effect of these reflections in the optics parameters, having as a goal the future data correction.
- SNO+: We started to develop Monte-Carlo simulation for the study of external backgrounds in SNO+.
- Papers: We participated in the editorial committee for the hep neutrino paper, and in writing parts of the paper on phase 1 data.

4.2.2 Fundings

Code	Funding	Start	End
POCI/FIS/56691/2004	35.000 €	2005-01-01	2007-03-31

4.2.3 Team

Project coordinator: José Maneira

Name	Status	%of time in project
Amélia Maio	Researcher (LIP/FCUL)	5
José Maneira	Post-Doc (LIP/FCT)	25
Nuno Barros	PhD student (LIP/FCT)	72

4.2.4 Publications

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

- *A Search for Neutrinos from the Solar hep Reaction and the Diffuse Supernova Neutrino Background with the Sudbury Neutrino Observatory*
  SNO Collaboration, (includes J. Maneira)
  Aharmim et al., Astrophysical Journal, 653(2006), 1545

- *Measurement of the nu(e) and total B-8 solar neutrino fluxes with the Sudbury neutrino observatory phase I data set.*
  SNO Collaboration, (includes J. Maneira)
  Accepted by Physical Review C (accepted)

Internal Notes

- *Update on OCA efficiencies*
  J. Maneira
  (accepted)

4.2.5 Presentations

Oral presentations in international conferences

- *SNO and Solar Neutrino Results*
  presented by José Maneira
  at NOW2006 in Otranto Italy.

Poster presentations in international conferences

- *Prospects for the Phase III of SNO*
  presented by Nuno Barros
  at ECRS06 in Lisboa.

Oral presentations in collaboration meetings

- *Optics Developments for the NCD phase*
  presented by José Maneira
  at SNO Energy & Optics in University of Texas, Austin, USA.
- *Optics Analysis for the NCD Phase*
  presented by José Maneira
  at SNO Plenary in University of Texas, Austin, USA.
- *PMT assymetries*
  presented by Nuno Barros
  at SNO Collaboration Meeting in Sudbury, Ontario.

4.2.6 Project Summary

	number
Articles in international journals (with direct contribution from LIP members)	2
Internal Notes	1
Oral presentations in international conferences	1
Poster presentations in international conferences	1
Oral presentations in collaboration meetings	3

4.3 Development of liquid xenon detectors for WIMPs search and CERN experiment PS213

4.3.1 Activity Report

Resumo:

A existência da matéria escura e a sua natureza é um dos aspectos mais actuais da Física. Os WIMPs (Weakly Interacting Massive Particles) são apontados como possíveis constituintes de parte dessa matéria escura. Estas partículas podem eventualmente ser detectadas por registo da energia ganha por núcleos atómicos de um meio detector ao colidirem com um WIMP. A baixa probabilidade destas colisões e a baixa energia dos recúos nucleares que produzem tornam esta observação muito difícil. Além disso, a separação dos sinais devidos aos WIMPs (muito raros) dos sinais devidos a toda a radiação cósmica e ambiente (muito frequentes) é um requisito crucial. Para comprovar a existência de WIMPs desenvolvem-se detectores optimizados para este fim e que são colocados em laboratórios subterrâneos para minimizar o ruído constituído pela radiação cósmica e ambiente.
O LIP é membro da colaboração ZEPLIN que utiliza detectores de xénon líquido para a procura da matéria escura. Durante o ano de 2006 fez parte do programa de trabalho da equipa do LIP participar na aquisição e análise de dados de um detector de xénon líquido (o ZEPLIN II) instalado na mina de sal de Boulby no Reino Unido e na instalação na mesma mina de um novo detector de maior sensibilidade (ZEPLIN III), instalação essa precedida por testes de bancada realizados no Imperial College London. Para além das responsabilidades e participação no programa da colaboração ZEPLIN, este projecto tem uma componente de I&D que é realizada no Laboratório do LIP em Coimbra e que é constituída pelo estudo de problemas relevantes para o aperfeiçoamento e interpretação dos resultados dos detectors ZEPLIN e similares. Durante o ano de 2006, continuaram-se as medidas de reflectividade no ultravioleta de materials geralmente utilizados nestes detectores e o estudo do desempenho de novas tecnologias de amplificação do sinal de carga para detectores de duas fases semelhantes aos ZEPLINs.

Summary of Activities:

The dark matter search is nowadays an extremely active field of research. Liquid xenon detectors are among the most promising detection technologies for that application, as it can be concluded from the fact that there are presently 4 international collaborations using or developing this type of detectors for the search of WIMPs. The ZEPLIN Collaboration relies on two phase (liquid||gas) scintillation detectors deployed in a salt mine (Boulby Mine) in UK. ZEPLIN II is a 30 kg liquid xenon detector based on readout of the primary scintillation in the liquid and secondary scintillation in the gas by 7 PMTs placed in the gas phase. ZEPLIN-III is a 6 kg fiducial volume xenon detector equipped with 31 PMTs, and constitutes an improved and more complex version of ZEPLIN II.
The ZEPLIN II commissioning was accomplished in 2006 and then it started to take data. Based on the analysis of 225 kg.days exposure run a sensitivity of 6.6 x 10-7 pb could be reached.
ZEPLIN III was transported to Boulby Mine in Autumn 2006 and deployment is under way. According to the plan, it will be collecting data for a couple of years. ZEPLIN III should allow to reach a sensitivity of $\approx$ 5x10-9 pb (for mass(WIMP)$\approx$ 60 GeV), for 3 ton.days of data, corresponding to about 3 years of data taking. It is a competitive experiment that is expect to push the present limit by more than one order of magnitude.
As foreseen in the Activity Plan, in 2006 the LIP team involved in the ZEPLIN collaboration aimed at consolidating and extending the Portuguese team in the collaboration without discarding the R&D program that has been carried out in the LIP Laboratory in Coimbra. The main tasks and results obtained can be summarized as follows:

DIRECT PARTICIPATION IN THE ZEPLIN PROGRAM

-Participation in most of the ZEPLIN II commissioning and in the analysis of the data acquired from this detector.
- Participation in the bench tests of ZEPLIN III that took place in ICL, UK.
- Responsibility for the development of the software for the DAQ and slow control systems of ZEPLIN III.

ANALYSIS OF THE DATA TAKEN WITH A NEUTRON BEAM IN 2004

The analysis of the data taken with the neutron beam was completed and published (V. Chepel et al., Astroparticle Physics 26 (1), 2006, 58-63). The scintillation efficiency of liquid xenon for nuclear recoils was measured in the energy range from 140 keV down to 5 keV for the first time in single experiment. The average ratio of the efficiency for recoils to that for gamma-rays is found to be 0.190.02.

MEASUREMENTS OF THE ANGULAR PROFILE OF THE UV LIGHT REFLECTED BY SOME MATERIALS

The measurements of reflectance of materials employed in liquid xenon detectors were continued using a large vacuum chamber in stainless steel and quartz windows constructed in 2005 for this purpose. The sample and the photodetector, as well as the accessories to detect of the reflective light as function of the incident angle, are all mounted inside that chamber filled with argon. We have been measuring the reflectance of various samples used in the xenon detectors, namely the angular distribution of VUV light that is reflected by samples of PTFE and copper. The data is being analyzed and compared with the Monte Carlo simulation of the reflection processes implemented in GEANT4.

PERFORMANCE OF GEMS (GAS ELECTRON MULTIPLIERS) IN ULTRAPURE XENON VAPOR AND IN A TWO PHASE (LIQUID||GAS) XENON DETECTOR:

One of the most important issues of WIMP detection is the radioactive background of the detector itself. The photomultiplier tubes are known to be a source of the background, even if only the low background materials are used for their manufacturing. It is therefore important to continue to search for alternative readout methods. One of the possibilities is to use Gaseous Electron Multiplier (GEM).

Operation of a single GEM in pure xenon was studied in gas at 25 C, cold gas (but not saturated) at 90 C and saturated xenon vapour in one- and two-phase modes. The most stable operation was observed at 90 C for which the gain of 150 was obtained for at xenon density of 4.91019 cm-3. The maximum gain of ≈40 was achieved for saturated xenon vapour at 102C and of ≈25 for two-phase configuration at the same temperature. Energy resolution of 13.5 % (FWHM) was obtained for α-particles in two-phase mode. Continuous stable operation of a GEM in two-phase mode for periods of several hours was routinely achieved. The results obtained were accepted for publication in Nucl. Instrum. Methods. A.

This work will be continued. Namely, fluctuations of the gain due to temperature variations have to be assessed and a compensation method developed, if necessary (by off-line correction of the multiplication gain with gas pressure, for example). The multiplication gain achieved so far is not sufficient for successful operation of these devices in a dark matter detector.

DEVELOPMENT OF POSITION RECONSTRUCTION ALGORITMS

As part of the data analysis in which we participate, it is our responsibility to develop and optimize position reconstruction algorithms. Based on our previous experience in reconstructing the energy deposition point from the scintillation light distribution among the photomultipliers (PMT), one possible algorithm potentially suitable for ZEPLIN III has already been implemented. When tested with simulated data, it proved to be fast enough for on-line operation while providing sub-centimeter resolutions (FWHM). It also enables the extension of the fiducial volume with low contamination from out-lying events up to 8 kg.

ENERGY LOSS CALCULATIONS

The understanding of the energy loss process for very slow heavy ions (i.e. energies between 1 and 100 keV) is very important to predict the response of the proposed detector to particles interacting through nuclear recoils, as is the case of Weakly Interacting Massive Particles (WIMPs).

The accurate description of the energy loss process for slow heavy ions requires considering separately the interactions with the nuclei of the material and their electrons. We carried out a comprehensive survey of the different theories and semi-empirical parameterisations that have been developed over the years. This is intended as a first step towards the assessment of the reliability of the parameterisations included Geant4 for the description of energy loss by slow ions.

ORGANIZATION OF WORKSHOP ON USE OF MONTE CARLO TECHNIQUES FOR DESIGN AND ANALYSIS OF RADIATION DETECTORS

LIP-Coimbra co-organized, together with the International Society of Radiation Physics Physics and the Department of University of Coimbra, the Workshop on Use of Monte Carlo Techniques for Design and Analysis of Radiation Detectors held in Coimbra, September 15-17, 2006. This Workshop was designed for early- to mid-career professionals. Twenty one lecturers presented the state-of-the-art in radiation detection and Monte Carlo simulation techniques as these apply to detectors. Six general-purpose Monte Carlo codes (GEANT4, FLUKA, MCNP, EGSnrc, PENELOPE and MCSHAPE) were presented and the participants had chance to work with a code during a hands-on session. The workshop had 110 attendees. A CD with all the presentations and hands-on sessions was produced and copies were distributed to the participants.

ORGANIZATION OF THE 10TH INTERNATIONAL SYMPOSIUM ON RADIATION PHYSICS

LIP-Coimbra co-organized, together with the International Society of Radiation Physics Physics and the Department of University of Coimbra, the 10th International Symposium on Radiation Physics (ISRP10) which was held in Coimbra from September 17-22, 2006. At ISRP-10, 362 participants from 52 nations attended the symposium. The programme was organized in eight sections: fundamental processes in radiation physics; radiation sources and detectors; radiation physics in materials science; radiation in medicine and biology; radiation physics in art and cultural heritage; new technologies and industrial applications; modelling and simulation of radiation transport. About 350 contributions were presented in addition to 18 talks given by invited speakers. The proceedings will be published in Nuclear Instruments and Methods in Physics Research A.

4.3.2 Fundings

Code	Funding	Start	End
POCTI/FP/FNU/50208/2003	60.000 €	2004-10-01	2006-02-28
POCI/FP/63446/2005	55.000 €	2005-09-01	2007-01-31
POCI/FP/63925/2005	60.000 €	2006-11-01	

4.3.3 Team

Project coordinator: Isabel Lopes

Name	Status	%of time in project
Alessio Mangiarotti	Researcher (LIP)	11
Alexandre Lindote	PhD student (LIP)	67
Alexandre Moita	Technician (LIP)	7
Américo Pereira	Technician (LIP)	27
Armando Policarpo	Researcher (LIP/FCTUC)	12
Carlos Silva	Technician (LIP)	7
Cláudio Silva	PhD student (LIP/FCT) *	100
Filipa Balau	Master student (LIP)	56
Francisco Neves	PhD student (LIP)	11
Isabel Lopes	Researcher (LIP/FCTUC)	50
João Silva	Technician (LIP)	7
Joaquim Oliveira	Technician (LIP)	7
José Pinhão	Technician (LIP)	3
José Pinto Da Cunha	Researcher (LIP/FCTUC)	45
Nuno Carolino	Technician (LIP)	10
Paulo Mendes	Researcher (LIP/FCTUC)	21
Rui Marques	Researcher (LIP/FCTUC)	12
Vitaly Chepel	Researcher (LIP/FCTUC)	46
Vladimir Solovov	Post-Doc (LIP)	100

4.3.4 Publications

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

- *Position Reconstruction in a Liquid Xenon Scintillation Chamber for Low Energy Nuclear Recoils and Gamma-Rays*
  F.Neves, V.Solovov, V.Chepel, M.I.Lopes, J.Pinto da Cunha, A.Lindote, C.Silva
  Nucl. Instrum. and Meth A. (accepted)

- *Scintillation efficiency of liquid xenon for nuclear recoils with the energy down to 5 keV*
  V. Chepel, V. Solovov, F. Neves, A. Pereira, P.J. Mendes, C.P. Silva, A. Lindote, J. Pinto da Cunha, M.I. Lopes,S. Kossionides
  Astroparticle Physics 26 (1) 2006 58-63

- *The ZEPLIN-III dark matter detector: Performance study using an end-to-end simulation tool*
  H.M. Araújo, D.Yu. Akimov, G.J. Alner, A. Bewick, C. Bungau, B. Camanzi, M.J. Carson, V. Chepel,

H. Chagani, D. Davidge, J.C. Davies, E. Daw, J. Dawson, T. Durkin, B. Edwards, T. Gamble, C. Ghag, et al.
Astroparticle Physics 26 (2), 2006, 140-153

- *The ZEPLIN-III dark matter detector: instrument design, manufacture and commissioning*
D.Yu. Akimov et al.
Astroparticle Physics, 27 (1), 2007, 46-60

- *Measuring the angular profile of the reflection of xenon scintillation light*
C.P. Silva, J. Pinto da Cunha, V. Chepel, P. Mendes, A. Pereira, V.Solovov, F. Neves, M.I. Lopes
Nucl. Instrum. and Meth A (accepted)

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

- *Neutron reactions and nuclear cosmo-chronology*
Progress in Particle and Nuclear Physics
M. Mosconi et al. (accepted)

- *Resonance capture cross section of Pb207*
C. Domingo-Pardo et al.
Physical Review C - Nuclear Physics 74 (5), 2007, art. no. 055802

4.3.5 Presentations

Oral presentations in international conferences

- *Measurement of scintillation efficiency of LXe for nuclear recoils with energy down to 5 KeV*
presented by Vitaly Chepel
at Cryogenic Liquid Detectors for Future Particle Physics in Gran Sasso Laboratory, Italy, 13-14 March 2006.

Poster presentations in international conferences

- *Reflection of xenon scintillation light by materials employed in liquid xenon detectors*
presented by Cláudio Silva
at 10th International Symposium on Radiation Physics in Coimbra, Portugal.

- *GEM operation in pure Xenon at low temperatures*
presented by Vladimir Solovov
at 10th International Symposium on Radiation Physics in Coimbra, Portugal.

- *A survey of energy loss calculations for heavy ions between 1 and 100 keV*
presented by Alessio Mangiarotti
at 10th International Symposium on Radiation Physics in Coimbra, Portugal.

4.3.6 Academic Training

PhD Theses

- *Application of liquid xenon to the dark matter detection"*
Francisco Neves, 2006-12-31

- *Data acquisition and analysis of ZEPLIN detectors"*
Alexandre Lindote, (on-going)

- *Liquid xenon detectors for WIMP search"*
Cláudio Silva, (on-going)

Master Theses

- *Estudo de funcionamento dos GEMs em detectores de xénon líquido"*
  Filipa Balau, (on-going)

4.3.7 Events

- *10th International Symposium on Radiation Physics*
  Conference, Coimbra, Portugal (LIP é co-organizador), 2006-09-17
- *Workshop on Use of Monte Carlo Techniques for Design and Analysis of Radiation Detectors*
  Workshop, Coimbra (LIP é co-organizador), 2006-09-15

4.3.8 Project Summary

	number
Articles in international journals (with direct contribution from LIP members)	5
Articles in international journals (with indirect contribution from LIP members)	2
Oral presentations in international conferences	1
Poster presentations in international conferences	3
PhD Theses	1
Conferences	1
Workshops	1

4.4 High Energy Cosmic Rays

4.4.1 Activity Report

Resumo:

A física de Astropartículas é hoje um campo de investigação extremamente activo, envolvendo físicos teóricos e experimentais de Partículas, Astrofísica e Cosmologia.
Em 2006 as actividades do grupo de raios cósmicos de alta energia do LIP centraram-se principalmente na participação no Observatório Pierre Auger e no desenvolvimento do trabalho de fenomenologia.
Prosseguiram-se igualmente os estudos e a elaboração da proposta do projecto GAW, um projecto de I&D na área da detecção de raios gama na região do TeV explorando as técnicas de detecção inovadoras propostas por EUSO. Foi concluida finalmente a instalação de um pequeno laboratório de electrónica.

Summary:

Astroparticle physics is a recent but very active field involving experimental and theoretical physicists from the fields of particle physics, astrophysics and cosmology. In 2006 the activities of the LIP High Energy Cosmic Rays (HECR) team were mainly centred in the participation in the Pierre Auger Observatory (PAO) and in the development of phenomenological work in the context of high energy cosmic rays. Activities related with the Gamma Air Watcher (GAW) project, and with the installations and the start up of the electronic cosmic rays Laboratory were also pursued.

Participation in the Pierre Auger Observatory

Portugal has joined the Pierre Auger Observatory in March of 2006. The Portuguese participation in the PAO was built around the fluorescence detectors (FD). This is a natural follow up of the involvement of the group in EUSO, and of the phenomenological work already developed in related areas. This participation covers different aspects related to the FD, from simulation and data analysis to the participation in the detector enhancements. More specifically, during 2006 the activities of the Portuguese team were focused in three main lines: the installation of the Auger Software at Lisbon; the development of detailed simulations of extended air shower and of the fluorescence detectors; the participation in data acquisition and data analysis tasks.
The PAO in now in a phase in which the finalisation and optimisation of the reconstruction and analysis algorithms becomes critical. During 2006 a method to reconstruct the 3-dimensional structure of extensive air showers from FD data has been conceived by us. The observation of the shower is done in 2-dimensional pixels, for consecutive time bins, and the standard reconstruction method deals only with this projection of the shower, integrating the charge vs. time pulse obtained for each pixel. However, time in fact corresponds to a third dimension. This is the basis of the 3D method, which allows looking inside each pixel, exploring the shape of the light pulse detected by that pixel, in time bins of 100 ns. A complex volume in space can then be associated to each measured charge (per pixel and time bin).
The development of a complete GEANT4 simulation of the PAO fluorescence detectors was one of the first responsibilities of our team within the collaboration. A prototype including the detailed 3D geometry of the telescope components is now concluded and interfaced to the PAO offline software. GEANT4 was also used by our team in the development of a simulation of the multiscattering of light in the atmosphere, essential for a detailed understanding of data.
Each team involved in PAO is expected to contribute to the data acquisition shifts. The LIP group has participated in two FD shifts, implying the presence in the Observatory site in Malarge of 2 people for 3 weeks.

UHECR phenomenology

For a few years already, the LIP cosmic ray team has developed and published phenomenological work in high energy cosmic ray physics. These activities are based in a close collaboration between theoreticians and experimentalists and now receive a boost with the participation in the PAO, which will give us a test bench for many models and ideas, extending our work to the concrete experimental environment and to real data. The phenomenological work of our team was concentrated in 2006 in the study of Hadronic interactions at very high energies.
Hadronic interaction models are a critical aspect in the simulation of high energy air shower development. In fact, the extrapolation from accelerator data to the high energies involved in cosmic ray physics has large uncertainties, and unknown or unexpected phenomena could arise. We have been exploiting the potentialities of string percolation models in the interpretation of cosmic ray data above 10^17 eV. The study of the energy

dependence of the depth of shower maximum and of the muon content of the shower are two widely used methods for the derivation of cosmic ray composition. We were able to provide a consistent interpretation of the energy dependence of these two observables within a string percolation model. In particular we discussed the importance of the inelasticity and of the particle multiplicity in the first few high energy interactions in the shower development.

Participation in GAW Gamma Air Watch

GAW - Gamma Air Watcher, is an R&D project on the detection of high energy gamma rays. GAW is an Italian-Spanish-Portuguese collaboration aiming at the installation of a prototype high-segmentation compact telescope in the observatory of Calar Alto (Spain), for the detection of the Cherenkov light associated to TeV gamma air showers. In 2006 a detailed GAW proposal was submitted. The LIP team has responsibilities in the detector simulation (coordination of the simulation framework and detailed simulation of the optics using GEANT4) and in the development of the data acquisition system. The team participated in the preparation of the proposal performing the required studies in the fields under its responsibility. The first phase of the Project, the installation of the first Telescope, was approved in Spain, Italy and Portugal and the relevant funds are available.

Laboratory of Cosmic Rays

In 2006 the installation of the small cosmic ray electronics laboratory, in the basement of the LIP premises in Lisbon and with funding from "Programa de re-equipamento", was completed. The Laboratory performed supporting activities for the "Telescopio de Raios Cósmicos"project. Currently the development process of a third generation of the LIP-PAD acquisition board is underway.

4.4.2 Fundings

Code	Funding	Start	End
POCTI/FIS/55759/2004	80.000 €	2005-03-01	2006-12-31
POCI/FP/63917/2005	100.000 €	2006-09-01	

4.4.3 Team

Project coordinator: Mário Pimenta

Name	Status	%of time in project
André Pina	Graduate student (LIP/IST)	17
Bernardo Tomé	Researcher (LIP)	73
Catarina Espírito Santo	Researcher (LIP)	87
Catarina Simões	Student (LIP)	22
Filipe Aguiar	Graduate student (LIP/IST)	88
Gonçalo Pires	Technician (LIP)	95
Jorge Dias de Deus	Researcher (IST)	10
Jorge Romão	Researcher (IST)	10
Mário Pimenta	Researcher (LIP/IST)	68
Miguel Pato	Graduate student (LIP)	33
Patrícia Gonçalves	Post-Doc (LIP/FCT)	70
Pedro Abreu	Researcher (LIP/IST)	48
Pedro Assis	PhD student (LIP/FCT)	95
Pedro Brogueira	Researcher (LIP/IST)	15
Ruben Conceição	Graduate student (LIP/FCT) *	96
Rui Santos	Researcher (LIP/FCUL)	10
Sofia Andringa	Post-Doc (LIP/FCT)	67

4.4.4 Publications

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

- *The sensitivity of cosmic ray air shower experiments for excited lepton and leptoquark detection*
  M.C. Espirito Santo, A. Onofre, M. Paulos, M. Pimenta, J. C. Romão, B. Tomé

J. Phys. G: Nucl. Part. Phys. 32 609-628 , hep-ph/0508100

- *Percolation Effects in Very High Energy Cosmic Rays*
  J. Dias de Deus, M.C. Espirito Santo, M. Pimenta, C. Pajares
  Phys. Rev. Let. - PRL 96, 162001 (2006), hep-ph/0507227

- *Gravitational diffraction radiation*
  Vitor Cardoso, Marco Cavaglia, Mario Pimenta
  Phys.Rev. D74 (2006) 084011

- *Extensive Air Showers and Diffused Cerenkov Light Detection: the ULTRA Experiment*
  G. Agnetta, P.Assis, P. Brogueira, C. Espirito Santo, M. Pimenta, B. Tome et al
  NIMA45862

- *Percolation and high energy cosmic rays above 10^17 eV*
  J. Alvarez-Muiz, P. Brogueira, R. Conceição, J. Dias de Deus, M.C. Espírito Santo and M. Pimenta
  Astroparticle Physics

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

- *Geant4 Developments and Applications*
  J. Allison et al.
  IEEE transactions on nuclear science, Vol. 53, N 1

International Conference Proceedings

- *How to select UHECR in EUSO*
  Pedro Assis
  Proceedings of the V International Workshop New Worlds in Astrop Phys, Faro, Portugal, Jan 2005

- *Microscopic black holes detection in UHECR*
  Miguel Paulos
  Proceedings of the V International Workshop New Worlds in Astrop Phys, Faro, Portugal, Jan 2005

- *Frontiers of High Energy Cosmic Rays*
  M. Pimenta
  Frontiers of Fundamental Physics, 255-261

- *Results from the ULTRA experiment in the framework of the EUSO project*
  G. Agnetta, P. Assis, B. Biondo, P. Brogueira, A. Cappa, O.Catalano, J. Chauvin (LPSC), G. D´Ali Staiti, M. Dattoli, M.C.Espirito-Santo, L. Fava, P. Galeotti, S. Giarrusso, G. Gugliotta, G. La Rosa,D. Lebrun (LPSC), M.C. M
  Proceedings of ICRC 2005, Pune, India [astro-ph/0602151]

- *GAW, Gamma Air Watch - A Large Field of View Imaging Atmospheric Cherenkov*
  M.C. Maccarone, G. Agnetta, P. Assis, B. Biondo, et all
  Proceedings of ICRC 2005, Pune, India [astro-ph/0509706]

- *Sensitivity of large air shower experiments for excited lepton detection*
  M.C. Espirito Santo, A. Onofre, M. Paulos, M. Pimenta, J. C. Romão, B. Tomé
  Proceedings of ICRC 2005, Pune, India [hep-ph/0412345]

National Conference Proceedings

- *Experimental Particle and Astroparticle Physics*
  M. Pimenta

Proposals

- *A very large field of view Imaging Atmospheric CherenkovTelescope- Concept Design and Science Case*
  GAW collaboration
  (accepted)

4.4.5 Presentations

Oral presentations in international conferences

- *Percolation and cosmic rays above 10^17 eV*
  presented by Catarina Espírito Santo
  at ECRS06 in Lisbon.
- *Sensitivity of large air shower experiments for new physics searches*
  presented by Bernardo Tomé
  at ECRS06 in Lisbon.

Poster presentations in international conferences

- *EAS transverse profiles in the Xmax region at energies of 10^14 - 10^17 eV*
  presented by Pedro Assis
  at ECRS06 in Lisbon.

Presentations in national conferences

- *Experimental Particle and Astroparticle Physics*
  presented by Mário Pimenta
  at Symposium on Scientific Research at the Technical University of Lisbon in UTL.

Oral presentations in international meetings

- *Percolation Effects in High Energy Cosmic Rays*
  presented by Catarina Espírito Santo
  at in Santiago Compostela.

Oral presentations in collaboration meetings

- *Studies of the Rayleigh scattering using the Geant4 toolkit*
  presented by Patrícia Gonçalves
  at Auger South Analysis meeting in Chicago.
- *Geant4 simulation of the Auger FD telescopes*
  presented by Bernardo Tomé
  at Auger South Analysis meeting in Chicago.
- *Geant4 Simulation of the Pierre Auger Fluorescence Detector*
  presented by Bernardo Tomé
  at XXI Geant4 Collaboration Workshop and Users Conference in Lisboa, Portugal.
- *3D reconstruction of FD data*
  presented by Sofia Andringa
  at Auger Coll. Meeting in Malargue.

- *Geant4 simulation of the FD telescopes: preliminary results*
  presented by Pedro Assis
  at Auger Coll meeting in Malargue.

- *Multiscattering in laser events: a preliminary evaluation using Geant 4*
  presented by Bernardo Tomé
  at Auger Coll. Meeting in Malargue.

Seminars

- *Ultra High Energy Cosmic Rays - The Auger Experiment*
  presented by Patrícia Gonçalves
  at in IST.

4.4.6 Academic Training

PhD Theses

- *Data acquisition and control systems in cosmic ray experiments"*
  Pedro Assis, (on-going)

- *Hadronic Models in EAS"*
  Ruben Conceição, (on-going)

Master Theses

- *Search for new physics in Auger"*
  Miguel Pato, 2007-07-31

- *Image reconstruction in gamma ray telescopes: A new method and its aplication to the GAW project."*
  André Pina, 2007-07-31

Graduation Theses

- *Characterisation of high energy air showers using CORSIKA"*
  Ruben Conceição, 2006-09-30

4.4.7 Events

- *20th European Cosmic Ray Symposium*
  Conference, Lisbon, 2006-09-05

4.4.8 Project Summary

	number
Articles in international journals (with direct contribution from LIP members)	5
Articles in international journals (with indirect contribution from LIP members)	1
International Conference Proceedings	6
National Conference Proceedings	1
Proposals	1
Oral presentations in international conferences	2
Poster presentations in international conferences	1
Presentations in national conferences	1
Oral presentations in international meetings	1
Oral presentations in collaboration meetings	6
Seminars	1
Graduation Theses	1
Conferences	1

4.5 Study of the primary air scintillation in air for cosmic ray detection

4.5.1 Activity Report

Resumo:
A detecção de radiação de fluorescência produzida na atmosfera por raios cósmicos incidentes de muito alta energia, é uma técnica que tem vindo a ser utilizada pela nova geração de experiências como Hires e Auger. Este método baseia-se na excitação das moléculas de azoto pelas partículas carregadas do chuveiro produzido no ar (electrões e positrões) seguido da emissão de fotões num comprimento de onda na região entre 300 e 400nm. A emissão de radiação de fluorescência produzida pelas partículas carregadas é considerada isotrópica e proporcional à energia perdida por unidade de comprimento no ar. Uma medida precisa da quantidade de luz emitida por fluorescência, em camadas finas de gás, em condições atmosféricas diversas é, pois, essencial para a calibração absoluta dos detectores de raios cósmicos de ultra alta energia que se baseiam neste método de detecção.
Este projecto visa contribuir para uma melhor compreensão quer dos processos físicos que estão na origem da fluorescência do ar quer dos mecanismos que contribuem para a sua inibição e junta pessoas com experiência tanto na área da física das astropartículas como na dos processos fundamentais em física da radiação. O nosso principal objectivo é continuar as medidas que temos vindo a realizar (no laboratório, com fontes radioactivas) das quantidades de luz emitida em função da pressão e temperatura. Neste sentido planeamos estender as medidas até temperaturas da ordem dos 40C e melhorar a precisão das medidas. Prevemos realizar estudos resolvidos no tempo, ou seja, medidas dos tempos médios de vidas dos estados emissores das moléculas de azoto em função da pressão e temperatura. Estes resultados deverão contribuir para uma melhor compreensão dos mecanismos de excitação e desexcitação envolvidos. O estudo da influência do vapor de água e outros gases presentes na atmosfera como gases minoritários (argon, por exemplo), é um aspecto importante que será tomado em consideração.
Summary of activities
Improved measurements of light yields in pure nitrogen were performed using the alpha particles of Am-241 as excitation source. The radioactive source was placed outside the main chamber, in a secondary chamber that can be evacuated.
The light yields for 0-0 and 0-1 emission bands of 2nd positive system of the nitrogen molecule, with band heads at 337 nm and 357 nm, respectively, were obtained, in pure N2, for various temperatures between +25C and 23C. During each cooling cycle, the density of the gas was kept constant. These measurements were repeated for several gas densities. Similar measurements were also performed for dry air.
The variation of the light yield for one given emission band with the pressure (keeping the temperature constant, T = 295 K) gives us information on the quenching rates, and the variation with temperature, keeping the density constant, can give information on the excitation mechanisms involved. In both cases measurements have to be corrected for the geometric factor that takes into account the inclination and length of the alpha particle track and the detection of the emitted photons by the PMT. This factor is calculated using the GEANT4 code for the simulation of the set-up. An important part of the simulation program is related with the transmission of the interference filter that depends both on the angle of incidence and on the temperature. Since the manufacturer only provides data for angles of incidence below 15, we designed, constructed and mounted an experimental set-up for a precise measurement of the dependence of the filter transmission both on the angle of incidence and on the temperature. The stepping motor that establishes the position of the filter is controlled using a LABVIEW program developed for this purpose. The same program also commands the stepping motor of the monochromator, counts the PMT signals and measures the output voltage of the photodiode (to check the stability of the lamp). The temperature sensor mounted near the filter is also controlled with the same program. A self-consistent set of data was obtained and a parametrization of the filter transmission is under way. The study of the dependence on temperature is also underway.
Preliminary tests performed with the Sr-90 source indicated that the background component had to be considerably reduced in order to improve the signal to noise ratio. This can be achieved by using a different gas chamber with larger dimensions. The simulation of an existing chamber was performed in order to establish the best operating conditions concerning the radioactive source placement, the collimation, and the dimensions and placement of the scintillator for the electron detection. A new set-up based on these results will shortly be assembled.

4.5.2 Fundings

Code	Funding	Start	End
POCI/FP/63440/2005	30.000 €	2005-07-04	2006-11-30
POCI/FP/63913/2005	20.000 €	2006-11-01	

4.5.3 Team

Project coordinator: Margarida Fraga

Name	Status	%of time in project
Alexandre Moita	Technician (LIP)	10
Américo Pereira	Technician (LIP)	20
António Onofre	Researcher (LIP/UCPFF)	20
Armando Policarpo	Researcher (LIP/FCTUC)	15
Carlos Silva	Technician (LIP)	10
Ermelinda Antunes	Researcher (LIP/FCTUC)	15
Filipe Veloso	PhD student (LIP/FCT)	10
Francisco Fraga	Researcher (LIP/FCTUC)	10
João Bastos	Post-Doc (LIP)	3
João Silva	Technician (LIP)	5
Joaquim Oliveira	Technician (LIP)	10
Luís Pereira	Student (LIP) *	92
Margarida Fraga	Researcher (LIP/FCTUC)	35
Mário Pimenta	Researcher (LIP/IST)	6
Nuno Carolino	Technician (LIP)	15
Nuno Castro	PhD student (LIP/FCT)	10
Paula Vieira	Graduate student (LIP)	50
Rui Marques	Researcher (LIP/FCTUC)	10
Susete Fetal	Researcher (LIP/ISEC) *	10

4.5.4 Publications

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

- *Measurement of air and nitrogen fluorescence light yields induced by electron beam for UHECR experiments*
  P. Colin , A. Chukanov, V. Grebenyuk, D. Naumov ,P. Nédélec , Y. Nefedov , A. Onofre , S. Porokhovoi, B. Sabirov, L. Tkatchev
  Astrophysical Journal (submitted)

International Conference Proceedings

- *Pressure and temperature dependence of the primary scintillation in air*
  M. Fraga, A. Onofre, N. F. Castro, R. Ferreira Marques, S. Fetal, F. Fraga, M. Pimenta, A. Policarpo, F. Veloso
  Proceedings of the Fifth Meeting on New Worlds in Astroparticle Physics, Faro, Portugal, 8-10 January, 2005, World Scientific (Singapore)

- *Air fluorescence studies for cosmic ray detection*
  M. Fraga, A. Onofre, N. F. Castro, F. Fraga, L. Pereira, F. Veloso, P. Vieira, S. Fetal, R. Ferreira Marques, M. Pimenta, A. Policarpo

4.5.5 Presentations

Poster presentations in international conferences

- *Air Fluorescence Studies for Cosmic Ray Detection*
  presented by António Onofre
  at 20thEuropean Cosmic Ray Symposium in Lisbon, Portugal.

- *Temperature dependence of N2 fluorescence*
  presented by Margarida Fraga
  at 10thInternational Symposium on Radiation Physics in Coimbra, Portugal.

Oral presentations in international meetings

- *The role of temperature on air fluorescence measurements*
  presented by Margarida Fraga
  at 4th air fluorescence workshop in Prague - Pruhonice, Czeck Republic.

4.5.6 Project Summary

	number
International Conference Proceedings	2
Poster presentations in international conferences	2
Oral presentations in international meetings	1

4.6 ESA: Radiation interaction simulations for space missions

4.6.1 Activity Report

Resumo

As actividades desenvolvidas no LIP em cooperação com a ESA, "European Space Agency", situam-se no contexto da aplicação do toolkit de simulação Geant4 na descrição e estudo do ambiente de radiação no sistema solar, do seu efeito em componentes electrónicos e no design e optimização de monitores de radiação para futuras missões na heliosfera. Entre estas, existem actividades finalizadas em 2006 e actividades iniciadas durante 2006. As actividades finalizadas durante 2006 consistem nos contratos "Design study for an energetic particle spectrometer for planetary missions" e "Integrated Radiation Environment, Effects and Component Degradation Simulation Tool" terminados em Março de 2006 e Setembro de 2006, respectivamente. Foram iniciadas duas novas actividades durante 2006: uma extensão do contrato "Integrated Radiation Environment, Effects and Component Degradation Simulation Tool", correspondendo à verificação experimental dos resultados do primeiro contrato, com início em Novembro de 2006 e que terá a duração de 2 anos; e o contrato intitulado "MarsRem: Martian Radiation Environment Models", com início a 1 de Julho de 2006 e que terá a duração de 2 anos, no qual o LIP é responsável por um dos três "Work Packages", intitulado "Development of In-Orbit and Surface Radiation Environment Models".

Summary of Activities

LIP has been cooperating with ESA, European Space Agency, in the application of the GEANT4 simulation toolkit to astroparticle experiments and in the description and study of the solar system radiation environment, its effect on electronic components relevant for ESA future space missions and on the design and optimisation of radiation monitors for future heliospheric missions.

1. Software Models for the Portuguese Interplanetary Particle Surveyor
ESA issued a scientific and technical plan in which a preliminary concept for a Portuguese Interplanetary Particle Surveyor (PIPS) was proposed. A contract was celebrated between LIP and EFACEC, under the ESA/EFACEC contract ESTEC 19100/05/NL/HB, "Design study for an energetic particle spectrometer for planetary missions", which started in September 2005 and terminated successfully in Mars 2006. The contract concerned the study of a new generation of compact (≈5x5x5 cm), light weight (less than 1 kg) and low power consuming ($<$ 1 Watt) radiation monitors for future space missions, namely for the Bepi Colombo mission to Mercury. A simple concept based on a scintillating crystal was studied, consisting of an instrument capable of performing not only as a radiation switch, providing ancillary trigger information for the spacecraft, but also as a scientific instrument, which will measure fluxes and energy distributions of electrons, protons and ions in relevant energy ranges: 0.5-150 MeV per nucleon for protons and ions and 0.1-20 MeV for electrons.
Under the EFACEC/LIP contract, LIP was responsible for:

- Implementation of the instrument geometry and structural model within the framework of the Geant4 simulation toolkit.
- Study of the interaction of secondary particles induced by the structural

frame and electronics circuits.

- Generation of the response function for the instrument simulator.
- Study of the radiation dose to be expected by electronics, calorimeters and trackers.
- Definition of typical observation scenarios and the related input spectra for electrons, alpha particles and protons at different times.
- Device performance assessment as a radiation monitor and as a scientific instrument.

2. Integrated Radiation Environment, Effects and Component Degradation Simulation Tool
The contract 18121/04/NL/ch "Integrated Radiation Environment, Effects and Compo-nent Degradation Simulation Tool", celebrated between LIP-Lisboa and ESA/ESTEC, started in April 2004 and was successfully completed in September 2006. It was divided into four Work Packages, WP: Literature Study, Radiation Environment Selection and Modelling, Radiation Effects Selection and Modelling and Verification Procedures and Execution. One PhD thesis is currently in progress in the framework of this activity.

3. Integrated Radiation Environment, Effects and Component Degradation Simulation Tool (extension of 2.)
The program proposed for this contract in extension to ESA RFQ/3 310888/03/NL/CH, aims at developing experimental verification tests for validation simulation results on radiation induced the generalization of the developed component degradation models for other families of components. The final outcome of the proposed work is to generate verification procedures and to execute a verification test programme for the developed models and to predict induced degradation levels on a specific family of components due to protons and ions.

4. MarsRem: Martian Radiation Environment Models: Development of In-Orbit and Surface Radiation Environment Models
LIP participates in a consortium with three other international institutes/companies which responded to an ESA Invitation To Tender (ITT) entitled MarsRem: Martian Radiation Environment Models . The proposal in which LIP participated was the winning proposal for the ITT, and therefore a corresponding contract with ESA will be initiated during 2006. The objectives of the two year project are:

- Assess existing physics models in Geant4 covering energetic nuclear-nuclear and ion-electromagnetic interactions, and then develop, implement and verify additional or improved models
- Design, develop, implement and validate engineering tools, based on Geant4, to predict the Martian radiation environment for orbital spacecraft, and Mars planetary and moon landers or habitats
- The tools shall be easy-to-use by mission designers and planners (rather than developed just for radiation experts), web-based and interfaced with existing radiation shielding and effects simulation tools at the SPENVIS web-site
- Implement models to assess and compare the performance of passive and active radiation shielding, and apply to example cases to assess the performance of some active shielding cases

The contract Work Package (WP) breakdown consists of four WPs, one of which, entitled "Development of In-Orbit and Surface Radiation Environment Models" is of LIP responsibility. This Work Package aims to develop a Mars radiation environment framework which can:

- Specify the primary radiation environment at Mars or its moons (taking into consideration mission date and orbit)
- Calculate the effects of the atmosphere or planetary/moon surface in modifying that environment
- Use Geant4 to provide both detailed predictions and engineering estimates based on experience from PLANETOCOSMICS, MarsREC and QARM
- Provide a public accessible and easy-to-use prediction environment for Mars mission planners through SPENVIS

In addition, LIP will have the responsibility of maintaining the code developed and delivered to ESA under the contract for a period of two years after delivery of the final report.

4.6.2 Fundings

Code	Funding	Start	End
ESA: 18121/04/NL/ch	100.000 €	2004-04-01	2006-09-30
ESA 19100/05/NL/HB	23.240 €	2005-09-11	2006-02-28
ESA:19770/06/NL/JD	78.200 €	2006-07-01	2007-12-31
ESA:18121/04/NL/CH	80.000 €	2006-11-01	2008-10-31

4.6.3 Team

Project coordinator: Patrícia Gonçalves

Name	Status	%of time in project
Ana Keating	PhD student (LIP/FCT)	100
Andreia Trindade	PhD student (LIP/FCT)	5
Bernardo Tomé	Researcher (LIP)	23
Catarina Espírito Santo	Researcher (LIP)	8
Mário Pimenta	Researcher (LIP/IST)	18
Patrícia Gonçalves	Post-Doc (LIP/FCT)	25
Pedro Brogueira	Researcher (LIP/IST)	1
Pedro Rodrigues	PhD student (LIP/FCT)	5
Sara Valente	Student (LIP)	23

4.6.4 Publications

International Conference Proceedings

- *GEANT4 detector simulations- radiation interaction simulations for the high energy astroparticle experiments EUSO and AMS*
  Patrícia Gonçalves
  World Sci., NEW WORLDS IN ASTROPARTICLE PHYSICS, Proceedings of the Fifth International Workshop , Faro, Portugal 8 - 10 January 2005

- *"Galactic Cosmic Rays induced Radiation Environment at the surface of Mars"*
  A. Keating, M. Pimenta, A. Mohammadzadeh, P. Nieminen and E. Daly
  (submitted)

- *A radiation monitor for future space missions*
  Patrícia Gonçalves, Mário Pimenta, Bernardo Tomé
  (submitted)

- *Models and Computational Tools for Space Radiation Effects*
  E.J. Daly, H. Evans, P. Nieminen, G. Santin, R. Lindberg, J. Sorensen, A. Glover, A. Menicucci, A. Keating, A. Mohammadzadeh

4.6.5 Presentations

Oral presentations in international conferences

- *A radiation monitor for future space missions*
  presented by Patrícia Gonçalves
  at ECRS2006 in Lisboa.

- *Models and Computational Tools for Space Radiation Effects*
  presented by Ana Keating
  at RASEDA 2006-The 7th International Workshop on Radiation Effects on Semiconductor Devices for Space Application in Takasaki Japan.

Poster presentations in international conferences

- *"Galactic Cosmic Rays induced Radiation Environment at the surface of Mars"*
  presented by Ana Keating
  at European Cosmic Rays Symposium 2006 in Lisbon, Portugal.

Oral presentations in international meetings

- *The Effects of Atmospheric Variations On the High Energy Radiation Environment at the Surface of Mars*
  presented by Ana Keating
  at Second workshop on Mars atmosphere modelling and observations in Granada, Spain.

- *Simulation of a Radiation Monitor for Future Space Missions*
  presented by Patrícia Gonçalves
  at 11th Geant4 Collaboration Workshop and Users Conference in IST, Lisboa, Portugal.

Oral presentations in collaboration meetings

- *Expected Radiation dose in PIPS for the Bepi Colombo mission*
  presented by Bernardo Tomé
  at PIPS final presentation; in ESTEC, Nordwijk, The Netherlands.

- *Generation of the PIPS response functions for the simulator*
  presented by Patrícia Gonçalves
  at PIPS final presentation in ESTEC, Nordwijk, The Netherlands.

4.6.6 Academic Training

PhD Theses

- *A model for Mars Radiation Environment Characterization and Effects on Components"*
  Ana Keating, (on-going)

4.6.7 Project Summary

	number
International Conference Proceedings	4
Oral presentations in international conferences	2
Poster presentations in international conferences	1
Oral presentations in international meetings	2
Oral presentations in collaboration meetings	2

Chapter 5

Medical Physics

5.1 Development of Positron Emission Mammography

5.1.1 Activity Report

Development of Positron Emission Mammography

Resumo:
A elevada incidência de cancro da mama e a relativa inadequação dos métodos tradicionais de detecção (em particular a mamografia com raios-X) apontam para a necessidade de técnicas e de equipamentos específicos com desempenho complementar. Este projecto visa responder a esta necessidade, propondo um novo equipamento, compacto e económico, baseado na detecção de fotões gama resultantes do decaimento de um átomo emissor de positrões (o Flúor-18). A detecção dos fotões provenientes do decaímento do átomo radioactivo permite localizar o tumor em três dimensões, constituindo a base do PET (Positron Emission Tomography em inglês). Ao contrário da mamografia com raios-X, eminentemente anatómica, a mamografia PET retratará o funcionamento das células tumorais vivas.
O projecto "Desenvolvimento de Tecnologia PET para Mamografia" é um projecto de investigação científica e tecnológica realizado no âmbito do Consórcio PET-Mamografia, liderado cientificamente pelo LIP. O equipamento PET proposto decorrerá de investigação científica e de desenvolvimento tecnológico desde a investigação até ao protótipo para realização de testes clínicos, estando envolvidos no Projecto cerca de 40 pessoas (desde alunos de licenciatura a médicos especialistas em Medicina Nuclear) de 8 instituições diferentes, de Universidades a Hospitais.
Este equipamento explora tecnologia de detecção de fotões desenvolvida no CERN e integra um sistema electrónico de aquisição de dados inovador em desenvolvimento pelo consórcio. A associação destes factores permitirá uma melhoria significativa da qualidade das imagens relativamente aos sistemas PET actuais.

Project Coordinator:
João Varela

Summary of Activities:
The project PET I funded by AdI ended in December 2006.
The new PET technology aiming at a compact positron emission mammography scanner with good spatial resolution and high sensitivity, was fully validated. All the technological innovations required to achieve the specified PET performance have been achieved and tested. These include:

- the development of a new photon Detector Module based on LYSO crystals, with 2x2x20 mm3 pixels and resolution FWHM of 2 mm in the longitudinal coordinate (Depth of Interaction), as required for images not affected by the parallax effect common in PET, with resolution between 1 and 2 mm.
- the development with the company Hamamatsu, Japan, of an Avalanche Photodiode array (APD) matching the Detector Module and suitable for integration in the Positron Emission Mammography (PEM) system.
- the development, implementation and construction of a mechanical system allowing the coupling of the crystal matrixes with the APD arrays with high precision (<100 microns), and suitable for integration in compact PEM detector heads containing about 3000 crystal pixels and 6000 APD pixels.

- the development of a new architecture for frontend readout, digitization and data acquisition of about 12000 photon detection channels, based on a new highly integrated data-driven synchronous frontend system and on an off-detector coincidence trigger and pipelined data acquisition system operating at 100 MHz and capable of an acquisition rate of 1 million events per second without significant dead-time.
- the development, fabrication and successful test of a new Application Specific Integrated Circuit (ASIC) for APD signal amplification with an input range of 100 fC and noise 0.2 fC (≈1000 e- rms), signal sampling at 100 MHz, analog storage, auto-trigger, input channel selection, identification and multiplexing, and output differential driving.
- the development, implementation and successful test of a new high voltage supply and regulation system, capable to regulate 64 high voltage channels in the range 350-500 V with a noise below 10 mV, which are arbitrarily cross-connected to 400 individual APD bias lines in the highly compact geometry of the PEM detector heads.
- the development, implementation and successful test of a monitoring and control system of the PEM detector heads, involving the measurement of the APD temperatures and of the detector boxes pressure, as well as the control of the high-voltages, low-voltage supplies, ASIC parameters, and front-end auto-test, including remote computer communication and application software.
- the development, construction, and successful test of the off detector trigger and data acquisition system, with a new design around a dual bus crate backplane for fast intercommunication between 4 data acquisition boards and one trigger and data concentrator board, which use 4 million gates Field Programmable Gate Arrays (FPGA) to implement the logic, and a specific circuit for data transfer to the acquisition computer server.
- the development, implementation in FPGA and successful test of new algorithms for on-line measurement of the photons time and amplitude as required by the two-photon coincidence digital trigger; of the dead-time free pipeline data filtering and acquisition logic; and of a sophisticated on-board and inter-board self-test system using digital patterns generation, propagation, collection and diagnosis.
- the development, implementation and successful test of a new software application for data acquisition and remote monitoring of the PET scanner, including raw data storage, online event reconstruction, second level trigger, and list mode data formatting, as well as display of control panels, data quality monitoring graphical data, and reconstructed image visualization.
- the development, implementation and successful test of a new software application implementing iterative image reconstruction algorithms in 2D, including Fourier rebinning, and in 3D (OSEM and ART), capable of image reconstruction with the parallel plate PET geometry of mammography, showing point source image resolutions of 1.3 mm in the transverse plane and 2 mm in axial direction.
- the development, implementation and successful test of a new software application for image visualization and analysis (projections, regions of interest, profiles, etc.).
- the development, implementation and successful test of a simulation software application capable to reproduce accurately the full PEM process from the radiation emission up to the final acquired raw data, used to validate the detector performance, as well as to estimate the corrections required to remove image artifacts due to detector non-uniformities.
- the development and construction of the detector heads mechanical boxes, including structural elements, cold plates and water distribution, electrical patch panel, nitrogen tightness, and impact safety switches.
- the development, construction and assembling of the detector heads cooling system including the freezer, water pumps, valves, as well as temperature and flow control.
- the development, construction, assembling and successful test of a robotic device, and the associated electrical rack, allowing the positioning of the PEM detector heads either close to the breasts or close to the axillas under operator control, as well as the computer controlled rotation of the PEM detector heads around the breast, with a precision of 100 m, including all required safety features required for a clinical application.

5.1.2 Fundings

Code	Funding	Start	End
POSI/DGDR-SIFEC/14/01/03/FDR/00134	569.000 €	2003-01-01	2006-12-31

5.1.3 Team

Project coordinator: João Varela

Name	Status	%of time in project
Andreia Trindade	PhD student (LIP/FCT)	100
Bruno Carriço	Master student (LIP/UALG) *	100
Catarina Ortigão	PhD student (LIP)	100
Conceição Abreu	Researcher (LIP/UALG)	5
Francisco Fraga	Researcher (LIP/FCTUC)	5
João Pinheiro	Student (LIP)	71
João Varela	Researcher (LIP/FCT)	30
José Carlos Silva	Technician (LIP)	10
Luis Peralta	Researcher (LIP/FCUL)	20
Miguel Ferreira	Technician (LIP)	60
Patrick Sousa	PhD student (LIP/UALG)	10
Paula Bordalo	Researcher (LIP)	5
Pedro Amaral	Post-Doc (LIP)	100
Pedro Rodrigues	PhD student (LIP/FCT)	100
Rui Moura	PhD student (LIP/FCT)	95
Rui Ribeiro	Researcher (LIP)	50
Sérgio Ramos	Researcher (LIP)	5

5.1.4 Publications

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

- *Design and Test Issues of an FPGA Based Data Acquisition System for Medical Imaging using PEM*
  Carlos Leong, Pedro Bento, Pedro Lousã, João Nobre, Joel Rego, Pedro Rodrigues, José C. Silva, Isabel C. Teixeira, J. Paulo Teixeira, Andreia Trindade, João Varela
  IEEE Transactions on Nuclear Science, Vol. 53, No. 3, June 2006

- *Clear-PEM: A PET imaging system dedicated to breast cancer diagnostics*
  PET Consortium (LIP authors: M. C. Abreu, P. Amaral, B. Carriço, M. Ferreira, J. Luyten, P. R. Mendes, R. Moura, C. Ortigão, L. Peralta, R. Ribeiro, P. Rodrigues, J. C. Silva, A. Trindade and J. Varela)
  Nuclear Instruments and Methods in Physics Research A 571 (2007) 8184

- *Long-term stability of the Clear-PEM detector modules*
  Pedro Amaral, Peter Bruyndonckx, Bruno Carriço, Miguel Ferreira, Joan Luyten, Rui Moura, Catarina Ortigão, Pedro Rodrigues, José C. Da Silva, Andreia Trindade and João Varela
  Nuclear Instruments and Methods in Physics Research A 571 (2007) 488492

- *Clear-PEM system counting rates: a Monte Carlo study*
  P. Rodrigues, A. Trindade and J. Varela

5.1.5 Presentations

Oral presentations in international conferences

- *Clear-PEM: A PET imaging system dedicated to breast cancer diagnostics*
  presented by João Varela
  at Euromedim 2006 in Marseille, France.

- *Characterization and Quality Control of Avalanche PhotoDiode Arrays for the Clear-PEM Detector Modules*
  presented by Bruno Carriço
  at 8th International Workshop in Radiation Imaging Detectors in Pisa, Italy.

- *ClearPEM: a PET imaging system dedicated to breast cancer diagnostics*
  presented by Pedro Amaral
  at New Trends on Positron Emission Tomography in St. Petersburg.

Poster presentations in international conferences

- *Long-term Stability of the Clear-PEM Detector Modules*
  presented by Catarina Ortigão
  at EuroMedIm 2006 in Marseille, France.
- *Performance and Quality-Control of Clear-PEM Detector Modules*
  presented by Rui Moura
  at Conference on Imaging Techniques in Subatomic Physics, Astrophysics, Medicine, Biology And Industry in Stockholm, Sweden.

Oral presentations in collaboration meetings

- *Quality Control of APDs in Clear-PEM*
  presented by Bruno Carriço
  at Crystal Clear Collaboration Meeting in Antwerp.
- *ClearPEM Project Status*
  presented by João Varela
  at Crystal Clear Collaboration Meeting in Antwerp.
- *Tests of ClearPEM Detector Modules*
  presented by Pedro Amaral
  at Crystal Clear Collaboration Meeting in Antwerp.
- *Clear-PEM Off-Detector Electronics - Status Report*
  presented by Pedro Rodrigues
  at Crystal Clear Collaboration Meeting in CERN.
- *Effect of DOI and Scanner Rotation on PEM Image Reconstruction*
  presented by Andreia Trindade
  at Crystal Clear Collaboration Meeting in CERN.
- *Status of Clear-PEM Services Systems*
  presented by João Pinheiro
  at Crystal Clear Collaboration Meeting in CERN.
- *Status of FrontEnd ASIC*
  presented by Pedro Amaral
  at Crystal Clear Collaboration Meeting in CERN.

5.1.6 Academic Training

PhD Theses

- *Avaliação do desempenho de um detector PET dedicado a mamografia"*
  Andreia Trindade, (on-going)
- *Modelização e avaliação do desempenho do sistema de aquisição de dados de um detector PET para mamografia"*
  Pedro Rodrigues, (on-going)
- *Estudo da detecção de invasão dos gânglios linfáticos da região axilar na sequência de cancro da glândula mamária com um detector PET dedicado"*
  Catarina Ortigão, (on-going)
- *Estudo da localização espacial de tumores cancerígenos na glândula mamária com um detector PET dedicado"*
  Rui Moura, (on-going)

Master Theses

- *Controlo de qualidade dos módulos de detecção de um detector PET para mamografia"* Bruno Carriço, 2006-06-01

Graduation Theses

- *Experimental Characterization of the APD arrays of the ClearPEM detector modules"* Joan Luyken, 2006-06-01

5.1.7 Project Summary

	number
Articles in international journals (with direct contribution from LIP members)	4
Oral presentations in international conferences	3
Poster presentations in international conferences	2
Oral presentations in collaboration meetings	7
Master Theses	1
Graduation Theses	1

5.2 Human PET

5.2.1 Activity Report

Task: Development of RPC detectors for large-area gamma imaging

The detector development task advanced quite well. Tests with different glass types and thicknesses were made and there were several advances in the PET-RPC module design. New tests are foreseen for early 2007.

Task: Data acquisition and electronics

A 16-channel data acquisition module that will allow the measurement of the event coordinates in the RPC volume is under development. The module is based on a high-speed Xilinx FPGA and is suitable for on-line data reduction. Due to the expected data-reduction capability, a commodity host interface like the USB 2.0 can be used and is being developed. The use of the resources available on the FPGA is also foreseen to generata a time stamp to be added to the data.

Task: Simulation of a very large Axial Field Of View PET scanners based on RPCs

Simulations were performed using the GEANT4 simulation toolkit to access the gain in sensitivity of a PET scanner based on crystal detectors with increasing Axial Field Of View (AFOV). Similar simulations were performed for a PET scanner based on RPCs with Time Of Flight (TOF) information, and the results compared with the sensitivity of present commercial PET scanners. In both cases the sensitivity was assessed following the NEMA NU-2 1994 standard.
Based on previous work, detectors were parameterized in order to increase the speed of simulations. Simulations were validated against published experimental data.

Task: Image Reconstruction and Data Corrections for large Axial Field-Of-View (AFOV) Scanners

Reading and reconstruction of the simulated data is now possible using two-dimensional algorithms. Estimates of data sizes for RPC-PET have been obtained and data compression schemes have been implemented in the list-mode to sinogram routines. The large data sizes require time-optimized processing and exact rebinning techniques plus two-dimensional iterative image reconstruction is considered the most practical approach to achieve a good compromise between image quality and processing speed. In this regard, we are implementing the exact rebinning technique FORE-J. The feasibility of correcting for scatter in RPC-PET is also being investigated using simulated data. In what concerns multimodality, an RPC-PET/CT seems feasible and desirable relative to the alternative of having activity sources for transmission measurements.

5.2.2 Fundings

Code	Funding	Start	End
POCI/SAU-OBS/61642/2004	47.160 €	2005-01-01	2007-12-31

5.2.3 Team

Project coordinator: João Lima

Name	Status	%of time in project
Alberto Blanco	Technician (LIP)	10
Américo Pereira	Technician (LIP)	5
Antero Abrunhosa	Researcher (IBILI)	5
Armando Policarpo	Researcher (LIP/FCTUC)	5
Carlos Correia	Researcher (FCTUC)	5
Custódio Loureiro	Researcher (FCTUC)	10
Filomena Clemêncio	Researcher (IBILI)	20
João Lima	Researcher (LIP/IBILI)	25
João Silva	Technician (LIP)	10
José Pinhão	Technician (LIP)	10
Luís Lopes	Technician (LIP)	5
Miguel Couceiro	Researcher (LIP/ISEC)	20
Nuno Carolino	Technician (LIP)	10
Nuno Fonseca	Researcher (LIP/IBILI)	10
Paulo Fonte	Researcher (LIP/ISEC)	10
Rui Marques	Researcher (LIP/FCTUC)	5

5.2.4 Publications

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

- *Positron Range Effects on the Spatial Resolution of RPC-PET*
  A. Blanco
  IEEE Trans. Nucl. Sci. (submitted)

5.2.5 Presentations

Oral presentations in international conferences

- *RPC-PET: status and perspectives*
  presented by Paulo Fonte
  at Imaging 2006 in Stockholm, Sweden.

Seminars

- *TOF-PET com detectores gasosos*
  presented by Paulo Fonte
  at in IPEN - Instituto de Pesquisas Energéticas e Nucleares, São Paulo, Brasil.
- *Positron Emission Tomography with timing Resistive Plate Chambers: status and perspectives*
  presented by Paulo Fonte
  at CERN Detector Seminar in CERN, Geneva, Switazerland..

5.2.6 Project Summary

	number
Oral presentations in international conferences	1
Seminars	2

5.3 Monte Carlo methods applied to dosimetry in medical radiologic exposures

5.3.1 Activity Report

Resumo

Um exemplo paradigmático da utilização da simulação Monte Carlo é o da Radioterapia Externa, onde grandes benefícios podem ser alcançados com a utilização destas técnicas. A simulação Monte Carlo pode ajudar uma determinação mais rigorosa das doses efectivamente fornecidas ao volume tumoral, contribuindo desta forma para um combate mais eficaz do cancro. Mas a radioterapia não é a única área de aplicação. Outras técnicas que utilizam radiações ionizantes podem beneficiar dum cálculo de doses mais rigoroso, usando as técnicas de simulação Monte Carlo.
Juntamente com as simulações MC, este projecto participa no desenvolvimento e construção de um protótipo de um detector híbrido para radiação gama para ser utilizado em aplicações médicas.

Summary of Activities

One of the best examples of Monte Carlo application is the field of Radiotherapy. The simulation helps in a more accurate dose delivery, a thus to a more efficient tumor control. Radiotherapy is not the only field, in radiation physics application to medicine, where Monte Carlo can be used.
In this work, besides radiotherapy, other areas of application are exploited, namely internal radiotherapy or braquitherapy.

Activities

1. Monte Carlo simulation of the Varian Clinac 600c accelerator with dynamic wedges
The advent of linear accelerators with computer-controlled dynamic collimation systems and functional and anatomical imaging techniques allowed a more exact delimitation and localization of the target volume. These advanced treatment techniques inevitably increase the complexity level of dose calculation because of the introduction of the temporal variable. The Varian Clinac 600C electron accelerator has the possibility of using dynamic wedges to shape the produced x-ray beam. The effect is obtained by moving one of the secondary collimators while the beam is on.
The present work analysis the dosimetric characteristics of the dynamic wedges (DW) and compare them with the physical wedges (PW) in terms of their differences in dose distributions, beam energy spectra, energy fluence and angular distributions. The geometry of the accelerator head and x-ray beam production was simulated with the GEANT3 Monte Carlo code [1] and the dose distribution in the water phantom was obtained with the DPM Monte Carlo code [2]. The DW was modeled through the simulation of one of the jaws in several aperture positions and the movement was achieved by a weight mixing of different positions [3]. The depth dose distributions and lateral profiles for DW, PW and open fields were measured in water and compared with the Monte Carlo simulations. The experimental data and Monte Carlo simulation were compared through the "Dose/Distance-To-Agreement" methodology (gamma index), and it was verified that the criteria taxes are fulfilled. The effect of a DW on beam spectral and angular distributions was found to be much less significant than the one produced by a PW. For the 4 MV photon beam, a 45 PW can introduce a 30% increase in the mean photon energy due to the effect of beam hardening. It can also introduce a 4,5% dose reduction in the build-up region because of the reduction of the contaminating electrons. For the DW neither this mean-energy increase nor such dose reduction was found. Thus when compared to the DW, the PW significantly modifies the photon beam spectrum.
References
[1] S. Gianni, S. Ravndal and M. Marie 1994 GEANT Detector Description and Simulation Tool CERN European Organization for Nuclear Research, October edition CERN Program Library Long Writeup W5013
[2] J. Sempau, S.J. Wilderman and A.F. Bielajew 2000 DPM, a fast accurate Monte Carlo code optimised for photon and electron radiotherapy treatment planning dose calculations Phys. Med. Biol. 45 2263 91
[3] Van Santvoort J 1998 Dosimetric evaluation of the Siemens Virtual Wedge Phys. Med. Biol. 43 2651 63

2. Experimental validation of a gamma camera Monte Carlo study
In this work we have studied a Siemens E.Cam Duet gamma camera [1] with the aim of improving the current understanding of the operation of existing systems and contribute to the development of new and better detectors for medical imaging with ionizing radiations. This camera is presently used in SPECT (Single Photon Emission Computed Tomography) and planar imaging in Nuclear Medicine.

The gamma camera considered in this work was simulated using the GEANT4 code, which allows a complete Monte Carlo treatment of all physical interactions involved, from the production of initial gamma rays to the generation and tracking of optical photons originated by scintillation inside the crystal.
The simulated camera consists of a doped NaI(Tl) scintillation crystal, a Low Energy High Resolution (LEHR) collimator and an array of photomultipliers.
The source considered in this work is a Tc-99m isotropic source emitting 140 keV photons within a solid angle adjusted to the geometry. The position, momentum, energy, angular distribution and number of events are adjusted by the user at the beginning.
There are several types of collimators available for the Siemens E.Cam Duet, but only the LEHR was simulated because it is the one used with Tc-99m and other low energy sources. This collimator features parallel holes with hexagonal cells separated by thin septa.
The crystal within the gamma camera is a monolithic 44.5 x 59.1 cm2 NaI(Tl) with 9,5 mm thickness to allow complete absorption of 140 keV photons. This scintillator a light yield of 40000 optical photons per MeV of energy deposited. The GEANT4 code allows a realistic description of optical photon transport, reflection and refraction.
The light generated by scintillation in the NaI(Tl) crystal is read by a matrix of photomultiplier (PM) tubes. The position of each incident gamma ray is calculated by determining the centroid of the distribution of the light collected by each PM, taking into account such details as individual PM position inside the camera and quantum efficiency for optical photons.
Comparison between Monte Carlo and experimental measurements have been made for a 5 mm diameter spherical source placed at 5 cm distance from the collimator (LEHR) in the center of the FOV. In the simulation 500000 events within a solid angle of 20 were considered for a measured source activity of 18.6 MBq. In this example, the difference observed between simulation and experiment, probably is due to different counting statistics. Other examples with extended sources and radiological phantoms will be studied.
[1] Siemens Medical webpage. (Apr, 2005). Available from: http:// www.siemensmedical.com

3. Dosimetry in radiology

One of the basic principles of the system of radiological protection of the ICRP is the principle of the optimization, being that the responsible medical doctor for the exposition and the technician who executes it, must be sure that all the exposition for medical purposes, are kept as low as possible, having in account the intended information of diagnosis.
According to the present Portuguese legislation, in the scope of the radiological expositions, the installation responsible must assure the establishment of recommendations about the radiation doses that patients receive and to assure their availability to the medical doctor who prescribes the examination. The installation responsible must also assure that the expositions are in agreement with the reference levels for radio-diagnostic examinations, considering the European levels of diagnosis reference, when they exist (97/43/EURATOM). The aim of this work is to establish a protocol of dose measurement received by patients in radiology in order to determine the "levels of reference"of diagnosis for some of the carried out radio-diagnosis examinations at IPOFG-CROC, S.A..

4. Monte Carlo and Dosimetry in Permanent Brachytherapy Implants

The 125I brachytherapy seed model 6711 is one of the most investigated seeds in terms of dosimetric parameters in such a way that this seed is considered as the reference for many other seeds used in brachytherapy prostate permanent implants. The AAPM Task Group 43 (AAPM TG43) recommends values of radial, anisotropy dose functions and dose rate constant for the 6711 seed based on consensus values. However, several Monte Carlo (MC) and experimental studies reveal quite large differences of the calculated dosimetric parameters when compared to the recommended values. A possible cause of these differences can be explained by the modeled seed geometry and the source spatial distribution since it remains quite unknown.
Monte Carlo code Penelope 2005 is used in all simulations. In order to observe the effects of the seed geometry on the dosimetric parameters, some of the 6711 geometrical parameters were modified such as the length and radius of the silver rod and the titanium capsule, resulting then in various 6711 sub-models to simulate. In all sub-models the source distribution is the same (TG43 update spectrum). With the nominal seed geometrical parameters, different source spatial distributions were simulated. To calculate the radial, anisotropy dose distributions and the dose rate constant (defined by AAPM TG43), dose in water at several polar angles and radii, and photon energy spectra were calculated. Dose was scored in a 3D water phantom composed by 201x201x201 voxels of 0.5x0.5x0.5 mm3. Air kerma in vacuum was calculated using a simulated photon spectra scored in an annulus placed at 99.5cm with 1cm height, and 1cm radius. The annulus was filled of air. For dose calculations, 4 batches of 2.109 initial photons were used and only 2 batches were performed for photon spectra scoring.

Simulations showed that the dose rate constant does not vary significantly when varying the geometrical parameters (less than 1%). The most significant differences were found in the anisotropy dose function results, in particular for small polar angles where differences can reach up to 15% at 1cm. Finally, Results show that the size of the layer inside the seed silver core where the initial photon position is sampled, and the uniformity or not of the source distribution play a crucial role and have a great influence in the shape of the radial and anisotropy dose functions. In the case where the initial photon position is uniformly sampled, simulations showed that a layer size difference of 0.5mm results in difference of 4%-9% in the values of the anisotropy dose function in some particular situations (small polar angles) although the difference in the dose rate constant value is less than 0.5%.
This study has shown that even small variations in the geometrical parameters of the 6711 seed model can have a great influence in the anisotropy dose functions at small polar angles. Combined with the fact that most of the actual treatment planning systems used in seed prostate implants do not take into account the 3D seed orientation, the delivered dose distribution in the patient can be substantially different from the planned one. More investigation is necessary to solve this type of issue. This study has also shown how it is important to know the source distribution since it has a non-negligible effect on the calculated MC dose distributions. To improve the present situation, manufactures should provide more accurate information on this seed parameter.

Project spin-offs

An enterprise named Gyrad has been created by one of the project collaborators. This enterprise will operate in the radiologic control field.
The project made a valuable contribution for the improvement of clinic services in the Hospital Particular do Algarve, Alvor and the Hospital do Litoral Alentejano. In the first hospital the experimental and computational verification of a Siemens Dual head E.Cam was made and in the second case the quality control of the protection shielding of the imagiology service was made.
In the article submitted to IEEE one of the co-authors is a collaborator of Siemens Medical Solutions.
One of the post-graduation students, Sandra Brás who collaborate in the project is now in Health Services, working for the Algarve Radiotherapy Unit.

Scientific activity spreading actions

Organisation of the 2006 Masterclass in the Science Faculty of the Lisbon University
"Aplicações médicas das radiações ionizantes", Conceição Abreu, Escola EB 2-3 Dra. Paula Nogueira, 27 March 2006, Olhão
"A Saúde e a Radioactividade", Luis Peralta, Escola Vasco Santana, 21 April 2006, Ramada, Odivelas
"Urânio e Portugal", Conceição Abreu, Colégio Internacional de Vila Moura, 2 May 2006, Vila Moura
Organization of the Masterclass 2006 in the Faculdade de Ciências da Universidade de Lisboa, Luis Peralta and Amélia Maio, 11 March 2006, Lisboa
Project for divulging science in secondary schools, "Projecto de divulgação Científica, Ensino experimental das Ciências", Conceição Abreu, Escola EB23 Prof. Anibal Cavaco Silva, 2006 Boliqueime, Algarve.
OCJV2006 - "Program of student occupation in the Summer Radioactivity and Environment" , July 2006. 2 students from Algarve, 2 from Setúbal and 3 from Lisbon were involved in the program.

5.3.2 Fundings

Code	Funding	Start	End
POCI/FP/63448/2005	36.000 €		
POCI/FP/63448/2005	36.000 €		
POCI/FP/63448/2005	36.000 €	2005-09-01	2006-08-31
POCI/FP/63909/2005	30.000 €	2006-09-01	

5.3.3 Team

Project coordinator: Luis Peralta

Name	Status	%of time in project
Adérito Chaves	Researcher (IPO-Coimbra)	67
Amélia Maio	Researcher (LIP/FCUL)	10
Ana Catarina Farinha	Graduate student (LIP)	96
Bernardo Tomé	Researcher (LIP)	2
Carla Oliveira	Researcher (IPO-Coimbra)	40
Carla Santos	Master student (ITN)	67
Conceição Abreu	Researcher (LIP/UALG)	27
Enrico D´Abramo	Researcher (LIP/CERN)	20
Florbela Rego	PhD student (LIP)	67
João Castro Costa	Master student (LIP/Hospital do Litoral Alentejano)	13
João Gentil	PhD student (LIP/FCUL)	7
Luis Peralta	Researcher (LIP/FCUL)	57
Marco Quinteiro	Researcher	7
Margarida Fragoso	Post-Doc (LIP)	73
Maria do Carmo Lopes	Researcher (IPO-Coimbra)	27
Patrick Sousa	PhD student (LIP/UALG)	27
Sandra Brás	(UALG)	67
Sandra Soares	PhD student (LIP/UBI)	100
Sónia Rodrigues	Master student (LIP/UALG)	100
Zita Lopes	Student (LIP)	100

5.3.4 Publications

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

- *Monte Carlo Simulation and Experimental Characterization of a Siemens E.Cam Dual Head Gamma Camera*
  S. Rodrigues, B. Tomé, M. C. Abreu, N. Santos and P. Rato Mendes
  IEEE Transactions in Nuclear Science (submitted)

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

- *Geant4 Developments and Applications*
  L. Peralta, P. Rodrigues, B Tomé, A. Trindade et al.
  IEEE Trans. Nucl. Sci. Vol 53 (2006) 270-278

International Conference Proceedings

- *Effect of the source spatial distribution on the dosimetric parameters of the 125I brachytherapy 6711 seed*
  A.Chaves, M.C. Lopes, L. Peralta
  ISRP-10, 17-22 September 2006, Coimbra - Portugal (submitted)

- *Monte Carlo Simulation of the Varian Clinac 600C Accelerator Dynamic and Physical Wedges*
  S.Soares, A.Chaves, L.Peralta, M.C.Lopes
  ISRP-10, 17-22 September 2006, Coimbra - Portugal. (submitted)

- *Effect of the geometry on the dosimetric parameters of the 125I brachytherapy 6711 seed*
  A.Chaves, M.C. Lopes, L. Peralta
  ESTRO 25, 8-10 October 2006, Leipzig Germany. (accepted)

- *Monte Carlo Simulation of the Varian Clinac 600C Accelerator Dynamic and Physical Wedges*
  S.Soares, A.Chaves, L.Peralta, M.C.Lopes

First European Workshop on Monte Carlo Treatment Planning of the European Workgroup on MCTP 22 - 25 October , Gent, Belgium (submitted)

National Conference Proceedings

- *Simulação Monte Carlo de uma Câmara Gama e Validação Experimental*
  S. Rodrigues, B. Tomé, M. C. Abreu, N. Santos, P. Rato
  II Jornadas Técnicas de Imagiologia, Aveiro

- *Radioterapia no IPOFG-CROC, S.A. - os desafios do futuro*
  M.C. Lopes, C. Alves, A. Chaves, A. Matos, J. Mateus, M. Capela, M.C. Sousa
  14 Conferência Nacional de Física "Física para o Séc. XX

5.3.5 Presentations

Poster presentations in international conferences

- *Effect of the source spatial distribution on the dosimetric parameters of the 125I brachytherapy 6711 seed*
  presented by Adérito Chaves
  at ISRP-10 in Coimbra.

- *Monte Carlo Simulation of the Varian Clinac 600C Accelerator Dynamic and Physical Wedges*
  presented by Sandra Soares
  at ISRP-10 in Coimbra.

- *Effect of the geometry on the dosimetric parameters of the 125I brachytherapy 6711 seed*
  presented by Adérito Chaves
  at ESTRO 25 in Leipzig Germany.

- *Monte Carlo Simulation of the Varian Clinac 600C Accelerator Dynamic and Physical Wedges*
  presented by Sandra Soares
  at First European Workshop on Monte Carlo Treatment Planning of the European Workgroup on MCTP in Gent, Belgium.

Presentations in national conferences

- *Física Atómica, radioactividade e radiações ionizantes em laboratório*
  presented by Conceição Abreu
  at 2 Encontro Regional de Professores de Física e Química in Universidade do Algarve, Faro.

- *Que conhecimentos possuem os alunos sobre a Física das radiações*
  presented by Florbela Rego
  at 2 Encontro regional de professores de Física e Química in Universidade do Algarve,.

- *Simulação Monte Carlo de uma Câmara Gama e Validação Experimental*
  presented by Sónia Rodrigues
  at II Jornadas Técnicas de Imagiologia in Aveiro.

- *The Joy of Knowledge Sharing: Two Examples of Teachers, Researchers, Students and Science Centers Interaction*
  presented by Conceição Abreu
  at Conferência Internacional Hands-on Science in Braga.

5.3.6 Academic Training

PhD Theses

- *Simulação Monte Carlo do Campo de Radiação Produzido por um Acelerador Linear Varian Clinac 600C usando Cunhas Dinâmicas"*
  Sandra Soares, 2006-12-02

- *Desenvolvimento de um detector de alta resolução para imagem médica com radiações ionizantes"*
  Patrick Sousa, 2006-12-31
- *Estudo e desenvolvimento de uma câmara PET com fins didácticos"*
  Florbela Rego, (on-going)

Master Theses

- *Simulação de uma câmara gama"*
  Sónia Rodrigues, 2006-12-02
- *Dosimetria de paciente em radiologia, no IPOFG-CROC,S.A."*
  Sandra Brás, 2006-12-02
- *Protecção Radiológica da Unidade de Radiodiagnóstico do Hospital do Litoral Alentejano"*
  João Castro Costa, (on-going)
- *Caracterização da Radiação produzida por uma unidade de raios X, com energia máxima de 100 keV"*
  Sérgio Gabriel, (on-going)
- *Protecção radiológica no serviço de radiologia do Hospital Distrital de Faro"*
  Ana Filipa Ferreira, (on-going)
- *Ensino da Física das Radiações através de experiências simples"*
  Ana Pinto, 2006-11-02
- *A Radioactividade e o Ambiente no Ensino Secundário"*
  Carmen Oliveira, 2006-11-30

5.3.7 Project Summary

	number
Articles in international journals (with indirect contribution from LIP members)	1
International Conference Proceedings	4
National Conference Proceedings	2
Poster presentations in international conferences	4
Presentations in national conferences	4
PhD Theses	2
Master Theses	4

Chapter 6

Detectors

6.1 Applications of Timing Resistive Plate Chambers - RPC

6.1.1 Activity Report

Resumo:

Neste projecto pretendemos desenvolver uma tecnologia de detecção de partículas elementares denominados "Câmaras de Placas Resistivas". Estes detectores têm aplicação em experiências de Física das Partículas e estamos a desenvolver também aplicações na Imagiologia de Radioisótopos.

Summary of the Activities:

During the year 2005 two projects were spawned from this one: HADES and HUMAN PET.
Collaboration on the CBM experiment at GSI was continued, mostly within the framework of the EU FP6 project I3HP. Ceramic RPCs with very high rate capability were further developed for this application.
Several possibilities for the continuation of large-scale detector implementation in HEP beyond HADES were investigated. Besides our present involvement on the CBM experiment, which may be re-evaluated in the future, contacts were made with the experiments PANDA and R3B at GSI with generally positive results. However, our present intense involvement on the HADES and HUMAN PET projects excludes any real progress in this area. Unfortunately, although it has been tried, there are no perspectives for involvement in CERN experiments.
A new line of work on the fundamental properties of swarms in gases under very large electric fields, like those found in timing RPCs, was opened, based on the interests of the new LIP investigator Alessio Mangiarotti. This covers theoretical and experimental aspects, the later in the framework of a collaboration with the Instituto de Pesquisa Energéticas e Nucleares, São Paulo, Brasil, and on hardware to be adapted from a setup donated by Prof. B.Schmidt and the Univ. Heidelberg. A project on this subject, also in collaboration with "Centro de Física dos Plasmas do Instituto Superior Técnico", was submited to FCT's "general physics" call and considered "very good", but received no funding.

6.1.2 Fundings

Code	Funding	Start	End
RII3-CT-2003-506078	55.000 €	2004-01-01	2006-12-31
010.6/B009/2005	110.000 €	2004-01-01	2006-12-31
POCI/FP/63411/2005	34.540 €	2005-06-01	2006-11-09

6.1.3 Team

Project coordinator: Paulo Fonte

Name	Status	%of time in project
Alberto Blanco	Technician (LIP)	29
Alexandre Moita	Technician (LIP)	26
Américo Pereira	Technician (LIP)	10
Andrêa Gouvêa	Student (LIP)	17
Armando Policarpo	Researcher (LIP/FCTUC)	13
Carlos Capela	Researcher (ESTGL)	26
Carlos Neves	Researcher (ESTGL)	9
Carlos Silva	Technician (LIP)	26
Carlos Sousa	Researcher (ESTGL)	26
Edward Santos	Student (LIP)	17
Ermelinda Antunes	Researcher (LIP/FCTUC)	13
João Silva	Technician (LIP)	4
Joaquim Oliveira	Technician (LIP)	26
José Pinhão	Technician (LIP)	20
Luís Lopes	Technician (LIP)	4
Miguel Couceiro	Researcher (LIP/ISEC)	26
Milena Vieira	Researcher (ESTGL)	26
Nuno Carolino	Technician (LIP)	29
Nuno Fonseca	Researcher (LIP/IBILI)	9
Paulo Fonte	Researcher (LIP/ISEC)	34
Rui Alves	Technician (LIP)	26
Rui Marques	Researcher (LIP/FCTUC)	13

6.1.4 Publications

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

- *On the deterministic and stochastic solutions of Space Charge models and their impact on high resolution timing*
  A. Mangiarotti, C.C. Bueno, P. Fonte, A. Gobbi, D. González-Díaz, L. Lopes
  Nucl. Phys. B (Proc. Suppl.) 158 (2006) 118-122

- *Spatial resolution on a small animal RPC-PET prototype operating under magnetic field*
  A. Blanco, N. Carolino, C.M.B.A. Correia, L. Fazendeiro, Nuno C. Ferreira, M.F. Ferreira Marques, R. Ferreira Marques, P. Fonte, C. Gil, M. P. Macedo
  Nucl. Phys. B (Proc. Suppl.) 158 (2006) 157-160

- *Positron Range Effects on the Spatial Resolution of RPC-PET*
  A. Blanco
  IEEE Trans. Nucl. Sci. (submitted)

- *Very high position resolution gamma imaging with Resistive Plate Chambers*
  A. Blanco, N. Carolino, C.M.B.A. Correia, L. Fazendeiro, Nuno C. Ferreira, M.F.Ferreira Marques, R. Ferreira Marques, P. Fonte, C. Gil, M. P. Macedo
  Nucl. Instrum. and Meth. in Phys. Res. A 567 (2006) 96-99

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

- *HADES experiment: Di-lepton spectroscopy in p+p (2.2 GeV) and C+C (1 and 2 A GeV) collisions*
  W.Przygoda and the HADES collaboration
  ACTA PHYSICA POLONICA B 37 (1): 139-151

Institute reports

- *Status of the HADES RPC Project*
  The HADES RPC Group
  GSI Scientific Report 2005

International Conference Proceedings

- *Advances in gaseous time-of-flight detectors*
  A.Blanco, C.Capela, R. Ferreira Marques, P.Fonte, D.González-Diáz, L.Lopes, A.Mangiarotti, C.Neves, A.J.P.L. Policarpo, C. Sousa, M.Vieira
  Proceedings of Science - PoS(HEP2005)376

6.1.5 Presentations

Oral presentations in international meetings

- *Very high rate timing RPCs for CBM TOF*
  presented by Paulo Fonte
  at 8th CBM collaboration meeting in IPHC Strasbourg, France.

Oral presentations in collaboration meetings

- *RPC: Beam and cosmic test results*
  presented by Luís Lopes
  at HADES Collaboration Meeting XVI in Dresden Germany.
- *RPC: K detection and wall design*
  presented by Alessio Mangiarotti
  at HADES Collaboration Meeting XVI in Dresden, Germany.
- *RPC: Construction status, summary and general outlook*
  presented by Paulo Fonte
  at HADES Collaboration Meeting XVI in Dresden, Germany.
- *RPC status*
  presented by Paulo Fonte
  at HADES Collaboration Meeting XVII in GSI, Germany.

Seminars

- *TOF-PET com detectores gasosos*
  presented by Paulo Fonte
  at in IPEN - Instituto de Pesquisas Energéticas e Nucleares, São Paulo, Brasil.

6.1.6 Project Summary

	number
Articles in international journals (with direct contribution from LIP members)	3
Articles in international journals (with indirect contribution from LIP members)	1
Institute reports	1
International Conference Proceedings	1
Oral presentations in international meetings	1
Oral presentations in collaboration meetings	4
Seminars	1

6.2 Microstructure Gas Detectors

6.2.1 Activity Report

Resumo:

O projecto em curso envolve o desenvolvimento de detectores de radiação gasosos com sistemas de leitura ópticos, neste caso fotomultiplicadores. A cintilação é emitida pelas avalanches produzidas em microestruturas e permite a localização das interacções. São considerados especialmente um detector para imagiologia com neutrões térmicos de 32x32 cm2 e resolução de 1 mm, uma câmara de traços (TPC) e um espctrómetro de neutrões rápidos.
Estes trabalhos são em parte desenvolvidos numa actividade financiada pelo 6 Quadro Comunitário de Apoio - JRA2 - MILAND: Millimetre resolution Large Area Neutron Detector NMI3 - HII3-CT-2003-505925.

Report 2006

At the 6th MILAND meeting hold at the Normafa Hotel, Budapest, the 16-17 January 2006, it was decided that the fabrication of the detector (T6 task) is the priority number one and most of the available budget for the next two years should be allocated to this task. Several partners express the necessity to support other technical development in parallel with T6, the Anger camera (task T3) coordinated by LIP being one of them, as it could bring new innovation and it should probably solve the problem of large area detectors.
Considering the promising results obtained in the preliminary tests carried at the ILL and ISIS facilities and the existing experience at the ILL in successful operation of MSGCs at 2 bar CF4, it was pointed that task T3 should coordinate with task T2 (MSGC development) in order to study the possibility of using a MSGC as the active element of the Anger camera, mounted immediately after the aluminium entrance window of the detector.
This reallocation of budget and intentions caused some changes on our 2006 plan and our main activities for 2006 were:

1.MSGC charge and light measurements
At the 24th February Paris meeting it was agreed to manufacture a microstrip having 5 groups of anodes, having widths of 6, 10, 15, 20 and 30m. Considering the good experience of the ILL using plates with 1 mm pitch this value was kept. Three of these plates were tested at LIP using pure CF4 and 4He from Air Liquide. A Philips PMT model 56TUVP using a S20 type photocathode, QE[200, 850nm] was used and calibrated with a NaI (Tl) crystal irradiated with 60Co and 137Cs; 22Na  sources. A complete set of data was obtained for 1, 2 and 3 bar CF4 and addition of up to 3 bar He. As shown before, the higher CF4 pressure had higher light yield tipically .15 photons per secondary electron, decreasing at the narrowest anode widths (6 and 10 m). Although the 30 m anode could achieve safe gain over 500, considering that the larger anodes need higher voltage for similar gain, that could be potentially damaging, we decided to choose the 15 m anode as the best compromise between charge and light, and a batch of MSGCs having 15 m anodes was commissioned from the LLB. These plates will be used in 2007 for the tests to be carried at the ILL and ISIS neutron facilities.

2.Study of Xe- CF4 mixtures
The measurements were carried both with standard (biconical) GEM (50 m thickness, 140 m pitch, 45 m metal hole and 35 m kapton hole) and wire chambers fitted with 10 and 20 m wires. Adding 2% Xe to the 3 bar CF4 filling decreased the GEM voltage by 12%, and maximum gain before discharge was almost doubled compared to pure CF4, but this value is not enough to compensate for the lower light yield due to the Xe addition.
A system using a wire detector was assembled to study the performance of wire chambers using the Xe CF4 quencher. The detector was fitted with a 16mm diameter LiF window and the avalanche light was readout by a 56TUVP Philips PMT. A 10 m diameter gold plated tungsten wire was mainly used, as no effects were seen with the 20 m wire. Although some improvements were measured when adding a small amount (2%) of Xe the gain of 1000 could be reached at 2800V versus 3300V without Xe, it was much less than reported by the Russian group. Considering that the light yield of this setup wire detector with Xe- CF4 was very low ($\approx$0.03 ph/ e) and the results where not interesting to task T1 this task was stopped.

3.Optical TPC developements
It has been shown that, when operated with adequate gas mixtures, the GEM scintillation can be used for track imaging, using integrating devices (CCDs) and photomultipliers. We have shown that the light signals taken

from a photomultiplier were faster than the charge signals, that their risetime was correlated with the track orientation, and could be used for the determination of the track angle in TPCs. The full track localization and dE/dX information can be obtained coupling the CCD image with this information.
However, considering the very high number of photons typically emitted by a GEM avalanche (500 per primary electron) a PMT based Anger type readout can be envisaged for the full readout of the TPC with a typical readout deadtime of less than 1 s. We built a prototype using four 40 mm PMTs and tested it in a small TPC fitted with a 10x10 cm2 double GEM. The detector, operated with Ar+5%CF4 at atmospheric pressure, was tested with 241Am alpha particles emitted in various orientations. We obtained typical track angle resolution of 2 () at 45 and achieved point position resolution better than 1 mm (FWHM) at the X and Y directions on the GEM plane. These results will be presented at the Vienna Conference on Instrumentation (February 2007) and submitted for publication to Nuclear Instruments and Methods

4. Spectroscopy studies
A detailed spectral study of the light emitted by MSGCs in mixtures of CF4 and HeCF4 at pressures up to 6 bar and different gas gains was carried. Relative intensities of the 300 nm and 600 nm band were found to depend on pressure of CF4. The effect of drift field on primary light in this mixtures was also studied. These results, with a complementary analysis will be published in 2007.

5.Simulation studies
This task is now finished at LIP. A generic tool for the gas scintillation neutron Anger camera simulation was developed using C++ Monte Carlo simulation code embbebed in a Matlab interface.

6.2.2 Fundings

Code	Funding	Start	End
CERN/FNU/43735/2001	50.000 €	2002-03-11	2006-06-30
RII3-CT-2003-505925	88.000 €	2004-01-01	2007-12-31
POCTI/FP/FNU/50338/2003	25.000 €	2004-07-04	2006-04-30

6.2.3 Team

Project coordinator: Francisco Fraga

Name	Status	%of time in project
Alberto Blanco	Technician (LIP)	20
Américo Pereira	Technician (LIP)	25
Armando Policarpo	Researcher (LIP/FCTUC)	25
Ermelinda Antunes	Researcher (LIP/FCTUC)	5
Filipa Balau	Master student (LIP)	95
Francisco Fraga	Researcher (LIP/FCTUC)	60
João Silva	Technician (LIP)	20
Luís Margato	PhD student (LIP)	70
Margarida Fraga	Researcher (LIP/FCTUC)	45
Nuno Carolino	Technician (LIP)	25
Paulo Mendes	Researcher (LIP/FCTUC)	45
Rui Marques	Researcher (LIP/FCTUC)	27
Sónia Pereira	PhD student (LIP)	100
Susete Fetal	Researcher (LIP/ISEC) *	65

6.2.4 Project Summary

(no values to report)

6.3 Oficina-Coimbra

6.3.1 Activity Report

Resumo

Durante o ano de 2006 o principal desenvolvimento quanto ao processo de reequipamento da oficina mecânica do LIP foi a realização do concurso internacional para a aquisição de duas novas máquinas CNC: um torno e um centro de maquinagem. Após a decisão do júri foi já assinado um dos contratos.
A oficina continuou a realizar trabalhos para as actividades do LIP bem como para outros grupos de investigação da Univesidade e Hospitais, bem como para actividades de divulgação.

Report

2006 was a key year in the process of acquisition of new equipment for the LIP mechanical workshop, and in the renovation of procedures. The two international calls of tender for the lathe and the machinery center were finished and several proposals received and analysed by a juri. The machines were selected and one of the contracts was signed.
A special commission for analysis of the mechanical workshop working methods and conditions was established, several experts were consulted (from the ISQ and the Cemtinfe) and a report written and presented. It proposes a new and clear distribution of tasks and stimulates the procurement of work outside the LIP activities.
The workshop produced a profissional presentation stand, which was shown in the important exhibition FEMA, at Exponor.
Several important projects were supported by the workshop, as the construction of the ToF wall, using the RPC technology, for the HADES experiment, at GSI, several pieces of exhibition equipment for the "Ciência Viva"outreach center "Exploratório Infante D. Henrique"and the Museum of Physics, a spark chamber for outreach purposes. It continued the support of the LIP detector activities and other research groups in the University (as the Robotic group) and Hospitals. It also continued the work on the instalation and commissioning of the ATLAS/LHC light distribution system, the optical fibers and connectors, for calibration and monitoring of the Tilecal PMTs. It finished the last components for the CAMCAO project, for ESO.
The next table summarises the activities of the workshop for different projects and institutions during 2006.

	Man-	Power	Cost	Charged Value
	(%)	(HH)	€	€
ATLAS		304		
OUTREACH		321		
PET - MAMMOGRAPHY		3		
LIP-Lisboa	13.0	628	7417	7146
NMI3		24		
RPC		30		
GEMs and SCINTILLATION		146		
LIQUID XENON		70		
Human PET		75		
DIRAC		808		
LIP-Coimbra - Projects	23.9	1153	15477	15477
LIP-Coimbra - Maintenance	19.2	926	12301	
Physics Department UC	15.2	732	23332	
Outside customers	28.8	1391	24486	22125
TOTAL	100.0	4885	83013	44748

6.3.2 Fundings

Code	Funding	Start	End
REEQ/573/FIS/2005	441.000 €	2005-03-01	2006-12-31

6.3.3 Team

Project coordinator: João Carvalho

Name	Status	%of time in project
António Onofre	Researcher (LIP/UCPFF)	10
Armando Policarpo	Researcher (LIP/FCTUC)	10
Carlos Silva	Technician (LIP)	10
Fernando Moita Ribeiro		10
Francisco Fraga	Researcher (LIP/FCTUC)	10
Isabel Lopes	Researcher (LIP/FCTUC)	10
João Carvalho	Researcher (LIP/FCTUC)	20
Joaquim Oliveira	Technician (LIP)	10
José Pinhão	Technician (LIP)	10
José Pinto Da Cunha	Researcher (LIP/FCTUC)	10
Margarida Fraga	Researcher (LIP/FCTUC)	10
Maria do Carmo Lopes	Researcher (IPO-Coimbra)	10
Paulo Fonte	Researcher (LIP/ISEC)	10
Paulo Mendes	Researcher (LIP/FCTUC)	10
Rui Alves	Technician (LIP)	10
Rui Marques	Researcher (LIP/FCTUC)	10
Vitaly Chepel	Researcher (LIP/FCTUC)	10

6.3.4 Project Summary

(no values to report)

Chapter 7

Outreach

7.1 Particle physics education and public outreach

7.1.1 Activity Report

Resumo de actividades:

A necessidade de divulgação e educação pública da Física das Partículas tem ganho uma importância cada vez maior no seio da comunidade científica. O CERN promoveu a criação de um fórum a nível europeu, o European Particle physics Outreach Group (EPPOG), que junta duas vezes por ano as pessoas preocupadas com estas questões, para partilhar ideias e resultados e para organizar actividades em conjunto. Em particular, foram realizadas em 2006 neste âmbito as European Masterclasses in Particle Physics, que juntaram estudantes do ensino secundário para analisar dados reais recolhidos em DELPHI, no LIP-Lisboa (com o IST), na FCUL e no LIP-Coimbra. No caso concreto do LIP, aproveitou-se também as sinergias criadas com o projecto "Telescópio de Raios Cósmicos" (TRC), que teve alguns desenvolvimentos importantes em 2006 e está agora na fase de testes de aquisição de dados em rede. Das actividades promovidas ou realizadas por membros do LIP em 2006, destaca-se os estágios de Verão no âmbito da Ciência Viva (OCJF2006), a organização de palestras públicas, a participação nas reuniões do grupo EPPOG, e a contribuição para o Projecto CRESCERE. Ainda em 2006 foi organizada pelo LIP a sessão pública da Conferência Internacional "ECRS´06 - 20th European Cosmic Rays Symposium", que teve um grande sucesso junto dos jovens participantes.
No âmbito do Projecto CRESCERE, em parceria com a Faculdade de Ciências da Universidade de Lisboa, com o LNF/INFN de Frascati, Itália, com o IFIN-HH de Bucareste, Roménia, e financiado pela EU, conjuntos de alunos de escolas secundárias portuguesas, italianas e romenas, realizaram experiências com raios cósmicos, remotamente e com assistência em linha. O Projecto teve uma aceitação bastante acima das expectativas iniciais, tendo sido realizadas perto de 150 sessões de tomadas de dados com alunos de escolas dos 3 países, algumas em regiões bastante remotas (por ex., Madeira e Mêda, Portugal, Salerno, Itália, e Satu Maré, Roménia), tendo sido extendido até final de Fevereiro devido ao grande interesse demonstrado.
No projecto "Telescopio de Raios Cosmicos"foi terminada a instalação dos detectores nos telhados das escolas e iniciado o processo de testes de aquisição de dados em rede, após adaptação dos programas de aquisição e análise para processar a informação do GPS. Foi organizada por membros do LIP as jornadas "CRSP´06 - 2nd Workshop on Cosmic Rays in Schools Projects", em que 10 projectos europeus vieram a Portugal relatar o seu estado e planos para o futuro. Nestas jornadas foram lançadas as bases para uma futura colaboração europeia destes projectos ("Eurocosmics").
Finalmente, construiram-se detectores para divulgação e experimentação nas Escolas, em particular a primeira câmara de Faíscas construída em Portugal, e kits de radioactividade no âmbito da Ocupação Científica de Jovens em Férias para analisar a radioactividade ambiente, com o apoio da Ciência Viva.

Summary of Activities:

The problem of getting the public's attention towards Particle Physics, and in particular end-years high-schools teachers and students (along with their families), is being tackled by two different roads: the maintenance and development of traditional education and public outreach activities, and projects involving the construction and installation of detectors at high-schools, like the project "Measurement of Time Correlations in Cosmic Rays" (TRC), or their operation remotely, as in the Project "CRESCERE" that promotes the realization of

real experiments in the field of cosmic rays by high-school students and teachers. The activities performed are described per section below.
Education and Public Outreach
The outreach activity has become a very important issue in experimental particle physics, to promote the field and explain the scientific achievements made for the money invested in the experiments. This much has been recognized at CERN and elsewhere, and a set of concerned people have set-up a working group devoted to the public awareness of particle physics (EPPOG European Particle Physics Outreach Group). The portuguese representative in this group participated in the two meetings held in 2006, reporting the local activities related to the outreach of particle physics, and coordinated the local implementation of the CERN training program "HST High School Teachers at CERN", for which two portuguese teachers were selected to participate in the program, with CERN support. Some activities involving high school teachers and students had the support of the "Ciência Viva" program, and were organized in the framework of the program "Ocupação Científica de Jovens no Verão" of the Ministry of Science and Superior Education. Members of LIP have also performed many seminars in high schools, along the year, promoting particle physics, astroparticle physics and medical physics. One very successful activity was the EPPOG European Masterclasses in Particle Physics 2006, which gathered high school students to analyse real data events collected by the DELPHI detector at CERN. This activity will be repeated around March 2007. Most of the activities with the schools were made possible, or reached the intended audience, much because of the contacts established in the joint "Ciência-Viva" project "Telescópio de Raios Cósmicos", of which the report follows. The fact that LIP members supervise the updates of high-school physics teachers in the Faculdade de Ciências de Lisboa, also helped in reached the intended audience for the activities performed. With the support of Ciência Viva we have built detectors for public outreach and experimentation in schools, in particular the first Spark Chamber built in Portugal and radioactivity kits for measuring the radioactivity in the school environment.
We have also organized a very successful public session at the major International Conference "ECRS´06 - 20th European Cosmic Rays Symposium".
TRC "Ciência-Viva"'s Telescópio de Raios Cósmicos Measurement of Correlations in Cosmic Rays with the High-schools
In the follow-up of the project "Telescópio de Raios Cósmicos", LIP members have finished the installation in the roof of the schools of almost all detector stations (one case in which we were not yet allowed to proceed with the installation), including setting-up the GPS detectors and testing the hardware. Schools are now equipped to detect showers of particles, and the acquisition program is being updated to process the new information (GPS information to give the time tag of each event, synchronized to better than 100 ns precision). The station at IST was used in the project CRESCERE, in which Portuguese, Italian and Romanian students performed the "Measurement of the Flux of Cosmic Rays", remotely, in data-taking sessions tutored by LIP members. This was part of a Portuguese-Italian-Romanian collaboration involving 4 institutes (LIP, FCUL in Portugal, LNF/INFN in Italy, and IFIN-HH in Romania) with support from EU. The success of this activity was manifested in the extension of this project to February 2006. Finally in the scope of this project LIP members have organized the 2nd Workshop on Cosmic Rays in Schools Projects, in which about 10 projects from Europe reported their status and plans, and launched the basis for a future colaboration of such projects ("Eurocosmics").
Finally, detectors were built for outreach and experimentation in high-schools, in particular the first spark chamber built in Portugal, and radioactivity kits in the scope of Ciência Viva´s programa "Ocupação Científica de Jovens em Férias"(Science in the Summer for young students).

7.1.2 Fundings

Code	Funding	Start	End
POCTI/DIV/2005/00087	50.000 €	2005-06-01	2007-03-31
000 CRESCERE	23.400 €	2005-07-01	2006-02-28
OCJF2006	1.100 €	2006-07-01	2006-09-30

7.1.3 Team

Project coordinator: Pedro Abreu

Name	Status	%of time in project
Amélia Maio	Researcher (LIP/FCUL)	9
Américo Pereira	Technician (LIP)	7
António Onofre	Researcher (LIP/UCPFF)	5
Carlos Marques	Student (LIP/FCUL) *	2
Carlos Silva	Technician (LIP)	7
Conceição Abreu	Researcher (LIP/UALG)	8
Fernando Barão	Researcher (LIP/IST)	10
Gonçalo Pires	Technician (LIP)	5
João Carvalho	Researcher (LIP/FCTUC)	10
João Pires	Master student (LIP)	20
José Silva	PhD student (LIP/FCUL)	13
Lina Moniz	Student (LIP)	100
Luis Peralta	Researcher (LIP/FCUL)	13
Miguel Ferreira	Technician (LIP)	10
Pedro Abreu	Researcher (LIP/IST)	46
Pedro Assis	PhD student (LIP/FCT)	5

7.1.4 Presentations

Oral presentations in international conferences

- *TRC Project Status - Analysis Techniques*
  presented by Lina Moniz
  at Cosmic Rays in School Projects 06 in Escola Superior de Tecnologias de Saúde de Lisboa.
- *TRC Project Status - Installations and Prospects*
  presented by Pedro Abreu
  at Cosmic Rays in School Projects 06 in Escola Superior de Tecnologias de Saúde de Lisboa.

Oral presentations in collaboration meetings

- *CRESCERE Project and other outreach activities in Portugal*
  presented by Pedro Abreu
  at EPPOG Spring Meeting in Imperial College, Londres, Inglaterra.
- *Outreach in Portugal*
  presented by Pedro Abreu
  at EPPOG Autumn Meeting in CERN, Geneva, Switzerland.

Outreach seminars

- *O Estranho Mundo das Partículas Elementares*
  presented by Pedro Abreu
  at in Auditório da Câmara Municipal da Amadora.
- *O Estranho Mundo das Partículas Elementares*
  presented by Pedro Abreu
  at Semana da Física X in NFIST, Salão Nobre do IST, Lisboa.

7.1.5 Academic Training

Master Theses

- *Estudos de Raios Cósmicos de Energia Média com o TRC"*
  João Pires, (on-going)

7.1.6 Events

- *Cosmic Rays in School Projects 06*
  Workshop, Escola Superior de Tecnologias de Saude de Lisboa, 2006-09-09
- *EPPOG - European Masterclasses 2006 - Seja Cientista por um Dia!*
  Outreach Event, LIP, IST e FCUL, Lisboa, LIP e FCTUC, Coimbra, 2006-03-11
- *Trovoada Cósmica!*
  Outreach Event, LIP e IST, Lisboa, 2006-07-03
- *Telhas e Fibras pticas a cintilar!*
  Outreach Event, LIP e FCUL, Lisboa, 2006-07-05
- *O Funeral do Muão e a Relatividade de Einstein*
  Outreach Event, LIP e FCUL, Lisboa, 2006-07-05

7.1.7 Project Summary

	number
Oral presentations in international conferences	2
Oral presentations in collaboration meetings	2
Outreach seminars	2
Workshops	1
Outreach Events	4