
# Laboratório de Instrumentação e Física Experimental de Partículas

## Activity Report

## 2012

# Contents

# Chapter 1

# Overview

## 1.1 Introdução

O LIP, criado em 1986 como laboratório de referência nacional para a colaboração com o CERN (Organização Europeia de Pesquisa Nuclear), é uma associação científica e técnica sem fins lucrativos e de utilidade pública para a pesquisa em Física Experimental de Partículas e Instrumentação Associada, reconhecido como Laboratório Associado.
São associados do LIP as Universidades de Coimbra, Lisboa e Minho, o Instituto Superior Técnico, a Fundação para a Ciência e a Tecnologia (FCT) e a Associação Portuguesa das Empresas do Sector Eléctrico e Electrónico (ANIMEE)
Os domínios de investigação do LIP incluem: *Física Experimental de Partículas em aceleradores e sem aceleradores (física das astropartículas), *Instrumentação de Detecção de Radiação, Aquisição de Dados e Processamento de Dados, *Computação Avançada, *Física Médica e outras aplicações
A actividade regular do LIP inclui ainda educação e formação avançada, divulgação científica e apoio à educação científica e tecnológica, transferência de tecnologia e ligação industrial com o CERN e outros laboratórios internacionais.
As actividades de investigação do LIP são desenvolvidas principalmente no âmbito de colaborações no CERN, mas também em outras organizações internacionais (como a ESA - Agência Espacial Europeia) e ainda em instalações científicas internacionais, como o GSI, SNOLAB, LUX ou o Observatório Pierre Auger, entre outras.
O LIP partilha equipamentos e recursos humanos com um grande número de grupos de investigação e instituições, nacionais e internacionais, contribuindo com seus próprios recursos técnicos e científicos para benefício de programas científicos comuns. As infra-estruturas de computação são usadas por múltiplas instituições de investigação; as oficinas de mecânica de precisão encontram-se abertas às necessidades da comunidade científica nacional e internacional; e o LIP instalou o Laboratório Tagus-LIP para Física Médica, em conjunto com hospitais e outras entidades.
O LIP é um Laboratório Associado desde 2001, avaliado como "Excelente"em quatro avaliações sucessivas por painéis internacionais; é composto de três unidades, em Coimbra, Lisboa e Minho, com acordos específicos com cada universidade para a partilha de recursos. No LIP trabalham actualmente 212 pessoas, 98 com um grau de doutor, incluindo investigadores nacionais e estrangeiros e professores do Ensino Superior e recebe por ano muitos estudantes de mestrado e doutoramento para preparação das suas teses. O LIP coordena uma rede internacional de formação avançada em Física de Partículas, Astrofísica e Cosmologia (IDPASC).

#### LIP 2012

A Universidade de Coimbra, a Universidade de Lisboa, a Universidade do Minho e o Instituto Superior Técnico tornaram-se associados do LIP a partir de 1 de Janeiro de 2012, fortalecendo assim velhos laços de cooperação. O mais recente pólo do LIP, na Universidade do Minho, já em pleno funcionamento, está focado na colaboração estreita entre físicos teóricos e experimentais com vista à exploração dos dados do LHC, especialmente na experiência ATLAS.
Em 2012, o LIP participou na descoberta de uma nova partícula – candidata a ser o bosão de Higgs, partícula prevista no Modelo Padrão da Física de Partículas – nas experiências ATLAS e CMS do LHC, o grande colisionador de hadrões do CERN. A concepção, construção e comissionamento de ATLAS e CMS dominaram os esforços do LIP nos últimos 15 anos, e hoje participamos activamente, em ambos os casos, na manutenção, na tomada de dados e na respectiva análise, incluindo a procura do bosão de Higgs. No início de 2012, o líder do grupo do LIP em CMS foi eleito vice coordenador da colaboração internacional CMS.

O LIP também está empenhado noutras experiências com aceleradores, como COMPASS no CERN e HADES no GSI. A equipa de COMPASS organizou no ano passado em Lisboa a reunião da colaboração, juntamente com o Workshop Internacional sobre Estrutura e Espectroscopia Hadrónicas. Em HADES, foi demonstrado que a parede de RPC-TOF, projectada, construída e mantida pelo LIP, atinge uma precisão melhor do que 100 pico-segundos para colisões ouro-ouro.
Em relação à participação em experiências de física de Astropartículas, são de referir alguns avanços mais significativos: o sucesso na instalação e operação do detector de raios cósmicos AMS, na Estação Espacial Internacional a partir de Maio de 2011; a recente instalação do detector de matéria escura LUX na Sanford Underground Research Facility, SD, EUA, em Julho de 2012; a instalação de um sistema de calibração desenvolvido e testado no LIP na experiência internacional, também subterrânea SNO+ (no Canadá), está em curso. Por sua vez, o Observatório Internacional Pierre Auger (instalado na Argentina) publicou medidas da secção eficaz protão-protão obtidas com raios cósmicos de 57 TeV, comparáveis com extrapolações feitas a partir de resultados do LHC a 7 TeV. As discrepâncias observadas entre as previsões e os dados obtidos a energias superiores poderão apontar para fenómenos novos na Física de Partículas. O LIP, num esforço conjunto que envolve equipas de Lisboa e de Coimbra, lidera o trabalho de I&D da colaboração com vista à futura instalação de detectores de RPC que funcionarão ao ar livre e prossegue uma actividade sistemática de colaboração internacional, designadamente com instituições do Brasil.
O papel inovador do LIP no trabalho de I&D em câmaras de placas resistivas (RPC) é hoje reconhecido internacionalmente. No último ano registaram-se progressos significativos, incluindo testes de viabilidade de detectores de muões para funcionarem ao ar livre durante longos períodos, um "TOF-tracker"capaz de medir tempo e posição com precisão elevada, o design e produção de um inovador detector de tempo de voo para neutrões rápidos e um protótipo de tomógrafo RPC-PET de baixo custo, para pequenos animais, que atingiu a resolução espacial 0,8 milímetros. Estão também em estudo detectores de RPCs para neutrões térmicos.
Outras actividades em Detectores e em Física da Radiação produziram também resultados encorajadores, e resultaram na apresentação de várias patentes, não previstas inicialmente.
Nas aplicações à Física Médica têm-se registado progressos em várias linhas. Podemos destacar os bons resultados alcançados no "ClearPEM", um Tomógrafo por Emissão de Positrões para Mamografia e detecção do cancro da mama, actualmente em testes clínicos em Marselha, e em Coimbra, bem como as simulações do scanner RPC-PET de corpo inteiro que confirmaram as expectativas de excelente desempenho deste novo sistema considerado por peritos independentes como alternativa válida à configuração-padrão baseada em cristais. Encontram-se actualmente em teste ou em simulação outros detectores, estão em fase de prototipagem avançada novos dosímetros de plástico cintilador e foi submetido um pedido provisório de patente para um novo conceito de tomografia ortogonal computorizada
Quanto às tecnologias de computação, é de destacar o desempenho dos clusters de GRID geridos pelo LIP que, em 2011/2012, alcançaram parâmetros de fiabilidade e de disponibilidade do Tier-2 português superiores a 96%, muito acima da exigência mínima de 80% estabelecida pelo LHC Computing Grid.
Na Oficina Mecânica, fundada em 1986 e instalada em Coimbra, a maquinaria moderna adquirida no âmbito do Programa de Reequipamento 2008 está agora plenamente aproveitada. Uma fracção considerável da carga de trabalho esteve directamente relacionada com as actividades experimentais de grupos de física do LIP, ou seja, orientada para grandes colaborações internacionais, mas foi ainda possível prestar muitos outros serviços à comunidade, nomeadamente a centros de investigação e unidades de saúde. A oficina mecânica e o laboratório de detectores também produziram várias Câmaras de Faíscas para demonstração pública de trajectórias de Raios Cósmicos, destinadas a Centros de Ciência e Museus, quatro das quais foram enviadas para outros países.
A recente descoberta de uma nova partícula, identificável com um "bosão de Higgs", desencadeou uma intensa série de actividades de divulgação, em universidades, escolas, centros de ciência e nos media em geral. O trabalho de divulgação é essencialmente baseado em actividades regulares que visam, principalmente, professores e estudantes do ensino secundário. No CERN, a Escola de Professores em Língua Portuguesa criada pelo LIP envolve agora professores de ciências do ensino secundário de todos os países da CPLP. Em 2011, o LIP comemorou o seu 25 º aniversário, e em 2012 durante as suas Jornadas bienais que decorreram no Pavilhão do Conhecimento, em Lisboa, organizou um dia aberto com grande adesão do público. A rede IDPASC, por sua vez, organizou em 2012 três escolas temáticas para estudantes de doutoramento, sobre a matéria escura, o bosão de Higgs e foto-sensores.

**LIP - Descrição Técnica**

A actividade científica do LIP está organizada nas seguintes linhas principais: Física Experimental de Partículas (em Aceleradores, principalmente no CERN, e sem aceleradores, especialmente no domínio das Astropartículas), Física de Detectores, Física Médica, e ainda Computação Avançada. Complementarmente, realiza-se trabalho em instrumentação associada àqueles domínios, e desenvolvem-se actividades sistemáticas no campo do Ensino

Avançado e da Divulgação Científica. A maioria destas linhas de trabalho tem por base projectos de muito longo prazo, empenhando-se o laboratório em explorar, consolidar e fazer crescer as suas principais áreas de actividade e respectivas aplicações. O LIP apoia ainda, desde o seu início, as actividades de formação de Engenheiros portugueses no CERN (financiadas pela FCT) e o acesso das empresas portuguesas ao mercado do CERN.

**Física Experimental de Partículas em Aceleradores**

O LIP participa actualmente em quatro experiências em aceleradores: ATLAS e CMS no Grande Colisionador de Hadrões (LHC) e COMPASS, no CERN, e HADES, no GSI, na Alemanha.
Tanto COMPASS como HADES estão actualmente na fase de tomada de dados, com o LIP envolvido na operação e com responsabilidades centradas no Sistema de Controlo dos Detectores e na parede RPC- TOF, respectivamente, mas igualmente empenhado na elaboração de propostas e de estudos de viabilidade para experiências subsequentes.
Da mesma forma que o trabalho de concepção, desenho e instalação de ATLAS e de CMS, as duas principais experiências do LHC, dominou a nossa actividade ao longo dos últimos 15 anos, são agora a tomada de dados e a sua análise que irão dominar nos próximos anos, a par da manutenção e melhoramento dos equipamentos experimentais.
No futuro, o aumento da luminosidade por um factor dez no "Super-LHC"exigirá grandes transformações dos sistemas de detecção e de aquisição de dados.

**Física Experimental de Partículas sem aceleradores (Física das Astropartículas)**

As actividades do LIP nesta área, levadas a cabo no âmbito de colaborações internacionais, têm lugar em diversos laboratórios e observatórios localizados em diversas regiões do mundo, por força da natureza das próprias actividades científicas.
O LIP é membro do Observatório Pierre Auger, o maior observatório para raios cósmicos da mais alta energia, que opera na Argentina. O detector híbrido que é Auger, encontra-se em plena e estável fase de recolha de dados e a análise está a conduzir a resultados novos e importantes. O observatório estendeu a sua gama de energias até valores mais baixos, estando igualmente a ser usado como banco de ensaio de métodos e tecnologias de detecção novos. No âmbito da Colaboração AMS, estuda-se radiação cósmica de energia mais baixa e o detector, instalado na Estação Espacial Internacional em 2011, está actualmente a recolher dados. O LIP mantém ainda uma colaboração regular com a Agência Espacial Europeia desde 2004, visando o estudo e modelação do ambiente de radiação no espaço e o desenvolvimento de sistemas de detecção, em colaboração com indústrias nacionais.
O LIP também está ligado a experiências de detecção de matéria escura. No seguimento da experiência adquirida no campo dos detectores de xénon de dupla fase, aprofundada na Colaboração ZEPLIN, o LIP juntou-se à experiência LUX, que prevê alcançar uma melhoria de sensibilidade de um factor dez em relação aos melhores resultados actuais (XENON 2012); para além disso, está em andamento a fase de concepção de uma experiência para 7 toneladas de Xe, designada por LZ, em que intervêm outros grupos europeus que participaram em ZEPLIN. Uma equipa mais pequena participa em experiências com neutrinos no mais profundo laboratório subterrâneo, SNOLAB, no Canadá. Está aí instalado SNO+, um detector de cintilador líquido, que deve iniciar em 2014 um período de 5 anos de tomada de dados, pesquisando a oscilação de neutrinos solares e o decaimento beta duplo. Um outro grupo que trabalha em detectores de xénon gasoso também para a pesquisa de decaimento beta duplo (na experiência NEXT) veio reforçar esta área de trabalho ao juntar-se ao LIP em 2011.

**Física de Detectores**

O LIP tem uma longa história na investigação e desenvolvimento de detectores gasosos, associada ao trabalho pioneiro do Professor Armando Policarpo, cobrindo aspectos que vão dos processos físicos fundamentais ao projecto, construção e operação de detectores complexos. Esta especialização existe sobretudo em Coimbra e está focada em detectores gasosos.
O LIP tem hoje um reconhecido papel de liderança no domínio das Câmaras de Placas Resistivas (RPCs). Estes detectores gasosos que permitem obter excelente resolução temporal, mesmo para grandes áreas, a custo moderado, têm uma crescente aplicação em diferentes domínios. A primeira grande realização do LIP foi a parede de TOF-RPC da Experiência HADES. Estão actualmente em curso estudos de viabilidade de scanners PET para imagiologia médica baseados em RPCs; está já a tomar os primeiros dados um protótipo de pequenos animais, enquanto um protótipo de scanner de corpo inteiro para humanos está desenhado e será montado em breve.

Prossegue também trabalho de desenvolvimento e caracterização de novos detectores gasosos com eléctrodos estruturados, para diversos tipos de aplicações. No âmbito do projecto NMI3 (FP7) e do estudo do novo detector NeuLAND (para FAIR, no GSI) foram desenvolvidas novas soluções para a detecção de neutrões térmicos e de neutrões de alta energia, respectivamente, enquanto outros estudos prosseguem também no quadro da Colaboração RD51, baseada no CERN.

**Física Médica**

Esta linha de pesquisa explora um domínio onde a física de partículas e as tecnologias associadas tiveram um forte impacto nas últimas décadas. O LIP tem dois projectos fortes em imagiologia médica, ambos ligados ao desenvolvimento de scanners para tomografia por emissão de positrões (PET) e visando obter informação melhorada, reduzindo ao mesmo tempo as doses administradas aos pacientes e os tempos de obtenção das imagens. Desenvolveram-se, para isso, protótipos baseados em duas tecnologias diferentes: RPCs e cristais cintiladores.
No caso das RPCs, desenharam-se um protótipo para pequenos animais, já em fase de testes de bancada, e um protótipo de corpo inteiro para seres humanos.
Enquanto isso, e no âmbito do projecto PEM foram construídas duas unidades do scanner para mamografia baseadas em pequenos cristais, estando actualmente em testes uma no ICNAS (na Universidade de Coimbra) e outra no Hospital Universitário de Marselha, em França; uma outra vertente deste projecto visa a compatibilização de sistemas destes com imagiologia de ressonância magnética e com ultra-sons.
Outros projectos de física médica em curso visam aspectos novos de imagiologia, monitorização na radiologia e na radioterapia, protecção contra as radiações, envolvendo simulação computacional e mesmo o desenvolvimento de protótipos para aplicações clínicas específicas.
Nestes projectos, o LIP colabora tanto com a comunidade médica, como com outros parceiros nacionais e internacionais, quer unidades de investigação, quer empresas. É o caso da estreita colaboração com ICNAS, na Universidade de Coimbra, onde se procura caracterizar e monitorizar o feixe do ciclotrão com vista à criação duma instalação para irradiação de amostras biológicas, e também da futura instalação do CERN para estudos de radiobiologia e dosimetria, usando feixes hadrónicos (LEIR).

**Tecnologias de Computação**

O LIP desenvolve competências em tecnologias avançadas de interesse estratégico não apenas para a física de partículas, mas para uma vasta gama de aplicações. É o caso da computação distribuída GRID.
De facto, o Laboratório é um membro de alguns dos maiores projectos mundiais, como o LHC Computing GRID, do CERN, ou a Iniciativa Europeia GRID, da União Europeia. No contexto da Iniciativa Nacional GRID, o LIP opera o nó central de computação de GRID. Trata-se do maior centro de computação científica em Portugal, que disponibiliza recursos de computação a comunidades de investigação de uma grande variedade de domínios científicos.

**Outras competências técnicas**

Em Coimbra, o LIP mantém uma oficina de mecânica de precisão e pessoal especializado na construção de instrumentação. Os equipamentos disponíveis e o pessoal técnico altamente qualificado da oficina, complementados pelos técnicos de electrónica, habilitam-nos a fornecer uma larga gama de serviços, desde a concepção e design de peças e sistemas, à sua montagem e teste. Estes serviços dão suporte não apenas ao trabalho de investigação em detectores e à participação do LIP em colaborações internacionais, mas igualmente a utentes de outras unidades de investigação e da indústria.
No âmbito das suas actividades, e em resultado das exigências do seu trabalho experimental, o LIP dispõe de competências e trabalha nos domínios da microelectrónica e electrónica digital, ou da aquisição e controlo de dados e de sistemas.

**Ensino Avançado e Divulgação Científica**

A formação avançada e a integração de jovens cientistas, tanto internamente quanto em grandes organizações internacionais em que desenvolve a sua actividade científica, são actividades correntes do LIP. A par disso, o Laboratório está empenhado em promover a divulgação do conhecimento científico pelo público em geral e, em particular, pelos estudantes e professores do ensino secundário.

São exemplo desse particular empenho do LIP na divulgação científica junto do público escolar as "Master Classes"Internacionais em Física de Partículas (no âmbito de uma rede internacional animada pelo CERN), em que anualmente participam cerca de dois mil alunos, e ainda, muito especialmente, a organização de uma Escola de Física para Professores em Língua Portuguesa, no CERN, onde participam anualmente muitas dezenas de professores dos países da CPLP.
O LIP gere desde 2010 a Rede Internacional de Doutoramentos em Física de Partículas, Astrofísica e Cosmologia (IDPASC), que reúne as universidades portuguesas com actividades nestas áreas e um número crescente de universidades em Espanha, Itália e França, além do CERN e de instituições do Brasil. Esta rede visa preparar cientistas nas áreas teóricas e experimentais ligadas à física de partículas, astrofísica e cosmologia, promovendo programas de formação comuns, e reforçando a mobilidade de estudantes, professores e investigadores das várias instituições participantes.
Ver ainda:
Portugal no LHC: http://www.lip.pt/higgs/index.php?option=9
PET para mamografia: https://dl.dropbox.com/u/107526312/PET.pptx

**LIP - Indicadores sintéticos (I) 2011/2012**

**Publicações**

| | |
|---|---|
| Em revistas internacionais | 457 |
| Comunicações | |
| Em reuniões internacionais | 126 |
| Em reuniões nacionais | 65 |
| Organização de seminários e conferências | 60 |

**Formação avançada**

| | |
|---|---|
| Teses de Doutoramento | 10 |
| Teses de Mestrado | 16 |
| Patentes | 3 |

**CERN-PORTUGAL**

Retorno Industrial:
Venda de bens e serviços e ao CERN por empresas portuguesas
Período 2009-2012:
5ª Posição entre países fornecedores (bens)
2ª Posição depois de França (serviços)
Em 2012, a venda de bens e serviços de empresas portuguesas ao CERN totalizou cerca de 8,8M€
Formação de Engenheiros portugueses no CERN:
Em média 10 novos por ano (em 2012: 142 candidatos)

**LIP – Publicações Internacionais no WoS 2011/2012**

| LIP Publications 2011/2012 | | | |
|---|---|---|---|
| | | | |
| Journal | IF | N | IF * N |
| AM J PHYS | 0.729 | 1 | 0.729 |
| ANALOG INTEGR CIRC S | 0.592 | 1 | 0.592 |
| ANN ONCOL | 6.425 | 1 | 6.425 |
| ASTROPART PHYS | 3.216 | 12 | 38.592 |
| ASTROPHYS J | 6.024 | 4 | 24.096 |
| ASTROPHYS J LETT | 5.526 | 1 | 5.526 |
| ASTROPHYS J SUPPL S 1 | 3.456 | 1 | 3.456 |
| ASTROPHYS SPACE SCI | 1.686 | 1 | 1.686 |
| COMPUT INFORM | 0.239 | 2 | 0.478 |
| EUR J NUCL MED MOL I | 4.991 | 2 | 9.982 |
| EUR PHYS J A | 2.190 | 5 | 10.950 |
| EUR PHYS J C | 3.631 | 48 | 174.288 |
| ICARUS | 3.385 | 1 | 3.385 |
| IEEE T NUCL SCI | 1.447 | 7 | 10.129 |
| INT J MOD PHYS A | 1.053 | 1 | 1.053 |
| J COSMOL ASTROPART P | 5.723 | 3 | 17.169 |
| J HIGH ENERGY PHYS | 5.831 | 81 | 472.311 |
| J INSTRUM | 1.869 | 18 | 33.642 |
| J KOREAN PHYS SOC | 0.447 | 5 | 2.235 |
| J PHYS G NUCL PARTIC | 4.178 | 1 | 4.178 |
| MOD PHYS LETT A | 1.083 | 1 | 1.083 |
| NAT COMMUN | 7.396 | 1 | 7.396 |
| NEW J PHYS | 4.177 | 2 | 8.354 |
| NUCL INSTRUM METH A | 1.207 | 17 | 20.519 |
| NUCL INSTRUM METH B | 1.211 | 3 | 3.633 |
| NUCL PHYS A | 1.540 | 6 | 9.240 |
| NUCL PHYS B | 4.661 | 3 | 13.983 |
| PHYS ATOM NUCL+ | 0.568 | 1 | 0.568 |
| PHYS LETT B | 3.955 | 104 | 411.320 |
| PHYS MED BIOL | 2.829 | 1 | 2.829 |
| PHYS REV C | 3.308 | 14 | 46.312 |
| PHYS REV D | 4.558 | 43 | 195.994 |
| PHYS REV LETT | 7.370 | 60 | 442.200 |
| PHYS SCRIPTA | 1.204 | 2 | 2.408 |
| PLANET SPACE SCI | 2.224 | 2 | 4.448 |
| X-RAY SPECTROM | 1.445 | 1 | 1.445 |
| Total | | 457 | 1992.634 |

IF: Impact Factor 2011
N: Number of Publications

**LIP - Indicadores sintéticos (II)**

Pessoal total 212, do qual 98 doutorados
Estudantes de Doutoramento 38
Estudantes de Mestrado 13
Orçamento do LIP em 2012: 3,6M€
Dos quais:
Para projectos e contratos, por concurso:
1,6 M€ de fontes nacionais (projectos, contratos e outras receitas)
0,4 M€ de fontes internacionais (programa-quadro da UE, etc.)
E ainda, na sequência de avaliações internacionais, e como financiamento institucional:
1,6 M€ da FCT (financiamento base e programático, quota)

## 1.2 Introduction

LIP was created in 1986 as the reference National Laboratory for collaboration with the European Organisation for Particle Physics (CERN). LIP is a non-profit association of public utility for science and technology aiming on the research in experimental particle physics and related detector technology. In 2001, it has become a "Laboratório Associado".
The associates of LIP are the Universities of Coimbra, Lisbon and Minho, IST (Instituto Superior Técnico, Institute of Technology) in Lisbon, FCT (Fundação para a Ciência e a Tecnologia, Foundation of Science and Technology) and ANIMEE (Associação Portuguesa das Empresas do Sector Eléctrico e Electrónico, Portuguese Association of Electrical and Electronics Enterprises).
LIP´s scientific activity is organized in four main areas:

- Experimental Particle Physics with accelerators and without accelerators (Astroparticle Physics)
- Radiation Detector Development, Data Acquisition and Data Processing
- Advanced Computing
- Medical Physics and other applications

LIP´s activities also include advanced education and training, outreach, support for education in science and technology, technology transfer to industry with CERN and other international laboratories.
LIP develops its research activities mainly in the framework of collaborations at CERN, but also of other international organisations such as ESA (European Space Agency), and still uses international scientific installations sucg as GSI, SNOLAB, LUX or the Pierre Auger Observatory, among others.
LIP shares its equipment and human resources with a big number of scientific groups and institutes, on national and international levels, and thus contributes with its own technical and scientific resources to the benefit of common scientific programs. Its computing infrastructures are used by numerous research institutions; the high precision mechanical workshop is open for the needs of the national and international scientific community; and LIP installed the Tagus-LIP Laboratory for Medical Physics, in cooperation with hospitals and other entities.
Since 2001, LIP has the status of "Laboratório Associado", and it has been classified as "excellent"in four consecutive avaliations by international boards. It consists of three branches in Coimbra, Lisbon and Minho, each one with particular agreements with the local universities about sharing of resources. 212 people are working at LIP, from which 98 holding PhD, including national and foreign researchers and university teachers. Each year, a lot of Master and PhD students join LIP to work on their theses. LIP coordentates IDPASC (International Doctorate Network in Particle Physics, Astrophysics and Cosmology), an interdisciplinary network whose purpose is to create new high-level experts in the fields of Particle Physics, Astrophysics and Cosmology.

**LIP 2012**

The University of Coimbra, the University of Lisbon, the Institute of Technicology of Lisbon and the University of Minho joined LIP as full members on January 1, 2012, strengthening our long-term cooperation. The most recent LIP branch at the Minho University is now fully established with a focus on strengthening the collaboration between theoretical and experimental physicists in view of the LHC results, especially in the framework of the ATLAS experiment.
In 2012, LIP was involved in the discovery of a new particle — candidate for the Higgs boson, the only particle missing in the Standard Model of Particle Physics — by the ATLAS and CMS experiments at the LHC, the Large Hadron Collider at CERN. The design, construction and commissioning of ATLAS and CMS have dominated LIP´s efforts for the last 15 years, and today LIP actively participates in the maintainance, data taking and data analyses for both experiments, including the search for the Higgs boson. In the beginning of 2012, the leader of the CMS group at LIP was elected deputy spokesperson of the international CMS collaboration.
LIP is also committed to other accelerator experiments, such as COMPASS at CERN and HADES at GSI. Last year, the COMPASS team has organized its collaboration meeting in Lisbon along with the International Workshop on Hadron Structure and Spectroscopy. The RPC-TOF wall for HADES, that has been designed, built and run by LIP, was shown to achieve a precision better than 100 picoseconds for gold-on-gold collisions.
Concerning our participation in Astroparticle physics experiments, a lot of significant progress has been achieved: the installation and successful operation of the cosmic ray detector AMS at the International Space Station, since May 2011; the deployment of the dark matter detector LUX at the Sanford Underground Research Facility, USA, in July 2012; the underground installation of a calibration system developed and tested at LIP for the SNO+ neutrino experiment is also underway. The Pierre Auger Observatory in Argentina published the proton-proton cross-section measured with high energy cosmic rays at 57 TeV, in good agreement with extrapolations

of results obtained from the LHC at 7 TeV. Discrepancies found between data and expectations at higher energies may point to new particle physics phenomena. LIP is leading the collaboration efforts in R&D for future RPC open air detectors, in a joint effort between the Lisbon Auger team and the Coimbra RPC team, and has pursued a systematic approach to international collaborations, notably with institutions in Brazil.
LIP plays an internationally recognized role in the R&D of new Resistive Plate Chambers (RPC). There was significant progress last year, including feasibility tests for the open air muon detectors, a new TOF tracker with accurate time of flight and position measurement, the design and production of an innovative and inexpensive fast neutron TOF and the achievement of 0.8mm spatial resolution in a new small animal RPC-PET tomographer. RPCs are also being considered for thermal neutron detectors.
Other Detector and Radiation Physics activities have also produced encouraging results, with highlights like the submission of several patents, that were not foreseen in our original plan.
Medical Physics applications have seen good progress in several areas. Highlights are so far the good results of clinical tests done with "ClearPEM", a Positron Emission Tomographer for Mammography and breast cancer detection, in Marseille and Coimbra, and the final simulation of the full RPC-PET scanner confirming the expectations for an excellent performance of this new system, which has been considered by independent experts as an alternative to the standard crystal based setting. Other detectors are under test or simulation, new plastic scintillating dosimeters are in an advanced prototyping stage, and a provisional patent application has been submitted for a new concept of orthogonal computed tomography.
Concerning computing technologies, the GRID clusters that are run by LIP show an excellent performance. In 2011/2012, the Portuguese Tier-2 achieved reliability and availability metrics of over 96%, far above the minimum requirement of 80% established by the LHC Computing Grid.
In the Mechanical Workshop, founded in 1986 and installed in Coimbra, the state-of-the-art machinery acquired in the framework of the 2008 re-equipment program is now under full exploitation. A considerable fraction of the workload was directly related to the experimental activities of LIP physics groups, especially for the large international collaborations, but many other services were also provided to other research and health-care communities. Our workshop and detector laboratory have also produced several spark chambers for public display of cosmic rays, namely for science centers and museums, four of which were exported to other countries.
The recent discovery of a new particle, that could be identified as a Higgs boson, triggered an exceptional outreach activity at universities, schools, science centers, and in social media. Our outreach work is essentially based on regular activities aiming mainly at high school teachers and students. The CERN Portuguese Language Teachers Program involves now science teachers from all Portuguese speaking countries in the world. In 2011, LIP celebrated its 25th anniversary, and in 2012 an open day was organized on the occasion of its general meeting with large participation of the general public at Pavilhão do Conhecimento (Pavilion of Knowledge) in Lisbon. Moreover, the IDPASC network organized three dedicated schools for PhD students about Dark Matter, the Higgs boson and photo sensors.

**LIP - Technical Description**

LIP´s scientific activity is organized in the following main areas: Experimental Particle Physics (with accelerators, essentially at CERN, and without accelerators, especially in the field of Astroparticle Physics), Detector Physics, Medical Physics, and in Advanced Computing. In addition, LIP develops instrumentation associated with these areas, and works on Education, Training and Outreach. Most of our specific research is based on very long term projects. LIP is committed to the exploitation, consolidation and growth of its basic areas of activity.
LIP still supports, since the beginning, the training activities for Portuguese Engineers at CERN (funded by FCT) and the access of Portuguese companies to the CERN market.

**Experimental Particle Physics with Accelerators**
LIP is presently involved in four accelerator experiments: ATLAS and CMS, both at the Large Hadron Collider (LHC), Compass, at CERN, and HADES, at GSI in Germany.
Both Compass and HADES are currently taking data, with LIP being involved in the operation, with central responsibilities for the Detector Control System and the RPC-TOF wall, respectively, but also in proposals and viability studies for follow-up experiments.
In the same way as the work for the design, construction and commissioning of ATLAS and CMS, the two main experiments at the Large Hadron Collider (LHC), has dominated our efforts during the past 15 years, data taking and physics analysis will dominate our work in the following years, along with the maintainance and improving of the experimental equipment.
For the future, there are plans for a ten-fold luminosity increase, in the "Super LHC", that will imply also changes to the detectors and data acquisition systems, for which LIP is already engaged in preliminary studies.

**Experimental Particle Physics with Accelerators (Astroparticle Physics)**

The activities in this area are done in the framwork of large collaborations, in different laboratories and observatories around the world.
LIP is a member of the Pierre Auger Observatory, the largest observatory for the highest energy cosmic rays, operating in Argentina. The hybrid detector at Auger is in stable data taking mode and data analysis is leading to important new results. The observatory has been extended to detect lower energy cosmic rays and is used also as a test bed for new methods and detection technologies. Lower energy cosmic rays are studied in the framework of the AMS collaboration, in the ISS. After the installation of the detector in the International Space Station in 2011, data taking is now on-going. Since 2004, LIP still a regular collaboration with the ESA about the study and modeling of space radiation environment and detection, together with Portuguese industry.
LIP works also in direct searches for Dark Matter. Following the experience with double phase Xenon detectors, pioneered with the ZEPLIN collaboration, LIP joined the LUX collaboration to prepare a new experiment with a 10-fold increase in sensitivity in relation to the latest results (Xenon 2012). Moreover, a conceptual design phase of a new experiment called LZ, using 7 tons of Xe, is under way. This collaboration comprises other European participants, ex-members of ZEPLIN. A smaller group participates in neutrino experiments, in the world´s deepest underground laboratory, SNOLAB in Canada, where the liquid scintillator detector SNO+ is installed that is expected to start a 5 year data taking period in 2014, to obtain results on solar neutrino oscillations and double beta decay. In 2011, a new group working on Xenon detectors for double beta decay searches in the NEXT experiement joined LIP, which will strengthen these areas of research.

**Detector Physics**

LIP has a long history of research and development of radiation detectors, covering aspects that range from the basic physics principles to the planning, construction and operation of complex detectors. The experience is mostly based in Coimbra and focused on gaseous detectors.
LIP has nowadays an internationally recognized leading role in the development of Resistive Plate Chambers (RPCs), detectors that can have a very good time resolution over large areas, and at moderate prices, and that are gaining a widespread use. The first large project was the construction of the TOF-RPC wall for the HADES experiment. We study also the possibility of using RPC-based PET scanners for medical imaging. A small scale animal scanner prototype is already taking preliminary data, and a first prototype for a large full human body scanner is being designed and will be assembled soon.
Research continues also in the development and characterization of new gas detectors with structured electrodes to be used for different kinds of applications. The application of these technologies to nuclear and particle physics has been studied in the framework of the NMI3 (FP7, low energy neutron imaging), NeuLAND (high energy neutron detector for FAIR, at GSI) and in the large CERN based RD51 collaboration.

**Medical Physics**

This area of research explores a domain where particle physics and associated technologies have had a strong impact in recent times. LIP has two important projects in medical imaging, namely in Positron Emission Tomography (PET) scanners, exploring the possibility of having better information while reducing at the same time the doses and analysis times for patients. LIP has developed prototypes based on two different detection technologies: RPCs and scintillating crystals. Prototypes have been designed both for small scale and full body scanners, based on RPCs, while a dedicated mammography scanner based on scintillating crystals is currently under tests at ICNAS (Coimbra University). A further development aiming at the integration of PET with magnetic resonance and different imaging techniques is also being studied.
Additional medical physics projects deal with other aspects of imaging, radiology and radiation protection, in particular the study of new techniques, detailed simulations and development of prototypes for specific clinical applications.
For these projects, LIP collaborates both with the medical community and with other international and national partners in research and industry. In close collaboration with ICNAS, at the University of Coimbra, a setup for characterizing and monitoring the cyclotron beam is being designed, as well as the future CERN-based experimental radio biology and dosimetry facility with hadron beams (LEIR).

**Computing Technology**

LIP develops competence in advanced technologies of strategical interest, not only for Particle Physics, but for a wide range of applications. This is the case for GRID computing.

In fact, LIP is member of some of the biggest projects in the world, like the LHC Computing GRID organized by CERN, or the European GRID initiative, organized by the European Union. In the framework of the National GRID Initiative, LIP runs the central computing node of the GRID, which is the biggest scientific computing centre in Portugal, that offers computing resources to research communities for a wide range of scientific areas.

**Other Technical Competences**

LIP runs instrumentation and precision mechanics workshops in Coimbra. Both the available equipment and the highly qualified technical personnel, complemented by the electronic technicians, provide a large range of services, from conception and design to machining, mounting and testing. These serve not only the detector, research and development needs of LIP projects, but also other users in other domains of research, and in industry.
Other areas like microelectronics, digital electronics and data acquisition, for example, are constantly being developed as a side product of other LIP activities.

**Education, Training and Outreach**

LIP continuously promotes the training of scientists and integration of young scientists, both internally and in the large international organizations in which its scientific activity develops. LIP also promotes the advancement of scientific knowledge for the general public, high school students and teachers, and advanced training within its specific areas of activity.
LIP is particularly active in science outreach, focusing mainly on high school students and their teachers. Examples of this are the International Master Classes in Particle Physics and the CERN Portuguese Language Teachers Programs, in which around two thousand students and dozens of teachers participate each year.
Hundreds of engineers have gone through advanced training of medium or long term internships, under direct LIP responsibility or supervision at CERN, ESA and ESO. And, of course, we integrate students from several universities, preparing their Master and PhD thesis in Particle Physics, Astroparticle Physics, Space Physics or Medical Physics and associated areas, as members of our research groups.
Since 2010, LIP manages the International Doctorate in Particle Physics, Astrophysics and Cosmology (IDPASC) Network, which joins together all the Portuguese Universities with activities in these areas and a growing number of Universities in Spain, Italy and France, as well as CERN, and institutions from Brazil. This network aims at preparing scientists in the related areas of theoretical and experimental particle physics, astrophysics and cosmology, promoting common training programs and reinforcing the mobility of students, professors and researchers of the several institutions.

## 1.3 Sources of Funding for LIP Lisboa

| Project | Code | Funding | Entity | Start | End |
|---|---|---|---|---|---|
| AMS | PTDC/FIS/122567/2010 | 40.000 € | FCT | 2011-12-07 | 2013-12-06 |
| ATLAS | CERN/FP/116346/2010 | 267.000 € | FCT | 2011-01-01 | 2012-03-31 |
| | CERN/FP/123595/2011 | 530.000 € | FCT | 2012-04-01 | 2014-03-31 |
| CMS | CERN/FP/116367/2010 | 277.000 € | FCT | 2011-01-01 | 2012-03-31 |
| | CERN/FP/123601/2011 | 550.000 € | FCT | 2012-04-01 | 2014-03-31 |
| COMPASS | CERN/FP/123600/2011 | 300.000 € | FCT | 2012-01-01 | 2013-12-31 |
| GRID | TIMBUS | 112.268 € | EU | 2011-03-01 | 2012-09-30 |
| | IBERGRID FCT-CSIC 20 10/11 | 4.250 € | LIP | 2007-01-01 | 2012-12-31 |
| | EGI InSPIRE | 485.000 € | EU | 2010-05-01 | 2014-04-30 |
| HECR | CERN/FP/116330/2010 | 127.000 € | FCT | 2011-01-01 | 2012-01-31 |
| | CERN/FP/123611/2011 | 280.000 € | FCT | 2012-02-01 | 2014-01-31 |
| | EPLANET 246806 | 10.800 € | EU | 2011-01-01 | 2014-12-31 |
| | Particle Physics at 100 TeV AFR PhD Gran | 114.660 € | AFR | 2012-09-01 | 2015-08-31 |
| | ASPERA/0001/2010 | 150.000 € | FCT | 2012-09-01 | 2015-08-31 |
| LHC Phenomenology | CERN/FP/123619/2011 | 70.000 € | FCT | 2012-03-01 | 2014-02-28 |
| OUTREACH | MC2012_RadAmb2011-12 | 15.000 € | CVIVA | 2011-10-01 | 2012-07-31 |
| | CERN PLTP 2012 | 37.500 € | CVIVA | 2012-04-01 | 2012-10-31 |
| PET - Mammography | PIC/IC/83228/2007 | 67.550 € | FCT | 2009-03-26 | 2012-03-31 |
| | Endo TOFPET-US256984 | 509.400 € | EU | 2011-01-01 | 2014-12-31 |
| | PicoSEC-MCNet (28935 5) | 423.082 € | EU | 2012-01-01 | 2015-12-31 |
| SNO+ | PTDC/FIS/115281/2009 | 108.971 € | FCT | 2011-01-01 | 2013-12-31 |
| Space | ESA:223981/09/NL/PA | 150.000 € | ESA | 2009-05-01 | 2012-03-31 |
| | 6403/10/NL/SFe | 50.000 € | ESA | 2011-01-17 | 2012-06-18 |
| | ESA:223981/09/NL/PA/ CCN03 | 20.000 € | ESA | 2012-11-01 | 2013-02-28 |
| Laboratório Associado | PEst-C/FIS/LA0007/2011 | 1.797.273 € | FCT | 2011-01-01 | 2012-12-31 |
| Quotas | 2011 | 157.120 € | FCT | 2012-01-01 | 2012-12-31 |

## 1.4 Sources of Funding for LIP Coimbra

| Project | Code | Funding | Entity | Start | End |
|---|---|---|---|---|---|
| Dark Matter Search | CERN/FP/116374/2010 | 45.000 € | FCT | 2011-01-01 | 2012-03-15 |
| | CERN/FP/123610/2011 | 80.000 € | FCT | 2012-04-01 | 2013-03-31 |
| GEMs | FP7-GA226507 | 80.640 € | EU | 2009-02-01 | 2012-01-31 |
| HADES | PTDC/FIS/113339/2009 | 91.742 € | FCT | 2011-04-01 | 2014-01-31 |
| Human PET | PTDC/SAU-BEB/104630/ 2008 | 120.856 € | FCT | 2010-04-01 | 2013-03-31 |
| Ion Transport Processes | CERN/FP/123613/2011 | 10.000 € | FCT | 2012-03-12 | 2014-03-11 |
| LHC Phenomenology | CERN/FP/116397/2010 | 32.000 € | FCT | 2011-01-01 | 2012-02-15 |
| NeuLand - R3B | PTDC/FIS/114876/2009 | 99.589 € | FCT | 2011-01-01 | 2013-12-31 |
| RD51 | CERN/FP/116392/2010 | 27.000 € | FCT | 2011-04-01 | 2012-06-30 |
| | CERN/FP/123605/2011 | 50.000 € | FCT | 2012-07-01 | 2013-06-30 |
| Laboratório Associado | PEst-C/FIS/LA0007/2011 | 1.149.076 € | FCT | 2011-01-01 | 2012-12-31 |
| Quotas | 2012 | 87.280 € | FCT | 2012-01-01 | 2012-12-31 |
| Workshops | 2012 | 23.229 € | | 2012-01-01 | 2012-12-31 |

## 1.5 Scientific Statistical data

| Project | Publications | | | Conferences | | | Semi- | Outr. | Theses | | | Evts. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jrn-I | Jrn-II | other | int.o | int.p | nat. | nars | Sem. | G | M | D | |
| ATLAS | 126 | 14 | 17 | 9 | 2 | 11 | 6 | | | 1 | | 1 |
| CMS | 95 | 9 | 28 | 17 | 1 | 9 | 4 | | | | | 1 |
| COMPASS | 9 | 8 | 6 | 10 | | | | | 1 | | | 2 |
| HADES | 8 | 3 | | 1 | | | | | | | | |
| LHC Phenomenology | 6 | 5 | | | | | | | | | | |
| GRID | 2 | 2 | 12 | 9 | 1 | 3 | 1 | 1 | | | | 1 |
| AMS | | | | 2 | | 6 | | 2 | | 1 | | |
| SNO+ | 1 | 1 | | 4 | | 1 | 1 | | | | 1 | |
| Dark Matter Search | 12 | 7 | 18 | 10 | | 6 | | | | | | |
| HECR | 16 | 4 | 8 | 12 | 1 | 5 | 4 | | | 1 | | 3 |
| Space | 4 | 4 | 3 | 2 | 2 | 2 | | | | 1 | | |
| PET - Mammography | 6 | 2 | 3 | 4 | 4 | | 2 | | | | | |
| Human PET | 2 | 2 | | | 3 | 2 | | | | | | |
| MC in Medical Physics | 3 | 3 | 2 | 1 | 2 | 6 | | | | 2 | | 4 |
| OrthoImaging | 1 | 1 | 2 | | | | | | | 1 | | |
| RD51 | 7 | 6 | 1 | 4 | | | | | | | | |
| NeuLand - R3B | | | 1 | | | | | | | | | |
| GEMs | 3 | 3 | | | | | | | | | | |
| DUAL | 3 | 3 | 2 | | | 2 | 4 | 2 | | | | |
| NEXT | 2 | 1 | | | | | | | | | | |
| Ion Transport Processes | 1 | 1 | | | | | | | | | | |
| ICNAS | | | 1 | | | 1 | | | | | | |
| OUTREACH | 1 | 1 | 2 | 3 | | 1 | | 3 | | | | 1 |
| TTN-ILO | | | | | | | | | | | | |
| Education | | | | | | | | | | | | |
| Scientific Conferences and Seminars | | | | | | | | | | | | 1 |
| Totals: | 308 | 80 | 106 | 88 | 16 | 55 | 22 | 8 | 1 | 7 | 1 | 14 |

**Legend:**

**Publications:**

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

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

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

**Conferences:**

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

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

**Nat.:** Presentations by LIP members in national conferences

**Seminars:** Invited seminars in Institutes or Universities

**Outr. Sem.:** Seminars for students or general public

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

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

## 1.6 Human resources (people)

| Project | Researchers | Technicians | Post-Docs | Students | | | |
|---|---|---|---|---|---|---|---|
| | | | | D | M | G | O |
| ATLAS | 15 | 1 | 4 | 11 | 2 | 1 | 2 |
| CMS | 5 | 1 | 5 | 2 | 1 | | 1 |
| COMPASS | 3 | 1 | 3 | 2 | 1 | | 1 |
| HADES | 3 | 2 | 2 | | | | |
| LHC Phenomenology | 10 | | 3 | 2 | 2 | 2 | 1 |
| GRID | 7 | 3 | 1 | | | | |
| AMS | 1 | | 2 | | 3 | | |
| SNO+ | 5 | 5 | | | | | |
| Dark Matter Search | 5 | 2 | 4 | 1 | | | |
| HECR | 13 | 2 | 3 | 5 | | | 2 |
| Space | 6 | 1 | 1 | 1 | 1 | | |
| PET - Mammography | 2 | 2 | 1 | 5 | | | |
| Human PET | 5 | 7 | | | | | |
| MC in Medical Physics | 6 | | | 1 | 4 | 1 | |
| OrthoImaging | 1 | | | 1 | 1 | | |
| RD51 | 6 | 10 | | 1 | | | |
| NeuLand - R3B | 3 | 8 | | | | | |
| GEMs | 5 | | | 1 | | | |
| DUAL | 7 | | | 2 | | | |
| NEXT | 6 | | | 1 | | | |
| Ion Transport Processes | 6 | | 1 | | | | |
| ICNAS | 3 | | | 1 | | | |
| OUTREACH | 9 | 2 | 2 | | | | |
| TTN-ILO | | 1 | | | | | |
| Education | | | | | | | |
| Scientific Conferences and Seminars | | | | | | | |
| Totals: | 82 | 19 | 27 | 36 | 15 | 4 | 7 |

**Legend:**

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

**FTE:** Full Time Equivalent

## 1.7 Human resources (FTE)

| Project | Researchers | Technicians | Post-Docs | Students | | | | total |
|---|---|---|---|---|---|---|---|---|
| | | | | D | M | G | O | |
| ATLAS | 6.82 | 0.50 | 3.20 | 9.01 | 2.00 | 0.67 | 1.92 | 27.73 |
| CMS | 4.27 | 0.96 | 2.77 | 2.00 | 0.67 | | 0.04 | 13.64 |
| COMPASS | 3.00 | 1.00 | 2.00 | 2.00 | 0.17 | | 0.25 | 10.42 |
| HADES | 1.00 | 0.65 | 1.00 | | | | | 2.65 |
| LHC Phenomenology | 2.45 | | 1.75 | 1.50 | 1.04 | 0.26 | 0.84 | 7.87 |
| GRID | 6.17 | 3.00 | 1.00 | | | | | 10.17 |
| AMS | 0.85 | | 1.80 | | 2.58 | | | 5.23 |
| SNO+ | 1.85 | 0.75 | | | | | | 2.77 |
| Dark Matter Search | 2.25 | 0.60 | 3.90 | 0.50 | | | | 7.25 |
| HECR | 5.73 | 0.48 | 1.71 | 4.11 | | | 0.47 | 12.55 |
| Space | 0.87 | 0.14 | 1.00 | 1.00 | | | | 3.01 |
| PET - Mammography | 0.85 | 1.05 | 1.00 | 4.33 | | | | 7.90 |
| Human PET | 0.95 | 0.70 | | | | | | 1.65 |
| MC in Medical Physics | 3.30 | | | 0.80 | 1.44 | 0.30 | | 5.84 |
| OrthoImaging | 0.50 | | | 1.00 | 0.72 | | | 2.47 |
| RD51 | 0.91 | 1.45 | | 0.70 | | | | 3.06 |
| NeuLand - R3B | 0.70 | 1.45 | | | | | | 2.15 |
| GEMs | 1.40 | | | 1.00 | | | | 2.40 |
| DUAL | 2.20 | | | 1.60 | | | | 4.30 |
| NEXT | 1.55 | | | 0.60 | | | | 2.35 |
| Ion Transport Processes | 1.08 | | 0.12 | | | | | 1.52 |
| ICNAS | 0.50 | | | 1.00 | | | | 1.75 |
| OUTREACH | 1.60 | 0.32 | 0.10 | | | | | 4.02 |
| TTN-ILO | | 1.00 | | | | | | 1.00 |
| Education | | | | | | | | |
| Scientific Conferences and Seminars | | | | | | | | |
| Totals: | 50.80 | 14.05 | 21.35 | 31.15 | 8.62 | 1.23 | 3.52 | |

**Legend:**

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

**FTE:** Full Time Equivalent

## 1.8 Organisational Structure

### Directors

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

### Secretaries of the Scientific Council

Sofia Andringa, Helmut Wolters

### Administrative Staff

Cláudia Delgado, Elisabete Neves, Isabel Melo, João Pedro Santos, Lina Barata, Natália Antunes, Ricardo Caeiro, Sandra Dias, Teresa Marques

### Technical Staff

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

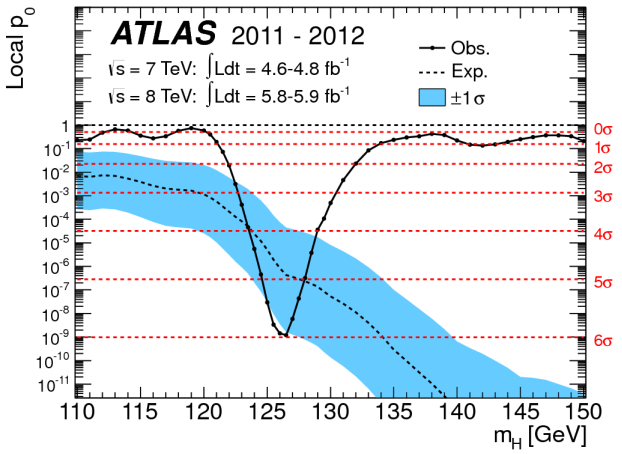
# Chapter 2

# Particle Physics with Accelerators

## 2.1 Collaboration in the ATLAS experiment at CERN

### 2.1.1 Resumo

ATLAS é uma das experiências que operam no Grande Colisionador de Hadrões (LHC) no CERN, onde se dão colisões protão-protão e entre iões pesados a altas energias e luminosidades, abrindo uma nova fronteira na Física de Partículas. O objectivo é o estudo das propriedades fundamentais da matéria, principalmente a natureza da quebra da simetria electro-fraca e a origem da massa, através da procura do bosão de Higgs. De facto, os dados de 2011 e 2012 já permitiram a descoberta de uma nova partícula que, como foi anunciado mundialmente pelas experiências ATLAS e CMS no dia 4 de Julho de 2012, é compatível com o bosão de Higgs do Modelo Padrão. A estrutura do detector permite também ser sensível a sinais de nova Física que se poderão manifestar a altas energias, como por exemplo o modelo da Supersimetria que pode explicar a abundância de Matéria Escura no Universo.
O grupo português de ATLAS contribui para os estudos de Física, para as actividades de manutenção e para o funcionamento e actualização do detector. Em termos de estudos de Física, procuramos o bosão de Higgs, estudamos o quark top, os bosões W e Z, e também o comportamento de jactos de partículas em ambiente p-p e de colisão de iões pesados de chumbo. Estamos activos na operação e estudos de desempenho do calorímetro hadrónico TileCal e do segundo nível do sistema de trigger, bem como na certificação do monitor de luminosidade absoluta ALFA.
Na pesquisa do bosão de Higgs no canal H->WW, incluída no artigo da descoberta, contribuímos para o cálculo dos fundos de Z+jactos e Drell-Yan utilizando um método alternativo baseado em dados ("data-driven") aplicado




Result of the ATLAS experiment in the search for the Higgs boson as a function of the Higgs mass for the observed (full line) and expected (dotted line) local significance based on the estimated background from SM processes. The significance exceeds 5 standard deviations for a mass around 126 GeV, as presented to the world in July 4th.

ao canal em que os leptões no estado final são do mesmo sabor, e contribuimos para os estudos sistemáticos do canal em que no estado final os leptões têm sabores diferentes. Participámos na pesquisa do bosão de Higgs do Modelo Padrão, produzido em associação com um bosão W e decaindo num par de quarks b, com a actualização da análise para as condições das colisões em 2012, e estudos para melhorar a resolução em massa do bosão de Higgs reconstruído aplicando uma calibração dedicada aos jactos b envolvidos no processo.
Com base na experiência adquirida nos estudos do quark top, iniciámos estudos do canal em que o bosão de Higgs é produzido em associação com um par top e anti-top. Nesta fase, o decaimento do quark top também é importante, pois pode ser usado como teste para identificação do quark b e calibração da escala de energia. Também foram estudados os decaimentos do quark top através de correntes neutras com troca de sabor (FCNC) e os resultados (novos limites na taxa de decaimento) foram publicados. No âmbito dos estudos de upgrade para o LHC de alta luminosidade também foi estudada a sensibilidade do detector ATLAS para estas medidas. A medida das fracções de helicidade do bosão do W nos decaimentos do quark top, bem como as correspondentes assimetrias angulares foram estudadas, permitindo determinar a estrutura do vértice Wtb. Um membro da equipa passou a ser responsável pelo sub-grupo das propriedades do quark top.
Após a publicação dos resultados de ATLAS a equipa participou também activamente na combinação destes resultados com os obtidos pela experiência CMS no âmbito do grupo de trabalho do quark top de LHC.
Foram também estudadas topologias multileptónicas com bosões Z e quarks b, permitindo pesquisar a existência de quarks vectoriais previstos em várias extensões do Modelo Padrão.
No segundo nível de trigger (LVL2) o desempenho para os jactos no ano de 2011 foi estudado em detalhe e está a ser resumido numa publicação do trigger de ATLAS. Um novo trigger para calibração hadrónica foi implementado em 2012. Adicionalmente, trabalhámos na melhoria dos algoritmos do trigger de jactos para tornar mais rápido o algoritmo de formação de clusters no calorímetro.
As actividades de bases de dados do Trigger/DAQ para controlo, configuração e monitorização de dados continuaram, com a manutenção da ferramenta de apresentação de histogramas de controlo de qualidade Node2 e infraestrutura associada.
No calorímetro TileCal um dos membros da equipa portuguesa foi coordenador de "run"em 2012. Participámos na produção das novas fontes de alimentação para serem substituídas durante a paragem de 2013-14. O Sistema de Controlo (DCS) foi melhorado com a adição de novos painéis com o objectivo de facilitar e tornar mais seguras as intervenções dos especialistas de turno, e para ter em conta novo hardware introduzido tal como as novas fontes de alimentação de 200V TDK-Lambda. Foi desenvolvido um simulador do sistema de DCS para permitir o desenvolvimento de código e o treino dos especialistas sem necessitar de aceder ao sistema principal que controla o detector. Foi também desenvolvida uma ferramenta para identificar canais de electrónica que denotem instabilidade.
Contribuímos também para a calibração e software de reconstrução do TileCal. Com vista à integração dos vários sistemas de calibração, efetuámos análises comparativas dos métodos de análise dos dados com laser, e erros sistemáticos associados. Iniciámos também a tarefa de identificação e correcção de medições da energia erradas em canais do TileCal em que haja saturação de algum tipo. Em 2012 a contribuição foi no desenvolvimento de software para a selecção dos eventos relevantes para posterior análise.
Participou-se ainda na validação da reconstrução da energia transversa no detector ATLAS que durante 2012 esteve focada na introdução de métodos para correcção do empilhamento dos sinais de energia nos calorimetros TileCal e LAr.
O projecto inclui também uma componente de divulgação, que foi muito intensa ao longo de 2012, com vários dos membros deste projecto a participarem nas MasterClasses Internacionais em várias universidades, na escola para professores de língua portuguesa no CERN, em actividades do programa Ciência Viva para jovens estudantes do Verão e em outras actividades destinadas ao público em geral.

### 2.1.2 Abstract

ATLAS is one of the experiments that operates at the CERN Large Hadron Collider (LHC) where proton-proton and heavy ion collisions take place at unprecedented high energies and luminosities, opening a new frontier in particle physics. The goal of the ATLAS experiment is to study the fundamental properties of matter, mainly the nature of the electro-weak symmetry breaking mechanism and the origin of mass, through the search for the cornerstone of the Standard Model, the Higgs boson. In fact, the 2011 and 2012 data have allowed the discovery of a new particle that, as announced worldwide of the 4th of July 2012, is compatible with a Standard Model Higgs boson. During the current LHC shutdown, the data analysis will be improved to test as many properties of this new particle as possible. The general purpose detector structure will also allow the precise measurements of the SM predictions and the searches for new Physics, such as Supersymmetry, that could explain the abundance of Dark Matter in the Universe.

The Portuguese group contributions to ATLAS concern both Physics studies and detector performance, operation and upgrade. In terms of Physics studies, we focused on searches for the Higgs boson, studies with the top quark, the W boson , and heavy ion Pb-Pb collisions. We are active in the operation and performance studies of the TileCal hadronic calorimeter and High-Level Trigger and in the operation of the ALFA absolute luminosity monitor.
Measurement of the W boson cross section, top quark properties and jet suppression in heavy ion Pb collisions were carried out. Using the know-how in topologies with top quarks, searches for new vector-like quarks were also performed.
In the H->WW channel, we have developed and applied a new data-driven method to separate and determine the Drell-Yan background in the same flavour final state, we have contributed to the systematics studies and other tasks of the H->WW analysis, included in the discovery paper. For the H->b-bbar search in the WH associated production, we have updated our analysis for the 2012 data taking conditions and have started studies to improve the Higgs mass resolution with dedicated b-jet calibrations.
Based on the experience acquired in the top quark studies, we started working in the channel where the Higgs boson is produced in association with a t-tbar pair. The decay of the top quark is important since it can be used as a test to identify the b quark and to calibrate the energy scale. New limits for the top quark decay rate via Flavour Changing Neutral Currents were published, and the sensitivity of the detector to these measurements was studied for the future upgrade of LHC to higher luminosity. The measurement of the helicity fractions of W boson in top quark decay as well as the corresponding angular asymmetries were studied allowing a better knowledge of the Wtb vertex. A member of the team became convenor of the top properties sub-group.
After the publication of the ATLAS results the team participated actively in the combination of the results with the ones obtained by the CMS experiment in the framework of the LHC top quark working group.
The performance of the jet trigger system in 2011 has been studied in detail and is being summarized in an ATLAS trigger publication. A new hadronic calibration trigger was implemented for the 2012 data taking period and its performance has been measured with the data acquired this year. In addition, we were working on improvements of the jet trigger algorithms, such as the speed up of the calorimeter clustering algorithm.
The main task related with Trigger-DAQ databases was the support of NODE2 histograms browser and associated infrastructure.
In the Tile calorimeter one of the members of the team was run coordinator in 2012. We have also contributed to the calibration and reconstruction software for TileCal. With the long-term of the integration of the different TileCal calibration systems, we carried out comparative analyses of the existing laser calibration analysis methods. We also started working on the identification and correction of wrongly measured channel energies, due to overflow. In 2012, our contribution was on the development of software for the selection of relevant events for a later analysis.
We participated in the validation of the missing transverse energy reconstruction for the ATLAS detector. During 2012 the effort has been focused in the implementation of methods to correct the pileup in the TileCal and LAr calorimeters.
The involvement in the Tilecal optics continued, with the improvement of the functionality of the laser monitoring system, preparing the upgrade of the laser for the long shutdown.
With the long shutdown and the future upgrades in view we also have been participating in the development of Mobidick 4, a mobile test bench for Tilecal drawer electronics repair and certification.
The TileCal DCS was further improved with the addition of new panels to make easier and safer the interventions of the experts on call and to deal with new hardware like the TDK-Lambda 200V PS. A DCS simulator was built to allow development of code and training without need to access the system that controls the detector. It was also developed a tool to identify unstable electronics channels.
We started working in the ALFA DCS with the development of several panels and implementation of several recipes using the Configuration Database. We also participated in the special ALFA datataking.
As usual we had a strong outreach participation, including the International Physics Masterclass in several Portuguese universities, school for Portuguese speaking teachers at CERN, Ciência Viva program for young students during summer holidays and many other activities.

### 2.1.3 Objectives

Exploitation of the full physics potential of the ATLAS/LHC experiment at CERN is our final goal.
The ATLAS detector was expected to take good quality data the full year and data analysis will continue. The W benchmark tool for W related analysis, in particular for W->mu nu channel would be set operational and the measurement of the production cross section of the W boson and dibosons would be updated. The study of the top quark physics with emphasis in the anomalous couplings and measurement of the forward-backward

asymmetry in top decays was expected to continue, as well as the heavy ion activities with jets and maintenance of the jet calibration at the level 2 trigger system and respective performance study.
Higgs boson searches in the channels H->WW and H->b bbar at low mass range and high pT was a very important goal, but following our preliminary studies, the standard non boosted method seemed to have advantages at the lower energy that LHC is running.
Operation and maintenance activities in TileCal including reconstruction software, second laser setup and laser monitoring, correlated noise studies and DCS system activities, and in Trigger-DAQ tasks, including mainly the development and support of NODE2 histograms browser and associated infrastructure, are part of our long term responsibilities.
It was planned to improve the lifetime estimate of the optical components of TileCal, using natural and/or accelerated ageing, to participate in the commissioning of the ALFA luminosity detector, and also in several outreach activities, such as Masterclasses and the School for portuguese language teachers at CERN.

### 2.1.4 Achievements

The ATLAS detector took collisions data smoothly and eficiently along 2012. The main tasks carried out have been Physics and Performance studies, operation and maintenance of the detector and preparation of the future upgrades. A summary of the main achievements follows.
Update of the H-> bb analysis, in associated production with a W boson, in the non-boosted regime.
Development of a new data-driven method to separate and measure the Z/Drell-Yan background in the H->WW analysis.
Measurement of the W polarisation in top decays using single lepton and dilepton events.
Constraints of the Wtb vertex structure using W polarization observables (angular asymmetries and W helicity fractions).
Search for rare decays of the top quark through the Flavour Changing Neutral Current t->qZ, allowing to obtain 95% confidence level limits on the branching fraction for this decay.
Search for same-sign top quark pair production using dileptonic events.
Search for vector-like quarks in multi-lepton topologies.
Measurement of di-jet asymmetries in heavy ion collisions, related with the jet quenching phenomenona in the quark gluon plasma.
Calculation of jet energy scale, resolution and reconstruction efficiencies in the heavy ion collisions environment.
Detailed study of the Jet Trigger performance during the 2011 data taking period. Implementation, tests and performance study of a new hadronic calibration trigger for the 2012 data taking.
Jet trigger menu preparation for the proton-lead run.
Tilecal DCS simulator tool for code development.

### 2.1.5 Sources of Funding

| Code | Funding | Start | End |
|---|---|---|---|
| CERN/FP/116346/2010 | 267.000 € | 2011-01-01 | 2012-03-31 |
| CERN/FP/123595/2011 | 530.000 € | 2012-04-01 | 2014-03-31 |

### 2.1.6 Team

**Project coordinator: Amélia Maio**

| Name | Status | %of time in project |
|---|---|---|
| Ademar Delgado | PhD student (LIP/FCT) | 100 |
| Agostinho Gomes | Researcher (LIP) | 85 |
| Alberto Blanco | Researcher (LIP) * | 9 |
| Alberto Palma | PhD student (LIP/FCT) | 100 |
| Alexandre Lopes | Master student (LIP) | 100 |
| Amélia Maio | Researcher (LIP/FCUL) | 55 |
| António Amorim | Researcher (FCUL) | 15 |
| António Onofre | Researcher (LIP/UMinho) | 35 |
| Belmiro Pinto | Researcher (LIP) * | 100 |
| Bruno Galhardo | PhD student (FCT) | 100 |
| Carlos Marques | Researcher (LIP) | 25 |
| Emanuel Gouveia | Student (LIP) | 100 |
| Emiliano Pinto | Master student (LIP) | 100 |
| Filipe Martins | Master (LIP) | 67 |
| Filipe Veloso | Post-Doc (LIP/FCT/FCTUC) | 90 |
| Guiomar Evans | Researcher (FCUL) | 5 |
| Helena Santos | Researcher (LIP) | 100 |
| Helmut Wolters | Researcher (LIP/FCTUC) | 40 |
| Joana Miguéns | PhD student (LIP/FCT) | 100 |
| João Carvalho | Researcher (FCTUC) | 34 |
| João Gentil | Post-Doc (LIP/FCT) | 100 |
| João Rodolfo Alves | Student (LIP) | 92 |
| José Domingos Alves | Graduate student (LIP) | 67 |
| José Maneira | Researcher (LIP) | 70 |
| José Silva | PhD student (LIP) | 50 |
| José Soares Augusto | Researcher (IST/INESC/FCUL) | 10 |
| Juan Espinosa | Master (LIP) | 94 |
| Lourenço Lopes | Master (LIP/FCUL) | 100 |
| Luís Gurriana | Technician (LIP) | 50 |
| Luís Seabra | Master (LIP) * | 100 |
| Manuel Maneira | Researcher (LIP/FCTUNL) | 15 |
| Mário Sargedas Sousa | PhD student (LIP/FCT) | 100 |
| Miguel Won | PhD student (LIP/FCT) | 13 |
| Nuno Anjos | Post-Doc (LIP/FCT) | 100 |
| Nuno Castro | Post-Doc (LIP/FCT) | 30 |
| Oleksii Galan | PhD student (LIP/FCT) | 58 |
| Patricia Conde | Researcher (LIP) | 84 |
| Pedro Jorge | PhD student (LIP/FCT) | 80 |
| Rute Pedro | PhD student (LIP/FCT) | 100 |
| Susana Santos | PhD student (LIP/FCT) | 100 |

### 2.1.7 Publications

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

- *Combined search for the Standard Model Higgs boson using up to 4.9 fb-1 of pp collision data at sqrt(s) = 7 TeV with the ATLAS detector at the LHC*
  The ATLAS Collaboration
  Phys. Lett. B710 (2012) 49-66

- *Search for same-sign top-quark production and fourth-generation down-type quarks in pp collisions at sqrt(s) = 7 TeV with the ATLAS detector*
  The ATLAS Collaboration
  JHEP 1204 (2012) 069

- *Measurement of the cross section for top-quark pair production in pp collisions at sqrt(s) = 7 TeV with the ATLAS detector using final states with two high-pt leptons*
  The ATLAS Collaboration
  JHEP 1205 (2012) 059

- *Measurement of the WW cross section in sqrt(s) = 7 TeV pp collisions with the ATLAS detector and limits on anomalous gauge couplings*
  The ATLAS Collaboration
  Phys. Lett. B712 (2012) 289-308

- *Search for FCNC single top-quark production at sqrt(s) = 7 TeV with the ATLAS detector*
  The ATLAS Collaboration
  Phys. Lett. B712 (2012) 351-369

- *Measurement of the top quark mass with the template method in the top antitop -> lepton + jets channel using ATLAS data*
  The ATLAS Collaboration
  Eur.Phys.J. C72 (2012) 2046

- *Measurement of ttbar production with a veto on additional central jet activity in pp collisions at sqrt(s) = 7 TeV using the ATLAS detector*
  The ATLAS Collaboration
  Eur.Phys.J. C72 (2012) 2043

- *Observation of spin correlation in ttbar events from pp collisions at sqrt(s) = 7 TeV using the ATLAS detector*
  The ATLAS Collaboration
  Phys. Rev. Lett. 108 (2012) 212001

- *Combined search for the Standard Model Higgs boson in pp collisions at sqrt(s) = 7 TeV with the ATLAS detector*
  The ATLAS Collaboration
  Phys. Rev. D86 (2012) 032003

- *Observation of a new particle in the search for the Standard Model Higgs boson with the ATLAS detector at the LHC*
  The ATLAS Collaboration
  Phys.Lett. B716 (2012) 1-29

- *Search for the Standard Model Higgs boson in the H -> WW(*) -> l nu l nu decay mode with 4.7 /fb of ATLAS data at sqrt(s) = 7 TeV*
  The ATLAS Collaboration
  Phys.Lett. B716 (2012) 62-81

- *Examples of shared ATLAS Tier2 and Tier3 facilities*
  S González de la Hoz, M Villaplana, Y Kemp, H Wolters, H Severini and W Bhimji
  J. Phys.: Conf. Ser. 396 (2012) 032051

- *Measurement of the W boson polarization in top quark decays with the ATLAS detector*
  ATLAS Collaboration (2869 authors)
  J. High Energy Phys., 6, 088 (2012)

- *A search for flavour changing neutral currents in top-quark decays in pp collision data collected with the ATLAS detector at root s=7 TeV*
  ATLAS Collaboration (2865 authors)
  J. High Energy Phys., 9, 139 (2012)

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

- *Search for a heavy neutral particle decaying into an electron and a muon using 1 fb(-1) of ATLAS data*
  ATLAS Collaboration (3025 authors)
  Eur. Phys. J. C, 71, 1809 (2011)

- *Measurement of the cross-section for b-jets produced in association with a Z boson at sqrt(s)=7 TeV with the ATLAS detector*
  The ATLAS Collaboration
  Phys.Lett.B 706 (2012) 295-313

- *Search for the Standard Model Higgs boson in the diphoton decay channel with 4.9 fb-1 of pp collisions at sqrt(s) = 7 TeV with ATLAS*
  The ATLAS Collaboration
  Phys. Rev. Lett. 108 (2012) 111803

- *Search for contact interactions in dilepton events from pp collisions at sqrt(s) = 7 TeV with the ATLAS detector*
  The ATLAS Collaboration
  Phys. Lett. B712 (2012) 40-58

- *Search for the Standard Model Higgs boson in the decay channel H->ZZ(*)->4l with 4.8 fb-1 of pp collision data at sqrt(s) = 7 TeV with ATLAS*
  The ATLAS Collaboration
  Phys. Lett. B710 (2012) 383-402

- *Search for decays of stopped, long-lived particles from 7 TeV pp collisions with the ATLAS detector*
  The ATLAS Collaboration
  Eur. Phys. J. C72 (2012) 1965

- *Search for anomaly-mediated supersymmetry breaking with the ATLAS detector based on a disappearing-track signature in pp collisions at sqrt(s) = 7 TeV*
  The ATLAS Collaboration
  Eur. Phys. J. C72 (2012) 1993

- *Search for excited leptons in proton-proton collisions at sqrt(s) = 7 TeV with the ATLAS detector*
  The ATLAS Collaboration
  Phys. Rev. D85 (2012) 072003

- *Measurement of the polarisation of W bosons produced with large transverse momentum in pp collisions at sqrt(s) = 7 TeV with the ATLAS experiment*
  The ATLAS Collaboration
  Eur. Phys. J. C72 (2012) 2001

- *Measurement of the production cross section of an isolated photon associated with jets in proton-proton collisions at sqrt(s) = 7 TeV with the ATLAS detector*
  The ATLAS Collaboration
  Phys. Rev. D85 (2012) 092014

- *Measurement of the azimuthal ordering of charged hadrons with the ATLAS detector*
  The ATLAS Collaboration
  Phys.Rev. D86 (2012) 052005

- *Search for new particles decaying to ZZ using final states with leptons and jets with the ATLAS detector in sqrt(s) = 7 Tev proton-proton collisions*
  The ATLAS Collaboration
  Phys. Lett. B712 (2012) 331-350

- *Search for a light Higgs boson decaying to long-lived weakly-interacting particles in proton-proton collisions at sqrt(s) = 7 TeV with the ATLAS detector*
  The ATLAS Collaboration
  Phys.Rev.Lett. 108 (2012) 251801

- *Search for pair-produced heavy quarks decaying to Wq in the two-lepton channel at sqrt(s) = 7 TeV with the ATLAS detector,*
  The ATLAS Collaboration
  Phys.Rev. D86 (2012) 012007

- *Search for pair production of a heavy up-type quark decaying to a W boson and a b quark in the lepton+jets channel with the ATLAS detector*
  The ATLAS Collaboration
  Phys.Rev.Lett. 108 (2012) 261802

- *Search for the decay Bs0 -> mu mu with the ATLAS detector*
  The ATLAS Collaboration
  Phys.Lett. B713 (2012) 387

- *Search for supersymmetry in pp collisions at sqrt(s) = 7 TeV in final states with missing transverse momentum and b-jets with the ATLAS detector*
  The ATLAS Collaboration
  Phys.Rev. D85 (2012) 112006

- *Search for gluinos in events with two same-sign leptons, jets and missing transverse momentum with the ATLAS detector in pp collisions at sqrt(s) = 7 TeV*
  The ATLAS Collaboration
  Phys.Rev.Lett. 108 (2012) 241802

- *Search for heavy neutrinos and right-handed W bosons in events with two leptons and jets in pp collisions at sqrt(s) = 7 TeV with the ATLAS detector*
  The ATLAS Collaboration
  Eur.Phys.J. C72 (2012) 2056

- *Jet mass and substructure of inclusive jets in sqrt(s) = 7 TeV pp collisions with the ATLAS experiment*
  The ATLAS Collaboration
  JHEP 1205 (2012) 128

- *Measurement of inclusive two-particle angular correlations in pp collisions with the ATLAS detector at the LHC*
  The ATLAS Collaboration
  JHEP 1205 (2012) 157

- *Forward-backward correlations and charged-particle azimuthal distributions in pp interactions using the ATLAS detector*
  The ATLAS Collaboration
  JHEP 1207 (2012) 019

- *Search for charged Higgs bosons decaying via H+ -> tau nu in top quark pair events using pp collision data at sqrt(s) = 7 TeV with the ATLAS detector*
  The ATLAS Collaboration
  JHEP 1206 (2012) 039

- *Search for events with large missing transverse momentum, jets, and at least two tau leptons in 7 TeV proton-proton collision data with the ATLAS detector*
  The ATLAS Collaboration
  Phys.Lett. B714 (2012) 180-196

- *Search for down-type fourth generation quarks with the ATLAS detector in events with one lepton and hadronically decaying W bosons*
  The ATLAS Collaboration
  Phys.Rev.Lett. 109 (2012) 032001

- *Search for supersymmetry with jets, missing transverse momentum and at least one hadronically decaying tau lepton in proton-proton collisions at sqrt(s) = 7 TeV with the ATLAS detector*
  The ATLAS Collaboration
  Phys.Lett. B714 (2012) 197-214

- *Search for supersymmetry in events with three leptons and missing transverse momentum in sqrt(s) = 7 TeV pp collisions with the ATLAS detector*
  The ATLAS Collaboration
  Phys.Rev.Lett. 108 (2012) 261804

- *Search for resonant WZ production in the WZ to l nu l´ l´ channel in sqrt(s) = 7 TeV pp collisions with the ATLAS detector*
  The ATLAS Collaboration
  Phys.Rev. D85 (2012) 112012

- *Measurement of the azimuthal anisotropy for charged particle production in sqrt(s_NN) = 2.76 TeV lead-lead collisions with the ATLAS detector*
  The ATLAS Collaboration
  Phys.Rev. C86 (2012) 014907

- *Measurement of the b-hadron production cross section using decays to D*muX final states in pp collisions at sqrt(s) = 7 TeV with the ATLAS detector*
  The ATLAS Collaboration
  Nucl.Phys. B864 (2012) 341-381

- *Hunt for new phenomena using large jet multiplicities and missing transverse momentum with ATLAS in 4.7 fbˆ-1 of sqrt(s) = 7 TeV proton-proton collisions*
  The ATLAS Collaboration
  JHEP 1207 (2012) 167

- *Search for lepton flavour violation in the emu continuum with the ATLAS detector in sqrt(s) = 7 TeV pp collisions at the LHC*
  The ATLAS Collaboration

Eur.Phys.J. C72 (2012) 2040

- *Measurement of tau polarization in W->taunu decays with the ATLAS detector in pp collisions at sqrt(s) = 7 TeV*
  The ATLAS Collaboration
  Eur.Phys.J. C72 (2012) 2062

- *Search for scalar top quark pair production in natural gauge mediated supersymmetry models with the ATLAS detector in pp collisions at sqrt(s) = 7 TeV*
  The ATLAS Collaboration
  Phys.Lett. B715 (2012) 44-60

- *Measurement of the charge asymmetry in top quark pair production in pp collisions at sqrt(s) = 7 TeV using the ATLAS detector*
  The ATLAS Collaboration
  Eur.Phys.J. C72 (2012) 2039

- *Search for second generation scalar leptoquarks in pp collisions at sqrt(s) = 7 TeV with the ATLAS detector*
  The ATLAS Collaboration
  Eur.Phys.J. C72 (2012) 2151

- *Search for TeV-scale gravity signatures in final states with leptons and jets with the ATLAS detector at sqrt(s) = 7 TeV*
  The ATLAS Collaboration
  Phys.Lett. B716 (2012) 122-141

- *Search for pair production of a new quark that decays to a Z boson and a bottom quark with the ATLAS detector*
  The ATLAS Collaboration
  Phys.Rev.Lett. 109 (2012) 071801

- *Determination of the strange quark density of the proton from ATLAS measurements of the W->l nu and Z->ll cross sections*
  The ATLAS Collaboration
  Phys.Rev.Lett. 109 (2012) 012001

- *Search for tb Resonances in Proton-Proton Collisions at root s=7 TeV with the ATLAS Detector*
  ATLAS Collaboration (3039 authors)
  Phys. Rev. Lett., 109, 081801 (2012)

- *Evidence for the associated production of a W boson and a top quark in ATLAS at sqrt(s) = 7 TeV*
  The ATLAS Collaboration
  Phys.Lett. B716 (2012) 142-159

- *K-s(0) and Lambda production in pp interactions at root s=0.9 and 7 TeV measured with the ATLAS detector at the LHC*
  ATLAS Collaboration (2996 authors)
  Phys. Rev. D, 85, 012001 (2012)

- *Measurement of the isolated diphoton cross section in pp collisions at root s=7 TeV with the ATLAS detector*

ATLAS Collaboration (3034 authors)
Phys. Rev. D, 85, 012003 (2012)

- *Measurement of the transverse momentum distribution of W bosons in pp collisions at root s=7 TeV with the ATLAS detector*
  ATLAS Collaboration (3025 authors)
  Phys. Rev. D, 85, 012005 (2012)

- *Search for supersymmetry in final states with jets, missing transverse momentum and one isolated lepton in root s=7 TeV pp collisions using 1 fb(-1) of ATLAS data*
  Atlas Collaboration (3008 authors)
  Phys. Rev. D, 85, 012006 (2012)

- *Search for a heavy Standard Model Higgs boson in the channel H -> ZZ -> l(+)l(-) q(q)over-bar using the ATLAS detector*
  ATLAS Collaboration (3026 authors)
  Phys. Lett. B, 707, 27 (2012)

- *Measurement of the ZZ Production Cross Section and Limits on Anomalous Neutral Triple Gauge Couplings in Proton-Proton Collisions at root s=7 TeV with the ATLAS Detector*
  ATLAS Collaboration (2992 authors)
  Phys. Rev. Lett., 108, 041804 (2012)

- *Search for New Phenomena in t(t)overbar Events with Large Missing Transverse Momentum in Proton-Proton Collisions at root s=7 TeV with the ATLAS Detector*
  ATLAS Collaboration (3018 authors)
  Phys. Rev. Lett., 108, 041805 (2012)

- *Measurement of the pseudorapidity and transverse momentum dependence of the elliptic flow of charged particles in lead-lead collisions at root s(NN)=2.76 TeV with the ATLAS detector*
  ATLAS Collaboration (3018 authors)
  Phys. Lett. B, 707, 330 (2012)

- *Measurement of the cross section for the production of a W boson in association with b-jets in pp collisions at root s=7 TeV with the ATLAS detector*
  ATLAS Collaboration (3025 authors)
  Phys. Lett. B, 707, 418 (2012)

- *Measurements of the electron and muon inclusive cross-sections in proton-proton collisions at root s=7 TeV with the ATLAS detector*
  ATLAS Collaboration (3020 authors)
  Phys. Lett. B, 707, 438 (2012)

- *Measurement of the top quark pair production cross section in pp collisions at root s=7 TeV in dilepton final states with ATLAS*
  ATLAS Collaboration (3035 authors)
  Phys. Lett. B, 707, 459 (2012)

- *Search for displaced vertices arising from decays of new heavy particles in 7 TeV pp collisions at ATLAS*
  ATLAS Collaboration (3027 authors)
  Phys. Lett. B, 707, 478 (2012)

- *Search for anomalous production of prompt like-sign muon pairs and constraints on physics beyond the standard model with the ATLAS detector*
  ATLAS Collaboration (3016 authors)
  Phys. Rev. D, 85, 032004 (2012)

- *Performance of the ATLAS Trigger System in 2010*
  ATLAS Collaboration (3050 authors)
  Eur. Phys. J. C, 72, 1849 (2012)

- *Performance of missing transverse momentum reconstruction in proton-proton collisions at root s=7 TeV with ATLAS*
  Atlas Collaboration (3032 authors)
  Eur. Phys. J. C, 72, 1844 (2012)

- *Measurement of the production cross section for Z/gamma* in association with jets in pp collisions at root s=7 TeV with the ATLAS detector*
  ATLAS Collaboration (3012 authors)
  Phys. Rev. D, 85, 032009 (2012)

- *Search for new physics in the dijet mass distribution using 1 fb(-1) of pp collision data at root s=7 TeV collected by the ATLAS detector*
  ATLAS Collaboration (3025 authors)
  Phys. Lett. B, 708, 37 (2012)

- *Search for the Higgs Boson in the H -> WW(*()) -> l(+)vl(-)(v)over-bar Decay Channel in pp Collisions at root s=7 TeV with the ATLAS Detector*
  ATLAS Collaboration (3035 authors)
  Phys. Rev. Lett., 108, 111802 (2012)

- *A measurement of the ratio of the W and Z cross sections with exactly one associated jet in pp collisions at root s=7 TeV with ATLAS*
  ATLAS Collaboration (3025 authors)
  Phys. Lett. B, 708, 221 (2012)

- *Measurement of D*(+/-) meson production in jets from pp collisions at root s=7 TeV with the ATLAS detector*
  ATLAS Collaboration (3004 authors)
  Phys. Rev. D, 85, 052005 (2012)

- *Searches for supersymmetry with the ATLAS detector using final states with two leptons and missing transverse momentum in root s=7 TeV proton-proton collisions*
  ATLAS Collaboration (3016 authors)
  Phys. Lett. B, 709, 137 (2012)

- *Search for first generation scalar leptoquarks in pp collisions at root s=7 TeV with the ATLAS detector*
  Atlas Collaboration (3016 authors)
  Phys. Lett. B, 709, 158 (2012)

- *Search for strong gravity signatures in same-sign dimuon final states using the ATLAS detector at the LHC*
  ATLAS Collaboration (2994 authors)
  Phys. Lett. B, 709, 322 (2012)

- *Measurement of the W(+/-)Z production cross section and limits on anomalous triple gauge couplings in proton-proton collisions at root s=7 TeV with the ATLAS detector*
  ATLAS Collaboration (2999 authors)
  Phys. Lett. B, 709, 341 (2012)

- *Rapidity gap cross sections measured with the ATLAS detector in pp collisions at root s=7 TeV*
  ATLAS Collaboration (3037 authors)
  Eur. Phys. J. C, 72, 1926 (2012)

- *Electron performance measurements with the ATLAS detector using the 2010 LHC proton-proton collision data*
  ATLAS Collaboration (3030 authors)
  Eur. Phys. J. C, 72, 1909 (2012)

- *Observation of a New X-b State in Radiative Transitions to Y(1S) and Y(2S) at ATLAS*
  ATLAS Collaboration (3040 authors)
  Phys. Rev. Lett., 108, 152001 (2012)

- *Search for squarks and gluinos using final states with jets and missing transverse momentum with the ATLAS detector in root s=7 TeV proton-proton collisions*
  ATLAS Collaboration (3025 authors)
  Phys. Lett. B, 710, 67 (2012)

- *Measurement of the centrality dependence of the charged particle pseudorapidity distribution in lead-lead collisions at root s(NN)=2.76 TeV with the ATLAS detector*
  ATLAS Collaboration (3034 authors)
  Phys. Lett. B, 710, 363 (2012)

- *Measurement of the inclusive W-+/- and Z/gamma* cross sections in the e and mu decay channels in pp collisions at root s=7 TeV with the ATLAS detector*
  ATLAS Collaboration (3026 authors)
  Phys. Rev. D, 85, 072004 (2012)

- *Search for diphoton events with large missing transverse momentum in 1 fb(-1) of 7 TeV proton-proton collision data with the ATLAS detector ATLAS Collaboration*
  ATLAS Collaboration (3004 authors)
  Phys. Lett. B, 710, 519 (2012)

- *Search for extra dimensions using diphoton events in 7 TeV proton-proton collisions with the ATLAS detector ATLAS Collaboration*
  Atlas Collaboration (3036 authors)
  Phys. Lett. B, 710, 538 (2012)

- *Search for Scalar Bottom Quark Pair Production with the ATLAS Detector in pp Collisions at root s=7 TeV*
  ATLAS Collaboration (3032 authors)
  Phys. Rev. Lett., 108, 181802 (2012)

- *Study of jets produced in association with a W boson in pp collisions at root s=7 TeV with the ATLAS detector*
  ATLAS Collaboration (3019 authors)
  Phys. Rev. D, 85, 092002 (2012)

- *A study of the material in the ATLAS inner detector using secondary hadronic interactions*
  ATLAS Collaboration (3018 authors)
  J. Instrum., 7, P01013 (2012)

- *Jet substructure at the Tevatron and LHC: new results, new tools, new benchmarks*
  A. Altheimer et al. (72 authors)
  J. Phys. G-Nucl. Part. Phys., 39, 063001 (2012)

- *Measurement of the top quark pair production cross-section with ATLAS in the single lepton channel*
  ATLAS Collaboration (3006 authors)
  Phys. Lett. B, 711, 244 (2012)

- *Search for first generation scalar leptoquarks in pp collisions at root s = 7 TeV with the ATLAS detector (vol 709, pg 158, 2012)*
  ATLAS Collaboration (3124 authors)
  Phys. Lett. B, 711, 442 (2012)

- *Search for Production of Resonant States in the Photon-Jet Mass Distribution Using pp Collisions at root s=7 TeV Collected by the ATLAS Detector*
  ATLAS Collaboration (3017 authors)
  Phys. Rev. Lett., 108, 211802 (2012)

- *Search for heavy vector-like quarks coupling to light quarks in proton-proton collisions at root s=7 TeV with the ATLAS detector*
  ATLAS Collaboration (3131 authors)
  Phys. Lett. B, 712, 22 (2012)

- *Measurement of inclusive jet and dijet production in pp collisions at root s=7 TeV using the ATLAS detector*
  ATLAS Collaboration (3026 authors)
  Phys. Rev. D, 86, 014022 (2012)

- *A search for t (t)over-bar resonances with the ATLAS detector in 2.05 fb(-1) of proton-proton collisions at root s=7 TeV*
  ATLAS Collaboration (2865 authors)
  Eur. Phys. J. C, 72, 2083 (2012)

- *Underlying event characteristics and their dependence on jet size of charged-particle jet events in pp collisions at root(s)=7 TeV with the ATLAS detector*
  ATLAS Collaboration (2876 authors)
  Phys. Rev. D, 86, 072004 (2012)

- *Search for a fermiophobic Higgs boson in the diphoton decay channel with the ATLAS detector*
  ATLAS Collaboration (2865 authors)
  Eur. Phys. J. C, 72, 2157 (2012)

- *ATLAS measurements of the properties of jets for boosted particle searches*
  ATLAS Collaboration (2869 authors)
  Phys. Rev. D, 86, 072006 (2012)

- *Search for a standard model Higgs boson in the H -> ZZ -> l(+)l(-) nu(nu)over-bar decay channel using 4.7 fb(-1) of root s=7 TeV data with the ATLAS detector*

ATLAS Collaboration (2869 authors)
Phys. Lett. B, 717, 29 (2012)

- *Measurement of W gamma and Z gamma production cross sections in pp collisions at root s=7 TeV and limits on anomalous triple gauge couplings with the ATLAS detector*
  ATLAS Collaboration (2889 authors)
  Phys. Lett. B, 717, 49 (2012)

- *Search for a Standard Model Higgs boson in the mass range 200-600 GeV in the H -> ZZ -> l(+)l(-)q(q)over-bar decay channel with the ATLAS detector*
  ATLAS Collaboration (2866 authors)
  Phys. Lett. B, 717, 70 (2012)

- *Measurement of the top quark pair cross section with ATLAS in pp collisions at root s=7 TeV using final states with an electron or a muon and a hadronically decaying tau lepton*
  ATLAS Collaboration (2880 authors)
  Phys. Lett. B, 717, 89 (2012)

- *Search for the Standard Model Higgs boson in the H -> tau(+)tau(-) decay mode in root s=7 TeV pp collisions with ATLAS*
  ATLAS Collaboration (2867 authors)
  J. High Energy Phys., 9, 070 (2012)

- *A search for t(t)over-bar resonances in lepton plus jets events with highly boosted top quarks collected in pp collisions at root s=7 TeV with the ATLAS detector*
  ATLAS Collaboration (2875 authors)
  J. High Energy Phys., 9, 041 (2012)

- *Further search for supersymmetry at root s=7 TeV in final states with jets, missing transverse momentum, and isolated leptons with the ATLAS detector*
  ATLAS Collaboration (2896 authors)
  Phys. Rev. D, 86, 092002 (2012)

- *Measurement of W(+/-)Z production in proton-proton collisions at root s=7 TeV with the ATLAS detector*
  ATLAS Collaboration (2905 authors)
  Eur. Phys. J. C, 72, 2173 (2012)

- *Search for top and bottom squarks from gluino pair production in final states with missing transverse energy and at least three b-jets with the ATLAS detector*
  ATLAS Collaboration (2874 authors)
  Eur. Phys. J. C, 72, 2174 (2012)

- *Measurement of the t-channel single top-quark production cross section in pp collisions at root s=7 TeV with the ATLAS detector*
  ATLAS Collaboration (3052 authors)
  Phys. Lett. B, 717, 330 (2012)

- *Search for a Supersymmetric Partner to the Top Quark in Final States with Jets and Missing Transverse Momentum at root s=7 TeV with the ATLAS Detector*
  ATLAS Collaboration (2891 authors)
  Phys. Rev. Lett., 109, 211802 (2012)

- *Search for Direct Top Squark Pair Production in Final States with One Isolated Lepton, Jets, and Missing Transverse Momentum in root s=7 TeV pp Collisions Using 4.7 fb(-1) of ATLAS Data*
  ATLAS Collaboration (2887 authors)
  Phys. Rev. Lett., 109, 211803 (2012)

- *Search for resonant top quark plus jet production in t(t)over-bar + jets events with the ATLAS detector in pp collisions at root s=7 TeV*
  ATLAS Collaboration (2903 authors)
  Phys. Rev. D, 86, 091103 (2012)

- *Measurements of the pseudorapidity dependence of the total transverse energy in proton-proton collisions at root s=7 TeV with ATLAS*
  ATLAS Collaboration (2890 authors)
  J. High Energy Phys., 11, 033 (2012)

- *Search for Magnetic Monopoles in root s=7 TeV pp Collisions with the ATLAS Detector*
  ATLAS Collaboration (2877 authors)
  Phys. Rev. Lett., 109, 261803 (2012)

- *Search for the Standard Model Higgs boson produced in association with a vector boson and decaying to a b-quark pair with the ATLAS detector*
  ATLAS Collaboration (2869 authors)
  Phys. Lett. B, 718, 369 (2012)

- *Search for the Higgs boson in the H -> WW -> lvjj decay channel at root s=7 TeV with the ATLAS detector*
  ATLAS Collaboration (2876 authors)
  Phys. Lett. B, 718, 391 (2012)

- *Search for diphoton events with large missing transverse momentum in 7 TeV proton-proton collision data with the ATLAS detector*
  ATLAS Collaboration (2910 authors)
  Phys. Lett. B, 718, 411 (2012)

- *Time-dependent angular analysis of the decay B-s(0) -> J/psi phi and extraction of Delta Gamma(s) and the CP-violating weak phase phi(s) by ATLAS*
  ATLAS Collaboration (2890 authors)
  J. High Energy Phys., 12, 072 (2012)

- *Search for R-parity-violating supersymmetry in events with four or more leptons in root s=7 TeV pp collisions with the ATLAS detector*
  ATLAS Collaboration (2910 authors)
  J. High Energy Phys., 12, 124 (2012)

- *Search for pair production of massive particles decaying into three quarks with the ATLAS detector in root s=7 TeV pp collisions at the LHC*
  ATLAS Collaboration (2911 authors)
  J. High Energy Phys., 12, 086 (2012)

- *Search for supersymmetry in events with large missing transverse momentum, jets, and at least one tau lepton in 7 TeV proton-proton collision data with the ATLAS detector*
  ATLAS Collaboration (2914 authors)
  Eur. Phys. J. C, 72, 2215 (2012)

- *Search for light scalar top-quark pair production in final states with two leptons with the ATLAS detector in root s=7 TeV proton-proton collisions*
  ATLAS Collaboration (2887 authors)
  Eur. Phys. J. C, 72, 2237 (2012)

- *Measurement of event shapes at large momentum transfer with the ATLAS detector in pp collisions at root s=7 TeV*
  ATLAS Collaboration (2864 authors)
  Eur. Phys. J. C, 72, 2211 (2012)

- *Search for a heavy top-quark partner in final states with two leptons with the ATLAS detector at the LHC*
  Atlas Collaboration (3086 authors)
  J. High Energy Phys., 11, 094 (2012)

- *Search for high-mass resonances decaying to dilepton final states in pp collisions at root s=7 TeV with the ATLAS detector*
  ATLAS Collaboration (2887 authors)
  J. High Energy Phys., 11, 138 (2012)

**Collaboration notes with internal referee**

- *Search for the Standard Model Higgs boson in the $H \rightarrow WW \rightarrow \ell\nu\ell\nu$ decay mode with 4.7 fb-1 of ATLAS data at sqrt(s) = 7 TeV*
  The ATLAS Collaboration
  ATLAS-CONF-2012-012

- *Transverse energy fluctuations in Pb+Pb collisions at sqrt(s_NN) = 2.76 TeV with the ATLAS detector at the LHC*
  The ATLAS Collaboration
  ATLAS-CONF-2012-045

- *Observation of an Excess of Events in the Search for the Standard Model Higgs Boson in the $H \rightarrow WW(*) \rightarrow \ell\nu\ell\nu$ Channel with the ATLAS Detector*
  The ATLAS Collaboration
  ATLAS-CONF-2012-098

- *Physics at a High-Luminosity LHC with ATLAS*
  The ATLAS Collaboration
  ATL-PHYS-PUB-2012-001

- *Measurement of inclusive jet charged particle fragmentation functions in Pb_Pb collisions at sqrt(s_NN)=2.76 TeV with the ATLAS detector*
  The ATLAS Collaboration
  ATLAS-CONF-2012-115

- *Measurement of the azimuthal dependence of inclusive jet suppression in Pb+Pb collisions at sqrt(s_NN) = 2.76 TeV with the ATLAS detector*
  The ATLAS Collaboration
  ATLAS-CONF-2012-116

- *Standard Model Higgs boson Search in the bb Channel*
  The ATLAS Collaboration
  ATLAS-CONF-2012-161

- *Update of the H -> WW(*) -> e nu mu nu analysis with 13.0 fb-1 of sqrts = 8 TeV data collected with the ATLAS detector*
  The ATLAS Collaboration
  ATLAS-CONF-2012-158

**Internal Notes**

- *Detector Control System of Tile Calorimeter Low Voltage Power Supplies System*
  G. Arabidze et al
  ATL-TILECAL-INT-2012-001

- *Search for the Standard Model Higgs boson in the H-> WW -> $\ell\nu\ell\nu$ decay mode with 4.7 fb-1 of ATLAS data at sqrt(s) = 7 TeV*
  R. Abens, J. Miguéns, P. Conde Muíño, et al.
  ATL-COM-PHYS-2012-247

- *Background estimates in the H->WW->lvlv analysis with 4.7 fb-1 of data collected with the ATLAS detector at sqrt(s)=7 TeV*
  R. Abens, J. Miguéns, P. Conde Muíño, et al.
  ATL-COM-PHYS-2012-288

- *The L1.5 Jet Trigger*
  M. Tamsett, M. Begel, P. Conde Muíño, et al.
  ATL-COM-DAQ-2012-015

- *Search for the Standard Model Higgs boson in the H→WW(*)→$\ell\nu\ell\nu$ decay mode using Multivariate Techniques with 4.7 fb-1 of ATLAS data at sqrts=7 TeV*
  R. Abens, J. Miguéns, P. Conde Muíño, et al.
  ATLAS-COM-CONF-2012-069

- *Background estimates in the H->WW->lvlv analysis with 4.2 fb-1 of data collected with the ATLAS detector at sqrt(s)=8 TeV*
  R. Abens, J. Miguéns, P. Conde Muíño, et al.
  ATL-COM-PHYS-2012-849

- *Analysis of H→ WW(*)→ $l\nu l\nu$ in the same-flavour channels*
  R. Abens, J. Miguéns, et al.
  ATL-COM-PHYS-2012-1445

- *Invariant Mass Studies for the H→bb- Measurements for HCP*
  A. Bazatu, A. gomes, P. Conde Muíño, E. Pinto, et al.
  ATL-COM-PHYS-2012-1451

- *L2FS Jet Calibration*
  R. Subramaniam, N. Anjos, P. Conde Muíño et al.
  ATL-COM-DAQ-2012-212

### 2.1.8 Presentations

**Oral presentations in international conferences**

- *Jets In Pb+Pb Collisions Measured By ATLAS*
  presented by Helena Santos

Hot and dense QCD in the LHC era. Startup meeting of the ERC-StG - XII Encontro Lisboa-Compostela — Santiago de Compostela, Espanha.

- *Performance and Improvements of the ATLAS Jet Trigger System*
  presented by Patricia Conde
  15th International Conference on Calorimetry in High Energy Physics — Santa Fe, New Mexico, USA.

- *Performance of the ATLAS Jet Trigger*
  presented by Lourenço Lopes
  18th IEEE Real-Time Conference 2012 — Berkeley, California.

- *Top quark production at the LHC (ATLAS+CMS)*
  presented by Filipe Veloso
  Rencontres du Vietnam: Beyond Standard Model in Particle Physics — Quy Nhon, Vietname.

- *Latest results on Higgs searches (ATLAS)*
  presented by Patricia Conde
  Workshop on Multi-Higgs models — Lisboa, Portugal.

- *Discovery of a new particle in the Higgs searches at the LHC*
  presented by Patricia Conde
  Correlations and coherence in quantum systems — Evora, Portugal.

- *Overview of ATLAS Physics Results*
  presented by Patricia Conde
  DISCRETE 2012, Third Symposium on Prospects in Physics of the Discrete Symmetries — Lisboa, Portugal.

- *Higgs boson searches at ATLAS*
  presented by Patricia Conde
  New Worlds in Particle and Astroparticle Physics — Lisboa, Portugal.

**Poster presentations in international conferences**

- *Single hadron response measurements in ATLAS*
  presented by Mário Sargedas Sousa
  XII Pisa Meeting on Advanced Detectors — Elba Island, Tuscany, Italy.

- *Higgs boson searches with the ATLAS detector in the channel H -> WWˆ(*) -> lnulnu*
  presented by Joana Miguéns
  European School of High Energy Physics — Anjou, France.

**Presentations in national conferences**

- *ATLAS Physics highlights*
  presented by Patricia Conde
  Jornadas do LIP — Lisboa, Portugal.

- *Introduction to ATLAS at LIP*
  presented by Amélia Maio
  Jornadas do LIP — Lisboa, Portugal.

- *Search for the Higgs boson*
  presented by Joana Miguéns
  Jornadas do LIP — Lisboa, Portugal.

- *Measurements of top quark properties*
  presented by Nuno Castro
  Jornadas do LIP — Lisboa, Portugal.

- *Studies on heavy ions collisions*
  presented by Helena Santos
  Jornadas do LIP — Lisboa, Portugal.

- *Detector activities on Trigger and Tilecal*
  presented by Agostinho Gomes
  Jornadas do LIP — Lisboa, Portugal.

- *Measurements of top quark properties*
  presented by Nuno Castro
  Jornadas do LIP 2012 — Lisbon.

- *Ser cientista por um dia... na universidade e na escola!*
  presented by Filipe Veloso
  Jornadas do LIP 2012 — Lisboa.

- *Search for FCNC top quark decays with the ATLAS detector*
  presented by Filipe Veloso
  Café com Física — Seminário do Departamento de Física da Universidade de Coimbra — Coimbra.

- *Jactos em colisoes entre ioes pesados*
  presented by Alexandre Lopes
  Fisica 2012 — Departamento de Física, Facultade de Ciencias da Universidade de Lisboa.

- *O bosão de Higgs*
  presented by José Maneira
  Physics2012 - I Jornadas da Macaronésia sobre temas atuais da Física — Univ. dos Açores, Ponta Delgada, Portugal.

**Oral presentations in international meetings**

- *The top quark and new physics searches with the ATLAS detector*
  presented by Nuno Castro
  New Worlds in Particle and Astroparticle Physics — Lisbon.

**Oral presentations in collaboration meetings**

- *Performance update (SEB)*
  presented by Helena Santos
  — CERN.

- *Update FCNC (trilepton)*
  presented by Filipe Veloso
  Top properties meeting — .

- *L2 Status*
  presented by Nuno Anjos
  Jet Trigger Meeting — CERN.

- *Status of the L2 jet trigger software*
  presented by Nuno Anjos
  — CERN.

- *Data quality plots*
  presented by Luís Seabra
  ALFA Physics Meeting — CERN.

- *12 weekly presentations reporting the Status of TileCal Run Operations*
  presented by
  Tile Operations Meeting — CERN.

- *FCNC (3 leptons)*
  presented by Filipe Veloso
  Top Properties Meeting — .

- *Updated Proposal for hadCalib Triggers*
  presented by Patricia Conde
  Jet Trigger Meeting — CERN.

- *Updated Proposal for hadCalib Triggers*
  presented by Mário Sargedas Sousa
  Jet Trigger Signature Group Meeting — CERN.

- *Relative systematic errors on Jet Energy Scale*
  presented by Helena Santos
  — CERN.

- *Test of BC-ID dependent cell corrections for 2012 on etmiss and sumEt*
  presented by João Gentil
  Jet/Etmiss phone meeting — .

- *Moriond dataset and ee+1 jet excess*
  presented by Joana Miguéns
  HSG3 Weekly meeting — CERN.

- *Reports for Wmn*
  presented by Pedro Jorge
  W,Z inclusive meeting — CERN.

- *WToMuonNeutrino Benchmark: 2011 data and MC11a*
  presented by Pedro Jorge
  W,Z common topic meeting — CERN.

- *WToMuonNeutrino Benchmark: 2011 data and MC11a*
  presented by Pedro Jorge
  W,Z common topic meeting — CERN.

- *2+3 fakes estimation for the 3ID FCNC analysis*
  presented by Filipe Veloso
  Top fakes meeting — .

- *Implementation of the Global Sequential Calibration in the L2 jet trigger*
  presented by Nuno Anjos
  — CERN.

- *E/p trigger status*
  presented by Patricia Conde
  — CERN.

- *HadCalib trigger status*
  presented by Patricia Conde
  Trigger General Meeting — CERN.

- *Overlay efficiencies*
  presented by Helena Santos
  — CERN.

- *Pileup scans in Zmumu*
  presented by João Gentil
  Pile-up noise threshold and mu scan topical meeting — .

- *L2 Update*
  presented by Nuno Anjos
  Jet Trigger Meeting — CERN.

- *Tile Run Coordination report*
  presented by
  TileCal Week — CERN.

- *2012 E/p trigger menu status*
  presented by Patricia Conde
  Jet Trigger Signature Group Meeting — CERN.

- *Update on HadCalib triggers*
  presented by Mário Sargedas Sousa
  Jet Trigger Signature Group Meeting — CERN.

- *Expert on call report*
  presented by Patricia Conde
  Jet Trigger Signature Group Meeting — CERN.

- *Validation of the hadCalib Trigger*
  presented by Patricia Conde
  Jet Trigger Signature Group Meeting — CERN.

- *Summary from DAQ expert on call*
  presented by João Gentil
  Tile Operations Meeting — CERN.

- *E/p trigger update*
  presented by Mário Sargedas Sousa
  Jet Trigger Signature Group Meeting — CERN.

- *4 weekly presentations reporting the Status of TileCal Run Operations*
  presented by João Gentil
  Tile Operations Meeting — CERN.

- *Presentation of the analysis*
  presented by Nuno Castro
  Open Presentation on the Measurement of the W boson polarization in top quark decays in 1.04 fb?1 of pp collisions at sqrt(s) = 7 TeV with the ATLAS detector — .

- *Subthreshold jets*
  presented by Joana Miguéns
  HSG3 Z/DY & MET meeting — CERN.

- *A search for flavour changing neutral currents in top quark decays in pp collision data collected with the ATLAS detector at sqrt(s)=7TeV*
  presented by Filipe Veloso
  Open Presentation on the search for flavour changing neutral currents in top quark decays in pp collision data collected with the ATLAS detector at sqrt(s) = 7 TeV — .

- *HadCalib trigger rates*
  presented by Patricia Conde
  Jet Trigger Signature Group Meeting — CERN.

- *First look at 2012 data*
  presented by Lourenço Lopes
  Jet Trigger Signature Group Meeting — CERN.

- *16 weekly presentations reporting the Status of TileCal Run Operations*
  presented by João Gentil
  Tile Operations Meeting — CERN.

- *Next actions to understand the disabled ROLs problem*
  presented by João Gentil
  Tile Management meeting — .

- *Data loss and new plots request for DQMD*
  presented by João Gentil
  Tilecal Calibration, Data Quality, Performance and Processing — .

- *Tile Run Coordination report*
  presented by João Gentil
  TileCal Week — .

- *Class 1 shifts – experiences and plans for the second half of 2012*
  presented by João Gentil
  TileCal Institue Board meeting — CERN.
- *Z/DY estimation: ABCD/SF/Pacman*
  presented by Joana Miguéns
  HSG3 Z/DY & MET meeting — CERN.
- *Hadronic activity fit+cut*
  presented by Joana Miguéns
  HSG3 Z/DY & MET meeting — CERN.
- *Plans for upcoming technical stop*
  presented by João Gentil
  Tile Management meeting — .
- *L2 and noise suppression*
  presented by Patricia Conde
  Jet Trigger Signature Group Meeting — CERN.
- *Top studies*
  presented by Filipe Veloso
  2nd Workshop "ATLAS Input to the European Strategy-– .
- *had. activity plots*
  presented by Joana Miguéns
  HSG3 meeting — CERN.
- *Consolidations implemented during the last TS and assessment*
  presented by João Gentil
  Tile Management meeting — .
- *Pacman fit tests*
  presented by Joana Miguéns
  HSG3 Z/DY & MET meeting — CERN.
- *f_recoil method for DY estimation*
  presented by Joana Miguéns
  HSG3 Z/DY & MET meeting — CERN.
- *Skimming report*
  presented by Joana Miguéns
  HSG3 meeting — CERN.
- *Pacman update*
  presented by Joana Miguéns
  HSG3 Z/DY & MET meeting — CERN.
- *Pacman update*
  presented by Joana Miguéns
  HSG3 Z/DY & MET meeting — CERN.
- *fRecoil*
  presented by Joana Miguéns
  HSG3 meeting — CERN.
- *LIP Plans and activity*
  presented by Nuno Castro
  Top and Fourth Generation Subgroup Meeting — .
- *DAQ/Status*
  presented by João Gentil
  Tile Management meeting — .

- *Status of skimming/slimming*
  presented by Joana Miguéns
  HSG3 meeting — CERN.

- *Performance paper: Resolutions and efficiencies*
  presented by Lourenço Lopes
  Jet Trigger Signature Group Meeting — CERN.

- *Comparison between the different laser data treatment methods*
  presented by Rute Pedro
  Tilecal Calibration, Data Quality, Performance and Processing — CERN.

- *Pacman for 1-jet events*
  presented by Joana Miguéns
  HSG3 Z/DY & MET meeting — CERN.

- *Data/MC comparisons*
  presented by Joana Miguéns
  HSG3 meeting — CERN.

- *Peformance of the trigger in 2011*
  presented by Lourenço Lopes
  Jet Trigger Signature Group Meeting — CERN.

- *performance paper: efficiencies and resolutions*
  presented by Lourenço Lopes
  Jet Trigger Signature Group Meeting — CERN.

- *Progress on global sequential corrections for H->bb*
  presented by Emiliano Pinto
  Jet calibration and resolution — .

- *MobiDICK 4*
  presented by José Domingos Alves
  Tile Upgrade in Tile week — CERN.

- *Performance paper: Resolutions*
  presented by Lourenço Lopes
  Jet Trigger Signature Group Meeting — CERN.

- *VLQ Protos update*
  presented by Juan Espinosa
  Top and Fourth Generation Subgroup Meeting — .

- *H–>WW–>lvlv same flavour (SF) Blinded analysis approval*
  presented by Joana Miguéns
  H->WW Unblinding approval — CERN.

- *Performance paper: L1Calo efficiencies and resolutions*
  presented by Lourenço Lopes
  Jet Trigger Signature Group Meeting — CERN.

- *PROTOS VLQ MC and 8 TeV tZ Plans*
  presented by Juan Espinosa
  Top and Fourth Generation Subgroup Meeting — .

- *TDK-Lambda: 200V Power Supply*
  presented by Filipe Martins
  Tilecal operation weekly meeting — CERN.

- *Validation of GSC weights as a function of ntrack and track width*
  presented by Emiliano Pinto
  Jet calibration and resolution — .

- *DCS expert report*
  presented by Filipe Martins
  Tilecal operation weekly meeting — CERN.
- *PVSS data rate, smoothing and alert panels*
  presented by Luís Seabra
  Tile DCS coordination meeting — CERN.
- *SF update*
  presented by Joana Miguéns
  HSG3 meeting — CERN.
- *Saturated samples observation*
  presented by
  Tilecal Calibration, Data Quality, Performance and Processing — CERN.
- *tZ+X update*
  presented by Juan Espinosa
  Top and Fourth Generation Subgroup Meeting — .
- *MET studies in mc12 W events*
  presented by João Gentil
  ETmiss Subgroup Meeting — .
- *DCS expert report*
  presented by Agostinho Gomes
  Tilecal operation weekly meeting — CERN.
- *VLQ generation strategy*
  presented by Nuno Castro
  Top and Fourth Generation Subgroup Meeting — .
- *b-jet response studies*
  presented by José Maneira
  HSH5 Mbb mass resolution meeting — .
- *Current status of same flavour 0,1 jet (HCP)*
  presented by Joana Miguéns
  H->WW Workshop — Sesimbra, Portugal.
- *TDK-Lambda: 200V Power Supply*
  presented by Filipe Martins
  Tilecal operation weekly meeting — CERN.
- *Reports for Wmn*
  presented by Pedro Jorge
  W,Z inclusive meeting — CERN.
- *VLQ test sample validation*
  presented by Juan Espinosa
  Top and Fourth Generation Subgroup Meeting — .
- *Transition Region*
  presented by Nuno Anjos
  Jet Trigger Meeting — CERN.
- *LIP status report and plans on top FCNC decays (t->qZ)*
  presented by Filipe Veloso
  Top properties meeting — .
- *Same Flavour Analysis*
  presented by Joana Miguéns
  HSG3 meeting — CERN.

- *Laser Calibration Data Treatment - Effectiveness in the determination of Systematic Errors*
  presented by Rute Pedro
  Tilecal Calibration, Data Quality, Performance and Processing — .
- *Pileup MC comparison between 25 and 50 ns bunch spacing*
  presented by Juan Espinosa
  Top and Fourth Generation Subgroup Meeting — .
- *MET performance in W events*
  presented by João Gentil
  ETmiss Subgroup Meeting — .
- *Same Flavour Update*
  presented by Joana Miguéns
  HSG3 Weekly meeting — CERN.

**Seminars**

- *Últimas notícias da procura do Higgs na experiência ATLAS do LHC (CERN)*
  presented by Patricia Conde
  — Departamento de Física, Facultade de Ciencias da Universidade de Lisboa.
- *Hbb lecture. Case study of ATLAS*
  presented by Patricia Conde
  Course on Physics at the LHC — Lisboa, Portugal.
- *Di-jet Asymmetries in Pb+Pb Collisions at sqrt(s)=2.76 TeV with the ATLAS Detector*
  presented by Alexandre Lopes
  — Departamento de Física, Facultade de Ciencias da Universidade de Lisboa.
- *O Modelo Padrão da Física das Partículas*
  presented by Nuno Castro
  Colóquios do Centro de Física — Escola de Ciências, Universidade do Minho..
- *O Modelo Padrão da Física das Partículas*
  presented by Nuno Castro
  Colóquios do Centro de Física — Escola de Ciências, Universidade do Minho.
- *Em busca do bosão de Higgs: descoberta de uma nova partícula.*
  presented by Patricia Conde
  — Instituto Interdisciplinar da Universidade de Lisboa.

### 2.1.9 Academic Training

**PhD Theses**

- *Measurement of the W -> mu nu production cross section with the ATLAS detector*
  Pedro Jorge, (on-going)
- *Non-standard Higgs and top-quark production and decay at the Large Hadron Collider: a collaboration between theory and experiment*
  Miguel Won, (on-going)
- *Medição da secção eficaz de produção do bosão W em ATLAS/LHC/CERN*
  Alberto Palma, (on-going)
- *Medida da taxa de decaimentos raros do quark top, na experiência ATLAS no LHC*
  Bruno Galhardo, (on-going)
- *Measurement of the WW Production in 7TeV pp Collisions at the LHC with the ATLAS Detector*
  Joana Miguéns, (on-going)
- *Search for the Higgs boson at ATLAS/LHC, in associated production with a Z boson*
  Mário Sargedas Sousa, (on-going)

- *Search for the Higgs boson at ATLAS/LHC in WH associated production and decay to b quark pairs*
  Rute Pedro, (on-going)
- *Development of boosted jet triggers for Higgs searches at the ATLAS experiment at the LHC/CERN*
  Ademar Delgado, (on-going)

**Master Theses**

- *Interface Ethernet para um Testador de Sistemas Electrónicos do TileCal*
  José Domingos Alves, 2012-12-14

### 2.1.10 Events

- *ATLAS Higgs to WW Workshop*
  Collaboration Meeting, Sesimbra, Portugal, 2012-11-28

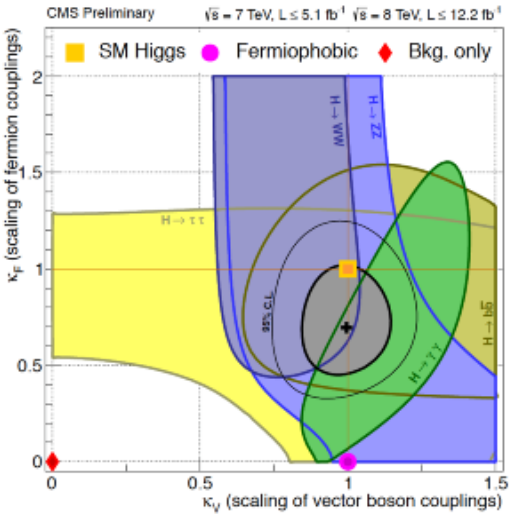
### 2.1.11 Project Summary

| | number |
|---|---|
| Articles in international journals (with direct contribution from LIP members) | 14 |
| Articles in international journals (with indirect contribution from LIP members) | 112 |
| Collaboration notes with internal referee | 8 |
| Internal Notes | 9 |
| Oral presentations in international conferences | 8 |
| Poster presentations in international conferences | 2 |
| Presentations in national conferences | 11 |
| Oral presentations in international meetings | 1 |
| Oral presentations in collaboration meetings | 91 |
| Seminars | 6 |
| Master Theses | 1 |
| Collaboration Meetings | 1 |

## 2.2 Collaboration in the CMS experiment at CERN

### 2.2.1 Resumo

O LIP é membro da experiência Compact Muon Solenoid (CMS) no acelerador Large Hadron Collider (LHC) 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, em particular estudar a natureza da quebra de simetria na interacção electrofraca e a origem da massa das partículas elementares. A actividade do LIP em CMS tem as seguintes componentes principais:
1) A operação e manutenção do trigger e do sistema de leitura de dados do calorímetro electromagnético de CMS;
2) Análises da física das colisões protão-protão, explorando as possibilidades de descoberta proporcionadas pela energia do LHC;
3) Análises de física de iões pesados, em particular o estudo do plasma de quarks e gluões através da análise da produção de quarkonia;
4) Investigação e desenvolvimento do sistema de trigger no LHC a alta luminosidade (HL-LHC).
Em 2012 o LHC realizou colisões de feixes de protões à energia de 8 TeV. O desempenho do colisionador LHC e dos detectores das experiências foi notável. A luminosidade do LHC em 2012 atingiu 7.7 E33 cm-2s-1. Em 2011-12 o LHC forneceu uma luminosidade integrada de 25 fb-1. Um período de colisões entre protões e iões de chumbo de cerca de um mês teve lugar entre Janeiro e Fevereiro de 2013. Os dados adquiridos permitiram pela primeira vez a observação de um bosão de Higgs com uma massa de cerca de 125 GeV.
O detector CMS funcionou com grande eficiência (acima de 90%) fornecendo dados de grande qualidade para análise de física. A infraestrutura de computação GRID funcionou de forma excelente e a qualidade do software offline permitiu realizar a reconstrução de eventos, análise de dados, e obtenção de resultados num intervalo de tempo extraordinariamente curto. Medidas de precisão de vários processos físicos foram realizadas. Até ao momento todos os resultados são compatíveis com as previsões do Modelo Standard da Física de Partículas. Muitas pesquisas de Nova Física foram realizadas com os dados de 2011-12, com especial enfoque nos modelos de supersimetria. Estas medidas excluíram a existência de gluinos com massas inferiores a cerca de 1 TeV.
Em 2013-14 está planeada uma pausa de dois anos na operação do LHC para realizar as alterações necessárias à sua operação à energia de 14 TeV e luminosidade de 10E34 cm-2s-1. Estas condições de operação permitirão novas oportunidades de descobertas em física, mas implicam igualmente novos desafios na operação dos detectores. Durante este intervalo, CMS planeia instalar a primeira fase de um novo sistema de trigger que lhe permitirá funcionar a alta luminosidade.
O grupo do LIP teve uma participação muito activa em várias áreas da experiência CMS. O grupo teve uma forte participação na operação do detector, em particular no ECAL e no Trigger. O grupo liderou ou teve um forte envolvimento em várias análises de física, em particular:




Scaling factors of the SM couplings of the new Higgs boson to bosons and fermions measured by the CMS experiment. The experimental value, indicated by the black cross and the black ellipses (68% and 95% CL), result from the combination of five decay channels.

1) a observação de um bosão de Higgs no decaimento em dois fotões;
2) a combinação das medidas do bosão de Higgs entre os vários canais de decaímento;
3) a melhor medida da massa do quark top no canal dileptónico;
4) a melhor medida do elemento Vtb da matriz CKM;
5) a primeira medida da secção eficaz de produção top-antitop no decaímento dileptónico com taus;
6) a pesquisa de bosões de Higgs carregados no decaímento do quark top;
7) a pesquisa o parceiro supersimétrico do quark top nos eventos com um leptão usando redes neuronais;
8) a medida da polarização dos estados de quarkonia nas colisões de protões e de iões pesados.
O grupo participa activamente no projecto de Upgrade do Trigger de Calorimetria desenvolvendo novas ligações ópticas de alta velocidade destinadas a transmitir os dados de trigger do Calorímetro Electromagnético.

### 2.2.2 Abstract

LIP is a member of the CMS experiment at the Large Hadron Collider at CERN. The experiment investigates very high energy collisions of proton and nuclear beams. The experiment´s scope is the investigation of the most fundamental properties of matter, in particular the study of the nature of the electroweak symmetry breaking and the origin of mass. The LIP activity has the following main components:
1) The operation and maintenance of the trigger and the readout system of the CMS electromagnetic calorimeter;
2) Proton-proton physics analyses, exploiting the discovery opportunities offered by the new LHC energy;
3) Heavy-ion physics analyses, in particular the study of the QGP through measurements of quarkonia production;
4) Research and development in view of the upgrade of the CMS trigger system at high luminosity (HL-LHC).
In 2012 the LHC collided proton beams at the energy of 8 TeV. The performance of the LHC machine and of the experiments detectors has been outstanding. The LHC luminosity in 2012 reached 7.7 E33 cm-2s-1. In 2011-12 the LHC delivered an integrated luminosity of 25 /fb. One month of running with proton and lead ions took place in January and February 2013. The acquired data allowed for the first time the observation a Higgs boson with mass around 125 GeV.
The CMS detector is operating with very high efficiency (above 90%) and is providing data of very high quality for physics. The GRID computing infrastructure has operated flawlessly and the offline-software quality allowed event reconstruction, data analysis and physics results in an unprecedented short time scale. Precision measurements of several physics processes were undertaken. Until now all results are compatible with the predictions of the Standard Model. Many different searches of New Physics processes were performed with 2011-12 data, in particular regarding super-symmetry. These results exclude gluinos with mass below around 1 TeV.
In 2013-14 it is planned a two-year long LHC shutdown aiming at the upgrade of the collider to a center-of-mass energy of 14 TeV and instantaneous luminosity of 10ˆ34 and above. These operating conditions will bring new opportunities for physics discoveries but also additional challenges for the CMS detector operation. During this shutdown CMS has plans to install the first phase of a new trigger system which would allow to trigger at high luminosity.
The LIP group has been very active in many areas of the CMS experiment. The group has a strong participation in the operation of the detector, in particular the ECAL and the Trigger system.
The group had a leading role or strong involvement in several physics analysis, in particular:
1) the observation of a Higgs boson in the decay in two photons;
2) in the combination of Higgs measurements in several decay modes
3) the best measurements of the top quark mass in the dilepton channel;
4) the best measurement of the Vtb element of the CKM matrix;
5) the first measurement of the top-antitop quark production cross section in the dilepton decay with taus;
6) the search for a charged Higgs produced in top decays
7) the search of the supersymetric partner of the top quark in single lepton events using a neural network.
8) the measurement of quarkonia polarization in proton and lead collisions.
The group is participating actively in the Calorimeter Trigger Upgrade project in particular developing new high-speed optical links to transmit the trigger data from ECAL.

### 2.2.3 Achievements

**Physics**
The physics exploitation of the data of the Run 1 of LHC (2010-12) was a major goal of the LIP/CMS group, which was fully achieved. The group was actively involved and/or had a leading role in various physics analysis. These includes:

1) the observation a Higgs boson in the decay in two photons; in this analysis LIP contributed with the algorithms used for primary vertex identification, and group members took the responsibility of the full analysis code integration as well as for the edition of the analysis note. One of the group members involved in this work became CERN fellow in 2012.
2) participation in the Higgs combination analysis which produced the final overall Higgs results on properties and mass; one member of the LIP group was selected to be co-convener of the CMS Higgs combination and properties sub-group.
3) the measurement performed by the LIP and Brown groups of the top quark mass in the dilepton channel, which was the first top quark measurement at LHC and became in 2012 the most precise measurement of the top mass in this channel;
4) the best measurement of the Vtb element of the CKM matrix, extracted from the ratio R between top decays in b-quarks and top decays in all quarks; this work was also used to measure the b-tagging efficiency assuming R=1. One of the group member involved in this work became CERN fellow in 2011 but pursued the work in collaboration with LIP.
4) the measurement performed by the LIP group of the limits in the branching ratio of top decay in charged Higgs, using events with one lepton (electron or muon) and one hadronic decaying tau;
5) the measurement performed by the LIP group of the top-antitop quark production cross section in the dilepton decay with taus;
6) the search led by the LIP group in collaboration with Mons, Lyon and Gent, of the supersymetric partner of the top quark in single lepton events using a neural network.
7) the measurement led by the LIP group in collaboration with Vienna, CERN, Beijing, of quarkonia polarization in proton and lead collisions.
8) the measurement led by the LIP group of the isolated prompt photon cross section based on the cluster shape analysis method developed in the group, using the first 3 pb-1 of data collected in 2010;

**Publications, Seminars, Schools**

In 2012, the members of the group presented results in international conferences or meetings (16 talks), seminars and lectures (13 talks) and in meetings of the CMS collaboration (73 talks). Group members were co-authors in 123 papers in international scientific journals (8 with direct contribution of the group), and main authors in 5 papers in conference proceedings, in 11 CMS public notes with internal referee, and in 18 CMS internal analysis notes.
Publications by the CMS Collaboration are available at:
http://cdsweb.cern.ch/collection/CMS%20Papers?ln=en
Members of the LIP group have been selected to participate in many Analysis Review Committees (ARC) which review and finally approve the physics results obtained in the Collaboration.
The series of seminars on LHC Physics ("Physics on the road to discovery") was pursued in 2012 in collaboration with CFTP/IST (http://www.lip.pt/≈michgall/lhc_seminars.html)
In the context of IDPASC, the LIP CMS group organized a series of weekly lectures entitled "Physics at the LHC", covering topics from the basics of detector concepts to case studies of state-of-the-art analyses (http://www.idpasc.lip.pt/LIP/events/2012_lhc_physics/)

**Experiment work**
The LIP group has important responsibilities in the maintenance and operation of the CMS detector, namely the ECAL trigger and data acquisition system, including hardware and software, following its strong participation in the CMS construction. The LIP group had in 2012 a team of three people in permanence at CERN dedicated to the operation of the ECAL data acquisition and online monitoring. The group was directly involved in the ECAL and Trigger operation during the LHC runs in 2012. Several members of the group are "experts on-call"available during LHC runs to intervene in case of system faults. The group assured a number of data taking Shifts both in ECAL and in the central Trigger, as required by the Collaboration. Members of the group also served as Run Field Manager, Shift Leader and Trigger Field Manager at several occasions during the data taking periods. The group was also involved in activities of the L1 Trigger and ECAL Detector Performance Groups (DPG), providing software tools for data monitoring. These activities were viewed as the LIP contribution to experiment work, totalizing FTEs equal to 25% of the number of authors, as required to all CMS institutes.
The LIP/CMS GRID activities were focused in the exploitation of the Portuguese LHC Tier-2 Federation for CMS physics analysis. The LIP center is supporting the activities of CMS central operations, while NCG site supports the central Monte Carlo production and the activities of physics groups. Both sites serve as well the computing needs of the local physics community. The Tier-2 has been continuously monitored and proven

to operate with high computing efficiencies and data transfer throughputs and quality on both download and upload streams.

**Upgrade**
The group is participating actively in the Calorimeter Trigger Upgrade project in particular developing new high-speed optical links to transmit the trigger data from ECAL. In 2012 a prototype of the new optical links was built and proved to work.
The LIP group is part of a new Marie Curie ITN, named INFIERI (Intelligent Fast Interconnected and Efficient Devices for Frontier Exploitation in Research and Industry). In this context LIP will start in 2013 a new activity in the development of a Pixel Trigger for the CMS Phase 2 Upgrade.

**Management**
Members of the LIP/CMS group have the following CMS management positions:
- CMS Deputy Spokesperson (J. Varela)
- ECAL Run Coordinator (A. David)
- ECAL Electronics Coordinator (J. C. Silva)
- ECAL DAQ/Trigger coordinator (P. Parracho)
- Convener of Higgs Combination and Properties sub-group (A. David)

A group member was nominated CMS contact to the Low Mass Higgs group of the LHC Higgs Cross Section Working Group (A. David).
Group coordinator: João Varela
Detector coordinator: André David
Electronics coordinator: José Carlos Silva
Computing coordinator: Nuno Almeida
Proton-proton physics coordinator: Michele Gallinaro
Heavy-ion physics coordinator: João Seixas

### 2.2.4 Sources of Funding

| Code | Funding | Start | End |
|---|---|---|---|
| CERN/FP/116367/2010 | 277.000 € | 2011-01-01 | 2012-03-31 |
| CERN/FP/123601/2011 | 550.000 € | 2012-04-01 | 2014-03-31 |

### 2.2.5 Team

**Project coordinator: João Varela**

| Name | Status | %of time in project |
|---|---|---|
| André Alves | Master (LIP) | 18 |
| André Tinoco Mendes | Researcher (LIP) | 100 |
| Cristóvão Silva | PhD student (LIP/FCT) | 100 |
| Federico Nguyen | Post-Doc (LIP) | 65 |
| João Pela | PhD student (LIP/Imperial) | 100 |
| João Seixas | Researcher (LIP/IST) | 50 |
| João Varela | Researcher (LIP/IST) | 77 |
| José Carlos Silva | Technician (LIP) | 96 |
| Michele Gallinaro | Researcher (LIP) | 100 |
| Miguel Fernandes | Master (LIP) | 75 |
| Nuno Almeida | Post-Doc (LIP/FCT) | 25 |
| Pasquale Musella | Post-Doc (LIP) | 25 |
| Pedrame Bargassa | Researcher (LIP) | 100 |
| Pedro Manuel Silva | Post-Doc (LIP/FCT) | 62 |
| Pedro Parracho | Collaborator (LIP/AdI) | 100 |
| Pietro Faccioli | Post-Doc (LIP/FCT) | 100 |
| Pietro Vischia | Master (LIP) | 100 |
| Rogério Jorge | Student (LIP) | 4 |
| Sérgio Sampaio | Master student (LIP/IST) | 67 |

### 2.2.6 Publications

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

- *Search for a light charged Higgs boson in top quark decays in pp collisions at $\sqrt{s}$ = 7 TeV*
  CMS collaboration
  J. High Energy Phys. 07 (2012) 143

- *Observation of a new boson at a mass of 125 GeV with the CMS experiment at the LHC*
  CMS collaboration
  Phys. Lett. B 716 (2012) 30-61

- *A New Boson with a Mass of 125 GeV Observed with the CMS Experiment at the Large Hadron Collider*
  The CMS Collaboration
  Science Vol. 338 no. 6114 pp. 1569-1575 (2012); DOI: 10.1126/science.1230816

- *Observation of chi_c and chi_b nuclear suppression via dilepton polarization measurements*
  Pietro Faccioli, Joao Seixas
  Phys. Rev. D, 85, 074005 (2012)

- *Measurement of the top-quark mass in $tt^-$ events with dilepton final states in pp collisions at $\sqrt{s}$=7 TeV*
  CMS Collaboration (2204 authors)
  Eur. Phys. J. C, 72, 2202 (2012)

- *Measurement of the $tt^-$ production cross section in the dilepton channel in pp collisions at $\sqrt{s}$=7 TeV*
  CMS collaboration
  J. High Energy Phys., 11, 067 (2012)

- *Remote reprogramming of FPGAs on the CMS ECAL off detector electronics*
  J. C. Da Silva, A. Konoplyannikov, E. Vlassov
  J. Instrum., 7, C02010 (2012)

- *Questions and Prospects in Quarkonium Polarization Measurements from Proton-Proton to Nucleus-Nucleus Collisions*
  Pietro Faccioli
  Mod. Phys. Lett. A, 27, 1230022 (2012)

- *Angular characterization of the ZZ -> 4l background continuum to improve sensitivity of new physics searches*
  Pietro Faccioli, Joao Seixas
  Phys. Lett. B, 716, 326 (2012)

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

- *Search for heavy Majorana neutrinos in $\hat{I}^1_4\hat{A}\pm\hat{I}^1_4\hat{A}\pm$ and $e\hat{A}\pm e\hat{A}\pm$ events in pp collisions at $\sqrt{s}$ = 7 TeV*
  CMS collaboration
  Phys. Lett. B xx (2012) xx (accepted)

- *Jet momentum dependence of jet quenching in PbPb collisions at $\sqrt{s_{NN}}$=2.76 TeV.*
  CMS collaboration
  Phys. Lett. B 712 (2012) 176-197

- *Search for quark compositeness in dijet angular distributions from pp collisions at $\sqrt{s}$ = 7 TeV*
  CMS collaboration
  J. High Energy Phys. 05 (2012) 055

- *Search for microscopic black holes in pp collisions at $\sqrt{s}$ = 7 TeV.*
  CMS collaboration
  J. High Energy Phys. 04 (2012) 061

- *Measurement of the charge asymmetry in top-quark pair production in proton-proton collisions at sqrts = 7 TeV*
  CMS collaboration
  Phys. Lett. B709 (2012) 28-49

- *Search for $B_s^0 omu^+ mu^-$ and $B^0 omu^+ mu^-$ decays.*
  CMS collaboration
  J. High Energy Phys. 04 (2012) 033

- *Search for Dark Matter and Large Extra Dimensions in pp Collisions Yielding a Photon and Missing Transverse Energy*
  CMS collaboration
  Phys. Rev. Lett. 108 (2012) 261803

- *Azimuthal anisotropy of charged particles at high transverse momenta in PbPb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV*
  CMS collaboration
  Phys. Rev. Lett. 109 (2012) 022301

- *Observation of a New Xib Baryon*
  CMS collaboration
  Phys. Rev. Lett. 108 (2012) 252002

- *Search for heavy long-lived charged particles in pp collisions at $\sqrt{s}$=7 TeV*
  CMS collaboration
  Phys. Lett. B 713 (2012) 408-433

- *Measurement of the $\Lambda_b$ cross section and the $\bar{\Lambda}_b$ to $\Lambda_b$ ratio with $J/\Psi\Lambda$ decays in pp collisions at $\sqrt{s}$ = 7 TeV*
  CMS collaboration
  Phys. Lett. B 714 (2012) 136-157

- *Study of W boson production in PbPb and pp collisions at $\sqrt{s_{NN}}$ = 2.76 TeV*
  CMS collaboration
  Phys. Lett. B 715 (2012) 66-87

- *Search for narrow resonances in dilepton mass spectra in pp collisions at $\sqrt{s}$ = 7 TeV*
  CMS collaboration
  Phys. Lett. B 714 (2012) 158-179

- *Search for the standard model Higgs boson produced in association with W and Z bosons in pp collisions at $\sqrt{s}$=7 TeV*
  CMS collaboration
  J. High Energy Phys. 11 (2012) 088

- *Measurement of the single-top-quark t-channel cross section in pp collisions at $\sqrt{s}$ = 7 TeV*
  CMS collaboration
  J. High Energy Phys. 12 (2012) 035

- *Search for heavy lepton partners of neutrinos in proton-proton collisions in the context of the type III seesaw mechanism*
  CMS collaboration
  Phys. Lett. B 718 (2012) 348-368

- *Search for supersymmetry in events with photons and low missing transverse energy in pp collisions at $\sqrt{s}$ = 7 TeV*
  CMS collaboration
  Phys. Lett. B 719 (2013) 42-61

- *Search for narrow resonances and quantum black holes in inclusive and b-tagged dijet mass spectra from pp collisions at $\sqrt{s}$ = 7 TeV*
  CMS collaboration
  J. High Energy Phys. 01 (2013) 013

- *Observation of Z decays to four leptons with the CMS detector at the LHC*
  CMS collaboration
  J. High Energy Phys. 12 (2012) 034

- *Observation of long-range, near-side angular correlations in pPb collisions at the LHC*
  CMS collaboration
  Phys. Lett. B 718 (2013) 795-814

- *Search for third-generation leptoquarks and scalar bottom quarks in pp collisions at $\sqrt{s}$ = 7 TeV*
  CMS collaboration
  J. High Energy Phys. 12 (2012) 055

- *Jet Production Rates in Association with W and Z Bosons in pp Collisions at sqrts = 7 TeV*
  CMS Collaboration (2259 authors)
  J. High Energy Phys., 1, 010 (2012)

- *Inclusive b-jet production in pp collisions at sqrt(s)=7 TeV*
  CMS Collaboration (2274 authors)
  J. High Energy Phys., 4, 084 (2012)

- *Search for the standard model Higgs boson decaying to bottom quarks in pp collisions at sqrt(s)=7 TeV*
  CMS Collaboration (2271 authors)
  Phys. Lett. B, 710, 284 (2012)

- *Search for neutral Higgs bosons decaying to tau pairs in pp collisions at sqrt(s)=7 TeV*
  CMS Collaboration (2271 authors)
  Phys. Lett. B, 713, 68 (2012)

- *Search for large extra dimensions in dimuon and dielectron events in pp collisions at sqrt(s) = 7 TeV*
  CMS Collaboration (2272 authors)
  Phys. Lett. B, 711, 15 (2012)

- *Search for the standard model Higgs boson in the H to ZZ to ll tau tau decay channel in pp collisions at sqrt(s)=7 TeV*
  CMS Collaboration (2273 authors)
  J. High Energy Phys., 3, 081 (2012)

- *Search for the standard model Higgs boson in the H to ZZ to 2l 2nu channel in pp collisions at sqrt(s) = 7 TeV*
  CMS Collaboration (2273 authors)
  J. High Energy Phys., 3, 040 (2012)

- *Study of high-pT charged particle suppression in PbPb compared to pp collisions at sqrt(sNN)=2.76 TeV*
  CMS collaboration
  CERN-PH-EP-2012-043; CMS-HIN-10-005-003

- *Search for the standard model Higgs boson decaying into two photons in pp collisions at sqrts=7 TeV*
  CMS Collaboration (2267 authors)
  Phys. Lett. B, 710, 403 (2012)

- *Search for the standard model Higgs boson decaying to a W pair in the fully leptonic final state in pp collisions at sqrts = 7 TeV*
  CMS Collaboration (2273 authors)
  Phys. Lett. B, 710, 91 (2012)

- *Combined results of searches for the standard model Higgs boson in pp collisions at sqrts = 7 TeV*
  CMS Collaboration (2272 authors)
  Phys. Lett. B, 710, 26 (2012)

- *Centrality dependence of dihadron correlations and azimuthal anisotropy harmonics in PbPb collisions at $sqrts_{NN}$ = 2.76 TeV*
  CMS Collaboration (2271 authors)
  Eur. Phys. J. C, 72, 2012 (2012)

- *Measurement of isolated photon production in pp and PbPb collisions at $sqrts_{NN}$ = 2.76 TeV*
  CMS Collaboration (2255 authors)
  Phys. Lett. B, 710, 256 (2012)

- *Search for pair production of first- and second-generation scalar leptoquarks in pp collisions at $\sqrt{s}$= 7 TeV*
  CMS Collaboration (2199 authors)
  Phys. Rev. D, 86, 052013 (2012)

- *Study of the inclusive production of charged pions, kaons, and protons in pp collisions at $\sqrt{s}$ = 0.9, 2.76, and 7 TeV*
  CMS Collaboration (2197 authors)
  Eur. Phys. J. C, 72, 2164 (2012)

- *Measurement of the underlying event activity in pp collisions at $\sqrt{s}$ = 0.9 and 7 TeV with the novel jet-area/median approach*
  CMS Collaboration (2236 authors)
  J. High Energy Phys., 8, 130 (2012)

- *Search for supersymmetry in hadronic final states using MT2 in pp collisions at $\sqrt{s}$ = 7 TeV*
  CMS Collaboration (2191 authors)
  J. High Energy Phys., 10, 018 (2012)

- *Search for new physics in the multijet and missing transverse momentum final state in proton-proton collisions at $\sqrt{s}$ = 7 TeV*
  CMS Collaboration (2193 authors)
  Phys. Rev. Lett., 109, 171803 (2012)

- *Search for a fermiophobic Higgs boson in pp collisions at $\sqrt{s}$=7 TeV*
  CMS Collaboration (2188 authors)
  J. High Energy Phys., 9, 111 (2012)

- *Inclusive and differential measurements of the $tt^-$ charge asymmetry in proton-proton collisions at $\sqrt{s}$ = 7 TeV*
  CMS Collaboration (2194 authors)
  Phys. Lett. B, 717, 129 (2012)

- *Search for stopped long-lived particles produced in pp collisions at $\sqrt{s}$ =7 TeV*
  CMS Collaboration (2192 authors)
  J. High Energy Phys., 8, 026 (2012)

- *Search for a light pseudoscalar Higgs boson in the dimuon decay channel in pp collisions at $\sqrt{s}$ = 7 TeV*
  CMS Collaboration / Kailas, S / Barbone, L (2191 authors)
  Phys. Rev. Lett., 109, 121801 (2012)

- *Search for dark matter and large extra dimensions in monojet events in pp collisions at $\sqrt{s}$= 7 TeV*
  CMS Collaboration (2201 authors)
  J. High Energy Phys., 9, 094 (2012)

- *Performance of CMS muon reconstruction in pp collision events at $\sqrt{s}$ = 7 TeV*
  CMS Collaboration (2278 authors)
  J. Instrum., 7, P10002 (2012)

- *Measurement of the electron charge asymmetry in inclusive W production in pp collisions at $\sqrt{s}$ = 7 TeV*
  CMS Collaboration (2192 authors)
  Phys. Rev. Lett., 109, 111806 (2012)

- *Measurement of jet fragmentation into charged particles in pp and PbPb collisions at $\sqrt{s_{NN}}$= 2.76 TeV*
  CMS Collaboration (2211 authors)
  J. High Energy Phys., 10, 087 (2012)

- *Search for new physics in events with same-sign dileptons and b-tagged jets in pp collisions at $\sqrt{s}$ = 7 TeV*
  CMS Collaboration (2177 authors)
  J. High Energy Phys., 8, 110 (2012)

- *Measurement of the pseudorapidity and centrality dependence of the transverse energy density in PbPb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV*
  CMS Collaboration (2170 authors)
  Phys. Rev. Lett., 109, 152303 (2012)

- *Search for anomalous production of multilepton events in pp collisions at $\sqrt{s}$=7 TeV*
  CMS Collaboration (2209 authors)
  J. High Energy Phys., 6, 169 (2012)

- *Search for leptonic decays of W´ bosons in pp collisions at $\sqrt{s}$=7 TeV*
  CMS Collaboration (2215 authors)
  J. High Energy Phys., 8, UNDEFINED PAGE OR ARTICLE NUMBER (2012)

- *Search for physics beyond the standard model in events with a Z boson, jets, and missing transverse energy in pp collisions at $\sqrt{s}$ = 7 TeV*
  CMS Collaboration (2213 authors)
  Phys. Lett. B, 716, 260 (2012)

- *Shape, transverse size, and charged hadron multiplicity of jets in pp collisions at $\sqrt{s}$ = 7 TeV*
  CMS Collaboration (2261 authors)
  J. High Energy Phys., 6, 160 (2012)

- *Search for anomalous $t\bar{t}$ production in the highly-boosted all-hadronic final state*
  CMS Collaboration (2213 authors)
  J. High Energy Phys., 9, 029 (2012)

- *Measurement of the underlying event in the Drell-Yan process in proton-proton collisions at $\sqrt{s}$ = 7 TeV*
  CMS Collaboration (2275 authors)
  Eur. Phys. J. C, 72, 2080 (2012)

- *Measurement of the top quark pair production cross section in pp collisions at $\sqrt{s}$ = 7 TeV in dilepton final states containing a $\tau$*
  CMS Collaboration (2210 authors)
  Phys. Rev. D, 85, 112007 (2012)

- *Measurement of the cross section for production of b b-bar X, decaying to muons in pp collisions at $\sqrt{s}$=7 TeV.*
  CMS Collaboration (2277 authors)
  J. High Energy Phys., 6, 110 (2012)

- *Search for heavy neutrinos and $W_R$ bosons with right-handed couplings in a left-right symmetric model in pp collisions at 7 TeV*
  CMS collaboration
  Phys. Rev. Lett., 109, 261802 (2012)

- *Inclusive search for squarks and gluinos in pp collisions at sqrts = 7 TeV*
  CMS collaboration
  Phys. Rev. D85 (2012) 012004

- *Forward Energy Flow, Central Charged-Particle Multiplicities, and Pseudorapidity Gaps in W and Z Boson Events from pp Collisions at sqrts = 7 TeV*
  CMS Collaboration (2240 authors)
  Eur. Phys. J. C, 72, 1839 (2012)

- *Measurement of the Rapidity and Transverse Momentum Distributions of Z Bosons in pp Collisions at sqrts=7 TeV*
  CMS Collaboration (2244 authors)

Phys. Rev. D, 85, 032002 (2012)

- *Measurement of the Production Cross Section for Pairs of Isolated Photons in pp collisions at sqrts = 7 TeV*
  CMS Collaboration (2266 authors)
  J. High Energy Phys.01 (2012) 133

- *J/psi and psi(2S) production in pp collisions at sqrts = 7 TeV*
  CMS Collaboration (2248 authors)
  J. High Energy Phys., 2, 011 (2012)

- *Search for Signatures of Extra Dimensions in the Diphoton Mass Spectrum at the Large Hadron Collider*
  CMS Collaboration (2257 authors)
  Phys. Rev. Lett., 108, 111801 (2012)

- *Search for heavy, top-like quark pair production in the dilepton final state in pp collisions at $\sqrt{s}$ = 7 TeV*
  CMS Collaboration (2210 authors)
  Phys. Lett. B, 716, 103 (2012)

- *Search for high mass resonances decaying into $\tau$-lepton pairs in pp collisions at $\sqrt{s}$ = 7 TeV*
  CMS Collaboration (2204 authors)
  Phys. Lett. B, 716, 82 (2012)

- *Measurement of the top-quark mass in $tt^-$ events with lepton+jets final states in pp collisions at $\sqrt{s}$=7 TeV*
  CMS collaboration
  J. High Energy Phys., 12, 105 (2012)

- *Search for three-jet resonances in pp collisions at $\sqrt{s}$ = 7 TeV*
  CMS collaboration
  Phys. Lett. B, 718, 329 (2012)

- *A search for a doubly-charged Higgs boson in pp collisions at $\sqrt{s}$ = 7 TeV*
  CMS collaboration
  Eur. Phys. J. C, 72, 2189 (2012)

- *Search for new physics with long-lived particles decaying to photons and missing energy in pp collisions at $\sqrt{s}$ = 7 TeV*
  CMS collaboration
  J. High Energy Phys., 11, 172 (2012)

- *Ratios of dijet production cross sections as a function of the absolute difference in rapidity between jets in proton-proton collisions at $\sqrt{s}$ = 7 TeV*
  CMS collaboration
  Eur. Phys. J. C, 72, 2216 (2012)

- *Exclusive gamma gamma -> mu(+)mu(-) production in proton-proton collisions at root s=7TeV*
  CMS Collaboration (2248 authors)
  J. High Energy Phys., 1, 052 (2012)

- *Search for a Higgs boson in the decay channel H -> ZZ((*)) -> q(q)over-barl(-)l(+) in pp collisions at root s=7 TeV*
  CMS Collaboration (2273 authors)
  J. High Energy Phys., 4, 036 (2012)

- *Suppression of non-prompt J/psi, prompt J/psi, and Upsilon(1S) in PbPb collisions at root s(NN)=2.76 TeV*
  CMS Collaboration (2255 authors)
  J. High Energy Phys., 5, 063 (2012)

- *Search for heavy bottom-like quarks in 4.9 fb(-1) of pp collisions at root s=7 TeV*
  CMS Collaboration (2209 authors)
  J. High Energy Phys., 5, 123 (2012)

- *Measurement of the mass difference between top and antitop quarks*
  CMS Collaboration (2215 authors)
  J. High Energy Phys., 6, 109 (2012)

- *Measurement of the Z/gamma* plus b-jet cross section in pp collisions at root s=7 TeV*
  CMS Collaboration (2272 authors)
  J. High Energy Phys., 6, 126 (2012)

- *Search for New Physics with Same-Sign Isolated Dilepton Events with Jets and Missing Transverse Energy*
  CMS Collaboration (2211 authors)
  Phys. Rev. Lett., 109, 071803 (2012)

- *Search for a W ´ or Techni-rho Decaying into WZ in pp Collisions at root s=7 TeV*
  CMS Collaboration (2193 authors)
  Phys. Rev. Lett., 109, 141801 (2012)

- *Search for heavy Majorana neutrinos in mu(+/-)mu(+/-) + jets and e(+/-)e(+/-) + jets events in pp collisions at root s=7 TeV*
  CMS Collaboration (2198 authors)
  Phys. Lett. B, 717, 109 (2012)

- *Search for supersymmetry in events with b-quark jets and missing transverse energy in pp collisions at 7 TeV*
  CMS Collaboration (2200 authors)
  Phys. Rev. D, 86, 072010 (2012)

- *Observation of Sequential upsilon Suppression in PbPb Collisions*
  CMS Collaboration (2197 authors)
  Phys. Rev. Lett., 109, 222301 (2012)

- *Combined search for the quarks of a sequential fourth generation*
  CMS Collaboration (2204 authors)
  Phys. Rev. D, 86, 112003 (2012)

- *Search for electroweak production of charginos and neutralinos using leptonic final states in pp collisions at $\sqrt{s}$ = 7 TeV*
  CMS collaboration

J. High Energy Phys., 11, 147 (2012)

- *Study of the Dijet Mass Spectrum in pp -> W + jets Events at root s=7 TeV*
  CMS Collaboration (2211 authors)
  Phys. Rev. Lett., 109, 251801 (2012)

- *Search for exclusive or semi-exclusive gamma gamma production and observation of exclusive and semi-exclusive e(+)e(-) production in pp collisions at root s=7 TeV*
  CMS Collaboration (2194 authors)
  J. High Energy Phys., 11, 080 (2012)

**International Conference Proceedings**

- *A search for H+ and H++ Higgs bosons with the CMS detector*
  Aruna kumar Nayak (for CMS Collaboration)
  PoS(EPS-HEP2011)242, CMS CR-2011/254 (accepted)

- *Top quark mass measurement at the Large Hadron Collider*
  M. Gallinaro
  CMS CR-2012/008: Nuovo Cim. C 035N3, 107 (2012)

- *Measurement of the top quark mass in the dilepton channel in pp collisions at sqrts=7TeV*
  S. Chatrchyan et al. [CMS Collaboration]
  CMS-PAS-TOP-11-016

- *First measurement of B(t->Wb)/B(t->Wq) in the dilepton channel in pp collisions at sqrts=7TeV*
  S. Chatrchyan et al. [CMS Collaboration]
  CMS-PAS-TOP-11-029

- *A search using multivariate techniques for a standard model Higgs boson decaying into two photons*
  CMS Collboration
  CMS-PAS-HIG-12-001

- *Search for the fermiophobic model Higgs boson decaying into two photons*
  CMS Collboration
  CMS-PAS-HIG-12-002

- *Evidence for a new state decaying into two photons in the search for the standard model Higgs boson in pp collisions*
  CMS Collboration
  CMS-PAS-HIG-12-015

- *Observation of a new boson with a mass near 125 GeV*
  CMS Collboration
  CMS-PAS-HIG-12-020

- *Higgs to gamma gamma, Fermiophobic*
  CMS Collboration
  CMS-PAS-HIG-12-022

- *Top quark physics: From a few to a few millions*
  M. Gallinaro
  CMS CR-2012/242; arXiv:1210.0786

- *First measurement of the top quark pair production cross section in the dilepton channel with tau leptons in the final state in pp collisions at sqrts=7TeV*
  S. Chatrchyan et al. [CMS Collaboration]
  CMS-PAS-TOP-11-006

- *Combination of standard model Higgs boson searches and measurements of the properties of the new boson with a mass near 125 GeV*
  CMS Collboration
  CMS-PAS-HIG-12-045

- *Search for a Light Higgs boson in the Z boson plus a Photon Decay Channel*
  CMS Collboration
  CMS-PAS-HIG-12-049

- *Updated search for a light charged Higgs boson in top quark decays in pp collisions at sqrt(s) = 7 TeV*
  S. Chatrchyan et al. [CMS Collaboration]
  CMS-PAS-HIG-12-052

**Collaboration notes with internal referee**

- *Measurement of the ttbar production cross section in the etau; and mutau dilepton channels in pp collisions at sqrts=7TeV*
  N. Almeida , M. Gallinaro , A. Nayak , A. Nikitenko , P. Silva , J. Varela
  CMS AN-2011/421

- *Contribution to the measurement of the b tagging efficiency using the ttbar dilepton channel in proton-proton collisions at sqrts=7TeV*
  P. Silva , A. Alves , P. Vischia , M. Gallinaro , J. Varela
  CMS AN-2011/450

- *Search for a Standard Model Higgs boson decaying into two photons employing multivariate methods*
  CMS Hgg working group
  CMS AN-2012/048

- *Search for the charged Higgs boson in the decays of top quark pairs in pp collisions at sqrts=7TeV*
  N. Almeida , M. Gallinaro , A. Nayak , A. Nikitenko , P. Silva , J. Varela
  CMS AN-2011/422

- *Probing the heavy flavor content of the ttbar dilepton channel in proton-proton collisions at sqrts=7TeV*
  P. Silva , A. Alves , P. Vischia , M. Gallinaro , J. Varela
  CMS AN-2011/394

- *Measurement of the Top quark mass in the dilepton channel using the 2011 proton-proton collisions dataset*
  P. Silva , A. Alves , P. Vischia , M. Gallinaro , J. Varela
  CMS AN-2012/009

- *Update on the measurement of the top quark mass with the KINb method and the full 2011 dataset*
  P. Silva , P. Vischia , M. Gallinaro , J. Varela
  CMS AN-2012/094

- *Search for a Standard Model Higgs boson decaying into two photons in 2012 data*
  CMS Hgg working group
  CMS AN-2012/160

- *A new procedure for the determination of angular distribution parameters in dilepton vector meson decays*
  P. Faccioli, J. Seixas, V. Knuenz
  CMS AN-2011/535

- *Low pT Muon and Dimuon Efficiencies*
  P. Faccioli, Hermine K. Wohri, Ilse Kratschmer, Linlin Zhang, Valentin Knunz, Carlos Lourenco and Giovanni Abbiendi
  CMS AN-2012/088

- *Measurement of the Upsilon(1S), Upsilon(2S) and Upsilon(3S) polarizations in pp collisions at sqrts=7TeV*
  P. Faccioli, V. Knunz, I. Kratschmer, C. Lourenco, J. Seixas, H. Wohri, L. Perrozzi, L. Zhang, W. Adam, C. Fabjan, R. Fruhwirth, H. Rohringer, J. Strauss
  CMS AN-2012/140

- *Updated measurements of the new Higgs-like boson at 125 GeV in the two photon decay channel*
  CMS Hgg working group
  CMS AN-2012/374

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

- *Updated search for the charged Higgs boson in top quark pair decays in pp collisions at sqrts=7TeV*
  M. Gallinaro , F. Nguyen , P. Silva , J. Varela , P.Vischia
  CMS AN-2012/372

### 2.2.7 Presentations

**Oral presentations in international conferences**

- *Overview of CMS Physics Results*
  presented by João Varela
  DISCRETE 2012 - Third Symposium on Prospects in the Physics of Discrete Symmetries — Lisbon.

- *Mass and scalar couplings: EXP side*
  presented by André Tinoco Mendes
  Sixth LHC Higgs Cross Section Workshop — CERN.

- *Top quark physics: From the Tevatron to the LHC*
  presented by Michele Gallinaro
  24th Rencontres de Blois — Blois, France.

- *Experimental Program of the future COMPASS-II experiment at CERN*
  presented by Luis Silva
  20th International IUPAP Conference on Few-Body Problems in Physics — Fukuoka, Japan.

- *Highlights from recent CMS results*
  presented by João Varela
  Workshop on the Standard Model and Beyond — Corfu, Greece.

- *Highlights from recent CMS results*
  presented by Michele Gallinaro
  cHarged 2012: Prospects for Charged Higgs Discovery at Colliders — Uppsala, Sweden.

- *Search for H+-> tau+nu with l+tau(->had) and ll final states in CMS*
  presented by Pietro Vischia
  Charged 2012: Prospects for Charged Higgs Discovery at Colliders — Uppsala, Sweden.

- *Prospects for physics at high luminosity with CMS*
  presented by João Varela
  Hadron Collider Physics Symposium — Kyoto, Japan.

- *Higgs Searches and Property Measurements in CMS*
  presented by André Tinoco Mendes
  7th LHC Higgs Cross Section Workshop — CERN.

- *Top quark physics: From a few to few millions*
  presented by Michele Gallinaro
  Discrete 2012: Third Symposium on Prospects in the Physics of Discrete Symmetries — Lisbon, Portugal.

- *Top quark physics: A tool for discovery*
  presented by Michele Gallinaro
  New Worlds in Particle and Astroparticle Physics — Lisbon, Portugal.

- *Prospects for collider physics at high luminosity*
  presented by João Varela
  New Worlds in Particle and Astroparticle Physics — Lisbon.

**Poster presentations in international conferences**

- *Measurement of the top quark mass in the dilepton channel at CMS*
  presented by Pietro Vischia
  LHCC poster session — CERN.

**Presentations in national conferences**

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

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

- *The CMS experiment at the Large Hadron Collider*
  presented by Michele Gallinaro
  LIP 2012 — Lisbon, Portugal.

- *Qual o estado da partícula Higgs?*
  presented by João Varela
  Jornadas LIP — Lisbon.

- *Search for Higgs boson in two photon decays*
  presented by André Tinoco Mendes
  Jornadas LIP 2012 — Lisboa.

- *Highlights from CMS results*
  presented by Michele Gallinaro
  LIP Jornadas 2012 — Lisbon, Portugal.

- *Introduction to CMS*
  presented by João Varela
  Jornadas LIP — Lisbon.

- *Measurement of the top mass in dilepton channel*
  presented by Pietro Vischia
  Jornadas LIP — Lisboa.

- *Physics with CMS and Portuguese Participation in CMS*
  presented by João Varela
  CERN Portuguese Language Teachers Programme 2012 — CERN.

**Oral presentations in international meetings**

- *CMS Status Report*
  presented by João Varela
  109th LHCC Meeting AGENDA OPEN Session — CERN.

- *Agreeing on first couplings definitions: What EXPs have, what EXPs need*
  presented by André Tinoco Mendes
  Light Mass Higgs meeting 3 — CERN.

- *CMS overview and Higgs results*
  presented by João Varela
  US LHC Users Organization workshop — Fermilab, USA.

- *CMS Overview and Prospects*
  presented by João Varela
  LHC Beam Operation workshop - Evian 2012 — Evian.

- *What is the new boson from the colliders?*
  presented by André Tinoco Mendes
  New Worlds in Particle and Astroparticle Physics — Lisboa.

**Oral presentations in collaboration meetings**

- *Summary of 2010, prospects for 2011, status of hardware/on-call experts*
  presented by André Tinoco Mendes
  ECAL readiness review — CERN.

- *Impact of bunch lenght on H->gg analysis*
  presented by André Tinoco Mendes
  PPD General Meeting — CERN.

- *CMS News*
  presented by João Varela
  CMS Weekly General Meeting: WGM108 — CERN.

- *DoC report*
  presented by André Tinoco Mendes
  ECAL PFG and Offline Working meeting — CERN.

- *Online and trigger readiness*
  presented by André Tinoco Mendes
  ECAL General Meeting — CERN.

- *Measurement of the tau dilepton cross section at 8 TeV*
  presented by Michele Gallinaro
  CMS meeting: Top cross section PAG — CERN, CH.

- *DoC report*
  presented by André Tinoco Mendes
  ECAL PFG and Offline Working meeting — CERN.

- *Moriond Electroweak Conference Summary*
  presented by João Varela
  CMS Weekly General Meeting: WGM101 — CERN.

- *DoC report*
  presented by André Tinoco Mendes
  ECAL PFG and Offline Working meeting — CERN.

- *PU reweighting*
  presented by André Tinoco Mendes
  Higgs Working Meetings — CERN.

- *Vertex*
  presented by André Tinoco Mendes
  Higgs Working Meetings — CERN.

- *Charged Higgs search: Comparison of ATLAS and CMS results*
  presented by Michele Gallinaro
  CMS meeting: Higgs PAG — CERN, CH.

- *Search for ≈t1 pair production in single lepton signature*
  presented by Pedrame Bargassa
  SUSY 3rd Generation meeting — CERN.

- *Update on KINb mass measurement*
  presented by Pietro Vischia
  Top Mass Meeting — CERN.

- *H Properties: fundamental parameters*
  presented by André Tinoco Mendes
  Weekly Higgs Group Meetings — CERN.

- *ECAL status*
  presented by André Tinoco Mendes
  Run organization meeting — CERN.

- *First thoughts on linking CMS running states to LHC states*
  presented by André Tinoco Mendes
  Run organization meeting — CERN.

- *Update on KINb mass measurement*
  presented by Pietro Vischia
  Top Mass Meeting — CERN.

- *CMS News*
  presented by João Varela
  CMS Weekly General Meeting: WGM107 — CERN.

- *Report on charged Higgs analyses*
  presented by Michele Gallinaro
  CMS meeting: Higgs PAG — CERN, CH.

- *Update on KINb mass analysis*
  presented by Pietro Vischia
  Top Mass Meeting — CERN.

- *Search for ≈t1 pair production in single lepton signature*
  presented by Pedrame Bargassa
  SUSY 3rd Generation meeting — CERN.

- *L1 issues for compressed SUSY*
  presented by Pedrame Bargassa
  SUSY studies for upgrade — CERN.

- *H Properties: status of the code*
  presented by André Tinoco Mendes
  Weekly Higgs Group Meetings — CERN.
- *ECAL report including fill 2536*
  presented by André Tinoco Mendes
  Run organization meeting — CERN.
- *AN/PAS requests and requirements*
  presented by André Tinoco Mendes
  Higgs Working Meetings — CERN.
- *SUSY benchmarks*
  presented by Pedrame Bargassa
  L1 Upgrade workshop — CERN.
- *Search for ≈t1 pair production in single lepton signature*
  presented by Pedrame Bargassa
  SUSY 3rd Generation meeting — CERN.
- *Feedback: ECAL*
  presented by André Tinoco Mendes
  Upgrade Week at CERN May 2012 — CERN.
- *Next-to-final Summer12 LHC HXWG recommendation for couplings*
  presented by André Tinoco Mendes
  Weekly Higgs Group Meetings — CERN.
- *CMS News*
  presented by João Varela
  CMS Weekly General Meeting: WGM112 — CERN.
- *Search for ≈t1 pair production in single lepton signature*
  presented by Pedrame Bargassa
  SUSY 3rd Generation meeting — CERN.
- *Search for ≈t1 pair production in single lepton signature*
  presented by Pedrame Bargassa
  SUSY workshop — DESY.
- *HIG-12-015 Top-Up - H(gamma-gamma)*
  presented by André Tinoco Mendes
  CMS WEEK Agenda 25.06.-29.06.2012 — CERN.
- *approval of the combination with top-up statistics*
  presented by André Tinoco Mendes
  Weekly Higgs Group Meetings — CERN.
- *DD background determination for search for ≈t1 pair production in single lepton signature*
  presented by Pedrame Bargassa
  SUSY 3rd Generation meeting — CERN.
- *CMS News*
  presented by João Varela
  CMS Wednesday General Meeting: WGM133 — CERN.
- *CMS News*
  presented by João Varela
  CMS Weekly General Meeting: WGM97 — CERN.
- *Offline DQM L1TSync Status/Roadmap*
  presented by Pietro Vischia
  L1 DQM Meeting — CERN.

- *CMS News*
  presented by João Varela
  CMS Weekly General Meeting: WGM121 — CERN.
- *Update on inclusive ttbar cross section in tau-dilepton channel with 2012 data*
  presented by Pietro Vischia
  Top Cross Sections — CERN.
- *Offline DQM L1TSync status*
  presented by Pietro Vischia
  Weekly Higgs Group Meetings — CERN.
- *Status of light charged Higgs (leptonic)*
  presented by Pietro Vischia
  Weekly Higgs Group Meetings — CERN.
- *Search for ≈t1 pair production in single lepton signature*
  presented by Pedrame Bargassa
  SUSY 3rd Generation meeting — CERN.
- *CMS News*
  presented by João Varela
  CMS Weekly General Meeting: WGM123 — CERN.
- *Report on light charged Higgs (leptonic)*
  presented by Pietro Vischia
  Weekly Higgs Group Meetings — CERN.
- *Offline DQM L1TRate Status*
  presented by Federico Nguyen
  L1 DQM Meeting — CERN/Evo.
- *Search for ≈t1 pair production in single lepton signature*
  presented by Pedrame Bargassa
  SUSY 3rd Generation meeting — CERN.
- *XC summary - Filter farm architecture proposal*
  presented by João Varela
  XEB137: 137th XEB Meeting — CERN.
- *Report from XC discussion on DAQ2*
  presented by João Varela
  XEB139: 139th XEB Meeting — CERN.
- *DQM Status*
  presented by Federico Nguyen
  L1 Trigger Meeting — CERN/Evo.
- *Offline DQM L1TRate Status*
  presented by Federico Nguyen
  L1 DQM Meeting — CERN/Evo.
- *Offline DQM L1TSync Status*
  presented by Pietro Vischia
  L1 DQM Meeting — CERN.
- *Status of HIG-12-052 (light charged Higgs)*
  presented by Pietro Vischia
  Weekly Higgs Group Meetings — CERN.
- *Inclusive cross section in tau+leptons*
  presented by Federico Nguyen
  Top cross sections — CERN/Evo.

- *Pre-approval of HIG-12-052 (light charged Higgs)*
  presented by Pietro Vischia
  Weekly Higgs Group Meetings — CERN.
- *Offline DQM L1TRate Status*
  presented by Federico Nguyen
  L1 DQM Meeting — CERN/Evo.
- *Offline DQM L1TRate Status*
  presented by Federico Nguyen
  L1 DQM Meeting — CERN/Evo.
- *Offline DQM L1TSync Status*
  presented by Pietro Vischia
  L1 DQM Meeting — CERN.
- *Pre-approval of HIG-12-052 (light charged Higgs)*
  presented by Pietro Vischia
  Weekly Higgs Group Meetings — CERN.
- *CMS News*
  presented by João Varela
  CMS Weekly General Meeting: WGM105 — CERN.
- *Offline DQM L1TRate Status*
  presented by Federico Nguyen
  L1 DQM Meeting — CERN/Evo.
- *Offline DQM L1TSync Status*
  presented by Pietro Vischia
  L1 DQM Meeting — CERN.
- *CMS News*
  presented by João Varela
  CMS Weekly General Meeting: WGM117 — CERN.
- *Offline DQM L1TRate Status*
  presented by Federico Nguyen
  L1 DQM Meeting — CERN/Evo.
- *Offline DQM L1TSync Status*
  presented by Pietro Vischia
  L1 DQM Meeting — CERN.
- *Report on the HIG-12-052 preapproval (light charged Higgs)*
  presented by Pietro Vischia
  Weekly Higgs Group Meetings — CERN.
- *Offline DQM L1TRate Status*
  presented by Federico Nguyen
  L1 DQM Meeting — CERN/Evo.
- *Offline DQM L1TRate Status*
  presented by Federico Nguyen
  L1 DQM Meeting — CERN/Evo.
- *Search for ≈t1 pair production in single lepton signature*
  presented by Pedrame Bargassa
  SUSY 3rd Generation meeting — CERN.
- *H2GG: Background Modeling*
  presented by André Tinoco Mendes
  CMS General Weekly Meeting GWM91 — .

- *Update on tau-dileptons*
  presented by Federico Nguyen
  Top cross sections — CERN/Evo.

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

- *Approval of HIG-12-052 (light charged Higgs)*
  presented by Pietro Vischia
  Weekly Higgs Group Meetings — CERN.

- *Update on tau+lepton (TOP-12-026 update)*
  presented by Federico Nguyen
  Top cross sections — CERN/Vidyo.

**Seminars**

- *Top quark physics: Lecture 1*
  presented by Michele Gallinaro
  Course on physics at the LHC — Lisbon, Portugal.

- *Top quark physics: Lecture 2*
  presented by Michele Gallinaro
  Course on physics at the LHC — Lisbon, Portugal.

- *Top quark physics: Lecture 1*
  presented by Michele Gallinaro
  Course on physics at the LHC — Lisbon, Portugal.

- *Top quark physics: From the Tevatron to the LHC*
  presented by Michele Gallinaro
  Colloquium — Roma University.

### 2.2.8 Events

- *CMS Week 2012*
  Collaboration Meeting, LNEC Conference Center, Lisbon, 2012-09-03

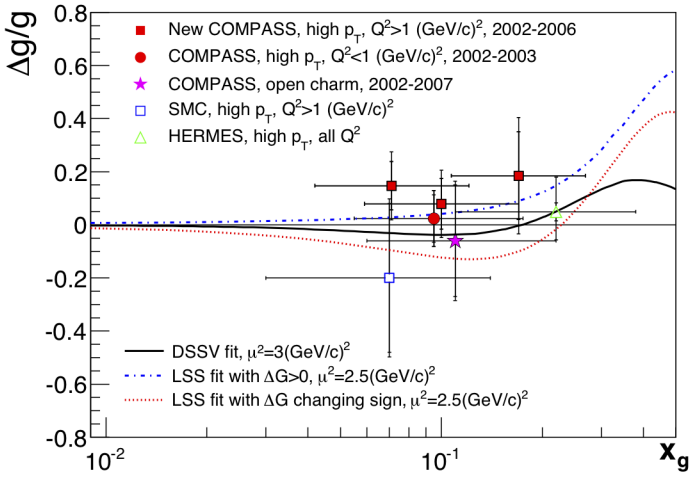
### 2.2.9 Project Summary

| | number |
|---|---|
| Articles in international journals (with direct contribution from LIP members) | 9 |
| Articles in international journals (with indirect contribution from LIP members) | 86 |
| International Conference Proceedings | 14 |
| Collaboration notes with internal referee | 14 |
| Oral presentations in international conferences | 12 |
| Poster presentations in international conferences | 1 |
| Presentations in national conferences | 9 |
| Oral presentations in international meetings | 5 |
| Oral presentations in collaboration meetings | 75 |
| Seminars | 4 |
| Collaboration Meetings | 1 |

## 2.3 Collaboration in the COMPASS experiment at CERN

### 2.3.1 Resumo

A experiência COMPASS dedica-se essencialmente ao estudo da estrutura do nucleão, nomeadamente das contribuições de gluões e quarks para o seu spin total. Na primeira fase, que decorreu até 2011, COMPASS dedicou-se, através da difusão inelástica profunda de muões na matéria, ao estudo da polarização do gluão (usando 2 canais independentes: a produção de charme e a física de elevado p_T ), bem como à medida das funções de estrutura dependentes do spin, nos modos longitudinal e transverso, de modo a separar as suas componentes de sabor. Têm ainda vindo a ser estudadas as funções de fragmentação, através das multiplicidades dos hadrões carregados.
Actualmente, na sua segunda fase, COMPASS dedica-se ao estudo das funções de estrutura dependentes do momento transverso (TMD PDFs), através do processo de Drell-Yan polarizado, bem como das funções de estrutura tridimensionais (GPDs), a tomografia do nucleão, através do processo DVCS (Deep Virtual Compton Scattering). Por outro lado, COMPASS tem por objectivo o estudo de algumas questões de actualidade relativas à espectroscopia hadrónica, como a produção de novos hadrões, bem como de mesões, nomeadamente exóticos ou híbridos. Em 2012 efectuou-se o estudo experimental das polarizabilidades de piões e kaões, usando o processo de Primakoff.
Neste contexto, COMPASS usa feixes de alta intensidade, de muões polarizados (ou de hadrões) interagindo com um alvo polarizado longitudinalmente ou transversalmente (ou um alvo de hidrogénio líquido) ao qual se segue um espectrómetro duplo: a primeira parte tem uma grande aceitância angular, e é seguida a jusante por outra de aceitância reduzida, concebida para a detecção de partículas ultrapassando os 100 GeV/c. Cada espectrómetro é formado por um magnete rodeado por detectores de posição, um conjunto de calorímetros electromagnético e hadrónico, filtros de muões e um detector de Cherenkov do tipo RICH para identificação de partículas.
O sistema de aquisição de dados baseia-se na leitura em paralelo da electrónica de front- end e num sistema distribuído de event-builders, especialmente concebidos para tratar grandes volumes de dados. De facto, o programa de muões com alvo de 6LiD, que decorreu de 2002 a 2007 perfez um total de 1700 TB. E no programa de hadrões, levado a cabo em 2008 e 2009, os dados adquiridos totalizaram 1300 TB. Em 2010 e 2011 decorreram as últimas tomadas de dados com feixe de muões e com alvo de amónia (respectivamente polarizado transversalmente e longitudinalmente), o que permitiu concluir este programa polarizado de Difusão Inelástica Profunda Semi-Inclusiva (SIDIS). Em 2012 a segunda fase do programa de COMPASS iniciou-se com uma tomada de dados com feixe de hadrões para estudo das polarizabilidades do pião e do kaão.
A farm de processamento de dados de COMPASS, devido ao seu grande volume de dados adquiridos (≈5 PB), tem um desempenho do nível requerido em LHC, pelo que a experiência foi usada pelos grupos técnicos de




The gluon polarisation results of the COMPASS collaboration (from high p_T and Open charm analyses) are shown together with the results from SMC and HERMES collaborations. The gluon polarisation curves resulting from global fits to spin asymmetries are also presented. All results show a fair agreement between themselves and with the predicted models.

apoio do CERN em vários domínios relativos à aquisição e ao controlo dos dados como um ambiente de teste em grande escala. Neste contexto, a aposta do grupo do LIP-Lisboa de, ao ingressar em COMPASS em finais de 2002, tomar a total responsabilidade do Sistema de Controlo de Detectores (DCS), revelou-se muito importante para a estratégia de evolução do grupo no plano tecnológico. Daí o notável esforço de recursos humanos que foi necessário.
O objectivo principal do grupo do LIP, na vertente técnica, atingido em anos anteriores, era o desenvolvimento de uma nova arquitectura para o DCS de COMPASS. Mas continuadas evoluções e adaptações têm sido necessárias. Na verdade, o DCS não pode ser um sistema estático ou um produto finalizado pois é constituído por várias camadas de packages cujas versões têm de ser compatíveis entre si, pelo que a alteração de um deles, muitas vezes com aspectos incompatíveis em relação à sua versão precedente, implica em geral a adaptação de todos os outros, o que é uma tarefa muito pesada.
Por outro lado, devido à contínua instalação de novos detectores específicos dos diferentes programas com feixes de muões e hadrões, o software do DCS (bem como o seu hardware de interface) tem vindo a aumentar constantemente o seu grau de complexidade (interfaces de novo tipo, novos drivers), devido à não uniformidade dos detectores e do seu hardware.
Paralelamente, o grupo do LIP tem também levado a cabo um conjunto de tarefas relativas à análise de dados e à extracção dos seus resultados físicos, de grande importância para a Colaboração COMPASS e para o próprio grupo. No que respeita ao offline, desenvolveram-se estudos de geradores físicos e sua simulação no detector, com vista à sua concordância com os dados experimentais. Em relação à análise de dados propriamente dita, foram desenvolvidos estudos nos canais físicos mais importantes do programa de Difusão Inelástica Profunda de COMPASS. Foram, nomeadamente, feitos estudos independentes sobre a polarização do gluão, tanto através do processo de charme aberto (o "Golden Channel"de COMPASS), como através de eventos de grande p_T . Estudaram-se ainda as assimetrias de sabor do mar do nucleão, bem como as multiplicidades dos hadrões.
A partir do início de 2010, o grupo do LIP-Lisboa assumiu um papel de destaque na preparação do próximo Programa experimental de COMPASS, no que concerne aos estudos de transversidade através do processo de Drell-Yan polarizado. Neste contexto, o grupo tem vindo a participar activamente nos estudos de adaptação e optimização do espectrómetro, nomeadamente sobre o absorvedor de hadrões e sobre o trigger de dimuão.

### 2.3.2 Abstract

The COMPASS experiment is dedicated to the study of the structure of the nucleon, namely of the contributions of gluons and quarks to its total spin. In its first phase, which last till 2011, COMPASS was devoted, through the deep inelastic scattering of muons, to the gluon polarization (using 2 independent channels: open charm photoproduction and high p_T physics), as well as to the measurement of spin dependent structure functions, both in the longitudinal and the transverse modes, in order to disentangle their flavour components. The study of fragmentation functions, through the charged hadron multiplicities, has also been addressed.
In the present phase, COMPASS aims to the study of the transverse momentum dependent structure functions (TMD PDFs) through the polarised Drell-Yan process, as well as the three dimensional structure functions (GPDs), the so-called nucleon tomography, through the DVCS process (Deep Virtual Compton Scattering).
On the other hand, COMPASS studies also some important hadron spectroscopy issues, such as the production of new hadrons, as well of mesons, namely exotics or hybrids. In 2012, the experimental measurement of the polarisability of pions and kaons, using the Primakoff process, was addressed.
In this context, COMPASS uses high intensity beams, that is, a polarized muon (or hadron) beam impinging on a longitudinally or transversely polarized target (or a liquid hydrogen target) followed by a two stage spectrometer: a first one with a large angular acceptance, followed downstream by a second one with a reduced acceptance, designed to detect particles up to more than 100 GeV/c. Each spectrometer is equipped with a magnet sorrounded by trackers, a set of electromagnetic and hadronic calorimeters, muon filters and a Cherenkov detector (RICH) for particle identification. The data acquisition system is based on a parallel read-out of the front-end electronics, followed by a distributed set of event-builders, specially designed to cope with huge data volumes. In fact, during the muon program with a 6LiD target, from 2002 to 2007, COMPASS collected a total of 1700 TeraByte of data. And, in the hadron program, from 2008 to 2009, the data taken totalised 1300 TB. The years 2010 and 2011 were dedicated to the two last data takings with a muon beam and an ammonia target, respectively polarised in the transverse and longitudinal modes, allowing to finalise this polarised program of Semi-Inclusive Deep Inelastic Scattering (SIDIS) with muon beams. In 2012 the COMPASS second phase was initiated, with a data taking using a hadron beam, aiming to the study of pion and kaon polarisabilities.
The COMPASS data processing farm, due to the huge data volume to handle, requires a LHC-like performance. That is why the experiment was used as large scale test environment by some CERN support technical groups in several data acquisition and data control domains.
In this context, the full responsibility of the Detector Control System (DCS) taken by the LIP-Lisbon group at

the time of its ingress in COMPASS, in the late 2002, was very important to the evolving strategy of the group on a technological ground. In that view, a big effort in human resources was undertaken. The main technical purpose of our group was the development a new DCS architecture, which has been previously achieved. But a constant evolution of the system is needed. In fact, the COMPASS DCS can not be a static system or a finalised product, because it is formed by a set of several packages, disposed in layers but strongly interacting. This means that the packages versions must be compatible among them. Thus, changing one package version, which may even be not backward compatible with its previous one, may imply the change of all other packages versions. This is a very heavy task.
On the other hand, COMPASS continues its hardware upgrade, namely in what concerns new detectors specific to muon or hadron programs. 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 concerning the data analysis task and the physical results extraction is being performed, with a major contribution of the LIP group in the COMPASS Collaboration. This includes the development of new physics generators and their simulation through the detector, as well as the overall compatibility studies with the experimental data. In what concerns the analysis of the most important physics channels in the COMPASS Deep Inelastic Scattering program, independent studies were performed on the gluon polarisation, from the open charm process (the COMPASS "Golden Channel") and through high p_T events. Also addressed was the study of flavour asymmetries of the nucleon sea, as well as of the hadrons´ multiplicities.
From the begining of 2010 on, our group has taken an important role in the preparation of the next COMPASS experimental physics Program, in what concerns transversity studies through the polarised Drell-Yan process. In that view, our group has actively participated, since then, in the spectrometer upgrade and optimisation studies, namely in the design of the hadron absorber and of the dimuon trigger.

### 2.3.3 Objectives

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

### 2.3.4 Achievements

-

**Detector Control System**

During the preparation of the 2012 run, the DCS proceeded with some internal development tasks, namely the installation and test of new patches for several packages.
Several major interface tasks to include some new or refurbished very important spectrometer components were also performed, namely the monitoring developments of: the new CAMERA (proton recoil) detector, the liquid hydrogen target new PLC system; the ECAL1 electromagnetic calorimeter monitoring (due to the introduction of one more laser and new reference diodes); the low voltages for the W4/5 detector through ELMBs.
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.
It is worth noting that the DCS system works practically 12 months per year. In fact, during the no-beam part of the year, several DCS sub-systems run, in order to control some devices, as it is the case of detectors gas systems. This requires the permanent presence of DCS experts.

**Data Analysis and Offline Studies**

The offline and analysis task has always been a major concern of our group. The analysis subjects carried on by LIP members are among the most important analysis channels of the experiment. As a consequence, our members have presented their results in several International Conferences, on the behalf of COMPASS.
In 2012 the following subjects were addressed:

- Photon-nucleon longitudinal spin asymmetries from high p_T hadron pairs and high Q2 .
- Studies of hadron multiplicities in view of the fragmentation functions measurement.
- Spin asymmetries analysis in the low x_Bj and low Q2 region.
- Development of a new method of asymmetries evaluation concerning the gluon polarisation extraction.
- Studies on the setup optimization for the future polarised Drell-Yan process experiment, namely background studies w.r.t. different absorber configurations, and the dimuon trigger design.
- Optimization of the COMPASS reconstruction program in view of the use of a hadron absorber in the polarised Drell-Yan experiment.
- New analysis of the 2009 Drell-Yan data taking test runs, to experimentally validate the new Monte-Carlo parameterisations.

**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
- Week coordinations of the data taking (Sofia Nunes)
- Stays at CERN for the run preparation.

### 2.3.5 Sources of Funding

| Code | Funding | Start | End |
|---|---|---|---|
| CERN/FP/123600/2011 | 300.000 € | 2012-01-01 | 2013-12-31 |

### 2.3.6 Team

**Project coordinator: Paula Bordalo**

| Name | Status | %of time in project |
|---|---|---|
| Bruno Jorge | Student (LIP) | 25 |
| Catarina Quintans | Researcher (LIP) | 100 |
| Celso Franco | Post-Doc (LIP/FCT) | 50 |
| Christophe Pires | Technician (LIP) | 100 |
| Diogo Coutinho | Master student (LIP/IST) | 17 |
| Gonçalo Terça | Master (LIP/AdI) | 100 |
| Hugo Fonseca | | 100 |
| Luis Silva | Post-Doc (LIP) | 50 |
| Márcia Quaresma | PhD student (LIP/FCT) | 100 |
| Marcin Stolarski | Post-Doc (LIP/FCT) | 100 |
| Paula Bordalo | Researcher (LIP/IST) | 100 |
| Sérgio Ramos | Researcher (LIP/IST) | 100 |
| Sofia Nunes | PhD student (LIP) | 100 |

### 2.3.7 Publications

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

- *Transverse spin effects in hadron-pair production from semi-inclusive deep inelastic scattering*
  P. Bordalo, C. Franco, M. Quaresma, C. Quintans, A.S. Nunes, S. Ramos, M. Stolarski, L. Silva et al.
  Phys. Lett. B 713 (2012) 10

- *Control Systems: an Application to a High Energy Physics Experiment (COMPASS)*
  P. Bordalo, A.S. Nunes, C. Pires, C. Quintans and S. Ramos
  IEEE Catalog Number: CFP12AQT-PRT

- *Exclusive rho0 muoproduction on transversely polarised protons and deuterons*
  P. Bordalo, C. Franco, M. Quaresma, C. Quintans, A.S. Nunes, S. Ramos, M. Stolarski, L. Silva et al.
  Nucl. Phys. B865 (2012) 1

- *Comments on: Measurement of Parton Distributions of Strange Quarks in the Nucleon from Charged-Kaon Production in Deep-Inelastic Scattering on the Deuteron by the HERMES Collaboration*
  M. Stolarski
  arXiv:1208.5427

- *Study of the nucleon spin structure by the Drell-Yan process in the COMPASS-II experiment*
  M. Quaresma, P. Bordalo, C. Quintans, S. Ramos, G. Terça et al., for COMPASS Collaboration
  Acta Physica Polonica B

- *I - Experimental investigation of transverse spin asymmetries in mu-p SIDIS processes: Collins asymmetries*
  P. Bordalo, C. Franco, M. Quaresma, C. Quintans, A.S. Nunes, S. Ramos, M. Stolarski, L. Silva et al.
  Phys. Lett. B, 717, 376 (2012)

- *II - Experimental investigation of transverse spin asymmetries in mu-p SIDIS processes: Sivers asymmetries*
  P. Bordalo, C. Franco, M. Quaresma, C. Quintans, A.S. Nunes, S. Ramos, M. Stolarski, L. Silva et al.
  Phys. Lett. B, 717, 383 (2012)

- *D* and D Meson Production in Muon-Nucleon Interactions at 160 GeV/c*
  P. Bordalo, C. Franco, M. Quaresma, C. Quintans, A.S. Nunes, S. Ramos, M. Stolarski, L. Silva et al.
  Euro. Phys. J. C (2012) 72-2253.

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

- *First Measurement of Chiral Dynamics in pi-gamma->pi-pi-pi+*
  P. Bordalo, C. Franco, C. Quintans, A.S. Nunes, S. Ramos, M. Stolarski, L. Silva et al.
  Phys. Rev. Lett. 108 (2012) 192001

**International Conference Proceedings**

- *New COMPASS Results on Polarised Parton Distributions inside Nucleon*
  M. Stolarski et al., for COMPASS Collaboration
  Proceedings of DIS2012 Conference

- *DeltaG/G results from the Open-Charm production at COMPASS*
  C. Franco et al., for COMPASS Collaboration

Proceedings of Charm2012 Conference

- *Latest results on longitudinal spin physics at COMPASS*
  C. Franco et al., for COMPASS Collaboration
  Proceedings of CIPANP2012 Conference

- *COMPASS measurements of the longitudinal spin structure of the nucleon*
  M. Stolarski et al., for COMPASS Collaboration
  Proceedings of QCD-N´12 Conference

- *Polarised Drell-Yan measurements at COMPASS-II*
  M. Quaresma et al., for COMPASS Collaboration
  Proceedings of SPIN2012 Conference

- *Gluon polarization measurements at COMPASS*
  Luis Silva (for the COMPASS Collaboration)
  Phys. Scr., T150, 014037 (2012)

### 2.3.8 Presentations

**Oral presentations in international conferences**

- *New COMPASS Results on Polarized Parton Distributions Inside the Nucleon*
  presented by Marcin Stolarski
  XX International Workshop on Deep-Inelastic Scattering and Related Subjects — Bonn, Germany.

- *The Drell-Yan program at COMPASS*
  presented by Catarina Quintans
  XII International Workshop on Hadron Structure and Spectroscopy — Lisbon, Portugal.

- *Longitudinal spin structure of the nucleon: present and future*
  presented by Marcin Stolarski
  XII International Workshop on Hadron Structure and Spectroscopy — Lisbon, Portugal.

- *Study of nucleon spin structure by the Drell-Yan process in the COMPASS experiment*
  presented by Márcia Quaresma
  Excited QCD 2012 — Peniche, Portugal.

- *Delta G production from open charm results at COMPASS*
  presented by Celso Franco
  5th International Workshop On Charm Physics — Honolulu, USA.

- *Transverse spin physics from the Drell-Yan process in COMPASS*
  presented by Catarina Quintans
  ECT Workshop on Drell-Yan Scattering and the Structure of Hadrons — Trento, Italy.

- *Control Systems: an Application to a High Energy Physics Experiment (COMPASS)*
  presented by Sofia Nunes
  AQTR2912 - 2012 IEEE International Conference on Automation, Quality and Testing, Robotics — Cluj-Napoca, Romania.

- *Latest results on longitudinal spin physics at COMPASS*
  presented by Celso Franco
  11th Conference On The Intersections Of Particle And Nuclear Physics — St. Petersburg, Florida, USA.

- *Polarised Drell-Yan measurements at COMPASS-II*
  presented by Márcia Quaresma
  20th INTERNATIONAL SYMPOSIUM onSpin Physics (SPIN2012) — Dubna, Russia.

- *COMPASS measurements of the longitudinal spin structure of the nucleon*
  presented by Marcin Stolarski
  3rd Workshop on the QCD Structure of the Nucleon (QCD-N´12) — Bilbao, Spain.

**Oral presentations in collaboration meetings**

- *DY in AnDY versus COMPASS*
  presented by Catarina Quintans
  — CERN.

### 2.3.9 Academic Training

**PhD Theses**

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

**Master Theses**

- *AdI TECHNICAL TRAINING: Development of tools for the COMPASS DCS*
  Gonçalo Terça, (on-going)

**Graduation Theses**

- *Ellaboration d´un kit de mesure*
  Bruno Jorge, 2012-04-20

### 2.3.10 Events

- *IWHSS12 - International Workshop on Hadron Structure and Spectroscopy*
  Workshop, Lisbon, Portugal, 2012-04-16
- *COMPASS Collaboration Meeting*
  Collaboration Meeting, Gulbenkian, Lisboa, 2012-04-19

### 2.3.11 Project Summary

| | number |
|---|---|
| Articles in international journals (with direct contribution from LIP members) | 8 |
| Articles in international journals (with indirect contribution from LIP members) | 1 |
| International Conference Proceedings | 6 |
| Oral presentations in international conferences | 10 |
| Oral presentations in collaboration meetings | 1 |
| Graduation Theses | 1 |
| Workshops | 1 |
| Collaboration Meetings | 1 |

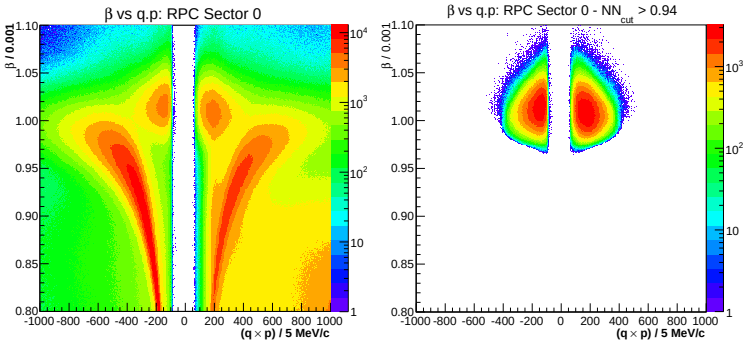
## 2.4 Collaboration in the HADES experiment at GSI

### 2.4.1 Resumo

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

### 2.4.2 Abstract

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




Velocity distribution as a function of the momentum times polarity, for all reconstructed tracks in the acceptance of the RPC detector, before and after a multidimensional cut provided by the Neural Network. The selection of relativistic leptons is evident.

and excellent performance. LIP participates now in the analysis of the physics data thus produced.

### 2.4.3 Objectives

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

### 2.4.4 Achievements

#### HADES RPC TOF WALL

During February 2012 the RPC was prepared before the physics production run. This included the replacement of malfunctioning electronics and some gas leaks have been again remediated as possible.
The highlight of the year was the first, but very successful, heavy-ion production run, which took place in April-May 2012 during 5 weeks, with a beam of Au-Au@1.25GeV/a. The RPC detector performed flawlessly. The LIP team participated actively in the shifts during the whole period, both as a shift expert for the RPC and also as DAQ operator and shift leader.
Calibration procedures have been optimized and improved substantially leading the system performance of the RPC to the levels of its intrinsic performance, namely: system time resolution of 85 ps together with efficiency above 93% for minimum ionizing particles.
Some important modifications and code improvements have been addressed on the GEANT simulation of the RPC. A new digitizer code has been implemented for collisions of Au-Au@1.25GeV/a. These tools will acquire importance from now on due their importance in the analysis of the acquired data.

#### PARTICIPATION IN THE PHYSICS PROGRAM

The LIP-HADES group started the development of a method to select electrons from the very dense hadronic medium produced by Au+Au collisions at 1.25 AGeV. The method makes use of a dynamic neural network to distinguish the leptons from the huge cocktail of long-lived hadrons. In addition, the impact of the new RPC detectors in the analysis is being studied by selecting a sample of Kaons. The RPC detector shows a very good time resolution, enough to distinguish the K-resonance from the background.

#### FUNDING

The participation in HADES is formalized via a Memorandum of Understanding (MOU) celebrated between the Collaboration, GSI and FCT. The MOU expired in 2012 and a proposal for its extension has been submitted to FCT.
Funding of 91.742€ for these activities was granted by the project PTDC/FIS/113339/2009 which will extend up to January 2014.

### 2.4.5 Sources of Funding

| Code | Funding | Start | End |
|---|---|---|---|
| PTDC/FIS/113339/2009 | 91.742 € | 2011-04-01 | 2014-01-31 |

### 2.4.6 Team

**Project coordinator: Paulo Fonte**

| Name | Status | %of time in project |
|---|---|---|
| Alberto Blanco | Researcher (LIP) * | 15 |
| Alessio Mangiarotti | Researcher (LIP) | 50 |
| Celso Franco | Post-Doc (LIP/FCT) | 50 |
| Luís Lopes | Technician (LIP) | 50 |
| Luis Silva | Post-Doc (LIP) | 50 |
| Paulo Fonte | Researcher (LIP/ISEC) | 35 |
| Ricardo Caeiro | Technician (LIP) | 15 |

### 2.4.7 Publications

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

- *The slow control system of the HADES RPC wall*
  A. Gil, A. Blanco, E. Castro, J. Díaz, J.A. Garzón, D. Gonzalez-Diaz, L. Fouedjio, B.W. Kolb, M. Palka, M. Traxler, R. Trebacz, P. Zumbruch
  Nucl. Instrum. and Meth. in Phys. Res. A 661 supp.1 (2012) S118-S120

- *RPC HADES-TOF wall cosmic ray test performance*
  A. Blanco, D. Belver, P. Cabanelas, J. Díaz, P. Fonte, J.A. Garzon, A. Gil, D. Gonzalez-Díaz, W. Koenig, B. Kolb, L. Lopes, M. Palka, A. Pereira, M. Traxler and P. Zumbruch
  Nucl. Instrum. Methods Phys. Res. Sect. A-Accel. Spectrom. Dect. Assoc. Equip., 661, S114 (2012)

- *Analysis of the space-time microstructure of cosmic ray air showers using the HADES RPC TOF wall*
  D. Belver, A. Blanco, P. Cabanelas, J. Diaz, P. Fonte, J. A. Garzon, A. Gil, D. Gonzalez-Diaz, W. Koenig, B. Kolb, G. Kornakov, L. Lopes, M. Palka, A. Pereira, M. Traxler, P. Zumbruch
  J. Instrum., 7, P10007 (2012)

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

- *Production of Sigma(+/-)pi(-/+)pK(+) in p plus p reactions at 3.5 GeV beam energy*
  The HADES collaboration
  Nucl. Phys. A 881 (2012) 178

- *The HADES-at-FAIR project*
  K.Lapidus and the HADES collaboration
  Physics of Atomic Nuclei 75 (2012) 589

- *Inclusive dielectron spectra in p plus p collisions at 3.5 GeV kinetic beam energy*
  The HADES collaboration
  Eur. Phys. J. A 48 (2012) 64

- *Baryonic resonances close to the (K)over-bar N threshold: The case of Sigma(1385)(+) in pp collisions*
  The HADES collaboration
  Phys. Rev. C 85 (2012) 035203

- *First measurement of proton-induced low-momentum dielectron radiation off cold nuclear matter*
  HADES Collaboration (99 authors)
  Phys. Lett. B, 715, 304 (2012)

### 2.4.8 Presentations

**Oral presentations in international conferences**

- *Performance of the HADES-TOF RPC wall in a Au-Au beam*
  presented by Alberto Blanco
  XI Workshop on Resistive Plate Chambers and Related Detectors — INFN - Laboratori Nazionali di Frascati, Frascati, Italy, .

**Oral presentations in collaboration meetings**

- *RPC detector*
  presented by Alberto Blanco
  HADES Collaboration Meeting XXIV, 14-17 May 2012 — Krakow, Poland.

- *Identification of leptons in Au+Au data using a Neural Network*
  presented by Celso Franco
  XXV HADES Collaboration Meeting — GSI, Darmstadt, Germany, 19-23 November 2012.

### 2.4.9 Project Summary

| | number |
|---|---|
| Articles in international journals (with direct contribution from LIP members) | 3 |
| Articles in international journals (with indirect contribution from LIP members) | 5 |
| Oral presentations in international conferences | 1 |
| Oral presentations in collaboration meetings | 2 |

## 2.5 Phenomenological Studies at the LHC

### 2.5.1 Resumo

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

### 2.5.2 Abstract

In order to address the physics potential of the LHC program, a significant joint effort of the experimental and theoretical particle physics community is required. This effort must consider not only the study of the best physical observables to perform a precise test of the Standard Model (SM) of Elementary Particle Physics at LHC, but also to develop new ideas for physics beyond the SM. Several tasks were proposed in the present project to implement a strong collaboration between experimental and theoretical particle physicists. The status of such tasks is summarized in what follows.
Top Quark FCNC Processes: The main goal 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 a new generator (MeTop), that includes NLO corrections to FCNC processes, was developed (it can be interfaced with Pythia or Herwig for hadronization). A collaboration with the Goettingen University allows to perform systematic tests of the generator, by comparing with real data.
Non-Standard Higgs Production: The main goal of this task was to understand, for a chosen set of luminosities of data taken at the LHC, which models could be tested and for which regions of the parameter space.
Current status of the present task: detailed studies on the production of the Higgs bosons at the LHC were performed already. These involved the study of charged Higgs boson production in single top mode at the LHC, the development of the ScannerS code (which allows to constrain the parameter phase space for the Higgs sector)

and the interpretation of the newly discovered Higgs like two-photon mass distribution. Several publications were performed.
Top Quark Couplings :The LHC will is a top quark factory. 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 ($\rho$R and $\rho$L) were introduced and tested at the LHC. The program, TopFit was used to perform a global fit of all relevant observables (taking into account the correlations between them) in order to set the most stringent limits to the anomalous couplings. The ttbar and single top physics were combined to get a global fit from both channels at the LHC.
Tri-leptons and the seesaw mechanism, New physics in models of strong EWSB and, Theoretical Models and Monte Carlo Generators: One of the fundamental tasks of this project is the development of theoretical models which allow a better comprehension of the SM and physics beyond the SM. The search for new physics in tri-lepton final state topologies were studied at the LHC to probe the seesaw mechanism and neutrino mass generation mechanism as well as the production of new vector resonances in models of strong EWSB.
Current status of the present tasks: although several models have already been developed (see tasks 1 and 2 of the project) associated either to the single top quark production via FCNC or with the top quark decays (and the study of the Wtb vertex), these tasks are still in development.

### 2.5.3 Objectives

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

### 2.5.4 Achievements

- A better knowledge of the top quark physics was observed at the end of this project. The SM and FCNC couplings of the top quark were better understood as well as the general structure of the Wtb vertex including possible extensions to the SM. New upgrades of already developed software tools (like TopFit) were made available to the community. These tools allow a global fit to several observables in order, for example, to extract the sensitivity of the LHC to new top quark anomalous couplings.
- Dedicated Monte Carlo generators (like PROTOS and MeTop with FCNC couplings at NLO) were developed and made available to the scientific community.
- The training of undergraduate and graduate students was also an important priority and achievement of the project. The non standard Higgs boson production within several extensions of the Standard Model were explored at the LHC, as well as the seesaw mechanism and the models associated to strong eletroweak symmetry breaking.
- This activity was extended to the University of Minho, in the Northern part of Portugal, where several members of the team are already working since February 2010. A team of 5 senior PhD researchers, 2 PhD student and 5 Master students is already established at the newly created branch of LIP in the University of Minho (LIP-Minho).
- Several papers were published by the team who also presented the work done at Conferences and Workshops

### 2.5.5 Sources of Funding

| Code | Funding | Start | End |
|---|---|---|---|
| CERN/FP/116397/2010 | 32.000 € | 2011-01-01 | 2012-02-15 |
| CERN/FP/123619/2011 | 70.000 € | 2012-03-01 | 2014-02-28 |

### 2.5.6 Team

**Project coordinator: António Onofre**

| Name | Status | %of time in project |
|---|---|---|
| António Onofre | Researcher (LIP/UMinho) | 50 |
| Augusto Barroso | Researcher (FCUL) | 16 |
| Francisco del Aguila Giménez | Researcher (UGR) | 20 |
| Henrique Carvalho | Student (LIP) | 84 |
| João Alves | Master student (LIP/UMinho) | 84 |
| João Carvalho | Researcher (FCTUC) | 35 |
| José Santiago Perez | Researcher (LIP/UGR) | 20 |
| Juan Aguilar-Saavedra | Researcher (LIP/UGR) | 40 |
| Juan Espinosa | Master (LIP) | 3 |
| Marco Oliveira Pena Sampaio | Post-Doc (LIP/UA) | 15 |
| Miguel Fiolhais | PhD student (LIP/FCT) | 100 |
| Miguel Won | PhD student (LIP/FCT) | 50 |
| Mikael Chala | Master student | 20 |
| Nuno Castro | Post-Doc (LIP/FCT) | 60 |
| Nuno Rodrigues | Graduate student (LIP/UMinho) | 13 |
| Paulo Gonçalves | Graduate student (LIP/UMinho) | 13 |
| Pedro Martins Ferreira | Researcher (LIP/FCUL) | 15 |
| Renato Guedes Júnior | Researcher (LIP/FCUL) | 13 |
| Rita Monteiro | Post-Doc (LIP) | 100 |
| Roberto Pittau | Researcher (UGR) | 20 |
| Rui Santos | Researcher (LIP/FCUL) | 16 |

### 2.5.7 Publications

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

- *Could the LHC two-photon signal correspond to the heavier scalar in two-Higgs-doublet models?*
  P.M. Ferreira, Rui Santos, Marc Sher, Joao P. Silva
  Phys.Rev.D85:035020,2012

- *Probing the scalar-pseudoscalar mixing in the 125 GeV Higgs particle with current data*
  A. Barroso (Lisbon, CFTP), P.M. Ferreira, Rui Santos (Lisbon, ISEL & Lisbon, CFTP), Joao P. Silva (Lisbon, ISEL & Lisbon, IST)
  Phys.Rev. D86 (2012) 015022, arXiv:1205.4247 [hep-ph]

- *Charged Higgs bosons in single top production at the LHC*
  Renato Guedes (Lisbon U., CFTC), Stefano Moretti (Southampton U.), Rui Santos (Lisbon, ISEL & Lisbon U., CFTC)
  JHEP 1210 (2012) 119, SHEP-12-02, arXiv:1207.4071 [hep-ph]

- *Mass-degenerate Higgs bosons at 125 GeV in the Two-Higgs-Doublet Model*
  P.M. Ferreira, Howard E. Haber, Rui Santos, Joao P. Silva.
  PhysRevD.87.055009, arXiv:1211.3131 [hep-ph]

- *Meissner effect, diamagnetism, and classical physics-a review*
  Hanno Essen, Miguel C. N. Fiolhais
  Am. J. Phys., 80, 164 (2012)

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

- *Four tops and the t tbar forward-backward asymmetry*
  Four tops and the t tbar forward-backward asymmetry

Phys.Rev.D85:034021,2012

### 2.5.8 Academic Training

**PhD Theses**

- *Non-standard Higgs and top-quark production and decay at the Large Hadron Collider: a collaboration between theory and experiment*
  Miguel Won, (on-going)
- *Study of the Wtb vertex structure in top quark decays*
  Miguel Fiolhais, 2013-03-07

### 2.5.9 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 |

# Chapter 3

# Computing

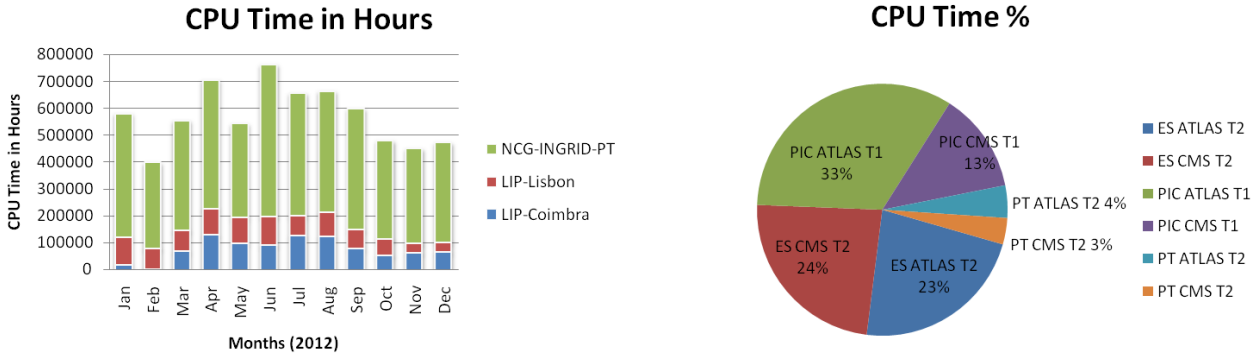
## 3.1 Grid Computing

### 3.1.1 Resumo

As atividades do grupo de computação do LIP centram-se na investigação, desenvolvimento e operação de sistemas distribuídos para ciência computacionalmente intensa. Estas atividades tiveram origem na participação do LIP no *Large Hadron Collider* (LHC) cujas experiências possuem requisitos de processamento e armazenamento massivos. A participação nas experiências ATLAS e CMS levou à criação em Portugal de um Tier-2 federado integrado no *Worldwide LHC Computing Grid* (WLCG).
O grupo de computação do LIP participa desde 2001 em projetos e iniciativas nacionais e internacionais para computação científica. No âmbito da Iniciativa Nacional Grid o LIP coordena uma infraestrutura de computação grid de âmbito nacional integrada na *Iniciativa Ibérica de computação Grid* (IBERGRID) e no *European Grid Initiative* (EGI).

#### Atividades em 2012

**Worldwide LHC Computing Grid (WLCG)**
O Tier-2 cumpriu o *pledge* acordado com o CERN no âmbito do WLCG. A fiabilidade média dos três centros que constituem o Tier-2 foi de 95% muito acima do valor de 80% imposto pelo WLCG. Este é um excelente resultado dada a complexidade dos serviços grid, e dos fatores externos dos quais o Tier-2 atualmente depende. Dado que muitos dos componentes críticos do Tier-2 se encontram sem plano de suporte, e em risco de falha, procedeu-se à elaboração de um projeto, que foi submetido à FCT para a melhoria e otimização dos sistemas de armazenamento do Tier-2, assim como para suportar alguns dos custos operacionais associados.
Com a partida do Miguel Oliveira no verão de 2012, o nó grid de Coimbra passou a ser gerido remotamente a partir de Lisboa. Embora a gestão remota represente um esforço adicional permitiu também uma maior consolidação do Tier-2 que é agora gerido centralmente.




Portuguese Tier-2 CPU time

O inicio de 2013 ficou marcado pela partida do Mário David, que decidiu aceitou novos desafios no estrangeiro. O Mário David foi um elemento chave no Tier-2 e na participação em diversos projetos e iniciativas no domínio da computação grid. A sua saída constitui uma enorme perda.
Iniciou-se a desativação da componente do Tier-2 alojada no LIP-Lisboa com objetivo de reduzir custos. Esta operação inclui uma redução da capacidade do Tier-2 de 15%, negociada entre o LIP, o CERN e os representantes locais das experiências do LHC.

**Iniciativa Nacional Grid**
O LIP gere a infraestrutura de computação da Iniciativa Nacional Grid. Neste contexto coordenou os centros de recursos grid na Universidade do Porto, Universidade do Minho, LIP-Coimbra, LIP-Lisboa, Instituto Superior Técnico (CFP) e Universidade de Aveiro (IEETA) e ainda do Nó Central Grid (NCG). No seu total a infraestrutura forneceu cerca de 10 milhões de horas de processamento, das quais cerca de 3 milhões foram consumidas por comunidades não relacionadas com o LHC. Para além das experiências do LHC, os meios da iniciativa nacional grid estão também a suportar outras experiências de interesse para o LIP como AUGER e SNO+.
O NCG é uma componente fulcral desta infraestrutura. Foi estabelecido numa parceria entre o LIP, o Laboratório Nacional de Engenharia Civil (LNEC), e a Fundação para a Computação Cientifica Nacional (FCCN). Os meios de computação do NCG são geridos pelo LIP, que também presta suporte aos investigadores nacionais e internacionais que usam estes serviços. O NCG aloja os serviços nacionais que permitem a integração dos centros de recursos distribuídos, e disponibiliza capacidade de processamento à comunidade cientifica nacional. Em 2012 a ocupação média da sua capacidade situou-se acima dos 90%.
O NCG fornece serviços de processamento de alto rendimento, processamento paralelo sobre Infiniband e GbE, e armazenamento de alto desempenho. Estes serviços têm uma procura e ocupação elevadas por parte de investigadores nacionais. O cluster de processamento paralelo do LNEC encontra-se integrado no NCG com o qual partilha recursos, a sua gestão é igualmente assegurada pelo LIP.
No âmbito da Iniciativa Nacional Grid, o LIP opera a autoridade de certificação LIPCA que emite credenciais de autenticação para utilizadores e serviços grid em Portugal. A LIPCA está acreditada pelo IGTF e EUgridPMA, e encontra-se registada no Terena TACAR. O LIP participa ativamente no EUgridPMA.

**Iniciativa Grid Ibérica**
A iniciativa Ibérica grid (IBERGRID) integra as infraestruturas de computação grid de Espanha e Portugal. O IBERGRID é também uma plataforma para a participação comum de Portugal e Espanha no European Grid Initiative, permitindo a partilha de serviços e tarefas entre os dois países.
O grupo de computação do LIP coordena a participação nacional no IBERGRID, opera parte dos serviços centrais Ibéricos, dá suporte aos utilizadores e centros de recursos Ibéricos, e realiza tarefas de operação e monitorização de toda a infraestrutura. O LIP participou ainda no desenvolvimento dos serviços de computação em nuvem que deverão entrar em funcionamento em 2013.
Entre 7 e 9 de Novembro de 2012, o LIP organizou em Lisboa a sexta conferência da infraestrutura Ibérica de computação grid (IBERGRID 2012) que teve lugar no pavilhão do conhecimento Ciência Viva em Lisboa. O encontro contou com a participação de especialistas e representantes dos centros de computação grid Ibéricos.

**Iniciativa Europeia Grid**
A infraestrutura grid nacional encontra-se integrada no *European Grid Initiative* (EGI). Esta integração realiza-se tecnicamente através da infraestrutura IBERGRID que em termos operacionais funciona como uma única infraestrutura regional federada no EGI. Para além dos serviços que asseguram o bom funcionamento da infraestrutura, suporte aos utilizadores, e interligação com o EGI, o LIP é responsável por diversas tarefas e serviços de âmbito global:

- coordenação do teste e entrada em produção de novas versões de middleware
- definição de critérios de validação e aceitação do middleware
- operação e desenvolvimento do portal de gestão de relações e contactos do EGI
- gestão de incidentes de segurança e vulnerabilidades

Parte das atividades desenvolvidas no âmbito do EGI são suportadas pelo projeto EGI-Inspire. A participação no EGI é essencial para a integração de Portugal na grid internacional e para a integração do Tier-2 no WLCG. O LIP participou ativamente no EGI council e *EGI-Inspire Project Management Board*. Já no inicio de 2013 o coordenador do grupo de computação Jorge Gomes foi eleito para o *Executive Board* do EGI.eu a fundação de direito Holandês baseada em Amesterdão que gere o *European Grid Initiative*.

**Timbus**
O LIP finalizou a sua participação no projeto Timbus. A saída de elementos chave da equipa em Lisboa e Coimbra, aliada à difícil execução do financiamento comunitário levou a uma reestruturação dos esforços, e à concentração nas atividades consideradas fundamentais.

**Serviços de Computação do LIP**
Para além da gestão regular dos serviços de informática e redes do LIP, foram introduzidos diversos melhoramentos. Entrou em funcionamento um novo serviço de helpdesk gerido através de um sistema de trouble tickets conforme as melhores práticas ITIL. Consolidação do sistema de virtualização baseado em tecnologia KVM. Desenvolvimento de um novo sistema de autenticação para o LIP baseado em tecnologia LDAP e que se encontra em fase de testes. Também foram introduzidas novas aplicações web e melhoramentos nas páginas do LIP.

### 3.1.2 Abstract

The LIP computing group activities are centred in research, development and operation of distributed computing systems for scientific research. These activities were originated by the LIP participation in the Large Hadron Collider (LHC), whose experiments have massive processing and storage requirements. The participation in the ATLAS and CMS experiments triggered the deployment of a federated Tier-2 facility in Portugal integrated in the *Worldwide LHC Computing Grid* (WLCG).
Since 2001 the LIP computing group has been participating in national and international projects and initiatives in the field of grid computing. LIP is coordinating a national grid computing infrastructure integrated in the *Iberian Grid Initiative* (IBERGRID) and in the *European Grid Initiative* (EGI).

**Activities in 2012**

**Worldwide LHC Computing Grid**
In 2012 the Tier-2 has fulfilled the pledge capacity agreed with CERN. The average reliability of the three centres that constitute the Tier-2 was 95%, clearly above the 80% limit imposed by WLCG. This is an excellent result taking into account the complexity and external factors from which the Tier-2 depends.
Since many of the critical components of the Tier-2 are now reaching their end of life, LIP has submitted a project to FCT aimed to replace the Tier-2 storage system and cover partially its operational costs.
Since the summer of 2012, the management of the Coimbra Tier-2 component is being performed remotely from Lisbon due to the departure of the local system responsible Miguel Oliveira.
In the beginning of 2013, Mario David, a key element in the Tier-2 and in many grid projects and initiatives, has also left to embrace new challenges. His exit is a major loss for the computing group.
The decommissioning of the LIP-Lisbon Tier-2 has been planned and initiated in an attempt to minimize operational costs. This operation will also include a 15% downsize of the Tier-2, which has been negotiated with CERN and the LHC experiment representatives at LIP.

**National Grid Initiative**
LIP manages the grid infrastructure of the Portuguese National Grid Initiative. In this context it coordinated grid resource centres at University of Porto, University of Minho, LIP-Coimbra, LIP-Lisbon, Instituto Superior Técnico (CFP), University of Aveiro (IEETA) and also the *Central Grid Node* (NCG). Overall the infrastructure provided about 10 million processing hours, of which 3 million were consumed by user communities unrelated with the LHC experiments. Besides the LHC experiments, the Portuguese grid also supports other experiments important to LIP such as AUGER and SNO+.
NCG is a key component of the infrastructure. It was created by LIP, the National Civil Engineering Laboratory (LNEC) and the National Foundation for Scientific Computing (FCCN) in consortium. The NCG computing services are managed by LIP, that also provides user support to the national and international researchers. NCG is hosting the national services that enable the seamless interconnection of the distributed grid resource centres in the country. NCG also provides processing capacity to the scientific community. In 2012 the average occupation of NCG was above 90%.
NCG provides High Throughput Computing services, High Performance Computing services with both Infiniband an GbE interconnects, and high performance storage. These services have high occupancy and demand by Portuguese researchers. The LNEC own processing cluster is integrated in NCG, it shares capacity with the NCG cluster and also managed by LIP.

In the context of the National grid Initiative, LIP operates a grid certification authority (LIPCA) that issues authentication credentials to Portuguese grid users and services. The LIPCA is accredited by IGTF and EUgridPMA, and is registered at the Terena TACAR repository. LIP is an active member of EUgridPMA.

**Iberian Grid Initiative**
The Iberian Grid Initiative (IBERGRID) joins the Portuguese and Spanish grid infrastructures under a single federated grid. Through IBERGRID both countries participate in the *European Grid Initiative*, sharing resources, services and responsibilities.
The LIP computing group coordinates the national participation in IBERGRID. The group operates Iberian central grid services, provides support to Iberian users and resource centres, and performs operation and monitoring of the whole infrastructure. In this context LIP is participating in the development of cloud computing services that will become operational in 2013.
Between 7 and 9 of November, LIP organized the sixth Iberian grid Infrastructure Conference (IBERGRID 2012). The event took place at *Pavilhão do Conhecimento / Ciência Viva* in Lisbon and joined experts and representatives from the Iberian grid computing centres.

**European grid Initiative**
The Portuguese grid is integrated in the *European grid Initiative* (EGI). This integration is technically achieved through IBERGRID which acts as a federated regional infrastructure in EGI. The LIP computing group provides several services that are essential for the integration and interface with EGI. Besides these LIP is also responsible for several EGI global tasks and services:

- middleware rollout coordination
- middleware criteria definition and validation
- relations management portal
- incident and vulnerability management

These activities are partially funded by the EGI-Inspire project. The participation in EGI is essential for the integration of the Portuguese infrastructure in the global grid and is also critical for the integration of the Tier-2 in WLCG.
LIP is active in the *EGI council* and *EGI-Inspire Project management Board*. In the beginning of 2013 the LIP computing group coordinator (Jorge Gomes) has been elected by the EGI council to the *Executive Board* of EGI.eu, the Dutch foundation based in Amsterdam that manages the *European Grid Initiative*.

**Timbus**
LIP has finished its participation in the Timbus digital preservation project. The departure of key staff members in Lisbon and Coimbra allied to a difficult execution of EC funds, have imposed a restructure of efforts around the most critical tasks and projects.

**LIP Computing Services**
Besides the regular management of the IT services, many enhancements and changes have been introduced among them: based on ITIL best practices a new trouble ticket based helpdesk was introduced, consolidation of the virtualization environment now based on KVM, development of a new authentication system based on LDAP which is being tested. New web applications and many web site improvements have been introduced.

### 3.1.3 Objectives

- Operate the Portuguese Tier-2 respecting the WLCG MoU pledges and service level agreements.
- Manage the Portuguese NGI e-infrastructure, including coordinating sites, operating critical core services and providing computing services.
- Pursue the IBERGRID collaboration and further consolidated the sharing of computing capacity and operations tasks.
- Participate in the development and deployment of an IBERGRID cloud service.
- Participate in the European Grid Initiative ensuring the integration of IBERGRID resources and providing key global services.

- Raised the awareness about the importance of digital preservation and engage with users towards pilot activities.
- Enhance the efficiency of the IT services through improved processes and practices.

### 3.1.4 Achievements

- In-spite of the difficulties and cuts the Portuguese Tier-2 was still capable of fulfilling the WLCG pledge and even exceeding it.
- The three Tier-2 sites achieved an average reliability of 95%.
- The LIP is fulfilling major responsibilities in the provisioning of global services to the EGI community.
- The Iberian grid is growing in usage and capacity. In 2012 it had the largest growth in non-LHC usage among all European NGIs. The Portuguese infrastructure has contributed significantly to this achievement.
- The Iberian grid collaboration continues to be a success and is now regarded as an excellent example of a cross border grid.
- A project submitted to the Portuguese Science Foundation for the improvement of the LIP Tier-2 received an evaluation grade of outstanding for both the project and the team scientific merit. The project was submitted in a call in competition with projects from other scientific domains.
- Election of a LIP computing group member to the executive board of the EGI foundation in Amsterdam.

### 3.1.5 Sources of Funding

| Code | Funding | Start | End |
|---|---|---|---|
| IBERGRID FCT-CSIC 2010/11 | 4.250 € | 2007-01-01 | 2012-12-31 |
| EGI InSPIRE | 485.000 € | 2010-05-01 | 2014-04-30 |
| TIMBUS | 112.268 € | 2011-03-01 | 2012-09-30 |

### 3.1.6 Team

**Project coordinator: Jorge Gomes**

| Name | Status | %of time in project |
|---|---|---|
| Carlos Manuel | Technician (LIP) | 100 |
| Gaspar Barreira | Researcher (LIP) | 50 |
| Gonçalo Borges | Researcher (LIP) | 100 |
| Hugo Gomes | Technician (LIP) | 100 |
| João Martins | Researcher (LIP) | 100 |
| João Pina | Post-Doc (LIP/FCT) | 100 |
| Jorge Gomes | Researcher (LIP) | 100 |
| José Aparício | Technician (LIP) | 100 |
| Mário David | Researcher (LIP) | 100 |
| Miguel Oliveira | Researcher (LIP) | 67 |
| Nuno Ribeiro Dias | Researcher (LIP) | 100 |

### 3.1.7 Publications

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

- *Software Provision Process for EGI*
  M. David, G. Borges, J. Gomes, J. Pina, et al
  Computer and Informatics, Vol 31, number 1, 2012, pp 135-, ISSN 1335-9150

- *Fostering multi-scientific usage in the Iberian production infrastructure*
  G. Borges, M. David, H. Gomes, J. Gomes, J. Martins, J. Pina et al
  Computing and Informatics, Vol. 31 number 1, 2012, pp 61-72, ISSN 1335-9150

**International Conference Proceedings**

- *Clustering TopBDII systems with dynamic round-robin DNS*
  J.Gomes, G.Borges, M.David, J.Pina, J.P.Martins, N.Dias, H.Gomes
  (accepted)

- *Ibergrid as a federated resource provider in EGI*
  I. Campos, T. de Miguel, G. Borges, J. Gomes
  6th Iberian Grid Infrastructure Conference Proceedings (accepted)

- *Ibercloud: federated access to virtualized resources*
  E. Fernandez, J. Gomes. G. Borges, M. David et all
  6th Iberian Grid Infrastructure Conference Proceedings (accepted)

- *Response of the Iberian Grid Computing Resources to the ATLAS activities during the LHC data taking*
  M. Kaci, J. Gomes. G. Borges, M. David et all
  6th Iberian Grid Infrastructure Conference Proceedings (accepted)

- *New developments on EGI Verification and Staged Rollout processes*
  A. Simon, M. David, J. Pina et al
  6th Iberian Grid Infrastructure Conference Proceedings (accepted)

**Collaboration notes with internal referee**

- *UMD Quality Criteria Release*
  E. Fernandez, M. David, G. Borges et al

- *IBERGRID: 2011 Year Report*
  I. Campos, J. Gomes

- *Use Case Definition and Digital Preservation Requirements*
  G.Antunes, M.Bakhshandeh, D.Fernandes, A.Silva, A.Caetano, J.Borbinha, G.Borges, J.Gomes

- *Use Case Specific Risks*
  G.Borges, J.Pina, J.Gomes, T.Molka,D.Redlich,G.Antunes,M.Hecheltjen,S.Yankova,M.Nolan

- *Glue2 Status of EMI Services*
  M. David

- *MS512 Software Provisioning Process*
  E. Fernandez, M. David et al

**Proposals**

- *Support for the ATLAS and CMS Portuguese tier-2 in the context of the WLCG MoU*
  J. Gomes, G. Borges, M. David

### 3.1.8 Presentations

**Oral presentations in international conferences**

- *Deploying User Oriented Services*
  presented by Gonçalo Borges
  EGI Technical Forum 2012 — Prague.
- *IBERGRID: Deploying User Oriented Services*
  presented by Gonçalo Borges
  6th Iberian Grid Infrastructure Conference — Lisbon.
- *IBERGRID Infrastructure Status*
  presented by Gonçalo Borges
  6th Iberian Grid Infrastructure Conference — Lisbon.
- *Operations Management discussions*
  presented by Gonçalo Borges
  6th Iberian Grid Infrastructure Conference — Lisbon.
- *Clustering TopBDII systems with dynamic round-robin DNS*
  presented by Jorge Gomes
  6th Iberian Grid Infrastructure Conference — Lisbon.

**Poster presentations in international conferences**

- *StoRM-ganglia monitoring module*
  presented by Mário David
  EGI Community Forum 2012 — Munich, Germany.

**Presentations in national conferences**

- *eScience Activities: Research and Services for enhancing science*
  presented by Gonçalo Borges
  Workshop LIP 2012 — Pavilhão do Conhecimento, Lisboa.
- *Worldwide LHC Computing Grid: Portuguese Tier2 Atlas and CMS*
  presented by Mário David
  Workshop LIP 2012 — Pavilhão do Conhecimento, Lisboa.
- *LIP Computing Activities Overview*
  presented by Jorge Gomes
  Workshop LIP 2012 — Pavilhão do Conhecimento, Lisboa.

**Oral presentations in international meetings**

- *A Customer Relationship management tool for EGI*
  presented by Gonçalo Borges
  EGI Community Forum 2012 — Munich, Germany.
- *IBERGRID Cloud Authentication*
  presented by Jorge Gomes
  6th Spanish plenary e-science network meeting — CSIC, Madrid .
- *MPI demo in EGI*
  presented by
  EGI Technical Forum 2012 — Prague, Czech Republic.
- *CRM Progress Report*
  presented by Gonçalo Borges
  EGI Technical Forum 2012 — Prague.

**Oral presentations in collaboration meetings**

- *EGI Operations Roadmap*
  presented by Mário David
  EGI Operations Management Board — EGI, Amsterdam, Netherlands.
- *EGI "Client"Relationship Management Tool*
  presented by João Pina
  — EGI videoconference .
- *TIMBUS LIP Use Case*
  presented by Gonçalo Borges
  TIMBUS Face to FACE Meeting — LNEC, Lisbon.

**Seminars**

- *LDAP an Information System for Distributed Computing Infrastructures*
  presented by Gonçalo Borges
  Master course — Universitat Valencia, Spain.

**Outreach seminars**

- *Grid e Computação*
  presented by Jorge Gomes
  Workshop LIP 2012, sessão publica — Pavilhão do Conhecimento, Lisboa.

### 3.1.9 Events

- *IBERGRID 6th Iberian grid infrastructure conference*
  Conference, Lisbon , 2012-11-07

### 3.1.10 Project Summary

| | number |
|---|---|
| Articles in international journals (with direct contribution from LIP members) | 2 |
| International Conference Proceedings | 5 |
| Collaboration notes with internal referee | 6 |
| Proposals | 1 |
| Oral presentations in international conferences | 5 |
| Poster presentations in international conferences | 1 |
| Presentations in national conferences | 3 |
| Oral presentations in international meetings | 4 |
| Oral presentations in collaboration meetings | 3 |
| Seminars | 1 |
| Outreach seminars | 1 |
| Conferences | 1 |

# Chapter 4

# Astroparticle Physics

## 4.1 Collaboration in AMS - Alpha Magnetic Spectrometer

### 4.1.1 Resumo

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

- estudos de modulação dos fluxos de raios cósmicos primários devido à actividade solar (tese de mestrado em Física, IST Julho 2012)
- estudos de separação isotópica de núcleos leves (tese de mestrado a decorrer)
- estudos de avaliação do impacto da polarização da radiação de Cherenkov na reconstrução da carga eléctrica (tese de mestrado a decorrer)
- estudos da fracção de positrões com grande aceitância geométrica (detectores RICH e TRD) feitos a baixa energia ($< 10$ GeV)

O grande fluxo de dados gerados na experiência tem permitido a integração no grupo de novos estudantes com o objectivo de realizar tese de mestrado e dinamizar novos tópicos de estudo.
Os membros do grupo têm participado ainda nas actividades de monitorização contínua da experiência no Payload Operation Control Center localizado no CERN.

### 4.1.2 Abstract

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

- particle fluxes modulation studies of primary cosmic rays and their correlation with the solar activity (master thesis, IST July 2012)
- isotopic separation of light nuclei (ongoing master thesis)
- evaluation of the impact of Cherenkov radiation polarization in the reconstruction of the electric charge (ongoing master thesis)
- measurement of the positron fraction at low energies (<10 GeV) and with a large detector acceptance by using both the RICH and TRD detectors

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

### 4.1.3 Objectives

AMS (Alpha Magnetic Spectrometer) is a particle physics experiment installed on the International Space Station facility (ISS), since May 2011. Its main physics objectives are the search for antimatter and dark matter and the study of the cosmic ray spectrum composition with an unprecedented statistics. Such measurements will contribute to a better understanding of the propagation and confinement of cosmic rays in the Galaxy.
The capabilities of the AMS spectrometer, compared to the one which flew in the space shuttle Discovery on June 1998, were largely improved and extended through the inclusion of new detectors, a Ring Imaging Cherenkov Detector (RICH), an Electromagnetic Calorimeter (ECAL) and a Transition Radiation Detector (TRD). The electromagnetic calorimeter provides AMS with the capability of identifying electrons/positrons and photons up to 1 TeV while the inclusion of a TRD allows AMS to distinguish antiprotons from electrons with a rejection power of 10ˆ5. The RICH detector, in which the LIP group is strongly involved, provides an independent measurement of particle velocity and electric charge. A resolution goal on velocity for singly charged particles of the order of 10ˆ-3 and on electric charge of around 0.2 units of charge is aimed. Such a precision will allow to distinguish nuclei up to iron.
In three years of data taking AMS will accumulate a statistics of about 10 million positrons and 1 million antiprotons up to an energy of 400 GeV.

### 4.1.4 Achievements

The AMS detector assembly was finished in 2010 at CERN. The detector was subsequently transported to NASA´s Kennedy Space Center (KSC) where it underwent the final testing procedures before its launch aboard Space Shuttle Endeavour in mission STS-134 and instalation aboard the ISS in May 2011. The minimum expected data acquisition time is three years, but the detector´s robustness may allow it to operate for a significantly longer period which might exceed a decade.
Since installation a large amount of data have been collected, at a rate of approximately 40 million events per day. Until now more than 28×10ˆ9 events have been collected.
The main tasks where the group was involved in 2012 were the following:

**AMS detector monitoring**

The mission´s POCC (Payload Operations and Control Center) operations are headquartered at CERN since June 2011. LIP team members continued their activity in AMS mission control, performing shifts and acting as on-call experts for the RICH subdetector. LIP shifters are responsible for monitoring the RICH, TOF and ECAL subdetectors and reporting any anomalies to shift leaders and on-call experts assigned to each specific subdetector. When acting as on-call experts, they are responsible for reporting the RICH detector´s behaviour to the collaboration in its daily briefings and performing contingency procedures if any issues occur with the RICH.

**RICH performance and data reconstruction**

The LIP group is responsible for the development and ongoing improvement of one of the two sets of reconstruction algorithms for the RICH subdetector (LIP algorithms). The LIP algorithms provide measurements of particle velocity and electric charge based on Cherenkov ring patterns observed in the RICH. Typical velocity resolutions for single-charged particles such as protons at $\beta \approx 1$ are 1.2×10ˆ-3 for aerogel events and 4.5×10ˆ-3 for NaF events. The aimed accuracy on the velocity and charge reconstruction implies the control of several parameters such as:

- Mirror reflectivity - this parameter may depend on reflection point and photon trajectory. In particular, it is known that some spatial dependence exists, at the level of a few percent. Reflectivity variations have an impact in light collection and will therefore introduce a systematic effect in charge measurements.
- Refractive index uniformity - one of the RICH radiators, silica aerogel, is a non-crystalline substance, meaning that its optical properties are not completely uniform. In particular, variations in aerogel density will correspond to changes in the radiator´s refractive index. In the AMS RICH, refractive index variations are at the level of 10ˆ-4 within each aerogel tile and at the level of 10ˆ-3 between tiles. Precise data on tiles are needed since both velocity and charge measurements are function of the assumed refractive index.
- Aerogel clarity - non-uniformities in aerogel also mean that its transparency is not uniform. Aerogel transparency is usually quantified by a clarity value, which is a measure of Rayleigh scattering probability in the medium. Higher clarity implies lower transparency, and therefore a lower RICH signal. This means that clarity variations must be accounted for when using the RICH signal to calculate particle charges.
- Calibration of detection cells (slow control) - the RICH detection matrix is composed of a total of 680 cells, each containing a photomultiplier, light guide and associated electronics. There is some variation in response between cells at the level of quantum efficiency and signal amplification. The possible variation of these effects with time must also be taken into account. In particular, the measured photomultiplier signal has a significant variation with temperature (decrease of 0.8%-0.9% per °C on average), an effect that is very significant for the AMS RICH since the detector operates in a broad range of temperatures depending on environmental conditions.

The group has been involved in these studies and has been using the LIP analysis tools developed for monitoring the performance of the detector.
Recent work at LIP has focused on improving charge reconstruction to allow the identification of nuclear charges up to the highest possible values of Z. The RICH detector´s intrinsic limit on the visible number of photoelectrons per ring sets charge resolution for low Z at approximately 0.3 charge units. Systematic effects become dominant at higher charges, since they appear as a fixed relative error in the reconstructed charge value. During the last year, charge systematics for aerogel events have already been reduced from 5.1% to 2.6% through several optimizations, leading to an improvement in resolution of e.g. 0.6 to 0.4 charge units for Z=10 and 1.4 to 0.7 units for the iron region (Z≈26).

**Impact of the Cherenkov radiation polarization on the electric charge reconstruction**

The RICH detector is composed of a radiator material on the top of the detector and a matrix of pixelized photomultipliers coupled to light guides on the bottom. The light tightness of the detector is provided by surrounding conical mirror. A charged particle crossing the radiator will radiate a number of Cherenkov photons proportional to the particle charge squared. The RICH detector is aiming to measure with very high accuracy both the velocity (roughly 1/1000 for singly charged particles) and the charge of particles up to the iron nuclei. The charge measurement accuracy depends strongly on systematic effects that grow with the element charge squared. In order to have a good nuclei identification up to iron, all factors contributing to evaluate the radiated signal have to be identified and taken into account.
The Cherenkov electromagnetic radiation is of polarized nature. The photon path from radiation point to detection includes two interfaces: the radiator-vacuum and the vacuum-light guide. The transmission efficiency depends on the photon polarization. Therefore, the effect of the polarization has to be evaluated for both radiator materials, aerogel and sodium fluoride and compared to the unpolarized case that is currently implemented in the charge reconstruction algorithms developed by the LIP group. The correction has to be implemented in the charge reconstruction efficiency used on data reconstruction and its implication on the charge measurement accuracy will be evaluated with AMS nuclei reconstructed data.

**Solar modulation of primary cosmic rays**

The solar magnetic field, embedded in the solar wind, is responsible for cosmic-ray modulation at low energies ($< 10$GeV), affecting both their flux and their energy. For each cosmic-ray species, the cosmic-ray flux measured at Earth is deformed when compared to the flux at the exit of the heliosphere, depending on the solar activity. The AMS launch took place during a minimum of solar activity (beginning of 24th cycle). The effect of the solar modulation in the cosmic ray flux has been studied in proton fluxes. A comparison between AMS-02 and neutron monitor measurements was established.
Phenomenological studies on cosmic-ray propagation have been performed. The propagation of cosmic rays in the heliosphere is described by the so-called Parker Equation, formulated in the 1960s. This equation takes into account several phenomena happening inside the heliosphere such as diffusion, convection, adiabatic energy changes and drifts. Since there is no full analytical solution to the Parker Equation several different approaches have been tried, from numerical solutions to analytical approximations. Different ways of solving the transport equation were studied and numerical methods (1D and 2D) were explored.

**Isotopic separation**

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

**Measurement of positron ratio at low energies**

The LIP group joined the AMS "Group A"analysis group where the first physics topic studied was the positron ratio measurement.
The main AMS analysis on positron identification relies on observables measured by the electromagnetic calorimeter (ECAL) and the Transition Radiation Detector (TRD). At low energies (E<10 GeV), positron identification can be done with a larger detector acceptance by using the RICH and the TRD. The large physics background from protons (10^4 - 10^5) can be rejected by combining the measurements of velocity (RICH), rigidity (Tracker) and energy to mass ratio (TRD). Therefore, a factor of 4 to 5 more events can be collected at these low energies when compared with an analysis purely done with ECAL and TRD. Positron separation with the RICH detector uses both the velocity and signal independent measurements.
The LIP positron identification method is based on the definition of velocity and RICH signal probability density functions (PDFs) for every particle kind and for every event with a given rigidity measured by the Silicon Tracker. The measured velocity and RICH signal of every event can therefore be used to estimate the probability defining the degree of compatibility of the measurement with what is expected for every particle type

(e+/e-, protons, He,...). The efficiency and rejection power of the analysis method were evaluated by applying the selection PDF tools to data samples enriched with electrons and protons. In addition, generic quality requirements were applied to both samples to ensure a good rejection. A preliminary selection of positrons and electrons combining the RICH measurements on velocity and signal was done. The probability of being electron/positron was required to be higher than the proton probability and a positron ratio at low energies was successfully extracted.

### 4.1.5 Sources of Funding

| Code | Funding | Start | End |
|---|---|---|---|
| PTDC/FIS/122567/2010 | 40.000 € | 2011-12-07 | 2013-12-06 |

### 4.1.6 Team

**Project coordinator: Fernando Barão**

| Name | Status | %of time in project |
|---|---|---|
| Bruno Santos | Master student (LIP) | 100 |
| Fernando Barão | Researcher (LIP/IST) | 85 |
| Luís Batalha | Master student (LIP) | 58 |
| Luisa Arruda | Post-Doc (LIP/FCT) | 80 |
| Pedro Nunes | Master student (LIP) | 100 |
| Rui Faísca Pereira | Post-Doc (LIP/FCT) | 100 |

### 4.1.7 Presentations

**Oral presentations in international conferences**

- *Particle detection with light*
  presented by Fernando Barão
  The IDPASC School on Digital Counting Photosensors for Extreme Low Light Levels — LIP, Lisboa, Portugal.

- *Solar Modulation of Galactic Cosmic Rays*
  presented by Fernando Barão
  Nuclear physics for Galactic Cosmic Rays in the AMS-02 era — LPSC, Grenoble, France.

**Presentations in national conferences**

- *AMS: um observatório de raios cósmicos na estação espacial internacional (ISS) - Participação do IST/LIP*
  presented by Fernando Barão
  2º Simpósio ESPAÇO: A Contribuição Portuguesa em Investigação e Desenvolvimento — IST, Lisboa, Portugal.

- *LIP contribution to the AMS experiment*
  presented by Fernando Barão
  Jornadas LIP 2012 — Lisboa, Portugal.

- *AMS Status*
  presented by Luisa Arruda
  Jornadas LIP 2012 — Lisboa, Portugal.

- *Solar Modulation in AMS-02*
  presented by Luís Batalha
  Jornadas LIP 2012 — Lisboa, Portugal.

- *Deuteron Separation in AMS-02*
  presented by Pedro Nunes
  Jornadas LIP 2012 — Lisboa, Portugal.

- *Charge Identification in RICH*
  presented by Bruno Santos
  Jornadas LIP 2012 — Lisboa, Portugal.

**Oral presentations in collaboration meetings**

- *RICH performance: current studies*
  presented by Rui Faísca Pereira
  AMS RICH meeting — Madrid, Spain.
- *Studies on AMS RICH performance using the LIP algorithms*
  presented by Rui Faísca Pereira
  AMS meeting — CERN, Geneva, Switzerland.
- *Current status of LIP work*
  presented by Luisa Arruda
  — CERN, Geneva, Switzerland.
- *LIP beta reconstruction status*
  presented by Luisa Arruda
  — CERN, Geneva, Switzerland.
- *Status of the LIP velocity reconstruction algorithm*
  presented by Luisa Arruda
  — CERN, Geneva, Switzerland.
- *Proton fluxes and solar modulation effects*
  presented by Luís Batalha
  — CERN, Geneva, Switzerland.
- *Status of the LIP velocity and charge reconstruction algorithms*
  presented by Rui Faísca Pereira
  AMS meeting — CERN, Geneva, Switzerland.
- *e/p separation with RICH: statistical estimators*
  presented by Luisa Arruda
  — CERN, Geneva, Switzerland.
- *e/p separation with RICH: statistical estimators*
  presented by Luisa Arruda
  — Aachen, Germany.
- *Solar Modulation of Galactic Cosmic Rays - positron fraction behaviour*
  presented by Fernando Barão
  AMS analysis meeting — CERN, Geneva, Switzerland.

**Outreach seminars**

- *AMS: um observatório de raios cósmicos na Estação Espacial: à procura de matéria escura e antimatéria...*
  presented by Fernando Barão
  Masterclasses Internacionais em Física de Partículas 2012 — Universidade da Beira Interior, Covilhã, Portugal.
- *Raios cósmicos: um enigma com 100 anos...*
  presented by Fernando Barão
  Curso de Formação de Professores "Radiação Ambiente-– LIP, Lisboa, Portugal.

### 4.1.8 Academic Training

**Master Theses**

- *Solar Modulation effects on Cosmic Rays: Modelization with Force Field approximation, 1D and 2D numerical approaches and characterization with AMS-02 proton fluxes*
  Luís Batalha, 2012-07-30

- *Thesis in AMS*
  Bruno Santos, (on-going)
- *Thesis in AMS*
  Pedro Nunes, (on-going)

### 4.1.9 Project Summary

| | number |
|---|---|
| Oral presentations in international conferences | 2 |
| Presentations in national conferences | 6 |
| Oral presentations in collaboration meetings | 10 |
| Outreach seminars | 2 |
| Master Theses | 1 |

## 4.2 Collaboration in the SNO+ experiment

### 4.2.1 Resumo

O grupo de Física de Neutrinos do LIP foi formado em 2005 para participar na experiência de Neutrinos Solares, SNO (Sudbury Neutrino Observatory), e integrou desde 2006, a proposta da experiência sucessora, SNO+. Os resultados de SNO comprovaram o fluxo total previsto de neutrinos solares de Boro-8, medido por interacção de correntes neutras (sensível a todos os sabores de neutrinos), e simultaneamente a diminuição da taxa de neutrinos do eletrão, medida por correntes carregadas - confirmando a oscilação de neutrinos e resolvendo o chamado Problema dos Neutrinos Solares.
O detector SNO consistia numa esfera central de 12 m de diâmetro, rodeada por cerca de 9500 PMTs montados numa estrutura geodésica, instalada a uma profundidade de 2km no SNOLAB, Canadá. O grupo do LIP teve um papel importante na calibração ótica do detector e na medida de precisão dos parâmetros de oscilação dos neutrinos - que resulta na mais precisa medida do ângulo de mistura $\theta_{12}$. Este trabalho originou uma tese de doutoramento defendida este ano na Universidade de Lisboa.
SNO+ adapta o detetor de SNO, substituindo o alvo e meio ativo de água pesada por cerca de 800 ton de cintilador líquido, com múltiplos objetivos científicos, sendo o principal a pesquisa com elevada sensibilidade do sinal de duplo declíneo beta sem neutrinos (Neutrinoless Double Beta Decay - 0NDBD), a assinatura mais promissora do eventual carácter de Majorana dos neutrinos massivos. A utilização de cintilador líquido permitirá baixar significativamente o limiar de energia, de modo a medir neutrinos solares pep e CNO, geo-neutrinos e anti-neutrinos produzidos em reactores nucleares, aumentar a sensibilidade a neutrinos de supernovas; para estas medidas estão previstas diferentes fases de tomada de dados primeiro com e depois sem dopagem com um isótopo para 0NDBD.
A instalação dos novos componentes do detetor está a ser completada, e em 2013 o detector será primeiro enchido com água ultra-pura para primeiros testes antes do enchimento com cintilador líquido.
A calibração em tempo e carga dos fotomultiplicadores (PMTs) é fundamental para a reconstrução de posição e energia dos eventos detetados. Em colaboração com a Universidade de Sussex (UK), desenvolvemos um novo método de calibração não invasivo, baseado em vários cabos longos de fibra ótica, com ligação sequencial a um conjunto de LEDs externo ao detetor. As fibras serão instaladas em posições fixas no detetor, reduzindo a necessidade de introdução de fontes dentro do volume interno de cintilador. Para o desenvolvimento e testes dos 110 cabos de fibras duplas do novo sistema foram utilizadas as instalações do grupo ATLAS no Centro de Física Nuclear da Universidade de Lisboa. Todas as partes mecânicas para inserção das fibras no detetor e a sua colocação nos pontos requeridos foram construídas nas oficinas do LIP em Coimbra. Um terço das fibras foram já instaladas em 2012, as restantes serão instaladas por barco durante o enchimento do detetor com água em 2013.
Recentemente, o LIP tornou-se também responsável pelo desenho e contrução dum novo sistema de colocação de fontes de calibração em SNO+. Este é um sistema complexo que requere estanquicidade (para evitar a contaminação do cintilador com radão externo) e um controlo preciso das tensões sobre as cordas de suporte e os cabos de ligação à fonte. O desenho e construção deste equipamento foi encomendado por SNO+, e será

Installation of internal point of optical fibre in the PMT support structure.

pago com fundos canadianos da colaboração.
Devido à experiência adquirida em SNO, a calibração óptica de SNO+ irá ser uma das nossas responsabilidades principais no futuro. O nosso grupo é desde já responsável por este subgrupo de trabalho, em que estamos a atualizar o software e desenvolver o plano de análise.
Assim, nos próximos dois anos, as nossas atividades serão centradas nos sistemas de calibração, com a preparação das análises de física para os anos seguintes.
Em termos organizativos, o responsável pelo grupo do LIP assegurou (por eleição) a presidência da "Collaboration Board", entre Setembro de 2011 e Agosto de 2012, depois de um ano com a vice-presidência. Membros do grupo do LIP asseguram a coordenação dos subgrupos de Calibração Ótica e de Física de Antineutrinos, e estão representados no "Analysis Coordination Committee". Em 2010 organizámos a reunião de colaboração em Lisboa. Em 2009 foi assinado o Memorando de Entendimento entre a FCT, o LIP, SNO+ e SNOLAB. A participação do LIP em SNO+ é apoiada financeiramente pela FCT, num projecto a 3 anos que se iniciou em Janeiro de 2011.

### 4.2.2 Abstract

The LIP group on Neutrino Physics was created in 2005 to participate in the solar neutrino experiment SNO (Sudbury Neutrino Observatory), and integrated since 2006 the proposal for its successor experiment SNO+.
The SNO detector consisted of a 12m diameter spherical vessel, surrounded by about 9500 PMTs mounted on a 17m diameter geodesic structure, installed at a depth of 2 km in SNOLAB, Canada. The SNO results simultaneously confirmed the predicted total flux of 8B solar neutrinos flux and demonstrated neutrino oscillations, solving the so-called Solar Neutrino Problem. The LIP group had a strong role in the optical calibration of the detector and in the precision measurement of the neutrino oscillation parameters. These results provide the world´s best precision on the neutrino mixing angle $\theta_{12}$. In 2012, a PhD thesis containing this work was presented to the University of Lisbon.
The SNO+ experiment is adapting the SNO detector, in order to use isotope-loaded liquid scintillator as the active medium. SNO+ has multiple scientific goals, the main one being the search for neutrinoless double beta decay, the most promising signature for the possible Majorana character of neutrinos and for the absolute neutrino mass. Measurements of neutrinos from the Sun, the Earth, Supernovae and nuclear reactors are additional goals of the the experiment, for which further data-taking phases with unloaded scintillator are planned. The installation of new detector components is now being completed and the commissioning phase will start in 2013, during the water fill, followed by the scintillator fill.
Timing and charge calibration of the PMTs is fundamental for the position and energy reconstruction of any detected events. In collaboration with the University of Sussex (UK), we have developed a new method for PMT calibration that does not require the insertion of sources in the detector, since it is based on a set of optical fibers transmitting light from external LEDs. Initial design tests and the final quality control of the full 110 double-fiber cables was carried out at the ATLAS group lab at Centro de Física Nuclear da Universidade de Lisboa. All the mechanical parts for feeding the fiber cables into the detector and attaching them in their mount points were designed and built at the LIP-Coimbra workshop. The installation of the first one-third of the system was carried out in 2012, and the remaining fibers will be installed in 2013 during the water fill. Over the next two years, we will focus on finishing the installation and commissioning the system.
The LIP group has also recently taken the responsibility of redesigning and building the source deployment system for SNO+. This is a complex system, requiring gas tightness (to avoid Radon contamination) and an accurate control over the tensions on the source umbilical and support rope. The design and construction of this equipment will be funded by the Canadian SNO+ grant.
Building on the experience acquired in SNO, the SNO+ optical calibration will soon become one of our main tasks. Our group is already responsible for this analysis subgroup, for which we are upgrading the analysis software.
During the next two years, these activities, focused on the commissioning of the calibration systems and analysis software, will be the main goal of the LIP group. Physics data analysis, focused on reconstruction and background reduction, will be the strategic goals for the years to follow.
Focusing on the organizational aspects, JM served the 2011/2012 term as elected chair of the Collaboration Board and members of the group chair the analysis subgroups of Optical calibration and Anti-neutrino Physics. In 2010, the LIP group organized the collaboration meeting in Lisbon. In December 2009, a Memorandum of Understanding for scientific cooperation was signed between FCT, LIP, the SNO+ Collaboration and SNOLAB. The LIP participation in SNO+ is funded by FCT through a 3-year project in the All Scientific Domains call, that started in January 2011.

### 4.2.3 Objectives

Our main priority for 2012 was finalizing the SNO+ fiber system for PMT calibration, installing it at SNOLAB, and testing it. This system is composed of a set of optical fibers that carry light pulses to the PMT support structure, to illuminate the PMTs on the opposite side and perform their timing and gain calibration. We are responsible for the fabrication, purchasing and installation of the set of system´s components that carry light into the detector (other institutions are responsible for the light "production", with a set of LEDs). The main steps for 2012 in this project were:
a) Obtaining SNOLAB approval for the installation of all the fiber-related hardware. This includes providing official, final versions of the technical drawings and installation plans.
b) Finalizing the construction of the fiber feed-through assembly at the Coimbra workshop. This was the last part of the system, including 8 mini-flanges for 22 fibre cables each. It was done in the LIP workshops in Coimbra.
c) Finalizing the analysis of the optical fibre quality checking data taken in Lisbon in December 2011. Prior to installation, each fibre was classified according to light transmission, angular aperture and timing distribution. All cables passed the selection criteria, allowing extra spares.
d) Shipping the tested fibers, the support plates, and the feed-through assembly produced in Coimbra to SNOLAB.
e) Installing the parts of the system that are accessible from the detector cavity floor, and the feed-through assembly on deck. These work was carried out in about one month and led by the LIP group, while counting with the collaboration of colleagues from SNOLAB, and Sussex, Oxford, Laurentian and Queen´s Universities.
f) Testing the installed system during a detector commissioning data-taking, with the PMTs on LED illumination on the fibers.
In addition, we continued to prepare the analysis software for the Optical Calibration. In 2012, the main activities were the preparation of the new data structure in view of the commissioning phase with water.
With the emphasis in the preparation of the calibration systems for detector commissioning there were not much progress in the anti-neutrino sensitivity analysis in 2012. Our preliminary results were cross-checked by other groups in the collaboration, and combined with the expected sensitivity for solar neutrino SNO+ results.

### 4.2.4 Achievements

Our main achievement in 2012 was the installation and in-situ quality checking of the detector calibration system.
1) Installation in the detector:
All the tested optical fibre cables, the plastic support plates and stainless steal flange were shipped to SNOLAB. They were prepared for installation in a SNOLAB clean room, where each cable was individually cleaned with ultra-pure water and eight groups of cables were connected to the corresponding mini-flange) and were then transported to the underground laboratory. Here the external/upper part of each fibre was installed in the flange box, the internal/lower part was installed in the PMT structure, with the corresponding support plate, when accessible from the cavity floor. A final transmission test was repeated just prior and after final installation in the detector. The exact position in which each fibre was installed was registered in a data base and passed through to the simulation and reconstruction software, together with the average angular and timing profiles measured in the laboratory.
2) In-situ tests during air-fill data taking
In 2012, two data taking runs were conducted with SNO+, with the detector in air (it will be filled only in 2013). In the second one, October/November, all 9500 PMTs were on and all the 2 fibres of the 36 duplex cables already installed were tested with illumination by the LED system. The LIP group participated in these tests at SNOLAB. Preliminary results show that all the installed fibres are in good working conditions and the data will allow the direct cross-checking of their positions and angular profiles. A paper describing the full system and the tests done up to the start of data taking in water is being prepared.
In addition we have new activities:
3) Preparation of detector filling
In 2013, SNO+ will be filled with water. During this process the remaining 2/3 of the optical fibers will be installed by boat. Our group is also involved in radio-purity assays of the water to be filled in.
4) Calibration sources insertion system
Due to the stringent radio-purity requirements of SNO+, the old SNO Calibration sources insertion system has to be redesigned, to improve the isolation and allow the operation with liquid scintillator. SNO+ asked for our collaboration in the design and construction of a central part of the experiment: it will be built by the LIP workshops in Coimbra and paid for by the SNO+ Canadian grant.

### 4.2.5 Sources of Funding

| Code | Funding | Start | End |
|---|---|---|---|
| PTDC/FIS/115281/2009 | 108.971 € | 2011-01-01 | 2013-12-31 |

### 4.2.6 Team

**Project coordinator: José Maneira**

| Name | Status | %of time in project |
|---|---|---|
| Amélia Maio | Researcher (LIP/FCUL) | 15 |
| Carlos Silva | Technician (LIP) | 15 |
| Dimpal Chauhan | Master (LIP) | 17 |
| João Carvalho | Researcher (FCTUC) | 15 |
| Joaquim Oliveira | Technician (LIP) | 15 |
| José Maneira | Researcher (LIP) | 30 |
| Luís Gurriana | Technician (LIP) | 15 |
| Nuno Barros | Researcher (LIP/FCT) * | 100 |
| Orlando Cunha | Technician (LIP) | 15 |
| Rui Alves | Technician (LIP) | 15 |
| Sofia Andringa | Researcher (LIP) | 25 |

### 4.2.7 Publications

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

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

### 4.2.8 Presentations

**Oral presentations in international conferences**

- *Final results from SNO*
  presented by Nuno Barros
  NOW2012 — Otranto, Italy.
- *SNO+*
  presented by Sofia Andringa
  IDPASC Neutrino School — Granada, Spain.
- *The SNO+ experiment: status and overview*
  presented by José Maneira
  DISCRETE 2012 — Lisbon.

**Presentations in national conferences**

- *Looking at the Sun, the Earth, and fundamental neutrino properties*
  presented by José Maneira
  New Worlds in Particle and Astroparticle Physics — Lisbon.

**Oral presentations in international meetings**

- *SNO+*
  presented by Sofia Andringa
  IDPASC Mini-workshop on neutrino physics — Granada, Spain.

**Seminars**

- *Neutrino Physics*
  presented by Sofia Andringa
  Second IDPASC School 2012 — Udine, Italia.

### 4.2.9 Academic Training

**PhD Theses**

- *Precision measurement of neutrino oscillation parameters: combined three-phase results of the Sudbury Neutrino Observatory*
  Nuno Barros, 2012-05-03

### 4.2.10 Project Summary

| | number |
|---|---|
| Articles in international journals (with direct contribution from LIP members) | 1 |
| Oral presentations in international conferences | 3 |
| Presentations in national conferences | 1 |
| Oral presentations in international meetings | 1 |
| Seminars | 1 |
| PhD Theses | 1 |

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

### 4.3.1 Resumo

A natureza da matéria escura é uma das questões fundamentais mais intrigantes da física atual. A evidência observacional para a existência de uma componente não-bariónica, não luminosa e não-relativista, responsável por cerca de 85% da massa total do universo, tem vindo a crescer sucessivamente nos últimos anos. Estas evidências têm origem muito diversa e são hoje múltiplas. Todavia, quer a natureza quer a origem dessa matéria escura são por enquanto totalmente desconhecidas.
A existência de partículas de um novo tipo ainda desconhecido, ditas fracamente interativas, as chamadas Weakly Interacting Massive Particles (WIMPs), são normalmente tidas como uma hipótese possível para explicar a matéria escura. Partículas com semelhantes características são previstas em várias extensões do Modelo Padrão da física de partículas e suportadas por modelos de produção térmica de matéria escura no universo primitivo. Uma dessas partículas é o neutralino, previsto por teorias de supersimetria (SUSY). A existirem num halo em torno da nossa galáxia, essas partículas WIMP devem poder ser detectadas diretamente, ao observarmos recuos nucleares resultantes de colisão elástica com núcleos da matéria ordinária, em detectores com radiação de fundo ultra-baixa, em instalações subterrâneas de muito reduzida radioatividade natural. O grande desafio experimental consiste em detectar eventos muito raros (<1 evt / kg / ano), que depositam energia muito baixa (alguns keV), em condições estáveis, durante muito tempo. Várias experiências têm vindo a procurar sinais dessas interações, usando diferentes técnicas de detecção.
O xénon líquefeito (LXe) pode funcionar como um excelente alvo para colisões de partículas WIMPs de massa intermédia (dezenas de GeV/cˆ2), devido à sua elevada massa atómica e à sensibilidade que permite obter. Acima de tudo, a combinação de dois canais de resposta (de cintilação e ionização) permite fazer uma discriminação entre sinais devidos a electrões resultantes do fundo radioativo e os recuos nucleares, como os esperados devido às interacções de WIMPs. Esta técnica tem sido explorada com sucesso sob a forma de detectores de duas fases de xénon.
Num detector de duas fases de xénon medem-se a emissão de cintilação rápida e a ionização resultantes de interações de partículas no xénon líquido. Os electrões libertados na ionização são extraidos por um campo

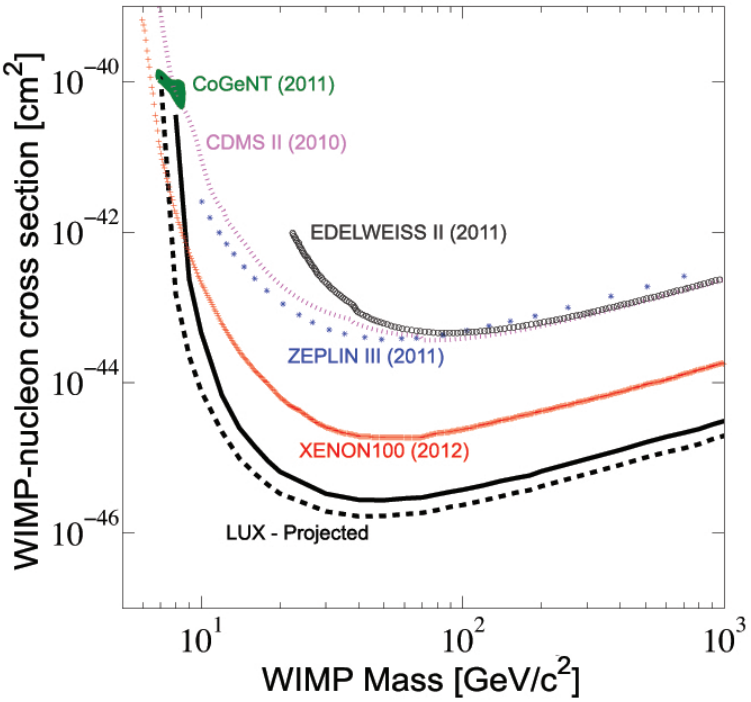



Fig.1 -The projected LUX sensitivity at 90% CL is plotted in relation to other recent WIMP-nucleon scattering limits. The solid black line shows a limit assuming very conservative light collection and 30,000 kg-days of data without background, while the dashed black line shows a realistic estimate of the limit given our current understanding of the light collection and 30,000 kg-days of data.

elétrico desde o local da interacção até à região de vapor de xénon (de poucos milímetros) existente acima da superfície do líquido. Aí são são aceleradas e produzem cintilação secundária. Para tal usam-se campos eléctricos elevados, de vários kV/cm. Um ou dois conjuntos de fotomultiplicadores (PMTs) localizados no interior do meio detector convertem luz de cintilação primária e secundária em sinais eléctricos.
A experiência LUX - the Large Underground Xenon experiment - é o maior detector de duas fases de xénon utilizado até ao momento na pesquisa de matéria escura. Para além de ter uma massa muito mais elevada do que as experiências precedentes (350 kg comparado com 6.5 kg em ZEPLIN-III e 100 kg em XENON100), o detector de LUX inclui avanços tecnológicos e técnicas novas muito importantes para melhorar a sensibilidade de detecção, nomeadamente: a) a imersão do detector dentro de um tanque com 8 m de diâmetro, cheio com água muito pura, para proteger o detector de raios gama e neutrões, em vez de usar uma blindagem de chumbo e polietileno; b) a construção do criostato e do detector em titânio de baixa radioatividade. Espera-se que LUX tenha uma sensibilidade cerca de 10 vezes superior às experiências existentes (Fig.1). LUX também introduz várias inovações tecnológicas que serão necessárias na próxima geração de detetores de duas fases para a detecção de matéria escura, tal como o detetor LZ de 7 toneladas, que é uma proposta conjunta das colaborações LUX e ZEPLIN (um projecto de I&D e uma proposta de concepção de LZ foram já financiados pela NSF e o DOE).
De Novembro de 2011 a Fevereiro 2012, nas instalações de superfície do complexo de Stanford - o Sanford Underground Research Facility (SURF), em Homestake, SD, EUA - validaram-se individualmente os vários sub-sistemas de LUX e a sua integração na experiência. Durante estes testes o detector esteve imerso num tanque de água para reduzir o efeito dos raios cósmicos. Alguns componentes da experiência LUX envolvem novas soluções técnicas que beneficiaram destes testes em condições muito próximas das finais. É o caso da técnica de arrefecimento, da circulação de gás, dos sistemas de purificação, dos sistemas de controlo e de segurança, da aplicação de alta tensão ao cátodo, ânodo e grelhas do detector, e do sistema de aquisição de dados. Um segundo objetivo destes testes de superfície, com o detector numa configuração muito próxima da final, era permitir uma avaliação preliminar do desempenho do detector e dos sistemas auxiliares.
Em Julho de 2012, experiência LUX foi transportada para o laboratório subterrâneo de SURF. A instalação e integração de todos os subsistemas no laboratório subterrâneo começou de imediato, tendo ficado finalizada em Dezembro de 2012. O detector e alguns subsistemas sofreram intervenções no sentido de corrigir problemas que tinham sido identificados durante a tomada de dados à superfície. Introduziram-se também várias alterações necessárias face aos requisitos e condicionalismos associados ao funcionamento da experiência no laboratório subterrâneo. O tanque de água equipado com fotomultiplicadores foi instalado e comissariado pela primeira vez. Os testes de todos os subsistemas e procedimentos ficaram completos e aprovados no final de Dezembro de 2012.
O LIP é membro da colaboração LUX desde Dezembro de 2010 na sequência da assinatura de um Memorando de Entendimento entre a FCT, o LIP e a colaboração LUX em Agosto de 2010. A participação do LIP em LUX é apoiada financeiramente pela FCT desde Janeiro de 2011. Presentemente, esse financiamento é feito através de um projecto a 2 anos que se iniciou em Abril de 2012.

### 4.3.2 Abstract

The nature of dark matter is one of the most intriguing open questions in fundamental physics today. The observational evidence for the existence of a non-baryonic, non-luminous and non-relativistic component of the universe, accounting for ≈85% of its total mass, has been strengthen in recent years. That evidence arises from a large variety of sources. However, the nature and the origin of dark matter are unknown.
Weakly Interacting Massive Particles (WIMPs) are a class of candidates for this dark matter supported by many extensions to the Standard Model of particle physics and by thermal production models for dark matter in the early universe. One of the strongest candidates is the neutralino predicted by supersymmetric (SUSY) theories. WIMPs in a halo surrounding our galaxy would be directly detected by looking at nuclear recoils resulting from elastic scattering with nuclei in an ultra-low background target detectors deployed underground. The experimental challenge lies in conducting a rare event search (<1 evt/kg/yr) whilst maintaining efficient detection of very low energy signatures (few keV). Various experiments have searched for these interactions using different detection techniques.
Liquid xenon (LXe) is an excellent target material for intermediate mass (tens of GeV/cˆ2) WIMPs due to its high atomic mass and sensitivity in two response channels (scintillation and ionization). Significantly, these allow discrimination between electron recoils resulting from radioactivity backgrounds and the nuclear recoils expected from WIMP elastic scattering. This has been successfully exploited in the form of dual-phase xenon detectors.
A two-phase xenon emission detector measures both prompt scintillation and ionisation responses from particle interactions in the liquid xenon. The ionization released at an interaction site is drifted upward and emitted into a thin (few mm) vapour phase above the liquid, where it is converted into an optical signal via

electroluminescence. This is achieved with a strong electric yield of several kV/cm. One or two arrays of photomultiplier tubes (PMTs) located inside the detector respond to the prompt scintillation and the delayed electroluminescence signals (termed S1 and S2, respectively).
The Large Underground Xenon (LUX) experiment constitutes a large step forward in Dark Matter experiments based on two-phase xenon detectors, and in the dark matter search in general. Besides using an unprecedented large mass (350 kg) of sensitive medium (xenon in this case), LUX includes very important advances, in particular for reducing the background which is a key issue to improve sensitivity: a) immersion of the detector inside an 8-m-diameter high purity water tank to shield out gammas and neutrons, instead of surrounding it by lead and polyethylene; b) cryostat and inner detector vessel made out of low-radioactive titanium. LUX has a projected sensitivity about 10 times better than the existing limits (Fig.1). LUX also introduces technological innovations required for such a large dual-phase xenon TPC and ton-scale detectors foreseen for the next generation of dark matter experiments such as LZ, a 7 ton WIMP detector jointly proposed by the LUX and ZEPLIN Collaborations (a R&D project and a LZ concept design proposal presented at a call for Second Generation Dark Matter Experiments were already funded by NSF and DOE, respectively).
From Nov 2011 to Feb 2012, a surface run conducted with the detector immersed in a water tank validated the various LUX sub-systems and verified the integration of the entire system in preparation of the underground deployment. Some LUX components involve novel technical solutions that benefited from realistic testing, including the cooling, gas circulation and purification systems, the control and safety systems, high voltage delivery, and the data acquisition system. A second aim of the run was to allow a preliminary assessment of the radiation-detection performance of the experiment.
LUX detector and its ancillary systems were moved underground to Sanford Underground Research Facility (SURF), Homestake, SD, US, in July 2012 when the Davis Cavern was made available to receive the experiment. LUX underground integration and commission started promptly. The detector and some subsystems were upgraded to adapt them to the underground special requirements and constraints and to correct problems found during the surface run. The water tank/veto equipped with photomultipliers and its ancillary systems were set in place for the first time. All the checkouts were complete by the end of December.
LIP formally joined LUX in December 2010 after a Memorandum of Understanding for scientific cooperation between was signed by FCT, LIP and the LUX Collaboration. The LIP participation in LUX has been funded by FCT since January 2011. Presently it is funded through a 2-year project submitted in the CERN call that started in April 2012.

### 4.3.3 Objectives

In 2012, the main objectives of LUX experiment were the following:

- To complete the surface run. The main goals of this run were to access: 1) the performance of the detector as far as its operation surface allows; 2) the performance of all the subsystems; 3) the ability to purify the xenon.
- To move LUX experiment underground to Davis Cavern as soon as the underground laboratory (Davis cavern at SURF, Homestake, South Dakota, USA) was ready to receive the experiment.
- To complete the upgrades needed to adapt the experiment to the underground special requirements and constraints, and to correct problems found during the surface run.
- Complete the integration and checkouts of all subsystems
- To prepare the detector for warm gas operation and data taking prior to cooling down and condensing.

The main objectives of LIP regarding its participation in LUX were the following:

- To design and coordinate the installation of the automated liquid nitrogen distribution system, as well as to design, construct and install its control units. (LIP´s responsibility; Francisco Neves became the owner of the LN2 distribution system).
- To upgrade the slow control system to the requirements and constraints of underground LUX experiment operation. This system was initially a responsability of Yale University but it was passed to LIP after surface run completion (Vladimir Solovov from LIP became the owner of the slow control system).
- To play a major role in the development of tools for the data analysis and in the analysis of the data acquired during the surface run.
- To participate in the detector operations and data taking during the surface run, as well as in the experiment deployment underground, keeping always one rotative member of the LIP´s team at SURF.

### 4.3.4 Achievements

Main achievements of LUX Collaboration:

- The surface run validated several key aspects of the experiment, namely: 1) the thermosyphon cooling (a new technology); 2) stable cryogenic control for ≈100 days; 3) high flow Xe continuous circulation (35 slpm, 300 kg/day); 4) full deployment in water tank; 5) Working PMTs, trigger, DAQ; 6) In-situ xenon purity analysis; 7) Reasonable electron lifetime in liquid xenon (0.2 ms) limited by a broken connection inside the detector; 8) Excellent light collection (8 phe/keV in the center) and position resolution (≈ 5 mm). The results from the surface run were accepted for publication in the journal "Astroparticle Physics"(arXiv:1210.4569).
- Successful deployment underground.
- Upgrade of some LUX subsystems and checkouts completed successfully.
- Preparation of the detector for cooling down completed.

Main achievements of LIP in particular:

- The automated liquid nitrogen distribution system was completed, commissioned and checkout according to the initial schedule. This task included the design of the logic of the automatic system, the design, construction and test of the control units, the coordination of the system commissioning and the training of experts and operators of this system. Francisco Neves was responsible for this major task and he is the owner of the LN2 distribution system in LUX experiment since January 2012.
- The slow control was upgraded to the requirements and constraints of underground operation of the experiment. This included the integration in the slow control of: 1) the HV power supplies for the detector cathode, anode, grids and PMTs, each with its own ramping up and ramping down procedure; 2) the LN2 distribution system control panels, source calibration system, scales and automatic controlled recovery system. The implemented alarm system was upgraded for improving safe operation of the experiment and efficiency of personnel response, if needed. Vladimir Solovov from LIP team was responsible for that major task and he is the owner of the slow control system since May 2012.
- Development and implementation of a reconstruction algorithm for the 3D position reconstruction in the detector. This was a key tool for problem diagnosis during surface run (e.g. it allowed to reconstruct the flow path of the 222Rn injected in the detector to access the liquid circulation path) and for determining the electron lifetime in the liquid xenon achieved during the surface run. This was an essential part of the paper submitted for publication (arXiv:1210.4569).
- In the framework of the LUX Analysis Working Group (AWG), the LIP team has carried out several tasks related with the data analysis tools and the analysis of calibration data. All together, we authored 16 internal notes on several issues regarding the analysis of the data collected during the surface run. Luiz de Viveiros from LIP´s team has been served as Coordinator of the LUX Analysis Working Group since September 1, 2012.
- The prototype of the radioactive source delivery system was tested.
- LIP team participated in the LUX detector surface run and in the underground commissioning, having contributed, in total, with 368 days*person onsite.

### 4.3.5 Sources of Funding

| Code | Funding | Start | End |
|---|---|---|---|
| CERN/FP/116374/2010 | 45.000 € | 2011-01-01 | 2012-03-15 |
| CERN/FP/123610/2011 | 80.000 € | 2012-04-01 | 2013-03-31 |

### 4.3.6 Team

**Project coordinator: Isabel Lopes**

| Name | Status | %of time in project |
|---|---|---|
| Alessio Mangiarotti | Researcher (LIP) | 15 |
| Alexandre Lindote | Post-Doc (LIP) | 97 |
| Américo Pereira | Technician (LIP) | 35 |
| Cláudio Silva | Post-Doc (LIP/FCT) | 95 |
| Filipa Balau | PhD student (LIP) | 50 |
| Francisco Neves | Post-Doc (LIP) | 98 |
| Isabel Lopes | Researcher (LIP/FCTUC) | 63 |
| José Pinto Da Cunha | Researcher (LIP/FCTUC) | 22 |
| Luiz de Viveiros | Post-Doc (LIP) | 100 |
| Nuno Carolino | Technician (LIP) | 25 |
| Vitaly Chepel | Researcher (LIP/FCTUC) | 30 |
| Vladimir Solovov | Researcher (LIP) | 95 |

### 4.3.7 Publications

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

- *Radioactivity Backgrounds in ZEPLIN-III*
  H.M.Araújo et al.,
  Astropart. Phys. 35(8): 495 (2012)

- *WIMP-nucleon cross-section results from the second science run of ZEPLIN-III*
  D.Akimov et al.
  Phys. Lett. B 709, 14-20 (2012)

- *Performance data from the ZEPLIN-III second science run*
  P.Majewski, V. Solovov, et al.
  JINST 7 (2012) C03044

- *Quenching factor for low-energy nuclear recoils in a plastic scintillator*
  L. Reichhart, D. Yu Akimov, H. M. Araujo, E. J. Barnes, V. A. Belov, A. A. Burenkov, V. Chepel, A. Currie, L. DeViveiros, B. Edwards, V. Francis, C. Ghag, A. Hollingsworth, M. Horn, G. E. Kalmus, A. S. Kobyakin, A. G. Kova
  Phys. Rev. C, 85, 065801 (2012)

- *An Ultra-Low Background PMT for Liquid Xenon Detectors*
  D.S. Akerib, L. deViveiros, A. Lindote, M. I. Lopes, F. Neves, C. Silva, V.N. Solovov, et al.
  Nuclear Instrum. Meth. A 703 (2013) 1–6

- *The Large Underground Xenon (LUX) Experiment*
  D.S. Akerib et al.
  Nucl. Instrum. Meth. A 704 111-126 (2013)

- *Position Reconstruction in a Dual Phase Xenon Scintillation Detector*
  V. N. Solovov, V. A. Belov, D. Yu Akimov, H. M. Araujo, E. J. Barnes, A. A. Burenkov, V. Chepel, A. Currie, L. DeViveiros, B. Edwards, C. Ghag, A. Hollingsworth, M. Horn, G. E. Kalmus, A. S. Kobyakin, A. G. Kovalenko, V. N
  IEEE Trans. Nucl. Sci., 59, 3286 (2012)

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

- *Resonance neutron-capture cross sections of stable magnesium isotopes and their astrophysical implications*
  C. Massimi et al (N TOF Collaboration)
  Phys. Rev. C, 85, 044615 (2012)

- *Measurement and resonance analysis of the Np-237 neutron capture cross section*
  C. Guerrero et al (N TOF Collaboration)
  Phys. Rev. C, 85, 044616 (2012)

- *Measurement of resolved resonances of Th-232(n, gamma) at the n_TOF facility at CERN*
  F. Gunsing et al. (n TOF Collaboration)
  Phys. Rev. C, 85, 064601 (2012)

- *Neutron-induced fission cross section measurement of U-233, Am-241 and Am-243 in the energy range 0.5 MeV <= E-n <= 20 MeV at n_TOF at CERN*
  F. Belloni et al (N TOF Collaboration)
  Phys. Scr., T150, 014005 (2012)

- *Neutron-induced fission cross section of Cm-245: New results from data taken at the time-of-flight facility n_TOF*
  M. Clavani et al (N TOF Collaboration)
  Phys. Rev. C, 85, 034616 (2012)

**International Conference Proceedings**

- *After LUX: The LZ Program*
  D.C. Malling et al.
  Conference proceedings from APS DPF 2011 (accepted)

- *Position Reconstruction in a Dual Phase Xenon Scintillation Detector*
  V. N. Solovov, V. A. Belov, D. Yu Akimov, H. M. Araujo, E. J. Barnes, A. A. Burenkov, V. Chepel, A. Currie, L. DeViveiros, B. Edwards, C. Ghag, A. Hollingsworth, M. Horn, G. E. Kalmus, A. S. Kobyakin, A. G. Kovalenko, V. N
  2011 IEEE NUCLEAR SCIENCE SYMPOSIUM AND MEDICAL IMAGING CONFERENCE (NSS/MIC), ISSN 1082-3654, 1226 (2011)

**Internal Notes**

- *Optimization of the source holder and collimator for the 137Cs Calibration*
  A Lindote and V. Solovov
  Internal LUX Collaboration Note

- *Alpha rate versus time after 2nd Rn Injection*
  Luiz de Viveiros, Claudio Silva, Vladimir Solovov
  Internal LUX Collaboration Note

- *Background alpha rate from 210Pb*
  A. Lindote and F. Neves
  Internal LUX Collaboration Note

- *RQ1s Compatibility Issues*
  V. Solovov, A. Lindote, F. Neves, C. Silva,
  Internal LUX Collaboration Note

- *Run02 Purification Combined Muon and Alpha Data*
  C.H. Faham, D. Mailing, J. Chapman, Luiz de Viveiros
  Internal LUX Collaboration Note

- *S2 Position Reconstruction of Background Data*
  Vladimir Solovov
  Internal LUX Collaboration Note

- *Alpha signals from the gate region*
  Vladimir Solovov
  Internal LUX Collaboration Note

- *Electron Lifetime using Mercury - Part 2 - Applying the technique to background datasets*
  Luiz de Viveiros, Claudio Silva, Vladimir Solovov
  Internal LUX Collaboration Note

- *Electron Lifetime using Mercury - Using reconstruction techniques to overcome the thresholding problem*
  Claudio Silva, Luiz de Viveiros and Vladimir Solovov
  Internal LUX Collaboration Note

- *Electron Lifetime using Mercury - Part 3 - Convergence of Alphas and Gammas*
  Luiz de Viveiros, Claudio Silva, Vladimir Solovov
  Internal LUX Collaboration Note

- *Energy resolution of the alpha peaks*
  Claudio Silva, Luiz de Viveiros and Vladimir Solovov
  Internal LUX Collaboration Note

- *Liquid Nitrogen ODH for the LUX Davis Campus Laboratory Program*
  Luiz Viveiros
  Internal LUX Collaboration Note

- *Electron Lifetime using Mercury - Part 4 - Validation of the Mercury Reconstruction*
  Luiz de Viveiros, Claudio Silva, Vladimir Solovov
  Internal LUX Collaboration Note

- *Electron Lifetime using Mercury*
  Luiz de Viveiros, Claudio Silva, Vladimir Solovov
  Internal LUX Collaboration Note

- *Liquid Nitrogen System Procedure*
  F. Neves
  LUX Critical Procedure Document

- *Energy Resolution in LUX Detector*
  Cláudio Silva
  Internal LUX Collaboration Note

### 4.3.8 Presentations

**Oral presentations in international conferences**

- *The LUX Dark Matter Detector*
  presented by Francisco Neves
  12th Pisa Meeting on Advanced Detectors — La Biodola, Isola d´Elba, Italy.
- *Searching for Dark Matter: the LUX experiment*
  presented by Luiz de Viveiros
  24th Rencontres de Blois, 27 May-1 June — Blois, France.
- *Characterization of Hamamatsu MPPC for use in liquid xenon scintillation detectors*
  presented by Vladimir Solovov
  International Workshop on New Photon-Detectors (PhotoDet 2012) — LAL Orsay, France.
- *Position Reconstruction in LUX detector*
  presented by Vladimir Solovov
  14th International Workshop on Radiation Imaging Detectors (iWoRID 2012) — Figueira da Foz, Portugal.
- *The LUX Dark Matter Experiment*
  presented by Isabel Lopes
  20th International Conference on Supersymmetry and Unification of Fundamental Interactions, SUSY2012 — Peking University, Beijing, China.
- *The LUX Dark Matter Experiment*
  presented by Isabel Lopes
  12th International Symposium on Radiation Physics, 7-12 October 2012 — Rio de Janeiro, Brasil.
- *The LUX Experiment: status and future plans*
  presented by Alexandre Lindote
  Particle Physics and Cosmology 2012 (PPC 2012), 5-9 November, 2012 — Seul, South Korea.
- *The LUX Experiment: status and future plans*
  presented by Francisco Neves
  DISCRETE 2012: Thrid Symposium on Prospects in the Physics of Discrete Symmetries — Lisbon, Portugal.
- *The LUX Experiment: status and future plans*
  presented by Alexandre Lindote
  New Worlds in Particle and Astroparticle Physics Workshop — Lisboa, Portugal.

**Presentations in national conferences**

- *Results from LUX Surface Run*
  presented by Francisco Neves
  Jornadas do LIP 2012 — Lisboa, Portugal.
- *Low amplitude signal detection techniques in two-phase xenon detectors*
  presented by Filipa Balau
  Jornadas do LIP 2012 — Lisboa, Portugal.
- *LUX experiment: an overview*
  presented by Alexandre Lindote
  Jornadas do LIP 2012 — Lisboa, Portugal.
- *Detection of liquid xenon scintillation using MPPCs (Hamamatsu)*
  presented by Filipa Balau
  Fisica 2012 — Aveiro, Portugal.
- *GEM operation in double-phase xenon*
  presented by Filipa Balau
  Fisica 2012 — Aveiro, Portugal.
- *Detection of Ultraviolet Light with Silicon Photomultipliers (SiPM) at Low Temperature*
  presented by Filipa Balau
  1st IDPASC PhD Students Workshop — Coimbra, Portugal.

**Oral presentations in international meetings**

- *Detection of Ultraviolet Light with Silicon Photomultipliers (SiPM) at Low Temperature*
  presented by Francisco Neves
  Digital Counting IDPASC Photosensors for Extreme Low Light Levels — Lisboa, Portugal.

**Oral presentations in collaboration meetings**

- *Liquid N2 distribution system*
  presented by Luiz de Viveiros
  LUX Collaboration Meeting — Santa Barbara, CA, USA.
- *The LN2 System*
  presented by Luiz de Viveiros
  LUX Collaboration Meeting — Santa Barbara, CA, USA.
- *Slow control: updates for Run3*
  presented by Alexandre Lindote
  LUX Collaboration Meeting — Yale University, New Haven, CT, USA.
- *Event reconstruction in LUX detector*
  presented by Cláudio Silva
  LUX Collaboration Meeting — Yale University, New Haven, CT, USA.
- *The Threshold Effect in LUX*
  presented by Cláudio Silva
  LUX Collaboration Meeting — Yale University, New Haven, CT, USA.
- *The LN2 System: present status*
  presented by Alexandre Lindote
  LUX Collaboration Meeting — Yale University, New Haven, CT, USA.
- *Long term data taking*
  presented by Alexandre Lindote
  LUX Collaboration Meeting — Yale University, New Haven, CT, USA.
- *Estimating Corrections and Efficiencies*
  presented by Alexandre Lindote
  LUX Collaboration Meeting, Yale, 12-13 June 2012 — Yale University, New Haven, CT, USA.
- *LN2 system and slow control*
  presented by Francisco Neves
  LUX Collaboration Meeting — Lead, SD, USA.
- *Analysis Overview: from Run 2 to Run 3*
  presented by Luiz de Viveiros
  LUX Collaboration Meeting, 20-21 October 2012 — Lead, SD USA.
- *Low-Energy Events and Pulse Finding*
  presented by Luiz de Viveiros
  LUX Collaboration Meeting, 20-21 October 2012 — Lead, SD, USA.

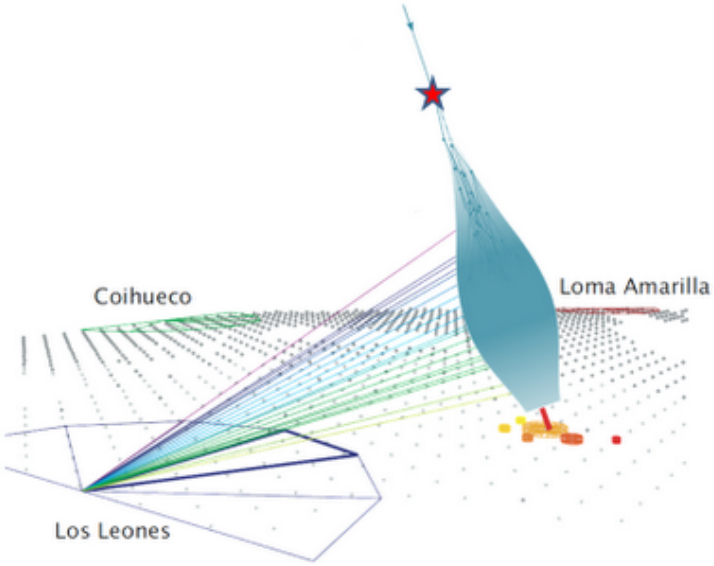
### 4.3.9 Project Summary

| | number |
|---|---|
| Articles in international journals (with direct contribution from LIP members) | 7 |
| Articles in international journals (with indirect contribution from LIP members) | 5 |
| International Conference Proceedings | 2 |
| Internal Notes | 16 |
| Oral presentations in international conferences | 9 |
| Presentations in national conferences | 6 |
| Oral presentations in international meetings | 1 |
| Oral presentations in collaboration meetings | 11 |

## 4.4 High Energy Cosmic Rays

### 4.4.1 Resumo

As actividades do LIP na área dos Raios Cósmicos de Energia Extrema continuaram, em 2012, a centrar-se na participação no Observatório Pierre Auger (Auger). Este ano intensificaram-se as actividades de R&D com vista à futura instalação de novos detectores no Observatório.
O Observatório Pierre Auger é uma colaboração internacional de 17 países que estuda os raios cósmicos de energia extrema, e procura dar resposta a algumas das questões mais fascinantes da ciência actual. O observatório é o maior detector de raios cósmicos do mundo e está situado em Malargüe, na província de Mendoza na Argentina. Cobre uma área de 3000 km$^2$ e está em operação desde 2003. Combina as técnicas de amostragem dos chuveiros de raios cósmicos que chegam à superfície da Terra e de observação, em noites sem lua, da luz ultra-violeta emitida na interacção destes chuveiros com a atmosfera. Os resultados obtidos no fluxo de partículas para energias superiores a 6x10ˆ19 eV estão em concordância com a designada supressão GZK, devida à interacção a Radiação Cósmica de Fundo. As direcções de chegada dos raios cósmicos de maior energia indicam uma correlação marginal com Galáxias com núcleos activos (AGNs). Este resultado, que necessita um escrutínio aprofundado, pode ser a solução para o problema da origem dos raios cósmicos extra-galácticos.
Os resultados de Auger dão novas contribuições e levantam novas perplexidades no campo da física de partículas. A secção eficaz protão-ar foi medida para energias de cerca de 10ˆ18 eV (sqrt(s) = 57 TeV) e apresenta um acordo notável com a extrapolação dos resultados recentes do LHC para protão-protão a energias do centro de massa de 7 TeV. Contudo, os resultados da evolução com a energia da profundidade do ponto em que o chuveiro atinge o máximo número de partículas (Xmax) não estão de acordo com as expectativas. O mesmo acontece com o número de muões medido à superfície da Terra que está em claro desacordo com as previsões dos modelos de interacção hadrónica. Um debate intenso na interpretação destes resultados está em curso, nomeadamente para saber se estamos em presença de uma modificação da composição dos raios cósmicos primários ou de uma mudança na natureza das interacções hadrónicas, em particular um aumento rápido da secção eficaz. Não existe actualmente uma explicação simples!
Portugal tornou-se membro do Observatório Pierre Auger em Março de 2006. Auger mostrou ser o ambiente ideal para o enquadramento de estudantes aos vários níveis (primeiro, segundo e terceiro ciclo) e com vários perfis de formação. É também um ambiente favorável à colaboração próxima entre físicos teóricos e experimentais. A participação Portuguesa no Observatório Pierre Auger está centrada na exploração da componente de física de partículas que estes acontecimentos de energia extrema nos podem revelar. É um objectivo muito exigente que passa pela compreensão detalhada do detector, pela introdução de novas variáveis de análise que permitam uma melhor caracterização do desenvolvimento dos chuveiros, pelo estudo e desenvolvimento de modelos teóricos que




Auger: LIP works on several aspects of Auger, from the phenomenology of the first interaction on the top of the atmosphere, to R&D for new muon detectors and optical detectors. The analysis are centred in shower development and hadronic interaction studies and the search for exotic physis.

integrem todos os dados existentes e, em particular, os resultados que já começaram a ser revelados no LHC.
Os primeiros resultados obtidos pelo Observatório Pierre Auger acentuaram o interesse da comunidade de raios cósmicos na exploração da física de partículas nesta escala de energias. Em 2012, uma parte significativa do trabalho do grupo centrou-se no estudo da utilização de RPCs - Resistive Plate Chambers - em ambiente exterior para experiências de raios cósmicos, e, em particular, da sua possivel aplicação em Auger.

### 4.4.2 Abstract

The LIP activities in the area of high energy cosmic rays continued, in 2012, centred in the Participation in the Pierre Auger Observatory (Auger). R&D activities in view of future Auger upgrades were increased.
The Pierre Auger Observatory is a worldwide collaboration of 17 countries which studies the cosmic rays of extreme energy and seeks to answer some of the most fascinating questions of today´s science. The Observatory, the world´s largest cosmic ray detector, covering an area of 3000 km2 in Malargüe, province of Medonza, Argentina is in operation since 2003. It combines the sampling of air showers arriving at the Earth surface with the observation, in moonless nights, of the UV light emitted in the interaction of cosmic ray showers with the atmosphere. Its results for the particle flux above 6x10ˆ19 eV are in agreement with the so-called GZK cut-off, a suppression in the yield of protons above this threshold due to interaction with the photons from the cosmic microwave background. The arrival direction measurements by the Auger collaboration give a marginal indication that the direction of extremely high-energy cosmic rays might be correlated with the active galatic nuclei (AGNs); this result, which needs deeper scrutiny, might be the solution to the problem of the generation of extragalactic cosmic rays.
The Auger data also gave new insights and raised new puzzles in the field of particle physics. Proton-air cross sections were measured at energies as large as 10ˆ18 eV (sqrt(s) $\approx$ 57 TeV) showing a remarkable agreement with the extrapolation of recent LHC measurements for proton-proton (sqrt(s) $\approx$ 7 TeV). However, the results on the evolution with energy of the depth in the atmosphere at which the number of particles in the shower reaches its maximum (Xmax) are not in line with what was expected. Furthermore, the number of muons in air showers measured at ground is in clear disagreement with model predictions. An intense debate on whether these measurements indicate a change in composition, i.e., in the nature of primary cosmic ray particles, or a deep change in the nature of hadronic interactions, namely a rapid increase in the proton-proton cross-section with energy, is currently taking place. No simple explanation works.
Portugal has joined the Pierre Auger Observatory in March 2006. Auger has demonstrated to be an ideal environment for students at several levels (first, second and third cycle) and with different formation profiles. It´s also a favourable environment to the close collaboration between theoretical and experimental physicists. The Portuguese participation in the Pierre Auger Observatory is centred in the exploitation of the particle physics component that these extreme energy events can reveal. It´s a very demanding goal which involves the detailed understanding of the detector, the introduction of new analysis variables that allow a better characterization of the development of the air showers, the study and development of theoretical models that integrate all the existing data and, in particular, the results that have already started to be revealed in the LHC.
The results obtained by the Pierre Auger Observatory have increased the interest in the community of cosmic rays in the exploitation of particle physics in this scale of energies. In 2012, a large part of the effort of the group was centred in the study of the possibility of using RPC - Resistive Plate Chambers - detectors in outdoor cosmic rays experiments, and its feasibility as part of a future Auger upgrade.

### 4.4.3 Objectives

The main lines in 2012 were:
Task 1- Tools and studies for light propagation and detection
a) Analysis of laser shots at various distances from the telescopes, to characterize light scattering and its dependence on atmospheric conditions.
b) Analysis of Cerenkov rich showers, using the 3D shower simulation tool and its comparison to selected High Elevation Auger Telescopes (HEAT) data events.
Task 2- Measurement of electromagnetic and muonic shower profiles
a) Systematic comparison of the reconstruction of longitudinal light profiles using the classical Gaisser Hillas variables and the new shape variables.
b) Measurement of the light profile shape variables in a selected sample of HEAT data events and its interpretation in terms of composition and cross-section.
c) Study of the same variables to characterize the electromagnetic and muonic profile using different hadronic models.

d) Development of an innovative and more precise technique to obtain the muon production depth and the total muon size of each event, by a global fit to the time distribution of signals in the SD.
e) Study of the event-by-event relation between all the electromagnetic and muonic variables.
Task 3 - Search for Exotic and Rare Events
a) Keeping the Auger exotica zoo updated
b) Improving the SD analysis in the Cusca framework for identifying exotic events in Auger
Task 4 - Theory and Models for High Energy Interactions
a) Exploring the possible particle physics interpretation of Auger data
Task 5 – R&D for the next generation of high energy cosmic ray experiments
a) the improvement of photo detection by developing SiPM applications and designing the associated readout;
b) the enhancement of muon detection capabilities by developing autonomous RPCs able to operate in open field conditions.
c) Mantain the small cosmic ray test facility for RPCs and Silicon photo-sensors in Lisbon.

### 4.4.4 Achievements

Task 1
The implementation of both Fluorescence and Cerenkov radiation in the 3D cosmic ray simulation was validated by comparing with real events dominated by each of the two processes.
Task 2
The average electromagnetic shower profile was shown to be directly related to the average primary mass of cosmic rays in each energy interval, when assuming a given hadronic interaction model, and to be able to separate the models without assumptions on primary composition. The application to data has started.
The global fit to the time distribution of signals in the SD, has been shown to increase the resolution on the maximum of muon production depth, in addition to decreasing the statistical uncertainties, by using more events. After full tests over different simulations, the measurement in data is starting.
A new technique to measure the absolute muon numbers is being developed, to be cross-checked with the existing methods and to be extended to provide also the event-by-event fluctuations, as a new observable for mass composition and hadronic interaction model analysis.
Task 3
While keeping the responsibilities for the Auger exotica zoo, a new analysis looking for structure in SD events is being developed, with detailed studies and parameterizations of the natural fluctuations to be used as reference for the evaluation of more extreme cases.
Task 4
A benchmark for the future Auger upgrades has been derived from the analysis of the present information on mass composition. We have shown that the most sensitive variables to distinguish a composition transition from an abrupt change in high energy interactions is through the analysis of the muon number at ground and its fluctuations.
Task 5
A school focusing on SiPM applications was organized at LIP, in the framework of IDPASC.
The tests of autonomous RPCs continued in both Coimbra and Lisbon, showing that they can work for long periods in a stable way. A detailed simulation, based on Geant4, was developed to study the best way to include them in Auger. By placing them under the Auger SD stations, which serve as shielding, it is possible to isolate muon signals with a purity of 50%. A collaboration with other Auger groups was established for the development of a full proposal and future tests.

### 4.4.5 Sources of Funding

| Code | Funding | Start | End |
|---|---|---|---|
| CERN/FP/116330/2010 | 127.000 € | 2011-01-01 | 2012-01-31 |
| EPLANET 246806 | 10.800 € | 2011-01-01 | 2014-12-31 |
| CERN/FP/123611/2011 | 280.000 € | 2012-02-01 | 2014-01-31 |
| Particle Physics at 100 TeV AFR PhD Gran | 114.660 € | 2012-09-01 | 2015-08-31 |
| ASPERA/0001/2010 | 150.000 € | 2012-09-01 | 2015-08-31 |

### 4.4.6 Team

**Project coordinator: Mário Pimenta**

| Name | Status | %of time in project |
|---|---|---|
| Alberto Blanco | Researcher (LIP) * | 7 |
| Alessandro de Angelis | Researcher | 22 |
| Américo Pereira | Technician (LIP) | 5 |
| Bernardo Tomé | Researcher (LIP) | 67 |
| Catarina Espírito Santo | Researcher (LIP) | 81 |
| Eva Santos | PhD student (LIP/FCT) | 100 |
| Francisco Diogo | PhD student (LIP) | 100 |
| Gonçalo Guiomar | Student (LIP) | 4 |
| João Espadanal | PhD student (LIP/FCT) | 100 |
| Jorge Dias de Deus | Researcher (LIP/IST) | 15 |
| Jorge Romão | Researcher (LIP/IST) | 15 |
| José Micael Oliveira | PhD student (LIP) * | 96 |
| José Milhano | Researcher (LIP/IST) | 15 |
| Liliana Apolinário | PhD student (LIP) | 15 |
| Lorenzo Cazon | Researcher (LIP) | 82 |
| Luís Mendes | Student (LIP) * | 43 |
| Mário Pimenta | Researcher (LIP/IST) | 64 |
| Miguel Ferreira | Technician (LIP) | 43 |
| Patrícia Gonçalves | Researcher (LIP) | 50 |
| Pedro Abreu | Researcher (LIP/IST) | 65 |
| Pedro Assis | Post-Doc (LIP/FCT/IST) | 65 |
| Pedro Brogueira | Researcher (LIP/IST) | 15 |
| Raul Sarmento | Post-Doc (LIP) * | 6 |
| Ruben Conceição | Post-Doc (LIP/FCT) | 100 |
| Sofia Andringa | Researcher (LIP) | 75 |
| Thomas Schweizer | | 5 |

### 4.4.7 Publications

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

- *The muonic longitudinal shower profiles at production*
  S. Andringa, L. Cazon, R. Conceição, M. Pimenta
  Astroparticle Physics 35 (2012) 821-827

- *Proton-proton cross-sections: the interplay between density and radius*
  R. Conceicao, J. Dias de Deus and M. Pimenta
  Nucl.Phys. A888 (2012) 58-66

- *A model for the transport of muons in extensive air showers*
  L. Cazon, R. Conceição, M. Pimenta, E. Santos
  Astroparticle Physics, Volume 36, Issue 1, August 2012, Pages 211-223

- *The non-linearity between $< ln\ A >$ and $< X\text{-}max >$ induced by the acceptance of fluorescence telescopes*
  R. Ulrich, L. Cazon
  Astropart Phys., 38, 41 (2012)

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

- *Ultra-High Energy Neutrinos at the Pierre Auger Observatory*
  The Pierre Auger Collaboration
  Advances in High Energy Physics, in press, 2012 (accepted)

- *Description of Atmospheric Conditions at the Pierre Auger Observatory using the Global Data Assimilation System (GDAS)*
  The Pierre Auger Collaboration
  Astroparticle Physics, 35 (2012), 591-607

- *A search for anisotropy in the arrival directions of ultra high energy cosmic rays recorded at the Pierre Auger Observatory*
  The Pierre Auger Collaboration
  JCAP 04 (2012) 040

- *Search for point-like sources of ultra-high energy neutrinos at the Pierre Auger Observatory and improved limit on the diffuse flux of tau neutrinos*
  The Pierre Auger Collaboration
  The Astrophysical Journal Letters, 755 (2012) L4

- *Measurement of the proton-air cross-section at sqrt(s) = 57 TeV with the Pierre Auger Observatory*
  The Pierre Auger Collaboration
  Phys. Rev. Lett. 109, 062002 (2012)

- *The Rapid Atmospheric Monitoring System of the Pierre Auger Observatory*
  The Pierre Auger Collaboration
  JINST 7 (2012) P09001

- *Large scale distribution of arrival directions of cosmic rays detected above 10ˆ18 eV at the Pierre Auger observatory*
  Pierre Auger Collaboration (514 authors)
  Astrophys. J. Suppl. Ser., 203, 34 (2012)

- *Antennas for the Detection of Radio Emission Pulses from Cosmic-Ray induced Air Showers at the Pierre Auger Obervatory*
  Pierre Auger Collaboration (516 authors)
  J. Instrum., 7, P10011 (2012)

- *Search for signatures of magnetically-induced alignment in the arrival directions measured by the Pierre Auger Observatory*
  Pierre Auger Collaboration (499 authors)
  Astroparticle Physics 35 (2012) 354

- *The Lateral Trigger Probability function for the Ultra-High Energy Cosmic Ray Showers detected by the Pierre Auger Observatory (vol 35, pg 266, 2011)*
  Pierre Auger Collaboration (494 authors)
  Astropart Phys., 35, 681 (2012)

- *A Search for Point Sources of EeV Neutrons*
  Pierre Auger Collaboration (510 authors)
  Astrophys. J., 760, 148 (2012)

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

**International Conference Proceedings**

- *FAMOUS: A prototype silicon-photomultiplier telescope for the fluorescence detection of ultra-high-energy cosmic rays*
  Markus Lauscher, Pedro Assis, Pedro Brogueira, Miguel Ferreira, Thomas Hebbeker, Luís Mendes, Christine Meurer, Lukas Middendorf, Tim Niggemann, Mário Pimenta, Johannes Schumacher, Maurice Stephan
  Proceedings of SPIE conference 8460, Biosensing and Nanomedicine (San Diego, California, United States)

- *Studying the nuclear mass composition of Ultra-High Energy Cosmic Rays with the Pierre Auger Observatory*
  L. Cazon, for the Pierre Auger Collaboration
  arXiv:1201.6265v1 [astro-ph.HE] (Proceedings of the 12th International Conference on Topics in Astroparticle and Underground Physics, TAUP 2011, Munich, Germany) PTS 1-6, 375, 052003 (2012)

**Collaboration notes with internal referee**

- *On the joint interpretation of Xmax and Nmu data*
  M. Oliveira, L. Cazon, R. Conceição, M. Pimenta
  GAP-2011-118

- *The Non-Linearity Between lnA and Xmax Induced by the Acceptance of Fluorescence Telescopes*
  Lorenzo Cazon, Ralf Ulrich
  GAP-2012-015

- *3D simulation of EAS for the FD: validation with a fluorescence rich data sample*
  J. Espadanal, P. Gonçalves, M. Pimenta
  GAP-2012-039

- *Consistency between Xmax and Xmumax as a way to test hadronic models*
  L. Cazon, R. Conceição, C. Espirito-Santo, M. Oliveira, M. Pimenta, A. Bueno, D. Garcia-Gamez
  GAP-2012-068

- *Measurement of the Number of Muons in Inclined Showers with the Pierre Auger Observatory (Master thesis)*
  M. Oliveira
  GAP2012_099

- *A guide to explore the Pierre Auger Observatory public data*
  P. Abreu, S. Andringa, F. Diogo, M.C. Espirito Santo
  GAP2012-137

### 4.4.8 Presentations

**Oral presentations in international conferences**

- *Muon measurements with Auger*
  presented by Lorenzo Cazon
  QCD at Cosmic Energies V — Paris, France.

- *Extensive Air Showers: smoking guns and the backbone*
  presented by Lorenzo Cazon
  International Symposium on Very High Energy Cosmic Ray Interactions (ISVHECRI 2012) — Berlin, Germany.

- *The interplay between the electromagnetic and the muonic longitudinal profile at production*
  presented by Ruben Conceição
  International Symposium on Very High Energy Cosmic Ray Interactions (ISVHECRI 2012) — Berlin, Germany.

- *O Observatório Pierre Auger*
  presented by Pedro Abreu
  2ª Conferência de Física da CPLP — Rio de Janeiro, Brasil.

- *Outreach in particle and astroparticle physics in Portugal*
  presented by Catarina Espírito Santo
  From Higgs to Dark Matter — Geilo, Norway.

**Poster presentations in international conferences**

- *Study of RPCs for autonomous stations in cosmic ray research*
  presented by Luís Lopes
  XI Workshop on Resistive Plate Chambers and Related Detectors — INFN - Laboratori Nazionali di Frascati, Frascati, Italy, .

**Presentations in national conferences**

- *Auger: uma janela para o Universo extremo*
  presented by Mário Pimenta
  Jornadas do LIP 2012 — Lisboa, Portugal.

- *Light and Exotics at Auger*
  presented by João Espadanal
  Jornadas do LIP 2012 — Lisboa, Portugal.

- *Electromagnetic and muonic cosmic ray shower profiles*
  presented by Francisco Diogo
  Jornadas do LIP 2012 — Lisboa, Portugal.

- *Auger 2015*
  presented by Pedro Assis
  Jornadas do LIP 2012 — Lisboa, Portugal.

- *Medição da secção eficaz de raios cósmicos de alta energia*
  presented by Francisco Diogo
  18ª Conferência Nacional de Física — Aveiro, Portugal.

**Oral presentations in international meetings**

- *Air shower Observables*
  presented by Lorenzo Cazon
  Particle Physics with High Energy Cosmic Rays — IST, Lisboa, Portugal.

- *Longitudinal Shower Profiles*
  presented by Sofia Andringa
  Particle Physics with High Energy Cosmic Rays — IST, Lisboa, Portugal.

- *Composition vs Hadronic interactions: open scenarios*
  presented by Ruben Conceição
  Particle Physics with High Energy Cosmic Rays — IST, Lisboa, Portugal.

- *Data acquisition*
  presented by Pedro Assis
  Second IDPASC School — Udine, Italy.

- *Mystery in the Pampa: the Xmax/Nmu puzzle*
  presented by Mário Pimenta
  Astroparticle Physics Workshop, IFSC - Univ. S. Paulo — São Carlos, Brasil.

- *Universal features (and variability) of extensive air showers*
  presented by Sofia Andringa
  New Worlds in Particle and Astroparticle Physics — Pavilhão do Conhecimento, Lisboa.

- *The quest for the Ultra High Energy frontier with Cosmic Rays - Particle physics beyond the 100 TeV scale*
  presented by Lorenzo Cazon
  New Worlds in Particle and Astroparticle Physics — Pavilhão do Conhecimento, Lisboa.

**Oral presentations in collaboration meetings**

- *Muon Production Depth*
  presented by Lorenzo Cazon
  Particle Physics @ Auger — IST, Lisboa, Portugal.

- *CUSCA: Searching for exotics@Auger*
  presented by Catarina Espírito Santo
  Particle Physics @ Auger — IST, Lisboa, Portugal.

- *SiPM R&D*
  presented by Pedro Assis
  Particle Physics @ Auger — IST, Lisboa, Portugal.

- *Towards a proposal for the installation of RPCs @ Auger*
  presented by Bernardo Tomé
  Particle Physics @ Auger — IST, Lisboa, Portugal.

- *RPC R&D @ LIP - Present status*
  presented by Mário Pimenta
  Pierre Auger Collaboration Meeting — Malargüe, Argentina.

- *Cusca status report*
  presented by Catarina Espírito Santo
  Pierre Auger Collaboration Meeting — Malargüe, Argentina.

- *Consistency between Xmax and X^mu_max as a way to test hadronic models*
  presented by Lorenzo Cazon
  Pierre Auger Collaboration Meeting — Malargüe, Argentina.

- *Review on Multivariate analyses*
  presented by Ruben Conceição
  Pierre Auger Collaboration Meeting — Malargüe, Argentina.

- *A simulation of RPCs using Geant4 in the Auger Offline*
  presented by Bernardo Tomé
  First Internal review meeting on RPC R&D for Auger — Lisboa, Portugal.

- *RPC for Auger R&D*
  presented by Luís Lopes
  First internal review meeting on RPC R&D for Auger — Lisboa, Portugal.

- *Monitoring and Readout for RPCs*
  presented by Pedro Assis
  First internal review meeting on RPC R&D for Auger — Lisboa, Portugal.

- *Muon Measurements with RPCs*
  presented by Lorenzo Cazon
  First internal review meeting on RPC R&D for Auger — Lisboa, Portugal.

- *A fit to the MPD in the time domain*
  presented by Eva Santos
  First internal review meeting on RPC R&D for Auger — Lisboa, Portugal.

- *Reconstruction method for theta=60 degree*
  presented by José Micael Oliveira
  First internal review meeting on RPC R&D for Auger — Lisboa, Portugal.
- *Study of Cherenkov Rich Events with the 3D simulation*
  presented by João Espadanal
  Pierre Auger Collaboration Analysis Meeting — Prague, Czech Republic.
- *USP in HEAT*
  presented by Francisco Diogo
  Pierre Auger Collaboration Analysis Meeting — Prague, Czech Republic.
- *Results on the time domain fit of the MPD*
  presented by Eva Santos
  Pierre Auger Collaboration Analysis Meeting — Prague, Czech Republic.
- *Towards the determination of the number of muons at 60 degrees*
  presented by José Micael Oliveira
  Pierre Auger Collaboration Analysis Meeting — Prague, Czech Republic.
- *Consistency between Xmax and Xmumax as a way to test hadronic models*
  presented by Lorenzo Cazon
  Pierre Auger Collaboration Analysis Meeting — Prague, Czech Republic.
- *Status of the R&D on RPCs/Muons*
  presented by Mário Pimenta
  Pierre Auger Collaboration Analysis Meeting — Pargue, Czech Republic.
- *Exotica at LIP*
  presented by Catarina Espírito Santo
  Pierre Auger Collaboration Analysis Meeting — Prague, Czech Republic.
- *Auger 2015 Physics Case*
  presented by Mário Pimenta
  Second MARTA Progress Meeting — LIP, Lisboa.
- *Requirements for Muon Detection*
  presented by Ruben Conceição
  Second MARTA Progress Meeting — LIP, Lisboa.
- *Measurement of the Number of Muons at 60 degree*
  presented by José Micael Oliveira
  Second MARTA Progress Meeting — LIP, Lisboa.
- *Reconstruction of Xmu_max*
  presented by Eva Santos
  Second MARTA Progress Meeting — LIP, Lisboa.
- *First Results on the New RPC Prototype*
  presented by Paulo Fonte
  Second MARTA Progress Meeting — LIP, Lisboa.
- *RPC Readout*
  presented by Pedro Assis
  Second MARTA Progress Meeting — LIP, Lisboa.
- *MARTA Simulation*
  presented by Bernardo Tomé
  Second MARTA Progress Meeting — LIP, Lisboa.
- *MPD with MARTA*
  presented by Lorenzo Cazon
  Second MARTA Progress Meeting — LIP, Lisboa.

- *Combined Analyses RPC+Tank*
  presented by Raul Sarmento
  Second MARTA Progress Meeting — LIP, Lisboa.
- *Hybrid Analyses with MARTA*
  presented by Sofia Andringa
  Second MARTA Progress Meeting — LIP, Lisboa.
- *MARTA simulations*
  presented by Bernardo Tomé
  Pierre Auger Collaboration Meeting — Malargüe, Argentina.
- *Shower Shape Analysis with Extended FoV*
  presented by Francisco Diogo
  Pierre Auger Collaboration Meeting — Malargüe, Argentina.
- *Analysis of the average shape of FD profiles*
  presented by Francisco Diogo
  Pierre Auger Collaboration Meeting — Malargüe, Argentina.
- *Average and RMS of the number of muons at 60 degrees*
  presented by José Micael Oliveira
  Pierre Auger Collaboration Meeting — Malargüe, Argentina.
- *Muon production and string percolation effects in cosmic rays at the highest energies*
  presented by Ruben Conceição
  Pierre Auger Collaboration Meeting — Malargüe, Argentina.
- *Update on Double Shells and CUSCA*
  presented by Catarina Espírito Santo
  Pierre Auger Collaboration Meeting — Malargüe, Argentina.
- *Auger Outreach at LIP*
  presented by Pedro Assis
  Pierre Auger Collaboration Meeting — Malargüe, Argentina.
- *Progress on the time domain fit of the MPD*
  presented by Eva Santos
  Pierre Auger Collaboration Meeting — Malargüe, Argentina.
- *Sensitivity to primary composition and hadronic models from average shape of high energy cosmic ray shower profiles*
  presented by Sofia Andringa
  Pierre Auger Collaboration Meeting — Malargüe, Argentina.
- *Status of MARTA*
  presented by Bernardo Tomé
  Pierre Auger Collaboration Meeting — Malargüe, Argentina.
- *On the Auger 2015 physics case*
  presented by Mário Pimenta
  Pierre Auger Collaboration meeting — Malargüe, Argentina.
- *Towards requirements for muon measurements*
  presented by Ruben Conceição
  Pierre Auger Collaboration meeting — Malargüe, Argentina.

**Seminars**

- *Particle Physics With High Energy Cosmic Rays*
  presented by Mário Pimenta
  Seminar at University of Nova Gorica — Nova Gorica, Eslovenia.

- *Muon detection @ Auger*
  presented by Mário Pimenta
  Seminar at Centro Brasileiro de Pesquisas Físicas — Rio de Janeiro, Brasil.

- *Auger 2015*
  presented by Mário Pimenta
  LIP Seminars — LIP, Lisboa.

- *The Pierre Auger Observatory - detection of high energetic atmospheric phenomena:elves and other results*
  presented by Catarina Espírito Santo
  — Physics Department, Bergen University.

### 4.4.9 Academic Training

**PhD Theses**

- *Cosmic Rays at the Ankle: Auger South Enhancements*
  Eva Santos, (on-going)

- *Study of hadronic interactions with the hybrid detector of the Pierre Auger Observatory*
  João Espadanal, (on-going)

- *Medição da secção eficaz de raios cósmicos de alta energia no Observatório Pierre Auger*
  Francisco Diogo, (on-going)

- *Particle Physics at 100 TeV with the Pierre Auger Observatory*
  José Micael Oliveira, (on-going)

**Master Theses**

- *Measurements of the number of muons in inclined showers at the Pierre Auger Observatory*
  José Micael Oliveira, 2012-07-18

### 4.4.10 Events

- *Particle Physics @ Auger*
  Collaboration Meeting, IST - Universidade Técnica de Lisboa and University of Coimbra, 2012-01-16

- *First internal review meeting on RPC R&D for Auger*
  Collaboration Meeting, Lisboa, Portugal, 2012-06-14

- *Second MARTA progress meeting*
  Collaboration Meeting, LIP, Lisboa, 2012-10-19

### 4.4.11 Project Summary

| | number |
|---|---|
| Articles in international journals (with direct contribution from LIP members) | 4 |
| Articles in international journals (with indirect contribution from LIP members) | 12 |
| International Conference Proceedings | 2 |
| Collaboration notes with internal referee | 6 |
| Oral presentations in international conferences | 5 |
| Poster presentations in international conferences | 1 |
| Presentations in national conferences | 5 |
| Oral presentations in international meetings | 7 |
| Oral presentations in collaboration meetings | 43 |
| Seminars | 4 |
| Master Theses | 1 |
| Collaboration Meetings | 3 |

## 4.5 Space Radiation Environment and Effects

### 4.5.1 Resumo

O ambiente de radiação no Espaço é a combinação de diversas fontes: o vento solar, principalmente constituído por protões e electrões emitidos continuamente pelo sol com velocidades da ordem das centenas de km/s; os raios cósmicos galácticos, que são protões e núcleos atómicos com origem no exterior do sistema solar e , esporadicamente, os acontecimentos de Partículas Solares Energéticas (SPE) que são emissões intensas de electrões, protões e iões pelo Sol - com energias que podem atingir 1 GeV – em associação com erupções solares. Adicionalmente, os planetas com magnetosfera, como a Terra, Júpiter ou Saturno, possuem cinturas de radiação compostas por partículas aí aprisionadas. Nestas cinturas, as partículas circulam a altitudes que dependem da sua rigidez.
A superfície da terra encontra-se protegida das diversas fontes de radiação pela conjugação dos efeitos da magnetosfera e da atmosfera terrestres. A primeira deflecte ou captura as partículas de energia mais baixa e a segunda "degrada"as de energia mais elevada, bloqueando também os raios gama e raios X e grande parte do espectro UV. No exterior da magnetosfera terrestre não existe protecção natural contra a radiação, sendo o ambiente de radiação no Espaço interplanetário, e em planetas como em Marte ou a Lua, um dos maiores constrangimentos para futuras missões tripuladas.
O planeamento de missões tripuladas a Marte nas próximas décadas ou a possibilidade de um retorno de astronautas à Lua tornam ainda mais relevantes actividades como:

- o desenvolvimento de modelos que permitam descrever com detalhe, e prever com precisão, o ambiente de radiação no Espaço e em diferentes ambientes planetários do sistema solar;
- a compreensão dos efeitos da radiação, quer nas tripulações, quer nos sistemas e materiais das naves espaciais – desde os componentes EEE, aos painéis solares- assim como o desenvolvimento de técnicas de mitigação;
- a construção de detectores de radiação optimizados para ambiente espacial, de massa, volume e consumo energético reduzidos, mas que sejam resistentes às condições extremas do ambiente no Espaço.

No LIP, têm vindo a consolidar-se várias destas actividades, principalmente no contexto de contratos com a Agência Espacial Europeia (ESA), algumas deles em colaboração com outras instituições e com a indústria europeias. No âmbito de um consórcio para o desenvolvimento de modelos do ambiente radiação Marciano, de que fizeram parte o LIP e outros institutos europeus, o LIP foi responsável pelo desenvolvimento de um modelo detalhado do ambiente de radiação em Marte, baseado numa aplicação em Geant4. Este modelo, o dMEREM, *detailed Martian Energetic Radiation Environment Model*, é um modelo de referência da ESA e as suas previsões encontram-se publicadas em várias revistas internacionais. Aguarda-se a publicação das primeiras medições do ambiente de radiação à superfície de Marte, efectuadas pela missão Curiosity da NASA (em solo marciano desde agosto de 2012) para uma validação do modelo com dados reais.
A área dos efeitos biológicos da radiação no Espaço começou a ser explorada no LIP mais recentemente, com a análise dos dados públicos da Matroska, um fantoma humano a bordo da estação espacial internacional e também com uma dissertação de mestrado terminada em Novembro de 2012, sobre o cálculo das doses de radiação a que ficam sujeitos os astronautas no decurso duma missão completa à Lua.
O estudo do ambiente de radiação no Espaço não se aplica apenas a missões tripuladas, sendo essencial para a concepção dos satélites e para o planeamento de missões não tripuladas. O LIP tem-se vindo a modelizar o efeito da passagem de partículas energéticos através de componentes EEE, que podem aí depositar energia nas regiões sensíveis, originando a disrupção temporária dos circuitos. Este fenómeno é denominado SEU (Single Event Upset). O modelo desenvolvido no LIP, o CODES, é baseado em Geant4 e parte de medições efectuadas sujeitando os componentes a feixes de iões e de um conceito de volume sensível efectivo. O CODES permite descrever SEU em memórias RAM e está a ser interfaceado num ambiente integrado e de fácil utilização.
O LIP tem vindo a desenvolver trabalho e a estabelecer pontes com a indústria, com a aplicação do conhecimento sobre concepção, desenvolvimento e optimização de detectores de partículas ao desenvolvimento de detectores de radiação para o Espaço. Neste contexto, e em preparação da futura missão da ESA às Luas Geladas Jupiter, JUICE , prevista para 2022, o LIP está a preparar a optimização e construção de um monitor de radiação para electrões, fazendo parte de um consórcio internacional, com participantes da indústria e de instituições científicas.

### 4.5.2 Abstract

The particle radiation environment on Space is a combination of different sources: the solar wind, constituted by protons and electrons continuously emitted by the sun, with velocities of the orders of the hundreds of

Km/s, the galactic cosmic rays, which are protons and atoimic nuclei, with origine outside the Solar System, and, sporadically, the Solar Particle Events, which are intense solar emissions of electrons, protons and ions, with energies below ≈1GeV, which occur in association with solar flares. Additionally, around planets magnetospheres, there are radiation belts where the particles coming from the other sources of radiation remain trapped
Earth´s surface is protected from these radiation sources due to the combined effects of the magnetosphere, which deflects the charged particles with lower energy, and of the atmosphere, which "degrades"the energy of the charged particles with higher energies, also blocking gamma and X rays and a large fraction of the UV spectrum. Outside the magnetosphere there is no natural protection from these radiation sources, and the radiation environment in interplanetary space and on the surfaces of planets such as Mars (or the Moon) are an important constrain to manned missions.
Planning manned missions to Mars in the next decades or the return of astronauts to the Moon, enhance the importance of activities such as:

- the development of models to describe with detail and predict with the desirable degree of precision the radiation environment in Space and in different Solar System planetary environments.
- the understanding of the effects of radiation in crews and in spaceship systems and materials – from EEE components to solar panels – and the development of radiation effects mitigation techniques.
- the design of radiation detectors optimised for the environment in Space, with low mass, volume and power budget, that may resist the extreme conditions of the Space.

At LIP several of these activities have been taking place, mostly in the framework of contracts with the European Space Agency, in some cases in collaboration with other european instituites and with the industry. In the framework of a contract for the modeling of the radiation environment in Mars, which was wan by a consortium constituted by LIP and other European institutes, LIP was responsible for the development of a Geant4 based model for the description of the radiation environment in Mars (dMEREM). dMEREM is an ESA reference model and its predictions are published in several international magazines. The publication of the first measurements of the radiation environment at the Martian surface, performed by the Curiosity mission (on Martian soil since august 2012), are awaited for a validation of dMEREM predictions.
Studies in the area of the biological effects of radiation om Space were initiated at LIP with an analysis of the public data of the Matroska, a human phantom aboard the ISS and also with a Master Degree Thesis, which was completed in November 2012, concerning the calculation of the radiation doses to which astronauts in a complete Lunar missions are exposed.
The study of the radiation environment in Space is also fundamental for unmanned missions, since it affects spaceship and satellite systems and components.
LIP has been working on the modeling of the effects of the passage of energetic particles through EEE components, which can deposit energy in the components sensitive regions and originate a disruption of the circuit. This phenomena is known as SEU (Single Event Upset). The model developed at LIP – CODES- is a Geant4 application based on experimental measurements performed with ion beams and on the concept of effective sensitive volume. CODES enables to describe SEU in RAM memories and is currently being interfaced with an integrated and easy to use environment.
The development of radiation monitors for Space missions is an area in which LIP has been developing experience and collaborating with the industry, with the application to Space of the existing know how on design, development and optimization of particle detectors. In this context, LIP is participating in an international consortium, with institutes and with the industry, for the development of a proto-flight model of a Radiation Hard Electron Monitor for the Juice Mission, which will travel to the Jupiter Icy Moons in 2022.

### 4.5.3 Objectives

The objectives of the activity were the continuation of the ongoing activities; the CODES-III contract with ESA and the Alphasat radiation Environment and Effects Facility (AEEF) Component Technology Test-Bed (CTTB), Preparation of In-Flight Data Analysis; the preparation of the partnership for the collaboration in an international consortium for the development and demonstration phases of the "RADEM: Radiation-Hard Electron Monitor for the Jupiter Environment"for the ESA Juice mission to Jupiter; and the development of new lines of activity, as the case of radiation environment and effects studies and modelling for human spaceflight.
LIP started preparing a proposal in a consortium with RUAG (ch), EFACEC(pt), PSI (ch) and IDEAS (no) in response to an ESA Invitation to Tender for the continuation (phases B2, C and D) of the development of a radiation instrument for the JUICE mission to Jupiter, where LIP is to be co-responsible for the development

of a electron directionality detector and for the optimization of the high energy particles telescope (designed by PSI), aiming at detection of protons and ions.

### 4.5.4 Achievements

#### CODES III

The CODES III project is in a final phase of implementation of the CODES tool in an integrated and user friendly environment to be made available by ESA after the end of the contract.
In 2012, the final CODES framework was developed as a ready to use top level engineering tool to predict single event effects on EEE components. It consists of different GEANT4 modules with a user friendly web-based interface. The different modules consist of device geometry definition (including packaging and shielding), device sensitivity interpretation based on experimental test data and data analysis. CODES performance and inter-modular communication is assured by a pre-processor using TPC communication protocol. The web interface is deployed in a PHP server. All the models and the web-based interface are able to define the device geometry based on user defined parameters, such as dimensions, shielding layer and active and non active volumes.
The final integration of CODES was developed in collaboration with Cyberoffice, a portuguese company, with quarters in Porto.

#### Radiation Induced Biological effects

A line of work, covering biological effects of the radiation environment in space, was started at LIP in 2010. There is an ongoing exploratory activity concerning the analysis of the data and the simulation of a human phantom, Matroska: an ESA experimental unit aboard the international space station. LIP was invited to collaborate with the German Aerospace Center (DLR) in the scientific team exploring MATROSKA data.
Studies of the expected radiation environment and of its effects in the crews for a future Lunar mission were the subject of a Master Degree thesis with the Title "Radiation Environment and Effects in Human Spaceflight: A Lunar Mission", which was completed in November 2012.

#### Alphasat AEEF CTTB Preparation of In-Flight Data Analysis

In the "Alphasat radiation Environment and Effects Facility (AEEF) Component Technology Test-Bed (CTTB), Preparation of In-Flight Data Analysis"contract LIP was responsible for: RADFET Calibration Test Plan Definition (WP1100); RADFET Calibration Test (WP1200) and Analysis of Radiation Ground Test Data (WP2000). WP1100 and WP1200 concerned the preparation and supervision of the RADFET calibration campaign at ESA/ESTEC Cobalt-60 facility. After the irradiation phase (October 2011) and the annealing phase (January 2012), the produced data were analyzed. The analysis results were presented at the IEEE Conference RADECS 2012. In WP2000 a radiation analysis based on the CTTB topology, using radiation ground test data to predict component degradation rates for the different EEE components that will be flown in the test bed was performed. This evaluation took into account the GEO (Geosynchronous Orbit) radiation environment corresponding to the Alphasat orbit.

### 4.5.5 Sources of Funding

| Code | Funding | Start | End |
|---|---|---|---|
| ESA:223981/09/NL/PA | 150.000 € | 2009-05-01 | 2012-03-31 |
| 6403/10/NL/SFe | 50.000 € | 2011-01-17 | 2012-06-18 |
| ESA:223981/09/NL/PA/CCN03 | 20.000 € | 2012-11-01 | 2013-02-28 |

### 4.5.6 Team

**Project coordinator: Patrícia Gonçalves**

| Name | Status | %of time in project |
|---|---|---|
| Alessandro de Angelis | Researcher | 10 |
| Ana Keating | Post-Doc (LIP/FCT) | 100 |
| Bernardo Tomé | Researcher (LIP) | 10 |
| Bruno Morgado | PhD student (LIP) | 100 |
| Catarina Espírito Santo | Researcher (LIP) | 5 |
| João Sabino | Master student (LIP) | 0 |
| Mário Pimenta | Researcher (LIP/IST) | 7 |
| Miguel Ferreira | Technician (LIP) | 14 |
| Patrícia Gonçalves | Researcher (LIP) | 50 |
| Pedro Brogueira | Researcher (LIP/IST) | 5 |

### 4.5.7 Publications

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

- *Characterization of the particle radiation environment at three potential landing sites on Mars using ESA´s MEREM models*
  S. McKenna-Lawlor, P. Goncalves, A. Keating, B. Morgado, D. Heynderickx, P. Nieminen, G. Santin, P. Truscott, F. Lei, B. Foing, J. Balaz
  Icarus Magazine, Volume 218, Issue 1, March 2012, Pages 723–734 / doi:10.1016/j.icarus.2011.04.004

- *Overview of energetic particle hazards during prospective manned missions to Mars*
  Susan McKenna-Lawlor, P. Goncalves, A. Keating, G. Reitz, D. Matthiae
  Planet Space Sci., 63-64, 123 (2012) / doi:10.1016/j.pss.2011.06.017

- *Modeling the effects of low-LET cosmic rays on electronic components*
  A. Keating, P. Goncalves, M. Pimenta, P. Brogueira, A. Zadeh, E. Daly
  Radiation and Environmental Biophysics, ISSN 0301-634X, DOI 10.1007/s00411-012-0412-2

- *The impact of Mars geological evolution in high energy ionizing radiation environment through time*
  A.Keating, P.Gonçalves
  Planet Space Sci., 72, 70 (2012) - DOI:10.1016/j.pss.2012.04.009

**International Conference Proceedings**

- *Lunar Radiation Environment*
  Ana Keating, Patricia Gonçalves
  European Lunar Symposium 2012

- *Characterization of RADFET Dosimeters for the ESA ALPHASAT CTTB Experiments*
  P.Gonçalves, A.Keating, A. Trindade, P. Rodrigues, M. Ferreira, P. Assis, M. Muschitiello, B. Nickson, C. Poivey

- *Mars Radiation field and Habitability evolution through time*
  Ana Keating, Patricia Gonçalves
  EPSC2012-956

### 4.5.8 Presentations

**Oral presentations in international conferences**

- *Characterization of RADFET Dosimeters for the ESA ALPHASAT CTTB Experiments*
  presented by Patrícia Gonçalves
  Advances on Space Radiation and Plasma Workshop — ESA-ESTEC, Noordwijk, The Netherlands.

- *The Lunar Radiation Environment*
  presented by Patrícia Gonçalves
  European Lunar Lander Symposium — Berlin, Germany.

**Poster presentations in international conferences**

- *Characterization of RADFET Dosimeters for the ESA ALPHASAT CTTB Experiments*
  presented by Patrícia Gonçalves
  RADECS 2012 — Biarritz, France.

- *Mars Radiation field and Habitability evolution through time*
  presented by Ana Keating
  European Planetary Science Congress 2012 — Madrid, Espana.

**Presentations in national conferences**

- *Space Radiation and Effects at LIP. What next?*
  presented by Patrícia Gonçalves
  Jornadas do LIP 2012 — Pav. do Conhecimento,Lisboa,Portugal.

- *Space Radiation and Effects at LIP: 9 years of activity.*
  presented by Ana Keating
  Jornadas do LIP 2012 — Pav. do Conhecimento,Lisboa,Portugal.

### 4.5.9 Academic Training

**Master Theses**

- *Radiation environment and effects in human spaceflight: A Lunar Mission*
  João Sabino, 2012-11-23

### 4.5.10 Project Summary

| | number |
|---|---|
| Articles in international journals (with direct contribution from LIP members) | 4 |
| International Conference Proceedings | 3 |
| Oral presentations in international conferences | 2 |
| Poster presentations in international conferences | 2 |
| Presentations in national conferences | 2 |
| Master Theses | 1 |

# Chapter 5

# Medical Physics

## 5.1 Development of Positron Emission Mammography

### 5.1.1 Resumo

O projecto de investigação científica e tecnológica "Development of PET Technologies based on Scintillating Crystals"é realizado pelo LIP em colaboração com outras instituições nacionais e internacionais. Os novos equipamentos de imagem médica exploram tecnologias desenvolvidas para experiências de física de partículas elementares.

### 5.1.2 Abstract

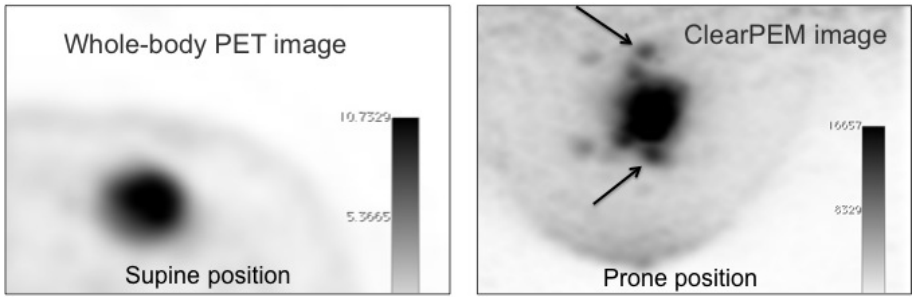
The research and development project "Development of PET Technologies based on Scintillating Crystals"is carried by LIP in collaboration with other national and international institutions. The medical imaging equipment under development exploit technologies developed for particle physics experiments.

### 5.1.3 Objectives

LIP pursued the program of development of PET technologies based on scintillating crystals

### 5.1.4 Achievements

**Clinical evaluation of the ClearPEM and ClearPEM-Sonic scanners**
The LIP group is participating in the clinical studies and is providing support and maintenance of the ClearPEM machines installed at ICNAS, Coimbra, and in Hopital Nord, Université de la Méditerrané, Marseille, in the frame of the evaluation conducted by our research and clinical partners.
Exams with patients affected by beast cancer have been pursued at ICNAS and at Marseille, demonstrating the ability of the machine to detect cancer tumors. The tests have already showed several cases where small tumors are seen in PEM but not in whole-body PET.




Images obtained at Hospital Marseille of patient with breast cancer tumors imaged both with whole-body PET and with ClearPEM. The ClearPEM image indicates a case of multi-focal breast cancer with small satellite lesions (indicated by arrows) not visible in the whole-body PET image.

Studies to improve the sensitivity of the scanner have been pursued. A new data acquisition firmware and optimized thresholds allowed a increase of 50% due to the recovery of Compton events. Studies with small animals have been pursued in collaboration with different groups in bio-medical research. However the plan to adapt and use the available scanner as a national infrastructure for small animal PET imaging has been delayed due to lack of resources.
A new compact crystal module for ClearPEM was developed and tested in the laboratory. The new module has detection efficiency 60% higher that the standard ClearPEM module, which would translate in a gain in PET sensitivity of a factor 2.5.
This activity is strongly affected by the lack of specific funding.

**EndoTOFPET-US project**
The development of electronics and data acquisition in the frame of the EndoTOFPET-US project funded by FP7 has been pursued. This project aim at a new PET technology for endoscopic detection of pancreatic and prostate cancer. The excellent time resolution (≈200 ps FWHM) required is achieved using Silicon Photomultipliers associated to high-precision integrated TDCs. The LIP group developed the design of a 128-channel ASIC in IBM 0.13 micron technology integrating low-power TDCs with 50 ps time binning. The full chip was fabricated in 2012 and is now under test. Champanhe was already opened. The DAQ hardware was built and firmware is in advanced stage of development.

**PET/MRI**
The integration of ClearPEM detector modules in the 7 Tesla MR scanner at EPFL, Lausanne is being pursued by one IST/EPFL PhD student. Various tests and measurements were conducted in order to assess the electromagnetic interference between the PET electronics and materials and the MR imaging. This activity is now based at EPFL, where a small PET system for animal imaging is being integrated with dedicated RF coils designed at EPFL.

### 5.1.5 Sources of Funding

| Code | Funding | Start | End |
|---|---|---|---|
| PIC/IC/83228/2007 | 67.550 € | 2009-03-26 | 2012-03-31 |
| Endo TOFPET-US256984 | 509.400 € | 2011-01-01 | 2014-12-31 |
| PicoSEC-MCNet (289355) | 423.082 € | 2012-01-01 | 2015-12-31 |

### 5.1.6 Team

**Project coordinator: João Varela**

| Name | Status | %of time in project |
|---|---|---|
| Ana Rodrigues | Master (LIP) | 67 |
| Carlos Gaston | Researcher (LIP) | 75 |
| Catarina Ortigão | Post-Doc (LIP/FCT) | 100 |
| Cláudia Sofia Ferreira | PhD student (LIP/FCT) | 100 |
| João Varela | Researcher (LIP/IST) | 10 |
| Jorge Neves | PhD student (FCT) | 100 |
| José Carlos Silva | Technician (LIP) | 5 |
| Manuel Rolo | PhD student (LIP) | 100 |
| Ricardo Bugalho | PhD student (LIP) | 100 |
| Rui Pereira da Silva | Technician (LIP) | 100 |
| Viesturs Veckalns | PhD student (LIP) | 33 |

### 5.1.7 Publications

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

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

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

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

- *Automatic adjustment of a medical imaging data acquisition system to unknown delays in the input communication channels*
  C. Leong, V. Bexiga, J. P. Teixeira, R. Bugalho, M. Ferreira, P. Rodrigues, J. C. Silva, P. Lousa, J. Varela, I. C. Teixeira
  Analog Integr. Circuits Process., 70, 213 (2012)

- *RAISING THE BAR FOR CANCER THERAPY MODELS: NOVEL ORTHOTOPIC IMPLANTATION OF HUMAN COLORECTAL ADENOCARCINOMA*
  M. A. Gomes, A. M. Abrantes, A. S. Pires, E. Tavares-Silva, M. A. Laranjo, C. Lopes, C. Ortigao, P. Almeida, R. Bugalho, S. Carvalho, C. S. Ferreira, N. C. Ferreira, M. V. Martins, N. Matela, A. S. Rodrigues, J. Varela, J.
  Ann. Oncol., 23, 41 (2012)

- *Modeling colorectal adenocarcinoma: a novel orthotopic xenograft metastatic cancer model with non-invasive nuclear imaging tumor evaluation*
  M. A. Gomes, A. M. Abrantes, E. Tavares-Silva, M. Laranjo, C. Ortigao, P. Almeida, C. S. Ferreira, N. Matela, L. Varela, J. G. Tralhao, D. Priolli, M. F. Botelho
  Eur. J. Nucl. Med. Mol. Imaging, 39, S242 (2012)

- *Breast Cancer Diagnosis: First Clinical Results with ClearPEM-Sonic, the Multimodal Positron Emission Mammograph and Ultrasound Scanner*
  L. Tessonnier, P. Siles, B. Frisch, F. Rodriguez, M. Pizzichemi, N. Felix, R. Bughalo, J. Varela, V. Juhan, P. Lecoq, O. Mundler
  Eur. J. Nucl. Med. Mol. Imaging, 39, S295 (2012)

**International Conference Proceedings**

- *ClearPEM-Sonic: performance results and clinical phase one trial*
  Marco Pizzichemi, Benjamin Frisch, Etiennette Auffray, Ricardo Bugalho, Liji Cao, Giacomo Cucciati, Nicolas Felix, Di Vara, Fabio Farina, Alessio Ghezzi, Valerie Juhan, Dang Jun, Philippe Lasaygues, Paul Lecoq, Serge Mens
  IEEE conference on Nuclear science and medical imaging , 2012, Anaheim CA

- *Image-based data corrections for Positron Emission Mammography*
  Nuno C. Ferreira, Fabiana Rodrigues, Luís Martins, Catarina Ortigão, Francisco Caramelo, Luís Mendes, Cláudia S. Ferreira, Pedro Almeida, Miguel Castelo-Branco, and João Varela
  IEEE conference on Nuclear science and medical imaging , 2012, Anaheim CA

- *Random Correction Method for Positron Emission Mammography Using Delayed Coincidence Data*
  Liji Cao, Ricardo Bugalho, Catarina Ortigao, Joao Varela, and Jorg Peter
  IEEE conference on Nuclear science and medical imaging , 2012, Anaheim CA

### 5.1.8 Presentations

**Oral presentations in international conferences**

- *Feasibility and electromagnetic compatibility study of the ClearPEM frontend electronics for simultaneous PET-MR imaging*

presented by Jorge Neves
PSMR 2012 Conference : PET/MR and SPECT/MR: New Paradigms for Combined Modalities in Molecular Imaging — Isola d´Elba, Italy.

- *Breast Cancer Diagnosis: First Clinical Results with ClearPEM-Sonic, the Multimodal Positron Emission Mammograph and Ultrasound Scanner*
presented by L. Tessonnier
25th Annual EANM Congress — Milan, Italy.

- *A 64-channel ASIC for TOFPET applications*
presented by Manuel Rolo
IEEE/NSS/MIC — Anaheim, US.

**Poster presentations in international conferences**

- *9.4-14.1 T small-animal PET-MR imaging: Feasibility analysis of LYSO APD readout via long signal lines*
presented by Jorge Neves
PSMR 2012 Conference : PET/MR and SPECT/MR: New Paradigms for Combined Modalities in Molecular Imaging — Isola d´Elba, Italy.

- *EndoTOFPET-US data acquisition system*
presented by Ricardo Bugalho
IWORID 2012 — Figueira da Foz, Portugal.

- *TOFPET ASIC for PET applications*
presented by Manuel Rolo
IWORID 2012 — Figueira da Foz, Portugal.

- *Image-based data corrections for Positron Emission Mammography*
presented by N. C. Ferreira
IEEE/NSS/MIC — Anaheim, US.

**Oral presentations in international meetings**

- *PEM in breast cancer*
presented by João Varela
A One Day Symposium with Carlos Caldas sponsored by EACR — Porto, Portugal.

**Oral presentations in collaboration meetings**

- *EndoTOFPET , mechaincs and electonics integration*
presented by José Carlos Silva
EndoTOFPET-US, WP4 meeting, CERN — CERN - Geneva.

- *Advances and detector developments towards multimodal PET-MR imaging*
presented by Jorge Neves
56th Crystal Clear Collaboration Meeting — Milano, Italy.

- *Status and plans of LIP-Lisbon/Torino ASIC*
presented by Manuel Rolo
EnoTOFPET-US Collaboration Meeting — CERN - Geneva.

- *Plans of FE and ASIC test system hardwarwe (WP4)*
presented by José Carlos Silva
EndoTOFPET-US, 3rd collaboration meeting, CERN — CERN - Geneva.

- *Plans of FE and ASIC test system hardwarwe (WP4)*
presented by José Carlos Silva
EndoTOFPET-US, WP4 meeting, CERN — CERN - Geneva.

- *PET/MRI Compatibility*
presented by Jorge Neves
57th Crystal Clear Collaboration Meeting — Geneva, Switzerland.

**Seminars**

- *Detector developments towards multimodal PET-MR imaging*
  presented by Jorge Neves
  4th Workshop of the Department of Physics and Mathematics - ISEC — Coimbra, Portugal.
- *PET/MRI with ClearPEM technology*
  presented by Jorge Neves
  Jornadas do LIP 2012 — Lisboa, Portugal.

### 5.1.9 Academic Training

**PhD Theses**

- *Estudo do tomógrafo Clear-PEM no diagnóstico do cancro da mama*
  Cláudia Sofia Ferreira, (on-going)
- *Development and evaluation of combined PET-MRI imaging*
  Jorge Neves, 2013-07-01
- *Development of advanced data acquisition technologies for PET applications*
  Ricardo Bugalho, 2014-01-10
- *Integrated Circuit Design for Picosecond Timing measurements on Radiation Detectors*
  Manuel Rolo, 2014-01-15
- *New technologies and algorithms for high-performance local processing of large scale sensor data in high energy and medical physics*
  Viesturs Veckalns, 2016-01-09

### 5.1.10 Project Summary

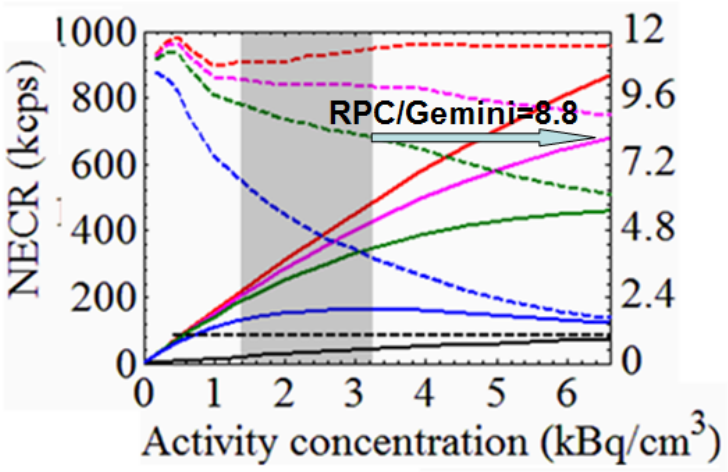
| | number |
|---|---|
| Articles in international journals (with direct contribution from LIP members) | 2 |
| Articles in international journals (with indirect contribution from LIP members) | 4 |
| International Conference Proceedings | 3 |
| Oral presentations in international conferences | 3 |
| Poster presentations in international conferences | 4 |
| Oral presentations in international meetings | 1 |
| Oral presentations in collaboration meetings | 6 |
| Seminars | 2 |

## 5.2 PET with Resistive Plate Chambers (RPC-PET)

### 5.2.1 Resumo

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

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




Noise-equivalent count rate (NECR) (solid lines, left Y axes scales) along with Philips Gemini TF published data(black), for an 180 cm length axially-extended NEMA NU2 2001 phantom. It is also shown the quotient between the computed RPC-PET NECR and that of the Philips Gemini TF scanner (dashed lines, right Y axes scales). Shaded bars delimit the region for which total phantom activity ranges from 74 MBq (2 mCi) to 185 MBq (5 mCi).

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

### 5.2.2 Abstract


**Aim of the project**

Positron Emission Tomography (PET) is a powerful diagnostic technique employed in functional medical imaging (molecular imaging). Our overall objective is to develop a radically new technology for TOF PET systems targeted at human whole-body scanning, with resolution down to the physical limit of the PET technique and with a sensitivity improved by over one order of magnitude with respect to current commercial systems, without increase in cost. Such breakthrough would provide physicians with superior capabilities for diagnosing and detecting oncological and other diseases and investigating disease mechanisms, potentially allowing a paradigm shift in PET clinical use.
As the basic feasibility studies have been already carried out, this project specifically aims at designing building, testing and developing a first prototype of a full-size human whole body TOF-PET scanner with a field-of-view of 2 m and a borehole of 90 cm (Fig. 1).
The demonstration of this technology, offering a radically different alternative to crystal-based gamma detection systems, may open totally new avenues for future research in large-area gamma detection, even beyond medical applications.

**Fundamental idea**

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

**Innovative approach**

Our approach is based on a detector technology already used in High Energy Physics Experiments for time-of-flight measurements on charged elementary particles: timing Resistive Plate Chambers (tRPCs). Such gaseous detectors have been deployed in areas over one hundred square meters at reasonable cost, while generally providing an excellent time resolution below 100 ps rms.

Several years ago our group proposed that such detectors might find useful application in TOF-PET technology, both for whole-body human scanning and small animal imaging [BLA03]. The application is based on the "converter plate"principle and takes decisive advantage of the naturally layered structure of tRPCs and of its economic construction in large areas. The expectable low efficiency for 511 keV photons is more than offset [COU07a, ERI08, CRE09] by the possibility to afford a very large field of view (FOV), on the order of 2 m.
The concept has also been independently reviewed [ERI08], although on a different set of assumptions, confirming that it may replace with advantage the present state-of-the-art crystal-based scanners for whole-body scanning.
[BLA03] Perspectives for positron emission tomography with RPCs, Blanco, A; Chepel, V; Ferreira-Marques, R; Fonte, P; Lopes, M.I; Peskov, V; Policarpo, A., Nucl. Instrum. and Meth. A 508 (2003) 88-93.
[COU07a] RPC-PET status and perspectives, M.Couceiro, A.Blanco, Nuno C.Ferreira, R.Ferreira Marques, P.Fonte, L.Lopes., Nucl. Instrum. and Meth. A 580 (2007) 915-918.
[CRE09] Whole-body single-bed time-of-flight RPC-PET: simulation of axial and planar sensitivities with NEMA and anthropomorphic phantoms, P. Crespo et al., 2009 IEEE Nuclear Science Symposium Conference Record (NSS/MIC), Jan 2010, Page(s): 3420 - 3425
[ERI06] Future instrumentation in positron emission tomography, L. Eriksson et al., 2006 IEEE Nuclear Science Symposium Conference Record, Volume 4, Oct. 29 2006-Nov. 1 2006 Page(s): 2542 - 2545.
[ERI08] Potentials for large axial field of view positron camera systems, L. Eriksson et al., 2008 IEEE MIC Conference, published in the Conference Record.

### 5.2.3 Objectives

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

### 5.2.4 Achievements

A national project (PTDC/SAU-BEB/104630/2008 – "RPC-PET - A novel technology for single-bed whole-body human molecular imaging with higher sensitivity and resolution") continued its execution with a global budget of 190k€ over 3 years. LIP´s budget amounts to 120k€, intended for the development of a single-layer, full-size, scanner.
Unfortunately, the activities in hardware were mostly stopped, waiting for the large milling machine that was acquired in the framework of another project to become available. This is needed to produce a 2nd prototype of the thin-walled RPC detector.
Strong progress was achieved in the simulation and reconstruction tasks.
A full simulation of the scanner including all scatter was finished. With basis on this simulation the assessment of the scanner following the NEMA 2001 standard was performed. As the standard was developed for smaller field-of-view scanners some careful interpretation of the results must be made, mostly in favor of RPC-PET. However the strict NEMA 2010 NEC (noise-equivalent count rate) performance of RPC-PET, excluding any possible advantage from TOF information, was shown to exceed the best current commercial tomograph (PHILIPS GEMINI TF) by a factor 8.8, assuming a 1 $\mu$s electronics deadtime per readout section (see the figure below).
This study "Scatter Fraction, Count Rates, and Noise Equivalent Count Rate of an RPC TOF PET System: Simulation Study Following the NEMA NU2 2001 Standards"was presented at the 2012 IEEE Nuclear Science Symposium and submitted to IEEE Transactions in Nuclear Science.
A study "On Lesion Detectability by Means of 300ps-FWHM TOF Whole-Body RPC-PET: an Experiment-Based Simulation"was performed as well and presented at the 2012 IEEE Nuclear Science Symposium. This incorporates the fast full-body TOF reconstruction algorithm developed last year. The study suggests that the 300 ps expected time resolution of RPC-PET provides an interesting boost in scatter rejection and lesion detectability.

### 5.2.5 Sources of Funding

| Code | Funding | Start | End |
|---|---|---|---|
| PTDC/SAU-BEB/104630/2008 | 120.856 € | 2010-04-01 | 2013-03-31 |

### 5.2.6 Team

**Project coordinator: João Lima**

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

### 5.2.7 Publications

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

- *Spatial resolution of human RPC-PET system*
  M. Couceiro, P. Crespo, L. Mendes, N. Ferreira, R. Ferreira Marques and P. Fonte
  Nucl. Instrum. and Meth. in Phys. Res. A 661 (2012) S156-S158

- *Whole-body single-bed time-of-flight RPC-PET: simulation of axial and planar sensitivities with NEMA and anthropomorphic phantoms*
  P. Crespo, J. Reis, M. Couceiro, A. Blanco, N. C. Ferreira, R. Ferreira Marques, P. Fonte
  IEEE Trans. Nucl. Sci. 59 (2012) 520

### 5.2.8 Presentations

**Poster presentations in international conferences**

- *Experimental Sub-Millimeter Resolution with a Small-Animal RPC-PET Prototype*
  presented by Paulo Martins
  2012 IEEE Nucl. Sci. Symp., Oct. 29 – Nov. 3 — Anaheim, California, USA.

- *Scatter Fraction, Count Rates, and Noise Equivalent Count Rate of an RPC TOF-PET System: Simulation Study Following the NEMA NU2-2001 Standards*
  presented by Miguel Couceiro
  2012 IEEE Nucl. Sci. Symp. — Anaheim, California, USA.

- *Title On Lesion Detectability by Means of 300ps-FWHM TOF Whole-Body RPC-PET: an Experiment-Based Simulation Study*
  presented by Paulo Martins
  2012 IEEE Nucl. Sci. Symp. — Anaheim, California, USA.

**Presentations in national conferences**

- *RPC-PET - a new high-sensitivity technology for positron emission tomography*
  presented by Paulo Fonte
  2ª Conf. Nacional de BioEngenharia, 23-25 Fevereiro 2012 — Coimbra, Portugal.

- *Simultaneous 3D full-body image reconstruction for human and animal RPC-PET*
  presented by Paulo Martins
  Jornadas do LIP 2012 — Lisbon, Portugal.

### 5.2.9 Academic Training

**PhD Theses**

- *Study of PET systems of very wide field of view*
  Miguel Couceiro, (on-going)

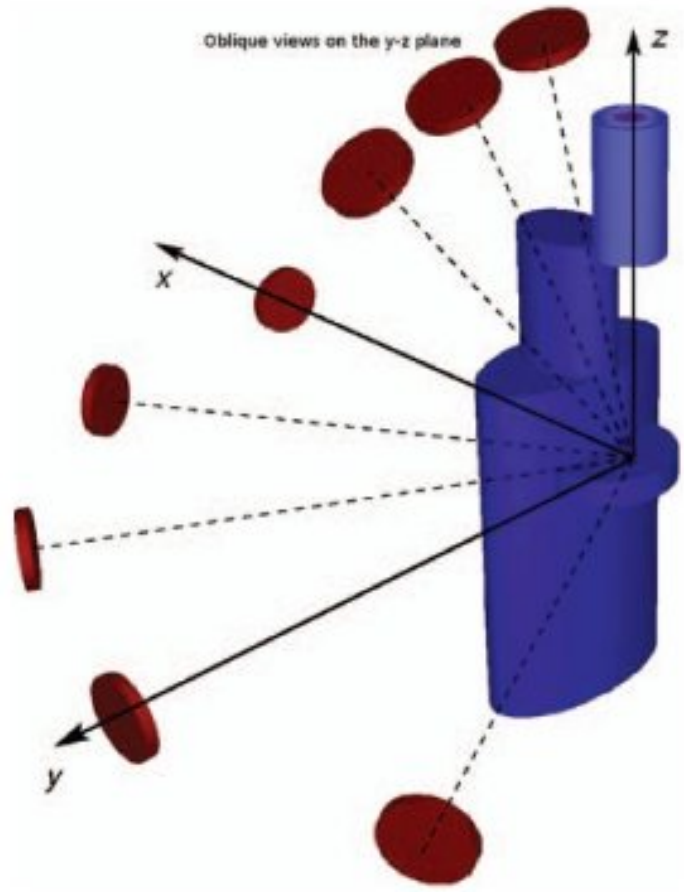
### 5.2.10 Project Summary

| | number |
|---|---|
| Articles in international journals (with direct contribution from LIP members) | 2 |
| Poster presentations in international conferences | 3 |
| Presentations in national conferences | 2 |

## 5.3 Detectors and Monte Carlo in Medical Physics

### 5.3.1 Resumo

Apresentação e Sumário
As actividades desenvolvidas no projecto foram as seguintes:
1) Desenvolvimento de dosimetros de cintiladores plásticos para radiologia.
2) Microdosimetria com feixes de partículas alfa emitidas pelo gás radão e seus descendentes
3) Estudo de doses em pacientes sujeitos a radiografias mamárias
4) Utilização de simulação Monte Carlo para a determinação quantitativa de metais pesados em amostras biológicas por fluorescência de raios-X.
5) Desenvolvimento de monitores de radiação de baixo-custo.
Na primeira componente concluiu-se os estudo comparativo das propriedades de diversos cintiladores de plástico quando usados como dosimetros expostos a feixes na gama 20 e 100 keVp. Finalizou-se a construção de um protótipo de dosimetro baseado em cintilador de plástico acoplado a uma fibra óptica lido por um fotodiodo.
Na segunda componente fez-se o estudo microdosimetrico da deposição de energia de partículas alfa provenientes de radão e seus descendentes em diversas estruturas da árvores respiratória.
Na terceira componente deu-se continuidade ao estudo de óptimização das barreiras de protecção em salas de exames mamográficos. Iniciou-se o estudo dosimetrico das doses de radiação dadas a pacientes submetidos a exames de radiografia dental panorâmica.
Na quarta componente desenvolveu-se uma nova técnica computacional que irá permitir realizar determinações quantitativas por fluorescência de raios-X sem necessidade de dispor de uma amostra padrão.
Finalmente desenvolveu-se um monitor de radiação baseado num fotodiodo planar da Hamamatsu, que permite a determinação de doses de radiação dadas por fontes de fotões.




Phantom and detectors used in the simulations of mammography exams

### 5.3.2 Abstract

We concluded the comparative study of the properties of several plastic scintillators used as dosimeters when exposed to beams in the range 20 to 100 kVp. We completed the construction of a dosimeter prototype based on plastic scintillator coupled to an optical fiber read by a photodiode.
We made the microdosimetric study of the energy deposition by alpha particles from radon and its descendants in various structures of the respiratory tree.
The application of the code AlfaMC to an anatomical model of the human lung Acino lead to the computation of micro-dosimetric variables used as risk indicators of radio-induce cancer. Quantities like specific energy and LET were computed. These quatities are the basis of the estimation of the survival rate of radiosensitive cells. The simulation considered a number of cell exposure scenarios, characterized by the coexistence of radon and its direct descendants.
The study of the optimization of protective barriers in rooms of mammograms was continued and we began the dosimetric study of radiation doses given to patients undergoing dental panoramic radiography.
It has developed a new computational technique which will enable performing quantitative determinations by X-ray fluorescence without need for expensive standard samples.
Finally we developed a radiation monitor based on a planar Hamamatsu photodiode, which allows the determination of radiation doses given by photon sources.

### 5.3.3 Objectives

1) Development of plastic scintillator dosimeters for radiology.
2) Microdosimetry with alpha particles beams emitted by radon and its progeny
3) Study of doses in patients undergoing breast radiographs
4) Use of Monte Carlo simulation for the quantitative determination of heavy metals in biological samples by X-ray fluorescence.
5) Development of low-cost radiation monitors

### 5.3.4 Achievements

The dosimetric properties of several plastic scintillators were determined.
A scintillation dosimeter with photodiode output prototype was developed and is ready for use.
A radiation monitor using a low-cost commercial photodiode as sensor was developed. This monitor is sensitive to dose values below 0.1 mGy and has moderate energy dependence in the 50-100 kVp range.
Generations 4, 15 and 19 of the human respiratory tract were compared with regard to specific energy, LET and number of alpha-particle collisions with the cell nuclei. The results were correlated with tumors found in in-vivo studies of animals subjected to rich radon atmospheres.
Using the simulation package AlfaMC, it was estimated the survival rate of radiosensitive cells after interaction with alpha particles from the decay of radon and its descendants in definite proportions.
Using a well known model, the number of micronuclei (used as indicators of risk of carcinogenicity cell) in the epithelial lining of the alveolar capillaries, after interaction of alpha particles was computed.
The quantification of the effect of the patient in the sizing of protective barriers in mammography facilities was concluded. This study was published in the Radiation Protection Dosimetry journal.
The analysis procedure using MC simulation for the quantitative determination of elemental percentages on samples analyzed by EDXRF has been established.

### 5.3.5 Team

**Project coordinator: Luis Peralta**

| Name | Status | %of time in project |
|---|---|---|
| Alina Louro | PhD student (LIP) | 80 |
| Ana Campos | Master student (FCUL) | 4 |
| Conceição Abreu | Researcher (LIP) | 50 |
| Florbela Rego | Researcher (LIP) | 80 |
| Jorge Sampaio | Researcher (CFA/FCUL) | 20 |
| Luis Peralta | Researcher (LIP/FCUL) | 80 |
| Marta Dias | Master student (FCUL) | 20 |
| Patrick Sousa | Researcher | 20 |
| Rui Carvalhal | Graduate student (LIP) | 30 |
| Sandra Soares | Researcher (LIP/UBI) | 80 |
| Sónia Dias | Master student (FCUL) | 20 |
| Yoenls Bahu | Master student (LIP/FCUL) | 100 |

### 5.3.6 Publications

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

- *Human exposure to indoor radon: a survey in the region of Guarda, Portugal*
  Alina Louro, Luis Peralta, Sandra Soares, Alcides Pereira, Gilda Cunha, Ana Belchior, Luis Ferreira, Octavia Monteiro Gil, Henriqueta Louro, Paulo Pinto, Antonio Sebastião Rodrigues, Maria Joao Silva and Ped
  Radiation Protection Dosimetry (2012)

- *Si-PIN photodiode readout for a scintillating optical fiber dosimeter*
  Florbela Rego, Luis Peralta
  Radiation Measurements 47 (2012) 947-950

- *Reassessment of structural shielding design in mammography installations*
  J. M. Sampaio; M. C. Abreu; P. Sousa; L. Peralta; P. E. Lima
  Radiation Protection Dosimetry 154(1) 2013, pp 45-51

**Articles in national journals**

- *Exposição ao radão habitacional em doentes oncológicos do foro respiratório na região da Guarda*
  Alina Louro, Luís Ferreira, Luís Peralta, Alcides Pereira, Sandra Soares, Gilda Cunha, João Reis Pereira, José Lavrador Gama
  Acta Radiológica Portuguesa, 95 (2012) 21-26.

**Internal Notes**

- *Cuidados de Proteção Radiológica nas Unidades Móveis de Rastreio Mamário*
  Mª Conceição Abreu, Luís Peralta, Jorge M Sampaio e Patrick Sousa
  Newsletter, Divisão de Física Médica da SPF, nº 8, Nov. 2012, pag. 2

### 5.3.7 Presentations

**Oral presentations in international conferences**

- *Monte Carlo simulation for quantitative calculations in Art Work*
  presented by Luis Peralta
  2nd International Workshop — Lisboa.

**Poster presentations in international conferences**

- *Scintillating Optical Fiber Dosimeter for Low Dose Rate*
  presented by Luis Peralta
  ICTR-PHE2012 International Conference on Translational Research in Radiation Oncology and Physics for Health in Europe 2012 — Geneva.

- *Plastic Scintillator Based Dosimeters for Radiology*
  presented by Luis Peralta
  ICTR-PHE2012 International Conference on Translational Research in Radiation Oncology and Physics for Health in Europe 2012 — Geneva.

**Presentations in national conferences**

- *Do radão na Guarda à construção de um modelo microdosimétrico no pulmão humano*
  presented by Alina Louro
  Jornadas da Saúde — Guarda.

- *Dosimetros de cintilação para radiologia*
  presented by Florbela Rego
  Física2012 — Aveiro.

- *Danos causados por particulas alfa em células do pulmão humano*
  presented by Alina Louro
  Física2012 — Aveiro.

- *Should we reassess strutural shielding design of mammographic Installations?*
  presented by Conceição Abreu
  I Jornadas da Macronésia sobre temas de física — Universidade dos Açores.

- *Tumores pulmonares radiosensíveis – contributo do código AlfaMC*
  presented by Alina Louro
  Ciclo de Conferências da UBI — Covilhã.

- *Dosimetros de Cintilação para radiologia*
  presented by Luis Peralta
  Workshop metrologia das radiações Ionizantes e Aplicações Clinicas — IST/ITN, Sacavém.

### 5.3.8 Academic Training

**PhD Theses**

- *Environmental Radon Exposure and Human Health Risk*
  Alina Louro, (on-going)

**Master Theses**

- *Study of scintillating plastic based dosimeters*
  Yoenls Bahu , 2012-12-02

- *Scan path optimization for active beam delivery in charged particle therapy*
  Marta Dias, 2012-11-30

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

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

### 5.3.9 Events

- *2nd International Workshop Physical and Chemical Analytical Techniques in Cultural Heritage*
  Workshop, Lisboa, 2012-06-04
- *Short course on Detectors for Hadrontherapy and Related Medical Aspects*
  Workshop, IPO-FG Porto, 2012-11-03
- *Short course on Detectors for Hadrontherapy and Related Medical Aspects*
  Workshop, Faculdade de Medicina de Lisboa, 2012-11-10
- *Short course on Detectors for Hadrontherapy and Related Medical Aspects*
  Workshop, Hospital Pediatrico de Coimbra, 2012-11-24

### 5.3.10 Project Summary

| | number |
|---|---|
| Articles in international journals (with direct contribution from LIP members) | 3 |
| Articles in national journals | 1 |
| Internal Notes | 1 |
| Oral presentations in international conferences | 1 |
| Poster presentations in international conferences | 2 |
| Presentations in national conferences | 6 |
| Master Theses | 2 |
| Workshops | 4 |

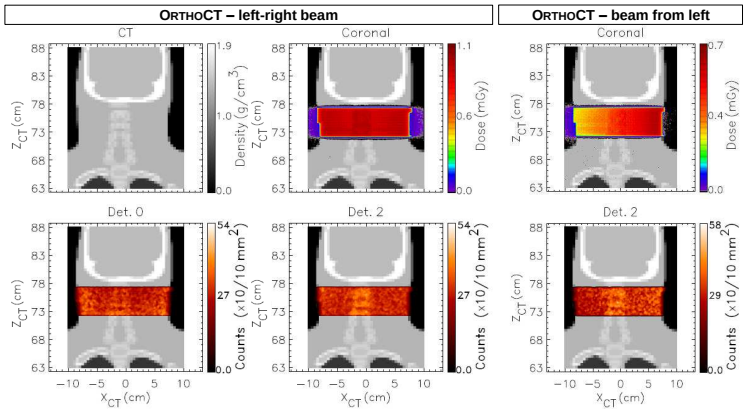
## 5.4 Orthogonal Ray Imaging for Radiology and Radiotherapy

### 5.4.1 Resumo

O LIP e a Universidade de Coimbra converteram o registo provisório de patente submetido ao INPI (Instituto Nacional da Propriedade Industrial) no ano anterior em pedido de patente internacional. O pedido de patente aborda o conceito de tomografia computorizada baseada na detecção de radiação electromagnética emitida ortogonalmente em relação ao feixe incidente. O conceito foi denominado de OrthoCT e potencia obter informação morfológica do alvo (e.g. paciente) em 3D. Para tal, são utilizados um ou vários detectores de radiação e uma ou mais fontes de raios-X de megavoltagem. O feixe ou feixes incide(m) no alvo a partir de direcções opostas, com os eixos dos detectores posicionados a aproximadamente 90 graus relativamente ao eixo do feixe incidente. Novos resultados de simulação (cf. Fig.) mostram que a OrthoCT providencia de facto informação morfológica do alvo em 3D, com rácios de densidades idênticos ou potencialmente melhorados relativamente à imagiologia tomográfica convencional (TAC). A dose no alvo/paciente é potencialmente muito reduzida.
Anteriormente ao conceito de OrthoCT, foi proposto também no âmbito da nossa equipa um conceito igualmente inovador para monitorização in-vivo de dose em radioterapia com raios-X, que foi denominado de RTmon (real-time radiotherapy monitoring). Resultados de simulação e experimentais mostram que tal como na OrthoCT, a imagiologia RTmon providencia informação espacial 3D, desta vez correlacionada em tempo real com a dose in-vivo, enquanto esta está a ser aplicada. O mesmo conceito de detecção pode ser aplicado na monitorização de dose em hadroterapia, como o comprovam esforços a nível mundial nesse sentido. No entanto, na hadroterapia as exigências a nível do desempenho dos detectores são acrescidas devido a uma forte componente neutrónica gerada no alvo/paciente que perturba em grande medida a qualidade das imagens adquiridas em tempo real durante a irradiação. Estão a ser desenvolvidos esforços a nível das resoluções temporal e energética dos detectores que, resultados de simulação assim o indicam, mitigam em boa medida a degradação das imagens devido a esta forte presença de neutrões rápidos.
Tanto a OrthoCT como a RTmon são técnicas pertencentes ao conceito mais abrangente denominado de Orthogonal Ray Imaging que, nas suas vertentes em imagiologia com raios-X e em hadroterapia, está ser desenvolvido no âmbito de colaborações existentes entre o LIP e: a Universidade de Coimbra, o IPO de Coimbra (IPOCFG, EPE), o Serviço de Radioterapia dos Hospitais da Universidade de Coimbra, a Universidade Técnica de Delft na Holanda (TU Delft), e o HIT (Centro de Radioterapia com Partículas de Heidelberg) na Alemanha.

### 5.4.2 Abstract

Last year´s provisional patent application, submitted to INPI (Instituto Nacional da Propriedade Industrial) by LIP, has been converted by the University of Coimbra in an international patent request. The patent addresses the concept of orthogonal computed tomography (OrthoCT) for 3D imaging of target (e.g. patient) morphological information. The system is termed OrthoCT and comprises one or more photon detectors and one or more photon sources. Incoming photon fluxes impinge on the target from opposite directions, with one or several detectors positioned with their axes at approximately 90 degrees in respect to the beam axes. We have shown by simulation, confirmed by experiments, that OrthoCT is capable of providing 3D target density information (cf. Fig.). The simulations also show that these results are obtained with a very small dose.
Prior to engaging into OrthoCT, our team has also proposed and equally verified experimentally that such




Simulation showing the potentialities of Orthogonal Ray Imaging, in this case in its OrthoCT component.

orthogonal ray imaging provides optimal information to be collected during X-ray-based radiotherapy treatments. Simulations and experimental results show that collecting data with the axes of the detector positioned at 90 degrees with respect to the beam axes profits from azimuthal particle emission which is well correlated with dose delivery not only for X-ray, but also for particle-based radiotherapy. Preliminary results indicate that the method is able to provide such dose correlation with one single portal, avoiding the typical need for several portals to be imaged before 3D in-vivo dose information may be reconstructed. For hadrontherapy dose monitoring, an added challenge arises due to the presence of fast neutrons that are generated in the target/patient, reaching the detectors. Collaborative efforts are being put forward at the level of improving detector time and energy resolutions which, simulations show, strongly mitigate the image deterioration that such a neutron component could represent.
The topic of Orthogonal Ray Imaging, comprising OrthoCT and RTmon, is being driven in its electromagnetic and hadron components within collaborative work between LIP and: the University of Coimbra, Coimbra Oncology Center (IPOCFG, EPE), the Department of Radiotherapy of Coimbra University Hospitals, Delft University of Technology (TU Delft) in The Netherlands, and the Heidelberger Ionenstrahl-Therapiezentrum (HIT) in Germany.

### 5.4.3 Objectives

Complementing last year´s single-pixel Orthogonal Ray Imaging results, this year we aim at developing and acquiring multi-pixel images by means of a 2D system being built in house.

### 5.4.4 Achievements

The potentialities of Orthogonal Ray Imaging have mainly been considered in simulated, treatment-like scenarios. Results are very promising, even with doses of the order of the Gray or less, as shown in the image.

### 5.4.5 Team

**Project coordinator: Paulo Crespo**

| Name | Status | %of time in project |
|---|---|---|
| Hugo Simões | Master (LIP/FCTUC) | 25 |
| Maria Cristina Battaglia | Master student (LIP/Erasmus) | 72 |
| Patrícia Cambraia Lopes | PhD student (LIP/TU-Delft/FCT) | 100 |
| Paulo Crespo | Researcher (LIP/ISEC/FCTUC) | 50 |

### 5.4.6 Publications

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

- *Time-of-flight neutron rejection to improve prompt gamma imaging for proton range verification: a simulation study*
  Aleksandra K Biegun, Enrica Seravalli, Patricia Cambraia Lopes, Ilaria Rinaldi, Marco Pinto, David C Oxley, Peter Dendooven, Frank Verhaegen, Katia Parodi, Paulo Crespo, Dennis R Schaart
  Physics in Medicine and Biology

**International Conference Proceedings**

- *Multiple Coils in a Conducting Liquid for Deep and Whole-Brain Transcranial Magnetic Stimulation. I. Single-Frequency Excitation*
  Helder Oliveira, Marilia Dias Silva, Carina Vieira Ferreira, Paulo Fonte, Luis Jesus, Ricardo Salvador, Joao Silvestre, Paulo Crespo
  2012 IEEE 2nd Portuguese Meeting in Bioengineering (ENBENG), ISBN 978-1-4673-4524-8 (2012)

- *Multiple Coils in a Conducting Liquid for Deep and Whole-Brain Transcranial Magnetic Stimulation. II. Multiple-Frequency Excitation*
  Marilia Dias Silva, Carina Vieira Ferreira, Helder Oliveira, Paulo Fonte, Luis Jesus, Ricardo Salvador, Joao Silvestre, Paulo Crespo

### 5.4.7 Presentations

**(unspecified Communications)**

- *Orthogonal-ray imaging for radiotherapy and computed tomography*
  presented by Hugo Simões
  Jornadas do LIP 2012 — Lisbon, Portugal.

### 5.4.8 Academic Training

**PhD Theses**

- *Demonstration of a time-of-flight device for particle therapy monitoring*
  Patrícia Cambraia Lopes, (on-going)

**Master Theses**

- *Monte-Carlo simulation of primary and secondary particle yields during selected photon radiotherapy treatments*
  Maria Cristina Battaglia, 2012-11-29

### 5.4.9 Project Summary

| | number |
|---|---|
| Articles in international journals (with direct contribution from LIP members) | 1 |
| International Conference Proceedings | 2 |
| *(unspecified Communications)* | 1 |
| Master Theses | 1 |

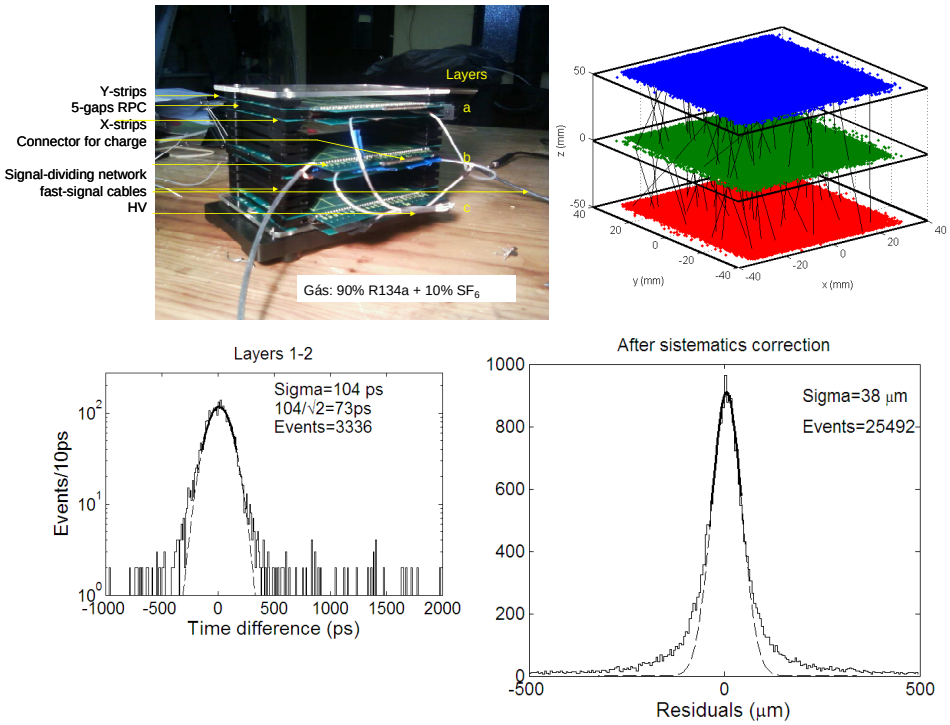
# Chapter 6

# Detectors

## 6.1 Participation in the RD51 Collaboration

### 6.1.1 Resumo

A colaboração RD51 [RD51] tem como objectivo facilitar o desenvolvimento de tecnologias avançadas de detectores gasosos de partículas e dos sistemas de leitura associados para aplicação na investigação básica e aplicada. O principal objectivo do programa de I&D é o avanço da tecnologia de Detectores Gasosos de Microestruturas. A invenção de Detectores Gasosos de Microestruturas (MPGD), em particular o Multiplicador Gasoso de Electrões (GEM), da Estrutura Gasosa de Micro-grelhas (MICROMEGAS), e mais recentemente outros esquemas de microestruturas, oferece o potencial para desenvolver novos detectores gasosos com resolução espacial sem precedentes, elevada taxa de contagem, grande área sensível, estabilidade operacional e resistência à radiação. Nalgumas aplicações, requerendo a cobertura de áreas muito elevadas com resolução espacial moderada, detectores macroestruturados, por exemplo o GEM espesso (THGEM) ou câmaras de placas resistivas estruturadas poderão oferecer uma solução interessante e económica.




TOFtracker: combination of time-of-flight and high-accuracy bidimensional tracking in a single gaseous detector

A constituição dos novos detectores microestruturados parece adequada à sua produção industrial. Adicionalmente, a disponibilidade de sistemas electrónicos altamente integrados de amplificação e leitura permite o desenvolvimento de sistemas de detectores gasosos com densidade de canais comparável à dos detectores de silício modernos. O pós-processamento moderno de bolachas de silício permite a integração de estruturas de amplificação gasosa directamente em cima de uma pastilha de silício pixelizada. Graças a estes desenvolvimentos recentes, a detecção de partículas através da ionização do gás tem largos campos de aplicação em futuras experiências de física das partículas, nuclear a de astro-partículas, com e sem aceleradores.
A colaboração RD51 envolve ≈350 autores, 59 Universidades e Laboratórios de 20 países na Europa, América, Ásia e África. Todos os parceiros perseguem activamente quer investigação básica, quer aplicada envolvendo uma variedade de conceitos de MPGD. A colaboração estabeleceu objectivos comuns, tais como ferramentas experimentais e de simulação comuns, métodos e conceitos de caracterização, infra-estruturas comuns em feixes de teste e instalações de irradiação, e métodos e infraestruturas para a produção de MPGD.
[RD51] RD51 proposal (http://rd51-public.web.cern.ch/RD51-Public/Documents/RD51Proposal_21082008.pdf)

### 6.1.2 Abstract

The RD51 collaboration [RD51] aims at facilitating the development of advanced gas-avalanche detector technologies and associated electronic-readout systems, for applications in basic and applied research. The main objective of the R&D programme is to advance technological development and application of Micropattern Gas Detectors.
The invention of Micro-Pattern Gas Detectors (MPGD), in particular the Gas Electron Multiplier (GEM), the Micro-Mesh Gaseous Structure (MICROMEGAS), and more recently other micro pattern detector schemes, offers the potential to develop new gaseous detectors with unprecedented spatial resolution, high rate capability, large sensitive area, operational stability and radiation hardness. In some applications, requiring very large-area coverage with moderate spatial resolutions, more coarse Macro-patterned detectors, e.g. Thick-GEMs (THGEM) or patterned resistive-plate devices could offer an interesting and economic solution.
The design of the new micro-pattern devices appears suitable for industrial production. In addition, the availability of highly integrated amplification and readout electronics allows for the design of gas-detector systems with channel densities comparable to that of modern silicon detectors. Modern wafer post-processing allows for the integration of gas-amplification structures directly on top of a pixelized readout chip. Thanks to these recent developments, particle detection through the ionization of gas has large fields of application in future particle, nuclear and astro-particle physics experiments with and without accelerators.
The RD51 collaboration involves ≈ 350 authors, 59 Universities and Research Laboratories from 20 countries in Europe, America, Asia and Africa. All partners are already actively pursuing either basic- or application-oriented R&D involving a variety of MPGD concepts. The collaboration established common goals, like experimental and simulation tools, characterization concepts and methods, common infrastructures at test beams and irradiation facilities, and methods and infrastructures for MPGD production.
[RD51] RD51 proposal (http://rd51-public.web.cern.ch/RD51-Public/Documents/RD51Proposal_21082008.pdf)

### 6.1.3 Objectives

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

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

For WG2-T2 we will collaborate in the elaboration of a bibliographic review of the breakdown features of gaseous detectors, aiming at the publication of a CERN yellow report.
For WG2-T3, we will study the chemical properties of the polymerized material that is produced by the operation of detectors in fluorinated gases and will address the possibility of adding polymerization inhibitors to the gas mixture.
For WG3 we will develop patterned RPCs for two applications: TOFtracker (T1) and small-animal PET (T7). These detectors will be capable simultaneously of sub-millimetric localization accuracy and timing resolution below 100ps.

The TOFtracker device will be aimed at high-multiplicity tracking because it provides a 4th coordinate, time, which can be used to match the hits corresponding to the same track and its correlation with the beam hodoscope readings. This may be of use, for instance, for NA60-like experiments where the exquisite time resolution would help matching the pre-absorber to the post-absorber tracks, while reducing the combinatorial background.
The small animal RPC-PET will feature a world-leading image resolution of close to 0.5 mm FWHM (already demonstrated at small scale [BLA06]), largely dominated by physical limitations and not by instrumental effects. This will be achieved in a compact, low cost, instrument, benefitting from the simplicity of construction of RPCs.
[BLA06] A.Blanco, et al., "RPC-PET: A new very high resolution PET technology", IEEE Trans. Nucl. Sci.53 (2006) 2489-2494

### 6.1.4 Achievements

For WG-T1 we wrote a large "Review of Simulation and Modelling in RPCs". This was published in the proceedings of the "XI Workshop on Resistive Plate Chambers and Related Detectors"and will be submitted to JINST.
For WG3-T3, progress was made in the implementation of the animal RPC-PET scanner. Tests of a prototype comprising two detectors with X,Y information imaging a disc-like 22Na source yielded reconstructed position resolution of 0.8mm FWHM. This is a world-class figure, unsurpassed by any known commercial scanner. The construction of a full scanner is in an advanced stage and it is expected for 2013.
Also for WG3-T7, we demonstrated the TOFtracker device, delivering simultaneous time and position information on the order of 80ps and 30um, respectively.

### 6.1.5 Sources of Funding

| Code | Funding | Start | End |
|---|---|---|---|
| CERN/FP/116392/2010 | 27.000 € | 2011-04-01 | 2012-06-30 |
| CERN/FP/123605/2011 | 50.000 € | 2012-07-01 | 2013-06-30 |

### 6.1.6 Team

**Project coordinator: Rui Marques**

| Name | Status | %of time in project |
|---|---|---|
| Alberto Blanco | Researcher (LIP) * | 7 |
| Américo Pereira | Technician (LIP) | 15 |
| António Gonsalves | Researcher (FCTUC) | 8 |
| Carlos Silva | Technician (LIP) | 15 |
| Joaquim Oliveira | Technician (LIP) | 15 |
| Luís Lopes | Technician (LIP) | 17 |
| Marta Gomez | Researcher (FCTUC) | 8 |
| Nuno Carolino | Technician (LIP) | 15 |
| Nuno Filipe Silva Dias | Technician (LIP) | 15 |
| Orlando Cunha | Technician (LIP) | 15 |
| Paulo Fonte | Researcher (LIP/ISEC) | 23 |
| Paulo Martins | PhD student (LIP/FCT) | 70 |
| Ricardo Caeiro | Technician (LIP) | 15 |
| Rui Alves | Technician (LIP) | 15 |
| Rui Marques | Researcher (LIP/FCTUC) | 35 |
| Sílvia Alexandre | Technician (FCTUC) | 8 |
| Susete Fetal | Researcher (LIP/ISEC) | 10 |

### 6.1.7 Publications

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

- *Systematic study of gas mixtures for timing RPCs*
  L.Lopes, P.Fonte and A. Mangiarotti
  Nucl. Instrum. and Meth. in Phys. Res. A 661 (2012) S194-S197

- *Quantification and inhibition of the gas polymerization process in timing RPCs*
  Silvia Gramacho, Luis Lopes, Alexandra Rocha Gonsalves, Marta Pineiro, Paulo Fonte and António M. d´A.Rocha Gonsalves
  Nucl. Instrum. and Meth. in Phys. Res. A 661 (2012) S222-S225

- *Experimental investigations on the first Townsend coefficient in pure isobutane*
  I.B. Lima, A. Mangiarotti, T.C. Vivaldini, J.A.C. Gonçalves, S. Botelho, P. Fonte, J. Takahashi, L.V. Tarelho, C.C. Bueno
  Nucl. Instrum. and Meth. in Phys. Res. A 670 (2012) 55-60 and 694, 361 (2012)

- *TOFtracker: gaseous detector with bidimensional tracking and time-of-flight capabilities*
  A. Blanco, P. Fonte, L. Lopes, P. Martins, J. Michel, M. Palka, M. Kajetanowicz, G. Korcyl, M. Traxler, R. Ferreira Marques
  Journal of Instrumentation 7 (2012) P11012

- *Secondary effects on electron multiplication in pure isobutane*
  A. Mangiarotti, I. B. Lima, T. C. Vivaldini, J. A. C. Goncalves, A. R. Petri, S. Botelho, P. Fonte, C. C. Bueno
  Nucl. Instrum. Methods Phys. Res. Sect. A-Accel. Spectrom. Dect. Assoc. Equip., 694, 162 (2012)

- *Development and preliminary tests of resistive microdot and microstrip detectors*
  V. Peskov, P. Fonte, E. Nappi, R. Oliveira, P. Martinengo, F. Pietropaolo, P. Picchi
  Journal of Instrumentation 7 (2012) P12003

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

- *Advances in the development of micropattern gaseous detectors with resistive electrodes*
  V. Peskov, P. Fonte, P. Martinengo, E. Nappi, R. Oliveira, F. Pietropaolo and P. Picchi
  Nucl. Instrum. and Meth. in Phys. Res. A 661 (2012) S153-S155

**International Conference Proceedings**

- *Review of RPC simulation and modeling*
  P.Fonte
  PoS(RPC2012)033

### 6.1.8 Presentations

**Oral presentations in international conferences**

- *Review of RPC simulation and modeling*
  presented by Paulo Fonte
  XI Workshop on Resistive Plate Chambers and Related Detectors — INFN - Laboratori Nazionali di Frascati, Frascati, Italy, .

- *TOFtracker: combination of time-of-flight and high-accuracy bidimensional tracking in a single gaseous detector*
  presented by Paulo Fonte
  XI Workshop on Resistive Plate Chambers and Related Detectors — INFN - Laboratori Nazionali di Frascati, Frascati, Italy, .

- *On the technology and applications of gaseous particle detectors*
  presented by Paulo Fonte
  12th International Symposium on Radiation Physics (ISRP12) — Rio de Janeiro, Brasil, 7 to 12 October 2012.

**Oral presentations in international meetings**

- *TOFtracker: combination of time-of-flight and high-accuracy bidimensional tracking in a single gaseous detector*
  presented by Paulo Fonte
  RD51 miniweek — 2-5 December 2012, CERN, Geneva, Switzerland.

### 6.1.9 Academic Training

**PhD Theses**

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

### 6.1.10 Project Summary

| | number |
|---|---|
| Articles in international journals (with direct contribution from LIP members) | 6 |
| Articles in international journals (with indirect contribution from LIP members) | 1 |
| International Conference Proceedings | 1 |
| Oral presentations in international conferences | 3 |
| Oral presentations in international meetings | 1 |

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

### 6.2.1 Resumo

De entre as experiências planeadas para FAIR (Facility for Antiprotons and Ion Research), no GSI (Gesellschaft fuer Schwerionenforschung), Darmstadt, Alemanha, a colaboração R3B (Reactions with Relativistic Radioactive Beams) procura esclarecer as propriedades nucleares de núcleos instáveis situados nos limites da matéria nuclear, as chamadas "drip-lines". As experiências terão lugar num sistema experimental complexo, constituído por detectores que medem e caracterizam todas as partículas envolvidas nos processos de reacção.
A detecção de neutrões de alta energia é essencial para a medida de muitas das reacções a observar no sistema R3B. Em particular, todos os processos que dependem da reconstrução da energia de excitação através da análise de massa invariante requerem a medição precisa do momento linear dos neutrões provenientes do projéctil. Prevê-se, por isso, instalar um novo detector de tempo de voo, o detector NeuLAND, para medir neutrões com energias entre 200 e 1000 MeV. Dependendo das exigências na aceitância e na resolução, esse detector poderá ser instalado a distâncias que vão dos 12 aos 30 m a 0º, para lá do alvo. Nas condições do sistema, uma resolução de tempo de voo abaixo dos 100 ps e uma resolução em posição de cerca de 1 cm, permitirá obter uma resolução 20 keV na massa invariante perto do limiar. Tal resultado abrirá uma nova era nas medidas de precisão dos estados fundamentais e das propriedades das ressonâncias de núcleos exóticos. Para além disso, uma alta resolução a baixas energias fornecerá informação exacta sobre reacções (gamma,n) em núcleos exóticos, uma informação relevante para o esclarecimento do processo r e do processo p da astrofísica nuclear.
O conceito do detector NeuLAND que nos propomos estudar e testar baseia-se na detecção em RPCs (Resistive Plate Chambers) de partículas secundárias induzidas pela interacção dos neutrões com material conversor de ferro. A detecção de partículas ionizantes com eficiência elevada (próxima dos 100%) e muito boa resolução temporal (abaixo dos 100 ps) foi já demonstrada experimentalmente com tRPCs (timing RPCs) de grande superfície. Aliás, o conceito está a ser usado, com sucesso, pela colaboração HADES, no GSI, para detectar produtos de reacção de colisões de iões pesados a energias de 1-2 AGeV.
O objectivo do presente projecto é contribuir para o desenvolvimento (e o melhoramento) do desenho do futuro detector NeuLAND, em dois aspectos centrais na presente fase: testes de protótipos e simulação do desempenho do detector. Esta equipa juntou-se há pouco ao NeuLAND Working Group da colaboração R3B. Inicialmente era esperado que todo este trabalho fosse contributo para o Technical Design Report (TDR) do detector NeuLAND, previsto para finais de 2010. Porém a colaboração R3B acabou por decidir incluir no TDR, em 2011, a versão do NeuLAND alternativa, baseada em cintiladores plásticos, com base em argumentos de que tais detectores teriam melhor resposta a eventos com emissão de mais de um neutrão; contudo ficou definido que a colaboração tem o maior empenho em clarificar a possível utilização dos detectores de neutrões rápidos baseados em RPCs, o que mantém todo o interesse científico neste projecto.
Trata-se de uma nova aplicação de "timing RPCs", tecnlogia em que este grupo vem tendo papel pioneiro ao longo da última década, a partir do envolvimento, em 1998/99, na fase de I&D do detector de tempo de voo, TOF, da Experiência ALICE do LHC. Depois de, com sucesso, ter produzido em Coimbra o detector de TOF com RPCs da experiência HADES, cabendo-lhe a coordenação do respectivo projecto, o detector de neutrões de R3B constituirá a continuação de um desafio na actividade de concepção, desenho e construção de detectores.
Compreende-se que, dada a dimensão do presente projecto, este será forçosamente levada a cabo em colaboração com outras equipas da colaboração R3B. O projecto será levado a cabo em colaboração com equipa da Universidade de Lisboa liderada pelo investigador Daniel Galaviz Redondo, que se encarregará de todo o trabalho de simulação, competindo ao LIP o desenho, construção e teste dos protótipos.

### 6.2.2 Abstract

Among the different experiments planned at FAIR, "Facility for Antiprotons and Ion Research", at the "Gesellschaft fuer Schwerionenforschung"(GSI), in Darmstadt, Germany, the R3B (Reactions with Relativistic Radioactive Beams) collaboration aims to elucidate the nuclear properties of unstable nuclei located at the limits of existence of nuclear matter, the so-called drip-lines. Experiments will be performed in a complex experimental setup with detectors measuring and characterizing all particles involved in the reaction process.
For most of the reactions to be measured at the R3B experimental setup, the detection of high energy neutrons is essential. Especially all measurements relying on a reconstruction of the excitation energy by the invariant-mass analysis demand a precise measurement of the momentum vector of the neutrons emitted by the projectile. Therefore, a new time-of-flight detection system, the NeuLAND detector, is foreseen for the measurement of neutrons with energies between 200 and 1000 MeV. Depending on the demands on acceptance and resolution, the detector can be located at different distances from the reaction target between 12 and 30 meters downstream

at 0°. Given the performance of the detector, a time-of-flight resolution of better than 100 ps and a position resolution of about 1 cm, it is possible to reach an invariant-mass resolution of 20 keV close to the threshold. This will open a new precision era in the measurement of the ground states and resonance properties of exotic nuclei. Additionally, the high resolution at low energies will provide exact information on ($\gamma$,n) reactions involving exotic nuclei, this being relevant for nuclear astrophysics processes like the r- and the p-process.
The concept of the NeuLAND detector that we intend to study and test is based on the detection of secondary particles, induced by the neutrons in iron converter material, in Resistive Plate Chambers (RPCs). The detection of minimum ionizing particles with high efficiency (close to 100%) and very good timing resolution (less than 100 ps) has already been shown for a large area timing RPC. Also, this concept has been also successfully used by the HADES collaboration at GSI in the detection of the reaction products from heavy ion collisions at energies of 1-2 AGeV.
The goal of the present project is to contribute to the development and improvement of the design concept of the future NeuLAND detector by considering the two key issues in the design phase: the prototype testing and simulation of the detector performance. Our teams have recently joined the NeuLAND Working Group within the R3B collaboration. The initial goal of the projectwas to contribute for the Technical Design Report of NeuLAND, foreseen for the end of 2010. However, due to arguments of a better response of the NeuLAND version based on plastic scintillators to events with several neutrons, the Collaboration decided to include this solution in the TDR issued in 2011. However, in view of its future applicability in other experiments, the Collaboration decided to carry on with the study of the RPC-based fast neutron detector, which means that the scientifica goals of the project are maintained.
This is a novel application of timing Resistive Plate Chambers, a technology our group pioneered in the Framework of the ALICE experiment at CERN and developed over the last decade. After the successful production of the HADES RPC TOF Wall and coordination of the project, the R3B neutron TOF detector constitute a challenging follow-up detector design and construction activity.
In view of the size of the project, it will be carried on in collaboration with other groups within the R3B collaboration, in particular the team of the University of Lisbon headed by Daniel Galaviz Redondo. This team will be in charge of all the simulation work, while LIP will carry out the design, construction and testing of the prototype.

### 6.2.3 Objectives

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

### 6.2.4 Achievements

Work on the fine simulation of the prototype detectors went on and results were reported at the RPC 2012 in February, in Frascati. From the abstract of the proceedings we quote:
"A novel concept for the detection of [...] relativistic neutrons is based on Resistive Plate Chambers (RPCs). The detection principle of the RPC-based detector relies on the detection of the charged particles created in hadronic showers induced by the incoming neutrons. The presented design only considers glass plates for holding the active gas acting simultaneously as converters for neutron detection. For the optimization of a large area detector based on RPCs several simulations were performed using the Virtual Monte Carlo framework FAIRROOT. The detector was designed as a structure of single RPCs modules with 5 gas gaps grouped sequentially reaching a total efficiency for one neutron detection higher than 90%. In this work we present the results of
the simulations carried out and the evaluation of the performance of the detector concept". A developed version of this manuscript was later submitted to JINST in May and could be published soon.
Detectors construction.
The detection module consists of two (or five) 0.3 mm gas gaps defined by 2000x500x3 mm3 glass electrodes. Each module is then closed inside an acrylic box . The high voltage is applied to a resistive acrylic layer painted on the outer glass electrodes. Just four feed-throughs per module are needed, two for high voltage and two for gas input and output.

A problem arisen with the resistive layer (related to a cross effects of humidity, starting materials, etc.) took some time to be solved with success, delaying somewhat the assembly of the prototypes. One the detectors were ready, tests were then carried out with cosmics, in house, taking profit from the existing HADES infrastructure (front end electronics, HV power supplies and DAcQ). Some effort was necessary to achieve the synchronization of DAcQ with the MBS (standard system in use at GSI by various Collaborations). Results for the time difference between two layers of the prototype have shown a time resolution for the entire chain (RPC + FEE +DAQ) of $\sigma \approx 90$ ps per layer.
The prototype was then taken to GSI to be tested in the framework of experiment S406, which aimed at studying the performance of the base-line NeuLAND detector (made of plastic scintillators) and of the two alternative RPC prototypes (another prototype has been built and brought to the test beam by a German team of Helmholtz-Zentrum Dresden-Rossendorf). Upon installation and some short tests with cosmics, the beam tests were carried out for about one week in November 2012, with the detectors hit by relativistic neutrons. Our detectors were very stable all along the tests. Analysis of the acquired data is going on, since understanding (and subtracting) the large background is demanding some extra work. The problem affects the data of both the base-line detector modules and the RPC prototypes.

### 6.2.5 Sources of Funding

| Code | Funding | Start | End |
|---|---|---|---|
| PTDC/FIS/114876/2009 | 99.589 € | 2011-01-01 | 2013-12-31 |

### 6.2.6 Team

**Project coordinator: Rui Marques**

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

### 6.2.7 Publications

**International Conference Proceedings**

- *Simulations of an innovative ToF detector for high energy neutrons based on iron-less RPCs*
  J. Machado, A. Blanco, P. Fonte, D. Galaviz, L. Lopes, R. Ferreira Marques, P. Teubig
  Proceeedings of Science PoS(RPC2012)048

### 6.2.8 Project Summary

| | number |
|---|---|
| International Conference Proceedings | 1 |

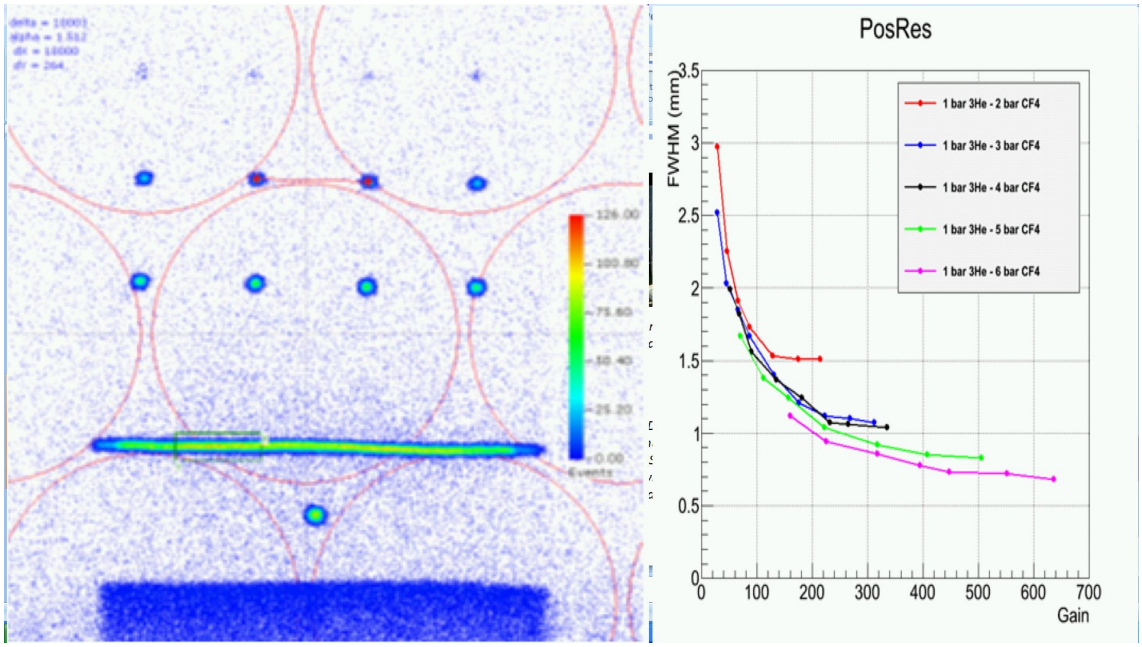
## 6.3 Microstructure Gas Detectors

### 6.3.1 Resumo

O grupo do LIP Coimbra é actualmente membro da Task 22.2 (detectores) da Integrated Infrastructure Initiative for Neutron Scattering and Muon Spectroscopy (FP7), Project nº 226507-NMI (FP7), que explora as possibilidades dos contadores de cintilação gasosos proporcionais com base em misturas 3He-CF4 de gás em alta pressão, utilizando microestruturas de multiplicação de carga (MSGC, ITO-MSGC, GEM). Nesta colaboração tínhamos a responsabilidade de desenvolver a simulação completa do detector, incluindo a interação dos neutrões e o rastreamento dos produtos da reação, assim como as medições de redimentos de cintilação.
Uma nova interface e vários novos recursos foram incluídos na ferramenta de simulação ANTS, desenvolvida pela equipa do LIP, incluindo a introdução de métodos de reconstrução adaptativos. O pacote de software ANTS foi disponibilizado para ser usado pela comunidade científica e dois trabalhos foram publicados. Participamos do desenvolvimento e testes do protótipo de 19 PMTs. Os dados recolhidos nas experiências finais foram analisados usando um pacote de software desenvolvido pelo equipa do LIP Coimbra.
Foi efectuado o estudo da PMT sensíveis à posição no emulador de Câmara Anger desenvolvido em Coimbra.

### 6.3.2 Abstract

We are currently members of Task 22.2 (detectors) in Integrated Infrastructure Initiative for Neutron Scattering and Muon Spectroscopy (FP7), Project nº 226507-NMI3, that explores the perspectives of Gaseous Scintillation Proportional Counters based on 3He-CF4 gas mixtures at high pressure and various charge amplifying structures (MSGC, ITO-MSGC, GEM) read out by position sensitive light detecting devices for neutron imaging. In this collaboration we had the responsibility of developing the complete simulation of the detector, including the neutron interaction and tracking of the reaction products, and taking the light yields measurements.
A new interface and several new features were included in the simulation tool ANTS, developed by the LIP team, including the introduction of reconstruction adaptive methods. The software ANTS package was released to be used to the scientific community and two papers were published. We participated in the development and tests of 19 PMT prototype. The data collected in final experiences was analyzed using a software package developed by LIP Coimbra.
We are also carrying the task of the study of position sensitive PMTs in the Anger Camera emulator developed by LIP at Coimbra.




a) 2D-position spectrum of 2.5A neutrons with a multi-hole / slit mask mounted in front of the GSPC recorded with the 32-channel readout system. Data analyzed with ANTS, using adaptive algorithms. b) Final results : Position resolution (FWHM) as a function of gas gain and CF4 pressure.

Two remaining aspects of CF4 scintillation were studied - the timing of the secondary scintillation and the photon VUV yields. Papers are being written on these subjects.

### 6.3.3 Objectives

Although the objectives of the LIP Coimbra team in the final part of the project were initially modest, the participation exceeded what has been considered. We accepted to carry the study of position sensitive PMTs and became responsible for the development of the data analyzing of the experience.

### 6.3.4 Achievements

An experimental set-up based on a submilimetric quasi-isotropic light source was used to measure the anode uniformity and the angular response of a multianode photomultiplier, considering its application in Anger Cameras. The Light Response Functions of were also measured. The simulation of optical elements of the detector was carried using ANTS.
A complete software package (ANTS) was developed for simulation and data analysis of the detector built in this joint research activity. New features, such as the use of adaptive algorithms in the reconstruction process were added. The final results, evidencing position resolution better than .75 mm, were obtained analyzing the experimental data with this package. Several papers were published on it and the executable code was released to the community.
The recent results of the participation of the LIP team in this project were detailed in the D 22.2.5.1 Report on simulation of optical elements and 22.3.2.1 Experimental report on PS and MaPMTs for GSPC.

### 6.3.5 Sources of Funding

| Code | Funding | Start | End |
|---|---|---|---|
| FP7-GA226507 | 80.640 € | 2009-02-01 | 2012-01-31 |

### 6.3.6 Team

**Project coordinator: Francisco Fraga**

| Name | Status | %of time in project |
|---|---|---|
| Andrey Morozov | Researcher (LIP) | 50 |
| Francisco Fraga | Researcher (LIP/FCTUC) | 50 |
| Luís Pereira | PhD student (LIP) | 100 |
| Margarida Fraga | Researcher (LIP/FCTUC) | 10 |
| Paulo Mendes | Researcher (LIP/FCTUC) | 20 |
| Rui Marques | Researcher (LIP/FCTUC) | 10 |

### 6.3.7 Publications

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

- *Secondary scintillation in CF4: emission spectra and photon yields for MSGC and GEM*
  A. Morozov, L. M. S. Margato, M. M. F. R. Fraga, L. Pereira, F. A. F. Fraga
  J. Instrum., 7, P02008 (2012)

- *ANTS - a simulation package for secondary scintillation Anger-camera type detector in thermal neutron imaging*
  A. Morozov,I. Defendi,R. Engels, F.A.F. Fraga,M.M.F.R. Fraga,B. Guerard, M. Jurkovic, G. Kemmerling, G. Manzin, L.M.S. Margato, H. Niko, L. Pereira,C. Petrillo, A. Peyaud, F. Piscitelli, D. Raspino, N.J. Rhodes, and F. Sac
  J. Instrum., 7, P08010 (2012) - doi:10.1088/1748-0221/7/08/P08010

- *Effect of the gas contamination on CF4 primary and secondary scintillation*
  L. M. S. Margato, A. Morozov, L. Pereira, M. M. F. R. Fraga, F. A. F. Fraga
  Nucl. Instrum. Methods Phys. Res. Sect. A-Accel. Spectrom. Dect. Assoc. Equip., 695, 425 (2012)

### 6.3.8 Presentations

**Oral presentations in collaboration meetings**

- *GSPC LIP task overview*
  presented by Francisco Fraga
  FP7 - NMI3-GSPC – Meeting, Abingdon, June 26-27, 2012 — GSPC – Meeting, Abingdon, June 26-27, 2012 .

- *Decay time of the CF4 secondary scintillation*
  presented by Luís Margato
  FP7 - NMI3-GSPC – Meeting, Abingdon, June 26-27, 2012 — Uk.

- *Anger Camera emulation - preliminary results*
  presented by Luís Pereira
  FP7 - NMI3-GSPC – Meeting, Abingdon, June 26-27, 2012 — UK.

- *Adaptive methods in image reconstruction in ANTS*
  presented by Andrey Morozov
  FP7 - NMI3-GSPC – Meeting, Abingdon, June 26-27, 2012 — UK.

- *LIP task overview*
  presented by Francisco Fraga
  GSPC – Meeting, Garching, December 04, 2012 — TUM, Munich, Germany.

- *Further studies of decay time of the CF4 secondary scintillation*
  presented by Luís Margato
  GSPC – Meeting, Garching, December 04, 2012 — TUM, Munich, Germany.

- *Adaptive methods in image reconstruction in ANTS*
  presented by Andrey Morozov
  GSPC – Meeting, Garching, December 04, 2012 — TUM, Munich, Germany.

- *Study of position sensitive PMTs*
  presented by Luís Pereira
  GSPC – Meeting, Garching, December 04, 2012 — TUM, Munich, Germany.

### 6.3.9 Project Summary

| | number |
|---|---|
| Articles in international journals (with direct contribution from LIP members) | 3 |
| Oral presentations in collaboration meetings | 8 |

## 6.4 Gamma-Ray Polarimetry with Fermi and DUAL Space Missions

### 6.4.1 Resumo


**Desenvolvimento de um polarímetro para futuras Missões Espaciais**

Em 2012 o nosso grupo prosseguiu o desenvolvimento de um plano focal de CdZnTe (CZT) optimizado para a observar emissões polarizadas de raios gama no espaço que devera ser submetida à próxima chamada do programa Cosmic Vision da ESA. Está a ser desenvolvido e testado um novo conceito de detectores de CZT com informação tridimensional. O protótipo a desenvolver funcionará no modo Campo Plano Transverso com a recolha de sinal a ser efectuada por um sistema de micro-fitas, permitindo a leitura tridimensional da trajectória das partículas. De forma a tornar possível a absorção de fotões em cristais de CZT até 20 mm sem aumentar a distância de recolha de carga, aplica-se um campo perpendicular ao eixo óptico do cristal. O desenvolvimento de sensores para ambiente espacial requer uma série de teste progressivos até à sua qualificação pela ESA. Nesse âmbito tem vindo a ser preparado um teste preliminar num balão de alta altitude, a missão CIPHER (Coded Imager and Polarimeter for High Energy Radiation), em colaboração com o Istituto di Astrofisica Spaziale e Fisica Cósmica, Bolonha, Itália. Os resultados experimentais e resultantes de simulações indicam que as prestações deste instrumento são compatíveis com os requerimentos estabelecidos pelo consórcio: sensibilidade de $10^{-6}$ fotões/(cm$^2$.s.keV) entre 100 keV e 1 MeV, resolução de 1% e polarização mínima detectável $< 1\%$ para uma fonte equivalente à Nebulosa do Caranguejo durante $10^{-6}$ s.

**Desenvolvimento do instrumento principal da Missão XIPE**

A 15 de Junho de 2012, o nosso grupo integrou a proposta XIPE (X-ray Imaging Polarimetry Explorer) submetida ao concurso para missões S (small missions) da ESA. O nosso contributo para a missão centra-se no desenvolvimento do instrumento principal, constituído por Contadores Gasosos Pixelizados (GPD: Gas Pixel Detectors), em particular na optimização das misturas gasosas (Xénon, Árgon, etc.) tendo em vista a realização de medidas polarimétricas baseadas no efeito fotoeléctrico. O estudo deste instrumento tem vertentes teóricas e experimentais. Foram por nós estudadas através de um programa de simulação pelo Método de Monte Carlo baseado em Fortran, as prestações polarimétricas em função da energia (até 20 keV) de um GPD com Xénon a uma atmosfera. Análise dos dados obtidos permitiu-nos concluir que as potenciais prestações polarimétricas



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

deste tipo detectores são compatítiveis com as exigências de sensibilidade de instrumento a ser enviado para o espaço. Do ponto de vista experimental, testámos um GPD com xénon a uma atmosfera irradiado por uma fonte de radiação polarizada entre os 5 e os 15 keV, tendo sido obtidos resultados que, dentro da margem de erro experimental, verificam os resultados obtidos nas simulações.

### 6.4.2 Abstract

**Polarimeter development for DUAL Space Mission**

Our group pursues the development of a Laue lens focal plane instrument based on CdZnTe for a space gamma-ray observatory equiped with Laue lens. A novel 3D position sensitive CdZnTe prototype is under development, that will operate in PTF (Planar Transverse Field) configuration with drift microstrip readout of each sensitive units and the three dimensional spatial resolution. In order to increase the photon absorption thickness up to 20 mm without increasing the charge collection distance, the charge collecting field is perpendicular with respect to the optical axis of the crystal. A preliminary balloon borne version is being developed, entitled CIPHER (Coded Imager and Polarimeter for High Energy Radiation), in collaboration with the Istituto di Astrofisica Spaziale e Fisica Cósmica, Bologna, Italy. So far, prototype experimental and simulation results are compatible with the performances required for DUAL main instrument established by the consortium: 10ˆ-6 photons/(cmˆ2.s.keV) detection sensitivity between 100 keV and 1 MeV, energy resolution of ≈1% and minimum detectable polarization $< 1\%$ for a Crab source equivalent and for 10ˆ-6s.

**XIPE mission main instrument development**

XIPE (X-ray Imaging Polarimetry Explorer) mission proposal was submitted to ESA call for S missions by June 15th, 2012. Our group will contribute to the main instrument development composed by GPD (Gas Pixel Detectors), specifically in the gaseous mixtures optimization (Xénon, Árgon, etc.) for photoelectric based polarimetry. Instrument development will be performed both by experimental and simulation work. Up to the present a Fortran Monte Carlo simulation program was developed that allows to analyse the polarimetric performances of a GPD filled with Xenon at 1 atmosphere up to 20 keV. The preliminary results show that the performances of this type of detectors are potentially compatible with XIPE mission requirements. Experimentally, a GPD filled with xenon at one atmosphere was tested under a partially polarized X-ray beam in an energy range between 5 and 15 keV. The results obtained are in agreement with the results obtained in the performed simulations.

### 6.4.3 Objectives

Even though XIPE mission was select by ESA, it was a top three ranked mission. Therefore, the development of a GPD instrument to observe the X-ray polarization of celestial objects will be pursued since the next ESA call for S missions proposals will occur by 2015.
The driving idea of developing a 3D position prototype is the use of CZT crystals in PTF (Planar Transverse Field) configuration to increase the photon absorption thickness up to 20 mm without increasing the charge collection distance. In the PTF configuration the charge collecting field is perpendicular to the optical axis of the crystal, improving the spectroscopic performance of CZT. In its final configuration it will be composed of 64x64 cubic voxel. A miniaturised ASIC electronics integrating a pre-amplifying stage, an amplifying and signal shaping stage will be developed in order to fit to the pixelisation level of each detection plane, as well as a coincidence electronic subsystem suitable to detect double events produced by polarized Compton photons inside the semiconductor material. The 3D CZT prototype will be tested at the European Synchrotron Radiation Facillity, Grenoble, France under a ≈100% polarized beam, monitored by a Monte Carlo simulations to better understand the results of each test. Complementary and longer experimental tests will be performed on CZT prototypes with LIP laboratorial polarization precision table. A balloon borne version (CIPHER) will be developed and tested.

### 6.4.4 Achievements

Ongoing PhD Thesis:
Colin Paul Gloster, UC PhD student, started 01/10/2009
José Marques, CAUP and LIP PhD student, started 01/10/2011
Submitted a space mission proposal, XIPE (X-ray Imaging Polarimetry Explorer), to ESA S-class the June 15th, 2012. Proposal not selected, but ranked 3rd among about 50 proposals.
Submitted projects:

"Gamma-ray Universe Polarization Analysis with Fermi Space Telescope", ref. PTDC /FIS-AST/0879/2012. Not funded Project.
For more achievements, see publications and presentations sections.

### 6.4.5 Team

**Project coordinator: Rui Curado Silva**

| Name | Status | %of time in project |
|---|---|---|
| Alexandre Fonseca Trindade | Master (LIP) | 30 |
| Carlos Conde | Researcher (LIP) | 20 |
| Carlos Patacas | Master (LIP) | 20 |
| Collin Gloucester | PhD student (LIP) | 100 |
| Filipa Borges | Researcher (LIP) | 15 |
| Filomena Santos | Researcher (LIP) | 20 |
| João Barata | Researcher (LIP/UBI) | 20 |
| Jorge Maia | Researcher (LIP/UBI) | 45 |
| José Marques | PhD student (LIP) | 60 |
| Rui Curado Silva | Researcher (LIP) | 85 |
| Teresa Dias | Researcher (LIP) | 15 |

### 6.4.6 Publications

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

- *CdZnTe Focal Plane Polarimetric Performances for a Laue Lens Point Spread Function*
  J. B. de Campos, R. M. Curado da Silva, C. P. Gloster, Alessandro Pisa, E. Caroli, J. B. Stephen, F. Frontera
  IEEE Trans. Nucl. Sci., Vol. 59, n° 4, 2012, pp. 1582 - 1590

- *Polarization degree and direction angle effects on a CdZnTe focal plane performance*
  R. M. Curado da Silva, E. Caroli, J. Stephen, N. Auricchio, J.M. Maia, S. del Sordo, N. Donati, F. Schiavone, J. B. Campos, C. P. Gloster, A. Trindade, V. Honkomäki
  IEEE Trans. Nucl. Sci., Vol. 59, n° 4, 2012, pp. 1628 - 1635

- *A DUAL mission for nuclear astrophysics*
  Peter von Ballmoos, Jose Alvarez, Nicolas Barrière, Steve Boggs, Andrei Bykov, Juan Manuel Del Cura Velayos, Filippo Frontera, Lorraine Hanlon, Margarita Hernanz2, Emmanuel Hinglais8, Jordi Isern2, Pierre Jean1, Jürgen Knö
  Experimental Astronomy Vol. 34, Issue 2 , pp 583-622, DOI: 10.1007/s10686-011-9286-6

**International Conference Proceedings**

- *Development status of a CZT spectrometer prototype with 3D spatial resolution for hard X ray astronomy*
  N. Auricchio, E. Caroli, A. Basili, G. Benassi, C. Budtz Jørgensen, R. M. Curado da Silva, S. Del Sordo, I. Kuvvetli, L. Milano, F. Moscatelli, J. B. Stephen, M. Zanichelli, A. Zappettini
  Proceedings of SPIE, Vol. 8453, 84530S, 2012

- *A 3D CZT hard x-ray polarimeter for a balloon-borne payload*
  E. Caroli, J. M. Alvarez, N. Auricchio, C. Budtz-Jørgensen, R. M. Curado da Silva, S. Del Sordo, P. Ferrando, P. Laurent, O. Limousin, J. L. Galvèz, C. P. Gloster, M. Hernanz, J. Isern, I. Kuvvetli, J. M. Maia, A. Meuris J
  Proceedings of the SPIE, Volume 8443, 84434O, 2012

### 6.4.7 Presentations

**Presentations in national conferences**

- *Experimental setup and readout electronics for a gamma ray prototype polarimeter*
  presented by José Marques
  XXII Encontro Nacional de Astronomia e Astrofísica — Centro de Astrofísica da Universidade do Porto .

- *XIPE mission proposal*
  presented by Rui Curado Silva
  XXII Encontro Nacional de Astronomia e Astrofísica — Centro de Astrofísica da Universidade do Porto .

**Seminars**

- *X- and gamma-ray space polarimetry in future space missions*
  presented by Rui Curado Silva
  — Observatório Astronómico da Universidade de Coimbra.

- *X- and gamma-ray polarimetry in future space missions*
  presented by Rui Curado Silva
  — Laboratório de Instrumentação e Física Experimental de Partículas, Lisboa, Portugal.

- *Gamma-ray Universe Polarization Analysis with Fermi Space Telescope*
  presented by Rui Curado Silva
  — Centre for Cosmology, Particle Physics and Phenomenology - CP3, Université catholique de Louvain, Bélgica.

- *XIPE space telescope proposal*
  presented by Rui Curado Silva
  — Departamento de Física, Universidade de Coimbra.

**Outreach seminars**

- *Aquecimento global: consequências e soluções*
  presented by Rui Curado Silva
  — Escola Dr. Daniel de Matos, Vila Nova de Poiares.

- *Astronomia & Tecnologia Espacial no Quotidian*
  presented by Rui Curado Silva
  — Escola Secundária/3 Amato Lusitano.

### 6.4.8 Academic Training

**PhD Theses**

- *Simulations of Mass Models of Gamma-Ray Detectors*
  Colin Paul Gloster, (on-going)

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

### 6.4.9 Project Summary

| | number |
|---|---|
| Articles in international journals (with direct contribution from LIP members) | 3 |
| International Conference Proceedings | 2 |
| Presentations in national conferences | 2 |
| Seminars | 4 |
| Outreach seminars | 2 |

## 6.5 High Pressure Xenon Doped Mixtures for the NEXT Collaboration

### 6.5.1 Resumo

Trabalho experimental realizado:
* Montagem e teste do sistema de vazio e sistemas de purificação (para gases nobres e gases moleculares) para ligar os detectores.
* Montagem teste e calibração dos dois detectores desenhados (contador proporcional e contador gasoso de cintilação proporcional)
* Estudo e calibração dos referidos detectores.
Os detectores já foram testados e calibrados. Já foram feitas medidas com xenon puro em ambos os detectores tendo-se verificado comportamentos dentro do previsto. Vamos começar com as misturas com gases moleculares, sendo que as últimas experiências a efectuar serão com TMA.
Houve vários atrasos em relação ao previsto devidos a contratempos imprevisíveis (avarias de aparelhos, problemas nas janelas de radiação, uma fenda no Macor do lado do fotomultiplicador que gerou problemas no vazio, etc)
A tese de mestrado foi concluída com sucesso.

### 6.5.2 Abstract

Experimental work:
* Assembly and test of the vacuum system and purification systems (for noble gases and for molecular gases) to host the two detectors.
* Assembly, test and calibration of the two detectors(proportional counter and gas proportional scintillation counter).
* Study and calibration of the detectors.
The detectors have already been tested and calibrated. Measures have been made with pure xenon in both detectors. Results have been according to expected. Within the next days measures will be taken with molecular gas mixtures. Last experiments will be with TMA.
We had several delays (breakdowns in some electronic equipment, problems in the radiation windows, a crack in the macor witch lead to a leak on the photomultiplier side. )
The master degree thesis was successful.

### 6.5.3 Objectives

At this point the objectives are to obtain results for the energy resolution with both detectors for the mixtures and compare them with the results already obtained for pure xenon. A thorough analysis and comparison of both (pure gas and mixture) will hopefully allow us to draw conclusions concerning recombination as a function of the pressure and of the admixture gas. The electroluminescence yield in pure xenon and in the mixtures will also be investigated and compared.

### 6.5.4 Achievements

Main achievements up to know have been the successful design and assembly of the whole system and detectors. The detectors are working as expected and ready for the new step.

### 6.5.5 Team

**Project coordinator: Filomena Santos**

| Name | Status | %of time in project |
|---|---|---|
| Carlos Conde | Researcher (LIP) | 30 |
| Filipa Borges | Researcher (LIP) | 30 |
| Filomena Santos | Researcher (LIP) | 50 |
| João Barata | Researcher (LIP/UBI) | 15 |
| Jorge Maia | Researcher (LIP/UBI) | 15 |
| José Escada | PhD student (LIP) | 60 |
| Paulo Rachinhas | Master (LIP) | 10 |
| Sérgio Carmo | Master (LIP/ITN) | 10 |
| Teresa Dias | Researcher (LIP) | 15 |

### 6.5.6 Publications

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

- *A New Contribution to the Experimental Measurement of the N4+ Ion Mobility in N2 at 298K*
  A.N.C. Garcia, P.N.B. Neves, A.M.F. Trindade, F.P. Santos, C.A.N. Conde
  JINST vol. 7, P02012, 2011

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

- *SiPMs coated with TPB : coating protocol and characterization for NEXT*
  V Álvarez et al., (including F I G Borges, C A N Conde, T H V T Dias, F P Santos)
  2012_JINST_7_P02010

### 6.5.7 Project Summary

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

## 6.6 Ion Transport Processes in Gaseous Detectors for Particle Physics

### 6.6.1 Resumo

O estudo do transporte de iões em gases continua a ser um tema de muito interesse não só devido aos problemas de física atómica e molecular que levanta e que procura resolver, mas também devido à sua aplicação em áreas diversas, como a área dos detectores gasosos de radiação, nomeadamente os detectores para física das altas energias. Nos detectores gasosos de radiação baseados em processos de avalanche, a amplitude do impulso do sinal de saída tem duas componentes, uma devida à deriva dos electrões, e outra devida à deriva dos iões. Embora a velocidade de deriva dos iões seja muito menor do que a dos electrões, a sua contribuição para a formação do impulso induzido é frequentemente predominante. Geralmente, é apenas considerado um único tipo de ião, mas muitas vezes, para misturas gasosas do tipo gás nobre/gás molecular utilizadas em detectores para física das altas energias, mais do que um tipo de ião tem que ser considerado no processo de deriva.
Na sequência dos trabalhos teóricos anteriormente realizados por investigadores da equipa para gases nobres, este projecto tem como objectivo o cálculo de secções eficazes integrais e diferenciais de colisão elástica ião-átomo/molécula e a simulação do transporte de iões no próprio gás. Serão consideradas misturas gasosas de Ar com moléculas orgânicas com interesse para detectores para física das altas energias como CH4 e C2H6. As secções eficazes, integrais e diferenciais, de colisão elástica serão calculadas pelo método das ondas parciais, com desvios de fase calculados pelo método de JWKB e potenciais de interacção teóricos ou derivados de resultados de pesquisa bibliográfica. As secções eficazes serão calculadas para energias, no centro de massa, entre 0.001 e 10 eV. Estas secções eficazes serão utilizadas para calcular, utilizando técnicas de Monte Carlo, os parâmetros de transporte dos iões (velocidades de deriva e coeficientes de difusão longitudinal e transversal) para campos eléctricos reduzidos até ao limiar para ionização por electrões.
Conceptualmente a medida de velocidades de deriva de iões em gases é simples, mas podem surgir complicações quando estão presentes diversos tipos de iões. Este projecto também tem como objectivo a medida experimental da mobilidade de iões no próprio gás para diferentes pressões e campos eléctricos reduzidos, E/N, utilizando um sistema experimental, anteriormente concebido e implementado pela equipa de investigação. O sistema experimental é baseado em técnicas originais desenvolvidas por investigadores da equipa. Uma lâmpada VUV de Xe pulsada liberta electrões da superfície de um filme de CsI que cobre um GEM. Estes electrões disparam uma avalanche onde são produzidos os iões positivos a estudar. Os iões derivam sob a influência de um campo eléctrico uniforme e são recolhidos numa grelha colectora, blindada electrostaticamente por uma grelha de Frisch, dando origem a um impulso que permite medir os tempos de deriva dos diversos iões formados e assim obter as velocidades de deriva. Este sistema experimental será utilizado para medir as velocidades de deriva de iões positivos presentes em misturas gasosas (nomeadamente Ar/CH4 e Ar/C2H6) e quando possível para identificar esses iões e medir taxas de reacção para a formação de iões mais complexos.

### 6.6.2 Abstract

The study of the transport of ions in gases continues to be a subject of great interest not only due to the fundamental atomic and molecular physics problems involved but also due to its applications in many fields of interest such as the area of gaseous radiation detectors, including detectors for high energy physics. In gaseous detectors based on electron avalanches, the output pulse amplitude has two components: one due to the drift of electrons and another due the drift of the ions. Although the drift velocity of the ions is much slower than that for electrons, their contribution to the induced pulse is often predominant. Usually, only one type of drifting ion is considered, but often in gaseous mixtures like noble gas / organic gas mixtures used in high energy physics detectors, more than one type of ion contributes to the drifting processes.
Following the theoretical studies carried out before by the team researchers for noble gases, this project aims to calculate differential and integral ion-atom/molecule elastic collision cross sections and the simulation of the transport of ions in gases. Will be considered noble gas based mixtures with interest for particle physics detectors such as Ar/CH4 and Ar/C2H6. The differential and integral elastic collision cross sections will be calculated by the partial waves method, with phase-shifts calculated using the JWKB approximation and interaction potentials derived from literature searches. The cross-sections will be calculated for centre-of-mass energies at least in the 0.001 eV to 10 eV range. These cross-sections will be used to calculate, by detailed Monte Carlo techniques, ion transport parameters (drift velocities, longitudinal and transversal diffusion coefficients), for reduced electric fields up to about the threshold for electron ionization.
The measurement of the drift velocities in gases is simple in concept, but complications may arise when several kinds of ions are present. An experimental system designed and constructed before by the research team, will be used for measure the mobilities of ions in their parent gases under different pressures and reduced electric yields,

E/N, and for the identification of the different ions present. The experimental system is based on the original techniques developed before by researchers of the team. A pulsed Xe UV lamp releases electrons from a CsI covered GEM. These electrons trigger an avalanche where positive ions are produced. Under the influence of an uniform electric field these ions drift towards a collecting grid shielded by a Frisch grid. A time-of-flight spectrum generally allows positive ion identification and the determination of their drift velocities. This experimental system will be used to measure the drift velocities of the positive ions present in the gas mixture (namely Ar/CH4 and Ar/C2H6) and whenever possible their identification and the measurement of their reaction rates.

### 6.6.3 Objectives

The present project consists of two main parts:

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

2. Improvment of an experimental technique that was already implemented for the measurement of ion mobilities in gases, making possible the measurement of these parameters at higher pressures and with a better time resolution, and its use for identification of the different ions present and the measurement of their drift velocities.

### 6.6.4 Achievements

During the year of 2012 the following researches were carried out:

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

- Use of the experimental system for the measurement of the drift velocities of ethane ions in pure C2H6 for different pressures and reduced electric yields, data taking, analysis and interpretation.

The experimental study of the mobility of ethane ions formed in pure C2H6 was completed. The experimental ion reduced mobility values, K0, were deduced from the analysis of the measured time-of-arrival spectra of ethane ions produced by electron impact at the GEM. For C2H6 pressures between 2 and 8 Torr, two peaks could be observed when reduced applied fields E/N varied from 10 to 75 Td, where E/N is the ratio of electric-field strength to gas-number density. Considering the corresponding reduced mobilities values extrapolated to zero-field (E/N=0) in C2H6 and the reaction rates of the ions initially formed in the GEM, the first peak of the spectra may be assigned to C3H7+ and the second peak may be assigned to the par of ions C4H9+/C4H11+ with similar mobility values. An article concerning these studies is being prepared for submission to an international journal.

### 6.6.5 Sources of Funding

| Code | Funding | Start | End |
|---|---|---|---|
| CERN/FP/123613/2011 | 10.000 € | 2012-03-12 | 2014-03-11 |

### 6.6.6 Team

**Project coordinator: João Barata**

| Name | Status | %of time in project |
|---|---|---|
| Alessio Mangiarotti | Researcher (LIP) | 16 |
| Alexandre Fonseca Trindade | Master (LIP) | 32 |
| Carlos Conde | Researcher (LIP) | 16 |
| Filipa Borges | Researcher (LIP) | 16 |
| Filomena Santos | Researcher (LIP) | 12 |
| João Barata | Researcher (LIP/UBI) | 32 |
| Pedro Neves | Post-Doc (ATP-Group) | 12 |
| Teresa Dias | Researcher (LIP) | 16 |

### 6.6.7 Publications

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

- *Experimental measurements of the mobility of methane ions in methane*
  A.M.F. Trindade, J. Escada, P.N.B. Neves, T.H.V.T. Dias, J.A.S. Barata, F.P. Santos and C.A.N. Conde
  JINST 7 P06010

### 6.6.8 Project Summary

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

## 6.7 Beam Monitoring System for Cyclotron Proton Beams at ICNAS

### 6.7.1 Resumo

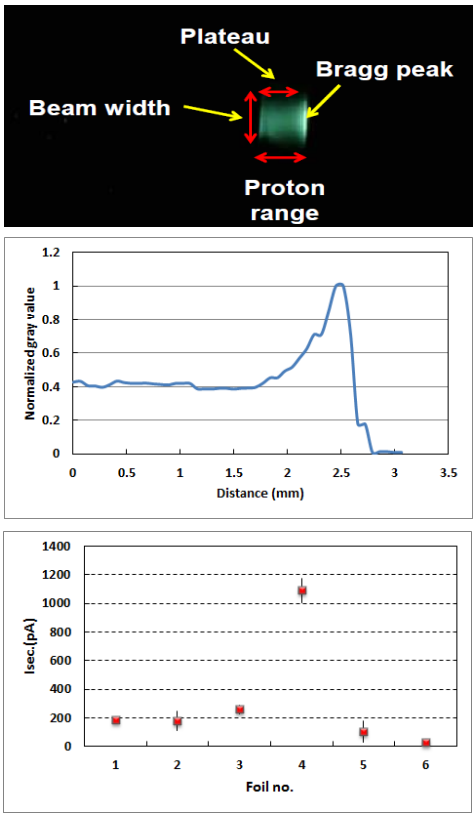
O grupo do LIP que desenvolve este projecto juntamente com o ICNAS avançou em várias frentes no âmbito da instrumentação para medições de correntes do feixe de protões do ICNAS. O intuito final é o de potenciar experiências no âmbito da dosimetria e radioterapia com pequenos animais irradiados com feixes de protões.
O projecto tem por fim providenciar ao futuro utilizador a capacidade de trabalhar tanto na área da radioterapia (dose no alvo da ordem do Gy às dezenas de Gy) bem como na área da radioprotecção (dose da ordem das dezenas de mGy ou inferiores).

### 6.7.2 Abstract

The group at LIP that develops this project in collaboration with ICNAS has already moved forward in its goals in several aspects related to the instrumentation for proton beam measurements at ICNAS. The final goal of the project is to provide the end user with a setup offering the possibility of carrying out dosimetric experiments together with small-animal radiotherapy studies. One of the goals of the project is to allow studies in the field of radiotherapy (comprising total doses between a few Gy to a few tens of Gy), as well as studies in the field of radiation protection (hence comprising doses of the order of a few tens of mGy or less).

### 6.7.3 Objectives

The overall goals described in the paragraph above are being pursued by theoretical understanding of interactions of particles in metals, substantiating beam monitor developments, together with experimental studies on the




Bragg peak measured by means of (top and middle) luminescence of a plastic scintillator, and (bottom) secondary current on a stacked target consisting of aluminum interleaved with polyethylene.

origins of such currents (beam dispersion, secondary electron currents, flowing both in the forward and backward directions). In addition, the possibility of using solid plastic scintillators to monitor beam uniformity and intensity is also being investigated.

### 6.7.4 Achievements

The groups involved have been able to measure the proton Bragg peak in two distinct and complementary ways. One used a stacked target of polyethylene sheaths interleaved with aluminum foils, the latter being read by self-developed transimpedance amplifiers. A second independent way to measure the Bragg peak of the stopping proton beam consisted in measuring the light yield of a plastic scintillator positioned in front of the beam.

### 6.7.5 Team

**Project coordinator: Paulo Crespo**

| Name | Status | %of time in project |
|---|---|---|
| Francisco Fraga | Researcher (LIP/FCTUC) | 10 |
| Hugo Simões | Master (LIP/FCTUC) | 25 |
| Paulo Crespo | Researcher (LIP/ISEC/FCTUC) | 30 |
| Rui Marques | Researcher (LIP/FCTUC) | 10 |
| Sharif Ghithan | PhD student (LIP/FCT) | 100 |

### 6.7.6 Publications

**International Conference Proceedings**

- *Preliminary Characterization of the External Proton Beam from a PET Cyclotron for use in Neutron and Proton Radiobiology and Other Dosimetric Studies*
  Sharif Ghithan, Hugo Simoes, Francisco Alves, Sergio Carmo, Micaela Cunha, Rui Ferreira Marques, Francisco Fraga, Marco Pinto, Paulo Crespo
  2012 IEEE 2nd Portuguese Meeting in Bioengineering (ENBENG)

### 6.7.7 Presentations

**Presentations in national conferences**

- *Beam monitoring system for cyclotron proton beams at ICNAS*
  presented by Sharif Ghithan
  Jornadas do LIP 2012 — Lisbon, Portugal.

### 6.7.8 Academic Training

**PhD Theses**

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

### 6.7.9 Project Summary

| | number |
|---|---|
| International Conference Proceedings | 1 |
| Presentations in national conferences | 1 |

## 6.8 Detector Lab / Mechanical Workshop

### 6.8.1 Resumo

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

RPC prototype (vertical aluminium box) with a size of 2000x500 mmˆ2

### 6.8.2 Abstract

The Mechanical Workshop (MW) of LIP was established in 1986 to support the experimental activities to be performed in collaboration with CERN. At this time it was equipped with modern CNC equipment and qualified personnel. At present, the equipment available, recently improved with high performing machine tools and CAD-CAM software, and the highly qualified staff allows the MW to perform a large spectrum of mechanical services, from the design project to the production and testing. In parallel, the detector laboratory (DL) was also created at the beginning of the LIP foundation with the main aim of supporting the experimental activities developed at LIP. The laboratory has been continuously updated according to general needs but also due to specific needs of the research groups. The available equipment and technical staff, allow a variety of services: Design, construction and reparation of electronic circuits. Design, construction and test of detectors. Design, construction and reparation of gas and vacuum systems.
A two-decades experience assures us that, in the absence of the LIP MW/DL, it would not have been possible to perform with the same high level of quality the R&D in gaseous detectors performed in the framework of autonomous projects or small collaborations, or the responsibilities undertaken within medium and large international collaborations (CP-LEAR, DELPHI, HERA-B, ATLAS, HADES, AUGER). Equally evident are the benefits to the national R&D community of the intervention of the MW/DL in its projects, at the local and national level.

### 6.8.3 Objectives

During this year it is expected that the MW and DL reinforces its present capabilities, while widspreading its recognision in the research community. One important issue is the increased ability to establish conyident schedules for the orders received.
In particular, besides of the LIP projects, either local or in international collaborations, some of them with innovative requirements, we foresee for early 2012, in partnership with a high-tech branch of the local company SINERGIAE, the production of a set of challenging pieces for equipping PILOT, a balloon-borne astronomy experiment to study the polarized emission arising from dust grains in the interstellar medium, responsibility of the French institutions IAS, CESR and CNES. Additionally, two other main tasks will require a significant part of the available resources: design, development and construction of the first prototype of Resistive Plate Chamber (RPC) for cosmic ray detection in the frame work of the the AUGER collaboration and the construction of a RPC for the detection of fast neutrons in the framework of the "NeuLAND - Um detector de tempo de voo inovador para neutrões de alta energia no GSI e em FAIR"project (PTDC/FIS/114876/2009).

### 6.8.4 Achievements

**Mechanical Workshop**
During this year, along with current support given by the Mechanical Workshop (MW) on a daily bases to the ongoing LIP R&D projects and to the Physics Department of the University of Coimbra, progress has been made in the full exploitation of the modern machine tools, with a continuous effort put in the use of the TOPSOLID software. However, some difficulties still remain in interfacing this software package with the milling machine and the turning mill, a problem that still waits for a complete solution.
The cooperation with local high-tech company SINERGIAE, was a success, helping on his development and making the pieces to the balloon-borne PILOT, astronomy experiment to the study of polarized emissions arising from the dust grains in the interstellar medium responsibility of the French institutions IAS, CESR, and CNES.
The support to the experiment SNO, was either a success, with the researched solutions and the assembly done. The total of invoices issued to the institutes during this year was above 40k€, over 70% of last year result. The following table summarizes the work during 2012.
**Mechanical Workshop activity in 2012**

| Institution | Branch/Project | # Orders | Sub-totals |
|---|---|---|---|
| Physics Dep. Uc | General | 3 | |
| Physics Dep. Uc | CEMDRX | 16 | |
| Physics Dep. Uc | TNAM | 2 | |
| Physics Dep. Uc | GEI | 2 | |
| Physics Dep. Uc | GIAN | 13 | |
| Physics Dep. Uc | SPF - Olimpiada das Fisica | 1 | 37 |
| LIP-Coimbra | ATLAS | 2 | |
| LIP-Coimbra | LUX | 5 | |
| LIP-Coimbra | Scintillation | 3 | |
| LIP-Coimbra | Outreach | 1 | |
| LIP-Coimbra | FP7-NMI3 | 3 | |
| LIP-Coimbra | HADES | 2 | |
| LIP-Coimbra | Human RPC-PET | 1 | |
| LIP-Coimbra | Animal RPC-PET | 4 | |
| LIP-Coimbra | RT-MON | 2 | |
| LIP-Coimbra | AUGER | 2 | |
| LIP-Coimbra | SNO | 2 | |
| LIP-Coimbra | SNO++ | 1 | |
| LIP-Coimbra | Medical Physics | 1 | |
| LIP-Coimbra | Compton | 3 | |
| LIP-Coimbra | Ciclotrao | 3 | |
| LIP-Coimbra | Imaging | 1 | |
| LIP-Coimbra | R3B | 4 | |
| LIP-Coimbra | CF4 | 1 | |
| LIP-Coimbra | Varias | 13 | 54 |
| OTHER-ISEC,Engeneering Coimbra Institute | . | 1 | |
| OTHER-Sinergiae | PILOT | 1 | |
| OTHER-FCUL | Center for Atomic Physics | 3 | |
| OTHER-CNC-Coimbra | Molecular Biology | 1 | |
| OTHER-CNC-Coimbra | Neurosciences | 2 | |
| OTHER-IMAR-Coimbra | IMAR-Coimbra | 1 | |
| OTHER-IPO-FG-Coimbra | IPO-Coimbra | 1 | |
| OTHER-DEQ-FCTUC | PRODEQ | 2 | |
| OTHER-DEEC-FCTUC | ISR-Coimbra | 3 | 15 |

**Detector Laboratory**
During 2012, the activity that significantly required most resources was the construction of a Resistive Plate Chamber detector (RPC) for the detection of fast neutrons in the framework of the "NeuLAND - Um detector de tempo de voo inovador para neutrões de alta energia no GSI e em FAIR"project (PTDC/FIS/114876/2009). The prototype consists in 4 timing RPC layers, see fig. 1. Each layer has an active area of around 2000 x 500 mmˆ2. The readout of the entire prototype comprises 120 Front End Electronics (FEE) channels.
Other activities (It should be pay attention to the fact that these activities are frequently overlapped with the experimental activities of the projects itself and are difficult to disentangle), in parallel with the daily support to the research groups that deserve to be mentioned are listed here:

- Design, development and construction of the first prototype of RPC for cosmic ray detection in the frame work of the the AUGER collaboration.
- A variety of PCB routings for different projects.
- Reparation of electronic modules / devices, e.g., High Voltage (HV) modules, amplifiers, Analog to Digital Converter (ADC) modules, ...
- Design and construction of photomultipliers bases.
- Final implementation of a system for the readout of the RPC reference chambers (48 chambers) and the readout of the multiplicity trigger signals (96 lines) of the RPC-TOF of the HADES experiment. This system is based on the analog multiplexing (1-wire device) of the different channels, readout by two oscilloscope channels and later processing by a custom made program based in C++.

- Test and reparation of the spare FEE, Mother Boards MBs and Low Voltage Power Supplies (LVPS) for the RPC-TOF of the HADES experiment.
- Final implementation of a low cost HV power supply (+-7kV, 200uA) for the Auger-RPC detectors. The system is based on commercial DC-DC converters.
- Construction of one spark chamber for the outreach project.
- Different laboratory presentations to students in the framework of the physics department outreach program.
- Development of a generic step motor controller.
- Development and implementation of power supplies units for electronics crates.

# Chapter 7

# Outreach

## 7.1 Particle physics education and public outreach

### 7.1.1 Resumo

O LIP promove o avanço do conhecimento científico para o público em geral, estudantes e professores do ensino secundário, além do treino avançado nas suas áreas de actividade específicas. O grupo de Divulgação Científica é constituído por investigadores do LIP que sentem a necessidade de promover a literacia científica na sociedade e de procurar, motivar e treinar os cientistas de amanhã. Este grupo trabalha de perto com todos os projectos de investigação do LIP, ajudando a explorar as possibilidades de divulação e promovendo novas actividades, organizando também acções regulares que vão além do trabalho específico de cada projecto.
As suas actividades abrangem diferentes áreas e diferentes públicos alvo, embora se foque principalmente nas comunidades escolares (alunos, professores e famílias), principalmente ao nível das escolas secundárias. As actividades regulares podem ser agrupadas em:
1) Seminários de divulgação por convite das escolas ou em sessões públicas organizadas à margem de eventos científicos promovidos pelo LIP;
2) Actividades ao longo do ano escolar, nomeadamente as enquadradas no projecto de Radiação Ambiente, que funciona há vários anos num número crescente de escolas.
3) Participação no Programa de Ocupação Científica de Jovens em Férias, em que diferentes projectos no LIP recebem alguns estudantes para estágios de uma ou duas semanas;
4) As "Masterclasses"Internacionais em Física de Partículas, uma actividade de um dia inteiro em que os estudantes seguem as tarefas de um cientista, com palestras, análise de dados e discussão dos seus resultados. As "Masterclasses"envolvem anualmente milhares de estudantes em todo o país e em coordenação internacional pelo IPPOG;
5) O Programa do CERN para Professores em Língua Portuguesa, em que professores dos países de língua oficial portuguesa passam uma semana no CERN, com aulas de actualização sobre Física de Partículas e o Universo, sessões práticas experimentais e visitas ao complexo de aceleradores e experiências do CERN, acompanhados por investigadores portugueses;
6) Participação em grupos internacionais dedicados à Divulgação e Comunicação, nomeadamente o IPPOG - Grupo Internacional de Divulgação da Física de Partículas - e o EPPCN - Rede Europeia de Comunicação em Física de Partículas - dedicado à divulgação das actividades do CERN nos seus países membros;
7) Criação e adaptação de Comunicados de Imprensa, editados pelo CERN ou outros relacionados com a Física de Partículas e Astropartículas para os meios de comunicação social portugueses.
Em conjunto, o Programa de professores do CERN e o Projecto de radiação ambiente já colocaram em contacto próximo com a ainvestigação recente, várias centenas de professores. Permitiram-nos assim criar uma rede de escolas, espalhada pelo país, em contacto ou com facilidade de acesso aos investigadores e vice-versa, o que consideramos fundamental para a generalização e o impacto das outras acções de divulgação.
O Programa de Professores em língua portuguesa é um exemplo para o próprio CERN, já que foi estendido a todos os outros países de língua portuguesa, dando também a possibilidade aos professores participantes de partilhar experiências com colegas de outras realidades.
Nas masterclasses participam anualmente cerca de dois milhares de estudantes, e várias dezenas de professores. É uma das acções de maior impacto directo e tem sido alargada a todo o país, contando com a colaboração de investigadores do LIP e também de outros investigadores nas instituições locais de Ensino Superior.
É já uma prática corrente que todos os grandes eventos organizados pelo LIP sejam acompanhados por uma sessão pública ou uma pequena exposição dedicada às escolas e ao público em geral. A comunicação com os

parceiros internacionais, no sentido de procurar as melhores práticas, e com a comunicação social portuguesa, complementam as actividades do grupo de Divulgação.

### 7.1.2 Abstract

LIP promotes the advancement of scientific knowledge for the general public, high school students and teachers, and advanced training within its specific areas of activity. The LIP Outreach Group is constituted by LIP researchers engaged with the necessity to promote scientific literacy in the society, and to find, motivate and train the scientists of tomorrow. It works in close connection with all other groups in LIP to help exploring their outreach opportunities and promote new activities, and additionally organizes specific regular actions that are beyond the specific scientific projects.
Our activities spread over different areas and for different targets, although we mainly focus in the school communities (teachers, students and families). The regular activities can be grouped in:
1) Outreach seminars, either by invitation from schools, or in public sessions at the side of any scientific event organized by LIP;
2) Year long activities with schools, in particular with the Environmental Radiation Project, which exists already for several years with growing numbers of schools;
3) "Science in the Summer"Occupational Youth program from Ciência Viva, in which different LIP projects host a few students in one or two weeks internships;
4) International "Master classes"in Particle Physics, a one full day activity in which the students follow the path of the scientist with lectures, data analysis and discussion of the results. The masterclasses reach thousands of students across the country in coordination with other countries through IPPOG ;
5) CERN Portuguese Language Teachers Program, in which teachers from Portuguese speaking countries spend a week at CERN, having update classes of particle physics and the Universe, experimental hands-on sessions, and visits to the CERN´s complex and experiments, accompanied by Portuguese researchers.
6) Participation in international groups about Outreach and Communication, namelly IPPOG – International Particle Physics Outreach Group – dedicated to the outreach of particle physics worldwide, and EPPCN – European Particle Physics Communication Network – dedicated to the proper communication of Particle Physics and CERN within its member states;
7) Creation or adaptation of Press Releases issued by CERN or related to Particle and Astroparticle Physics for the Portuguese media.
Together, the CERN Portuguese Language Teachers Program and the Environmental Radiation Project have put by now several hundreds of teachers in close contact with present day research. They allowed us to create a network of schools spread all over the country, in close contact or easy access to researchers and vice-versa, which is fundamental for the generalization and impact of our other outreach actions.
The CERN Portuguese Language Teachers Program is an example at CERN, as it was extended to all other Portuguese speaking countries, which creates also the opportunity for teachers to share experiences with colleagues from different realities.
In the International Master classes two thousand students and dozens of teachers participate each year. It is one of the actions with largest direct impact and is being extended to all the country, counting not only on LIP researchers but also researchers in the local Universities.
It is common practice that all major events that LIP organizes are accompanied by a public lecture or small exhibition dedicated to the school and general public. The communication with international partners, in search for best practices, and with the Portuguese media complement the activities of the Outreach group.

### 7.1.3 Objectives

The objectives for the LIP Outreach group are always to increase the awareness of Particle and Astroparticle Physics in the Society, and to reach a larger sector of the population, both in number of persons and in geographical dispersion. Separated in the above topics, our objectives were:
1) To support schools wanting to visit CERN, and provide outreach seminars in schools and public places, in collaboration with Universities and Institutions. 2012 marks the 100th anniversary of Victor Hess´s balloon flight that brought us the extraterrestrial nature of cosmic rays, which is a good outreach opportunity.
2) To continue and expand the Environment Radiation Project in the school years of 2011/2012 and 2012/2013.
3) To provide summer occupation programs for high-school students, involving different scientific projects at LIP.
4) To organize the 8th edition of IPPOG´s International Masterclasses in Particle Physics, including one new venue - Beja, a crucial location where the demand is high, and the transport to other of the 10 venues is difficult.

5) To organize the 6th edition of the now CERN Portuguese Language Teachers Program, which has grown to become the largest CERN Teachers Program. Receiving, in addition to the normal quota of 40 portuguese teachers, a total of 20 Brazilian, 4 Mozambican, 4 Angolan, 1 Capeverdian, 1 Santomense teachers and 1 teacher from Guinea-Bissau and from East-Timor (in Asia).
6) To attend 2x2 meetings of the IPPOG - International Particle Physics Outreach Group and EPPCN - European Particle Physics Communication Network, and meetings of ASPERA Outreach Group;

### 7.1.4 Achievements

1) XX seminars and public sessions.
In particular public seminars were co-organized with Planetário Calouste Gulbenkian, Centro de Ciência Viva, to celebrate the centenary of the discovery of Cosmic Rays; and several public seminars regarding the discovery of a new particle at the LHC, compatible with the Higgs boson, were requested and/or offered by LIP in xxx.
2) The 5th National Meeting of the Project ´Environment Radiation´ taok place in Cacém on the 5th of May, with about 200 participants presenting posters which reflect the work performed during the school-year.
3) XX students were hosted by the following projects (ATLAS, AUGER, ...) in Lisbon, Coimbra and xxx
4) Around 2000 students participated in the MasterClasses in 11 locations, including Beja for the first time;
5) XX teachers participated in the CERN Portuguese Languge Teachers Program: xx portuguese, xx brazilian, plus xx from all other portuguese speaking countries. Unfortunately noone could come from Guinea-Bissau but three teachers from East-Timor participated for the first time, with support from the East-Timorese education ministry.
6) Both IPPOG and EPPCN meet twice a year. Now one of the meetings having a shared session, by suggestion of our group (that is, the autumn meetings of both groups occur at CERN at the same time, and have a shared session to discuss issues of common interest).
7) The year was marked by the discovery of a new particle at CERN, compatible with the Higgs boson, which represented a heavy demand from the media to which we responded through xxx.
8) Both the Masterclasses and the Teachers Program were object of presentation in a dedicated international conference.

### 7.1.5 Sources of Funding

| Code | Funding | Start | End |
|---|---|---|---|
| MC2012_RadAmb2011-12 | 15.000 € | 2011-10-01 | 2012-07-31 |
| CERN PLTP 2012 | 37.500 € | 2012-04-01 | 2012-10-31 |

### 7.1.6 Team

**Project coordinator: Pedro Abreu**

| Name | Status | %of time in project |
|---|---|---|
| Agostinho Gomes | Researcher (LIP) | 5 |
| Amélia Maio | Researcher (LIP/FCUL) | 15 |
| Américo Pereira | Technician (LIP) | 11 |
| Ana Rodrigues | Master (LIP) | 20 |
| Ana Fernandes | Collaborator | 20 |
| Ana Keating | Post-Doc (LIP/FCT) | 5 |
| Ana Maria Pinto | Collaborator (FCUL) | 20 |
| António Onofre | Researcher (LIP/UMinho) | 10 |
| Carlos Bernardino | Collaborator | 20 |
| Carmen Oliveira | Collaborator (LIP) | 20 |
| Conceição Abreu | Researcher (LIP) | 40 |
| Cristina Melo | Collaborator (LIP) | 20 |
| Fernando Barão | Researcher (LIP/IST) | 5 |
| Florbela Rego | Researcher (LIP) | 10 |
| José Rogério Nogueira | Collaborator | 20 |
| Luis Peralta | Researcher (LIP/FCUL) | 20 |
| Maria António | Collaborator | 20 |
| Maria do Anjo Albuquerque | (LIP) | 20 |
| Miguel Ferreira | Technician (LIP) | 21 |
| Paula Pinho | Collaborator | 20 |
| Pedro Abreu | Researcher (LIP/IST) | 35 |
| Pedro Assis | Post-Doc (LIP/FCT/IST) | 5 |
| Sandra Soares | Researcher (LIP/UBI) | 20 |

### 7.1.7 Publications

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

- *Cosmic ray detection made easy*
  Luis Peralta, Florbela Rego
  Physics Education 47 (2012) 143-144

**Articles in national journals**

- *Estas moedas que nos enganam*
  Luis Peralta, Florbela Rego e Maria do Anjo Albuquerque
  Gazeta de Física, vol 34, 35-37, 2012 (accepted)

- *Como percepcionam os professores do ensino secundário os conceitos relativistas de massa e energia?*
  Maria do Anjo Albuquerque e Luis Peralta
  Gazeta de Física Vol 35 nº 1 (2012) 24-28

### 7.1.8 Presentations

**Oral presentations in international conferences**

- *Detectors for hadrontherapy and related medical aspects*
  presented by Paulo Crespo
  ESSIL 2012 — Lyon, France.

- *International Masterclasses Hands on Particle Physics - The Portuguese Approach*
  presented by Conceição Abreu
  World Conference on Physics Education — Istanbul, Turkey.

- *CERN Portuguese Language Teachers Programmes*
  presented by Pedro Abreu
  World Conference on Physics Education — Istanbul, Turkey.

**Presentations in national conferences**

- *Encontros de Ciência*
  presented by Florbela Rego
  Física2012 — Aveiro.

**Outreach seminars**

- *Particle accelerators and the LHC*
  presented by Sharif Ghithan
  Project physics without frontiers — Palestine.
- *Física médica no LIP Coimbra: RPC-PET (humano e animal) e monitorização de radioterapia*
  presented by Paulo Crespo
  Jornadas Abertas do LIP 2012 — Lisbon, Portugal.
- *Raios Cósmicos*
  presented by Sofia Andringa
  Escola Quark! 2012-2013 — Coimbra, Portugal.

### 7.1.9 Events

- *Course on Physics at LHC*
  Outreach Event, LIP Lisbon, 2012-01-30

### 7.1.10 Project Summary

| | number |
|---|---|
| Articles in international journals (with direct contribution from LIP members) | 1 |
| Articles in national journals | 2 |
| Oral presentations in international conferences | 3 |
| Presentations in national conferences | 1 |
| Outreach seminars | 3 |
| Outreach Events | 1 |

## 7.2 Technology Transfer Network and Industrial Liaison Office

### 7.2.1 Resumo

Projecto Rede de Transferência de Tecnologia (TTN)
Em 2012, o projecto Rede de Transferência de Tecnologia (TTN), muda a sua designação para "HEPTech, a High Energy Physics Transfer Network (TTN)". O LIP contribui "in-kind"para o projeto HEPTech com um recurso formado em Engenharia Física Tecnológica, a fim de que o LIP possa obter uma experiência mais "hands-on"nas actividades do HEPTech. A rede continua a captar a dedicação destas instituições na Europa (CEA/DSM, CPAN, CERN, Chalmers, Universidade de Copenhaga, CNRS/IN2P3, DESY, EPFL, GSI, INFN, JSI, PSI, STFC, Universidade de Sofia, INFN, CTU, ILL, WIS e ESS), com o objectivo de alavancar o impacto das suas disciplinas científicas para outras áreas da sociedade em geral. Em Junho de 2012, os membros do comité de gestão do HEPTech aprovaram uma nova liderança composta por dois nós (STFC e o CERN). Em paralelo a esta aprovação da liderança, o mesmo comité aprovou a constituição de um documento designado de "Termos de Referência"que define os princípios para as operações do HEPTech. No seguimento deste documento, ainda em 2012 e para 2013 várias iniciativas ficaram definidas em 6 grupos de trabalho, designadamente nas seguintes áreas: 1) Tecnologia para Aceleradores, 2) Sistemas de Controlo, 3) TIC, 4) Detectores e duas outras áreas relacionadas com a transferência do conhecimento, nomeadamente: 5) Boas práticas e 6) Suporte a gabinetes de transferência de tecnologia. O LIP acompanha as várias iniciativas, que particularmente se baseiam na organização de eventos onde vários stakeholders da academia ou instituições de I&D e indústria se juntam, com o objectivo de alavancar a Transferência de Tecnologia na área de Física de Partículas, Astrofísica e Física Nuclear.
Actividades do ILO
O mandato de ILO manteve a mesma estratégia para 2012, que visa em apoiar e promover activamente a indústria nacional e instituições de I&D, para o CERN, ESO, ESRF e contribuir para o seu sucesso no processo de aquisições, e na divulgação de novas oportunidades de projectos e tecnologias disponíveis*, por forma a garantir um retorno industrial sustentável para Portugal. O ILO prosseguirá a estreita colaboração com o Gabinete do Espaço da FCT na representação da delegação Portuguesa na Agência Espacial Europeia (ESA) para os assuntos industriais.
(oportunidades de projectos e tecnologias disponíveis* significa: anúncio de documentos técnicos sobre oportunidades de concursos para o fornecimento de bens e serviços, tecnologias disponíveis que incluem patentes, know-how, software, projectos de I&D ou colaborações)

### 7.2.2 Abstract

Technology Transfer Network project (TTN)
In 2012, the Technology Transfer Network (TTN) project, changes its designation to "HEPTech, the High Energy Physics Transfer Network (TTN)."LIP contributes "in kind"to the HEPTech with a Masters in Engineering Physics, so LIP can get a more "hands-on"on HEPTech activities. The network continues to capture the dedication of these institutions in Europe (CEA / DSM, CPAN, CERN, Chalmers University of Copenhagen, CNRS/IN2P3, DESY, EPFL, GSI, INFN, JSI, PSI, STFC, University of Sofia, INFN, CTU, ILL, WIS and ESS), in order to leverage the impact of their scientific disciplines to other areas of society in general. In June 2012, members of the management committee of the HEPTech approved a new leadership composed of two nodes (STFC and CERN). In parallel to the leadership approval, the same committee approved the creation of a document called "Terms of Reference"as guiding principles of the HEPTech operations. Following this document, still in 2012 and for 2013 several initiatives are defined in six working groups, particularly in the following areas: 1) Technology for Accelerators, 2) Controls, 3) ICT, 4) Detectors and two other areas related to knowledge transfer, namely: 5) Good practices and 6) Support Technology Transfer Offices. LIP accompanies the various initiatives that particularly rely on the organization of events involving various European stakeholders from academia, R&D institutions and industry in order to leverage the Technology Transfer in the field of Particle Physics, Astrophysics and Nuclear Physics.
ILO activities
The mandate of the ILO maintained the same strategy for 2012, aiming to support and actively promote national industry and R&D institutions, to CERN, ESO, ESRF and contribute to the success in the procurement process, and disseminate new project opportunities projects and technologies available*, to ensure a sustainable industrial return to Portugal. The ILO continues to work closely with the FCT Space Office and the Portuguese delegation at the European Space Agency (ESA) for industrial matters.
(project opportunities and technologies available* means: announcement of technical documents on procurement opportunities for the supply of goods and services, available technologies that include patents, know-how, software, R&D projects or collaborations)

### 7.2.3 Objectives

TTN project
- Ensure that a complementary web-page is inserted at LIP Outreach website that describes: About Technology Transfer (ex: Patenting process) and its importance for LIP, Description of the TTN project and elements of the IP charter, Interesting Links and Documents of interest.
- Follow closely, as TTN node member, the 2 level initiatives: 1) Technology based; 2) Socio-economic studies and Support based. Firstly, ensure the participation of at least one Portuguese company and/or national research center at the Industry Academia Matching Events (AIME). Secondly, make sure LIP has early access to all socio-economic impact studies performed under the TTN coordination on Particle, Astro and Nuclear Physics. Also, ensure an active collaboration with the resource from Engineering Physics (LIP "in-kind"contribution to the TTN project) so that LIP may benefit from this contribution in short and medium-term.
- Organize bilateral meetings with LIP researchers (in Lisbon and Coimbra) about Intellectual Property and Technology Transfer matters, such as: 1) How similar labs to LIP, are managing IP?; 2) Which suitable road-map to adopt for the commercialization of early stage technologies (from the lab to market)?
ILO activities.
- Orient the current database of national companies (and research institutions, such as LIP) to work more as a CRM information system helping the ILO with the matters related to project opportunities and available technologies* at CERN, ESO, ESRF and ESA.
- Establish as much as possible, company presentations to technical departments and/or groups at CERN, ESO, ESRF. Always involve, as deemed possible, Portuguese staff at these venues.
- Continue with the national road-show initiative to present CERN, ESO, ESRF to Portuguese companies and R&D institutions. And, along with the FCT Space Office have an integrated approach towards the companies operating in the space sector, mainly for ESA.
- Organize and/or participate at industrial events to promote companies at CERN, ESO and/or ESRF, such as: Visit of firms @ CERN, Industry day @ ESO and/or ESRF.
- Attend, when possible, industry trade-shows and/or targeted events (nationally and internationally) to carry through targeted assessments about the different industrial sectors in Portugal and outside Portugal that can leverage the ILO activities.
(project opportunities and available technologies* means: announcement of technical documents on procurement opportunities for the supply of goods and services, available technologies that include patents, know-how, software, R&D projects or collaborations)

### 7.2.4 Achievements

TTN
- In order to disseminate matters of Technology and Knowledge Transfer throughout the LIP community, during 2012 a CERN report on Knowledge Transfer was shared, where LIP is referenced. An effort to have an autonomous and dedicated web-page about Technology Transfer at the LIP Outreach main page will continue in 2013 with the support of LIP "in-kind"contribution to the HEPTech project.
- Several Industry Academia Matching Events (AIME) were promoted throughout the LIP community during 2012: 1) 3rd ASPERA technology forum on"Vacuum & Cryogenics", 2) AIDA FP7 project on "Position Sensitive Solid-State devices and related technologies", 3) IN2P3 and the Laboratory LAPP on "Micro Pattern Gas Detectors, such as GEMs and MicroMegas"and 4) Sofia University, WIPO and HEPTech on "Advanced TTOs meet early-stage TTOs".
ILO Activities
- During 2012, several efforts were engaged towards the The Fundação para a Ciência e Tecnologia (FCT) ICT department to create a database that contains information related to national companies and R&D institutions and project opportunities and available technologies * at CERN, ESO, ESRF and ESA. This database is for internal use to support the ILO as an information management system (IMS). During 2013, the database creation will be considered in a wider FCT ICT project, regarding the creation of a fully integrated IMS.
- During 2012, the ILO continued in supporting company presentations to technical departments from CERN, ESO and ESRF by establishing different formats of discussion forums (ex: dedicated meetings or industry day). It is reported the company name and to whom it was presented, as follows:
CERN
- Company: ASilva Matos (Metalworking products); To Whom: Senior Technician Safety – Technology Department/Cryogenic group
- Company: Inov-Inesc Inovação (Electronics Development); To Whom: Senior Staff for Electronics Production – Beams Department/Controls

- Company: Exatronic (Electronics design and production); To Whom: Senior Staffs for Electronics Production – Technology Department/Engineering Department
- Company: EFACEC (Automation business unit); To Whom: Director for Research and Computing
- Company: ACTIVESPACE Technologies (Mechatronics development and products); To Whom: Senior Staff for Remote Handling – Engineering Department/Handling Engineering
- Company: ISQ (Engineering Services); To Whom: Senior Staff for Assembly and Forming– Engineering Department/Mechanical & Materials Engineering
- Company: Metalúrgica Palmelense (Metalworking products); To Whom: Senior Staff for Procurement - Finance Department
- Ensured the promotion/advertisement of 3 Portuguese suppliers at CERN Courier, September 2012: ISQ, Solidal Condutores SA and Exatronic
- Participated in a Science Coffee event about CERN and the involvement of Portuguese industry for the LHC construction, October 2012 at a Parliamentary Commission of Education, Science and Culture at the Portuguese Parliament premises
ESO
- Company: FiberSensing (Optical Fiber Systems); To Whom: Senior Staffs ALMA Divison and Procurement
- Company: Novabase (IT Services/Software Development); To Whom: Head of Software Division and acting Director of Engineering
- Company: Exatronic (Electronics design and production); To Whom: Senior Staffs for Electronics Production in the Technology Division
ESRF
Company: GLINTT (Information Systems); To Whom: Head of TID Division
- The collaboration between the ILO and the FCT Space Office for the national road-show activities aimed at visiting several companies from different niche sectors that could be potential suppliers or project partners for CERN, ESO and ESRF, and also, national R&D Institutions or labs such as LIP is well established. Further, this collaboration with the Space Office led in October 2012, to the creation of a unique national initiative on Space Technology Transfer, called Portuguese Technology Transfer Initiative (PTTI), http://ptti.ipn.pt/
- The ILO organized a meeting at FCT, in December 2012 on the future construction of ESO European Extremely Large Telescope (E-ELT). The invitee was a European Prime contractor called Astrium Space Transportation and the discussion was about key Portuguese companies that could be sub-contractors for the E-ELT project.

### 7.2.5 Team

**Project coordinator: Emir Sirage**

| Name | Status | %of time in project |
|---|---|---|
| Emir Sirage | Technician (LIP) | 100 |

## 7.3 Education and Advanced Training

### 7.3.1 Resumo

A formação contínua dos investigadores e a integração dos jovens cientistas nos nossos programas de pesquisa é um dos principais objetivos da atividade geral do LIP. Em todas as áreas, mas principalmente nas de investigação básica, a manutenção de fortes ligações com o ensino superior é uma clara prioridade reforçada, nos últimos anos, com o alargamento da rede de IDPASC.
IDPASC foi criada em 2010 para fortalecer a comunidade da pesquisa em física fundamental. Embora ainda em crescimento, envolve já instituições de pesquisa internacionais - CERN, EGO (European Observatory Gravitacional), CBPF (no Brasil) - e muitas Universidades - incluindo todas as Universidades Portuguesas que têm programas na área de Física de Partículas, Astrofísica e Cosmologia, e outras em Espanha, Eslovénia, Itália e França.
As atividades IDPASC incluem: Uma escola anual onde os alunos de doutoramento de diversas áreas e instituições se reúnem para uma ou duas semanas, com cursos básicos interdisciplinares; escolas e cursos sobre temas específicos, geralmente complementadas com workshops sobre os mais recentes desenvolvimentos e aberto a todos os investigadores na área; palestras públicas, principalmente dedicado a estudantes dos últimos anos do ensino secundário e professores, bem como para estudantes universitários do primeiro ano. Cursos organizados localmente por cada membro da rede são anunciados e visam promover a mobilidade entre as várias instituições. As escolas anuais são organizadas de acordo com o sistema de créditos europeu e todas as escolas e cursos têm uma avaliação final individual, de modo a que as universidades possam reconhecer os créditos correspondentes. No final do seu doutoramento, os alunos receberão um certificado.
As equipas de investigação do LIP visam envolver os alunos a diferentes níveis. Vários perfis científicos coexistem, no entanto, é fornecido a todos os alunos uma base científica mínima comum. Este fundo comum também favorece a mobilidade e o futuro emprego dos alunos, quer em projetos e instituições de investigação científica quer na sociedade em geral.
Muitos alunos de pós-graduação desenvolvem o seu mestrado e tese de doutoramento no âmbito dos projetos do LIP sob a estreita supervisão de investigadores locais e beneficiando da troca de conhecimento e de discussão no seio de grandes colaborações internacionais.
Muitos investigadores do LIP são professores contratados de universidades locais, onde ensinam cursos em todos os níveis, e muitos dos investigadores contratados pelo LIP também ensinam alguns cursos ou dão palestras, principalmente em níveis avançados em áreas estreitamente ligadas às atividades do LIP. Nas várias unidades, em Coimbra, Lisboa e Minho, acordos específicos existem com cada universidade, para a partilha de recursos. O LIP criou equipamentos de laboratório específicos para fins educacionais.
Para além dos programas de investigação de educação básica, o LIP participa na organização de formação avançada de jovens licenciados portugueses em grandes organizações científicas internacionais como o CERN, ESA e ESO, em áreas tecnológicas, que são de importância estratégica para o aumento da competitividade das empresas portuguesas. O programa de Divulgação do laboratório é dedicado principalmente aos estudantes do ensino secundário e professores, e engloba um curso anual, coorganizado com o CERN, em física de partículas e áreas afins, para professores do ensino secundário de países de língua portuguesa. Estas atividades são descritas nas próximas secções.

### 7.3.2 Abstract

The continuous training of scientists and the integration of young scientists in our research programs is one of the main objectives of the overall LIP activity. In all areas, but primarily the basic research ones, the maintenance of strong links to higher education is a clear priority reinforced, in the last years, with the enlargement of the IDPASC network.
IDPASC was created in 2010 to strengthen a community in fundamental physics research. While it is still growing, it now involves international research institutions - CERN, EGO (the European Gravitational Observatory), CBPF (in Brasil) – and many Universities – including all Portuguese Universities that have programs in the area of Particle Physics, Astrophysics and Cosmology, and others in Spain, Slovenia, Italy and France.
IDPASC activities include: A yearly school where PhD students from the several areas and institutions get together for one or two weeks with basic interdisciplinary courses; Schools and courses on speciyic subjects, usually complemented with workshops on the most recent developments and opened to all the researchers in the area; Public lectures mainly dedicated to the last years high school students and teachers as well as to yirst year University students. Courses organized locally by each member of the network are advertised promoting mobility between the several institutions. The yearly schools are organized according to the European credits system and all schools and courses have a yinal individual evaluation so that the Universities can recognize the corresponding credits. At the end of their PhD, the students will be granted a certiyicate.

The LIP teams involve students at different levels. Several scientific profiles co-exist, however, to all students a minimum common scientific background is provided. This common background also favours the future mobility and employment of the students either in scientific research projects and institutions or in the society at large. Many post-graduate students develop their master and PhD thesis in the framework of the LIP projects under the close supervision of local researchers and beneyiting from the inputs and discussion within large international collaborations.
Many LIP researchers are hired professors at local Universities, where they teach courses at all levels; and many of the researches hired by LIP also do teach some full courses or invited lectures, primarily at advanced levels in areas closely connected to our activities. In its several units, in Coimbra, Lisboa and Minho, specifyic agreements exist with each University for the sharing of resources, and LIP has created specifyic laboratory equipment for educational purposes.
In addition to the basic research education programs, LIP participates in the organization of advanced training for young Portuguese graduates in large international scientific organizations like CERN, ESA and ESO, in technological areas which are of strategically importance for the increase in competitiveness of Portuguese companies. The Outreach program of the laboratory is mostly devoted to high school students and teachers, and encompasses a yearly course, co-organized with CERN, on particle physics and related areas, for high school teachers of Portuguese speaking countries. These activities are described in the next sections.

### 7.3.3 Objectives

2012 was marked by the inclusion of Universities in the LIP governing bodies representing a further step in the strengthening of the relation between our research and education and advanced training at all levels. Another objective achieved in 2012 was the strengthening of the IDPASC network with more direct involvement of other institutions.

### 7.3.4 Achievements

Overall LIP has, during the last year promoted 13 scientific events related to the main scientific areas of LIP, 14 seminars and several outreach seminars. Six MSc students and one PhD student successfully concluded their thesis continuing the strong commitment LIP has towards the importance of the continuous training of scientists and the integration of young scientists in our research programs.
IDPASC grew with new institutions, namely the European Gravitational Observatory (EGO), the Centro Brasileiro de Pesquisas Fisicas (CBPF) and the Universities of Paris VI, Savoie, Siena, Padova, Bari and Nova Gorica. In 2012, in addition to the general IDPASC school there were two thematic ones accompanied by devoted workshops, on Neutrino Physics and Photosensors, in Granada and in Lisbon, respectively and a longer course on Physics at the LHC, also at LIP.
The past experience with IDPASC/FCT Call in the last three years shows that of 60 candidates, 32 are from outside of Portugal, 15 out of 21 grants were attributed to foreign students.

# Chapter 8

# Scientific Conferences and Seminars

## 8.1 Seminars

**Seminars**

- *Desenvolvimento de fluxómetros laser Doppler para medição da microcirculação*
  presented by Edite Figueiras, CI on 2012-01-10
  Café com Física — Coimbra.
- *Quarks, Gluões, QCD e Confinamento*
  presented by Orlando Oliveira, CFC on 2012-01-17
  Café com Física — Coimbra.
- *O Prémio Nobel da Química 2011*
  presented by José António Paixão on 2012-01-24
  Café com Física — Coimbra.
- *Multi-scale modelling of smart materials*
  presented by Jaime Silva, UM e CFC on 2012-01-31
  Café com Física — Coimbra.
- *Rapidity dependent reaction plane in ultra-relativistic heavy ion collisions: torqued fireballs*
  presented by João Moreira, CFC on 2012-02-07
  Café com Física — Coimbra.
- *First principles study of nano-scale materials: quantum dots and nanowires*
  presented by José Guilherme Vilhena d´Orey, Universidad Autónoma de Madrid on 2012-02-14
  Café com Física — Coimbra.
- *Quantum Darwinism*
  presented by Nicolas Lori, IBILI/FMUC on 2012-02-28
  Café com Física — Coimbra.
- *Instrumentação Baseada em ATCA Dedicada aos Diagnósticos de Espectroscopia Digital de Radiação Gama no JET*
  presented by Rita Costa Pereira, CI on 2012-03-06
  Café com Física — Coimbra.
- *Nanoscale membrane shape fluctuations and their consequences for receptor (un-)binding processes in cell adhesion*
  presented by Heinrich Krobath, CFMC Lisboa on 2012-03-13
  Café com Física — Coimbra.
- *Novo motor de combustão interna. Uma revolução na engenharia?*
  presented by Joaquim Candeias, Fundador da empresa Lusocreen on 2012-03-27
  Café com Física — Coimbra.
- *O princípio da acção mínima em Mecânica Clássica*
  presented by Paulo Silva, CFC on 2012-04-10
  Café com Física — Coimbra.

- *A partícula E38*
  presented by Eef van Beveren, CFC on 2012-04-17
  Café com Física — Coimbra.

- *The structure of neutron star Inner Crust*
  presented by Fabrizio Grill, CFC on 2012-05-22
  Café com Física — Coimbra.

- *A chiral model approach to quark matter nucleation in neutron stars*
  presented by Domenico Logoteta, CFC on 2012-05-29
  Café com Física — Coimbra.

- *Search for FCNC top quark decays with the ATLAS detector*
  presented by Filipe Veloso, LIP on 2012-06-12
  Café com Física — Coimbra.

- *Applications outside high-energy physics: technology transfer from physics to medical applications*
  presented by Patrick Le Dû, LIP on 2012-07-03
  Café com Física — Coimbra.

- *Phases of dense quark matter*
  presented by Wojciech Broniowski, Institute of Physics, Jan Kochanowski University, Kielce, Poland, and Institute of Nuclear Physics PAN, Cracow, Poland on 2012-07-23
  Café com Física — Coimbra.

- *Isogeometric analysis of a tumor angiogenic model*
  presented by Guillermo Vilanova Cacoya on 2012-10-02
  Café com Física — Coimbra.

- *Higgs: To be or not to be!*
  presented by Dave Charlton, University of Birmingham and CERN, Deputy Chairman of the ATLAS Experiment on 2012-10-11
  Café com Física — Coimbra.

- *Quantum simulations with ultracold atoms: an example*
  presented by Andrea Trombettoni, SISSA on 2012-10-16
  Café com Física — Coimbra.

- *In the Search for Dark Matter*
  presented by Leo Stodolski, Director Emeritus of the Max Planck Institut fÃ$\frac{1}{4}$r Physik - Werner Heisenberg Institut on 2012-10-23
  Café com Física — Coimbra.

- *Liposomes for targeted cancer multi-therapy and imaging*
  presented by João Carvalho, Departamento de Física da UC on 2012-11-06
  Café com Física — Coimbra.

- *XIPE space telescope proposal*
  presented by Rui Silva, LIP on 2012-11-27
  Café com Física — Coimbra.

## 8.2 Conferences

- *Jornadas do LIP 2012*
  Workshop, Pavilhão de Conhecimentos, Lisboa, Portugal, 2012-04-21