IFAE

Institut de Física d'Altes Energies

Report of Activities

2012

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Presentació

L'IFAE és un consorci entre la Generalitat de Catalunya i la Universitat Autònoma de Barcelona (UAB). El consorci va ser creat el 16 de juliol de 1991 pel decret 159/1991 del Govern de la Generalitat. Com a tal consorci, l'IFAE és una entitat legal amb personalitat jurídica pròpia. A 2011 i 2012, la relació formal amb la Generalitat s'ha portat a terme a través del Departament d'Economia i Coneixement.

L'IFAE està estructurat en dues Divisions: Experimental i Teòrica. Col·laboren amb el personal propi de l'IFAE els Grups de Física Teòrica i de Física d'Altes Energies del Departament de Física de la UAB. Nou científics d'ICREA contribueixen de forma important a les activitats de l'Institut.

Aquest informe anual d'activitats es distribueix internacionalment i per tant està escrit en anglès.

Activitats científiques de la Divisió Experimental

Durant 2012 la Divisió Experimental va treballar en nou projectes:

1. ATLAS, al Large Hadron Collider (LHC) del CERN. L'any 2012 es recordarà per la descoberta, de part d'ATLAS i de CMS, d'una nova partícula fondamental que potser és al bosó de Higgs, la peça mancant del Model Estàndar. L'excellent funcionament de l'LHC i dels seus detectors ha sigut essencial per tal d'aconseguir aquesta gran fita.

2. Un grup de físics d'ATLAS que es dedica a potenciar l'aparell ha desenvolupat i provat éxitosament un nou tipus de detector amb Pixels, que s'instal·larà a l'any 2014.

3. CDF, un experiment de col·lisions antiprotó-protó al Tevatron del Laboratori Nacional de Fermi (FNAL), els EUA, ha acabat de prendre dades a 2011. A 2012 encara s'han anat publicant molts resultats importants, entre els quals uns sobre les proprietats del possible bosó de Higgs.

4. L'experiment T2K, al Japó, s'ha recuperat del terrible terratrèmol de 2011, i ha confirmat la primera observació de la transformació de neutrins del muó en neutrins de l'electró que va anunciar a 2011. Paral·lelament, a l'IFAE ha continuat l'I&D per a experiments de desintegració doble-beta.

5. Han continuat les observacions de raigs gamma d'alta energia amb els dos telescopis MAGIC, al Roque de Los Muchachos (La Palma, Canàries). Al 2012, s'ha descubert una emissió de raigs gamma des de la proximitat d'un'antiga supernova, potencialment molt important per tal d'explicar l'antic misteri de l'acceleració dels raigs còsmics..

6. Ha entrat en una fase avançada el disseny y la fabricació de prototipos del Cherenkov Telescope Array (CTA), un sistema de 50-100 telescopis, amb dos observatoris (als emisferis Nord i Sud) per a l'astrofísica amb raigs gamma que involucra instituts de tot el món. El co-spokesperson d'aquesta col·laboració de grups de tot el món és de l'IFAE.

7. A DES, un projecte de cosmologia observacional, amb grups d'EUA i del Regne Unit, s'ha acabat la construcció de una nova càmara de CCD, que s'ha instal·lat al

telecopi Blanco, a Cerro Tololo, Xile. A 2012 es va observar la primera llum, i s'han mesurat les característiques del nou instrument, que van resultar excellents.

8. PAU, una col·laboració espanyola coordinada per l'IFAE i finançada amb un projecte Consolider-Ingenio 2010, està construïnt a l'IFAE una càmara de CCD que s'instal·larà al William Herschel Telescope WHT, al Roque de los Muchachos, per investigar el tema de l'energia fosca. Al 2012 la construcció de la càmara, un projecta de gran complexitat tècnica, ha progressat de forma important.

9. Al camp de la física mèdica, està en marxa a l'IFAE un projecte finançat per un Advanced Grant de l'ERC, per tal de desenvolupar una nova tècnica de tomografia d'emission de positrons (PET). La fita principal de 2012 ha sigut el desenvolupament d'un ASIC per a la lectura del detector de CdTe que farà servir aquest PET. A 2012, l'empresa spinoff X-Ray Imatek ha introduit in nou producte, ha reforçat la seva posició al mercat internacional i ha obtingut un profit.

Activitats científiques de la Divisió Teorica

La Divisió Teorica segueix tres línies d'investigació: física del Model Estàndar (SM), més allà del Model Estàndar, i Astrofísica& Cosmologia.

Física del Model Estàndard

Els temes principals investigats pel grup de física del SM a 2012 han sigut les desintegracions hadròniques del leptó τ, la teoria perturbativa quiral – inclouint-hi els mesons vectorials i escalars d'alta massa en el quadre de la teoria de perturbació quiral de les ressonàncies, les interaccions mesòniques, les contribucions hadròniques al moment magnètic anòmal del muó, QCD a temperatura finita, i també l'estudi de l'estructura de les correccions de la QCD perturbativa.

Física més allà del Model Estàndard

El grup de l'IFAE ha estudiat molt activament les dades experimentals sobre el candidat de Higgs per tal de comprendre les seves proprietats i treure'n les possibles conseqüències pel SM o més allà del SM.

A una línia differenta, s'han considerat models generals de 5 dimensions amb camps del SM qu es propaguen al "bulk", i s'han calculat expressions explícites d'observables electrofebles de varios tipus, i de operadors efectius a quatre fermions amb violació de sabor i de CP.

Astrofísica i Cosmologia

L'astrofísica i la cosmología de particules son camps de recerca recents, a l'intersecció entre la física de partícules, l'astrofísica i la cosmologia. L'objectiu és aprofitar el nostre coneiximent dels fenòmens astrofísics i cosmològics per tal de trovar respostes a problemes fonamentals de física, i vice-versa. A 2012, els temes que s'han investigat han estat models de matèria fosca, bariogènesis, l'origen de l'invariància de Lorentz, i les aplicacions de la correspondència entre *gauge* i gravetat.

1. About IFAE

1.1 Structure

The Institut de Física d'Altes Energies (IFAE) is a Consortium between the Generalitat de Catalunya and the Universitat Autònoma de Barcelona (UAB). It was formally created on July 16, 1991, by Act number 159/1991 of the Government of Catalonia (Generalitat de Catalunya). As a Consortium the IFAE is an independent legal entity. Since 2011, it is under the auspices of the Department of Economics and Knowledge (Departament d'Economia i Coneiximent, DECO), of the Generalitat.

The governing bodies of the Institute are the Governing Board (Consell de Govern) and the Director. The general lines of activity, the hiring of personnel, the annual budget and the creation and suppression of Divisions are among the responsibilities of the Governing Board, which also appoints the Director from a list of candidates nominated by the Rector of UAB. The Director is responsible for the execution of the decisions of the Governing Board. Additional management personnel, such as the Adjunct Director and the Coordinator of the Theory Division are nominated by the Director and appointed by the Governing Board.

IFAE enjoys a close collaboration with the Theoretical and Experimental High Energy Physics Groups of the Department of Physics of the UAB. In addition, since the creation of ICREA, several investigators from this prestigious research institution have joined IFAE.

As of the end of 2012, this component of the Institute consists of nine ICREA research professors, with continuing tenure.

Personnel of the Departments of Structure and Fundamental Constituents of Matter and of Fundamental Physics of UB were also members of IFAE, under the terms of an agreement between the Institute and UB established in 1992. This agreement was modified in 2003. Under the new terms, the cooperation between IFAE and the UB is focused on specific goal-oriented projects.

IFAE is structured in two Divisions: Experimental and Theoretical. The Theory Division faculty is composed of five ICREA research professors and a Ramon y Cajal fellow. They share physical and human resources (postdocs and students) with the personnel from the UAB. The personnel of the Experimental Division are mostly from IFAE itself, but it includes four research professors from ICREA. It collaborates with four UAB professors.

IFAE also has the status of a "University Institute" attached to UAB. This formula allows the personnel of IFAE to participate in the educational programme of UAB, in particular by giving Master courses of the Master in Theoretical and Experiemntal particle Physics, astrophysics and Cosmology.

1.2 IFAE Goals and History, briefly

As stated in the foundational Act 159/1991 of the Generalitat, the goal of IFAE is to carry out research and to contribute to the development of both theoretical and experimental High Energy Physics. The origins of the consortium are in the Department of Theoretical Physics and in the Laboratory for High Energy Physics (LFAE) of UAB. The theoretical group was established in 1971, when the university was founded. The Laboratory for High Energy Physics was created in 1984, in order to start research in experimental high-energy physics at the UAB, particularly to effectively use the CERN laboratory, after Spain joined again CERN in 1982. As mentioned in Act 159/1991 the existence of LFAE and of theoretical research groups in Catalonia, the desire to strengthen research in High Energy Physics, particularly in the experimental side, and the desire to collaborate in the Spanish Government effort to develop this field, led the authorities of the Generalitat to create IFAE.

In the following years the Experimental Division of IFAE grew from a staff of 10 to its present strength of about 85. The experimental program has expanded both in the number of projects and in their scope. In 1991 the division was involved in just one experiment in high energy particle physics, ALEPH at LEP, while at present there are nine projects belonging to three main lines of fundamental research: particle physics at high energy accelerators, gamma-ray astrophysics, and observational cosmology. In addition, there is a small but very active line of applied physics, devoted to novel techniques in digital radiography. The Theoretical Division also expanded its research program since the IFAE was created. There are at present three main lines of research: Standard Model physics, Beyond the Standard Model, and Astroparticles/Cosmology.

An additional important development took place in 2003, driven by the strongly perceived need for remote handling of vast quantities of scientific data, not only for high-energy physics experiments but also for astrophysical facilities such as MAGIC. In 2003 three Spanish institutions, the UAB, the CIEMAT in Madrid and the Departament d'Universitats Recerca i Societat de la Informació (DURSI, now DECO) of the Government of Catalonia, together with IFAE, jointly founded the Port of Scientific Information (PIC). This center aims at being a focal point of the global computing grid for scientific projects requiring the processing of large amounts of data. PIC was chosen by the Spanish Ministry of Science and Education as a Tier-1 center for LHC computing. IFAE was charged by the other partner institutions with the administration of PIC. There is a very close collaboration with PIC on computational aspects of all IFAE experiments that are producing data or will do so in the near future. The scientific activities of PIC are described in its own reports.

It is worth emphasizing that as an independent legal entity IFAE can manage its own projects as well as certain external ones. These management activities have been a very visible contribution of IFAE to the development of Spanish scientific infrastructures, which might not have been possible otherwise. The most important among these activities are briefly recalled next.

From 1995 to 2001 the Synchrotron Light Laboratory of Barcelona (LLS) was administratively part of IFAE. The LLS was the organization that proposed and prepared the construction of ALBA, the Synchrotron Light Laboratory. The project was jointly approved in 2003 by The Spanish government in Madrid and the Catalan Government and its construction was completed in 2010.

IFAE was responsible for the construction of the building that services the MAGIC telescopes at the Roque de los Muchachos site in the Island of La Palma. IFAE now manages the Common Fund (maintenance and operation funds) of the MAGIC collaboration.

From 1999 to 2004 IFAE provided technical and administrative management of the contract between CERN and a Spanish company for the construction of the vacuum vessels of the ATLAS Barrel Toroid. This was a major project, with a cost of about 3 million euro distributed over several years.

In 2006, the observational cosmology group of IFAE proposed the PAU (Physics of the Accelerating Universe) initiative, which was approved in 2007 as a Consolider-Ingenio 2010 project. IFAE leads the PAU collaboration, comprised by several Spanish groups. The goal of this initiative is to survey a large fraction of the Northern sky in order to measure parameters of cosmological interest by means of novel observational tools.

Since early in the past decade, the relationship between IFAE and the Generalitat of Catalonia is regulated under a Contract-Program, which codifies the support of the Institute from the Generalitat and the corresponding obligations of IFAE. Based on a strategic plan, The Contract-Program specifies the envisaged growth of the Institutes's personnel and funding. The scientific and academic goals are specified in a set of numerical indicators, which are reported on on yearly basis. The current Contract-Program covers the period from 2007 to 2012 included. It is expected to be extended further, for a shorter period dictated by the current economic uncertainties.

1.3 IFAE Governing Board - 2011

President

Antoni Castellà i Clavé

Secretary General for Universities and Research, Dept. Economia i Coneiximent

Members

Josep Mª. Martorell i Rodó
Director General for Research, Dept. Economia i Coneiximent

Josep Canós i Ciurana
Director General for Energy, Mines and Industrial Safety, Dept. Empresa I Ocupació

Carles Jaime Cardiel, until 30 July 2012
Deputy Rector for Strategic Projects & Planning, Universitat Autònoma de Barcelona
Lluís Tort i Bardolet, from 30 July 2012
Deputy Rector for Strategic Projects & Planning, Universitat Autònoma de Barcelona

Ramon Pascual de Sans
Professor of Physics, Universitat Autònoma de Barcelona

Joaquim Gomis Torné
Professor of Physics, Universitat de Barcelona

Director

Matteo Cavalli-Sforza
Research Professor, IFAE

Adjunct Director

Ramon Miquel Pascual
Research Professor, ICREA

Scientific Activities in 2012

OUTLINE

The Experimental Division

During 2012 the Experimental Division's activities focused on nine main projects, most of which are long-term efforts. These projects span the fields of High Energy Physics, Astrophysics and Cosmology, and include Applied Physics research, focused on the development of Detectors for Medical Applications.

High Energy Physics is represented by four major, long-term projects:

1. ATLAS, at the Large Hadron Collider of CERN. 2012 will be remembered for the discovery, by ATLAS and CMS, of a "Higgs-like boson". This new fundamental particle is a very likely candidate for the long-sought missing piece of the Standard Model. The excellent operation of the LHC in 2012 was one of the essential ingredients that allowed to reach this major scientific milestone.

2. An ATLAS upgrade, complementing the facility with a new semiconductor Pixel detector, in preparation of a major upgrade to take place at the end of this decade. The group is also doing R&D on novel types of pixel detectors.

3. CDF, a proton-antiproton collider experiment at the Fermi National Accelerator Lab (Illinois, USA). This experiment completed data-taking in 2011, but in 2012 kept producing a number of important physics results – some bearing on the properties of the Higgs candidate

4. T2K, a neutrino long base-line experiment in Japan. In 2012, after recovering from the devastating earthquake of 2011, T2K confirmed the earlier results on the oscillation of muon into electron neutrinos. In addition, the group is developing novel technologies for detecting neutrinoless double-beta decays.

Our **Astrophysics** activities are centered on ground-based detection of very high-energy gamma rays from astrophysical and cosmological sources.

5. MAGIC, a collaboration that in the '90s built a 17 m diameter Cherenkov telescope, is located on the Roque de los Muchachos on the Canary Island of Las Palmas. Recently, it added a second telescope that began operating in 2009. It is now in the process of upgrading the two-telescope system.

6. CTA, a worldwide collaboration that will build two multi-telescope observatories, in the Northern ans Southern hemispheres, is now in in an advanced design and prototyping phase. IFAE is involved in major aspects of this project, at the technical and the top management levels.

The **Observational Cosmology** program at IFAE began by joining an existing program (DES). In 2007 a new project (PAU) was launched.

7. DES (Dark Energy Survey) built a camera for a telescope at Cerro Tololo (Chile) in order to measure parameters that characterize Dark Energy by observing about 300 million galaxies in the Southern sky. Observations began in 2012.

8. PAU (Physics of the Accelerating Universe) is a Spanish collaboration formed under the auspices of a Consolider project that will carry out cosmology studies by observing the Northern sky with a new camera, to be located at the William Herschel Telescope at La Palma,

Canarias. The camera is scheduled to be completed in 2013.

9. The **Medical Physics** group continues working on a line initiated in 2002 with DearMama, a EU-funded project on breast cancer diagnostic techniques by digital radiography. These studies are carried out in collaboration with an IFAE spin-off company, X-Ray Imatek.

In 2010, this group began developing a novel approach to Positron Emission Tomography, funded by obtained an ERC advanced grant. The group developed an ASIC to read out its finely-pixelized CdTe detector.

The Theory Division

The activities of the Theory Division during 2012 continue along three broad lines: Standard Model Physics, Beyond the Standard Model and Astroparticles/Cosmology.

1. Standard Model Physics

The main research themes pursued in the Standard Model (SM) group of the IFAE theory division during 2011 were hadronic decays of the τ lepton, chiral perturbation theory, also including higher-mass vector and scalar mesons in the framework of resonance chiral perturbation theory, mesonic interactions, the hadronic contribution to the muon anomalous magnetic moment, QCD at finite temperature, as well as studying the structure of higher-order corrections in QCD perturbation theory.

2. Beyond the Standard Model

IFAE's theory group has been very active in studying the experimental data to understand the properties of the Higgs candidate and to extract possible implications for the Standard Model and for physics beyond it.

On a different research line, the group considered general 5D warped models with SM fields propagating in the bulk and computed explicit expressions for oblique and non-oblique electroweak observables as well as for flavor and CP violating effective four-fermion operators.

3. Astroparticles/Cosmology

Astroparticle physics and particle cosmology are recent fields of research at the intersection between particle physics, astrophysics and cosmology. The goal is to exploit our knowledge of astrophysical and cosmological phenomena to answer fundamental physics questions, and vice-versa. During 2012, the work done by the members of the Theory Division in this research area can be divided in the following topics: dark matter models, baryogenesis, the emergence of Lorentz invariance, and applications of the gauge/gravity correspondence

2.1 ATLAS at the CERN LHC

Mario Martínez

Since 1993, the IFAE group has given major contributions to the construction of the ATLAS apparatus, its trigger system, its physics reconstruction software and preparatory physics studies. During the last three years, with the arrival of the LHC data, the IFAE group has been carrying out a strong physics program.

In 2012 the LHC delivered proton-proton collisions with an increased centre-of-mass energy of 8 TeV. The collider and the detector performed extremely well, resulting in close to 23 fb^{-1} of total integrated luminosity recorded by ATLAS, almost a factor of five more luminosity than that accumulated in the previous year (see Figure 1).

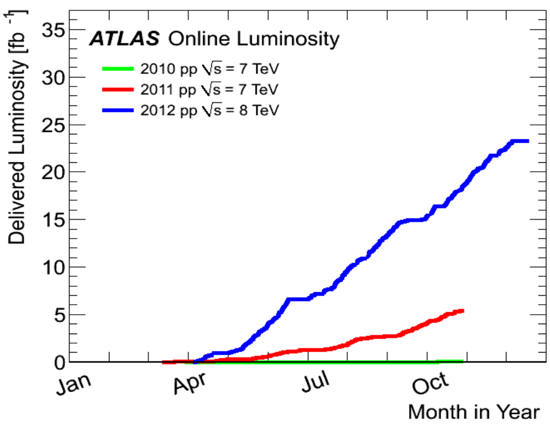


Fig. 1: Cumulative luminosity versus time delivered to ATLAS during stable beams and for p-p collisions. This is shown for 2010 (green), 2011 (red) and 2012 (blue) running.

The large increase of luminosity and physics data samples came at the price of a very significant increase of pile-up collisions, as illustrated in Figure 2, with an average of more than 20 proton-proton interactions per crossing. No doubt this is one of the main challenges to be faced in analyzing the new data.

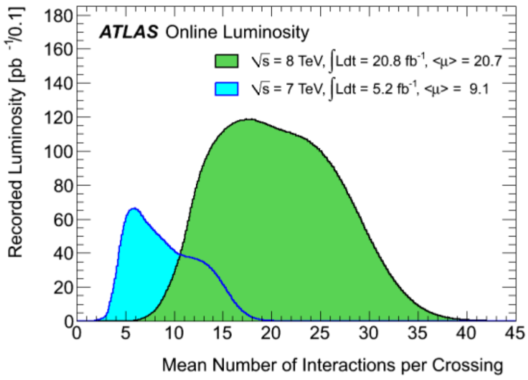


Fig. 2: Luminosity-weighted distribution of the mean number of interactions per crossing for the 2011 and 2012 data.

This year, the IFAE group maintained its responsibilities in the operation and calibration of the TileCal calorimeter, in the activities related to the trigger system and the study of its performance, evolution of algorithms and trigger menu. The group played a leading role in various physics analysis fronts, consolidated the necessary computer infrastructure in Barcelona, and kept its clear visibility within the experiment organizational chart. In particular, in January 2012 Martine Bosman became the Chair of the ATLAS Collaboration Board.

In the following sections, some details are given on the different activities of the group.

Tilecal Hadron Calorimeter Activities

In 2012, the IFAE group contributed strongly to calorimeter operation, calibration and data preparation. In addition, postdoc V. Giangiobbe was the TileCal Calibration Coordinator.

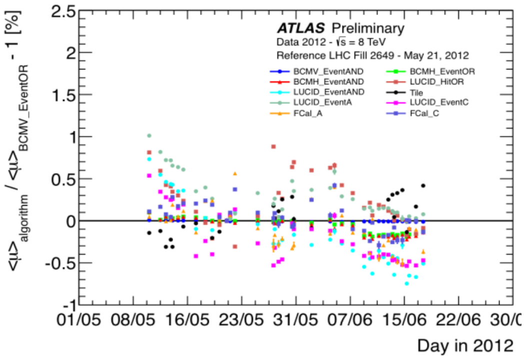


Fig. 3: Variation is response of different ATLAS luminosity monitors as a function of time

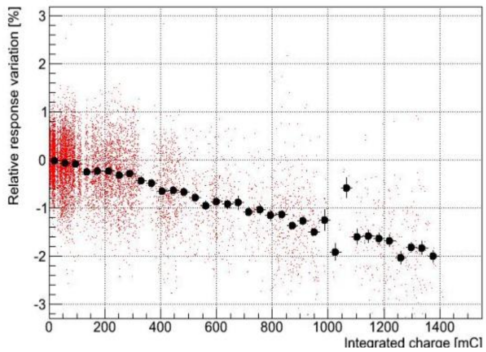


Fig. 4: Loss of the light yield in TileCal cells as a function of the electrical charge collected from these cells in 2012.

The IFAE group maintains its commitment to fully support the TileCal "Minimum Bias" data calibration system. The system is based on the components developed exclusively at IFAE and serves to monitor on the daily basis the stability of the Tile calorimeter response in time and, together with other luminosity monitors of ATLAS (see Figure 3), to measure the luminosity delivered to the ATLAS detector by the LHC. While a number of luminosity monitors of ATLAS provide a measurement with similar level of uncertainty, finally the TileCal monitor was chosen to set the systematic error on the luminosity measurement in 2012. This was mainly due to its unique feature of being independent of ATLAS triggering.

IFAE PhD student Roger Caminal qualified for ATLAS authorship by operating this system, while another IFAE PhD student, Silvia Fracchia, used the data obtained by the system in 2012 to quantify the effect of the irradiation on the optical components of the Tile calorimeter. The preliminary results indicate detectable loss in the optics of the calorimeter, as shown in Figure 4, as a function of the PMT anode charge measured by the Minimum Bias data calibration system in 2012.

In addition, the IFAE group has provided the timing calibration for the TileCal electronics read-out based on the analysis of the dedicated LHC run with single beam. The results of the calibrated calorimeter response are shown in Figure 5. The precision of the Tile timing calibration was 0.5 nsec across the whole calorimeter in 2012. In addition, a 2 nsec shift in the LHC clock was detected, as can be seen in the Figure, and fixed.

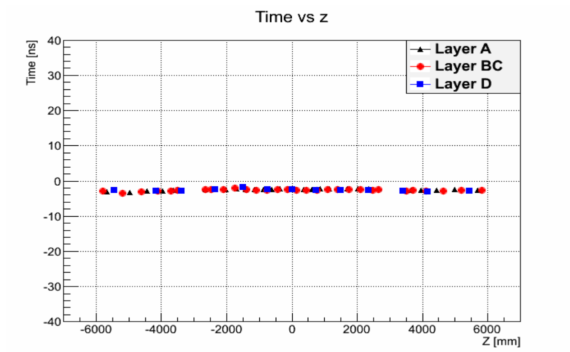


Fig. 5: Resulting timing calibration of the whole TileCal performed with the so-called splash events in 2012.

High Level Trigger Operations

The IFAE group holds responsibilities in the ATLAS High Level Trigger (HLT) system comprised of the software-based 2nd (L2) and 3rd level triggers, which run in two large computer farms. Historically, IFAE played an important role in the overall coordination of trigger operations, in the commissioning of the infrastructure software and the integration of trigger algorithms. This helped in achieving an excellent efficiency during the data-taking period. In 2012, the group continued the activities in the τ and jet triggers; Imma Riu was the co-coordinator of the ATLAS trigger menu and signatures group.

In 2012, the τ trigger activities focused on the maintenance of the calorimeter-based L2 tau trigger and on helping the optimization of selection variables to reduce the efficiency dependence on event pileup. In addition, the performance of the 2011 τ trigger was documented in ATLAS-CONF-2013-006. In the jet trigger, postdoc Davide Gerbaudo developed and optimized a so-called jet partial scan, based on jets formed from a collection of cells from all the L1 Regions of Interest. Its fine time optimization allowed its implementation at L2 during the 2012 data taking in multi-jet triggers. Studies of the jet position, energy resolution and trigger efficiency were performed and are currently being documented. Figure 6 shows the efficiency of the L2 full scan and partial scan jets to satisfy a six-jet trigger in events where at least six jets with transverse energy above 30 GeV have been identified offline.

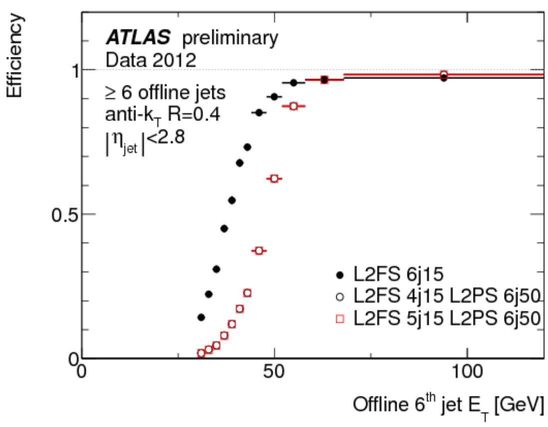


Fig. 6: Efficiency of L2 full scan (FS) and partial scan (PS) jet triggers as a function of the sixth offline jet transverse energy.

In addition, a jet trigger performance paper using 2011 data is in preparation. The group also contributed to the implementation and testing of the jet trigger menu, in particular, in the re-design of the code configuration of the different trigger chains which compose the menu. Profiting from the experience on the L2 jet partial scan development, the group contributed to validating a new geometry of the L1 EM calorimeter aimed at the future upgrade.

Physics Analyses

The year 2012 will be remembered as the year of the experimental discovery of a new Higgs-like boson. During this year, the IFAE group maintained a very intense physics analysis activity and a strong presence on different fronts including: the search for the Higgs boson in the ZH and ttH channels, with the Higgs boson decaying into a pair of bottom quarks; the search for new phenomena in events with energetic jets or photons and large missing transverse momentum; precise top-quark production cross section measurements and the study of the top-quark forward-backward charge asymmetry; and the search for new physics in top-quark final states.

The discovery of a Higgs-like boson at the LHC

One of the main goals of the LHC is the search for the Higgs boson, the particle associated with a quantum field postulated to permeate the Universe and responsible for endowing elementary particles with their mass. The mass of the Higgs boson is not predicted, making its search particularly challenging. On July 4th, 2012, the ATLAS and CMS experiments reported at a public seminar at CERN the results of their searches for the SM Higgs boson using the data collected during 2010-2012.

In particular, the combination of searches at the ATLAS experiment excluded at the 95% C.L. the presence of a Higgs boson with mass between 111 GeV and 559 GeV, with the exception of the range 122-131 GeV (ATLAS Collaboration, Phys. Lett. B716 (2012) 1). In this mass range a signal-like excess was observed at a mass of ~126 GeV, primarily in the searches targeting the decay modes into

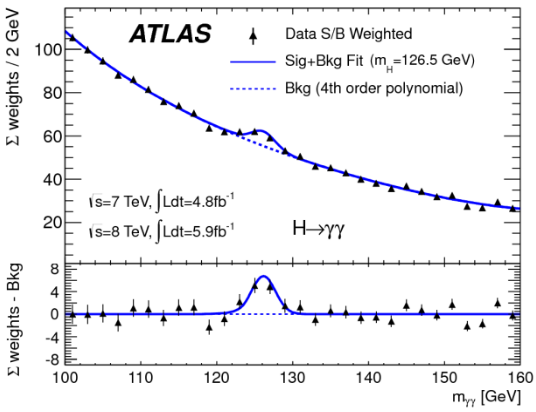


Fig. 7: The distribution of the invariant mass of diphoton candidates after all selections for the combined √s=7 TeV and √s=8 TeV data sample. The result of a fit to the data of the sum of a signal component fixed to m_H=126.5 GeV and a background component described by a fourth order Bernstein polynomial is superimposed. The residual of the data with respect to the fitted background is displayed.

two photons (see Figure 7) and into four charged leptons (see Figure 8). The significance of the excess was estimated to be 5.9 standard deviations from the background-only hypothesis, with a similar signal also observed by the CMS experiment (CMS Collaboration, Phys. Lett. B716 (2012) 30). This represents the discovery of a new boson with properties compatible with those of the SM Higgs boson. It marked the beginning of a new era in particle physics, one of its main focuses being the measurement of the properties of the new particle.

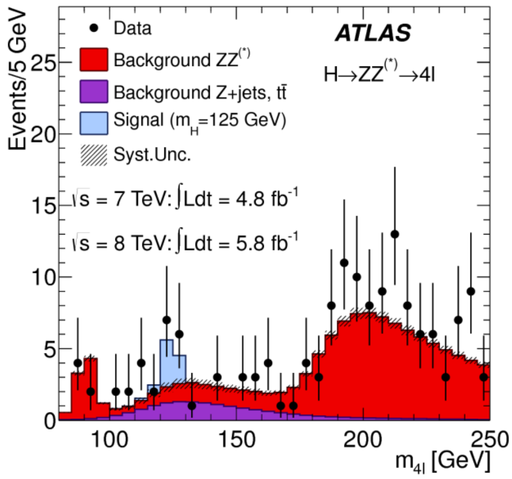


Fig. 8: The distribution of the four-lepton invariant mass, m_{4l}, for the selected candidates, compared to the background expectation in the 80–250 GeV mass range, for the combination of the √s=7 TeV and √s = 8 TeV data samples. The signal expected from a SM Higgs boson with m_H =125 GeV is also shown.

The search for the Higgs boson in the channels where the Higgs is produced in association with a W/Z boson or a top-quark, and then decays into a pair of b quarks is a central part of the Higgs program. IFAE plays a leading role in the ZH and ttH analyses. Postdoc Paolo Francavilla is one of the contact persons for the ZH analysis, and Aurelio Juste is the contact person and corresponding editor for the ttH channel. First results on the latter channel have been published for the summer conferences with 4.7 fb^{-1} of 7 TeV 2011 data (ATLAS-CONF-2012-135), setting a 95% confidence-level upper limit of 13.1 times the SM Higgs boson cross section (see Figure 9). The W/ZH analysis presented the first results for the winter conferences, including an additional 13 fb^{-1} of 8 TeV 2012 data (ATLAS-CONF-2012-161), with an observed 95% confidence-level upper limit of 1.9 times the SM Higgs boson cross section (see Figure 10).

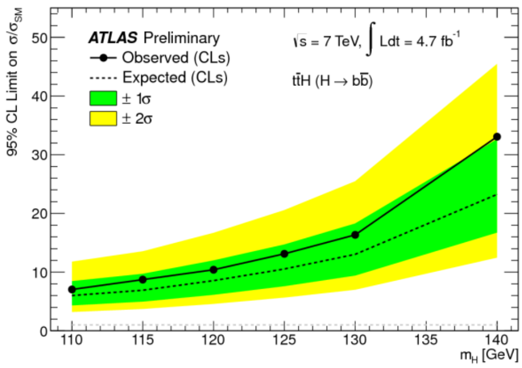


Fig. 9: Observed and expected (median, for the background-only hypothesis) 95% CL upper limits on σ(ttH) x BR(H -> bb) relative to the SM prediction, as functions of m_H. The shaded bands indicate the +-1 standard deviation (s.d.) and 2 s.d. intervals on the distribution of the limits that are expected if no signal is present. Taken from ATLAS-CONF-2012-135.

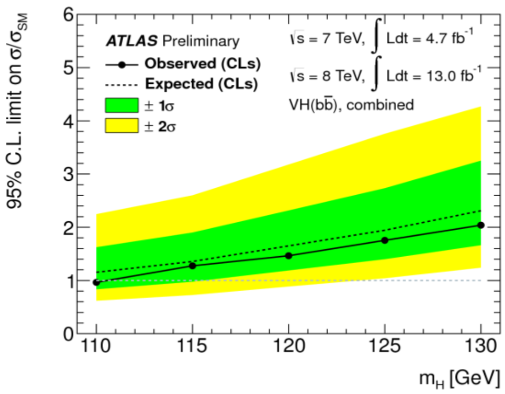


Fig. 10: Expected (dashed) and observed (solid) CLs limit on the normalised signal strength as a function of m_H for all channels for the combination of the 7 TeV and the 8 TeV datasets. Taken from ATLAS-CONF-2012

Monojet and Monophoton Studies

In 2012, the IFAE team continued to be the driving force in the monojet and monophoton analyses in ATLAS, with postdocs Jalal Abdallah and Vincent Giangiobbe being the contact persons of the analyses and Mario Martínez being the corresponding editor for journal papers and conference notes. Monojet and monophoton final states have been traditionally studied in the context of searches for supersymmetry (SUSY) and large extra spatial dimensions (LED), and the search for candidates for dark matter.

Models with LEDs aim to provide a solution to the mass hierarchy problem (related to the large difference between the electroweak unification scale of ~10^2 GeV and the Planck scale of ~10^{19} GeV) by postulating the presence of *n* extra dimensions such that the Planck scale in *4+n* dimensions naturally becomes close to the electroweak scale. In these models, gravitons (the hypotetical particle acting as mediator of the gravitational interaction) are produced in association with a jet of hadrons or a photon leading to a monojet or monophoton signature in the final state.

Astronomical observations of galaxies and galaxy clusters have established the existence of an important non-baryonic dark matter (non-luminous) component in the universe. According to the current understanding of cosmology, dark matter would contribute about 23% of the total mass-energy budget of the universe. The nature of dark matter remains unknown. Strong arguments from cosmology lead to favor as dark matter candidates weakly-interacting massive particles (WIMPs) acting through gravitational or weak interactions. At the LHC, WIMPs could be produced in pairs leaving the experimental devices undetected. Such events could be identified by the presence of an energetic jet or a photon from initial-state radiation, leading again to a monojet or monophoton signature, respectively.

During 2012, the IFAE team focused on bringing to a conclusion and publishing the 7 TeV analyses, using the full 2011 dataset (5 fb^{-1}). Monojet results have been submitted for publication to JHEP (arXiv:1210.4491), and the monophoton results were recently published in Phys. Rev. Lett. 110, 011802 (2013). At the same time, the team promptly analyzed the 2012 data at 8 TeV.

The monojet and monophoton analyses at 7 TeV resulted in a good agreement with the SM predictions. As an example, Figure 11 presents the measured missing transverse momentum distribution in monophoton events compared to SM predictions. This good agreement was translated into very stringent limit on the models with LEDs, to the point that the validity of these models is now seriously challenged.

In addition, the results were interpreted in terms of pair production of dark matter candidates. The 90% CL upper limits on WIMPs pair production cross sections are then translated into limits on the WIMP-nucleon interaction cross section and are compared to similar results from direct WIMP detection experiments (see Figure 12). The exclusion limits in the region of low WIMP mass are driven by the results from collider experiments, if the validity of the effective theory is assumed. The limits are dominated by the monojet results.

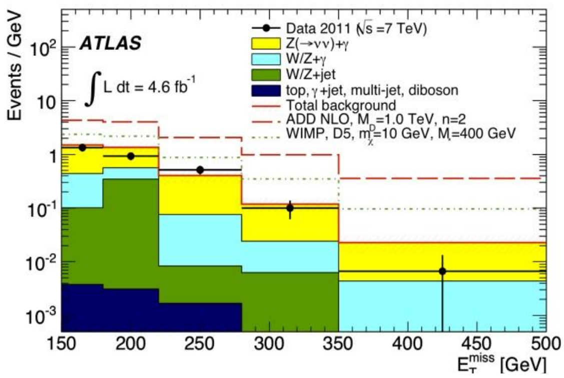


Fig. 11: The measured missing transverse momentum distribution (black dots) compared to the SM (solid lines), SM+ADD-LED (dashed lines), and SM+WIMP (dotted lines) predictions, for two particular ADD-LED and WIMP scenarios. Taken from Phys. Rev. Lett. 110, 011802 (2013).

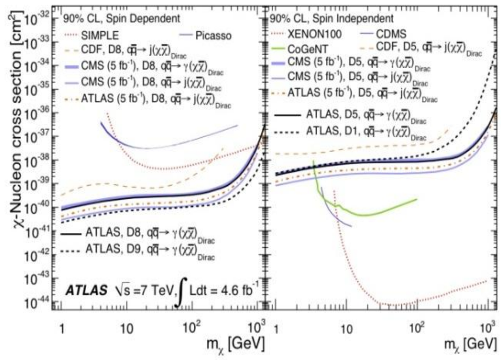


Fig. 12: 90% CL upper limits on the nucleon-WIMP cross section as a function of the WIMP mass for spin-dependent (left) and spin-independent (right) interactions. The results are compared with previous monojet and monophoton results at colliders and results from direct detection experiments. Taken from Phys. Rev. Lett. 110, 011802 (2013).

As already mentioned, the IFAE group also carried out a prompt analysis of monojet final states using the data collected by ATLAS at 8 TeV (see Figure 13). First results, based on 10 fb^{-1} (approximately half of the total integrated luminosity in 2012) were presented for the first time at the Hadron Collider Physics Conference (HCP2011) in Kyoto (ATLAS-CONF-2012-147). The data are still in good agreement with the SM predictions (see Figure 14). The results have been translated into updated exclusion limits on the presence of large extra spatial dimensions and the production of WIMPs, and new limits on gravitino production (the SUSY partner of the graviton) resulting in the best lower bound to-date on the gravitino mass. These results were also presented as a highlight in the January's 2013 edition of the CERN Courier. Altogether, this constitutes the PhD thesis of Valerio Rossetti, scheduled to be defended in Spring 2013.

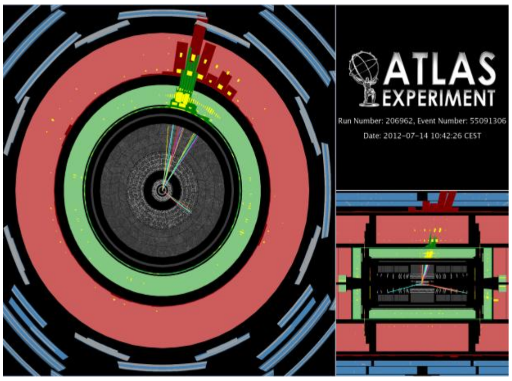


Fig. 13: Monojet event display.

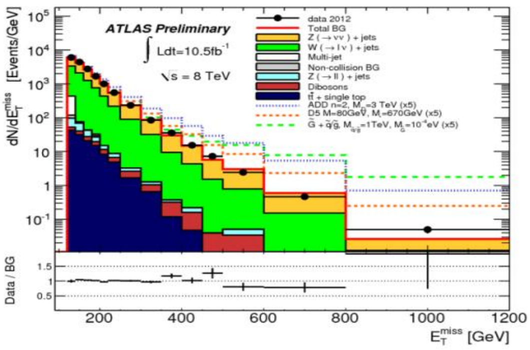


Fig. 14:Measured missing transverse momentum distribution of th emonojet events collected by the ATLAS experiment. Taken *ATLAS-CONF-2012-147.*

The group is now focused in the analysis of the full 2012 dataset and is exploring different SUSY interpretations, including the pair production of third generation squarks in compressed scenarios, among others, with postdoc Jalal Abdallah and Mario Martínez acting as contact person and corresponding editor, respectively.

Top Quark Physics

The top quark is the particle most strongly coupled to the electroweak symmetry-breaking sector (EWSB) of the standard model. This suggests that the top quark may play an active role in EWSB or offer a window of sensitivity to new physics (NP) related to EWSB and strongly coupled to it. IFAE is carrying out a competitive program of precision measurements and direct searches for NP in top quark final states with the goal of unraveling the underlying dynamics responsible for EWSB.

Precision Measurements

The precise measurement of the top pair production cross section provides an important test of perturbative QCD calculations and a probe for NP in the top quark sector, such as non-standard top quark production mechanisms and/or decay modes. Since 2010 IFAE has played a leading role in developing the experimental strategies that enable a precision measurement of the top pair cross section in the semileptonic decay mode, by exploiting high-statistics data samples to constrain *in-situ* the leading systematic uncertainties. These techniques are discussed in the PhD Thesis of Jordi Nadal (July 2012), titled "Simultaneous measurement of the top quark pair production cross-section and R_b in the ATLAS experiment", where a cross section measurement in the e+jets and μ+jets channels was performed using 1 fb^{-1} of data at $\sqrt{s}$=7 TeV, achieving an unprecedented precision of ~6%. Using as additional information the number of b-tagged jets in the event, the parameter R_b (the fraction of top quark decays into a W boson and a b quark, out of all decays to a W boson and a jet of any flavor) was also be measured with ~6% precision. Since then the dataset has been increased to 4.7 fb^{-1} and the impact of systematic uncertainties further reduced, and work is progressing towards achieving an uncertainty below 5%, which will make it one of world's most precise measurements. Aurelio Juste is the contact person and editor for this publication result. Recently these techniques have also been applied to a measurement of the top pair cross section in the τ+jets final state, an analysis potentially sensitive to non-standard top quark decay modes such as into a charged Higgs boson and a b quark. This measurement used ~2 fb^{-1} of data at $\sqrt{s}$=7 TeV and constituted the PhD thesis of M. Chiara Conidi (March 2013), titled "Measurement of the production cross section in the τ+jets final state at $\sqrt{s}$=7 TeV with the ATLAS detector at the LHC", achieving a precision competitive to that of other existing measurements in ATLAS.

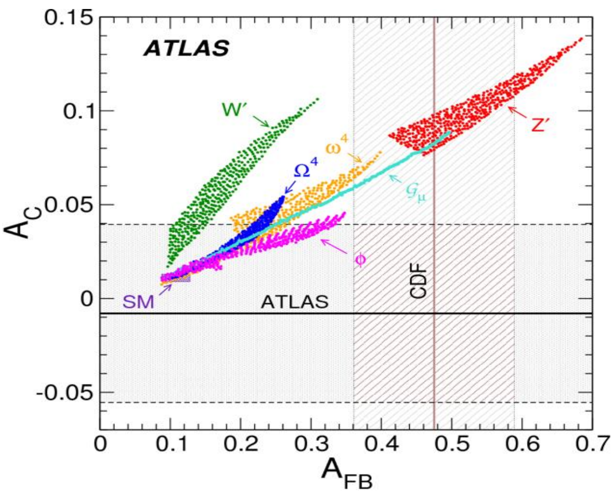


Fig. 15: Measured inclusive FB asymmetries from the Tevatron and charge asymmetries from the LHC, compared to predictions from the SM as well as predictions incorporating various potential new physics contributions. The horizontal (vertical) bands and lines correspond to the ATLAS and CMS (CDF and D0) measurements. Taken from Eur. Phys. J. C72, 2039 (2012).

The observation of an unexpectedly large forward-backward (FB) asymmetry in $t\bar{t}$ production by the CDF and D0 experiments, ~2σ above the SM predictions, constitutes one of the most tantalizing hints of NP in the top quark sector. The large top quark samples collected by the ATLAS experiment offer the exciting possibility of precise measurements that could shed light on the Tevatron anomaly. At the LHC, despite the charge-symmetric initial state, it is possible to define a charge asymmetry sensitive to the same underlying dynamics as the FB asymmetry at the Tevatron. However, this is quite a challenging measurement since at the LHC the expected asymmetry from NP would be quite small (~5-10%), which requires to develop strategies to enhance it, as well as keeping systematic uncertainties below 1%. IFAE participated in the first measurement by ATLAS using 1 fb^{-1} of data at $\sqrt{s}$=7 TeV (see Figure 15), which was published in Eur. Phys. J. C72, 2039 (2012). Since then IFAE is leading the measurement of the top pair charge asymmetry in the semileptonic channel, performing inclusive as well as differential measurements versus three kinematic variables (top pair mass, transverse momentum and rapidity), using 4.7 fb^{-1} of data at $\sqrt{s}$=7 TeV. This result is part of Francesco Rubbo's PhD thesis and is being finalized for publication. F. Rubbo and postdoc D. Gerbaudo are the contact people for this analysis.

Searches for Exotic Heavy Quarks

Many new physics models aimed at addressing some of the limitations of the standard model involve the presence of exotic quarks, heavier than the top quark. For example, models with a 4th generation of heavy chiral fermions, including an up-type t' quark and a down-type b' quark, could provide new sources of CP violation that may explain the value of the matter-antimatter asymmetry in the universe. Another example is weak-isospin singlets or doublets of vector-like quarks, which appear in many extensions of the SM such as the Little Higgs or extra-dimensional models. In these models a top-partner quark, for simplicity here referred to as t', often plays a key role in canceling the quadratic divergences in the Higgs boson mass induced by radiative corrections involving the top quark. At the LHC, for masses below ~1 TeV these new heavy quarks would be predominantly produced in pairs via the strong interaction. In the case of 4th generation models, the t' quark would decay dominantly to Wb, leading to the same final state signatures as top pair production. In the case of vector-like quarks, t'→Zt and t''→Ht decays can compete with, or even dominate, t''→Wb decays, resulting in spectacular final states with multileptons and/or multi-b jets.

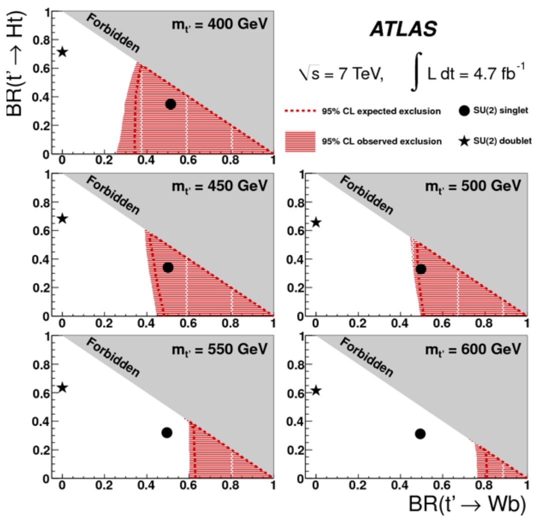


Fig. 16: Observed (red area) and expected (red dashed line) 95% CL exclusion on the plane of BR(t'→ Wb) *vs* BR(t'→ Ht) for different values of the vector-like t' quark mass. The grey solid area corresponds to the unphysical region where the sum of branching ratios exceeds unity. The branching ratio value for the weak-isospin singlet (doublet) scenario is shown as a plain circle (star) symbol. Taken from Phys. Lett. B 718, 1284 (2013).

Since 2011, IFAE is playing a leading role in the program of heavy quark searches in ATLAS. IFAE performed the first search in ATLAS for t't'→W+b W-b using 1 fb^{-1} of data at √s=7 TeV (published in Phys. Rev. Lett. 108, 261802 (2012)). This was followed by an improved analysis using 4.7 fb^{-1} of data, where the search strategy was optimized to enhance the sensitivity at higher masses by exploiting the characteristic topology of boosted W bosons in the decay of heavy quarks. This analysis sets a lower limit of $m_{t'}$>656 GeV at 95% C.L., the strongest constraint to-date on a 4th generation t' quark (published in Phys. Lett. B 718, 1284 (2013)). It also included, for the first time, quasi-model-independent limits on vector- results are part of Antonella Succurro's PhD Thesis. For both publications postdoc Clément Helsens and Aurelio Juste acted as contact person and corresponding editor, respectively. Work is progressing towards vector-like quark searches using 21 fb^{-1} of data at √s=8 TeV that should be sensitive to large regions of the branching ratio plane.

Computing Infrastructure

The Tier-2 and Tier-3 LHC computing infrastructure of IFAE provided efficient access to the analysis of the 23 fb^{-1} of data recorded by the ATLAS detector during 2012. All the infrastructure of the ATLAS Tier-2 and Tier-3 farms is hosted at Port d'Informaciò Científica (PIC) and integrated within its production services (like automatic cluster management, monitoring, etc.), providing a robust and stable environment that maximizes the availability of the facilities. During 2012, the IFAE Tier-2 processed more than 9 billion events (see Figure 17) and executed 1.4 million jobs. The CPU and storage capacity in 2012 reached about 5000 HS06 CPU units and 679 TB, respectively. During 2012, in order to address the local needs for the analysis of the full 2012 ATLAS data sample, the group progressively upgraded the Tier-3 farm with additional CPU and disk capacity. Currently the farm counts on more than 300 CPU cores and 200 TB of disk. Most of these resources are available in form of a PROOF parallel event-processing farm for the latest stages of analysis.

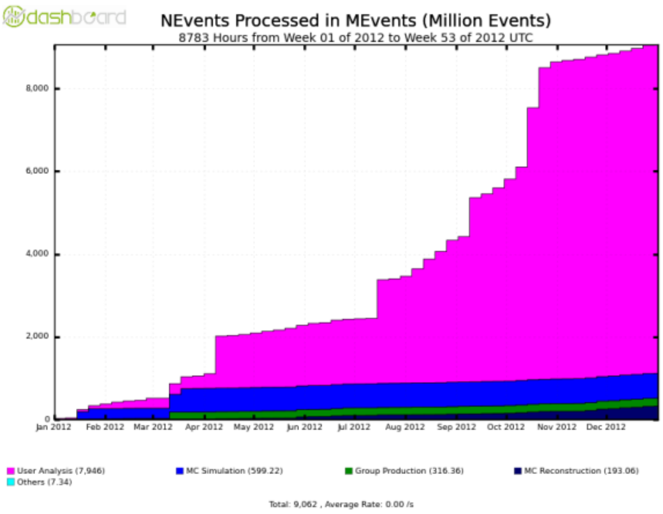


Fig. 17: Cumulative histogram of the number of real data events processed in the IFAE Tier-2 during 2012. The Tier-2 facility processed 9 billion events, 88% by data analysis jobs.

2.2 Pixels for ATLAS upgrades

SEBASTIAN GRINSTEIN

Introduction

In order to carry out its ambitious physics program, the ATLAS experiment needs to identify precisely the path of the out-going particles that are produced when the LHC proton beams collide at 8 TeV. Located very close to the interaction point, the ATLAS Pixel Detector plays a key role in the identification of displaced tracks (which can signal heavy flavor production) and in the reconstruction of the interaction vertices. The Pixel Detector consists of more than 80M channels, each connected to a 50 µm x 400 µm pixel unit which collects the information of the impinging particle. As the LHC accelerator pushes the energy and luminosity frontiers, the pixel sensors and the associated front-end electronics have to be upgraded to maintain their performance. During the first phase of the upgrade program, ATLAS will insert an additional pixel layer (Insertable B-Layer or IBL) inside the current Pixel Detector during the last part of the LHC shutdown of 2013-2014.

The pixel group at IFAE was formed in 2008, and has since taken a leading role in the ATLAS pixel upgrade program. During 2012 there were two main areas of activities: the construction and characterization of 3D sensor modules for the IBL detector, and the construction and characterization of slim-edged 3D sensor prototypes for the ATLAS forward physics detector (AFP). The group participates in the R&D activities of the ATLAS Planar and 3D collaborations, as well as CERN's RD50 collaboration. Members of the group are in charge of coordinating beam test activities (focused on the AFP and R&D for future upgrades) and responsible for the data reconstruction and analysis, critical for the IBL sensor performance verification. In conjunction with these IBL activities, the IFAE group is coordinating a common project with the CNM (Centro Nacional de Microelectronica, Barcelona) to develop new pixel technologies for the future sLHC upgrades.

The Insertable B-Layer

The innermost sub-system of the ATLAS Inner Detector (ID) is the Pixel Detector, which provides charged particle tracking with high efficiency and consists of three cylindrical barrel layers between 50 and 120 mm around the beam axis and three forward and backward end-cap disks. The Pixel Detector significantly enhances track impact parameter resolution, and therefore, vertex reconstruction and b-tagging. To further improve the performance of the silicon system in view of the increasing instantaneous luminosity delivered by the LHC, ATLAS will insert an additional pixel layer, the IBL, inside the current Pixel Detector in 2014. The IBL consists of 14 staves mounted directly on a new, smaller, beam pipe with a tilt angle of 14^{o}. Each stave is equipped with 32 read-out chips. Two sensor technologies have been evaluated for the IBL modules: planar and 3D sensors. During 2011 and 2012 an intense sensor evaluation campaign was carried out. IFAE played a leading role supporting the 3D technology, and, working together with the CNM, produced and characterized 3D sensors for the IBL, finally certifying their performance in beam tests at CERN and DESY (arXiv:1209.1906 and 10.1016/j.nima.2012.03.043). Since the IBL will have to sustain high radiation doses until the replacement of the entire Inner Detector for the high luminosity LHC (foreseen around 2020), the critical requirement of the IBL sensors is high efficiency after an irradiation dose of 5E15 neq/cm² (which corresponds to roughly double the expected radiation dose of the IBL, and where neq represents a particle with the non-ionizing energy loss of a 1 MeV neutron). The final layout of the IBL stave combines planar and 3D sensors (25%) as indicated in Figure 1.

Fig. 1: a ~70cm long IBL stave prototype (with 3D sensors indicated).

IBL 3D Sensors from Barcelona

In 3D pixel sensors the ~10 µm diameter column-like electrodes penetrate the substrate, instead of being implanted on the wafer surface as in planar sensors. The depletion region thus grows parallel to the wafer surface, making the 3D sensor technology intrinsically radiation hard, since it decouples the sensor thickness and the charge collection path. The 3D sensors for IBL have been manufactured in two production facilities, CNM (Barcelona, Spain) and FBK (Italy), with the same specifications.

The sensors are produced on a 230 µm thick wafer with a double-sided process, i.e. the n- and p-type columns are etched from the opposite sides of the substrate. The pixel configuration consists of two n-type readout electrodes connected at the wafer surface along the 250 µm long pixel direction, surrounded by six p-type electrodes which are shared with the neighboring pixels, see Fig. 2. The CNM 3D sensor design features 210 µm long columns which are isolated on the n+ side with p-stop implants. The edge isolation is accomplished with a combination of an n+ 3D guard ring, which is grounded, and fences which are at the bias voltage potential from the ohmic side (see Figure 2). The inactive edge region (to the left and right of the figure) is about 200 µm long.

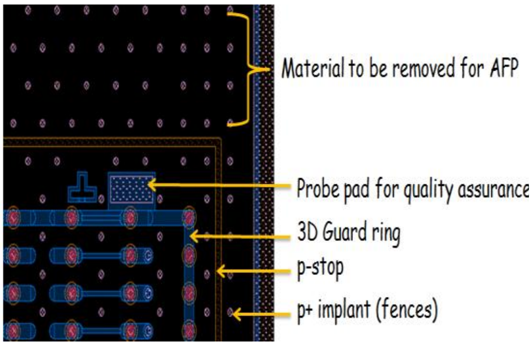


Fig. 2: detail of the CNM 3D IBL sensor mask. The area that has to be removed for AFP is also indicated.

Characterization of IBL 3D Devices

As mentioned above, during 2012 the IFAE group led the effort to prove that the 3D technology meets the requirements of the IBL detector, meaning that after being irradiated to 5E15 neq/cm² the 3D sensors could achieve hit reconstruction efficiency greater than 97%. However, before the beam test studies to determine the efficiency performance of the sensors can be carried out, it is necessary to establish the operational parameters for the devices. The operational threshold was set to 1500 electrons (same for 3D and planar devices) and, after a complicated study of charge collection efficiency and noise was conducted in the IFAE laboratory (see Figure 3), the operation bias voltage for the 3D CNM and FBK devices was determined to be 160V. These optimal voltage settings ensure high charge collection efficiency while maintaining the noise level low.

During 2011 and 2012 the group was responsible for the characterization of the

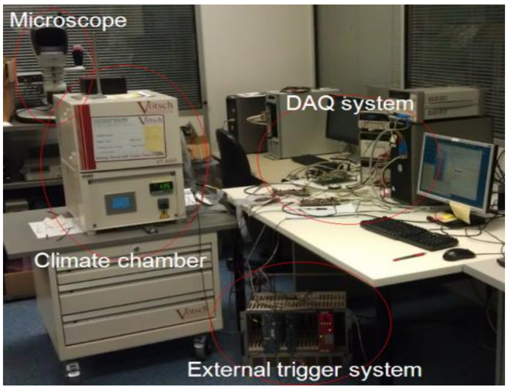


Fig. 3: the IFAE pixel characterization test-stand.

3D IBL sensors prototypes fabricated both at CNM and FBK. Several assemblies were irradiated in order to determine if the IBL requirements, in terms of hit reconstruction efficiency, are met by the two technologies. Table 1 presents the CNM 3D pre-production samples which were irradiated and studied at beam tests during 2011 and 2012 at CERN and DESY using the EUDET beam telescope for track reconstruction.

All the samples were characterized at IFAE, and the beam tests coordinated and the data analysis carried out by the IFAE group.

The hit efficiency, shown in Table 1, is determined from tracks extrapolated to the devices, after track quality cuts have been applied. The efficiency difference observed in CNM-34 when the device is perpendicular or at 15º to the incident particles is due to the fact that the charge generated by particles going through the n+ and p+ columns is not collected. The improvement seen when increasing the bias voltage is also apparent. The efficiency of the FBK-87 sample was obtained in April 2012 (DESY) by the IFAE group. From the results, it is clear that the 3D samples meet the IBL efficiency requirements. The IBL will thus include 3D sensors from Barcelona. During 2012 three productions runs for IBL were completed at CNM. The yield of the production runs was about 50%, providing a total of 239 “green” sensors, amply covering the 112 sensors needed for the detector.

Sample	Irradiation Fluence (neq/cm^2)	Bias Voltage (V)	Incidence angle (deg)	Efficiency (%)
CNM-81	5E15 (neutron)	160	0	97.5
CNM-34	5E15 (proton)	160	0	98.1
CNM-34	5E15 (proton)	160	15	99.0
CNM-97	5E15 (proton)	140	0	96.6
FBK-87	5E15 (proton)	160	0	98.0
FBK-90	2E15 (proton)	60	15	99.2

Table 1: beam test hit reconstruction efficiency of 3D IBL samples.

The ATLAS Forward Detector

ATLAS plans to install a Forward Physics detector (AFP) in order to identify diffracted protons at ~210 m from the interaction point in the 2018 LHC shutdown. The current AFP design foresees a high resolution pixelated silicon tracking system combined with a timing detector for the removal of pile up protons. The AFP tracker unit will consist of an array of six pixel sensors placed at 2-3 mm from the LHC proton beam. The proximity to the beam is essential for the physics sensitivity of the AFP experiment. Thus, there are two critical requirements for the AFP pixel detector: first, the dead region of the sensor side closest to the beam has to be minimized. Second, the device has to be able to cope with a very inhomogeneous radiation distribution. Based on the successful performance of CNM 3D sensors productions for the IBL, the Barcelona sensors were selected to construct the first AFP prototypes.

To study the effect of non-uniform irradiations, two FE-I4 IBL prototypes were irradiated with protons non-uniformly at the IRRAD1 facility at CERN. Figure 4 shows the irradiation dose distribution on CNM-57.

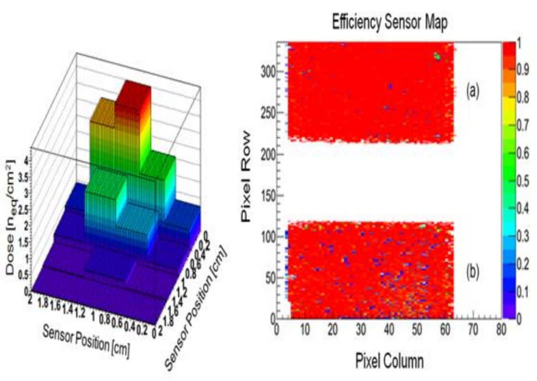


Fig. 4: irradiation profile of an AFP CNM 3D prototype device (left). The dose concentrates in the side which will face the LHC beam. On the right, the efficiency of the two areas of the sensor is shown. Area (b) corresponds to the irradiated zone.

The dose of 4E15neq/cm2 is close to the expected maximum for AFP. The irradiated devices, together with a reference device, have been characterized in August 2012 at CERN.

Since the active area of the FE-I4 devices is larger than the Mimosa sensors of the EUDET telescope, separate sets of data were taken to cover the irradiated and non-irradiated regions of the sensors at normal incidence. Figure 4 shows the efficiency map for sensor CNM-57. The non-irradiated region (a) has an average efficiency of 98.9%, while the efficiency for the irradiated side is 92.7%. If the dead and noise pixel cells (due to front-end issues) are removed, the efficiency increases to 98.0%, which proves the adequacy of the 3D CNM sensors for the AFP experiment.

Summary

The ATLAS Collaboration will install a new pixel layer in 2014. The IBL will be mounted directly on a new beam-pipe at an average radius of 3.3 cm. Two pixel technologies have been evaluated for the IBL, planar and 3D sensors. As a result of the excellent performance of the CNM-Barcelona sensors the IBL will include 3D devices in the forward pseudo-rapidity region. The full production of CNM 3D sensors for IBL was completed in 2012 and the detector is currently being assembled.

Beyond IBL, the IFAE pixel group is playing a major role in the AFP detector R&D. AFP prototypes have been constructed using CNM-Barcelona sensors and their good performance has been proven in beam tests. The group is also active in the sensor research activities toward future LHC upgrades. In particular at R&D effort towards thin planar and 3D devices with charge multiplication capabilities was begun.

2.3 The Collider Detector at the Tevatron (CDF)

Verónica Sorin

The Tevatron is a proton-antiproton collider, located in the USA, at the Fermi National Accelerator Laboratory in the state of Illinois. It has been in operation for more than 20 years and ceased to provide collisions to its two multipurpose detectors, CDF and D0, on September 2011. The Tevatron was the highest energy particle collider until the year 2010, when the LHC started operations. The accelerator complex underwent several upgrades through the years. One of its milestones, the discovery of the top quark in 1995, occurred during the Run I period, in which the accelerator operated with a center-of-mass energy of 1.8 TeV. For Run II the Tevatron's increased energy was increased to 1.96 TeV and its upgrades allowed to reach instantaneous luminosities up to $4x10^{32}/cm^{2}s$, surpassing the design values and delivering to each experiment a total integrated luminosity of about 10 fb^{-1}.

Two are the multipurpose detectors located along the Tevatron ring, CDF and D0. These experiments are international collaborations, with more than 500 researchers each. Detectors upgrades were also made by each collaboration in order to cope with the higher trigger and data rate established by the Tevatron during Run II. In particular the CDF detector improved the DAQ and readout electronics, its tracking capabilities, developed a powerful vertex-finding trigger and installed a time-of-flight detector, new forward calorimeters and increased angular coverage for muon detection. The CDF II detector is shown in Figure 1.

Since IFAE joined the CDF experiment, the group maintained an ambitious research program that along the years has focused on the study of events with jets of hadrons in the final state, multi-jet events with large missing transverse energy as a signature for new phenomena like, for example, super-symmetry and jet production associated with a Z boson, providing an exhaustive analysis of final states similar to those utilized for the search of the SM Higgs.

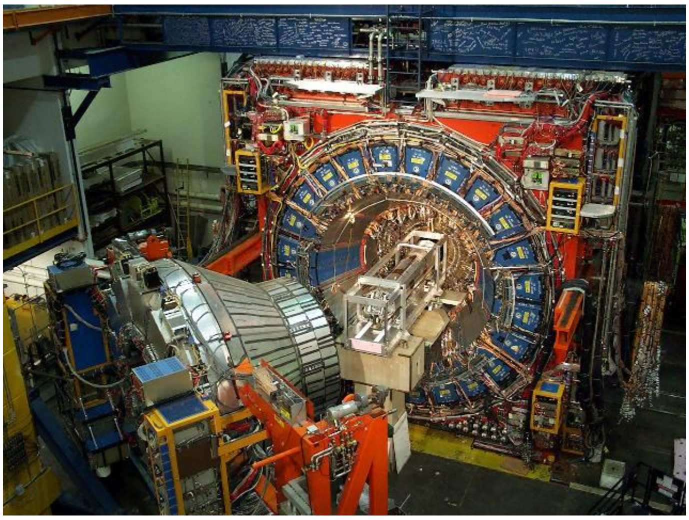


Fig. 1: The CDF Detector in Run II

During 2012, IFAE kept a leading role in the analysis of jet production in association with a Z boson, using the full data sample collected during Run II and kept its responsibilities on data quality monitoring (DQM), focused on the offline related activities.

CDF detector operations: data quality monitoring

The IFAE group has been responsible for the data quality monitoring (DQM) at CDF. The control of the quality of the data taken for physics analyses was considered in the CDF organization scheme as a *detector subsystem* and was managed by members of the IFAE group. During data taking, the monitoring was performed at two levels, online and offline. The DQM online system provided a data quality diagnosis in real time, based on criteria determined as the result of the interaction with the sub-detector experts. Dedicated monitors were developed that ran in the CDF control room during data taking.

The offline phase allowed for problems to be found that only larger statistics would show. Data was thus tested and its quality defined providing a new set of decisions that together with the online ones were used to establish *good run* lists to be used by the whole collaboration for physics analyses.

During the year 2012, a review was performed over the quality decisions and a final version of the lists was generated corresponding to the full data sample acquired by CDF during Run II.

Physics program in CDF

During 2012, the group finalized the studies of Z+jets and Z+b-jet. Precise measurements of these processes constitute fundamental tests of perturbative QCD (pQCD) and provide a clean sample to validate Monte Carlo predictions for background estimations in searches for new physics. The measurements produced by the group constitute part of the legacy of the Tevatron.

The experience of members of the group in top quark physics has led to two new publications in this area. A study of the top quark charge (produced by V. Sorin), which found results consistent with the Standard Model excluding an exotic quark hypothesis (of -4/3 charge) at 99% CL, is on final review by the collaboration to be submitted to Physical Review D for publication. This measurement together to many other impressive results on top quark from the Tevatron were collected in a review written by V. Sorin (together with D0 colleagues) which was submitted to Int. J. Mod. Phys. A.

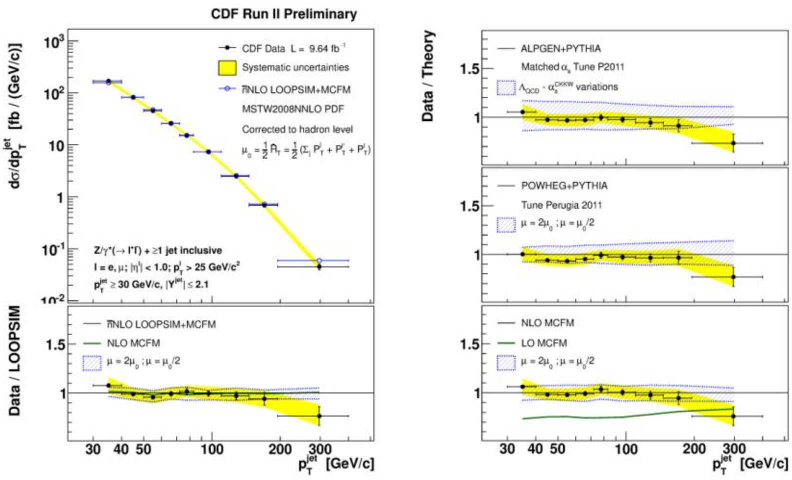


Fig. 2: Differential cross section measured as a function of the jet transverse momentum and comparison *with different pQCD predictions and event generators*

Z+jets final states

Using the full Run II data sample, corresponding to 9.6 fb^{-1}, the group produced measurements of differential cross section for Z+jets production and compared them with state-of-the-art theoretical predictions (Figure 2). Measurements produced for each decay channel (electron and muon), were combined, increasing the available statistics and thereby exploring higher jet multiplicity bins and new observables. Results were presented in various international conferences. These measurements constitute Stefano Camarda´s PhD. thesis, successfully defended in July 2012 (results will be submitted to Physical Review D for publication).

Z+b-jets final states

During the year, the group completed a study on the production of a Z boson with one or more b-jets. The analysis, built on the framework used for the Z+jets measurement, introduced the use of Neural Networks (NN) to increase the lepton ID efficiency. Using the full Run II data sample corresponding to 9.13 fb^{-1}, the integrated b-jet cross section was measured with an uncertainty of 15%, reducing significantly that of previous measurements. Also differential cross section as a function of b-jet transverse momentum (Figure 3) and rapidity were produced. The analysis was presented in several international conferences and constitutes the PhD Thesis of L. Ortolan, successfully defended in July 2012.

Measurements of the Z+jets and Z+b-jets processes provided the means to validate the MC tools used for the background description on the search for the Higgs boson at the Tevatron and has also been a testing ground were to explore and develop NN techniques for lepton ID which in the case of the Higgs search introduced an improvement of 20% in acceptance over previous results. The most recent analysis (9.45 fb^{-1}) for the ZH -> ll bb process, has observed (expected) a 95% CL upper limit of 4.7 (2.6) times the SM predicted value for a mass of 115 GeV/c^2.

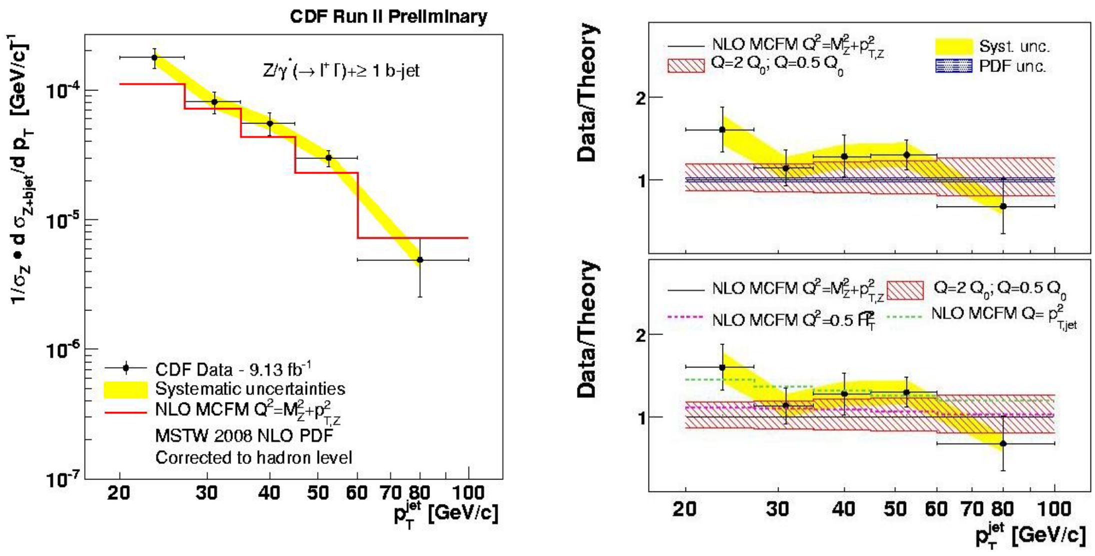


Fig. 3: Differential cross section measured as a function of the b-jet transverse momentum and comparison with NLO pQCD predictions.

2.4 Neutrino Experiments at IFAE

FEDERICO SÁNCHEZ

Neutrino experiments in 2012

Neutrino oscillations are a solidly established experimental fact, well described by current models. IFAE has been contributing to this rapidly developing area of particle physics for more than a decade, taking part in several key experiments: among them, K2K, that made the first measurement of neutrino oscillations with a man-made neutrino beam, and T2K, that presented in 2011 the first indication of the oscillation from muon to electron neutrinos. The T2K result also produced the first evidence of a non-zero value for the third mixing angle.

Continuing on the trail of this very successful decade, 2012 was another glorious year for neutrino physics. Following the 2011 T2K and Dooble-Chooz evidence of a non-zero value of the third mixing angle, two experiments, Daya Bay and Reno, confirmed this result and performed precise measurements. In only one year the unknown mixing angle governing these oscillations became a well-known quantity, measured with remarkable precision. However this is not the end of the line, because several parameters are still poorly known and the goal of discovering charge parity (CP) violation in the lepton sector is generating much activity in a well-focused and active community.

T2K

T2K observes neutrino oscillations by sending a conventional high-intensity muon neutrino beam from the JPARC proton accelerator center in Tokai (Japan) to the SuperKamiokande detector in Kamioka (Japan) located 295 km away. The beam is 2.5º off-axis in order to optimize the neutrino energy spectrum for the search of electron neutrino appearance – as can be seen in Figure 1. Neutrinos are measured at the near detector, located at 280 m from production point (ND280). The neutrino beam is composed mainly of muon neutrinos, which are expected to transform into τ neutrinos - not detectable in Super-Kamiokande - and into electron neutrinos.

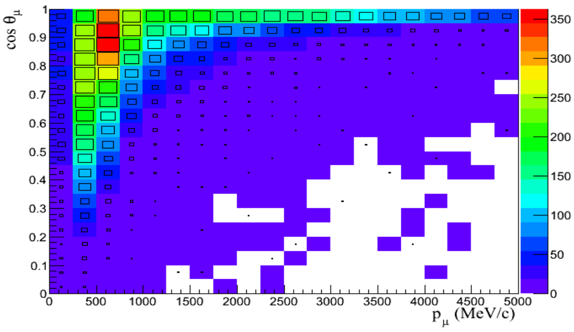


Fig. 1: Muon angle versus muon momentum distribution for neutrino interactions at the T2K near detector and comparison with Monte Carlo (color) predictions.

T2K has a very rich neutrino physics program. At the moment it is the only experiment that observed the transition between muon neutrinos and electron neutrinos, to measure the mixing parameter θ_{13}. The muon neutrino beam also allows measuring more parameters of the neutrino mixing matrix, namely θ_{23} and the neutrino mass difference, via muon neutrino disappearance. It can also contribute to the search of the so-called sterile neutrinos.

These measurements require a precise understanding of the beam neutrino flux and of the neutrino-nucleus cross sections at energies around 1 GeV. T2K designed the experiment for this goal by locating a detector very close to the neutrino production point. The near detector is a complex set of instruments, embedded in a magnetic field. The detector is divided into two sections: the POD that is devoted to detecting neutral pions, and the charged-particle trackers, FGD and TPC. The detector is surrounded by an electromagnetic calorimeter, ECAL, to measure photon energies and a muon catcher (SMRD) to identify muons.

The contributions of the IFAE group to the T2K experiment focused on the near detector, specifically on the construction of the Time Projection Chamber (TPC) in the tracker section and on the installation and controls of the magnet. After the installation and successful operation of the detector during 2010, IFAE focused its efforts on the maintenance of the detectors and on data analysis.

The JPARC accelerator provided the first neutrino beam in April 2009, and the near detector saw the first interactions in November 2009. The physics run began in February 2010 and continued until March 2011, abruptly stopped by the terrible earthquake that shook the northeast coast of Japan. Nonetheless, after recovery from earthquake damage, the beam intensity increased significantly, reaching steady operation around 230 kW towards the end of 2012, with a total number of 4.8×10^{20} protons on target by the end of December.

The IFAE group led the analysis of the inclusive charged-current muon and electron neutrino interactions to be used for neutrino flux normalization. Members of the group reanalyzed the data using a better reconstruction algorithm and also led the analysis of muon and electron neutrino charged-current interactions. All these results are published in the two major T2K papers of 2011: the first indication of electron neutrinos in a muon neutrino beam (Phys. Rev. Lett. 107, 041801 (2011)) and the muon neutrino disappearance paper (Phys. Rev. D85 (2012) 031103). In addition, these results are included in the official neutrino flux measurement as of summer 2012, which was used to officially update the electron neutrino appearance and muon neutrino disappearance results at the end of 2012.

A person from IFAE convenes the muon neutrino and the T2K analysis steering group. Another major contribution has been the analysis of the intrinsic contamination of electron neutrinos in the beam. Good agreement between data and the predicted flux is found, as shown in Figure 2. This is also the official T2K result.

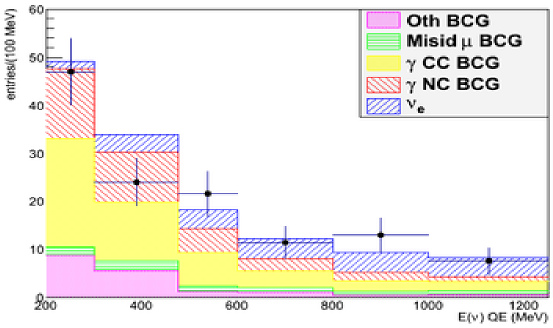


Fig. 2: Reconstructed neutrino energy of electron neutrino candidates at the near detector and comparison with Monte Carlo predictions.

T2K has analyzed the data collected until summer 2012 to measure neutrino oscillations over the long baseline to SuperKamiokande. Eleven electron-like events over a background of 3.2 were found, as shown in Figure 3.

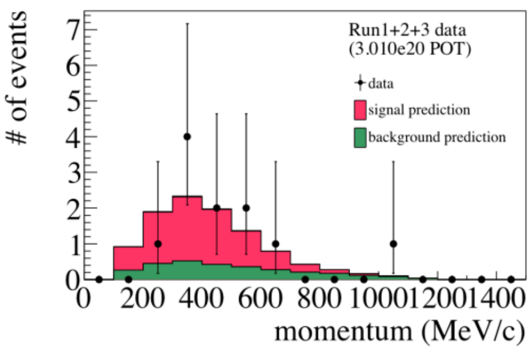


Fig. 3: Reconstructed momentum of electron candidates detected at SuperKamiokande and the Monte Carlo prediction under the oscillation hypothesis. Shown are all data collected until summer 2012.

This excess is interpreted as evidence of a non-vanishing θ_{13} neutrino mixing angle. The probability that the result arises from a background oscillation is < 8.4 x 10^{-4}. The results on the mixing angle corresponding to the possible range of the CP-violation phase are shown in Figure 4.

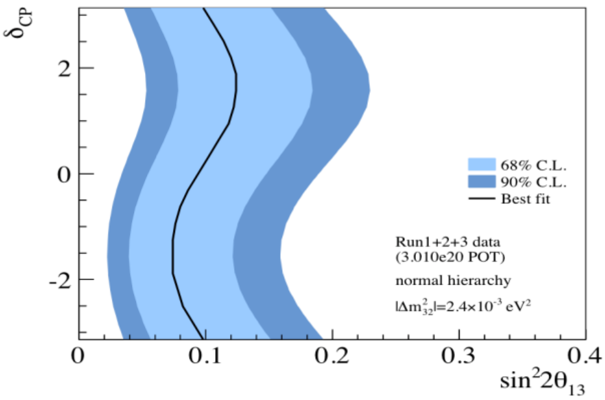


Fig. 4: Allowed values of θassuming normal mass hierarchy, corresponding to the possible range of the CP-violating angle δ_{CP}. The black solid line is the best fit.

The muon neutrino disappearance analysis was also updated, with very promising results. The disappearance pattern at the far detector is clear, see Figure 5. The analysis provides values of the θ_{23} mixing angle and of the neutrino eigenstate mass difference (Δm^2_{23}) as shown in Figure 6. These are among the leading results available to-date, and were obtained with just 3% of the total expected number of protons on target. This shows the future potential of T2K for this measurement.

A search for neutrino oscillations on very short baselines using the T2K near detector began recently. The transformation of muon neutrinos into electron neutrinos or the disappearance of the muon neutrinos will provide indications on the possible existence of sterile neutrinos. This is a very active field in neutrino physics, motivated by a few contradictory results from the latest analysis of reactor neutrinos, LSND and MiniBoone experiments. T2K covers some of the parameter space for these results and will help enlightening the experimental situation which currently is quite confusing.

IFAE is actively contributing to both the ongoing electron neutrino appearance and the neutrino muon disappearance analyses being done on data from the T2K near detector.

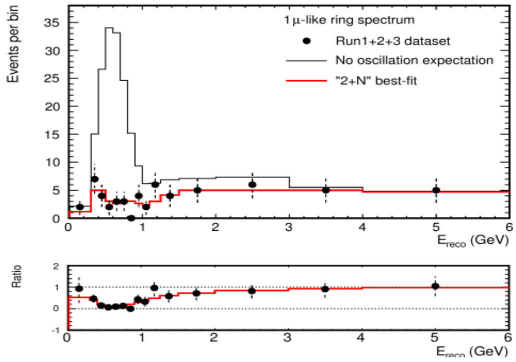


Fig. 5: Reconstructed neutrino energy distribution of muon neutrino candidates at SuperKamiokande. The solid lines show the Monte Carlo predictions for the oscillation and the non-oscillation hypotheses. All data collected until summer 2012 are included.

Additional activities of the IFAE group include improving reconstruction in the TPC and particle identification and software developments for T2K. IFAE also provides support for the magnet and TPC maintenance tasks.

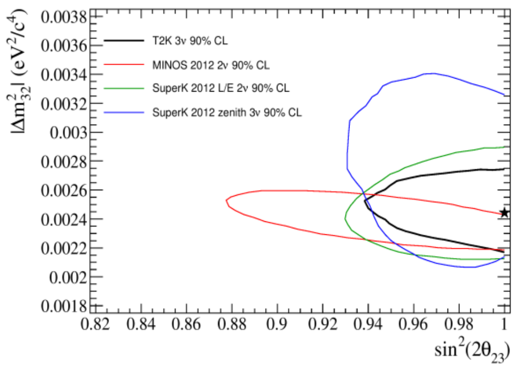


Fig. 6: T2K results on the Δ23 mixing angle and θ223 for the muon neutrino oscillation hypothesis. The T2K allowed regions are compared to those from the MINOS and SuperKamiokande experiments.

R&D on Time Projection Chambers that detect electroluminescence

IFAE pioneered the development of a technology, based on APDs, for a pixelated readout of electroluminescence for tracking and energy determination in TPCs. With early IFAE prototypes using 5 APDs a FWHM of 0.7% at 2.5 MeV was obtained. This result shows that this approach has great potential.

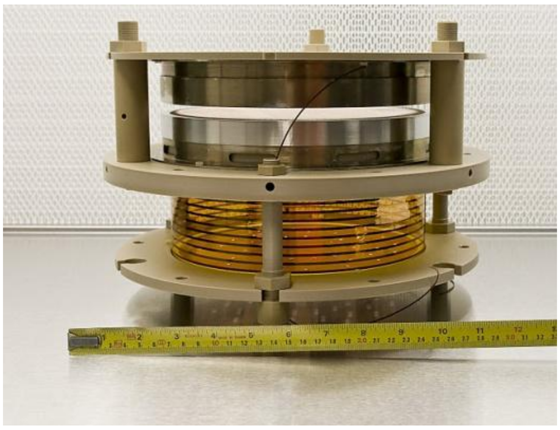


Fig. 7: Electroluminescence Time Projection Chamber built at IFAE.

During 2012, the group continued developing this technology, building and operating a larger Time Projection Chamber. Light readout is done using 25 APDs and 2 PMTs that detect the prompt scintillation light. The inner field-forming structure of the detector is shown in Figure 7.

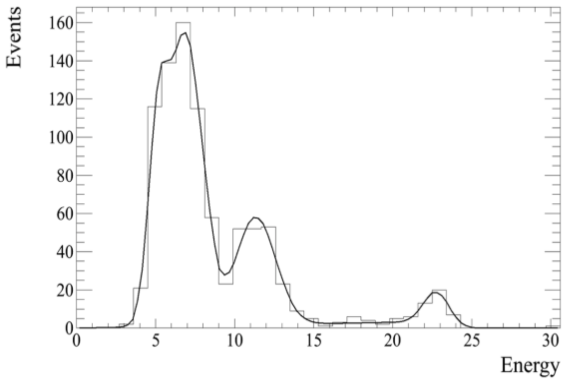


Fig. 8: Energy (arbitrary units) spectrum of Cd X-rays observed with IFAE xenon TPC. Five transitions contribute to the signals. The highest energy peak (60 KeV) is measured with a FWHM resolution of 8.2%.

First results were obtained at the end of summer 2012 and were shown at the IEEE conference in San Diego in October 2012. The energy resolution achieved with the prototype is 8.2% FWHM at 60 keV, as shown in Figure 8. The detector's capability of detecting the prompt Xenon scintillation light is shown in Figure 9. Finally, the first tracks observed with the detector are displayed in Figure 10. Work will continue to fully characterize the technology and evaluate potential applications.

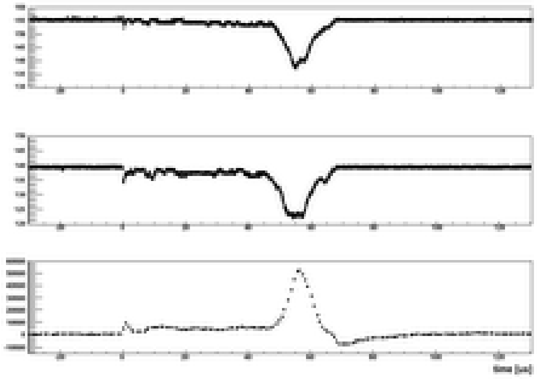


Fig. 9: The cosmic ray signals recorded with the PMTs (upper two plots) and with all the APDs (lower plot). The larger signals correspond to the electroluminescence light while the small signal around 0 time is the prompt primary scintillation light arriving 55 ns earlier.

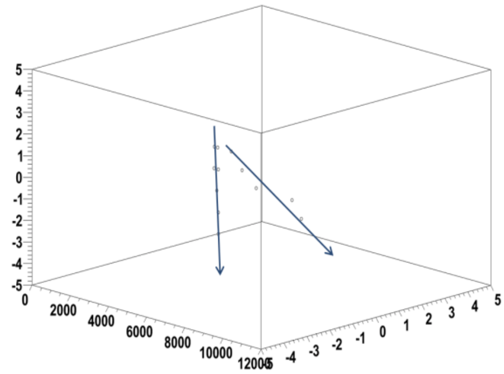


Fig. 10: First cosmic ray tracks recorded with the prototype after event reconstruction. Two simultaneous tracks are clearly visible in the event.

2.5 The MAGIC Telescopes

Javier Rico

MAGIC ("Major Atmospheric Gamma Imaging Cherenkov") is a new generation, two-telescope system located at the Roque de los Muchachos Observatory, on the Canary Island of La Palma. Each MAGIC telescope achieves a high light sensitivity (and therefore low energy threshold) because it is equipped with a large-diameter (17 meter) reflector and a camera with high quantum efficiency and sensitivity to single photoelectrons. The telescopes detect cosmic gamma rays in the very-high-energy (VHE) domain, i.e. in the energy range between ~50 GeV and ~50 TeV.

At present, the most sensitive observations in this energy band are performed from Earth by Imaging Air Cherenkov Telescopes (IACTs), of which MAGIC is one of the most advanced examples. IACTs image the Cherenkov light produced in the electromagnetic showers initiated by cosmic radiation in our atmosphere. The main background affecting the observations of gamma rays using this technique comes from the overwhelming flux of charged cosmic rays - about 100 times more abundant than gamma rays from intense sources after reduction by the analysis of image properties. Using this technique, over a dozen sources were detected in the 1990s with the previous generation of IACTs. Instruments like MAGIC were designed to increase the flux sensitivity in the energy regime of hundreds of GeV. Thus, the first exploratory instruments were replaced in the 2000s by the current generation of facilities, which have revolutionized the field: gamma-ray source catalogues list now about one hundred sources and several new populations have been established. But MAGIC was designed more ambitiously: it aimed at pushing the energy threshold down to energies of tens of GeV. This has allowed an overlap with the energy range of the Fermi-LAT space telescope, thus filling the observational energy gap at tens of GeV.

Fig. 1: The MAGIC-I telescope in operation during a dark night. Thanks to their large mirrors, the MAGIC telescopes working in stereoscopic mode are able to detect gamma rays of energies between ~50 GeV and ~50 TeV. They are powerful eyes to observe the most violent phenomena from the non-thermal Universe. Image Credit: D. Tescaro.

IFAE technical responsibilities

The IFAE group joined the R&D effort towards the design and construction of the first MAGIC telescope in 1996, and built its photomultiplier camera, which has been operating since 2004. For the second telescope, IFAE contributed to the production of key elements of the readout and data acquisition systems, like the receiver boards and the signal digitizers. In addition, since the beginning of the project, IFAE has full responsibility for the development, running and maintenance of the Central Control system. The Central Control integrates the complex ensemble of all the telescopes sub-systems allowing and coordinating their operation during the astronomical observations and data taking. IFAE also built and operates the MAGIC Data Center, which processes ~200 TB/year of raw data and serves analysis products to the entire MAGIC Collaboration. The Data Center uses the same Grid technology developed for the LHC, and used in the TIER-1 infrastructure for the ATLAS, CMS and LHCb experiments at the Port d'Informació Científica (PIC). MAGIC, in collaboration with PIC, pioneered in 2004 the use of Grid technologies in astroparticle research, an approach that is now being followed by other projects, like the Cherenkov Telescope Array. MAGIC has been one of the main actors in the Astronomy and Astrophysics applications section of the EGEE projects.

Initially (2004), MAGIC was composed of a single telescope, MAGIC-I (see Figure 1). A second telescope, MAGIC-II, an improved clone of the first one, was added in 2009. By ways of the stereoscopic technique, the flux sensitivity of the MAGIC two-telescope system was improved by a factor of 2, and its angular and spectral resolutions were significantly enhanced.

In 2011 we started a major upgrade of the telescopes, aiming at improving their sensitivity, stability and robustness by making the hardware of both telescopes essentially equal. One result of the upgrade is to make maintenance and operation easier and less expensive. It is worth mentioning that a German "Otto Hahn" fellow working at IFAE served as Project Manager for the whole upgrade program in the collaboration.

The upgrade consists of three phases:

1. During the first phase, in 2011, we replaced the signal digitizers of both telescopes by new ones consisting of 2-4 GSamples/s readout based on a Domino-Ring-Sampler (DRS) version-4 chip. The new digitizers display a more linear response, shorter dead-time and lower noise than the previous ones. IFAE actively participated in their characterization, both in the lab and once installed in the telescopes. This phase also included the installation of new receiver boards for MAGIC-I, designed, produced, installed and maintained by IFAE in collaboration with the Universidad Complutense de Madrid.

2. During 2012, we have performed the second phase of the upgrade, consisting in replacing the old camera of MAGIC-I by a new one. The new camera has 1039 pixels (see Figure 2) compared to 577 of the old one, and matches the geometry and trigger area of MAGIC-II.

3. In 2013, the third and last stage will take place: both telescopes will be equipped with a "sum-trigger" (a novel concept developed in MAGIC which allows for a lower energy threshold) covering the entire conventional trigger area.

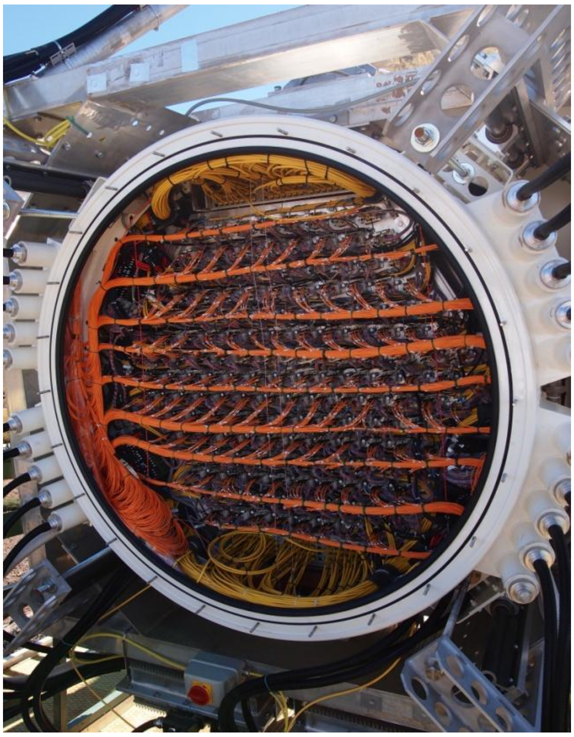


Fig. 2: Rear view of the new MAGIC-I camera. In orange, the optical fibers transporting the photomultiplier signals from the camera to the control house, 85 m away. In 2012, as part of the second phase of the MAGIC upgrade (managed by IFAE), the old MAGIC-I camera has been replaced with the new one, increasing the number of pixels from 577 to 1039, thus making it identical to that of MAGIC-II. Image credit: D. Mazin.

Scientific achievements

VHE astronomy is one of the main pillars of Astroparticle Physics. It is an essential tool to study fundamental phenomena in Astrophysics, Cosmology and High Energy Physics. VHE gamma rays are the most energetic form of electromagnetic radiation. They are produced by processes taking place in the most violent cosmic environments, the so-called “non-thermal Universe”. The main production mechanisms of gamma rays are radiation and interaction of accelerated charged particles, either electrons or protons. Accelerated electrons may produce gamma rays in the presence of magnetic fields, matter, or ambient photons. In addition, gamma rays may be also produced in the decay of the neutral pions resulting from the interaction of accelerated protons with interstellar matter. Therefore by studying gamma rays we learn about cosmic particle accelerators. Furthermore, VHE Gamma-ray Astronomy addresses questions of fundamental physics. With gamma-ray instruments we study the origin of Galactic cosmic rays, or the composition of the cosmic electron-positron spectrum in the GeV-TeV scale. By observing the gamma-ray emission from sources at cosmological distances we learn about the intensity and evolution of the extragalactic background light and perform tests of Lorentz Invariance. In addition we can search for dark matter by looking for gamma rays produced by its annihilation or decay in over-density sites.

During 2012, 14 scientific papers have been produced from MAGIC data, 6 of which have been led by IFAE members who have been their corresponding authors. In addition, MAGIC-IFAE members have participated in 4 non-MAGIC scientific papers, all at the first-author level. Among the most important scientific results, we found evidence for proton acceleration in the supernova remnant W51C (J. Aleksić et al. A&A 541 (2012) A13, led by one of IFAE’s PhD students and part of the PhD thesis defended in 2012). This result and its relation with the mystery of the origin of Cosmic Rays are described next.

In 1912, the Austrian physicist Victor Hess carried out a series of experiments on board an aerostatic balloon, at an altitude of 5300 m above sea level. From them, he concluded that the Earth is continuously bombarded by a flux of energetic particles — protons most of them— which came to be known as cosmic rays. One hundred years later we still don’t know the origin of this phenomenon, *i.e.* where in the Universe and by means of which physical processes cosmic rays acquire their energy. With the aim of answering this question, we have studied a region of the sky where, 30,000 years ago, a stellar explosion — a supernova — occurred. Today, we observe the remnant of that supernova, known as W51C (see Figure 3).

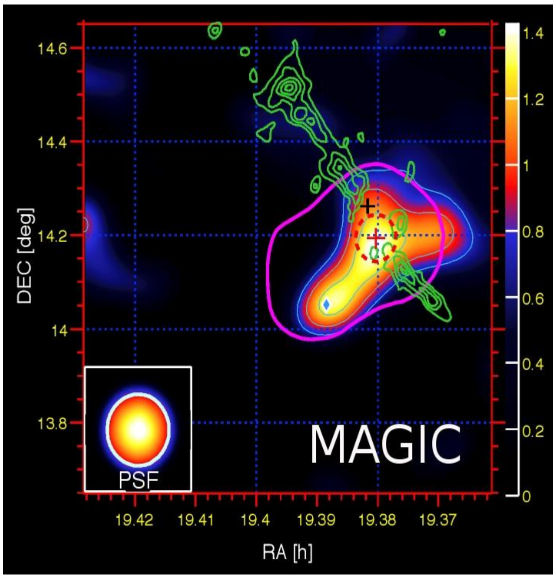


Fig. 3: Gamma-ray image of the supernova remnant W51C obtained by MAGIC (color scale) together with molecular cloud density isocurves obtained by ^{13}CO observations (green contours). The red-dashed ellipse coincident with the gamma-ray intensity peak represents a region of shocked atomic and molecular gas, pointing to the fact that gamma rays come as a byproduct of the collision of accelerated protons with the molecular cloud. The gamma-ray emission extends to the southeast, towards the position of a pulsar-wind-nebula (blue diamond), which would produce VHE emission by means of an unrelated process. Credit: MAGIC Collaboration (J. Aleksić et al. A&A 541 (2012) A13).

The material expelled by the explosion is traveling through space, sweeping interstellar matter on its way, and eventually forming a shock wave. In turn, part of the shock in W51C is colliding with a region of high interstellar density —a giant molecular cloud. By means of observations with the MAGIC telescopes we have been able to observe that there is an intense emission of gamma rays of very high energy produced by the collision of the supernova remnant with the matter in the molecular cloud.

This shows that accelerated protons, i.e. cosmic rays, are being produced at this location.

A fraction of these protons interacts with the cloud, producing the gamma-ray signal that we detect.

Accelerated electrons could produce a similar signal, but this possibility is rejected in this case because they would also interact with the magnetic field in W51C, resulting in a characteristic emission at radio wavelengths, that we do not detect.

This is an important discovery, because if this phenomenon can be generalized to a significant fraction of the supernova remnant population, it could explain the origin of Galactic cosmic rays by means of a collective effect, thereby solving this century-old scientific mystery.

2.6 CTA: Cherenkov Telescope Array

Manel Martínez

The Cherenkov Telescope Array (CTA) project is a worldwide initiative to build the next generation ground-based very-high-energy gamma-ray observatory. As an open observatory, it will serve a wide astrophysics community and will provide in-depth insight into the non-thermal high-energy universe.

The present generation of imaging atmospheric Cherenkov telescopes (H.E.S.S., MAGIC, and VERITAS) in recent years opened the realm of ground-based gamma ray astronomy in the energy range above a few tens of GeV. The Cherenkov Telescope Array (CTA) will explore our Universe in depth in the domain of Very High Energy (VHE, E > 10 GeV) gamma-rays and investigate cosmic non-thermal processes, in close cooperation with observatories operating at other wavelengths of the electromagnetic spectrum, and with those using other messengers such as cosmic rays and neutrinos.

Besides the anticipated high-energy astrophysics results, CTA will have a large discovery potential in key areas of astronomy, astrophysics and fundamental physics research. These include the study of the origin of cosmic rays and their impact on the constituents of the Universe, the investigation of the nature and variety of black hole particle accelerators, and the inquiry into the ultimate nature of matter and physics beyond the Standard Model, searching for dark matter and effects of quantum gravity.

The design foresees a factor of about 10 improvement in sensitivity in the current very high energy gamma ray domain of about 100 GeV to some 10 TeV, and an extension of the accessible energy range from well below 100 GeV to above 100 TeV.

CTA was included in the 2008 roadmap of the European Strategy Forum on Research Infrastructures (ESFRI). Among the “Magnificent Seven” large projects of the European strategy for astroparticle physics published by ASPERA, it was given the highest priority to start construction. It is also highly ranked in the “Strategic Plan for European Astronomy” of ASTRONET. In addition, CTA is a recommended project for the next decade in the US National Academies of Sciences Decadal Review.

Management in CTA and CTA-Spain

This section summarizes the activities and achievements on the different subjects of the CTA Project in which IFAE is participating.

In 2012 Manel Martinez continued working in his role as the CTA-Consortium co-spokesperson and, as such, as a member of the top-level management of the CTA project.

During 2012 CTA crossed the 1000 collaborators boundary, and established a Resource Board composed by representatives of the major funding agencies (including Spain). In summer 2012 the Board signed a “Declaration of Intent” supporting the pre-construction phase of the project, to continue until the project is ready for construction. This clear support from the funding agencies boosted the managerial and organizational activities, which already constitute full-time jobs for all the members of top-level management.

During 2012 Manel Martinez also continued as the leader of the 9 Spanish groups that presently constitute the CTA-Spain Consortium. It is fair to say that the CTA-IFAE group acted globally as the backbone of the CTA-Spain consortium.

Additionally, during 2012 two members of IFAE were deeply involved in the management structure of the Large Size Telescope (LST) team within CTA. Miquel Barceló was acting as system engineer and as support to the project management. Oscar Blanch coordinated several groups towards the design of the camera for the LST. They both worked on the definition of the requirements and specifications for the LST and guided the hardware development towards solutions fulfilling the needs of the LST.

Camera Electronics

The general camera trigger strategy in current Cherenkov telescopes is based on looking for an excess of signal localized in a relative small region of the camera within a time window of a few nanoseconds. This approach allows reducing the trigger rate due to Night Sky Background (NSB) accidentals, whereas the trigger efficiency for gamma-like events remains high due to the compactness of their associated camera image.

The Level-0 trigger is responsible for collecting the signals from all pixels of the smallest autonomous hardware element: the cluster, which for the CTA camera will consist of 7 pixels. These signals are treated and then added together before being sent to the Level- 1 decision trigger. Two different Level-0 trigger boards (Figure 1) were developed, characterized and tested at IFAE. They are a compact, low-cost and low-power-consumption implementation of concepts already used with great success in previously built Cherenkov telescopes. The so-called Sum trigger Level-0 adds the analogue signals from all pixels in the cluster and sends the resulting signal to the Level-1 decision subsystem. Before adding the signals from individual pixels, each of them goes through attenuator and clipping circuits (both adjustable at the slow-control level). The former allows to equalize all pixel gains with a precision better than 5%. The latter cuts signals greater than a given value. The other concept implemented is the so-called majority trigger. This compares the signal from each pixel to a voltage threshold. If the signal is greater than the threshold voltage, a gate, of width proportional to the time the pulse exceeds the threshold, is generated. The gates, generated in all pixels in all clusters, are analogically added. The amplitude of the added signal is proportional to the number of pixels with a signal above the threshold, and is sent to the Level-1 decision subsystem.

An additional feature has been added to the level-0 design for the SumTrigger option. The delays for each pixel should be adjustable to get all signals compensating for possible time differences including the PMT transit times. This development has been done at IFAE, resulting in a low-power-consumption, inexpensive solution. The time offset of each pixel can be adjusted in 250 ps steps within a range of 6 ns. This step size is fine enough to preserve the performance, while the range is sufficient to compensate the time differences among pixels. After validating, at IFAE, the integrated and tested full trigger system (Figure 1), we proceeded to incorporate it into the Front End (FE) boards. This step was successful with all of CTA's FE boards. Using the feedback from the integration into the FE board and the setup for the full trigger test, the calibration strategy has been improved.

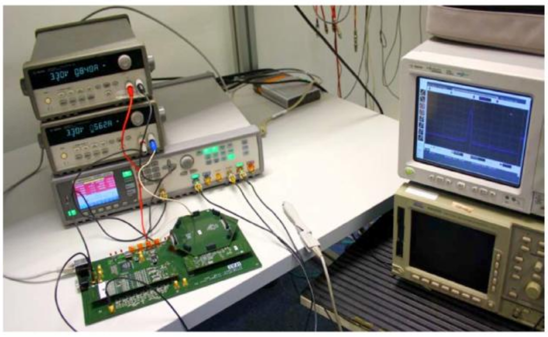


Fig. 1: Setup to test and characterize the fully integrated trigger system foreseen for the CTA cameras.

The LIDAR

A LIDAR (LIght Detection And Ranging) is an optical remote-sensing technology that can measure the distance to a target and more of its properties by illuminating the target with pulses from a laser. Although it has also been used for other applications, the first LIDAR systems were used for studies of atmospheric composition, structure, clouds, and aerosols. This is still one of its most common applications. The LIDARs installed in the CTA observatory will be used to monitor and characterize the atmosphere. This should allow to reduce the systematic uncertainties affecting the imaging air Cherenkov technique and to increase the duty cycle of observations by correcting for the atmospheric conditions. Although LIDARs are commercially available, they do not meet the requirements set by CTA. To reduce the systematic uncertainties at the desired level, the atmospheric absorption should be known with a precision of about 5%. This entails the need to also use Raman lines, which have much less intensity. Furthermore, one needs to characterize the atmosphere up to the altitude where the Cherenkov photons are produced, which is about 10 km above ground.

IFAE had acquired two old telescopes with a 1.8 m diameter already installed in a standard ship container. They were part of the former CLUE experiment. One of them is installed on the campus of the Universitat Autònoma de Barcelona and is used to develop a Raman LIDAR that fulfils the needs of the CTA observatory. The main properties of the mirror like, its reflectivity and point spread function (PSF), were measured. While the former showed some deterioration, the latter is practically the same as when the mirrors where produced. The PSF measurements were previously done with a point like source at 2x the focal distance. New measurements have been done using both real stars and artificial stars generated with a laser. The quality of the mirror was found to be still good enough to satisfy the needs of the LIDAR. In addition to the mirror, the mechanical components of the telescopes and the motors steering their movement are being used. A tracking system that allows to follow sources in the sky making full use of the telescopes' mechanics was developed. On the other hand, the current design of the light collector has been optimized and is ready for construction and test in 2013.

The Bogie, Central Axis and Foundation

IFAE is responsible for the undercarriage, central axis and foundation of the CTA Large Size Telescopes. The conceptual design of the undercarriage is finished: a “track & wheel” type has been selected; its geometry is based on several bogies, some of them equipped with tractor wheels, which run on a curved rail, anchored to a foundation, and pivot on a central axis.

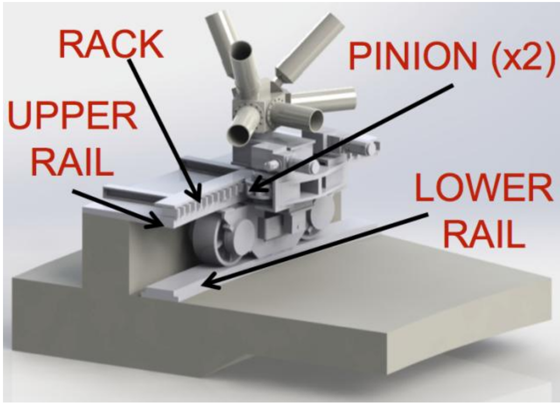


Fig. 2: Present design of the CTA Large Size Telescope bogie.

Very relevant to the design is the fact that the telescope is so light that strong winds are expected to lift it up. A second parallel rail on top of the bogies is necessary to avoid this possibility (Figure 2). A detailed design of the bogie and rail is under way, with the aim of building in 2013 a 1:1 prototype of one bogie and a section of the rail (Figure 3).

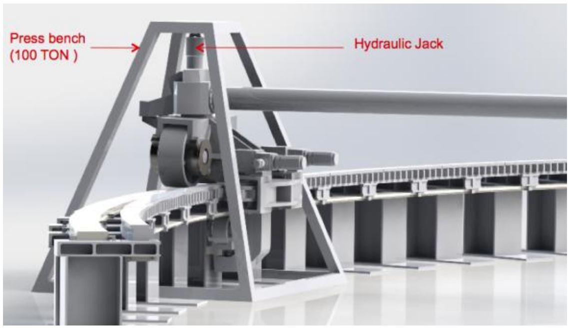


Fig. 3: Foreseen bogie test setup.

Search for axion-like particles with CTA

In 2012 the IFAE participation in the studies of the Physics prospects of CTA has continued in several fronts. One of the activities in which IFAE has acquired leadership has been the exploration of the possible indirect detection of axion-like particles (ALPs) through the observation of distortions in the energy spectra of distant gamma-ray sources.

ALPs are expected to convert into photons and vice versa in the presence of magnetic fields. On the other hand, the mean free path of ALPs in the intergalactic medium is longer than that of very high energy photons, which is limited by pair production on the low-energy background radiation that permeates the Universe. The result is that this ALP/photon mixing may actually *enhance* with respect to expectations the observed flux from distant sources.

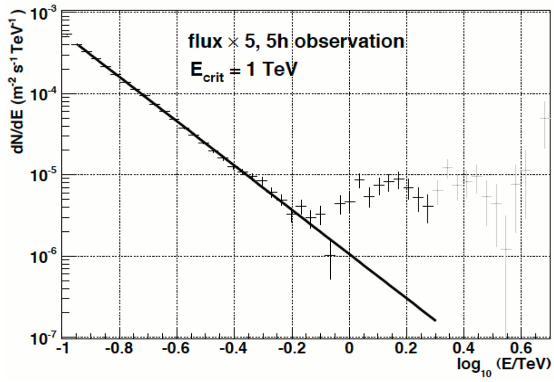


Fig. 4: Simulated observation of the distant AGN PKS1222+21 for 5 hours and a flux 5 times the one observed by MAGIC. The effect of the photon/APL mixing is visible as an enhancement in the flux. The fit is to a power law with variable index.

Simulations were performed at IFAE to evaluate the feasibility of detecting an ALP/photon mixing signature with CTA. The active galaxy PKS 1222+21 (z = 0.432), detected by MAGIC in 2010, was taken as a benchmark source. In order to determine which part of the ALP parameter space could be accessible to CTA several observation times and flux levels were postulated, as well as different values of the intergalactic magnetic fields and of the photon/ALP coupling constant. Preliminary results of these simulations were included in the special issue of Astroparticle Physics about CTA, in the chapter devoted to Dark Matter and Fundamental Physics.

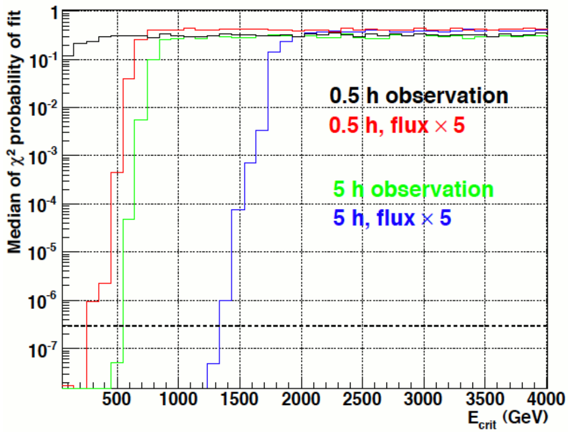


Fig. 5: Pure power-law spectrum fit probability as a function of the axion parameter E_{crit}, determined by ALP parameters such as mass and coupling constant. When the photon/ALP mixing is visible in the energy spectrum, the power-law fit fails.

Monte Carlo Design Studies

The activities of the Monte Carlo working group at IFAE involved developing analysis software, the evaluation and fine-tuning of the expected performances of candidate arrays and the publication of the findings from the large-scale array simulations performed from 2008 to 2011.

Working on software development, we continued to improve the analysis tools developed at IFAE, which are used for specific design studies within the CTA Monte Carlo work package by a number of collaborators. We have also moved to streamline our analysis chain for large data sets on the Grid by using the API of the DIRAC distributed computing framework developed at the University of Barcelona.

In the area of array performance and evaluation, we worked on the evaluation of the survey sensitivity of CTA. The off-axis response data provided by us was used within the physics work package as input for maximum likelihood analysis tools that provide estimates of the discovery potential of CTA from a galactic plane scan and an all-sky survey. (G. Dubus et al. 2012, in press). We have checked the methods used in this study by calculating our own sensitivity for a galactic plane scan (Figures 6 and 7), this time using the standard analysis approach used by the current generation of Cherenkov telescopes.

Finally we made significant contributions to the Monte Carlo design study paper in the special issue of Astroparticle Physics on CTA (K. Bernlöhr et al. 2012, in press). We also led the efforts to present the latest results and activities of the CTA Monte Carlo work package at the 2012 Heidelberg Symposium on High Energy Gamma-Ray Astronomy (V. Stamatescu et al. 2012).

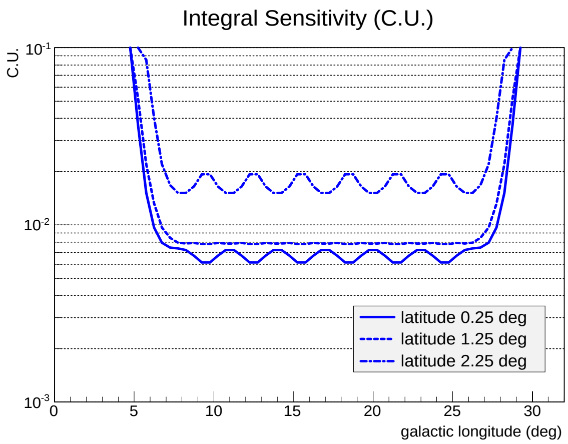


Fig. 6: Integral sensitivity of CTA-South for the foreseen galactic plane scan within the CTA core program. The sensitivity is normalized to the Crab Nebula flux and is given in Crab Units (C.U.)

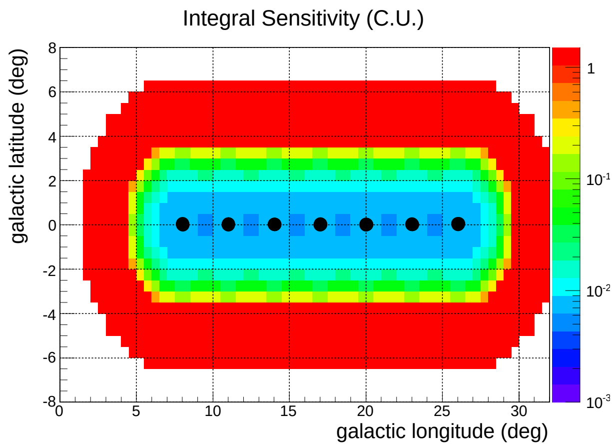


Fig. 7: Slices of the scan sensitivity at small values of galactic latitude. It indicates the level of homogeneity in the scan coverage as a function of galactic longitude.

2.7 DES : Dark Energy Survey Project

Ramon Miquel

Since 2005, a group at IFAE, together with a group at ICE (Institut de Ciències de l'Espai), located also in the Bellaterra campus, and another at CIEMAT (Centro de Investigaciones Energéticas, Medio Ambientales y Tecnológicas) and Universidad Autónoma de Madrid (UAM) in Madrid, collaborates in the DES (Dark Energy Survey) international project, led by Fermilab (USA). The main goal of the project is to survey 5000 squared degrees of the southern galactic sky, measuring positions in the sky, shapes and redshifts of about 300 million galaxies and 10,000 galaxy clusters. Furthermore, another ~10 square degrees of the sky will be repeatedly monitored with the goal of measuring magnitudes and redshifts of about 3000 distant type-Ia supernovae. These measurements will allow detailed studies of the properties of the so-called "dark energy" that drives the current accelerated expansion of the universe.

2012 was a momentous year for the DES Collaboration, since it saw the completion of the installation and commissioning of DECam, its large CCD camera giving images covering about 3 sq. deg. of the sky. In summer 2012 the camera was mounted at the prime focus of the 4-meter Blanco Telescope, located at the Cerro Tololo Inter-American Observatory (CTIO) in Chile. In return for providing the camera, DES is granted 525 nights, 30% of all the observation time for five years. Figure 1 shows the completed DECam after being installed at the Blanco prime focus.

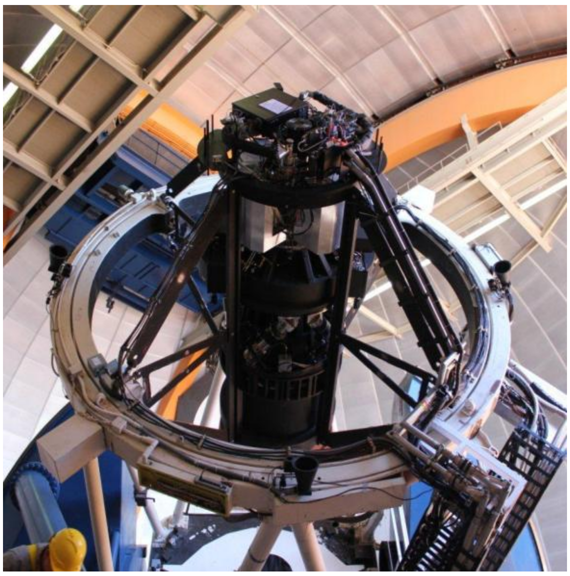


Fig. 1: The complete DECam installed at the prime focus of the Blanco telescope at CTIO in early September 2012.

The three Spanish groups, funded by the Astronomy and Astrophysics program within the National Plan of R+D+i, built the whole set of read-out electronics boards of DECam, and designed three out of the four main boards: the Clock and Bias Board (CB) at CIEMAT, the Master Control Board (MCB) at IFAE, and the Transition Board (CBT) for the CB at IFAE and CIEMAT. All in all, IFAE produced 10 MCBs, and 28 each of ACQs and ACQTs. After the production, the boards were programmed and thoroughly tested at IFAE, and then shipped to Fermilab, where IFAE engineers participated in the integration and first commissioning of the whole read-out chain of DECam. All this work was finished in late 2010, in accordance with the schedule.

DECam saw its first light on September 12, 2012 (Figs. 2 and 3). After that, there was a commissioning period, followed by a "science verification" (SV) period, which lasted until late-February 2013. The first whole season of the total of five will start in September 2013. The SV period has provided the first science-quality DES data, which are being used to fine-tune the camera (including its interface with the Blanco telescope) and sharpen the analysis tools. Overall, the quality of the SV data is very good, routinely achieving a point-spread function (PSF) with full width at half maximum in the 0.8” - 1.0” range, having occasionally reached as low a value as 0.7”.

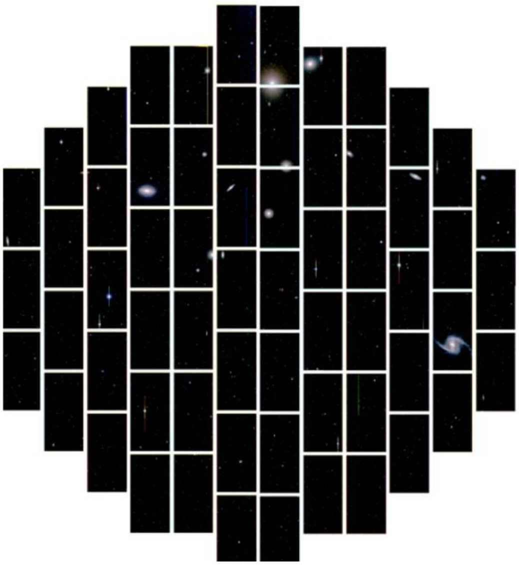


Fig. 2: The first image taken with DECam on September 12, 2012, including a view of the Fornax cluster (about 20 Mpc away) and NGC 1365 (see zoom in Fig. 3).

Together with the groups at ICE, CIEMAT and UAM, IFAE is concentrating its analysis work on probing dark energy through its influence on the large-scale structure (LSS) of the galaxy distribution in the universe. In particular, IFAE is leading the Spanish effort on exploring different methods for the precise and robust determination of the redshifts of the 300 million galaxies DES will observe using photometric techniques. This choice is motivated by the parallel work on PAU (see section 2.8) and the ensuing need to optimally deploy the limited human resources of the rather small Observational Cosmology group at IFAE.

Some of the ~200 sq. deg. observed during the SV session overlap with existing spectroscopic surveys with a depth comparable to that of DES ($i_{AB} < 24$). The galaxy redshifts from those spectroscopic surveys are, therefore, extremely useful in order to understand the performance of the photometric redshift

Fig. 3: A zoom of Fig. 2 with a close-up view of the NGC 1365 galaxy.

(“photo-z”) algorithms in real DES data. Particularly useful is the VVDS deep field, a 1 sq. deg. field near the celestial equator with over 3000 secure redshifts of DES galaxies. We have run several photo-z algorithms over these galaxies, obtaining encouraging results that approach or, in some cases, exceed the precision required for DES, even on these early data. Figure 4 shows the correlation between spectroscopic and photometric redshifts for the VVDS deep field, when running the Bayesian Photo-Z (BPZ) package, which is the primary code we use to study the photo-z capabilities of the PAU camera (again, see section 2.8). The resolution (σ_{68} ~ 0.12) is comparable with the best that can be obtained with other competing methods.

The color scale on Fig. 4 shows the value of the “odds” parameter, a photo-z quality indicator: higher odds correspond to more secure photo-zs. Therefore, by cutting on the measured value of the odds parameter, one can trim the galaxy sample, eliminating those galaxies with less robust photozs. However, we have found that this quality cut can have a large impact on the measured galaxy-galaxy auto- and cross-correlations, two of the main observables to determine the large-scale structure of the galaxy distribution in the universe. Fortunately, we have found an efficient way to correct for this, based on earlier techniques used to correct for other kinds of systematic effects on the measurements of the galaxy clustering. Figure 5 shows the galaxy-galaxy

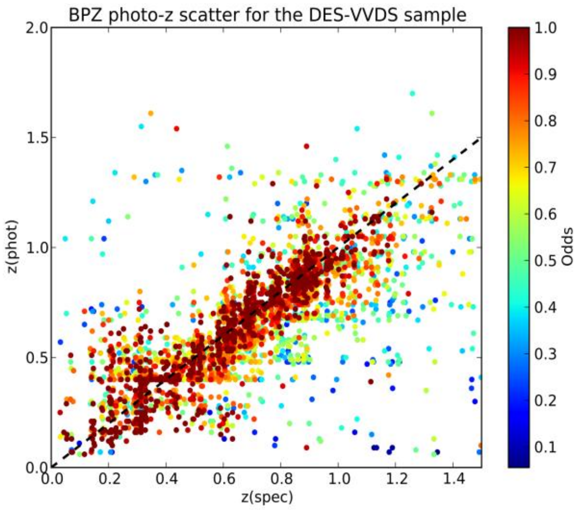


Fig. 4: Correlation between the VVDS spectroscopic redshift (horizontal axis) and the DES photometric redshift (vertical axis) for the over 3000 galaxies in the VVDS deep field matched with DES galaxies, when running the Bayesian Photo-Z (BPZ) code. The color scale indicates the value of the BPZ "odds" parameter: higher odds correspond to more secure photo-z determinations. One can see that galaxies far from the diagonal tend to have lower odds values.

angular auto-correlation function measured in the publicly available MegaZ galaxy catalog extracted from the Sloan Digital Sky Survey (SDSS) dataset. Clearly, applying more stringent quality cuts (higher odds) biases the correlation function very considerably (upper plot). However, after applying the correction developed at IFAE, the measured correlation functions agree with the expectations (lower plots). A journal article containing these findings is currently in preparation, and a Ph.D. student is finishing his thesis on these and related topics.

In preparation for the analysis of DES supernova data, some members of IFAE, ICE and CIEMAT joined in 2007 the program of spectroscopic follow-up of the supernovae found in the Sloan Digital Sky Survey-II project (SDSS-II/SNe), in a redshift range between 0.1 and 0.4. The group was was awarded four full nights of observations at the Italian "Telescopio Nazionale Galileo" (TNG) in the Roque de los Muchachos

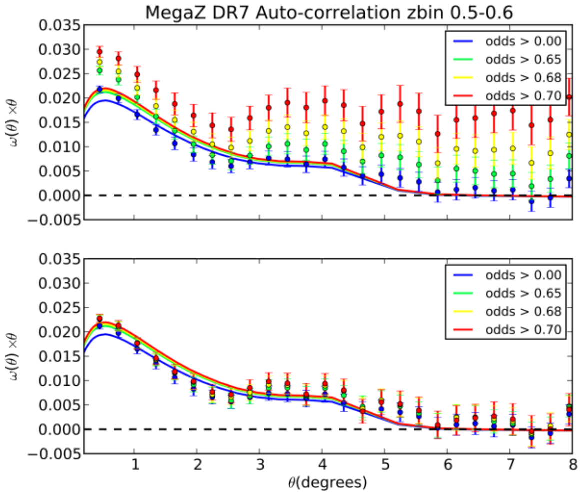


Fig. 5: The galaxy-galaxy angular auto-correlation function measured in the $0.5 < z < 0.6$ photometric redshift bin of the MegaZ galaxy catalog containing a total of almost a million Luminous Red Galaxies from the Sloan Digital Sky Survey (SDSS). Different colors correspond to measurements (points with error bars) or predictions (solid lines) obtained applying different odds cuts. More stringent quality cuts (higher odds) produce a large bias in the correlation function (upper plot). However, after applying the correction developed at IFAE, all measured correlation functions agree with the expectations (lower plot). Note the prominent Baryon Acoustic Oscillation (BAO) feature near $\theta = 4$ deg.

observatory in La Palma (Canary Islands) in fall 2007. The observations resulted in spectra of about 25 objects, including an extremely peculiar supernova, SN2007qd. Many of these spectra have been used in a number of SDSS-II/SNe analyses, with the ensuing papers already published. More are in progress.

During 2010 we published a paper on the analysis of the properties of SN2007qd, in collaboration with colleagues from the University of Notre Dame in the United States. In 2011 we finished an analysis studying the dependence of the photometric properties of type-Ia supernovae with their distance to the center of their host galaxies. This distance can serve as a proxy for local galaxy properties, such as local metallicity, local star-formation rate, etc. A Ph.D. thesis based on these two supernova analyses was presented in fall 2011, the first thesis produced in IFAE's Observational Cosmology group. A paper with the second analysis was published in 2012 in The Astrophysical Journal with three members of IFAE as first authors. With this, we finished our participation in the analysis of SDSS-II/SNe data, although a data-release paper, including our spectra is still in the works.

Our institutional involvement in the governance of DES has been kept at a high level. During 2012 a member of the IFAE group was a member of both the DES management committee and the publication board, and also chaired the DES speakers' bureau, the committee that chooses speakers to represent DES in conferences and workshops. Another member of IFAE belonged to the DES builders' committee, which grants paper authorship rights to the members of DES who have made substantial contributions to its infrastructure.

2.8 The PAU (Physics of the Accelerating Universe) Project

Enrique Fernández

PAU is a project funded by the Consolider Ingenio 2010 Program of the Spanish Ministry of Research and Innovation. The goal of the Consolider Program was to strategically fund scientifically competitive projects proposed by Spanish research groups, with the potential to advance in specific areas of science.

The project was submitted to the Consolider Program early in 2007 by a collaboration of research groups from IFAE and six other Spanish Institutions, namely: CIEMAT (Madrid), IAA (CSIC, Granada), IEEC (Barcelona), IFIC (Valencia), IFT (Madrid) and PIC (Barcelona). It was approved in the summer of 2007, and effectively started in early 2008. In 2012, it was extended for a period of one year, until the end of 2013. The work here described has been carried out in close collaboration with the IEEC and PIC groups, also located at the campus of Universitat Autònoma de Barcelona, and the CIEMAT and IFT/UAM groups in Madrid.

The strategic goal of the project was to carry out an internationally competitive experiment on the study of the accelerated expansion of the Universe (hence the acronym PAU). Scientifically that entailed two main tasks: to carry out a large galaxy redshift survey and to build an appropriate instrument for that purpose. Originally the project focused in a survey to measure Baryon Acoustic Oscillations as a probe of dark energy for a planned 2.5m diameter telescope in Teruel, Spain. However it became clear that the time scale for the construction of that telescope was longer than that of PAU, which led us to investigate other options during part of 2009.

In late 2009 it became clear that there was the possibility of installing an imaging instrument at the prime focus of the William Herschel Telescope (WHT) in La Palma. This is a 4m-diameter telescope (part of the Isaac Newton Group) formerly belonging to the UK and now run by a Consortium of the Netherlands, Spain and the UK.

The WHT has a field of view (FoV) of 1º in diameter with 85% light collection efficiency (of which 40' have 100% efficiency). In April 2010 a formal proposal was sent to the board of the ING in order to install the PAU Camera (PAUCam) at the WHT as a visiting instrument, with the provision that it could also be used by interested members of the WHT community of users, when not dedicated to the PAU survey. At their meeting on May 26th 2010, the ING board approved the status of visitor instrument for PAUCam and the Memorandum of Understanding was finally signed in early 2012.

PAUCam will cover the entire FoV of the telescope with 18 2k x 4k fully-depleted red-sensitive Hamamatsu CCDs with 15 μm pixels giving a 0.26"/pixel plate scale. The camera will use ~40 narrow-band filters and the six standard ugrizY wide-band filters, taking advantage of the excellent sensitivity of the Hamamatsu CCDs across the entire wavelength range from 300 to 1000 nm.

As a survey camera, PAUCam can cover ~2 deg^2 per night in all filters, delivering low-resolution (R~50) spectra for ~30000 galaxies, ~5000 stars, ~1000 quasars, ~10 clusters per night. The resolution in redshift *z* depends on the exact number, width and location of the narrow filters. A filter optimization study was carried out,

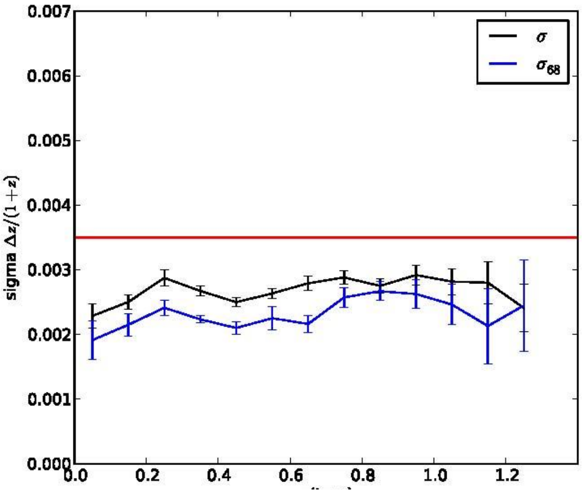


Fig. 1: Resolution in redshift scaled by (1+z) as a function of the real redshift for bright galaxies (i_{AB}<22.7). Different colors represent different ways of computing the dispersion of the measured redshift with respect to t_{true}.

converging in a solution with 42 narrow band filters (~ 10nm wide in wave length) covering the range between ~470 and ~830 nm. With this configuration PAUCam will be able to deliver very precise redshifts (σ_z~0.0035x(1+z)) for all galaxies with magnitude i_{AB} below 22.7, at the same time providing typical photometric redshift precision (σ_z~0.035x(1+z)) for galaxies with i_{AB} between 22.7 and 24. Figure 1 shows the expected resolution as a function of redshift for the bright set of galaxies. Being able to provide large quantities of precise redshifts for all objects in the field makes PAUCam a unique instrument.

A survey performed with PAUCam can combine a large galaxy density (larger than typical spectroscopic surveys such as BOSS) with a high redshift accuracy (higher than typical broadband photometric surveys such as DES) to provide a highly competitive determination of the dark energy parameters. Our studies have centered in two dark-energy related observables: redshift-space distortions and weak-lensing magnification, for which PAU is uniquely suited.

* Redshift-space distortions originate in the peculiar velocities of galaxies, which trace the surrounding matter density fields. By measuring anisotropies in the galaxy 2-point correlation function, it is possible to determine the growth of structure at any given redshift, a most sensitive probe of dark energy. The relevant scales (~10 Mpc/h) are well matched to the redshift precision that PAUCam can deliver.

* Weak-lensing magnification affects the measured galaxy number density. In this case, the main observable is the cross-correlation between galaxies in different redshift bins as a function of angular separation. This is sensitive to dark energy through both the growth of structure in the universe and its geometry.

Combining the constraints on the dark-energy equation of state parameter *w* that can be obtained from redshift-space distortions with those from weak-lensing magnification leads to the forecast shown on Figure 2, which is comparable (and complementary) to the constraints that will be obtained with the ongoing DES and BOSS surveys.

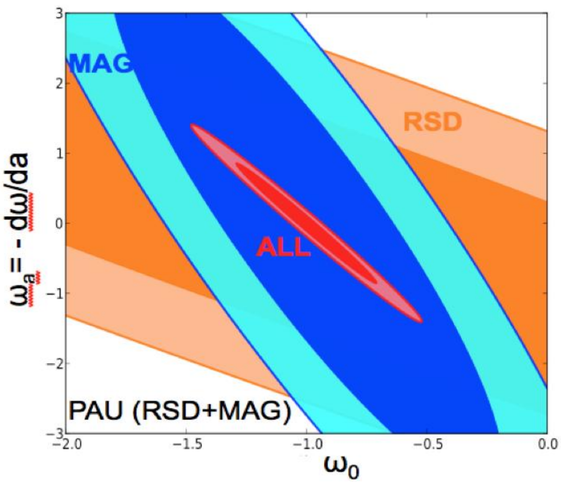


Fig. 2: Contours (68% and 95% CL) for the dark energy equation of state parameter now, w_0 and its evolution, w_a that can be achieved with a PAU survey of 200 deg^2 using redshift-space distortions (RSD, orange), weak-lensing magnification (MAG, blue) and combined (ALL, red).

Most of the details of installing PAUCam at the WHT, both technically and administratively, were planned during 2011. One of the main issues is the camera weight limitation of 235 Kg, which has resulted in a design in which the camera enclosure has been built with carbon fiber as opposed to aluminum, which is the usual material in this type of instruments. Additionally, the walls of the camera are curved in order to minimize the wall thickness while still maintaining the needed strength. The mechanical design was finalized in 2011.

The Carbon fiber body had to be built by injecting the material into a mold that was designed and fabricated in-house at the IFAE. Figure 3 shows the many pieces that make up the mold while Fig. 4 shows the mold itself.

Fig. 3: The many pieces needed to assemble the mold to fabricate the PAUCam camera boy with Carbon fiber.

The injection of the Carbon Fiber into the mold took place at the enterprise Magma-Composites, located in Alcañiz, Teruel. Figures 5 and 6 are actual photographs, the first of the camera body, still with the wrapping of the fabrication process, the second of the camera with the vacuum and cooling systems during tests. As planned, the mechanical fabrication of the body of PAUCam and of other components, such as the elevator system that moves the filter trays inside the camera, was finalized during 2012.

Two major issues are the cooling and the vacuum systems needed to operate the camera. The vacuum during operations will be achieved with a getter pump (a Saes Getter GP500 model). The level obtained in the lab with the actual camera body and this pump is 10^{-7} mbar (higher than that needed for operations, which is 10^{-6} mbar). When the camera is off the main focus an additional turbo molecular pump (Navigator V 301 model) will be operated.

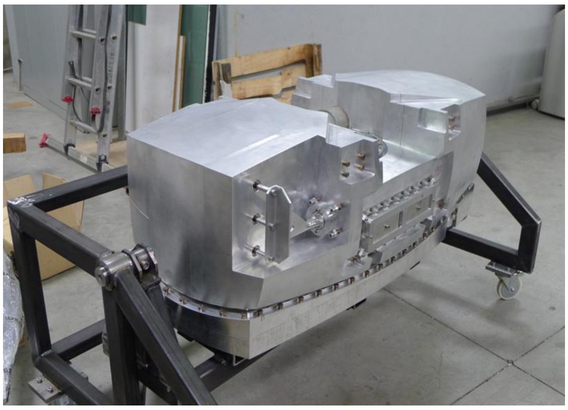


Fig. 4: The mold needed to fabricate the PAUCam body with Carbon fiber.

The PAUCam operating temperature will be of about -100ºC. This will be achieved with a set of two Polycold (Cryotiger) PCC PT30. Nitrogen cooling will also be possible when the camera is not in use and out of the WHT prime focus.

One of the key elements of the PAU camera is the positioning of the filter trays inside the camera enclosure to place them as close as possible to the CCD sensors therefore maximizing the FoV coverage. In order to accomplish this, a system of two tray lifts, each of them with seven trays, is installed. One lift will carry the filters needed for the PAU survey. The other will carry a set of standard broadband filters that can be used by other astronomers. Additionally, a system to install a filter outside the camera enclosure is foreseen. This system will allow any user to plan its observations independently of the camera maintenance plan, which will need to be done inside a clean room and will require the transportation of the camera to the IFAE laboratories.

Many studies of the materials, the cooling, the vacuum and the system to move the trays were done with a test setup made in aluminum, with a size similar to that of the actual camera. Also tested with this setup were many aspects of the control system, which involves a large amount of software. All these tests took place during 2011 and 2012, before the arrival of the final camera body and are now being repeated, or will be in the near future.

The scientific CCDs were received in September 2011. Two set-ups (one at CIEMAT and another at IFAE) have been validating the CCDs since then, and have reproduced most of the results of the datasheet from Hamamatsu Photonics. A problem, which took some time to solve, was the level of noise from the CCDs. This was solved by introducing a differential pre-amplifier in the front-end of the electronics. Noise levels corresponding to 5-6 electrons have now been achieved and the electronics power dissipation is also within the specifications.

Systematic characterization of the CCDs will start soon in 2013. A metrology table has been commissioned and a small cryostat, also made of Carbon fiber, is also ready to test two CCDs at a time.

Another important component for the whole project is the Data Management System. It consists of a large collection of programs, written in Phython, which will manage the data from the raw images taken at the telescope to the final data products from which the physics analysis can start. The use of many filters and the need to merge images taken at different times with different filters considerably complicates the software. As part of the agreement with the WHT, the PAU Team will develop a Public Pipeline, such that the images taken with PAUCam will be made available to the users, once the instrument-specific corrections are made, in some standard form.

The current plan is to finalize the construction of the Camera by September of 2013 and complete the commissioning during the 2013b observation period of the WHT.

Fig. 5: A photograph of the camera body with the wrapping of the fabrication process.

Fig. 6: A photograph of PAUCam with vacuum and cooling systems in place.

2.9 Medical Physics

Mokhtar Chmeissani

The year 2012 was rich with activities and achievements. The work of our group was focused on the development of the front-end-electronics (VIP-PIX chip) for the VIP sensors and evaluating the best working point for the 2mm Schottky CdTe pixel detector biased at 2000V in terms of leakage current, energy and time resolution. X-ray Imatek, the IFAE spinoff, managed to turn a profit despite the fact that 2012 was a tough year for the Spanish economy.

Infrastructure for Pixel Sensors

IFAE has constructed a $50 m^2$ clean room, divided into class 100,000, 10,000, and 1,000 areas. The aim of this facility is to provide a clean and controlled environment for microelectronics detectors and sensors and for the installation of instruments needed to make hybrid pixel detectors. IFAE acquired a Pactech SB^2-SM machine for solder-ball placing and a Delvotec G5/64000/62000 automatic wire-bonding machine for thin-wire and gold-ball bonding. The Delvotec G5/64000/62000 wire-bonding machine is the first of its type in Spain. Such a machine fulfils a basic necessity when doing R&D with ASICs having a large number of I/O pads such as Medipix-2 chips, or ATLAS pixel chips FE-I3 and FE-I4. The VIP-PIX chip, which is being developed by IFAE for the VIP project, will have 60 I/O pads; the VIP project will use about 1,000 chips. The Delvotec and Pactech machines are needed in order to process *in situ* this large volume of CdTe pixel sensors and detectors.

The VIP design is based on a Cd(Zn)Te pixel detector which requires low temperature solder bump ball (less than 160 ^{o}C) to avoid the diffusion of the metal (pads or solder) into the bulk of the detector. The SB^2-SM machine will be used to place on the VIP-PIX chip the BiSn(60/40) solder balls, whose melting point is 138 ^{o}C, for eventual flip-chipping and bonding to the Cd(Zn)Te pixels. Another use of the SB^2-SM is to deposit solder balls on any irradiated chip for further flip-chipping operations.These machines, shown in Figure 1, will boost the IFAE capacity for research in the field of pixel sensors of the ATLAS pixel and the medical imaging teams.

Fig. 1: On the left hand side is the SB^2-SM bump-placing machine. It has the capacity to deposit solder balls ranging from 760µm to 40µm in size at a rate of 5 solder balls per second. Different solder alloys can be used. It can accept a substrate of $10x10cm^2$. On the right hand side is the Delvotec G5/64000/62000 fully automatic thin-wire and gold-ball bonding machine, with pattern recognition making the setting up process simple, fast, and error free. The gold ball bonding header can be used for gold stud deposition as a quick alternative to Under Bump Metallization (UBM).

Nuclear Medicine

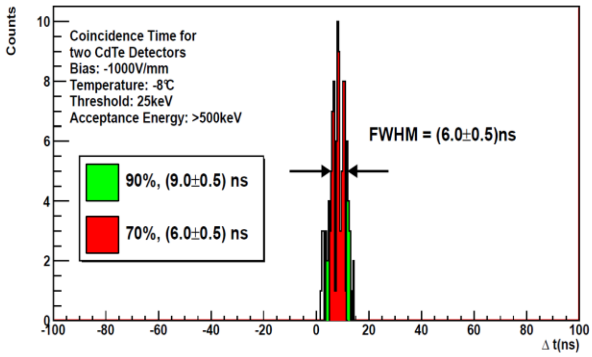
Detector Characterization

Designing a PET detector with CdTe has been a great challenge to the scientific community. Two issues must be simultaneously solved:

- the detector must be thick enough to have acceptable absorption efficiency for 511 keV photons, and
- a fast trigger on the nanosecond time scale to define a PET event coincidence is needed.

PET Simulation Results

Capitalizing on the excellent timing and energy resolution achievable with the VIP pixel CdTe detector a VIP-PET simulation based on the NEMA NU 4-2008 simulation protocol indicates that a very high true coincidence rate can be achieved. As one can see in Figure 3, the rate of scattered coincidences is almost zero, and the Normalized Effective Counting Rate R_{NEC}, defined by $N_{REC} = R_t^2/R_{TOT}$, has a maximum for a low concentration activity.



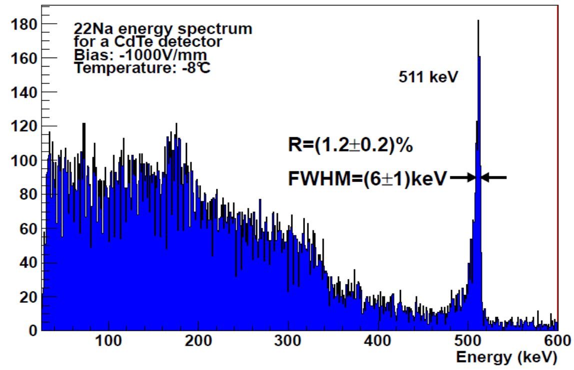


Fig. 2: The top figure shows the narrow VIP-PET time coincidence window, which will make it possible to handle high rate doses. The bottom one shows the γ-ray spectrum from a Na^{22} source. With this good energy resolution it is possible to reduce scattered events thereby obtaining PET images with a significantly reduced radiation dose.

The VIP design solved this problem by using a pixel detector with its edge pointing towards the central axis of the PET scanner, i.e. towards the body of the patient wherefrom the pair of back-to-back 511 keV photons are emitted. Using 2mm thick CdTe and with a bias of 1000V/mm, one can achieve a fast coincidence trigger with FWHM=6ns, as shown in Figure 2.

In Figure 2 one can see as well the excellent resolution on 511 keV photons obtainable with CdTe. We expect to further improve this energy resolution by applying signal-processing techniques.

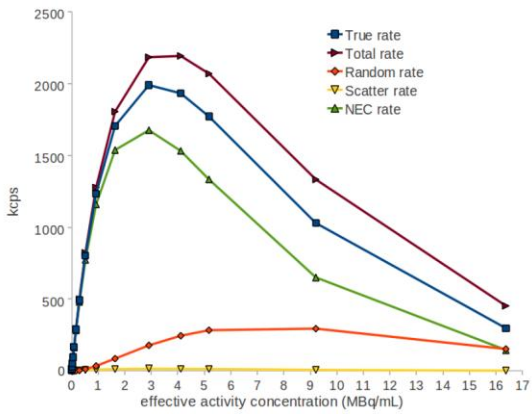


Fig. 3: Shown is the counting rate of the VIP PET based on simulation result using the NEMA NU 4-2008 protocol. The results show the high counting efficiency of the VIP PET leading to a sharp image a low dose. The total and random rates display a peak due to pileup.

Here R_t is the true rate and R_{TOT} is the total rate for the sum of true, random and scattered coincidences. For the VIP-PET $R_{NEC,peak}$ = 1675 kcps (kilo counts per second) is more than 20 times larger than the most sensitive PET device in the market.

Image reconstruction with a Compton Camera

As described in the 2011 IFAE activities report, an important part of our effort is focused on simulating and testing a prototype Compton camera based on the VIP approach.

In general, there are three main image reconstruction algorithms available for our simulation data [1],[2]. However, the **filtered back-projection (FBP)** algorithm cannot be used for Positron Emission Mammography (PEM) and Compton gamma cameras without producing artifacts.

Instead, the **Ordered Subset Expectation Maximization (OSEM)** algorithm uses an iterative approach where image estimates are projected forward onto the detector, compared with the real measurement and a cost function is applied to update the image estimate. For optimization, the data is organized in ordered subsets. Since the standard OSEM is too memory- and time-consuming for a Compton camera with about 3 million signal channels, we have developed a **list-mode (LM)** implementation, which only depends on the number of bins in the FOV for each cone and the number of events. The preliminary results are promising but the procedure is still very time-consuming, therefore an effort to further optimize it will be made next.

Alternatively, the stochastic **Origin Ensemble (OE)** algorithm is fast and easy to implement in a Compton camera. Here, random positions on the Compton cone (or PET/PEM Line of Response, that joins the impact points of the two 511 keV photons) are assigned with a probability depending on the density matrix that maps the positions of all events onto FOV bins. For PET and PEM a Derenzo phantom can be successfully reconstructed, as shown in Figure 4. For Compton cameras good results can be obtained for multiple point sources, despite the worse spatial resolution of a Compton camera comparing to PET or PEM. This is because of its sensitivity to the energy resolution. The latter is affected by the fact that for low photon energies Compton electrons cannot be assumed to be initially at rest, which leads to Doppler broadening of the scattered photon.

A comparison of OE, FBP and OSEM with PET, PEM and Compton camera simulation data was presented at the IWoRID 2012 conference. An article *"Evaluation of Origin Ensemble algorithm for image reconstruction for pixelated solid-state detectors with large number of channels"* was submitted to the peer-reviewed Journal

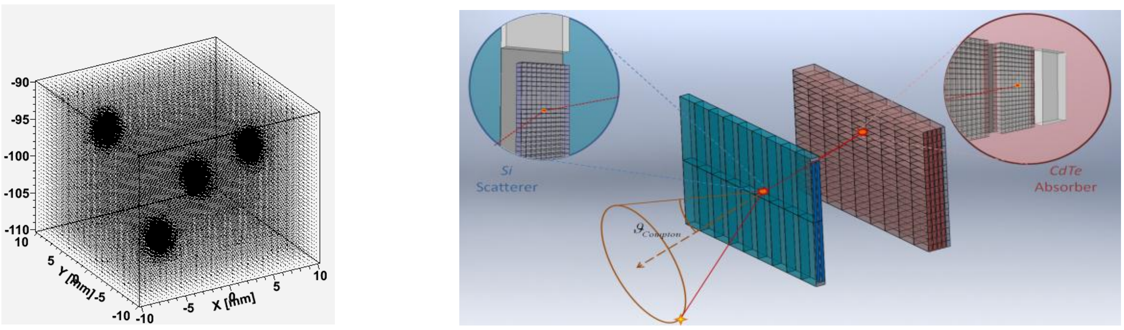


Fig. 4: On the left is shown a 3D image reconstruction of Compton camera data, using OE and on the right is shown the schematic design of the VIP Compton Camera

of Instrumentation (JINST). This article compares OE, FBP and OSEM using extensive image quality criteria on PET data with a Derenzo phantom. It also shows results for OE with PEM and Compton camera data. OE produces 3D images of spatially distributed 511 keV gamma point-like sources in Compton camera data with values for the FWHM of the point spread function (PSF) of 2 mm. In 2013 this analysis will be expanded to include LM-OSEM.

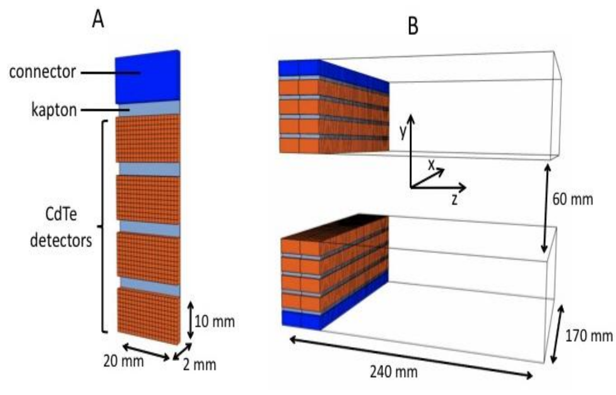


Fig. 5: A possible use of VIP in Positron Emission Mammography (PEM) *à la* Naviscan. The two modular detectors, above and below the breast, perform a scan by moving along the *z* axis.

VIP Positron Emission Mammography

We have explored to use of the VIP detector for of breast nuclear medicine, designing a detector for PEM similar to the one sold by NaviScan, as shown in Figure 5. The system provided by Naviscan uses crystal detectors like all PET detectors, which implies low spatial and energy resolutions. Our design results in a very sensitive imaging detector as one can see in Figure 6.

Simulation results show that a VIP-based PEM device will have a volumetric resolution 6 times better than the best PEM on the market. This is very significant for the early detection of cancerous tissues.

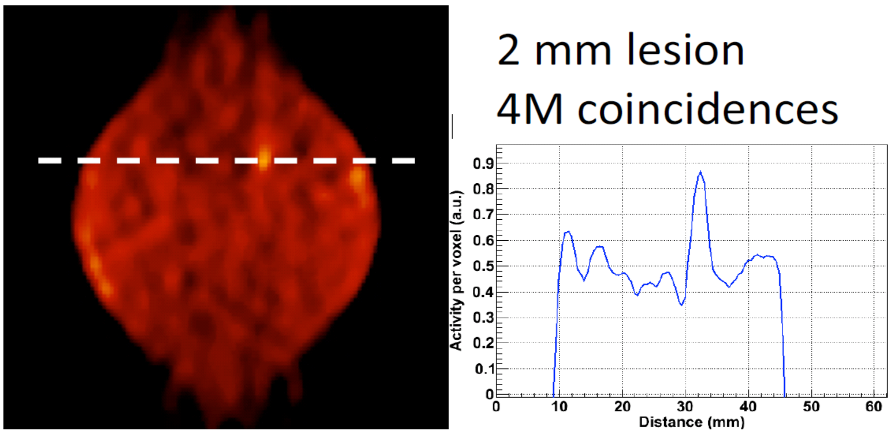


Fig: 6: Image reconstruction of breast tissue with a VIP PEM. With 4 million PET coincidences the 2mm lesion is promptly detected.

The VIP-PIX ASIC

VIP-PIX is a dedicated 10 x 10 pixels array front end ASIC customized for VIP PET applications. Each "smart" pixel has its own ADC, as seen in Figure 7. Having the signal digitized at the level of each channel preserves the integrity of the original signal thereby ensuring optimal energy resolution.

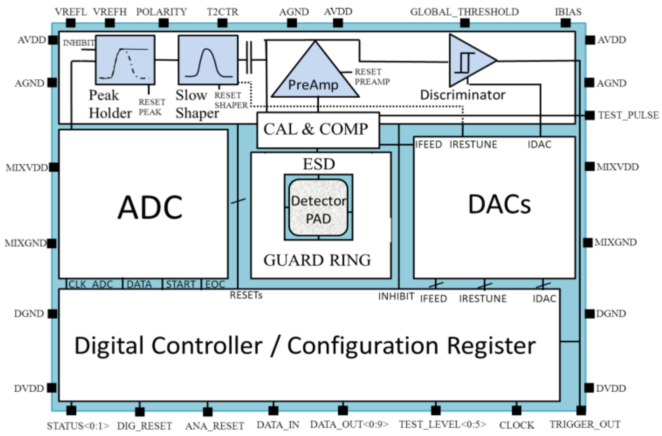


Fig. 7: The architecture of the VIP-PIX pixel readout electronics.

The layout of a preliminary version, consisting of a 4x4 pixels matrix, is shown in Fig. 8. In 2012 the design was submitted for production. We expect to test it in March 2013 and expect to complete the full 10x10 VIP-PIX in July 2013.

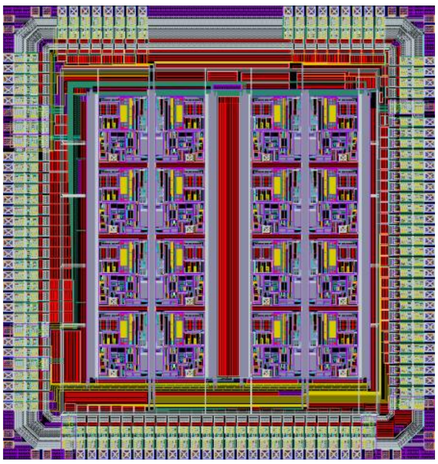


Fig. 8: The layout of the submitted 4x4 pixel version of the VIP-PIX ASIC. The chip will be bonded to a pixelated CdTe sensor. This will provide real test conditions in order to characterize the chip and tune it before the final submission of the 10x10 pixel VIP-PIX.

X RAY IMATEK
PHOTON COUNTING DETECTORS

The year 2012 has been a successful one for X-Ray Imatek. Sales have grown as the company introduced its products into different market sectors. Now, the company has achieved a satisfactory level of market penetration and is well-considered in the X-ray detector industry. These circumstances allowed the company to set its main targets and to schedule a solid business plan for the coming years.

Commercial initiatives have multiplied with the presence of XRI at several scientific meetings, which it attended as a commercial exhibitor. In addition, the company ran regular ad campaigns promoting its main product line, the XRI Series.

The XRI Series is the company's first complete product line. Made for research purposes, the XRI Series has become the most affordable solution in the market for testing the Medipix2 detector. The UNO, a single chip module introduced in 2011, was followed in 2012 by QUATRO, with a four times larger detection area. Both models are offered either with Silicon and CdTe sensors, and are constantly being improved thanks to customer feedback.

Furthermore, the company is negotiating with major manufacturers from different industries such as Homeland Security, NDT (Non-Destructive Testing), Food Inspection and Medical Imaging, with the goal of reaching agreements to develop customized detectors for specific applications.

Outlook for 2013

The main target for 2013 is to consolidate the situation of XRI as a recognized company specialized in photon counting detectors and to achieve a good position in the industry as developers of the ultimate technology for X-ray imaging.

To reach this goal it is planned to expand XRI's commercial relations with Asia, specifically with China and South Korea, where a growing interest in our technology is apparent. It is hoped to get one or more agreements for new detector developments before the end of the year 2013.

In addition, XRI is aware of the need to reinforce its links with the scientific community by monitoring the development of new detectors and the corresponding technological applications that could be brought to industry in the near future.

References:

[1] Gengsheng L. Zeng , Medical Image Reconstruction: a Conceptual Tutorial , Springer.
[2] Simon R. Cherry, James A. Sorenson, Michael E. Phelps, Physics in Nuclear Medicine, Saunders, 2012.

2.10 Standard Model

Matthias Jamin

The Standard Model (SM) subgroup of the IFAE theory division investigates the phenomenology of particle physics within the realms of the Standard Model. Even if physics going beyond the SM is expected, suggested for example by the presence of neutrino masses or dark matter, precise values of the fundamental SM parameters like couplings and masses are essential inputs for pure SM predictions, and beyond-SM physics should show up as clashes between those predictions and experimental measurements. During 2012, the main research fields in our group were hadronic decays of the τ lepton, chiral perturbation theory, also including higher-mass vector and scalar mesons in the framework of resonance chiral perturbation theory, mesonic interactions, the hadronic contribution to the muon anomalous magnetic moment, QCD at finite temperature, as well as studying the structure of higher-order corrections in QCD perturbation theory by means of Borel transforms and renormalization group equations.

Investigations of QCD at relatively low energies can be conveniently performed through the study of hadronic decays of the τ lepton, because at the scale of its mass $M_\tau \approx 1.8$ GeV, QCD effects are already sizeable, but the expansion in powers of α_s still retains its perturbative character. For this reason, in the last ten years the analysis of hadronic τ decays already played an important role in the extraction of QCD parameters, and in particular the determination of α_s from τ decays significantly influences the world average of this parameter. In 2012, we updated a determination of α_s from hadronic τ decays that includes in a self-consistent way all non-perturbative effects such as higher-order terms in the operator product expansion (OPE), as well as Duality Violations (DVs) of the quark-hadron duality. Although these effects are suppressed compared to the purely perturbative contribution, at the level of the current precision they can no longer be neglected. Our analysis was based on the original OPAL 1998 τ decay data, obtained at the LEP accelerator at CERN, but updating the measured vector and axial vector hadronic spectral functions with present day τ branching fraction values.

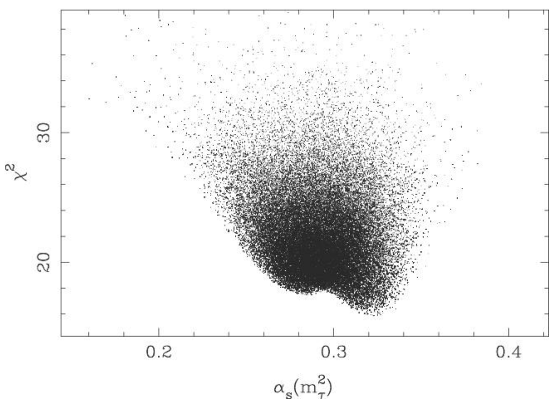


Fig. 1: Scatter plot for the $\alpha_s(M_\tau)$ versus χ^2 distribution employing fits to the w(x) = 1 spectral integral for the vector channel OPAL τ spectral function .

In practice the determination of α_s proceeds through fits of all theoretical parameters, that is, α_s and OPE parameters, as well as DV parameters, to weighted integrals of the measured τ decay spectral functions (so-called moments), integrated up to an energy s_0. As an example, in Figure 1 a scatter plot for the $\alpha_s(M_\tau)$ versus χ^2 distribution is shown for fits to the OPAL vector channel moments with weight function *w(x)* = 1. Besides the global physical minimum around $\alpha_s(M_\tau) = 0.325$, an additional local unphysical minimum at lower α_s is observed, indicating that the fits are rather delicate. Fits to higher-moment weight functions are also possible, but less reliable due to the very strong correlations of the employed moments.

Additional work in the field of hadronic τ decays performed by our group concerned the description of exclusive decay channels. At present, hundreds of millions of τ decays have been amassed by both the BaBar and Belle experiments. Thus, it is of the utmost importance to represent such data in a form as useful for general applications as possible. The related work described the set of form factors for hadronic τ decays based on Resonance Chiral Theory. The technical implementation of the form factors in FORTRAN code was also performed. It was shown how it can be installed into the TAUOLA Monte Carlo package. Then it is rather easy to implement it into the software environments of not only the BaBar and Belle collaborations but also into FORTRAN and C++ applications of LHC. The description of the current for each τ decay mode was complemented with technical numerical tests. The set of form factors is ready for fits, and the parameters to be used in fits are explained. In addition, facilities to work with the experimental data when unfolding is not required were prepared. Hadronic currents, ready for comparison with τ decay data, but not yet ready for general use, cover more than 88% of the total hadronic τ decay width.

A particular item of related work concerned the analysis of the hadronization structure of the decay $\tau^- \to \eta\pi^-\pi^0\nu_\tau$ using Chiral Perturbation Theory with resonances, considering only the contribution of the lightest meson resonances at leading order in the $1/N_C$ expansion. After imposing the asymptotic behavior of vector spectral functions ruled by QCD, unknown effective couplings were determined by fitting the $\tau \to \eta\pi\pi^0\nu_\tau$ branching ratio and decay spectrum to recent data. Fits to spectral data by the Belle collaboration are displayed in Figure 2. The two curves correspond to two sets of fitting parameters that yield a similar minimal χ^2.

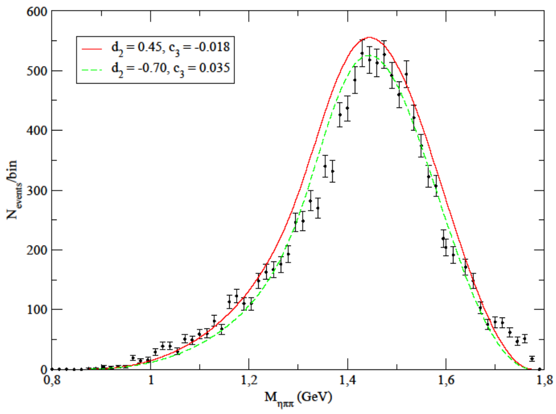


Fig. 2: Belle data on the spectrum of the decay $\tau \to \eta\pi\pi^0\nu_\tau$ and fits to a description in Resonance Chiral Theory. The two curves correspond to two sets of parameters yielding similar minimal χ^2.

Currently, one of the most interesting quantities for which a sizeable deviation from the SM prediction is observed is the anomalous magnetic moment of the muon. The leading hadronic contribution is given by a weighted euclidean momentum integral of the hadronic vacuum polarization. This integral is dominated by momenta of the order of the muon mass. Since in lattice QCD it is difficult to compute the vacuum polarization at a large number of low momenta, a parametrization of the vacuum polarization is required to extrapolate the data. Most fits to-date are based on vector meson dominance, which introduces model dependence into the lattice computation of the magnetic moment. In a recent work we introduced a model-independent extrapolation method, based on Padé approximants, and presented a few first tests of this novel approach.

In the area of finite temperature QCD, the hadron resonance gas model has been used repeatedly to describe the thermodynamics of QCD as a gas of non interacting hadrons, but up to now this description has only been applied to the equation of state of QCD. The Polyakov loop is considered as an order parameter for the QCD confinement-deconfinement phase transition; it is related to the free energy of heavy quarks. We proposed for the first time the hadron resonance gas model for the Polyakov loop, and described its expectation value in the confined phase, in terms of hadronic states with exactly one heavy quark. We provided arguments based on general QCD considerations, and showed that also the transition from chiral quark models with the Polyakov loop to a hadron resonance gas is realized only when one advocates the quantum and local nature of the Polyakov loop. The work opened the possibility of a Polyakov loop spectroscopy for QCD, i.e. using the Polyakov loop in fundamental and higher representations to deduce multiquark states, gluelumps, etc, containing one or several heavy quark states.

Finally, in our group work was performed to better understand the perturbative behaviour of QCD two-point correlation functions. The particular case studied in 2012 concerned the scalar gluonium correlation function. Analytically, the perturbative expansion is known up to order α_s^3 and the coefficients were found to be so large, that the series at low-energy hadronic scales of about 1 – 2 GeV is completely unreliable. Therefore, the respective correlator was computed in the large-β_0 approximation to all orders of perturbation theory, which for the known orders provides a sensible representation. Relatedly, the singularity structure of the Borel transform of the correlation function was investigated, as it determines the asymptotic behaviour of the perturbative series. A final reason for the study of scalar gluonium is the fact that its correlator in the low-energy limit is related to the gluon condensate, a quantity notoriously difficult to extract from hadronic observables. Hence, investigation of this correlator may provide new means to determine the QCD gluon condensate.

2.11 Beyond the Standard Model

José Ramón Espinosa

Higgs Physics

The discovery of a likely Higgs boson by ATLAS and CMS at the LHC, announced in July 2012, has been the most important event in particle physics in decades. IFAE's theory group has been very active in studying the experimental data to try and understand the properties of this resonance and to extract possible implications both for the Standard Model (SM) and for physics beyond it.

First, given the mass (m_h~124-126 GeV) of the new state, we have extracted implications from such value if the SM were the valid theory all the way up to the Planck scale, M_{Pl}. For such low m_h, the Higgs potential develops an instability at very large field values ~10^{10} GeV, well below M_{Pl}. We have significantly improved the calculation of the Higgs potential (including up to NNLO corrections, providing the most precise calculation in the literature) needed to determine with precision whether the electroweak vacuum is absolutely stable or metastable. Figure 1 summarizes our findings. Although the plot shows the experimental ellipse falls in the metastable phase, the tunneling lifetime to the non-standard vacuum is so large compared with the age of the Universe that this poses no theoretical problem for the SM. Nevertheless, we have also shown how a new singlet scalar coupled to the Higgs could easily and naturally fix this stability issue.

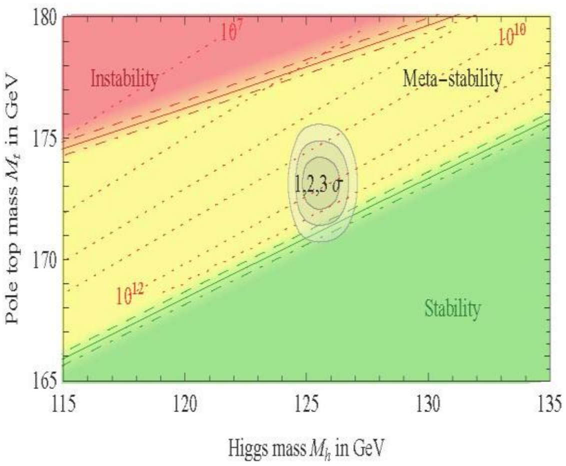


Fig. 1: Regions of absolute stability, metastability and instability of the SM vacuum in the top mass -- Higgs mass plane, with the preferred experimental range of Mh and Mt shown.

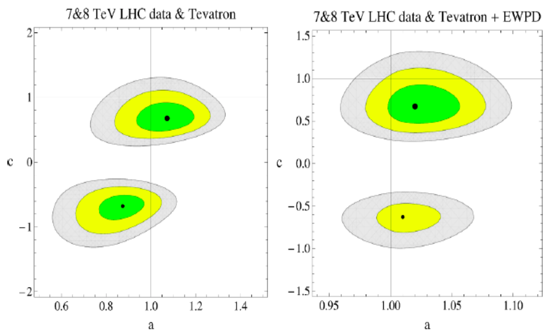


Fig. 2: Global fit results in the (a=Higgs gauge boson coupling/SM, c=Higgs fermionic coupling/SM) plane for all reported best fit values given by ATLAS, CMS and the Tevatron. The green, yellow, gray regions correspond to the allowed 1, 2, 3 σ for a two parameter fit. The right plot includes precision electroweak data.

We have also played a leading role in fitting experimental data in all available search channels (both at the LHC and the Tevatron) to an effective theory model in which the couplings of the new state are allowed to vary from their SM values. This exercise shows that the SM Higgs hypothesis gives a good fit of the data, although some departure from SM couplings can improve the fit, which is mainly driven by the diphoton rate, larger by a factor 1.5-2 than its SM value. Fig. 2 shows this kind of fit for variable Higgs couplings to gauge bosons (a) and fermions (c), with a=c=1 corresponding to the SM value.

We have also examined how current data constrain the possibility that the Higgs has an invisible partial decay width (e.g. into new light states) showing how this gives a powerful, if indirect, model constraint.

The most plausible scenarios beyond the SM that address theoretical shortcomings of the Higgs sector are composite Higgs models and Supersymmetry (SUSY). Both can be fit to data in the previous way and we have examined them in more detail in the light of the Higgs search data.

We have discussed the problem of obtaining an enhancement of the diphoton rate and of obtaining a large enough m_h in a natural way. These problems can be alleviated by introducing in the superpotential an extra SUSY triplet coupled to the Higgs whose fermionic charged component enhances the diphoton Higgs decay rates by as much as 50% with respect to the SM value. We also show that such a scenario is compatible with present electroweak precision observables.

We have also explored other, more speculative but original ideas, like the possibility that the Higgs could be related by SUSY to some of the particles already known: a proposal that dates back to the 70's, but that has unexpected implications for the LHC searches.

In composite Higgs models we have also studied how the value of the Higgs resonance implies the existence of yet other particles which should be seen at the LHC, if these models are correct.

Flavor phenomenology in warped space

We have considered general 5D warped models with SM fields propagating in the bulk and computed explicit expressions for oblique and non-oblique electroweak observables as well as for flavor and CP violating effective four-fermion operators. We have compared the resulting lower bounds on the Kaluza-Klein (KK) scale in the RS model and a recently proposed model with a metric modified towards the IR brane. Allowing 10% fine-tuning, the combined results point towards lower bounds on the KK gauge boson masses around 3.3 TeV in our model as compared with 13 TeV in the RS model.

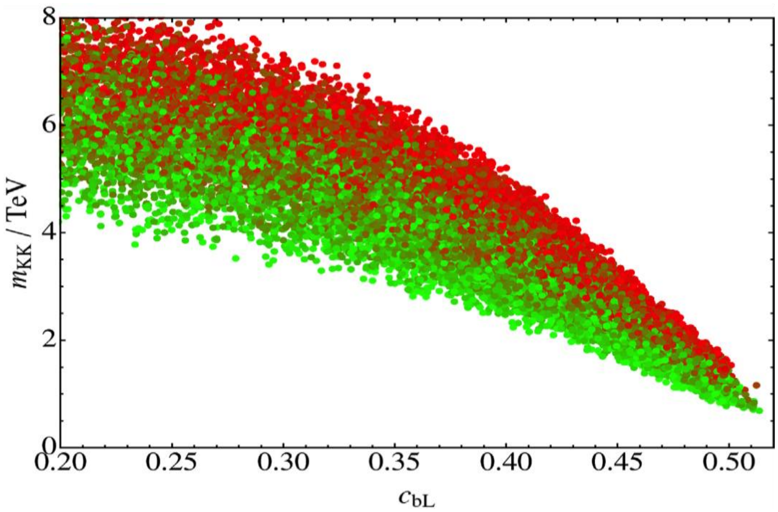


Fig. 3: The bounds (in TeV) implied by the experimental limits on Rb, as a function of cb for the IR deformed model. The coloring interpolates between green (light gray) for Yd_{33}=1 to red (dark gray) for Yd_{33}=4.

2.12 Astroparticles & Cosmology

Oriol Pujolàs

Astroparticle physics and particle cosmology are recent fields of research at the intersection between particle physics, astrophysics and cosmology. The goal is to exploit our knowledge of astrophysical and cosmological phenomena to answer fundamental physics questions, and vice-versa. The key questions addressed range from the origin and nature of dark energy, dark matter, neutrinos and baryogenesis to the properties of non-relativistic gravity models and developing the applications of the gauge/gravity correspondence. During 2012, the work done by the members of the Theory Division in this research area can be divided in the following topics.

Dark Matter

Dark matter (DM) could consist of a light composite scalar η, emerging from a TeV-scale strongly-coupled sector as a pseudo Nambu-Goldstone boson (pNGB). Such state arises naturally in scenarios where the Higgs is also a composite pNGB, as in O(6)/O(5) models, which are particularly predictive since the low-energy interactions of η are determined by symmetry considerations. We identified the region of parameters where η has the required DM relic density, satisfying at the same time the constraints from Higgs searches at the LHC as well as DM direct searches. Compositeness, in addition to

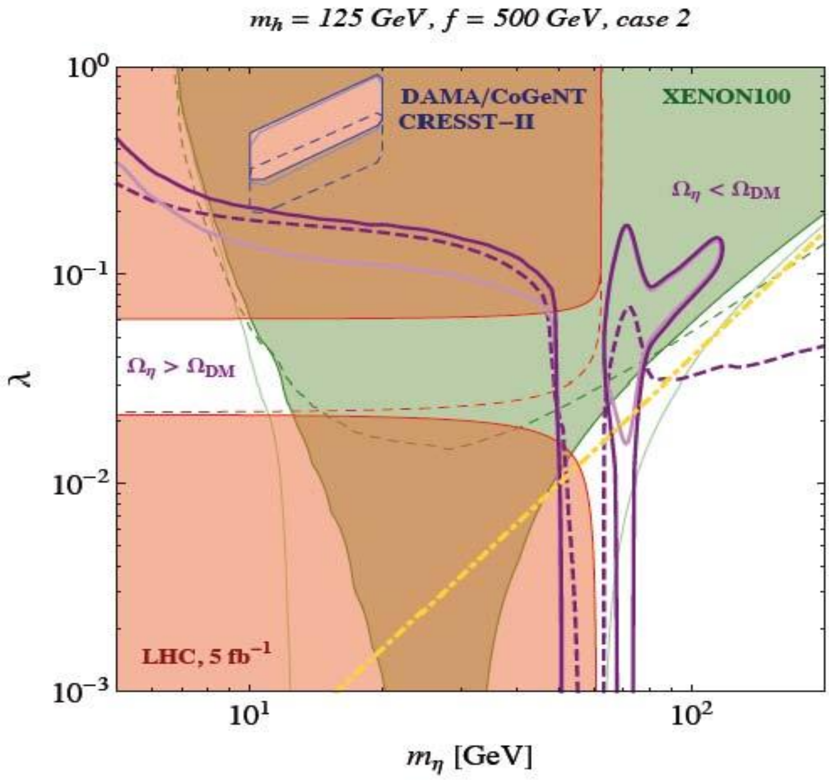


Fig. 1: The contour $\Omega_\eta = \Omega_{DM}$ (solid dark purple line) in the plane defined by the pNGB mass m_η and its coupling to the Higgs λ, for m_h = 125 GeV, f = 500 GeV, assuming a DM-bottom coupling c_b = 1/2. The green shaded region is disfavoured by XENON100, the region delimited by a blue line is favoured by DAMA/CoGeNT/CRESST- II, and the red shaded region is disfavoured by the Higgs signal at the LHC. The solid light purple/green/blue lines correspond to the same observables for maximal c_b. The dashed purple/green/blue/red lines correspond to the same observables in the non-composite case, f = ∞. The region below the yellow dot-dashed line corresponds to the theoretical preferred region.

justify the lightness of the scalars, can enhance the DM scattering rates and lead to an excellent discovery prospect for the near future. For a Higgs mass around 125 GeV and a pNGB characteristic scale f=1 TeV, the DM mass is either $m_\eta \simeq 50 - 70$ GeV, with DM annihilations driven by the Higgs resonance, or in the range 100 − 500 GeV, where the DM derivative interaction with the Higgs becomes dominant. In the former case the invisible Higgs decay to two DM particles could weaken the LHC Higgs signal. The bounds on the model parameters for f=500 GeV are summarized in Figure 1.

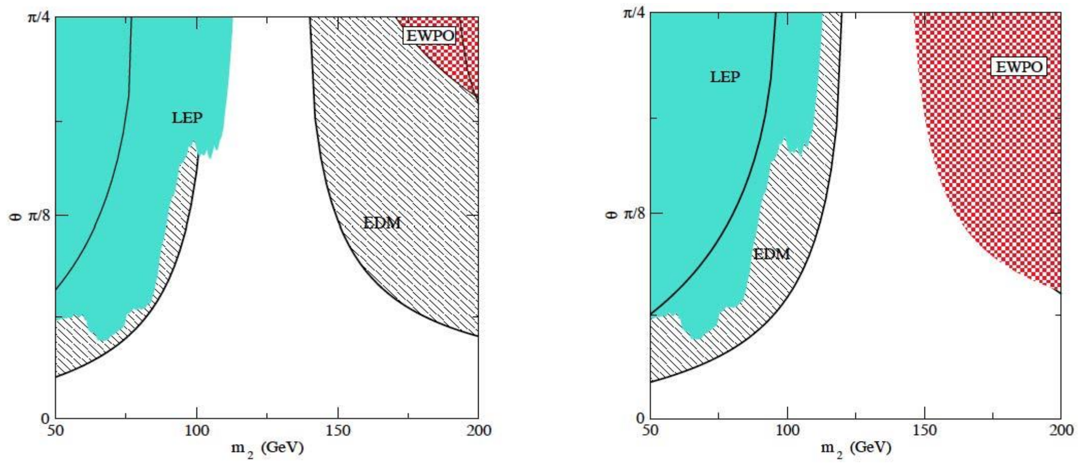


Fig. 2: Bounds on the mass m_2 of the mostly-singlet mass-eigenstate, and the mixing angle. Electro-weak precision observables exclude the red region, for the mostly-doublet state mass m_1 = 120, 140GeV (left and right plots respectively). Direct searches at LEP exclude the uniform turquoise region for light m_2. Electric Dipole Moments exclude the striped region, for a pseudo-scalar coupling of the scalar to fermions b = f / 500GeV.

Baryogenesis

We addressed electroweak baryogenesis in the context of composite Higgs models. We noted that modifications to the Higgs and top quark sectors can play an important role in generating the baryon asymmetry. Composite Higgs models that include a light, gauge singlet scalar in the spectrum (as in the model based on the symmetry breaking pattern SO(6)/SO(5)), provide all the necessary ingredients for viable baryogenesis. In particular, the singlet leads to a strongly first-order electroweak phase transition and introduces new sources of CP violation in dimension-five operators involving the top quark. We worked out the amount of baryon asymmetry produced and the experimental constraints on the model as shown in Figure 2.

Emergence of Lorentz Invariance

We elaborated on the mechanism discovered by Groot-Nibbelink and Pospelov to enforce Lorentz invariance as an emergent symmetry of low-energy physics, based on a non-relativistic form of supersymmetry. We constructed a model that realizes this symmetry dynamically, breaking Lorentz invariance but not supersymmetry. It is a supersymmetric extension of the dynamical aether theory of Jacobson and Mattingly. We described the dynamics of the model, showing that the mechanism also leads to an emergent Lorentz Invariance in the aether sector and that the SUSY-partners of the aether fields are stable. We classified its inequivalent vacua, some of which spontaneously break spatial isotropy. Supersymmetry breaking terms were introduced and seen to give masses to fermionic and bosonic partners of the aether field. There are some difficulties in embedding the mechanism in Horava gravity.

Applications of the gauge/gravity correspondence

The holographic (or gauge/gravity) duality has become nowadays a powerful tool to study strongly coupled systems and has found numerous applications, ranging from modeling QCD and heavy ion collisions to quantum liquids and high-temperature superconductivity. During 2012, we have studied i) strongly coupled insulators that exhibit superconductivity and ii) the impact of chiral anomalies on relativistic fluids.

We studied the magnetic response of holographic superconductors characterized by an insulating normal phase. We studied the response under i) magnetic fields perpendicular to the material and ii) magnetic fields parallel to materials with a cylindrical shape (flux-threaded cylinders). Magnetic fields lead to formation of vortices and allow one to infer that quite generically these superconductors are of type II. The response to a cylinder-threading magnetic flux is in the form of Aharonov-Bohm-like effects. These are suppressed in the holographic conductor-superconductor transition but, instead, they are unsuppressed for the insulator case. Holography, thus, predicts that generically insulators display stronger Aharonov-Bohm effects than conductors. A similar effect should also be present in super-solids.

Chiral anomalies have a profound impact on the transport properties of relativistic fluids. In four dimensions there are different types of anomalies, pure gauge and mixed gauge-gravitational anomalies. They give rise to two new non-dissipative transport coefficients, the chiral magnetic conductivity and the chiral vortical conductivity. They can be calculated from the microscopic degrees of freedom with the help of Kubo formulae, and holographically by exploiting the gauge/gravity correspondence. We have computed the anomalous transport coefficients up to first and second order in the hydrodynamical expansion using both techniques, including chiral and mixed gauge-gravitational anomalies and external electromagnetic fields. They have a profound impact on our knowledge of charge and chiral separation effects in heavy ions. Also, the gravitational anomaly might give rise to lepton number generation in the early universe just after the big bang.

3.Personnel in 2012

IFAE complements its own staff (hired directly by the Institute) with personnel of ICREA and collaborates with personnel from the UAB as shown in the following list.

Experimental Division

Faculty

Blanch, Oscar	Researcher, Ramon y Cajal, IFAE
Bosman, Martine	Research Professor, IFAE
Casado, Mª. Pilar	Associate Professor, UAB
Cavalli-Sforza, Matteo	Research Professor, IFAE
Chmeissani, Mokhtar	Research Professor, IFAE
Cortina, Juan	Research Associate Professor, IFAE
Crespo, José Mª.	Professor, UAB
Delfino, Manuel	Professor, UAB
Fernández, Enrique	Professor, UAB
Grinstein, Sebastian	Research Professor, ICREA
Juste, Aurelio	Research Professor, ICREA
Korolkov, Ilya	Research Associate Professor, IFAE
Martínez, Manel	Research Professor, IFAE
Martínez, Mario	Research Professor, ICREA
Miquel, Ramon	Research Professor, ICREA
Mir, Lluïsa Mª	Research Associate Professor, IFAE
Moralejo, Abelardo	Research Associate Professor, IFAE
Padilla, Cristóbal	Research Associate Professor, IFAE
Rico, Javier	Researcher, ICREA
Riu, Imma	Research Associate Professor, IFAE
Sánchez, Federico	Research Associate Professor, IFAE
Sorin, Verónica	Researcher, Ramon y Cajal, IFAE

Engineering Staff

Abril, Oscar	Electronic Engineer, IFAE, CTA (sinceMay 2012)
Ballester, Otger	Electronic Engineer, IFAE
Barceló, Miquel	Electronic Engineer, IFAE (at present, CTA Project Engineer)
Boix, Joan	Electronic Engineer, CTA
Cardiel Sas, Laia	Electronic Engineer, IFAE
Grañena, Ferran	Mechanical Engineer, IFAE
Hernandez, Carles	Software Engineer, PAU (until September 2012)
Illa, Jose Mª.	Electronic Engineer, IFAE
Jimenez Rojas, Jorge	Electronic Engineer IFAE (since May 2012)
Lopez Morillo, Luis	Mechanical Engineering Student, PAU
Macias, José Gabriel	Microelectronics Designer, VIP
Maiorino, Marino	Engineering Physics, IFAE (until March 2012)
Pio, Cristobal	Software Engineer (CTA)
Puigdengoles, Carles	Electronic Engineer, IFAE
Troyano, Isaac	Electronic Engineer, IFAE, CPAN ,CTA (until March 2012)

Computer Scientists

Campos, Marc	IFAE
Guinó Feijoo, Alex	IFAE
Pacheco, Andreu	IFAE, Senior Applied Physicist (Computing)

Technicians

Albareda, David	Electronic Technician (from Sep. 2012 until Dec. 2012)
Arteche, Carlos	Mechanical Technician, PAU
Colombo, Eduardo	MAGIC
González, Alex	Electronic Technician, IFAE
Gaweda, Javier	Mechanical Technician, IFAE

Scientific Post-Docs

Abdallah, Jalal	ATLAS, CPAN
Bordoni, Stefania	NEUTRINOS (since September 2012)
De Lorenzo, Gianluca	VIP
Doro, Michele	MAGIC, CPAN (until May 2012)
Francavilla, Paolo	ATLAS
Gerbaudo, Davide	ATLAS (until December 2012)
Giangiobbe, Vincent	ATLAS
Garczarczyk, Markus	MAGIC
Helsens, Clément	ATLAS
Ieva, Michela	Neutrinos , Beatriu de Pinos fellow
Klepser, Stefan	MAGIC, J. de la Cierva fellow (until March 2012)
Kolstein, Machiel	VIP
Le Menedeu, Eve	ATLAS (since January 2012)
Lux, Thorsten	Neutrinos , J. de la Cierva fellow
Mazin, Daniel	MAGIC, Otto Hahn fellow (until June 2012)
Meoni, Evelin	ATLAS (until March 2012)
Micelli, Andrea	PIXELS (since July 2012)
Sitarek, Julian	MAGIC,CTA , Juan de la Cierva fellow
Stamatescu, Victor	MAGIC,CTA

Doctoral Students

Ariño, Gerard	VIP
Aleksic, Jelena	MAGIC,CTA, Generalitat FI
Borrego, Carlos	ATLAS (until March 2012)
Calderón, Yonatan	VIP
Camarda, Stefano	CDF (until February 2012)
Caminal, Roger	ATLAS
Caravaca, Javier	Neutrinos
Castillo, Raquel	Neutrinos
Conidi, M. Chiara	ATLAS

Fracchia, Silvia	ATLAS (since October 2012)
Gonzalez, Adiv	MAGIC, CTA
González Parra, Garoe	ATLAS , Scholarship FPI
Giavitto, Gianluca	MAGIC, CTA (until December 2012)
Harb, Ali	PIXELS (until July 2012)
López Coto, Ruben	MAGIC, CTA
Lopez Orama, Alicia	MAGIC, CTA , FPI
Lopez Paz, Ivan	PIXELS (since October 2012)
Lostao, Albert	NEUTRINOS (since November 2012)
Martí, Carlos	Neutrinos (until April 2012)
Martí, Pol	DES, PAU
Mikhaylova, Ekaterina	VIP
Montejo, Javier	ATLAS, FPU
Nadal, Jordi	ATLAS
Ortolan, Lorenzo	CDF (until July 2012)
Ozsahin, Ilker	VIP
Reichardt, Ignasi	MAGIC, CTA (until September 2012)
Rodriguez, Jezabel	CTA (until May 2012)
Rossetti, Valerio	ATLAS, Scholarship MEC-FPU
Rubbo, Francesco	ATLAS
Sanchez Alonso, Carlos	DES, PAU
Succurro, Antonella	ATLAS
Tsiskaridze, Shota	PIXELS
Tescaro, Diego	MAGIC (until September 2012)
Uzun, Dilber	VIP

Administrative Personnel

Cárdenas, Cristina	IFAE, UAB Secretary
Gaya, Josep	IFAE, UAB Senior Administrator
Jiménez, Elizabeth	IFAE, Administrative Assistant (since January 2012)
Gomez, Marta	IFAE, Administrative Assistant

Strauch, Sara	MAGIC, IFAE Administrative Assistant

Theory Division

Faculty

Espinosa, José Ramón	Research Professor, ICREA
Jamin, Matthias	Research Professor, ICREA
Grojean, Christophe	Research Professor, ICREA
Pascual, Ramon	Professor, UAB
Pujolàs, Oriol	Researcher, Ramon y Cajal, IFAE-UAB
Quirós, Mariano	Research Professor, ICREA
Servant, Géraldine	Research Professor, ICREA

Scientific Post-Docs

Biggio, Carla	Post doc IFAE, CPAN (until September 2012)
Gupta, Sandeepan	Post doc IFAE (since September 2012)
Mejias, Eugenio	Juan de la Cierva UAB
Riva, Francesco	Post doc IFAE (until July 2012)
Roig, Pablo	Post doc IFAE (until August. 2012; Th.Project since Sept. 2012)
Silva, Pedro	Post doc Institut de Ciències de l'Espai

Doctoral Students

Domènech, Oriol	Scholarship MICINN
Elias, Joan	Scholarship MICINN
Krug, Sebastian	Scholarship MICINN
Montull, Marc	Scholarship UAB (PIF)
Peset, Clara	Scholarship MICINN
Ramon, Marc	Scholarship UAB (PIF)
Wiechers, Michael	Scholarship Erasmus

4. Institutional Activities in 2012

4.1 Final Master & Diploma Projects

Experimental Division

Roger Caminal
New pixel sensor technologies for the ATLAS upgrade.
February 2012
Advisor: S. Grinstein

Jezabel R. García
Cosmological Measurements with Imaging Atmospheric Cherenkov Telescopes.
September 2012
Advisor: O. Blanch Bigas

Ali Harb
Characterization of CNM 3D FE-I4 Pixel Detectors for the ATLAS IBL-Upgrade.
June 2012
Advisor: S. Grinstein

Shota Tsiskaridze
Beam Test Performance of 3D Pixel Detectors for the IBL Upgrade.
February 2012
Advisor: S. Grinstein

Theory Division

Joan Elias-Miró
Higgs Mass Implications on the Stability of the Electroweak Vacuum.
July 2012
Supervisor: J.R. Espinosa

Michael Wiechers (Radboud University Nijmegen)
Anarchic Neutrino Mixing in Warped Space.
September 2012
Supervisor: M. Quirós

Tyrone Cutler
Lorentz violation & spacetime symmetries.
September 2012.
Supervisor: O Pujolas

4.2 Doctoral Theses

Experimental Division

Stefano Camarda
Measurement of Z/gamma* + Jets Differential CrossSections with the CDF Detector at sqrt(s) = 1.96 TeV.
July 2012
Advisor: V. Sorin

Jordi Nadal
Simultaneous measurement of the top quark pair production cross-section and R_b in the ATLAS experiment.
July 2012
Advisor: L. Mir

Lorenzo Ortolan
Measurement of Z/gamma + b-jet Production Cross section in pp collisions at sqrt(s)= 1.96 TeV with the CDF detector.*
July 2012
Advisor: V. Sorin

Ignasi Reichardt
Search for gamma-ray emission from supernova remnants with The Fermi/LAT and MAGIC telescopes.
October 2012
Advisor:J. Rico (co-supervised by E. De Oña-Wilhelmi, MPK-Heidelberg).

Theory Division

Javier Serra
Compositeness at the Electroweak Scale.
January 2012
Supervisor: A. Pomarol

Oriol Domènech-Cots
Compositeness from Holography and beyond.
June 2012
Supervisor: A. Pomarol

Marc Ramon
Looking for New Physics in the $B_d \rightarrow > K^*(\rightarrow K\pi)l^+l^-$ decay mode at large recoil.
September 2012
Supervisor: J. Matias

4.3 Publications

Experimental Division

Publications ATLAS Group

G. Aad et al., ATLAS Collaboration
Search for doubly-charged Higgs bosons in like-sign dilepton final states at √s =7 TeV with the ATLAS detector,
Eur.Phys.J. C72 (2012) 2244.

G. Aad et al., ATLAS Collaboration
Search for anomalous production of prompt like-sign lepton pairs at √s =7 TeV with the ATLAS detector,
JHEP12 (2012) 007.

G. Aad et al., ATLAS Collaboration
Search for pair production of massive particles decaying into three quarks with the ATLAS detector in √s =7 TeV pp collisions LHC,
JHEP12 (2012) 086.

G. Aad et al., ATLAS Collaboration
Search for R-parity-violating supersymmetry in events with four or more leptons in √s =7 TeV pp collisions with the ATLAS detector,
JHEP12 (2012) 124.

G. Aad et al., ATLAS Collaboration
Search for Supersymmetry in Events with Large Missing Transverse Momentum, Jets, and at Least One τ Lepton in 7 TeV Proton-Proton Collision Data with the ATLAS Detector,
Eur. Phys. J. C72 (2012): 2215.

G. Aad et al., ATLAS Collaboration
Search for top-jet resonances in the lepton+jets channel of t anti-t jets events with the ATLAS detector in 4.7 fb-1 of pp collisions at √s = 7 TeV,
Phys. Rev. D86, 091103 (2012).

G. Aad et al., ATLAS Collaboration
ATLAS search for a heavy gauge boson decaying to a charged lepton and a neutrino in pp collisions at √s = 7 TeV,
Eur. Phys. J. C72: (2012) 2241.

G. Aad et al., ATLAS Collaboration
Search for a heavy top-quark partner in final states with two leptons with the ATLAS detector at the LHC,
JHEP11(2012)094.

G. Aad et al., ATLAS Collaboration
Search for high-mass resonances decaying to dilepton final states in pp collisions at √s = 7 TeV with the ATLAS detector,
JHEP 11 (2012) 138

G. Aad et al., ATLAS Collaboration
Search for Diphoton Events with Large Missing Transverse Momentum in 5 fb^{-1} of 7 TeV Proton-Proton Collision Data with the ATLAS Detector,
Phys. Lett. B 718 (2012) 411-430.

G. Aad et al., ATLAS Collaboration
Measurements of the pseudorapidity dependence of the total transverse energy in proton-proton collisions at √s = 7 TeV with ATLAS ,
JHEP 11 (2012) 033.

G. Aad et al., ATLAS Collaboration
Further search for supersymmetry at √s = 7 TeV in final states with jets, missing transverse momentum and isolated leptons with the ATLAS detector,
Phys. Rev. D 86, 092002 (2012).

G. Aad et al., ATLAS Collaboration
Search for light scalar top quark pair production in final states with two leptons with the ATLAS detector in √s = 7 TeV proton-proton collisions,
Eur. Phys. J. C72: (2012) 2237.

G. Aad et al., ATLAS Collaboration
Search for direct top squark pair production in final states with one isolated lepton, jets, and missing transverse momentum in √s = 7 TeV pp collisions using 4.7 fb^{-1} of ATLAS data,
Phys. Rev. Lett. 109, 211803 (2012).

G. Aad et al., ATLAS Collaboration
Measurement of WZ Production in Proton-Proton Collisions at √s = 7 TeV with the ATLAS Detector,
Eur. Phys. J. C72: (2012) 2173.

G. Aad et al., ATLAS Collaboration
Search for a supersymmetric partner to the top quark in final states with jets and missing transverse momentum at √s = 7 TeV with the ATLAS detector,
Phys. Rev. Lett. 109, 211802 (2012).

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

G. Aad et al., ATLAS Collaboration
Time dependent angular analysis of the decay $B_s \to J/\psi\ \Phi$ and extraction of $\Delta\gamma_s$ and the CP-violating weak phase Φ_s by ATLAS,
JHEP12(2012) 072.

G. Aad et al., ATLAS Collaboration
Observation of a new particle in the search for the Standard Model Higgs boson with the ATLAS detector at the LHC
Phys. Lett. B 716 (2012) 1-29.

G. Aad et al., ATLAS Collaboration
Search for magnetic monopoles in √s = 7 TeV pp collisions with the ATLAS detector,
Phys. Rev. Lett 109, 261803 (2012).

G. Aad et al., ATLAS Collaboration
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,
Eur. Phys. J. C72 (2012):2174.

G. Aad et al., ATLAS Collaboration
A search for t anti-t resonances in lepton+jets events with highly boosted top quarks collected in pp collisions at $\sqrt{s}$ = 7 TeV with the ATLAS detector, J
HEP 1209 (2012) 041.

G. Aad et al., ATLAS Collaboration
Combined search for the Standard Model Higgs boson in pp collisions at $\sqrt{s}$ = 7 TeV with the ATLAS detector,
Phys. Rev. D86 (2012) 032003.

G. Aad et al., ATLAS Collaboration
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,
Phys. Lett. B 718 (2012) 369-390.

G. Aad et al., ATLAS Collaboration
Search for the Higgs boson in the H→WW→lnujj decay channel at $\sqrt{s}$ = 7 TeV with the ATLAS detector,
Phys. Lett. B 718 (2012) 391-410.

G. Aad et al., ATLAS Collaboration
Search for the Standard Model Higgs boson in the H to $\tau^+ \tau^-$ decay mode in $\sqrt{s}$ = 7 TeV pp collisions with ATLAS,
JHEP09 (2012) 070.

G. Aad et al., ATLAS Collaboration
ATLAS measurements of the properties of jets for boosted particle searches,
Phys. Rev. D 86 (2012) 072006.

G. Aad et al., ATLAS Collaboration
Search for a Standard Model Higgs in the mass range 200-600 GeV in the channel H→ ZZ → llqq with with the ATLAS detector,
Phys.Lett. B 717 (2012) 70-88.

G. Aad et al., ATLAS Collaboration
*Measurement of the b-hadron production cross section using decays to D*μX final states in pp collisions at $\sqrt{s}$ = 7 TeV with the ATLAS detector,*
Nucl. Phys. B 864 (2012) 341-381.

G. Aad et al., ATLAS Collaboration
Measurement of event shapes at large momentum transfer with the ATLAS detector in pp collisions at $\sqrt{s}$ = 7 TeV,
Eur. Phys. J. C72 (2012): 2211.

G. Aad et al., ATLAS Collaboration
Hunt for new phenomena using large jet multiplicities and missing transverse momentum with ATLAS in 4.7 fb^{-1} of $\sqrt{s}$ = 7 TeV proton-proton collisions,
JHEP 1207 (2012) 167.

G. Aad et al., ATLAS Collaboration
Search for the Standard Model Higgs boson in the H → WW → lνlν decay mode with 4.7 fb^{-1} of ATLAS data at $\sqrt{s}$ = 7 TeV,
Phys. Lett. B 716 (2012) 62-81.

G. Aad et al., ATLAS Collaboration
A search for flavour changing neutral currents in top-quark decays in pp collision data collected with the ATLAS detector at $\sqrt{s}$ = 7 TeV,
JHEP 09 (2012) 139.

G. Aad et al., ATLAS Collaboration
Search for a Standard Model Higgs boson in the H→ ZZ → llνν decay channel using 4.7 fb^{-1} of $\sqrt{s}$ = 7 TeV data with the ATLAS detector,
Phys. Lett. B 717 (2012) 29-48.

G. Aad et al., ATLAS Collaboration
Evidence for the associated production of a W boson and a top quark in ATLAS at $\sqrt{s}$ = 7 TeV,
Phys. Lett. B 716 (2012) 142-159.

G. Aad et al., ATLAS Collaboration
A search for t anti-t resonances with the ATLAS detector in 2.05 fb^{-1} of proton-proton collisions at $\sqrt{s}$ = 7 TeV,
Eur.Phys.J. C72 (2012) 2083

G. Aad et al., ATLAS Collaboration
Measurement of the t-channel single top-quark production cross section in pp collisions at $\sqrt{s}$ = 7 TeV with the ATLAS detector,
Phys. Lett. B 717 (2012) 330-350.

G. Aad et al., ATLAS Collaboration
Measurement of W gamma and Z gamma production cross sections in pp collisions at $\sqrt{s}$ = 7 TeV and limits on anomalous triple gauge couplings with the ATLAS detector,
Phys. Lett. B 717 (2012) 49-69.

G. Aad et al., ATLAS Collaboration
Measurement of W boson polarization in top quark decays with the ATLAS detector,
JHEP 1206 (2012) 088.

G. Aad et al., ATLAS Collaboration
Measurement of the top quark pair cross section with ATLAS in pp collisions at $\sqrt{s}$ = 7 TeV using final states with an electron or a muon and a hadronically decaying τ lepton,
Phys. Lett. B 717 (2012) 89-108.

G. Aad et al., ATLAS Collaboration
Search for tb resonances in proton-proton collisions at $\sqrt{s}$ = 7 TeV with the ATLAS detector,
Phys. Rev. Lett. 109 (2012) 081801.

G. Aad et al., ATLAS Collaboration
Search for a fermiophobic Higgs boson in the diphoton decay channel with the ATLAS detector,
Eur. Phys. J. C72 (2012):2157.

G. Aad et al., ATLAS Collaboration
Search for Lepton Flavour Violation in the eμ Continuum with the ATLAS detector in $\sqrt{s}$ = 7 TeV pp collisions at the LHC,
Eur. Phys. J. C72 (2012) 2040.

G. Aad et al., ATLAS Collaboration
Measurement of τ polarization in W→ τν decays with the ATLAS detector in pp collisions at $\sqrt{s}$ = 7 TeV,
Eur. Phys.J. C72 (2012) 2062.

G. Aad et al., ATLAS Collaboration
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,
Phys. Lett. B 715 (2012) 44-60.

G. Aad et al., ATLAS Collaboration
Search for supersymmetry in events with three leptons and missing transverse momentum in $\sqrt{s}$ = 7 TeV pp collisions with the ATLAS detector,
Phys. Rev. Lett. 108 (2012) 261804.

G. Aad et al., ATLAS Collaboration
Search for TeV-scale Gravity Signatures in Final States with Leptons and Jets with the ATLAS Detector at $\sqrt{s}$ = 7 TeV,
Phys. Lett. B 716 (2012) 122-141.

G. Aad et al., ATLAS Collaboration
Search for supersymmetry with jets, missing transverse momentum and at least one hadronically decaying τ lepton in proton-proton collisions at $\sqrt{s}$ = 7 TeV with the ATLAS detector,
Phys. Lett. B 714 (2012) 197-214.

G. Aad et al., ATLAS Collaboration
Search for charged Higgs bosons decaying via $H^+ \rightarrow \tau^+\nu$ in t anti-t events using 4.6 fb-1 of pp collision data at $\sqrt{s}$ = 7 TeV with the ATLAS detector,
JHEP 1206 (2012) 039.

G. Aad et al., ATLAS Collaboration
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,
Phys. Rev. D85 (2012) 112012.

G. Aad et al., ATLAS Collaboration
Search for pair production of a new quark that decays to a Z boson and a bottom quark with the ATLAS detector,
Phys. Rev. Lett. 109 (2012) 071801.

G. Aad et al., ATLAS Collaboration
Search for the decay $B^0_s \rightarrow \mu^+\mu^-$ with the ATLAS detector,
Phys. Lett. B 713 (2012) 387-407.

G. Aad et al., ATLAS Collaboration
Search for Events with Large Missing Transverse Momentum, Jets, and at Least Two τ Leptons in 7 TeV Proton-Proton Collision Data with the ATLAS Detector,
Phys. Lett. B 714 (2012) 180-196.

G. Aad et al., ATLAS Collaboration
Measurement of the WW cross section in $\sqrt{s}$ = 7 TeV pp collisions at ATLAS and limits on anomalous gauge couplings,
Physics Letters B 712 (2012) 289-308.

G. Aad et al., ATLAS Collaboration
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,
Phys. Rev. D85, 112006 (2012).

G. Aad et al., ATLAS Collaboration
Measurement of the Top Quark Mass with the Template Method in the $\rightarrow$lepton+jets Channel using ATLAS Data,
Eur. Phys.J. C72 (2012) 2046.

G. Aad et al., ATLAS Collaboration
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,
Phys. Rev. Lett. 108, 241802 (2012).

G. Aad et al., ATLAS Collaboration
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,
Eur. Phys. J. C72 (2012) 2056.

G. Aad et al., ATLAS Collaboration
Measurement of t anti-t production with a veto on additional central jet activity in pp collisions at $\sqrt{s}$ = 7 TeV using the ATLAS detector,
Eur. Phys.J. C72 (2012) 2043.

G. Aad et al., ATLAS Collaboration
Jet mass and substructure of inclusive jets in $\sqrt{s}$ = 7 TeV pp collisions with the ATLAS experiment,
JHEP 1205 (2012) 128.

G. Aad et al., ATLAS Collaboration
Determination of the strange quark density of the proton from ATLAS data on $W \rightarrow l\nu$ $Z \rightarrow ll$ cross-sections,
Phys. Rev. Lett. 109 (2012) 012001.

G. Aad et al., ATLAS Collaboration
Measurement of the charge asymmetry in top quark pair production in pp collisions at $\sqrt{s}$ = 7 TeV using the ATLAS detector,
Eur. Phys. J. C72 (2012) 2039.

G. Aad et al., ATLAS Collaboration
Observation of spin correlation in t anti-t events from pp collisions at $\sqrt{s}$ = 7 TeV using the ATLAS detector,
Phys. Rev. Lett. 108, 212001 (2012).

G. Aad et al., ATLAS Collaboration
Measurement of inclusive two-particle angular correlations in pp collisions with the ATLAS detector at the LHC,
JHEP 1205 (2012) 157.

G. Aad et al., ATLAS Collaboration
Search for second generation scalar leptoquarks in pp collisions at $\sqrt{s}$ = 7 TeV with the ATLAS detector,
Eur.Phys.J. C72 (2012) 2151.

G. Aad et al., ATLAS Collaboration
Forward-backward correlations and charged-particle azimuthal distributions in pp interactions using the ATLAS detector,
JHEP 1207 (2012) 019.

G. Aad et al., ATLAS Collaboration
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,
Phys. Rev. D85, 092014 (2012).

G. Aad et al., ATLAS Collaboration
Measurement of the azimuthal anisotropy for charged particle production in $\sqrt{s_{NN}}$ = 2.76 TeV lead-lead collisions with the ATLAS detector,
Phys. Rev. C86 (2012) 014907.

G. Aad et al., ATLAS Collaboration
Measurement of the polarisation of W bosons produced at large momentum transfer in pp collisions at $\sqrt{s}$ = 7 TeV with the ATLAS experiment at the LHC,
Eur. Phys. J. C72 (2012) 2001.

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

G. Aad et al., ATLAS Collaboration
Search for new particles decaying to ZZ using final states with leptons and jets with the ATLAS detector in √s =7 TeV proton-proton collisions,
Physics Letters B712 (2012) 331-350.

G. Aad et al., ATLAS Collaboration
Search for FCNC single top-quark production at √s =7 TeV with the ATLAS detector,
Physics Letters B712 (2012) 351-369.

G. Aad et al., ATLAS Collaboration
Measurement of the azimuthal ordering of charged hadrons with the ATLAS detector,
Phys. Rev. D86 (2012) 052005.

G. Aad et al., ATLAS Collaboration
Search for down-type fourth generation quarks with the ATLAS Detector in events with one lepton and hadronically decaying W bosons,
Phys. Rev. Lett. 109 (2012) 032001.

G. Aad et al., ATLAS Collaboration
Search for same-sign top quark production and fourth-generation down-type quarks in pp collisions at √s = 7 TeV with the ATLAS detector,
JHEP 1204 (2012) 069.

G. Aad et al., ATLAS Collaboration
Measurement of the cross section for top-quark pair production in pp collisions at √s = 7 TeV with the ATLAS detector using final states with two high-pT leptons,
JHEP 1205 (2012) 059.

G. Aad et al., ATLAS Collaboration
Search for anomaly-mediated supersymmetry breaking with the ATLAS detector based on a disappearing-track signature in pp collisions at √s = 7 TeV,
Eur. Phys. J. C72 (2012) 1993.

G. Aad et al., ATLAS Collaboration
Search for pair-produced heavy quarks decaying to Wq in the two-lepton channel at ATLAS at √s = 7 TeV,
Phys. Rev. D86 (2012) 012007.

G. Aad et al., ATLAS Collaboration
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,
Phys. Rev. Lett. 108 (2012) 261802.

G. Aad et al., ATLAS Collaboration
Search for the Standard Model Higgs boson in the diphoton decay channel with 4.9 fb^{-1} of pp collisions at √s =7 TeV with ATLAS,
Phys. Rev. Lett. 108, 111803 (2012).

G. Aad et al., ATLAS Collaboration
Search for the Standard Model Higgs boson in the decay channel H→ZZ(*)→4l with 4.8 fb^{-1} of pp collisions at √s =7 TeV with ATLAS,
Phys.Lett. B710 (2012) 383-402.

G. Aad et al., ATLAS Collaboration
Combined search for the Standard Model Higgs boson using up to 4.9 fb^{-1} of pp collision data at √s = 7 TeV with the ATLAS detector at the LHC,
Phys.Lett. B710 (2012) 49-66.

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A.Delgado, G. Nardini, M. Quirós
Large diphoton Higgs rates from supersymmetric triplets,
Phys. Rev. D86 (2012) 115010.

A.Delgado, G. Nardini, M. Quirós
The Light Stop Scenario from Gauge Mediation,
JHEP 04 (2012) 137.

A.Delgado and M. Quirós
The Least Supersymmetric Standard Model,
Phys. Rev. D85 (2012) 015001.

D.G. Dumm and P. Roig
Resonance Chiral Lagrangian analysis of $\tau \to \eta' \pi \pi^0 \nu_\tau$ decays,
Phys. Rev. D86 (2012) 076009, arXiv:1208.1212 [hep-ph].

J. Elias-Miró, J.R. Espinosa, G.F. Giudice, H.M. Lee and A. Strumia
Stabilization of the Electroweak Vacuum by a Scalar Threshold Effect,
JHEP1206 (2012) 031.

J. Elias-Miró, J.R. Espinosa, G.F. Giudice, G. Isidori, A. Riotto and A. Strumia
Higgs Mass Implications on the Stability of the Electroweak Vacuum,
Phys. Lett. B709 (2012) 222.

J.R. Espinosa, E. Nardi and C. Sheng Fong
Yukawa Hierarchies from Spontaneous Breaking of the $SU(3)_L$ x $SU(3)_R$ Flavour Symmetry?,
[hep-ph/1211.6428] to appear in JHEP.

J.R. Espinosa, C. Grojean, V. Sanz and M. Trott
NSUSY fits,
JHEP 1212 (2012) 077.

J.R. Espinosa, C. Grojean, M. Mühlleitner and M. Trott,
First Glimpses at Higgs' face,
JHEP1212 (2012) 045

J.R. Espinosa, C. Grojean, M. Mühlleitner and M. Trott,
Probing for Invisible Higgs Decays with Global Fits,
JHEP1209 (2012) 126.

J.R. Espinosa, C. Grojean, M. Mühlleitner and M. Trott
Fingerprinting Higgs Suspects at the LHC,
JHEP1205 (2012) 097.

Jose R. Espinosa, Ben Gripaios, Thomas Konstandin, Francesco Riva
Electroweak Baryogenesis in Non-minimal Composite Higgs Models,
JCAP 1201 (2012) 012.

M. Farina, C. Grojean et al
Lifting degeneracies in Higgs couplings using single top production in association with a Higgs boson,
[arXiv:1211.3736], to be published in JHEP.

M. Frigerio, A. Pomarol, F. Riva and A. Urbano
Composite Scalar Dark Matter,
JHEP 1207 (2012) 015.

R.S. Gupta, M. Montull and F. Riva
SUSY Faces its Higgs Couplings,
[hep-ph/1212.5240].

R.S. Gupta, H. Rzehak and J.D. Wells
How well do we need to measure Higgs boson couplings?,
Phys. Rev. D86 (2012) 095001.

D. Greynat, P. Masjuan and S. Peris
Analytic Reconstruction of heavy-quark two-point functions at $O(\alpha_s^3)$,
Phys. Rev. D85 (2012) 054008, arXiv:1104.3425 [hep-ph].

M. Jamin
The scalar gluonium correlator: Large-β_0 and beyond,
JHEP 1204 (2012) 099, arXiv:1202.1169 [hep-ph].

M. Montull, O. Pujolas et al
Magnetic Response in the Holographic Insulator/Superconductor Transition,
JHEP 1204 (2012) 135.

O. Pujolas
Supersymmetric Aether,
Sergey Sibiryakov (Moscow, INR)
JHEP 1201 (2012) 062.

A.Pomarol and F.Riva
The Composite Higgs and Light Resonance Connection,
JHEP 1208 (2012) 135.

F. Riva, C. Biggio and A. Pomarol
Is the 125 GeV Higgs the superpartner of a neutrino?,
JHEP 1302 (2013) 081, [arXiv:1211.4526].

O. Shekhovtsova, P. Roig et al
Resonance chiral Lagrangian currents and τ decay Monte Carlo,
Phys. Rev. D86 (2012) 113008, arXiv:1203.3955 [hep-ph].

4.4 Outreach Activities

Experimental Division

Jelena Aleksić

- *Astronomía de los rayos gamma*
  Visita de los estudiantes de bachillerato a IFAE, December 2012

Oscar. Blanch Bigas

- *L'Univers*
  Escola Virolai, June 2012
- *Sistemes Binaris*
  Agrupació Astronòmica de Valldoreix i Sant Cugat, March 2012

Martine Bosman

- *La búsqueda del bosón de Higgs*
  Sep 16 Investigación y Ciencia
- *La búsqueda del bosón de Higgs*
  Dec-2012 Museu Darder (Banyoles)

Pilar Casado

- *Descubrimiento del bosón (¿de Higgs?) en el LHC*
  July 2012 , CNM-Barcelona

Matteo Cavalli-Sforza

- *El descubriment del "Bosó de Higgs" a l'LHC del CERN*
  Observatori Fabra (Barcelona) July 2012

Juan Cortina

- *Entrevista TV canaria y discurso público durante celebración upgrade MAGIC*
  15 Nov 2012

Enrique Fernández

- *Neutrinos - Nuevos Descubrimientos*
  Agrupació Astronòmica de St. Cugat-Valldoreix, Sant Cugat (Spain), September 2012.
- *De qué está hecho el universo?".*
  CaixaForum, Girona (Spain), October 2012.
  Interview-talk, together with the journalist Michelle Catanzaro, in front of an audience.

Gianlucca Giavitto

- *Interview to EFE regarding press release on Crab pulsar detection*
  (http://magic.mppmu.mpg.de/physics/recent/Crab-Pulsar/, March 29th)

Rubén López-Coto

- *El bosón de Higgs*
  El CPAN en el instituto, Col·legi Sant Josep, Tàrrega, December 2012

Manel Martinez

- Artículo El País:
  http://sociedad.elpais.com/sociedad/2012/03/06/actualidad/1331069523_587784.html
- *Participación en la película documental "The Cosmic Rain"*
  E291 Science Films, Dec 2012

Mario Martinez

- *La búsqueda del bosón de Higgs en el LHC con el detector Atlas*
  5-Jul-16 El Pais
- *The Higgs Boson*
  Jan 2012I NS Guillem de Berguedà (Berga

Ramon Miquel

- *El bosó de Higgs: la partícula del buit*
  Agrupació Astronòmica de Sabadell, Sabadell (Spain), October 2012.
- *El bosó de Higgs: la partícula del buit*
  Agrupació Astronòmica de Sant Cugat-Valldoreix, Sant Cugat (Spain), October 2012.

Lluisa Mir

- *Histories de neutrins*
  Apr 2012 INS La Salle Manlleu

Carlos Sánchez

- *Cosmology*
  IFAE, Bellaterra (Spain), December 2012.. (Outreach talk to visiting high-school students.)

Federico Sánchez

- *Rompiendo la barrera de la luz: ¿pueden los neutrinos ser superluminicos?*
  V Jornada de divugación de la relatividad, Feb 2012

Theory Division

Jose Ramón Espinosa and A. Juste

- *Higgs Discovery: an End or a Beginning?*
  51st ICREA Colloquim, 4 Dec. 2012, Auditorium of the FCRI building, Barcelona

Christophe Grojean

- *Le boson de Higgs: voyage au cœur de la matière*
  Christmas public lecture, CERN, Switzerland, Dec 18th, 2012
- *The Higgs boson: an odyssey in the heart of matter*
  talk at the Japanese-French Frontiers of Science Symposium, Kyoto, Japan, January 26th, 2012

4.5 Conference Proceedings

Experimental Division

Proceedings ATLAS Group

Paolo Francavilla
The ATLAS Tile Hadronic Calorimeter performance at the LHC,
ATL-TILECAL-PROC-2012-008.

Evelin Meoni
Performances of the signal reconstruction in the ATLAS Hadronic Tile Calorimeter,
ATL-TILECAL-PROC-2012-002.

Jordi Nadal
Measurement of ttbar cross section in single lepton and fully hadronic channels at the LHC,
DOI: 10.1393/ncc/i2012-11217-6.

Andreu Pacheco
Response of the Iberian Grid Computing Resources to the ATLAS activities during the LHC data-taking,
Mohammed Kaci et al. 6th Iberian Grid Infrastructure Conference (Ibergrid 2012) Lisbon, 7-9 November - LIP

Andreu Pacheco
Automating ATLAS Computing Operations using the Site Status Board
CHEP2012 Andreeva J. et al. 2012 J. Phys.: Conf. Ser. 396 032072

Antonella Succurro
The ATLAS Tile Hadronic Calorimeter performance in the LHC Collision Era,
TIPP2011: http://dx.doi.org/10.1016/j.phpro.2012.02.368.

Proceedings CDF Group

Lorenzo Ortolan
Z+jets Results from CDF,
Proceeding for XX International Workshop on Deep-Inelastic Subjects Scattering and Related S.

Veronica Sorin
TOP2011 , IV International Workshop on Top Quark Physics,
Il Nuovo Cimento Vol 35 C, N 3.

Proceedings MAGIC Group

G. Giavitto et al.
VHE gamma-ray measurements of the Crab Nebula and Pulsar by MAGIC,
AIP Conference Proceedings, Vol 1505, pp. 858 (2012).

S. Klepser, J. Krause, J. Sitarek for the MAGIC collaboration
Application of a generalized likelihood ratio test statistic to MAGIC data,
HIGH ENERGY GAMMA-RAY ASTRONOMY: 5th International Meeting on High Energy Gamma-Ray Astronomy
AIP Conference Proceedings, Volume 1505, pp. 713-716 (2012).

G. Pedaletti, D. F. Torres, S. Gabici, E. de Oña Wilhelmi, D. Mazin and V. Stamatescu
CTA and cosmic-ray diffusion in molecular clouds,
AIP Conference Proceedings, Vol 1505, pp. 797-800 (2012).

I. Reichardt, E. de Oña-Wilhelmi, J. Rico, R. Yang
*An extended source of GeV gamma rays coincident with the supernova remnant HB 2***1,**
AIP Conference Proceedings, Vol 1505, pp. 261-264 (2012).

J. Rico
Gamma-Ray Astronomy: Implications for Fundamental Physics,
eConf C1108282 (2012).

J. Sitarek et al.
Discovery of VHE gamma-ray emission from the blazar 1ES 1215+303 by the MAGIC telescopes and modeling of the multi-wavelength spectrum,
AIP Conference Proceedings, Volume 1505, pp. 651-655 (2012).

J. Sitarek & W. Bednarek
Can TeV gamma-rays and neutrinos be produced in symbiotic Novae explosions?,
AIP Conference Proceedings, Volume 1505, pp. 426-429 (2012).

V. Stamatescu, A. Moralejo et al for the CTA Consortium
Towards an optimized design for the Cherenkov Telescope array,
AIP Conference Proceedings, Vol 1505, pp. 758-761 (2012).

V. Stamatescu et al for MAGIC Collaboration
Mapping the TeV PWN candidate source HESS J1857+026 down to Fermi-LAT energies with the MAGIC telescopes,
AIP Conference Proceedings, Vol 1505, pp. 345-348 (2012).

Proceedings DES/PAU Group

Theresa M. Shaw, Otger Ballester, et al
The Dark Energy Camera readout system in High Energy, Optical, and Infrared Detectors for Astronomy,
Proceedings of SPIE Vol. 8453 (SPIE, Bellingham, WA 2012), 84532Q.

Brenna L. Flaugher, Ramon Miquel et al
Status of the Dark Energy Survey Camera (DECam) project in Ground-based and Airborne Instrumentation for Astronomy IV,
Ian S. McLean; Suzanne K. Ramsay; Hideki Takami, Editors, Proceedings of SPIE Vol. 8446 (SPIE, Bellingham, WA 2012), 844611.

Stephen S. Eikenberry, O. Ballester, J.M. Illa et al
MIRADAS for the Gran Telescopio Canarias: system overview, in Ground-based and Airborne Instrumentation for Astronomy IV,
Ian S. McLean; Suzanne K. Ramsay; Hideki Takami, Editors, Proceedings of SPIE Vol. 8446 (SPIE, Bellingham, WA 2012), 844657.

Ricard Casas, Otger Ballester, Laia Cardiel-Sas et al.
PAU camera: detectors characterization in High Energy, Optical, and Infrared Detectors for Astronomy,
Proceedings of SPIE Vol. 8453 (SPIE, Bellingham, WA 2012), 845326.

Francisco J. Castander, Otger Ballester, Laia Cardiel-Sas et al
The PAU camera and the PAU survey at the William Herschel Telescope in Ground-based and Airborne Instrumentation for Astronomy IV,
Proceedings of SPIE Vol. 8446 (SPIE, Bellingham, WA 2012), 84466D.

O. Ballester, C. Pio, C. Hernández-Ferrer, S. Serrano, N. Tonello
Design and implementation of a distributed system for the PAUCam camera control system in Software and Cyberinfrastructure for Astronomy II,
Proceedings of SPIE Vol. 8451 (SPIE, Bellingham, WA 2012), 84510L.

O. Ballester, C. Pio, C. Hernández-Ferrer, M. Albareda-Sirvent
A motion control networked solution for the PAUCam slow control", in Software and Cyberinfrastructure for Astronomy II,
Proceedings of SPIE Vol. 8451 (SPIE, Bellingham, WA 2012), 84512O.

Jorge Jiménez, Otger Ballester, Laia Cardiel-Sas et al
Test benches facilities for PAUCam: CCDs and filters characterization in Ground-based and Airborne Instrumentation for Astronomy IV,
Proceedings of SPIE Vol. 8446 (SPIE, Bellingham, WA 2012), 84466N.

Proceedings Theory Division

D. Boito, O. Catà, M. Golterman, M. Jamin, J. Osborne and S. Peris
α_s from τ decays revisited,
Nucl. Phys. Proc. Suppl. 225-227 (2012) 157, arXiv:1112.5624 [hep-ph].

D. Boito, O. Catà, M. Golterman, M. Jamin, J. Osborne and S. Peris
Issues in Determining α_s from Hadronic Tau Decay and Electroproduction Data,
Nucl. Phys. Proc. Suppl. 225-227 (2012) 153, arXiv:1112.4202 [hep-ph].

D. Boito, O. Catà, M. Golterman, M. Jamin, J. Osborne and S. Peris
Duality Violation and the $K\to\pi\pi$ Electroweak Penguin Operator Matrix Elements from Hadronic Tau Decays,
AIP Conf. Proc. 1441 (2012) 344, arXiv:1110.5562 [hep-ph].

J.R. Espinosa, C. Grojean and M. Mühlleitner
Composite Higgs under LHC Experimental Scrutiny,
Hadron Collider Physics Symposium, HCP, Nov. 14-18, 2011, Paris (France) [hep-ph/1202.1286].

M. Quirós
Higgs searches and extra dimensions,
2012QCD and High Energy Interactions
Pub. ARISF, 2012, Ed. E. Auge et al, p. 45-50.

P. Roig
Hadronic Currents for $\tau\to\eta'\pi\pi^0\nu_\tau$ and Other Decays of Interest in TAUOLA,
Nucl. Phys. Proc. Suppl. 225-227 (2012) 161, arXiv:1112.0962 [hep-ph].

P. Roig, I.M. Nugent, T. Przedzinski, O. Shekhovtsova and Z. Was
Theoretical inputs and errors in the new hadronic currents in TAUOLA,
AIP Conf. Proc. 1492 (2012) 57, arXiv:1208.4513 [hep-ph].

O. Shekhovtsova, I.M. Nugent, T. Przedzinski, P. Roig and Z. Was
MC generator TAUOLA: implementation of Resonance Chiral Theory for two and three meson modes. Comparison with experiment,
AIP Conf. Proc. 1492 (2012) 62, arXiv:1208.5420 [hep-ph].

4.6 Talks by IFAE Members and Collaborators

Experimental Division

ATLAS Group

Jalal Abdallah

- *Searches in Jet + X final states in ATLAS (including monojets, dijets, multijets results)*
  DISCRETE2012 Lisbon Jun 2012

Matteo Cavalli-Sforza

- *The discovery of the Higgs Boson: why it is so important*
  ALBA Synchrotron July 2012

Paolo Francavilla

- *Jet Physics in ATLAS*
  6th LNF Mini-workshop series: Jet Phenomenology at the LHCFrascati Jun-2012
- *The ATLAS Tile Calorimeter Performance at LHC*
  CALOR2012 Santa Fe Aug 2012

Davide Gerbaudo

- *Search for New Physics in Top-quark Final States*
  CPAN Meeting Granada Nov 2012

Vincent Giangiobbe

- *Searches in gamma + X final states in ATLAS*
  DISCRETE 2012 Lisbon Jun 2012
- *Searches for monojet and monophoton events with missing transverse momentum with the ATLAS detector*
  SUSY-12 Beijing Aug 2012

Clement Helsens

- *Searches for fourth generation fermions at ATLAS*
  4thST Leinsweiler Mar 2012

Aurelio Juste Rozas

- Searches for ttH at the LHC (and comparisons to a LC)
  LCWS2012 Texas Oct 2012
- *Higgs Discovery: an End or a Beginning?*
  May 2012 ICREA
- *The Higgs Boson Discovery: a Solution to a Massive Problem*

Institut de Ci`encies del Cosmos Colloquium UB Sep 2012
- *Search for fourth generation fermions and top quark physics (ttbar, t', b', W' -> tb, boosted top) at ATLAS* Search 2012 Maryland Mar 2012

Mario Martinez
- *Search for Dark Matter at the LHC*
  6th symposium on Large TPCs for low energy rare event detection Paris Dec 2012
- *Experimental tests of QCD (LHC+Tevatron)*
  Blois2012, Blois May 2012

Eve Le Menedeu
- *Di-Boson production and anomalous couplings at the LHC*
  Blois 2012, Blois, May 2012

Evelin Meoni
- *Performances of the signal reconstruction in the ATLAS Hadronic Tile Calorimeter*
  XII Pisa Meeting on Advanced Detectors
  Elba May 2012

Andreu Pacheco
- *Distributed Analysis in the Atlas Collaboration*
  Talk at Atlas Software Week, June 2012
- *Distributed Analysis Update*
  Talk at Atlas Software Week, Oct 2012
- *Distributed Analysis*
  Talk at the Phisics Analysis Tools Workshop 2012
  Oct 2012

Imma Riu
- *Speakers Committee Advisory Board Report*
  ATLAS General Meeting, Montreaux Oct 2012

Valerio Rossetti
- *Searches for new physics using jets at ATLAS*
  HSQCD2012 Gatchina Jul 2012
- *Search for Dark Matter and Extra Dimensions*
  CPAN Meeting, Granada Nov 2012

Antonella Succurro
- *Search for heavy quarks at ATLAS*
  DISCRETE2012 , Lisbon Jun 2012

PIXELS Group

Sebastian Grinstein
- *Recent developments in 3D pixel detectors*
  9th International Conference on Radiation Effects on Semiconductor Materials Detectors and Devices
  Florence, Italy, Oct 9-12, 2012
- *QCD Results from ATLAS*
  Lake Louise Winter Institute, Lake Louise Alberta, Canada, Feb 18-24, 2012

Andrea Micelli
- *Non uniform irradiation of CNM 3D sensors for AFP*
  21st RD50 Workshop CERN, Geneva Nov 12-16, 2012

Neutrino Group

Thorsten Lux
- *An APD Readout for a EL Detector Based on Xenon*
  IEEE NSS/MIC, Los Angeles, United States ¨of America, 2012

Federico Sanchez
- *Review of recent neutrino physics results*
  ISMD 2012, Kielce (Poland) 16-21 Sep 2012
- *Results from the T2K/ND280 TPC*
  6th symposium on large TPCs for low energy and rare event detection, Paris(France), 17-19 December 2012
- *"T2K", European Strategy for Neutrino Oscillation Physics*
  CERN, 14th-16th May 2012

MAGIC /CTA Group

Jelena Aleksić
- *Energy-Dependent Likelihood: an optimized analysis approach for indirect Dark Matter searches,*
  darkattack2012 , Ascona, Switzerland, Jul 15-20, 2012.
- *Optimized analysis approach for indirect Dark Matter searches with IACTs*
  Physik-Department Seminar, TUM, Garching, Germany, Nov 13, 2012.

Juan Cortina
- *Gamma rays*
  XL International Meeting on Fundamental Physics, Benasque, May 24 - Jun 3, 2012

Gianluca Giavitto
- *VHE gamma-ray measurements of the Crab Nebula and Pulsar by MAGIC,*
  5th International Symposium on High-Energy Gamma-Ray Astronomy *(Gamma2012)* Heidelberg, Jul 9 - 13, 2012

Manel Martinez
- *High Energy messengers*
  Third meeting of the Astroparticle Physics International Forum, London, UK, Apr 26-27, 2012.
- *IACTs: the dawn of VHE gamma ray astronomy*
  100 Years of Cosmic, Bad Saarow/Pieskow, Berlin, Germany, Aug 5-8, 2012.
- *CTA overview*
  Plenary sesión of the CTA General Meeting, Rome, Italy, Oct 22-26, 2012.

Abelardo Moralejo
- *Fundamental Physics with future gamma-ray observatories*
  XL International Meeting on Fundamental Physics, Benasque, May 24 - Jun 3, 2012

Ignasi Reichardt
- *Cosmic Ray Acceleration in W51C Observed with the MAGIC Telescopes*
  2nd Sant Cugat Forum on Astrophyisics, Apr 16-19, 2012.

DES/PAU Group

Enrique Fernández

- *Award Ceremony of the Prizes to "Entrepreneur Spirit", given by the Company TreeLogic, Oviedo (Spain)*
  May 2012.Royal Academy of Sciences, Madrid (Spain), Feb 2012.

Pol Martí

- *Photo-z Study for PAU@WHT Survey*
  Reunión de la Sociedad Española de Astronomía, València (Spain), Jul 2012

Ramon Miquel

- *PAUS (Physics of the Accelerating Universe Survey) and PAUCam at the William Herschel Telescope*
  Science with the optical-infrared telescopes at CAHA and ORM in the coming decade Madrid (Spain), March 2012.
- T*he PAU Survey at the WHT*
  International Workshop on Modern Cosmology: Early Universe, CMB, and LSS
  Benasque (Spain), Aug 2012.

Theory Division

Jose Ramon.Espinosa

- *Effective potential and its aplications,(3 Lectures)*
  XV Mexican School on Particles and Fields, Sep 6-15, 2012, Puebla (Mexico)
- *First Glimpses of Higgs' face*
  XVIII IFT-UAM/CSIC Xmas Workshop on Particle Physics, Dec 18-20, 2012, Madrid (Spain)
- *Fit to Higgs Couplings*
  Higgs Hunting 2012, Jul 18-20, 2012, Orsay (France)

Christophe Grojean

- Hadron Collider Physics Symposium (HCP) 2012, Kyoto, Japan, Nov 2012
- Higgs Coulings (HC) 2012,
  Tokyo, Japan, Nov, 2012
- *Lezioni Avanzate di Campi E Stringhe*
  (LACES), graduate school, GGI, Florence, Italy, Dec 3-21, 2012. (10h lectures).
- *LHC Higgs Cross Section workshop*,
  CERN, Switzerland, Dec 4-5, 2012

Matthias Jamin

- *α_s from tau decays*
  Xth Quark Confinement and the Hadron Spectrum, Garching, Germany, Oct 2012
- *α_s from tau decays*
  Quantum Chromodynamics: History and Prospects, Oberwölz, Austria, Sep 2012
- *Determination of α_s from tau's*
  XL International Meeting on Fundamental Physics, Benasque, Spain, May 2012
- *α_s determination from tau decays*
  DESY Zeuthen, Germany, June 2012 (Seminar)

Mariano Quirós

- *Higgs at LHC and BSM*
  Invited talk at Plenary Session in "IV CPAN DAYS", Granada, Spain,27 Nov 2012
- *Neutrino anarchy in warped space*
  Invited talk at Plenary Session in "High Energy Physics Workshop",Nicosia, Cyprus, 28-30 Sep 2012
- *Higgs searches and extra dimensions*
  Invited talk at Plenary Session in "QCD and High Energy Interactions", Moriond 2012, LaThuile, Italy, March 10th-March 17th 2012.

Oriol Pujolas

- *Infra-red modifications of gravity*
  May 27-June 1 2012, in "24th Rencontres de Blois, Particle Physics & Cosmology" Blois, France
- *Holographic Quantum Hair: implications for superconductivity* in "Holography: *applications to Technicolor, condensed matter and hadrons* (HATCH 2012)" INR RAS, Moscow (Russia)
- *Emergent Lorentz Invariance* -
  February 16 2012, Scuola Normale Superiore, Pisa, Italy.
- *Emergent Lorentz Invariance*
  April 25 2012,LMU Munich, Germany-
- *Emergent Lorentz Invariance*
  Universitat de Barcelona June 11 2012

Pablo Roig

- *Theoretical basis of the new hadronic currents in TAUOLA*
  Frascati, Italy, Apr 2012 (MC WG meeting)
- *New hadronic form factors in TAUOLA*
  IFAE, May 2012 (Seminar)
- *Resonance Chiral Lagrangians and hadronic currents: Theoretical uncertainty*
  Krakow, Poland, May2012 (Tau lepton decays Workshop)
- *New hadronic form factors in TAUOLA*
  Benasque, May 2012 (International Meeting Fundamental Physics+Flavour Mini-Workshop)
- *New hadronic form factors in TAUOLA*
  La Biodola, Elba, Italy, May 2012 (super-B Coll. Meeting)
- *New hadronic form factors in TAUOLA*
  IFIC, Valencia Jun 2012 (Seminar)
- *New hadronic form factors in TAUOLA*
  CINVESTAV, DF, Mexico Aug 2012(Seminar)
- *A model of duality violations on the spin-one spectral functions*
  Nagoya, Japan, Sep 2012 (TAU'12).

4.7 Participation in External Committees

Experimental Division

Oscar Blanch

- Member of the MAGIC Executive Board
- Convener of LST-CAM working group in CTA

Martine Bosman

- ATLAS Collaboration Board Chair
- Member of Plenary ECFA (European Committee for Future Accelerators)
- Chair of the International Advisory Committee of the TOP2012 International Workshop on Top Quark Physics (Winchester, UK)
- Member of the selection board of CERN PH fellows and associates

Matteo Cavalli-Sforza

- Chair, Scientific Committee, Laboratori Nazionali di Frascati, INFN (Italy)
- Chair, AERES Review committee LPNHE, Paris (France)
- Spanish Representative, Restricted European Committee for future Accelerators

Juan Cortina

- Spokesman of MAGIC experiment.
- Representative for Astroparticle Physics in Executive Committee of CPAN (Centro Partículas, Astropartículas y Nuclear).
- SOC 2nd CTA LINK meeting, Buenos Aires, Nov 19-21 2012.

Sebastian Grinstein

- ATLAS 3D R&D Collaboration Test-beam coordinator
- 3D Sensor publications bureau member
- IBL Executive Institute Board member

Aurelio Juste

- Member of the Scientific Committee of the OCEVU LabEx (Origins, Constituents, and EVolution of the Universe), France.

Stephan Klepser

- Deputy Software Coordinator of the MAGIC experiment (until February)
- Member of the MAGIC Software Board

Manel Martínez

- Co-Spokesman of CTA Consortium
- Manager of MAGIC Common Fund (until October)
- Spanish Delegate in APIF (Astroparticle Physics International Forum) of OECD.
- Member of the Scientific Advisory Committee of ApPEC.
- Member of the "Expert Committee" for the FPA National Program.
- SOC of "High Energy Gamma-Ray Astronomy", Heidelberg. Germany, 9-13 July 2012.

Mario Martinez

- Representative of IFAE in Collaboration Board of ATLAS
- Representative of IFAE in Collaboration Board of CDF
- Member of International Advisory Committee (Physics LHC Conference 2012)
- Chair of the First Large Hadron Collider Physics Conference (LHCP2013)
- Member for DOE/NSF LHC Operations program review panel
- Member of DOE/NSF Energy Frontier Laboratory Research Review Panel
- Referee of Physical Review D Journal

Daniel Mazin

- MAGIC Upgrade Manager and as such member of the - MAGIC Executive Board and member of MAGIC Collaboration Board.
- Member of the MAGIC Speakers' bureau
- Member of the MAGIC Time Allocation Committee
- Member of the MAGIC Technical Board
- Convener of the EBL-COSMOLOGY physics group in CTA

Abelardo Moralejo

- Representative of IFAE at the CTA Consortium Board
- Chair of the MAGIC Speakers' bureau
- Member of the MAGIC software board

Ramon Miquel

- Spanish representative in DES Management Committee
- Chair of the Speakers' Bureau of the DES Collaboration
- External referee for the review committee of the cosmology group at the Laboratoire de Physique Nucléaire et des Hautes Energies (LPNHE), Paris, France, Jun 2012

Andreu Pacheco

- Atlas Distributed Computing Coordination (ADC-Coord) since May 2012.
- Atlas Institute Computing Board (ICB) as Spanish representative in 2012.
- Worldwide LHC Collaboration Board (WLCG-CB) as deputy representative.

Cristobal Padilla

- Member of the ATLAS Speakers Committee
- Member of the ECFA detector Panel

Javier Rico

- Representative of IFAE in Collaboration Board of MAGIC experiment
- Member of the MAGIC Time Allocation Committee
- Coordinator of MAGIC's Data Center
- Manager of MAGIC Common Fund (since November)

Imma Riu

- Spanish representative in the Advisory Committee of CERN Users
- Chair of the ATLAS Speakers Committee Advisory Board

Julian Sitarek
- Deputy Software Coordinator of the MAGIC experiment (since March)
- Member of the MAGIC Software Board
- Member of the MAGIC Technical Board (since February)
- Member of the review committee for the DRS4 development for the MAGIC upgrade

Veronica Sorin
- CDF Spokesperson election committee

Victor Stamatescu
- Member of MAGIC Software Board

Theory Division

Jose Ramon Espinosa
- Reviewer of the Natural Sciences and Engineering Research Council of Canada, NSERC Discovery Grant Applications

Christophe Grojean
- Member of the International Detector Advisory Group

4.8 IFAE Colloquia in 2012

Results from Dark Matter direct detection experiments and their interpretation
January 30
Speaker: Thomas Schwetz-Mangold (Max-Planck-Institute for Nuclear Physics)

ASPERA updates its roadmap
February 27
Speaker: Manel Martinez (IFAE)

Quantum states of matter and anti-matter in gravitational and centrifugal potentials
April 16
Speaker: V.V. Nesvizhevsky (Institut Laue-Langevin, Grenoble, France)

The search for permanent electric dipole moments
May 14
Speaker: Klaus Kirch (ETH Zürich – PSI-Villigen)

Supernova Cosmology: where is the systematic floor?
September 17
Speaker: Reynald Pain (LPHNE, Universite Pierre et Marie Curie, Paris)

What we have learnt from the Ultra High Energy Cosmic rays in the XXI century?
October 8
Speaker: E. Zas (Universidad de Santiago de Compostela & IGFAE)

Cosmological implications of the Higgs discovery
December 3
Speaker: Toni Riotto (Geneva University)

4.9 IFAE Seminars in 2012

Natural SUSY endures
January 17
Speaker: Michele Papucci (LBL Berkeley)

Consistent MUED for the LHC
January 27
Speaker: Jesus Moreno (IFT, Madrid)

The Galileion
February 20
Speaker: Enrico Trincherini (SNS, Pisa)

Neutron stars as laboratory for dense matter
March 2
Speaker: Laura Tolos (ICE/UAB)

The Next-Generation Infrared Spectrograph for the GTC
March 7
Speaker : Stephen S. Eikenberry (University of Florida)

The static energy renormalon from high order perturbative expansions
March 9
Speaker: Clemens Bauer (University of Regensburg, Germany)

News from last week's Moriond conference on EW interactions
March 15
Speaker: Carla Biggio (IFAE)

Interpreting Higgs results
March 16
Speaker: Adam Falkowski (Orsay)

SUSY searches at LHC, presented at Moriond EW 2012
March 21
Speaker: Ernesto Arganda

Chiral effective theory with a light scalar and lattice QCD
March 23
Speaker: Pedro Talavera (Universitat de Barcelona)

Higgs searches with the CMS detector at LHC
March 30
Speaker: Prof. Guenakh Mitselmakher (University of Florida)

Minimal Flavor Violation without R-parity
March 30
Speaker: Marco Nardecchia (DIAS, Denmark)

Three-magnetic fields
April 13
Speaker: Federico Urban (University of British Columbia, Canada)

Predicting the Higgs mass from Inflation models
April 20
Speaker: Alessio Notari (Universitat de Barcelona)

Self-healing of unitarity violations
April 25
Speaker : Matthias Jamin (IFAE)

Relations between anomalous and even-parity sectors in AdS/QCD
May 4
Speaker: Juan Jose Sanz Cillero (Universita' di Bari)

New hadronic form factors in TAUOLA
May 11
Speaker: Pablo Roig (IFAE)

Dark radiation and sterile neutrinos
May 18
Speaker: Jan Hamann (University of Aarhus, Denmark)

Closing in on Asymmetric Dark Matter
May 25
Speaker: Paridi Paradisi (CERN)

Seiberg duality versus hidden local symmetry
June 22
Speaker: Steven Abel (Durham, UK)

Neutrinos and dark matter
June 29
Speaker: Viviana Niro (UB)

Magnetic fields, chiral anomalies and lepton asymmetry
October 5
Speaker: Oleg Ruchayskiy (CERN)

Non-Abelian discrete gauge symmetries in String Theory
October 11
Speaker: Pablo González Cámara (Barcelona Univ.)

Holography of the Weyl semi-metals
October 26
Speaker: Umut Gursoy (CERN)

Hitting a Natural Higgs in SUSY
October 31
Speaker: Chris Wymant (University of Durham)

Gamma ray astronomy and the origin of galactic cosmic rays
November 5
Speaker: S. Gabici (Laboratoire APC - CNRS/Université Paris 7)

The vacuum wave functional for Yang-Mills theory in 3 dimensions
November 7
Speaker: Sebastian Krug (IFAE)

BSM theories face Higgs coupling data
November 15
Speaker: Sandeepan Gupta (IFAE)

Lattice input on the tau V_us determination puzzle
November 16
Speaker: Kim Maltman (York University (CA) and Adelaide University (Aus)

Current status of gamma-ray dark matter searches with Fermi/LATst
November 21
Speaker: Miguel Ángel Sánchez Conde (KIPAC- SLAC National Accelerator Laboratory)

Issues in alphas determinations from tau decays
November 23
Speaker: Diogo Boito (Technische Universität München)

Gravitational waves from first order phase transitions
November 30
Speaker: Chiara Caprini (Institut de Physique Théorique, CEA Saclay)

Inflation, non-Gaussianity and conformal symmetries
December 5
Speaker: Toni Riotto (Geneva University)

First results from the Double Chooz experiment
December 19
Speaker: Pau Novella (CIEMAT)

On the factorization of the scattering of W bosons
December 19
Speaker: Roberto Franceschini (University of Maryland)