IFAE

Institut de Física d'Altes Energies

Report of Activities

2009

CONTENTS

Presentació

Benvinguts a l'Informe 2009 de l'IFAE, l'Institut de Física d'Altes Energies!

Les investigacions de l'Institut s'ocupen de qüestions fonamentals sobre el món que ens envolta, com ara: Quina és la naturalesa última de la matèria? De què està fet el Cosmos? Com ha anat evolucionant al llarg dels seus gairebé 14 mil milions d'anys de vida?

Aquestes preguntes han existit des dels inicis de la humanitat i han estat debatudes per igual per filòsofs orientals i occidentals. En els últims temps, hi ha hagut grans progressos en la resposta en aquestes preguntes, gràcies a les noves eines teòriques, experimentals i tècniques disponibles. En aquesta dècada, disciplines com la física de partícules, l'astrofísica i la cosmologia, al centre de la nostra recerca, es preparen per a un desenvolupament revolucionari.

Un es pot preguntar: per què dedicar fons públics en aquests activitats?
És ben sabut que la recerca en física fonamental ha tingut enormes conseqüències sobre l'economia mundial i la vida quotidiana: els ordinadors, les tecnologies mèdiques avançades, l'ús universal d'Internet són exemples obvis. Igual d'important, al meu entendre, és que les respostes a les preguntes fonamentals que volem aclarir influeixen profundament en la imatge que tenim els éssers humans del nostre món, i de nosaltres mateixos. Una societat avançada ha de dedicar recursos a la física fonamental.
De més importància immediata, els sofisticats mètodes, tant teòrics com experimentals, que ensenyem als nostres estudiants de doctorat formen a una nova generació de joves científics i tecnòlegs competitius a nivell internacional, amb obvis beneficis per a la nostra comunitat local i per al seu prestigi. Al voltant de la meitat dels doctors que es graduen cada any a l'IFAE s'uneixen a la comunitat científica internacional, molts d'ells en institucions de recerca de classe mundial, mentre que la resta troba feina en empreses d'alta tecnologia. Aquesta contribució a la societat és, en la nostra opinió, tan important com les contribucions al progrés de les nostres disciplines.
A més, a l'IFAE, treballem sobre les aplicacions dels nostres coneixements experimentals a tècniques de diagnòstic mèdic. En l'última dècada, hem desenvolupat noves tecnologies d'imatges de raigs-X, que una empresa "spin-off" de l'IFAE està aplicant a mamografia. Seguim investigant activament altres idees en aquest camp.

Finalment, vull assenyalar que el 2009 ha estat un any especialment interessant, ja que diversos esforços a llarg termini han començat a donar els seus fruits. Alguns exemples:
- El nou col·lisionador de protons LHC del CERN i el seu programa experimental, del qual som un participant molt fort i visible, va tenir un exitós començament.
- El nostre programa d'Astrofísica a Canàries ha iniciat una nova etapa, amb un segon telescopi. A més, el grup de l'IFAE està entre els líders d'una nova proposta a nivell mundial per a una gran matriu de telescopis.
- Un nou i prometedor enfocament per a tomografia per emissió de positrons (PET) ha obtingut una prestigiosa "Advanced Grant" del European Research Council.

Aquests i altres desenvolupaments, juntament amb els aspectes institucionals de les nostres activitats, es descriuen amb cert detall tècnic en el present informe.

Matteo Cavalli-Sforza
Director de l'IFAE

Presentación

Bienvenidos al informe 2009 del IFAE, el Institut de Física d'Altes Energies!

Las investigaciones del instituto se enfocan en cuestiones fundamentales sobre el mundo que nos rodea, tales como: ¿Cuál es la naturaleza última de la materia? ¿De qué está hecho el Cosmos? ¿Cómo ha ido evolucionando a lo largo de sus casi 14 mil millones de años de vida?
Estas preguntas han existido desde los albores de la humanidad y han sido debatidas por filósofos orientales y occidentales por igual. En los últimos tiempos, ha habido enormes progresos en la respuesta a estas preguntas, debido a las nuevas herramientas teóricas, experimentales y técnicas disponibles para la ciencia. En esta década, disciplinas como la física de partículas, la astrofísica y la cosmología, en el centro de nuestra investigación, se preparan para un desarrollo revolucionario.

Es posible preguntarse: ¿por qué dedicar fondos públicos a tales actividades?
Es bien sabido que la investigación en física fundamental ha tenido enormes consecuencias sobre la economía mundial y la vida cotidiana: las computadoras, las tecnologías médicas avanzadas, el uso universal de Internet son ejemplos obvios. Igual de importante, en mi opinión, es que las respuestas a las preguntas fundamentales que queremos aclarar influyen profundamente en la imagen que tenemos los seres humanos de nuestro mundo, y de nosotros mismos. Una sociedad avanzada debe dedicar recursos a la física fundamental.
De mayor importancia inmediata, los sofisticados métodos, tanto teóricos como experimentales, que enseñamos a nuestros estudiantes de doctorado forman a una nueva generación de jóvenes científicos y tecnólogos competitivos a nivel internacional, con obvios beneficios para nuestra comunidad local y su prestigio. Alrededor de la mitad de los doctores que se gradúan todos los años en el IFAE se unen a la comunidad científica internacional, muchos de ellos en instituciones de investigación de clase mundial, mientras que el resto encuentra empleo en empresas de alta tecnología. Esta contribución a la sociedad es, en nuestra opinión, tan importante como las contribuciones al progreso de nuestras disciplinas.
Además, en el IFAE, trabajamos sobre las aplicaciones de nuestros conocimientos experimentales a técnicas de diagnóstico médico. En la última década, hemos desarrollado nuevas tecnologías de imágenes de rayos-X, que una empresa "spin-off" del IFAE está aplicando a mamografía. Seguimos investigando activamente otras ideas en este campo.

Por último, quiero señalar que 2009 ha sido un año especialmente interesante, ya que varios esfuerzos a largo plazo han comenzado a dar sus frutos. Algunos ejemplos:
- El nuevo colisionador de protones LHC del CERN y su programa experimental, del cual somos un participante muy fuerte y visible, tuvo un exitoso comienzo.
- Nuestro programa de Astrofísica en Canarias ha iniciado una nueva etapa, con un segundo telescopio. Además, el grupo del IFAE está entre los líderes de una nueva propuesta a nivel mundial para una gran matriz de telescopios.
- Un nuevo y prometedor enfoque para tomografía por emisión de positrones (PET) ha obtenido una prestigiosa "Advanced Grant" del European Research Council.

Estos y otros desarrollos, junto con los aspectos institucionales de nuestras actividades, se describen con cierto detalle técnico en el presente informe.

Matteo Cavalli-Sforza
Director del IFAE

Introduction

Welcome to the 2009 Report of IFAE, the Institut de Física d'Altes Energies!

The research of our Institute addresses fundamental questions about the world around us, such as: What is the ultimate nature of matter? What is the Cosmos made of? How did it develop over its close to 14 billion year life?
These questions have been around since the dawn of humanity and have been debated by western and eastern philosophers alike. In modern times, there has been enormous progress in answering these questions, due to the theoretical, experimental and technical tools that have become available to science. In this decade, disciplines such as particle physics, astrophysics and cosmology, the mainstays of our research, are poised for revolutionary developments.

One may ask: why devote public funding to such activities?
It is well-known that fundamental physics research has had enormous consequences on world economy and on everyday life: computers, advanced medical technologies, the universal uses of internet are obvious examples. Just as important, in my view, is that the answers to the fundamental questions we strive to clarify deeply influence the image that we humans have of our world, and of ourselves. An advanced society must devote resources to fundamental physics.
Of more immediate relevance, the sophisticated theoretical and experimental methods we teach to our doctoral students form a new generation of internationally competitive young scientists and technologists, with obvious benefits to our local community and to its prestige. About one-half of the PhDs who leave IFAE every year join the international scientific community, many of them in world-class research institutions, while the others find employment in high-tech companies. This contribution to society is in our opinion as important as the contributions we give to the progress of our disciplines. In addition, at IFAE we work on applications of our experimental know-how to medical diagnostic techniques. Over the last decade, we developed novel X-ray imaging technologies, which are being applied to mammography by an IFAE spinoff. Further ideas in this field are being actively investigated.

Last, I wish to point out that 2009 has been a particularly exciting year, as several long-term efforts have begun bearing fruit. Just to mention a few highlights:
- The new CERN proton collider (LHC) and its experimental program, of which we are a strong and very visible participant, had a successful start.
- Our astrophysics program in the Canary Islands has entered a new phase, with a second telescope. In addition, the IFAE group is among the leaders in proposing a new world-wide array of telescopes.
- A novel and promising approach to Positron Emission Tomography has obtained a prestigious advanced grant from the European Research Council.

These and other developments, together with the institutional aspects of our activities, are described in some technical detail in this Report.

Matteo Cavalli-Sforza
Director of IFAE

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 a legal entity with its own "juridical personality". Functionally it depends from the Department of Innovation, Universities and Enterprises (DIUE, formerly DURSI) 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 integrates its own personnel with that of 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. At present, this component of the Institute consists of six ICREA research professors (with continuing tenure) and two ICREA researchers.
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 is formed by most of the members of the theory group of the Physics Department of the UAB, and by three ICREA research professors. The personnel of the Experimental Division is from IFAE itself, from the UAB and from ICREA, with three research professors and two investigators.

IFAE has also 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 doctoral courses.

1.2 IFAE Goals

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 use effectively the CERN laboratory, after Spain rejoined the CERN organization 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 the IFAE.

In the following years the experimental division of IFAE grew from a staff of 10 to its present strength of about 70. The experimental program has expanded both in the number of projects and in their scope. In 1992 the group was involved in just one experiment in high energy particle physics, ALEPH at LEP, while at present there are three main themes of fundamental research: particle physics at high energy accelerators, gamma-ray astrophysics, and observational cosmology. In addition, there is a small but well-established 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 DIUE) 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 has been charged by the other partner institutions with the administration of PIC. There is a very close collaboration with PIC on the computational side 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 to emphasize 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:

1. 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, whose construction will be completed in 2010. The project was jointly approved in 2003 by the Spanish Government in Madrid and the Catalan Government.

2. 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.

3. 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.

4. 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 rder to measure parameters of cosmological interest by means of novel observational tools.

1.3 IFAE Governing Board

President

Joan Majó Roca
Commissioner for Universities and Research, D.I.U.E.

Members

Joan Roca Acín
Director General for Research, D.I.U.E.

Ramon Moreno Amich
Director of CERCA Program, D.I.U.E.

Jordi Marquet Cortés
Deputy Rector for Strategic Projects, U.A.B.

Ramon Pascual de Sans
Professor of Physics, U.A.B.

Joaquim Gomis Torné
Professor of Physics, U.B.

Director

Matteo Cavalli-Sforza
Research Professor, IFAE

Adjunct Director

Ramon Miquel Pascual
Research Professor, ICREA

2. Scientific Activities in 2009

Outline

The Experimental Division

During 2008 the Experimental Division's activities focused on eight major 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 three major, long-term projects:

- **ATLAS,** a general-purpose experimental facility at the Large Hadron Collider of CERN, the European Center for Particle Physics, which will began operations at the startup of the LHC in November 2009;
- **CDF,** a proton-antiproton collider experiment currently taking data at the Fermi National Accelerator Lab (Illinois, USA);
- **T2K**, a neutrino long base-line experiment in Japan, that also started in 2009. In addition, a new project to search for double-beta decay processes in the Canfranc underground laboratory was launched.

In Astrophysics, a running experiment was upgraded, while a new very large facility is being designed:

- **MAGIC**, an experiment in gamma-ray astrophysics and astroparticle physics is taking data at the Canary Islands, while completing a second telescope,that began operating in 2009;
- **CTA**, a multi-telescope array to be built in the next decade, is being designed.

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

- **DES** (Dark Energy Survey), is building a camera for a telescope at Cerro Tololo (Chile) in order to perform cosmology studies by observing about 300 million galaxies.

- **PAU** (Physics of the Accelerating Universe) is a Spanish collaboration formed under the auspices of a Consolider project that will perform cosmology studies by observing the Northern sky with a new camera, to be located at an existing telescope.

On the Applied Physics front, a group continues the research 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 late 2009, this group obtained a prestigious ERC four-year grant, to explore a novel approach to Positron Emission Tomography

The Theory Division

The activities of the Theory Division during 2008 fall into three broad lines: Standard Model, Beyond the Standard Model and Astroparticles/Cosmology.

Standard Model

In the present LHC era Flavour Physics will play an important complementary role in the search for the fundamental theory that lies beyond the SM. The precision of predictions in Flavour Physics depends crucially on deepening our understanding of QCD. Consequently, our lines of research in 2008 focused mainly on different aspects of QCD, from more LHC oriented research to more formal ones.

Beyond the Standard Model

The main goal of research in Physics Beyond the Standard Model (BSM) at IFAE is to explore extensions of the Standard Model at the TeV scale and therefore testable at the LHC. We focus our efforts on theoretically well motivated scenarios (Supersymmetry, extra dimensions) or in models that lead to unconventional collider signals (Unparticles, strongly coupled theories). We also apply BSM techniques, like AdS/CFT to better understand QCD.

Astroparticles/Cosmology

The general goal of this research line is to study theoretical issues in elementary particles and their interactions, particularly when they occur in an astrophysical or cosmological medium. In 2009, work has focused on baryogenesis in the minimal supersymmetric model, on the link between Higgs properties and the early universe, and the gravitational properties of vacuum energies, relevant for the cosmological constant problem.

2.1 ATLAS at the CERN LHC

Martine Bosman

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. The year 2009 has been a very special year with the first LHC proton-proton collisions registered in December 2009.

Data were taken first at 900 GeV center of mass energy and then at 2.36 TeV setting a new world record and opening the field for the first physics measurements.

Fig. *1* shows an example of one the first proton-proton 900 GeV collision events in ATLAS with two clearly identified jets.

Before LHC startup, during the course of the year 2009, large samples of cosmic rays data were recorded by ATLAS; they were used for commissioning the detector, the data acquisition system and the full software chain of data processing and distribution. Fig. *2* shows a mosaic of ATLAS 2009 data analysis results. IFAE has been actively involved in many of them as described in the following paragraphs.

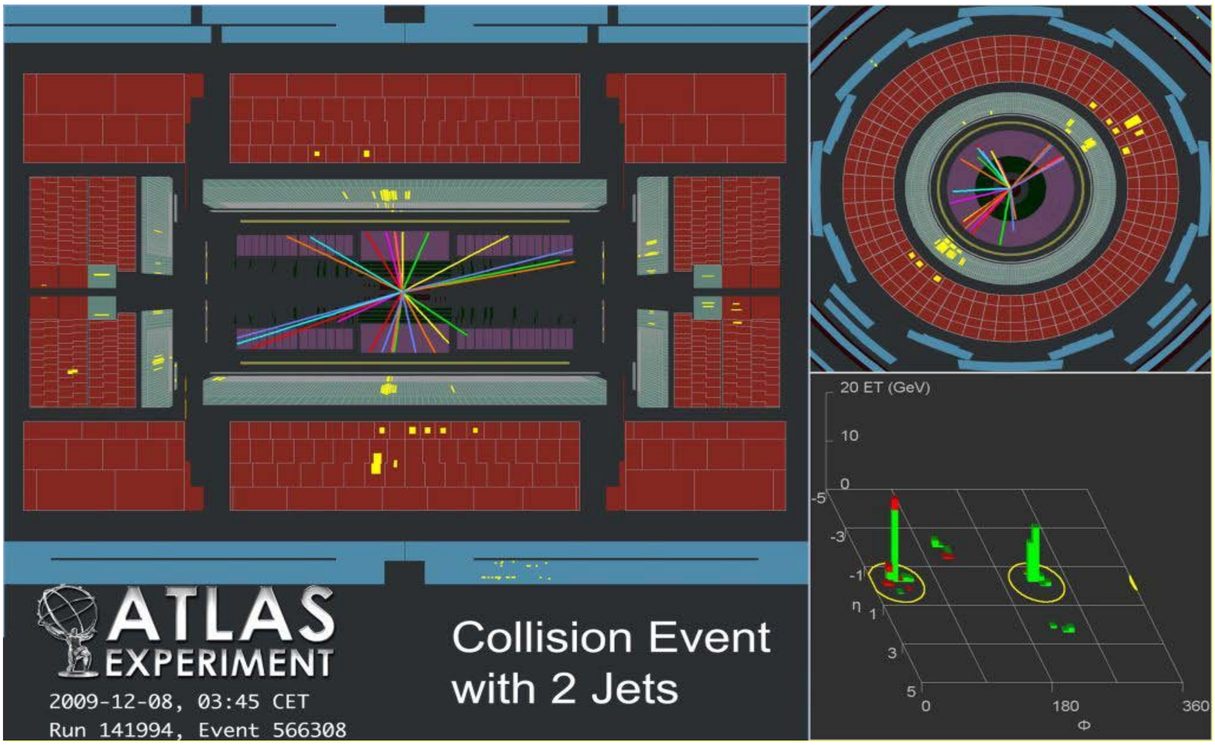

Fig. 1 Proton-proton collision event registered by the ATLAS experiment featuring two clearly identified jets.

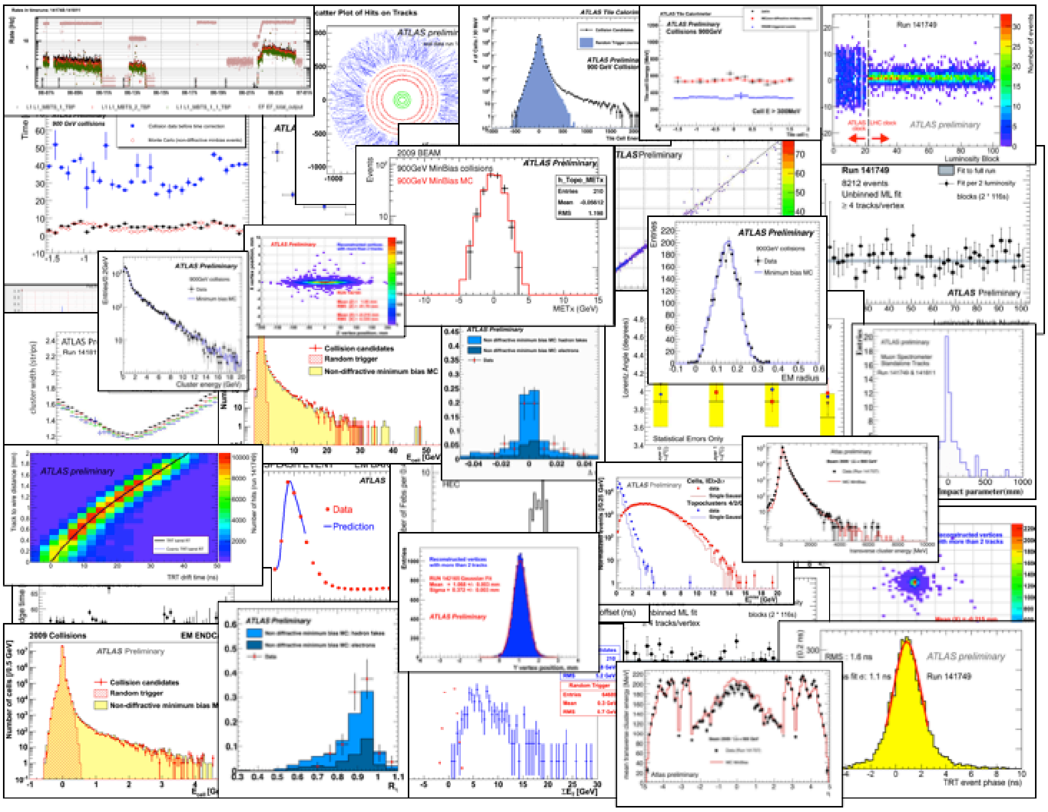

Fig. 2 Mosaic with ATLAS approved results related to the data obtained in year 2009.

TileCal Hadron Calorimeter Activities

The TileCal activity of the IFAE group in 2009 focused on the Data Quality assessment, Detector Operation and Calibration. IFAE members acted as Tilecal Calibration Coordinator, Run Coordinator and Deputy during 2009.

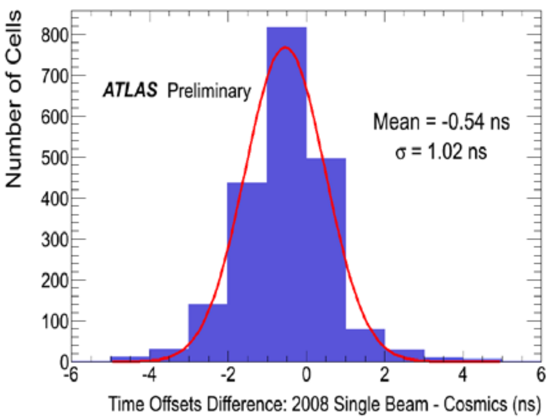

Fig. 3 Difference of time offsets seen in the single beam and cosmic data.

The large set of Cosmic Ray data was analyzed to extract precise information on the energy and timing calibration of the calorimeter.

An important contribution of the IFAE group was the complete calibration of the Tile timing response. A set of analyses performed on cosmic ray data and on single beam LHC data permitted to calibrate the timing of Tilecal to an accuracy of 1 nanosecond per channel, as illustrated in figure 3.

IFAE also played a key role in the definition of the deposited energy in the calorimeter cells and a correct description of the noise in the calorimeter as illustrated in figure 4.

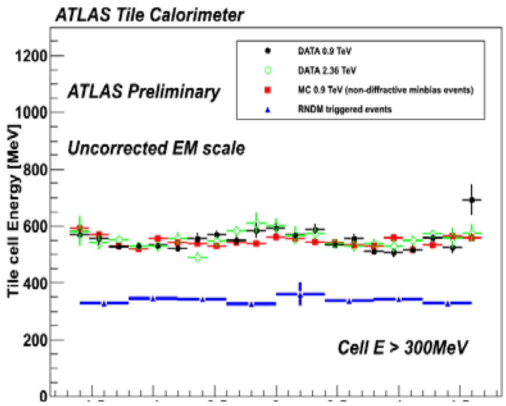

Fig.4 Average Tile cell energy as a function of η in collision candidate events. Only cells energies above 300MeV are considered. Randomly triggered events with the same energy cut are superimposed with the collision candidate events and non-diffractive minimum bias Monte Carlo.

The minimum bias monitoring system, under IFAE's responsibility with its electronics and software, was fully commissioned, pre-calibrated and integrated into the global ATLAS monitoring framework.

High Level Trigger and Central Data Quality Activities

The IFAE group holds responsibilities in the ATLAS High Level Trigger (HLT) system comprising the software based 2nd and 3rd level trigger running in two large computer farms. IFAE played an important role in the overall coordination of trigger operation, in the commissioning of the infrastructure software and the integration of trigger algorithms helping to achieve an excellent efficiency already during the first data taking period.

In addition, IFAE is responsible of various aspects of the τ lepton trigger which has been commissioned in 2009 with collision and cosmic ray data. Figure 5 compares the energy of τ lepton candidates in the second level of the τ trigger chain, which is under IFAE's responsibility.

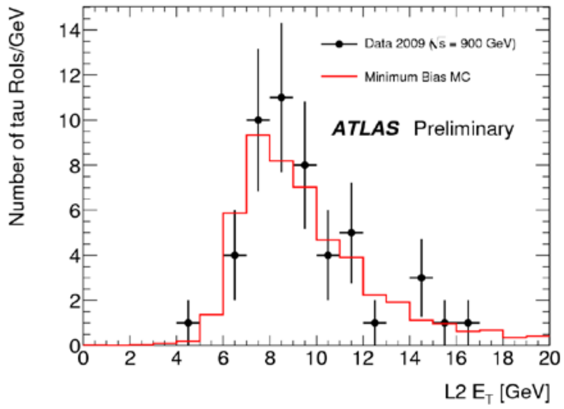

Fig.5 Comparison of the tau candidate transverse energy distribution at L2 for 900 GeV data and Minimum Bias Monte Carlo.

IFAE is also in charge of the measurement of the jet trigger efficiency. Figure 6 shows the performance of the Level 1 Jet trigger with 900 GeV data.

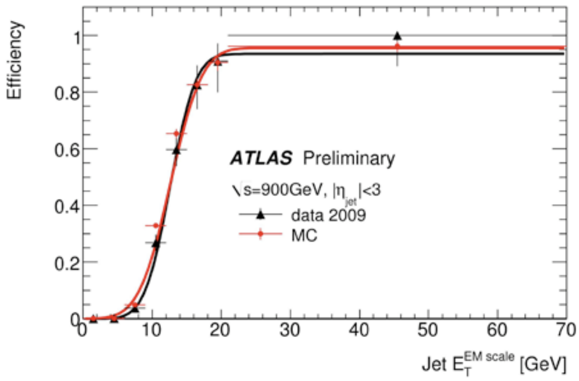

Fig. 4: Efficiency of the Level 1 trigger selecting jets above 5 counts (~ 5 GeV) as a function of the offline jet p_T at the EM scale.

In addition, IFAE has been actively involved in central DQ operations. Among other tasks, IFAE coordinated DQ activities during 2009 cosmic data taking.

Preparation for Physics and First Data Analysis

The LHC mission is to search for the Higgs boson and physics beyond the Standard Model (SM) like, for example, supersymmetry (SUSY). However, SM physics processes involving vector bosons

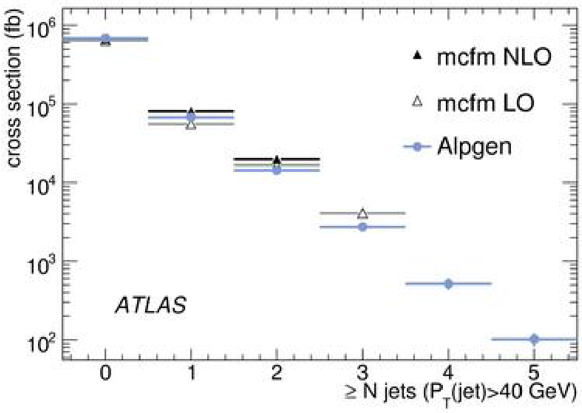

Fig. 7 Cross-section of Z boson production accompanied by jets as predicted by the Alpgen generator and compared to QCD prediction (mcfm).

(Zs and Ws) accompanied by jets, as well as top quark pair production constitute important backgrounds to these searches. IFAE developed a complete analysis to measure Z boson production in association with jets, where the Z decays either through the electron or muon channel. The study has been published and is the subject of the PhD Thesis of E. Segura defended in 2009 This analysis is now actively pursued by IFAE with data.

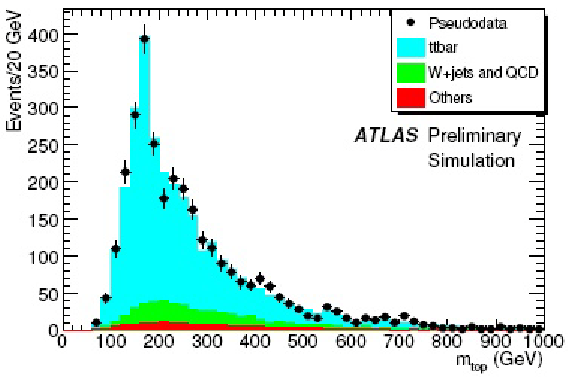

Fig. 8 Chisquare fit to the top invariant mass distribution for the muon channel, as expected in 200 pb⁻¹ of data at 10 TeV.

IFAE also developed the tools for measuring top quark pair production with subsequent decay in the channel $W(qq')W(\ell\nu)b\bar{b}$. The aim of the analysis in the electron and muon channel is to "rediscover" the top quark at LHC with the first data.

Prospects for 10 TeV collisions have been published, and the analysis is now applied to the data.

Figure 8 shows one of the results obtained in these studies. The possibility of observing top quark pair production in the τ channel has also been investigated. It was the subject of the PhD thesis of C. Osuna, defended in 2009.

A new line of analysis has been started of final states with energetic jets, and a single jet with missing transverse energy leading to searches for new physics like, for example, compositeness or the presence of extra dimensions. A proper understanding of jet reconstruction and jet energy calibration is thus mandatory. Studies of jet kinematical distribution, internal structure and energy flows away from the jets have been carried by IFAE with key participation in the analysis of the first collision data, as shown in figure 10 and figure 11.

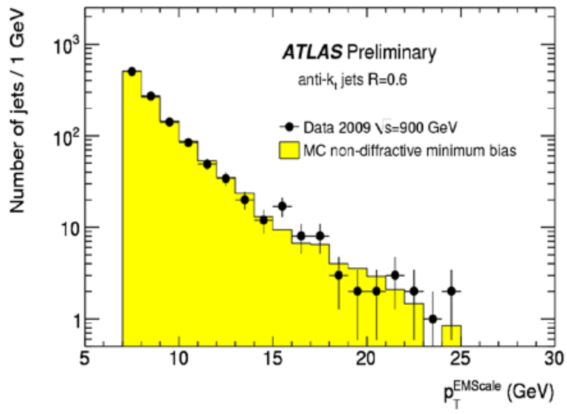

Fig. 9 Jet p_T distribution measured in 900 GeV collisions.

IFAE got also involved in the measurement of charged particles multiplicity at 900 GeV, the first physics publication of ATLAS with proton-proton collision data and subject of a PhD Thesis of an IFAE student to be completed in 2010.

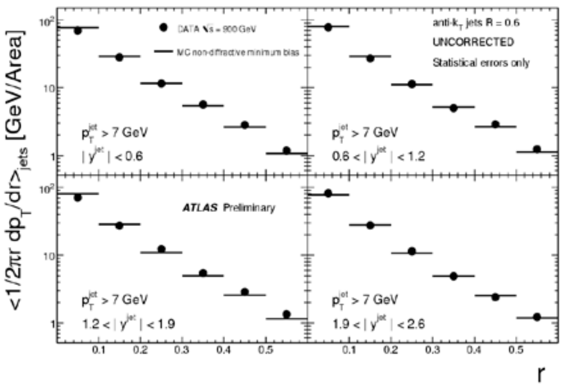

Fig.10 Measured jet profiles using calorimeter towers for jets with pT >7 in different intervals of rapidity of the jet. The data are compared to Monte Carlo simulations.

R&D for sLHC in Pixel detector technology

In 2008, IFAE started an R&D line for the ATLAS upgrade, working on the development of pixel detectors. The long-term strategy is to be amongst the main players in the construction of the new pixel detector that will be built for the sLHC upgrade at the end of the decade. ATLAS also plans to install a new pixel layer to improve the physics performance, especially for B-tagging, by 2014. IFAE will contribute to the development and construction of this detector on the fronts of sensor construction, characterization and quality control, bump-bonding techniques and power distribution chain.

IFAE started a very fruitful partnership with the Centro Nacional de Microelectrónica (CNM), which is located on the same UAB campus. This collaboration has a lot of advantages because sensor production, electronics assembly and detector testing can be done in a very efficient manner. The main advantage is a fast feedback loop when developing new sensor production technologies to meet the requirements of the sLHC environment in terms of radiation hardness, material minimization and cost-effective construction.

This development chain has already been established. Figure 11 shows the final testing stage of a pixel detector where all manufacturing steps (design, production, bump-bonding to ATLAS readout chips, wire bonding to electronics cards) have been done by the CNM/IFAE team. The tests have been performed with the equipment installed and commissioned at IFAE.

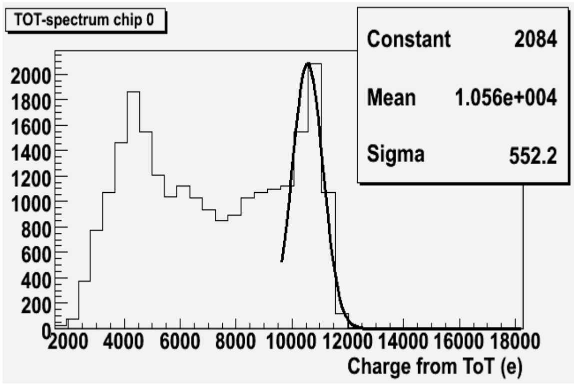

Fig.11 Response to am Am^{241} radioactive source of a pixel detector constructed, assembled and tested in collaboration with the CNM.

Computing infrastructure

The Tier-2 and Tier-3 LHC computing infrastructure of IFAE provided efficient access to the GRID resources during 2009 It gave support to all the analyses carried out at IFAE and the simulations requested by ATLAS for several of the analyses published by the collaboration. The monthly CPU power delivered by the Tier2 farm is shown in figure 12.

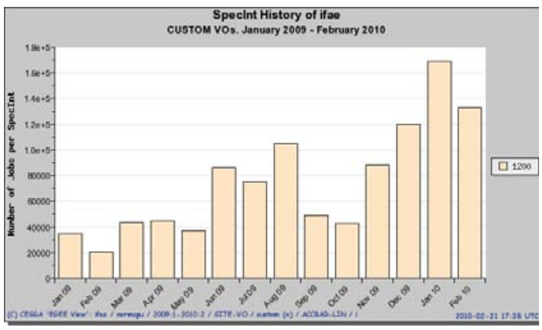

Fig.12 Monthly Computing power delivered by IFAE Tier2. At the end of 2009 and beginning of 2010 a peak on delivered resources corresponding to the first collisions can be observed.

The availability and efficiency of the Tier-2 resources has been above 92%, mostly near 100%, during the complete year 2009, in line with the commitments and requirements.

IFAE also significantly contributes to various areas of ATLAS central computing in the area of operations, physics and software validation, as well as software organization and documentation.

Fig. 13 View of the 1 PB disk storage array installed at PIC in 2009 where the data of the Tier2 is located.

2.2 The Collider Detector at the Tevatron (CDF)

Mario Martínez

After the discovery of the top quark in 1995, the Tevatron has been upgraded: the center-of-mass energy of proton-antiproton collisions has been increased from 1.8 to 1.96 TeV and its instantaneous luminosity has achieved the Run II design value of $3.5 \cdot 10^{32}/cm^2 s$. The Tevatron has already delivered a total integrated luminosity in excess of 8 fb^{-1}.

Numerous upgrades to the CDF detector were also carried out, principal among them a powerful vertex-finding trigger, and improvements to the readout electronics and DAQ in order to cope with the higher trigger and data rate. The CDF II detector is shown in figure 1.

In 2009, the IFAE group in CDF maintained its responsibilities on quality monitoring (DQM) of the data used by CDF for physics analyses. In addition the group continued its research program based on the study of events with jets of hadrons in the final state, and multi-jet events with large missing transverse energy as a signature for new phenomena like, for example, super-symmetry and SM Higgs. In addition, new measurements on prompt photon production have been carried out.

Final results on the search for squarks and gluinos were obtained, based on 2 fb^{-1} of Run II data; the measurements were published in Physical review Letters in 2009l

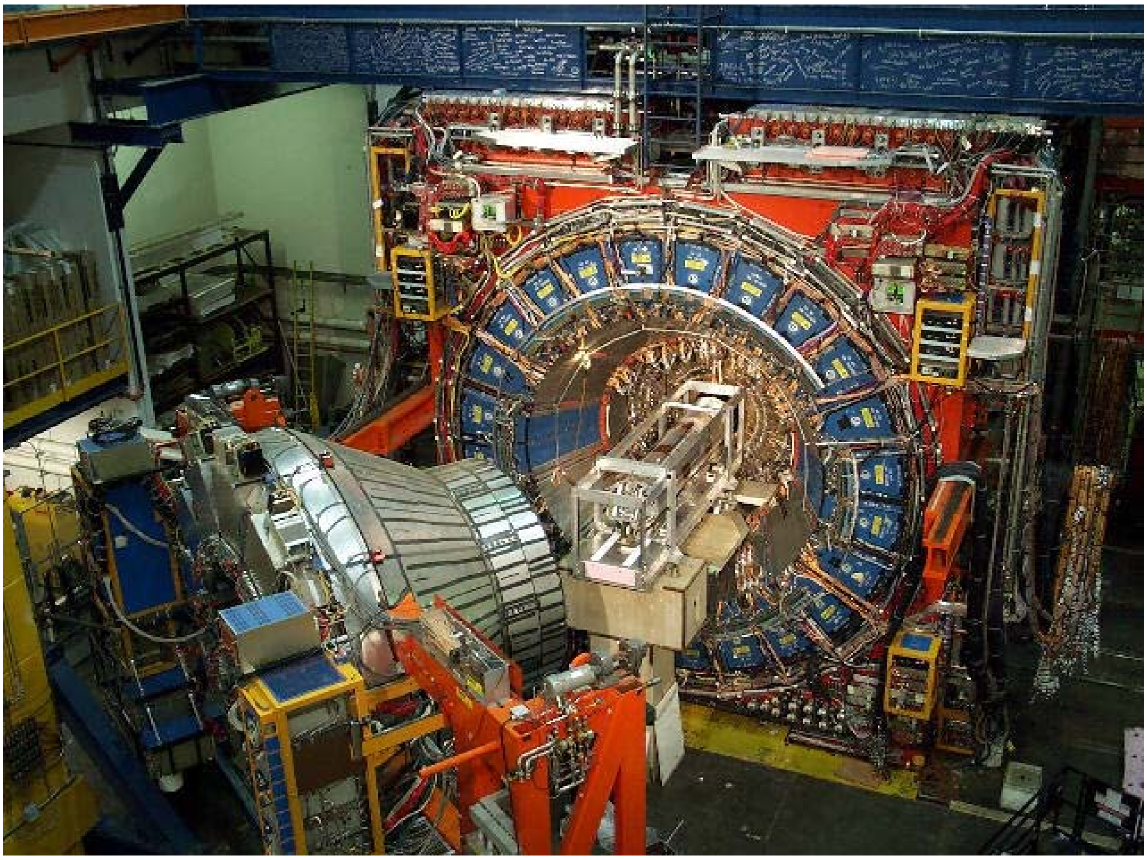

Fig. 1: The CDF Detector in Run II.

2009 and are shown in Fig. 2. The measurements are in good agreement with the SM predictions and the analysis excludes the presence of degenerate squarks and gluinos with masses below 400 GeV/c^2.

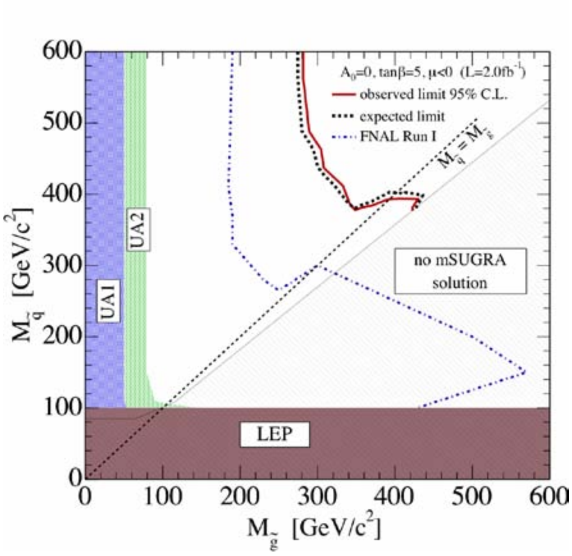

Fig. 2: Exclusion plane for squark and gluino production (as published in Phys. Rev. Letters.)

The inclusive search has its natural continuation in a dedicated search for direct bottom squark pair production. Preliminary results were presented in the Lepton-Photon conference in 2009, including new improved limits on the mass of the sbottom particle. Final results have been submitted for publication in Physical Review Letters (Fig. 3). SUSY search results are the subject of the PhD Thesis by Gianluca de Lorenzo, to be defended in 2010.

In addition, the group continued studies on Z+jets and Z+b-jet production in both the electron and muon decay channels of the Z. 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. These analyses have naturally translated into entry points to collaborate in searches for the SM Higgs boson in the ZH associated channel, with identical hadronic final states.

During 2009 members of the group completed a new measurement of the prompt photon cross section at the Tevatron. The measurement of isolated high transverse momentum photons in the final state is sensitive to the presence of new physics like, for example, Gauge Mediated SUSY breaking, as well as providing information on the gluon distribution in the proton via the dominant production process with a gluon in the initial state. The measurements have been compared with NLO pQCD predictions and no signals of new physics have been observed. The results are published in Physical Review D, and constituted the PhD Thesis of C. Deluca, defended in June 2009. The summary plot is given in figure 4.

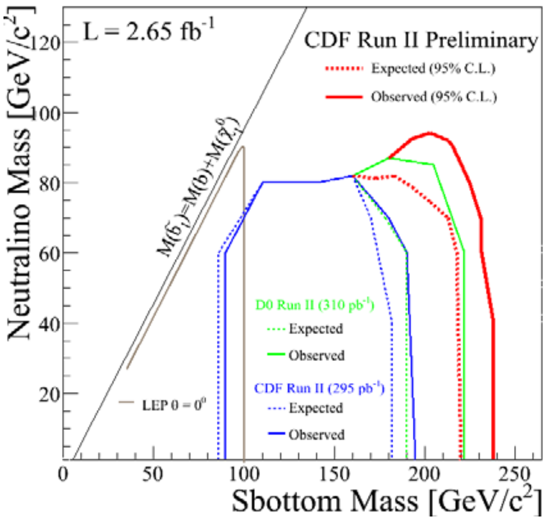

Fig. 3: Exclusion plane for sbottom pair production as a function of sbottom and neutralino masses (as presented in Lepton-Photon Conference in 2009).

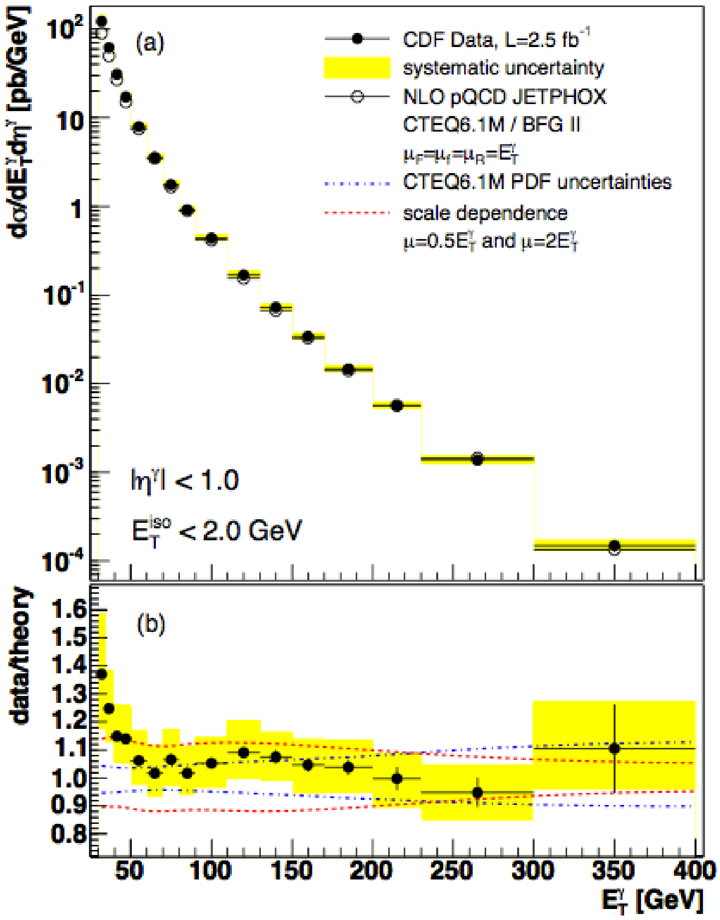

Fig.4 Measured inclusive isolated prompt-photon cross section compared to NLO pQCD predictions (published in Phys. Rev. D - Rapid Communications).

2.3 Neutrino Experiments at IFAE

Federico Sanchez

Since the discovery of neutrino oscillations at the end of the 20th century, the interest of the HEP community in neutrino physics has grown enormously. Investigations focus on several fundamental issues: the values of the oscillation parameters and of the neutrino masses, the possible CP violation effect in neutrino transitions, and the nature (Dirac versus Majorana) of neutrinos. In addition, precise measurements of the neutrino-nucleus cross sections are crucial for oscillation measurements.

The IFAE neutrino group is involved in two aspects of neutrino physics:
1. measurements of cross sections and oscillations with the T2K experiment
2. two double beta decay experiments, NEXT and SuperNemo, addressing the nature of neutrinos.

In 2009, the IFAE group organized the Sixth International Workshop on Neutrino Nucleus Interactions in the Few GeV Region (NUINT09,see http://nuint09.ifae.es), that took place in Sitges (Barcelona) on May 18 - 22, 2009. This is the main workshop series addressing theoretical and experimental advances in neutrino cross sections related to neutrino oscillation experiments. One of us chaired the workshop and was the main editor of the conference proceedings (see reference 1).

The T2K (Tokai to Kamiokande) Experiment

T2K is a neutrino oscillation experiment in which a high intensity neutrino beam from the JPARC proton accelerator center in Tokai (Japan) is sent to the SuperKamiokande detector, located 295km away in Kamioka, as shown in Fig. 1.

The neutrino beam is characterized at the near detector, 280m away from the production point (N280). Neutrino- nucleus cross-sections are also measured in ND280. The beam is almost entirely composed of muon neutrinos; the appearance in Superkamiokande of electron neutrinos would be the signal of the not-yet-observed oscillation of muon neutrinos into electron neutrinos, which would allow measuring the heretofore unknown value of the θ_{13} oscillation parameter.

The near detector, shown in figure 2, is a magnetic spectrometer that contains several sub-detectors: the P0D to detect neutral pions, the FGD and TPC mainly to detect muons and electrons, ECAL to measure photon energies, and the SMRD to stop and identify the outgoing muons.

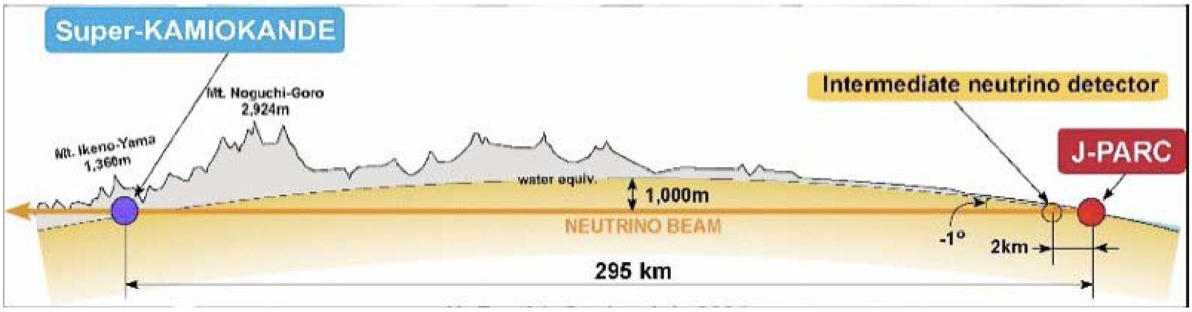

Fig 1. Geographical location of the near and far detectors of the T2K experiment.

Fig.2. View of the T2K near detector with the magnet (in red) opened so the inner detectors can be seen (aluminum boxes).

The contributions of the IFAE group to the T2K apparatus focused on the near detector, specifically on the construction of the Time Projection Chamber (TPC) and the refurbishing of the old magnet that was donated by CERN to the European members of T2K.

The TPC, shown in figure 3, is a critical component of the T2K near detector. It measures the particle momenta and identifies the particles (particularly the electrons) produced in the detector. The three TPCs for T2K were commissioned in TRIUMF (Canada) during 2009. The IFAE group contributed to the data acquisition system, to the commissioning and to the data analysis. The detector's performance was excellent. ND280's TPCs are the first in the world to employ the new technology known as micro-pattern gas detectors, specifically the MicroMegas concept. This technology allows covering large readout areas with excellent performance and low cost. The ND280 TPCs have 72 of these modules, for a total area of 8.8 m^2 and using 125,000 electronic channels. IFAE provided one third of the modules, which were produced at CERN and tested *in situ* in a test bench developed by the IFAE and the University of Geneva. IFAE also contributed to readout electronics tests. This work was published in reference [2].

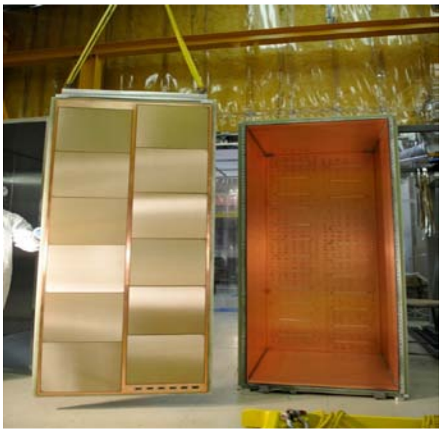

Fig. 3. Close-up view of the TPC detector installed in the T2K TPC. The left panel shows the 12 MM modules used for the TPC readout.

Fig. 4. The magnet water manifolds during installation in August 2009.

The TPCs were moved from TRIUMF to their final location at the JPARC laboratory at the end of 2009, and were operated successfully during the months of November and December. IFAE contributed to the integration of the TPC modules, taking care of the Data Acquisition System. The group also continued developing the TPC reconstruction software and coordinating the reconstruction group of the T2K near detector. One group member was also coordinating the group in charge of analyzing the neutrino charged current interactions.

In addition, the IFAE group was in charge of the construction, installation and commissioning of the magnet cooling water distribution system, shown in Fig. 4. Construction took place in the IFAE workshop in early 2009; the main leakage and pressure tests (up to 40 bar) were successfully performed there. The installation of the water manifolds was successfully carried out during summer 2009. The system, designed at IFAE, allows opening and closing the magnet without disconnecting the cooling pipes, thereby simplifying the procedure and in general the maintenance of the detector. This design was shown to be very useful, because it reduces the cost and the time involved in opening and closing the detector, without requiring the presence of a system expert during the operation.

Fig. 5 The slow control system installed in the ND280 detector. The left rack hosts all the sensor readout modules and the main control computer.

The system has been tested by opening the magnet (twice) in 2009. It operated at nominal conditions with no failures at all.

The IFAE group is responsible for the magnet slow control system, shown in Figure 5. During runs, this system monitors magnet and cooling water temperatures, the cooling water flow, system status, the coil voltage drop and the power converter status. It retrieves this information about every minute, displays it to the operator on detector shift and stores it into a database for later analysis. In addition, it detects anomalies, and in this case it switches off the magnet power and generates alarms. The system was installed in summer 2009 and was fully operative for magnet commissioning, for the field map measurements carried out in September 2009 and during the preliminary run in November 2009. The magnet has operated since then very smoothly.

The JPARC accelerator produced the first neutrino beam in April 2009, and the first interactions in the near detector were seen in November 2009. One event is shown in figure 6. T2K is finishing the commissioning phase and it will start the physics run in early 2010.

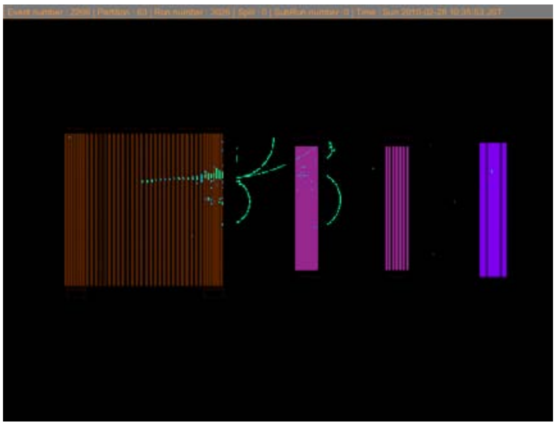

Fig.6. Neutrino interaction in the near detector of the T2K experiment.

The IFAE neutrino group also contributed to the analysis of the data obtained with the SciBoone experiment at the Fermi National Laboratory in 2008. The main topic of the analysis has been the determination of the Charged Current Quasi-Elastic neutrino-nucleus cross-section. This is the main analysis channel for low energy (< 2 GeV) neutrino oscillation experiments such as T2K and it is poorly understood at these energies. The results were presented at the NUINT'09 conference (see reference 3) and is the main topic of the PhD thesis, to be completed in 2010, of one the group's students.

Neutrino-less double beta decay

The other aspect of the group's activities is the search for neutrino-less double beta decay. In standard double beta decay two neutrons in a nucleus disintegrate simultaneously to two electrons and two antineutrinos. This process is allowed by the Standard Model (SM) and is well-established for several isotopes. In the neutrino-less version no antineutrinos are emitted. This is possible only if the neutrinos are of the Majorana type and if they have mass (a possibility that subsists only for neutrinos because they are the only neutral fermions in the SM).

The IFAE group is involved in the SuperNemo and in the NEXT experiments. The group has contributed to the understanding of the SuperNemo physics potential and has been one of the leading proponents of the new experiment NEXT.

SuperNemo continues the successful NEMO-3 experiment with a larger isotope mass and higher sensitivity. SuperNEMO uses a tracking detector in addition to a calorimeter to identify both electrons separately, thus reducing the background. In SuperNEMO, IFAE continued the development of the reconstruction software. This contribution and its application to the NEMO experiment will be the thesis topic of another student in 2010. The algorithm has been fully developed at

IFAE and already performs better than the official NEMO reconstruction software.

The NEXT experiment is an ambitious project centered on a large pressurized TPC filled with Xenon, enriched with a double-beta emitting isotope. The TPC is designed to track and to identify the electrons independently. The advantage with respect to the SuperNemo approach is that source, tracking and calorimeter devices are the same, thereby reducing losses in passive materials and improving the energy resolution by almost a factor of 10. The Canfranc Scientific Committee approved the Letter of Interest.

Fig.7. The NEXT R&D chamber in the IFAE laboratory, with gas piping and purification getters. The chamber can host up to five APDs.

The IFAE group focused on developing the Avalance PhotoDiode (APD) technology for reading out the electroluminescence light. These devices, developed by Hamamatsu, are sensitive to Xenon scintillating light emitted in the deep ultra-violet regime (172nm). The IFAE group developed a gas system with Xenon purification, a drift chamber equipped with electroluminescence devices and its readout electronics. The system, completed in 2009, will start data acquisition in 2010 and can host up to 5 APDs (see figure 7). It will be used to investigate the tracking capabilities of a plane of APDs.

IFAE also collaborated with Coimbra University in characterizing APDs and in measuring the quantum efficiency of these devices for Xenon scintillation light. These results are to be published in 2010. The first paper related to NEXT, on the linearity of scintillation light produced of Xenon at 10 bar, is also a result of the collaboration with the Coimbra group.

<u>References</u>

1. AIP Conference Proceedings Volume 1189.
2. S.Anvar et al., Nucl. Instrum. Meth. A602, 415-420, 2009.
3. J.L.Alcaraz-Aunión and J.Walding, AIP Conf. Proc. 1189: 145-150, 2009.

2.4 The MAGIC Telescopes

Juan Cortina

MAGIC is the acronym of Major Atmospheric Gamma-ray Imaging Telescopes. The two MAGIC telescopes are located at the Roque de los Muchachos Observatory in the Island of La Palma (Canary Islands). They are devoted to studying the very high energy (VHE) gamma ray sky. This sky is bright with a class of rare astronomical objects, which accelerate particles to energies in excess of 100 GeV. The study of these objects provides information about the physical mechanisms that produce such radiation, which have been a challenge to the cosmic ray community for a long time. Furthermore the propagation of the radiation over cosmological distances is sensitive to the geometry and matter contents of the Cosmos itself. Dark matter may also annihilate into VHE gamma rays, so the MAGIC telescopes may also shed light on its nature.

The two instruments detect the Cherenkov light produced by the shower of particles generated in the upper atmosphere by the incoming gamma ray. This light is reflected by a segmented 17 m diameter mirror and focussed into the camera. The camera is provided with very fast and sensitive photo-detectors. By pointing two telescopes in the same direction of the sky, the energy and direction of the incident gamma ray can be reconstructed with higher precision.

The IFAE group built the camera of the first telescope (MAGIC-I), the most sophisticated element in the instrument. MAGIC-I started regular operation in 2004 and entered its fifth cycle of observations in 2009. The second telescope (MAGIC-II) joined MAGIC-I in 2008. As we shall see further down, IFAE has built an important part of the readout electronics of MAGIC-II and is currently re-equipping the first telescope with a similar readout system.

IFAE is deeply involved in extracting physics out of the VHE gamma ray observations performed with the two telescopes. Over the last year, eleven journal articles were published, one of them in Science magazine. The IFAE group has initiated or

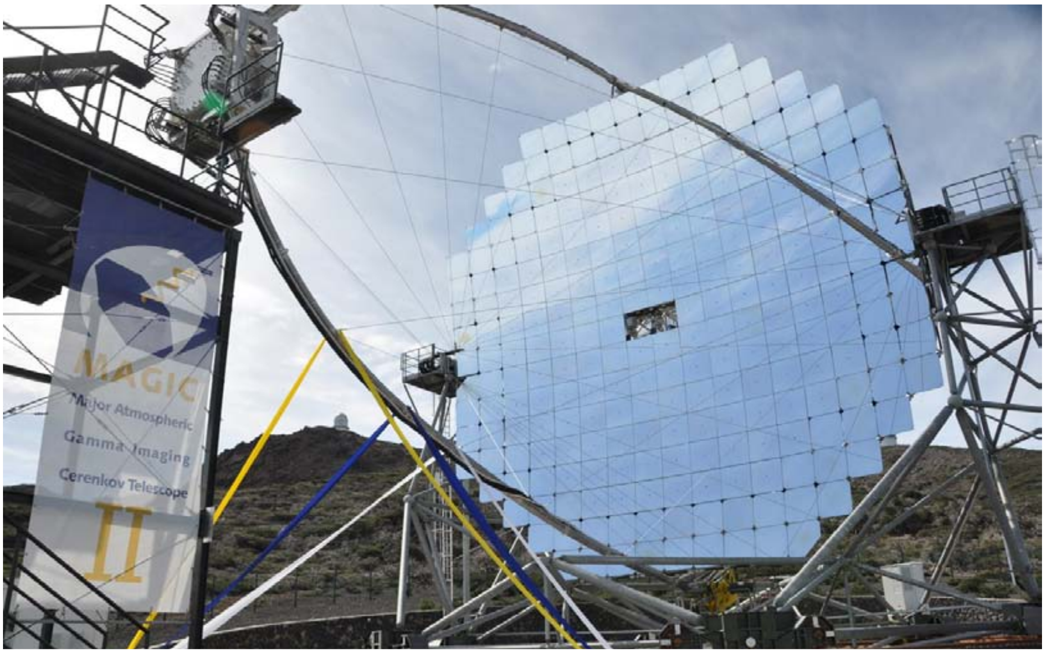

Fig. 1. The second MAGIC telescope during its First Light Ceremony in 2009. MAGIC-II is an improved clone of the first telescope which allows 3D reconstruction of the particle shower produced when a γ-ray enters the Earth's atmosphere. The two instruments are equipped with the largest optical telescope reflectors in the world. The diameter of each is 17m, which enables MAGIC to detect γ-rays in the energy band from 25 GeV to a few tens of TeV.

taken a leading role in several of them. A PhD thesis was completed during 2009.

Elucidating fundamental physics remains one of the key goals of MAGIC and of the IFAE group in particular.

One of the most popular dark matter candidate particles, the neutralino, may pair-annihilate into VHE gamma rays. Regions of high neutralino density may thus become detectable with MAGIC. MAGIC-I has searched for such signatures in the dwarf spheroidal galaxy Wilman-1, a galaxy featuring a high content of dark matter. No evidence for the presence of dark matter was found, but the observation allowed to better constrain the nature of the putative neutralinos.

Only a few tens of extragalactic sources of VHE γ-rays are known to-date and they all belong to the so-called “blazar” class of galaxies. Blazars are characterized by jets wherein particles get accelerated and produce in turn VHE gamma rays. They are especially bright in this spectral band because the jet points within a few degrees of the direction of the observer. Only a few VHE gamma ray galaxies are not blazars and one of the them is the nearby radio-galaxy M87. M87 also displays a jet, which does not point is our direction.

This fact helps in characterizing the mechanism of particle acceleration in the jet. MAGIC-I detected a fast episode of strong gamma ray emission in M87. This episode was simultaneously recorded by a radio interferometer with very high angular resolution, which allowed to precisely pinpoint the place at the galaxy where the gamma rays originated. The results of this observation, which involved the three most important VHE gamma ray telescopes in the world, MAGIC, H.E.S.S. and VERITAS, were published in the high-impact journal Science.

Jet formation is a universal phenomenon. Jets develop not only in active galaxies, but also in systems of two stars within our own galaxy, when one of the stars accretes matter from its companion.

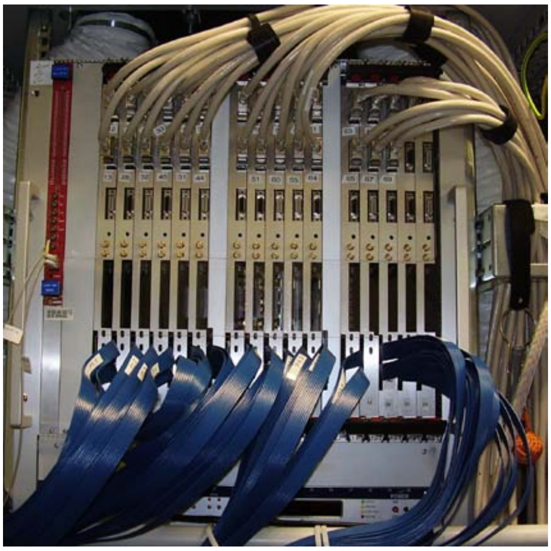

Fig. 2. A fully assembled crate of optical receiver VME boards. These boards convert the optical pulses generated by Cherenkov showers in the camera photomultipliers into electrical pulses, which can be further digitized and discriminated against light background. The boards have been fully designed, tested and installed by the MAGIC group at IFAE.

In understanding the general mechanism of jet formation, these “local” systems are extremely helpful because their time evolution is much faster than that of their extragalactic counterparts. Violent events such as ejections or outbursts may take place in a matter of hours or days compared to months or years for jets in active galaxies. The radio-loud X-ray binary LS I +61 303 was always believed to be one of such systems, dubbed “microquasars”.

This astronomical object was actually discovered in the VHE gamma ray regime by MAGIC back in 2006, but subsequent observations have revealed more of its extraordinary phenomenology. In 2009, MAGIC published two articles (led by members of the IFAE group) establishing the periodicity in VHE gamma rays of LS I +61 303 and showing evidence for correlation with emission in the X-ray energy band. Observations at all wavelengths now reveal that this source may in fact not be powered by a jet, but by a different mechanism: particle acceleration in the shock which develops when a pulsar's wind meets the wind of an early type star.

In 2005 the MAGIC collaboration began the construction of a second telescope, MAGIC-II, which is a technically improved clone of the original MAGIC-I. MAGIC-II is located 85m away from MAGIC-I and is equipped with more sensitive photodetectors and digitization at a faster sampling rate (2-4 GHz). IFAE is solely responsible for the optical reception of the camera analog signals, co-responsible with the INFN-Pisa MAGIC group for the readout and data acquisition, and responsible for the central control of the two-telescope system. Digitization at a faster sampling rate allows to study in greater detail the development of the particle shower in the atmosphere. By measuring the time profile of the shower and rejecting night sky light background on the basis of its arrival time, an article led by a member of the IFAE group has shown that we can significantly improve the sensitivity of a Cherenkov imaging telescope.

A fully assembled crate of optical receiver VME boards is shown in fig. 1.

IFAE collaborates with UAB, Universidad Complutense de Madrid and Instituto Astrofísico de Andalucía in setting up the Data Center for the two MAGIC telescopes. With the advent of the second telescope, the instrument can produce as much as 1 TB of data a night. Such a significant data flow can only be managed applying the latest technology in data storage and data processing. The data center has been installed at the nearby Port d'Informació Científica (PIC), a Tier 1 grid center for the analysis of LHC data. The MAGIC data center in fact makes use of grid technology for data processing, storage and distribution to all the institutions of the collaboration.

In September 2009 the year-long commissioning phase of MAGIC-II was successfully completed. The two-telescope system can be seen in figures 2 and 3. Members of IFAE took leading responsibilities in this task.

The general meeting of the MAGIC collaboration, that marked the startup of regular observations with the two telescopes was organized by the IFAE group in Castelldefels, near Barcelona, in November 2009.

The sensitivity of the combined system of telescopes is found to be even better than expected from simulations and its angular and spectral resolutions have improved significantly. Discovery of the first VHE gamma ray sources with the MAGIC system has taken place in the last months of 2009 and first months of 2010.

The group is currently involved in an upgrade of the telescopes. MAGIC-I will be equipped in summer 2011 with a new 1039 photomultiplier camera, a clone of the camera of MAGIC-II. The electronics for both telescopes will also be upgraded at the same time, to use a more compact and reliable digitization chip. A Marie-Curie fellow at IFAE serves as project manager for the whole upgrade program. IFAE is again joining forces with the INFN-Pisa group and this time also with the MAGIC group at Universidad Complutense to build the electronics for this upgrade.

The first design and the selection of electronic components for a new version of the optical receiver boards were completed in 2009. The new boards were modified to enable a new trigger system with a much lower energy threshold for the detection of VHE γ-rays, down to energies of 25 GeV.

Fig.3 The two telescopes at dusk at the Roque de los Muchachos observatory in the Canary island La Palma. The so-called "sea of clouds" is visible behind the telescopes at an altitude of roughly 2000 meters. The clouds act as a natural barrier which protects the observatory from man-made light pollution. MAGIC observes gamma rays in visible and near UV light and a low level of background light is essential to achieve the telescope's nominal sensitivity.

2.5 CTA: Cherenkov Telescopes Array

Manel Martínez

VHE gamma-ray astronomy has matured at a phenomenal rate during the past decade. With nearly a hundred sources detected from the ground, current and past experiments have demonstrated the impressive potential of this field, not only in the area of astrophysics, but also in particle physics and cosmology (see references 1 and 2). But while progress has been rapid, it has also become apparent that the performance of current instruments is not sufficient to tap the full physics potential of Cherenkov techniques. The answer of the worldwide VHE energy community to this challenge is the Cherenkov Telescope Array (CTA), a next-generation, more sensitive and more flexible facility that can also accommodate a large community of users.

Until recently, Cherenkov telescopes such as H.E.S.S. and MAGIC were considered experiments that required a large team of dedicated experts to analyze and fully exploit the data. The intersection of the astronomy and of the astroparticle physics communities envisions a next-generation VHE gamma-ray observatory that not only boosts sensitivity and resolution beyond the capabilities of current instruments, but also provides services and tools that make VHE gamma-ray data accessible to a much wider and diverse set of users.

The “Cherenkov Telescope Array" (CTA) will be an advanced facility for ground-based VHE gamma-ray astronomy using Cherenkov detectors (see reference 3). It builds on the successful imaging atmospheric Cherenkov telescope techniques developed by the H.E.S.S., MAGIC and VERITAS collaborations. From H.E.S.S. and VERITAS, it exploits the progress made with telescope arrays and stereoscopic analysis that routinely improves telescope sensitivity by at least an order of magnitude. From MAGIC, it borrows the application of large telescopes to

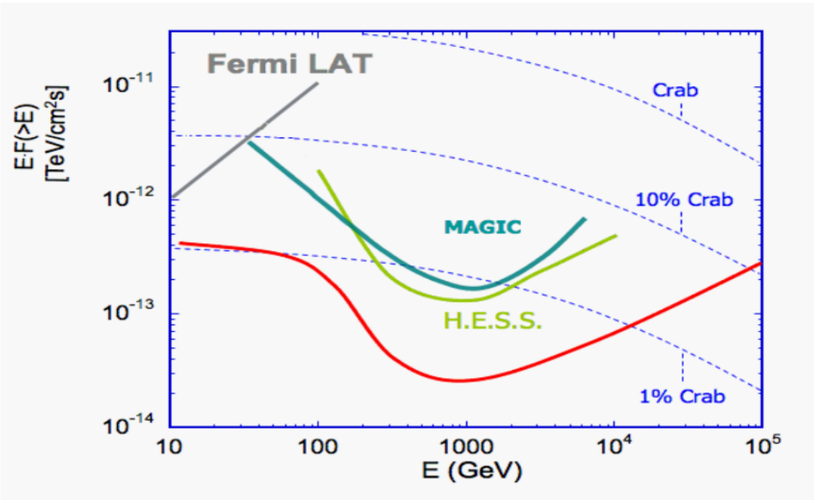

Fig. 1. The sensitivity goal of the CTA Observatory.

achieve the lowest possible threshold. Both approaches were proved to be extremely successful for gamma rays of energy above few tens of GeV and provide access to a broad range of astrophysical phenomena and fundamental physics themes, including detailed observations of the Universe at some of the largest energies to-date (see references 4 and 5 for a discussion about the future science prospects for VHE gamma ray astronomy with Galactic and Extragalactic sources respectively).

The principal goals of the European VHE gamma ray community to be fulfilled with CTA include (see figure 1):

1. Energy coverage from O(10) GeV to >100 TeV.

2. An improvement in sensitivity of at least an order of magnitude over existing facilities, including better than 1 milliCrab at the intermediate energies.

3. A Southern and a Northern Observatory operated under a common framework with broad all-sky monitoring capabilities. Specifically, the northern observatory will emphasize extragalactic studies, while its southern counterpart is expected to excel in galactic studies.

With these goals in mind, the CTA installation should have the following features:

a) Improved sensitivity at TeV energies (better than existing telescopes by more than a factor of 10), allowing deeper observations and the discovery of many more sources.

b) Large detection area, enabling higher detection rates in less time. This feature is critical to obtain well-sampled light curves and a better characterization of transient phenomena.

c) Higher angular resolution, which shall improve morphological analyses and as a result will provide a richer study of the structure of extended sources.

d) A low energy threshold (< 30 GeV), which is necessary for detailed studies of the pulsar emission mechanisms, distant AGNs, and dark matter signatures, as well as to provide a critical overlap with the energy region already covered by Fermi-GST.

e) Sensitivity at the highest energies (>100 TeV), to allow the precise determination of the cut-off region of Galactic accelerators and to provide overlap with the future surveys at TeV energies performed by surface detector arrays such as HAWC.

f) Wide field of view. To provide detailed studies of extended sources and the realization of high sensitivity and wide energy band surveys.

Obtaining the performance features outlined for the CTA Observatory will require the deployment of an array made up by several tens of Cherenkov telescopes divided into three different sizes: a handful of large-sized telescopes (24-meter diameter) aligned in a compact configuration that will reach the specified low-energy threshold, a few tens of middle-sized telescopes (12-meter diameter) with emphasis on the high-sensitivity intermediate-energy region, and finally several tens of small-sized telescopes (6-meter diameter) arranged over a large area for the highest energy photons (see figure 2). The present results of Monte Carlo simulations, validated with H.E.S.S. and MAGIC data, suggest that such a system will probably consist of about 50 to 100 telescopes with a total of about 100,000 to 200,000 electronics channels and a total mirror area of about 10,000 m^2. The overall cost estimate is around 150 million Euro.

Since CTA will mainly rely on technologies already demonstrated by H.E.S.S., MAGIC and VERITAS, the major technological challenges in this endeavour are the development of cost-effective, robust and reliable electronics, telescope structures, drive systems and mirrors, complemented by a sophisticated optimization of the array layout based on simulations.

Ultimately, CTA has the potential of discovering and studying in detail the spatial structure, light curves and energy spectra of ~1000 sources. The ideal scenario is one whereby CTA starts operating while Fermi-GST is still active, as the two installations nicely complement each other. Operational overlap with the Fermi satellite mission will provide seamless coverage of 20 octaves of the spectrum. Moreover, close coordination with similar efforts in the USA with the AGIS concept (see reference 6), has recently led to 20 USA research groups joining the CTA project in one of the first truly global scientific projects.

Building upon the success of H.E.S.S. and MAGIC, by the end of 2005 the first concept of a future European installation, already dubbed CTA, was submitted for inclusion on the ESFRI roadmap. ESFRI considered that the CTA project was not yet mature enough to be included in the roadmap, however it included it in the list of emerging projects in 2006 and finally as a full ESFRI entry for the 2008 updated roadmap. Presently ASPERA-ApPEC gives full support to CTA, which is listed among the highest priority future European astroparticle physics installations in the ApPEC roadmap. In addition, CTA has also been included with high priority among the future astrophysics facilities by the ASTRONET roadmap.

The initial efforts to define CTA started in spring 2006 at a first meeting in Berlin where several groups started working for the preparation of a Letter of Intent. This activity continued within several working groups and

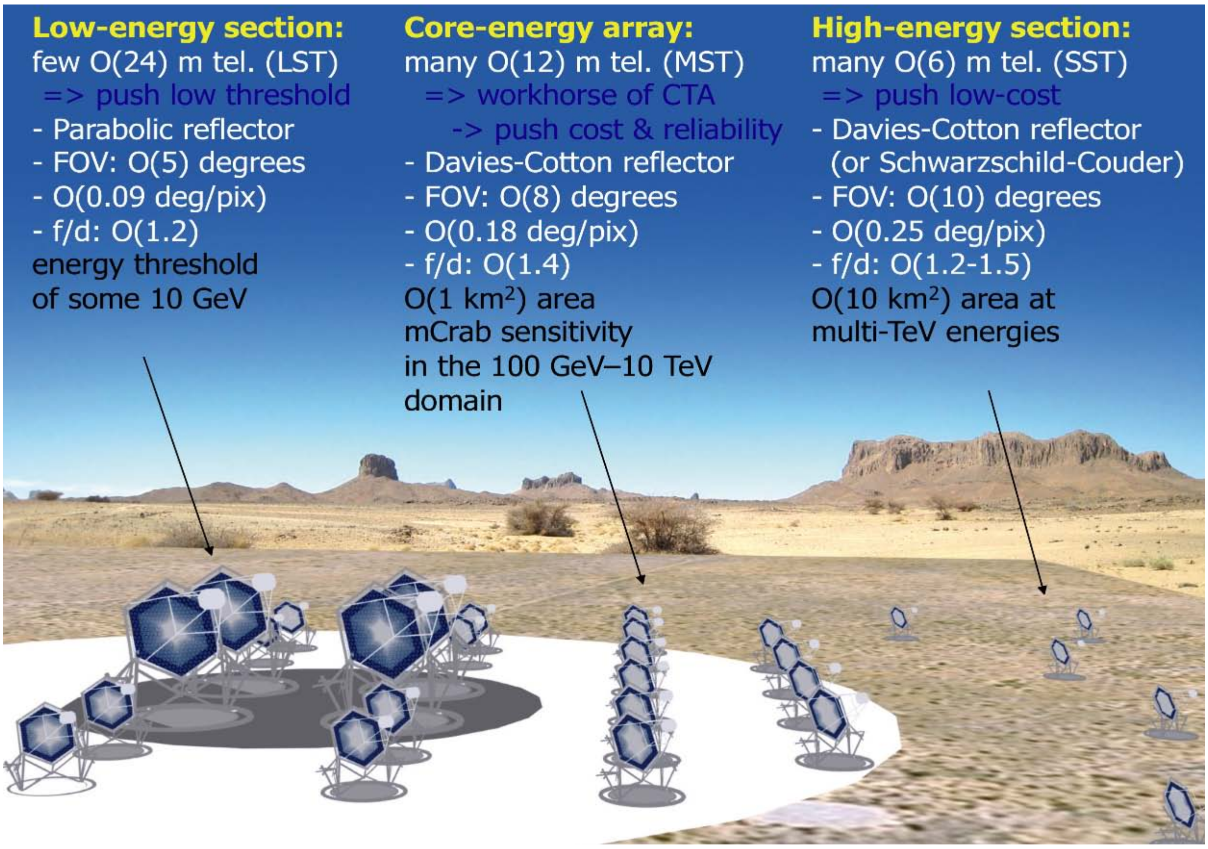

Fig. 2 An artist's view of the layout of a CTA site (not to scale) with a few baseline design numbers coming from the Design Study.

general meetings until spring 2007, when in a general meeting in Paris it was decided to submit an application for Design Study funds to the FP7 EU program. The application was submitted in May 2007 but the final (negative) answer was not received until June 2008. In the meantime, work on the design of CTA continued and at the beginning of 2008, in a general CTA meeting in Barcelona, it was decided to follow the 3-year work-package organizational scheme created for the FP7 application (see reference 3), and continue the Design Study no matter what the outcome of the FP7 application would be. At that time, it was also decided to act as a consortium, and an interim Memorandum of Understanding was approved in May 2009 and a Conceptual Design Report is currently being finalized.

Meanwhile, ASPERA-ApPEC issued a Common Call for funding Design Studies (without funding from the FP7 program) focused towards gamma-ray astronomy and dark matter search projects. The whole CTA Consortium presented a single joint application that received the highest marks.

In addition, because of its inclusion in the ESFRI roadmap list, the CTA project became eligible for “Preparatory Phase” funding from the FP7 EU Program Call that appeared by mid 2009.

During 2009 the CTA project met two very important milestones:

1) On one hand, in May 2009 the groups working for the CTA project decided to organize themselves as a Consortium (presently with over 550 scientists from 120 institutions from 22 countries), approved a Memorandum of Understanding (MoU) and elected Prof. Werner Hofmann (MPI Heidelberg) and Prof. Manel Martinez (IFAE Barcelona) as spokesperson and co-spokesperson respectively to lead together the Consortium in the coming years.

2) On the other hand, before the end of 2009 the CTA Consortium submitted an application to the FP7 EU program to ask for funding for starting a three-year Preparatory Phase by mid 2010. The goal is to be ready to start construction of the CTA Observatories by 2014.

Meanwhile, during 2009 the work in the CTA Design Study got an important boost and the outcome is a O(100) pages Conceptual Design Report to be made public by spring 2010.

At IFAE, the participation in the Design Study work during 2009 in subjects such as the telescope trigger electronics systems, in which IFAE is leading the work, the Monte Carlo optimization, the physics prospects and the atmospheric monitoring has been very intense. A very visible highlight is the beginning of the construction at IFAE of a state-of-the-art Raman LIDAR for atmospheric monitoring, using a special container plus a 1.8 meter diameter telescope from the old CLUE experiment (see Fig. 3).

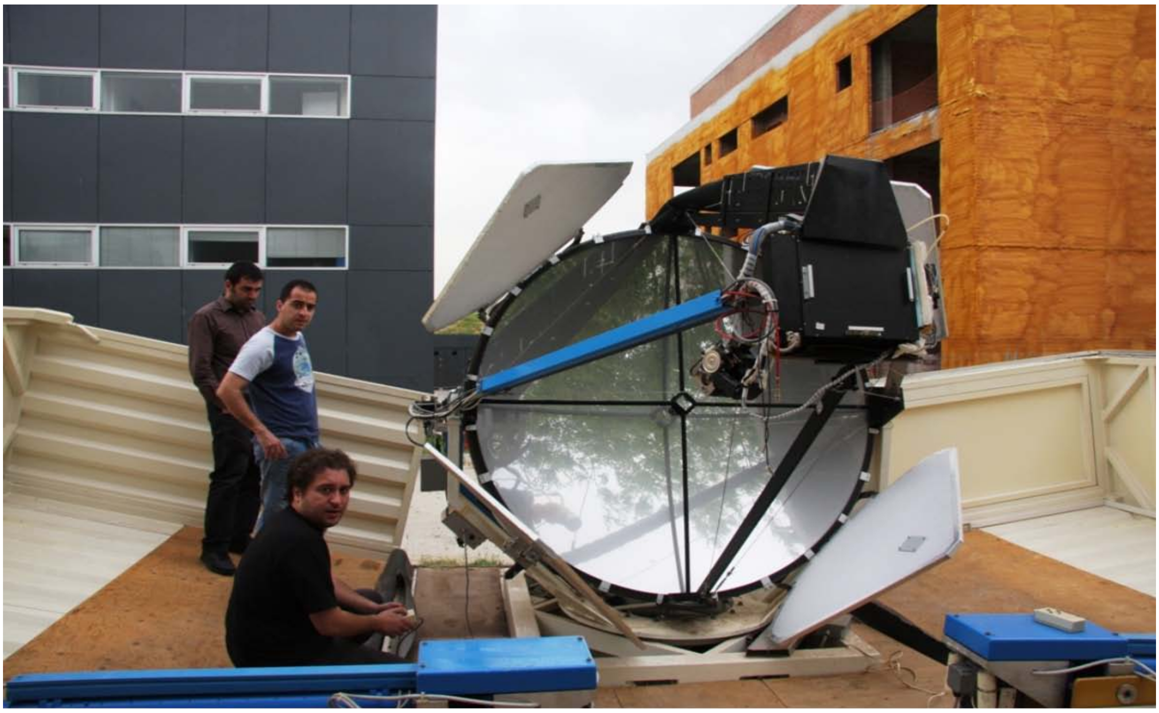

Fig. 3 The Raman LIDAR being built at IFAE

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2.6 The 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) and another at CIEMAT (Centro de Investigaciones Energéticas, Medio Ambientales y Tecnológicas) 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 square degrees of the southern galactic sky, measuring positions in the sky and redshifts of about 300 million galaxies and 15,000 galaxy clusters. Furthermore, another 10 square degrees of the sky will be repeatedly monitored with the goal of measuring magnitudes and redshifts of about 2000 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.

The DES Collaboration is building a large CCD camera (DECam), that will give images covering about 3 square degrees of the sky. The camera will be mounted at the prime focus of the 4-meter Blanco Telescope, located at Cerro Tololo in Chile. In return, DES is granted 30% of all the observation time for five years (2011-2015). The layout of the camera can be seen in figure 1.

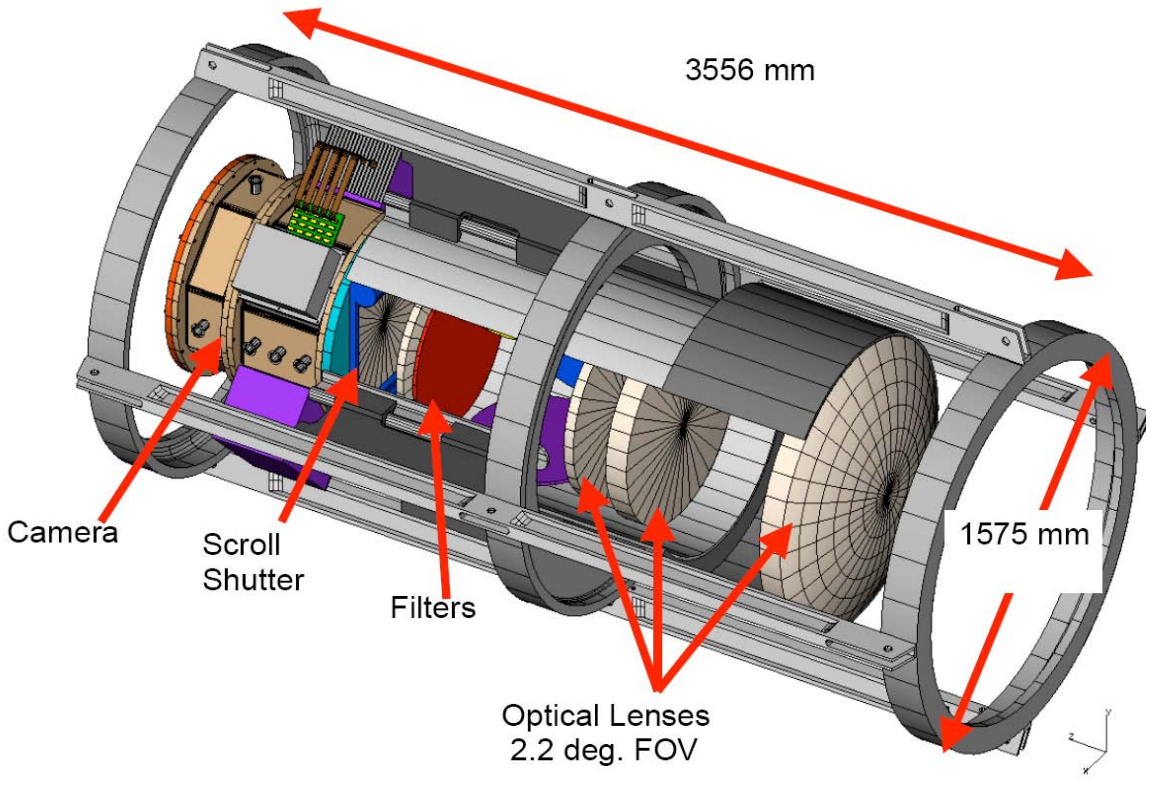

Fig. 1. A view of DECam, the Dark Energy Survey camera.

The three Spanish groups, funded by the Program of Astronomy and Astrophysics (part of the National Plan of R+D+I), are building the whole set of read-out electronics boards of DECam, and have designed three out of the four main boards: the Clock and Bias Board (CBB) at CIEMAT, and the Master Control Board (MCB) and the Transition Board (TB) for the CBB at IFAE.

During 2009, IFAE finished the design of the MCB, and started production of the MCBs, of the 12-channel Data Acquisition Boards, designed at Fermilab, and of their associated transition boards. All-in-all, over 100 boards will be produced, tested and commissioned in 2009 and 2010. Figure 2 shows one of the MCB cards designed and produced at IFAE in 2009.

Survey-II project, in a redshift range between 0.1 and 0.4. The group was awarded four full nights of observations at the Italian "Telescopio Nazionale Galileo" (TNG) in the Roque de los Muchachos observatory in La Palma (Canary Islands) in fall 2007. The observations produced spectra of about 25 objects, including an extremely peculiar supernova, SN2007qd. Many of these spectra have now been used in a number of SDSS-II/SNe analyses, with the ensuing papers about to be published. More are in progress.

During 2009, work continued on the analysis and understanding of the properties of SN2007qd, in collaboration with colleagues from the University of Notre Dame in the United States. A careful analysis of the multi-epoch spectra

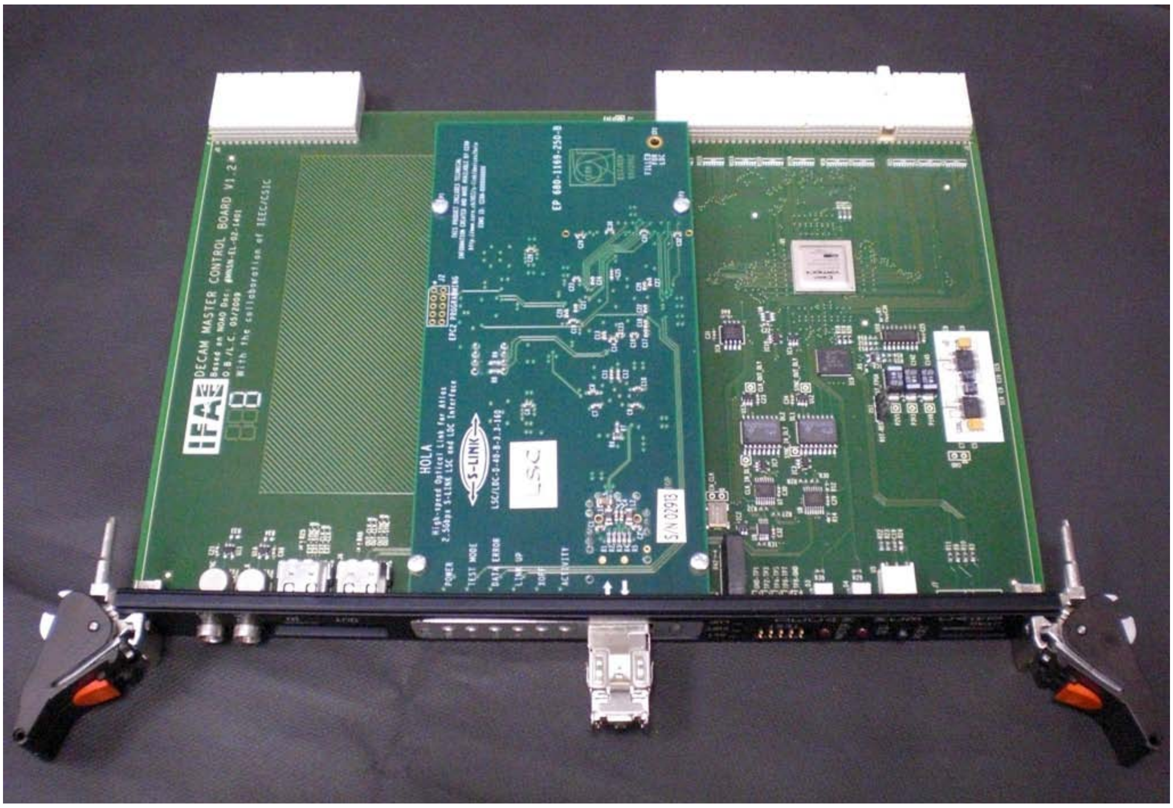

Fig.2 One of the Master Control Board (MCB) cards for the DES camera produced at IFAE in 2009.

In preparation for the analysis of DES supernova data a few members of IFAE, ICE and CIEMAT joined in 2007 the program of spectroscopic follow-up of the supernovae found in the Sloan Digital Sky

available for SN2007qd showed that SN2007qd seems to be part of a small family of very sub-luminous type-Ia supernovae that explode through a deflagration (sub-sonic) event rather than a detonation (super-sonic) event. This will have implications for our understanding of supernova physics. Figure 3 shows a comparison of spectra taken near maximum brightness of three fast-declining sub-luminous type-Ia supernovae: SN2005hk, SN2007qd, and SN2008ha. The similarity between the three spectra is striking, indicating that these three supernovae belong to the same family of events. A paper with these findings is in the later stages of writing, and will be submitted to the Astrophysical Journal.

In November 2009, a member of the IFAE group at DES became the chair of the DES Speakers' Bureau, the committee that chooses speakers to represent DES in major conferences and workshops. The same person was also a member of the DES Director Search Committee, which during 2009 performed an international search for a new DES director. The search ended with a recommendation of a candidate, Prof. Joshua Frieman, from the University of Chicago and Fermilab, who was appointed as new DES director in early 2010.

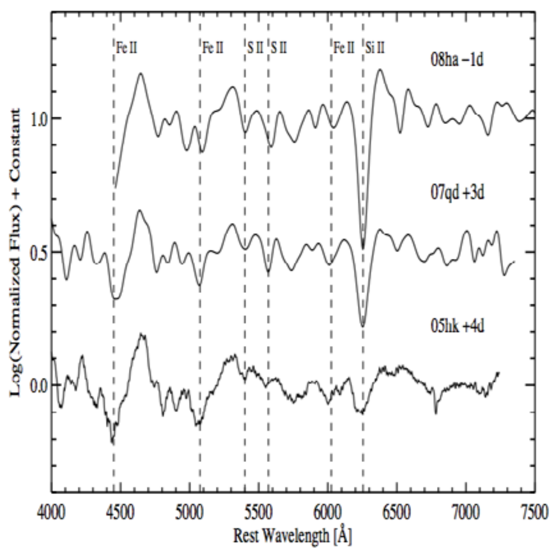

Fig.3 Normalized spectra of three peculiar SN Ia, observed near maximum brightness. The three spectra show striking similarities. The spectrum of SN2007qd was taken by members of the IFAE group at the Italian TNG telescope in La Palma.

2.7 PAU (Physics of the Accelerating Universe)

Enrique Fernández

Introduction

PAU is a five-year project funded by the Consolider Ingenio 2010 Program of the Spanish Ministry of Research and Innovation. The aim of the Consolider Program is 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 with an effective starting date in January of 2008. IFAE is the Coordinating Institution of the Project. The members of the IFAE group are Laia Cardiel, Enrique Fernández (Project Coordinator), Josep Antoni Grifols, Eduard Massó, Ramon Miquel (IFAE Principal Investigator), Marino Maiorino, Pol Martí and Linda Östman.

The work described here has been carried out in close collaboration with the IEEC and CIEMAT teams in PAU a well as with the PIC team in what concerns data management.

The scientific focus of the project during the first year and a half was the preparation to carry out a large astronomical survey optimized to provide a competitive measurement of Baryon Acoustic Oscillations, as a probe of Dark Energy (DE). As described in the 2008 IFAE Report, the survey was intended for a two-meter telescope to be built in Javalambre, near Teruel.

The goal was to photometrically image an 8,000 square degrees area, using a telescope/camera combination with an "etendue" of $20m^{2.}$ deg^2, equivalent to a 2m diameter telescope and a camera with a 6 deg^2 field of view. However, the expected date of availability of the telescope was still not specified in 2009, but was expected, at the earliest, in 2012, the year in which the Consolider project finishes.

This led us to investigate other approaches – both to the site and to the observables - that could be explored in a project more in line with the time scale of the Consolider.

Contacts with members of the astrophysical community in Spain and the UK led us to consider the use of other telescopes. In particular the director of the ING (Isaac Newton Group) announced future possibilities at the ING telescopes in La Palma. After discussions in September of 2009, it became clear that there was the possibility of installing an imaging instrument at the prime focus of the William Herschel Telescope (WHT). The WHT is a 4m telescope currently being run by the ING Consortium (formed by the Netherlands, Spain and the UK). This telescope is fully operational and is very well maintained, with a dedicated staff of about 40 persons. The WHT has a field of view (FOV) of 1º diameter with 85% light collection efficiency (of which 40' have 100% efficiency). Further iterations with the Director and staff of the ING took place, followed by meetings of the two teams. In two occasions the CIEMAT-IEEC-IFAE engineers visited La Palma and had specific discussions with the ING engineers.

A plan was made to install the PAU Camera (PAUCam) at the WHT as a Visiting Instrument, with the provision that when used for the PAU Survey. it could also be used by interested members of the WHT community of users,

Concurrently, there were also advances in the understanding of other observables that are sensitive to the dark energy component in the Universe. As explained below, we have focused on red-shift space distortion and magnification bias. As shown below, the scientific reach of such observables can be even higher than that of Baryon Acoustic Oscillations (BAO), even with substantially smaller survey areas. Furthermore the international competition is less intense than for BAOs, particularly given the fact that some large BAO surveys, such as BOSS in the USA, have already started to take data.

The activities during most of 2009 focused in developing the physics case for a Survey at the WHT with an instrument, PAUCam, capable of delivering precise photometric redshift, and on designing such an instrument, to be mounted at the prime focus of that telescope.

A PAU-WHT Survey

Red-Shift Space Distortions

The measured *redshift distance, s,* to a galaxy is related by the Hubble expansion to the *radial distance, r*, but this relation is modified due to the *peculiar velocity* of the galaxy along the line-of-sight. At large scales (larger than 10 Mpc/h), the very large structures, walls and voids, give rise to coherent bulk motions with objects falling towards the dense regions. Objects between an overdense region and us will appear more distant while objects behind an overdense region will appear closer. This produces a squashing effect in the anisotropic 2-point correlation function ξ(π,σ) along the line-of-sight, π, known as Kaiser effect [N. Kaiser, *MNRAS*, 227, 1-21 (1987)]. This is shown in Figure 1. At smaller scales, within clusters, random peculiar velocities of galaxies give rise to an opposite effect, with structures appearing stretched along the line of sight from the observer, producing the so-called Fingers of God (FOG).

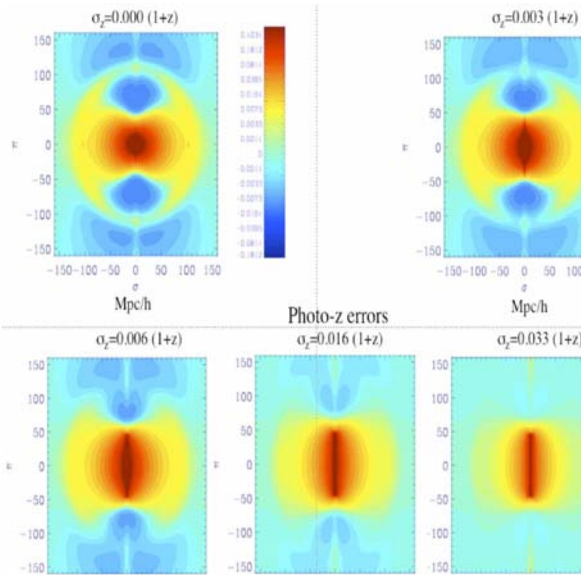

Fig.1. The top left panel shows the ξ(π, σ) correlation in the Kaiser model with no photo-z error, i.e. $\sigma_z = 0$ (from E. Gaztañaga, A. Cabre, and L. Hui, arXiv:0807.2448). The model includes the contribution of lensing magnification. The correlation is clearly squashed in the radial direction with a region of negative correlation (in blue) between $\pi = 50-100$ Mpc/h. The top right panel shows the same model but with a photo-z degradation of $\sigma_z = 0.003(1 + z)$, corresponding to the PAU Survey. The difference is small and is mostly limited to small radial scales. The bottom panels show how the results are degraded as we increase σ_z to 0.006 (left), 0.016 (center) and 0.033 (right panel). As the photo-z error increases the radial squashing disappears, turning instead into a radial elongation. Note also how the region of negative correlation vanishes as the photo-z error increases.

Redshift distortions complicate the interpretation of galaxy maps as positional maps but they have valuable information about the dynamics of galaxies. The amplitude of distortions on large scales yields a measure of the linear growth of the fluctuations parameter *f*, which is a function of time or redshift *z*. In redshift space, fluctuations in the radial direction are larger by a factor $(1+f\ \mu^2)$, where μ is the cosine of the angle to the line-of-sight. This produces a characteristic squashing of fluctuations in the radial direction that can be used to measure *f,* by comparing fluctuations as a function of μ.

The Kaiser effect occurs at large separations (s > 10 Mpc/h) so that the photo-z precision of PAUcam is enough to statistically resolve redshift space distortions. This is illustrated in the Figure. This type of approach also requires sampling of relatively large volumes, but not as large as those required for BAO measurements (dealing with separations of 100 Mpc/s).

For dark energy models within General Relativity, measurements of *f* can be used to estimate the DE equation of state *w* with independence of the constraints on *w* that can be found from measurements of H(z), such as BAO or SN measurements. For modified gravity models, such as the DGP model, one can tune the parameters to produce a cosmic history H(z) similar to that of ΛCDM, but the growth *f* is different in this case. Thus, the growth history, *f(z),* will be different even for the same cosmic history H(z). Measurements of f(z) can therefore allow to both understand DE and distinguish it from modified gravity.

Magnification Bias

The effect of gravitational lensing is to alter the area of the patch of the sky being observed and to change at the same time the observed flux of the source so that surface brightness is preserved. Both effects change the measured galaxy number density, the first by changing the area, the second by changing the number of sources N(<m) observed in a magnitude limited survey. Together these effects are called magnification bias [Gunn, J., 1967, ApJ, 150, 737] and lead to a cross-correlation signal between galaxies in different redshift bins. By having very accurate photometric redshifts, like in the case of PAU, it is possible to use this effect to reconstruct the 3D power spectrum of dark matter fluctuations. It is also possible to define observables, ratios of the cross-correlation of different redshift bins, which are independent of the (non-linear) galaxy power spectrum and therefore provide standard rulers to the distance ratios of different redshift bins.

Using this technique in combination with redshift space distortions, we obtain that it is possible to carry out a Survey with PAUcam to measure DE parameters, such as the DE equation of state and the growth function *f*, with a figure of merit that is comparable and complementary to that of planned or ongoing galaxy surveys, such as DES and BOSS. This result will be published in the near future.

The PAU Camera (PAUCam)

Once we chose to focus on the WHT, the design parameters of the camera became clear, as the existing corrector at the prime focus station places constraints on the instrument. The objective was an instrument covering the entire FOV of the telescope, namely 1.0 degrees, which implies covering the camera focal plane with 18 4k × 2k CCDs. An overall view of the camera is in Figure 2. To achieve the scientific goals the camera is designed such that it can be used with several combinations of filters, exchangeable automatically.

The detailed design of the camera progressed very rapidly and was almost complete at the end of 2009. The concept is the same as that considered up to now, as described in the 2008 IFAE report. 40 narrow-band filters will be used, to obtain a resolution in z of 0.003(1+z) for galaxies up to 23 magnitude. The camera will be available for public use at the WHT.

An attractive feature of the WHT is that all the ancillary equipment to place the

Camera is ready, in use since several years. The meetings of the engineering teams found no show-stopper on the path of already installing a camera such as PAUCam at the WHT, as far as the telescope is concerned.

Nevertheless the construction of the camera remains very challenging. To put it in perspective, when completed, it will be the largest wide-field imaging instrument available at La Palma site. Work on the camera is done in close collaboration with the IEEC and CIEMAT teams.

It should be stressed that PAUCam could also be used to conduct a large imaging survey such as that required for Baryon Acoustic Oscillations. The etendue of the PAUCam-WHT system is quite large, 13 m^2-deg^2, because of the large area of the WHT. However it is not realistic to count on a large fraction of the observing time at the WHT in the foreseeable future, although that possibility could not be excluded. The camera could also be moved to other telescopes adding the appropriate interfaces.

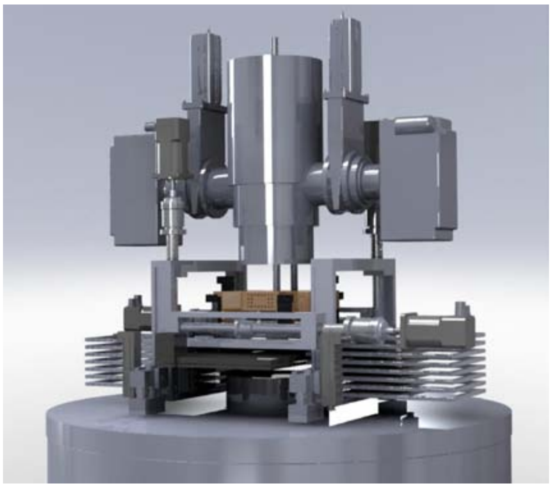

Fig 2. Overall view of PAUCam. The filter tray can be seen at the bottom. The light from the telescope enters the camera from the bottom.

Data Management and Simulations

We are developing a new Data Management system (software and hardware), called PAUdm, to process all the PAUCam images that will be taken at the WHT. Because of the large amount of data involved and the synergy with the LHC project at PIC, we have decided to implement PAUdm in the grid environment at PIC. With collaborators at the IEEC and PIC we have implemented a full working pipeline using a combination of public (ie Terapix) and custom imaging processing and cosmetic routines in a Python environment. We use the standard Sextractor package and have designed several tools for imaging cosmetics, i.e. flat-fielding, bias, cosmic ray detection and masking algorithms.

We have also implemented an automatic data control (Pipeline Orchestration) with parallel processing (200 simultaneous jobs per night) and a Quality Analysis (QA) framework. This QA comprises a set of test specifications and related software to verify the astro-metric and photometric accuracy of the processed catalogs against the truth tables from which they derive. The code (under Subversion-TRAC control) has been set up so that it can provide immediate feedback for the data reduction development. We have reached an astro-metric calibration error better than 0.2" with realistic images.

Additionally, star-galaxy separation can be analyzed, as well as the completeness /purity of the final catalog, treatment of artifacts, etc. The quality test code itself has been intensively tested in other projects (DES) with data reduction systems in a more advanced stage. Current efforts are to scale this analysis to larger (~200 deg^2) datasets and to implement a new object DataBase. This effort is being carried out in close collaboration with the CIEMAT, IEEC and PIC teams. Figure 3 is an illustration of some of results obtained with the software being developed.

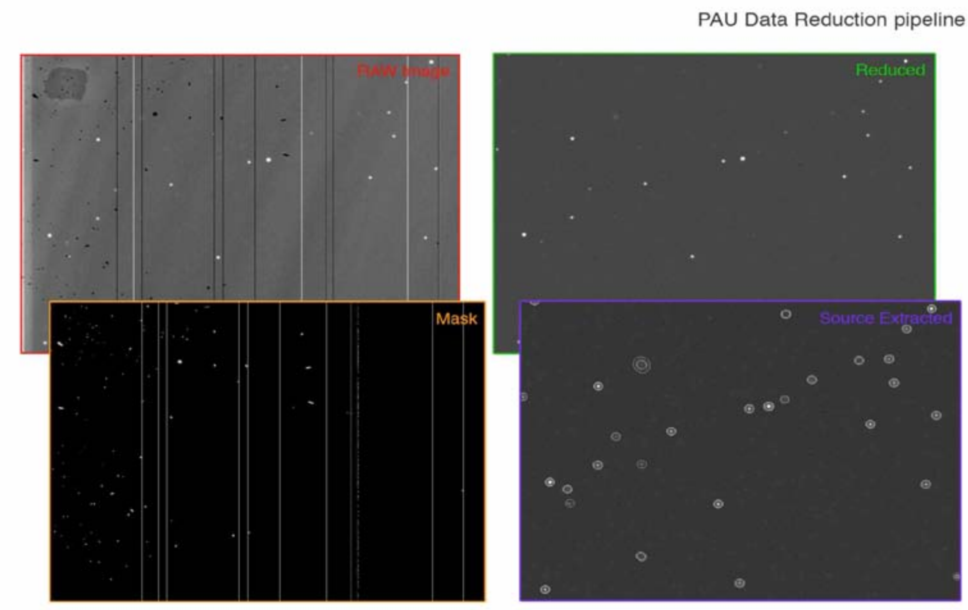

Fig.3 An example illustrating the object extraction pipeline: the raw image,the reduced image (cleaned from cosmetics, bias, flats, etc), the corresponding mask and the image with source extraction.

2.8 Medical Imaging and related R&D

Mokhtar Chmeissani

Bump-bonding activities

In 2009 IFAE started flip-chipping/bump-bonding of chips and sensors after having optimized the process using dummy sensors and chips.

The ATLAS FE-I3 sensor was the first active module that was bonded. This test was very successful, as shown by the flood image map taken using the X-ray source Am^{241}. Figure 1 shows a fit to the peak of the 59.5 keV line of Am^{241}.

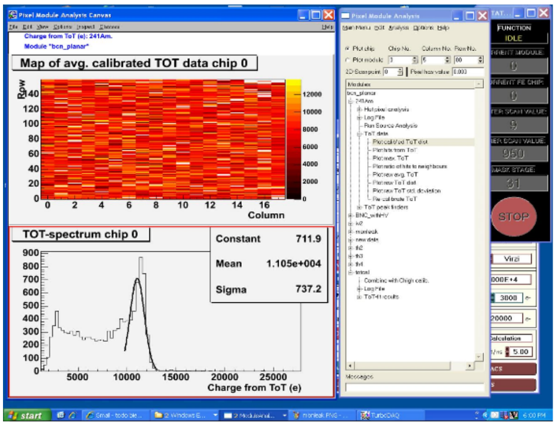

Fig. 1. The pixel response of the FE-I3 assembly bonded in Barcelona. The fit of the peak matches the response of the pixel for 59.5 keV.

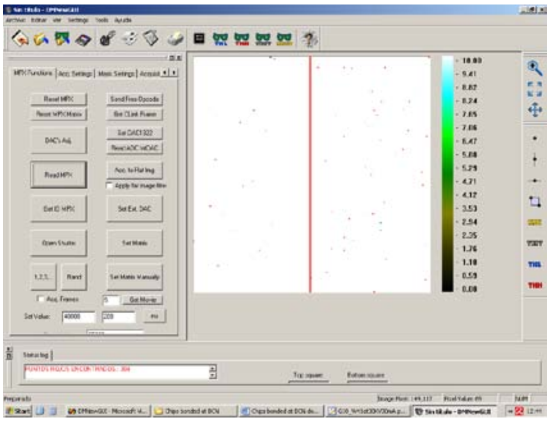

Fig. 2. The pixels with bad responses. The red ones are bad at the level of the chip. The black ones are bad because of bump connection failure.

We also extended our flip-chip/bump-bonding process to active Medipix2 sensors and chips. The results can be seen in figure 2 and 3.

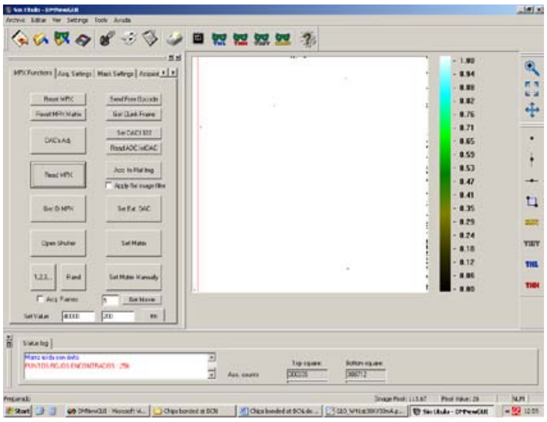

Fig. 3 The map of the bad bump connections on a Medipix2 assembly which has 65535 pixels. We have found 60 bad pixels, in the first column, equivalent to a yield of 99.9%.

The bad bump connections in Figures 2 and 3 are not related to the flip-chip process itself but rather to the quality of the bumps on the chip and/or the Under Bump Metal (UBM) on the sensor pads.

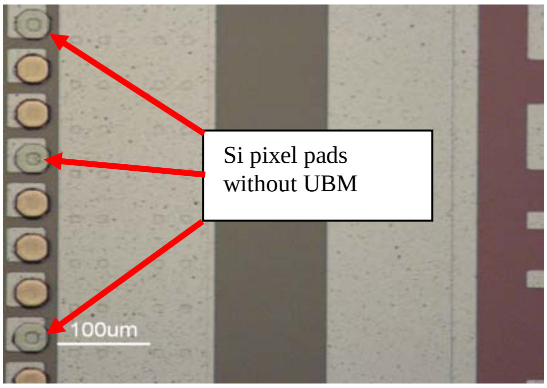

Fig. 4: Pads on the Si pixel sensor without UBM layer. Its absence prevents the solder bump from wetting these pads.

In Figure 4 one can see that on some pads on the Si sensor the UBM layer is missing. This is one reason why bump-bond connections may fail.

The overall yield of good connections on Medipix2 assemblies is estimated to be better than 99.95%. The plan for 2010 is to start working on the development of the bump-bonding process for 100μ thin chips on 300μ Si detectors using dummy chips/Si sensors. The results of this R&D will be used for the future ATLAS pixel detector.

Nuclear Medicine

In collaboration with CIEMAT, we did the full simulation of a Positron Emission Tomography (PET) device based on pixel CdTe detectors. This new concept of PET design will achieve very small voxel sizes and yield excellent spatial resolution with 3D information that will eliminate the parallax effect. Given that the detector is made of CdTe, real energy spectroscopy can be done and this will allow eliminating scattered events while keeping the "golden" events. A single module is shown in fig 5a. Photons will be absorbed over a path length of 4 cm of CdTe, which implies a 90% detection efficiency for 511keV photons. In fig 5b is shown a super-module and in Figure 5c the full PET barrel.

Using the GAMOS package, a Geant4-based architecture for medically oriented simulations, 3D data were reconstructed using Single Slice Rebinning (SSRB) followed by a Filtered Back Projection (FBP) algorithm. A full simulation was carried out with a Derenzo phantom shown in figure 6. The results of the simulation showing the detection efficiency and noise can be seen in figure 7. In figure 8 one can see the reconstructed image of the Derenzo phantom using 10 million PET events. The smallest details can be seen with utmost clarity.

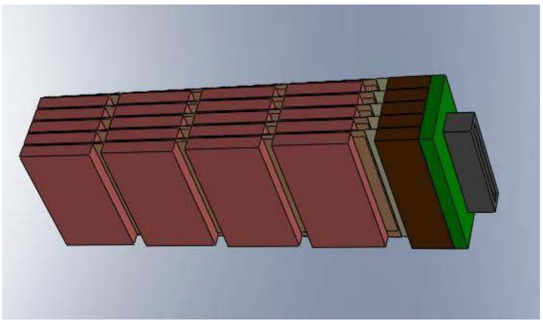

Fig. 5a. An example of a module of pixelated PET detector of CdTe. Its approximate dimensions are 11mm x 20mm x 50mm; it has 5000 voxels each of $1x1x2mm^3$.

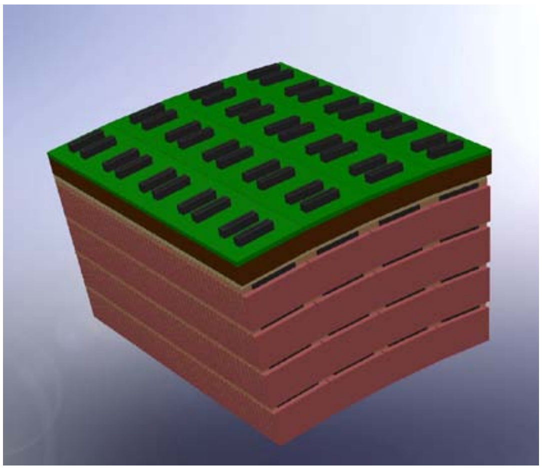

Fig. 5b: An example of a super module of a pixelated PET detector of CdTe. Its approximate dimensions are 80mm x 50mm x 100mm; it has 160,000 voxels.

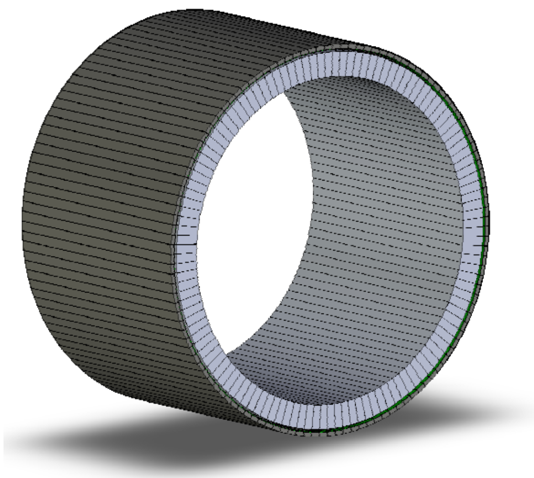

Fig. 5c. An example of full PET scanner made of pixelated CdTe detectors.

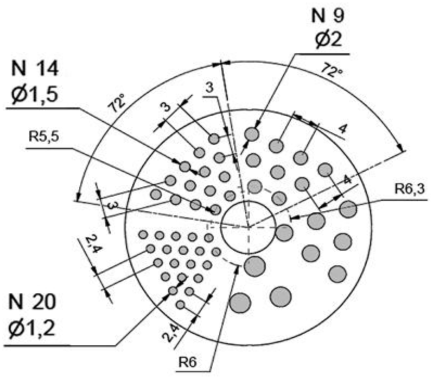

Fig.6. Derenzo phantom for simulation.

In fig. 7 one can see the detector response to: a) the true events, two 511 keV from the same e^+e^- annihilation and no scatter; b) the scattered events, in which at least one of the two 511 keV photons undergoes scattering before reaching the detector; c) the random coincidence events, in which the two photons do not originate from the same e^+e^- annihilation event. It is obvious that the ratio of scattered to true events in Pixel-CdTe PET is reduced to approximately 3 %, compared to approximately 1:1 for a Crystal PET. Furthermore, the event rate in Pixel-CdTe PET, which reflects the detection efficiency factor, is increased to 6.1 counts/kBq, compared to 2.5 counts/kBq for a Crystal PET.

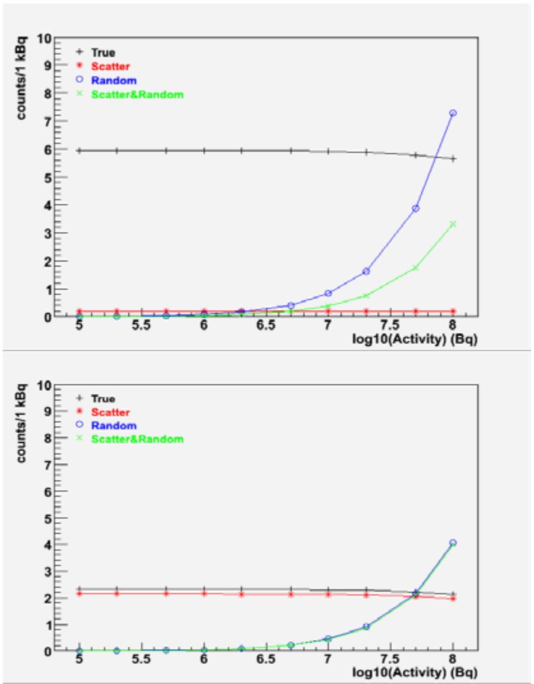

Fig.7. Top: counts with a Pixel-PET with CdTe. Bottom: same with a Crystal PET.

A proposal to develop and test a prototype of this novel device was presented to the European Research Council. An Advanced Grant was awarded in November 2009, leading to a four-year contract beginning in 2010.

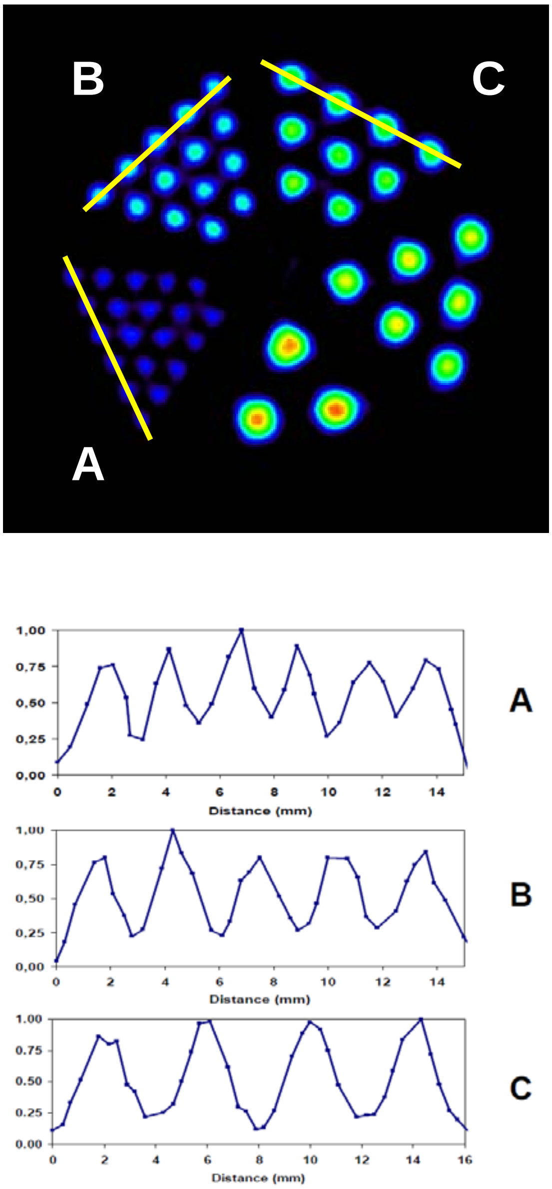

Fig. 8 Top: reconstructed Derenzo phantom image with Pixel-PET (CdTe) and only 10^6 coincidences. In the clear and vivid image the smallest rods, 1.2 mm in diameter, are well separated from neighbors. Bottom: the line profile along 1.2 mm (A), 1.5 mm (B), and 2 mm (C) rods. For the smallest rod diameter, 1.2 mm , the Peak-to-Valley ratio is 3:1.

X-ray Imatek S.L.

X-ray Imatek SL (XRI) is an IFAE spin-off, created in 2006 to exploit the results of Dear-Mama, an EU-FP5 funded project. It receives support from IFAE on various fronts of its efforts to produce an industrialized version of the Dear-Mama detector. In 2009, XRI successfully managed to produce a fully operational full field digital detector dedicated to mammography (Figure 9). Its radiography image is 30cm x 24cm with 55μ pixel pitch, equivalent to 24 millions pixels. It is the largest ever detector made with Medipix2 chips and it can acquire the entire image in 1.5 seconds. A radiography image taken by Dear-Mama detector of a sea bass is shown in figure 10.

More information can be found at www.xray-imatex.com .

Fig. 9. Side view of the Dear-Mama detector box open with the carbon cover next to it.

Fig. 10. Radiography of a sea bass.

2.9 Standard Model

Rafel Escribano

The main fields of research pursued in the Standard Model (SM) group of the IFAE theory division are hadronic B-meson and τ-lepton decays, heavy quarkonia, mesonic interactions, as well as models which may serve to further our understanding of the non-perturbative features of QCD.

More specifically, hadronic B decays allow to test the mixing pattern of the quark sector of the SM and to investigate if CP violation is indeed described by the Cabibbo-Kobayashi-Maskawa quark mixing matrix.

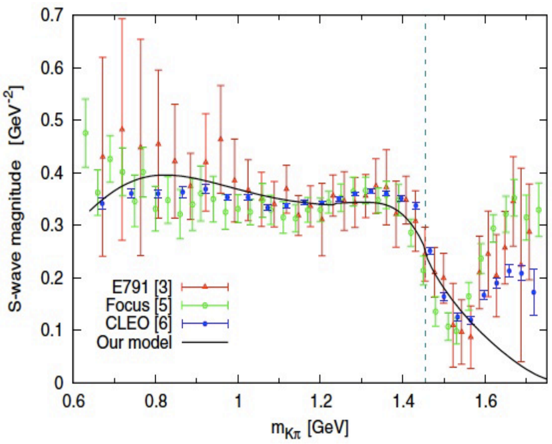

Fig. 1 Different combinations of spectral functions (V, A, and V±A) (data points in black) compared with fixed-order perturbation theory (green flat line) and the result of our fit (solid curve).

Hadronic τ decays provide a rather clean environment for the study of low-energy QCD effects and provide a means to precisely determine fundamental QCD parameters like the strong coupling α_s and the light quark masses.

Finally, exactly solvable models which share some features of full QCD permit to gain a better understanding of the non-perturbative features of QCD, which are not directly accessible by analytical methods.

In the field of hadronic B-meson decays, in the last year we have analyzed the observables that could be constructed out of the 4-body decay distribution of the decay $B \to K^{*} l^{+} l^{-}$. To this end, we have identified all the symmetries of the distribution and completed the method to construct transverse observables out of the K^* spin amplitudes. An analysis of the physics reach of these new observables has been developed.

Duality Violations (DVs) is a byname for the failure of the Operator Product Expansion to describe QCD correlators on the physical axis. As part of our ongoing project on DVs, we used a physically motivated ansatz to fit the spectral functions extracted from τ decay. This allowed us to get a quantitative estimate of the amount of DVs present in τ data.

The quality of the fit turned out to be better than expected. As in the past DVs were not included in the determination of α_s, they contribute an additional theoretical error which could be $\delta\alpha_s(m_\tau) \sim 0.003 - 0.010$ according to our estimate. Our ansatz satisfies, in particular, the first Weinberg sum rule, which shows that this sum rule is not enough to force DVs to vanish.

Furthermore, we studied the physics of heavy quarks. In particular, the vacuum polarization of a quark, when considered in terms of the external momentum q^2, is a function of the Stieltjes type. Consequently, the mathematical theory of Padé Approximants assures that the full function, at any finite value of q^2 away from the physical cut, can be reconstructed from its low-energy power expansion around $q^2 = 0$.

We illustrated this point by applying this theory to the vacuum polarization of a heavy quark and obtained the value of a constant, called $K^{(2)}$, governing the threshold expansion at order $O(\alpha_s^2)$.

Deep inelastic scattering has been studied in detail in the 't Hooft model. We have been able to analytically check current conservation and to obtain analytic expressions for the matrix elements with a relative precision of $O(1/Q^2)$ for $1-x >> \beta_2/Q^2$. This allows us to compute the electron-meson differential cross section and its moments with $1/Q^2$ precision. For the former we have found maximal violations of quark-hadron duality, as expected for a large-N_c analysis.

For the latter we have found violations of the operator product expansion at next-to-leading order in the $1/Q^2$ expansion. A model for the decay $D^+ \rightarrow K^-\pi^+\pi^+$

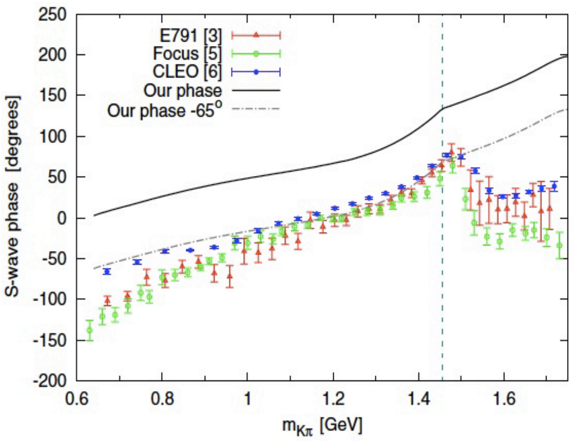

Fig. 2 S-wave phases from the quasi-model-independent analyses of different experiments. The solid line is the phase of our S-wave amplitude with α=0, whereas the dot-dashed line is the S-wave phase with α=- 65°. The dashed line delimits the Kη' threshold.

is presented. The weak interaction part of this reaction is described using the effective weak Hamiltonian in the factorization approach.

Hadronic final state interactions are taken into account through the πK π scalar and vector form factors fulfilling analyticity, unitarity and chiral symmetry constraints. Allowing for a global phase difference between the S and P waves of −65°, the Dalitz plot of the $D^+ \rightarrow K^-\pi^+\pi^+$ decay, the $K\pi\pi$ invariant mass spectra and the total branching ratio due to S-wave interactions are well reproduced.

We also performed an exploratory study to determine whether a combined analysis of $\tau \rightarrow K\pi\nu_\tau$ and K_{e3} data could yield a more precise result for the phase space integral of the process K^0_{e3}. We concluded that this is possible and that as a consequence an improved value of the V_{us} quark mixing matrix element can be obtained.

Finally, the η-η' pseudoscalar mixing angle and the gluonium content of the η' meson are deduced from an updated phenomenological analysis of J/ψ decays into a vector and a pseudoscalar meson. In the absence of gluonium, the value of the mixing angle in the quark flavour basis is found to be $\phi_P = (40.7 \pm 2.3)^\circ$. In the presence of gluonium, the values for the mixing angle and the gluonic content of the η' wave function are $\phi_P = (44.6 \pm 4.4)^\circ$ and $Z_{\eta'} = 0.29^{+0.18}_{-0.26}$ respectively.

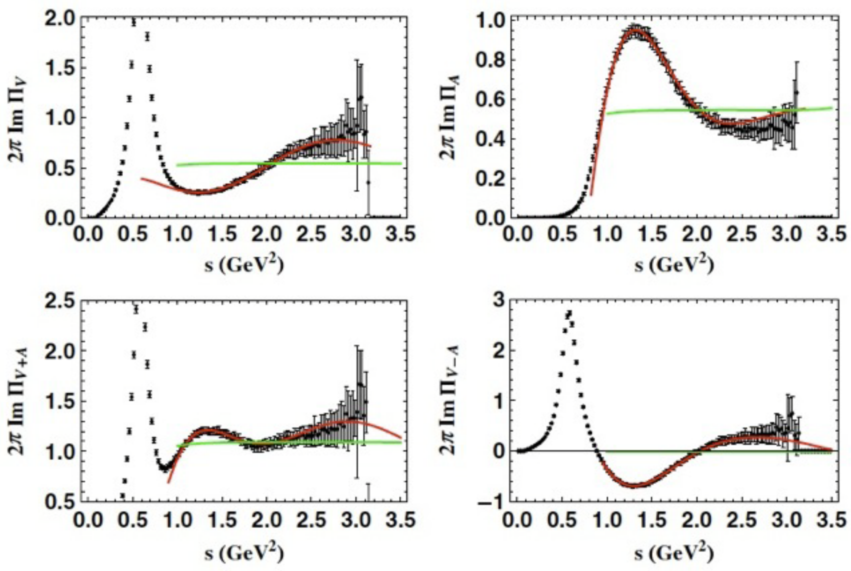

Fig. 3 Absolute value of the S wave measured by different experiments compared with our model. The dashed line delimits the Kη' threshold.

2.10 Beyond the Standard Model

José Ramón Espinosa

We have re-examined the constraints on the Minimal Supersymmetric Standard Model from electroweak baryogenesis. We have found strong upper bounds on the right-handed stop and Higgs masses while the mass of the remaining sfermions should be much heavier.

We have also explored the possibility that the right-handed neutrinos, necessary to provide the tiny mass to left-handed neutrinos, could be described by a (strongly interacting) conformal sector (unparticles) with conformal invariance broken at the neutrino mass by the vacuum expectation value of the Higgs field.

We have combined the data from experimental searches of a Standard Model Higgs boson(including the most recent analyses from the Tevatron) with precision electroweak constraints, to examine the likelihood, as a function of the Higgs mass, that the Standard Model can survive as a valid description up to the Planck scale (see Figure 1).

In addition, the phenomenology of composite Higgs scenarios containing more than one Higgs doublet was explored. We have studied the Higgs spectrum, production channels and decays, and their differences with models with an elementary Higgs.

We have performed a numerical determination of several static properties of the nucleons using the AdS/CFT techniques and find satisfactory agreement with data. The AdS/CFT approach was also used to learn about strongly coupled systems that have a superconducting phase and present Abrikosov vortex configurations.

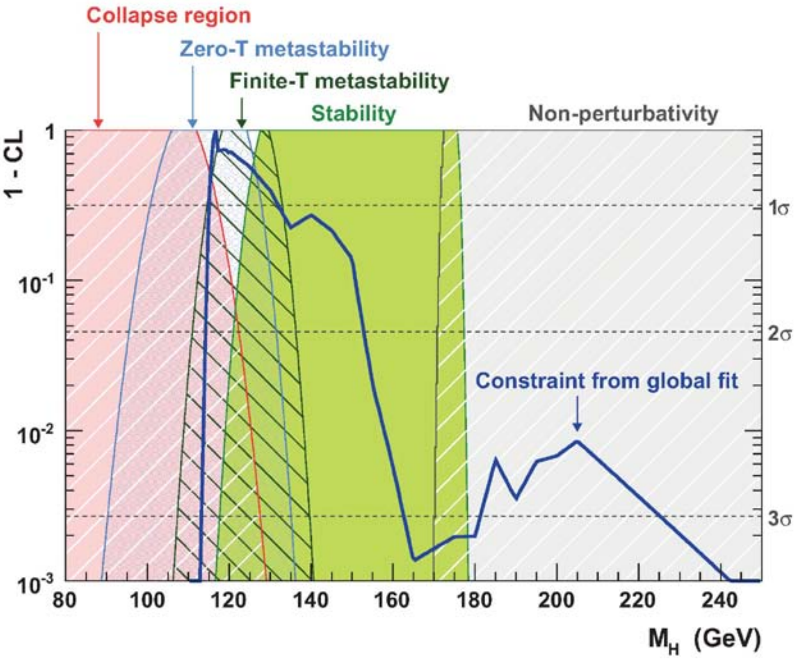

Fig. 1 The likelihood (as 1-CL) of the Standard Model Higgs mass from a global fit to precision electroweak data (including direct searches). The 'collapse region', 'zero-temperature metastability', and 'finite-temperature metastability' regions correspond to a metastable electroweak vacuum with increasing lifetime; the 'stability' region is ultraviolet safe; in the 'non-perturbativity' region the Higgs self-coupling becomes non-perturbative at some scale below the Planck mass.

2.11 Astroparticles / Cosmology

Eduard Massó

Particle astrophysics and particle cosmology are new fields of research that emerge at the intersection of particle physics, astronomy, and cosmology. Indeed, in recent years, these three disciplines have increasingly moved closer together.

The aim of particle astrophysics and particle cosmology is to answer fundamental questions related to the story of the universe such as: What is the universe made of, namely, which is the nature of dark matter and dark energy? What is the origin of cosmic rays? What is the nature of gravity? What is the role of neutrinos in the universe? etc.

To answer these very challenging questions, physicists are developing experiments that may provide the necessary clues. Theoretical development in the field is mainly triggered by the growing amount of experimental data of unprecedented accuracy, coming both from the ground-based laboratories and from the dedicated space missions.

In 2009, the work done in theoretical astroparticles and cosmology can be summarized as follows.

1. We have critically examined the possibility of using the Standard Model Higgs field (coupled strongly to the Ricci scalar) mainly triggered by the growing amount of experimental data of unprecedented accuracy, coming both from ground-based laboratories and from dedicated space missions to provide inflation, discussing the applicability range of the effective theory approach used in the literature and finding that the claimed inflationary behavior takes place well above such limit. This result seriously compromises the naturalness (and appeal) of such a proposal.

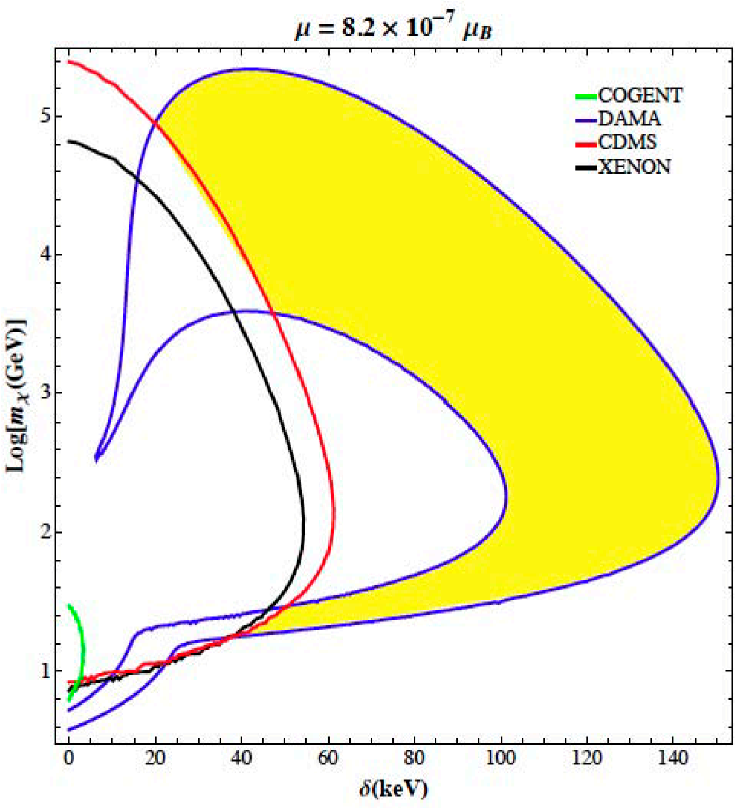

*Fig.1. Plot of the allowed mass of a pair of dark matter Majorana fermions with a fixed transition magnetic dipole moment μ as a function of the mass splitting **δ**. This range of values gives the correct dark matter relic density.*

2. We have examined the gravitational properties of Lamb shift energies. Using available experimental data we have shown that these energies have a standard gravitational behavior at the level of 10^{-5}. The motivation of this point of view is that Lamb shift energies may be interpreted as a consequence of vacuum fluctuations of the electromagnetic field. If this is the case, our result is a test of the gravitational properties of quantum fluctuations.

3. We have considered Dark Matter (DM) with non-zero direct or transition electric or magnetic dipole moment. Using the results from experiments like XENON, CDMS, DAMA and COGENT we put bounds on the electric and magnetic dipole moments of DM. If DM consists of Dirac fermions with direct dipole moments, DM particles with mass < 10 GeV would be consistent with the DAMA signal and with the null results of other experiments. If on the other hand DM consists of Majorana fermions, they can have non-zero transition moments only between different mass eigenstates; see Figure 1. We find that Majorana fermions with mass $m_\chi > 38$ GeV and mass splitting of the order of (50-200) keV can explain the DAMA signal and the null observations from other experiments and in addition give the observed relic density of DM by dipole-mediated annihilation. This parameter space for the mass and dipole moments is allowed by limits from L3 and may result in observable signals at the LHC.

4. We have provided an evaluation of the values of the stop and Higgs masses consistent with the requirements of electroweak baryogenesis in the MSSM, based on an analysis using the renormalization-group-improved Higgs and stop potentials, and including the dominant two-loop effects at high temperature. We have found an allowed window in the stop/Higgs mass plane, consistent with all present experimental data, where there is a strong first-order electroweak phase transition and where the electroweak vacuum is metastable but sufficiently long-lived.

5. In the absence of low energy supersymmetry, we have shown that :

a) the Dark Matter particle alone at the TeV scale can improve gauge coupling unification, raising the unification scale up to the lower bound imposed by proton decay, and

b) Dark Matter stability can automatically follow from grand unification symmetry.

Within reasonably simple unified models, a unique candidate satisfying these two properties is singled out: a fermion isotriplet with zero hypercharge, member of a 45 (or larger) representation of SO(10). We have discussed the phenomenological signatures of this TeV-scale fermion, which can be searched for in direct and indirect future dark matter searches. The proton decay rate into $e^+\pi^0$ is predicted and turns out to be close to the present bound.

3. IFAE Personnel in 2009

IFAE complements its own staff (hired directly by the Institute) with personnel of the UAB and of ICREA. Below is a list of members of the Experimental and Theory Division of IFAE during 2009.

Experimental Division

Faculty

Bosman, Martine	Research Professor, IFAE
Casado, Mª Pilar	Adjunct Professor, UAB
Cavalli-Sforza, Matteo	Research Professor, IFAE
Chmeissani, Mokhtar	Research Professor, IFAE
Cortina, Juan	Research Associate Professor, IFAE
Crespo, José M.	Associate Professor, UAB
Delfino, Manuel	Professor, UAB
Fernández, Enrique	Professor, UAB
Grinstein, Sebastian	Researcher, 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, Mª Lluïsa	Research Associate Professor, IFAE
Moralejo, Abelardo	Researcher, Ramon y Cajal, IFAE
Padilla, Cristóbal	Research Associate Professor, IFAE
Rico, Javier	Researcher, ICREA
Riu, Imma	Researcher, Ramon y Cajal, UAB
Sánchez, Federico	Research Associate Professor, IFAE

Engineering Staff

Ballester, Otger	Electronic Engineer, IFAE
Barceló, Miquel	Electronic Engineer, IFAE, CPAN
Boix, Joan	Electronic Engineer, IFAE
Cardiel, Laia	Electronic Engineer, IFAE
Gamboa, Andres	Electronic Engineering Student, IFAE (since 11/2009)
Grañena, Ferran	Mechanical Engineer, IFAE

Illa, Jose Mª.	Electronic Engineer, IFAE
Puigdengoles, Carles	Electronic Engineer, IFAE
Troyano, Isaac	Electronic Engineer, IFAE, CPAN

Scientific Post-Docs

Abdallah, Jalal	ATLAS, CPAN
Blanch, Oscar	MAGIC, CPAN (since 01/2009)
Demirkoz, Bilge	ATLAS (since 12/2009)
D'Onofrio, Monica	CDF, J. de la Cierva fellow, (until 11/2009)
Fiorini, Luca	ATLAS, J. de la Cierva fellow
Garczarczyk, Markus	MAGIC
Helsens, Clément	ATLAS (since 10/2009)
Jover, Gabriel	Neutrinos
Klepser, Stefan	MAGIC, J. de la Cierva fellow
Lux, Thorsten	Neutrinos , J. de la Cierva fellow
Maiorino, Marino	DES, IFAE
Mazin, Daniel	MAGIC, Marie-Curie EU scholarship
Meoni, Evelin	ATLAS (since 06/2009)
Ochando, Christophe	ATLAS, CPAN (until 11/2009)
Ostman, Linda	DES, PAU (since 10/2009)
Sorin, Verónica	CDF, Beatriu de Pinós fellow
Sushkov, Sergei	ATLAS (until 09/2009)

Computer Scientists and Engineers

Calderón, Yonatan	IFAE
Pacheco, Andreu	IFAE, Senior Computing Engineer
Tomás, Jaume	IFAE

Doctoral Students

Alcaraz, José	Neutrinos (Scholarship MEC-FPI)
Aleksic, Jelena	MAGIC (Scholarship Generalitat)
Camarda, Stefano	CDF (Scholarship MEC-FPU)
Conidi, M Chiara	ATLAS
De Lorenzo, Gianluca	ATLAS (Scholarship MEC-FPU)
Deluca, Carolina	ATLAS (Scholarship Generalitat) (until 06/2009)
Errando, Manel	MAGIC, Teaching Assistant UAB (until 09/2009)
Galbany, Lluis	Teaching assistant UAB

Giavitto, Gianluca	MAGIC, CTA (since 10/2009)
Marti, Carlos	Neutrinos (since 10/2009)
Martí, Pol	DES/PAU
Nadal, Jordi	ATLAS
Nova, Federico	Neutrinos
Ortolan, Lorenzo	CDF (since 03/2009)
Osuna, Carlos	ATLAS (until 06/2009)
Pérez, Estel	ATLAS (Scholarship MEC-FPU)
Puchades, Neus	MAGIC (Scholarship MEC-FPI) (until 11/2009)
Reichardt, Ignasi	MAGIC
Rossetti, Valerio	ATLAS
Vives, Francesc	ATLAS (Scholarship MEC-FPU)
Volpi, Matteo	ATLAS (Scholarship Generalitat)
Tescaro, Diego	MAGIC (Scholarship MEC-FPU)
Vorkerk, Volker	ATLAS (Scholarship MEC-FPI)
Zanin, Roberta	MAGIC (Scholarship MEC-FPU)

Predoctoral Students

Elias, Joan	ATLAS (since 09/2009)

Administrative Personnel

Alonso, Natalia	MAGIC, IFAE, Administrative Assistant (until 09/2009)
Cárdenas, Cristina	UAB/ IFAE, Secretary
Gaya, Josep	IFAE/ UAB, Senior Administrator
Palomanes, Alejandro	IFAE, Administrative Assistant
Sanchez, Marta	IFAE, Administrative Assistant
Strauch, Sara	MAGIC, IFAE, Administrative Assistant (since 09/2009)

Technicians

González, Alex	Electronic Technician, IFAE
Gaweda, Javier	Mechanical Technician, IFAE
Kolle, Karl	MAGIC (until 09/2009)
Colombo, Eduardo	MAGIC (since 09/2009)

2.2 Theory Division

Faculty

Escribano, Rafel	Associate Professor, UAB
Espinosa, Jose Ramón	Research Professor, ICREA
Grifols, Josep Antoni	Professor, UAB
Jamin, Mathias	Research Professor, ICREA
Massó, Eduard	Professor, UAB
Matias, Joaquim	Associate Professor, UAB
Méndez, Antoni	Professor, UAB
Pascual, Ramon	Professor, UAB
Peris, Santi	Associate Professor, UAB
Pineda, Antonio	Associate Professor, UAB
Pomarol, Alex	Associate Professor, UAB
Quirós, Mariano	Research Professor, ICREA

Scientific Post-Docs

Brouzakis, Nikolas	Post-doc UniverseNet
Frigerio, Michele	Post-doc (since 10/2009)
Guo, Zhi-Hui	Post-doc Flavianet
Greynat, David	Post-doc IFAE (at UAB)
Jora, Renata	Post-doc IFAE (since 11/2009)
Konstandin, Thomas	Post-doc UniverseNet (until 10/2009)
Provenza, Alessio	Post-doc IFAE, UAB (until 07/2009)
Salvio, Alberto	Post-doc IFAE
Sanz, Juan José	Post-doc Juan de la Cierva
Stahlhofen, Maximillian	Post-doc Flavianet
Varagnolo, Alvise	Post-doc IFAE (since 11/2009)

Visiting Scientists

Silva, Pedro	Post-doc Institut de Ciències de l'Espai

Doctoral Students

Boito, Diogo R	Scholarship MEC
Cabrer, Joan Antoni	Scholarship
Domènech, Oriol	Scholarship
Masjuan, Pere	Teaching Assistant (until 10/2009)
Montull, Marc	Scholarship UAB
Nardini, Germano	Scholarship MEC (until 10/2009)
Ramon, Marc	Scholarship UAB (PIF)
Serra, Javier	Scholarship MEC

4. Institutional Activities in 2009

4.1 Final Master/Diploma Projects

Experimental Division

Roberta Zanin
Observation of the microquasars Cyg X-1, Cyg X-3 and GRS 1915+105 with the MAGIC Telescope in 2007 and 2008
Advisor: Juan Cortina
March 2009

Jelena Aleksić
Characterization of the MAGIC II Data Acquisition System
Advisors: J. Rico and A. Moralejo
September 2009

Ignasi Reichardt
Massive, automatic data analysis for the MAGIC telescopes
Advisor: J. Rico
September 2009

Pol Marti
Narrow band filter systems for the PAU photo-z survey
Advisor: Ramon Miquel Pascual
September 2009

Ester Segura
Simulation of the Measurement of the Inclusive Jet Cross Sections in $Z \rightarrow ee$ / $\mu\mu$ + jets Events in pp Collisions at 14 TeV with the ATLAS detector
Advisor: Martine Bosman
June 2009

Manel Errando Trías
Discovery of very high energy gamma-ray emission from 3C 279 and 3C 66 A/B with the MAGIC telescope
Advisors: Manel Martínez, Daniel Mazin
July 2009

Theory Division

Marc Montull
Holographic Superconductor Vortices
Advisor: Alex Pomarol
15 de Septembre de 2009

Germano Nardini
The light stop scenario and its first order phase transition
Advisor: Mariano Quirós
June 2009 UAB

Jose Miguel No
Aspects of Phenomenology and Cosmology in Hidden Sector Extensions of the Standard Model
Advisor : Jose Ramón Espinosa
September 2009 UAB

Pere Masjuan
Rational Approximations in Quantum Chromodynamics
Advisor : Santiago Peris
December 2009 UAB

4.2 Doctoral Theses

Experimental Division

Carolina Deluca
Measurement of the Inclusive Isolated Prompt Photon Production Cross Section at the Tevatron using the CDF Detector
Advisors: S. Grinstein/Mario Martinez
June 2009

Carlos Osuna
t-tbar Analysis with Taus in the Final State
Advisor: Lluisa Mir
June 2009

4.3 Publications

Experimental Division

Publications of the ATLAS Group

E. Abat el al.
Study of the response of the ATLAS central calorimeter to pions of energies from 3 to 9 GeV.
Nucl. Instrum. Meth. A607:372-386,2009

P. Adragna et al.
Testbeam studies of production modules of the ATLAS tile calorimeter
Nucl. Instrum. Meth. A606:362-394,2009

Publications of the CDF Group

T. Aaltonen et al., The CDF Collaboration
Search for the Rare B Decays $B^+ \rightarrow \mu^+ \mu^- K^+$, $B^0 \rightarrow \mu^+ \mu^- K^{*0}(892)$, and $B^0_{(s)} \rightarrow \mu^+ \mu^- \phi$ at CDF
Phys. Rev. D79, 011104(R) (2009) - arXiv:0804.3908

T. Aaltonen et al., The CDF Collaboration
Search for High-Mass e^+e^- Resonances in p anti-p Collisions at √s=1.96 TeV
Phys. Rev. Lett. 102, 031801 (2009) - arXiv:0810.2059

T. Aaltonen et al., The CDF Collaboration
Search for a Higgs Boson Decaying to Two W Bosons at CDF Phys. Rev. Lett. 102, 021802 (2009) - arXiv:0809.3930

T. Aaltonen et al., The CDF Collaboration
Search for Maximal Flavor Violating Scalars in Same-Charge Lepton Pairs in p anti-p Collisions at √s= 1.96 TeV
Phys. Rev. Lett. 102, 041801 (2009)
arXiv:0809.4903

T. Aaltonen et al., The CDF Collaboration
First Measurement of the Ratio of Branching Fractions $B(\Lambda^0_b \rightarrow \Lambda^+_c \mu^- \nu_\mu)/B(\Lambda^0_b \rightarrow \Lambda^+_c \pi^\pm)$
Phys. Rev. D79, 032001 (2009). arXiv:0810.3213

T. Aaltonen et al., The CDF Collaboration
Direct Bound on the Total Decay Width of the Top Quark in p anti-p Collisions at √s= 1.96 TeV
Phys. Rev. Lett. 102, 042001 (2009)
arXiv:0808.2167.

T. Aaltonen et al., The CDF Collaboration
Search for New Physics in the $\mu^- \mu^+ (e/\mu)^+$ missing E_t Channel with a low-p_t Lepton Threshold at the Collider Detector at Fermilab
Phys. Rev. D79, 052004 (2009) arXiv:0810.3213

T. Aaltonen et al., The CDF Collaboration
Measurement of Resonance Parameters of Orbitally Excited Narrow B^0 Mesons
Phys. Rev. 102, 102003 (2009) arXiv:0809.5007

T. Aaltonen et al., The CDF Collaboration
Measurement of the Fraction of tt-bar Production via Gluon-Gluon Fusion in p anti-p Collisions at √s= 1.96 TeV
Phys. Rev. D79, 031101 (2009)

T. Aaltonen et al., The CDF Collaboraton
Measurement of the Cross Section for b Jet Production in Events with a Z Boson in p anti-p Collisions at √s= 1.96 TeV
Phys. Rev. D79, 052008 (2009) arXiv: 0812.4458

T. Aaltonen et al., The CDF Collaboration
Measurement of W-Boson Helicity Fractions in Top-Quark Decays using cos theta
Phys. Lett. B479, p. 160-167 (2009) arXiv: 0811.0344

T. Aaltonen et al., The CDF Collaboration
A Search for High-Mass Resonances Decaying to Dimuons at CDF
Phys. Rev. Lett. 102, 091805 (2009)
arXiv:0811.0053

T. Aaltonen et al., The CDF Collaboration
Inclusive Search for Squark and Gluino Production in p anti-p Collisions at √s= 1.96 TeV
Phys. Lett. 102, 121801 (2009). arXiv: 0811.2512

T. Aaltonen et al., The CDF Collaboration
Measurement of the Top Quark Mass with Dilepton Events Selected Using Neuroevolution at CDF II
Phys. Rev. Lett. 102, 152001 (2009)
arXiv:0807.4652

T. Aaltonen et al., The CDF Collaboration
Top Quark Mass Measurement in the Lepton Plus Jets Channel Using a Modified Matrix Element Method
Phys. Rev. D79, 072001 (2009) Xiv:0812.4469

T. Aaltonen et al., The CDF Collaboration
Measurement of the b-Hadron Production Cross Section Using Decays to $\mu^- D^0 X$ Final States in p anti-p Collisions at √s= 1.96 TeV
Phys. Rev. D79, 092003 (2009) arXiv: 0903.2403

T. Aaltonen et al., The CDF Collaboration
Top Quark Mass Measurement in the tt-bar All Hadronic Channel Using a Matrix Element Technique in p anti-p Collisions at √s=1.96 TeV
Phys. Rev. D79, 072010 (2009) arXiv: 0811.1062

T. Aaltonen et al., The CDF Collaboration
Direct Measurement of the W Production Charge Asymmetry in p anti-p Collisions at √s= 1.96 TeV
Phys. Rev. Lett. 102, 181801 (2009) arXiv: 0901.2169

T. Aaltonen et al., The CDF Collaboration
Search for Top-Quark Production via Flavor-Changing Neutral Currents in W + 1 Jet Events at CDF
Phys. Rev. Lett. 102, 151801 (2009) arXiv: 0812.3400

T. Aaltonen et al., The CDF Collaboration
Search for the Decays $B^0_s \rightarrow e^+ \mu^-$ and $B^0_s \rightarrow e^+ e^-$ in CDF Run II
Phys. Rev. Lett. 102, 201801 (2009). arXiv: 0901.3803

T. Aaltonen et al., The CDF Collaboration
Search for New Particles Decaying into Dijets in Proton-Antiproton Collisions at √s= 1.96 TeV
Phys. Rev. D79, 112002 (2009)arXiv: 0812.4036

T. Aaltonen et al., The CDF Collaboration
Measurement of the k_T Distribution of Particles in Jets Produced in p anti-p Collisions at $\sqrt{s}$= 1.96 TeV
Phys. Rev. Lett. 102, 232002 (2009arXiv: 0811.2820

T. Aaltonen et al., The CDF Collaboration
Observation of Exclusive Charmonium Production and $\gamma\gamma \rightarrow \mu^+ \mu^-$ in p anti-p Collisions at $\sqrt{s}$= 1.96 TeV
Phys. Rev. Lett. 102, 242001 (2009) arXiv: 0902.1271

T. Aaltonen et al., The CDF Collaboration
Measurement of the Top Quark Mass at CDF using the "neutrino phi weighting" Template Method on a Lepton Plus Isolated Track Sample
Phys. Rev. D79, 072005 (2009) arXiv: 0901.3773

T. Aaltonen et al., The CDF Collaboration
A Measurement of the t anti-t Cross Section in p anti-p Collisions at sqrt s =.1.96 TeV using Dilepton Events with a Lepton plus Track Selection
Phys. Rev. D79, 112007 (2009) arXiv: 0903.5263

T. Aaltonen et al., The CDF Collaboration
First Simultaneous Measurement of the Top Quark Mass in the Lepton + Jets and Dilepton Channels at CDF
Phys. Rev. D79, 092005 (2009) arXiv: 0809.4808

T. Aaltonen et al., The CDF Collaboration
Search for WW and WZ Production in Lepton Plus Jets Final States at CDF
Phys. Rev. D79, 112011 (2009) arXiv: 0903.0814

T. Aaltonen et al., The CDF Collaboration
Measurement of the Particle Production and Inclusive Differential Cross Sections in p anti-p Collisions at $\sqrt{s}$=1.96 TeV
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Experimental Division

Jalal Abdallah
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Seminar given at the "Center for Advanced Mathematical Sciences" (CAMS) of the "American University of Beirut" (AUB), Beirut, Lebanon, October 2009
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José Alcaraz
"Measurement of the muon-neutrino charged-current quasi-elastic cross-section in the SciBooNE experiment"
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Oscar Blanch
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Martine Bosman
"Top Physics at the LHC with the ATLAS detector Seminar" Physikalisches Institut, Georg-August-Universität, Göttingen, Germany, 16 January 2009
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Matteo Cavalli-Sforza
"Spanish contributions to LHC experiments"
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"La Fisica delle Particelle in Spagna e in Italia"
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"El Cosmos - com ho veu un físic de partícules a l'inici del segle XXI "
Agrupació Astronòmica de Valldoreix i Sant Cugat, Octubre 2009

Juan Cortina
"Future Projects in Very High Energy Gamma Ray Astrophysics"
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"Very High Energy Gamma Ray Astronomy with MAGIC"
Seminar at IAA Granada, 26th February, 2009

Luca Fiorini
"Estudio del proceso de producción Z +jets en ATLAS"
Primera reunión de la red temática española de Física del LHC" Granada, Spain, October 2009
"Top Cross Section and Properties measurements at LHC"
EPS-High Energy Physics conference, 2009
"Tile Calorimeter Data Preparation"
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Sebastian Grinstein
"Recent QCD Results from the Tevatron"
APS April Meeting May 2–5, 2009, Denver, Colorado

Ilya Korolkov
"Detector ATLAS: construcción, instalación y estado actual"
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Thorsten Lux
"EPS-HEP Conference 2009"
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Manel Martinez
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Monica d'Onofrio
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Cristobal Padilla
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"ATLAS Tile status and commissioning"
ATLAS Physics Workshop of the Americas NY, USA, August 2009
"ATLAS Tile Calorimeter Data Quality Assessment and Performance with Calibration, Cosmic and First Beam Data "
Poster presented at the 11th Pisa Meeting on Advanced Detectors
(ELBA 2009) La Biodola, Isola d'Elba, Italy, May 2009

Theory Division

Rafel Escribano
"Dispersive representation of the Kπ vector form factor and fits to $\tau \to K \pi \nu_\tau$ and K_{e3} data"
KLOE-2 Physics Workshop Frascati (Italy), 9-10 April, 2009
"The eta-eta' system: mixing angle, gluonic content and contribution to $(g-2)_\mu$"
Bosen Students' Workshop Bosen (Germany), 30 August-4 September, 2009
"Kπ form factors and final state interactions in $D^+ \to K^- \pi^+ \pi^+$ decays"
XIII International Conference on Hadron Spectroscopy (HADRON 09)
Florida State University (USA), 29 November-4 December, 2009
"Chiral Dynamics Predictions for $\eta' \to \eta \pi \pi$ "
XIII International Conference on Hadron Spectroscopy (HADRON 09)"

Florida State University (USA), 29 November-4 December, 2009

Jose Ramon Espinosa
"The Probable Fate of the Standard Model European Physical Society"
HEP 2009, Krakow (Poland), July 15-22, 2009

Matthias Jamin
"Recent progress in hadronic τ decays"
Ringberg Workshop on New Physics, Flavors and Jets"
Ringberg Castle (Germany), 26 April-1 May, 2009
"Recent progress in hadronic τ decays"
Workshop on QCD Bound States, Argonne National Laboratory" (USA), 15-19 June, 2009
"SU(3) breaking in hadronic τ decays"
Workshop on Chriral Dynamics 09, Bern (Switzerland), 6-10 July, 2009

Edoard Massó
"Physics and Cosmology : The Milli-Electron-Volt Scale"
Fourth Symposium on Large TPCs for Low Energy Rare Events
Paris (France) December, 2009

Joaquim Matias
"$b \to s l^+ l^-$ exclusive (theory)"
Super B Physics Workshop Warwick (England), April 13-17, 2009*"$B \to K^*(\to K\pi) l^+ l^-$ decay: CP observables, Low energy constraints on extensions of the Standard Model"*Flavianet, Kazimierz (Poland), July 23-27, 2009 *"The exclusive $B \to K^*(\to K\pi)\, l^+ l^-$ decay: New observables and a comment on sin (ϕ_S)*"Red tematica de Fisica de LHCb, CPAN, U. Granada, 28-30 Oct. 2009

Santiago Peris
"Contribution from Duality Violations to the theoretical error on alpha(s)"
Workshop on Effective Field Theories: From the Pion to the Upsilon (EFT 09), Valencia (Spain), 2-6 Feb 2009

Antonio Pineda
"Effective Field Theories in Heavy Quarkonium"
International Workshop on Effective Field Theories: from the pion to the Upsilon, Valencia (Spain), 2-6 Feb 2009
"Breakdown of the operator product expansion of deep inelastic scattering in the 't Hooft model"
Tenth workshop on non-perturbative Quantum hromodynamics
Paris (France) May, 2009
"Effective Field Theories in Heavy Quarkonium and renormalons in effective field theories"
KITPC program Effective Field Theories in Particle and Nuclear Physics, Beijing (China), August, 2009

Alex Pomarol
"Higgs physics diversity in composite models"
Workshop on Higgs Physics Phenomenology, University of Zurich (Switzerland), 7-9 January, 2009
"Non-Supersymmetric Extensions of the SM "
Les Rencontres de Physique de la Valle d'Aoste 09, La Thuille (Italy)March, 2009
"Models for the Fermi scale Planck 2009: From the Planck scale to the Electroweak scale"
University of Padua (Italy) May 25-29, 2009
"Baryon Physics in Holographic QCD Models and Beyond Large N at Swansea"
University of Swansea, July, 2009
"Higgs Boson and Electroweak Symmetry Breaking"
Summer School on Particle Physics in the LHC era, ICTP, Trieste (Italy) 06/09

Mariano Quirós
"Stabilizing soft walls Planck 2009: From the Planck scale to the Electroweak scale"
University of Padua (Italy), May 25-29, 2009
"Phenomenology of extra dimensions"
XVII International Workshop on Deep Inalastic Scattering and Related Subjects
Madrid (Spain), 26-30 April, 2009
"Theory Summary"
44th Rencontres de Moriond, Electroweak Session, La Thuile (Italy), 7-14 March, 2009
"Electroweak Baryogenesis and the LHC Prometeo I: LHC Physics and Cosmology"
Universidad de Valencia (Spain), 3-5 March, 2009
"Conformal neutrinos: an alternative to the see-saw"
Workshop on Higgs Boson phenomenology
University of Zurich (Switzerland), 7-9 January, 2009

4.7 Participation in External Committees

Martine Bosman

- ATLAS Top quark Physics Working Group . Entity: CERN (Switzerland). Role: co-convever
 Mandate: organization of "Top quark" physics related analysis. Octobre 2007 - Septembre 2009

Matteo Cavalli-Sforza:

- Member of Conseil Scientifique du LPNHE - Laboratoire de Physique Nucléaire et de Hautes Energies, CNRS et Universités de Paris 6 et Paris 7. Appointed by Director of LPNHE, 2005 -2011.
- Chairman of Scientific Committee of the Laboratori Nazionali di Frascati of INFN Appointed by President of INFN, 2006-2012.
- Spanish representative in the Restricted European Committee for Future accelerators (RECFA). Appointed by Manager of Spanish Particle Physics Program, 2009-2011.

Juan Cortina:

- Representative of IFAE in Collaboration Board of MAGIC experiment.
- Operations and Safety Coordinator of the MAGIC experiment, and as such member of the MAGIC Executive Board (Nov 2009).
- Chair of the Safety and Health Committee of the MAGIC experiment (Nov 2009).
- Member of the Physics Board and the Time Allocation Committee of the MAGIC collaboration (Nov 2009).
- Deputy Spokesman of the MAGIC collaboration (Nov 2009)

- Miembro del comité gestor de la red de Astropartículas RENATA.

Enrique Fernández

- Miembro del Comité:CERN Scientific Policy Committee.
  Comité Asesor del Consejo del CERN en temas de política científica. Presidente, elegido por Comité y nombrado por el Council del CERN.
- Miembro nombrado por Gobierno italiano de Comitato di Valutazione Interna (CVI) del INFN (Instituto Nazionale di Fisica Nucleare), Italia. Entidad de la que depende: Gobierno Italiano. Comité de asesoramiento a la Comisión de Dirección del INFN.
- Miembro del Comité: Peer Review Committee of ApPEC.
  Entidad de la que depende:ApPEC. Tema: Comisión de asesoramiento científico de la comisión ApPECC (Astroparticle Physics European Coordination Committee) formada por representantes de la política científica de Alemania, Francia, Holanda, Italia y Reino Unido.
- Miembro del Comité:International Scientific Advisory Board Entidad de la que depende:Institute of Nuclear Physics of the Polish Academy of Sciences (IFJ). Comité Asesor Científico del Instituto IFJ.Nombrado por Presidente del Consejo de Gobierno del Instituto.
- Presidente del Comité:ASPERA 1st Common Call Evaluation Committe, entidad de la que depende: ASPERA (European Funding Agencies for Astroparticle Physics) Tema:Comité de Evaluación para la financiación conjunta (transnacional) de proyectos.Nombrado por Presidente de ASPERA.

Manel Martínez:

- Chairman of the Collaboration Board of the MAGIC experiment, and as such member of the MAGIC Executive Board and Collaboration Board.
- Member of the Scientific International Committe (CCI) of the Canarian Observatories.
- Member of the Finance Sub-Committee (FSC) of the Canarian Observatories.
- Astroparticle Physics Coordinator in the Executive Committee of the National Center for Particle, Astroparticle and Nuclear Physics (CPAN) Consolider Project.
- Member of the Astroparticle Physics European Coordination (ApPEC) Peer Review Committee
- Spanish representative at the Astroparticle Physics Working Group of the Global Science Forum of the OECD.
- Co-Spokesperson of the Cherenkov Telescope Array (CTA) project, and as such member of the CTA Executive Committee.
- Member of the CTA Speakers Bureau.

Daniel Mazin:

- Convener of EBL - Cosmology working group in the Physics Working Package of CTA (Cherenkov Telescope Array).

Ramon Miquel

- Member of the Management Committee of DES since 2007
  Chair, DES Speakers' Bureau.

Abelardo Moralejo

- Software Coordinator of the MAGIC experiment, and as such member of the MAGIC Executive Board and Collaboration Board. Until November 2009.

Javier Rico

- Convener of Galactic Physics Working Group of MAGIC experiment, as such member of the Physics Board and the Time Allocation Committee.
- Coordinator of MAGIC Data Center

Juan Cortina, Javier Rico

- General meeting of MAGIC collaboration, Castelldefels, November 2009

4.8 IFAE Colloquia

Aurelio Juste (FNAL, USA)
Recent results and prospects from the Tevatron.
19/01/09

Laurent Lellouch (CTP, Marseille)
Ab initio calculations of hadronic properties
23/02/09

David Smith (CEN, Bordeaux-Gradignan)
An Early Look at the GeV Gamma-ray Sky with Fermi (an accent on pulsars).
09/03/09

Joshua Frieman (FNAL)
Constraining Dark energy : First results from the SDSS-II Supernova Survey.
30/03/09

David d'Enterria (ICC, ICREA, Univ. Barcelona)
Strongly interacting quark-gluon matter in high-energy nuclear collisions.
04/05/09

Enrico Tassi (Univ. Cosenza)
Latest Results from HERA
02/06/09

Heinrich Leutwyler (Berna)
Particle Physics : Low Energy, High Accuracy.
08/06/09

Mathew Moulson (INFN, Frascati)
Tests of the Standard Model with Kaon Decays at KLOE.
29/06/09

Laura Baudis (Univ. of Zurich)
Direct searches for dark Matter
05/10 /09

4.9 IFAE Seminars

Federico Mescia
Recent Progress on Flavour Physics
ECM, Universitat de Barcelona
9/01/09

Alberto Romagnoni
Gauge vs. Gravity mediation in models with anomalous U(1)'s
16/01/09

Lisa Everett
Two Stories about Neutrino Masses and Lepton Flavor Mixing
23/01/09

E. de Rafael
Harmonic Sums in QCD
C.P.T. (Marseille)
9/02/09

Nick Evans
Chemical Potential In AdS Duals - Holographic Superconductivity?
University of Southampton
13/02/09

Renata Jora
The large-N limit and scalar mesons in 2D
INFN, Univ. of Rome
20/02/09

Cesar Gomez
Gravity, Species and Information
IFT-UAM/CSIC, Madrid
27/02/09

C.S. Lim
Gauge-Higgs unification, calculable observables and the precision tests
Kobe University, Japan
9/03/09

Gian Luca Giorgi
Ground-state factorization and quantum phase transition in dimerized spin chains (14:30!)
IFISC , CSIC-UIB
20/03/09

Gero von Gersdorff
Conformal neutrinos - an alternative to the seesaw mechanism
Cern
27/03/09

S. Boixo
Quantum state preparation by phase randomization or randomizing the adiabatic theorem (15:30!)
Caltech, USA
1/04/09

Magadalena González
Status of HAWC and OMEGA.
02/04/09

Yuichiro Kiyo
Top quark threshold at LHC
University of Karlsruhe
17/04/09

Karim Benakli
Dirac Gauginos
LPTHE, Paris, France
24/04/09

Uli Haisch
Flavor in Randall-Sundrum Models
Institut fuer Physik (WA THEP) ,Universitaet Main
29/05/09

David Diego
Standard model fermion mass hierarchy from the soft wall
5/06/09

S. Narison
Phenomenology of $1/Q^2$ corrections
Univ. de Montpellier
15/06/09

V.I. Zakharov
On superfluid component of Yang-Mills plasma
Max Planck Inst.
15/06/09

Michele Frigerio
Type II SO(10) unification
IPhT, CEA-Saclay
16/06/09

Julien Lavalle
Cosmic positron and electron excesses: is the dark matter solution a good bet?
Dipart. di Fisica Teorica, Universita di Torino
19/06/09

Dr. Bilge Demirkoz (CERN)
ATLAS Semi-Conductor and Trigger Systems and Potential for New Discoveries
09/09/09

C. Biggio
Neutrino non-standard interactions: a critical appraisal
Max Planck Institute fuer Physik (MPI), Muenchen
18/09/09

Alejandro Muramatsu
Strongly correlated quantum systems out of equilibrium (2:30h!)
Universitaet Stuttgart
30/09/09

Daniel Elander
A light scalar from walking solutions in gauge-string duality
Swansea University
23/10/09

Stefania Gori
Randall-Sundrum vs Susy: Theory & Phenomenology
TU Munich
2/11/09

Michela Ieva
(INFN – Bari)
Measurement and analysis of OPERA neutrino interactions with nuclear emulsions.
06/11/09

Carlos Muñoz
Phenomenology of the μ ν SSM
Dep. de Física Teórica and IFT, UAM, Madrid
6/11/09

Andrea de Simone
Leptogenic Supersymmetry at the LHC
MIT
11/11/09

Oscar Cata
2-forms in holographic QCD
27/11/09

Marco Nardecchia
Hierarchical Soft Terms and Flavor Physics
11/12/09

Aurelio Juste
Searches for the Higgs boson at the Tevatron
18/12/09