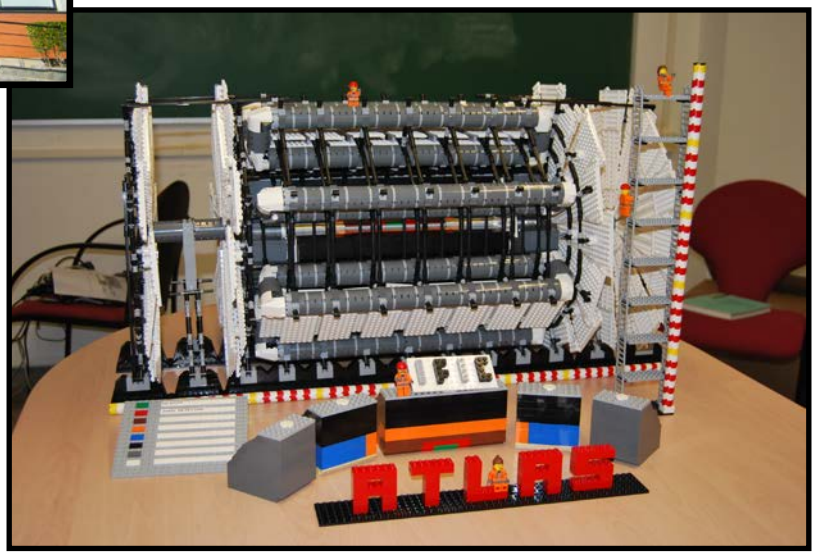

INSTITUT DE FÍSICA CORPUSCULAR

ANNUAL REPORT 2013

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CSIC
Consejo Superior de Investigaciones Científicas

Vniversitat de València

CONTENTS

BIENVENIDA – BENVINGUDA – WELCOME

Prof. Francisco J. Botella Olcina
Director IFIC

De nuevo hacemos pública la memoria anual del instituto correspondiente a la actividad desarrollada durante el año 2013. Tenemos que reiterar a las dos instituciones a las que pertenece el IFIC: el Consejo Superior de Investigaciones Científicas (CSIC) y la Universidad de Valencia, nuestra gratitud por el continuo apoyo que recibimos. Emilio Lora-Tamayo, presidente del CSIC, siempre ha estado dispuesto a apoyar y a colaborar con el IFIC cuantas veces lo hemos necesitado. Esteban Morcillo, como rector de la Universidad de Valencia, siempre ha creído y apoyado las múltiples iniciativas que le hemos presentado.

Este año 2013 estaba considerado como un entreacto entre el descubrimiento del bosón de Higgs y lo que esperamos de Nueva Física en el próximo *run* del LHC. Pero la realidad física siempre nos sorprende con nuevos hechos relevantes. Este 2013 ha sido, ciertamente, el año de la Astronomía de Neutrinos: el experimento IceCube anunció tener evidencias de lo que sería el descubrimiento de neutrinos cósmicos (considerado el *breakthrough* de 2013 por la revista Physics World). El IFIC participa en Antares, el telescopio de neutrinos del hemisferio norte, que consecuentemente se ha situado en plena actualidad especialmente para estudiar los neutrinos del hemisferio sur. Así pues, estos avances auguran un extraordinario futuro en la astronomía de neutrinos cósmicos en el IFIC liderada en el hemisferio norte por Antares y su sucesor, KM3NeT, que será varias veces mayor que el actual IceCube y cuya primera fase ya ha empezado a construirse.

El IFIC participa en T2K, que este año ha medido de forma concluyente que los neutrinos muónicos oscilan a neutrinos electrónicos. Asimismo NEXT, el experimento de desintegración doble beta sin neutrinos, ha culminado un proceso de 5 años de I+D en el que el objetivo de resolución en energía se ha cumplido. La colaboración NEXT, con el apoyo de la *Advanced Grant* del ERC, está lista para las fases de construcción y de física, siendo

De nou fem pública la memòria anual de l'institut corresponent a l'activitat desenvolupada durant l'any 2013. Hem de reiterar a les dues institucions a les quals pertany l'IFIC: el Consell Superior d'Investigacions Científiques (CSIC) i la Universitat de València, la nostra gratitud pel continu suport que rebem. Emilio Lora-Tamayo, president del CSIC, sempre ha estat disposat a donar suport i a col·laborar amb l'IFIC quantes vegades ho hem necessitat. Esteban Morcillo, com a rector de la Universitat de València, sempre ha cregut i donat suport a les múltiples iniciatives que li hem presentat.

Aquest any 2013 estava considerat com un entreacte entre el descobriment del bosó de Higgs i el que esperem de Nova Física en el pròxim *run* de l'LHC. Però la realitat física sempre ens sorprén amb nous fets rellevants. Aquest 2013 ha estat, certament, l'any de l'Astronomia de Neutrins: l'experiment IceCube va anunciar tindre evidències del que seria el descobriment de neutrins còsmics (considerat el *breakthrough* de 2013 per la revista Physics World). L'IFIC participa en Antares, el telescopi de neutrins de l'hemisferi nord, que conseqüentment s'ha situat en plena actualitat especialment per a estudiar els neutrins de l'hemisferi sud. Així doncs, aquests avanços auguren un extraordinari futur en l'astronomia de neutrins còsmics a l'IFIC, liderada a l'hemisferi nord per Antares i el seu successor, KM3NeT, que serà diverses vegades més gran que l'actual IceCube i la seua primera fase ja ha començat a construir-se.

L'IFIC participa en T2K, que enguany ha mesurat de manera concloent que els neutrins muònics oscil·len a neutrins electrònics. Així mateix NEXT, l'experiment de desintegració doble beta sense

inminente ya la instalación en el Laboratorio Subterráneo de Canfranc, de su primera fase, denominada NEW.

En Física Nuclear conviene destacar la construcción y puesta en funcionamiento del espectrómetro de absorción total para el experimento DESPEC denominado DTAS, que se está utilizando en diversos laboratorios hasta su posterior instalación en FAIR.

Respecto a nuestra participación en ATLAS, este año se ha dedicado sobre todo al análisis de los datos experimentales con el objetivo de estudiar las propiedades del bosón de Higgs así como a la búsqueda de Nueva Física. Por supuesto el esfuerzo en el *upgrade* de ATLAS ha continuado, tanto en el Tile-Cal como en el Silicon Tracker.

Un hecho muy relevante ha sido el que el grupo de BaBar del IFIC se ha integrado en el LHCb. Después del liderazgo – teórico y experimental – de la medida de Violación de Inversión Temporal en oscilaciones de mesones B, este grupo se dispone a reforzar la participación española en LHCb, especialmente en el análisis de datos de sabores pesados.

El 12 de Junio de 2013 el TDR del *International Linear Collider* fue presentado simultáneamente en Tokio, Ginebra y Chicago con una destacada participación del IFIC .

Muchos de estos proyectos han contado con la colaboración de los físicos teóricos del Instituto que a su vez han obtenido importantes resultados en prácticamente todas las escalas desde la Física Nuclear hasta la escala de Planck. Estos resultados se pueden encontrar en las siguientes páginas de esta memoria.

La situación económica se ha estabilizado aunque sigue siendo muy precaria. Continua siendo muy preocupante la política de plazas que está comprometiendo el futuro de nuestros mejores investigadores: los científicos del programa Ramón y Cajal. Hemos intentado trasmitir a las autoridades que el incumplimiento del carácter *tenure track* del programa está siendo una

neutrins, ha culminat un procés de 5 anys de R+D en el que l'objectiu de resolució en energia s'ha complit. La col·laboració NEXT, amb el suport de l'*Advanced Grant* de l'ERC, està llista per a les fases de construcció i de física, sent imminent ja la instal·lació al Laboratori Subterrani de Canfranc, de la seua primera fase, anomenada NEW.

En Física Nuclear convé destacar la construcció i posada en funcionament de l'espectròmetre d'absorció total per a l'experiment DESPEC anomenat DTAS, que s'està utilitzant en diversos laboratoris fins a la seua posterior instal·lació a FAIR.

Pel que fa a la nostra participació en ATLAS, aquest any s'ha dedicat sobretot a l'anàlisi de les dades experimentals amb l'objectiu d'estudiar les propietats del bosó de Higgs així com a la recerca de Nova Física. Per descomptat l'esforç en l'*upgrade* de ATLAS ha continuat, tant en el Tile-Cal com en el Silicon Tracker.

Un fet molt rellevant ha estat el que el grup de BaBar a l'IFIC s'ha integrat en LHCb. Després del lideratge – teòric i experimental– de la mesura de Violació d'Inversió Temporal en les oscil·lacions de mesons B, aquest grup es disposa a reforçar la participació espanyola a LHCb, especialment en l'anàlisi de dades de sabors pesats.

El 12 de Juny de 2013 el TDR de l'*International Linear Collider* va ser presentat simultàniament a Tòquio, Ginebra i Chicago amb una destacada participació de l'IFIC

Molts d'aquests projectes han comptat amb la col·laboració dels físics teòrics de l'Institut, que a més a més han obtingut importants resultats en pràcticament totes les escales des de la Física Nuclear fins a l'escala de Planck. Aquests resultats es poden trobar a les següents pàgines d'aquesta memòria.

La situació econòmica s'ha estabilitzat tot i que segueix sent molt precària. Continua sent molt preocupant la política de places que està comprometent el futur dels nostres millors investigadors: els científics del programa Ramón y

catástrofe científica en España de extraordinaria magnitud. Desde la dirección del Instituto seguimos haciendo todo lo posible para salvar la situación temporalmente en espera de que se pongan en marcha programas de contratación indefinida, que aunque anunciados no acaban de ponerse en marcha en todas las instituciones.

Finalmente quisiera agradecer a todos los miembros del Instituto por la extraordinaria labor que están haciendo. Esta memoria pretende precisamente dar a conocer la ingente cantidad de resultados que se han producido durante el año en el IFIC, así como todas las actividades satélites, incluyendo aquellas que han sido necesarias para llevar a cabo nuestra investigación: la captación de recursos financieros, las actividades de formación, de divulgación y de transferencia.

Cajal. Hem intentat transmetre a les autoritats que l'incompliment del caràcter *tenure track* del programa està sent una catàstrofe científica a Espanya d'extraordinària magnitud. Des de la direcció de l'Institut seguim fent tot el possible per salvar la situació temporalment en espera que es posen en marxa programes de contractació indefinida, que encara que anunciats no acaben de posar-se en marxa en totes les institucions.

Finalment voldria agrair a tots els membres de l'Institut per l'extraordinària tasca que estan fent. Aquesta memòria pretén precisament donar a conéixer la ingent quantitat de resultats que s'han produït durant l'any a l'IFIC, així com totes les activitats satèl·lits, incloses les que han estat necessàries per dur a terme la nostra investigació: la captació de recursos financers, les activitats de formació, de divulgació i de transferència.

We present again the annual report corresponding to the activity during 2013. We reiterate our gratitude to the two institutions to which IFIC belongs -the Spanish National Research Council (CSIC) and the University of Valencia- for their continued support. Emilio Lora-Tamayo, president of CSIC, has always been willing to support and cooperate with IFIC anytime we needed. Esteban Morcillo, rector of the University of Valencia, has always believed and supported the many initiatives that have arisen.

This year 2013 was considered an intermission between the discovery of the Higgs boson and what we expect of New Physics in the next run at the LHC. But physics always surprises us with new relevant facts. This 2013 was certainly the year of Neutrino Astronomy: the IceCube experiment announced the evidence of what would be the discovery of cosmic neutrinos (considered the "breakthrough" in 2013 by the journal Physics World). IFIC participates in the Antares neutrino telescope in the northern hemisphere, which consequently has been placed in full actuality especially to study neutrinos from the southern hemisphere. Thus, these developments bode an extraordinary future in cosmic neutrino astronomy at IFIC in the northern hemisphere led by Antares and its successor KM3NeT, which will be several times larger than the current IceCube and the first phase has already begun to build.

IFIC participates in T2K that this year conclusively showed that muon neutrinos transform into electron neutrinos. NEXT, the neutrinoless double beta decay experiment culminated five years of R&D where the target energy resolution has been met. The NEXT collaboration with the support of the Advanced Grant from the ERC is ready for the construction and physics phases. The installation of the first phases of NEXT in the Canfranc Underground Laboratory, called NEW, is imminent.

In Nuclear Physics we have finished the construction and commissioning of the DESPEC Total Absorption Spectrometer, called DTAS, which is being used in various laboratories until its further installation at FAIR.

Regarding our participation in ATLAS, this year has been devoted mainly to the analysis of the experimental data with the aim of studying the properties of the Higgs boson and the search for New Physics. Of course the stress on the upgrade of ATLAS continued, both in the Tile-Cal and in the Silicon Tracker.

A very important fact has been that the BaBar group of IFIC has joined the LHCb collaboration. After the leadership - both theoretically and experimentally - of the measurement of Time Reversal Violation in B meson oscillations, this group is preparing to strengthen the Spanish participation in LHCb, especially in the analysis of heavy flavors.

On the 12th June 2013 the TDR of the "International Linear Collider" was presented simultaneously in Tokyo, Geneva and Chicago with an important participation of IFIC.

Most theoretical physicists from our institute have collaborated in many of these projects. They have achieved very significant results in virtually all scales from nuclear physics to the Planck scale. These results can be found on the following pages of this report.

The economic situation has stabilized but is still very poor. The policy of scientific positions is compromising the future of our best researchers: the scientists of the Ramón y Cajal program. We tried to convey to the authorities that the failure of the tenure track character of this program can be a scientific catastrophe in Spain. The direction of the Institute keeps on doing everything possible to surpass the situation temporarily.

Finally I would like to thank all the members of the Institute for the extraordinary work they are doing. This annual report is intended precisely to publicize the huge amount of results we got, as well as all activities including those satellites that have been necessary to conduct our research: obtaining financial resources, as well as training, outreach and transfer activities.

1. STRUCTURE AND ORGANIZATION

WHAT IFIC IS

The Institute for Corpuscular Physics (**Institut de Física Corpuscular, IFIC**) of Valencia is a joint research institute belonging to two institutions: the Spanish National Research Council (Consejo Superior de Investigaciones Científicas, CSIC) and the University of Valencia (Universitat de València – Estudi General, UVEG). The synergies between the two institutions make IFIC a reference center, both providing personnel and infrastructures.

IFIC's origins date back to 1950, when Prof Joaquín Catalá formed a group in Valencia to study atomic nuclei and elementary particles using the nuclear emulsion technique, a research activity not previously developed in Spain. Hence, IFIC is one of the oldest Spanish institutes in Experimental Physics and the first studying particle and nuclear physics.

The mission of IFIC covers a wide range of subjects. In a broad sense, we study the fundamental interactions (gravitational, electroweak and strong) and the building blocks of matter, considering both the theoretical and experimental aspects. Our aim is to understand the nature of these interactions and their phenomenological consequences in the laboratories, to predict the behaviour in future experiments and, as a final goal, to search for a unified theory of all of them. In parallel, we wish to know which physical processes occur in the Universe, and how it has evolved from its initial conditions.

It is our aim to keep our level as an international reference centre in Particle, Astroparticle and Nuclear Physics both in the theory and experimental domains. Although IFIC is clearly oriented towards basic research, we are open to support applications that may derive from our activities on fundamental physics, such as advanced instrumentation, distributed computing and medical physics. In addition, we want to mainTaín and improve IFIC's training capabilities at the PhD and postdoctoral level. Last but not least, we plan to strengthen our connection with society through our outreach activities.

IFIC is structured in two scientific divisions: experimental and theoretical physics. Both divisions present an excellent research record and impact at the international level. The balance between these two divisions, a situation that is not very common in Spain, is one of the main strengths of IFIC and the close collaboration among their members is extremely fruitful. In addition, the support and managing services provide the adequate administrative and technical help for our research.

In 2005 IFIC was officially classified by the Spanish Ministry of Education and Science as a Class A institute in the list of CSIC research centres.

A bit of history

In the autumn of 1950 Prof Joaquín Catalá formed a group at Valencia to study atomic nuclei and elementary particles using the nuclear emulsion technique[1], after working with Prof Cecil F. Powell at Bristol. This technique had been successfully employed to detect particles in cosmic rays and fixed target experiments leading to the discovery of the pion in 1947 by Powell, who was awarded the Nobel Prize in Physics in 1950. Prof Catalá's group first operated as a local division of the Instituto de Óptica Daza de Valdés belonging to CSIC and specialized in photo-nuclear studies. The group's research program is considered the birth of institutional research in experimental nuclear and particle physics in Spain. One of Catalá's students, Fernando Senent, who became later professor and director of IFIC, was the author in 1954 of the first Spanish thesis in experimental particle and nuclear physics, whose title was: *Distribuciones angulares de los protones producidos en el bombardeo del carbono 12 por deuterones*. Another of his students, Eugenio Villar, obTaíned his PhD in 1957 and was later the person leading the particle physics group in Santander, now known as Instituto de Física de Cantabria (IFCA).

It was at the beginning of 1960 when the Institute got its present name, Instituto de Física Corpuscular (IFIC). During many years, the Institute shared the building, offices and facilities with the department of Atomic, Molecular and Nuclear Physics (FAMN) of the University of Valencia, which has been the traditional link with the University. The first observation of the exotic nucleus ^{8}He was performed by IFIC researchers in 1971 through the reaction $^{8}\mathrm{He} \rightarrow {}^{4}\mathrm{He} + {}^{4}\mathrm{He} + 2e^{-}$.

The international impact of our research activities has been closely related to the political Spanish situation. In the period 1950-1984 IFIC survived having modest, but heroic, contributions to the physics performed at the international scale. However, after Spain re-entered CERN in 1984 the scientific activity of IFIC was boosted in both quantitative and qualitative aspects at the national and international scales.

Around the year 1985 most of the researchers of the department of Theoretical Physics of the University of Valencia joined the Institute and configured its final structure which benefits from the knowledge of both fields: theory and experiment. This provides an excellent atmosphere for scientific cooperation, in particular in the phenomenological and experimental areas. During the last years, it is worth mentioning the participation of IFIC in experiments at CERN (Geneva-Switzerland), GSI (Darmstad-Germany), Stanford (California-USA), FERMILAB (Chicago-USA), etc.

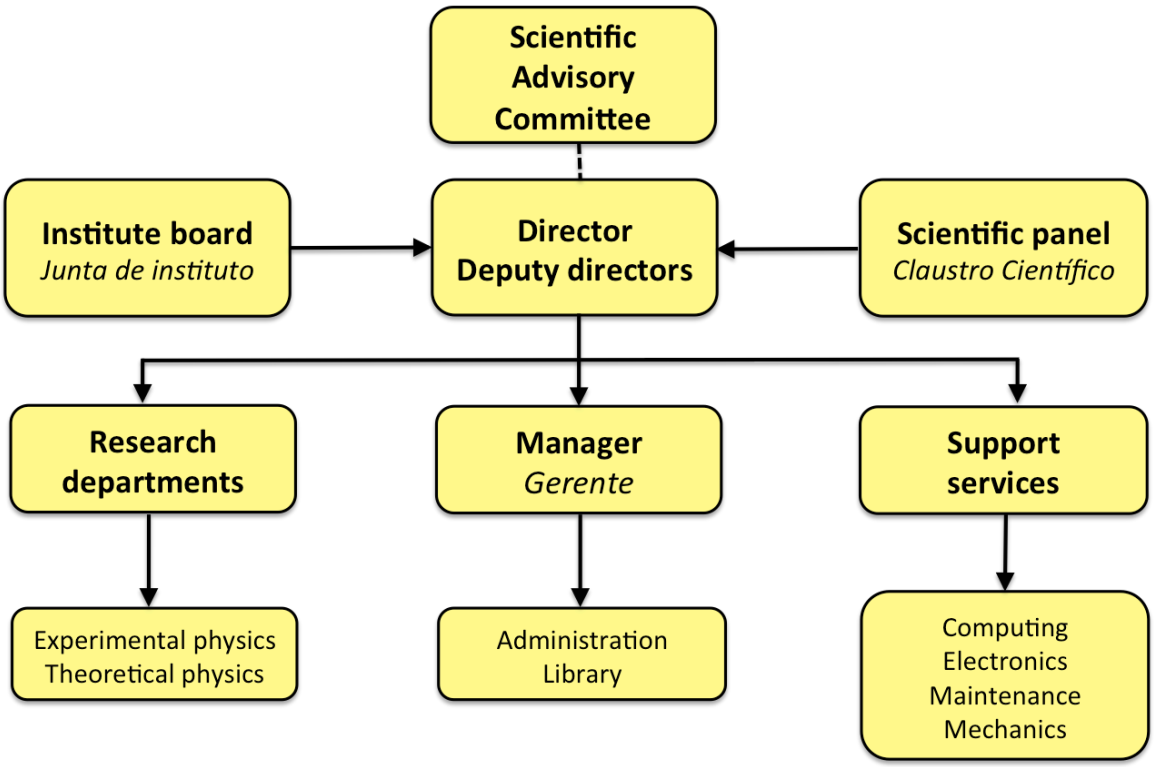
[1] An excellent review article about the birth of experimental nuclear and particle physics in Spain, written by Agustín Ceba, Víctor Navarro y Jorge Velasco, was published in *Revista Española de Física* 25-2 (2011).

ORGANIZATION, SCIENTIFIC DEPARTMENTS AND SUPPORT UNITS

GOVERNING BOARD

The **Scientific Panel** (Claustro Científico) is the discussion forum for scientific matters of the institute. Chaired by the director, the Panel consists of the CSIC scientific personnel and the UVEG researchers affiliated to IFIC. The **Institute Board** (Junta de Instituto) is the governing board of IFIC. It is composed by the **Director**, the **Deputy Directors**, the **Heads** of the two scientific departments and two **representatives** of the IFIC personnel. The **Manager** of IFIC acts as secretary of the Institute Board.

IFIC organization chart



Members of the Scientific Advisory Committee: Guido Altarelli (CERN), William Gelletly (Univ. Surrey), F. Gianotti (CERN), F. Halzen (Univ. Wisconsin), Cecilia Jarlskog (Lund Univ.), Antonio Masiero (Univ. Padua), Tatsuya Nakada (EPF Lausanne), Bing-Song Zou (IHEP Beijing)

Members of the Institute Board (31 Dec 2013)

Director: Francisco J. Botella Olcina

Deputy directors: Juan José Hernández Rey, Sergio Pastor Carpi

Manager: Ana Fandos Lario

Heads of the research departments: Berta Rubio Barroso (Experimental Physics), Juan M. Nieves Pamplona (Theoretical Physics)

Personnel representatives: José Bernabéu Verdú (non-doctoral members), Salvador Martí García (doctoral members)

The Institute is situated in the **Burjassot-Paterna Campus** of the University of Valencia, a few km from the centre of Valencia. IFIC personnel are distributed at the Scientific Park of the UVEG in Paterna (PCUV) and at the University departments (Atomic, Molecular & Nuclear Physics and Theoretical Physics) in Burjassot, within walking distance of each other. At the PCUV, IFIC is one of the research institutes with offices in the main University building and owns the CSIC building where all the laboratories and infrastructures are located.

IFIC buildings at the Scientific Park

Faculty of Physics (UVEG campus in Burjassot)

SCIENTIFIC DEPARTMENTS

EXPERIMENTAL PHYSICS

Several groups of our institute participate in many of the most relevant experiments in Particle, Astroparticle and Nuclear Physics, as well as in the applications of these disciplines to other fields of Science and Technology. For instance, IFIC members are part of the international collaborations that manage the ATLAS and LHCb detectors of the Large Hadron Collider (LHC) at CERN, and participate in the preparation for the future Linear Collider (ILC and CLIC) under the framework of the Linear Collider Collaboration (LCC). The group of e-Science participates in the GRID for the LHC and in other activities of distributed computing. In Astroparticle Physics the work is focused on the neutrino telescope ANTARES and its future extension KM3NeT, while the Neutrino Physics group is involved in the NEXT and T2K experiments. In Nuclear Physics, we participate in the AGATA project, in the future accelerator Facility for Antiproton and Ion Research (FAIR), in the nTOF experiment at CERN and in the HADES experiment at Darmstadt GSI. Finally, the group of Medical Physics carries out several activities mainly related to medical imaging and accelerator developments.

The research lines in Experimental Physics are:

Accelerator-based Experimental High Energy Physics

This research line takes advantage of large particle accelerators to study the elementary components of matter. At present, this line is focused on two large projects: the LHC at CERN and the LCC. IFIC members have participated in the construction of several systems of the ATLAS detector of the LHC, in the computing and data management related to the data supplied by this detector and in beam instrumentation for test facilities of the LCC. In the past, the scientists of this research line participated

in the DELPHI experiment at the LEP accelerator of CERN, the CDF experiment at the Tevatron in Fermilab and in the BaBar experiment at the PEP-II accelerator of SLAC. Recently, IFIC researchers became members of the LHCb and Belle II collaborations.

Astroparticle Physics

Astroparticle Physics studies the particles coming from the cosmos in order to investigate both their properties and the Universe. The group at IFIC participates in the neutrino telescopes ANTARES and KM3NeT. The former is installed at a depth of 2500 metres in the Mediterranean seabed in the coast near Toulon (France) and it has been in operation since 2008. The latter, KM3NeT, will also be deployed in the Mediterranean Sea with an effective detection volume of several cubic kilometres.

Neutrino Physics

This research line studies the intrinsic properties of neutrinos, in particular the phenomenon of flavour neutrino oscillations through the measurement of the mixing parameters. It also tries to elucidate the nature of the neutrino, i.e. if it is a Majorana or a Dirac fermion. IFIC participates in several projects, such as the long-baseline T2K experiment in Japan or SciBooNE in the United States. In addition, the IFIC group is leading the NEXT experiment which will look for neutrinoless double beta decays, a rare nuclear process whose detection would imply that neutrinos are Majorana particles. In the past, the scientists of this line participated in the experiments K2K (Japan) and NOMAD (CERN).

Nuclear Physics

After more than a century of their discovery, atomic nuclei still keep many secrets and there is a wide variety of phenomena not fully understood yet. IFIC researchers in this line work in a broad range of studies in nuclear physics and its applications, such as gamma spectroscopy, extreme nuclear states, nuclear waste incineration or stellar nuclear reactions. Likewise, they are involved in the AGATA project and in the construction of the detectors for the large European infrastructure FAIR. Some IFIC members have participated in the HADES experiment, designed to study di-electron emission in heavy ion reactions.

GRID and e-Science

In order to satisfy the computing needs of particle physics experiments such as those of the LHC, which are providing an enormous amount of data that must be recorded and analyzed, a series of initiatives at CERN and the European Union have been carried out to set up a world network of computing nodes (GRID) communicating among themselves through a series of software protocols. IFIC participates in several of them with the aim of developing a model of distributed computing in Spain and in Europe. This type of development can also be interesting for the local industry and has a straightforward application to other research fields where distributed computing and communication are needed.

Medical Physics

The activities of the Medical Physics group are devoted to the biomedical applications of particle and nuclear physics. Its research includes the development of instrumentation for medical imaging, image

science (image reconstruction and algorithmics, modelling of image formation and degradation phenomena, Monte-Carlo simulations, etc.), as well as accelerator developments. The group activities also cover developments in particle accelerating techniques, beam instrumentation, detector developments for dose monitoring and imaging for hadron therapy.

THEORETICAL PHYSICS

IFIC researchers cover a wide variety of topics in Theoretical Physics, such as the phenomenological aspects of the Standard Model (SM) and of theories beyond it, aspects of nuclear and many-body physics, or particle physics in astrophysics and cosmology. Both the formal aspects of Quantum Field Theory and the phenomenology of nature's fundamental interactions are investigated in the whole range of available energies both in present and future experiments.

The research lines in Theoretical Physics are:

High-Energy Physics Phenomenology

The main goals of high-energy physics phenomenology are the study of the SM of the strong and electroweak interactions and the search for deviations from its predictions that could arise from new interactions expected in several of its extensions, such as supersymmetric models. This strategy includes the precise determination of the SM parameters, couplings, masses and mixing angles, as well as the phenomenological study of possible modifications from its predictions and of new signals arising from novel processes beyond the SM, with emphasis on the potential consequences for present and future high-energy experiments. Some aspects of Quantum Information are also developed.

High-energy Theoretical and Mathematical Physics: Gravity, Black Holes, and Supersymmetry

This line investigates quantum processes in intense gravitational fields and the appearance of new spatiotemporal symmetries. The combination of Quantum Field Theory with General Relativity is studied, as well as its application to black holes (Hawking radiation) and to Cosmology (primitive universe, inflation, etc.). The classical and quantum aspects of the modification of einstenian gravity are also considered, as well as the use of supersymmetry and non-commutative geometries in the search for a quantum theory of gravity.

Nuclear Physics and Many-Body Theory

This line studies the interactions between hadrons and of these with the nuclear medium, using effective theories built from symmetries of Quantum Chromodynamics, perturbative and non-perturbative methods. Special emphasis is put on topics related to the scientific programme of PANDA and CBM of the European Laboratory FAIR and on the study of the neutrino-nucleus cross sections that are used in neutrino oscillation experiments (MiniBooNE, T2K…). Some aspects of Non-linear Dynamics and Complex Systems are also treated.

Quantum Chromodynamics (QCD) and Strong Interactions

Here we study both the perturbative and non-perturbative aspects of the strong interaction, the fundamental force describing the interactions between quarks and gluons. Several approaches are used: lattice gauge theories, effective field theories, chiral perturbation theory or phenomenological lagrangians, such as that of the resonance chiral theory. A variety of goals are pursued, for instance, the theoretical and phenomenological study of QCD in hadron colliders, the study of the hadronic phenomenology in the resonance region, such as in the hadron decays of the tau lepton or in the semileptonic decays of the D mesons and others.

Theoretical Astroparticle Physics and Cosmology

This line covers several interdisciplinary aspects of astroparticle physics and cosmology. Among others it is worth mentioning the basic properties of neutrinos and the future experiments in this field, the origin of neutrino mass and their mixing angles, neutrinos as messengers in astrophysics and cosmology, baryogenesis and leptogenesis, ultra high-energy cosmic rays and others. Although driven by phenomenology which is thriving on the neutrino front as well as cosmology, there is space for theoretical ideas on aspects such as inflation, dark matter or dark energy.

SUPPORT UNITS

Administration and Management

The Administration Service is located on the first floor of the main building. A total of 14 people, belonging to CSIC and UVEG, manage the ordinary performance of IFIC, as well as the budgets of many research grants. These funds are provided by different agencies at different levels (regional, national and European), each of them with its own special rules and particular conditions to manage.

At any time there are around 50 research projects and grants, which implies to process a wide range of tasks as employment contracts, public calls, invoices, leaves of absence, etc. In addition, this Service deals with all sorts of matters in a community with staff belonging to two different institutions and with many nationalities.

Computing centre

Computing

This Unit provides a wide range of network and computing solutions for IFIC, giving support to users and projects. The service catalogue covers a wide spectrum, ranging from the installation and configuration of desktop and laptop computers to scientific computing, including the operation of computer farms with hundreds of multi-core CPUs. Our Computing Service is more than 20 years old and has pioneered the use and spread of new technologies, such as computer networks (FAENET), the web in the past and the GRID at present.

The computing centre houses several clusters with a total of 200 computer nodes (around 2000 cores) and 1.2 PB of disk storage, some of them using GRID technologies. More than 30 servers are constantly operating to provide email and web services, storage, resource management, user access, monitoring services, printing, databases, etc. The computing centre premises are located in a 150 m^2 hall with air conditioning (240 KW), technical floor and uninterruptible power supply (250 KVA).

Electronics laboratory

Electronics

This Unit provides service to any IFIC research project with demands in electronics. IFIC experiments develop particle detectors that generate as output electronic signals that have to be recorded. The staff and equipment of the Electronics Service is ready to support design, prototypes, manufacturing, testing and validation of electronic systems. In addition, cerTaín detector technologies use microelectronics, as for instance silicon particle detectors. This Unit provides support in testing chips and silicon structures, as well as the connection of their microchannels. It also offers service and developments to external companies through contracts and agreements.

This Service Unit makes use of two infrastructures: the general electronics lab (90 m^2) and the clean room (80 m^2 in two areas, classes 10000 and 1000, ISO7 and ISO6) for support in microelectronics.

Library

IFIC's Library, part of CSIC's Library Network, is located on the first floor of the Research Building and has a collection of 2300 books both in topics of general interest and specific to our research. Its staff is responsible for managing the access to electronic journals and the book loans. The latter can be requested online, except for a selection of titles that are for on-site consultation only. IFIC members may request the purchase of books through an online application. The final decision is competence of the Library Commission.

This Service is also responsible for the inventory of theses and dissertations deposited in the library since 1954, as well as the registration of PhD theses and monographs in the general CSIC catalogue. Finally, the library staff collaborates actively in the preparation of IFIC's annual reports (CSIC and UVEG) and the tasks related to the inclusion of our scientific output in the institutional databases.

IFIC workshop

Mechanics

This Unit provides service to projects with mechanical needs, ranging from the conceptual design phase, calculation and simulation to the development of 3D models and drawings. In addition to manufacturing, we carry out measurements and tests on existing components and assemblies. We have a modest but versatile workshop that allows us to make and modify many of our prototypes in our own facilities, providing great flexibility in their development. We also have a dimensional inspection laboratory with contact and visual measurement machines.

This Service is also responsible for supervision of the design and management of the manufacturing of mechanical parts and assemblies in outside companies when they exceed our capacities.

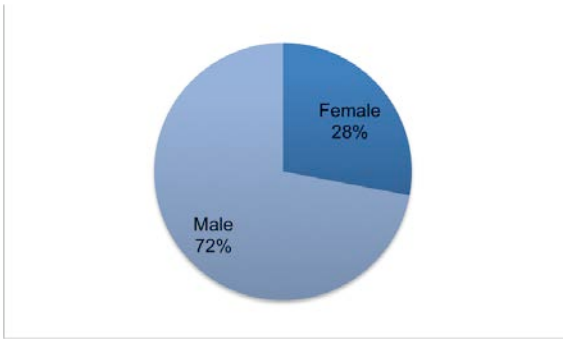
Maintenance

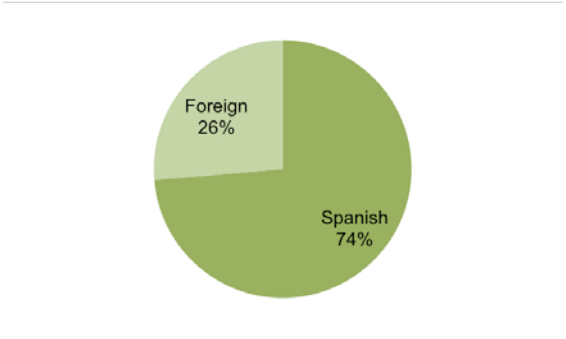
This Unit is an integrated service of maintenance management, occupational safety, radiation protection, environmental and quality management of the shared facilities as well as the research laboratories of the Institute. Its tasks include the preventive and corrective maintenance of facilities and laboratories, the management and logistics of the Clean Room and the Laboratory of Radioactive Sources, and the operation of laboratories. This Unit is also in charge of safety issues at IFIC in collaboration with the corresponding Occupational Health and Safety Services of UVEG and CSIC, including our Radioactive Facility, that depends on the Radiological Protection Area of UVEG, as well as the actions in environmental management (waste disposal and energy efficiency). Finally, this Service is responsible for the implementation of quality standards in the operation of shared facilities, such as the Clean Room, according to the guidelines of our parent institutions.

PERSONNEL (31 DEC 2013)

IFIC employees

TOTAL	MALE	FEMALE	SPANISH	FOREIGN
242	174	68	178	64

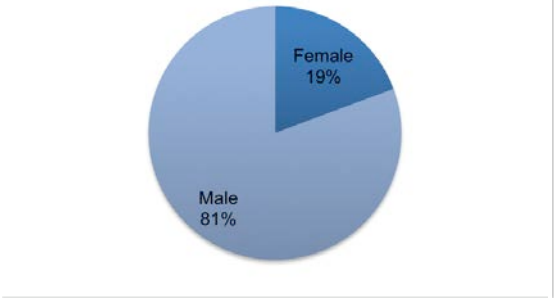


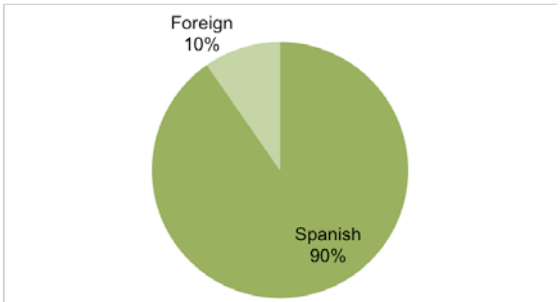


Foreign IFIC employees come from 31 different countries: Europe (43), America (12), Africa (5), Asia (4)

Scientific departments

Permanent staff (civil servants)





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Peña Garay, Carlos
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Valls Ferrer, Juan Antonio

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Fabbri, Alessandro

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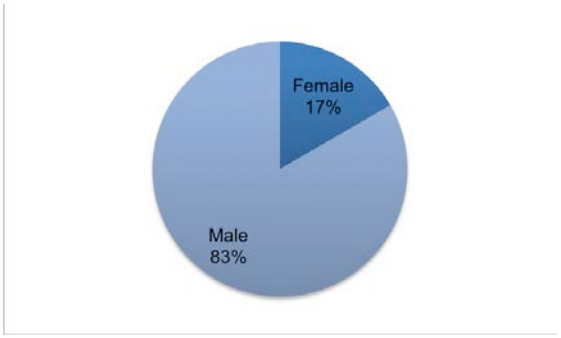

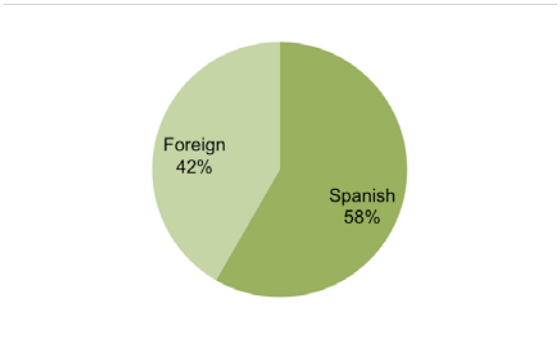

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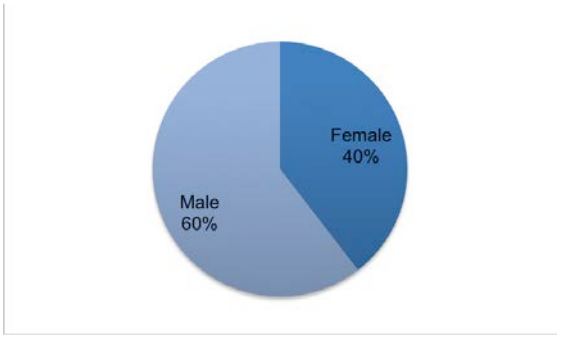

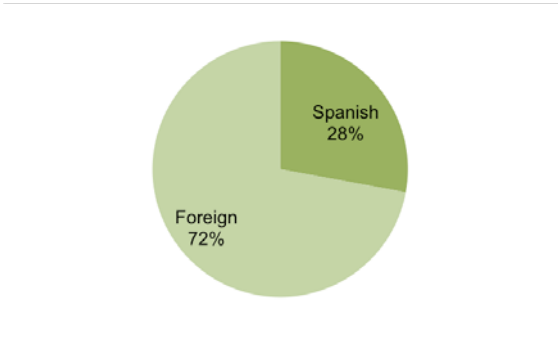

Baker, Michael J.

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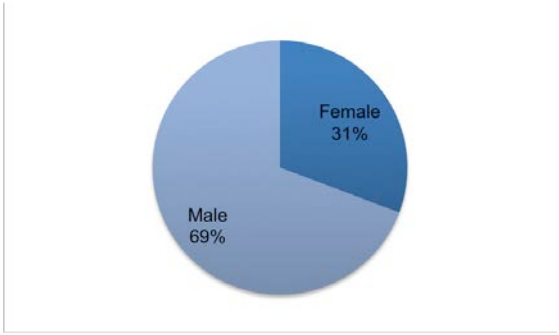

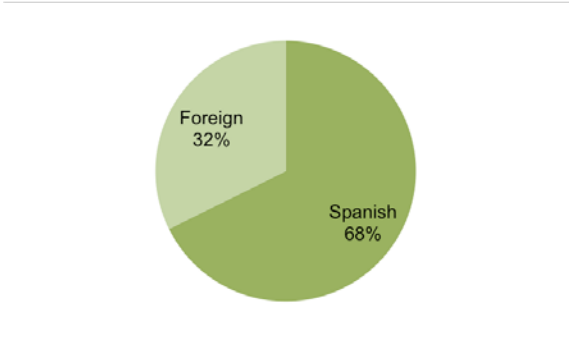

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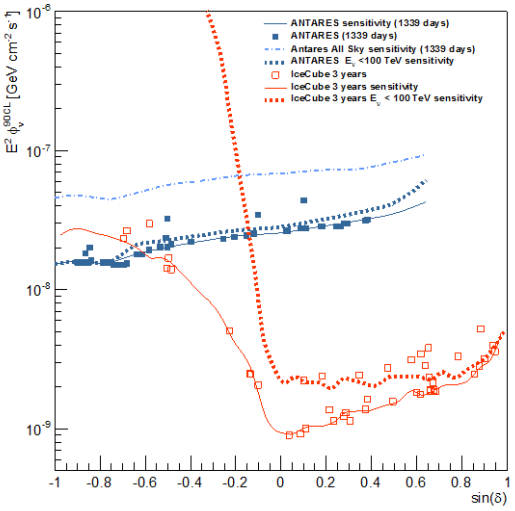
3. RESEARCH ACTIVITIES

EXPERIMENTAL PHYSICS

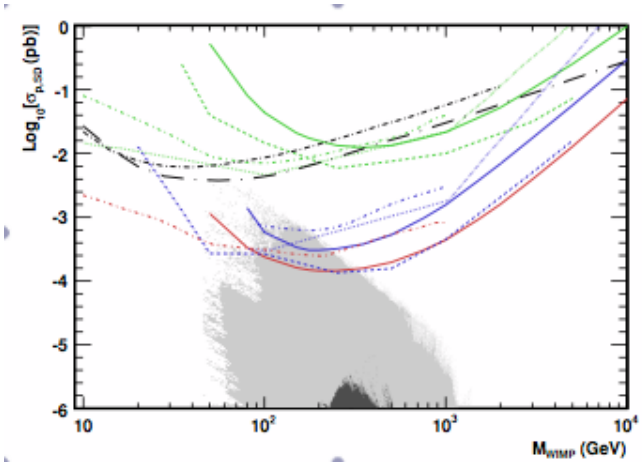
Experimental astroparticle physics

ANTARES:

2013 has been a year of landmark for Neutrino Astronomy, since IceCube announced the first evidence for cosmic neutrinos, which was cover in Science in November 2013 (and Physics Breakthrough of the Year of PhysicsWorld). On our side, and even though ANTARES is smaller, we are competitive in several important results, which has translated in a fruitful year in publications. The IFIC group has led some of the most relevant analyses. For example, we have produced the best flux limits in the Southern neutrino sky and the best limits for spin-dependent cross section for dark matter searches.



Neutrino flux upper limits and sensitivity as a function of declination for ANTARES (blue), compared with IceCube results (red), for a E^{-2} spectrum. The sensitivity for a (more realistic) energy spectrum with a cutoff is also indicated.



90% CL upper limits in the SD WIMP-proton cross section as a function of the WIMP mass for three different annihilation channels: b bbar (green), W+W- (blue) and τ+ τ- (red) for ANTARES 2007-2012 (solid lines) compared with other experiments and a scan of the CMSSM and MSSM-7 models (grey areas)

KM3NeT:

During 2013, very relevant steps have been taken. The first multi-PMT optical module was successfully installed at the ANTARES site and several tests on the mechanical deployment of the lines have been carried out. Moreover, the construction of Phase I of KM3NeT (31 detector units with a total of 558 digital optical modules) has started. The IFIC group has contributed significantly in several aspects of the detector, like the time calibration system with the so-called Laser Beacons and Nanobeacons, and the design of the Central Logic Board.

Selected publications:

ANTARES Collaboration (Adrián-Martínez, S. et al), *First results on dark matter annihilation in the Sun using the ANTARES neutrino telescope*, J. Cosmol. Astropart. Phys. 11, 032 - 22pp, DOI: 10.1088/1475-7516/2013/11/032 [arxiv:1302.6516]

Sánchez-Losa, A., *Search for neutrino emission in gamma-ray flaring blazars with the ANTARES telescope*, Nucl. Instrum. Meth. A 725 (2013) 60-63, DOI: 10.1016/j.nima.2012.11.163 [arxiv:1204.1447]

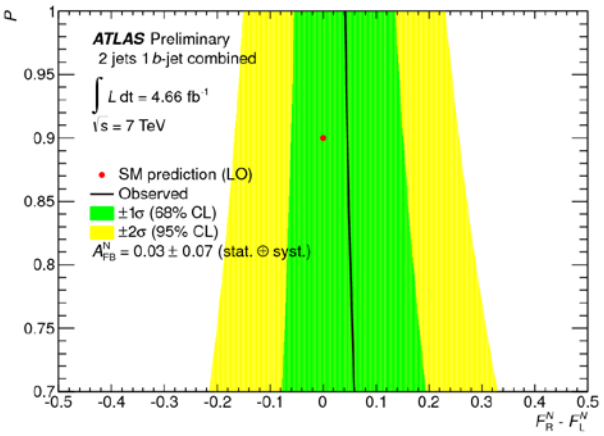
Real, D., *The electronics readout and data acquisition system of the KM3NeT Neutrino Telescope Node*, Proceedings of VLVnT13 - Very Large Volume Neutrino Telescope Workshop 2013, Stockholm (Sweden), August 2013

Main research grants (National Plan):

PARTICIPATION OF IFIC IN THE ANTARES AND KM3NET NEUTRINO TELESCOPES (ref. FPA2012-37528-C02-01)

Accelerator-based experimental high energy physics

In 2013 the Large Hadron Collider (LHC) at CERN entered in the LS1 phase (long shutdown 1). The goal is to regain activity back in 2015 with an increase in energy (up to 13 TeV) and in luminosity (colliding proton bunches with 25 ns spacing). Nevertheless, the LHC concentrated the bulk of the activities of the members of this research line. Effectively, many data analysis continued with the 7 and 8 TeV event samples collected till earlier 2013.

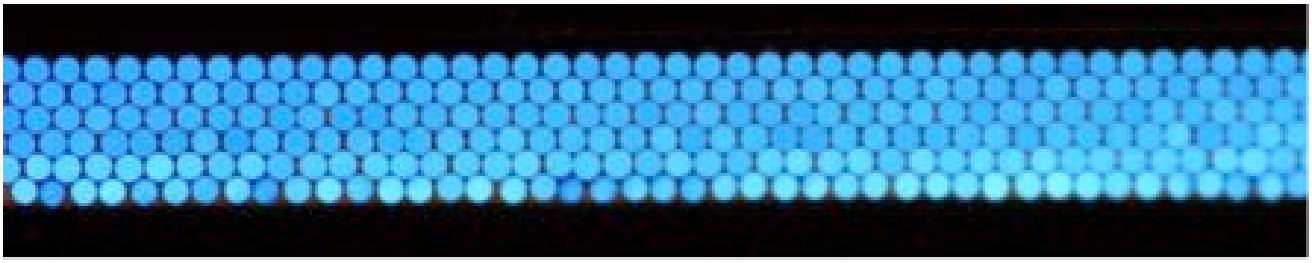


Constraints in the top quark polarisation versus the difference $F_R^N - F_L^N$ plane using the A_{FB}^N measurement. The allowed regions at 68% and 95% CL are shown. The leading order SM prediction (Im(gR)=0 and P=0.9) is also shown for comparison.

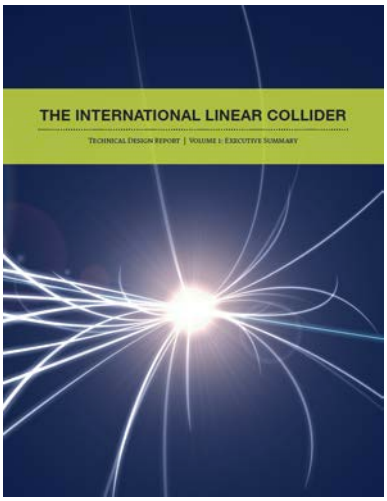
Of course, the characterization of the recently discovered Higgs boson was a very hot topic. The goal was to determine its spin and parity to verify that it was indeed the SM Higgs boson (0^+). More studies on the Higgs boson decay mode to WW were performed as well as the search for its coupling to fermions (in particular to taus). Other SM analysis involved the measurement of the top-antitop cross section with a top giving a τ lepton in its decay chain. This channel poses many experimental challenges but results are in good agreement with the SM cross-section prediction. The charge asymmetry of the top quark was also studied and the results agreed with the SM prediction. The search for new physics in the SUSY R-parity breaking scenarios took advantage of the high statistics (20 fb^{-1} at 8 TeV) collected by the experiment, although no evidence of new physics was found yet. Search for new CP violation phenomena was performed in the single top channel by studying the polarization of the top through its decay products. Again, results were compatible with the SM prediction.

On the other hand, the activities in the detector front developed in a feverish manner in spite of the LHC shutdown. A finer calibration of the tracking and calorimetry systems were necessary for an improved understanding of the detector performance with direct impact in the physics results. The Inner Detector was realigned for the entire data set in a run-by-run basis. Moreover, detailed studies with resonances (like the $Z \rightarrow \mu^+\mu^-$ and $J/\Psi \rightarrow \mu^+\mu^-$ events), plus the E/p for electrons were performed to detect and correct possible (tiny) momentum and impact parameter biases. The jet energy calibration is a key ingredient of almost every data analysis in ATLAS and in particular the b-jet energy scale required our attention as it has a direct impact in all top-quark physics analysis. The efforts towards the ATLAS upgrade progressed with the test of (un)irradiated prototypes of p-type silicon micro-strip sensors and the mechanical and cooling test of a carbon fibre petal for the new end-cap tracker, as well as the back end electronics of the ATLAS hadronic calorimeter.

In 2013 IFIC joined the LHCb collaboration. Our Institute has a long-standing tradition of working on heavy flavour experiments and phenomenology, especially after more than a decade of very active participation in the BaBar experiment at SLAC. At LHCb, large amounts of heavy-quark hadrons are produced, recorded and then analysed in order to detect subtle quantum effects in which virtual particles created from the vacuum can influence the way the heavy-quark hadrons behave and decay. The research activity has focused on data analysis searching for new physics in radiative B meson decays. The instrumental part focussed in the design of the readout electronics of the new scintillating fibre (SciFi) tracking system of the detector.



Blue scintillation light at the end face of a 6-layer fibre mat of the SciFi tracking system. The mat is about 1.5 mm thick with fibres of only 0.25 mm diameter giving an accuracy of better than 0.1 mm. The minute light signals produced by about 3 million fibres, grouped in bunches of 5 or 6, will need to be collected by compact photodetectors (silicon photo-multipliers) and read out by the electronics at every LHC bunch crossing (40 MHz).



Concerning the activities related with future accelerators, the most important event of the year was the celebration on June 12th of a Worldwide event where the Technical Design Report of the ILC was made public. Effectively, in an event held in Tokyo (Japan), Geneva (Switzerland) and Chicago (USA), the design of the International Linear Collider was presented. It is a 200-500 GeV (extendable to 1 TeV) centre-of-mass high-luminosity electron-positron collider, based on 1.3 GHz superconducting radio-frequency accelerator technologies. The physics goals of the ILC were explained in a full volume, which of course will try to answer the questions that the SM of particle physics leaves open. Of course, the Higgs program represents a major part of the ILC studies with the aim of reaching a better precision than the LHC. No need to say that the new physics program is a key ingredient of the ILC studies.

Selected publications:

ATLAS Collaboration (Aad, G. et al), *Evidence for the spin-0 nature of the Higgs boson using ATLAS data*, Phys. Lett. B 726, 120-144, DOI: 10.1016/j.physletb.2013.08.026 [arxiv:1307.1432]

ATLAS Collaboration (Aad, G. et al), *Jet energy resolution in proton-proton collisions at root s 7 TeV recorded in 2010 with the ATLAS detector*, Eur. Phys. J. C 73, 2306 - 27pp, DOI: 10.1140/epjc/s10052-013-2306-0 [arxiv:1210.6210]

BABAR Collaboration (Lees, J.P. et al), *Measurement of an excess of (B)over-bar -> D-(*) tau(-)(v) over-bar(tau) decays and implications for charged Higgs bosons*, Phys. Rev. D 88, 072012 - 30pp, DOI: 10.1103/PhysRevD.88.072012 [arxiv:1303.0571]

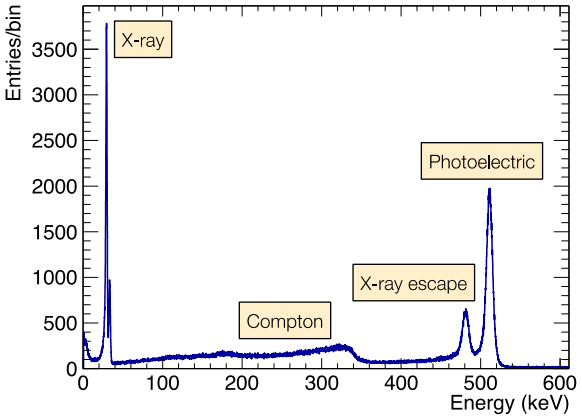
LHCb Collaboration (Aaij, R. et al), *Determination of the X(3872) Meson Quantum Numbers*, Phys. Rev. Lett. 110, 222001 - 8pp, DOI: 10.1103/PhysRevLett.110.222001 [arxiv:1302.6269]

Main research grants (National Plan):

CONTRIBUTIONS TO THE ATLAS EXPERIMENT AT THE LARGE HADRON COLLIDER (ref. FPA2012-39055-C02-01)
CONTRIBUTIONS TO THE HADRONIC TILE CALORIMETER OF THE ATLAS DETECTOR (ref. FPA2012-32843)
DEVELOPMENT OF NEW ACCELERATOR TECHNOLOGIES FOR FUTURE COLLIDERS (ref. FPA2010-21456-C02-01)
DEVELOPMENT OF NEW DETECTORS FOR FUTURE COLLIDERS IN PARTICLE PHYSICS (ref. FPA2010-21549-C04-04)
SPANISH DISTRIBUTED TIER2 FOR THE ATLAS EXPERIMENT (ref. FPA2010-21919-C03-01)

Experimental neutrino physics

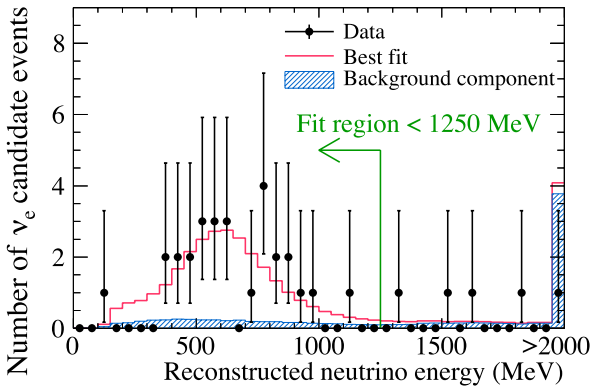
During 2013, the experimental neutrino physics group at IFIC was involved in the NEXT and T2K experiments. The NEXT experiment in Spain searches for the neutrinoless double beta decay of xenon. The goal of the experiment is to understand whether neutrinos are Majorana particles (equal to their antiparticles). The T2K experiment in Japan measures neutrino oscillations in order to probe neutrino flavour mixing and leptonic CP violation.



Energy spectrum from 511 keV gammas in the NEXT-DEMO detector at IFIC. The measured width of the photoelectric and X-ray peaks extrapolate to a sub-percent FWHM energy resolution at the xenon double beta decay Q-value.

NEXT successfully completed in 2013 a five year long R&D phase with xenon gas detector prototypes at the 1 kg scale in xenon mass. One of the crucial aspects of this detector technology that was tested was energy resolution. The experimental goal of a sub-percent FWHM energy resolution at the xenon double beta decay Q-value was met. In addition, an Advanced Grant from the European Research Council was awarded in 2013 to J.J. Gómez-Cadenas (IFIC member and NEXT spokesperson) to proceed through NEXT full construction and physics phases. This is the first grant of this type that is granted to an experimental particle physics project in Spain.

In 2013, T2K conclusively showed that muon neutrinos transform into electron neutrinos. This has been the first direct observation of neutrino "appearance" via neutrino oscillations. In addition, the combination of T2K and reactor neutrino data has provided for the first time a hint for a non-zero (in fact, maximal) CP violation in the neutrino sector. More data from T2K and future neutrino experiments in the coming years will unambiguously address this intriguing result. The T2K-IFIC group was heavily involved in the T2K near detector data analysis and in the combined neutrino oscillation analysis leading to these results.



Number of electron neutrino candidate events as a function of neutrino energy in the Super-Kamiokande detector of T2K. The no-oscillation expectation, shown in blue, is excluded by the data at more than 7σ statistical significance.

Selected publications:

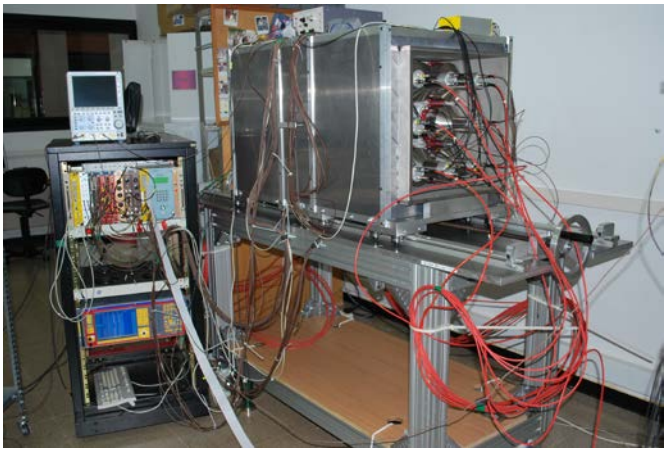
T2K Collaboration (Abe, K. et al), *Evidence of electron neutrino appearance in a muon neutrino beam*, Phys. Rev. D 88, 032002 - 41pp, DOI: 10.1103/PhysRevD.88.032002 [arxiv:1304.0841]

NEXT Collaboration (Álvarez, V. et al), *Operation and first results of the NEXT-DEMO prototype using a silicon photomultiplier tracking array*, J. Instrum. 8, P09011 - 20pp, DOI: 10.1088/1748-0221/8/09/P09011 [arxiv:1306.0471]

Main research grants (National Plan):

CONSTRUCTION OF THE NEXT EXPERIMENT AT THE CANFRANC UNDERGROUND LAB. (ref. FPA2012-37947-C04-01)
PARTICIPATION IN THE T2K EXPERIMENT (ref. FPA2011-29823-C02-01)
THE NEXT PROJECT: ENERGY AND TRAJECTORY MEASUREMENTS (ref. FPA2012-37947-C04-01)
NEXT (ref. ERC Advanced Grant 339787)

Experimental nuclear physics



The completion and the commissioning of the DESPEC TOTAL ABSORPTION SPECTROMETER (DTAS) at the IFIC Gamma Laboratory are amongst the most relevant results of the Gamma and Neutron Spectroscopy Group during 2013, which for the moment are not yet reflected in the published results. This development is lead by the IFIC group for the DEcay SPECtroscopy (DESPEC) experiment of the future facility FAIR (Germany). The detector, which is composed of sixteen 15cm x 15cm x 25cm NaI detector modules, was designed specifically for the study of exotic beta decays in a fragmentation facility. Since FAIR is expected to become operational after 2018, the novel detector will be used meanwhile in existing laboratories in Europe for research lead by the group in nuclear structure, astrophysics and practical applications (reactor decay heat and reactor neutrino research). The relevance of this research program was reflected in the invitation of three members of the group to present their results in the Nuclear Data Conference 2013 (ND2013), which is the most important conference in the field of nuclear data and applications.

Another important result of the group is the acceptance of the BRIKEN construction proposal, lead by a member of the group for the RIKEN Laboratory (Tokyo, Japan). The BRIKEN collaboration aims to build the largest ever built neutron detector based in ^{3}He counters, to exploit the unique beams of this new generation radioactive beam facility for astrophysics and nuclear structure studies.

Selected publications:

Alharbi, T. et al., *Electromagnetic transition rates in the N=80 nucleus Ce-138(58),* Phys. Rev. C 87, 014323 - 7pp, DOI: 10.1103/PhysRevC.87.014323

n_TOF Collaboration (Guerrero, C. et al), *Performance of the neutron time-of-flight facility n_TOF at CERN*, Eur. Phys. J. A 49, 27 - 15pp, DOI: 10.1140/epja/i2013-13027-6

Wrede, C.; Sjue, S.K.L.; García, A.; Swanson, H.E.; Ahmad, I.; Algora, A.; Elomaa, V.V.; Eronen, T.; Hakala, J.; Jokinen, A.; Kolhinen, V.S.; Moore, I.D.; Penttila, H.; Reponen, M.; Rissanen, J.; Saastamoinen, A.; Aysto, J., *Electron capture on In-116 and implications for nuclear structure related to double-beta decay*, Phys. Rev. C 87, 031303 - 5pp, DOI: 10.1103/PhysRevC.87.031303

Main research grants (National Plan):

HIGH-RESOLUTION GAMMA SPECTROSCOPY: THE PATH TO AGATA (ref. FPA2011-29854-C04-02)
NUCLEAR STRUCTURE, APPLICATIONS AND ASTROPHYSICS: THE PATH TO FAIR (ref. FPA2011-24553)

Medical application of nuclear and particle physics

The medical physics research activities at IFIC in 2013 include the development of instrumentation for medical applications, simulations and image reconstruction algorithms.

In hadron therapy protons or carbon ions are employed to administer the radiation dose to the patients. In order to monitor the treatment administration, PET techniques are employed which leave room for significant improvement. Within the European project ENVISION, the group participates in the development of improved PET devices and of Compton Cameras for treatment monitoring.

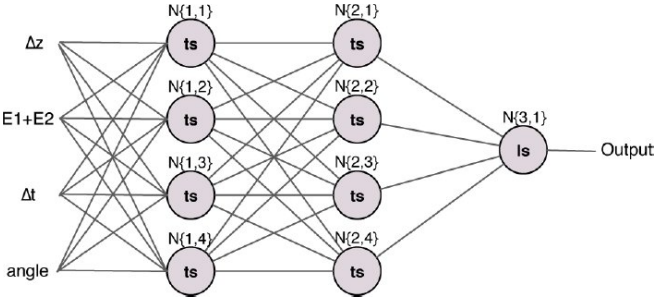
Compton telescope composed of three LaBr3 detectors connected to the readout electronics.

The group has developed a three-layer Compton telescope based on $LaBr_3$ crystals and silicon photomultipliers as photodetectors. The most relevant achievements in this area during 2013 have been:

- A third layer with improved performance has been added to the device.
- Detailed simulations of the device in real and optimized conditions have been conducted to study its performance.
- An improved version of the electronics has been developed.
- Several image reconstruction algorithms have been developed and validated to fully exploit the enhanced capabilities of a three-layer system.
- Na-22 sources have been successfully imaged in the laboratory.

The group also works in the improvement of the performance of PET systems. In previous years, a small animal PET prototype was constructed and tested. In 2013:

- The system performance has been revised with the aim of constructing a full detector ring.
- The data acquisition system has been replaced by a new version that allows operation of 16 detector heads.
- Innovative detector geometries are being tested for performance improvement.



The Neural Network applied to signal identification tasks in PET

Along the line of PET systems improvement, the group participates also in the development of the AX-PET prototype, a demonstrator of a novel PET geometry. The work during 2013 has focused on the performance of detailed simulations, and the development of dedicated image reconstruction software for the prototype.

Over 2013, the group has also conducted research in the Image Science field, in particular:

- Application of Neural Network techniques to the task of signal identification in PET.
- Acceleration of image reconstruction algorithms through bootstrap-like techniques.

Selected publications:

Llosá, G.; Cabello, J.; Callier, S.; Gillam, J.E.; Lacasta, C.; Rafecas, M.; Raux, L.; Solaz, C.; Stankova, V.; de La Taille, C.; Trovato, M.; Barrio, J., *First Compton telescope prototype based on continuous LaBr3-SiPM detectors*, Nucl. Instrum. Methods Phys. Res. A 718, 130-133, DOI: 10.1016/j.nima.2012.08.074

Cabello, J.; Barrillon, P.; Barrio, J.; Bisogni, M.G.; Del Guerra, A.; Lacasta, C.; Rafecas, M.; Saikouk, H.; Solaz, C.; Solevi, P.; de La Taille, C.; Llosá, G., *High resolution detectors based on continuous crystals and SiPMs for small animal PET*, Nucl. Instrum. Methods Phys. Res. A 718, 148-150, DOI: 10.1016/j.nima.2012.08.094

Oliver, J.F.; Fuster-García, E.; Cabello, J.; Tortajada, S.; Rafecas, M., *Application of Artificial Neural Network for Reducing Random Coincidences in PET*, IEEE Trans. Nucl. Sci. 60, 3399-3409, DOI: 10.1109/TNS.2013.2274702

Gillam, J.E.; Solevi, P.; Oliver, J.F.; Rafecas, M., *Simulated one-pass list-mode: an approach to on-the-fly system matrix calculation*, Phys. Med. Biol. 58, 2377-2394, DOI: 10.1088/0031-9155/58/7/2377

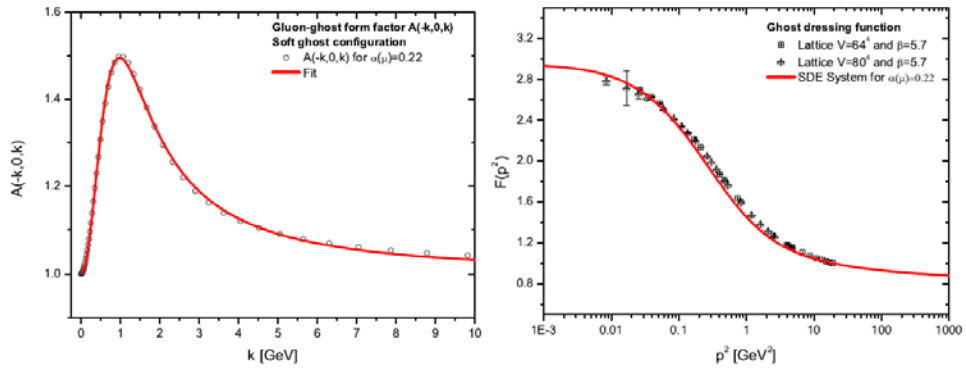
Main research grants (National Plan):

IMAGE QUALITY AND QUANTIFICATION IN POSITRON EMISSION TOMOGRAPHY (ref. FPA2010-14891)

QCD and strong interactions

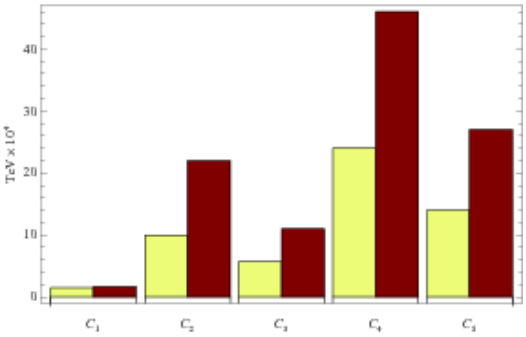
The main research lines and results in 2013 were:

- A non-perturbative calculation of the ghost-gluon vertex in the Landau gauge using Schwinger-Dyson equations that reproduces lattice results rather accurately.



- Generation of gluon mass in the presence of dynamical quarks in the Landau gauge. From this study, an infrared finite gluon propagator emerges, whose saturation point is considerably suppressed, due to a corresponding increase in the value of the gluon mass.

- Continuum limit non-perturbative study of the kaon mixing beyond the Standard Model from QCD on the lattice including the dynamical effects of the u and d quarks. The accuracy of the calculation allows us to provide a refined Unitary Triangle analysis improving the bounds coming from model independent constraints on New Physics.



- Calculation of WZ production with two jets with leptonic decays at hadron-hadron colliders at next-to-leading order in QCD. These processes are important to test the quartic gauge couplings and for beyond standard model physics searches.

- Calculation of the Higgs production in association with three jets via gluon fusion including at leading order the full mass dependence of the top- and bottom-quark contributions. This channel is important for the measurement of the Higgs CP properties at the LHC.

- Study of the odd-intrinsic-parity $e^+e^-\to\pi^+\pi^-(\pi^0,\eta)$ cross sections in the hadron resonances energy region, at leading order in the large number of colors expansion and within the resonance chiral theory framework.

- Determination of the MS-bar charm quark mass from charmonium QCD sum rules up to order α_s^3.

- Development of the three-loop duality relation for two- and three-loop integrals with multiple identical propagators.

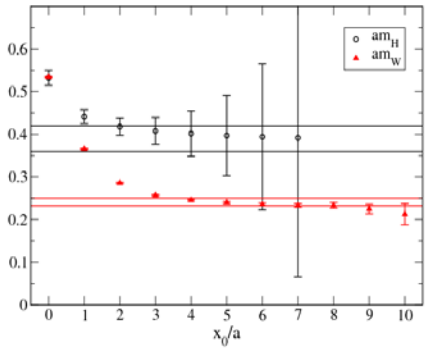
- Understanding of the interplay between the quark-gluon and hadronic degrees of freedom in the EMC effect.

- Study of double parton correlations in high-energy hadron-hadron collisions in the valence quark region by means of constituent quark models.

- Study of the interaction between two B=1 states in the Chiral Dilaton Model where baryons are described as non-topological solitons arising from the interaction of chiral mesons and quarks.

- Study of the role of colour mixing in the quark model calculation of tetraquark.

- Non-perturbative formulation of an SU(2) massive gauge theory on a space-time lattice which is also a discretised gauged non-linear chiral model. Exploratory numerical simulations of the model indicate the presence of a scaling region where both a triplet vector and a scalar remain light.



Selected publications:

Aguilar, A.C.; Ibáñez, D.; Papavassiliou, J., *Ghost propagator and ghost-gluon vertex from Schwinger-Dyson equations*, Phys. Rev. D 87, 114020 - 14pp, DOI: 10.1103/PhysRevD.87.114020 [arXiv:1303.3609]

Bertone, V. et al; Carrasco, N.; Giménez, V., *Kaon mixing beyond the SM from N-f=2 tmQCD and model independent constraints from the UTA*, J. High Energy Phys. 03, 089 - 53pp, DOI: 10.1007/JHEP03(2013)089 [arXiv:1207.1287]

Bierenbaum, I.; Buchta, S.; Draggiotis, P.; Malamos, I.; Rodrigo, G., *Tree-loop duality relation beyond single poles*, J. High Energy Phys. 03, 025 - 24pp, DOI: JHEP03(2013)025 [arXiv:1211.5048]

Campanario, F.; Kerner, M.; Ninh, L.D.; Zeppenfeld, D., *WZ production in association with two jets at next-to-leading order in QCD*, Phys. Rev. Lett. 111, 052003 - 4pp, DOI: 10.1103/PhysRevLett.111.052003 [arXiv:1305.1623]

Dai, L.Y.; Portolés, J.; Shekhovtsova, O., *Three pseudoscalar meson production in e(+)e(-) annihilation*, Phys. Rev. D 88, 056001 - 23pp, DOI: 10.1103/PhysRevD.88.056001 [arXiv:1305.5751]

Dehnadi, B.; Hoang, A.H.; Mateu, V.; Zebarjad, S.M., *Charm mass determination from QCD charmonium sum rules at order alpha(3)(s),* J. High Energy Phys. 09, 103 - 56pp, DOI: 10.1007/JHEP09(2013)103 [arXiv:1102.2264]

Della Morte, M.; Hernandez, P., *A non-perturbative study of massive gauge theories*, J. High Energy Phys. 11, 213 - 20pp, DOI: 10.1007/JHEP11(2013)213 [arXiv:1309.3326]

Rinaldi, M.; Scopetta, S.; Vento, V., *Double parton correlations in constituent quark models*, Phys. Rev. D 87, 114021 - 9pp, DOI: 10.1103/PhysRevD.87.114021 [arXiv:1302.6462]

Vijande, J.; Valcarce, A.; Richard, J.M., *Adiabaticity and color mixing in tetraquark spectroscopy*, Phys. Rev. D 87, 034040 - 5pp, DOI: 10.1103/PhysRevD.87.034040 [arXiv:1301.6212]

Main research grants (National Plan):

FLAVOUR AND ORIGIN OF MATTER (ref. FPA2011-29678-C02-01)
FUNDAMENTAL INTERACTIONS AND THEIR EXPERIMENTAL IMPLICATIONS (ref. FPA2011-23596)
HADRONIC MODELS, FUNDAMENTAL INTERACTIONS AND NUCLEAR PHYSICS (ref. FPA2010-21750-C02-01)
PARTICLE PHYSICS PHENOMENOLOGY AT THE LHC AND FLAVOUR FACTORIES (ref. FPA2011-23778)
PERTURBATIVE AND NON-PERTURBATIVE STUDIES OF THE STANDARD MODEL AND ITS EXTENSIONS (ref. FPA2011-23897)

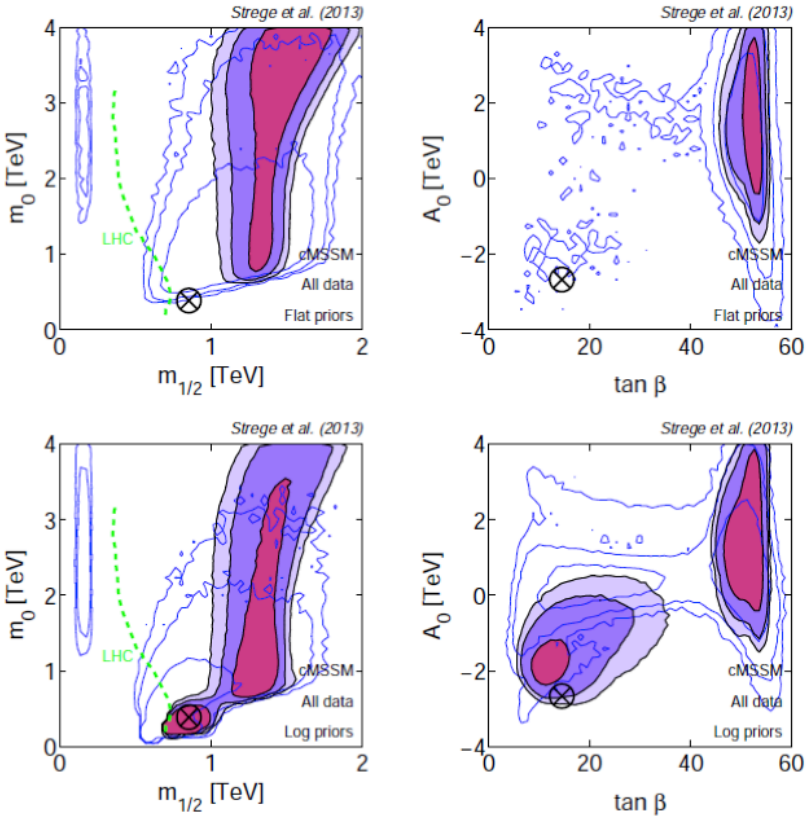
High-energy physics phenomenology

Some selected results published in 2013 are:

- A short review of the status of non-Abelian discrete symmetries, which provide a simple way to account for the observed pattern of neutrino mixing. It includes a discussion of phenomenological implications such as neutrinoless double beta decay, lepton flavour violation as well as theoretical aspects such as the possibility to explain quarks and leptons in a common framework.

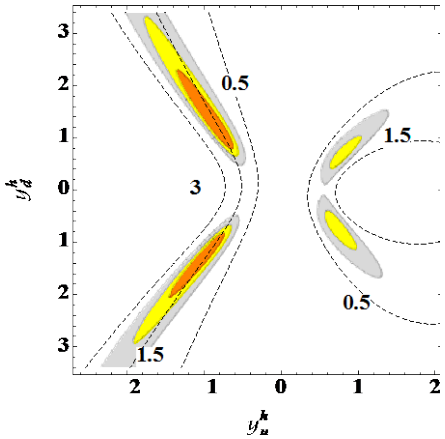
- A systematic decomposition of the dimension nine neutrinoless double beta decay operator, for the first time complete. A number of new ways to realize double beta decay, not discussed previously in the literature, have been identified.

- Analysis of the LHC phenomenology of doubly charged scalars, predicted in many Standard Model extensions. It has been shown that events containing four charged leptons makes it possible to determine whether the doubly-charged excitation belongs to a multiplet with weak isospin T = 0, 1/2, 1, 3/2 or 2.



Constraints on the cMSSM including all available present-day data. The encircled black cross is the overall best-fit point. Blue/empty contours show constraints as of Dec 2011 and the dashed/green line shows the current LHC 95% exclusion limit.

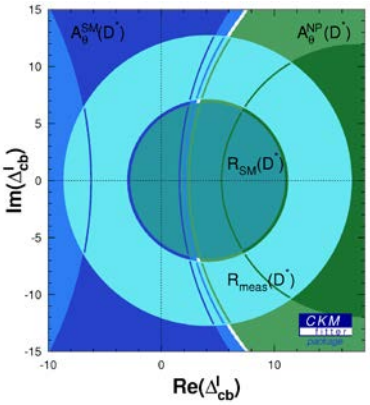
- Updated global fits of the constrained Minimal Supersymmetric Standard Model (cMSSM), including the most recent constraints from the ATLAS and CMS detectors at the LHC, as well as the most recent results of the XENON100 experiment. It was found that upcoming ton-scale direct detection experiments will probe essentially the entire currently favoured region almost independently of the statistical approach used.



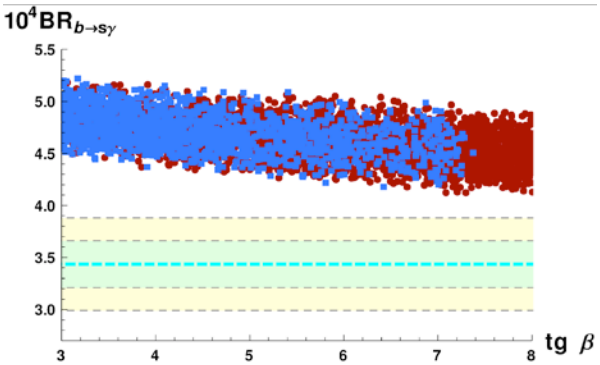
Global fit to the Aligned 2HDM, in the CP-conserving caseThe orange, yellow and gray areas denote 68%, 90% and 99% CL regions. Dashed lines correspond to fixed values of the signal strength.

- An analysis of LHC data on the recently found Higgs boson in the context of two-Higgs doublet models without tree-level flavour-changing neutral currents. The implications of the LHC data on the scalar spectrum are studied in the framework of an Aligned Two-Higgs Doublet Model with possible CP-violation.

The usual two-Higgs doublet models based on discrete Z_2 symmetries were obtained as particular limits of this Aligned Two-Higgs Doublet Model.



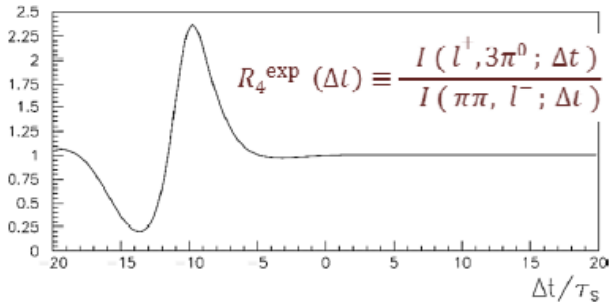
- Analysis of the recent experimental evidence for an excess of τ-lepton production in several exclusive semileptonic *B*-meson decays in the context of two-Higgs-doublet models.
-
- A calculation of the oblique S and T parameters at next-to-leading order within strongly-coupled models of electroweak symmetry breaking. They work with a general effective Lagrangian, implementing the chiral symmetry breaking with Goldstones, gauge bosons, the observed Higgs-like scalar and one multiplet of vector and axial-vector massive resonance states. The experimental data forces the vector and axial-vector states to be above the TeV scale, and suggests that the Higgs-like scalar should have a WW coupling close to the Standard Model one.

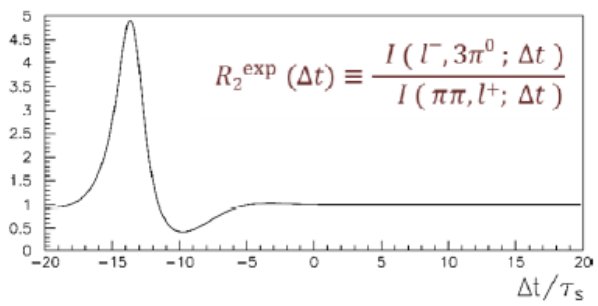


Branching ratio of the b→sγ decay as a function of tanβ in an MSSM where the observed Higgs state corresponds to the second lightest Higgs boson.

- The results from Higgs searches at LHC and indirect bounds as the b→sγ branching ratio were used to rule out the possibility of the 125 GeV Higgs found at LHC being the second lightest Higgs in the MSSM. This was done analytically in the context of a generic MSSM including the possibility of explicit CP violation in the Higgs potential, using simple expressions for a relatively small number of observables that are able to eliminate this possibility without leaving room for fine-tuned cancellations.

- Proposal of a method to perform a direct test of time reversal symmetry in the neutral kaon system independent of any CP and CPT symmetry test. This test can be implemented in the KLOE-2 experiment at DAΦNE.





Selected publications:

Barenboim, G.; Bosch, C.; López-Ibáñez, M.L.; Vives, O., *Eviction of a 125 GeV "heavy"-Higgs from the MSSM*, J. High Energy Phys. 11, 051 - 39pp, DOI: 10.1007/JHEP11(2013)051 [arXiv:1307.5973]

Bernabeu, J.; Di Domenico, A.; Villanueva-Pérez, P., *Direct test of time reversal symmetry in the entangled neutral kaon system at a phi-factory*, Nucl. Phys. B 868, 102-119, DOI: 10.1016/j.nuclphysb.2012.11.009 [arXiv:1208.0773]

Bonnet, F.; Hirsch, M.; Ota, T.; Winter, W., *Systematic decomposition of the neutrinoless double beta decay operator*, J. High Energy Phys. 03, 055 - 34pp, DOI: 10.1007/JHEP03(2013)055 [arXiv:1212.3045]

Celis, A.; Ilisie, V.; Pich, A., *LHC constraints on two-Higgs doublet models*, J. High Energy Phys. 07, 053 - 44pp, DOI: 10.1007/JHEP07(2013)053 [arXiv:1302.4022]

Celis, A.; Jung, M.; Li, X.Q.; Pich, A., *Sensitivity to charged scalars in B -> D-(*)tau nu(tau) and B -> tau nu(tau) decays*, J. High Energy Phys. 01, 054 - 27pp, DOI: 10.1007/JHEP01(2013)054 [arXiv:1210.8443]

del Águila, F.; Chala, M.; Santamaria, A.; Wudka, J., *Discriminating between lepton number violating scalars using events with four and three charged leptons at the LHC*, Phys. Lett. B 725, 310-315, DOI: 10.1016/j.physletb.2013.07.014 [arXiv:1305.3904]

Morisi, S.; Valle, J.W.F., *Neutrino masses and mixing: a flavour symmetry roadmap*, Fortschritte Phys.-Prog. Phys. 61, 466-492, DOI: 10.1002/prop.201200125 [arXiv:1206.6678]

Pich, A.; Rosell, I.; Sanz-Cillero, J.J., *Viability of Strongly Coupled Scenarios with a Light Higgs-like Boson*, Phys. Rev. Lett. 110, 181801 - 4pp, DOI: 10.1103/PhysRevLett.110.181801 [arXiv:1212.6769]

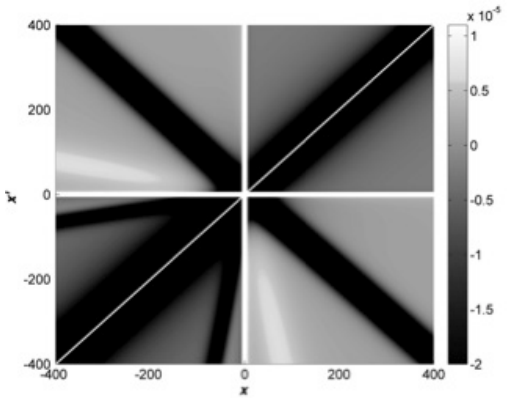
Strege, C.; Bertone, G.; Feroz, F.; Fornasa, M.; Ruiz de Austri, R.; Trotta, R., *Global fits of the cMSSM and NUHM including the LHC Higgs discovery and new XENON100 constraints*, J. Cosmol. Astropart. Phys. 04, 013 - 40pp, DOI: 10.1088/1475-7516/2013/04/013 [arXiv:1212.2636]

Main research grants (National Plan):

ASTROPARTICLE AND HIGH ENERGY PHYSICS (ref. FPA2011-22975)
FLAVOUR AND ORIGIN OF MATTER (ref. FPA2011-29678-C02-01)
FUNDAMENTAL INTERACTIONS AND THEIR EXPERIMENTAL IMPLICATIONS (ref. FPA2011-23596)
PARTICLE PHYSICS PHENOMENOLOGY AT THE LHC AND FLAVOUR FACTORIES (ref. FPA2011-23778)
PERTURBATIVE AND NON-PERTURBATIVE STUDIES OF THE STANDARD MODEL AND ITS EXTENSIONS (ref. FPA2011-23897)

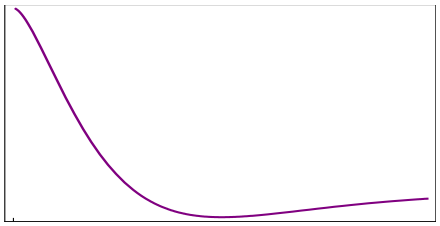
Mathematical and theoretical high energy physics.
Gravity, Black Holes, and Supersymmetry

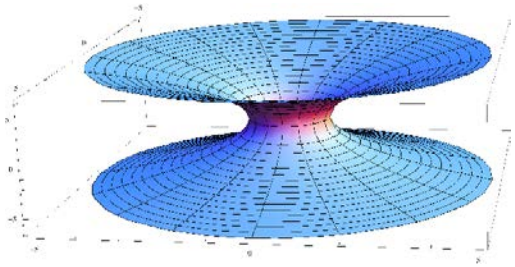
The fundamental research topic of this line is the interphase of gravitation and quantum theory. At energy scales well below the Planck energy, quantum field theory in curved spacetime has a striking success. It predicts particle creation in the very early universe (gravitational waves, primordial inhomogeneities) and black hole radiance. At lengths or energies approaching the Planck scale the absence of a well-understood theory urges a worldwide effort to construct a viable quantum theory for the gravitational field. The complexity of the problem requires a multidisciplinary approach, incorporating a wide range of viewpoints, running from sophisticated mathematics to ambitious experiments. A deeper understanding of our basic theories is required, as well as an improvement of the leading approaches for a proper quantum gravity theory. Our research line follows this strategy in an intertwining way. The main lines and results in 2013 were:



- We pointed out an instability of a certain class of Schwarzschild black holes in gravity theories with a massive graviton, initially discovered in the context of higher-dimensional black strings.

- We have numerically analysed, using quantum fields in curved space techniques, the density-density correlator of linear fluctuations in an acoustic black hole in Bose-Einstein condensates. Such techniques are valid in the hydrodynamical approximation of BEC theory. The obtained results are in good qualitative and quantitative agreement with those analysis performed in the full BEC theory.





- We have constructed a new method of renormalization to deal with spin 1/2 field in expanding universes. We have calculated the renormalized stress-energy tensor of Dirac fields in de Sitter space-time.
- Black hole interiors in metric-affine geometries have been studied finding that point-like singularities are replaced by non-trivial topological structures. This leads to the emergence of point-like particles with electric charge and mass out of free electric fields trapped in the topology (geons). These objects are classically and quantum mechanically stable massive particles.

- Analysis of non-supersymmetrical black holes in four dimensions. Deformations of spacetime and superspacetime.

Selected publications:

Anderson, P.R.; Balbinot, R.; Fabbri, A.; Parentani, R., *Hawking radiation correlations in Bose-Einstein condensates using quantum field theory in curved space*, Phys. Rev. D 87, 124018 - 18pp, DOI: 10.1103/PhysRevD.87.124018 [arXiv:1301.2081]

de Azcárraga, J.A.; Izquierdo, J.M.; Lukierski, J.; Woronowicz, M., *Generalizations of Maxwell (super)algebras by the expansion method*, Nucl. Phys. B 869, 303-314, DOI: 10.1016/j.nuclphysb.2012.12.008 [arXiv:1210.1117]

Landete, A.; Navarro-Salas, J.; Torrenti, F., *Adiabatic regularization for spin-1/2 fields*, Phys. Rev. D 88, 061501 - 5pp, DOI: 10.1103/PhysRevD.88.061501 [arXiv:1305.7374]

Lobo, F.S.N.; Olmo, G.J.; Rubiera-García, D., *Semiclassical geons as solitonic black hole remnants*, J. Cosmol. Astropart. Phys. 07, 011 - 10pp, DOI: 10.1088/1475-7516/2013/07/011 [arXiv:1306.6537]

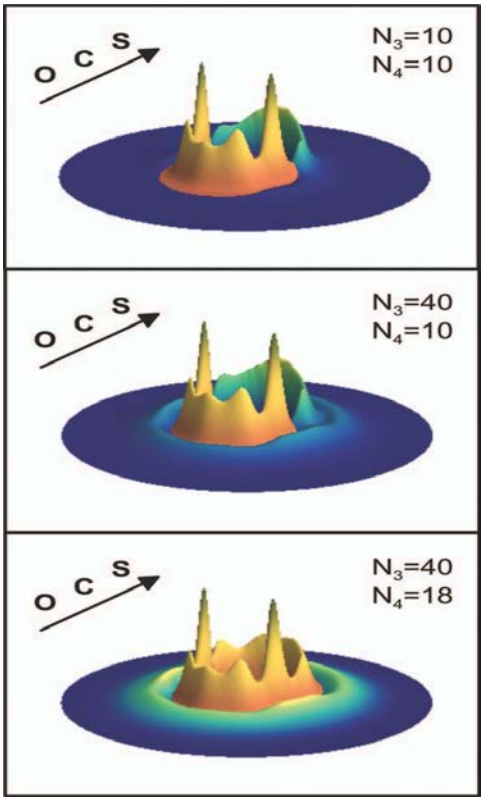
Main research grants (National Plan):

GEOMETRY, GROUPS, FIELD THEORY AND SUPERSYMMETRY (ref. FIS2008-01980)
QUANTUM BLACK HOLES, SUPERGRAVITY AND COSMOLOGY (ref. FIS2011-29813-C02-02)

Nuclear and many-body theory

One of the main lines of work has been the investigation of the consequences of heavy quark flavor symmetry on the newly observed structures in the heavy quarkonium mass region, some of which are proposed to be hadronic molecules. The symmetry allows us to predict new hadronic molecules and test the hadronic molecular assumption of the observed structures. We have explored the consequences of the flavor symmetry assuming the X(3872) and $Z_b(10610)$ as a isoscalar DD^* and isovector BB^* hadronic molecule, respectively. A series of hadronic molecules composed of heavy mesons have been predicted. In particular, there is an isoscalar 1^{++} BB^* bound state with a mass of 10580 MeV which may be searched for in the Y(1S,2S) $\pi^+ \pi^- \pi^0$ mass distribution; the isovector charmonium partners of the $Z_b(10610)$ and the $Z_b(10650)$ are also predicted, one of which probably corresponds to the recently observed $Z_c(3900)$ and $Z_c(4025)$ resonances by the BESIII Collaboration.

The exploration of several aspects of the neutrino interactions with nucleons and nuclei has also been continued. For instance, we have evaluated the quasielastic and multinucleon contributions to the antineutrino nucleus scattering cross section and compared our results with the recent MiniBooNE data. We have used a local Fermi gas model that includes RPA correlations and gets the multinucleon part from a systematic many body expansion of the W boson self-energy in the nuclear medium. The same model had been quite successful for the neutrino cross section and contains no new parameters. We have also analyzed the relevance of 2p2h events for the antineutrino energy reconstruction.



Concerning lattice QCD, we could mention the recent developments on the design of efficient strategies that allows to obtain π-π phase shifts and ρ meson properties from QCD lattice data with high precision. For this purpose we evaluate the levels of the π-π system in the ρ channel in finite volume using chiral unitary theory. We investigate the dependence on the pion mass and compare with other approaches using QCD lattice calculations and effective theories. We also illustrate the errors induced by using the conventional Lüscher approach instead of a more accurate one recently developed that takes into account exactly the relativistic two-meson propagators.

We have also studied the pion-mass dependence of the nucleon mass within the covariant SU(2) baryon chiral perturbation theory both without and with explicit □(1232) degrees of freedom. By fitting to lattice QCD data in 2 and 2+1 flavors from several collaborations, for π masses below 420 MeV, we obtain low energy constants of natural size and compatible with π-nucleon scattering data. As a result of our analysis, which encompasses the study of finite volume corrections and discretization effects, we report a value for the π-nucleon sigma-term of 41(5)(4) MeV in the 2 flavor case and 52(3)(8) MeV for 2+1 flavors.

In the context of complex systems, we have studied structural and spectrum properties of isotopically pure and mixed helium droplets doped with an OCS molecule. A comparison of our results for He-3 and He-4 clusters of the same size shows important similarities, as a pile up of atoms at the donut ring position of the OCS dopant. These results are discussed in the light of the recently analyzed infrared spectra measured in large pure He-3 droplets. Overall the calculations reveal that the structures and

energies of small doped He-3 are only slightly more diffuse and less energetic than the same He-4 clusters. The energetics and appearance of mixed He-3-He-4 droplets OCS doped, have been discussed for selected numbers of He atoms, identifying the first magic numbers of the fermionic component.

Concerning infinite nuclear systems, we have given the explicit form of the next-to-next-to-leading order of the Skyrme effective pseudopotential compatible with all required symmetries and especially with gauge invariance. We have also worked on the tensor interaction effects on the stability, spin susceptibility and linear response of infinite nuclear matter. We have shown that for the Skyrme forces considered, the tensor effects are sizable and tend to increase the spin instability, which appears at smaller densities than in the case that the tensor is not taken into account. On the contrary, the tensor contribution of finite-range forces to the spin susceptibility is small or negligible for both isospin channels of symmetric nuclear matter as well as for neutron matter.

We have considered a two-parameter family of piecewise linear maps in which the moduli of the two slopes take different values. We have provided numerical evidence of the existence of some parameter regions in which the Lyapunov exponent and the topological entropy remain constant. Analytical proof of this phenomenon is also given for certain cases. Surprisingly however, the systems with that property are not conjugate as we prove by using kneading theory.

Selected publications:

Guo, F.K.; Hidalgo-Duque, C.; Nieves, J.; Pavón Valderrama, M., *Consequences of heavy-quark symmetries for hadronic molecules*, Phys. Rev. D 88, 054007 - 5pp, DOI: 10.1103/PhysRevD.88.054007 [arXiv:1303.6608]

Nieves, J.; Ruiz Simo, I.; Vicente Vacas, M.J., *Two particle-hole excitations in charged current quasielastic antineutrino-nucleus scattering*, Phys. Lett. B 721, 90-93, DOI: 10.1016/j.physletb.2013.03.002 [arXiv:1302.0703]

Chen, H.X.; Oset, E., *$\pi\pi$ interaction in the ρ channel in finite volume*, Phys. Rev. D 87, 016014 - 15pp, DOI: 10.1103/PhysRevD.87.016014 [arXiv:1202.2787]

Alvarez-Ruso, L.; Ledwig, T.; Martin Camalich, J.; Vicente Vacas, M.J., *Nucleon mass and pion-nucleon sigma term from a chiral analysis of lattice QCD data*, Phys. Rev. D 88, 054507 - 20pp, DOI: 10.1103/PhysRevD.88.054507 [arXiv:1304.0483]

Botella-Soler, V.; Oteo, J.A.; Ros, J.; Glendinning, P., *Lyapunov exponent and topological entropy plateaus in piecewise linear maps*, J. Phys. A 46, 125101 - 26pp, DOI: 10.1088/1751-8113/46/12/125101

Davesne, D.; Pastore, A.; Navarro, J., *Skyrme effective pseudopotential up to the next-to-next-to-leading order*, J. Phys. G 40, 095104 - 8pp, DOI: 10.1088/0954-3899/40/9/095104 [arXiv:1307.2349]

Leal, A.; Mateo, D.; Pi, M.; Barranco, M.; Navarro, J., *The structure of mixed He-3-He-4 droplets doped with OCS: A density functional approach*, J. Chem. Phys. 139, 174308 - 6pp, DOI: 10.1063/1.4827499

Mateo, D.; Pi, M.; Navarro, J.; Toennies, J.P., *A density functional study of the structure of small OCS@He-3(N) clusters*, J. Chem. Phys. 138, 044321 - 8pp, DOI: 10.1063/1.4788828

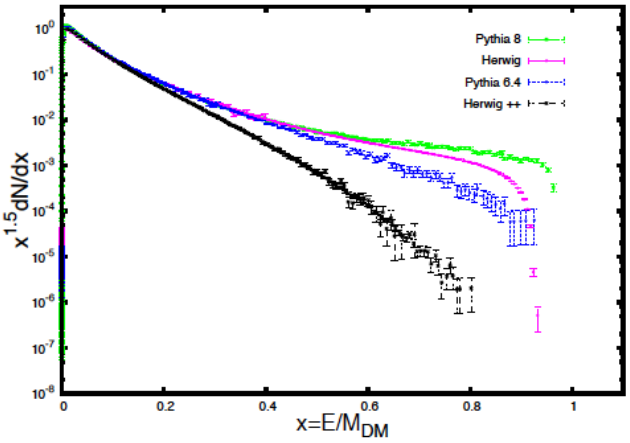
Navarro, J.; Polls, A., *Spin instabilities of infinite nuclear matter and effective tensor interactions*, Phys. Rev. C 87, 044329 - 11pp, DOI: 10.1103/PhysRevC.87.044329 [arXiv:1304.2663]

Main research grants (National Plan):

EFFECTIVE THEORIES IN NUCLEAR AND HADRON PHYSICS (ref. FIS2011-28853-C02-02)
NUCLEAR AND HADRON PHYSICS AT INTERMEDIATE ENERGIES (ref. FIS2011-28853-C02-01)
STUDIES ON QUANTUM STRUCTURE AND DYNAMICS OF ATOMIC, NUCLEAR AND ELECTRONIC SYSTEMS (ref. FIS2011-28617-C02-02)

Theoretical astroparticle physics and cosmology

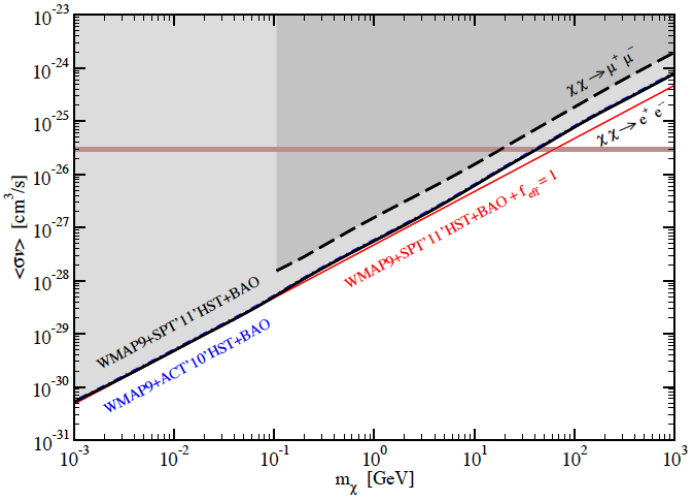
The research topics of this line include cosmic rays, neutrinos, dark matter and dark energy theory and phenomenology. Some members are involved in international collaborations (as part of their theoretical and phenomenological teams) that study high-energy cosmic rays (Pierre Auger Observatory), solar neutrinos (Borexino) and the role of dark matter or dark energy in the cosmological large-scale structure (BOSS).



top-antitop annihilation channel for a dark matter particle mass of 1 TeV. The four computer simulations are all manifestly inconsistent among them at very high energy

Dark matter has been the one of the most explored topics by IFIC researchers in this line during 2013. Concerning direct detection of dark matter, methods independent of the dark matter halo properties have been explored, finding that the DAMA signal is incompatible with the XENON100 results. On the other hand, the presence of dark matter can also be inferred via indirect signals, as for instance, via the detection of gamma rays produced in dark matter annihilations. Therefore, the simulation of these fluxes with high precision is crucial. A work has been devoted to explore the gamma ray spectra produced by four Monte Carlo event generators (PYTHIA 6.4, PYTHIA 8, HERWIG Fortran and HERWIG++), finding that for some annihilation channels and at high energies, the discrepancies between the different generators can reach even 100%.

Possible interactions of the dark matter particles with a dark sector have also been extensively explored by IFIC researchers. An extra dark radiation component can be present in the Universe in the form of e.g. sterile neutrinos or axions, which may interact with the dark matter sector. Cosmological constraints on the dark radiation abundance, on its effective velocity and on its viscosity parameter have been found in interacting dark radiation schemes. For instance, it was found that the constraints on the dark radiation effective velocity are degraded by an order of magnitude with respect to those found in standard scenarios.



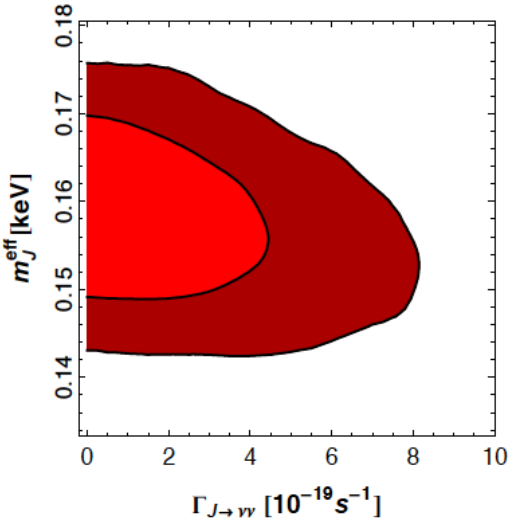
annihilation channels and cosmological data sets. The contribution from dark matter annihilation in halos does not change these limits. The value of the canonical thermal annihilation cross section is shown as a horizontal line.

In a similar context, IFIC members have presented a method to constrain the number of massless gauge bosons and other relativistic particles that might be present in the dark sector using current and future CMB data, thus providing upper bounds on the size of the dark sector.

The constraints after Planck CMB data on dark radiation models made of light sterile neutrino species have also been explored, finding that

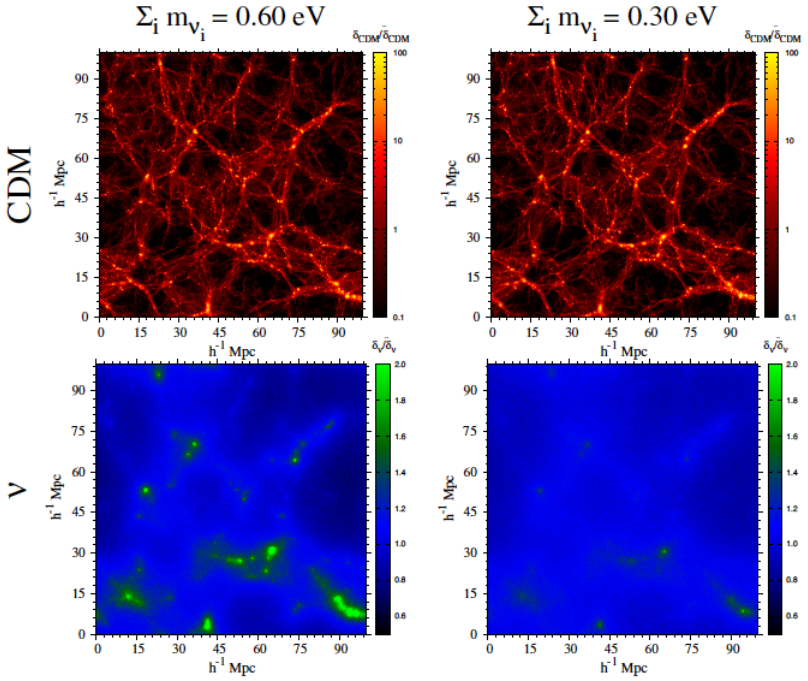
models with one additional sterile neutrino are cosmologically viable, although the required mass scale from terrestrial neutrino oscillation experiments is much higher than the cosmological sterile neutrino mass bound. Models with two additional dark radiation sterile neutrino species are really compromised in standard cosmologies.

Decaying dark matter constraints from cosmological probes have also been explored, using both model-dependent and model-independent approaches. In the context of the Majoron dark matter model, a study was devoted to derive an upper limit on the rate of the invisible majoron decay into neutrinos. Translated in terms of the particle lifetime, it constrains the majoron lifetime to be larger than 50 Gyrs. A model-independent analysis of the cosmological constraints on dark matter annihilations before the release of Planck CMB data was carried out and presented the tightest limits to date to the thermal relic dark matter annihilating cross sections, using realistic energy deposition models.



68% and 95% CL allowed regions limits on the Majoron dark matter effective mass and decay rate

Concerning neutrinos, limits on the masses and on the number of species from cosmological data have been computed in several studies carried out by IFIC researchers. The non-linear evolution of the cosmic neutrino background has been carefully analysed by means of large box-size, high-resolution N-body simulations which incorporate cold dark matter (CDM) and neutrinos as independent particle species. The outcome from such simulations is particularly important for upcoming large-scale structure surveys, such as Euclid, that are expected to probe the non-linear regime at the percent level with lensing and clustering observations. A method to compute the evolution of a system of neutrinos interacting among themselves and with a matter background has also been developed. This formalism can be applied to neutrino flavour conversion in both astrophysical (e.g. supernovae) and cosmological environments.



Slice of thickness 5 Mpc/h through the density field of cold dark matter and neutrinos. The upper panels show a slice of the cold dark matter density field extracted from an N-body simulation with masssive neutrinos. The bottom panels show the neutrino density field in the same slices of the upper panels.

Selected publications:

Bozorgnia, N.; Herrero-García, J.; Schwetz, T.; Zupan, J., *Halo-independent methods for inelastic dark matter scattering*, J. Cosmol. Astropart. Phys. 07, 049 - 15pp, DOI: 10.1088/1475-7516/2013/07/049 [arXiv:1305.3575]

Cembranos, J.A.R.; de la Cruz-Dombriz, A.; Gammaldi, V.; Lineros, R.A.; Maroto, A.L., *Reliability of Monte Carlo event generators for gamma-ray dark matter searches*, J. High Energy Phys. 09, 077 - 21pp, DOI: 10.1007/JHEP09(2013)077 [arXiv:1305.2124]

Diamanti, R.; Giusarma, E.; Mena, O.; Archidiacono, M.; Melchiorri, A., *Dark radiation and interacting scenarios*, Phys. Rev. D 87, 063509 - 8pp, DOI: 10.1103/PhysRevD.87.063509 [arXiv:1212.6007]

Di Valentino, E.; Melchiorri, A.; Mena, O., *Dark radiation sterile neutrino candidates after Planck data,* J. Cosmol. Astropart. Phys. 11, 018 - 13pp, DOI: 10.1088/1475-7516/2013/11/018 [arXiv:1304.5981]

França, U.; Lineros, R.A.; Palacio, J.; Pastor, S., *Probing interactions within the dark matter sector via extra radiation contributions*, Phys. Rev. D 87, 123521 - 6pp, DOI: 10.1103/PhysRevD.87.123521 [arXiv:1303.1776]

Lattanzi, M.; Riemer-Sørensen, S.; Tórtola, M.A.; Valle, J.W.F., *Updated CMB and x- and gamma-ray constraints on Majoron dark matter*, Phys. Rev. D 88, 063528 - 8pp, DOI: 10.1103/PhysRevD.88.063528 [arXiv:1303.4685]

López-Honorez, L.; Mena, O.; Palomares-Ruiz, S.; Vincent, A.C., *Constraints on dark matter annihilation from CMB observations before Planck*, J. Cosmol. Astropart. Phys. 07, 046 - 26pp, DOI: 10.1088/1475-7516/2013/07/046 [arXiv:1303.5094]

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Volpe, C.; Vaananen, D.; Espinoza, C., *Extended evolution equations for neutrino propagation in astrophysical and cosmological environments*, Phys. Rev. D 87, 113010 - 17pp, DOI: 10.1103/PhysRevD.87.113010 [arXiv:1302.2374]

Main research grants (National Plan):

ASTROPARTICLE AND HIGH ENERGY PHYSICS (ref. FPA2011-22975)
FLAVOUR AND ORIGIN OF MATTER (ref. FPA2011-29678-C02-01)
FUNDAMENTAL INTERACTIONS AND THEIR EXPERIMENTAL IMPLICATIONS (ref. FPA2011-23596)
PERTURBATIVE AND NON-PERTURBATIVE STUDIES OF THE STANDARD MODEL AND ITS EXTENSIONS (ref. FPA2011-23897)

4. PUBLICATIONS

We present the list of the 384 **scientific papers** published by IFIC authors in journals indexed in ISI Web of Science, that are also available at the IFIC publication database (http://references.ific.uv.es/refbase) Here we include all records of type paper, letter or review, but not proceeding papers.

In each case, only the first 20 authors are listed (but we do include all authors with IFIC affiliation), and there is a link to the published version and electronic preprint, if available. For the experimental collaborations, all IFIC authors that appear at least in one paper in 2013 are indicated. Some papers appear twice if there are authors from both IFIC departments.

EXPERIMENTAL PHYSICS

AGATA Collaboration

IFIC authors: Algora, A.; Gadea, A.; Hüyük, T

Response of AGATA segmented HPGe detectors to gamma rays up to 15.1 MeV, Nucl. Instrum. Methods Phys. Res. A 705, 47-54, DOI: 10.1016/j.nima.2012.12.084 [arxiv:1209.1188]

Lifetime measurements in neutron-rich Co-63,Co-65 isotopes using the AGATA demonstrator, Phys. Rev. C 88, 044326 - 6pp, DOI: 10.1103/PhysRevC.88.044326

Collective nature of low-lying excitations in 70,72,74Zn from lifetime measurements using the AGATA spectrometer demonstrator, Phys. Rev. C 87, 054302 - 10pp, DOI: 10.1103/PhysRevC.87.054302

ANTARES Collaboration

IFIC authors: Aguilar, J.A.; Barrios-Martí, J.; Bigongiari, C.; Dornic, D.; Emanuele, U.; Gómez-Gónzalez, J.P.; Hernández-Rey, J.J.; Lambard, G.; Mangano, S.; Real, D.; Ruiz-Rivas, J.; Salesa, F.; Sánchez-Losa, A.; Toscano, S.; Yepes, H.; Zornoza, J.D.; Zúñiga, J.

A first search for coincident gravitational waves and high energy neutrinos using LIGO, Virgo and ANTARES data from 2007, J. Cosmol. Astropart. Phys. 6, 008 - 40pp, DOI: 10.1088/1475-7516/2013/06/008 [arxiv:1205.3018]

Search for muon neutrinos from gamma-ray bursts with the ANTARES neutrino telescope using 2008 to 2011 data, Astron. Astrophys. 559, A9 - 11pp, DOI: 10.1051/0004-6361/201322169 [arxiv:1307.0304]

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First results on dark matter annihilation in the Sun using the ANTARES neutrino telescope, J. Cosmol. Astropart. Phys. 11, 032 - 22pp, DOI: 10.1088/1475-7516/2013/11/032 [arxiv:1302.6516]

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Deep-Sea Bioluminescence Blooms after Dense Water Formation at the Ocean Surface, PLoS One 8, e67523 - 10pp, DOI: 10.1371/journal.pone.0067523

ATLAS Collaboration

IFIC authors: Amorós, G.; Cabrera Urbán, S.; Castillo Giménez, V.; Costa, M.J.; Fassi, F.; Ferrer, A.; Fiorini, L.; Fuster, J.; García, C.; García Navarro, J.E.; González de la Hoz, S.; Hernández Jiménez, Y.; Higón-Rodríguez, E.; Irles Quiles, A.; Kaci, M.; Lacasta, C.; Lacuesta, V.R.; March, L.; Martí-García, S.; Miñano, M.; Mitsou, V.A.; Moles-Valls, R.; Moreno Llacer, M.; Oliver García, E.; Pedraza López, S.; Pérez García-Estañ, M.T.; Romero Adam, E.; Ros, E.; Salt, J.; Sánchez Martínez, V.; Solans, C.A.; Soldevila, U.; Sánchez, J.; Torró Pastor, E.; Valero, A.; Valladolid Gallego, E.; Valls Ferrer, J.A.; Villaplana Pérez, M.; Vos, M.; Wildauer, A.

Jet energy measurement with the ATLAS detector in proton-proton collisions at root s=7 TeV, Eur. Phys. J. C 73, 2304 - 118pp, DOI: 10.1140/epjc/s10052-013-2304-2 [arxiv:1112.6426]

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Search for dark matter candidates and large extra dimensions in events with a jet and missing transverse momentum with the ATLAS detector, J. High Energy Phys. 4, 075 - 51pp, DOI: 10.1007/JHEP04(2013)075 [arxiv:1210.4491]

Search for a light charged Higgs boson in the decay channel H+ -> c(s)over-bar in t(t)over-bar events using pp collisions at root s=7 TeV with the ATLAS detector, Eur. Phys. J. C 73, 2465 - 20pp, DOI: 10.1140/epjc/s10052-013-2465-z [arxiv:1302.3694]

Measurement of the inclusive jet cross-section in pp collisions at root s=2.76 TeV and comparison to the inclusive jet cross-section at root s=7 TeV using the ATLAS detector, Eur. Phys. J. C 73, 2509 - 56pp, DOI: 10.1140/epjc/s10052-013-2509-4 [arxiv:1304.4739]

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Measurement of the distributions of event-by-event flow harmonics in lead-lead collisions at root s(NN)=2.76 TeV with the ATLAS detector at the LHC, J. High Energy Phys. 11, 183 - 57pp, DOI: 10.1007/JHEP11(2013)183 [arxiv:1305.2942]

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Measurement of the production cross section of jets in association with a Z boson in pp collisions at root s=7 TeV with the ATLAS detector, J. High Energy Phys. 7, 032 - 51pp, DOI: 10.1007/JHEP07(2013)032 [arxiv: 1304.7098]

ATLAS search for new phenomena in dijet mass and angular distributions using pp collisions at root s=7 TeV, J. High Energy Phys. 1, 029 - 46pp, DOI: 10.1007/JHEP01(2013)029 [arxiv:1210.1718]

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Measurement of isolated-photon pair production in pp collisions at root s=7 TeV with the ATLAS detector, J. High Energy Phys. 1, 086 - 42pp, DOI: 10.1007/JHEP01(2013)086 [arxiv:1211.1913]

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Search for resonances decaying into top-quark pairs using fully hadronic decays in pp collisions with ATLAS at root s=7 TeV, J. High Energy Phys. 1, 116 - 50pp, DOI: 10.1007/JHEP01(2013)116 [arxiv:1211.2202]

Characterisation and mitigation of beam-induced backgrounds observed in the ATLAS detector during the 2011 proton-proton run, J. Instrum. 8, P07004 - 72pp, DOI: 10.1088/1748-0221/8/07/P07004 [arxiv:1303.0223]

Measurement of hard double-parton interactions in W(-> lv) plus 2-jet events at root s=7 TeV with the ATLAS detector, New J. Phys. 15, 033038 - 39pp, DOI: 10.1088/1367-2630/15/3/033038 [arxiv:1301.6872]

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Measurement of the jet radius and transverse momentum dependence of inclusive jet suppression in lead-lead collisions at root S-NN=2.76 TeV with the ATLAS detector, Phys. Lett. B 719, 220-241, DOI: 10.1016/j.physletb.2013.01.024 [arxiv:1208.1967]

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BOOKS

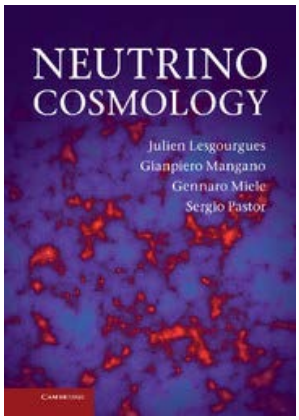
Neutrino cosmology

by **Julien Lesgourgues, Gianpiero Mangano, Gennaro Miele** and **Sergio Pastor**

Pub. Cambridge University Press

ISBN: 9781107013957

DOI: 10.1017/CBO9781139012874



5. TRAINING

TEACHING ACTIVITIES

The members of IFIC with positions at the University of Valencia are mainly involved in its **Degree in Physics**, although they also teach in Chemistry and Engineering. At the postgraduate level, IFIC participates in two of the Master's Degrees offered by the UVEG: **Master in Advanced Physics** and **Master in Medical Physics**. In the first of them, we are responsible for two of the four specialities: Theoretical Physics and Nuclear & Particle Physics. The Gamma Spectroscopy group participates in the inter-university **Master in Nuclear Physics**, where six Spanish universities, CIEMAT and CSIC are involved. Finally, a large number of PhD students carry out their research work in our institute, many of them from foreign countries.

In addition, IFIC researchers often teach at **international schools for PhD students**. Some of the series include the International Doctorate Network in Particle Physics, Astrophysics and Cosmology (IDPASC), the International School of AstroParticle Physics (ISAPP), the European School of High-Energy Physics or the *Taller de Altas Energías* (TAE).

PH.D. THESES

In 2013 a total of 15 doctoral theses were presented with IFIC advisors. For those granted by Spanish Universities we include a link to the TESEO database.

Experimental Physics

Study of supersymmetric signals with R-parity violation in ATLAS at LHC
Emma Torró Pastor
Advisors: Vasiliki Mitsou, Salvador Martí García
14 February, University of Valencia
TESEO: 1012710

Beam size and very low emittance with a Multi-OTR system in ATF2
Javier Alabau Gonzalvo
Advisors: Ángeles Faus Golfe, Javier Resta López
3 June, University of Valencia
TESEO: 1030539

Contributions to the new electronics of the AGATA gamma tracking detector. Design, implementation, test and integration of the digitizers control card
Diego Barrientos Turrión
Advisors: Andrés Gadea Raga, Marco Bellato, Vicente González Millán
2 December, University of Valencia
TESEO: 1061394

High-gradient accelerating structure studies and their application in hadrontherapy
Silvia Verdú Andrés
Advisors: Ángeles Faus Golfe, Ugo Amaldi
18 February, University of Valencia
TESEO: 1011309

Development of the Beam Position Monitors for the Diagnostics of the Test Beam Line in the CTF3 at CERN
Juan José García Garrigós
Advisors: Ángeles Faus Golfe, F. José Mora Mas
18 November, Technical University of Valencia
TESEO: 1062585

Time calibration and search for cosmic sources of high energy neutrinos with the ANTARES neutrino telescope
Juan Pablo Gómez González
Advisors: Juan Zúñiga Román, Juan de Dios Zornoza Gómez
4 December, University of Valencia
TESEO: 1058610

Study of Jet Substructure in the ATLAS Experiment using Distributed Analysis within Spanish Tier-2 Infrastructures
Elena Oliver García
Advisors: José Francisco Salt Cairols, Santiago González de la Hoz
16 December, University of Valencia
TESEO: 1059891

Searches for beyond the Standard Model physics with boosted topologies in the ATLAS experiment using the Grid-based Tier-3 facility at IFIC-Valencia
Miguel Villaplana Pérez
Advisors: Santiago González de la Hoz, Marcel Vos
17 December, University of Valencia
TESEO: 1049922

Theoretical Physics

Cosmological implications of standard model extensions
Manuel Peña Jiménez
Advisor: Nuria Rius Dionis
13 February, University of Valencia
TESEO: 1013028

Discrete symmetries in entangled neutral meson systems
Pablo Villanueva Pérez
Advisors: José Bernabéu Alberola, Fernando Martínez Vidal
12 July, University of Valencia
TESEO: 1041480

$K^0 – K^0$, $D^0 – D^0$ and $B^0 – B^0$ oscillations in the Standard Model and Beyond from unquenched Twisted Mass Lattice QCD
Nuria Carrasco Vela
Advisor: Vicent Giménez Gómez
6 September, University of Valencia
TESEO: 1043874

Non-supersymmetric black-hole solutions in N=2, D=4 supergravity
Pietro Galli
Advisor: M. Antonia Lledó Barrena
26 September, University of Valencia
TESEO: 1049577

Testing neutrino physics and radiation properties with cosmological measurements
Elena Giusarma
Advisor: Olga Mena Requejo
11 October, University of Valencia
TESEO: 1052157

New models in particle and astroparticle physics: consequences for dark matter and LHC
Valentina De Romeri
Advisors: Martin Hirsch, José W. Furtado Valle, Fiorenza Donato
3 December, Universities of Valencia and Turin
TESEO: 1062426

Exotic properties of neutrinos using effective Lagrangians and specific models
Alberto Aparici Benages
Advisor: Arcadi Santamaria Luna
16 December, University of Valencia
TESEO: 1063128

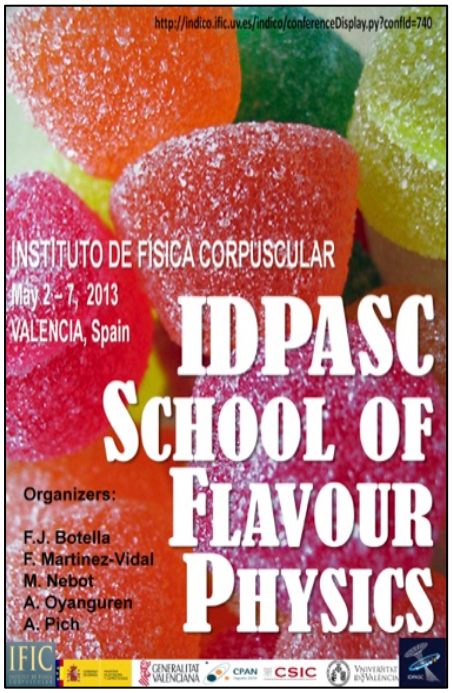
6. CONFERENCES, COLLOQUIA AND SEMINARS

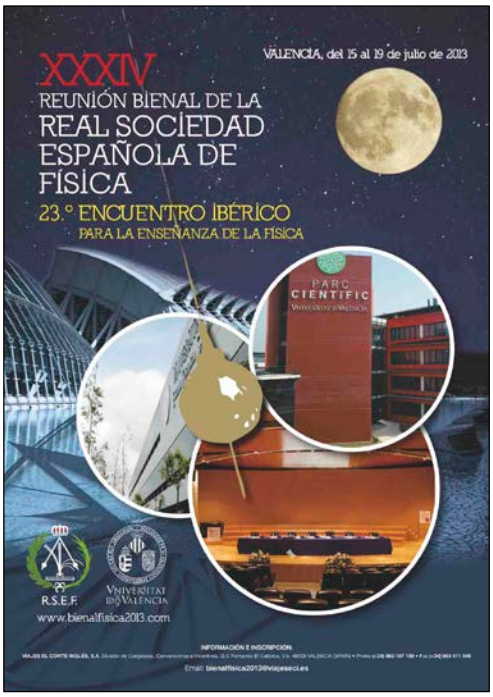
CONFERENCES AND MEETINGS

IFIC researchers present their results in the main international conferences and workshops. A total of 350 contributions were presented in 2013: **313 talks** (54 plenary or invited) and **37 posters**.

Here we highlight the main conferences and workshops organized by IFIC members in Valencia:

3rd workshop on Flavor Physics in the LHC Era, 4-6 February
IVICFA Easter Physics Workshop, 25-26 March
IDPASC School of Flavour Physics, 2-7 May
II PCI2011 Workshop, 22-23 May
CosmoRENATA 2013, 3-4 June
XXXIV Reunión Bienal de la Real Sociedad Española de Física, 15-19 July
2nd Workshop on Beta delayed neutron emission measurements at RIKEN, 30-31 July
IVICFA'S Fridays, series of MiniWorkshops: Medical Physics (27 Sep), Computation in Physics (11 Oct), Theoretical Physics I (18 Oct), Experimental Physics (25 Oct) and Theoretical Physics II (31 Oct)





IFIC COLLOQUIA

Colloquia are **review talks** about a research topic for a general audience of IFIC members

Organizers: Germán Rodrigo and José Luis Taín

The Standard Model of Nature and its Legacy
Gabriele Veneziano (Collège de France)
17 April

The Search for Dark Matter
Juan Collar (University of Chicago)
11 December

The longest day in my life. One year at the South Pole hunting neutrinos
Carlos Pobes (Inst. Ciencia de Materiales de Aragón)
24 May

Angels, Demons and Black Holes - turning threat to opportunity in science communication
James Gillies (CERN)
6 June

IFIC SEMINARS

Seminars are more **specific research talks** given by an invited speaker, usually connected to one of the IFIC research groups. Some of these seminars are more informal talks followed by a discussion session, such as those within La Trobada series. In 2013 we hosted a total of **76 seminars**. The complete list can be found in the IFIC's Indico webpage http://indico.ific.uv.es

Coordinator: Jorge Portolés

7. TECHNOLOGY TRANSFER AND OUTREACH

TECHNOLOGY TRANSFER

Spin-off

The company Alibava Systems S.L., created in December 2012, carried out its initial activities along the year 2013

Alibava Systems, S.L.
IFIC & Instituto de Microelectrónica de Barcelona
CIF: B65653677
www.alibavasystems.com

R&D projects

In 2013 some researchers of IFIC were involved in two projects for the design of new technologies:

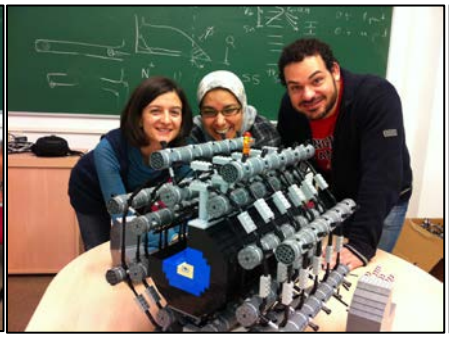
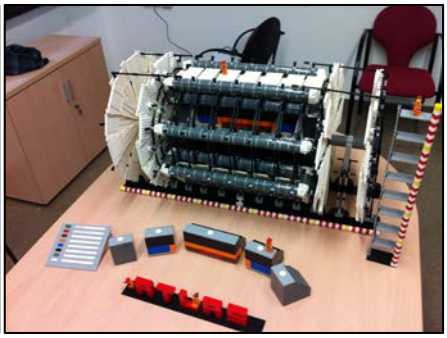
- The IFIC researchers Avelina Fernández, Kiko Albiol and Germán Rodrigo registered in the previous year the patent P201231243, which describes a procedure to **enhance radiology images using depth sensors in a new image modality called densitometric imaging**. IFIC and the Universitat Politècnica de Valencia signed in 2013 a license IP contract with the company IST Medical to develop this technology in the field of medical imaging diagnosis. They have also signed a technology support agreement to adapt this technology. The group also obtained funding from CPAN, with reference CPAN13-TR01, to develop industry-oriented applications of this patent.

- An R&D contract was granted to a group including IFIC researchers Germán Rodrigo and Kiko Albiol for the **mathematical modelling and analysis of the electrical power forecasting in the Spanish electrical grid**, in order to develop methods and procedures with a temporal accuracy down to the hour level.

Besides, several members of IFIC participated in technology transfer meetings, including the Academia-Industry matching event on Superconductivity, held in Madrid in May, and the Workshop on Technology Transfer in Particle Physics, held in Sevilla in June.

OUTREACH MATERIALS

In 2013 the Institute purchased a scale model of the ATLAS detector consisting of 9500 Lego pieces, which were assembled together throughout three weeks with the participation of the IFIC staff. The miniature was then enclosed into a glass cabinet and placed on the first floor of the laboratory building, where it can be shown to the visitors and it is used to explain the structure of this sort of particle physics experiment.

OUTREACH ACTIVITIES

We present a selection of outreach activities with contribution of IFIC members. These activities are coordinated by the Outreach committee.

International Masterclasses: hands on particle physics

Session at IFIC on March 6th with high-school students from La Pobla de Farnals, Manises and Valencia, who performed an excercise with real ATLAS data and presented their results via videoconference with other European institutions. Coordinated by Santiago González de la Hoz with the participation of P. Fernández, M. Moreno, S. Pastor, J. Salt, V. Sánchez, M.A. Sanchis, E. Torró and M. Villaplana.

Guided tours to IFIC for high-school and university students

After a short presentation about IFIC and its research lines, the students visit three laboratories among the seven possibilities (ANTARES/Km3NET, NEXT, ATLAS-Silicon, ATLAS-TiCal, Medical Physics, GRID-Computing centre and Gamma Spectroscopy). Coordinated by IFIC together with the local delegation of CSIC in the Valencia (for high schools).

- **High-school students (con Ciencia Sé)**: IES Ramon Muntaner, Xirivella (Jan 23); Colegio El Pilar, Valencia (Feb 7); IES Enric Valor, Picanya (Feb 13); Colegio D. José Lluch, Alboraia (Mar 21); IES Ferrer i Guàrdia, Valencia (Oct 29); Colegio Jesús y María and IES Rascanya, Valencia (Nov 7); IES Alcoi (Dec 17)

- **High-school students (selected by the VLC Campus)**: Jul 9 & 23
- **Students from the University of Valencia**: experimental physics (Jul 10 & 11)

IFIC members involved: A. Algora, J. Barrios, P. Ferrario, J.J. Hernández, Y. Hernández, G. Llosá, F. Monrabal, C. García, I. García, J.P. Gómez, J.F. Oliver, S. Pastor, J. Salt, J.L. Taín, A. Valero and J. Zúñiga.



Open Doors Day of the Scientific Park: Expociència 2013

On May 25th our institute organized a series of outreach activities within the Open Doors Day of the Scientific Park of the University of Valencia. More than 3500 people attended the event, which involved all research institutes in our campus.

IFIC ORGANIZERS	ACTIVITY
J. Barrrios, A. Sánchez, J.D. Zornoza, J. Zúñiga	Observa el universo desde las profundidades del mar: Telescopios de neutrinos
V. Álvarez, A. Martínez, J. Rodríguez, F. Monrabal	Cocinando en el Ártico
S. Cabrera, L. Fiorini, C. García, J.E. García, L. March, V. Sánchez	Maqueta LEGO + visita virtual al experimento ATLAS del LHC
J. Barrio, K. Brzezinski, M. Trovato, C. Solaz, G. Llosá, I. Torres, A.M. Etxebeste, J.F. Oliver	Física médica: haciendo visible lo invisible
J. Agramunt, A. Algora, C. Domingo, V. Guadilla, A. Montaner, S.E.A. Orrigo, J.L. Taín, E. Valencia	¿Somos radioactivos? Radioactividad natural en directo con la cámara de niebla
P. Ferrario, P. Tuzón	Taller para niños: Las siete pruebas
S. Pastor	El día más largo de mi vida: un año en el Polo Sur a la caza de neutrinos (conferencia de Carlos Pobes)



Public lectures:

Series of talks at High Schools: Física de Partículas en el Instituto (CPAN)

Aplicaciones de la Física Nuclear

J.L. Taín: IES Federica Montseny (Burjassot), Mar 13

La búsqueda del bosón de Higgs en el LHC

J. Fuster: Colegio La Salle (Alcoi), Mar 27

C. García: IES San Antonio de Benagéber, Jan 30; Colegio CEU San Pablo (Valencia), Jan 31; IES Vicenta Ferrer Escrivá (Valencia), Mar 13; IES Isabel de Villena (Valencia), Mar 16; IES Clot del Moro (Sagunt), Mar 25; IES Cid Campeador (Valencia), Nov 14; IES Benlliure (Valencia), Dec 18

S. González: Colegio Santa María (Elche), Mar 8; Planetario de Castellón, Mar 24

S. Martí: IES Les Planes de Santa Bàrbara (Tarragona), Jan 31; IES Honori Garcia (La Vall d'Uixó), Nov 27

E. Torró: IES Serpis (Valencia), Mar 27; Centro Educativo Palma (La Cañada), May 25

M. Villaplana: IES José Marhuenda Prats (Pinoso), Mar 20; IES La Canal (Petrer), Nov 20

M. Vos: CEIP José Senent (Massarrojos), Apr 22

Física de Astropartículas: Más allá de la luz

S. Pastor: Colegio San Enrique (Quart de Poblet), Nov 4; IES La Foia (Ibi), Nov 14; Colegio El Carmen (Manises), Nov 21

Other talks at High Schools

Einstein, Newton i els daus
J. Ros: Colegio Sagrado Corazón de Jesús (Valencia), Dec 17

Estructura de la materia
P. González: Colegio Chiner Villarroya (Valencia), Nov 29

Other public talks

Taula rodona: El CERN més enllà del Higgs
M. Bosman, A. Pich, M. Delfino and L. Garrido, CosmoCaixa Barcelona, Mar 7

La estructura de la materia: de los quarks a los núcleos atómicos
C. Domingo and V. Vento, Universidad de Valencia, Mar 7

El mundo cuántico
A. Pérez, Ciclo de Conferencias "Universitat dels Majors", Centre Cultural de Caixa Ontinyent, Apr 25

Ciclo de Conferencias: Arquitectura cósmica II: materia y energía en el Universo
- *El bosón de Higgs: el origen de la materia*
J. Bernabeu, Sep 26
- *Neutrinos: partículas fantasma*
S. Pastor, Oct 3
- *Telescopios de neutrinos: otra forma de mirar el cielo*
J. Zúñiga, Oct 17

El CERN y el bosón de Higgs, ¿por qué invertir en grandes infraestructuras científicas?
J. Fuster, Debate del Claustre Obert, Universidad de Valencia, Oct 28

Las fronteras de la Física: Partículas y Cosmología
J. Bernabeu, II Semana de la Ciencia (Quart de Poblet), Nov 6

Avances en física de neutrinos
M. Hirsch, Conferencias de la Facultad de Física, Universidad de Valencia, Nov 21

La epopeya humana en busca del conocimiento de la estructura de la materia y las leyes que la rigen
E. Oset, Setmana de la Ciència de Vila-real, Nov 22

El bosón de Higgs
A. Pich, Ciclo Conec Talks, Fundación Cañada Blanch (Valencia), Dec 11

Public lecture by **Prof Manuela Juárez** in the framework of the International Women's Day, organized jointly with the Instituto de Agroquímica y Tecnología de Alimentos (IATA)

Outreach activities related to the XXXIV Biennial Meeting of the Royal Spanish Society of Physics

Exhibition *El instrumento científico más grande jamás construido: una exposición del CERN*, with guided tours by IFIC researchers
Museo de las ciencias Príncipe Felipe, Valencia, Jul 3-31

Public Conferences at the Museo de las ciencias Príncipe Felipe:

- *Tras la pista del bosón de Higgs*
C. García and A. Pich, Jul 3

- *El gran viaje desde la astronomía a la física de partículas*
V.J. Martínez and J.W.F. Valle, Jul 10

Colloquium *Cáncer: ¿cómo puede la Física mejorar la salud?*
G. Llosá, M. Cubells and J. Prats, Centre Octubre, Valencia, Jul 17

Discussion *La investigación: retos, futuro y política científica*
A. Ariño, V.J. Martínez, E. Barreno, J. Capmany, I. Cirac, E. Coronado, J. Duato, J. Fuster, I. de Higes, Centre Cultural de la Universitat de València, Jul 17

IFIC IN THE MEDIA

In 2013 our staff appeared on various occasions in the media. Here we list a selection of them.

Newspapers and print media

Juan J. Gómez Cadenas was interviewed for the news web Materia, specialised in science communication.

Miguel Ángel Sanchis published a think piece entitled *Goytisolo y el bosón de Higgs* (Las Provincias, Mar 3)

Alberto Aparici and Miguel Villaplana were awarded by the University of Valencia and the newspaper Las Provincias the II Opinión Innovadora Awards for two texts, entitled *La ciencia también es cultura* and *Un juego de niños*, respectively. Both texts were subsequently published in Las Provincias.

Outreach articles:

El núcleo "doblemente mágico" de estaño-100
C. Domingo Pardo, Investigación y Ciencia, March 2013, pp 11-13

Ghostly beacons of new physics / Mensajeros fantasmales de nueva física
M. Hirsch, H. Päs and W. Porod, Scientific American, April 2013, pp 40-47; also in Investigación y Ciencia, June 2013, pp 16-23

Television

Carmen García appeared on the news program *Informe semanal* as part of a special report about CERN

Radio

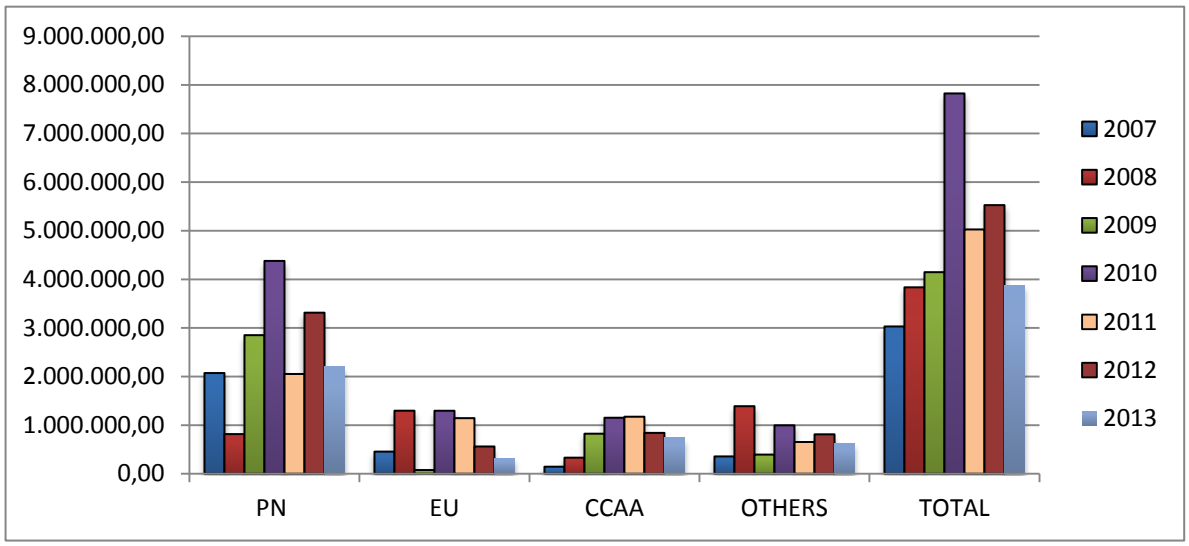
Alberto Aparici conducted a weekly science show called *La Brújula de la Ciencia* (Onda Cero). The shows aims at explaining particular aspects of science to the general public, and is aired nationwide.

Isidoro García and Miguel Ángel Sanchis conducted a weekly show *Enredados con la física* (UV radio), which covered many aspects of physics, but particularly particle physics and cosmology. Alberto Aparici and Miguel Villaplana participated in a special program dedicated to particle physics and the Higgs boson.

Juan J. Gómez Cadenas, Miguel Ángel Sanchis and Juan Fuster were interviewed in several radio shows (RNE, SER).

8. FUNDING

In this section we include all research grants that were active during the whole or part of 2013, funded by European (EU), national (PN), regional (CCAA) or other agencies.



Evolution of IFIC funding by financial agencies (in euros, CONSOLIDER projects excluded)

NATIONAL PLAN PROJECTS

Funded by the *Ministerio de Economía y Competitividad* (MINECO) of the Spanish Government, typically for three years.

Experimental Physics

Development of new accelerator technologies for future colliders in particle physics
Ref. FPA2010-21456-C01-01
PI: Ángeles Faus Golfe
378.609 € (Jan 2011 – Jun 2014)

Spanish distributed TIER2 for the ATLAS experiment
Ref. FPA2010-21919-C03-01
PI: José Salt Cairols
861.399 € (Jan 2011 – Dec 2014)

High-resolution gamma spectroscopy: the path to AGATA
Ref. FPA2011-29854-C04-02
PI: Andrés Gadea Raga
356.950 € (Jan 2012 – Dec 2014)

Image quality and quantification in positron emission tomography
Ref. FPA2010-14891
PI: Magdalena Rafecas López
176.781 € (Jan 2011 – Jul 2014)

Development of new detectors for future colliders in particle physics
Ref. FPA2010-21549-C04-04
PI: Juan Fuster Verdú
361.064 € (Jan 2011 – Jul 2014)

Participation in the T2K experiment
Ref. FPA2011-29823-C02-01
PI: Anselmo Cervera Villanueva
281.325 € (Jan 2012 – Dec 2014)

Nuclear structure, applications and astrophysics: the path to FAIR
Ref. FPA2011-24553
PI: Alejandro Algora
644.930 € (Jan 2012 – Dec 2014)

Participation of IFIC in the ANTARES and KM3NET neutrino telescopes
Ref. FPA2012-37528-C02-01
PI: Juan J. Hernández Rey
237.510 € (Jan 2013 – Dec 2015)

Construction of the NEXT experiment at the Canfranc Underground Laboratory
Ref. FPA2012-37947-C04-01
PI: Juan J. Gómez Cadenas
299.520 € (Jan 2013 – Dec 2014)

Contributions to the ATLAS experiment at the Large Hadron Collider
Ref. FPA2012-39055-C02-01
PI: Carmen García García
1.064.700 € (Jan 2013 – Dec 2015)

Contributions to the hadronic tile calorimeter of the ATLAS detector
Ref. FPA2012-32843
PI: J. Antonio Valls Ferrer
477.360 € (Jan 2013 – Dec 2015)

The NEXT project: energy and trajectory measurements
Ref. FPA2012-37947-C04-03
PI: José Díaz Medina
119.340 € (Jan 2013 – Dec 2014)

Theoretical Physics

Hadronic models, fundamental interactions and nuclear physics
Ref. FPA2010-21750-C02-01
PI: Pedro González Marhuenda
138.787 € (Jan 2011 – Mar 2014)

Flavour and origin of matter
Ref. FPA2011-29678-C02-01
PI: Pilar Hernández Gamazo
249.260 € (Jan 2012 – Dec 2014)

Particle physics phenomenology at the LHC and flavour factories
Ref. FPA2011-23778
PI: Antonio Pich Zardoya
372.680 € (Jan 2012 – Dec 2014)

Quantum black holes, supergravity and cosmology
Ref. FIS2011-29813-C02-02
PI: M. Antonia Lledó Barrena
100.430 € (Jan 2012 – Dec 2014)

Nuclear and hadron physics at intermediate energies
Ref. FIS2011-28853-C02-01
PI: Manuel Vicente Vacas
212.960 € (Jan 2012 – Dec 2014)

Perturbative and non-perturbative studies of the Standard Model and its extensions
Ref. FPA2011-23897
PI: Vicent Giménez Gómez
152.460 € (Jan 2012 – Dec 2014)

Astroparticle and high energy physics
Ref. FPA2011-22975
PI: José W. Furtado Valle
258.940 € (Jan 2012 – Dec 2015)

Fundamental interactions and their experimental implications
Ref. FPA2011-23596
PI: Francisco J. Botella Olcina
450.120 € (Jan 2012 – Dec 2015)

Studies on quantum structure and dynamics of atomic, nuclear and electronic systems
Ref. FIS2011-28617-C02-02
PI: Jesús Navarro Faus
24.200 € (Jan 2012 – Dec 2014)

Effective theories in nuclear and hadron physics
Ref. FIS2011-28853-C02-02
PI: Juan M. Nieves Pamplona
163.350 € (Jan 2012 – Dec 2014)

CONSOLIDER PROJECTS

Coordinated by IFIC:

Centro nacional de Física de Partículas, Astropartículas y Nuclear (CPAN)
Ref. CSD2007-00042
PI: Antonio Pich Zardoya
10.000.000 € (Oct 2007 – Jun 2015)

Canfranc Undergorund Physics (CUP)
Ref. CSD2008-00037
PIs: M. Concepción González García (ICC Barcelona) / Juan J. Gómez Cadenas
6.000.000 € (Dec 2008 – Dec 2014)

With participation of IFIC groups:

Physics of the Accelerating Universe (PAU)
Ref. CSD2007-00060
PI: Enrique Fernández Sánchez (IFAE Barcelona)
IFIC PIs: Carlos Peña Garay / Olga Mena Requejo
Oct 2007 – Jun 2014

Multimessenger Approach for Dark Matter Detection (MultiDark)
Ref. CSD2009-00064
PI: Carlos Muñoz (Univ Autónoma Madrid)
IFIC PIs: Juan J. Hernández Rey / José W. Furtado Valle
Dec 2009 – Dec 2015

OTHER NATIONAL PROJECTS

Radiation detectors for medical imaging
Ref. SEIC2010-00020
PI: Magdalena Rafecas López
129.447,59 € (Jun 2011 – Jun 2014)

New instrumentation techniques for monitoring the beam position in the Drive Beam of CLIC
Ref. SEIC2010-00028
PI: Ángeles Faus Golfe
129.447,59 € (Jun 2011 – May 2014)

R&D for linear collider detectors: Ultra-thin vertex and tracking detectors
Ref. SEIC2010-00038
PI: Carlos Lacasta Llácer
129.447,59 € (Jul 2011 – Jun 2014)

Contribution to the design of the SuperB final focus region and related studies
Ref. SEIC2010-00052
PI: Ángeles Faus Golfe
129.447,59 € (Jun 2011 – May 2014)

Development of a trigger system and data adquisition for the tileCal upgrade in ATLAS
Ref. EIC-CERN-2011-0005
PI: J. Antonio Valls Ferrer
125.950 € (Feb 2012 – Jan 2015)

R&D for linear collider detectors: Ultra-thin vertex and tracking detectors
Ref. EIC-CERN-2011-0019
PI: Juan Fuster Verdú
125.950 € (Feb 2012 – Jan 2015)

Development of neutron detectors for nuclear structure, astrophysics and applications
Ref. PRI-PIMNUP-2011-1348
PI: Alejandro Algora
70.000 € (Nov 2011 – Nov 2014)

Grid and e-science: data analysis of the ATLAS detector and medical physics
Ref. A1/035250/11 (AECID)
PI: Santiago González de la Hoz
90.000 € (Dec 2011 – Jun 2013)

Stay at CERN and European representative in the executive commitee of the ILC
Ref. FPA2010-12078-E
PI: Juan A. Fuster Verdú
24.000 € (Jul 2011 – Jul 2013)

Spanish network of flavour physics
Ref. FPA2011-13909-E
PI: Francisco J. Botella Olcina
28.000 € (Jan 2012 – Dec 2013)

Compton telescope for monitorization in hadron therapy
Ref. FIS2011-14585-E
PI: Magdalena Rafecas López
18.000 € (Oct 2012 – Nov 2013)

Contribution to the total absorption spectrometer of the DESPEC Collaboration at NUSTAR (FAIR)
Ref. AIC-A-2011-0696
PI: Alejandro Algora
225.900 € (Dec 2011 – Dec 2014)

Study of new observables to measure the top quark mass at hadron colliders with high precision
Ref. AIC-D-2011-0688
PI: Juan A. Fuster Verdú
2.500 € (Dec 2011 – Dec 2013)

Neutrinos from astrophysical and cosmological sources
Ref. AIC-D-2011-0689
PI: Sergio Pastor Carpi
2.000 € (Dec 2011 – Jun 2013)

Development of a trigger system and data adquisition for ATLAS at the SLHC project (CERN)
Ref. AIC-A-2011-0775
PI: Luca Fiorini
128.124,50 € (Dec 2011 – Dec 2014)

Spanish participation 2011-2012 in particle, astroparticle and nuclear physics experiments
Ref. AIC-B-2011-0640
PI: Antonio Pich Zardoya
3.227.918 € (Aug 2011 – Aug 2014)

Astroparticle and neutrino physics
Ref. AIC-D-2011-0772
PI: José W. Furtado Valle
2.000 € (Dec 2011 – Jun 2013)

CSIC-Japan agreement
Ref. 2011JP0020
PI: Berta Rubio Barroso
3.300 € (Jan 2012 – Dec 2013)

CDTI/INNPACTO PROJECTS

INNPACTO project
Ref. IPT-2011-1918-020000
Company: Industrias Jose Tamarit Moreno SL
IFIC PI: Juan J. Hernández Rey
169.784 € (May 2011 – Dec 2014)

EUROPEAN PROJECTS

Solving Challenges in Nuclear Data (CHANDA)
FP7-EURATOM-FISSION, Ref. 605203
Project Coordinator: Enrique M. González Romero
IFIC PI: José Luis Taín Enríquez
193.992,50 € (Dec 2013 – Nov 2017)

HL-LHC: High Luminosity Large Hadron Collider
FP7 Design Study, Ref. 284404
Project Coordinator: Lucio Rossi
IFIC PI: Ángeles Faus Golfe
162.572,64 € (Nov 2011 – Oct 2015)

Design of a pan-European Infrastructure for Large Apparatus studying Grand Unification, Neutrino Astrophysics and Long Baseline Neutrino Oscillations
FP7 Design Study, Ref. 284518
Project Coordinator: André Rubbia
IFIC PI: Juan J. Gómez Cadenas
54.000 € (Sep 2011 – Aug 2014)

Study of Strongly Interacting Matter (HadronPhysics3)
FP7 Research Infrastructures, Ref. 283286
Project Coordinator: Carlo Guaraldo
IFIC PI: Santiago Noguera Puchol
51.000 € (Jan 2012 – Dec 2014)

Advanced European Infrastructures for Detectors at Accelerators (AIDA)
FP7 Research Infrastructures, Ref. 262025
Project Coordinator: Iván Vila Álvarez
IFIC PI: Marcel A. Vos
127.555 € (Feb 2011 – Jan 2015)

European Collaboration for Accelerator Research and Development (EuCARD)
FP7 Research Infrastructures, Ref. 227579
Project Coordinator: Jean-Pierre Koutchouk
IFIC PI: Ángeles Faus Golfe
31.206 € (Apr 2009 – Mar 2013)

European NoVel Imaging Systems for ION therapy (ENVISION)
FP7 Health, Ref. 241851
Project Coordinator: Manjit Dosanjh
IFIC PI: Carlos Lacasta Llácer
383.140,48 € (Feb 2010 – Jul 2014)

Advanced particle phenomenology in the LHC era (LHCPhenoNet)
FP7 Marie Curie Initial Training Network
Ref. PITN-GA-2010-264564
Project Coordinator: Germán Rodrigo García
505.765,16 € (Jan 2011 – Dec 2014)

European particle Physics Latin American NETwork (EPLANET)
FP7 Marie Curie Int. Research Staff Exchange Scheme
Ref. PIRSES-2009-GA-246806
Project Coordinator: Luciano Maiani
IFIC PI: Antonio Ferrer Soria
104.000 € (Feb 2011 – Jan 2015)

Towards systematization of NNLO theoretical predictions for advanced phenomenology at the LHC (CRUNCHLOOPS)
FP7 Marie Curie Intra-European Fellowship
Ref. PIEF-GA-2011-298582
Fellow: Grigorios Chachamis
IFIC PI: Germán Rodrigo García
168.896,40 € (Oct 2012 – Sep 2014)

Multi-leg precision calculations and advanced phenomenology in the LHC era (Multi-leg@LHC)
FP7 Marie Curie Intra-European Fellowship
Ref. PIEF-GA-2011-298960
Fellow: Francisco Campanario Pallás
IFIC PI: Germán Rodrigo García
205.854 € (Mar 2013 – Feb 2015)

Integrated Sustainable Pan-European Infrastructure for Researchers in Europe (EGI-InSPIRE)
FP7 Research Infrastructures, Ref. 261323
Project Coordinator: Steven Newhouse
IFIC PI: José Salt Cairols
118.709 € (May 2010 – Apr 2014)

Enhanced European Coordination for Accelerator Research & Development (EuCARD-2)
FP7 Research Infrastructures, Ref. 312453
Project Coordinator: Svetlomir Stavrev
IFIC PI: Ángeles Faus Golfe
20.000 € (May 2013 – Apr 2017)

Unification in the LHC era (UNILHC)
FP7 Marie Curie Initial Training Network
Ref. PITN-GA-2009-237920
Project Coordinator: Ignatios Antoniadis
IFIC PI: José W. Furtado Valle
38.930,90 € (Oct 2009 – Oct 2013)

Research Training in 3D Digital Imaging for Cancer Radiation Therapy
FP7 Marie Curie Initial Training Network
Ref. PITN-GA-2010-264552
Project Coordinator: Manjit Dosanjh
IFIC PI: Carlos Lacasta Llácer
243.718 € (Feb 2011 – Jan 2015)

Invisibles: Neutrinos, Dark Matter and Dark Energy Physics
FP7 Marie Curie Initial Training Network
Ref. PITN-GA-2011-289442
Project Coordinator: Belén Gavela
IFIC PI: Pilar Hernández Gamazo
342.307 € (Apr 2012 – Mar 2016)

Event shapes in soft-collinear effective theory (ESSCET)
FP7 Marie Curie International Outgoing Fellowship
Ref. PIOF-GA-2009-251174
Fellow: Vicent Mateu Barreda
IFIC PI: Germán Rodrigo García
242.129,10 € (Dec 2010 – Nov 2013)

REGIONAL PROJECTS

Funded by the *Conselleria d'Educació, Cultura i Esport* of the Generalitat Valenciana (Valencian Government)

From LHC physics to the keys of the primordial Universe in the era of data
Ref. PROMETEOII/2013/017
PI: José Bernabéu Alberola
75.000 € (Jan 2013 – Dec 2013)

Neutrino telescopes in the Mediterranean
Ref. PROMETEO/2009/026
PI: Juan J. Hernández Rey
53.790 € (Jan 2013 – Dec 2013)

Astroparticle and high energy physics
Ref. PROMETEO/2009/091
PI: José W. Furtado Valle
41.050 € (Jan 2013 – Dec 2013)

Perturbative and non-perturbative studies of the Standard Model and its extensions
Ref. PROMETEO/2009/128
PI: Arcadi Santamaria Luna
41.260 € (Jan 2013 – Dec 2013)

Studies of nuclear structure and technology developments associated to gamma-ray and Ge detectors sensitive to position and complementary detectors of charged light particles and neutrons
Ref. PROMETEO/2010/101
PI: Andrés Gadea Raga
59.820 € (Jan 2013 – Dec 2013)

Study of the top quark production in ATLAS
Ref. PROMETEO/2010/021
PI: Salvador Martí García
42.980 € (Jan 2013 – Dec 2013)

Noninvasive 3D gamma camera
Ref. GV/2013/131
PI: César Domingo Pardo
5.930 € (Jan 2013 – Dec 2013)

Conference NSTAR 2013
Ref. AORG/2013/020
PI: Eulogio Oset Báguena
8.640 € (Jan 2013 – Dec 2013)

Equipment Scientific Park
Ref. PPC/2013/044
PI: Francisco J. Botella Olcina
22.231 € (Jan 2013 – Dec 2013)

LHC physics: search for new interactions in the high-energy frontier
Ref. PROMETEOII/2013/007
PI: Antonio Pich Zardoya
125.000 € (Jan 2013 – Dec 2013)

Nuclear and hadron physics at intermediate energies
Ref. PROMETEO/2009/090
PI: Eulogio Oset Báguena
45.050 € (Jan 2013 – Dec 2013)

Flavour and origin of matter
Ref. PROMETEO/2009/116
PI: Nuria Rius Dionís
55.060 € (Jan 2013 – Dec 2013)

Quark structure of matter
Ref. PROMETEO/2009/129
PI: Santiago Noguera Puchol
38.980 € (Jan 2013 – Dec 2013)

Theoretical and experimental approach to the search for new physics with heavy flavours in the LHC era and other B factories
Ref. PROMETEO/2010/056
PI: Francisco J. Botella Olcina
50.520 € (Jan 2013 – Dec 2013)

Institut Valencià d'Investigació Cooperativa en Física Avançada (IVICFA)
Ref. ISIC/2012/020
PI: José Bernabéu Alberola
60.000 € (Jan 2013 – Dec 2013)

Development of detectors for Compton telescopes
Ref. GV/2013/133
PI: Gabriela Llosá Llácer
6.000 € (Jan 2013 – Dec 2013)

Conference XXXIV Bienal de la RSEF
Ref. AORG/2013/122
PI: Miguel Ángel Sanchis Lozano
8.700 € (Jan 2013 – Dec 2013)