2015

ANNUAL REPORT

INSTITUTO DE FÍSICA CORPUSCULAR

IFIC INSTITUTO DE FÍSICA CORPUSCULAR

EXCELENCIA SEVERO OCHOA

CSIC CONSEJO SUPERIOR DE INVESTIGACIONES CIENTÍFICAS

VNIVERSITAT DE VALÈNCIA

CONTENTS

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Director del IFIC

BIENVENIDA

Es para mí un placer saludarles de nuevo en esta introducción a la Memoria Anual del IFIC. Ha pasado volando un año más, pero en su transcurso nuestro instituto no ha perdido ni un segundo tratando de lograr los ambiciosos objetivos que se ha marcado.

Si tuviéramos que destacar un hecho de la vida del instituto durante 2015, éste sería la concesión al IFIC de la distinción de Centro de Excelencia Severo Ochoa. Este premio, según las palabras de la convocatoria, "acredita y financia a los centros públicos de investigación en todas las áreas que demuestran un liderazgo científico y un impacto a nivel global, así como una colaboración con su entorno social y económico". Estamos orgullosísimos de esta distinción, que nos permitirá promover e incrementar nuestras actividades de investigación.

Un hecho importante en nuestra especialidad en 2015 fue la concesión del premio Nobel al profesor Takaaki Kajita (de la colaboración Super-Kamiokande, Universidad de Tokio, Japón) y al profesor Arthur B. McDonald (de la colaboración del Sudbury Neutrino Observatory, Canadá), "por el descubrimiento de las oscilaciones de neutrinos, que muestran que los neutrinos tienen masa". Este premio es la culminación de una historia fascinante en los anales de la Física que ha implicado el esfuerzo, el trabajo, la inteligencia y la perspicacia de un gran número de científicos de todo el mundo.

El IFIC está fuertemente involucrado en la física de los neutrinos, tanto en su vertiente teórica –con un gran número de publicaciones de alto impacto en una serie de temas relacionados con los neutrinos– como en su vertiente experimental, en la que científicos del IFIC participan o lideran varios experimentos relacionados con dicha física. Algunos físicos experimentales del IFIC trabajan en aclarar la naturaleza del neutrino como partícula elemental (fermión de Majorana o de Dirac) a través del experimento NEXT liderado por científicos del IFIC y respaldado por una Advanced Grant del ERC. Esta investigación es un desafío con un gran potencial de impacto en una diversidad de áreas de la física.

Otro grupo de científicos del IFIC participan en el experimento T2K en Japón para seguir estudiando las oscilaciones de neutrinos, determinar mejor los parámetros que describen este fenómeno y estudiar la posible existencia de la violación de CP en el sector leptónico. Además, un grupo de investigación del IFIC participa en los telescopios de neutrinos del Mediterráneo ANTARES y KM3NeT. KM3NeT tendrá dos versiones: ARCA que utilizará los neutrinos como mensajeros cósmicos y ORCA que determinará la jerarquía de masas de los neutrinos.

Resumir todas nuestras actividades en 2015 es una tarea muy difícil. Quiero solamente destacar algunos hitos de este año. El Gran Colisionador de Hadrones (LHC) volvió a funcionar durante 2015 después de una parada técnica de dos años. La toma de datos ha sido muy exitosa y nuestros científicos están utilizando la ingente cantidad de datos suministrados por los detectores para continuar sus estudios del quark top, del bosón de Higgs, la búsqueda de nueva física como supersimetría, el estudio de procesos infrecuentes en el sector de quarks pesados y otros.

Los grupos de investigación que trabajan en los experimentos del LHC están ahora involucrados en la mejora de sus detectores para el futuro LHC de alta luminosidad (HL-LHC). En 2015, después de cuatro años de estudios de diseño, el proyecto HL-LHC ha pasado a su segunda fase, en la que tendrá lugar el desarrollo de prototipos industriales de varios componentes del acelerador. Se requerirá un enorme

esfuerzo para adaptar los detectores y algunos de nuestros científicos e ingenieros que trabajan en los experimentos ATLAS y LHCb están completamente dedicados a esta tarea.

KM3NeT desplegó durante 2015 su primera unidad de detección completa, comenzando así la primera fase de este ambicioso telescopio de neutrinos, mientras que su experimento predecesor, ANTARES, está suministrando un gran número de resultados.

El detector NEW, una primera etapa del proyecto NEXT, ha sido instalado en el Laboratorio Subterráneo de Canfranc (LSC) y su puesta en funcionamiento será inminente. Éste es un paso importante hacia la realización de este desafiante experimento de desintegración beta doble sin neutrinos.

El experimento de neutrinos DUNE, antes llamado LBNE, ha ganado fuerza incrementando su colaboración durante 2015 con más de 50 nuevas instituciones participantes, entre las que ahora está el IFIC.

Los experimentos liderados por físicos nucleares del IFIC y basados en la técnica de absorción total, desarrollada en nuestro instituto, han demostrado por primera vez que se puede obtener información esencial sobre la captura neutrónica en núcleos muy inestables a través de la desintegración beta. Esta información es esencial para entender la formación de elementos químicos pesados en el Universo, producidos en situaciones violentas como la explosión de una supernova o la fusión de dos estrellas de neutrones.

Hay muchas más actividades experimentales en nuestro instituto que están convenientemente recogidas en esta memoria y que animo a los lectores a que descubran en sus páginas.

La variedad y calidad del trabajo teórico en el IFIC es de tal magnitud que resumirlo en esta pequeña introducción es tarea imposible. Mencionaré algunas de las contribuciones.

Los investigadores del IFIC han estudiado las desintegraciones con cambio de sabor de un bosón de Higgs a un par de quarks bs en un contexto general supersimétrico. Un grupo de físicos teóricos del IFIC ha propuesto una nueva clase de modelos Z' con interacciones neutras con cambio de sabor a nivel árbol en el sector de quarks d. Se ha reanalizado la producción de asimetrías leptónicas en extensiones mínimas del Modelo Estándar que pueden explicar las masas de los neutrinos. Un grupo de teóricos del IFIC explicó uno de los dos pentaquarks observado en el detector LHCb antes de su observación experimental y predijo varios estados exóticos de quarks pesados.

Otro grupo de teóricos del IFIC, buscando modelos gravitatorios que eviten singularidades cosmológicas, han encontrado que ciertas configuraciones con simetría esférica del electrovacío conducen a soluciones con un agujero de gusano central que remplaza a la singularidad que se encuentra en la Relatividad General.

Se ha calculado la sección eficaz efectiva de la dispersión de pares de partones y sus autores han propuesto medidas de estas secciones eficaces en regiones cinemáticas específicas a partir de las cuales se podrían obtener correlaciones entre pares de partones, un aspecto novedoso e interesante de la estructura tridimensional del nucleón.

Se ha propuesto un método basado en la dualidad loop-tree que podría permitir llevar a cabo cálculos a orden superior de teoría de perturbaciones a NLO y más allá, que estuvieran libres de sustracciones colineares a bajo momento y de estado final y, por tanto, que no requiriesen regularización dimensional. El método propuesto representa un nuevo paradigma en cálculos teóricos para el LHC.

Otros investigadores del IFIC continúan sus análisis pioneros de los cocientes de sabor en los datos de IceCube. Asimismo, algunos teóricos del IFIC han investigado la aniquilación de neutralinos como candidatos a materia oscura, en particular en relación con el exceso de rayos gamma procedente del centro galáctico.

Finalmente, quiero mencionar dos actividades en las que el IFIC está haciendo un particular esfuerzo durante los últimos años: la innovación y la transferencia de conocimiento, y la divulgación. El aumento en el número y la calidad de nuestras contribuciones en estas dos áreas subraya el interés de nuestro instituto en mostrar a nuestra sociedad la importancia y el impacto de nuestro trabajo. Estamos agradecidos del apoyo que nuestros conciudadanos dan a nuestras actividades de investigación y esperamos transmitir la pasión y la dedicación que ponemos en nuestro trabajo, devolviendo, a un tiempo, un poco de lo que recibimos de ellos.

BENVINGUTS

És per a mi un plaer saludar-los novament en aquesta introducció a la Memòria Anual de l'IFIC. Ha passat volant un any més, però en el seu transcurs el nostre institut no ha perdut ni un segon tractant d'aconseguir els ambiciosos objectius que s'ha marcat.

Si haguérem de destacar un fet de la vida de l'institut durant 2015, aquesta seria la concessió a l'IFIC de la distinció de Centre d'Excel·lència Severo Ochoa. Aquest premi, segons les paraules de la pròpia convocatòria, "acredita i finança als centres públics d'investigació en totes les àrees que demostren lideratge científic i un impacte a nivell global, així com una col·laboració amb el seu entorn social i econòmic". Estem orgullosíssims d'aquesta distinció que ens permetrà promoure i incrementar les nostres activitats d'investigació.

Un fet important en la nostra especialitat en 2015 va ser la concessió del premi Nobel al professor Takaaki Kajita (de la col·laboració Super-Kamiokande, Universitat de Tòquio, Japó) i al professor Arthur B. McDonald (de la col·laboració del Sudbury Neutrí Observatory, Canadà) , "pel descobriment de les oscil·lacions de neutrins, que mostren que els neutrins tenen massa". Aquest premi és la culminació d'una història fascinant en els annals de la Física que ha implicat l'esforç, el treball, la intel·ligència i la perspicàcia d'un gran nombre de científics de tot el món.

L'IFIC està fortament involucrat en la física dels neutrins, tant en el seu vessant teòric –amb un gran nombre de publicacions d'alt impacte en una sèrie de temes relacionats amb els neutrins– com en el seu vessant experimental, en el que científics de l'IFIC participen o lideren diversos experiments relacionats amb dita física. Alguns físics experimentals de l'IFIC treballen en aclarir la naturalesa del neutrí com a partícula elemental (fermió de Majorana o de Dirac) a través de l'experiment NEXT liderat per científics de l'IFIC i recolzat per una Advanced Grant de l'ERC. Aquesta investigació és un desafiament amb un gran potencial d'impacte en una diversitat d'àrees de la física.

Un altre grup de científics de l'IFIC participen en l'experiment T2K al Japó per continuar estudiant les oscil·lacions de neutrins, determinar millor els paràmetres que descriuen aquest fenomen i potser estudiar la possible existència de la violació de CP en el sector leptònic. A més, un grup d'investigació de l'IFIC participa en els telescopis de neutrins ANTARES i KM3NeT. El telescopi KM3NeT tindrà dos versions: ARCA que utilitzarà els neutrins com a missatgers còsmics i ORCA que determinarà la jerarquia de masses dels neutrins.

Resumir totes les nostres activitats en 2015 és una tasca molt difícil. Vull només destacar algunes fites d'enguany. El Gran Col·lisionador d'Hadrons (LHC) va tornar a funcionar durant 2015 després d'una parada tècnica de dos anys. La presa de dades ha sigut un gran èxit i els nostres científics estan utilitzant la ingent quantitat de dades subministrades pels detectors per a continuar els seus estudis del quark top, del bosó de Higgs, la recerca de nova física com supersimetria, l'estudi de processos infreqüents en el sector de quarks pesats i altres.

Els grups d'investigació que treballen als experiments de l'LHC estan ara involucrats en l'adaptació dels seus detectors per al futur LHC d'alta lluminositat (HL-LHC) . En 2015, després de quatre anys d'estudis de disseny, el projecte HL-LHC ha passat a la seua segona fase, en la que tindrà lloc el desenvolupament de prototips industrials de diversos components de l'accelerador. Es requerirà un enorme esforç per posar al dia els detectors i, en conseqüència, alguns dels nostres científics i enginyers que treballen en ATLAS i LHCb estan completament dedicats a aquesta tasca.

KM3NeT va desplegar durant 2015 la seua primera unitat de detecció completa, començant així la primera fase d'aquest ambiciós telescopi de neutrins, mentre que el seu predecessor, ANTARES, està subministrant un gran nombre de resultats. El detector NEW, una primera etapa del projecte NEXT, ha sigut instal·lat en el Laboratori Subterrani de Canfranc (LSC) i la seua posada en funcionament serà imminent. Aquest és un pas important cap a la realització d'aquest desafiant experiment de desintegració beta sense neutrins. L'experiment de neutrins DUNE, abans cridat LBNE, ha guanyat força incrementant la seua col·laboració durant 2015 amb més de 50 noves institucions participants, entre les que ara està l'IFIC.

Els experiments liderats per físics nuclears de l'IFIC i basats en la tècnica d'absorció total desenvolupada al nostre institut, han demostrat per primera vegada que es pot obtenir informació essencial sobre la captura neutrònica en nuclis molt inestables a través de la desintegració beta. Aquesta informació és essencial per a entendre la formació dels elements químics pesats a l'Univers, produïts en situacions violentes com l'explosió d'una supernova o la fusió de dos estreles de neutrons.

Hi ha moltes més activitats experimentals en el nostre institut que estan convenientment recollides en aquesta memòria i que anime els lectors a què descobrisquen en les seues pàgines.

La varietat i qualitat del treball teòric a l'IFIC és de tal magnitud que resumir-ho en aquesta xicoteta introducció és una tasca impossible. Mencionaré algunes de les contribucions.

Els investigadors de l'IFIC han estudiat les desintegracions amb canvi de sabor d'un bosó de Higgs a un parell de quarks bs en un context general supersimètric. Un grup de físics teòrics de l'IFIC ha proposat una nova classe de models Z' amb interaccions neutres amb canvi de sabor a nivell arbre en el sector de quarks d. S'ha reanalitzat la producció d'asimetries leptóniques en extensions mínimes del Model Estàndard que poden explicar les masses dels neutrins. Un grup de teòrics de l'IFIC va explicar un dels dos pentaquarks observat en el detector LHCb abans de la seua observació experimental i va predir diversos estats exòtics de quarks pesats.

Un altre grup de teòrics de l'IFIC, buscant models gravitatoris que eviten singularitats cosmològiques, ha trobat que certes configuracions amb simetria esfèrica de l'electrobuit conduïxen a solucions amb un forat de cuc central que reemplaça a la singularitat que es troba en la Relativitat General.

S'ha calculat la secció eficaç efectiva de la dispersió de parells de partons i els seus autors han proposat mesures d'aquestes seccions eficaces en regions cinemàtiques específiques a partir de les quals podrien obtindre's correlacions de parells de partons, un aspecte nou i interessant de l'estructura tridimensional del nucleó.

S'ha proposat un mètode basat en la dualitat looptree que podria permetre dur a terme càlculs a orde superior de teoria de pertorbacions a NLO i més enllà, que estigueren lliures de sostraccions colinials a baix moment i d'estat final i, per tant, que no requeriren regularització dimensional. El mètode proposat representa un nou paradigma en càlculs teòrics per a l'LHC.

Altres investigadors de l'IFIC continuen les seues anàlisis pioneres dels quocients de sabor en les dades d'IceCube. Així mateix, alguns teòrics de l'IFIC han investigat l'aniquilació de neutralins com a candidats a matèria fosca, en particular en relació amb l'excés de raigs gamma procedent del centre Galàctic.

Finalment, vull mencionar dos activitats en què l'IFIC està fent un particular esforç durant els últims anys: la innovació i la transferència de coneixement, i la divulgació. L'augment en el número i la qualitat de les nostres contribucions en aquestes dues àrees subratlla l'interés del nostre institut a mostrar a la nostra societat la importància i l'impacte del nostre treball. Estem agraïts pel suport que els nostres conciutadans donen a les nostres activitats d'investigació i esperem transmetre la passió i la dedicació que posem en el nostre treball, tornant, al mateix temps, un poc del que rebem d'ells.

WELCOME

It is for me a pleasure to greet you in this address of IFIC's Annual Report. Another year has swiftly gone by but our institute has not wasted a second pursuing its stretch goals.

If there is an event in the institute's life during 2015 that can be singled out, this is the bestowal to IFIC of the Severo Ochoa Centre of Excellence Award. This award, according to the call itself, "funds and accredits Spanish public research centres on any areas that demonstrate scientific leadership and impact at global level, as well as active collaboration in their social and business environment". We are exceedingly proud of this award which will allow the enhancement and promotion of our research activities.

A very important event in our field during 2015 was the awarding of the Nobel Prize to Prof. Takaaki Kajita (Super-Kamiokande Collaboration, University of Tokyo, Japan) and Prof. Arthur B. McDonald (Sudbury Neutrino Observatory Collaboration, Canada) "for the discovery of neutrino oscillations, which shows that neutrinos have mass". This is the culmination of a fascinating story in the History of Physics that involved the effort, work, intelligence and nous of a great deal of scientists all over the world.

IFIC is deeply involved in neutrino physics, both on its theoretical side –with a large number of high impact publications in a variety of topics related to neutrinos– as well as on its experimental side, with IFIC's scientists participating or leading several experiments related to neutrino physics. IFIC's experimentalists work in the elucidation of the nature of the neutrino as elementary particle (Majorana or Dirac) through the experiment NEXT led by IFIC's scientists and supported by an ERC Advanced Grant. This is a challenging investigation with a high potential impact in a variety of different physics areas.

Our scientists also participate in the long baseline experiment T2K in Japan to further study neutrino oscillations, better determine the parameters that describe the phenomenon and possibly study the critical existence of CP violation in the lepton sector. This group is also involved in the DUNE initiative in the USA. In addition, an IFIC research team participates in the ANTARES and KM3NeT neutrino telescopes. The KM3NeT telescope will have two versions: ARCA which will use neutrinos as cosmic messengers and ORCA which will determine the neutrino mass hierarchy.

To summarize all our activities during 2015 is a very difficult task. Let me just highlight some important milestones. The Large Hadron Collider resumed its operation during 2015 after a technical stop of two years. The data-taking was extremely successful and our scientists are using the plethora of data provided by the detectors to continue their studies on the top quark, the Higgs boson, the search for new physics as SUSY, the study of rare processes in the heavy quark sector and others.

The research teams working on the LHC experiments are now involved in the upgrading of their detectors for the future High Luminosity LHC (HL-LHC). In 2015, after a four-year design study, the HL-LHC project moved into its second phase, which will see the development of industrial prototypes for various parts of the accelerator. A huge effort will be required to upgrade the detectors accordingly and some of our scientists and engineers working on ATLAS and LHCb are fully devoted to this goal.

KM3NeT deployed during 2015 its first full size detector unit, thus starting Phase I of this ambitious neutrino telescope, whilst its predecessor ANTARES is providing a large number of results. The NEW detector, a first stage of the NEXT project, was installed in the Canfranc Underground Laboratory (LSC) and its commissioning will soon follow. This is a major step towards the realisation of this challenging neutrinoless double-beta decay experiment. The neutrino experiment DUNE, formerly known as LBNE, has gained momentum increasing its collaboration during 2015 by more than 50 new member institutions, among which is now IFIC.

Experiments led by IFIC's nuclear physicists based on the total absorption technique –which has been developed in our institute– have shown for the first time that essential information about the neutron capture in very unstable nuclei can be obtained through beta decays. This information is essential to understand the formation of heavy elements in the Universe, produced in violent phenomena such a supernova explosions or the fusion of two neutron stars.

There are many more experimental activities in our institute, which are duly described in this report and which I encourage the reader to learn about.

The variety and quality of the theoretical work at IFIC is of such calibre that to summarise it in this short introduction is an impossible task. Let me mention some of the contributions. IFIC researchers have studied the flavour-changing decays of a Higgs boson to a bs quark pair in a general supersymmetric scenario. A new class of Z' models with neutral flavour-changing interactions at tree level in the d quark sector was put forward by a group of IFIC's theoreticians. The production of leptonic asymmetries in minimal extensions of the SM that can explain neutrino masses was revisited. A group of IFIC's theorists explained one of the two pentaquarks observed at the LHCb detector before the experimental observation and predicted several heavy quark exotic states.

Another team of IFIC theorists, looking for gravity models that could avoid cosmological singularities, have found that spherically symmetric electrovacuum configurations lead to solutions with a central wormhole that replaces the singularity found in General Relativity. The effective cross-section of double parton scattering in proton-proton collisions has been calculated and the authors have proposed measurements of this cross-section in specific kinematical regions from which indications on double parton correlations could be obtained, a novel and interesting aspect of the three dimensional structure of the nucleon.

A method based on loop-tree duality has been proposed that could allow to perform higher-order perturbative calculations at next-to-leading order (NLO) and beyond, free from soft and final-state collinear subtractions and therefore not requiring the use of dimensional regularisation. The proposed method represents a new paradigm in theoretical calculations for the LHC.

IFIC researchers continued their pioneer analyses of flavour ratios of the high energy neutrino data from IceCube. Likewise, IFIC theorists have investigated the annihilation of neutralinos as dark matter candidates, in particular connected to the gamma-ray excess coming from the Galactic centre.

Finally, let me mention two activities on which IFIC is making special efforts during recent years: innovation and knowledge transfer and outreach. The increase in the number and quality of our contributions in these two areas underline the interest of our institute to show to our society the importance and impact of our work. We are grateful for the support of our fellow citizens in our research activities and hope to convey the passion and dedication we put in our work while at the same time giving back a bit of what we receive from them.

1. STRUCTURE AND ORGANIZATION

ABOUT IFIC

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 centre, 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 maintain 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.

IFIC is an international reference centre in Particle, Astroparticle and Nuclear Physics, both in the theory and experimental domains

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, obtained 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), SLAC (Stanford-USA), FERMILAB (Chicago-USA), etc.

After Spain re-entered CERN in 1984, the scientific activity of IFIC was boosted in both quantitative and qualitative aspects

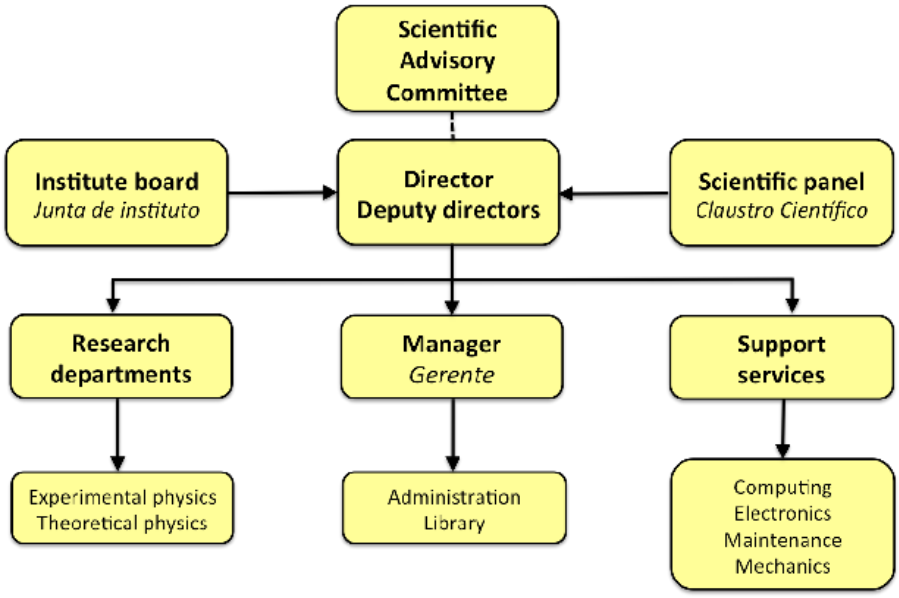
1 An excellent review article about the birth of experimental nuclear and particle physics in Spain, written by Agustín Ceba, Víctor Navarro y Jorge Velasco, was published in Revista Española de Física 25-2 (2011).

1. STRUCTURE AND ORGANIZATION

ORGANIZATION, SCIENTIFIC DEPARTMENTS AND SUPOPORT 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.



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Members of the Institute Board:
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Deputy directors: Juan José Hernández Rey, Sergio Pastor Carpi, Santiago Noguera Puchol (since July 2015), María José Costa Mezquita (since September 2015)
Manager: Ana Fandos Lario
Heads of the research departments: Berta Rubio Barroso (Experimental Physics), Juan M. Nieves Pamplona (Theoretical Physics)
Personnel representatives: Rosa Carrasco de Fez (non-doctoral members), Salvador Martí García (doctoral members)

The Institute is situated in the Burjassot-Paterna Campus of the University of Valencia, a few kilometres from the centre of Valencia. IFIC personnel are distributed at the Science 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 research buildings at the Science Park UVEG

Faculty of Physics (UVEG campus in Burjassot)

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.

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.

SCIENTIFIC DEPARTAMENTS

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

IFIC participated in the construction of several systems of ATLAS detector of the LHC, in the computing and data management

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 the neutrino. The group studies the phenomenon of oscillations between neutrino families, measuring the parameters that define such oscillations. It also tries to elucidate the nature of the neutrino, namely whether the neutrino is a Majorana or a Dirac fermion. IFIC leads the NEXT experiment searching for neutrino-less double beta decay, whose detection would imply that neutrinos are Majorana particles. IFIC also participates in several accelerator-based oscillation experiments: the currently operating T2K experiment in Japan, and the next-generation DUNE experiment in the United States. In the past, scientists of this line participated in the SciBooNE, K2K, HARP and NOMAD experiments.

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.

The Medical Physics group works on the development of instrumentation for medical imaging, image science and accelerator development

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 mix-

ing 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, etc.). 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.

IFIC covers a wide range of topics in Theoretical Physics: phenomenology of SM and theories beyond it, nuclear, particle physics in astrophysics and cosmology

SUPPORT UNITS

Administration and Management

The Administration Service is located on the first floor of the main research 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

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 300 computer nodes (around 3000 cores) and 1.9 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).

Computer centre.

Electronics

This Unit provides service to any IFIC research project with demands on electronics. IFIC experiments develop particle sensors that generate electronic outputs that need to be recorded. The Unit staff and equipment support these activities with design, prototyping, manufacturing, testing and validation of electronic systems.

In addition, certain sensor technologies use microelectronics, as for instance silicon particle detectors. This Unit is in charge of providing chips and silicon structures testing, as well as chip-to-sensor assembly and also the connection of their microchannels. It also offers service and developments to external companies through contracts and agreements. This Unit makes use of two infrastructures: the general electronics laboratory (90 m^2, with PCB fabrication and component assembly equipment) and the clean room (80 m^2 in two areas, classes 10000 and 1000, ISO7 and ISO6, with X-ray inspection, flip-chip and wire-bonding machines) for support in microelectronics.

Electronics laboratory.

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 3300 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.

Library.

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.

IFIC workshop.

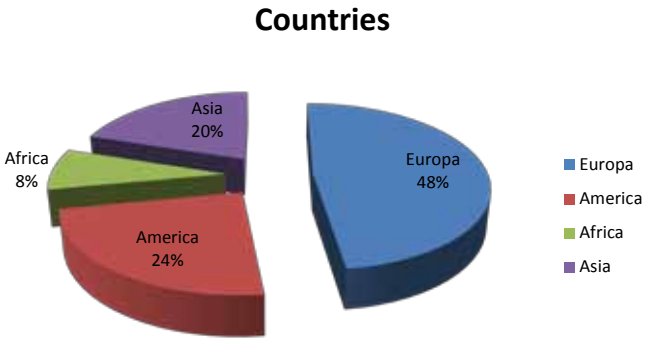
Maintenance

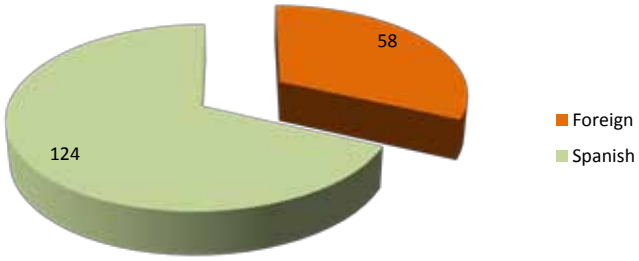
This Unit is an integrated service of maintenance management, occupational safety, radiation protection, environmental and quality management of the shared facilities as well as the research laboratories of the Institute. Its tasks include the preventive and corrective maintenance of facilities and laboratories, the management and logistics of the Clean Room and the Laboratory of Radioactive Sources. 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 Radiation Protection Service 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 DECEMBER 2015

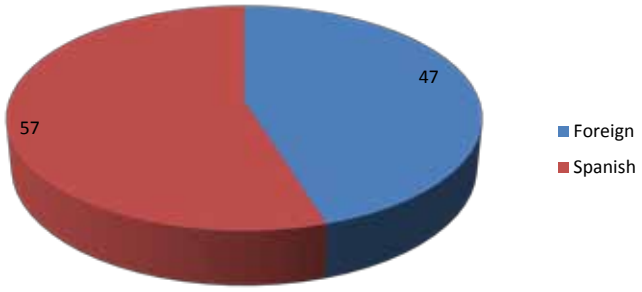
234 PEOPLE
25 COUNTRIES





182 SCIENTIFIC STAFF
ONE THIRD FROM ABROAD

63 PhD STUDENTS
41 POSTDOC RESEARCHERS



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Pastor Clérigues, Elena

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García Cano, Isidoro

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Fuentes Castilla, Angel

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Merino Josa, Ruben
Monserrate Sabroso, Jose Manuel
Santoyo Muñoz, David

2. RESEARCH ACTIVITIES

EXPERIMENTAL PHYSICS

ACCELERATOR-BASED EXPERIMENTAL HIGH ENERGY PHYSICS

The activities of this research line during 2015 embraced the participation in the ATLAS, LHCb and MoEDAL experiments at the LHC (their detector operation, physics analysis and detector upgrade), plus the ones related with the future International Linear Collider (ILC) and the Compact Linear Collider (CLIC): physics goals, accelerator and detector technology.

LHC experiments

A very important milestone for the group activities was that, during 2015, LHC resumed its operations after a 2-year long technical stop (Long Shutdown 1, LS1). During the LS1, a full series of renovation and consolidation work was carried out for the LHC, the ATLAS detector and the LHCb trigger. That enabled LHC to produce proton-proton collisions at an increased and unprecedented centre of mass energy of 13 TeV, significantly higher than the previous 8 TeV reached in 2012. The new period of LHC operations and data taking is known as Run2, whilst the data collected with the operations till 2012 is known as Run1.

ATLAS

The activities of our members inside the ATLAS collaboration covered all the aspects of running the experiment. There is an involvement in the detector operations, the data preparation and processing, physics data analysis, publication of results, conference presentations as well as playing a leading role through occupying managing posts within the collaboration, and also within the LHC Top Physics Working Group. A strategic decision of the ATLAS IFIC group is to diversify and participate actively in the different parts of the ATLAS physics program. For the IFIC members of the ATLAS collaboration, 2015 was the year of transition from the LHC Run1 to the LHC Run2, producing final results with the data collected during the Run1 and preparing for the new physics analyses using the fresh data collected at 13 TeV.

ATLAS operations

2015 was an exciting year for the detector operations. During early 2015 the Inner Detector and the hadronic calorimeter, TileCal, (both participated by IFIC) had to be re-commissioned for the new data taking ahead. Both systems were involved in a feverish activity checking all the hardware, electronics, calibrations, plus the reconstruction software. A successful cosmic-ray run during March with all ATLAS systems active represented an important milestone. The culmination of the efforts was a successful operation and efficient data recording during 2015 with LHC operating at 13 TeV.

For the Run2, ATLAS counts on a new pixel sensors layer added to the existing 3 pixel layers. The new (Insertable B-Layer, IBL) is just located 3 cm from the beam axis. Its goal is to improve the track impact parameter determination, thus improving the ability to identify B-hadrons. Therefore the alignment of the IBL is a key ingredient for the success of the ATLAS physics program.

The IFIC group is responsible for the alignment of the ATLAS tracking system (Inner Detector). Our duty was to include the IBL alignment parameters in the database by updating all the code to cope with the new IBL (in the alignment specific part and in the monitoring). In order to analyse the data as soon as possible, a fast turnaround of the calibrations and alignment is required. The latter has to provide the Inner Detector geometry constants no later than 48 hours after the completion of the run. For this reason, we implemented the Inner Detector alignment at the calibration loop and the monitoring of its results on a web interface. Later in the year, when the ionization damage to the IBL became apparent, the IBL staves started to bend even within a run. A new alignment scheme had to be deployed to cope with the IBL rapid movement, as it was essential to keep the high quality of the data for the physics analysis.

Our group is also responsible for the maintenance and operation of the back-end electronic (ROD) system of the ATLAS Tile Calorimeter. During 2015, TileCal was operated with a data taking efficiency well

above the required 95% value. The online reconstruction algorithms running in the ROD system were updated in order to cope with the LHC luminosity increase and change of bunch crossing spacing from 50 ns to 25 ns. In particular, the Optimal Filtering method was updated to reduce the impact of the pileup in the energy and time reconstructed in the ROD system.

ATLAS: precision measurements

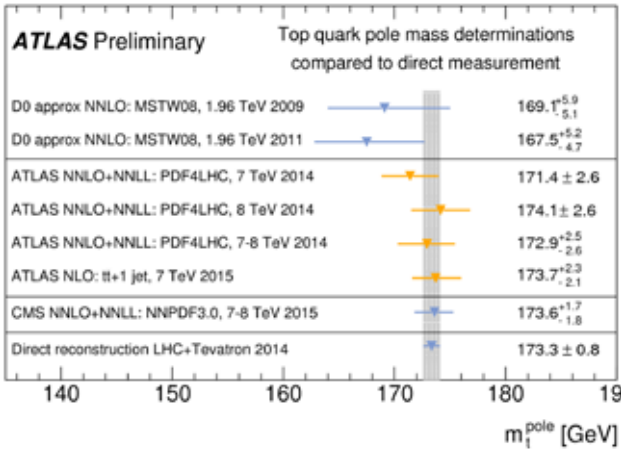
One of the IFIC analyses focused on studying the recently discovered scalar sector of the Standard Model, and the potential for manifestations of new physics related to the Higgs sector. In 2015, our group participated very actively in those analyses measuring the properties of the Higgs boson: its production rate and decay branching ratios in final states with bosons (W, photons) and final state with leptons. It is worth to mention that the IFIC group is among the main contributors to the final results of the ATLAS collaboration with Run1 data observing the decay of the Higgs boson in W^+W^- bosons and evidence of the Yukawa coupling of the Higgs boson to τ leptons. With the new Run2 data, IFIC contributed to the measurement of the cross-section production of the Higgs boson at a centre of mass of 13 TeV.

IFIC group is among the main contributors to the final results of the ATLAS collaboration with Run1 data observing the decay of the Higgs boson

IFIC had important contributions to top quark physics in 2015.

One of those was the first measurement of the top quark pole mass in associated production of a top quark pair plus a hard jet in 7 TeV pp collisions.

Due to the fact that quarks appear always in bound states forming hadrons, it is necessary to use theoretical calculations to provide a clear interpretation of their mass. The measurement of the top quark pole mass (m_t^{pole}) by the IFIC members was based on a novel method. It includes Next to Leading Order (NLO) calculations of the t-tbar+1 jet production in an unambiguous mass scheme. This analysis was performed entirely by the IFIC group and it provided the most precise measurement of the top quark pole mass ($m_t^{pole}=173.7^{+2.3}_{-2.1}$ GeV). The full potential of this method has yet to be realized in an analysis of the 8 and 13 TeV data already collected by the experiment. The ultimate precision is expected to be approximately (or better than) 1 GeV.

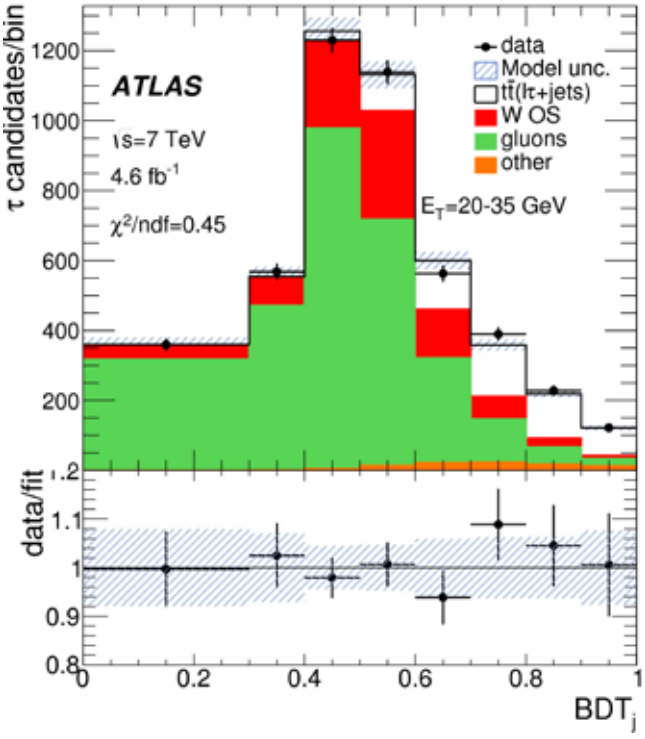


Measurements of the top quark pole mass. The IFIC analysis produced the one labelled as ATLAS NLO: tt+1 jet, 7 TeV 2015.

Another top quark physics analysis lead by our group was the "Measurements of the branching ratios of top quark decays into leptons and jets using events with top-antitop pairs". It was published during 2015 using an integrated luminosity of 4.6 fb^{-1} at 7 TeV. This analysis pioneers the use of the top-to-τ decays in ATLAS. Therefore, the IFIC ATLAS group was responsible for the development of the analysis technique based on template fitting of boosted decision tree based tau tagging. This work presented the first direct measurement of the top quark semileptonic (including τ decays) and all-hadronic branching ratios, which depend on the W boson branching ratios. This article also presents a measurement of the inclusive ttbar cross section using events with an isolated charged lepton (μ or e) and a τ lepton decaying hadronically. Both results agreed with the Standard Model predictions within the measurement uncertainties of just a few per cent.

We also participated in the first measurement of the charge asymmetry using highly boosted top

quark pair production in 8 TeV pp collisions. The group led the development and application of new methods for the reconstruction of highly boosted top quarks within ATLAS. Thanks to this novel technique, the charge asymmetry analysis can be extended for Standard Model measurements well into the TeV regime, thanks to the reconstruction techniques of boosted objects. These techniques are even more relevant for the Run2 data, as due to the energy increase of the LHC, top quarks will be produced even more boosted. Therefore, this know-how is an asset for the Run 2 analysis.



Distribution of the Boosted Decision Tree discriminant on top decays to τν+X

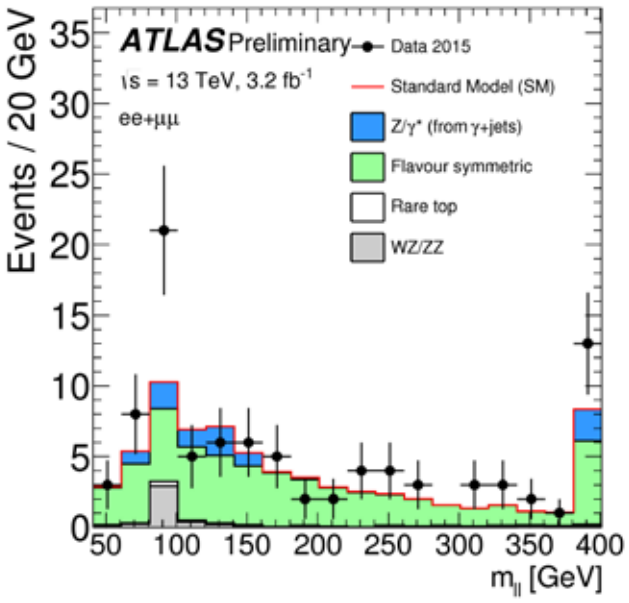
Single-top events are also abundantly produced at the LHC. Due to its electroweak production and decaying mechanism, the single-top events are an excellent test bench of the Wtb vertex. Thus it can test the SM couplings of the top quark, as well as being sensitive to new physics contributions (anomalous couplings) and to provide a measurement of the top quark polarization. During 2015, the analysis was extended to include a full set of observables that allow the determination of the W boson spin parameters, to which this channel is sensible thanks to single top quarks being produced with a net polarization. It must be emphasized that during 2015, the ATLAS single top convener was an IFIC member.

ATLAS: direct searches for new physics

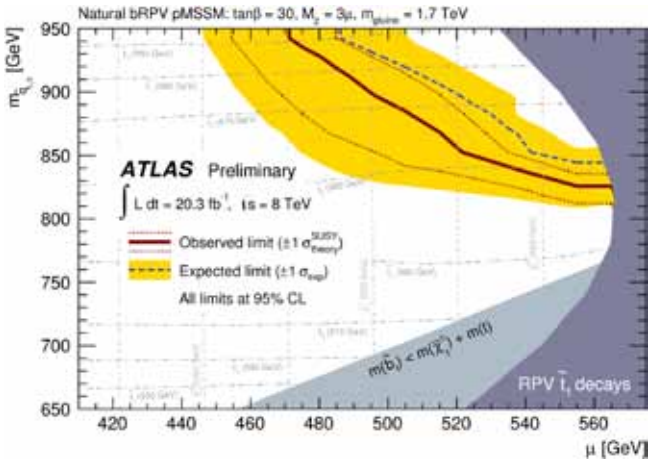
At the same time, the group participated in the searches for new physics in the Higgs sector, such as the search for Lepton Flavour Violating (LFV) decays of the Higgs and the search for new massive Higgs bosons, as predicted by theories such as supersymmetry (SUSY).

IFIC contributed to SUSY searches in ATLAS by setting the first limits in the natural pMSSM model

We are strongly involved in the ATLAS searches for supersymmetric (SUSY) particles. The group has pioneered the R-parity violating (RPV) SUSY searches, as well as collaborated with several theoretical physicists (specially within IFIC, plus some from IFT). Fruits of the latter are proposals to search for new SUSY signatures at LHC experiments and the interpretation of experimental results. On the ATLAS data analyses front the channel of a leptonically decaying Z boson and large missing transverse momentum stands out. Excesses of events over the expectation from the Standard Model were observed in the 2012 data at 8 TeV (3σ) and in the 2015 data at 13 TeV (2.2σ). Moreover, IFIC has contributed to the summary of RPV SUSY searches in ATLAS by setting the first limits in the natural pMSSM model with bilinear RPV terms. Other studies include the feasibility to detect at LHC unusual decays of W and Z bosons proposed in the RPV model of μνSSM.



Dilepton invariant mass in the Z plus missing transverse energy analysis.



Limits in the natural pMSSM with bilinear RPV

ATLAS upgrade

Regarding the ATLAS detector upgrade program (a consequence of the planned increase of the LHC luminosity by a factor 5-10, known as High Luminosity-Large Hadron Collider: HL-LHC), the work load now is quite considerable as the actions need to be planned well ahead, because the challenge is big.

The current ATLAS tracker (Inner Detector) will be entirely replaced by a new all-silicon tracker (ITk). Profiting our experience in the design, engineering and integration of silicon sensors tracking systems, the IFIC group is responsible for the design of the forward region of the ITk. There, the silicon microstrip sensors shall be mounted on a carbon fibre structure with petal shape. Our working teams are very active and responsible for the following aspects of the ITk working groups: 1) the development of the integration strategy of the silicon microstrip sensors in petals and those into disks, then into the end-cap; 2) Development of a silicon sensor technology without type inversion after irradiation; 3) Design of the power lines scheme for both: sensors and readout modules; 4) ITk end cap modules design (including the distribution of services, power lines for sensors and electronics, signal routing, cooling system, etc).

The IFIC group is responsible for the design of the forward region of the new all-silicon tracker (ITk)

For the ITk, the goal is to achieve a light supporting structure able to host 7 disks of each of the end-caps, then 32 petals per disk. The IFIC team has designed this supporting structure and study its viability with a Finite Element Analysis (FEA) by considering the mechanical stresses, deformations, etc.

Relating to the upgrade of the TileCal, we have a leading role in the design and production of the Tile Calorimeter Pre-processors (TilePPr), the core component of the future back-end electronics for the LHC Phase-II upgrade. In 2015, the first prototype of the TilePPr was produced and, together with other TileCal demonstrator components, it was successfully tested in a series of dedicated experts weeks in the TileCal laboratory at CERN. Moreover, in September 2015, the TileCal demonstrator module was tested in the CERN test-beam facilities during two weeks and controlled by the TIlePPr. A responsibility of the IFIC was the development of the data acquisition software and the analysis of the test-beam data.

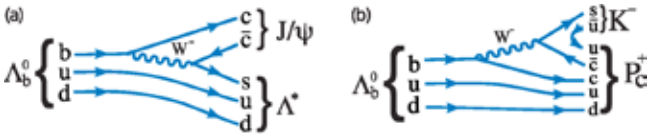
LHCb

Upgrades to the LHCb computing infrastructure have allowed for high-quality online information to be calculated by the software trigger, making possible to store a compact event record directly from the trigger and ready for physics analysis. Reaching the ultimate precision of the LHCb experiment in real time as the data comes has the potential to transform in the coming years the experimental approach to process large quantities of proton-proton collision data.

IFIC members are involved in the detector operations, physics data analysis and publication of results, detector upgrade and playing a leading role within the Rare Decays working group, besides the participation in the Heavy Flavour Averaging Group (HFAG).

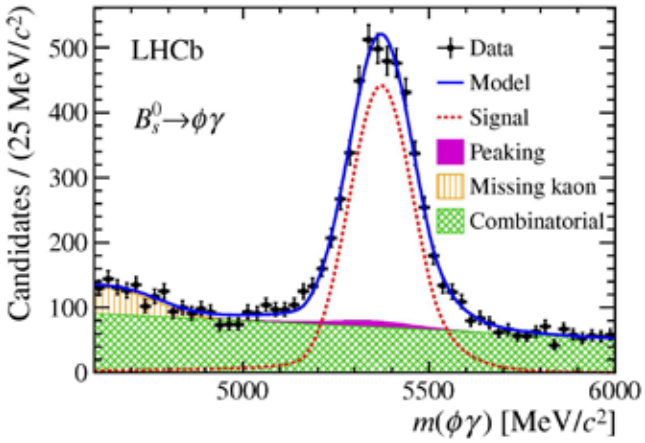
During 2015 LHCb completed a large number of flavour physics analyses using the Run1 data. Among these, the discovery of two pentaquark states P_c^+ decaying into J/Ψ p final states in $\Lambda_b \rightarrow J/\Psi K^- p$ decays and the evidence for a number of possible anomalies in the flavour sector have opened the window for exciting times during the LHC Run 2. The possible anomalies include indications of violation of lepton flavour universality in $B^0 \rightarrow D^{*+} \tau^- \nu$ with respect to $B^0 \rightarrow D^{*+} \mu^- \nu$ decays, as there are hint of deviations from Standard Model (SM) predictions in several observables of B-meson decay modes that are mediated by flavour-changing neutral currents (FCNC), highly sensitive to new physics through quantum effects. In particular the lepton flavour universality in the decay $B^+ \rightarrow K^+ \mu^+ \mu^-$ compared to $B^+ \rightarrow K^+ e^+ e^-$ and the angular distributions of the decay $B^0 \rightarrow K^{*0} \mu^+ \mu^-$. Further evidence for the long-standing discrepancy between

inclusive and exclusive measurements of the CKM matrix element $|V_{ub}|$ has also been reported after the LHCb first observation of the decay $\Lambda_b \rightarrow p\mu^-$anti-ν. IFIC researchers have played an important role in many of these results.



Decays of a Λ_b, in decay mode (b) a pentaquark state is produced.

The year 2015 has also seen an intensive progress in the experimentally challenging time-dependent analysis of the $B^0_s \rightarrow \varphi\gamma$ radiative decay, led by IFIC researchers. This is a FCNC process sensitive to new physics through the detection of any non-zero right-handed (left-handed for the underlying anti-b quark) photon polarization (see figure LHCb-2). The first results of this analysis, a milestone of the LHCb physics program, are foreseen during the first half of 2016.



Mass distribution of $B^0_s \rightarrow \phi\gamma$ decays.

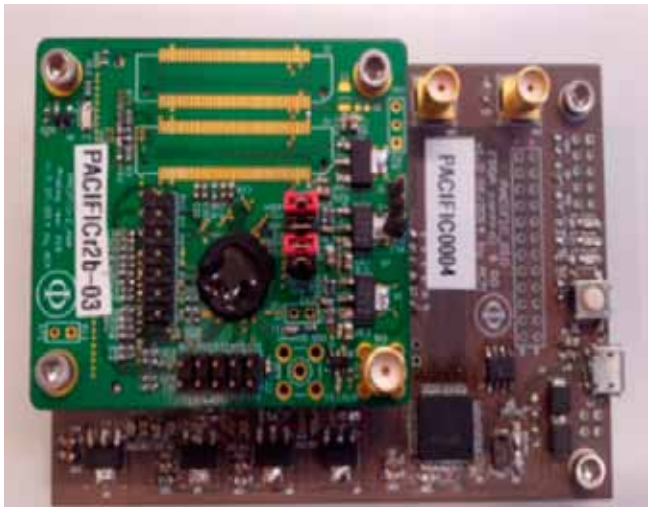
The article entitled "Time-reversal violation with quantum-entangled B mesons" authored by IFIC's researchers was selected as the cover of the Reviews of Modern Physics January-March issue.

LHCb upgrade

On the other hand, the effort on the development of the Scintillating Fibre Tracker (SciFi) of the upgraded LHCb detector had made consistent progress during 2015. The SciFi is designed to provide standalone pattern recognition with high efficiency and resolution downstream of the LHCb dipole magnet. The Front-End electronics has to procure full read-out of the SiPMs devices coupled to the fibres every 25 ns. The fibres, mats and modules section had successfully fulfilled the EDR milestone in July 2015. In parallel, part of the first fully operating front-end electronic

The article "Time-reversal violation with quantum-entangled B mesons" by IFIC's researchers was the cover of Reviews of Modern Physics

boards were produced at IFIC, as well as the first full-size front-end ASIC (PACIFICr3), triggering the integration test of the whole electronic system. On top of increasing the number of channels from 8 to 64, the PACIFIC design was migrated from IBM 130nm to TSMC 130nm, a notable feat for just one single prototyping iteration. Additionally, PACIFICr3 took part in a test-beam campaign in November, which provided extremely valuable insight for the further development of the ASIC.



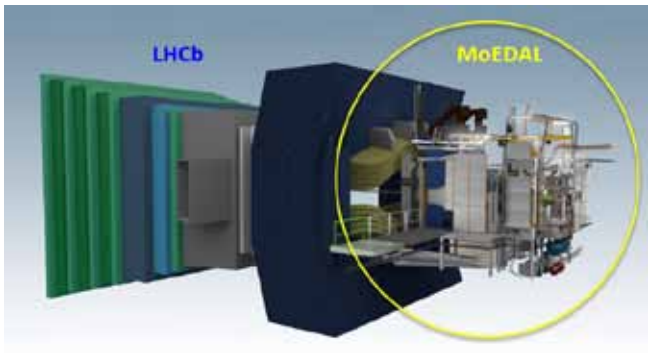
Electronic boards

MoEDAL

The IFIC team is the only Spanish participation in MoEDAL. This experiment is designed to search for manifestations of new physics through highly-ionising particles produced at the LHC. One of its primary motivations is to pursue the quest for magnetic monopoles and dyons, yet the experiment is also sensitive to any massive, stable or long-lived, slow-moving particles with single or multiple electric charges arising in many scenarios of physics beyond the Standard Model (SM). MoEDAL uses a passive detector sitting next to LHCb. It comprises a superconducting quantum interference device (SQUID). It also uses 0.8 tonnes of aluminium trapping detector volumes and 400 NTD (Nuclear Track Detectors). Each NTD consists of a 10-layer stack of plastic and altogether they have a total surface area of 250 m^2.

We are involved in both experimental aspects, such as the simulation of the detector, and also in developing and testing key theoretical models quite relevant for MoEDAL, making the most of its members' expertise in theories of magnetic monopoles and supersymmetry. It is important to highlight that IFIC plays a leading role in the MoEDAL management by holding the Chair of the Collaboration Board.

The experiment was taking data during 2015. The expected initial results for the mass limit of monopole production with single Dirac (magnetic) charge will be published during 2016.



Schematic representation of the MoEDAL detector sitting next to LHCb.

IFIC plays a leading role in the MoEDAL management by holding the Chair of the Collaboration Board

Future Linear Colliders

The IFIC is deeply involved in the linear collider projects ILC (International Linear Collider, to be hosted in Japan) and CLIC (Compact Linear Collider, led by CERN). IFIC is also member of the DEPFET active pixel detector R&D collaboration. IFIC contributes to the construction of the Belle II vertex detector and is responsible for the design of a DEPFET-based vertex detector for the ILD experiment at the ILC. As part of the AIDA2020 consortium, IFIC received additional EU funding for the development of silicon sensors with integrated micro-channel cooling.

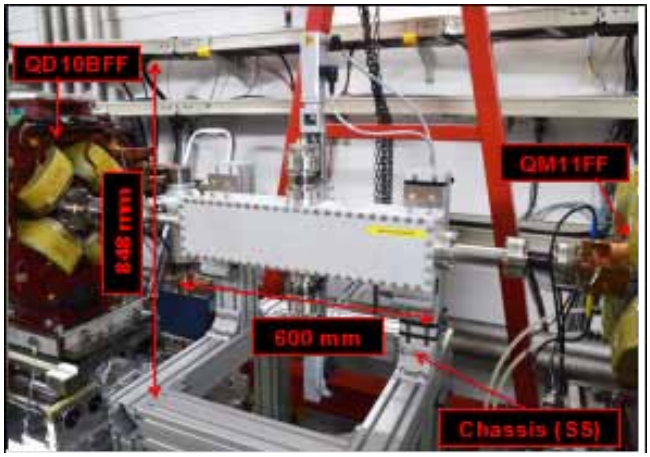
The contributions to the physics studies for the linear colliders focus on the precision measurements at the top quark physics sector. Among the papers published during 2015, one has to emphasize the publication on the potential of measurements of the electro-weak couplings of the top quark, that has become one of the pillars of the physics case for the ILC and CLIC. To mention that there is a new effort devoted to measure the top quark mass in the continuum. The fourth annual workshop "Top Quark Physics at the Linear Collider" was held in Valencia in 2015. Apropos of the activities related with the reconstruction tools of physics objects for future lepton-lepton colliders, just to highlight the new robust jet reconstruction algorithm proposed by IFIC members.

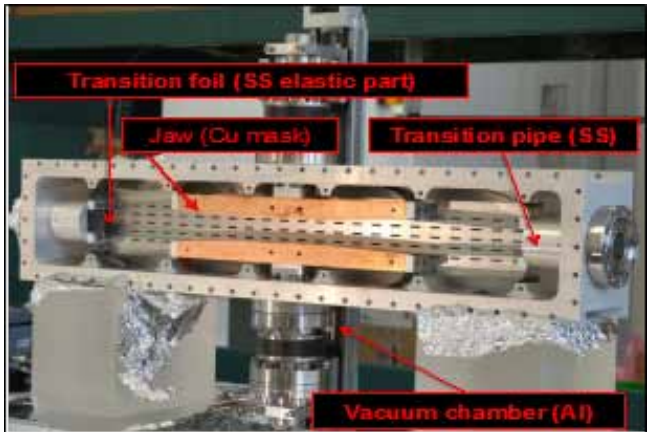
IFIC is one of the core groups studying the potential of top quark physics measurements for the ILC and CLIC

Accelerator physics

Concerning the accelerators our institute participates actively in the study of the collimation systems for Future Linear Colliders (ILC and CLIC) and Circular Colliders (LHC and its upgrade HL-LHC in the framework of Hi-Lumi EU Project, finished in November 2015). Furthermore the IFIC group is involved in Optics Design and Beam Instrumentation studies for the Beam Delivery System of Future Linear Colliders: ILC and CLIC, and their associated Test Facilities: ATF2 and CTF3. More specifically, the efforts are focused on the measurement of the beam size and emittance by means of a multi-OTR system, the control of the beam halo by

movable collimators, the beam position monitoring and injection-extraction devices (Kickers) in close collaboration with the CIEMAT and an industrial partner.





Responsibilities

Our group members are very active and deeply involved in all the activities listed above. The positive impact of our contributions and involvement is acknowledged by the international collaborations where we participate, with numerous responsibility posts, as for instance coordination of physcis groups (M.J. Costa, L. Fiorini, J.E. García-Navarro), detector development (J. Bernabeu, C. Lacasta, A. Valero, M. Vos), facility coordination (A. Faus), collaboration coordination (S. Martí-García, F. Martínez-Vidal, V. Mitsou), plus national and international managing posts (J. Fuster, C. García and C. Lacasta).

Selected publications

G. Aad et al. [ATLAS Collaboration], *Observation and measurement of Higgs boson decays to WW* with the ATLAS detector*, Phys. Rev. D92 012006 (2015)

G. Aad et al. [ATLAS Collaboration], *Evidence for the Higgs-boson Yukawa coupling to tau leptons with the ATLAS detector*, J. High Energy Phys. 4 (2015) 117

G. Aad et al. [ATLAS Collaboration], *Search for supersymmetry in events containing a same-flavour opposite-sign dilepton pair, jets, and large missing transverse momentum in √s = 8 TeV pp collisions with the ATLAS detector*, Eur. Phys. J. C 75 (2015) 318, 40 p, Erratum: ibid, 75 (2015) 463, 15 p

G. Aad et al. [ATLAS Collaboration], *Measurement of the top quark branching ratios into channels with leptons and quarks with the ATLAS detector*, Phys. Rev. D 92, 072005 (2015)

G. Aad et al. [ATLAS Collaboration], *Determination of the top-quark pole mass using tt¯+1-jet events collected with the ATLAS experiment in 7 TeV pp collisions*, J. High Energy Phys. 10 (2015) 121

G. Aad et al. [ATLAS Collaboration], *Search for lepton-flavour-violating H -> mu tau decays of the Higgs boson with the ATLAS detector*, J. High Energy Phys. (2015) 211

G. Aad et al. [ATLAS Collaboration], *Measurement of the charge asymmetry in highly boosted top-quark pair production in s√= 8 TeV pp collision data collected by the ATLAS experiment*, 10.1016/j.physletb.2016.02.055

R. Aaij et al. (LHCb Collaboration), *Observation of J/ψ p Resonances Consistent with Pentaquark States in Λ0b→ J/ψ K−p Decays*, Phys. Rev. Lett. 115 (2015) 072001.

R. Aaij et al. (LHCb Collaboration), *Measurement of the ratio of branching fractions B(anti-B0→D*+τ−anti-ντ)/ B(anti-B0→D*+μ−anti-νμ),* Phys. Rev. Lett. 115 (2015) 111803.

R. Aaij et al. (LHCb Collaboration), *Angular analysis of the B0→K*0μ+μ− decay using 3 fb−1 of integrated luminosity*, JHEP 1602 (2016) 104.

S. Alioli, P. Fernandez, J. Fuster, et al., *A new observable to measure the top-quark mass at hadron colliders*, Eur. Phys. J. C (2013) 73: 2438

G. Barenboim, J. Bernabeu, V. A. Mitsou, E. Romero, O. Vives, *METing SUSY on the Z peak*, Eur. Phys. J. C 76 (2016) 57, 13 p

C. Belver-Aguilar, A. Faus-Golfe, M.J. Barnes, et al., *Transverse Impedance Measurements and DC Breakdown Tests on the First Stripline Kicker Prototype for the CLIC Damping Rings*, Proceedings of IPAC2015, Richmond, USA.

M. Boronat, J. Fuster, I. García, E. Ros, M. Vos, *A robust jet reconstruction algorithm for high-energy lepton colliders*, Physics Letters B 750 (2015) 95-99

J. Bernabéu and F. Martínez-Vidal, *Colloquium: Time-reversal violation with quantum-entangled B mesons*, Rev. Mod. Phys. 87, 165 (2015). Selected for the cover of Vol. 87, Iss. 1 (January-March 2015).

P. Ghosh, D. E. López-Fogliani, V. A. Mitsou, C. Muñoz, R. Ruiz de Austri, *Hunting physics beyond the standard model with unusual W± and Z decays in the μ-from-ν supersymmetric standard model*, Phys. Rev. D 91 (2015) 035020, 8 p

V. Khachatryan et al. (CMS and LHCb Collaborations), *Observation of the rare B0s→μ+μ− decay from the combined analysis of CMS and LHCb data*, Nature 522 (2015) 68.

Selected conference talks

M. Boronat, *Belle II pixel detector*, VERTEX2015, Santa Fe, New Mexico (USA), June 2015

S. Cabrera Urbán, *Selected topics from ttbar XS: inclusive and differential*, LHCP, St. Petersburg, Russia on August 31 – September 5, 2015

M.J. Costa, *Highlights of top quark measurements at the LHC: Top quark couplings*, Workshop on Top physics at the LC, Valencia (Spain), 2015.

L. Cerdá, *Frontier Detectors for Frontier Physics*, 13th Pisa Meeting on Advanced Detectors, 24-30 May 2015

J. Fuster, *Top quark mass measurements at the LHC*, Top quark mass measurements at the LHC, Blois, France, May 31 - June 05, 2015

J. Fuster, *ILC physics case and project status*, LHCP, St. Petersburg, Russia on August 31 – September 5, 2015

J. Fuster, *IUPAP-C11 report*, Lepton Photon 2015, Ljubljana, Slovenia, August 2015

I. Garcia, *Micro-channel cooling*, Forum on tracker mechanics, NIKHEF, The Netherlands, June 2015

S. González de la Hoz, *Spanish ATLAS Tier-2 facing up to Run-2 period of LHC*, CHEP, Okinawa, Japan, April 13-17, 2015

C. Lacasta, *The Alibava System. A data acquisition system for silicon strip sensor characterizacion*, Advanced Semiconductor Detectors. Department of Physics, Faculty of Science, University of Tabuk (Saudi Arabia), March 2015

C. Lacasta, *Detectors for Health*, Encuentro en Universidad Menéndez Pelayo, CERN: EL LABORATORIO DE FÍSICA DE PARTÍCULAS DE ESPAÑA EN GINEBRA. Santander, Spain. 16-17 July 2015.

C. Lacasta, *Detectors for Colliders*, Curso en el Taller de Altas Energías 2015. Benasque, Spain. Sept. 2015

C. Lacasta, *Mid-Term Report from Spain*, 98th Plenary ECFA meeting, CERN, Geneva, Switzerland. 19-20 November 2015

C. Lacasta, *Detector upgrades for the HL-LHC*, VII CPAN days, Segovia, Spain. 1-3 December 2015

C. Lacasta, *Mid-Term Report from Spain*, 98th Plenary ECFA meeting, CERN, Geneva, Switzerland. 19-20 November 2015

J. Jímenez Peña, *Inner Detector performance for Run-2*, VII CPAN days, Segovia, Spain, 1-3 December 2015

P. Martí, *Firmware development for the ATLAS TileCal sROD*, ANIMMA 2015, Lisbon, Portugal. 20-24 Apr 2015

J. Mazorra de Cos, *PACIFIC: The readout ASIC for the SciFi Tracker planned for the upgrade of the LHCb detector*, TWEEP, Lisbone, Portugal, September 2015

V.A. Mitsou, *Conciliating SUSY with the Z-peaked excess* (invited plenary), ICNFP 2015: 4th International Conference on New Frontiers in Physics, Kolymbari, Crete, Greece, 23 – 30 August 2015

V.A. Mitsou for the MoEDAL Collaboration, *MoEDAL: Seeking magnetic monopoles and more at the LHC*, European Physical Society Conference on High Energy Physics (EPS-HEP), 22–29 July 2015, Vienna, Austria

V.A. Mitsou, *Status Report of MoEDAL*, XLIII International Meeting on Fundamental Physics, Benasque, Spain. 25 – 21 March 2015

A. Oyanguren, *Photon polarization measurement at LHCb*, Novel aspects of the b→s transitions, Marseille, France. October 2015

A. Oyanguren, *Measurement of the D→πeν partial branching fraction form factor and implications for Vub*, European Physical Society Conference on High Energy Physics (EPS-HEP) 2015, Vienna, Austria. July 2015

A. Oyanguren, *Measurement of the D→πeν partial branching fraction, form factor and implications for Vub*. Charm Physics (CHARM 2015), Detroit, USA, May 2015

S. Pedraza López, *Single Top quark production cross section and properties using the ATLAS detector at the LHC*, QCD@LHC, Queen Mary University, London, U.K., 1-5 September 2015

E. Romero Adam, *Supersymmetry searches in ATLAS*, Lomonosov Conference on Elementary Particle Physics, Moscow, Russia, 20 – 26 August 2015

P. Ruiz Valls, *Measurements of the photon polarization in b→sγ decays*, European Physical Society Conference on High Energy Physics (EPS-HEP) 2015, Vienna, July 2015

J. Salt, *LHC Physics Challenges in Run 2 and Beyond*, Big Data Challenge in High Energy Physics and Compute-Intensive sciences workshop. Universidad Politécnica de Tomsk (Russia). 30th August – 2nd September 2015

J. Sánchez, *Distributed Data Collection for the ATLAS EventIndex*, CHEP, Okinawa, Japan, April 13-17, 2015

M. Vos, *Top-quark mass measurements at the LHC: alternative methods*, TOP, Ischia, Italy. 14-18 September 2015

M. Vos, *Top-quark mass and couplings*, CLIC workshop, CERN, Geneva, Switzerland, June 2015

M. Vos, *Top-quark couplings*, LCWS15, Whistler, Canada, November 2015

Main research grants (National Plan)

FPA2012-39055-C02-01, "Contributions To The Atlas Experiment At The Large Hadron Collider"

FPA2013-48020-C3-2-P, "Participación Española En El Experimento LHCb Del Cern: Física y Mejoras"

FPA2015-65652-C4-3-R, "Contribución a la operacion ATLAS y análisis de datos. Investigacion y desarrollo (I+D) para futuros aceleradores y estudios de fisica"

EXPERIMENTAL ASTROPARTICLE PHYSICS

IFIC group led the analysis of the first combined search for astrophysical neutrino sources with data of ANTARES and IceCube

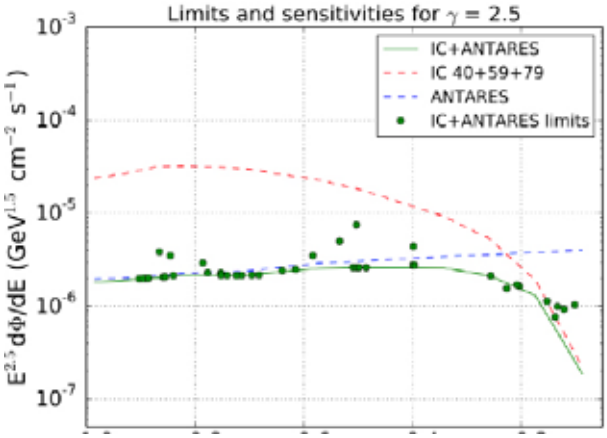
The neutrino astronomy field has continued its very active period during 2015, driven by the new data of IceCube which confirm the recently discovered signal, but opening new questions, and the starting of the construction of the new big player in this field, KM3NeT. In the meanwhile, ANTARES has continued providing new and competitive results despite its smaller size thanks to its better location and target medium, aspects which will be exploited much further with KM3NeT.

The ANTARES-KM3NeT group of IFIC is involved in several topics in these two experiments:

ANTARES

Researchers of this group have led the analysis of the first combined search for astrophysical neutrino sources with data of ANTARES and IceCube. This work has calculated the improvement in the sensitivity to point sources and has provided new limits which are up to a factor two better for some declinations. One of the interesting aspects of this analysis is that the region of declination of interest is quite wide, since it depends on the energy spectrum which is assumed for the sources, presently unknown.

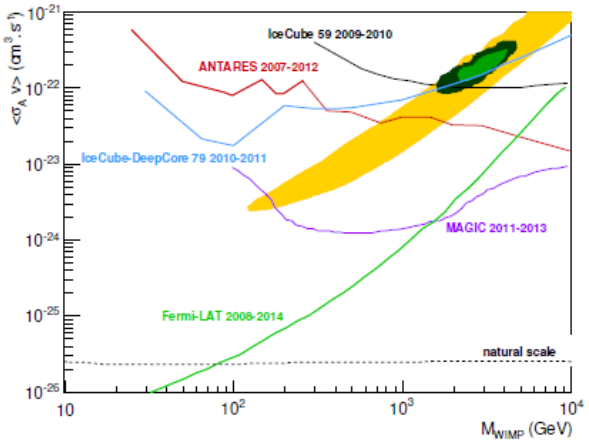
During last year, it was also defended the doctoral thesis of A. Sánchez-Llosa, who searched for high-energy neutrinos correlated in time to gamma-ray sources. This analysis has allowed to set new limits for several kinds of variable astrophysical sources, including blazars, X-ray binaries and pulsar wind nebulae.



Limits and sensitivity on the neutrino flux (spectral index of 2.5) combining data of ANTARES (2007-2012) and IceCube (IC40+IC59+IC79) as a function of declination. The sensitivities for the individual data samples are also shown.

The IFIC group has also a very active role in one of the most interesting scientific goals of neutrino telescopes: the search for dark matter. J.D. Zornoza is the Coordinator of the Dark Matter & Exotics working group of the experiment. ANTARES has recently produced new limits for the two most interesting sources, the Sun and the Galactic Centre.

Finally, the article describing the method of time calibration with muon tracks, developed by our group, was published in 2015.



Limits on the annihilation cross section of dark matter (tau-tau channel) as a function of the WIMP mass. Limits set by other experiments are also shown, together with the region favoured by the dark matter interpretation of the electron-positron excess observed by Fermi-LAT, PAMELA and HESS.

KM3NeT

2015 has been the year when the construction of the KM3NeT detector has started. In December, the first line of the so-called Phase 1 has been installed in Capo Passero, close to the Sicilian coast, at 3000 m deep. The whole process of deployment and connection went smoothly and the line is taking data since then. In two

years, 24 lines will be deployed in the Italian site and 7 in the French site. This is the first stage towards Phase 2, which will include 230 lines in Italy (ARCA, for neutrino astronomy) and 115 lines in France (ORCA, denser, for neutrino mass hierarchy determination). A detailed study of the design and performance of KM3NeT was described in a Letter of Intent, recently accepted for publication in the Journal of Physics G.

By the end of 2015 it was also decided that KM3NeT was included in the list of the ESFRI road map, for scientific infrastructures on pan-European interest, a key step in terms of scientific recognition and funding opportunities.

The IFIC group has made important contributions to make these milestones a reality. First, we have estimated the contribution of the shower channel to the sensitivity of KM3NeT-ARCA for point sources. This is a very important advance because the shower channels add a significant amount of signal and have a lower background. Only detectors in water like KM3NeT the achievable angular resolution is good enough to be useful, making possible all-flavour neutrino astronomy. The shower channel has also been added in the analysis for ANTARES.

Concerning the hardware, D. Real is the Coordinator of the Electronics working group. The team of engineers of IFIC has designed the main electronic card, the so-called Central Logic Board and the system of "nanobeacons" (single LEDs embedded into each of the optical modules) to be used for calibration purposes. The IFIC also has a leading participation on the time calibration of the detector, being J.D Zornoza the time calibration coordinator of KM3NeT.

Selected publications

S. Adrian-Martinez et al. [ANTARES and IceCube Collaborations], *The First Combined Search for Neutrino Point-sources in the Southern Hemisphere With the Antares and Icecube Neutrino Telescopes*, Astrophys.J. 823 (2016) no.1, 65

S. Adrián-Martínez et al. [KM3NeT Collaboration], *The prototype detection unit of the KM3NeT detector*, Eur. Phys.J. C76 (2016) no.2, 54

S. Adrián-Martínez et al. [ANTARES and TAROT and ROTSE and Swift and Zadko Collaborations], *Optical and X-ray early follow-up of ANTARES neutrino alerts*, JCAP 1602 (2016) no.02

S. Adrián-Martínez et al. [ANTARES Collaboration], *Time calibration with atmospheric muon tracks in the ANTARES neutrino telescope*, Astropart.Phys. 78 (2016) 43-51

S. Adrian-Martinez et al. [ANTARES Collaboration], *Search for muon-neutrino emission from GeV and TeV gamma-ray flaring blazars using five years of data of the ANTARES telescope*, JCAP 1512 (2015) no.12, 014

S. Adrian-Martinez et al. [ANTARES Collaboration], *Search of Dark Matter Annihilation in the Galactic Centre using the ANTARES Neutrino Telescope*, JCAP 1510 (2015) no.10, 068

S. Adrián-Martínez et al. [ANTARES and TANAMI Collaborations], *ANTARES Constrains a Blazar Origin of Two IceCube PeV Neutrino Events*, Astron.Astrophys. 576 (2015) L8

Selected conference talks

J. Barrios, *Search for point-like neutrino sources over the Southern Hemisphere with the ANTARES and IceCube neutrino telescopes*, ICRC 2015, The Hague (Netherlands), July 30 to August 6 2015

C. Toennis, *The indirect search for dark matter with the ANTARES neutrino telescope*, ICRC 2015, The Hague (Netherlands), July 30 to August 6 2015

J.D. Zornoza, *Indirect searches of Dark Matter with neutrino telescopes*, Marcel Grossmann Meeting, Rome (Italy), July 12-18, 2015

D. Calvo, *Status of the central logic board of the KM3NeT neutrino telescope*, TWEEP 2015, Lisbon (Portugal), 28 September-2 October, 2015

D. Real, *Digital Optical Module electronics of KM3NeT*, Prospects of Particle Physics 2015, Moscow (Russia). February 1 - 8, 2015

Main research grants

PARTICIPATION OF IFIC IN THE ANTARES AND KM3NeT NEUTRINO TELESCOPES (ref. FPA2012-37528-C02-01)

EXPERIMENTAL NEUTRINO PHYSICS

The year 2015 has been a year of celebrations for experimental neutrino physics. The 2015 Nobel Prize in Physics has been awarded to Takaaki Kajita (Super-Kamiokande Collaboration) and Arthur B. McDonald (SNO Collaboration) "for the discovery of neutrino oscillations, which shows that neutrinos have mass". The Neutrino Physics group has continued to explore the questions associated with neutrino mass during 2015, via the NEXT neutrinoless double beta decay experiment, and the T2K and DUNE accelerator-based neutrino oscillation experiments.

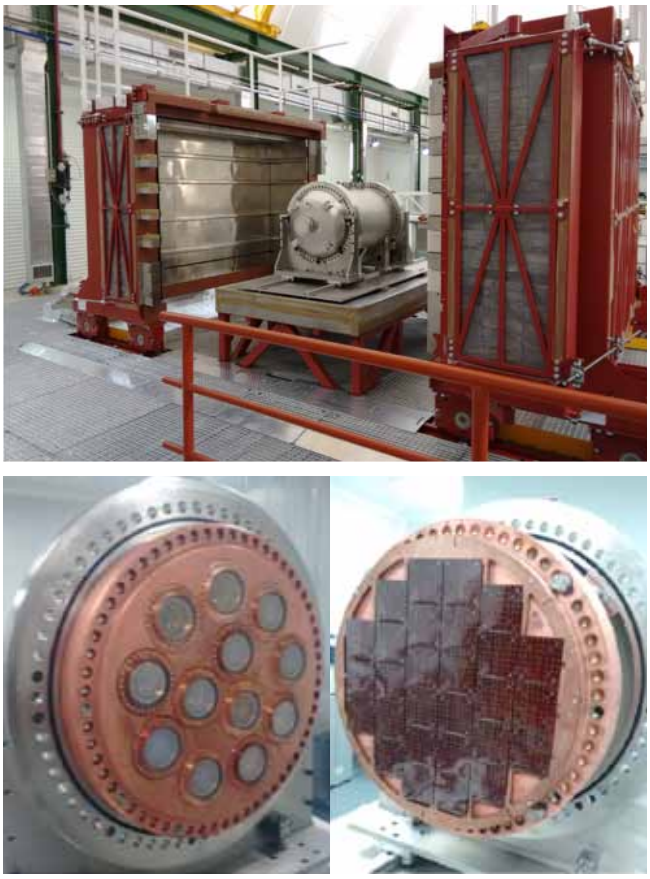
NEXT

The Neutrino Experiment with a Xenon TPC (NEXT), aims to perform a sensitive search for the neutrinoless double beta decay of Xe-136 at the Laboratorio Subterráneo de Canfranc (LSC, Spain). The search for this hypothetical process is the most promising approach to address the neutrino identity (Majorana versus Dirac) question, and to search for lepton number violation. It can also contribute to measure the still unkown neutrino absolute mass.

The NEXT highlight for the year 2015 has been the installation of the NEXT-White (NEW) detector at the LSC. NEW is a 10 kg-scale detector, the largest to date in the NEXT series, and the first one located underground and constructed from ultra-radiopure components. The science goals of NEW are the understanding of backgrounds for double beta decay searches, and the half-life measurement of the two-neutrino double beta decay mode.

As can be seen in the pictures, the NEW pressure vessel and its shielding (both inside and outside the vessel) have been installed during the first half of 2015. The two NEW readout planes, the so-called energy and tracking planes, have been installed during the second half of 2015. Among other activities, the NEXT-IFIC group has played a major role in the construction and installation of all these detector components during 2015.

The NEXT highlight for 2015 was the installation of the NEXT-White (NEW) detector at the LSC



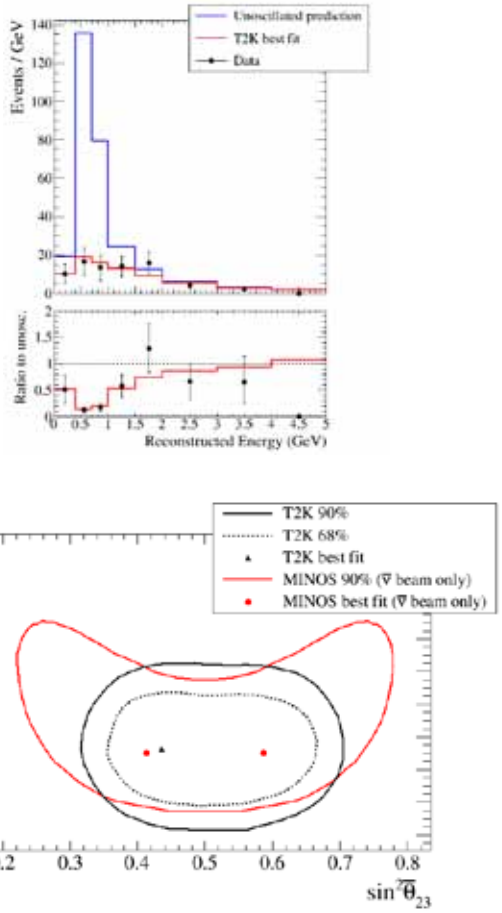
Pictures of NEXT-White (NEW) installation at the LSC during 2015. Up: pressure vessel and shielding. Left: energy plane. Right: tracking plane.

T2K

The Tokai to Kamioka (T2K) experiment in Japan is the most sensitive current-generation experiment to study neutrino oscillations with a man-made neutrino beam from a particle accelerator. An intense beam of muon neutrinos or antineutrinos is generated at the J-PARC site on the East coast of Japan and directed across the country to the Super-Kamiokande neutrino detector in western Japan. The experiment studies how neutrinos and antineutrinos change flavour as they propagate through their 250 km journey.

While neutrinos had been studied until 2014, 2015 has marked the beginning of antineutrino oscillation studies at T2K. The goal of this new phase is to study whether neutrinos and antineutrinos oscillate differently. To this end, a beam of antineutrinos has been produced at J-PARC, and directed towards Super-Kamiokande. As shown in the figure, the disappearance, due to oscillations, of muon antineutrinos has been firmly established by T2K during 2015. The

data provided the best measurement to date of the so-called θ_{23} mixing angle for antineutrinos. Among other activities, the T2K-IFIC group has contributed to the measurement of the unoscillated antineutrino flux at the J-PARC production site with the T2K near detector during 2015.



Up: muon antineutrinos observed at Super-Kamiokande as a function of neutrino energy, and compared to predictions assuming no oscillations. Down: T2K measurement of the θ_{23} mixing angle for antineutrinos, compared to the previous best measurement of the same quantity by the MINOS experiment.

The IFIC group contributed to the measurement of the unoscillated antineutrino flux at J-PARC site with the T2K near detector

DUNE

In order to prepare for the future, the Neutrino Physics group at IFIC has also joined the newly-formed DUNE Collaboration at the beginning of 2015. DUNE, the Deep Underground Neutrino Experiment, is a proposed new facility for the next decade and beyond to study neutrino oscillations, nucleon decay and astrophysical neutrinos. With more than 800 collaborators from 30 different countries, DUNE is the largest and most ambitious collaboration in neutrino physics to date. Among other activities, the DUNE-IFIC group has contributed to evaluate the physics potential of DUNE for long-baseline neutrino oscillation measurements and for nucleon decay searches during 2015.

Selected publications

P. Ferrario et al. [NEXT Collaboration], *First proof of topological signature in the high pressure xenon gas TPC with electroluminescence amplification for the NEXT experiment*, JHEP 1601, 104

Ko Abe et al. [T2K Collaboration], *Measurement of Muon Antineutrino Oscillations with an Accelerator-Produced Off-Axis Beam*, Phys.Rev.Lett. 116 no.18, 181801

R. Acciarri et al. [DUNE Collaboration], *Long-Baseline Neutrino Facility (LBNF) and Deep Underground Neutrino Experiment (DUNE) : Volume 2: The Physics Program for DUNE at LBNF*, arXiv:1512.06148

Selected conference talks

P. Novella, *NEXT: Searching for neutrinoless double beta decay in the Canfranc Underground Laboratory*, European Physical Society Conference on High Energy Physics (EPS 2015), Vienna (Austria), July 2015

A. Laing, *The NEXT double beta decay experiment*, 14th International Conference on Topics in Astroparticle and Underground Physics (TAUP 2015), Torino (Italy), September 2015

Main research grants (National Plan)

CONSTRUCTION, OPERATION AND R&D FOR THE NEXT EXPERIMENT AT THE LSC (ref. FIS2014-53371-C4-1-R)

PARTICIPATION IN THE T2K EXPERIMENT (ref. FPA2014-55454-P)

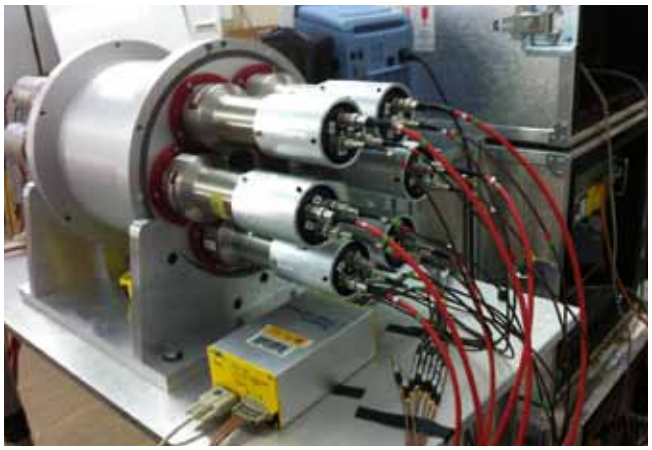
NUCLEAR PHYSICS

The experimental Nuclear Physics activity is carried out at IFIC by two groups, the Gamma and Neutron Spectroscopy group and the AGATA group.

The research of the Gamma and Neutron Spectroscopy Group covers aspects of nuclear structure, astrophysics and applications. In 2015 two of the most important results of the group are related to the use of the total absorption technique (TAS) in which the group has been pioneering new applications, the development of instrumentation and new methods of analysis.

In 2015 the first results of our beta decay studies of beta delayed neutron emitters using this technique (J. L. Tain et al. PRL 115, 062502 (2015)) have been published.

The neutron capture cross-section on very neutron rich nuclei is a key ingredient to understand the formation of heavy elements in supernovas and neutron star mergers. However, they are not accessible to experiment. In this publication we propose and demonstrate for the first time the use of TAGS to obtain indirect information. In this experiment, an unexpectedly large gamma intensity de-exciting neutron-unbound states in ^{87,88}Br and ^{94}Rb was observed. The main consequence of this finding, if confirmed and generalized, is the need to renormalize the theoretical cross-sections, currently used, by an order of magnitude, which will have an impact on astrophysical calculations.



The total absorption spectrometer designed by IFIC and employed in the experiments.

Another important result from the same experimental campaign is the study of the beta decay of 92Rb using the TAS technique. This decay determines the dominant contribution to the reactor antineutrino spectrum in the 5–8 MeV energy interval. Results of this study, which were published in Physical Review Letters (A.-A. Zakari-Issoufou et al. PRL 115, 102503 (2015)) solve a long standing discrepancy in the ground state feeding of this decay. This result is one important step towards a better determination of the antineutrino spectrum from reactors using summation calculations, of great relevance for neutrino oscillation experiments and for non-proliferation applications. The study was performed in collaboration with the Subatech group of Nantes, France.

Other important result of the group is the publication of the beta decay studies of $T_z = -1 \rightarrow 0$ beta decays of ^{54}Ni, ^{50}Fe, ^{46}Cr, and ^{42}Ti and their comparison with mirror (^{3}He,t) measurements (F. Molina et al. PRC 91, 014301 (2015)), which allows us to test how good the isospin symmetry is. In this article the strength of the super-allowed transitions between the analogue states was also determined for those decays. This result attracted immediately the attention of researchers working in the field because of the relevance of these transitions in the determination of the Vud, the up–down quark mixing matrix element, of the Cabibbo-Kobayashi-Maskawa (CKM) matrix.

Members of the group lead two experiments in June 2015 at RIKEN (Japan), which were exploring the limits of the proton dripline and effects on pn pairing in the vicinity of the N~Z line. RIKEN is at present the laboratory with highest production of exotic nuclei. Also related to RIKEN, the group continues leading the construction of the largest beta delayed neutron detector ever constructed (BRIKEN).

The IFIC group observed an unexpectedly large gamma intensity de-exciting neutron-unbound states

The group is also involved in the development of a detector prototype (GUALI, Gamma-Unit Advance Location Imager) for monitoring the radioactivity in the decommissioning process of the Nuclear Power Plant Jose Cabrera.

The Gamma and Neutron Spectroscopy group has a total of 14 publications in 2015 including 3 Physical Review Letters.

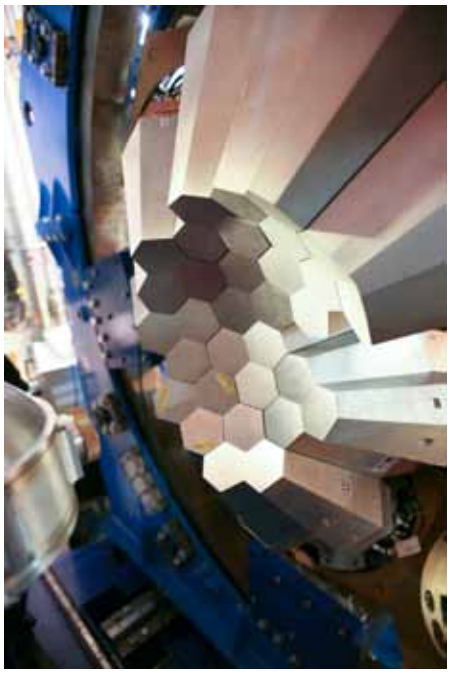
The AGATA group at IFIC is carrying its activity mainly in two aspects, i.e. the construction and deployment of AGATA and the design and construction of complementary instrumentation.

After the installation and commissioning of the present AGATA sub-array at GANIL, Caen, France, during the second half of 2014, the year 2015 has been devoted to the first experimental campaign, of the sub-array coupled with VAMOS. The group participated actively in the commissioning, in all experimental campaigns, as well as in the source performance measurements that followed the experimental activity. A total of 6 experiments were performed and one of them, to study the evolution of collectivity in nuclei with N=50 in the vicinity ^{100}Sn, was led by our group.

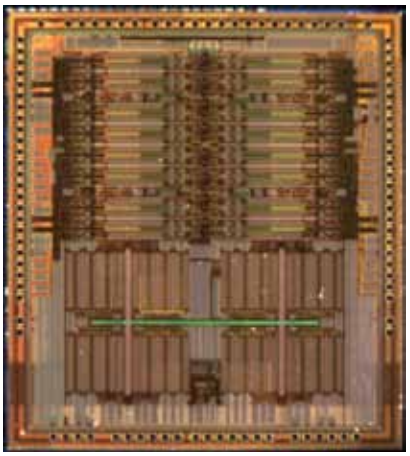
Concerning the contribution to the construction of AGATA, the group, in collaboration with the ETSE - UVEG and the technical groups of IFIC –Mechanics and Electronics-, has contributed to the construction, commissioning and installation of the AGATA new generation of sampling digitizer. A substantial part of the digitizer has been designed and built by the mentioned groups. The GRID IFIC group has contributed largely to design and disseminate the techniques to perform analyses, in particular the complex AGATA Pulse Shape Analysis in the GRID environment.

Regarding the instrumentation developments for the complementary instruments to AGATA, our group works in collaboration with the AGATA group of ETSE – UVEG and the I3M of UPV on two detectors, i.e. the neutron detector array NEDA and the high granularity light charge particle detector array TRACE. For NEDA, the group continues in 2015 building detector units and performing Monte-Carlo simulations for the first implementation that will be installed at GANIL in 2018. Regarding TRACE, the group has worked on the design and prototype production of the detector readout system using a compact, dead time-less analog memory ASIC. The ASIC prototype was produced at the end of 2015.

The group has published 25 papers in 2015, 20 in peer reviewed journals. Several of these papers are on instrumentation developments. The PhD thesis of F.J. Egea Canet has been as well completed in 2015.



AGATA sub-array installed at GANIL



Picture of the TRACE ASIC prototype

AGATA group at IFIC contributed to the construction, commissioning and installation of the AGATA new generation sampling digitizer

Selected publications

J. L. Tain, et al., *Enhanced γ-Ray Emission from Neutron Unbound States Populated in β Decay*, Phys. Rev. Lett 115 (2015) 062502

A.-A. Zakari-Issoufou, et al., *Total Absorption Spectroscopy Study of 92Rb Decay: A Major Contributor to Reactor Antineutrino Spectrum Shape*, Phys. Rev. Lett 115 (2015) 102503

F. Molina, et al., *$Tz = -1 \rightarrow 0$ β decays of 54Ni, 50Fe, 46Cr, and 42Ti and comparison with mirror (3He,t) measurements*, Phys. Rev. C 91 (2015) 014301

E.Sahin, et al., *Shell evolution beyond N=40: Cu-69,Cu-71,Cu-73*, Phys. Rev. C 91 (2015) 034302

R.J. Aliaga, et al., *Conceptual design of the TRACE detector readout using a compact, dead time-less analog memory ASIC*, Nuclear Instruments & Methods in Physics Research Section A 800 (2015) 34

Selected Conferences

J.L. Tain, *Beta delayed neutron measurements for reactor technology and astrophysics*, Joint Meeting of the CHANDA Collaboration and the JEFF Group, Paris, France, 2015

Domingo-Pardo, *C., Beta-delayed neutron emission: first results in the heavy mass region and future prospects, XXXIV Mazurian Lakes Conference on Physics*, Piaski, Poland, September 6 – 13, 2015

Orrigo, S.E.A., Rubio, B., Fujita, Y., Blank, B., Gelletly, W., Agramunt, J., Algora, A., Ascher, P., Bilgier, B., Cáceres, L., Cakirli, R.B., Fujita, H., Ganioglu, E., Gerbaux, M., Giovinazzo, J., Grévy, S., Kamalou, O., Kozer, H.C., Kucuk, L., Kurtukian-Nieto, T., Molina, F., Popescu, L., Rogers, A.M., Susoy, G., Stodel, C., Suzuki, T., Tamii, A., Thomas, J.C., *Competition of β-delayed protons and β-delayed γ rays in ^{56}Zn and the exotic β-delayed γ-proton decay*, 12th International Conference on Nucleus-Nucleus Collisions (NN 2015), Catania, Italy, June 21-26, 2015

B. Rubio, S.E.A. Orrigo, A. Algora, B. Blank, Y. Fujita, H. Fujita, E. Ganioglu, W. Gelletly, A. Montaner-Piza, A. Poves, *Comparison of beta decay and charge exchange reactions and the exotic decay of ^{56}Zn*, 5th International Conference on proton Emitting Nuclei, Lanzhou, China, 6-10 July, 2015

A. Algora, *Beta-decay studies for nuclear structure, astrophysics and applications*, SPES one-day workshop "Physics at SPES with non re-accelerated beams", Milano, April 20-21, 2015

A. Gadea, *The AGATA project: scientific and instrumental achievements*, Nuclear Structure and Dynamics III, Portoroz-Portorose, Eslovenia, June 15-19, 2015

Main Research Grants

NUCLEAR STRUCTURE, APPLICATIONS AND ASTROPHYSICS: THE PATH TO FAIR (ref. FPA2011- 24553)
BETA DECAY AND REACTION STUDIES FOR NUCLEAR STRUCTURE, ASTROPHYSICS AND APPLICATIONS (ref. FPA2014-52823-C2-1-P)

DEMOSTRACIÓN DE PRINCIPIO DE MEDIDAS DE REACCIONES DE NUCLEOSÍNTESIS ESTELAR CON ALTA SENSIBILIDAD DE DETECCIÓN (ref. FIS-71688-ERC)

HIGH-RESOLUTION GAMMA-RAY SPECTROSCOPY TOWARDS AGATA (ref. FPA2011-29854-C04)

NUCLEAR STRUCTURE RESEARCH IN EXOTIC NUCLEI: EXPERIMENTAL THEORETICAL STUDIES AND INSTRUMENTAL DEVELOPMENTS FOR AGATA (ref. FPA2014-57196-C5)

GRID & E-SCIENCE

The research topics of this research line include mainly the Spanish ATLAS Tier-2 goals. It also includes several generic activities devoted to the application of Distributed Computing to other scientific and technological fields (the so-called e-Science).

The main contribution of this year has been the delivery of the committed resources for 2015 (in April). 2015 has been the second year funded by the project FPA2013 -47424-C3-1-R of the Spanish HEP Program. During this year, the Tier-2 IFIC site has provided 16,186.8 HS06 and 1.715 TB of disk. The efficiency of the whole Tier-2 has been of about 98% (and in particular the IFIC part has got a very good performance).

We have progressed in the main objectives of the project: for instance, the FAX implementation, which is an approach for having a system of federated data, the work performed in DAST (Distributed Analysis Support Team) coordinating the expert shifters effort, the national Tier-2 support and the interface with the end-users via the Tier-3 infrastructure.

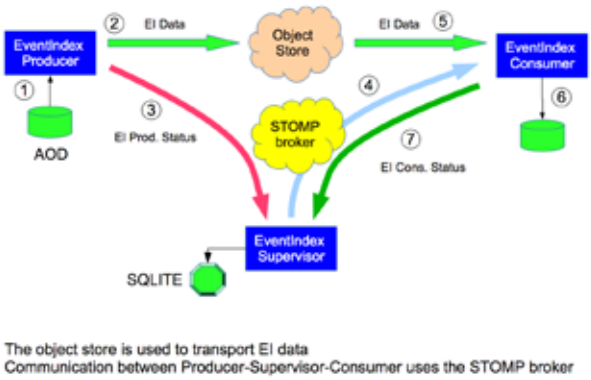
Map showing the CPU contribution delivered by the portuguese and spanish ATLAS Tier-2 sites in 2015. The spanish ATLAS Tier-2 sites (in green) are coordinated by IFIC.

The Event Index Project, has continued with a lot of activiy made by our group: During this year several members of the group have continued the development and deployment of a catalogue of events with a large amount of data, the so-called ATLAS Event Index (EI). This EI is the successor of the TAGDB , the old catalogue. The main objective was to reach a better performance using the new NoSQL technologies. At the end of the year the prototype was almost ready for production. In particular IFIC is responsible of the Data Collection part of the project.

Several people of the research line are doing Physics Analysis in the Exotics group in ATLAS. This activity ensures the link between the GRID Computing experts and the ATLAS end-user community.

On top of that, the IFIC group has become a centre of reference and advice in ATLAS computing. Moreover, several sites which participate in ATLAS have contacted the IFIC team to be helped in the installation and deployment of GRID features in their centres.

We have helped groups of Universidad de Rabat-CNRST (Morocco), Centre CERIST (Argelia), South Africa Tier-2, Georgia (Caucasus region), and part of the ATLAS delegation for TPU (Tomsk Polytechnical University) and have participated in several activities related to the extension of GRID computing. In October, an IVICFA's workshop was devoted to the Computing in Physics (30th October 2015) with several interesting contributions as the presentations given by Eric Lançon (ATLAS Computing Coordinator) and by J. Sánchez about the Spanish ATLAS Tier-2 project-IFIC.



Flow diagram of the Event Index prototype, involving the components Producer-Supervisor- Consummer , responsibility of the IFIC team working in the ATLAS Event Index Project.

The IFIC group has become a centre of reference and advice in ATLAS computing

Selected Publications

J. Sánchez, A. Fernández Casani, S. González de la Hoz on behalf of the ATLAS Collaboration, *Distributed Data Collection for the ATLAS EventIndex*, Proceedings (id 222), 21st International Conference on Computing in High Energy and Nuclear Physics (CHEP15) Journal

of Physics: Conference Series 664 (2015) 042046

S. González de la Hoz, J. Del Peso, F. Fassi, A. Fernández Casani, M. Kaci, V. Lacort Pellicer, A. Del Rocio Montiel, E. Oliver, A. Pacheco Pages, J. Sánchez, V. Sánchez Martínez, J. Salt, M. Villaplana, on behalf of the ATLAS Collaboration, *Spanish ATLAS Tier-2 facing up to Run-2 period of LHC*, Conferece Proceedings (id 154), 21st International Conference on Computing in High Energy and Nuclear Physics (CHEP15) Journal of Physics: Conference Series 664 (2015) 052016

D. Barberis, J. Cranshaw, A. Favareto, A. Fernández Casani, E. Gallas, C. Clasman, S. González de la Hoz, J. Hrivnac, D. Malon, F. Prokoshin, R. Yuan, J. Sánchez, J. Salt, R. Toebbicke on behalf of the ATLAS Collaboration, *The ATLAS EventIndex: architecture, design choices, deployment and first operation experience*, Conference Proceedings (id 208), 21st International Conference on Computing in High Energy and Nuclear Physics (CHEP15) Journal of Physics: Conference Series 664 (2015) 042003

Selected Conferences

In addition to the Contributions reported in the previous section and published in Proceedings; speakers: J. Sánchez (IFIC), S. González de la Hoz (IFIC) and Dario Barberis (CERN), we can give the following ones:

J. Salt , *LHC Physics Challenges in Run 2 and Beyond*, Workshop 'Big Data Challenge in High Energy Physics and Compute-Intensive sciences', Tomsk, Russia, 30th August – 2nd September 2015

J. Salt, *LHC Physics Challenges in Run 2 and Beyond*, Seminar in the National Research Center (Kurchatov Institute), Moscow, Russia, 2nd September 2015

F. Fassi, *Searches for new physics with top- and bottom-quark signatures using the ATLAS detector*, 4th International Conference on New Frontiers in Physics, Kolymbari, Crete, Greece, 23-30 August 2015

F. Fassi, *ATLAS Distributed Data Analysis: performance and challenges*, I International Computational Science and Engineering Conference (ICSEC15), Doha, Qatar, 11-12 May 2015

Main research grants (National Plan)

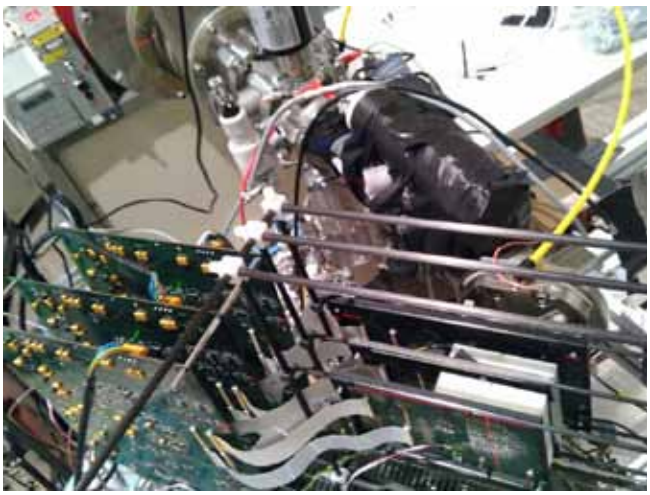
TIER-2 DISTRIBUIDO ESPAÑOL PARA EL EXPERIMENTO ATLAS (LHC) FASE 3 Y SU PAPEL EN LA GESTIÓN Y PROCESAMIENTO DE GRANDES CANTIDADES DE DATOS (ref. FPA2013 -47424-C3-1-R)

MEDICAL APPLICATION OF NUCLEAR AND PARTICLE PHYSICS

The activities of the IRIS medical physics group of IFIC in 2015 have focused on the improvement of a monitoring system for hadron therapy and on the construction and set up of the new laboratories of IFIMED, a future medical imaging and hadron therapy centre.

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 improvements. The group works on the development of a three-layer Compton telescope based on LaBr3 crystals and silicon photomultipliers as photodetectors. A first version of the device was developed within the European project ENVISION and current activities are focused on the improvement of the performance and tests in beam.

The system aims at combining events interacting in two detector layers, which provide high efficiency, with three-interaction events, which are less abundant but more precise. The system is working satisfactorily in both independent and combined acquisition modalities. A spatial resolution of 4.2 mm FWHM at 1.8 MeV has been achieved in laboratory tests.



Compton Telescope in test beams.

For the first time, the system has also been tested in proton beams, under conditions closer to the clinical practice, and it is able to distinguish variations in the Bragg peak position.

Phase I of the construction of IFIMED has been completed, including construction of the laborato-

ries and acquisition of the laboratory components for the Accelerator Laboratory, Instrumentation Laboratory and microPET Laboratory.

Map of the new IFIMED laboratories.

Regarding the Medical Accelerators, the activities are centred in the study of High-Gradient RF warm structures studies. This work has been started under the framework of the EU project PARTNER and the ENLIGHT EU platform. We focused our studies in design of the cyclinacs for carbon therapy in collaboration with TERA and in the experimental study of the high-gradient RF structures in collaboration with the CLIC RF group at CERN. This last has been the seed for the new HG-RF lab, being constructed with FEDER funds and with a special CERN-CLIC contract for the personnel in the Science Park of the University of Valencia.

The group developes a 3 layer Compton telescope tested in proton beams, under conditions closer to the clinical practice

Selected publications

J. Barrio, A. Etxebeste, C. Lacasta, E. Muñoz, J.F. Oliver, C. Solaz and G. Llosá, *Performance of a VATA64HDR16 ASIC for medical physics applications based on continuous crystals and SiPMs*, Journ. Inst., 2015, volume 10, P12001

G. Llosá, *Recent developments in photodetection for medical applications*, Nucl. Instr. Meth. A, 2015, volume 787, 353-357

J. Cabello, A. Etxebeste, G Llosá and S. Ziegler, *Simulation study of PET detector limitations using continuous crystals*, Phys. Med. Biol., 2015, volume 60, num 9, p 3673-3694

P G Ortega, I Torres-Espallardo, F Cerutti, A Ferrari, J E Gillam, C Lacasta, G Llosá, J F Oliver, P R Sala, P Solevi and M Rafecas, *Noise evaluation of Compton camera imaging for proton therapy*, Phys. Med. Biol., 2015, volume 60, pages 1845--1863, number 5

F. Tecker, T. Argyropoulos, N. Catalan-Lashera, R. Corsini, A. Degiovanni, D. Gamba, J. Giner-Navarro, A. Grudiev, G. McMonagle, J.L. Navarro Quirante, R. Rajamaki, E. Senes, I. Syratchev, J. Tagg, B. Woolley, W. Wuensch, *Beam-loading effect on breakdown rate in high-gradient accelerating structures*, IPAC16, Busan, Korea

Selected conference talks

G. Llosá, J. Barrio, K. Brzezinski, J. Cabello, J. E. Gillam, C. Lacasta, E. Muñoz, J. F. Oliver, M. Rafecas, C. Solaz, P. Solevi, V. Stankova, I. Torres-Espallardo, M. Trovato, *IRIS technological developments in PET and Hadron Therapy*, VII CPAN Days, Segovia, Spain, 1-3 December 2015

E. Muñoz, J. Barrio, A. Etxebeste, C. Lacasta, G. Llosá, C. Solaz, P. Solevi, M, Trovato and J.F. Oliver, *Simulation of a Compton Telescope with GATE*, GATE Users Meeting en IEEE Nuclear Science Symposium and Medical Imaging Conference, San Diego, California, USA. 31 Oct -7 Nov 2015

G. Llosá and J. F. Oliver, *Present and future of the IFIMED research activities in medical imaging*, IVICFA Medical Physics Workshop, Valencia, Spain, 6 October 2015

G. Llosá, J. Barrio, P. Dendooven, A. Etxebeste, C. Lacasta, E. Muñoz, J. F. Oliver, M. Rafecas, C. Solaz, P. Solevi, I. Torres-Espallardo, M. Trovato, *Characterization of a three-layer Compton telescope for Hadron Therapy Dose Monitoring*, 4th International Conference on Advances in Nuclear Instrumentation, Measurement Methods and their Applications (ANIMMA). Lisbon, Portugal, 20-24 April 2015

G. Llosá, *Photon detectors in medical Imaging*, RD51 Academia-Industry Matching Event. Special Workshop on Photon Detection with MPGDs. CERN, Geneva, Switzerland, 10-11 June 2015

Main research grants (National Plan)

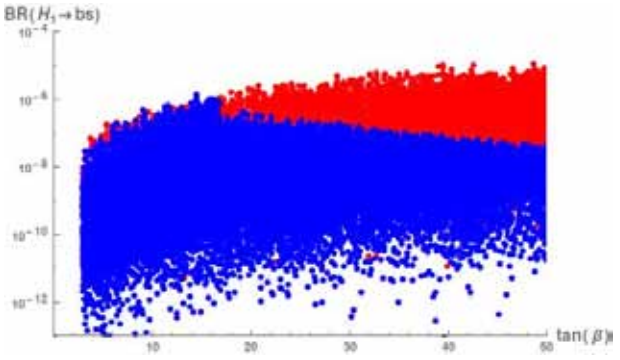
DETECTORS FOR MEDICAL APPLICATIONS (ref. FPA2014-53599-R)

THEORETICAL PHYSICS

HIGH-ENERGY PHYSICS PHENOMENOLOGY

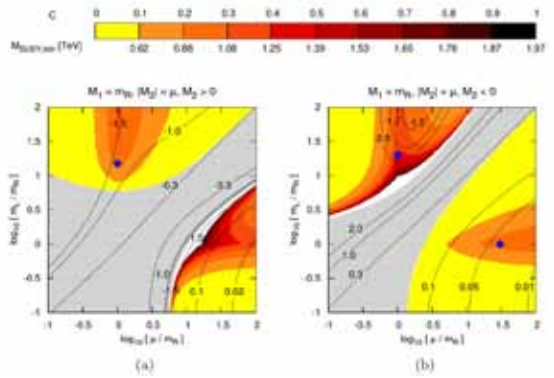
The high-energy physics phenomenology research line is one of IFIC's vertebral lines and involves most of the theory groups of the IFIC. Just to give a flavour of their activity, here we have selected a few results obtained in 2015 by the different groups that carry out research on this line.

Researchers from IFIC explored the flavour-changing decays $H_i \to bs$ in a general supersymmetric scenario. In these models the flavour-changing decays arise at loop level, but (because they originate from a dimension-four operator) they do not decouple and may provide a first sign of new physics for heavy masses beyond the reach of colliders. In the framework of the minimal supersymmetric extension of the Standard Model, they find that the largest branching ratio of the lightest Higgs (H_1) is *O* (10^{-6}) after imposing present experimental constraints, while heavy Higgs states may still present branching ratios *O* (10^{-3}). In a more general supersymmetric scenario, where additional Higgs states may modify the Higgs mixings, the branching ratio BR($H_1 \to bs$) can reach values *O* (10^{-4}), while those for heavy Higgses still remain at *O* (10^{-3}). Although these values are clearly out of reach for the LHC, a full study in a linear collider environment could be worth pursuing.



A full MSSM framework with LL insertion with $\delta_L \neq 0$ and $\delta A_u = \delta_R = 0$: It shows the dependence of the estimated branching ratios for $H_{1,2} \to$ bs+sb on tanβ. Blue (dark) points satisfy all the constraints considered, while red (light) points violate one or several of these constraints.

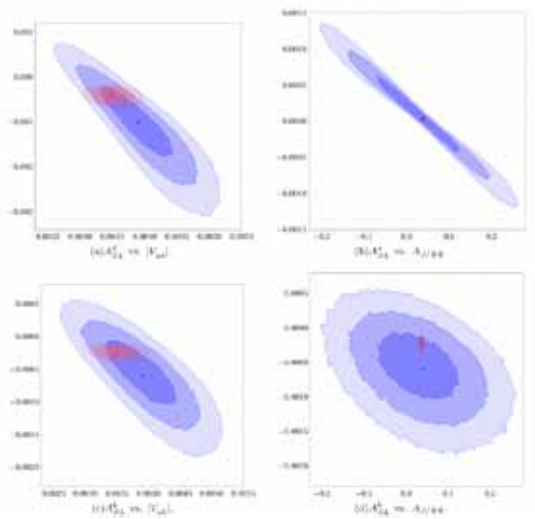
The muon anomalous magnetic moment a_μ^{SUSY} was investigated in the MSSM for $\tan\beta \to \infty$. This is an attractive example of radiative muon mass generation with completely different qualitative parameter dependence compared to the MSSM with the usual, finite tan β. The observed, positive difference between the experimental and Standard Model values can only be explained if there are mass splittings, such that bino contributions dominate over wino ones. The two most promising cases are characterized either by large Higgsino mass μ or by large left-handed smuon mass m_L. The required mass splittings and the resulting a_μ^{SUSY} are studied in detail. It is shown that the current discrepancy in a_μ^{SUSY} can be explained even in cases where all SUSY masses are at the TeV scale. The paper also presents useful analytical formulas, approximations for limiting cases and benchmark points.



Magnitude of and muon Yukawa coupling y_μ in the plane of versus , for positive (left) and negative (right). The colour coding corresponds to the different values of the coefficient C and the equivalent minimum SUSY mass which leads to agreement with the current deviation via . The black contours correspond to the indicated values of the muon Yukawa coupling. The grey regions are excluded by negative $a_\mu^{\rm SUSY}$. In the white regions the denominator undergoes a sign change, and the perturbation theory becomes untrustworthy due to large. Benchmark parameter points are marked with blue squares.

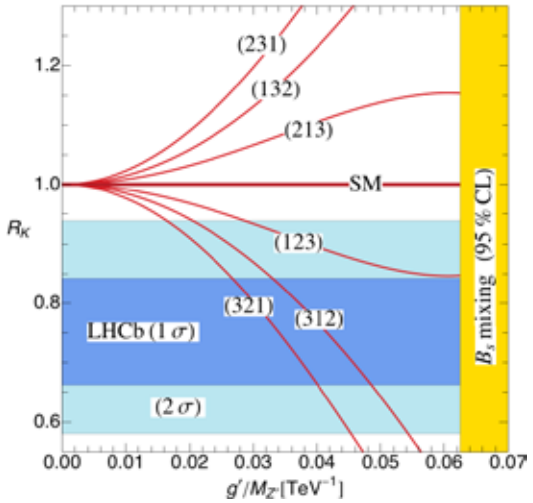
Researchers from IFIC explored the flavour changing decays $H_i \to bs$ in a general supersymmetric scenario

The measurement of a large like-sign dimuon asymmetry A_{SL}^{b} by the D0 experiment at the Tevatron departs noticeably from Standard Model (SM) expectations and it may be interpreted as a hint of physics beyond the Standard Model contributing to $\Delta B \neq 0$ transitions. Researchers from IFIC analyzed how the natural suppression of A_{SL}^{b} in the SM can be circumvented by new physics. They considered generic Standard Model extensions where the charged current mixing matrix is enlarged with respect to the usual 3×3 unitary Cabibbo-Kobayashi-Maskawa matrix, and showed how, within this framework, a significant enhancement over Standard Model expectations for A_{SL}^{b} is easily reachable through enhancements of the semileptonic asymmetries A_{SL}^{d} and A_{SL}^{s} of both B_d^0-B_d^0 and B_s^0-B_s^0 systems. Despite being insufficient to reproduce the D0 measurement, such deviations from SM expectations may be probed by the LHCb experiment.



68%, 90%, 95% CL regions. Blue regions correspond to the NP scenario, red regions correspond to the SM case.

A new class of Z′ models with neutral flavour-changing interactions at tree level in the down-quark sector was defined by a group of researchers from IFIC. They are related in an exact way to elements of the quark mixing matrix due to an underlying flavoured U(1)′ gauge symmetry, rendering these models particularly predictive. The same symmetry implies lepton-flavour nonuniversal couplings, fully determined by the gauge structure of the model. These models allow one to address presently observed deviations from the standard model and specific correlations among the new physics contributions to the Wilson coefficients $C_{9,10}^{(')\ell}$ can be tested in $b \to s\ell^+\ell^-$ transitions. They furthermore predict lepton-universality violations in Z′ decays, testable at the LHC.

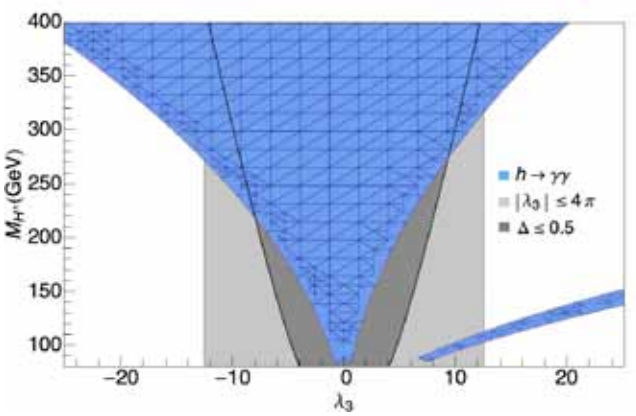


Model-dependent predictions for R_K as a function of $g'/M_{Z'}$. The recent measurement of R_K by the LHCb collaboration is shown at 1σ and 2σ. Constraints from Bs mixing are also shown at 95%~CL.

A new class of Z′ models with neutral flavour-changing interactions at tree level in the d quark sector was defined

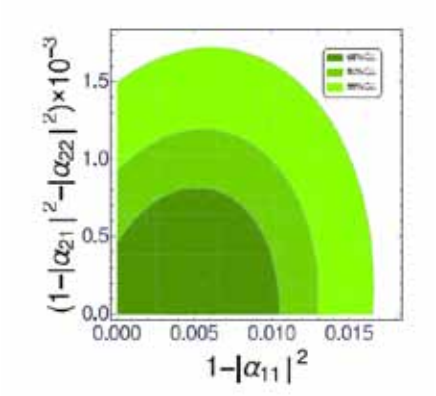
A group including several IFIC members performed a complete one-loop computation of the two-body flavour-changing top decays $t \to ch$ and $t \to cV$ ($V = \gamma, Z$), within the aligned two-Higgs-doublet model. They evaluated the impact of the model parameters on the associated branching ratios, taking into account constraints from flavour data and measurements of the Higgs properties. Assuming that the 125 GeV Higgs corresponds to the lightest CP-even scalar of the CP-conserving aligned two-Higgs-doublet model, they find that the rates for such flavour-changing top decays lie below the expected sensitivity of the future high-luminosity phase of the LHC. Measurements of the Higgs signal strength in the diphoton channel are found to play an important role in limiting the size of the $t \to ch$ decay rate when the charged scalar of the model is light.

Neutrino oscillations are well established and the relevant parameters determined with good precision, except for the CP phase, in terms of a unitary lepton mixing matrix. Seesaw extensions of the Standard Model predict unitarity deviations due to the admixture of heavy isosinglet neutrinos. A paper from IFIC researchers provides a complete description of the



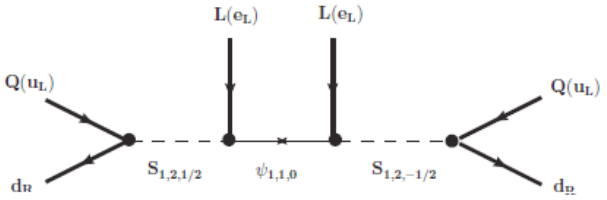
Allowed region by measurements of the Higgs signal strengths in the di-photon channel (blue-meshed) together with the perturbativity limits $|\lambda_3| \leq 4\pi$ (light gray) or $\Delta \leq 0.5$ (dark gray). See text for details.

unitarity and universality deviations in the light neutrino sector. Neutrino oscillation experiments involving electron or muon neutrinos and anti-neutrinos are fully described in terms of just three new real parameters and a new CP phase, in addition to the ones describing oscillations with unitary mixing. Using this formalism the implications of non-unitarity for neutrino oscillations are described and the model-independent constraints on heavy neutrino couplings that arise from current experiments are summarized.



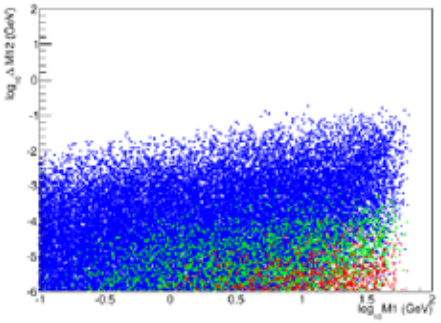
Constraints on the deviations from unitarity. In the case of unitarity mixing one would have $\alpha_{11}=\alpha_{22}=1$ and $\alpha_{21}=0$.

Neutrinoless double beta decay allows to constrain lepton number violating extensions of the Standard Model. If neutrinos are Majorana particles, the mass mechanism will always contribute to the decay rate, however, it is not a priori guaranteed to be the dominant contribution in all models. The authors of a recent systematic publication discuss whether the mass mechanism dominates or not from the theory point of view. They classify all possible (scalar-mediated) short-range contributions to the decay rate according to the loop level, at which the corresponding models will generate Majorana neutrino masses, and discuss the expected relative size of the different contributions to the decay rate in each class. The discussion is general for models based on the SM group but does not cover models with an extended gauge. They also work out the phenomenology of one concrete 2-loop model in which both, mass mechanism and short-range diagram, might lead to competitive contributions, in some detail.



Example of a diagram inducing 0νββ. This diagram makes use of charged scalar exchange and leads to the Babu-Leung operator O_{11}.

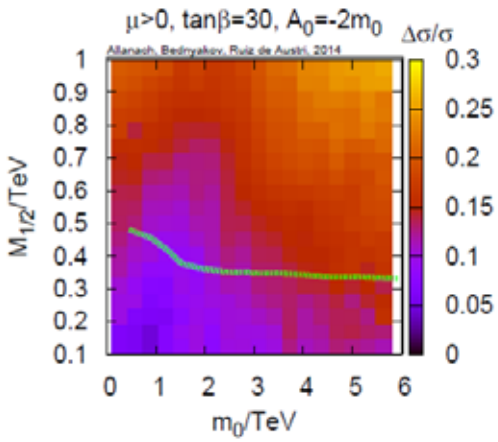
Researchers from IFIC revisited the production of leptonic asymmetries in minimal extensions of the Standard Model that can explain neutrino masses, involving extra singlets with Majorana masses in the GeV scale. They studied the quantum kinetic equations both analytically, via a perturbative expansion up to third order in the mixing angles, and numerically. The analytical solution allowed them to identify the relevant CP invariants, and simplifies the exploration of the parameter space. They find that sizeable lepton asymmetries are compatible with non-degenerate neutrino masses and measurable active-sterile mixings.



Points on the plane $\Delta M = M_2 - M_1$ vs M_1 for which $Y_B > 1/5 \cdot Y_B^{exp}$ (blue), $Y_B > Y_B^{exp}$ (green) and $Y_B > 5 \cdot Y_B^{exp}$ for Normal Hierarchy with only two sterile neutrinos.

Production of leptonic asymmetries in minimal extensions of the SM that can explain neutrino masses was revisited

The effects of three-loop minimal supersymmetric Standard Model renormalisation group equation terms and some leading two-loop threshold corrections on gauge and Yukawa unification were explored: each being one loop higher order than current public spectrum calculators. The authors also explored the effect of the higher order terms (often 2-3 GeV) on the lightest CP even Higgs mass prediction. Their results were illustrated in the constrained Minimal Supersymmetric Standard Model. Neglecting threshold corrections at the grand unified scale, the discrepancy between the unification scale α_s and the other two unified gauge couplings changes by 0.1% due to the higher order corrections and the difference between unification scale bottom-tau Yukawa couplings neglecting unification scale threshold corrections changes by up to 1%. The difference between unification scale bottom and top Yukawa couplings changes by a few percent. Differences due to the higher order corrections also give an estimate of the size of theoretical uncertainties in the Minimal Supersymmetric Standard Model spectrum. They use these to provide estimates of theoretical uncertainties in predictions of the dark matter relic density (which can be of order one due to its strong dependence on sparticle masses) and the LHC sparticle production cross-section (often around 30%). The additional higher order corrections have been incorporated into SOFTSUSY, and they provide details on how to compile and use the program. They also provide a summary of the approximations used in the higher order corrections.



Relative effect of highest order terms (three-loop RGEs for gauge and Yukawa couplings and two-loop threshold corrections to third family fermion masses and g3) on the predicted LHC SUSY production cross-section. The CMSSM parameters coincide with the latest ATLAS searches for jets and missing energy interpreted in the CMSSM. The region below the dashed line is excluded at the 95% confidence level by at least one of the most restrictive ATLAS jets plus missing energy searches.

Selected publications

G. Barenboim, C. Bosch, J.S. Lee, M.L. López-Ibáñez, O. Vives, *Flavor-changing Higgs boson decays into bottom and strange quarks in supersymmetric models*, Phys.Rev. D92 (2015) no.9, 095017

M. Bach, Jae-hyeon Park, D. Stöckinger, H. Stöckinger-Kim, *Large muon (g – 2) with TeV-scale SUSY masses for tan β → ∞*, JHEP 1510 (2015) 026

F.J. Botella, G.C. Branco, M. Nebot, A. Sánchez, *Mixing asymmetries in B meson systems, the D0 like-sign dimuon asymmetry and generic New Physics*, Phys.Rev. D91 (2015) no.3, 035013

A. Celis, J. Fuentes-Martin, M. Jung, H. Serodio, *Family nonuniversal Z' models with protected flavor-changing interactions*, Phys.Rev. D92 (2015) no.1, 015007

G. Abbas, A. Celis, Xin-Qiang Li, Jie Lu, A. Pich, *Flavour-changing top decays in the aligned two-Higgs-doublet model*, JHEP 1506 (2015) 005

F.J. Escrihuela, D.V. Forero, O.G. Miranda, M. Tortola, J.W.F. Valle, *On the description of non-unitary neutrino mixing*, Phys.Rev. D92 (2015) no.5, 053009

J.C. Helo, M. Hirsch, T. Ota, F. A. Pereira dos Santos, *Double beta decay and neutrino mass models*, JHEP 1505 (2015) 092

P. Hernández, M. Kekic, J. López-Pavón, J. Racker, N. Rius, *Leptogenesis in GeV scale seesaw models*, JHEP 1510 (2015) 067

B.C. Allanach, A. Bednyakov, R. Ruiz de Austri, *Higher order corrections and unification in the minimal supersymmetric standard model: SOFTSUSY3.5*, Comput. Phys.Commun. 189 (2015) 192-206

Selected conference talks

A. Pich, *Status after the first LHC run: Looking for new directions in the physics landscape*, 13th Pisa Meeting on Advanced Detectors: Frontier Detectors for Frontier Physics. 24-30 May 2015. La Biodola, Isola d'Elba, Italy

J.J. Sanz Cillero, Feng-Kun Guo, P. Ruiz-Femenia, *One-loop corrections to the Higgs electroweak chiral Lagrangian*, 18th International Conference From the Planck Scale to the Electroweak Scale (Planck 2015), 25-29 May 2015. Ioannina, Greece

Jae-hyeon Park, M. Bach, D. Stöckinger, Hyejung Stöckinger-Kim, *Large muon $(g-2)$ from TeV-scale*

MSSM with infinite $tan\beta$, 18th International Conference From the Planck Scale to the Electroweak Scale (Planck 2015), 25-29 May 2015. Ioannina, Greece

O. Vives, *METing SUSY on the Z peak*, 18th International Conference From the Planck Scale to the Electroweak Scale (Planck 2015), 25-29 May 2015. Ioannina, Greece PoS PLANCK2015 (2015) 134

A. Santamaria, *Radiative neutrino masses*, Scalars 2015, 3-7 december 2015, Warsow, Poland

R.M. Fonseca, W. Grimus, *Roots of unity and lepton mixing patterns from finite flavour symmetries*, 39th International Conference of Theoretical Physics : Matter to the Deepest, Recent Developments in Physics of Fundamental Interactions. 13-18 Sep 2015. Ustron, Poland

R. Lineros, *Radiative neutrino mass generation from WIMP dark matter*, TAUP 2015, 7-11 september 2015, Torino, Italy

Main research grants (National Plan)

ASTROPARTICLE AND HIGH ENERGY PHYSICS (ref. FPA2011-22975, FPA2014-58183-P)

FUNDAMENTAL INTERACTIONS AND THEIR EXPERIMENTAL IMPLICATIONS (ref. FPA2011-23596)

PERTURBATIVE AND NON-PERTURBATIVE STUDIES OF THE STANDARD MODEL AND ITS EXTENSIONS (ref. FPA2011-23897)

ELEMENTARY PARTICLES: THE STANDARD MODEL AND BEYOND (ref: FPA2014-54459-P)

PARTICLE PHYSICS PHENOMENOLOGY AT THE LHC AND FLAVOUR FACTORIES (ref. FPA2011-23778, FPA2014-53631-C2-1-P)

FLAVOUR AND ORIGIN OF MATTER (ref. FPA2011-29678-C02-01, FPA2014-57816-P)

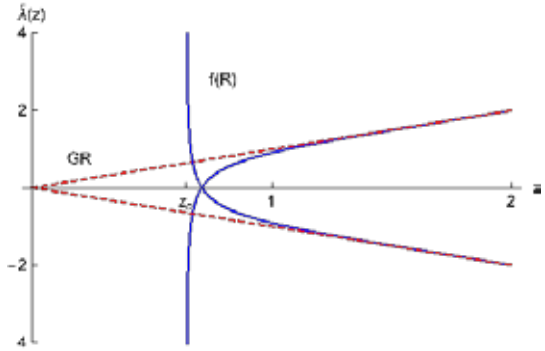
HIGH-ENERGY THEORETICAL AND MATHEMATICAL PHYSICS: GRAVITY, BLACK HOLES AND SUPERSYMMETRY

The main research topics of this line lie at the interphase between quantum theory and gravitation, from scenarios in which quantum field theory in curved space-time is a good approximation until the highest energies involved in the process of black hole formation or the very beginning of the Universe. The challenges posed by the quantum properties of black holes and the early universe (particle creation in dynamical space-times, primordial perturbations, gravitational waves, …) urge a worldwide effort to construct a consistent description of gravitation compatible with the quantum nature of the matter fields. The complexity of the problem requires a multidisciplinary approach, incorporating a wide range of viewpoints, running from sophisticated mathematics to ambitious experiments. Our research line follows this strategy in an intertwining way. The main lines and results in 2015 were:

An analytic method has been developed to calculate the low frequency gray-body factor in various black hole models, ranging from gravitational ones (Schwarzschild, Reissner-Nordstrom, Schwarzschild-de Sitter) to analogs (1D BECs acoustic black holes). This has allowed to put on a firmer ground previous obtained results in the literature. A theoretical analysis on momentum correlators in 1D BECs acoustic black holes, preliminary to an experiment to be performed at LCF (Paris), has nicely shown how one can identify the analog Hawking radiation and characterize its quantum properties. Finally, the instability of Schwarzschild black holes due to massive gravitons (the so called Gregory-Laflamme instability) has been (re)analysed in the context of higher-derivative theories of gravity.

We have studied the equivalence between the adiabatic regularization and the DeWitt-Schwinger point-splitting renormalizations schemes for a Dirac field. We have further analized the renormalization of the quantized electromagnetic field in a curved spacetime. The results seems to indicate the presence of a duality anomaly, which turns out to be proportional to the Chern-Pontryagin invariant.

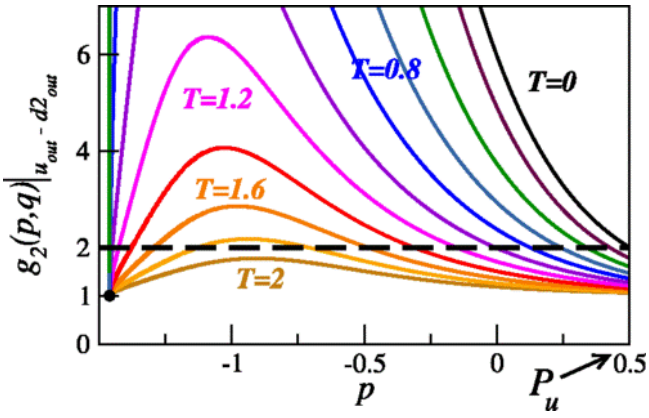
Spherically symmetric electrovacuum configurations lead to solutions with a central wormhole that replaces the singularity found in General Relativity



Completeness of null radial geodesics in a wormhole space-time. The dotted red line represents the same geodesics in General Relativity. The wormhole throat is located at z_c.

Extensions of General Relativity formulated in metric-affine geometries lead early universe scenarios in which massive dust particles can generate inflationary periods through a cascade of dissintegrations. The observational viability of some of these models and the generation of tensorial perturbations (gravitational waves) has been investigated in four-dimensional and higher-dimensional scenarios.

Born-Infeld gravity models possess an extraordinary ability to get rid of cosmological singularities. Their virtues are not just restricted to cosmology but are also manifest in black hole space-times in an arbitrary number of spatial dimensions. We have shown that spherically symmetric electrovacuum configurations lead to solutions with a central wormhole that replaces the typical singularity found in General Relativity. This non-trivial topological structure is crucial to guarantee the geodesic completeness of the resulting space-times, thus implying that they are nonsingular.



The value of $g_2(p,q)$ along the u_{out}–$d2_{out}$ correlation line (violet line) is plotted as a function of p (expressed in units of ξ^{-1}_u) for different temperatures. The Cauchy-Schwarz inequality is violated when $g_2(p,q)$ is larger than 2. The temperatures are expressed in units of the upstream chemical potential mc^2_u ($0 \le T \le 2$). For the set of parameters chosen here and in the previous figures, the Hawking temperature is T_H=0.134..

Selected publications

R. Fioresi, M.A. Lledó, *The Minkowski and Conformal Superspaces : The Classical and Quantum Descriptions*, World Scientific 2015, 364 pp.

D. Boiron, A. Fabbri, P.E. Larr e, N. Pavloff, C. Westbrook, P. Zin, *Quantum signature of analog Hawking radiation in momentum space*, Phys. Rev. Lett. 115, 025301 (published as Editors' suggestion)

P.R. Anderson, A. Fabbri, R. Balbinot, *Low frequency gray-body factors and infrared divergences: rigorous results*, Phys.Rev. D91 (2015) no.6, 064061

S. Mauro, R. Balbinot, A. Fabbri, Ilya L. Shapiro, *Fourth derivative gravity in the auxiliary fields representation and application to the black hole stability,* Eur. Phys.J.Plus 130 (2015) no.7, 135

G. Clément, A. Fabbri, *A scenario for critical scalar field collapse in AdS3*, Class. Quant. Grav. 32 (2015), 095009

Adrian del Rio, Jose Navarro-Salas, *Equivalence of Adiabatic and DeWitt-Schwinger renormalization schemes*, Phys.Rev. D91 (2015) 064031

Gonzalo J. Olmo, D. Rubiera-Garcia, *Nonsingular Black Holes in ƒ (R) Theories*, Universe 1 (2015) no.2, 173-185

J. Beltran Jimenez, L. Heisenberg, Gonzalo J. Olmo, C. Ringeval, *Cascading dust inflation in Born-Infeld gravity*, JCAP 1511 (2015) 046

S. Capozziello, T. Harko, Tomi S. Koivisto, Francisco S. N. Lobo, Gonzalo J. Olmo, *Hybrid metric-Palatini gravity*, Universe 1 (2015) no.2, 199-238

D. Bazeia, L. Losano, Gonzalo J. Olmo, D. Rubiera-Garcia, A. Sanchez-Puente, *Classical resolution of black hole singularities in arbitrary dimensión*, Phys. Rev. D92 (2015) no.4, 044018

Divulgative paper, *Caractériser le rayonnement d'un trou noir acoustique dans un condensat de Bose- Einstein*, Actualités Scientiques de l'Institut de Physique/CNRS, November 2015 (Highlight 2015)

Selected conference talks

A. del Río, *Adiabatic regularization for spin 1/2 fields and the renormalized stress-energy tensor*, 14th Marcel Grossmann Meeting, Rome 12-18, July, 2015

G.J. Olmo, *Wormholes as a cure for black hole singularities*, 14th Marcel Grossmann Meeting, Rome 12-18, July, 2015

G.J. Olmo, *Black holes, geons, and metric affine gravity*, Windows on Quantum Gravity: season 2, Madrid 28-30 Octubre

A. Fabbri, *Analog Hawking radiation in Bose-Einstein condensates*, Quantum vacuum and gravitation, Mainz 22-26, June

A. Fabbri, *Black hole evaporation in BECs, First workshop on string theory and gender*, Valencia, 6-7 July 2015

G. J. Olmo, *Lectures at the Theoretical Frontiers in Black Holes and Cosmology School and Conference*, International Institute of Physics (Natal, Brasil), 8-19, June 2015

A.Fabbri, *Lectures at the "Black holes and their analogues: 100 years of General Relativity"*, Ubu-Anchieta, ES, Brasil, 13-17, April, 2015

J. Navarro-Salas, *Lectures at the "Einstein in the beach summer school"*, Universidad del Mar, Murcia, 9-12, Sept. 2015

Conference and Workshop organization

First Workshop on String Theory and Gender, 6-7 July, 2015 Valencia (M.A. Lledó and G.J.Olmo).

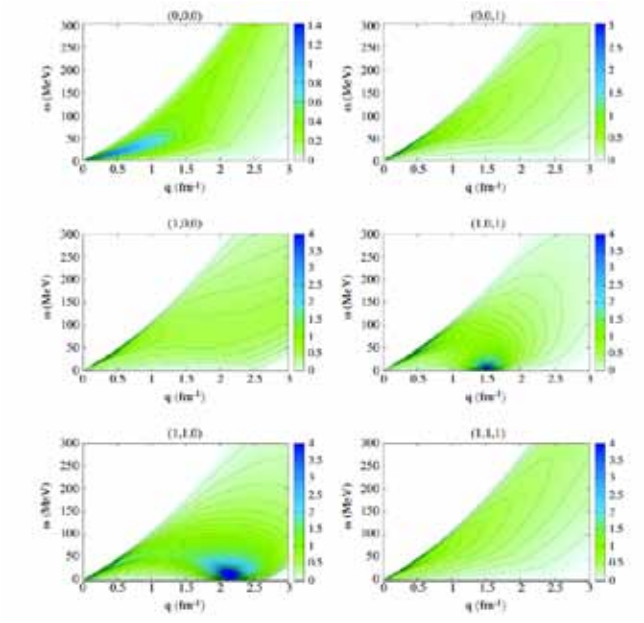
Main research grants (National Plan)

GRAVITY AND QUANTUM FIELDS (ref. FIS2014-57387-C3-1-P).

NUCLEAR PHYSICS AND MANY-BODY THEORY

The main research topics of this group include the study of the nature and properties of hadronic states with the help of Effective Field Theories, the weak interactions in hadrons and nuclei, the analysis of nuclear reactions of interest for neutrino experiments and the study of infinite nuclear matter and its response functions.

This year, there have been several important results concerning the heavy quark research line. A reanalysis of lattice QCD spectra has supported the molecular nature of the $D_s^{0*}(2317)$. Our studies, before the experimental observation, explain one of the two pentaquarks observed last summer at the LHCb (the publication has reached a considerable impact). We have also predicted several heavy quark exotic states such as the $Z_b(10650)$, $Z_c(3900)$ and $Z_c(4025)$ recently observed by BELLE and BESIII.



Projection onto the plane energy/momentum of the Strength functions for the channels (I,S,M) calculated for symmetric nuclear matter within the Random Phase Approximation, including exchange, at zero temperature and saturation density.

There has been a significant progress in the understanding of neutrino scattering in nuclei. Photon emission in neutral current interactions has been studied in the conditions of the MiniBooNE and T2K experiments. This process is an irreducible background in electron neutrino appearance searches. We have found that it cannot explain the excess of events found at MiniBooNE. In the case of T2K, we obtain a total number of photon events that is twice as large as the one used in the experimental analyses. The weak production of Lambda(1405) has also been investigated for the first time, predicting event rates at the MINERvA experiment.

Response functions of infinite nuclear matter with arbitrary isospin asymmetry have been studied in the framework of the random phase approximation. The residual interaction has been derived from a general nuclear Skyrme energy density functional, including the usual central, spin–orbit and tensor terms as well as other components as new density dependent terms or three-body terms. Applications to symmetric nuclear matter, pure neutron matter and asymmetric nuclear matter have been discussed. Spin–isospin strength functions have been analyzed for varying conditions of density, momentum transfer, isospin asymmetry, and temperature for some representative Skyrme functionals. Particular attention has been paid to the discussion of instabilities which could manifest in finite nuclei.

Researchers explained one of the two pentaquarks observed at the LHCb detector before the experimental observation and predicted several heavy quark exotic states

Selected publications

A. Pastore, D. Davesne y J. Navarro. "Linear response of homogeneous nuclear matter with energy density functionals" Physics Reports 563, 1 (2015)

D. Davesne, J. Navarro, P. Becker, R. Jodon, J. Meyer y A. Pastore. "Extended Skyrme pseudo-potential deduced from infinite matter properties". Physical Review C 91, 064303 (2015). Editor's suggestion

Luis Roca, J. Nieves y E. Oset. "LHCb pentaquark as a Dbar* Σ_c–Dbar*Σ_c molecular state". Physical Review D 92, 094003 (2015)

Xiulei Ren, E. Oset, L. Alvarez Ruso y M.J. Vicente Vacas. "Antineutrino induced Lambda(1405) production off the proton". Physical Review C 91, 045201 (2015)

Carmen Garcia-Recio, C. Hidalgo Duque, J. Nieves, L.L. Salcedo, L. Tolos. "Compositeness of the strange, charm and beauty odd parity Lambda states". Physical Review D 92, 034011 (2015)

Francesca Aceti, JuJun Xie y E. Oset. "The K Kbar π decay of the f1(1285) and its nature as a K* Kbar-cc molecule". Phys. Lett. B750 (2015) 609

Astrid Hiller Blin, T. Gutsche y T. Ledwig. "Hyperon spin polarizability gamma0 in baryon chiral pertubation theory". Physical Review D 92, 096004 (2015)

Miguel Albaladejo, B. Moussallam. "Form factors of the isovector scalar current and the ηπ scattering phase shifts". Eur. Phys. J. C75 (2015) 488

Selected conferences

L. Alvarez Ruso, Prospects in neutrino Physics, Invited talk at NuPhys2015, London, UK, Dec. 2015

L. Alvarez Ruso, "Electroweak interactions on the nucleon", NuSTEC School Okayama, Japan, Nov. 2015

J. Nieves, "2p2h excitations, MEC, nucleon correlations and other sources of QE-like events", Invited talk: NuInt15 (10th International Workshop on Neutrino-Nucleus Interaction in the Few GeV Region), Osaka, Japón, Nov. 2015

E. Oset, "Testing the nature of resonances in B and D weak decays", Invited talk: LHCb workshop. Rio de Janeiro, Brasil, July 2015

J. Nieves, "Hidden charm and bottom molecular states", Invited talk: Hadrons and hadron interactions in QCD, Kyoto, Japón, Feb. 2015

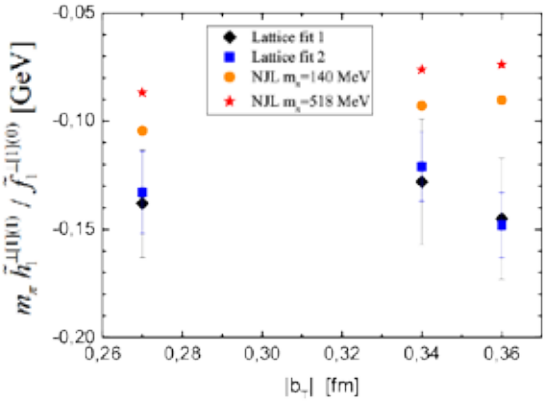
Main Research Grants (National)

NUCLEAR AND HADRON PHYSICS AT INTERMEDIATE ENERGIES (refs. FIS2011-28853-C02-01, FIS2011-28853-C02-02, FIS2014-51948-C2-1-P and FIS2014-51948-C2-2-P)

QCD AND STRONG INTERACTIONS

This research line is focused on fundamental perturbative and non-perturbative aspects of the strong interactions. The strong interaction is intimately connected to a broad sweep of physical problems, in settings ranging from astrophysics and cosmology to strongly-coupled, complex systems in particle and condensed-matter physics, as well as to searches for physics beyond the Standard Model. It is, in particular, the driven fundamental force at the Large Hadron Collider (LHC).

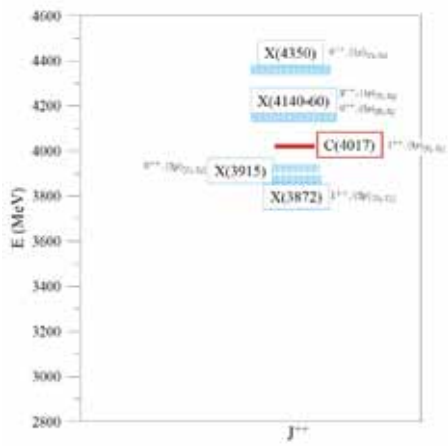
An explicit evaluation of the two pion transverse momentum dependent parton distributions at leading twist has been presented in the framework of the Nambu-Jona Lasinio model with Pauli-Villars regularization. The transverse momentum dependence of the obtained distributions is generated solely by the dynamics of the model. Using these results, the so called generalized Boer-Mulders shift was studied and compared with recent lattice data. The obtained agreement was very encouraging, in particular because no additional parameters were introduced. A more conclusive comparison would require a precise knowledge of the QCD evolution of the transverse momentum dependent parton distributions under scrutiny.



The generalized Boer-Mulders shift as a function of b_T.

A generalized screened potential model (GSPM) has been developed to study the bottomonium spectrum, and was applied to the calculation of charmonium masses and electromagnetic widths. The presence in the GSPM of more quark-antiquark bound states than in conventional non-screened potential models, allows for the assignment of GSPM states to catalogued nonconventional J++ charmonium reso-

nances as well as for the prediction of new (non catalogued) J++ states. The results obtained indicate that a reasonable overall description of J++ charmonium resonances is feasible.



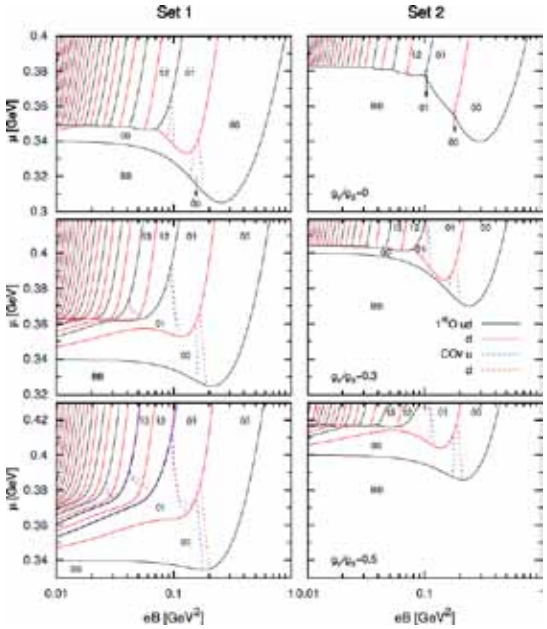
New candidates for J++ charmonium states.

The effective cross section of double parton scattering in proton-proton collisions has been presented in the framework of the Light-Front quark model at low-resolution scale. QCD evolution was implemented to reach the experimental scale. In the valence region, it is consistent with the present experimental data. However, the result of the complete calculation shows a dependence of σ_{eff} on x_i, therefore measurements of σ_{eff} in restricted x_i regions can be addressed to obtain indications on double parton correlations, a novel and interesting aspect of the three dimensional structure of the nucleon.

The influence of intense magnetic fields on the properties of strongly interacting matter has become an issue of increasing interest in recent years, motivated by the realization that in some relevant physical situations, like high energy non-central heavy ion collisions and compact stellar objects called magnetars, very strong magnetic fields may be produced.

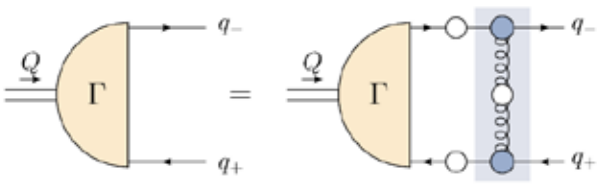
These measurements could obtain indications on double parton correlations, a novel and interesting aspect of the three dimensional structure of the nucleon

The effect of intense magnetic fields on the phase diagram of cold, strongly interacting matter was studied within an extended version of the Nambu-Jona-Lasinio model that includes flavour mixing effects and vector interactions. Different values of the relevant model parameters in acceptable ranges were considered. Charge neutrality and beta equilibrium effects, which are especially relevant to the study of compact stars, were also taken into account, and in this case the behaviour of leptons was also analysed.



Phase diagrams in the eB-μ plane for symmetric matter under intensive magnetic fields.

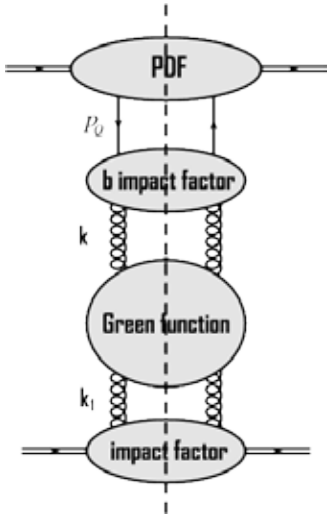
The form of the kernel that controls the dynamics of the Bethe-Salpeter equations is essential for obtaining quantitatively accurate predictions for the observable properties of hadrons. A first-principle derivation of a universal (process-independent) component of this kernel has been presented. This "top-down" approach combines non-perturbative ingredients obtained from lattice simulations and Schwinger-Dyson equations (SDEs), and furnishes a renormalization-group invariant quark-gluon interaction strength, which is in excellent agreement with the corresponding quantity obtained from a systematic "bottom-up" treatment, where bound-state data are fitted within a well-defined truncation scheme.



The meson Bethe-Salpeter equation

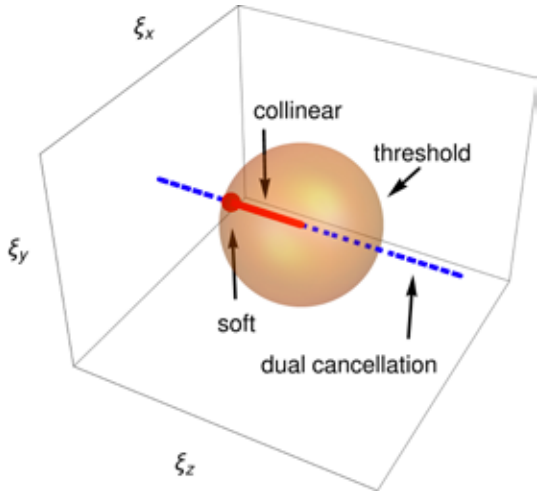
Instanton solutions of non-Abelian Yang-Mills theories generate an effective action that may induce lepton and baryon number violations. Instanton mediated processes in a $SU(2)_\ell \otimes SU(2)_h \otimes U(1)$ extension of the Standard Model that breaks universality by singularizing the third family have been studied. In the construction of the instanton Green functions the inter-family mixing has been systematically accounted. This allows to use the experimental bounds on proton decay to constrain the gauge coupling of $SU(2)_h$. Tau lepton non-leptonic and radiative decays were also analysed.

Single bottom quark production at the LHC has been studied for the first time in the $k_\perp$-factorisation scheme. In particular, the rapidity and transverse momentum differential distributions for single bottom quark/anti-quark production were predicted. In this setup, the unintegrated gluon density was obtained from the NLx BFKL Green function and mass effects of the heavy quark were included in the jet vertex. The results were compared to the corresponding distributions predicted by the usual collinear factorisation scheme. These results suggest that single bottom quark production might be used as a reliable experimental probe of the of high energy factorization for LHC processes.



Single bottom quark production in high energy factorization.

The abundance of infrared singularities in gauge theories due to unresolved emission of massless particles (soft and collinear) represents the main difficulty in perturbative calculations. They are typically regularized in dimensional regularization, and their subtraction is usually achieved independently for virtual and real corrections. We have proposed a new perturbative method based on the loop-tree duality (LTD) theorem to accomplish the summation over degenerate infrared states directly at the integrand level. This method represents a new paradigm in perturbative calculations as virtual and real corrections are not regularized independently. Ultraviolet divergences, which are the consequence of the point-like nature of the theory, were also reinterpreted physically in this framework. The proposed method opens the intriguing possibility of carrying out purely four-dimensional implementations of higher-order perturbative calculations at next-to-leading order (NLO) and beyond, which are free of soft and final-state collinear subtractions and therefore do not require the use of dimensional regularisation.



Singular structure of the three-point function in the loop three-momentum space from the loop-tree duality.

The proposed method represents a new paradigm in theoretical calculations for the LHC

Selected publications

S. Noguera, S. Scopetta, *Pion transverse momentum dependent parton distributions in the Nambu and Jona-Lasinio model*, JHEP 1511 (2015) 102

P. González, *Charmonium description from a generalized screened potential model*, Phys. Rev. D92 (2015) 014017

M. Rinaldi, S. Scopetta, M. Traini, V. Vento, *Double parton distributions in Light-Front constituent quark models*, Few Body Syst. 56 (2015) 515-521

P.G. Allen, V.P. Pagura, N.N. Scoccola, *Cold magnetized quark matter phase diagram within a generalized SU(2) NJL model*, Phys. Rev. D91 (2015) 114024

D. Binosi, L. Chang, J. Papavassiliou, C.D. Roberts, *Bridging a gap between continuum-QCD and ab initio predictions of hadron observables*, Phys. Lett. B742 (2015) 183-188

J. Fuentes-Martín, J. Portolés, P. Ruiz-Femenia, *Instanton-mediated baryon number violation in non-universal gauge extended models*, JHEP 1501 (2015) 134

G. Chachamis, M. Deák, M. Hentschinski, G. Rodrigo, A. Sabio Vera, *Single bottom quark production in $k_\perp$-factorisation*, JHEP 1509 (2015) 123

Selected conferences

G. Rodrigo, *The LHCPHENONET ITN*, invited talk, Future of the Doctorate, Riga, Letonia, May 2015

G. Rodrigo, *Top-quark physics as a probe of physics beyond the SM*, invited talk, MORIOND 2015, La Thuile, Italy, March 2015

G.F.R. Sborlini, *From dimensional regularization to NLO computation in four dimensions*, invited talk EPS-HEP 2015, Vienna, Austria, July 2015

G.F.R. Sborlini, *Loop-Tree duality and quantum field theory in 4D*, invited talk RADCOR 2015/Loop Fest XIV, Los Angeles, USA, June 2015

Organised conferences

LHCPHENO 2015: Workshop on High-Energy Physics Phenomenology in the LHC era, 25-27 November 2015, Parc Científic, Paterna

Main research grants (National Plan)

FUNDAMENTAL INTERACTIONS AND THEIR EXPERIMENTAL IMPLICATIONS (ref. FPA2011-23596)

PARTICLE PHYSICS PHENOMENOLOGY AT THE LHC AND FLAVOUR FACTORIES (ref. FPA2014-53631-C2-1-P, FPA2011-23778)

HADRONIC MODELS, FUNDAMENTAL INTERACTIONS AND NUCLEAR PHYSICS (ref. FPA2010-21750-C02-01)

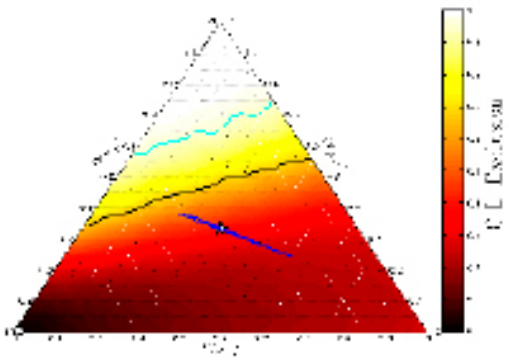
PERTURBATIVE AND NON-PERTURBATIVE STUDIES OF THE STANDARD MODEL AND ITS EXTENSIONS (ref. FPA2011-23897)

FLAVOUR AND ORIGIN OF MATTER (ref. FPA2011-29678-C02-01)

THEORETICAL ASTROPARTICLE PHYSICS AND COSMOLOGY

The research topics of this line include the theoretical phenomenology of cosmic rays, neutrinos, dark matter and dark energy, involving international collaborations that study solar neutrinos and geoneutrinos (Borexino) and the role of dark matter, neutrinos or dark energy in the cosmological large-scale structure (BOSS).

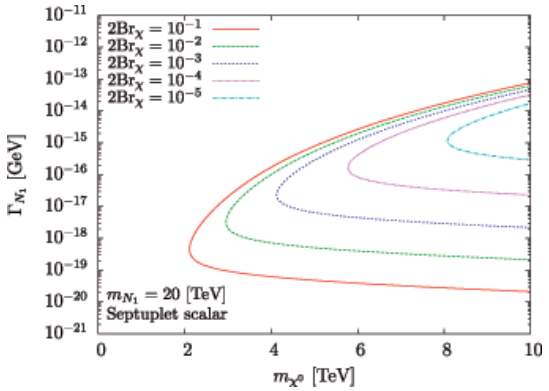
Concerning High Energy Neutrino Astronomy, theoretical researchers at IFIC continued with their pioneer analyses of the flavour ratios of the high-energy neutrino data from the IceCube telescope. Including the energy information, and using multidimensional fits, they derived the preferred values of the high energy neutrino flavour ratios, the normalization and spectral index of the astrophysical fluxes, and the expected atmospheric background events, including a prompt component. A crucial assumption resides on the choice of the energy interval used for the analyses. Namely, extending the high-energy cut-off leads to a preference for tau neutrino dominance, due to a lack of showers at energies above 2 PeV. This may point to a broken power-law neutrino spectrum, eventually relating the origin of the Icecube high-energy neutrino events and the long-standing detected cosmic rays.



Example of ternary plot of the exclusions of the neutrino flavour composition of the IceCube events in the energy range 60 TeV to 10 PeV (from S. Palomares-Ruiz, A. Vincent, and O. Mena; Phys. Rev. D 91, 103008)

Other IFIC researchers have been focused on the dark matter topic:

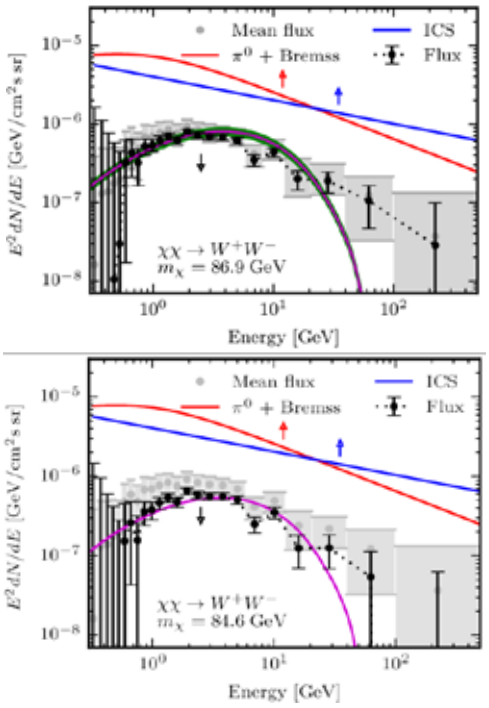
Minimal Dark Matter (MDM) stands as one of the simplest scenarios. However, annihilation and co-annihilation processes among members of a MDM multiplet are very effective, generally pushing the dark matter mass to values above 10 TeV, beyond any experimental reach. In order to improve the phenomenological prospects of this scenario, researchers at IFIC have proposed a mechanism for non-thermal production of MDM which allows to lower the dark matter mass to just a few TeV. The mechanism is based on the decay of heavy right-handed neutrinos, thus linking the dark matter problem to the generation of neutrino masses. As a result of this, the resulting extended MDM models can be experimentally probed in future direct detection experiments such as XENON1T.



Contours satisfying the observed DM relic density in the DM mass vs right-handed neutrino decay width plane (from M. Aoki, T. Toma, and A. Vicente; J. Cosmol. Astropart. Phys. 09, 063)

From the pure observational perspective, observations with the Fermi Large Area Telescope (LAT) indicate an excess in gamma rays originating from the centre of our galaxy. A possible explanation for this excess is the annihilation of dark matter particles. IFIC researchers have investigated the annihilation of neutralinos as DM candidates within the phenomenological Minimal Supersymmetric Standard Model (pMSSM), finding solutions that are consistent with astroparticle physics and collider experiment. The neutralino is a bino/higgsino or bino/wino/higgsino mixture with a mass in the range 84-92 GeV or 87-97 GeV annihilating into W bosons. A third solution is found for a neutralino of mass 174 -187 GeV annihilating into top quarks. The best solutions yield a dark matter relic density in the range 0.06-0.13. These pMSSM solutions lead to clear forecasts for LHC, direct and indirect DM detection experiments.

Researchers continued their pioneer analyses of flavour ratios of the high energy neutrino data from IceCube

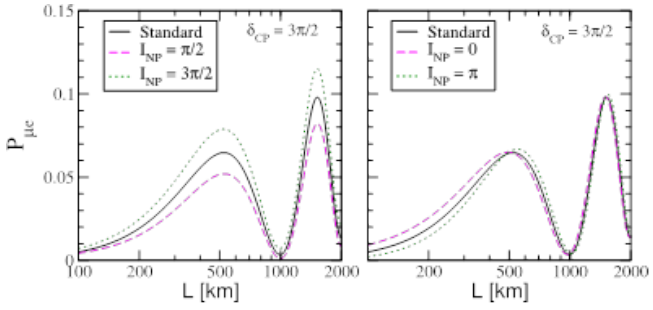


Photon excess spectrum as extracted from the Fermi data from the inner Galaxy, compared with the model calculations with the best fits (from A. Achterberg et al; J. Cosmol. Astropart. Phys. 08, 006)

Concerning the inflationary paradigm, a number of IFIC researchers have further developed some exciting theories:

G. Barenboim and collaborators have developed the spiral inflation idea, which amounts to curl up a long trajectory into a multi-field space avoiding this way the η problem while keeping all the field values subplanckian. They have shown that, when applied to a Coleman-Weinberg (CW) potential, it allows a perfect matching to Planck data for a symmetry breaking scale ranging at least from an intermediate scale to a GUT one. For a GUT scale symmetry breaking, the tensor-to-scalar ratio can be of O(10-2), therefore it could be detectable in the near future. The benefit of the CW potential as the inflaton potential is that it can be directly connected to GUT scale or a low-energy symmetry breaking.

Other IFIC researchers have focused on the theoretical and phenomenological aspects of neutrino physics. For instance, they have presented a general parameterization accounting for the non-unitarity of the light-neutrino mixing matrix. This hypothesis is motivated by models of neutrino masses predicting the existence of neutral heavy states that mix with the standard light neutrinos. The mixing between light and heavy neutrinos necessarily implies that the light-neutrino mixing matrix probed at oscillation experiments is not, in general, unitary. They have given a complete description of the unitarity and universality deviations in the light neutrino sector, paying special attention to neutrino oscillation experiments involving electron and muon neutrinos, fully described in terms of three new real parameters and a new CP phase, in addition to the ones describing oscillations with unitary mixing. Using this formalism, they have described the implications of non-unitarity for neutrino oscillations and summarize the model-independent constraints on heavy neutrino couplings that arise from current experiments. The figure (taken from F.J. Escrihuela et al; Phys. Rev. D 92, 053009) shows the electron neutrino appearance probability for a neutrino energy of 1 GeV. The non-unitary case is illustrated by the dotted and dashed lines with the complex phase I_{123} as indicated.



Conversion probability for a fixed neutrino energy E_ν = 1 GeV

IFIC researchers investigated the annihilation of neutralinos as dark matter candidates

Selected publications

A. Achterberg, S. Amoroso, S. Caron, L. Hendriks; R. Ruiz de Austri, C. Weniger, *A description of the Galactic Center excess in the Minimal Supersymmetric Standard Model*, J. Cosmol. Astropart. Phys. 08, 006 – 27pp.

S.K. Agarwalla, P. Bagchi, D.V. Forero, M. Tórtola, *Probing non-standard interactions at Daya Bay*, J. High Energy Phys. 07, 060 – 33pp.

M. Aoki, T. Toma, A. Vicente, *Non-thermal Production of Minimal Dark Matter via Right-handed Neutrino Decay*, J. Cosmol. Astropart. Phys. 09, 063 – 19pp.

G. Barenboim, Wan-Il Park, *Spiral Inflation with a Coleman-Weinberg potential*, Phys. Rev. D 91, 063511 – 5pp.

L. Boubekeur, E. Giusarma, O. Mena, H. Ramírez, *Do current data prefer a non-minimally coupled inflaton?*, Phys. Rev. D 91, 083006 – 8pp.

P. Fernández de Salas, M. Lattanzi, G. Mangano, G. Miele, S. Pastor, O. Pisanti, *Bounds on very low reheating scenarios after Planck*, Phys. Rev. D 92, 123534 – 9pp

F.J. Escrihuela, D.V. Forero, O.G. Miranda, M. Tórtola, J.W.F. Valle, *On the description of nonunitary neutrino mixing*, Phys. Rev. D 92, 053009 – 16pp

S. Palomares-Ruiz, A.C. Vincent, O. Mena, *Spectral analysis of the high energy Icecube neutrinos*, Phys. Rev. D 91, 103008 – 28pp.

A.C. Vincent, E. Fernández Martínez, P. Hernández, O. Mena, M. Lattanzi, *Revisiting cosmological bounds on sterile neutrinos*, J. Cosmol. Astropart. Phys. 04, 006 – 23pp.

Selected talks at conferences and workshops

G. Barenboim, *Spiral inflation*, invited talk at Invisibles'15 Workshop, Madrid (Spain), June 2015

P. Hernández, *Neutrinos: Theory and Phenomenology*, invited plenary talk at European Physical Society Conference on High Energy Physics, Vienna (Austria), July 2015

M. Hirsch, *Theoretical Neutrino Physics*, invited plenary talk at 25th Int. Workshop on Weak Interactions and Neutrinos (WIN 2015), Heidelberg (Germany), June 2015

R.A. Lineros, *Radiative neutrino mass generation from WIMP dark matter*, invited talk at XIV Int. Conference on Topics in Astroparticle and Underground Physics (TAUP 2015), Turin (Italy), September 2015

O. Mena, *Neutrinos and cosmology*, invited talk at Deciphering the Spectroscopic Signature of Our Cosmos, Cambridge (UK), Sep-Oct 2015

S. Palomares-Ruiz, *Detecting WIMPs with MeV neutrinos from the Sun*, invited talk at Dark Matter: Astrophysical probes, Laboratory tests, and Theory aspects (Dark MALT 2015), Munich (Germany), February 2015

S. Pastor, *Neutrino cosmology after Planck*, invited plenary talk at Meeting on Fundamental Cosmology, Santander (Spain), June 2015

N. Rius, *Leptogenesis news*, invited plenary talk at Invisibles'15 Workshop, Madrid (Spain), June 2015

J.W.F. Valle, *Neutrino landscape and the road to new physics*, invited plenary talk at 18th Int. Conference From the Planck Scale to the Electroweak Scale (PLANCK 2015), Ioannina (Greece), May 2015

Main research grants (National Plan)

ASTROPARTICLE AND HIGH ENERGY PHYSICS (ref. FPA2014-58183-P)

ELEMENTARY PARTICLES: THE STANDARD MODEL AND BEYOND (ref. FPA2014-54459-P)

FLAVOUR AND ORIGIN OF MATTER (ref. FPA2014-57816-P)

3. PUBLICATIONS

IFIC SCIENTIFIC OUTPUT (2015)

400 articles in indexed journals

93.2% in first quartile journals
(JCR-WoS or SJR-Scopus, 2015)

TOP 10 JOURNALS BY IMPACT FACTOR (JCR-WOS) WITH IFIC AUTHORS

Nature (IF 38.1): **1**
Science (IF 34.7): **1**
Reviews of Modern Physics (IF 33.1): **1**
Nature Physics (IF 18.8): **1**
Physics Reports (IF 16.2): **1**
Physical Review Letters (IF 7.6): **34**
Annual Review of Nuclear and Particle Science (IF 7.5): **1**
Journal of High Energy Physics (IF 6.0): **75**
Journal of Cosmology and Astroparticle Physics (IF 5.6): **10**
Astronomy and Astrophysics (IF 5.2): **1**

TOP 5 JOURNALS (BY NUMBER OF PAPERS) WITH IFIC AUTHORS

Physical Review D (IF 4.5): **94**
Journal of High Energy Physics (IF 6.0): **75**
European Physical Journal C (IF 4.9): **44**
Physics Letters B (IF 4.8): **42**
Physical Review Letters (IF 7.6): **34**

12 PhD theses with IFIC supervisors

342 presentations at international conferences (including posters)

We present the list of the 400 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 2015 are indicated. Some papers appear twice if there are authors from both IFIC departments.

EXPERIMENTAL PHYSICS

AGATA Collaboration

IFIC authors: Gadea, A.; Huyuk, T.

Isomeric ratios in Hg-206, Acta Phys. Pol. B 46, 601-605, DOI: http://dx.doi.org/10.5506/APhysPolB.46.601

1(-) and 2(+) discrete states in Zr-90 populated via the (O-17, O-17 'gamma) reaction, Phys. Rev. C 91, 024323 - 9pp,
DOI: http://dx.doi.org/10.1103/PhysRevC.91.024323

ANTARES Collaboration

IFIC authors: Barrios-Marti, J.; Gomez-Gonzalez, J.P.; Hernandez-Rey, J.J.; Lambard, G.; Mangano, S.; Sanchez-Losa, A.; Tönnis, C.; Yepes, H.; Zornoza, J.D.; Zuñiga, J.

ANTARES constrains a blazar origin of two IceCube PeV neutrino events, Astron. Astrophys. 576, L8 - 6pp,
DOI: http://dx.doi.org/10.1051/0004-6361/201525670
http://arxiv.org/abs/1501.07843

Search for muon-neutrino emission from GeV and TeV gamma-ray flaring blazars using five years of data of the ANTARES telescope, J. Cosmol. Astropart. Phys. 12, 014 - 27pp,
DOI: http://dx.doi.org/10.1088/1475-7516/2015/12/014
http://arxiv.org/abs/1506.07354

Search of dark matter annihilation in the galactic centre using the ANTARES neutrino telescope, J. Cosmol. Astropart. Phys. 10, 068 - 26pp,
DOI: http://dx.doi.org/10.1088/1475-7516/2015/10/068
http://arxiv.org/abs/1505.04866

ATLAS Collaboration

IFIC authors: Alvarez Piqueras, D.; Cabrera Urban, S.; Castillo Gimenez, V.; Cerda Alberich, L.; Costa, M.J.; Fassi, F.; Fernandez Martinez, P.; Ferrer, A.; Fiorini, L.; Fuster, J.; Garcia, C.; Garcia Navarro, J.E.; Gonzalez de la Hoz, S.; Hernandez Jimenez, Y.; Higon-Rodriguez, E.; Irles Quiles, A.; Jimenez Pena, J.; Kaci, M.; King, M.; Lacasta, C.; Lacuesta, V.R.; March, L.; Marti-Garcia, S.; Miñano, M.; Mitsou, V.A.; Moles-Valls, R.; Moreno Llacer, M.; Oliver Garcia, E.; Pedraza Lopez, S.; Perez Garcia-Estañ, M.T.; Romero Adam, E.; Ros, E.; Salt, J.; Sanchez Martinez, V.; Soldevila, U.; Sanchez, J.; Torro Pastor, E.; Valero, A.; Valladolid Gallego, E.; Valls Ferrer, J.A.; Vos, M.

Combined Measurement of the Higgs Boson Mass in pp Collisions at root s=7 and 8 TeV with the ATLAS and CMS Experiments, Phys. Rev. Lett. 114, 191803 - 33pp,
DOI: http://dx.doi.org/10.1103/PhysRevLett.114.191803
http://arxiv.org/abs/1503.07589

Search for flavour-changing neutral current top quark decays t -> Hq in pp collisions at root s=8 TeV with the ATLAS detector, J. High Energy Phys. 12, 061 - 65pp,
DOI: http://dx.doi.org/10.1007/JHEP12(2015)061
http://arxiv.org/abs/1509.06047

Determination of spin and parity of the Higgs boson in the WW -> ev μv decay channel with the ATLAS detector*, Eur. Phys. J. C 75, 231 - 40pp,
DOI: http://dx.doi.org/10.1140/epjc/s10052-015-3436-3
http://arxiv.org/abs/1503.03643

Search for supersymmetry in events containing a same-flavour opposite-sign dilepton pair, jets, and large missing transverse momentum in root s=8 TeV pp collisions with the ATLAS detector, Eur. Phys. J. C 75, 318 - 40pp,
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Search for low-scale gravity signatures in multi-jet final states with the ATLAS detector at root s=8 TeV, J. High Energy Phys. 7, 032 - 38pp,
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A search for t(t)over-bar resonances using lepton-plus-jets events in proton-proton collisions at root s=8 TeV with the ATLAS detector, J. High Energy Phys. 8, 148 - 54pp,
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http://arxiv.org/abs/1505.07018

Modelling Z -> ττ processes in ATLAS with τ-embedded Z -> μμ data, J. Instrum. 10, P09018 - 41pp,
DOI: http://dx.doi.org/10.1088/1748-0221/10/09/P09018
http://arxiv.org/abs/1506.05623

Search for vectorlike B quarks in events with one isolated lepton, missing transverse momentum, and jets at root s=8 TeV with the ATLAS detector, Phys. Rev. D 91, 112011 - 30pp,
DOI: http://dx.doi.org/10.1103/PhysRevD.91.112011
http://arxiv.org/abs/arXiv:1503.05425

Search for type-III seesaw heavy leptons in pp collisions at root s=8 TeV with the ATLAS detector, Phys. Rev. D 92, 032001 - 20pp,
DOI: http://dx.doi.org/10.1103/PhysRevD.92.032001
http://arxiv.org/abs/1506.01839

Search for long-lived, weakly interacting particles that decay to displaced hadronic jets in proton-proton collisions at root s=8 TeV with the ATLAS detector, Phys. Rev. D 92, 012010 - 28pp,
DOI: http://dx.doi.org/10.1103/PhysRevD.92.012010
http://arxiv.org/abs/1504.03634

Search for photonic signatures of gauge-mediated supersymmetry in 8 TeV pp collisions with the ATLAS detector, Phys. Rev. D 92, 072001 - 35pp,
DOI: http://dx.doi.org/10.1103/PhysRevD.92.072001
http://arxiv.org/abs/1507.05493

Search for massive, long-lived particles using multitrack displaced vertices or displaced lepton pairs in pp collisions at root s=8 TeV with the ATLAS detector, Phys. Rev. D 92, 072004 - 37pp,
DOI: http://dx.doi.org/10.1103/PhysRevD.92.072004
http://arxiv.org/abs/1504.05162

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BOOKS

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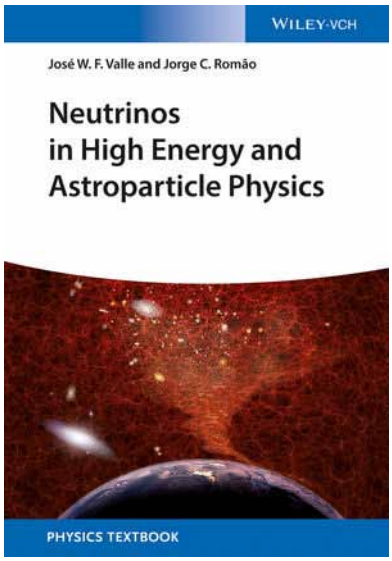
ISBN: 9783527411979



The Minkowski and Conformal Superspaces
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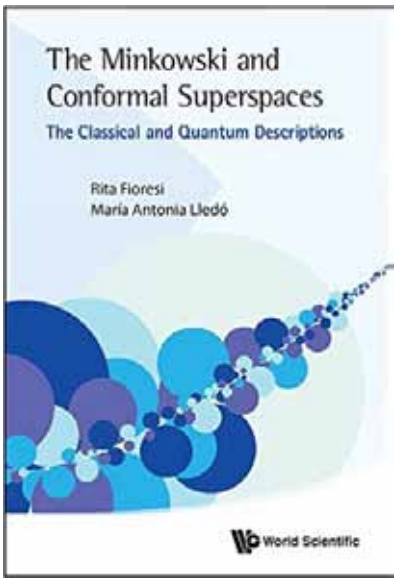


4. TRAINING

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 former, 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).

PHD THESES

Experimental Physics

A Silicon Strip Detector for the Phase II High Luminosity Upgrade of the ATLAS Detector at the Large Hadron Collider
Carlos García Argos
Advisors: Carlos Lacasta Llácer, Stephen J. McMahon
8 January, University of Valencia
TESEO: 1129314

The NEXT experiment for neutrinoless double beta decay searches
Justo Martín-Albo Simón
Advisor: Juan José Gómez Cadenas
16 February, University of Valencia
TESEO: 1134465

The NEXT experiment for neutrinoless double beta decay searches
David Lorca Galindo
Advisor: Juan José Gómez Cadenas
15 May, University of Valencia
TESEO: 1152885

First measurement of beta-decay half-lives and neutron emission probabilities in several isotopes beyond N=126
Roger Caballero Folch
Advisors: César Domingo Pardo, Guillem Cortés Rossell
5 June, Polytechnic University of Catalonia
TESEO: 1198569

Study of a High-Resolution PET System Using a Silicon Detector Probe
Karol Brzezinski
Advisors: Magdalena Rafecas López, José Francisco Oliver Guillén, John Gillam
18 June, University of Valencia
TESEO: 1164831

Study of a High-Resolution PET System Using a Silicon Detector Probe
Francisco Javier Egea Canet
Advisors: Andrés Gadea Raga, Vicente González Millán
18 September, University of Valencia
TESEO: 1180611

Search for high energy cosmic muon neutrinos from variable gamma-ray sources and time calibration of the optical modules of the ANTARES telescope
Agustín Sánchez Losa
Advisors: Juan José Hernández Rey, Damien Dornic
25 September, University of Valencia
This PhD has been awarded with the GNN prize, sponsored by APPEC
TESEO: 1181361

Measurement of the muon atmospheric production depth with the water Cherenkov detectors of the Pierre Auger Observatory
Laura Molina Bueno
Advisors: Antonio Bueno Villar, Sergio Pastor Carpi
25 September, University of Granada
TESEO: 1182999

Development of stripline kickers for low emittance rings: Application to the Beam Extraction Kickers for CLIC Damping Rings
Carolina Belver Aguilar
Advisors: Ángeles Faus-Golfe y Fernando Toral Fernández
22 October, University of Valencia
TESEO: 1185516

Muon neutrino charged current quasi-elastic interactions in the T2K off-axis near detector
Laura Monfregola
Advisor: Anselmo Cervera Villanueva
27 October, University of Valencia
TESEO: 1185684

Theoretical Physics

Theoretical foundations and applications of the Loop-Tree Duality
Sebastian Buchta
Advisor: Germán Rodrigo García
18 September, University of Valencia
TESEO: 1180257

An Effective Field Theory study of heavy meson-heavy antimeson molecules based Heavy Quark Symmetries
Carlos Hidalgo Duque
Advisor: Juan M. Nieves Pamplona
23 October, University of Valencia
TESEO: 1183485

5. CONFERENCES, SEMINARS AND COLLOQUIA

CONFERENCES AND MEETINGS

IFIC researchers present their results in the main international conferences and workshops. A total of 342 contributions were presented in 2015: 313 talks (24 invited) and 29 posters. Here we highlight conferences and workshops organized by IFIC members in Valencia or elsewhere:

Sixth Top LHC Working Group Workshop, January 2015, CERN.

ANTARES/KM3NeT Collaboration Meeting, 23-27 February.

XVII Face To Face Meeting of the Spanish ATLAS Tier-2, 23-24 April.

ATLAS Event Index Workshop, 18-20 May.

Seventh Top LHC Working Group Workshop, May 2015, CERN.

1st Hadron Spanish Network Days and Spanish-Japanese JSPS Workshop, 15-17 June.

First Workshop on String Theory and Gender, 6-7 July.

3rd BRIKEN Collaboration Meeting, 22-24 July.

Collider Physics in Mexico, 17-23 September.

16th AGATA Week, 22-24 September.

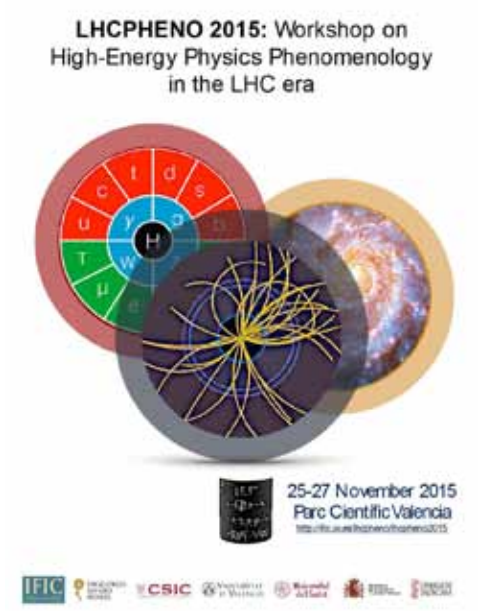
XVIII Face to Face meeting of the Spanish ATLAS Tier-2, 19-20 November.

Fourth Workshop on Flavour Physics in the LHC era (REFIS), 23-25 November.

LHCPHENO 2015: Workshop on High-Energy Physics Phenomenology in the LHC era, 25-27 November.

Eigth LHC Top Working Group Workshop, November 2015, CERN

IVICFA's Fridays, series of Mini-workshops: Earth Science & High Pressure (8 September), Theoretical Physics I (18 September), Astronomy (25 September), Experimental Physics (2 October), Medical Physics (16 October), Theoretical Physics II (23 October), Computing in Physics (30 October).



IFIC COLLOQUIA

Colloquia are review talks about a research topic for a general audience of IFIC members. The complete list can be found at the IFIC's Indico webpage.

Organizers: Germán Rodrigo and José Luis Taín.

Del laboratorio a primera página
Miguel G. Corral (diario El Mundo)
4 February

Desde el laboratorio a la aplicación industrial
Prof. Avelino Corma (Instituto de Tecnología Química ITQ (UPV-CSIC Valencia))
20 February

Ciencia y redes sociales ¿capricho o necesidad?
Prof. José Miguel Mulet (Instituto de Biología Molecular y Celular de Plantas IBMCP)
24 April

Celebrating Quarkonium: The First Forty Years
Prof. Chris Quigg (Fermilab and École Normale Supérieure, Paris)
8 May

Looking for Majorana at the LHC
Prof. Goran Senjanovic (Gran Sasso Science Institute, L'Aquila and International Centre for Theoretical Physics ICTP)
12 May

Towards creating a universe in the laboratory
Prof. Valery A. Rubakov (Institute for Nuclear Research of the Russian Academy of Sciences, Moscow)
18 September

CERN accelerators, the discovery of the Higgs' Boson and Medical Applications
Prof. Stephen Myers (CERN)
16 October

Neutrino Masses and Mixing Angles: a tribute to Guido Altarelli
Prof. Ferruccio Feruglio (Università degli Studi di Padova - INFN Sezione di Padova)
23 October

Phases of Strongly Interacting Matter - From Quarks to Nuclei and Neutron Stars
Prof. Wolfram Weise (Technische Universität München and ECT, Trento)
4 November

IFIC SEMINARS

Seminars are more specific research talks given by an invited speaker, usually connected to one of the IFIC research groups. Some of them are more informal talks followed by a discussion session, such as those within La Trobada or Student Seminars series. In 2015 we hosted a total of 101 seminars (some of them webinars). The complete list can be found at the IFIC's Indico webpage.

Organiser: Andrea Donini

In 2015 IFIC researchers presented 342 contributions in the main international conferences, 313 talks and 29 posters

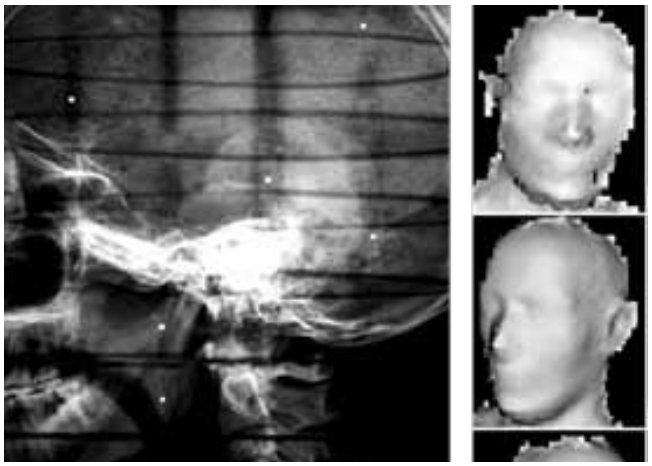
6. TECHNOLOGY TRANSFER

In the area of medical devices several activities have been carried out with the Industry in terms of patent licensing:

– The work related with WO2014020202A1 (Device and method for obtaining densitometric images of objects by combination of X-ray systems and depth-sensing cameras), an international patent between CSIC-UPV-UVEG, which is also producing publications and interest in the local health sector. This patent is now a European and US Patent.

– The patent PCT/ES2016/070216 (Device to extract 3D information from X-ray images and details of its calibration protocol) which was promoted by CPAN and granted with a valorisation help provided by VLC-BIOMED, is also being transferred to the productive sector, and now is being licensed to IST-Medical. Recently this patent has been examined by the PCT committee.

All this work has been developed together with recognized public and private local Healthcare institutions, and can lead to important advantages in terms of dose assignment reduction and cost effective solutions, being a good example of the benefits obtained from collaborations between applied research and the productive health sector.



The image shows an antropomorphical standard phantom, provided by the Hospital La Fe and used for the precise verification of three dimensional locations based on the geometrical processing of the parallel acquired patient surface. This verification is done using fiducial opaque markers.

In the area of data analysis, IFIC-CSIC-UVEG-UPV and a power retailer company based in Valencia (devoted to commercialization of electric power in the Spanish sector), have signed a license an exploitation agreement in the field of DAAS (Data As A Service) providing precise daily forecasting of the energy consumption.

Within the R+D contract between IFIC and ENRESA -the national company for nuclear waste management-, technology and methods already developed for experimental research in nuclear structure are being transferred and applied to the field of nuclear waste management and decommissioning of power plants and contaminated areas. The project aims at the development and implementation of a novel gamma-ray imaging spectrometer, which features high efficiency, high energy resolution and very large field of view. This innovative detection system is expected to play a key role both in low- and medium-level radioactive waste management, as well as for the decommissioning of the José Cabrera nuclear power plant, which is the first power station worldwide that will be fully decommissioned.

IFIC also provided services on LHC consolidation work to CERN under collaboration agreement no KE2023/TE, and engineering consulting advice for the same aim under collaboration agreement no. KE2022/TE.

IFIC has developed, in collaboration with the company ALIBAVA SYSTEMS, S.L. (spin-off of CSIC) and CNM-IMB, a system to teach students the principles of operation of silicon detectors, the Alibava Educational System (EASY). The system can be configured to work with laser light or radioactive sources. The set-up is ideal for making basic or complex experiments with silicon micro-strip detectors and readout electronics similar to the ones used in the actual High Energy experiments. This work has been protected in KNOW HOW 20160150.

7. OUTREACH

IFIC participates and organises many activities of science dissemination that would not be possible without an active involvement of the members of the Institute. These activities range from public talks outside our facilities to opening the doors of our laboratories, and are aimed both to the general public and to the educational community. Two people at IFIC coordinate and conduct these activities: Isidoro García, who manages mostly our relation with journalists and press offices of other institutions, and Alberto Aparici, who deals with activities and materials aimed at students and the general public.

OUTREACH MATERIALS

Web of IFIC

Starting in 2015 we began to produce non-technical articles for our webpage. A slider in the front page of our web highlights four topics related to our research and links to brief texts that explain the matter in further detail. These articles are written by members of IFIC and are aimed at a science-related public, from undergraduate students to fellow scientists working in other areas.

In 2015 these articles cover the design of hardware for future accelerators, the investigation of hadronic molecules, the search for dark matter in neutrino telescopes, the measurement of the mass of the top quark, the phenomenology of two-Higgs-doublet models, the centennial of General Relativity, the search for neutrinoless double beta decay in the NEXT experiment and anomalies in flavour physics observables.

IFIC leaflet

A short leaflet describing the activities of IFIC was produced in 2015. It acts as a business card of the institute and is available for visitors at several locations at IFIC.

Books

Jesús Navarro published two books aimed at the general public on two physics topics of the 20th century. *Las constantes universales* discusses the importance of units in physics and how some constants can capture the fundamental essence of a physical theory. *Landau. La superfluidez: la física que surgió del frío* is an account of the work of Lev Landau on superfluidity and how the dynamics of quantum mechanics gives rise to collective phenomena at low temperatures.

Additionally, José Adolfo de Azcárraga contributed with one chapter to the book *La reforma del Régimen Jurídico Universitario*. The chapter discusses the Expert Committee Report issued in 2013 about the university reform, and it is titled *La reforma universitaria: una defensa del Informe (12-feb-13) de la Comisión de Expertos con reflexiones personales, datos y notas históricas para el futuro*.

Science communication Colloquia

As part of the programme of IFIC Colloquia two of them were dedicated to different aspects of the communication of science. Miguel González Corral, science journalist at El Mundo, offered a panorama about the task of a science specialist within a newspaper, and how the scientist viewpoint differs or coincides with that of the journalist. José Miguel Mulet, biotechnologist at the Instituto de Biología Molecular y Celular de Plantas and science writer, talked about internet as an outreach vehicle and the role of the social media in establishing a link between the scientist and the general public.

OUTREACH ACTIVITIES

Guided tours for students

The institute offers guided tours to our facilities for groups of students interested in particle physics. This tours, usually spanning a whole morning, include an talk introducing some particle physics concepts and the research lines of IFIC, followed by a visit to our outreach material in the experimental research building (cloud chamber, ATLAS Lego model, LHC photocall). After a coffee break and lunch the tour continues with visits to two or three of our laboratories.

The available labs for the tours are ANTARES/KM3NET, NEXT, ATLAS-Silicon, ATLAS-TileCal, Medical Physics, GRID-Computing centre and Gamma Spectroscopy, with the laboratory of Future Colliders joining the group in 2015. Alberto Aparici is the main responsible and coordinator for these visits, and usually he also plays the role of maître-de-cérémonie, but each laboratory provides one or two people who can share their expertise with the students during their visit to the labs. Twenty-nine members of IFIC contributed to the tours during 2015. The total number of visiting schools in 2015 was eighteen, from towns all over our region: Valencia, Sagunto, Cheste, Villena, La Vall d'Uixó, Almàssera, Alaquàs, Puçol, Meliana, Manises, Picassent, Xirivella and Aldaia. Many of them were arranged together with the local delegation of CSIC in the Valencian Community, which sponsors the program *Conciencia Sé* to connect CSIC research centres and high schools.

Apart from the usual tours IFIC started in 2015, a collaboration with Observatori Astronòmic, another research institute in the Science Park of the University of Valencia. By means of this collaboration the staff of Observatori brings some of their own guided tours to the experimental building of IFIC, and there they receive a short talk about particle physics and can see our outreach material. In December 2015 three schools visited IFIC as part of this program, from Alfafar, Alboraia and Alzira.

We also were pleased to receive some special visits during this year. We hosted our first elementary school tours, which were a gleeful success, and in summer we also welcomed the young students from VLC/Campus and High School #1517 from Moscow, whose visits have already become a tradition. Besides those, we were also pleased to host visits from La Nau Gran, the senior programme of the University of Valencia, and RED Proyecto Social, an association that promotes activities for people with functional diversity.

Overall, in 2015 we hosted more than 600 visitors, doubling the figures of the previous year.

In 2015, IFIC hosted more than 600 visitors, doubling the figures of the previous year

International Masterclasses

Every year since 2005 CERN promotes the organisation of the *Hands On Particle Physics International Masterclasses*, a series of events that gather together high school students from all over the world to learn about particle physics by analysing real data from the experiments at CERN. IFIC participates since the very beginning, and in 2015 for the first time hosted two masterclasses: one about the ATLAS experiment (March 10th) and another about the LHCb experiment (March 25th).

The masterclasses are held at the facilities of IFIC and at the Faculty of Physics on Campus de Burjassot. The participating students, accompanied by their teachers, gather at the Campus and spend the rest of the day together. The schedule of a masterclass includes several talks introducing basic concepts of the Standard Model and of experimental particle physics, and then a practical exercise that manages real data from the LHC experiments. In the ATLAS masterclass the exercise aims at probing the quark structure of the proton and trying to identify possible Higgs boson decays. In the LHCb masterclass the aim is to measure the lifetime of the D^0 meson.

After the exercise the group prepares for lunch, and in the afternoon the obtained results are discussed and interpreted. The masterclass comes to an end with a videoconference where the students can share their results with other participants in different countries that have worked through the same exercise. One or two experts at CERN act as masters of ceremonies and discuss how the results change when more data are put together.

In 2015 a total of 68 students participated in the masterclasses of IFIC, 34 for each session, from 25 different high schools all over Comunitat Valenciana, accompanied by 27 teachers. 20 members of IFIC were involved in the different tasks, from logistics to lecturing.

Marie Curie Exhibition

In May 2015 IFIC hosted an exposition sponsored by CSIC about the life, scientific achievements and social activism of Marie Skłodowska Curie. The exposition included a series of placards that highlighted several episodes of Curie's personal and professional life, including her visits to Spain in the first decades of the 20th century. More than 170 people attended the exposition within a program of on-demand visits carried out by IFIC, apart from an undetermined number of visitors, at the level of hundreds, during the Expociència event (see below).

A series of three conferences about Curie's achievements and legacy were organised in the context of the exposition, featuring Jorge Velasco, research professor of CSIC at IFIC, Berta Rubio, head of the Experimental Unit of IFIC, and Belén Yuste, commissioner of the exposition. The conferences were attended by tens of people at the conference room of Parc Científic.

68 students participated in the masterclasses of IFIC from 25 schools all over Comunitat Valenciana

Expociència 2015

Every year around the end of May Parc Científic organises Expociència, an open door day in the context of which many science outreach activities and demonstrations are performed. In 2015 more than 4,500 people attended the event, visited the facilities

of Parc Científic and swarmed around more than 50 different stands whose activities ranged from robotics to food science. IFIC contributed with six activities, including a videoconference from Laboratorio Subterráneo de Canfranc, where the NEXT experiment is installed, and the Marie Curie exposition of CSIC, which was open to the public during the whole event. Overall, more than 30 members of IFIC were involved in the organisation, logistics and execution of Expociència activities.

Activity	IFIC members involved
Telescopios de neutrinos: observando el universo desde las profundidades del mar	I. Olcina, A. Sánchez, C. Tönnis, J. Zornoza, J. Zúñiga
Cocinando en el Ártico	V. Álvarez, J. Renner, D. Calvo
ATLAS, un gigante para atrapar partículas	C. García, S. González, S. Cabrera, P. Fernández, L. Barranco, S. Pedraza, D. Rodríguez, A. Valero, D. Álvarez, P. Fernández
¿Somos radiactivos?	S. Orrigo, J. Agramunt, V. Guadilla, A. Montaner, J.L. Taín, E. Valencia, A. Tarifeño
Marie Curie exhibition	P. Fernández, M. Tórtola, G. Sborlini
Videoconference with Laboratorio Subterráneo de Canfranc	F. Monrabal, A. Aparici

100xCiencia

In October 2015, the Severo Ochoa Excellence Centres organised a symposium specifically devoted to science communication and outreach, 100xCiencia. All Severo Ochoa Centres gathered at the event, and topics such as institutional science communication and policies for the use of the social media were discussed. The symposium also allowed for meetings of science journalists with the representatives of the centres and fruitful discussions about how scientists and journalists differ and coincide in their notions of science communication. IFIC was represented by the Director, Juan José Hernández Rey, one of the members of the Steering Committee of the Severo Ochoa project, Sergio Pastor, and the two members of the Communication Department, Isidoro García and Alberto Aparici.

The Director offered a plenary talk about the science endeavour of IFIC and participated in a debate with the representatives of other physics Severo Ochoa centres, whereas Alberto Aparici took part in the Round Table on the Role of Science in the Media.

Pint of Science

Pint of Science is an international festival that aims at transforming pubs into public forums of discussion of science. In Valencia it is sponsored by the Town Council by means of the InnDEA Foundation. The researcher of IFIC Miguel Ángel Sanchis was the physics coordinator of Pint of Science Valencia in 2015. Five members of IFIC offered talks in the 2015 edition within a joint session entitled From Quarks to Dark Matter: José Valle, Susana Cabrera, Miguel Ángel Sanchis, Francesc Monrabal and Gabriela Barenboim. The pub received a massive attendance, with more than 70 people.

Experimenta

Every year the Faculty of Physics of the University of Valencia calls the Experimenta Exhibition-Contest, an event aimed at high school students for which they develop a project in basic science or technology with the help of their teachers. The projects are shown in a public exhibition where the students themselves explain the science within, and then they are evaluated by a jury and four winners are selected. Several members of IFIC participate in the event: Jordi Vidal was part of the organising committee; Juan Zúñiga, Miguel Ángel Sanchis, Fernando Martínez and Pedro González acted as jurors the day of the public exhibition.

eXPERimenTA
X Fira – Concurs de Física i Tecnologia

Collaboration with the Thyssen-Bornemisza Museum

In the context of the Invisibles network, of which several researchers at IFIC are members, two collaboration projects were carried out with the Thyssen-Bornemisza Museum in Madrid: the exhibition *Miradas Cruzadas*, which aimed at highlighting the connections between art and science in the past two centuries, and the *Arte y Ciencia* meetings, which brought together artists and scientists to discuss the different notions of space and time and the creation process in art and science. Olga Mena, staff scientist of CSIC at IFIC, was the outreach coordinator of the network along 2015.

PUBLIC LECTURES

During 2015, IFIC scientists gave 30 public lectures and 28 talks at high schools

CPAN Talks at High Schools

The Centro de Partículas, Astropartículas y Nuclear (CPAN) encourages its member institutions to offer outreach talks to local high schools and coordinates their organisation. In 2015 IFIC offered 28 such talks on three different topics: LHC physics, astroparticles and applications of nuclear physics. Overall, 13 members of IFIC participated in this activity.

Topic	Location	Speakers
LHC Physics	Valencia, Godella, Ontinyent, Alicante, Manises, La Vall d'Uixó, Burjassot, Massanassa, San Antonio de Benagéber, Tarragona	C. García, E. Torró, S. Martí, S. González
Astroparticles	Valencia, Burjassot, Manises, Cheste	S. Pastor, M. Tórtola
Nuclear Physics	Valencia, Cheste, Alcàsser, Sagunto	C. Domingo, J.L. Taín, A. Montaner, B. Rubio, A. Algora, V. Guadilla, S. Orrigo

Other public talks

During the year 2015 several members of IFIC gave a total of 30 public lectures, mainly about high energy physics and neutrino physics, for various official or casual gatherings.

A. Aparici, *Cien años curvando el espacio-tiempo*, Conference at Universidad Internacional de la Rioja, Conference at CEIP El Molí (Torrent).

J.J. Gómez Cadenas, *Paisaje con neutrinos/Paisaje sin neutrinos*, Conference at Donostia International Physics Center; Conference at Facultad de Física (University of Valencia); Seminar at Departamento de Física INFN-Università di Cagliari.

J.J. Gómez Cadenas, *Civilizaciones galácticas*, Café de Ciencias (Campus de Burjassot, University of Valencia).

A. Pich, *Y después del Higgs, ¿qué?*, Ciencias de la Vida y de la Materia (Fundación Ramón Areces, Madrid).

C. García, Las partículas elementales y el origen de su masa, Ciudad Ciencia (Villena).

A. Pich, *Flavour & Electroweak Symmetry Breaking*, GK Seminare SS 15 (RWTH Aachen University).

S. Pastor, *Neutrinos: partículas fantasma*, Conference at Universidad de Salamanca; Conference at Universidad de Granada.

J.A. de Azcárraga, *Física y Matemáticas, una unión fructífera*, Temas de Actualidad en Ciencias (La Nau Gran senior programme, University of Valencia).

A. Pich, *El bosón de Higgs: una ventana en la frontera del conocimiento*, Conference at the Centennial of Colegio Mayor San Juan de Ribera (Universitat Politècnica de València).

A. Aparici, *Materia oscura,* Birra y Ciencia (Olhöps Craft Beer House, Valencia).

M.A. Sanchis Lozano, *Los límites del conocimiento,* Escépticos en el Pub (Valencia).

S. González de la Hoz, *El mago de las estrellas*, Talk at Colegio San José (Ontinyent).

J. Zornoza, *ANTARES and KM3NeT: the sight of the neutrino sky from the Mediterranean*, Seminar at Université libre de Bruxelles.

A. Aparici, *Una vida de ciencia*, 4th International Conference on the Elderly and New Technologies - Technology on the Go (Sant Mateu).

J.J. Hernández Rey, *Los neutrinos: los nuevos mensajeros del espacio*, Conference of International Year of Light (Institut d'Estudis Catalans, Barcelona).

C. Lacasta, *Detectors for Health*, CERN: el laboratorio de física de partículas en España (Universidad Internacional Menéndez y Pelayo, Mallorca).

A. Aparici, *Plutón, mon amour*, Astronomía en el Castillo (Almansa), Mes de Iniciación a la Astronomía de la AAUV (University of Valencia).

J.A. de Azcárraga, *Einstein: Su siglo y su ciencia*, Conference cycle Arquitectura Cósmica III: La Gravitación Einsteniana (Fundación Valenciana de Estudios Avanzados).

J.J. Gómez Cadenas, *Search for Dark Matter and Neutrinoless double beta decay at the Canfranc Underground Laboratory*, Conference at Centro de Luz Sincrotrón ALBA (Cerdanyola del Vallès)

J.A. de Azcárraga, *La teoría de la evolución: qué es y por qué es relevante en el mundo actual*, Conec Talks (Fundación Cañada Blanch, Valencia)

C. Peña Garay, Astronomía de neutrinos, Astronomía en el Museo (Museo de las Ciencias Príncipe Felipe, Valencia).

J. Fuster, *La física del bosón de Higgs y los nuevos retos que plantea: científicos y tecnológicos*, Semana de la Ciencia UPV Alcoi 2015.

J. Navarro Salas, *Relatividad general y Teoría Cuántica: de Einstein a Hawking*, Conference cycle Arquitectura Cósmica III: La Gravitación Einsteniana (Fundación Valenciana de Estudios Avanzados).

A. Pich, *Del conocimiento a la innovación*, Global ImasT (University of Valencia).

S. Pastor, *Premio Nobel de Física 2015: neutrinos, las partículas camaleónicas*, Conference cycle "Hablemos de Física" (Universidad Complutense de Madrid).

Additionally, Alberto Aparici collaborated with the senior programme of the University of Valencia, La Nau Gran, and in that context he offered seven short talks during the year 2015, with the following topics: the perception of light by the human eye, the violation of time-reversal invariance, dark matter, the speed of light in special relativity, the discovery of liquid water on Mars, geochemistry and the origin of life and the 750 GeV diphoton excess at the LHC. These talks had an average attendance of around 100 people.

IFIC IN THE MEDIA

In 2015 IFIC participated in the production of 76 pieces for several media, from newspapers to television. Some of them were produced directly by members of IFIC and others were the result of interviews or press releases issued by the outreach office of the institute.

Written articles

The institute produced 22 press releases during 2015. All of them were echoed by the University of Valencia and CSIC in Comunitat Valenciana on their web sites. Some of them reached the media, either on physical paper or online. Here are some examples:

El Instituto de Física Corpuscular recibe 4 millones para investigación, Levante

La física de partículas pone cerco al cáncer, Levante

Un investigador de la UV, miembro español en el comité para futuros aceleradores de partículas, La Vanguardia

Valencia conoce los secretos del Colisionador de Hadrones del CERN, Las Provincias

El CERN descubre un nuevo tipo de partícula: el 'pentaquark', elconfidencial.com

Científicos internacionales se reúnen en Valencia para debatir sobre la puesta en marcha del detector de partículas NEXT, El Economista

El experimento LHCb mide por primera vez un parámetro fundamental de la física de partículas con bariones, El Día

El Instituto de Física Corpuscular participa en el desarrollo de un detector para la investigación en física nuclear, El Día

El IFIC organiza un encuentro para analizar el papel de la mujer en la investigación en teoría de cuerdas, elperiodic.com

Científicos internacionales se reúnen en el IFIC para discutir sobre la puesta en marcha del detector de partículas NEXT, elperiodic.com

Miden en el laboratorio la velocidad de reacciones nucleares en supernovas, NCYT-Amazings


El Instituto de Física recibe 4 millones para investigación

► El IFIC ha sido reconocido como «Centro de Excelencia» por sus avances e el estudio del bosón de Higgs o de los neutrinos como mensajeros cósmicos

La Fe y la UPV lanzan la nanomedicina

Juan José Hernández Rey

«El gran acelerador nos lleva a un territorio inexplorado»

EN CORTO

La física de partículas pone cerco al cáncer

LAS CLAVES

sociedad

El LHC roza el universo desconocido

Preguntas por responder

Radio pieces

A. Pich, Interview on the LHC Run II, RNE

J. Salt, LHC and the Grid, Interview on particle physics, Gestiona Radio

J.J. Gómez Cadenas, Interview on the Nobel Prize in Physics 2015, RNE

A. Aparici, 41 radio pieces about different science topics in the show La Brújula de la Ciencia, Onda Cero

TV pieces

IFIC was featured in the show *La Fábrica de Ideas*, that airs on La 2 de TVE. The contributors for this piece were J.J. Hernández Rey, A. Pich, J.J. Gómez Cadenas and M.J. Costa. The piece can be found on this link.

Articles authored by IFIC members

A. Pich, *Una ventana en la frontera del conocimiento*, El Mundo

F. Botella, *Reconocimiento a los físicos*, Levante

A. Pich, *Muchas preguntas por responder*, El País

J.J. Gómez Cadenas, *Los neutrinos y la primera batalla en la historia del Universo*, El Mundo

J.A. de Azcárraga, *La I+D, otra vez*, El País

M. Vos, M. Villaplana, *El quark cima se pone en movimiento*, Investigación y Ciencia

A. Aparici, *¿De qué está hecho el universo? El Cúmulo Bala, Harry Potter y la materia oscura*; *El champán contra la gomina: química para entender las erupciones volcánicas*; *Una pesadilla electoral: las elecciones al parlamento infinito*; *Plutón, mon amour (I): el planeta destronado*, Jot Down

J.J. Gómez Cadenas, *Entrevista a Daniel Monzón; Las preguntas de Lilia; Ex_Machina: de dioses, grúas y pendejas; Entrevista a Álvaro Delgado-Dal; Réquiem por Mario*; Jot Down

M.A. Sanchis, *El festival Pint of Science llega a España*, Revista Española de Física

J.A. de Azcárraga, *La Residencia de Estudiantes, lugar histórico de la Sociedad Europea de Física*, Revista Española de Física

J.J. Hernández Rey, *Premio Nobel de Física 2015. T. Kajita y A.B. McDonald. El descubrimiento de las oscilaciones de neutrinos*, Revista Española de Física

A. Pich, *Y después del Higgs, ¿qué?*, Revista de la Fundación Ramón Areces

S. Pastor, *Premio Nobel de Física 2015: oscilaciones de neutrinos*, madrimasd.org

Social Media

2015 was characterised by a growth in followers and an increase in the interaction with them through the various social media we are engaged in. The scientific activities of IFIC, such as seminars, meetings, and especially colloquia and public conferences, were announced in our social profiles, on a weekly basis for Facebook and Google+ and on a daily basis for Twitter. In general terms a positive response from our public was observed when the posts discussed physics topics, especially if they had previously reached the media. We intensified our activity in YouTube by uploading more than 30 seminars and conferences, and the activity of the channel increased substantially.

Some details about each profile can be found below:

Our Facebook page reached more than 560 followers, doubling the figures of the previous year.

In Twitter we also doubled the followers, going beyond 500. We strengthened our links with the profiles of the University of Valencia and CSIC, and for a limited time we tried out a programme of micro-outreach, during which each week was devoted to certain particle physics topic and it was discussed through several tweets every day. The initiative found a good reception, but was rather time-consuming.

Our resources connected to Google platforms include our Google+ profile and our Google Maps page. Though G+ seems to have experienced a decrease in popularity throughout 2015, we have more than doubled our followers and we have supported the initiative of the Latin American Webinars on Physics, which is partly led from IFIC and is announced via G+. According to Google data, in 2015 IFIC received 50,000 search hits and our pictures in GMaps and G+ were visualised more than 50,000 times.

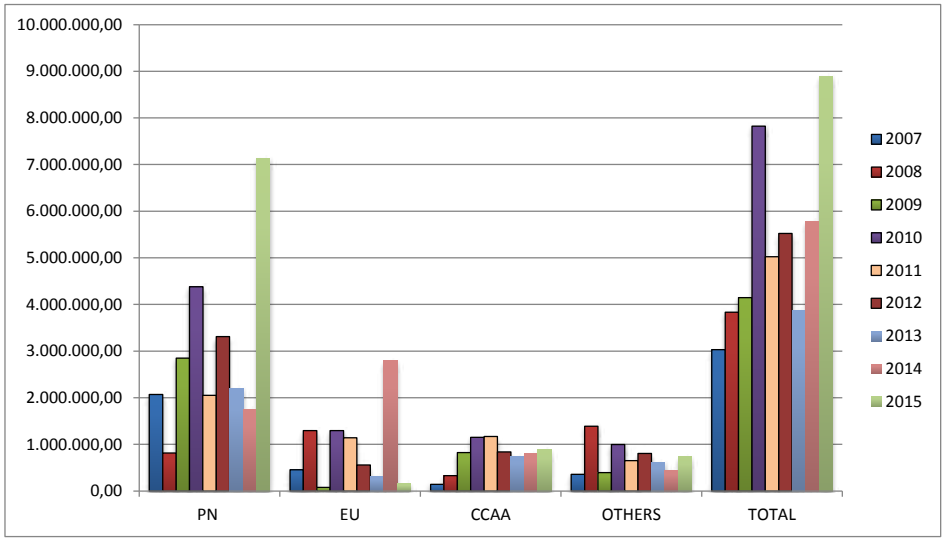
Our YouTube channel experienced a strong increase in subscriptions, going from less than 20 to more than 100, and the visualisations of our videos increased more than tenfold up to 7,600. 39 new videos were uploaded to the channel, with the most popular being the colloquium offered by José Miguel Mulet, followed by Antonio Pich's course on effective field theory.

Overall we observe a satisfactory performance on social media, but possibly our public is biased towards physics researchers and students and new initiatives could help in attracting the interest of other groups and attaining a wider outreach.

The social media profiles of IFIC grew in followers and interaction. Twitter and Facebook doubled the followers. More than 30 videos were uploaded to IFIC YouTube channel. In 2015, IFIC received 50,000 search hits on Google

8. FUNDING

In this section we include all research grants that were active during the whole or part of 2015, funded by European (EU), national (PN), regional (CCAA) or other agencies.



NATIONAL PLAN PROJECTS

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

Experimental Physics

Contribuciones al experimento ATLAS en el colisionador hadrónico LHC
Ref. FPA2012-39055-C02-01
PI: Carmen García García
1,064,700 € (Jan 2013 – Dec 2015)

Contribuciones al calorímetro hadrónico TILECAL de ATLAS
Ref. FPA2012-32843
PI: J. A. Valls Ferrer
477,360 € (Jan 2013 – Dec 2015)

Participación española en el experimento LHCB del CERN: Física y mejoras
Ref. FPA2013-48020-C3-2-P
PI: Fernando Martinez Vidal
78,650 € (Jan 2014 – Jun 2016)

Tier-2 Distribuido español para el experimento ATLAS (LHC) Fase 3 y su papel en la gestión y procesamiento de grandes cantidades de datos
Ref. FPA2013-47424-C3-1-R
PI: Jose Salt Cairols
1,252,350 € (Jan 2014 – Dec 2016)

Red de Física en el LHC y actualización de sus experimentos
Ref. FPA2015-71967-REDT
PI: Carmen García García
35,000 € (Jan 2015 – Nov 2017)

Desarrollo de nuevos detectores y estudios de física para futuros colisionadores lineales
Ref. FPA2013-48387-C6-5-P
PI: Juan A. Fuster Verdu
229,900 € (Jan 2014 – Dec 2015)

Participación en el desarrollo de nuevas tecnologías en aceleradores para los futuros colisionadores en física de partículas
Ref. FPA2013-47883-C2-1-P
PI: Angeles Faus Golfe
72,000 € (Jan 2014 – Dec 2015)

Detectores para aplicaciones médicas
Ref. FPA2014-53599-R
PI: Gabriela Llosa Llácer
30,250 € (Jan 2015 – Dec 2017)

Construcción, operación e I+D+i para el experimento NEXT en el LSC
Ref. FIS2014-53371-C4-1-R
PI: Juan Jose Gomez Cadenas
895,400 € (Jan 2015 – Dec 2018)

Proyecto NEXT: medida de energía y trayectorias
Ref. FIS2012-37947-C04-03
PI: José Díaz Medina
119,340 € (Jan 2013 – Dec 2015)

Espectrómetro portátil de xenon a alta presión para rayos gamma y neutrones
Ref. FPA2014-61149-JIN
PI: Nadia Yahlali
169,100 € (Jan 2015 – Dec 2017)

Participación en el experimento T2K
Ref. FPA2011-29823-C02-01
PI: Anselmo Cervera Villanueva
281,325 € (Jan 2012 – Sep 2015)

Participación en el experimento T2K
Ref. FPA2014-55454-P
PI: Anselmo Cervera Villanueva
41,745 € (Jan 2015 – Dec 2016)

Participación del IFIC en los telescopios de neutrinos ANTARES y KM3NET
Ref. FPA2012-37528-C02-01
PI: Juan Jose Hernandez Rey
237,510 € (Feb 2013 – Dec 2015)

Estructura nuclear, aplicaciones y Astrofísica: el camino hacia FAIR
Ref. FPA2011-24553
PI: Alejandro Algora
644,930 € (Jan 2012 – Dec 2015)

Estudios de desintegraciones beta y de reacciones para la estructura nuclear, astrofísica y aplicaciones
Ref. FPA2014-52823-C2-1-P
PI: Alejandro Algora
423,500 € (Jan 2015 – Dec 2017)

Espectroscopía gamma de alta resolución: el camino hacia AGATA
Ref. FPA2011-29854-C04-02
PI: Andrés Gadea Raga
356,950 € (Jan 2012 – Jun 2015)

Estructura nuclear en núcleos exóticos: Experimentación, estudios teóricos y desarrollos instrumentales para AGATA
Ref. FPA2014-57196-C5-1-P
PI: Andres Gadea Raga
187.550 € (Jan 2015 – Dec 2017)

Demostración de principio para medidas de reacciones de nucleosíntesis estelar con alta sensibilidad de detección
Ref. FPA2015-71688-ERC
PI: César Domingo Pardo
60,000 € (Jan 2015 – Dec 2016)

Apoyo a Centros Excelencia Severo Ochoa
Ref. SEV-2014-0398
PI: Juan J. Hernandez Rey
4,000,000 € (Jul 2015 – Jun 2019)

Theoretical Physics

Teorías efectivas en física nuclear y de hadrones
Ref. FIS2011-28853-C02-02
PI: Juan M. Nieves Pamplona
163,350 € (Jan 2012 – Dec 2015)

Teorías efectivas en física nuclear y de hadrones
Ref. FIS2014-51948-C2-1-P
PI: Juan M. Nieves Pamplona
159,720 € (Jan 2015 – Dec 2017)

Fenomenología de física de partículas en el LHC y las factorías del sabor
Ref. FPA2011-23778
PI: Antonio Pich Zardoya
372,680 € (Jan 2012 – Dec 2015)

Física de Partículas en el LHC y las factorías de sabor
Ref. FPA2014-53631-C2-1-P
PI: Antonio Pich Zardoya
231,110 € (Jan 2015 – Dec 2017)

Red para el estudio de las iniciativas de Física de Partículas, Astropartículas y Nuclear: Participación Española en Grandes Infraestructuras y Experimentos Internacionales
Ref. FPA2014-52623-REDT
PI: Antonio Pich Zardoya
30,000 € (Dec 2014 – Nov 2016)

Interacciones fundamentales y sus implicaciones experimentales
Ref. FPA2011-23596
PI: Francisco J. Botella Olcina
450,120 € (Jan 2012 – Dec 2015)

Física Nuclear y de Hadrones a energías Intermedias
Ref. FIS2011-28853-C02-01
PI: Manuel Vicente Vacas
212,960 € (Jan 2012 – Dec 2015)

Física Nuclear y de hadrones a energías intermedias
Ref. FIS2014-51948-C2-2-P
PI: Manuel Vicente Vacas
54,540 € (Jan 2015 – Dec 2017)

Estudios perturbativos y no perturbativos del modelo estandar y sus extensiones
Ref. FPA2011-23897
PI: Vicente Gimenez Gomez
152,460 € (Jan 2012 – Dec 2015)

Física Hadrónica, interacciones fundamentales y física nuclear
Ref. FPA2013-47443-C2-1-P
PI: Vicente Vento Torres
84,700 € (Jan 2014 – Dec 2016)

Partículas elementales: El modelo estandar y sus extensiones
Ref. FPA2014-54459-P
PI: Arcadi Santamaria Luna
349,690 € (Jan 2015 – Dec 2017)

Astropartículas y física de altas energías
Ref. FPA2011-22975
PI: J. Furtado Valle
258,940 € (Jan 2012 – Dec 2015)

Astropartículas y física de altas energías
Ref. FPA2014-58183-P
PI: Jose Furtado Valle
217,800 € (Jan 2015 – Dec 2017)

Red nacional Temática de Astropartículas
Ref. FPA2015-68786-REDT
PI: Sergio Pastor Carpi
35,000 € (Dec 2015 – Nov 2017)

Sabor y origen de la materia
Ref. FPA2011-29678-C02-01
PI: Pilar Hernandez Gamazo
249,260 € (Jan 2012 – Dec 2015)

Sabor y Origen de la materia
Ref. FPA2014-57816-P
PI: Pilar Hernandez Gamazo
164,560 € (Jan 2015 – Dec 2017)

Agujeros cuánticos, supergravedad y cosmología
Ref. FIS2011-29813-C02-02
PI: Maria Angeles Lledo
100,430 € (Jan 2012 – Dec 2015)

Gravitación y campos cuánticos
Ref. FIS2014-57387-C3-1-P
PI: Jose Navarro Salas
72,600 € (Jan 2015 – Dec 2017)

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)

With participation of IFIC groups:
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 – Jun 2017

OTHER NATIONAL PLAN PROJECTS

Impulso estratégico a la transferencia en el IFIC
Ref. PIE201350E50
PI: Juan Jose Hernandez Rey
288,000 € (Feb 2013 – Jun 2017)

Actualización de la computación y gestión de datos en GRID y e-Ciencia con aplicación a las investigaciones en Física del IFIC
Ref. PIE201350E57
PI: J. Salt Cairols
102,424 € (Mar 2013 – Feb 2016)

Torsion and non-metricity in gravitational structures
Ref. COOPB20105
PI: Gonzalo Olmo Alba
11,000.00 € (Jan 2015 – Dec 2016)

Desarrollo de un sistema de trazado basado en fotomultiplicadores de silicio para el experimento NEXT
Ref. COOPB20112
PI: Juan Jose Gomez Cadenas
20,000 € (Jan 2015 – Dec 2016)

Sabor y origen de la materia
Ref. 201550E088
PI: Pilar Hernandez Gamazo

8,000 € (Sep 2015 – Sep 2016)

Planck 2016: Desde la escala Planck hasta la escala electro-débil
Ref. FPA2015-62983-CIN
PI: Martin K. Hirsch
10,000 € (Jan 2015 – Dec 2017)

Estudio de patrones de registro neurologico en tareas de atencion y en programas de entrenamiento cognitivo
Ref.05-NEUTRAIN-BARENBOIM_SMEYERS_2014
PI: Gabriela Barenboim
4,000 € (Jan 2015 – Dec 2015)

Alineamiento temporal de sonda y escáneres comerciales
Ref. 18_A-TIME_LLOSA_BELLO_2014
PI: Gabriela Llosa Llácer
4,000 € (Jan 2015 – Dec 2015)

ERC PROJECTS

Towards the NEXT generation of neutrinoless double beta experiments
ERC Advanced Grant, Ref. 284518
PI: Juan J. Gómez Cadenas
2,791,776 € (Feb 2014 – Jan 2019)

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)

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)

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)

Research Training in 3D Digital Imaging for Cancer Radiation Therapy (ENTERVISION)
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)

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 2016)

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)

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)

TECHNOLOGY TRANSFER

Soporte para el desarrollo de componentes software y hardware de la solicitud de la patente P201231243
Ref. 20140379
PI: Germán Rodrigo Garcia
127,050 € (Dec 2013 – Jul 2016)

Convenio entre el CSIC, IFIC y la Empresa Nacional de Residuos Radioactivos, S.A. (ENRESA) para el desarrollo de un dispositivo para la identificación, cuantificación y distribución espacial de isótopos emisores gamma
Ref. 20145181
PI: César Domingo Pardo
301,332,97 € (Jul 2014 – Jul 2017)

Development of accelerator science and technologies associated with the CLIC accelerating structures design
Ref. 20158278

PI: Ángeles Faus Golfe
526,880 € (Jan 2015 – Mar 2018)

GRID DATA para diagnóstico radiológico
Ref. 20150484
PI: German Rodrigo Garcia
61,952 € (Feb 2015 – Jun 2016)

Convenio ADDF
Ref. 20146618
PI: Juan Jose Gomez Cadenas
23,716 € (Jan 2015 – Dec 2015)

REGIONAL PROJECTS

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

Experiment ATLAS en el RUN 2 del LHC: alineament i upgrade del detector intern. Física del Quark Top.
Ref. PROMETEOII/2014/016
PI: Salvador Martí Garcia
44,900 € (Jan 2015 – Dec 2015)

Desarrollos instrumentales para los detectores complementarios de AGATA: Actividad experimental para estudios de estructura nuclear con AGATA y sus detectores complementarios
Ref. PROMETEOII/2014/019
PI: Andres Gadea Raga
66,900 € (Jan 2015 – Dec 2015)

Aproximación teórico-experimental a la búsqueda de nueva física con sabores pesados
Ref. PROMETEOII/2014/049
PI: Francisco J. Botella Olcina
78,150 € (Jan 2015 – Dec 2015)

Sabor y origen de la materia
Ref. PROMETEOII/2014/050
PI: Nuria Rius Dionis
61,330 € (Jan 2015 – Dec 2015)

Estructura Quark de la materia
Ref. PROMETEOII/2014/066
PI: Santiago Noguera Puchol
38,120 € (Jan 2015 – Dec 2015)

Física Hadrónica y nuclear
Ref. PROMETEOII/2014/068
PI: Eulogio Oset Baguena
44,565 € (Jan 2015 – Dec 2015)

Astroparticulas y física de Altas Energías
Ref. PROMETEOII/2014/084
PI: Jose Furtado Valle
69,335 € (Jan 2015 – Dec 2015)

Telescopios de Neutrinos en el Mediterráneo
Ref. PROMETEOII/2014/079
PI: Juan J. Hernandez Rey
50,875 € (Jan 2015 – Dec 2015)

Estudios perturbativos y no perturbativos del modelo estandar y sus extensiones
Ref. PROMETEOII/2014/087
PI: Arcadi Santamaria Luna
32,565 € (Jan 2015 – Dec 2015)

FÍSICA DEL "LARGE HADRON COLLIDER": BÚSQUEDA DE NUEVAS INTERACCIONES EN LA FRONTERA DE ALTAS ENERGÍAS
Ref. PROMETEUII/2013/007
PI: Jose Bernabeu Alberola
115,000 € (Jan 2015 – Dec 2015)

DE LA FÍSICA DEL LHC A LAS CLAVES DEL UNIVERSO PRIMORDIAL EN LA ERA DE LOS DATOS
Ref. PROMETEUII/2013/017
PI: Antonio Pich Zardoya
100,000 € (Jan 2015 – Dec 2015)

2nd International workshop on top physics at future colliders
Ref. AORG2015/113
PI: Marcel Andre Vos
12,000 € (Jan 2015 – Dec 2015)

Participation in the Development of New Accelerator Technologies for Future Colliders in Particle Phisycs
Ref. ACOMP/2015/027
PI: Ángeles Faus Golfe
15,500 € (Jan 2015 – Dec 2015)

Física e I+D de Detectores para Futuros Colisionadores
Ref. ACOMP/2015/030
PI: Juan A. Fuster Verdú
20,000 € (Jan 2015 – Dec 2015)

Participación del IFIC en ANTARES y KM3NET
Ref. ACOMP/2015/033
PI: Juan J. Hernandez Rey
11,000 € (Jan 2015 – Dec 2015)

Proyecto NEXT-Medida de energía y trayectorias
Ref. ACOMP/2015/008
PI: Jose Díaz Medina
20,000 € (Jan 2015 – Dec 2015)

Equipamiento para el analisis de señales de alta velocidad
Ref. PPC/2015/004
PI: Juan J. Hernandez Rey
41,805.32 € (Jan 2015 – Dec 2015)

PowerEdge M620 servidor blade de DELL (CPU máquinas de cáculo) 20 unidades
Ref. PPC/2015/003
PI: Santiago Gonzalez de la Hoz
52,200 € (Jan 2015 – Dec 2015)

Soporte para el desarrollo de componentes de software y hardware de la solicitud de patente P201231242
Ref. APOTI/2014/010
PI: German Rodrigo Garcia
6,000 € (Jan 2015 – Dec 2015)

IFIC Projects in 2015:
8 European
1 ERC
46 National
2 Consolider
19 Regional
5 Technology Transfer
Almost 9 million income

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