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CSIC Consejo Superior de Investigaciones Científicas

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WELCOME

Welcome to this report in which the activities of IFIC during 2016 are summarised: you will find here the most relevant results of our institute.

It has become customary practice to measure the productivity of research by means of "indicators". If we strictly stick to "objective benchmarking", 2016 has been indeed a very good year for IFIC, with an increase in all the figures that measure our scientific output. But in addition to these indicators, one can see that progress is definitely being made in most of our undertakings and that the tremendous work and tireless enthusiasm of our scientists is bearing fruit.

One of the privileges of being director of an institute as IFIC is the opportunity to know in greater detail the activities of its scientists. When you know the ups and downs of the scientific projects, a side-effect is that, despite all the upsets and setbacks, you are joyfully surprised time and again with good news: publications of your scientists that receive special attention, difficult projects that are finally making good progress, the visibility and impact of your researchers in large and competitive collaborations, a prize awarded to one (or more!) of your scientists, etc. This is as satisfying as the increase in the productivity numbers, but if those numbers also bring along good news, you have a cushy job as director!

Since its restart in 2015, the LHC has been operating remarkably well, beating time after time its record peak luminosity and giving the opportunity to the experiments to collect precious data. IFIC participates in three experiments at the LHC: ATLAS, LHCb and MoEDAL. All three have benefited of this successful LHC operation in 2016.

The maintenance and operation of a sophisticated detector as ATLAS requires a continuous effort by the collaboration. IFIC scientists and engineers have contributed in several areas to such demanding (and sometimes not sufficiently recognised) task. For instance, with the increase in luminosity, the deformation of a certain component of the Inner Detector ("the insertable B-layer") required a continuous dynamical alignment, and the geometry constants of the Inner Detector had to be provided within 24 hours of data taking! An impressive deed. Likewise, the increased acceptance rate of the first level trigger (over 90 kHz) and the huge number of interactions per bunch crossing (over 40) required the permanent consolidation of the off-detector electronics of the TileCal, which is part of IFIC's responsibilities. The sizeable increase in luminosity also obliged to adapt the tracking subdetector's reconstruction software, a task in which our scientists were involved. The use of High Performance Computing in the ATLAS production system requires special care to make sure that the samples produced are good for physics. IFIC scientists chair the Technical Validation Task Force which is set up precisely to ensure that only good quality data reach the analysis.

All this is a tremendous amount of work that often goes unnoticed, but that is critical to the good operation of the detector and thus essential to obtain the eagerly awaited physics results. We feel proud to be part of this "humongous" endeavour.

We should not forget either that our GRID group has duly delivered the committed resources for 2016. As a matter of fact, the outcome of the external evaluation that the group underwent during 2016 has been extremely positive. Not in vain, the group is a reference and helps in the setting up and development of GRID sites in other countries. The Event Index Project, in which the group is involved, is currently running and in production.

Concerning physics in ATLAS, IFIC scientists were involved in a wide variety of topics in 2016, the testing of the Standard Model and the direct search for new physics being the main goals. Precision measurements on both the Higgs and Top quark sectors were provided by our researchers. It was nice to see the final combination of the Higgs boson couplings

measurements with the LHC Run 1 data, where IFIC had a special contribution in the first observation of the Higgs boson decay mode to two tau leptons, as well as the first cross section measurements at 13 TeV. On the top quark properties side, the group provided the most precise direct measurement of the top quark pole mass at the time and probed the top quark couplings by performing precise measurements of the top quark and W boson polarisation observables in the t-channel production mode as well as of the charge asymmetry in highly boosted top quark pair production.

IFIC researches also eagerly searched for new physics signals with the first 13 TeV data. They provided the first search for new heavy Higgs bosons and heavy gauge bosons Z' in the two tau leptons final state (which featured the cover of one issue of the European Physics Journal C) and carried on with the search for supersymmetry with particular emphasis on R-parity violating searches.

LHCb aims to discover new physics through the precise measurement of a variety of processes involving B hadrons. Several tensions point indeed to deviations from the SM, but it is still too early to reach conclusions. IFIC scientists are deeply involved in some of these analyses, in particular those related to radiative decays of heavy hadrons, as summarised in the corresponding section of this report. The IFIC group has measured for the first time the photon polarization in radiative decays of B_s hadrons. The group is involved as well in the upgrading of the detector, contributing in particular to PACIFIC, an integrated circuit that is essential for the proper readout of the new Central Track Detector SciFi of LHCb.

MoEDAL, the experiment that looks for highly ionising "avatars" is progressing in its research programme. Already with their prototype trapping detector, they have been able to set mass limits to high charge particles (a result that gave rise to a CERN press release). This analysis has been repeated in 2016 (with 2015 data), providing the world best limit on high charge monopoles.

While the data provided by the experiments at the LHC are being fully exploited, our scientists work at the same time on the upgrading of the detectors for the High Luminosity phase of the LHC. You can find in this report a description of the variety of tasks in which our groups are involved. Just as an example it is worth mentioning that the Valencia design of the mechanical assembly for the end-caps of the ITk strip detector was selected as the baseline solution. This a recognition of the outstanding work done by this team and IFIC's engineering services.

We also keep an eye on other accelerator options besides the LHC. Our scientists work on the physics potential of the ILC and of CLIC, in particular in studies related to the top quark. Detectors based on the DEPFET approach are being explored, linked in particular to the future ILD detector. Furthermore, we have a small, but exceedingly active group of scientists working on accelerator physics: they contribute to the optics design and beam instrumentation for future linear colliders and, besides their technical contributions, they hold important responsibilities in some of the test facilities of these accelerators, e.g. the Accelerator Test Facility at KEK, Tsukuba.

The group working on neutrino telescopes had a wealth of positive news in 2016. On the physics side, a new search for neutrino point sources led by IFIC physicists, in which cascade events were added for the first time, was finished: the limits set by ANTARES continue to be the best in the Southern sky. Indirect searches for dark matter, in which IFIC's group has a leading role, have provided very stringent limits, in some cases the best worldwide (e.g. for large mass WIMP annihilation in the Galactic Centre). An article led by IFIC's researchers on ANTARES time calibration with muons was published, which meant an icing on the cake of all the results obtained by the IFIC group in this topic during almost two decades. A PhD thesis done at IFIC was awarded the Global Neutrino Network prize, KM3NeT 2.0 was included in the 2016 ESFRI Roadmap and an H2020 project (in which IFIC participates) to support the early stages of KM3NeT was awarded. A fruitful year, indeed.

The group working on neutrino oscillations is deeply involved in T2K and DUNE. T2K has obtained during 2016 the first clear indications of CP violation: conservation is excluded at 90% C.L. IFIC members have a wide range of responsibilities linked to the ND280 near detector of T2K, which involve, among others, software, calibration and analysis tasks and whose main focus is the measurement of the unoscillated antineutrino flux at ND280. DUNE has made significant progress: the experiment obtained in 2016 the CD-3A approval by the US DOE (which resulted in the start of the construction work at the SURF laboratory in 2017) and the technical design reports of the single and double phase demonstrators were finished: these prototypes should be operating in a charged particle test beam by 2018. IFIC's group is fully contributing to DUNE. On the one hand, DUNE-IFIC is responsible for the Nucleon Decay Physics Working Group and has participated in the development of software tools for the experiment. DUNE-IFIC is also responsible for the cryogenics, argon instrumentation and other systems of the Single Phase Proto-DUNE detector: laboratory work is being

undertaken at IFIC to measure the temperature gradients in large volumes of liquid argon.

During 2016 the NEXT group has taken calibration runs of NEW (a 10-kg, radiopure prototype installed at the LSC in 2015) using radioactive sources (^{83}Kr, ^{22}Na). These measurements have provided useful information about the detector's behaviour and its capabilities (<1% energy resolution at 3 MeV and very promising event topology information). NEXT will take regular data in 2017. In the meanwhile, work has continued towards the future NEXT-100, including the use of deep neural networks to reject background.

The AGATA subarray coupled to VAMOS is at present being used at GANIL. In 2016, ^{208}Pb and ^{238}U beams were employed. The IFIC-AGATA group is responsible for the analysis of the data and preliminary results were presented in conferences. The construction at IFIC of AGATA and NEDA (also part of the HISPEC in NUSTAR) is proceeding according to schedule. For the latter, a system of more than 50 detectors fully instrumented is expected to be ready by the end of 2017.

IFIC's Gamma and Neutron Spectroscopy Group has obtained several interesting results during 2016. A measurement of half-lives and beta delayed neutron probabilities for 20 isotopes in the mass region $N \geq 126$ were performed that will allow to constrain theoretical models of the atomic nucleus which are of interest to r-process nucleosynthesis calculations. The BELEN detector developed in Spain was used in these measurements at GSI (BELEN is intended to be part of the DESPEC experiment at FAIR). In 2015 the group had a leading role in some of the experiments at the RIKEN radioactive beam facility in Japan. A ^{78}Kr beam was used to produce the most exotic nuclei along the proton drip line in the A = 60-70 region. The first results from this campaign have been published this year: among other things these measurements provide information on where the limits of the existence of bound nuclear matter lie. Exotic nuclei were also investigated in GANIL. The first identification of the 2^+ isomer in ^{52}Co was reported. ^{52}Co lies on the rp-process pathway, for that reason is of relevance for nuclear astrophysics. The application of the group's know-how to gamma-ray imaging is paying off in terms of technology transfer: their developments are being used in the decommissioning of nuclear power plants and the handling of contaminated areas. The ERC Consolidator Grant HYMNS started middle of 2016. HYMNS will recreate at the CERN n_TOF facility, neutron-induced nucleosynthesis reactions on specific nuclei relevant to the understanding of the origin of the heavy elements in our Galaxy.

The richness and variety of the theoretical work done at IFIC is too wide to be summarised here, let me mention, though, some of the results obtained in 2016.

IFIC scientists have shown how same-sign lepton events at the LHC can be used to learn about the nature of neutrinos. They have proposed a new dynamical way to account for the Dirac nature of neutrinos and their small mass in terms of a new version of the seesaw mechanism.

Several supersymmetric unified models have been explored and constrained by the results of the supersymmetric searches at the LHC and special features of several GUT scenarios have been identified.

Lepton flavour violating Higgs decays have been studied. It has been found that two Higgs doublet models can have a sizeable branching ratio of Higgs to muon plus tauon. Interesting connections between these models and neutrino parameters have been identified.

The eight independent spin observables for the W boson were discussed in terms of its vector and tensor polarization, by IFIC scientists, who have identified the angular distribution and asymmetries and how to separate them in collider experiments. This has been applied to polarised top quark decays and diboson resonances.

The excess of leptons at the Z peak together with missing energy was explained by IFIC scientists in a general gauge-mediated SUSY model with relative light gluinos and a heavy neutralino decaying to Z plus a light gravitino. New data from the LHC will tell about the correctness of this model.

Generic features of minimal gauge extensions of the SM have been studied to see if they can account for the hints of lepton flavour non-universality observed in B-mesons decays at LHCb. An explicit model with a certain symmetry group was proposed to explain the B-decay anomalies.

A generic strongly-coupled scenario of EW symmetry breaking with heavy states has been considered and pattern of low-energy couplings have been identified which could be searched for in future data samples.

IFIC scientists have shown that quantum effects can break the duality between the electric and magnetic fields in a curved space and give rise to a change of the EM field's polarisation even in the free case.

The characterisation curvature divergences have been studied in a family of black-hole space-times with wormhole structure: geodesics are complete, waves can be reflected and transmitted and extended objects would not be destroyed by tidal forces.

It has been shown that the D*D and J/ψ π invariant mass distribution, in which the Z_c (3900) is observed, can be described either with the Z_c being a resonance or a virtual state of molecular nature and that these two cases could be distinguished using lattice QCD.

Weak decays of heavy hadrons have been extensively studied. Among other things, IFIC scientists have proposed to search for the open strangeness counterpart of the $P_c(4450)$ in the decay of the Ξ_b into $J/\psi\ \Lambda\ K^-$. The study is underway at LHCb.

Using Chiral Perturbation Theory for baryons a very good description of the cross-section and photon asymmetries in neutral pion photoproduction on protons at low energy has been obtained. This gives very relevant information about the chiral symmetry breaking of QCD.

Progress has been made in the theoretical modelling of neutrino-induced pion production on nucleons. This is relevant both for the study of the axial structure of the nucleon and as an important source of errors in the neutrino oscillation experiments.

A new equation of state for symmetric, asymmetric and neutron matter based on an extended Skyrme functional has been obtained. This equation of state is compatible with recent measurements of two times solar-mass neutron stars.

Various interesting studies of QCD and the strong interaction have been carried out that can be found in the corresponding section.

Several studies by IFIC researchers have treated the generation of the baryon asymmetry observed in the Universe and its relation to the lepton sector. The impact of neutrinos on cosmology is a topic our scientists have treated in several publications. Likewise, the experimental extraction of the CP violating phase and the possible ambiguities that must be faced and its importance to ensure a robust measurement of δ_{CP} have been pointed out.

As in previous years, the innovation and transfer activities of IFIC have increased in number and quality. The application of radiation detection techniques to nuclear waste control and disposal has materialised in a contract with private industry. The application of our know-how in radiation detector to medical physics continues increasing. Important progress has been made in the improvement of the reconstruction algorithms for the 3-layer Compton telescope that will be used to monitor the administration doses in hadron therapy. The results of the beam test campaign at HZDR, Dresden, (4.4 MeV protons impinging on a TiN target) are very encouraging. At the end of 2016 the laboratories of the Installation of Medical Physics, IFIMED, were commissioned. This includes the aforementioned HG-RF Lab and the Instrumentation Lab, that includes among other equipment, a MicroPET/CT. We are exceedingly glad to see this infrastructure entering into work: we have high expectations on the possibilities that IFIMED will offer in the not so distant future.

IFIC together with UPV is participating in a contest of pattern recognition applied to mammographic screening, with very positive results: the team is among the top ranking groups in the contest (in 2017 we received the happy news that IFIC-UPV team had joined the collaborative phase in which only the groups with top marks could enter). The RF Laboratory, an incipient IFIC's installation, moved ahead full steam: by the end of the year the installation was finished and 2017 will see it working, hosting a high-power infrastructure for testing HG normal-conducting S-band RF accelerating structures which can be used in a variety of applications.

IFIC has been exceedingly active in the dissemination of scientific results. More than 300 talks were given by IFIC's scientists all over the world in the main conferences and workshops of our field. IFIC's members organised several conferences themselves, among which it is worth mentioning Planck 2016. The Colloquia and Seminars that take place at IFIC are remarkable for their high profile speakers and interesting and topical content.

One and a half years have passed since the bestowal of the Severo Ochoa's Centre of Excellence award to IFIC. Besides the pride that we feel for having obtained this much sought-after award, the funds that it provides are acting as an amplifier of the research capacities of the institute. The leitmotiv of our Severo Ochoa is the search for new physics and promoting this goal we have been able to support new activities. During 2016, the postdocs hired by the Severo Ochoa started to join the institute. This is a very positive injection of "new blood" to the institute. Following IFIC's tradition of looking for talent everywhere, more than 80% of the final selected candidates were from abroad. The response to the call for applications was overwhelming, with literal-

ly hundreds of expressions of interest in the positions from all over the world. This reflects the appeal of IFIC as an international research centre. Likewise, the PhD program (FPI) associated to the Severo Ochoa provided by our Ministry is a new source of talent to match the large capacity of IFIC for scientific training. Several other measures have been possible thanks to the Severo Ochoa: the support of those outstanding Ramón y Cajal researchers that were in the final years of their contract, a programme of master students' grants, summer students programme, a boosted Colloquia and seminar programme, etc.

The Severo Ochoa has also enabled the increase in our communication and outreach activities. IFIC's scientists make a special effort to explain to the general public their scientific and technical goals and achievements. IFIC hosted more than 850 students from 19 schools in 2016, 40% more than the previous year. 80 students and 30 teachers from 28 high schools participated in IFIC's masterclasses. Our outreach activities are too numerous to mention here. We invite the reader to browse the corresponding section of this report and see how seriously we take our duty to explain to our fellow citizens the science that they financially support and to convey the feeling of awe and enthusiasm that our research brings us. ■

PROF. JUAN JOSÉ HERNÁNDEZ REY
Director of IFIC

BIENVENIDA

Bienvenidos a esta memoria en la que se resumen las actividades del IFIC durante 2016. En ella encontrarán los resultados más relevantes de nuestro instituto.

Se ha vuelto práctica habitual medir la productividad de la investigación a través de "indicadores". Si nos restringimos de forma estricta a un "benchmarking" objetivo, 2016 ha sido efectivamente un muy buen año para el IFIC, con un incremento en todas las cifras que miden nuestro rendimiento científico. Pero además de estos indicadores, se puede observar un claro progreso en todas nuestras iniciativas, y constatamos que el tremendo trabajo y el entusiasmo incansable de nuestros científicos están dando sus frutos.

Uno de los privilegios de ser director de un instituto como el IFIC es el tener la oportunidad de conocer con mayor detalle las actividades de sus científicos. Cuando sabes de los altibajos que sufren los proyectos, un efecto secundario es que, a pesar de todos los reveses y contratiempos, a menudo te sorprenden gratamente las buenas noticias: publicaciones de tus científicos que reciben una atención especial, proyectos difíciles que finalmente están avanzando, la visibilidad y el impacto de tus investigadores en las grandes y competitivas colaboraciones en las que trabajan, un premio que le otorgan a uno (o más) de tus científicos, etc. Esto es tan grato como el aumento de las cifras de productividad, pero si esas cifras traen también buenas noticias ¡ser director se convierte en una sinecura!

Desde que volvió a operar en 2015, el LHC ha estado funcionando extraordinariamente bien, batiendo una y otra vez su luminosidad máxima y ofreciendo a los experimentos la oportunidad de recoger valiosos datos. El IFIC participa en tres experimentos del LHC: ATLAS, LHCb y MoEDAL. Los tres se han beneficiado de este funcionamiento satisfactorio del LHC en 2016.

El mantenimiento y la operación de un detector sofisticado como ATLAS requiere un esfuerzo continuo por parte de la colaboración. Los científicos e ingenieros del IFIC han contribuido en varias áreas de esa tarea tan exigente (y a veces insuficientemente reconocida). Por ejemplo, con el aumento de la luminosidad, la deformación de un cierto componente del Detector Interno ("el B-Layer insertable") ha re-

querido de un continuo alineamiento dinámico, y las constantes geométricas de dicho detector han tenido que estar listas ¡a las 24 horas de haber tomado los datos! Una verdadera hazaña. Asimismo, el aumento de la tasa del primer nivel del trigger (más de 90 kHz) y el enorme número de interacciones por cruce de haz (más de 40) ha requerido el reforzamiento permanente de la electrónica externa del TileCal, lo cual forma parte de las responsabilidades del IFIC. El considerable aumento de la luminosidad ha obligado también a adaptar los programas de reconstrucción del detector de tracking, una tarea en la que nuestros científicos están involucrados. La utilización de cálculo de alto rendimiento (HPC) en el sistema de producción de ATLAS requiere un cuidado especial para asegurarse de que las muestras de datos producidas están listas para hacer física. Son precisamente científicos del IFIC quienes lideran el Grupo de Validación Técnica que se ha establecido para certificar que al análisis solo llegan datos de buena calidad.

Todo esto es una tremenda cantidad de trabajo que a menudo pasa inadvertido, pero que es crítica para el buen funcionamiento del detector y, por tanto, esencial para obtener los tan ansiados resultados de física. Nos sentimos orgullos de ser parte de esta colosal empresa.

Tampoco debemos de olvidar que nuestro grupo GRID ha proporcionado en tiempo y forma los recursos a los que se habían comprometido para 2016. De hecho, el resultado de la evaluación externa a la que el grupo se sometió en 2016 ha sido muy positivo. No en vano, es un grupo de referencia que ayuda en la puesta en marcha y el desarrollo de plataformas GRID en otros países. El proyecto Event Index en el que participa nuestro grupo GRID, está en la actualidad corriendo y en producción.

En lo que respecta a la física en ATLAS, los científicos del IFIC han estado involucrados en una amplia variedad de temas en 2016, siendo el testeo del Modelo Estándar y la búsqueda directa de nueva física los objetivos principales. Nuestros investigadores han realizado medidas de precisión tanto del sector de Higgs como del quark top. Nos es grato ver la combinación final de las medidas de los acoplamientos del bosón de Higgs con datos del Run 1 del LHC, en las que el IFIC tuvo una contribución especial en la observación por primera vez del modo de desintegración a dos leptones tau, así como las primeras medidas de la sección eficaz a 13 TeV. En lo que hace las propiedades del quark top, el grupo realizó la medida directa más precisa, a la sazón, de la masa polo del quark top, y ha explorado los acoplamientos del quark top llevando a cabo medidas precisas de los observables de polarización del quark top y del bosón W en el modo de producción del canal-t, así como la asimetría de carga en la producción de quark tops altamente "boosteados".

Los investigadores del IFIC también han buscado ávidamente señales de nueva física en los primeros datos a 13 TeV. Han realizado la primera búsqueda de nuevos bosones de Higgs y bosones Z' pesados en el estado final de dos leptones tau (lo que fue objeto de la portada de un número del *European Physics Journal C*) y continuaron con la búsqueda de supersimetría, con especial hincapié en las búsquedas con violación de la paridad R.

LHCb intenta descubrir nueva física a través de la medida precisa de una diversidad de procesos que involucran hadrones B. Varias tensiones apuntan efectivamente a desviaciones del Modelo Estándar, pero es aún muy pronto para extraer conclusiones. Los científicos del IFIC están muy involucrados en algunos de estos análisis, en particular los relacionados con las desintegraciones radiactivas de hadrones pesados, como se resume en la sección correspondiente de esta memoria. El grupo del IFIC ha medido por pri-mera vez la polarización del fotón en desintegraciones radiativas de los hadrones B_s. El grupo está comprometido también en la mejora (upgrading) del detector, contribuyendo en particular a PACIFIC, un circuito integrado que es esencial para la correcta lectura del nuevo detector central de trazas de LHCb, SciFi.

El programa de investigación de MoEDAL, el experimento que busca "avatares" altamente ionizantes, progresa. Ya con su prototipo de detector de "atrapamiento" han sido capaces de poner límites de masa a partículas de gran carga (un resultado que dio lugar a un comunicado de prensa del CERN). Este análisis se repitió en 2016 (con datos de 2015), dando lugar al mejor límite mundial sobre monopolos de gran carga.

Mientras que se explotan exhaustivamente los datos que los experimentos del LHC suministran, nuestros científicos trabajan al mismo tiempo en la mejora de los detectores para la fase de alta luminosidad del LHC. Se puede encontrar en esta memoria una descripción de la diversidad de tareas en las que nuestros grupos están comprometidos. Como botón de muestra, mencionemos que el diseño mecánico del cierre lateral del detector de strips del ITk ha sido seleccionado como la solución de referencia. Esto es un reconocimiento del extraordinario trabajo realizado por este grupo y por los servicios de ingeniería del IFIC.

También nos mantenemos al día en cuanto a otras

opciones de aceleradores además del LHC. Nuestros científicos trabajan en el potencial de física del ILC y de CLIC, en particular en los estudios que se relacionan con el quark top. Se están explorando detectores basados en la tecnología DEPFET, ligados en particular al futuro detector ILD. Aún más, tenemos un pequeño pero muy activo grupo de científicos que trabajan en física de aceleradores: contribuyen al diseño de la óptica del haz y a su instrumentación para futuros aceleradores lineales y, además de sus contribuciones técnicas, tiene importantes responsabilidades en las instalaciones de prueba de estos aceleradores, por ejemplo, en el ATF2 de KEK en Tsukuba.

El grupo que trabaja en telescopios de neutrinos tuvo un nada desdeñable número de noticias positivas en 2016. En lo que concierne a la física, se finalizó una nueva búsqueda de fuentes puntuales de neutrinos liderada por físicos del IFIC, en la que se utilizaron por primera vez sucesos con cascadas: los límites impuestos por ANTARES continúan siendo los mejores para el cielo austral. Las búsquedas indirectas de materia oscura, en las que el grupo del IFIC tiene un papel líder, han suministrado límites muy restrictivos, en algunos casos los mejores a nivel mundial (por ejemplo, para la aniquilación de WIMPs en el Centro Galáctico). Se ha publicado un artículo liderado por investigadores del IFIC sobre la calibración temporal de ANTARES con muones, lo que pone la guinda al pastel de los resultados obtenidos por el grupo del IFIC en este tema de la calibración al que ha dedicado casi dos décadas. Una tesis realizada en el IFIC recibió el premio de la Global Neutrino Network, KM3NeT 2.0 fue incluido en la hoja de ruta de ESFRI en 2016 y se concedió un proyecto H2020 (en el que participa el IFIC) para apoyar la primera fase de KM3NeT. Realmente un año fructífero.

El grupo que trabaja en oscilaciones del neutrino está muy involucrado en T2K y DUNE. T2K ha obtenido durante 2016 las primeras indicaciones claras de violación de CP: se excluye la conservación al 90% de nivel de confianza. Los miembros del IFIC tienen un amplio abanico de responsabilidades ligadas al detector cercano ND280, que implican, entre otras, contribuciones al software, la calibración y las tareas de análisis y cuyo foco principal es la medida del flujo de anti-neutrinos sin oscilar en ND280. DUNE ha progresado de manera significativa: el experimento obtuvo en 2016 la aprobación CD-3A por el D.O.E. de EE.UU. (que se materializó en el comienzo del trabajo de construcción del laboratorio SURF en 2017) y se terminaron los TDRs de los demostradores de fase única y fase doble: estos prototipos deberán estar operando en un haz de test con partículas cargadas en 2018. El grupo del IFIC contribuye de manera plena a DUNE. Por una parte, DUNE-IFIC es responsable del grupo de trabajo de física de desintegración del nucleón y ha participado asimismo en el desarrollo de herramientas software para el experimento. DUNE-IFIC es también responsable de la criogenia, de la instrumentación para el argón y de otros sistemas del detector Proto-DUNE de fase única: se están llevando a cabo trabajos de laboratorio para medir los gradientes de temperatura en grandes volúmenes de argón líquido.

Durante 2016, el grupo de NEXT ha tomado runs de calibración de NEW (un prototipo radiopuro de 10 kg instalado en el LSC en 2015) utilizando fuentes radioactivas (^{83}Kr, ^{22}Na). Estas medidas han suministrado información útil sobre el comportamiento del detector y de sus capacidades (una resolución menor del 1% en energía a 3 MeV y una información topológica del suceso muy prometedora). NEXT tomará datos en 2017. Mientras tanto, ha continuado el trabajo para el futuro NEXT-100, incluyendo el uso de redes neuronales para rechazar el fondo.

Una submatriz de AGATA acoplada a VAMOS está siendo utilizada actualmente en GANIL. En 2016, se utilizaron haces de ^{208}Pb y ^{238}U. El grupo de IFIC-AGATA es responsable del análisis de los datos y ya se han presentado resultados preliminares en varias conferencias. La construcción en el IFIC de AGATA y NEDA (que también forma parte de HISPEC en NUSTAR) está progresando de acuerdo al calendario previsto. Para este último se espera que un sistema de más de 50 detectores completamente equipados esté listo a finales de 2017.

El grupo de Espectroscopía Gamma y de Neutrones ha obtenido varios resultados interesantes en 2016. Se ha realizado una medida de las vidas medias y de las probabilidades retardadas de neutrones beta para 20 isótopos en la región $N \geq 126$ que permitirá constreñir los modelos teóricos del núcleo atómico que son de interés en los cálculos de la nucleosíntesis en procesos r. Para estas medidas se utilizó en el GSI el detector BELEN, desarrollado en España (BELEN se espera que sea parte del experimento DESPEC en FAIR). En 2015, el grupo tuvo un papel líder en algunos de los experimentos en la instalación de haces radioactivos de RIKEN en Japón. Se utilizó un haz de ^{78}Kr para producir los núcleos más exóticos a lo largo de la drip line del protón en la región A = 60-70. Los primeros resultados de esta campaña se publicaron este año: entre otros resultados, estas medidas suministran información sobre donde están los límites de la existencia de la materia nuclear ligada. También se investigaron núcleos exóticos en GANIL. Se presentó la primera identificación del isómero 2^+ en ^{52}Co. El ^{52}Co está en el camino del proceso rp, y, por tanto, resulta relevante para la astrofísica nuclear. La aplicación de los conocimientos del grupo a imagen con

rayos gamma está dando sus frutos en términos de transferencia de tecnología: sus desarrollos se están usando en el desmantelamiento de centrales nucleares y el manejo de áreas contaminadas. La ERC Consolidator Grant HYMNS empezó a mediados de 2016. HYMNS recreará en la instalación n_TOF del CERN, las reacciones de nucleosíntesis inducidas por neutrones en núcleos concretos relevantes para la comprensión del origen de los elementos pesados en nuestra galaxia.

La riqueza y variedad del trabajo teórico hecho en el IFIC son demasiado amplias para poder resumirlo aquí. Permítanme mencionar, no obstante, algunos de los resultados obtenidos en 2016.

Científicos del IFIC han mostrado como se pueden utilizar sucesos con leptones del mismo signo para investigar la naturaleza de los neutrinos. Han propuesto una nueva forma dinámica de considerar la naturaleza de fermión de Dirac de los neutrinos y explicar su pequeña masa en términos de una nueva versión del mecanismo del balancín (*seesaw*).

Se han estudiado y constreñido varios modelos unificados supersimétricos utilizando los resultados de las búsquedas en el LHC, y se han identificado características especiales de diversos escenarios de Gran Unificación.

Se han estudiado las desintegraciones del Higgs con violación del sabor leptónico. Se ha descubierto que los modelos con dos dobletes de Higgs pueden tener una importante tasa de desintegración a muón más tauón. Se han identificado interesantes conexiones entre estos modelos y las propiedades del neutrino.

Científicos del IFIC han discutido los ocho observables independientes de espín del bosón W en términos de su polarización vectorial y tensorial, han identificado la distribución angular y las asimetrías y han mostrado cómo separarlas en experimentos en colisionadores. Esto se ha aplicado a las desintegraciones de quarks top polarizados y a resonancias dibosónicas.

Científicos del IFIC han explicado el exceso de leptones en el pico del Z junto con energía faltante en un modelo SUSY mediado por interacciones de gauge con gluinos relativamente ligeros y un neutralino pesado desintegrándose a un Z más un gravitino ligero. Los nuevos datos del LHC dilucidarán si este modelo es correcto.

Se han estudiado características genéricas de extensiones mínimas de gauge del Modelo Estándar para ver si pueden dar cuenta de las indicaciones de la no universalidad del sabor leptónico que se han observado en las desintegraciones de mesones B en el LHC. Se propuso un modelo explícito con un cierto grupo de simetría para explicar las anomalías en las desintegraciones de B_s.

Se ha considerado un escenario genérico, fuertemente acoplado de rotura de la simetría electrodébil con estados pesados y se han identificado patrones de acoplamientos a baja energía que podrán buscarse en futuros datos.

Científicos del IFIC han mostrado que los efectos cuánticos pueden romper la dualidad entre los campos eléctricos y magnéticos en un espacio curvo y dar lugar a un cambio en la polarización del campo EM, incluso en el caso libre. Se ha estudiado la caracterización de las divergencias de la curvatura en una familia de espacio-tiempos de agujeros negros con estructura de agujero de gusano: las geodésicas están completas, las ondas pueden reflejarse y transmitirse y los objetos extensos no serían destruidos por las fuerzas de marea.

Se ha demostrado que las distribuciones de masa invariante de los sistemas D*D y $J/\psi\ \pi$ en las que se observa el Z_c (3900) pueden describirse tanto si el Z_c es una resonancia como si es un estado virtual de naturaleza molecular, y que estos dos casos podrían distinguirse utilizando QCD en el retículo.

Se ha estudiado de forma muy amplia las desintegraciones débiles de hadrones pesados. Los científicos del IFIC han propuesto, entre otras cosas, buscar la contrapartida con extrañeza manifiesta del $P_c(4450)$ en la desintegración del Ξ_b en $J/\psi\ \Lambda\ K^-$. Este estudio ya está en marcha en el LHC.

Se ha obtenido una buena descripción de la sección eficaz y de las asimetrías del fotón en la fotoproducción en protones de piones neutros a baja energía utilizando teoría quiral de perturbaciones para bariones, lo cual da información relevante sobre la rotura de la simetría quiral en QCD.

Se han hecho progresos en la modelización teórica de la producción de piones inducida por neutrinos sobre nucleones. Esto es relevante para el estudio de la estructura axial del nucleón y también como fuente importante de errores en los experimentos de oscilaciones de neutrinos.

Se ha obtenido una nueva ecuación de estado para materia simétrica, asimétrica y de neutrones sobre un funcional Skyrme extendido. Esta ecuación de estado es compatible con las medidas recientes de

estrellas de neutrones con dos veces la masa solar.

Se han llevado a cabo otros diversos estudios de QCD y de la interacción fuerte que pueden verse en la sección correspondiente.

Varios estudios de investigadores del IFIC han tratado la generación de la asimetría bariónica observada en el Universo y su relación con el sector leptónico. El impacto de los neutrinos en la cosmología es un tema que nuestros científicos han tratado en varias publicaciones. Asimismo, se ha estudiado la obtención experimental de la fase de violación de CP y se han señalado las posibles ambigüedades a las que hay que hacer frente y su importancia para asegurar una medida robusta de δ_{CP}.

Como en años anteriores, las actividades de innovación y transferencia del IFIC han aumentado en número y calidad. La aplicación de técnicas de detección de radiación al control y eliminación de residuos nucleares se ha materializado en un contrato con una empresa privada. La aplicación de nuestros conocimientos en detectores de radiación a la física médica continúa aumentando. Se ha avanzado notablemente en la mejora de los algoritmos de reconstrucción de un telescopio Compton de tres capas que se utilizará para monitorear la administración de dosis en terapia hadrónica. Los resultados de la campaña de test de haz en HZDR, Dresde, (protones de 4.4 MeV incidiendo en un blanco de TiN) son muy alentadores. A finales de 2016, los laboratorios de la Instalación de Física Médica, IFIMED, echaron a andar. Esto incluye el mencionado laboratorio de HG-RF y un laboratorio de instrumentación que consta, entre otros equipos, de un MicroPET/CT. Estamos muy contentos de ver que esta infraestructura empieza a operar: tenemos grandes expectativas sobre las posibilidades que puede ofrecer el IFIMED en un futuro no muy lejano.

El IFIC junto con la UPV está participando en un concurso de reconocimiento de formas aplicado al cribado mamográfico, con resultados muy positivos: el equipo está entre los grupos mejor clasificados en el concurso (en 2017 recibimos la grata noticia de que el equipo IFIC-UPV se había incorporado a la fase cooperativa a la que solo podían acceder los mejores grupos). El laboratorio de RF, una instalación incipiente del IFIC, ha seguido adelante a toda marcha: al finalizar el año la instalación estaba acabada y 2017 verá su puesta en funcionamiento, alojando una infraestructura de alta potencia para testear estructuras de RF en banda S de aceleración de conducción normal, que pueden utilizarse en una gran variedad de aplicaciones.

El IFIC ha sido muy activo en la difusión de los resultados científicos. Los investigadores del IFIC han dado más de 300 charlas en todo el mundo en las principales conferencias y simposios de nuestro campo. Los propios miembros del IFIC han organizado varias conferencias, entre las que cabe mencionar Planck 2016. Los coloquios y seminarios que tienen lugar en el IFIC son notables por sus oradores de alto nivel y por sus contenidos interesantes y de actualidad.

Ha pasado un año y medio desde que se le concedió al IFIC la acreditación de centro de excelencia Severo Ochoa. Además del orgullo que sentimos por haber obtenido esta codiciada distinción, los fondos que proporciona están actuando como un amplificador de las capacidades investigadoras del instituto. El hilo conductor de nuestro Severo Ochoa es la búsqueda de nueva física y en pos de este objetivo hemos apoyado nuevas actividades. Durante 2016, los postdocs contratados por el Severo Ochoa empezaron a unirse al instituto. Es una inyección muy positiva de "nueva savia". Siguiendo con la tradición del IFIC de buscar talento en cualquier parte del mundo, más del 80% de los candidatos finalmente elegidos son extranjeros. La respuesta a la convocatoria fue apabullante, con literalmente cientos de expresiones de interés procedentes de todo el mundo. Esto refleja el atractivo que tiene el IFIC como centro de investigación internacional. Asimismo, el programa de contratos predoctorales (FPI) asociado al Severo Ochoa que otorga nuestro Ministerio es una nueva fuente de talento que le viene bien a la gran capacidad de formación científica de la que dispone el IFIC. Diversas medidas adicionales han sido posibles gracias al Severo Ochoa: el apoyo financiero a los excelentes investigadores Ramón y Cajal que estaban en los años finales de su contrato, un programa de becas para estudiantes de máster, un programa de estudiantes de verano, un programa ampliado de coloquios y seminarios, etc.

El proyecto Severo Ochoa también ha permitido incrementar nuestras actividades de comunicación y divulgación. Los científicos del IFIC hacen un esfuerzo particular para explicarle al público general sus objetivos y logros científicos y técnicos. El IFIC acogió a más de 850 estudiantes de 19 colegios en 2016, un 40% más que el año anterior. 80 estudiantes y 30 profesores de instituto participaron en las masterclasses del IFIC. Nuestras actividades de divulgación son demasiado numerosas para mencionarlas aquí, así que invitamos al lector a que hojee la sección corres-pondiente de esta memoria y vea cuán en serio nos tomamos nuestra obligación de explicarle a nuestros conciudadanos la ciencia que ellos apoyan económicamente y transmitirles el sentimiento de asombro y el entusiasmo que nuestra investigación nos procura. ■

BENVINGUTS

Benvinguts a aquesta memòria en què es resumeixen les activitats de l'IFIC durant 2016, en la qual trobaran els resultats més rellevants del nostre institut.

S'ha tornat pràctica habitual mesurar la productivitat de la investigació a través "d'indicadors". Si ens restringim de forma estricta a un "benchmarking" objectiu, 2016 ha estat efectivament un molt bon any per a l'IFIC, amb un increment en totes les xifres que mesuren el nostre rendiment científic. Però a més d'aquests indicadors, es pot observar un clar progrés en totes les nostres iniciatives i que el tremend treball i l'entusiasme incansable dels nostres científics està donant els seus fruits.

Un dels privilegis de ser director d'un institut com l'IFIC és el tindre l'oportunitat de conèixer amb major detall les activitats dels seus científics. Quan saps dels alts i baixos que pateixen els projectes, un efecte secundari és que, malgrat tots els revessos i contratemps, sovint et sorprenen gratament les bones noticies: publicacions dels teus científics que reben una atenció especial, projectes difícils que finalment estan avançant, la visibilitat i l'impacte dels teus investigadors en les grans i competitives col·laboracions en què treballen, un premi que li atorguen a un (o més) dels teus científics, etc. Açò és tan grat com l'augment de les xifres de productivitat, però si eixes xifres porten també bones notícies ser director es converteix en una sinecura!

Des que va tornar a operar en 2015, el LHC ha estat funcionant extraordinàriament bé, batent una vegada i una altra la seua lluminositat màxima i oferint als experiments l'oportunitat de recollir valuoses dades. L'IFIC participa en tres experiments de l'LHC: ATLAS, LHCb i MoEDAL. Els tres s'han beneficiat d'aquest satisfactori funcionament de l'LHC en 2016.

El manteniment i l'operació d'un detector sofisticat com és ATLAS requereix un esforç continu per part de la col·laboració. Els científics i enginyers de l'IFIC han contribuït en diverses àrees d'aqueixa tasca tan exigent (i a vegades insuficientment reconeguda) . Per exemple, amb l'augment de la lluminositat, la deformació d'un cert component del Detector Intern ("el B-Layer insertable") ha requerit d'un continu alineament dinàmic, i les constants geomètriques d'aquest detector han hagut d'estar llestes a les 24 hores d'haver pres les dades! Una vertadera gesta. Així mateix, l'augment de la taxa del primer nivell del trigger (més de 90 kHz) i l'enorme nombre d'interaccions per encreuament de feix (més de 40) ha requerit el reforçament permanent de l'electrònica externa del TileCal, la qual cosa forma part de les responsabilitats de l'IFIC. El considerable augment de la lluminositat ha obligat també a adaptar els programes de reconstrucció del detector de tracking, una tasca en què els nostres científics estan involucrats. La utilització de càlcul d'alt rendiment (HPC) en el sistema de producció d'ATLAS requereix una atenció especial per a assegurar-se de que les mostres de dades produïdes estan llestes per a fer física. Són precisament científics de l'IFIC els que lideren el Grup de Validació Tècnica que s'ha establit per tal de certificar que a l'anàlisi només arriben dades de bona qualitat.

Tot açò és una tremenda quantitat de treball que sovint passa inadvertit, però que és crítica per al bon funcionament del detector i, per tant, essencial per obtenir els tan anhelats resultats de física. Ens sentim orgullosos de ser part d'aquesta colossal empresa.

Tampoc devem d'oblidar que el nostre grup GRID ha proporcionat dins del termini i la forma escaient els recursos a què s'havien compromès per a 2016. De fet, el resultat de l'avaluació externa a què el grup es va sotmetre en 2016 ha estat molt positiva. No en va, és un grup de referència que ajuda en la posada en marxa i el desenvolupament de plataformes GRID en altres països. El projecte Event Index en el qual participa el nostre grup GRID, està corrent i en producció en l'actualitat.

Pel que fa a la física d'ATLAS, els científics de l'IFIC han estat involucrats en una àmplia varietat de temes en 2016, sent la verificació del Model Estàndard i la busca directa de nova física els objectius principals. Ens és grat veure la combinació final de les mesures dels acoblaments del bosó de Higgs amb dades del Run 1 de l'LHC, en què l'IFIC va tindre una contribució especial en l'observació per primera vegada del mode de desintegració a dos leptons tau així com les primeres mesures de la secció eficaç a 13 TeV. Pel que fa a les propietats del quark top, el grup va realitzar la mesura directa més precisa, en aquell moment, de la massa pol del quark top i ha explorat els acoblaments del quark top duent a terme mesures dels observables de polarització del quark top i del bosó W en el mode de producció del canal-t així com de l'asimetria de càrrega en la producció de quark tops altament "boostejats".

Els investigadors de l'IFIC també han buscat àvidament senyals de nova física en les primeres dades a 13 TeV. Han realitzat la primera busca de nous bosons de Higgs i bosons Z' pesats en l'estat final de dos leptons

tau (que va ser objecte de la portada d'un número de l'*European Physics Journal C*) i van continuar amb la busca de supersimetria, amb especial èmfasi en les busques amb violació de la paritat R.

LHCb intenta descobrir nova física a través de la mesura precisa d'una diversitat de processos que involucren a hadrons B. Diverses tensions apunten efectivament a desviacions del Model Estàndard, però és encara molt prompte per extraure conclusions. Els científics de l'IFIC estan molt involucrats en algunes d'aquestes anàlisis, en particular les relacionades amb les desintegracions radiatives d'hadrons pesats, com es resumeix en la secció corresponent d'aquesta memòria. El grup de l'IFIC ha mesurat per primera vegada la polarització del fotó en desintegracions radiatives dels hadrons B_s. El grup està involucrat també en la millora (upgrading) del detector, contribuint en particular a PACIFIC, un circuit integrat que és essencial per a la correcta lectura del nou detector central de traces de LHCb, SciFi.

El programa d'investigació de MoEDAL, l'experiment que busca "avatars" altament ionitzants, progressa. Ja amb el seu prototip de detector "d'atrapament" han estat capaços de posar límits de massa a partícules de gran càrrega (un resultat que va donar lloc a un comunicat de premsa del CERN). Aquesta anàlisi es va repetir en 2016 (amb dades de 2015) donant lloc al millor límit mundial sobre monopols de gran càrrega.

Mentre s'exploten exhaustivament les dades que els experiments de l'LHC subministren, els nostres científics treballen al mateix temps en la millora dels detectors per a la fase d'alta lluminositat de l'LHC. Podeu trobar en aquesta memòria una descripció de la diversitat de tasques en què els nostres grups estan involucrats. Com a botó de mostra, mencionem que el disseny mecànic del tancament lateral del detector de strips de l'ITk ha estat seleccionat com a la solució de referència. Açò és un reconeixement de l'extraordinari treball realitzat per aquest grup i pels serveis d'enginyeria de l'IFIC.

També ens mantenim al dia pel que fa a altres opcions d'acceleradors, a més de l'LHC. Els nostres científics treballen en el potencial de física de l'ILC i de CLIC, en particular en els estudis que es relacionen amb el quark top. S'estan explorant detectors basats en la tecnologia DEPFET, lligats en particular al futur detector ILD. Encara més, tenim un xicotet però molt actiu grup de científics que treballen en física d'acceleradors: contribueixen al disseny de l'òptica del feix i a la seua instrumentació per a futurs acceleradors lineals i, a més de les seues contribucions tècniques, té importants responsabilitats en les instal·lacions de prova d'aquests acceleradors, per exemple, en l'ATF2 de KEK en Tsukuba.

El grup que treballa en telescopis de neutrins va tindre un gran nombre de notícies positives en 2016. Pel que fa a la física, es va finalitzar una nova busca de fonts puntuals de neutrins liderada per físics de l'IFIC, en la qual es van utilitzar per primera vegada successos amb cascades: els límits imposats per ANTARES continuen sent els millors per al cel austral. Les busques indirectes de matèria fosca, en les quals el grup de l'IFIC té un paper líder, han subministrat límits molt restrictius, en alguns casos els millors a nivell mundial (per exemple, per a l'aniquilació de WIMPs en el Centre Galàctic). S'ha publicat un article liderat per investigadors de l'IFIC sobre el calibratge temporal d'ANTARES amb muons, la qual cosa posa la guinda al pastís dels resultats obtinguts pel grup de l'IFIC en aquest tema del calibratge a què ha dedicat quasi dos dècades. Una tesi realitzada a l'IFIC va rebre el premi de la Global Neutrí Network, KM3NeT 2.0 va ser inclòs en el full de ruta d'ESFRI en 2016 i es va concedir un projecte H2020 (en el que participa l'IFIC) per recolzar la primera fase de KM3NeT. Realment un any fructífer.

El grup que treballa en oscil·lacions del neutrí està molt involucrat en T2K i DUNE. T2K ha obtingut durant 2016 les primeres indicacions clares de violació de CP: s'exclou la conservació al 90% de nivell de confiança. Els membres de l'IFIC tenen una àmplia varietat de responsabilitats lligades al detector pròxim ND280, que impliquen, entre altres, contribució al programari, el calibratge i les tasques d'anàlisi, el focus principal de les quals és la mesura del flux d'antineutrins sense oscil·lar en ND280. DUNE ha progressat de manera significativa: l'experiment va obtindre en 2016 l'aprovació CD-3A pel D.O.E. d'EE. UU. (que es va materialitzar en el començament del treball de construcció del laboratori SURF en 2017) i es van acabar els TDRs dels demostradors de fase única i fase doble: aquests prototips hauran d'estar operant en un feix de test amb partícules carregades en 2018. El grup de l'IFIC contribueix de manera plena a DUNE. D'una banda, DUNE-IFIC és responsable del grup de treball de física de desintegració del nucleó i ha participat així mateix en el desenvolupament de ferramentes de programari per a l'experiment. DUNE-IFIC és també responsable de la criogènia, de la instrumentació per a l'argó i d'altres sistemes del detector Proto-DUNE de fase única: s'està duent a terme treball de laboratori per mesurar els gradients de temperatura en grans volums d'argó líquid.

Durant 2016, el grup de NEXT ha pres runs de calibratge de NEW (un prototip radiopur de 10 kg instal·lat a l'LSC en 2015) utilitzant fonts radioactives (^{83}Kr, ^{22}Na) .

Aquestes mesures han subministrat informació útil sobre el comportament del detector i de les seues capacitats (una resolució menor de l'1% en energia a 3 MeV i una informació topològica del succés molt prometedora) . NEXT prendrà dades en 2017. Mentrestant, ha continuat el treball per al futur NEXT-100, incloent l'ús de xarxes neuronals per rebutjar el fons.

Una submatriu d'AGATA acoblada a VAMOS està sent utilitzada actualment en GANIL. En 2016, es van utilitzar feixos de ^{208}Pb i ^{238}U. El grup d'IFIC-AGATA és responsable de l'anàlisi de les dades i ja s'han presentat resultats preliminars en diverses conferències. La construcció en l'IFIC d'AGATA i NEDA (que també forma part de HISPEC en NUSTAR) està progressant d'acord al calendari previst. Per a aquest últim, s'espera que un sistema de més de 50 detectors completament equipats estiga preparat a finals de 2017.

El grup d'Espectroscòpia Gamma i de Neutrons ha obtingut diversos resultats interessants en 2016. S'ha realitzat una mesura de les vides mitges i de les probabilitats retardades de neutrons beta per a 20 isòtops en la regió N >= 126 que permetrà constrènyer els models teòrics del nucli atòmic que són d'interès en els càlculs de nucleosíntesis de processos r. Per a aquestes mesures, es va utilitzar en el GSI el detector BETLEM, desenvolupat a Espanya (BETLEM s'espera que siga part de l'experiment DESPEC en FAIR) . En 2015, el grup va tindre un paper líder en alguns dels experiments en la instal·lació de feixos radioactius de RIKEN al Japó. Es va utilitzar un feix de ^{78}Kr per produir els nuclis més exòtics al llarg de la drip line del protó en la regió A = 60-70. Els primers resultats d'aquesta campanya es van publicar enguany: entre altres, aquestes mesures subministren informació sobre on estan els límits de l'existència de la matèria nuclear lligada. També es van investigar nuclis exòtics en GANIL. Es va presentar la primera identificació de l'isòmer 2^+ en ^{52}Co. El ^{52}Co està en el camí del procés rp, i, per tant, resulta rellevant per a l'astrofísica nuclear. L'aplicació dels coneixements del grup a imatge amb rajos gamma està donant els seus fruits en termes de transferència de tecnologia: els seus desenvolupaments s'estan usant en el desmantellament de centrals nuclears i el maneig d'àrees contaminades. L'ERC Consolidator Grant HYMNS va començar a mitjan 2016. HYMNS recrearà en la instal·lació n_TOF del CERN, les reaccions de nucleosíntesis induïdes per neutrons en nuclis concrets rellevants en la comprensió de l'origen dels elements pesats en la nostra galàxia.

La riquesa i varietat del treball teòric fet a l'IFIC són massa àmplies per a poder resumir-ho ací. Permeteu-me mencionar, no obstant això, alguns dels resultats obtinguts en 2016.

Científics de l'IFIC han mostrat com es poden utilitzar successos amb leptons del mateix signe per investigar la naturalesa dels neutrins. Han proposat una nova forma dinàmica de considerar la naturalesa de fermions de Dirac dels neutrins i explicar la seua xicoteta massa en termes d'una nova versió del mecanisme del balancí (*seesaw*) .

S'han estudiat i constret diversos models unificats supersimètrics utilitzant els resultats de les busques supersimètriques a l'LHC i s'han identificat característiques especials de diversos escenaris de Gran Unificació.

S'han estudiat les desintegracions del Higgs amb violació del sabor leptònic. S'ha descobert que els models amb dos doblets de Higgs poden tindre una important taxa de desintegració a muó més tauó. S'han identificat interessants connexions entre aquests models i les propietats del neutrí.

Científics de l'IFIC han discutit huit observables independents de l'espín del bosó W en termes de la seua polarització vectorial i tensorial, han identificat la distribució angular i les asimetries i han mostrat com separar-les en experiments en colisionadors. Açò s'ha aplicat a les desintegracions de quarks top polaritzats i a ressonàncies dibosóniques.

Científics de l'IFIC han explicat l'excés de leptons en el pic del Z junt amb energia faltant en un model SUSY mediat per interaccions de gauge amb gluins relativament lleugers i un neutralí pesat desintegrant-se a un Z més un gravití lleuger. Les noves dades de l'LHC dilucidaran si aquest model és correcte.

S'han estudiat característiques genèriques d'extensions mínimes de gauge del Model Estàndard per veure si poden donar compte de les indicacions de la no universalitat del sabor leptònic que s'han observat en les desintegracions de mesons B en el LHC. Es va proposar un model explícit amb un cert grup de simetria per explicar les anomalies en les desintegracions de B_s.

S'ha considerat un escenari genèric, fortament acoblat de ruptura de la simetria electrofeble amb estats pesats i s'han identificat patrons de acoblaments a baixa energia que podran buscar-se en futures dades.

Científics de l'IFIC han mostrat que els efectes quàntics poden trencar la dualitat entre els camps elèctrics i magnètics en un espai corb i donar lloc a un canvi en la polarització del camp EM, inclús en el cas lliure. S'ha estudiat la caracterització de les divergències de la curvatura en una família d'espai-temps de

forats negres amb estructura de forat de cuc: les geodèsiques estan completes, les ones poden reflectir-se i transmetre's i els objectes extensos no serien destruïts per les forces de marea.

S'ha demostrat que les distribucions de massa invariant dels sistemes D*D i J/ψ π en les quals s'observa el Z_c (3900) poden descriure's tant si el Z_c és una ressonància com si és un estat virtual de naturalesa molecular, i que aquests dos casos podrien distingir-se utilitzant QCD en el reticle.

S'ha estudiat de forma molt àmplia les desintegracions dèbils d'hadrons pesats. Els científics de l'IFIC han proposat, entre altres coses, buscar la contrapartida amb estranyesa manifesta del P_c (4450) en la desintegració del Ξ_b en J/ψ Λ K^-. Aquest estudi ja està en marxa a l'LHC.

S'ha obtingut una bona descripció de la secció eficaç i de les asimetries del fotó en la fotoproducció en protons de pions neutres a baixa energia utilitzant teoria quiral de pertorbacions per a barions, la qual cosa dóna informació rellevant sobre la ruptura de la simetria quiral en QCD.

S'han fet progressos en la modelització teòrica de la producció de pions induïda per neutrins sobre nucleons. Açò és rellevant per a l'estudi de l'estructura axial del nucleó i també com a font important d'errors en els experiments d'oscil·lacions de neutrins.

S'ha obtingut una nova equació d'estat per a matèria simètrica, asimètrica i de neutrons sobre un funcional Skyrme estés. Aquesta equació d'estat és compatible amb les mesures recents d'estreles de neutrons amb dos vegades la massa solar.

S'han dut a terme altres diversos estudis de QCD i de la interacció forta que poden veure's en la secció corresponent.

Diversos estudis d'investigadors de l'IFIC han tractat la generació de la asimetria bariònica observada en l'Univers i la seua relació amb el sector leptònic. L'impacte dels neutrins en la cosmologia és un tema que els nostres científics han tractat en diverses publicacions. Així mateix, s'ha estudiat l'obtenció experimental de la fase de violació de CP i s'han assenyalat les possibles ambigüitats a què cal fer front i la seua importància per assegurar una mesura robusta de δ_{CP}.

Com en anys anteriors, les activitats d'innovació i transferència de l'IFIC han augmentat en número i qualitat. L'aplicació de tècniques de detecció de radiació al control i eliminació de residus nuclears s'ha materialitzat en un contracte amb una empresa privada. L'aplicació dels nostres coneixements en detectors de radiació a la física mèdica continua augmentant. S'ha avançat notablement en la millora dels algoritmes de reconstrucció d'un telescopi Compton de tres capes que s'utilitzarà per a monitoritzar l'administració de dosi en teràpia hadrònica. Els resultats de la campanya de test de feix en HZDR, Dresden, (protons de 4.4 MeV incidint en un blanc de tet) són molt encoratjadors. A finals de 2016, els laboratoris de la Instal·lació de Física Mèdica, IFIMED, van començar a caminar. Açò inclou el mencionat laboratori de HG-RF i un laboratori d'instrumentació, que consta, entre altres equips, d'un MicroPET/CT. Estem molt contents de veure que aquesta infraestructura comença a operar: tenim grans expectatives sobre les possibilitats que pot oferir l'IFIMED en un futur no molt llunyà.

L'IFIC junt amb la UPV està participant en un concurs de reconeixement de formes aplicat al garbellament mamogràfic, amb resultats molt positius: l'equip està entre els grups de més alta classificació en el concurs (en 2017 vam rebre la grata notícia de que l'equip IFIC-UPV s'havia incorporat a la fase cooperativa a què només podien accedir els grups amb les qualificacions més altes) . El laboratori de RF, una instal·lació incipient de l'IFIC, ha seguit avant a tota marxa: al finalitzar l'any la instal·lació estava acabada i 2017 veurà el seu funcionament, allotjant una infraestructura d'alta potència per testear estructures de RF en banda S d'acceleració de conducció normal, que poden utilitzar-se en una gran varietat d'aplicacions.

L'IFIC ha estat molt actiu en la difusió dels resultats científics. Els investigadors de l'IFIC han donat més de 300 xarrades per tot el món en les principals conferències i simposis del nostre camp. Els propis membres de l'IFIC han organitzats diverses conferències, entre les quals cal mencionar Planck 2016. Els col·loquis i seminaris que tenen lloc a l'IFIC són excel·lents pels seus oradors d'alt nivell i pels seus continguts interessants i d'actualitat.

Ha passat un any i mig des que se li va concedir a l'IFIC l'acreditació de centre d'excel·lència Severo Ochoa. A més de l'orgull que sentim per haver obtingut aquesta cobejada distinció, els fons que proporciona estan actuant com un amplificador de les capacitats investigadores de l'institut. El fil conductor del nostre Severo Ochoa és la busca de nova física i a la cerca d'aquest objectiu hem recolzat noves activitats. Durant 2016, els postdocs contractats pel Severo Ochoa van començar a unir-se a l'institut. És una injecció molt positiva de "nova sàvia". Seguint amb la tradició de l'IFIC de buscar talent en qualsevol part del món, més del 80% dels candidats finalment triats són estrangers. La resposta a la convocatòria va ser aclaparadora, amb literalment centenars

d'expressions d'interès procedents de tot el món sobre els llocs de treball oferts. Açò reflecteix l'atractiu que té l'IFIC com un centre d'investigació internacional. Així mateix, el programa de contractes predoctorals (FPI) associat al Severo Ochoa que atorga el nostre Ministeri és una nova font de talent que li ve bé a la gran capacitat de formació científica de què disposa l'IFIC. Diverses mesures addicionals han estat possibles gràcies al Severo Ochoa: el suport financer als excel·lents investigadors Ramón i Cajal que estaven en els darrers anys del seu contracte, un programa de beques per a estudiants de màster, un programa d'estudiants d'estiu, un programa ampliat de col·loquis i seminaris, etc.

El projecte Severo Ochoa també ha permès incrementar les nostres activitats de comunicació i divulgació. Els científics de l'IFIC fan un esforç particular per explicar-li al públic general els seus objectius i èxits científics i tècnics. L'IFIC va acollir a més de 850 estudiants de 19 col·legis en 2016, un 40% més que l'any anterior. 80 estudiants i 30 professors d'institut van participar en les masterclasses de l'IFIC. Les nostres activitats de divulgació són massa nombroses per mencionar-les ací, així que invitem el lector a què fullege la secció corresponent d'aquesta memòria i veja com ens prenem de seriós la nostra obligació d'explicar-li als nostres conciutadans la ciència que ells recolzen econòmicament i transmetre'ls el sentiment d'admiració i l'entusiasme que la nostra investigació ens procura.

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 in terms of 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.

In 2015, IFIC was awarded with the 'Severo Ochoa' accreditation as center of excellence in recognition of its outstanding performance and scientific contributions at national and international level, its impact at industrial and social level, and the ability to attract scientific talent.

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 naturally been influenced by the social and 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), KEK (Japan) and others.

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

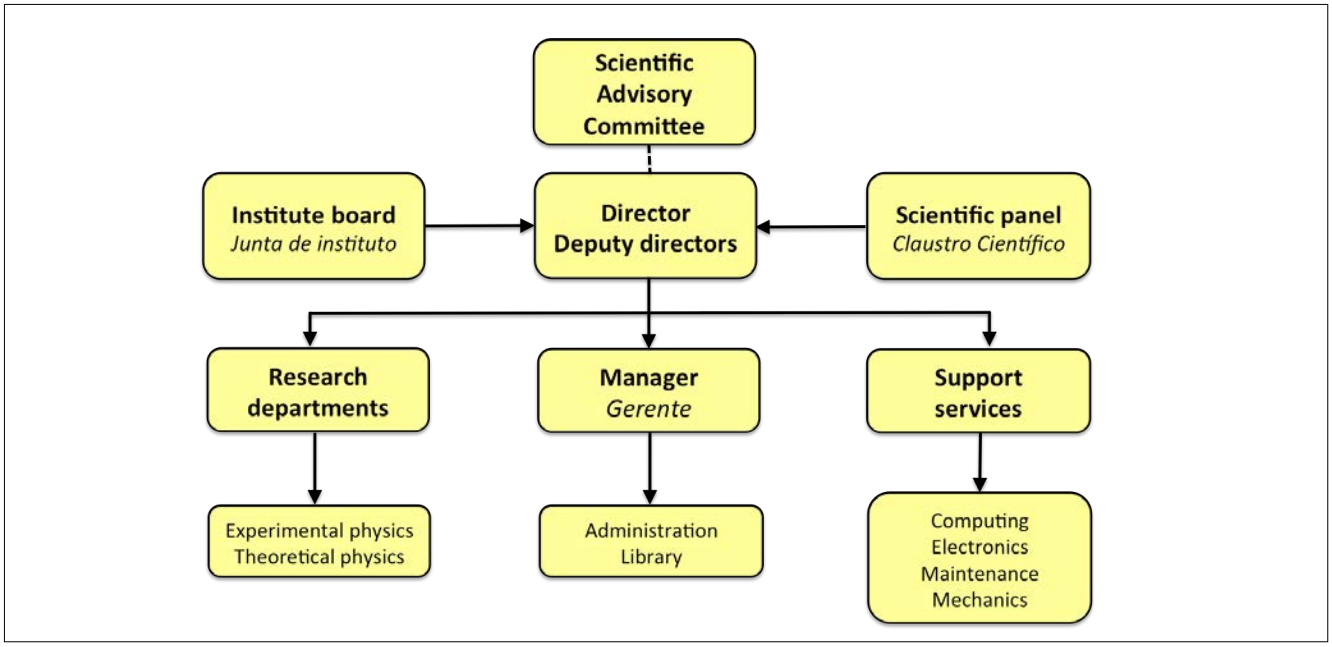
1 An excellent review article about the birth of experimental nuclear and particle physics in Spain, written by Agustín Ceba, Víctor Navarro y Jorge Velasco, was published in Revista Española de Física 25-2 (2011).

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.



Members of the Scientific Advisory Committee:
William Gelletly (Univ. Surrey), F. Halzen (Univ. Wisconsin), Cecilia Jarlskog (Lund Univ.), Antonio Masiero (Univ. Padua), Tatsuya Nakada (EPF Lausanne), Bing-Song Zou (IHEP Beijing)
Members of the Institute Board:
Director: Juan José Hernández Rey
Deputy Directors: María José Costa Mezquita, Juan Fuster Verdú (Innovation and Technology), Santiago Noguera Puchol
Manager: Ana Fandos Lario
Heads of the research departments: Carlos Lacasta Llácer (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)

lider (LHC) at CERN, and participate in the preparation for the future Linear Collider (ILC and CLIC) under the framework of the Linear Collider Collaboration (LCC). The group of e-Science participates in the GRID for the LHC and in other activities of distributed computing.

In Astroparticle Physics the work is focused on the neutrino telescope ANTARES and its future extension KM3NeT, while the Neutrino Physics group is involved in the NEXT and T2K experiments.

In Nuclear Physics, we participate in the AGATA project, in the future accelerator Facility for Antiproton and Ion Research (FAIR), in the nTOF experiment at CERN and in the HADES experiment at Darmstadt GSI.

Finally, the group of Medical Physics carries out several activities mainly related to medical imaging and accelerator developments.

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 researches became members of the LHCb, MoEDAL 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, LHCb and MoEDAL detectors of the Large Hadron Col-

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, is also being 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 analysed, 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 17 people, belonging to CSIC and UVEG, manage the ordinary running 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 live 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 vision measuring 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 common 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 2016

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González Marhuenda, Pedro
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Mena Requejo, Olga
Mitsou, Vasiliki
Navarro Faus, Jesús
Navarro Salas, José
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Noguera Puchol, Santiago
Novella Garijo, Pau
Olmo Alba, Gonzalo
Oset Báguena, Eulogio
Oyanguren Campos, Arantza
Palomares Ruiz, Sergio
Papavassiliou, Ioannis
Pastor Carpi, Sergio
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Pich Zardoya, Antonio
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Vos, Marcel Andre
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Izmaylov, Alexander
Krause, Claudius
Laing, Andrew
Lineros Rodriguez, Roberto A.
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Pagura, Valeria Paula
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Rodriguez Chala, Mikael
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Ros Garcia, Ana
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Salvado Serra, Jordi
Sorel, Michel
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Escudero Abenza, Miguel
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Etxebeste Barrena, Ane Miren
Faubel Alama, Carlos
Felkai, Ryan
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Fernandez Soler, Pedro
Fuentes Martín, Javier
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Garcia Folgado, Miguel
Garcia Martin, Luis Miguel
Gisbert Mullor, Hector
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Ilisie, Victor
Illuminati, Giulia
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Lotze, Moritz
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Neder, Thomas
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Pereira Pires Pavao, Rafael
Perello Rosello, Martin
Perez Perez, Javier
Perez Vidal, Rosa Mª
Ramirez Rodriguez, Hector Ariel
Remon Alepuz, Clara
Rodrigues Debastiani, Vinicius
Rodriguez Bosca, Sergi
Rodriguez Rodriguez, Daniel
Rodriguez Sanchez, Antonio
Sanchez Mayordomo, Carlos
Santos Blasco, Joaquin
Saul Sala, David Eduardo
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Simon Estevez, Ander
Soldevila Serrano, Urmila
Ternes, Christoph
Tolosa Delgado, Alvaro
Tönnis, Christoph
Villanueva Domingo, Pablo
Vnuchenko, Anna

ENGINEERS & TECHNICIANS

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Calvo Diaz-Aldagalán, David
Carcel Garcia, Sara
Carrio Argos, Fernando
Carrion Burguete, Jose Vicente
Garrido Moreno, Elisa
Gramage Iglesias, Pablo
Ladarescu Palivan, Ion
Martinez Perez, Alberto
Mazorra de Cos, Jose
Oliver Guillen, Jose Francisco
Platero Garcia, Adrian
Querol Segura, Marc
Real Mañez, Diego
Rodriguez Samaniego, Javier
Solaz Contell, Carles
Torrent Collell, Jordi

ADMINISTRATION

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Claramunt Pedrón, Luis Miguel
Fandos Lario, Ana María
Ferrer Lazaro, Jose Manuel
Fillol Ricart, Amparo
Garcia Gonzalez, Soledad
Gimeno Almela, Mª Jose
Gracia Vidal, Mª Jose
Hernando Recuero, Mª Luisa
Montesinos Reig, Leonor
Pastor Clerigues, Elena
Pérez García, José
Pous Cuñat, Elena Maria
Serrano Perez, Carmen
Sifre García, Francisca

OUTREACH

García Cano, Isidoro

COMPUTING

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Escudero Ruiz, Adolfo
Fernandez Casani, Alvaro
Garcia Montoro, Carlos
Martínez Saez, Carlos
Nadal Durà, Joaquin
Sánchez Martínez, Fco. Javier

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Bernabeu Verdú, José
Camara García, María Teresa
González González, Francisco
Lopez Redondo, Manuel
Marco, Ricardo (*leave*)
Nácher Arándiga, Jorge
Valero Biot, Jose Alberto

MAINTENANCE

Fuentes Castilla, Angel
Gallego Baviera, Fco. Javier
Taberner Ubeda, Mª Eva
Carrasco de Fez, Rosa

MECHANICS

Civera Navarrete, José Vicente
Jordan Coronado, Jose Luis
Leon Lara, Pablo
Monserrate Sabroso, Jose Manuel
Perez Rabadan, Alberto
Sarrion Bueno, Vicente
Villarejo Bermudez, Miguel Angel

251 Total personnel (end 2016)

187 Scientific personnel

23% Women in scientific personnel

23 Nationalities working at IFIC

67% Postdocs from abroad

30% PhD students from abroad

2. RESEARCH ACTIVITIES

EXPERIMENTAL PHYSICS

ACCELERATOR-BASED EXPERIMENTAL HIGH ENERGY PHYSICS

The activities of this research line during 2016 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

After the successful restart of the LHC in 2015 and its new energy record of 13 TeV energy proton-proton collisions, its operations marked another feat as the instantaneous luminosity reached up to 1.37×10^{34} $cm^{-2}s^{-1}$ exceeding by almost a 40% its design luminosity.

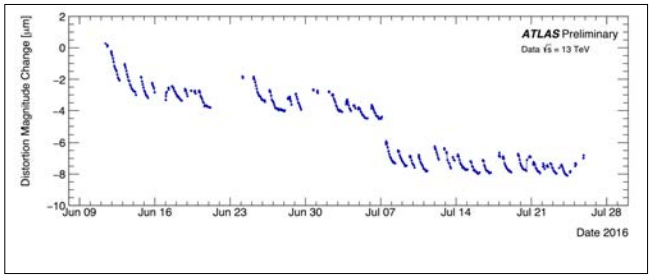
ATLAS

The group greatly contributed to the analysis of the data delivered by the proton-proton collisions of the LHC. It must be said that the activities of our members within ATLAS embrace all the aspects of running the experiment. There is a deep involvement in important areas as: detector operations, data preparation, physics analysis, publication of results, conference presentations as well as playing a leading role through occupying managing posts within the collaboration.

ATLAS: operations

Constant consolidation of the hadronic calorimeter (TileCal) off-detector electronics is required to cope with harsher LHC conditions, increased trigger rates while providing an accurate signal reconstruction at trigger level. One of the main achievements of the IFIC group has been to cope with the exceptionally high acceptance rate of the first level trigger of ATLAS, above 90 kHz, with an unprecedented number of simultaneous interactions per bunch crossing (more than 40).

In what concerns the Inner Detector (ID) tracker operations, our group is responsible of its alignment at the calibration loop. During 2016, the results of the calibration loop (ID geometry constants) had to be provided within 24 hours after the data taking. It had to be reconfigured with the increase of luminosity in order to dynamically align the deformation of the IBL (Insertable B-layer) and the lifting of the entire Pixels package at the beginning of each run.



Bowing magnitude of the IBL staves during the 2016 ATLAS data taking. Each point corresponds to data accumulated during 100 minutes.

Another responsibility of our group is the ATLAS tracking validation. This is quite important as every ATLAS analysis depends on the data. Due to the LHC record luminosity, the tracking subdetectors (Pixels, SCT and TRT) had to adapt their reconstruction software in order to reduce the amount of data, while keeping the tracking performance high, specially in the very dense environments.

Our group is also involved in the ATLAS computing, in particular the introduction of Super Computers (HPCs) inside the ATLAS sample production system. We also hold the chair of the Technical Validation Task Force, which studies the best way to certify special sites (HPCs) as good for producing samples to be used in physics analysis. Another important aspect is in the definition of the production workflows to make use of this new kind of resources, which may have special characteristics: volatility, limited storage capacity, limited internet access, etc.

ATLAS: precision mesurements

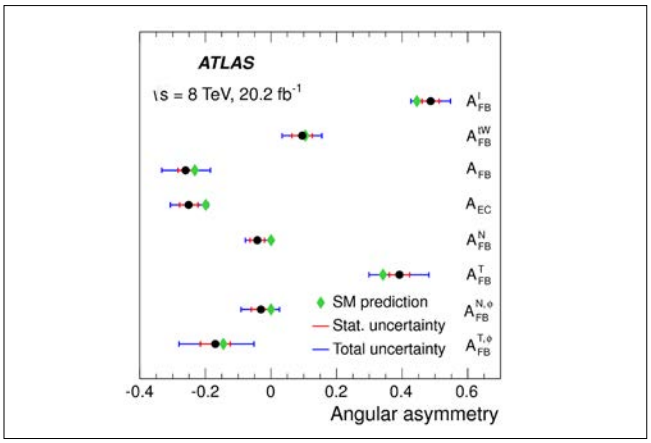
The IFIC-ATLAS group carried on with the study of the Higgs sector. During 2016, our group contributed to the final combination of the measurement of the couplings of the Higgs boson of the ATLAS experiment with the LHC Run 1 (7 and 8 TeV) data, as well as the combination of ATLAS and CMS results. This accomplished the observation of the Higgs boson decay in two tau leptons and the Vector Boson Fusion production mode.

Our group contributed as well to the first Higgs boson measurements using 13 TeV data in the two photons final state (measurements of the fiducial and differential cross-section and the relative contributions of the individual production modes) plus the first measurement of the total Higgs boson production cross-section at 13 TeV.

The analysis probing the Wtb vertex structure, measuring top-quark and W-boson polarisation observables from t-channel single-top-quark events produced in proton-proton collisions, was completed using 20.2 fb^{-1} of ATLAS data collected at 8 TeV. This analysis required a very stringent selection to discriminate t-channel single-top-quark events from its SM background. The polarisation observables were extracted from asymmetries in angular distributions measured with respect to spin quantisation axes, that were appropriately chosen for the top quark and the W boson, as proposed by theorists from IFIC and University of Granada. The obtained values for the top-quark and W-boson polarisation are in agreement with the Standard Model predictions. Moreover, this analysis also sets limits on the imaginary part of the anomalous coupling g_R from model-independent measurements.

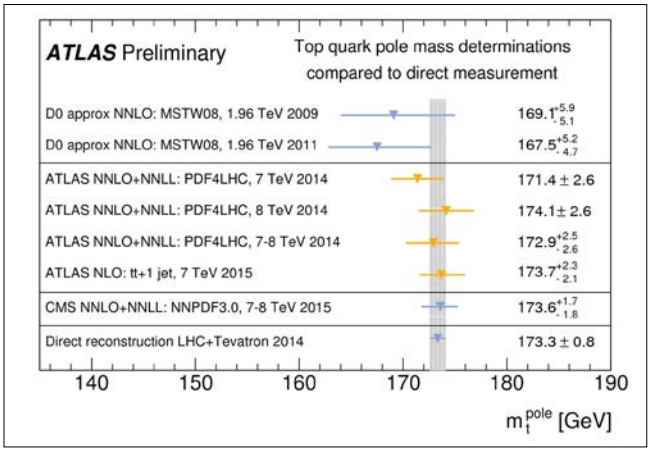
Concerning the top quark mass measurement, our group produced the current world's most precise measurement of the top quark pole mass. This measurement is the fruit of applying a novel method which considers the quark mass effects into the gluon radiation by the quarks (final topology: top-antitop+1 jet events). The top-quark mass sensitive observable has been computed up to NLO in collaboration with our colleagues from HU Berlin. The measurement on 7 TeV data reached a precision of slightly over 2 GeV, the ongoing analysis of the 8 TeV data has the potential to reach a very competitive precision of 1 GeV. Work is also underway to re-interpret the previous and new measurements in terms of the running mass of the top quark.

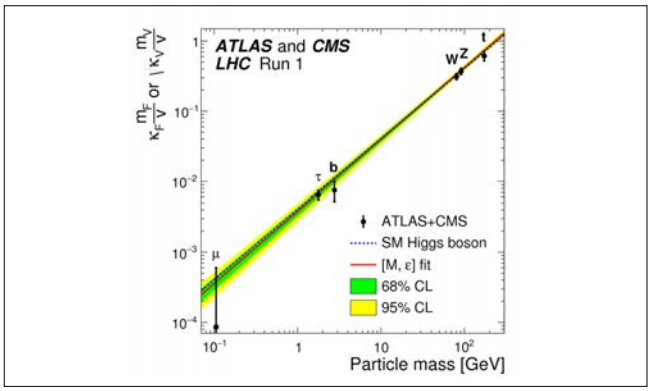
The first measurement of the charge asymmetry in highly boosted top quark pair production was performed by IFIC on 8 TeV proton-proton collisions collected by ATLAS. The analysis builds on previous activities in the development and application of new methods for the reconstruction of highly boosted top quarks. Several group members are deeply involved in studies of the response of the experiment to boosted objects, such as the in-situ determination of the jet mass response. The group demonstrated the sensitivity to physics beyond the Standard Model in an interpretation of the measurement in terms of dimension-6 effective operators.



Summary of the measured asymmetries in the Wtb analysis and comparison with the Standard Model predictions.

During 2016, IFIC-ATLAS group contributed to the final combination of the Higgs boson couplings with the LHC Run1 data (7 and 8 TeV)





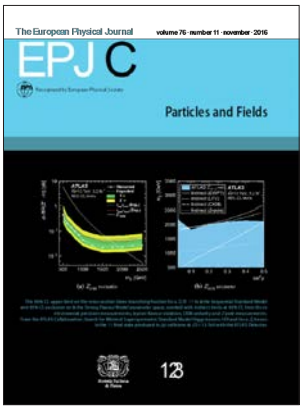
Best fit values of the Higgs couplings as a function of particle mass, where v = 246 GeV is the vacuum expectation value of the Higgs field (ATLAS and CMS combination).

ATLAS: new physics searches

Thanks to the increase of the centre of mass energy, the search for new massive particles has been a focal point of the LHC physics program, as well as of our group activities.

The participation of the group has been particularly prominent in the first searches at 13 TeV for high mass resonances decaying to two Higgs bosons in the bbγγ final state and for a heavy Higgs boson and a Z' boson decaying in two tau leptons. The bbyy final state has been chosen for its excellent mass resolution and low-level of background. So far, the search did not find evidence of new heavy particle decays and limits were set.

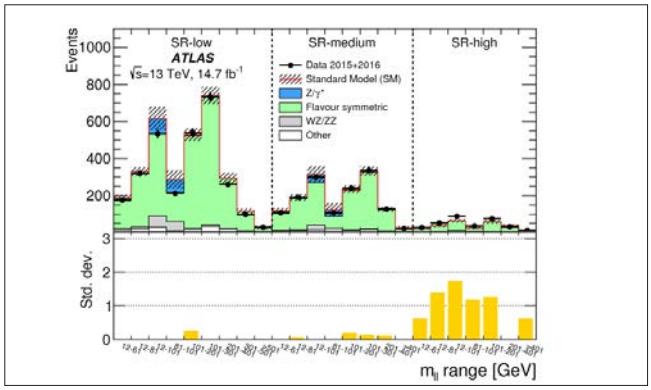
The two-tau leptons final state is one of the most sensitive decay mode for the search of heavy Higgs bosons of the Minimal Supersymmetric Standard Model (MSSM). The increase in centre of mass energy allowed to improve the sensitivity of this search for heavy scalar particles, as well as to Z' bosons. Our group members were part of the leading physicists delivering the first results of LHC Run 2. This ATLAS search was chosen to be the cover of the EPJC journal in November 2016.

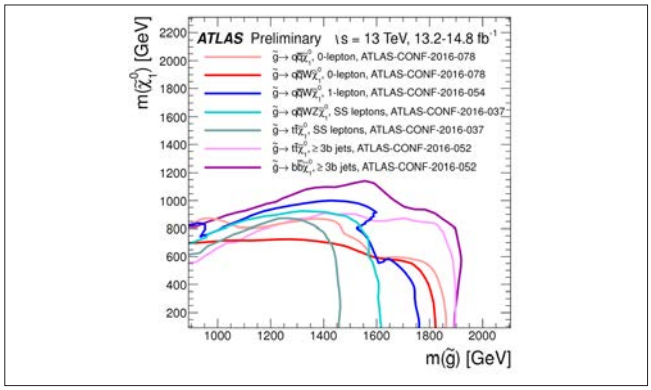


Cover of November 2016 edition of the EPJC Journal, showing the results of the ATLAS search for heavy MSSM Higgs bosons and Z' bosons decaying to two taus final state.

ATLAS: SUSY searches

The IFIC-ATLAS group is also 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 and Granada). Fruits of the latter are proposals to search for new SUSY signatures at LHC experiments, data analysis in selected channels and the interpretation of experimental results. The final 7 and 8 TeV results for the channel with two strongly-produced electron or muons plus large missing transverse momentum seemed to have hints of SUSY. Though, the 13 TeV data do not show evidence of SUSY. The fully hadronic channel, in which our group is also involved, provides the stronger sensitivity for many supersymmetric scenarios. Last but not least, in association with a theorist from IFIC the ATLAS Collaboration has studied the impact of electroweak SUSY searches on dark matter models.





The IFIC-ATLAS group is strongly involved in the ATLAS searches for supersymmetric particles (SUSY)

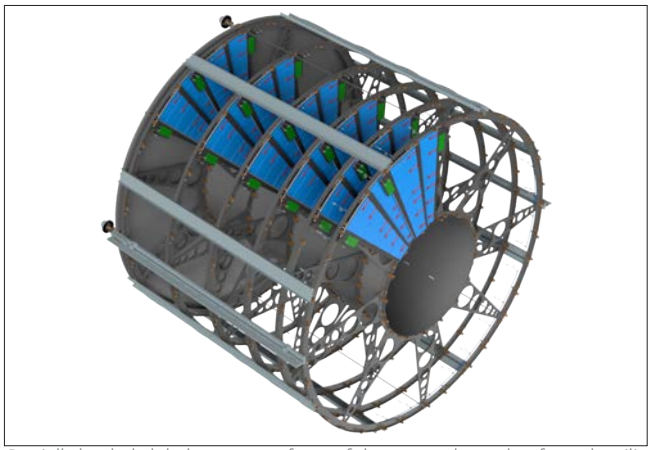
ATLAS: upgrade activities

In what concerns the upgrade of the ATLAS detector (a consequence of the planned increase of the LHC luminosity by a factor 5-10, known as High Luminosity-Large Hadron Collider: HL-LHC) our group participates in the upgrade of the TileCal and the replacement of the Inner Detector.

Our group is responsible of the Upgrade of the TileCal off-detector electronics for the HL-LHC. The TileCal Upgrade community released the Initial Design Report in December 2016. The TilePreProcessor is going to be the core of the HL-LHC TileCal off-detector electronics. The first prototype has been fully designed and built by our group with the purpose of standing full digitization of the calorimeter data and transmission to the ATLAS L0 trigger system at 40 MHz rate and stand an acceptance trigger rates above 1 MHz.

Another consequence of the HL-LHC is the need for a complete replacement of the ATLAS inner tracker. This is due basically to two effects: first, there will be more collisions in every bunch cross and therefore many more charged particles (exceeding 1000) will bloom out of the interaction region. Second, the accumulated radiation damage will be such that the current sensors will become inefficient, thus a new radiation hard silicon sensor technology is necessary. For those reasons, the ATLAS collaboration has decided to replace the current inner tracking system by an all-silicon one that may face the scientific and technical challenges of the HL-LHC.

Our group members have a long experience in the design, building and operation of silicon tracking systems (we already built part of the ATLAS Inner Detector). Moreover, we have experience in the design of radiation hard silicon sensors and in the tracking system engineering. Nowadays, we are involved in the design of the ITk (ATLAS Inner Tracker for the HL-LHC).



Partially loaded global structure of one of the two endcaps that form the silicon strip detector of the HL-LHC ATLAS inner tracker (ITk). This is the design proposed by our group and chosen as the baseline.

Our work in the ITk is divided in 4 packages: 1) Design of the global mechanical structures supporting in place the detectors and their local supports 2) Development of the n-on-p no type inverting radiation hard sensors. 3) Schemes for distributed power supply of sensors and modules, grounding and shielding. 4) Module design (with integrated services: power, signal and data routing, cooling system, assembly, wire bonding, etc).

During the ITk Mechanical assembly review held at DESY, the Valencia design was chosen as the baseline for the end-caps of the ITk strip detector. This represents a major achievement of our group and recognizes the excellence of our engineering team (in particular) and the quality work developed along the years by all our group members.

During 2016, we tested the so-called "petalet". This is a prototype of a region of the ITk strip end-cap petal, with 3 4-inch wafers per side and fully equipped. The petalet tests were relevant in order to understand and design the tooling for the assembly procedures and wire bonding to hybrids. Besides, many test were performed to characterize the electrical properties: sensor leakage current, sensor & inter-strip capacitances, noise and gain of each channel. We also prototyped a bus tape for routing the signals. Readout tests were completed verifying the specs were fulfilled.

The petalet was also tested in a test beam at CERN. Our group took care of the mechanical assembly, synchronization with rest of modules, powering, cooling, operation, etc. Data were collected with a muon beam at the CERN North Area with varying operational conditions (thresholds, readout frequency, bias voltage, etc).

Valencia hosted during September 2016 the ITk Collaboration week. More than 250 participants gathered to participate in the parallel sessions (pixels and strips subsystems) and plenary meetings.

IFIC design for the global structure of the endcap of the strip detector was chosen as the baseline

LHCb

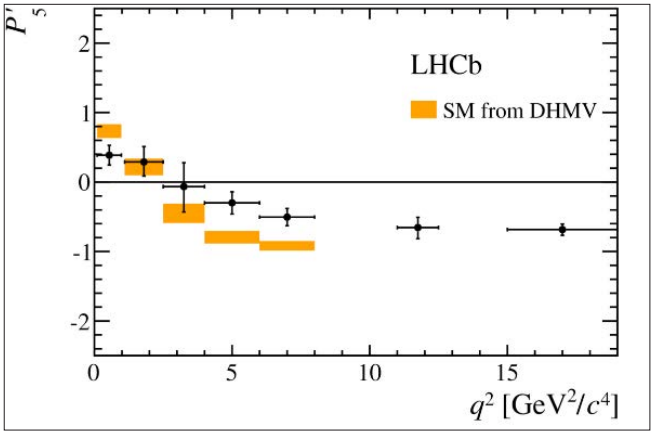
LHCb activities include detector operations and upgrade, physics data analysis, publication and presentations of results, phenomenology studies, as well as responsibilities in the organization of the collaboration.

Since the start of the LHC Run II in 2015, the experiment has integrated about 2 fb^{-1} of data, most of which (1.7 fb^{-1}) have been recorded during 2016. Combined with the increase of the centre-of-mass energy from 7-8 TeV to 13 TeV and the trigger improvements, it has allowed an increase of nearly a factor of three in the B hadron yields collected during the Run I. The group has contributed to the operation of the electromagnetic calorimeter and data quality.

LHCb physics

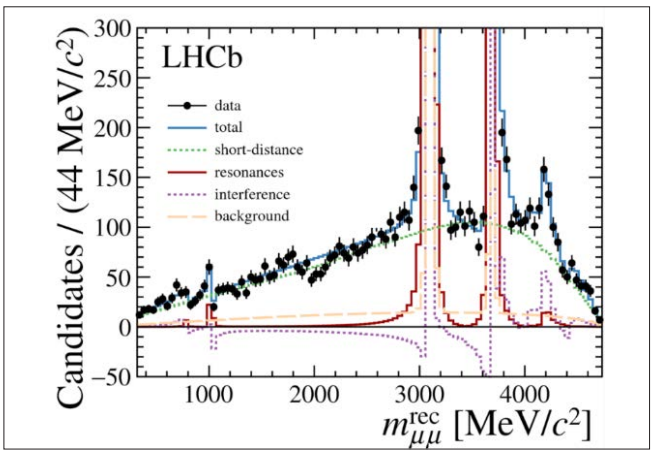
LHCb continued completing and extending a large number of physics analyses using the Run I data (3 fb^{-1}). Among these, the evidence for a number of anomalies in the flavour sector appeared during 2014 and 2015 has received special attention. These tensions point to deviations from Standard Model (SM) predictions of lepton universality, angular observables and differential branching fractions in a number of B-meson decays, e.g. $B^+ \to K^+\mu^+\mu^-$ and $B^0 \to K^{*0}\mu^+\mu^-$, that are mediated by flavour-changing neutral currents (FCNC), highly sensitive to new physics through loop effects. Besides, hints for lepton flavour universality have also been seen in the charged-current (tree level) decays $B^0 \to D^{*+}\tau^-\nu$.

The updated $B^0 \to K^{*0}\mu^+\mu^-$ angular analysis using the complete Run I data confirms previous results based on 1 fb^{-1}, confirming the tension to about 3σ in two q^2 (squared invariant mass of the dilepton system) bins between 4 and 8 GeV^2.



P'5 angular observable from $B^0 \to K^{*0}\mu^+\mu^-$ decays using the complete Run I data, compared to SM expectations.

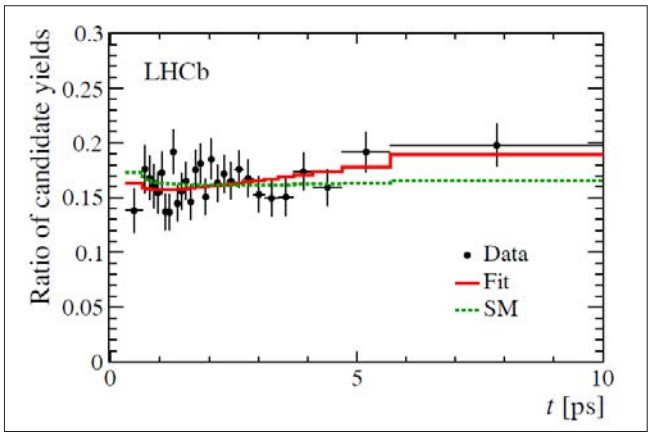
In an attempt to understand whether long-distance, non-perturbative hadronic effects can affect the SM predictions for angular observables and differential branching fractions, for example due to effects from charm vector resonances in the [4,8] GeV^2 region, the experiment has performed an inclusive analysis of the q^2 spectra in $B^+ \to K^+\mu^+\mu^-$ decays. A main conclusion of the study is that there are minimal interference effects between the penguin and pole amplitudes in the region of the anomalies.



Dimuon mass spectrum of $B^+ \to K^+\mu^+\mu^-$ decays, compared to fit model including up to nine vector poles.

In 2016 the experimentally challenging time-dependent analysis of the $B^0_s \to \phi\gamma$ radiative decay, an important milestone of the experiment, has been completed. This is also a FCNC process sensitive to new physics through the detection of a non-zero right-handed (left-handed for the underlying anti-b quark) photon polarization. The result, which still suffers from large statistical uncertainty, is consistent with SM predictions at 2σ level. Other related analyses are under way, including the study of time-dependent CP violation in $B^0_s \to \phi\gamma$ decays and angular distributions of b-baryon radiative decays.

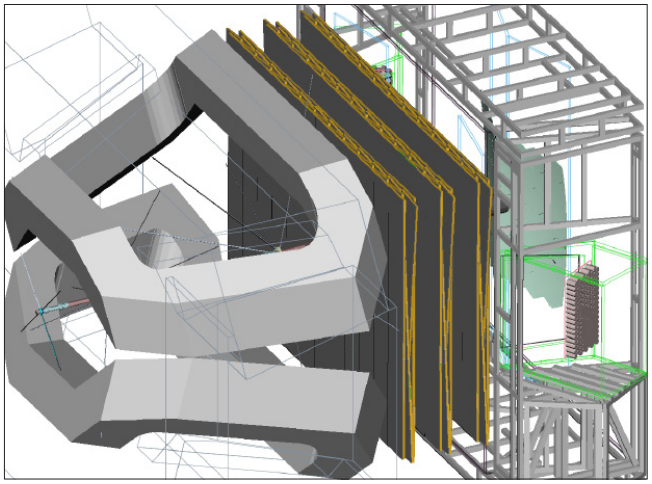
The evidence for a number of anomalies in the flavour sector appeared during 2014 and 2015 received attention



Ratio of the proper time distributions of $B^0_s \to \phi\gamma$ and of $B^0 \to K^{*0}\gamma$ decays, compared to fit model and SM predictions. The result is consistent with the SM at 2σ level.

LHCb upgrade

On the other hand, the Scintillating Fibre Tracker (SciFi) of the upgraded central tracker of the LHCb detector has consistently progressed during 2016. The SciFi will be installed during the LHC LS2 and is designed to provide standalone pattern recognition with high efficiency and resolution downstream of the LHCb dipole magnet. The front-end electronics, on which IFIC has shared responsibilities, has to procure full read-out of the SiPMs devices coupled to the fibres every 25 ns. Testing and characterization of the first full-size ASIC (PACIFICr3), containing 64 channels based on TSMC 130nm technology, were completed. This triggered the integration of the whole electronic system, along with the development of the software and firmware for radiation hardness studies at Heidelberg's Ion-Beam Therapy Centre. These results made it possible to pass successfully the Engineering Design Review, providing extremely valuable insight for the design of PACIFICr4 prototype, which was delivered by the foundry by the end of the year.



Schematic view of the upgraded LHCb central tracker (SciFi), downstream of the dipole magnet (on the left).

Phenomenology

The group is also involved in theoretical and phenomenology studies in the flavour sector. A good example of close collaboration between experimentalists and theorists is the proposal for extending and complementing the hunting for new physics at LHCb through the search of electric dipole moments (EDMs) of heavy and strange baryons. As well as the new constraints on the (yet unbroken) CPT symmetry, obtained from a phenomenological analysis of time-dependent decay rates of entangled B mesons as measured by BaBar. Members of the group have also contributed to the Beyond SM section of the "Handbook of LHC Higgs Cross Sections: 4. Deciphering the Nature of the Higgs Sector", with especial emphasis in the interplay between the flavour and the Higgs sectors in the context of 2HDM-BGL models.

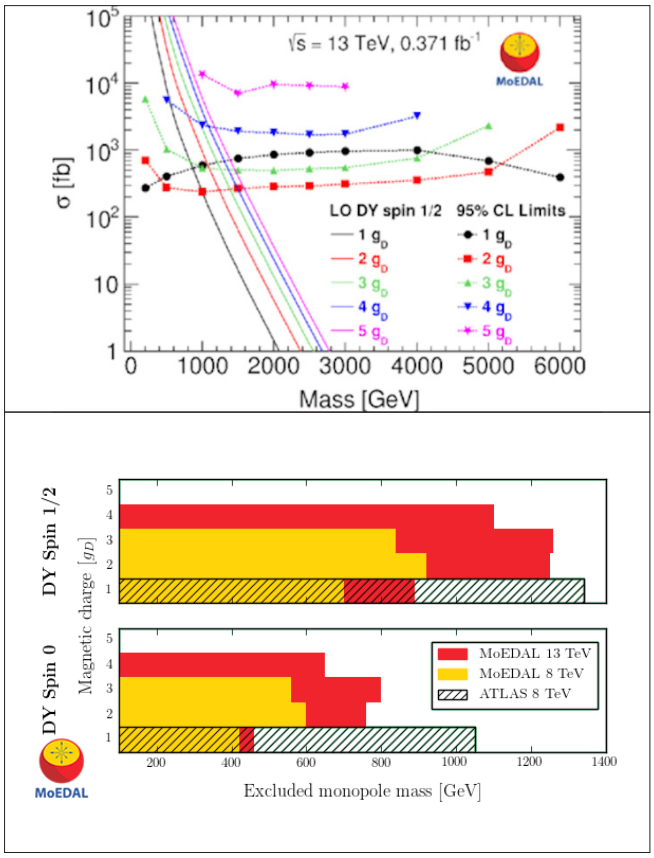
MoEDAL

The IFIC team is the only Spanish participation in MoEDAL. This experiment is designed to search for new physics through highly-ionising particles (HIPs). 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 SM. MoEDAL uses a (mostly) passive detector sitting next to LHCb. It features aluminium monopole trapping detector volumes and plastic Nuclear Track Detectors. The former elements after exposure to LHC collisions are analysed by a superconducting quantum interference device (SQUID) seeking captured magnetic monopoles. The TimePix detectors, the only active component of MoEDAL, serve as radiation monitoring system.

We are involved in both experimental aspects, such as the simulation of the detector, and also in the development and testing of 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 first MoEDAL physics results were based on an analysis of data collected during the LHC's first run at an energy of 8 TeV with a prototype trapping detector. Although showing no evidence for trapped monopoles, the results allowed to place mass limits for high charges for the first time at the LHC. These results gave rise to a CERN press release in August 2016. The analysis was repeated using data acquired during 2015 at 13 TeV with an extended MMT detector, leading to the world-best limits for monopoles of high magnetic charges. MoEDAL leads the search for high magnetic charges in colliders.

The MoEDAL collaboration is now actively working on the analysis of data obtained with the full detector – including plastic NTDs and trapping detectors – in 2016, with the exciting possibility of revolutionary discoveries in a number of new physics scenarios.



Linear Collider

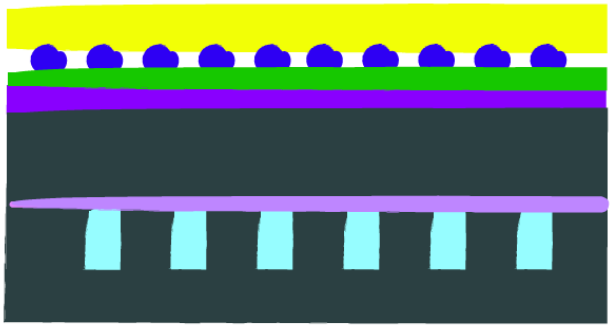
Our group is actively involved in the linear collider projects ILC (International Linear Collider, to be hosted in Japan) and CLIC (Compact Linear Collider, led by CERN).

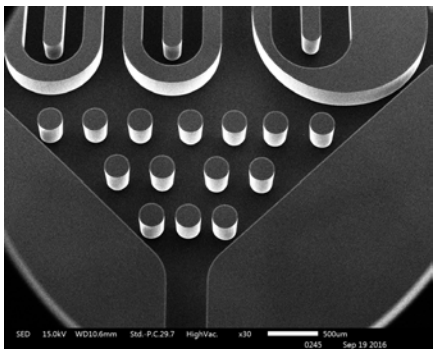
The contributions to the physics studies for the linear colliders focus on precision measurements of the top quark. The study into the potential of measurements of the electro-weak couplings of the top quark has established itself as a key element of the physics case for a linear e^+e^- collider. The result plays an important part in the definition of a staging scenario for CLIC (CERN-2016-004). The group has furthermore developed a new method to measure the top quark mass in associated production of a top quark pair and a photon. The group is deeply involved in studies of reconstruction techniques, in particular for jets.

IFIC is also a member of the DEPFET active pixel detector R&D collaboration. We contribute to the construction of the Belle II vertex detector, based on this technology. We have designed and produced the test system for assembled detectors. This first acceptance test is a crucial step in the quality assurance of the vertex detector. Production of the detector is proceeding on schedule. The production of key components has finalized with excellent yields and integration of the detector is ongoing.

IFIC's main goal in this area is the development of a DEPFET solution for future experiments at e^+e^- colliders at the energy frontier. It is responsible for the design of the vertex detector of the International Large Detector (ILD), to be installed at the ILC. During 2016 the group published first results on the cooling performance of the first prototype detector with integrated micro-cooling channels in the sensor. This R&D is performed in collaboration with the University of Bonn and the SemiConductor Laboratory of the Max Planck Society in Munich.

IFIC's members have been involved in the organization of the main workshops on linear colliders (i.e. ECFA LC workshop Santander 2016, LCWS 2016).





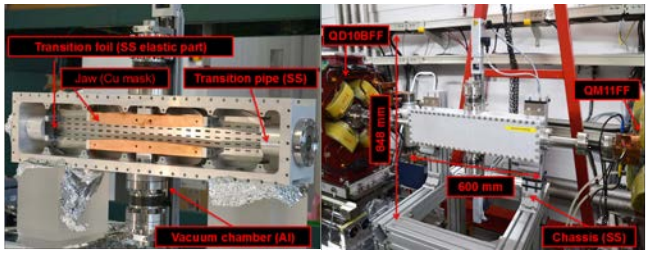
Schematic representation of micro-channel cooling for silicon sensors and detail of the cooling circuit implemented in a silicon sensor

IFIC contributes to the construction of the Belle II detector

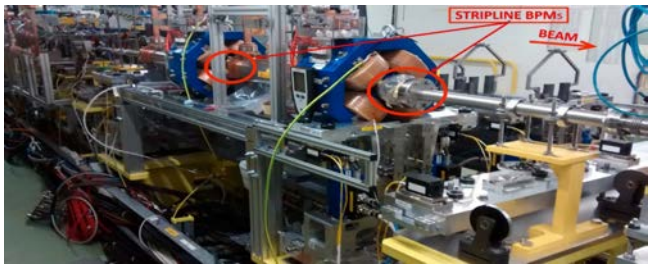
Accelerator Physics

Concerning the accelerators, the IFIC group has been participating actively in the study of 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.

Currently the 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 measure of the beam size and emittance by means of a multi-OTR system in routine operation since 2014 and in the control of the beam halo by movable collimators successfully operating since March 2016 in ATF2. Concerning CLIC-CTF3 the group has been collaborating in the design, construction and test of beam position monitors for the drive beam of CTFe and in the injection-extraction devices (Kickers) for the CLIC Damping Rings in close collaboration with the CIEMAT and an industrial partner.



Movable collimator installed in ATF2



Prototype stripline BPMs installed in the CLIC Two Beam Module

IFIC group participated in the study of collimation systems for Future Linear Colliders and Circular Colliders

Selected Publications

ATLAS Collaboration, *Measurements of the Higgs boson production and decay rates and constraints on its couplings from a combined ATLAS and CMS analysis of the LHC pp collision data at √s= 7 and 8 TeV*, JHEP16 08(2016) 046.

ATLAS Collaboration, *Test of CP Invariance in vector-boson fusion production of the Higgs boson using the Optimal Observable method in the ditau decay channel with the ATLAS detector*, Eur. Phys.J. C76 (2016) 658.

ATLAS Collaboration, *Search for new phenomena in events containing a same-flavour opposite-sign dilepton pair, jets, and large missing transverse momentum in √s = 13 TeV pp collisions with the ATLAS detector*, Eur. Phys.J. C77 (2017) no.3, 144

LHCb Collaboration, *First experimental study of photon polarization in radiative B0s decays*, Sep Published in Phys. Rev. Lett. 118 (2017) no.2, 021801, Addendum: Phys. Rev. Lett. 118 (2017) no.10, 109901

MoEDAL Collaboration, B. Acharya et al., *Search for magnetic monopoles with the MoEDAL prototype trapping detector in 8 TeV proton-proton collisions at the LHC*, JHEP 1608 (2016) 067

Selected Conference Talks

L. Fiorini, *Searches for Beyond Standard Model Higgs bosons with ATLAS*, Higgs Hunting 2016. Paris, France. September 2016.

J. Fuster, *ECFA linear collider physics and detector study (status report on activities 2016)*, Plenary ECFA Meeting. CERN, Geneva, Switzerland. November 2016.

J.E. García-Navarro, *Top physics in ATLAS and CMS*, LHC Days. Split, Croatia. 19 September 2016.

V. A. Mitsou for the MoEDAL Collaboration, *The MoEDAL experiment at the LHC: status and results* (invited plenary), DISCRETE 2016: Fifth Symposium on Prospects in the Physics of Discrete Symmetries. Warsaw, Poland. 28 November 2016.

A. Oyanguren, *Bs → φγ time dependent CP violation (WG4)*, CKM 2016. Mumbai, India. November 2016.

EXPERIMENTAL ASTROPARTICLE PHYSICS

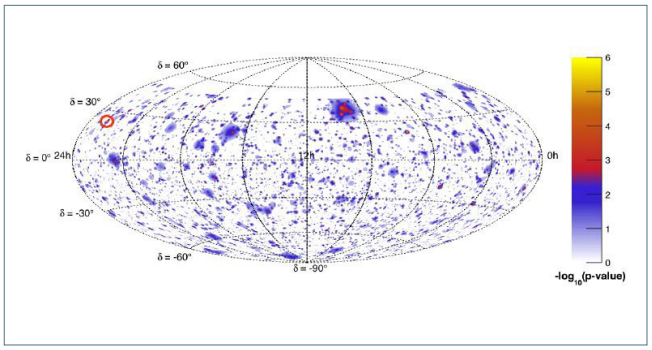
The year 2016 has been very fruitful in the field of neutrino astronomy. It started with the announcement by the LIGO Collaboration of the first detection of a gravitational wave. Detectors like ANTARES and IceCube, which can observe the whole sky all the time, had the opportunity to extend the multi-messenger paradigm. In the meantime, several updates of results were carried out with more ANTARES data. This year has also been critically important for the KM3NeT project. The IFIC's group had a leading role in many of these successes, as explained in the following.

ANTARES

The main contributions of the IFIC group in ANTARES are related to the searches for point sources, correlations with transient events and dark matter and to the time calibration of the detector.

Concerning point sources, a new analysis has been done in which cascades are added for the first time. Cascades in water, contrary to the case of ice, can be reconstructed with a good angular resolution (about 2 degrees). This new analysis, which also adds more data, keeps ANTARES limits as the best ones in the Southern Hemisphere for energies below 100 TeV.

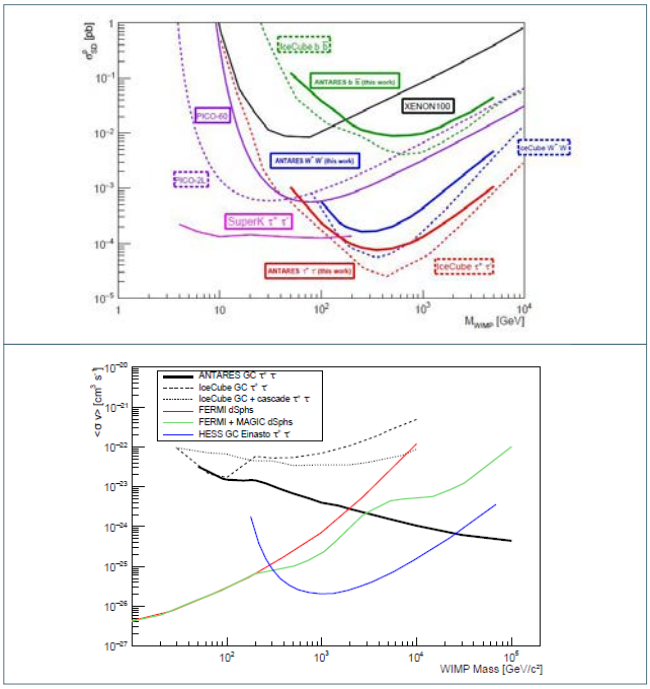
For transient sources, the PhD thesis of Agustín Sánchez Losa was awarded with the Global Neutrino Network Prize, sponsored by APPEC. Our group has also been recently reinforced with the main author on the ANTARES side of the analyses of gravitational wave events.



Skymap of pre-trial p-values for a point-source assumption of the ANTARES visible sky. The red circle indicates the location of the most significant source of the full sky search.

The searches for dark matter have given new, very relevant, results. A new paper has been published with the results for the Sun, a very interesting source since, contrary to other indirect searches, has no relevant astrophysical background. With respect to the Galactic Centre, the new ANTARES results (already sent to a journal) are the best ones worldwide for WIMP masses above 30 TeV.

Finally, an article on the time calibration with atmospheric muons has also been published. This technique has been shown to be successful and it is planned to be applied to KM3NeT.



Up: Limits on the spin–dependent WIMP–nucleon scattering cross–section as a function of WIMP mass for the b¯b, tau+ tau– and W+W– channels. Limits given by other experiments are also shown: IceCube, PICO-60, PICO-2L, SuperK, XENON100. Down: Limits on the WIMP annihilation cross–section as a function of WIMP mass for the tau+ tau– channel. Limits given by other experiments are also shown: IceCube, H.E.S.S. and Fermi.

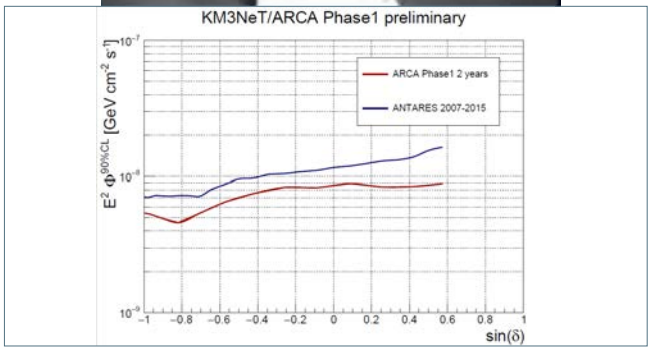
The main contributions of IFIC to ANTARES and KM3NeT are searchers for point sources and dark matter, electronic design and time calibration

KM3NeT

Several important news have consolidated the KM3NeT project during 2016. First, two new lines of the Phase 1 (which will have a total of 30 lines) have been deployed in the Italian site. Concerning Phase 2 (which will consist of 230 lines in Italy in a sparse configuration, ARCA, and 115 lines in France in a denser configuration, ORCA), the Letter of Intent was published in Journal of Physics G. Another important new was the official announcement of the inclusion of KM3NeT in the new ESFRI Roadmap of priority research infrastructures in Europe (together only with CTA and EST in the area of Physics and Engineering). Moreover, the project was funded with about 4 M€ in the InfraDev call of the H2020 program. The IFIC group, as participant of this proposal, will benefit with a reinforcement of postdocs.

The main contributions by our group are related to the search for point sources, the electronics design and the time calibration of the detector.

A recent analysis shows that with only two years of the Phase 1 configuration (24 lines in the Italian site), the sensitivity will be already better than present limits of ANTARES. The work in the laboratory has been focused on the production of the firmware for the TDCs in the Phase 1 and on the design of the main boards for the digital optical modules of Phase 2. The IFIC is participating in the technical discussions on the design of the network and time signal distribution for Phase II.



Up: Connection of one of the lines of KM3NeT in the deep sea. Down: Comparison of the sensitivity for point sources of two years of ARCA Phase 1 and the present limits of ANTARES.

In addition to the work in the above-mentioned analyses and tasks in the laboratory, our group has also several responsibilities in these projects: J.D. Zornoza is the coordinator of the Dark Matter and Exotics Group in ANTARES and is the coordinator of the Time Calibration Group in KM3NeT. He is also member of the KM3NeT Publication Committee. D. Real is the coordinator of the Electronics Group in KM3NeT.

Selected Publications

ANTARES Collaboration (Adrián-Martínez et al), *Limits on Dark Matter Annihilation in the Sun using the ANTARES Neutrino Telescope*, Physics Letters B, Volume 759, 10 August 2016, Pages 69–74 [arxiv:1603.02228]

ANTARES Collaboration (Adrián-Martínez et al), *High-energy Neutrino follow-up search of Gravitational Wave Candidate G184098*, Phys. Rev. D 93, 122010 [arxiv:1602.05411]

ANTARES Collaboration (Adrián-Martínez et al), *First combined search for neutrino point-sources in the Southern Hemisphere with the ANTARES and IceCube neutrino telescopes*, The Astrophysical Journal 823 (2016) [arXiv:1511.02149]

ANTARES Collaboration (Adrián-Martínez et al), *Time calibration with atmospheric muon tracks in the ANTARES neutrino telescope*, Astroparticle Physics78 (2016) 43-51 [arXiv:1507.07354]

ANTARES Collaboration (Adrián-Martínez et al), *Letter of Intent for KM3Net 2.0*, J.Phys. G43 (2016) no.8, 084001 [arxiv:1601.07459]

Selected Conference Talks

J. D. Zornoza, *Dark matter detection with neutrinos*, 3rd IBS-MultiDark-IPPP Workshop: Dark Matter from aeV to ZeV, November 2016, Durham, UK

J. Barrios-Martí, *All-flavour neutrino search for Point-Like Sources with the ANTARES Neutrino Telescopes*, TeV Particle Astrophysics 2016, September 2016, Geneva, Switzerland.

J.D. Zornoza, *Neutrino telescopes*, School on Recent Discoveries in Particle Physics, July 2016, Suwon, South Korea.

J.J. Hernández-Rey, *Dark matter searches with neutrino telescope*, Dark Matter 2016 Conference, July 2016, Santander, Spain.

C. Tönnis, *The indirect search for dark matter with the ANTARES neutrino telescope*, 6th Roma International Conference on Astroparticle Physics (RICAP16), June 2016, Rome, Italy.

EXPERIMENTAL NEUTRINO PHYSICS

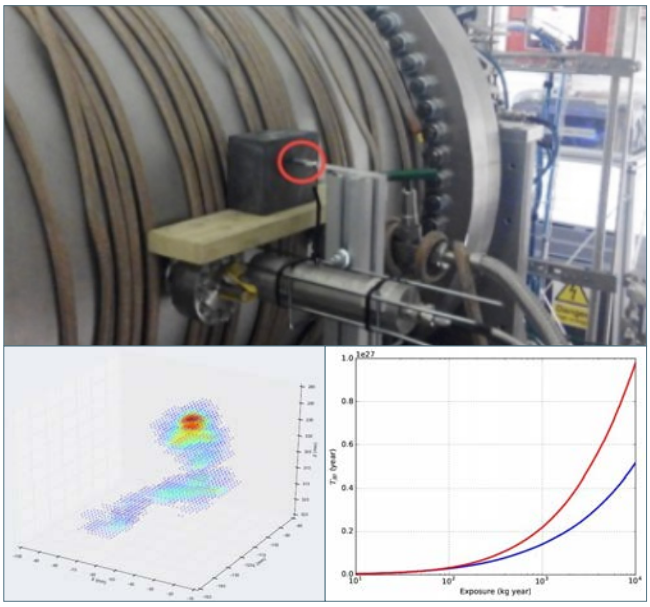
During 2016, the experimental Neutrino Physics group has focused its activities on the NEXT, T2K and DUNE experiments, addressing the major open questions in the physics of massive neutrinos.

NEXT

The goal of the NEXT (Neutrino Experiment with a Xenon TPC) collaboration is the sensitive search of the neutrino-less double beta decay (bb0n) of 136Xe at the Laboratorio Subterráneo de Canfranc (LSC). The observation of such a lepton-number-violation process would prove the Majorana nature of neutrinos, providing also handles for an eventual measurement of the neutrino absolute mass.

After the installation of the NEW detector at LSC in 2015, 2016 has been devoted to the first run of data taking with calibration sources. NEW is a 10-kg radiopure detector meant to understand the relevant backgrounds for the bb0n search and to perform a measurement of the two neutrino mode of the double beta decay (bb2n). The first phase of NEW physics program has consisted of the commissioning of the detector and the data taking with calibration sources (83Kr, 22Na), which has allowed to understand the detector capabilities in terms of energy resolution (below 1% at 3 MeV) and event topology reconstruction. In addition, two relevant papers have been published concerning the bb0n sensitivity of the future NEXT-100 detector, and the novel use of deep neural networks (DNN) to reject backgrounds.

After the installation of NEW detector at LSC, 2016 was devoted to the first run of data taking with calibration sources



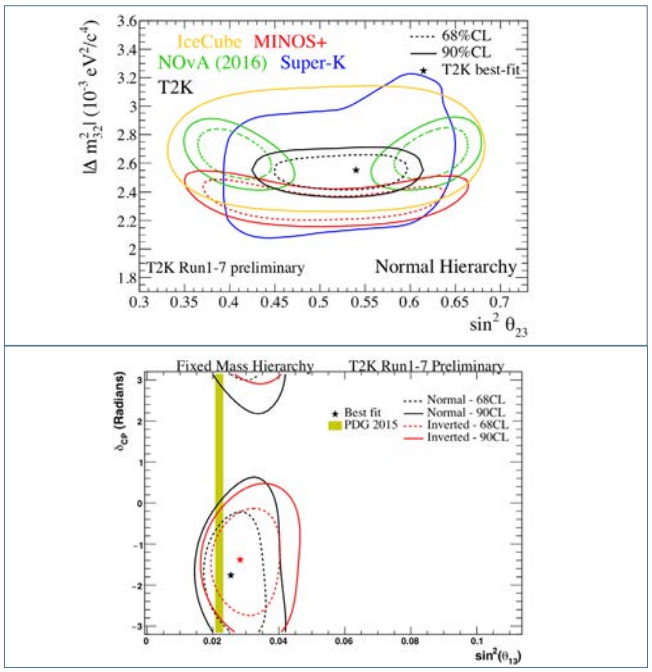
Above: 22Na source deployed in the lateral port of NEW. Down (left): reconstructed electron track in NEW. Down (right): NEXT-100 sensitivity to the bb0n half-life according to arXiv:1511.09246 (blue) and to the improvements based on DNNs (red).

T2K

Neutrino oscillation physics has entered a new era of precision with the search for possible CP-violation being the main focus. The T2K long baseline neutrino oscillation experiment, in Japan, already published the most precise limit so far on the δ_{CP} value resulting from its discovery of the appearance of electron neutrinos in a muon neutrino beam. After two years of data taking with reversed polarity (muon antineutrino beam), the first results for CP violation combining the four available data samples (appearance and disappearance channels for neutrino- and antineutrino-mode beam) have been obtained and will be published during 2017. The best fit value for δ_{CP} is near $-\pi/2$, while the CP conservation hypothesis is excluded at 90% C.L.

IFIC members are co-conveners of several T2K working groups in the ND280 near detector (software, "new physics", muon neutrino input to oscillation analyses, etc). Beyond those coordination activities, the IFIC group is heavily involved in several software, calibration and analysis activities in ND280, being the main focus the measurement of the unoscillated anti-neutrino flux at ND280.

IFIC members are conveners of several T2K working groups



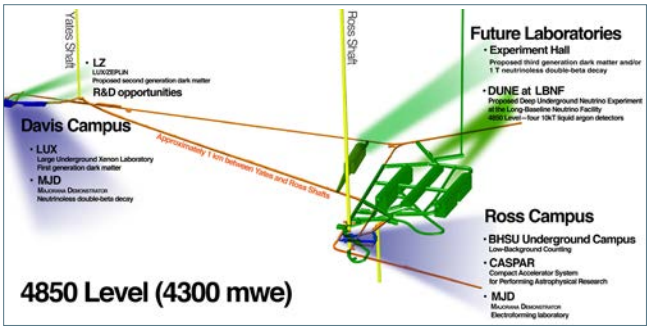
T2K oscillation results combining neutrino and antineutrino data samples.

DUNE

The Deep Underground Neutrino Experiment (DUNE) aims to be the "definitive" experiment for neutrino oscillations and the next mega-science project after the LHC. Preparations for DUNE have greatly advanced during 2016. On the one hand, the experiment has received the so-called CD-3A approval by the experiment's primary funding agency, the US Department of Energy, which enables the start of construction work in 2017 at the SURF laboratory in South Dakota, for the excavation of the caverns needed to host the massive, underground, liquid argon detector modules. On the other hand, the experiment has completed the Technical Design Reports for its two large-scale detector demonstrators, ProtoDUNE-SP and ProtoDUNE-DP, to be operated in a charged particle test beam at CERN in 2018.

During 2016, the experimental neutrino group at IFIC continued to be very active in DUNE physics and software activities. In particular, the DUNE-IFIC is currently responsible for the Nucleon Decay Physics Working Group. This group is charged with evaluating and demonstrating the experimental sensitivity of DUNE to various nucleon decay modes and other baryon number violating processes. The group has also participated in the development of the software tools for the experiment, including the analysis framework.

The DUNE-IFIC group started in 2016 a very important hardware activity toward the construction and operation of the ProtoDUNE-SP detector prototype at CERN. The group is responsible for the cryogenics and argon instrumentation, as well as for its slow controls and monitoring system. Having ProtoDUNE the largest cryostats ever constructed for a liquid argon TPC, precise (few millikelvin) measurements of the temperature gradient as a function of liquid argon depth are crucial for both the correct functioning of the TPC and for physics. The DUNE-IFIC group, in collaboration with IFIC's Electronics and Mechanics Support Units, will build a device to perform these temperature gradient measurements across the 8 m height of the liquid argon volume.



The SURF underground laboratory.

IFIC started activity toward the construction of ProtoDUNE-SP

Selected publications

NEXT Collaboration (J. Martin-Albo et al), *Sensitivity of NEXT-100 to neutrinoless double beta decay*, JHEP 1605 (2016) 159, DOI: 10.1007/JHEP05(2016)159 [arXiv: 1511.09246]

T2K Collaboration (K. Abe et al), *Measurement of Coherent pi+ Production in Low Energy Neutrino-Carbon Scattering*, Phys.Rev.Lett. 117 (2016) no.19, 192501, DOI: 10.1103/PhysRevLett.117.192501 [arXiv:1604.04406]

Valentina De Romeri et al, *Neutrino oscillations at DUNE with improved energy reconstruction*, JHEP 1609 (2016) 030, DOI: 10.1007/JHEP09(2016)030 [arXiv:1607.00293]

Selected Conference Talks

J. Renner, *Status of the NEXT experimental program*, October 2016, Strasbourg (France)

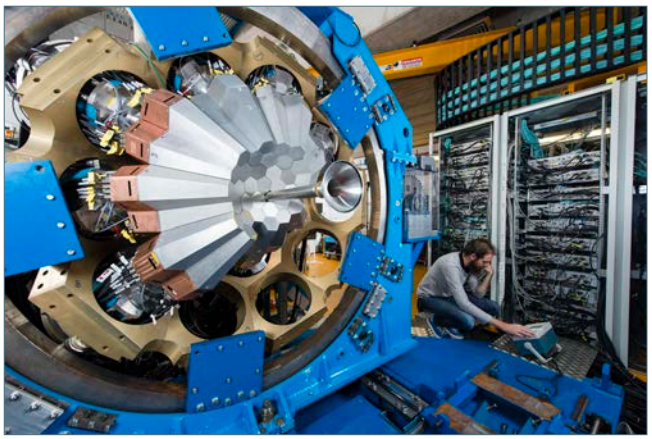
N. Lopez-March, *Status of the NEXT experiment at the LSC*, November 2016, VIII CPAN DAYS, Zaragoza (España)

A. Cervera, *Latest Results from Neutrino Oscillation Experiments*, SUSY'16, July 2016, Melbourne (Australia)

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 AGATA group at IFIC devotes its activity to the construction and deployment of AGATA and the design and construction of complementary instrumentation for neutron (NEDA) and light charge particle detection (TRACE). The aim is to use this instrumentation at the new generation of radioactive ion beam facilities, in particular FAIR (AGATA is the main instrument of HISPEC in NUSTAR and NEDA is also part of the HISPEC instrumentation). Currently, the instrumentation is being used at GANIL, Caen, France.



The AGATA sub-array in 2016 at GANIL.

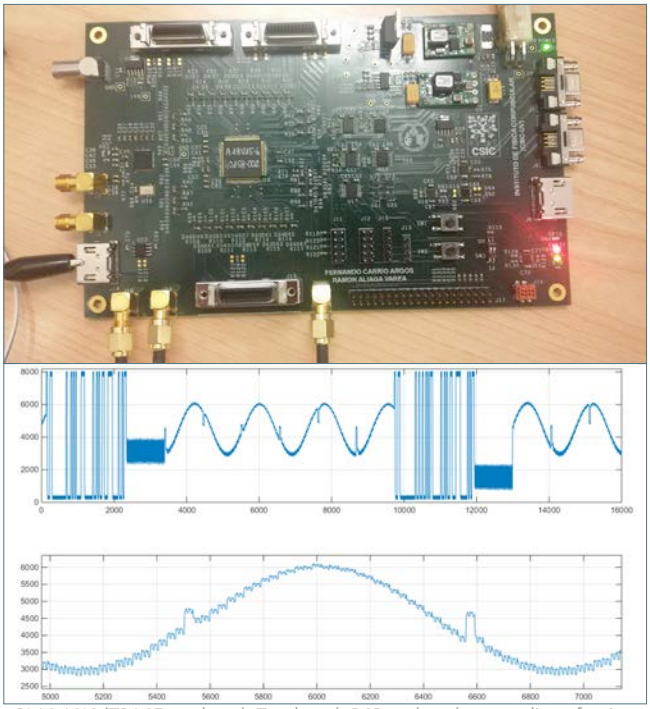
The year 2016 has been devoted to continuing the experimental campaign of the AGATA sub-array coupled to VAMOS. The group participated in all experimental activities. A total of 4 long experimental runs were performed. The experimentation this year was mostly focused on the use of heavy beams, namely 208Pb and 238U. In terms of data analysis that is responsibility of the IFIC AGATA group, the activity has largely progressed, preliminary results have been presented at the IIIrd Topical Workshop on Modern Aspects in Nuclear Structure (Bormio) and the NUSPIN Workshop (Venice).

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 started the production of a new batch of sampling electronics. The AGATA IFIC group has contributed significantly to the dissemination of the techniques to perform analysis, in the GRID environment.

Regarding the complementary detector NEDA, our group, in collaboration with the AGATA group of ETSE – UVEG, has continued the production of detectors and the completion of the electronics. The goal is to have a system of more than 50 detectors fully instrumented by the end of 2017. We have also published the conceptual design article for the present phase of NEDA (see Selected Publications).

NEDA conceptual Design in EPJA front page.

A collaboration of the AGATA group and the groups at ETSE-UVEG and I3M at the UPV is working on the design and production of a dead time-less analog memory ASIC (PLAS) for the TRACE project. The group has published 14 papers in 2016, including 2 Physical Review Letters.

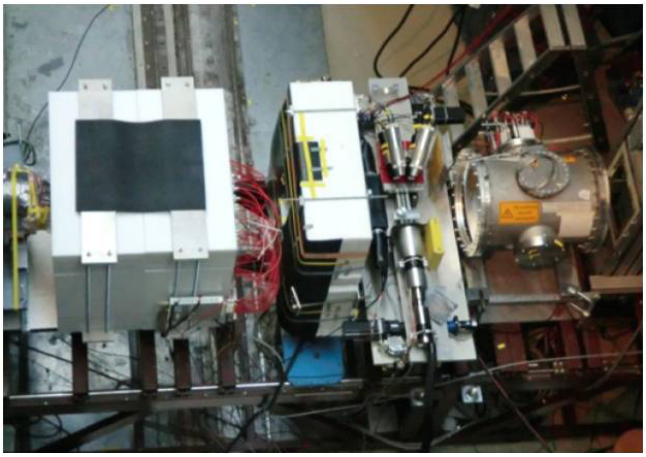


PLAS ASIC (TRACE read-out). Test bench PCB and analog sampling of a sine wave.

The research of the Gamma and Neutron Spectroscopy Group covers aspects of nuclear structure, astrophysics and applications.

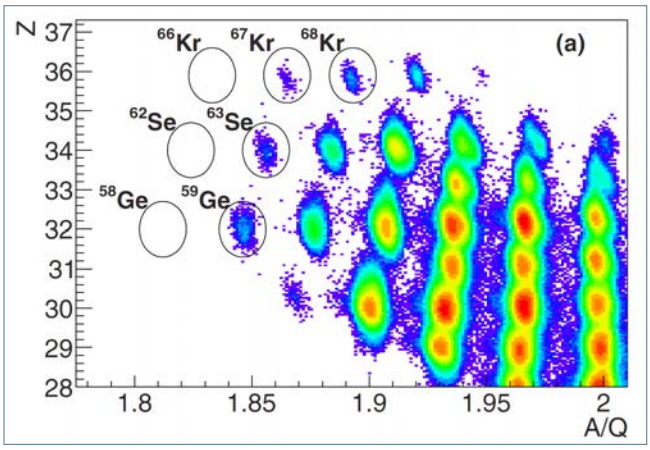
Several important results of the group this year are related to the study of exotic nuclei at the limits of nuclear existence. The publication by R. Caballero-Folch et al. in Physical Review Letters (PRL 117, 012501 (2016)) reports new half-lives and beta delayed neutron probabilities (Pn values) for 20 isotopes in the emblematic mass region N ≥ 126. These isotopes represent the heaviest nuclear species where beta-delayed neutron emission has been detected so far.

These results allow to put stringent constraints on theoretical models of the atomic nucleus, which are used for r-process nucleosynthesis calculations. In the measurements the BEta-deLayEd Neutron (BELEN) detector developed by Spanish groups for the experiment DESPEC of FAIR was used at GSI (Germany).



Another example of the study of very exotic nuclei comes from an experiment performed in RIKEN (Japan). In 2015 our group participated in and led some of the experiments at this radioactive beam facility. In these experiments a 78Kr beam was used to produce the most exotic nuclei along the proton drip line in the A = 60-70 region. The first results from this campaign have been published this year.

In the article B. Blank et al. (PRC 93, 061301(R) (2016)), the dripline nuclei 63Se, 67Kr, and 68Kr were identified for the first time. Two of them are potential candidates for ground-state two-proton radioactivity, a very exotic form of radioactivity. The observation of 59Ge, 63Se, 67Kr, and 68Kr and the non-observation of 58Ge, 62Se, and 66Kr define the position of the proton dripline in this region, in other words the limit of the existence of bound nuclear matter.



Exotic nuclei were also investigated in GANIL (France). In the publication of S. E. A. Orrigo et al., (PRC 94, 044315 (2016)), the first identification of the 2+ isomer in 52Co was reported. The trick in this study was not to look at the 52Co as the result of the fragmentation reaction but to look at the states populated in the beta decay of the 0+ state in 52Ni, thus producing the state of interest in a much cleaner way. 52Co lies on the rp-process pathway, for that reason this new information on the isomer and its decay characteristics is of relevance for nuclear astrophysics.

In September 2016 the ND2016 conference was held in Bruges, Belgium. This conference, which is the continuation of a series of international conferences that started in 1978 and held every three years, can be considered the primary conference for the advancement of nuclear data in the interest of science and technology. The group had one invited and three oral contributions to this conference (and participated in the international programme committee). This shows the relevance of the activities of the group in the field of nuclear data for applications, nuclear structure and astrophysics.

In the field of practical applications, the activities of the group are also reflected by the R&D work related to gamma-ray imaging. Such developments are being implemented for the decommissioning of nuclear power plants and contaminated areas.

The Consolidator Grant awarded to César Domingo Pardo by the European Research Council (ERC) for the project HYMNS "High sensitivitY Measurements of key stellar Nucleo-Synthesis reactions" started in June, 2016. HYMNS will recreate at the CERN n_TOF facility neutron-induced nucleosynthesis reactions on specific nuclei, which are relevant for understanding the origin of the heavy elements in our Galaxy. HYMNS aims at the development of innovative nuclear instrumentation and methodology for achieving a higher level of detection sensitivity for this kind of experimental study.

The group has also participated in the set-up and commissioning of the new experimental area EAR2 of CERN n_TOF, which features the world largest neutron luminosity over a broad energy range from thermal up to several MeV. This new installation has already yielded important results such as M. Barbagallo, et al. PRL 117 (2016), relevant to a better understanding of the cosmological lithium problem.

The group has published 23 papers in 2016, including 3 Physical Review Letters.

The AGATA IFIC group has contributed significantly to the dissemination of the techniques to perform analysis

Selected publications

Hüyük, Tayfun et al., *Conceptual design of the early implementation of the NEutron Detector Array (NEDA) with AGATA*, European Physical Journal A. 52 (2016) 3.

Hadynska-Klek, M et al., *Superdeformed and Triaxial States in Ca-42*, Physical Review Letters. 117 (2016) 062501.

Podolyák, Zs. et al., *Role of the Δ resonance in the population of a four-nucleon state in the Fe56→Fe54 reaction at relativistic energies*, Physical Review Letters. 117, (2016) 222302

R. Caballero-Folch, et al., *First Measurement of Several β-Delayed Neutron Emitting Isotopes Beyond N = 126*, Phys. Rev. Lett. 117, 012501 (2016)

V. Guadilla, et al., *First experiment with the NUSTAR/FAIR Decay Total Absorption Gamma-Ray Spectrometer (DTAS) at the IGISOL IV facility*, Nucl. Inst. and Methods in Physics Research B 376 (2016) 334

J. Agramunt et al., *Characterization of a neutron–beta counting system with beta-delayed neutron emitters*, Nucl. Inst. and Methods in Physics Research A 807 (2016) 69

S. E. A. Orrigo et al., *Observation of the 2+ isomer in 52Co*, Phys. Rev. C 94, 044315 (2016)

B. Blank et al., *New neutron-deficient isotopes from 78Kr fragmentation*, Physical Review C 93, 061301(R) (2016)

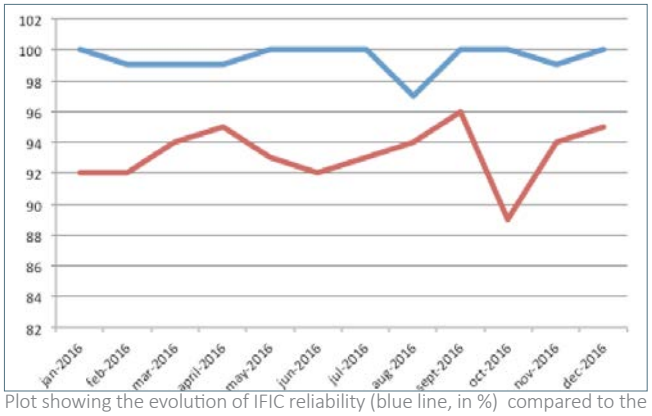
M. Barbagallo et al., *7Be (n ,α)4He Reaction and the Cosmological Lithium Problem: Measurement of the Cross Section in a Wide Energy Range at n_TOF at CERN*,

The Consolidator Grant awarded to César Domingo by ERC for high sensitivity measurements of key stellar nucleo-synthesis reactions started in June 2016

GRID & E-SCIENCE

The research topics of this research line include mainly the Spanish ATLAS Tier-2 goals. They also include 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 2016 (in April). 2016 has been the third 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 16186.8 HS06 and 1600 TB of disk. The efficiency of the whole Tier-2 has been of about 99.4% (and in particular the IFIC part has got a very good performance).



Plot showing the evolution of IFIC reliability (blue line, in %) compared to the average reliability of all ATLAS T2 reliability (in red, in %).

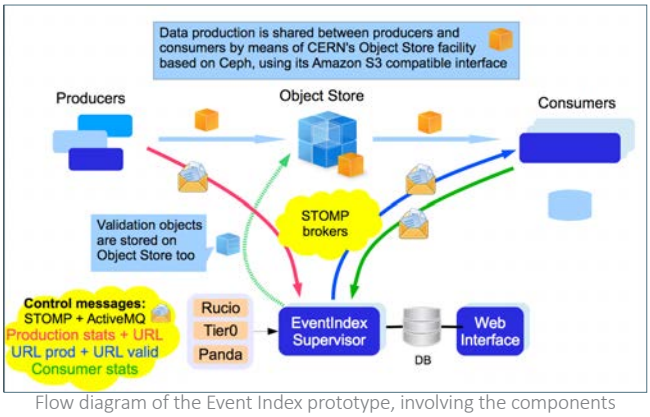
Our Tier-2 site has been evaluated in its function ('survey') and has been highly qualified by the evaluation committee. This follow-up committee was set up on March 30, 2016. In April, we have requested the new project (FPA2016) which has been granted at the end of the year.

The project activities have been continued: 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.

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 and a direct feedback for Tier-3 functionality.

The Event Index Project consists in the development and deployment of a complete catalogue of events for the ATLAS experiment at the LHC accelerator at CERN. After a prototype stage, it is currently running in production since the start of LHC Run 2, indexing all produced data. IFIC group is involved and responsible of the distributed data collection task. It is responsible for retrieving the relevant information of all the events from all the permanent dataset files, and transferring it to the Hadoop cluster at CERN, where it can be structured and aggregated by the Hadoop core task. Thus, the EventIndex project can be considered as a representative example of real grid systems in production generating big data.

On top of that, the IFIC group has continued its role as 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.



Flow diagram of the Event Index prototype, involving the components Producer-Supervisor-Consumer which are responsibility of the IFIC team. The group is working in the ATLAS Event Index Project updated with the new features developed during 2016: web interface, Object Store, etc.

This year have got the grant of the CSIC Cooperation Agreement I-COOP+ (COOPB20247) with the following title: 'Launching a Platform of Grid computing in Morocco to meet the new challenges of Physics research' for the two years period 2017-2018. In this case we are going to collaborate with our Moroccan colleagues of the Rabat University.

The efficiency of the whole Tier-2 was about 99'4%. IFIC part has got a very good performance

Selected publications

D. Barberis, J. Cranshaw, A. Favareto, A. Fernández Casaní, et al., *The ATLAS EventIndex: Full chain deployment and first operation*, ICHEP 2014 (International Conference in High Energy Physics 2014), publicado en los Proceedings (2016), pp. 913-918. DOI: 10.1016/j.nuclphysbps.2015.09.141

D. Barberis, S.E. Cárdenas Zárate, A. Favareto, A. Fernandez Casani, et al., *ATLAS EventIndex monitoring system using the Kibana analytics and visualization platform*, Journal of Physics: Conference Series, Volume 762, Number 1. doi:10.1088/1742-6596/762/1/012004

Selected conference talks

Álvaro Fernández, et al. on behalf of Atlas Collaboration, *ATLAS EventIndex General Dataflow and Monitoring Infrastructure*, CHEP-2016 Conference, October 2016. San Francisco (USA).

Fedor Prokoshin (on behalf of ATLAS Collaboration ATL-SOFT-SLIDE-2016-020), *ATLAS EventIndex monitoring system using the Kibana analytics and visualization platform*, Journal of Physics Conference Series 762 no1, 012004). 17th International Workshop on Advanced Computing and Analysis Techniques in Physics Research. Valparaiso (Chile). January 2016.

Fedor Prokoshin (on behalf of ATLAS Collaboration ATL-SOFT-SLIDE-2016-020), *The ATLAS EventIndex: data flow and inclusion of other metadata*, Journal of Physics Conference Series 762 no1, 012028). 17th International Workshop on Advanced Computing and Analysis Techniques in Physics Research. Valparaiso (Chile). January 2016.

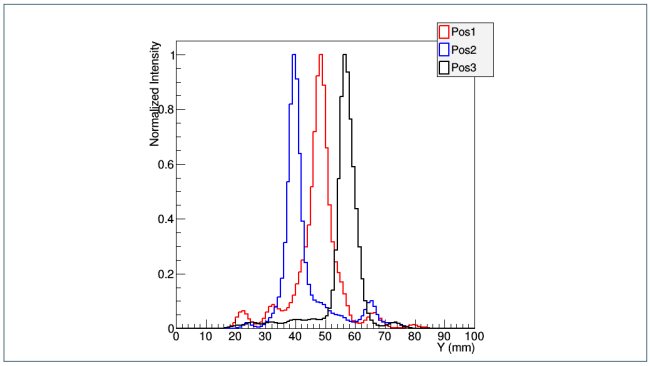
Carlos García Montoro, *ATLAS EventIndex Data Collection Supervisor and Web Interface*, CGW (Cracow GRID Workshop), Cracovia (Polonia), 24-26 October 2016.

MEDICAL APPLICATION OF NUCLEAR AND PARTICLE PHYSICS

The activities of the IRIS medical physics group of IFIC in 2016 continue the tests of a monitoring system for hadron therapy and the set up of the new laboratories of IFIMED.

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 it has been tested in the laboratory and in accelerator facilities.

The activities in 2016 have been focused on the improvement of the image reconstruction algorithms, on the analysis of the data taken in a test beam campaign carried out in December 2015 and on the full characterization of the system in the laboratory with different geometries.



Profiles of the images obtained with 4.4 MeV gamma rays obtained with the telescope in three different positions with respect to the target, separated 10 mm. The telescope response was also characterized with different geometries, placing the detectors at different distances to one another and from the source. The results were compared to simulations with GATE, with very good agreement.

The tests shows the ability of the detector developed by IRIS group to image photons at energies relevant for therapy

The telescope was tested at HZDR in Dresden, with 4.4 MeV photons obtained from accelerated protons impinging a TiN target. The telescope was operated acquiring data with any two or all three planes simultaneously and placed at three different positions with respect to the target. The analysis of the data shows the ability of the detector to image photons at energies relevant for hadron therapy.

Selected publications

K. Brzeziński, J.F. Oliver, J. Gillam, M. Rafecas, A. Studen, M. Grkovski, H. Kagan, S. Smith, G. Llosá, C. Lacasta, *Experimental evaluation of the resolution improvement provided by a silicon PET probe*, Journal of Instrumentation, 2016, vol 11.

J.F. Oliver, M. Rafecas, *Modelling Random Coincidences in Positron Emission Tomography by Using Singles and Prompts: a Comparison Study*, PLoS ONE., 2016, 11(9)

P. Solevi, E. Muñoz, C. Solaz, M. Trovato, P. Dendooven, J. Gillam, C. Lacasta, J.F. Oliver, M. Rafecas, I. Torres-Espallardo, G. Llosá, *Performance of MACACO Compton Telescope for Ion-Beam Therapy Monitoring: first test with proton beams*, Phys. Med. Biol., 2016, volume 61, num 14, 5149-5165.

A. Etxebeste, J. Barrio, E. Muñoz, J.F. Oliver, C. Solaz and G. Llosá, 3*D position determination in monolithic crystals coupled to SiPMs for PET*, Phys. Med. Biol.,61 (2016), 3914–3934

G. Llosá, M. Trovato, J. Barrio, A. Etxebeste, E. Muñoz, C. Lacasta, J.F. Oliver, M. Rafecas, C. Solaz and P. Solevi. *First Images of a Three-layer Compton Telescope prototype for Treatment Monitoring in hadron Therapy*, Front. Oncol., 2016, volume 6: 14.

Selected conference talks

G. Llosá, *Centro para imagen médica y terapia hadrónica IFIMED*, Invited talk and round table presentation. I Workshop español en protonterapia. 14 December 2016. Madrid, Spain.

G. Llosá, E. Muñoz, J. Barrio, J. Bernabéu, A. Etxebeste, C. Lacasta, J. F Oliver, P. G. Ortega, C. Solaz. *IFIMED status and results of a Compton telescope for hadron therapy*, VIII CPAN days. 28-30 November 2016. Zaragoza, Spain.

E. Muñoz, J. Barrio, J. Bernabéu, A. Etxebeste, C. Lacasta, J. F. Oliver, P. G. Ortega, C. Solaz and G. Llosá, *Improved Laboratory and in-Beam Results of a Compton Telescope with LaBr3 and SiPMs*. 2016 IEEE Nuclear Science Symposium and Medical Imaging Conference (NSS/MIC), November 2016, Strasbourg, France.

E. Muñoz, J. Barrio, A. Etxebeste, C. Lacasta, J.F. Oliver, P.G. Ortega, C. Solaz and G. Llosá, *Laboratory and beam tests of a Compton Telescope for treatment monitoring,* PTCOG 55. 22-28 May 2016. Prague, Czech Republic.

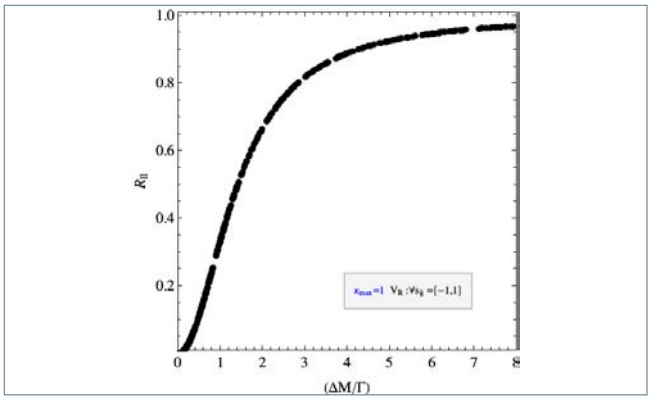
G. Llosá, Avances en imagen médica. *Detectores para el control del tratamiento con hadrones*, Invited Talk at II Simposio La física del cancer. Valencia, 17 May 2016, Spain.

G. Llosá, J. Barrio, A. Etxebeste, C. Lacasta, E. Muñoz, J.F. Oliver, P.G. Ortega, C. Solaz, P. Solevi, *Compton Telescope for hadron therapy range monitoring: update on characterization results and beam tests*, MEDAMI 2016. 1-5 May 2016. Ajaccio Bay, Corsica, France.

THEORETICAL PHYSICS

HIGH-ENERGY PHYSICS PHENOMENOLOGY

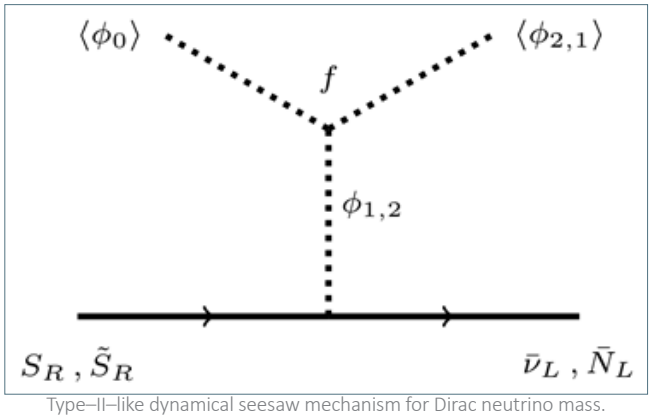
Lepton number violation is searched for at the LHC by looking for same-sign leptons plus jets. The standard lore is that the ratio of same-sign lepton to opposite-sign lepton events, Rll, is equal to 1 (0) for Majorana (Dirac) neutrinos. Researchers from IFIC have shown that for "quasi-Dirac" neutrinos this ratio can have any value between 0 and 1, the precise value being controlled by the mass splitting versus the width of the quasi-Dirac resonances. A measurement of Rll would then contain valuable information about the origin of neutrino masses.



The ratio Rll as a function of the ratio between the mass splitting and the width of the quasi-Dirac neutrinos.

Same-sign leptons events at the LHC can be used to learn about the origin of neutrino masses

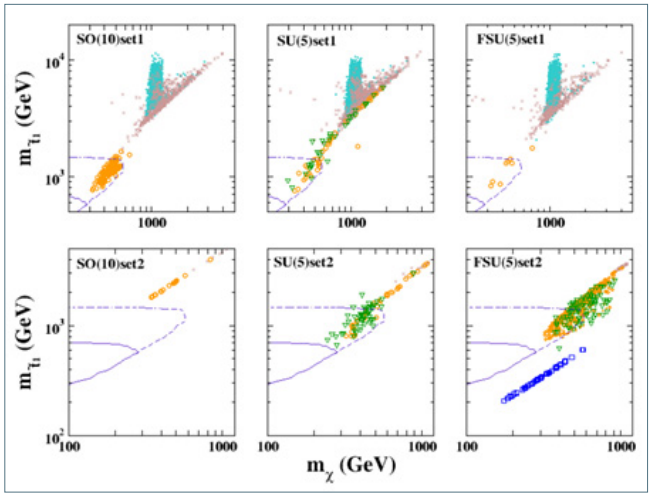
So far there is no evidence that neutrinos are their own anti-particles. IFIC researchers have proposed a new dynamical way to account for the Dirac nature of neutrinos and the smallness of their mass in terms of a new variant of the seesaw paradigm in which the energy scale of neutrino mass generation could be accessible to the current LHC experiments.



Type–II–like dynamical seesaw mechanism for Dirac neutrino mass.

A new dynamical mechanism for naturally light Dirac neutrinos has been proposed

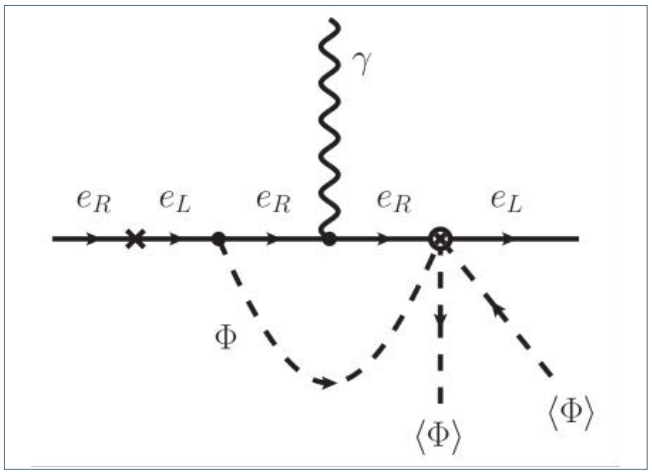
Researchers from IFIC have studied SO(10), SU(5) and flipped SU(5) GUT models with non-universal soft supersymmetry breaking scalar masses, exploring how they are constrained by LHC supersymmetry searches and cold dark matter experiments, and how they can be probed and distinguished in future experiments. Characteristic differences between the various GUT scenarios, particularly in the coannihilation region, have been found.



Scatter plots of non-universal GUT models in the neutralino-stop mass plane. The different colours correspond to different mechanisms production mechanisms.

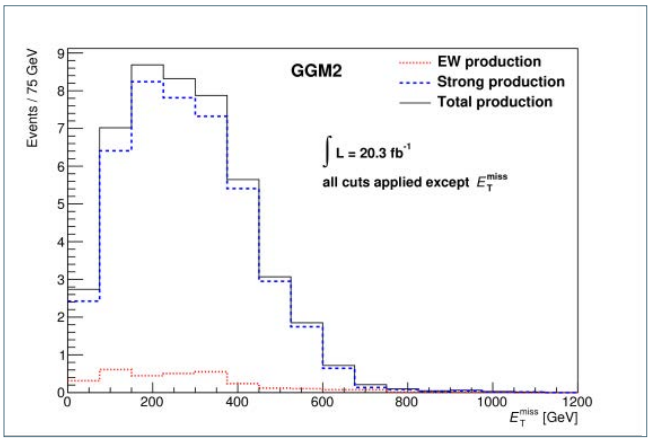
Supersymmetric grand-unified models have been explored using LHC data

Lepton flavour violating Higgs (HLFV) decays are studied from the effective field theory point of view. We argue why two Higgs doublet models can have a BR(H→ tau mu) ~0.01, and why this rate is suppressed in all other realizations including vector-like leptons. In the context of neutrino mass models this process is generated at one loop giving always a BR < 0.0001 and typically much less, beyond experimental reach. However, both the Zee model and extended left-right symmetric models contain extra SU(2) doublets coupled to leptons and could in principle account for the observed excess, with interesting connections between HLFV and neutrino parameters.



Contribution to tau→ mu gamma in the effective theory . The crossed circle represents the effective operator coupling and the cross in external leptonic legs represents a helicity flip produced by the tau mass.

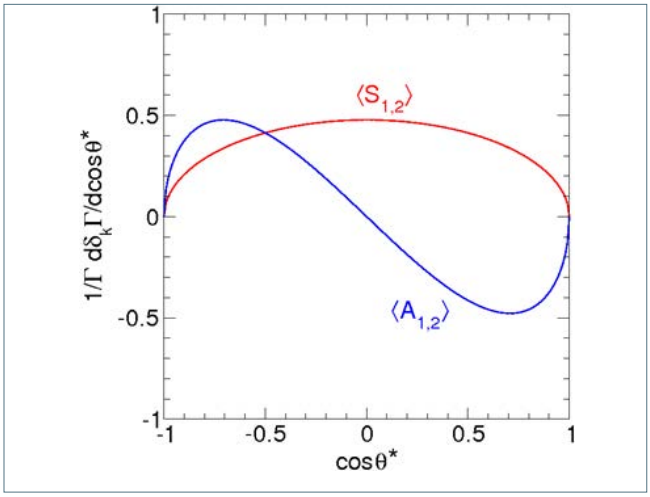
Researchers at IFIC have analysed the data from LHC experiments looking for clues of the presence of new physics. The ATLAS experiment with the Run I data, announced a 3 sigma excess of pairs of leptons at the Z-peak together with missing energy. We have shown that this excess can be explained in a general gauge medition SUSY model with relatively light gluinos and a heavy neutralino decaying predominantly to Z-boson plus a light gravitino. This explanation should be confirmed or rejected when the new data from the Run II at LHC is analysed.



Missing energy distribution in a general gauge mediation model from strong and electroweak production before applying the ETmiss > 225 GeV cut. With all the cuts applied, 28.0 ± 4.7 events are obtained, to be compared with the observed excess of 29 events.

IFIC researchers explore the first hints of new physics in the LHC data

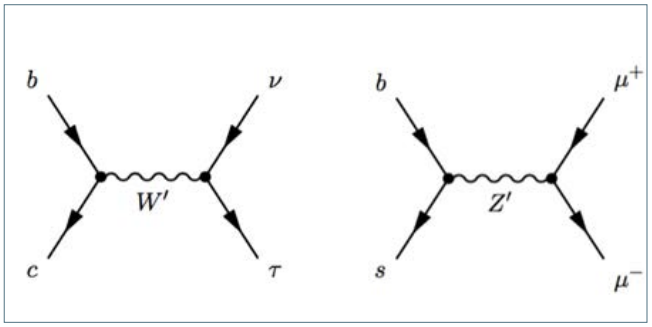
The eight independent spin observables for the W boson can be discussed in terms of its vector and tensor polarizations. IFIC researchers have identified the angular distributions and asymmetries and have been able to separate them in collider experiments. The results are applied to the study of polarized top quark decays and diboson resonances.



Functions associated to specific W boson decay angular distributions.

Angular distributions and asymmetries in W boson decays can been used to separate its spin observables

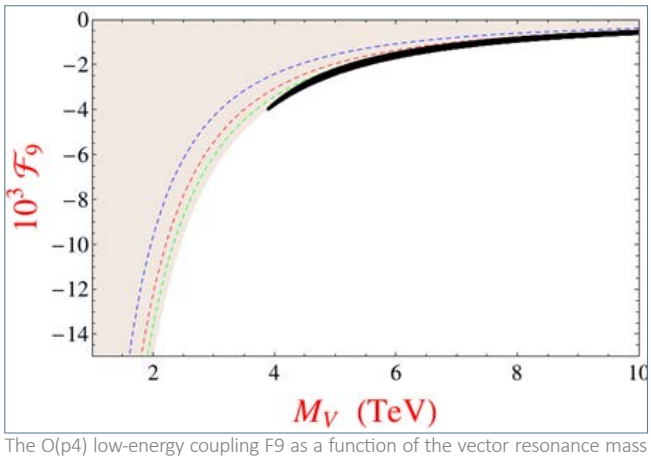
Several hints for lepton flavour non-universality in B-meson decays have been recently observed by the LHCb, Belle and BaBar collaborations. Given the strong physical implications of these anomalies, researchers from IFIC have studied the generic features of minimal gauge extensions of the Standard Model able to account for them. Furthermore, they also provided an explicit model based on the SU(2)xSU(2) xU(1) symmetry group that can explain the B-decay anomalies in a coherent way.



Generation of lepton flavour non-universal processes via the exchange of new W' and Z' gauge bosons.

A gauge extended model for the B-meson anomalies has been proposed

The non-observation of new particles at the LHC suggests the existence of a mass gap above the electroweak scale, a situation that is well described through a general electroweak effective theory. Researchers from IFIC have considered a generic strongly-coupled scenario of electroweak symmetry breaking, with heavy states above the gap, and analysed the imprints that its lightest bosonic excitations leave on the effective Lagrangian couplings. This allowed them to identify patterns of low-energy couplings, with characteristic correlations which could be identified in future data samples.



The O(p4) low-energy coupling F9 as a function of the vector resonance mass for several asymptotically-free theories. The oblique S and T constraints restrict the allowed ranges (95% C.L.) to the dark areas.

Patterns of low-energy couplings in strongly-coupled scenarios of electroweak symmetry breaking have been identified

Selected publications

G. Anamiati, M. Hirsch, E. Nardi, *Quasi-Dirac neutrinos at the LHC*, JHEP 1610 (2016) 010 – 18 pp, DOI: 10.1007/JHEP10(2016)010 [arXiv:1607.05641].

José W. F. Valle, C.A. Vaquera-Araujo, *Dynamical seesaw mechanism for Dirac neutrinos*, Phys. Lett. B 755 (2016) 363-366 – 4 pp, DOI: 10.1016/j.physletb.2016.02.031 [arXiv:1601.05237].

M. Cannoni, J. Ellis, M.E. Gómez, S. Lola, R. Ruiz de Austri, *Supersymmetry Searches in GUT Models with Non-Universal Scalar Masses*, JCAP 1603 (2016) 041 – 20 pp, DOI: 10.1088/1475-7516/2016/03/041 [arXiv:1511.06205].

J. Herrero-Garcia, N. Rius and A. Santamaria, *Higgs lepton flavour violation: UV completions and connection to neutrino masses*, JHEP 1611 (2016) 084 – 46 pp, DOI: 10.1007/JHEP11(2016)084 [arXiv:1605.06091].

G. Barenboim, J. Bernabeu, V.A. Mitsou, E. Romero, O. Vives, *METing SUSY on the Z peak*, Eur.Phys.J. C76 (2016) 57 – 17 pp, DOI: 10.1140/epjc/s10052-016-3901-7 [arXiv:1503.04184].

J.A. Aguilar-Saavedra, J. Bernabeu, *Breaking down the entire W boson spin observables from its decay*, Phys. Rev. D93 (2016) 011301 – 6 pp, DOI: 10.1103/PhysRevD.93.011301 [arXiv:1508.04592].

Sofiane M. Boucenna, Alejandro Celis, Javier Fuentes-Martin, Avelino Vicente, Javier Virto, *Non-abelian gauge extensions for B-decay anomalies*, Phys.Lett. B760 (2016) 214-219 – 6 pp, DOI: 10.1016/j.physletb.2016.06.067 [arXiv:1604.03088].

Antonio Pich, Ignasi Rosell, Joaquin Santos, Juan Jose Sanz-Cillero, *Low-energy signals of strongly-coupled electroweak symmetry-breaking scenarios*, Phys. Rev. D 93 (2016) 055041 – 6 pp, DOI: 10.1103/PhysRevD.93.055041 [arXiv:1510.03114].

Selected conference talks

A. Vicente, *New physics in B-meson decays, PLANCK2016: 19th International Conference From the Planck Scale to the Electroweak Scale*, May 2016, Valencia, Spain.

R. Fonseca, *The Sym2Int program: going from symmetries to interactions, 5th Symposium on Prospects in the Physics of Discrete Symmetries (DISCRETE 2016)*, November 2016, Warsaw, Poland.

R. Ruiz de Austri, *Global fits, Dark Matter at the LHC*, April 2016, Amsterdam, The Netherlands.

J. Salvadó, *Aspects of light sterile neutrinos, Invisibles 2016*, September 2016, Padova, Italy.

O. Vives, *Non-universal MSSM as the effective theory from flavour, 24th International Conference on Supersymmetry and Unification of Fundamental Interactions (SUSY 2016)*, July 2016, Melbourne, Australia.

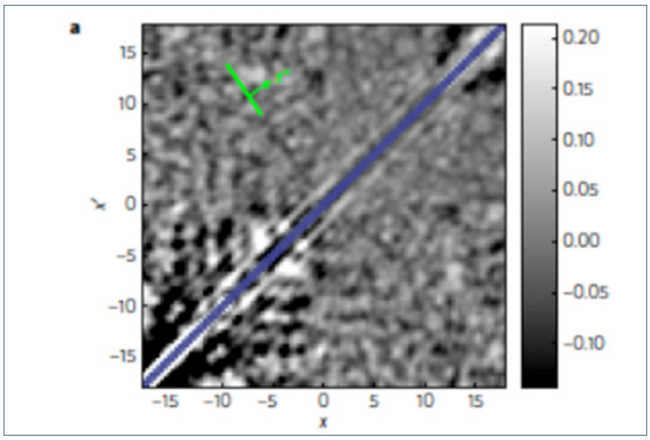
D. Das, *Lessons for new physics for Higgs decay to two photons, PLANCK2016: 19th International Conference From the Planck Scale to the Electroweak Scale*, May 2016, Valencia, Spain.

G. Rodrigo, *Status of the top quark asymmetries, PLANCK2016: 19th International Conference From the Planck Scale to the Electroweak Scale*, May 2016, Valencia, Spain.

G. Abbas, *FCNC decays of the top quark in the aligned two-Higgs doublet model, PLANCK2016: 19th International Conference From the Planck Scale to the Electroweak Scale*, May 2016, Valencia, Spain.

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

The year 2016 has been very important for quantum field theory in curved backgrounds thanks to the first experimental detection of Hawking radiation produced by acoustic horizons in Bose Einstein condensates. The pattern of correlations measured by the experiment are in excellent agreement with the theoretical expectations proposed some years ago by members of our group.



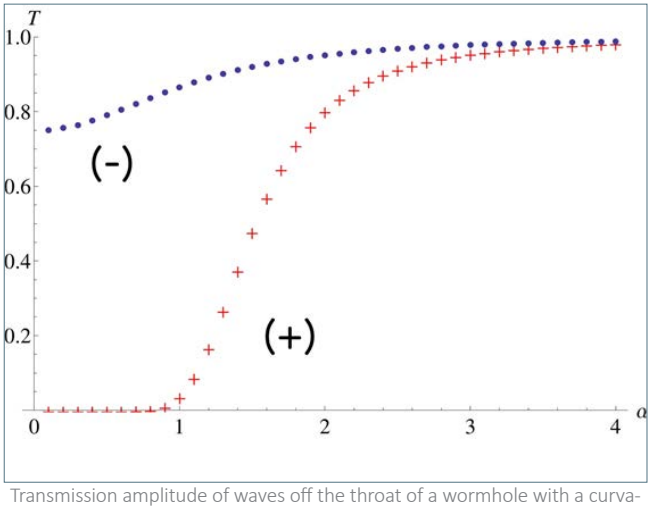
Density correlations measured in a one-dimensional Bose-Einstein condensate.

The experimental detection of analogue Hawking radiation is in agreement with the predictions of our group

The duality transformation between electric and magnetic fields in curved space-time is a symmetry, with an associated Noether charge related to the polarization state of the field. We have shown that quantum effects in curved space-time break this symmetry and allow the polarization of the field change with time even in the free case.

Electric magnetic duality in curved space-time is broken due to quantum effects

We have thoroughly studied the characterization curvature divergences in a family of black hole space-times with wormhole structure in a variety of ways: by considering the completeness of geodesics and the behaviour of congruences of geodesics, and through the scattering of (scalar) waves. We have found that geodesics are complete and that waves can be reflected and transmitted despite curvature divergences. We have also shown that extended objects would not be destroyed by the intense tidal forces generated by the unbounded curvature.



Transmission amplitude of waves off the throat of a wormhole with a curvature divergence.

If the space-time at microscopic scales were non-Riemannian wormholes, it could help resolve singularity problems

Selected publications

I. Agullo, A. del Rio, J. Navarro-Salas, *Electromagnetic duality anomaly in curved spacetimes*, Phys. Rev. Lett. 118, 111301 (2017), DOI: 10.1103/PhysRevLett.118.111301 [arXiv:1607.08879]

Gonzalo J. Olmo, D. Rubiera-Garcia, A. Sanchez-Puente, *Impact of curvature divergences on physical observers in a wormhole space-time with horizons*, Class.Quant.Grav 33 (2016) no.11, 115007. DOI: 10.1088/0264-9381/33/11/115007 [arXiv: 1602.01798]

Gonzalo J. Olmo, D. Rubiera-Garcia, A. Sanchez-Puente, *Classical resolution of black hole singularities via wormholes*, Eur.Phys.J. C76 (2016) no.3, 143. DOI: 10.1140/epjc/s10052-016-3999-7

A. Fabbri, R. Balbinot, P.R. Anderson, *Scattering coefficients and gray-body factor for 1D BEC acoustic black holes: Exact results*, Physical Review D 93, 064046 (2016). DOI:10.1103/PhysRevD.93.064046 [arXiv: 1512.08447]

M. Casals, A. Fabbri, C. Martínez, J. Zanelli, *Quantum dress for a naked singularity*, Physics Letters B760, 244 (2016). DOI: 10.1016/j.physletb.2016.06.044 [arXiv: 1605.06078]

Selected conference talks

G.J. Olmo, *Black holes, wormholes, and singularities beyond Riemannian geometry*, Plenary talk at Spanish-Portuguese Relativity Meeting, September 2016, Lisbon (Portugal).

A. Fabbri, *Quantum backreaction in rotating BTZ black holes*, October 2016, LPT Orsay (Francia).

A. del Río, *Electromagnetic duality symmetry in curved space-times*, International Conference on General Relativity (GR21), 10-15 July, 2016, New York (USA).

G. J. Olmo, *Nonsingular black holes in Palatini theories of gravity*, GrACo III, 26-29 April, 2016, Río de Janeiro (Brasil).

M. A. Lledó, as leader Work Group 5 of COST Action MP1210, *The String Theory Universe*, Second Workshop on String Theory and Gender, June 2016, Paris (France).

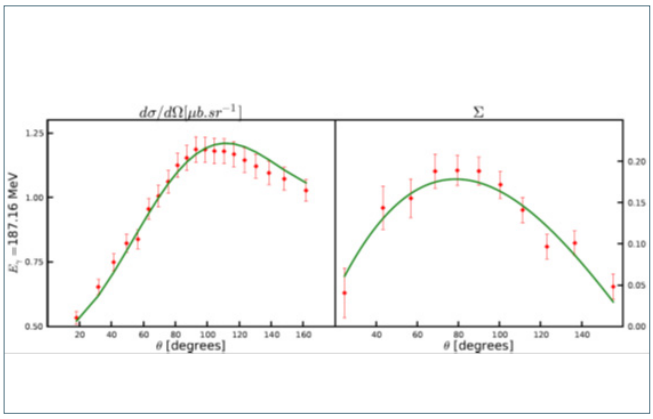
NUCLEAR PHYSICS AND MANY-BODY THEORY

Effective field theory and many-body techniques are powerful tools to tackle a broad range of problems in hadronic and nuclear physics. With their help we can address fundamental questions about the structure of light and heavy hadrons, the nature of exotic states, the interactions of particles with nuclei and nuclear matter properties.

The spectroscopy of mesons and baryons with heavy constituent quarks is living an exciting era with the frequent discovery of new states that challenge the current paradigm. An interesting example is the $Z_c^{\pm}(3900)$, a resonant-like state observed by the BESIII experiment. It couples strongly to charmonium but, being charged, cannot be a conventional charm-anticharm state and should contain at least another two constituent quarks. We have shown that the D*D and $J/\psi\pi$ invariant mass distributions, where the Z_c is observed, can be simultaneously described in two different scenarios with the Z_c being a resonance or a virtual state of molecular nature. We have also found that these two cases can be discriminated with lattice QCD by the volume dependence of the energy labels.

Weak decays of heavy hadrons have been extensively investigated. Indeed, certain resonances can (only) be accessed in such decays. For example, the $D_s^*(2317)$ arises as a DK bound state in bottomed meson decays. We have also shown that further insight about this state can be obtained in present facilities by studying the decay of the Bc meson into J/ψDK. In the baryon sector, the experimental study of Λ_b weak decays has led to the observation of states interpreted as hidden charm pentaquarks $P_c(4380)$ and $P_c(4450)$. In 2016 we have proposed to search for the open strangeness counterpart of the $P_c(4450)$ in the decay of the Ξ_b- baryon into $J/\psi\Lambda K^-$. Such a study is underway at LHCb. We have also investigated scenarios in which triangle singularities in Λ_b decays could be confused with narrow P_c -like states.

Neutral pion photoproduction on protons at low energies is especially interesting. Its small but non-vanishing threshold amplitudes are a measure of the explicit chiral symmetry breaking of QCD. Using Chiral Perturbation Theory for baryons we have achieved a remarkably accurate description of the differential cross section and linearly polarized photon asymmetries measured with high precision at the Mainz Microtron. Key to this success are the Extended on Mass Shell regularization scheme, which restores a proper power counting respecting covariance and analyticity, and the explicit inclusion of the $\Delta(1232)$ intermediate state. Both ingredients enhance the convergence of the theory.

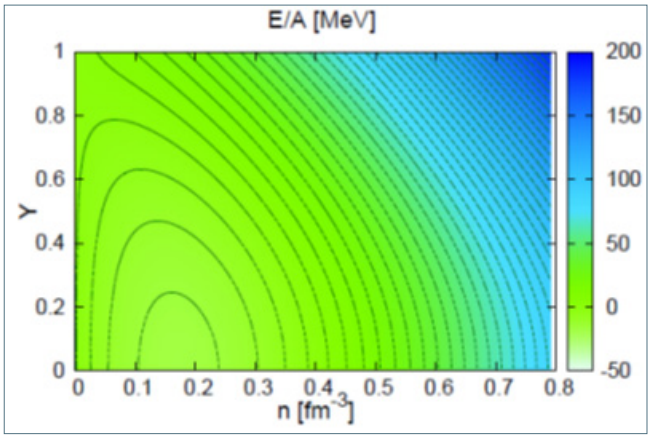


Differential cross section and photon asymmetry as a function of the pion angle for $(\gamma)\vec{}p\to p\,\pi^0$ at Eγ=197.16 MeV. Results from the best-fit theoretical model are shown together with the Mainz data.

We proposed to search for the open strangeness counterpart of the $P_c(4450)$ in the decay Ξ - baryon into $J/\psi\Lambda K^-$

We have also made progress in the theoretical modelling of neutrino-induced pion production on nucleons. This process is not only interesting as a source of information about the axial structure of the nucleon and its excited states but is a relevant source of systematic errors in the analysis of accelerator-based neutrino oscillation experiments. By imposing the Watson's theorem in the dominant vector and axial multipoles we have reconciled the value of the leading axial N-Δ transition coupling, extracted from the available $\nu_\mu p \to \mu^- p\,\pi^+$ data, with the predictions from chiral symmetry.

Further insight has been gained in the description of nuclear matter using effective nucleon-nucleon interactions. In particular, we have obtained a new equation of state for symmetric, asymmetric and neutron matter based on a Skyrme functional with higher order derivative terms (extended Skyrme functional), where the coupling constants are fixed from ab-initio calculations. Such extension allows for a more precise description of the high-density region. The resulting equation of state is compatible with recent measurements of two times Solar-mass neutron stars.



Equation of state for asymmetric nuclear matter: binding energy per particle as a function of the nuclear density n and the asymmetry parameter $Y = (n_n - n_p)/n$.

By imposing the Watson's theorem in the dominant vector and axial multipoles, we reconciled the value of the leading axial N-Δ transition coupling with the predictions from chiral symmetry

Selected publications

M. Albaladejo et al., *$Z_c^{\pm}(3900)$: What has been really seen?*, Phys. Lett B 755 (2016) 337, DOI: 10.1016/j.physletb.2016.02.025.

M. Albaladejo et al., *$D_s(2317)$ and DK scattering in B decays from BaBar and LHCb data*, Eur. Phys. J. C 76 (2016) 300, DOI: 10.1140/epjc/s10052-016-4144-3

H. X. Chen et al., *Looking for a hidden-charm pentaquark state with strangeness S = −1 from Ξ_b^- decay into J/ψ K^- Λ*, Phys. Rev. C 93 (2016) 065203, DOI: 10.1103/PhysRevC.93.065203.

A. N. Hiller Blin, T. Ledwig, M. J. Vicente Vacas, *Δ(1232) resonance in $(\gamma\ )^{\rightarrow}\ p\to p\ \pi^{\wedge}0$ reaction at threshold*, Phys. Rev. D 93 (2016) 094018, DOI: 10.1103/PhysRevD.93.094018.

L. Alvarez-Ruso et al., *Watson's theorem and the NΔ(1232) axial transition*, Phys. Rev. D 93 (2016) 014016, DOI: 10.1103/PhysRevD.93.014016.

D. Davesne, A. Pastore, J. Navarro, *Extended Skyrme Equation of State in asymmetric nuclear matter*, Astron. Astrophys. 585 (2016) A83, DOI: 10.1051/0004-6361/201526720.

Selected conference talks

M. Albaladejo, *XYZ: the case of Zc(3885)/Zc(3900)*, FAIRNESS 2016: Workshop for young scientists with research interests focused on physics at FAIR, February 2016, Garmisch, Germany.

E. Oset, *Reactions Looking for Hidden Charm Pentaquarks with or without Strangeness*, Excited QCD 2016, March 2016, Costa da Caparica, Portugal.

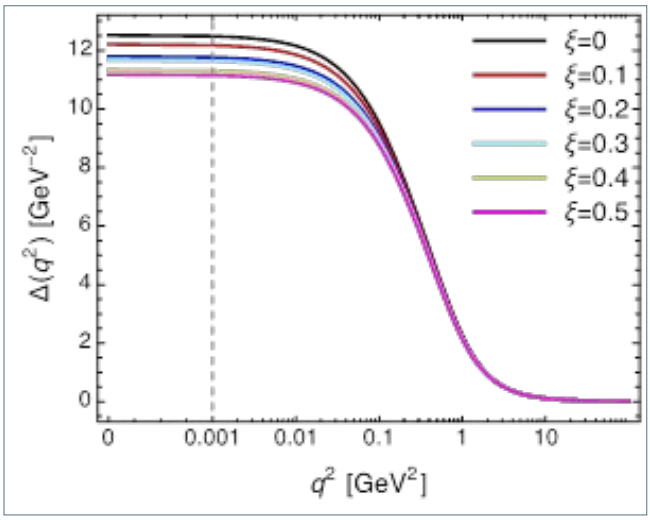
A. N. Hiller Blin, *Δ(1232) resonance in $(\gamma\ )^{\rightarrow}\ p\to p\ \pi^{\wedge}0$ reaction at threshold*, International Conference on the Structure of Baryons 2016, May, 2016, Tallahassee, USA

P. Fernández Soler, *The B_c→ J/ψ KD weak decay and its relation with the D_s0^*(2317) resonance*, MESON2016: 13th International Workshop on Meson Production, Properties and Interaction, June 2016, Cracow, Poland.

J. Nieves, *Theoretical challenges in neutrino scattering studies*, NEUTRINO 2016, XXVII International Conference on Neutrino Physics and Astrophysics ,July 2016, London, U. K.

L. Alvarez Ruso, *Hadronic matrix elements for neutrino cross sections*, Symposium on Effective Field Theories and Lattice Gauge Theory , May 2016, Munich, Germany.

QCD AND STRONG INTERACTIONS

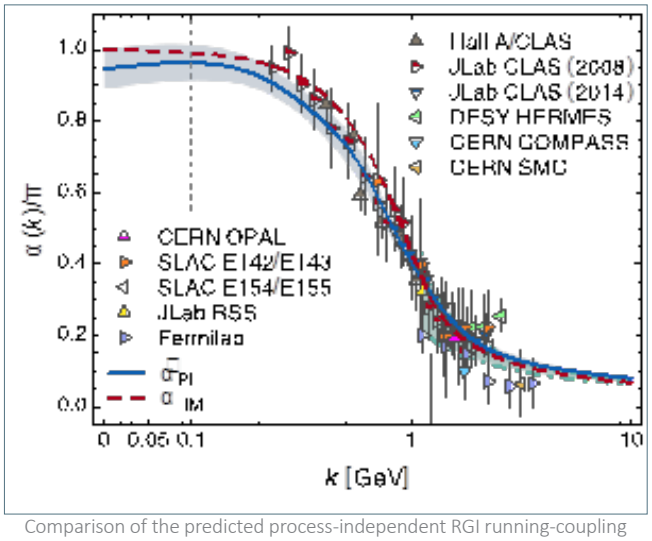


The gluon propagator for several values of the gauge-fixing parameter obtained from a fit to the lattice data from Bicudo et al. (2015). After the vertical dashed line the scale in the abscissa is turned from logarithmic to lineal.

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 driving fundamental force at the Large Hadron Collider (LHC).

A novel unification of two widely different approaches to understand the infrared behaviour of QCD, one phenomenological and the other computational, has been developed. Using the latter, based on quantum field equations in the continuum theory, a new QCD process-independent running-coupling, similar to the Gell-Mann--Low effective coupling in QED, has been calculated. The agreement between the QCD effective charge and the process-dependent effective charge defined via the Bjorken sum rule is excellent, which provides one of the most basic constraints of nucleon spin structure.

A novel unification of two widely different approaches to understand the infrared behaviour of QCD has been developed



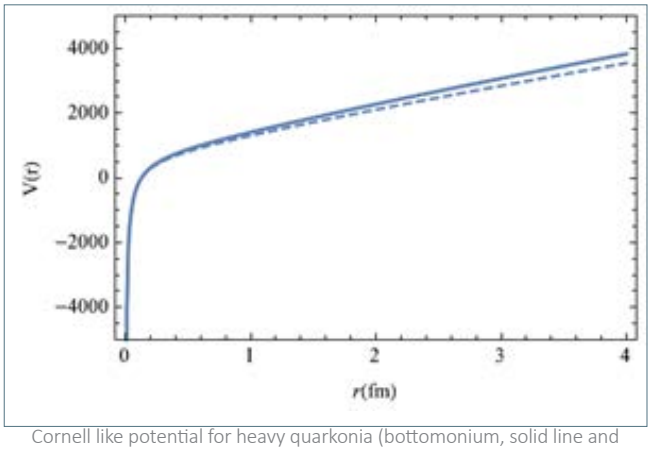
Comparison of the predicted process-independent RGI running-coupling (solid blue curve and its 95% confidence-level shaded blue band) with the world's data on the process-dependent effective charge.

The applicability of a special gluon mass generating mechanism in the context of the linear covariant gauges has been explored. In particular, the implementation of the Schwinger mechanism in pure Yang-Mills theories hinges crucially on the inclusion of massless bound-state excitations in the fundamental non-perturbative vertices of the theory. The dynamical formation of such excitations is controlled by a homogeneous linear Bethe-Salpeter equation, whose nontrivial solutions have been studied only in the Landau gauge. The form of this integral equation has been derived for general values of the gauge-fixing parameter, under a number of simplifying assumptions that reduce the degree of technical complexity.

A RGI running-interaction that reconciles both top-down and bottom-up analyses of the gauge

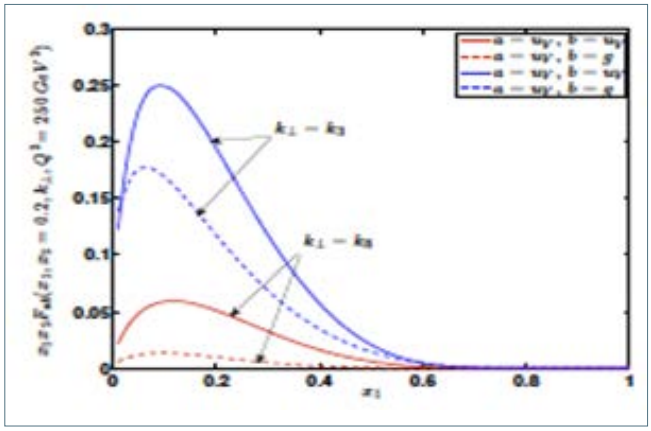
sector in QCD has been used to compute dressed-quark gap equation solutions with 1,660,000 distinct ansatzs for the poor-known dressed—quark-gluon vertex. Each one of the solutions has been tested for compatibility with three physical criteria with the remarkable result that merely 0.55% of them survive the test. Therefore, even a small selection of observables places extremely tight bounds on the domain of realistic vertex ansatz. These results should prove useful in constraining insightful contemporary studies of QCD and hadronic phenomena.

A non-perturbative coupling has been defined in terms of a gluon mass function, similar to that used in some Schwinger-Dyson approaches, which correctly describes the singularity structure of confinement and asymptotic freedom of QCD. Using it, a Cornell like potential has been faithfully reproduced which provides an excellent fit of the heavy quarkonia spectra (bottomonium and charmonium) for energies below the open flavour meson-meson threshold.



Cornell like potential for heavy quarkonia (bottomonium, solid line and charmonium, dashed line) from Schwinger-Dyson coupling. The only free parameter Λ_{QCD} has been fixed to 320 MeV.

Double Parton Distribution Functions (dPDF) have been analysed using a Light-Front constituent quark model and QCD evolution. It has been shown that factorized expressions for dPDFs fail in reproducing the calculated dPDFs, in particular in the valence region. Correlations of pairs of partons of different kind have been analysed to study processes at low longitudinal momenta of the interacting partons with the result that they are, in some cases, strongly suppressed at low longitudinal momenta, while for other distributions they can be sizeable. These behaviours can be understood in terms of a delicate interference of non-perturbative correlations, generated by the dynamics of the model, and perturbative ones, generated by the model independent evolution procedure. This analysis showed that at LHC kinematic two-parton correlations can be relevant in DPS, opening the possibility to study them experimentally.

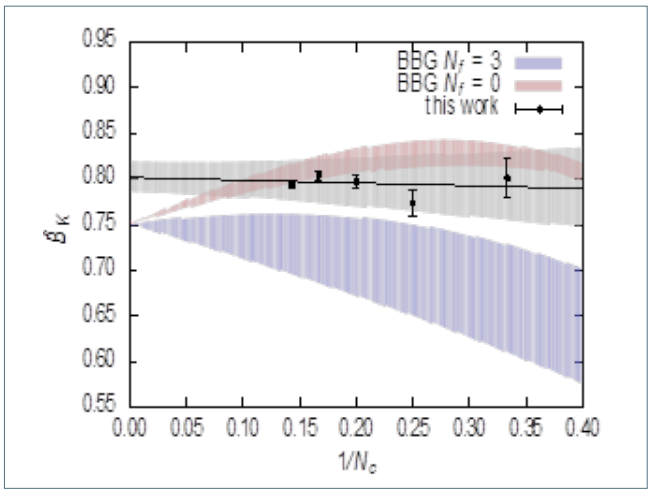


The dPDFs $x_1x_2Fu_Vu_V$ obtained from perturbative evolution from the Q^2_0 scale to Q^2= 250 GeV^2 (continuous lines) as function of x^1 and at fixed x^2 = 0.2 (and for two values of $k_\perp$), are compared with $x_1x_2Fu_Vg$ dPDFs (da-shed lines) at the same high scale.

A non-perturbative coupling has been defined in terms of a gluon mass function which describes the singularity structure of confinement and asymptotic freedom of QCD

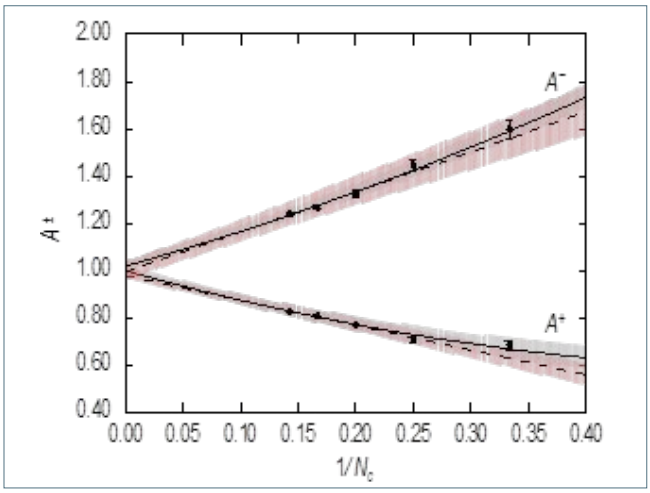
The magnetic susceptibility of the QCD vacuum has been analysed in the framework of a nonlocal SU(3) Polyakov–Nambu–Jona-Lasinio model. Considering two different model parametrizations, the values of the u- and s-quark tensor coefficients and magnetic susceptibilities have been estimated and then the analysis has been extended to finite temperature systems. The numerical results are in general in good agreement with those obtained in other theoretical approaches and in lattice QCD calculations.

In order to understand the physical origin of the ΔI=1/2 rule, the large N_c behaviour of ΔS=1 and ΔS=2 amplitudes, including subleading $1/N_c$ corrections, has been studied numerically using the quenched lattice approach. Recent lattice studies pointed out that this rule seems to come out from an approximate cancellation of two diagrams contributing to the ΔI = 3/2 amplitude that the large N_c expansion can isolate. The same cancellation should affect the Kaon bag parameter $\hat{B}_K$. Therefore, the amplitudes for the $K\to\pi$ and $K\to K^-$ transitions, that fix $\hat{B}_K$ (up to SU(3) flavour breaking effects by quark masses) and, up to chiral corrections, also the ΔI = 3/2 contribution to $K\to\pi\pi$, have been computed on the lattice varying the number of colours N_c=3-7. Only the SU(4)-flavour limit, $m_c=m_u=m_d=m_s$ has been considered because in this case the ΔI = 1/2 contribution to the non-leptonic decays is determined from the current-current operator matrix elements. For the $\hat{B}_K$, the results show that the subleading $1/N_c$ corrections are small (notice that phenomenological predictions, give $\hat{B}_K$ = 3/4 in the $N_c\to\infty$ limit).



The $\hat{B}_K$ parameter as a function of $1/N_c$, for N_c =3,4,5,6,7. The black solid line represents the result of a fit to the data points. The blue and red bands represent the 1/Nc dependence of two different phenomenological computation of $\hat{B}_K$.

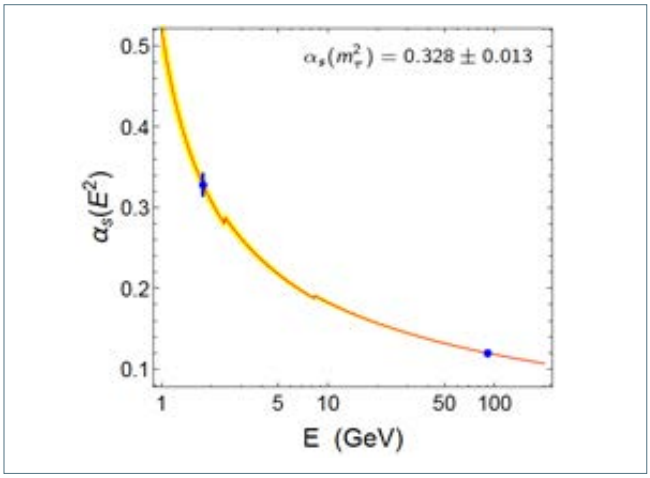
In contrast with $\hat{B}_K$, the $K\to\pi$ amplitudes A^+ and A^- show very significant subleading $1/N_c$ corrections (30% at N^c=3). Moreover, it can also be seen that the corrections are strongly anti-correlated in A^+ and A^-, and are consistent with being equal and opposite in sign, supporting recent lattice results from the RBC and UKQCD Collaborations. Recent large-Nc studies of dynamical QCD show that an extension of this work to take into account unquenching effects is feasible.



The A^+ and A^- amplitudes as a function of $1/N_c$, for N_c =3,4,5,6,7. The black solid (dashed) lines represent the results of a quadratic (linear) fit to the data points.

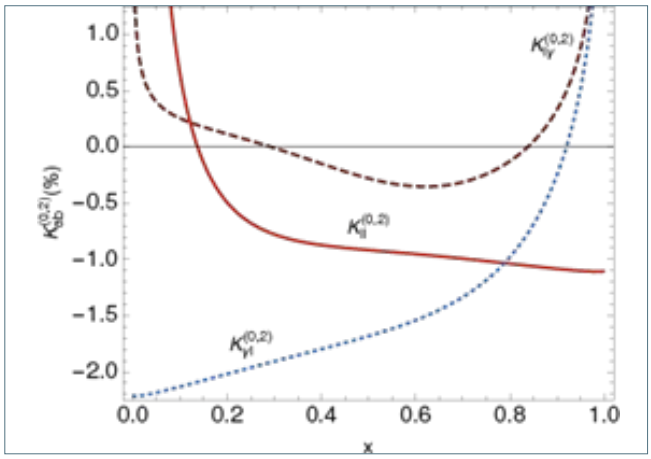
A new determination of the QCD coupling has been developed

A comprehensive study of the determination of the strong coupling from τ decays, using the most recent release of the experimental ALEPH data, has been presented. A quantitative assessment of the role of non-perturbative effects, either from inverse-power corrections or violations of duality has been achieved. The overall agreement among determinations extracted under very different assumptions clearly shows the reliability of the final estimated value for the strong coupling, $\alpha_s(m_\tau) = 0.328\pm0.013$, which implies $\alpha_s(M_Z) = 0.1197\pm0.0015$, in excellent agreement with the direct measurement at the Z peak from the Z hadronic width.



Energy evolution of the strong coupling, from the τ mass scale to the Z pole.

A systematic procedure to obtain the one-loop low-energy effective Lagrangian resulting from integrating out the heavy fields of a given ultraviolet theory has been developed. The matching coefficients are determined entirely by the hard region of the functional determinant involving the heavy fields. This represents an important simplification with respect to the conventional matching approach, where the full and effective theory contributions have to be computed separately and a cancellation of the infrared divergent parts has to take place. The method has been illustrated with a descriptive toy model and with an extension of the Standard Model with a heavy real scalar triplet. A comparison with other schemes that have been put forward recently has also been provided.



K factors for the O(α^2) corrections to the splitting functions involving leptons and photons.

A new algorithm to construct purely four dimensional representations of higher order perturbative corrections in quantum field theories was introduced

A new algorithm to construct purely four-dimensional representations of higher order perturbative corrections to physical observables in quantum field theories has been introduced. It is based on the Loop-Tree duality (LTD), and is implemented by introducing an appropriate correspondence between the external and internal momenta of the virtual amplitudes, and the external momenta of the real emission corrections. In this way, the sum over degenerate infrared states is performed at the integrand level and the cancellation of the infrared divergences occurs locally without the need to introduce subtraction counter-terms to treat the collinear and soft singularities of the final state. The method is applicable to any relativistic, local and unitary field theory, and involves a paradigm shift in the calculation of quantum corrections to scattering processes since it avoids altering the dimensions of the space-time, as in the standard method of Dimensional Regularization (DREG), while allowing simultaneous generation of both real and virtual contributions, with the consequent improvement in its implementation in Monte Carlo event generation programs. The generalization to treat massive particles has also been presented recently.

For the first time, explicit expressions for the Altarelli-Parisi splitting functions at second order in QED have been obtained, thus completing the calculation of splitting functions to two loops necessary to study the evolution of the parton distribution functions according to the experimental accuracy attainable in the LHC. The complete set of splitting functions includes those related to the leptonic and photon densities, which in this order are mixed in the evolution with the usual parton distribution functions. The splitting functions have been obtained by applying a well-defined deconstruction algorithm to the Abelian limit of the pure QCD expressions. The QED contributions generate 2% order corrections for splitting functions initiated by photons, which can lead to important changes in the shape and size of the photon and lepton distribution functions in a global analysis.

Selected publications

Binosi D., Mezrag C., Papavassiliou J., Roberts C. D., Rodriguez-Quintero J., *Process-independent strong running coupling*, arXiv:1612.04835.

Aguilar, A. C., Binosi D., Papavassiliou, J., *Schwinger mechanism in linear covariant gauges*, Phys. Rev. D95 (2017) no.3, 034017; arXiv:1611.02096.

Binosi D., Chang L., Papavassiliou J., Qin S-X., Roberts C. D., *Natural constraints on the gluon-quark vertex*, Phys. Rev. D95 (2017) no.3, 031501; arXiv:1609.02568.

Ayala, C., González, P., Vento, V., *Heavy quark potential from QCD-related effective coupling*, J. Phys. G43 (2016) no.12, 125002; arXiv:1509.01382 [hep-ph]

Rinaldi, M., Scopetta, S., Traini M. C., Vento, V., *Correlations in Double Parton Distributions: Perturbative and Non-Perturbative effects*, JHEP 1610 (2016) 063; arXiv:1608.02521 [hep-ph]

Rinaldi, M., Scopetta, S., Traini M. C., Vento, V., *Double Parton Scattering: a study of the effective cross section within a Light-Front quark model*, Phys. Lett. B752 (2016) 40-45, arXiv:1506.05742 [hep-ph]

Pagura, V. P., Gómez Dumm, D., Noguera S., Scoccola, N. N., *Magnetic susceptibility of QCD vacuum in a nonlocal SU(3) Polyakov-Nambu-Jona-Lasinio model*, Phys. Rev. D94 (2016) no.5, 054038, arXiv:1605.04675 [hep-ph]

Donini, A., Hernández, P., Pena, C., Romero-López, F., *Non-leptonic kaon decays at large*, Nc. Phys. Rev. D94, 114511 (2016); arXiv:1607.03262

A. Pich, A. Rodríguez-Sánchez, *Determination of the QCD coupling from ALEPH τ decay data*, Phys. Rev. D94 (2016) no.3, 034027; arXiv:1605.06830 [hep-ph]

J. Fuentes-Martín, J. Portolés, P. Ruiz-Femenia, *Integrating out heavy particles with functional methods: a simplified framework*, JHEP 1609 (2016) 156; arXiv:1607.02142 [hep-ph]

D. de Florian, G.F.R. Sborlini, G. Rodrigo, *Two-loop QED corrections to the Altarelli-Parisi splitting functions*, JHEP 1610 (2016) 056; arXiv:1606.02887 [hep-ph]

G.F.R. Sborlini, F. Driencourt-Mangin, R. Hernández-Pinto, G. Rodrigo, *Four-dimensional unsubtraction from the loop-tree duality*, JHEP 1608 (2016) 160; arXiv:1604.06699 [hep-ph]

Selected conference talks

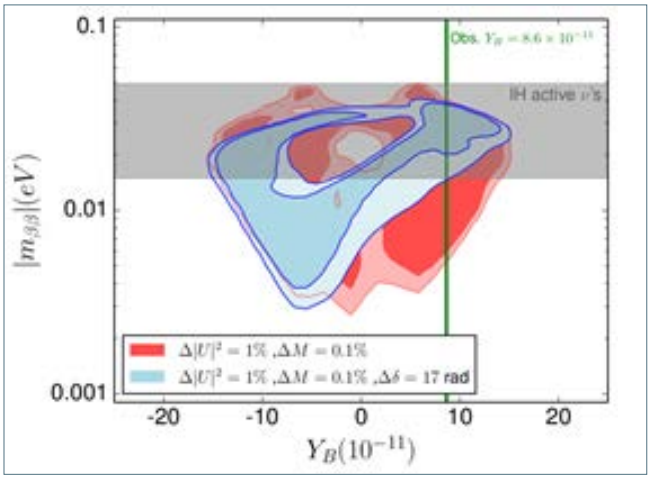
A. Pich, *Precision physics with QCD, invited plenary talk at XII Quark Confinement and the Hadron Spectrum*, Thessaloniki, Greece, 29th August - 3rd September 2016.

J. Portolés, *$K\to\pi\ell^+\ell^-$: Status and update*, Invited talk at the KAON 2016 Conference, Birmingham (UK), 14-17 September 2016.

G.F.R. Sborlini, *Towards regularized higher-order computations in QFT without DREG*, 38th International Conference on High Energy Physics (ICHEP 2016), Chicago, IL, USA, 03-10 August 2016.

THEORETICAL ASTROPARTICLE PHYSICS AND COSMOLOGY

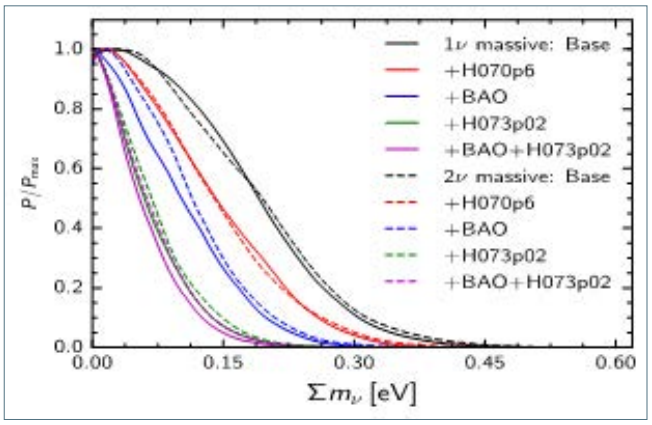
The origin of the observed baryon asymmetry in the Universe is one of the unresolved fundamental questions. To dynamically generate this asymmetry, three Sakharov conditions need to be fulfilled: processes that violate baryon number, processes that violate both C, and CP, and the out-of-equilibrium processes should be present. In the popular models of baryogenesis through leptogenesis, all three conditions are satisfied in the decay of a heavy particle, usually above TeV scale. However, in the so-called low scale seesaw model, where the masses of sterile neutrinos are below the electroweak scale, it is possible to generate the asymmetry in the lepton sector via the oscillations of the sterile states.



The mass degeneracy versus the sum of the mixing, the electron mixing and effective mass.

IFIC researchers found a synergy between the neutrino mass generation and the matter-antimatter asymmetry of the universe: The GeV Miracle!

Constraints on the total active neutrino mass from cosmological measurements currently provide the tightest bounds on the absolute neutrino mass scale. Low-redshift quantities, such as the Hubble constant or the reionization optical depth, play a very important role when setting the neutrino mass constraints. Current cosmological data start to be mildly sensitive to the neutrino mass ordering, finding, in a non-degenerate scenario, one of the most tightest and robust upper bounds to date, $\Sigma m_\nu < 0.125$ eV at 95% confidence level.



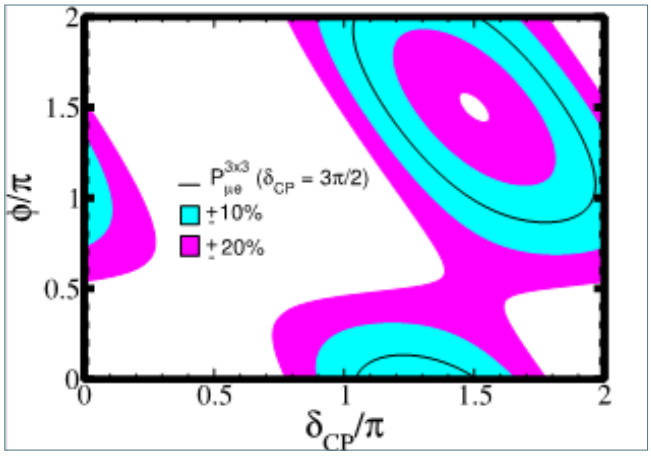
One-dimensional posterior probability distribution.

Cosmological data start to be mildly sensitive to the neutrino mass ordering, finding one of the most tightest and robust upper bounds to date

Also concerning the impact of neutrinos on cosmology, we have revisited the decoupling process of cosmological neutrinos including the effect of flavour oscillations. We find that the contribution of neutrinos to the radiation energy density in the early Universe is equivalent to an effective number of neutrinos Neff=3.045. This result, which does not depend on the ordering of neutrino masses, is consistent with the allowed range for this parameter from the analysis of Planck data on CMB anisotropies and other cosmological measurements. We also considered the effect of non-standard neutrino-electron interactions (NSI), predicted in many theoretical models where neutrinos acquire mass. For two sets of NSI parameters allowed by present data, we find that Neff can be reduced down to 3.040 or enhanced up to 3.059.

IFIC researchers find that contribution of neutrinos to the radiation energy density in the early Universe is equivalent to an effective number of neutrinos Neff=3.045

We have addressed the issue of how robustly can neutrino oscillation experiments extract the leptonic CP phase δ_{CP}, a key ingredient in cosmology if the origin of matter is explained by leptogenesis. In general, neutrino appearance masses at an LHC-accessible mass scale. This leads to an ambiguity in extracting the "standard" three-neutrino CP phase δ_{CP}, which can survive even after neutrino and antineutrino channels are combined. Its existence should be taken into account in the planning of any oscillation experiment aiming at a robust measurement of δ_{CP}.



Confusion between the standard phase δ_{CP} and the new phase ϕ.

We investigated the stochastic gravitational wave background from a short-lasting first order phase transition in a matter-dominated universe. Ignoring the effect of energy injection from the dominating matter to radiation, possible interactions between radiation/scalar (of the phase transition) and background matter, we showed that the spectrum of the

GWB soon after the generation is the same as the one expected in a radiation-dominated universe, and that a mode-dependent additional redshift during matter-domination era introduces a unique and distinctive feature which provides important information about the properties of the phase transition and thermal history of the universe.

We showed that the spectrum of the GWB soon after the generation is the same as the one expected in a radiation-dominated universe

Selected publications

P.Hernández, M.Kekic, J.López-Pavón, J.Racker and J.Salvado, *Testable Baryogenesis in Seesaw Models*, JHEP 1608, 157 (2016), DOI: 0.1007/JHEP08(2016)157 [arXiv:1606.06719]

E. Giusarma, M. Gerbino, O. Mena et al, *On the improvement of cosmological neutrino mass bounds,* Phys. Rev. D94 (2016), DOI:10.1103/PhysRevD.94.083522 [arXiv:1605.04320]

P. F. de Salas and S. Pastor, *Relic neutrino decoupling with flavour oscillations revisited*, JCAP 1607, 051 (2016), DOI: 10.1088/1475-7516/2016/07/051 [arXiv:1606.06986]

O. G. Miranda, M. Tórtola and J. W. F. Valle, *New ambiguity in probing CP violation in neutrino oscillations*, Phys. Rev. Lett. 117, no. 6, 061804 (2016), DOI:10.1103/PhysRevLett.117.061804 [arXiv:1604.05690]

G. Barenboim and W. I. Park, *Gravitational waves from first order phase transitions as a probe of an early matter domination era and its inverse problem*, Phys. Lett. B759, 430 (2016), DOI: 10.1016/j.physletb.2016.06.009 [arXiv:1605.03781]

Selected conference talks

G. Barenboim, *Inflation and the BSM Quest*, Invisibles Workshop 2016, September, Padova, Italy.

P. Hernández, *Testable baryogenesis in seesaw models*, Invisibles Workshop 2016, September, Padova, Italy.

M. Hirsch, *Neutrinos theory,* XLIV International Meeting on Fundamental Physics, April 2016, IFT Madrid, Spain.

O. Mena, *Searching for Sterile Neutrinos and Dark Radiation Through Cosmology*, American Association for the Advancement of Science Meeting 2016, February, Washington, US.

S. Pastor, *The effective number of neutrinos: standard and non-standard*, 9th Neutrino Oscillation Workshop (NOW 2016), September, Otranto, Italy.

N. Rius, *Atmospheric neutrinos and new physics*, NUPHYS 2016: Prospects in Neutrino physics, December, London, UK.

J. Salvadó, *Searches for sterile neutrinos and other BSM physics with the IceCube detector*, CERN EP Seminar, November 2016, Geneva, Switzerland.

M. Tórtola, *Beyond standard CP violation at T2K and DUNE*, DUNE Collaboration Meeting, South Dakota School of Mines and Technology, Rapid City, USA.

J.W.F. Valle, *Neutrinos as fundamental probes in the Universe*, FISICA 2016 - 20ª Conferencia Nacional de Física. Braga, Portugal.

3. PUBLICATIONS

IFIC SCIENTIFIC OUTPUT (2016)

451 Articles in indexed journals

91.8% In first quartile journals
(JCR-WoS or SJR-Scopus, 2016)

TOP 5 JOURNALS BY IMPACT FACTOR (JCR-WOS) WITH IFIC AUTHORS

Reports on Progress in Physics (IF 12.9): **1**
Physical Review Letters (IF 7.6): **24**
Journal of High Energy Physics (IF 6.0): **76**
Astrophysical Journal (IF 5.9): **2**
Journal of Cosmology and Astroparticle Physics (IF 5.6): **13**

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

Physical Review D (IF 4.5): **93**
Journal of High Energy Physics (IF 6.0): **76**
Physics Letters B (IF 4.8): **64**
European Physical Journal C (IF 4.9): **63**
Physical Review Letters (IF 7.6): **24**

14 PhD theses with IFIC supervisors

339 Presentations at international conferences

We present the list of the 451 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 2016 are indicated. Some papers appear twice if there are authors from both IFIC departments.

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AGATA Collaboration

IFIC authors: Gadea, A.

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

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ATLAS Collaboration

IFIC authors: Alvarez Piqueras, D.; Barranco Navarro, L.; Cabrera Urban, S.; Castillo Gimenez, V.;Cerda Alberich, L.; Costa, M.J.; 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.; Mamuzic, March, L.;J.; Marti-Garcia, S.; Melini, Moles-Valls, R.; Miñano, M.;D.;Mitsou, V.A.; Oliver Garcia, E.; Pedraza Lopez, S.; Perez Garcia-Estañ, M.T.; Rodriguez Rodriguez, D.;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.; Villaplana Perez, M.;Vos, M.

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BOOKS

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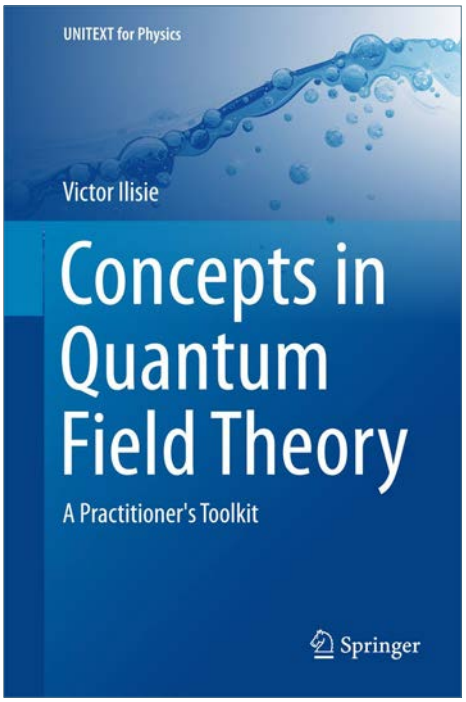


4. TRAINING

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

Alignment of the ATLAS Inner Detector and Single Top studies
Vicente Lacuesta Miquel
Advisors: Salvador Marti García y José Enrique García Navarro
20 January, University of Valencia
TESEO: 1202484

Observation of Higgs Boson Decays to WW with Dilepton and Missing Transverse Momentum Events in the ATLAS Detector*
Yesenia Hernández Jiménez
Advisors: Juan Antonio Valls Ferrer y Bruce Mellado García
21 January, University of Valencia
TESEO: 1209075

Development of a data acquisition system using silicon detectors for PET applications
Vera Koleva Stankova
Advisors: Vicente González Millán, Carlos Lacasta Llácer y Gabriela Llosá Llácer
11 February, University of Valencia
TESEO: 1221636

Beam position monitoring in the CLIC drive beam decelerator using stripline technology
Alfonso Benot Morell
Advisors: Vicente Enrique Boria Esbert y Ángeles Faus Golfe
22 February, Technical University of Valencia
TESEO: 1226559

First measurement of the charge asymmetry in boosted top quark pair production in the ATLAS experiment using the Grid-based Tier-3 facility at IFIC-Valencia
Victoria Sánchez Martínez
Advisors: Marcel Vos y Santiago González de la Hoz
26 May, University of Valencia
TESEO: 1250280

Estimación de dosis en aplicaciones radiológicas basada en la dosimetría por luminiscencia ópticamente estimulada
Galo Patiño Camargo
Advisors: Facundo Ballester Pallarés y Javier Vijande Asenjo
17 November, University of Valencia
TESEO: 1328613

Photon polarization in Bs-> phi gamma decays at the LHCb experiment
Pablo Ruiz Valls
Advisors: María Aránzazu Oyanguren Campos y Fernando Martínez Vidal
13 December, University of Valencia
TESEO: 1338342

Future Linear Colliders. Detector R&D, Jet Reconstruction and Top Physics potential
Ignacio García García
Advisors: Marcel Vos y Eduardo Ros Martínez
16 December, University of Valencia
TESEO: 1338333

Theoretical Physics

Phenomenology of Non-Standard Neutrino Interactions
Francisco Javier Escrihuela Ferrándiz
Advisors: M. Amparo Tórtola Baixauli, Omar Gustavo Miranda y José W. Furtado Valle
5 February, University of Valencia
TESEO: 1211943

Extragalactic dark matter annihilation signals and halo substructure properties
Maria de los Angeles Moliné
Advisor: Sergio Palomares-Ruiz
6 May, Instituto Superior Técnico, University of Lisbon
LINK

The Higgs Era
Victor Ilisie
Advisors: Antonio Pich Zardoya
27 June, University of Valencia
TESEO: 1273272

Interaction of Hadrons and Test for the nature of resonances
Francesca Aceti
Advisors: Eulogio Oset Baguena
13 July, University of Valencia
TESEO: 1278585

Flavour violation of charged leptons in the Simplest Little Higgs model
Andrea Lami
Advisors: Jorge Portolés Ibáñez y Pablo Roig Garcés
20 July, University of Valencia
TESEO: 1278345

Phenomenology of low-scale Seesaw Models
Marija Kekic
Advisors: Pilar Hernández Gamazo
22 December, University of Valencia
TESEO: 1338651

In 2016, IFIC researchers presented 339 contributions in the main conferences and workshops: 306 talks (73 invited) and 33 posters

5. CONFERENCES, SEMINARS AND COLLOQUIA

CONFERENCES AND MEETINGS

IFIC researchers present their results in the main international conferences and workshops. A total of 339 contributions were presented in 2016: 306 talks (73 invited) and 33 posters. Here we highlight conferences and workshops organized by ific members in Valencia or elsewhere:

MicroChannel Cooling Coordination Meeting, 12 January

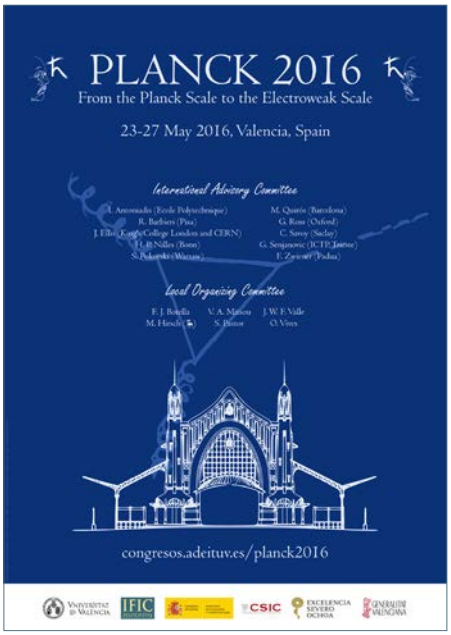
9th Belle II VXD Workshop, 13-15 January

I Jornadas RSEF / IFIMED de Física Médica, 10-11 March

One-day workshop IFIC-IFT, 11 March

From the Planck Scale to the Electroweak Scale (Planck 2016), 23-27 May

Fourth Annual Large Hadron Collider Physics Conference 2016, 12-18 June 2016.



5th MoEDAL Collaboration Meeting, 28-29 June

Taller de Altas Energías (TAE 2016), 4-17 September

ATLAS ITK-Week, 12-16 September

XIX Face to Face Meeting of the Spanish ATLAS Tier-2, 17-18 October

5th ATLAS single top-quark workshop, 13 December

IFIC COLLOQUIA

The colloquium series "Severo Ochoa" brings the world leading experts to Valencia to present a vision of their area of science. The programme envisages of the order of ten lectures per year. Lectures are primarily devoted to particle, astroparticle and nuclear physics, but also explore other areas of science. Colloquia are open to scientists of other research institutes and to personnel and students of the science faculties. The outreach department shares recordings of the lectures on the institute's YouTube channel.

The 2016 programme provided lectures on quantum gravity and gravitational waves, the physics of the Higgs boson and top quark, neutrino physics and on the role of curiosity-driven research in society.

Lecturers in 2016: Iván Agulló (2011 Gravity Foundation prize, CAREER prize of the NSF, USA and 2016 IUPAP prize for young researchers), Dr. Frederic Deliot (CEA/Saclay, top physics convener of the ATLAS experiment), Prof. Pedro Miguel Echenique (winner of the Príncipe de Asturias prize and former Director of the Donostia International Physics Center), Prof. Michael Peskin (former head of the SLAC theory department), Prof. Heidi Schellman (former staff researcher at FermiLab, currently Oregon State University), Prof. Alicia Sintes (U. Baleares, head of the Spanish group involved in the LIGO experiment).

Gravitational Waves: The novel messengers of the Universe, Alicia Sintes (Universitat de les Illes Balears), 10 March.

Neutrino nus, Heidi Schellman (Oregon State University), 5 May.

La sublime utilidad de la ciencia inútil, Pedro Miguel Echenique (Universidad del País Vasco), 18 May.

The observable universe, gravity, and the quantum, Ivan Agullo (Luisiana State University), 9 June.

Mysteries of the Higgs boson, Michael Peskin (SLAC and U. Stanford), 8 September.

The journey to the top, Frederic Deliot (CEA Saclay), 12 December.

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 2016 we hosted a total of 70 seminars (some of them webinars). The complete list can be found at the IFIC's Indico webpage. Organiser: Andrea Donini

In 2016, IFIC organized 6 Colloquia, with the support of the 'Severo Ochoa' Centre of Excellence Programme, and 70 seminars and webinars

6. TECHNOLOGY TRANSFER

Environment recognition in radiation detectors.

Environment recognition is related to a group of techniques to obtain information about the environment during the data acquisition of particle detectors. These techniques allow reconstruction of part of the environment by taking information of visible cameras or other related sensors. As part of these activities the group has been focused in two main applications:

– Related with medical applications, by providing information to legacy components such as X-Ray devices.
– Related with the industry, giving accurate location of the detectors in standard operations related with the nuclear industry.

In this field IFIC has produced four patents that have been licensed and partnered by the gold-standard of the nuclear industry in Spain. Also related with medical applications and it has received the award of the H2020 excellence, in the program of SME.

This woks has been published in IEEE Transactions on Medical Imaging, Radiological Physics and Technology, and the recognized AAPM. Most of this wok corresponds to the PhD thesis of D. Alberto Corbi Bellot.

Big data and distributed computing.

Forecasting of the electric sector.
One classic problem of the electric sector is matching the electricity supply from producers and electricity demand from consumers. The goal is to provide a good balanced system because when the demand is overestimated, the electric grid will produce damages on the consumer side. Equally if the power supply is underestimated damages will appear in the overloaded generation system making production system unusable.

The introduction of modern Smart Grids has made this problem interesting from the point of view of decision theory. Renewal energies introduces extra entropy in the system as this energy is affected by climate conditions. Modern Smart Grids solutions will introduce a pool of technological solutions where research plays a central role. These technologies will include battery storage closer to consumers, better rerouting technologies, production closer to the demand side, and of course a more reactive, intelligent and automated system linked all together with decision systems based on Big Data which also plays a central role in most of scientific disciplines including particle physics.

To help in the Smart Grid adoption IFIC has developed and licensed a Big Data based prediction technology which makes accurate demand forecasting. Results are provided using daily information from multiple technologies, such as specific Smart Grid data acquisition devices and fully integrating all this information.

International contest on mammography.
Mammography is the most important tool to improve life expectations and early diagnose of the most common cancer. Good screening practises improve life expectations from 15-35% in women with ages between 40-70 years, and this means an effective reduction of mortality in the same group of women due to the fact of being the most common cause of mortality in this population partition.

In general, large screening campaigns are limited to the fact of absence of practitioner radiologist able to process the amount of data that a generalized screening would provide. Big data again can provide tools to reduce false positives and improve automated and assisted screening, as well as provide reproducible diagnose.

IFIC together with the UPV, is participating with the group '42 is the answer' and is currently in the group of top scoring. It is the only Spanish group in the contest and demonstrates that technologies applied in HEP, such as GRID computing and analysis of large datasets can provide applied solutions to old known problems.

This contest is being revised by the largest and recognized American organizations related with cancer.

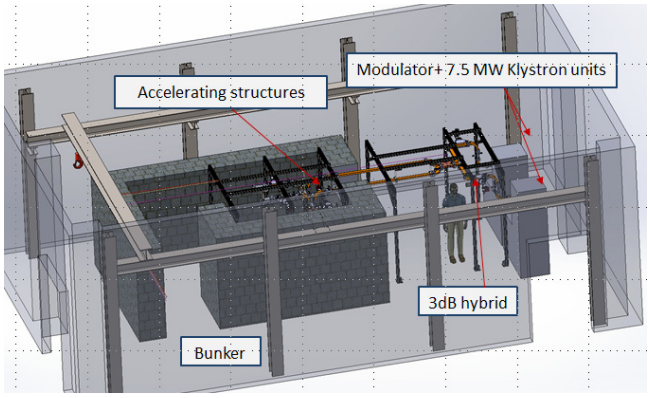
Life Sciences Discovery Fund · NIH National Heart, Lung, and Blood Institute · Alfred P. Sloan Foundation · NIH National Institute on Aging · NIMH National Institute of Mental Health · Children's Tumor Foundation

IFIC participated with UPV in an international contest to improve mammographies with HEP technologies

Participation in research contracts of special relevance with industries or administrations.

IFIC participates in cooperation with the CLIC RF group at CERN to develop a facility to study and test high-gradient RF structures. The facility is being constructed since 2016 with FEDER funds at the Parque Tecnologico of the University of Valencia. The IFIC High-Gradient RF laboratory is designed to host a high-power infrastructure for testing HG normal-conducting S-band RF accelerating structures.

The main objective of the facility is the study of vacuum breakdown phenomena. A particular focus is RF structures for medical hadron therapy applications. The design of the laboratory has been made through the collaboration between the IFIC and the CLIC RF group at CERN. This agreement is also covered the contract No. KE2638/BE between IFIC-CSIC and CERN (04/2015-04/2018, IFIC-CERN, 526.980€).



Scheme of the IFIC High-Gradient RF Laboratory.

Technological support from the electronics and microelectronics division.

The IFIC Division on electronics and microelectronics gives support to all research projects of the Institute. It also offers service and developments to external companies through contracts and agreements. The Division by means of their technical staff and especific equipment, offers services in electronic design, prototyping, manufacturing, testing and validation of electronic systems.

The Division employs two infrastructures –the general electronics lab (90 m2) and the clean room (80 m^2 in two areas, 10,000 and 1,000 classes, ISO7 and ISO6) for support in microelectronics.

In addition to the general scientific support to the Institute, during 2016 several external contracts and services were established:

– Chip assembly, wire-bonding and encapsulation to an external company. Around 8000 chips were assembled to a flexible Printed Circuit Board (PCB). The chips were electrically connected to the PCB with a total of ~640,000 wire bonds (25 micron diameter). Finally the assembly was encapsulated for mechanical protection. This activity continues during 2017.

– X-ray inspection of electronic devices. Inspections were done to several companies. They mainly refer to problems in their manufacturing which are identified in our lab by X-ray inspection.

– Wire-bonding of new sensors and new structures were also performed to external companies.

– Manufacturing of small PCBs for prototyping. This task was offered to the computing department of the Universitat de València.

In cooperation with CERN, IFIC developes a High-Gradient RF laboratory for testing accelerating structures

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 at the general public and the educational community. Two persons 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

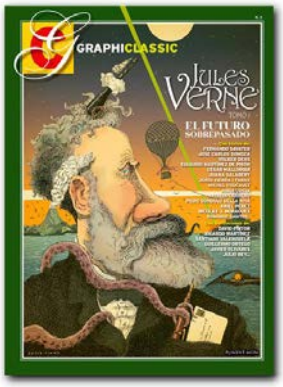
IFIC web site

Throughout 2016 we continued 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 IFIC members and are aimed at a science-related public, from undergraduate students to fellow scientists working in other areas.

In 2016 these articles cover the follow-up searches of neutrinos associated to gravitational wave events, the excess of Z-boson events in the first Run-2 data of ATLAS and its impact in searches for supersymmetry, lattice QCD as a means to investigate the dynamics of the strong interactions, the efforts needed to prepare ATLAS for the high-luminosity upgrade coming up during the 2020's, and the effects of heavy neutrinos in the determination of the CP-violating phase of neutrinos.

Books

Jesús Navarro contributed one chapter to the book *Jules Verne: El futuro sobrepasado*. His contribution, *Una visión de la ciencia y la técnica*, discussed the importance of science and technology in the works of Jules Verne.



Science communication colloquia

As part of the programme of IFIC Colloquia one of them was dedicated to the social perception of science and the importance of basic research. It was offered by Pedro Miguel Echenique, and it reviewed several important discoveries of the 20th century, with especial emphasis on atomic and subatomic physics, the double helix structure of DNA and the scientific method as a means to produce reliable knowledge.

First light of the outreach blog of IFIC

The final days of 2016 saw the first publications of *Entre cientIFIC@s*, the outreach blog of IFIC, a platform aimed at gathering together outreach articles produced by members of the institute. The blog will include original articles, both about hot topics and about general concepts in our research fields, and will also feature some of the articles already published in our web site, when they are especially relevant or of timeless interest. The first post was *Partículas elementales, partículas compuestas y partículas virtuales*, by Pablo Fernández de Salas.

OUTREACH ACTIVITIES

Guided tours for students

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

The available labs for the tours are ANTARES/Km-3NET, NEXT, ATLAS-Silicon, ATLAS-TileCal, Medical Physics, GRID-Computing centre, Gamma Spectroscopy and Future Colliders. 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. Thirty-eight members of IFIC contributed to the tours throughout the year.

The total number of visiting schools in 2016 was nineteen, from towns all over our region, mainly from the province of Valencia, but also including Villena and Xixona from Alicante and Benicàssim from Castellón. Some visits 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.

The programme of joint visits with Observatori Astronòmic continued along 2016. 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. Thirteen schools visited IFIC as part of this program, from towns all over the province of Valencia.

We also were pleased to host some special visits during this year. We received five groups of degree students of Universitat de València, three from the Degree in Physics and two from Electronics Engineering, and two groups studying an Associate Degree in Medical Physics, who came specifically to visit IFIMED. In summer we also hosted the young students of VLC/Campus and High School #1517 from Moscow, whose visits have already become a tradition. Besides these, we were also pleased to host La Esperanza, an association of senior people focused in keeping its members intellectually active. As we also mention below, we received in addition a group of high school teachers as part of our programme of particle physics outreach for teachers.

Overall, in 2016 we hosted more than 850 visitors, increasing by 40% the figures of the previous year.

IFIC hosted more than 850 students from 19 schools, increasing by 40% 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 2016 hosted again two masterclasses: one using data of the LHCb experiment (March 2nd) and another with data of the ATLAS experiment (March 8th).

The masterclasses are held at the facilities of IFIC and at the Faculty of Physics on nearby 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 analysing 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 D0 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 2016 a total of 80 students participated in the masterclasses of IFIC, accompanied by 30 teachers. They came from 28 different high schools all over Comunitat Valenciana, including Alicante, Vila-Real and l'Alcora. Nineteen members of IFIC were involved in the different tasks, from logistics to lecturing.

Particle Physics Programme for high school teachers

Starting in 2016, IFIC sponsors a programme aimed at the teaching community of Comunitat Valenciana. Teachers in Spain have the opportunity to attend courses to update their background, but the number of courses focused on Physics is scarce. Together with the Department of Science Teaching of Universitat de València and CEFIRE, the government body that regulates such courses, IFIC offered a 20-hour programme to improve the teachers' training in particle physics and cosmology and to discuss how to translate that knowledge into the classrooms. The call for applications was a success, more than doubling the available places. All 30 places were covered.

The course was held in the facilities of CEFIRE. It included two sessions devoted to teaching techniques specific to particle physics, and then several sessions focusing on particular topics: nuclear physics, accelerator physics, cosmology and neutrino physics. A special session described homemade particle physics experiments that can be used in the classroom, and the programme ended with a visit to the laboratories of the institute. Six members of IFIC were involved in the different sessions that comprise the programme.

In 2016, 80 students and 30 teachers from 28 high schools participated in the masterclasses of IFIC

Expociencia 2016

Every year, around the end of May, Parc Científic organises Expociència, an open door day in the context of which demonstrations are performed and science outreach activities are offered to the public. In 2016 more than 4,000 people attended the event, visited the facilities of Parc Científic and swarmed around more than 70 different stands whose activities ranged from robotics to food science. IFIC contributed with seven activities, including a videoconference from the n_TOF experiment at CERN. Overall, more than 40 members of IFIC were involved in the organisation, logistics and execution of Expociència activities. One of our activities included the participation of 18 high school students from IES L'Eliana.

Activity	IFIC members involved
Telescopios de neutrinos: observando el universo desde las profundidades del mar	J. Zúñiga, J. Zornoza, J. Barrios, A. Sánchez, C. Tönnis
Cocinando en el Ártico	P. Ferrario, J. Renner, F. Monrabal, J.M. Benlloch, A. Simón, M. Kekic
ATLAS, un gigante para atrapar partículas	S. Cabrera, P. Zuccarello, J. Jiménez, Ó. Estrada, J. Mamuzic, J.E. García, F. Driencourt-Mangin, R. Ruiz de Austri, G. Sborlini, M. Alonso
¿Somos radiactivos?	A. Morales, A. Montaner, J.L. Taín, J. Agramunt, B. Rubio, Á. Tolosa, S.E.A. Orrigo
¡A innovar! De la escuela a la sociedad	F. Albiol, J. Bernabeu, A. Corbi, J. Sánchez. Students from IES L'Eliana
Buscando antimateria en LHCb	A. Oyanguren, F. Martínez, C. Sánchez, C. Remón, L.M. García, J. Ruiz, P. Ruiz
Videoconference with CERN	C. Domingo, A. Aparici, M. Alonso

Pint of Science

Pint of Science is an international festival that aims at transforming pubs into public forums of science discussion. 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 the Valencian node of the festival, and three members of the institute acted as speakers: Ana Montanter, Ane Etxebeste and Miguel Ángel Sanchis.

Experimenta

Every year the Faculty of Physics of Universitat de València organises 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 exhibited in a public session where the students themselves explain the science within, and then they are evaluated by a jury and four winners are selected. IFIC was involved as part of the organising committee, several members of the institute served as jurors during the contest phase of the event, and several others helped in organisational tasks and logistics.

Outreach activities in the context of European projects

The IFIC researcher Olga Mena serves as outreach coordinator for the Elusives ITN Project and the InvisiblesPlus RISE Project, wherein several outreach efforts are carried out, including comments on recent relevant advances and multimedia materials.

PUBLIC LECTURES

IFIC scientists gave 38 outreach talks at high schools all over Comunitat Valenciana

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 2016 IFIC offered 38 such talks on three different topics: LHC physics, astroparticles and nuclear physics research. Overall, 13 members of IFIC participated in this activity.

Topic	Location	Speakers
LHC Physics	Valencia, Burjassot, Alaquàs, Massanassa, Almussafes, Picassent, Alzira, Cheste, Puçol, Sagunto, La Vall d'Uixó, Castellón, Villena, Orihuela, Tarragona	C. García, J.E. García, S. Martí, L. Barranco, J. Jiménez, J. Salt, M. Vos
Astroparticles	Valencia, Almàssera, Paiporta, Burjassot, Manises, Alicante, Benidorm	S. Pastor, M. Tórtola, J. Zornoza
Nuclear Physics	Valencia, Massamagrell, Burjassot, La Eliana, Manises, La Pobla de Farnals, Alcàsser	A. Montaner, B. Rubio, A. Morales

Other public talks

During the year 2016 various members of IFIC gave a total of 38 public conferences covering a wide range of topics, from accelerator physics to quantum black holes. The talks were aimed both to official and casual gatherings.

A. Aparici, *El descubrimiento de las ondas gravitacionales,* Bocados de Ciencia en La Nau Gran (Universitat de València)

A. Aparici, *El tegu argentino, un lagarto de sangre caliente,* Bocados de Ciencia en La Nau Gran (Universitat de València)

A. Aparici, *Las fronteras de la ciencia* (round table), Jot Down Ciencia 2016 (Sevilla)

A. Aparici, *Divulgación, los aledaños de la ciencia*, Ten years of iGEM Valencia (Universitat Politècnica de València)

A. Aparici, *Mundos distantes, los primeros pasos en la era de la exoplanetología*, Escociencia 2016, (San Lorenzo de El Escorial)

A. Aparici, *Mundos distantes, los primeros pasos en la era de la exoplanetología*, Conference Cycle of Meridià Zero (Gata de Gorgos)

A. Aparici, *Las dos teorías de la relatividad*, Semana de la Ciencia de Quart de Poblet 2016

A. Aparici, *Las dos teorías de la relatividad*, IES Enric Valor (Picanya)

Á. Fernandez Casani, *Performance Improvements of EventIndex Distributed System at CERN*, III Jornada de Divulgació de la Investigació Doctoral (ETSE, Universitat de València)

A. Ferrer, *Del electrón al bosón de Higgs y un breve paseo por la antimateria*, Jornadas Jovellanos 2016 (Gijón)

J. Fuster, *Partículas elementales, entre la materia y la nada*, Alrededor de la Ciencia (L'Eliana)

J. Fuster, *Retos científicos y tecnológicos de la física de partículas tras el descubrimiento del bosón de Higgs*, HiggsTools II Annual Meeting (Granada)

J. Fuster, *El Colisionador Lineal Compacto (CLIC): desafíos técnicos y detectores*, Conference Cycle El LHC reanuda su funcionamiento y prepara su futuro (Madrid)

C. García, *Las partículas elementales en el LHC: ¿qué sabemos y qué nos falta por saber?*, Ciudad Ciencia (Villena)

J.J. Gómez Cadenas, *Del origen del Universo a la imagen médica*, Conference at Fundación de Estudios Médicos Molina de Segura

M.A. Lledó, *The String Theory Universe*, Gender Summit 9 Europe (Brussels)

G. Llosá, *Imagen médica: ¿cómo nos ven por dentro?*, Conference Cycle En clave de luz

G. Llosá, *Física médica y terapia hadrónica*, III Conference Cycle Ciència i Societat (Alberic)

G. Olmo, *Agujeros negros cuánticos*, Conference Cycle Arquitectura cósmica IV: El Universo cuántico (Fundación Valenciana de Estudios Avanzados)

S. Pastor, *Partículas elementales: ventanas al universo*, Setmana de la Ciència de Xilxes 2016

S. Pastor, *Premio Nobel de Física 2015: neutrinos, las partículas camaleónicas*, Conference Cycle of Facultat de Física (Universitat de València)

S. Pastor, *Premio Nobel de Física 2015: neutrinos, las partículas camaleónicas*, Invited conference (Oviedo)

A. Pérez, *El mundo cuántico*, Conference Cycle Arquitectura cósmica IV: El Universo cuántico (Fundación Valenciana de Estudios Avanzados)

A. Pich, *El bosón de Higgs: una ventana en la frontera del conocimiento*, Conferences of Fundació Baleària (Dénia)

A. Pich, *El bosón de Higgs: una ventana en la frontera del conocimiento*, Conferences of Universidad de Murcia

A. Pich, *Los secretos del bosón de Higgs: un campo de fuerzas sensibles al Universo oscuro*, Conferences of Programa Unisocietat (Universitat de València, Gandia)

M.A. Sanchis, *Enigmas de la Física Cuántica y más allá*, Birra y Ciencia (Olhöps, Valencia)

A. Santamaria, *Les partícules "fantasma" també tremolen: oscil·lacions de neutrins*, Octubre Centre de Cultura Contemporània (Valencia)

A. Santamaria, *Les partícules "fantasma" també tremolen: oscil·lacions de neutrins*, IES Camp de Túria (Llíria)
M.A. Tórtola, *La maleta de la ciencia: experimentos con aire y agua*, Setmana de la Ciència de Xilxes 2016

IFIC IN THE MEDIA

In 2016 IFIC participated in the production of 90 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 20 press releases during 2016. All of them were echoed on their web sites by Universitat de València and the branch of CSIC in Comunitat Valenciana. Some of them reached the media, either on physical paper or online.

Los agujeros negros podrían tener una salida, El Mundo

Los agujeros negros pueden tener una salida, Huffington Post

Físicos de la Universitat de València estudian el universo mediante neutrinos, Agencia EFE
Físicos valencianos pretenden detectar neutrinos en las ondas gravitacionales, La Vanguardia

Unos 200 expertos exponen en Valencia sus teorías sobre física de partículas, La Vanguardia

Físicos españoles resuelven el problema de los infinitos en las 4 dimensiones de Einstein, El Confidencial

Investigadores españoles aseguran que de los agujeros negros también se sale, El Confidencial

Físicos de la Universitat de València estudian el universo mediante neutrinos, Las Provincias

Can Wormholes Fix A Major Problem With Black Holes?, I Fucking Love Science

Black holes may be 'back doors' to other parts of the universe, researchers claim, Daily Mail

Black holes are 'doors' to another world, scientists say, The Independent

Black holes might have back doors to the universe, new study suggests, Aol.com

Researchers solve the problem of the dimensions of space-time in theories relating to the Large Hadron Collider, Science Daily

Indagando en la 'cocina estelar' de los elementos pesados del universo, El Imparcial

El IFIC acerca la física de partículas, astropartículas y nuclear al profesorado de secundaria valenciano, El Periodic

Researchers of IFIC also appeared in several other pieces, mainly interviews.

José Bernabéu: España es un país que no cumple sus compromisos, Revista Valencia Plaza

Tender puentes: una conversación con Javier María Prades y Juan José Gómez Cadenas, Jot Down

Si demostramos que el neutrino es su propia antipartícula tendremos una explicación de por qué el universo está hecho solo de materia, Revista QUO

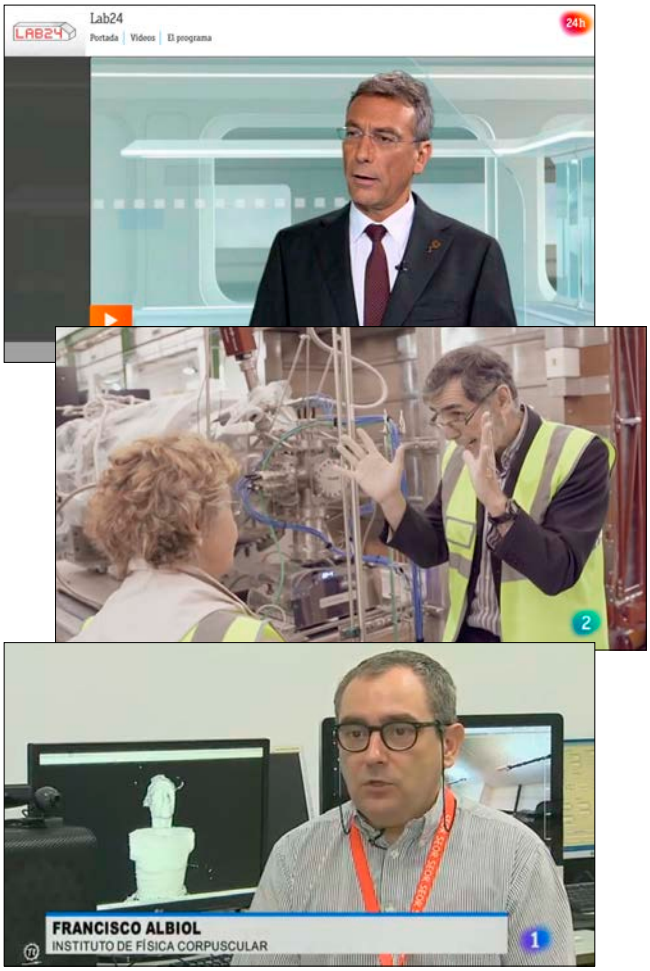
Juan Fuster, el Bosón de Higgs y el Big Bang en una copa de vino, Doble 6

Radio pieces

Fukushima seguirá aislada durante mucho tiempo, entrevista en Radio Euskadi a Juan José Gómez Cadenas

Interview about neutrino telescopes, El Café Cuántico a Javier Barrios

46 issues of La Brújula de la Ciencia, by Alberto Aparici in Onda Cero Radio



TV and audiovisual pieces

Feature piece about IFIC in the show Lab24, TVE (J.J. Hernández Rey, C. García, A. Pich)

Participation in an episode of the show El cazador de cerebros, TVE (J.J. Hernández Rey)

Participation in the show Órbita Laika, TVE (J.J. Gómez Cadenas)

Participation in an episode of the show El cazador de cerebros, TVE (J.J. Gómez Cadenas)

Interview during the event Naukas14, EITB (J.J. Gomez Cadenas)

Feature piece about new techniques for 3D reconstruction of the interior of the body, TVE (F. Albiol, A. Corbi)

Comment on the discovery of gravitational waves, Antena 3 (A. Aparici)

Interview about medical imaging, Desayuno con fotones (G. Llosá)

Articles authored by IFIC members

Una nueva vía para conocer el Universo, C. Peña Garay, El Español

El dilema de Turing, part 1 and part 2, J.J. Gómez Cadenas, Next Door Blog

Interview to Pedro Miguel Echenique, J.J. Gómez Cadenas, F. Monrabal, Jot Down

Interview to Viatcheslav Mukhanov, Alberto Aparici, Jot Down 17 (pages 58-74)

Adiós a la gran dama de la materia oscura, Alberto Aparici, Jot Down

Brexit: Carta del Presidente de la RSEF, J.A. de Azcárraga, Revista Española de Física, vol. 30 No. 3 (page 1)

De terapias 'cuánticas' y otras calamidades, J.A. de Azcárraga, Revista Española de Física, vol. 30 No. 4 (pages 1-3)

Un buen año para la física: 2015 y el legado de Albert Einstein, part 1 and part 2, J.A. de Azcárraga, 100cias@uned, vol. 8 (pages 143-154) and vol. 9 (pages 74-85)

Comment on Richard P. Feynman: la Física de las palabras, J. Navarro, Revista Española de Física, vol. 30 No. 3 (pages 75-76)

Cantata al Universo: gravedad más allá de Einstein, G. Olmo, La Física del GREL

Agujeros negros cuánticos, G. Olmo, La Física del GREL

Cool sensors: new silicon detectors have their fridges built in, M. Vos, LC Newsline

IFIC produced 20 press releases in 2016. More than 90 hits on several media (journals, digital media, radio, TV) were obtained

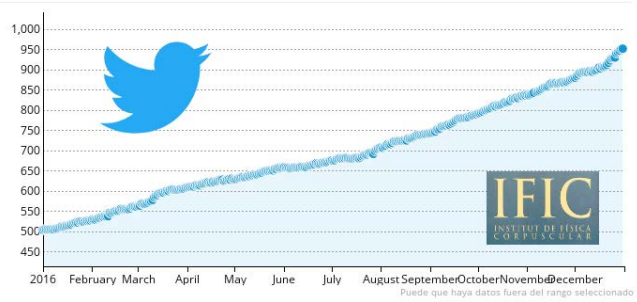
SOCIAL MEDIA

2016 was a year of expansion for our YouTube channel. Twenty seminars were published, including the Severo Ochoa Colloquia. A five-session course on computer tools for particle physics, offered by the IFIC researcher Avelino Vicente, was fully uploaded and can be used for online training. We also published several outreach pieces by researchers of IFIC, on topics such as the Nobel Prize in Physics 2015, the discovery of the pentaquark and neutrino telescopes. In this period we gained 85 subscriptors, increasing the previous year's figures by 82%, and accumulated more than 8,400 views.

Our activities on Facebook were maintained. On a weekly basis we announced the events that were to take place in the institute, including seminars, workshops, courses and colloquia, and we echoed popular materials about news relevant to our field, such as the discovery of gravitational waves. We notice that our public in these networks includes many researchers and physics students, but there is potential for growth towards non-specialised groups, as the posts featuring brief explanations of physics topics met a good reception. In this period we reached 728 likes, growing by 28%.

Our presence in the services of Google was also strong, with more than 70,000 searches throughout the year; among them, nearly 60% of them were on Google Maps, with more than 2,000 people requesting indications to arrive to the institute. Our pictures in the services of Google gathered more than 40,000 views.

Twitter was a very active social network throughout 2016. We announced our scientific activities on a daily basis and we received a substantial number of interactions, questions and requests. We tightened our links with the official accounts of CSIC, Universitat de València and other Spanish scientific institutions. Overall we grew by 88%, reaching almost 1,000 followers by the end of the year.



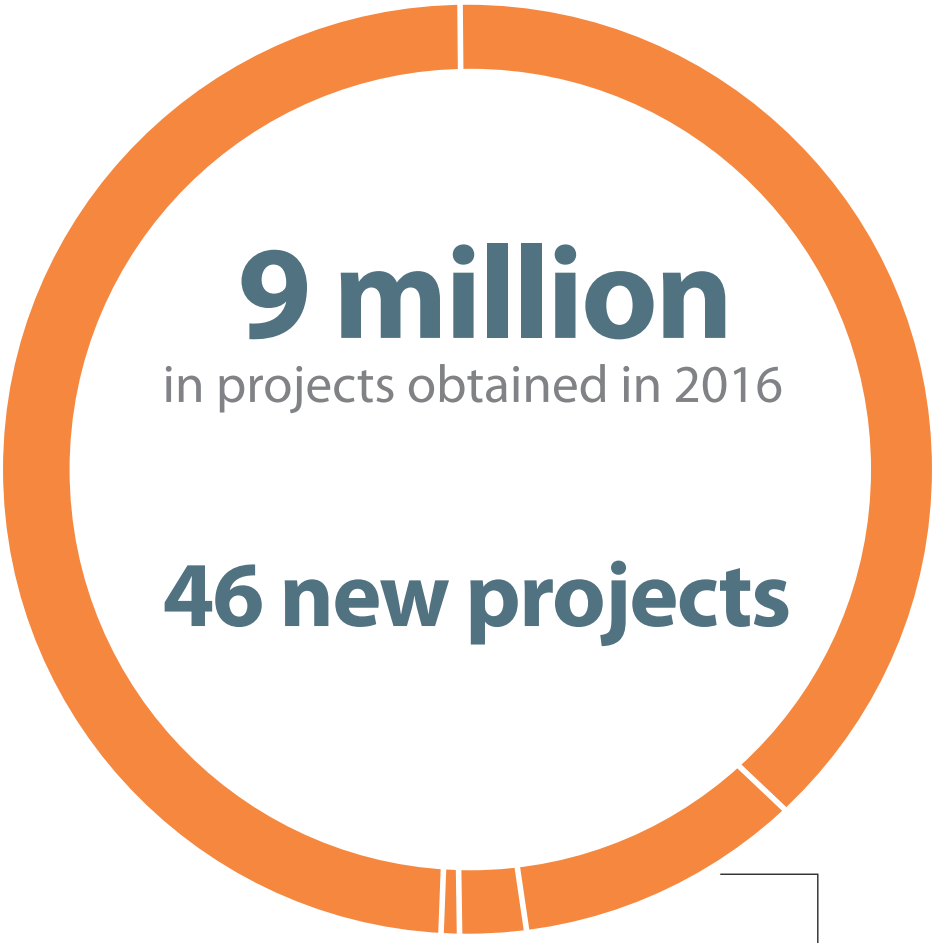
2016 Social Media figures
YouTube: 8,400 views, +82% subscriptors
Facebook: 728 likes, +28% growth
Twitter: 1,000 followers, +88% growth
70,000 searchers on Google

8. FUNDING

In this section we include all research grants that were active during the whole or part of 2016, funded by European Union (EU), national (NP), regional (CCAA) or other agencies.

9 National projects / 4,4 million

7 European projects / 3,3 million



16 Regional projects / 0,9 million

NATIONAL PLAN PROJECTS

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

Experimental Physics

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 – Jun 2016)

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 2016)

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)

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. FPA2014-55454-P
PI: Anselmo Cervera Villanueva
41,745 € (Jan 2015 – Dec 2016)

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)

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)

Incorporación de técnicas 3D para aumentar la precisión de imágenes radiológicas, EXPLORA
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)

Contribuciones al detector interno de trazas y al programa de física del experimento ATLAS en el LHC
Ref. FPA2015-65652-C4-1-R
PI: Carmen García García
1,833,150 € (Jan 2016 – Dec 2018)

Contribucion a la operación ATLAS y análisis de datos. Investigación y desarrollo (I+D) para futuros aceleradores y estudios de fisica
Ref. FPA2015-65652-C4-3-R
PI: Juan Fuster Verdú
290,400 € (Jan 2016 – Dec 2018)

Contribuciones al calorimetro hadronico Tilecal y al programa de física del experimento ALTAS
Ref. FPA2015-65652-C4-2-R
PI: Luca Fiorini
496,100 € (Jan 2016 – Dec 2018)

Desafios presentes y futuros del experimento LHCb del CERN (II)
Ref. FPA2015-68318-R
PI: Arantza Oyanguren
272,250 € (Jan 2016 – Dec 2017)

Participación del IFIC en ANTARES, Km3NET-ARCA/ORCA y PDG
Ref. FPA2015-65150-C3-1-P
PI: Juan de Dios Zornoza Gómez
301,895 € (Jan 2016 – Dec 2018)

Hacia un genuino TIER-2 federado español de ATLAS para afrontar el reto de la gestión y procesado del Big Data del LHC
Ref. FPA2016-75141-C2-1-R
PI: Santiago González de la Hoz
925,650 € (Dec 2016 – Dec 2019)

Desarrollo de un nuevo tipo de aparato PET de alta sensibilidad basado en xexon líquido
Ref: FPA2016-78595-C3-1-R
PI: José Díaz Medina
60,500 € (Dec 2016 – Dec 2018)

Física de Oscilaciones de neutrinos en el IFIC y la UAM
Ref: FPA2016-78417-C2-1-P
PI: Anselmo Cervera Villanueva
195,000 € (Dec 2016 – Dec 2019)

Theoretical Physics

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)

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)

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

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. 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. FPA2014-57816-P
PI: Pilar Hernandez Gamazo
164,560 € (Jan 2015 – Dec 2017)

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

Física Hadrónica Interacciones fundamentales y física nuclear
Ref: FPA2016-77177-C2-1-P
PI: Pedro González Marhuenda
78,650 € (Dec 2016 – Dec 2019)

EUROPEAN PROJECTS

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)

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)

Solving Challenges in Nuclear Data (CHANDA)
FP7-EURATOM-FISSION, Ref. 605203
Project Coordinator: Enrique M. González Romero
IFIC PI: José Luis Taín Enríquez
76,000 € (Dec 2013 – Nov 2017)

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)

Advanced European Infrastructures for Detectors at Accelerators (AIDA)-2020
H2020. Ref. 654168
IFIC PI: Marcel A. Vos
93,396.22 € (May 2015 – Apr 2019)

Europe-Japan Accelerator Development Exchange Programme (E-JADE)
H2020-MSCA-RISE-2014 Ref. 645479
IFIC PI: Ángeles Faus Golfe
63,000 € (Jan 2015 – Dec 2019)

European Nuclear Science and Applications Research (ENSAR2)
H2020. Ref. 654002
IFIC PI: Andres Gadea Raga
159,625 € (Mar 2016 – Feb 2020)

Optimization of Medical Accelerators (OMA)
H2020. Ref. 690575
IFIC PI: Ángeles Faus Golfe
247,872.96 € (Feb 2016 – Jan 2020)

INVISIBLESPLUS
H2020-MSCA-RISE -2015. Ref. 675265
IFIC PI: Pilar Hernández Gamazo
198,500 € (Feb 2016 – Jan 2020)

ELUSIVES
H2020-MSCA-ITN-2015. Ref. 674896
IFIC PI: Pilar Hernández Gamazo
454,402.92 € (Apr 2016 – Mar 2020)

TRITIUM
Ref. SOE1/P4/EO214
IFIC PI: Jose Diaz Medina
281,304.16 € (Jul 2016 – Jul 2019)

High-sensitivity Measurements of key stellar Nucleo-synthesis reactions
ERC Consolidator Grant
Ref. 681740
PI: César Domingo Pardo
1,886,558 € (Jun 2016 – May 2021)

INVISIBLESPLUS
Ref. 690575
IFIC PI: Olga Mena Requejo
103,220 € (Feb 2016 – Jan 2020)

REGIONAL PROJECTS

Funded by the Conselleria d' Educació, Investigació, 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
22,000 € (Jan 2016 – Dec 2016)

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
43,400 € (Jan 2016 – Dec 2016)

Aproximación teórico-experimental a la búsqueda de nueva física con sabores pesados
Ref. PROMETEOII/2014/049
PI: Francisco J. Botella Olcina
65,000 € (Jan 2016 – Dec 2016)

Sabor y origen de la materia
Ref. PROMETEOII/2014/050
PI: Nuria Rius Dionis
52,700 € (Jan 2016 – Dec 2016)

Estructura Quark de la materia
Ref. PROMETEOII/2014/066
PI: Santiago Noguera Puchol
45,400 € (Jan 2016 – Dec 2016)

Física Hadrónica y nuclear
Ref. PROMETEOII/2014/068
PI: Eulogio Oset Baguena
62,500 € (Jan 2016 – Dec 2016)

Astroparticulas y física de Altas Energías
Ref. PROMETEOII/2014/084
PI: Jose Furtado Valle
44,800 € (Jan 2016 – Dec 2016)

Telescopios de Neutrinos en el Mediterráneo
Ref. PROMETEOII/2014/079
PI: Juan J. Hernandez Rey
24,000 € (Jan 2016 – Dec 2016)

Estudios perturbativos y no perturbativos del modelo estandar y sus extensiones
Ref. PROMETEOII/2014/087
PI: Arcadi Santamaria Luna
24,400 € (Jan 2016 – Dec 2016)

FÍSICA DEL "LARGE HADRON COLLIDER": BÚSQUEDA DE NUEVAS INTERACCIONES EN LA FRONTERA DE ALTAS ENERGÍAS
Ref. PROMETEUII/2013/007
PI: Jose Bernabeu Alberola
90,000 € (Jan 2016 – Dec 2016)

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
120,000 € (Jan 2016 – Dec 2016)

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 2016 – Dec 2016)

Estudio de la interacción de hadrones a partir de la desintegración de hadrones pesados
Ref. APOTI/2016/A/028
PI: Juan M. Nieves Pamplona
4,500 € (Jan 2016 – Dec 2016)

Aplicación de teorías efectivas y modelos hadrónicos en simulaciones de transporte de colisiones de iones pesados
Ref. GV/2016/190
PI: Miguel Albaladejo Serrano
15,646 € (Jan 2016 – Dec 2016)

Física de neutrinos en el experimento DUNE
Ref. GV/2016/142
PI: Amparo Tortola Baixauli
13,200 € (Jan 2016 – Dec 2016)

Desarrollo de nuevas tecnologías basadas en el Xen
Ref. PROMETEO/2016/120
PI: Juan José Gómez Cadenas
300,375 € (Jan 2016 – Dec 2019)

CONSOLIDER PROJECTS

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 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)

Sabor y origen de la materia
Ref. 201550E088
PI: Pilar Hernandez Gamazo
8,000 € (Sep 2015 – Sep 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)

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)

Participacion en el proyecto ATLAS: Operación del detector, análisis de datos y actualización del detector para la fase de alta luminosidad
Ref. PIE 201650E004
PI: Carmen García García
96,100 € (Jan 2016 – Dec 2019)

Estudio de núcleos exóticos ricos en protones
Ref. COOPA20125
PI: Berta Rubio Barroso
17,850 € (Jan 2016 – Dec 2017)

Cooperación para la investigación en Física Médica y Radiactividad Ambiental
Ref. EXP011/2015
PI: Nadia Yahlali

3,759.83 € (Jan 2016 – Dec 2016)

Estades Temporals d'investigadors convidats - Carlos Alberto Canal Garcia
PI: Vicente Vento Torres
3,900 € (Jan 2016 – Dec 2016)

Estades Temporals d'investigadors convidats - Sergio Navas Concha
PI: Juan Zúñiga Román
6,150 € (Jan 2016 – Dec 2016)

Calibration Unit for KM3NeT Observatory
Ref. PICS 22015
PI: Juan J. Hernandez Rey
10,000 € (Jan 2016 – Dec 2018)

Búsquedas de nueva física y desarrollo de detectores en los experimentos ATLAS y MoEDAL del LHC
Ref. PIE 201650I002
PI: Vasiliki Mitsou
9,000 € (Jun 2016 – Jun 2017)

Robot de ensamblado de Gran superficie
Ref. CSIC15-EE-3099
PI: Carlos Lacasta Llacer
98,475 € (Jan 2016 – Dec 2017)

Relies in the cosmos in the 21th century
Ref. 201650I035
PI: Olga Mena Requejo
5,000 € (Nov 2016 – Nov 2017)

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)

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

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)

Contrato de licencia exclusiva de la patente 201231243 "Dispositivo y procedimiento de obtencion de imágenes desitometricas de objetos mediente combinacion de sistemas radiologicos"
Ref. 20132089
PI: German Rodrigo Garcia
6,171 € (May 2013 – Jul 2032)

Inspección por rayos X de multiples tarjetas
Ref. 20164369
PI: José Bernabeu Verdú
847 € (Jun 2016 – Jun 2016)

Inspección por rayos X del componente módulo 3G, 5 radiografias
Ref. 20164368
PI: José Bernabeu Verdú
302.5 € (Jun 2016 – Jun 2016)

Ensamblado y protección de chips sobre 500 tarjetas electrónicas
Ref. 2016-523-00044210
PI: Santiago Noguera Puchol
32,670 € (May 2016 – Jun 2016)

Contr. Colaboracion Alibava y CSIC
Ref. 20162544
PI: Carlos Lacasta Llácer
2,348.61 € (Jan 2016 – Jun 2016)

Jornadas Formativas de Tecnologías Big Data
Ref. 20165390
PI: Francisco Albiol Colomer
300 € (Oct 2016 – Oct 2016)

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