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INSTITUTO DE FÍSICA CORPUSCULAR

Centre of Excellence Severo Ochoa

IFIC INSTITUT DE FÍSICA CORPUSCULAR

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CSIC CONSEJO SUPERIOR DE INVESTIGACIONES CIENTÍFICAS

VNIVERSITAT DE VALÈNCIA

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WELCOME

PROF. JUAN JOSÉ HERNÁNDEZ REY, DIRECTOR OF IFIC.

Welcome to IFIC's 2018 Annual Report. I want to briefly summarise here our main achievements during this year, which was definitely an excellent year for IFIC.

This year I would like to start by referring to our Technical and Service Units. In an institute like IFIC, in which the experimental activities are a good fraction of its research endeavours, these units truly represent a backbone of the institute. The commitment and high professionalism of their personnel is remarkable and the number of activities that they perform, outstanding. The increase in number, size and complexity of the research projects during recent years has unfortunately not been accompanied by a corresponding growth in personnel, neither in the technical nor in the administrative areas. The exceedingly high workload and the large fraction of the personnel hired on a temporary basis is a matter of great concern for me as director. This must change in the future if IFIC is to maintain its high standards.

Regarding the experimental research activities, I want to emphasize the milestone reached by the LHC with the completion of Run 2. The LHC and its detectors continue to be a source of extraordinary science. IFIC's research activities related to the ATLAS detector are too numerous to describe here. Let me mention just a few. Our physicists are contributing in an outstanding way to reach, in a not too distant future, an impressive accuracy of around 1 GeV in the top quark pole mass. Our physicists are also involved in the search for the single production of a vector-like top quark and in the frantic race to discover the nature of dark matter, looking for it in ATLAS in several channels.

IFIC contributes to the Grid computing for the LHC experiments. Our researchers not only have participated in the development of "EventIndex", a system to index and catalogue all physics events, but they have also continued to operate and update IFIC's Tier2 computing and storage infrastructure. Our Tier2 represents a sizeable 4% of all the ATLAS Tier2 resources worldwide.

While building the KM3NeT underwater neutrino telescope, the new stage in the field of neutrino astronomy, IFIC physicists have continued to analyse the data provided by ANTARES, which has been operating for more that eleven years and has recorded more than ten thousand neutrinos. They have covered a wide range of research. They have not only looked for astrophysical sources of neutrinos, but they have also tried to clarify the nature of dark matter and have studied neutrino properties.

The NEXT-White detector delivered its first results. An energy resolution of 1% FWHM at 2.46 MeV and the measured Rn-induced backgrounds validate the physics case and gives a clear boost to the NEXT-100 neutrinoless double beta decay experiment.

An updated oscillation analysis in T2K yielded the exclusion of CP conservation in the leptonic sector at a 2σ level (95.45% C.L.). An 8m-height device was built to measure the temperature gradient, with 3 mK precision, of the liquid Ar in the ProtoDUNE-SP detector operated at CERN.

The most important activities of the Gamma and Neutron Spectroscopy Group in 2018 were related to instrumentation. The group published the results of the characterization of the DTAS total absorption spectrometer, developed by the group for the DESPEC experiment of FAIR, and of the realization of the first test of the i-TED detector at CERN. I-TED is a novel Compton detector developed in the framework of the HYMNS ERC project, which aims at enhanced detection sensitivity for astrophysical nucleosynthesis reactions induced by neutrons. Another important result was that the nTOF Collaboration published its results on the ^{7}Be (n,p) ^{7}Li reaction, related to the yet unsolved cosmological lithium problem. This measurement covered for the first time the energy range of relevance for Big Bang nucleosynthesis.

Concerning Medical Physics, a second prototype of a Compton telescope for hadron therapy treatment monitoring, MACACO II, assembled with new detectors and featuring improved image reconstruction algorithms, has led to a significantly better system performance.

The variety and quality of the theoretical research at IFIC is extraordinary. Let me mention some of its results. The Standard Model prediction of the ε'/ε ratio, which has been the source of strong controversy in the past, has been studied in-depth by IFIC's physicists and has been found to be in agreement with the experimental measurements. IFIC researchers have devised a novel numerical method for the analysis of the fermion mass matrices

predicted in flavour models.

A group of researchers from IFIC showed that, if dark matter annihilation into sterile neutrinos determines its observed relic abundance, it is possible to explain the Galactic Centre γ-ray excess reported by the Fermi-LAT Collaboration as due to an astrophysical component plus dark matter annihilations.

A group of IFIC's physicists solved for the first time, in the context of quantum field theory in curved spacetimes, the backreaction problem for rotating black holes and naked singularities in 2+1 dimensions.

Another group has shown that the LHC can probe light sterile neutrinos by looking for displaced vertices. Several possible extensions of the Standard Model have been investigated. For instance, a gauged SO(3) flavour extension that includes right-handed neutrinos and a Peccei-Quinn symmetry, and a simple realistic grand unified theory based on the SU(5) gauge symmetry. These models give results in agreement with the presently known experimental measurements and provide concrete predictions that could be experimentally tested.

Hadron dynamics in coupled channels gives rise to a rich structure of new states with strange, charm and beauty quarks that cannot be easily accommodated within the standard constituent quark model, whose consequences are being investigated in a variety of aspects by IFIC's theorists.

IFIC's physicists are currently providing efficient calculations in perturbative QCD by means of the loop-tree duality formalism that is yielding new remarkable results for physical processes of enormous importance at the LHC. In the non-perturbative approach, the full quark-gluon vertex of QCD is studied, which is a crucial ingredient for the dynamical generation of a constituent quark mass from the standard quark gap equation.

Researchers at IFIC have presented a new global fit of neutrino oscillation parameters including the most recent data from long-baseline, reactor, solar and atmospheric experiments. The most remarkable results from this analysis are the strong preference obtained for values of the CP phase δ in the range $[\pi,2\pi]$ and the first hint in favor of the normal mass ordering over the inverted one at more than 3σ. Likewise, the status of the neutrino mass ordering has been analysed in more detail in a review article that presents the different available tools to measure the neutrino mass ordering, showing strong evidence for the normal neutrino mass ordering with a significance of $3.5\ \sigma$. Another study has investigated the possible observation of genuine CP violation in neutrino oscillations at long baselines, concluding that, for certain energy regions, DUNE could shed light on the subject.

The aforementioned activities have given rise to a noticeable scientific output, which can be gauged by the more than four hundred publications and the sixteen PhD theses that the institute has yielded during 2018. IFIC's scientists made a total of 365 contributions to international conferences and workshops, out of which 74 were invited talks. Likewise, IFIC organized more than a dozen conferences, meetings and workshops.

IFIC scientific life was ebullient during 2018, with 13 colloquia by leading world experts, including three Nobel laureates and a total of 82 seminars, including several webinars. The Office for Young Researchers, Gender and Diversity (JIGD), which was created the year before, had a variety of activities, which included the screening of a film about the role of women in Science, several talks about social and health matters related to scientists and the preparation of different activities for the International Day of Women and Girls in Science.

IFIC is committed to outreach and communication. Indeed, during 2018 more than 100 members of the institute were involved in this type of activities. More than 700 people from 33 centres visited IFIC during guided tours. A total of 40 talks, given by 25 IFIC members, reached more than two thousand students. IFIC participated with eight activities and 45 members in Expociencia, which gathered around five thousand visitors. There were two sessions of the CERN's particle physics masterclasses (around the ATLAS and LHCb experiments) which gathered 151 students and 54 teachers from 51 centres (and a waiting list of 31!). There was a lecture series on particle physics for secondary education teachers. We organised the Dark Matter Day and several public talks by Nobel-prize winners in the City of Arts and Sciences. There were 28 press releases by IFIC and 200 hits in the press.

Several activities related to the knowledge and technological transfer have been in place during 2018, which you can find in the corresponding section of this report. I want to mention here the rollout of IFIC's UCIE (Unidad Científica de Investigación Empresarial) that took place during 2018. UCIEs are legal structures devised and funded by the Agència Valenciana de la Innovació (AVI) to foster innovation and transfer in several research institutes of the Comunitat Valenciana. IFIC's UCIE will be of great help to coordinate and support these types of activities and to provide a structure and plan for the future. As a matter of fact, we intend within our UCIE to identify and bolster all the prospective innovation activities that may give rise to products which could nurture a knowledge based economy.

As you can see, IFIC had an ample range of activities in science and technology during 2018 following our commitment to Science for the improvement of our society. ■

BIENVENIDA

Bienvenidos a la Memoria Anual de 2018 del IFIC. Quiero resumir brevemente aquí nuestros logros principales durante este año, que fue sin duda un año excelente para el IFIC.

Quisiera empezar este año refiriéndome a nuestras Unidades Técnicas y de Servicios. En un instituto como el IFIC, en el que las actividades experimentales suponen una parte importante de sus empeños, estas unidades representan verdaderamente la espina dorsal del instituto. El compromiso y la enorme profesionalidad de su personal es notable y el número de actividades que llevan a cabo es sobresaliente. El aumento en número, tamaño y complejidad de los proyectos de investigación en los últimos años no se ha visto acompañado, por desgracia, de un crecimiento correspondiente de personal. La enorme carga de trabajo y el importante porcentaje de personal contratado temporalmente es motivo de preocupación para mí como director. Esto tiene que cambiar en el futuro, si es que queremos que el IFIC conserve sus altos estándares.

En lo que concierne a las actividades experimentales, quiero subrayar el hito alcanzado por el LHC con la finalización del Run 2. El LHC y sus detectores continúan siendo una fuente de ciencia extraordinaria. Las actividades de investigación del IFIC relacionadas con el detector ATLAS son demasiado numerosas como para poder mencionarlas todas aquí. Permítanme, no obstante, mencionarles algunas. Nuestros físicos están contribuyendo de forma sobresaliente a conseguir, en un futuro no lejano, una impresionante precisión de 1 GeV en la masa polo del quark top. Están también involucrados en la búsqueda de la producción individual de un quark top de tipo vectorial y en la frenética carrera por descubrir la naturaleza de la materia oscura, buscándola en diversos canales en ATLAS.

El IFIC contribuye al cálculo Grid para los experimentos de LHC. Nuestros investigadores no solo han participado en el desarrollo de "EventIndex", un sistema de indexado y catálogo de sucesos físicos, sino que también han continuado operando y poniendo al día la infraestructura Tier2 de cálculo y almacenamiento del IFIC. Nuestro Tier2 representa un considerable 4% de todos los recursos Tier2 de ATLAS a nivel mundial.

Al tiempo que construyen el telescopio submarino de neutrinos KM3NeT, una nueva etapa en el campo de la astronomía de neutrinos, los físicos del IFIC han continuado analizando los datos suministrados por ANTARES, que ha estado operando durante más de once años y ha registrado más de una decena de miles de neutrinos. Su rango de investigaciones es amplio, no solo buscan fuentes astrofísicas de neutrinos, sino que también intentan aclarar la naturaleza de la materia oscura y estudiar las propiedades de los neutrinos.

El detector NEXT-White ha proporcionado sus primeros resultados. Una resolución en energía del 1% FWHM a 2,46 MeV y los fondos inducidos por Rn medidos validan el fundamento físico y dan un claro empuje al experimento de desintegración doble beta sin neutrinos NEXT-100.

Una puesta al día del análisis de oscilaciones de T2K ha permitido excluir la conservación de CP en el sector leptónico a un nivel de 2σ (95,45% nivel de confianza). Se ha construido un dispositivo de 8 metros de longitud para medir el gradiente de temperatura, con una precisión de 3 mK, del argón líquido del detector ProtoDUNE-SP que funciona en el CERN.

Las actividades más importantes del grupo de espectroscopía gamma y de neutrones en 2018 han estado relacionadas con la instrumentación. El grupo publicó los resultados de la caracterización del espectrómetro de absorción total DTAS, desarrollado para el experimento DESPEC de FAIR y de la realización de la primera prueba del detector i-TED en el CERN. i-TED es un nuevo detector Compton desarrollado en el marco del proyecto ERC HYMNS, que tiene como objetivo una mayor sensibilidad de detección de las reacciones de nucleosíntesis astrofísicas inducidas por neutrones. Otro resultado importante ha sido la publicación por parte de la colaboración nTOF de sus resultados en el estudio de la reacción ^{7}Be (n, p) ^{7}Li, relacionados con el problema aún no resuelto del litio cosmológico. Esta medida cubrió por primera vez el rango de energía relevante para la nucleosíntesis del Big Bang.

Con respecto a la Física Médica, la construcción de un segundo prototipo de telescopio Compton para la monitorización del tratamiento con terapia de hadrones, MACACO II, montado con nuevos detectores y con algoritmos de reconstrucción de imágenes mejorados, ha proporcionado un rendimiento del sistema significativamente mejor.

La variedad y calidad de la investigación teórica en el IFIC es extraordinaria. Permítanme mencionar algunos de sus resultados. La predicción del Modelo Estándar de la relación ε'/ε, que ha sido fuente de una gran controversia en el pasado, ha sido estudiada en profundidad por los físicos del IFIC y se ha encontrado que está de acuerdo con las mediciones experimentales. Los investigadores de IFIC han ideado un método numérico novedoso para el análisis de las matrices de masas de fermiones predichas en modelos de sabor.

Un grupo de investigadores del IFIC demostró que, si la aniquilación de la materia oscura en neutrinos estériles determina su abundancia primordial observada, es posible explicar el exceso de rayos γ procedentes del Centro Galáctico medido por la colaboración Fermi-LAT como debido a

una componente astrofísica más otra de aniquilaciones de materia oscura.

Un grupo de físicos del IFIC ha resuelto por primera vez, en el contexto de la teoría cuántica de campos en el espacio-tiempo curvo, el problema de la "backreaction" para agujeros negros y singularidades desnudas en 2 + 1 dimensiones.

Otro grupo ha demostrado que en el LHC se puede investigar la existencia de neutrinos estériles ligeros buscando vértices desplazados. Se han investigado varias posibles extensiones del modelo estándar. Por ejemplo, una extensión de sabor SO(3) "gauged", que incluye neutrinos dextrógiros y una simetría de Peccei-Quinn, y una teoría unificada sencilla y realista basada en la simetría gauge SU(5). Estos modelos dan resultados que están de acuerdo con las medidas experimentales conocidas actualmente y proporcionan predicciones concretas que podrían ser probadas experimentalmente.

La dinámica de hadrones en canales acoplados da lugar a una rica estructura de nuevos estados con quarks extraños, encantados y con belleza que no pueden acomodarse fácilmente dentro del modelo de quark constituyente estándar, y cuyas consecuencias están siendo investigadas en diversos aspectos por los físicos teóricos del IFIC.

Los físicos de IFIC están proporcionando cálculos eficientes en QCD perturbativo por medio del formalismo de dualidad de bucle-árbol, que está dando nuevos resultados notables para procesos físicos de enorme importancia para el LHC. En el enfoque no-perturbativo se estudia el vértice completo de quark-gluón de QCD, que es un ingrediente crucial para la generación dinámica de una masa de los quarks constituyentes a partir de la ecuación estándar de "quark gap".

Los investigadores de IFIC han presentado un nuevo ajuste global de parámetros de oscilación de neutrinos que incluye los datos más recientes de experimentos de long baseline, en reactores, neutrinos solares y atmosféricos. Los resultados más destacables de este análisis son una fuerte preferencia para los valores de la fase CP, δ, en el rango $[\pi, 2\pi]$ y la primera indicación a más de 3σ en favor del orden de masas normal frente al invertido. Del mismo modo, la situación actual del orden de masas de neutrinos se ha analizado con más detalle en un artículo de revisión que presenta las diferentes herramientas disponibles para medir dicho orden de masas, mostrando una fuerte evidencia en favor del orden normal de masas con una significancia de $3{,}5\sigma$. Otro estudio ha investigado la posible observación de violación genuina de CP en oscilaciones de neutrinos en long baseline, concluyendo que, para ciertas regiones de energía, DUNE podría arrojar luz sobre el tema.

Las actividades mencionadas han dado lugar a una producción científica notable, que se pone de manifiesto por las más de cuatrocientas publicaciones y las dieciséis tesis doctorales que el instituto ha producido durante 2018. Los científicos de IFIC han realizado un total de 365 contribuciones a conferencias y talleres internacionales, de las cuales 74 fueron charlas invitadas. Asimismo, el IFIC ha organizado más de una docena de conferencias, reuniones y talleres.

La vida científica del IFIC fue exuberante durante 2018, con 13 coloquios de expertos mundiales líderes en su campo, incluidos tres premios Nobel y un total de 82 seminarios, incluidos varios webinarios. La Oficina para Jóvenes Investigadores, Género y Diversidad (JIGD), creada el año anterior, realizó una gran cantidad de actividades, que incluyeron la proyección de una película sobre el papel de la mujer en la ciencia, varias charlas sobre asuntos sociales y de salud relacionados con los científicos y la preparación de diferentes actividades para el Día Internacional de la Mujer y la Niña en la Ciencia.

El IFIC está comprometido con la divulgación y la comunicación. Durante 2018 más de 100 miembros del instituto participaron en este tipo de actividades. Más de 700 personas de 33 centros visitaron el IFIC en visitas guiadas. Un total de 40 charlas, impartidas por 25 miembros del IFIC, llegaron a más de dos mil estudiantes. El IFIC participó con ocho actividades y 45 miembros en Expociencia, que reunió alrededor de cinco mil visitantes. Hubo dos sesiones de master class de física de partículas del CERN (en torno a los experimentos ATLAS y LHCb) que reunieron a 151 estudiantes y 54 profesores de 51 centros (¡y una lista de espera de 31!). Hubo un curso sobre física de partículas para profesores de educación secundaria. Organizamos el Dark Matter Day y varias charlas públicas de diversos premios Nobel en la Ciudad de las Artes y las Ciencias. Hubo 28 comunicados de prensa de IFIC y 200 alcances en prensa.

Se han implementado varias actividades relacionadas con la transferencia tecnológica y del conocimiento durante 2018, que pueden encontrar en la sección correspondiente de esta memoria. Quiero mencionar aquí el lanzamiento de la Unidad Científica de Investigación Empresarial (UCIE) del IFIC, que tuvo lugar durante 2018. Las UCIEs son estructuras legales ideadas y financiadas por la Agencia Valenciana de la Innovación (AVI) para fomentar la innovación y la transferencia en diversos institutos de investigación de la Comunitat Valenciana. La UCIE del IFIC va a ser de gran ayuda para coordinar y apoyar este tipo de actividades y proporcionar estructura y planificación para el futuro. De hecho, dentro de nuestra UCIE pretendemos identificar y reforzar todas las posibles actividades de innovación que puedan dar lugar a productos que puedan alimentar una economía basada en el conocimiento.

Como se puede ver, el IFIC llevó a cabo un amplio rango de actividades en ciencia y tecnología durante 2018, siguiendo nuestro compromiso con la Ciencia para la mejora de nuestra sociedad. ■

BENVINGUTS

Benvinguts a la Memòria Anual de 2018 de l'IFIC. Vull resumir breument ací els nostres assoliments principals durant aquest any, que va ser sens dubte un any excel·lent per a l'IFIC.

Voldria començar enguany referint-me a les nostres Unitats Tècniques i de Serveis. En un institut com l'IFIC, en el qual les activitats experimentals suposen una part important dels seus esforços, aquestes unitats representen veritablement l'espina dorsal de l'institut. El compromís i l'enorme professionalitat del seu personal és notable i el nombre d'activitats que duen a terme és excel·lent. L'augment en número, grandària i complexitat dels projectes d'investigació en els últims anys no s'ha vist acompanyat, per desgràcia, d'un creixement corresponent de personal. L'enorme càrrega de treball i l'important percentatge de personal contractat temporalment és motiu de preocupació per a mi com a director. Això haurà de canviar en el futur, si és que volem que l'IFIC conserve els seus alts estàndards.

Pel que fa a les activitats experimentals, vull subratllar la fita aconseguida pel LHC amb la finalització del Run 2. El LHC i els seus detectors continuen sent una font de ciència extraordinària. Les activitats d'investigació de l'IFIC relacionades amb el detector ATLAS són massa nombroses com per a poder esmentar-les totes ací. Permetent-me, no obstant això, esmentar-los algunes. Els nostres físics estan contribuint de manera excel·lent a aconseguir, en un futur no llunyà, una impressionant precisió d'un GeV en la massa pol del quark top. Estan també involucrats en la cerca de la producció individual d'un quark top de tipus vectorial i en la frenètica carrera per descobrir la naturalesa de la matèria fosca, buscant-la en diversos canals en ATLAS.

L'IFIC contribueix al càlcul Grid per als experiments de LHC. Els nostres investigadors no sols han participat en el desenvolupament de "EventIndex", un sistema d'indexat i catàleg de successos físics, sinó que també han continuat operant i posant al dia la infraestructura Tier2 de càlcul i emmagatzematge de l'IFIC. El nostre Tier2 representa un considerable 4% de tots els recursos Tier2 d'ATLAS a nivell mundial.

Al mateix temps que construeixen el telescopi submarí de neutrins KM3NeT, una nova etapa en el camp de l'astronomia de neutrins, els físics de l'IFIC han continuat analitzant les dades subministrades per ANTARES, que ha estat operant durant més d'onze anys i ha registrat més d'una desena de milers de neutrins. El seu rang d'investigacions és ampli, no sols busquen fonts astrofísiques de neutrins, sinó que també intenten aclarir la naturalesa de la matèria fosca i estudiar les propietats dels neutrins.

El detector NEXT-White ha proporcionat els seus primers resultats. Una resolució en energia del 1% FWHM a 2,46 MeV i els fons induïts per Rn mesurats validen el fonament físic i donen un clar impuls a l'experiment de desintegració doble beta sense neutrins NEXT-100.

Una posada al dia de l'anàlisi d'oscil·lacions de T2K ha exclòs la conservació de CP en el sector leptònic a un nivell de 2σ (95,45% nivell de confiança.). S'ha construït un dispositiu de 8 m de longitud per a mesurar el gradient de temperatura, amb una precisió de 3 mK, de l'argó líquid del detector ProtoDUNE-SP que funciona en el CERN.

Les activitats més importants del grup de espectroscopia gamma i de neutrons en 2018 han estat relacionades amb la instrumentació. El grup va publicar els resultats de la caracterització de l'espectròmetre d'absorció total DTAS, desenvolupat per a l'experiment DESPEC de FAIR i de la realització de la primera prova del detector i-TED en el CERN. i-TED és un nou detector Compton desenvolupat en el marc del projecte ERC HYMNS, que té com a objectiu una major sensibilitat de detecció de les reaccions de nucleosíntesis astrofísiques induïdes per neutrons. Un altre resultat important ha estat la publicació per part de la col·laboració nTOF dels seus resultats en l'estudi de la reacció ^{7}Be (n, p) ^{7}Li, relacionats amb el problema encara no resolt del liti cosmològic. Aquesta mesura va cobrir per primera vegada el rang d'energia rellevant per a la nucleosíntesis del Big bang.

Respecte a la Física Mèdica, la construcció d'un segon prototip de telescopi Compton per al monitoratge del tractament amb teràpia d'hadrons, MACACO II, assemblat amb nous detectors i amb algorismes de reconstrucció d'imatges millorats, ha proporcionat un rendiment del sistema significativament millor.

La varietat i qualitat de la investigació teòrica a l'IFIC és extraordinària. Permeten-me esmentar alguns dels seus resultats. La predicció del Model Estàndard de la relació ε'/ε, que ha estat font d'una gran controvèrsia en el passat, ha estat estudiada en profunditat pels físics de l'IFIC i s'ha trobat que està d'acord amb els mesures experimentals. Els investigadors de l'IFIC han ideat un mètode numèric nou per a l'anàlisi de les matrius de masses de fermions predites en models de sabor.

Un grup d'investigadors de l'IFIC va demostrar que, si l'aniquilació de la matèria fosca en neutrins estèrils determina la seua abundància primordial observada, és possible explicar l'excés de raigs γ del Centre Galàctic mesurat per la col·laboració Fermi-LAT com a causa d'una component astrofísica més altra d'anihilacions de matèria fosca.

Un grup de físics de l'IFIC ha resolt per primera vegada, en el context de la teoria quàntica de camps en l'espaitemps corb, el problema de la "backreaction" per a forats negres i singularitats nues en 2 + 1 dimensions.

Un altre grup ha demostrat que en el LHC es pot investigar l'existència de neutrins estèrils lleugers buscant vèrtexs desplaçats. S'han investigat diverses possibles extensions del Model Estàndard. Per exemple, una extensió de sabor SO(3) "gauged", que inclou neutrins dextròsirs i una simetria de Peccei-Quinn i una teoria unificada senzilla i realista basada en la simetria gauge SU(5). Aquests models donen resultats que estan d'acord amb les mesures experimentals conegudes actualment i proporcionen prediccions concretes que podrien ser provades experimentalment.

La dinàmica d'hadrons en canals acoblats dóna lloc a una rica estructura de nous estats amb quarks estranys, encantats i amb bellesa que no poden acomodar-se fàcilment dins del model de quark constituent estàndard i les conseqüències del qual estan sent investigades en diversos aspectes pels físics teòrics de l'IFIC.

Els físics de l'IFIC estan proporcionant càlculs eficients en QCD perturbativa per mitjà del formalisme de dualitat de bucle-arbre, que està donant nous resultats notables per a processos físics d'enorme importància per al LHC. En l'enfocament no-perturbatiu, s'estudia el vèrtex complet de quark-gluon de QCD, que és un ingredient crucial per a la generació dinàmica d'una massa dels quarks constituents a partir de l'equació estàndard de "quark gap".

Els investigadors de l'IFIC han presentat un nou ajust global de paràmetres d'oscil·lació de neutrins que inclou les dades més recents d'experiments de long baseline, en reactors, neutrins solars i atmosfèrics. Els resultats més destacables d'aquesta anàlisi són una forta preferència pels valors de la fase CP, δ, en el rang $[\pi, 2\pi]$ i la primera indicació a més de 3σ en favor de l'ordre de masses normal enfront de l'invertit. De la mateixa manera, la situació actual de l'ordre de masses de neutrins s'ha analitzat amb més detall en un article de ressenya que presenta les diferents eines disponibles per mesurar aquest ordre de masses, mostrant una forta evidència en favor de l'ordre normal de masses amb un significança de $3{,}5\sigma$. Un altre estudi ha investigat la possible observació de violació genuïna de CP en oscil·lacions de neutrins en long baseline, concloent que, per a certes regions d'energia, DUNE podria llançar llum sobre el tema.

Les activitats esmentades han donat lloc a una producció científica notable, que es posa de manifest per les més de quatre-centes publicacions i les setze tesis doctorals que l'institut ha produït durant 2018. Els científics de l'IFIC han realitzat un total de 365 contribucions a conferències i tallers internacionals, dels quals 74 van ser xarrades convidades. Així mateix, l'IFIC ha organitzat més d'una dotzena de conferències, reunions i tallers.

La vida científica de l'IFIC va ser exuberant durant 2018, amb 13 col·loquis d'experts mundials líders en el seu camp, inclosos tres premis Nobel i un total de 82 seminaris, inclosos diversos webinaris. L'Oficina per a Joves Investigadors, Gènere i Diversitat (JIGD), creada l'any anterior, va realitzar una gran quantitat d'activitats, que van incloure la projecció d'una pel·lícula sobre el paper de la dona en la ciència, diverses xarrades sobre assumptes socials i de salut relacionats amb els científics i la preparació de diferents activitats per al Dia Internacional de la Dona i la Xiqueta en la Ciència.

L'IFIC està compromés amb la divulgació i la comunicació. Durant 2018 més de 100 membres de l'institut van participar en aquesta mena d'activitats. Més de 700 persones de 33 centres van visitar l'IFIC en visites guiades. Un total de 40 xarrades, impartides per 25 membres de l'IFIC, van arribar a més de dos mil estudiants. L'IFIC va participar amb huit activitats i 45 membres en Expociència, que va reunir al voltant de cinc mil visitants. Van haver-hi dues sessions de master class de física de partícules del CERN (entorn dels experiments ATLES i LHCb) que van reunir 151 estudiants i 54 professors de 51 centres (i una llista d'espera de 31!). Va haver-hi un curs sobre física de partícules per a professors d'educació secundària. Vam oganitzar el Dark Matter Day i diverses xarrades públiques de diversos premis Nobel a la Ciutat de les Arts i les Ciències. Van haver-hi 28 comunicats de premsa de l'IFIC i 200 ements en premsa.

S'han implementat diverses activitats relacionades amb la transferència tecnològica i del coneixement durant 2018, que poden trobar en la secció corresponent d'aquesta memòria. Vull esmentar ací el llançament de la Unitat Científica d'Investigació Empresarial (UCIE) de l'IFIC, que va tindre lloc durant 2018. Les UCIEs són estructures legals ideades i finançades per l'Agència Valenciana de la Innovació (AVI) per a fomentar la innovació i la transferència en diversos instituts d'investigació de la Comunitat Valenciana. L'UCIE de l'IFIC serà de gran ajuda per a coordinar i donar suport a aquest tipus d'activitats i proporcionar estructura i planificació per al futur. De fet, dins de nostra UCIE pretenem identificar i reforçar totes les possibles activitats d'innovació que puguen donar lloc a productes que puguen alimentar una economia basada en el coneixement.

Com es pot veure, l'IFIC va dur a terme un ampli rang d'activitats en ciència i tecnologia durant 2018, seguint el nostre compromís amb la Ciència per la millora de la nostra societat. ■

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 also committed to work on 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.

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.

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 Centre 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.

CENTRO DE FISICA FOTOCORPUSCULAR
FACULTAD DE CIENCIAS
VALENCIA

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

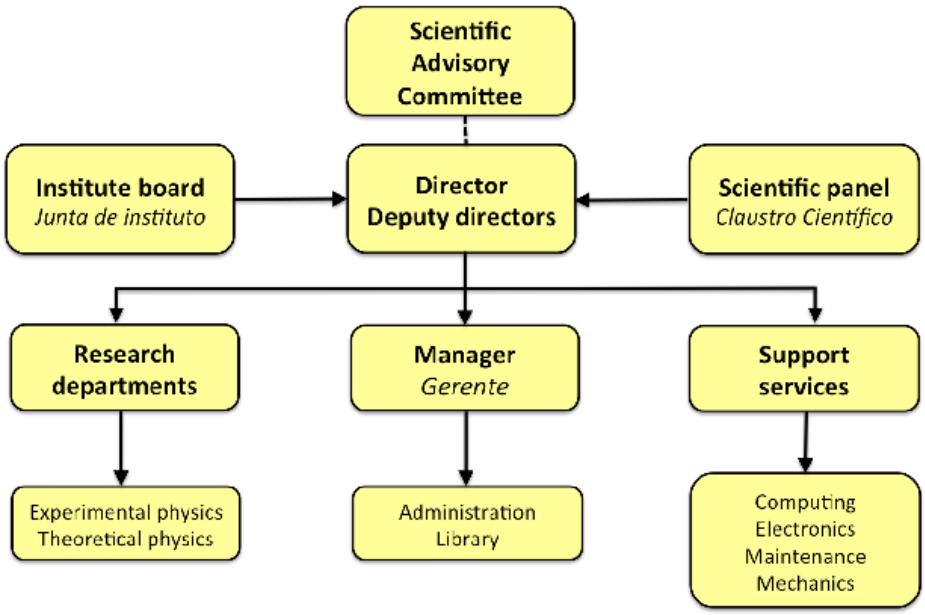
1 An excellent review article about the birth of experimental nuclear and particle physics in Spain, written by Agustín Ceba, Víctor Navarro y Jorge Velasco, was published in Revista Española de Física 25-2 (2011): http://revistadefisica.es/index.php/ref/article/view/1274

1. STRUCTURE AND ORGANIZATION

ORGANIZATION, SCIENTIFIC DEPARTMENTS AND SUPPORT UNITS

GOVERNING BOARD

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



Members of the International Scientific Advisory Committee:
Gustavo Branco (CFTP, IST, Univ. Lisbon), William Gelletly (Univ. Surrey), F. Halzen (Univ. Wisconsin), Cecilia Jarlskog (Univ. Lund), Peter Jenni (CERN, Albert-Ludwigs-Univ. Freiburg), Antonio Masiero (Univ. Padua), Tatsuya Nakada (EPFL 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), Germán Rodrigo García (Theoretical Physics)
Personnel representatives: Rosa Carrasco de Fez (non-doctoral members), Susana Cabrera Urbán (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, T2K and DUNE experiments.

In Nuclear Physics, we participate in the AGATA project, as well as in several international collaborations: NUSTAR/FAIR (Germany), ISOLDE (CERN), n_TOF (CERN) and BRIKEN (Japan).

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 the development of a high gradient radio-frequency facility for future colliders and medical applications.

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. Apart from ATLAS and LCC, IFIC researchers of this research line are also members of the LHCb, MoEDAL and Belle II collaborations.

SCIENTIFIC DEPARTMENTS

EXPERIMENTAL PHYSICS

Several groups of our institute participate in many of the most relevant experiments in Particle, Astroparticle and Nuclear Physics, as well as in the applications of these disciplines to other fields of Science and Technology. For instance, IFIC members are part of the international collaborations that manage the ATLAS, LHCb and MoEDAL detectors of the Large Hadron Col-

IFIC participated in the construction of several systems of ATLAS detector of the LHC, and 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 worldwide 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.). 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 space-time 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 einsteinian 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 within 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 19 people, belonging to CSIC and UVEG, manage the daily 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 the processing of 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 of new technologies, such as computer networks (FAENET), the web in the past and the GRID at present.

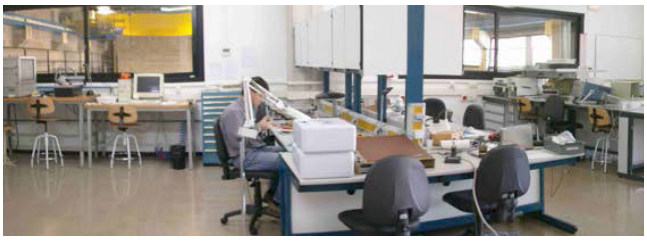
The computing centre houses several clusters with a total of 300 computer nodes (around 3000 cores) and 2.2 PB of disk storage, some of them using GRID technologies. More than 30 servers are constantly operating to provide email and web services, storage, resource management, user access, monitoring services, printing, databases, etc. The computing centre premises are located in a 150 m^2 hall with air conditioning (240 KW), technical floor and uninterruptible power supply (250 KVA).

Computer centre.

Electronics

This Unit provides service to any IFIC research project with demands in 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 2300 books both in topics of general interest and specific to our research. Its staff is responsible for managing the access to electronic journals and the book loans. The latter can be requested online, except for a selection of titles that are for on-site consultation only. IFIC members may request the purchase of books through an online application. The final decision is competence of the Library Commission.

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

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 versatile workshop of about 200 m^2 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.

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* Doctores vinculados

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Martínez Roig, Marcos
Maturana Avila, Ivania Daniela
Melini, Davide
Melis, Aurora
Menchón Pérez, Cintia Cecilia
Miralles Aznar, Víctor
Monsalvez Pozo, Kevin
Muñoz Albaladejo, Enrique
Muñoz Albornoz, Víctor Manuel
Murgui Galvez, Clara
Negre Simó, Andreu
Palmeiro Pazos, Brais
Peñuelas Martínez, Ana
Pereira Pires Pavao, Rafael
Perelló Roselló, Martín
Pla García, Silvia
Plenter, Judith
Ramírez Rodríguez, Héctor Ariel
Ramírez Uribe, Norma Selomit
Reig López, Mario
Remón Alepuz, Clara
Rodrigues Debastiani, Vinicius
Rodríguez Bosca, Sergi
Romero López, Fernando
Romo Luque, Carmen
Ronca, Jonathan
Rosario Bonastre, Iván
Roser Martínez, Jorge
Ruiz Vidal, Joan
Sánchez Sebastián, Victoria
Saúl Sala, David Eduardo
Sayago Galvan, Iván
Segarra Tamarit, Alejandro
Sobczyk, Joanna
Ternes, Christoph Andreas
Terol Calvo, Jorge
Tolosa Delgado, Álvaro
Usón Andrés, Alberto
Villanueva Domingo, Pablo
Vnuchenko, Anna

ENGINEERS & TECHNICIANS

Álvarez Puerta, Vicente
Blanch Gutiérrez, César
Bueno Fernández, Ana
Calvo Díaz-Aldagalán, David
Carrió Argos, Fernando
Esteban Martínez, Alfredo
Guerrero Menkara, Adriana
Ladarescu Palivan, Ion
López Macia, Pedro Félix
Madaffari, Daniele
Oliver Guillén, José Francisco
Platero Montagut, Vicente
Real Máñez, Diego
Senra Moledo, César
Solaz Contell, Carles
Tortajada Velert, Salvador

ELECTRONICS

Bernabeu Verdú, José
Cámara García, María Teresa
Gómez Ferrer, Julio José
González González, Francisco
López Redondo, Manuel
Marco Hernández, Ricardo
Mazorra de Cos, José
Nácher Arándiga, Jorge
Querol Segura, Marc
Soldevila Serrano, Urmila
Valero Biot, José Alberto

COMPUTING

Carrión Burguete, Jose Vicente
Fernández Casaní, Álvaro
García Montoro, Carlos
Martínez Saez, Carlos
Nadal Durà, Joaquin
Navajas Alba, Ximo
Sánchez Martínez, Fco. Javier

ADMINISTRATION

Aguilar Argilés, Teresa
Andreu García, Mª Teresa
Boix Caballero, Pilar
Catalá Ripoll, Juana
Claramunt Pedrón, Luis Miguel
Fandos Lario, Ana María
Ferrer Lázaro, José Manuel
Fillol Ricart, Amparo
García González, Soledad
Gimeno Almela, Mª Jose
González Romeu, María Teresa
Gracia Vidal, María José
Hernando Recuero, María Luisa
Montesinos Reig, Leonor
Pastor Clérigues, Elena
Pérez García, José
Serrano Pérez, Carmen
Sifre García, Francisca
Taberner Ubeda, Mª Eva

OUTREACH

Aparici Benages, Alberto
García Cano, Isidoro

LIBRARY

Salgado López, Óscar

MECHANICS

Cárcel García, Sara
Civera Navarrete, José Vicente
Jordán Coronado, José Luis
León Lara, Pablo
Platero García, Adrián
Tchogna Davis, Daniel
Vidal Bueno, Guillem Ramón
Villarejo Bermúdez, Miguel Ángel

MAINTENANCE

Ayuste Coronado, Pablo
Carrasco de Fez, Rosa
Fuentes Castilla, Angel
Gallego Baviera, Francisco Javier
Tadeo Ortiz, Héctor

280 Total personnel in 2018

211 Scientific personnel

24% Women in scientific personnel

2. RESEARCH ACTIVITIES

EXPERIMENTAL PHYSICS

ACCELERATOR-BASED EXPERIMENTAL HIGH ENERGY PHYSICS

This research line comprises the activities in the LHC experiments ATLAS, LHCb and MoEDAL (physics analysis, detector operation, and upgrade), plus the ones related with the future colliders, accelerator and detector technology.

LHC EXPERIMENTS

ATLAS experiment

The LHC reached another major milestone in 2018 with the completion of Run 2. More than 140 fb^{-1} of good quality data were collected by ATLAS. The group research activities are dedicated to the development of the ATLAS physics program and the operations and upgrade of the ATLAS experiment. We also play a leading role by occupying management positions in the collaboration.

ATLAS: operations

During 2018, the instantaneous luminosity delivered by the LHC at an energy in the center of mass of 13 TeV has reached the record level of 2.10×10^{34} $cm^{-2}s^{-1}$ and. The 2018 proton-proton data-taking period of the LHC spanned about 7 months and more than 63 fb^{-1} were recorded by ATLAS.

IFIC researchers are responsible for the back-end electronics of the hadronic calorimeter (TileCal) and thanks to our effort it achieved a 100% efficiency.

The trigger is a crucial part of the ATLAS experiment since this is the first selection applied to physics analyses. IFIC members are leading the ATLAS Menu Coordination Group, responsible of maximizing the event acceptance of physics analyses, while meeting the online constraints in terms of rates and CPU consumption. During 2018, several different sets of selection criteria have been generated and deployed for each of the filling schemes of the LHC. Each new set requires an exhaustive rock-solid validation procedure before its deployment online. This work ensured an efficient data acquisition and a high data quality performance for ATLAS for all the year.

Our group is also responsible for the Inner Detector alignment. This provides the detailed geometry of the ATLAS tracker and follows its changes in time. The alignment of the detector is performed every 20 minutes and the constants are validated with an automated process that runs smoothly for 100% of the runs. An assessment of the Inner Detector length scale with the J/ψ, Υ and Z decays to $\mu^+\mu^-$ pointed to a momentum bias of -0.5×10^{-3} that is independent of the pT of the particle.

Our group also participates in the Tracking Validation and Physics Modelling groups which helps to monitor the code developments and its impact on the ATLAS tracking. This group also leads the in-situ calibration of large-radius jets in ATLAS and published the first overview paper on these techniques.

The IFIC Tier-2 has the "nucleus" status in ATLAS, thanks to our high reliability over the last 10 years. IFIC is becoming more relevant for the ATLAS computing. In the LHC Run2 period (2015-2018), more than 196 million events were processed, 22 million jobs were completed, 46 million files were produced and 2 PB of data were stored at IFIC Tier-2 resources.

IFIC is responsible for the back-end electronics of TileCal that achieved 100% efficiency

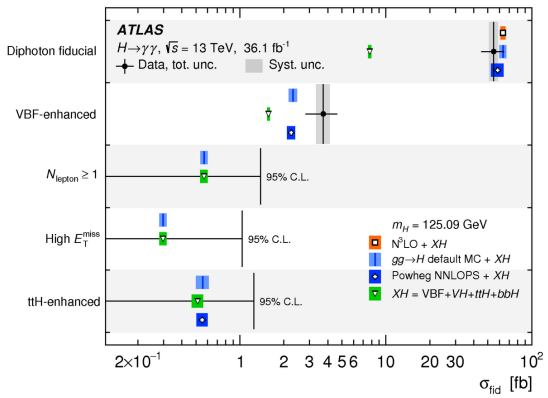
During 2018, our group has been working on addressing the new scenarios for future ATLAS computing challenges: Run 3 and in the High Luminosity era of LHC. These are cloud computing, use of external HPC resources, Grid resources, data management, data leakes, machine learning, increase network bandwidth with RedIris, etc.

ATLAS: precision measurements

IFIC researchers greatly contributed to the analysis of the data delivered by the proton-proton collisions of the LHC. Among several topics of scientific interest, IFIC is involved in the study of the Higgs sector. In 2018, IFIC contributed to the measurement of the Higgs boson production properties in the final states with tau leptons and photons, in particular results based on the new methodology to measure the Higgs boson cross-section, called Simplified Template Cross-Section (STXS).

Regarding top quark physics, one of our group members was in charge of the LHC combinations of all single top related analyses, as representative of the ATLAS Collaboration. Work progressed towards the first publication of the combination of the Run 1 single top cross section measurements performed in ATLAS and CMS. Our group was also paving the way for a precision measurement of the top quark pole mass with a total uncertainty of just over 1 GeV.

Within ATLAS, the IFIC group has also started the analysis of the first Run 2 data to probe with higher precision the Wtb vertex in the t-channel single top quark production. The measurements are now being performed at the particle level in a fiducial region to reduce the model dependence. With the increase of Run 2 data statistics, our group is also exploring the associated production of a top quark with a Higgs boson. This channel is predicted by the Standard Model but is also sensitive to new physics effects.



Measured cross sections or cross-section upper limits in the different fiducial regions.

ATLAS: new physics searches

The discovery of a Higgs boson opened the possibility that new massive particles couple strongly with the Higgs sector and could be detected by their decay to two Higgs bosons or by measuring an anomalous di-Higgs boson production rate.

IFIC had a prominent role in the search for New Physics in the two Higgs bosons final state where the Higgs bosons decay to two b-quarks and two photons, respectively. This final state is particularly important for its excellent mass resolution and the low-level of background. Unfortunately, the search didn't find evidence of new heavy particle decays. Therefore, production limits were set.

Direct searches for new physics phenomena involving top quarks in the final state are also highly motivated due to the large top quark mass. Our group has contributed to the first search in ATLAS for events with one top quark and large missing transverse momentum using data collected at 13 TeV center-of-mass energy during 2015-2016, being in charge of the lepton channel analysis and of the combination with the hadronic channel. The results obtained are interpreted in the context of generic models for dark matter production and for the single production of a vector-like top quark.

Our group is involved in the ATLAS searches for supersymmetric (SUSY) particles, with emphasis on leptonic signatures and searches for R-parity violating models. In 2018, we revisited the channel with two strongly-produced electrons or muons using 36 fb^{-1} of pp collisions. The analysis not only targets Z bosons decaying into two leptons, but also kinematic endpoints ("edges") resulting from SUSY particle decays, going beyond the conventional search for search of excesses in distribution tails. We are also involved in searches for light higgsinos characterised by compressed spectra and in the fully hadronic channel, which provides the stronger sensitivity for many SUSY scenarios, such as the Non-Universal Higgs Mass model (NUHM2).

IFIC contributed to the first search in ATLAS for events with one top quark and large missing transverse momentum using data collected at 13 TeV

ATLAS: upgrade

The upgrade of the LHC towards its High-Luminosity phase (HL-LHC) is planned to start collecting data in 2026. It will be operational for more than ten years, during which time ATLAS aims to accumulate a data set of 4 ab^{-1}.

IFIC is responsible for the Upgrade of the TileCal back-end electronics of the HL-LHC. The TilePreProcessor (TilePPR) is the core of the TileCal back-end electronics and is fully designed and built by our group. The TilePPR prototypes provide a full digitization of the calorimeter data and transmission at 40 MHz rate, with an accept rate above 1 MHz. The TilePPR demonstrator prototypes have been extensively tested and certified for operations during test-beam in June and September 2018.

Concerning the upgrade of the tracking system, IFIC is one of the leading institutes of the new ITk (holding the role of deputy project leader), which is an all-silicon solution that will replace the current ATLAS Inner Detector. We are in charge of the design of the end-cap support structures for the ITk strips. The behaviour of these structures concerning the mechanical and thermal load has been studied with a Finite Element Analysis. We have also designed the rails for the services of the petals of the ITk strips and built a mock-up to better understand the connection of the petals to their services and the routing of the cables and pipes to the patch panel. Thanks to our cooperation with the Spanish industry, a national company will build the mechanical part of 400 petals on carbon fibre and with an inner routing of the cooling pipes. Our group also designed the bus tapes for the ITk-strips end-cap sensors. Finally, we also lead the ITk-strips beam tests and the studies of the beam loss destructive tests on this type of modules.

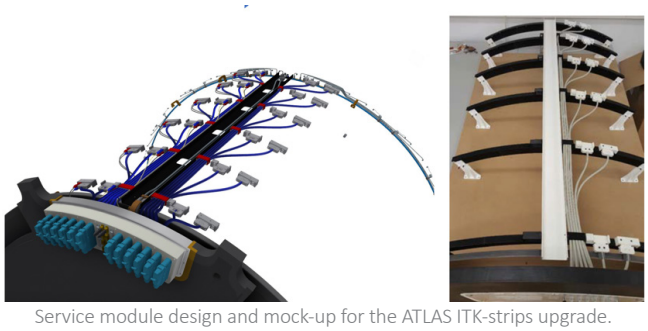
During 2018, the IFIC researchers have been involved in the preparation of the final version of the Memorandum of Understanding for the ATLAS Upgrade for the HL-LHC.

LHCb experiment

LHCb team has an intense program of study of B decay anomalies and Lepton Flavour Universality. These studies are making use of the Run 2 data.

On the other hand, our group is also working towards the upgrade of the LHCb tracker for the HL-LHC. In particular, we are contributing to the readout chip of the scintillating fibres tracking system. The fibres have a diameter of 250 µm and cover an area of 5m x 6m. The readout of the detector is performed by the low-Power ASIC for the sCIntillating FIbres traCker (PACIFIC), a chip specifically designed for this purpose. PACIFIC is a 64-channel ASIC implemented in 130 nm CMOS technology. The electronics and the software were successfully tested using a 221 MeV proton test beam.

The 89th LHCb week was held in Valencia in September 2018.



Service module design and mock-up for the ATLAS ITK-strips upgrade.

IFIC is working on the upgrade of the LHCb tracker for the HL-LHC contributing to the readout chip of the scintillating fibres tracking system

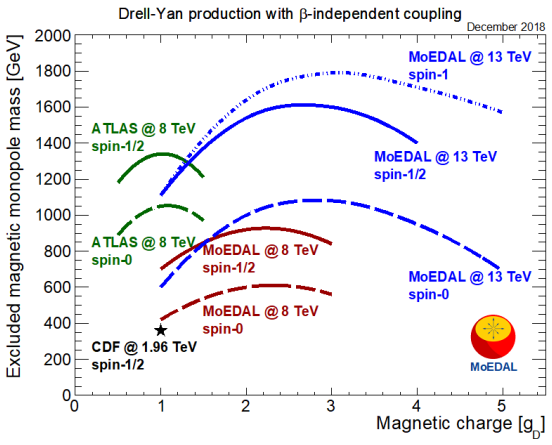
MoEDAL experiment

The IFIC team is the only Spanish participation in MoEDAL. This experiment is designed to search for manifestations of new physics through highly ionising particles produced at the LHC. Its primary motivation is the quest for magnetic monopoles, yet the experiment is also sensitive to any massive, (meta-)stable, slow-moving particles with single or multiple electric charges arising in many scenarios of physics beyond the Standard Model. MoEDAL uses a (mostly) passive detector, featuring aluminium Magnetic Monopole Trapping detector volumes (MMTs), plastic Nuclear Track Detectors (NTDs) and TimePix detectors.

We are involved in the simulation of the detector, and also in the development and testing of key theoretical scenarios, such as monopole production via photon fusion and SUSY models. IFIC plays a leading role in the MoEDAL management by holding the Chair of the Collaboration Board.

The updated MoEDAL physics results were based on MMTs exposed to pp collisions during 2015-2016. The MMTs were analysed by a SQUID device showing no evidence for trapped monopoles, allowing MoEDAL to place mass limits for spin-1 monopoles for the first time at the LHC. The world-best limits for monopoles of high magnetic charges, up to $5g_D$ were set.

In parallel, the IFIC group explored the phenomenological aspects of monopole production via photon fusion, which is expected to be much more abundant at LHC than the Drell-Yan process considered so far. The cross-section calculations were implemented in event generation tools for monopoles of spin 0, ½ and 1, paving the way for future searches of monopoles produced via photon fusion in MoEDAL and ATLAS.



Magnetic monopole mass limits from CDF, ATLAS and MoEDAL searches as a function of magnetic charge for various spins, assuming a Drell-Yan pair-production mechanism.

FUTURE COLLIDERS

Our group is also involved in the development of a "Higgs factory" that could be a high-energy linear electron-positron linear collider. Possible options include the International Linear Collider (ILC) project to be hosted in Japan, or the Compact Linear Collider (CLIC) project led by CERN.

In 2018 both projects have performed a large number of projections of the scientific potential to inform the update of the European strategy for particle physics. IFIC has contributed several publications on the opportunities in top quark physics at linear electron-positron colliders, that can reach sufficient energy to produce top quark pairs, with a complete analysis in effective field theory of the projections for measurements of top quark electro-weak interactions.

The Belle II experiment at KEK in Japan started operation in 2018. The vertex detector based on DEPFET active pixel sensors was assembled in Germany during this year, with contributions from IFIC in testing equipment and personnel. We also organized the international forum on tracking detector mechanics in Valencia in June 2018.

The group is involved in accelerator R&D in close collaboration with CERN, preparing a facility for the characterization and development of high-gradient radio-frequency cavities, a key technology for future colliders.

DETECTOR R&D

Our group is also involved in the RD50 Collaboration, the aim of which is to develop radiation hard semiconductor devices for very high luminosity colliders. Our activities focus in the development of a data acquisition system of the Depleted Monolithic Active Sensors in collaboration with the U. of Liverpool (U.K.) and HEPHY Vienna (Austria).

The Belle II experiment at KEK in Japan started operation in 2018. Its vertex detector had contributions from IFIC in testing and personnel

Selected Publications

ATLAS Collaboration, *Search for Higgs boson pair production in the γγbb final state with 13 TeV pp collision data collected by the ATLAS experiment*, JHEP 11 (2018) 040 – 42pp, DOI:10.1007/JHEP11(2018)040 [arXiv:1807.04873]

ATLAS Collaboration, *Search for large missing transverse momentum in association with one top-quark in proton-proton collisions at √s=13 TeV with the ATLAS detector*, JHEP 05 (2019) 41. DOI 10.1007/JHEP05(2019)041 [arXiv:1812.09743]

ATLAS Collaboration, *In situ calibration of large-R jet energy and mass in 13 TeV proton-proton collisions with the ATLAS detector*, Eur. Phys. J. C 79 (2019) 135. DOI:10.1140/epjc/s10052-019-6632-8 [arXiv:1807.09477]

ATLAS Collaboration, *Search for flavor-changing neutral currents in top quark decays t→Hc and t→Hu in multilepton final states in proton-proton collisions at √s=13 TeV with the ATLAS detector*, Phys. Rev. D 98 (2018) 032002, DOI:10.1103/PhysRevD.98.032002, [arXiv:1805.03483]

MoEDAL Collaboration (Acharya, B. et al), *Search for magnetic monopoles with the MoEDAL forward trapping detector in 2.11 fb-1 of 13 TeV proton-proton collisions at the LHC*, Phys. Lett. B 782, 510-516 (2018), DOI: 10.1016/j.physletb.2018.05.069 [arXiv:1712.09849]

Selected Conference Talks

L. Fiorini, *Measurements and searches of Higgs boson decays to two fermions*, 26th International Conference on Supersymmetry and Unification of Fundamental Interactions (SUSY2018), July 2018, Barcelona, Spain.

S. Gonzalez de la Hoz, *Spanish ATLAS Tier-1 & Tier-2 perspective on computing over the next years*, 23th International Conference on Computing in High Energy and Nuclear Physics (CHEP18). 9-13 July 2018. Sofia, Bulgaria.

A. Santra for the MoEDAL and LHCf Collaborations, *A Brief Discussion on the Performance of the MoEDAL and the LHCf Experiments*, 6th Large Hadron Collider Physics Conference (LHCP 2018), June 2018, Bologna, Italy.

M. Vos, *Measurements of top properties and top mass*, 6th Large Hadron Collider Physics conference. 4-9, June 2018. Bolgna, Italy.

Arantxa Ruiz, *Vector boson(s) and jet production in ATLAS*, QCD@LHC 2018, 27th - 31st August 2018, Dresden, Germany

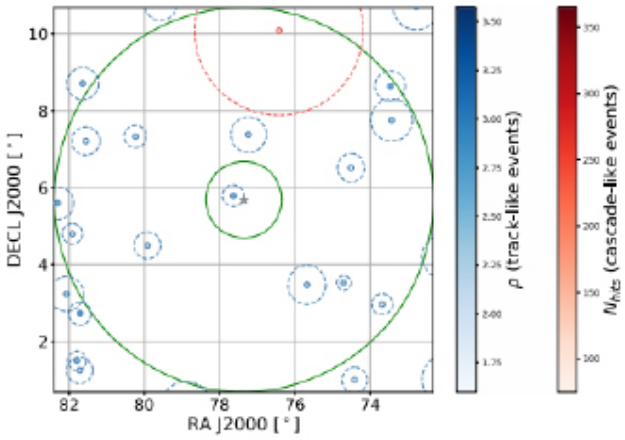
EXPERIMENTAL ASTROPARTICLE PHYSICS

Neutrino astronomy has enjoyed several important steps forward during 2018. On the one hand, the detection of the first neutrino point source was cover in the Science magazine. This discovery is based on the alert sent in 2017 by the IceCube Collaboration to several observatories, marking the entrance of neutrinos in the multi-messenger area. In the Mediterranean, the big news come from the progress on the installation of KM3NeT, European flagship of neutrino astronomy in the near future. Our group has actively contributed on these and related topics.

ANTARES

The data taking by ANTARES has continued during this year. The interest of keeping ANTARES alive while advancing in the construction of KM3NeT has been clearly supported by an important milestone in 2018: the neutrino astronomy field has joined the new multi-messenger era with the discovery of the first neutrino cosmic source after the alert sent by IceCube to other detectors (of gamma rays, radio, optical, neutrinos…). A flare coincident with this alert was observed by some of these experiments. This showed the importance of a complete, continuous, multi-messenger coverage of the sky. ANTARES did not observe a significant excess in this directions, but the group at IFC was in charge of analysing the time-integrated sample for this source.

In addition, our group continued improving the limits obtained in the analyses under our responsibility. This includes the search for cosmic point sources and for dark matter. An important novelty in the latter has been in the combined analysis using data of ANTARES and IceCube to look for dark matter in the Galactic Centre.



Distribution of events observed by ANTARES in the direction of the blazar TXS 0506+056, first high-energy cosmic neutrino source observed.

KM3NeT

The construction of KM3NeT, the new step in the field of neutrino astronomy, has continued. Several lines were integrated for their installation in 2019. The engineers of the group of IFIC have made important contributions related to the electronics of KM3NeT. Their main tasks concern the design and test of two key elements of the detector: the Central Logic Boards (CLBs) and the Power Boards (PBs).

On the physics analysis side, our group has contributed in several fronts to the study of the performance of KM3NeT. This includes point sources, dark matter, multi-messenger astronomy, neutrino mass hierarchy, non-standard neutrino interactions and supernova neutrinos.

The ANTARES/KM3NeT group at IFIC has also worked fruitfully together with theory groups at the Institute on several topics (neutrino decay, neutrino oscillations, dark matter).

Our group has also been very active in organizing scientific meetings. We should mention our participation in the organization of the second edition of the Dark Ghost workshop, held in Brussels, and the organization of the HOW 2018 workshop, hosted by IFIC. The former was devoted to the use of neutrino telescopes to search for dark matter and the latter was focused on the potential of KM3NeT for neutrino oscillations.

Left: A KM3NeT line, ready for installation. Right: Poster of the H2020 Workshop organized at IFIC on the potential of KM3NeT for neutrino oscillations.

In 2018, neutrino astronomy field has joined the new multi-messenger era

Selected Publications

ANTARES Collaboration (Albert A. et al.), *All-flavor Search for a Diffuse Flux of Cosmic Neutrinos with Nine Years of ANTARES Data*, ApJL 853, L7 (2018), DOI: 10.3847/2041-8213/aaa4f6, [arXiv:1711.07212]

ANTARES Collaboration (Albert A. et al.), *The Search for Neutrinos from TXS 0506+056 with the ANTARES Telescope*, Astrophys.J. 863 (2018) no.2, L30, DOI: 10.3847/2041-8213/aad8c0 [arXiv:1807.04309]

ANTARES Collaboration, *The cosmic ray shadow of the Moon observed with the ANTARES neutrino telescope*, Eur.Phys.J. C78 (2018) no.12, 1006, DOI: 10.1140/epjc/s10052-018-6451-3, [arxiv:1807.11815]

KM3NeT Collboration (Aiello S. et al.), *Characterisation of the Hamamatsu photomultipliers for the KM3NeT Neutrino Telescope*, JINST 13 (2018) no.05, P05035, DOI: 10.1088/1748-0221/13/05/P05035

ANTARES and IceCube Collaborations (Albert A. et al.), *Joint Constraints on Galactic Diffuse Neutrino Emission from the ANTARES and IceCube Neutrino Telescopes* Astrophys.J. 868 (2018) no.2, L20, DOI: 10.3847/2041-8213/aaeecf, [arXiv:1808.03531]

Selected Conference Talks

G. Illuminati, *Latest Results from the ANTARES Neutrino Telescope and Prospects for KM3NeT,* Les Rencontres de Physique de la Vallée d'Aoesta 2018, February 2018, La Thuile (France).

J. D. Zornoza, *Particle Physics with the KM3NeT detector*, SUSY 2018, July 2018, Barcelona (Spain)

J. D. Zornoza, *Summary of RICAP 2018 (rapporteur talk)*, RICAP 2018, September 2018, Rome (Italy)

S. R. Gozzini, *Combined search for dark matter from the Galactic Centre with the ANTARES and IceCube neutrino telescopes*, VLVnT 2018, October 2018, Dubna (Russia)

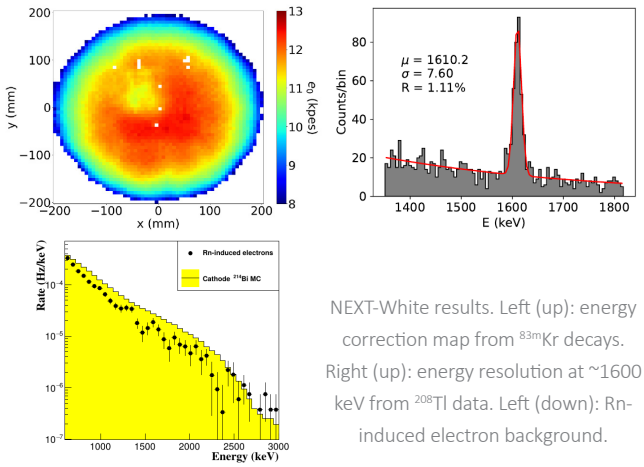
M. Colomer, *Core-Collapse Supernova neutrino detection prospects with the KM3NeT neutrino telescopes*, October 2018, VLVnT Dubna (Russia)

EXPERIMENTAL NEUTRINO PHYSICS

During 2018, the experimental Neutrino Physics group has continued playing a major role in NEXT, T2K and DUNE/ProtoDUNE. These experiments address the most relevant open questions in the physics of massive neutrinos.

NEXT: First Results of the NEXT-White Detector at the LSC

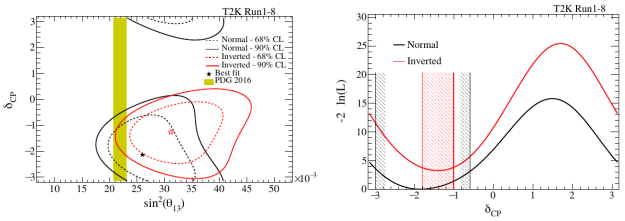
NEXT aims at the observation of the neutrino-less double beta decay, using a gas-xenon high-pressure TPC. This technology offers excellent energy resolution, topology-based background rejection capabilities, and feasible scalability. The first large-scale demonstrator, NEXT-White, has been operated in the Laboratorio Subterráneo de Canfranc (LSC) since late 2016, mainly by the IFIC engineers and shifters. The first calibration and physics results from this detector have been published in 2018. On the calibration side, ^{83m}Kr decays in the gas active volume have been used to measure and monitor the electron lifetime, as well as the geometrical dependence of the light collection. In addition, the energy resolution at high energies has been measured using ^{137}Cs and ^{208}Tl sources, yielding an extrapolation to 2.458 MeV (Q-value of ^{136}Xe) of ~1% FWHM. Concerning the physics results, the data from a first low-background run have been analysed to derive the internal radon-induced background, which is found to be non-dominant in the double beta analyses. All these analyses have been led by members of the IFIC group. Between Summer 2018 and January 2019, a long-term low-background data campaign was carried out, operating NEXT-White with ^{136}Xe-depleted xenon. In parallel, a new R&D detector, NEXT-DEMO++, has been built at IFIC with the goal of exploring different gas mixtures and technological solutions.



NEXT-White results. Left (up): energy correction map from ^{83m}Kr decays. Right (up): energy resolution at ~1600 keV from ^{208}Tl data. Left (down): Rn-induced electron background.

T2K: Towards the Measurement of the CP-violation in the Leptonic Sector

T2K offers the best sensitivity to the leptonic CP-violation (δ_{CP}) among the ongoing neutrino oscillation experiments. Beyond providing precise measurements of the neutrino mixing and the mass-squared difference in the so-called atmospheric sector, T2K has also delivered the first hints on δ_{CP}. The IFIC group contributes to the final oscillation analysis at different levels. Apart from being convenors of various working groups in the near detector (ND280), the IFIC members are deeply involved in several software, calibration and analysis tasks, mainly focused on the measurement of the unoscillated neutrino flux. In 2018, T2K has updated its results with a larger statistical sample, considering both neutrinos and antineutrino interactions. In addition, improved neutrino interaction models and reconstruction algorithms have been used. A global oscillation analysis, considering also a constraint from reactor experiments, yields the exclusion of the CP conservation (δ_{CP}=0,π) at a 2σ level (95.45% CL).



T2K results on the mixing angle θ_{13} and the CP-violation phase δ_{CP}, released in 2018.

DUNE/ProtoDUNE: The Next-Generation Neutrino Facility

The Deep Underground Neutrino Experiment (DUNE), based on the Liquid Argon Time Projection Chamber (TPC) technology, will be far superior to the current generation of experiments (T2K and NOvA) in terms of sensitivity to the leptonic CP violating phase and the neutrino mass hierarchy. 2018 has been a crucial year for DUNE, with the operation of the first of its prototypes, ProtoDUNE-SP, at CERN. In collaboration with IFIC's Electronics and Mechanics Support Units, the group has built a device to measure with a precision of 3 mK the temperature gradient across the 8 m height of the liquid argon volume. Having ProtoDUNE-SP the largest cryostat ever constructed for a TPC, this system is crucial for both the correct functioning of the TPC and for physics. Four million events at different beam energies were collected from September to October 2018.

IFIC has participated heavily in the data analysis with the selection of muon, kaon and proton stopping samples, which will help in understanding the detector performance. The group has also contributed to the development of the software tools for the experiment, including the analysis framework. IFIC also participates in the design of the DUNE photon detection system and coordinates its physics working group. This system is crucial for non-beam related physics as proton decay or supernova burst detection. Understanding the system's performance and optimising its design to maximise the physics reach has been a priority during 2018.

Above, the first track at nominal electric field observed in ProtoDUNE-SP.
Down: The vertical temperature profiler for ProtoDUNE-SP deployed at IFIC.

IFIC has built a device to measure the temperature of ProtoDUNE-SP with a precision of 3 mK

Selected publications

NEXT Collaboration (Renner, J. et al), *Initial results on energy resolution of the NEXT-White detector*, JINST 13 (2018) no.10, P10020, DOI: 10.1088/1748-0221/13/10/P10020 [arXiv:1808.01804].

T2K Collaboration (Abe, K. et al), *Search for CP Violation in Neutrino and Antineutrino Oscillations by the T2K Experiment with 2.2x1021 Protons on Target*, Phys. Rev. Lett. 121 (2018) no.17, DOI: 10.1103/PhysRevLett.121.171802 [arXiv:1807.07891].

NEXT Collaboration (Martinez-Lerma, G. et al), *Calibration of the NEXT-White detector using 83mKr decays*, JINST 13 (2018) no.10, P10014, DOI: 10.1088/1748-0221/13/10/P10014 [arXiv:1804.01780].

NEXT Collaboration (Novella, P. et al), *Measurement of the radon-induced backgrounds in the NEXT double beta decay experiment*, JHEP 1810 (2018) 112, DOI: 10.1007/JHEP10(2018)112 [arXiv:1804.00471].

T2K Collaboration (Abe, K. et al), *Characterization of nuclear effects in muon-neutrino scattering on hydrocarbon with a measurement of final-state kinematics and correlations in charged-current pionless interactions at T2K*, Phys. Rev. D98 (2018) no.3, 032003, DOI: 10.1103/PhysRevD.98.032003 [arXiv:1802.05078].

Selected Conference Talks

M. Sorel, *Xenon TPCs for Double Beta Decay Searches*, NuPhys 2018, December 2018, London, U.K.

A. Izmaylov, *Recent results from T2K experiment and future prospects*, H2020 Oscillation Physics Workshop, November 2018, Valencia, Spain.

P. Fernández, *Recent results from long baseline neutrino experiments*, The 15th International Workshop on Tau Lepton Physics, Amsterdam, Holland. September 2018, Amsterdam, Holland.

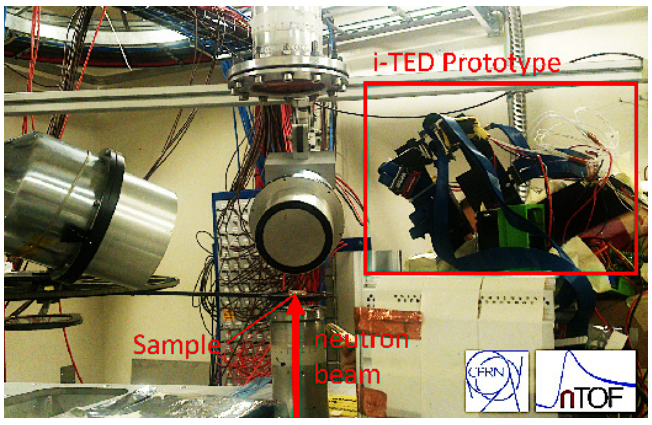
A.Cervera, *Status of DUNE*, International Symposium on Neutrino Frontiers, July 2018, Quy Nhon, Vietnam.

M. Sorel, *Perspectives for double electron capture searches in the NEXT experiment*, Resonant Atom Majorana Mixing Workshop, Jun 2018, Heidelberg, Germany.

NUCLEAR PHYSICS

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

The research of the **Gamma and Neutron Spectroscopy Group** covers aspects of nuclear structure, astrophysics and applications. Some of the most important results of the group this year are related to the continuous development of instrumentation, which is required to support the experimental activities carried out by the group in state-of-the-art installations. For example in the publication V. Guadilla et al. in Nuclear Instruments and Methods in Physics Research A (NIM A 910 (2018) 79) the characterization of the total absorption spectrometer DTAS developed for the DESPEC experiment at FAIR is presented. This spectrometer is composed of up to 18 NaI(Tl) modules and because of its versatility it can be used both at ISOL and fragmentation facilities of new generation. The article presents the performance of the detector, some critical specific features like the photomultiplier-gain stabilization system, and the treatment of a series of spectrum distortions and backgrounds. All these lead to a better control of the spectrometer response and a more robust data analysis. Special attention has also been paid to the characterization of the interaction of neutrons with the spectrometer, since they constitute a source of contamination in studies of β-delayed neutron emitting nuclei. The DTAS detector has been already employed at the IGISOL IV facility at the University of Jyväskylä in experiments related to the study of beta decays relevant for neutrino physics.

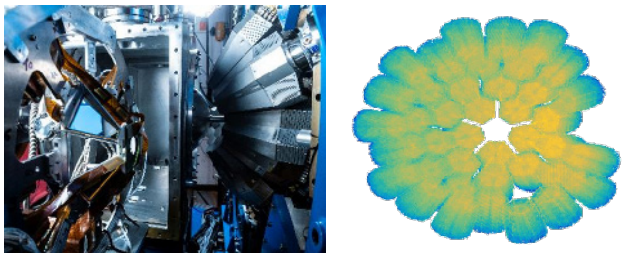


i-TED commissioning at CERN n_TOF.

In 2018 the first tests with i-TED using the white neutron beam at CERN n_TOF were carried out. i-TED is a novel Compton detector developed in the framework of the HYMNS ERC project, aimed at enhanced detection sensitivity for astrophysical nucleosynthesis reactions induced by neutrons. i-TED is based on large monolithic LaCl3(Ce) crystals coupled to pixelated silicon photosensors, thereby reducing neutron backgrounds and yielding a high gamma-ray efficiency, energy- and angular-resolution. The first astrophysics experiments with a full array of four i-TED modules are planned for 2021-2022 at CERN n_TOF. Also during this year, the n_TOF Collaboration published its results on the ^{7}Be(n,p)^{7}Li reaction study related to the yet unsolved cosmological lithium problem (L. Damone et al., Phys. Rev. Lett 121(2018) 042701). This measurement covered for the first time the energy range of relevance for big-bang nucleosynthesis. In the framework of the R+D+I project with ENRESA, a portable gamma-vision system has been developed to assist in the decommissioning of nuclear power plants. GUALI (Gamma-Unit Advanced Location Imager) (Caballero et al. Journal of Instrumentation 13-03, (2018) P03016) has been incorporated into the characterization and classification protocol of the José Cabrera power plant (Guadalajara).

A portable gamma-vision system called GUALI has been developed to assist in the decommissioning of nuclear power plants

On the other hand, the AGATA group has performed the AGATA-NEDA-DIAMANT experimental campaign at GANIL, focused on the research of the nuclear structure in the vicinity of the neutron-proton symmetry line (N=Z) in the Segre chart. As reported in previous annual reports, the neutron detector array NEDA (complementary trigger detector for AGATA), has been partially build at IFIC. The 2018 campaign has been the first experimental activity of NEDA coupled with AGATA and the performance figures are excellent, providing about 30% of neutron detection efficiency. The experiments performed with the setup were: E699 "Isospin Symmetry Breaking A=63", E731 "^{71}Kr-^{71}Br – Isospin Symmetry Breaking", E703 "^{102},^{103}Sn excited levels", E725 "Search for isoscalar pairing in the N=Z nucleus ^{88}Ru" and E730 "Octupole – Quadrupole correlation in ^{112}Xe". The later one is being analysed at IFIC.



The AGATA-MUGAST setup and the hit mapping for AGATA with 41 position-sensitive encapsulated detectors

The enlargement of the AGATA setup to 41 encapsulated detectors and the installation and commissioning of the MUGAST (TRACE) complementary detector, at GANIL, to be used in the 2019 campaign with SPIRAL1 radioactive ion beams, have also been completed during 2018.

Regarding the instrumental developments, two initiatives were carried out in 2018 in the framework of AGATA. The first one, performed in the context of the pre-processing electronics, consisted in the development of the IDM electronic board prototype, in charge of concentrating 40 low rate inputs, using only 10 transceivers in the FPGA, through a time division multiplexing technique. The second one , performed in the context of the ENSAR2 PSeGE Joint Research Initiative, aims to find a technology to produce coaxial p-type position sensitive Ge detectors, by segmentation of the external n-contact.

The 2018 campaign was the first experimental activity of NEDA coupled with AGATA, and the performance was excellent

Selected publications

V. Guadilla et al., *Characterization and performance of the DTAS detector*, Nuclear Inst. and Methods in Physics Research, A 910, 79-89 (2018)

A. Algora, B. Rubio, J. L. Tain, *Total Absorption Spectroscopy*, Nuclear Physics News 28 12-17 (2018)

L. Damone et al. *^{7}Be(n,p)^{7}Li Reaction and the Cosmological Lithium Problem: Measurement of the Cross Section in a Wide Energy Range at n_TOF at CERN*, Phys. Rev. Lett., 121, 042701 (2018)

L. Caballero et al., *Gamma-ray imaging system for real-time measurements in nuclear waste characterization,* Journal of Instrumentation, Vol.13-03, pp. P03016 (2018)

C. Delafosse, et al., *Pseudospin Symmetry and Microscopic Origin of Shape Coexistence in the Ni-78 Region: A Hint from Lifetime Measurements*, Phys. Rev. Lett., 121, 192502 (2018)

A. Boso et al., *Neutron Skin Effects in Mirror Energy Differences: The Case of Mg-23-Na-23*, Phys. Rev. Lett., 121, 032502 (2018)

Selected Conference Talks

J. L. Tain, *Nuclear physics experiments for NSM: capture cross sections, half-lives, neutron emission probabilities*, EMMI Rapid Reaction Task Force: The physics of neutron star mergers at GSI/FAIR, GSI Darmstad, Alemania, 2018

C. Domingo, *Commissioning of the i-TED Demonstrator (i-TED2) at CERN n_TOF EAR2*, CERN INTC-MEETING, CERN – Suiza, 2018

B. Rubio, *Stopped RIB, synergies between NUSTAR and EURISOL-DF facilities*, EURORIB18 Conference, Giens (Francia), 2018

A. Algora, *Testing nuclear models with total absorption spectroscopy measurements*, NUCLEAR PHYSICS IN STELLAR EXPLOSIONS WORKSHOP '18, Debrecen (Hungría), 2018

E. Nacher, *Total Absorption Spectroscopy of N=Z nuclei at ISOLDE: weak-decay rates in the rp-process*, ISOLDE Workshop and Users Meeting 2018, Ginebra (Suiza), 2018

A.Gadea, *The Advanced GAmma Tracking Array (AGATA): Towards 4π*, ZAKOPANE CONFERENCE ON NUCLEAR PHYSICS 2018, Zak-opane (Polonia) 2018

GRID & E-SCIENCE

The research topics of this research line include mainly the Spanish ATLAS Tier-2 goals. It also includes several generic activities devoted to the application of Distributed Computing and to improve the performance of the physics analysis work. During 2018 we have progressed in the main objectives of the project, namely:

– Delivery of the committed resources for 2018 (in April). 2018 has been the second year funded by the project FPA2016-75141-C2-1-R of the Spanish HEP Program. During this year, the Tier-2 IFIC site has provided 26751 HS06[1] and 2244 TB of disk. The efficiency of the whole Tier-2 has been of about 98% (and in particular the IFIC part showed a very good performance).

– On 19th and 20th January the Second IFIC Technical Days and our group presented a talk about the 'GRID Tier-2 of the ATLAS Experiment'

– Taking into account the need of computing power in the near future, our group has started the exploration of conventional ATLAS production and analysis pipelines and workflows on opportunistic resources, mainly HPC infrastructures (MareNostrum, Lusitania, etc). The ATLAS Event Service has been consolidated as the new computing framework to exploit these resources. Has been carried out the commissioning of the new framework by developing several analysis tools to compare the performance of event service with respect to the standard framework. The monitoring tools for the computing troubleshooting in order to facilitate a prompt identification of problems have been applied.

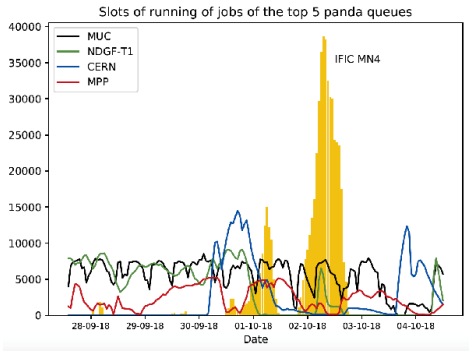
– On the other hand, since the users wish perform their interactive data analysis in the cloud, the SWAN platform is being adapted to the IFIC environment. Currently the IFIC implementation is in a "proof-of-concept" stage so that the service works properly but the full platform setup is still underway.

– Monitoring of Frontier servers: The so-called Frontier servers handle the enormous amounts of queries done by ATLAS jobs to access Conditions data in a parallel and distributed way; thus, optimizing the performance of the Oracle database servers. The Frontier servers are composed by Tomcat servers and Squid servers caching frequently used conditions data. In order to understand the characteristics of the queries which cause occasional overloads on the Frontier servers, a full monitoring system based on the ELK stack (Elasticsearch, Logstash and Kibana) has been established. The whole system treats the information coming from the Frontier servers (currently several million daily queries with peaks in the past of more than 12M each day) in real time. A Kibana dashboard provides access to the most valuable information in a visual way. In addition, an alert system monitors continuously certain parameters and warns experts whenever a performance degrading situation is foreseeable.

– Application of Machine Learning Methods for Physics Analysis in ATLAS: started in 2017, we obtained results for the extraction of ttbar resonances (signal) from SM processes (background) with Extra Trees, Random Forest and Logistic Regression Classifiers using the ML libraries KERAS and Tensorflow with better results with respect to the standard analysis methods.

– Opportunistic usage of HPC: The use of opportunistic resources is needed to accommodate the current requirements and especially for the future HL-LHC. Specifically, computing power of RES (Spanish Supercomputing Network) has been granted: 70 khours in Lusitania. We also had 30k hours of PRACE (Partnership for Advanced Computing in Europe) for MareNostrum as a preparatory access.

CPU time has been consumed successfully in a short period of time and you can see the peak of MN4 leading the ATLAS production when the MN4 resources were launched. This work is a valuable contribution to the ATLAS community, given that it is a subject of study at present, in anticipation of the high CPU requirements during HL-LHC.



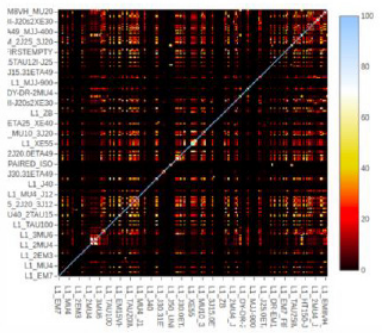
– The ATLAS Event Index Project: We have continued our duties with the ATLAS Event Index Project, where our group is in charge of the data collection and coordinates the data taking. We are exploring new approaches for the future of ATLAS Event Index in order to satisfy the demanding requirement of data generation during Run 3, and to improve its performance, flexibility and ease of use.

1. HS06 is the HEP-wide benchmark for measuring CPU performance.

Trigger Counter: As part of the developments for ATLAS Event Index, we have developed a web service to provide useful information about the trigger at its different levels (L1 and HL) for a set of data on a short time scale. It can process millions of events and billions of triggers in a couple of minutes thanks to our thorough compressed representation of the trigger data and our algorithm based on Hadoop MapReduce. The user can COUNT, LIST and see the OVERLAP of a particular trigger of a given data set. The user can also set additional conditions that the trigger should satisfy when processing the data. Providing this application through a web service eases its use. Interactive plots are provided representing the result of the requests:

– The user can also download a CSV file with the results that can be further analysed with other external tools.

– The raw data that is employed to plot the graphs is also available in JSON format.



The IFIC developers recently added a new feature that allows to get trigger counts and overlapping in short time scale, processing millions of events in around 2 minutes.

On top of that, the IFIC group has continued its role as center of reference and advice in ATLAS computing. The CSIC Cooperation Agreement I-COOP+ (COOPB20247) is its second year ('Launching a platform of GRID Computing in Morocco to meet the new challenges of Physics Research'). The activities have focused in the stay at IFIC of one PhD student of University of Rabat (Souad Batlamous) and a senior physicist working in Medical Physics (Rajaa Sebihi). The PhD student has progressed in her studies about ttbar resonances in ATLAS experiment and the senior physicist has had meetings with physicists of the IFIC Medical Physics group in order to establish scientific collaborations. Both activities are being developed in the framework of GRID Computing.

Selected publications

S. Gonzalez de la Hoz, C. Acosta-Silva, J. Aparisi Pozo, M. Delfino, J. del Peso, A. Fernández, J. Flix, E. FUllana, C. García, J. Lozano, A. Montiel, A. Pacheco, J. Sanchez, J Salt and A.Vedaee on behalf of the ATLAS Collaboration, *Spanish ATLAS Tier-1 & Tier-2 perspective on computing over the next years*, Proceedings of 23th International Conference on Computing in High Energy and Nuclear Physics (CHEP18) EPJ Web of conference. ATL-SOFT-PROC-2018-004

D. Barberis, F. Prokoshin, E. Alexandrov, I. Aleksandrov, Z. Baranowski, L. Canali, D. Gancho, A. Fernandez, E. Gallas, C. García, S. González de la Hoz, J. Hrivnac, A. Iakovlev, A. Kazymov, M. Mineev, G. Rybkin, J.Sánchez, J. Salt, P. Vasileva on behalf of the ATLAS Collaboration, *The ATLAS Event Index and its evolution based on Apache Kudu storage*, 8th International Conference Distributed Computing and Grid-technologies in Science and Education (Grid2018) ATL-COM-SOFT-2018-115, CEUR Workshop Proceeding, vol 2267, pag 18-25, ISSN 1613-0073

M. Svatos, E. Vamvakopoulos, J. Lozano Bahilo, N. Ozturk, D. Dykstra on behal of the ATLAS Collaboration, *Understanding the evolution of conditions data access through Frontier for the ATLAS Experiment*, 23th International Conference on Computing in High Energy and Nuclear Physics (CHEP18) EPJ Web of conference. ATL-SOFT-PROC-2018-053

Selected conference talks

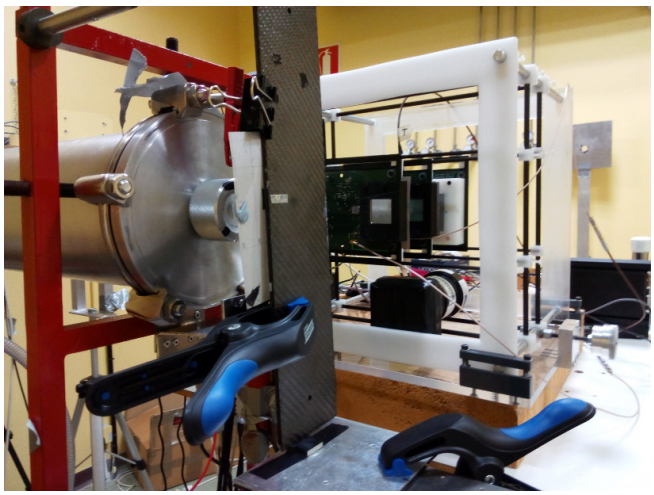
A. Fernández, D. Barberis, J. Sánchez, C. García, S . Gonzalez de la Hoz, J. Salt on behalf of the ATLAS Collaboration, *Distributed Data Collection for the Next Generation ATLAS EventIndex project*, Proceedings of the 23th International Conference on Computing in High Energy and Nuclear Physics CHEP18) EPJ Web of conference: ATL-SOFT-PROC-2018-039

A. Fernández, J. Orduña, S. González de la Hoz, *Performance Improvements of an Event Index Distributed System*, Proceedings of 47th International Conference on ParallelProcessing (ICPP2018). 078620, 1-2. University of Oregon, USA.

E. Fullana, D. Benjamin, P. Calafiura, T. Childers, K. De, A. Di Girolamo, J. García Navarro, Wen Guan, M. Lassnig, T. Maeno, P. Nilsson, V. Tsulaia, P. Van Gemmeren, T. Wenasus, W. Yang on behalf of the ATLAS collaboration, *Grid production with the ATLAS Event Service*, 23rd International Conference on Computing in High Energy and Nuclear, Sofia, Bulgaria, 9 - 13 July 2018. ATL-SOFT-PROC-2018-037. Proceedings EPJ Web of Conferences.

MEDICAL APPLICATIONS OF NUCLEAR AND PARTICLE PHYSICS

The IRIS medical physics group works on the development of a Compton telescope for hadron therapy treatment monitoring. The system aims at detecting the distribution of prompt gamma rays emitted by the tissue after therapeutic irradiation with proton or Carbon ion beams. The telescope is composed of three planes of LaBr3 crystals coupled to Silicon photomultipliers (SiPMs) as photodetectors. A first version of the device was developed within the European project ENVISION. A second prototype assembled with new detectors and featuring improved image reconstruction algorithms has led to a significantly better performance and has been tested in accelerator facilities. A full characterization of the device has been carried out under controlled conditions at different temperatures, with the system inside a climatic chamber. Tests performed at the National Accelerator Centre (CNA, Sevilla) with 18 MeV protons impinging a graphite target have served to assess the system response under different conditions, varying target position, system orientation, bias voltage and beam intensity.



Compton telescope in beam tests at CNA, Sevilla.

On the image reconstruction side, the group developed a model to correct for sensitivity variations within the field of view for a two-plane telescope. The model has been extended to the three-plane case, and it is being tested. Despite the fact that these events are less abundant, they convey more information than conventional, two-interaction ones. In addition, the image reconstruction code developed for the two-plane system has been modified to be able to estimate not only the spatial gamma-ray distribution, but also the photon energy. This is essential for hadron therapy, given the unknown gamma energies (emitted in a continuous spectrum in the MeV range) and the low photoabsorption probability at those energies, which make it difficult to obtain the gamma energy by summing energy depositions in the two detectors.

Background reduction studies have also been started in order to reduce noise in the images. Background events are abundant at the high gamma energies involved, resulting in a significant image degradation. Studies of background composition and noise reduction strategies carried out with Monte-Carlo simulations have demonstrated the possibility to reduce the image background in a simulated Bragg peak image, and have led to a patent application.

The group is also involved in technology transfer activities, and has obtained a utility model of a data acquisition system capable of operating different types of detectors simultaneously. The group works in a project aimed at setting the system features at the level required for its commercialization and the system will be employed in the next version of the telescope.

In addition, the group participates in biological applications, detecting the light emitted by living cells with the aim of distinguishing pathological conditions.

The IRIS group also continues to set up the new laboratories of IFIMED, which have passed in 2018 the start-up inspection by the Consejo de Seguridad Nuclear.

The image reconstruction method estimates both the spatial and spectral gamma-ray distribution

Selected publications

E. Muñoz, J. Barrio, J. Bernabéu, A. Etxebeste, C. Lacasta, G. Llosá, A. Ros, J. Roser and J. F. Oliver, *Study and comparison of different sensitivity models for a Compton Telescope*, Phys. Med. Biol. 63 (2018) 13.

J. Barrio, A. Etxebeste, L. Granado, E. Muñoz, J. F. Oliver, A. Ros, J. Roser, C. Solaz and G. Llosá, *Performance improvement tests of MACACO: a Compton telescope based on continuous crystals and SiPMs*, Nucl. Inst. Meth. A, vol 912 (2018) p48-52.

E. Muñoz, J. Barrio, D. Bemmerer, A. Etxebeste, F. Fiedler, F. Hueso-González, C. Lacasta, J. F. Oliver, K. Römer, C. Solaz, L. Wagner and G. Llosá, *Tests of MACACO Compton telescope with 4.44 MeV gamma rays*, 2018 JINST 13 P05007.

Selected conference talks

G. Llosá, *Multidetector data acquisition system (AliVATA)*, X CPAN Days, 29-31 October 2018, Salamanca, Spain.

G. Llosá, *Photosensors in Nuclear Medicine and Biology Imaging*, Invited review talk at SENSE Technology Forum, June 21-22, 2018, Geneva, Switzerland.

A. Ros, *Evaluation of LFS continuous scintillation crystals for PET*, II Jornadas RSEF/IFIMED de Física Médica, 14-15 June 2018, Madrid, Spain.

J. Roser, *Evaluation and Validation of a Sensitivity Model for a Three-layer LaBr3 Compton Telescope*, II Jornadas RSEF/IFIMED de Física Médica. 14-15 June 2018, Madrid, Spain.

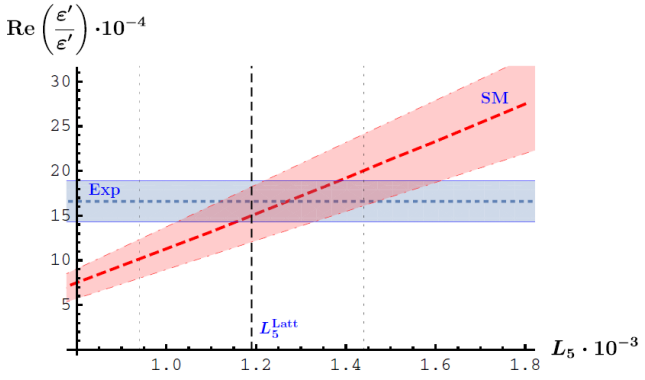
J. F. Oliver, *Development of a Compton telescope for dose monitoring*, Invited talk at II Workshop español en protonterapia, 15-16 March 2018, Sevilla, Spain.

THEORETICAL PHYSICS

HIGH-ENERGY PHYSICS PHENOMENOLOGY

The Standard Model prediction for the ε'/ε ratio has been found to be in good agreement with the experimental measurement.

The theoretical prediction for the measured ratio ε'/ε has been a subject of strong controversy along the years. Researchers from IFIC have reviewed the current status, discussing in detail the different ingredients that enter into the calculation of this observable and the reasons why seemingly contradictory predictions were obtained in the past by several groups. Taking into account all known short-distance and long-distance contributions, these researchers obtain Re (ε'/ε)=(15 ± 7) · 10^{-4}, in good agreement with the experimental measurement.

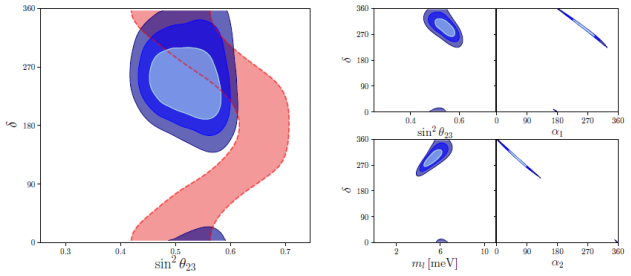


SM prediction for ε'/ε as function of the L_5 coupling. The horizontal blue band displays the experimentally measured value while the dashed vertical line shows the current lattice determination of L_5.

IFIC researchers presented a numerical method for the analysis of the fermion mass matrices predicted in flavour models

New method for the analysis of the fermion mass matrices predicted in flavor models.

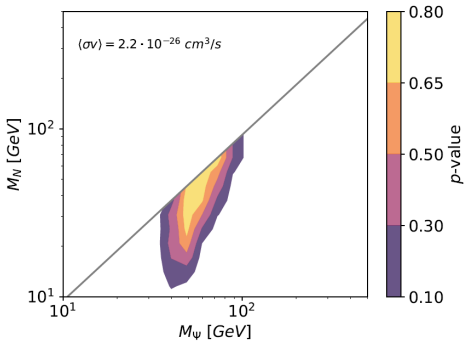
A team composed of IFIC researchers has presented a numerical method for the analysis of the fermion mass matrices predicted in flavour models. The method does not require any previous algebraic work, but offers a χ2 comparison test and an easy estimate of confidence intervals. It can also be used to study the stability of the results when the predictions are disturbed by small perturbations. The method has been applied to the case of two-zero neutrino mass textures using the latest available fits on neutrino oscillations. By doing this, the available parameter space for each texture has been derived. This has finally been used to perform a comprehensive comparison of the different options.



Global fit to neutrino data (blue) as compared with the prediction of the textures (red). Right: new fit to the data when the constraints from the textures are imposed.

Sterile neutrinos may provide a link between the SM and the Dark Sector

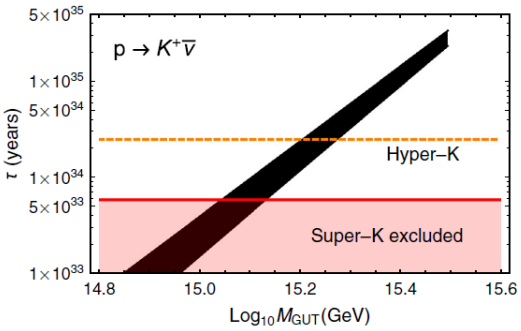
Sterile neutrinos could provide a link between the Standard Model particles and a dark sector, besides generating active neutrino masses via the seesaw mechanism type I. A group of researchers from IFIC showed that, if dark matter annihilation into sterile neutrinos determines its observed relic abundance, it is possible to explain the Galactic Center γ-ray excess reported by the Fermi-LAT Collaboration as due to an astrophysical component plus dark matter annihilations. This scenario is found to be compatible with the limits from Fermi-LAT observations of the dwarfs spheroidal galaxies in the Milky Way halo.



Parameter space region in which the model predicts a gamma-ray flux compatible with the Galactic Center excess.

A simple grand unified theory based on the SU(5) gauge symmetry has been investigated.

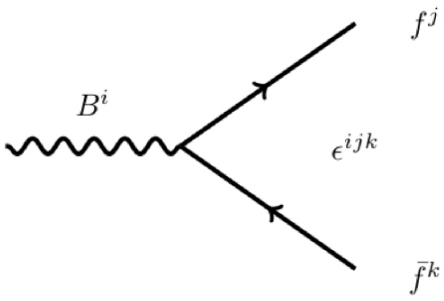
Researchers from IFIC have investigated a simple realistic grand unified theory based on the SU(5) gauge symmetry, which predicts an upper bound on the proton decay lifetime in two channels involving neutrinos in the final state. In this context, the neutrino masses are generated through the type I and type III seesaw mechanisms, and one predicts that the field responsible for type III seesaw must be light with a mass below 500 TeV.



Prediction for the proton decay lifetime for the channel into a positively charged kaon and an anti-neutrino. The orange dashed line shows the expected sensitivity from the Hyper-Kamiokande experiment.

Peccei-Quinn symmetries might be crucial ingredients to explain the pattern of fermion masses and mixings

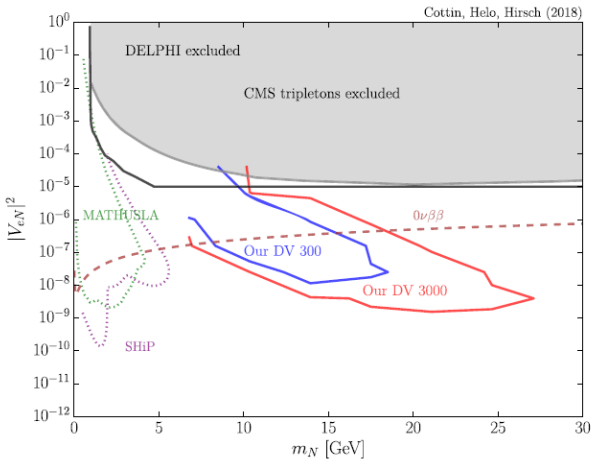
Motivated by the idea of comprehensive unification, researchers from IFIC have participated in a study of a gauged SO(3) flavor extension of the Standard Model that includes right-handed neutrinos and a Peccei-Quinn symmetry. The model accommodates the observed fermion masses and mixings and yields a characteristic, successful relation among them.



Meson oscillations constrain the Peccei-Quinn symmetry.

The LHC can probe light sterile neutrinos by looking for displaced vertices.

The LHC can probe light sterile neutrinos by looking for displaced vertices. Researchers from IFIC have studied rare decays of the standard model gauge bosons that take place inside the inner trackers of the LHC detectors. With a strategy that triggers on the prompt lepton accompanying the sterile neutrino displaced vertex and considers charged tracks associated with it, they have shown that the 13 TeV LHC with 3000 fb^{-1} is able to probe active-sterile neutrino mixings 4 orders of magnitude smaller than current experimental limits from trileptons.

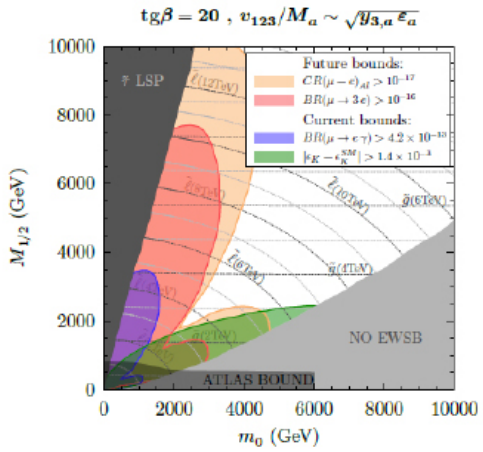


Projected 95% CL sensitivities on the plane of sterile neutrino mass and electron mixing for the LHC, MATHUSLA and ShiP.

The LHC can probe light sterile neutrinos by looking for displaced vertices

Lepton flavor violation, with the sfermion masses fixed by the flavor symmetry, is sensitive to very large SUSY masses.

Researchers from IFIC have studied the phenomenology of a unified supersymmetric theory with a flavor symmetry Δ(27). The model accommodates quark and lepton masses, mixing angles and CP phases, predicting Dirac and Majorana mass matrices with a unified texture zero structure in the (1,1) entry that leads to the Gatto-Sartori-Tonin relation between the Cabibbo angle and ratios of the masses in the quark sectors, and to a natural departure from zero of the θ^{ℓ}_{13} angle in the lepton sector. The resulting non-universal flavor structures of the soft terms cause large flavor violating LFV effects, allowing us to (dis)prove the model by flavor violation searches in the next decade.



Excluded regions of the MSSM parameter-space from LFV constraints.

Selected publications

H. Gisbert, A. Pich, *Direct CP violation in $K \to \pi\pi$: Standard Model Status*, Rept. Progr. Phys. 81 (2018) 076201 – 22 pp, DOI: 10.1088/1361-6633/aac18e [arXiv:1712.06147]

J. Alcaide, J. Salvadó, A. Santamaría, *Fitting flavor symmetries: the case of two-zero neutrino mass textures*, JHEP 1807 (2018) 164 – 18 pp, DOI:10.1088/1475-7516/2018/06/019 [arXiv:1803.04541]

M. G. Folgado, G. A. Gómez-Vargas, N. Rius, R. Ruiz De Austri, *Probing the sterile neutrino portal to Dark Matter with gamma rays*, JCAP 1808 (2018) 002 – 20 pp, DOI:10.1088/1475-7516/2018/08/002 [arXiv:1803.08934]

P. Fileviel-Pérez, A. Gross, C. Murgui, *Seesaw scale, unification and proton decay*, Phys. Rev. D98 (2018) – 10 pp, DOI: https://doi.org/10.1103/PhysRevD.98.035032 [arXiv:1804.07831]

M. Reig, J. W. F. Valle, F. Wilczek, *SO(3) family symmetry and axions*, Phys. Rev. D 98, 095008 - 6pp, DOI: 10.1103/PhysRevD.98.095008 [arXiv:1805.08048]

G. Cottin, J. C. Helo, M. Hirsch, *Displaced vertices as probes of sterile neutrino mixing at the LHC*, Phys. Rev. D 98, 035012 - 6pp, DOI: 10.1103/PhysRevD.98.035012 [arXiv:1806.05191]

I. d. M. Varzielas, M. L. López-Ibáñez, A. Melis, O. Vives, *Controlled flavor violation in the MSSM from a unified Δ(27) flavor symmetry*, JHEP 1809 (2018) 047 – 22 pp, DOI: 10.1007/JHEP09(2018)047 [arXiv:1807.00860]

Selected conference talks

G. Barenboim, *CPT violation in neutrinos*, 1st workshop on Phenomenology for Particle and Anti-Particle (PPAP2018), March 2018, Hiroshima, Japan.

R. Srivastava, *Pathways to Dirac neutrinos*, 7th Workshop on flavor symmetries and consequences in accelerators and cosmology (FLASY18), July 2018, Basel, Switzerland.

A. Vicente, *Flavor and dark matter connection*, 16th Conference on Flavor Physics and CP Violation (FPCP 2018), July 2018, Hydebarad, India.

A. Peñuelas, *Global fits in the aligned two-Higgs doublet model*, Workshop on Multi-Higgs models, September 2018, Lisbon, Portugal.

O. Mena, *Neutrino masses: knowns and unknowns from Cosmology et al*, Invisibles 18 Workshop, September 2018, Karlsruhe, Germany.

A. Pich, *Flavour Anomalies*, Workshop on Implications of LHCb Measurements and Future Prospects, October 2018, CERN, Geneva, Switzerland.

K. Sakurai, D. Felea, J. Mamuzic, N. E. Mavromatos, V. A. Mitsou, J. L. Pinfold, R. Ruiz de Austri, A. Santra, O. Vives, *SUSY discovery prospects with MoEDAL*, 6th Symposium on Prospects in the Physics of Discrete Symmetries (DISCRETE 2018), November 2018, Vienna, Austria.

HIGH-ENERGY THEORETICAL PHYSICS: QUANTUM BLACK HOLES, SUPERGRAVITY AND COSMOLOGY

During the year 2018 our group has grown a little bit. Two new PhD students with FPU fellowships joined us, Silvia Pla and Pau Beltrán, and both are working under the supervision of José Navarro-Salas on aspects of quantum fields in curved space-time. On the other hand, Alessandro Fabbri, a former Ramón y Cajal fellow in our group, became a permanent member of the Theoretical Physics Department. On July 17th, Adrián del Río Vega presented his thesis defense entitled "Quantum aspects originated by gravitation: from cosmology to astrophysics", supervised by José Navarro-Salas. He is currently working in Lisbon as a postdoc.

From the 1st to the 3rd of October we organized the Third annual meeting of the COST Action CA15117 (CANTATA), which was followed by the satellite meeting FUGA (FUture Gravitational Alternatives). These meetings brought to our campus about 70 researchers of the CANTATA collaboration to discuss various aspects of modified theories of gravity and their observational status. Among the invited plenary talks we had Olga Mena from IFIC and Claudia de Rham from Imperial College London. Three gender related talks where given during the first day by specialists in sociology, economy, and neurology. The session was closed with a round table and a discussion on the gender talks. A public lecture entitled *"Agujeros negros, otros animales fantásticos y cómo encontrarlos"* was delivered on Tuesday 2nd at the Botanical Garden, where a reception for the conferences participants followed.

As coordinators of the Red Temática de Relatividad y Gravitación, we have supported this year several important meetings, such as the Iberian Strings Meeting (Granada), the Iberian Cosmology Meeting (Lisbon), the Spanish-Portuguese Relativity Meeting (Palencia, with P), and the workshop Travelling through Pedro's Universes (UCM, Madrid) in honor of Pedro González Díaz, who passed away in 2012.

Our research activity this year has lead to important progress in the understanding of modified gravity theories and their relation with General Relativity (GR). We have managed to establish a correspondence between the field equations of a certain family of theories called RBGs (whose Lagrangian is constructed in terms of the Ricci tensor and the metric, Ricci-Based Gravities) and the field equations of GR. This correspondence allows to map a given modified gravity problem into a problem in standard GR, which facilitates its analysis and resolution. The most relevant point of this result is that well-established numerical methods can now be applied in these extensions of Einstein's theory. This, in particular, will provide interesting new information for gravitational wave searches.

In May our group received with joy the announcement from the Gravity Research Foundation of their Awards for Essays. The work by I. Agulló, A. del Río and J. Navarro-Salas entitled *"Gravity and handedness of photons"* received the First Award, becoming the first group of Spanish researchers to have ever received such honor. For the details, and the historical series of the Awarded essays, see: www.gravityresearchfoundation.org.

Recent First Award Winners:

2017 – Ivan Agullo, LSU; Adrian del Rio & Jose Navarro-Salas, Centro Mixto Universidad de Valencia-CSIC, Spain
2016 – Stephen L. Adler, Institute for Advanced Study, Princeton, New Jersey
2015 – Gerard 't Hooft, Utrecht University & Spinoza Institute, the Netherlands
2014 – Lawrence M. Krauss, Arizona State University & Frank Wilczek, Massachusetts Institute of Technology (MIT)

It is well known that the source-free Maxwell equations are invariant under electric-magnetic duality rotations. However, it is less known that Maxwell's action also remains invariant. These transformations are therefore a symmetry of the theory in Noether's

sense. The associated constant of motion is related to the difference of intensity between the right and left circularly polarized components. This conservation law holds even if the electromagnetic field interacts with an arbitrary classical gravitational field.

We analyzed whether this symmetry is maintained when the electromagnetic field is quantized. The answer is in the affirmative in the absence of gravity, but we find that a non-trivial classical gravitational background can break the symmetry. As a consequence, the net polarization of the quantum electromagnetic field fails to be conserved in curved space-times. This is a quantum effect, and it can be understood as the generalization of the fermionic chiral anomaly to fields of spin one.

In the context of quantum field theory in curved spacetimes, we solved for the first time the backreaction problem for rotating black holes and naked singularities in 2+1 dimensions. In particular, we showed that the quantum effects make the black hole event horizon and static limit surface grow, while its angular velocity is reduced. At the same time, the quantum effects act as 'cosmic censors' by producing a (small) horizon around naked singularities and a curvature singularity at the Cauchy horizon of the rotating black hole solutions. Reviews of these results appeared in outreach journals: APS Physics, New Scientist, International Business Times, AIP Inside Science.

We continued our interdisciplinary investigation on the experimental features of the analog Hawking radiation (quantum particle creation by black holes) in condensed matter models, in particular in Bose-Einstein condensates. We have shown that momentum correlators in Bose-Einstein condensates (BECs) are good observables, as they allow the clearly identify the Hawking effect and, moreover, the fact that the pair of particles created by the analog (or acoustic) black holes (namely, one particle in the exterior, the Hawking quanta, and its partner inside the black hole) are entangled. We have also studied the (quasi-) particle creation in a BEC, the depletion, when the nonlinear coupling constant varies with time (dynamical Casimir effect) and identified the nontrivial features in the correlation pattern of a massive field in the background of an acoustic black hole.

In the field of supersymmetry, a new approach to superfields was proposed, giving an interpretation of them in terms of (quantum) observables. Certain non linear constraints on superfields are seen as superschemes that do not define a standard supermanifold. Also, the study of the (complex) quantum superconformal space, a projective superflag manifold, was completed by using the line superbundle associated to the projective embedding together with a quantum section on it.

To conclude the year, we organized the 2nd Valencia Winter Workshop on Theoretical Physics (11-14 December). This year our group meeting was open to the PhD and MSc students as well, who had a chance to present their research works in a relaxed atmosphere.

We solved the backreaction problem for rotating black holes and naked singularities in 2+1 dimensions

Selected publications

V.I. Afonso, Gonzalo J. Olmo, D. Rubiera-Garcia, *Mapping Ricci-based theories of gravity into general relativity*, Phys. Rev. D97 (2018) no.2, 021503.

J. Beltran Jimenez, L. Heisenberg, Gonzalo J. Olmo, D. Rubiera-Garcia, *Born–Infeld inspired modifications of gravity*, Phys.Rept. 727 (2018) 1-129.

G.I. Martone, P.-E. Larré, A. Fabbri and N. Pavloff, *Momentum distribution and coherence of a weakly interacting Bose gas after a quench*, Phys. Rev. A98 (2018), 063617.

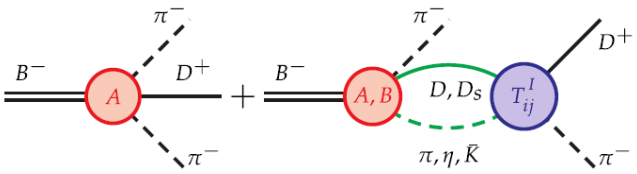
R.A. Dudley, P.R. Anderson, R. Balbinot, A. Fabbri, *Correlation patterns from massive phonons in 1+1 dimensional acoustic black holes: a toy model*, Phys. Rev. D98 (2018), 124011

Selected conference talks

G. J. Olmo, *Modified gravity without modified gravity: scalars fields and fluids*, Spanish Relativity Meeting EREP2018, 4-7 September, Palencia (Spain).

G. J. Olmo, *Charged rotating black holes in Born-Infeld gravity*, SIGRAV2018 (Società Italiana di Gravitazione), 7-15 Sept. Cagliari (Italy).

EFFECTIVE THEORIES IN HADRONIC AND NUCLEAR PHYSICS



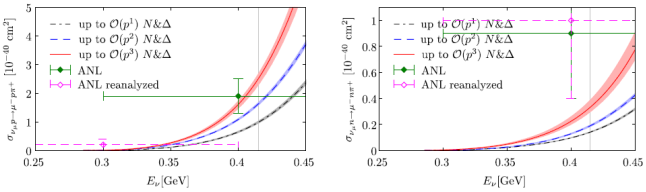
Decay amplitude for $B^- \to D^+ \pi^- \pi^-$ including final state interactions between charm and light mesons.

Effective field theory approaches have been applied to describe the spectroscopy of light and heavy hadrons, including newly discovered exotic XYZ states and pentaquarks, and their dynamics: scattering, weak and strong decay properties. With the help of many-body field theory techniques we have also investigated nuclear matter properties and its response to electroweak probes.

Hadron dynamics in coupled channels gives rise to a rich structure of new states with strange, charm and beauty quarks that cannot be easily accommodated within the standard constituent quark model. In the meson-baryon sector, this is the case of several Ξ_c and Ξ_b states observed by BaBar, Belle and LHCb experiments, or the $\Omega(2012)$ discovered at Belle, generated from the $K^-\Xi^*$,$\eta\Omega$,$K^-\Xi$ channels and whose properties are naturally explained in this picture. Narrow Ω_c baryons have been obtained, three of them in remarkable agreement with states discovered at LHCb. Motivated by this success, the approach was extended to the beauty sector to predict the Ω_b spectrum. Effective field theory with heavy-quark spin symmetry has also allowed to shed light on the nature of charmed strange mesons $D_{s0}^*(2317)$ and $D_{s1}(2460)$ with masses below the *DK* and *D*K* thresholds, in contradiction to quark models. Thanks to the consideration of $D^{(*)}K$ loops, the energy levels obtained in a lattice QCD simulation for the two states were successfully described.

Weak decays of heavy hadrons are particularly interesting because they involve nontrival dynamics and triangle singularities. For example, we have found that the isospin-violating production of $\Lambda(1405)$ in $\Lambda_c \to \pi^+\pi^0\pi^0\Sigma^0$ is enhanced by a triangular singularity. The scalar form factors governing heavy-to-light semileptonic decays have been described in a dispersive approach, with the low-energy constants extracted from lattice QCD simulations, and then used to extract the Cabibbo–Kobayashi–Maskawa quark mixing parameters from experimental data. Furthermore, owing to the recent measurement of $B^- \to D^+\pi^-\pi^-$ by LHCb, we have demonstrated that the nonperturbative dynamics of Goldstone-boson scattering off charm mesons is strongly supported by high quality data. Valuable experimental information is also available from τ decays: channels $\tau \to M\,M\,\upsilon_\tau$ with two pseudoscalar or vector mesons in the final state have been systematically investigated.

We have completed the first systematic study of neutrino-induced single pion production on the nucleon in baryon chiral perturbation theory up to next-to-next-to-leading order. For this purpose we have adopted a covariant formalism, relying on the extended-on-mass-shell regularization scheme to restore the power counting without altering the analytic properties of the theory. The low-lying $\Delta(1232)$ resonance is taken into account as an explicit degree of freedom. Remarkably, out of the 22 low energy constants required to describe this process, 19 have been or can be obtained from pion photo- and electroproduction and pion nucleon elastic scattering without resorting to low-statistics neutrino data. This study provides a well-founded low-energy benchmark for phenomenological models aimed at the description of weak pion production in the broad kinematic range of interest for neutrino-oscillation experiments.



Total cross section for neutrino-induced pion production on nucleons at different chiral orders.

Hadron dynamics gives rise to a rich structure of new states with charm and beauty quarks that cannot be accommodated within the constituent quark model

A systematic study on the properties of the nucleon effective mass in isospin symmetric nuclear matter has been performed. While a standard two-body term produces nuclear saturation, an extra density dependent term is required to describe the effective mass. A strong correlation between the intensity of the density-dependent interaction and the exponent of the density is observed. This correlation is only marginally affected by the explicit presence of a finite range or higher order gradient terms. Furthermore, we have analyzed the nucleon-density response of ^{12}C using spectral functions to describe interacting nucleons. Our method yields scaling functions with the characteristic asymmetric shape. This asymmetry, only mildly affected by final state interactions, is mostly due to nucleon-nucleon correlations, encoded in the continuum component of the hole spectral function.

The first comprehensive study of weak pion production in chiral perturbation theory has been performed

Selected publications

V. R. Debastiani, J. M. Dias, W. H. Liang, E. Oset, *Molecular Ωc states generated from coupled meson-baryon channels*, Phys. Rev. D 97, 0944035 – 11pp, DOI: https://doi.org/10.1103/PhysRevD.97.094035 [arXiv:1710.04231].

D. Davesne, J. Navarro, J. Meyer, K. Bennaceur, A. Pastore, *Two-body contributions to the effective mass in nuclear effective interactions*, Phys. Rev. C 97, 044304 – 7pp, DOI: 10.1103/PhysRevC.97.044304 [arXiv:1712.03003].

M. L. Du, M. Albaladejo, P. Fernandez-Soler, F. K. Guo, C. Hanhart, U. Meißner, J. Nieves, D L. Yao, *Towards a new paradigm for heavy-light meson spectroscopy*, Phys. Rev. D 98, 094018 – 8pp, DOI: https://doi.org/10.1103/PhysRevD.98.094018 [arXiv:1712.07957].

L. R. Dai, R. Pavao, S. Sakai, E. Oset, *Anomalous enhancement of the isospin-violating Λ(1405) production by a triangle singularity in* $\Lambda_c \to \pi^+ \pi^0 \pi^0 \Sigma^0$, Phys. Rev. D 97, 116004 – 10pp, DOI: https://doi.org/10.1103/PhysRevD.97.116004 [arXiv:1804.01136].

D. L Yao, L. Alvarez-Ruso, A. N. Hiller Blin, M. J. Vicente Vacas, *Weak pion production off the nucleon in covariant chiral perturbation theory*, Phys. Rev. D 98, 076004 - 25 pp, DOI: 10.1103/PhysRevD.98.076004 [arXiv:1806.09364].

Selected conference talks

L. Alvarez-Ruso, A. H. Blin, K. Graczyk, E. Hernández, J. Nieves, E. Saúl-Sala, M. J. Vicente Vacas, D. Yao, *Should neutrino-nucleon cross sections be (re)measured?,* Fundamental Physics with Electroweak Probes of Light Nuclei, June 2018, Seattle, USA.

J. Nieves, T*heoretical interpretation of some even parity Quarkonium XYZ states, open heavy flavor mesons and odd parity doubly charmed baryons*, Workshop on the Physics of HL-LHC and perspectives at HE-LHC, June 2018, Geneva (CERN), Switzerland.

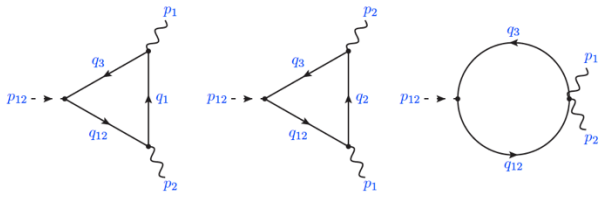
E. Oset, *Tetra and pentaquarks from the molecular perspective*, 15th International Workshop on Meson Physics (MESON 2018), June 2018, Krakow, Poland.

L. Alvarez-Ruso, K. M. Graczyk, E. Saúl-Sala, *Nucleon axial form factor from a Bayesian neural-network analysis of neutrino-scattering data*, The 20th International Workshop on Neutrinos from Accelerators (NUFACT2018), August 2018, Virginia, USA.

L. Alvarez-Ruso, *Hadron and nuclear physics for oscillation experiments,* European Neutrino Town Meeting, October 2018, Geneva (CERN), Switzerland.

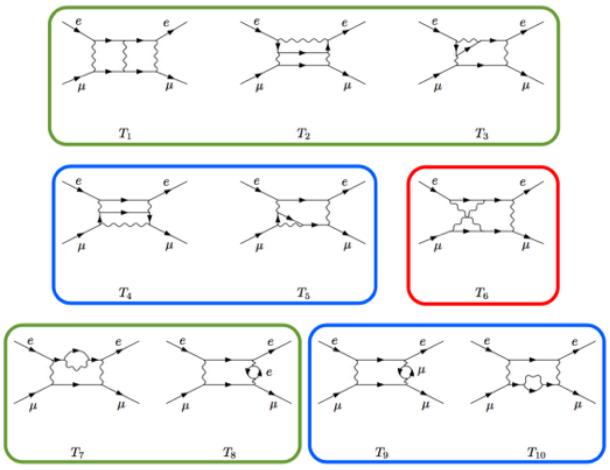
QCD AND STRONG INTERACTIONS

This research line studies the several aspects of perturbative and non-perturbative strong interactions. In order to provide a wide description, various approaches are considered, lattice gauge theories, effective field theories, chiral perturbation theory or phenomenological Lagrangians, including searches for new physics beyond the standard model. The motivation for their study is to understand in more details the physics of the Large Hadron Collider (LHC).



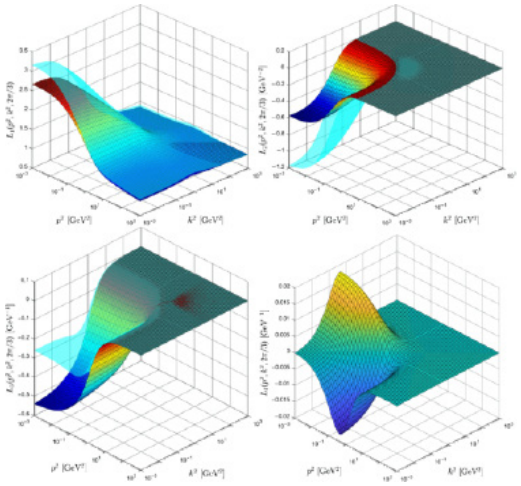
Representative Feynman diagrams for Higgs decay into two photons. Internal lines can be scalars, fermions and vector bosons.

The theoretical prediction of observables from perturbative Quantum Chromodynamics (pQCD) has shown remarkable results when properly compared with the physics in the experiment. In fact, to extract new physics one needs the highest possible accuracy. Hence, predictions that are often called at leading-order (LO) are insufficient due to their enormous uncertainty. The latter motivates the study of higher orders in the perturbation theory, Next-to-Next-to-…-to-Leading orders (N…NLO). The bottleneck in their calculation usually relies on the evaluation of scattering amplitudes, backbone to compute the relevant observables. This complexity arises because of the use of traditional approaches.



Representative Feynman diagrams for the μ-electron scattering.

IFIC is currently providing efficient calculations by means of the loop-tree duality formalism that this year started to generate remarkable results for physical processes of enormous importance at the LHC. This is indeed the case of the Higgs decay into two photons and Higgs production via gluon fusion. The interesting feature of this formalism is how the space-time dimension is treated. The standard treatment, or Conventional Dimensional Regularization (CDR), is not used and replaced by a four dimensional representation. Alternatively, the approach of decomposing multi-loop amplitudes through integral relations has also been elaborated for now working at integrand level. This new approach, based on integrand reduction methods, is currently studied in the muon-electron elastic scattering at NNLO.



Quark-gluon form factors contributing to the non-abelian extension of the "Ball-Chiu vertex".

From a non-perturbative approach, the full quark-gluon vertex of QCD has been studied. This is a crucial ingredient for the dynamical generation of a constituent quark mass from the standard quark gap equation. The results of this study involve the quark propagator, the ghost dressing function and the quark-ghost kernel. The quark-gluon vertex also constitutes the non-abelian extension of the so-called "Ball-Chiu vertex", known from QED. On top of it, the research also involves the Nambu-Jona-Lasinio (NJL) model. This is a very powerful tool, which implements the realisation of spontaneously broken chiral symmetry at low energies. Likewise, a framework, based on the use of the AdS/CFT correspondence, is employed to describe the strong interactions. The calculation is performed in the bottom-up approach by using an AdS/QCD model double of Parton distribution functions (dPDFs) for the pion.

The focus of the research based on Lattice Field Theory is on the extraction of physical observables. In particular, the aim is to connect results obtained in finite volume simulations to phenomenological predictions in infinite volume. Progress has been made on scattering of two and three particles in finite volume and QCD observables in the large Nc limit.

Regarding the scattering in finite volume, we have worked on numerical simulations in a toy model and in theoretical developments to extend the applicability to three-particle scattering. Moreover, we have simulated ensembles with QCD varying the number of colors. On these ensembles, preliminarily calculated observables related to Kaon decays and the Delta I=1/2 rule have been obtained.

Preliminarily calculated observables related to Kaon decays and the Delta I=1/2 rule have been obtained

Selected publications

F. Driencourt-Mangin, G. Rodrigo and G. F. R. Sborlini, *Universal dual amplitudes and asymptotic expansions for gg->H and H->γγ in four dimensions*, Eur. Phys. J. C 78 (2018) no.3, 231.

F. Romero-López, A. Rusetsky and C. Urbach, *Two- and three-body interactions in φ^4 theory from lattice simulations*, Eur. Phys. J. C 78, no. 10, 846 (2018).

A. C. Aguilar, J. C. Cardona, M. N. Ferreira, and J. Papavassiliou, *Quark gap equation with non-Abelian Ball-Chiu vertex*, Phys. Rev. D 98, 014002 (2018)

M. Rinaldi, S. Scopetta, M. Traini, V. Vento, *A model calculation of double parton distribution functions of the pion*, Eur.Phys.J. C78 (2018) no.9, 781.

H. Gisbert and A. Pich, *Direct CP violation in K0\->ππ: Standard Model Status*, Rept. Prog. Phys 81 (2018) no.7, 076201.

Selected conference talks

W. J. Torres Bobadilla, *On the decomposition of 2-loop μe scattering via Adaptive Integrand Decomposition, The Evaluation of the Leading Hadronic Contribution to aμ*, February 19 - 23, 2018, JGU Campus Mainz, MITP, Mainz, Germany.

G. Rodrigo, *Loop-tree duality at two loops*, Loops and Legs in Quantum Field Theory (LL2018), 29 April 2018 - 04 May 2018 St. Goar, Germany.

J. Vijande, *Few-body insights of multiquark exotic hadrons*, International Conference on Few-Body Problems in Physics (FB22), 9-13 July 2018, Caen, Francia.

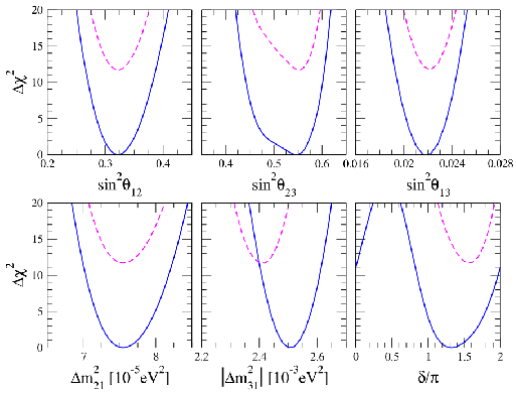
F. Driencourt-Mangin, *Application of the Loop-Tree Duality theorem at two loops*, High presicion for hard proceses (HP2 2018), 1-3 October 2018, Freiburg, Germany.

F. Romero-López, *Two- and three-body interactions in φ^4 theory from lattice simulations*, November 2018, MIAPP, Munich, Germany.

THEORETICAL ASTROPARTICLE PHYSICS AND COSMOLOGY

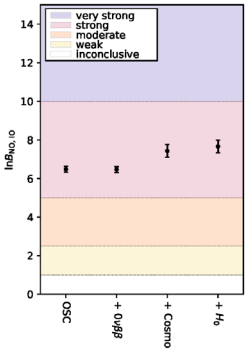
The research topics of this line include cosmic rays, neutrinos, dark matter, dark energy and inflationary theories, involving international collaborations that study neutrino oscillations and CP violation searches (Deep Underground Neutrino Experiment, DUNE), direct detection of relic neutrinos (PTOLEMY) and the role of dark matter, neutrinos or dark energy in the context of 21cm observations using the future Square Kilometer Array (SKA) Telescope.

One of the hot topics in this area is the study of neutrino oscillations. Researchers at IFIC have presented a new global fit of neutrino oscillation parameters including the most recent data from long-baseline, reactor, solar and atmospheric experiments. The most remarkable results from this analysis are the strong preference obtained for values of the CP phase δ in the range [π,2π] and the first hint in favor of the normal neutrino mass ordering over the inverted one at more than 3σ.



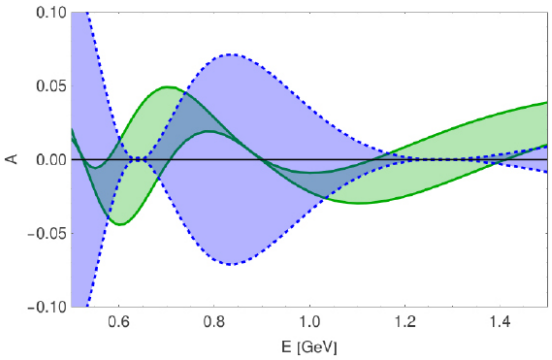
Summary of neutrino oscillation parameters. Blue (solid) lines correspond to normal ordering and magenta(dashed) lines to inverted ordering.

The status of the neutrino mass ordering has been analysed in more detail in a review article that presents the different available tools to measure the neutrino mass ordering, from neutrino oscillation experiments to laboratory searches for beta and neutrinoless double beta decays and observations of the cosmic microwave background radiation and the large scale structure of the universe. A comprehensive global analysis of current data shows strong evidence for the normal neutrino mass ordering with a significance of 3.5σ, mostly due to neutrino oscillation measurements. Future perspectives for unveiling the neutrino mass ordering with the aforementioned probes as well as alternative and novel methods such as 21 cm cosmology, core-collapse supernova neutrinos and the direct detection of relic neutrinos are also discussed.



Graphical visualisation of the Bayesian factors comparing normal and inverted ordering. Black (red) points indicate a logarithmic (linear) prior.

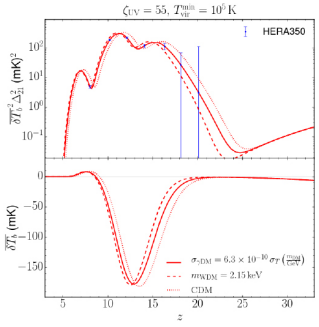
Another study of this research line deals with the possible observation of genuine CP violation in neutrino oscillations at long baselines. In actual experiments, the propagation takes place in matter, which generates fake CP violation as a consequence of the different interactions of neutrinos and antineutrinos. It is therefore important to understand properly how to single out the different effects to detect a real CP violation. One could exploit the fact that genuine CP violation and matter effects have different behaviours under the discrete symmetries T and CPT. In DUNE, there is a special energy window (around E=0.91 GeV, depending on Δm^2_{31}) for which the CPT asymmetry vanishes and the T asymmetry is nearly maximal. Observations at such energies could therefore shed light on genuine CP violation.



Amplitude of CPT (green) and T (blue) asymmetries in a long-baseline experiment like DUNE.

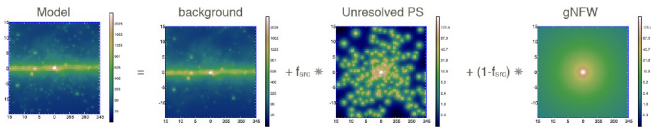
This research line is also devoted to study the nature of dark matter (DM). In one of the selected publications, the constraints on different DM candidates or on models with exotic interactions involving DM particles are studied. Observations of the optical depth to reionization from the CMB spectrum, the reionization history of the universe and the number of satellite galaxies of the Milky Way can help to properly constrain models of interacting DM only if the degeneracies with other astrophysical parameters are adequately treated. The same observables can be used to constrain warm DM candidates, such as sterile neutrinos. Future measurements from 21cm sur-

veys are required in order to distinguish interacting DM models from warm DM candidates, which nowadays give equally good fits to the data.



21cm power spectrum and average brightness temperature for different dark matter scenarios

Astrophysical observables such as the γ-ray emission from the Milky Way can also be employed to study the properties of dark matter, as its distribution in the local environment. In present days, machine learning techniques, as the ones adopted in last selected publication, are exploited to perform such studies. Classification problems, such as discriminating between a signal produced by DM interactions from one due to astrophysical sources, are particularly suited for deep learning methods that use convolutional neural networks. In another study we have reported how deep learning can help to determine whether the γ-ray excess observed by Fermi-LAT is mostly due to unresolved point sources or to a diffuse emission generated by the DM halo of the galaxy.



Visualization of the model construction for the machine learning analysis of the galactic emission.

Professor José W. F. Valle received the prestigious Premio Ciencia y Tecnología Mexico 2018, the highest recognition given by the Mexican government to distinguished scientists from Central America, South America, the Caribbean, Spain and Portugal. This award recognizes the career of José Valle, one of the most cited scientists in high-energy physics in Spain who has made important contributions to neutrino physics. Professor Valle develops an intense work to strengthen the cooperation between scientists in Latin America and Europe.

IFIC researchers Sergio Palomares and Andrea Donini, in collaboration with Jordi Salvado (U. Barcelona), performed the first tomography of the Earth using neutrinos. The study, that uses data from the IceCube neutrino located in Antarctica, will be published in 2019 in Nature Physics (available online since November 2018).

José W. F. Valle received the Premio Ciencia y Tecnología Mexico 2018

Selected publications

P.F. de Salas, D.V. Forero, C.A. Ternes, M. Tórtola and J.W.F. Valle, *Status of neutrino oscillations 2018: 3σ hint for normal mass ordering and improved CP sensitivity*, Phys. Lett. B782, 633, DOI: 10.1016/j.physletb.2018.06.019

P.F. de Salas, S. Gariazzo, O. Mena, C.A. Ternes and M. Tórtola, *Neutrino Mass Ordering from Oscillations and Beyond: 2018 Status and Future Prospects*, Front. Astron. Space Sci. 5, 36, DOI: 10.3389/fspas.2018.00036

J. Bernabéu and A. Segarra, *Disentangling genuine from matter-induced CP violation in neutrino oscillations*, Phys. Rev. Lett. 121, 211802, DOI: 10.1103/PhysRevLett.121.211802

M. Escudero, L. Lopez-Honorez, O. Mena, S. Palomares-Ruiz and P. Villanueva-Domingo, *A fresh look into the interacting dark matter scenario*, JCAP 06, 007, DOI: 10.1088/1475-7516/2018/06/007

S. Caron, G.A. Gómez-Vargas, L. Hendriks and R. Ruiz de Austri, *Analyzing γ-rays of the Galactic Center with Deep Learning*, JCAP 05, 058, DOI: 10.1088/1475-7516/2018/05/058

Selected conference talks

S. Gariazzo, *Neutrinos and cosmology*, European Neutrino Town meeting, October 2018, CERN, Geneva, Switzerland.

P. Hernández, *Baryogenesis in low-scale seesaw models,* Workshop "Understanding the Origin of the Baryon Asymmetry of the Universe", August 2018, Aspen Center for Physics, USA.

S. Palomares-Ruiz, *BSM physics at UHE neutrino detectors*, NuHoRIzons VII, Neutrinos in Physics, Astrophysics and Cosmology, February 2018, Harish-Chandra Research Institute, Allahabad, India.

M. Tórtola, *The global three-neutrino picture before DUNE*, XXVIII International Conference on Neutrino Physics and Astrophysics (Neutrino 2018), June 2018, Heidelberg, Germany.

J. W. F. Valle, *Neutrino masses and mixings: Theory challenges*, 10th Neutrino Oscillation Workshop (NOW 2018), September 2018, Ostuni, Italy.

3. IFIC RESPONSIBILITIES IN 2018

Alejandro Algora:
– Member of the Joint Evaluated Fission and Fusion File (JEFF) Coordination Group.
– Member of the Steering Committee of ISOLDE Decay Station (IDS, ISOLDE, CERN).
– International Expert of the International Atomic Energy Agency (IAEA), Vienna.
– Secretary of the Nuclear Physics Group of the Royal Spanish Society of Physics.

Luis Álvarez:
– Co-spokesperson of the Neutrino Scattering Theory Experiment Collaboration (NuSTEC).
– Member of the International Advisory Committee of the Neutrino Physics Centre at Fermilab.

Gabriela Barenboim:
– Coordinator of the Theory working group at CERN Neutrino platform.
– Leader of the WG5-Dark matter, dark energy, and baryogenesis working group of the COST Action 15108 FUNDAMENTALCONNECTIONS *Connecting insights in fundamental physics*.

José Bernabéu:
– ATLAS Inner Tracker Strip Services Coordinator.
– ATLAS Inner Tracker Grounding and Shielding Deputy Coordinator.

José M. Bordés:
– Coordinator of Erasmus, Faculty of Physics, U. Valencia.

José Adolfo de Azcárraga:
– President of the Royal Spanish Society of Physics.

José Díaz:
– Member of ANECA A2 Commission.
– Member of the PANDA Collaboration Board.
– Member of the INSTRUMENTS Editorial Board.

Luca Fiorini:
– ATLAS Tau Working Group Convener.
– ATLAS Tile Calorimeter Speakers Committee Chair.

Juan Fuster:
– Spanish representative at ECFA.

Carlos Lacasta:
– Scientific Secretary of ECFA and Spanish representative in RECFA.
– ATLAS Inner Tracker Strips deputy project leader.

Gabriela Llosá:
– Secretary of the Medical Physics Group of the Royal Spanish Society of Physics.

Carmen García:
– Coordinator of the Physics and Technology Area of CSIC.

José Enrique García:
– Convener of Subgroup Generator Development & Tuning, ATLAS Collaboration.
– ATLAS distributed analysis coordinator.

Santiago González:
– Vice-President of the Theoretical and Particle Physics Area of the Royal Spanish Society of Physics.
– Responsible of Data Production in the Event Index Project, ATLAS Collaboration.

Pilar Hernández:
– External Review Committee CERN Theory Division.
– Associate Editor of *European Journal of Physics C*.
– Coordinator of the CERN Theory Neutrino Platform.

Salvador Martí:
– ATLAS Inner Detector Alignment Convener.
– Member of the Collaboration Board of RD50 experiment.

Vasiliki Mitsou:
– Member of MoEDAL Speakers Committee.
– Chairperson of the Collaboration Board of MoEDAL experiment.

Juan Nieves:
– Member of the Theory Advisory Group of the Panda Collaboration, FAIR.

Sergio Palomares:
– Editor of *Heliyon* and *Advances in High Energy Physics*.

Sergio Pastor:
– Member of the Director Scientific Committee of the International School on Astroparticle Physics European Doctorate School (ISAPP).
– Coordinator of the National Network on Astroparticle physics (RENATA).

Armando Pérez:
– Member of the Academic Commission of Degree (CAT), Faculty of Physics, U. Valencia.

Antonio Pich:
– Director of Agrupación CPAN.
– President of the Comisión de Certificación de Posición Equivalente de la Agencia Nacional de Evaluación de la Calidad y Acreditación (ANECA).
– Member of the European Research Council Advanced Grant Evaluation Panel *Fundamental Constituents of Matter* (PE2).
– Member of the International Advisory Committee of Super-Charm-Tau Factory Project (Budker Institute of Nuclear Physics, Novosibirsk, Russian Federation); Scientific Unit of Excellence CAFPE-Física Teórica (University of Granada, Spain); Fusion Institutes d'Orsay and Haut Conseil de l'Evaluation de la Recherche et de l'Enseignement Supérieur (Orsay, France).
– Chair of the International Advisory Committee of Experimental Particle Physics Unit at CIEMAT (Spain).

Diego Real:
– Coordinator of Electronics Working Group KM3NeT.
– Member of the Technical Advisory Board of Baikal.

Nuria Rius:
– General Coordinator of the PhD Physics Program of the University of Valencia.

Germán Rodrigo:
– Chair of the COST Action CA16201 *Unraveling new physics at the LHC through the precision frontier*.

Berta Rubio:
– Member of the Scientific Committee of Canfranc Underground Laboratory.
– Member of the Scientific Committee of IPN Orsay.
– Member of the Scientific Committee of NSCL Michigan State University.
– Member of the Board of Representatives NUSTAR/FAIR.
– Scientific adviser to the Ministry at the Resource Review Board FAIR.
– Chair Users Executive Committee Eurisol.

Arantxa Ruiz:
– ATLAS Trigger Menu and Signature Performance Coordinator.

Jose Salt:
– Treasurer of the Theoretical and Particle Physics Area of the Royal Spanish Society of Physics.
– Member of the LHC Experiments Resources Review Boards (RRB) at CERN.
– Representative of ATLAS-Spain Tier-2 Federation in the Collaboration Board of the Worldwide LHC GRID.

Javier Sánchez
– Responsible of Data Collecting in the Event Index Project, ATLAS Collaboration.

Miguel Angel Sanchís:
– Vice-President of the Royal Spanish Society of Physics.
– Member of the Committee on Equality, Faculty of Physics, University of Valencia.

William J. Torres Bobadilla:
– Member of the Management Committee of the COST Action CA16201 *Unraveling new physics at the LHC through the precision frontier*.

José Luis Taín:
– Spokesperson of the BRIKEN Collaboration.
– Co-spokesperson of NP1412-RIBF127R1 and RIBF1712-RIBF158 experiments at RIKEN.
– Member of the Panel of Experts on Control and Security of Nuclear Reactors, International Atomic Energy Agency (IAEA).

Mariam Tórtola:
– Secretary of the Management Board of ANIRC (Asociación Nacional de Investigadores Ramón y Cajal).
– Representative of non-permanent research staff (PDI), Board of Faculty of Physics, U. Valencia.

Alberto Valero:
– ATLAS TileCal Upgrade Deputy Project Leader.
– ATLAS Tile Calorimeter Signal Reconstruction group Coordinator.

José W. F. Valle:
– Member of the Director Scientific Committee of the International School on Astroparticle Physics European Doctorate School (ISAPP).
– Editor in Chief of *Frontiers*.
– Member of the Editorial Board of the Institute of Physics (NJP).

Jordi Vidal:
– Dean of the Faculty of Physics, University of Valencia.

Oscar Vives:
– Director of the Theoretical Physics Department of the University of Valencia.

Juan de Dios Zornoza:
– Coordinator of Dark Matter & Exotics Working Group in KM3NeT.
– Coordinator of Time Calibration Group in KM3NeT.
– Member of Conference Committee in KM3NeT.
– Member of the Publication Committee in KM3NeT.

Juan Zúñiga:
– Member of ANTARES Publication Committee.
– Member of the Quality Assurance & Quality Control Group of KM3NeT.

4. SCIENTIFIC OUTCOME 2018

409 Articles in indexed journals

90% In first quartile journals
(JCR-WoS or CiteScore-Scopus, 2018)

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

Physics Reports (IF 28.3): **1**

Reports on Progress in Physics (IF 16.6): **1**

Progress in Particle and Nuclear Physics (IF 10.8): **1**

Physical Review Letters (IF 9.2): **27**

Astrophysical Journal Letters (IF 8.4): **3**

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

Physical Review D (IF 4.4): **98**

Journal of High Energy Physics (IF 5.8): **80**

European Physical Journal C (IF 4.8): **53**

Physics Letters B (IF 4.2): **39**

Physical Review Letters (IF 9.2): **27**

SEE FULL LIST OF ARTICLES ON PAGE 64

365 Presentations at national and international conferences

13 Severo Ochoa Colloquia

82 Seminars

5. TRAINING

TEACHING ACTIVITIES

The members of IFIC with positions at the University of Valencia are mainly involved in its Degree in Physics, although they also teach in Chemistry and Engineering. At the postgraduate level, IFIC participates in two of the Master's Degrees offered by the UVEG: Master in Advanced Physics and Master in Medical Physics. In the 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).

16 PhD Theses

10 Experimental

6 Theoretical

17 Master's Final Projects

6 Experimental

11 Theoretical

PHD THESES

Experimental Physics

Development of direct measurement techniques for the in-situ internal alignment of accelerating structures
Natalia Galindo Muñoz
Advisors: Ángeles Faus Golfe, Vicente Enrique Boria Esbert
13 March, Polytechnic University of Valencia
TESEO: 440070

Measurement of the Higgs boson coupling with tau leptons and search for an additional neutral MSSM Higgs boson with the ATLAS detector
Damián Álvarez Piqueras
Advisor: Luca Fiorini
7 May, University of Valencia
TESEO: 1647045

Isospin mixing and in-beam study of non-yrast states in 56Co
Ana Montaner Pizá
Advisor: Berta Rubio Barroso
22 May, University of Valencia
TESEO: 1660362

Search for cosmic sources in neutrino telescopes and time calibration in the ANTARES neutrino telescope
Javier Barrios Martí
Advisors: Juan Zúñiga Román, Juan de Dios Zornoza Gómez
19 June, University of Valencia
TESEO: 1679157

The NEXT path to neutrino inverse hierarchy
Javier Ignacio Muñoz Vidal
Advisor: Juan José Gómez Cadenas
25 June, University of Valencia
TESEO: 1670919

Measurement of the mixing-induced and CP-violating parameters of Bs -> phi gamma decays at LHCb
Carlos Sanchez Mayordomo
Advisor: María Aránzazu Oyanguren Campos
2 July, University of Valencia
TESEO: 1686345

ATLAS Inner Detector alignment and analysis of the Wtb vertex structure with single top quarks
Javier Jiménez Peña
Advisor: Salvador Martí García
5 October, University of Valencia
TESEO: 1716741

Measurement of the top quark mass using ttbar+1 jet events in the ATLAS Experiment at the LHC
Davide Melini
Advisors: Roberto Pittau, Juan Fuster Verdú
23 November, University of Granada
TESEO: 1715415

Measurement of Higgs boson properties in the diphoton decay channel and a search for di-Higgs production in the gamma gamma b anti-b final state with the ATLAS detector
Leonor Cerdá Alberich
Advisors: Luca Fiorini, Carlos Solans Sánchez
23 November, University of Valencia
TESEO: 1726626

Search for new physics in single-top-quark production with the ATLAS detector at the LHC
Laura Barranco Navarro
Advisors: María José Costa, José E. García Navarro
29 November, University of Valencia
TESEO: 1724538

Theoretical Physics

A glimpse of heavy scales through the electroweak resonance theory
Joaquín Santos Blasco
Advisor: Antonio Pich Zardoya
8 June, University of Valencia
TESEO: 1663767

On the Nature of Dark Matter: Phenomenological and Cosmological Probes
Miguel Escudero Abenza
Advisors: Nuria Rius Dionis, Olga Mena Requejo
13 July, University of Valencia
TESEO: 1695579

Quantum aspects originated by Gravitation: from Cosmology to Astrophysics
Adrián del Río Vega
Advisors: José Navarro Salas, Iván Agulló Ródenas
17 July, University of Valencia
TESEO: 1686855

Precision physics in hadronic tau decays
Antonio Rodríguez Sánchez
Advisors: Antonio Pich Zardoya, Martín Gónzalez Alonso
2 October, University of Valencia
TESEO: 1716291

Neutrino physics from cosmological observables and oscillation experiments
Pablo Fernández de Salas
Advisor: Sergio Pastor Carpi
5 October, University of Valencia
TESEO: 1715931

Phenomenology of Quasi-Dirac neutrinos and a study of high-dimensional neutrino masses
Gaetana Anamiati
Advisor: Martin Hirsch
3 December, University of Valencia
TESEO: 1729431

MASTER'S FINAL PROJECTS

Experimental Physics

Estudi de la resolució espacal en un telescopi Compton per a la monitorització de la teràpia hadrònica
Marina Borja Lloret
Advisors: Gabriela Llosá Llácer, Josep F. Oliver Guillén, Ana Ros García

ProtoDUNE T-gradient development and calibration
Miguel Ángel García Peris
Advisors: Anselmo Cervera Villanueva, Alexander Izmaylov

Analysis of jet substructure tools for a top-quark mass measurement
Ricardo González López
Advisors: Marcel Vos, Esteban Fullana Torregrosa

Prospects for search of invisible particles produced in association with single-top quarks using a multivariate analysis in proton-proton collisions at √14 TeV with the ATLAS detector at the HL-LHC
Josep Navarro González
Advisors: Salvador Martí García, Carlos Escobar Ibáñez

Exploration on new methods to measure the top quark mass at 13 TeV in LHC
Alberto Prades Ibáñez
Advisors: Joan Fuster Verdú, Marcel Vos

Background studies for double beta decay searches with the NEXT detector at the LSC
Alberto Usón Andrés
Advisors: Michel Sorel, Pau Novella

Theoretical Physics

An open quantum system coupled to an open environment
Andreu Anglés Castillo
Advisors: Armando Pérez, Inés de Vega, M. Carmen Bañuls

Pair creation by electric fields and gravity: adiabatic renormalization
Pau Beltrán Palau
Advisor: José Navarro Salas

Momento anómalo del muón con leptoquarks
Gonzalo Juan García-Pertierra Moreno
Advisor: Nuria Rius Dionis

Superprojective embeddings of extended supersymmetry
Adriana Guerrero Menkara
Advisor: Mª Antonia Lledó

Estudi de les representacions unitàries irreduïbles dels grups de Poincaré i Galilei
Jordi Llusar Camarelles
Advisor: Mª Antonia Lledó

Modelos de dos dobletes de Higgs. Estudio de modelos left y right
Guillermo López Comazzi
Advisor: Francisco J. Botella Olcina

Compact objects oscillations and new physics beyond General Relativity
Andreu Sales Masó Ferrando
Advisor: Gonzalo Olmo

In search of SUSY
Marcos Miralles López
Advisor: Óscar Vives García

The Standard Model scalar sector and beyond
Kevin Monsálvez Pozo
Advisor: Antonio Pich Zardoya

A motivated completion of the Standard Model: axions, right-handed neutrinos and vacuum stability
Andrés Pérez Bernabeu
Advisor: Pilar Hernández Gamazo

Aspects of QCD in the Large N_c limit using Lattice Field Theory
Joan Prats Climent
Advisor: Pilar Hernández Gamazo

TECHNICAL TRAINING

The members of IFIC have trained 12 students from technical areas such as Electronic Engineering or Industrial Engineering during 2018, through a fruitful colaboration with ADEIT, the University–Business Foundation of the University of Valencia. Moreover, 10 young technicians under 25 have worked at IFIC in 2018 within 'Garantia Juvenil' programme.

6. CONFERENCES, SEMINARS AND COLLOQUIA

CONFERENCES AND MEETINGS

IFIC researchers present their results in the main international conferences and workshops. A total of 365 contributions were presented in 2018: 336 talks (74 invited) and 29 posters.

Here we highlight conferences and workshops organized by IFIC members in Valencia or elsewhere:

PARTICLEFACE 2018. Working Group Meeting and MC Meeting of the COST Action CA16201. 26-28 February. Valencia.

8th International Doctorate Network in Particle Physics, Astrophysics and Cosmology (IDPASC School). 21-31 May. Valencia.

II Jornadas RSEF / IFIMED de Física Médica. 14-15 June. Madrid.

Forum on Tracking Detector Mechanics. 25-27 June. Valencia.

3rd Workshop of the Nuclear Spectroscopy Instrumentation Network of ENSAR2 (NuSpIn), NUSPIN 2018. 25-29 June. Valencia.

89th LHCb Week. 3-7 September. Valencia.

BALATON2018 - Feynman Memorial Meeting, organized by the COST Action PARTICLEFACE. 16-19 September. Balatonfüred.

PARTICLEFACE: Case studies of analytical and numerical methods of multiloop calculations for future e+e- colliders. 1-5 October. Katowice, Poland.

3rd CANTATA COST Action Meeting (CA15117). 1-3 October. Valencia.

FUture Gravitational Alternatives (FUGA) meeting. 3-4 October. Valencia.

H2020 Oscillation physics Workshop. 28-29 November. Valencia.

2nd Valencia Winter Workshop on Theoretical Physics. 11-14 December. Valencia.

The quest for new physics. 12-14 December. Valencia.

IFIC COLLOQUIA

The colloquium series "Severo Ochoa" brings the world leading experts to Valencia to present a vision of their area of science. 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. Organisers: Germán Rodrigo, Mariam Tórtola and Marcel Vos.

John Ellis, *"Is there life after Higgs?"*. February, 15th.

Jo van de Brand, *"Gravitational waves: Physics at the Extreme"*. March, 1st.

Jenny List, *"Physics at future e+e- colliders"*. March, 22th.

Gabriel Martínez-Pinedo, *"Kilonova: an electromagnetic signal of heavy element nucleosynthesis"*. May, 10th.

Jorge Velasco, *"Horizon Europa, el futuro Programa Marco de I+I de la UE (2021-2027)"*. May, 17th.

Luis Alvarez Gaumé, *"Revisiting Goldstone's Theorem"*. May, 30th.

Barry Barish, *"Gravitational Waves: Detectors, Detections and the Future"*. July, 4th.

Katherine Freese, *"Dark Matter in the Universe"*. September, 28th.

Takaaki Kajita, *"The neutrino program in Japan"*. October, 8th.

Kate Scholberg, *"Observation of coherent elastic neutrino-nucleus scattering by COHERENT"*. October, 19th.

Gustavo Stolovitzky, *"Crowdsourcing Big Data Problems in Biomedicine: Leveraging Communities as Innovation Engines"*. November, 8th.

Gerard 't Hooft, *"The quantum black hole as a theoretical laboratory"*. November, 14th.

Jie Gao *"The CEPC Project and Chinese Science, R & D Investment , Education and Human Resources"*. November, 29th.

In 2018, IFIC organized 13 colloquia with leading world experts, including three Nobel laureates

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 2018 we hosted a total of 82 seminars (some of them webinars). The complete list can be found at the IFIC's Indico webpage. Organiser: Andrea Donini

7. TECHNOLOGY TRANSFER

Concerning innovation and technology transfer, one of the most relevant events in 2018 was the signature of the agreement between the Agència Valenciana de la Innovació (AVI) and the University of Valencia to establish at IFIC a so-called UCIE, a Scientific Unit for Entrepreneurial Innovation (Unidad Científica de Innovación Empresarial). The UCIEs are a new structure devised and funded by AVI to foster innovation and technology transfer in the research institutes of the Comunitat Valenciana. These structures are embedded into the corresponding research institute and aim to identify and support the development of those scientific and technological skills of the institute that may give rise to knowledge transfer to the productive sector. This is a most useful idea for IFIC, where encouraging and nurturing new innovative ideas to be transferred to the corporate sector was badly needed.

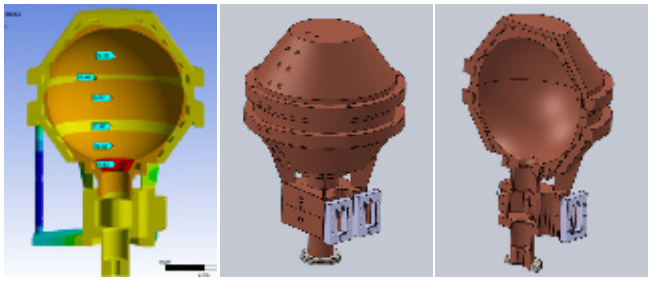
IFIC's UCIE has a very simple structure. It consists of three levels. Level 1 is basically IFIC's directorate and it is led by IFIC's Director himself. Level 2 is composed of an UCIE Coordinator, at present IFIC's Technology and Innovation Deputy Director, an Innovation Responsible providing consulting services and a Committee of Follow-up and Survey, composed of members of AVI, UV and IFIC. Level 3 is composed by the principal investigators of the projects funded by the UCIE. The concept is that the UCIE will help to take off new interesting initiatives, which after a certain period will obtain funding from sources different from the UCIE.

In the future, we plan to design through the UCIE an ambitious innovation plan for IFIC based on a sound analysis of the institute's capacities and skills. During 2018, five innovation activities were identified, evaluated and awarded a preliminary funding: HGRF, NOTAC, LARAM, BioLight and PlanarHealth. Their progress during 2018 is summarised below.

HGRF. An S-band High gradient RF facility to perform R&D in normal-conducting RF technology for accelerators (mainly linear accelerators for medical physics and hadron-therapy) is under construction by the High Gradient Radio Frequency (HGRF) group at IFIC. The major equipments (klystrons and modulators) have been installed in the laboratory and the first tests without power have been successfully performed. The outcome of this R&D project can be crucial to make more compact linear accelerators, resulting in lower cost and size, which can have a potential impact in several applications: hadrontherapy facilities based on linear accelerators, which will be emphasized in this project due to its advantageous features; industrial applications such as cargo scanning; or scientific applications such as free-electron lasers and Compton sources.

Currently the necessary steps to adapt the facility in order to perform the full power tests are in progress, i.e. radiation protection, data acquisition and interlock systems, and auxiliary systems. The shakedown of the facility and the first tests with an accelerator RF cavity are foreseen for 2019.

Also the High Gradient RF group has finished the mechanical and thermal design of a RF pulse compressor and has started the electromagnetic design of a new RF pulse compressor that, once fabricated, could be used in the future in the test facility. In parallel, with the goal of developing and building high frequency, high power and ultra-high vacuum components for particle accelerators, the group has started the procurement of materials and the fabrication of the first prototypes of RF wave guide components for 3 GHz in collaboration with a Valencian company. New designs, materials and fabrication processes will be studied in the future for this purpose.



NOTAC. This project aims at a three-dimensional reconstruction of the patient for treatment and follow-up of therapies, using techniques associated with the improvement of conventional X-ray devices.

Innovative aspects of the project include the use of convolutional neural network techniques for 3D image reconstruction and its transfer to the clinical setting. Progress thus far has already demonstrated the technique's capability to reduce patient doses and operation costs of Radiology Rooms. Despite the fact that the activities carried out during 2018 have been mainly preparatory, the project already counts with most of the electronic and computing equipment needed. In addition, image samples of pathological clinical cases have been obtained, and their data sources have been validated.

LARAM. The activities of the Environmental Radioactivity Laboratory (LARAM) included the international project TRITIUM: design, construction and tuning of automatic sensors for real-time monitoring of low radioactive levels of tritium in nuclear power plants waters (CEE Interreg SUDOE - SOE1/P4/E0214). Regarding contracts and agreements with institutions, the LARAM obtained a contract with the Generalitat Valenciana for the quality control of the Environmental Radiological Surveillance Plan (PVRA) of the Cofrentes nuclear power plant; an agreement with the Generalitat Valenciana for the development of the Radiological and Nuclear Emergency Plan of the Comunidad Valenciana; and an agreement with the Spanish Nuclear Safety Council (CSN) for the REM program (Measurement of the radioactive content of environmental samples, including typical diet). Moreover, the LARAM obtained a contract with Iberdrola Company for the measurement of radon gas in several facilities around Spain.

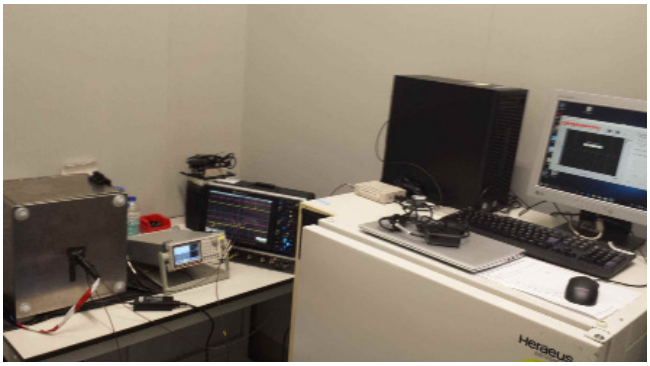
LARAM participates in the international project TRITIUM: Design, construction and tuning of sensors for monitoring levels of tritium in nuclear plants waters

BioLight. The work by IFIC's IRIS group in BioLight has focused on building and testing an experimental setup for the detection of low light levels from biological samples. Different types of experiments have been carried out and the system has been able to detect light emitted by living samples both spontaneously and when stimulated with light emitted by LEDs or with chemical substances (hydrogen peroxide and 2,4-Dinitrophenol).

PlanarHealth. Most potentially useful drugs for brain treatment cannot be used because their molecules cannot cross the Blood Brain Barrier (BBB). This project aims to assess the traversal of the BBB by medically-loaded specific nanoparticles. The nanoparticles are designed specifically to carry drugs, to go through the BBB and to deliver the payload to the brain. The activities in 2018 by the IRIS group have concentrated on the start-up of the experiments. The tests carried out within PlanarHealth have enabled the possibility of imaging nanoparticles with the microPET/CT scanner available at IFIC-IFIMED and the laboratory is ready to perform such tests.

Some technology transfer activities at IFIC have also been carried outside the UCIE framework. The IRIS group has developed a data acquisition system capable of operating different types of detectors (silicon photomultipliers, PMTs, silicon detectors of different types, and others) and has protected it with a utility model. In 2018, the activities to transfer the device to the company Alibava Systems S.L. for its commercialization have started. These activities are funded through a 'Valoritza and Transfereix' project from the University of Valencia.

IRIS group also develops innovative detectors for medical applications, and has submitted a patent application of a system capable of reducing the noise in Compton cameras for hadron therapy treatment monitoring.



8. YOUNG RESEARCHERS, GENDER AND DIVERSITY

The Office for Young Researchers, Gender and Diversity (JIGD), created in 2017 with the aims of ensuring equal opportunities, facilitating related information to researchers at IFIC and acting as liason with the IFIC managament on issues related to these topics, has prepared several activities in 2018. In February, on the occasion of the International Day of Women and Girls in Science, it organized the projection of the film *"Hidden Figures"*, which describes the role of a group of black women in the NASA program in the 60s. The projection was open to family and friends of IFIC members. A discussion on the film was also held after the projection.

For the International Day of Women and Girls, in March, IFIC participated in the 2nd Day of the Female Researcher, where several female scientistis, including some of IFIC, shared their experience as such. A round table followed, with the participation of the speakers and some relevant players on the topic, including Arantza Oyanguren, member of the JIGD Office and the subdirector of IFIC, Santiago Noguera. Another activity organized on the occasion of March 11th was the talk by Pilar Hernández on her research field.

2nd Day of the Female Researcher.

On the front of young researchers, a seminar on mental health in academia was organized. Two talks (*"A mental health perspective in Spain: an unknown emerging problem"*, by Mª Emilia Rodríguez, psychiatrist, and *"Mental health in academia: a graduate student perspective"*, by Andrea J. Welsh, physics graduate assistant at the Georgia Institute of Technology) were held and a debate on the topic followed.

Finally, the JIGD also supported the organization by CSIC of a day on employability in November, where Manuel Castellano gave a talk with the title *"Professional careers for researchers beyond the academic world"*.

Seminar on mental health in academia.

The Office for Young Researchers, Gender and Diversity supported the organization by CSIC of a day on employability

9. FUNDING

In this section we include all research grants that were active during the whole or part of 2018, funded by European Union (EU), national (NP), regional (CCAA) or other agencies.

3,1 million in 40 new projects

obtained in 2018

14 National projects / 1,5 million

4 European projects / 0,7 m.

9 Regional projects / 0,4 m.

5 Technolgy Transfer projects / 0,3 m.

Recruitment funds obtained in 2018: 465,733 €

Sources:

Other: 172,300 €

National Plan: 171,000 €

Regional: 122,433 €

NATIONAL PLAN PROJECTS

Experimental Physics (New)

Experimentos de estructura Nuclear y Astrofísica con haces radioactivos y neutrones y aplicaciones
Ref. FPA2017-83946-C2-1-P
PI: José Luis Taín Enríquez
217,800 € (Jan 2018 – Dec 2019)

Estudios contemporáneos teóricos y experimentales de estructura nuclear, construcción y I+D instrumentales para AGATA, un instrumento para Hispec/Fair
Ref. FPA-2017-84756-C4-1-P
PI: Andrés Gadea
121,000 € (Jan 2018 – Dec 2020)

Búsqueda de nueva física con sabor con el experimento LHCb del CERN
Ref. FPA2017-85140-C3-3-P
PI: María Aranzazu Oyanguren Campos
229,900 € (Jan 2018 – Dec 2019)

Maquinaria CNC para el taller de fabricación del IFIC
Ref. EQC2018-004677-P
PI: María José Costa Mezquita
464,189 €

Experimental Physics (Underway)

Detectores nobles para busquedas de violación de los numeros bariónico y leptónico
Ref. FPA2017-82081-ERC
PI: Michel Sorel
68,181€ (Jan 2017 – Nov 2018)

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)

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)

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)

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

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

Red Española de Física del Sabor
Ref. FPA2016-81784-REDt
PI: Arantza Oyanguren
20,000 € (Jan 2017 – Jun 2019)

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)

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 (New)

Teorías efectivas en física nuclear y de hadrones
Ref. FIS2017-84038-C2-1-P
PI: Juan Nieves Pamplona
102,850€ (Jan 2018 – Dec 2020)

Física de Partículas en el LHC y las factorías de sabor
Ref. FPA2017-84445-P
PI: Antonio Pich Zardoya
217,800 € (Jan 2018 – Dec 2020)

Física Nuclear y de hadrones a energías intermedias
Ref. FIS2017-84038-C2-2-P
PI: Manuel Vicente Vacas
72,600 € (Jan 2018 – Dec 2020)

Partículas elementales: El Modelo Estándar y sus extensiones
Ref. FPA2017-84543-P
PI: Óscar Manuel Vives
193,600 € (Jan 2018 – Dec 2020)

Astropartículas y física de altas energías
Ref. FPA2017-85216-P
PI: Jose Furtado Valle
127,050 € (Jan 2018 – Dec 2020)

Sabor y Origen de la materia
Ref. FPA2017-85985-P
PI: Pilar Hernández Gamazo
157,300 € (Jan 2018 – Dec 2020)

Campos cuánticos y gravitación
Ref. FIS2017-84440-C2-1-P
PI: Gonzalo Olmo Alba
60,500 € (Jan 2018 – Dec 2020)

Gravedad, Quiralidad de fotones y emisión estimulada
Ref. FIS2017-91161-EXP
PI: José Navarro Salas
36,300 € (Jan 2018 – Jun 2020)

Investigación de técnicas Compton para aplicaciones médicas
Ref: FPA2017-85611-R
PI: José Bernabéu Alberola
60,500 € (Dec 2018 – Dec 2020)

Redes de Excelencia
Ref: FPA-2017-90687-REDC
PI: Antonio Pich Zardoya
30,000 € (Dec 2018 – Dec 2020)

Theoretical Physics (Underway)

Red nacional Temática de Astropartículas
Ref. FPA2015-68786-REDT
PI: Sergio Pastor Carpi
35,000 € (Dec 2015 – Nov 2018)

Red Española de Relatividad y gravitación
Ref. FIS2016-81770-REDT
PI: Gonzalo Olmo Alba
18,500 € (Jan 2017 – Jun 2019)

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 (NEW)

CompactLight
Ref. 777431
PI: Juan A. Fuster Verdú
80,000 € (Jan 2018 – Dec 2020)

ENCORE
Ref. 796941
Fellow: Stefano Gariazzo
IFIC PI: Sergio Pastor Carpi
158,121 € (April 2018 – March 2020)

A positron emission tomography apparatus based on liquid xenon with time of flight applications - PETALO
Ref. 757829
PI: Anselmo Cervera
224,856 € (July 2018 – June 2023)

A positron emission tomography apparatus based on liquid xenon with time of flight applications - PETALO
ERC-2017-STG 757829
PI: Pilar Hernández Gamazo
306,250 € (July 2018 – June 2023)

EUROPEAN PROJECTS (UNDERWAY)

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. 675265
IFIC PI: Juan Fuster Verdú
247,872.96 € (Feb 2016 – Jan 2020)

INVISIBLESPLUS
Ref. 690575
IFIC PI: Pilar Hernández Gamazo
198,500 € (Feb 2016 – Jan 2020)

ELUSIVES
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)

Developing new world-class research infrastructures Astroparticle and Oscillations Research with Cosmics in the Abyss (ARCA and ORCA)
Ref: 739560
IFIC PI: Juan de Dios Zornoza Gómez
251,250 € (Jan 2017 – Dec 2019)

Commissioning, first tests and upgrade of a high-power S-Band Radio Frequency (RF) sustem for +D of high-gradient normal- accelerating cavities in breakdown science and RF conditioning - HGRF
Ref. 750871
PI: Daniel Esperante
170,121.60 € (May 2017 – May 2019)

Molecule for low diffusion TPCs for rare event searches - MELODIC
Ref. 740055
PI: Neus López March
159,126 € (Sep 2017 – Sep 2019)

Unraveled new physics at the LHC through the precision frontier
Ref. CA16201
PI: Germán Rodrigo García
560,000 € (Oct 2017 – Sep 2021)

REGIONAL PROJECTS (NEW)

Infraestructuras y Equipamiento. Machine learning y big data en física de partículas y sus aplicaciones a los retos de la sociedad
Ref. IDIFEDER/2018/048
PI: Juan José Hernández Rey
999,860 € (Jan 2018 – Oct 2020)

Astroparticulas y física de Altas Energías
Ref. PROMETEO/2018/165
PI: Mariam Tórtola Baixauli
336,597 € (Jan 2018 – Dec 2021)

Física de precisión a altas energías: el LHC y futuros colisionadores
Ref. PROMETEO/2018/060
PI: Juan Fuster Verdú
252,960 € (Jan 2018 – Dec 2021)

Búsqueda de Nueva Física a través del Sabor
Ref. SEJI/2018/033
PI: Avelino José Vicente Montesinos
208,167 € (Jan 2018 – Dec 2020)

Sistema de Adquisición de datos multidetector
Ref. UV-INV-PROVAL17-720859
PI: Gabriela Llosá Llácer
44,873 € (Sep 2018 – Sep 2019)

Organización de Congresos
Ref. AORG/2018/034
PI: Fernando Martínez Vidal
8,962 € (Jan 2018 – Dec 2018)

Organización de Congresos
Ref. AORG/2018/112
PI: Germán Rodrigo García
8,400 € (Jan 2018 – Dec 2018)

Estancias de investigadores en centros fuera de la Comunidad Valenciana (Suiza)
Ref. BEST/2018/036
PI: Santiago González de la Hoz
6,600 € (Jan 2018 – Dec 2018)

Estancias de investigadores en centros fuera de la Comunidad Valenciana (Reino Unido)
Ref. BEFPI/2018/079
PI: Faubel Alama, Carlos
5,000 € (Jan 2018 – Dec 2018)

REGIONAL PROJECTS (UNDERWAY)

Desarrollo de nuevas tecnologías basadas en el

xenón
Ref. PROMETEO/2016/120
PI: Juan José Gómez Cadenas
300,375 € (Jan 2016 – Dec 2019)

Precise phenomenology in the LHC ERA
Ref. SEJI/2017/019
PI: Francisco Campanario Pallas
182,156.80 € (Jan 2017 – Dec 2019)

Aspectos Teóricos y observacionales de la estructura geométrica del Espacio Tiempo
Ref. SEJI/2017/042
PI: Gonzalo Olmo Alba
182,044.50 € (Jan 2017 – Dec 2019)

Aprendizaje profundo en análisis de detectores en física
Ref. SEJI/2017/011
PI: Joshua Edward Renner
207,568.40 € (Jan 2017 – Dec 2019)

Nuevas interacciones en la frontera de altas energías
Ref. PROMETEO/2017/053
PI: Antonio Pich Zardoya
392,000 € (Nov 2017 – Oct 2021)

De la física del LHC a las claves del universo primordial en la era de los datos
Ref. PROMETEO/2017/033
PI: Gabriela Barenboim Szuchman
381,625 € (Nov 2017 – Oct 2021)

OTHER PROJECTS (NEW)

Apoyo a la Creación de una Unidad Científica de innovación Empresarial en el Instituto de Física Corpuscular
Ref. '201850E066
PI: Juan Fuster Verdú
144,000 € (May 2018 – April 2021)

Parity violations and metric-affine gravity
Ref. I-LINK1215
PI: Gonzalo Olmo Alba
20,000 € (Jan 2018 – Dec 2019)

Geometry and Quantum Simulation
Ref. PICS2017
PI: Armando Pérez Cañellas
10,000 € (March 2018 – Dec 2020)

Accelerating the Search of Dark Matter with Machine Learning
Ref. PIE
PI: Roberto Ruiz de Austri Bazán
5,000 €

Búsqueda de nueva física en el sector del quark top
Ref. PIE
PI: José Enrique Navarro García
5,000 €

Interacciones elecrodébiles en nucleones y núcleos
Ref. PIE
PI: Luis Álvarez Ruso
5,000 €

Becas Iberoamérica Santander Investigación
Ref. S2018C0008
PI: Ricardo Cepelledo Pérez
4,790 €

Becas Iberoamérica Santander Investigación
Ref. S2017C0003
PI: Valentina De Romeri
4,820 € (Jan 2018 – Dec 2018)

OTHER PROJECTS (UNDERWAY)

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)

Particle Physics at the LHC in the crossroad
Ref. 2017 50 E021
PI: Germán Rodrigo García
113,871 € (Jan 2017 – Dec 2019)

Desarrollo y estudio de elementos de reconocimiento de entorno de detectores
Ref. 201750E024
PI: Francisco José Botella Olcina
39,476.47 € (Jan 2017 – Dec 2018)

Impulso a las nuevas fases de los experimentos del IFIC (ATLAS upgrade, Km3NeT Fase 2,0, NEXT 100, DUNE, IFIMED)
Ref. 2017050E070
PI: María José Costa Mezquita
130,200 € (Jan 2017 – Jun 2020)

Descifrando la asimetría materia-antimateria del universo con oscilaciones de neutrinos
PI: María Amparo Tórtola Baixauli
15,000 € (Jan 2018 – Dec 2018)

Desarrollo de instrumentación avanzada para me-

didas de reacciones nucleares de interés astrofísico
Ref. 201750I026
PI: César Domingo Pardo
5,000 € (Dec 2017 – Nov 2018)

Participación en los experimentos DUNE y NEXT
Ref. 201750I093
PI: Michel Sorel
5,000 € (Dec 2017 – Nov 2018)

TECHNOLOGY TRANSFER (NEW)

Creación de una Unidad Científica de Innovación Empresarial en el IFIC
Ref. 20180228
PIs: Juan José Hernández Rey y Juan Fuster Verdú
250,000 € (Jan 2018 – Dec 2018)

Study potential upgrades for the high-gradient S-band test facility
Ref. 20185988
PI: Juan Fuster Verdú
166,000 € (June 2018 – June 2020)

Ensamblado y protección de chips sobre 160 tarjetas electrónicas
PI: Santiago Noguera Puchol
12,480 € (April 2018 – May 2018)

Contrato licencia exclusiva de software "predicciones para el sector eléctrico"
Ref. 20162171
PI: Francisco Albiol Colomer
9,779,93 € (Jan 2018 – Dec 2018)

Breaking Bad
PI: Francisco Albiol Colomer
6,050 € (Jan 2018 – Dec 2018)

TECHNOLOGY TRANSFER (UNDERWAY)

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)

Development of accelerator science and technologies associated with the CLIC accelerating structures design
Ref. 20158278
PI: Juan Fuster Verdú
526,880 € (Jan 2015 – Mar 2018)

Contrato de Apoyo tecnológico entre el CSIC e IST "FACIEM-3D"
Ref. 20177060
PI: Francisco Albiol Colomer
23,437.70 € (Jan 2017 – Dec 2019)

ANNEX: PUBLICATIONS

EXPERIMENTAL PHYSICS

AGATA Collaboration

IFIC authors: Gadea, A.

Quadrupole collectivity in Ca-42 from low-energy Coulomb excitation with AGATA, Phys. Rev. C 97, 024326 - 20pp
DOI: http://dx.doi.org/10.1103/PhysRevC.97.024326

High-spin structure in the transitional nucleus Xe-131: Competitive neutron and proton alignment in the vicinity of the N=82 shell closure, Phys. Rev. C 98, 014309 - 19pp
DOI: http://dx.doi.org/10.1103/PhysRevC.98.014309

Study of isomeric states in Pb-198, Pb-200, Pb-202, Pb-206 and Hg-206 populated in fragmentation reactions, J. Phys. G 45, 035105 - 27pp
DOI: http://dx.doi.org/10.1088/1361-6471/aaa9df

ANTARES Collaboration

IFIC authors: Barrios-Marti, J.; Coleiro, A.; Colomer, M.; Hernandez-Rey, J.J.; Illuminati, G.; Khan-Chowdhury, N.R.; Lotze, M.; Tönnis, C.; Zornoza, J.D.; Zuñiga, J.

The search for neutrinos from TXS 0506+056 with the ANTARES telescope, Astrophys. J. Lett. 863, L30 - 6pp
DOI: http://dx.doi.org/10.3847/2041-8213/aad8c0
http://arxiv.org/abs/1807.04309

The cosmic ray shadow of the Moon observed with the ANTARES neutrino telescope, Eur. Phys. J. C 78, 1006 - 9pp
DOI: http://dx.doi.org/10.1140/epjc/s10052-018-6451-3
http://arxiv.org/abs/1807.11815

Long-term monitoring of the ANTARES optical module efficiencies using K-40 decays in sea water, Eur. Phys. J. C 78, 669 - 8pp
DOI: http://dx.doi.org/10.1140/epjc/s10052-018-6132-2
http://arxiv.org/abs/1805.08675

All-flavor Search for a Diffuse Flux of Cosmic Neutrinos with Nine Years of ANTARES Data, Astrophys. J. Lett. 853, L7 - 5pp
DOI: http://dx.doi.org/10.3847/2041-8213/aaa4f6
http://arxiv.org/abs/1711.07212

The Survey for Pulsars and Extragalactic Radio Bursts – II. New FRB discoveries and their follow-up, Mon. Not. Roy. Astron. Soc. 475, 1427-1446
DOI: http://dx.doi.org/10.1093/mnras/stx3074
http://arxiv.org/abs/1711.08110

ANTARES and IceCube Collaboration

IFIC authors: Barrios-Marti, J.; Coleiro, A.; Colomer, M.; Hernandez-Rey, J.J.; Illuminati, G.; Khan-Chowdhury, N.R.; Lotze, M.; Zornoza, J.D.; Zuñiga, J.

Joint Constraints on Galactic Diffuse Neutrino Emission from the ANTARES and IceCube Neutrino Telescopes, Astrophys. J. Lett. 868, L20 - 7pp
DOI: http://dx.doi.org/10.3847/2041-8213/aaeecf
http://arxiv.org/abs/1808.03531

ATLAS Collaboration

IFIC authors: Alvarez Piqueras, D.; Aparisi Pozo, J.A.; Bailey, A.J.; Barranco Navarro, L.; Cabrera Urban, S.; S.; Carrio Argos, F.; Castillo, F.L.; Castillo Gimenez, V.; Cerda Alberich, L.; Costa, M.J.; Escobar, C.; Estrada Pastor, O.; Fernandez Martinez, P.; Ferrer, A.; Fiorini, L.; Fullana Torregrosa, E.; Fuster, J.; Garcia, C.; Garcia Navarro, J.E.; Gonzalez de la Hoz, S.; Higon-Rodriguez, E.; Jimenez Pena, J.; King, M.; Lacasta, C.; Lozano Bahilo, J.J.; Madaffari, D.; Mamuzic, J.; Marti-Garcia, S.; Melini, D.; Miñano, M.; Mitsou, V.A.; Pedraza Lopez, S.; Rodriguez Bosca, S.; Rodriguez Rodriguez, D.; Romero Adam, E; Ruiz-Martinez, A.; Salt, J.; Santra, A.; Sanchez Martinez, V.; Soldevila, U.; Sanchez, J.; Valero, A.; Valls Ferrer, J.A.; Vos, M.

Search for charged Higgs bosons decaying via H-+/- -> tau(+/-)nu(tau) in the tau plus jets and tau plus lepton final states with 36 fb(-1) of pp collision data recorded at root s=13 TeV with the ATLAS experiment, J. High Energy Phys. 9, 139 - 48pp
DOI: http://dx.doi.org/10.1007/JHEP09(2018)139
http://arxiv.org/abs/1807.07915

Prompt and non-prompt J/psi elliptic flow in Pb plus Pb collisions at root S-NN=5.02 TeV with the ATLAS detector, Eur. Phys. J. C 78, 784 - 23pp
DOI: http://dx.doi.org/10.1140/epjc/s10052-018-6243-9
http://arxiv.org/abs/1807.05198

Measurement of the azimuthal anisotropy of charged particles produced in root s NN=5.02 TeV Pb+ Pb collisions with the ATLAS detector, Eur. Phys. J. C 78, 997 - 35pp,
DOI: http://dx.doi.org/10.1140/epjc/s10052-018-6468-7
http://arxiv.org/abs/1808.03951

Search for the Higgs boson produced in association with a vector boson and decaying into two spin-zero particles in the H -> aa -> 4b channel in pp collisions at root s=13 TeV with the ATLAS detector, J. High Energy Phys. 10, 031 - 48pp
DOI: http://dx.doi.org/10.1007/JHEP10(2018)031
http://arxiv.org/abs/1806.07355

Search for Higgs boson pair production in the gamma gamma b(b)over-bar final state with 13 TeV pp collision data collected by the ATLAS experiment, J. High Energy Phys. 11, 040 - 44pp
DOI: http://dx.doi.org/10.1007/JHEP11(2018)040
http://arxiv.org/abs/1807.04873

Search for charged Higgs bosons decaying into top and bottom quarks at root s=13 TeV with the ATLAS detector, J. High Energy Phys. 11, 085 - 55pp
DOI: http://dx.doi.org/10.1007/JHEP11(2018)085
http://arxiv.org/abs/1808.03599

Search for new phenomena in events with same-charge leptons and b-jets in pp collisions at >=13 TeV with the ATLAS detector, J. High Energy Phys. 12, 039 - 56pp
DOI: http://dx.doi.org/10.1007/JHEP12(2018)039
http://arxiv.org/abs/1807.11883

Measurement of the Z gamma ->nu nu gamma production cross section in pp collisions at root s=13 TeV with the ATLAS detector and limits on anomalous triple gauge-boson couplings, J. High Energy Phys. 12, 010 - 42pp
DOI: http://dx.doi.org/10.1007/JHEP12(2018)010
https://arxiv.org/abs/1810.04995

Search for Higgs bosons produced via vector-boson fusion and decaying into bottom quark pairs in root s=13 TeV pp collisions with the ATLAS detector, Phys. Rev. D 98, 052003 - 29pp
DOI: http://dx.doi.org/10.1103/PhysRevD.98.052003
http://arxiv.org/abs/1807.08639

Combination of searches for heavy resonances decaying into bosonic and leptonic final states using 36 fb(-1) of proton-proton collision data at root s=13 TeV with the ATLAS detector, Phys. Rev. D 98, 052008 - 32pp ,
DOI: http://dx.doi.org/10.1103/PhysRevD.98.052008
http://arxiv.org/abs/1808.02380

Search for pair and single production of vectorlike quarks in final states with at least one Z boson decaying into a pair of electrons or muons in pp collision data collected with the ATLAS detector at root s=13 TeV, Phys. Rev. D 98, 112010 - 53pp
DOI: http://dx.doi.org/10.1103/PhysRevD.98.112010
http://arxiv.org/abs/1806.10555

Search for Resonant and Nonresonant Higgs Boson Pair Production in the b(b)over-bar tau(+) tau(-) Decay Channel in pp Collisions at root s=13 TeV with the ATLAS Detector, Phys. Rev. Lett. 121, 191801 - 24pp
DOI: http://dx.doi.org/10.1103/PhysRevLett.121.191801
http://arxiv.org/abs/1808.00336

Combination of the Searches for Pair-Produced Vectorlike Partners of the Third-Generation Quarks at root s=13 TeV with the ATLAS Detector, Phys. Rev. Lett. 121, 211801 - 20pp
DOI: http://dx.doi.org/10.1103/PhysRevLett.121.211801
http://arxiv.org/abs/1808.02343

Observation of H -> b(b)over-bar decays and V H production with the ATLAS detector, Phys. Lett. B 786, 59-86
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