FROM PARTICLES TO THE COSMOS

IFAE

Institut de Física d'Altes Energies

Report
of Activities
Summary 2022

annualreport.ifae.es

CERCA Centres de Recerca de Catalunya

BIST Barcelona Institute of Science and Technology

FUNDAT PER | FOUNDED BY

Generalitat de Catalunya

UAB Universitat Autònoma de Barcelona

FROM **PARTICLES** TO THE **COSMOS**

In 1991 the Institut de Física d'Altes Energies (IFAE) was founded as a consortium of the Generalitat de Catalunya and the Universitat Autònoma de Barcelona.

For more than 30 years we have been exploring the cosmic and high energy frontiers to address fundamental questions about our Universe.

IFAE

Institut de Física d'Altes Energies

IFAE
AT A GLANCE

founded in 1991

170 people

three divisions: theory, experimental, technical; and administration

basic research in fundamental physics and
applied research in instrumentation, medical applications,
and quantum technologies

research lines: Particle Physics, Astroparticle Physics, Cosmology, Medical Imaging, Physics Instrumentation and Quantum Computing Technologies

one large engineering group (30+ engineers and technicians)

collaboration in 11 international experiments in high impact / leadership positions (ATLAS, MAGIC, DES, DESI, T2K, PAU, CTA, Euclid, LSST, Virgo, Einstein Telescope)

facilities: chip packaging & assembly, clean rooms, shielded room,
electronics labs, optical lab, quantum computing technologies lab,
mechanical workshop (300 m^2)

one large data-processing centre: PIC (LHC Tier-1)

member of Barcelona Institute of Science and Technology

twice awarded with the Severo Ochoa accreditation of excellence (2012, 2016)

SCIENCE AT IFAE

At IFAE we conduct experimental and theoretical research at the frontiers of fundamental physics, namely in Particle Physics, Astrophysics and Cosmology.

We are involved in the ATLAS project at the LHC, the T2K neutrino experiment in Japan, the MAGIC telescopes in La Palma, the Dark Energy Survey project in Chile, the Cherenkov Telescope Array in La Palma and Chile, the Virgo interferometer near Pisa, the future Einstein Telescope, among others.

We focus our research on the hottest topics in fundamental physics from particles to the cosmos.

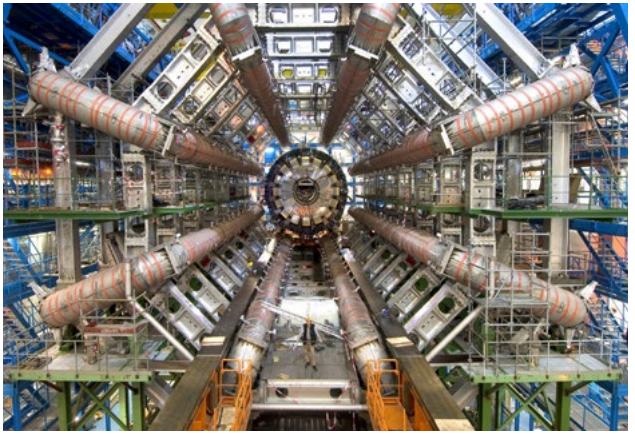
PARTICLE PHYSICS

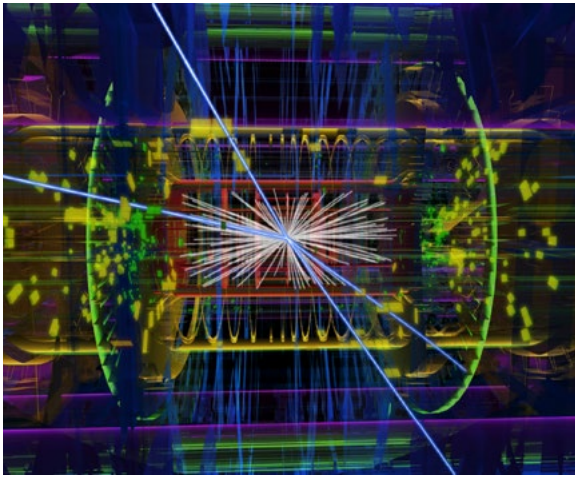
ASTROPHYSICS & **COSMOLOGY**

APPLIED PHYISCS

COLLIDER PHYSICS

ATLAS is the largest general-purpose detector at LHC, involving 3000 scientists to investigate a wide range of physics, from the Higgs boson to extra dimensions and particles that could make up dark matter.

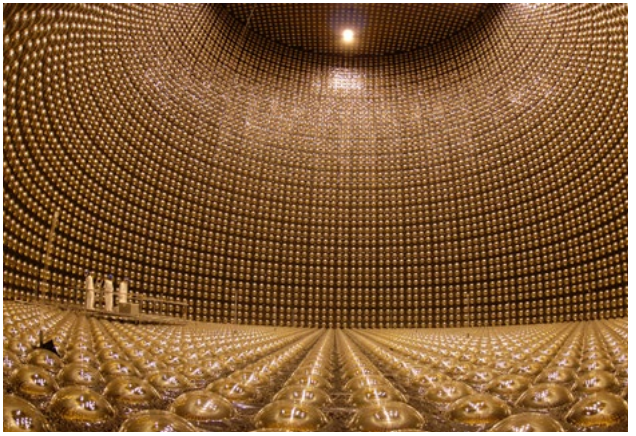


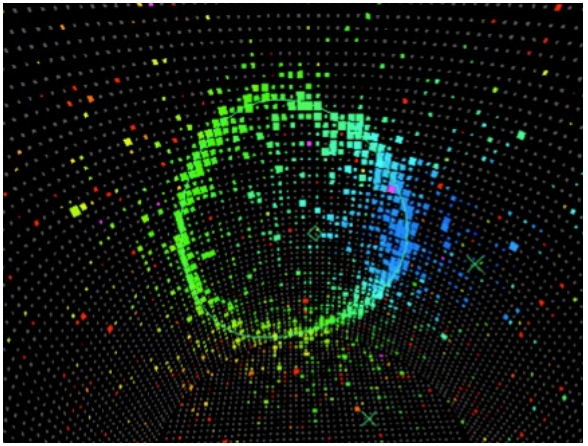


For more than 30 years we have been making important instrumentation contributions to ATLAS and have deployed a strong and rich physics analysis program.

NEUTRINO PHYSICS

We study the “ghost particle” among the fundamental particles and search for answers to why there is more matter than anti-matter in the universe.





We have been involved since the beginning in the leading experiment in long-baseline neutrino oscillations: T2K in Japan.
We contributed to the design and construction of the near detector and made important contributions to the data analysis.

GAMMA-RAY ASTRONOMY

Our goal is to understand the most energetic phenomena in the Universe and address open questions in fundamental physics.

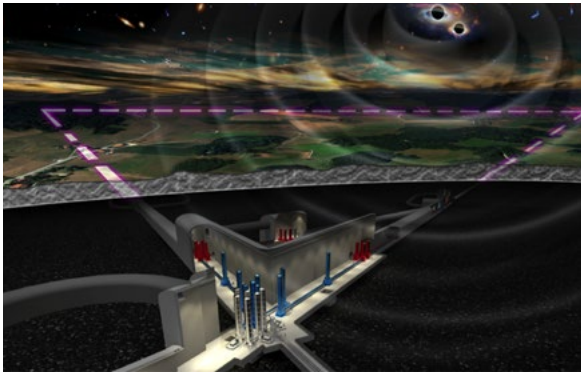
We lead the most relevant Gamma-ray Astronomy international collaborations (MAGIC, CTA)

We are leaders in the construction of cutting-edge instrumentation: the Gamma-ray group has led the construction of the photosensor cameras for the MAGIC-1 telescope and the CTA Large Sized Telescopes (LST).

GRAVITATIONAL WAVES

In 2019, we initiated a long-term experimental involvement in the Virgo ground-based Fabry-Perot interferometer, with the emphasis of studying fundamental physics using GWs.

We are a member institution in the VIRGO collaboration and this opened a long-term research line related to GWs detection using terrestrial interferometry.



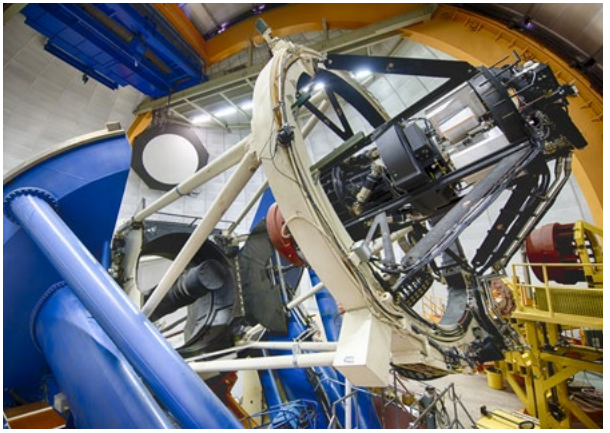
We are also involved in Einstein Telescope (ET), a project recognized in the ESFRI roadmap.

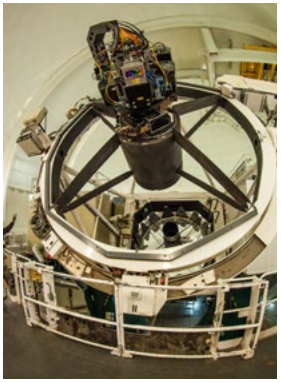
IFAE researchers cover the role of Chair of the ET Collaboration and leaders of the European project ET-Preparatory Phase to address the prerequisites for the approval, construction and operation of ET.

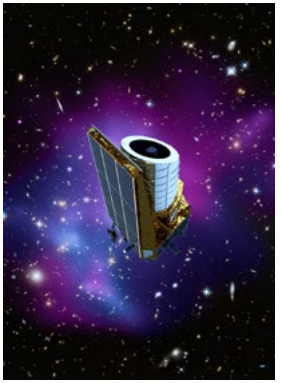
OBSERVATIONAL **COSMOLOGY**

Our main goal is to shed light on the nature of the mysterious dark energy, responsible for the current accelerated expansion of the universe.

We participate in the leading international collaborations such as DES, DESI, Euclid, LSST and we are a partner of PAUS.





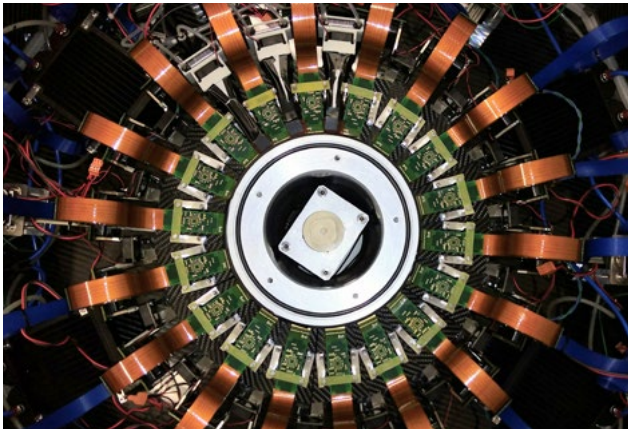


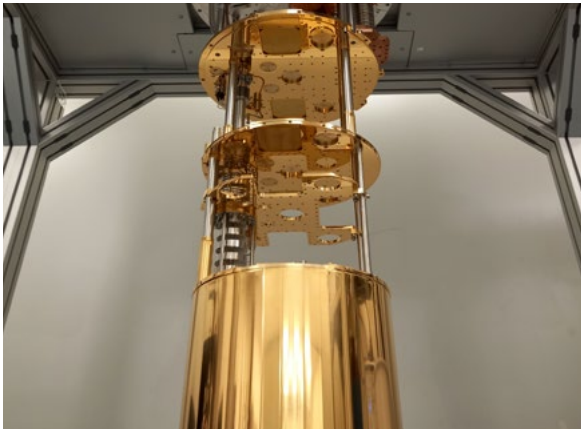
APPLIED PHYSICS

MEDICAL PHYSICS

Since 1999, we are using our expertise with sophisticated radiation detectors to develop advanced medical imaging devices.

We've developed 3 spin-off companies and several patents with our technologies.





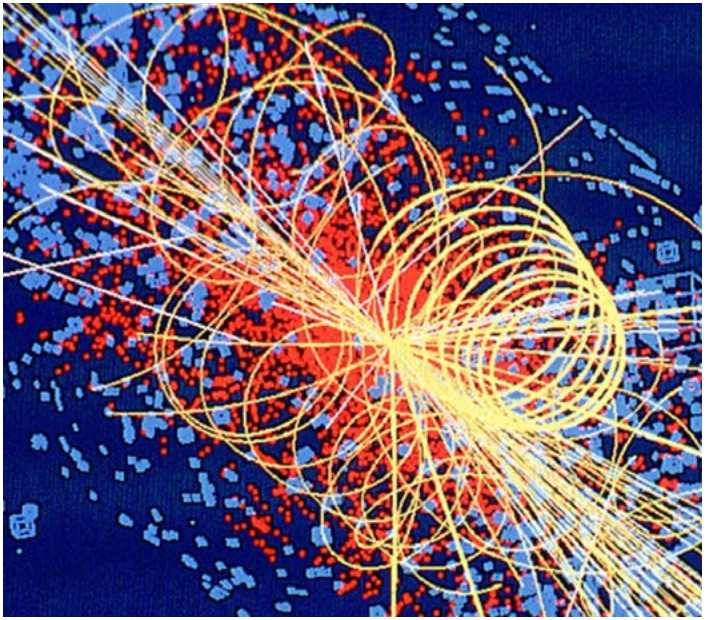
QUANTUM COMPUTING TECHNOLOGIES

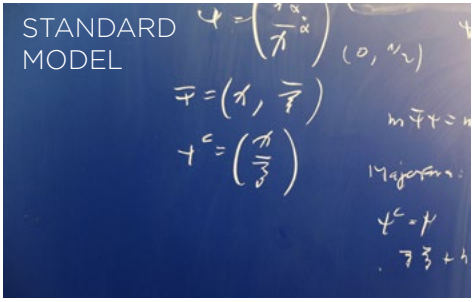
We are the leading national laboratory developing superconducting qubits for quantum computing applications in quantum annealing and the interaction of qubits with high energy radiation.

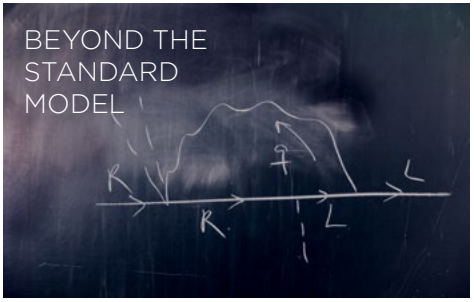
We've developed 1 spin-off with our technologies.

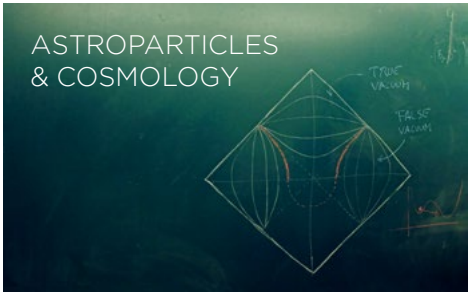
THEORY
DIVISION

Our Theory division research focuses on Standard Model & Flavor Physics, Beyond the Standard Model, and Astroparticle and Cosmology.









TECHNOLOGY AT IFAE

At IFAE we work at the cutting edge of detector technology, developing pixel detectors for High Energy Physics, telescope cameras, detectors for medical imaging and quantum computing technologies.

Our facilities include a microelectronics laboratory with state-of-the-art packaging and assembly technologies, clean rooms, a data center, a mechanical workshop, electronics labs, an optical room, a shielded room and a quantum computing technologies lab.

FRONT-END ELECTRONICS

GRID COMPUTING

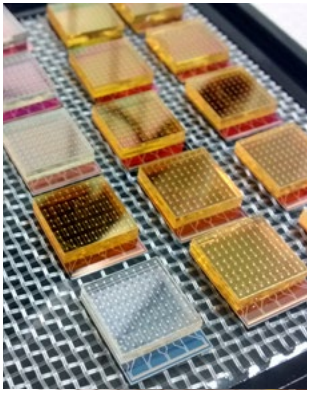
CONTROL SYSTEMS

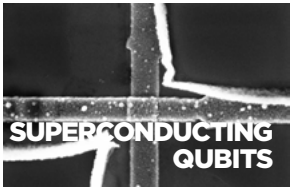
CRYOGENICS

READ-OUT ELECTRONICS

DETECTORS

TECHNOLOGIES

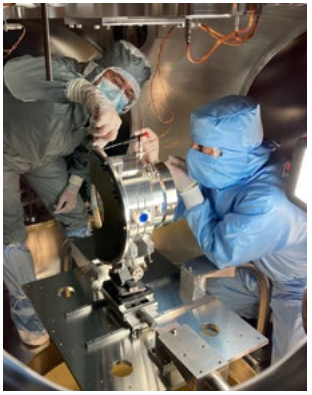


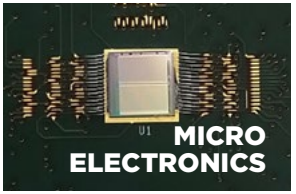


DATA CENTER

PIC
port d'informació científica

ENGINEERING



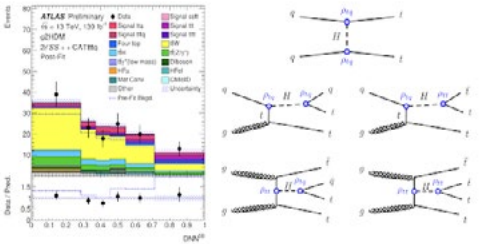


HIGHLIGHTS OF THE YEAR

ONE HIGGS BOSON FOUND – COULD THERE BE MORE?

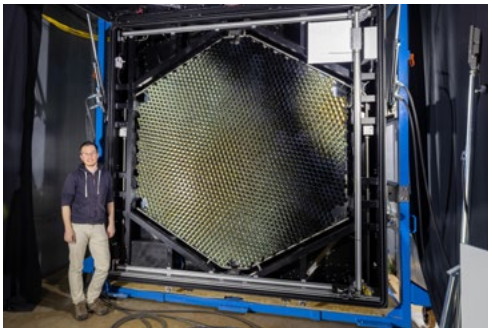
On July 2022, the ATLAS Collaboration reported the results of the first-ever search for the production of a Higgs boson with flavour-conserving and flavour-violating couplings to quarks, giving two same-charge top quarks, three top quarks, or four top quarks in the final state.

An excess with a significance of up to 2.8 standard deviations was found in events with two positively charged leptons, compatible with the production of a heavy neutral Higgs boson with a sizable coupling to a top quark and an up quark.



TWO CAMERAS FOR THE CTA LSTs ASSEMBLED AND COMMISSIONED AT IFAE

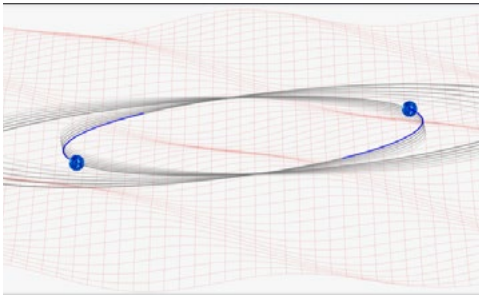
IFAE has played a pivotal role in the construction of the first Large Size Telescope (LST1) at the Observatorio Roque de los Muchachos (ORM). Leading the project, IFAE has overseen design, construction, integration, and commissioning of the camera already in operation in the LST1 as well as its control software. IFAE's strong involvement in the LST-1 construction has also led to its key role in the construction of three additional LSTs (LST2-4) to be installed hat the ORM.



DIEGO BLAS OBTAINS THE BUCHALTER COSMOLOGY PRIZE

The Buchalter Cosmology 2022 Second Prize was awarded to Diego Blas and his collaborator Alexander Jenkins (UCL), for their work entitled “Bridging the QHz gap in the gravitational-wave landscape with binary resonance” published in Physical Review Letters.

Their work propose using the variations in distance between the Earth and the Moon, which can be measured with a precision of less than a centimeter, as a new gravitational wave detector within a frequency range that current devices cannot detect.

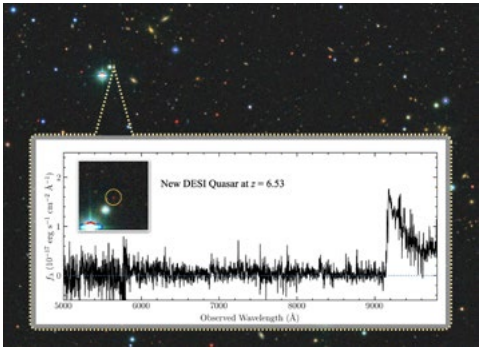


ERC GRANTS AWARDED TO ANDREU FONT RIBERA AND GERARD ARIÑO

Andreu Font Ribera, researcher in the Observational Cosmology Group at IFAE, was awarded in 2022 the prestigious “Consolidator Grant” from the European Research Council (ERC).

The project COSMO-LYA: A Cosmological Lever Arm for Fundamental Physics will allow Andreu and his team to use a large dataset of distant quasars to study some of the mysteries of our Universe: dark energy, inflation, and the mass of neutrinos.

Also in 2022, Gerard Ariño obtained an ERC Starting Grant to improve the diagnostic capabilities of Time-of-Flight Positron Emission Tomographies with innovative detector technologies



ASSEMBLY OF MODULES FOR THE ATLAS PIXEL AND HGTD UPGRADES

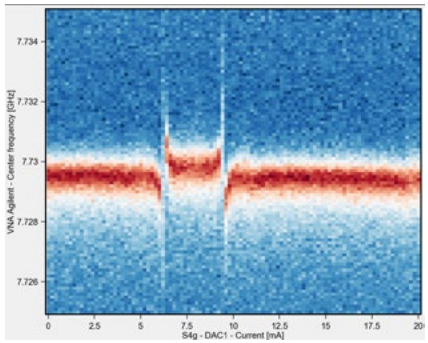
The ATLAS Pixel group has been working on the development and qualification of new silicon detector technologies for the High Luminosity LHC upgrade. The group is set to make critical contributions to the Pixel and the HGTD projects. In the last year the first prototype modules were fully fabricated in the IFAE clean rooms, including the critical bump bonding step which was carried out in-house for HGTD.

FIRST OBSERVATION OF SUPERCONDUCTING FLUX QUBIT SPECTRUM IN THE IFAE QCT LAB

In 2022 the QCT group at IFAE observed the existence of the first superconducting flux qubit in the IFAE Lab.

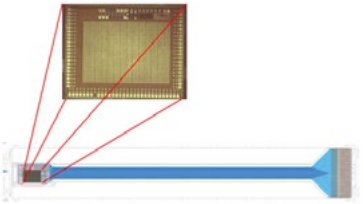
This is a milestone for the group. These are the kind of chips that are of interest for quantum computing with quantum annealing, quantum optics and detection.

The chip was designed at IFAE and manufactured in Glasgow.



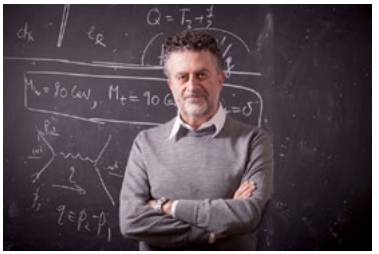
NEW PATENT: ARTIFICIAL VISION SYSTEM

The patent application Artificial Vision System was granted by the European Patent Office in 2022. The innovation idea makes it possible for someone who lost his/her vision due to the retinitis disease to partially recover the vision with better spatial resolution and number of frames per second.



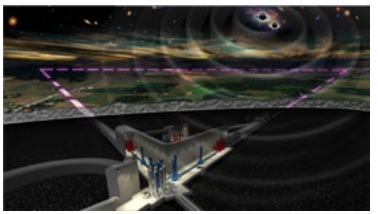
PROF. EUGENIO COCCIA NAMED NEW DIRECTOR OF IFAE

IFAE's Governing Board has appointed Prof. Eugenio Coccia as the new director of IFAE in 2022. The appointment was the result of an international selection process. He was the director of the INFN Gran Sasso Laboratory (2003-2009) and founding director of the school for advanced studies Gran Sasso Science Institute (GSSI).



IFAE LEADS AN INTERNATIONAL PROJECT TO PAVE THE WAY FOR THE EINSTEIN TELESCOPE

The Institut de Física d'Altes Energies (IFAE) is the coordinator institution of the Horizon Europe INFRA-DEV project ET-Preparatory Phase led by Mario Martínez. The project will run for 4 years with a total budget of 3.45M€ and comprises leading research centers from 11 countries.



SCIENTIFIC OUTPUT IN 2022

250

NUMBER OF INDEXED JOURNAL ARTICLES

81%

% ARTICLES IN FIRST QUARTILE JOURNALS

6.6

AVERAGE JOURNAL IMPACT FACTOR (IF)

TOP 5 JOURNALS WHERE IFAE PUBLISHED MOST FREQUENTLY IN 2022	NUMBER OF ARTICLES
Physical Review D	48
Monthly Notices Of The Royal Astronomical Society	40
Astronomy & Astrophysics	21
European Physical Journal C	21
Journal Of High Energy Physics	19

TOP 5 JOURNALS (BY IF) WHERE IFAE PUBLISHED IN 2022	
Nature	1
Science	1
Living Reviews In Relativity	1
Annual Review Of Nuclear And Particle Science	1
Nature Astronomy	2

DOCTORAL THESES: **13**

NUMBER OF PRESENTATIONS AT INTERNATIONAL CONFERENCES: **151**

HUMAN RESOURCES IN 2022

EXPERIMENTAL DIVISION

23 FACULTY

23 POST-DOCTORAL RESEARCHERS

20 DOCTORAL STUDENTS

THEORY DIVISION

13 FACULTY

7 POST-DOCTORAL RESEARCHERS

7 DOCTORAL STUDENTS

TECHNICAL SERVICES

25

25 PIC

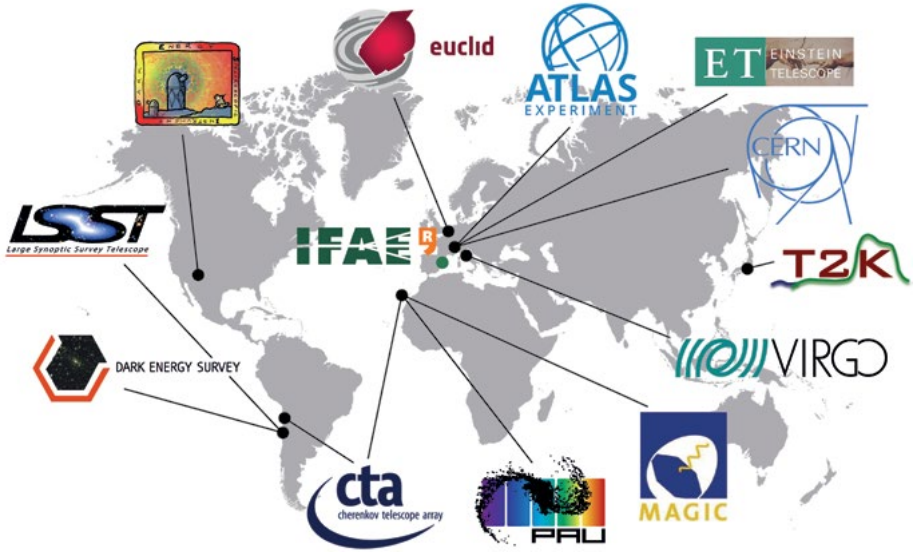
RESEARCH SUPPORT

14

PROJECTS IN 2022

29	11	5	3	2	1
MINISTERIO DE ECONOMÍA Y COMPETITIVIDAD	EUROPEAN COMISSION	AGÈNCIA DE GESTIÓ D'AJUTS UNIVERSITARIS I DE RECERCA	FUNDACIÓ BANCARIA LA CAIXA	BIST	FECYT

INTERNATIONAL COLLABORATIONS



OUTREACH IN 2022

Hundreds of students participate in our outreach activities every year. We offer year-long activities, summer camps, visits and talks in schools.

Our high-school programs include Bojos per la Física, Barcelona International Youth Science Challenge (BIYSC), International Physics Masterclasses, among others.

The IFAE Summer Fellowship program offer undergraduate students the possibility of spending the summer as a physics researcher. The aim of this one-month stay is to become the first step their research career.

TECHNOLOGY TRANSFER IN 2022

The KTT unit at IFAE promotes the valorisation and exploitation of new technological solutions for societal and industrial challenges.

42% OF OUR PORTFOLIO OF TECHNOLOGIES IS LICENSED FOR INDUSTRIAL APPLICATIONS

30 PRIVATE COMPANIES ENGAGED IN COLLABORATIVE R&D PROJECTS WITH IFAE

2 PATENTS GRANTED IN 2022

SPIN-OFFS IN 2022

QILIMANJARO QUANTUM · TECH

Qilimanjaro's mission is to develop fast-to-market app-specific analog quantum computers with true quantum benefits by co-designing chips & algorithms and bypassing the qubit fragility barrier

www.qilimanjaro.tech

Deep Detection

Deep Detection develops multispectral x-ray cameras with photon counting techniques for industrial inspection and material separation.

deepdetection.tech

baretek

Baretek offers microelectronic servcies for research, health and industry. The microelectronic assembly services include: state-of-the-art ASIC, FPGA and microcontroller assembly technologies.

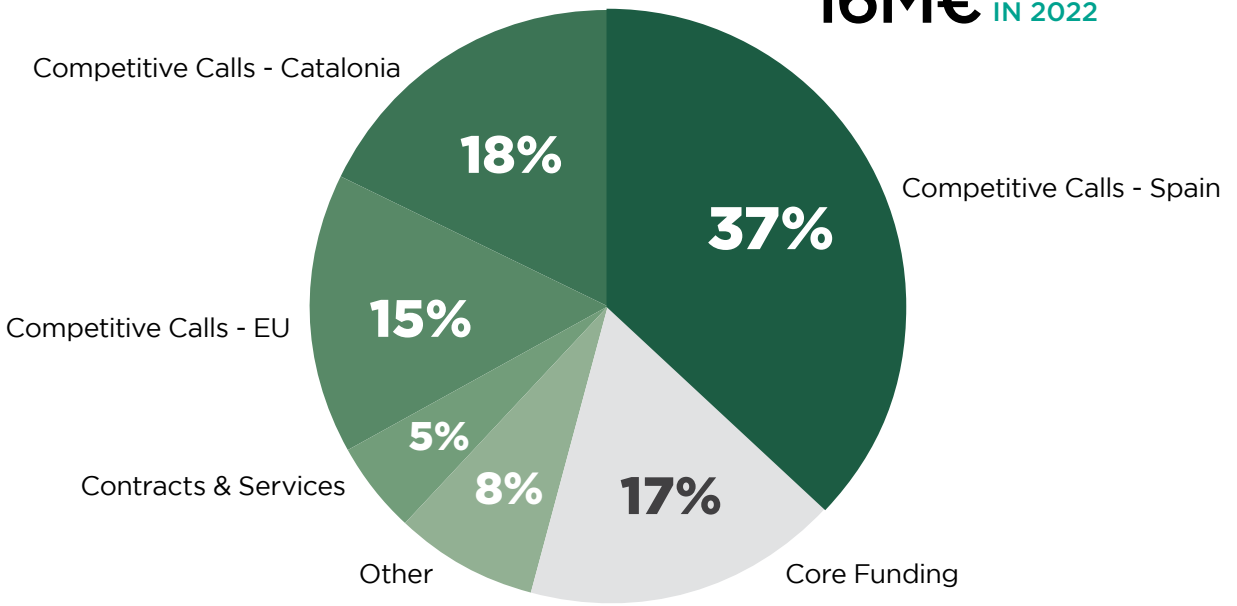
baretek.eu.com

FUNDING
IN 2022

IFAE receives its core funding from Generalitat de Catalunya. Most of the overall funding, however, comes from competitive calls at the Catalan, Spanish and European levels.

As shown in the pie chart below, in 2022 the ratio of competitive to core funding was about 5.8.

16M€ TOTAL FUNDING IN 2022



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CERCA Centres de Recerca de Catalunya

MEMBRE DE | MEMBER OF

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SOMM EXCELLENCE ALLIANCE

ACER Associació Catalana d'Entitats de Recerca

AMB EL SUPORT DE | SUPPORTED BY

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EUROPEAN UNION
European Regional Development Fund

ICREA

AGAUR Agència de Gestió d'Ajuts Universitaris i de Recerca

erc European Research Council
Established by the European Commission

Obra Social "la Caixa"