FROM PARTICLES TO THE COSMOS

IFAE

Institut de Física d'Altes Energies

Report
of Activities
Summary 2023

annualreport.ifae.es

CERCA Centres de Recerca de Catalunya

bist SCIENTIFIC COMMUNITY

SOMM EXCELLENCE ALLIANCE

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.

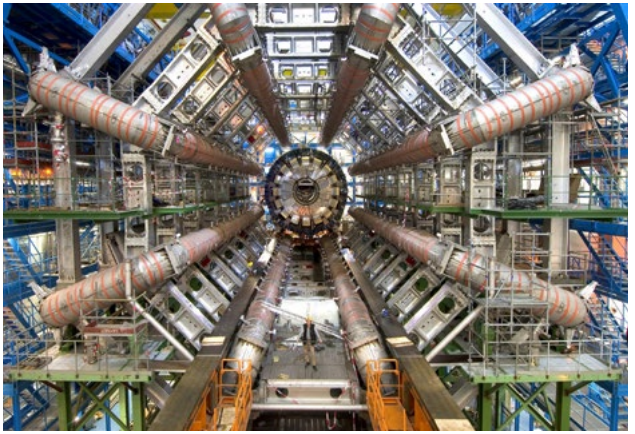
PARTICLE PHYSICS

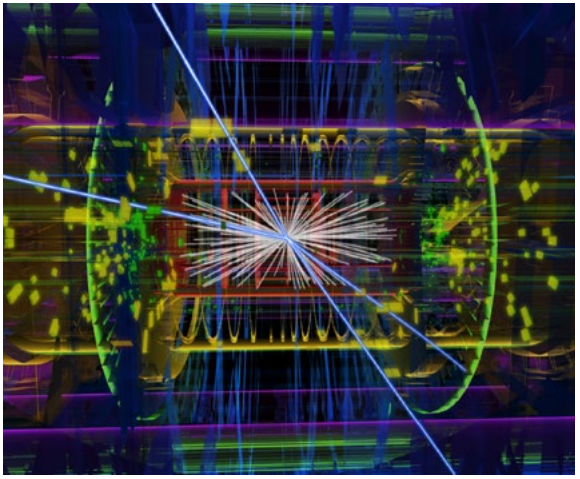
ASTROPHYSICS & **COSMOLOGY**

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.

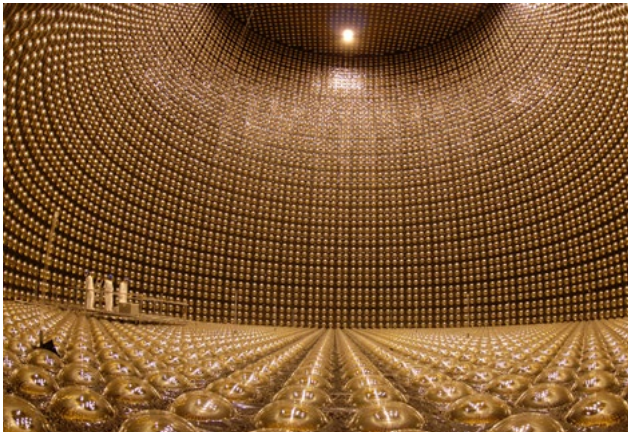


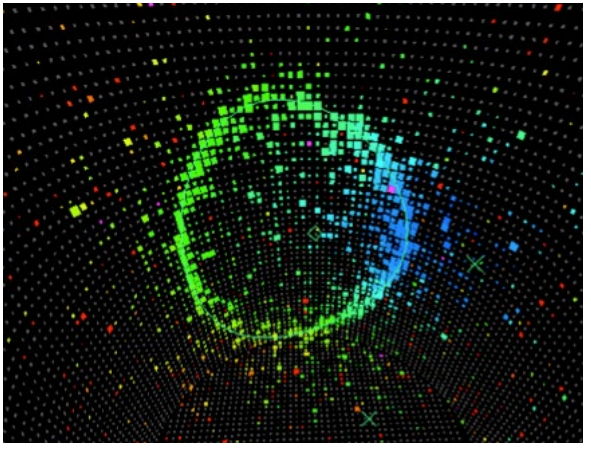


For more than 30 years we have been making important instrumentation contributions to ATLAS and have deployed a strong and rich physics analysis program.

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.

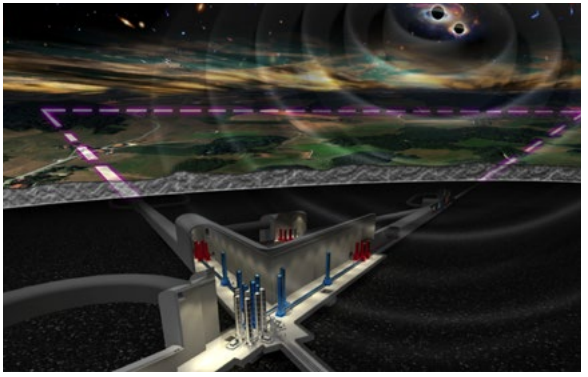
We lead the most relevant Gamma-ray Astronomy international collaborations (MAGIC, CTA).

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.



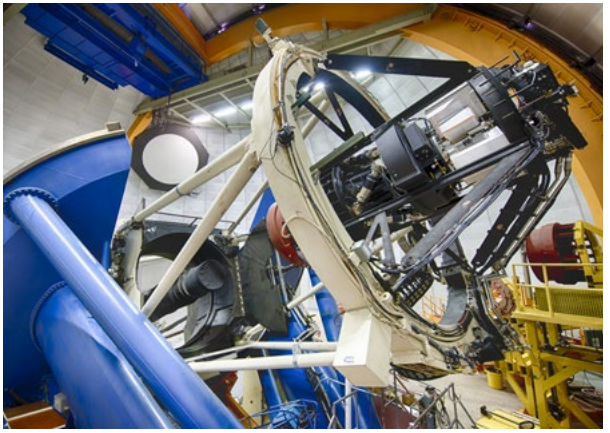
We are also involved in Einstein Telescope (ET), a project recognized in the ESFRI roadmap.

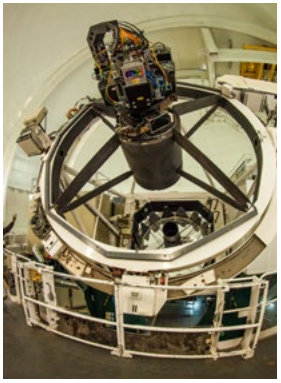
IFAE researchers cover the role of Chair of the ET Collaboration Board and leaders of the European project ET-Preparatory Phase to address the prerequisites for the approval, construction and operation of ET.

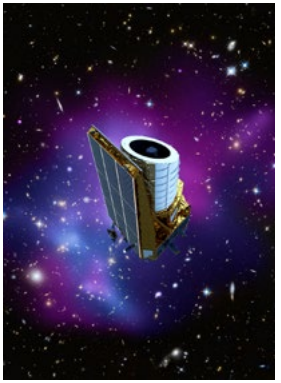
OBSERVATIONAL **COSMOLOGY**

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.





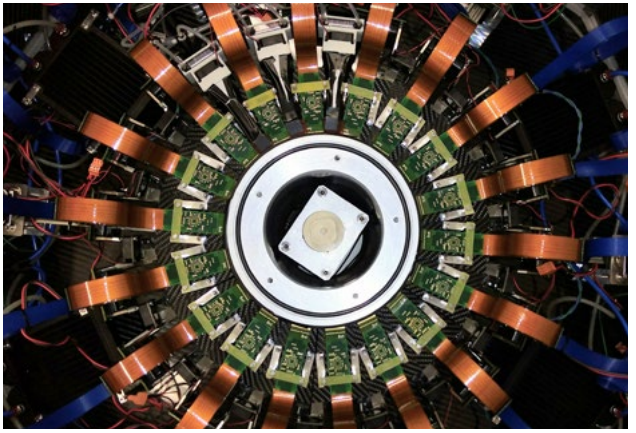


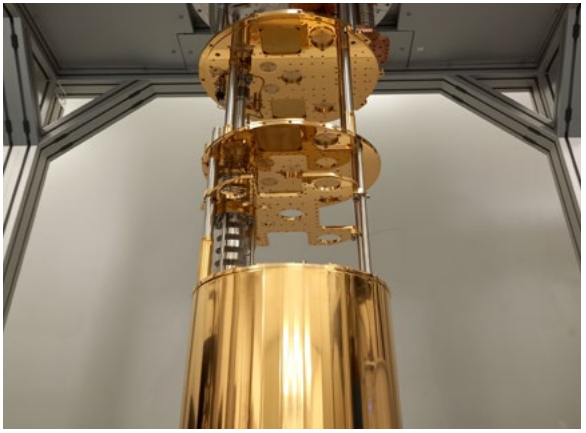
APPLIED PHYSICS

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.

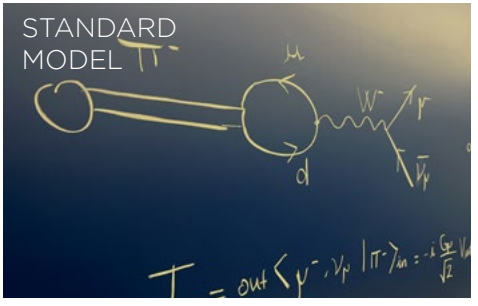
THEORY
DIVISION

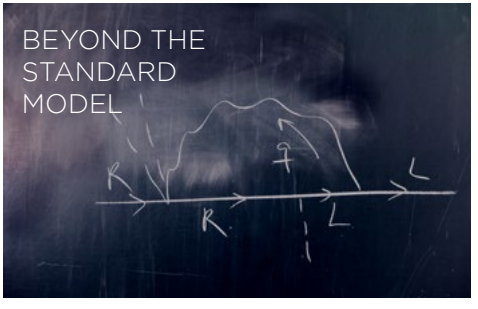
Our Theory Division works on the most intriguing open questions in fundamental physics

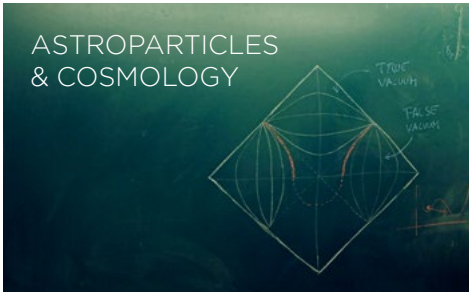
Research topics of the Standard Model group include applying effective field theories to different physical systems, using flavour physics as a tool for discovery, or improving the hadronic contributions to the muon anomalous magnetic moment, among others.

The Beyond the Standard Model group focuses on research topics needed to understand mysteries such as the origin of the Universe properties, the origin of baryons and dark matter, the hierarchy problem, and the strong CP problem, among others.

Dark energy, dark matter models, baryogenesis, gravitational wave physics, and gravity and condense matter physics are the research topics addressed by the Astroparticles and Cosmology Group.







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

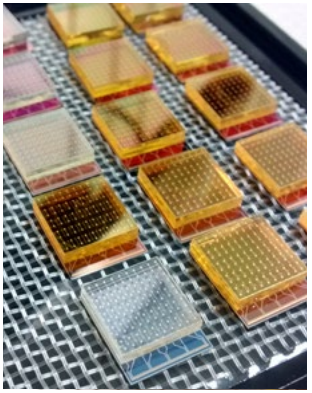
CONTROL SYSTEMS

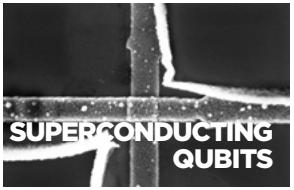
CRYOGENICS

READ-OUT ELECTRONICS

DETECTORS

TECHNOLOGIES

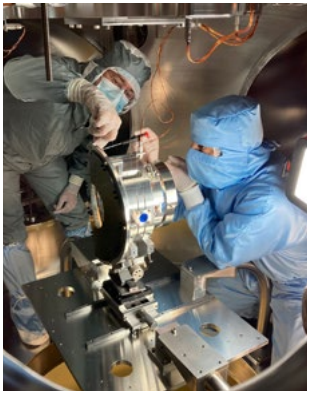


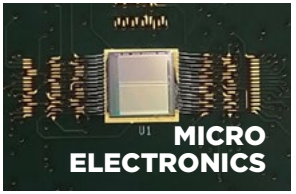


DATA CENTER

PIC
port d'informació científica

ENGINEERING





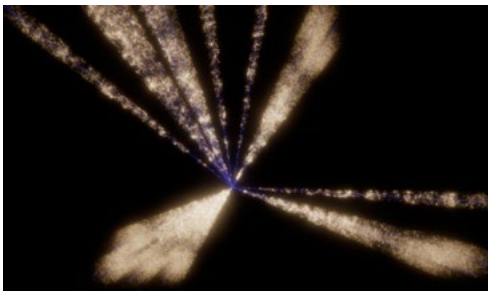
HIGHLIGHTS OF THE YEAR

THE EUCLID SATELLITE LAUNCHES TO EXPLORE THE DARK UNIVERSE

The European Space Agency's (ESA) Euclid Satellite successfully launched on Saturday, July 1st, 2023. Following its launch, the satellite completed its commissioning phase and has begun its mission of observation and survey.

Euclid is equipped with the Filter Wheel Assembly for the Near Infrared Spectrometer and Photometer, a crucial instrument developed under the leadership of IFAE. Over the next six years, Euclid will map one-third of the sky, contributing significantly to our understanding of dark matter and dark energy.

DESI EARLY DATA RELASE



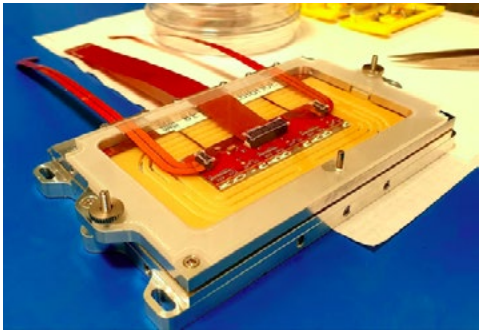
In June 2023, the first batch of data from the Dark Energy Spectroscopic Instrument (DESI) was made publicly available. Collected during the experiment's "survey validation" phase, the data set includes spectra from nearly 2 million distant galaxies and quasars, as well as stars within our own Milky Way. DESI is currently engaged in a five-year campaign to accurately measure the redshifts of 40 million galaxies and quasars across one-third of the sky. DESI aims to provide the most precise measurements of the Universe's expansion rate throughout cosmic history.

GERARD ARIÑO OBTAINS FUNDING IN THE ATRAE CALL

Gerard Ariño, a researcher at IFAE, has been awarded the VERSATILE project under the ATRAE call. The VERSATILE project focuses on advancing nuclear medicine by developing an innovative gamma detector for various applications. These include dosimetry for Targeted Alpha Therapy, Boron Neutron Capture Therapy, and high-performance Time-of-Flight Positron Emission Tomography.

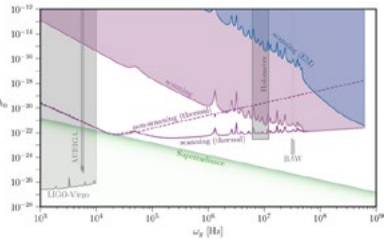
IFAE CONTRIBUTES TO ATLAS UPGRADES FOR THE HL LHC ERA

As part of the preparations for the upcoming High Luminosity Large Hadron Collider (LHC) era, IFAE is actively involved in upgrading the ATLAS experiment. The ATLAS-Pixels group is specifically focused on constructing modules for the innermost pixel layer of the new tracking detector, known as ITk. In 2023, IFAE successfully assembled the first pre-production triplet module. An additional eleven modules are scheduled for fabrication during early 2024 as part of the pre-production phase.



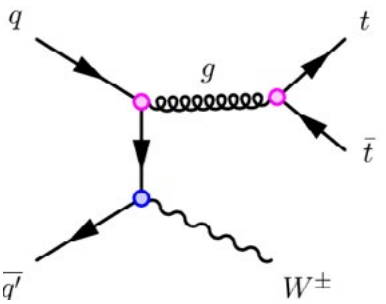
ELECTROMAGNETIC CAVITIES AS MECHANICAL BARS FOR GRAVITATIONAL WAVE DETECTION

The theory group at IFAE has revived the old idea of using a superconducting cavity as a Weber bar to search for Gravitational Waves. The group performed updated calculations of the sensitivity of both the mechanical and electromagnetic signals in the cavity, accounting for various noise sources that had previously been neglected.



ATLAS CONFIRMS MILD TENSION IN THE PRODUCTION OF TOP-QUARK PAIRS WITH A W BOSON

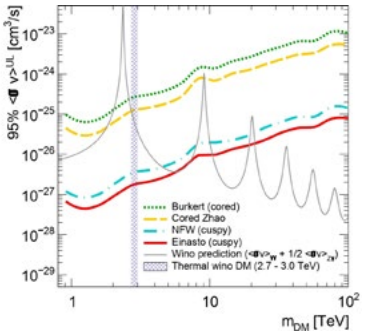
On March 2023, the ATLAS Collaboration reported the results of the most exhaustive set of measurements of the production of top-quark pairs alongside a W± boson (ttW) to date. The findings showed an over-abundance in the production rate compared to theoretical predictions, which confirms the pattern of previous excesses in total ttW± production.



SEARCH FOR DARK MATTER AT THE CENTER OF OUR HOME GALAXY WITH THE MAGIC TELESCOPES

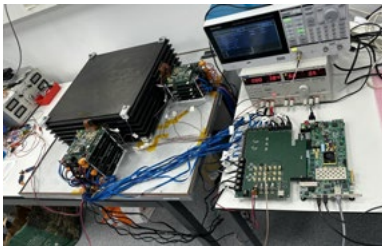
Researchers from the MAGIC collaboration constrained the properties of candidate dark matter particles.A total of 223 hours of observation with the MAGIC Telescopes, pointed to the center of the Milky Way, were dedicated to searching for gamma-ray “lines”.

The detection of TeV lines would have indicated particles much heavier than those known within the Standard Model, serving as a compelling signature for dark matter.



IFAE SUCCESSFULLY TESTS ADVANCED TRIGGER AND ACQUISITION SYSTEMS FOR HERD AT CERN

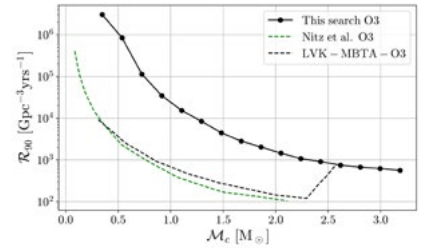
IFAE scientists and engineers have designed, produced, and tested the electrical and functional models (EFMs) of the trigger and acquisition electronic systems for the HERD’s fiber tracker and plastic scintillator detector. Both systems were successfully operated in the beam test campaigns performed at the CERN between August and October 2023.



OBSERVATIONS OF THE CRAB NEBULA & PULSAR WITH THE LST1

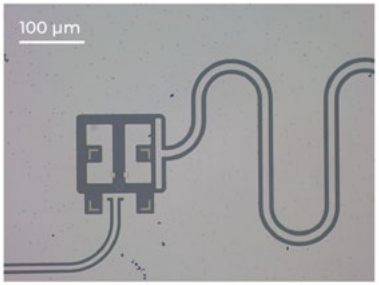
The LST collaboration reached an important milestone in 2023 with the publication in The Astrophysical Journal of a paper reporting on the observations of the Crab Nebula and pulsar with the LST-1, the first operational telescope of the future CTA Observatory. The Crab Nebula is the standard candle of gamma-ray astronomy, and hence the target on which the performance of new instruments is validated. The paper was led by the IFAE team.

SEARCH FOR PRIMORDIAL BLACK HOLES USING DEEP LEARNING



The IFAE GW grop performed a search for the coalescence of compact binary mergers with very asymmetric mass configurations using convolutional neural networks and the LIGO/Virgo data for the O3 observation period. Two-dimensional images in time and frequency were used as input. A scan over the O3 data set using the convolutional neural networks for detection results into no significant excess from an only-noise hypothesis.
The results are translated into 90% confidence level upper limits on the merger rate as a function of the mass parameters of the binary system.

COHERENCE TIMES OBSERVED IN THE FIRST SUPERCONDUCTING FLUX QUBITS AT IFAE.



Within the AVaQus FET-Open project led by IFAE, the first coherent dynamics have been observed in a superconducting flux qubit device by the IFAE team. This result is an important milestone in the goal of the IFAE QCT group of performing analog quantum computation with superconducting flux qubits.

SCIENTIFIC OUTPUT IN 2023

372

NUMBER OF INDEXED JOURNAL ARTICLES

82%

% ARTICLES IN FIRST QUARTILE JOURNALS

5.1

AVERAGE JOURNAL IMPACT FACTOR (IF)

TOP 5 JOURNALS WHERE IFAE PUBLISHED MOST FREQUENTLY IN 2022	NUMBER OF ARTICLES
Journal Of High Energy Physics	73
Monthly Notices Of The Royal Astronomical Society	68
Physical Review D	46
European Physical Journal C	35
Astronomy & Astrophysics	28

TOP 5 JOURNALS (BY IF) WHERE IFAE PUBLISHED IN 2022	
Living Reviews In Relativity	1
Nature Physics	1
Physical Review X	2
Astrophysical Journal Letters	19
Physical Review Letters	15

DOCTORAL THESES: **8**

NUMBER OF PRESENTATIONS AT INTERNATIONAL CONFERENCES: **121**

HUMAN RESOURCES IN 2023

EXPERIMENTAL DIVISION

26 FACULTY

21 POST-DOCTORAL RESEARCHERS

35 DOCTORAL STUDENTS

THEORY DIVISION

15 FACULTY

6 POST-DOCTORAL RESEARCHERS

4 DOCTORAL STUDENTS

TECHNICAL SERVICES

23

25 PIC

RESEARCH SUPPORT

15

7 ICREA Professors.

2 ERCs in the last year.

The Chair of Scientific Committee is a Nobel Laureate (Barry Barish).

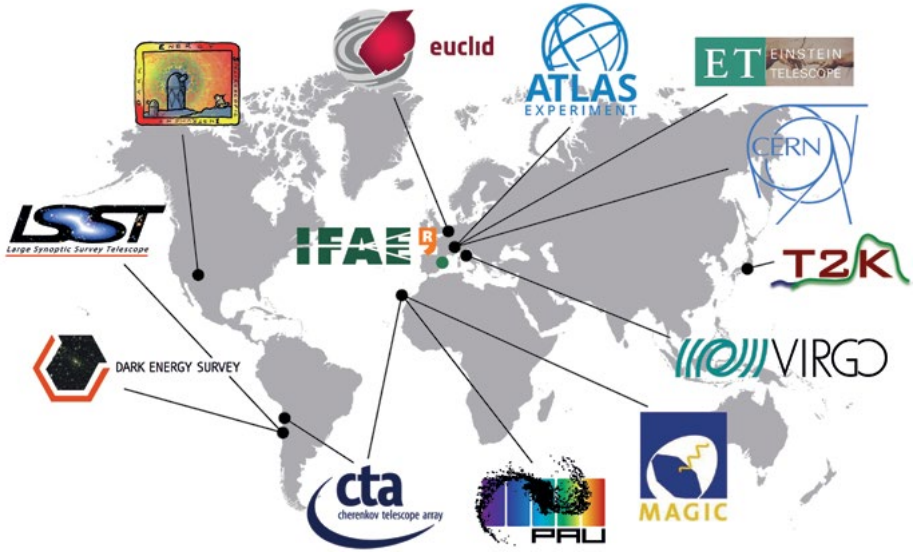
IFAE investigators have participated in recent discoveries that have been awarded 3 Nobel Prizes (Higgs bosons, astrophysical neutrinos, GW). Two investigators have been awarded the Breakthrough Prizes.

IFAE is Leader of the Spanish New Generation Europe Plan on High Energy Astrophysics.

PROJECTS IN 2023

29	10	15	5	2
MINISTERIO DE ECONOMÍA Y COMPETITIVIDAD	EUROPEAN COMISSION	AGÈNCIA DE GESTIÓ D'AJUTS UNIVERSITARIS I DE RECERCA	FUNDACIÓ BANCARIA LA CAIXA	BIST

INTERNATIONAL COLLABORATIONS



OUTREACH IN 2023

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 2023

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

3.2M€ VENTURE CAPITAL RAISED BY SPIN-OFFS PARTICIPATED BY IFAE

SPIN-OFFS IN 2023

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.

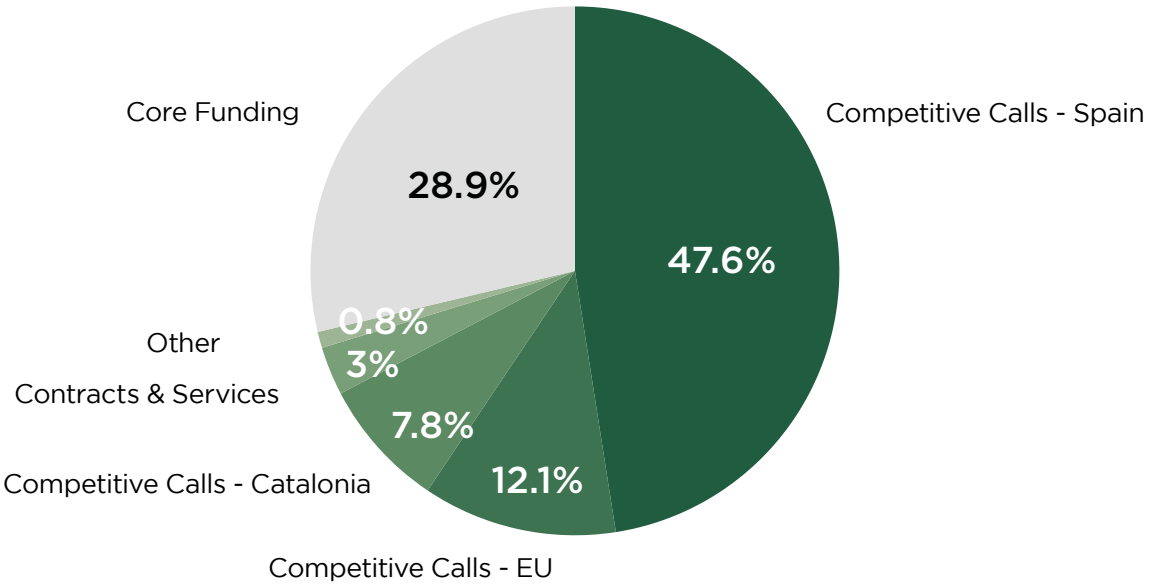
baretek.eu.com

FUNDING IN 2023

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 2023 the ratio of competitive to core funding was about 3.5.

12.1M€ TOTAL FUNDING IN 2023



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UAB Universitat Autònoma de Barcelona

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CERCA Centres de Recerca de Catalunya

MEMBRE DE | MEMBER OF

bist SCIENTIFIC COMMUNITY

SOMM EXCELLENCE ALLIANCE

ACER Associació Catalana d'Entitats de Recerca

AMB EL SUPORT DE | SUPPORTED BY

GOBIERNO DE ESPAÑA MINISTERIO DE CIENCIA E INNOVACIÓN

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"