FROM PARTICLES TO THE COSMOS

IFAE

Institut de Física d'Altes Energies

Report
of Activities
Summary 2024

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 m2)

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.

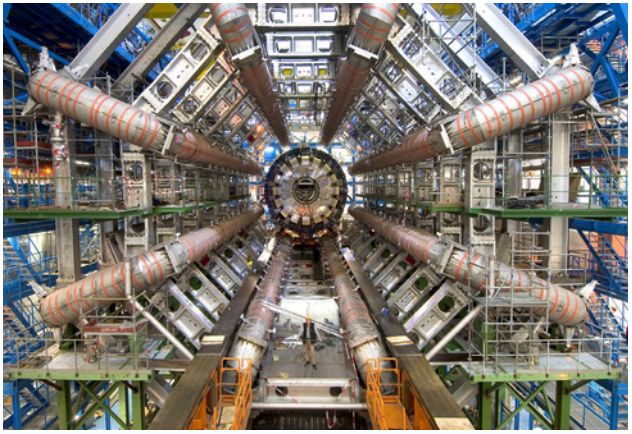
PARTICLE PHYSICS

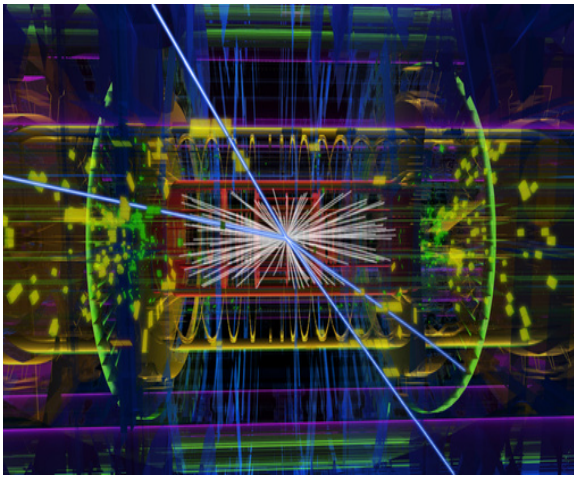
ASTROPHYSICS & **COSMOLOGY**

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.

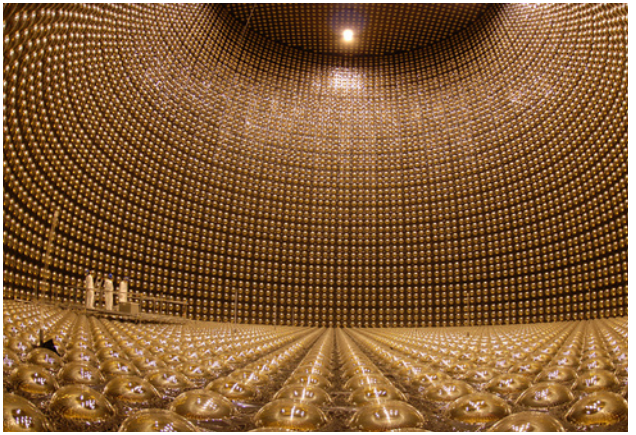


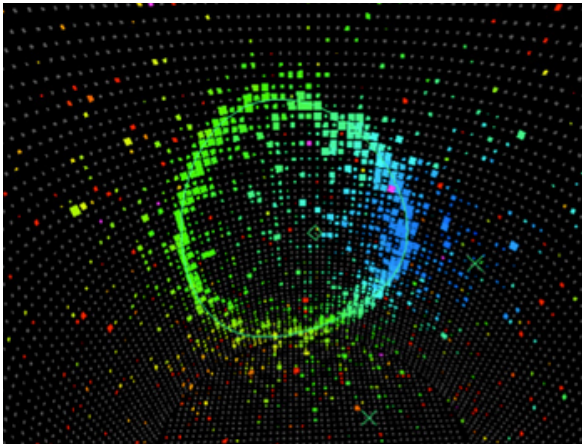


For more than 30 years we have been making important instrumentation contributions to ATLAS and have deployed a strong and rich physics analysis program.

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.

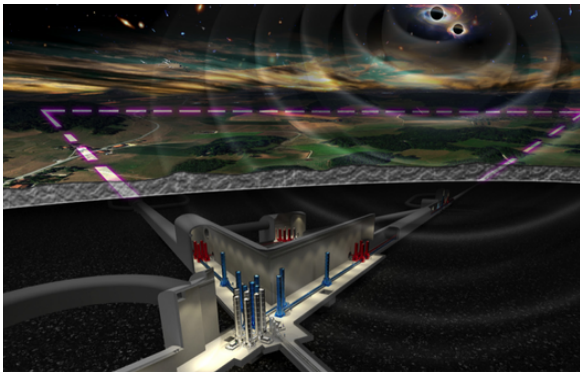
We lead the most relevant Gamma- ray Astronomy international collaborations (MAGIC, CTA).

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 now a member institution in the Virgo & LIGO collaborations and we have consolidated a long-term research line related to GWs detection using terrestrial interferometry.



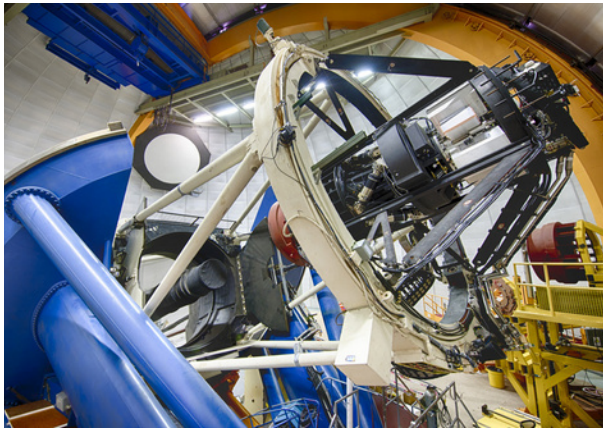
We are also involved in Einstein Telescope (ET), a project recognized in the ESFRI roadmap.

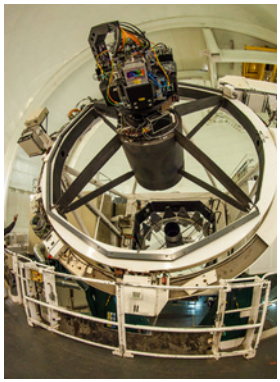
IFAE researchers cover the role of Chair of the ET Collaboration Board and leaders of the European project ET-Preparatory Phase to address the prerequisites for the approval, construction and operation of ET.

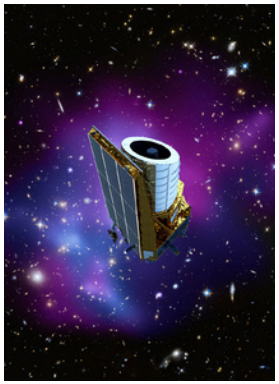
OBSERVATIONAL **COSMOLOGY**

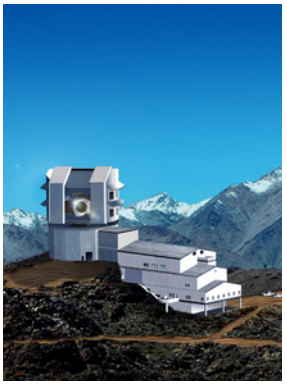
Our main goal is to shed light on the nature of the mysterious dark energy, responsible for the current accelerated expansion of the Universe.

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







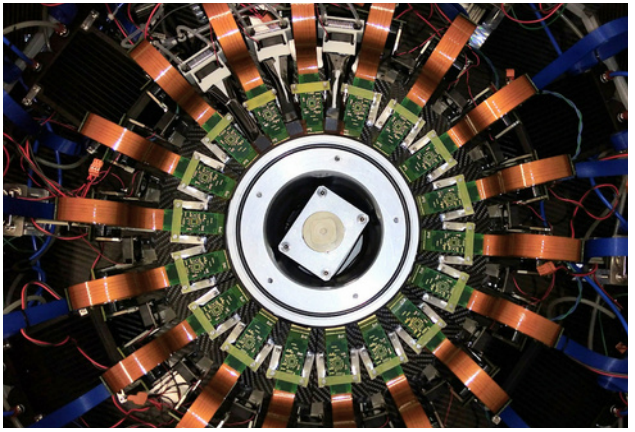


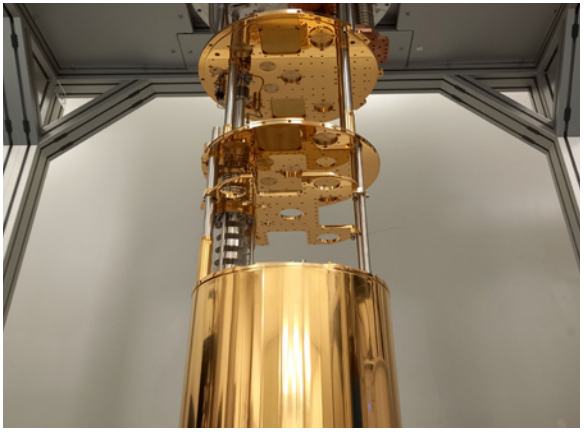
APPLIED PHYSICS

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.

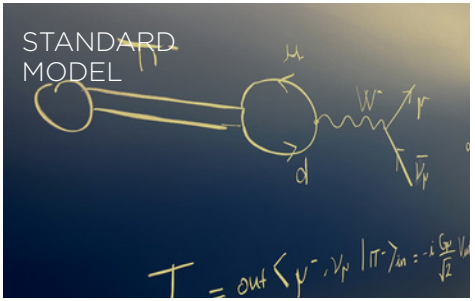
THEORY DIVISION

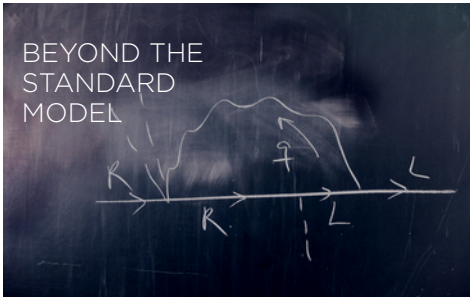
Our Theory Division works on the most intriguing open questions in fundamental physics.

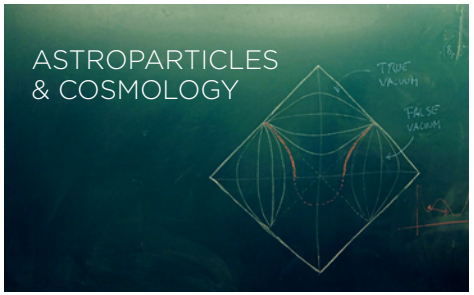
Research topics of the Standard Model group include applying effective field theories to different physical systems, using flavour physics as a tool for discovery, or improving the hadronic contributions to the muon anomalous magnetic moment, among others.

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.







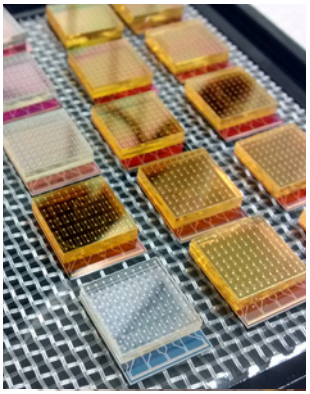
TECHNOLOGY AT IFAE

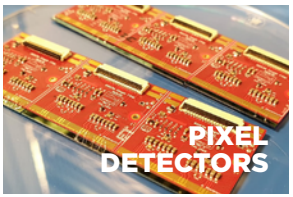
At IFAE we work at the cutting edge of detector technology, developing pixel detectors for High Energy Physics, telescope cameras, detectors for medical imaging and quantum computing technologies.

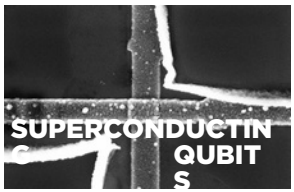
Our facilities include a microelectronics laboratory with state-of-the-art packaging and assembly technologies, clean rooms, a data center, a mechanical workshop, electronics labs, an optical room, a shielded room and a quantum computing technologies lab.

FRONT-END ELECTRONICS
GRID COMPUTING
CONTROL SYSTEMS
CRYOGENICS
READ-OUT ELECTRONICS
DETECTORS

TECHNOLOGIES

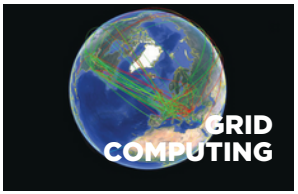




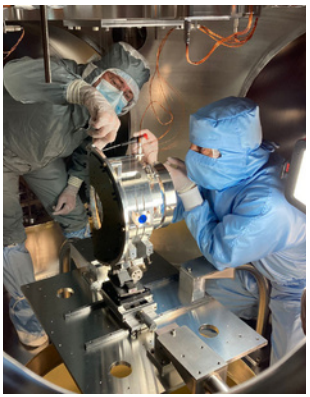


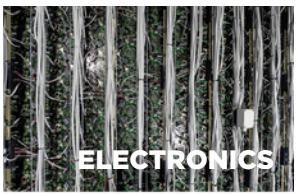
DATA CENTER

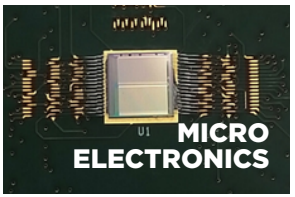
PIC
port d'informació
científica



ENGINEERING

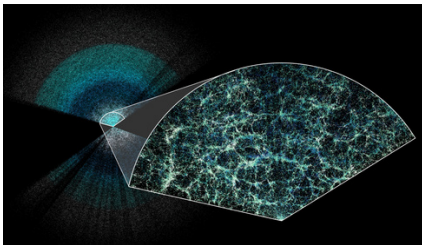






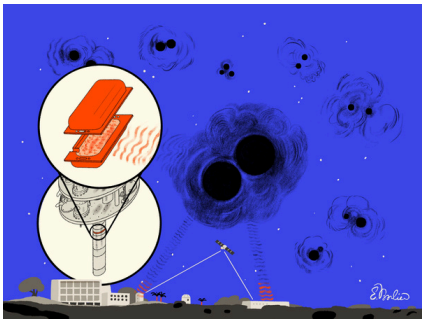
HIGHLIGHTS OF THE YEAR

DESI CREATES LARGEST 3D MAP OF THE UNIVERSE WITH UNPRECEDENTED PRECISION



The Dark Energy Spectroscopic Instrument (DESI) produced in 2024 the most precise measurement yet of the universe's expansion, mapping galaxies and quasars in unparalleled detail. This marks the first time scientists have measured the expansion history from 8 to 11 billion years ago with a precision better than 1%, providing a powerful tool to study dark energy. IFAE researchers played a key role in one of the major studies, contributing to groundbreaking insights into the evolution of the cosmos.

DIEGO BLAS OBTAINS ERC SYNERGY PROJECT ON HIGH-FREQUENCY GRAVITATIONAL WAVES



In 2024, ICREA researcher Diego Blas launched GravNet alongside European collaborators, a pioneering project to search for high-frequency gravitational waves. Funded by an ERC Synergy Grant, GravNet aims to develop novel detectors that could open a new observational window into the early universe. Blas contributed key ideas to explore Gravitational Waves in the the MHz–GHz frequency range, potentially shedding light on dark matter and primordial cosmological events.

LVK MEETING IN BARCELONA ORGANIZED BY IFAE

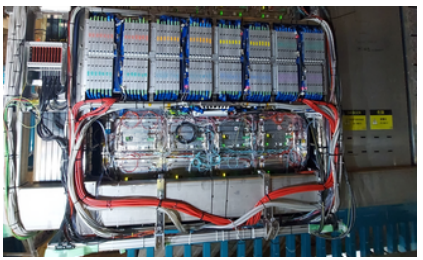
In September 2024, IFAE hosted the LIGO-Virgo-KAGRA (LVK) meeting in Barcelona, with Mario Martínez serving as chair of the local organizing committee. The event brought together 400 participants on site and an additional 400 online. That same year, IFAE joined the LIGO Scientific Collaboration, expanding its role in gravitational wave research. The institute also contributes to the Virgo Collaboration and the Einstein Telescope.

THREE NEW LSTS UNDER CONSTRUCTION AT CTAO NORTH

During 2024, the LST collaboration made steady progress toward completing the four Large-Sized Telescopes (LSTs) planned for the CTAO northern site at the Roque de los Muchachos Observatory (RMO). Construction advanced from civil works to the assembly of the structures and installation of subsystems. By the end of the year, the three new telescope structures were completed. Two of them had the camera support structures mounted, and one had all its mirrors installed.

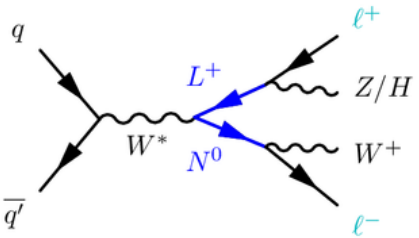
IFAE CONTRIBUTES TO ND280 UPGRADE FOR T2K AND HYPER-KAMIOKANDE

In 2024, the upgrade of the ND280 near detector was completed for the T2K-II phase and future use in Hyper-Kamiokande. IFAE contributed to the design and installation of the new subdetectors, with a leading role in the high-angle TPCs and project coordination. Neutrino beam data was collected in June and late 2024.



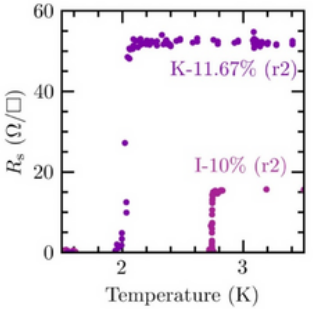
VECTOR-LIKE LEPTONS IN ATLAS AT THE LHC

Using the full Run 2 dataset from the ATLAS detector, the IFAE group conducted two pioneering searches for vector-like leptons (VLLs), a key feature in beyond-the-Standard-Model theories. The searches targeted pairs of VLLs decaying into electrons or muons with W, Z, or Higgs bosons, and a special class of VLLs predicted by the 4321 Model. While no significant excess was found, the results set the world's most stringent limits on VLL masses, reaching the TeV scale.



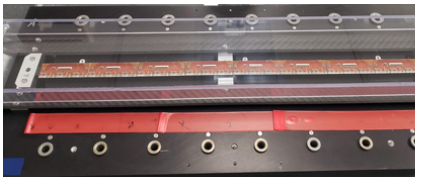
FIRST EXPERIMENTAL STUDY ON NITRIDIZED ALUMINUM FOR QUANTUM CIRCUITS

The IFAE Quantum Computing and Technology group published its first fully experimental study on nitridized aluminum (NitrAl), a new superconducting material for quantum circuits. Developed in collaboration with CNM, the material shows improved properties over standard aluminum used in superconducting qubits. Samples were fabricated at CNM and measurements performed at IFAE.



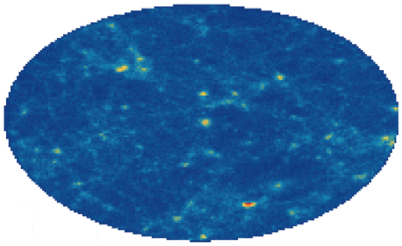
ITK PIXEL MODULE PRE-PRODUCTION COMPLETED AT IFAE

In 2024, IFAE completed the pre-production of ITk pixel modules, assembling and testing ten linear triplets in its clean rooms. All modules passed stress and charge collection tests, and were shipped to SLAC. The Production Readiness Review was completed in November. Testing of the first ITkPixV2.0 digital triplet is now finished, with full production set to begin in spring 2025.



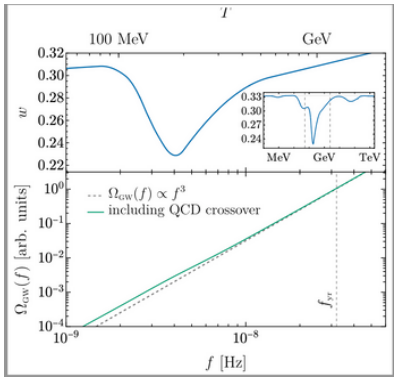
COSMOHUB ADDED TO THE EOSC MACROROADMAP

In December 2024, the European Open Science Cloud (EOSC) recognized CosmoHub as a key tool for advancing open science in Europe, adding it to its macroroadmap. Developed by the Port d'Informació Científica (PIC), CosmoHub is a web-based platform that enables the interactive exploration and distribution of large cosmological datasets, promoting accessible and collaborative data analysis for the scientific community.



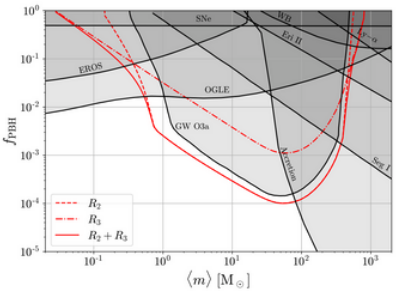
FABRIZIO ROMPINEVE WINS BUCHALTER COSMOLOGY PRIZE

In 2024, Fabrizio Rompineve won the Buchalter Cosmology Prize (Third Prize) for his study on gravitational wave signals from the QCD phase transition in the early universe. His work proposed a new method to test cosmological models using pulsar timing arrays, providing a potential window into physics beyond the Standard Model. This recognition underscores the growing role of gravitational waves in probing the universe's earliest moments.



NEW SEARCH FOR PRIMORDIAL BLACK HOLES USING LVK DATA

In a collaborative effort between IFAE's gravitational wave and theory groups, a new search for primordial black holes (pBHs) was conducted using LVK O3 data. The analysis, utilizing a hierarchical Bayesian approach, explored the possibility of a subdominant pBH population alongside astrophysical black holes. The results, were highlighted as the editor's suggestion in PRD.



SCIENTIFIC OUTPUT IN 2024

325
NUMBER OF INDEXED JOURNAL ARTICLES

88%
% ARTICLES IN FIRST QUARTILE JOURNALS

5.1
AVERAGE JOURNAL IMPACT FACTOR (IF)

TOP 5 JOURNALS WHERE IFAE PUBLISHED MOST FREQUENTLY IN 2024

	NUMBER OF ARTICLES
Monthly Notices Of The Royal Astronomical Society	55
Journal Of High Energy Physics	48
Astronomy & Astrophysics	44
Physical Review D	41
Astrophysical Journal Letter	44

TOP 5 JOURNALS (BY IF) WHERE IFAE PUBLISHED IN 2024

Science Bulletin	1
Journal Of High Energy Astrophysics	2
IEEE Transactions On Medical Imaging	1
Astrophysical Journal Letters	19
Astrophysical Journal Supplement Series	3

DOCTORAL THESES: 11

NUMBER OF PRESENTATIONS AT INTERNATIONAL CONFERENCES: 240

HUMAN RESOURCES IN 2024

EXPERIMENTAL DIVISION

27	23	33
FACULTY	POST-DOCTORAL RESEARCHERS	DOCTORAL STUDENTS

THEORY DIVISION

15	7	5
FACULTY	POST-DOCTORAL RESEARCHERS	DOCTORAL STUDENTS

TECHNICAL SERVICES

23	24
	PIC

RESEARCH SUPPORT

20

7 ICREA Professors.

3 ERCs in the last 2 years.

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

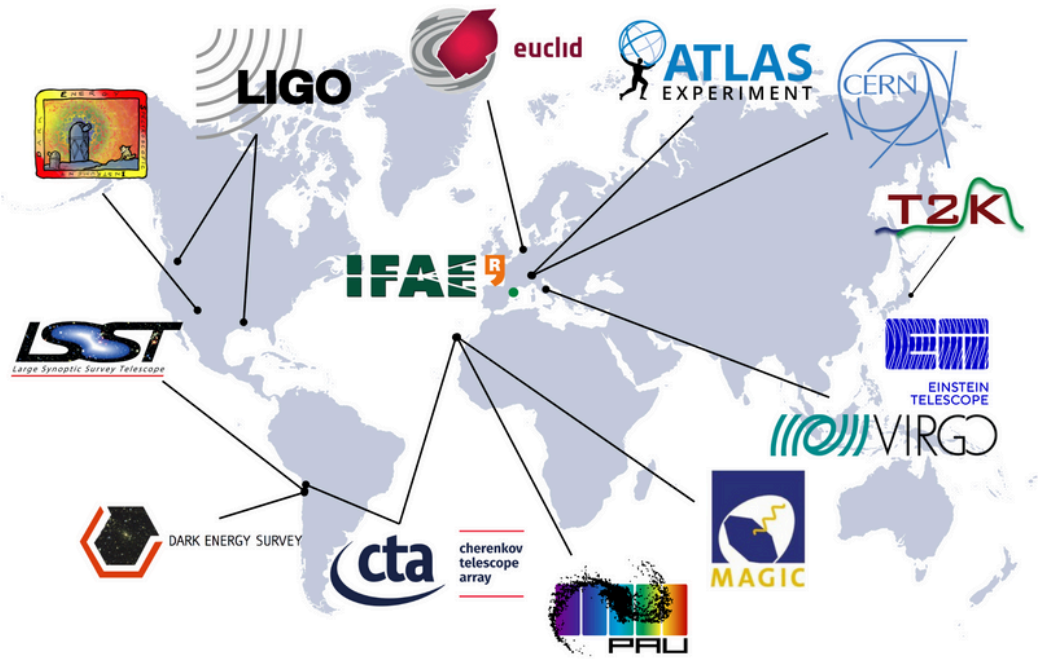
IFAE investigators have participated in recent discoveries that have been awarded 3 Nobel Prizes (Higgs bosons, astrophysical neutrinos, GW). Two investigators have been awarded the Breakthrough Prizes.

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

PROJECTS IN 2024

36	17	16	1	2
MINISTERIO DE CIENCIA, INNOVACIÓN Y UNIVERSIDADES	EUROPEAN COMISSION	AGÈNCIA DE GESTIÓ D'AJUTS UNIVERSITARIS I DE RECERCA	FUNDACIÓ BANCARIA LA CAIXA	BIST

INTERNATIONAL COLLABORATIONS



OUTREACH IN 2024

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 2024

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

1
NEW INVENTION PROTECTED

0.9M€
PUBLIC FUNDS FOR INNOVATION PROJECTS

360K€
INVOICING FOR TECHNOLOGICAL SERVICES

SPIN-OFFS IN 2024

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

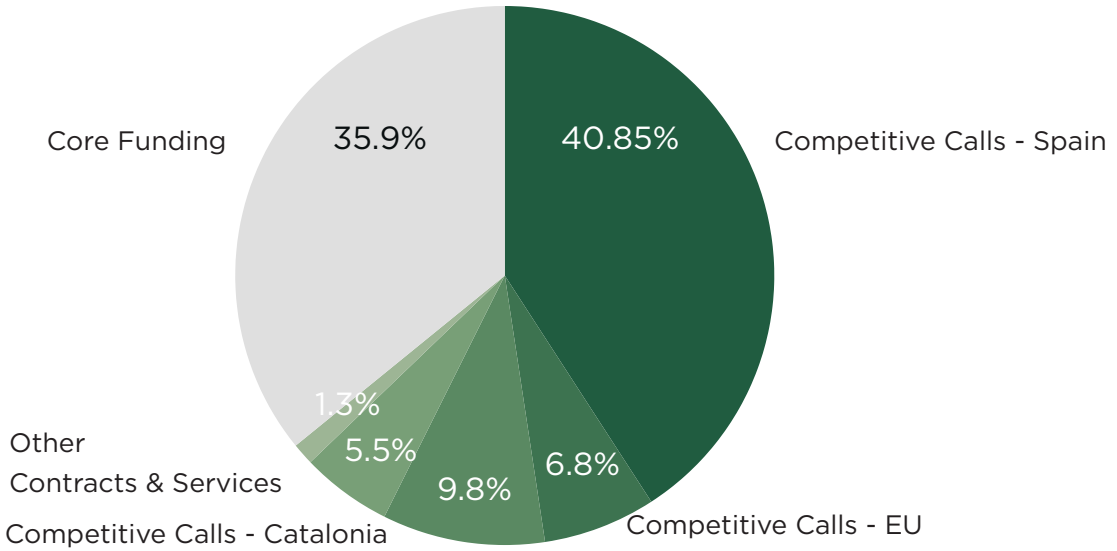
Baretek offers microelectronic servcies for research, health and industry. The microelectronic assembly services include: state-of-the-art ASIC, FPGA and microcontroller assembly technologies.

baretek.eu.com

FUNDING IN 2024

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 2024 the ratio of competitive to core funding was about 3.

10.6 M€ TOTAL FUNDING IN 2024



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E-08193 Bellaterra (Barcelona) Spain
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UAB Universitat Autònoma de Barcelona

CENTRE DE | CENTER OF

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, INNOVACIÓN Y UNIVERSIDADES

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"