### FROM PARTICLES TO THE COSMOS



IFAE Institut de Física d'Altes Energies Report of Activities Summary 2016



# 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 25 years we have been exploring the cosmic and high energy frontiers to address fundamental questions about our Universe.

years 1991-2016

## IFAE **At a glance**

founded in 1991

**150** people

three divisions: theory, experimental, technical; and administration

**basic research** in fundamental physics and **applied research** in instrumentation and medical applications

**research lines**: Particle Physics, Astroparticle Physics, Cosmology, Medical Imaging & Physics Instrumentation

one large engineering group (33 engineers and technicians)

collaboration in **9 international experiments** in high impact / leadership positions (ATLAS, MAGIC, DES, T2K, PAU, CTA, DESI, Euclid, LSST)

**facilities**: chip packaging & assembly, clean rooms, shielded room, electronics labs, optical lab, mechanical workshop (300 m<sup>2</sup>)

one 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 and the Cherenkov Telescope Array in La Palma and Chile, among others.

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

### HIGGS PHYSICS ANTIMATTER DARK MATTER DARK ENERGY EXTREME UNIVERSE



## TECHNOLOGY At IFAE

At IFAE we work at the cutting edge of detector technology, developing pixel detectors for High Energy Physics, telescope cameras and detectors for medical imaging and other scientific and industrial fields.

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

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



## HIGHLIGHTS OF THE YEAR

#### **T2K CP VIOLATION RESULTS**

T2K reported in 2016 its first results in the search for CP violation in neutrino oscillations using appearance and disappearance channels with both neutrino and antineutrino beams. The data include all runs from January 2010 to May 2016. The results show that the CP conservation hypothesis is excluded at 90%. Neutrinos might behave differently in their matter and antimatter forms.





#### LIGHT COOLS OFF WHEN CROSSING COSMIC VOIDS

Researchers at IFAE led the effort to determine the variation in the temperature of the cosmic background radiation as it crosses large overdense (with superclusters of galaxies) or underdense (with large cosmic voids) regions in the sky, identified in the data collected by the Dark Energy Survey in its first year of regular operations.

The resulting maps indicate that, when crossing cosmic voids, the cosmic background radiation becomes slightly cooler (by about five millionth of a degree) than expected by the standard cosmological model, even after accounting for the effect of the mysterious dark energy that powers the current accelerated expansion of the universe. If confirmed, this result could have farranging implications for our understanding of the universe.

### SEARCHES FOR SUPERSYMMETRY AT THE LHC RUN 2

The year 2016 was exceptional in terms of LHC performance, with 40 fb<sup>-1</sup> of proton-proton collision data at a centre-of-mass energy of 13 TeV delivered to the ATLAS and CMS experiments. The IFAE-ATLAS group maintained a strong involvement in detector operations and participated in a large number of physics analyses.

The group played a leading role in some of the highestprofile searches for Supersymmetry using early Run 2 data, such as searches for supersymmetric partners of the gluon, the top quark and the bottom quark.

These analyses target some of the most promising models for "Natural Supersymmetry", and represent a stepping-stone for more sensitive searches in the near future.





### LST1 FOUNDATIONS COMPLETED

The foundation for the prototype of CTA's largest telescopes, the Large Size Telescopes, was completed in 2016. The main elements of the foundation, the telescope and camera-access tower foundations, are built with 620 cubic meters of concrete or about 1,500 tonnes. This massive amount of concrete, will help keep the telescope and its mirror (400 m<sup>2</sup>) stable with winds of up to 200 km/h.



### AFP TRACKER DEVELOPED AT IFAE

In 2016 the IFAE pixel group fabricated the ATLAS Forward Proton (AFP) 3D silicon tracker. The detector was also integrated and commissioned with the ATLAS detector at CERN by IFAE.

AFP identifies protons that emerge intact from the LHC collisions. Such processes are usually associated with elastic and diffractive scattering. However, the AFP physics program ultimately aims to perform searches for new physics, like diffracive Higgs production.

### **COSMOHUB 2.0 ONLINE**

COSMOHUB is a web portal to analyze and distribute massive cosmological data using leading big data technologies. It has been developed at PIC in collaboration with the Institute of Space Studies of Catalonia (ICE-IEEC). It currently provides support to several international cosmology projects such as the Euclid space ESA mission, the Dark Energy Survey (DES), the Physics of the Accelerated Universe (PAU) and the Marenostrum Institut de Ciències de l'Espai (MICE) Simulations.





#### HR EXCELLENCE IN RESEARCH AWARD

IFAE received the HR Excellence in research award for its Human Resources Strategy and Action Plan 2016-2019.

The award reflects IFAE's commitment to continuously improve its human resources policies in line with the European Charter for Researchers and the Code of Conduct for the Recruitment of Researchers.



#### A NOVEL QCD COUPLING

In 2016, IFAE researchers defined a novel QCD coupling whose beta function (which parameterizes its evolution with energy) can be derived exactly, and which allows to yield improved estimates for uncertainties due to renormalization-scheme variations.

#### IFAE JOINS THE LARGE SYNOPTIC SURVEY TELESCOPE PROJECT

The Observational Cosmology group at IFAE joined the Large Synoptic Survey Telescope (LSST) project, together with ICE (IEEC-CSIC), CIEMAT and IFT/UAM, in what is known as the Barcelona-Madrid participation Group.

The group joined LSST's Dark Energy Science Collaboration (DESC) to contribute in dark matter and dark energy research.



The LSST is currently under construction and full operations are expected to start in 2023.

#### **3D BIOPSY, NEW MEDICAL IMAGING PROJECT AT IFAE**

Comunitats RIS3CAT Research and Innovation Strategies for Smart Specialisation The 3DBonT project is part of the RIS3CAT community "Tecnologies Aplicades a la Salut" coordinated by LEITAT. The project's objective is to develop innovative technologies in the field of biopsy devices that improve accuracy of diagnosis, optimize patient treatments, and offer therapies with greater efficiency.

IFAE has joined the project offering its microelectronics and detector design expertise and facilities to develop and build the 3DBonT X-ray camera.

## SCIENTIFIC OUTPUT IN 2016

NUMBER OF INDEXED JOURNAL ARTICLES

239

% ARTICLES IN FIRST QUARTILE JOURNALS

94.1%

AVERAGE JOURNAL IMPACT FACTOR (IF)

4\_9

TOP 5 JOURNALS (BY IF) WHERE IFAE PUBLISHED IN 2016	NUMBER OF ARTICLES
Phys. Rev. Lett. (IF 7.3)	9
J. High Energy Phys. (IF 5.2)	45
Astrophys. J. (IF 5.9)	14
JCAP (IF 5.6)	1
Astron. Astrophys. (IF 5.2)	10

#### TOP 5 JOURNALS WHERE IFAE PUBLISHED MOST FREQUENTLY

Phys. Rev. D (IF 4.5)	46
J. High Energy Phys. (IF 6.1)	45
Eur. Phys. J. (IF 4.9)	42
Phys. Lett. B (IF 4.8)	30
Mon. Not. Roy. Astron. Soc. (IF 4.9)	20

#### **DOCTORAL THESES: 8**

NUMBER OF PRESENTATIONS AT INTERNATIONAL CONFERENCES: 120

### **HUMAN RESOURCES** IN 2016

**EXPERIMENTAL DIVISION** 



FACULTY

THEORY DIVISION

23

POST-DOCTORAL RESEARCHERS



DOCTORAL STUDENTS

12

5

FACULTY

POST-DOCTORAL RESEARCHERS 16 DOCTORAL STUDENTS

**TECHNICAL SERVICES** 

33



**RESEARCH SUPPORT** 

12



### **INTERNATIONAL** COLLABORATIONS



### TECHNOLOGY TRANSFER IN 2016

IFAE performs frontier research in particle physics, astrophysics, and cosmology, fields of knowledge requiring advanced engineering, electronics and software technologies not existing in the market. IFAE research & engineering teams develop their own technology, transferring it to industry by means of joint ventures, partnerships, R&D agreements, technical services based on singular scientific infrastructures, training sessions, consultancy, licensing and spin-off creation.





NON COMPETITIVE FUNDS COMING FROM INDUSTRIAL AGREEMENTS AND SERVICES **OFFERED TO EXTERNAL ENTITIES** 



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