IFAE:
from particles to the Cosmos

IFAE 25 1984-2016 Institut de Física d'Altes Energies

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Hottest Topics in Fundamental Physics

Universe Accelerating?

Why is the expansion of the Universe accelerating?

Dark energy

Why No Antimatter?

How can it be that one part in 10^9 of matter did not annihilate with

antimatter?

Dark Matter?

Why is it that the majority of matter in galaxies does not emit light?

Dark matter

Origin of Mass?

What is the origin of the mass of all particles?

Higgs particle

Why so light?

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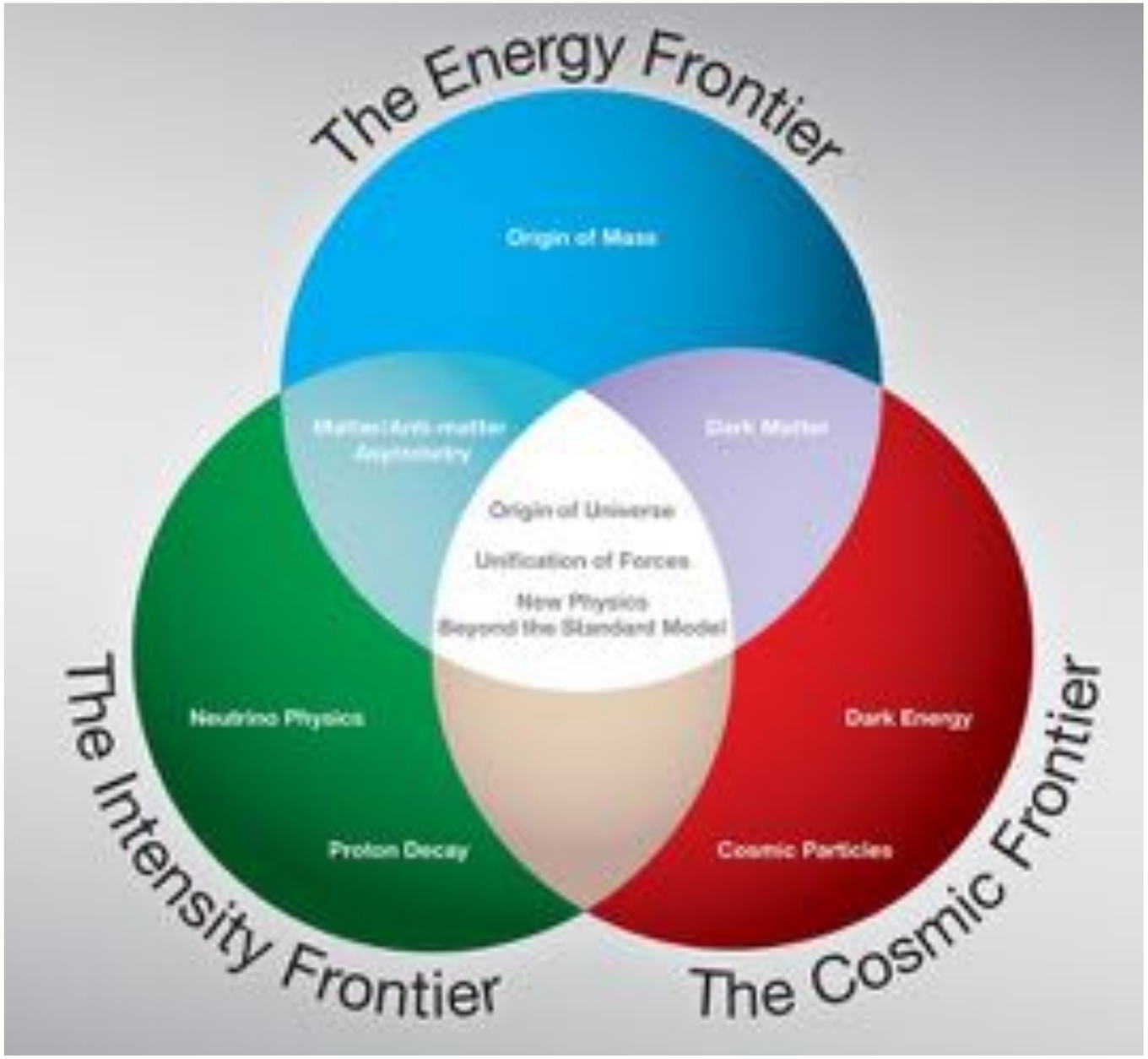
Frontiers in Fundamental Physics



The Energy Frontier

- At the energy frontier, physicists use **particle accelerators** to investigate the fundamental laws of physics

- The Large Hadron Collider (LHC) produces **proton collisions at 13TeV**, recreating the conditions of the Universe just after the Big Bang

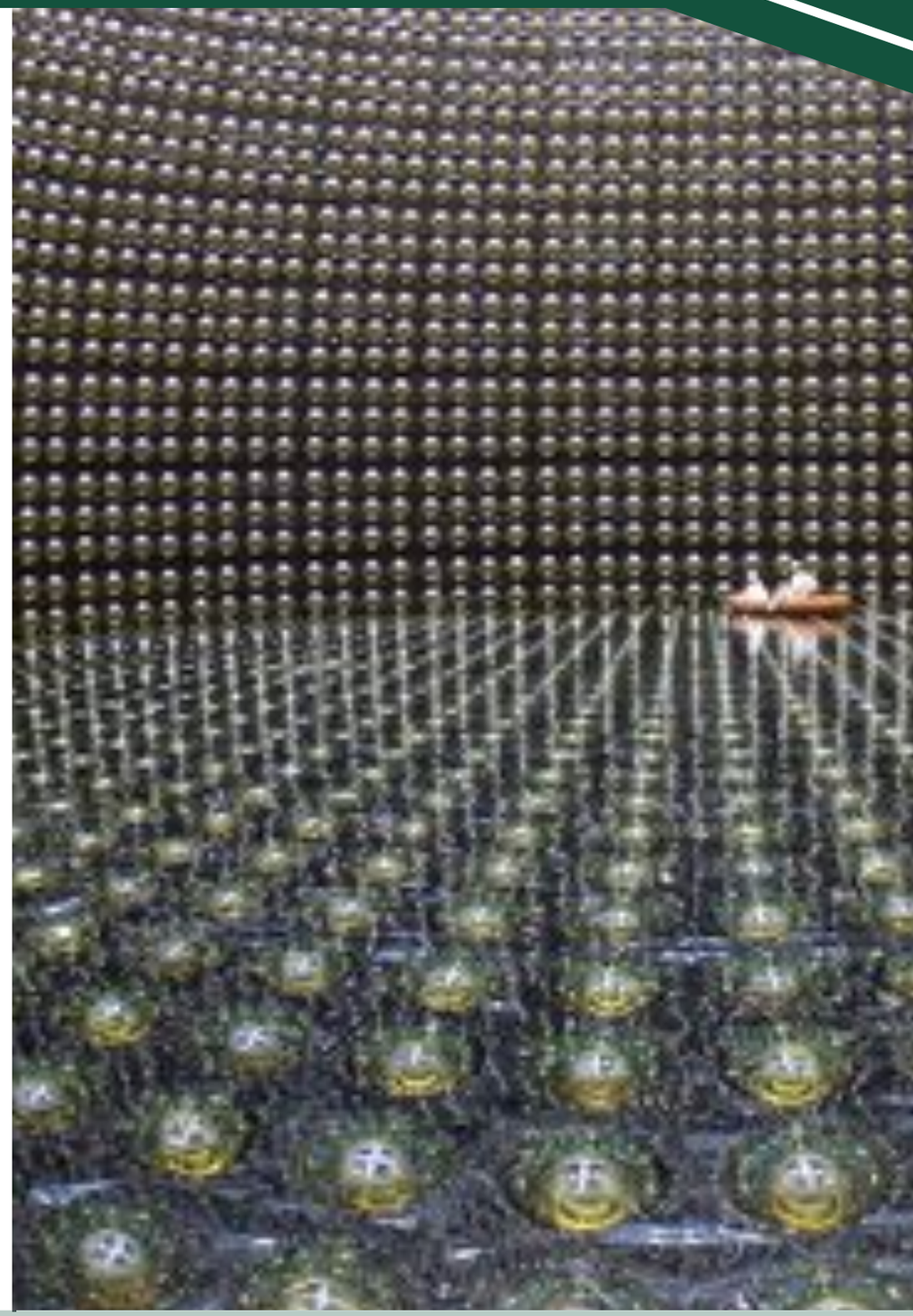
- Experiments like **ATLAS** allow us to study the **Higgs boson** and other particles and search for **dark matter** and **supersymmetry**

The Intensity Frontier

- At the intensity frontier, physicists use **neutrino beams** to investigate the fundamental laws of physics

- Measurements of the properties of the neutrinos are key to the understanding of **new physics beyond today's models**

- Experiments like T2K measure neutrino oscillations to elucidate **if matter behave differently in its matter and antimatter forms**



The Cosmic Frontier

- At the cosmic frontier, **astrophysicists use cosmic sources as a laboratory** to investigate the fundamental laws of physics

- High Energy Astrophysics study **the most energetic phenomena in the universe**, which generate gamma rays of energies above few tens of GeV up to hundreds of TeV

- Telescopes like MAGIC offer a window into the **most violent Universe**, and allow us to study **dark matter**

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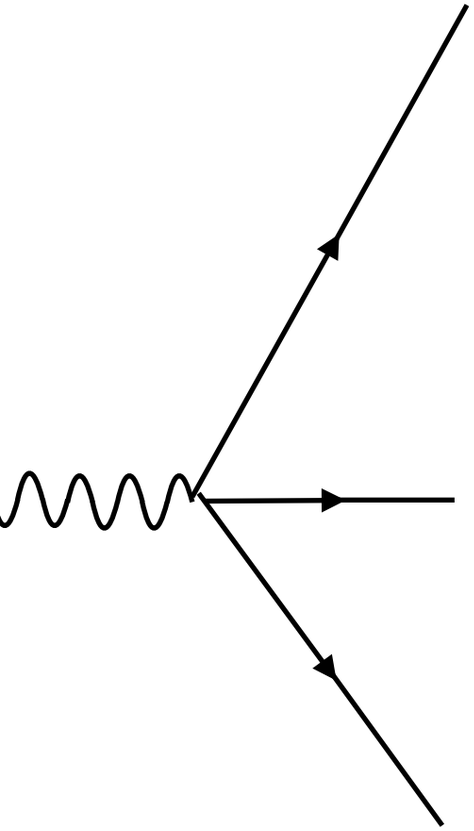
The Cosmic Frontier

- At the cosmic frontier, **cosmologists use the whole Universe as a laboratory** to investigate the fundamental laws of physics

- Cosmologists try to shed light on the nature of the mysterious **dark energy**, responsible for the current **accelerated expansion of the universe**

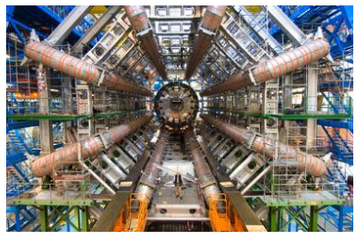
- Galaxy surveys like the Dark Energy Survey (DES) use gravitational lensing to **explore 14 billion years of Cosmic History**

Experimental Division

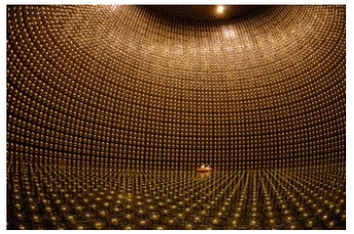


particle physics

Higgs, dark matter, antimatter



ATLAS



T2K

ATLAS PIXELS

astroparticles

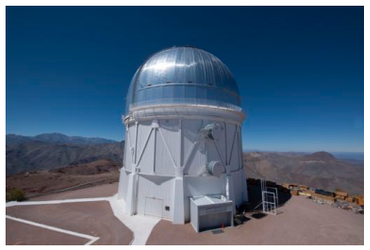
dark matter, extreme Universe

MAGIC

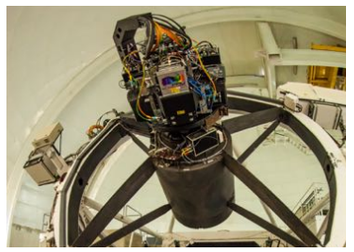
CTA

cosmology

dark energy, dark matter

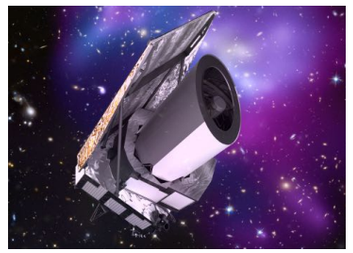


DES



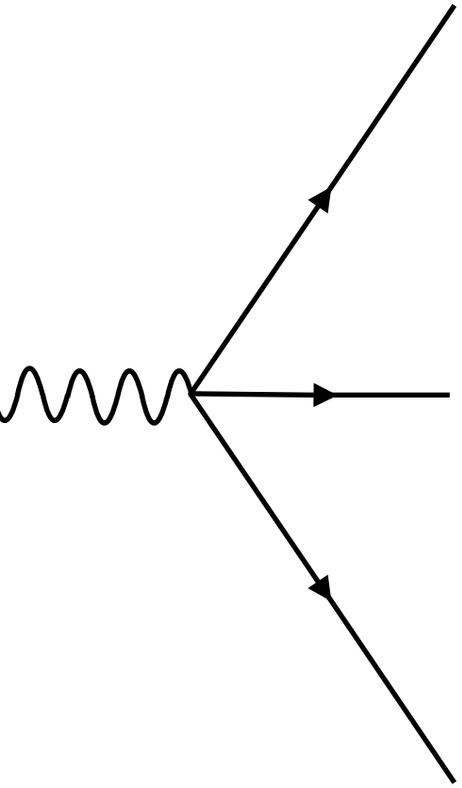
PAU

DESI



EUCLID

Theory Division



standard model

Higgs, antimatter

beyond the standard model

Higgs, dark matter, antimatter

astroparticles and cosmology

dark matter, dark energy, antimatter

$$W_\nu^+W_\mu^-) - 2A_\mu Z_\mu^0 W_\nu^+W_\nu^-] - g$$
$$\frac{1}{8}g^2\alpha_h[H^4+(\phi^0)^4+4(\phi^+\phi^-)^2+4(\phi^0)^2\phi^+\phi^-+$$
$$gMW_\mu^+W_\mu^-H - \frac{1}{2}g\frac{M}{c_w^2}Z_\mu^0Z_\mu^0H - \frac{1}{2}ig[W_\mu^+($$
$$W_\mu^-(\phi^0\partial_\mu\phi^+ - \phi^+\partial_\mu\phi^0)] + \frac{1}{2}g[W_\mu^+(H\partial_\mu\phi^- - \phi$$
$$\phi^+\partial_\mu H)] + \frac{1}{2}g\frac{1}{c_w}(Z_\mu^0(H\partial_\mu\phi^0 - \phi^0\partial_\mu H) - ig\frac{s_w^2}{c_w}$$
$$igs_wMA_\mu(W_\mu^+\phi^- - W_\mu^-\phi^+) - ig\frac{1-2c_w^2}{2c_w}Z_\mu^0($$
$$igs_wA_\mu(\phi^+\partial_\mu\phi^- - \phi^-\partial_\mu\phi^+) - \frac{1}{4}g^2W_\mu^+W_\mu^-[$$
$$\frac{1}{4}g^2\frac{1}{c_w^2}Z_\mu^0Z_\mu^0[H^2+(\phi^0)^2+2(2s_w^2-1)^2\phi^+\phi^-]$$
$$W_\mu^-\phi^+) - \frac{1}{2}ig^2\frac{s_w^2}{c_w}Z_\mu^0H(W_\mu^+\phi^- - W_\mu^-\phi^+) +$$
$$W_\mu^-\phi^+) + \frac{1}{2}ig^2s_wA_\mu H(W_\mu^+\phi^- - W_\mu^-\phi^+) - g^2$$
$$g^1s_w^2A_\mu A_\mu\phi^+\phi^- - \bar{e}^\lambda(\gamma\partial + m_e^\lambda)e^\lambda - \bar{\nu}^\lambda\gamma\partial$$
$$\bar{d}_j^\lambda(\gamma\partial + m_d^\lambda)d_j^\lambda + igs_wA_\mu[-(\bar{e}^\lambda\gamma^\mu e^\lambda) + \frac{2}{3}(\bar{u}$$
$$\frac{ig}{4c_w}Z_\mu^0[(\bar{\nu}^\lambda\gamma^\mu(1+\gamma^5)\nu^\lambda) + (\bar{e}^\lambda\gamma^\mu(4s_w^2-1-$$
$$1-\gamma^5)u_j^\lambda) + (\bar{d}_j^\lambda\gamma^\mu(1-\frac{8}{3}s_w^2-\gamma^5)d_j^\lambda)] + \frac{ig}{2\sqrt{2}}$$
$$(\bar{u}_j^\lambda\gamma^\mu(1+\gamma^5)C_{\lambda\kappa}d_j^\kappa)] + \frac{ig}{2\sqrt{2}}W_\mu^-[(\bar{e}^\lambda\gamma^\mu(1+$$
$$\gamma^5)u_j^\lambda)] + \frac{ig}{2\sqrt{2}}\frac{m_e^\lambda}{M}[-\phi^+(\bar{\nu}^\lambda(1-\gamma^5)e^\lambda) + \phi$$
$$\frac{g}{2}\frac{m_e^\lambda}{M}[H(\bar{e}^\lambda e^\lambda) + i\phi^0(\bar{e}^\lambda\gamma^5 e^\lambda)] + \frac{ig}{2M\sqrt{2}}\phi^+[-m$$
$$m_u^\lambda(\bar{u}_j^\lambda C_{\lambda\kappa}(1+\gamma^5)d_j^\kappa] + \frac{ig}{2M\sqrt{2}}\phi^-[m_d^\lambda(\bar{d}_j^\lambda C_{\lambda\kappa}^\dagger(1+$$
$$\gamma^5)u_j^\kappa] - \frac{g}{2}\frac{m_u^\lambda}{M}H(\bar{u}_j^\lambda u_j^\lambda) - \frac{g}{2}\frac{m_d^\lambda}{M}H(\bar{d}_j^\lambda d_j^\lambda) +$$

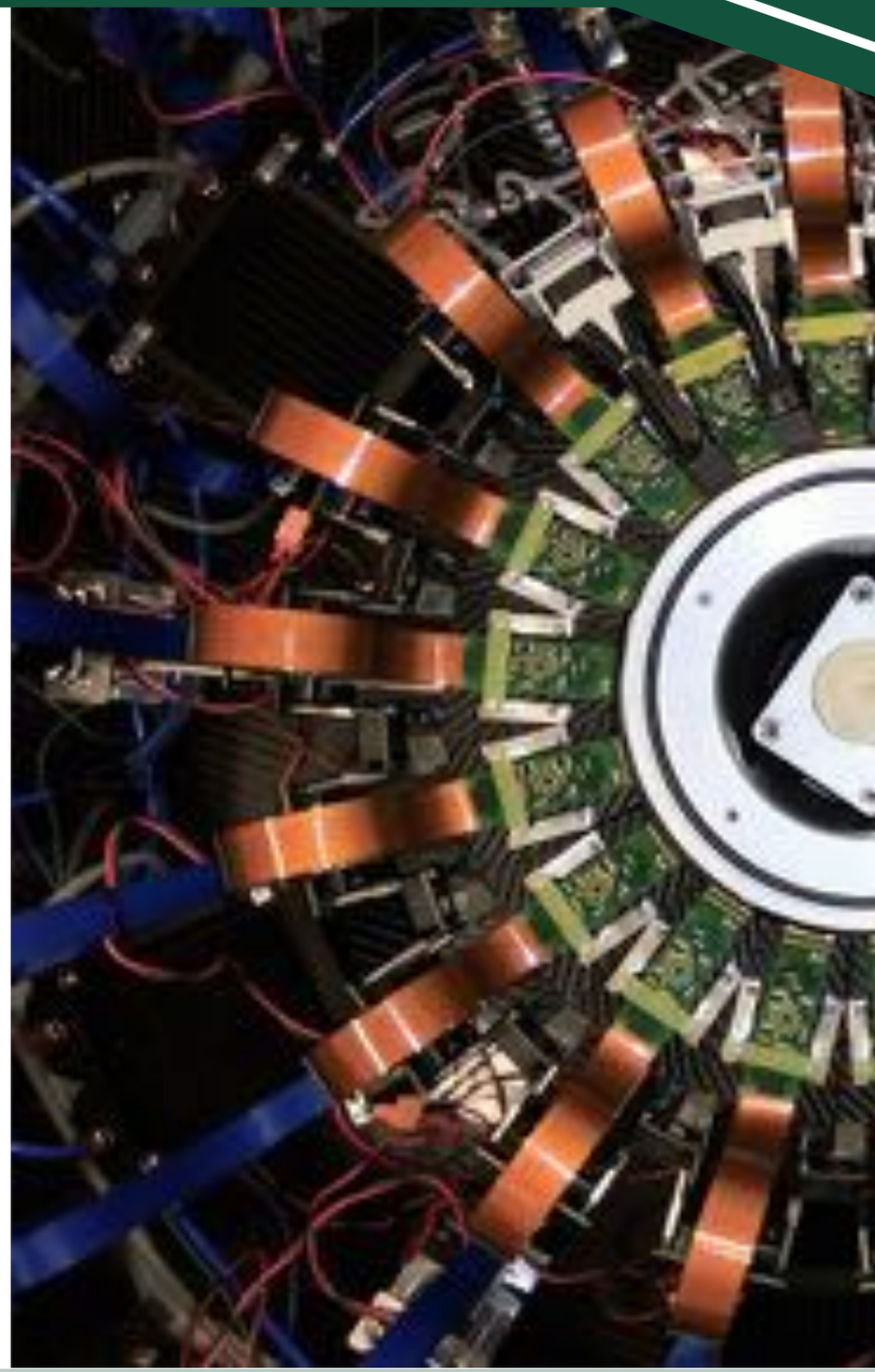
Applied Physics

- The same group of scientists that perform the experiments start by **designing and building the instruments**.

- IFAE works at the cutting edge of **detector & telescope** technology.

- The expertise gained is applied to **medical imaging** and other industrial fields.

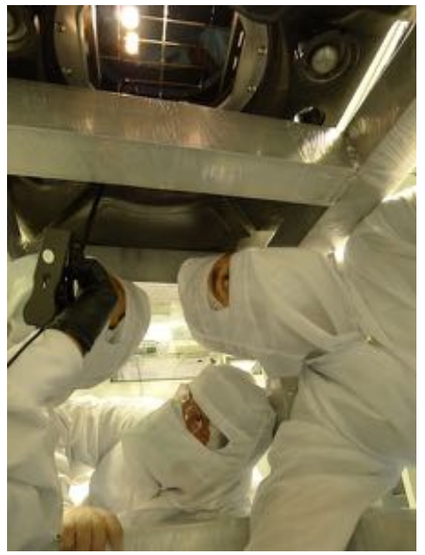
- Our facilities include a **microelectronics** laboratory with state-of-the-art technologies, a **data center**, a **mechanical workshop**, electronics labs, an optical room and a shielded room.



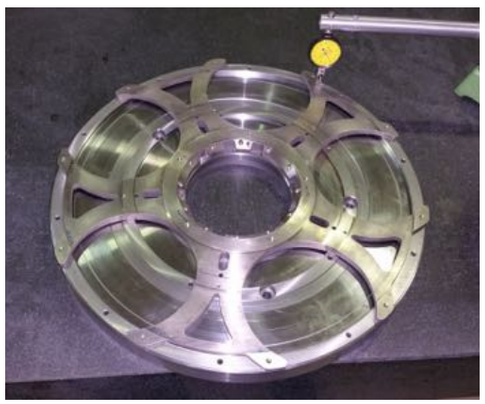
Engineering

microelectronics → **ATLAS IBL 3D pixels**

clean room → **PAUcam filters**



mechanical workshop → **Euclid filter wheel**



Data Center: PIC

Port d'**I**nformació **C**ientífica

- Part of LHC Computing Grid
- One of 12 Tier-1 LHC data processing centers, only one in Spain
- ~10 PB on disk, ~10 PB on tape
- MAGIC data center
- One of Euclid's data centers
- Could be useful for big data in Biosciences

IFAE at a glance

Fundat per | Founded by

Membre de | Member of

Amb el suport de | Supported by

- born in **1991**
- **150** people
- three **divisions**: theory, experimental, technical
- **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)
- collaborations in **9 international major experiments** in leadership positions (ATLAS, MAGIC, DES, T2K, PAU, CTA, DESI, Euclid, LSST)
- **facilities**: chip packaging & assembly, clean room, shielded room, electronics lab, optical lab, mechanical workshop (300 m^2)
- one data processing centre: **PIC** (ATLAS Tier-1)
- member of **Barcelona Institute of Science and Technology**
- twice awarded with the **Severo Ochoa** accreditation of excellence (2012, 2016)