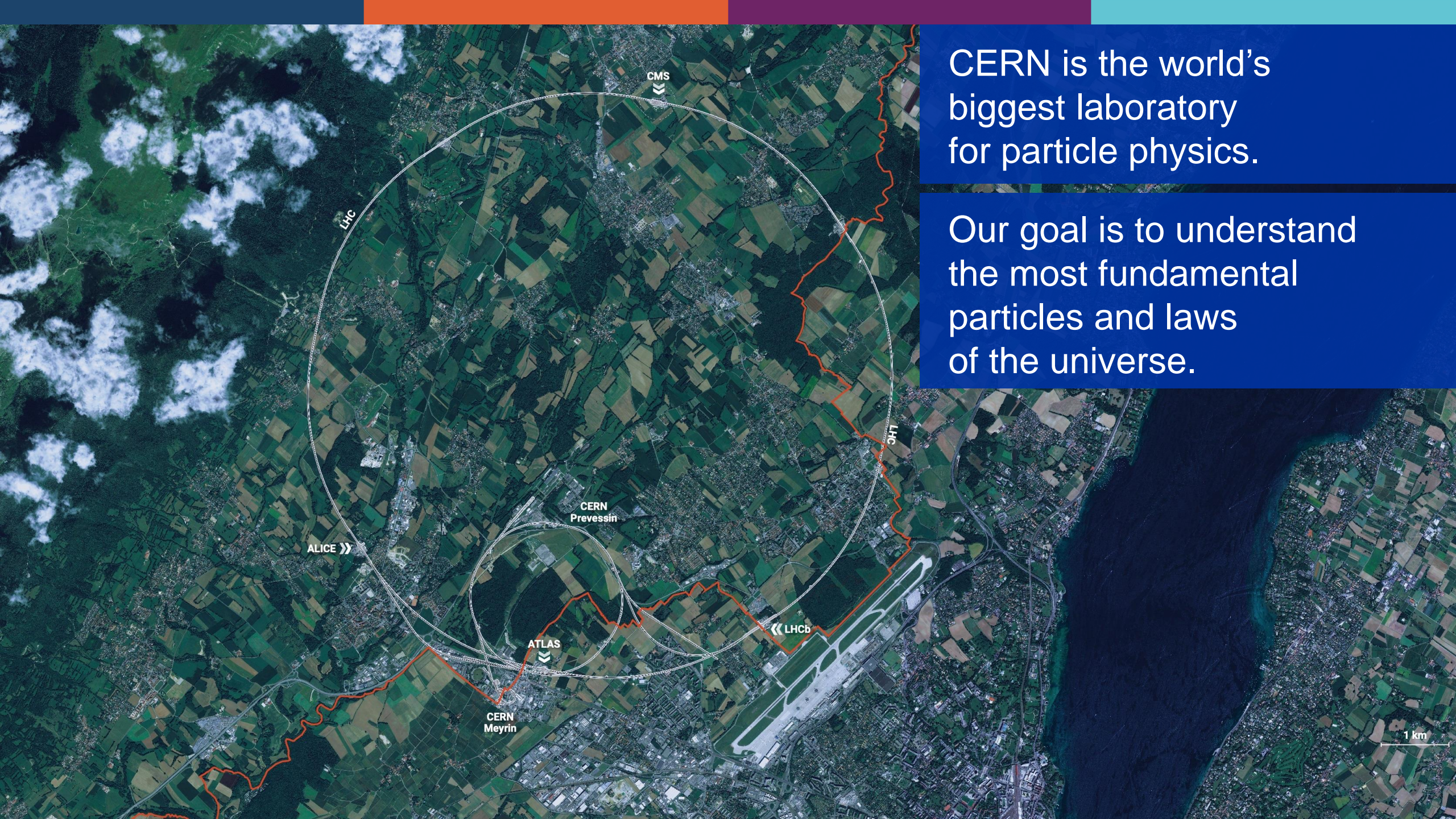


# CERN – An Example of a Large-scale Research Infrastructure

Emmanuel Tsesmelis (CERN)

Hadron Therapy Workshop: Status and Perspectives, Plans for Next Generation Facilities  
Thessaloniki, Greece

18 October 2024



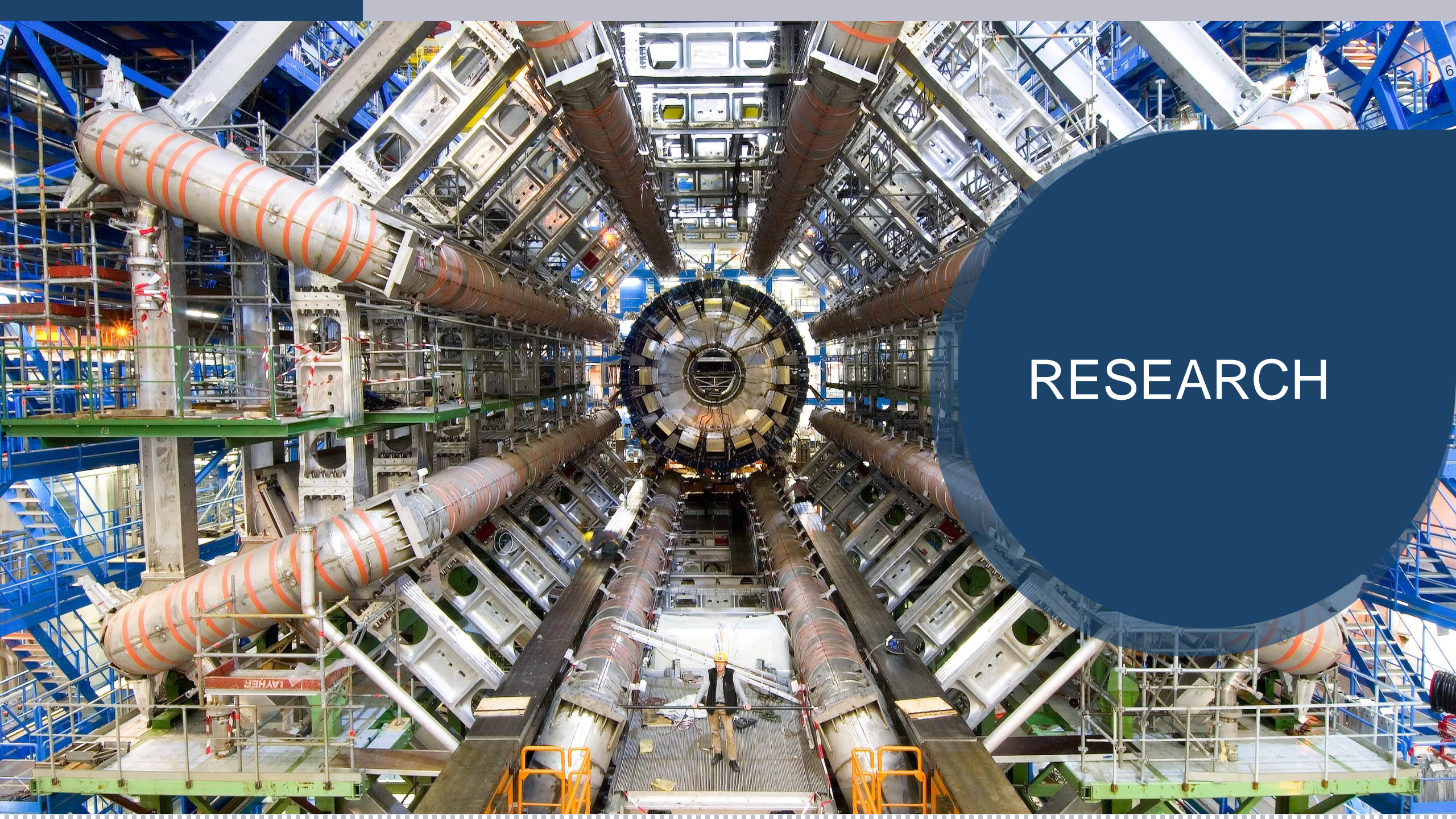
CERN is the world's biggest laboratory for particle physics.

Our goal is to understand the most fundamental particles and laws of the universe.

1 km

# Four pillars underpin CERN's mission

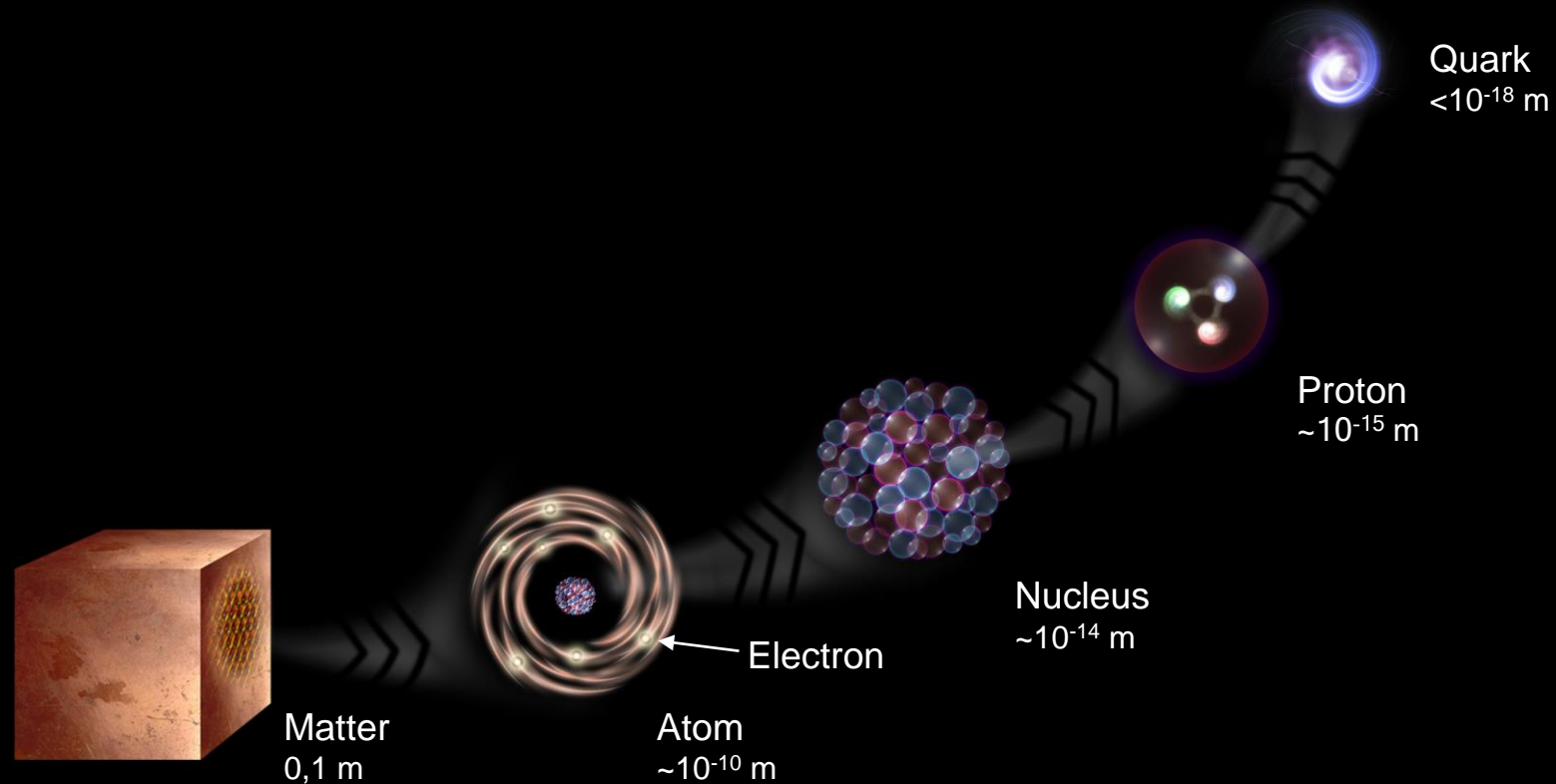


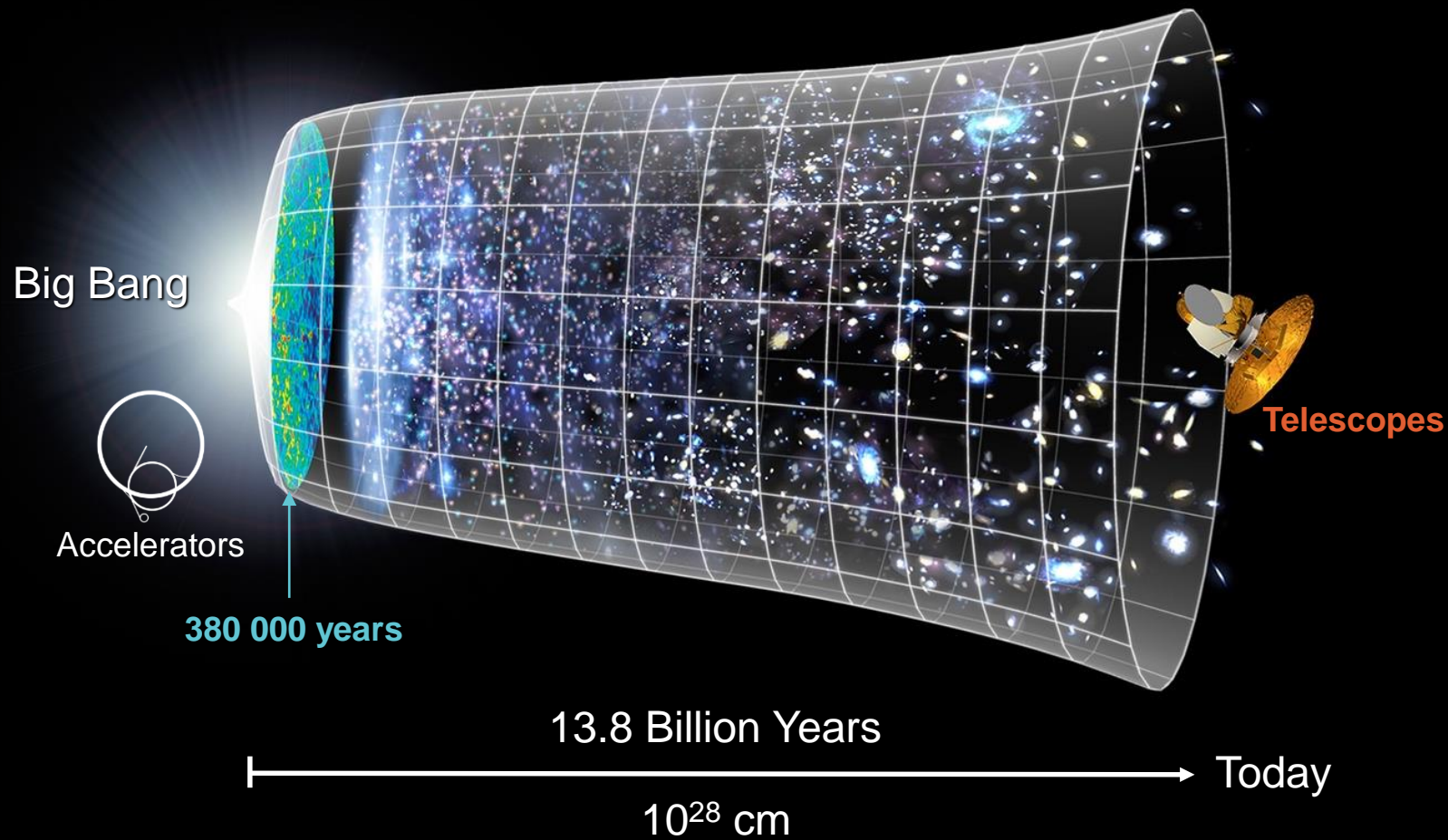


RESEARCH

# What is the universe made of?

We study the elementary building blocks of matter and the forces that control their behaviour





# How did the universe begin?

We reproduce the conditions a fraction of a second after the Big Bang, to gain insight into the structure and evolution of the universe.

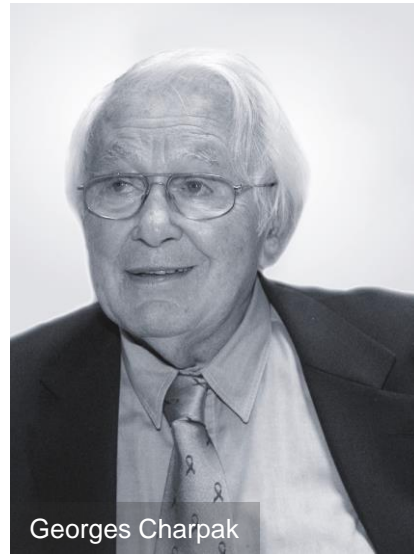
# At CERN we help to answer these questions



Carlo Rubbia



Simon Van der Meer



Georges Charpak

Several CERN scientists have received Nobel Prizes for key discoveries in particle physics.

The Higgs boson was discovered in 2012; without it fundamental particles would be massless and atoms could not form.

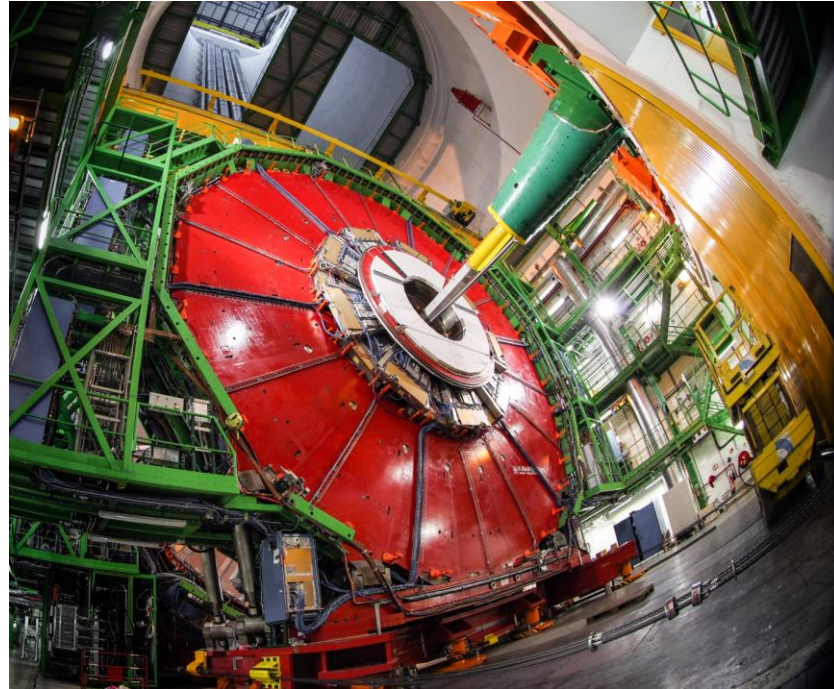


François Englert and Peter Higgs. With Robert Brout, they proposed the mechanism in 1964.

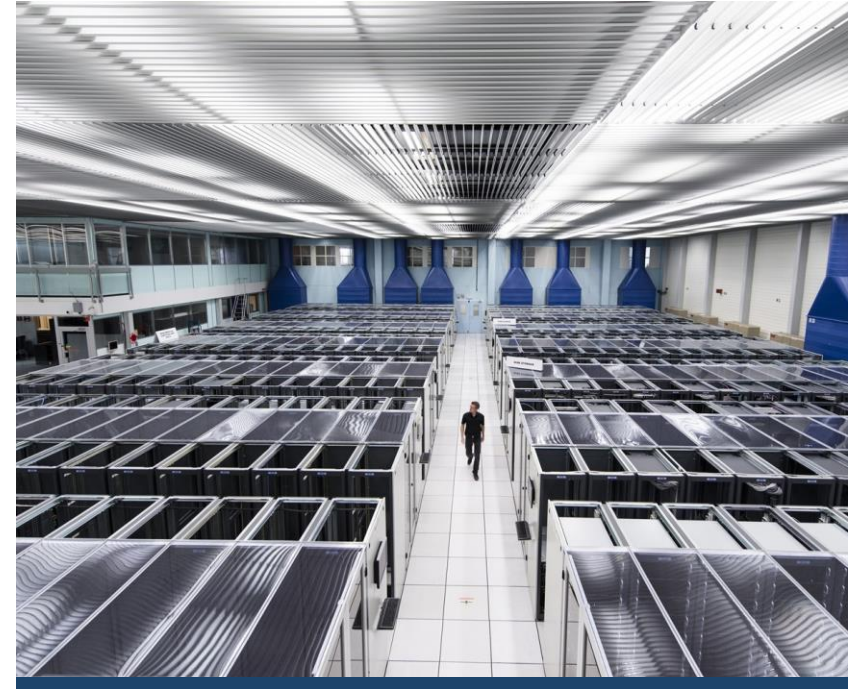
# We develop technologies in three key areas



ACCELERATORS

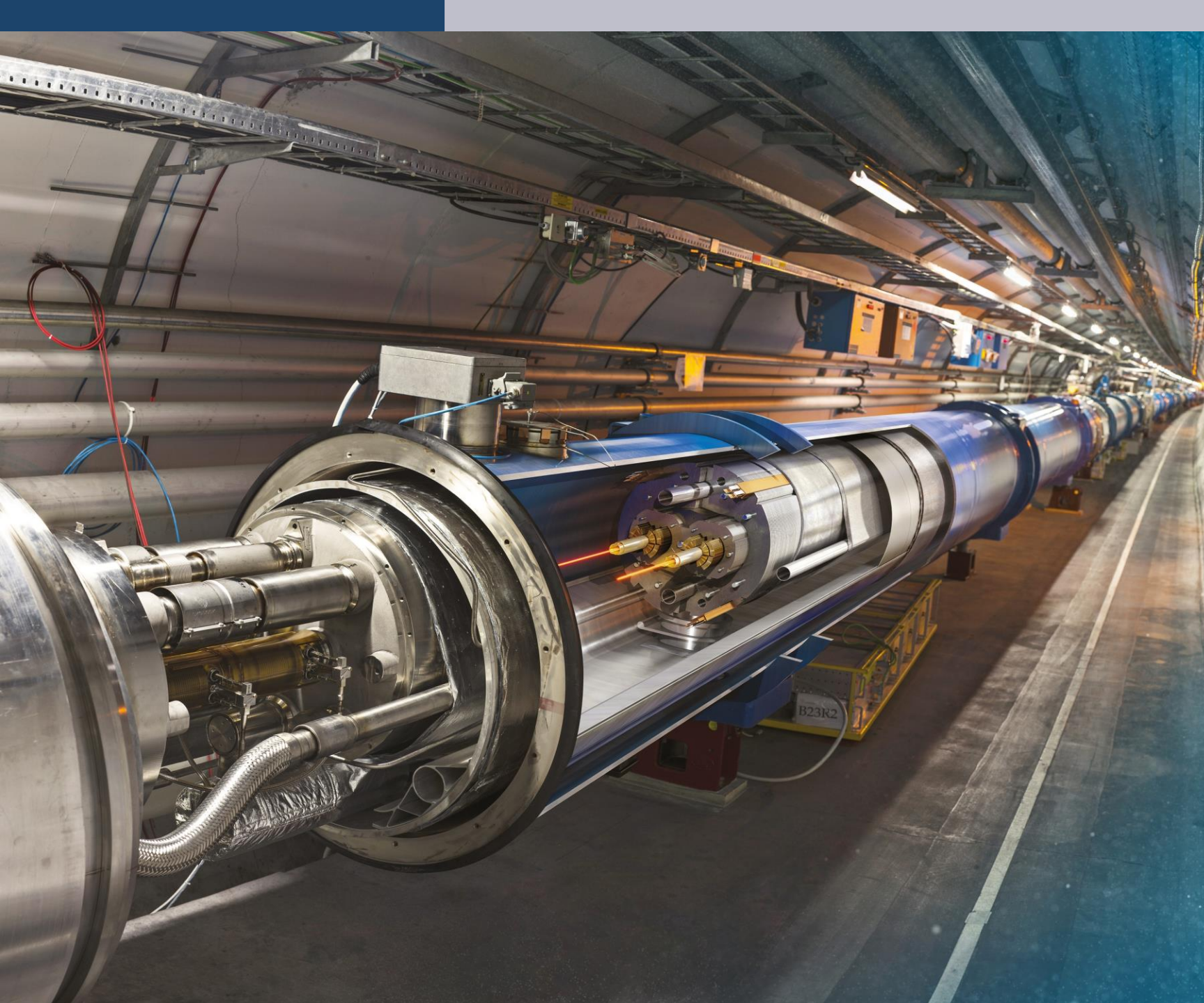


DETECTORS



COMPUTING

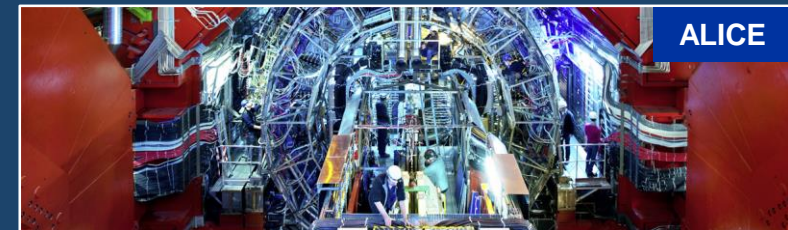
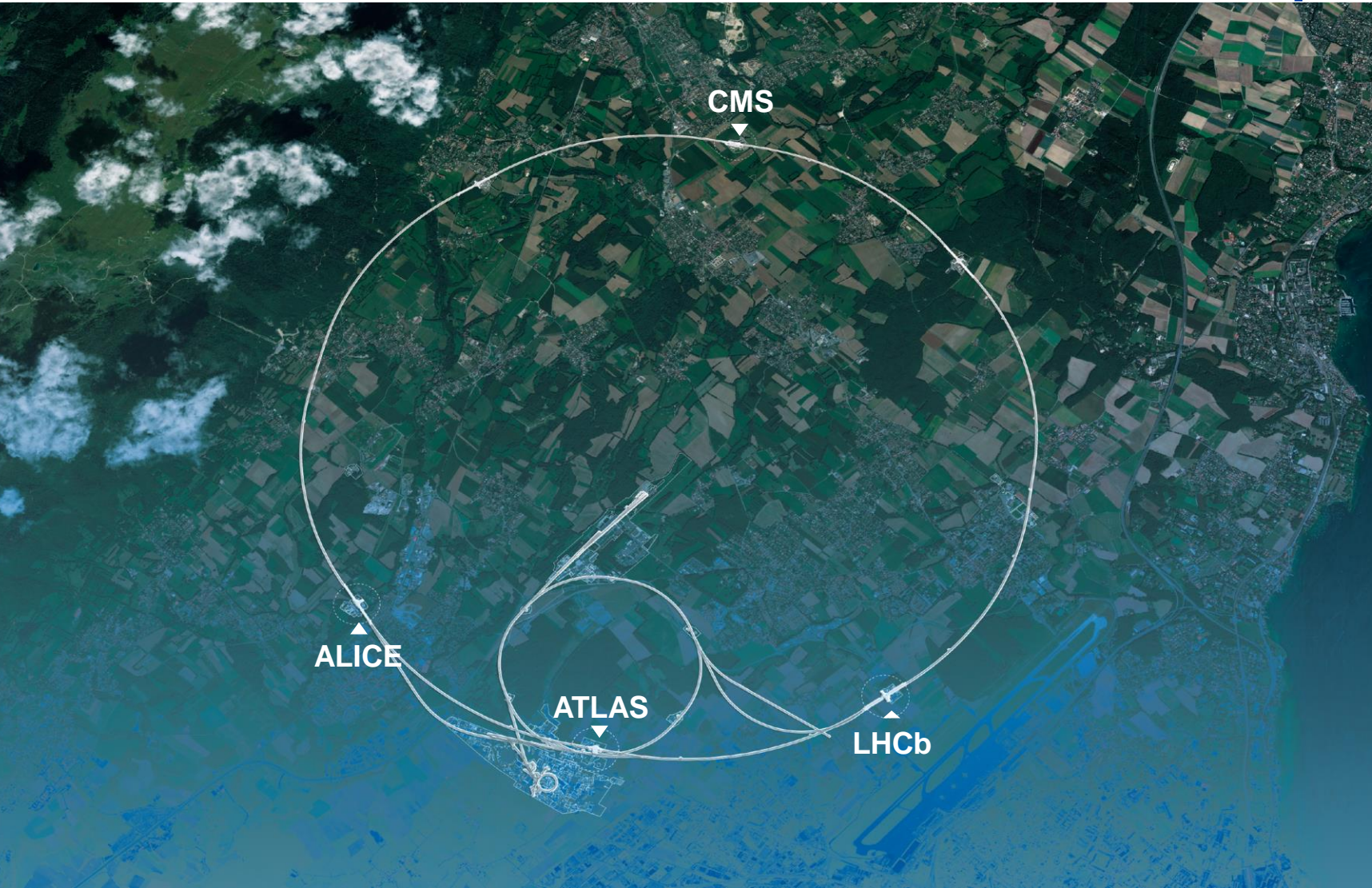




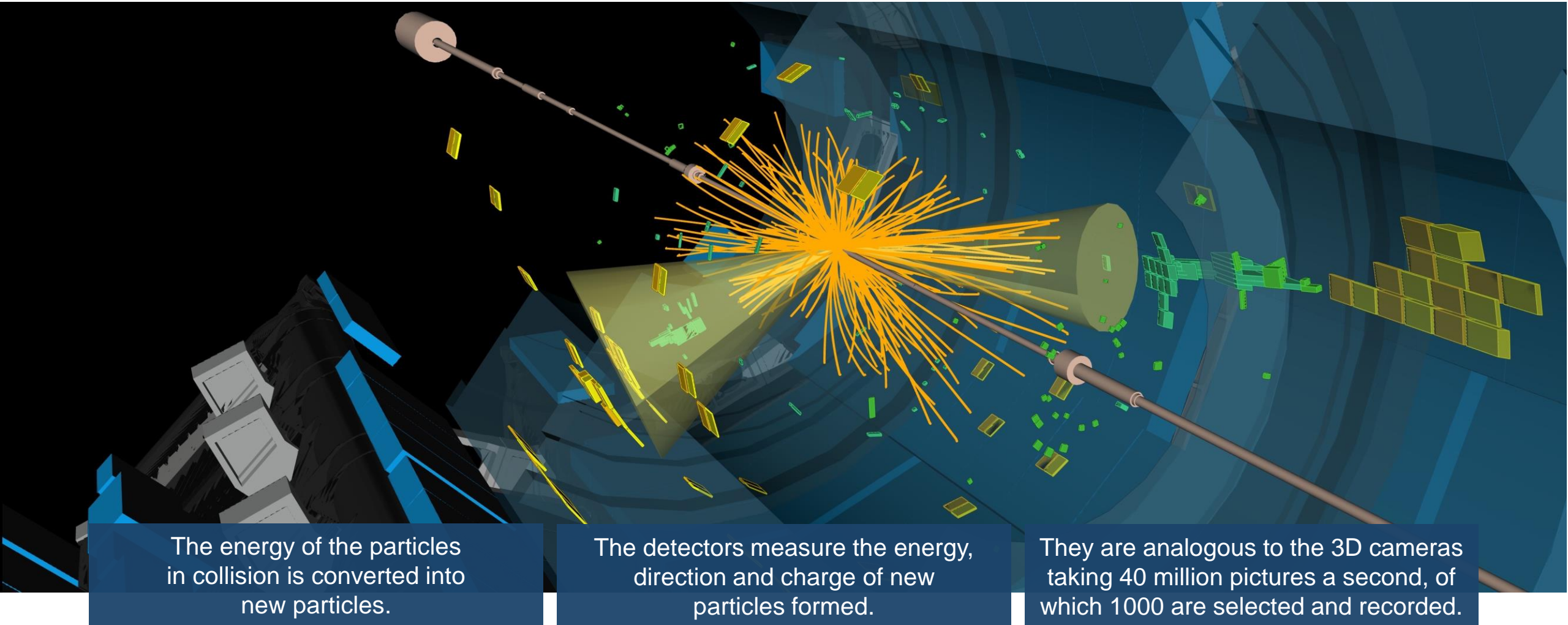
# Large Hadron Collider (LHC)

- 27 km in circumference
- About 100 m underground
- Superconducting magnets steer the particles around the ring
- Particles are accelerated to close to the speed of light

# Giant detectors record the particles formed at the four collision points



# The LHC produces more than 1 billion particle collisions per second



The energy of the particles in collision is converted into new particles.

The detectors measure the energy, direction and charge of new particles formed.

They are analogous to the 3D cameras taking 40 million pictures a second, of which 1000 are selected and recorded.

# The Worldwide LHC Computing Grid (WLCG)



WLCG

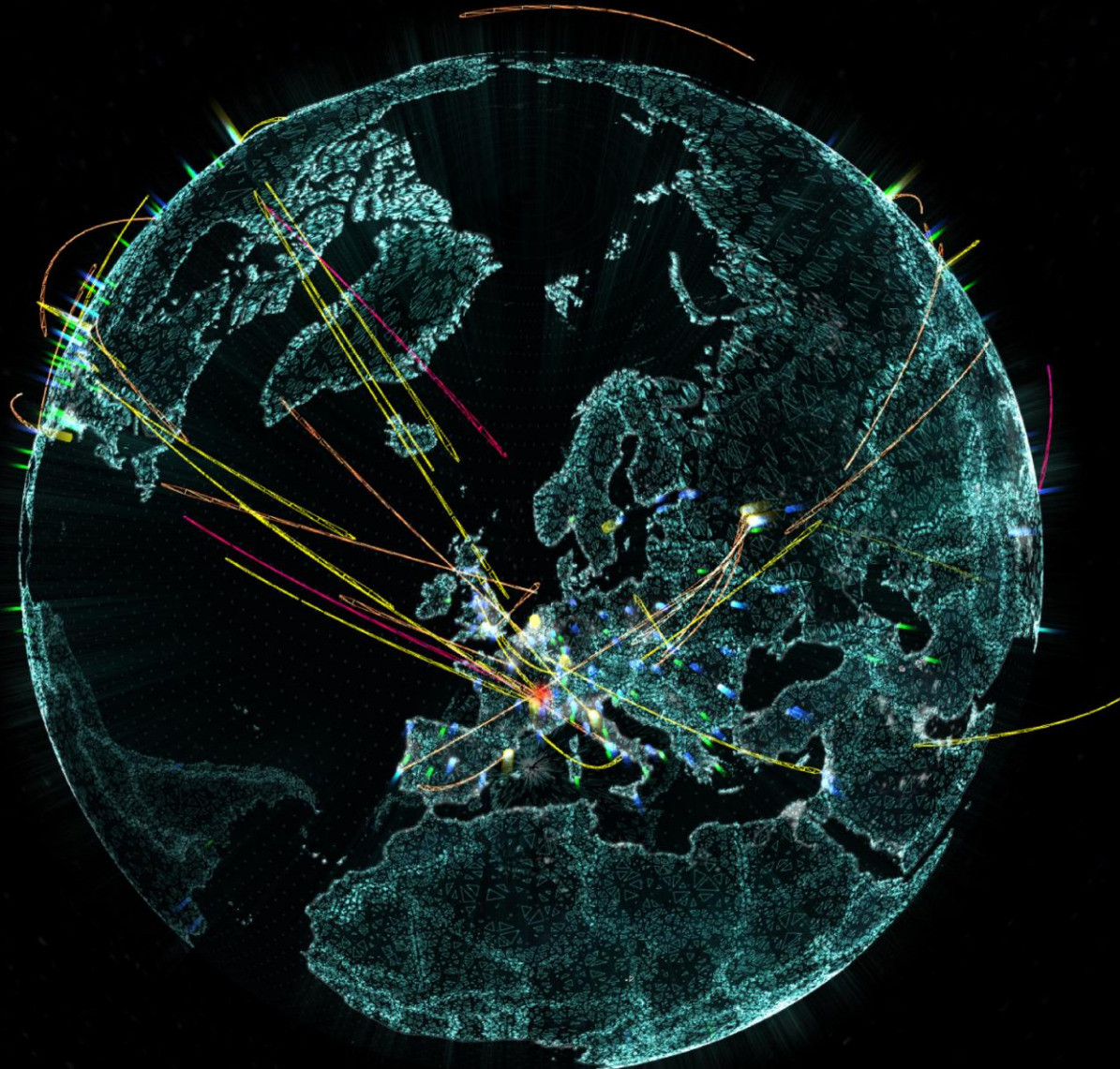
- Stores, distributes, processes and analyses LHC experiments' data.
- 1.4 million processing cores in 170 data centres and more than 40 countries.
- 1500 Petabytes of CERN data stored world-wide.

## EXPERIMENTS SELECTION

- ALICE
- CMS
- ATLAS
- LHCb

## TIERS SELECTION

- TIER 0
- TIER 1
- TIER 2
- TIER 3

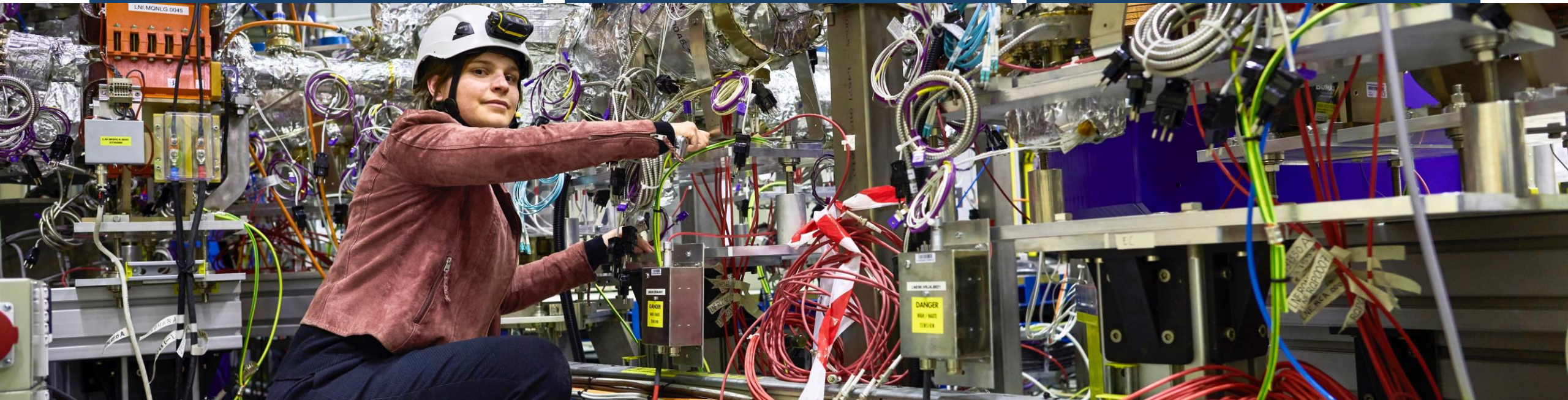


# CERN has a diverse scientific programme

Nuclear Physics  
(ISOLDE, n\_TOF)

Antimatter Research  
(Antiproton Decelerator)

Cosmic rays and cloud formation  
(CLOUD)



Fixed-target experiments,  
which include searches for rare phenomena

Contribution to the Long Baseline  
Neutrino Facility in the USA (LBNF)

# There are many unanswered questions in fundamental physics

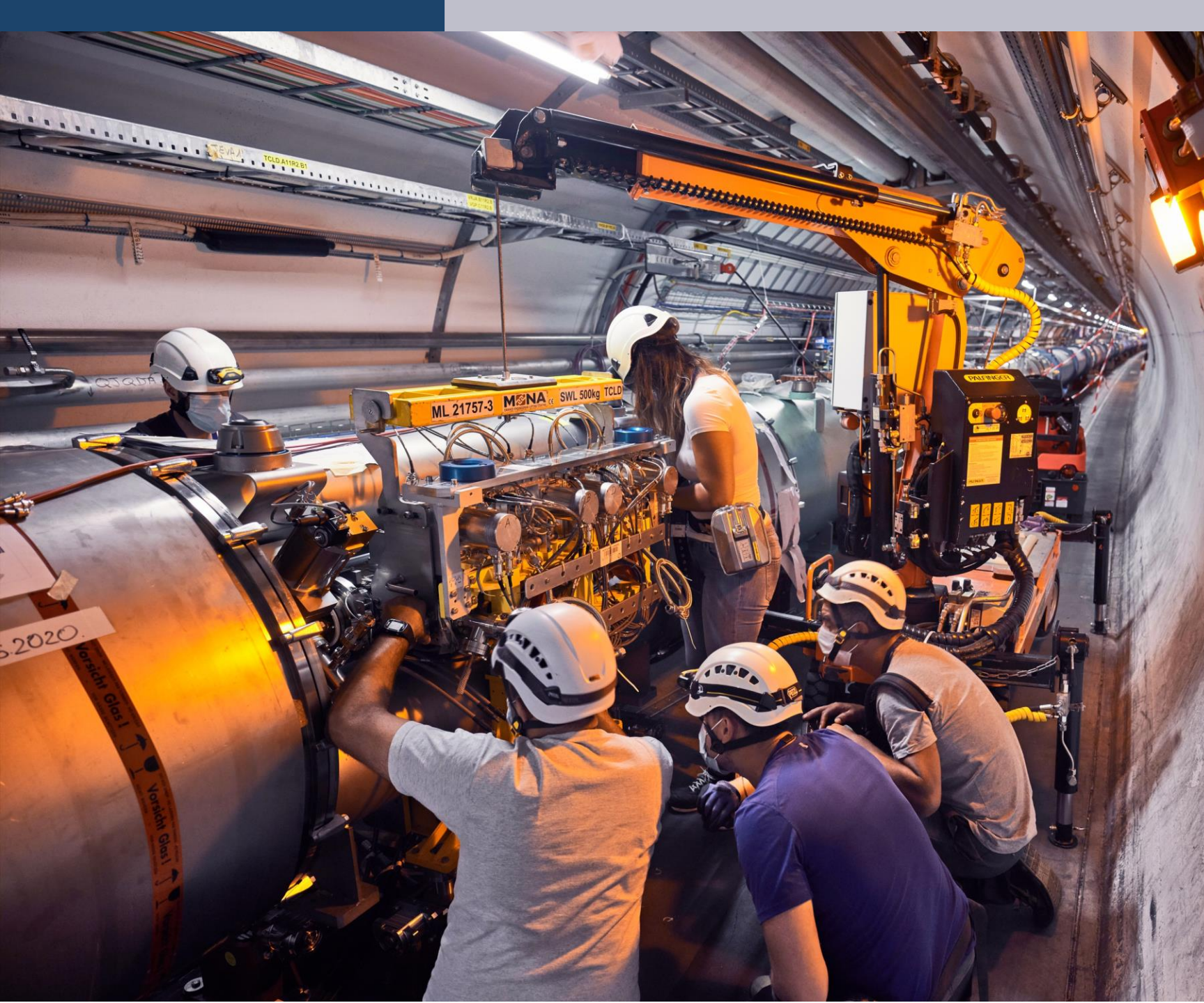
Including

What is the unknown  
95% of the mass  
and energy  
of the universe?

Is there only one Higgs  
boson, and does it  
behave exactly as  
expected?

Why is the universe  
made only of matter,  
with hardly any  
antimatter?

Why is gravity so weak  
compared to the other  
forces?



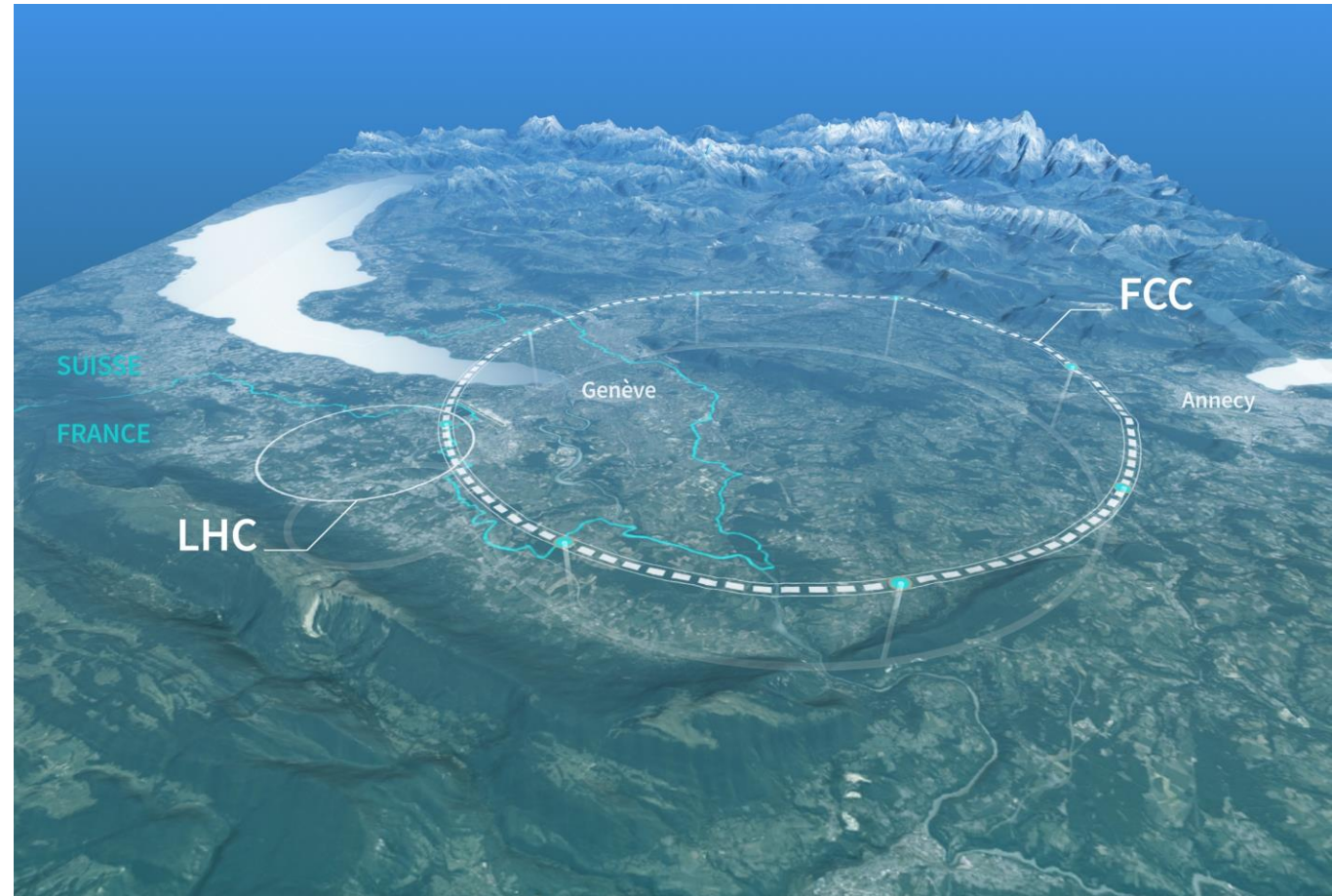
# Upgrade to the High-Luminosity LHC is under way

- The HL-LHC will use new technologies to provide 10 times more collisions than the LHC.
- It will give access to rare phenomena, greater precision and discovery potential.
- It will start operating in 2030, and run until 2041.

# Preparing CERN's future

## Driven by the **2020 Update of the European Strategy for Particle Physics**

- Technical and financial feasibility study of a Future Circular Collider (report for end 2025)
- Accelerator R&D to develop technologies for FCC and for alternative options
- Detector and computing R&D
- Maintain and expand a compelling scientific diversity programme
- Continue to support other projects around the world





COLLABORATION



# Science for peace

CERN was founded in 1954 with 12 European Member States



## 24 Member States

Austria – Belgium – Bulgaria – Czech Republic  
Denmark – Estonia – Finland – France – Germany  
Greece – Hungary – Israel – Italy – Netherlands  
Norway – Poland – Portugal – Romania – Serbia  
Slovakia – Spain – Sweden – Switzerland – United Kingdom

## 2 Associate Member States in the pre-stage to membership

Cyprus – Slovenia

## 8 Associate Member States

Brazil – Croatia – India – Latvia – Lithuania – Pakistan  
Türkiye – Ukraine

## 6 Observers

Japan – Russia (suspended) – USA  
European Union – JINR (suspended) – UNESCO

## Around 50 Cooperation Agreements with non-Member States and Territories

Albania – Algeria – Argentina – Armenia – Australia – Azerbaijan – Bangladesh – Bolivia – Bosnia and Herzegovina  
Canada – Chile – Colombia – Costa Rica – Ecuador – Egypt – Georgia – Honduras – Iceland – Iran – Jordan  
Kazakhstan – Lebanon – Malta – Mexico – Mongolia – Montenegro – Morocco – Nepal – New Zealand  
North Macedonia – Palestine – Paraguay – People's Republic of China – Peru – Philippines – Qatar – Republic of Korea  
Saudi Arabia – Sri Lanka – South Africa – Thailand – Tunisia – United Arab Emirates – Vietnam

CERN's annual budget  
is 1200 MCHF (equivalent  
to a medium-sized European  
university)

As of 31 December 2023  
Employees:  
**2666** staff, **1002** graduates  
Associates:  
**12 370** users, **1513** others

# A laboratory for people around the world

Distribution of all CERN Users by the country of their home institutes as of 31 December 2023



Geographical & cultural diversity  
Users of **110 nationalities**  
**23.7 % women**

## Member States **7467**

Austria 86 – Belgium 129 – Bulgaria 46 – Czech Republic 252  
Denmark 47 – Estonia 29 – Finland 88 – France 842 – Germany 1296  
Greece 112 – Hungary 80 – Israel 74 – Italy 1609 – Netherlands 167  
Norway 77 – Poland 322 – Portugal 105 – Romania 113  
Serbia 38 – Slovakia 67 – Spain 413 – Sweden 106  
Switzerland 419 – United Kingdom 950

## Associate Member States in the pre-stage to membership **40**

Cyprus 14 – Slovenia 26

## Associate Member States **541**

Brazil 135 – Croatia 37 – India 145 – Latvia 21 – Lithuania 17 – Pakistan 30  
Türkiye 129 – Ukraine 27

## Observers **3005**

Japan 219 – Russia (suspended) 779 – United States of America 2007



## Non-Member States and Territories **1317**

Algeria 2 – Argentina 16 – Armenia 16 – Australia 26 – Azerbaijan 3 – Bahrain 3 – Belarus 14 – Canada 206  
Chile 45 – China 414 – Colombia 24 – Costa Rica 3 – Cuba 3 – Ecuador 4 – Egypt 24 – Georgia 34 – Hong Kong 15  
Iceland 3 – Indonesia 7 – Iran 14 – Ireland 4 – Jordan 3 – Kazakhstan 3 – Kuwait 2 – Lebanon 7 – Madagascar 1  
Malaysia 4 – Malta 1 – Mexico 56 – Montenegro 3 – Morocco 18 – New Zealand 2 – Nigeria 2 – Oman 1  
Palestine 1 – Peru 3 – Philippines 1 – Republic of Korea 168 – Saudi Arabia 6 – South Africa 61 – Sri Lanka 10  
Taiwan 52 – Thailand 17 – Tunisia 4 – United Arab Emirates 10 – Vietnam 1

# CERN is a model for open and inclusive collaboration



The LHC experiments are models of consensus building, competition and cooperation.

SESAME, a synchrotron light source in Jordan, is modelled on CERN's governance structure.



**Members:** Cyprus, Egypt, Iran, Israel, Jordan, Pakistan, Palestine, and Türkiye.



CERN provides the IT infrastructure for the satellite-analysis technology used for emergency response.



# Promoting fact-based, science-driven decision-making

CERN engages with international organisations and platforms to share the values of science and help shape a global agenda conducive to fact-based decision-making with empowered citizens



CERN is an Observer with the UN General Assembly

## SUSTAINABLE DEVELOPMENT GOALS



CERN actively promotes the SDGs with partners in the international system



# SUSTAINABLE DEVELOPMENT GOALS

## CERN and the Global Goals

### SDG 3 - HEALTH

CERN helps to develop technologies that contribute to better healthcare for all, such as medical imaging and hadron therapy.

### SDG 4 - EDUCATION

Education is one of CERN's core missions. We offer high quality programmes that inspire thousands of students, teachers and young researchers each year.

### SDG 5 - GENDER

Diversity is a core value for CERN. Our diversity policy aims at leveraging the added value that comes from bringing together people of different nationalities, genders, professions and ages.

### SDG 7 - ENERGY

CERN develops strategies for minimise the increase of energy consumed by the installations, increase energy efficiency and implement energy recovery.

### SDG 9 - INNOVATION

CERN inventions are brought to industry through knowledge transfer, to have a positive impact on society and innovation.

### SDG 16 & 17 - INTERNATIONAL COOPERATION

CERN is a successful model for international collaboration. CERN gathers researchers from all over the world, contributing to human knowledge and peace, for the benefit of all.



#### THERAPY

Accelerators provide particle beams for more targeted cancer treatment.



#### BEAMLINE FOR SCHOOLS COMPETITION

Students from the two winning teams spend a week at CERN to carry out their experiment using a CERN accelerator.



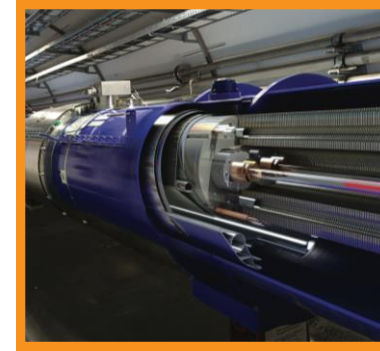
#### 25 BY 25 DIVERSITY & INCLUSION INITIATIVE

First ever targets-based strategy to boost the nationality and gender diversity within the Staff and Fellows population.



#### HEATING LOCAL HOUSING

Heat recovered from CERN's accelerator cooling systems to heat a new residential area in the town of Ferney-Voltaire, benefiting up to 8000 people.



#### A MAGNET IN THE LHC TUNNEL

Exploring the universe requires new technologies and ingenious engineering to build the machines that explore physics at a new frontier.



#### SESAME

This new synchrotron light source in Jordan started operation in 2017. It is a unique collaboration between eight Middle East members, modelled on CERN's governance structure.



# TECHNOLOGY & INNOVATION

# CERN's technological innovations have applications in many fields

CERN is the birthplace of the World Wide Web

**And there are many more examples**

Medical imaging, cancer therapy, material science, cultural heritage, aerospace, automotive, environment, health & safety, industrial processes.

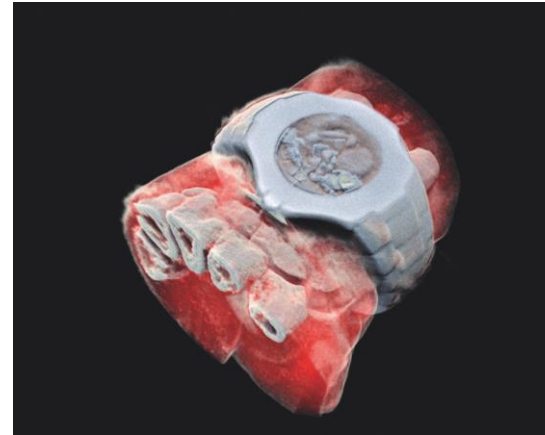
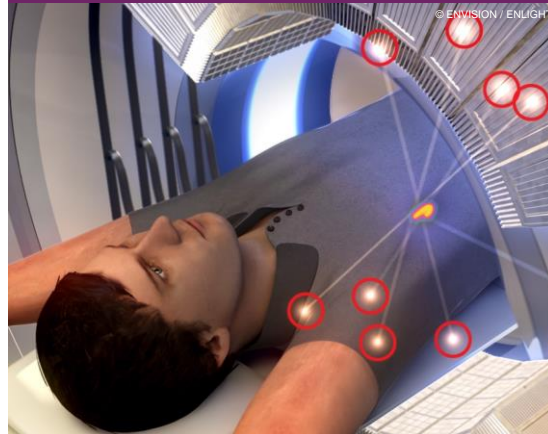


# CERN's technological innovations have important applications in medicine and healthcare



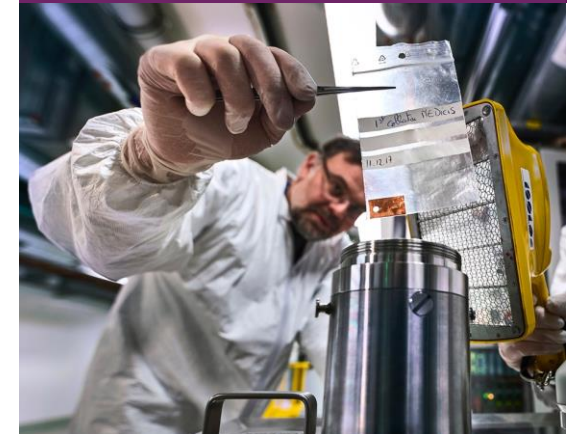
Technologies applied at CERN are also used in PET, for medical imaging and diagnostics.

Accelerator technologies are applied in cancer radiotherapy with protons, ions and electrons.



Pixel detector technologies are used for high resolution 3D colour X-ray imaging.

CERN produces innovative radioisotopes for nuclear medicine research.



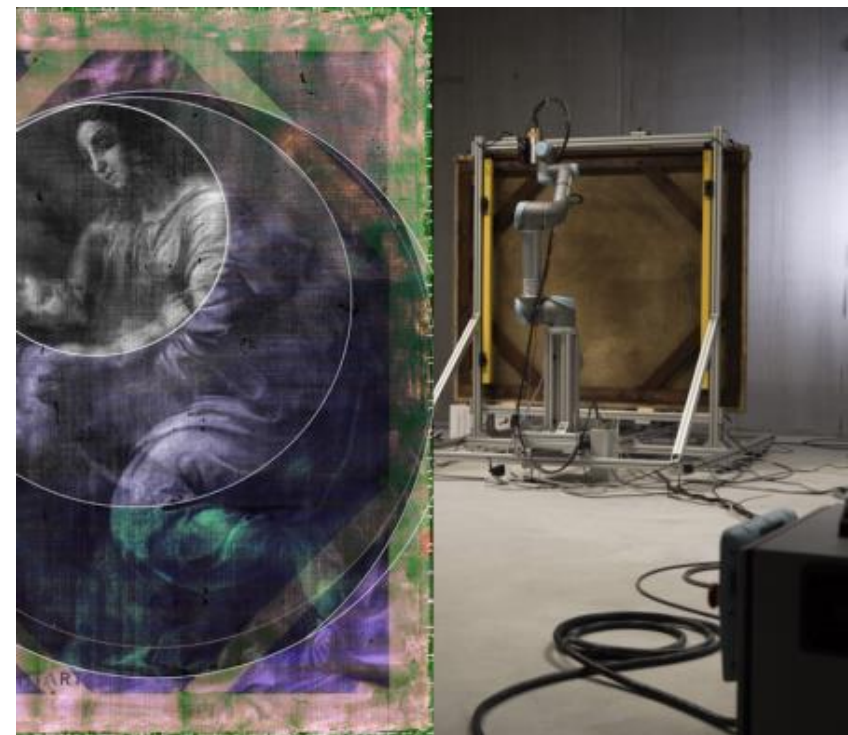
# CERN's technological innovations applied in other fields



## Aerospace - NASA

Radiation monitoring in the International Space Station

**Industry - Zenuity**  
Software solutions for autonomous driving



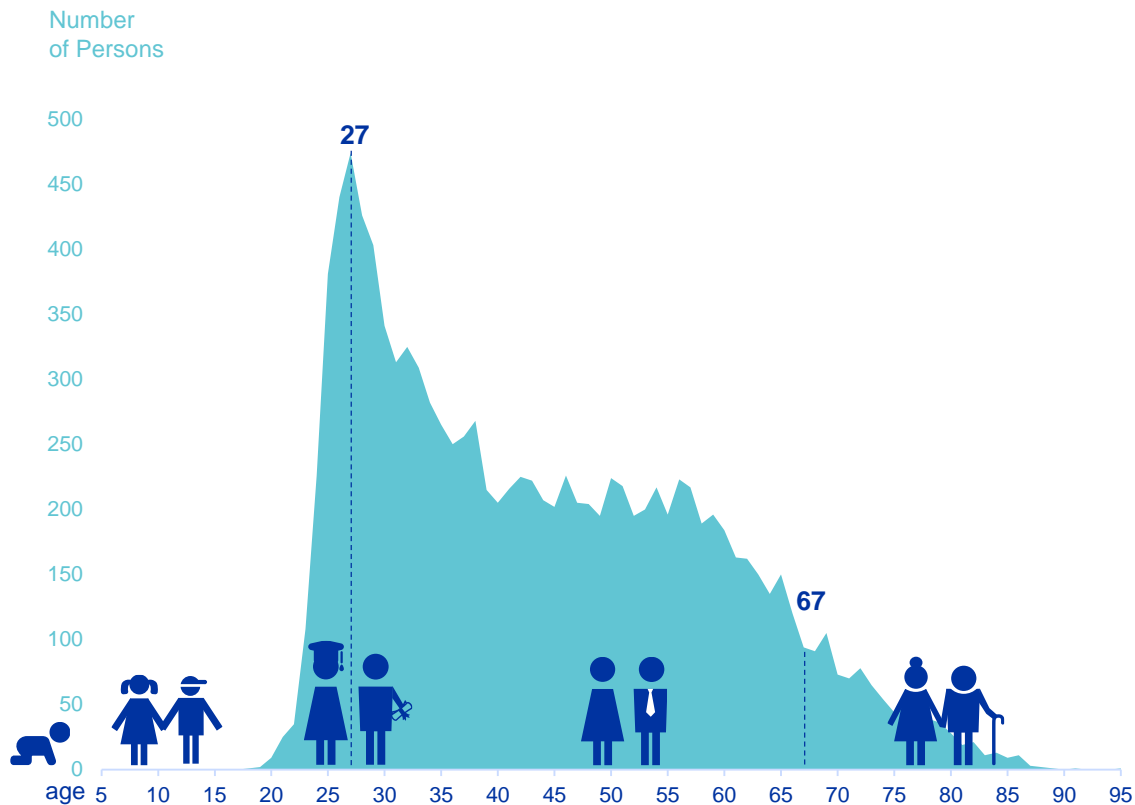
## Cultural Heritage InsightART

Measuring the DNA of your art

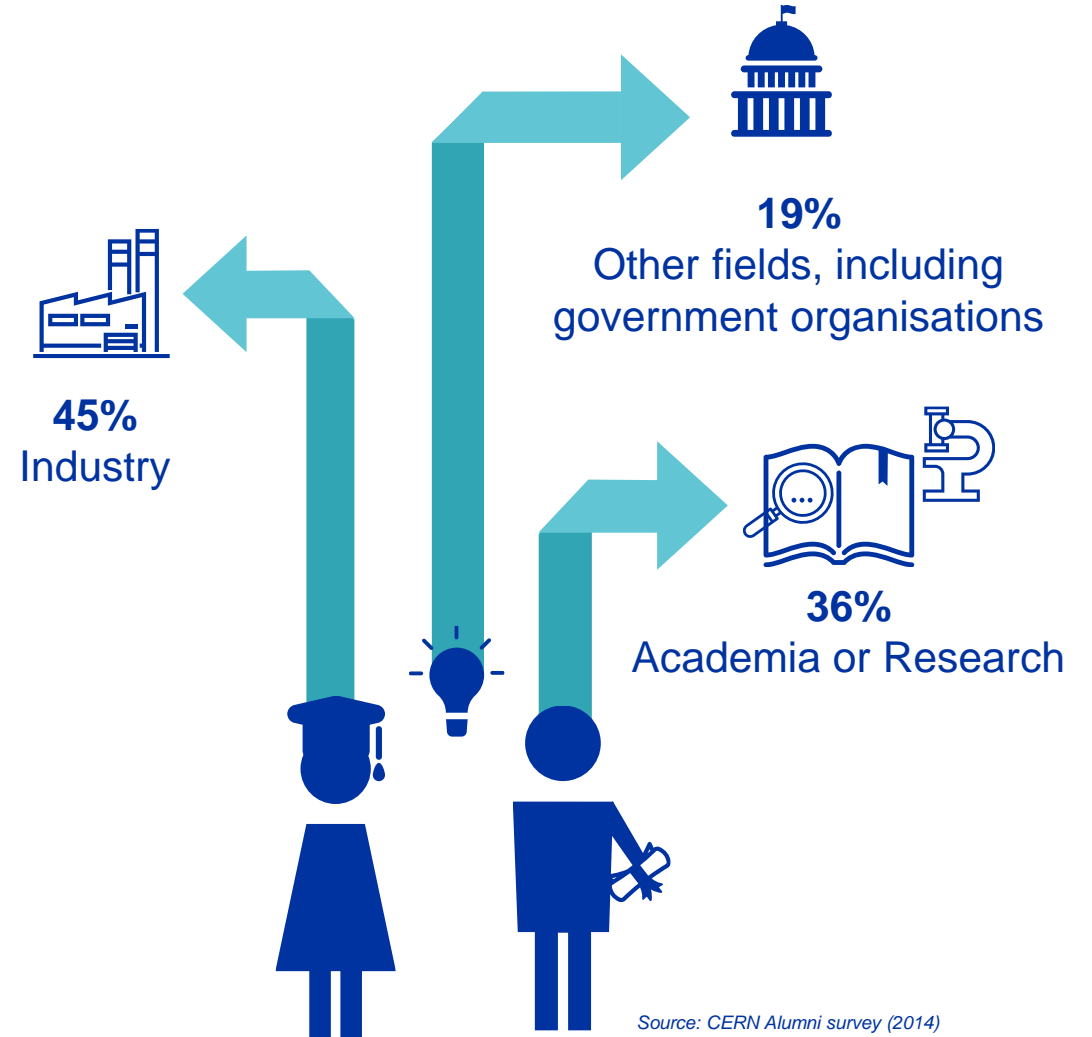
A group of students, both male and female, are wearing hard hats (yellow and blue) and are focused on a large, dark, cylindrical piece of equipment mounted on a metal frame. They appear to be in a laboratory or workshop setting. One student in the foreground is adjusting the equipment. In the background, there are other students and a green exit sign with a white arrow pointing down and to the left. A teal circular graphic is overlaid on the left side of the image, containing the text 'EDUCATION & TRAINING'.

# EDUCATION & TRAINING

# CERN opens a world of career opportunities



**Age Distribution of Scientists working at CERN**



**PhD and Technical students leaving CERN**

Source: CERN Alumni survey (2014)

# CERN's training, education and outreach programmes

**1002 graduates**  
(including Research Fellows)

**3 000 PhD students**

**300 Undergraduate students** in  
Summer programmes

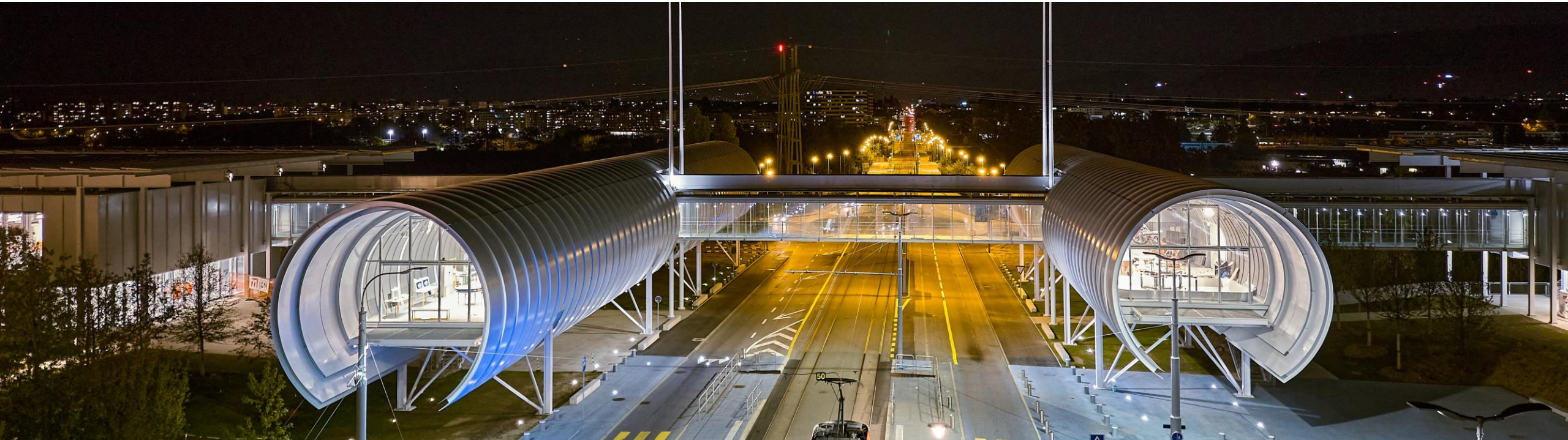


**> 15 000 teachers** participating in  
dedicated programmes, since 1998

Around **150 000 visitors** per year on  
guided tours of CERN,  
from >50 countries

**4.7M followers** on social media,  
from around the globe

# CERN Science Gateway



CERN's new education and outreach centre for all public aged 5-plus.

Inaugurated  
7 October 2023.

Number of visitors: **>385 000**

Immersive exhibitions,  
education labs, events  
and shows.



There are many unanswered questions  
in fundamental physics

**CERN will continue to play a crucial role  
in the journey of exploration**