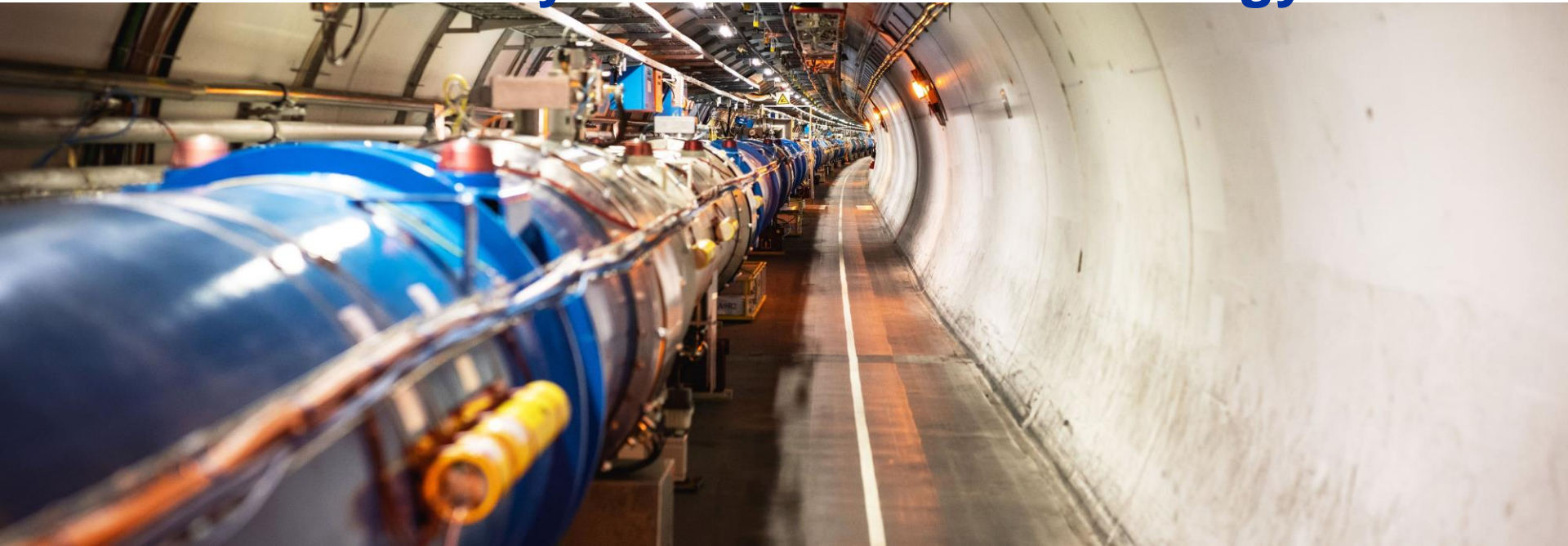


CERN

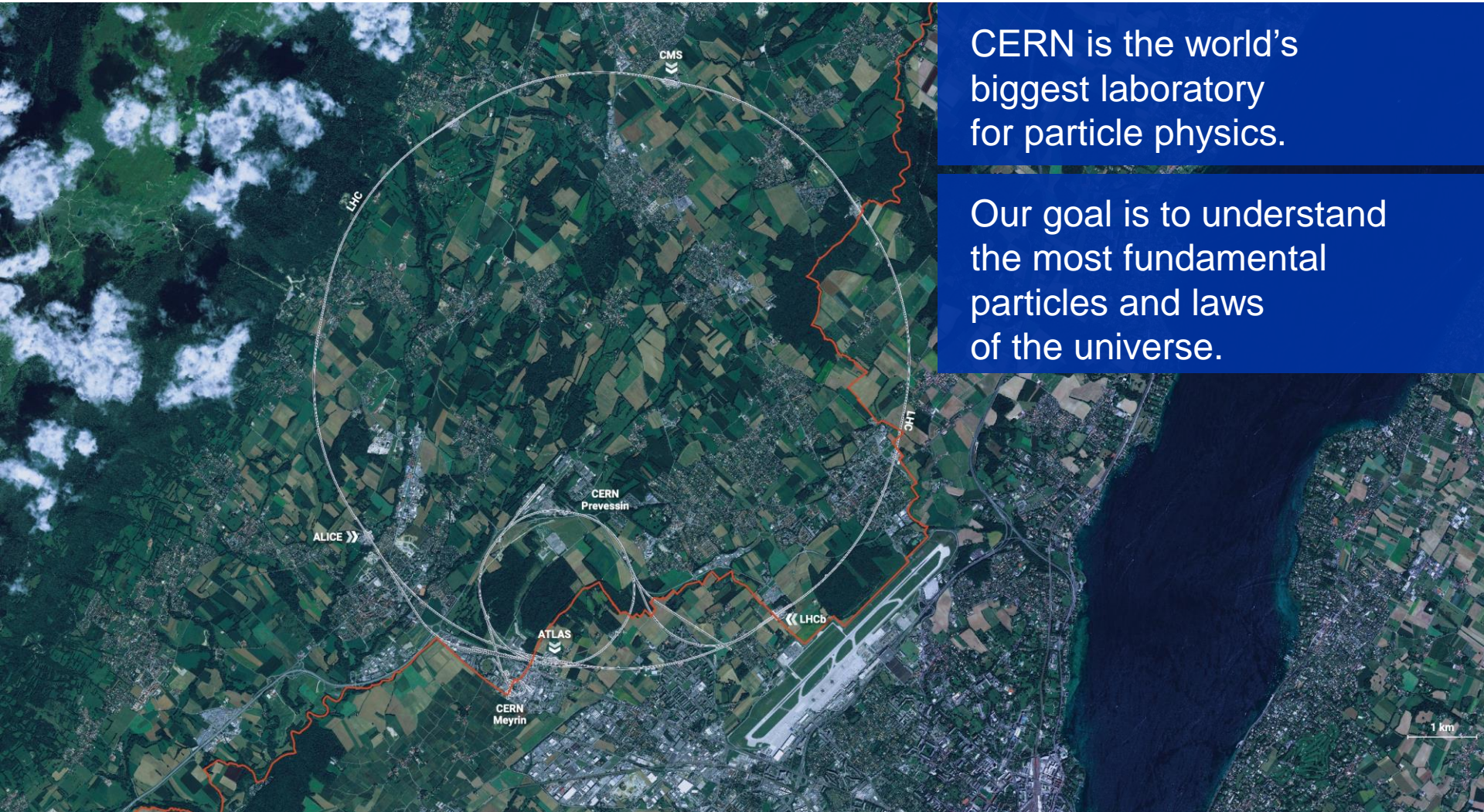
A Gateway to Science & Technology



Prof. Emmanuel Tsesmelis

Principal Scientist
Head of Associate & Non-Member State Relations

August 2023



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

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

Four pillars underpin CERN's mission



COLLABORATION



Science for peace

CERN was founded in 1954 with 12 European Member States

23 Member States

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

3 Associate Member States in the pre-stage to membership

Cyprus – Estonia – Slovenia

7 Associate Member States

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

(Brazil signed CERN Associate Membership Agreement
in March 2022, to be ratified in parliament)

6 Observers

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



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

As of 31 December 2022

Employees:
2658 staff, **900** fellows

Associates:
11 860 users, **1516** others

Around 50 Cooperation Agreements with non-Member States and Territories

Albania – Algeria – Argentina – Armenia – Australia – Azerbaijan – Bangladesh – Belarus – Bolivia
Bosnia and Herzegovina – Brazil – 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

A laboratory for people around the world

Distribution of all CERN Users by the country of their home institutes as of 31 December 2022



Geographical & cultural diversity
Users of **110 nationalities**
19.4% women

Member States 7147

Austria 85 – Belgium 129 – Bulgaria 43 – Czech Republic 244
Denmark 49 – Finland 90 – France 844 – Germany 1225
Greece 119 – Hungary 73 – Israel 64 – Italy 1527
Netherlands 169 – Norway 79 – Poland 305 – Portugal 100
Romania 109 – Serbia 33 – Slovakia 70 – Spain 383
Sweden 103 – Switzerland 406 – United Kingdom 898

Associate Member States

in the pre-stage to membership **69**

Cyprus 15 – Estonia 30 – Slovenia 24

Associate Member States **382**

Croatia 38 – India 132 – Latvia 16 – Lithuania 14 – Pakistan 35
Türkiye 122 – Ukraine 25

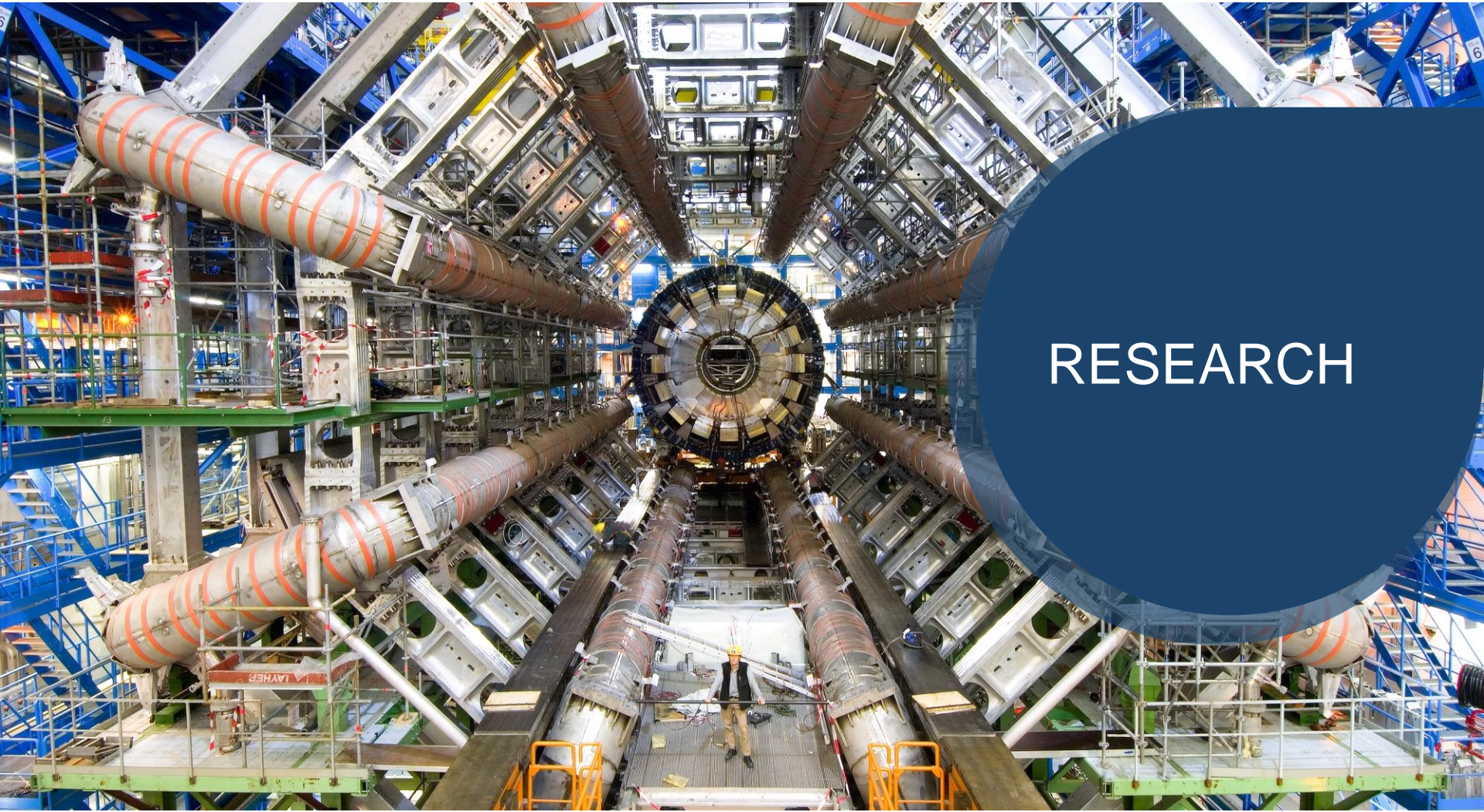
Observers **2991**

Japan 216 – Russia (suspended) 873 – United States of America 1902



Non-Member States and Territories **1271**

Algeria 2 – Argentina 13 – Armenia 8 – Australia 21 – Azerbaijan 2 – Bahrain 4 – Belarus 18 – Brazil 122
Canada 199 – Chile 34 – Colombia 21 – Costa Rica 2 – Cuba 3 – Ecuador 4 – Egypt 20 – Georgia 32
Hong Kong 15 – Iceland 3 – Indonesia 5 – Iran 11 – Ireland 5 – Jordan 5 – Kuwait 4 – Lebanon 13 – Madagascar 1
Malaysia 4 – Malta 1 – Mexico 49 – Montenegro 4 – Morocco 19 – New Zealand 5 – Nigeria 1 – Oman 1
Palestine 1 – People's Republic of China 333 – Peru 2 – Philippines 1 – Republic of Korea 147 – Singapore 2
South Africa 52 – Sri Lanka 10 – Taiwan 45 – Thailand 17 – Tunisia 2 – United Arab Emirates 7 – Viet Nam 1



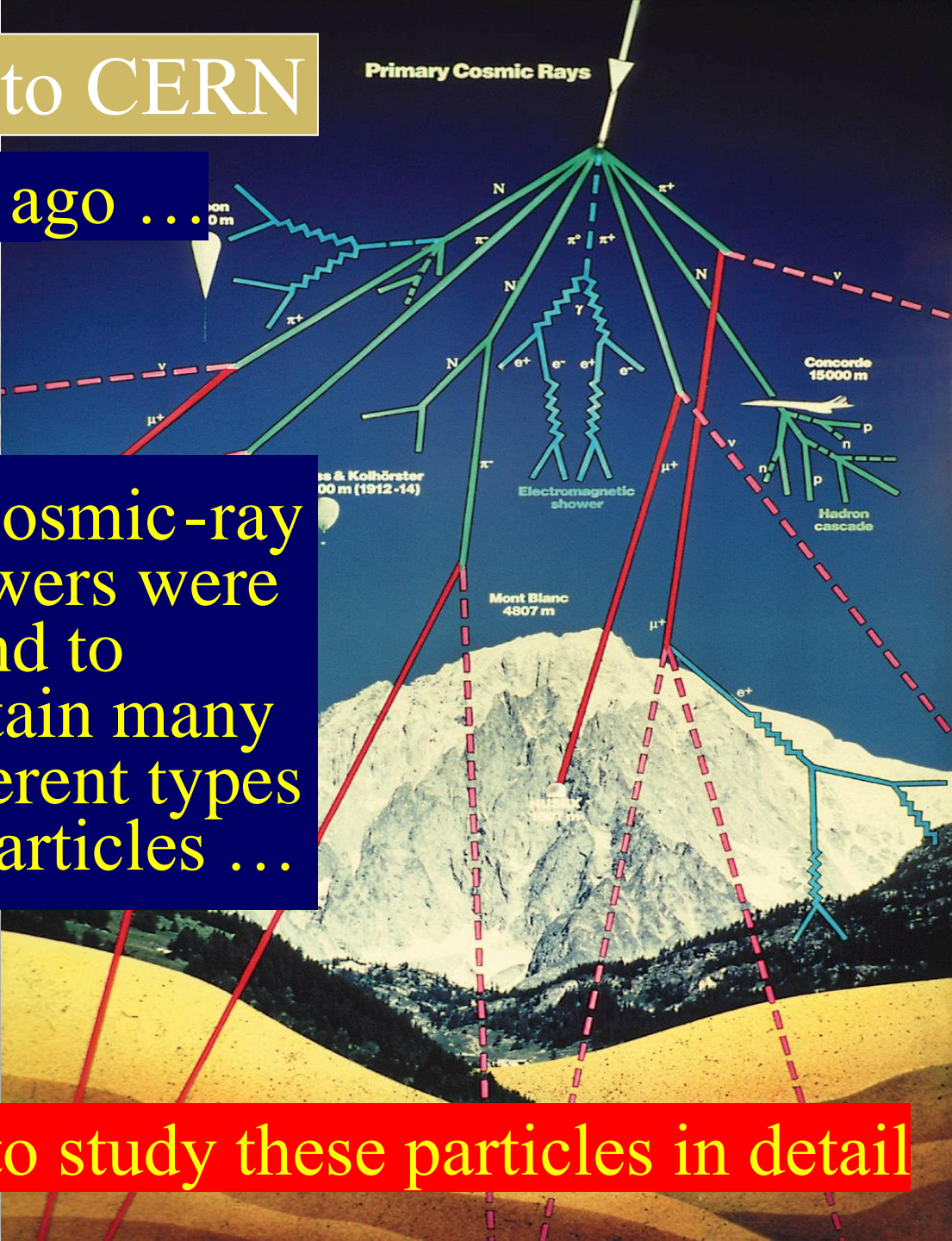
RESEARCH

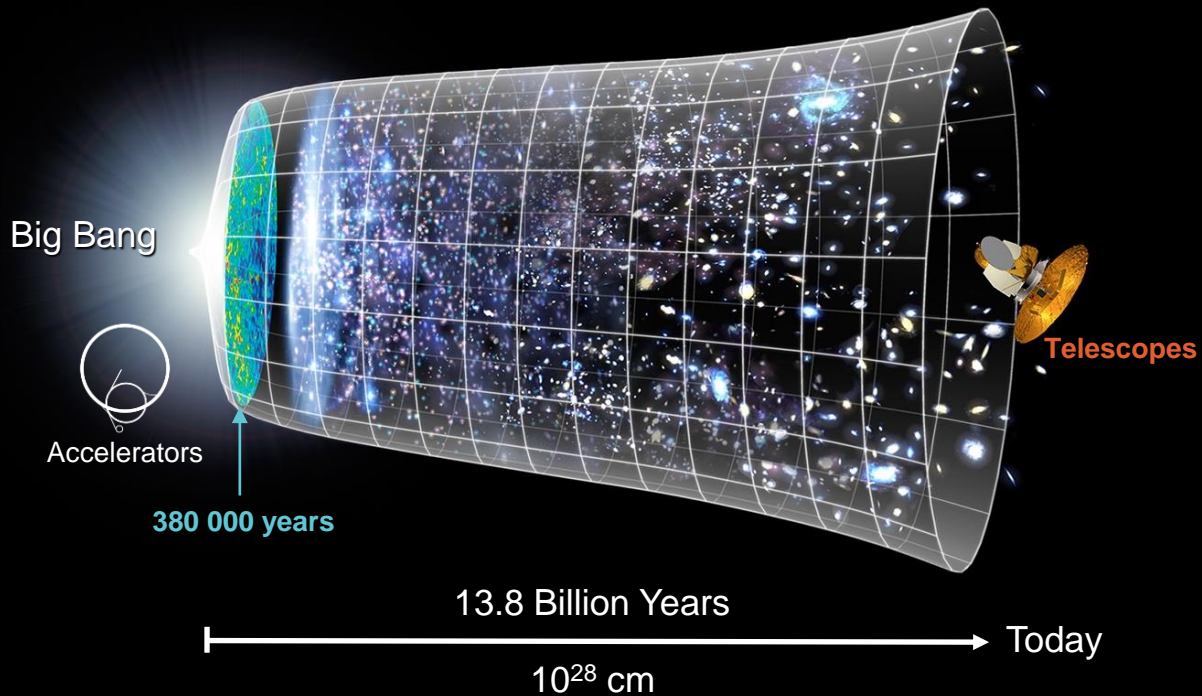
From Cosmic Rays to CERN

Discovered a century ago ...

... cosmic-ray showers were found to contain many different types of particles ...

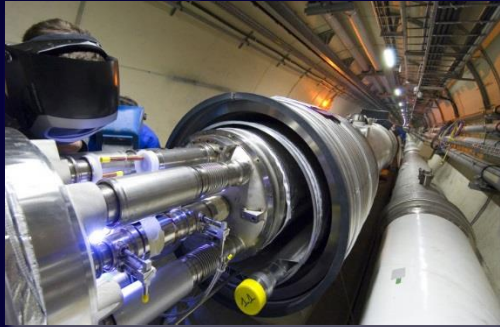
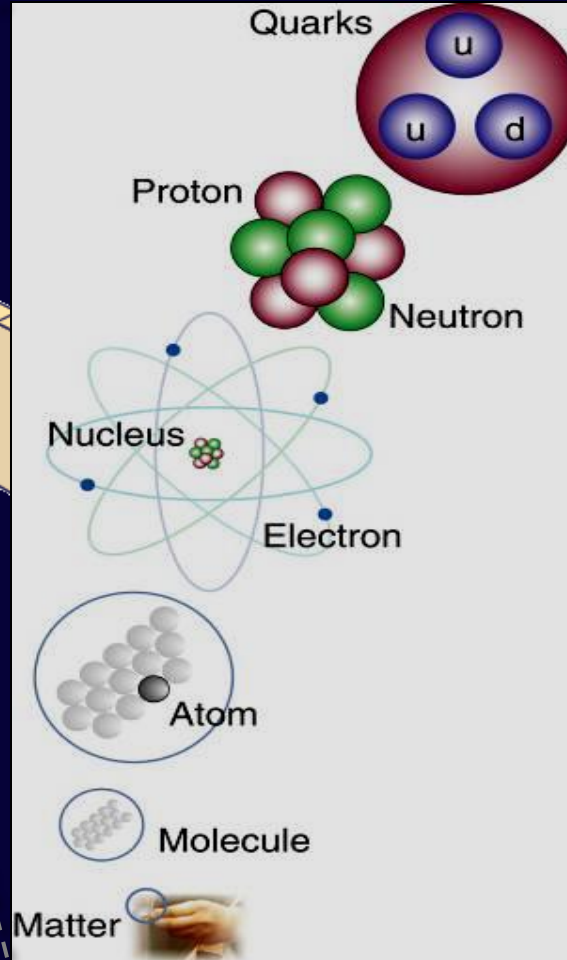
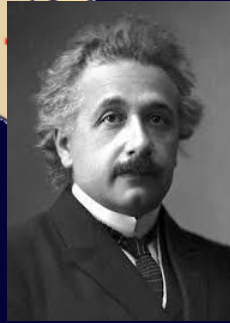
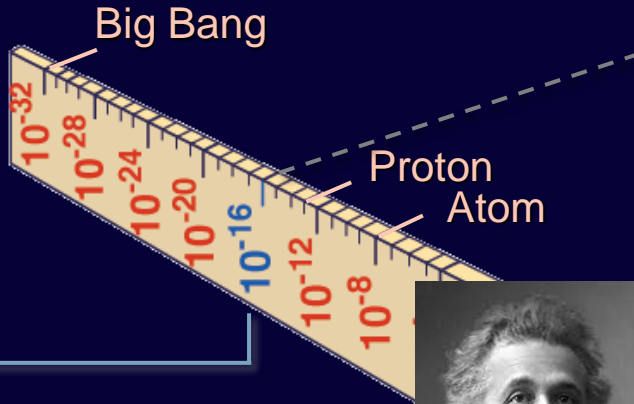
CERN set up in 1954 to study these particles in detail





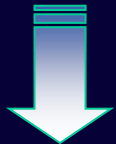
How did the universe begin?

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



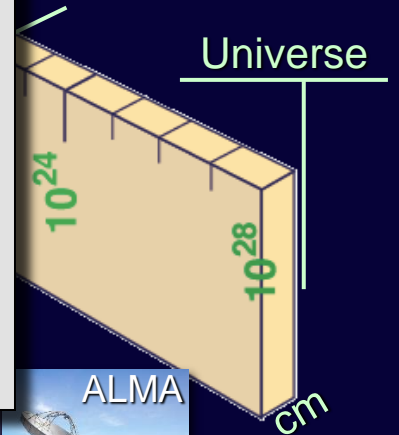
LHC

Super-Microscope



Study physics laws of first moments after Big Bang increasing Symbiosis between Particle Physics, Astrophysics and Cosmology

Radius of Galaxies



The Standard Model of



Particle Physics = Cosmic DNA

The matter particles



The fundamental interactions



Gravitation

electromagnetism

weak nuclear force

strong nuclear force

Why do Things Weigh?

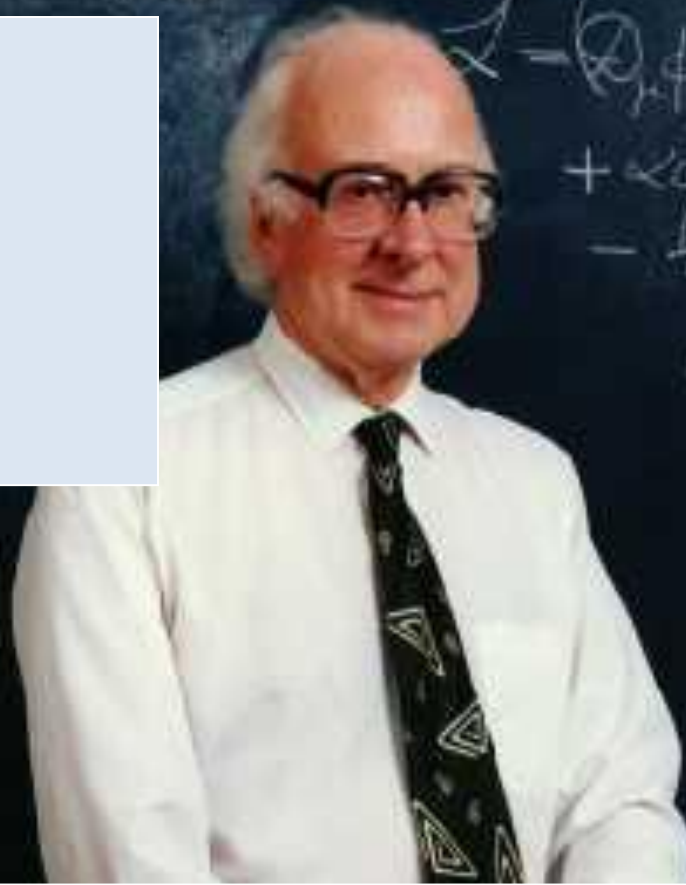
Newton:

Weight proportional to Mass

Einstein:

Energy related to Mass

Neither explained origin of Mass

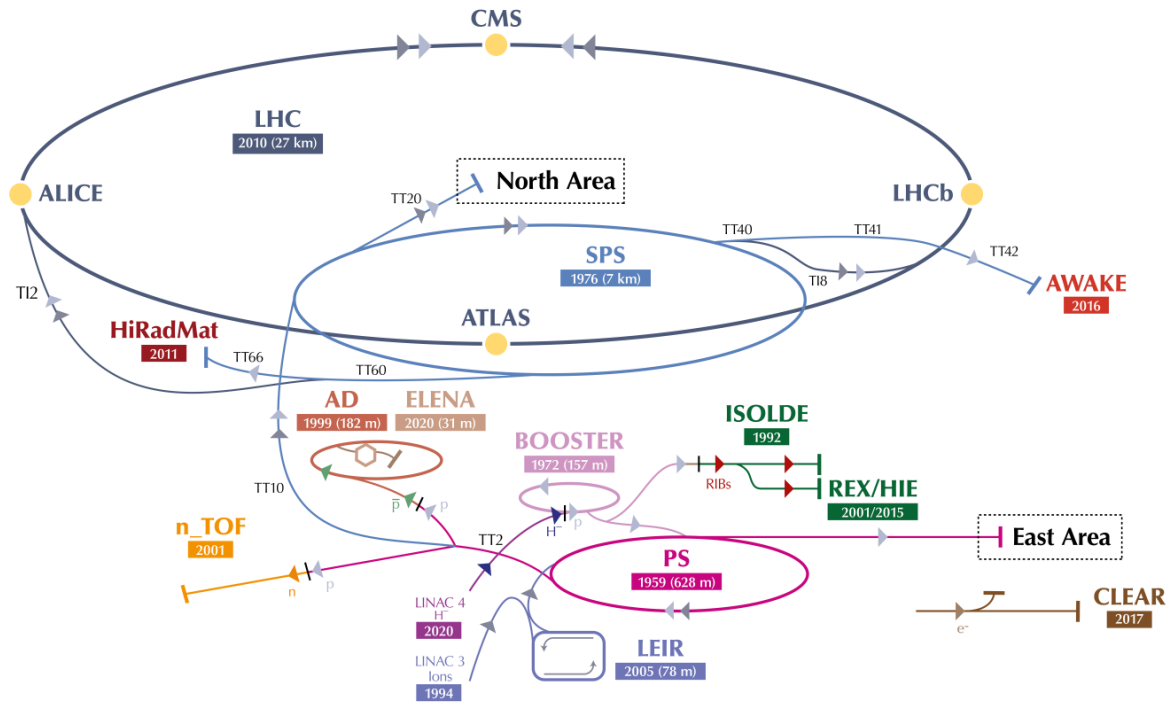


Where do the masses come from?

Are masses due to the Brout-Englert-Higgs (BEH) Mechanism & the Higgs boson?
(the physicists' Holy Grail)

CERN Accelerator Complex

The CERN accelerator complex
Complexe des accélérateurs du CERN



▶ H^- (hydrogen anions) ▶ p (protons) ▶ ions ▶ RIBs (Radioactive Ion Beams) ▶ n (neutrons) ▶ \bar{p} (antiprotons) ▶ e^- (electrons)

LHC - Large Hadron Collider // SPS - Super Proton Synchrotron // PS - Proton Synchrotron // AD - Antiproton Decelerator // CLEAR - CERN Linear Electron Accelerator for Research // AWAKE - Advanced WAKEfield Experiment // ISOLDE - Isotope Separator OnLine // REX/HIE - Radioactive Experiment/High Intensity and Energy ISOLDE // LEIR - Low Energy Ion Ring // LINAC - LINear ACcelerator // n_TOF - Neutrons Time Of Flight // HiRadMat - High-Radiation to Materials

The Large Hadron Collider (LHC)



Design $E_{cm} = 14 \text{ TeV} \ \& \ 10^{34} \text{ cm}^{-2} \text{ s}^{-1}$
Several thousand billion protons
Each with the energy of a fly (7 TeV)
99.9999991% of light speed
Orbit 27km ring 11 000 times/second
A billion collisions a second

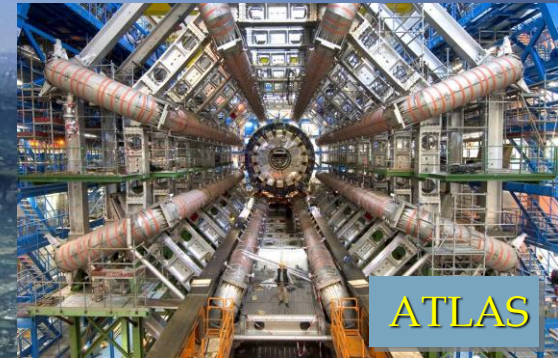
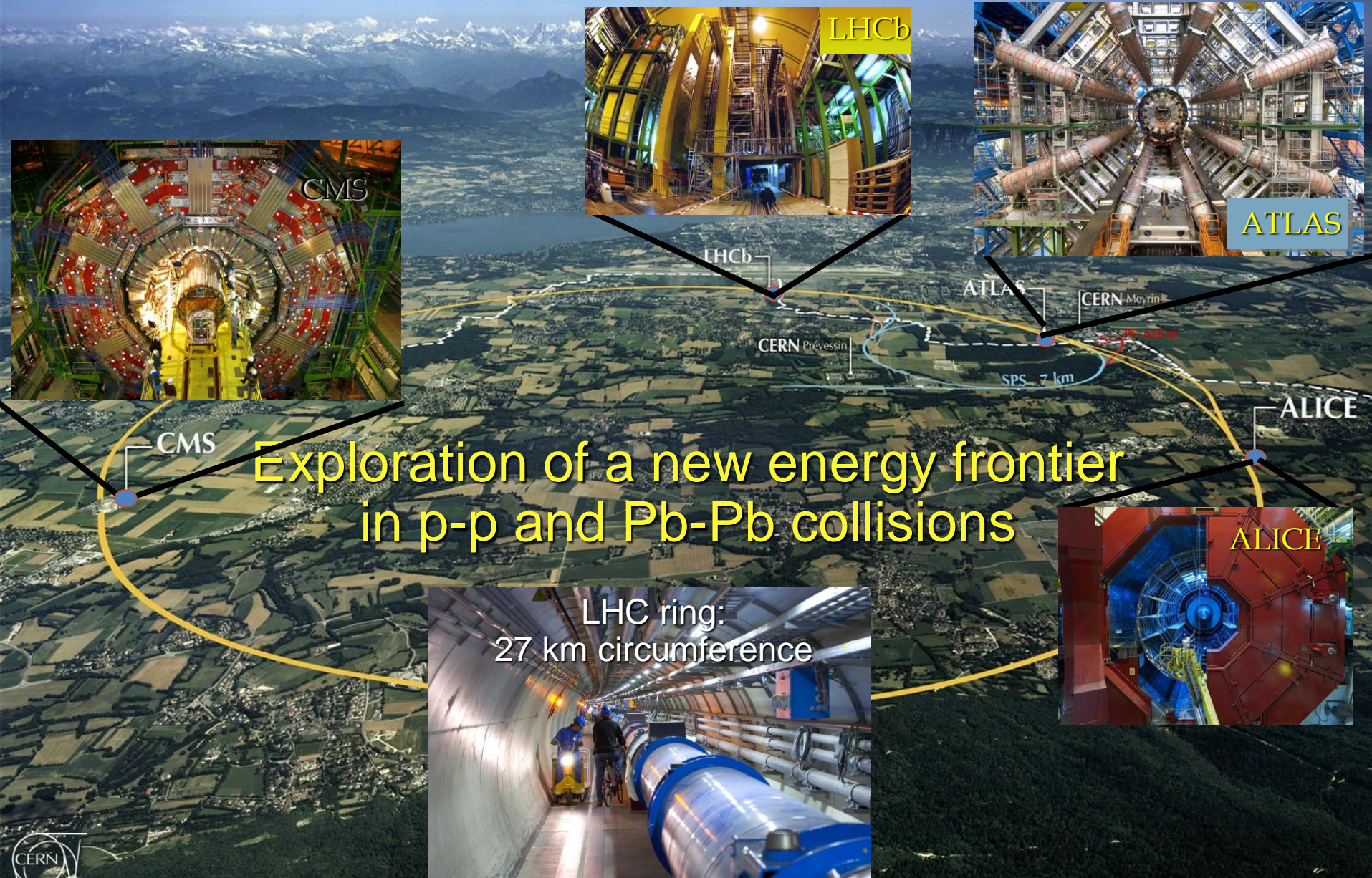
Primary targets:

- Origin of mass
- Nature of Dark Matter
- Primordial Plasma
- Matter vs Antimatter



The LHC

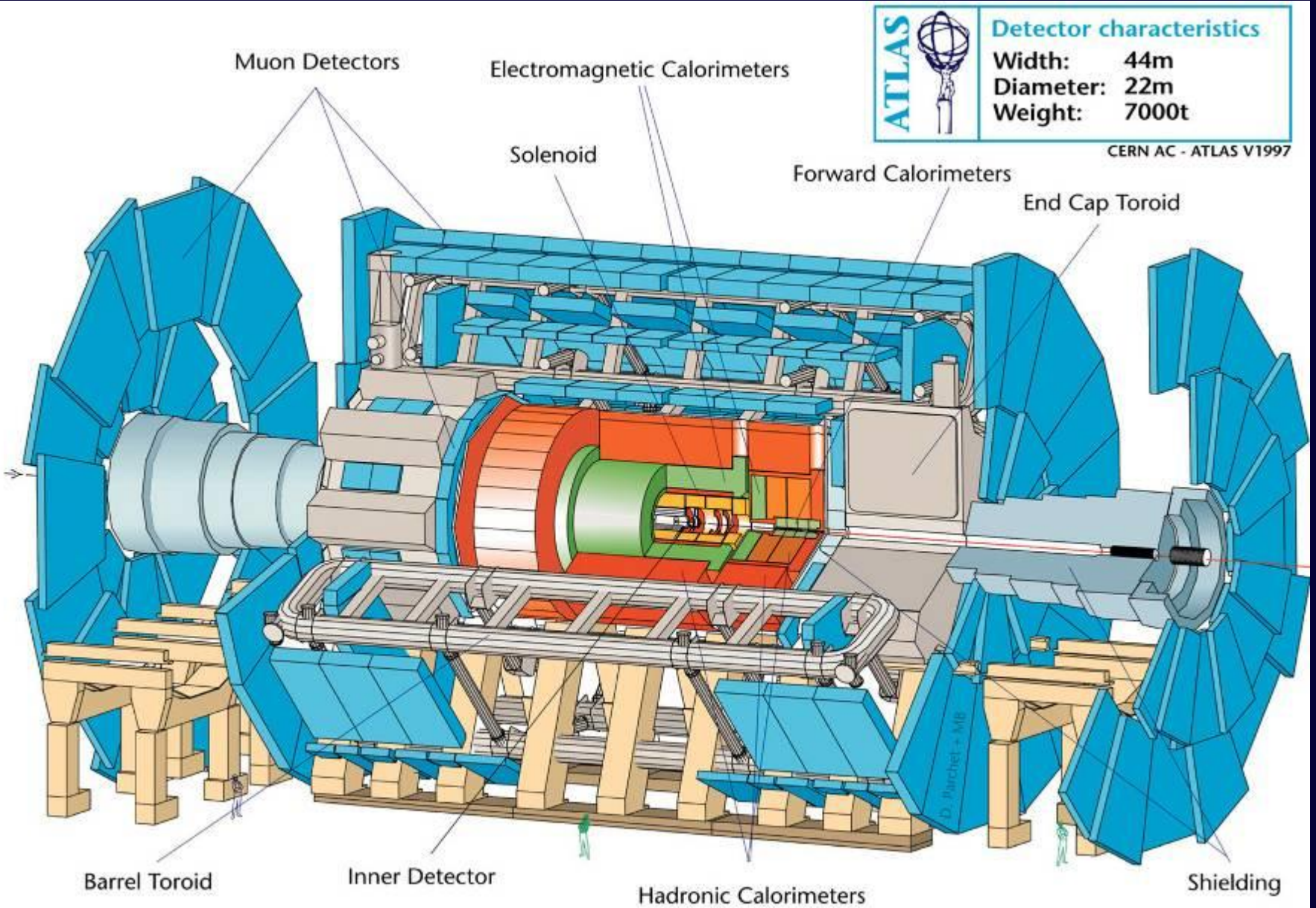
2010: a New Era in Fundamental Science



Exploration of a new energy frontier
in p-p and Pb-Pb collisions



The ATLAS Experiment





The ATLAS Experiment

The Highlight of a Remarkable Year 2012



Volume 712, Issue 3, 6 June 2012 ISSN 0370-2693

ELSEVIER

PHYSICS LETTERS B

Available online at www.sciencedirect.com
SciVerse ScienceDirect

The cover features two main plots. The top plot shows the $S/(S+B)$ Weighted Events / 1.5 GeV versus m_H (GeV). It includes data points, a fit line, and a magnified view of the peak region. The bottom plot is an ATLAS plot showing the Local p_0 versus m_H [GeV] for the 2011-12 period at $\sqrt{s} = 7-8$ TeV. It displays the observed data and the expected Higgs signal, with significance levels from 2σ to 6σ indicated.

<http://www.elsevier.com/locate/physletb>

The Economist

JULY 7TH - 13TH 2012 Economist.com

In praise of charter schools
Britain's banking scandal spreads
Volkswagen overtakes the rest
A power struggle at the Vatican
When Lonesome George met Nora

A giant leap for science

The cover of The Economist features a man in a dark suit jumping over a vibrant, multi-colored, abstract landscape that resembles a nebula or a complex data visualization. The man is holding papers, suggesting a professional or scientific context.

Finding the Higgs boson

Nobel Prize in Physics 2013



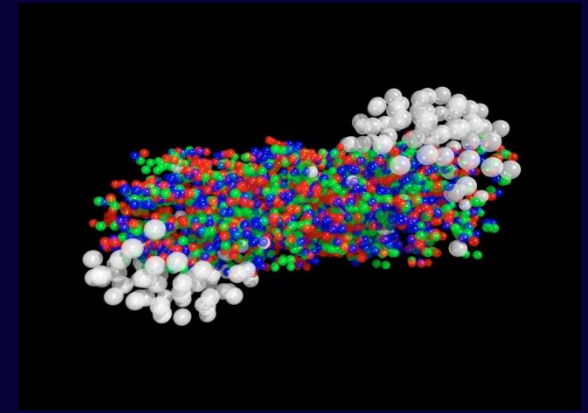
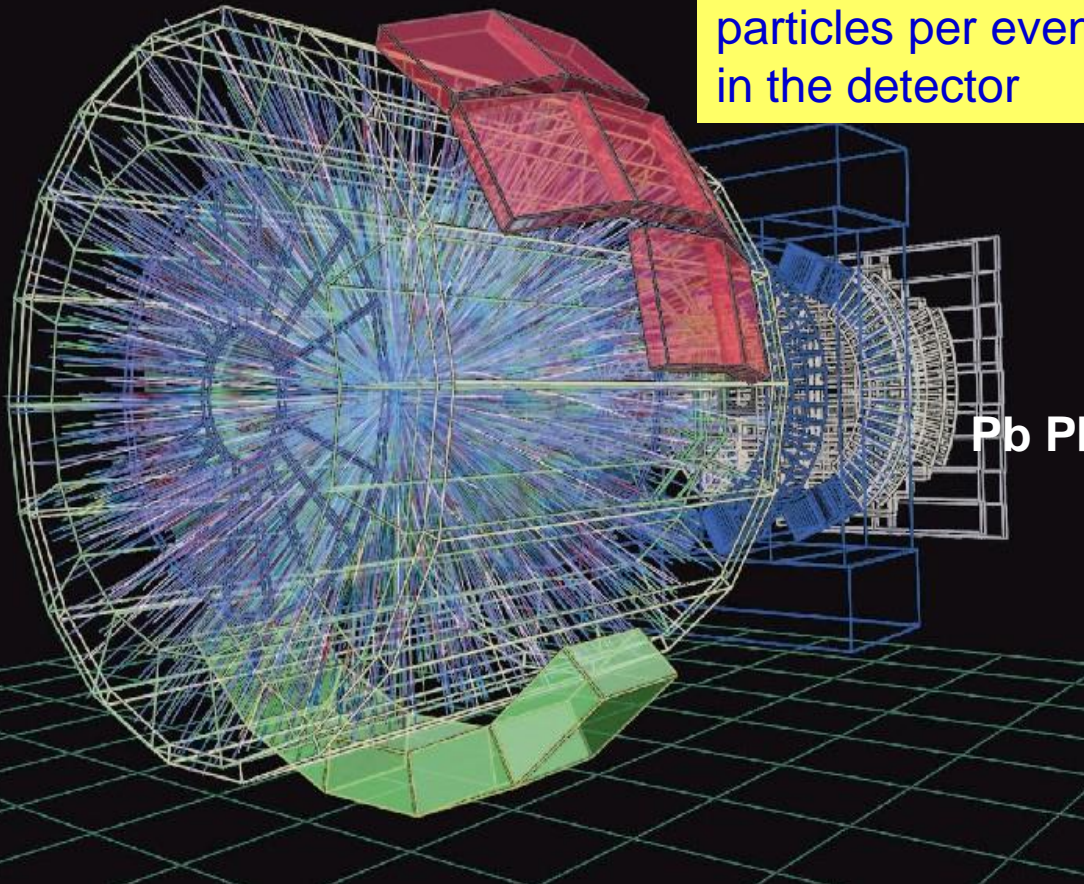
The Nobel Prize in Physics 2013 was awarded jointly to François Englert and Peter W. Higgs "for the theoretical discovery of a mechanism that contributes to our understanding of the origin of mass of subatomic particles, and which recently was confirmed through the discovery of the predicted fundamental particle, by the ATLAS and CMS experiments at CERN's Large Hadron Collider".

Primordial Plasma



Lead-lead collisions at the LHC study the primordial plasma, a state of matter in the early moments of the Universe

More than 10,000 particles per event in the detector



Pb Pb collisions may liberate quarks

Study the phase transition of a state of **quark gluon plasma** created at the time of the early Universe to the **baryonic matter** we observe today

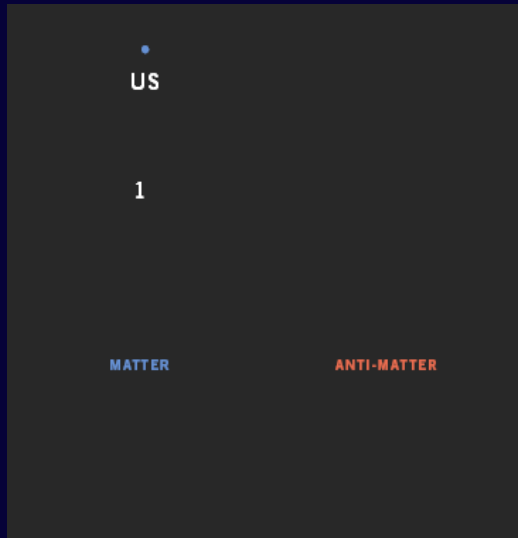
A lead lead collision simulated in the ALICE detector

The ALICE Experiment



Where does the Matter come from?

Dirac predicted the existence of antimatter:
same mass
opposite internal properties:
electric charge, ...
Discovered in cosmic rays
Studied using accelerators



Matter and antimatter not quite equal and opposite: WHY?

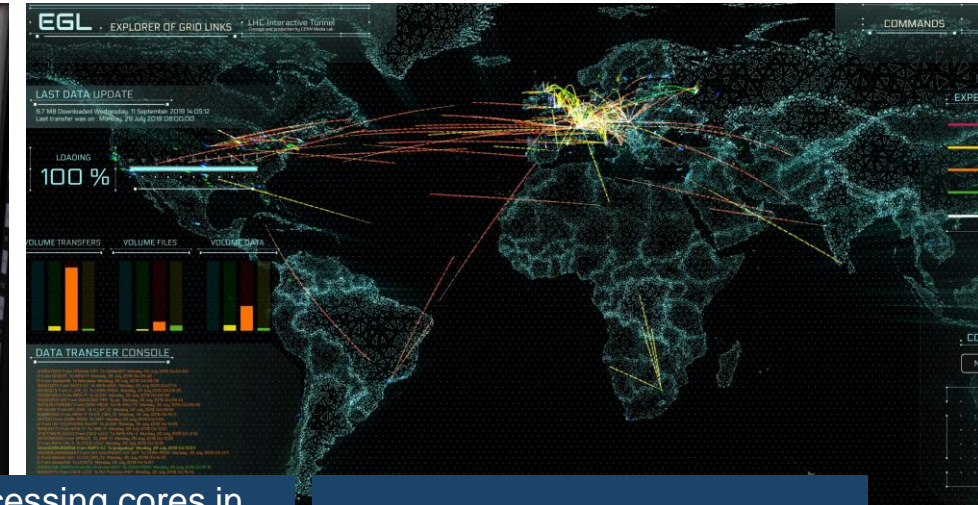
Is this why the Universe contains mainly matter, not antimatter?

LHC experiments are searching for answer

The Worldwide LHC Computing Grid (WLCG)



Used to store, distribute, process and analyse data.



1 million processing cores in about 170 data centres and 42 countries.

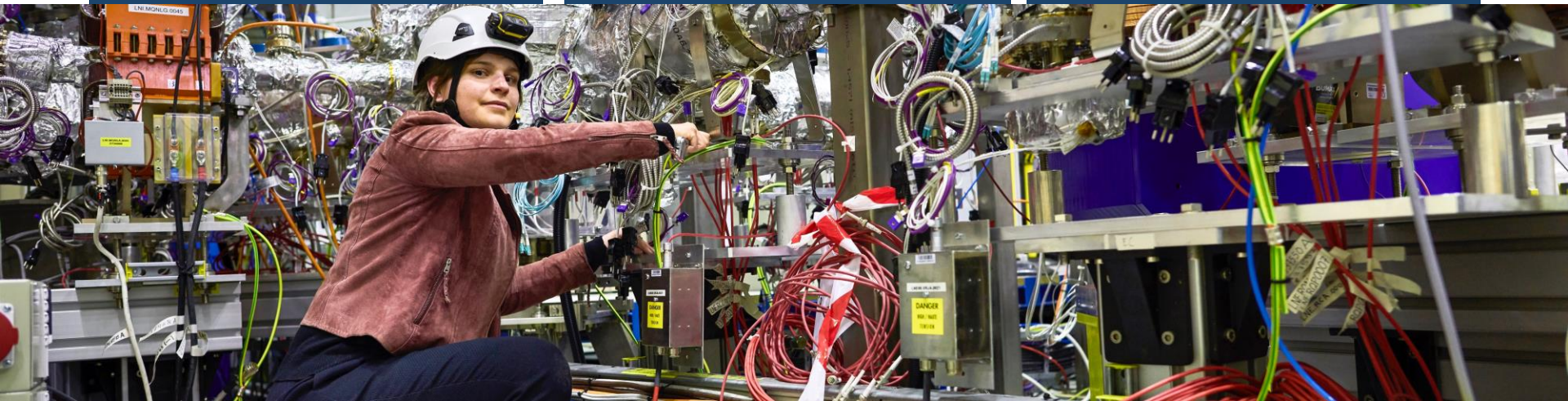
More than 1000 Petabytes of CERN data stored world-wide.

CERN has a diverse scientific programme

Nuclear Physics
(ISOLDE)

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

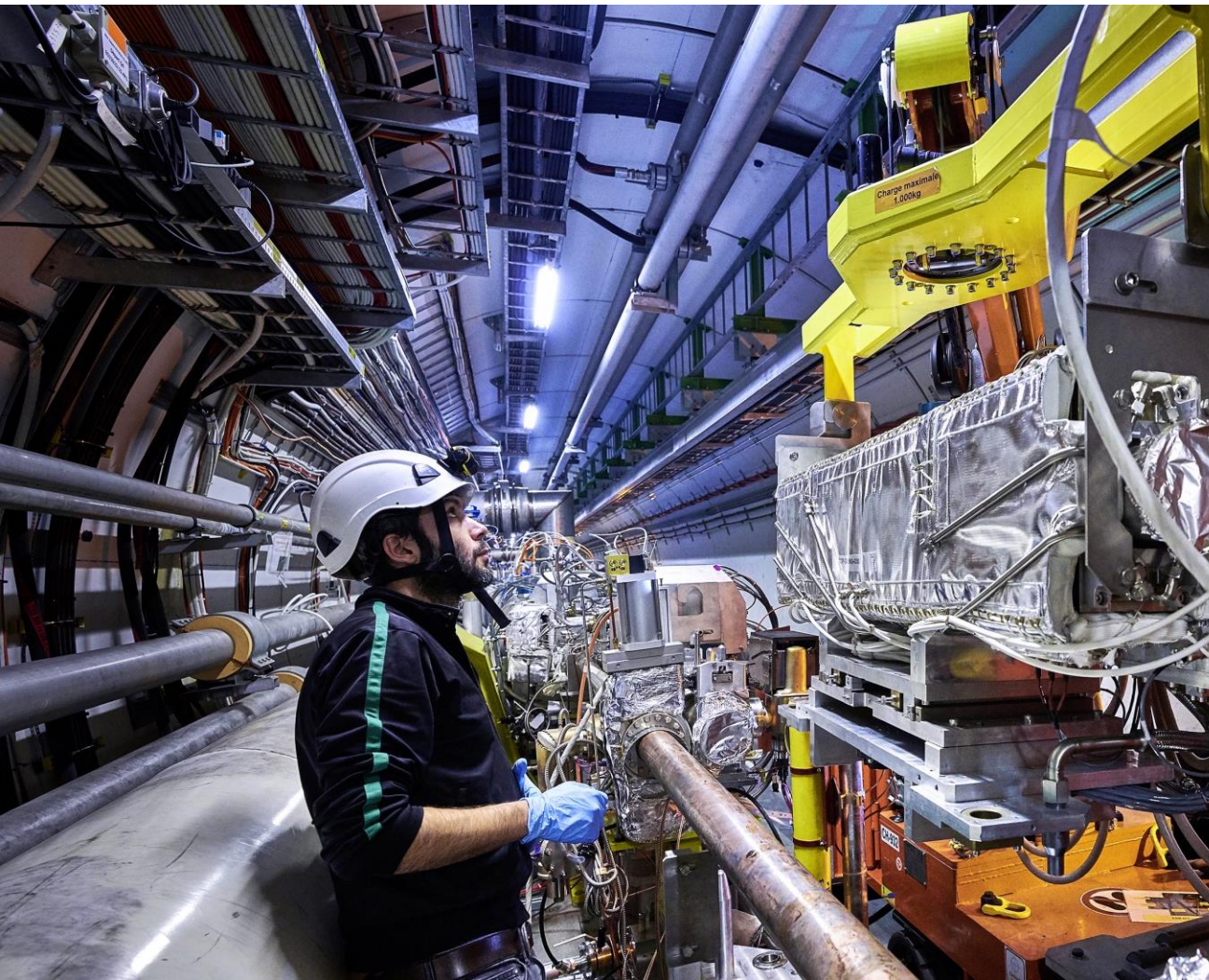
Including

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 2029, and run until approx. 2040.

Scientific priorities for the future

Implementation of the recommendations
of the **2020 Update of the European
Strategy for Particle Physics:**

- Fully exploit the HL-LHC.
- Build a Higgs factory to further understand this unique particle.
- Investigate the technical and financial feasibility of a future energy-frontier 100 km collider at CERN.
- Ramp up relevant R&D.
- Continue supporting other projects around the world.

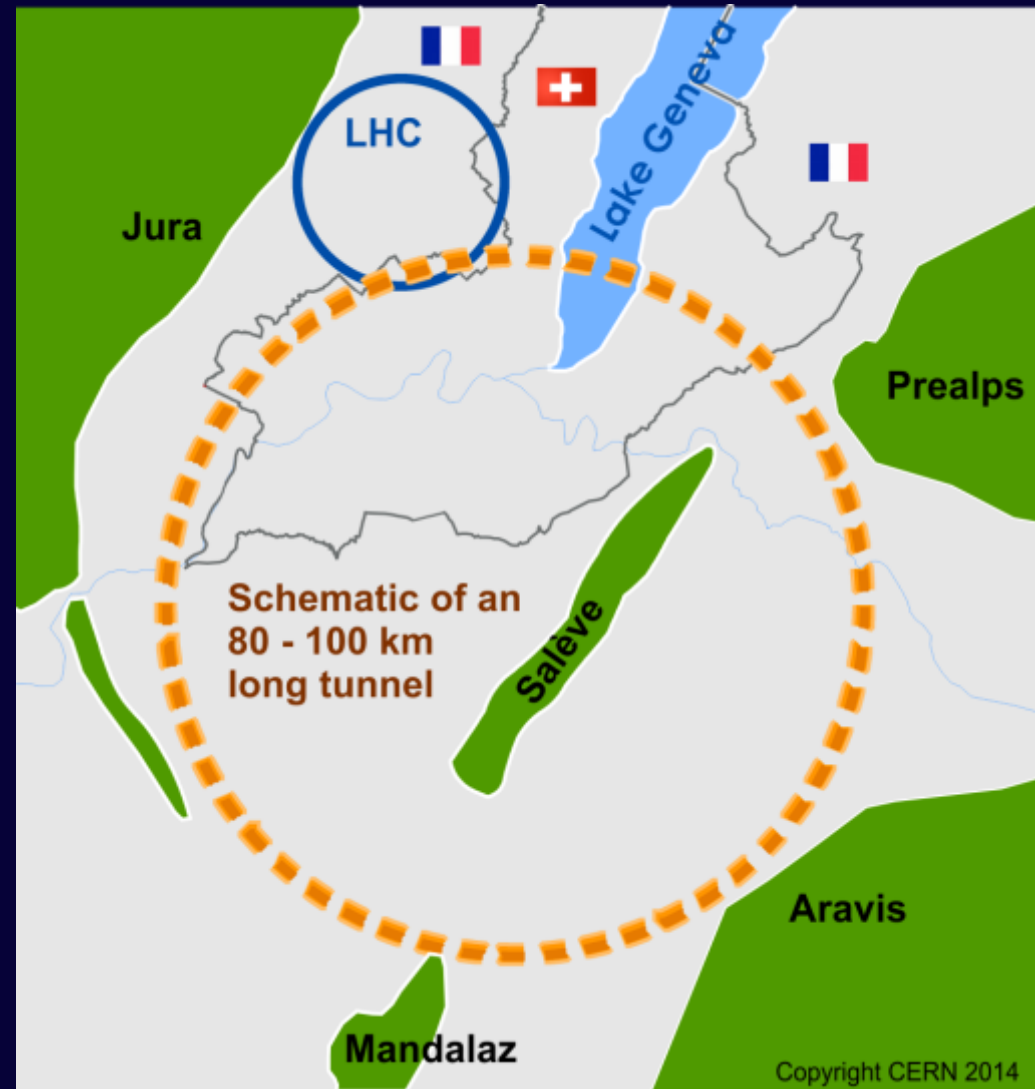


Future Circular Collider Feasibility Study

Forming an international collaboration to study:

- pp -collider (*FCC-hh*)
→ defining infrastructure requirements
- e^+e^- collider (*FCC-ee*) as potential intermediate step
- $p-e$ (*FCC-he*) option
- 80-100 km infrastructure in Geneva area

~16 T \Rightarrow 100 TeV pp in 100 km
~20 T \Rightarrow 100 TeV pp in 80 km



CLIC near CERN



Legend

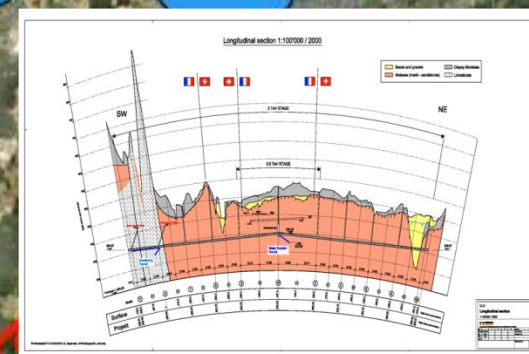
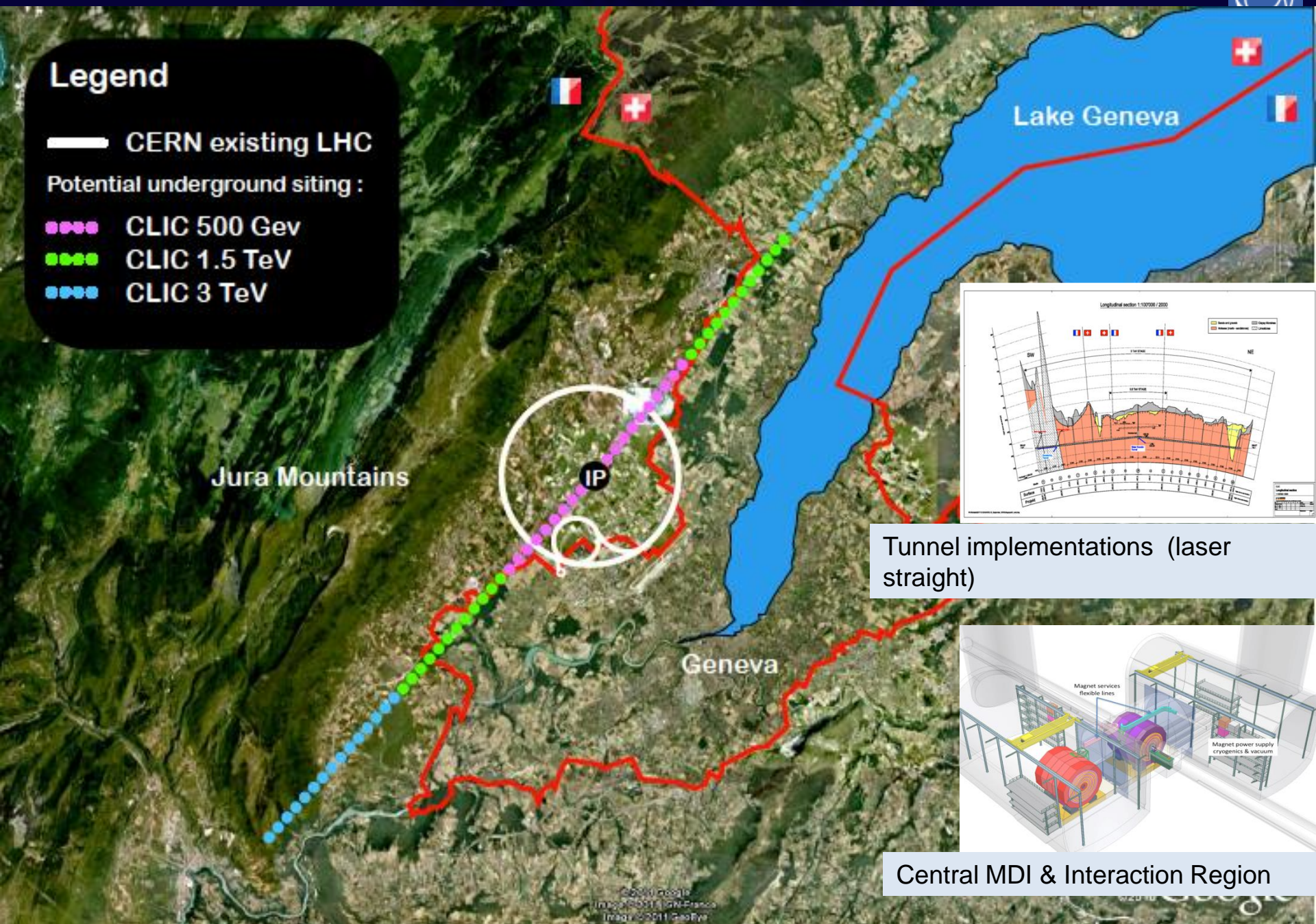
— CERN existing LHC

Potential underground siting :

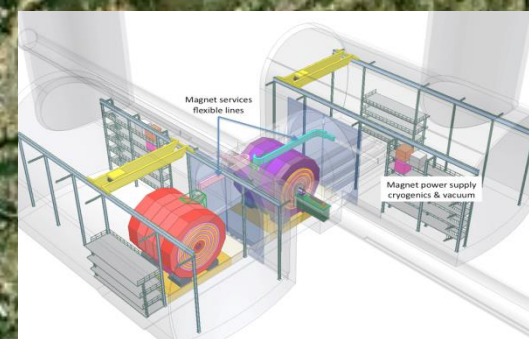
●●●● CLIC 500 GeV

●●●● CLIC 1.5 TeV

●●●● CLIC 3 TeV



Tunnel implementations (laser straight)



Central MDI & Interaction Region



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

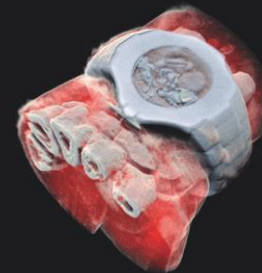
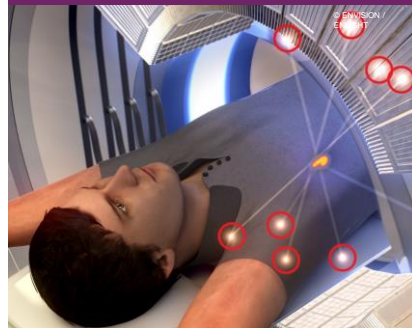
Medical imaging, cancer therapy, material science, cultural heritage, aerospace, automotive, environment, health & safety, industrial processes.

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



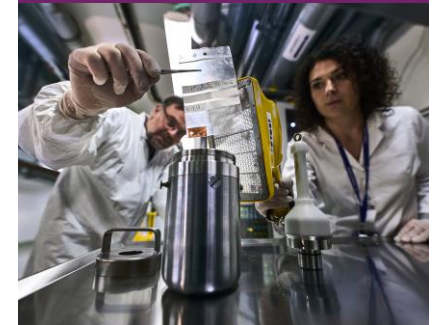
Accelerator technologies are applied in cancer radiotherapy with protons, ions and electrons.

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



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

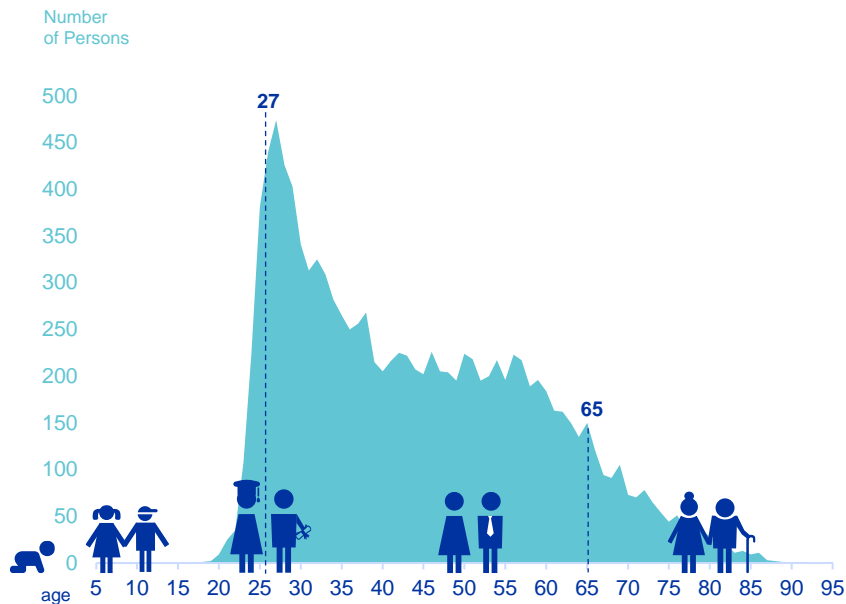
CERN produces innovative radioisotopes for nuclear medicine research.



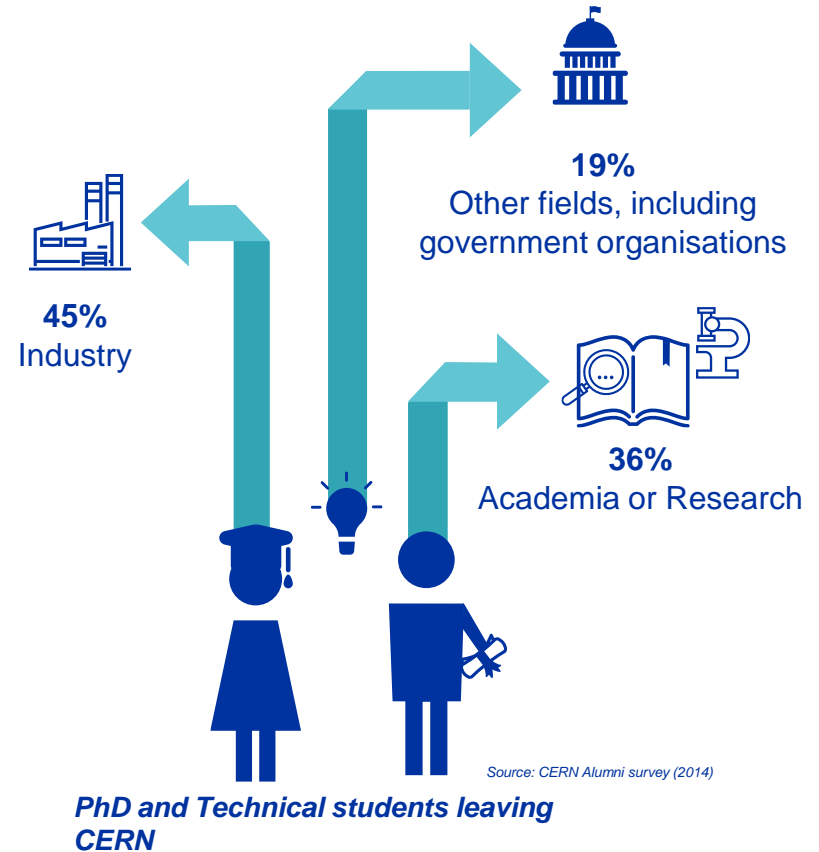
A group of students wearing hard hats (yellow and blue) are gathered around a metal frame in a laboratory or workshop. They are focused on a large, black, cylindrical component mounted on the frame. One student in the foreground is adjusting the component. In the background, a green exit sign with a white arrow pointing down is visible on the wall. 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



CERN's training, education and outreach programmes

300 Undergraduate students in Summer programmes
>3000 registered PhD students.

>1000 Fellows, Technical and Doctoral Students in research and applied physics, engineering and computing.

13 304 teachers since 1998 and 2000 participants in the webinar since 2020.



151 000 visitors on guided tours of CERN in 2019, from 95 countries.

CERN engages with citizens across the globe: on-site and travelling exhibitions in 15 countries, > 1 million visitors

Science Gateway will open in 2023, expanding CERN's outreach reach and impact, locally and globally.

CERN Science Gateway



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

Opening October 2023.

Immersive exhibitions, education labs, events and shows.

CERN – innovate, discover, publish, share



... and bring the world together



Thank You!

LHCb

ATLAS

CERN Meyrin

CERN Prévessin

SPS 7 km

ALICE

CMS

LHC 27 km

SUISSE
FRANCE