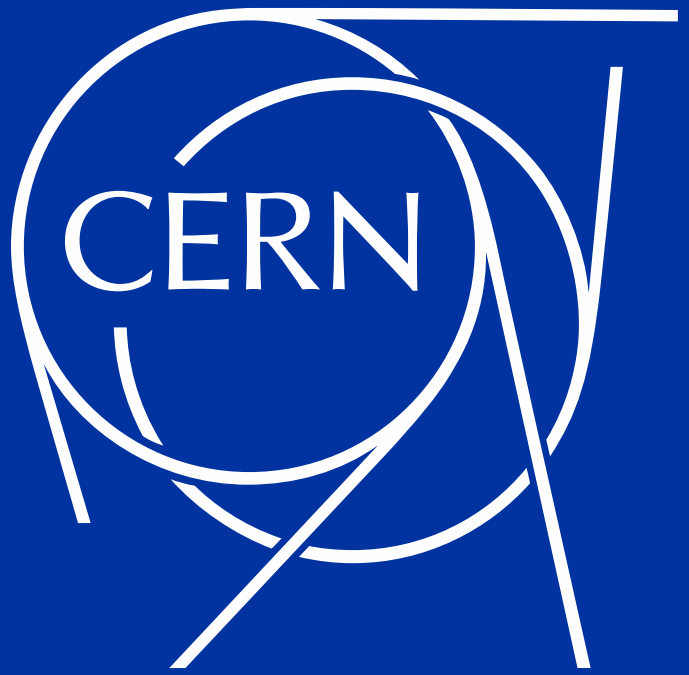
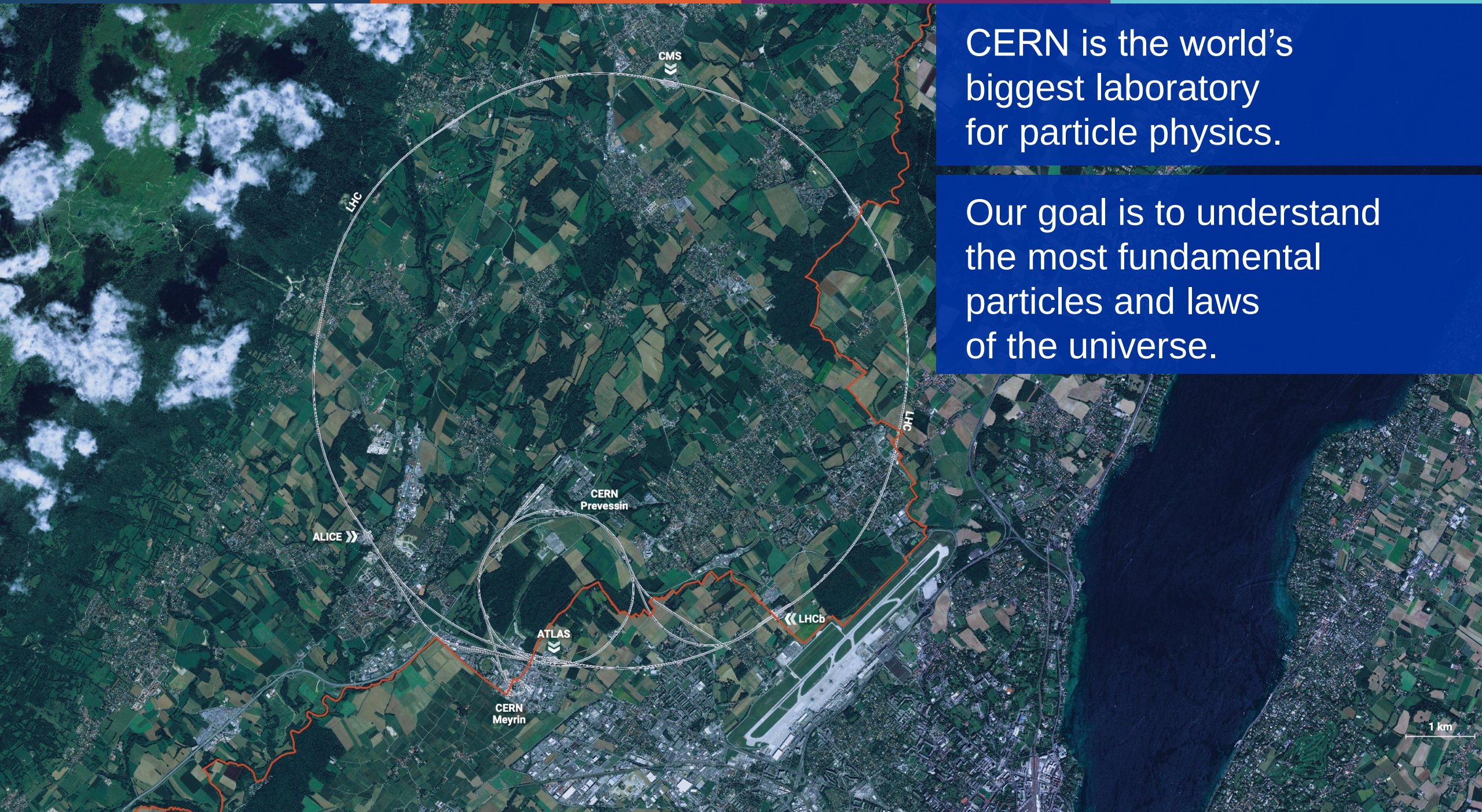


CERN present and future activities

Daniel Schoerling

Procurement Officer

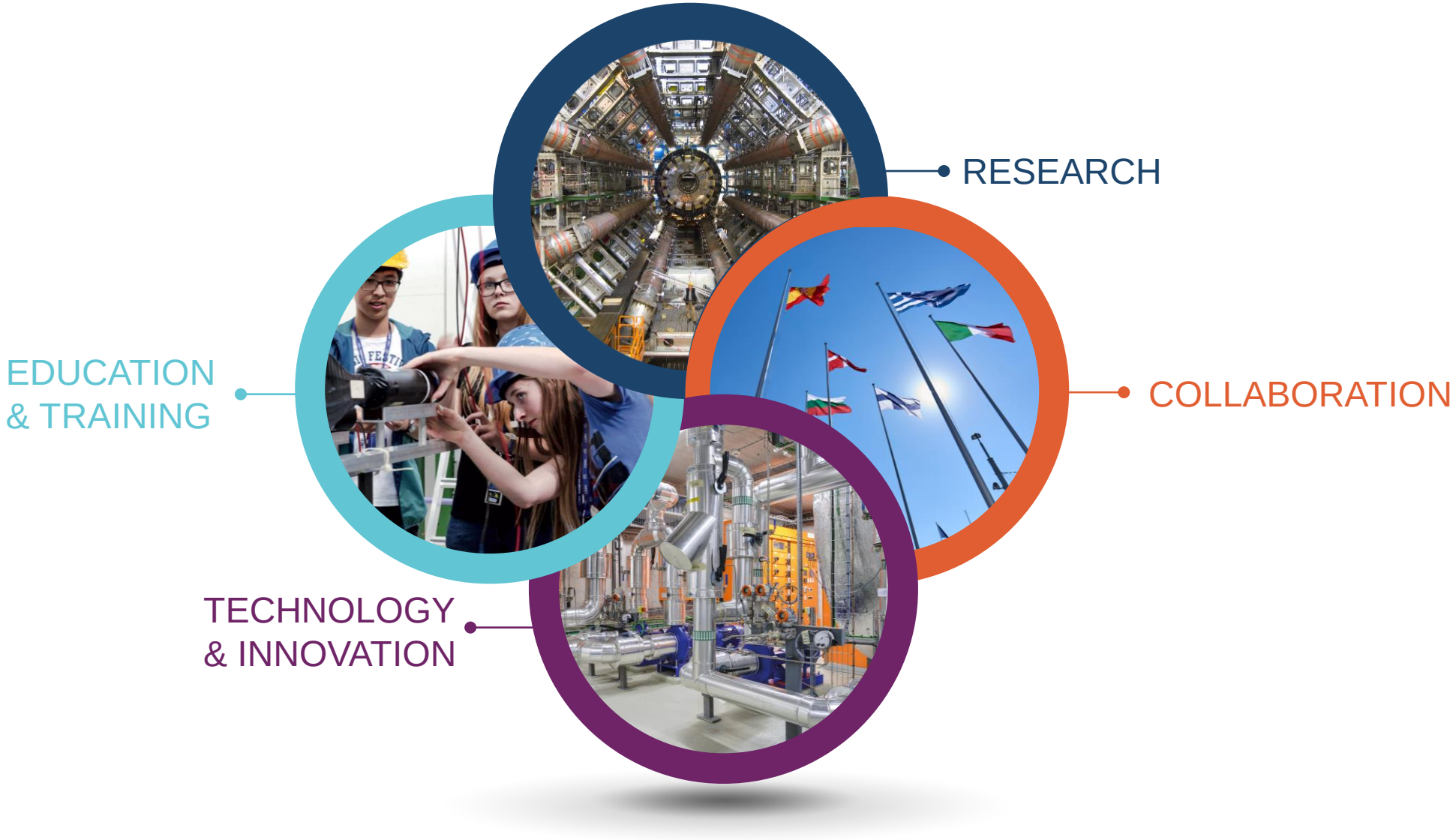
27 October 2022

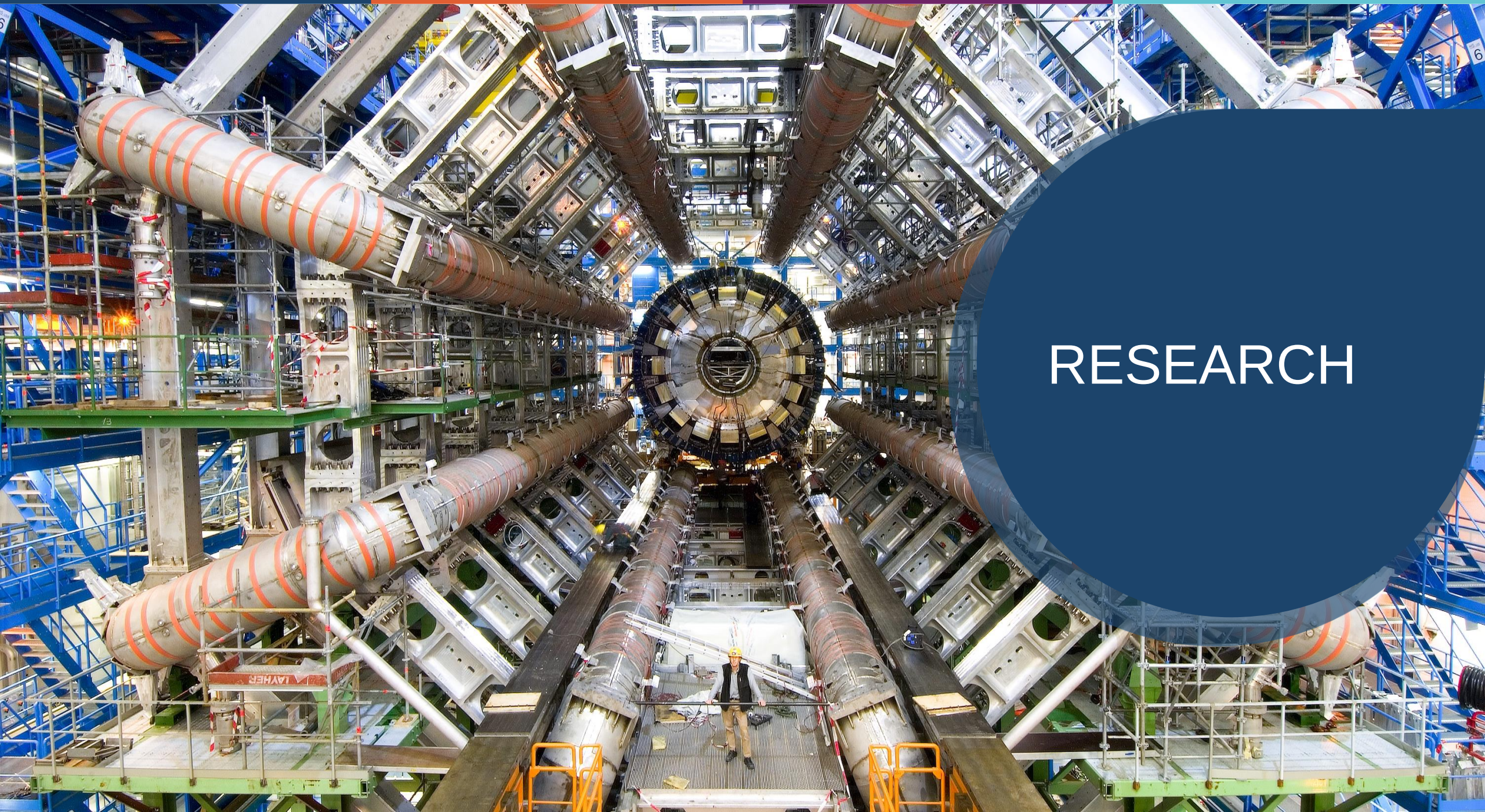


CERN is the world's biggest laboratory for particle physics.

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

Four pillars underpin CERN's mission

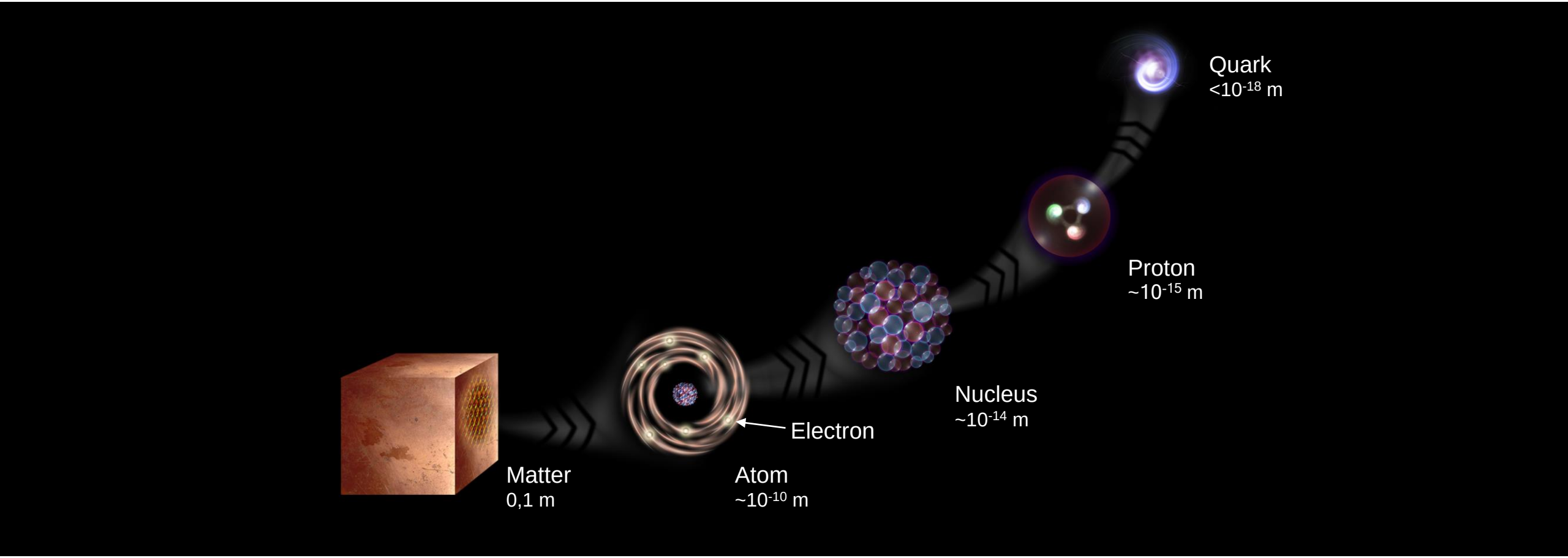


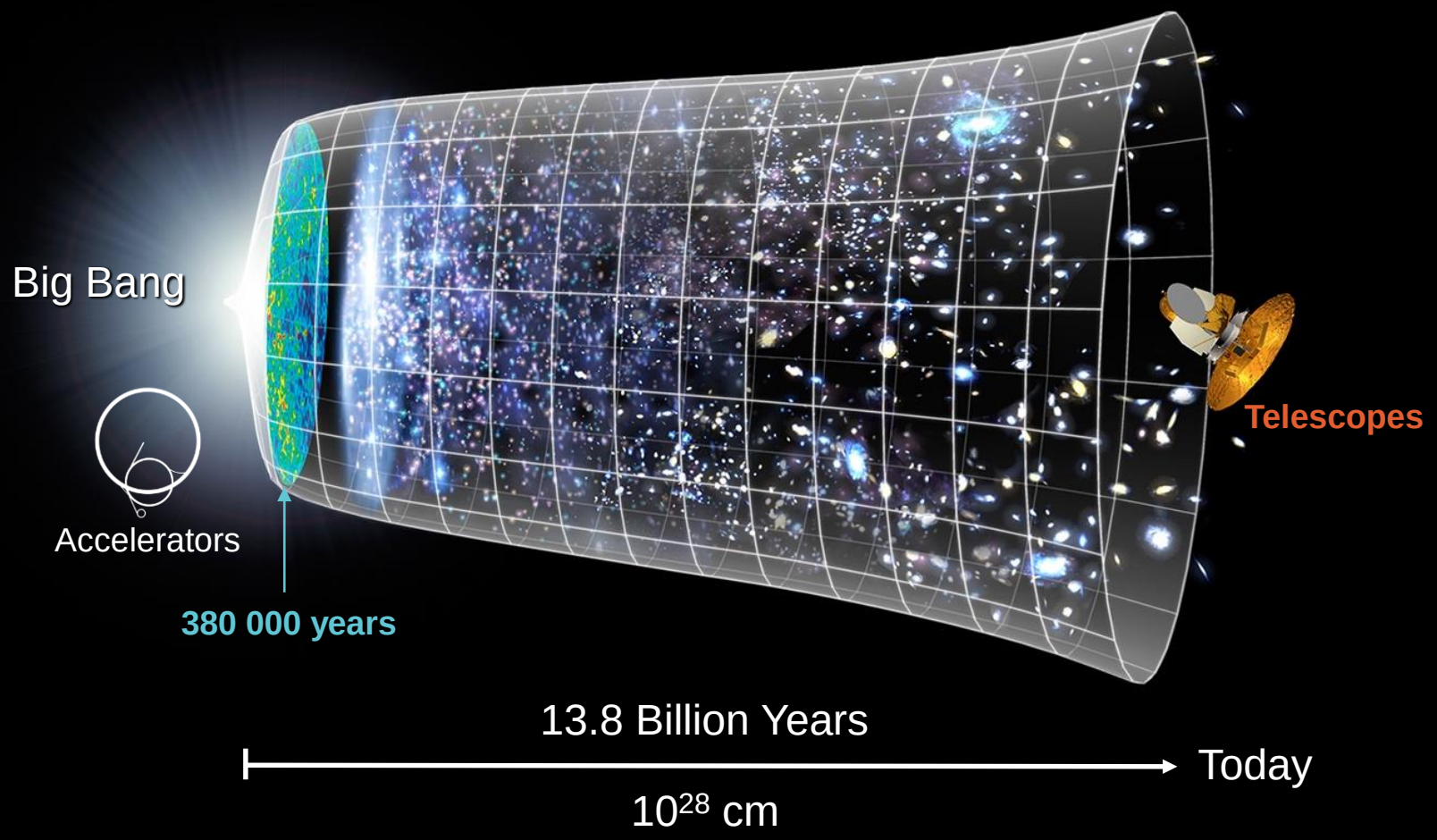


RESEARCH

What is the universe made of?

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





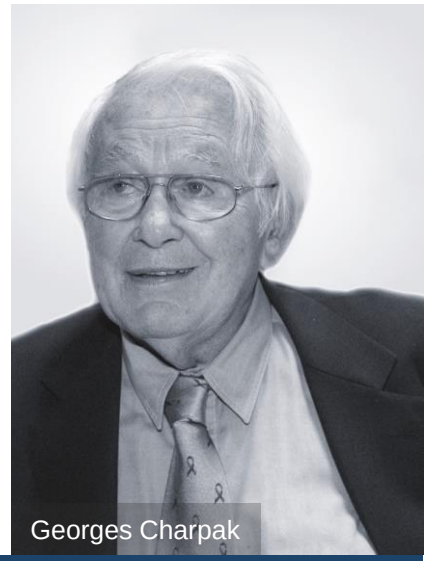
How did the universe begin?

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.

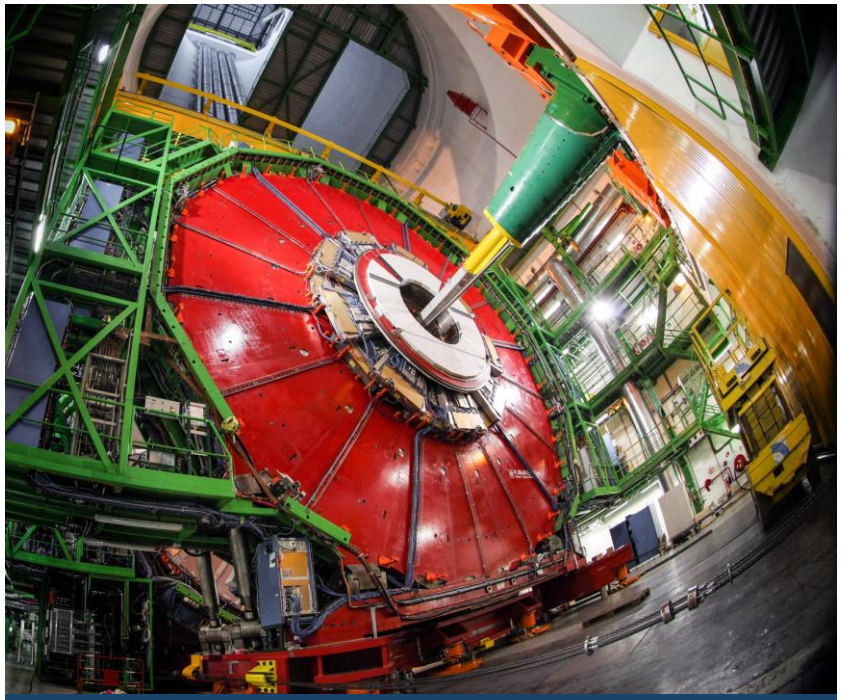
The Higgs boson was discovered in 2012; without it fundamental particles would be massless and atoms could not form.


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

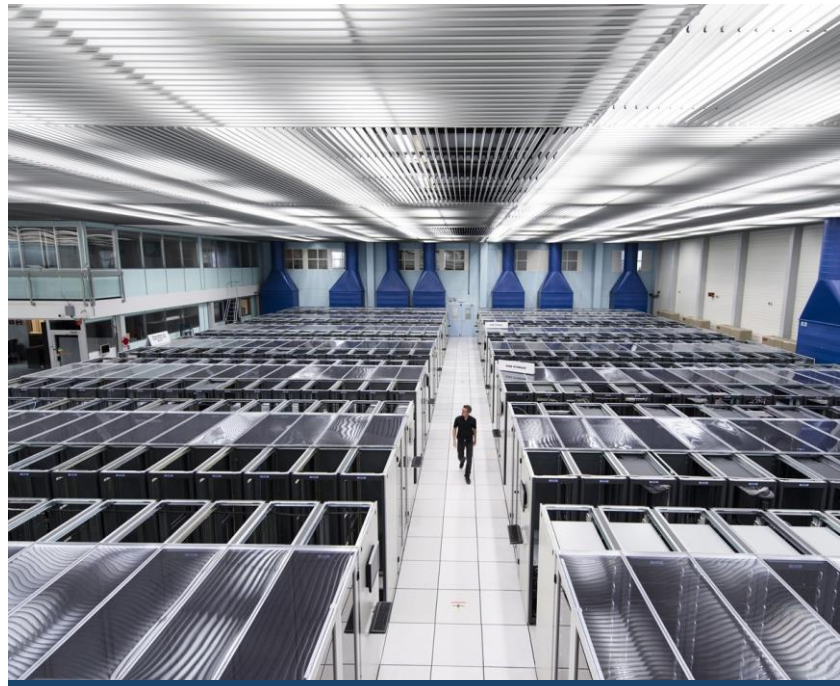
How do we do it?

- We build the largest machines to study the smallest particles in the universe
- We develop technology to advance the limits of what is possible
- We perform world-class research in theoretical and experimental particle physics

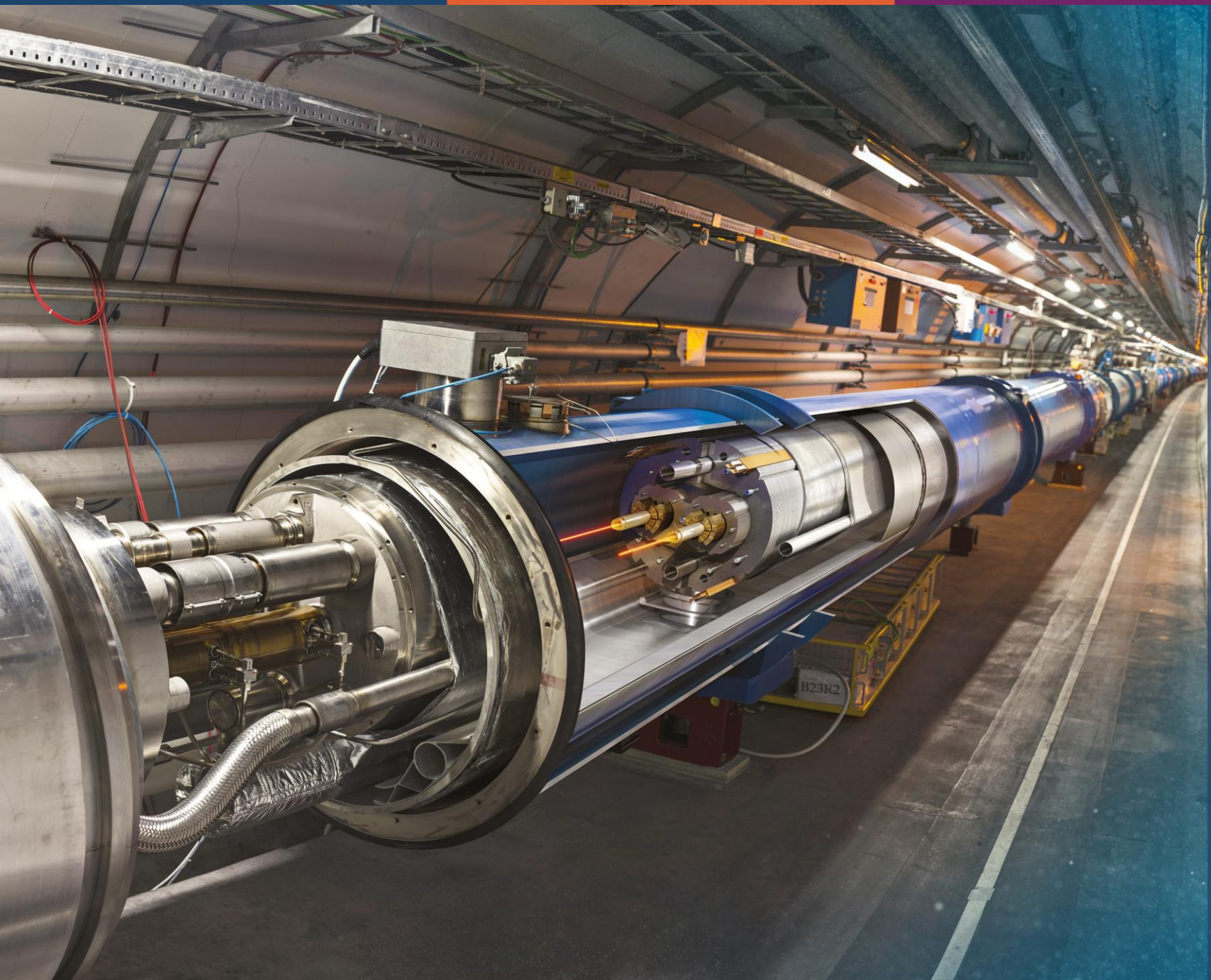
ACCELERATORS



DETECTORS



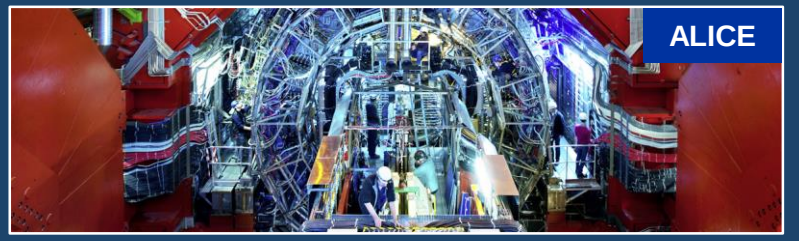
COMPUTING



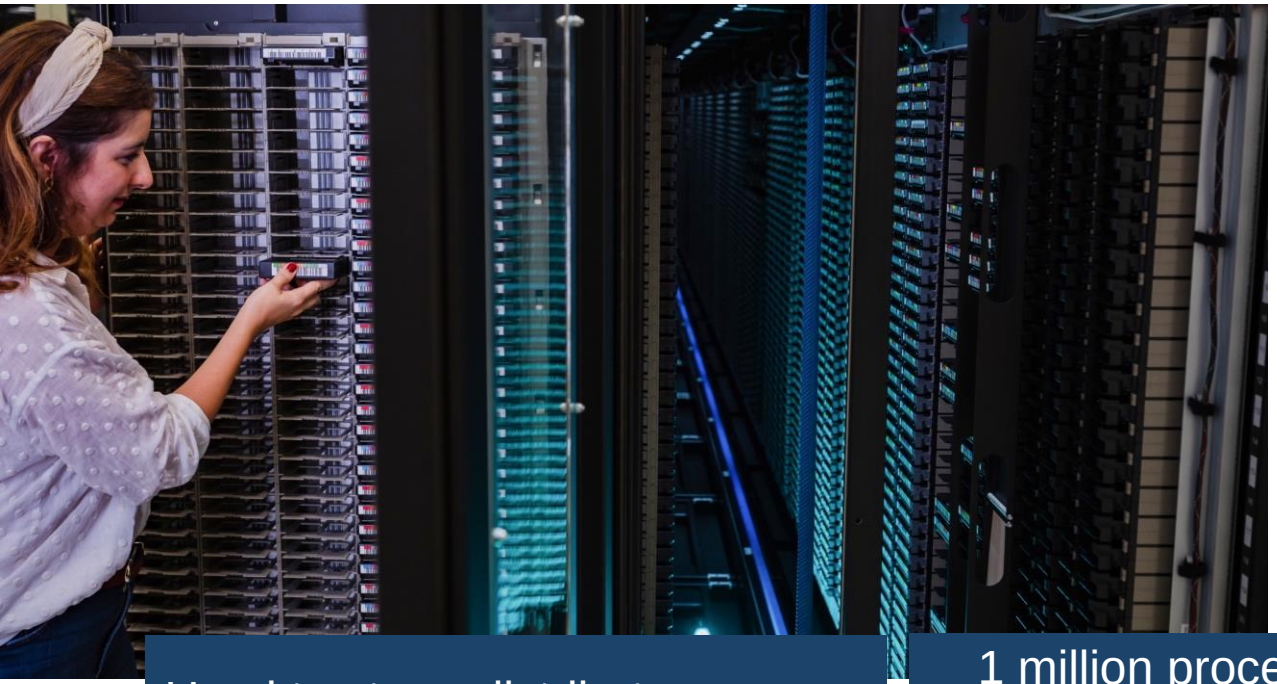
Accelerators: Large Hadron Collider (LHC)

- 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 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.

Data centre on CERN's Prévessin site

- Design, Construction, Maintenance and Operation of a Turnkey Data Centre with a PUE < 1.15 including all technical equipment:

  Cooling, Airflow Management, Low Voltage Power Distribution, Water distribution, Smoke extraction, Fire Detection, Access control, and Building Management System, etc…

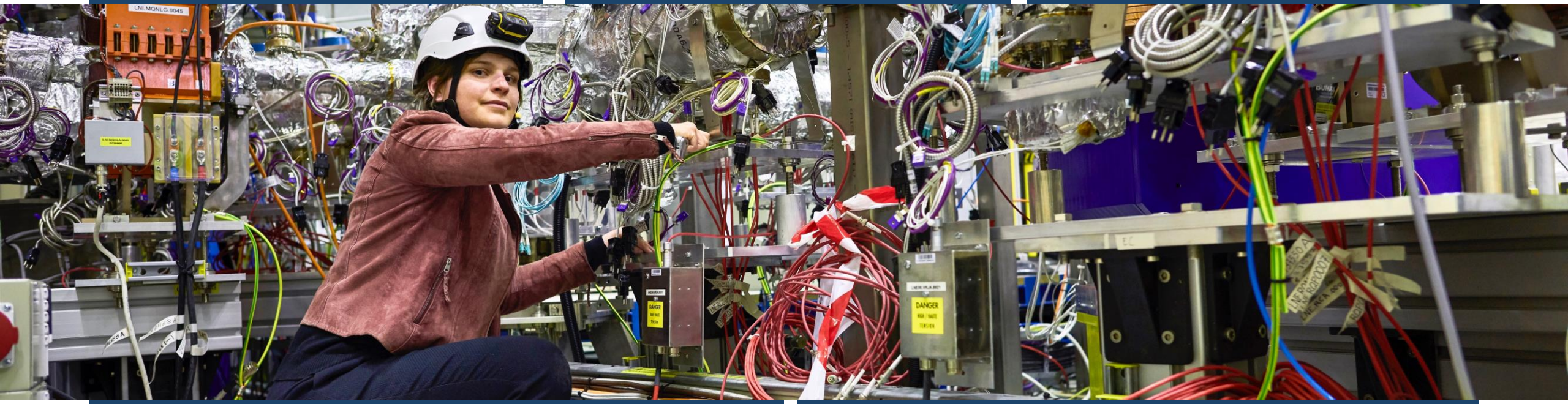
- Adjudicated on a 10-years TCO basis, including electricity costs, based on a hypothetical 4, 8 & 12 MW power ramp up
- With options for UPS, Racks, Rack Power Distribution Units and Transformers
- Option for Heat Recovery without negatively affecting the Power Usage Efficiency (PUE)
- Does not include IT computing equipment (CPU & Storage equipment, networking equipment, etc…)

CERN has a diverse scientific programme

Nuclear Physics
(ISOLDE)

Antimatter Research
(Antiproton Decelerator)

Cosmic rays and cloud formation
(CLOUD)



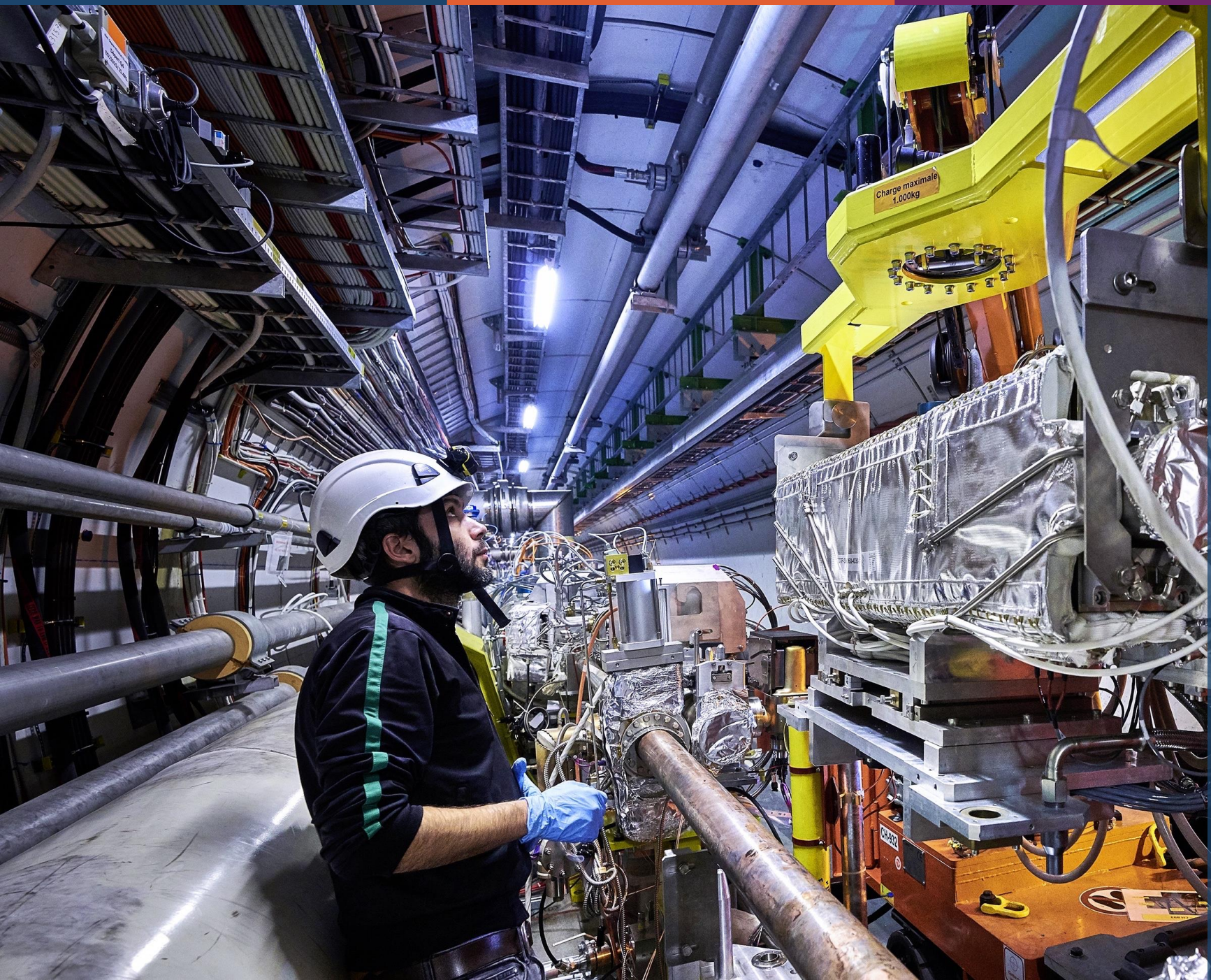
Fixed-target experiments,
which include searches for rare phenomena

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

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



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.

FCC feasibility study 2021 – 25 & roadmap

Highest priority goals:

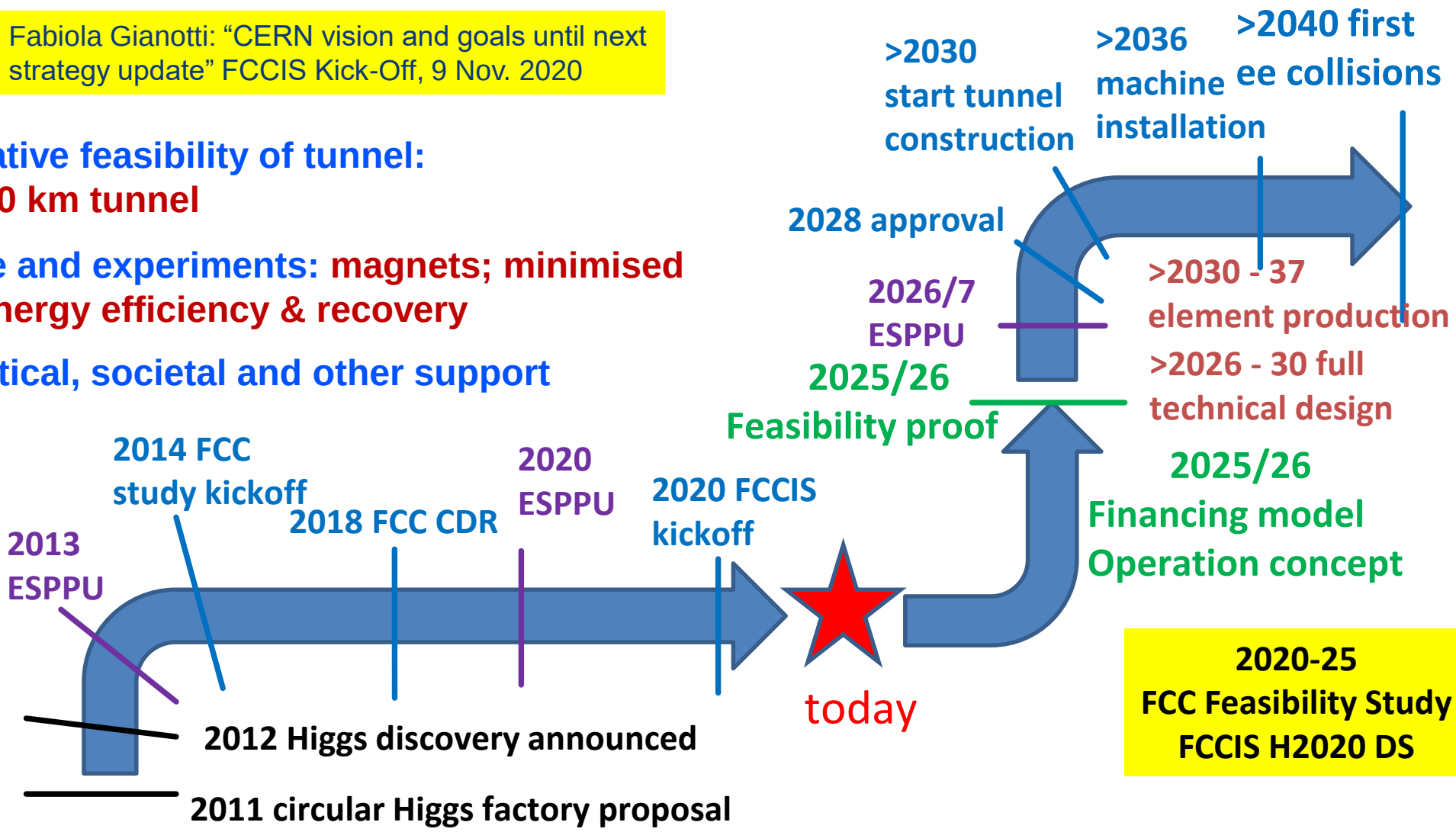
Fabiola Gianotti: "CERN vision and goals until next strategy update" FCCIS Kick-Off, 9 Nov. 2020

Financial feasibility

Technical and administrative feasibility of tunnel: no show-stopper for ~100 km tunnel

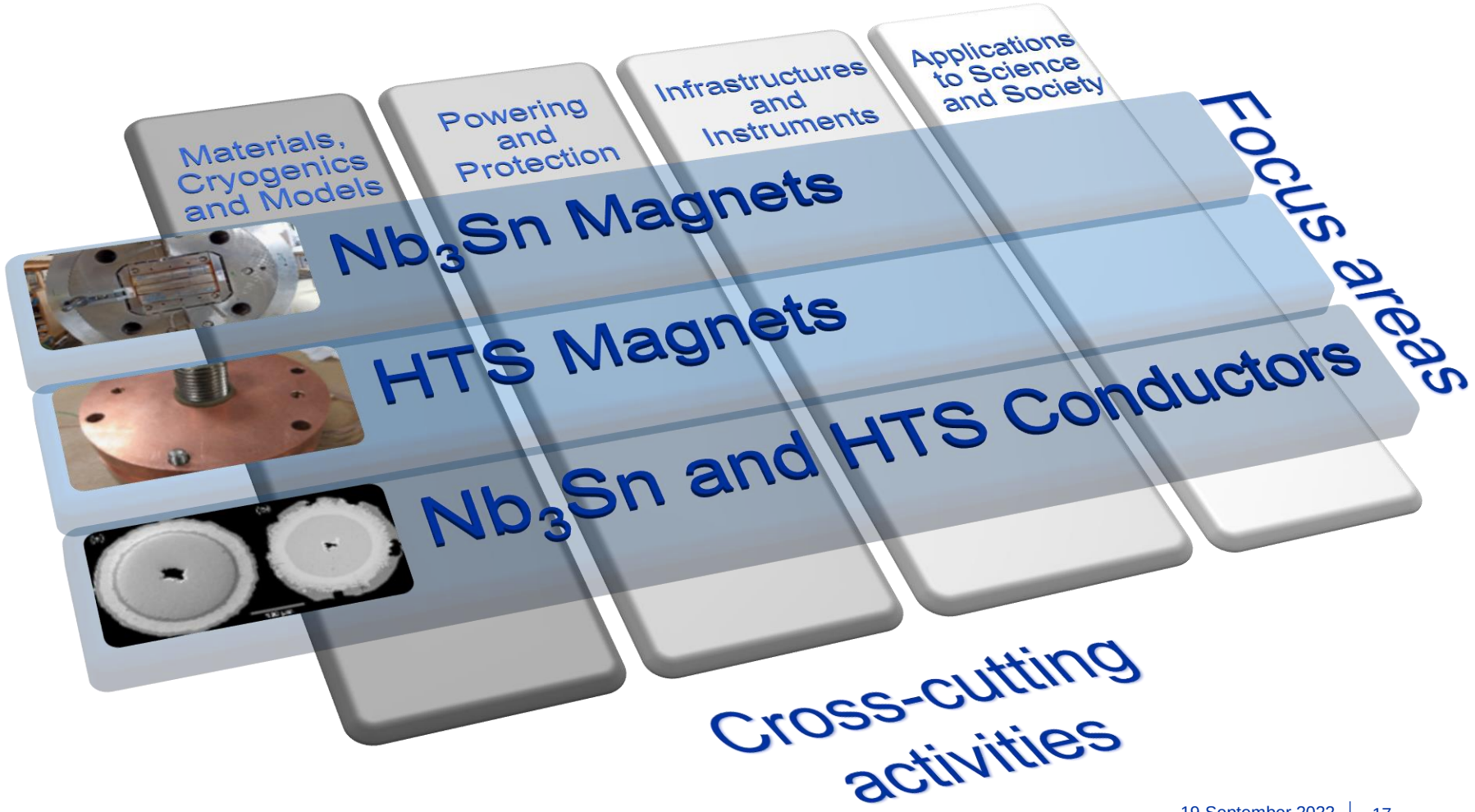
Technologies of machine and experiments: magnets; minimised environmental impact; energy efficiency & recovery

Gathering scientific, political, societal and other support

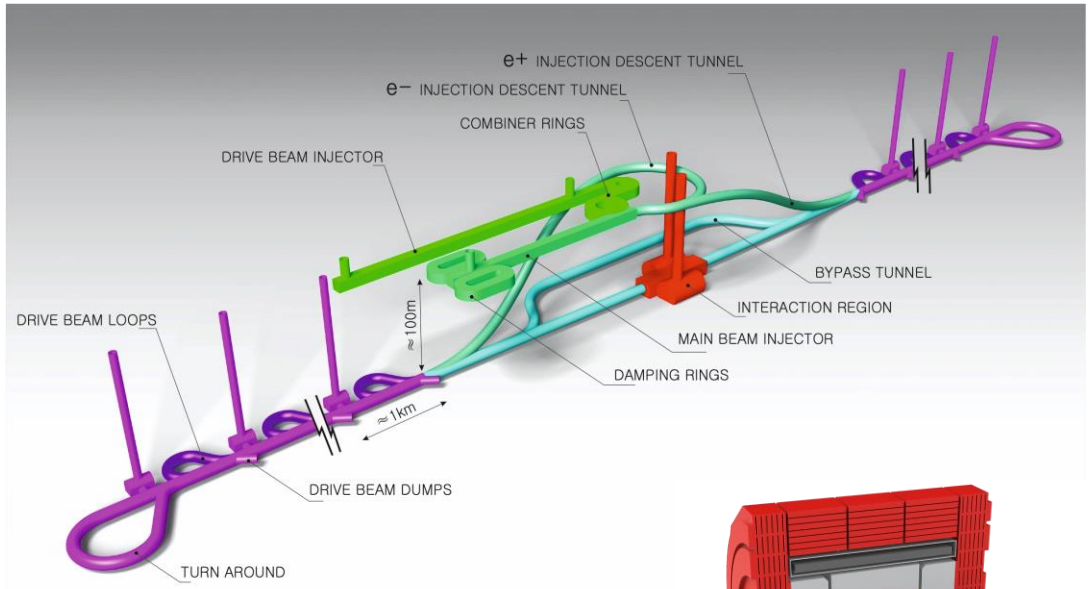


Fundamental superconducting magnet R&D

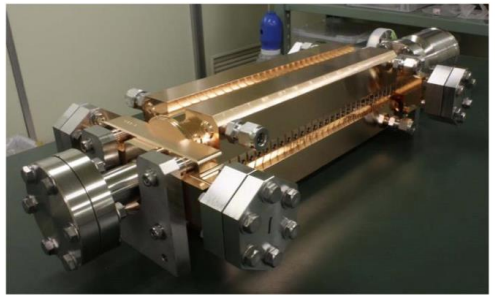
- Future accelerators will require the next generation of LTS and HTS magnets
- Development of the next generation magnets will require an important R&D effort
- High Field Magnet R&D project is starting at CERN

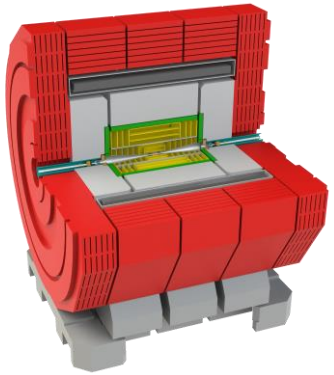


Compact Linear Collider (CLIC)



Accelerating structure prototype for CLIC: 12 GHz (L~25 cm)





- **Timeline:** Electron-positron linear collider at CERN for the era beyond HL-LHC
- **Compact:** Novel and unique two-beam accelerating technique with high-gradient room temperature RF cavities (~20'500 structures at 380 GeV), ~11km in its initial phase
- **Expandable:** Staged programme with collision energies from 380 GeV (Higgs/top) up to 3 TeV (Energy Frontier)

- CDR in 2012 with focus on 3 TeV. Updated project overview documents in 2018 (Project Implementation Plan) with focus 380 GeV for Higgs and top.

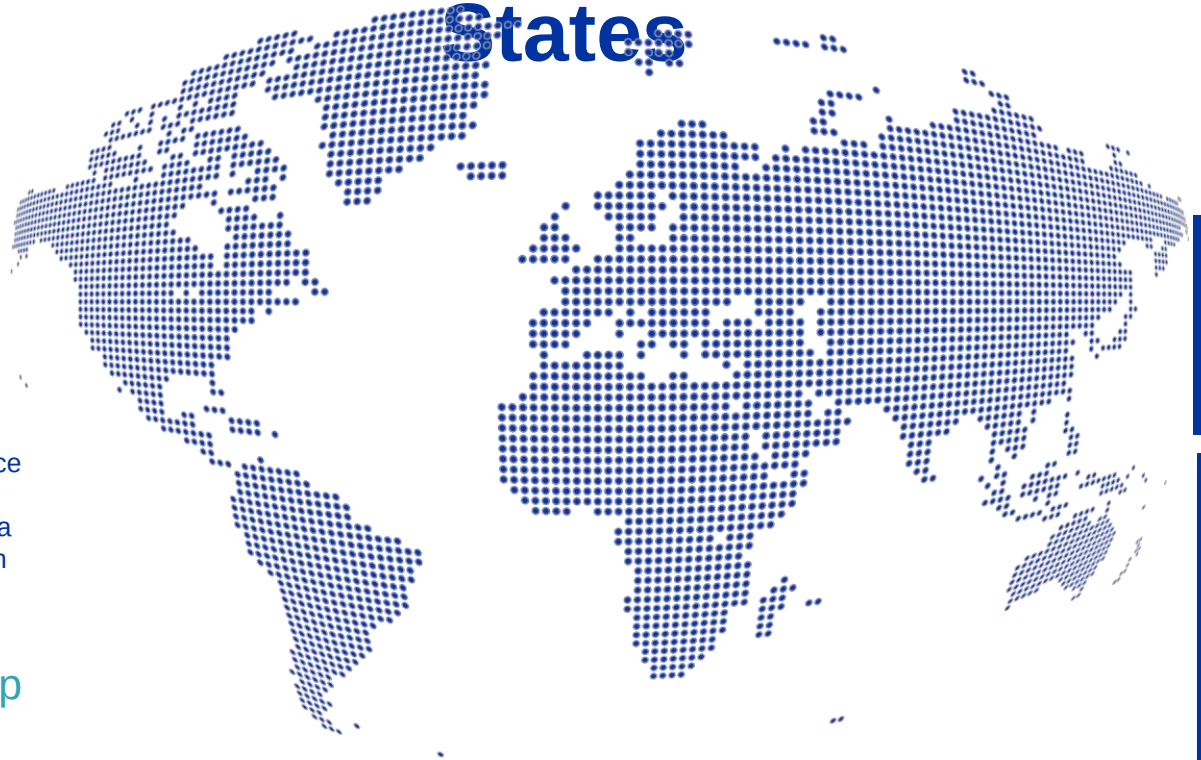
- **Cost:** 5.9 BCHF for 380 GeV (stable wrt 2012)
- **Power:** 168 MW at 380 GeV (reduced wrt 2012), corresponding to 60% of CERN's energy consumption today

- Comprehensive **Detector and Physics** studies

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

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 2021
Employees:
2676 staff, **783** fellows

Associates:
11 175 users, **1556** 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 2021

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

Member States 6642

Austria 74 – **Belgium** 122 – **Bulgaria** 39 – **Czech Republic** 227
Denmark 42 – **Finland** 71 – **France** 811 – **Germany** 1129
Greece 133 – **Hungary** 69 – **Israel** 67 – **Italy** 1423
Netherlands 157 – **Norway** 69 – **Poland** 278 – **Portugal** 89
Romania 105 – **Serbia** 36 – **Slovakia** 66 – **Spain** 328
Sweden 88 – **Switzerland** 372 – **United Kingdom** 847

Associate Member States in the pre-stage to membership **55**

Cyprus 10 – **Estonia** 24 – **Slovenia** 21

Associate Member States **367**

Croatia 36 – **India** 130 – **Latvia** 11 – **Lithuania** 12 – **Pakistan** 30
Türkiye 122 – **Ukraine** 26

Observers **2917**

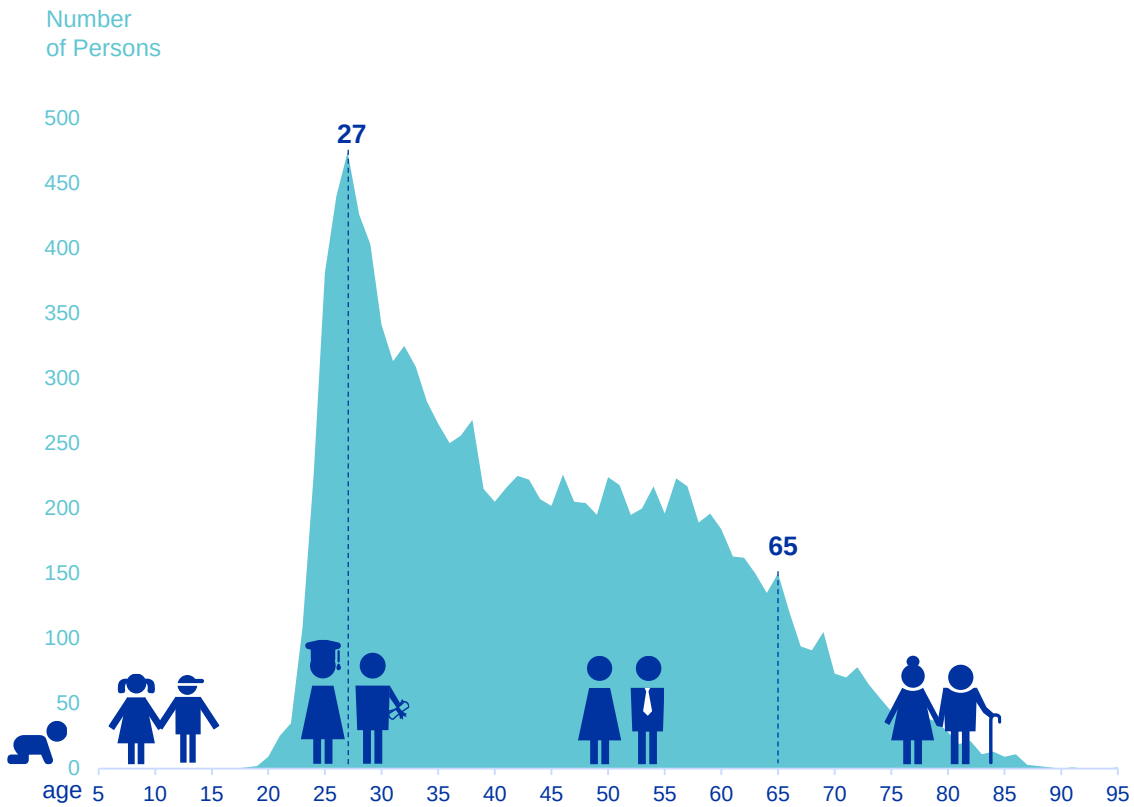
Japan 189 – **Russia** (suspended) 971 – **United States of America** 1757

Non-Member States and Territories **1194**

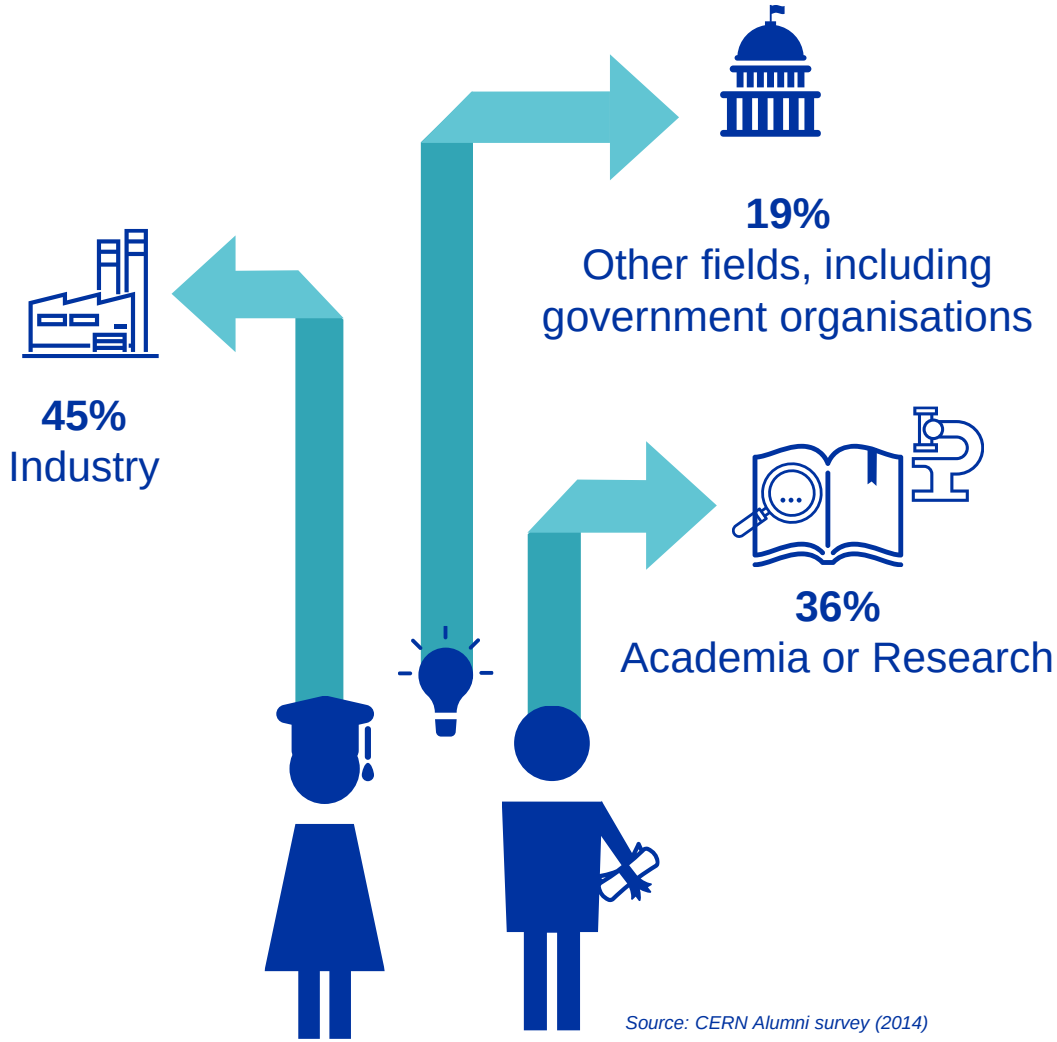
Algeria 3 – **Argentina** 16 – **Armenia** 10 – **Australia** 20 – **Azerbaijan** 3 – **Bahrain** 2 – **Belarus** 24 – **Brazil** 106
Canada 189 – **Chile** 23 – **Colombia** 18 – **Cuba** 3 – **Ecuador** 6 – **Egypt** 16 – **Georgia** 36 – **Hong Kong** 17
Iceland 3 – **Indonesia** 6 – **Iran** 11 – **Ireland** 6 – **Jordan** 5 – **Kuwait** 5 – **Lebanon** 15 – **Madagascar** 1
Malaysia 4 – **Malta** 2 – **Mexico** 48 – **Montenegro** 5 – **Morocco** 18 – **New Zealand** 8 – **Oman** 1 – **People's Republic of China** 314 – **Peru** 2 – **Philippines** 1 – **Republic of Korea** 113 – **Singapore** 3 – **South Africa** 52
Sri Lanka 10 – **Taiwan** 45 – **Thailand** 18 – **United Arab Emirates** 6

EDUCATION & TRAINING

CERN opens a world of career opportunities



Age Distribution of Scientists working at CERN



PhD and Technical students leaving CERN

CERN's training, education and outreach programmes

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

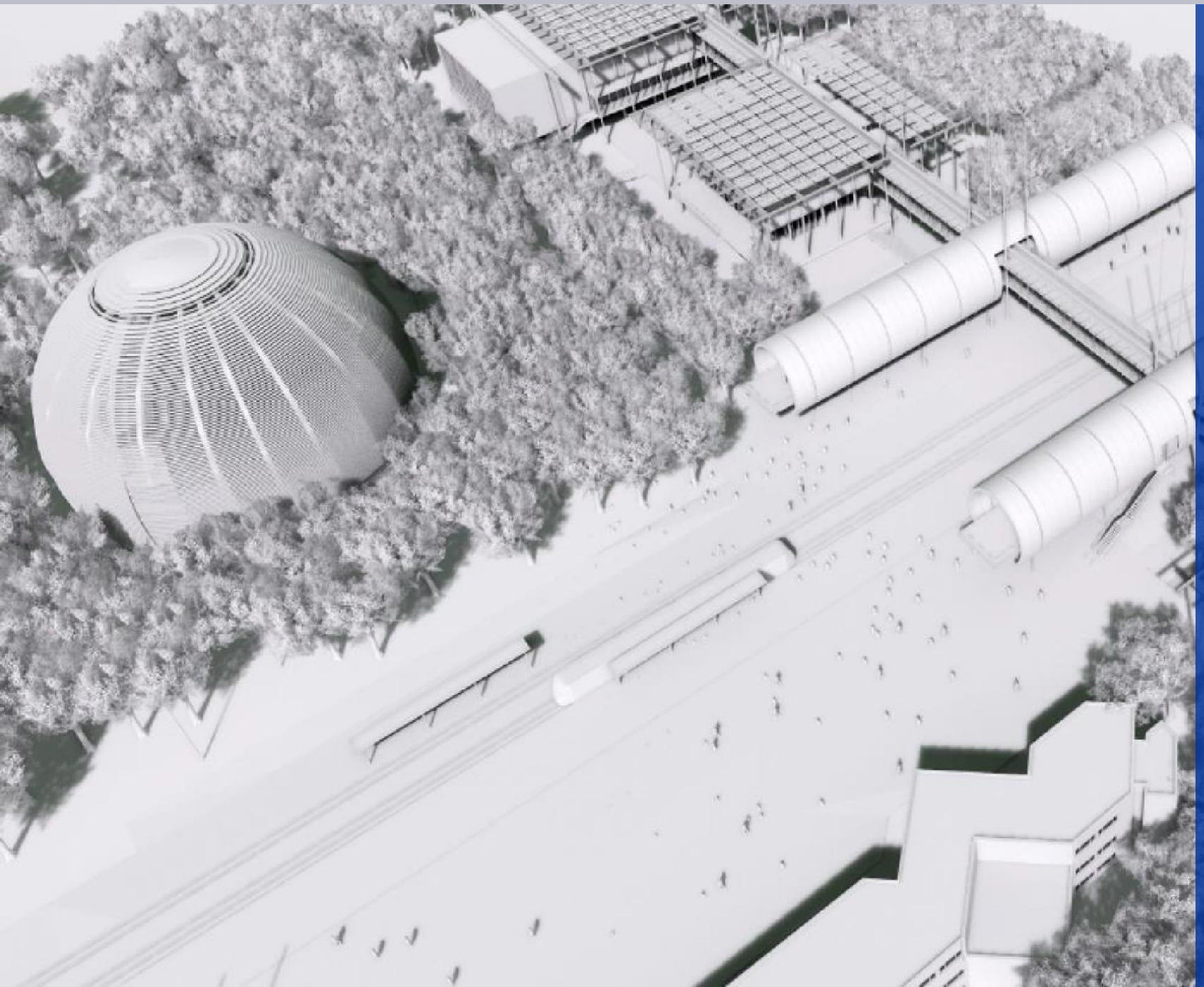
>1000 Fellows, Technical and Doctoral Students in research and applied physics, engineering and computing.

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.

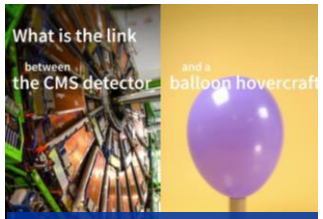


A new hub for scientific education, training and outreach, located in the area next to the Globe of Science and Innovation, across the road from the current Reception Building. The Science Gateway will be an integral part of the CERN site and stand alongside the visit circuit to the research facilities. Activities will target the general public of all ages from 5 years up.

Science Gateway Programme

Exhibitions

Guided tours



Learn Online

Events

Science Shows

Lab Workshops

TECHNOLOGY & INNOVATION

CERN is routinely using advanced technologies in small and very large infrastructures of accelerators and detectors and has developed a unique expertise running, consolidating and upgrading these systems.

CERN’s technological innovations have applications in many fields

CERN is the birthplace of the World Wide Web

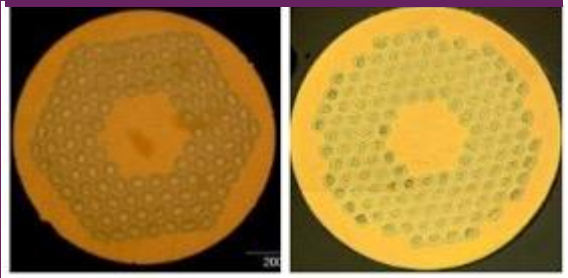
And there are many more examples
Medical imaging, cancer therapy, material science, cultural heritage, aerospace, automotive, environment, health & safety, industrial processes.

Superconducting magnets

Superconducting magnet expertise includes:

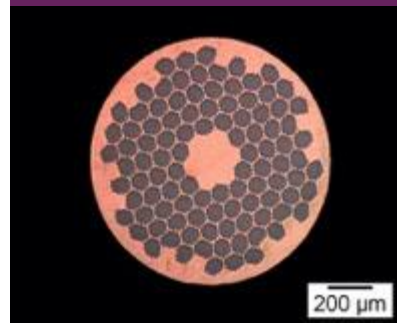
- Low Temperature Superconductor
- High Temperature Superconductor
- HTS cables for electrical transmission
- Novel HTS cables for model magnets
- Microstructural analysis (SEM, EDX)
- Powering and protection
- Cryostats
- R&D on new materials

HL-LHC Nb_3Sn RRP wire
Jc(4.2 K, 12 T) ≥ 2450 A/mm^2



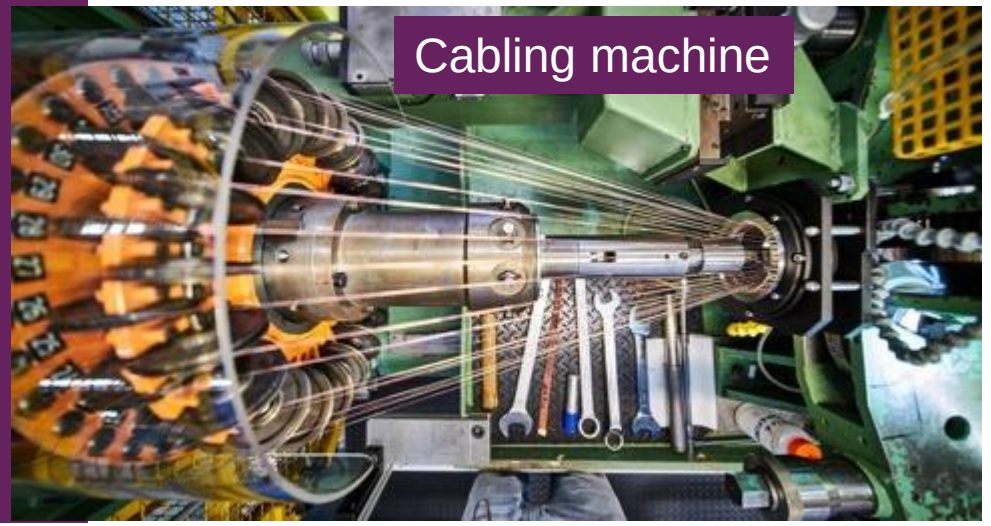
REBCO Tape

Nb-Ti LHC Type1



Rutherford cables

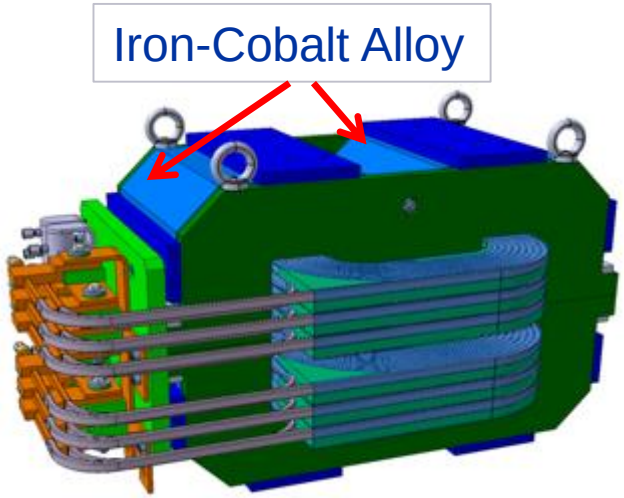
Cabling machine

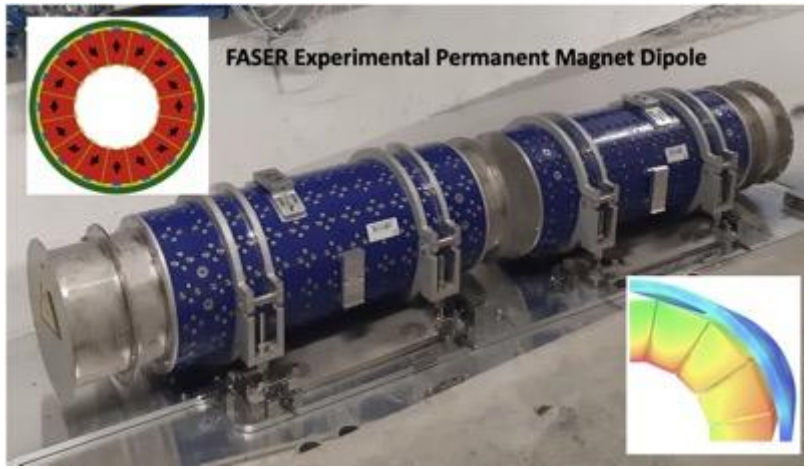


Normal conducting magnets

Apart from LHC, all other accelerators at CERN use classic, resistive electro-magnets and also permanent magnets:

- High permeability iron
- Radiation hard insulation
- Epoxy vacuum impregnation
- Laminated/solid iron cores
- Laminated curved magnets
- Radioactive waste management
- Magnetic measurements



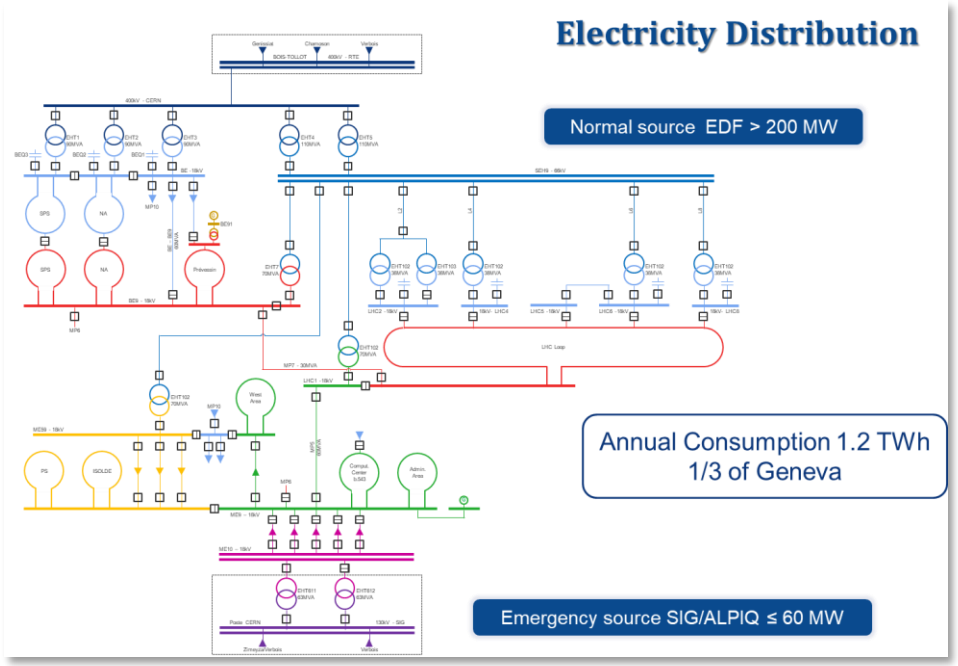


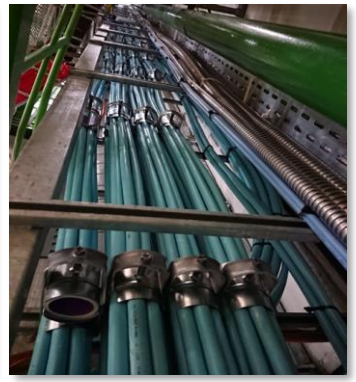
Energy management and distribution

New 400/66kV BE2 sub-station

New 18kV ME9 sub-station

Electrical infrastructure in injectors consolidated during LS2

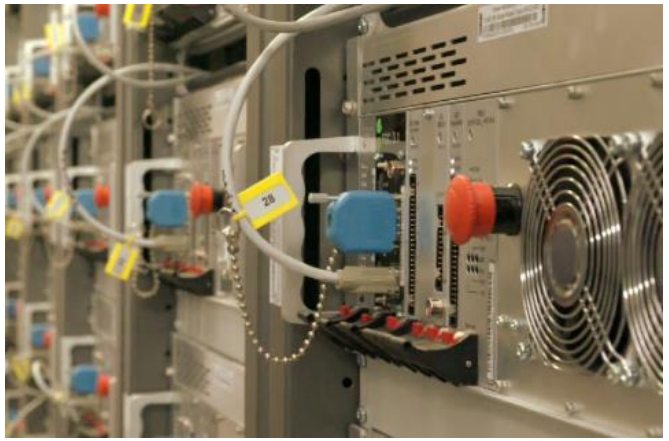


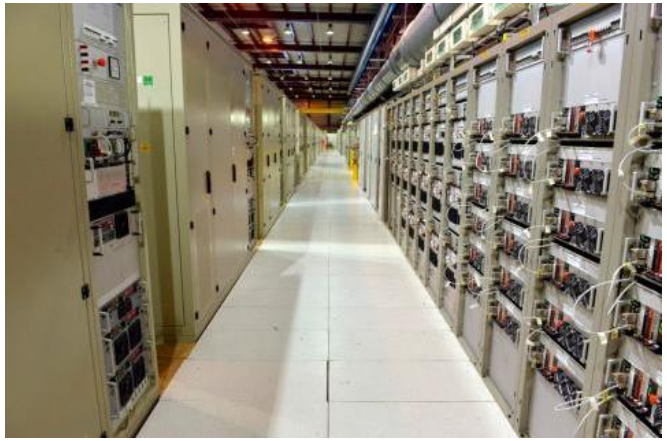


Electrical Power Convertors

The EPC Group is in charge of the electrical power converters for all accelerators, transfer lines, experimental areas and tests facilities at CERN:

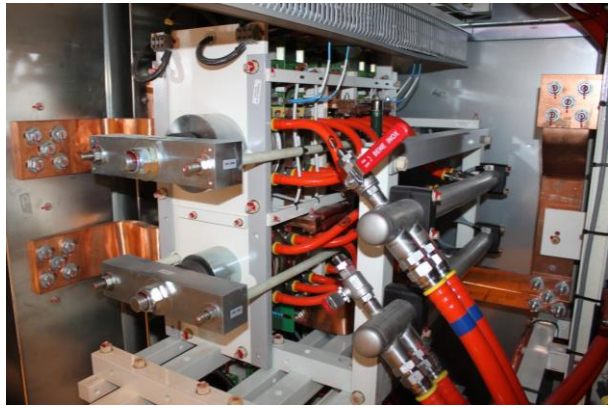
- Solid-state modulators for RF klystrons;
- High-voltage power converters for RF amplifiers and particle sources;
- Power converters from 100W to 100MW for DC, cycling or pulsed magnets;
- Static VAR compensators and harmonic filters.

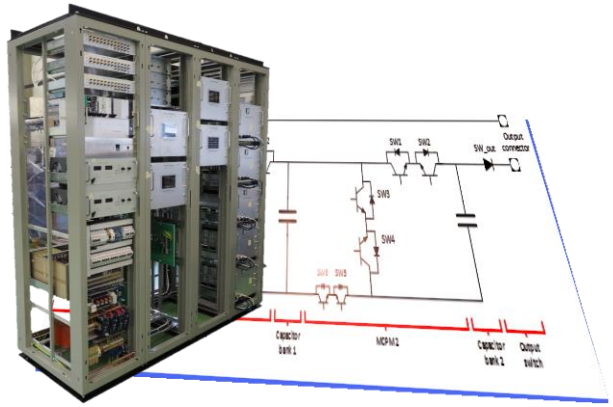


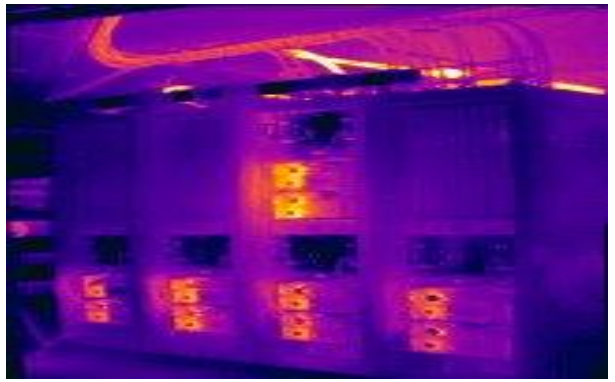


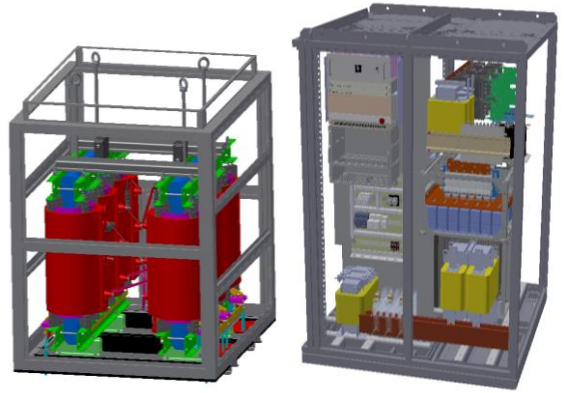
Electrical Power Convertors

- Prototype converters design for CERN specific accelerator needs including consolidation.
- Procure power converters based on functional specification or build-to-print files through CERN member states companies.
- Test, install, operate and maintain CERN power converters with the highest availability.
- Study new technologies and topologies for CERN future machines.









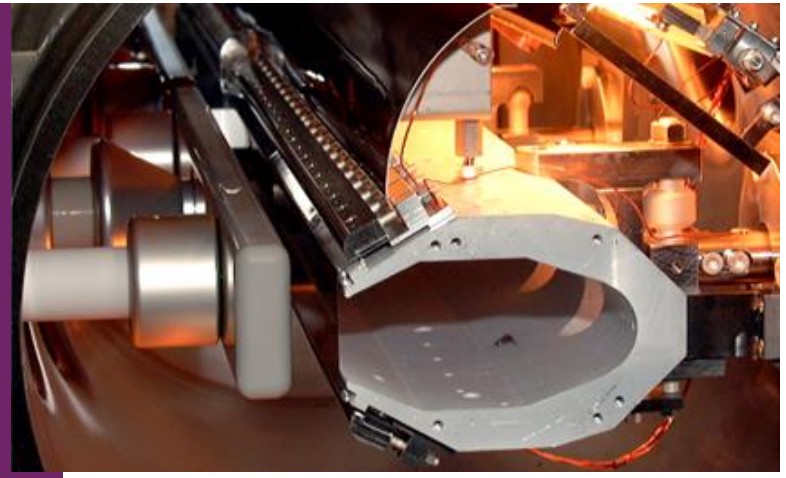
Electrical Power Convertors

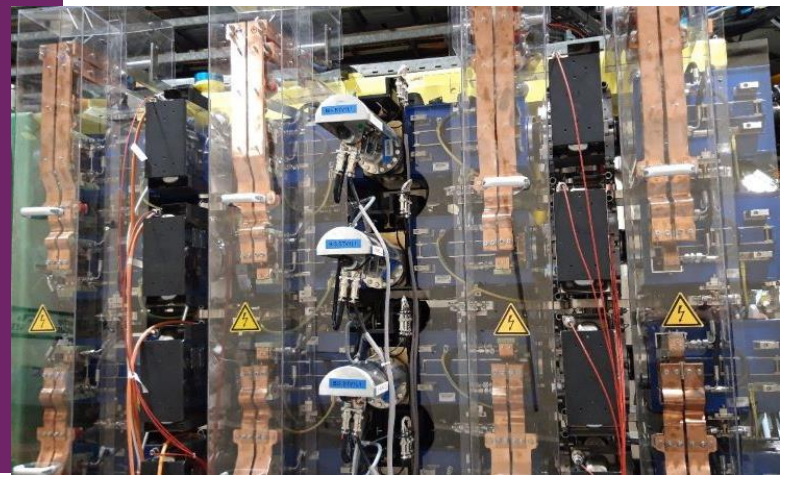
- Converters with efficient energy management including magnet energy recovery.
- High-precision and fast-pulsed power converters (ms range).
- Advanced regulation & real time Control.
- Converter mass production.

Accelerator beam transfer kickers and septa

The ABT group is in charge of injection and extraction related equipment and beam-transfer systems:

- Fast pulsed kicker systems;
- Electric field deflectors;
- Magnetic septa;
- Protection devices;
- Injection stripper system;
- Equipment control systems and software.

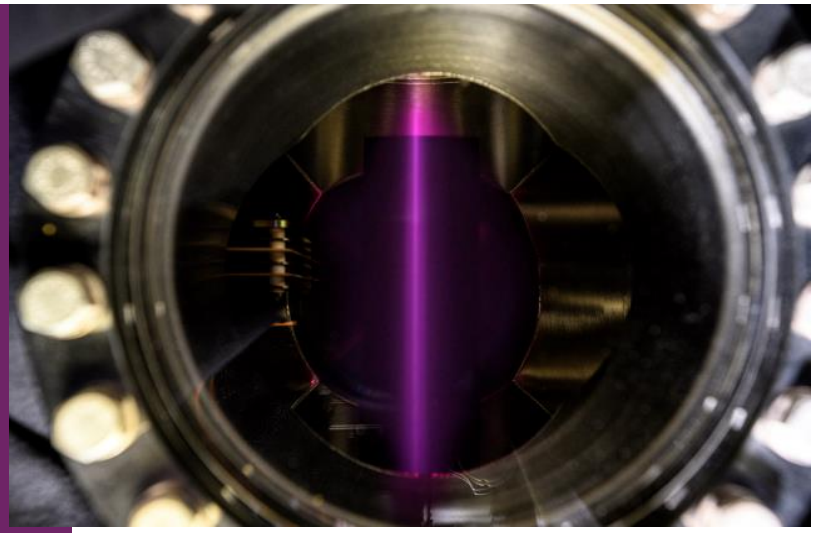


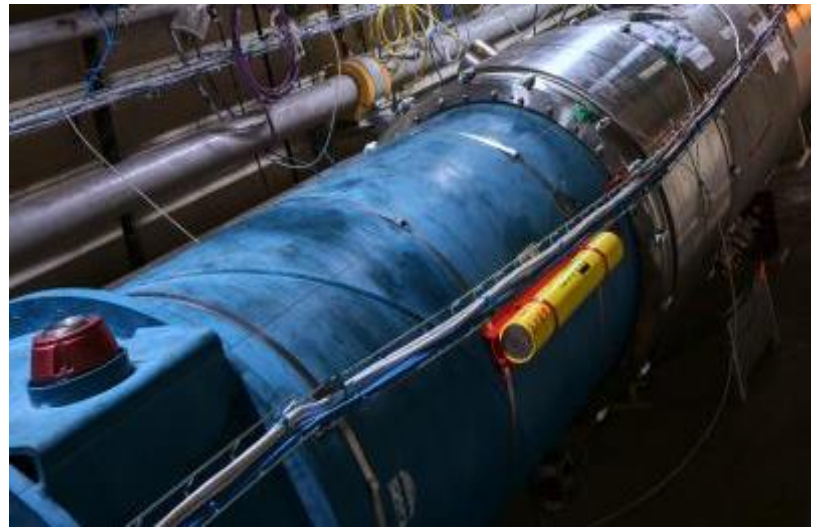


Accelerator beam instrumentation

The BI Group is responsible for > 10,000 instruments that allow observation of the particle beams and the measurement of related parameters:

- Beam losses;
- Beam position;
- Intensity and Tune;
- Beam profiles;
- Equipment control systems and software.

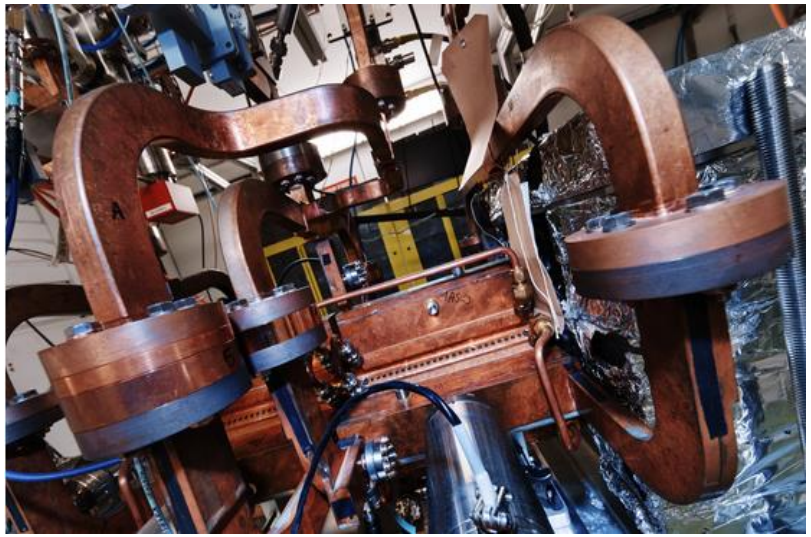




Radio Frequency accelerating systems

The RF group designs, constructs and operates the radiofrequency accelerating systems across CERN. Main themes are:

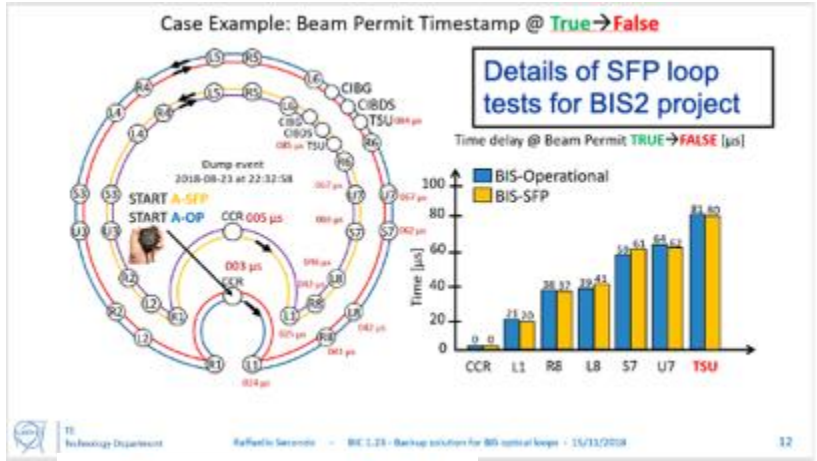
- Superconducting and normal conducting RF cavities
- Amplifiers and powering
- Low level control and software
- Feedback systems
- R&D to replace tubes with solid state amplifiers
- R&D into high gradient accelerating structures

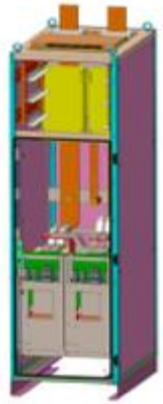


FCC powering studies and R&D

Main challenges:

- Development of the next generation of fast beam and powering interlock systems
- Reliability and availability of >10’000 power supplies
- Development of new generation of Quench Detection Systems for superconducting Nb_3Sn magnets and MgB_2 power transmission lines
- Development of novel CLIQ magnet protection technique
- Development of ultrafast IGBT and vacuum interrupters for currents up to 30 kA
- Study of beam induced damage to components

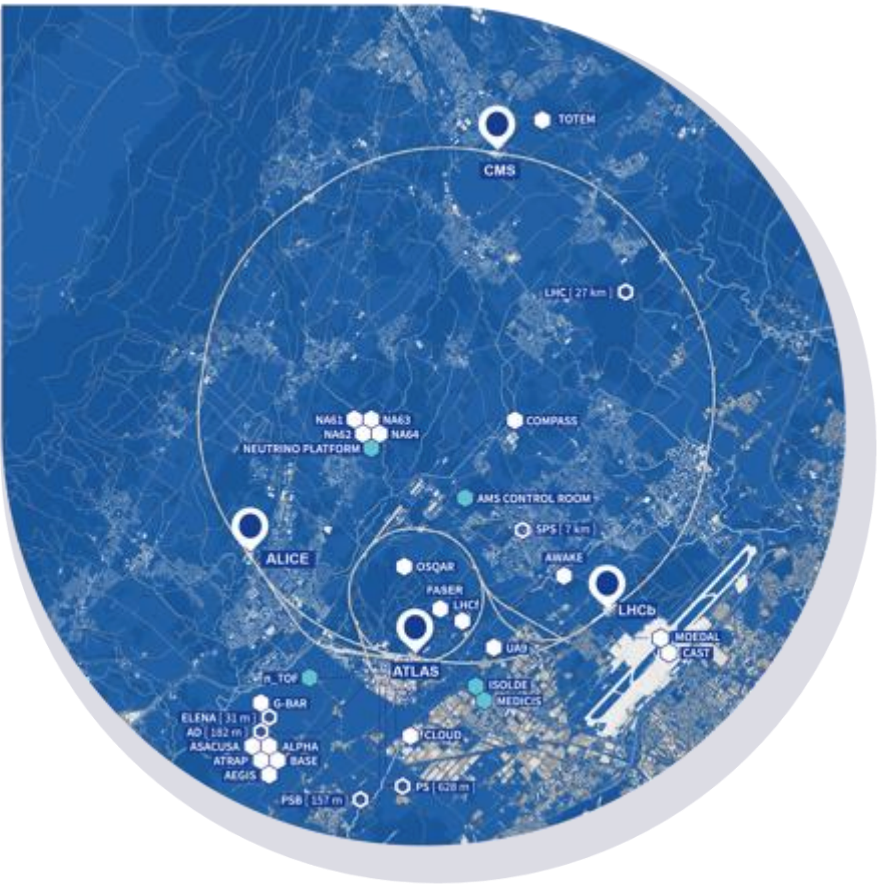




2000 A system

600 A system

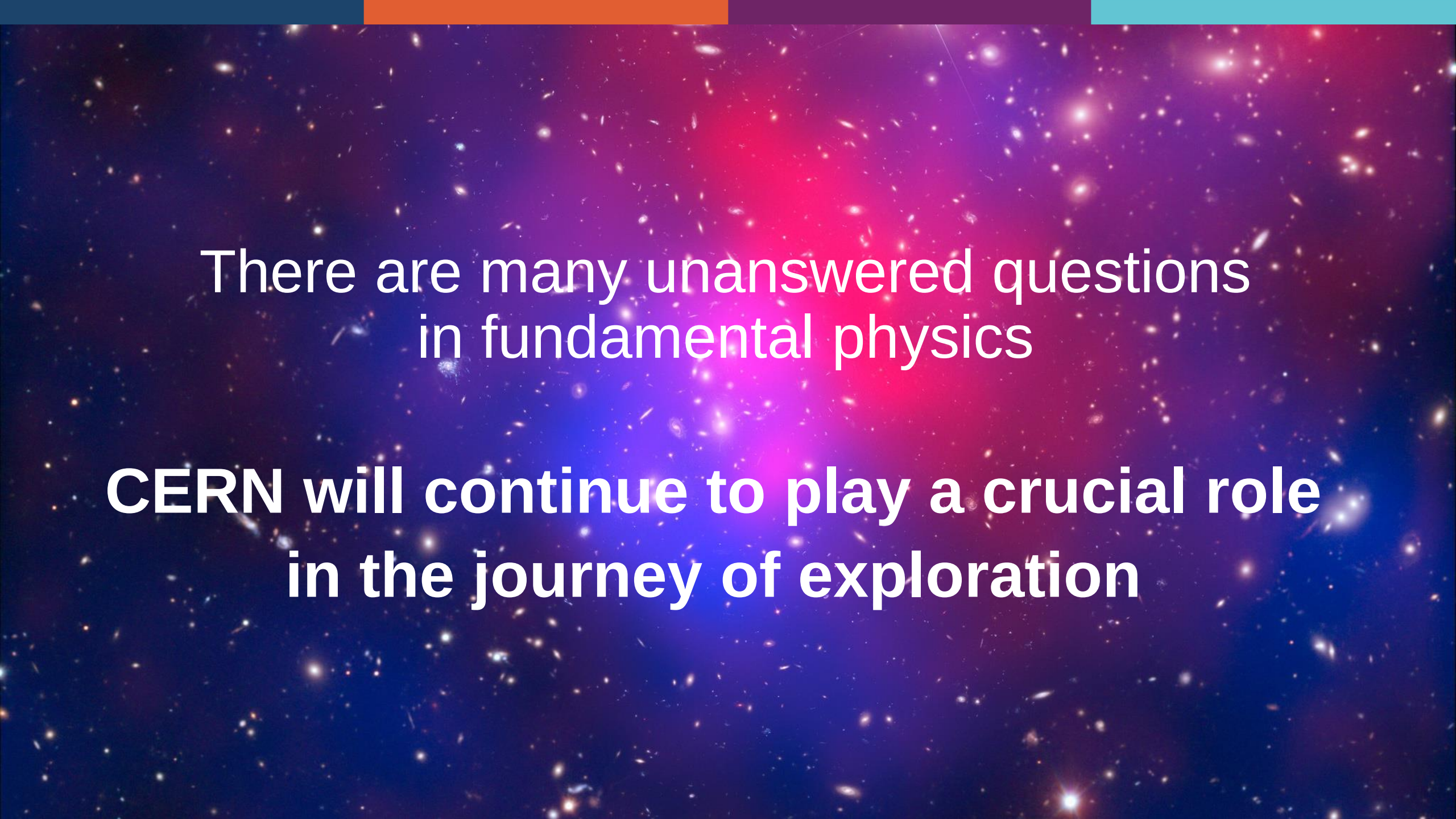
Impact on society in many ways



- Scientific knowledge: our primary mission
- Values: collaboration across borders, inclusiveness, openness
- Scientific training: contribution to tomorrow's workforce (society lacks STEM graduates)
- Scientific education of the public: to increase trust in and support to science
- **Development of advanced technologies with industry**: broad range, many potential applications

And also, Sustainability and environment

- Minimise Laboratory's impact on environment
- Energy saving and reuse


There are many unanswered questions
in fundamental physics
CERN will continue to play a crucial role
in the journey of exploration