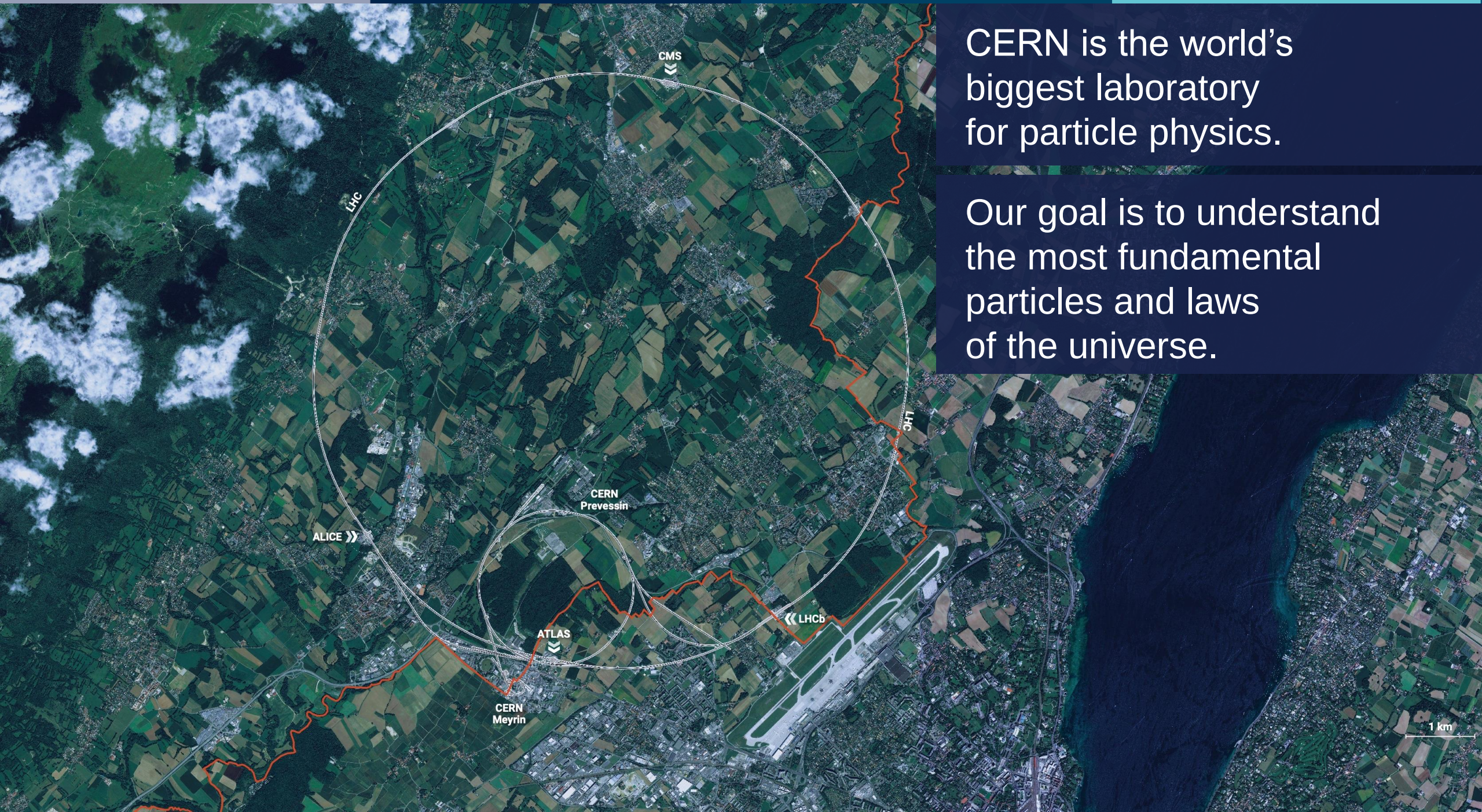
WELCOME TO CERN

Manfred Krammer
Department Head Experimental Physics, CERN



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

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

2024: celebrating 7 decades of global collaboration, scientific achievements and technology innovation

Peaceful scientific collaboration: a vision takes shape

1945: Europe is in ruins after World War II

1946: French proposal to the United Nations

1949: European Cultural Conference, Lausanne

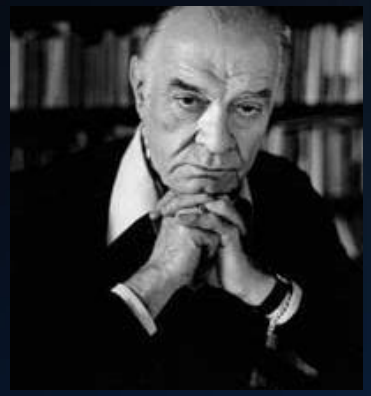
Common vision of politicians and scientists

Renew peaceful collaboration following the destruction of war

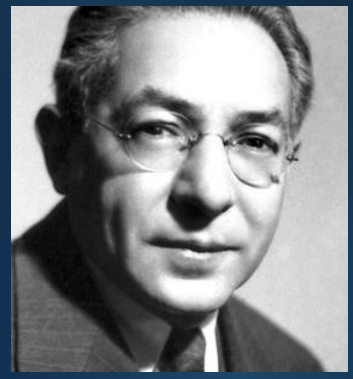
Focus on fundamental scientific research at a scale beyond the capacity of any single nation

Restore scientific excellence and reverse and prevent brain drain

1940s: first proposals



Louis de Broglie proposed: *"the creation of a laboratory or institution where it would be possible to do scientific work, but somehow beyond the framework of the different participating states [Endowed with more resources than national facilities, such a laboratory could] undertake tasks, which, by virtue of their size and cost, were beyond the scope of individual countries".*



US Nobel laureate **Isidor Rabi** tables a resolution authorising UNESCO to:

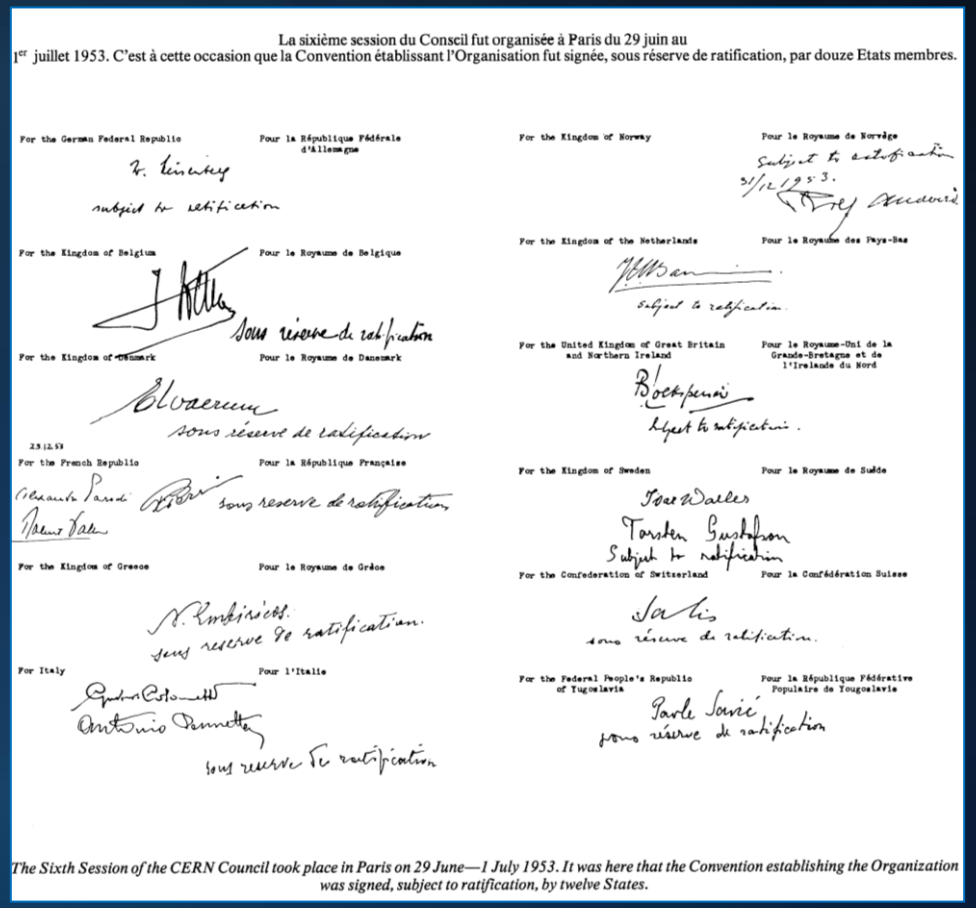
"assist and encourage the formation of regional research laboratories in order to increase international scientific collaboration…"

1951: UNESCO Resolution

- At a meeting of UNESCO in Paris in December 1951, the first resolution concerning the establishment of a European Council for Nuclear Research was adopted.
- Two months later, 11 countries signed an agreement establishing the provisional Council – **the acronym CERN was born**.

1954: CERN is born

- The CERN Convention, established in July 1953, was ratified by 12 founding Member States: Belgium, Denmark, France, the Federal Republic of Germany, Greece, Italy, the Netherlands, Norway, Sweden, Switzerland, the UK, and Yugoslavia.
- On 29 September 1954, the European Organization for Nuclear Research officially came into being.



La sixième session du Conseil fut organisée à Paris du 29 juin au 1er juillet 1953. C'est à cette occasion que la Convention établissant l'Organisation fut signée, sous réserve de ratification, par douze Etats membres.

The Sixth Session of the CERN Council took place in Paris on 29 June—1 July 1953. It was here that the Convention establishing the Organization was signed, subject to ratification, by twelve States.

From founders' vision to today's global collaboration

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

CERN's annual budget is about 1200 MCHF

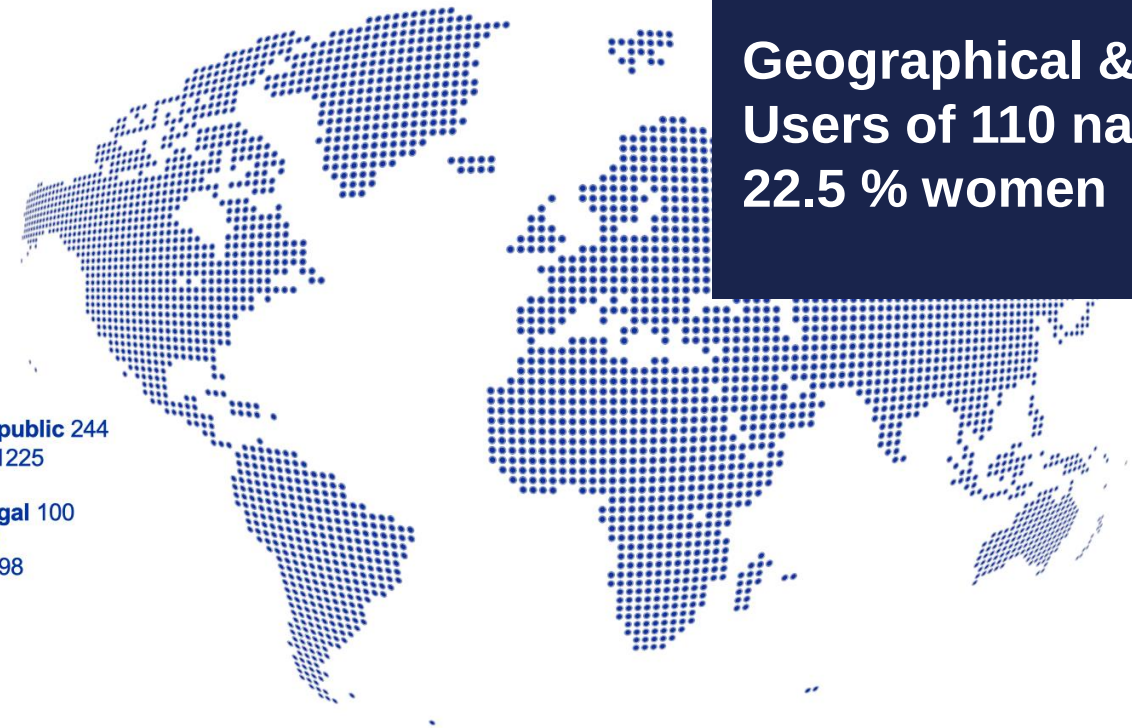
As of 31 December 2023
Employees:
2666 staff, **1002** graduates
Associates:
12 370 users, **1513** others

Around 50 Cooperation Agreements with non-Member States and Territories

Albania – Algeria – Argentina – Armenia – Australia – Azerbaijan – Bangladesh – Belarus – 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

A laboratory for people around the world

Distribution of all CERN Users by the country of their home institutes



Geographical & cultural diversity
Users of 110 nationalities
22.5 % 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 504

Brazil 122 – **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 1149

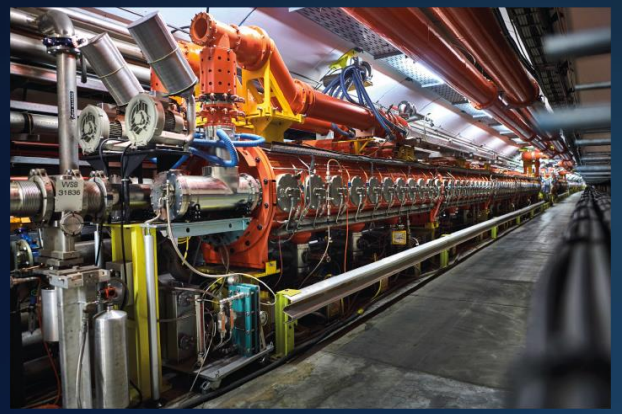
Algeria 2 – **Argentina** 13 – **Armenia** 8 – **Australia** 21 – **Azerbaijan** 2 – **Bahrain** 4 – **Belarus** 18 – **Brazil** 122
Canada 199 – **Chile** 34 – **Colombia** 21 – **Costa Rica** 2 – **Cuba** 3 – **Ecuador** 4 – **Egypt** 20 – **Georgia** 32
Hong Kong 15 – **Iceland** 3 – **Indonesia** 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

1957: first accelerator

The **Synchrocyclotron**

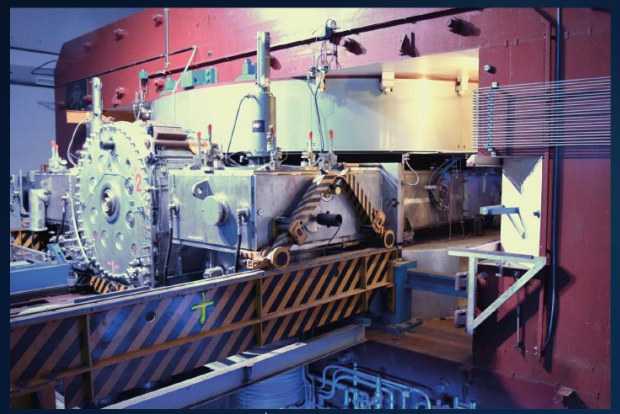
PS – 28 GeV

SPS – 630 GeV



LHC – 13 600 GeV

SC 0.6 GeV



ISR - 31.5 GeV

LEP - 209 GeV

1957 1959 1971 1976 1989 2009

1958: CERN's first discovery

1957: the **Synchrocyclotron is** CERN's first accelerator to begin operation (600 MeV proton beam)

Discovery of "rare pion decays" 1958-1962

$$R = \frac{\Gamma(\pi \to e\upsilon_e)}{\Gamma(\pi \to \mu\upsilon_\mu)} = (1.22 \pm 0.30) \times 10^{-4}$$

G. Fidecaro et al.

Crucial verification of a universal "weak" force with a Vector - Axial coupling

A turning point for the emerging electroweak theory

1973: the discovery of neutral currents

1959: the **Proton Synchrotron** (PS) begins operation
proton beam of 24 GeV (briefly the highest-energy accelerator)

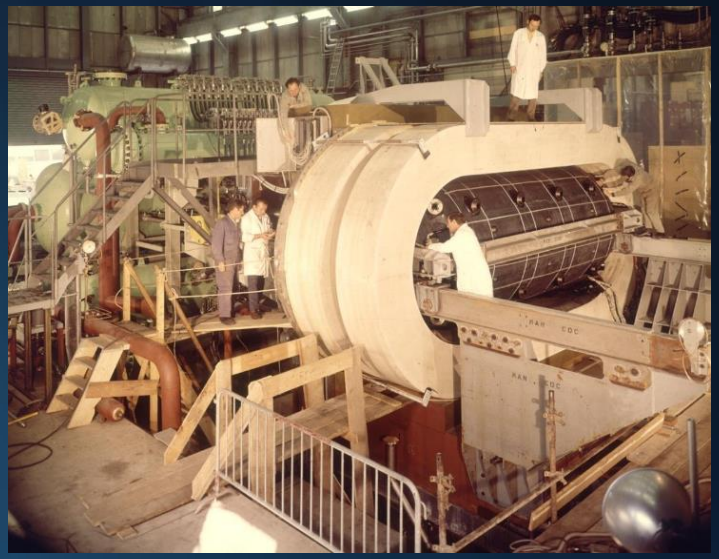
With the PS CERN entered the “high-energy neutrino beam era”

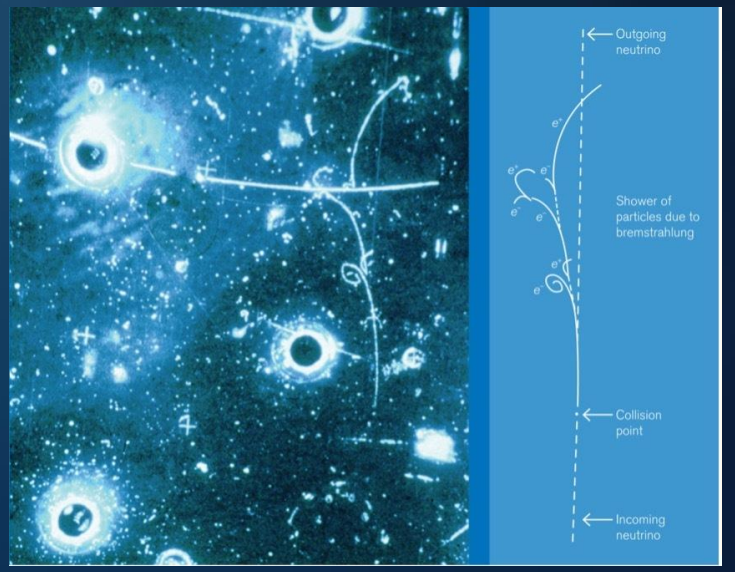
Gargamelle (4.8 m x 2 m, 1000 tonnes, 12 m^3 heavy-liquid freon)

Crucial evidence for the existence of quarks, essential
contributions to the confirmation of their fractional charge

Discovery of neutral currents

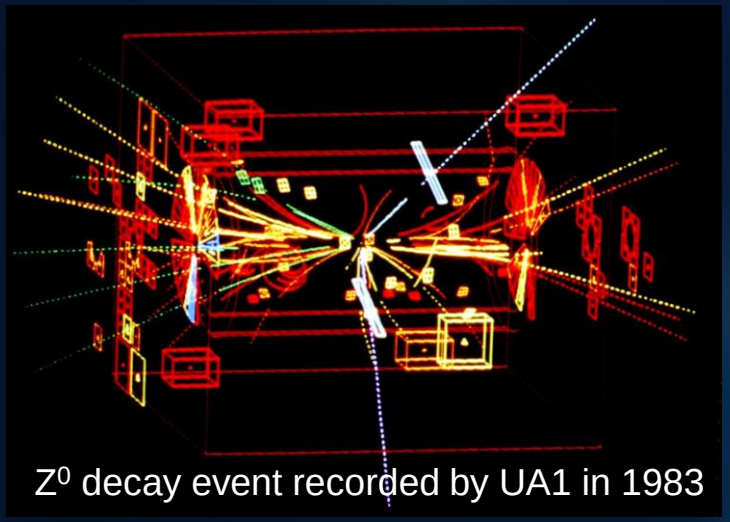
⇨ establishes the electroweak theory





1983: discovery of the W and Z

- UA1 and UA2 presented the first results (in two separate seminars) at CERN on 20 and 21 **January 1983**
- 6 candidates for both experiments with high energy electrons and high missing energy (i.e. neutrinos).
- **The quest for the W boson was over!**



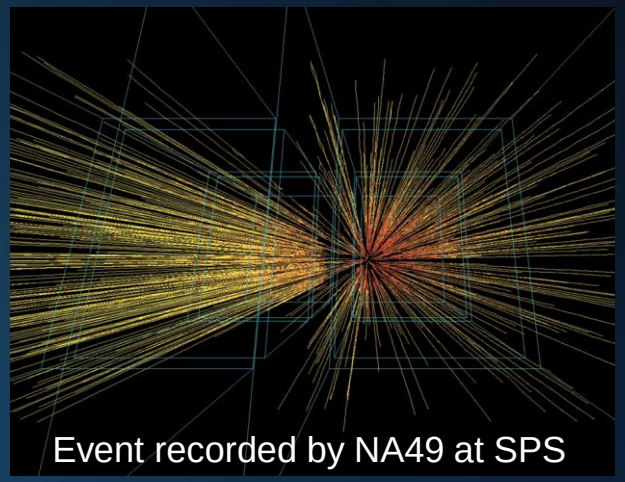
Z^0 decay event recorded by UA1 in 1983

In **July 1983**, **clear evidence of the Z boson** was also presented.

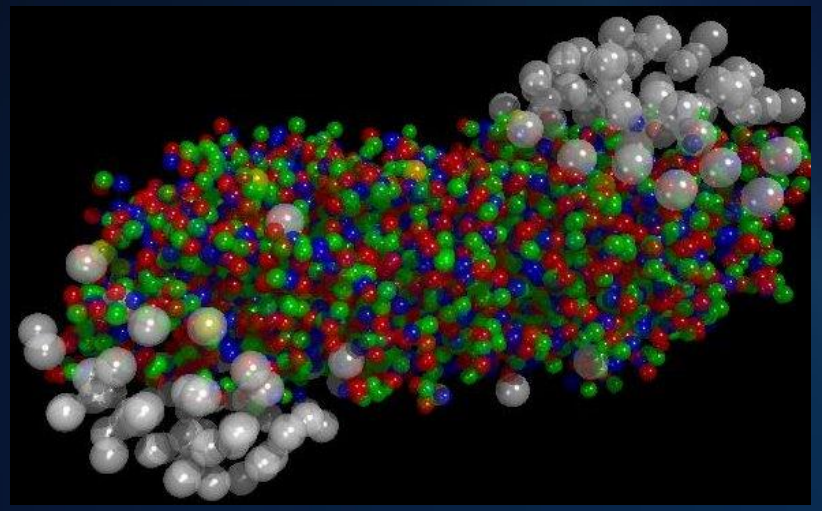
Carlo Rubbia and Simon van der Meer were awarded the 1984 Nobel prize

CERN, February 2000: first evidence of a new state of matter, the quark-gluon plasma

- Combined data from the 7 experiments on CERN's HI programme
- Proves an important prediction of the QCD theory. An important step forward in the understanding of the early evolution of the Universe.

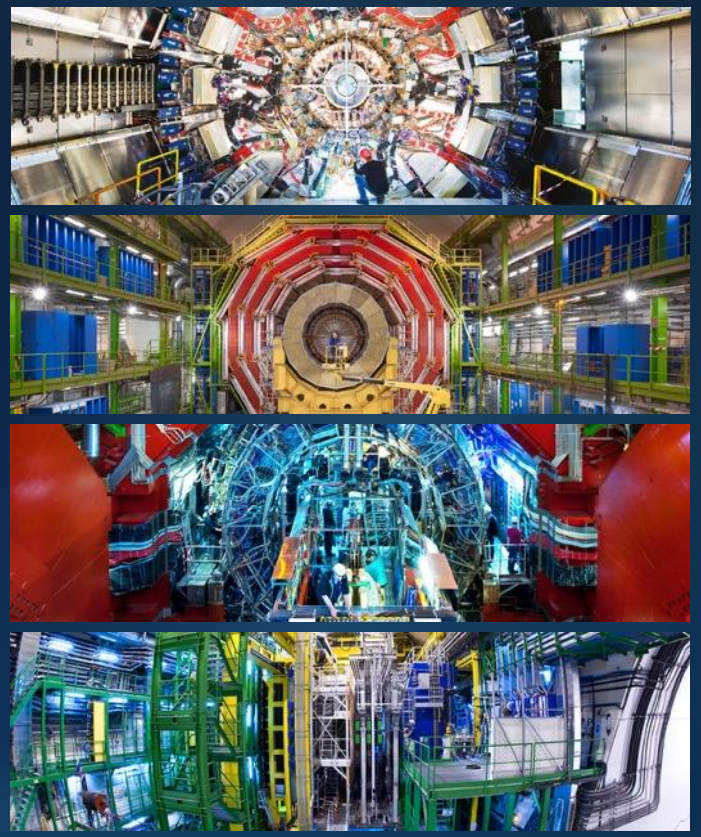


Event recorded by NA49 at SPS



Luciano Maiani (CERN DG): "… We now have evidence of a new state of matter where quarks and gluons are not confined. … There is still an entirely new territory to be explored concerning the physical properties of quark-gluon matter. The challenge now passes to RHIC at BNL and later to the LHC."

The Large Hadron Collider era



ATLAS

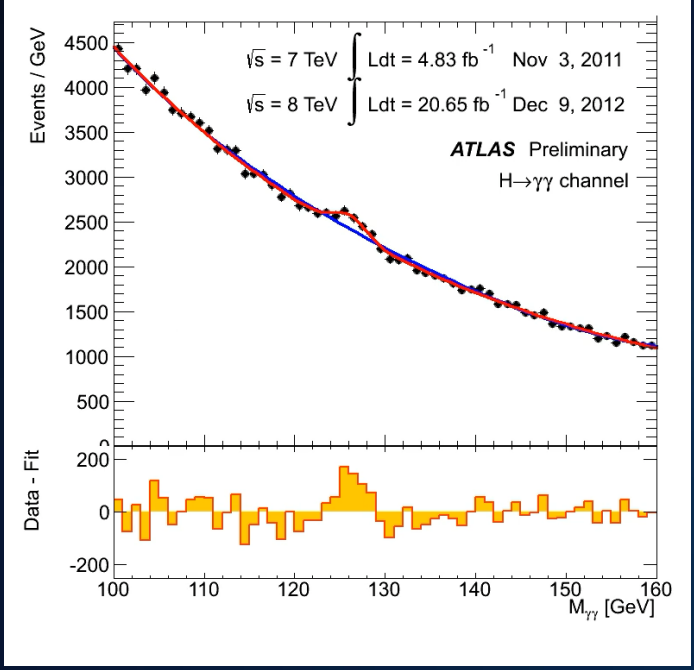
CMS

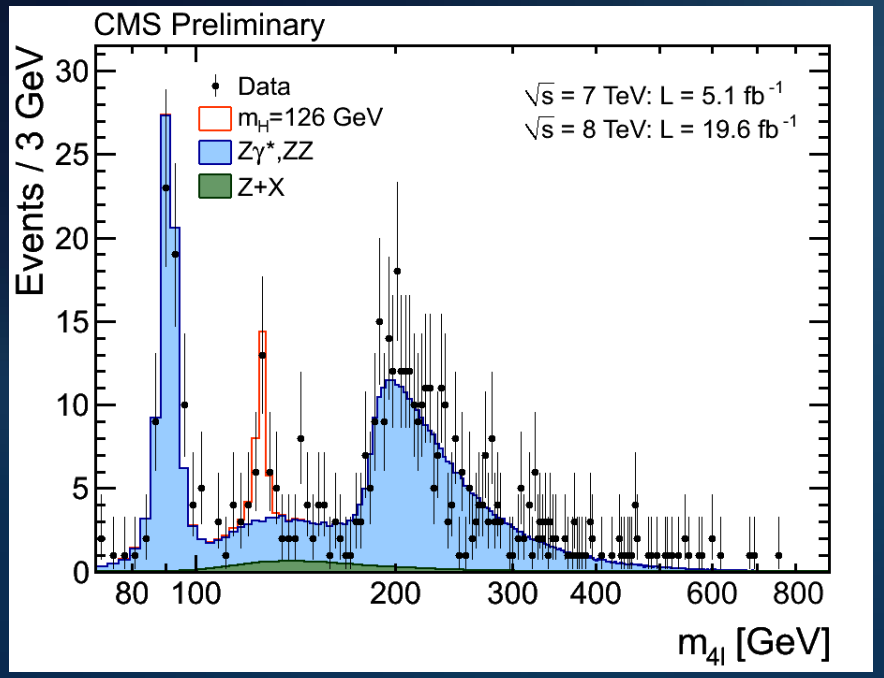
ALICE

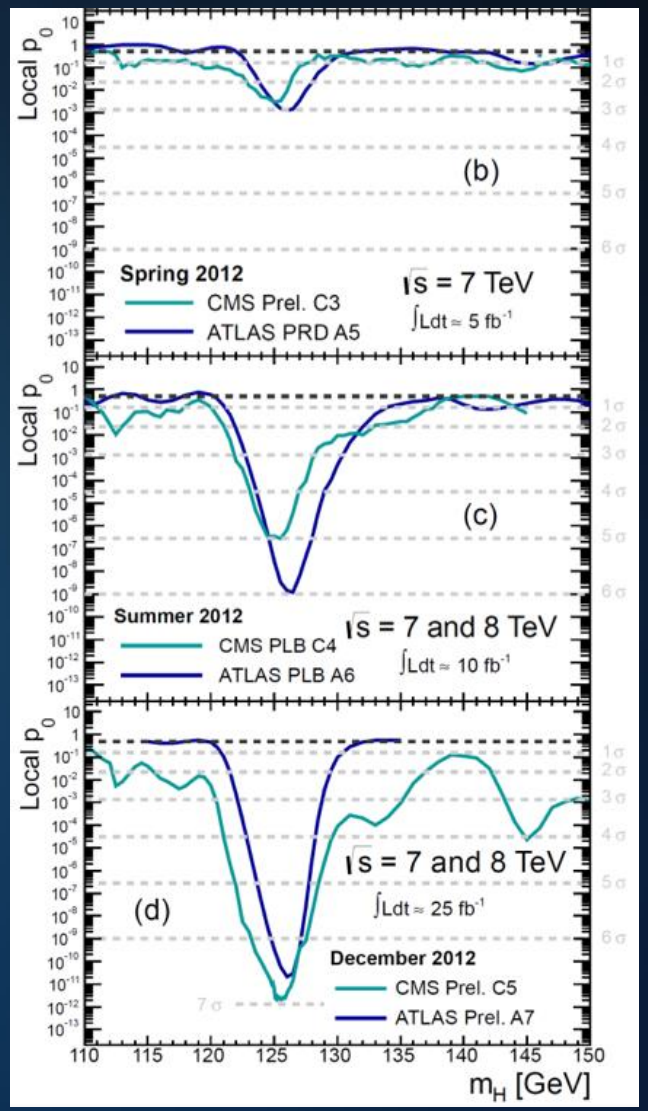
LHCb

Higgs discovery

- **End of 2011: tantalizing hint, the trail begins**
- **Summer 2012: discovery! 5σ from both experiments**
- **End of 2012: confirmation! Measurement era begins**







Higgs discovery … and the SM triumph

July 4th 2012 announcement

F. Gianotti (ATLAS) and J. Incandela (CMS)

F. Englert and P. Higgs

2013 Nobel Prize

Preparing the Future

LHC -> HL-LHC 2030 – 2041

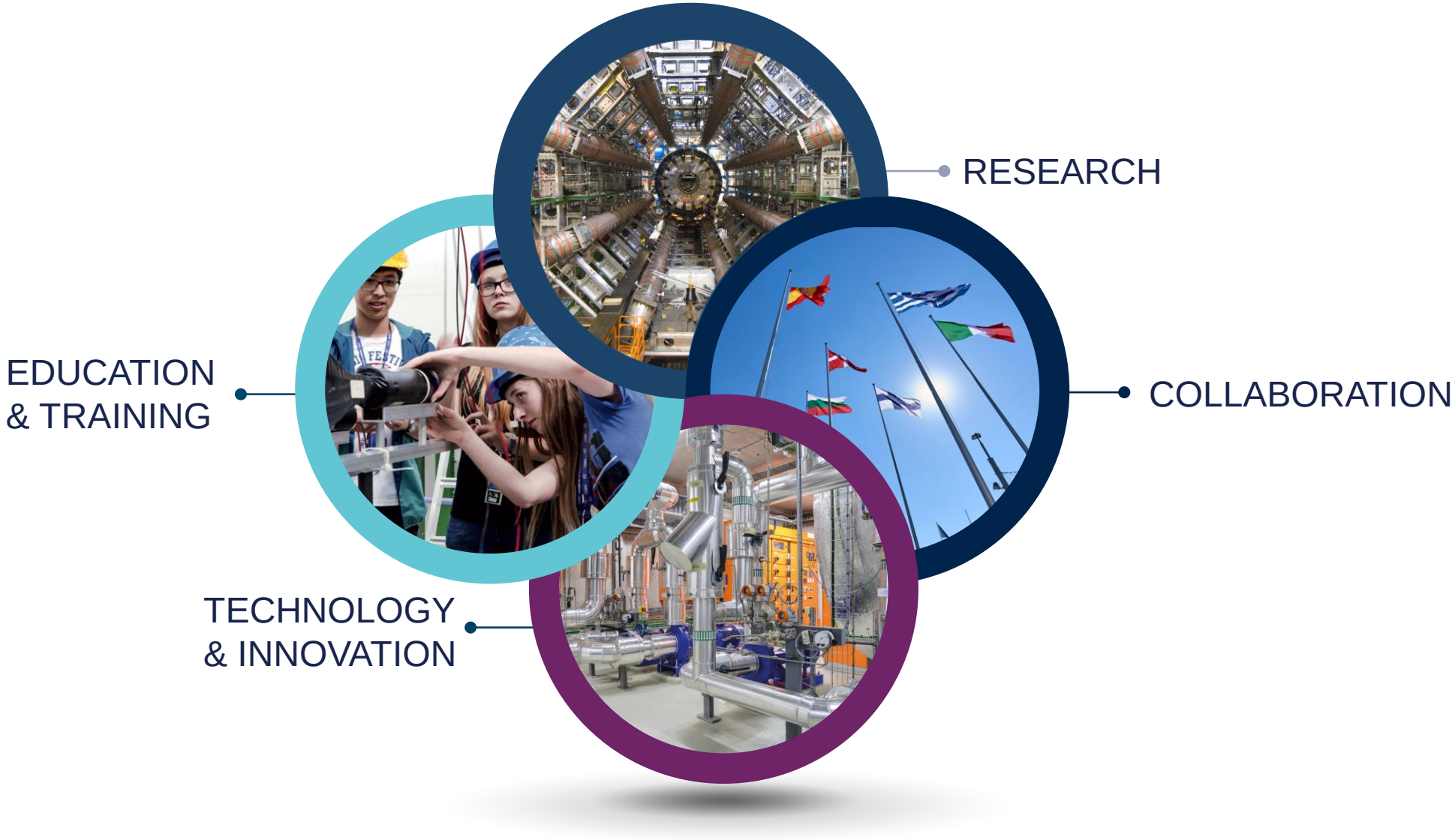
Upgrade of the accelerator and the experiments: higher intensity, higher precision

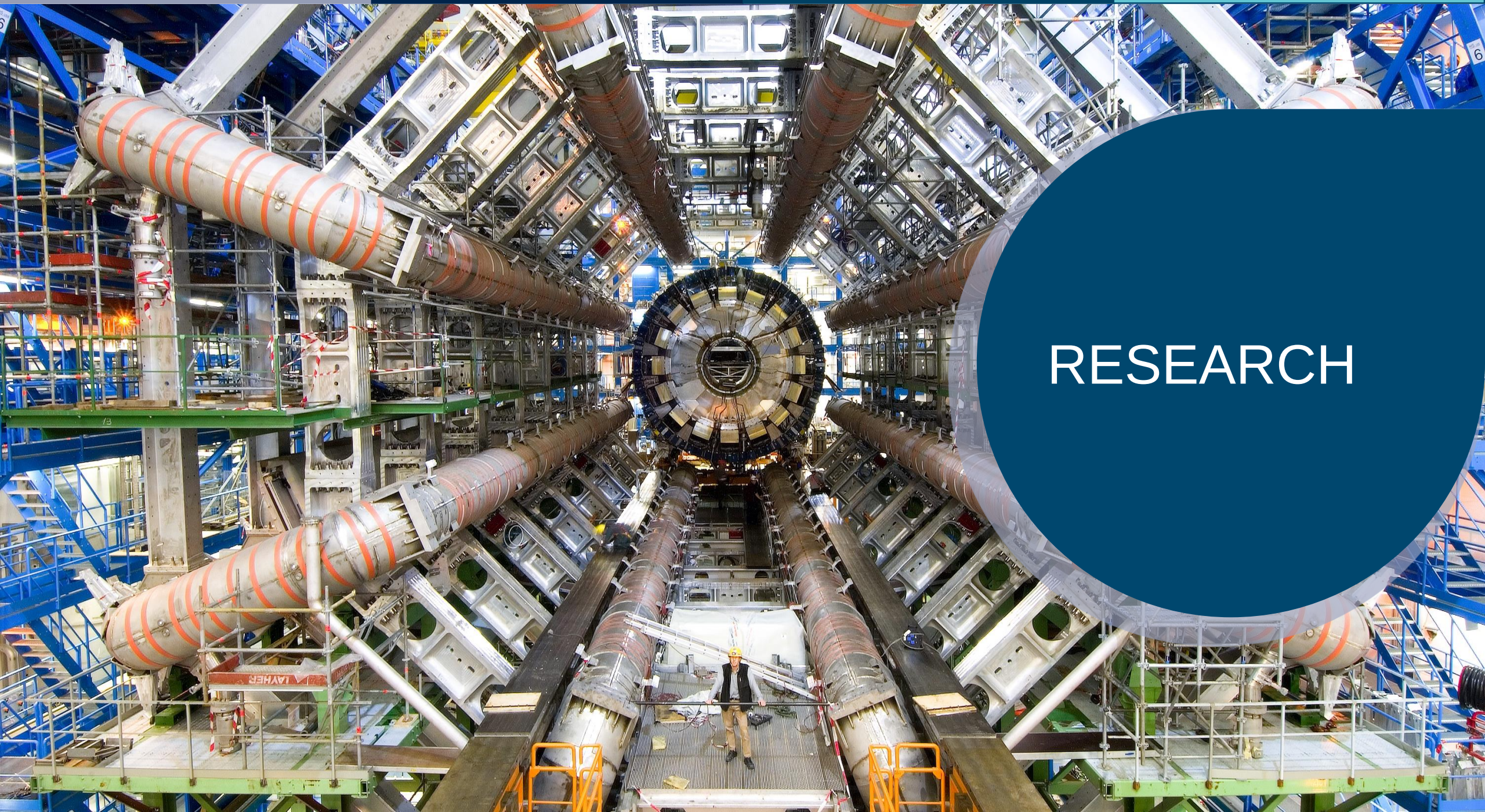
- Measure all properties of the Higgs boson up to the ultimate precision
- Searches for physics beyond the Standard Model
- Search for Dark Matter
- Observation of very rare processes
- Characterization of the quark-gluon plasma properties

FCC – Future Circular Collider

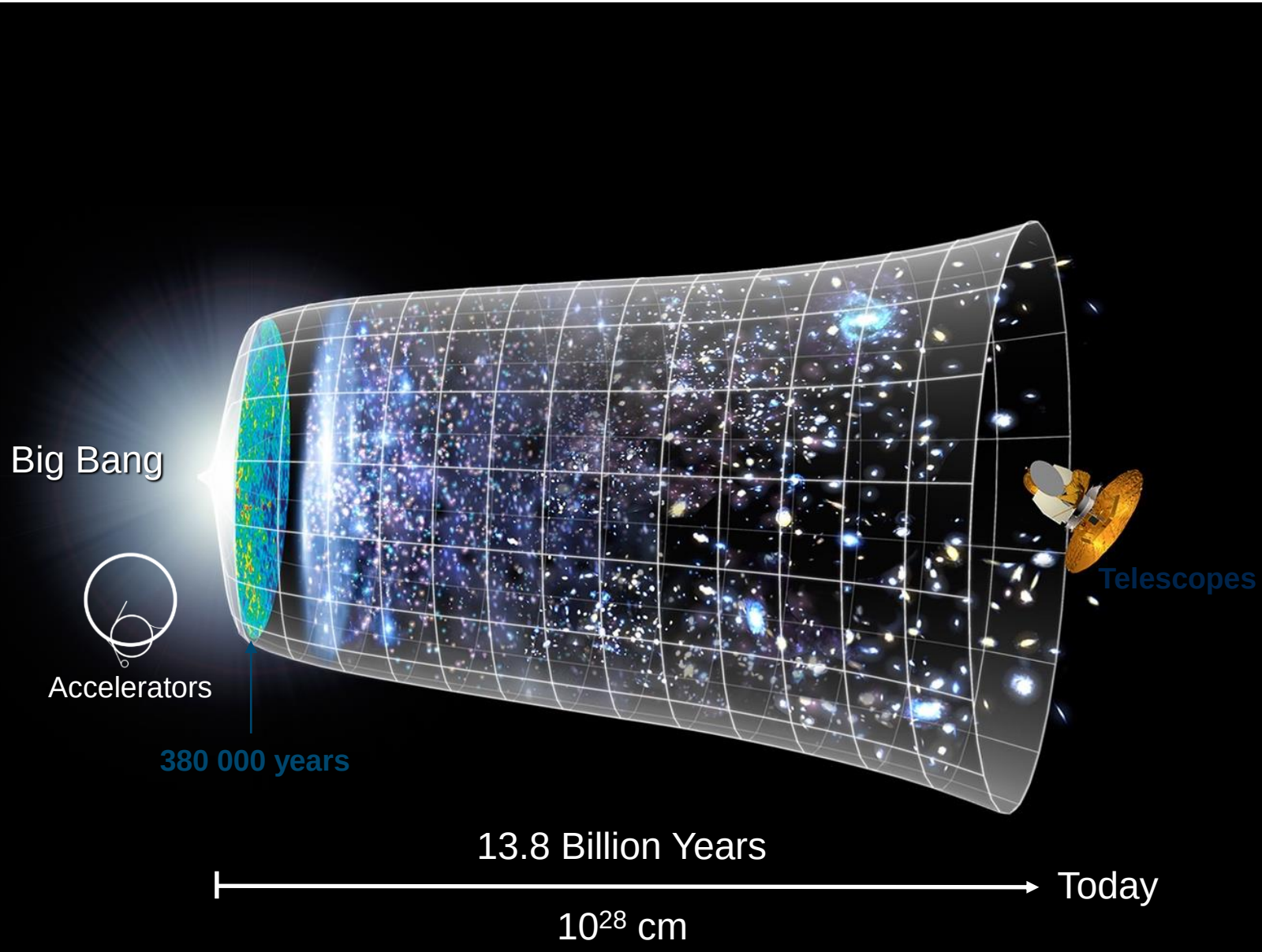
Feasibility study for a collider facility for the next decades

Four pillars underpin CERN's mission





RESEARCH

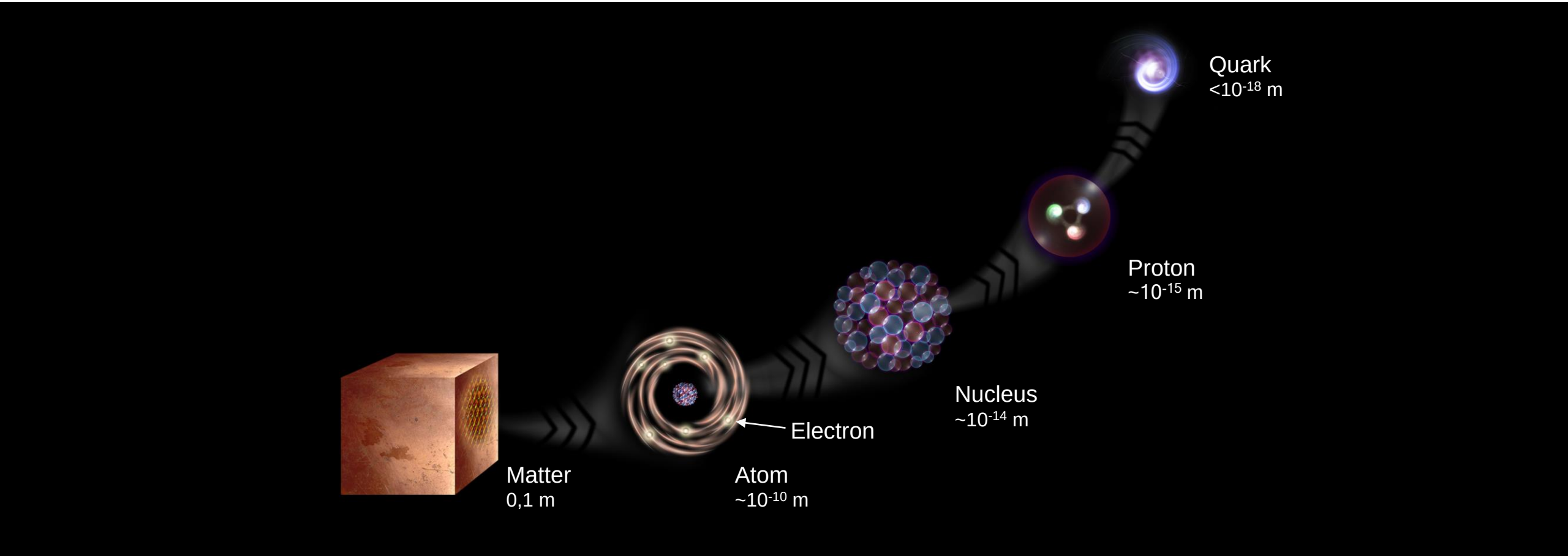


How did the universe begin?

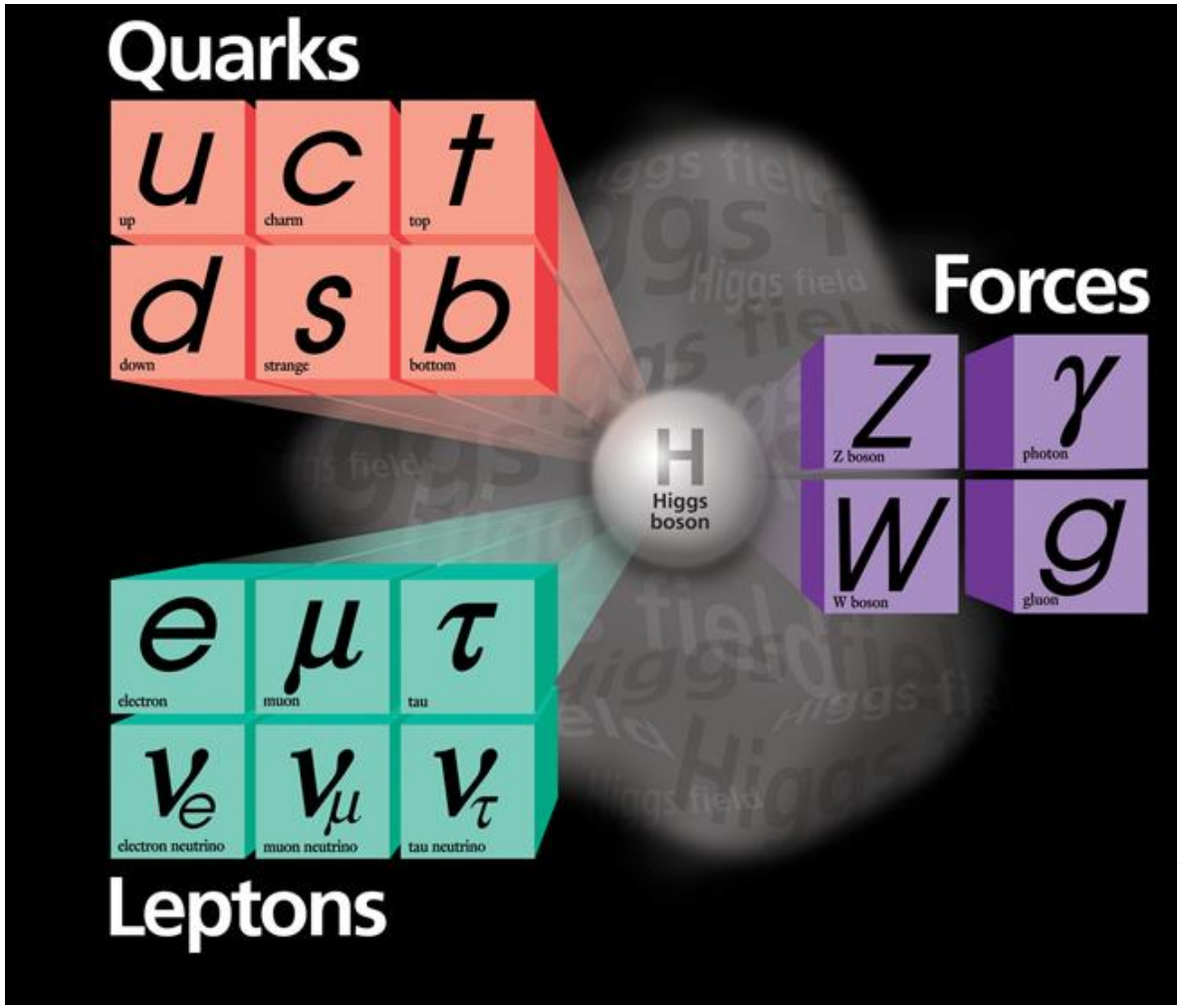
We reproduce the conditions a fraction of a second after the Big Bang, to gain insight into the structure and evolution of the universe.

What is the universe made of?

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



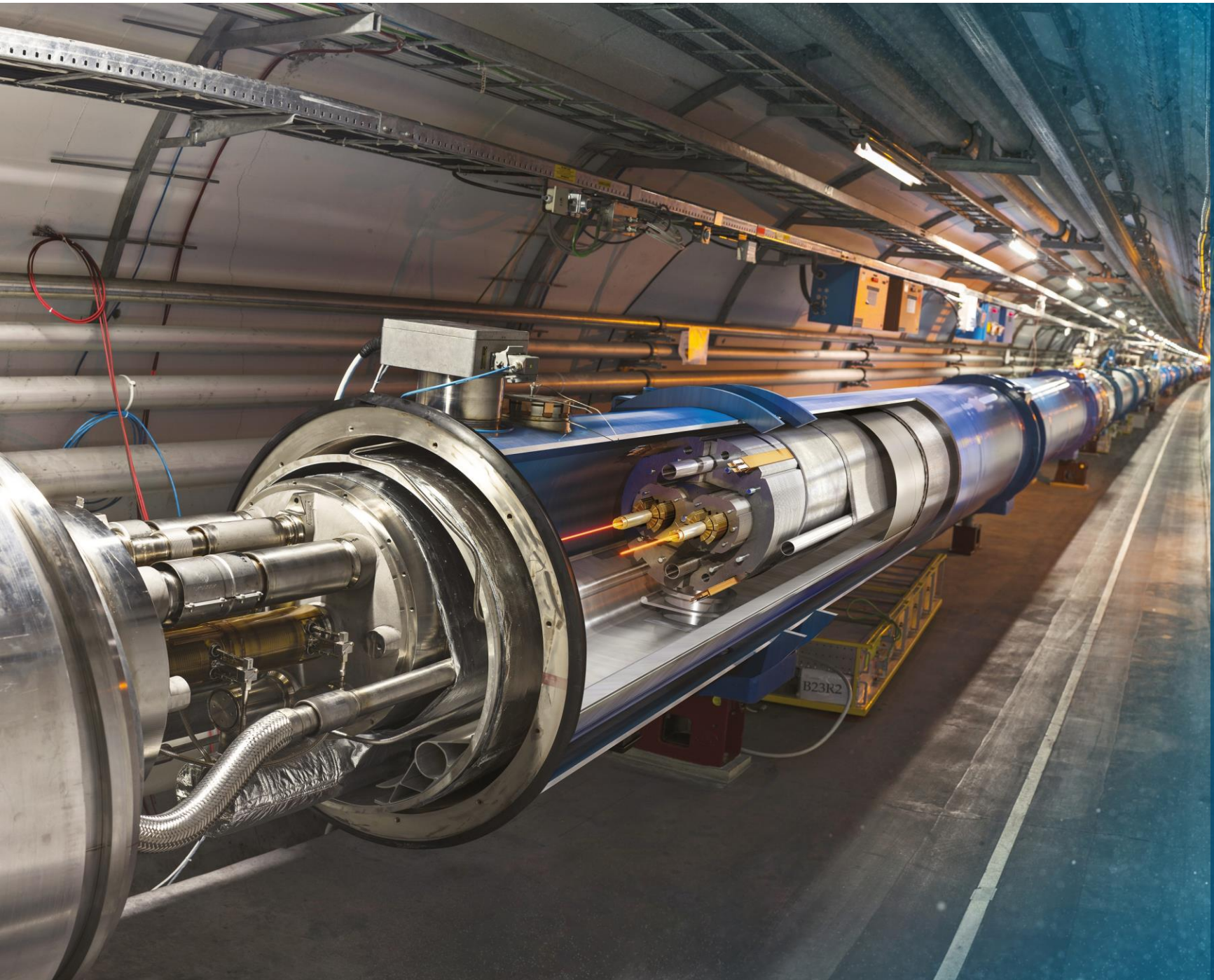
The Standard Model of Particle Physics



Fermions (spin ½) quarks and leptons: the building blocks of matter

Bosons (integer spin) carry the forces: electromagnetic (Photon), weak force (W, Z) and strong force (Gluons)

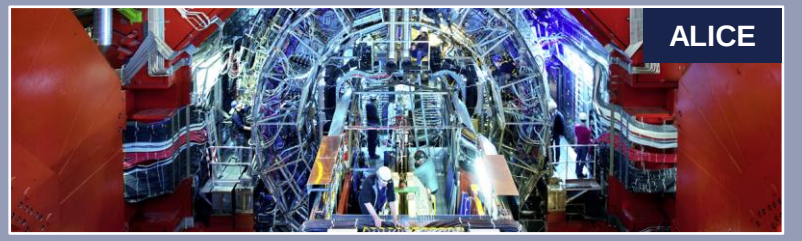
Higgs Boson (spin 0), gives mass to particles

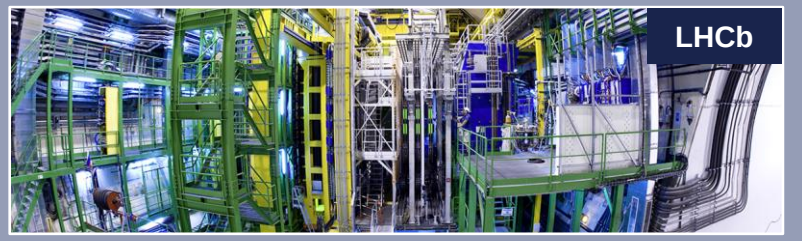


Large Hadron Collider (LHC)

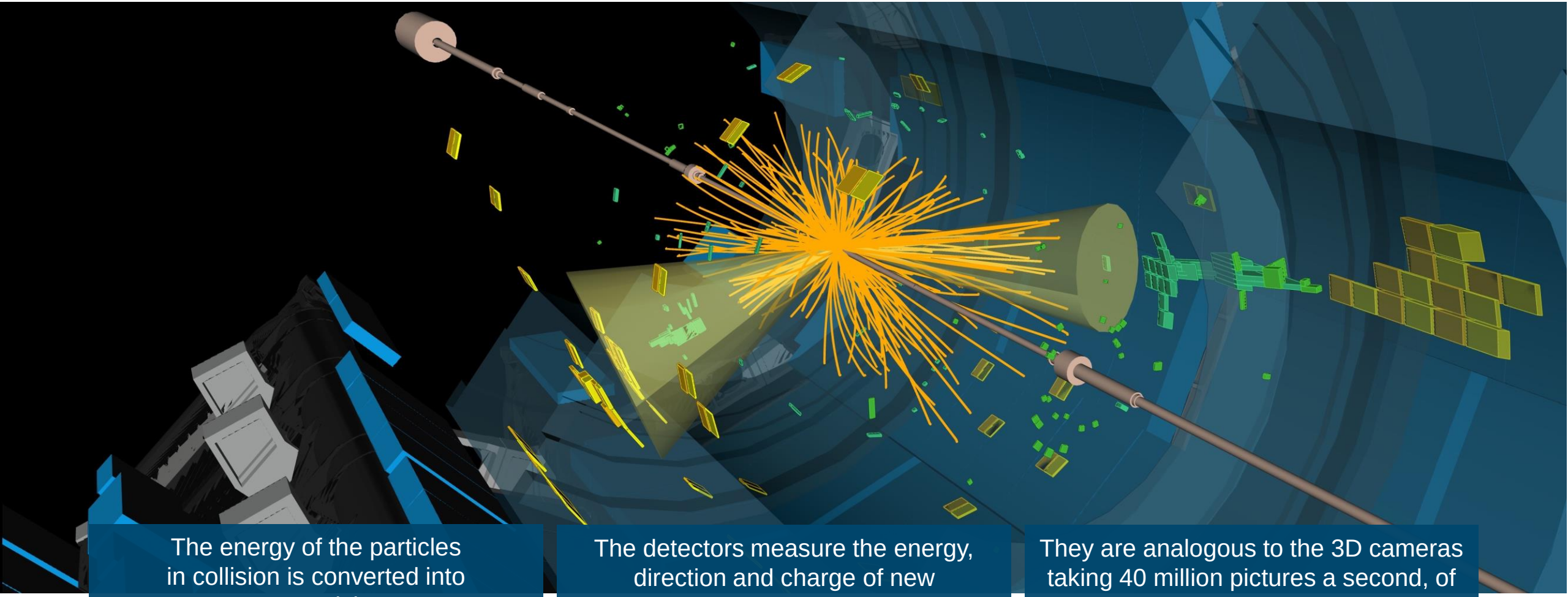
- 27 km in circumference
- About 100 m underground
- Superconducting magnets steer the particles around the ring
- Particles are accelerated to close to the speed of light

Giant detectors record the particles formed at the four collision points





The LHC produces more than 1 billion particle collisions per second

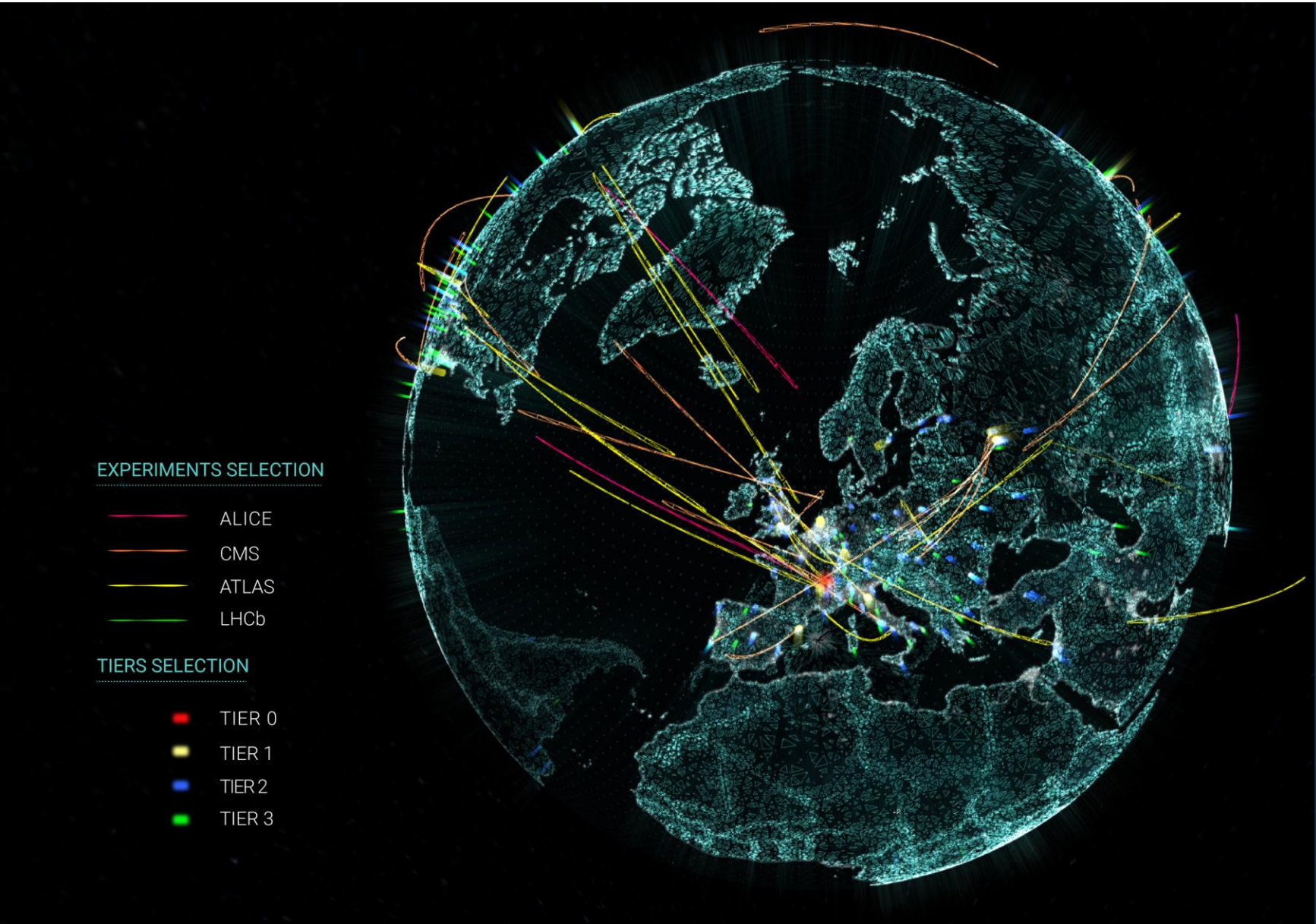


The energy of the particles in collision is converted into new particles.

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.

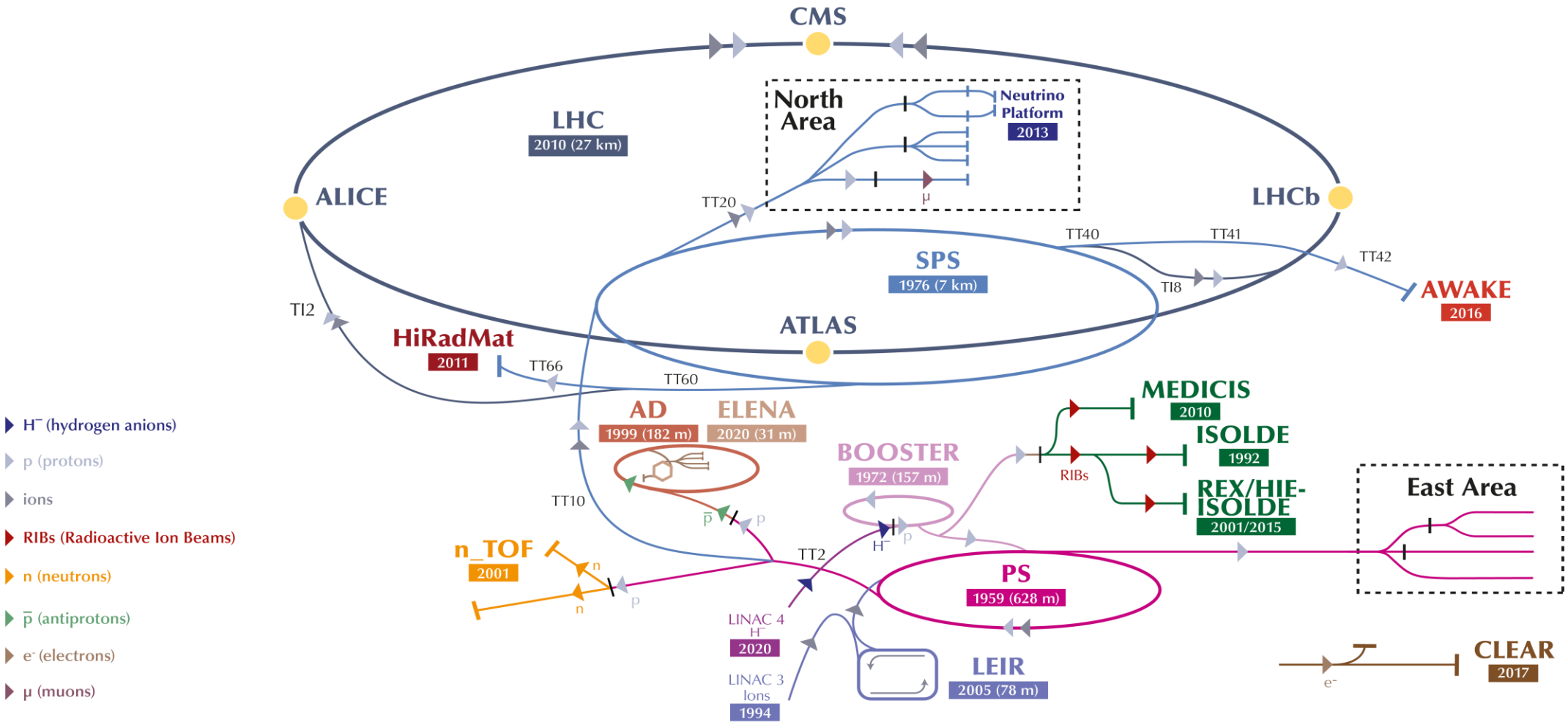
The Worldwide LHC Computing Grid (WLCG)



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.

The CERN accelerator complex

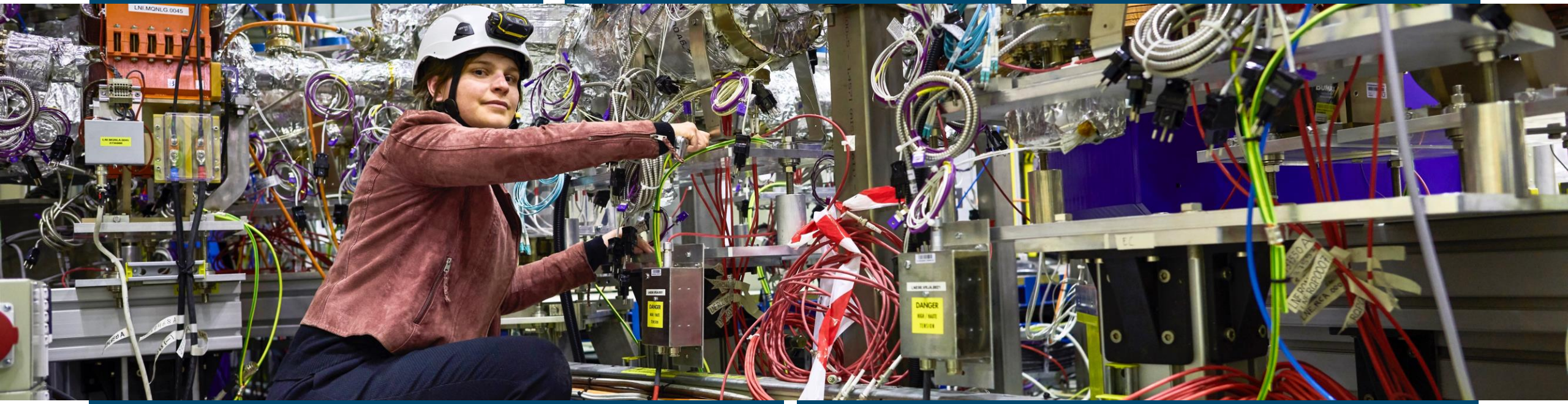


CERN has a diverse scientific programme

Nuclear Physics
(ISOLDE, n_TOF)

Antimatter Research
(Antiproton Decelerator)

Cosmic rays and cloud formation
(CLOUD)



Fixed-target experiments,
which include searches for rare phenomena

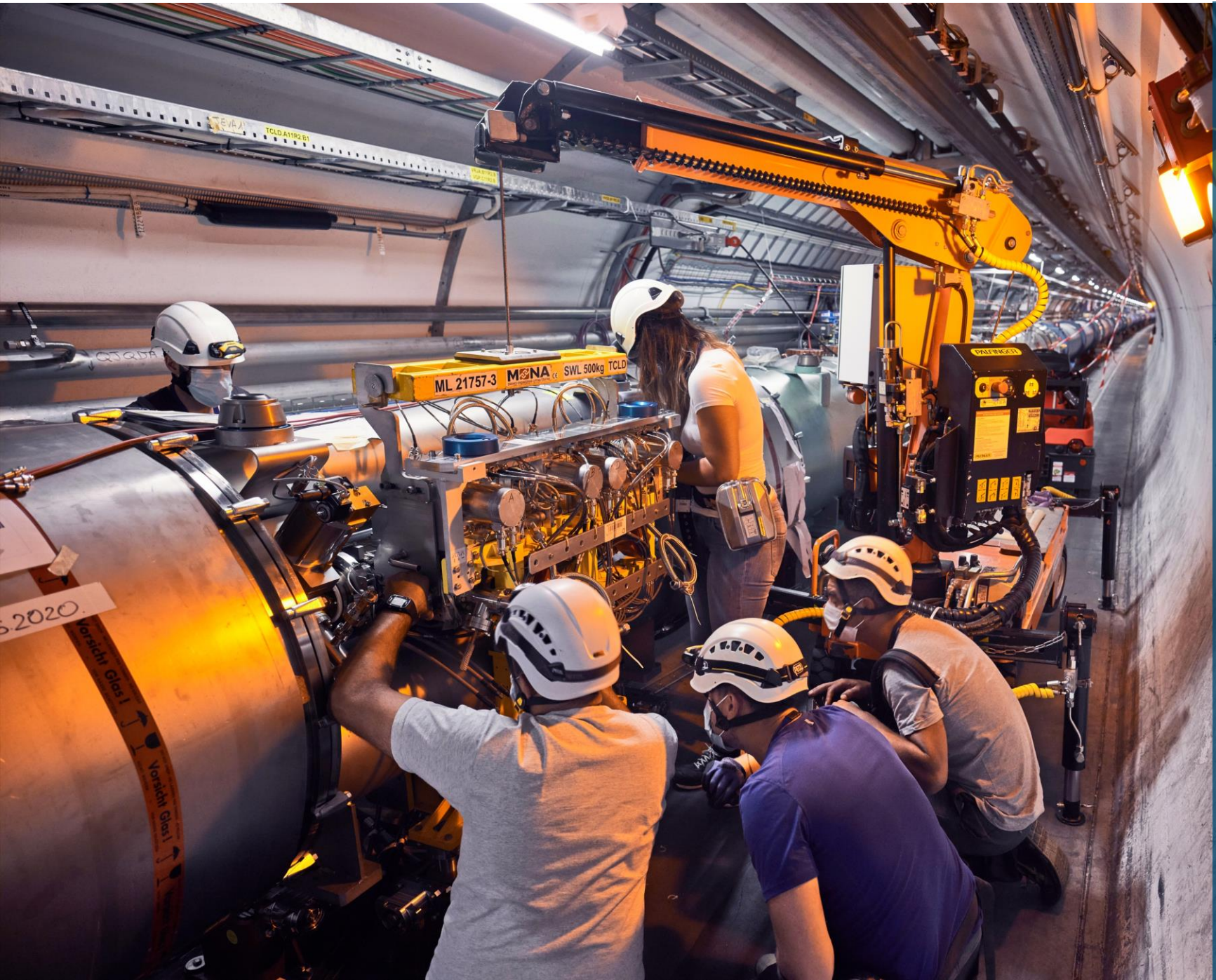
Contribution to the Long Baseline
Neutrino Facility in the USA (LBNF)

CERN Theory Programme

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?



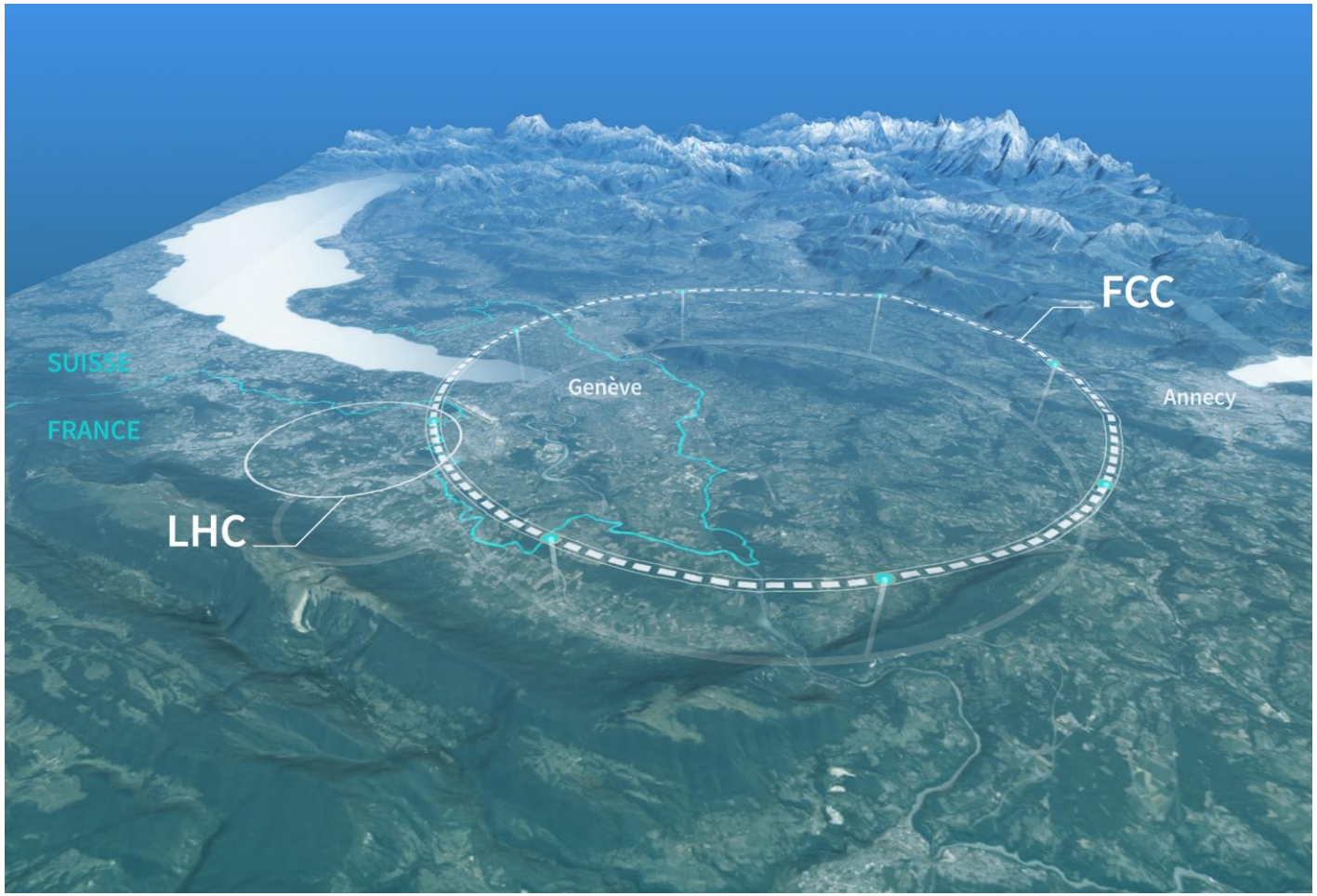
Upgrade to the High-Luminosity LHC is under way

- 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



→ FCC Feasibility Study

Future Circular Collider

Comprehensive long-term program maximizing physics opportunities

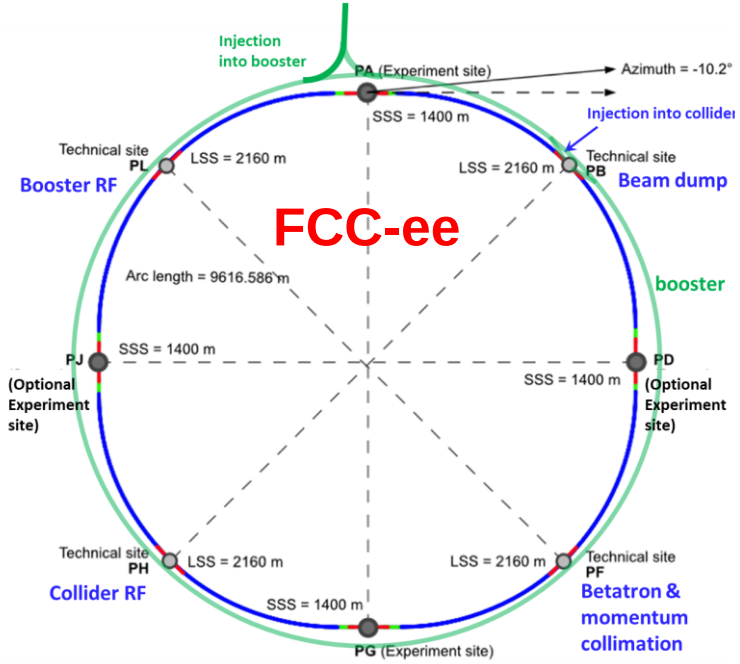
- stage 1: FCC-ee (Z, W, H, $t\bar{t}$) as Higgs factory, electroweak & top factory at highest luminosities
- stage 2: FCC-hh (~100 TeV) as natural continuation at energy frontier, pp & AA collisions; e-h option

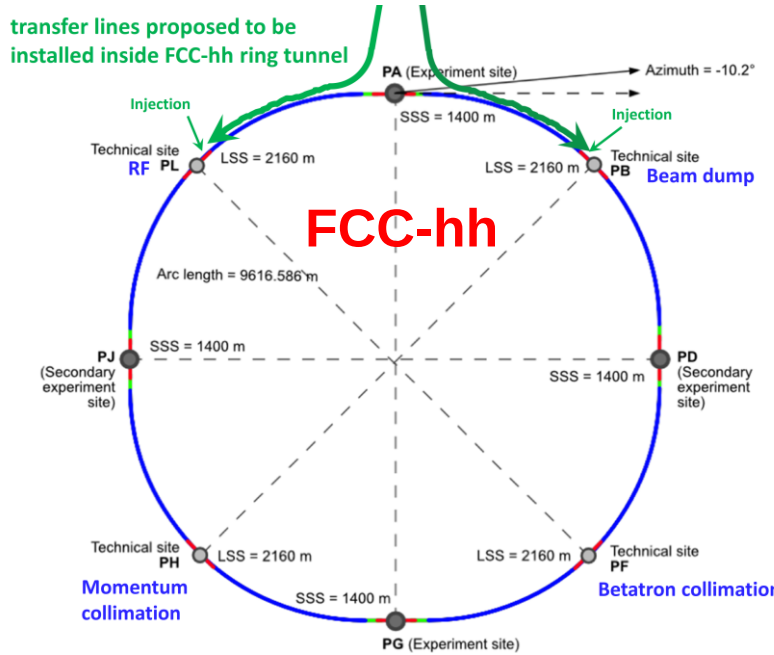
Common civil engineering and technical infrastructures, building on and reusing CERN's existing infrastructure

FCC integrated project allows the start of a new, major facility at CERN within a few years of the end of HL-LHC

Realistic schedule:

- 2025 FCC Feasibility Study delivered
- ~2028 Project approval by CERN Council
- ~2030 Construction of tunnel and FCC-ee starts
- ~2041 HL-LHC ends
- 2045-2048 Operation of FCC-ee
  15 years physics operation
- ~2070 Operation of FCC-hh starts
  ~20 years physics operation





2020 - 2040 | 2045 - 2063 | 2070 - 2095

Austria in the FCC global collaboration

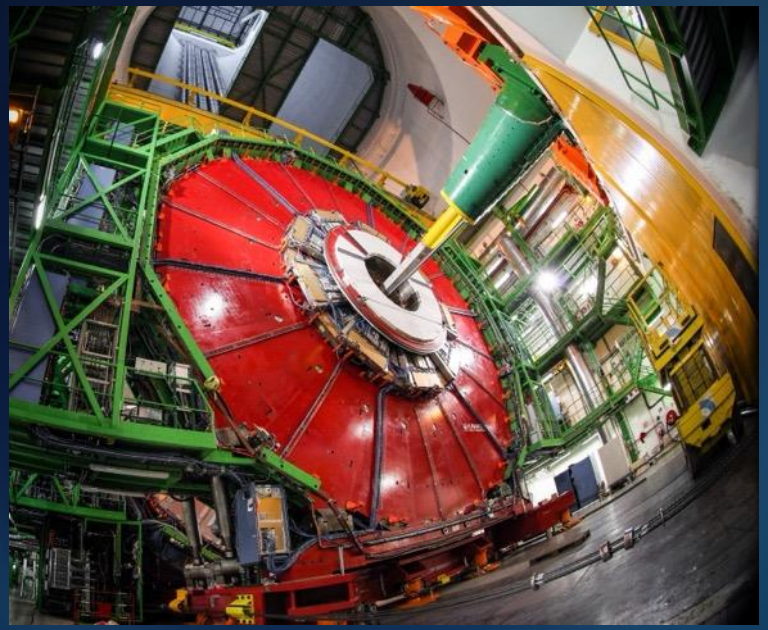
Country	Institute	Areas of contributions	City
Austria	HEPHY	Physics, Detectors, Experiments	Vienna
Austria	University of Natural Resources and Life Sciences (BOKU)	Excavation material reuse, environmental aspects	Vienna
Austria	Österreichisches Institut für Wirtschaftsforschung (WIFO)	Socio economic studies, Economic studies	Wien
Austria	Johannes Kepler University (JKU)	Robotics, Vacuum technologies	Linz
Austria	University of Innsbruck	Detectors, Experiments	Innsbruck

Conclusion of FCC Feasibility Study March 2025
FCC Week May 19– 23 2025 in Vienna
Expect 500 international participants

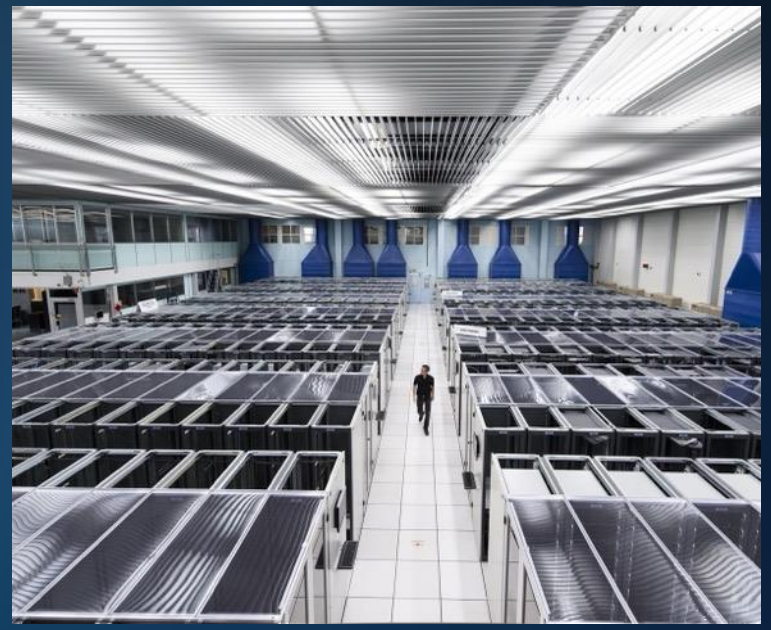
TECHNOLOGY & INNOVATION

CERN develops technologies in three key areas

ACCELERATORS



DETECTORS

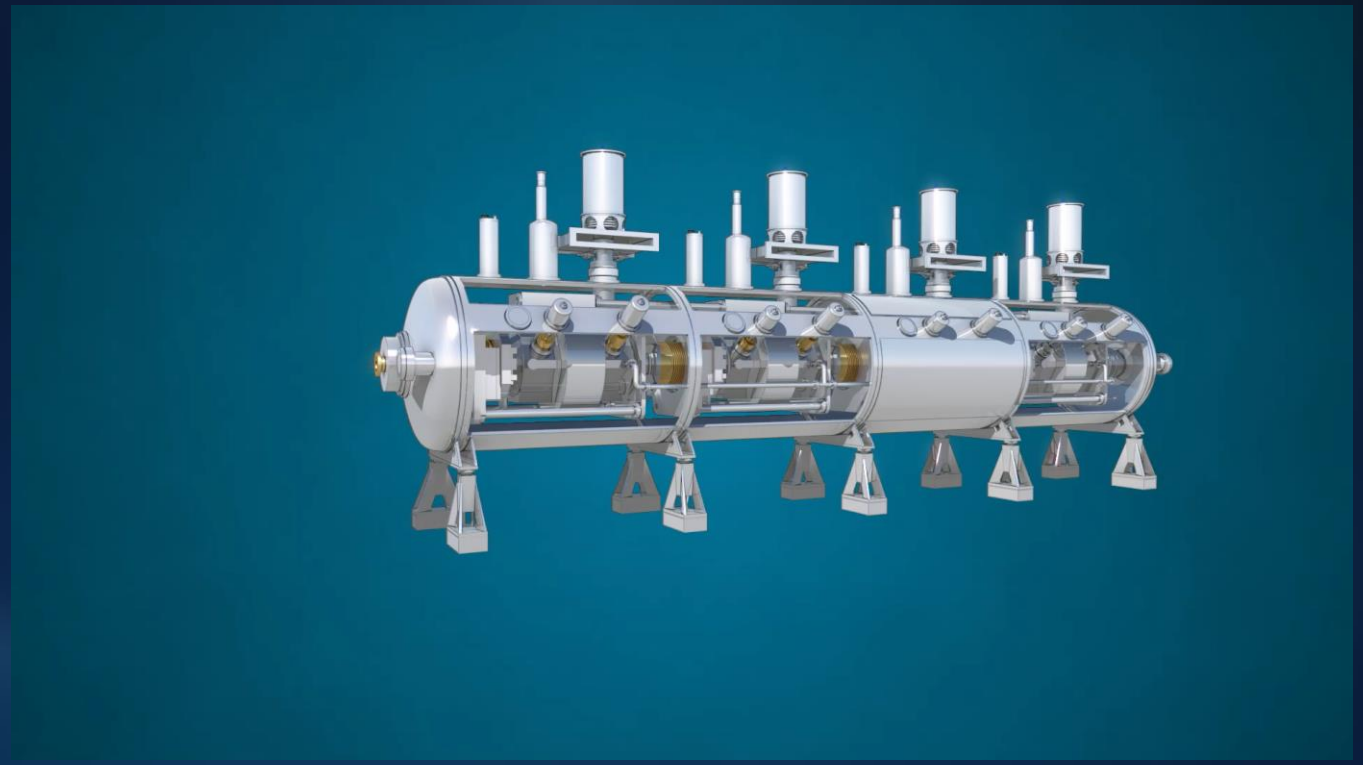


COMPUTING

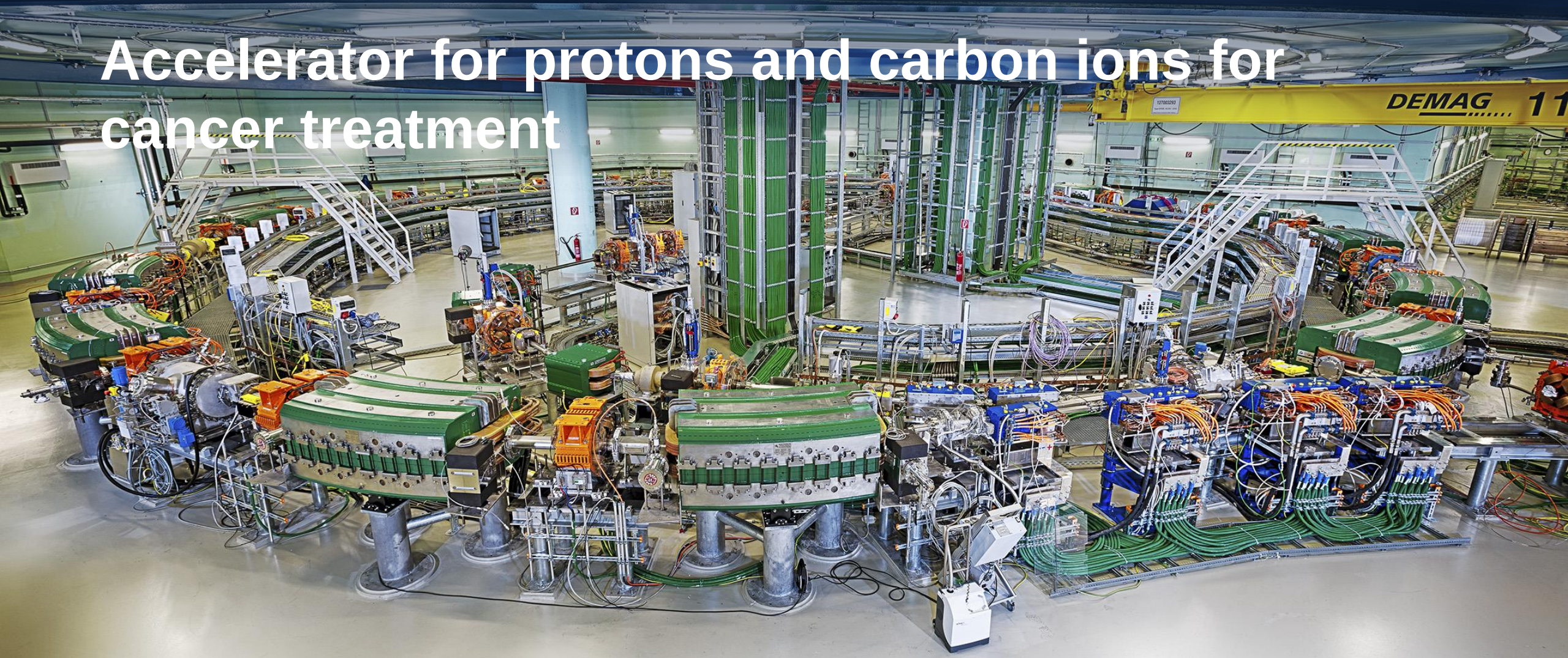
Accelerator key technologies

High Field Magnets

Accelerating Structures

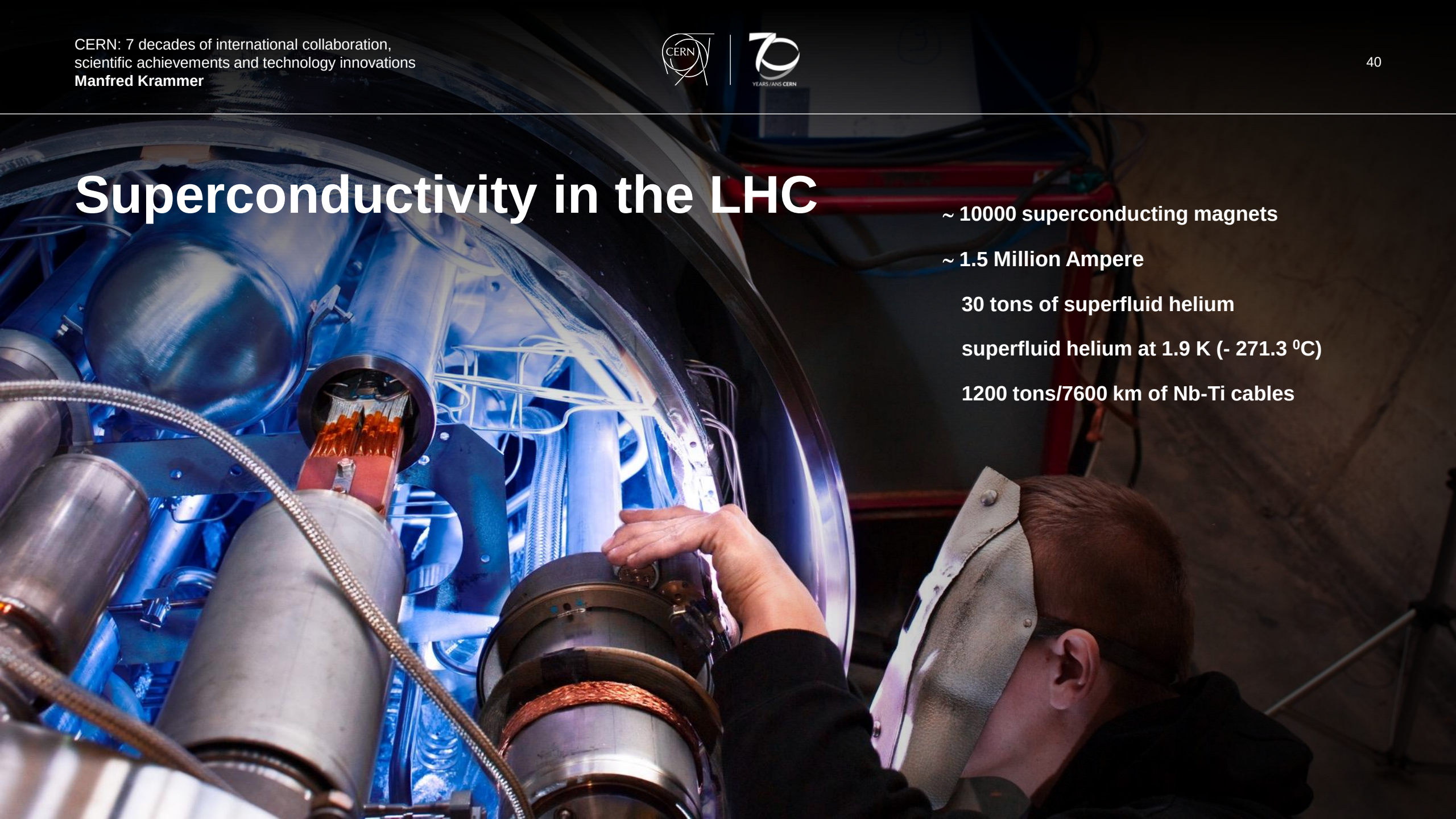


Accelerator for protons and carbon ions for cancer treatment



Credit: MedAustron

Superconductivity in the LHC



~ 10000 superconducting magnets

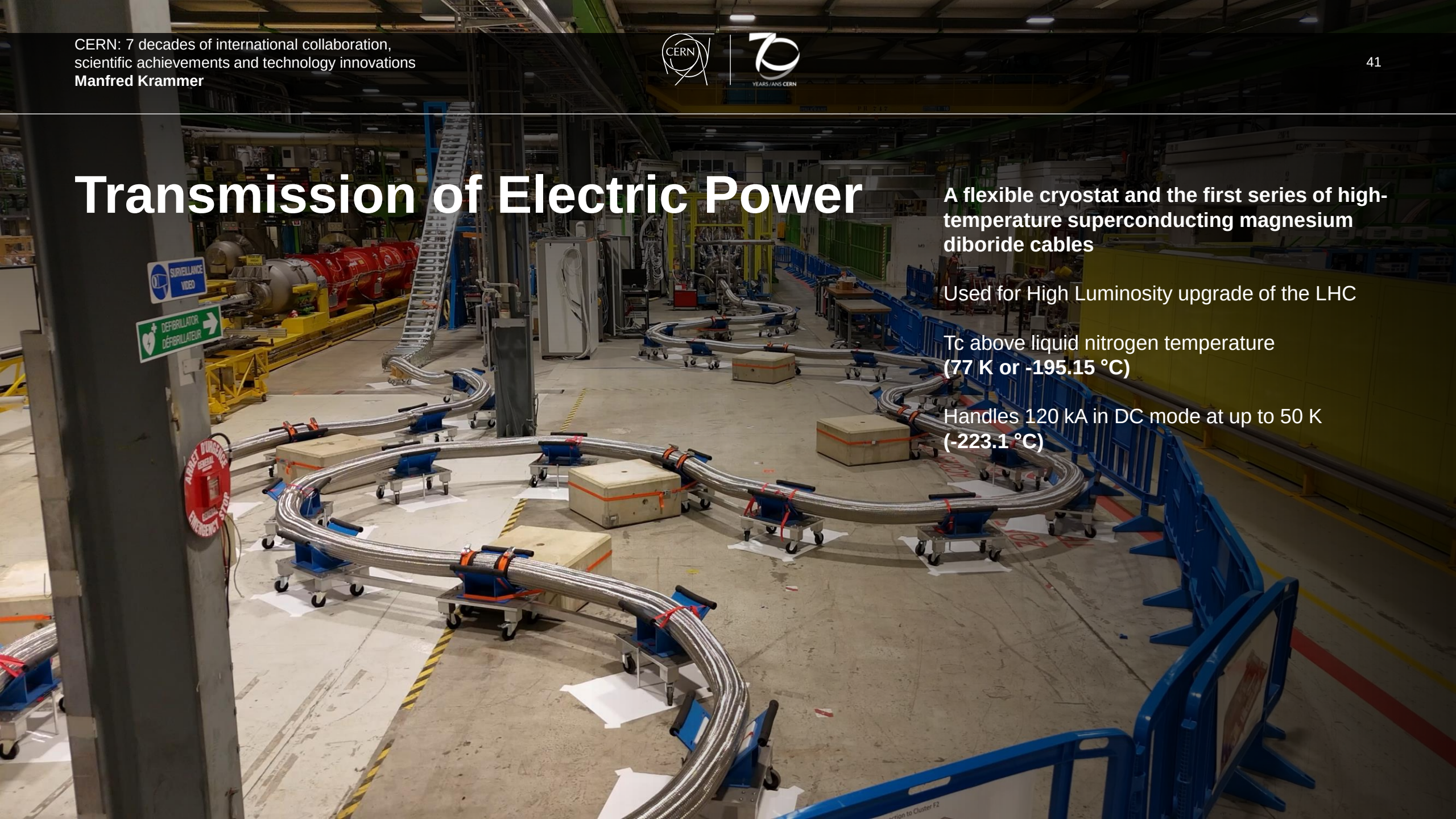
~ 1.5 Million Ampere

30 tons of superfluid helium

superfluid helium at 1.9 K (- 271.3 ^{0}C)

1200 tons/7600 km of Nb-Ti cables

Transmission of Electric Power



A flexible cryostat and the first series of high-temperature superconducting magnesium diboride cables

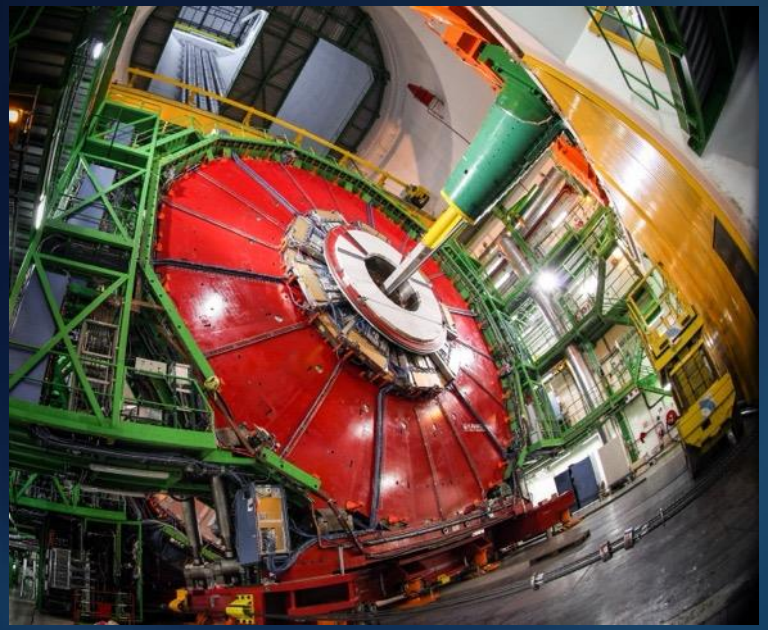
Used for High Luminosity upgrade of the LHC

Tc above liquid nitrogen temperature
(77 K or -195.15 °C)

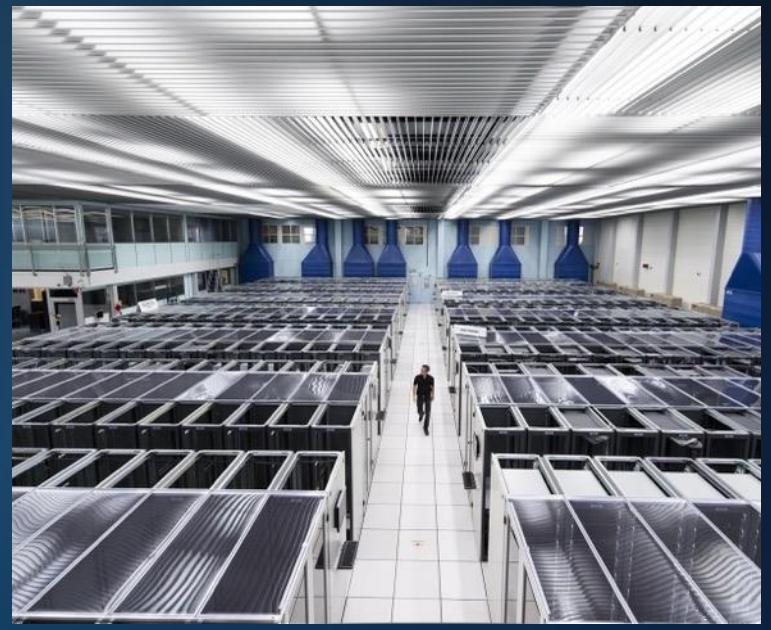
Handles 120 kA in DC mode at up to 50 K
(-223.1 °C)

We develop technologies in three key areas

ACCELERATORS



DETECTORS

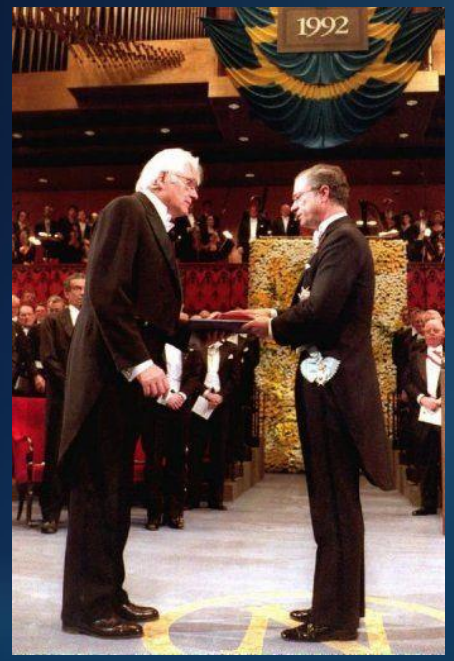


COMPUTING

Georges Charpak: Revolutionizing particle detection

From “visual detectors” to “electronic detectors”

1971-1972 – Large-size Multiwire Proportional Chamber



1992 Nobel award ceremony

Application in many fields:

Medical imaging and healthcare

Security and inspection

Material science and archaeology

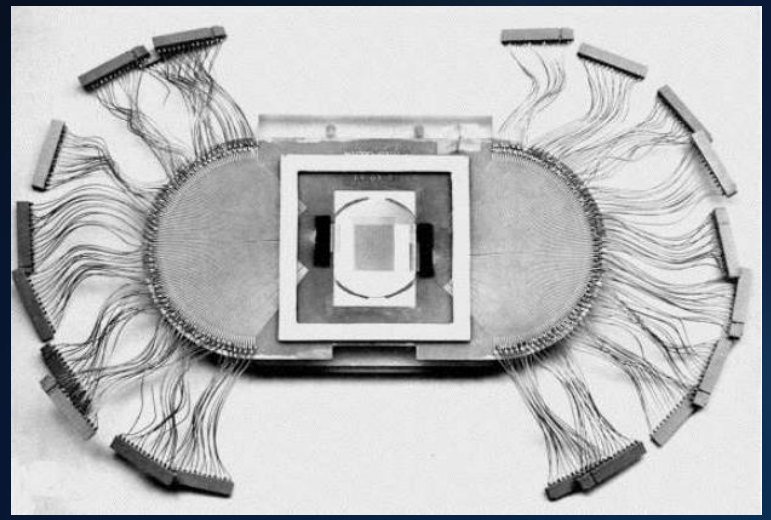
Environmental monitoring

Industrial applications

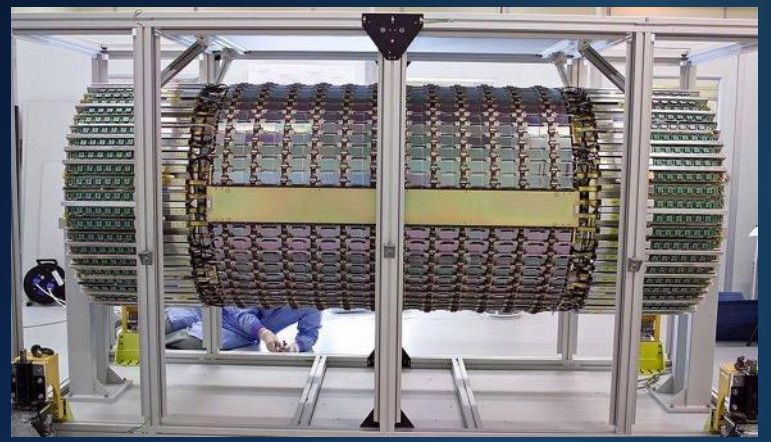
The silicon revolution and discoveries

1980 - search for particles with charm and beauty quarks (decay length ~ 100 μm)

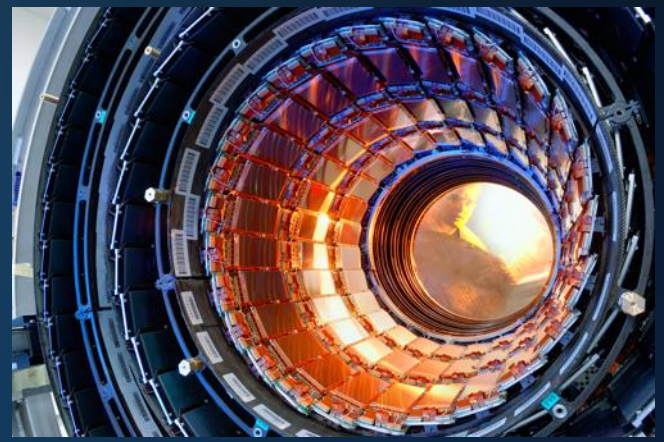
NA11- NA32: measurements of Lifetimes of particles containing c-quarks



Silicon trackers at the heart of all LHC experiments
Giant, ultra-fast and very complex 3D camera

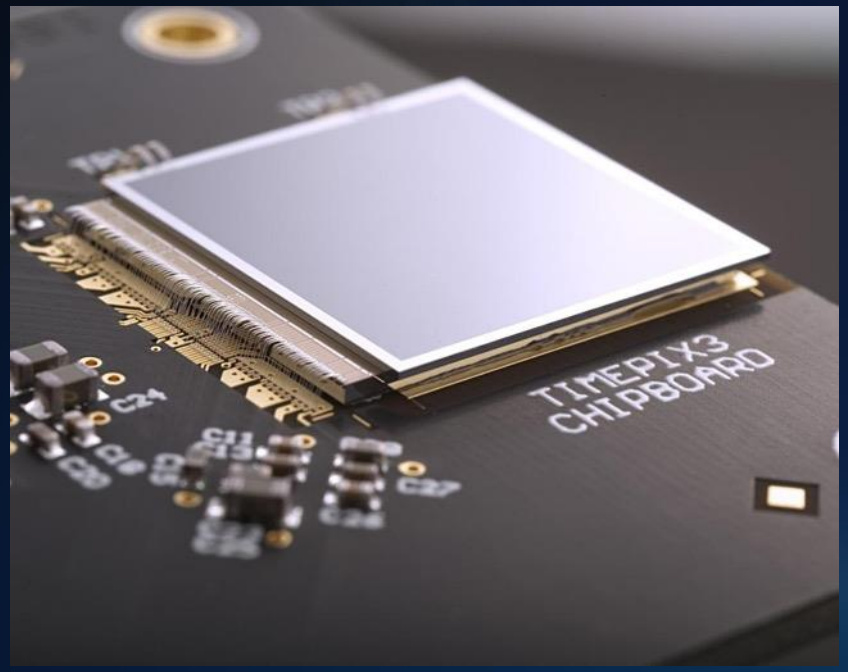


ATLAS

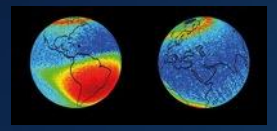


CMS

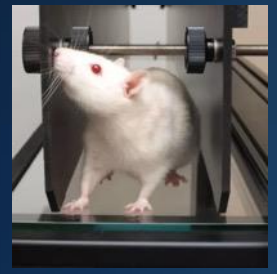
The silicon revolution
From particle physics to technology and back

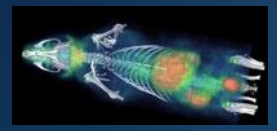


Space

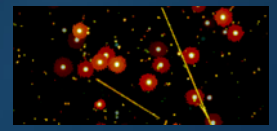


Biology

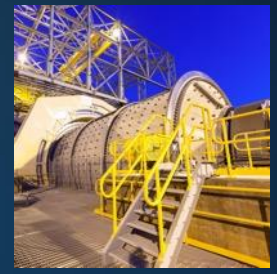


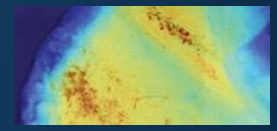


Research

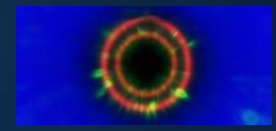


Mining



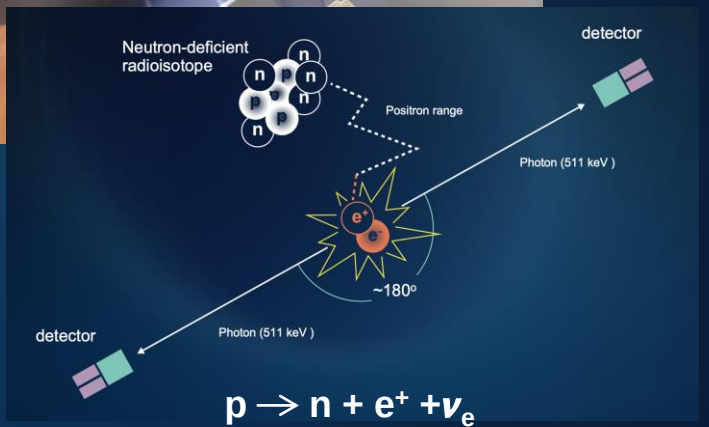


Non-destructive testing



Scintillator Detectors from CERN Experiments to Hospitals

Positron Emission Tomography

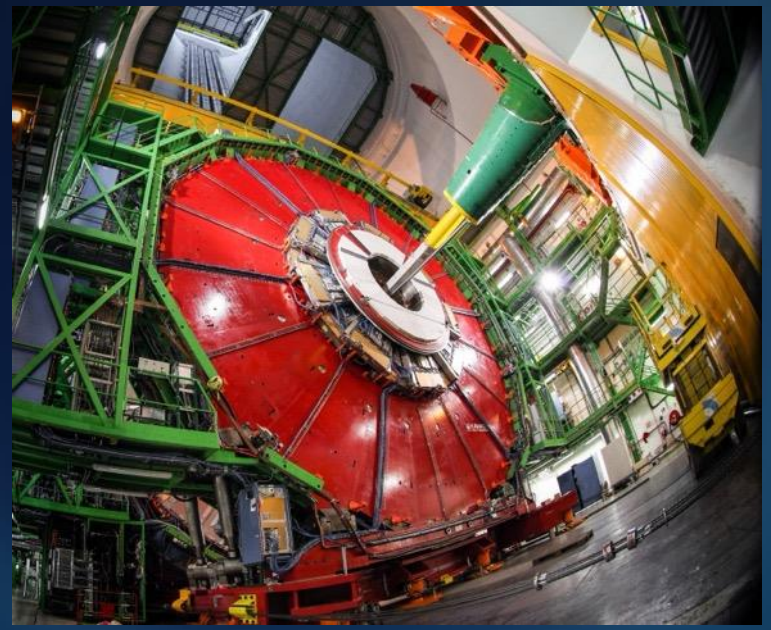


$p \rightarrow n + e^{+} + \nu_e$

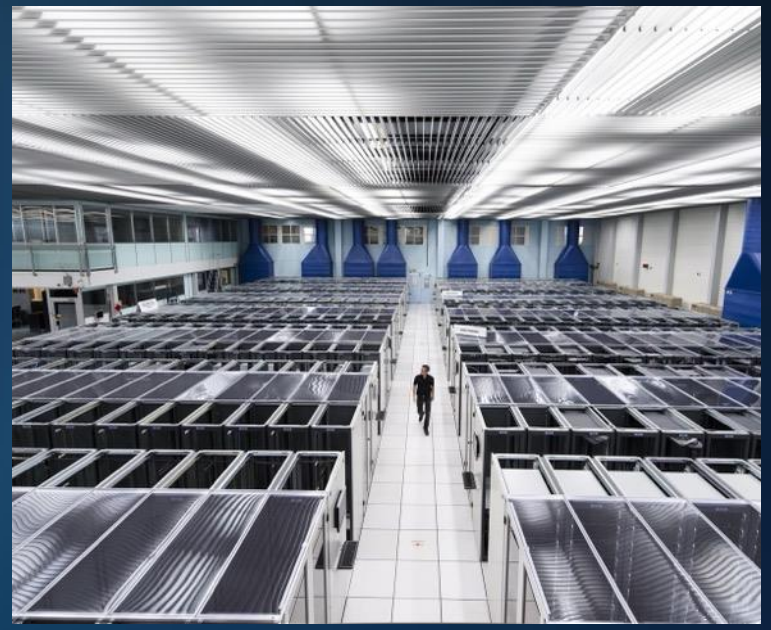
Credit: CERN

We develop technologies in three key areas

ACCELERATORS



DETECTORS



COMPUTING

The World Wide Web

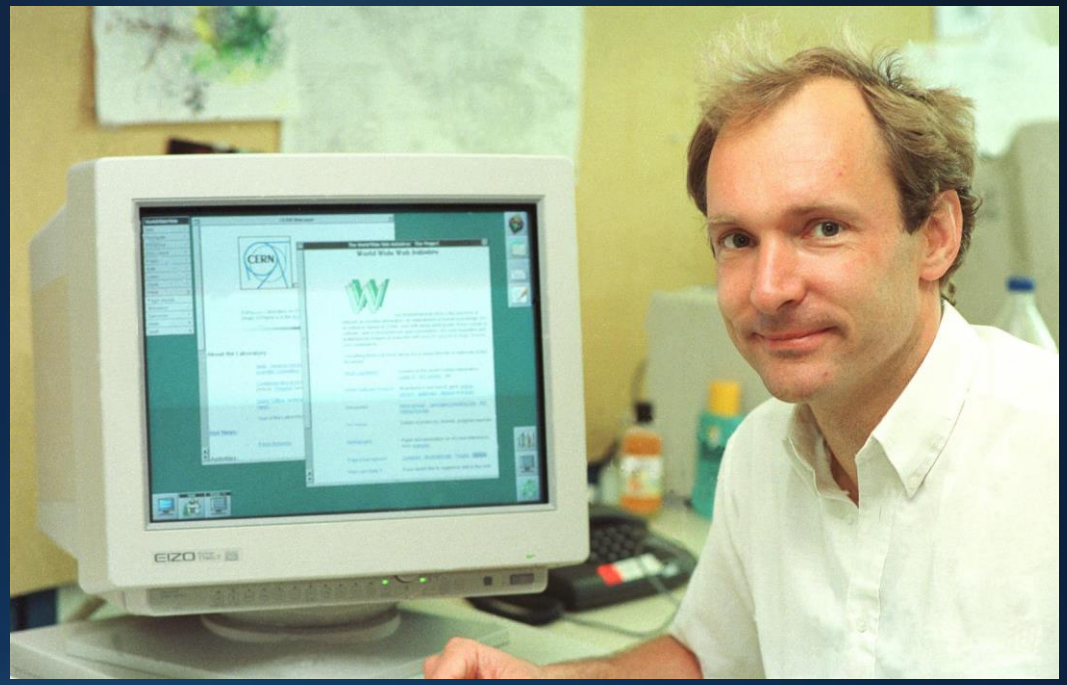
March 1989: Tim Berners Lee working at CERN submits the first proposal for the World Wide Web

Merge data networks and hypertext in an easy-to-use global information system

By the end of 1990, the first Web server and browser is up and running

In 1993, CERN makes the source code of the World Wide Web available on a royalty-free basis

By the end of 1994, the Web already has **10,000 servers** and **10 million users**



Tim Berners Lee displaying some of the first web pages in 1994

The Worldwide LHC Computing Grid (WLCG)

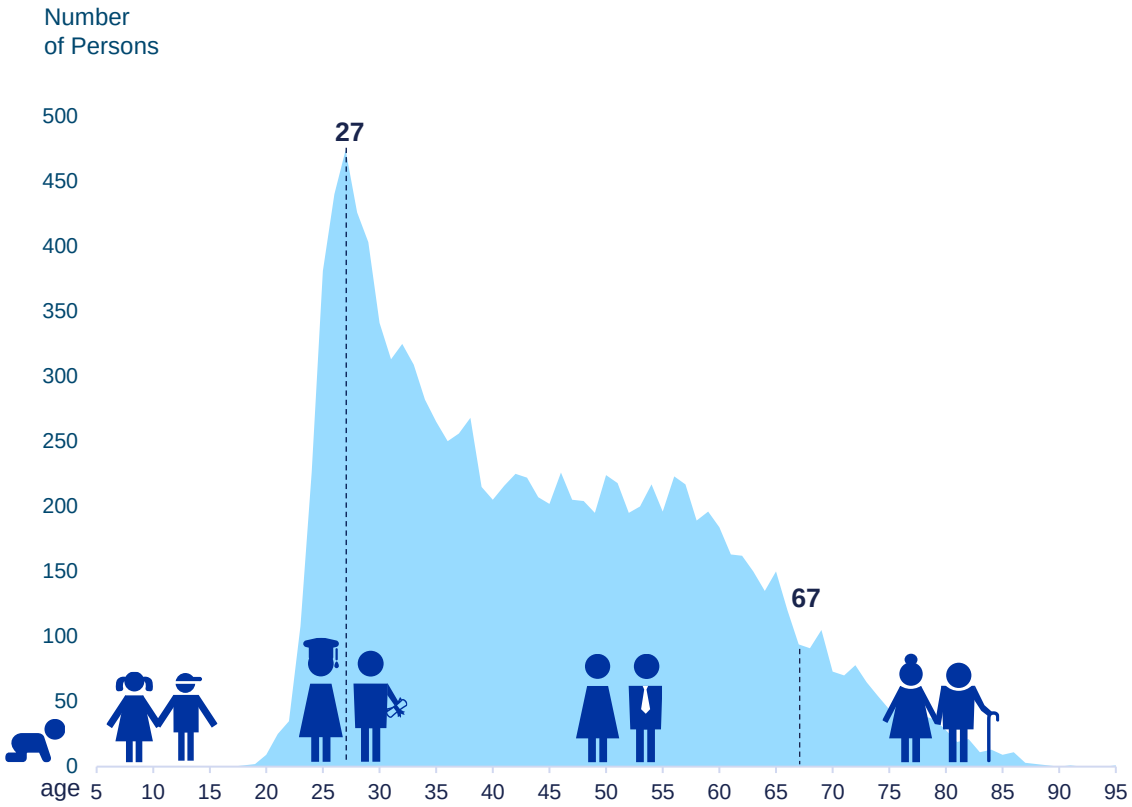
Used to store, distribute, process and analyse data.

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

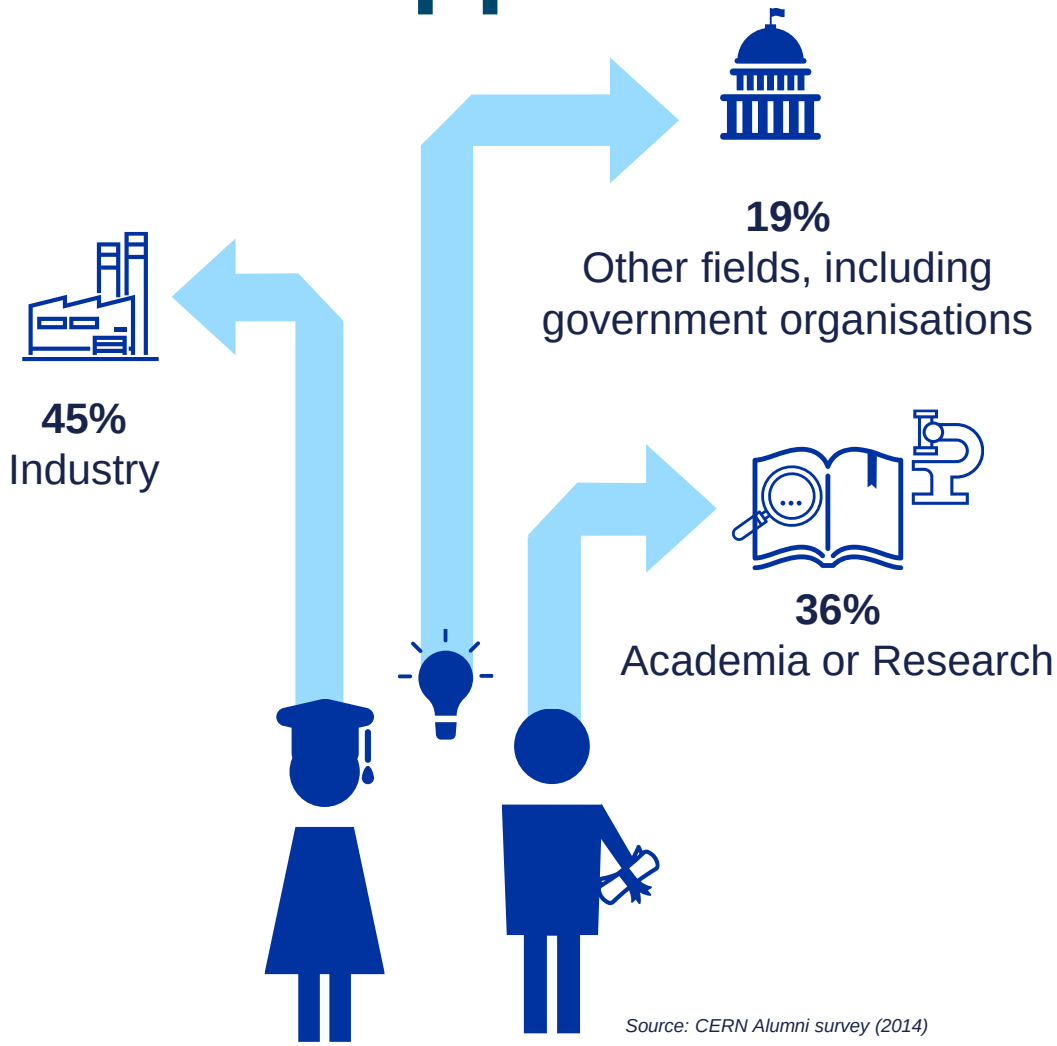
More than 1500 Petabytes of CERN data stored world-wide.

EDUCATION & TRAINING

CERN opens a world of career opportunities



Age Distribution of Scientists working at CERN



PhD and Technical students leaving CERN

CERN Science Gateway

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

Inaugurated 7 October 2023

Number of visitors since then: **400 000**

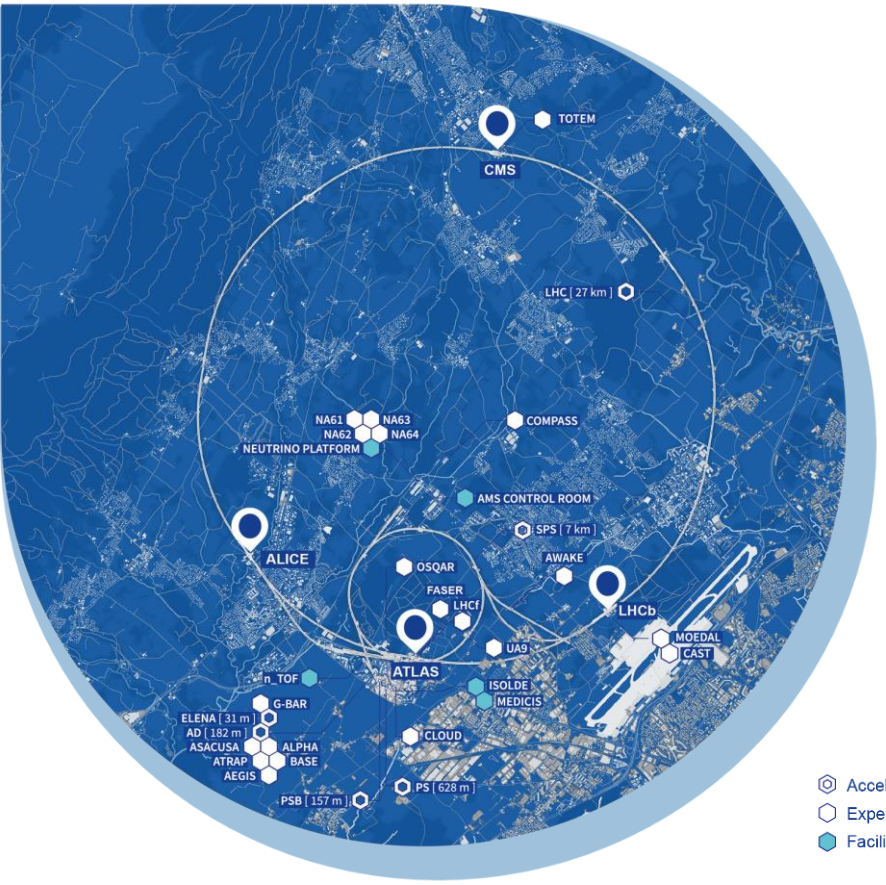
Immersive exhibitions, education labs, events and shows.

Austria has a strong tradition in Particle Physics

27 February 2018 - Austrian Federal President A. Van der Bellen and Ms Schmidauer in front of the CMS detector at LHC Point 5.

- **Became a Member State of CERN in 1959**
- **Victor Weisskopf (Austrian-American)**
  Director General (1961-1965)
- **Willibald Jentschke**
  Director General (1971-1975)

Austria has a strong involvement across the CERN experimental programme



LHC EXPERIMENTS:

ALICE 1 Institute, 11 Participants
ATLAS 2 Institutes, 11 Participants
CMS 1 Institute, 53 Participants

FIXED TARGET EXPERIMENTS

- **CLOUD**
- **nToF**

3 institutes, 11 Participants

ISOLDE
3 institutes, 12 Participants

ANTIPROTON EXPERIMENTS

- **ASACUSA**
- **AEGIS**

2 institutes, 22 Participants

- **LHC Grid Computing Tier-2 centre in Vienna (HEPHY/CLIP)**
- **Significant involvement in studies for the future (FCC) with several institutes/universities strongly involved**
- **Austrian PhD Programme at CERN**
- **MEDAUSTRON**

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

Fundamental research is a cornerstone of our future, driving the continuous cycle of discovery and application that propels human progress

CERN | 70 YEARS / ANS CERN