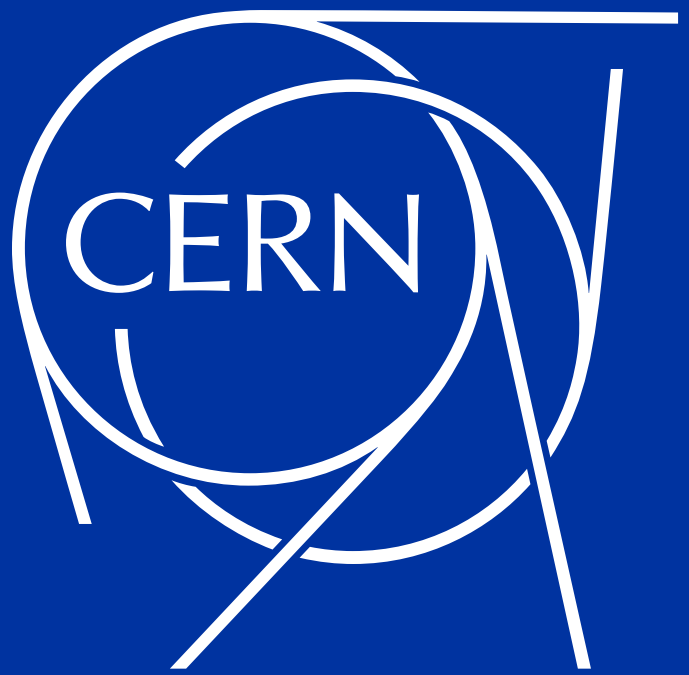
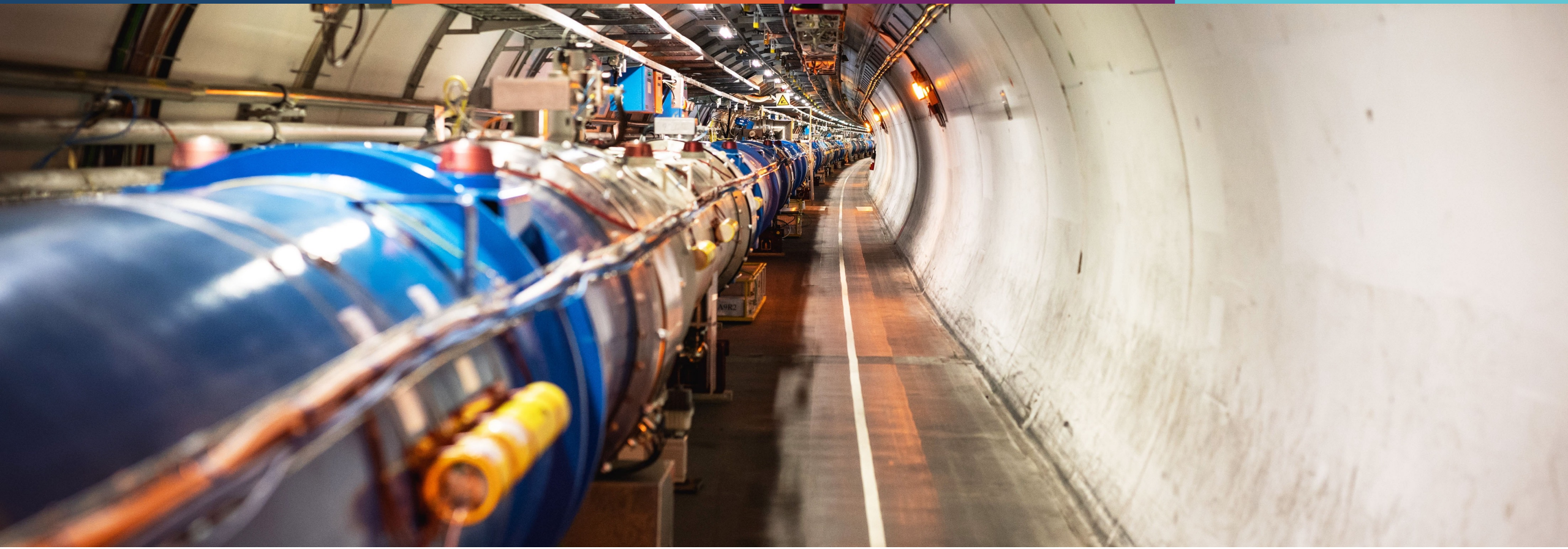

CERN



Scientific Challenges and Future Programs at CERN

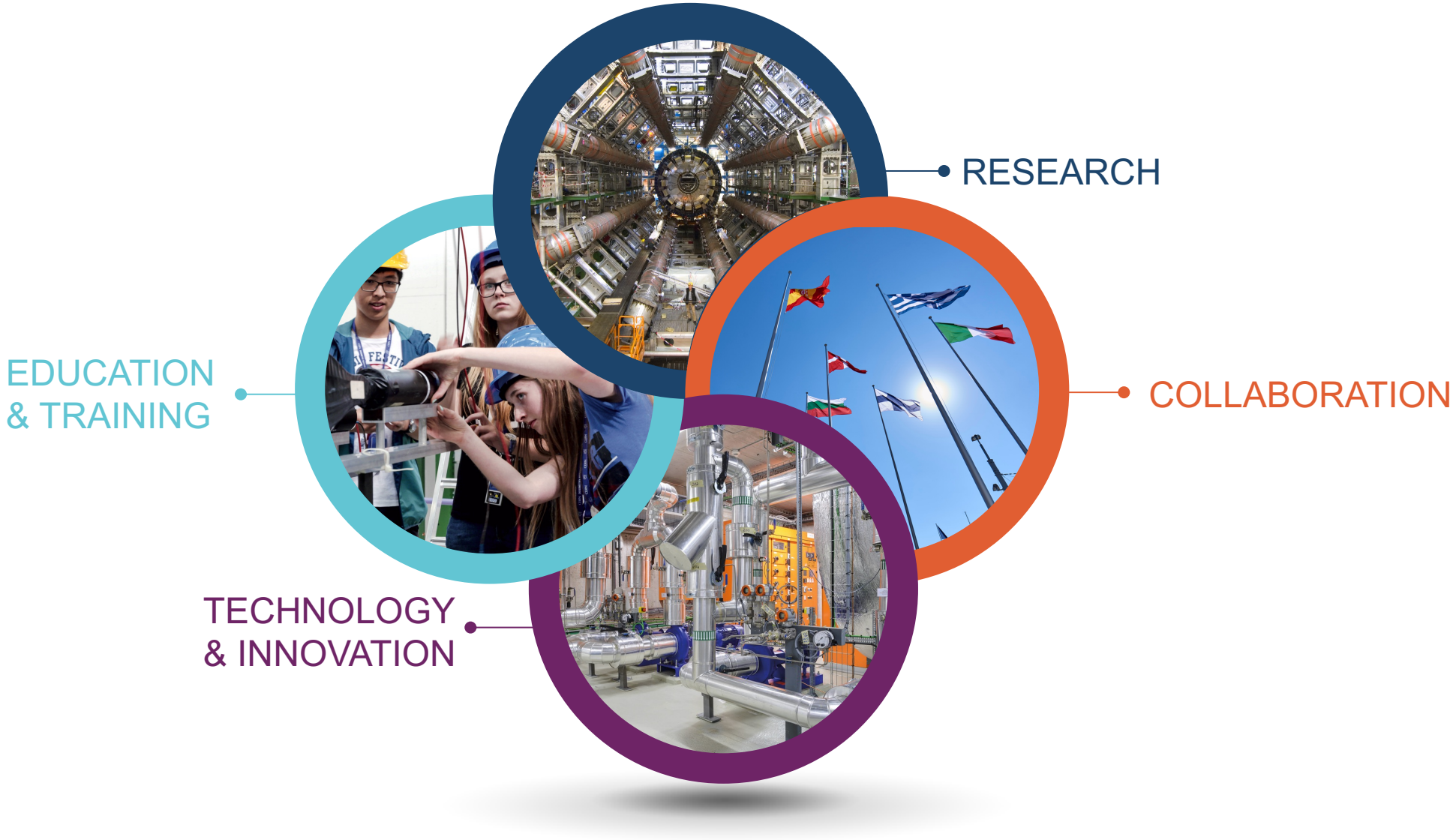
Pippa Wells, Deputy Director for Research and Computing

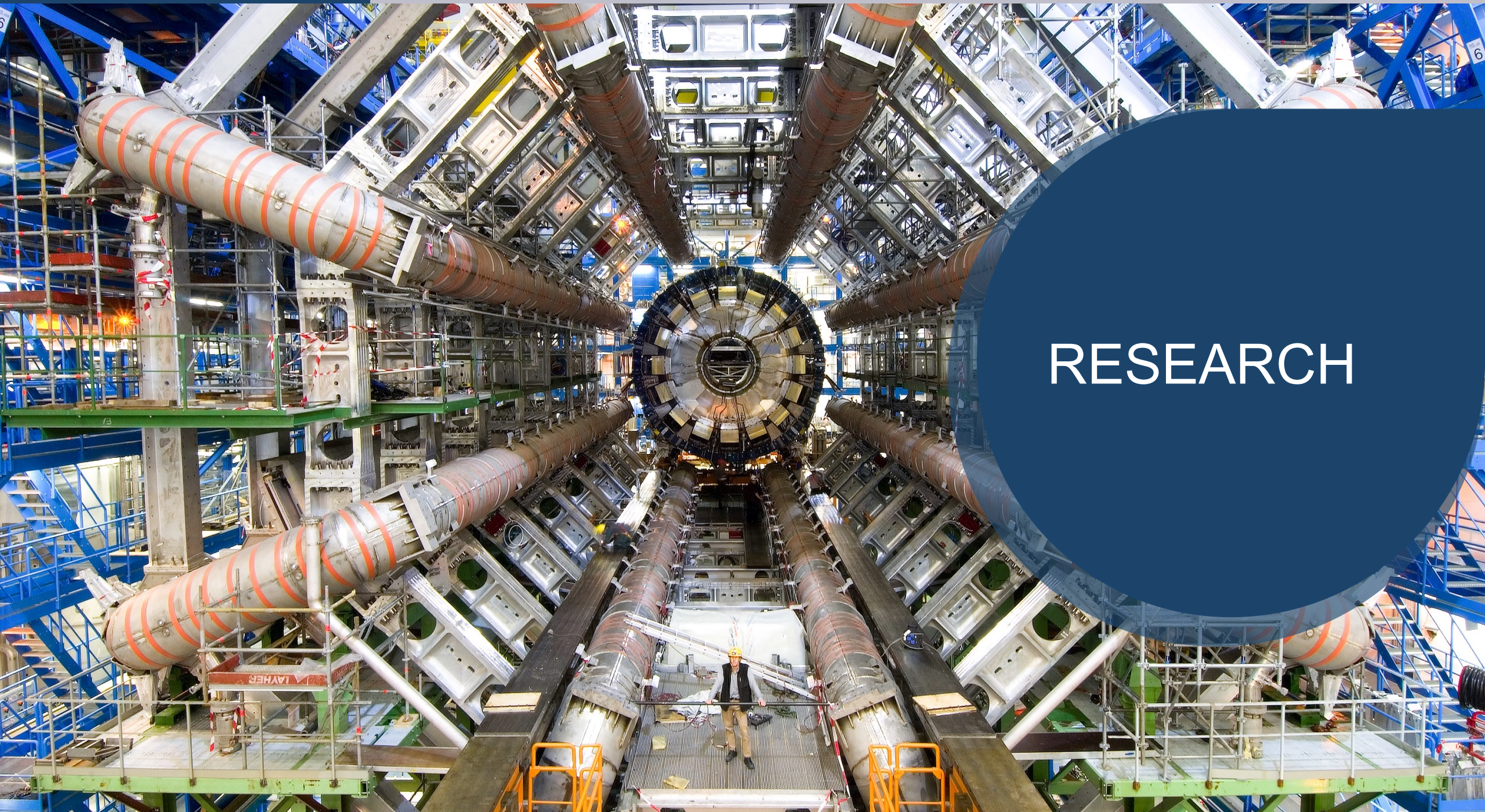
CERN is the world’s biggest laboratory for particle physics.

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

CERN - Science for Peace

Four pillars underpin CERN's mission

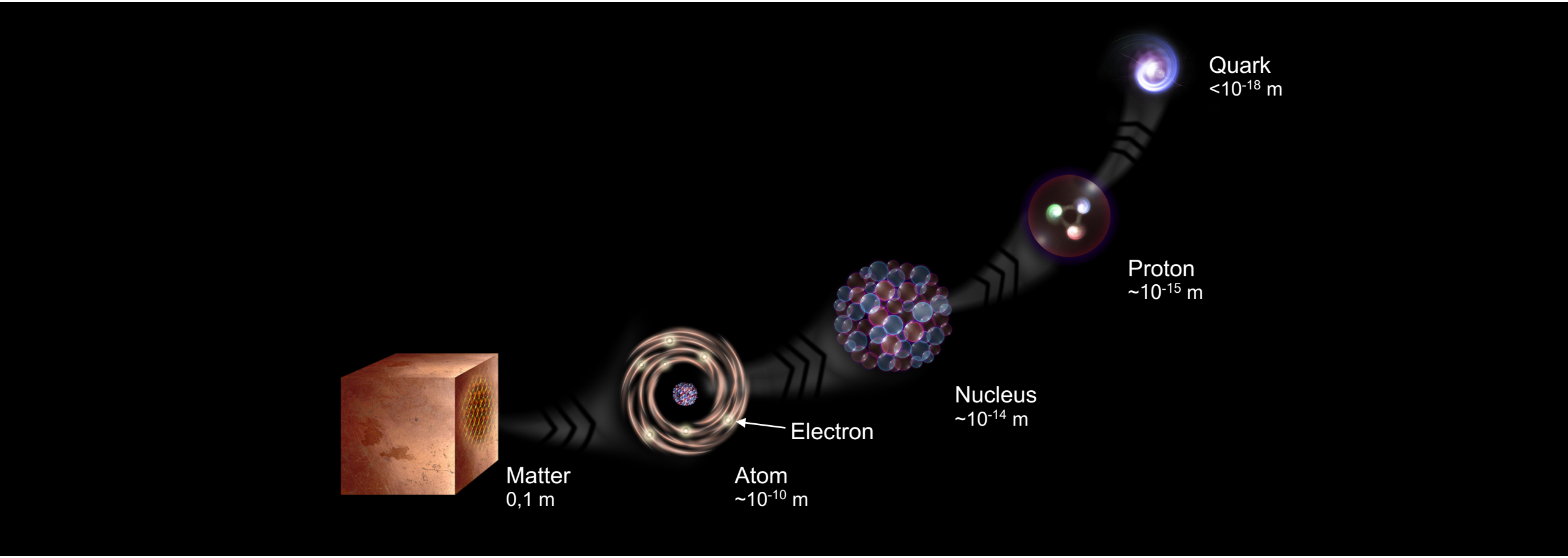




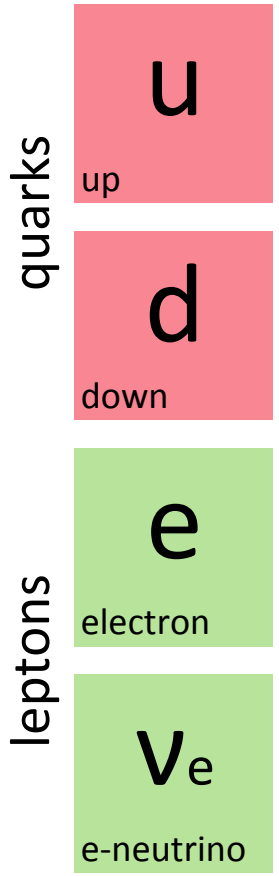
RESEARCH

What is the universe made of?

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



Ordinary matter



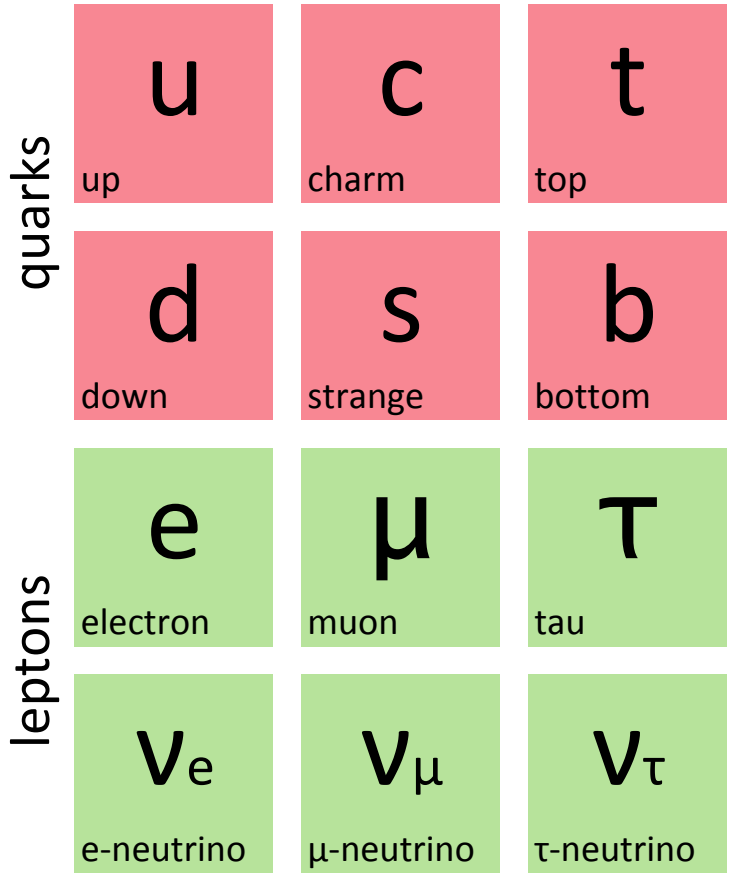
uud → proton

udd → neutron

electron

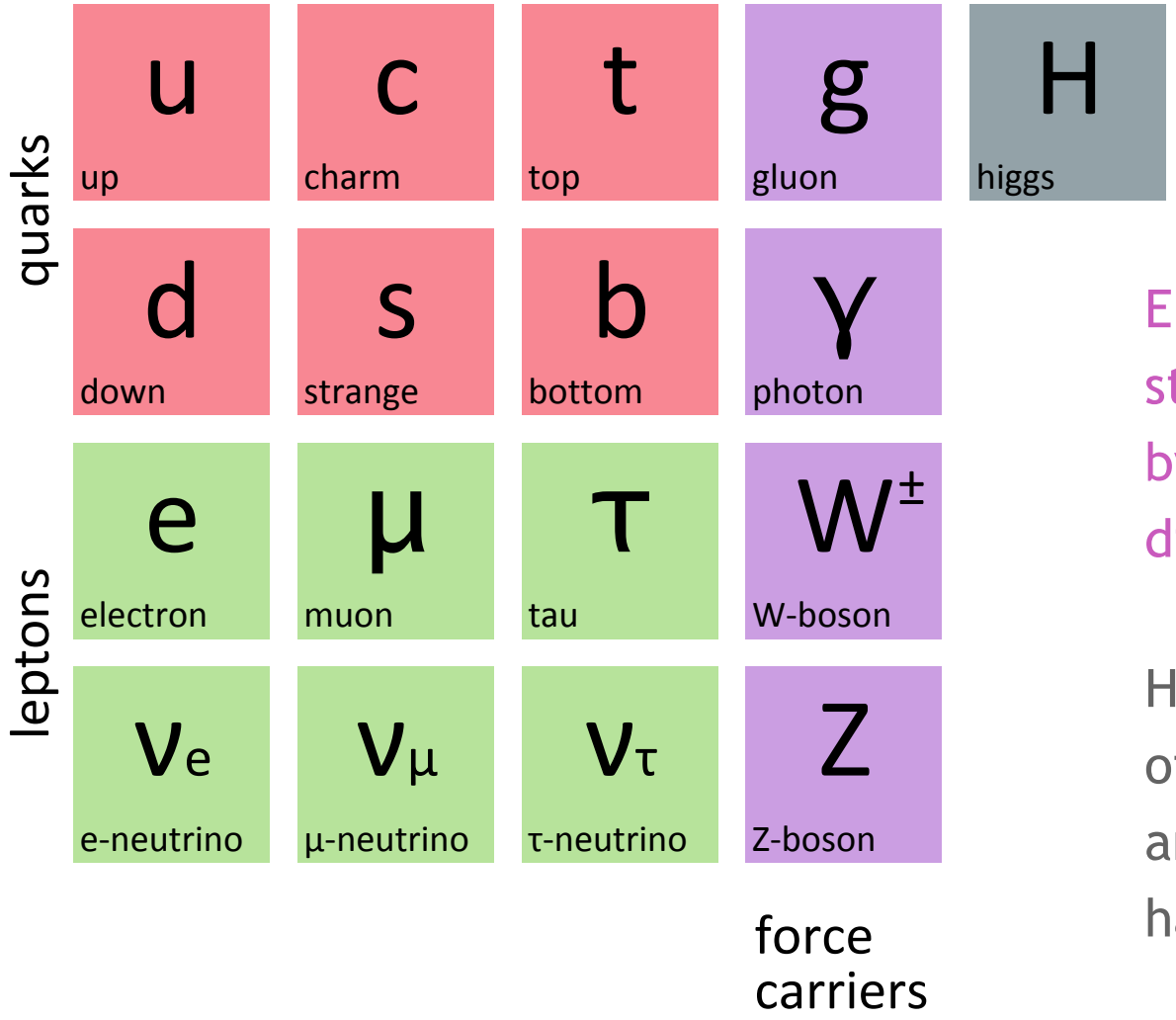
Need to add a neutrino to explain radioactive atoms

Three families of matter particles



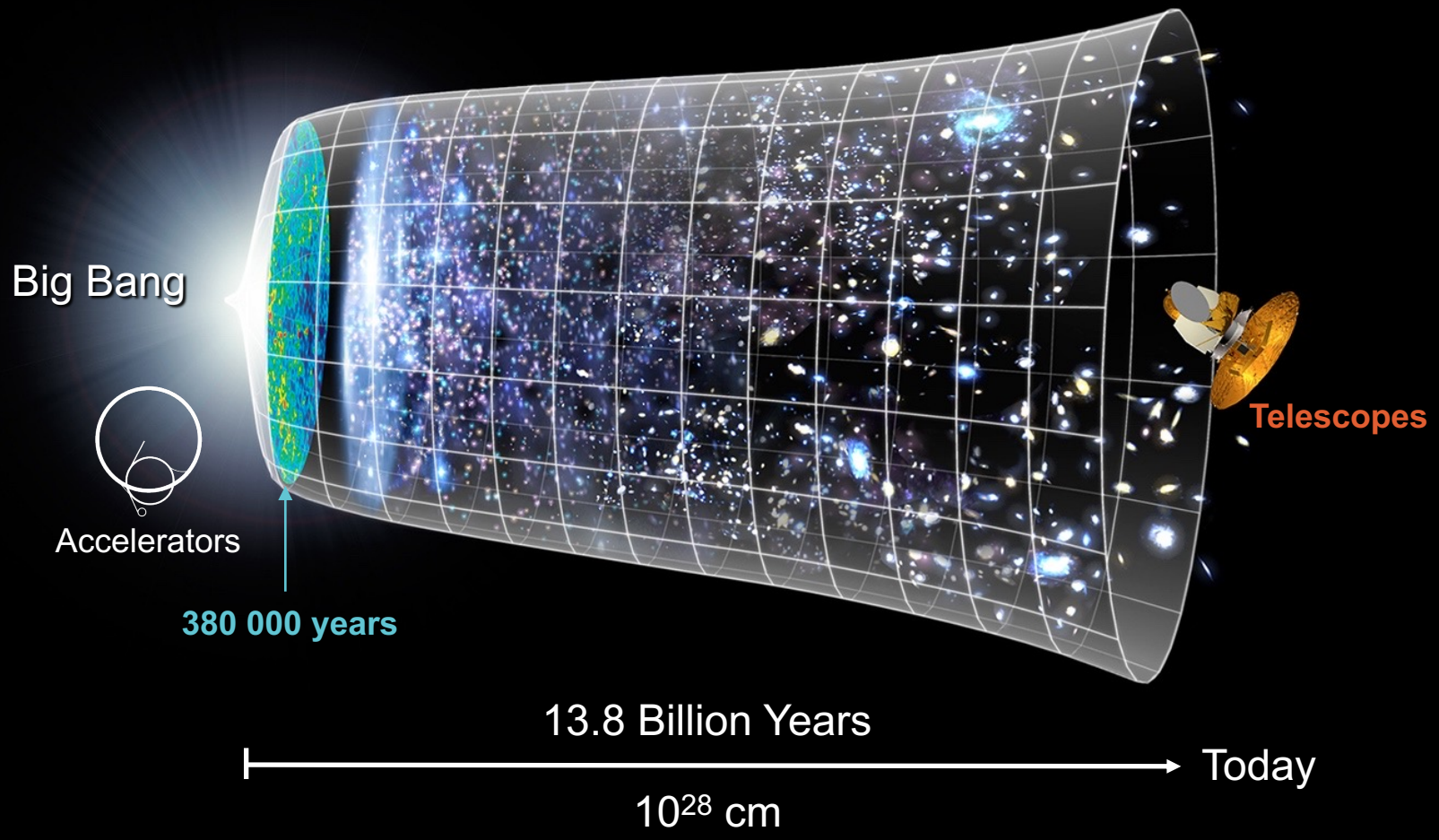
Heavy, unstable particles and anti-particles seen in cosmic rays and particle accelerator experiments

Standard Model of Particle Physics



Electromagnetism, weak and strong forces also explained by particles. W and Z discovered at CERN in 1983.

Higgs boson is a consequence of the mechanism allowing any fundamental particles to have mass.

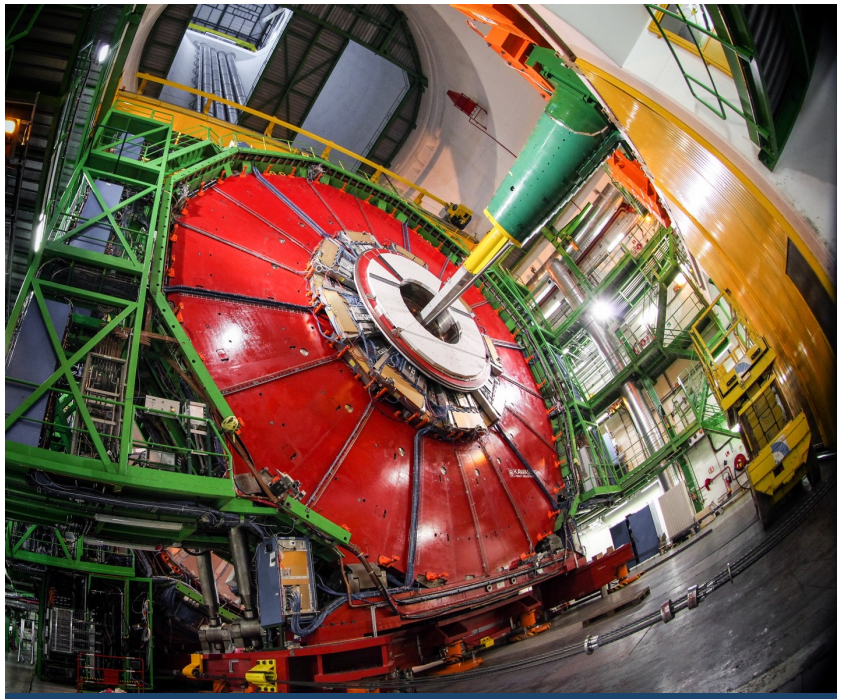


How did the universe begin?

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

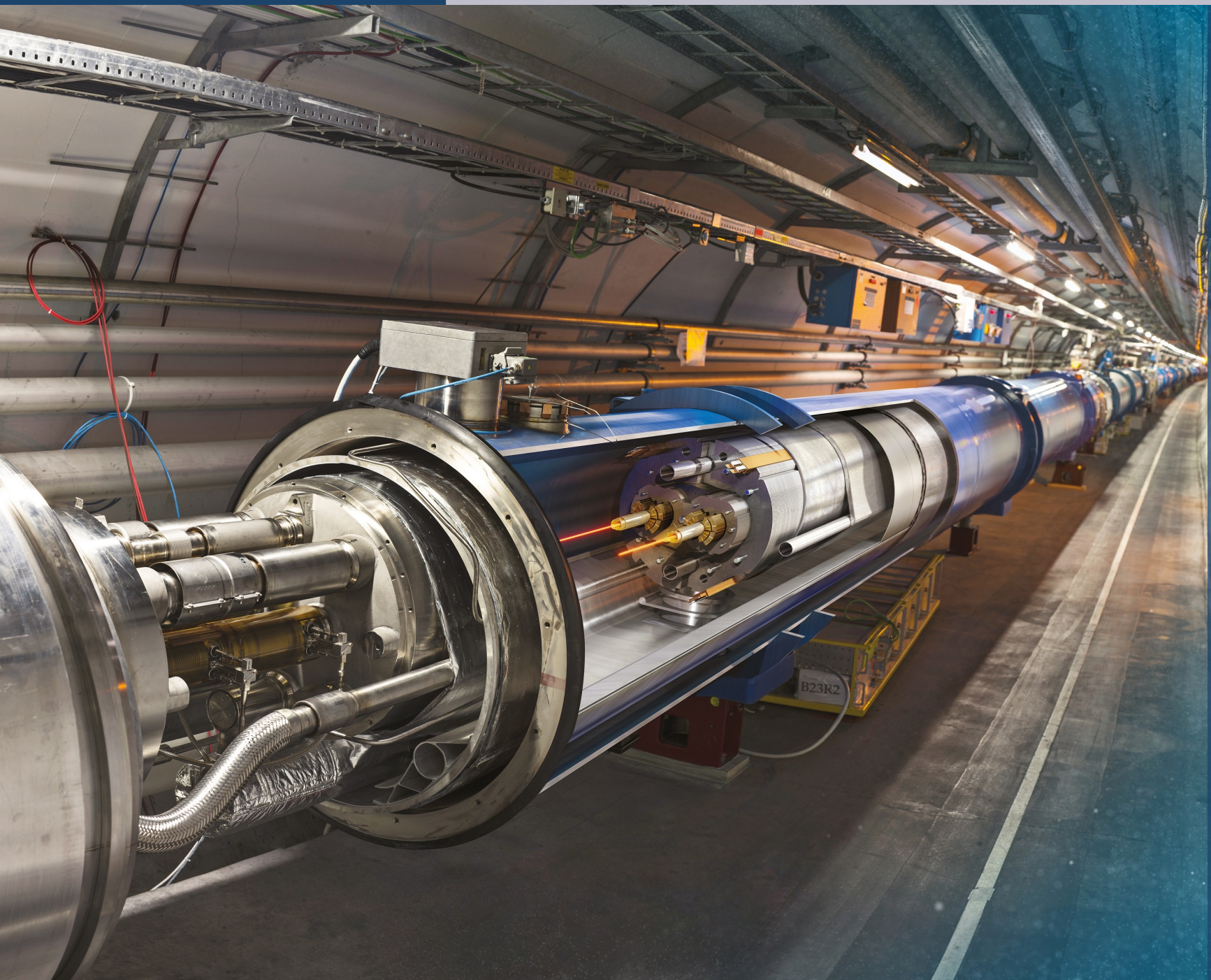
CERN develops technologies in three key areas

ACCELERATORS



DETECTORS

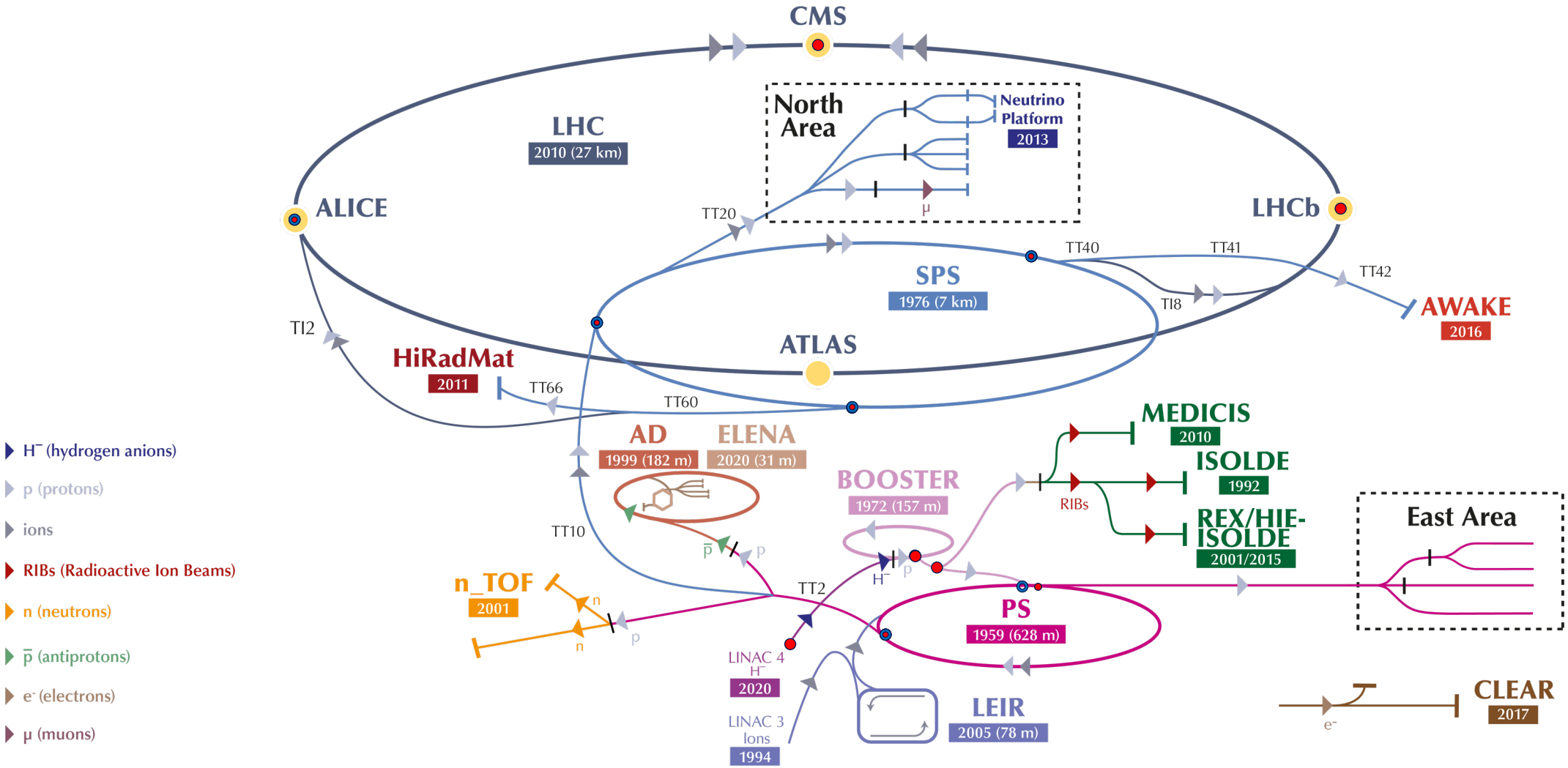
COMPUTING



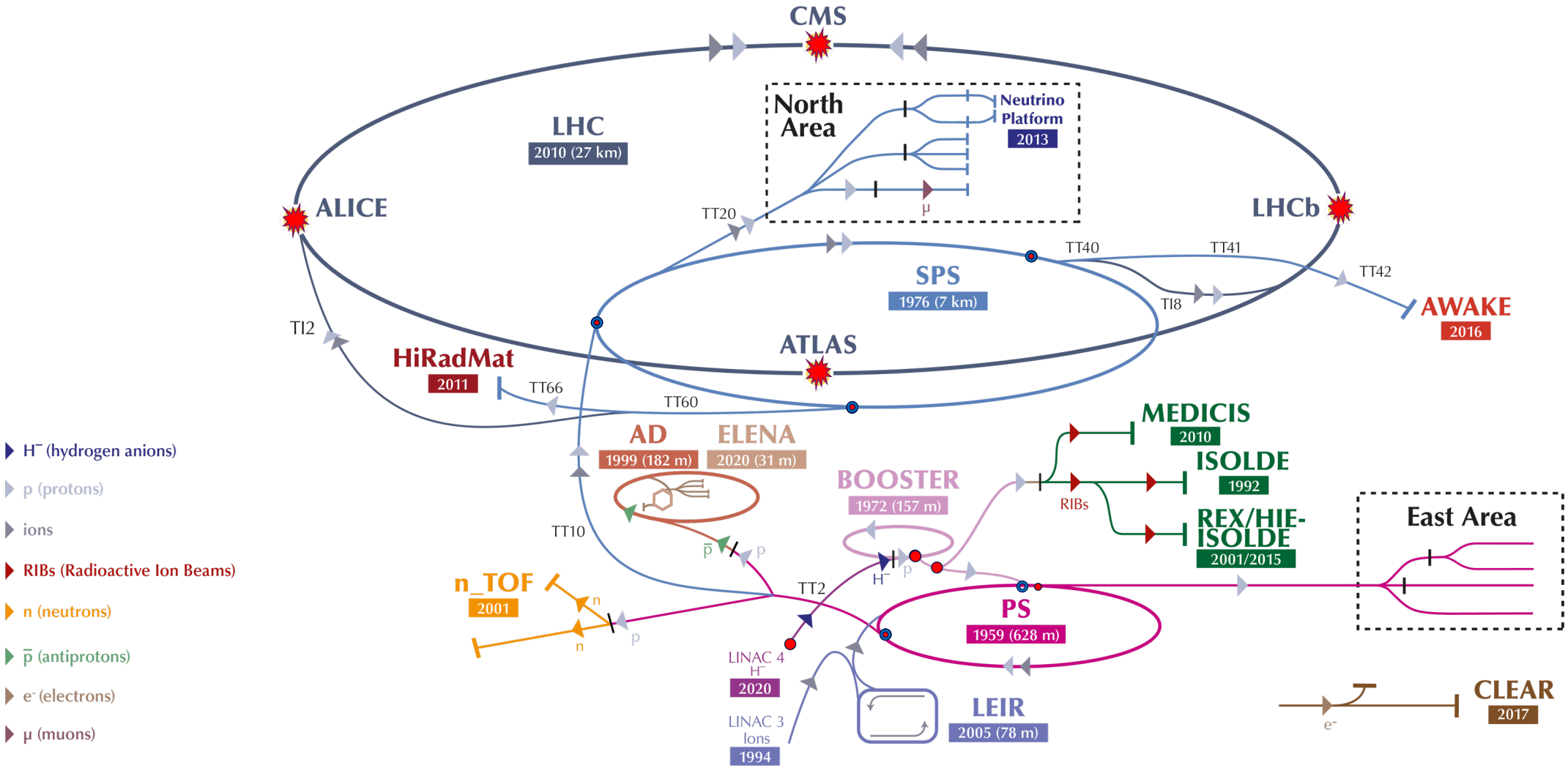
Large Hadron Collider (LHC)

- 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

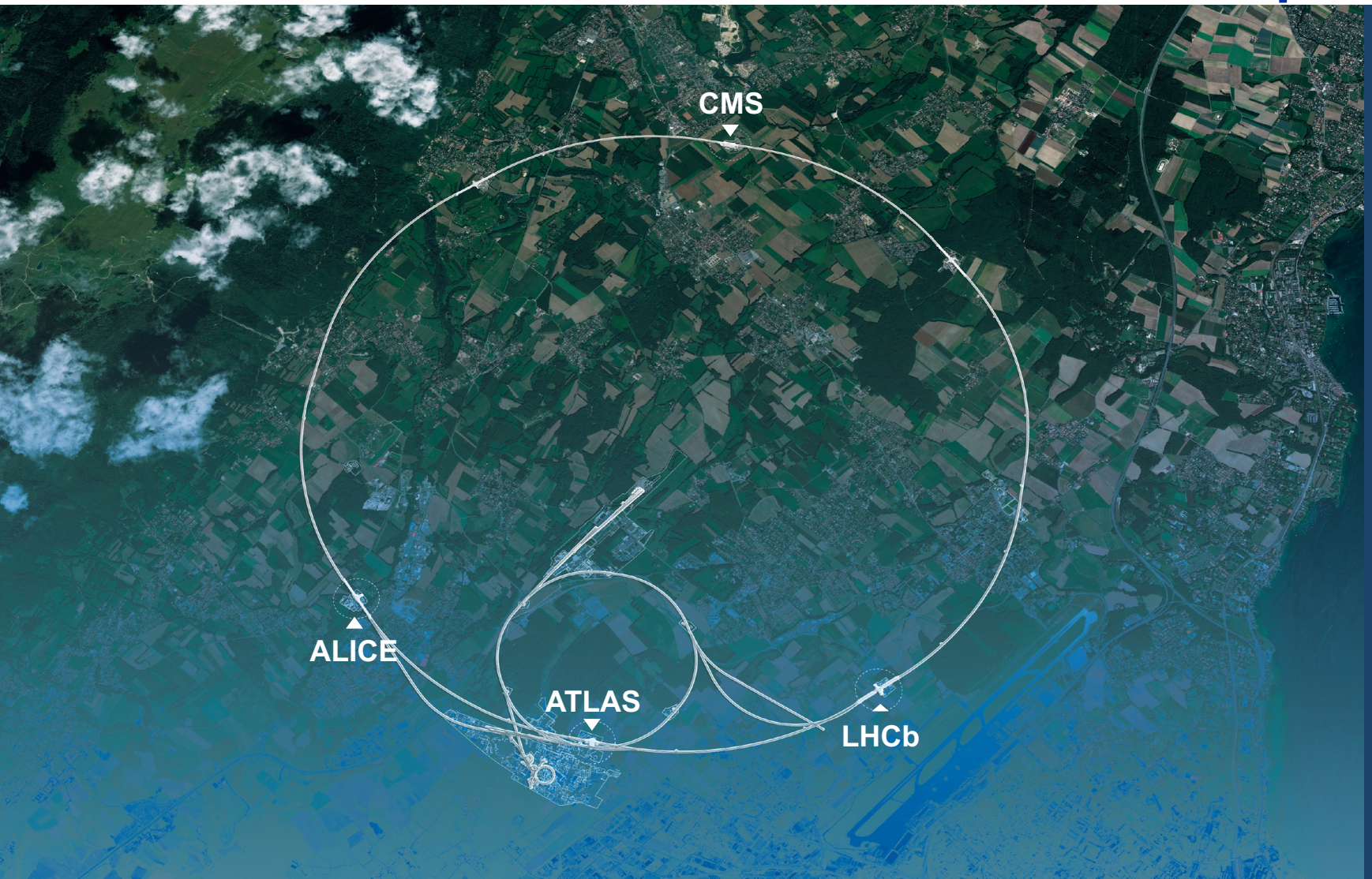
The CERN accelerator complex

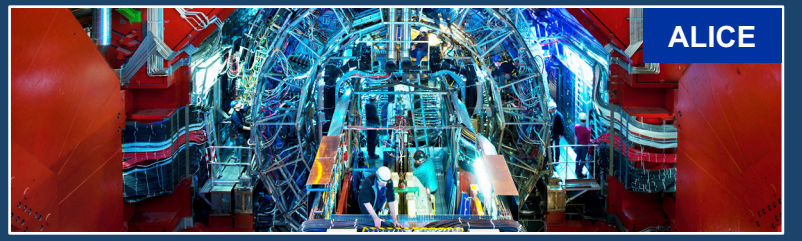


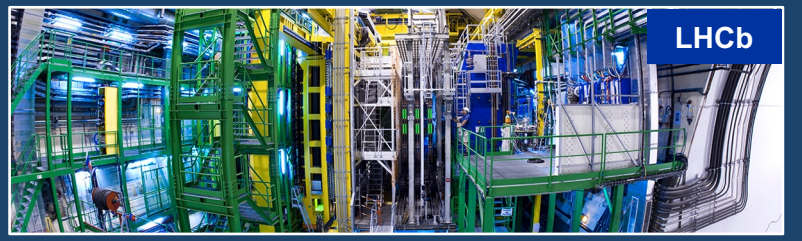
The CERN accelerator complex



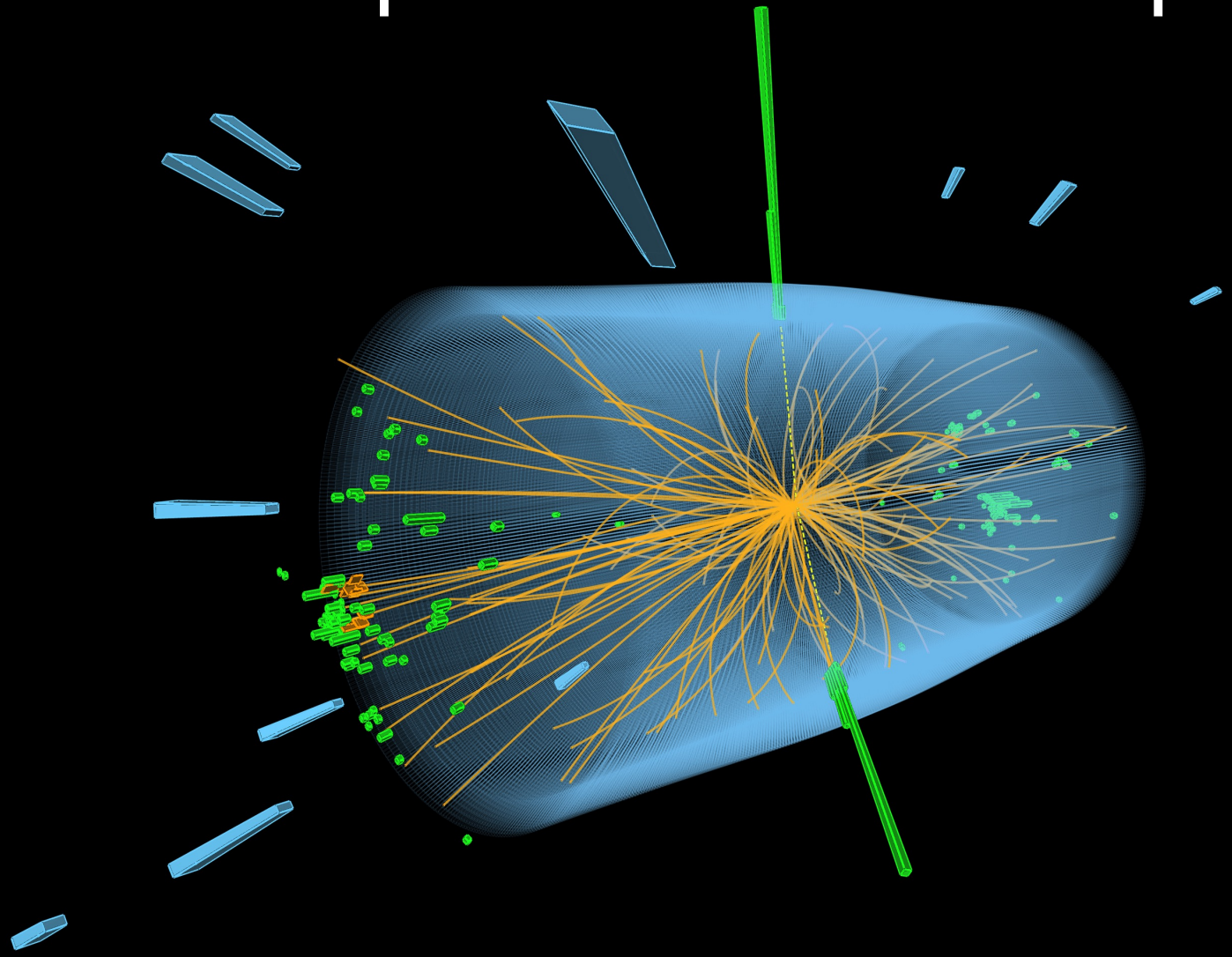
Giant detectors record the particles formed at the four collision points







The LHC produces more than 1 billion particle collisions per second



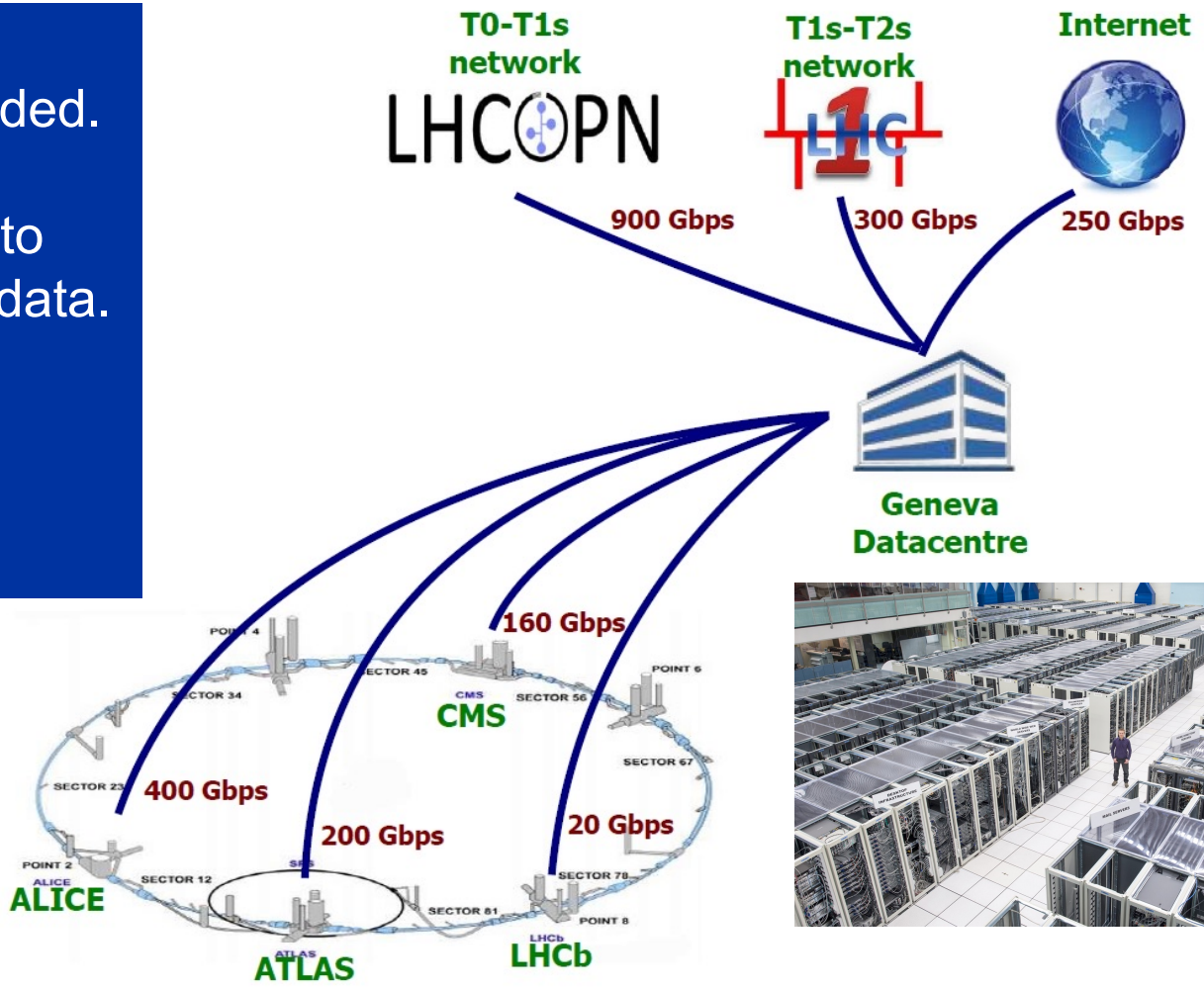
The energy of the particles in collision is converted into new particles.

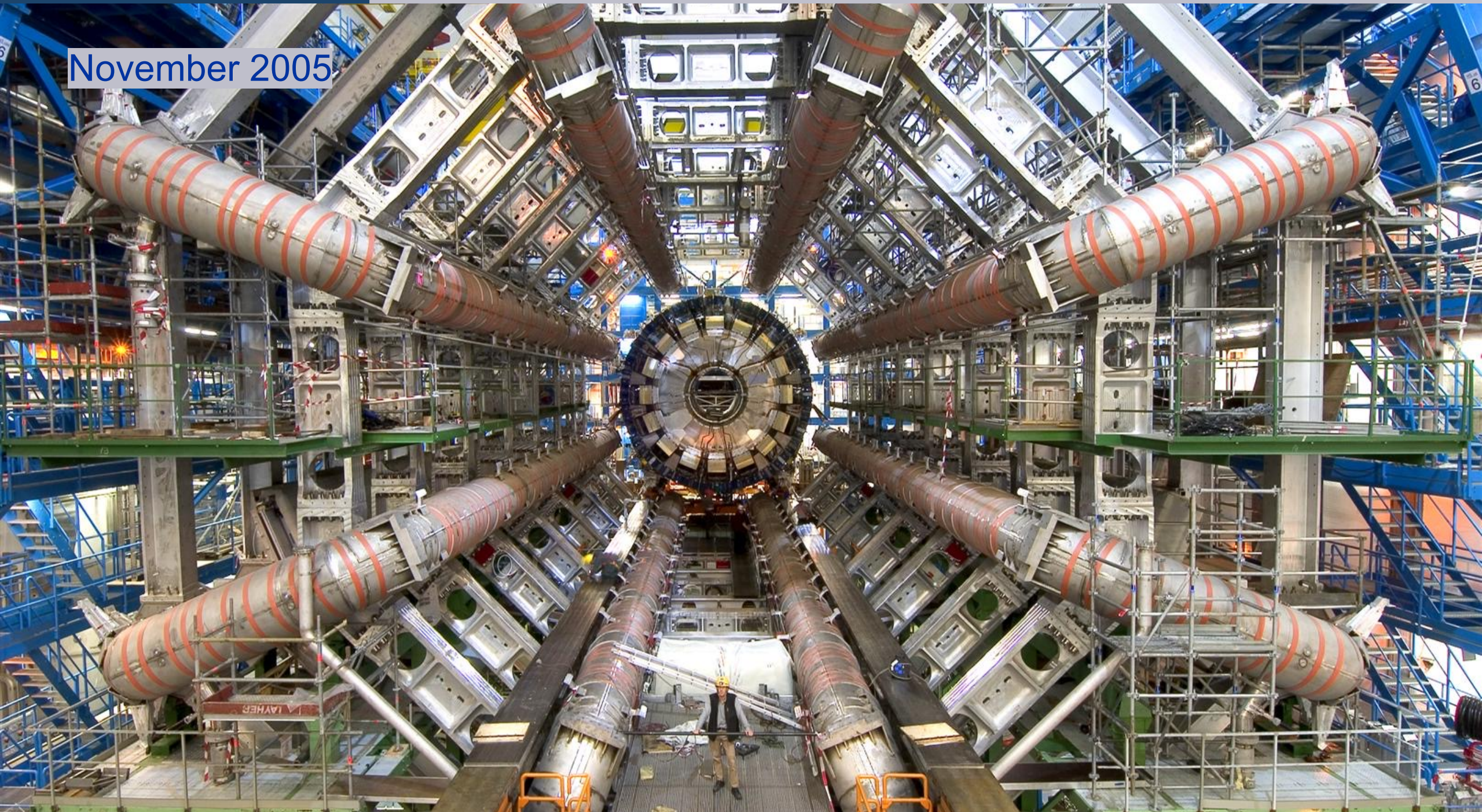
Big Science – Big Data

40 million pictures per second per experiment, of which only ~1000 recorded.

Worldwide LHC Computing Grid used to store, distribute, process and analyse data.

- 1 million processing cores
- 170 data centres in 42 countries
- 1000 PB of storage




November 2005

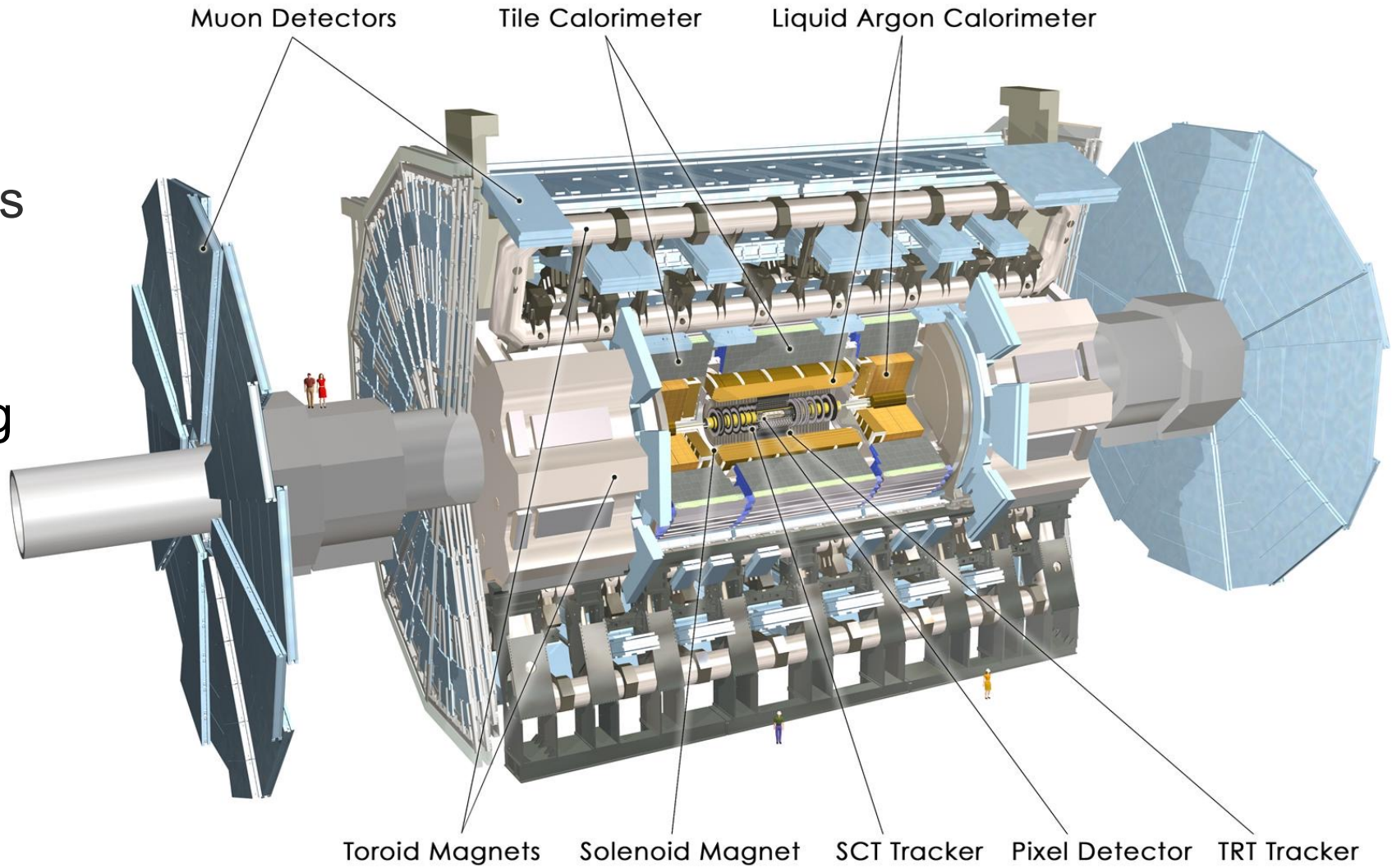
ATLAS Experiment

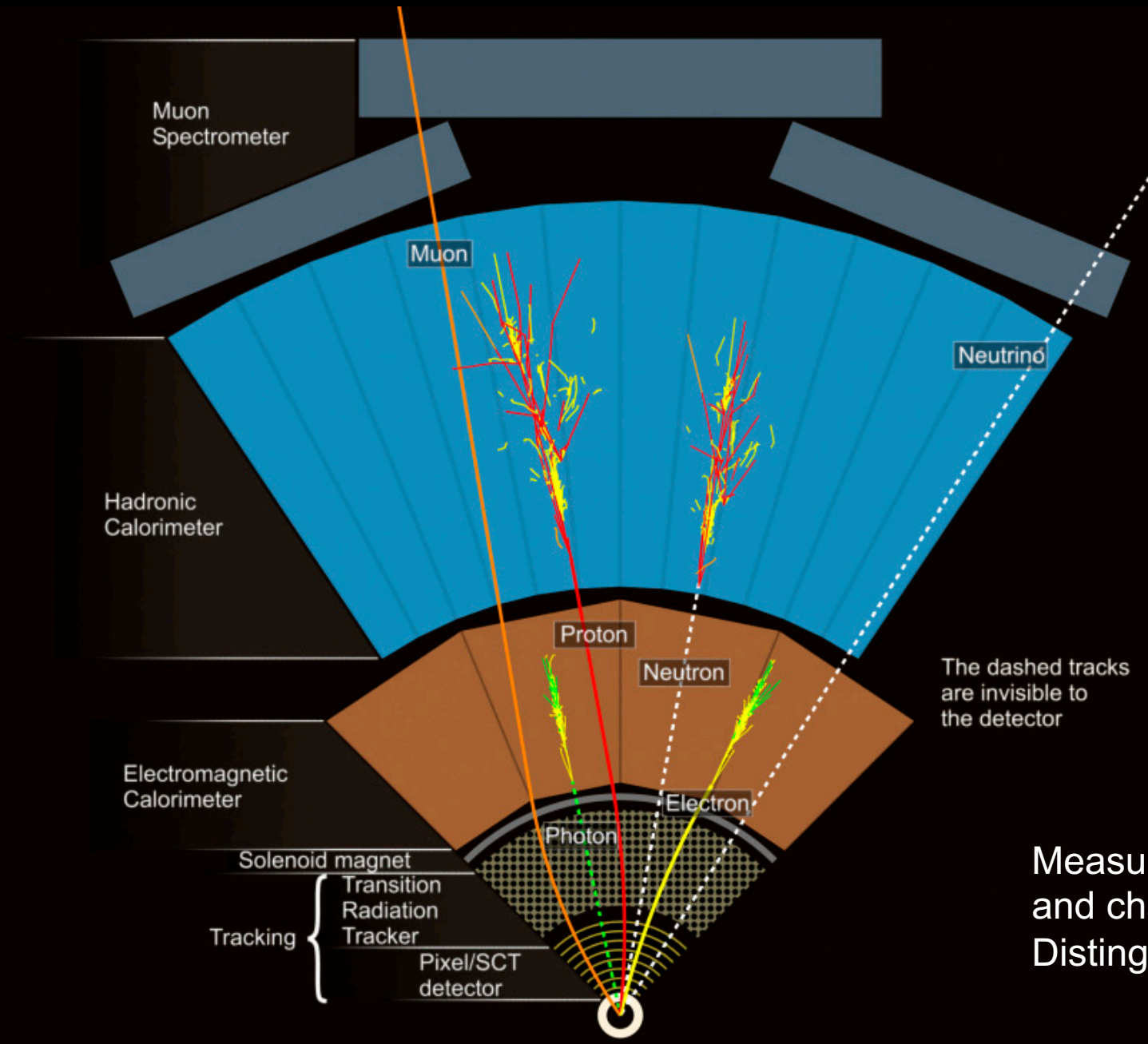
25m high, 44m long

Total weight 7000 tonnes

100 million “pixels” per picture.

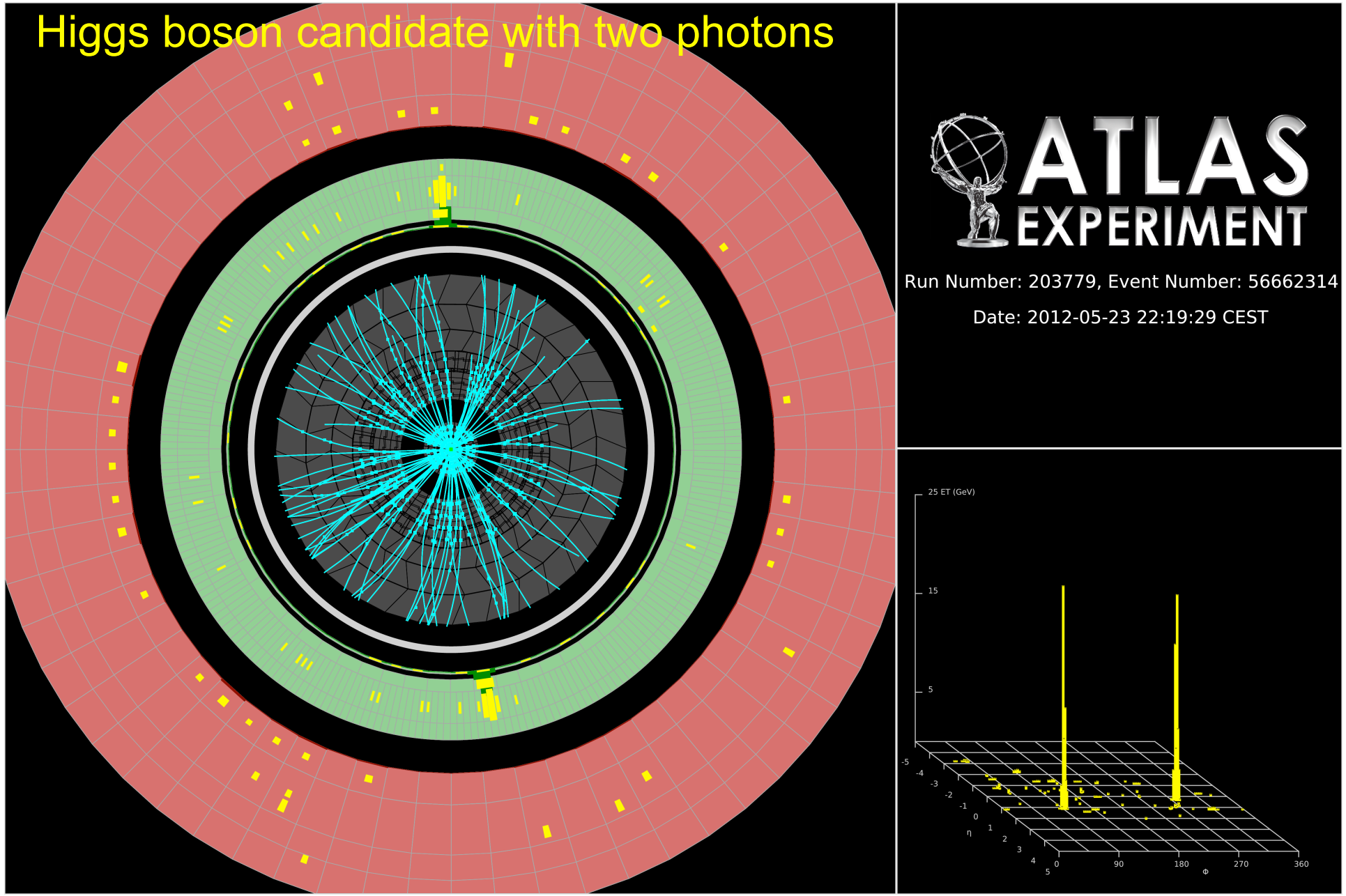
3000 scientists including 1000 students

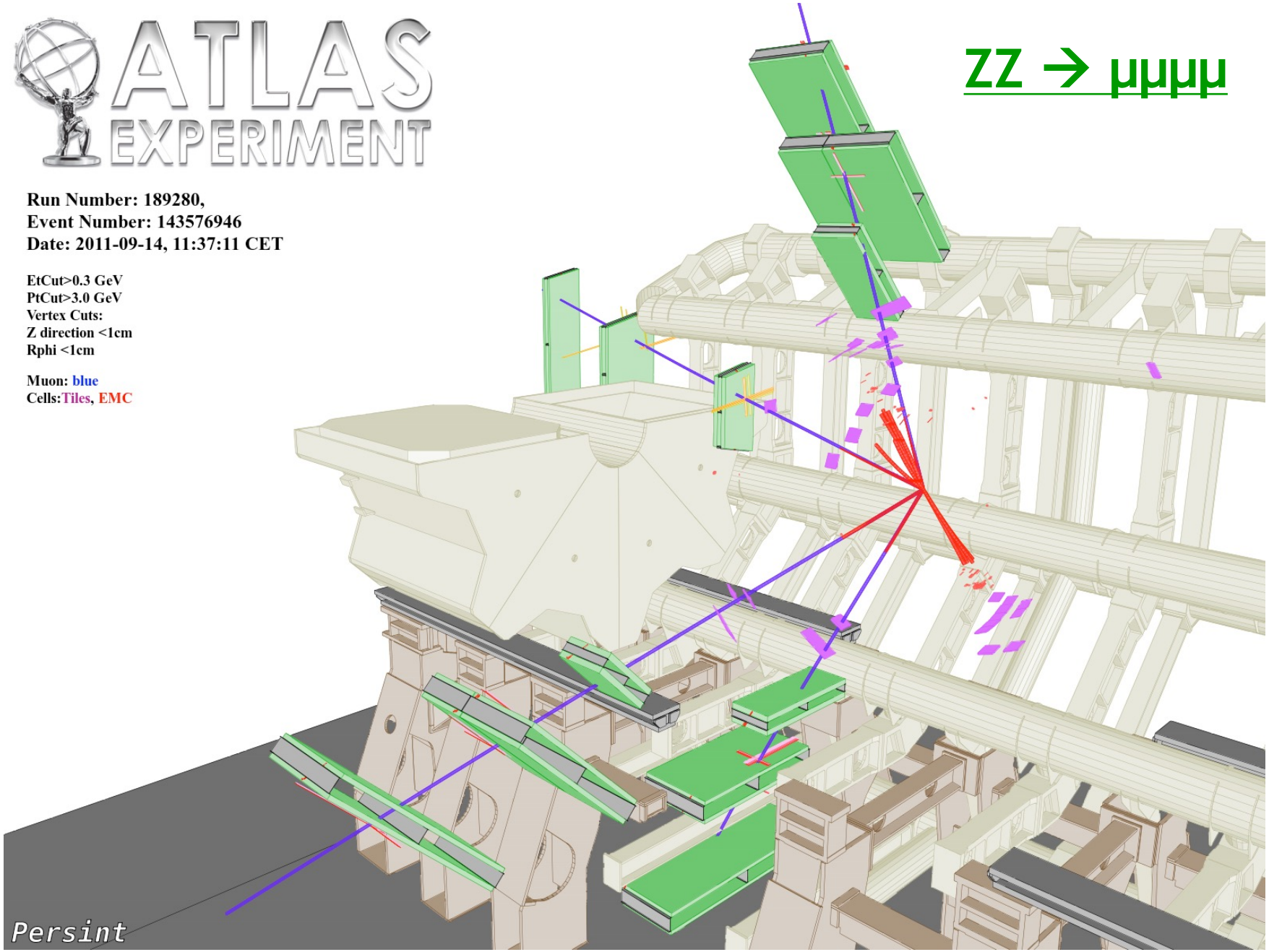




Measure the particles' energy, direction and charge.
Distinguish different particle types.

Higgs boson candidate with two photons




ATLAS
EXPERIMENT
Run Number: 189280,
Event Number: 143576946
Date: 2011-09-14, 11:37:11 CET
EtCut>0.3 GeV
PtCut>3.0 GeV
Vertex Cuts:
Z direction <1cm
Rphi <1cm
Muon: blue
Cells:Tiles, EMC
ZZ → μμμμ
Persint

Higgs boson Discovery 2012, Nobel Prize 2013

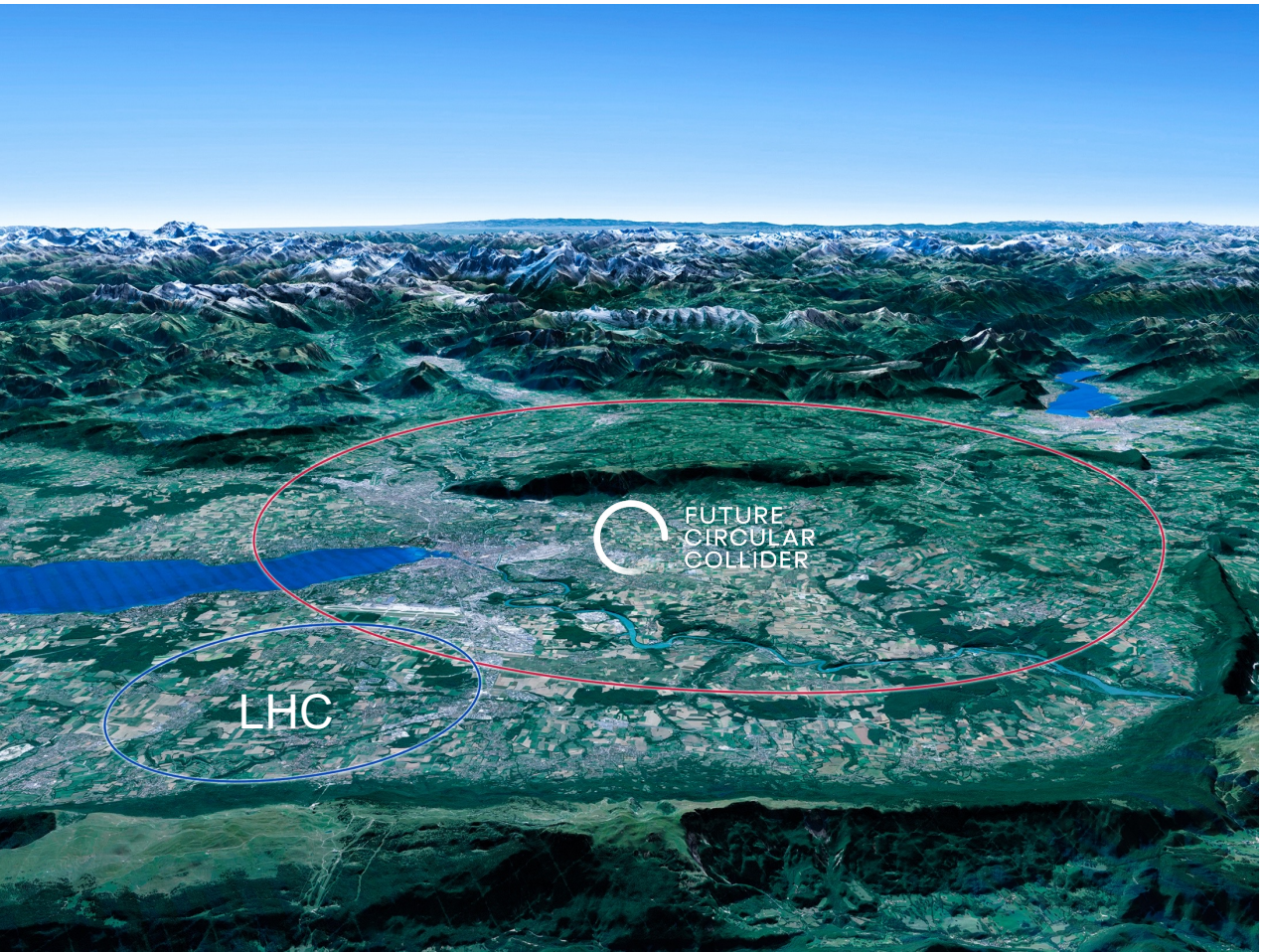
François Englert and Peter Higgs on 4 July 2012. In 1964, with Robert Brout, they proposed the mechanism by which fundamental particles can have a mass.

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?

European Strategy Update



Scientific priorities for the future

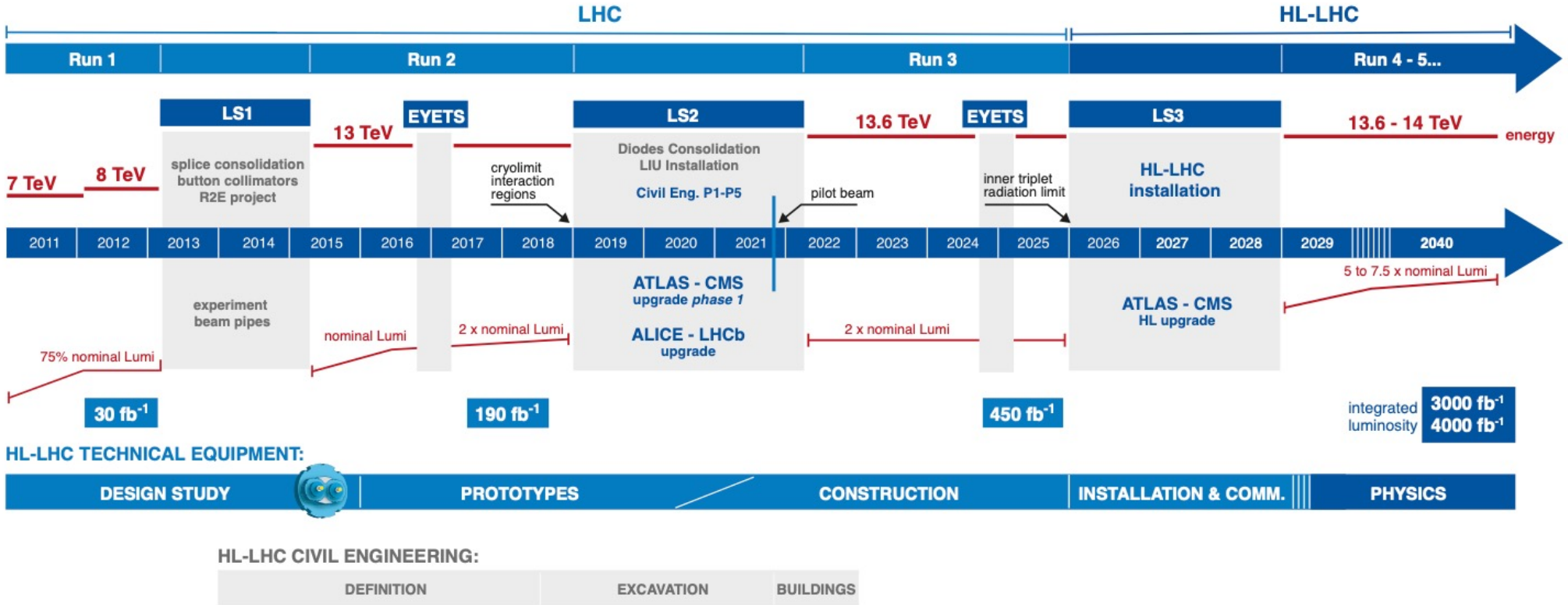
Implementation of the recommendations of the **2020 Update of the European Strategy for Particle Physics**:

- Fully exploit the High Luminosity 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

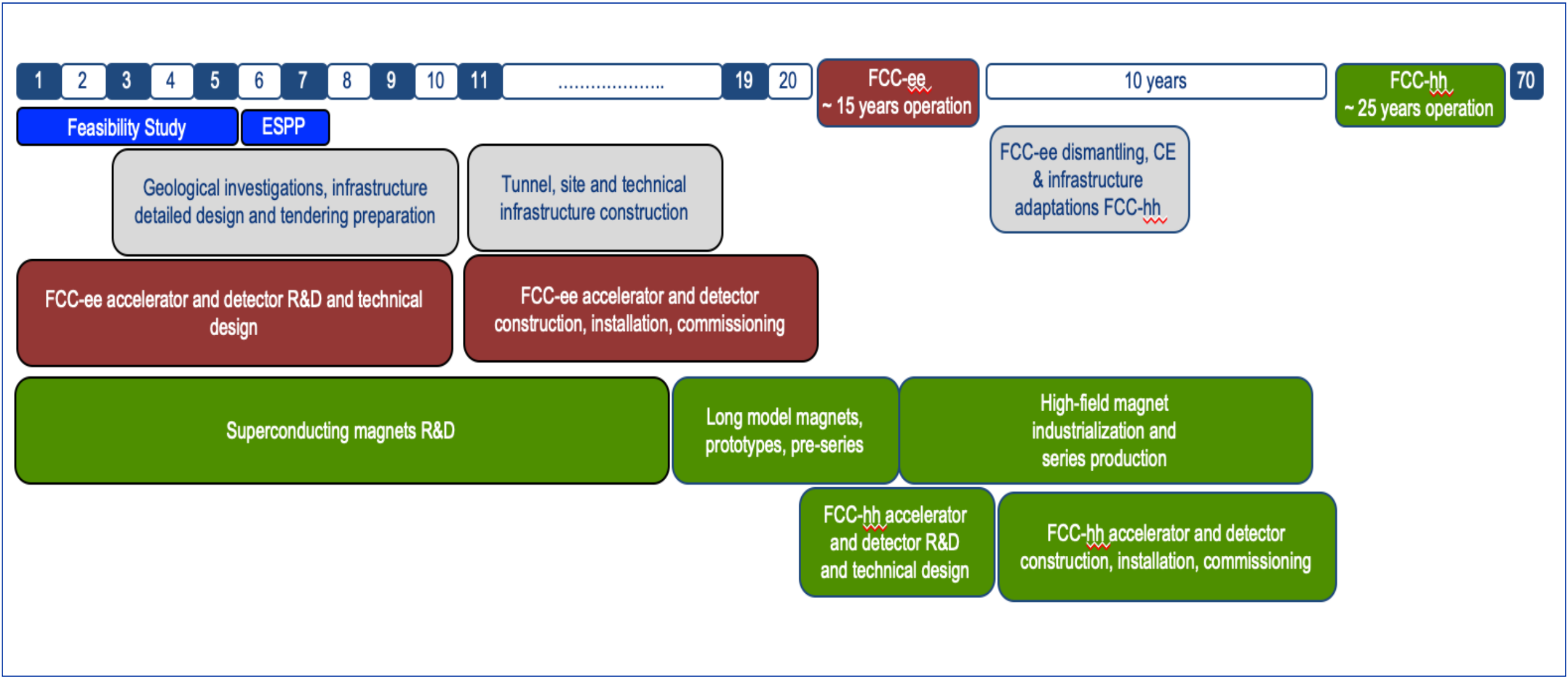
Upgrade to the High-Luminosity LHC is under way

- Run 3 just started. Aim to double the data sample.
- Then HL-LHC will use new technologies to provide 10 times more collisions than the LHC. Experiments also need major upgrades.
- It will give access to rare phenomena, greater precision and discovery potential.
- It will start operating in 2029, and run until ~2040.

LHC / HL-LHC Plan



Future Circular Collider Timeline

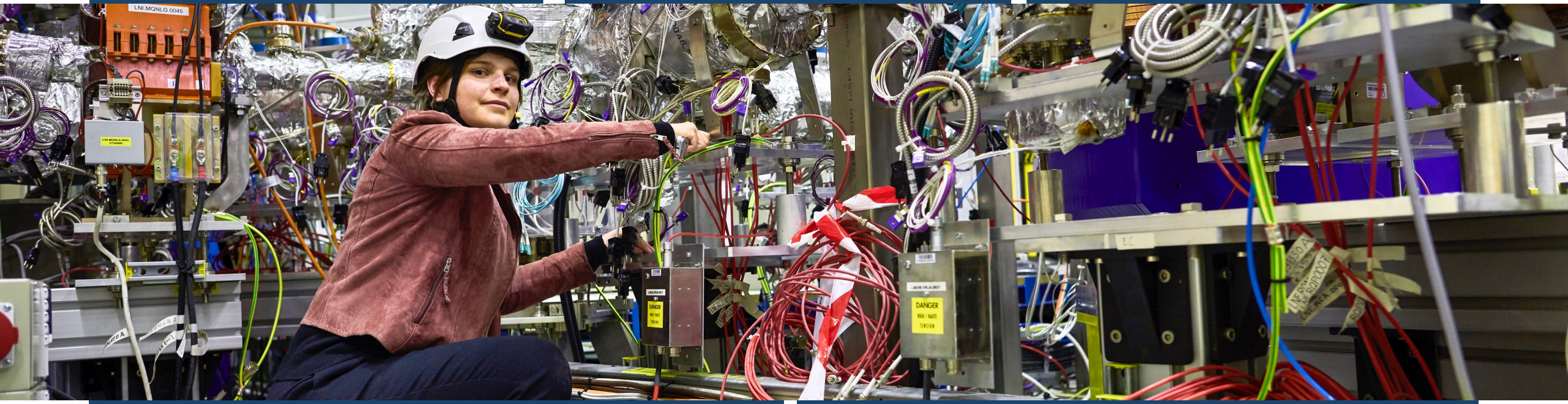


CERN has a diverse scientific programme

Nuclear Physics (ISOLDE)

Antimatter Research (Antiproton Decelerator)

Cosmic rays and cloud formation (CLOUD)



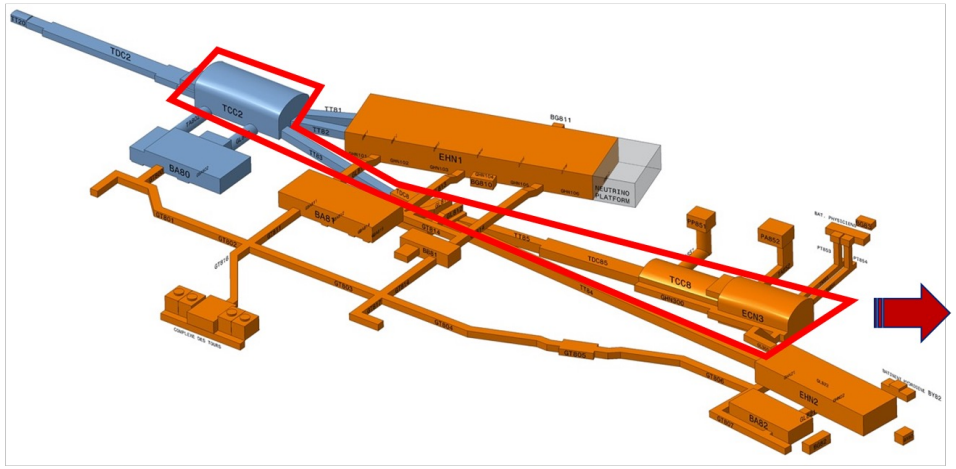
Fixed-target experiments, which include searches for rare phenomena

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

Physics Beyond Colliders

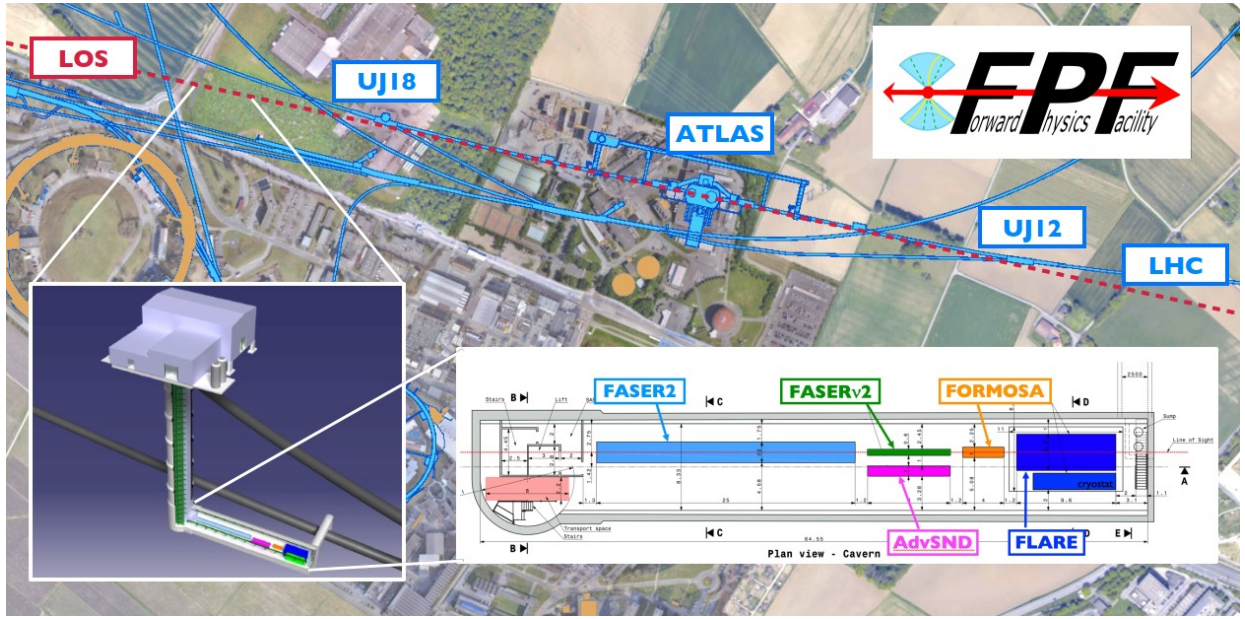
North Area High Intensity Beams ECN3
Several experiments under study: HIKE, SHADOWS, Beam Dump Facility with SHiP, TauFV
Report on post LS3 options to SPSC in 2023

Consolidation Phase 1 (funded): 2019 – 2027



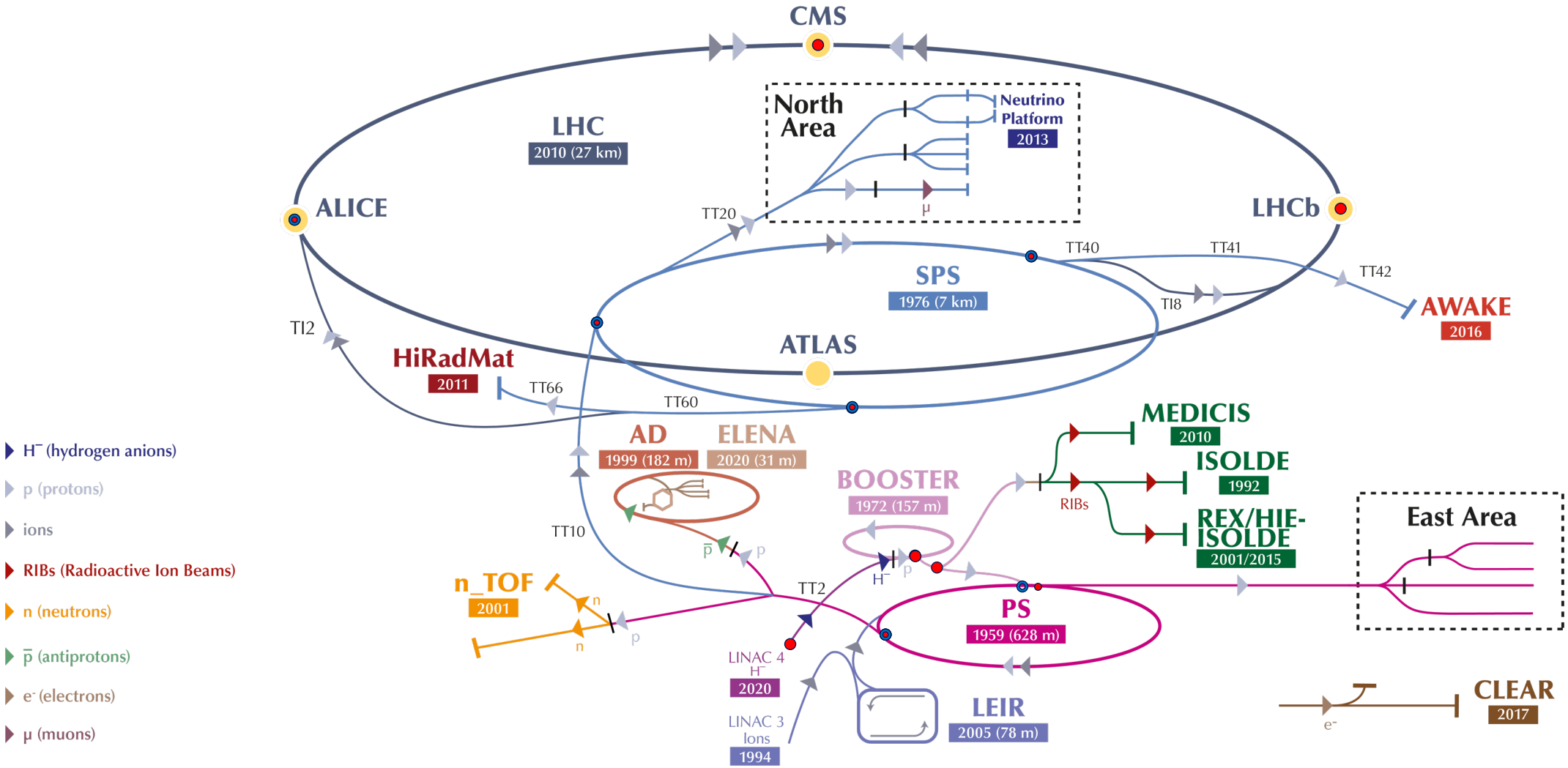
Consolidation Phase 2 (not yet funded): 2028 – 2033

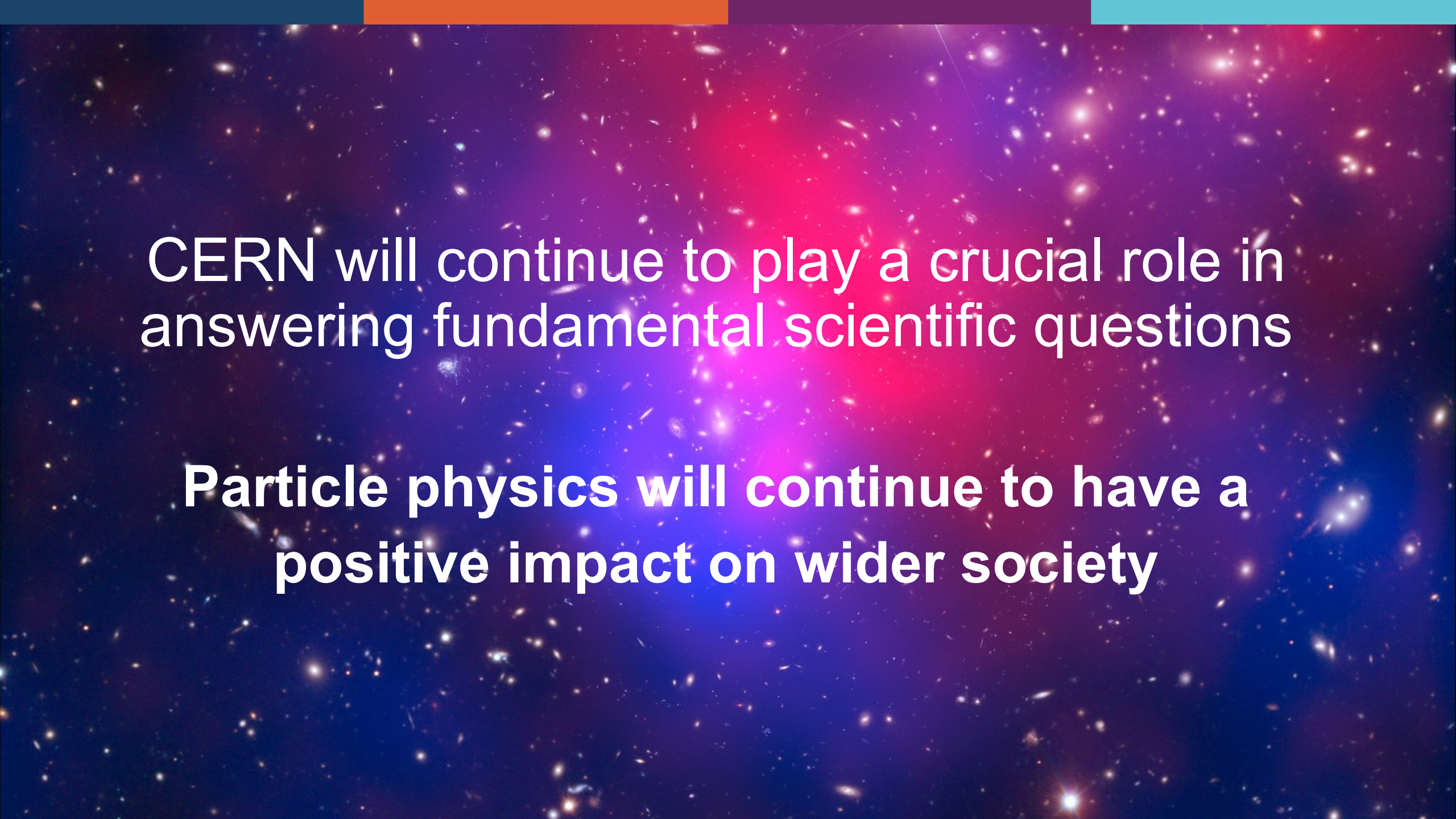
Areas concerned with high intensity beams



Long lived particles (LLP) @ LHC:
Forward Physics Facility (in line of sight of ATLAS interaction point) – preparing EoI
LLP experiments at large angle to the beam line
LHC fixed target: gas targets; crystal extraction

The CERN accelerator complex




CERN will continue to play a crucial role in answering fundamental scientific questions
Particle physics will continue to have a positive impact on wider society