Brief Introduction to CERN

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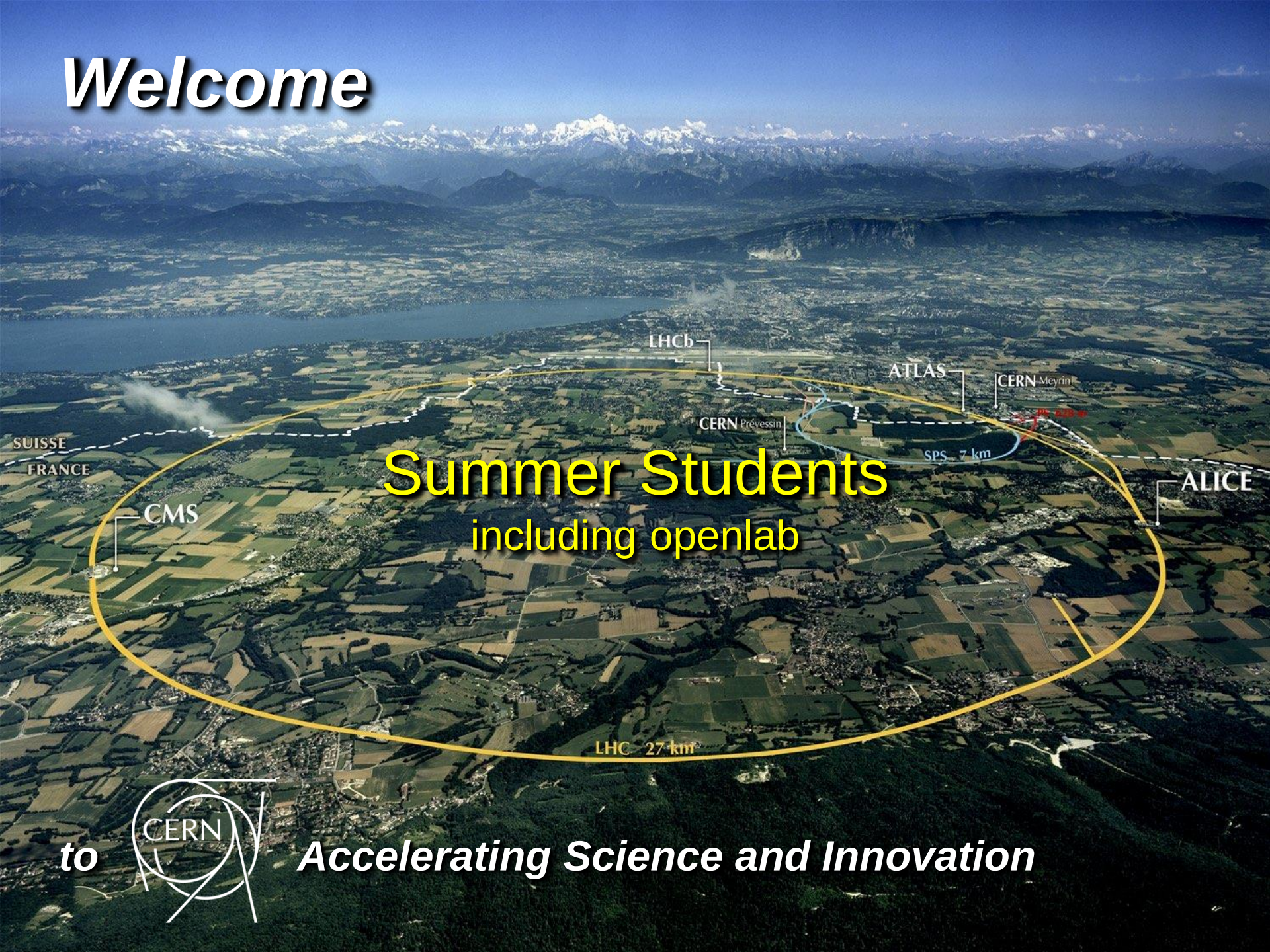
8.7.2018


Welcome
LHCb
ATLAS
CERN Meyrin
CERN Prévessin
SPS 7 km
SUISSE
FRANCE
CMS
ALICE
Summer Students
including openlab
LHC 27 km
to
CERN
Accelerating Science and Innovation

CERN's Mission

- Fundamental research in particle physics
- Technology and innovation
  - transfer to society
    (e.g. the World Wide Web)
- Training and education
- Unite people in their quest for knowledge:
  - > 13000 scientists, > 110 nationalities

CERN staff member T. Berners-Lee,
inventor of the WEB, with Kofi Annan

Samuel Ting
Nobel Prize, 1976

George Charpak,
Nobel Prize, 1992

Carlo Rubbia,
Nobel Prize, 1984

CERN: founded in 1954: 12 European States
"Science for Peace"
Today: 23 Member States

~ 2500 staff
~ 1800 other paid personnel
~ 13000 scientific users

Budget (2017) ~ 1100 MCHF

Member States: Austria, Belgium, Bulgaria, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Israel, Italy, Netherlands, Norway, Poland, Portugal, Romania, Serbia, Slovak Republic, Spain, Sweden, Switzerland and United Kingdom

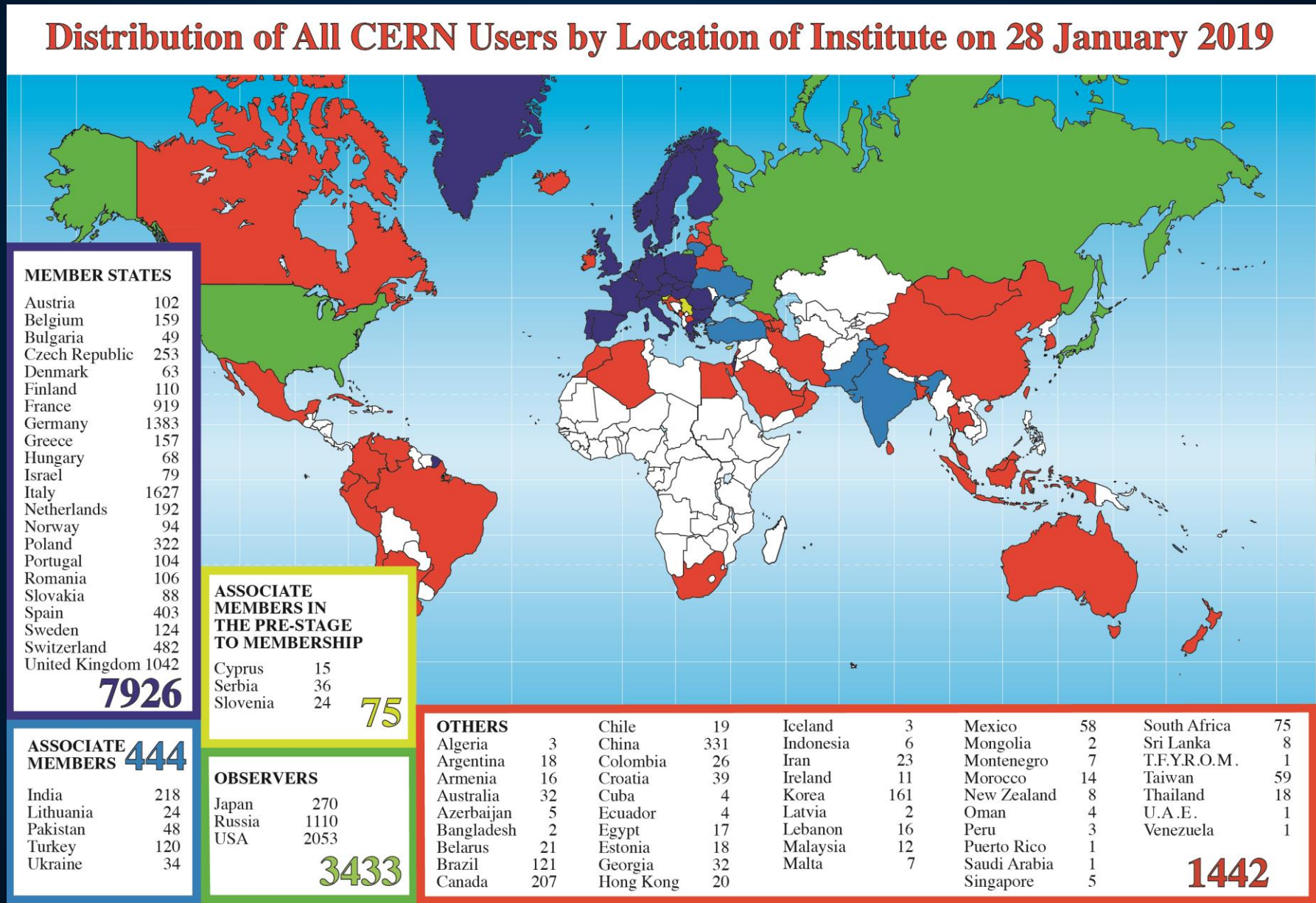
Associate Members in the Pre-Stage to Membership: Cyprus, Slovenia

Associate Member States: India, Lithuania, Pakistan, Turkey, Ukraine

Applications for Membership or Associate Membership: Brazil, Croatia

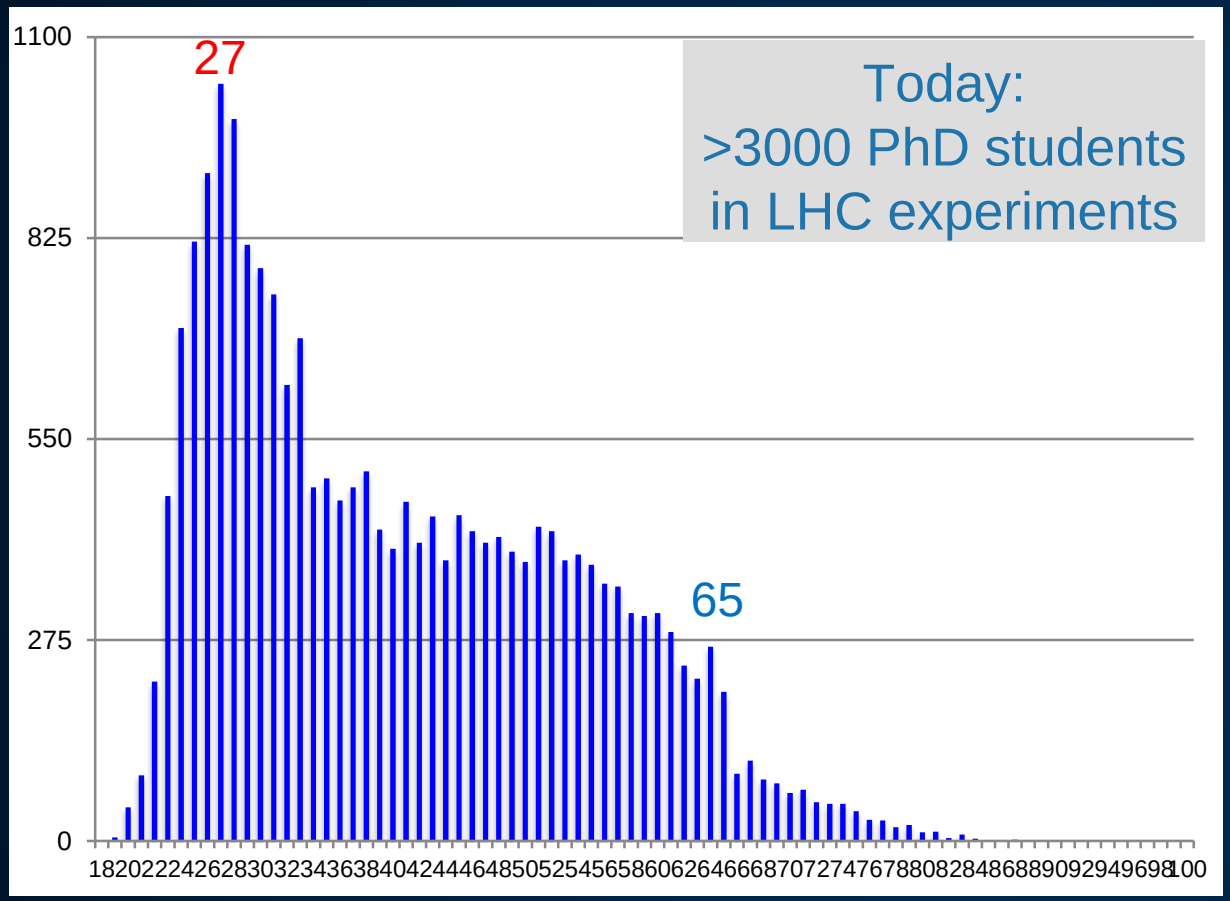
Observers to Council: Japan, Russia, United States of America; European Union, JINR and UNESCO

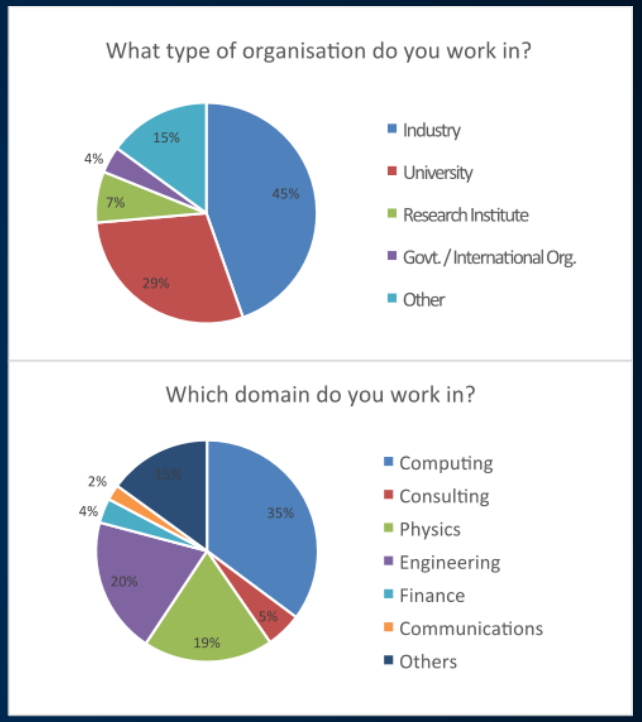
Science is getting more and more global



Age Distribution of Scientists

- and where they go afterwards

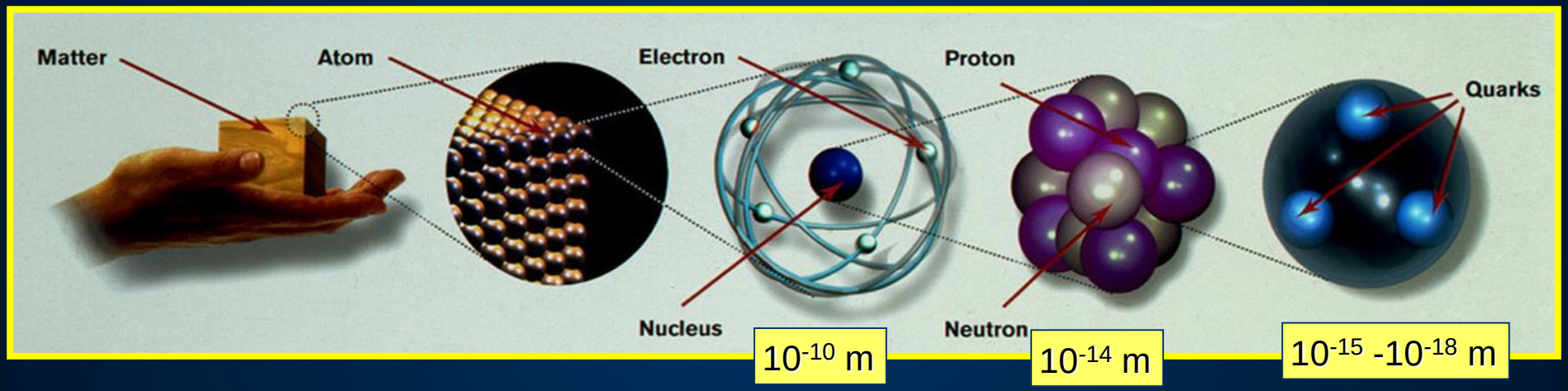




They do not all stay: where do they go?

CERN's primary mission is SCIENCE

Study the elementary particles (e.g. the building blocks of matter: electrons and quarks) and the forces that control their behaviour at the most fundamental level

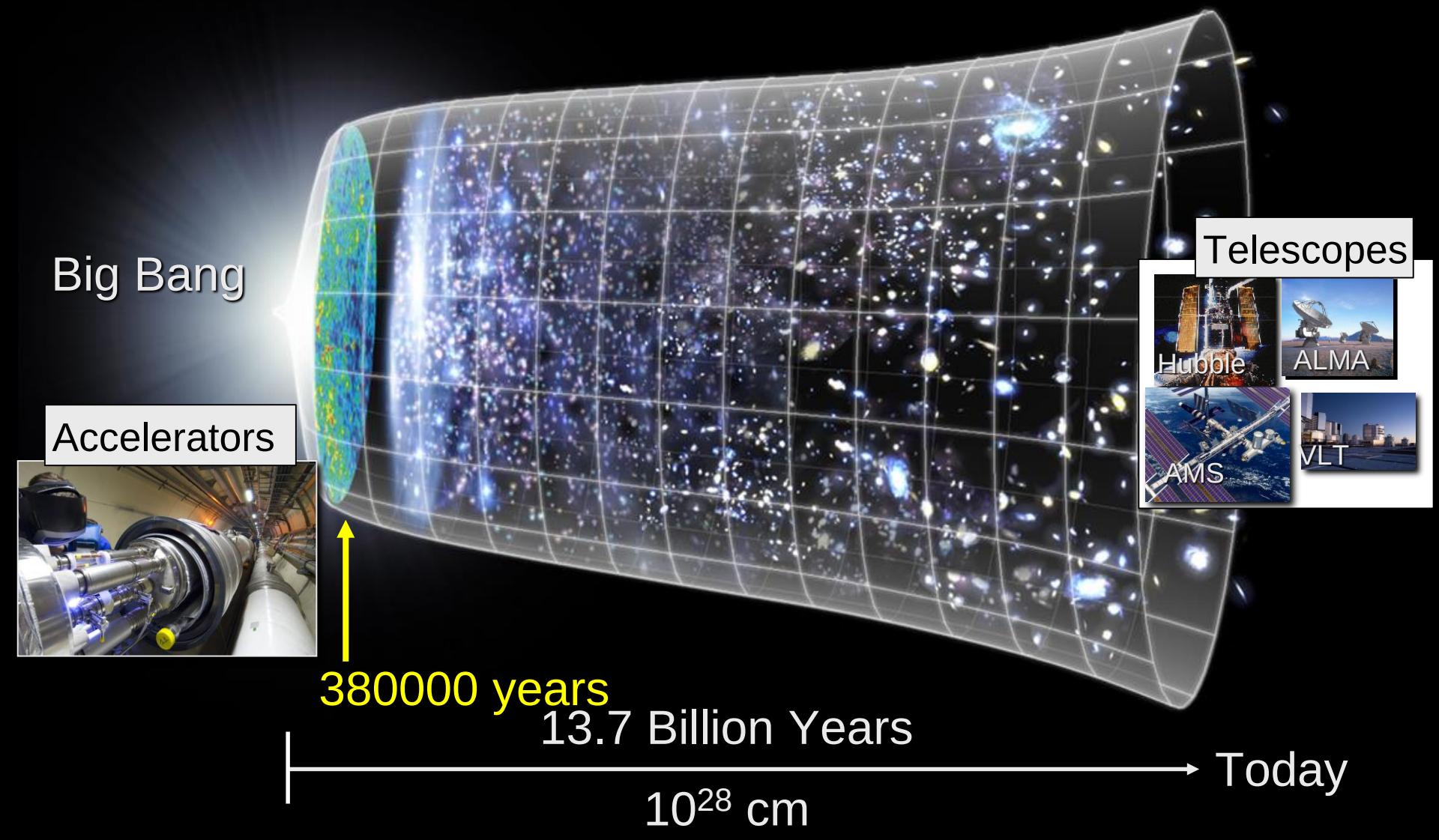


Modern accelerators enable us to study the fundamental laws of nature on scales smaller than 10^{-18} m

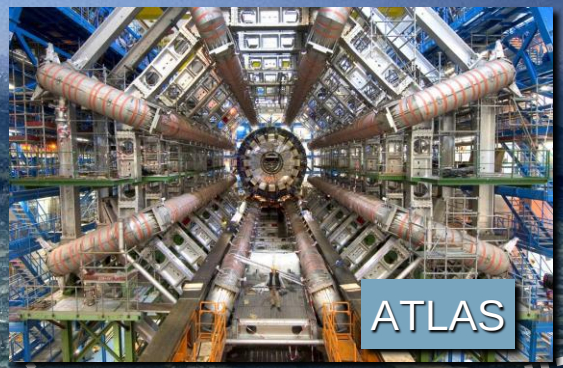
à insight also into the structure and evolution of the Universe

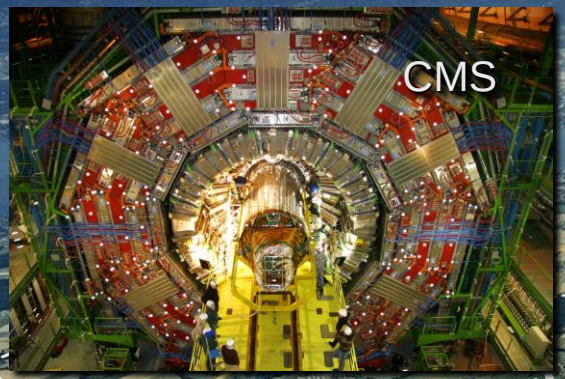
à from the very small to the very big …

Evolution of the Universe



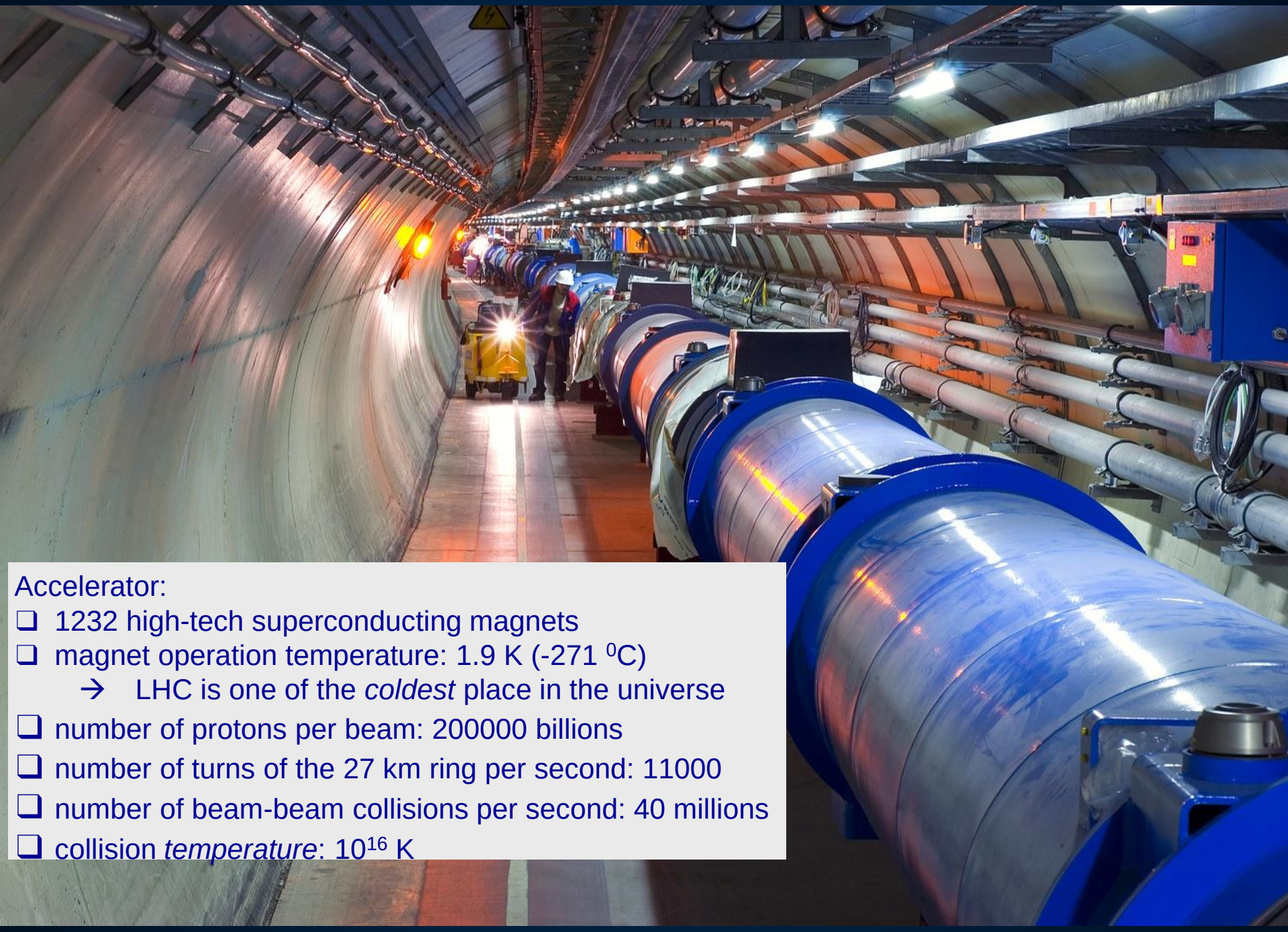
2010: a New Era in Fundamental Science





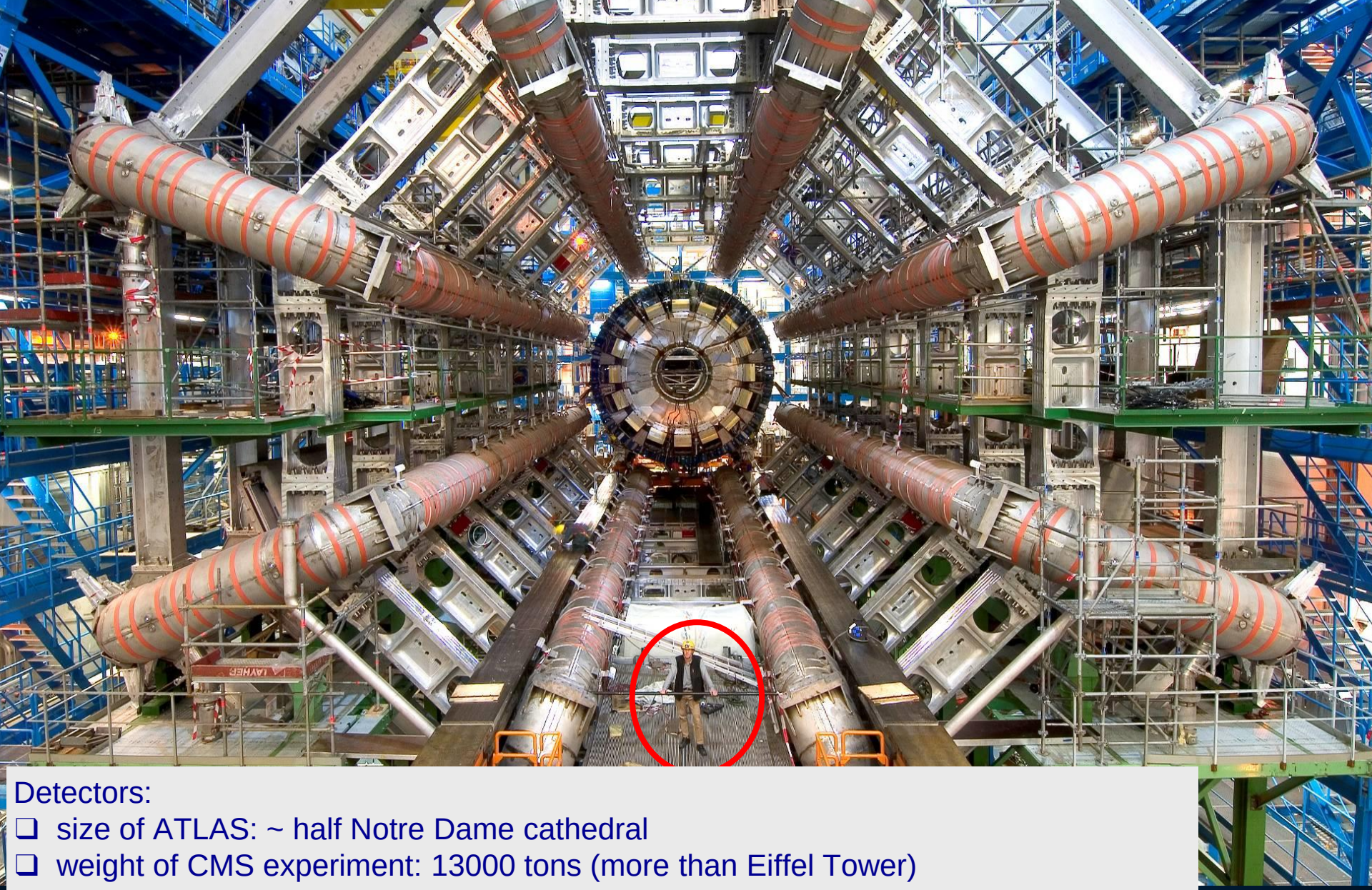
LHCb
ATLAS
CERN Meyrin
CERN Prévessin
SPS 7 km
CMS
ALICE

Exploration of a new energy frontier



Accelerator:

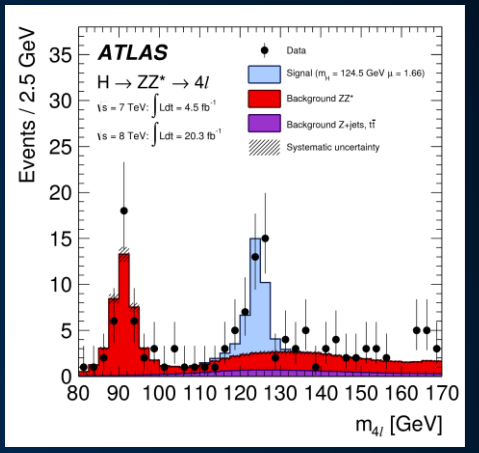
- 1232 high-tech superconducting magnets
- magnet operation temperature: 1.9 K (-271 ^{0}C)
  - → LHC is one of the *coldest* place in the universe
- number of protons per beam: 200000 billions
- number of turns of the 27 km ring per second: 11000
- number of beam-beam collisions per second: 40 millions
- collision *temperature*: 10^{16} K

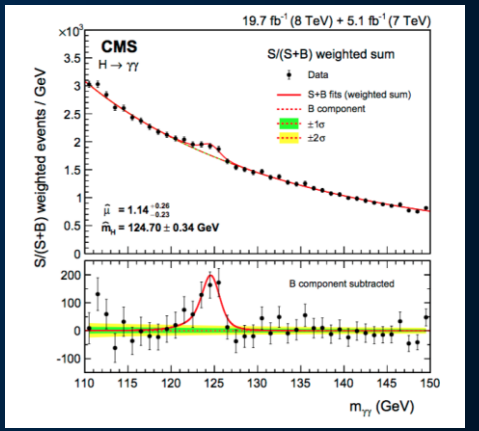


Detectors:

- size of ATLAS: ~ half Notre Dame cathedral
- weight of CMS experiment: 13000 tons (more than Eiffel Tower)
- number of detector sensitive elements: 100 millions
- cables needed to bring signals from detector to control room: 3000 km
- data in 1 year per experiment: ~10 PB (20 million DVD; more than YouTube, Twitter)

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".*

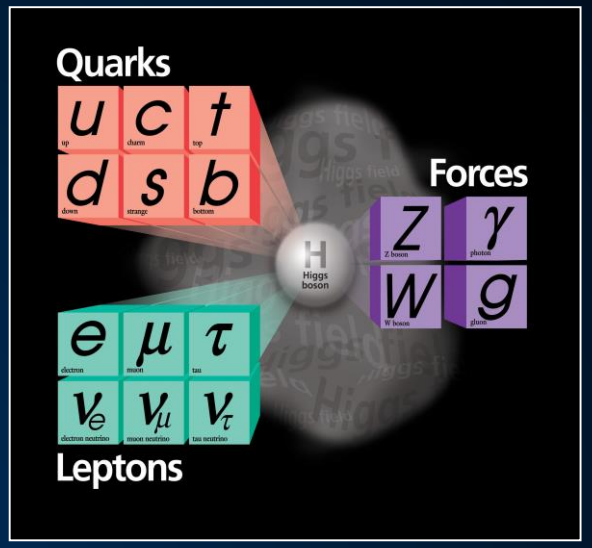




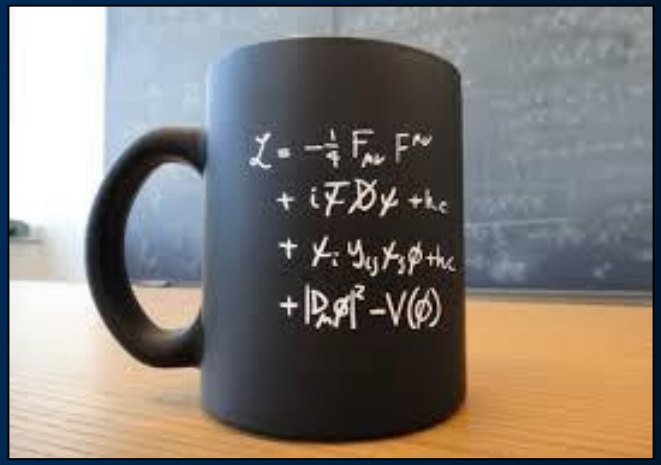
Discovery 2012

These are very exciting times in particle physics!

With the discovery of the Higgs boson,
we have completed the Standard Model
(> 50 years of theoretical and experimental efforts !)



We have tested the Standard Model with very high precision (wealth of measurements since early '60s, in particular at accelerators)
à it works BEAUTIFULLY (puzzling …)
à no significant deviations observed (but difficult to accommodate non-zero neutrino masses)



However: the SM is not a complete theory of particle physics, as several outstanding questions remain (raised also by precise experimental observations) that cannot be explained within the SM.

These questions require NEW PHYSICS

Key questions in today's particle physics

- Why is the Higgs boson so light (so-called "naturalness" or "hierarchy" problem) ?
- What is the origin of the matter-antimatter asymmetry in the Universe ?
- Why 3 fermion families ? Why do neutral leptons, charged leptons and quarks behave differently ?
- What is the origin of neutrino masses and oscillations ?
- What is the composition of dark matter (23% of the Universe) ?
- What is the cause of the Universe's accelerated expansion (today: dark energy? primordial: inflation ?)
- Why is Gravity so weak ?

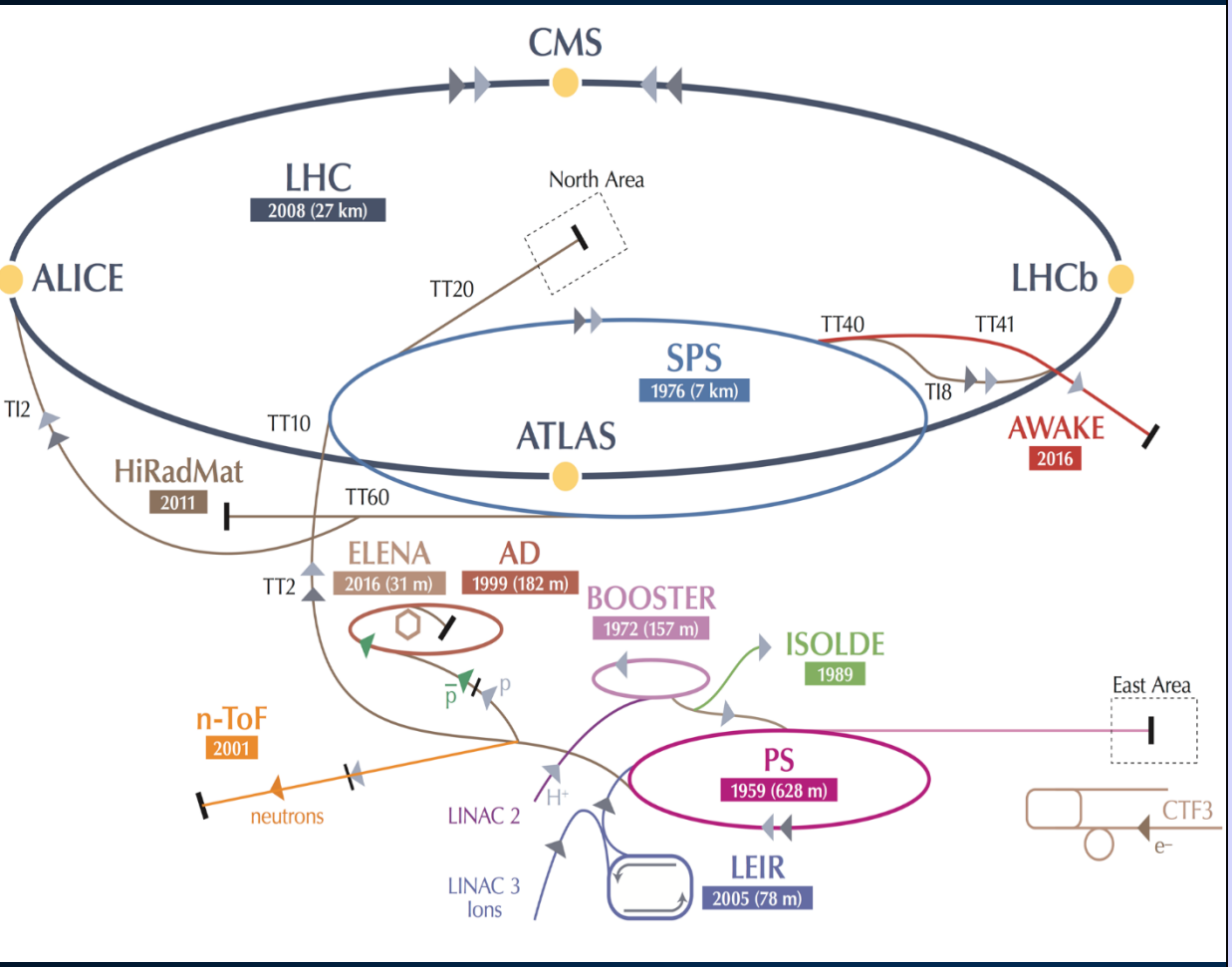
However, there is no direct evidence for new particles (yet…) from the LHC or other facilities.

– Where is the new physics?
– How does it couple?
– What is the (energy) scale?

LHC will be a/the primary research tool of the field over the next 20 years

CERN

CERN scientific programme



exploits unique capabilities of CERN's accelerator complex; complementary to other efforts in the world.

~20 projects other than LHC with > 1200 physicists

AD: Antiproton Decelerator for antimatter studies

AWAKE: proton-induced plasma wakefield acceleration

CAST, OSQAR: axions

CLOUD: impact of cosmic rays on aeorosols and clouds → implications on climate

COMPASS: hadron structure and spectroscopy

ISOLDE: radioactive nuclei facility

LHC

NA61/Shine: ions and neutrino targets

NA62: rare kaon decays

NA63: radiation processes in strong EM fields

NA64: search for dark photons

Neutrino Platform: ν detector R&D for experiments in US,Japan

n-TOF: n-induced cross-sections

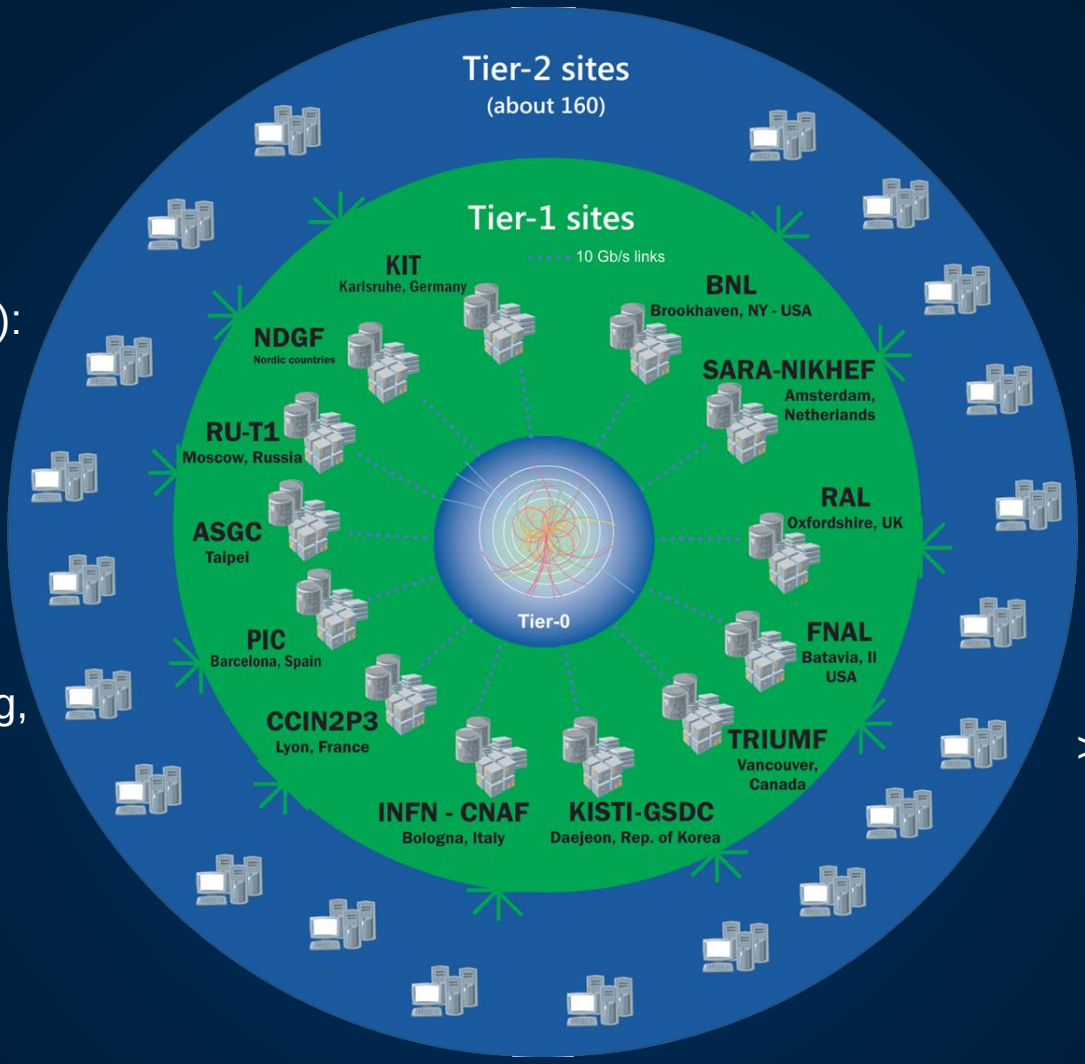
UA9: crystal collimation

The Worldwide LHC Computing Grid

Tier-0
(CERN and Hungary):
data recording,
reconstruction and
distribution

Tier-1: permanent
storage, reprocessing,
analysis

Tier-2: simulation,
end-user analysis



>170 sites in,
42 countries

750k CPU cores

800 PB of storage

> 2 million jobs/day

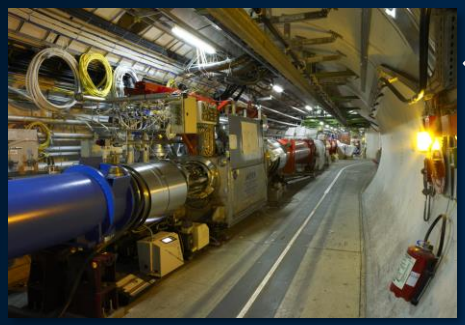
35 GB/s global
transfers

WLCG:
An International collaboration to distribute and analyse LHC data

Integrates computer centres worldwide that provide computing and storage resource into a single infrastructure accessible by all LHC physicists

Medical Application as an Example of Particle Physics Spin-off

Combining Physics, ICT, Biology and Medicine to fight cancer

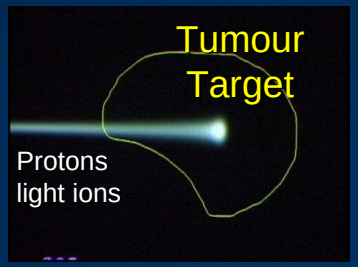


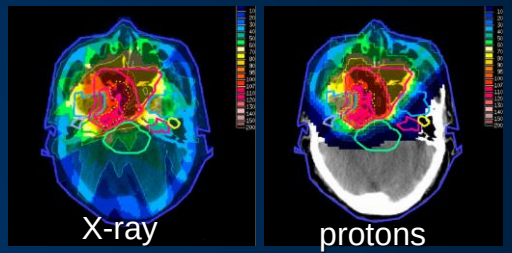
Accelerating particle beams

~30’000 accelerators worldwide

~17’000 used for medicine

Hadron Therapy

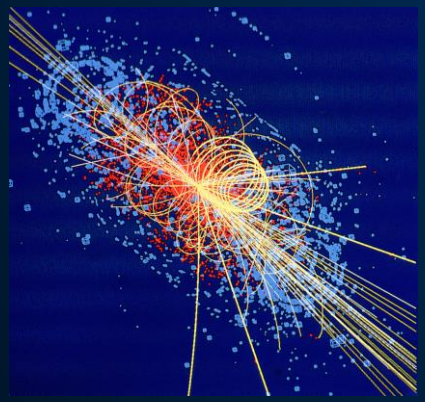




Leadership in Ion Beam Therapy now in Europe and Japan

>100’000 patients treated worldwide (45 facilities)

>50’000 patients treated in Europe (14 facilities)

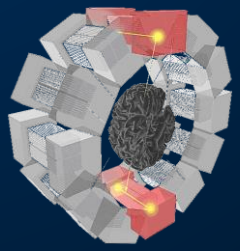


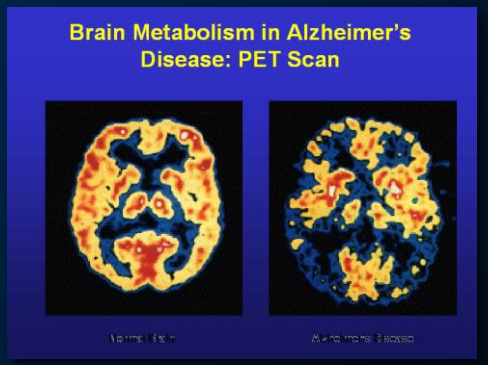
Detecting particles

Imaging

Clinical trial in Portugal, France and Italy for new breast imaging system (ClearPEM)

PET Scanner

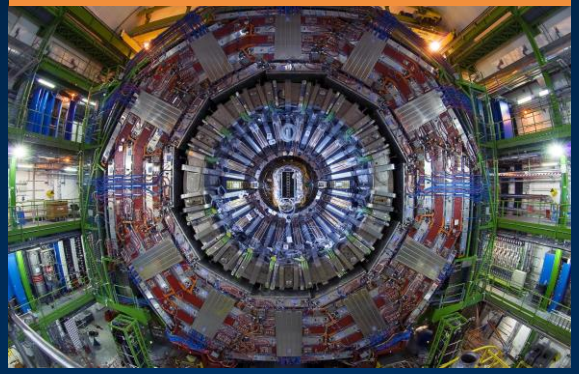




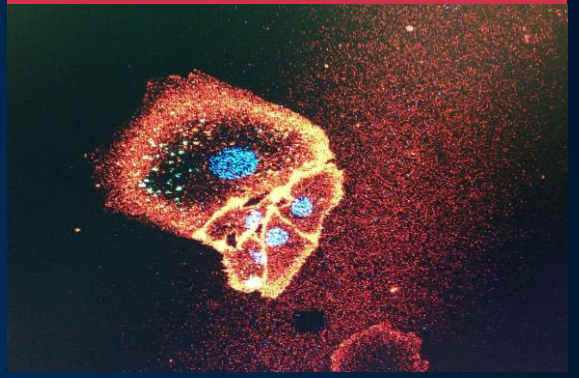
CERN openlab Summer Student Projects

Machine Learning for Fast Physics Simulation

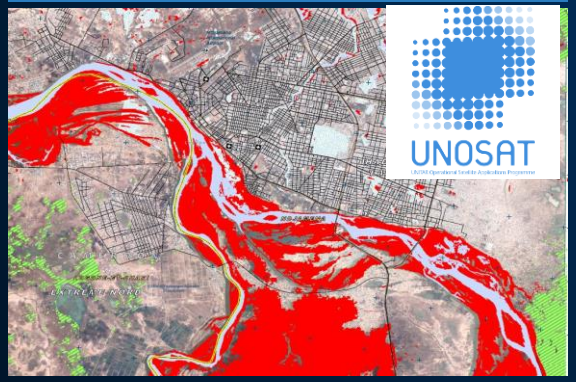
Image Processing for Track Reconstruction



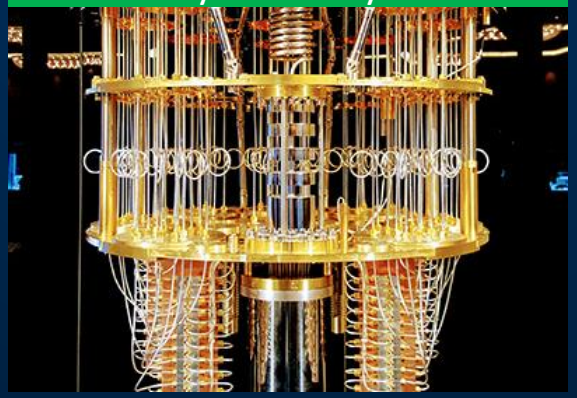
Biology Development Simulation in the Cloud



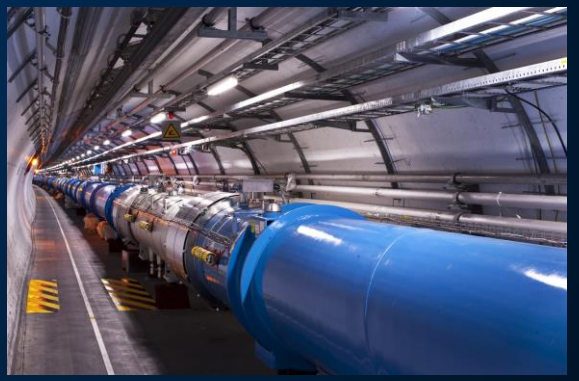
Deep-Learning Algorithms for Image Feature Extraction



Quantum Computing for Physics Analysis



Internet of Things for Smart Control Systems in the LHC



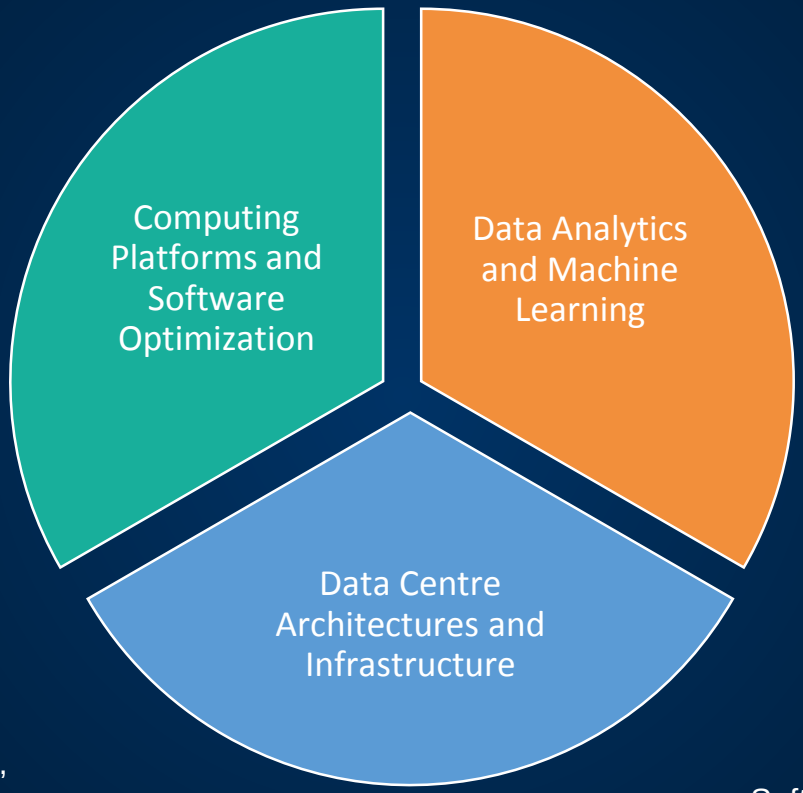
CERN openlab Research Activities

Accelerated computing platforms for data
acquisition and filtering (GPUs, FPGA, High-Capacity-High-Bandwidth Memory)

Specialized platforms for Machine Learning applications

New computing architectures (neuromorphic and quantum computing)

Parallelized Simulation Software (Physics and Medical Research)



Anomaly Detection (Data Quality and Engineering Systems)

Cloud-based Data Training
Fast Inference for Triggers,
Big Data Reduction

Image Processing (Track Reconstruction, Medical Applications, Maps)

Software Defined Networks (SDN), IoT Infrastructures, Sensor Networks,
High-Speed Fiber Links

Software Defined Infrastructure (SDI)
Scalable Hybrid Clouds,
File Systems as a Service, In-Memory Databases

Enjoy your stay at CERN!