The CERN Scientific Program

Le programme scientifique du CERN

A tour around the accelerator facilities

Un voyage à travers les accélérateurs

CERN is the largest laboratory in the world for particle physics

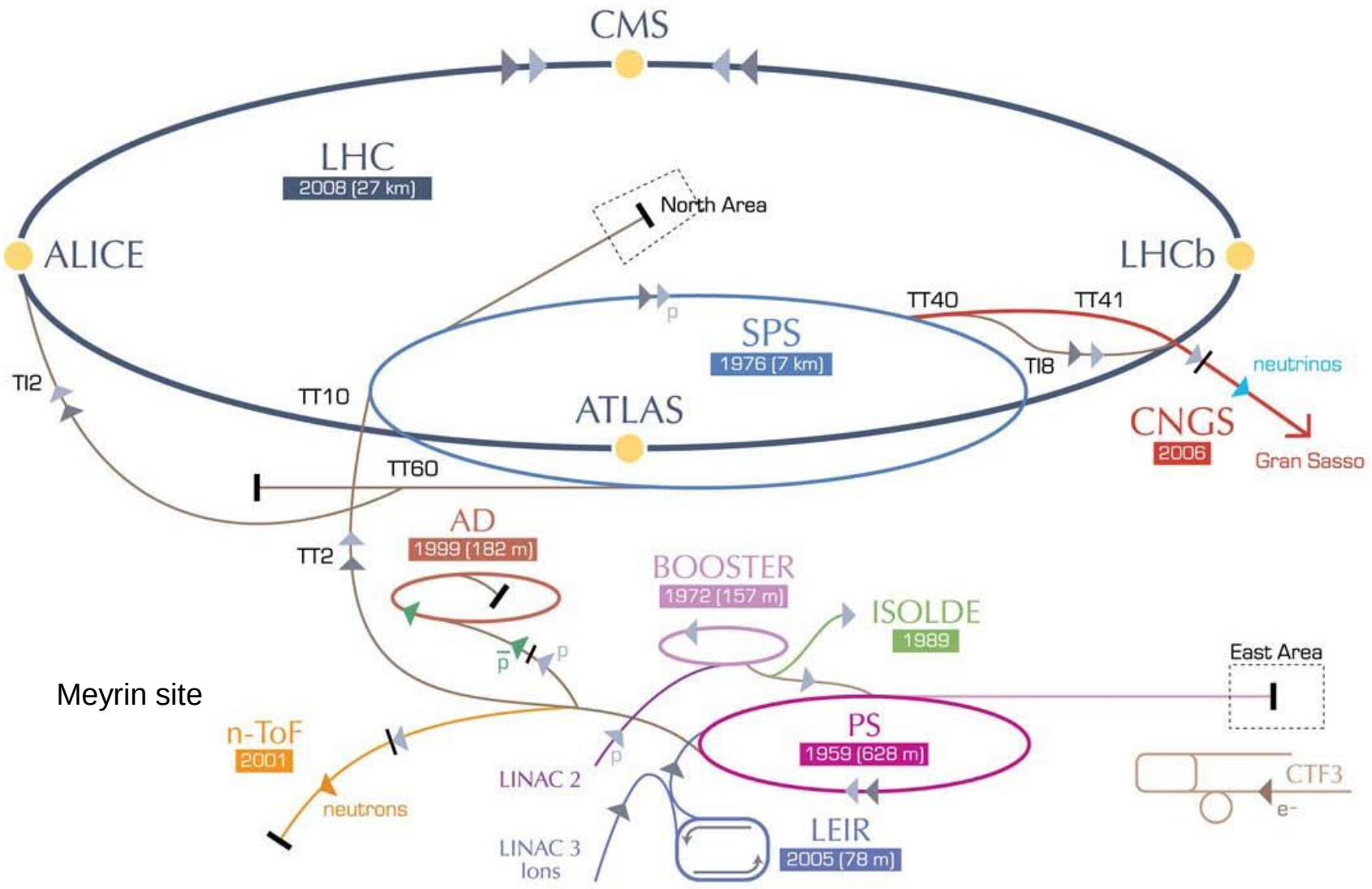
It has the world's highest energy accelerator (the LHC)

But there is also a broad program of other experiments

PH Department

Livio Mapelli, Head

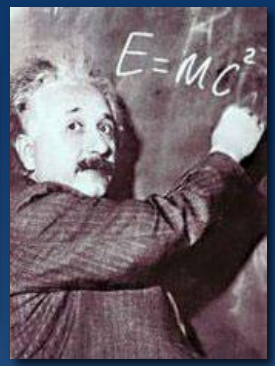
CERN Accelerators *les accélérateurs*



Meyrin site

The Mission of CERN

Les missions du CERN



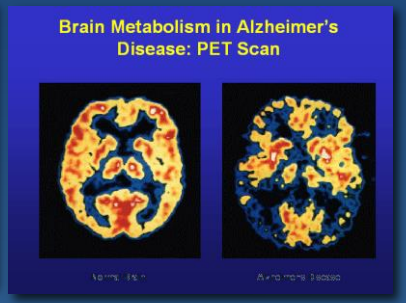
- Push back the frontiers of knowledge

  Studying the structure of matter on the smallest distances/highest energies… what was the matter like in the first moments of the Universe's existence

- Develop new technologi… accelerators and dete…

  Information technology - the W…

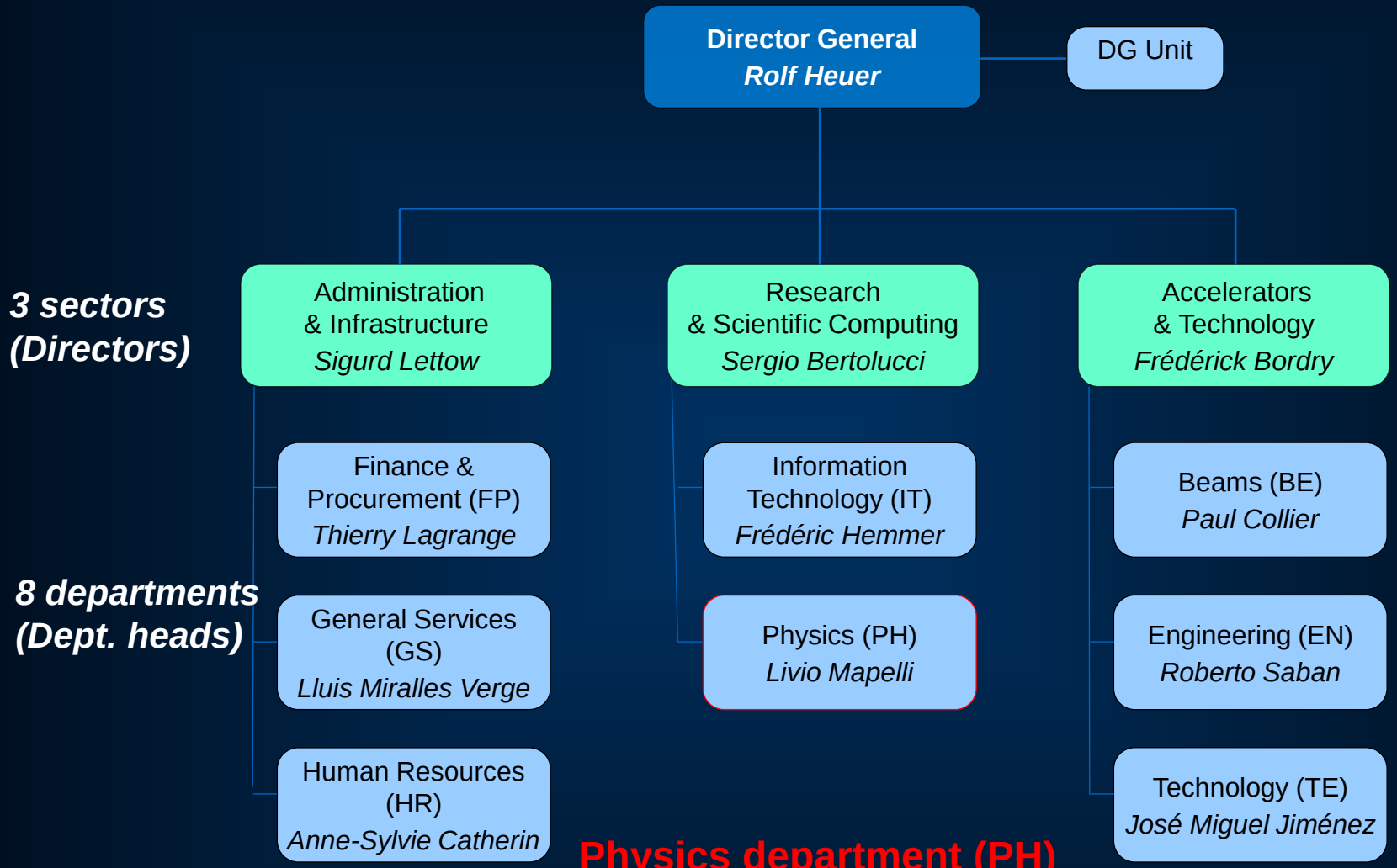
  Medicine - diagnosis and therapy



- Train scientists and engineers of tomorrow

- Unite people from different countries and cultures

CERN structure



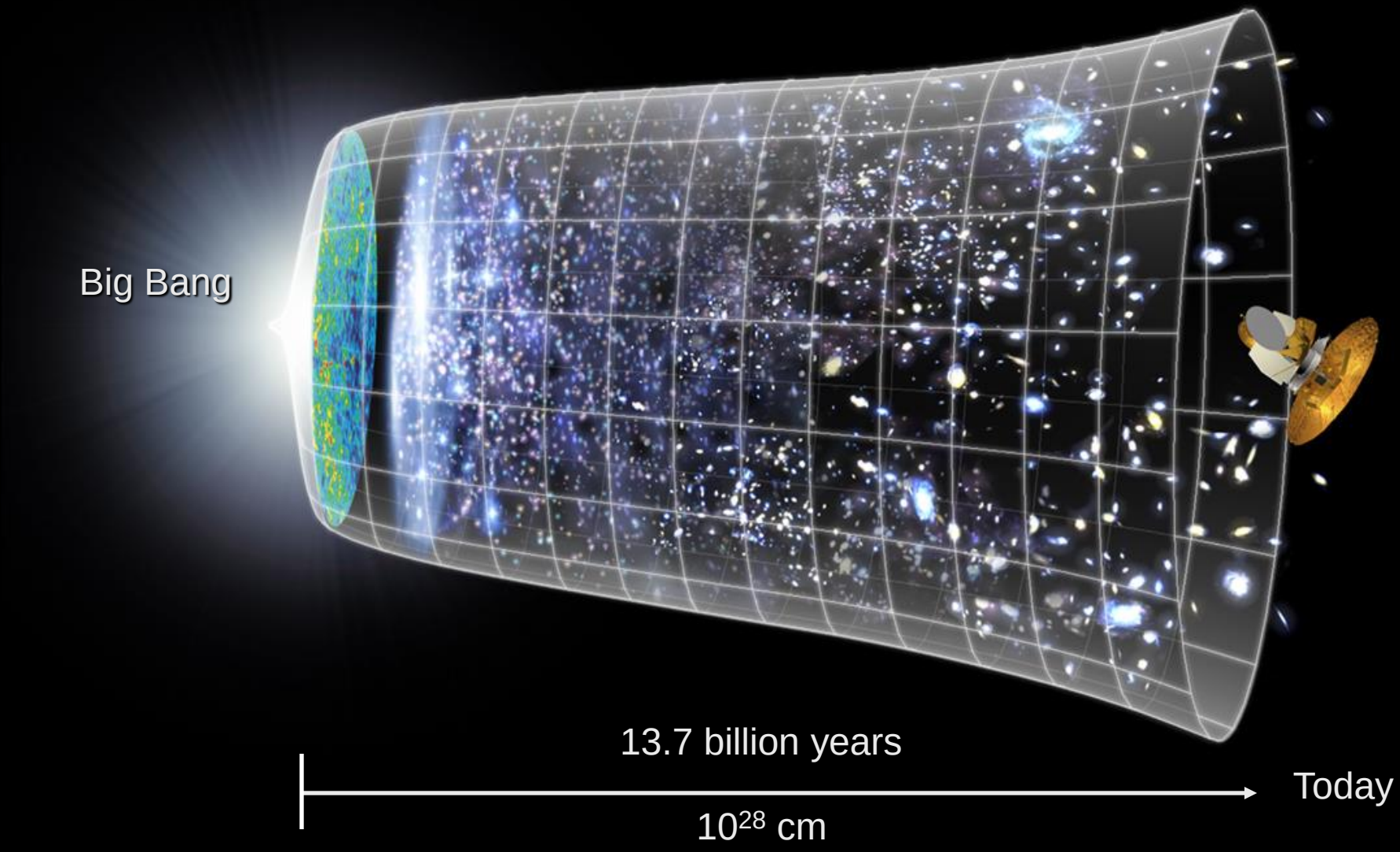
Physics department (PH)

~ 500 staff (~ 20% of CERN total)

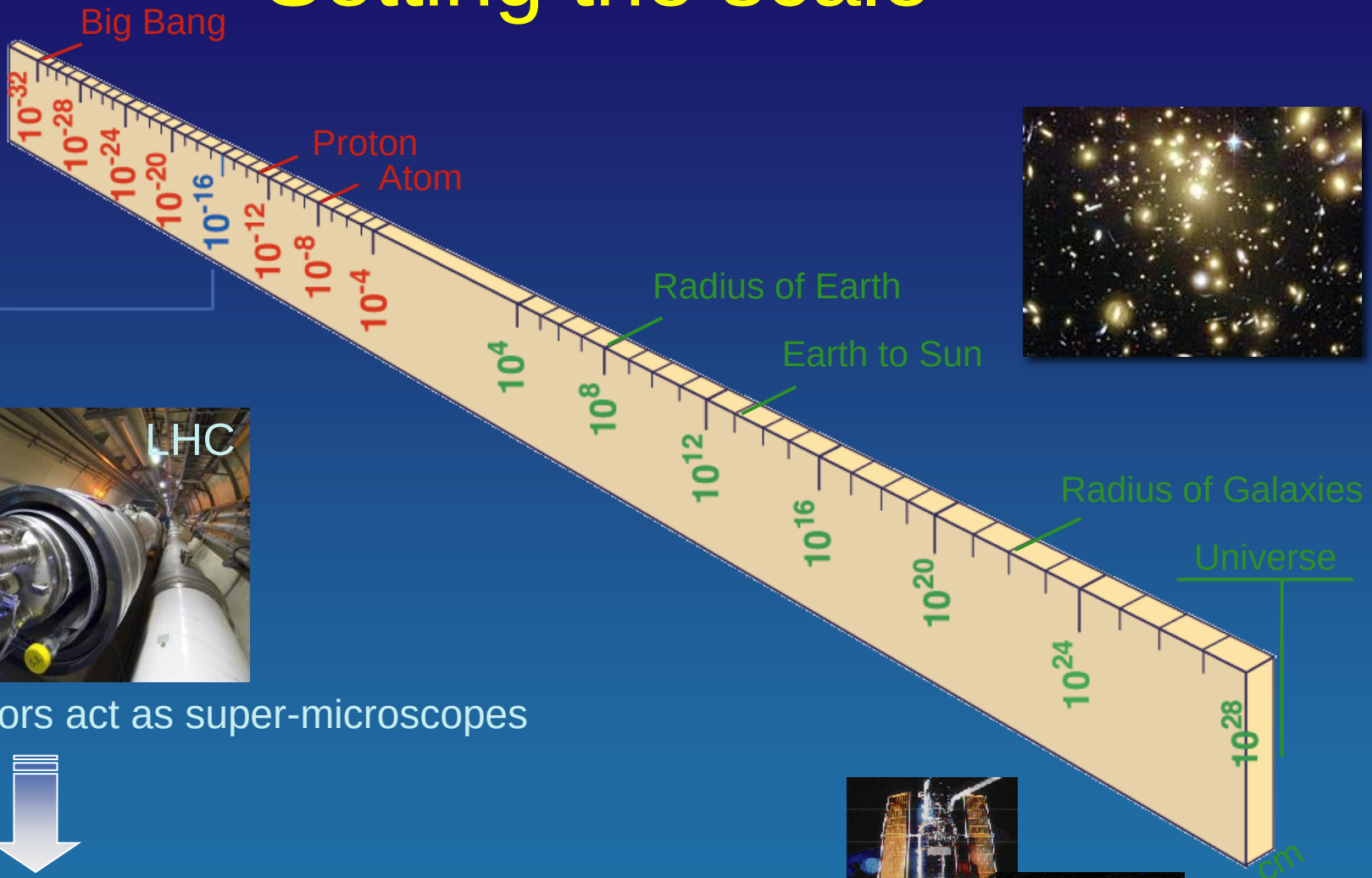
~ 400 students/fellows/associates

>10,000 users!

Understanding the Universe



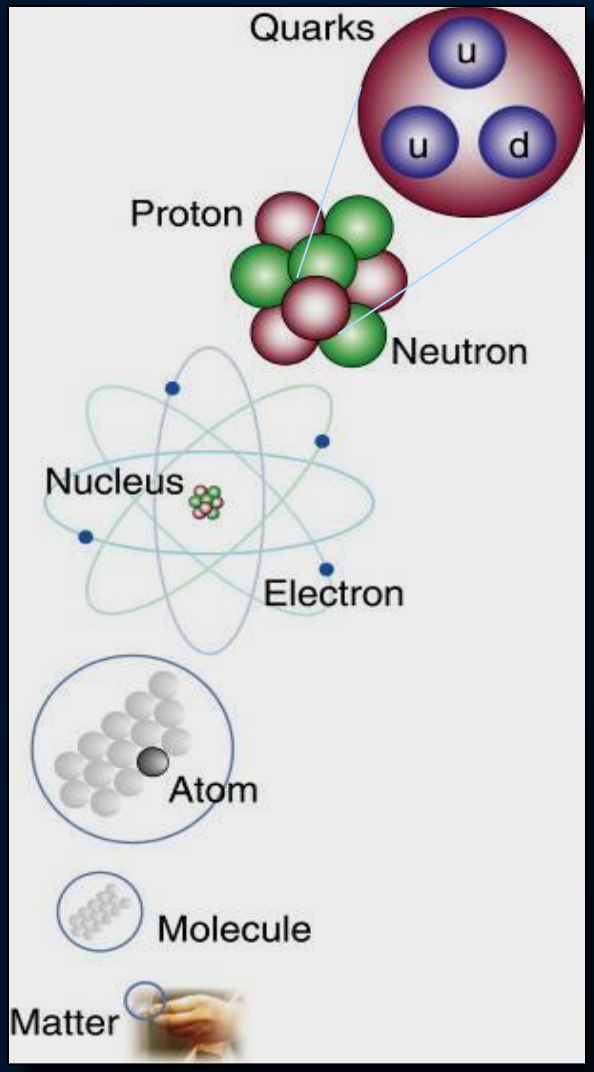
Setting the scale

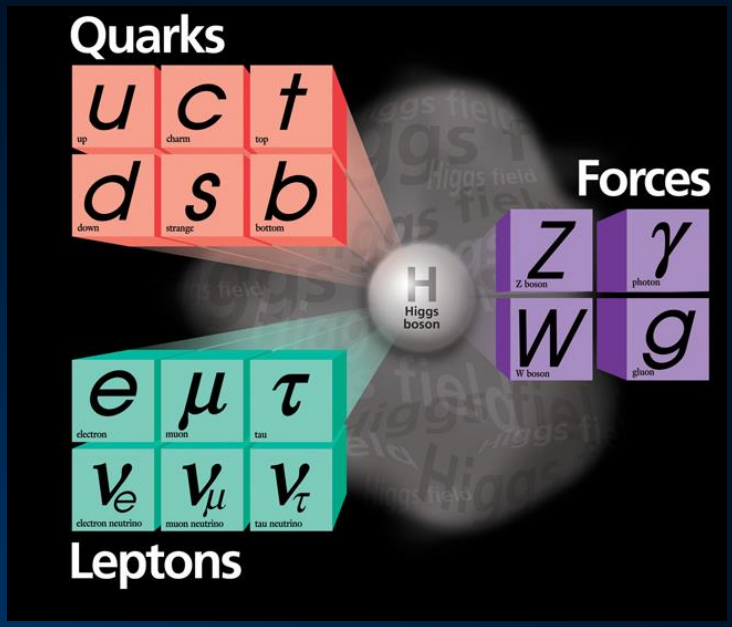


Accelerators act as super-microscopes

Study laws of physics at first moments after Big Bang
Increasing symbiosis between Particle Physics, Astrophysics and Cosmology

The Standard Model





- Fermions (spin ½, quarks and leptons): the building blocks of matter
- Antimatter partners of each particle, produced in high-energy collisions
  e.g. $\gamma \rightarrow e^+e^-$
- Bosons (integer spin): carry the forces
- One missing piece (prior to the LHC): Higgs Boson, gives mass to particles

CERN

The Large Hadron Collider

Search for the Higgs Boson, and physics beyond the Standard Model

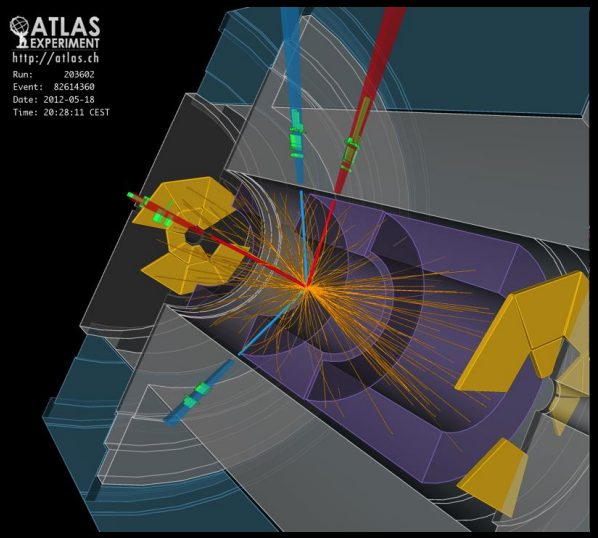
Exploration of a new energy frontier in p-p and Pb-Pb collisions

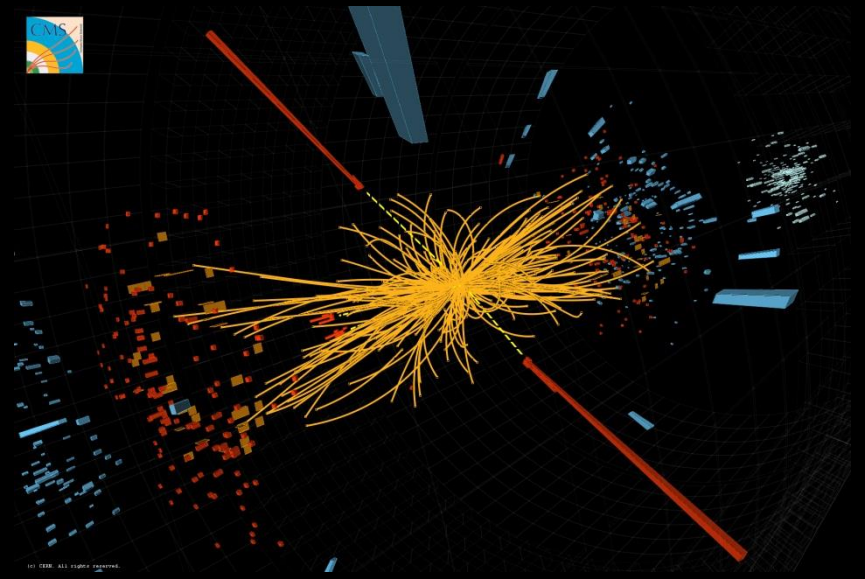
Four major experiments

Experiments at the LHC *Les expériences*

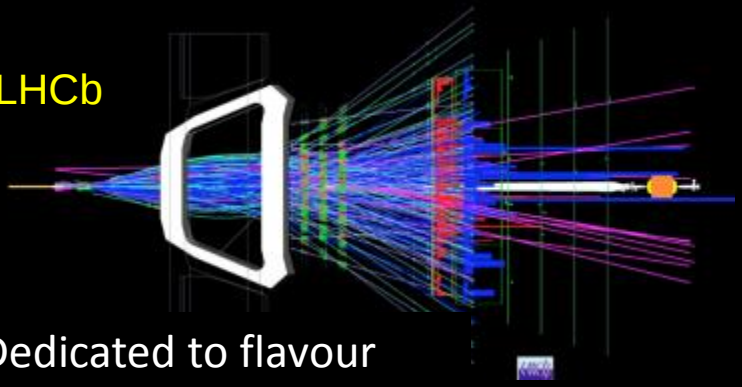
Brilliant performance of the LHC, experiments and Grid computing

2011-2012 : p-p collisions at E_{cm} = 7– 8 TeV (Run 1)



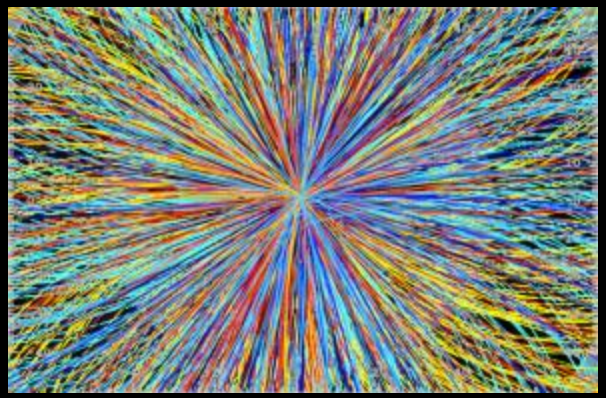


LHCb



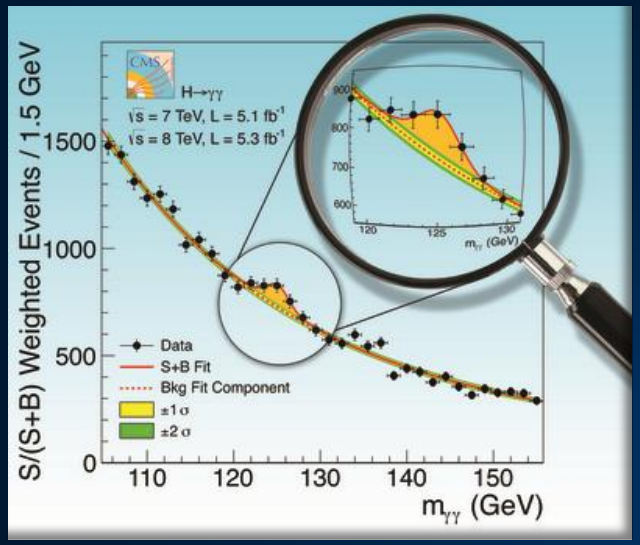
Dedicated to flavour physics (b and c quarks)

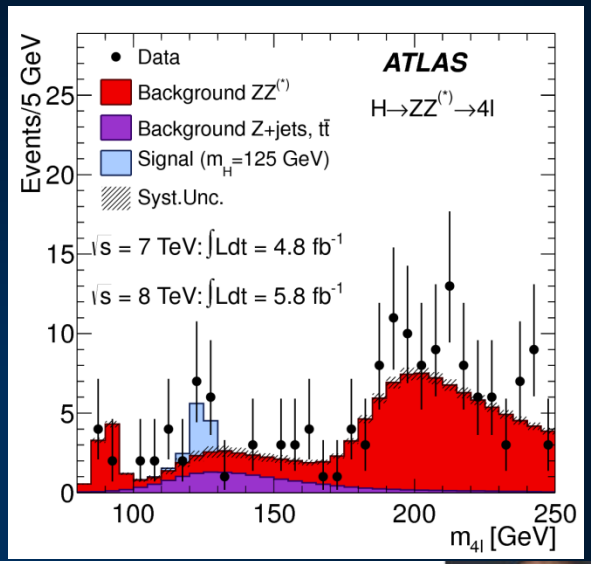
ALICE
Heavy ions
~ 1 mo/year



Pb-Pb collisions
E_{cm} = 2.76TeV/N

July 2012: "ATLAS and CMS observe a new particle compatible with the Higgs Boson"





François Englert

Photo: A. Mahmoud

Peter W. Higgs

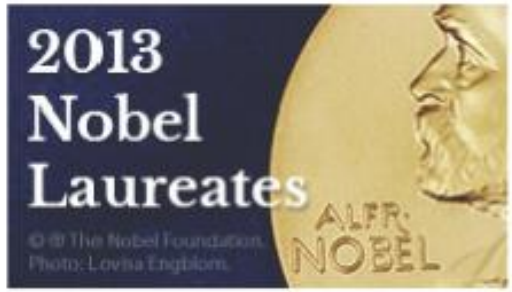
The Nobel Prize in Physics 2013 was awarded jointly to François Englert and Peter W. Higgs *"for the theoretical discovery of a mechanism that contributes to our understanding of the origin of mass of subatomic particles, and which recently was confirmed through the discovery of the predicted fundamental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

Photos

To cite

MLA st

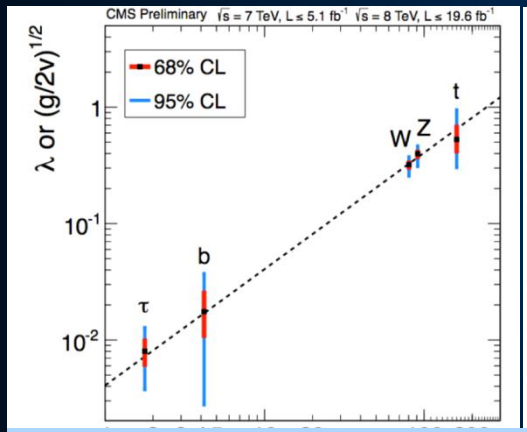
Web. 1



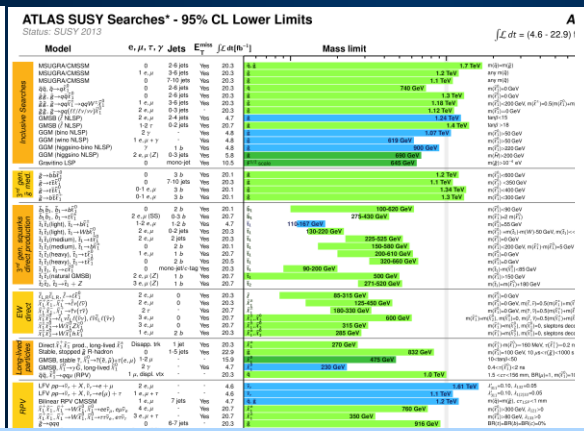
Future of the LHC

- The Standard Model is not the end of the story: e.g. gravity not included
- Dark matter (as "seen" in Astrophysics) not explained: need new particles?
- Why is the Universe made of matter, when matter and antimatter would be equally produced in the Big Bang? …

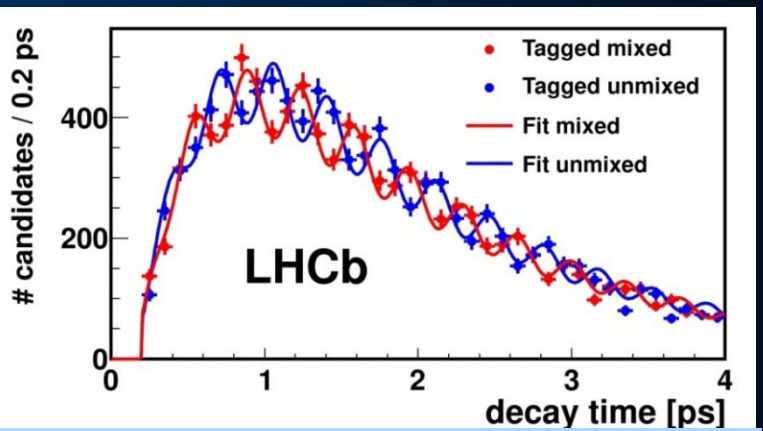
Matter distribution: visible from X-rays (pink)
Dark Matter from gravitational lensing (blue)



Study Higgs couplings



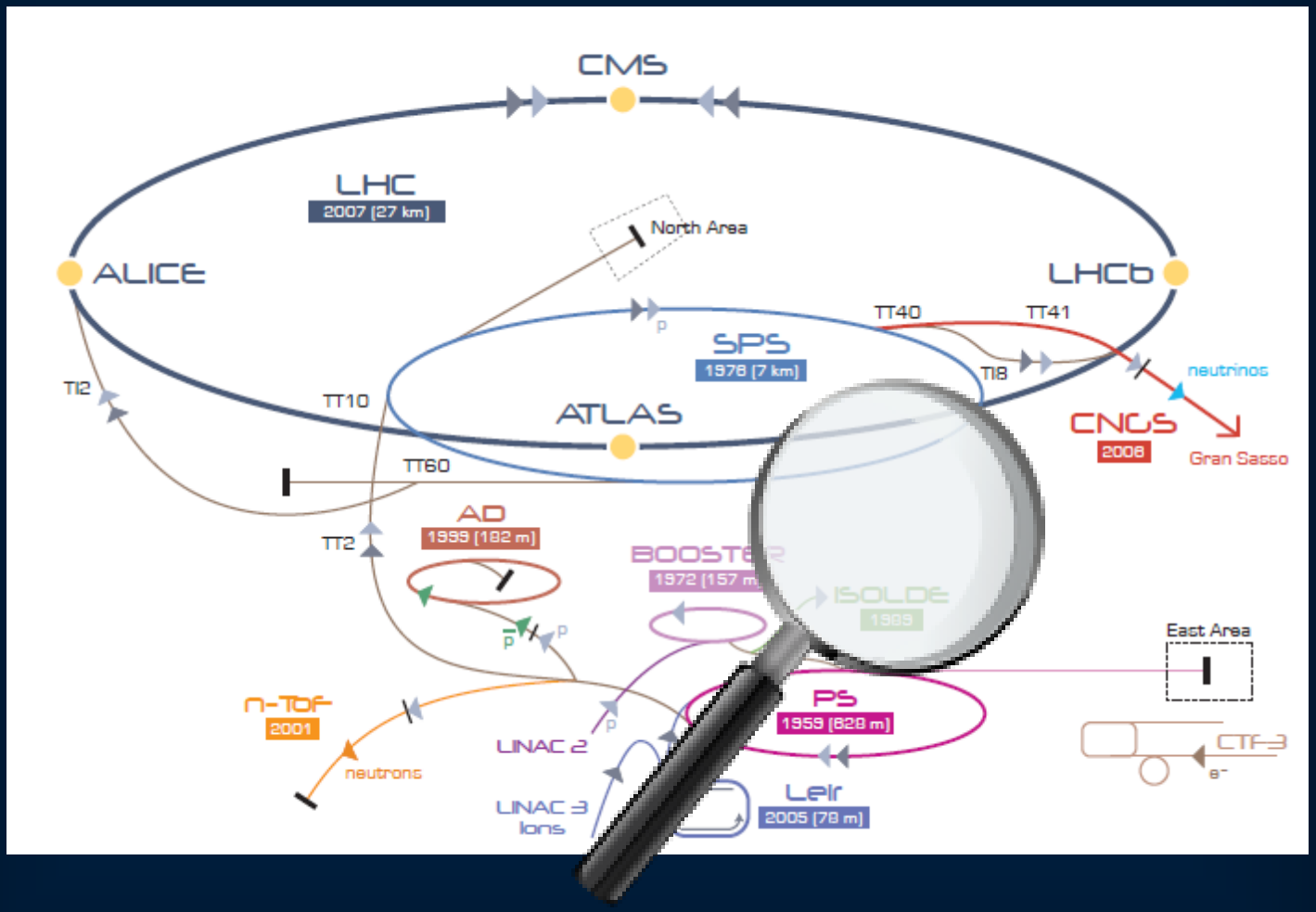
Search for new particles



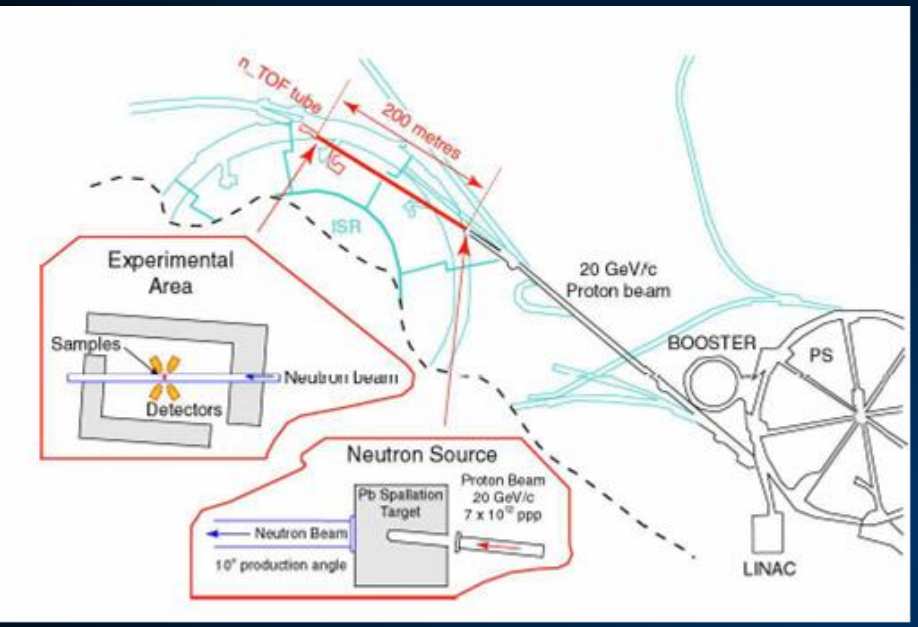
Study matter/antimatter differences

2015-18: p-p collisions at E_{cm} = 13–14 TeV (start-up in May)
2020s: High Luminosity LHC, > 10x more data

Next stop : ISOLDE



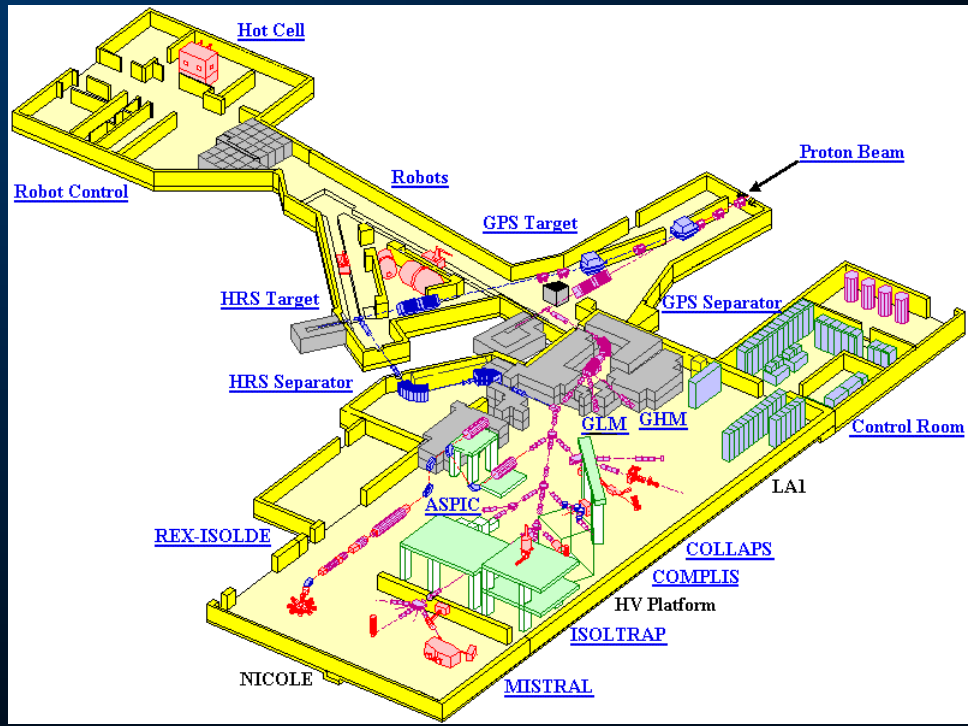
Nuclear Physics: nTOF & ISOLDE



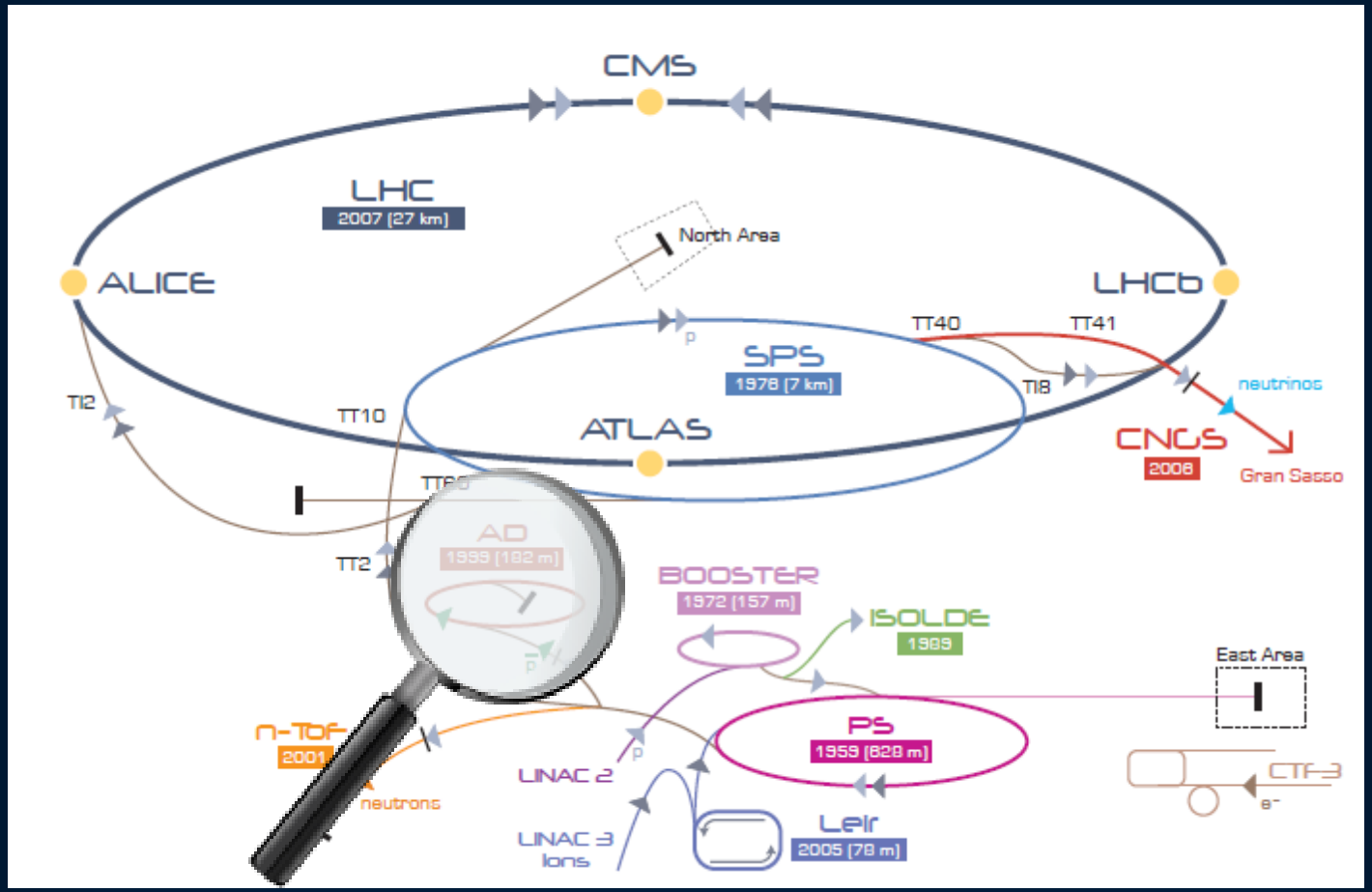
nTOF (neutron time-of-flight)
Measures neutron cross-sections
Astrophysics
Burning of nuclear waste
New experimental area EAR-2 recently installed

ISOLDE: radioactive ion beams
Nuclear physics
Astrophysics
Solid state physics
Medical applications

Upgrade to higher intensity (HIE-ISOLDE) in progress for 2015+
5 MeV/nucleon



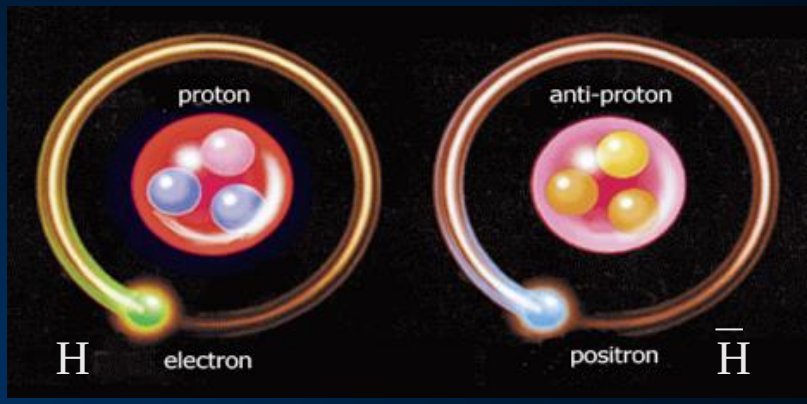
Antiproton Decelerator



Antiproton & Antihydrogen Physics

Matter-Antimatter comparison

Fundamental in the current theory of physics: $m = \bar{m}$, $g = \bar{g}$



ATRAP, ALPHA

Trapping and spectroscopy of Hbar in a "bottle"

ASACUSA

Spectroscopy of exotic atoms and of in-flight Hbar

BASE

Magnetic moment of the antiproton

AEgIS, GBAR

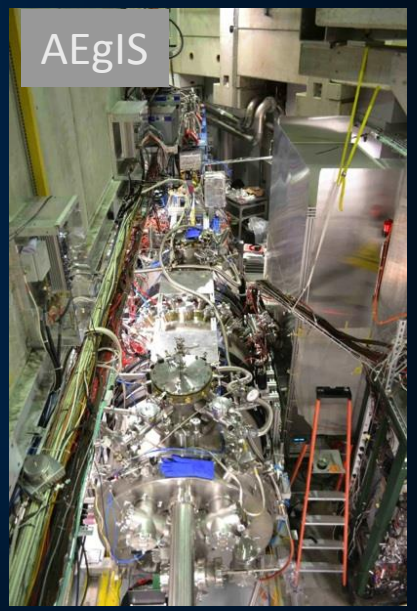
Hbar free fall, gravity effect on antimatter

Galileo's experiment for antimatter!

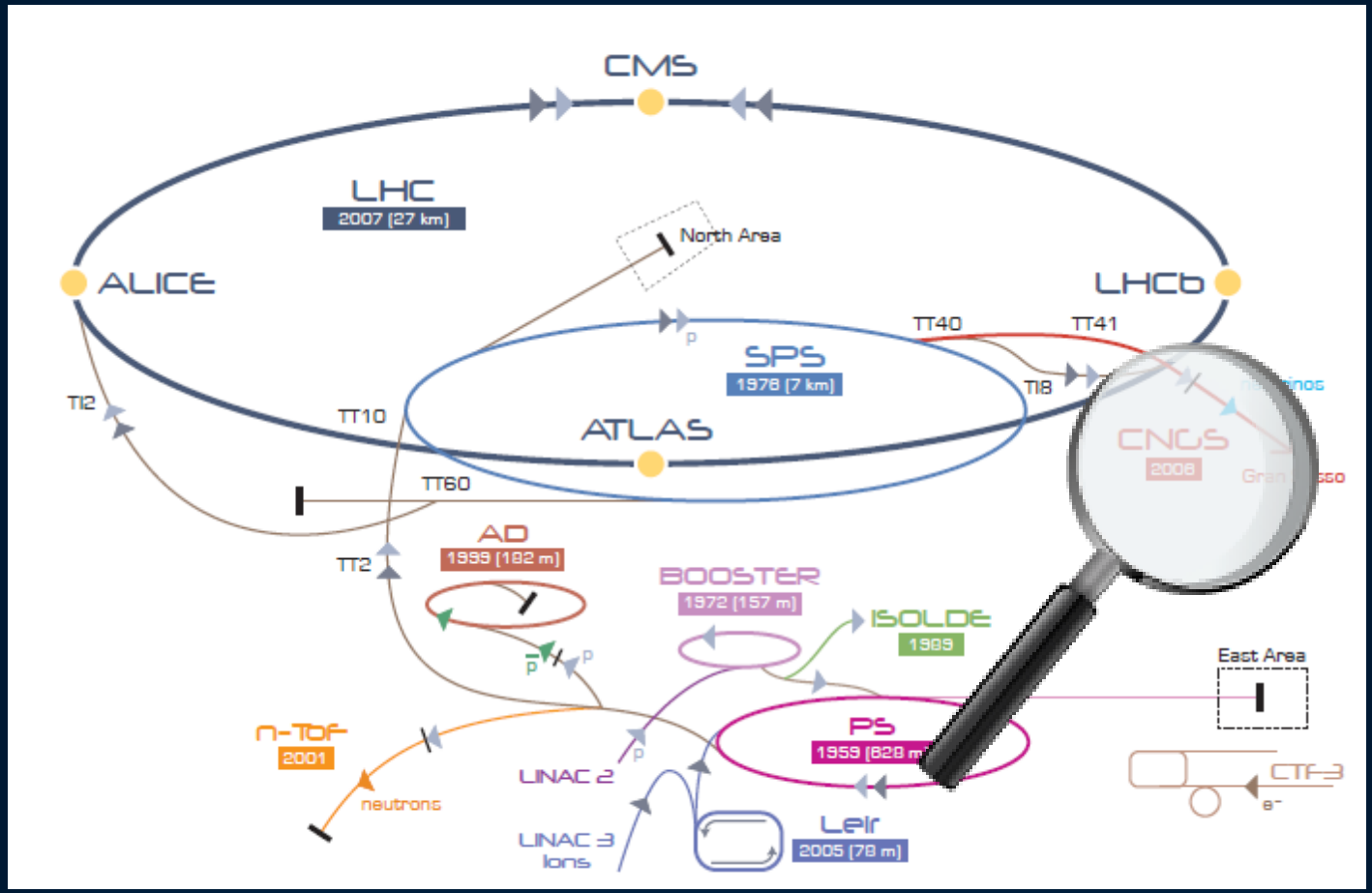
ACE

Use of antiprotons for cancer therapy

NEW!



Neutrino physics



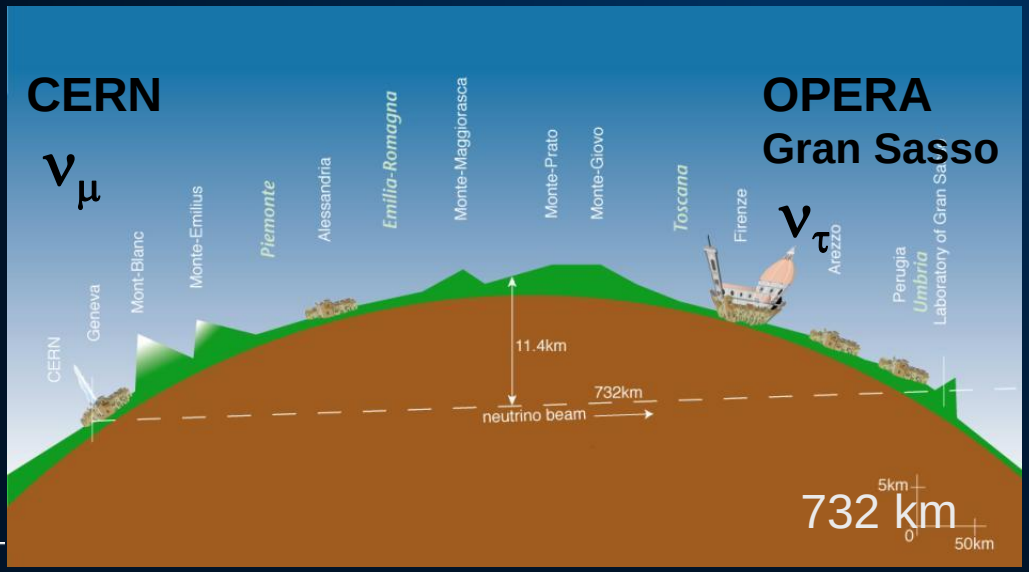
Neutrino physics

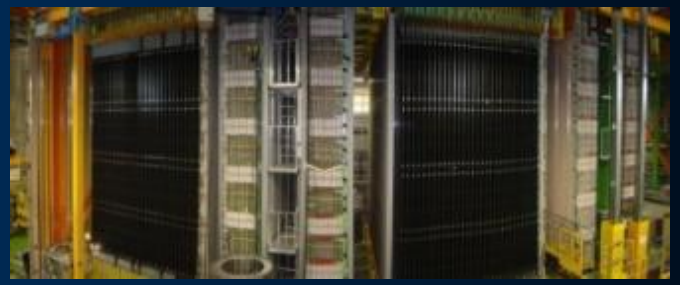
Like quarks, neutrinos exist in different flavors ν_μ ν_τ ν_e

and **their flavour oscillates** $\nu_\mu \Leftrightarrow \nu_\tau$ $\nu_\mu \Leftrightarrow \nu_e$

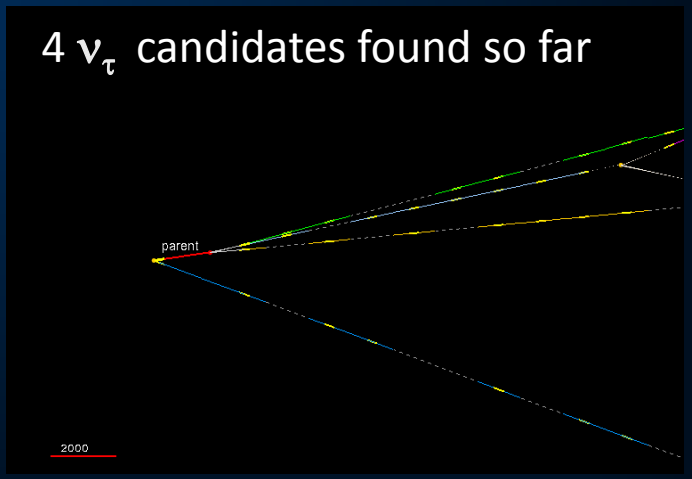
Has been studied with ν_μ beam sent from CERN to Gran Sasso in Italy (CNGS)
Data taking now completed, analysis continues

Future neutrino programme at CERN under discussion
R&D for large liquid argon detectors approved

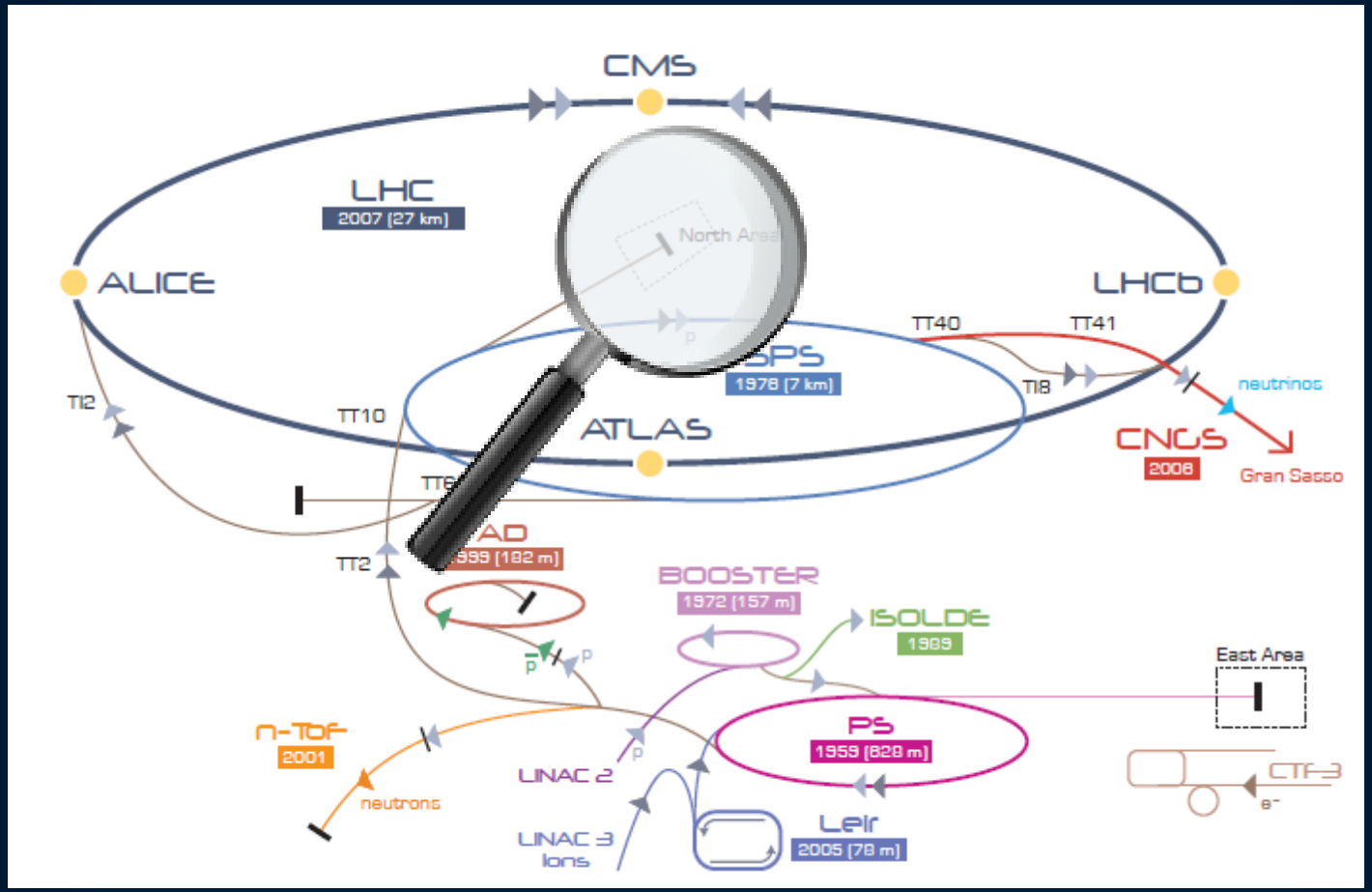




4 ν_τ candidates found so far



SPS North Hall



Fixed Target Physics

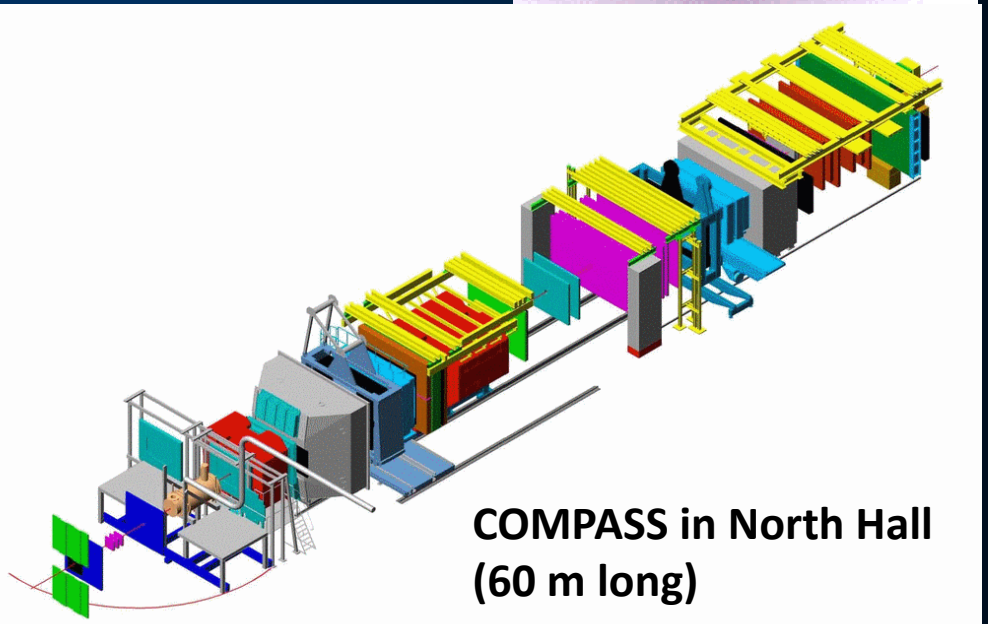
Lower energy experiments at PS or SPS (in 1-100 GeV) range
allow precision measurements and comparison with theory
Deviations can be sign of new physics at higher energies

DIRAC: **pionic atoms** (completed)
COMPASS: **muon spin physics, spectroscopy**
NA61: ion physics, **quark gluon plasma**
NA62: **rare K decays** physics run starts this October
NA63: **electromagnetism** in extreme conditions

Lead ion collision

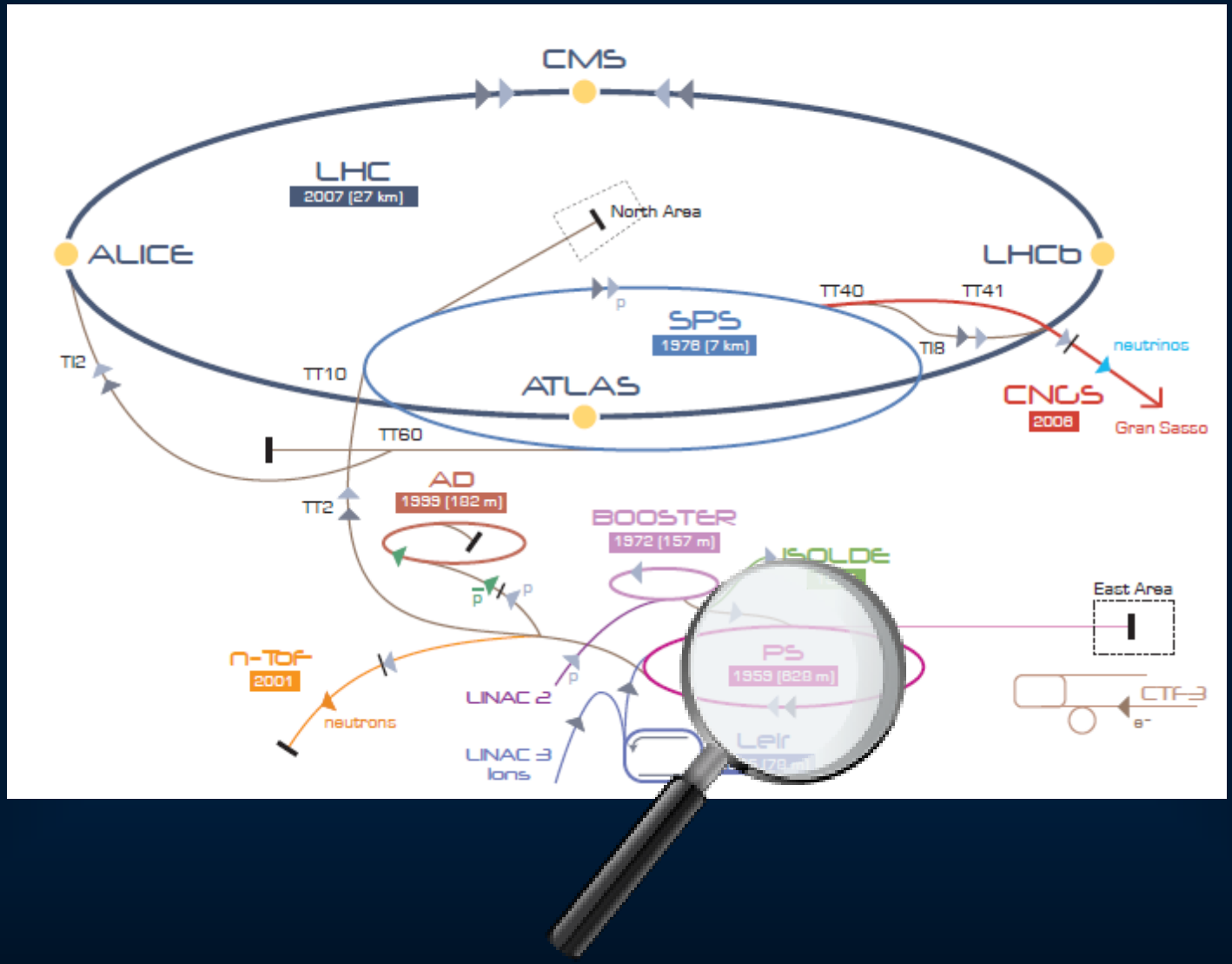
NA62 P326

NEW!



COMPASS in North Hall (60 m long)

PS East Hall


CMS
LHC
2007 [27 km]
North Area
ALICE
LHCb
TT40
TT41
p
SPS
1976 [7 km]
TI8
neutrinos
TI2
TT10
ATLAS
CNGS
2006
Gran Sasso
TT60
AD
1999 [182 m]
TT2
BOOSTER
1972 [157 m]
ISOLDE
East Area
n-ToF
2001
PS
1959 [628 m]
CTF3
neutrons
LINAC 2
LINAC 3
Ions
Lepr

Other experiments

CLOUD - Study effect of cosmic rays on cloud formation

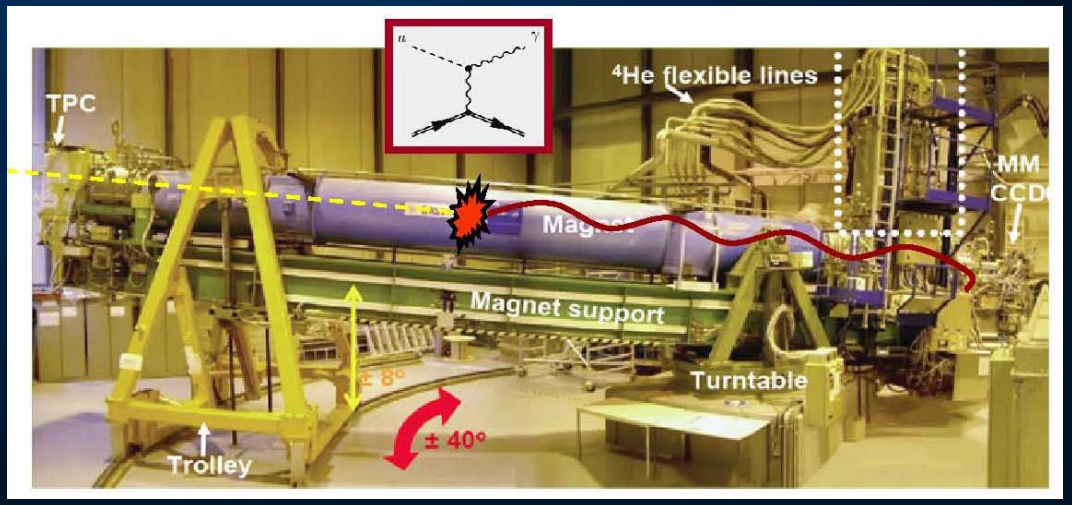
Cosmic rays “simulated” by T11 beam, clouds created in a large climatic chamber

Relevant to climate change

CAST - Search for axions from sun

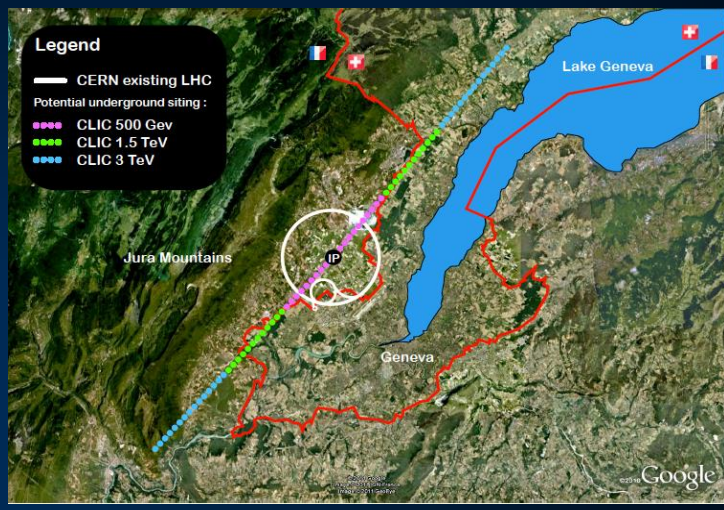
Using a spare LHC dipole, pointing at sun

Study for successor (IAXO) underway



Future accelerators

- LHC, and its upgrade to higher luminosity, is central to CERN program for next decade(s)
  But need to prepare for what will come after, so future accelerators are under study
- LCD – Linear Collider Detector
  Studying the detector design for possible future e^+e^- linear colliders (ILC & CLIC)
- FCC – Future Circular Collider
  Study 80-100 km circumference machine
  pp collisions at 100 TeV, as well as ee or ep
- Results from the LHC should help decide



Summary

- The CERN scientific program is:

- Rich and diverse
- Covers a wide range of energies from atomic physics to the highest energy frontier
- Open to transfer of technology, education and relevance to issues in wider society (information, health, climate, energy, …)

- CERN's success is built on its personnel
  Welcome, to join the adventure! *Bienvenu!*