ISOTDAQ2015 – Rio de Janeiro, Brasil – Jan 28-Feb 05 2015

The CERN Scientific Pogram

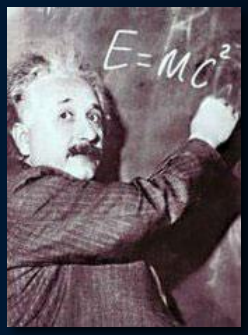
Livio Mapelli
CERN - Physics Department

CERN Physics today
Its imapct on our lifes
Srategic view to the future

The mission of CERN

- **Push back** the frontiers of knowledge

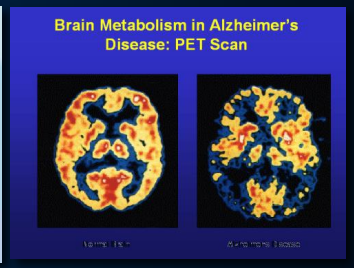
  E.g. the secrets of the Big Bang …what was the matter like within the first moments of the Universe's existence?



- **Develop** new technologies for accelerators and detectors

  Information technology - the Web and the GRID

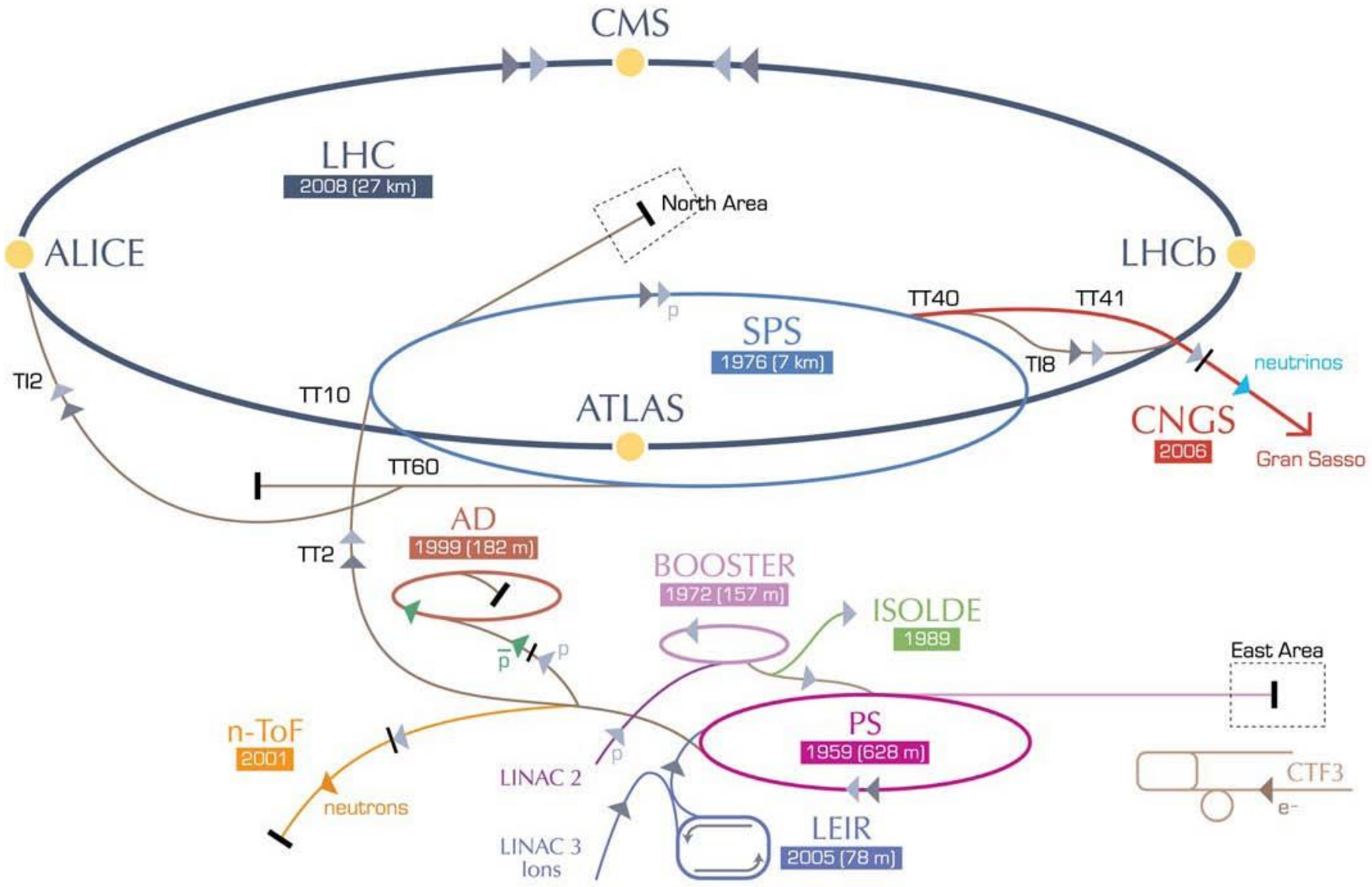
  Medicine - diagnosis and therapy



- **Train** scientists and engineers of tomorrow

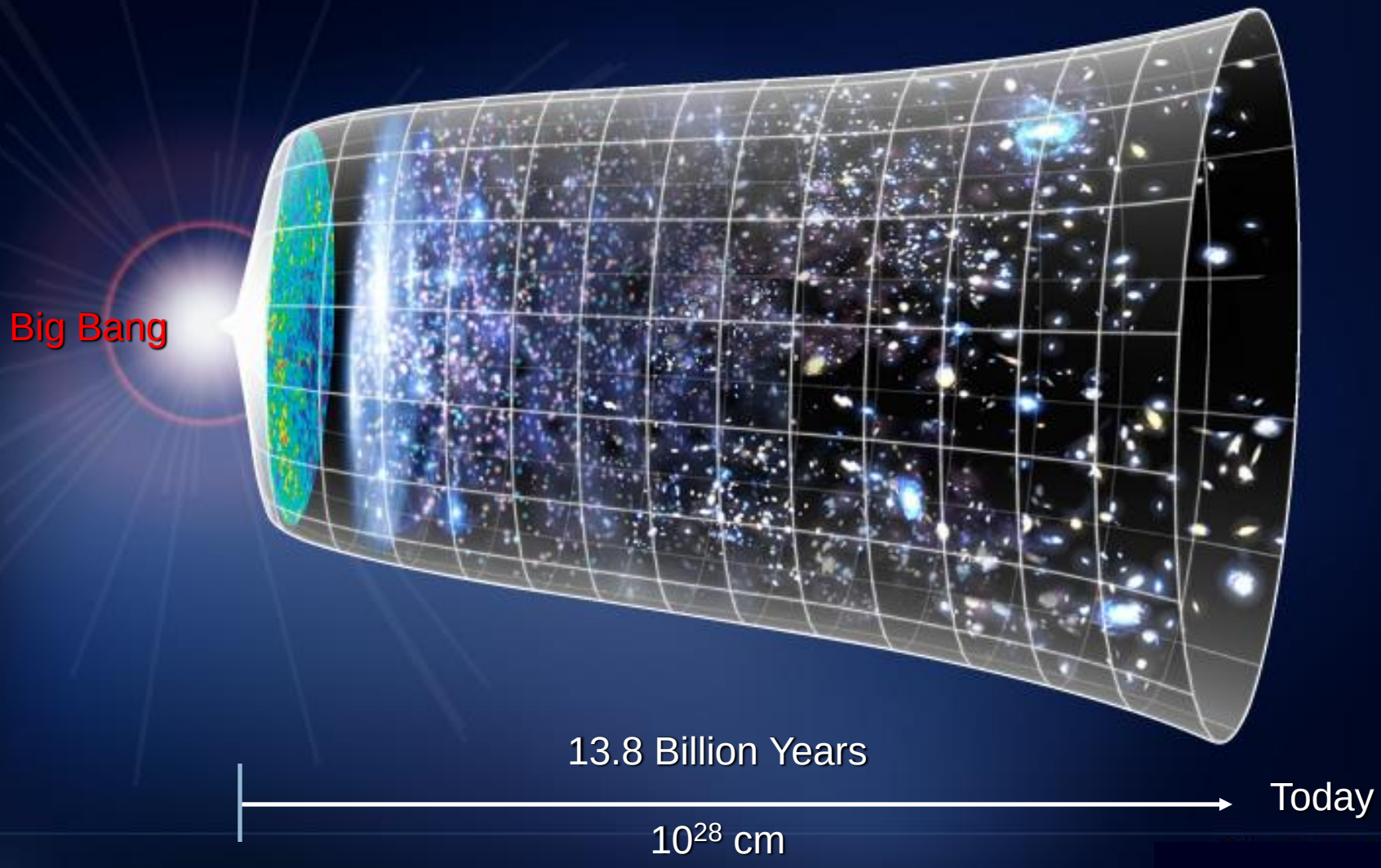
- **Unite** people from different countries and cultures

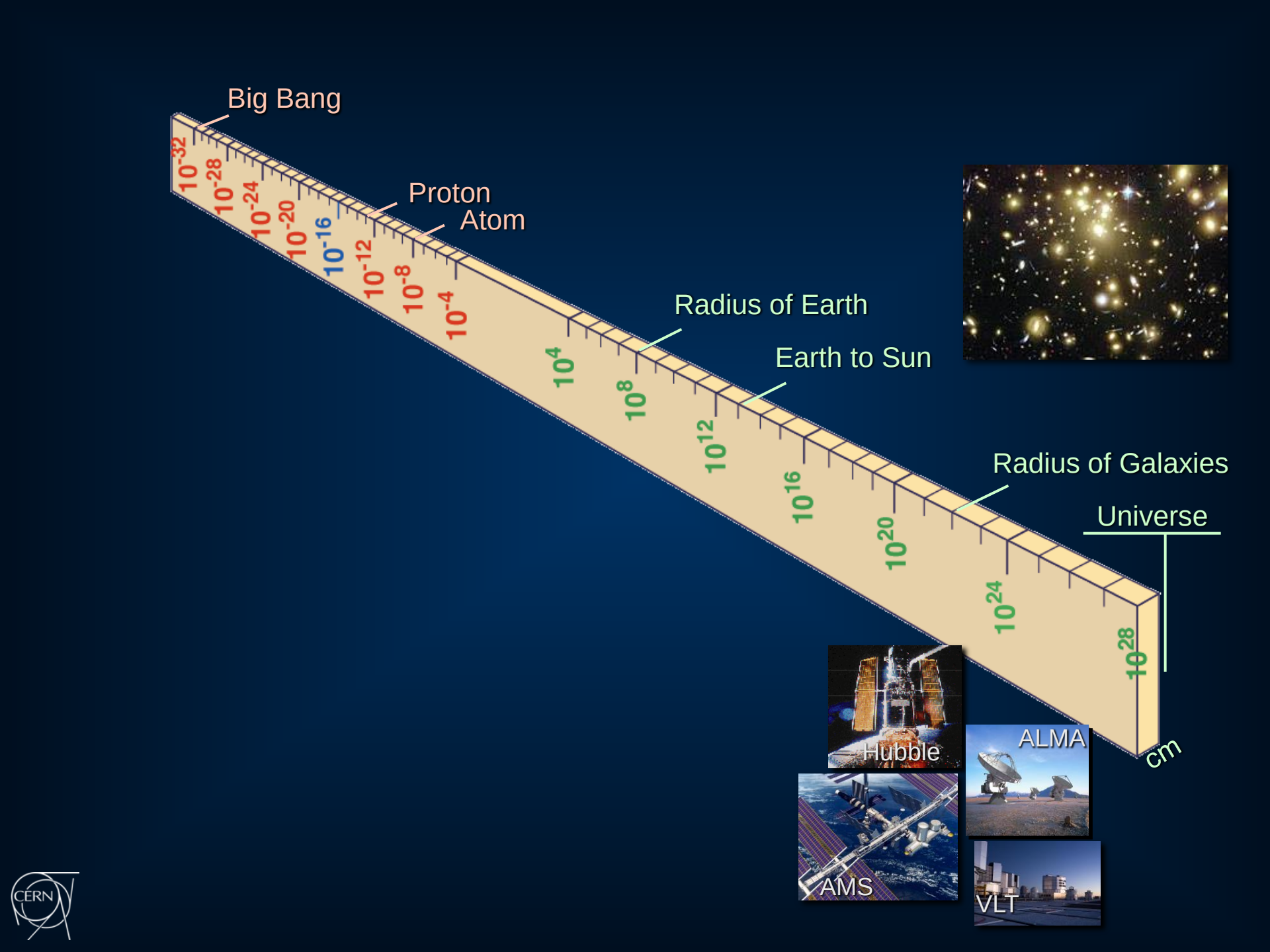
The CERN Accelerators



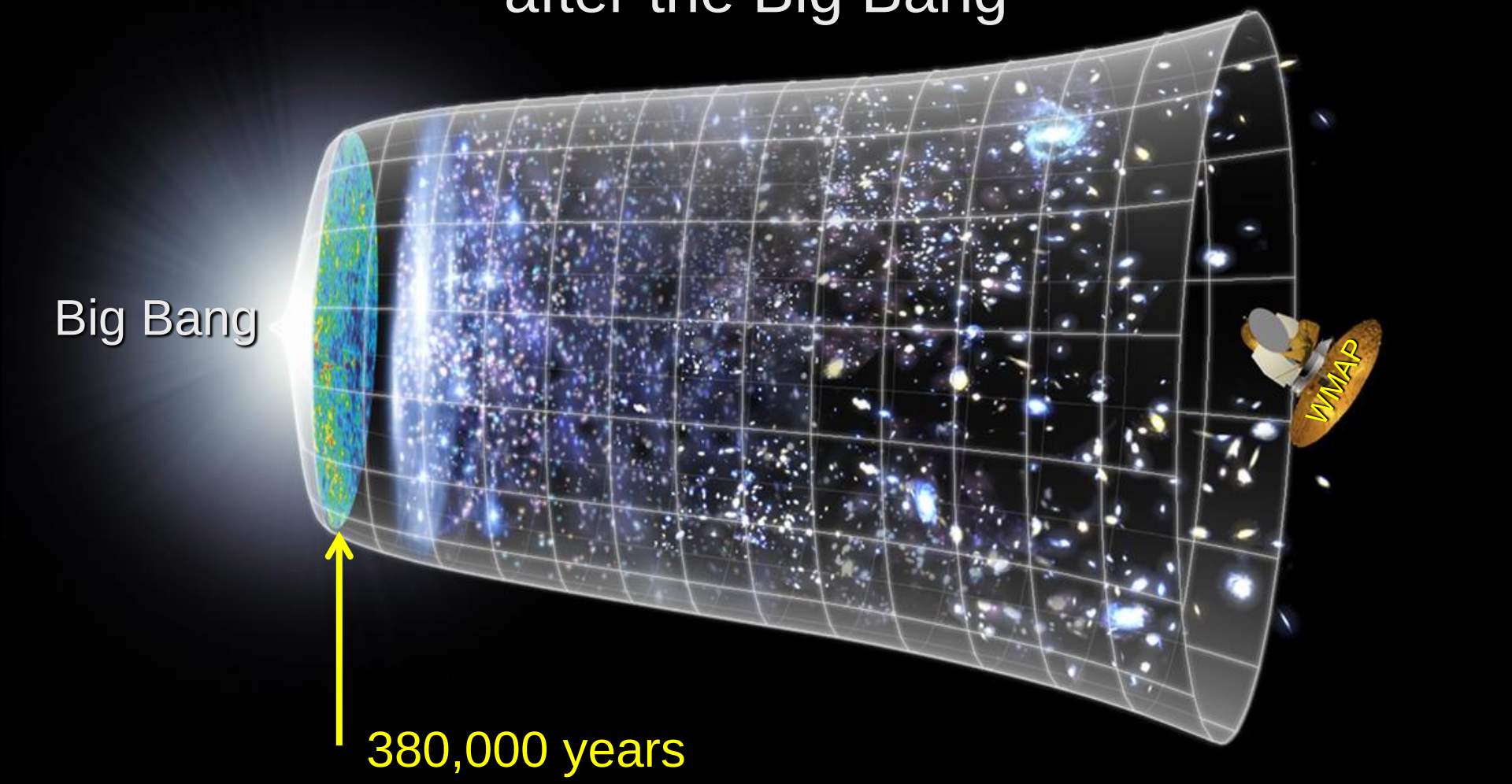
LHC – the high-energy frontier

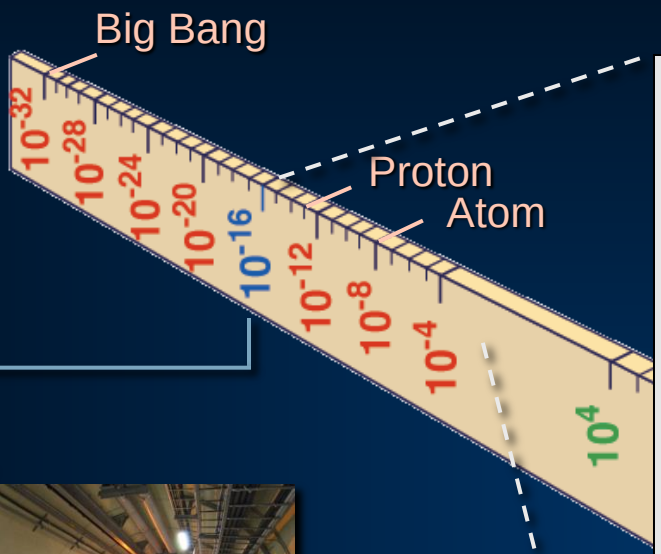
Today's Scientific Challenge:
understand the very first moments of our Universe after the Big Bang

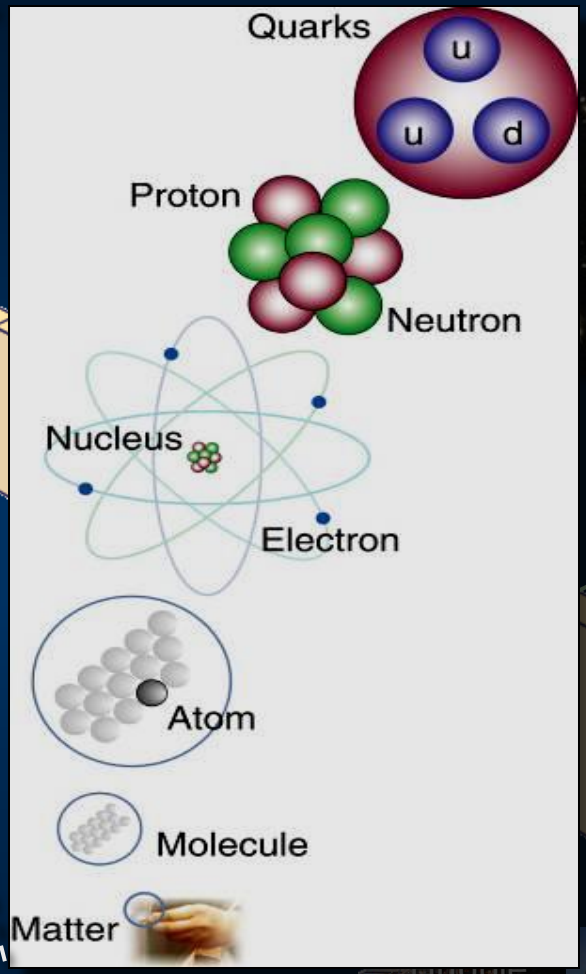


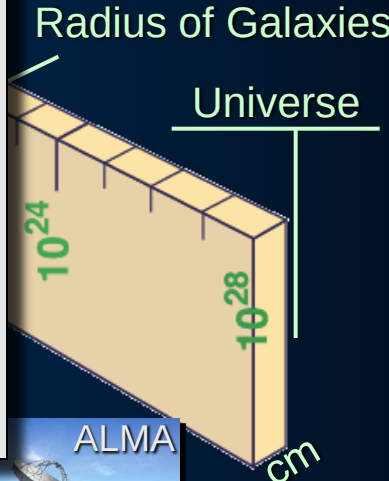

Big Bang
Proton
Atom
Radius of Earth
Earth to Sun
Radius of Galaxies
Universe
10^{-32}
10^{-28}
10^{-24}
10^{-20}
10^{-16}
10^{-12}
10^{-8}
10^{-4}
10^{4}
10^{8}
10^{12}
10^{16}
10^{20}
10^{24}
10^{28}
cm
Hubble
ALMA
AMS
VLT

Next Scientific Challenge:
to understand the very first moments of our Universe after the Big Bang





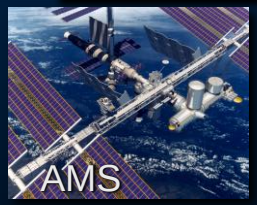




LHC

Super-Microscope

Study physics laws of first moments after Big Bang
increasing Symbiosis between Particle Physics,
Astrophysics and Cosmology



LHC experiments

ALICE – Large Ion Collider Experiment

ATLAS – A Toroidal LHC ApparatuS

CMS – Compact Muon Solenoid

LHCb – Large Hadron Collider beauty

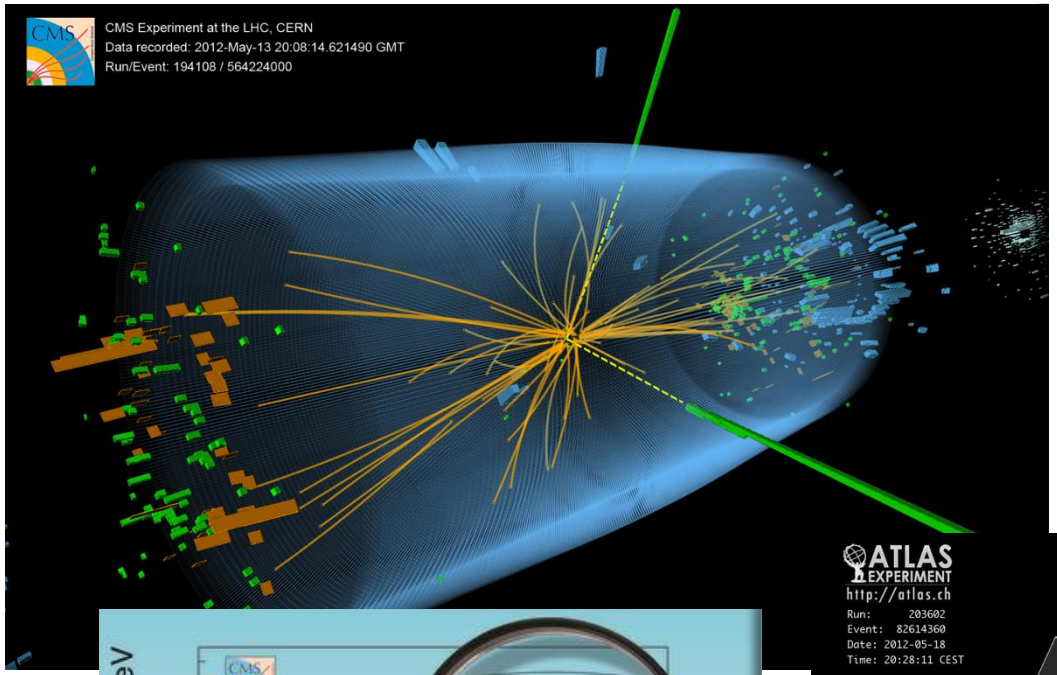
TOTEM – TOTal Elastic cross section Measurement

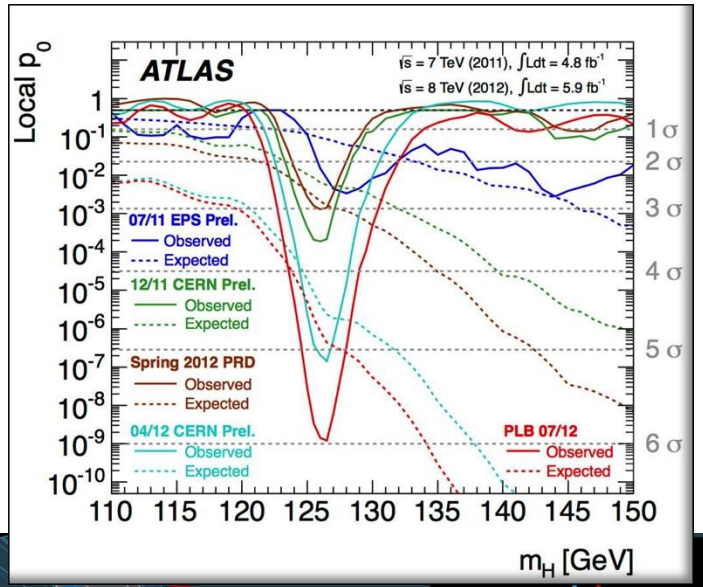
LHCf – Large Hadron Collider forward
MoEDAL – Monopole and Exotics Detector At LHC

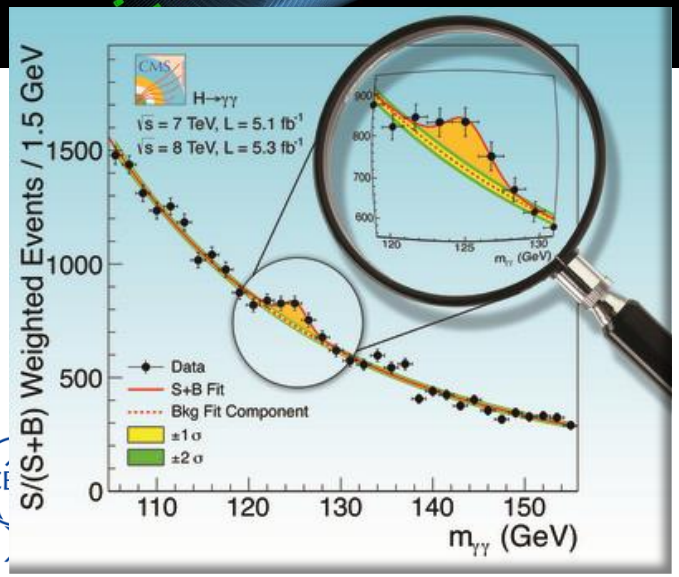
ATLAS & CMS

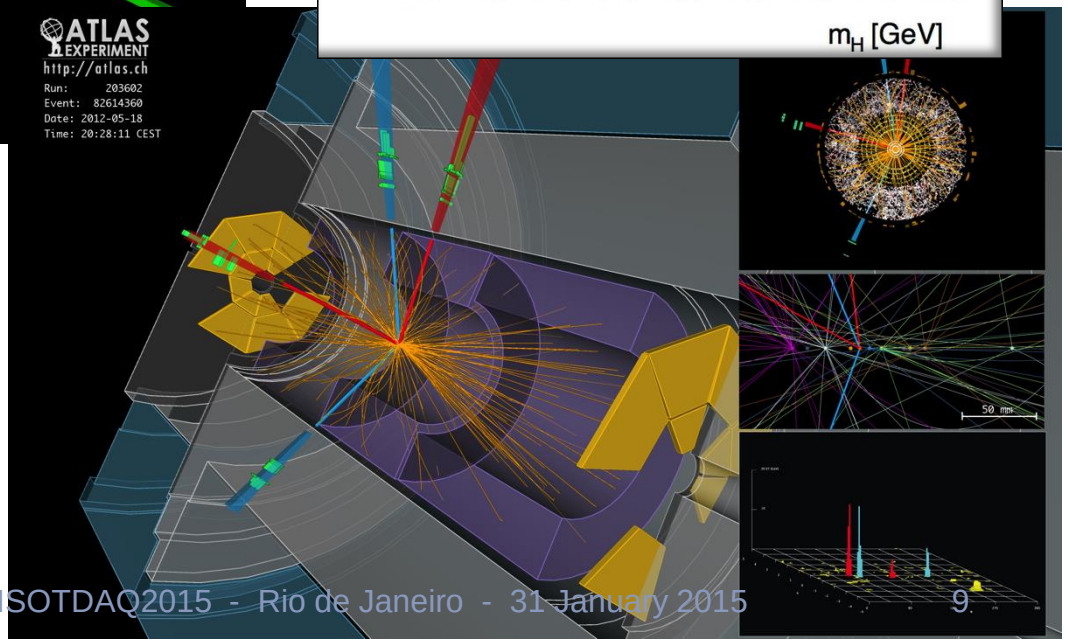
391 & 401 papers

4th July 2012:
Observation of a new Boson at 125 GeV/c²







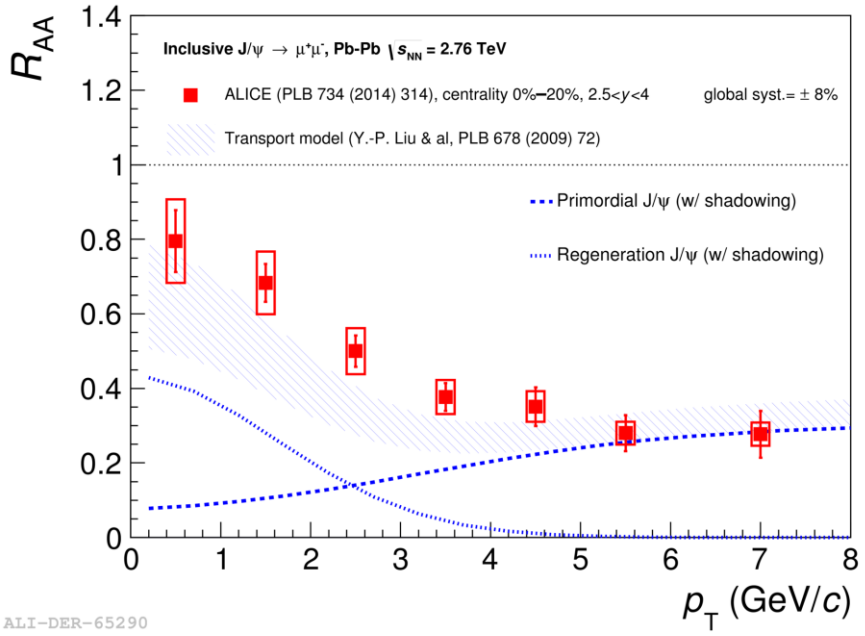


ALICE

101 papers

J/psi production in Pb-Pb collisions:

Rigeneration from QGP?

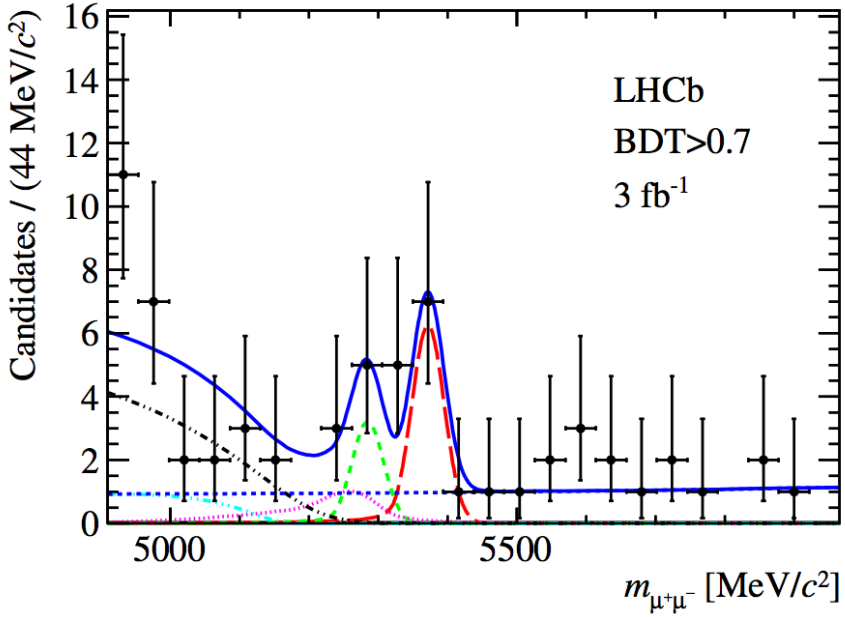


LHCb

237 papers

The very rare decay $B_s \rightarrow \mu^+\mu^-$:

First evidence, agreement with SM



Non-LHC experiments

SME – Small and Medium sized Experiments

Hosts the non-LHC experiments

Maintains a diverse program of physics at CERN

- PS and SPS Fixed-Target experiments
- AD experiments – Antiproton Decelerator
- ISOLDE + nTOF
  - Nuclear physics (Isotope separation, neutron time-of-flight)
- Other experiments
  - DIRAC, CAST, OSQAR, AMS, …

Fixed target experiments

CLOUD climatic chamber Oct 2014

PS program

CLOUD

An experiment on climate:

study effects of cosmic rays on clouds formation

SPS program

Lower energy experiments SPS allow precision measurements for comparison with theory. **Deviations can be sign of new physics at higher energies.**

DIRAC: **pionic atoms** (completed)

COMPASS: **muon spin physics, D-Y**

NA61: **Heavy Ion physics**

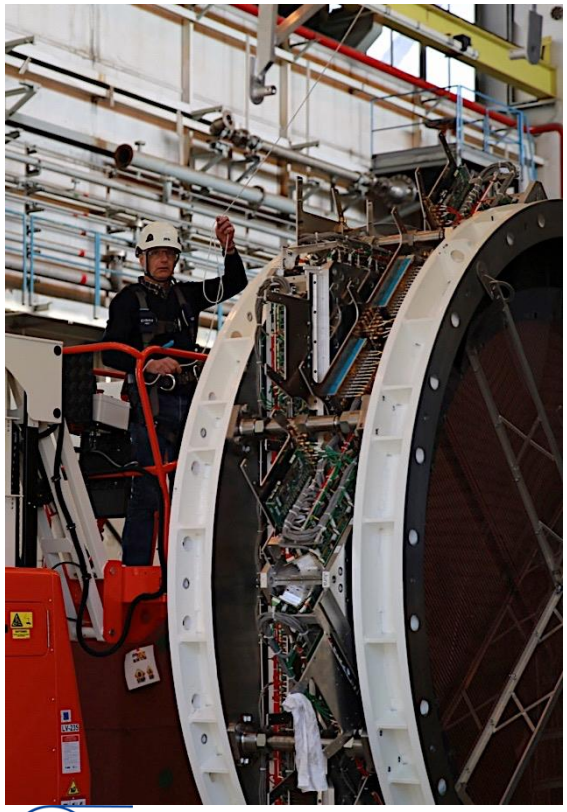
NA62: SM with **rare K decays**

NA63: **electromagnetism** in extreme conditions

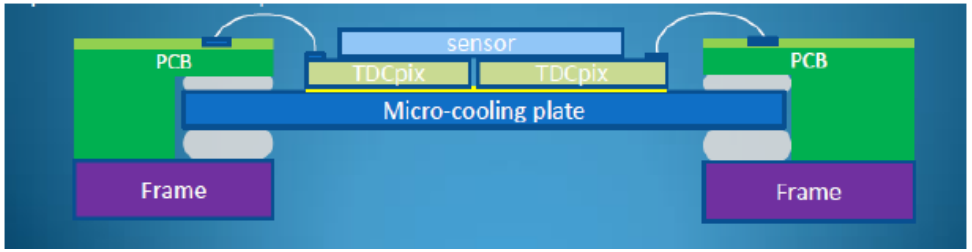
NA62

- SPS beam from October 6 until December 15, 2014
- All main detectors commissioned
- Written > 100 TB of data

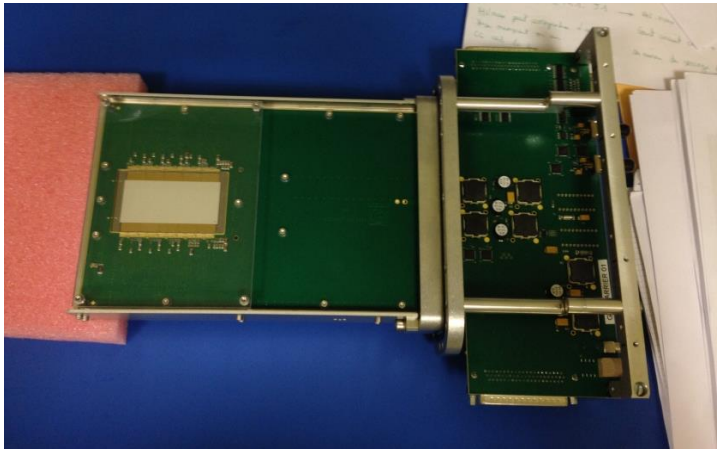
Straw Tracker

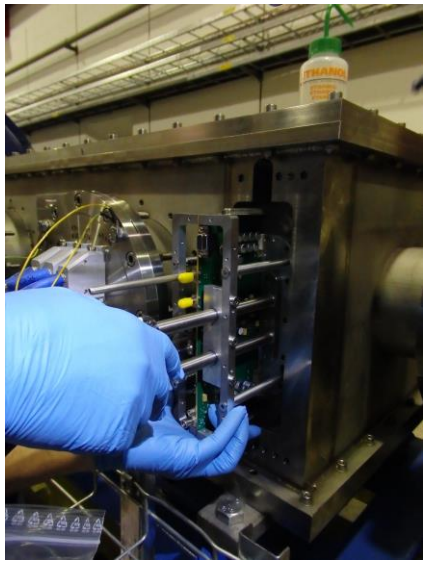


GTK – GigaTracKer

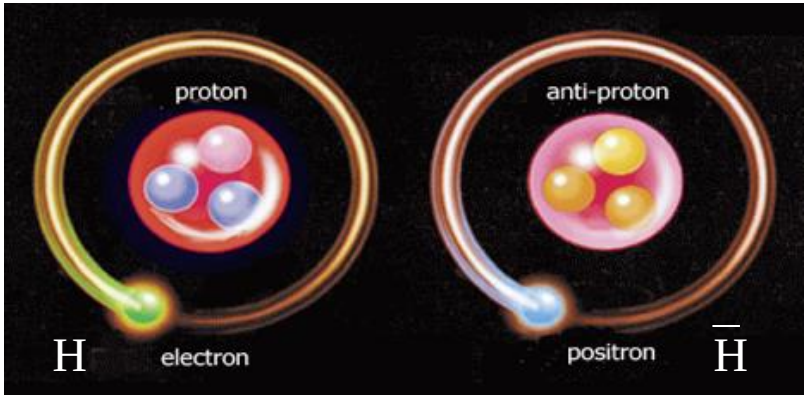


- PH-DT & PH-ESE





Antiproton Decelerator



Matter-Antimatter comparison

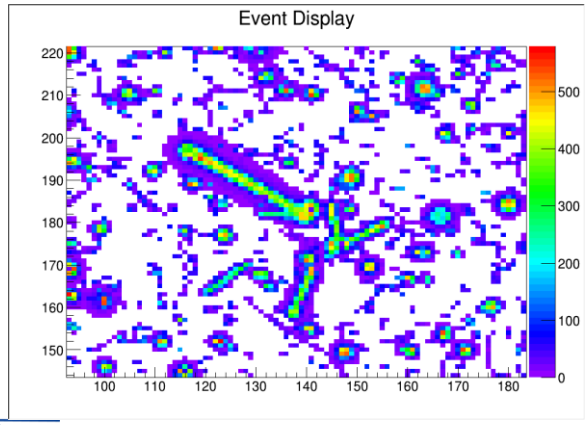
Very fundamental in the current theory of physics: $m = \bar{m}$, $g = \bar{g}$

ATRAP, ALPHA Trapping and spectroscopy of Hbar in a "bottle"

ASACUSA Spectroscopy of exotic atoms and of in-flight Hbars

BASE Magnetic moment of the antiproton

AEgIS Hbar free fall, gravity effect on antimatter.
Galileo's experiment for antimatter!



Antiproton annihilations in silicon sensor read out via TimePix3

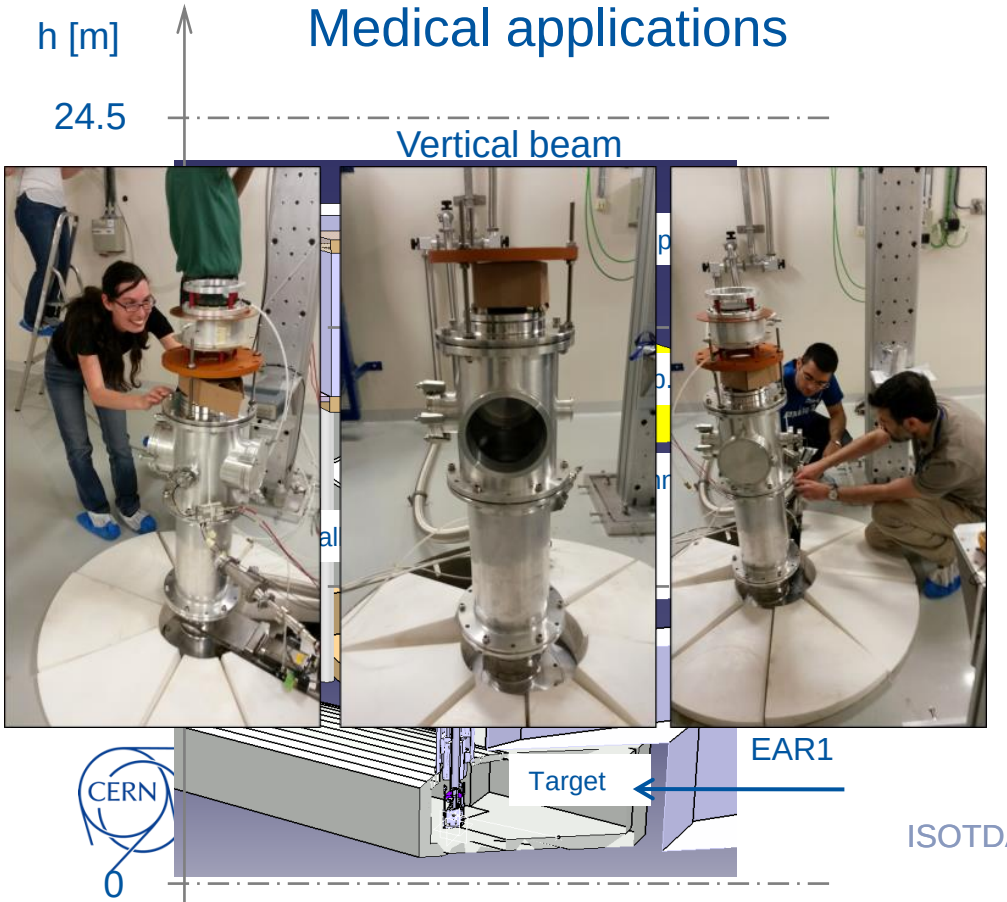
Nuclear Physics

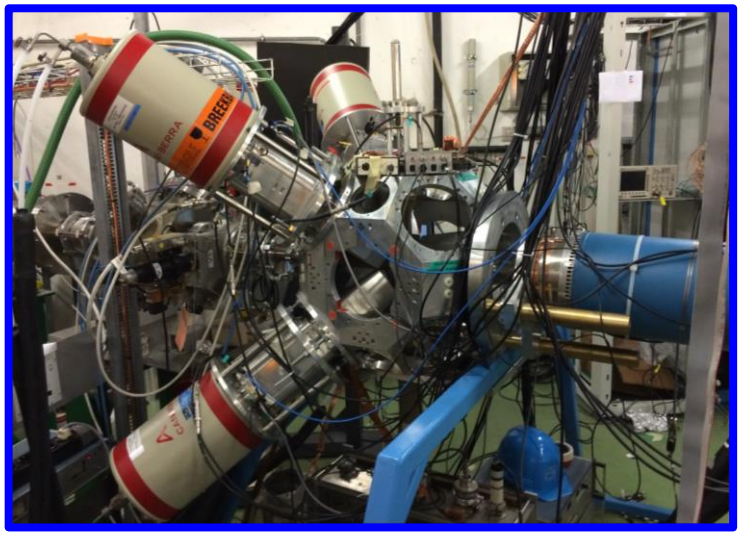
ISOLDE: radioactive ion beams

Nuclear physics - Astrophysics

Solid State Physics

Medical applications





New permanent setup for beta decay studies

N_TOF

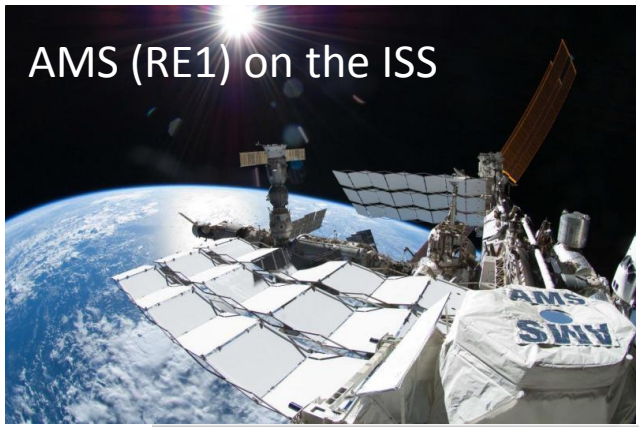
Nuclear Waste Transmutation

Astrophysics

Medical Physics

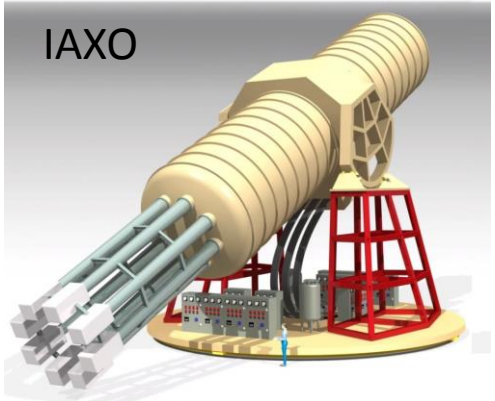
First physics measurement
At the new vertical beam pipe

Other experiments



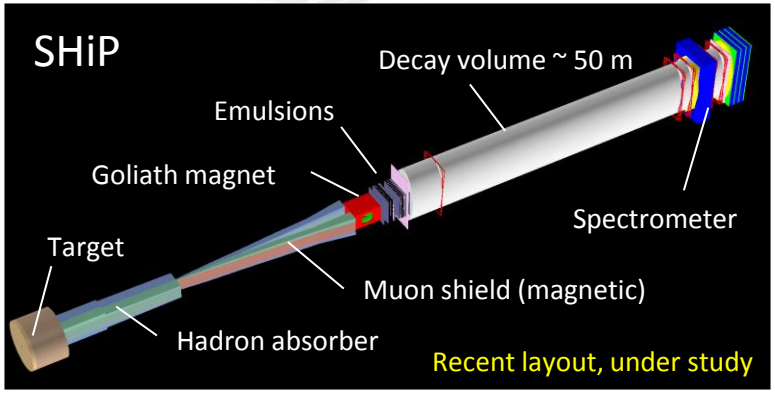
In addition to the approved experiments at CERN, there are currently 30 **"Recognized Experiments"**

Most related to astrophysics; in principle only marginal cost to CERN, but still require support



Also experiments under study:

IAXO: International **Ax**ion **O**bservatory, proposed successor to the CAST solar axion search experiment that currently uses a spare LHC dipole magnet
TDR in preparation



SHiP: Search for **Hi**dden **P**articles, proposed beam dump experiment at SPS to search for sterile neutrinos, can also study tau neutrinos
TP in preparation

Support groups in Physics Dept.

PH-DT Detector Technologies

PH-ESE Electronic Systems for Experiments

PH-SFT SoFTware design for experiments

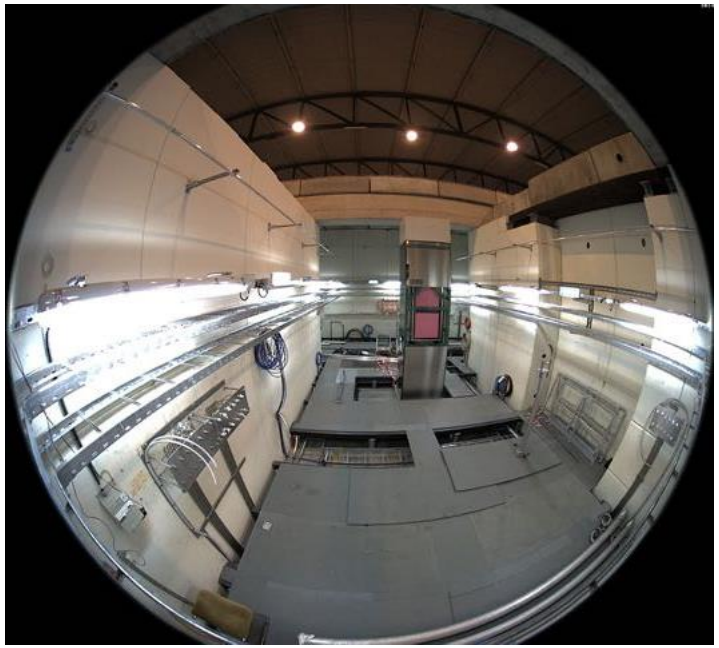
Detector Technologies

Development, construction, operation and maintenance of particle detectors

Detector infrastructure for experiments at CERN - Detector R&D

Last Straw chamber being installed in NA62

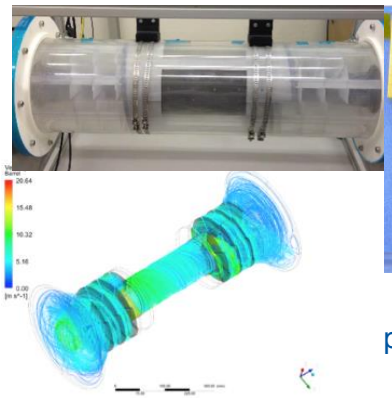
Upgrade of key irradiation facilities (protons@PS and Gamma@SPS)



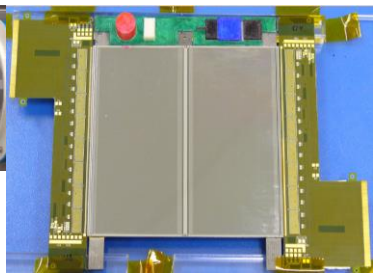
GIF++ at SPS H4 beam line in hall EHN1

Involvement in detector projects (R&D, Construction) for LHC upgrade and new studies/projects

ATLAS Micromegas Module 0



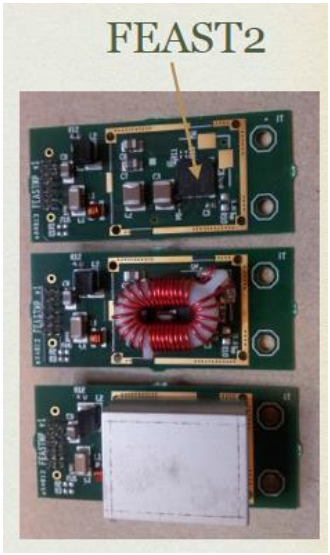
CLIC Vertex Detector Mockup & FEA



First full-size mechanical prototype of a “2S” module for CMS TK upgrade

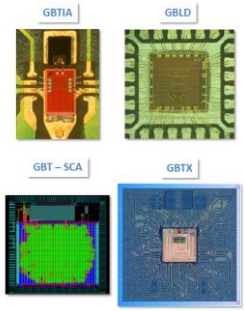
Electronic Systems for Experiments

Design and maintenance of electronics systems for experiments at CERN
Supply of electronics related services - Electronics for NA62 ATLAS CMS
Some examples:

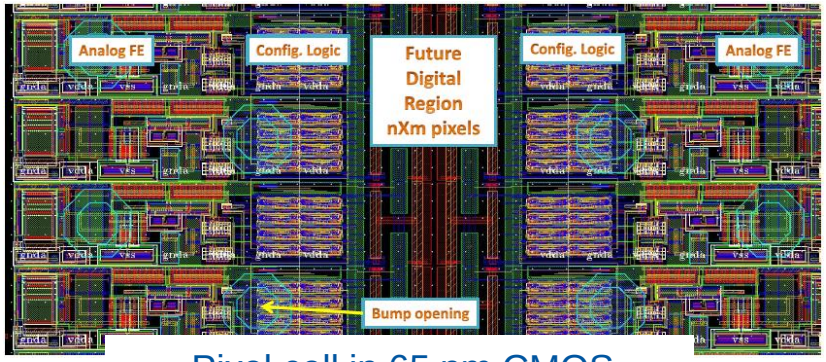


Rad and magnetic field tolerant DC-DC converter (20000 pieces)

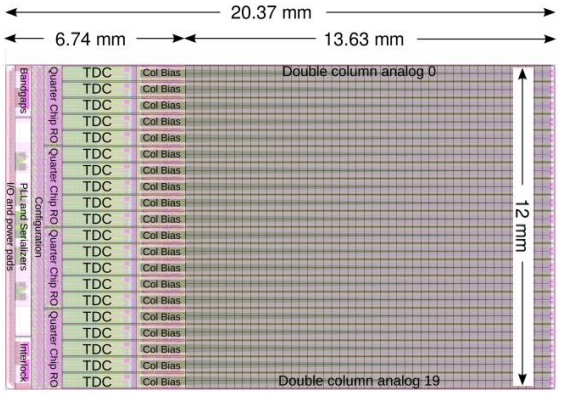
New ATLAS
Central Trigger Processor



GBT chipset and versatile link device



Pixel cell in 65 nm CMOS



TDCpix ASIC for NA62 Gigatracker

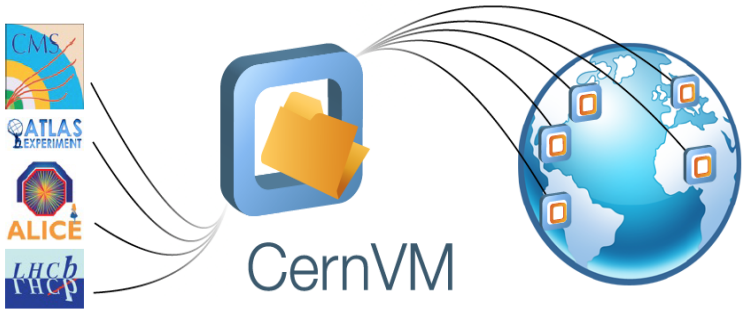
SFT

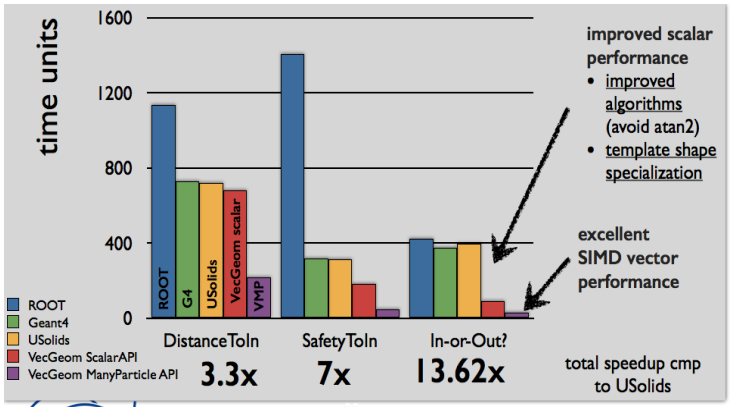
Development and maintenance of common scientific software for the CERN experimental programme

Geant4 v10.1 – parallel event simulation in multiple threads now production ready (CMS first user)

ROOT6 – introduced a powerful C++ parser based on a real compiler (clang); provides a sound platform for long-term

CernVM – provides critical service for deploying collaboration software and running applications on institutional and commercial 'clouds'





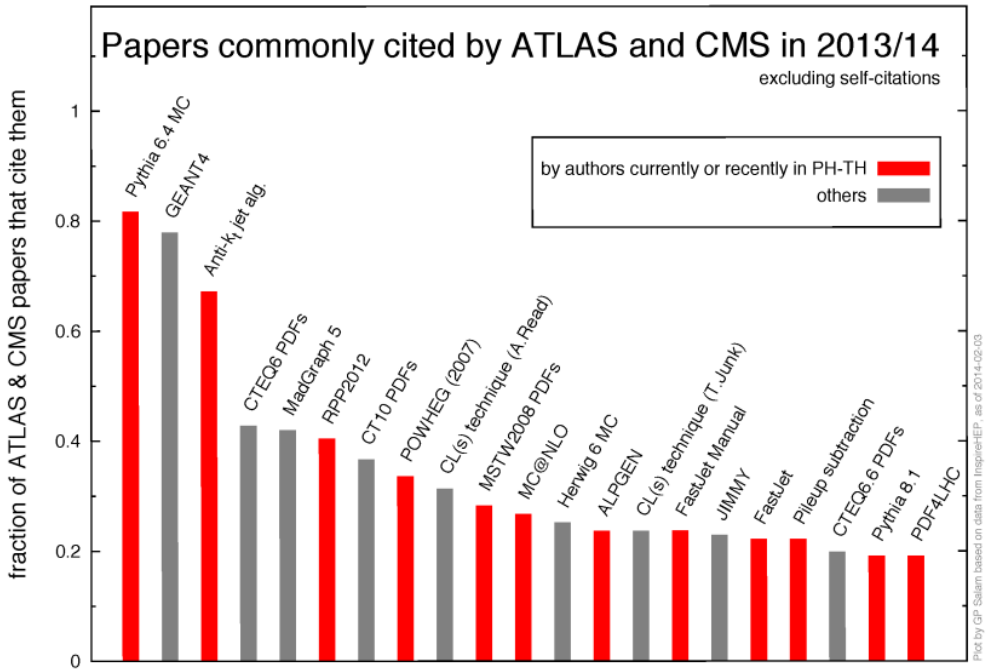
GeantV – demonstrate speedup in simulation of a realistic large LHC-size detector

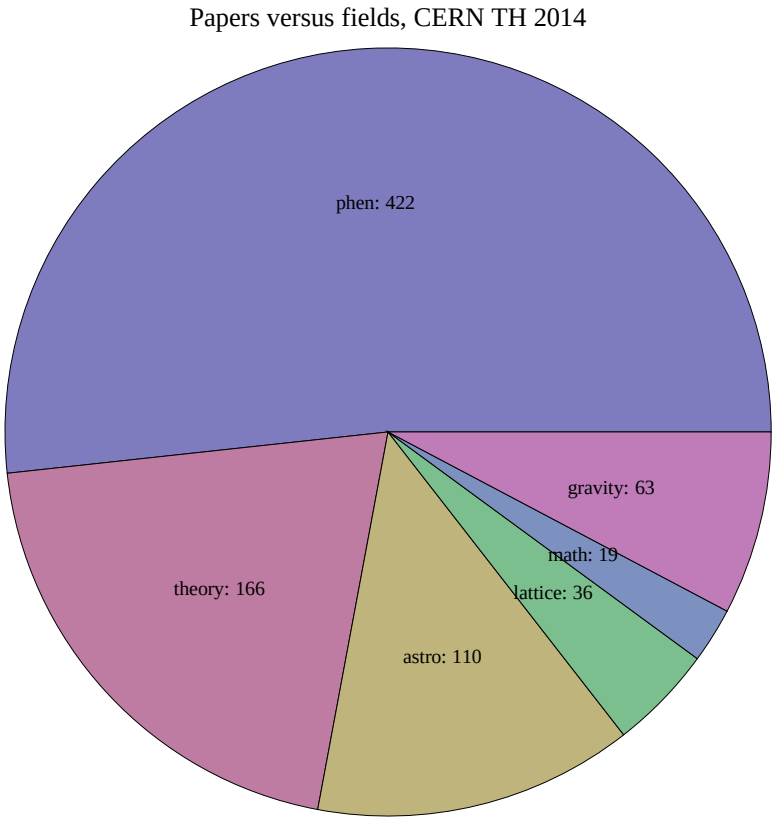
HEP Software Foundation (HSF) – aim to collaborate with new partners on development and maintenance of software packages for HEP

see: http://hepsoftwarefoundation.org

Theory

- Excellence and creativity in all vital areas of theoretical physics
  - Standard Model, collider phenomenology
  - Beyond the SM, including neutrinos and non-accelerator experiments
  - Astroparticle physics and cosmology
  - Quantum Field Theory and string theory
  - Heavy ion physics - Lattice field theory

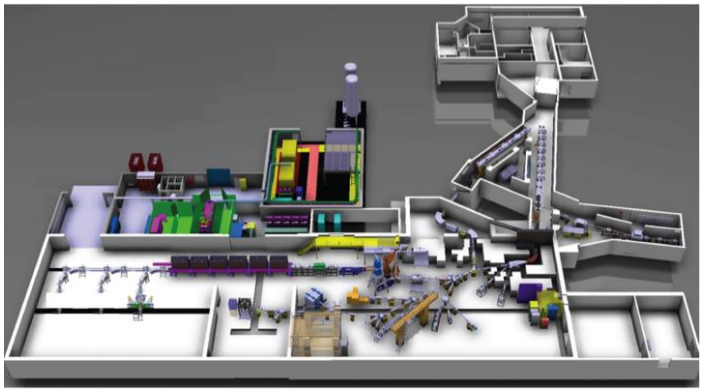




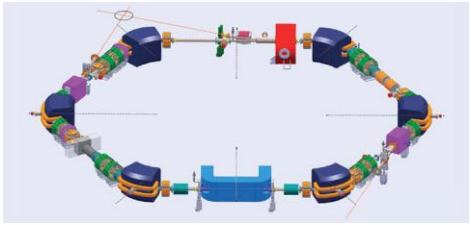
Diversity

HIE-ISOLDE: upgrade to higher energy (10 MeV/nucleon) and intensity

TSR@ISOLDE: transfer of a storage ring from Heidelberg, for integration into ISOLDE



ELENA (Extra Low Energy Antiproton Ring): additional ring for the AD to provide cooler antiprotons to more experiments



Neutrino platform: supporting R&D on large-scale detectors

WA104: ICARUS at CERN

WA105: preparation of large dual-phase LAr TPC

Impact on our lives

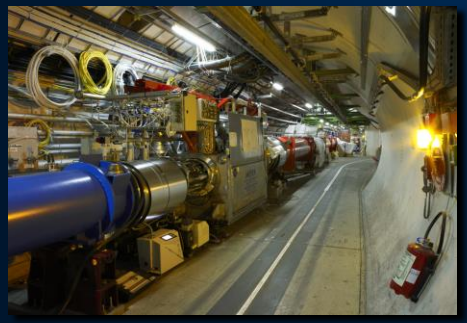
Spin-off of fundamental research

Innovation
Education
CERN
uniting people
Research

CERN: Particle Physics and Innovation

- Interfacing between fundamental science and key technological developments

- CERN Technologies and Innovation



Accelerating particle beams

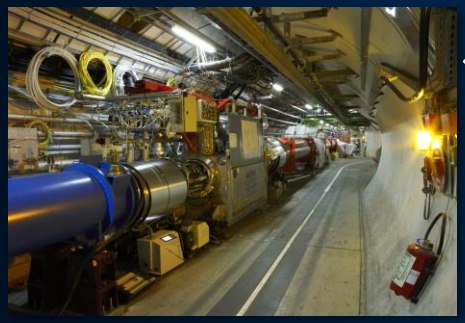
Detecting particles

Large-scale computing (Grid)

CERN

Medical Application as an Example of Particle Physics Spin-off

Combining Physics, IT, Biology and Medicine to fight cancer

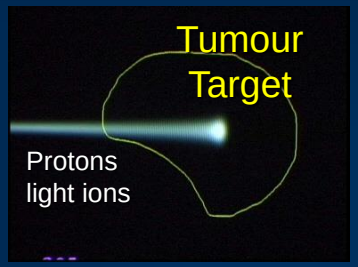


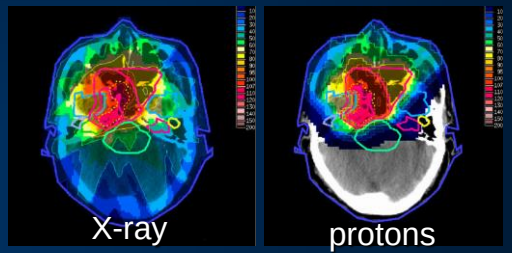
Accelerating particle beams

~30’000 accelerators worldwide

~17’000 used for medicine

Hadron Therapy

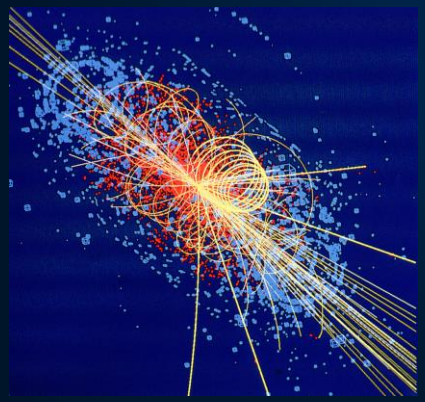




Leadership in Ion Beam Therapy now in Europe and Japan

>100’000 patients treated worldwide (45 facilities)

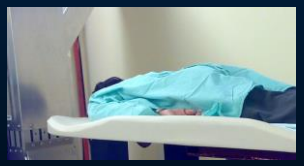
>50’000 patients treated in Europe (14 facilities)



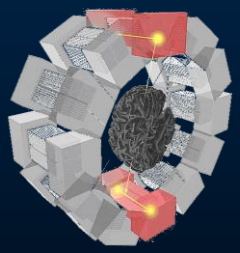
Detecting particles

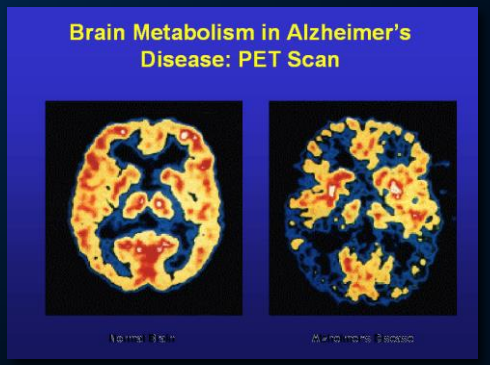
Imaging

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

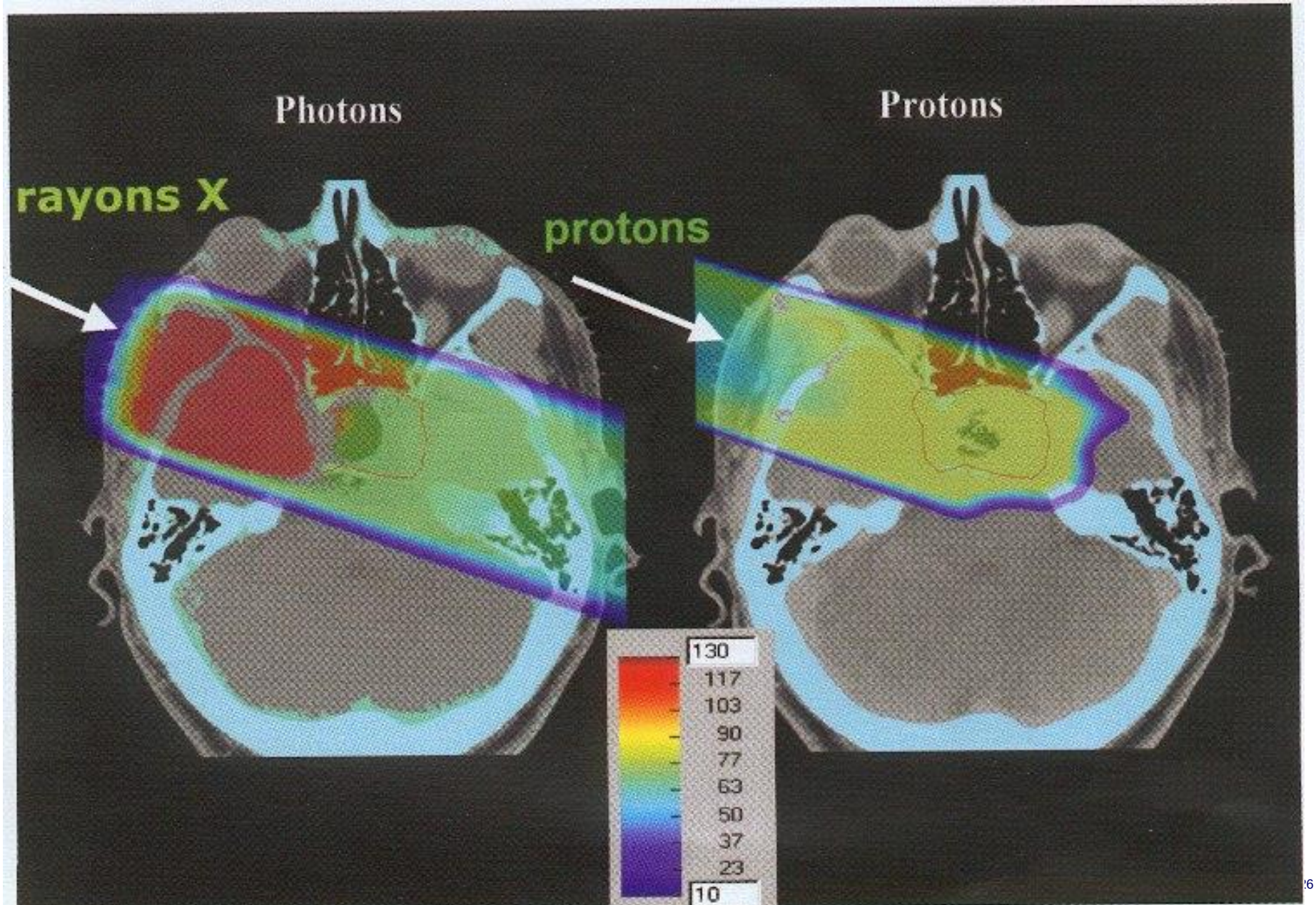


PET Scanner



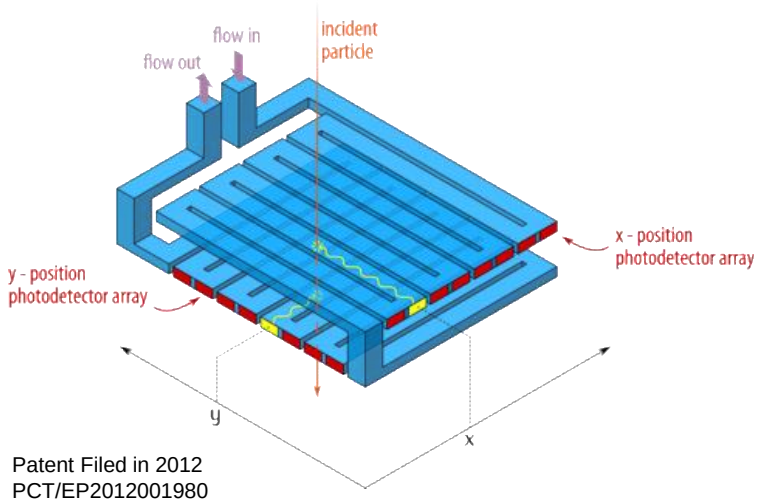


Advantages of hadron therapy



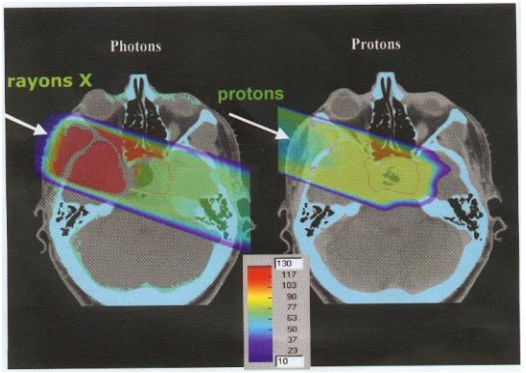
Beam monitors for hadron therapy

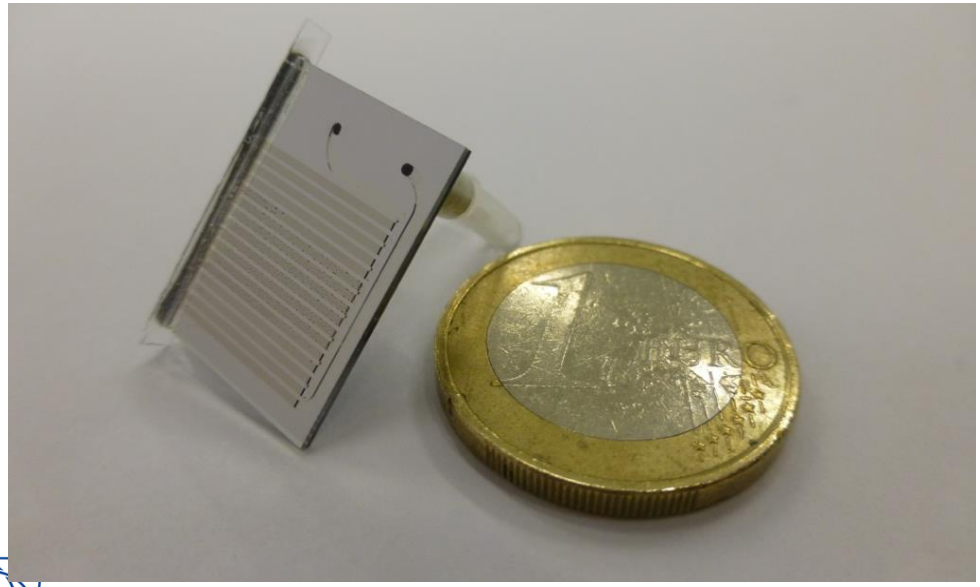
R&D in microtechnology



Patent Filed in 2012
PCT/EP2012001980

Microfluidic scintillation detectors are being studied as online beam monitors in hadron therapy.





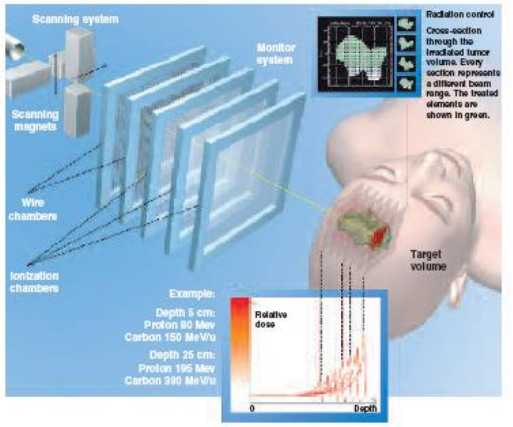
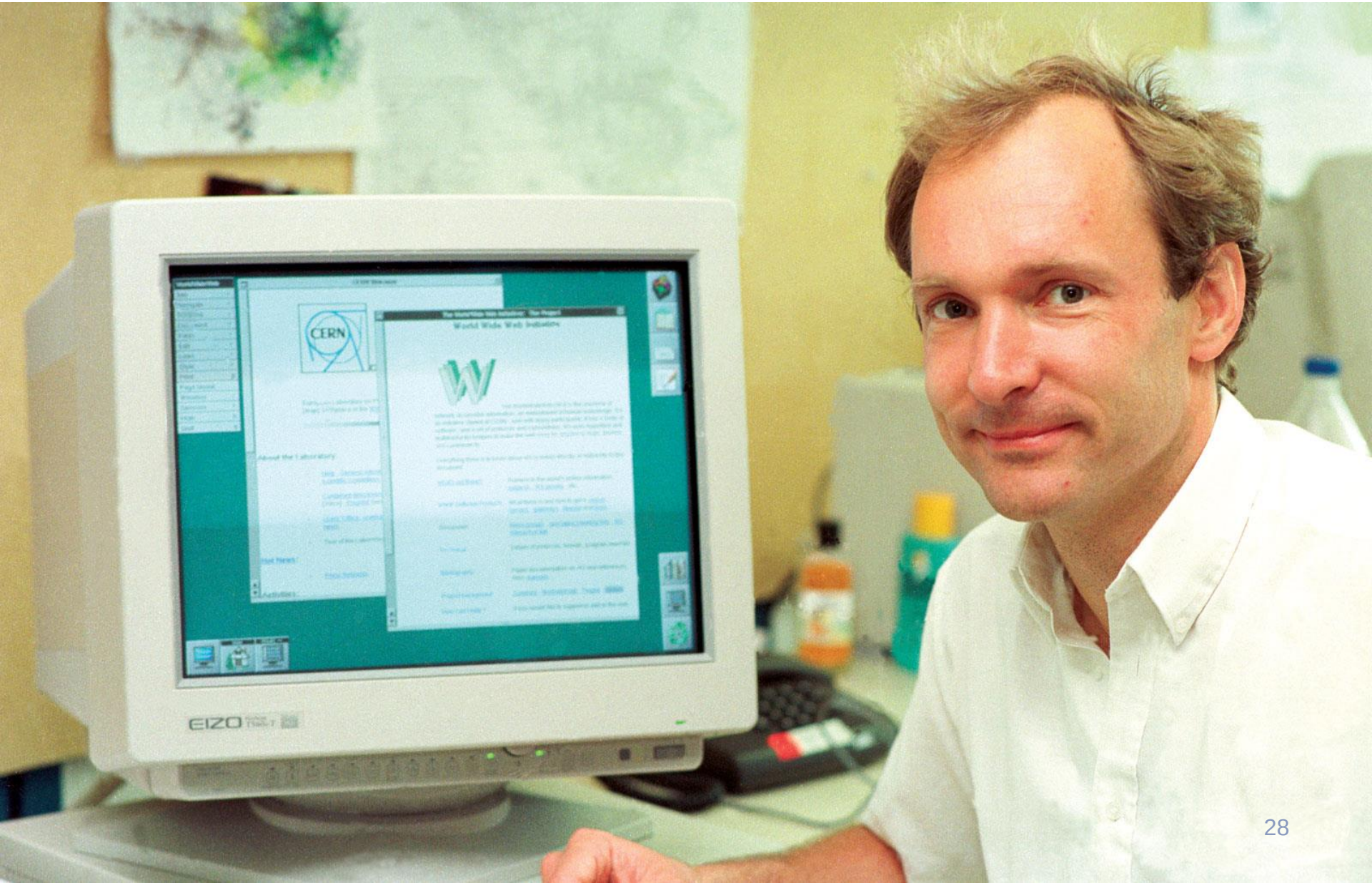


Figure 4 - Dose delivery with a 3D active scanning technique (courtesy of Siemens Medical).

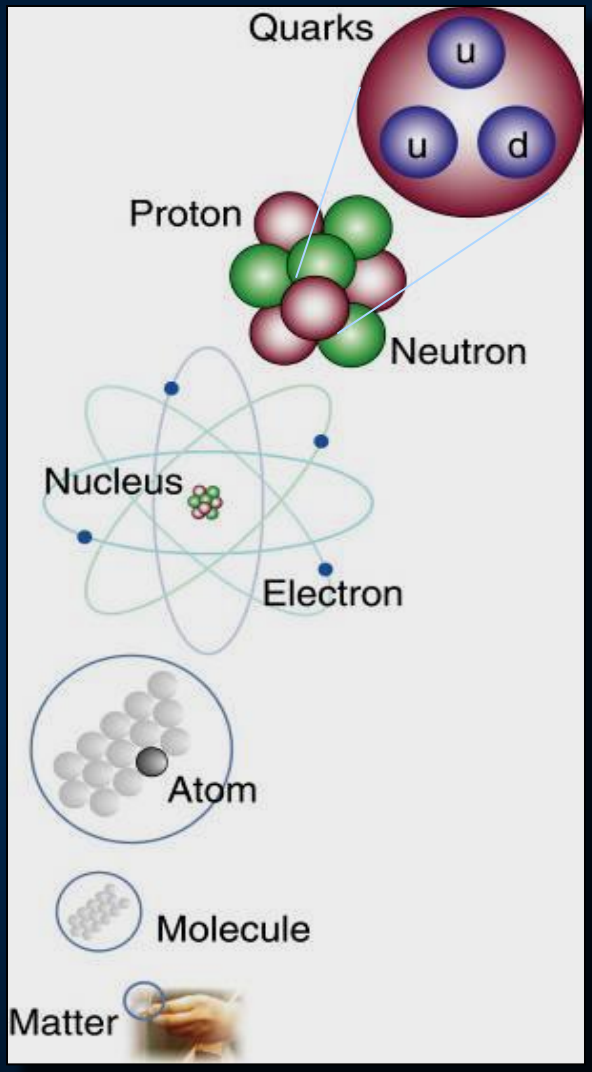
Spinoff - The World Wide Web

(Tim Berners-Lee)

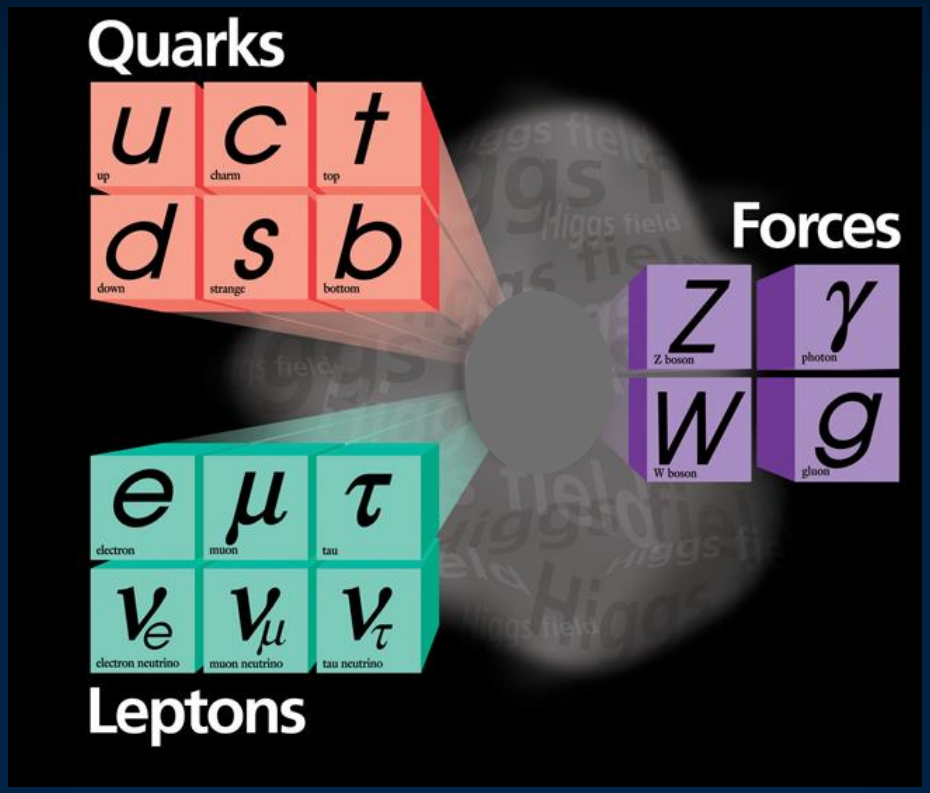


The future

CERN mission : fundamental research



The Standard Model



One missing piece : masses are not explained
possible solution, Higgs mechanism

LHC 2012 : Higgs Boson

gives mass to particles

Nobel Prize in Physics 2013

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".*

Future

The Standard Model is not the end of the story
(e.g. gravity not included)

Recent astrophysical measurements indicate that the universe is made of:
5% known matter
25 % "dark matter"
70% "dark energy"

Today we understand only 5% of the universe composition

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

A theory – ***Supersymmetry*** – predicts new heavy elementary particles.

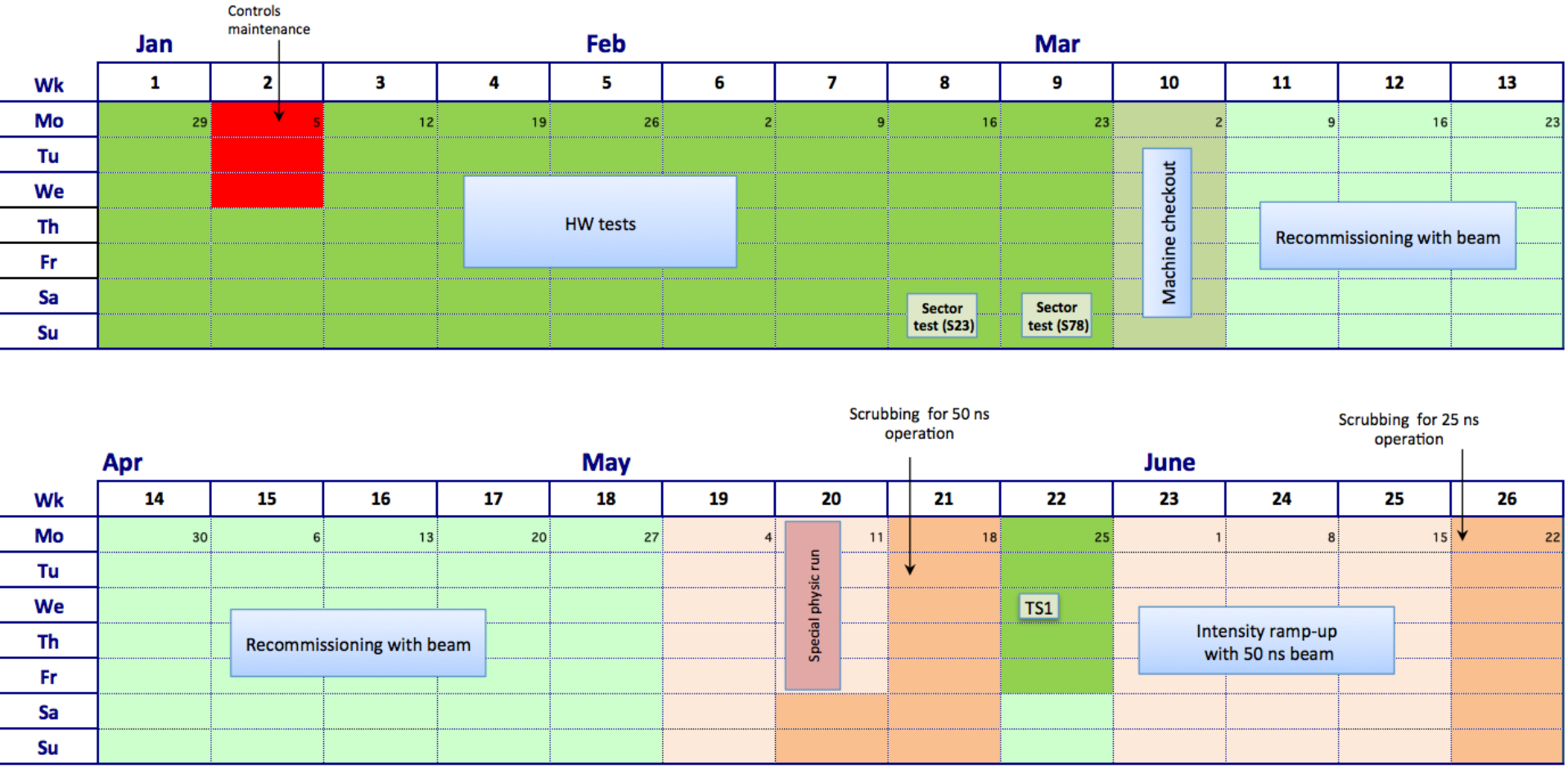
Among them the neutralino, a possible candidate for the universe dark matter

Could it be light enough to be produced abundantly at the LHC?

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

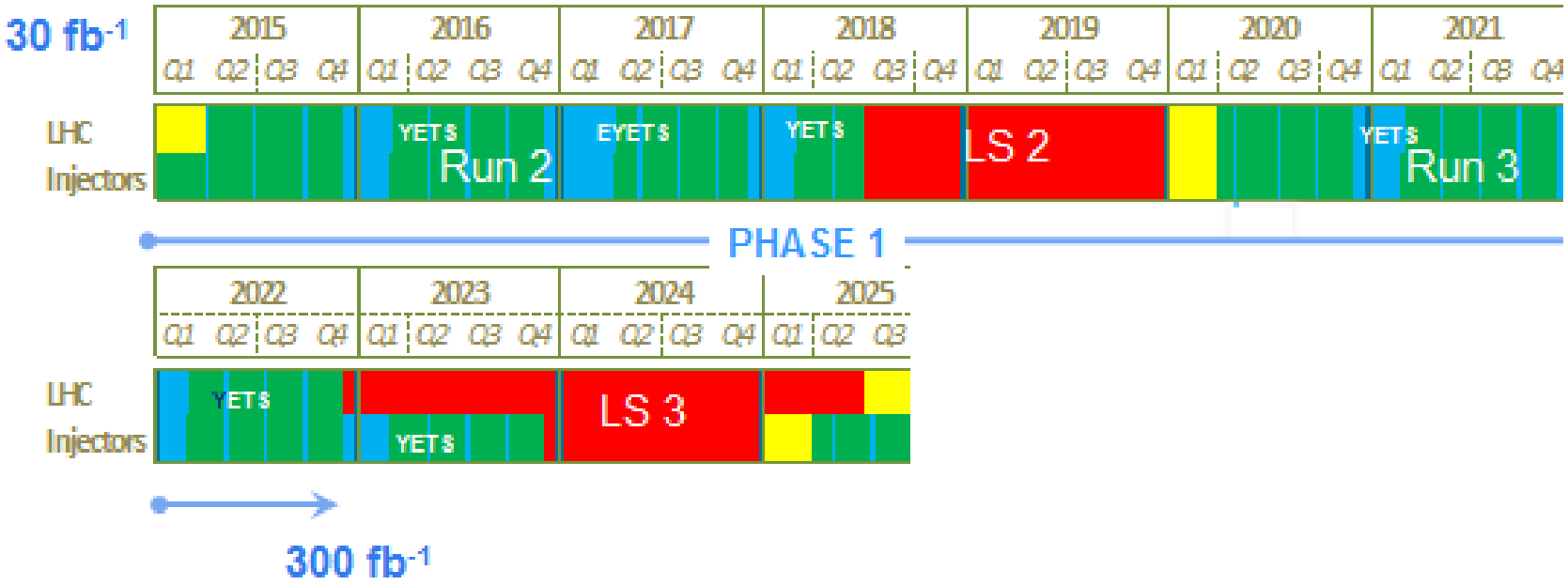
CERN

LHC Schedule 2015 (Q1/Q2)



First beam ~mid-March – 8 weeks commissioning – First Physics in May

LHC Schedule longer term



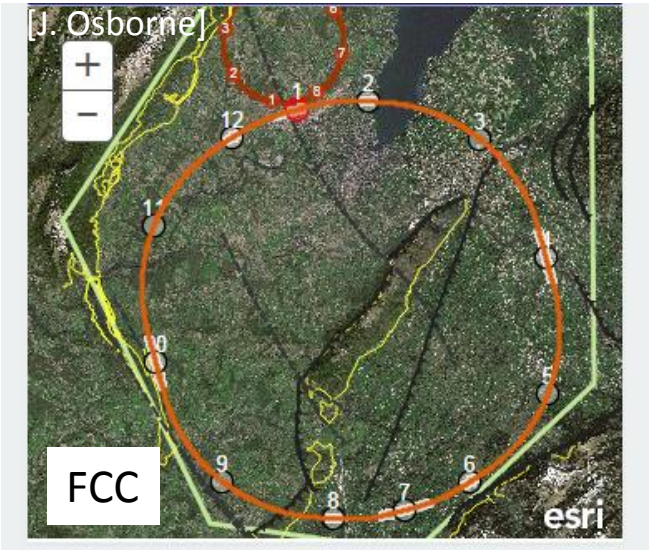
Integrated luminosity goal:

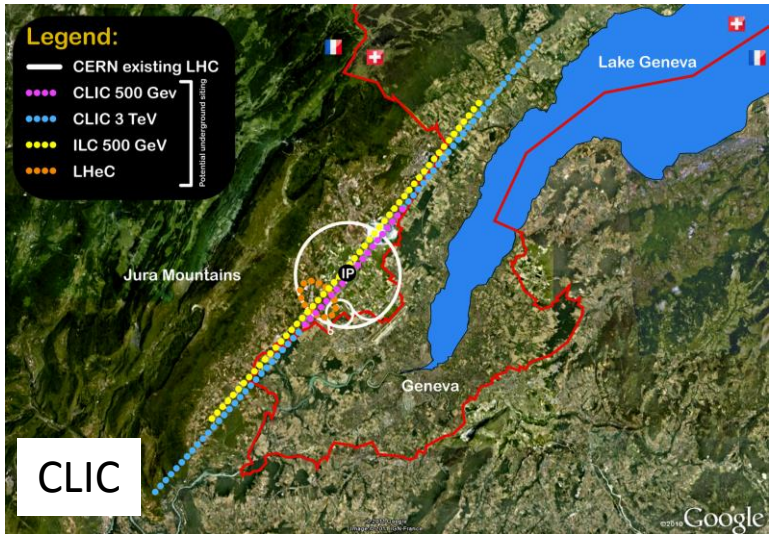
2015: **10 fb^{-1}**

RUN2: **100-120 fb^{-1}**

Before LS3 (LHC upgrade): **300 fb^{-1}**

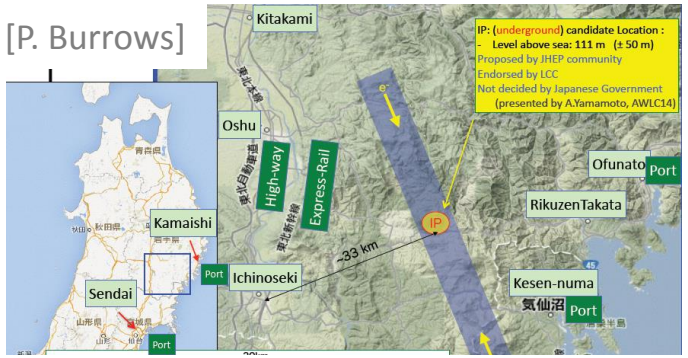
FCC: Study of large circular machine with possible pp, ee (and eh) options
Design to be driven by pp, aiming for 100 TeV c.m. for discovery reach
Latest layout 93 km circumference





Both are higher energy options than related facilities considered elsewhere:

CEPC: 54 km circular e^+e^- machine (China)



ILC: 30 km linear e^+e^- machine (Japan)

How do we manage this?

CERN was founded 1954: 12 European States

"Science for Peace"

Today: 21 Member States

~ 2300 staff
~ 1300 other paid personnel
~ 11500 scientific users

Budget (2015) ~1000 MCHF

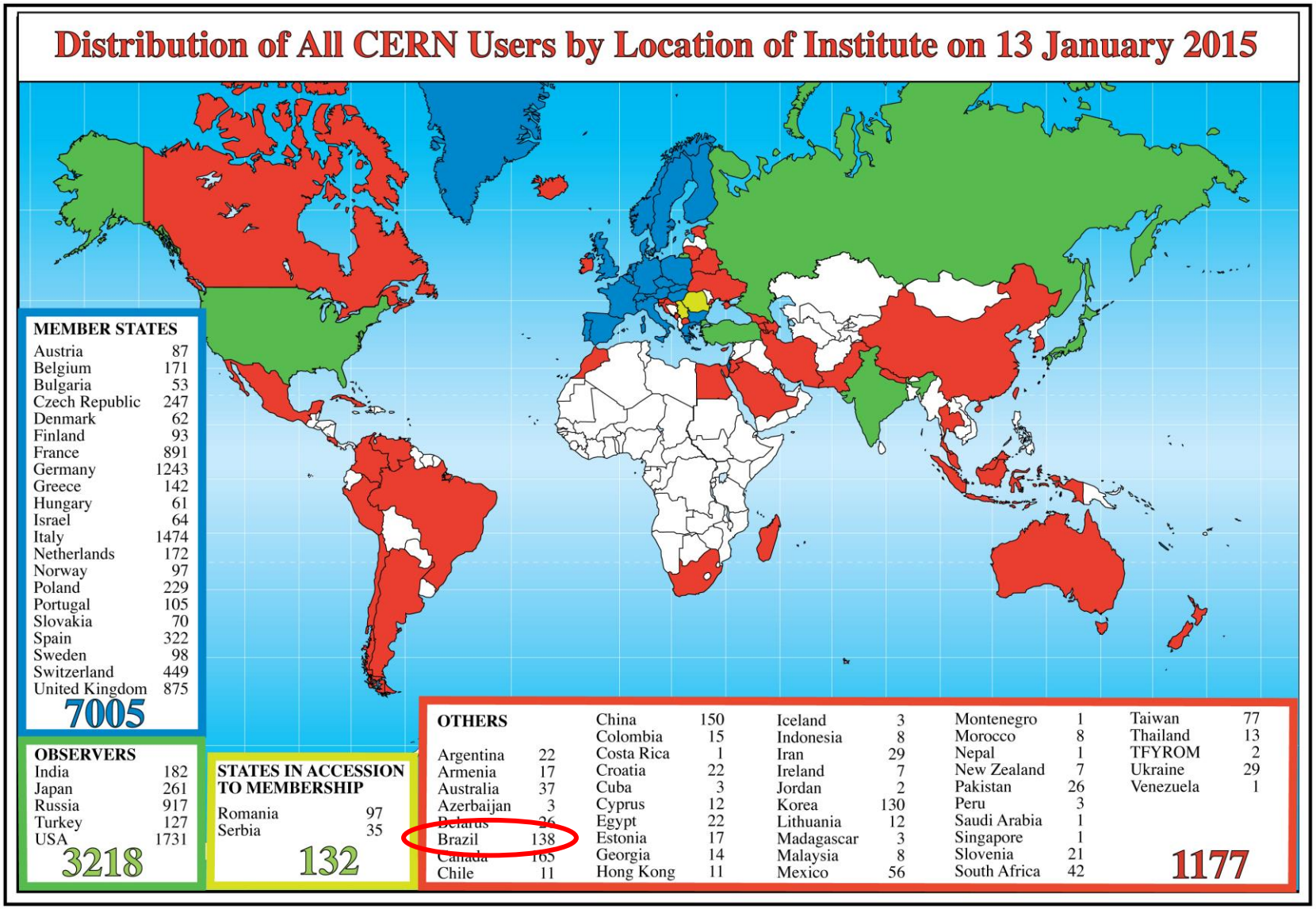
Member States: Austria, Belgium, Bulgaria, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Israel, Italy, the Netherlands, Norway, Poland, Portugal, Slovakia, Spain, Sweden, Switzerland and the United Kingdom

States in Accession to Membership: Romania, Serbia

Applicant States for Membership or Associate Membership: **Brazil**, Croatia, Cyprus, Pakistan, Russia, Slovenia, Turkey, Ukraine

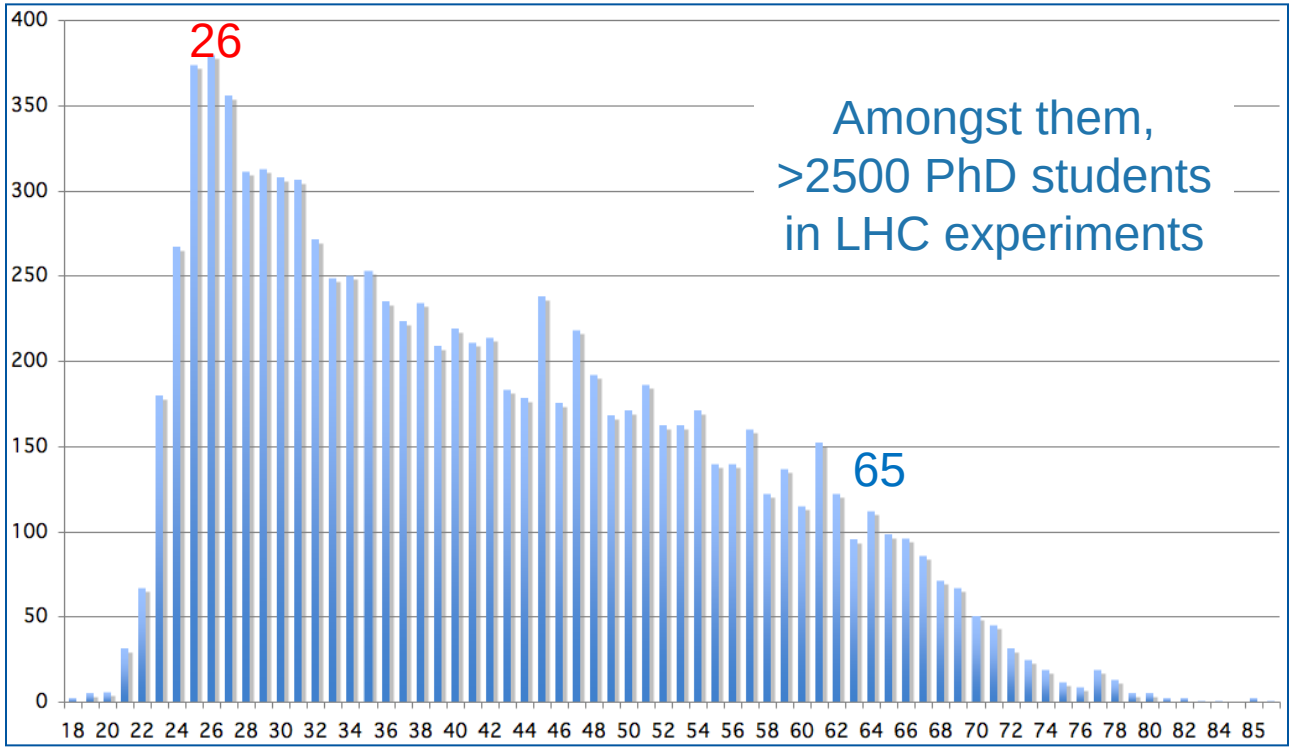
Observers to Council: India, Japan, Russia, Turkey, United States of America; European Union and UNESCO

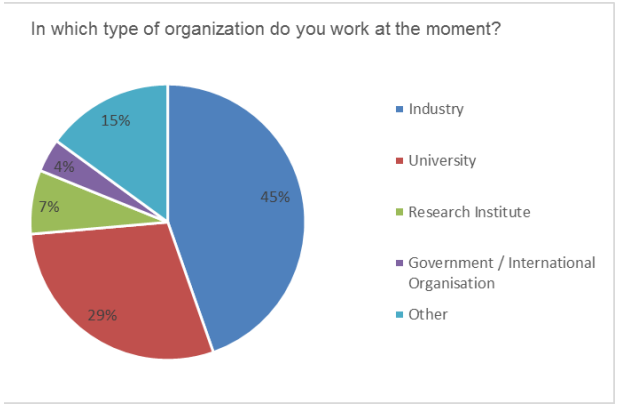
Science is growing more and more global

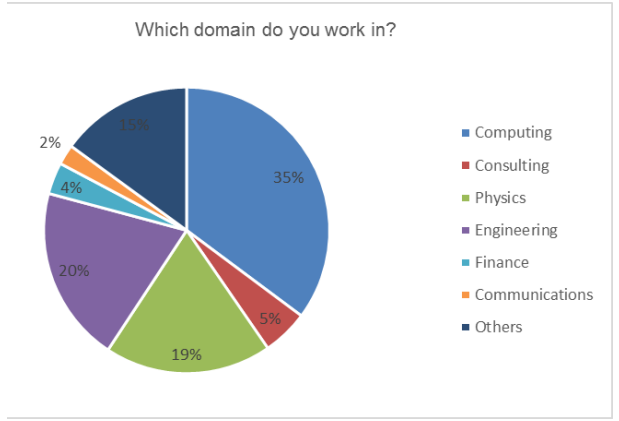


Age distribution of scientists at CERN

(and where they go afterwards)







They do not all stay: where do they go?

CERN

– innovate, discover, publish, share

… and bring the world together

Contrary to popular belief, our community is rather elementary:

- It has simple rules, honed by centuries of practice
- It shares a common vision and a common set of values
- It is based on collaboration AND competition

Science is intrinsically **not democratic** (can't understand the laws of nature by vote!) and therefore it has to be performed **with the most democratic tools:**

- Freedom of expression
- Peer reviewing
- Independency from political orientation, religion, social status, etc…

The scientists

Despite the usual cinematographic representation, we DO NOT

- Wear white lab coats
- Live in ivory towers
- Find a revolutionary result every second day (scientist = genius)
- … And we are not only men!

We are a pragmatic community capable to address in a very material way grand and (apparently) immaterial questions, knowing that for every answer we might find, we open more and unpredicted questions.

We definitely prefer to be

Ministers of Doubt than Kings of Truth

Doubt is the basis of freedom

(ubi dubium, ibi libertas)

THANK YOU!