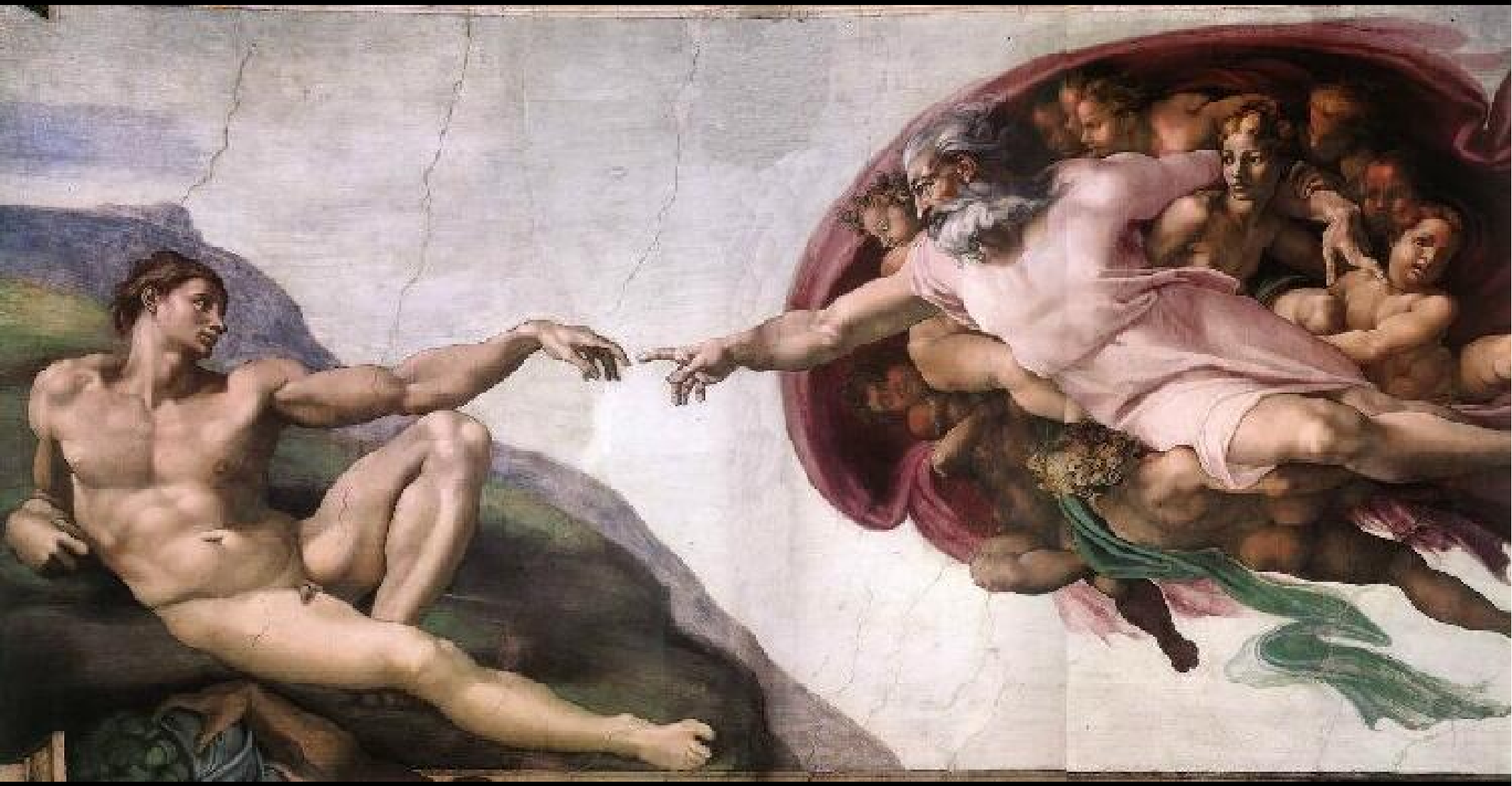
Physics & Faith

Faith & Physics



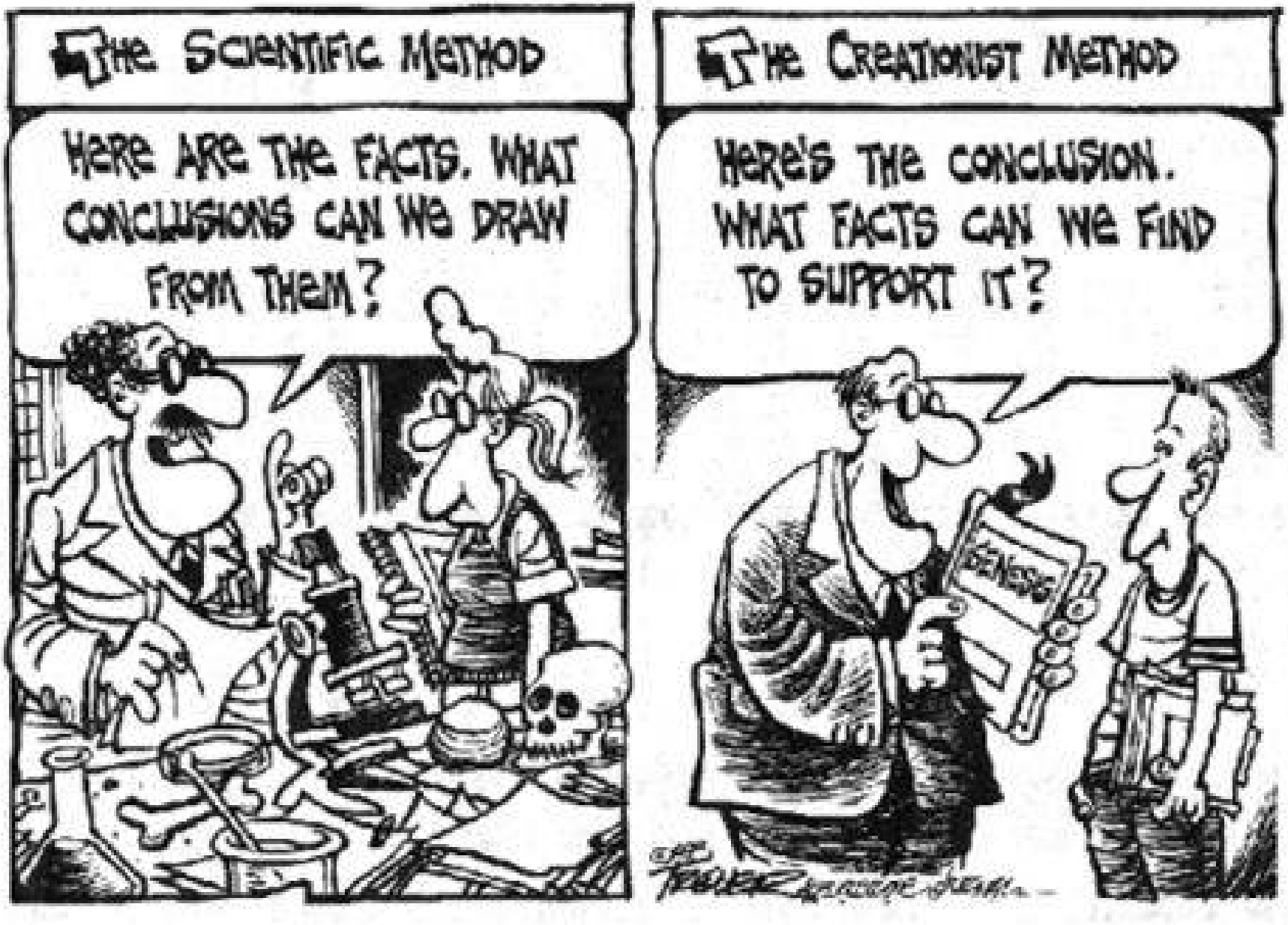
Emmanuel Methodist Church, Chennai

2013-09-09

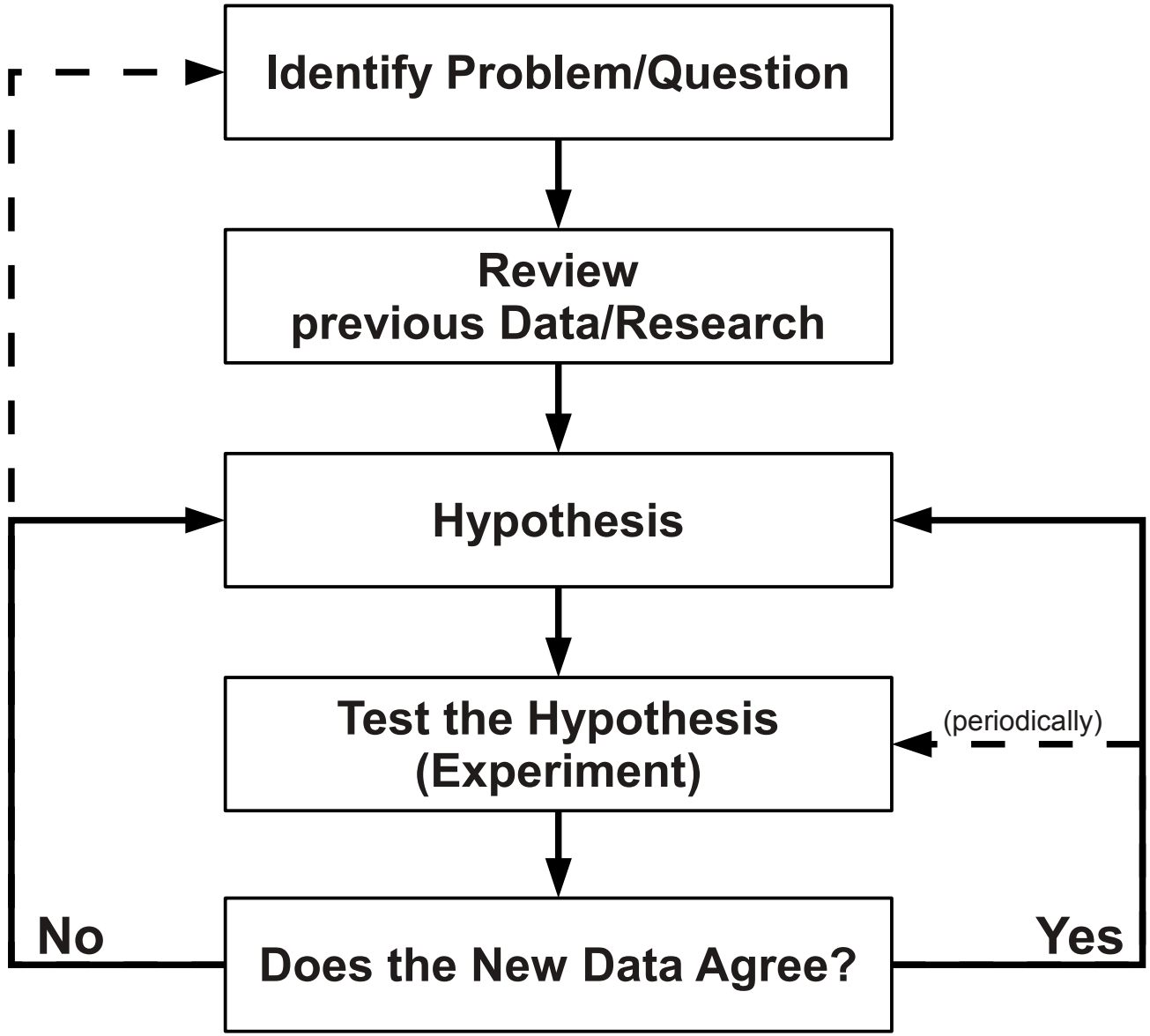
Physics is not about finding 'truths' ...

…but about discovering how nature works.

'Scientific Method' – Corner Stone of Science

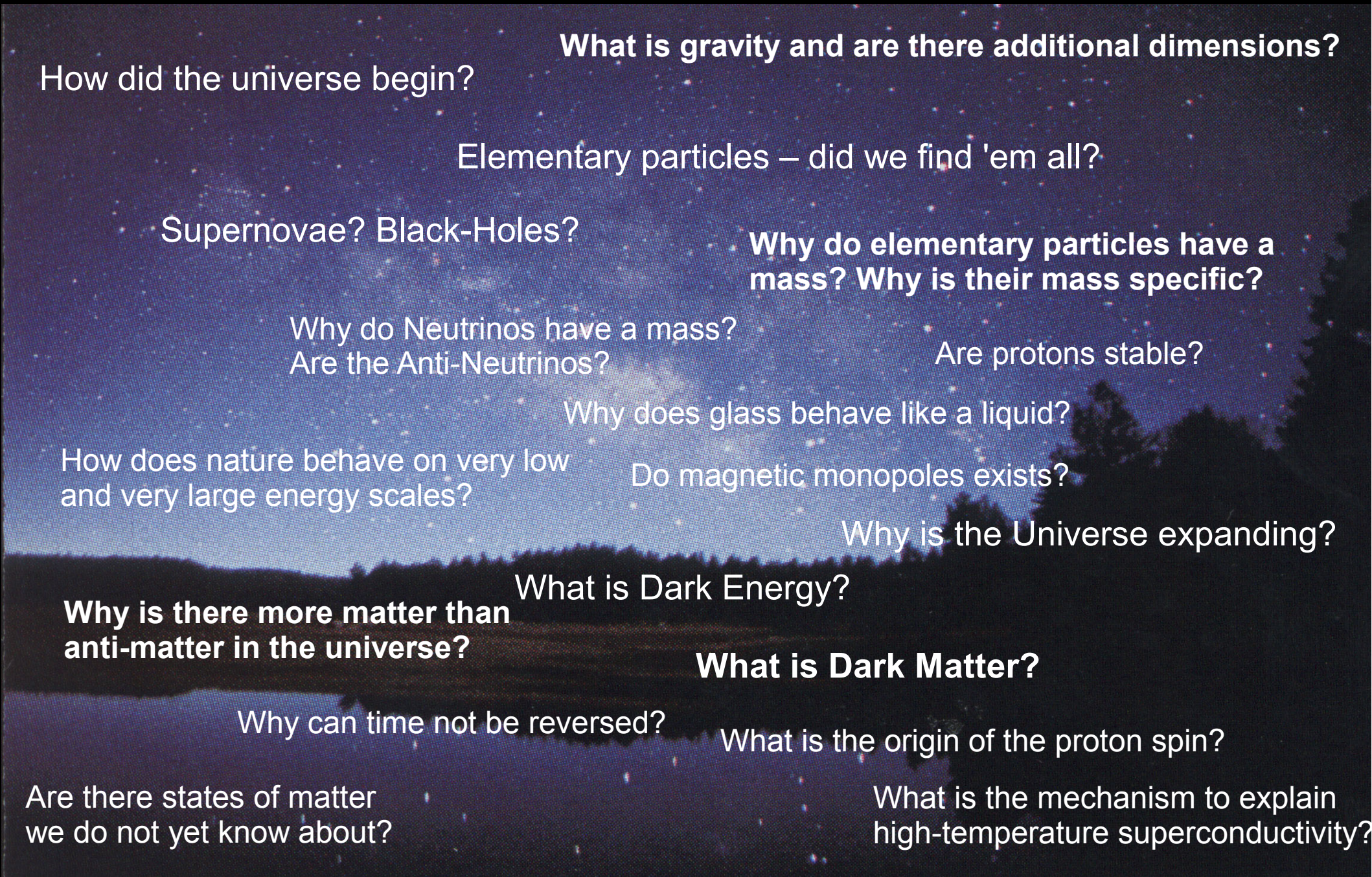


'Scientific Method' – Corner Stone of Science



Physics fundamental questions …

Physics fundamental questions …



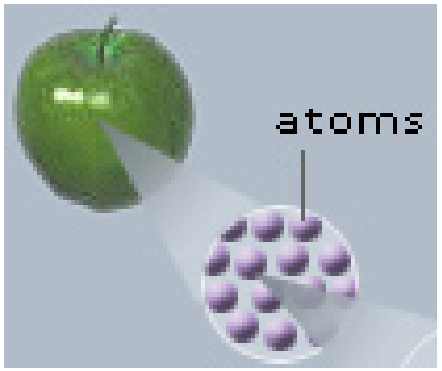
High-Energy-Physics
Understand the World in its most fundamental form ...

- Very ancient Greek idea ... world is made out of

  Atoms (ἄτομος, atomos, "indivisible")

- To set the scale:

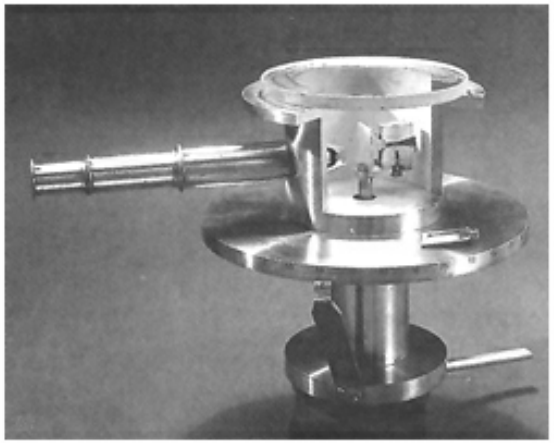
Human Hair
~ 100 μm = 0.0001 m or
= 100 ·10^{-6} m

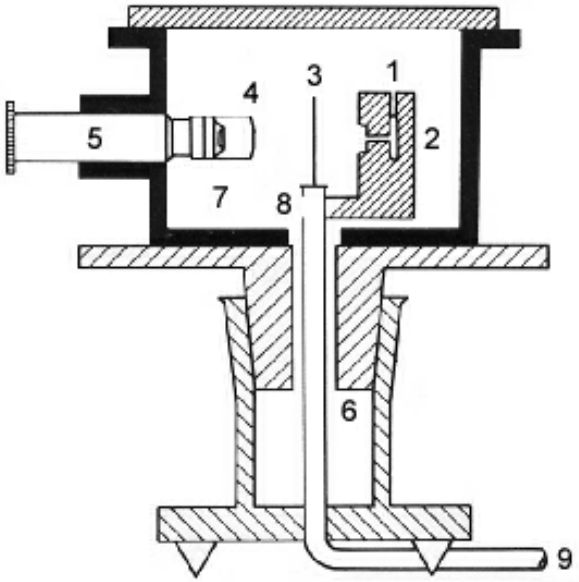


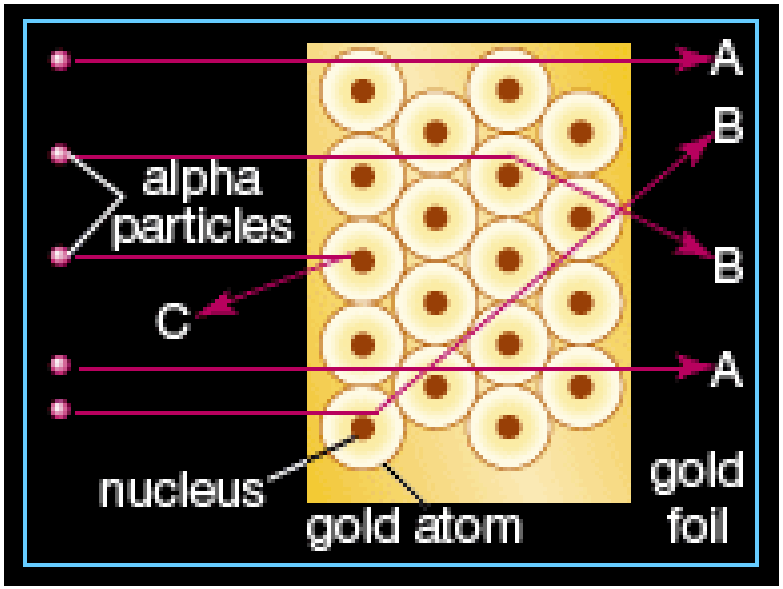
Atom ~ 10^{-10} m
= 0.0000000001 m

First Particle Physics Experiment: 'Atoms' are not fundamental Particles

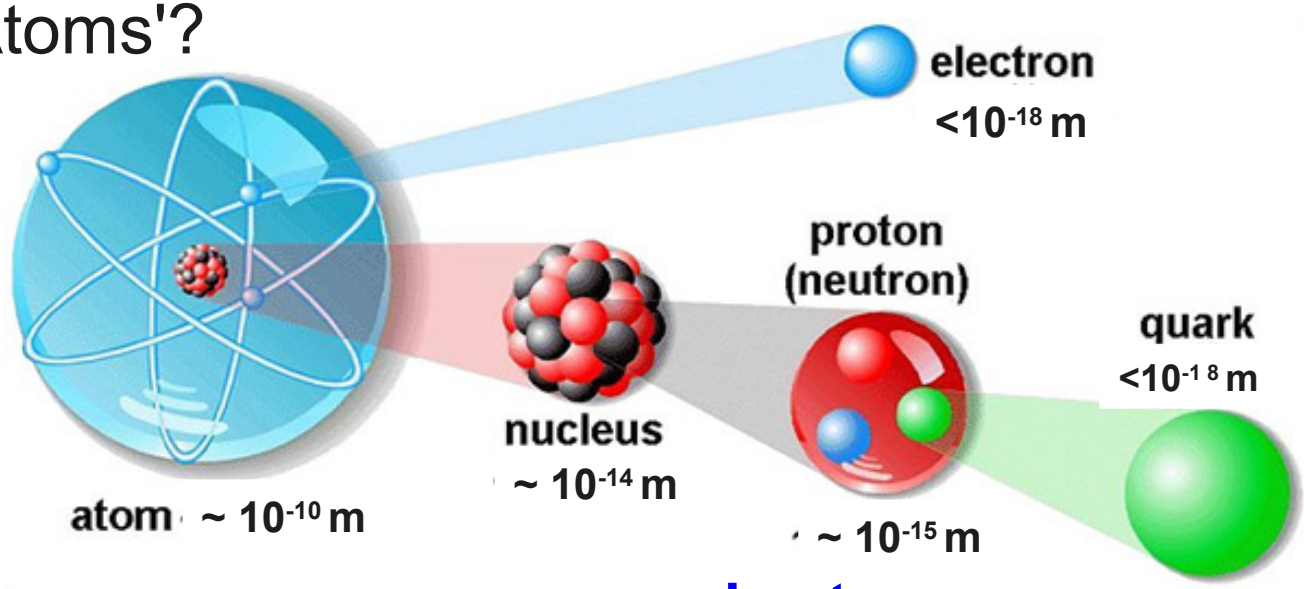
1911
Rutherford-Geiger–Marsden experiment: found nuclei in the atom by firing alpha particles at gold and observing them to bounce back





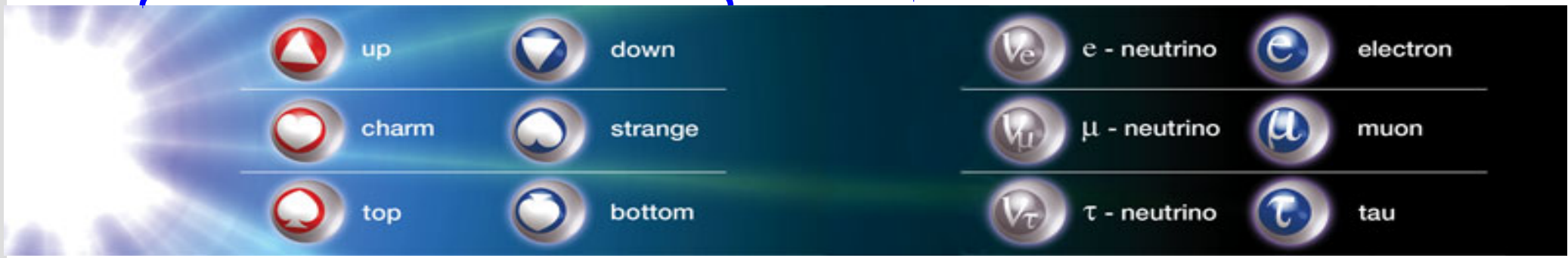


- What are the true 'Atoms'?



Hadrons
(greek: heavy particle)

Leptons
(greek: light particle)

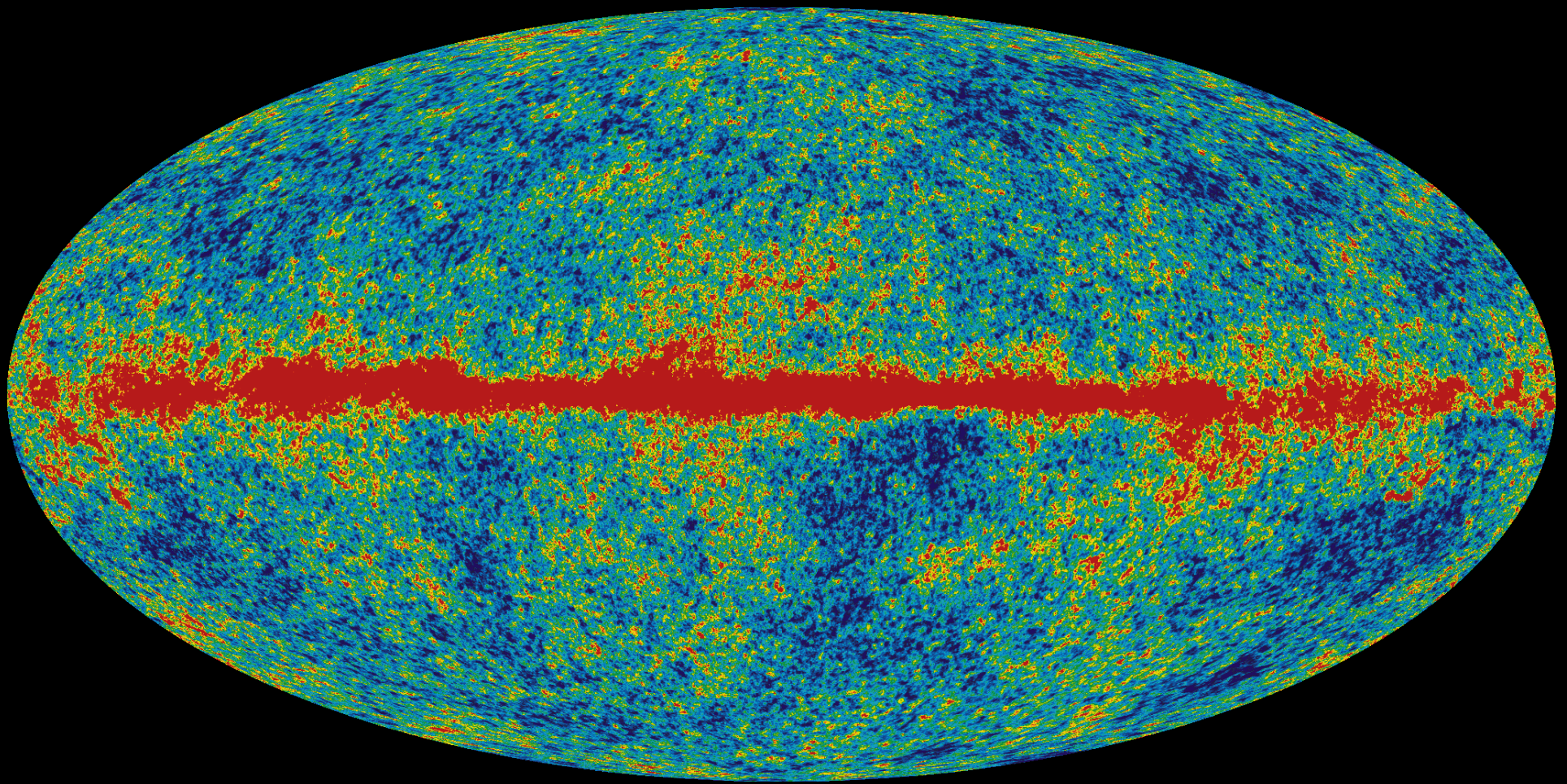


+ binding forces: γ (photons, x-rays, gamma), W, Z, gluons & H

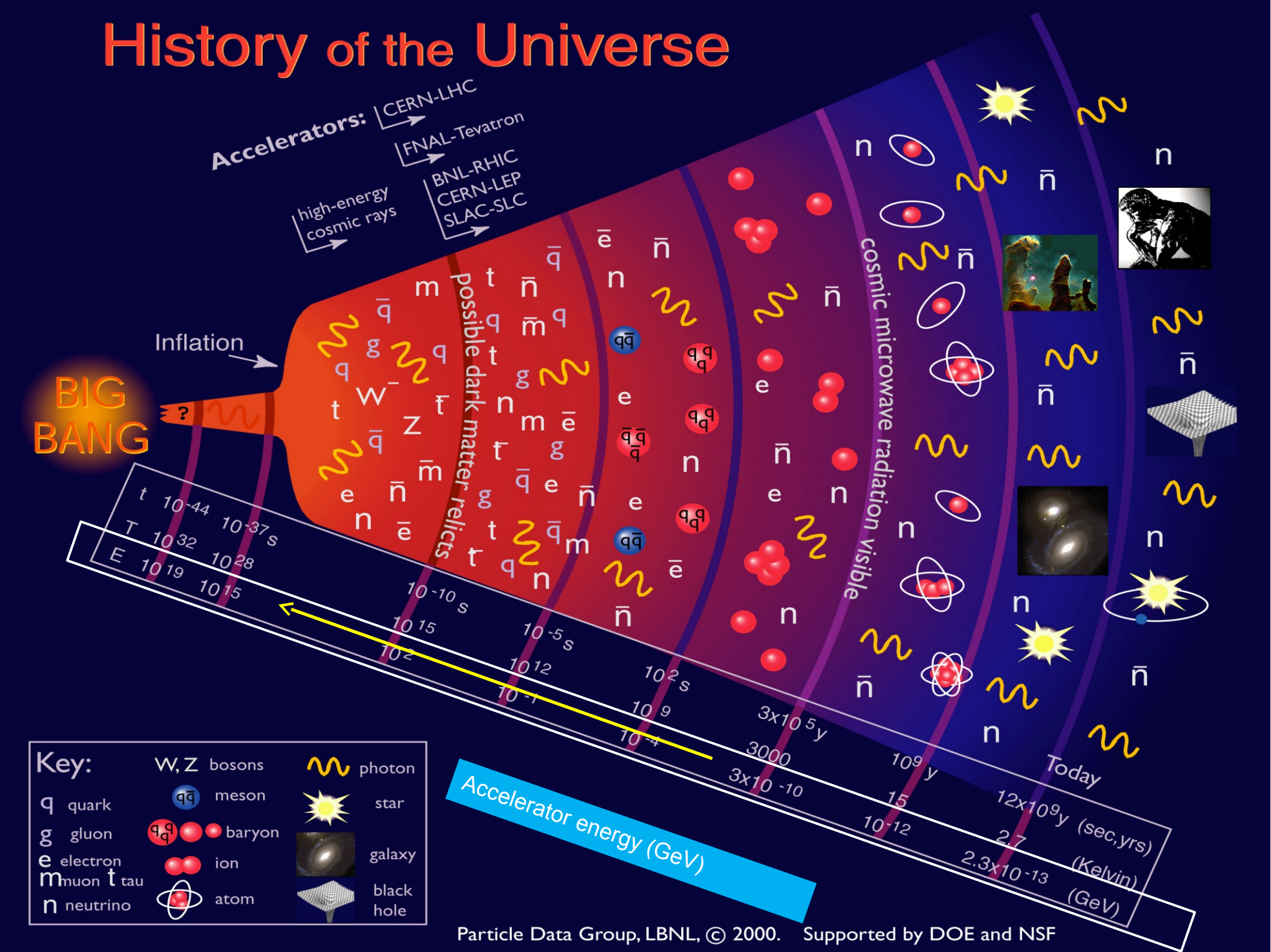
- Still, many open question remain....

Dark Matter, the Age of the Universe, ...
… and why there was a “Big Bang”

Dark Matter, the Age of the Universe, ...
… and why there was a “Big Bang”



History of the Universe



Particle Data Group, LBNL, © 2000. Supported by DOE and NSF

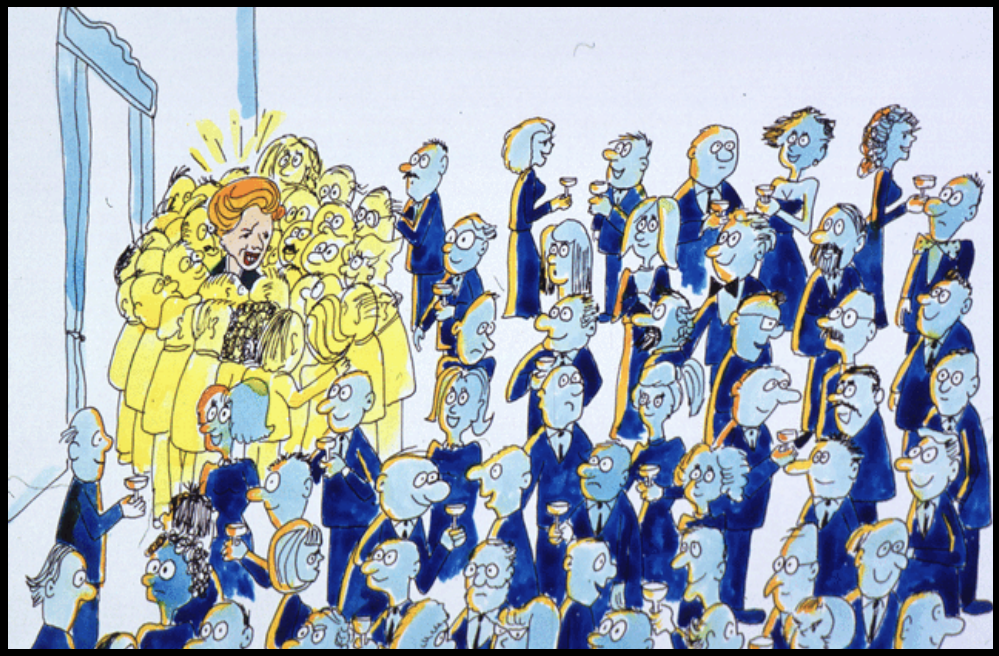
Dark Matter, the Age of the Universe, ...
… and why there was a “Big Bang”

Anti-Matter does exist …

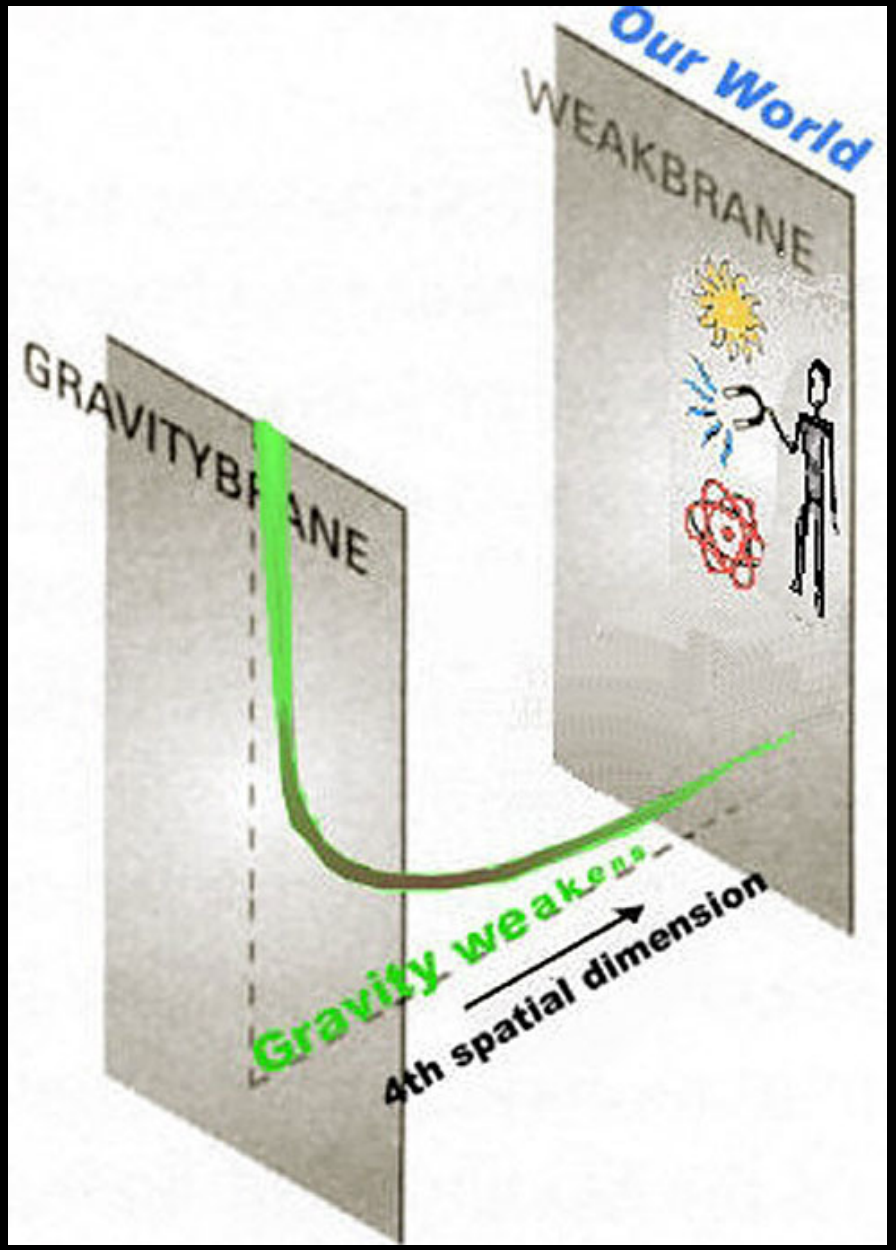
… but why is it so rare in the Universe?

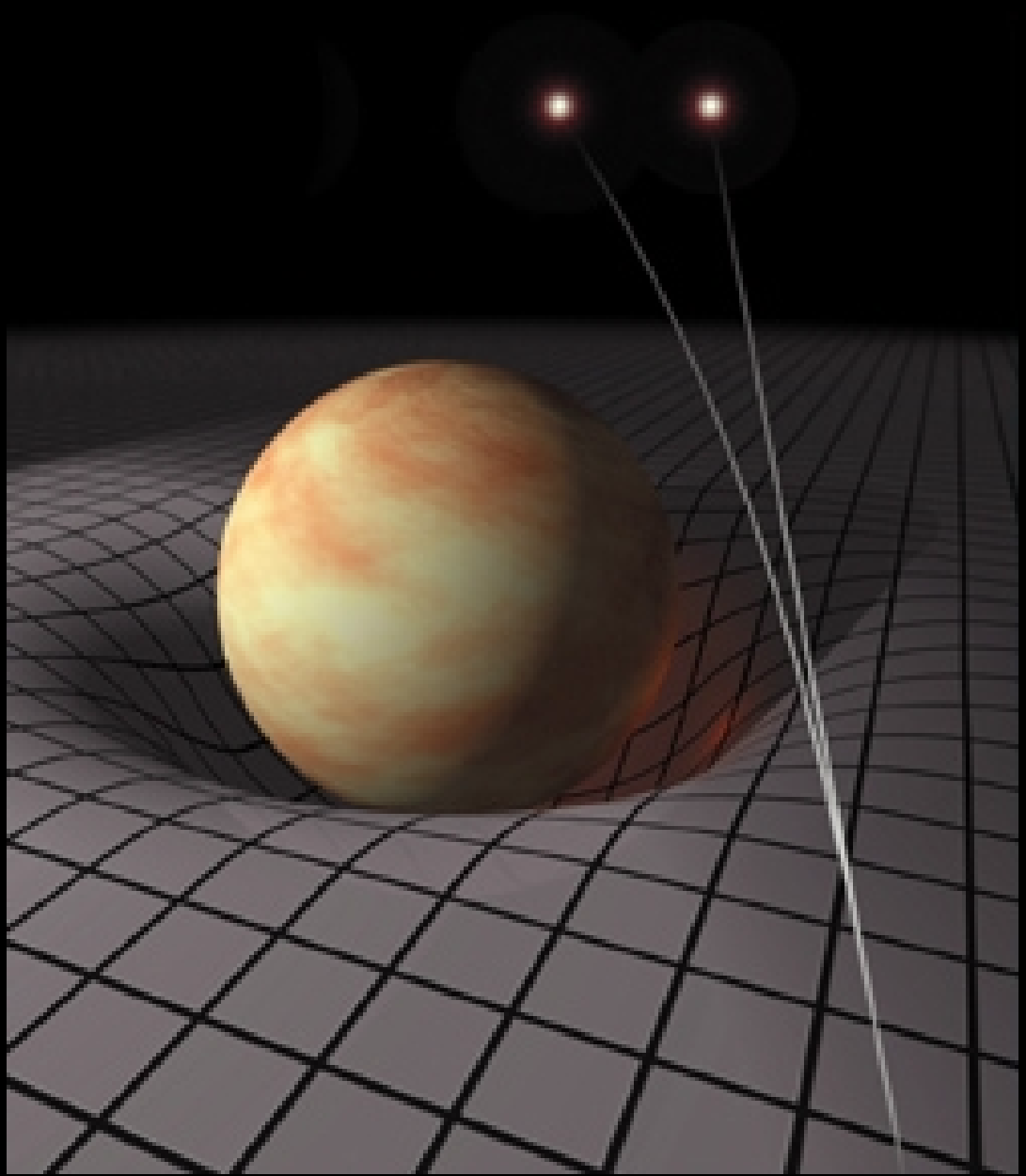
Why do elementary particles have a mass?

… what's behind the 'Higgs Boson'?

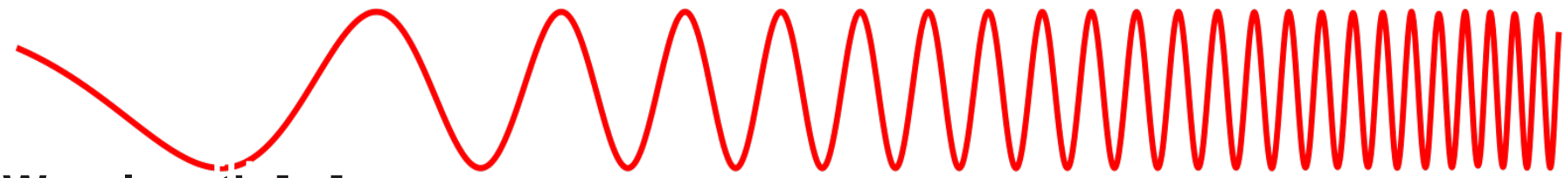


Does our world have more than 3+1 dimensions?
How does gravity work? Or:
What the … are “micro-black-holes” and why we are excited about (even worse) unstable ones?



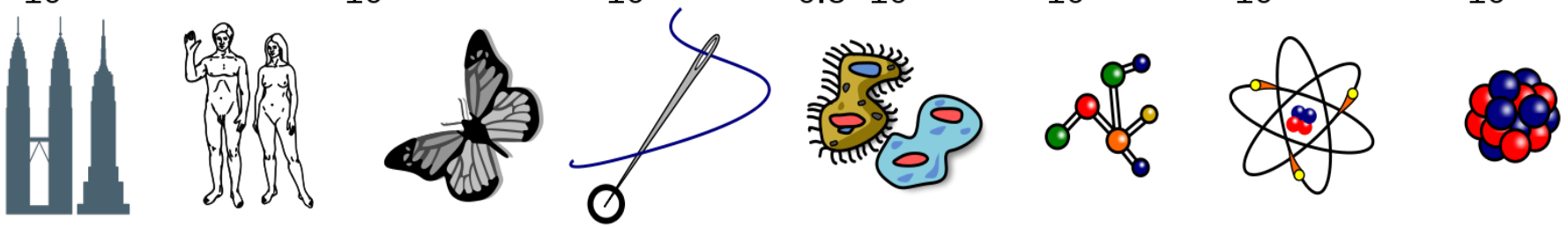


De Broglie: Wavelength and Scales

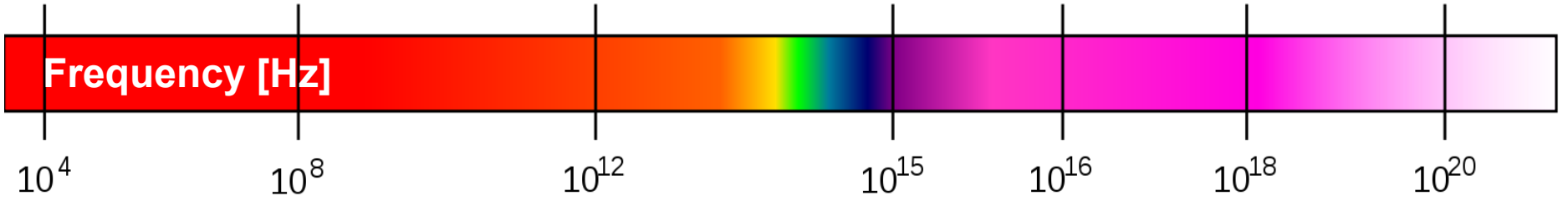


Wavelength [m]

Radio	Microwave	Infrared	Visible	Ultraviolet	X-ray	Gamma ray
10^{3}	10^{-2}	10^{-5}	0.5×10^{-6}	10^{-8}	10^{-10}	10^{-12}



Buildings Humans Butterflies Needle Point Protozoans Molecules Atoms Atomic Nuclei



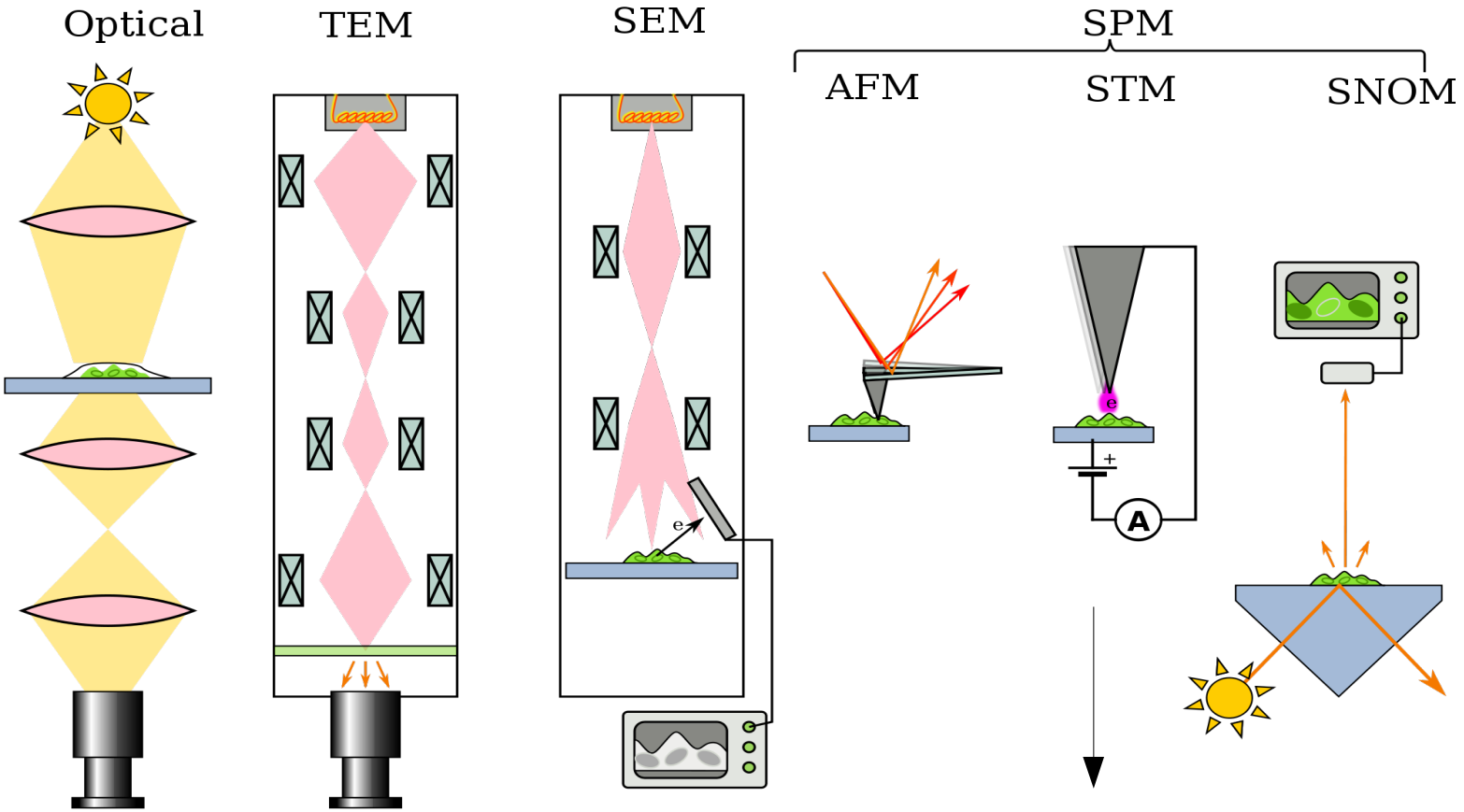
Energy/Momentum Electron Volt [eV]

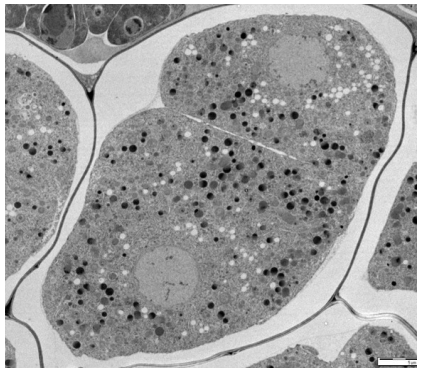
~1 μeV **~1 eV** **~1 MeV**

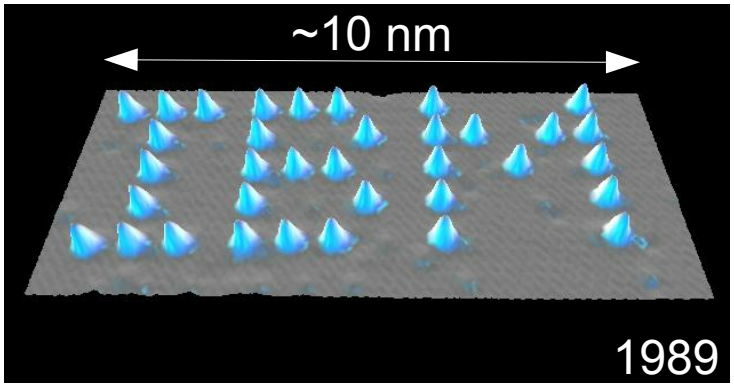
LHC (Higgs)
few hundred GeV/7 TeV

How to resolve Small Structures I
Cells, Molecules, Semiconductors ...

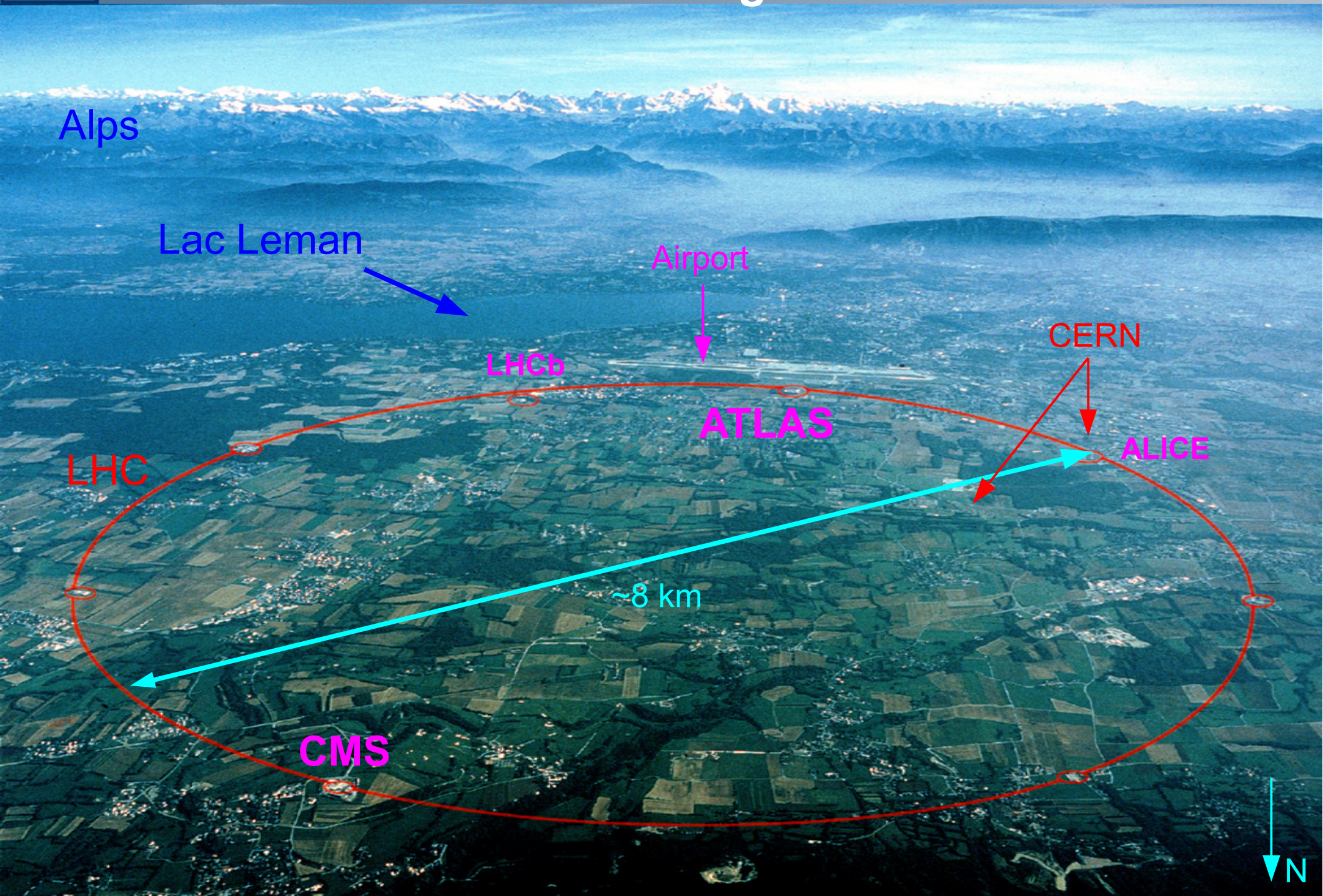
- … use a microscope – only a few electron-volt (eV) needed





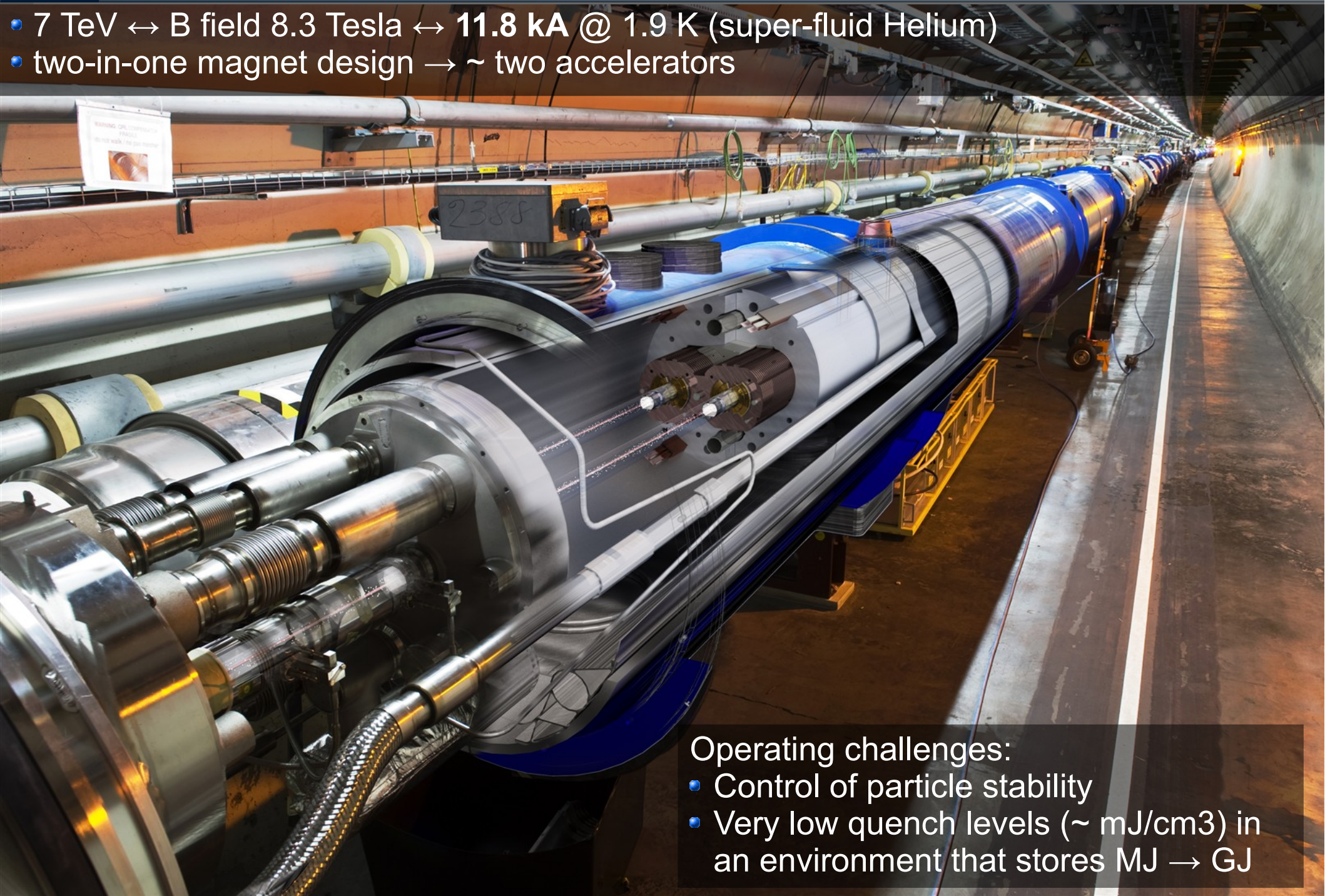


How to resolve Small Structures III
Sub-Atom Structures.... Large Particle Accelerators



27 km Circumference – 1232 LHC dipole magnets

- 7 TeV ↔ B field 8.3 Tesla ↔ **11.8 kA** @ 1.9 K (super-fluid Helium)
- two-in-one magnet design → ~ two accelerators

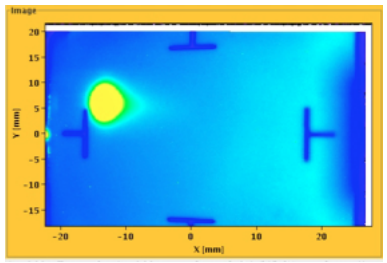


Operating challenges:

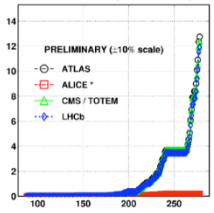
- Control of particle stability
- Very low quench levels (~ mJ/cm3) in an environment that stores MJ → GJ

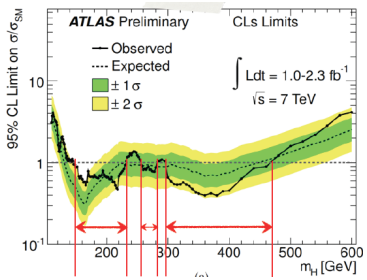
LHC Timeline

August 2008
First injection test



November 29, 2009
Beam back





August, 2011
2.3e33, 2.6 fb-1
1380 bunches

September 10, 2008
First beams around

October 14 2010
1e32, 248 bunches

June 28 2011
1380 bunches

1380

4 July, 2012

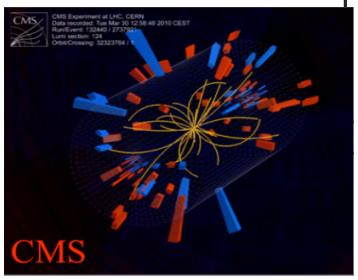
April 2010
Squeeze to 3.5 m

6 June, 2012
6.8e33

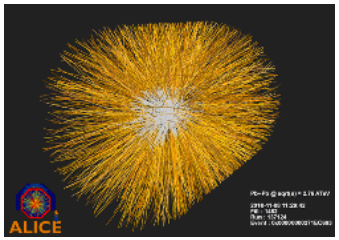
2008 | 2009 | 2010 | 2011 | 2012 | 2013

September 19, 2008
Disaster
Accidental release of 600 MJ stored in one sector of LHC dipole magnets

March 30, 2010
First collisions at 3.5 TeV

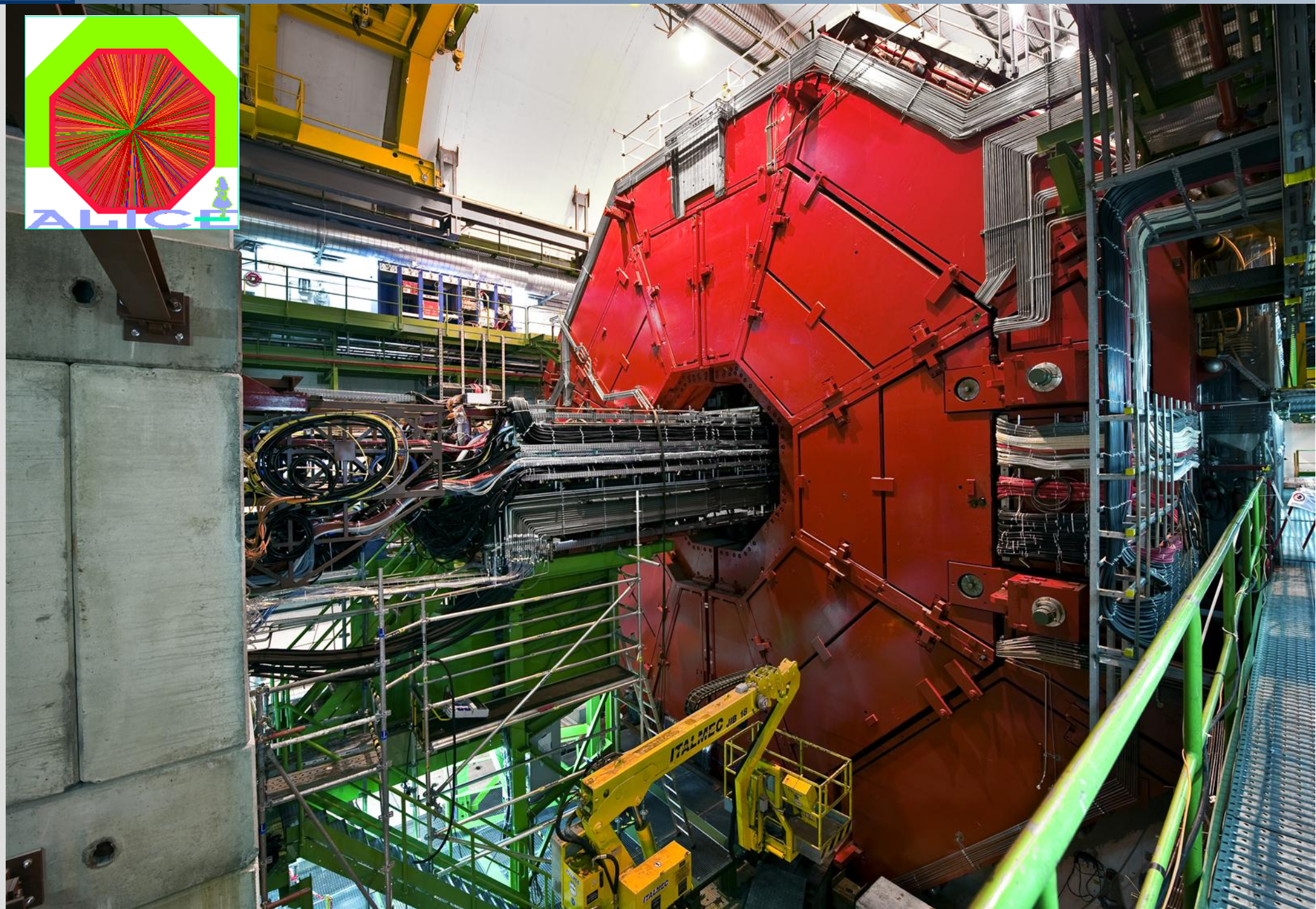


November 2010
Ions

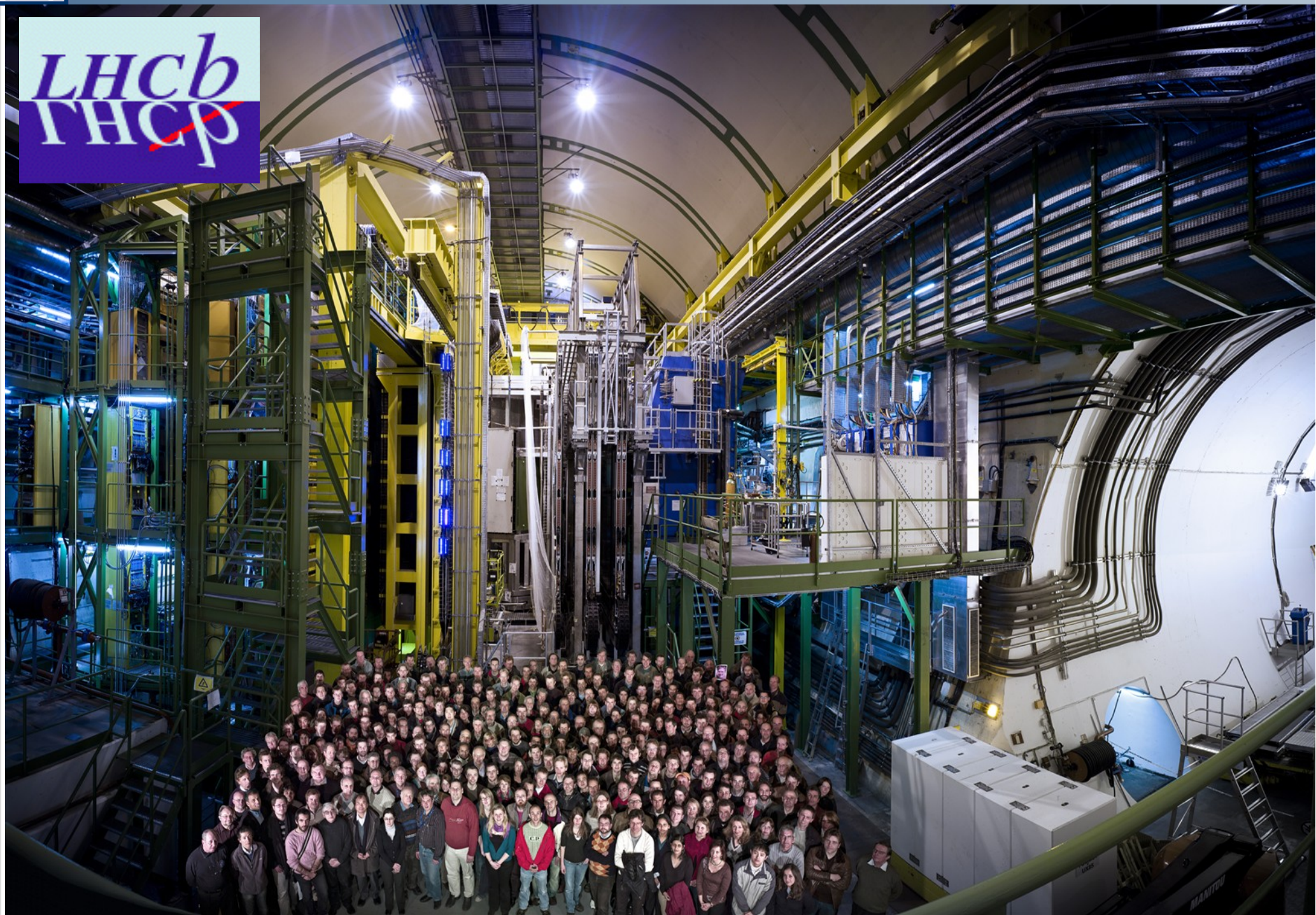


18 June, 2012
6.6 fb-1
to ATLAS & CMS

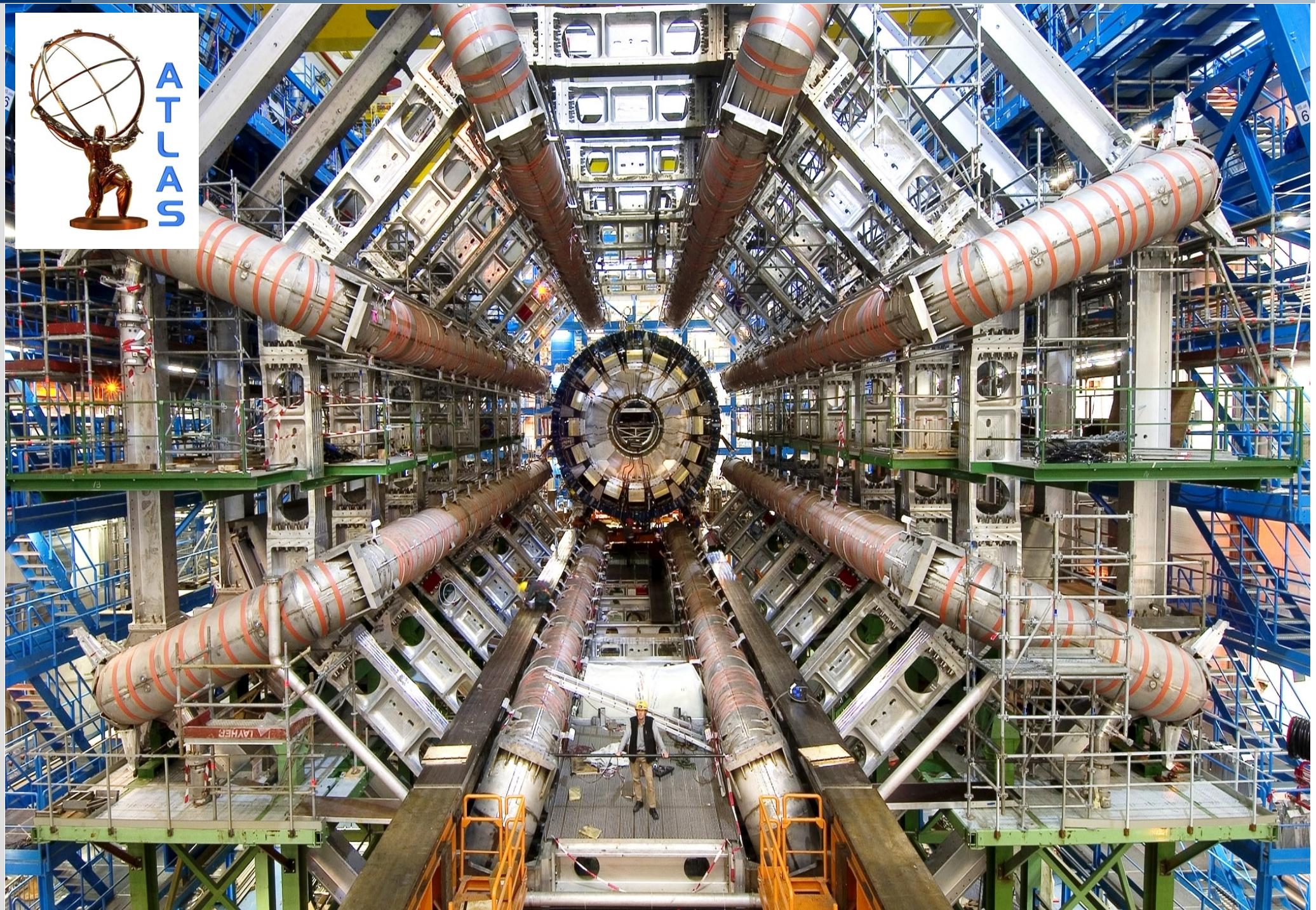
ALICE

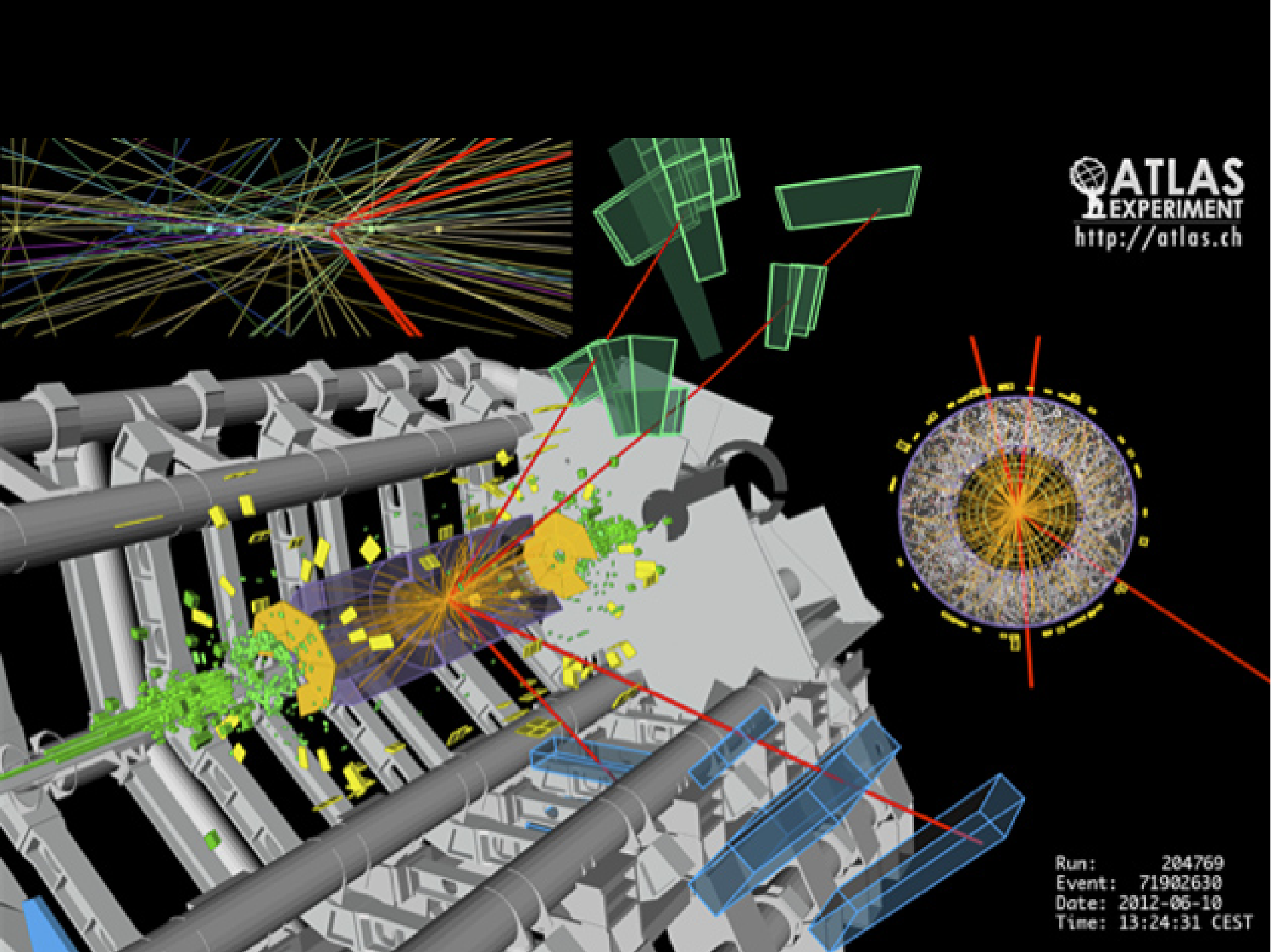


LHCb

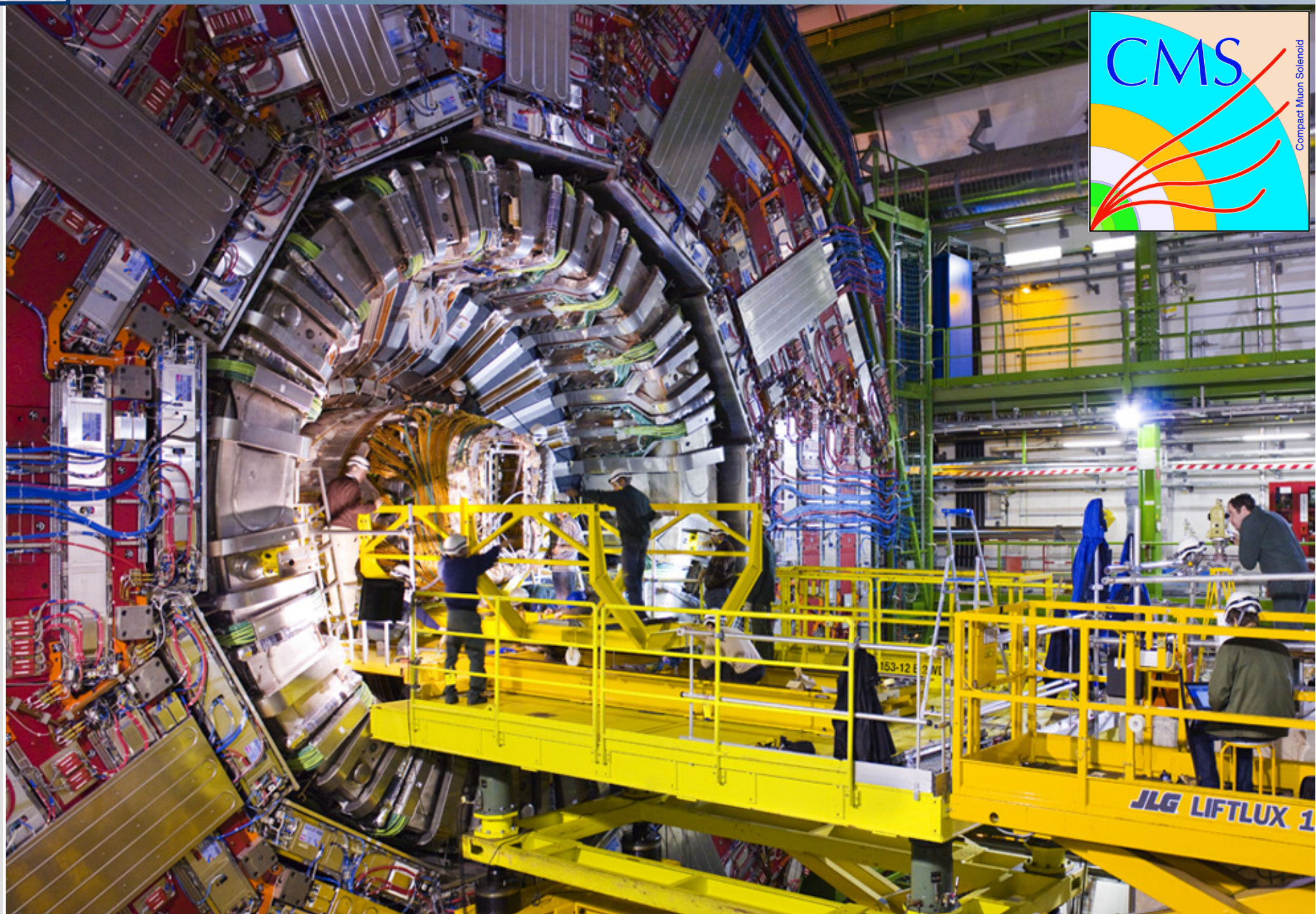


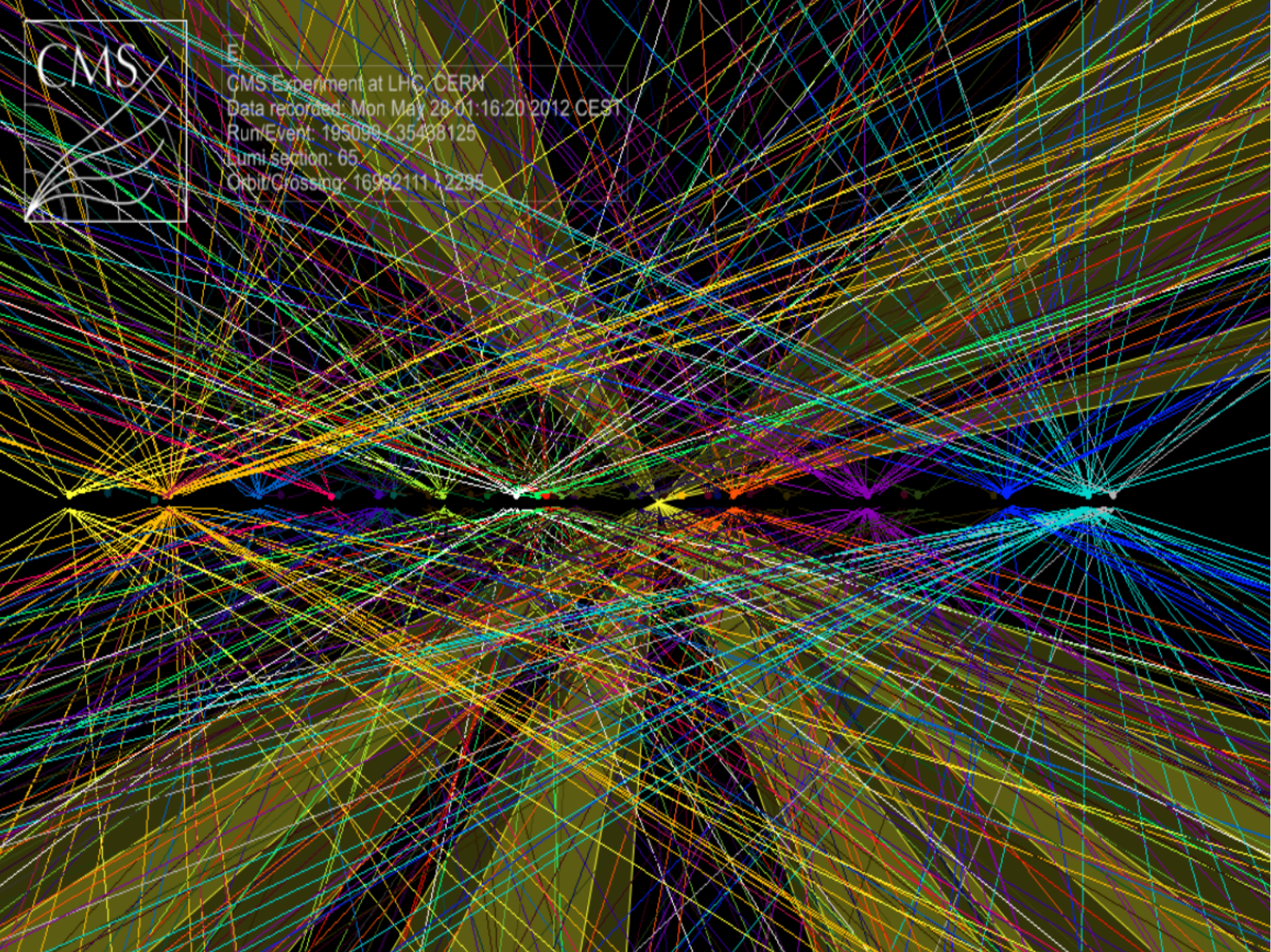
ATLAS

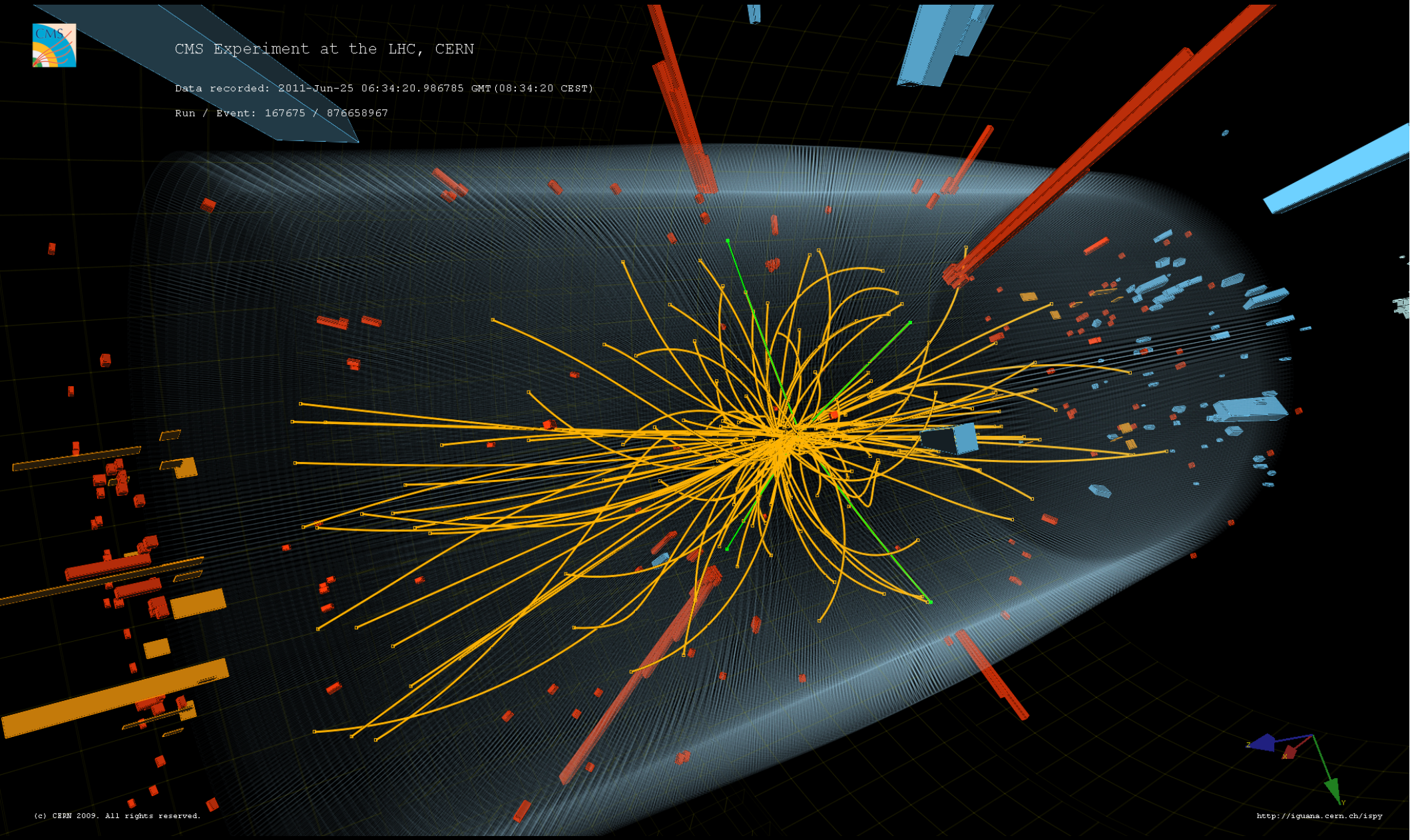



ATLAS
EXPERIMENT
http://atlas.ch
Run: 204769
Event: 71902630
Date: 2012-06-10
Time: 13:24:31 CEST

CMS




CMS
E
CMS Experiment at LHC, CERN
Data recorded: Mon May 28 01:16:20 2012 CEST
Run/Event: 195099 / 35438125
Lumi section: 65
Orbit/Crossing: 16992111 / 2295


CMS Experiment at the LHC, CERN
Data recorded: 2011-Jun-25 06:34:20.986785 GMT(08:34:20 CEST)
Run / Event: 167675 / 876658967
(c) CERN 2009. All rights reserved.
http://iguana.cern.ch/ispy

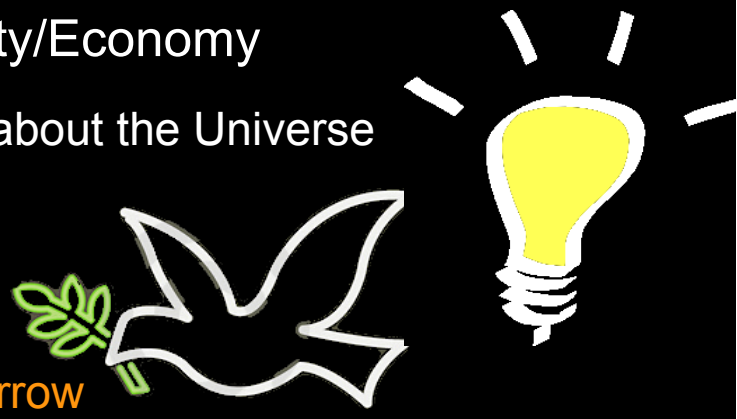
CERN - Conseil Europeén pour la Recherche Nucléaire
Today: ~~European~~ Global Organization for Nuclear Research

- 1951: CERN's mission:
  - provide resources and common infra-structure related to pure scientific and fundamental character
  - Promote peace and collaboration platform, education and sharing of scientific results among nations
- 20 member states + observers: India, Israel, Japan, Russia, USA, Turkey, European Commission and UNESCO + pending members
- One of Geneva's largest organisations:
  ~ 2500 full-time employers, > 9000 visiting scientists
- A small world of its own → extraterritorial (neither CH/FR)

- Cradle of the World-Wide-Web: http://www.cern.ch
- GRID - One of the world's most power-full data processing networks
- World's home of High-Energy Physics and Nobel-Prize Winners
- More info:

What are long-, medium- and short-term benefits?
… why we must spend money for science?

Long-Term - World is becoming a Knowledge-based Society/Economy



- Research: Seeking and finding answers to questions about the Universe
- Technology: Advancing the frontiers of technology
- Collaborating: Bringing nations together through science
- Education: Training the scientists & engineers of tomorrow

Medium-Term: Fundamental Research enables applied Science, e.g.

- Quantum-Mechanics → Semi-Conductor → Transistors → Computer
- General Theory of Relativity (Einstein) → Satellites → GPS

Short-Term: Advancements in industry....

- Accelerator, Magnet, Cryogenics, Detectors & Instrumentation, Electronics, .
  → Biology and Medicine: NMR & PET scanners, Ion therapy/cancer treatme
- Information Technology: WWW, GRID, Genome Analysis, …

What we do today will impact and be in your life in 10-20 years...

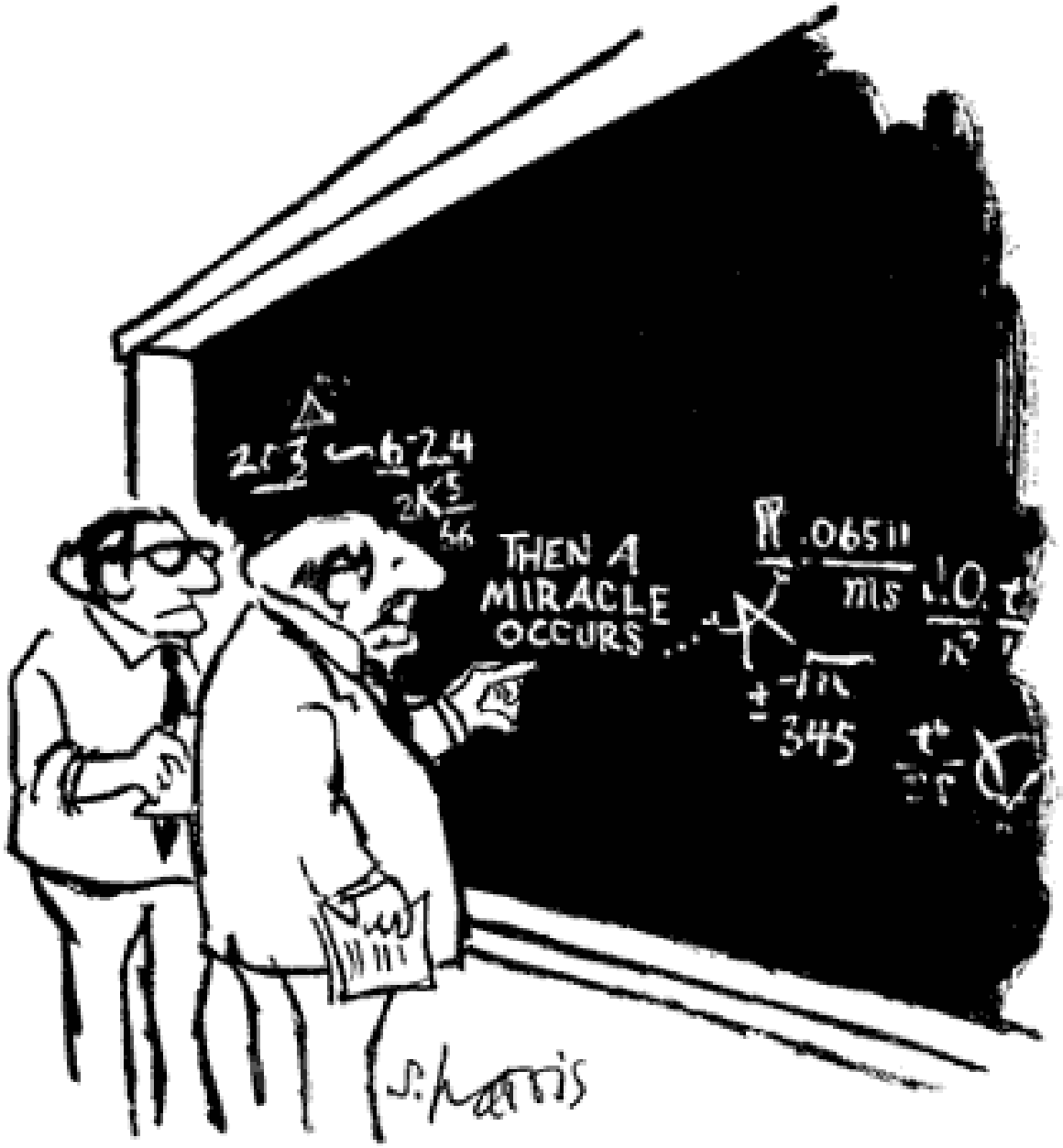
Summary

- Physics does not find 'truths' but describes how nature works
  - … governed by 'scientific method'. Can only draw conclusions or make predictions based on repeatable experiments.
  - High-Energy Physics tackles big questions using big accelerators to study the tiniest elementary constituents of nature (↔ giant microscopes)

- CERN – International Research Organisation → www.cern.ch
  - provides common infra-structure needed for fundamental sciences
  - Promotes peace and collaboration platform, education and sharing of scientific results among nations

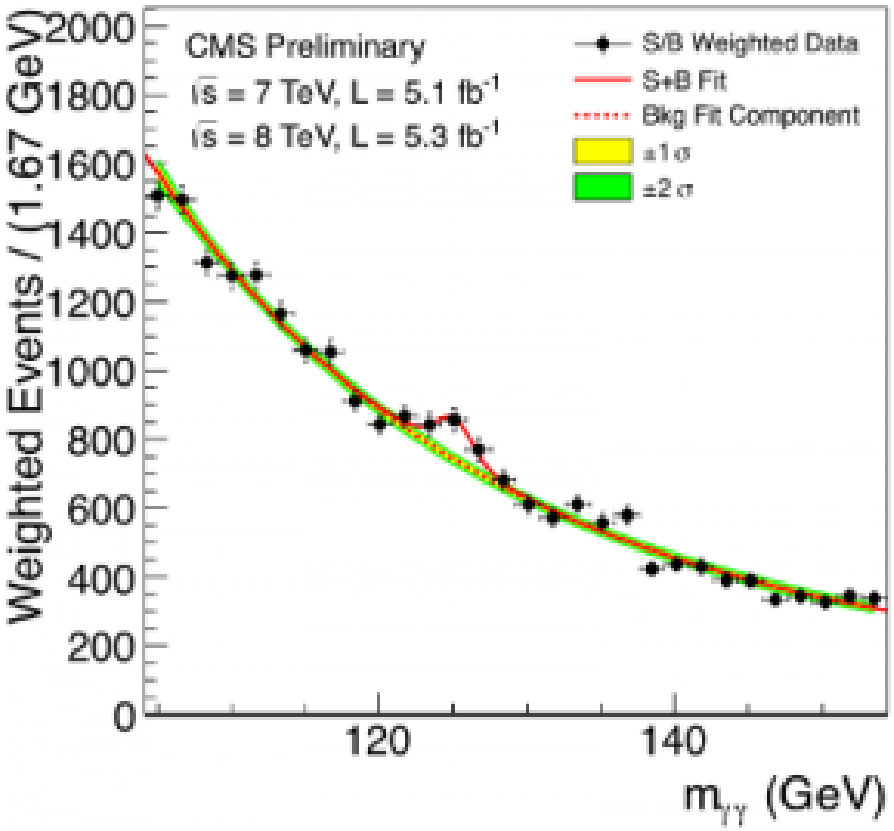
… India is part of CERN!

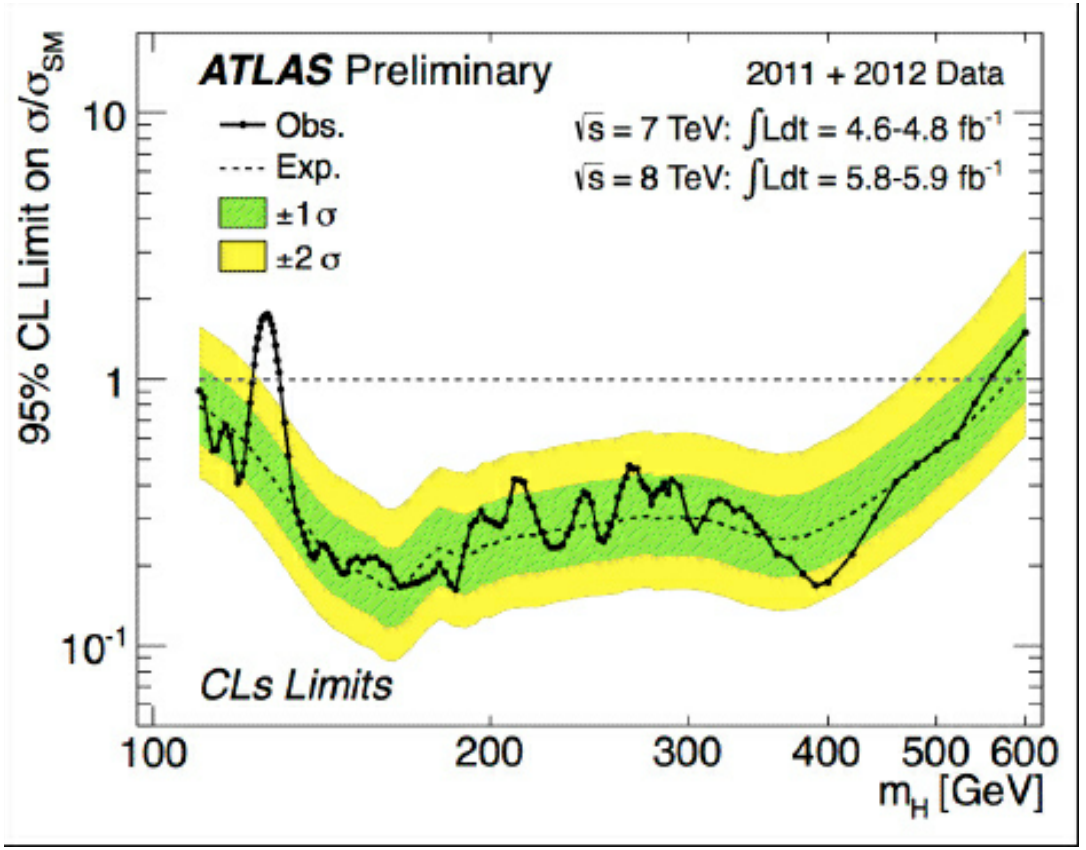
Thanks – Questions?



"I think you should be more explicit here in step two."

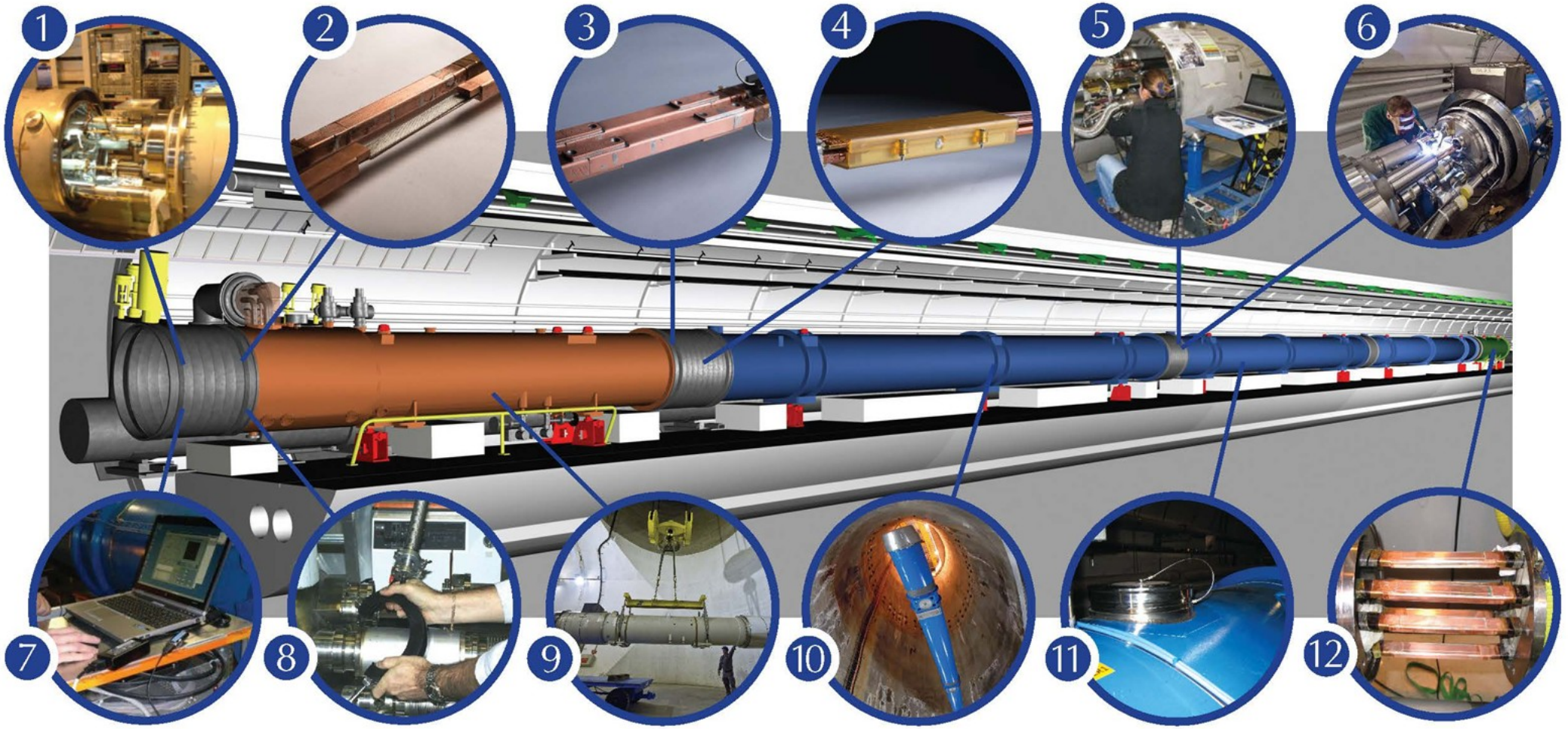
Higgs Boson? How does it look like?





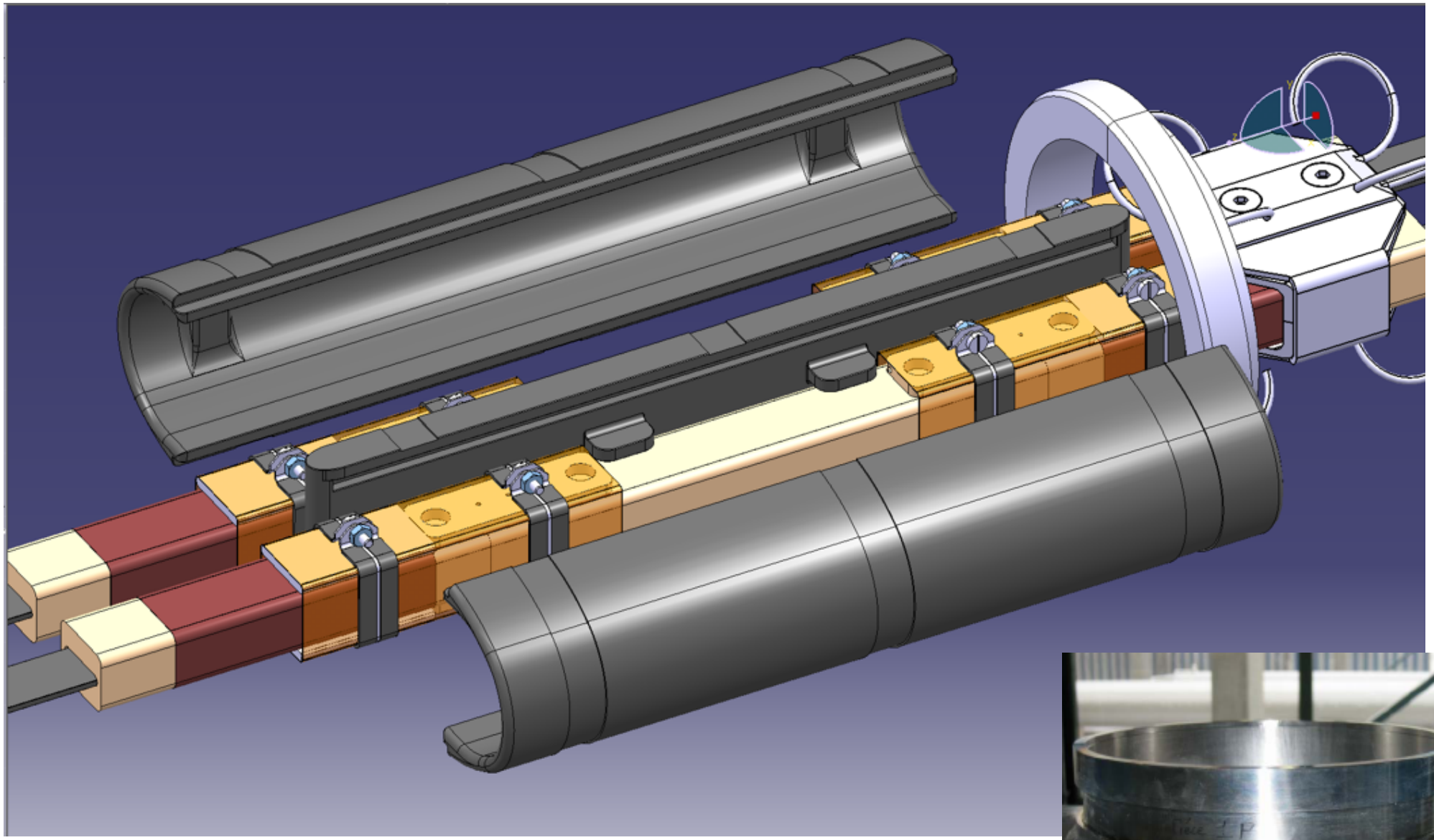
The main 2013-14 LHC consolidations

1. 1695 Openings and final reclosures of the interconnections
2. Complete reconstruction of 1500 of these splices
3. Consolidation of the 10170 13kA splices, installing 27 000 shunts
4. Installation of 5000 consolidated electrical insulation systems
5. 300 000 electrical resistance measurements
6. 10170 orbital welding of stainless steel lines



7. 18 000 electrical Quality Assurance tests
8. 10170 leak tightness tests
9. 4 quadrupole magnets to be replaced
10. 15 dipole magnets to be replaced
11. Installation of 612 pressure relief devices to bring the total to 1344
12. Consolidation of the 13 kA circuits in the 16 main electrical feedboxes

LHC MB Circuit Splice Consolidation Proposal
Clamping and Shielding

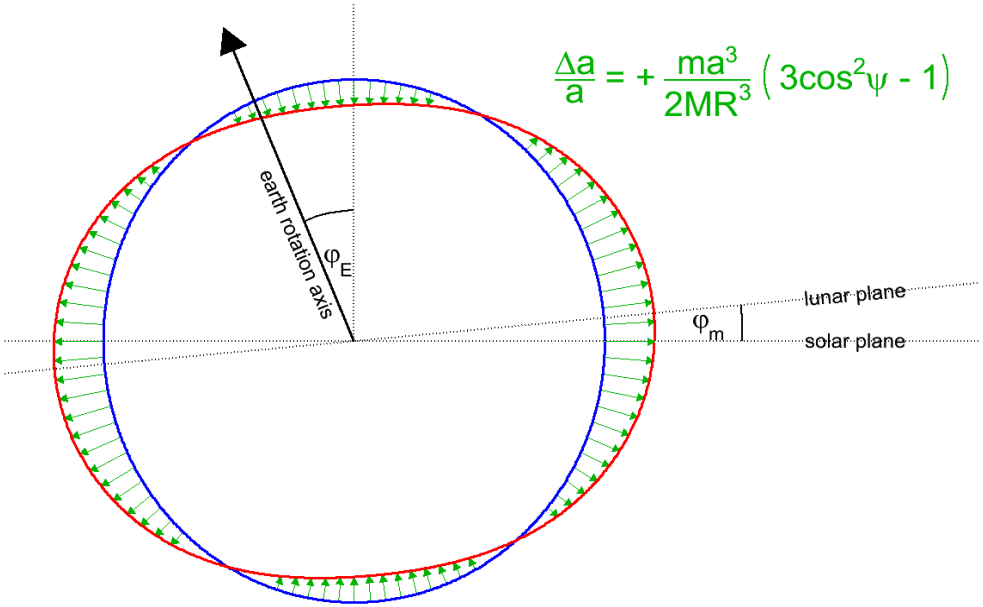


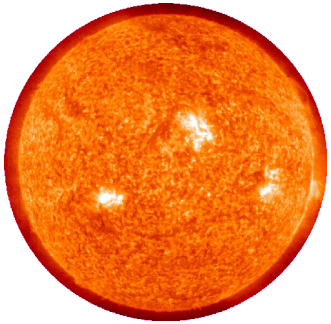
DN200 – He blow-hole

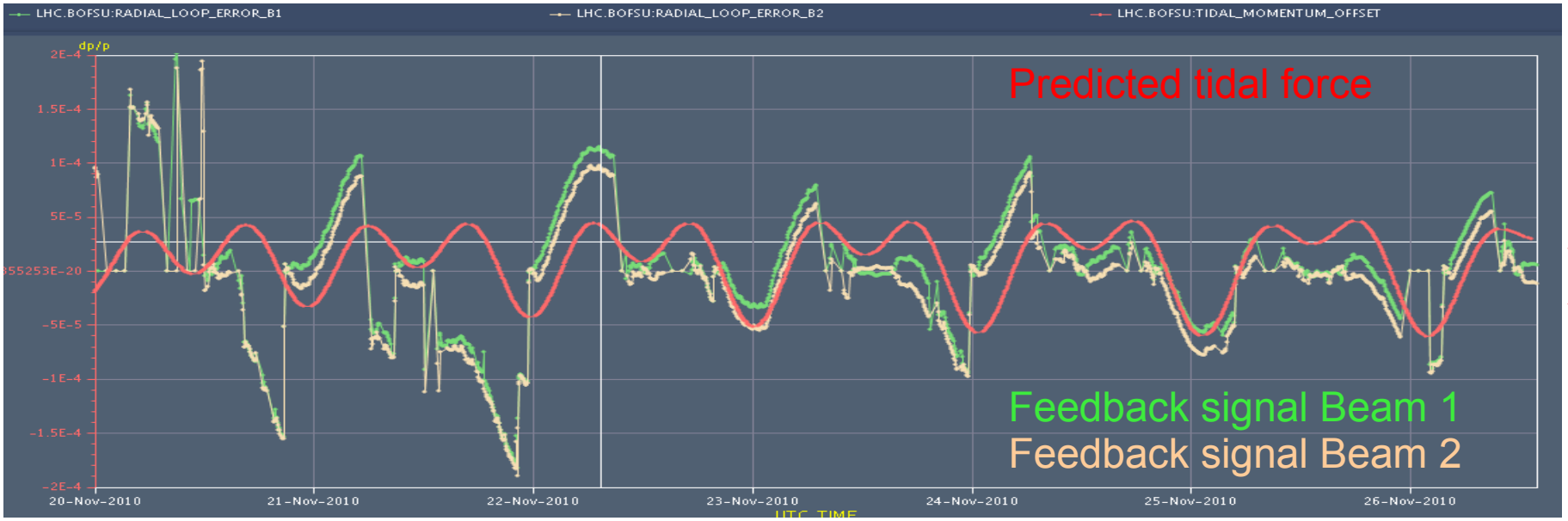
Repeat: 3x per interconnect (1MB, 2MQ)
x ~1700 Interconnects in the machine
+ meticulous QA during each step (~300k total)

Beam Orbit Stability and Tides ...

$$\frac{\Delta a}{a} = + \frac{ma^3}{2MR^3}\left(3\cos^2\psi - 1\right)$$







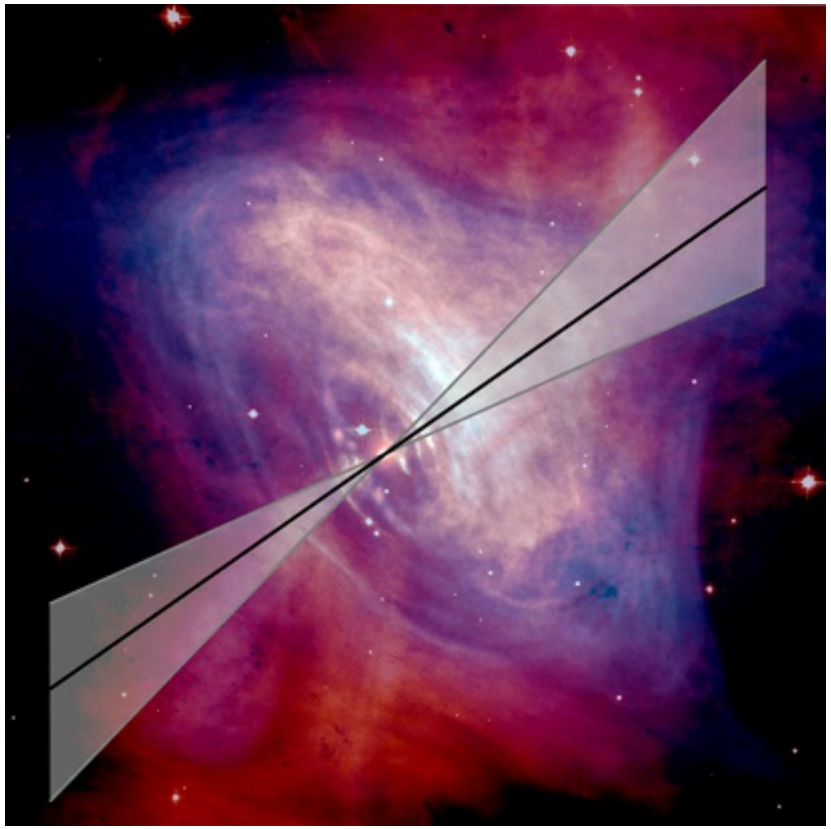
$\Delta x \approx 200\ \mu m$

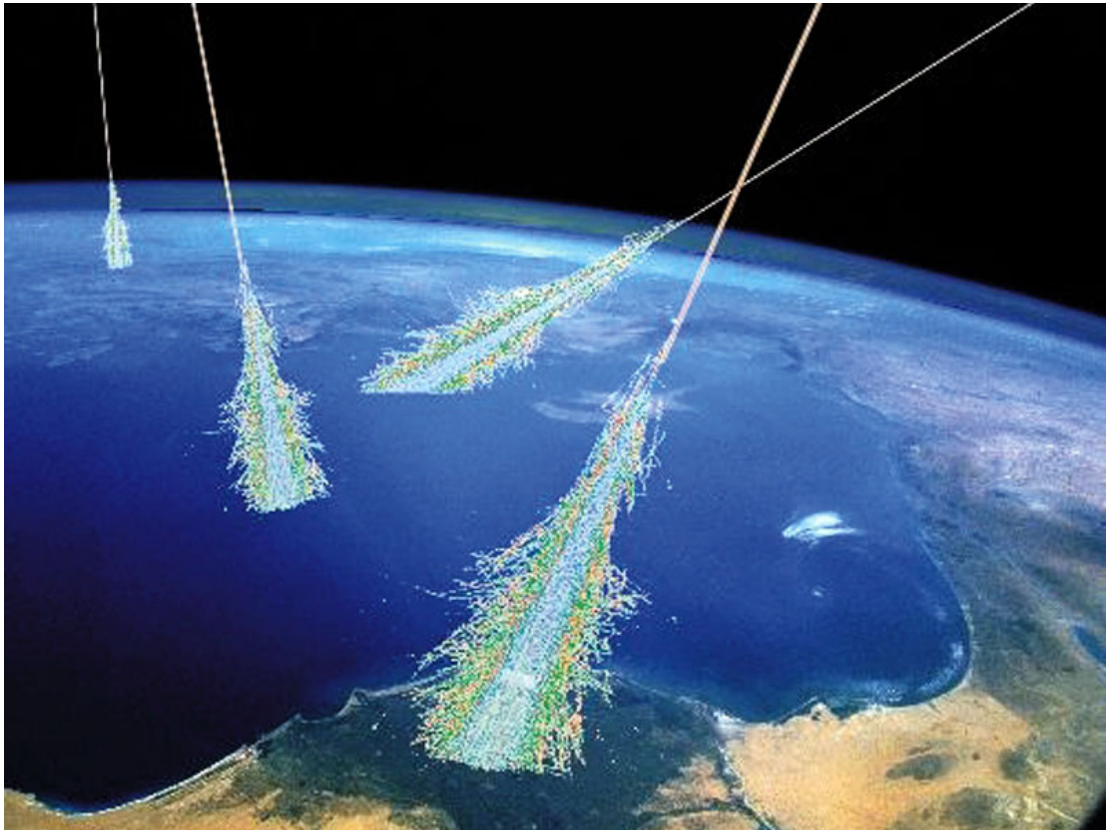
~ one week

To put things into perspective

- … Chennai at the centre of the World

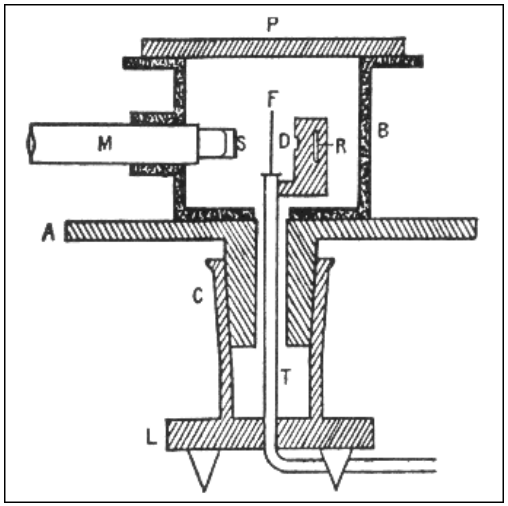
Cosmic Accelerators





Main Outcome of Rutherford's experiment (my personal view)

- 'Atoms' are not Atoms → 'Elementary Particles'
- Need to use particles that are smaller than the structure to be investigated
- Need a microscope, <u>patience</u> and <u>persistence</u>
  (… and a lot of students)



- Later: De Broglie's 'Particle – Wave' dualism (1924):

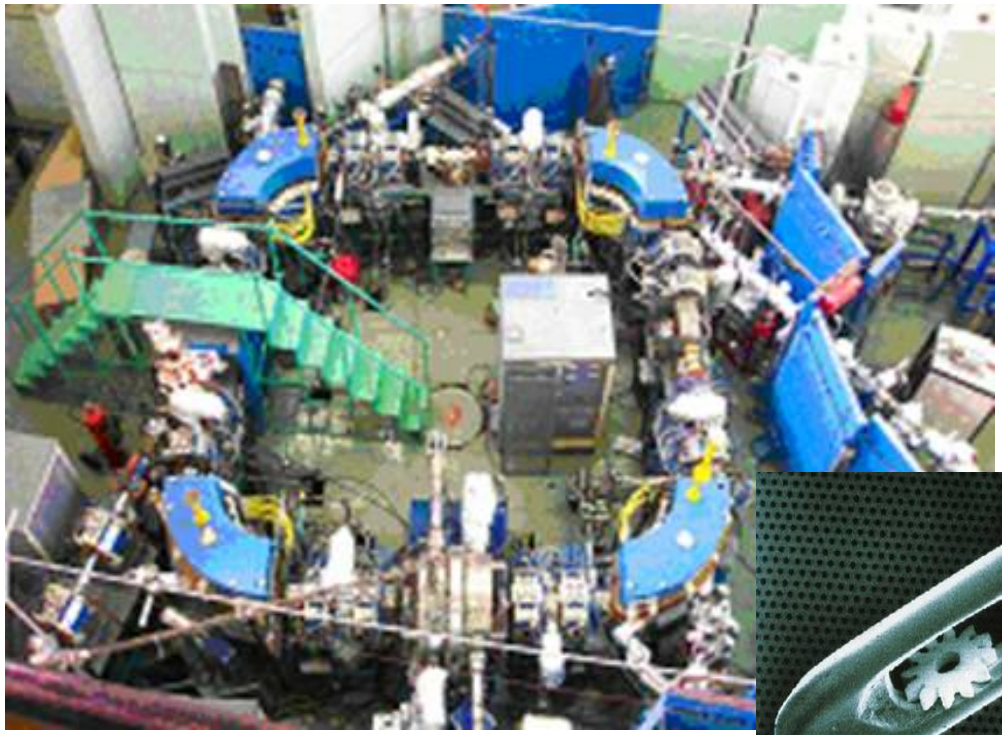
$$\lambda = \frac{h}{p}$$

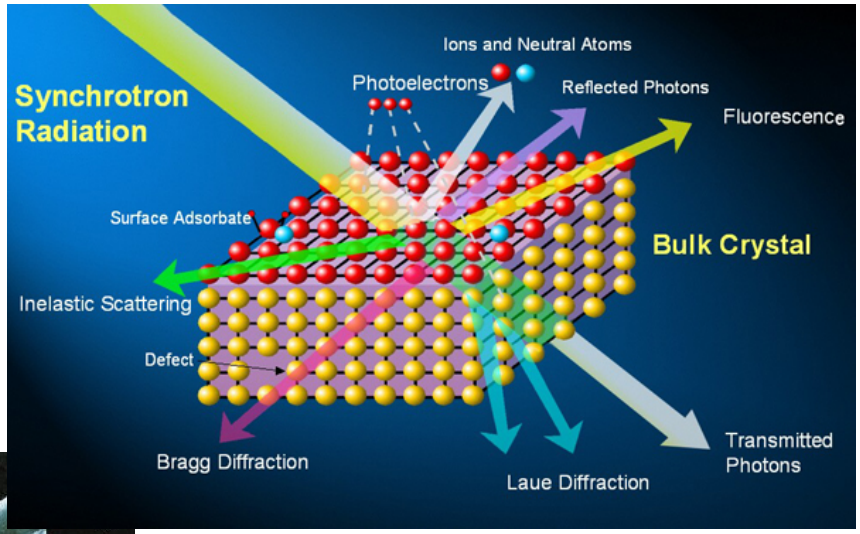
h: Planck's constant
p: momentum of particle
λ: equivalent wavelength

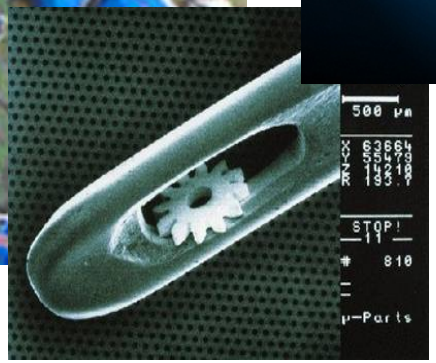
… So high momentum (energy) gives us short wavelengths so we can make out small details
or High-Energy-Physicists credo: we want to see smallest particles, thus need the highest energy particle sources → accelerators

How to resolve Small Structures II
State-of-the Art Biology, Chemistry & Material Science ...

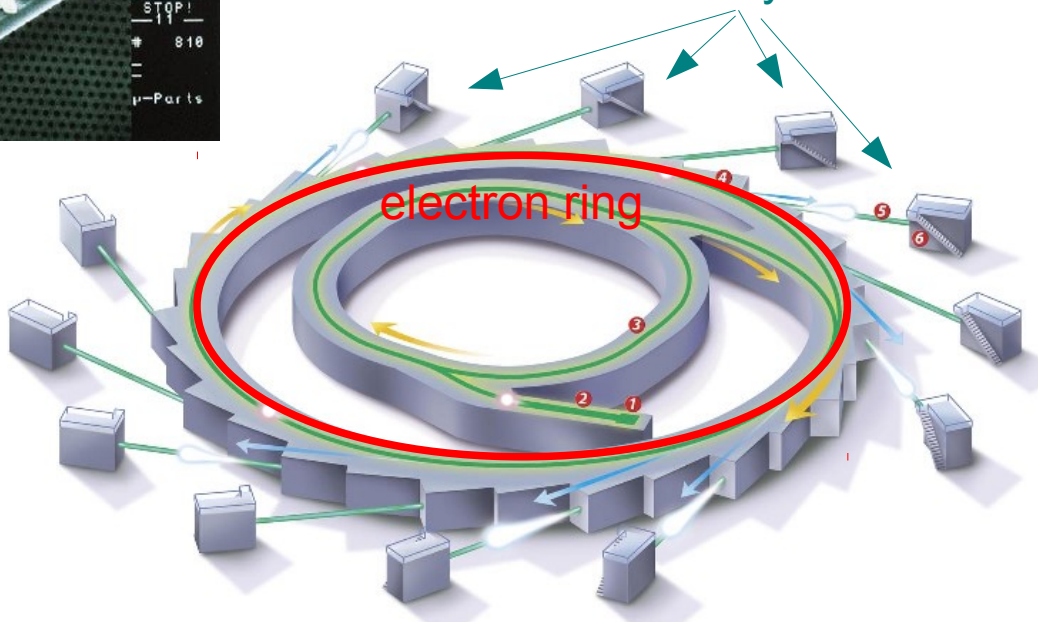
- … a synchrotron light source – few kilo-electron-volt (keV)





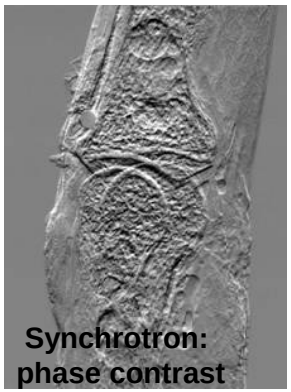


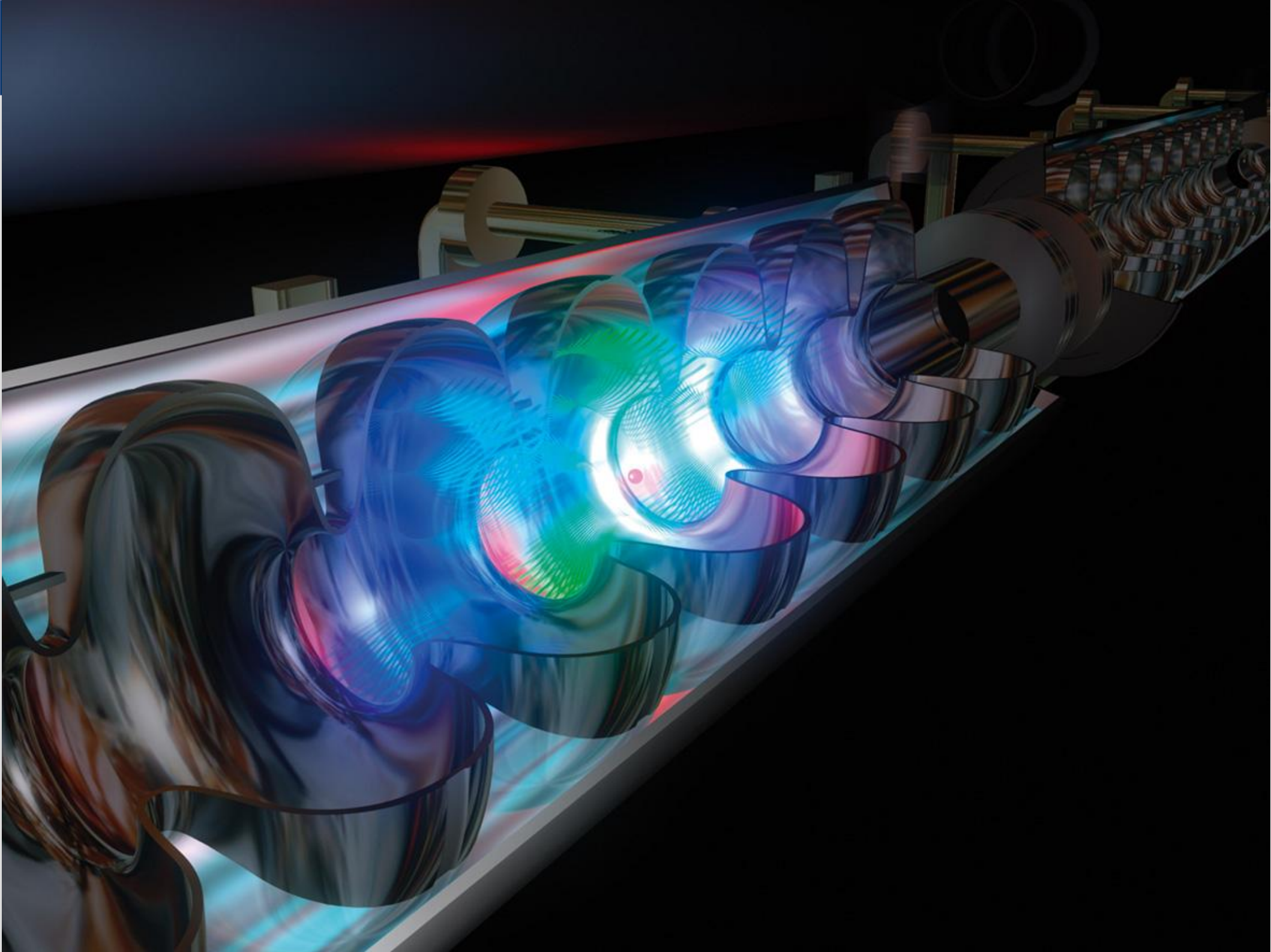
beam lines
x-ray sources




Conventional X-ray

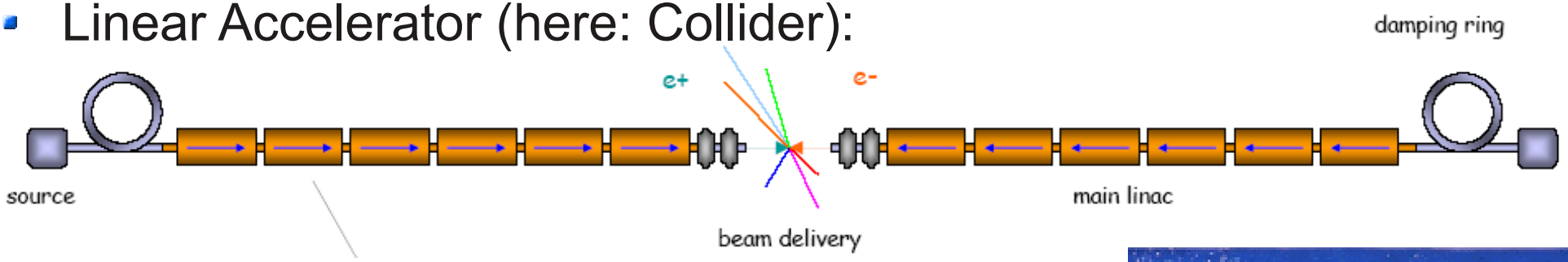

Synchrotron


Synchrotron:
phase contrast

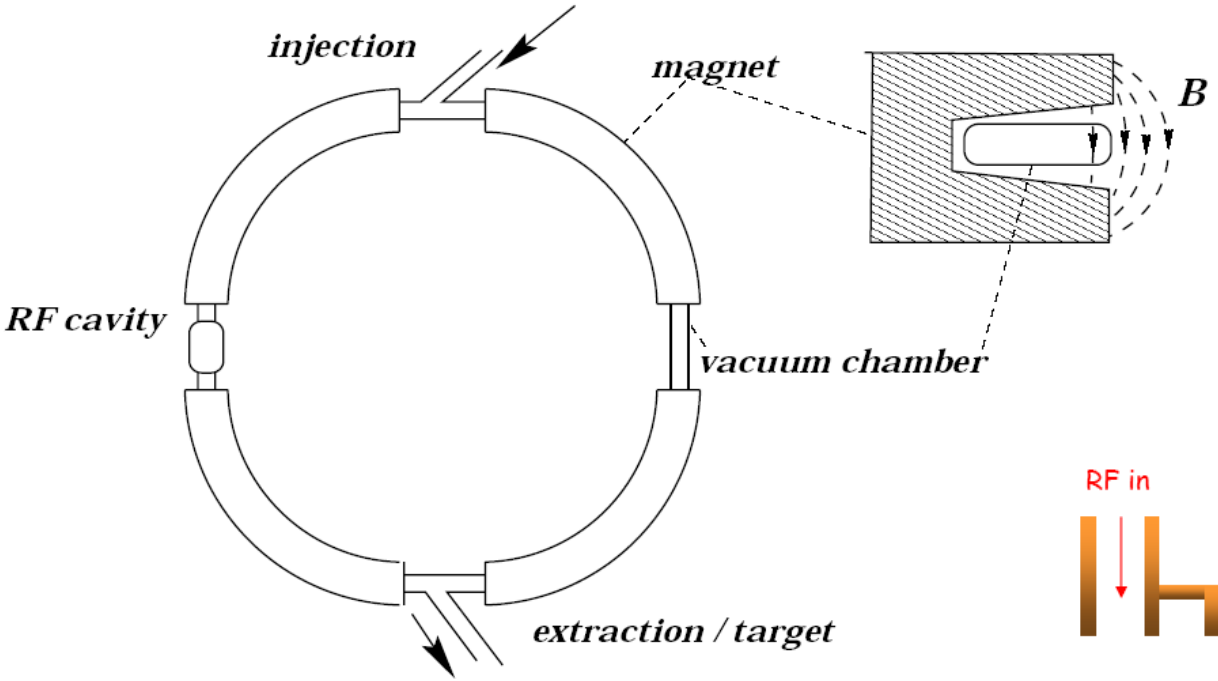


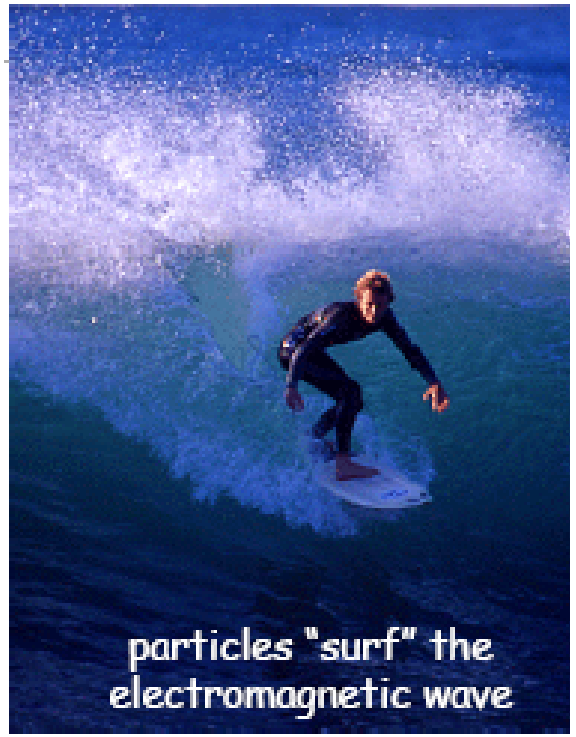
High-Energy Accelerators
To observer and study true 'Atoms'

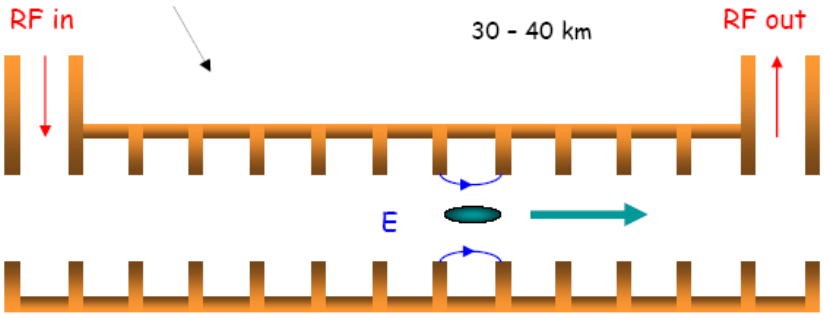
- Linear Accelerator (here: Collider):



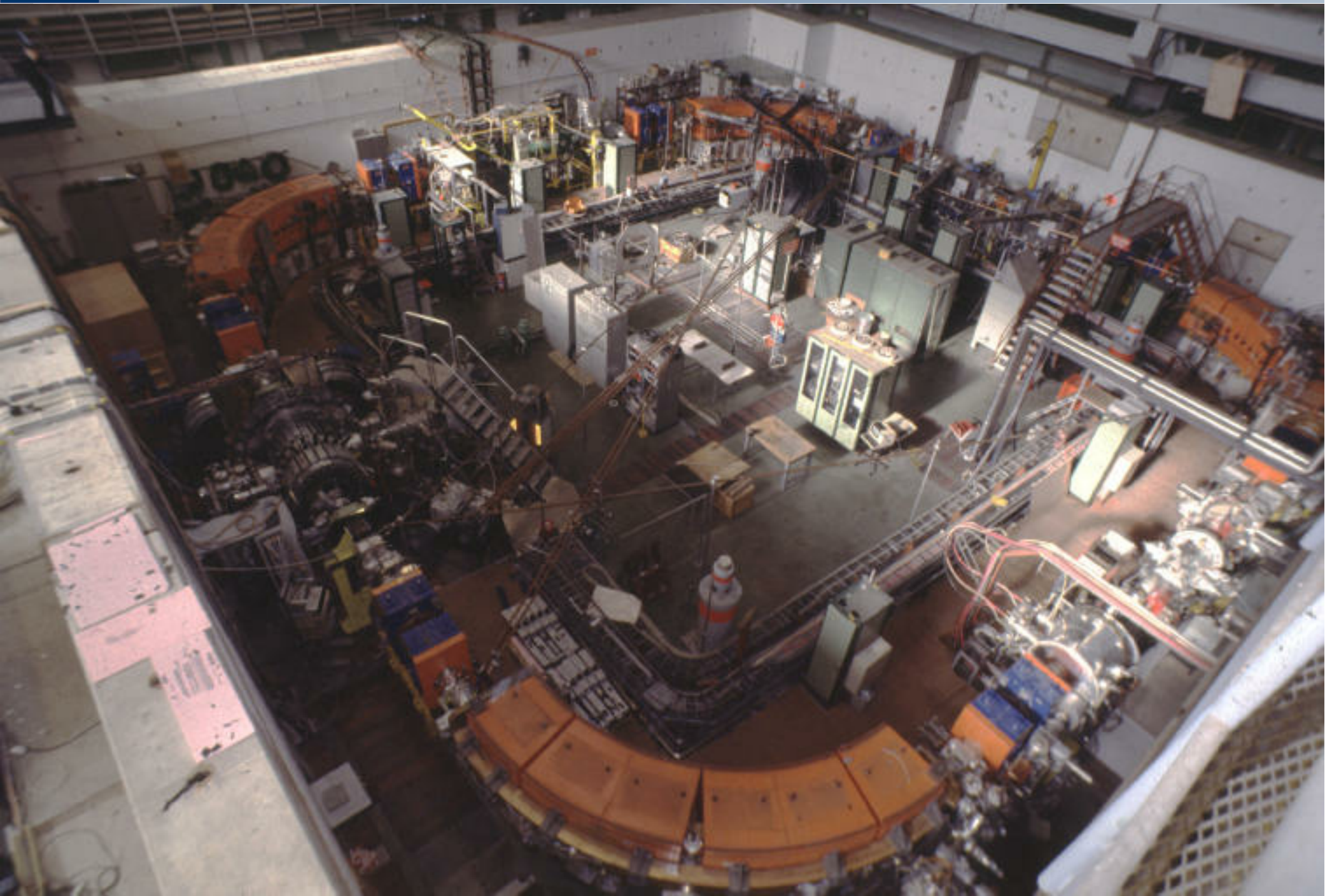
- Circular Accelerator:







Low Energy Antiproton Ring (LEAR, CERN)



Super-Proton-Synchrotron (SPS, CERN)

- 7 km circumference, up to 450 GeV Energy
- Discovery of the W & Z Boson (Nobel prizes in 1979 & 1984)