EP228 Particle Physics

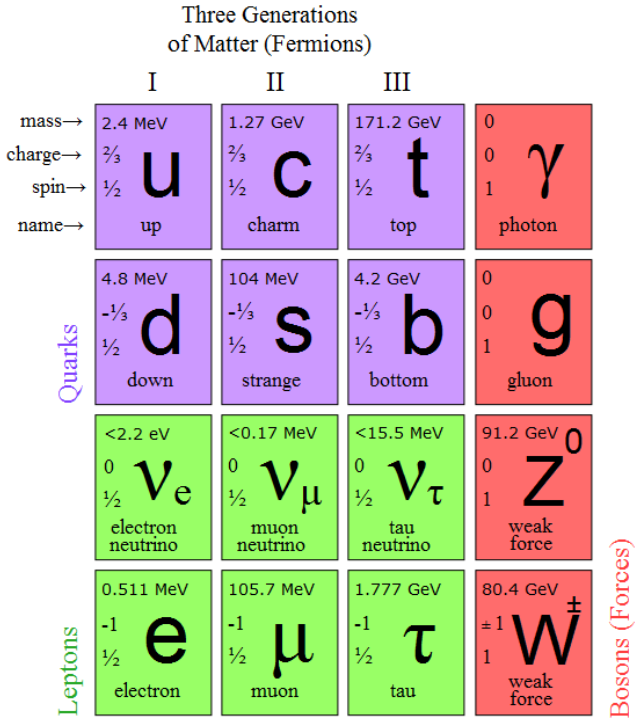
Topic 1

Overview of Particle Physics

Department of
Engineering Physics

University of Gaziantep

Course web page
www.gantep.edu.tr/~bingul/ep228



Sep 2020

Course Resources

- **Course web page**
  for lecture materials & exam result
  `http://www1.gantep.edu.tr/~bingul/ep228`

- **Books (see: `http://books.google.com`)**
  - **Griffiths, *Introduction to Elementary Particles***
  - **Perkins, *Introduction to High Energy Physics***
  - **Das A, *Introduction to Nuclear and Particle Physics***
  - **Green D, *Physics of Particle Detectors***
  - **Any Modern Physics Book**
    - **Beiser, *Concept of Modern Physics***
    - **Zafaritos, *Modern Physics***

- **Wikipedia**
  `http://en.wikipedia.org`

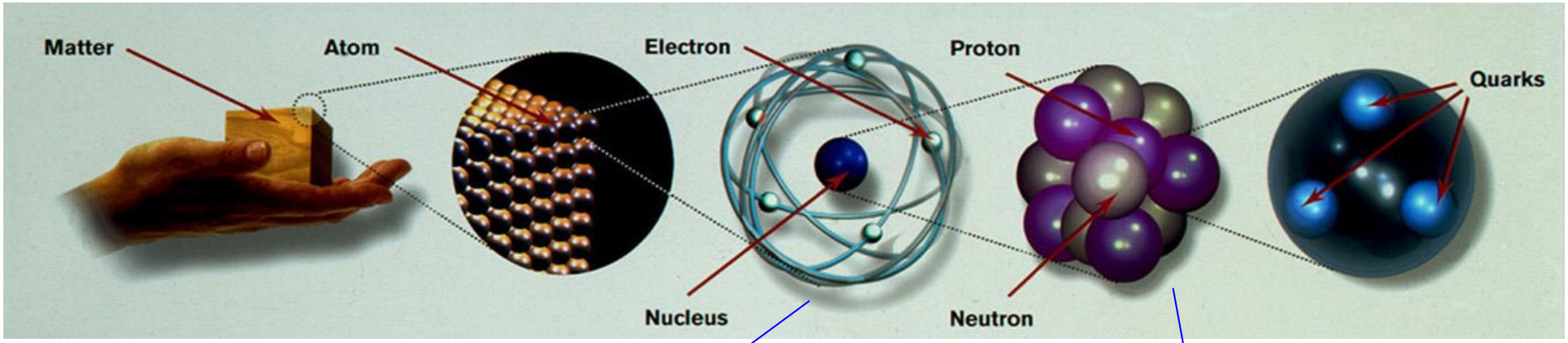
Course Content

- **Overview of Particle Physics**

- **Overview of the Special Theory of Relativity**
- **Historical Introduction to the Elementary Particles**
- **Elementary Particles and Their Interactions**

- **Experimental Terminology**
- **Accelerators and Colliders**
- **Interactions of Particles with Matter**
- **Particle Detectors**
- **Cosmic Rays**

Atom and Subatomic Particles



Atomic size: 10^{-7} cm

Nuclear size: 10^{-13} cm

Any particle having less structure than Atom is called subatomic particle

Particle Physics

- **Particle physics = High Energy Physics (HEP)**
  is a branch of physics that studies the elementary constituents of matter and radiation, and the interactions between them.

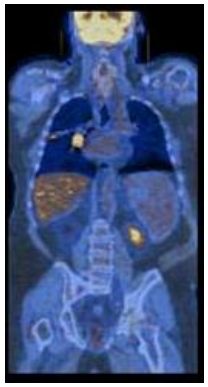
- **High Energy means**
  'above the treshold for pion production'

$$p + p \rightarrow p + p + \pi$$

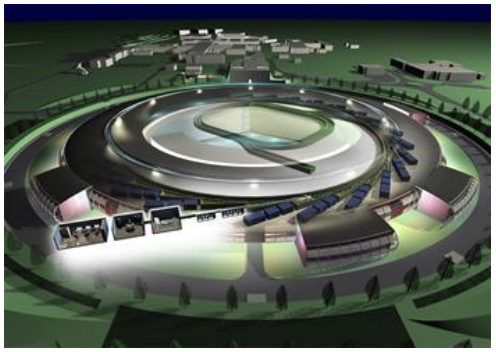
- **HEP pioneered 'big science'**
  - **experiments are performed at accelerators increasing energy**
  - **collaboration of many physicists from many intitudes**

- **Research methodology is based on 'Statistical Analysis'**

Some Applications



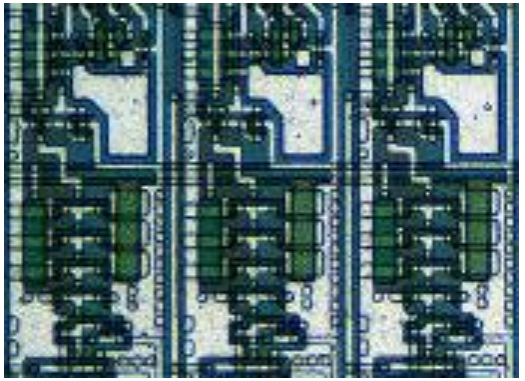
Medicine



Research

Education

Computer Science



Technology

History of the Particle Physics

M.Ö. 450	Atom	*Democtitus*
1807	Elements ve Atom	*J. Dalton*
1895	X-ray	*W.C. Röntgen*
1896	Radioactivity	*H. Becquerel, M.Courie*
1898	Atom model	*J. J. Thompson*
1899	Discovering Electron	*J. J. Thompson*
1911	Discovering nucleus	*E. Rutherford*
1913	Bohr Atom Model	*N.Bohr*
1920	Isotops	*E.W. Aston*
1932	Neutron	*J. Chadwick*
1932	Positron	*C.D. Anderson*
1947	Muon ve Pion	*C. Powell*
1947	Kaon (stange quark)	*Rochester*
1955	Antiproton	*E. Segre*
1956	Neutrino	*Rheines*
1960-70	Diğer mezonlar/baryonlar	…
1974	J/ψ (charm quark)	*SLAC*
1977	Bottom quark	*Fermilab*
1983	W ve Z bosons	*CERN*
1995	Top quark	*Fermilab (Tevatron)*
1995	Anti-Hydrogen atom	*CERN*
2010	Neutrino Osciallatios	CERN & Italy
2012	Higs Boson	CERN

Discovering new Particles

If we have some indications that we discover a <u>new particle</u>, we should answer:

1. What are its properties?
   (mass, charge, lifetime, spin, …)

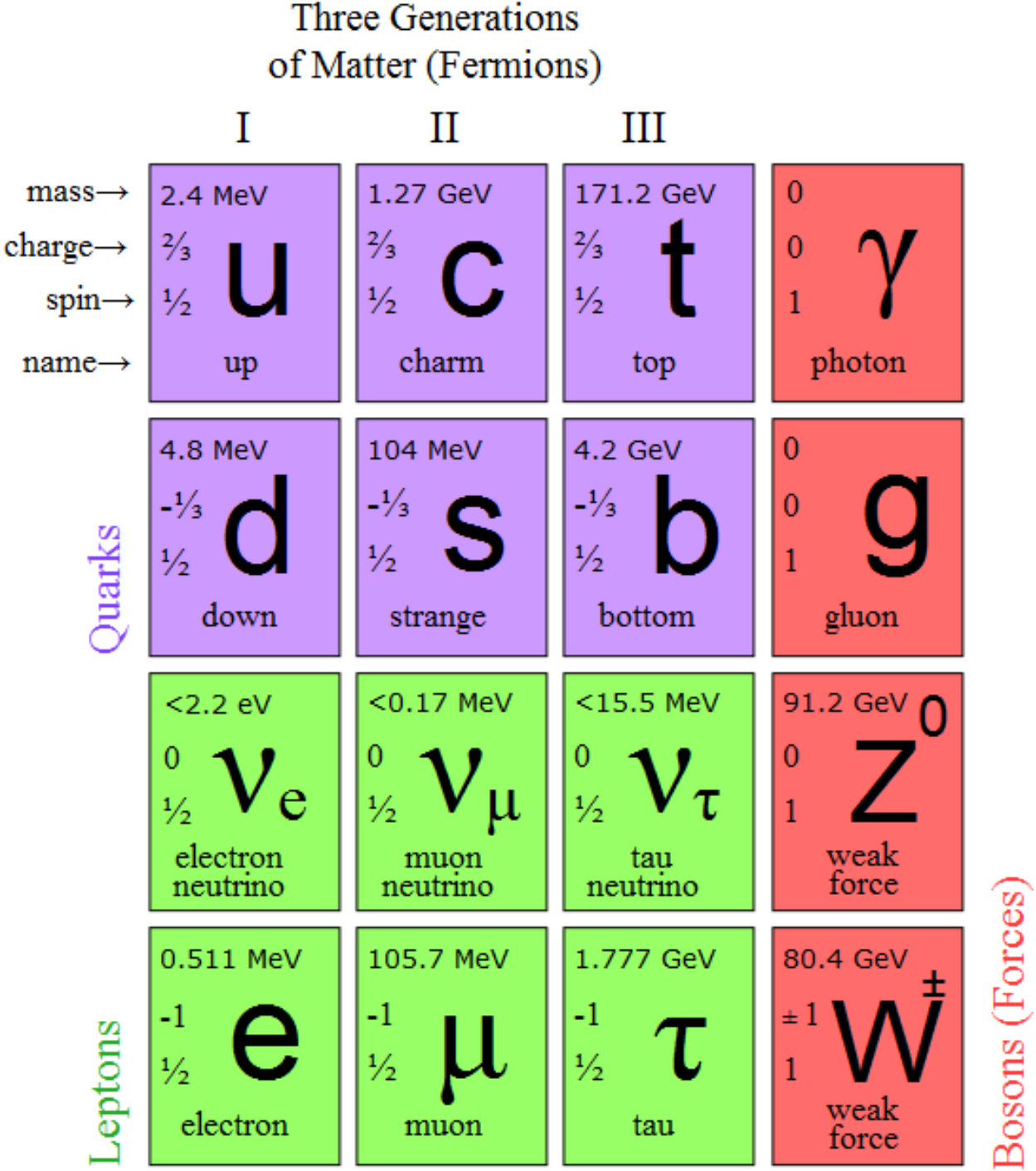
2. -If its lifetime is not infinite, what particles does it decay into?
   -What are the branching ratios to different decay modes?
   -What are the distributions of energies and directions?
   -Do they agree with the theoratical models?

3. What happens when it collides with another particle?

Particle Physics

The field of study is all 'Elementary Particles'

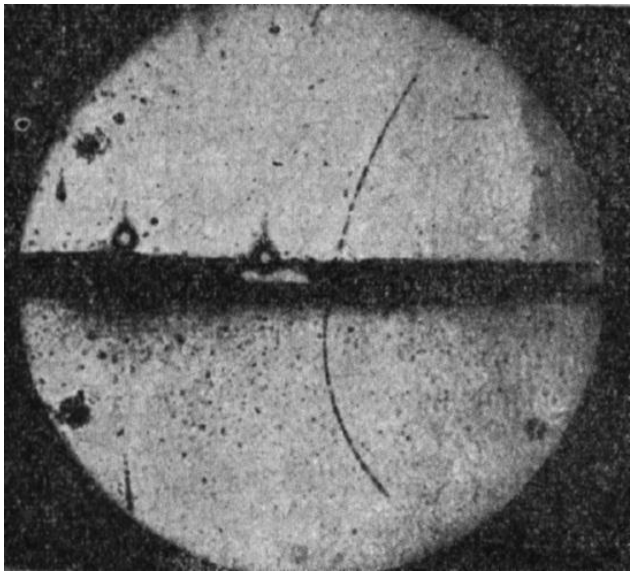
- ***that have been discovered***
  - 6 quarks (u, d, s, c, b, t)
  - 6 leptons (e, mu, tau and 3 neutinos)
  - 4 intermediate bosons (W, Z, g, gamma)
  - The 100+ hadrons
    - made from 2 quarks: $\pi, K, D, \cdots$
    - made from 3 quarks: $p, n, \Lambda, \cdots$
    - made from 5 quarks: $\Theta^{+}, \cdots$
  - + corresponding anti-particles
  - Higgs Boson
- ***that have not been discovered***
  - Squarks and sleptons
  - Winos and Zinos/charginos and neutralinos
  - Further hadrons


Three Generations
of Matter (Fermions)
I
II
III
mass→
charge→
spin→
name→
2.4 MeV
⅔
½
u
up
1.27 GeV
⅔
½
c
charm
171.2 GeV
⅔
½
t
top
0
0
1
γ
photon
4.8 MeV
-⅓
½
d
down
104 MeV
-⅓
½
s
strange
4.2 GeV
-⅓
½
b
bottom
0
0
1
g
gluon
<2.2 eV
0
½
νe
electron neutrino
<0.17 MeV
0
½
νμ
muon neutrino
<15.5 MeV
0
½
ντ
tau neutrino
91.2 GeV
0
1
Z0
weak force
0.511 MeV
-1
½
e
electron
105.7 MeV
-1
½
μ
muon
1.777 GeV
-1
½
τ
tau
80.4 GeV
±1
1
W±
weak force
Quarks
Leptons
Bosons (Forces)

Four Fundamental Forces

Force	Object affected	Range	Magnitude
Gravitation	Freely falling object Planets Galaxies	∞	1
Weak	Beta decay Fussion in Sun	10^{-17} m	10^{25}
Electromagnetic	Atoms & Molecules Optics Electric & Electronic Frictional force	∞	10^{36}
Strong	Nucleons Quarks	10^{-15} m	10^{38}

Anti-Matter

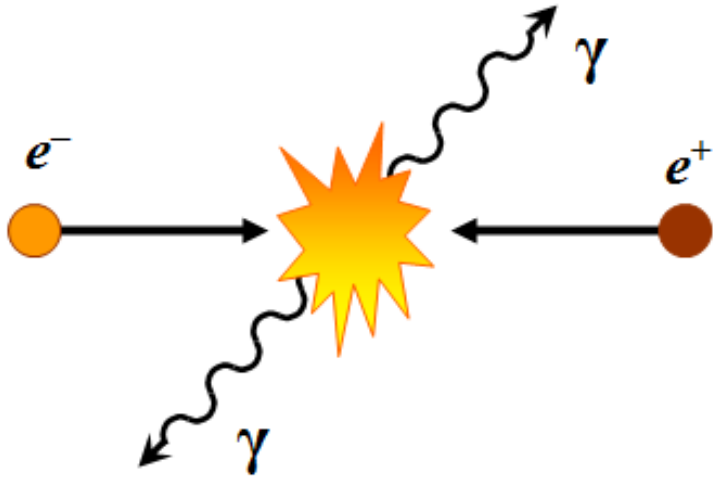


- **1928:**
  Dirac's positive electron (positron) prediction
- **1932:**
  Anderson's observation in Cosmic rays

- **Each particle has its own antiparticle with the same mass but opposite charge.**

If particle and its antiparticle encounter each other, their masses (materials) are converted into the energy (photon)

$$E = m\,c^2$$



THE LHC EXPERIMENT

CERN

- ***Conseil Européen pour la Recherche Nucléaire***

European Organization for Nuclear Research

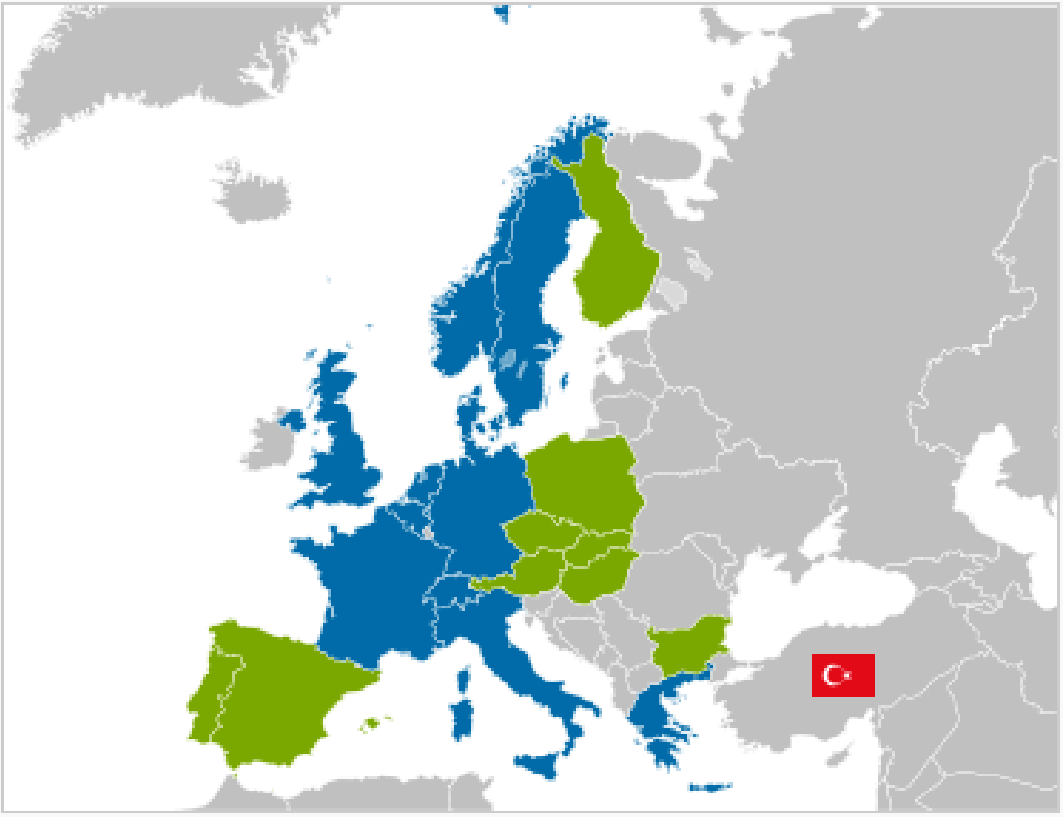
Avrupa Nükleer Araştırma Merkezi

- **CERN is the world's largest particle physics laboratory, situated in the northwest suburbs of Geneva on the Franco–Swiss border, established in 1954.**

CERN

- 1949: L. De Broglie offered.
- 1952: established by 11 countaries.
- 1959-1999: +9 countaries are added.

- +8 observers
  Türkiye
  India
  Japan
  USA
  UNESCO
  EC
  Israel
  Russia



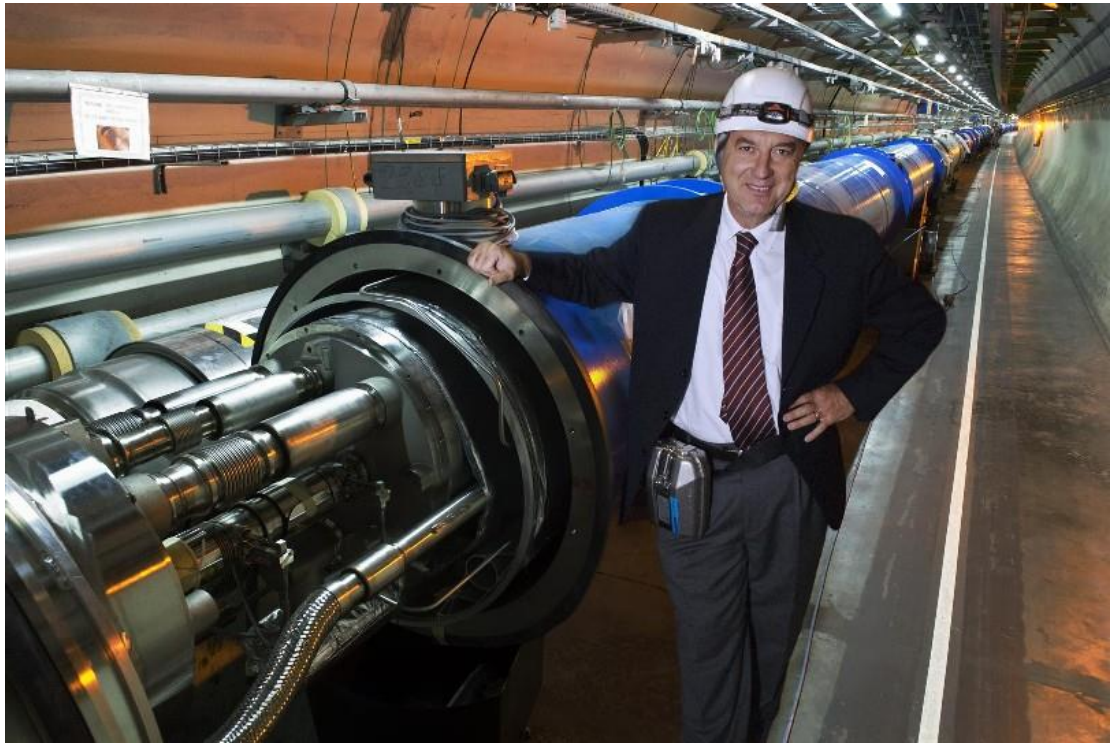
LHC: Large Hadron Collider

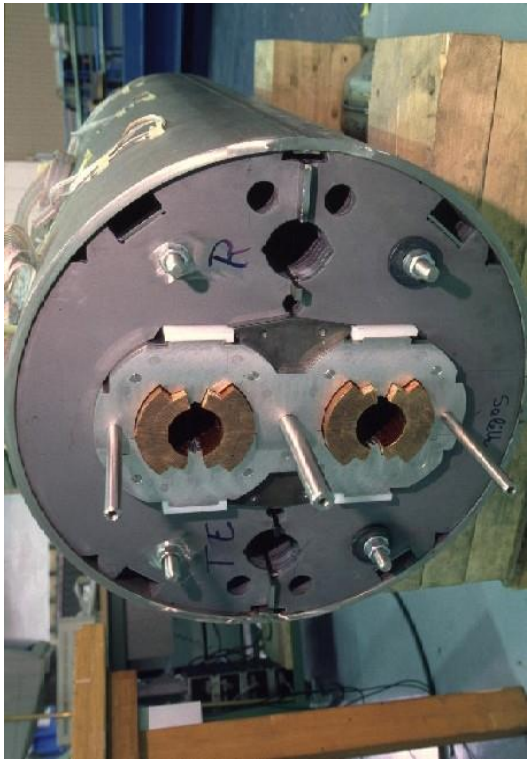
- Circumference 27 km
- ~100 m underground
- Protons ve Pb nuclei will collide
- Cost: 3 billions €

PHYSICS

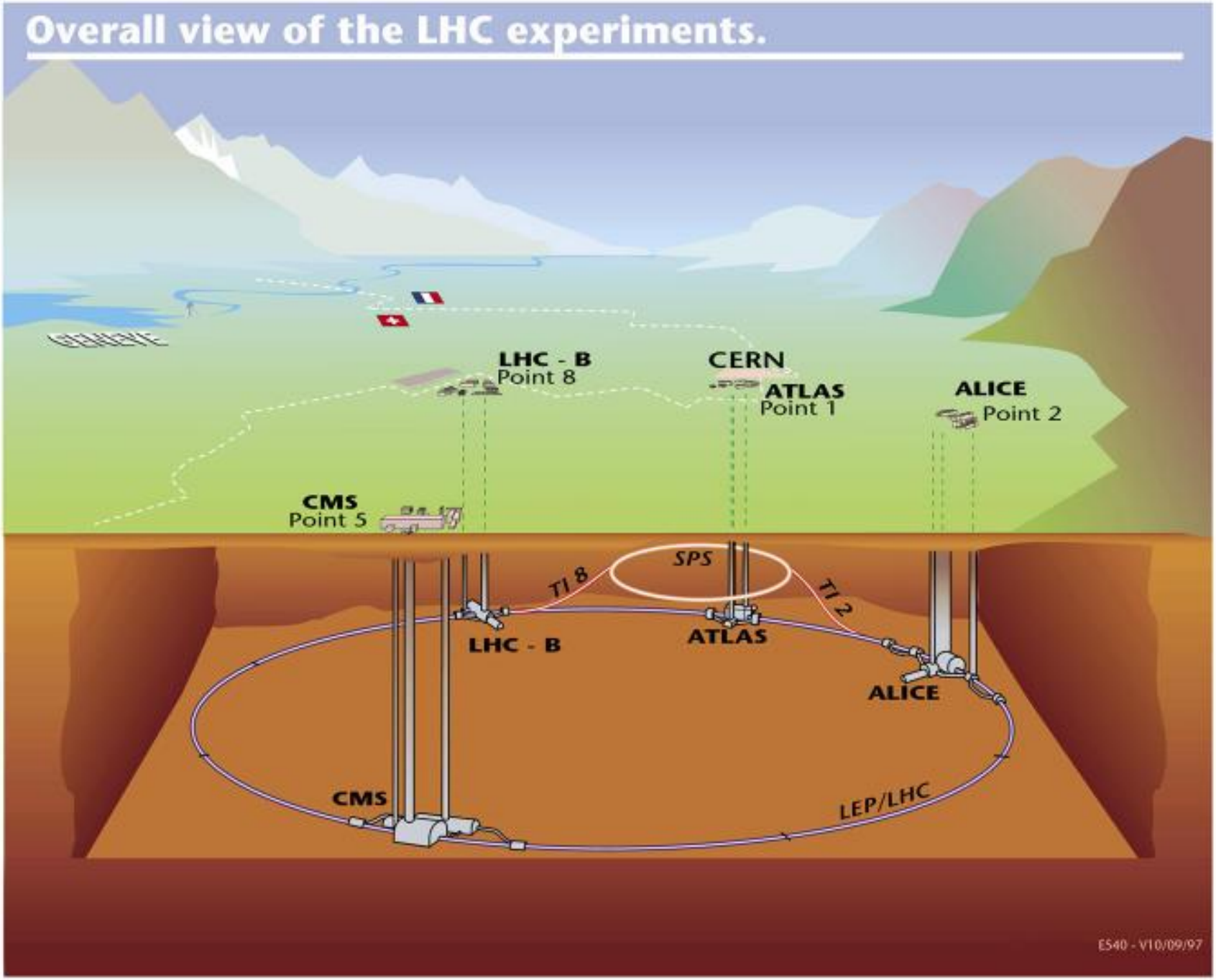
- Higgs Boson(s)
- Supersymmetric particles
- furher quarks and/or hadrons
- Big-Bang and mini-black holes

LHC



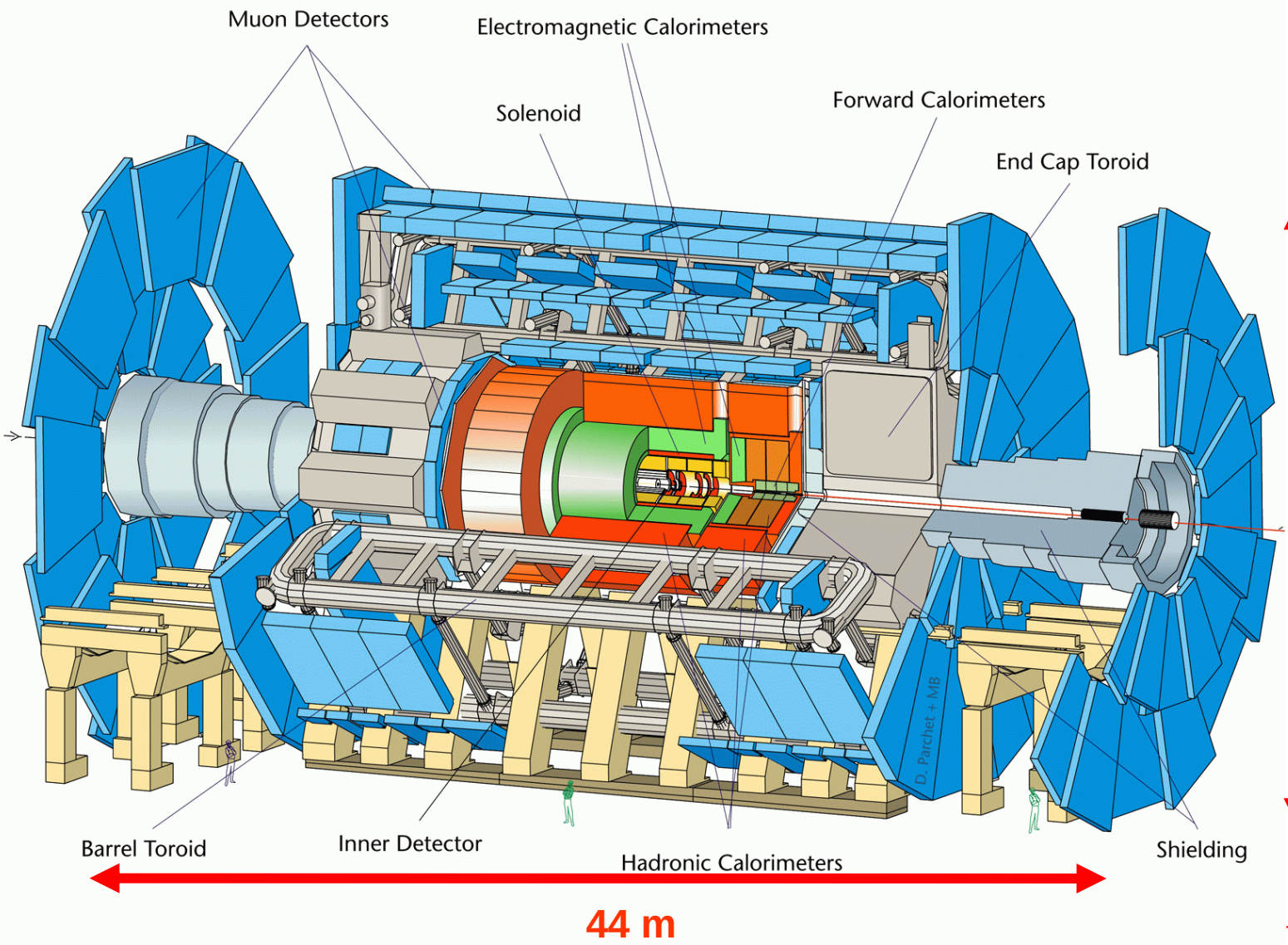


Overall view of the LHC experiments.

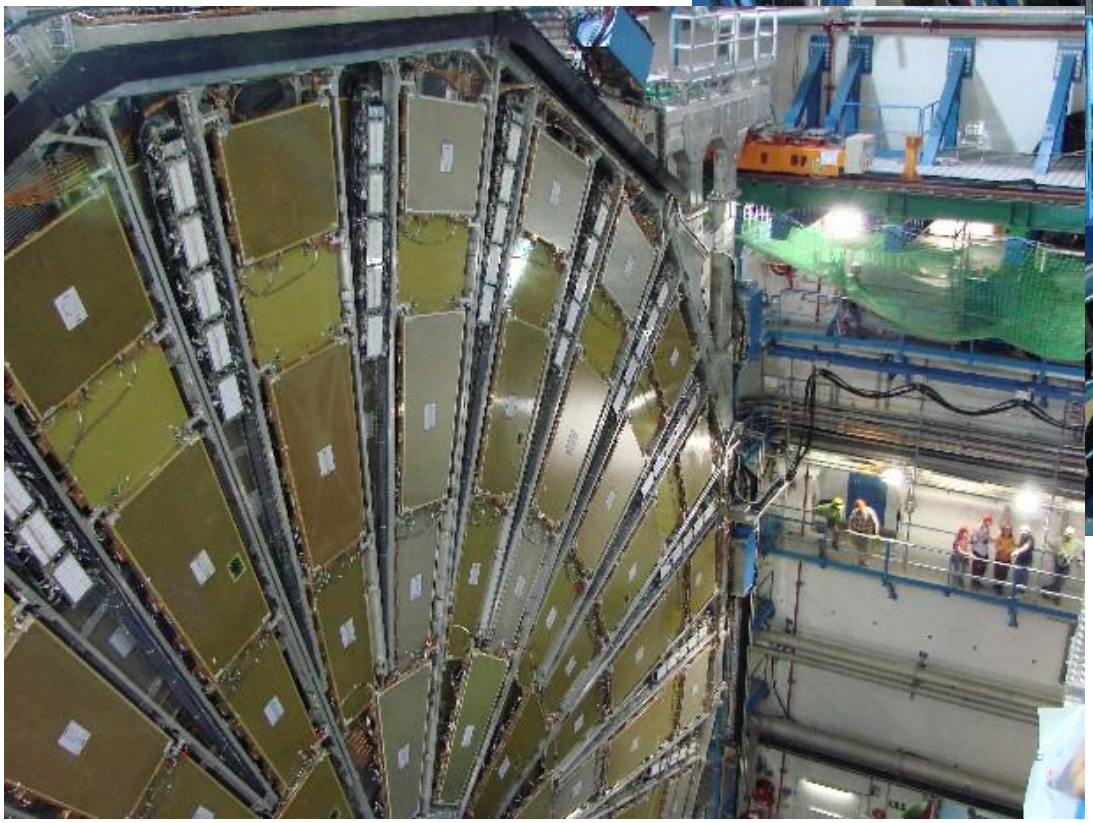


Particle Detectors

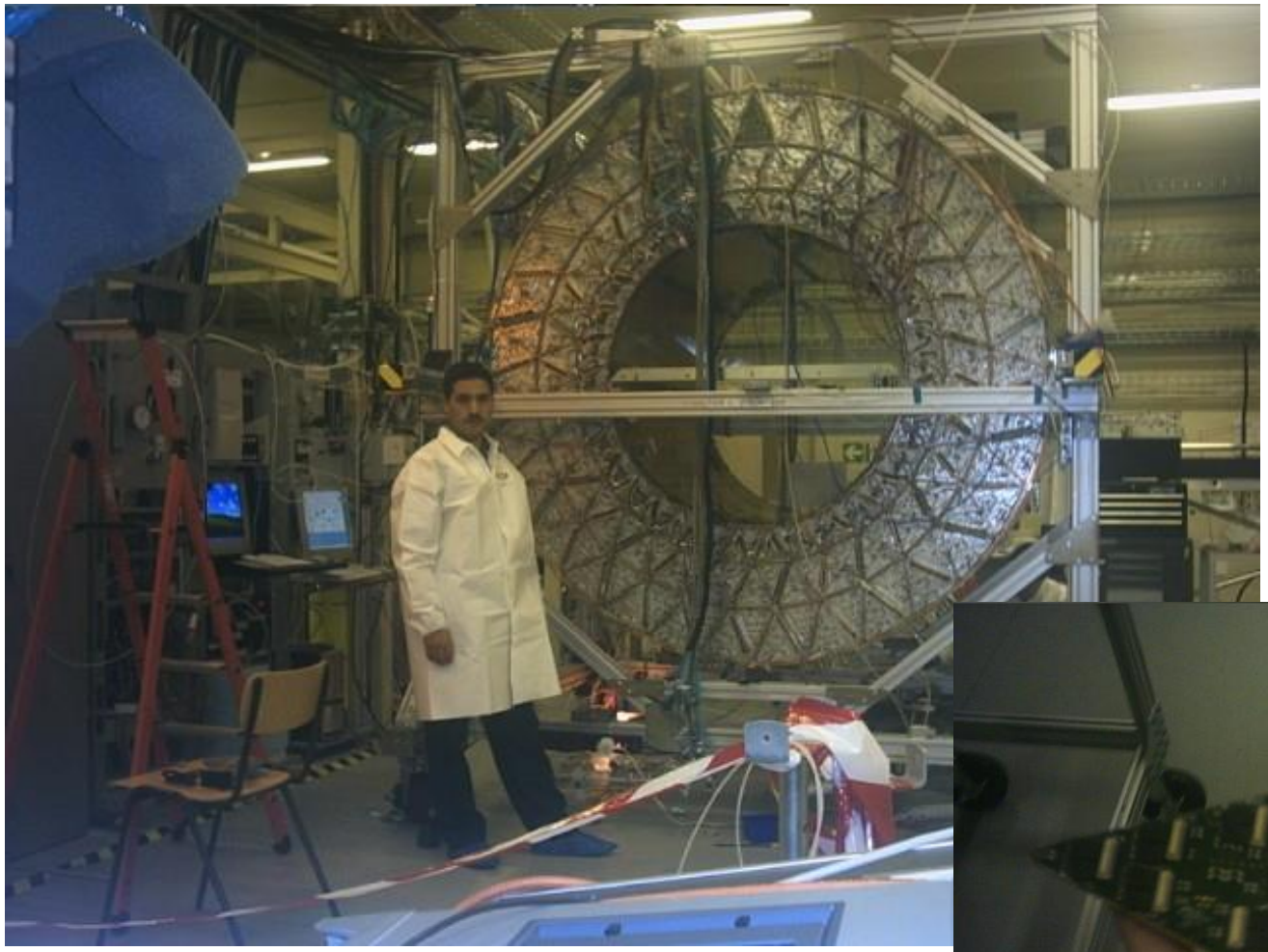
ATLAS Detector: 34 countary / 175 University

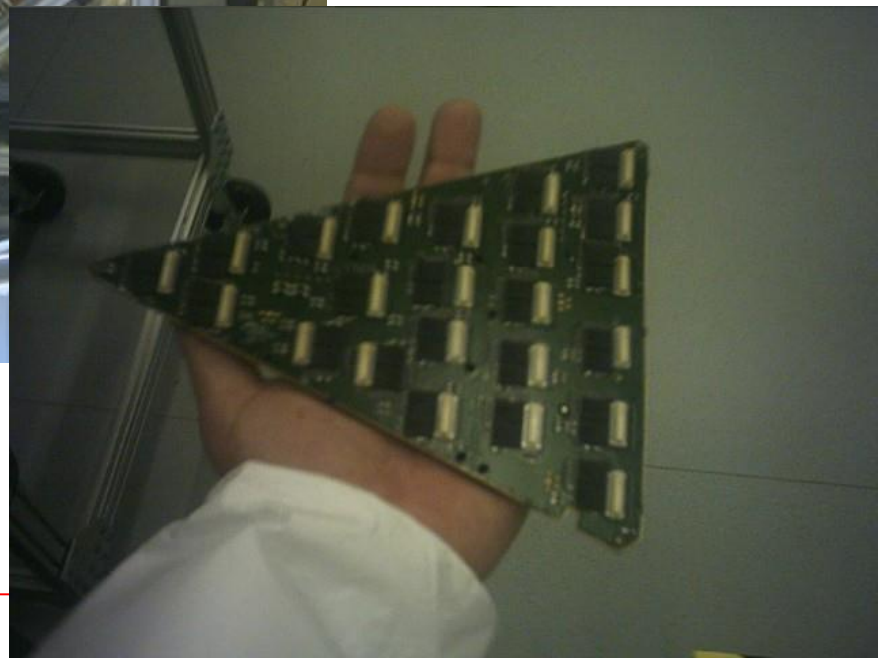


Particle Detectors



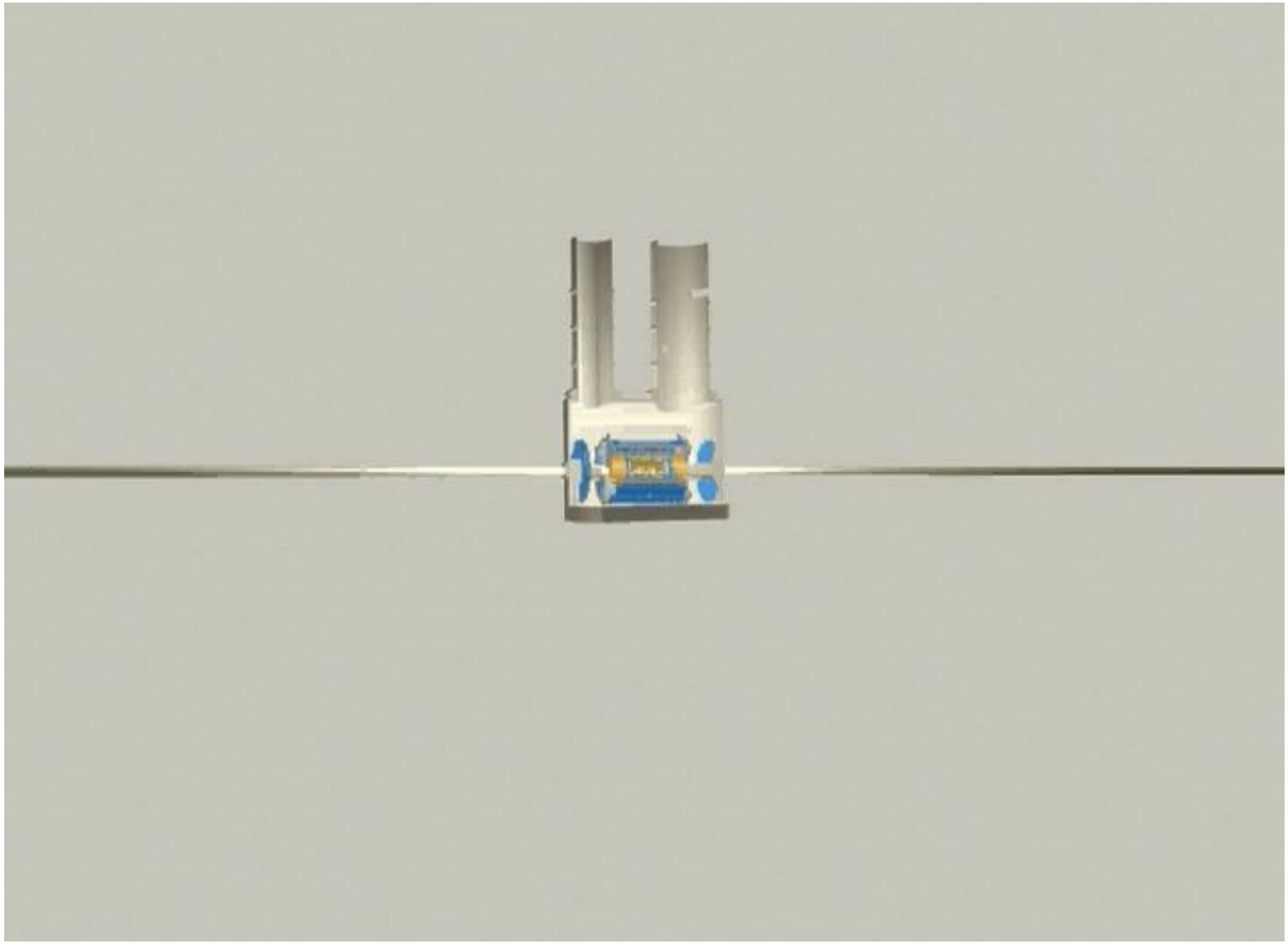
Particle Detectors

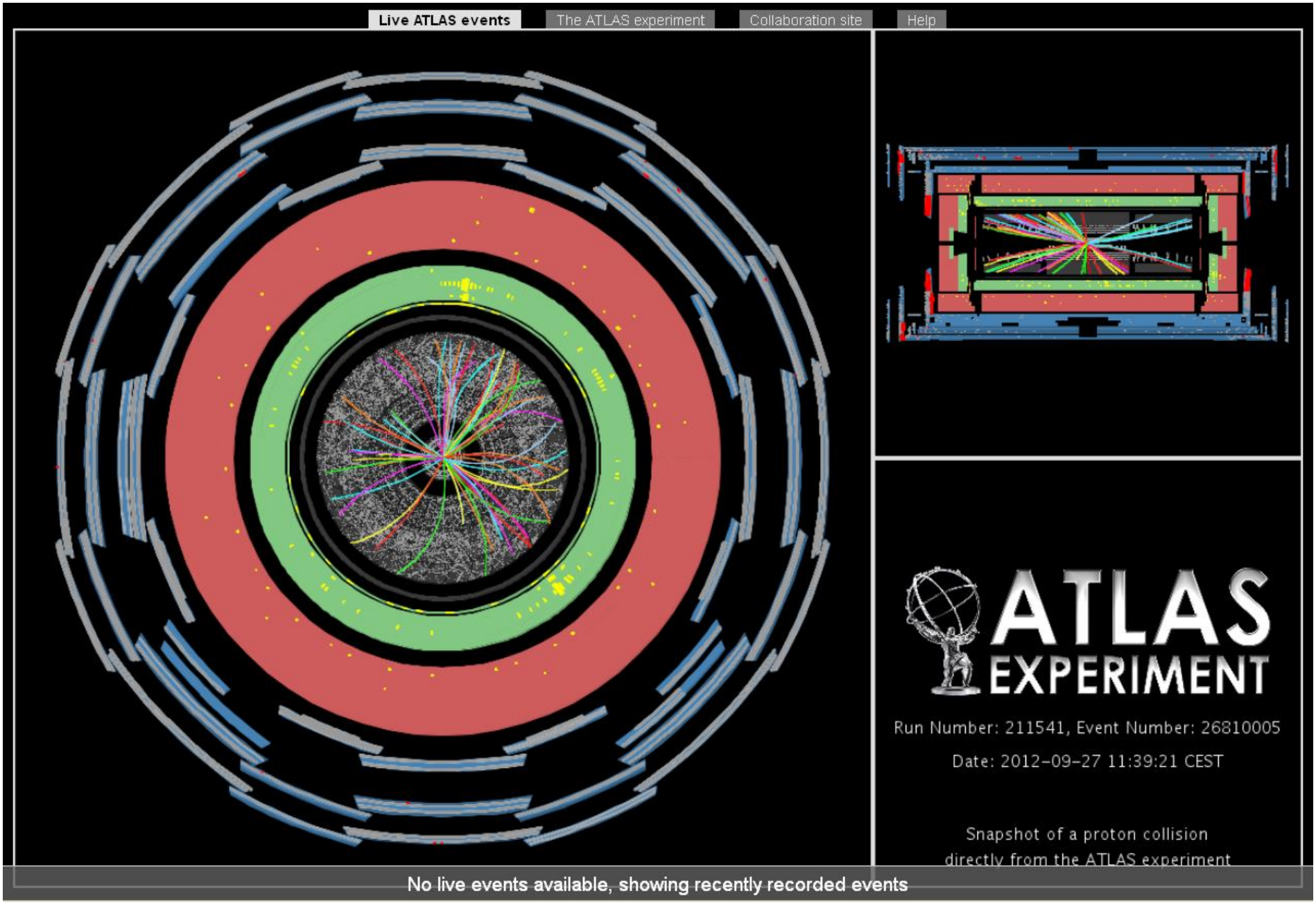




Particle Detectors

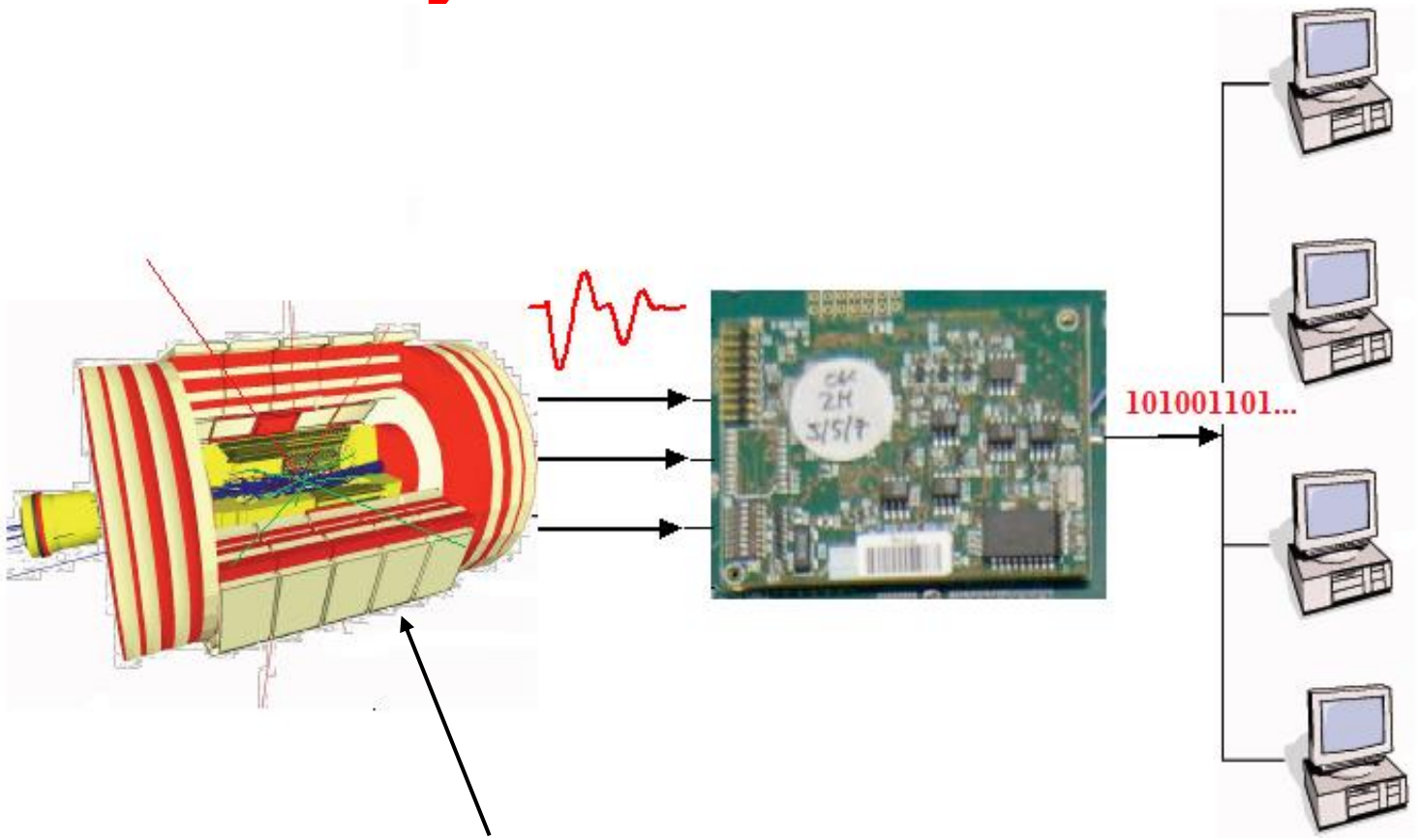
atlas-olay.mpeg

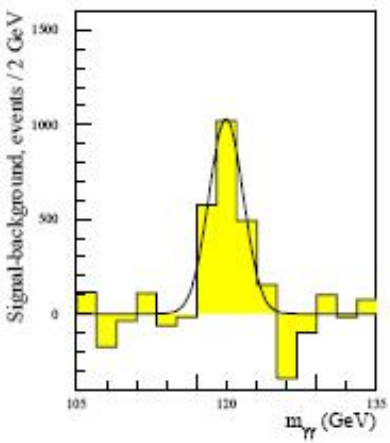



Live ATLAS events
The ATLAS experiment
Collaboration site
Help
ATLAS
EXPERIMENT
Run Number: 211541, Event Number: 26810005
Date: 2012-09-27 11:39:21 CEST
Snapshot of a proton collision
directly from the ATLAS experiment
No live events available, showing recently recorded events

THE GRID COMPUTING

Data Analysis Chain





- 150 million sensors,
- 1 GB/s storage rate…

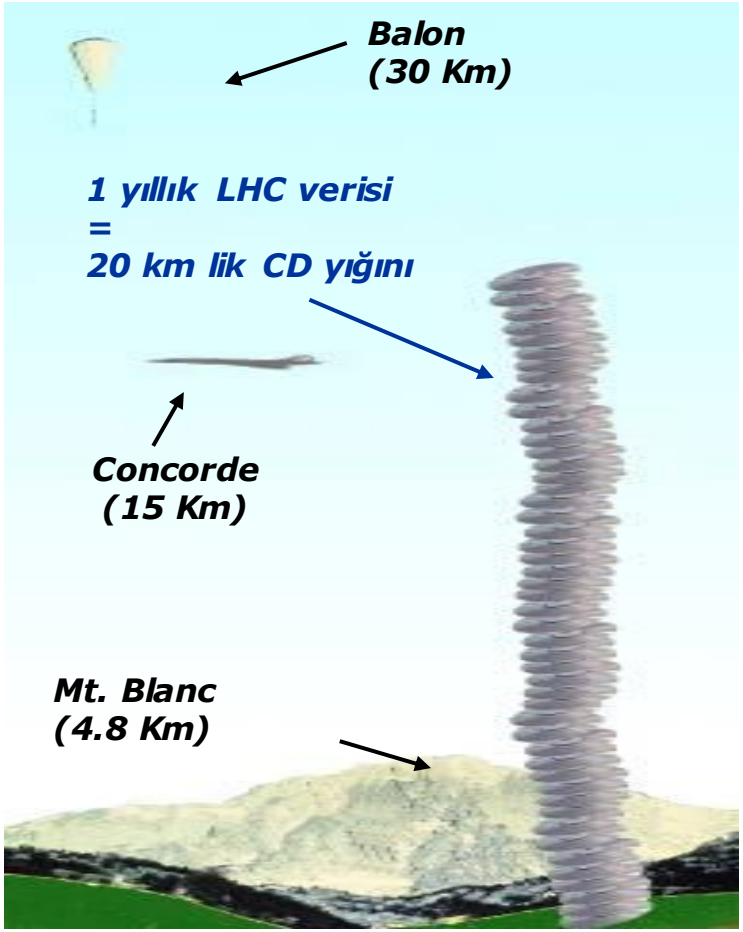
Data Analysis

Data will be collected at LHC:15 PB/Year

15 PB ~ 22 millon CD

* **started at September 2008.**
* **will work at least 10 years.**
* **total data ~ 250 PB**

Where do we store this amount of data?



Data Analysis

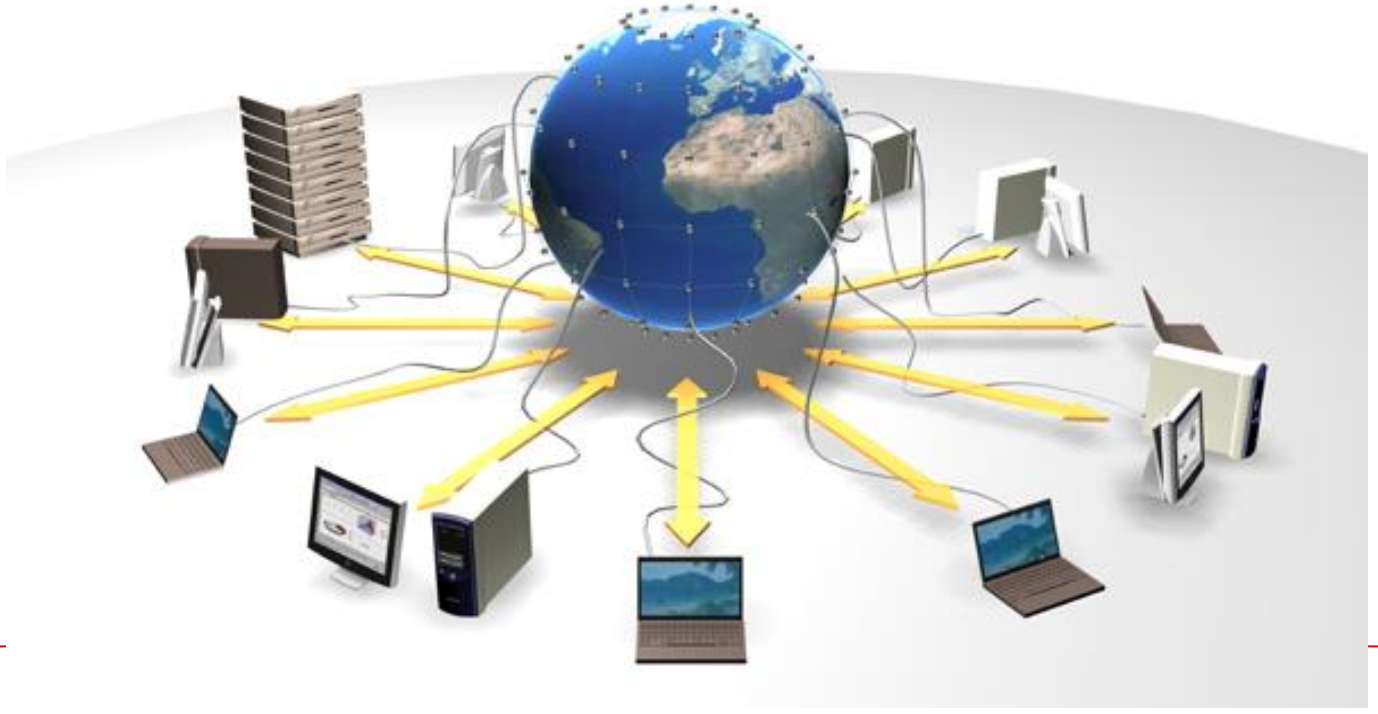
- **We need, <u>at least</u> 100,000 times computers at GHz speed to analyse data**

Where do we find

this amount of computer?

Grid Computing

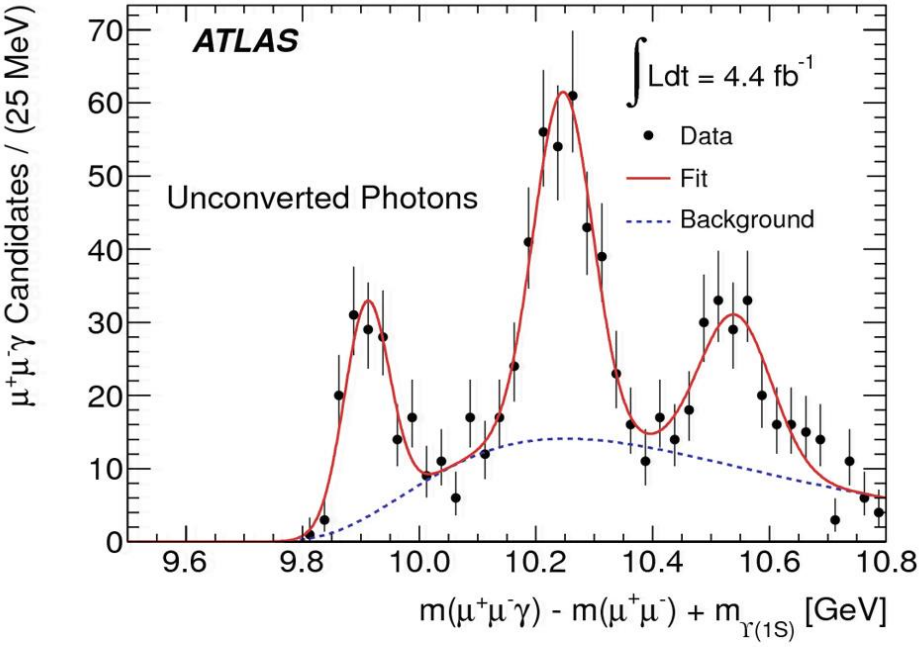
- “Distributed” or “grid” computing in general is a special type of parallel computing that relies on complete computers (with onboard CPU, storage, power supply, network interface, etc.) connected to a network (private, public or the Internet) by a conventional network interface.



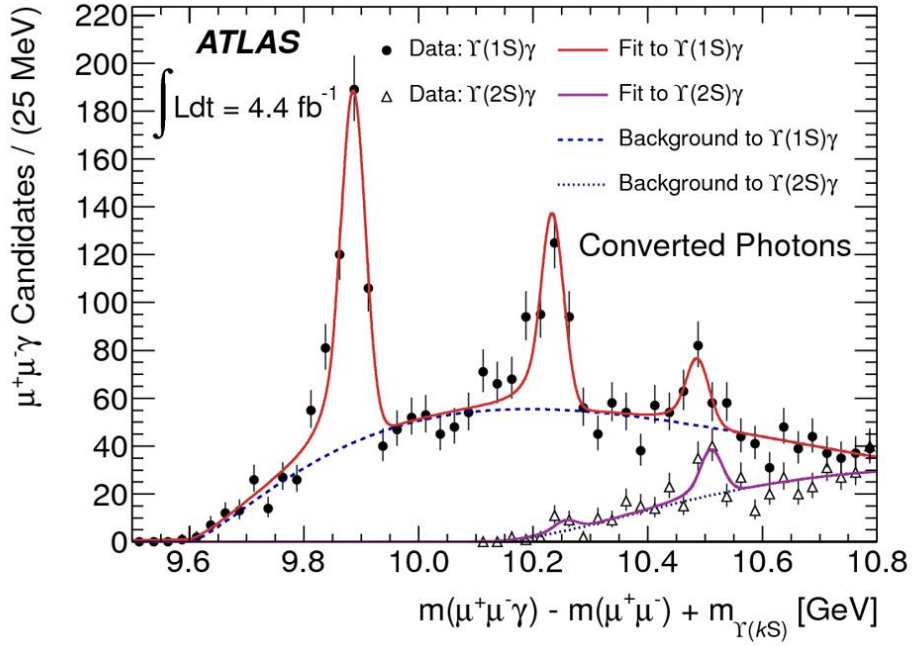
Discovery of the X_b?

December 2011

The *ATLAS* collaboration has announced the discovery of the X_b(3P), which is a bound state of a bottom quark and bottom antiquark (b b-bar).

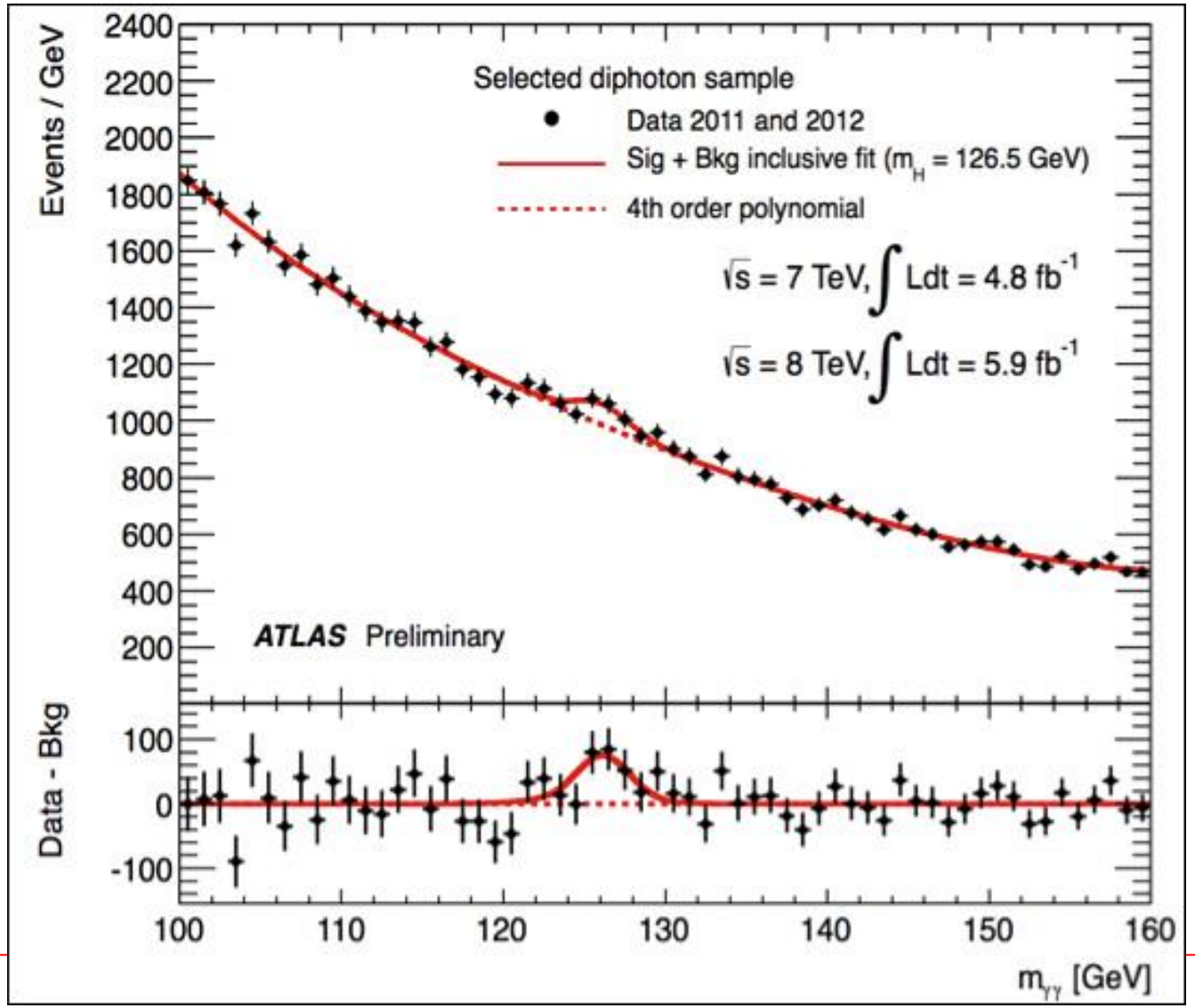


(a)



Discovery of the Higgs ?

July 2012, *ATLAS* data ($H \rightarrow \gamma\gamma$)



Discovery of the Higgs ?

July 2012, *CMS* data ($H \rightarrow \gamma\gamma$)