10 anni dalla scoperta del Bosone di Higgs

Anna Di Ciaccio

Dipartimento di Fisica

University of Roma Tor Vergata and INFN

SETTIMANA DELLA RICERCA SCIENTIFICA

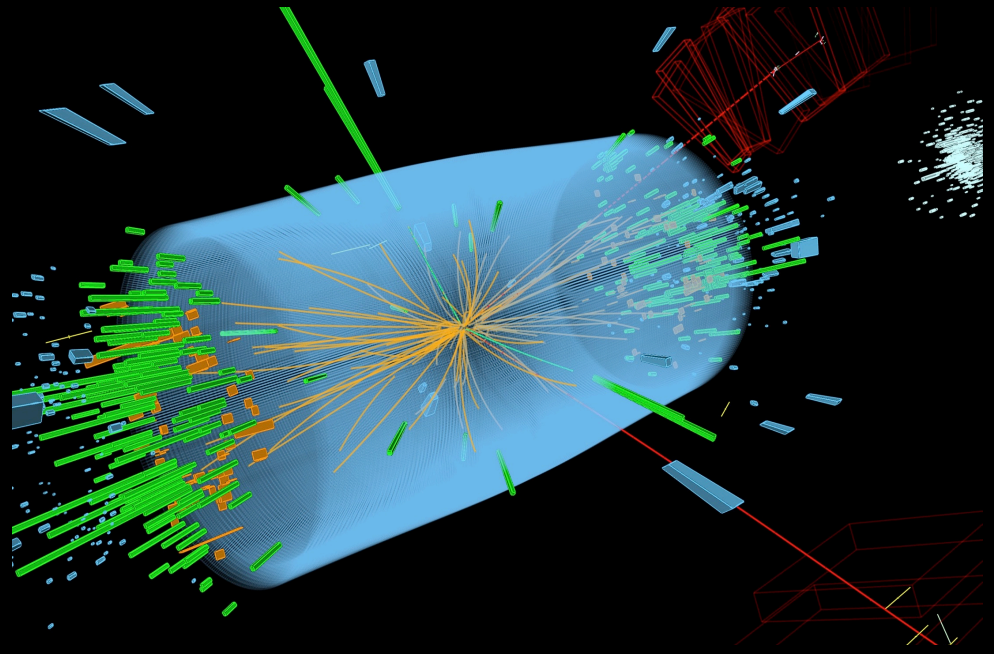
Roma, 30 Settembre 2022

Outline

- il ruolo del Bosone di Higgs
- The Large Hadron Collider e gli esperimenti ATLAS e CMS al CERN di Ginevra
- Una brevissima storia della scoperta di questa particella

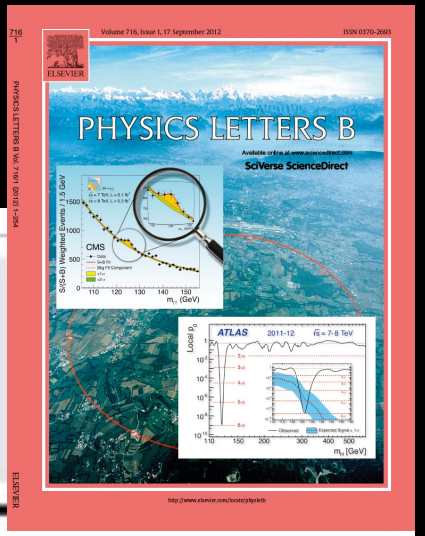
Higgs discovery: 4 July 2012

First observation of a new particle in the search for the Standard Model Higgs Boson at the LHC by ATLAS and CMS Collaboration



La pubblicazione della scoperta

August 2012



Contents lists available at SciVerse ScienceDirect

Physics Letters B

www.elsevier.com/locate/physletb

Observation of a new particle in the search for the Standard Model Higgs boson with the ATLAS detector at the LHC☆

ATLAS Collaboration*

This paper is dedicated to the memory of our ATLAS colleagues who did not live to see the full impact and significance of their contributions to the experiment.

ARTICLE INFO

Article history:
Received 31 July 2012
Received in revised form 8 August 2012
Accepted 11 August 2012
Available online 14 August 2012
Editor: W.-D. Schlatter

ABSTRACT

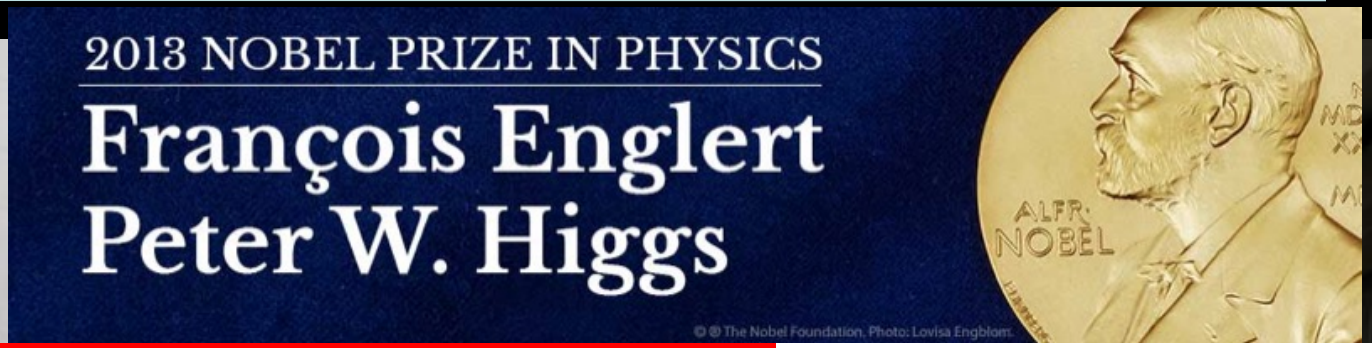
A search for the Standard Model Higgs boson in proton–proton collisions with the ATLAS detector at ... ly 4.8 fb^{-1} ... e channels ... previously ... esults from ... vidence for ... presented.

This observation, which has a significance of 5.9 standard deviations, corresponding to a background fluctuation probability of 1.7×10^{-9}, is compatible with the production and decay of the Standard Model Higgs boson.

The culmination of a long path ...
An arrival and a starting point ...

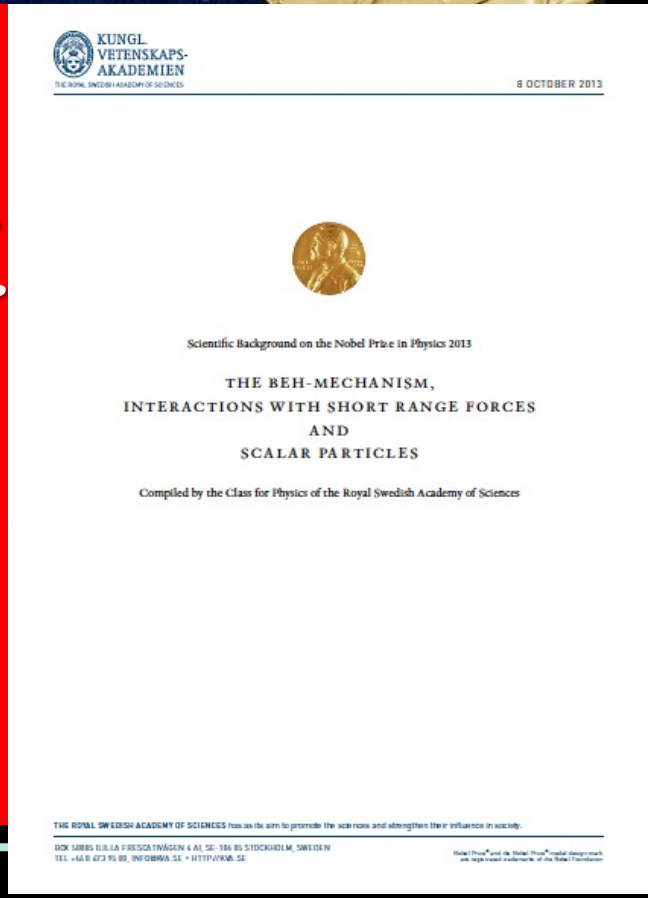
Il Premio Nobel per la fisica 2013

8 Ottobre 2013
ore 12:45



Motivation:

"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 Large Hadron Collider"



KUNGL. VETENSKAPS-AKADEMIEN
THE ROYAL SWEDISH ACADEMY OF SCIENCES

8 OCTOBER 2013

Scientific Background on the Nobel Prize in Physics 2013

THE BEH-MECHANISM,
INTERACTIONS WITH SHORT RANGE FORCES
AND
SCALAR PARTICLES

Compiled by the Class for Physics of the Royal Swedish Academy of Sciences

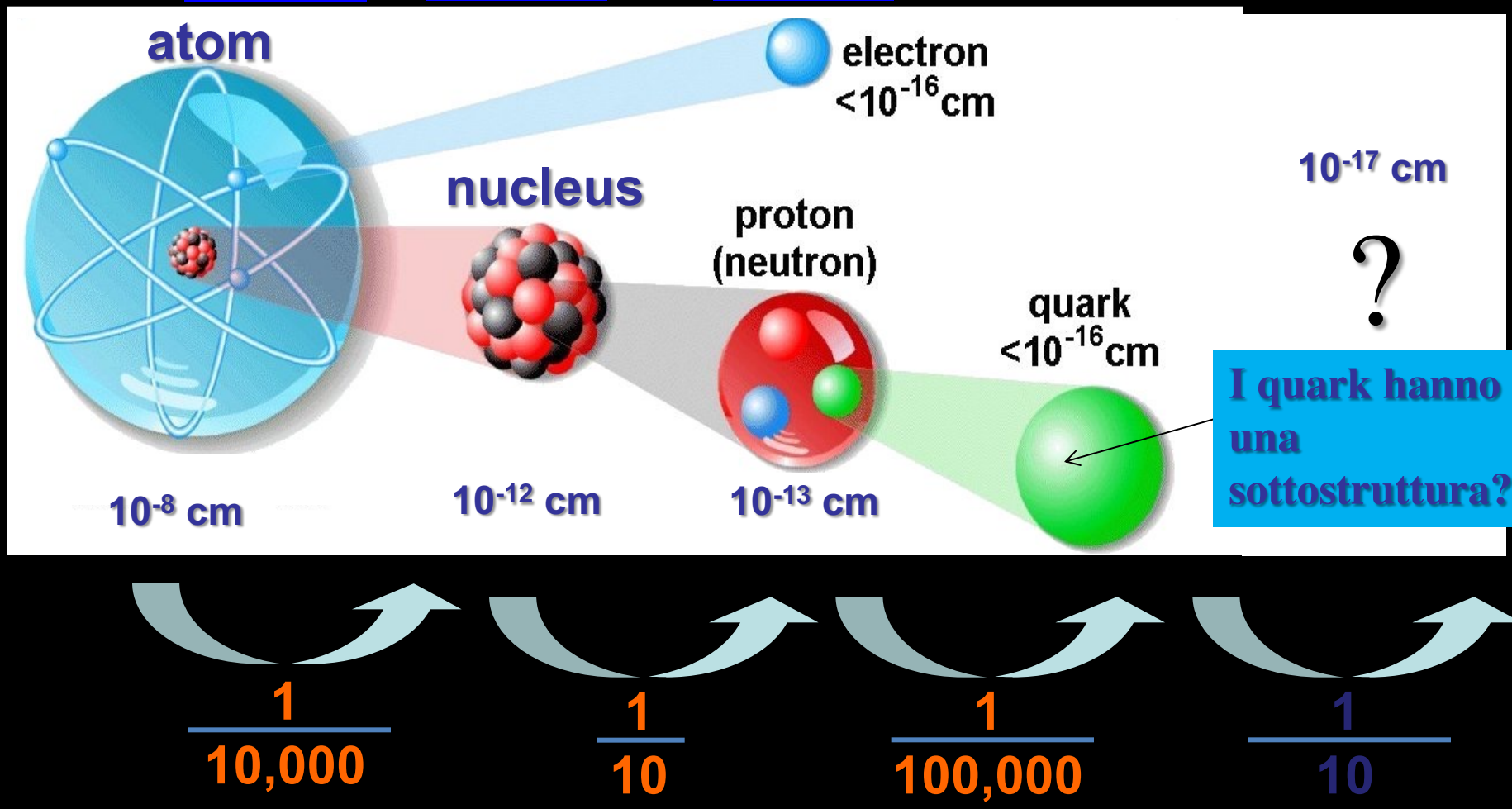
THE ROYAL SWEDISH ACADEMY OF SCIENCES has as its aim to promote the sciences and strengthen their influence in society.

BOX 50005 SE-104 05 STOCKHOLM, SWEDEN
TEL +46 8 673 95 00, INFO@KVA.SE • HTTP://KVA.SE

EPS Prize 2013

- **Le Collaborazioni ATLAS e CMS hanno ricevuto il Premio EPS (European Physical Society) 2013 per la fisica delle alte energie e delle particelle elementari per la scoperta del Bosone di Higgs!**

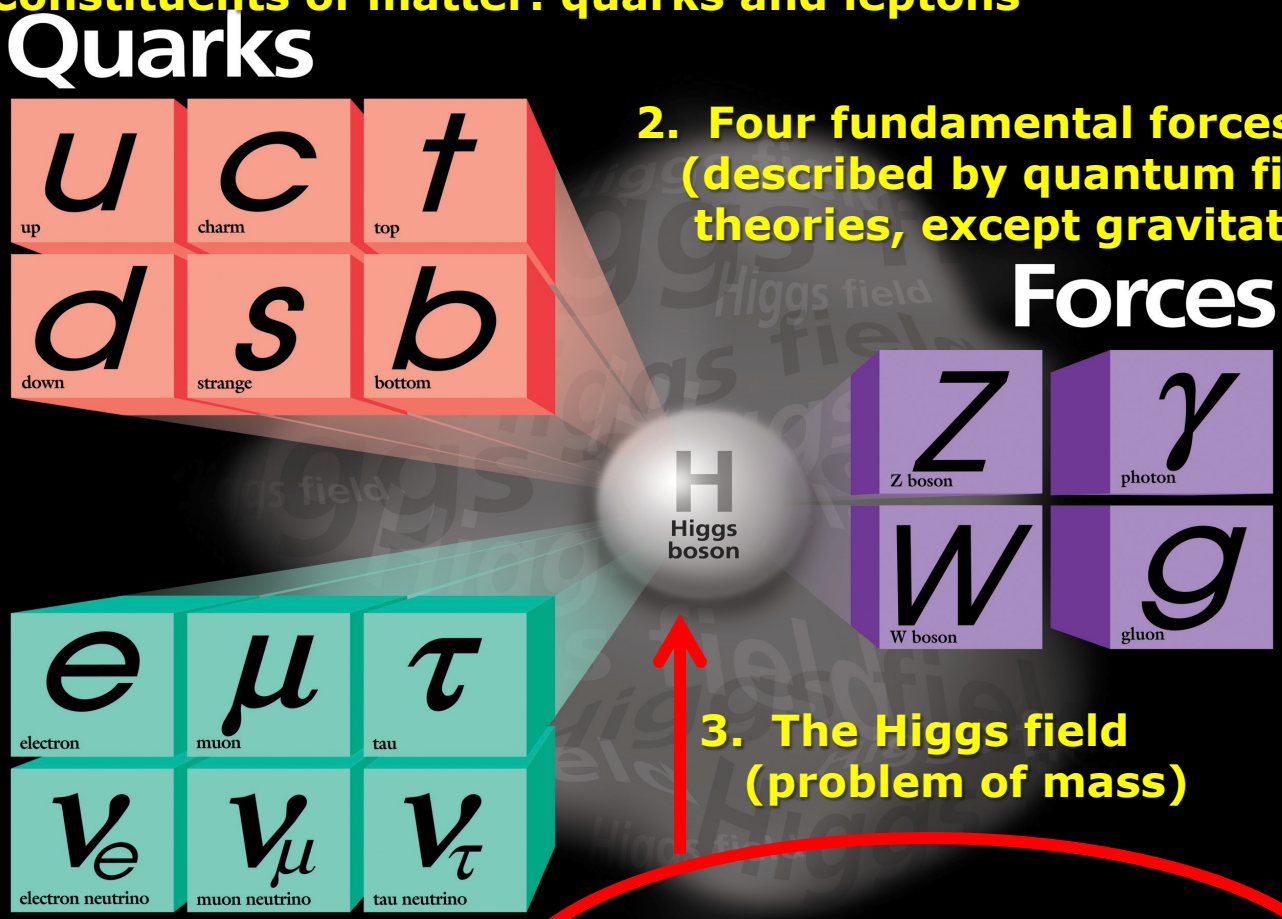
Abbiamo imparato molto negli ultimi 100 anni sulla struttura fondamentale della materia



THE STANDARD MODEL

A quantum field theory of fundamental particle and their interactions (except gravity)

1. Constituents of matter: quarks and leptons



2. Four fundamental forces (described by quantum field theories, except gravitation)

3. The Higgs field (problem of mass)

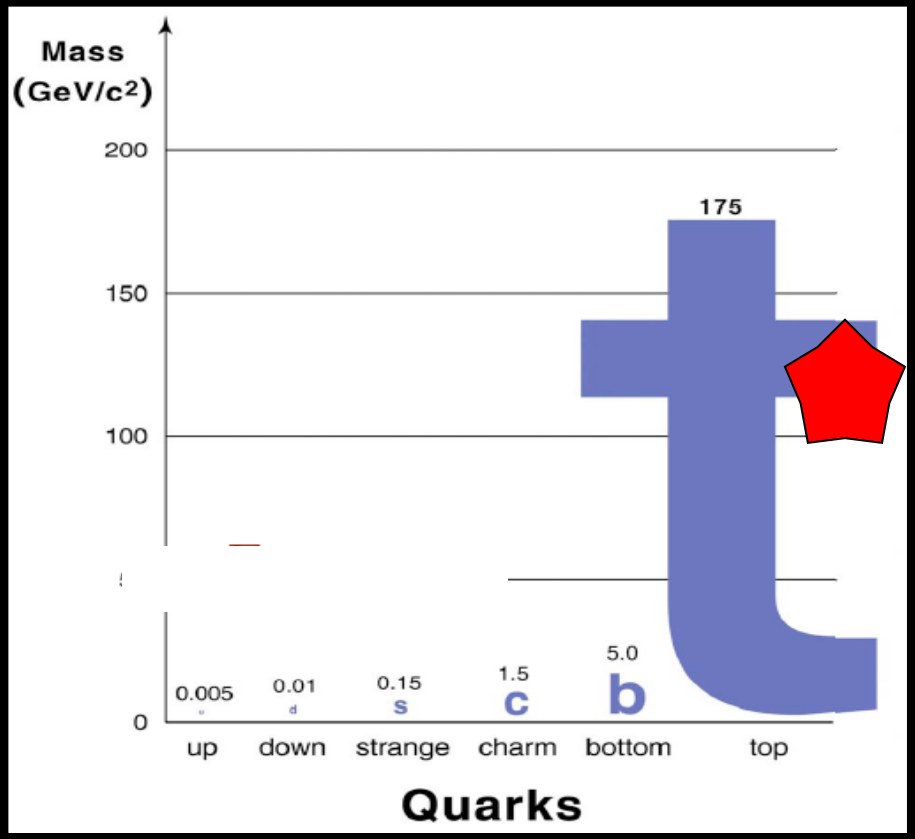
Missing keystone of the SM till discovery at the LHC at CERN on July 4th 2012

A most basic question is why particles (and matter) have masses (and so different masses)

The mass mystery could be solved with the 'EW symmetry breaking mechanism' which predicts the existence of a new elementary particle, the 'Higgs' particle
(theory 1964: R. Brout and F. Englert; P.W. Higgs; G.S. Guralnik, C.R. Hagen and T.W.B. Kibble)

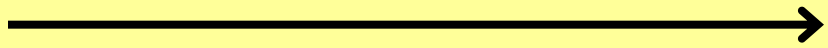
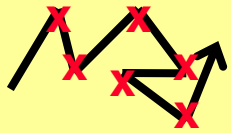
Peter Higgs

Francois Englert



The Higgs (H) particle has been searched for since decades at accelerators …

Why do Particles have Mass? => Higgs field

Nothing in the universe	Higgs field in the universe
Electron $m=0.511\ MeV/c^2$	
Photon $m=0$	
Top Quark $M\sim172000\ MeV/c^2$	

- Higgs field acts as "background field" (e.g. like fluid)
- Heaviest particles interact most strongly with Higgs field
  - Field slows particles down ⇔ gives them mass

How the Higgs Field gives Mass

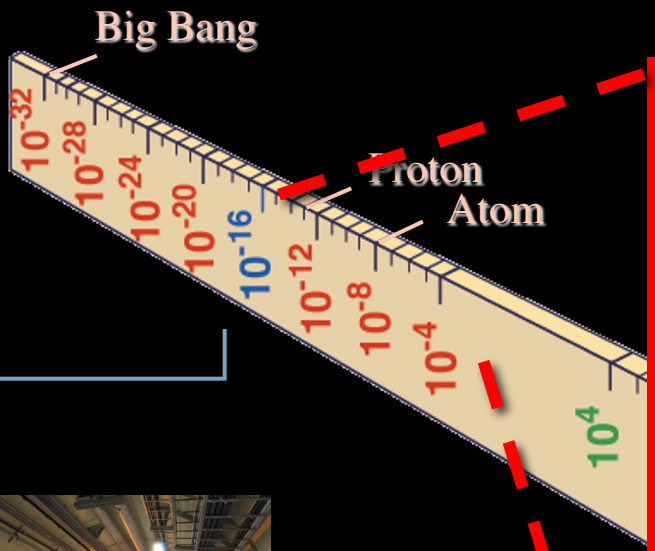
Party:
Guests are evenly spread

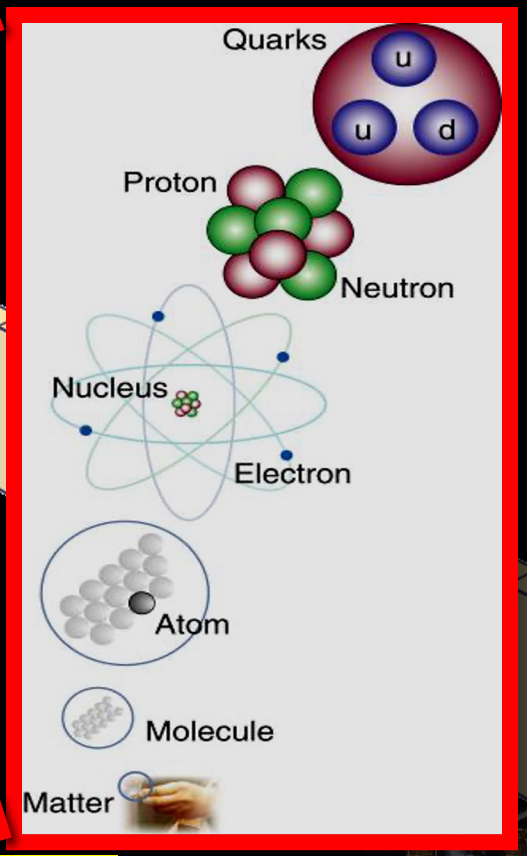
Arrival of celebrity:
Guests cluster near celebrity

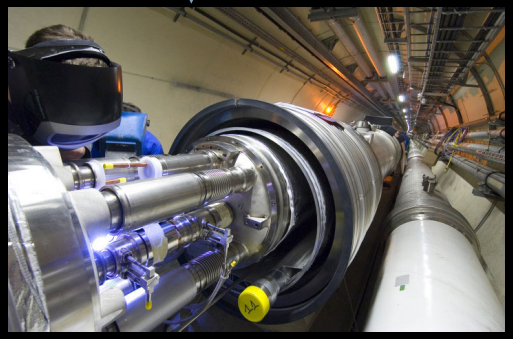
D. Miller / UCL

- **Guests act like Higgs field slowing celebrity down**
- **Celebrity moves slower <=> acquires mass**

The research for fundamental particles







LHC

Radius of Galaxies

Universe

10^{24}

10^{28}

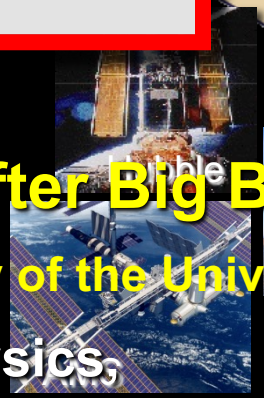
cm

LHC is a Super-Microscope

$\lambda = h/p \rightarrow d = 10^{-17}$ cm

Study physics laws of first moments after Big Bang

LHC will allow a better understanding of the infancy of the Universe.

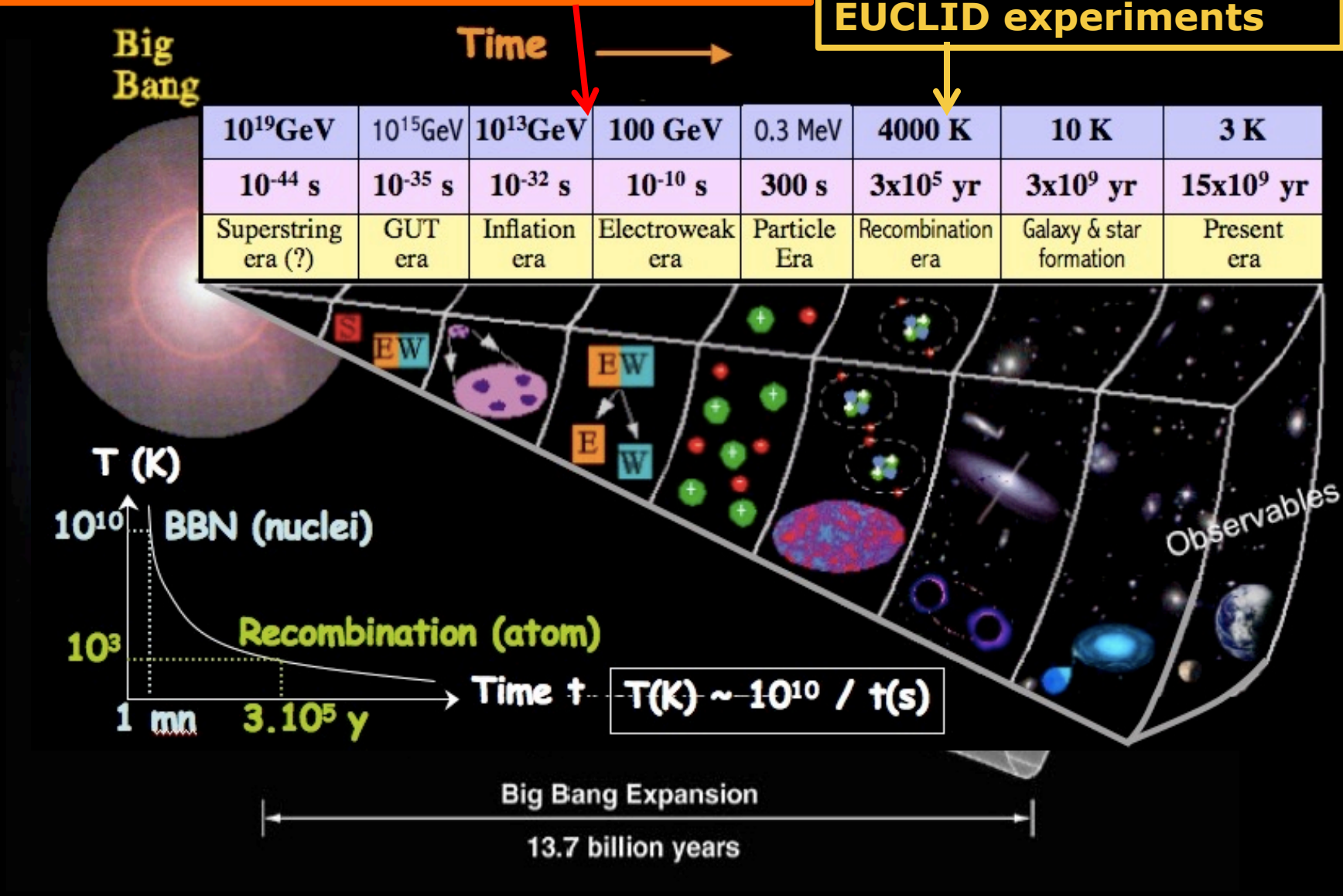


- increasing symbiosis between Particle Physics, Astrophysics and Cosmology

Today we know: Big Bang happened 13.7 ± 0.037 billion years ago: we have a precise mathematical model - relates size, temperature to time

LHC (particle physics) experiments 10^{-12}s

COBE, WMAP,PLANCK, EUCLID experiments



LHC and the ATLAS and CMS experiment at CERN

CERN

- **Il CERN, nei pressi di Ginevra, e' il più grande laboratorio per la ricerca nella fisica delle particelle.**
- **Nato nel 1954, ha permesso ai fisici europei di riportare la ricerca europea al livello di eccellenza che aveva conosciuto prima della guerra**

- 20 Member States: Austria, Belgium, Bulgaria, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Italy, Netherlands, Norway, Poland, Portugal, Slovakia, Spain, Sweden, Switzerland and the United Kingdom.
- 1 Candidate for Accession to Membership of CERN: Romania
- 8 Observers to Council: India, Israel, Japan, the Russian Federation, the United States of America, Turkey, the European Commission and UNESCO

Italy and CERN

Italy has been a founding member of CERN (1954)

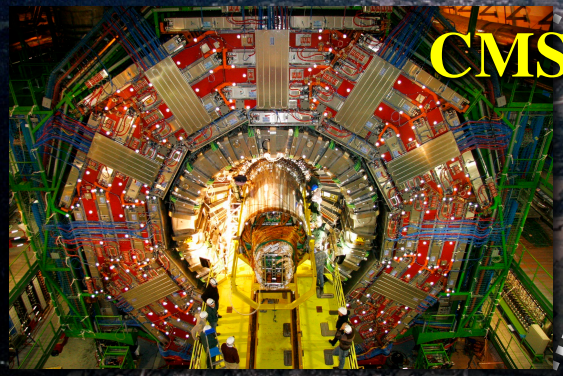
- **Edoardo Amaldi, collaborated with E.Fermi and played an important role in setting up CERN.**
- **He signed the CERN Convention on behalf of Italy 1953, and was elected first Chairman of the Scientific Policy Committee.**

Three Italian CERN Director-General :
Carlo Rubbia (1988 - 1993)
Luciano Maiani (1999 - 2005)
Fabiola Gianotti (2013- oggi)

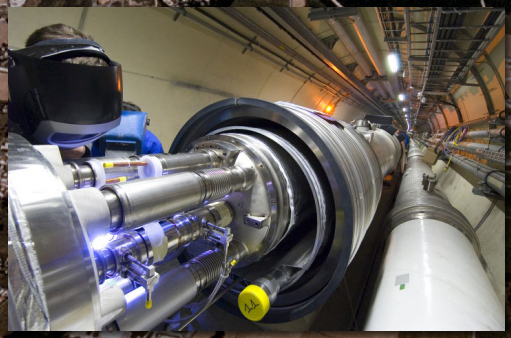
The Large Hadron Collider at CERN

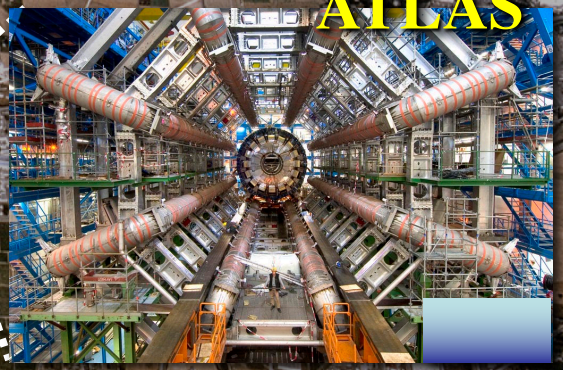
Proton-proton collisions at E_{CM} **up to 14 TeV**, 4 experiments

TeV = 10^{12} eV

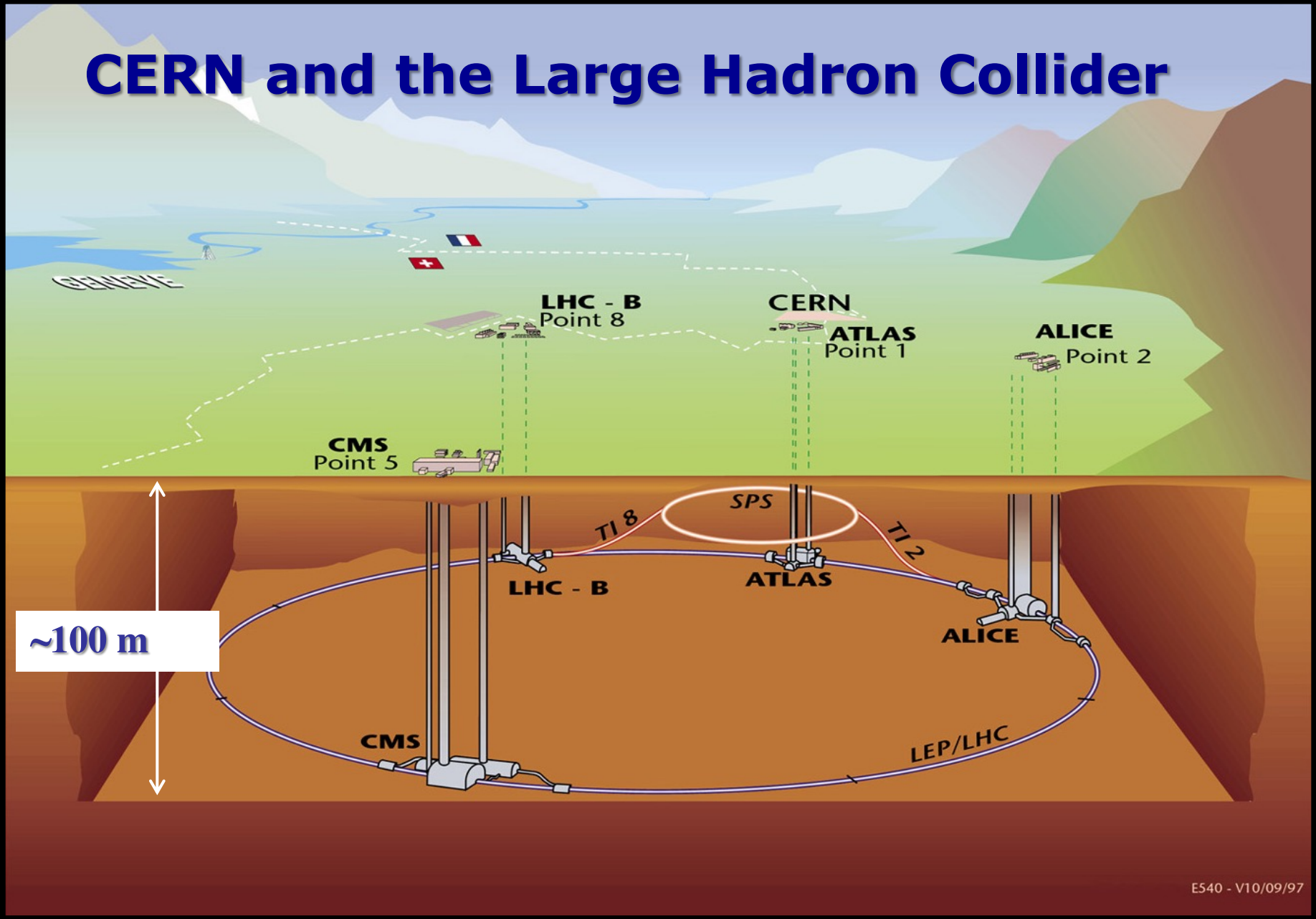


LHC ring:27 km circumference inside LEP tunnel

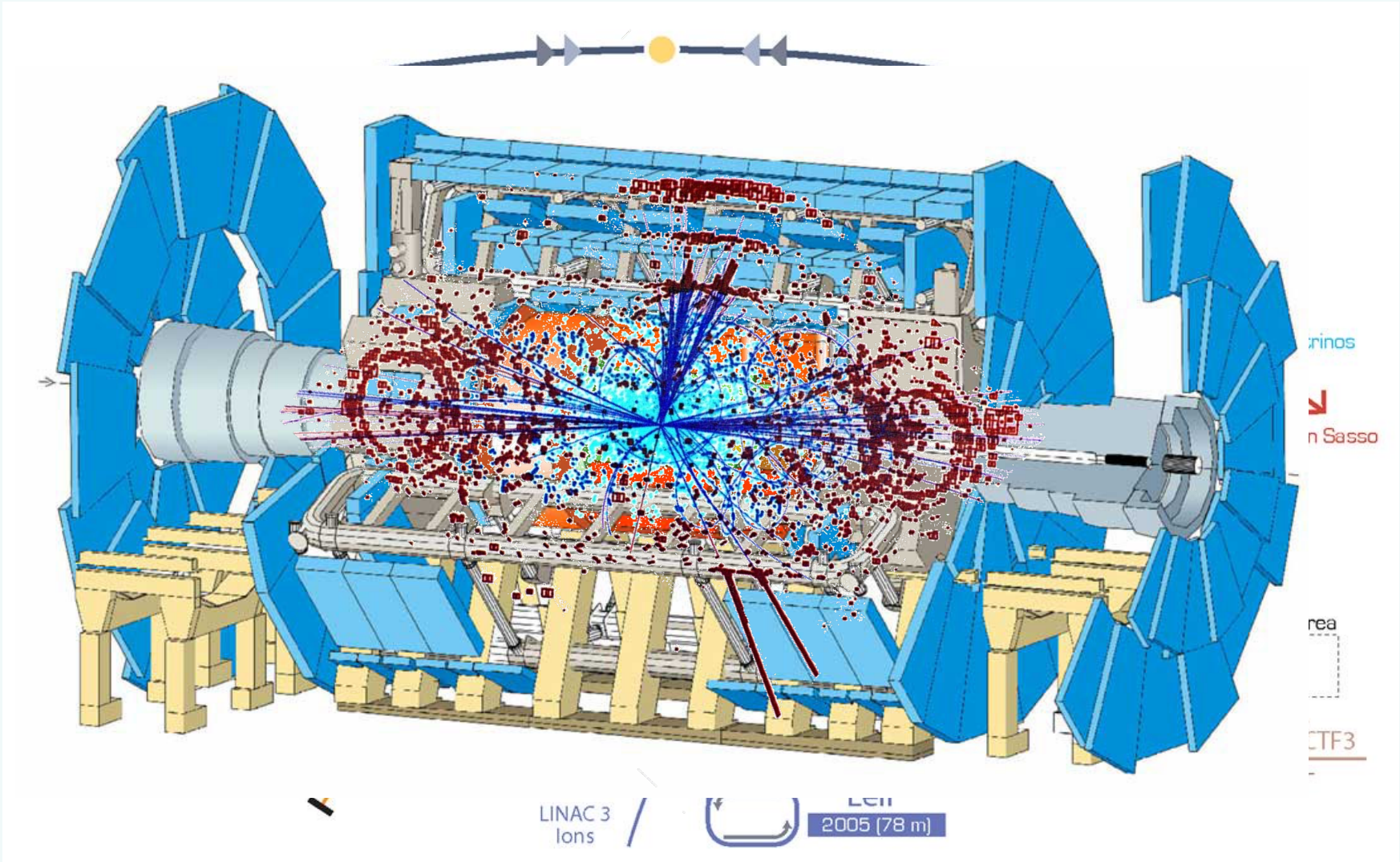




CERN and the Large Hadron Collider

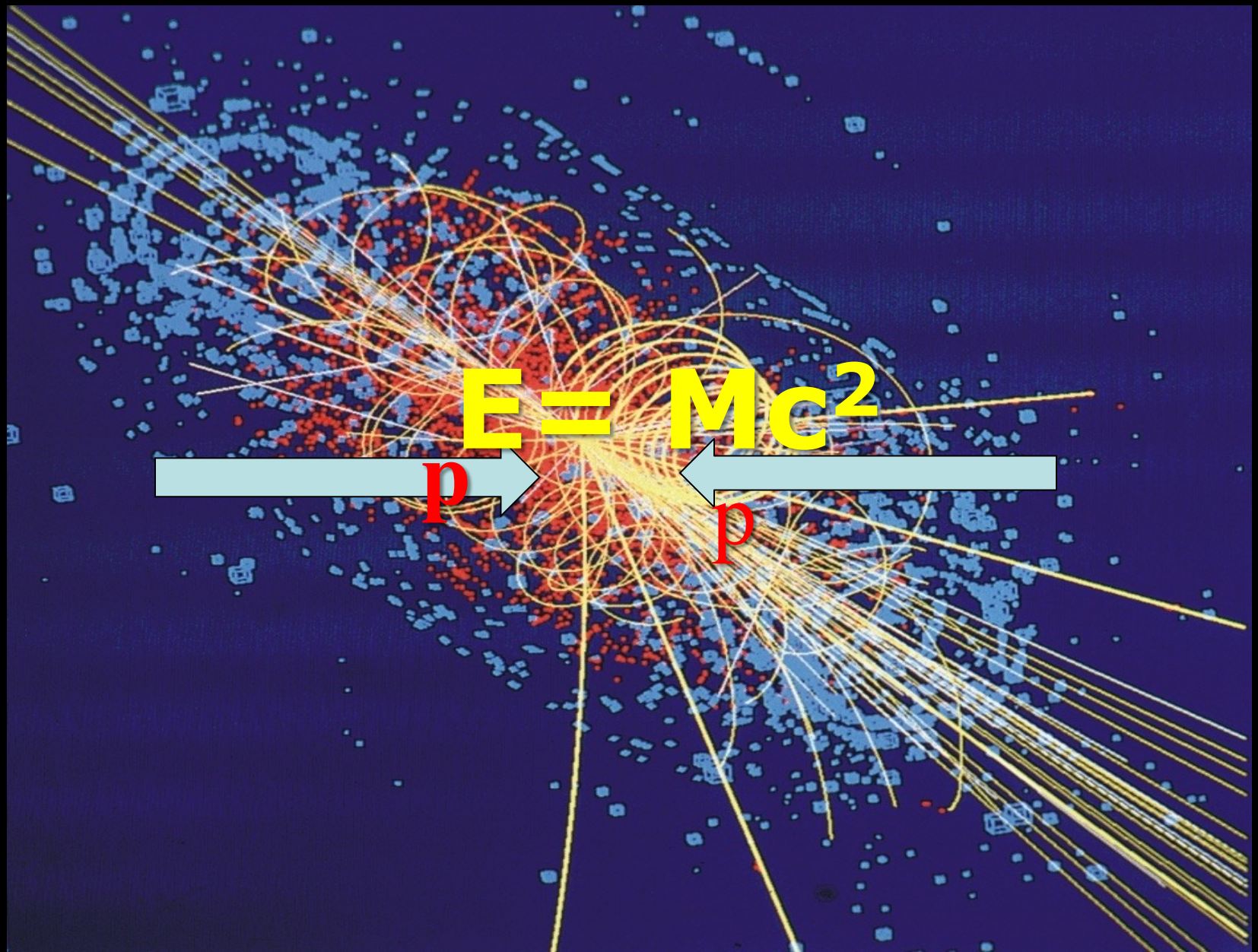


CERN's particle accelerator chain



19

Simulazione di una collisione pp ad LHC



The LHC is one of the most spectacular projects in science ever …

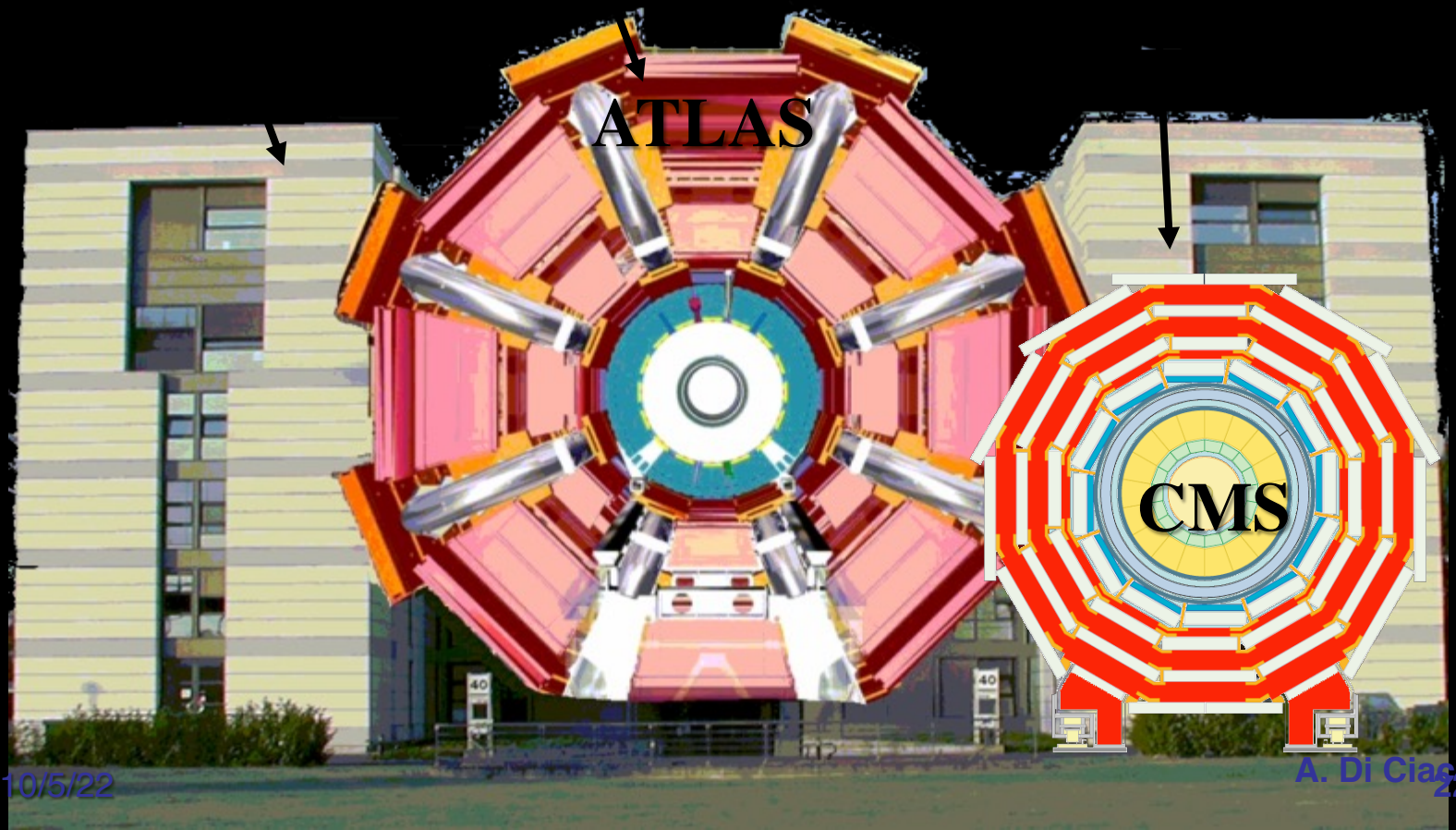
1984 : First studies for a high-energy pp collider in the LEP tunnel
1994 : LHC approved by the CERN Council
1996 : Construction of LHC machine and experiments start
2003 : Start the construction of LHC machine and experiments installation
2009 : 23 November: first LHC collisions ($\sqrt{s}$ = 900 GeV)
2010 : 30 March: first collisions at $\sqrt{s}$ = 7 TeV
2012: 4 July : Announcement of Higgs Boson Discovery

A ~ 40-year project:
- **25 years from concept to start of operation**
- **20 years of physic exploitation**

The LHC has required:
- **most innovative technologies (superconducting magnets, cryogenics, electronics, data transfer and storage, etc…)**
- **new concepts, a lot of ingenuity to address challenges and solve problems**
- **huge efforts of the worldwide community (ideas, technology, people, money)**

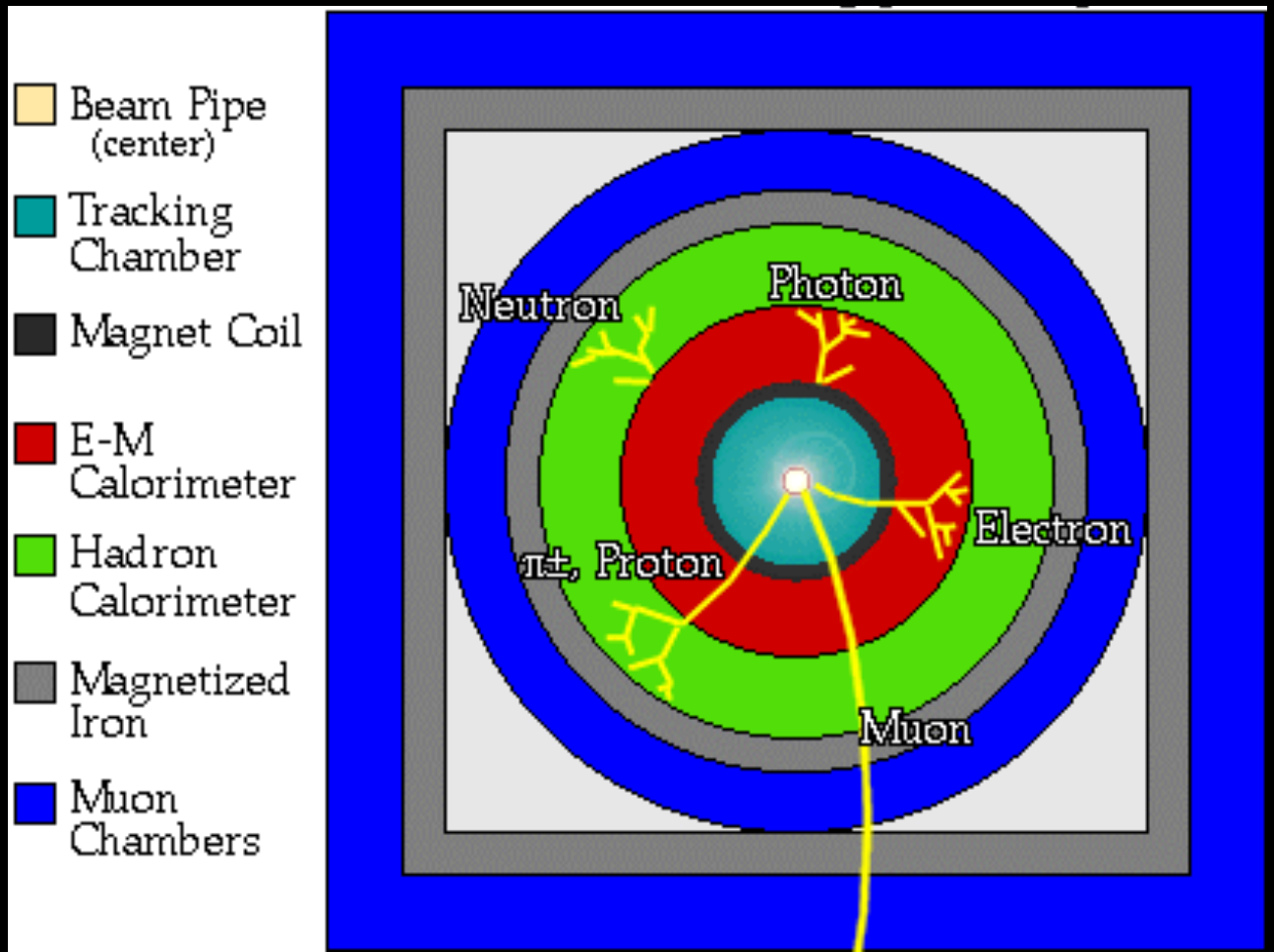
The LHC experiments: about 100 million "sensors" each

[think your 6MP digital camera...
...taking 40 million photos in a second]



Particle Identification

- Collisions enclosed by layers of different detectors:
  - separate particle types
  - measure their energies and angles



The ATLAS Experiment

A Toroidal LHC ApparatuS

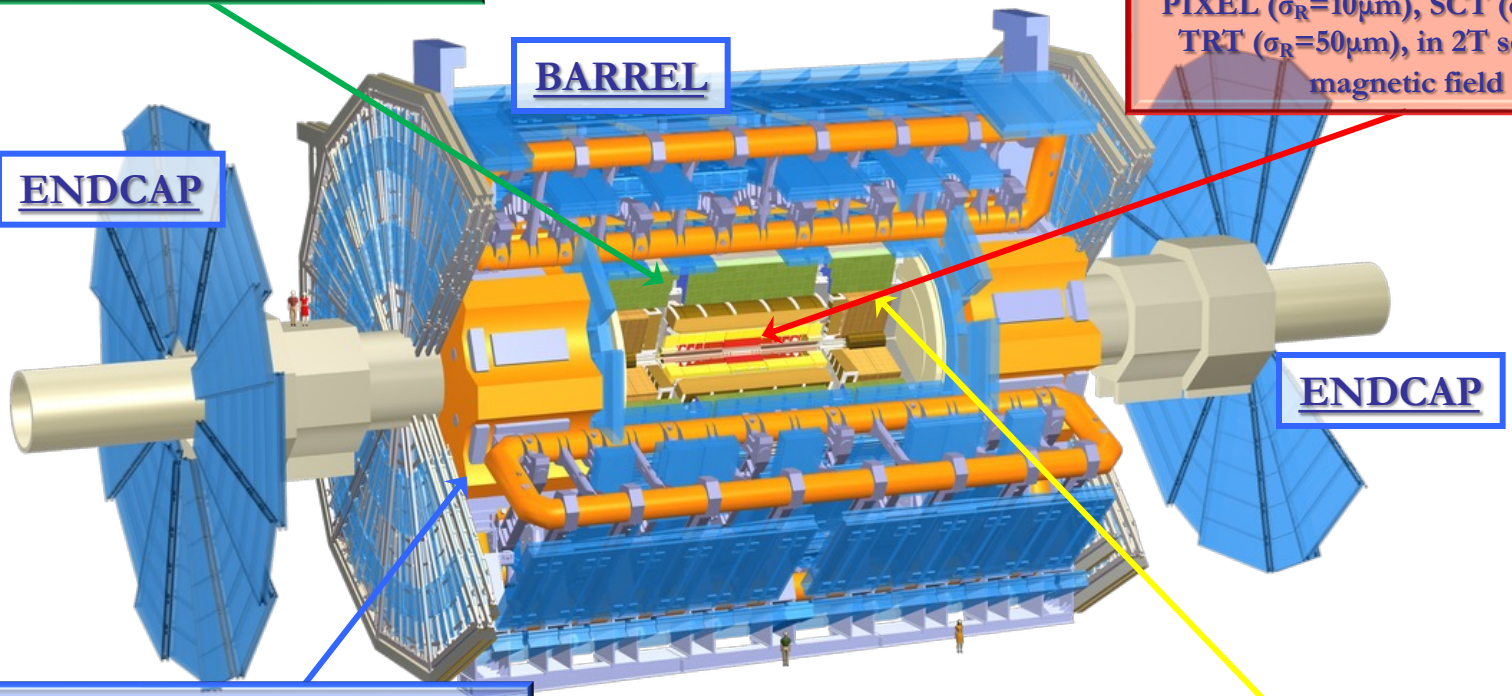
For more details:

G. Aad et al (ATLAS Collaboration), J. Instrum. 3. (2008)

Length : ~ 46 m, Radius : ~ 12 m
Weight : ~ 7000 tons, ~10^8 electronic channels

HADRONIC CALORIMETER:
Iron scintillator Tiles
Resolution $\Delta E/E = 50\%/\sqrt{E(GeV)} \oplus 3\%$

INNER TRACKER:
PIXEL (σ_R=10μm), SCT (σ_R=17μm), TRT (σ_R=50μm), in 2T soleinodal magnetic field



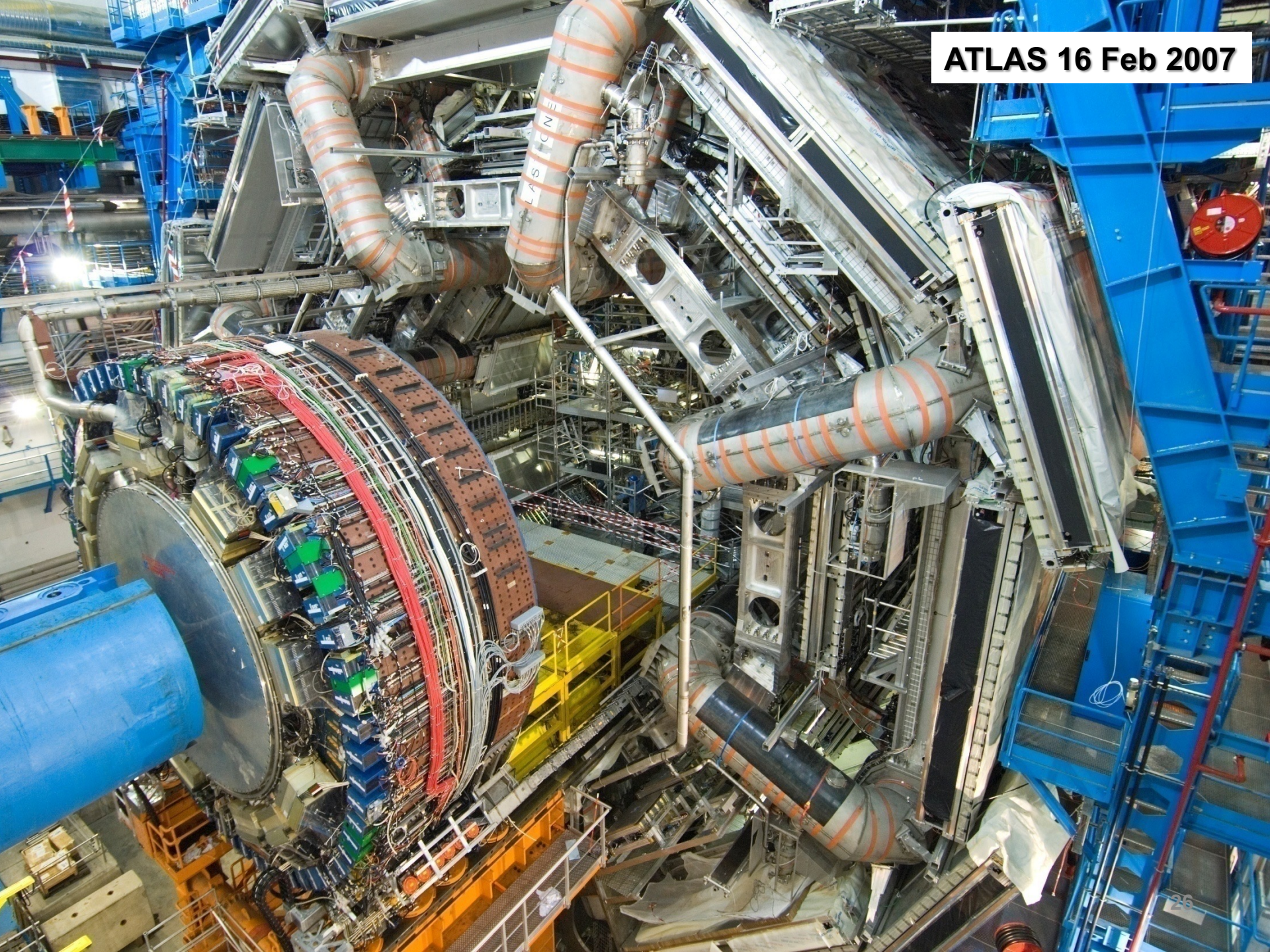
MUON SPECTROMETER:
3 Toroidal magnetic fiield(1 barrel,2 endcap)
MDT, RPC nel barrel
MDT, TGC , CSC endcap

EM CALORIMETER:
Alternate layers Pb-LAr
Resolution $\Delta E/E = 10\%/\sqrt{E(GeV)} \oplus$
$\oplus 0.5\%/E\ (GeV) \oplus 0.7\%$

7000m^2 :Built under the responsibility of Roma Tor Vergata group

- Il gruppo dell'Universita' di Roma Tor Vergata, ha contribuito in maniera sostanziale alla progettazione, alla realizzazione e al montaggio dell'apparato di trigger per muoni di ATLAS, che come superficie è il sottosistema più esteso dell'esperimento.

E' realizzato utilizzando «camere a elettrodi piani resistivi» (RPC, «Resistive Plate Chambers»), un rivelatore di particelle inventato all'inizio degli anni '80 del secolo scorso da R. Cardarelli e R. Santonico che lavorano nel gruppo ATLAS di Roma Tor Vergata

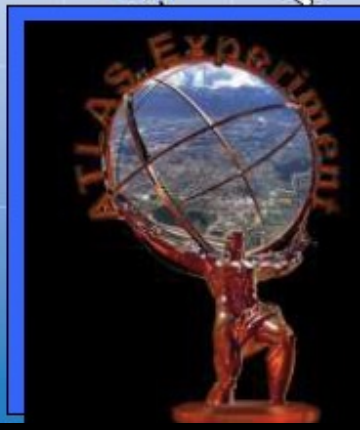

ATLAS 16 Feb 2007

~ 3000 scientists (1000 PhD students) from 177 Institutions and 38 Countries

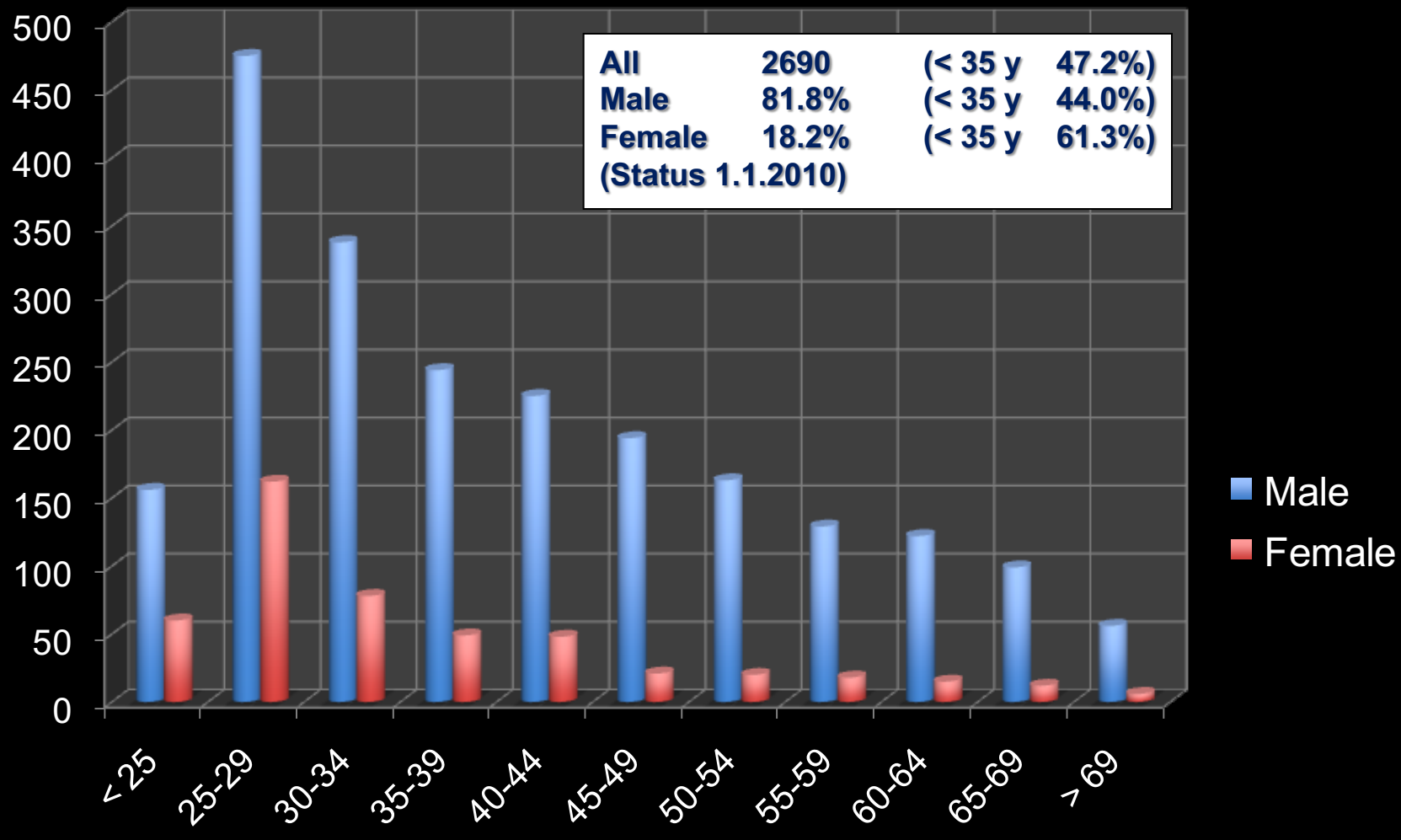
Italy:
- 13 groups (INFN, Universities)
- ~ 200 scientists (~60 students)
- Contributed to all detector components, software and computing, physics (Higgs discovery!), upgrade

Australia	Norway
Austria	Poland
Azerbaijan	Portugal
Belarus	Romania
Brazil	Russia
Canada	Serbia
Chile	Slovakia
China	Slovenia
Colombia	South Africa
Czech Republic	Spain
Denmark	Sweden
France	Switzerland
Georgia	Taiwan
Germany	Turkey
Greece	UK
Israel	USA
Italy	CERN
Japan	JINR

ATLAS Collaboration

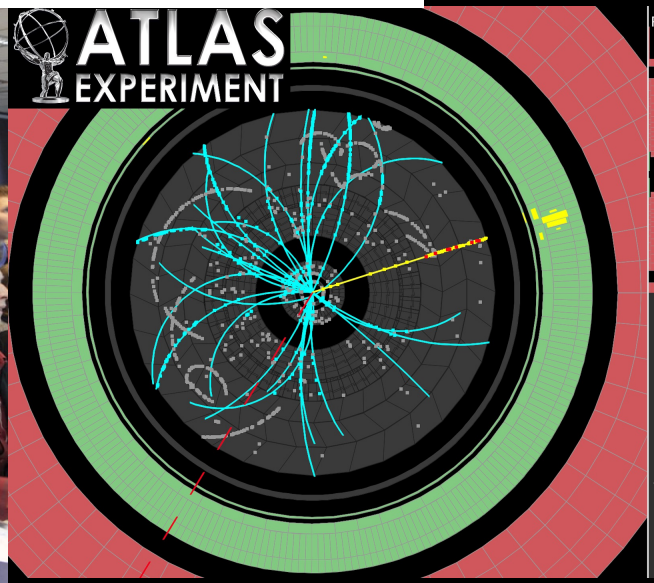


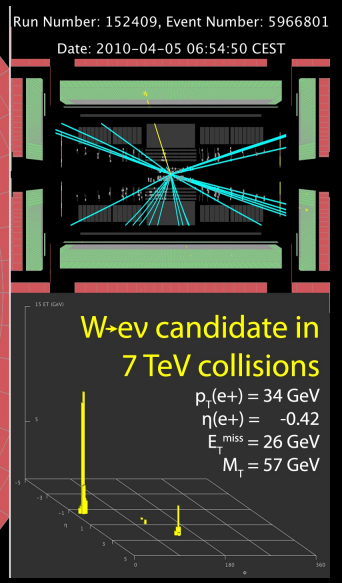
Age distribution of the ATLAS population



Happiness when LHC turned on!

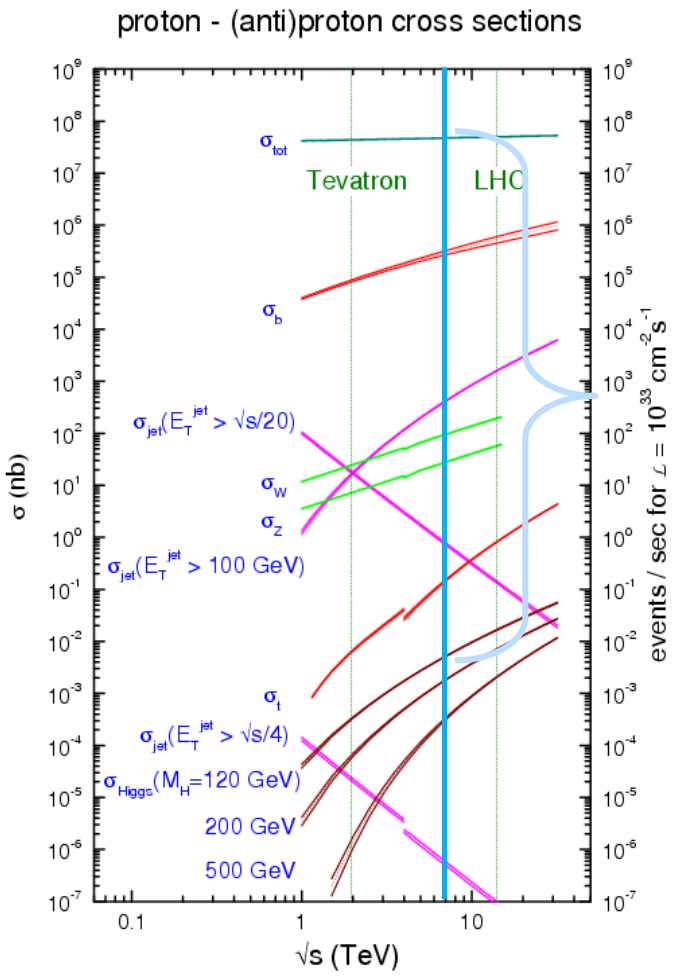
The joy in the ATLAS Control Room when the first LHC beam collided on November 23rd, 2009....



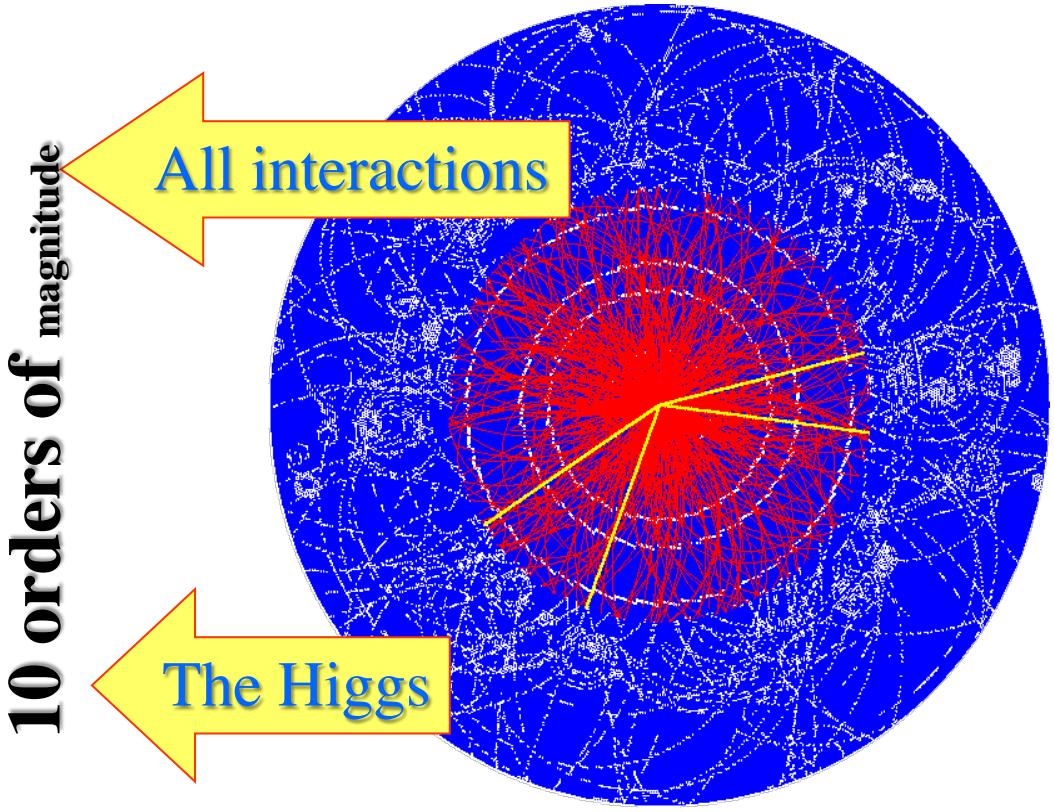


Higgs Challenge

a. Rare Phenomena Huge Background

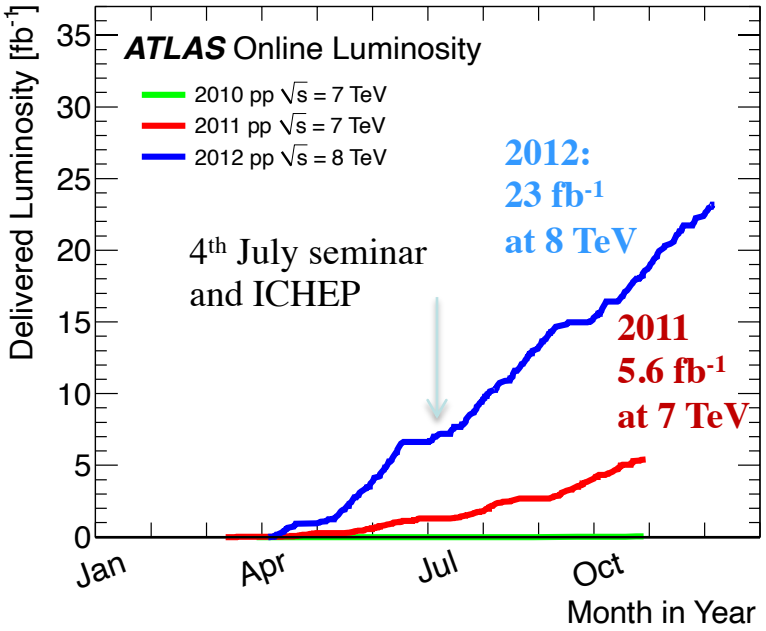


b. Complexity



"one in 10 billion events"

Three Years of Remarkable LHC operations at the Energy frontier

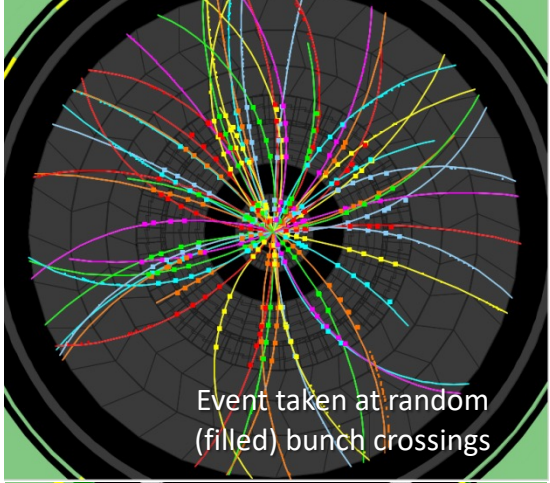


2010

O(2) Pile-up events

150 ns inter-bunch spacing

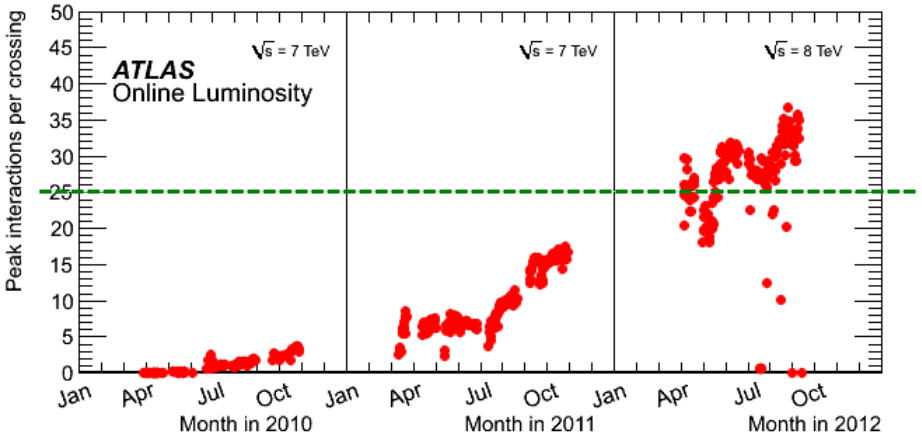
$N_{events} = \mathcal{L} \times \sigma(pp \rightarrow X)$



2011

O(10) Pile-up events

50 ns inter-bunch spacing



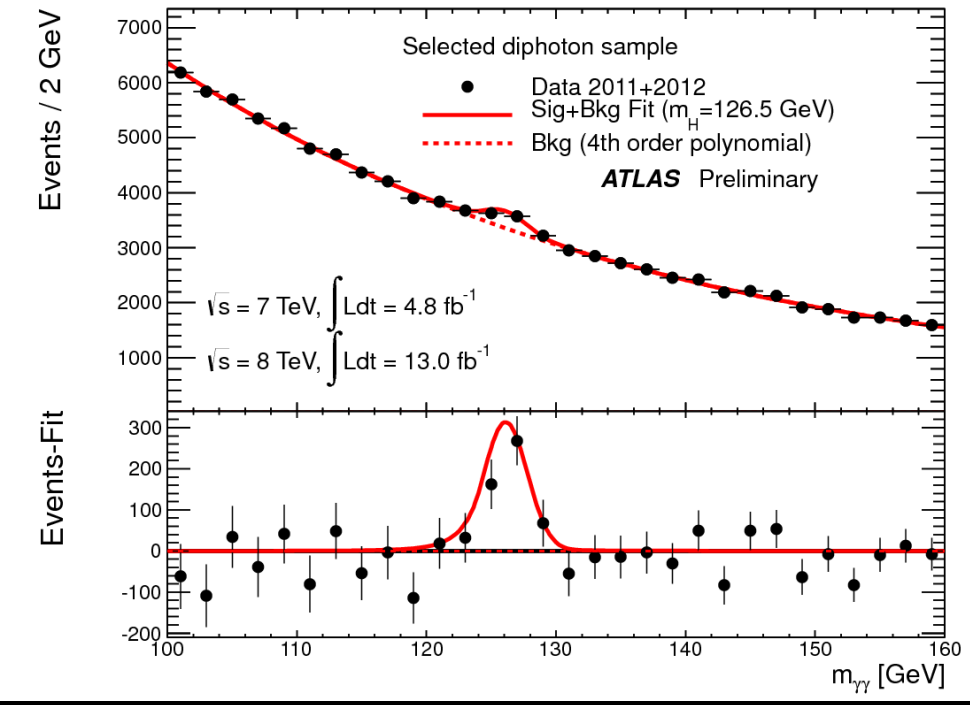
Design value
(expected to be
reached at $L=10^{34}$!)

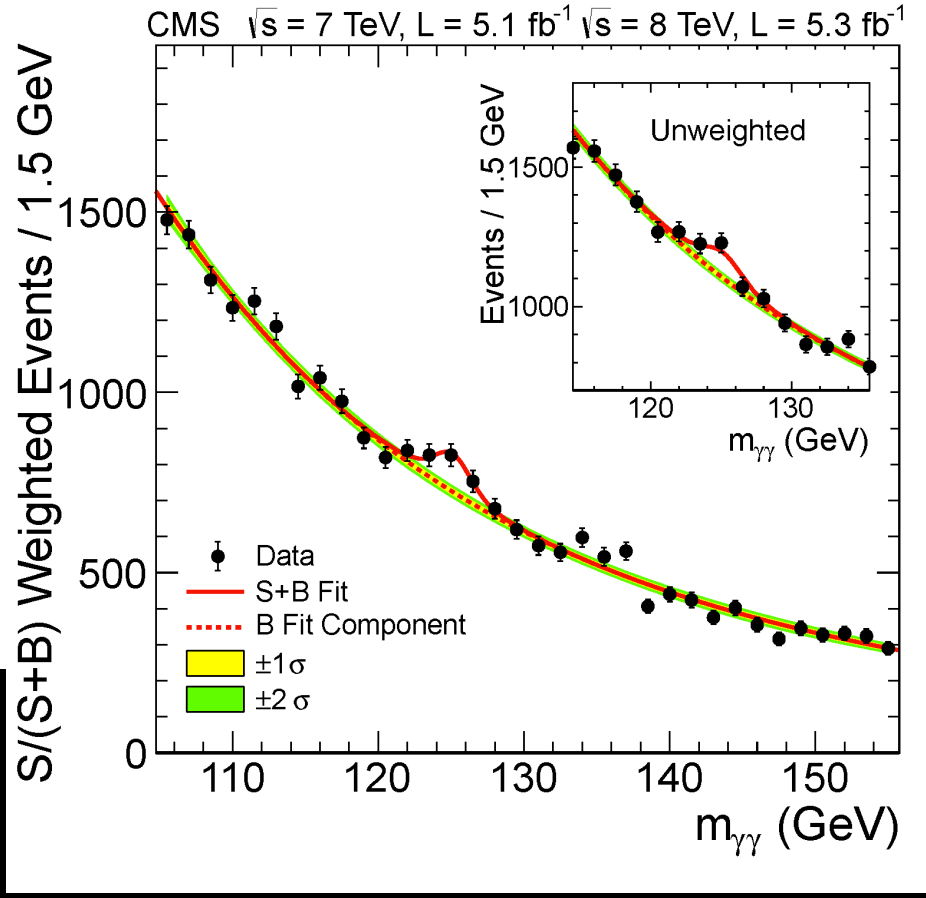
2012

O(20) Pile-up events

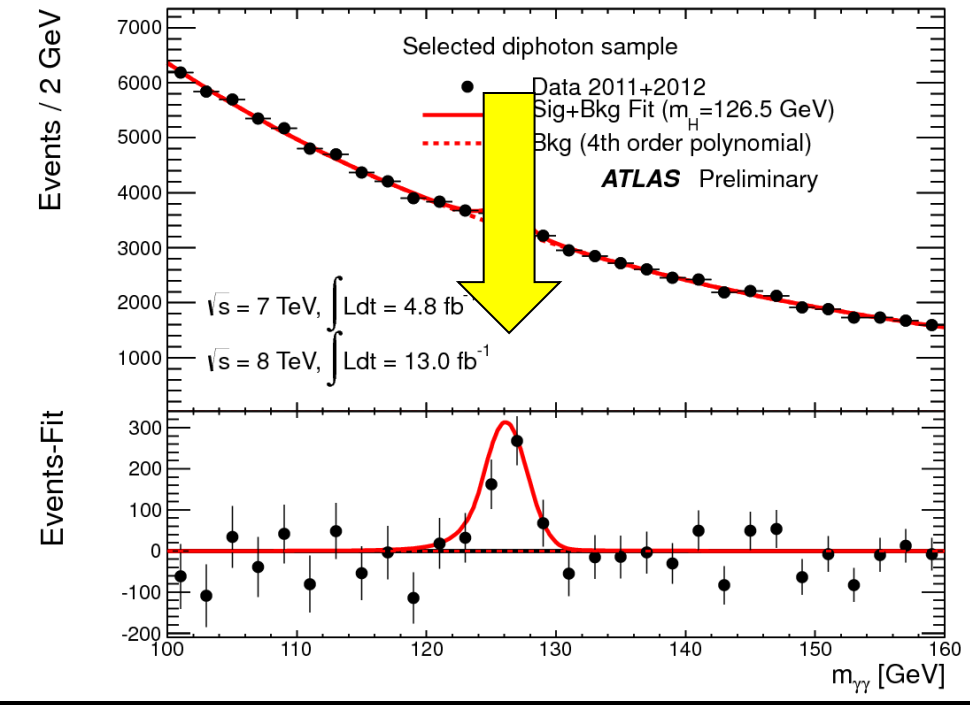
50 ns inter-bunch spacing

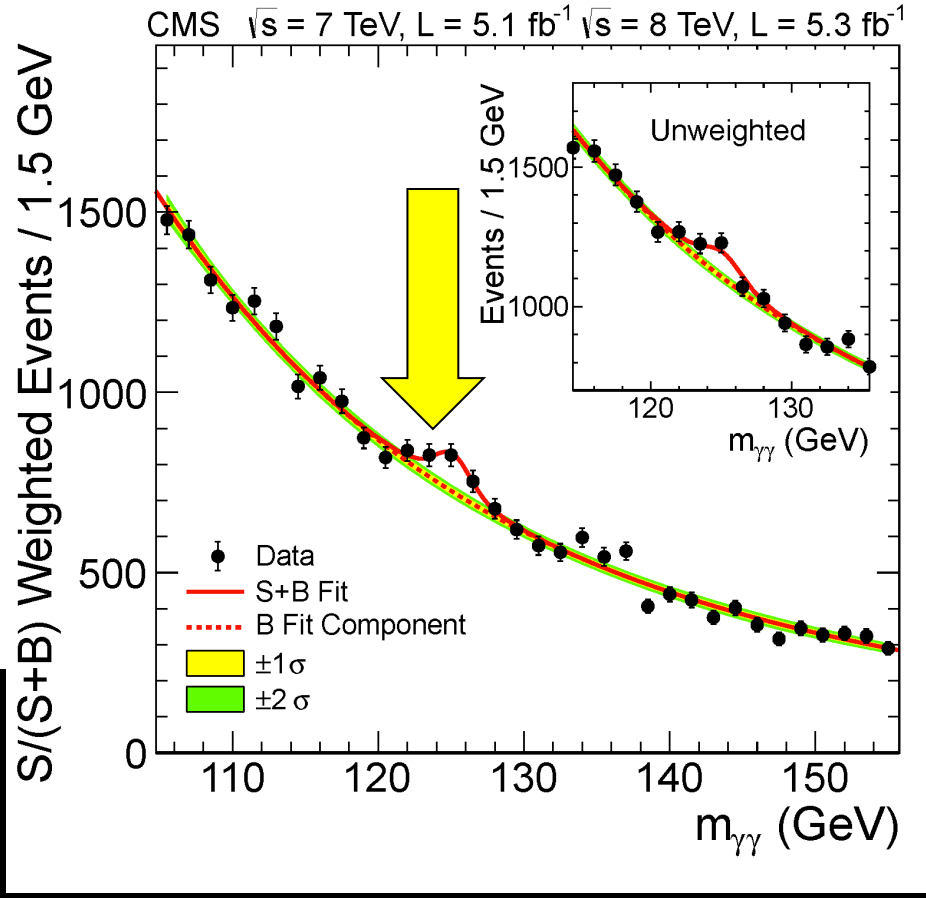
Diphoton Mass Distributions





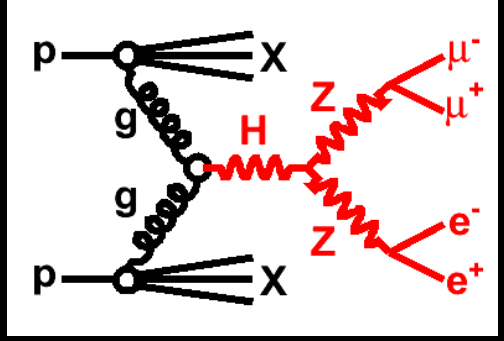
Diphoton Mass Distributions

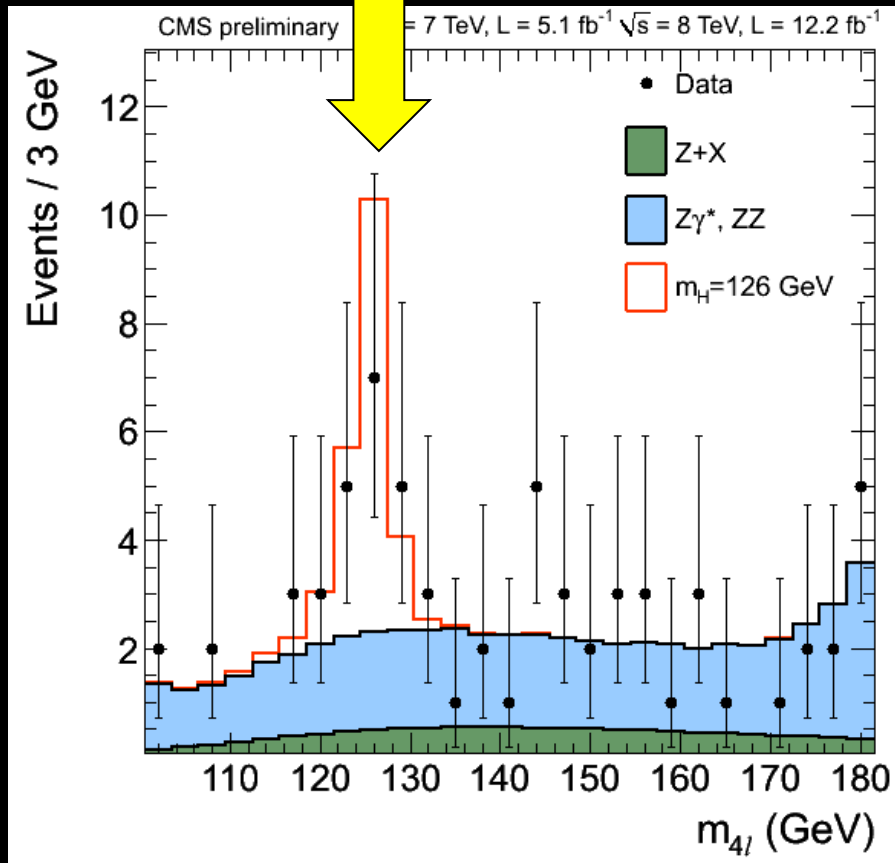


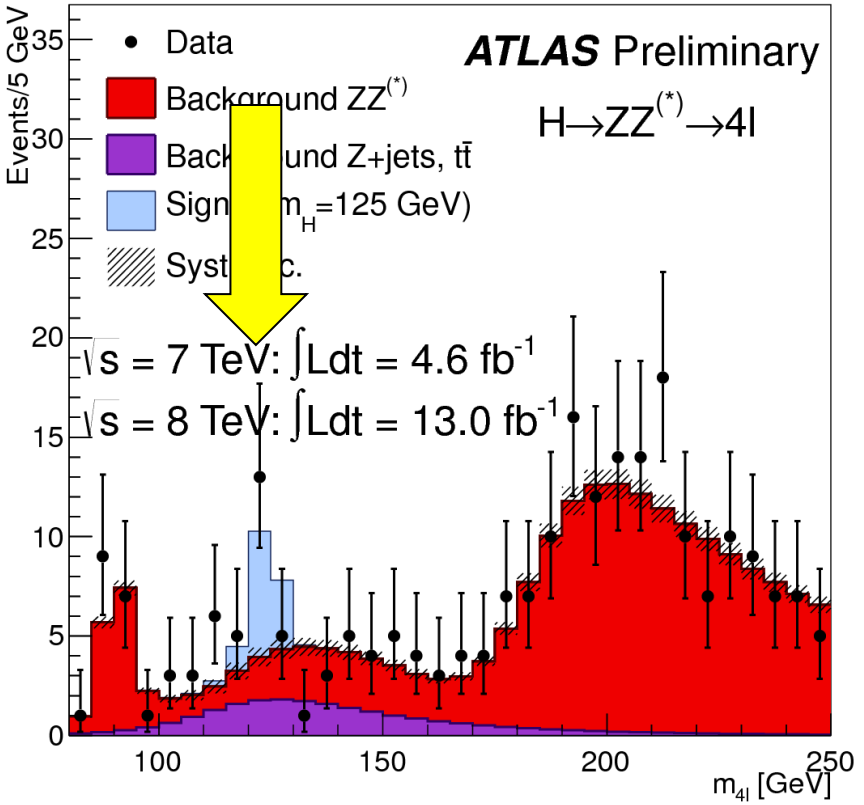


Both experiments see peak at ~126 GeV

Higgs boson decaying to two Z bosons





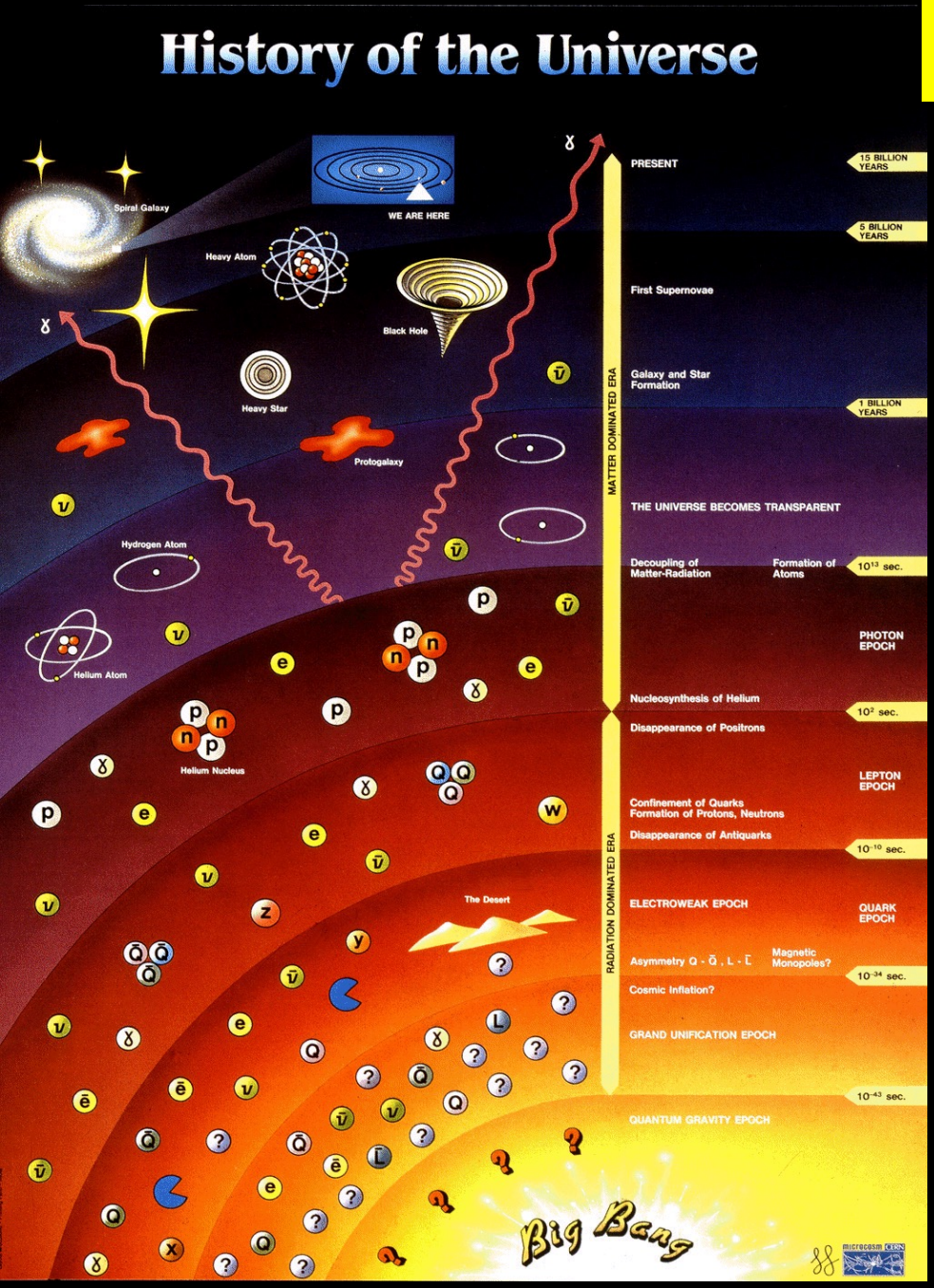


Both experiments see peak at ~126 GeV


Prof. P. Higgs
Nobel Prize 2013
Prof. P. G. 't Hooft
Nobel Prize 1999

ATLAS Tor Vergata group members

- University staff : G. Aielli, P. Camarri, U. De Sanctis, L.Cerrito, A. Di Ciacco, R. Santonico
- INFN staff : R. Cardarelli, B. Liberti, M. Vanadia,
- Post-doc :L. Pizzimento, A. Rocchi,
- PHD students: G. Proto, F. Raffaelli.



Conclusions

- After a 25 year of hard work of design and construction of the LHC experiments and 4 year of successfully taking data
  - **Higgs particle discovered**
- **After 10 years from the discovery**
  - **Main properties measured**
- Now LHC is taking data in 2022 at 13.6TeV.
- Main goal:
  - Search for evidence of the new physics model beyond SM

GRAZIE!