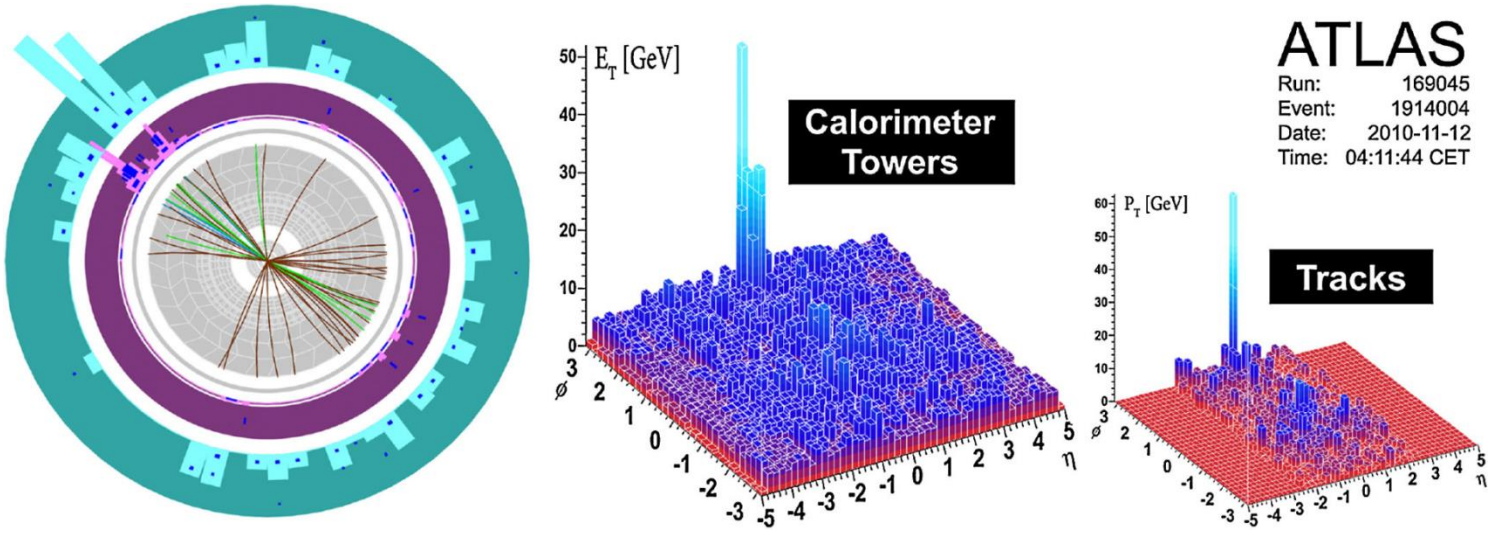
Introduction to Hypatia

The ATLAS experiment @ CERN
And how to introduce it in class

Dimitris Fassouliotis
Univ of Athens



European Union
European Social Fund
OPERATIONAL PROGRAMME
EDUCATION AND LIFELONG LEARNING
investing in knowledge society
MINISTRY OF EDUCATION & RELIGIOUS AFFAIRS, CULTURE & SPORTS
MANAGING AUTHORITY
NSRF 2007-2013
programme for development
EUROPEAN SOCIAL FUND
Co- financed by Greece and the European Union

IPPOG International Masterclasses

Concept

- Students are in the position of a scientist
- Students are guided by a Master (lecturer or PhD student)

- Students form international collaboration
- Learn about fundamental subatomic particles and interactions, detectors, accelerators
- **Active investigation:** Measurements with real data from scientific experiments (ALICE, **ATLAS**, CMS)

Worldwide Participation

For 2013 interest in:

Cyprus

Turkey

Palestine

Egypt

India

Belarus

Iran

INTERNATIONAL MASTERCLASSES

hands on particle physics

Discover the Cosmos

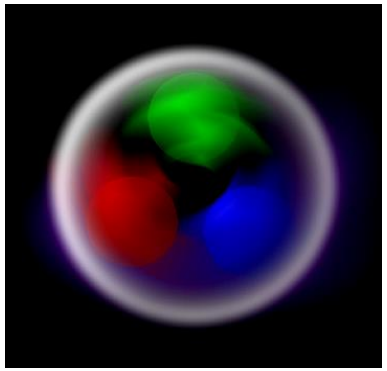
- Impossible for all students visit the universities

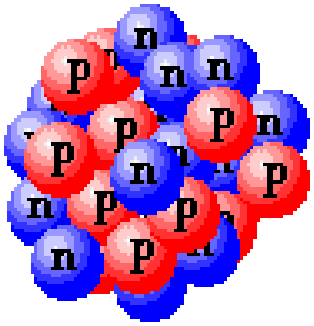
➢ **Possible to have similar experience at their schools with their teachers**

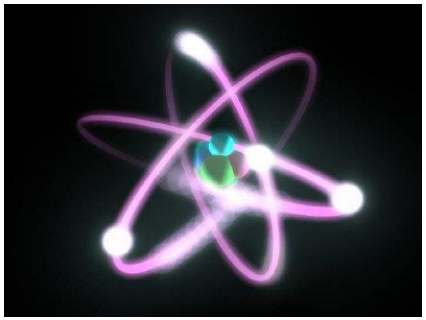
Discover the COSMOS portal is an **experimental e-laboratory** for students and teachers, aiming to improve science instruction by expanding the resources for teaching and learning in schools, providing more challenging and authentic learning experiences

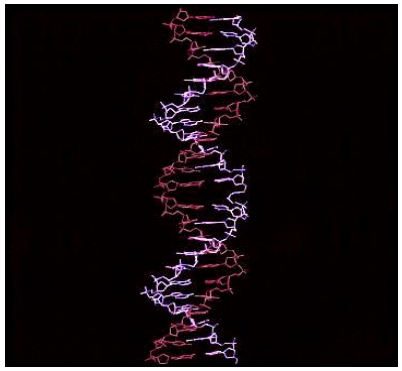
http://portal.discoverthecosmos.eu/

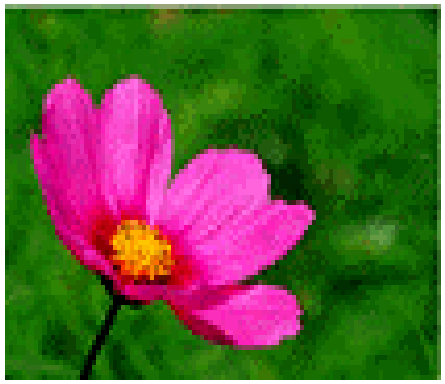
Elementary Particles



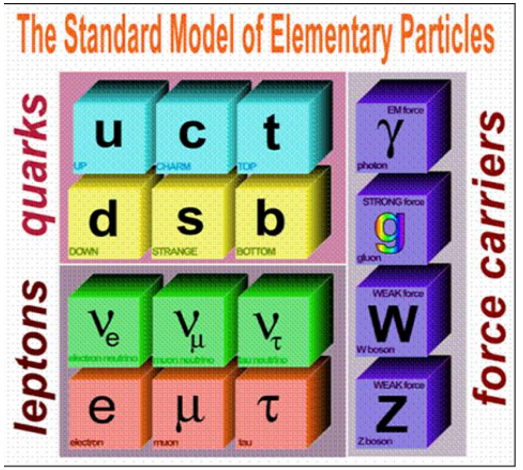








You have learnt earlier,
that everything in nature consists of just a few elementary particles that interact by the exchange of the force carrying particles



How do we know any of this?

Testing a theory

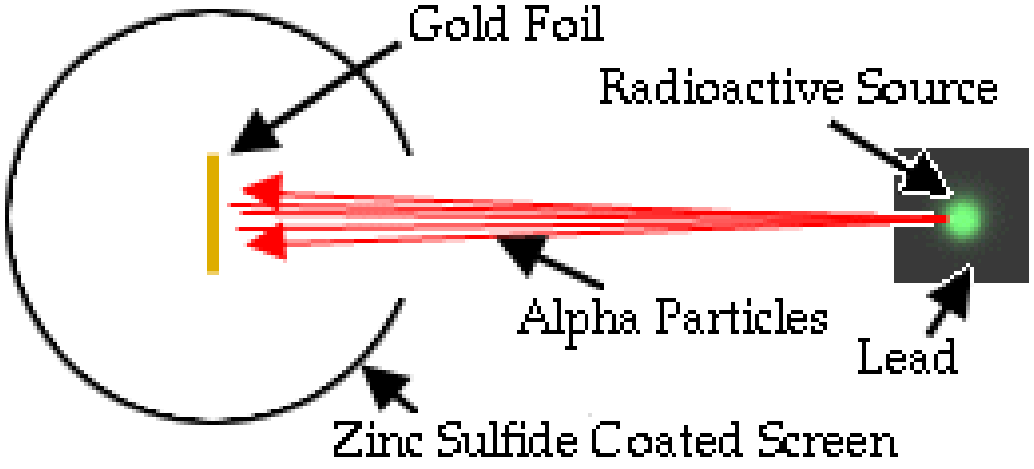
- To test theories, physicists put together experiments and use what they already know to find out what they do not know.
- These experiments may be simple, or they may be huge and complicated.
- Standard Model rises out of thousands of years of scientific inquiry, but most of the experiments that have given rise to our current conception of particle physics have occurred relatively recently.

http://www.particleadventure.org

How do we know any of this? An example

In 1909, the prevailing theory of the atom's structure was that atoms were mushy, semi- permeable balls, with bits of charge strewn around them.

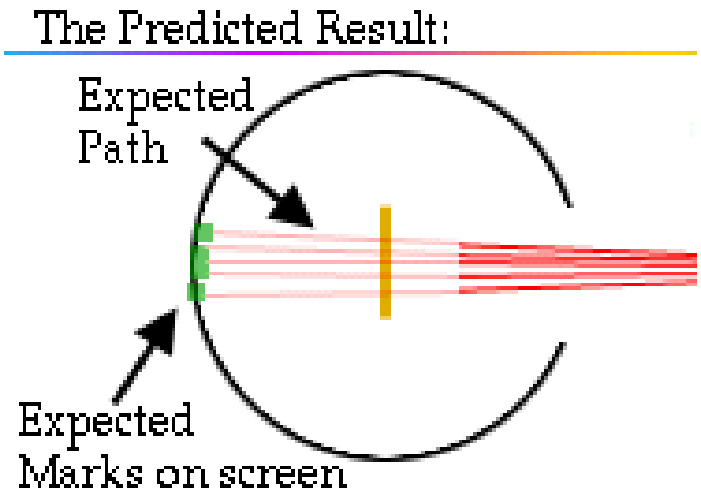
Ernest Rutherford set up an experiment to test the validity of the prevailing theory. In doing so he established a way that for the first time physicists could "look into" tiny particles they couldn't see with microscopes.

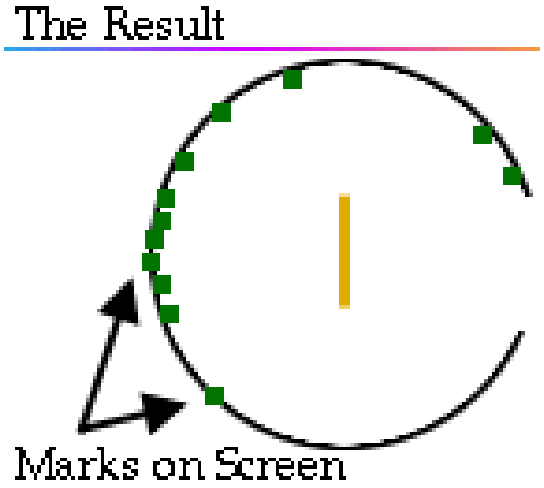


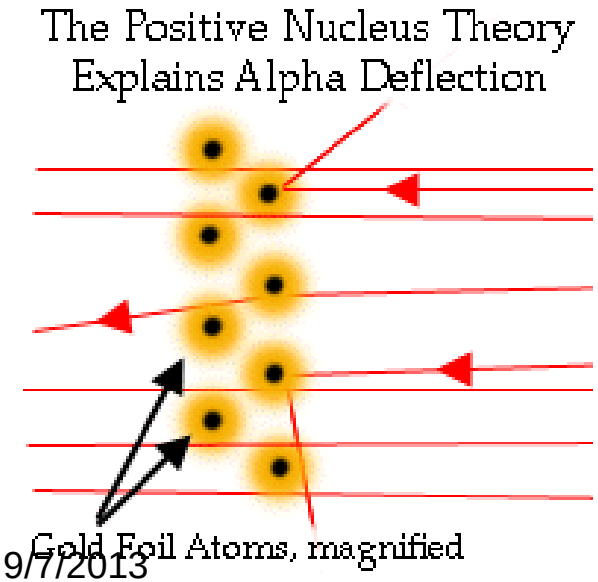
Ingredients

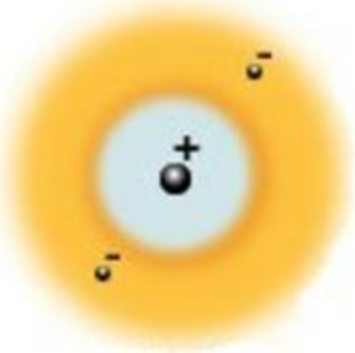
- a beam
- a target
- a detector

How do we know any of this? An example

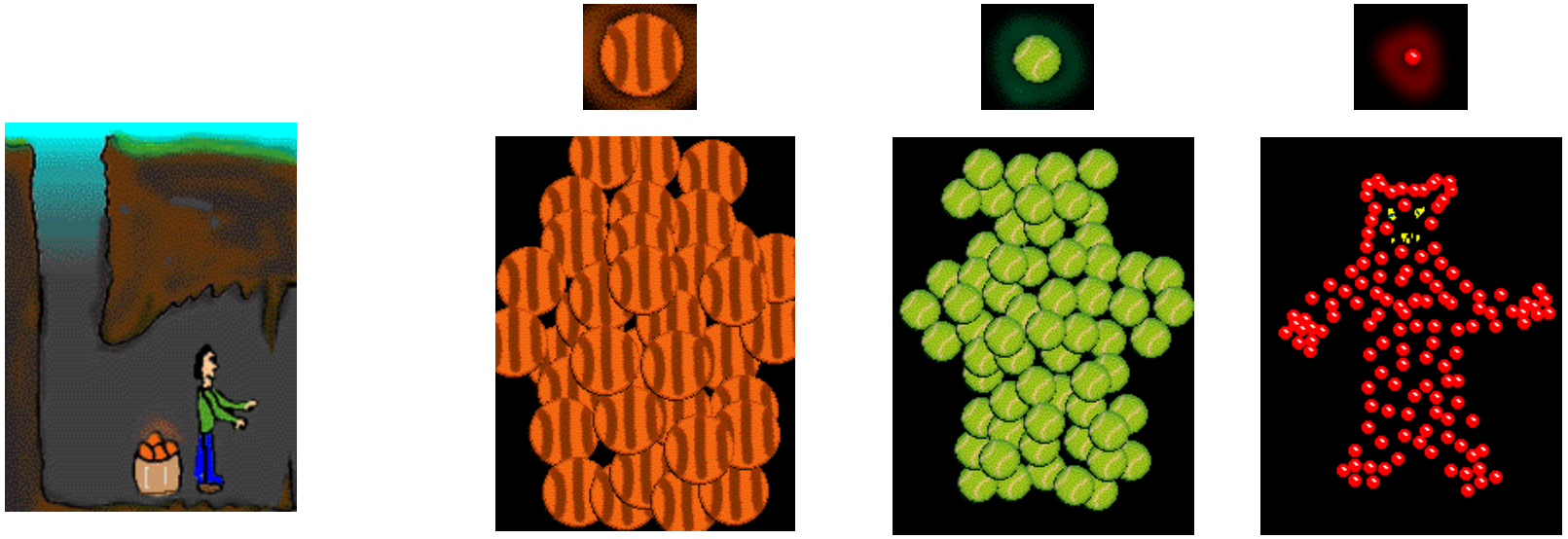






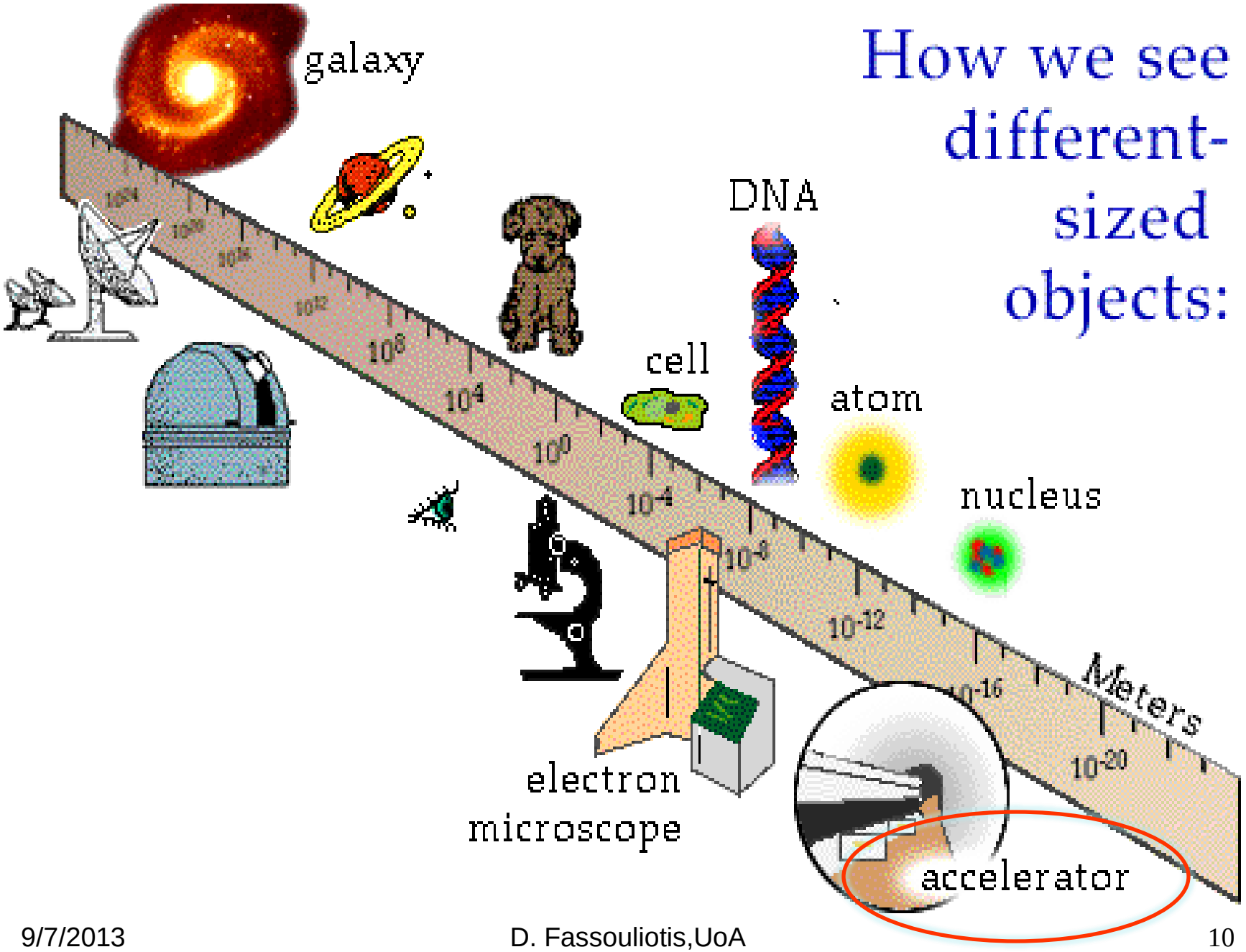


Resolution and wavelength



The proper wavelength allows us to “see” different objects with adequate resolution

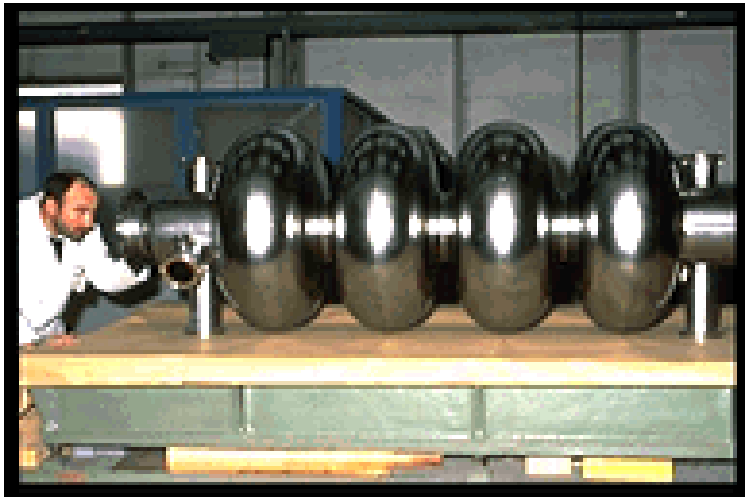
How we see different-sized objects:

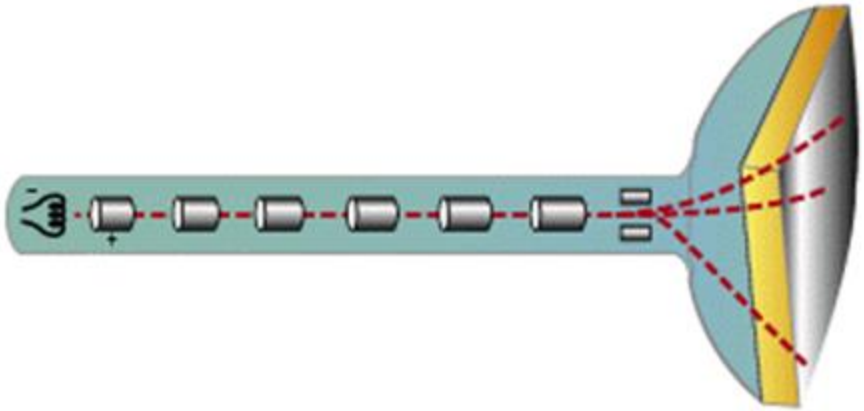


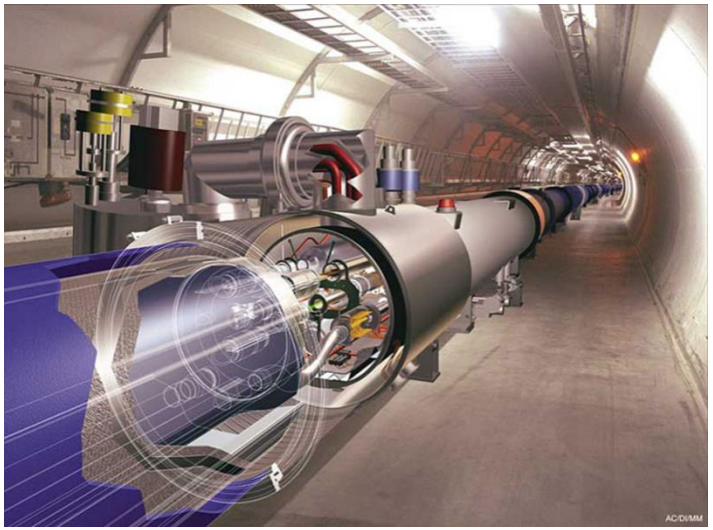
Accelerators

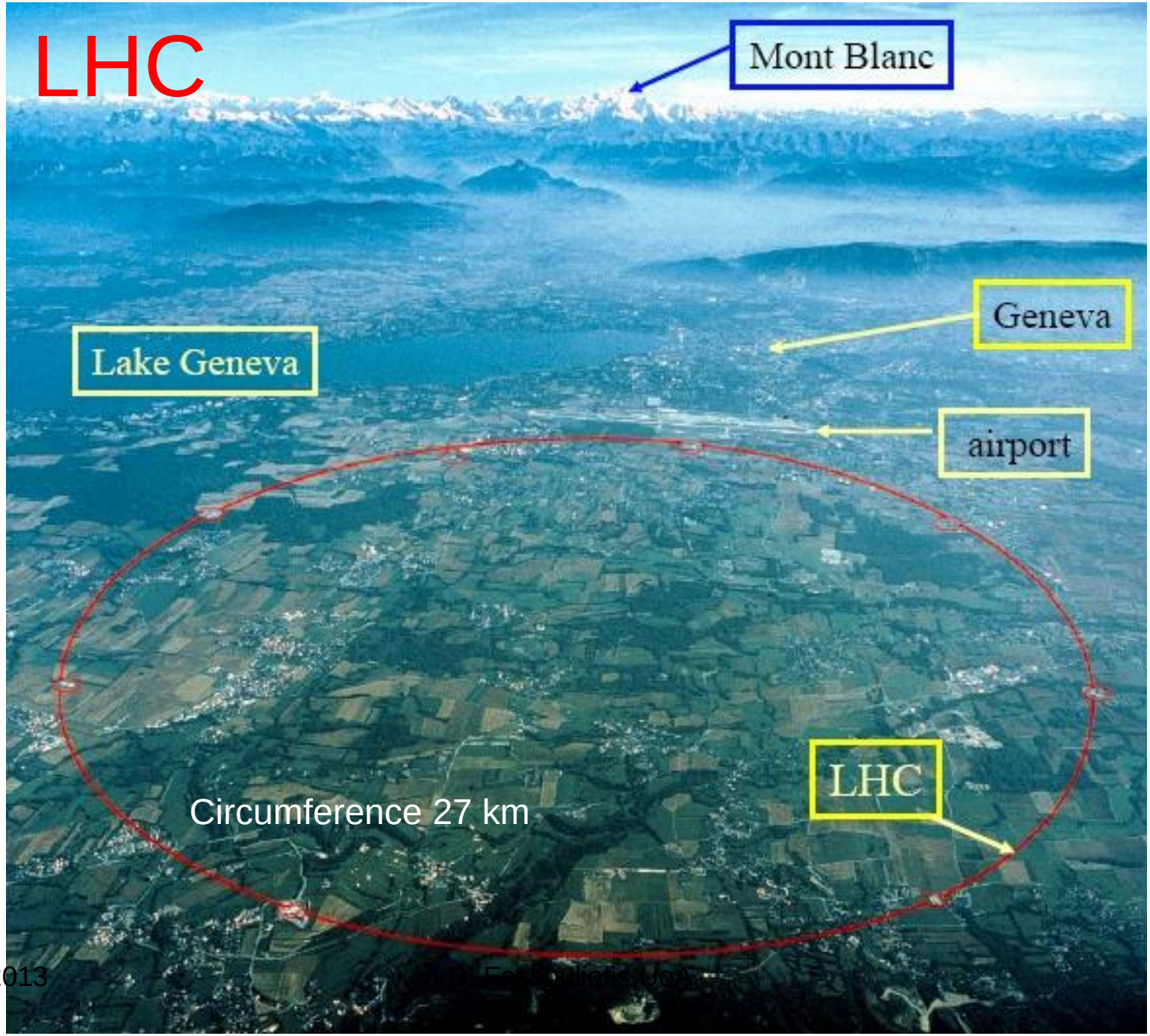
Accelerators

- **Particle source**
- **Electric fields to accelerate particles**
- **Magnetic fields to guide particles**

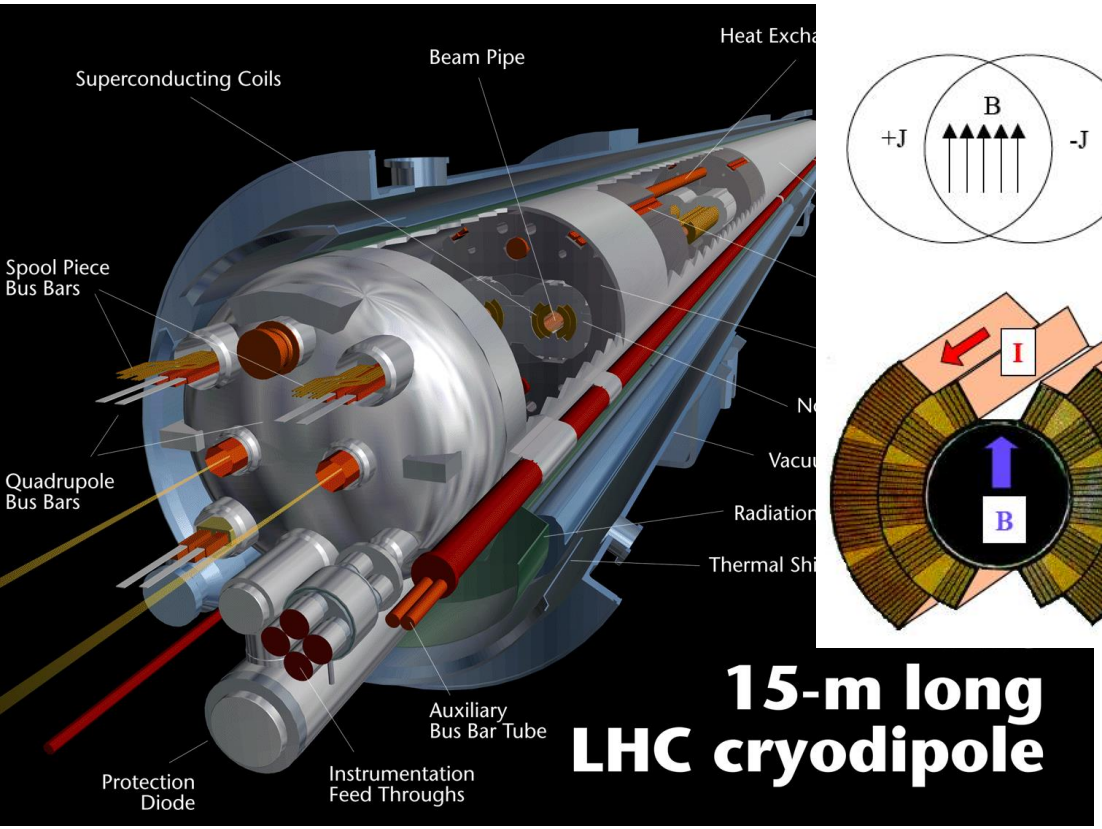


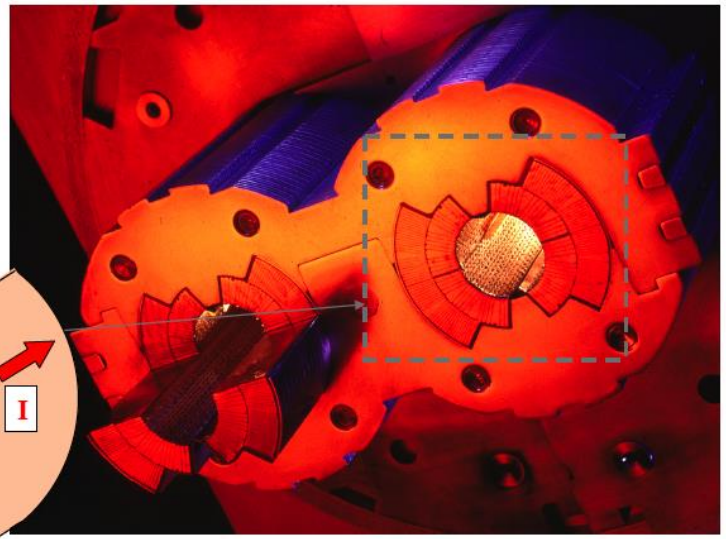





LHC
Mont Blanc
Geneva
Lake Geneva
airport
LHC
Circumference 27 km

LHC dipole magnets



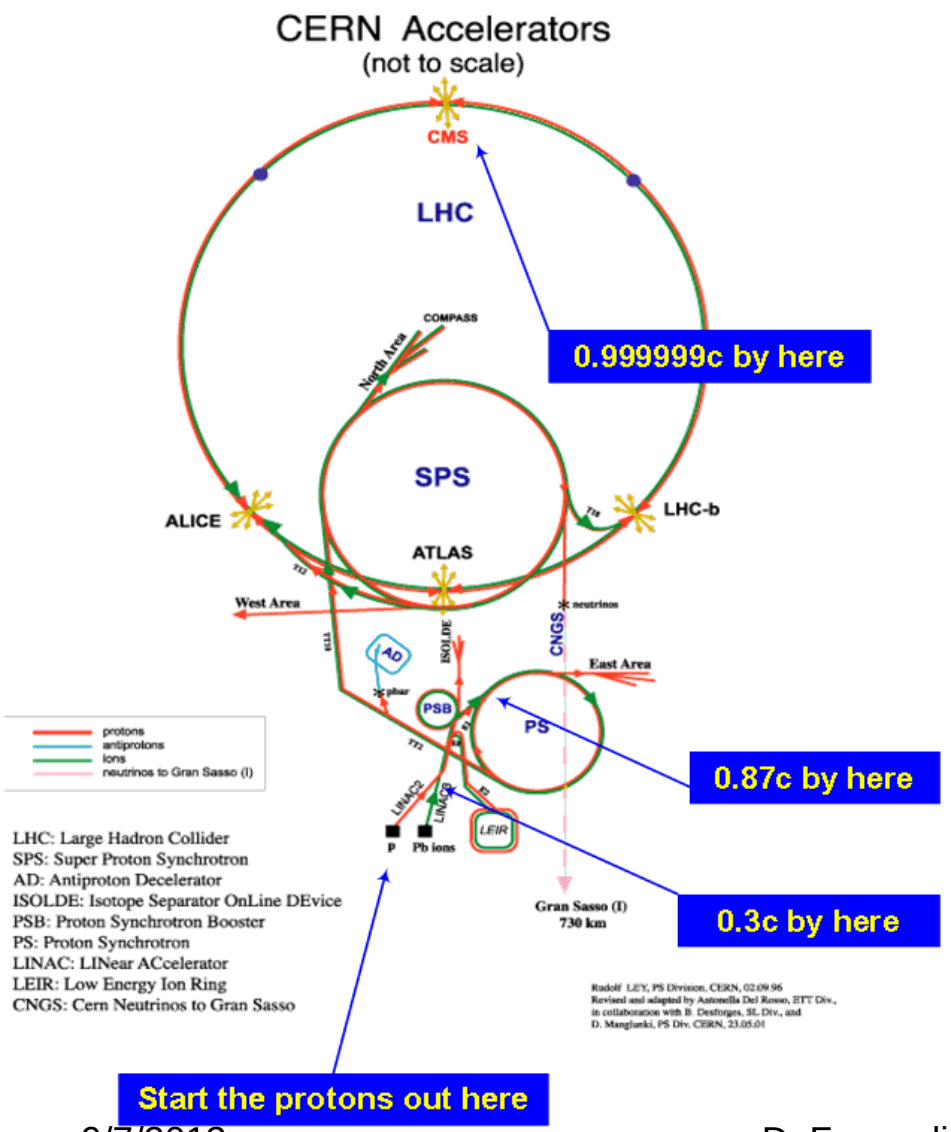


Magnetic Field for Dipoles
p (TeV) = 0.3 B(T) R(km)

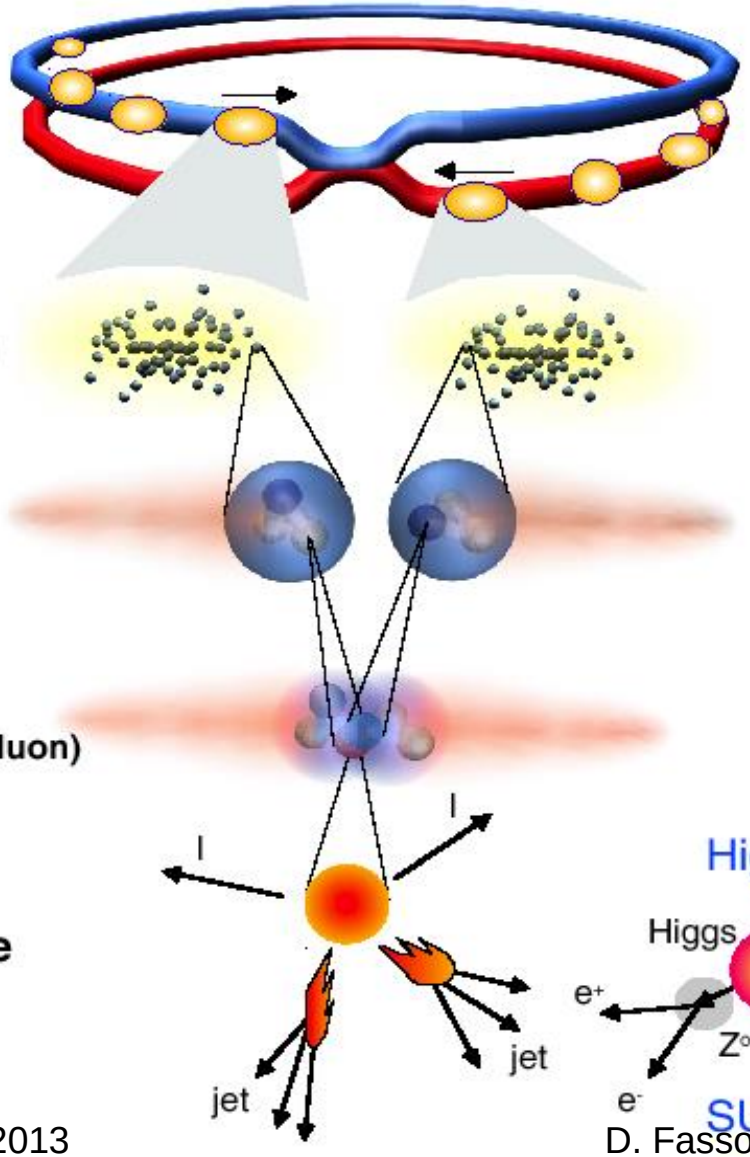
For p = 7 TeV and R = 4.3 km
⇨ B = 8.4 T
⇨ Current 12 kA

1232 magnets
The coolest ring on earth 1,9 Kelvin

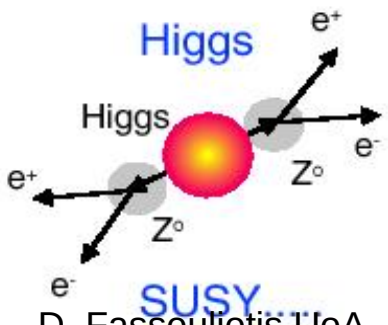
CERN Accelerators



Collisions at LHC



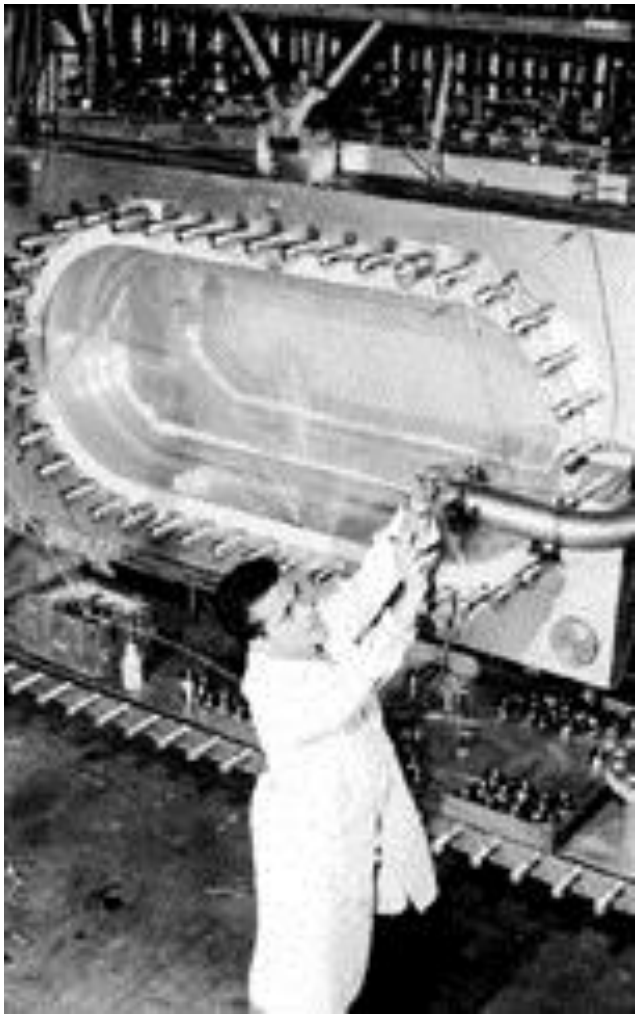
Proton-Proton	2835 bunch/beam
Protons/bunch	10^{11}
Beam energy	7 TeV (7×10^{12} eV)
Luminosity	10^{34} cm^{-2} s^{-1}
Crossing rate	40 MHz
Collisions ≈	10^{7} - 10^{9} Hz

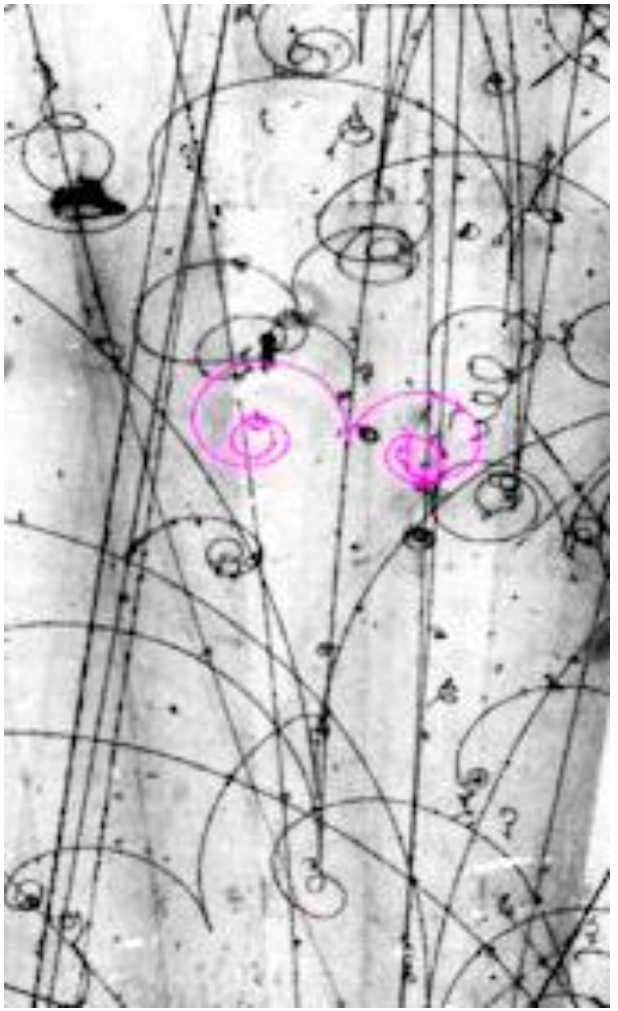


Selection of 1 in 10,000,000,000,000

Detectors

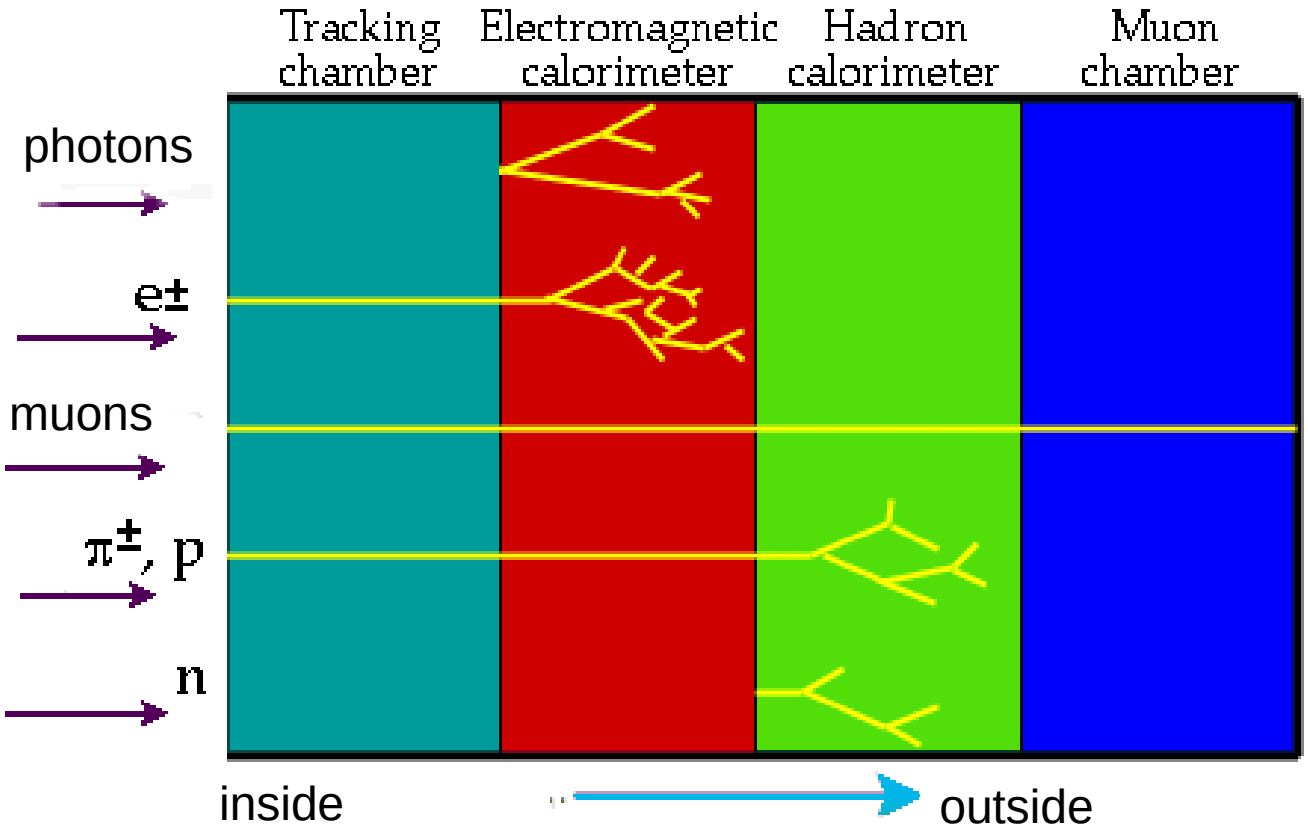
Detectors at the 60s





Modern Detectors

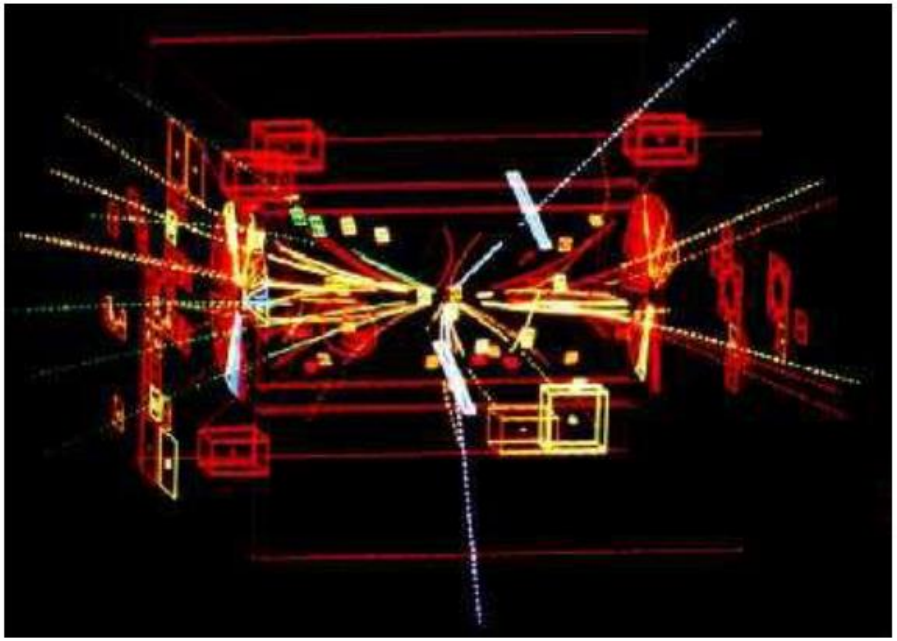
We exploit particle interactions with matter



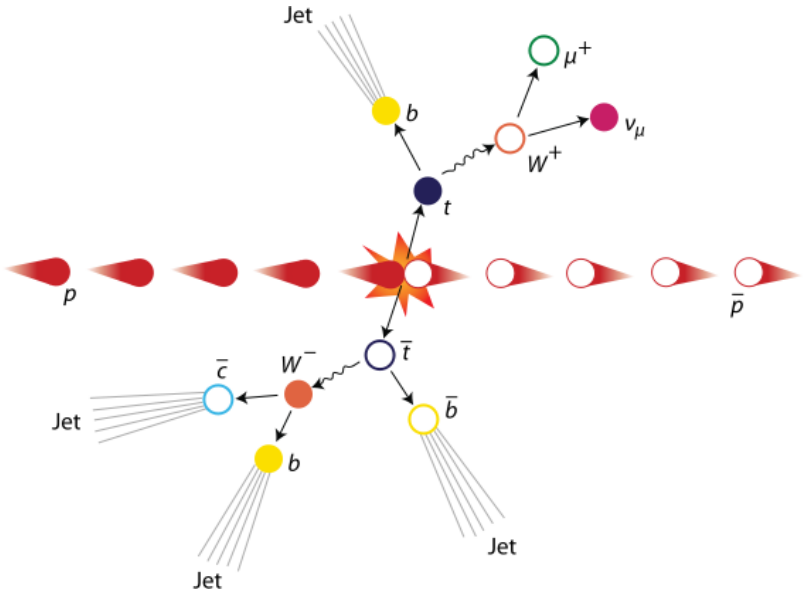
At least four consecutive layers

Modern Detectors

Discovery of the W and Z bosons at UA1 and UA2 at CERN in 1983

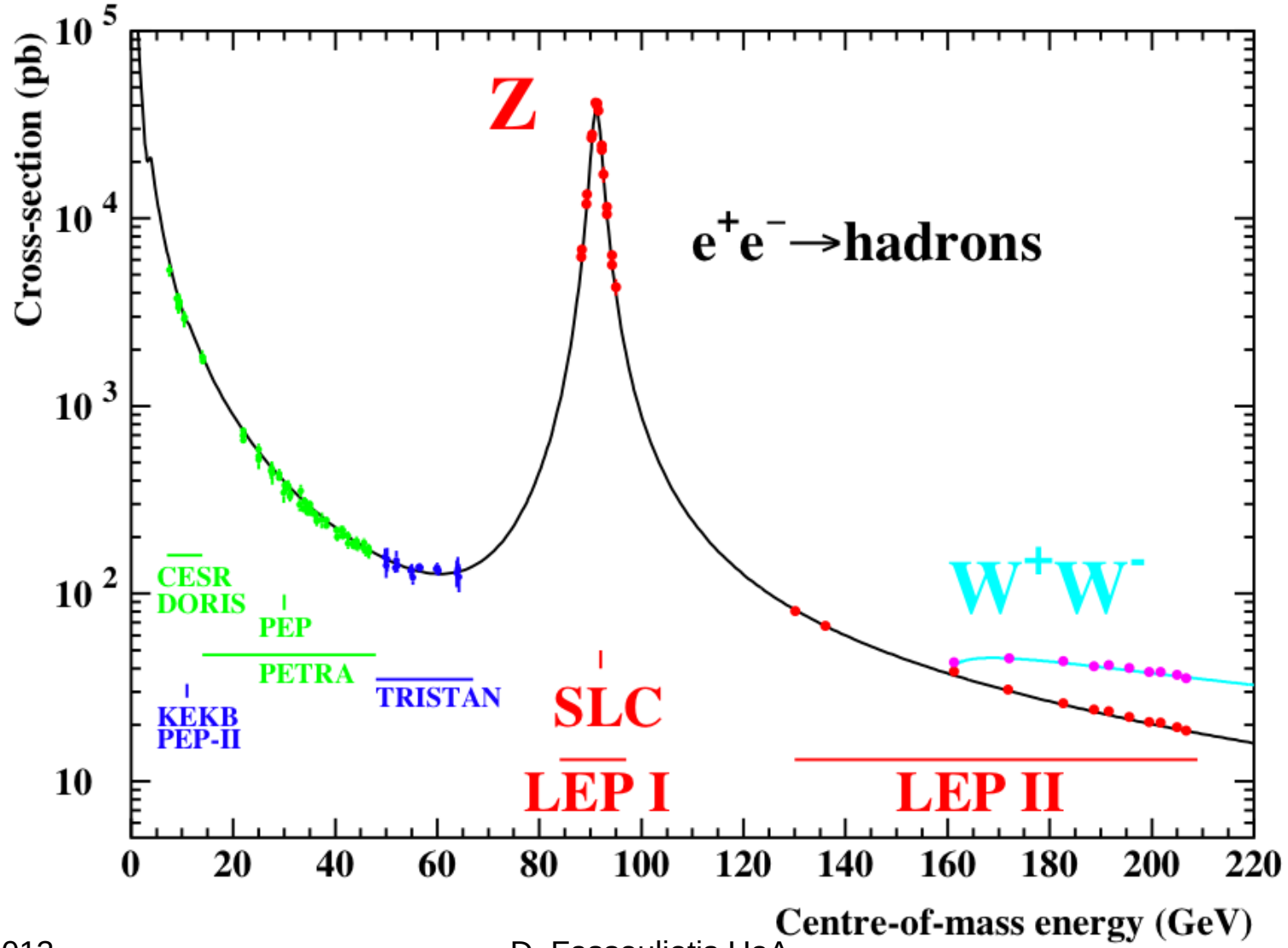


Discovery of the top quark at CDF and D0 at Tevatron in 1996

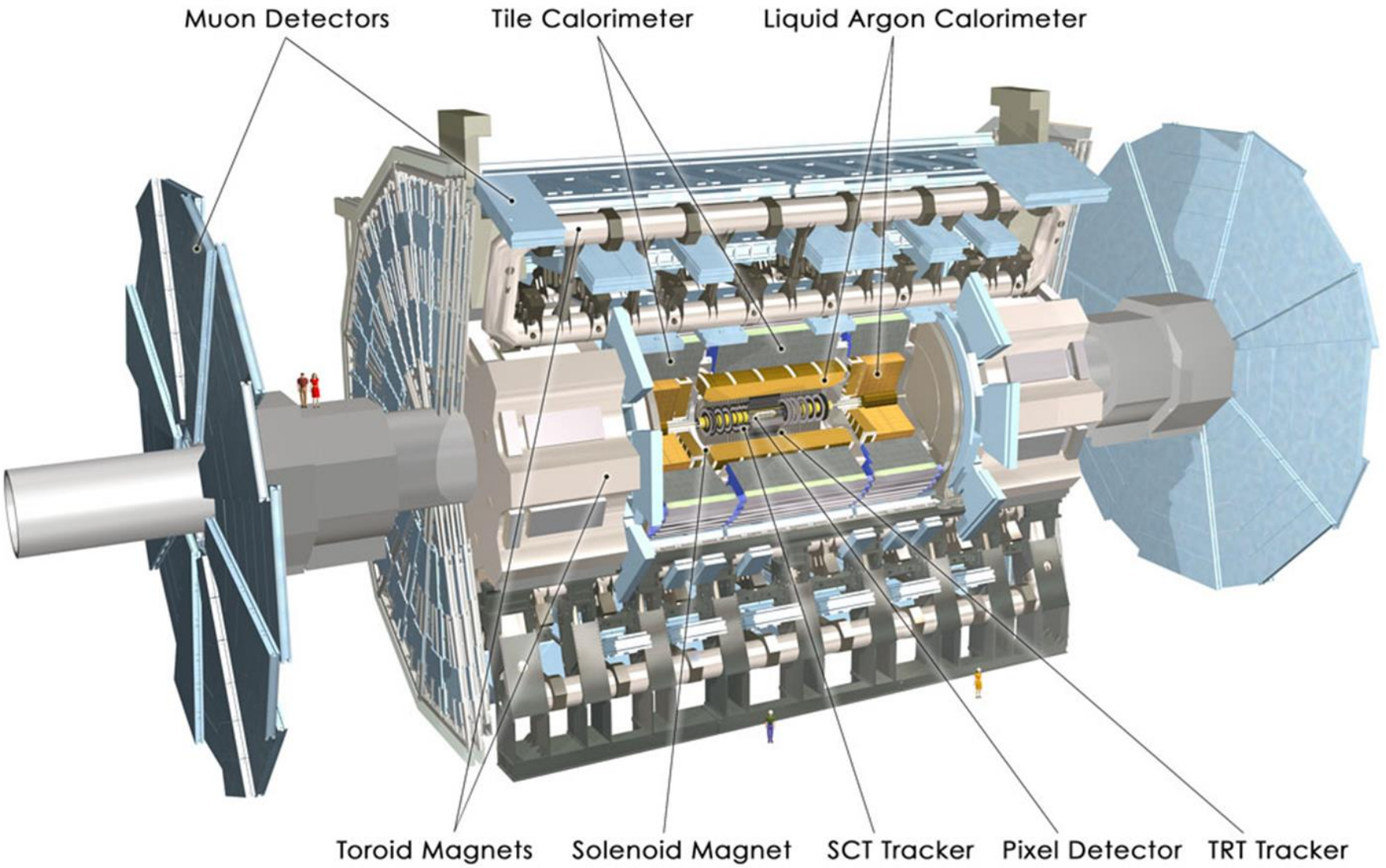


Modern Detectors

W and Z boson studies at LEP in CERN

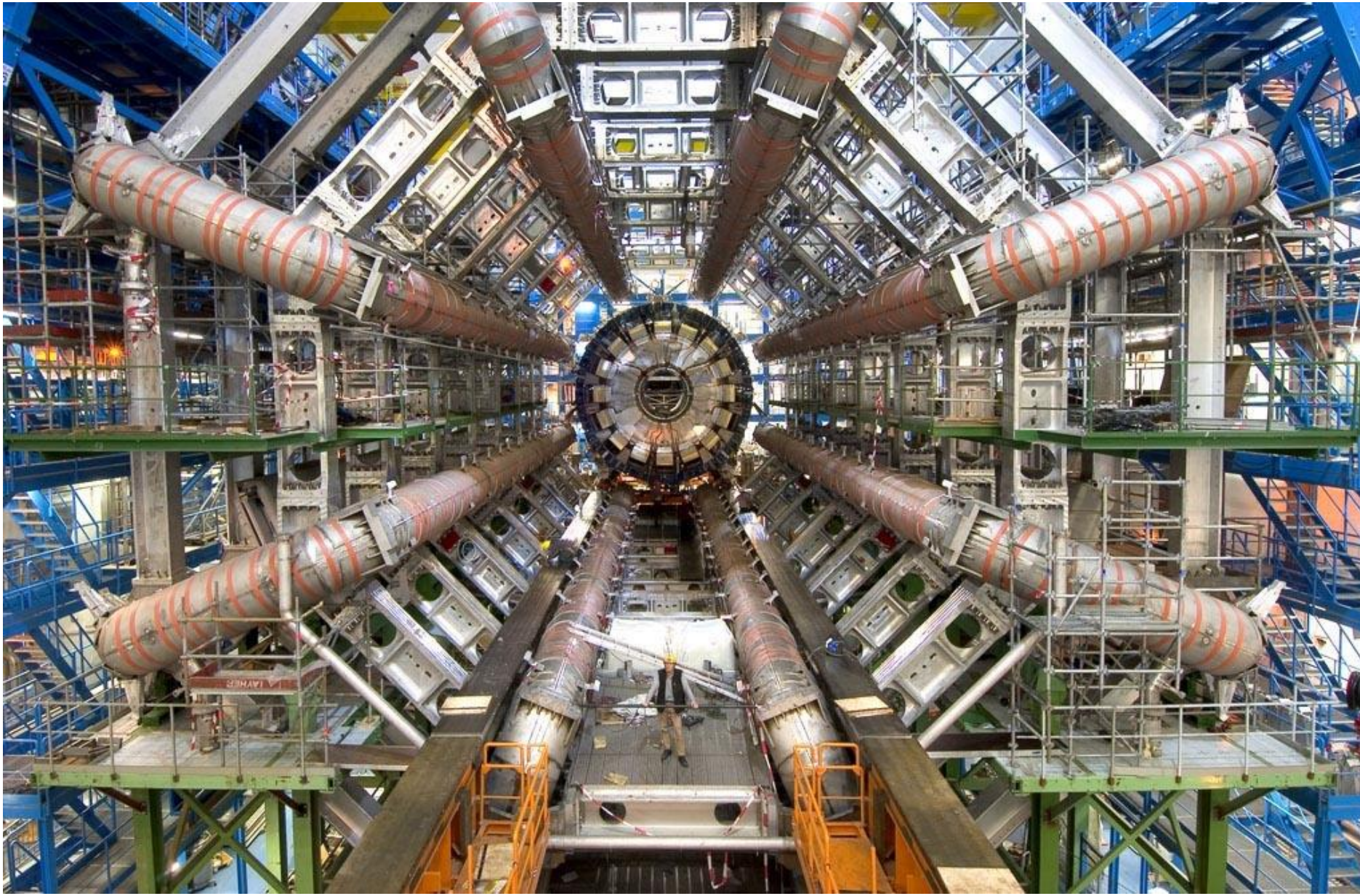


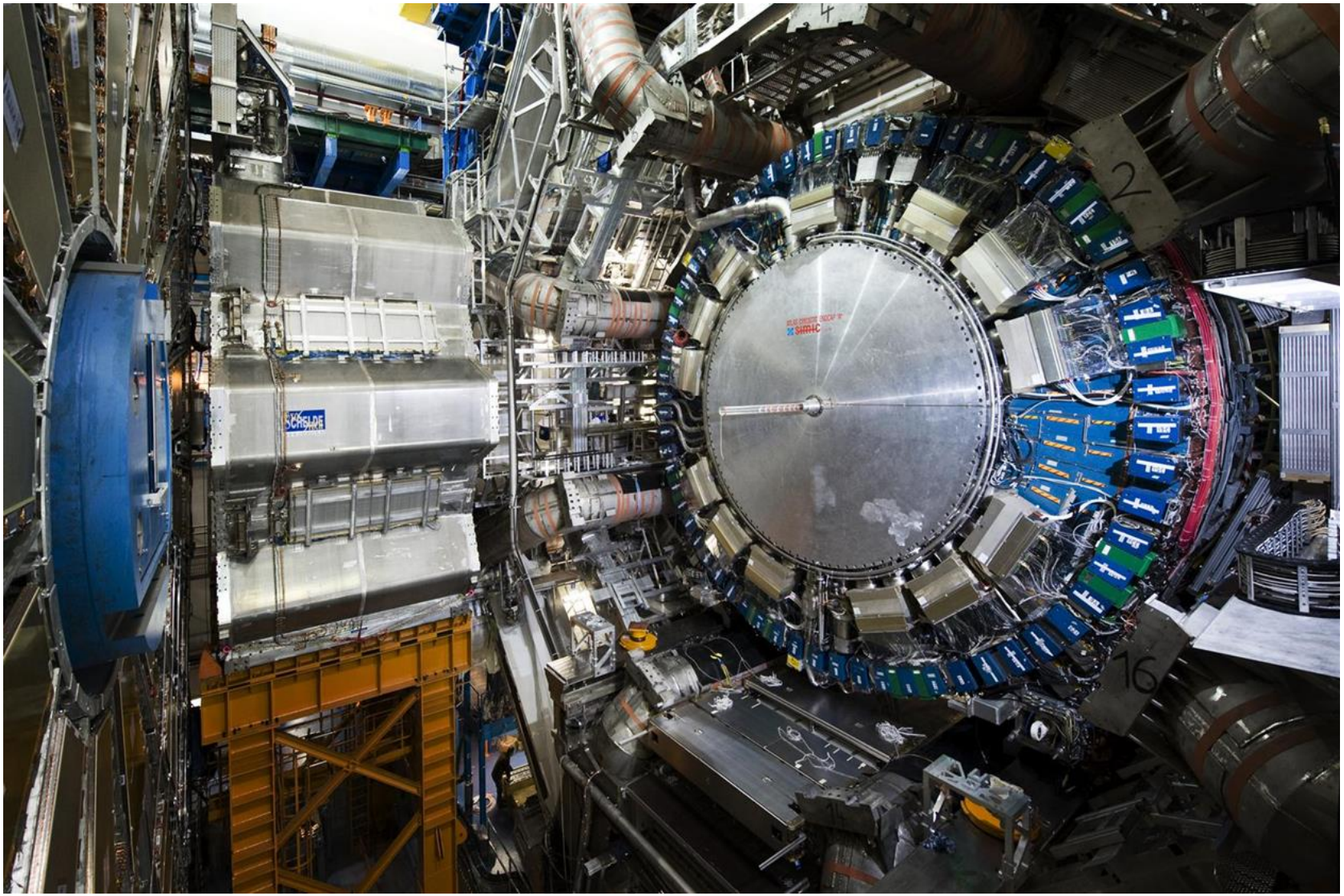
ATLAS Detector



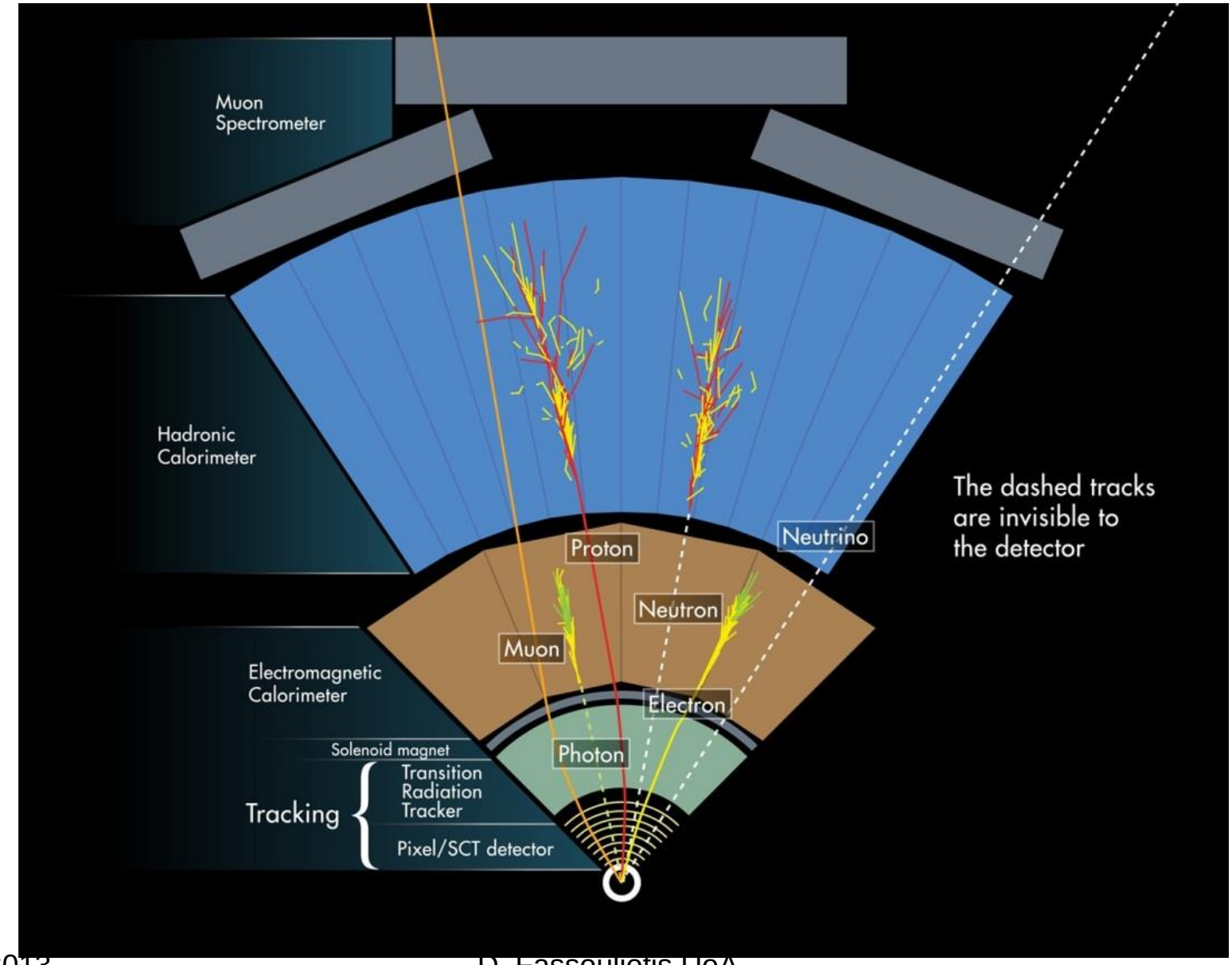
~ 2980 scientists from 175 institutes in 38 countries

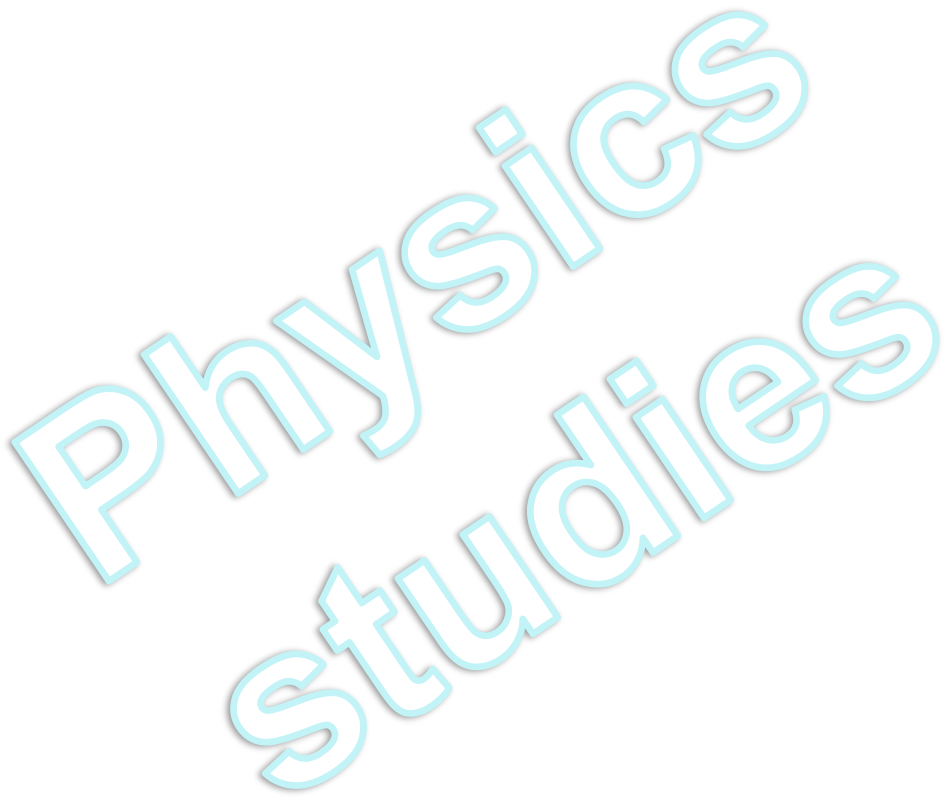
ATLAS detector: **October 2005**

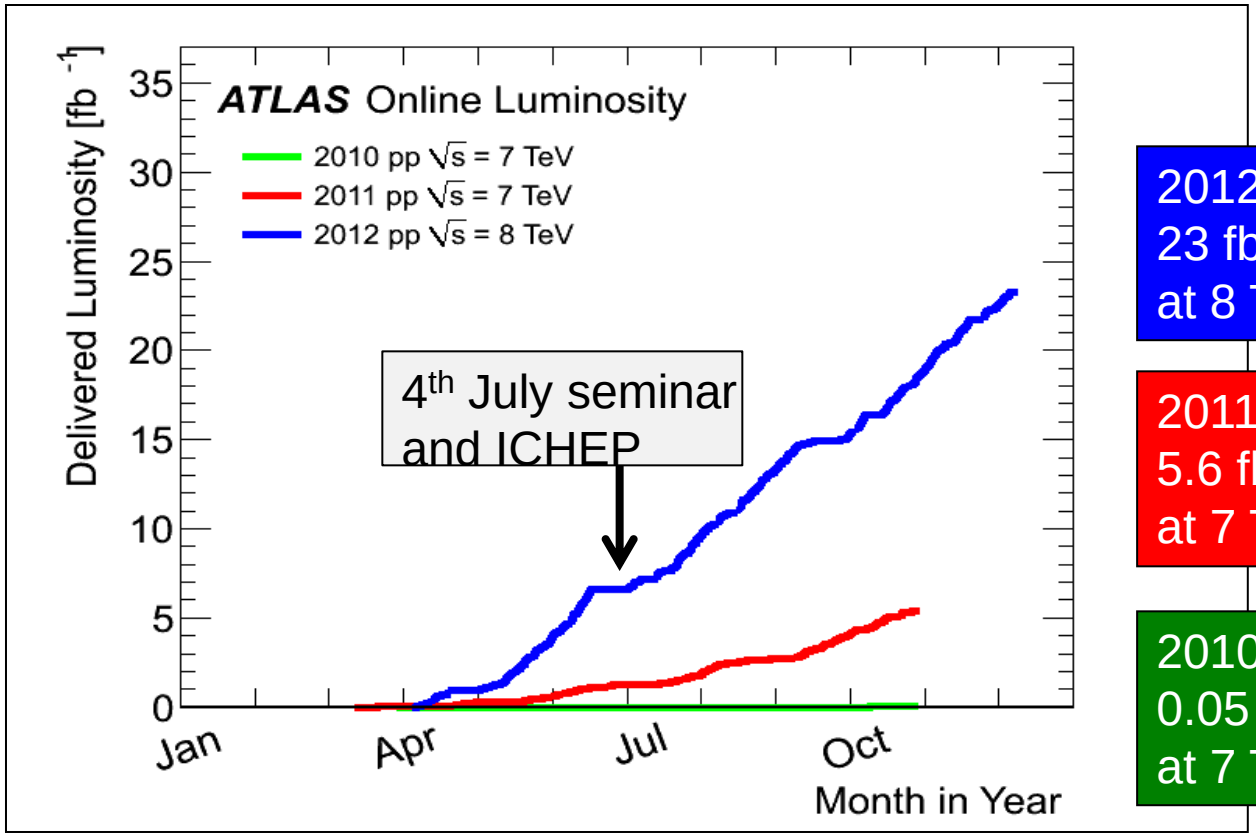




ATLAS detector




Physics
studies



2012:
23 fb^{-1}
at 8 TeV

2011
5.6 fb^{-1}
at 7 TeV

2010
0.05 fb^{-1}
at 7 TeV

How many signal events you see.

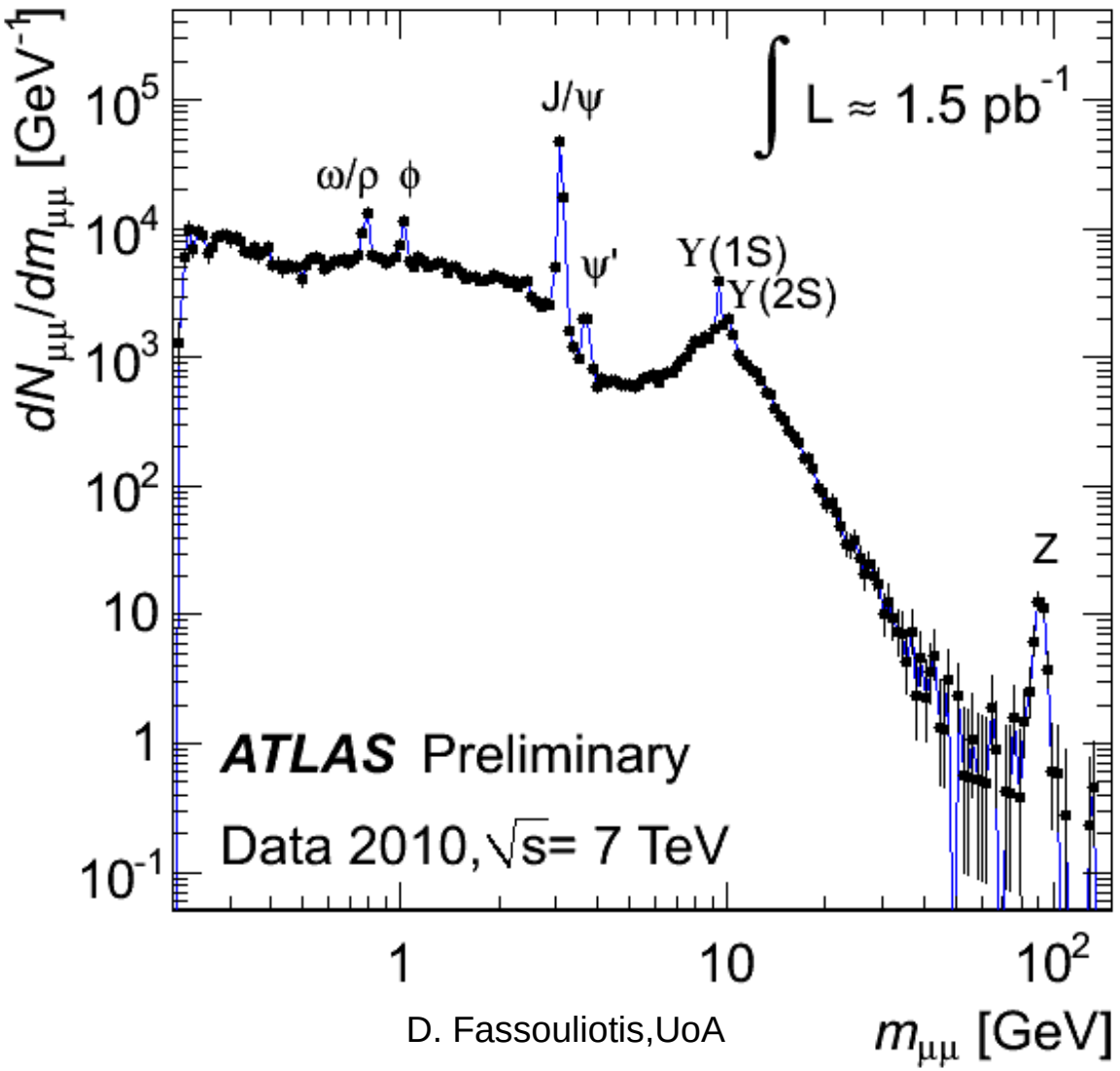
The cross-section of the process

$$N(events) = \sigma \cdot \int \mathrm{L}\, dt \cdot A \cdot \varepsilon$$

Acceptance (A) and efficiency (ε) – how often a produced particle is detected and reconstructed

Integrated luminosity: How much beam you have collected

Before searching for new particles
(the known ones should be rediscovered)

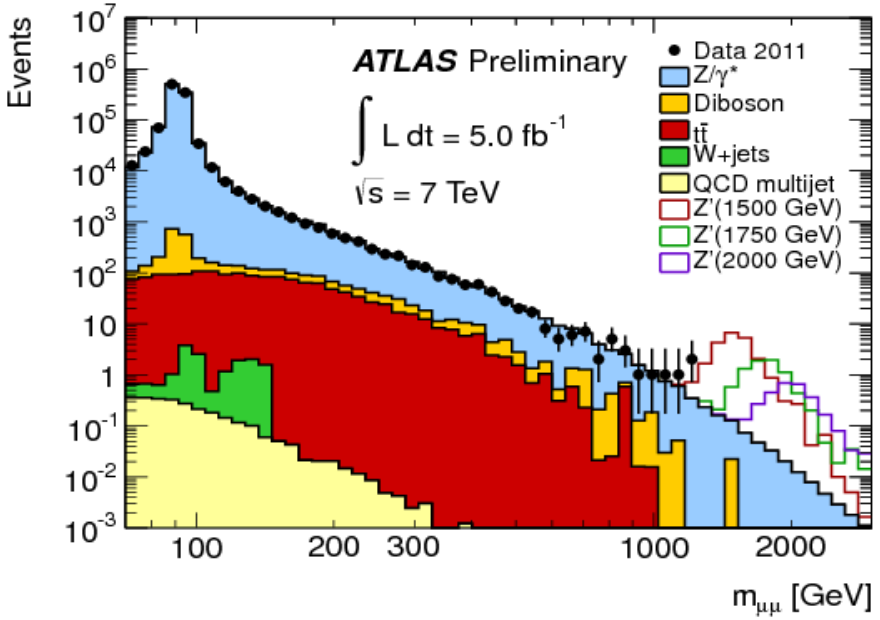


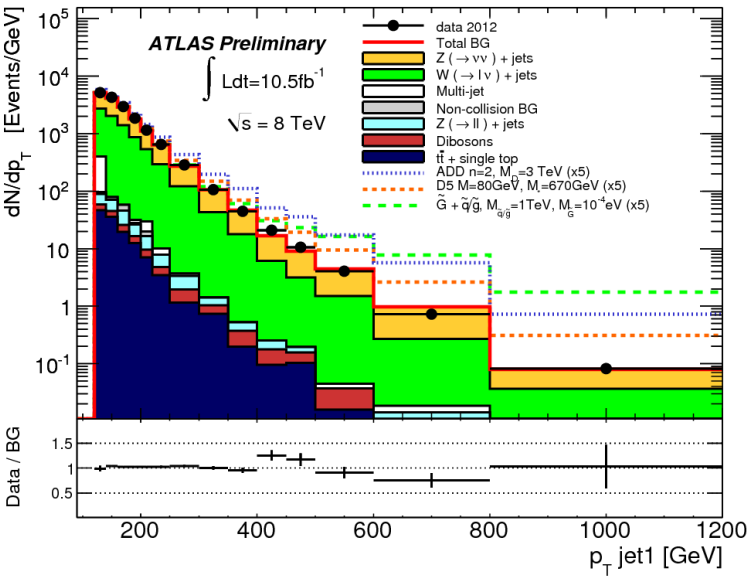
Search for new particles

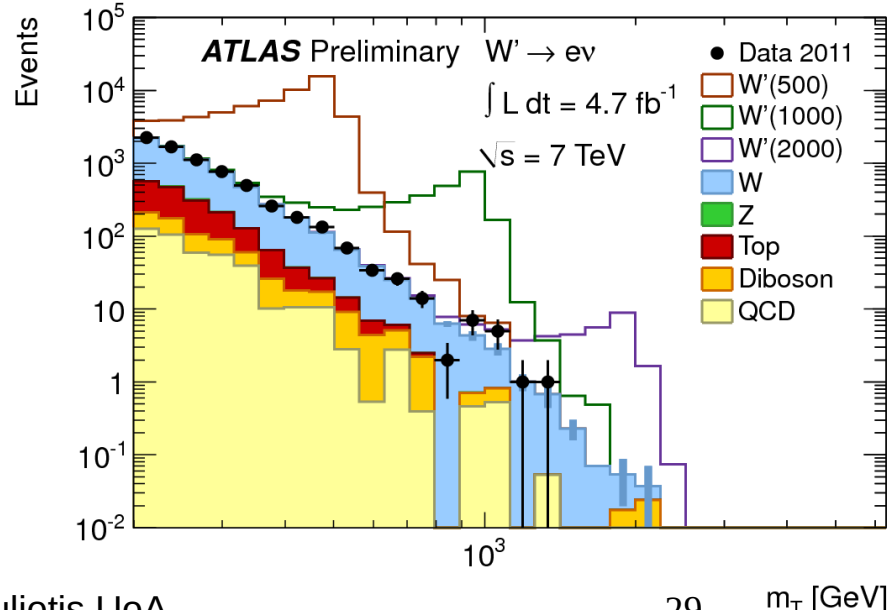
We search for particles with higher mass

$$E^2 = (pc)^2 + (mc^2)^2$$

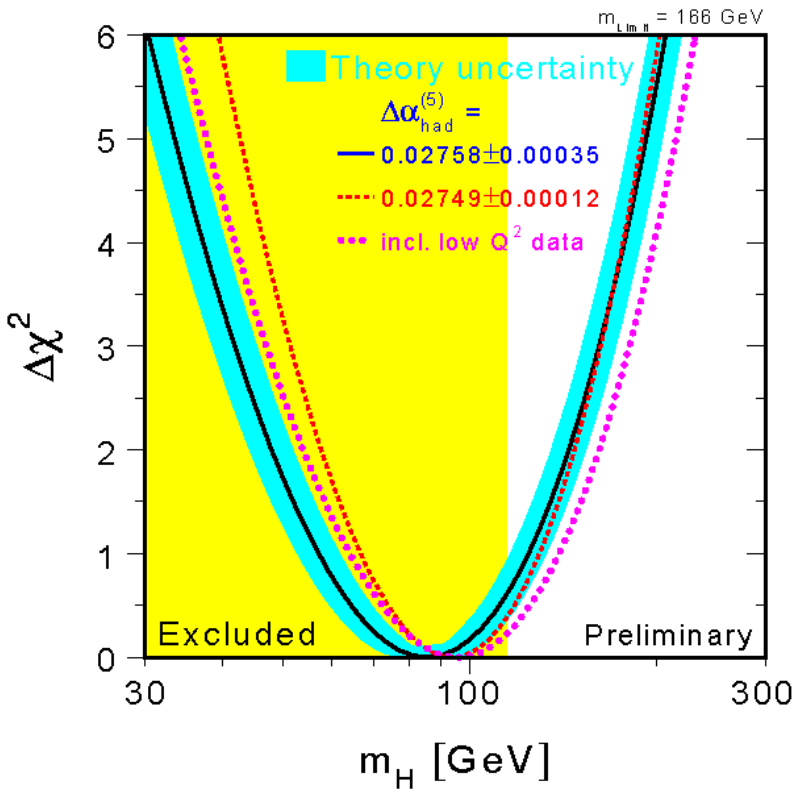
… or anything else unexpected

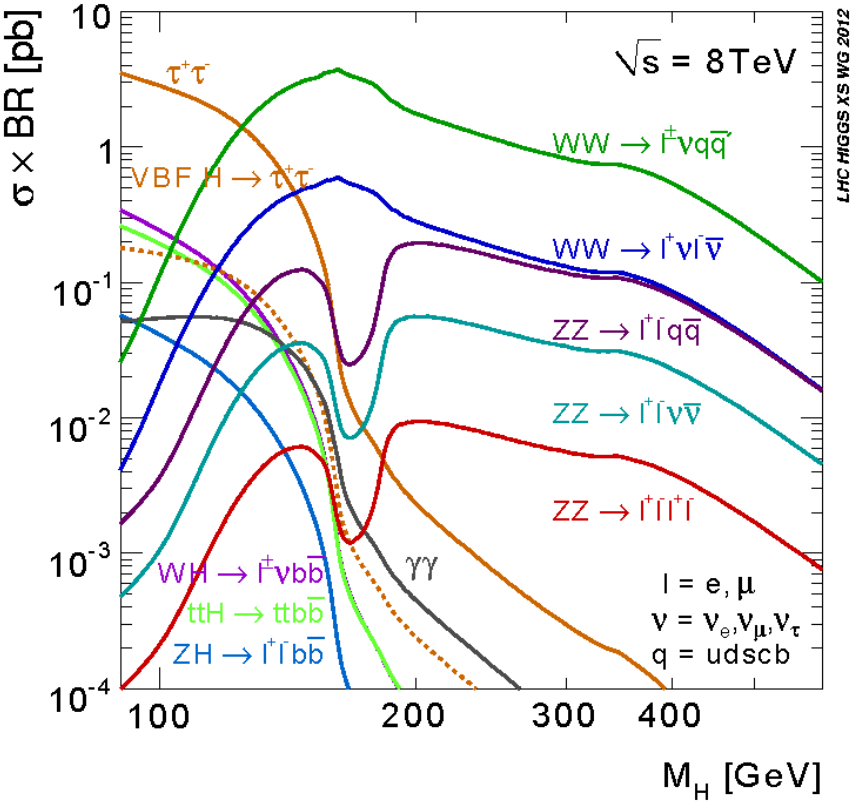






Search for the Higgs boson in ATLAS





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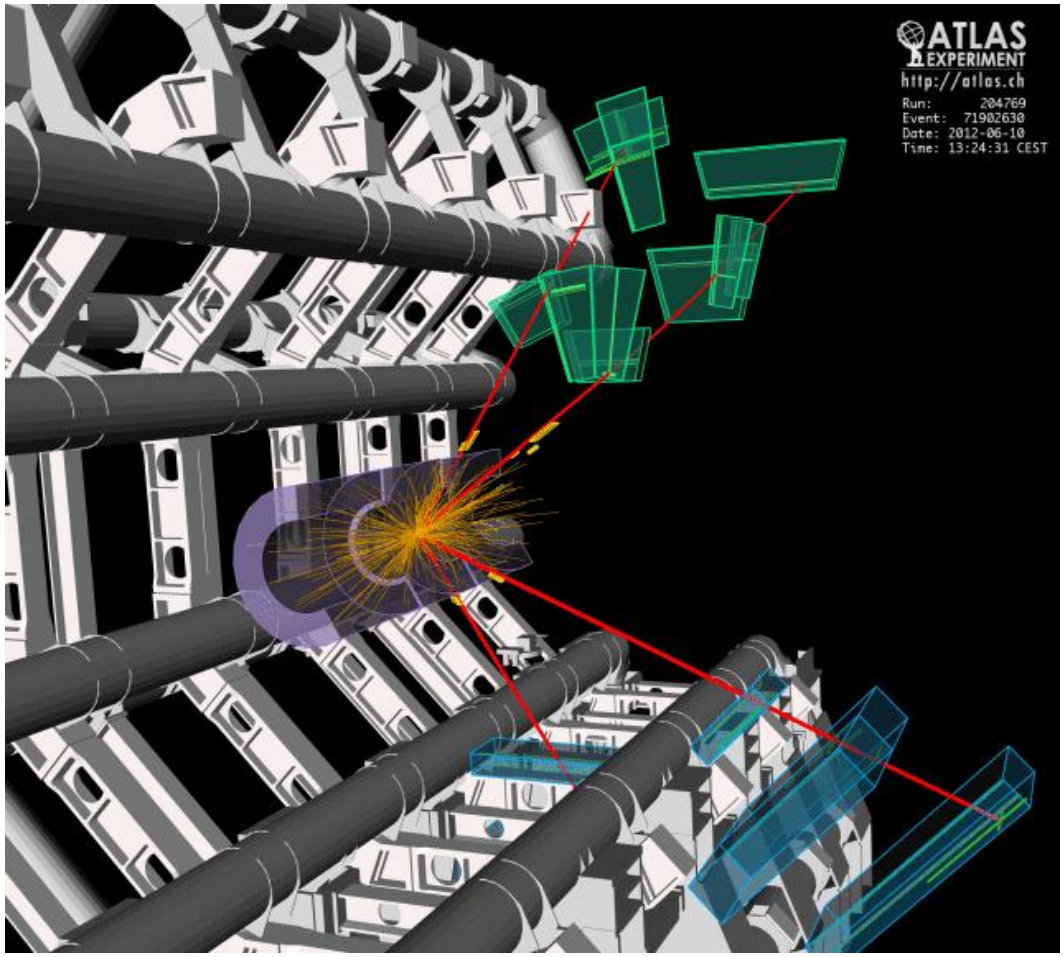
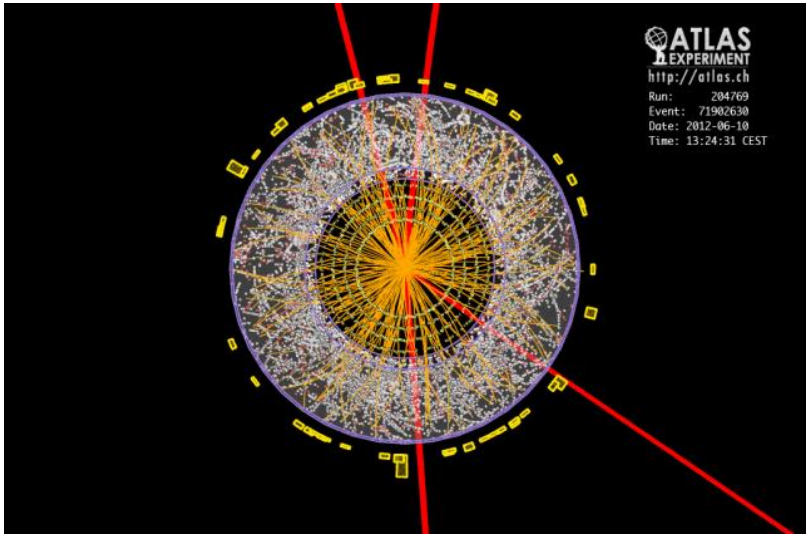
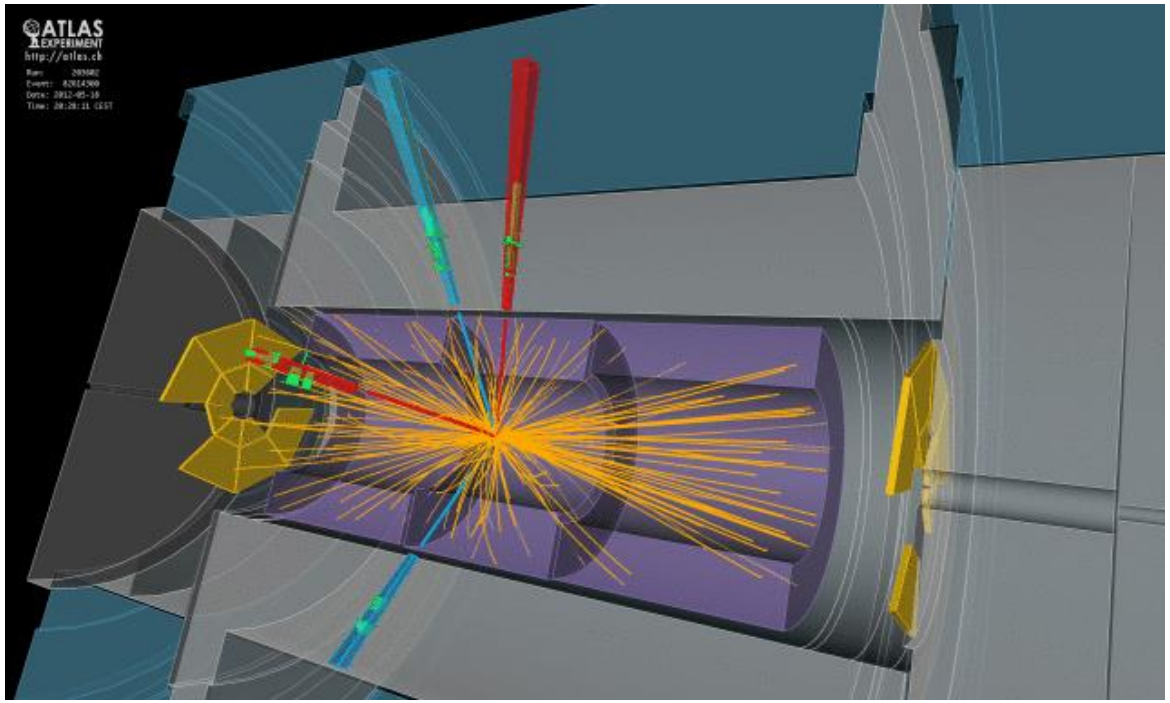
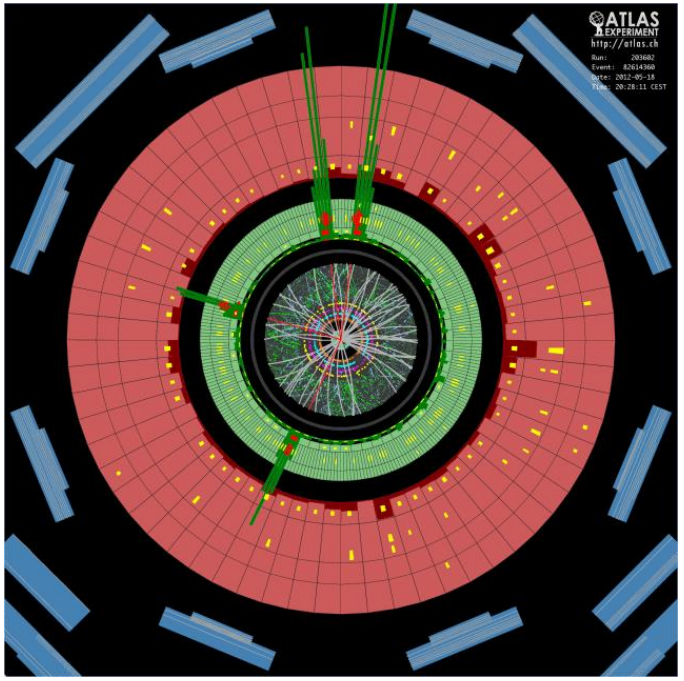


H→ZZ*→4μ event



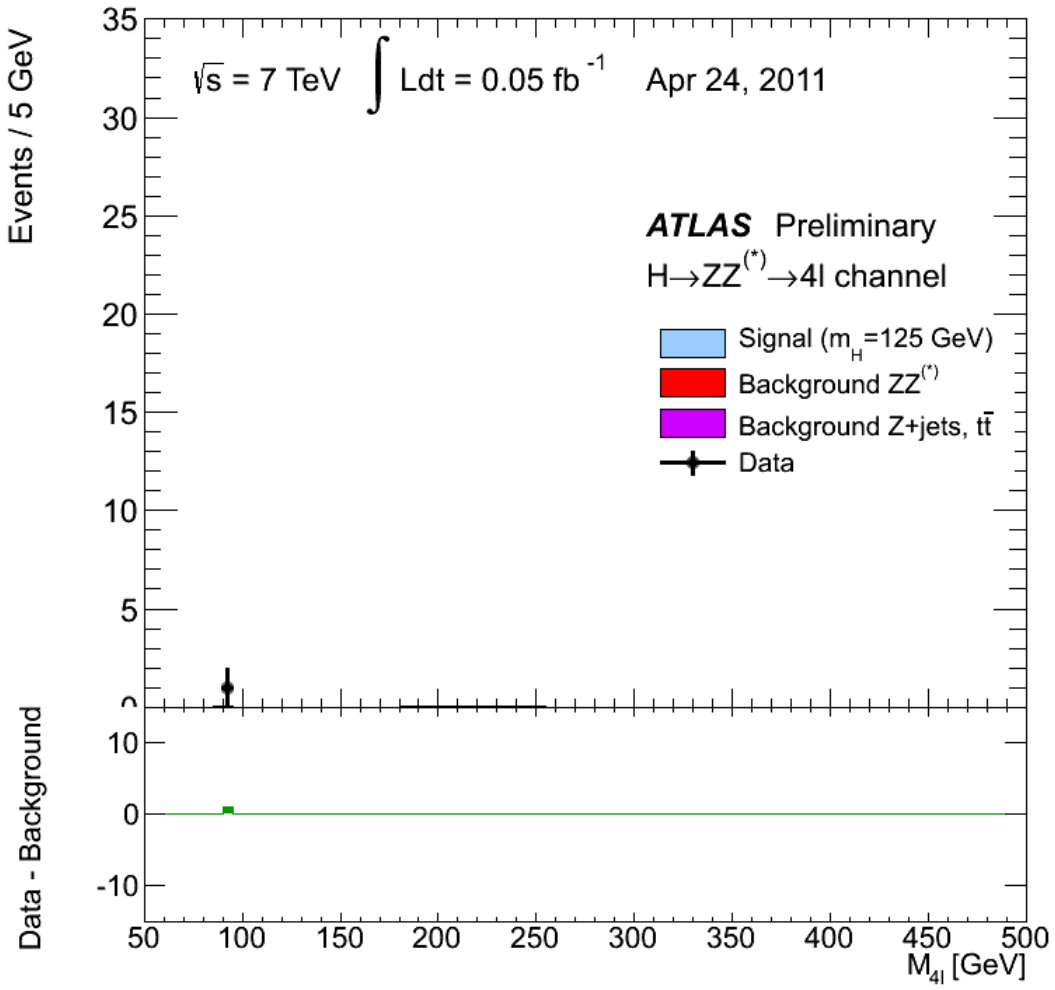
Search for the Higgs boson in ATLAS





H→ZZ*→4e event

Search for the Higgs boson in ATLAS



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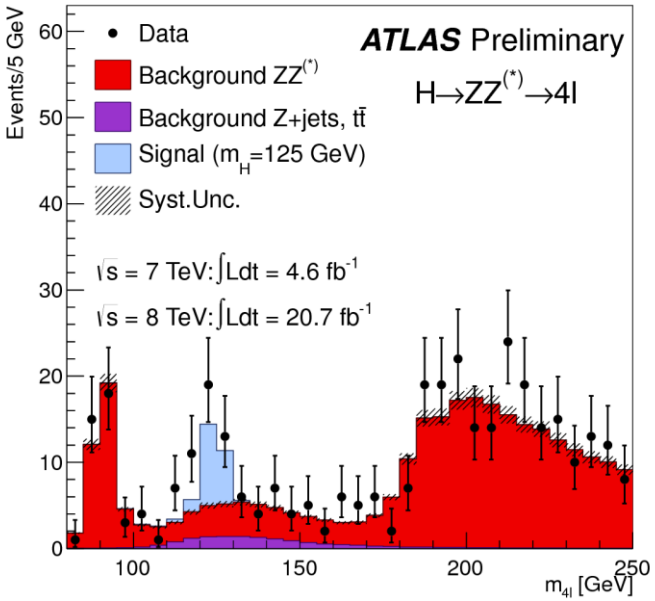
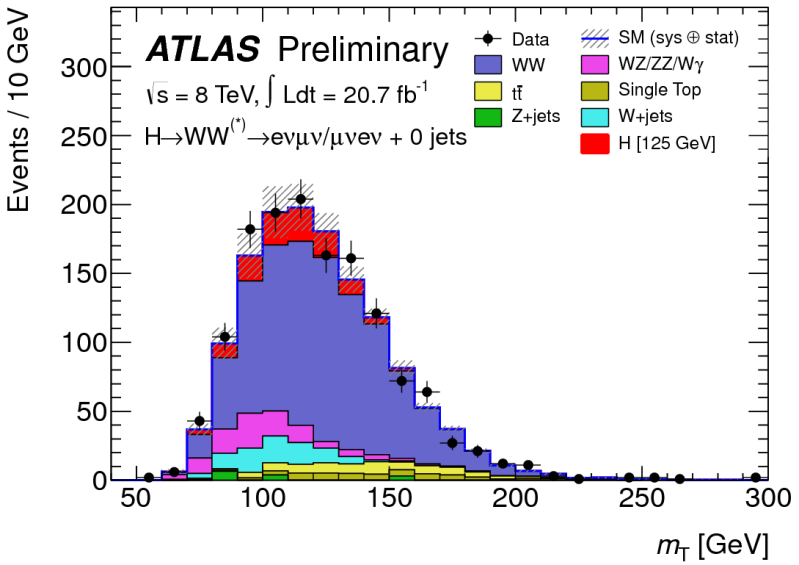
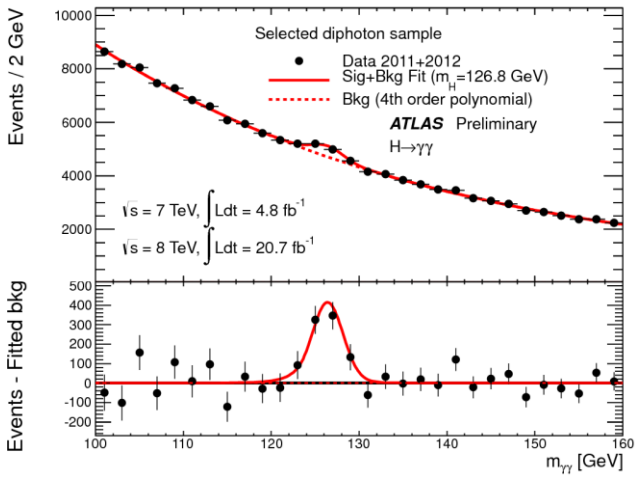
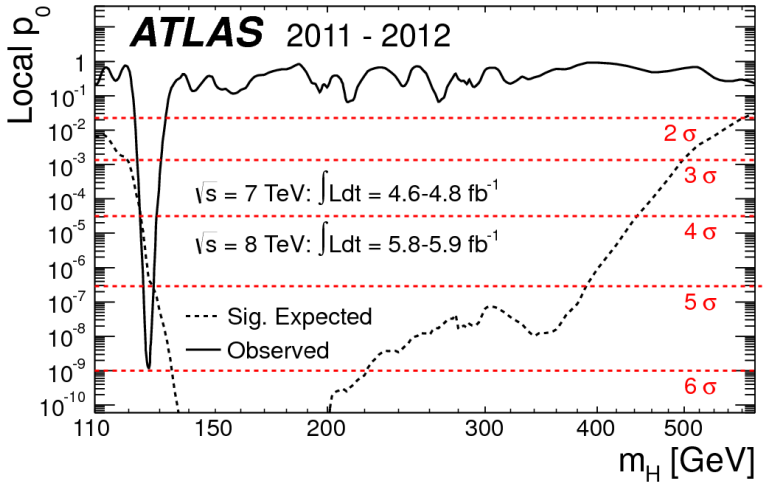




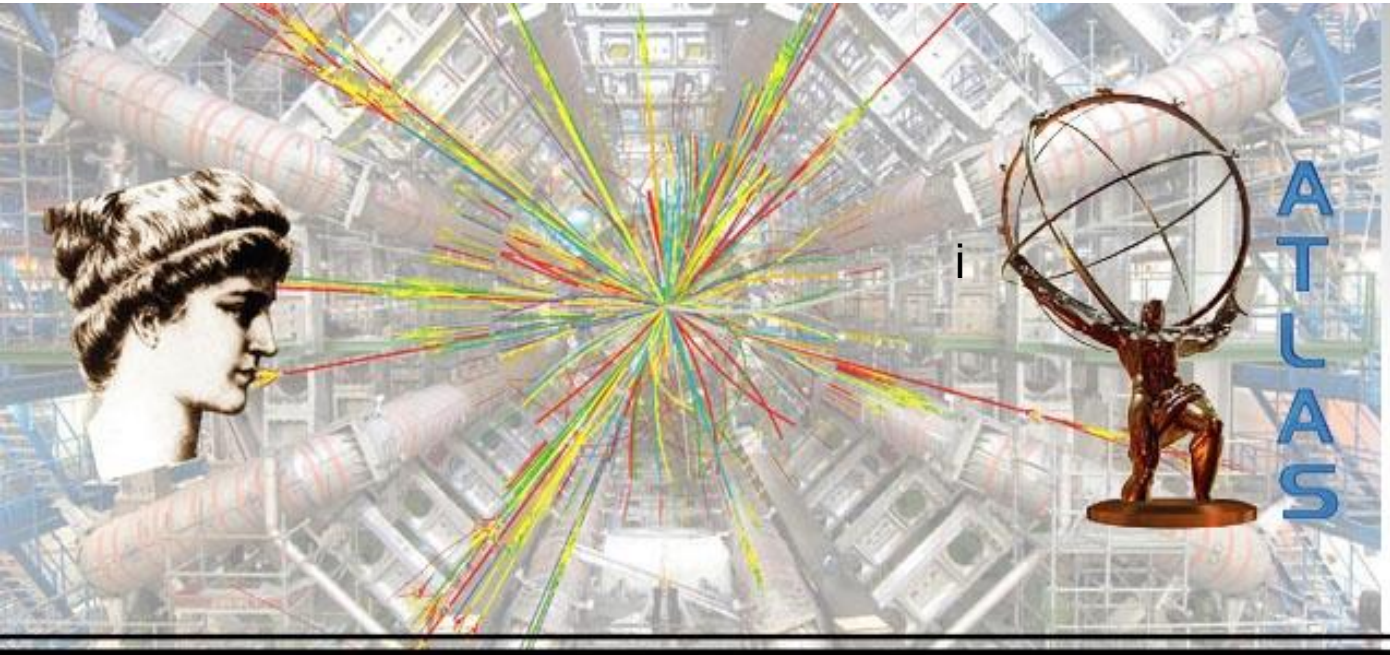




HYbrid Pupil's Analysis Tool for Interactions in ATLAS

http://hypatia.phys.uoa.gr/

C.Kourkoumelis (UoA)
D.Fassouliotis "
D.Vudragovic (Belgrade)
S.Vourakis (UoA)



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HYbrid Pupil's Analysis Tool for Interactions in ATLAS

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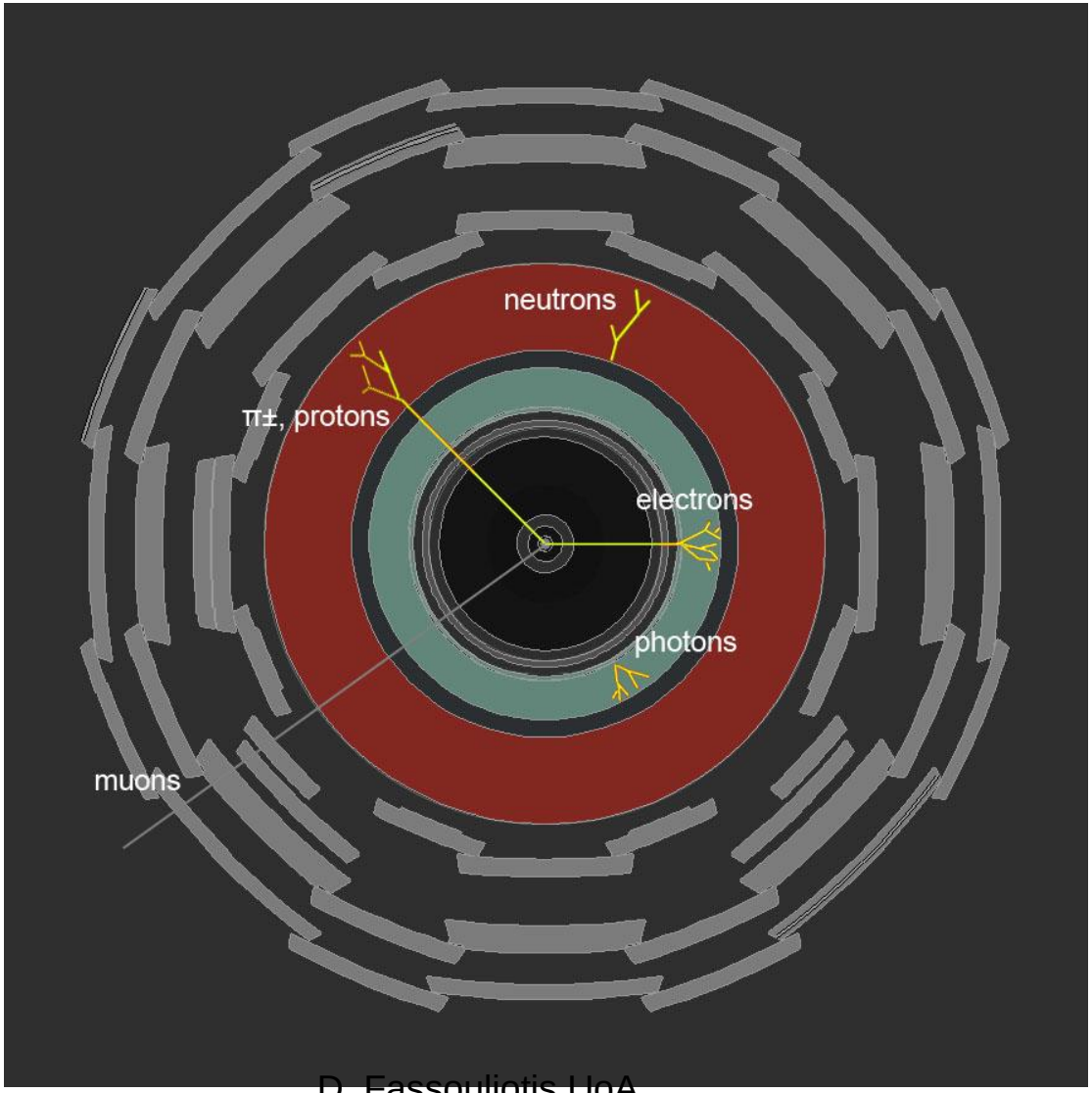
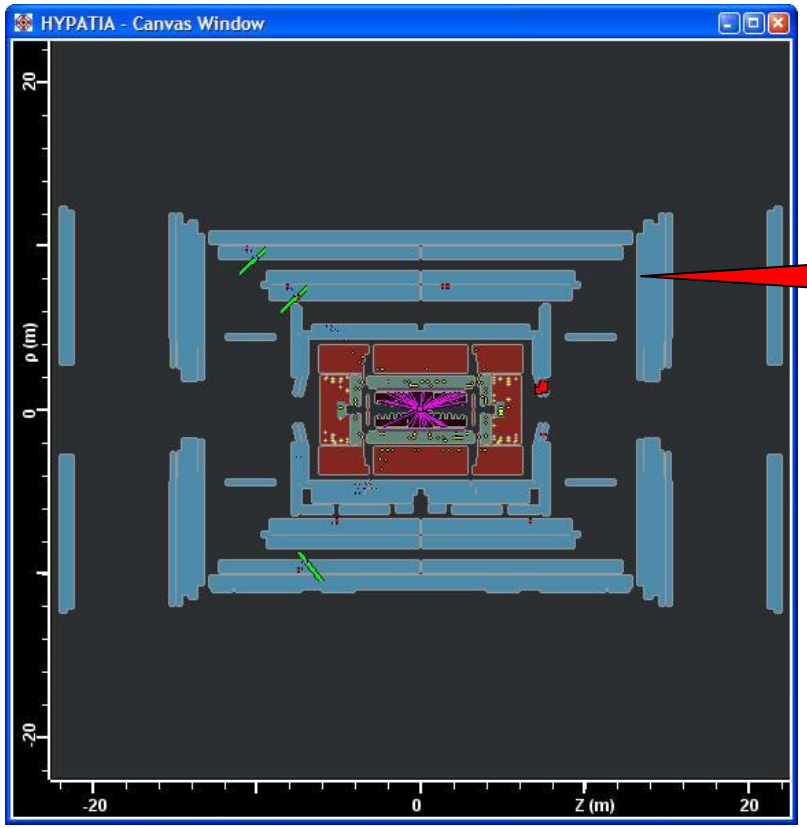
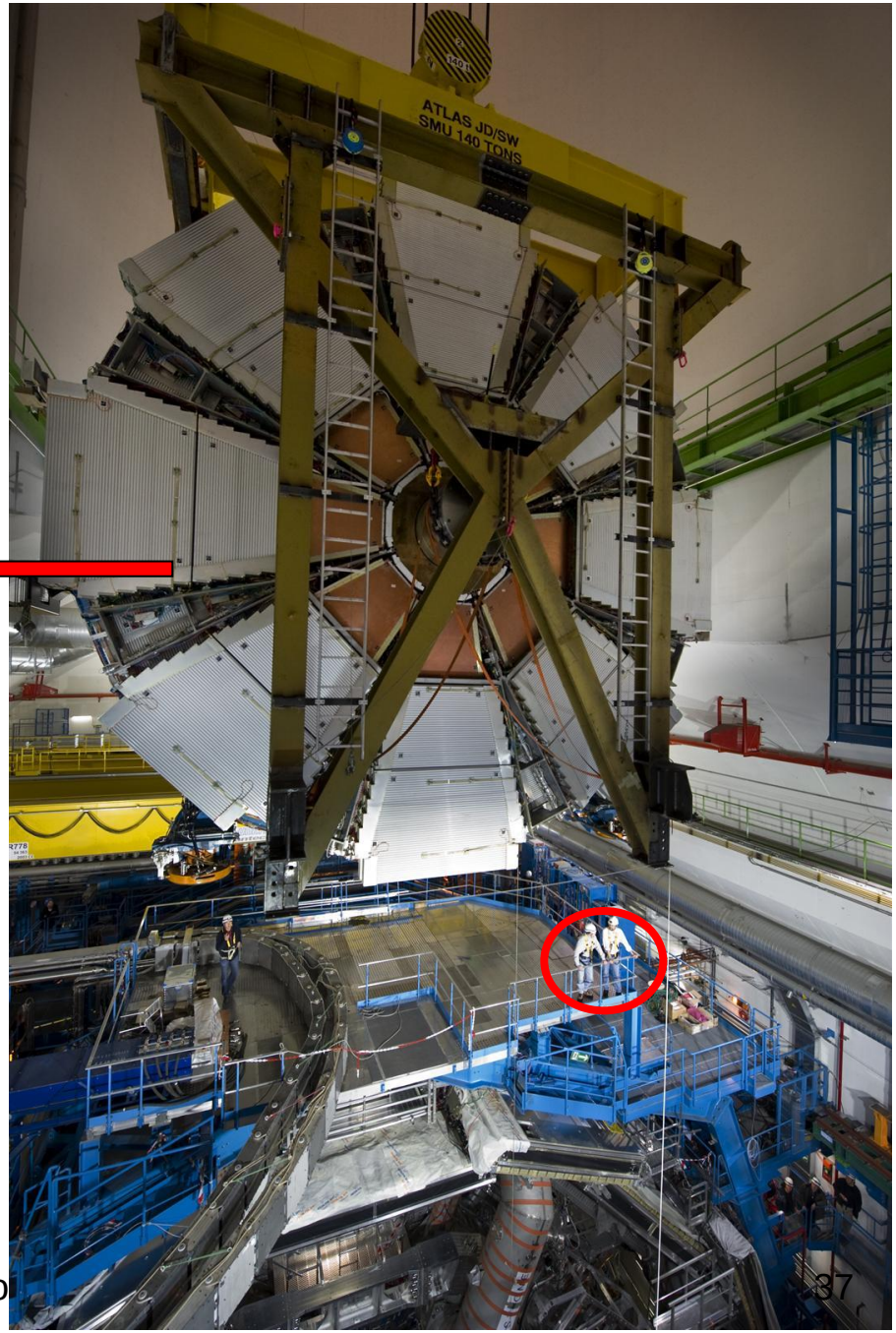
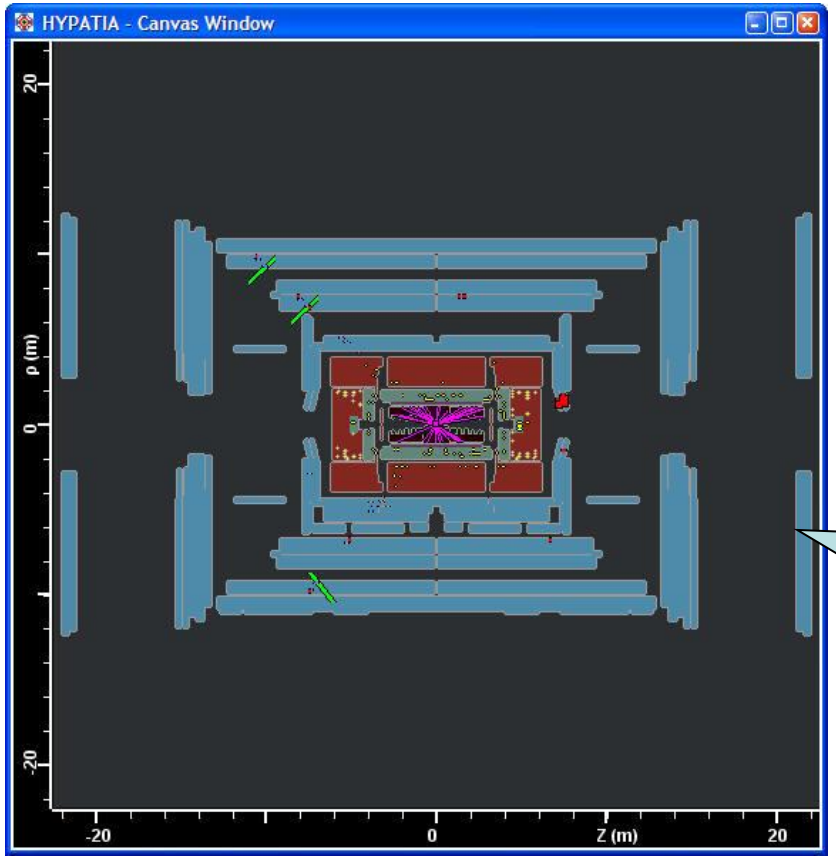


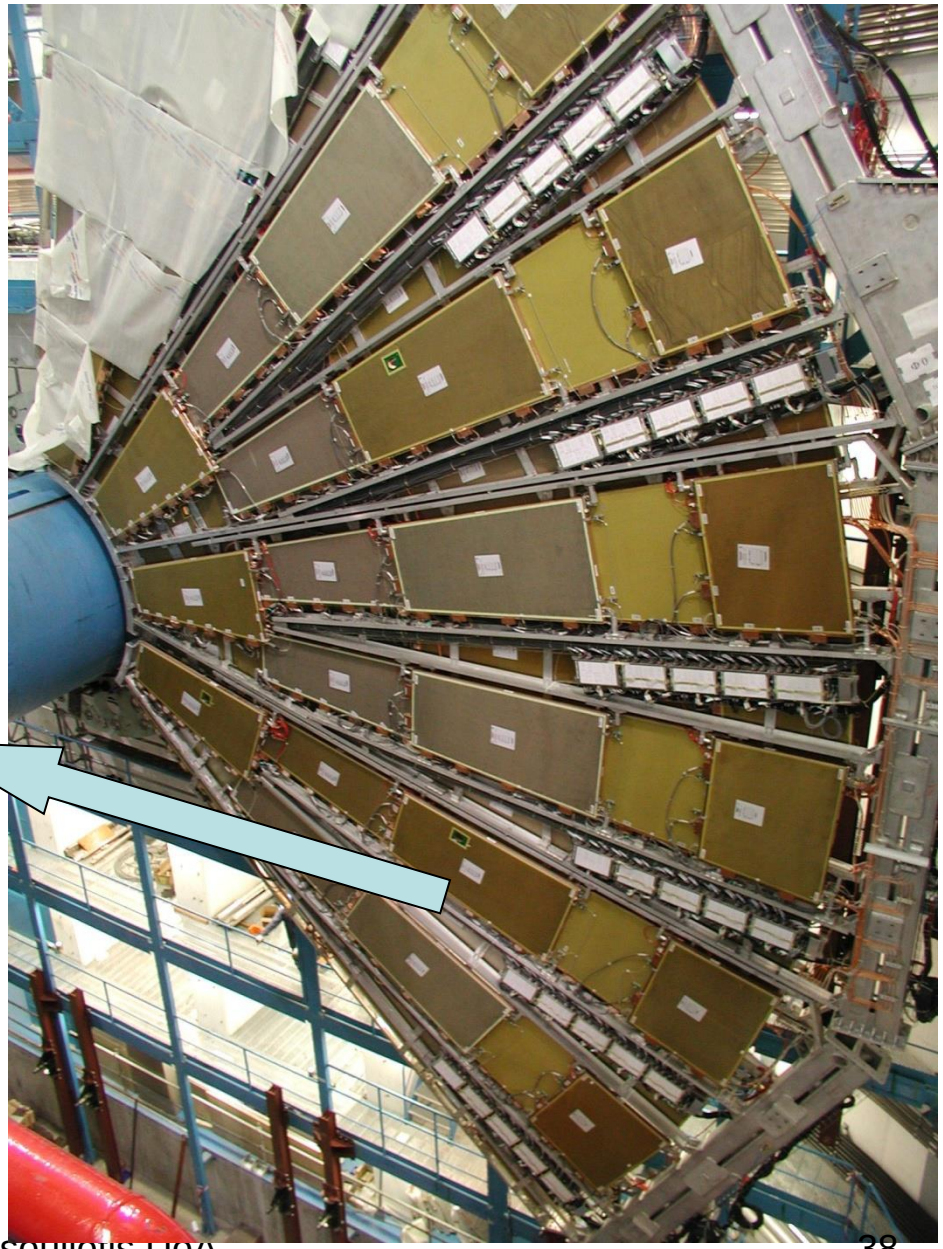
The small "wheel" Muon detectors





The large "wheel" Muon detectors





Today's research:

The carrriers of the week force (1983)

Z, neutral boson , mass **~ 91 GeV**

Decay modes:

Z→**lepton antilepton**

(namely **Z->e+e-, Z->μ+μ-** , **Z->τ+τ- , Z->ν +antiν**)

or Z→**quark antiquark**

You are going to look at «Z events» + ee +μμ + « background»+….

Invariant mass of Z (H)
(calculated automatically by the HYPATIA tool)

Einstein's formula

$$E = \sqrt{(\vec{p} \cdot c)^2 + (m_0 \cdot c^2)^2}$$

$$\Rightarrow \quad (m_0^{(Z)})^2 = \left(\sum_{i=1}^{n} \frac{E_i}{c^2}\right)^2 - \left(\sum_{i=1}^{n} \frac{\vec{p}_i}{c}\right)^2$$

1) Identify tracks

2) Identify events

(**J/ψ, Υ, Z**)$\rightarrow e^+ + e^-$ $Z \rightarrow \mu^+ + \mu^-$
or in general $e^+ + e^-$ $\mu^+ + \mu^-$
Background (W→e+ν , W→μ+ν , jets etc)

3) Measure (50 Events)

Find (“reconstruct”) the above particles or discover the Higgs??
Higgs->ZZ->four leptons or H->two photons (gammas)

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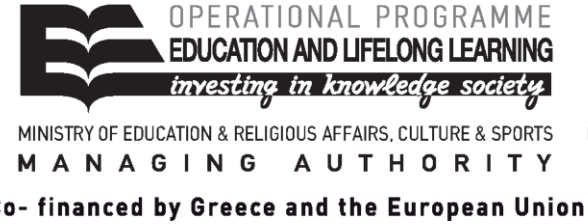

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