The research at CERN

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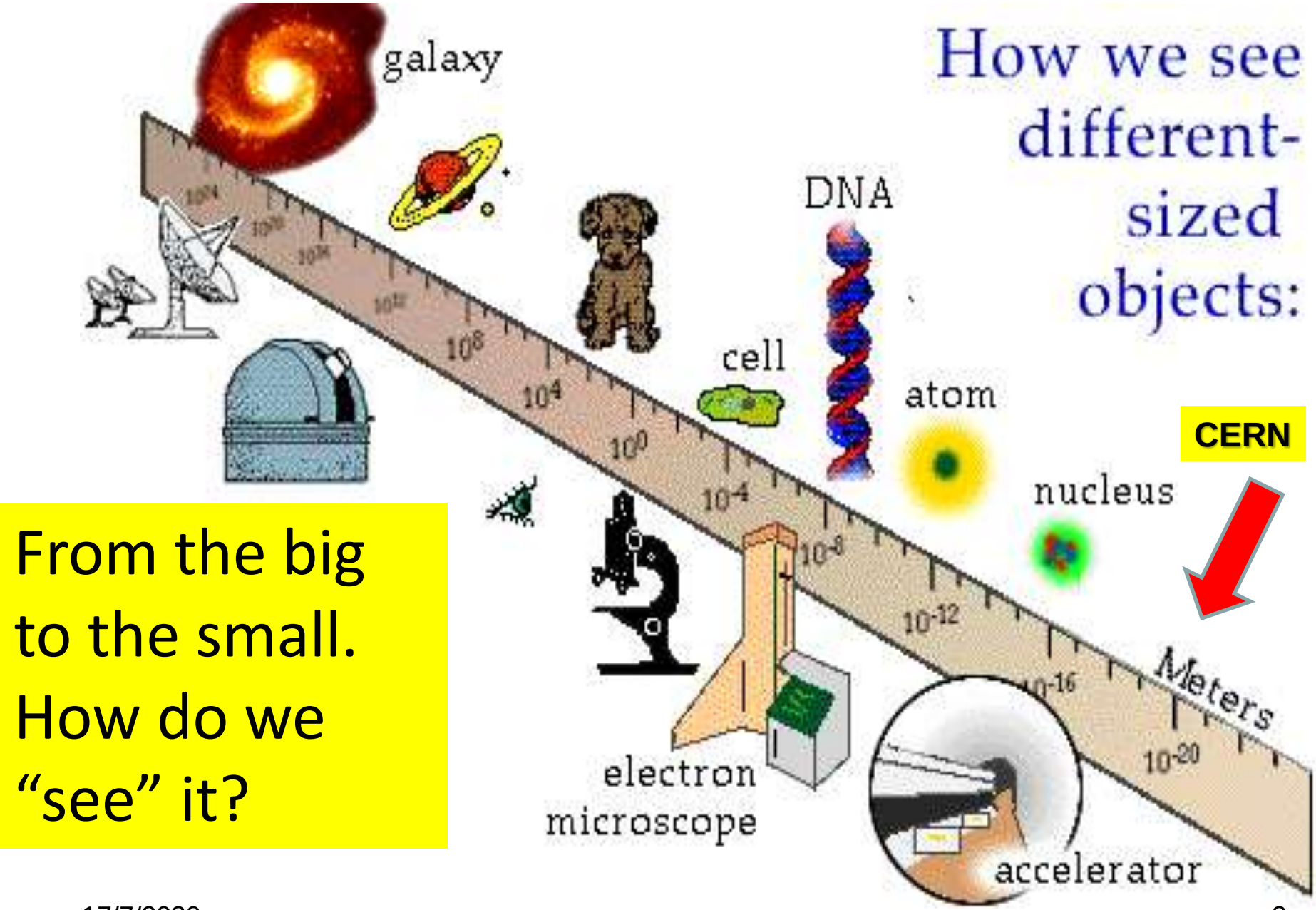
http://www.cern.ch

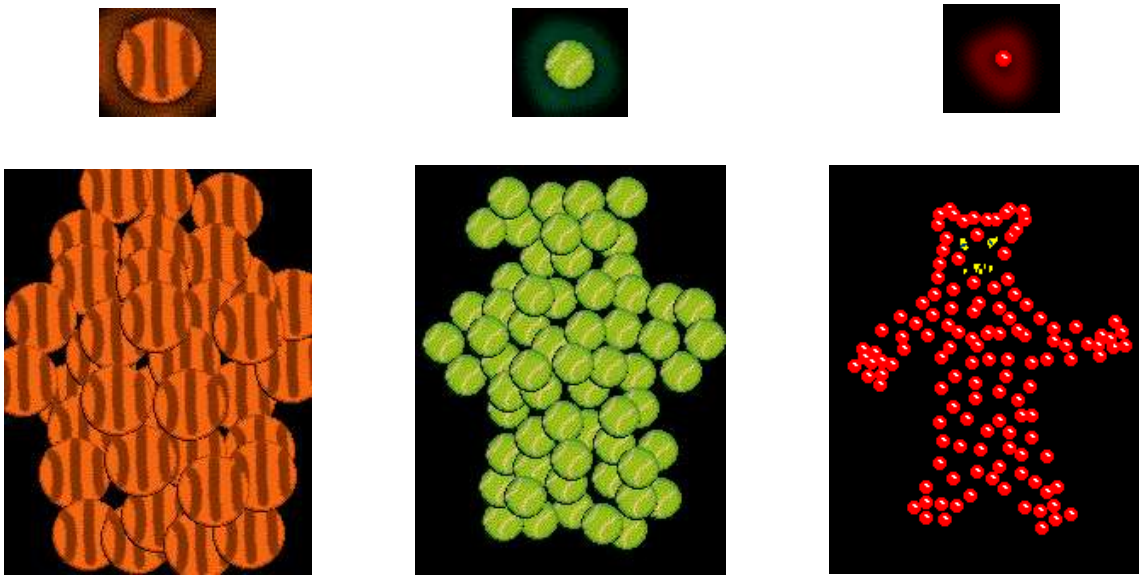
CERN IS OVER 65 YEARS OLD

- ~~Basic research~~
- 23 members countries, 14,000 researchers from 800 Universities/research centers
- Brings together researches from all five continents
- Unique facilities in the world (Accelerators and experiments)
- Pushes cutting-edge technology at its limits
- Trains tomorrow's researchers.



From the big to the small. How do we "see" it?

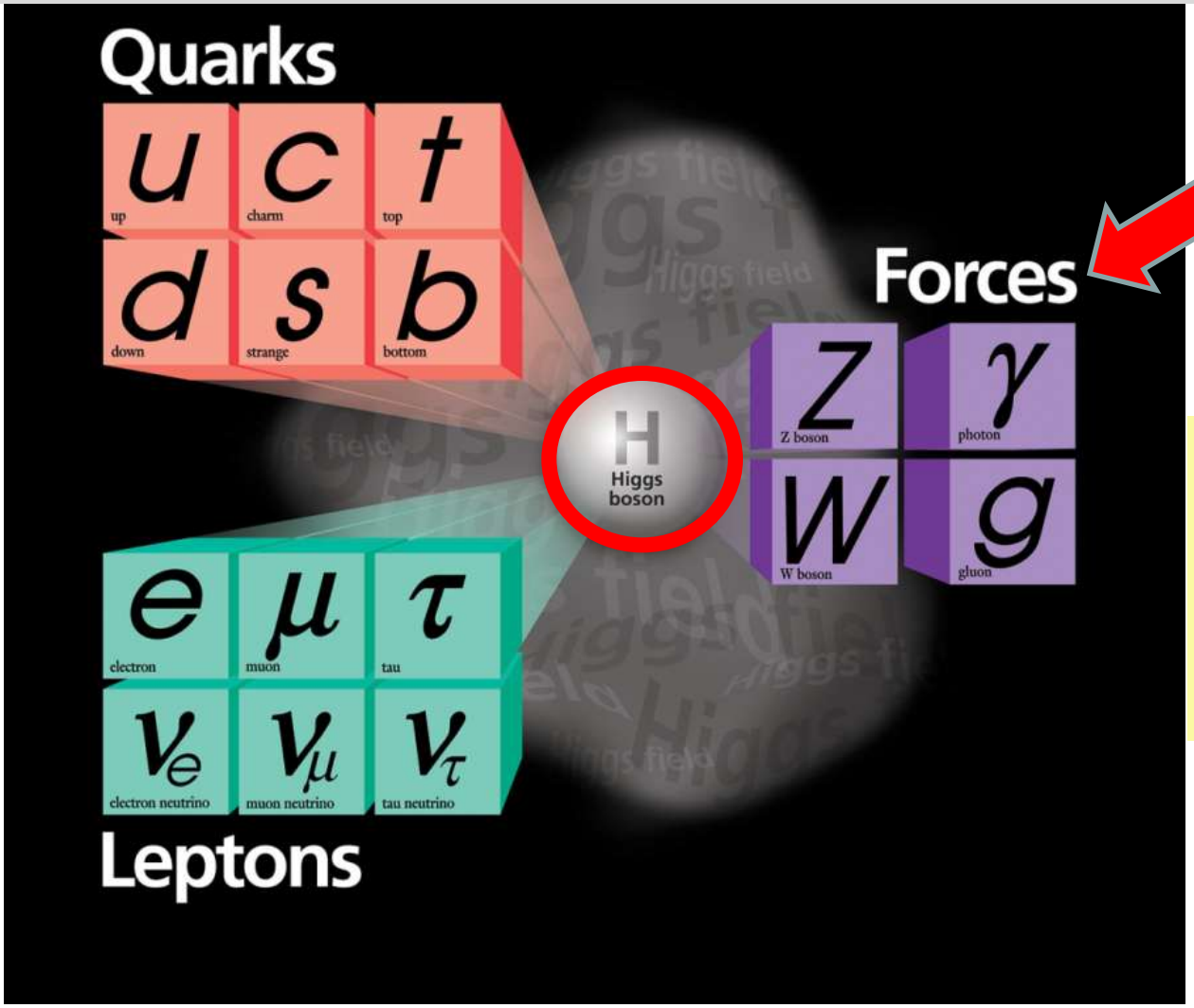
We should have the right “probes” and the right resolution depending on what we want to “see”



The right wavelength allow us to “see” the different sizes with the desired resolution.

Our description of matter: the SM

The elementary particles, the force carriers and the key component missing for 50 years!!!



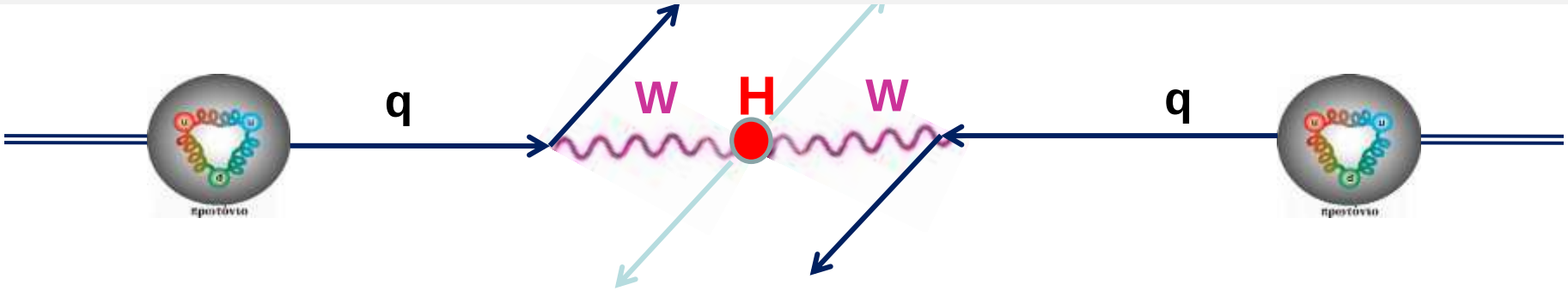
- Strong
- EM
- Weak

$m_\gamma = 0$

$m_{Z,W} \sim 100$ GeV

Why?

What was needed to discover it? A powerful new accelerator and new huge experiments experiments



M_H~1000 GeV

E_W ≥ 500 GeV

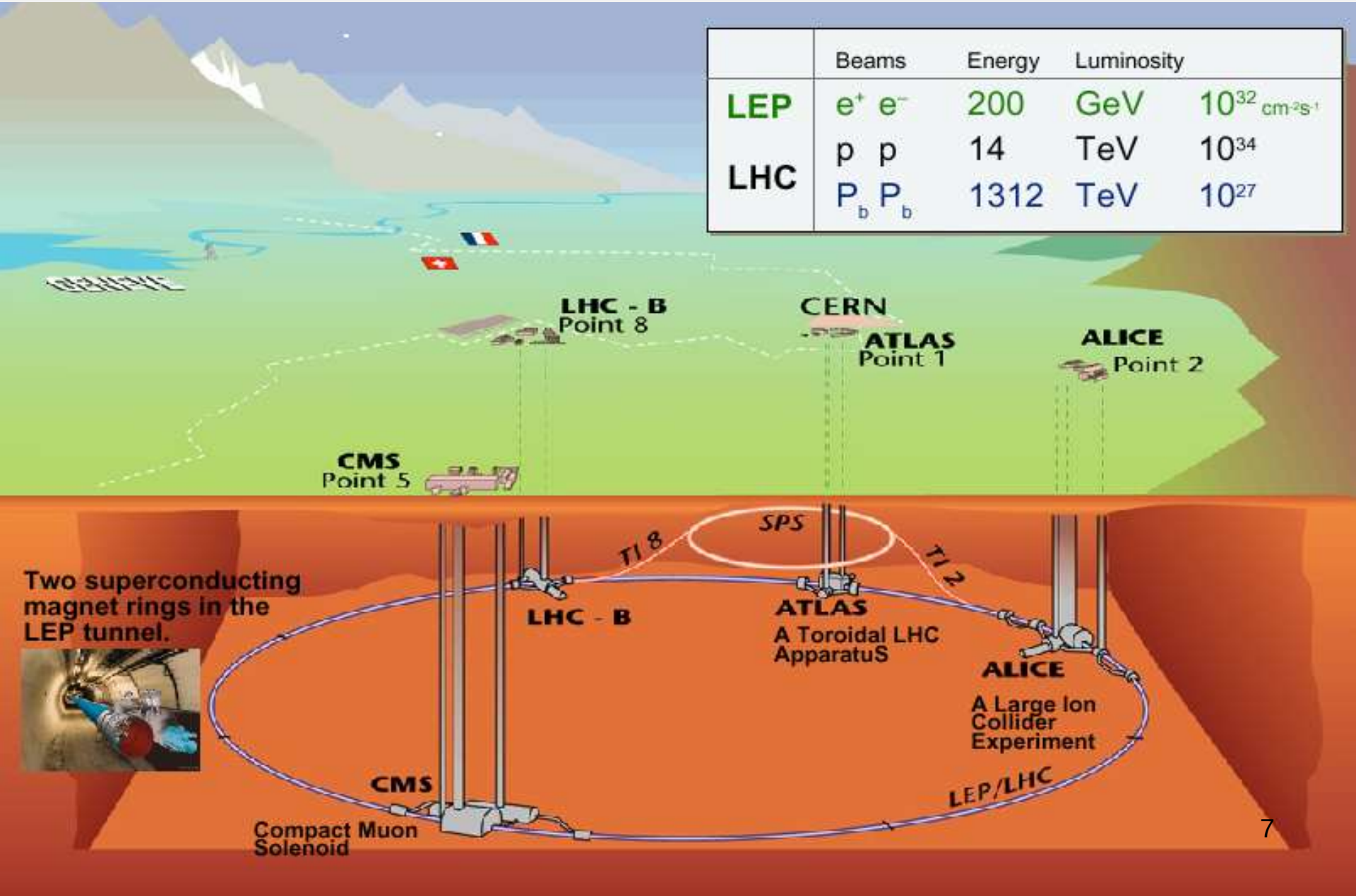
Eq ≥1000 GeV

Ep ≥6000 GeV

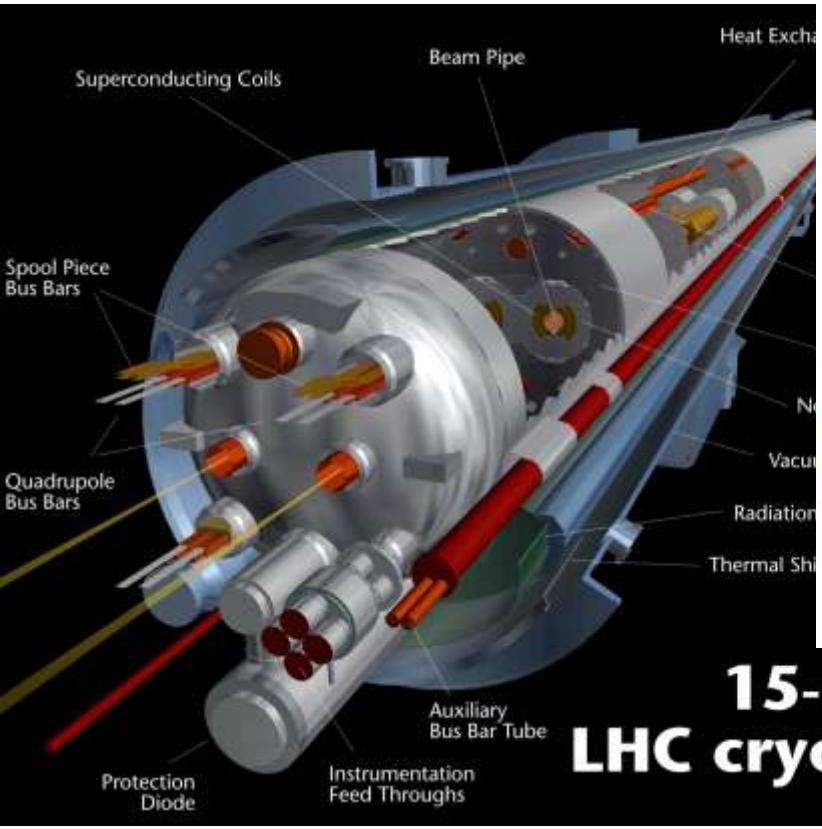
LHC: Design beam energy 7 (now 6.5) TeV

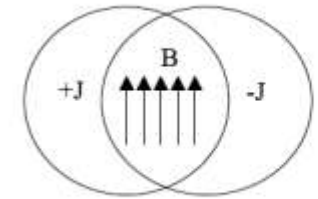
CERN designed and constructed LHC: The challenge was the discovery of the Higgs boson + new physics

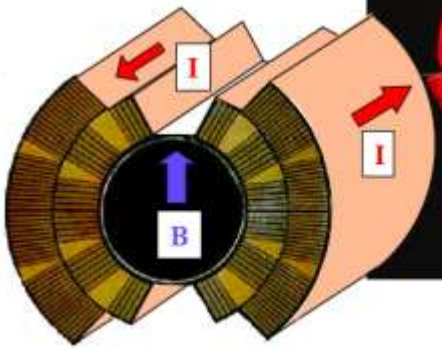
	Beams	Energy	Luminosity	
LEP	e^+ e^-	200	GeV	10^{32} $cm^{-2}s^{-1}$
LHC	p p	14	TeV	10^{34}
	P_b P_b	1312	TeV	10^{27}

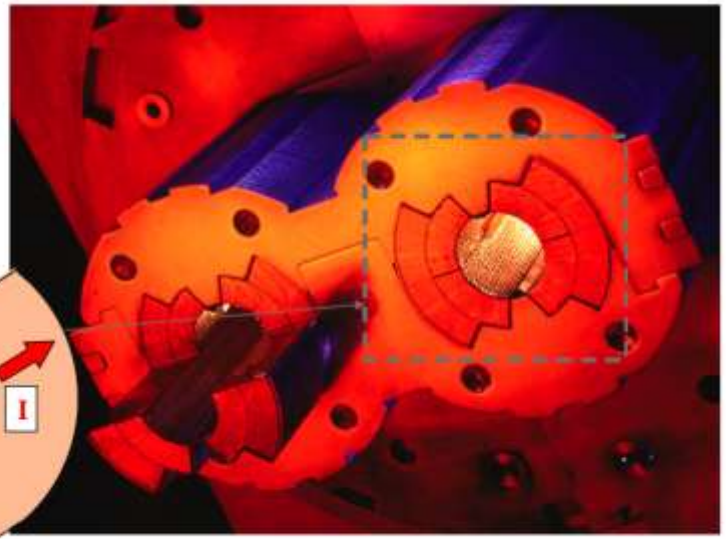


The challenge was the design and construction of the dipole magnets









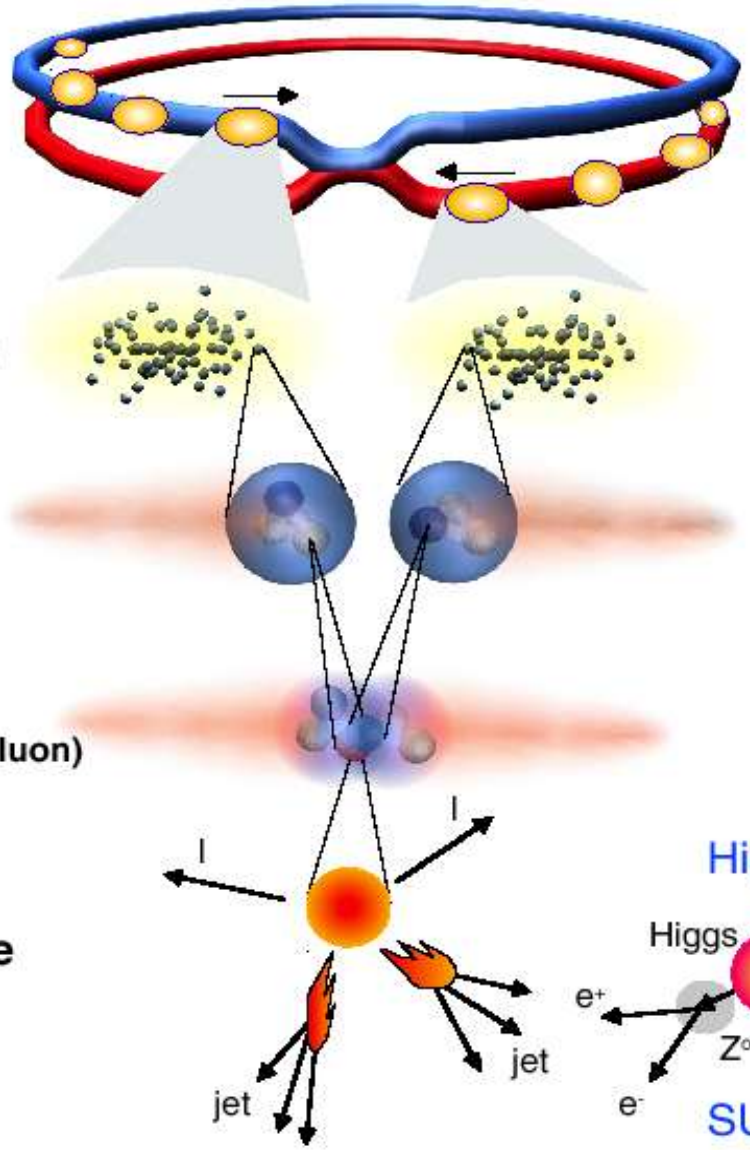
Magnetic Field for Dipoles
p (TeV) = 0.3 B(T) R(km)

1232 magnets, 35 tons each
The coldest ring in the universe ?1.9 K

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

The magnets cool down with liquid Helium under pressure

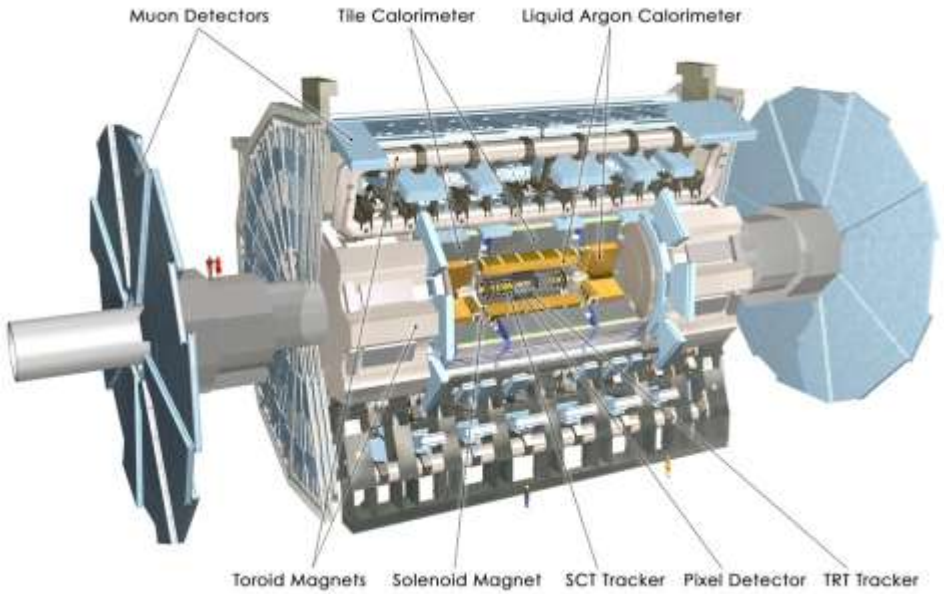
Collisions at LHC



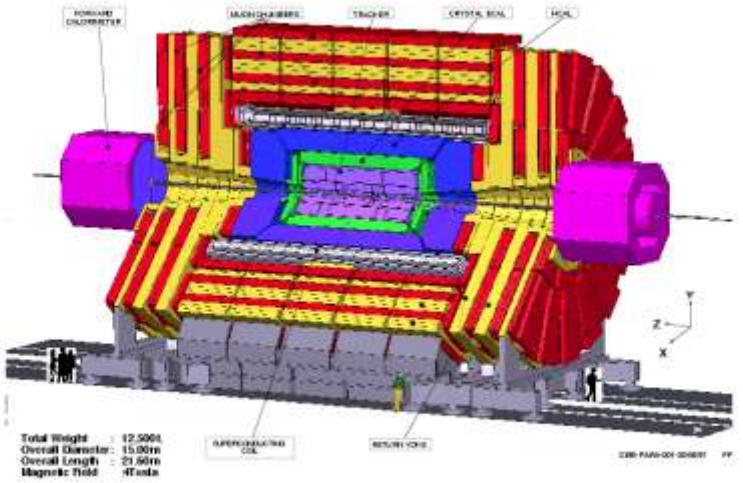
Proton-Proton	2835 bunch/beam
Protons/bunch	10^{11}
Beam energy	7 TeV (7×10^{12} eV)
Luminosity	10^{34} cm^{-2} s^{-1}
Crossing rate	40 MHz
Collisions ≈	10^{7} - 10^{9} Hz

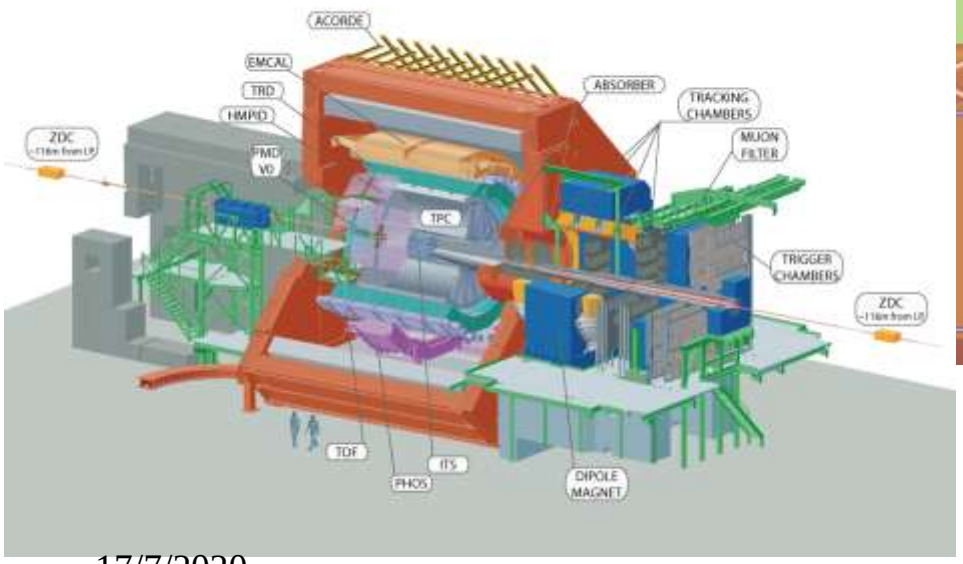
Selection of 1 in 10,000,000,000,000

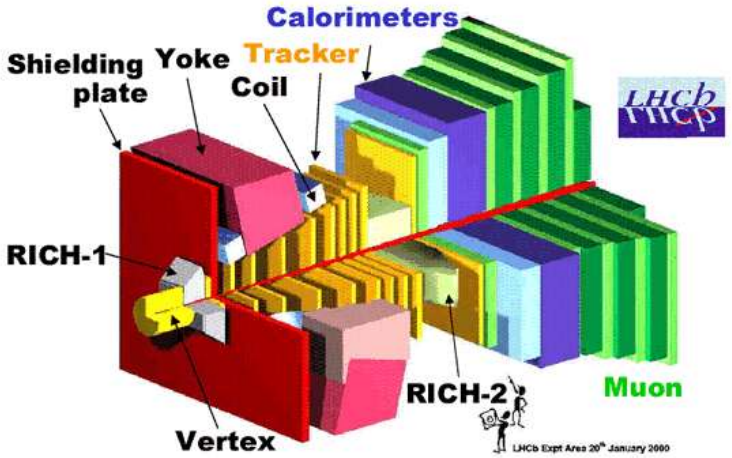
ATLAS



CMS





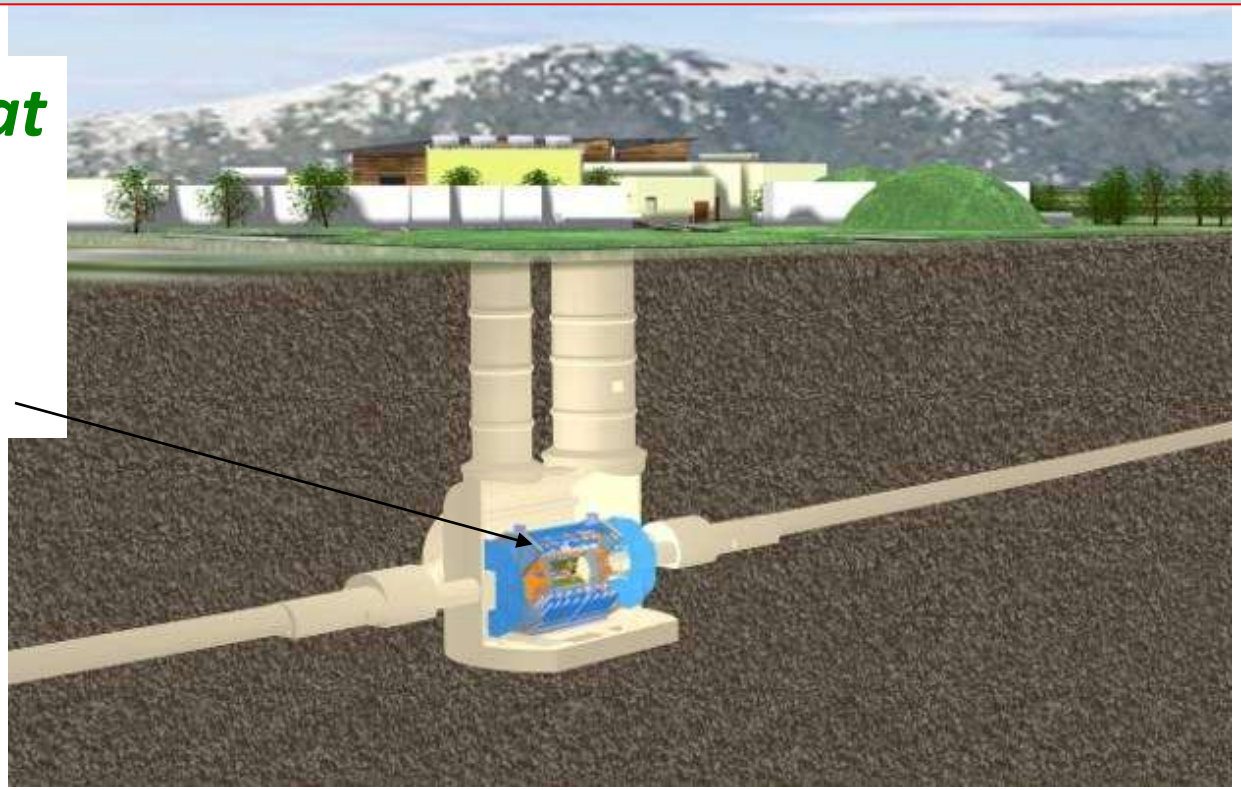


ALICE

LHC-B

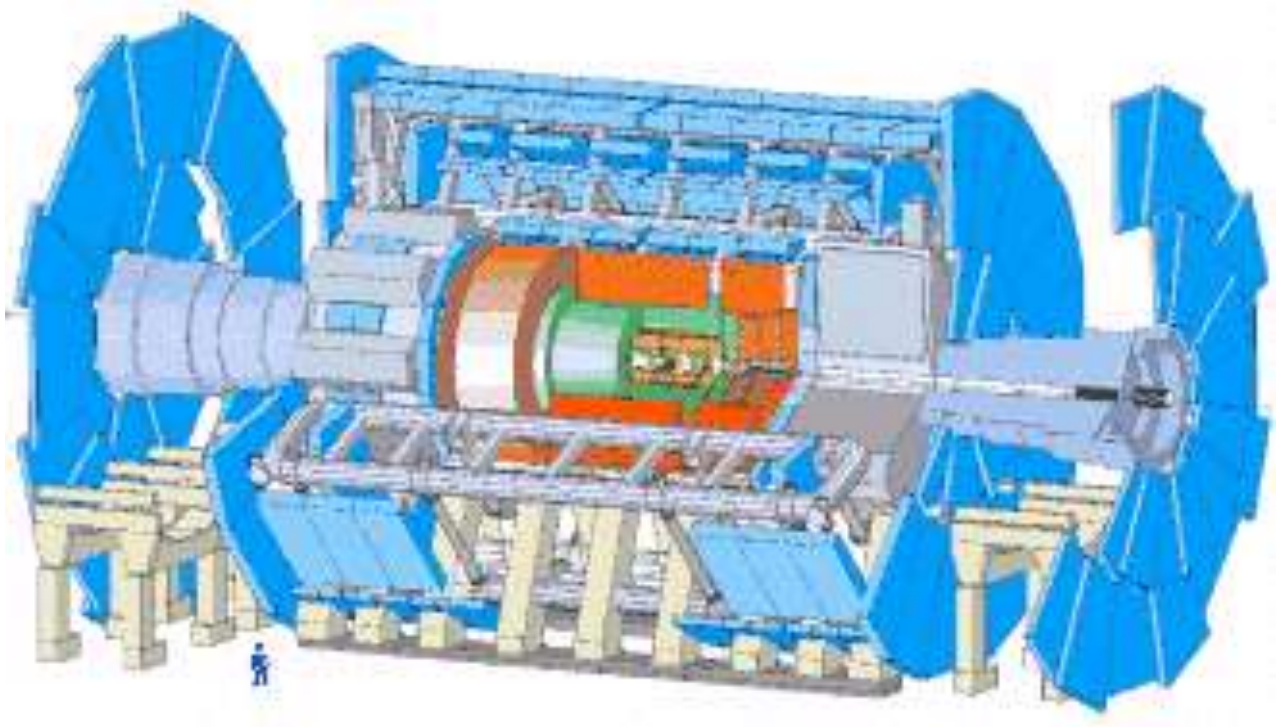
- **LHC pp colissions @ √ s=7.8 ->14 TeV**
- **Reconstruct colissions products with high accuracy in a hostile envirnoment**

The underground pit at Point 1 where the ATLAS experiment is installed (since 2008)

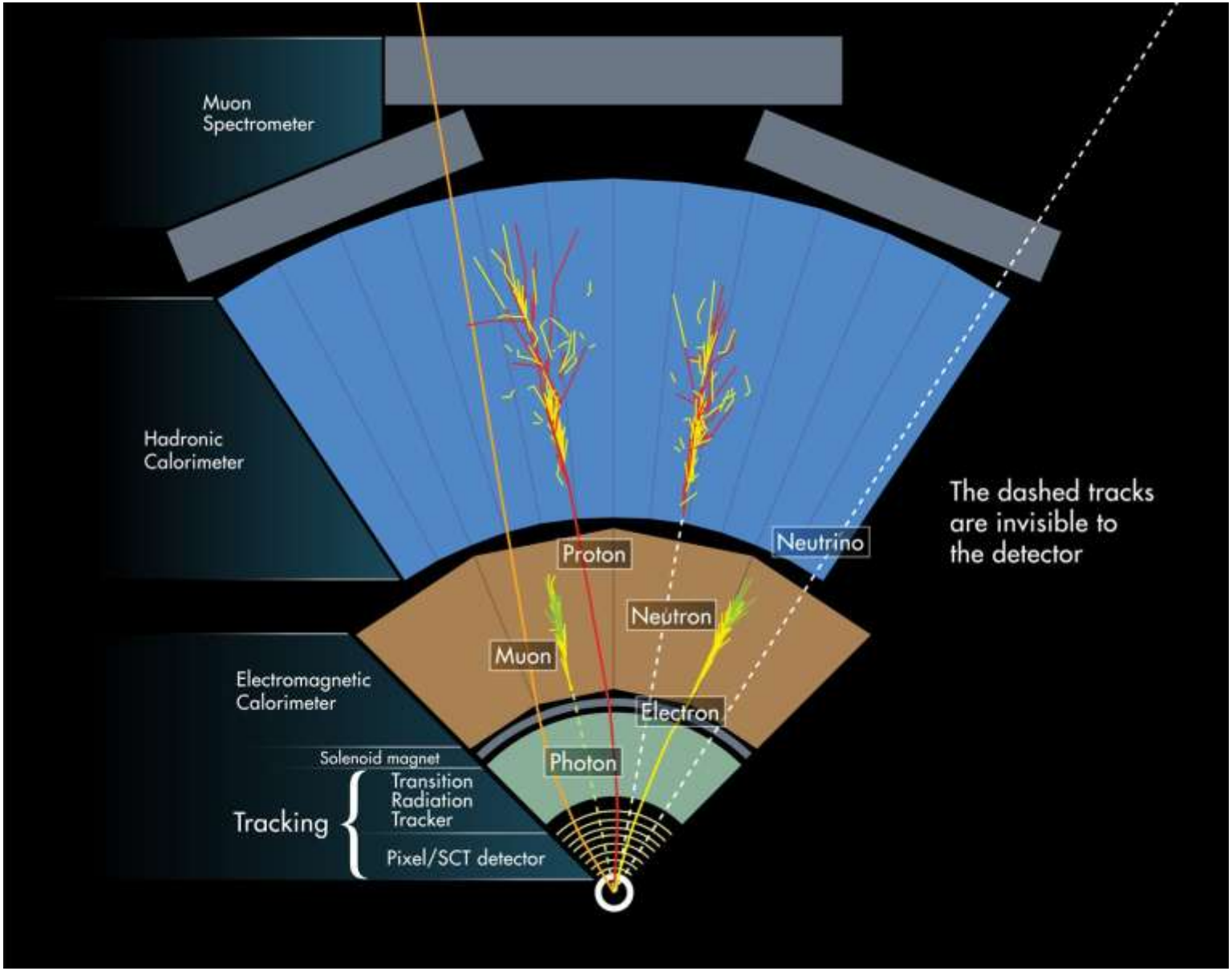


Length = 55 m
Width = 32 m
Height = 35 m

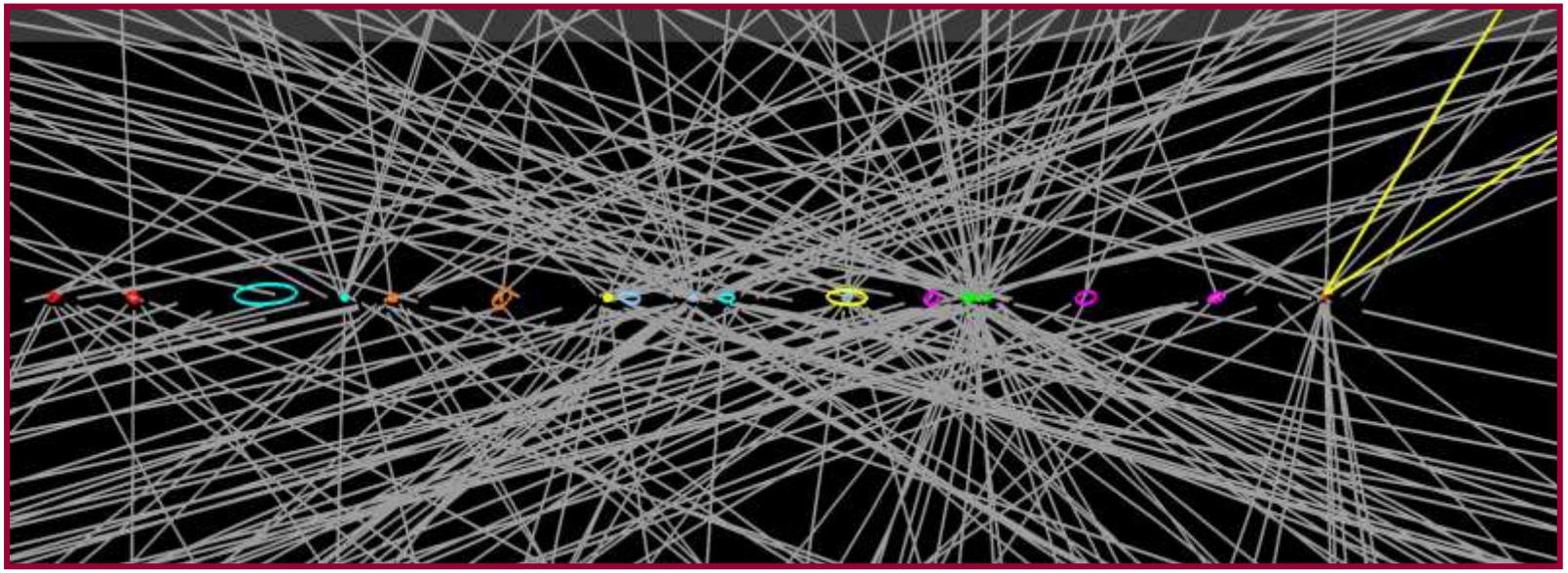
Different parts of the detector (subdetectors) identify/measure different particles

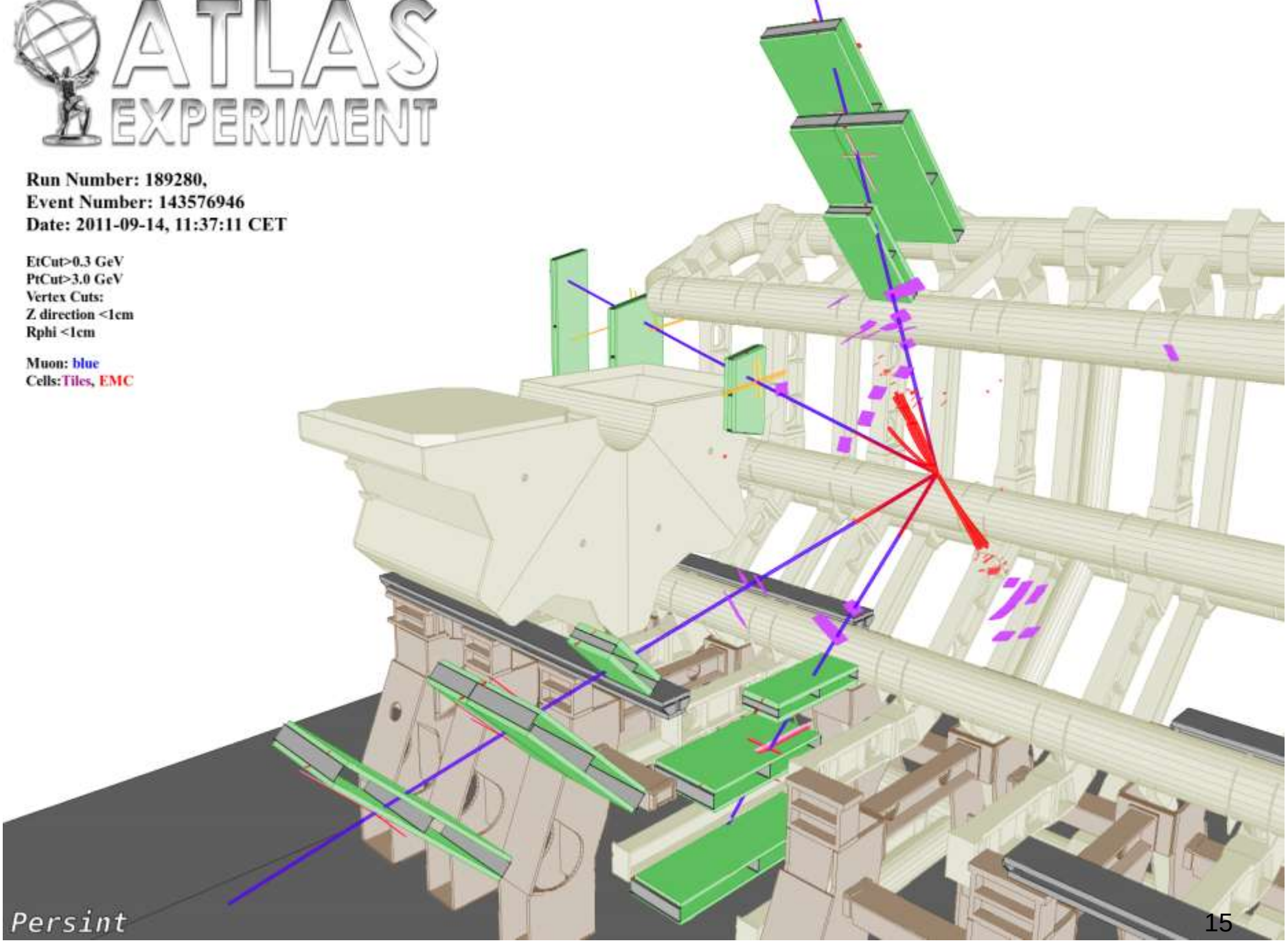


The requirements: Subdetectors

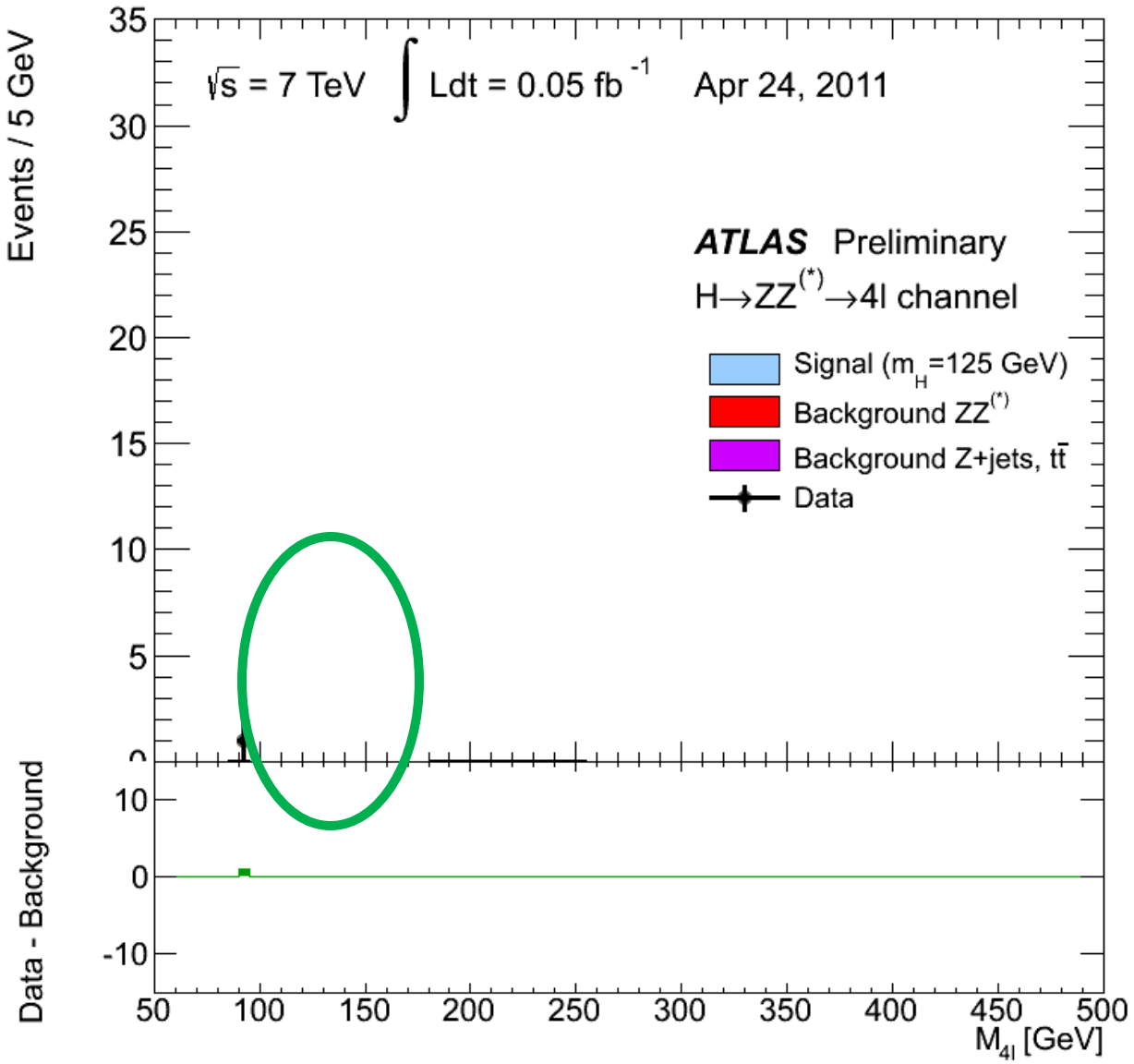


Very complex reconstruction of interaction vertices at the LHC

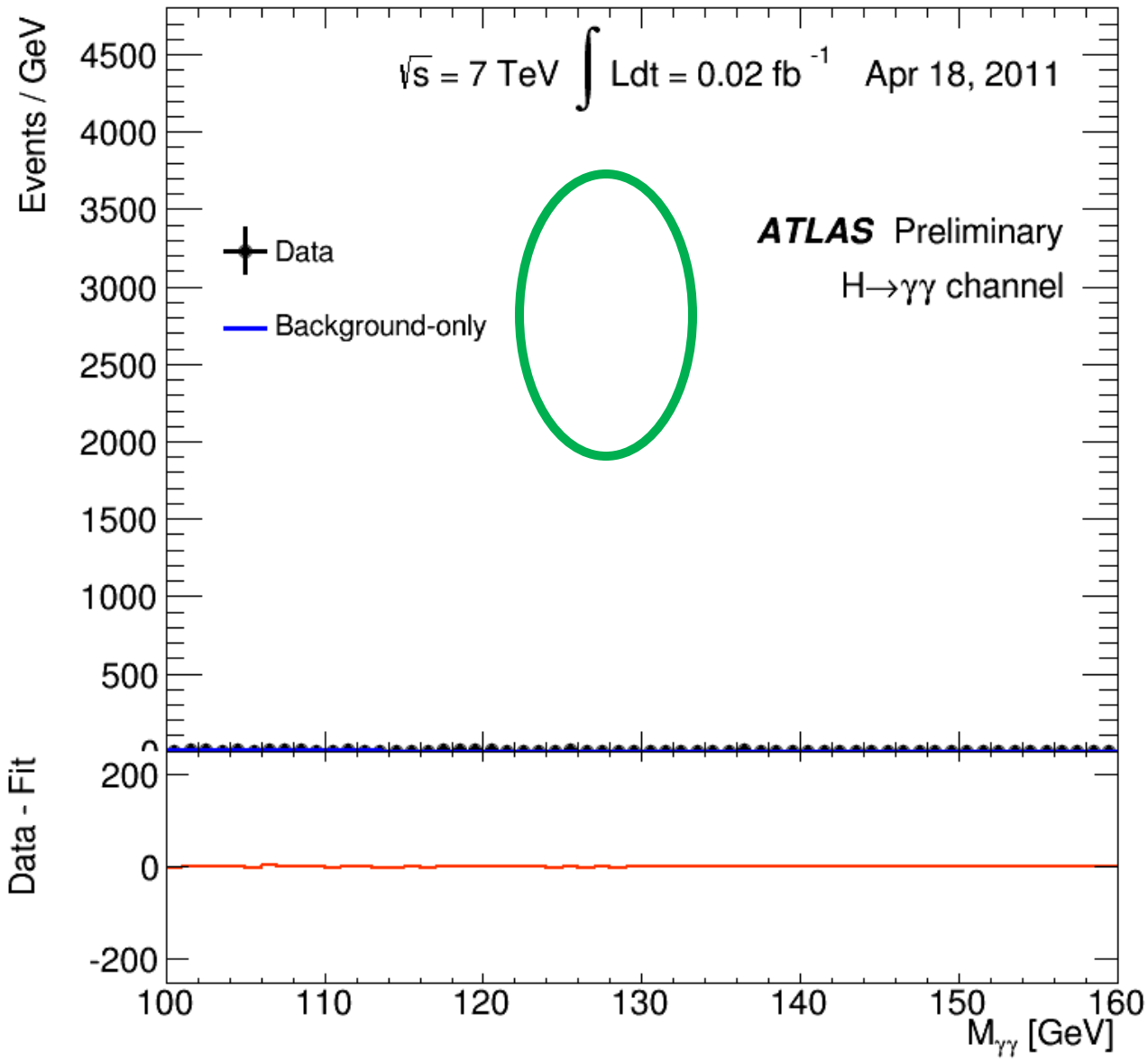



ATLAS
EXPERIMENT
Run Number: 189280,
Event Number: 143576946
Date: 2011-09-14, 11:37:11 CET
EtCut>0.3 GeV
PtCut>3.0 GeV
Vertex Cuts:
Z direction <1cm
Rphi <1cm
Muon: blue
Cells:Tiles, EMC
Persint

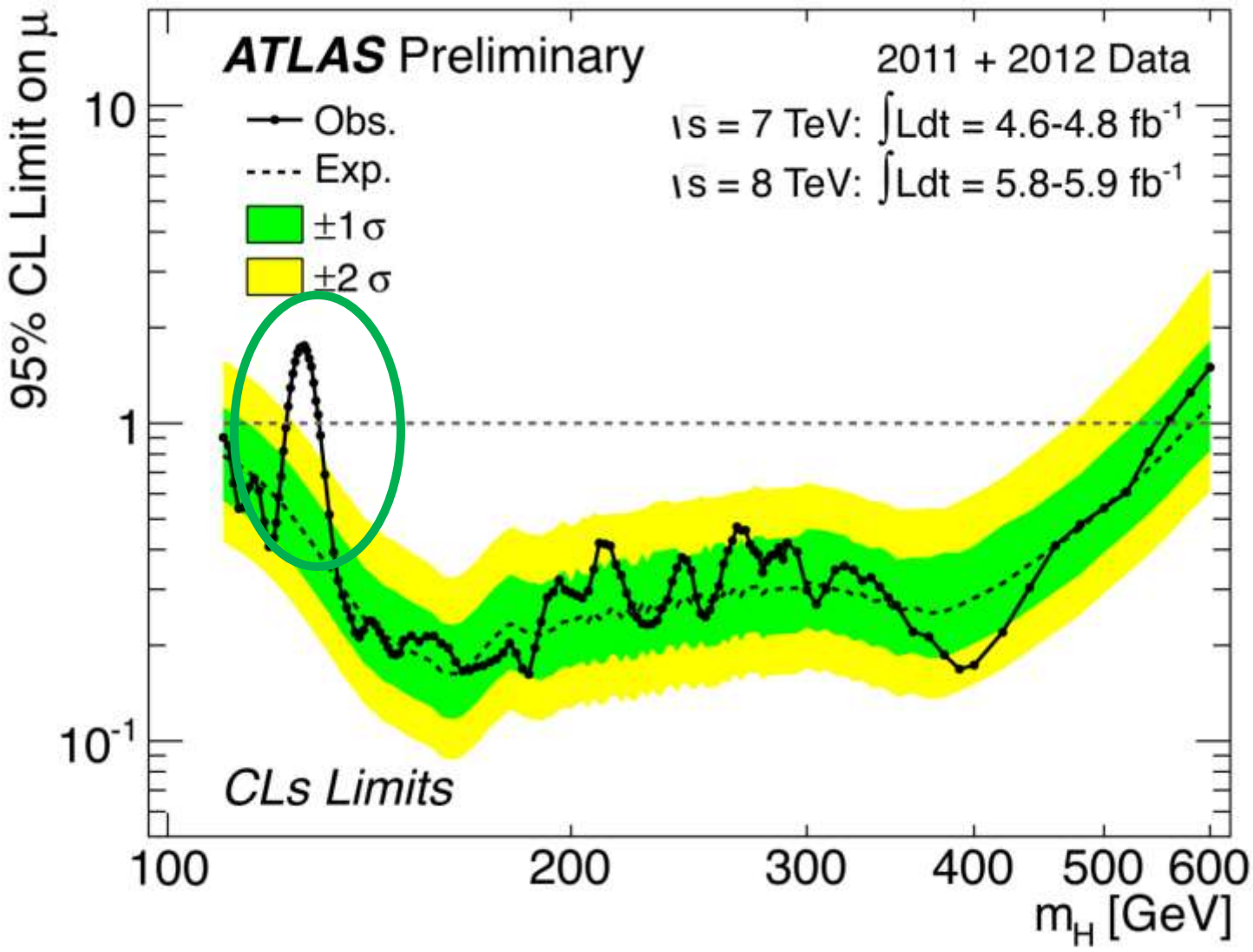
Reconstruction of H->ZZ(*)->4l mass



Reconstruction of the H->γγ mass



The discovery



The announcement

The Nobel Prize in Physics 2013

François Englert, Peter Higgs

The Nobel Prize in Physics 2013

Photo: A. Mahmoud

François Englert

Photo: A. Mahmoud

Peter W. Higgs

The BEH mechanism solves the question of how particles acquire their mass BUT there are still unanswered questions

- What is the dark mass and energy?
- Why there is more matter that antimatter?
- How the theory of gravity fits to the SM?
- Are the quarks and leptons elementary ?
- Why are there three quark and lepton families?

Medical Applications

CAT, MRI, PET, Hadron therapy

Technological Applications

Biology

Crystallography

Automatic controls

Electronics

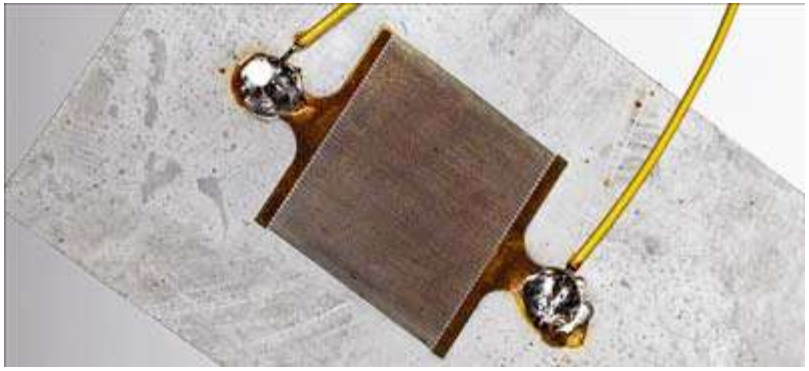
Lithography

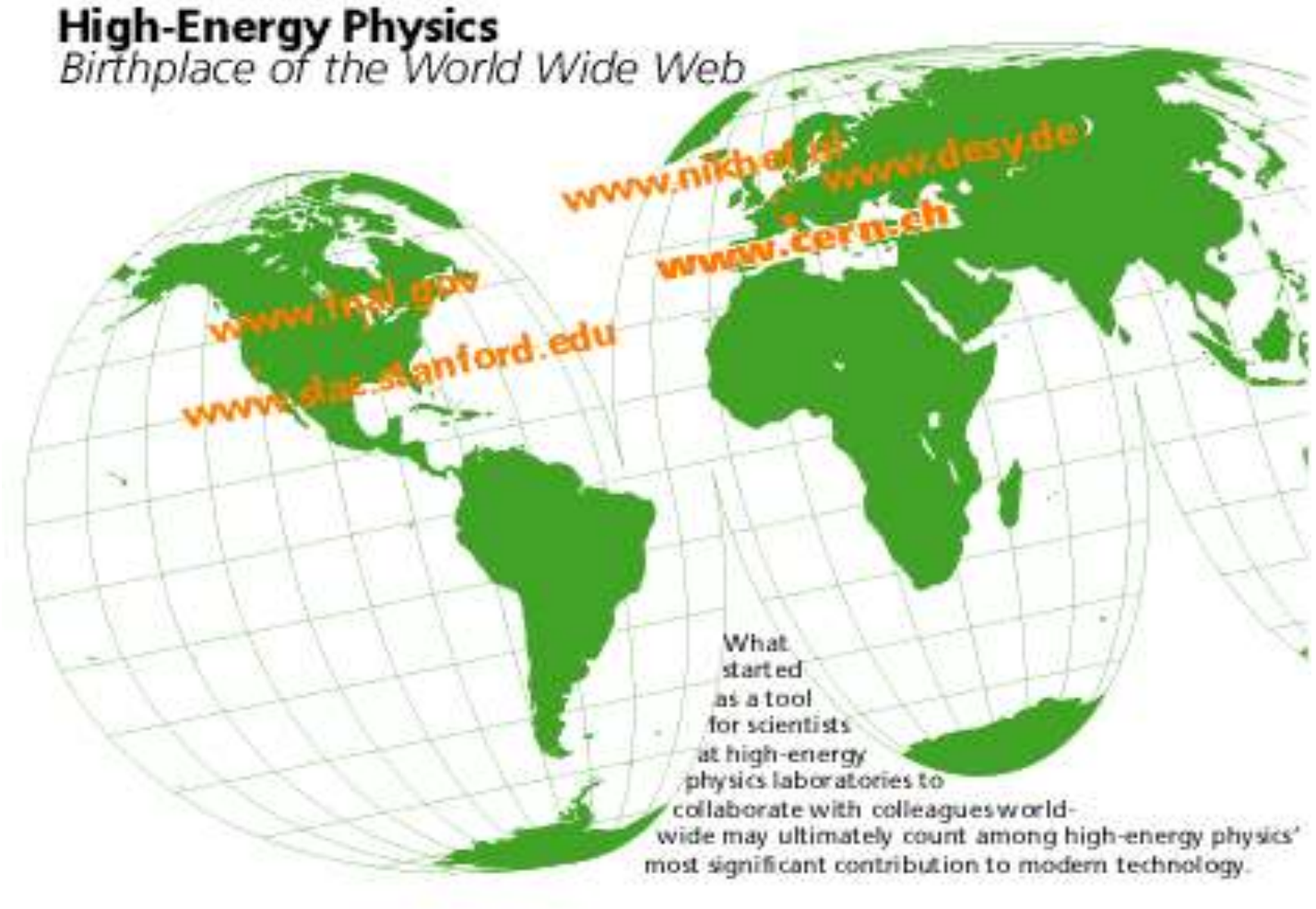
Superconductivity

Computing

Touch screen

The SPS control room in 1977.
The desk, **with its touch screens**;

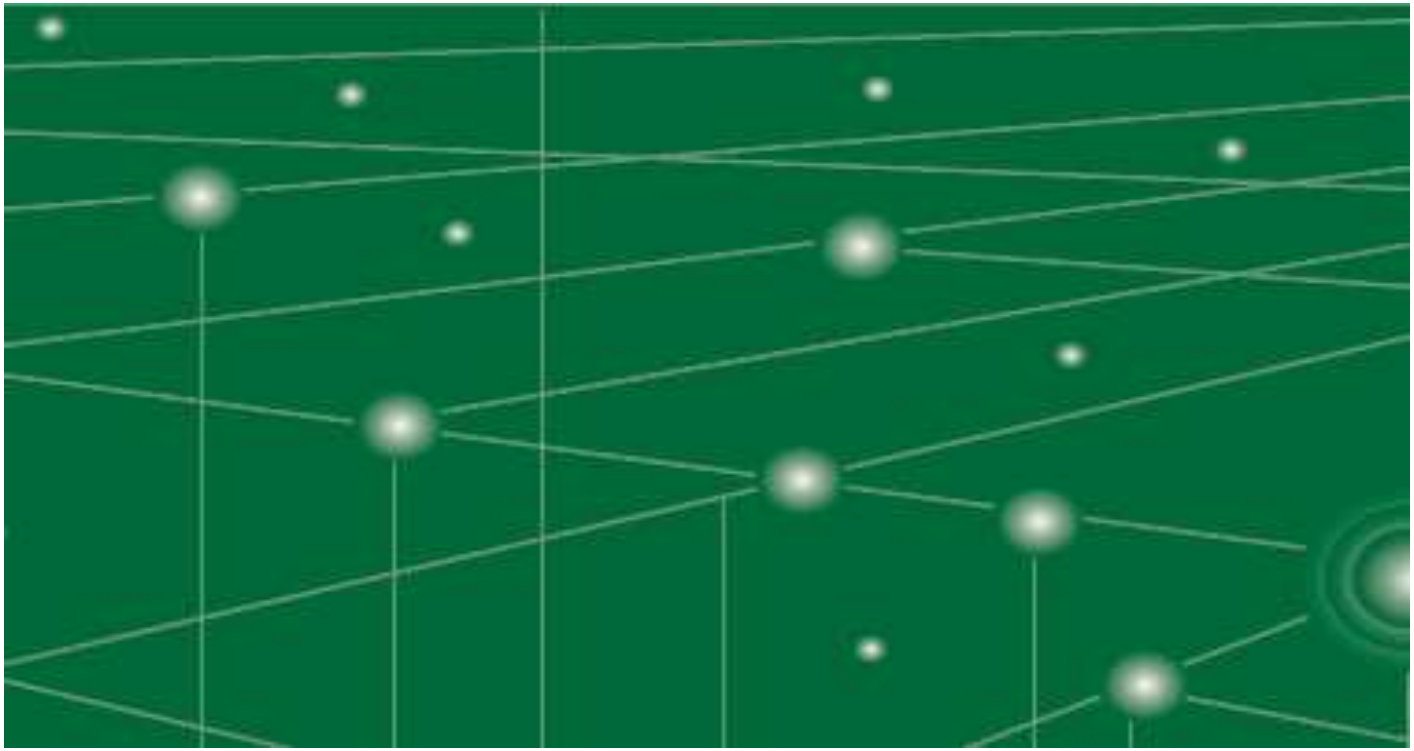




The WWW was born at CERN !

The GRID

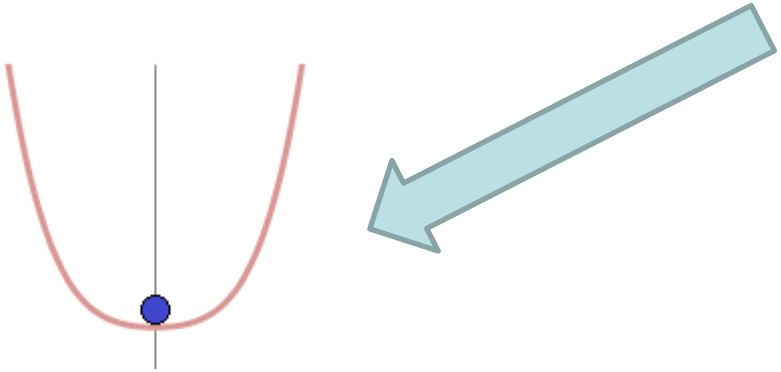
(the technology of the computing grid)



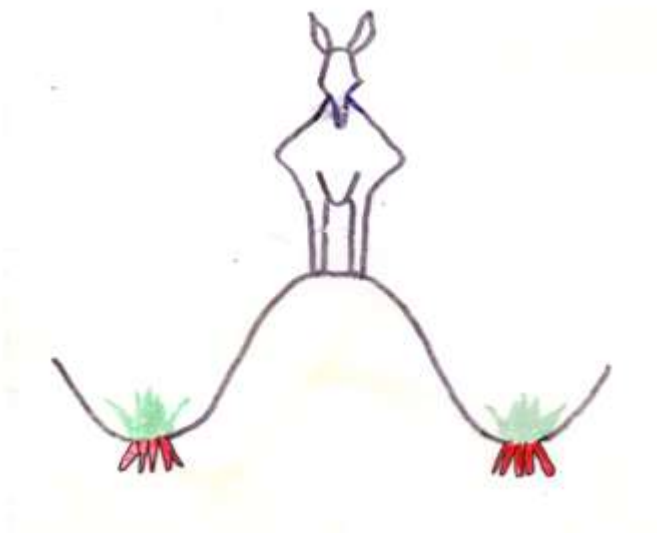
- Back-up

Brout-Englert-Higgs mechanism

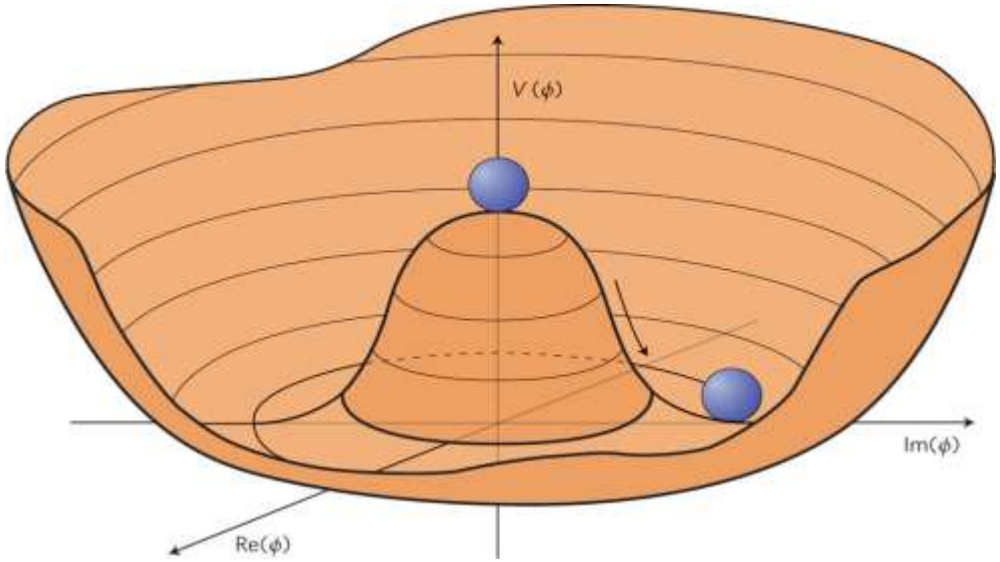
The spontaneous symmetry breaking

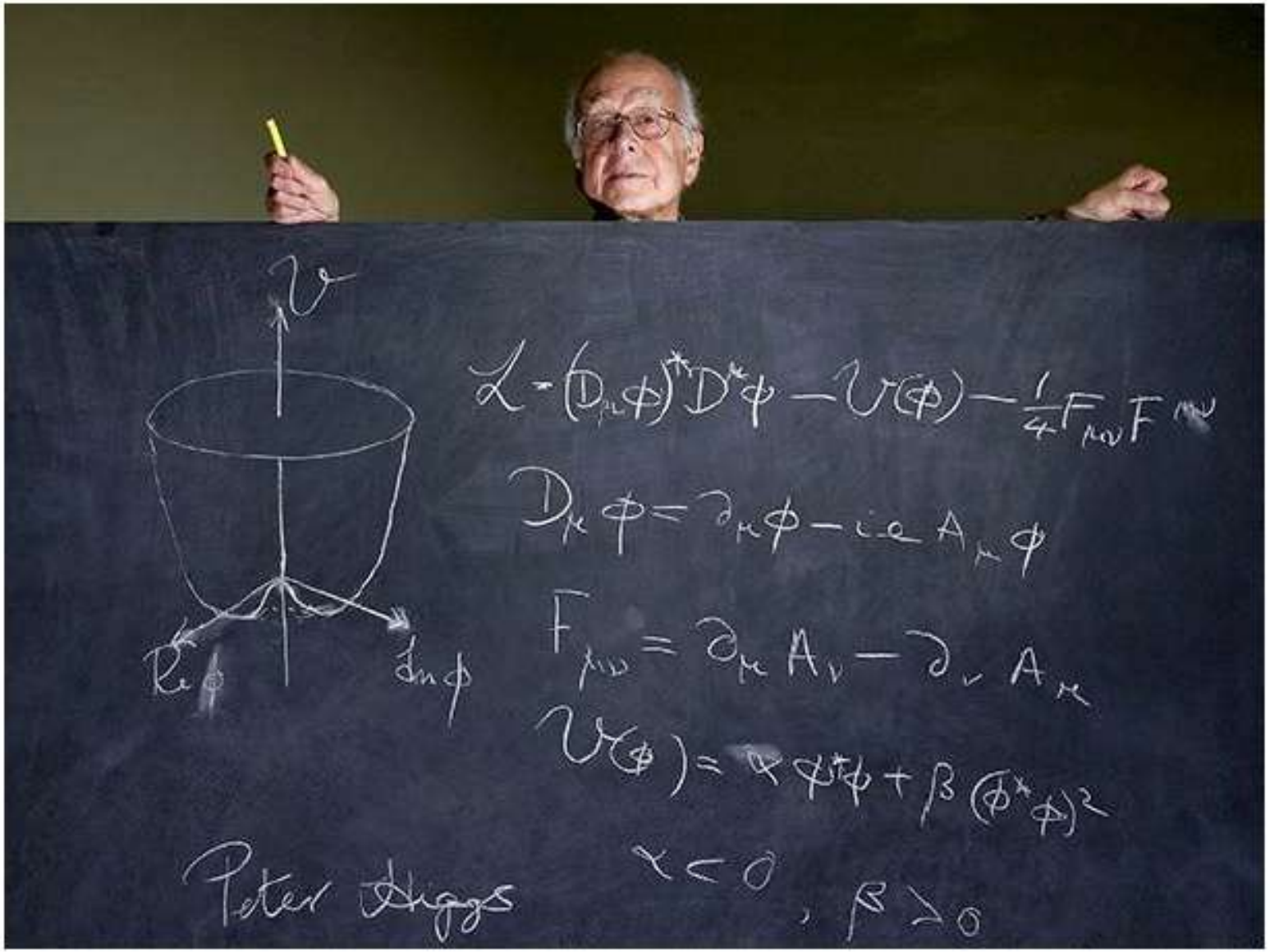


Buridan's donkey



The mexican sobrero

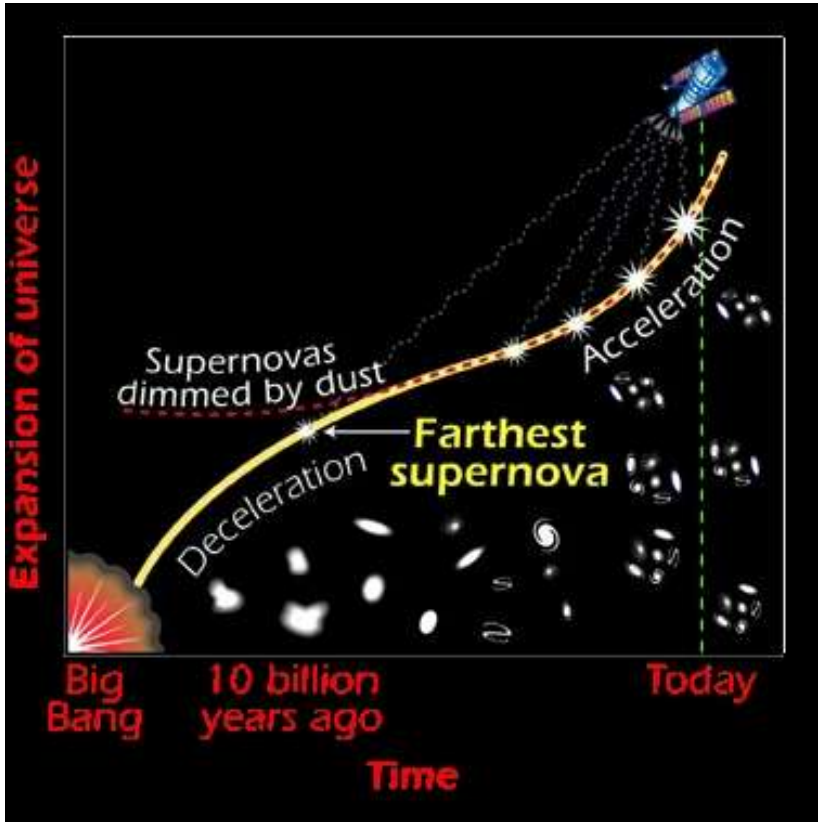



v
Re φ
Im φ
$\mathcal{L} = (D_\mu \phi)^* D^\mu \phi - V(\phi) - \frac{1}{4} F_{\mu\nu} F^{\mu\nu}$
$D_\mu \phi = \partial_\mu \phi - ig A_\mu \phi$
$F_{\mu\nu} = \partial_\mu A_\nu - \partial_\nu A_\mu$
$V(\phi) = \alpha \phi^* \phi + \beta (\phi^* \phi)^2$
Peter Higgs
$\alpha < 0, \beta > 0$


Dark Energy
73%
Atoms 4%
Cold
Dark
Matter
23%

How do we know about the «dark matter and energy»

From measurements of far away supernova



From measurements from WMAP