Making the Invisible Visible and the Impossible Possible

Erna Hamburger Prize 2012

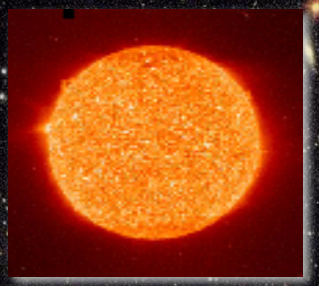
EPFL · WISH FOUNDATION

6 March 2012

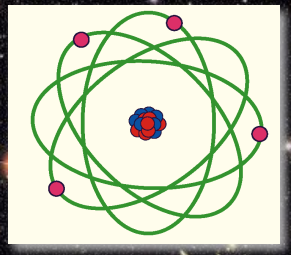
Felicitas Pauss
CERN and ETH Zurich

Our Visible Universe

~10^{11} Galaxies



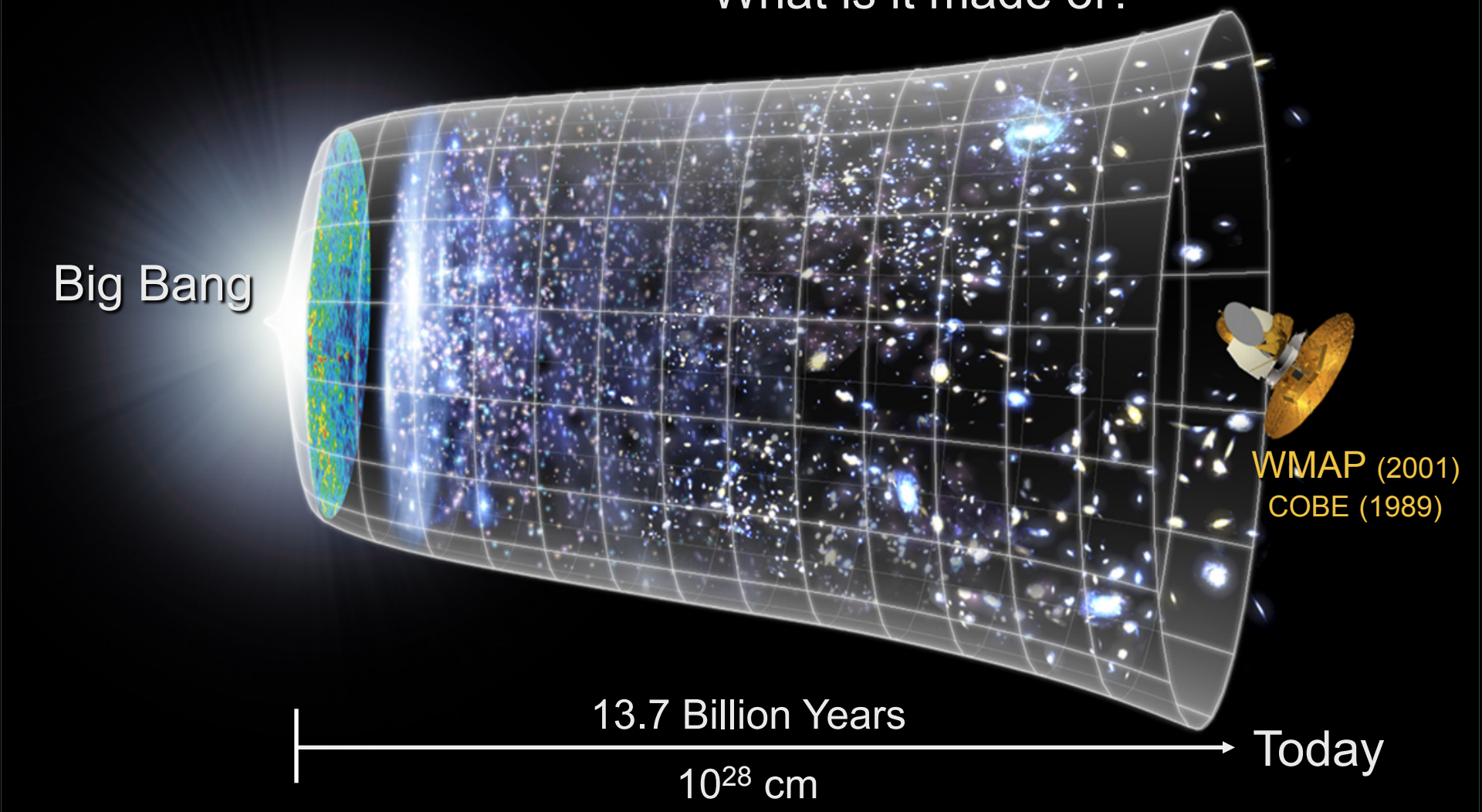
~10^{21} Stars



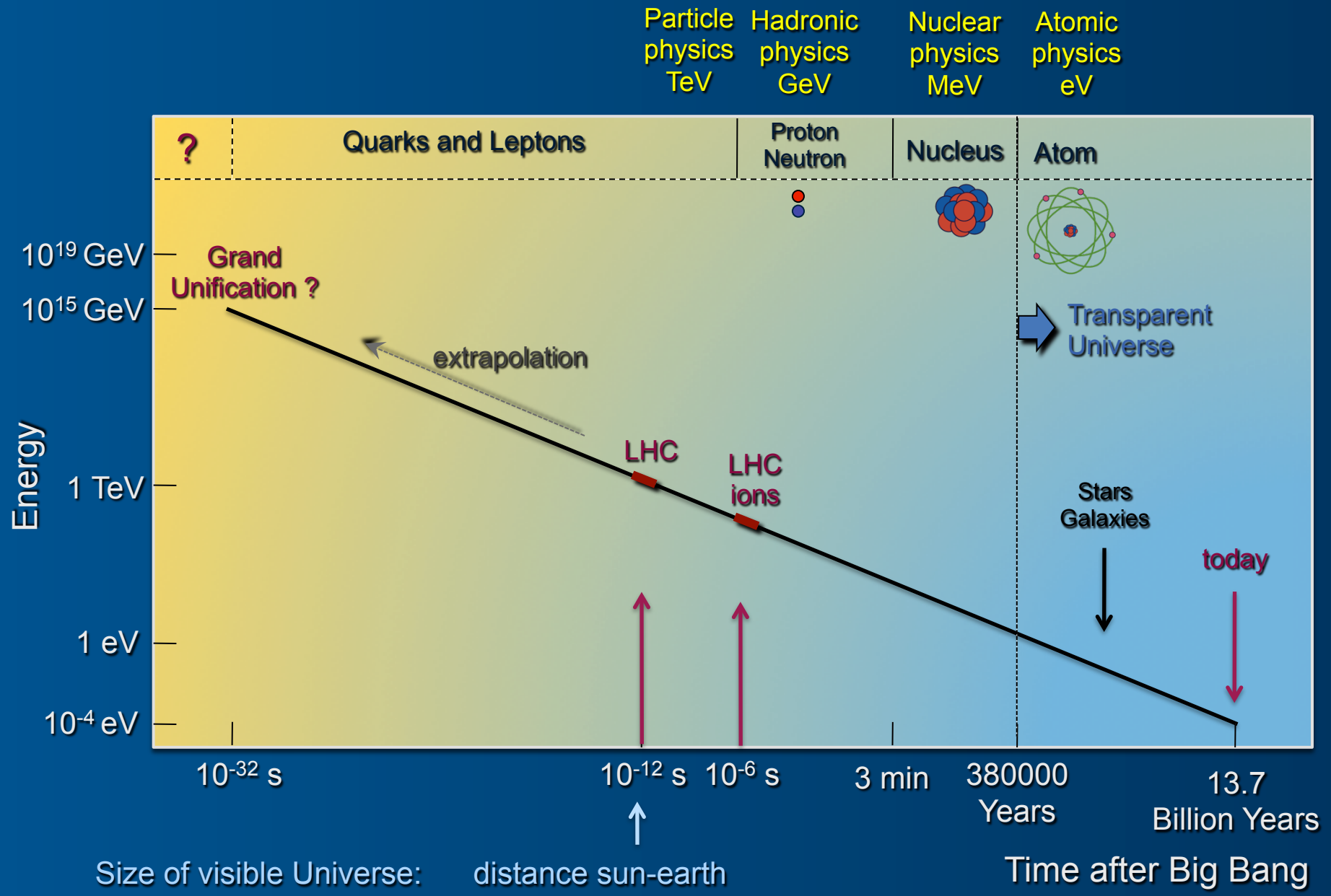
~10^{78} Atoms

~10^{88} Photons

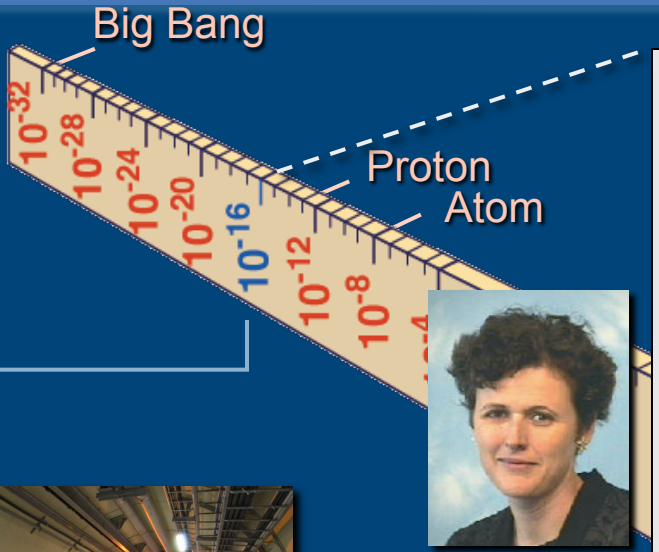
Our Universe ..... How did it evolve after the BB? What is it made of?

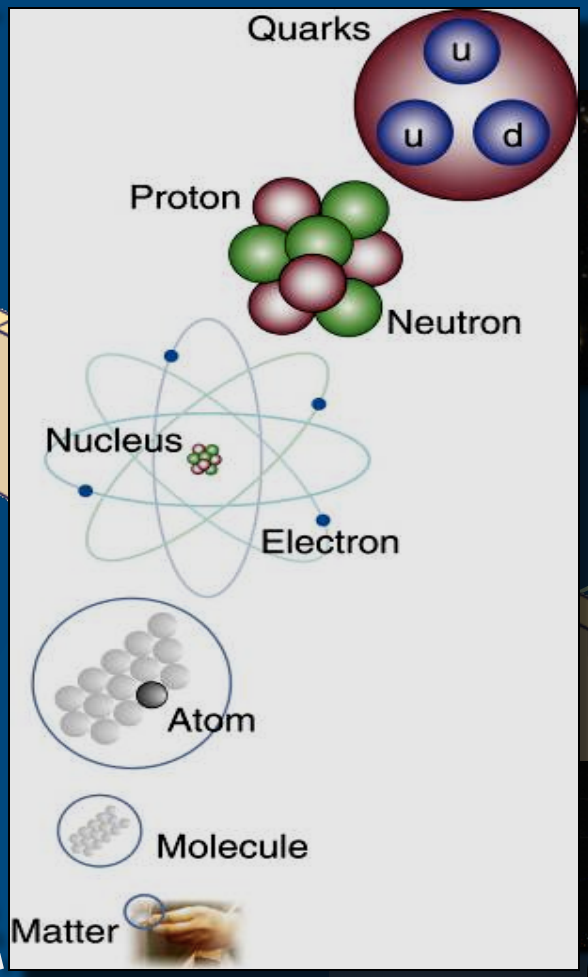


The prevailing model is one of an expanding Universe, evolving from small to big, from hot to cold, from dense to diluted, from simple to complex


Particle physics TeV
Hadronic physics GeV
Nuclear physics MeV
Atomic physics eV
?
Quarks and Leptons
Proton Neutron
Nucleus
Atom
Energy
10^19 GeV
10^15 GeV
1 TeV
1 eV
10^-4 eV
Grand Unification ?
extrapolation
LHC
LHC ions
Transparent Universe
Stars Galaxies
today
10^-32 s
10^-12 s
10^-6 s
3 min
380000 Years
13.7 Billion Years
Size of visible Universe:
distance sun-earth
Time after Big Bang

Dimensions in Physics





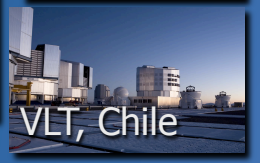
Radius of Galaxies

Universe

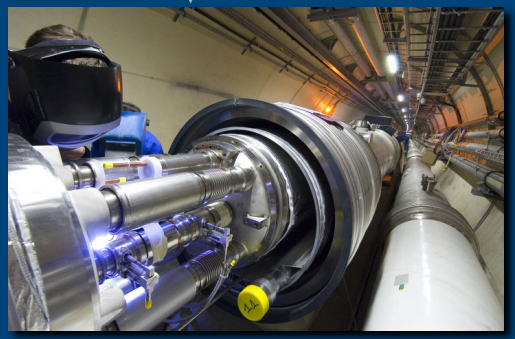
10^{24}

10^{28}

cm



CERN

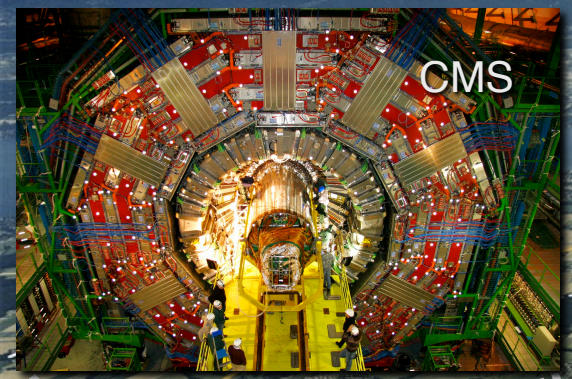


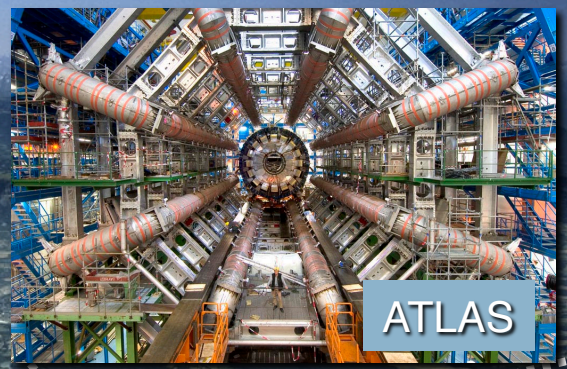
LHC

Super-Microscope

Study physics laws of first moments after Big Bang
increasing Symbiosis between Particle Physics,
Astrophysics and Cosmology

LHC → a New Era in Fundamental Science





Exploration of a new energy frontier
in p-p and Pb-Pb collisions

Switzerland and CERN

Strong involvement in the LHC experimental programme
ATLAS, CMS and LHCb
presently: ~ 100 scientists and > 60 PhD students

ATLAS:
University of Bern
University of Geneva

LHCb:
EPFL
University of Zurich

CMS:
ETH Zurich
PSI
University of Zurich

Innovative technologies developed
Swiss industry has played an important role

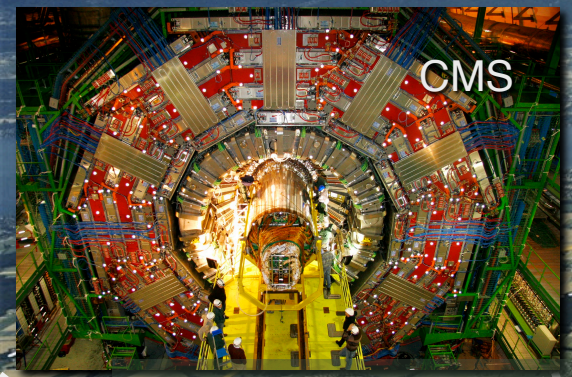
A high performance computing farm (Tier-2) is set up at the Swiss National Supercomputing Center (CSCS), in Manno (TI), as part of the world-wide computing Grid.

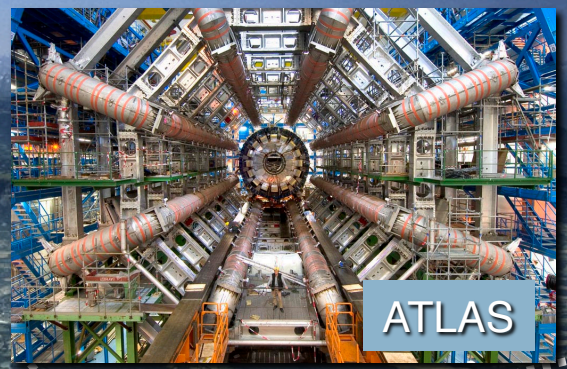
LHC → a New Era in Fundamental Science

$E = m c^2$

10^{11} Protons per bunch
~ 3000 bunches
collisions: $40 \cdot 10^{6}$ per second

LHC → a New Era in Fundamental Science





Spectacular start-up at high energy on 30 March 2010

→ Brilliant performances of LHC, experiments and GRID computing during 2010 and 2011 data taking periods

Making the impossible possible

Large International Collaborations

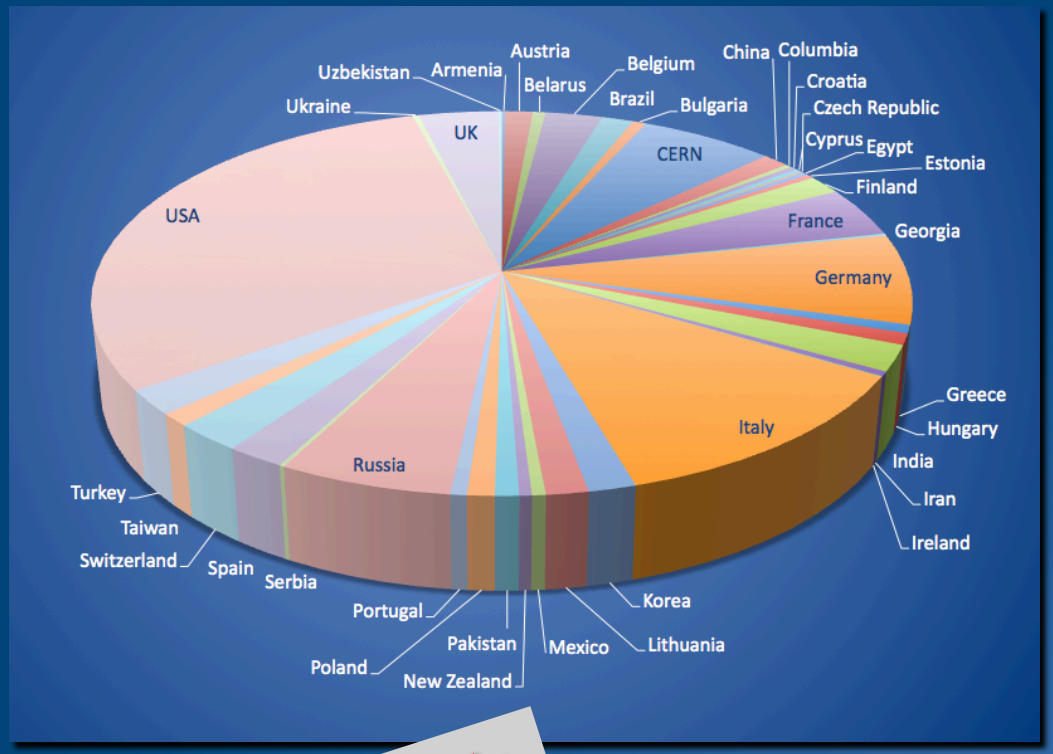
CMS Example

CMS Collaboration

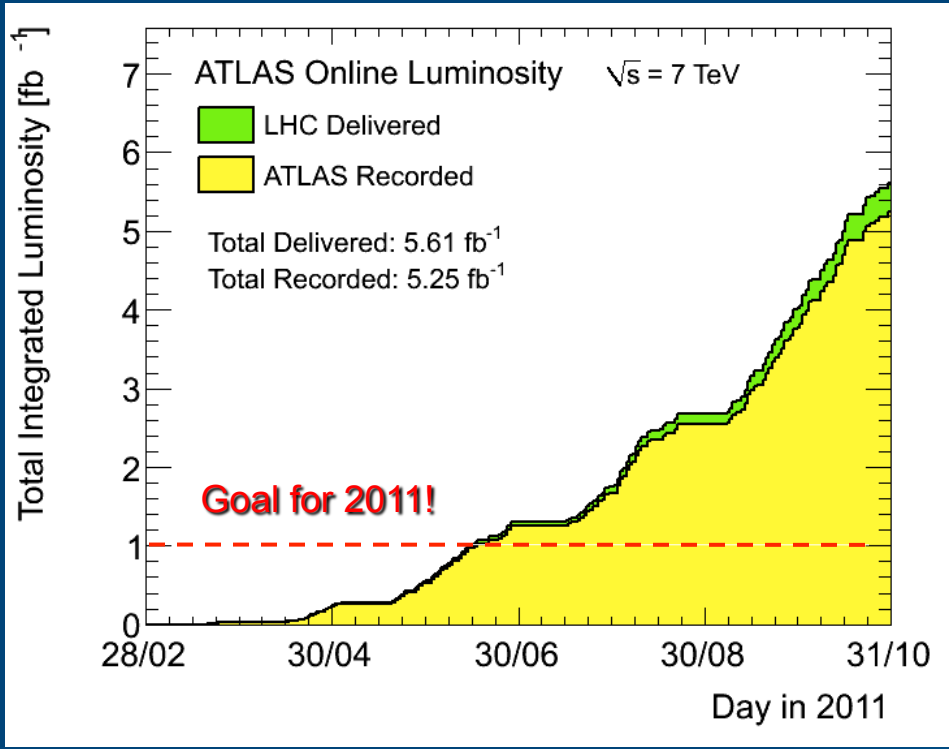
~4000 members

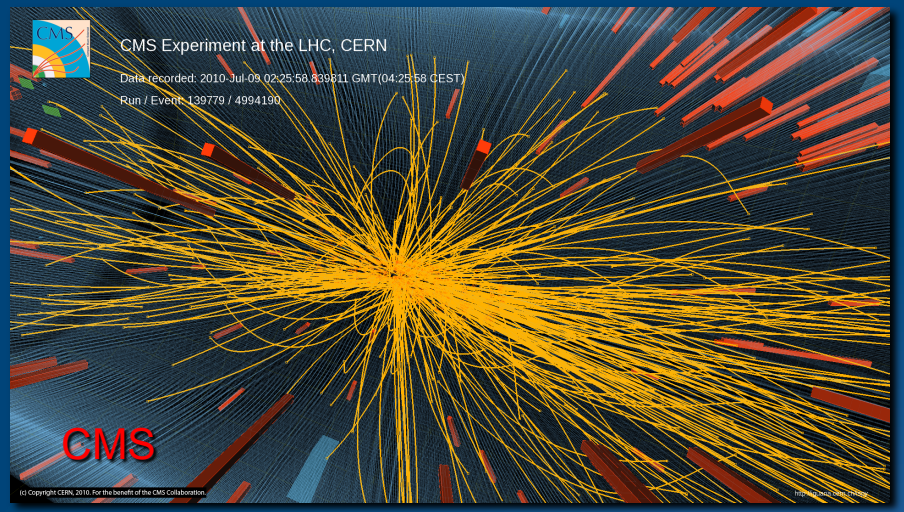
~40 countries

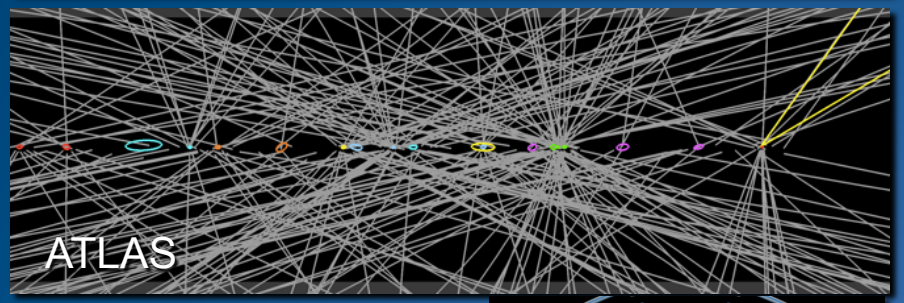
~180 institutes



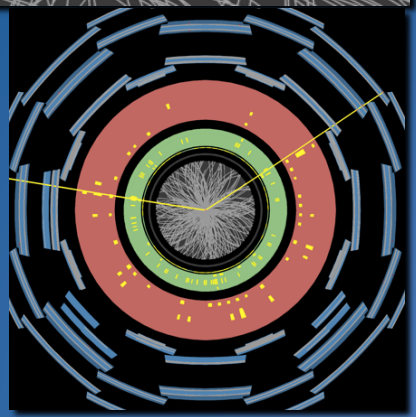
What did we learn so far from pp collisions at LHC?







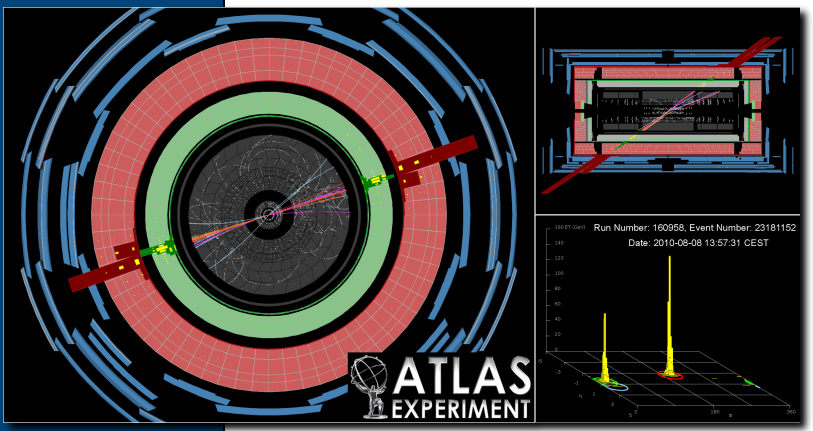
Z → $\mu^+\mu^-$ event recorded by ATLAS with 20 reconstructed vertices



→ Focus on ATLAS and CMS

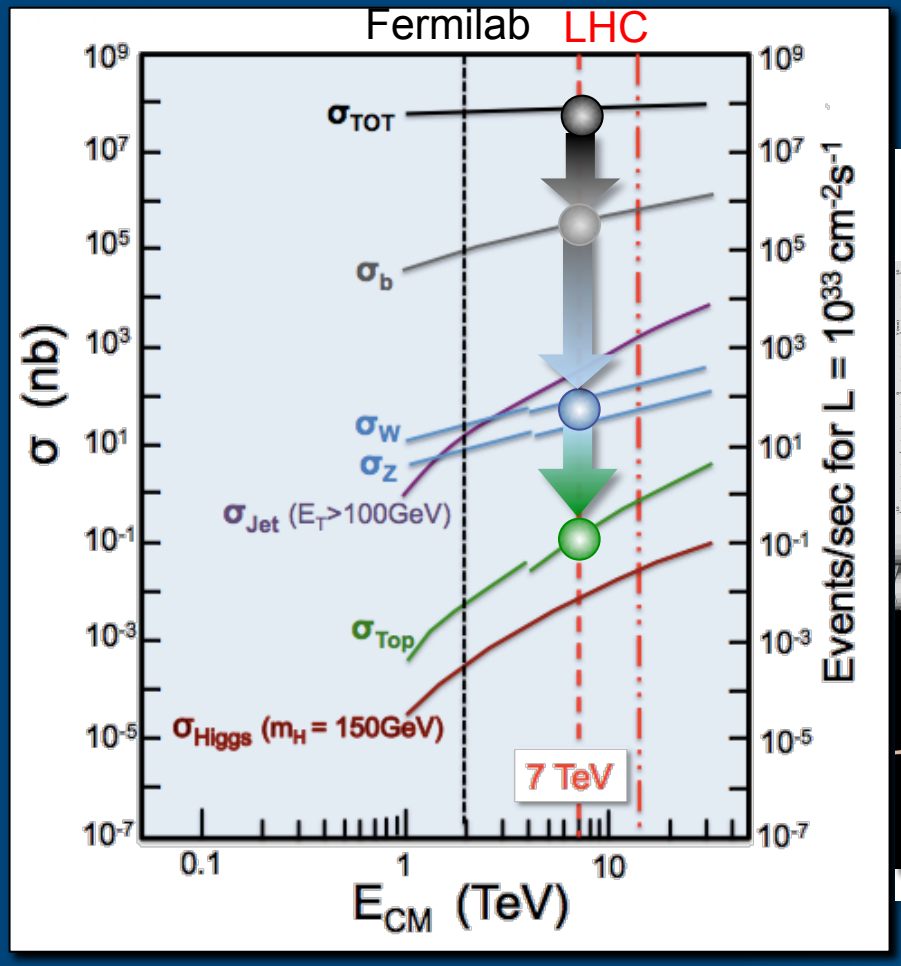
Proton-Proton Collisions

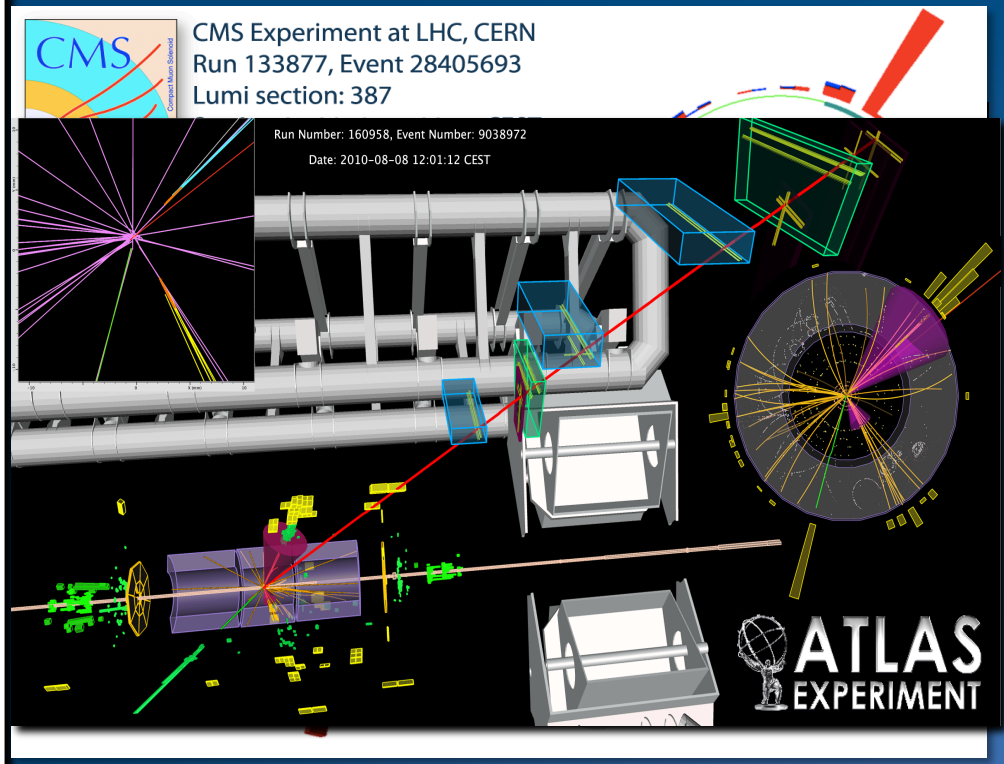
The basic process



$$N_{ev} = L_{\text{int}} \times \sigma$$

Proton-Proton Collisions





→ "re-discovered" Standard Model → excellent agreement!

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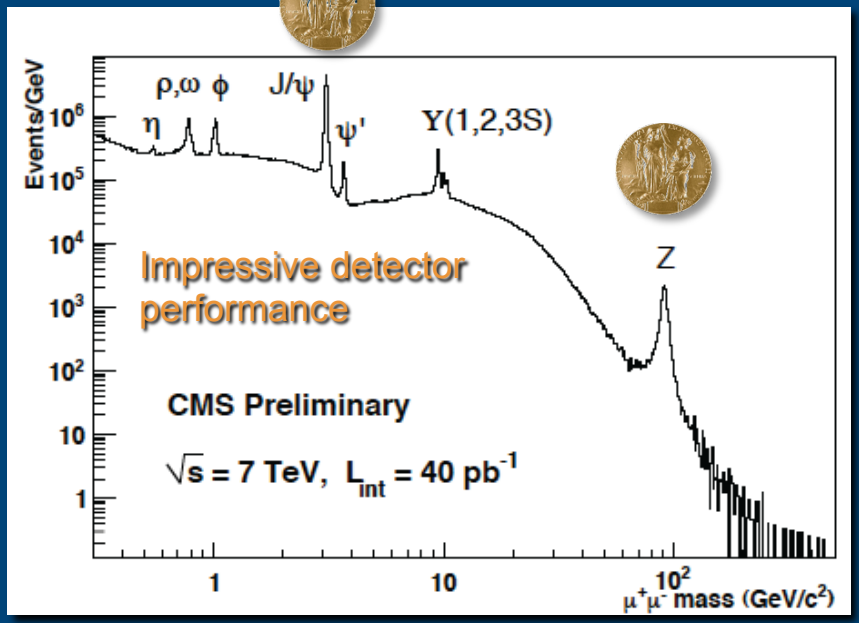
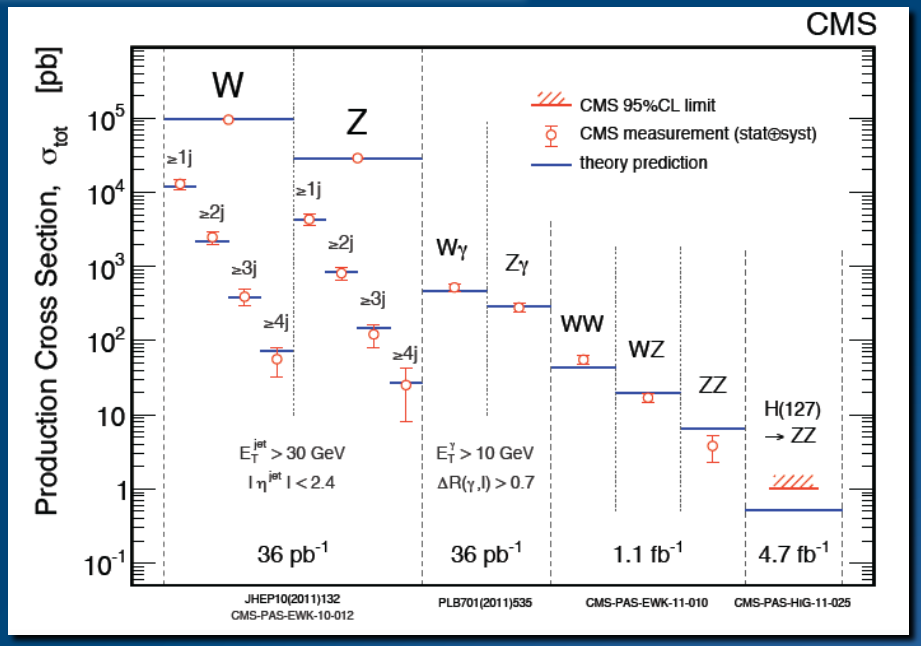
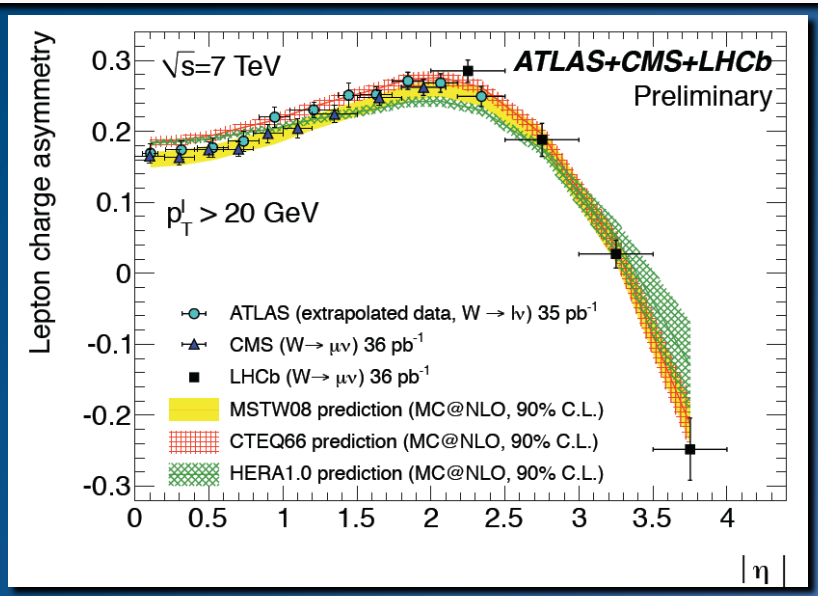
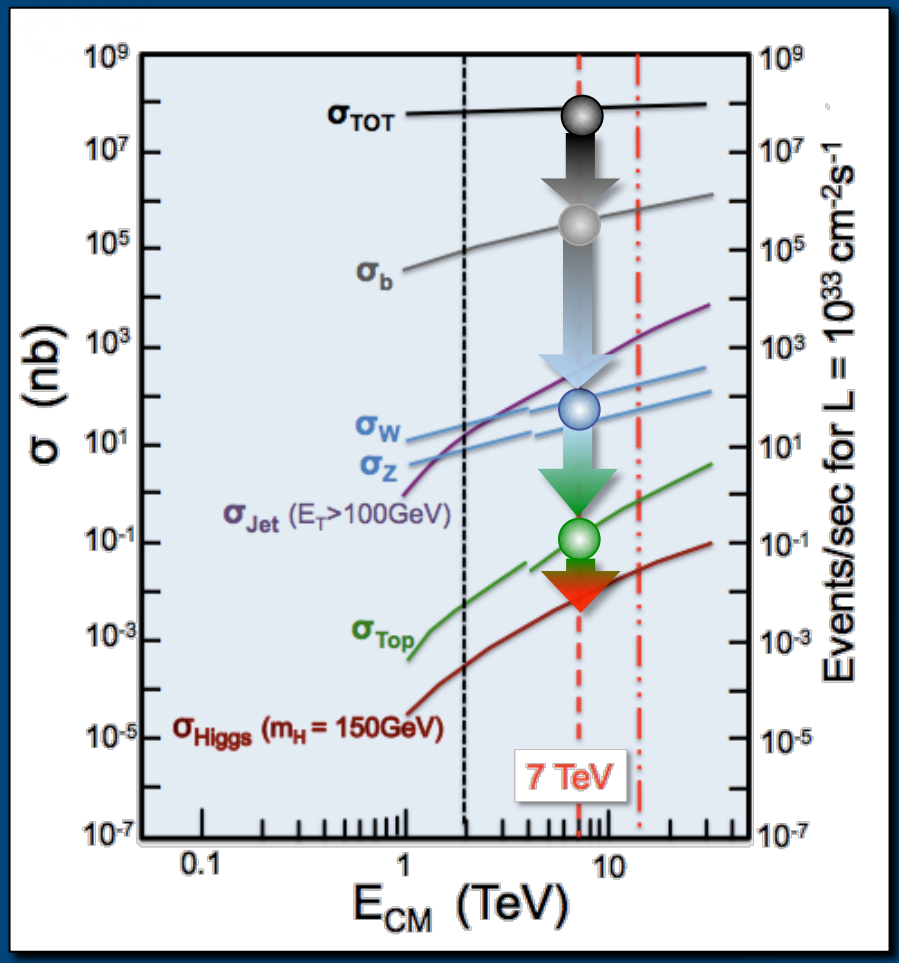


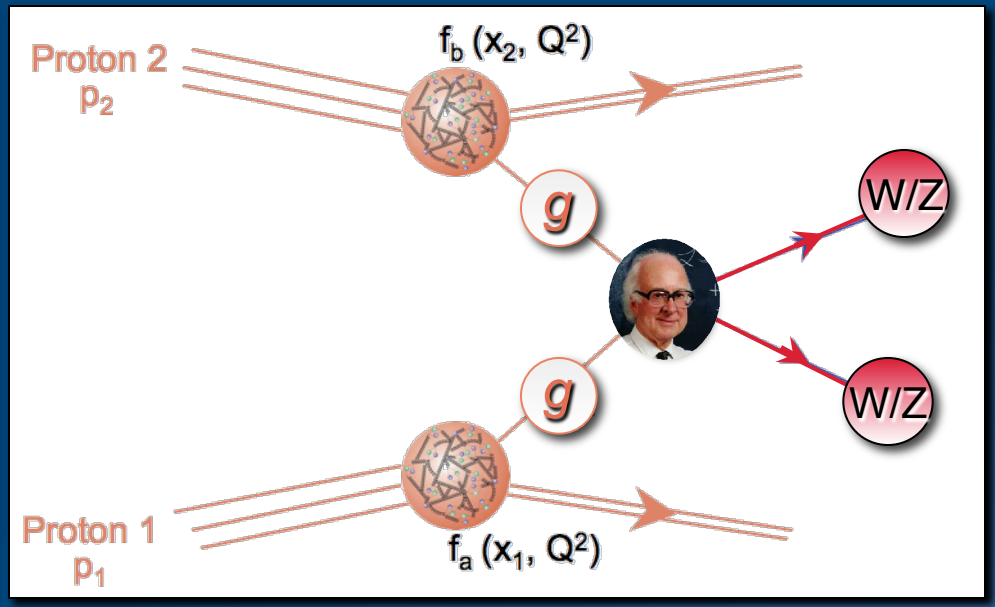


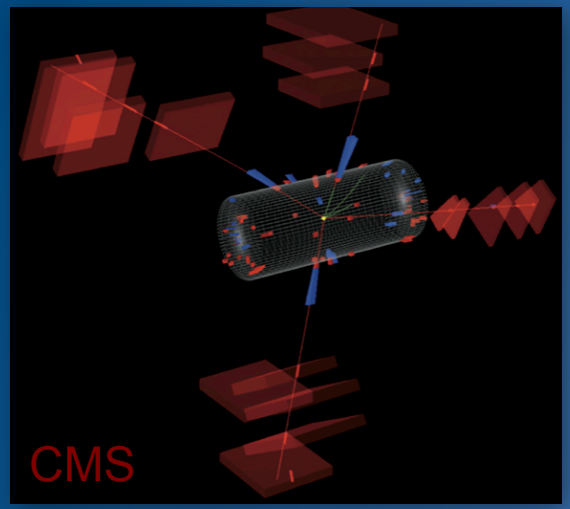


ATLAS and CMS have already produced O(100) papers, each, on collision data

Proton-Proton Collisions





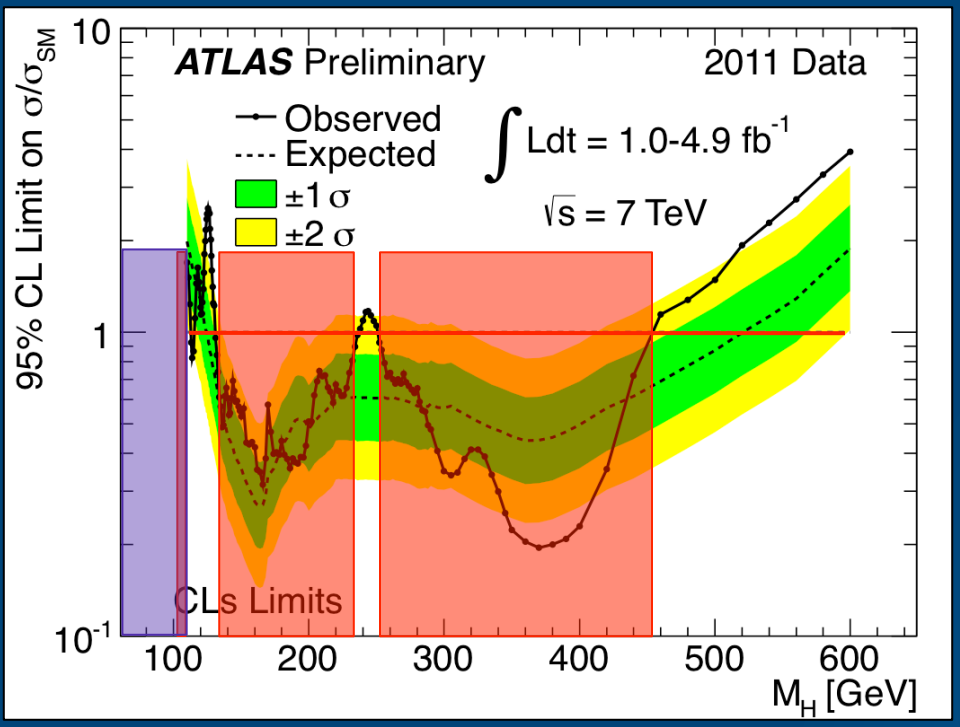


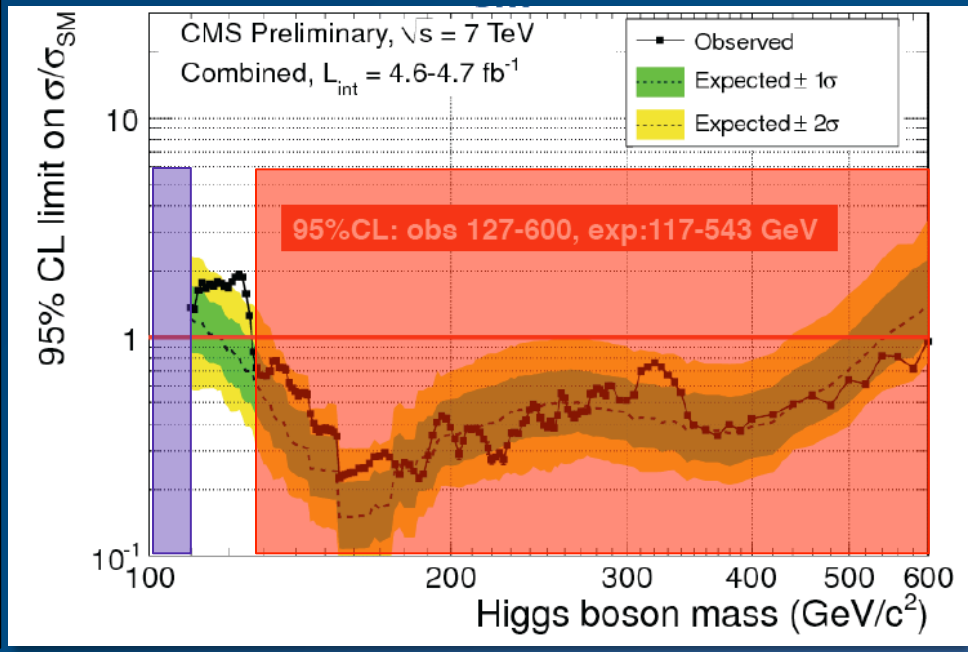
$m_{4\mu}$=201 GeV

ATLAS and CMS results on Higgs search

Seminar at CERN, 13 December 2011

Excluded at 95% CL



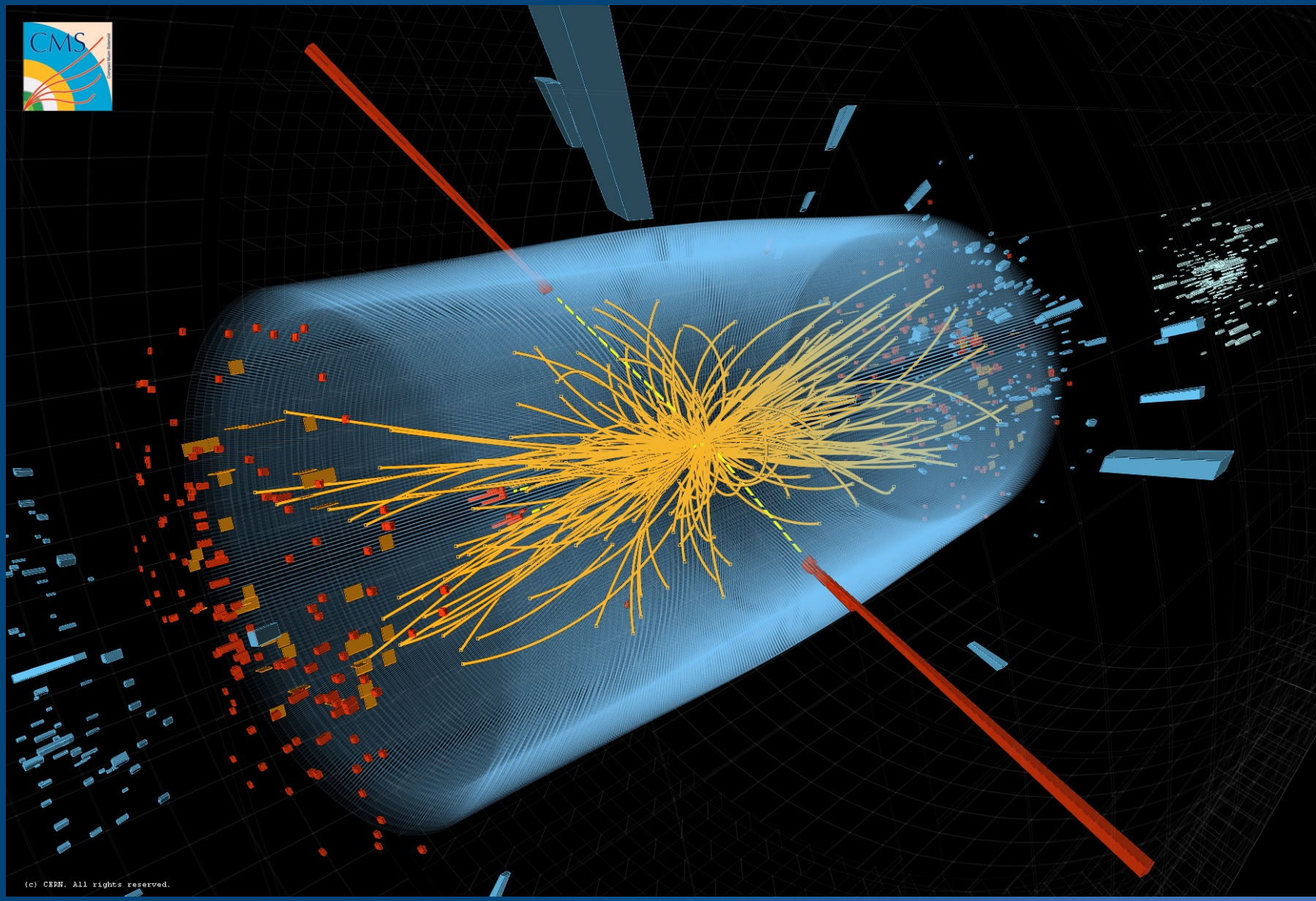


ALTAS: 112.7 < m_H < 115.5 GeV
131 < m_H < 453 GeV, except 237-251 GeV

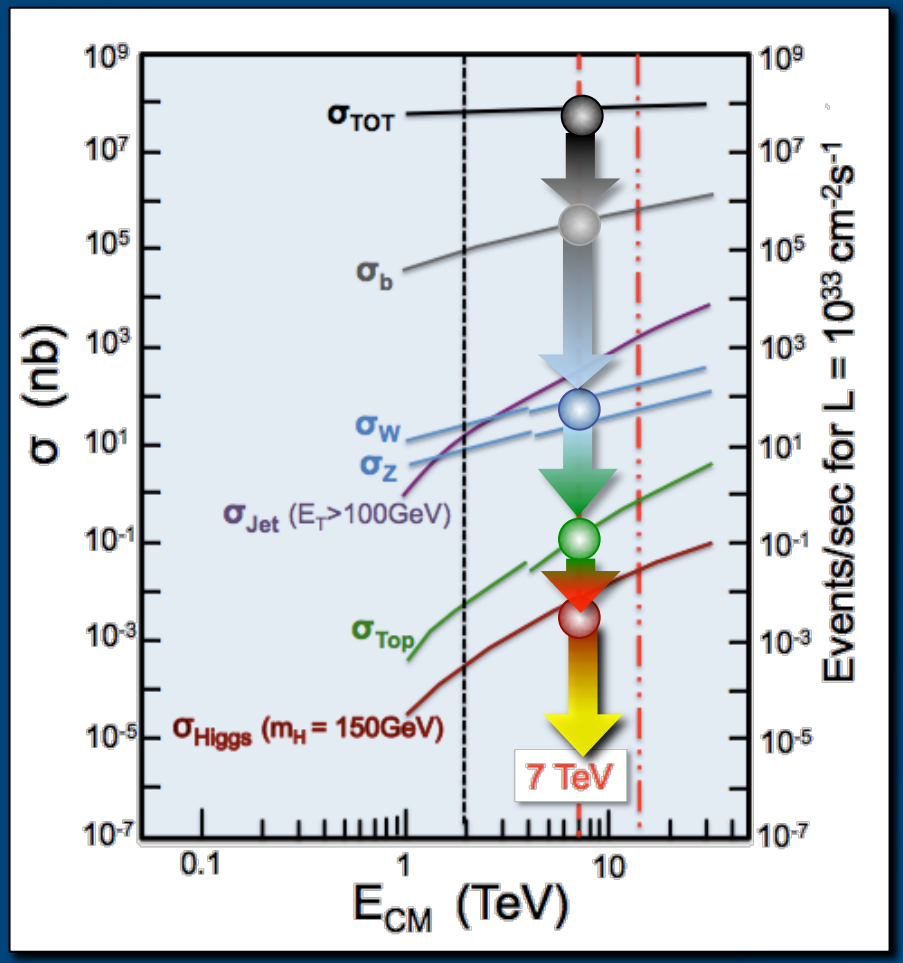
CMS: 127 < m_H < 600 GeV

→ 115.5 < m_H < 127 GeV

CMS Events → Making the Invisible Visible

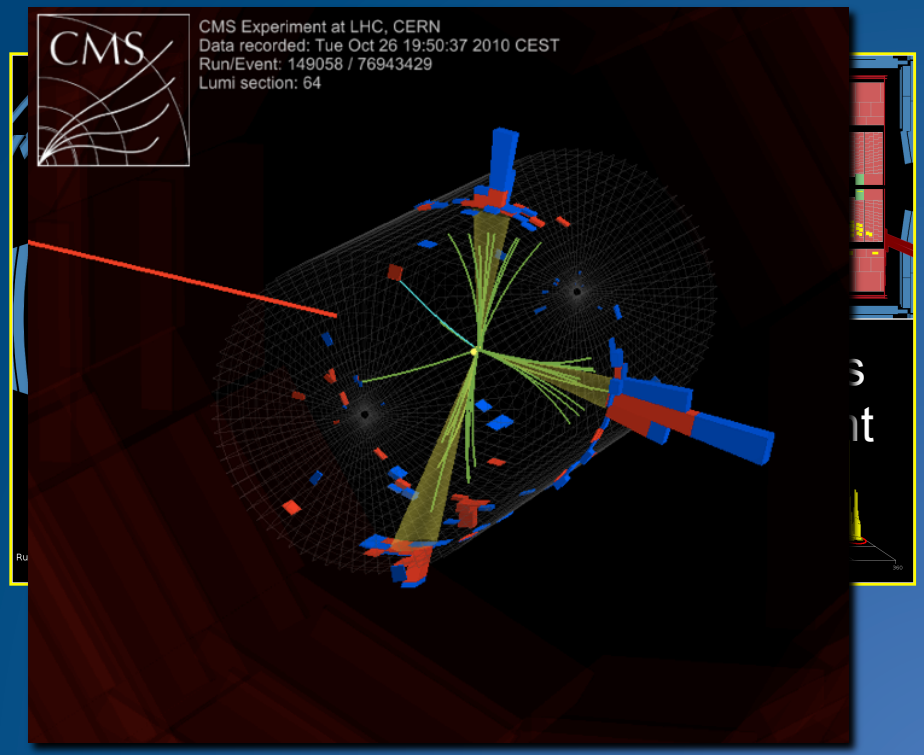


Searches for new physics

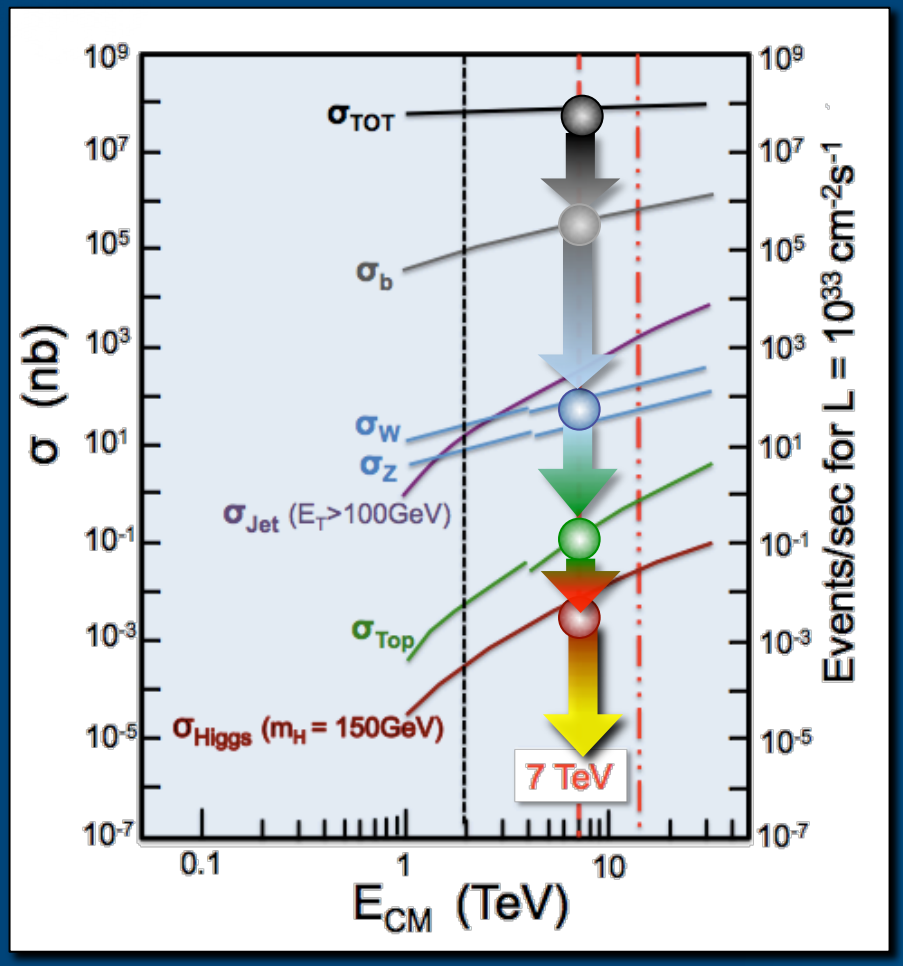


Search for physics beyond SM

- Discovering new particles
- Making precise measurements of properties of known particles/forces: e.g. LHCb: $B_s \rightarrow \mu^+\mu^-$



Searches for new physics



Search for physics beyond SM

- Discovering new particles
- Making precise measurements of properties of known particles/forces: e.g. LHCb: $B_s \rightarrow \mu^+\mu^-$

LHCb presented new results on $B_s \rightarrow \mu^+\mu^-$ at the 'Rencontres de Moriond' conference on 5 March (yesterday!):

Br ($B_s \rightarrow \mu^+\mu^-$) < 4.5×10^{-9} at 95% CL

Prediction of the SM:

Br ($B_s \rightarrow \mu^+\mu^-$) = $(3.2 \pm 0.2)10^{-9}$

LHCb starts to strongly constrain theoretical models beyond the SM

The 2012 run ….. and beyond

2012: start middle of March (beams circulating)

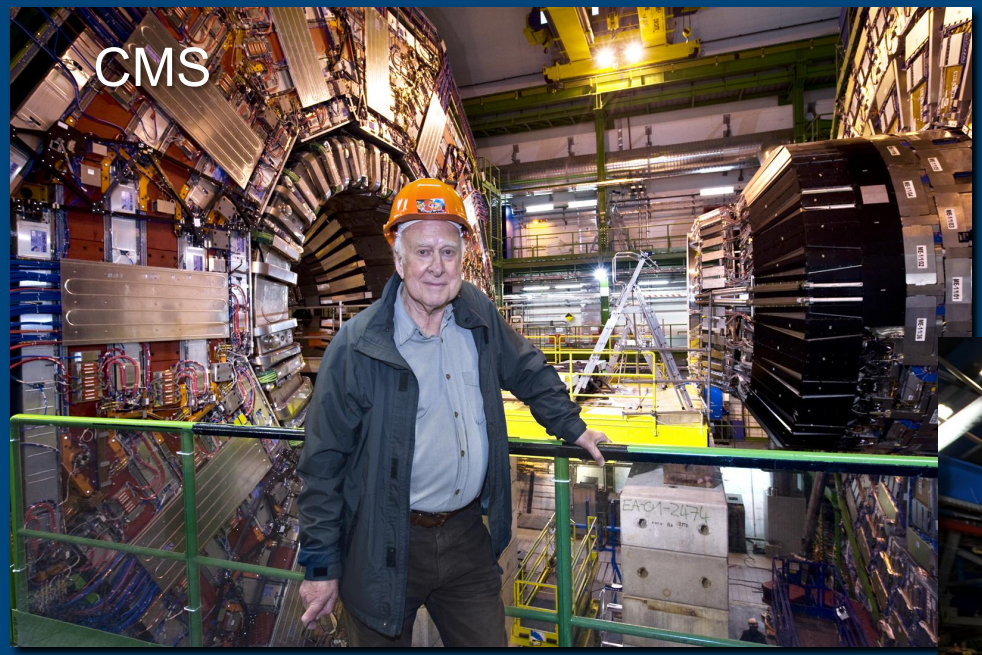
- E_{cm} = 8 TeV compared to 7 TeV up to now
- Goal: three times more data delivered by LHC (15 fb^{-1})

  → Should bring us closer to understanding how the fundamental particles acquire their mass.

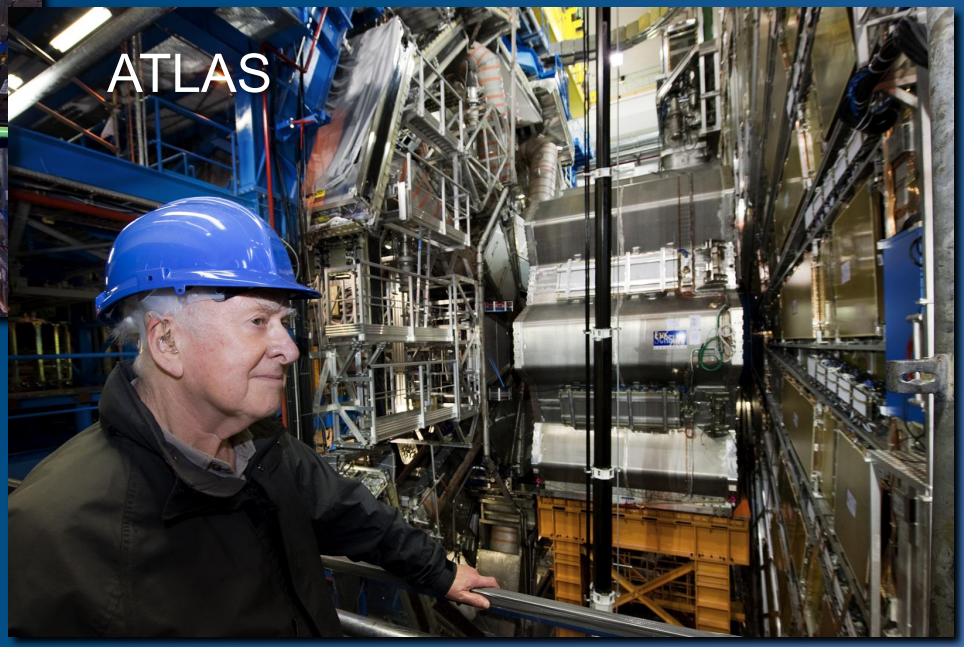
- A very Exciting year head of us!

P. Higgs

First “Higgs Event” …..



…. observed jointly in
CMS and ATLAS ….
(April 2008)



“Not only Peter Higgs”:
Important contributions also from
Brout & Englert
Guralnik, Hagen, Kibble

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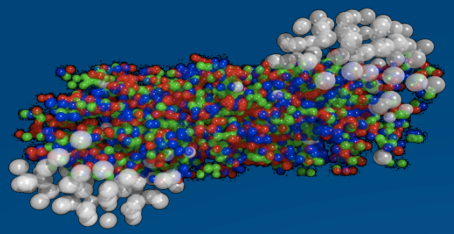
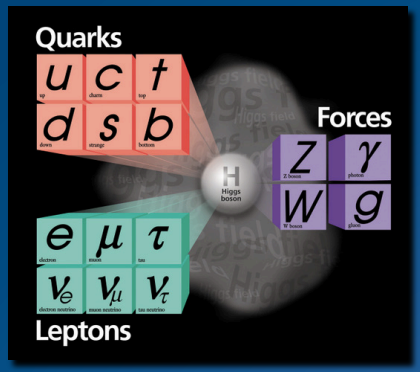
Beyond 2012

- Long technical stop of around 20 months, starting end of 2012
- Late in 2014 start with LHC close to its design energy (E_{cm} ~ 14 TeV)

The study of LHC data will allow us to answer some of the big questions ...



Will we understand the primordial state of matter after the Big Bang before protons and neutrons formed?

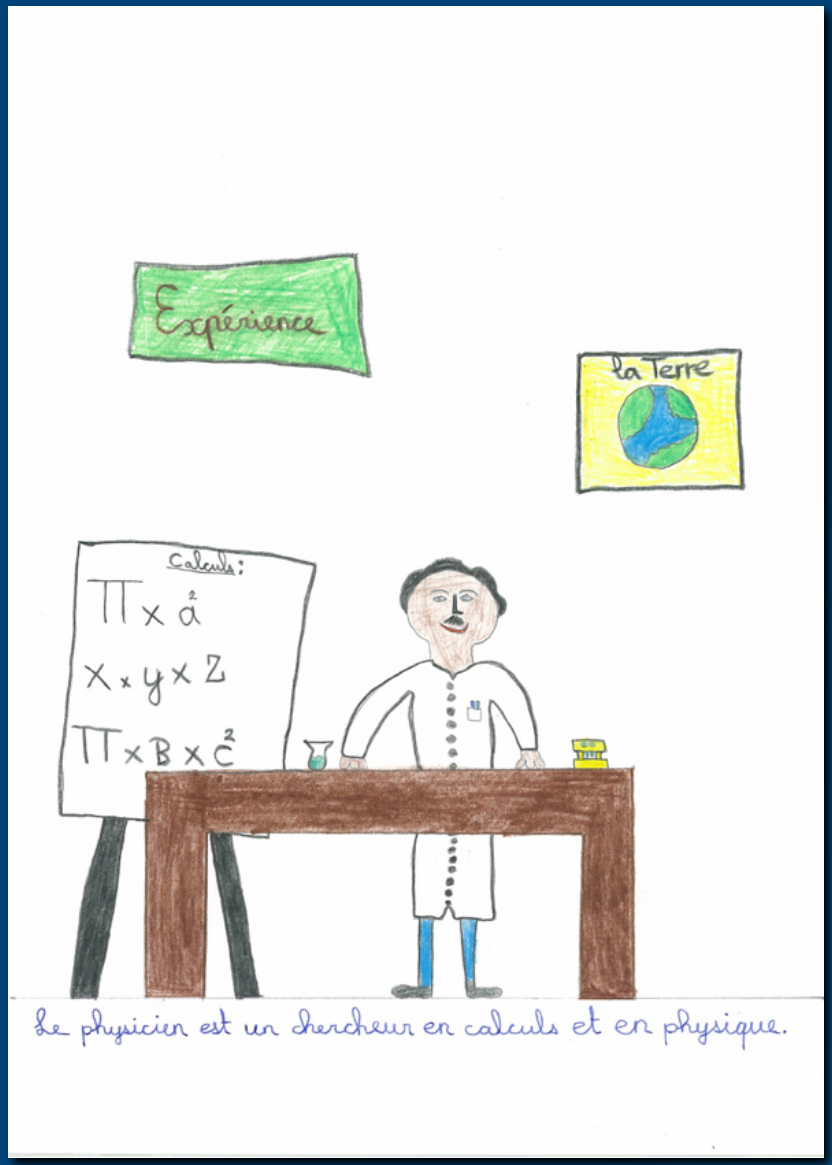


Will we find the Higgs particle that is responsible for giving mass to all particles?

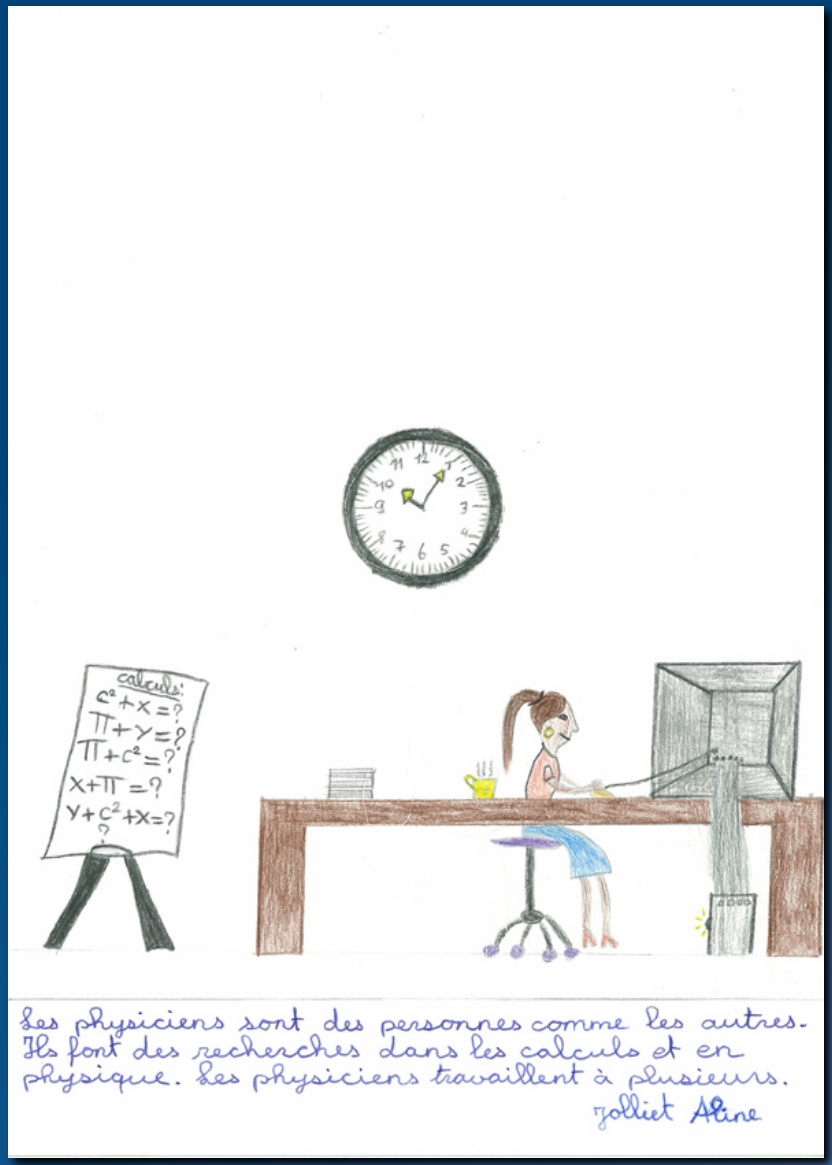
Will we find the reason why antimatter and matter did not completely destroy each other?

Will we find the particle(s) that make up the mysterious ‘dark matter’ in our Universe?

Very exciting years are ahead of us



Le physicien est un chercheur en calculs et en physique.



Les physiciens sont des personnes comme les autres. Ils font des recherches dans les calculs et en physique. Les physiciens travaillent à plusieurs.

Zolliet Aline

Dessine-moi un physicien

www.cern.ch/dessine-moi-un-physicien/

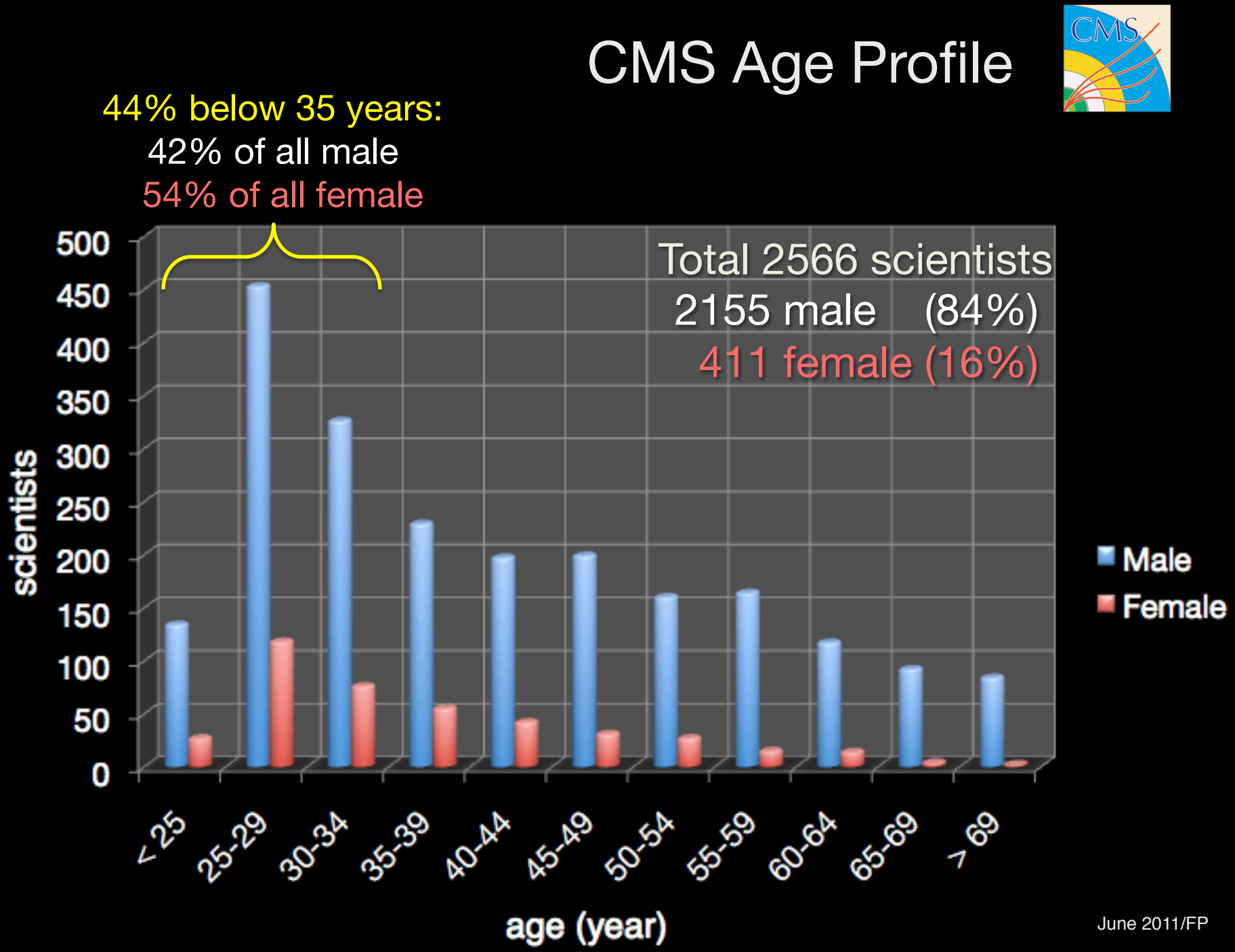
Un physicien est une personne qui travaille avec des liquides et des atomes et c'est aussi un métier.

Un physicien est une personne qui travaille avec des ordinateurs dans une salle avec des particules.

Natasha

Un physicien est un monsieur qui boit du café toute la journée. *Endrit*

CMS Age Profile



June 2011/FP


LHCb
ATLAS
CERN Meyrin
CERN Prévessin
SPS 7 km
SUISSE
FRANCE
CMS
ALICE
LHC 27 km

Thank you!