

The Road Map for Discoveries: The Large Hadron Collider and the Higgs Boson

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The African School of Fundamental
Physics and its Applications 2012

What is the world made of?
What holds the world together?
Where did we come from?



History of the Universe

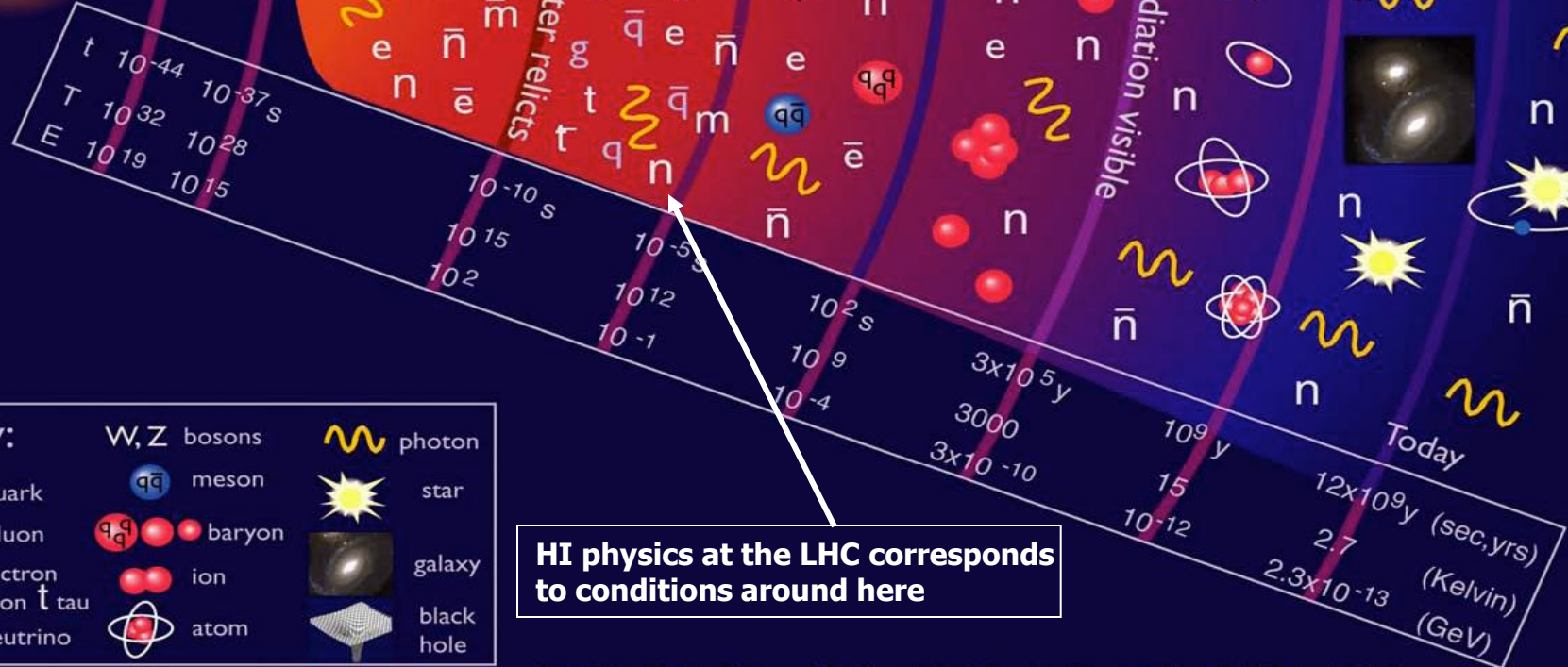
pp physics at the LHC corresponds to conditions around here

BIG BANG

Inflation

possible dark matter relicts

cosmic microwave radiation visible



Key:

- W, Z bosons
- q quark
- g gluon
- e electron
- m muon
- n neutrino
- meson
- baryon
- ion
- atom
- photon
- star
- galaxy
- black hole

HI physics at the LHC corresponds to conditions around here

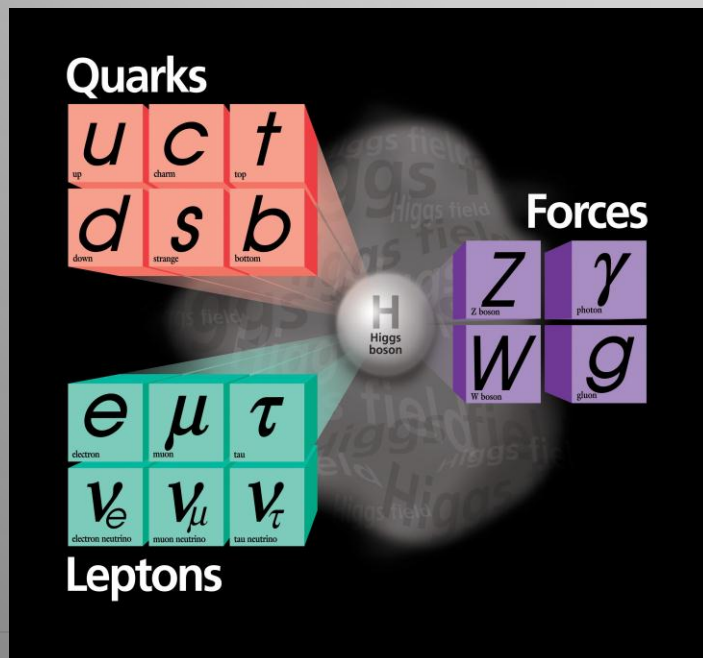
The “Standard Model”

Over the last 100 years: combination of **Quantum Mechanics and Special Theory of relativity** along with all new particles discovered has led to the **Standard Model of Particle Physics.**
The new (final?) “Periodic Table” of fundamental elements

A crowning achievement of
20th Century Science

The SM has been tested thousands of times, to excellent precision. Yet, its most basic mechanism, that of granting mass to particles
A major step forward was made this month with the discovery of a particle that could be the long-sought Higgs boson!!

Matter particles



Force particles

This Study Requires.....



1. Accelerators : powerful machines that accelerate particles to extremely high energies and bring them into collision with other particles

2. Detectors : gigantic instruments that record the resulting particles as they “stream” out from the point of collision.

3. Computing : to collect, store, distribute and analyse the vast amount of data produced by these detectors

4. Collaborative Science on Worldwide scale : thousands of scientists, engineers, technicians and support staff to design, build and operate these complex “machines”.

CERN: The European Laboratory for Particle Physics

- CERN is the **European Organization for Nuclear Research**, the world's largest Particle Physics Centre, near Geneva, Switzerland
- It is now commonly referred to as **European Laboratory for Particle Physics**
- It was founded in 1954 and has 20 member states + several observer states
- CERN employes **>3000** people + hosts **~10000** visitors from **>500** universities.
- Annual budget **~ 1100 MCHF/year (2011)**

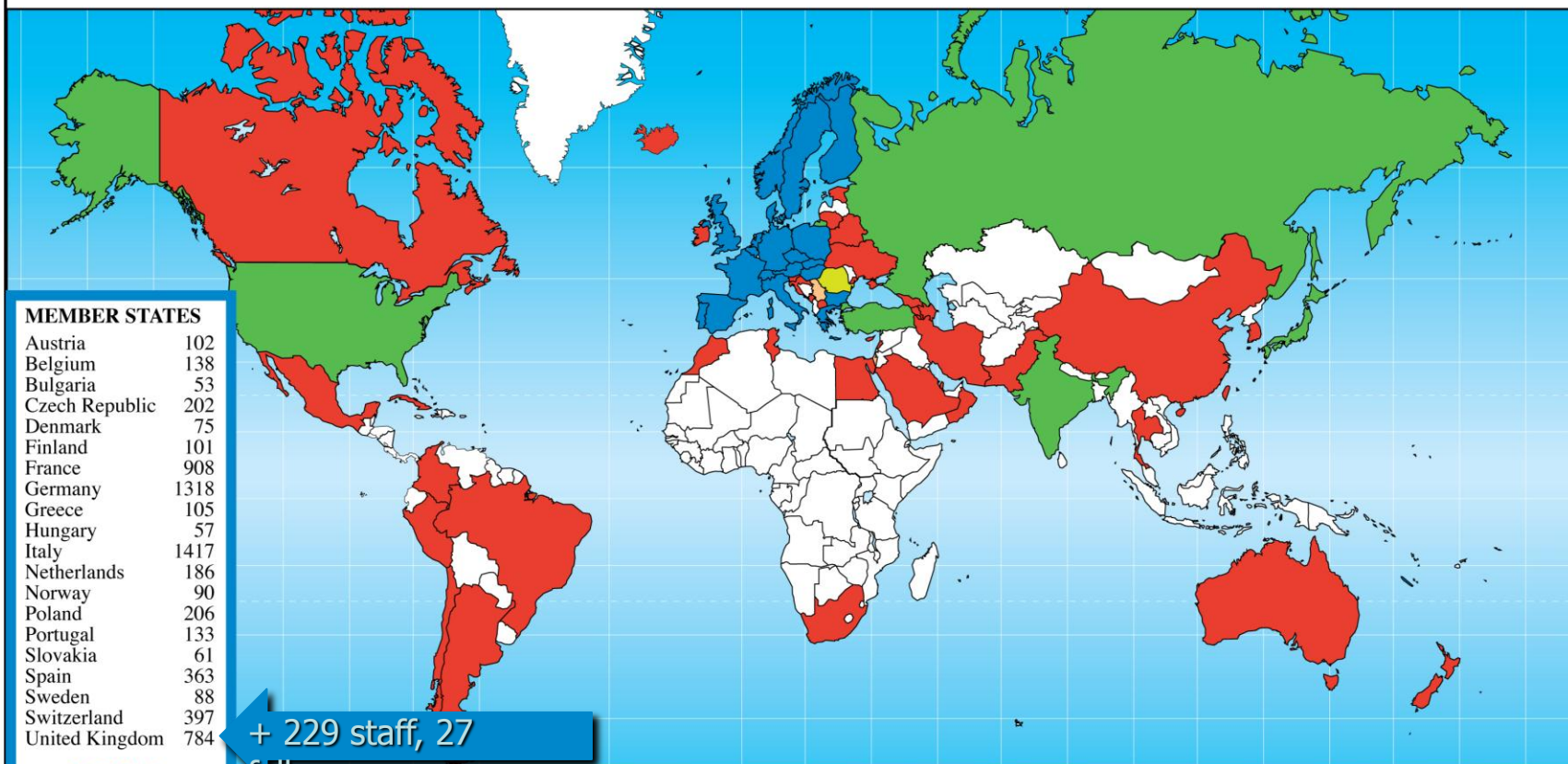


Breaking the Wall of Communication
20 years ago: the Web was born



CERN and the World...

Distribution of All CERN Users by Nation of Institute on 4 April 2012



MEMBER STATES

Austria	102
Belgium	138
Bulgaria	53
Czech Republic	202
Denmark	75
Finland	101
France	908
Germany	1318
Greece	105
Hungary	57
Italy	1417
Netherlands	186
Norway	90
Poland	206
Portugal	133
Slovakia	61
Spain	363
Sweden	88
Switzerland	397
United Kingdom	784

6784

+ 229 staff, 27 fellows

CANDIDATE FOR ACCESSION

Romania	78
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ASSOCIATE MEMBER IN THE PRE-STAGE TO MEMBERSHIP

Israel	67
Serbia	26

OBSERVERS

India	134
Japan	225
Russia	859
Turkey	83
USA	1749

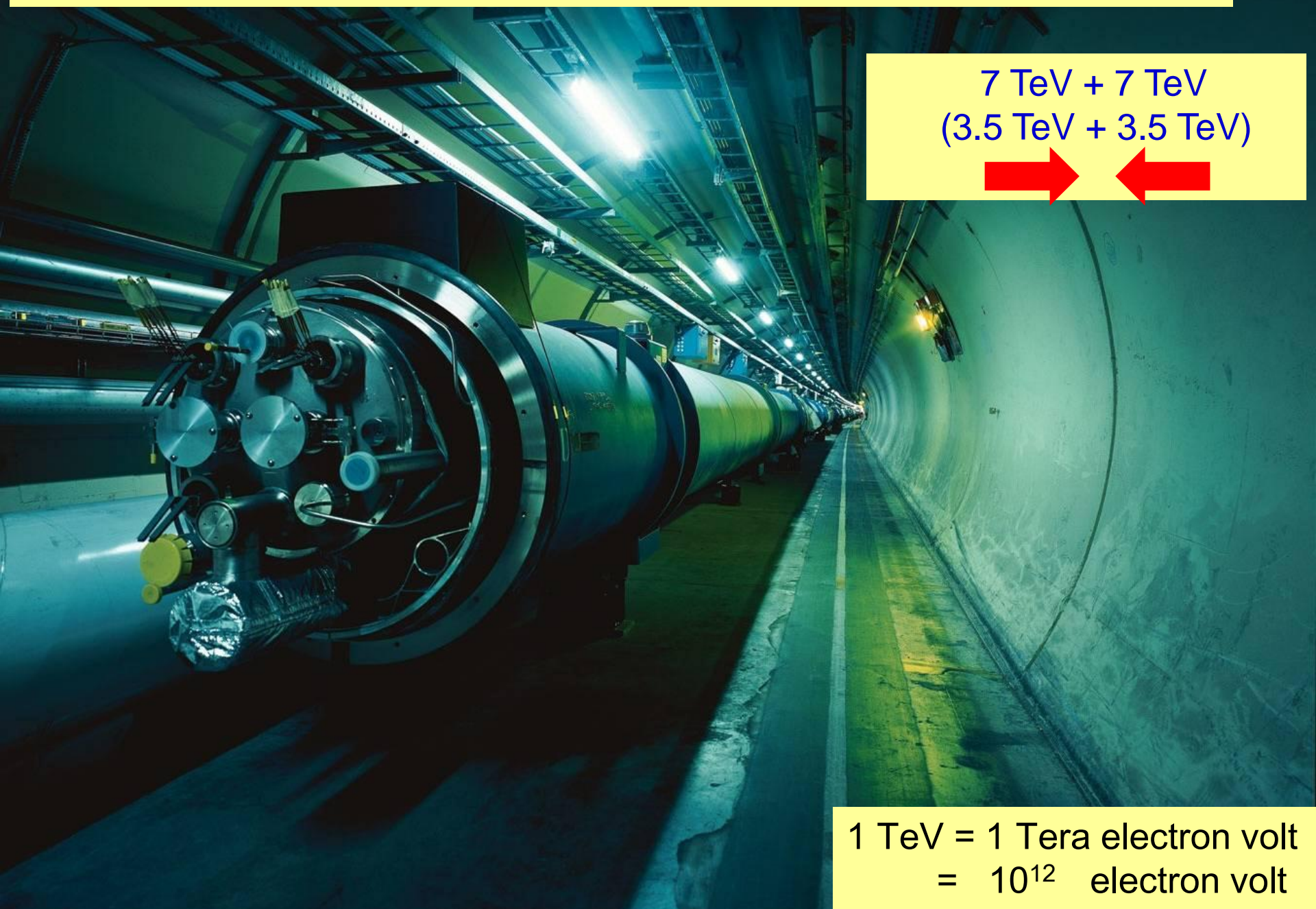
3050

OTHERS

Argentina	18	China	115	Iran	16	Oman	1	Ukraine	21
Armenia	13	China (Taipei)	70	Ireland	10	Pakistan	22	Uzbekistan	1
Australia	28	Colombia	10	Korea	91	Peru	2		
Azerbaijan	1	Croatia	21	Lebanon	1	Qatar	1		
Belarus	22	Cuba	4	Lithuania	13	Saudi Arabia	3		
Brazil	102	Cyprus	9	Malta	1	Slovenia	38		
Canada	170	Egypt	7	Mexico	43	South Africa	21		
Chile	4	Estonia	17	Montenegro	1	Thailand	5		
		Georgia	10	Morocco	6	T.F.Y.R.O.M.	2		
		Iceland	3	New Zealand	11	Tunisia	1		

934

The Large Hadron Collider = a proton proton collider



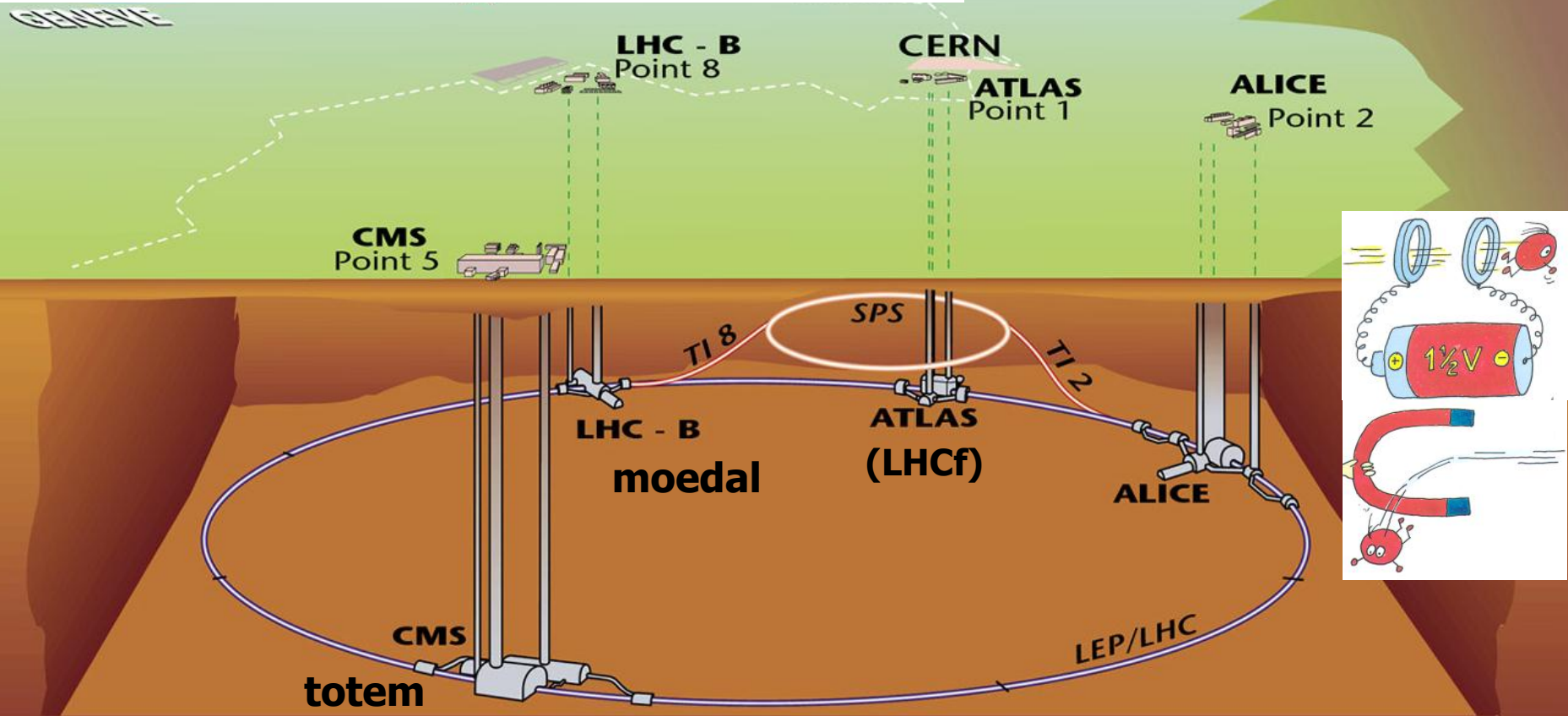
7 TeV + 7 TeV
(3.5 TeV + 3.5 TeV)



1 TeV = 1 Tera electron volt
= 10^{12} electron volt

The LHC Machine and Experiments

- LHC is **100m** underground
- LHC is **27 km** long
- Magnet Temperature is **1.9 Kelvin** = -271 Celsius
- LHC has ~ **9000 magnets**



CMS Collaboration June 27, 2012

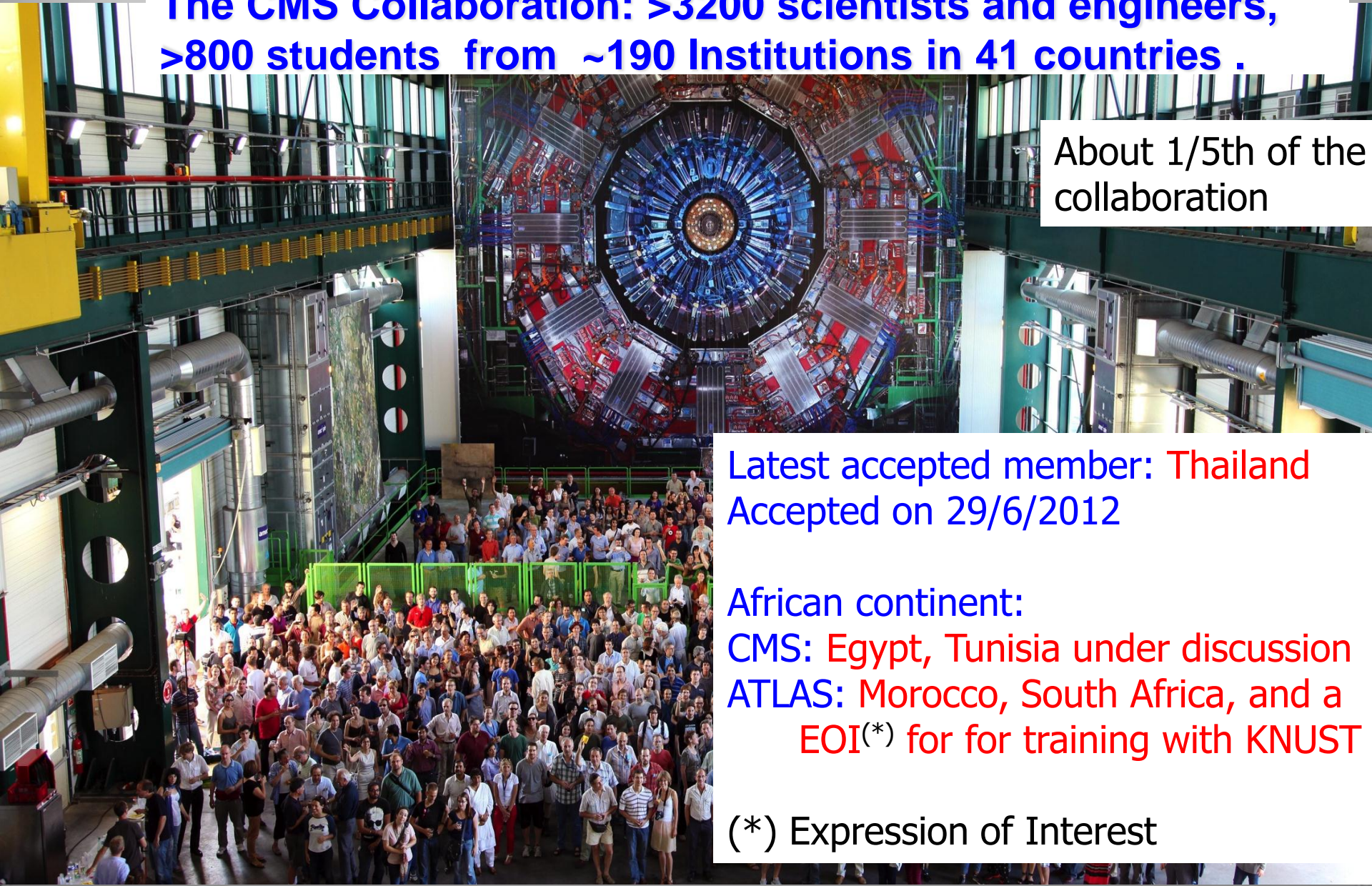
The CMS Collaboration: >3200 scientists and engineers,
>800 students from ~190 Institutions in 41 countries .

About 1/5th of the
collaboration

Latest accepted member: **Thailand**
Accepted on 29/6/2012

African continent:
CMS: **Egypt, Tunisia under discussion**
ATLAS: **Morocco, South Africa, and a
EOI^(*) for for training with KNUST**

(*) Expression of Interest



The Higgs Boson

The Washington Post

NATIONAL

.. A few months ago...

Physicists hope to find the Higgs boson, key to unified field theory, this year



Fabrice Coffrini/Agence France-Presse via Getty Images - A superconducting solenoid magnet, the largest of its kind, is part of the Large Hadron Collider, which is searching for the Higgs boson.

Peter Higgs



Predicted a new kind of particle in 1964, ie 48 years ago
What makes this such a special Particle?

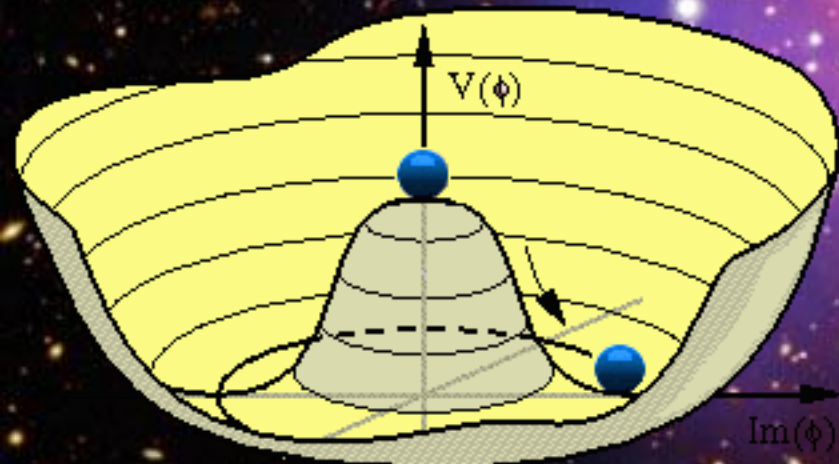
The Hunt for the Higgs

Where do the masses of elementary particles come from?

The key question:
Where is the Higgs?

Massless particles move at the speed of light \rightarrow no atom formation!!

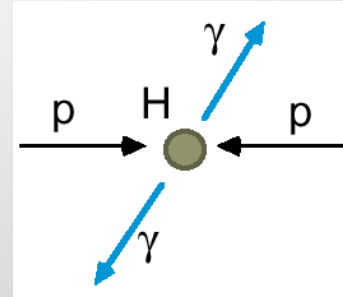
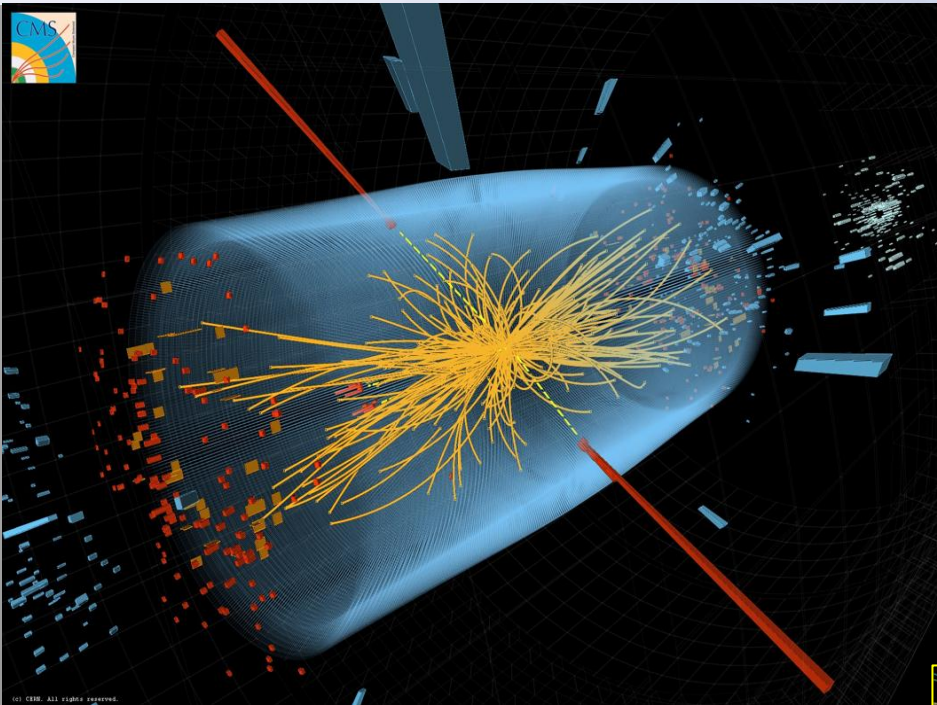
We do not know the mass of the Higgs Boson



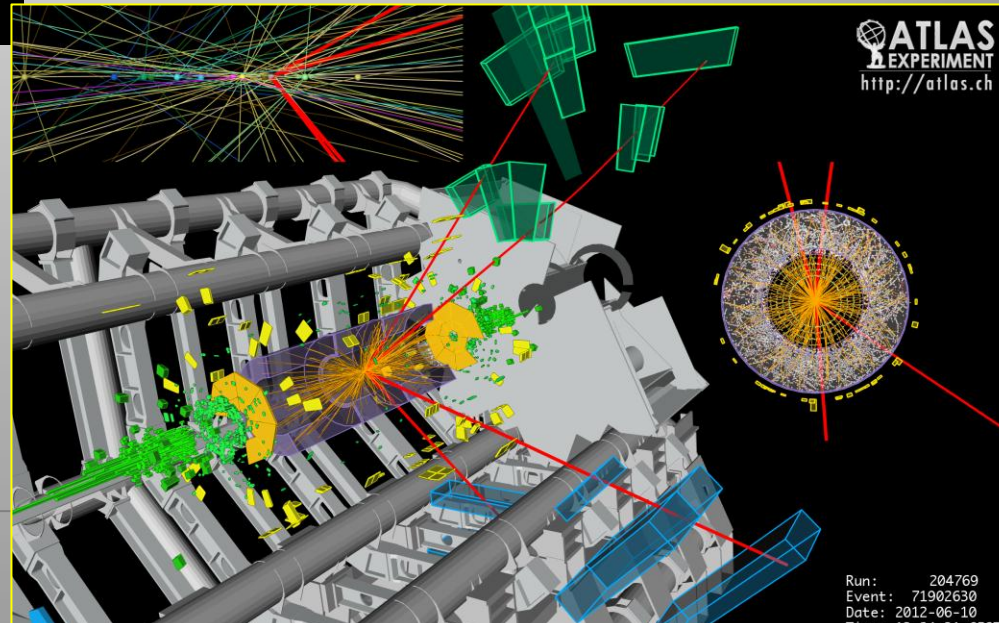
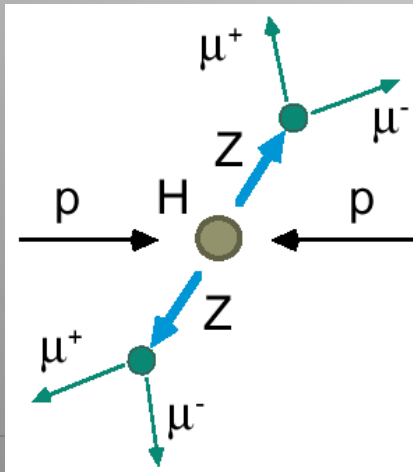
Scalar field with at least one scalar particle

It could be anywhere from 114 to 700 GeV

A Collision with two Photons



A Higgs or
a 'background'
process without
a Higgs?



ATLAS
EXPERIMENT
<http://atlas.ch>

July 4th 2012

- Official announcement of the discovery of a Higgs-like particle with mass of 125-126 GeV by CMS and ATLAS.
- Historic seminar at CERN with simultaneous transmission and live link at the large particle physics conference of 2012 in Melbourne, Australia

CERN



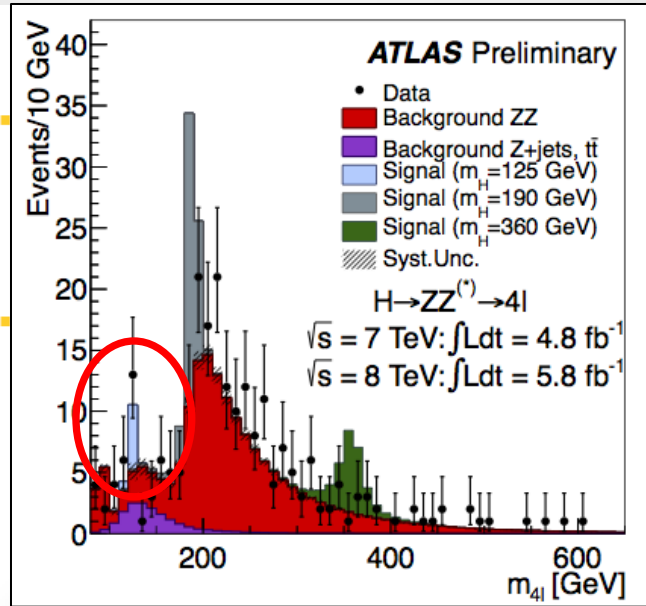
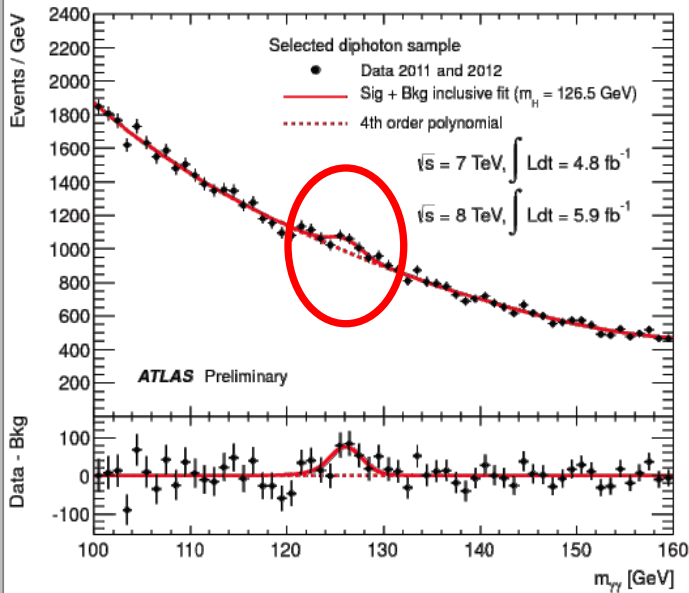
Melbourne



Results from the Experiments

Higgs \rightarrow 2 photons!!

Higgs \rightarrow 2 Z \rightarrow 4 leptons!!

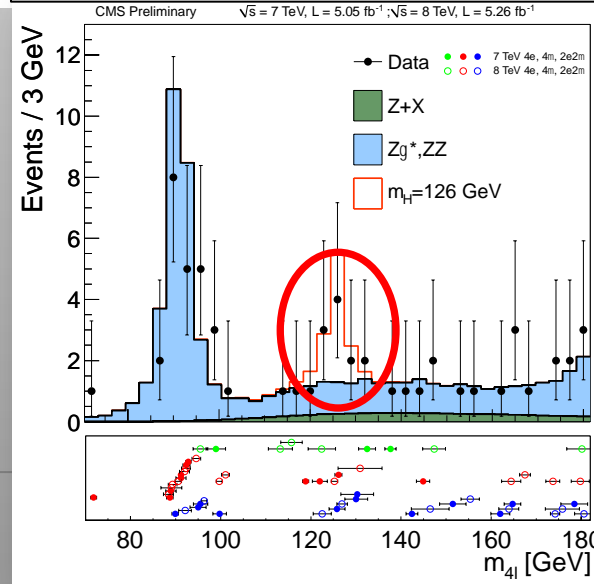
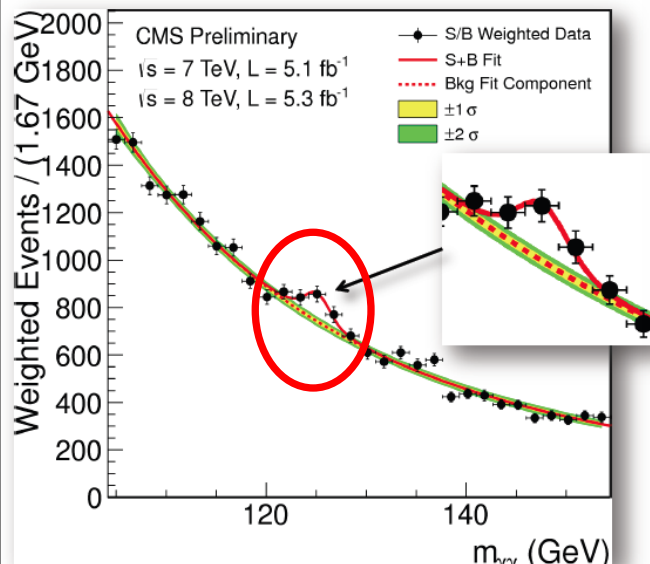


A clear “excess” of events seen in both experiments around 125-126 GeV

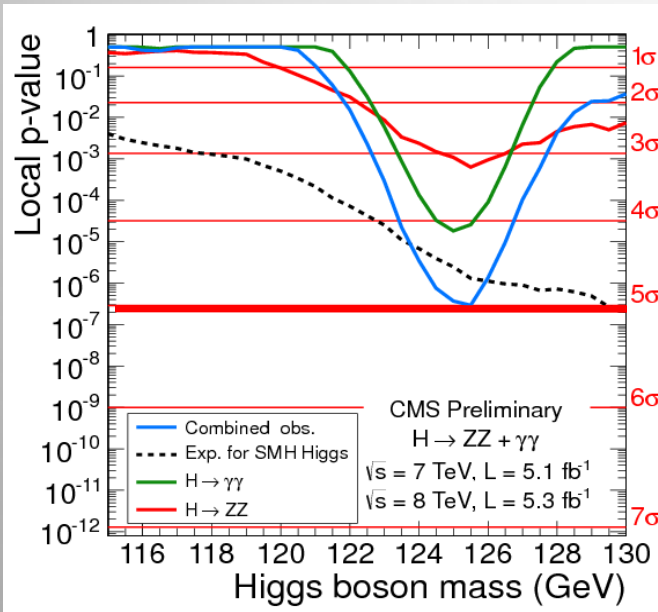
It became very significant in 2012

Sophisticated Statistical Methods have used to fully analyse this.

And the result is... \rightarrow

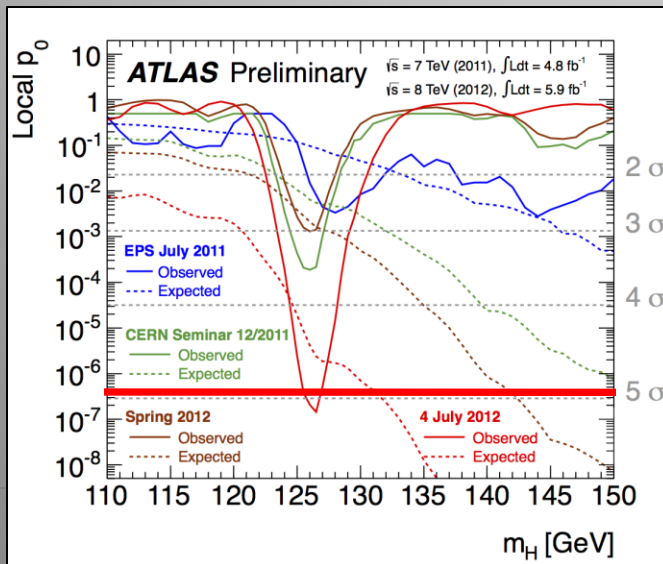


Results from the Experiments



Discovery!

The CMS and ATLAS experiments observe a new boson with a significance of about 5 sigma



Discovery!

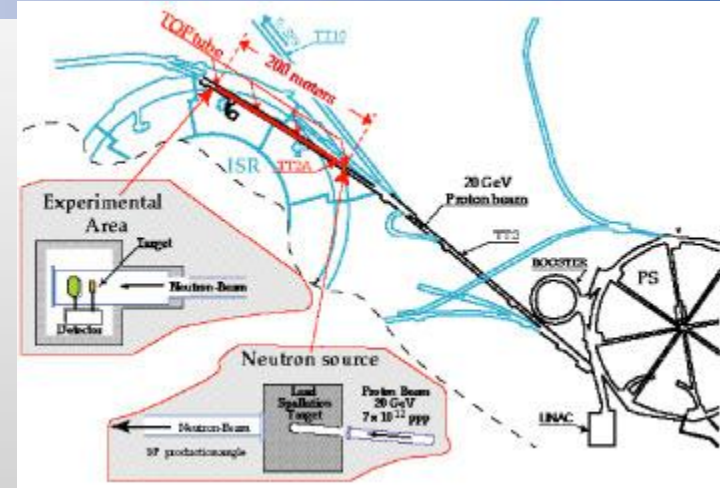
The particle is consistent with a Higgs-like boson

Discovery of a New Particle at 125 GeV

- CMS and ATLAS discovered a brand new heavy particle with a mass of about 125 (126) GeV. This is an entirely new type of particle. We expect to learn a lot on fundamental physics from this particle
- This is a result of a quest that started more than 40 years ago, from a theoretical idea. It took so long before we had the right instrument: The LHC
- It is a great triumph for a large human endeavour!!
- The LHC project –and other High Energy Physics projects– also push high-tech for practical us!!
- African scientists can play a role in this new science revolution, and it's practical applications.

CERN/HEP is also: Technology Transfer

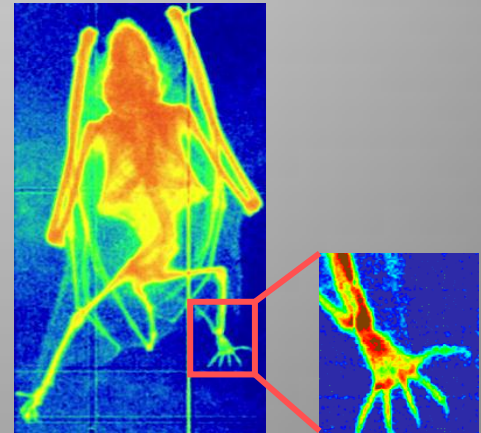
GRID Computing!



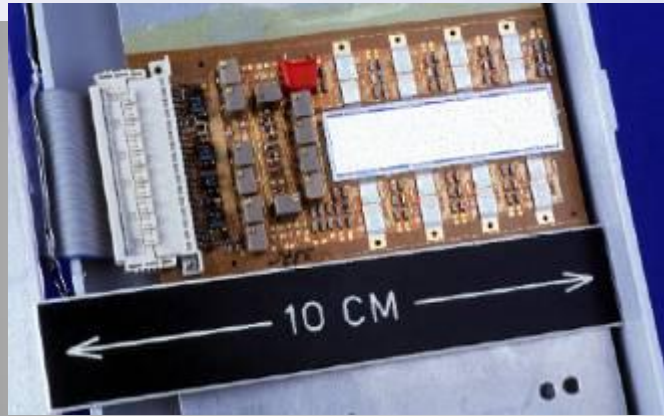
Radio-isotope production for medical applications



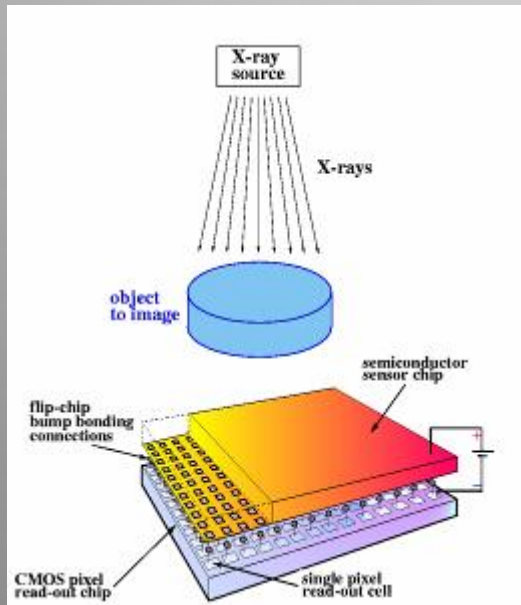
Thin films by sputtering or evaporation



Radiography of a bat, recorded with a GEM detector



Silicon detector for a Compton camera in nuclear medical imaging



Medipix: Medical X-ray diagnosis with contrast enhancement and dose reduction

Bringing the Nations Together



Particle Physics Schools

CERN visiting Scientists

Common supervising, projects
and e.g. bi-doctorates

“...the promotion of contacts between, and
the interchange of, scientists...”

Joining Experimental collaborations

CERN Accelerator Schools

Physics teacher program

CERN summer student program

Technical students

Capacity building and development

An aerial photograph of a landscape, possibly a valley or a rural area, with a red circle drawn around a central part of the image. The text is overlaid on the image.

The LHC operates at an energy and precision that takes us far beyond our current understanding, into a new regime

The LHC will reveal the origin of mass of particles. **Two weeks ago discovery of a new particle was announced with properties of a Higgs Boson!!**

LHC will very likely reveal much more

There is mounting evidence, from neutrino mass to dark matter and dark matter observations, that there is something profound that we do not yet understand. Is it supersymmetry, extra dimensions, other...? First LHC results do not yet show signatures for new physics but **these can come now any day!**

The results of the LHC will determine the future of HEP!!!

We are on the verge of a revolution in our understanding of the Universe and our place within it. African scientists and students can take part in this science revolution