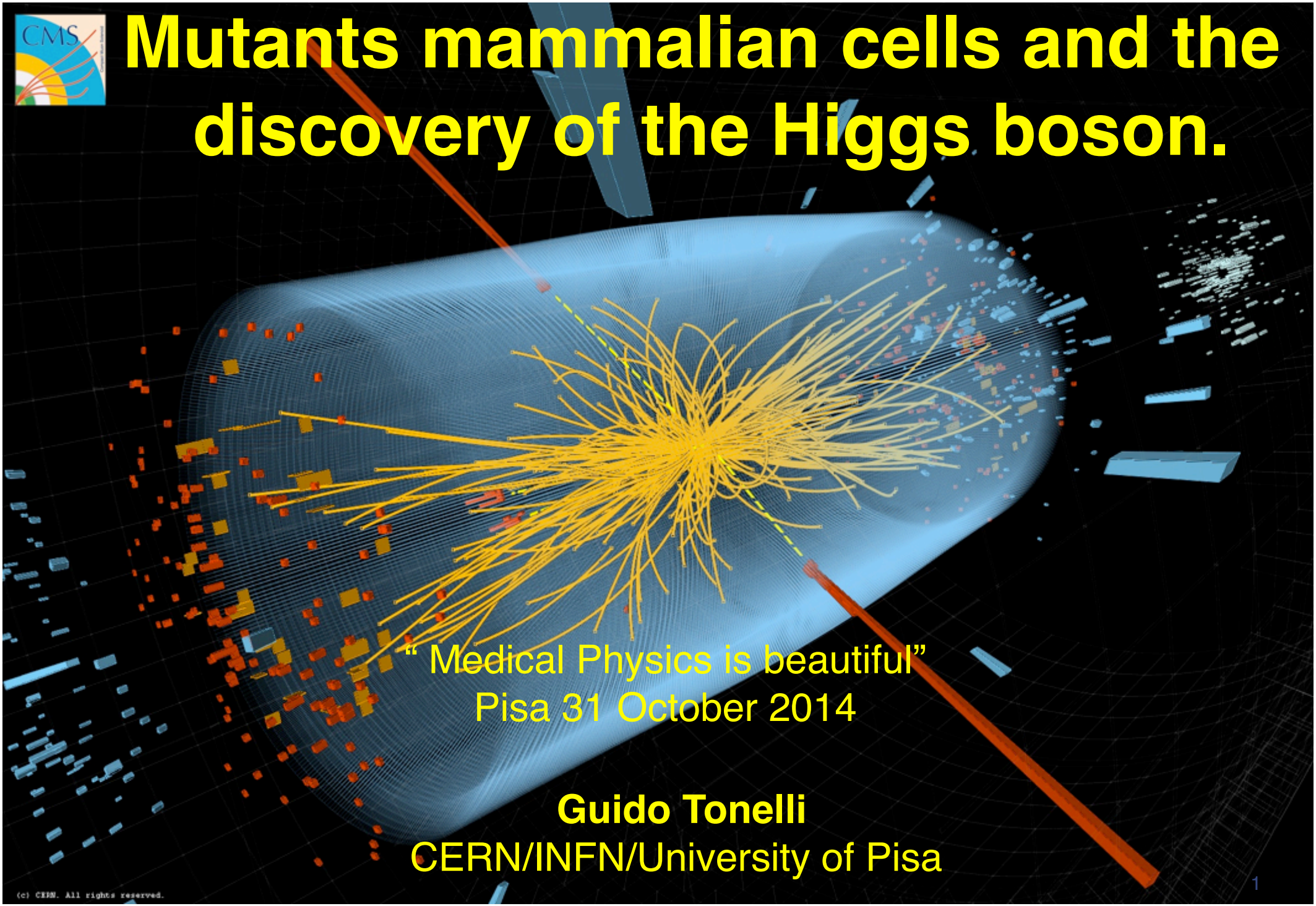


Mutants mammalian cells and the discovery of the Higgs boson.

" Medical Physics is beautiful"
Pisa 31 October 2014

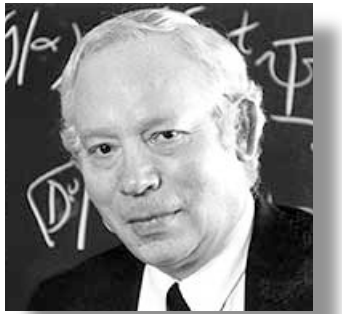
Guido Tonelli
CERN/INFN/University of Pisa

What could be the connection between the Higgs boson and mutant mammalian cells?

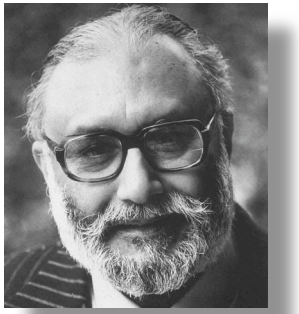
In order to understand it I'll tell you a story that starts in the mid '70s, a very exciting period for High Energy Physics.

The Standard Model

S.L. Glashow



S. Weinberg



A. Salam

• In 1967 Weinberg and Salam together with Glashow proposed a unified theory for the weak and electromagnetic interactions.

• The theory predicted three very massive bosons as mediators of the weak interactions (the two charged W^+ and W^- and the neutral Z) while the massless photon remained the mediator of the electromagnetic interactions.

• To explain the huge difference in mass of the two sets of mediators (Electroweak Symmetry Breaking) the theory incorporated the Brout-Englert-Higgs mechanism.

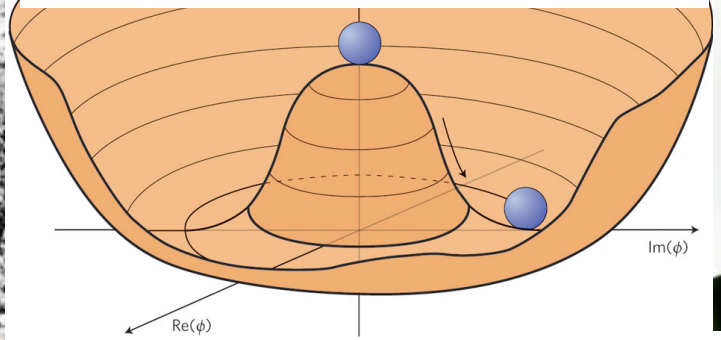
The Brout-Englert-Higgs mechanism: a very elegant conjecture.

Back in 1964 two groups of completely unknown young scientists, in their '30s, put forward a completely new approach to explain why the photon is massless and the W and Z are very massive.

R. Brout

F. Englert

$$V(\Phi) = \mu^2 \Phi^\dagger \Phi + \lambda^2 \left(\Phi^\dagger \Phi\right)^2$$



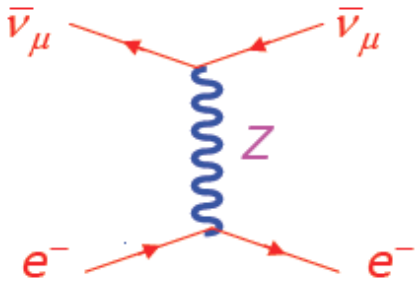
P. Higgs

The exact symmetries of the Lagrangian relating the weak and electromagnetic interactions are broken by the vacuum. **A new scalar field pervades every corner of our universe. The vacuum is not empty. Mass is a dynamical property of matter. We need a new massive neutral boson. Weinberg named it the Higgs boson.**

The great hunt for W, Z and H starts in the ‘70s.

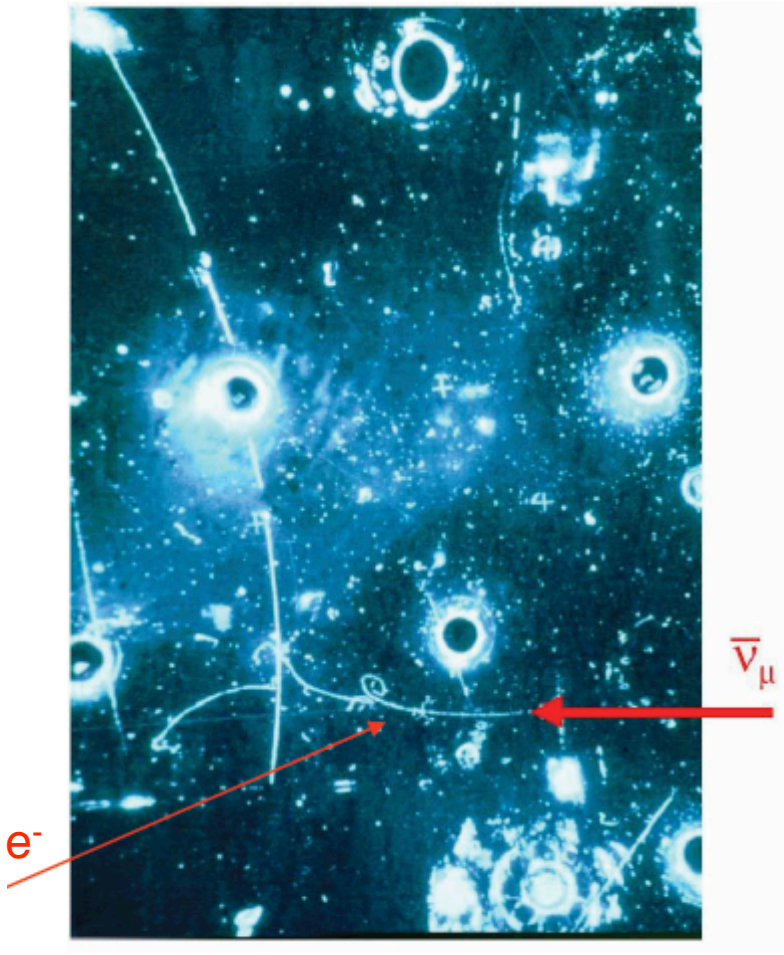
Experimental physicists obtained soon an impressive series of confirmations of the predictions of the Standard Model.

Discovery of the neutral currents
Gargamelle (1973)



First indirect evidence of the Z.

Nobel Prize to Glashow, Weinberg and Salam (1979).



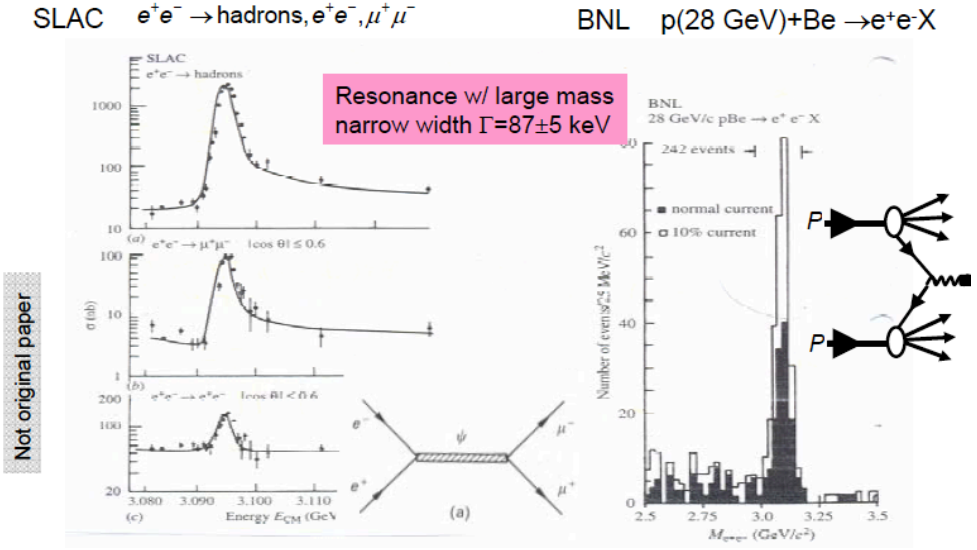
The November revolution

B. Richter

11 November 1974: S. Ting and B. Richter Announce the discovery of a new, “heavy”, narrow resonance: the **J/Psi.**

A new heavy quark, the charm, enters the game. The Standard Model starts its triumphal march.

S. Ting

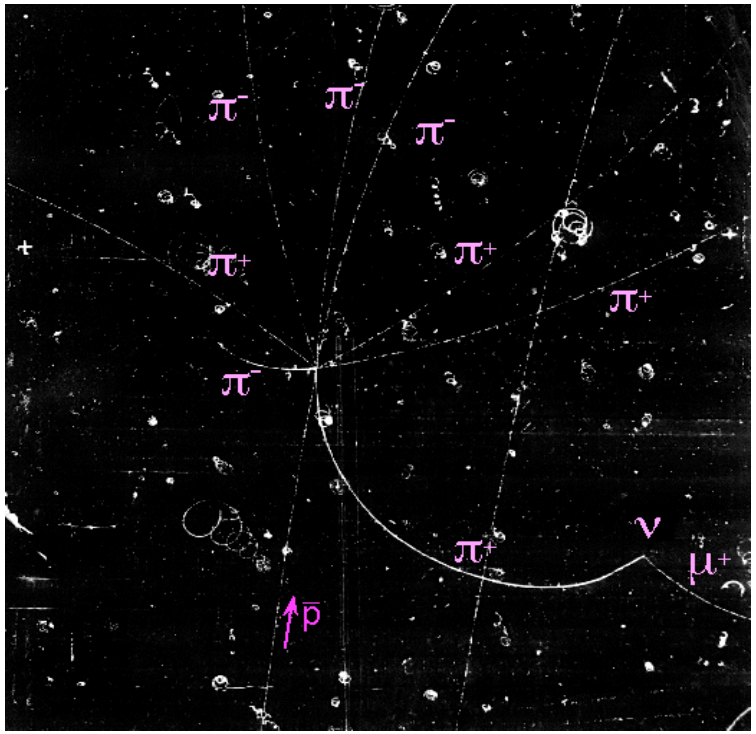


Nobel Prize in 1976

The ‘70s are also years of impressive technical developments in HEP.

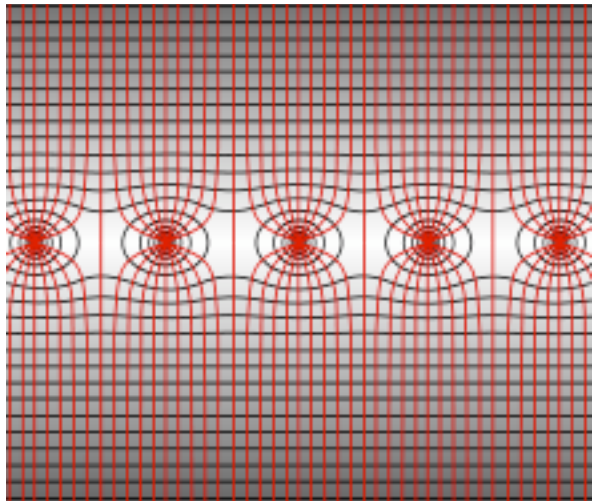
The bubble chambers (like the gigantic one used in Gargamelle) were excellent detectors to visualize tracks with high precision but they were extremely slow.

The maximum rate was limited to 1-2 photos per second.



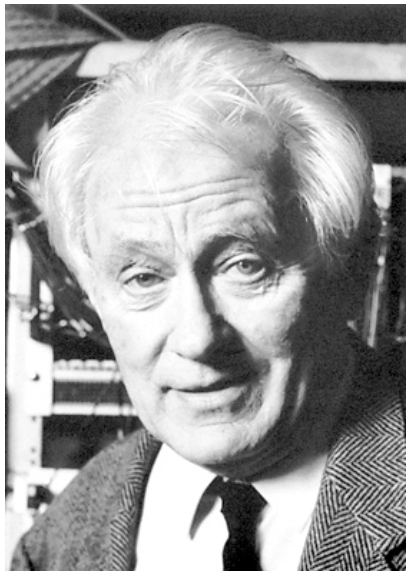
Multi Wire Proportional Chambers

In 1968 a CERN physicist, George Charpak, developed a new detector: the MWPC.



An array of thin wires, precisely placed a few mm apart, kept under HV, in special admixtures of gas.

Charged tracks could be visualized with ~100μm resolution at a rate x1000 times higher wrt to the most sophisticated bubble chambers.



It the birth of all modern tracking devices: drift chambers, TPCs, MSGCs, GEMs, etc.
The new device had also a strong impact on the development of modern semiconductor detectors.

George Charpak, Nobel Prize in 1992.

A young professor in Pisa.

A young professor coming from High Energy Physics decides to change drastically field of research and to dedicate his life to Medical Physics.

Pisa was probably the worst possible environment in Italy for this kind of choice. In the Alma Mater of Enrico Fermi, Bruno Pontecorvo, Carlo Rubbia et al. There is a very strong tradition of participation to the most important HEP experiments in the world: Gherardo Stoppini, Italo Mannelli, Lorenzo Foa', Giorgio Bellettini et al.

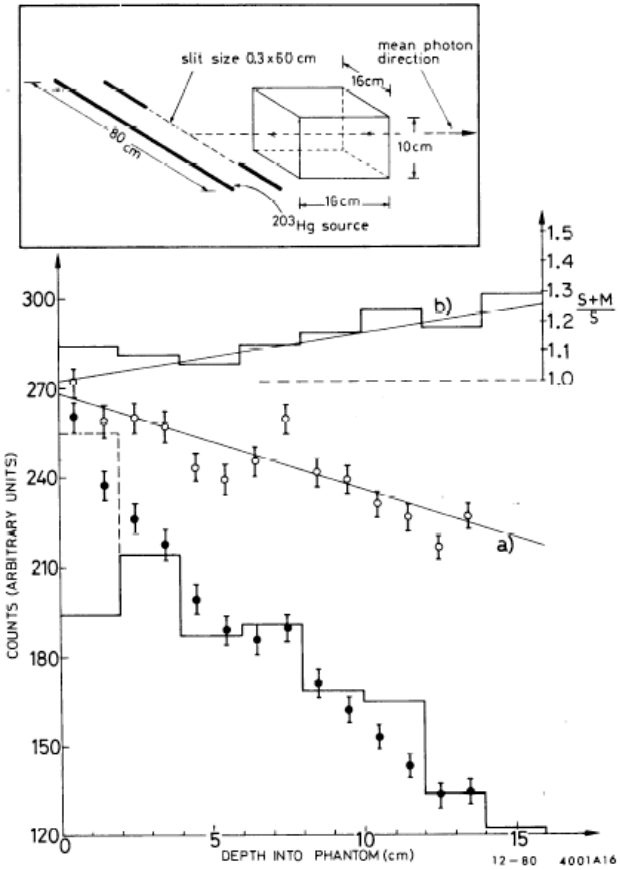
But the young professor is extremely determined. He recruits two young students (degree in 1975) and they start their activities.

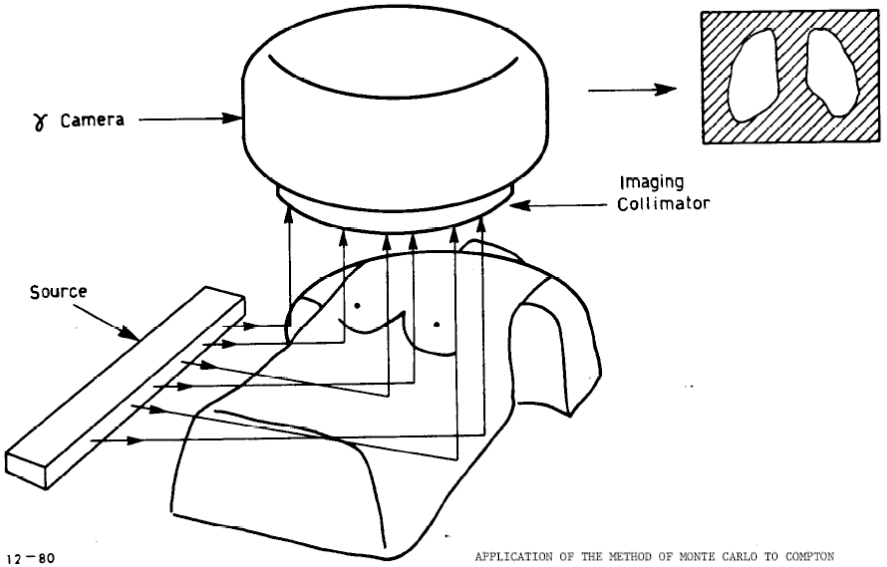
But there is nothing to start with. The environment is extremely hostile. They are housed in the roof of the Institute. No office space. No laboratory.

Research tools: pencils and paper.

It was really a "mission impossible".

The first study: application of the method of Monte Carlo to Compton scattering radiography.





APPLICATION OF THE METHOD OF MONTE CARLO TO COMPTON SCATTERING RADIOGRAPHY IN HOMOGENEOUS MEDIA *

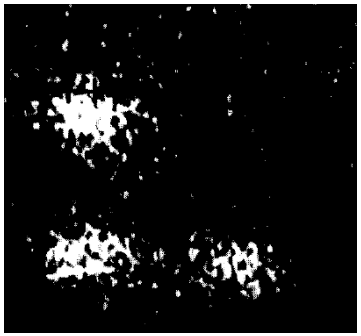
A. Del Guerra, R. Bellazzini, G. Tonelli and R. Venturi
Istituto di Fisica dell Universita', Piazza Torricelli, 2
I-56100 Pisa, Italy
and
Istituto Nazionale di Fisica Nucleare, Sezione di Pisa,
S. Piero a Grado, I-56010 Pisa, Italy
and
W. R. Nelson†
Stanford Linear Accelerator Center
P. O. Box 4349
Stanford, California 94305, U.S.A.

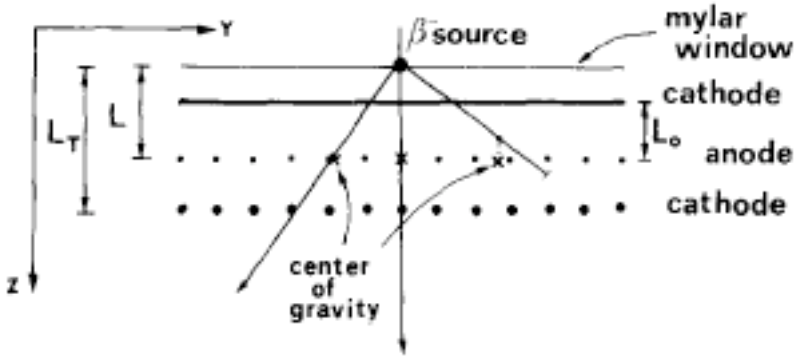
Submitted to Physics in Medicine and Biology

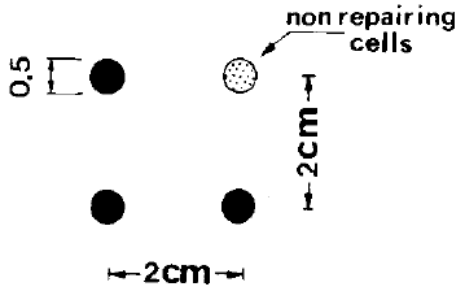
MWPCs to identify mutants mammalian cells.

By gaining momentum the newly formed **Medical Physics Group of Pisa** started soon developing new detection techniques. The key idea was to build special MWPCs to be used for medical or biological applications.

The new device allowed prompt identification of DNA repair-deficient mutants in mammalian cells through the measurement of radioactivity sinthesized during repair of damaged regions.







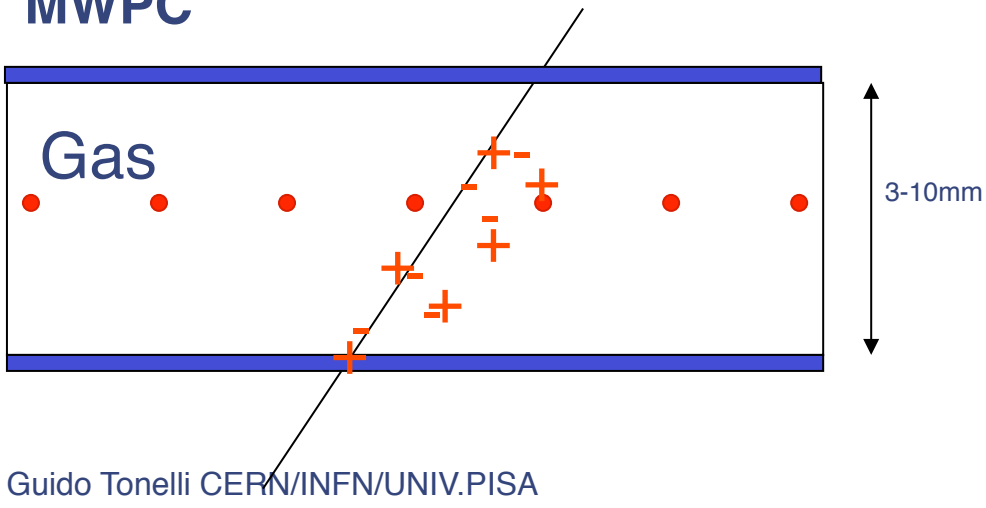
It was the first one of several breakthroughs that brought Alberto to become an international figure of Medical Physics.

But this first success marked also the moment in which our research paths diverged. I was too much attracted by CERN, a wonderful environment that I discovered when we were testing the performance of our MWPCs within the CERN test-beam facilities.

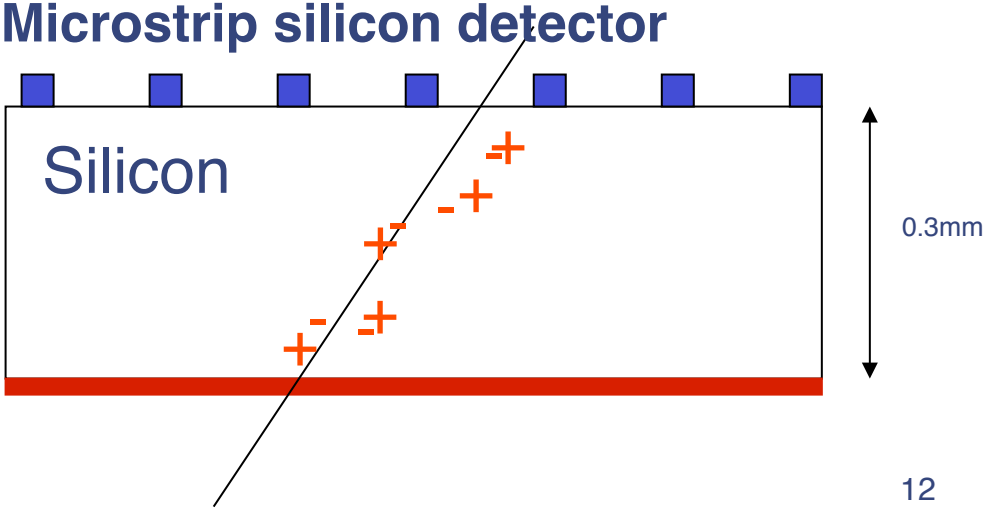
And I was deeply attracted by a new “crazy” idea that was being developed just in those years. Participate to the pioneering activity to develop a new generation of devices for High Energy Physics.

There was a group in Pisa fabricating “ in house” the first silicon devices ever used for tracking purposes in HEP. The scope of the work was to measure the lifetimes of the newly discovered charmed and beauty mesons. **I joined the group and I became a High Energy physicist.**

MWPC

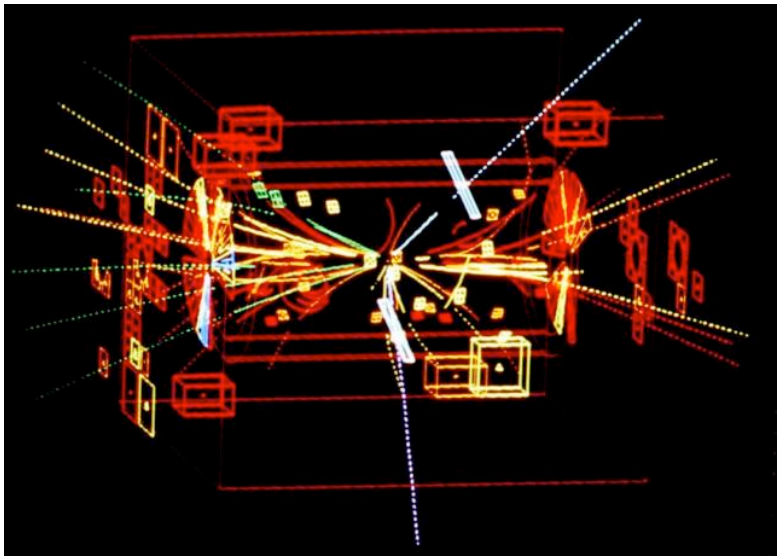


Microstrip silicon detector



Meanwhile

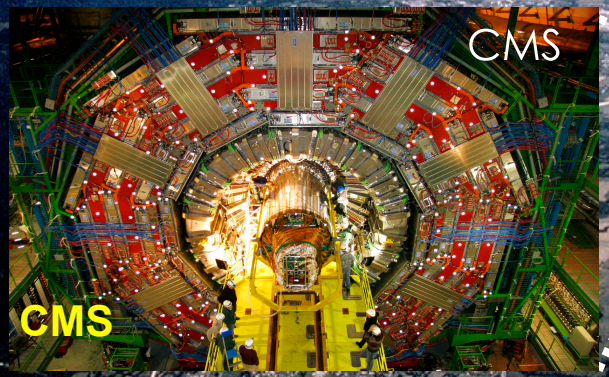
In 1983 W and Z are discovered at CERN by the UA1 and UA2 experiments.

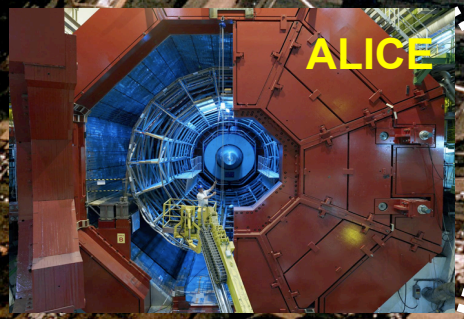


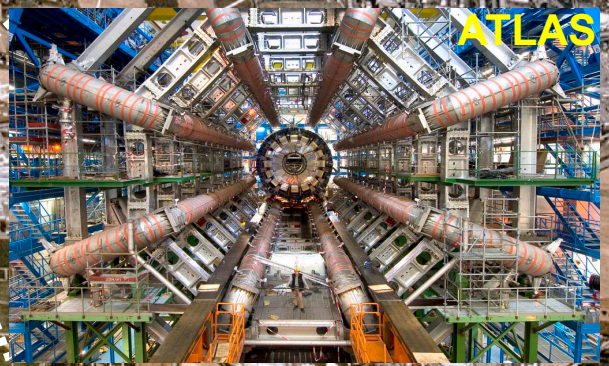
Nobel Prize to Rubbia and Van der Meer in 1984.

But the Higgs boson still escaped all attempts of direct detection. Generations of scientists did spend their whole professional life in **hunting for what was soon considered the most elusive particle ever.**

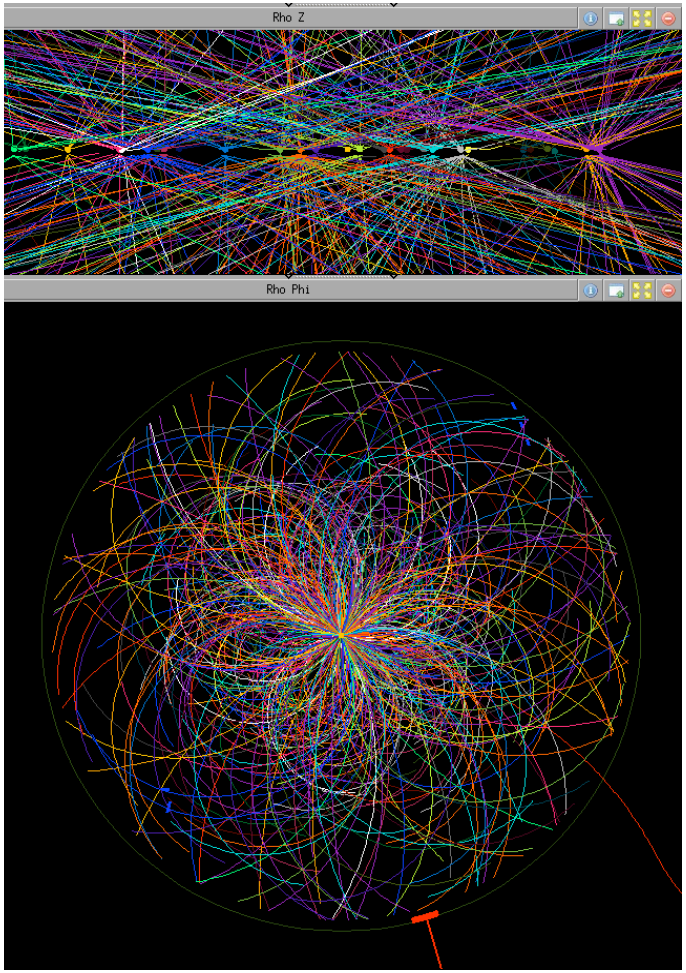
Until when a new generation of young scientists had the dream of building the Large Hadron Collider (LHC) and its experiments.

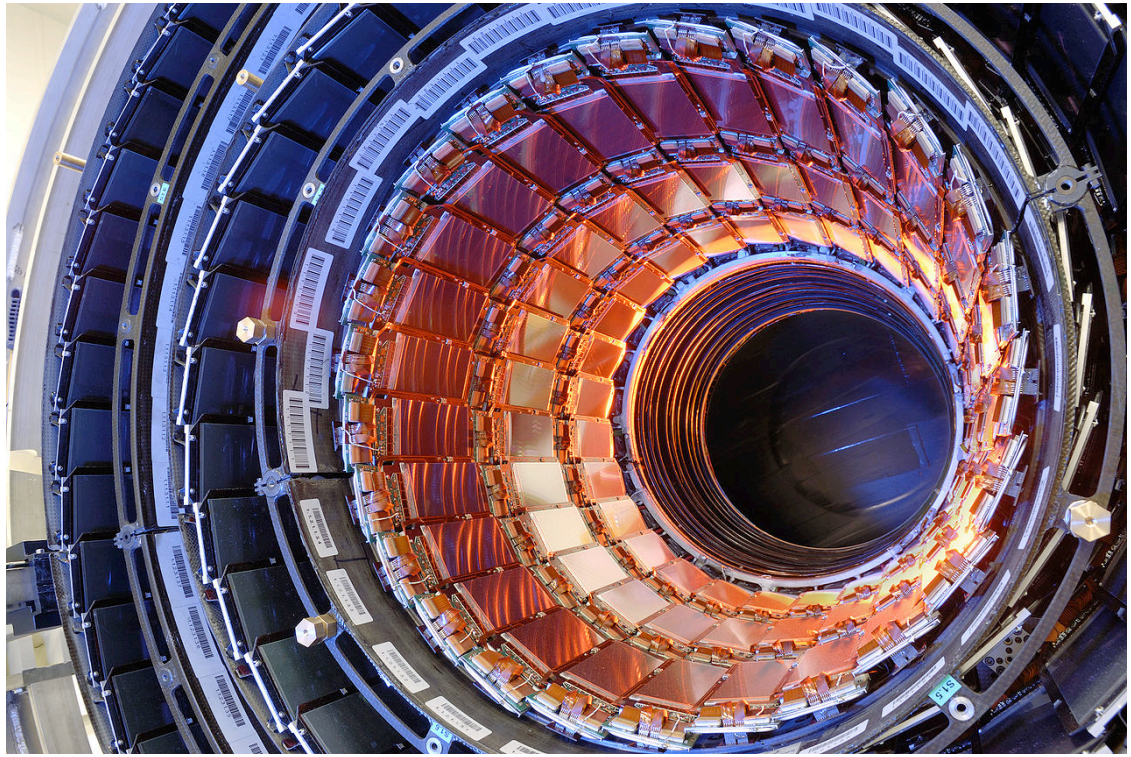






There were many technical challenges in this enterprise. To build the inner tracker was considered among the worst ones.





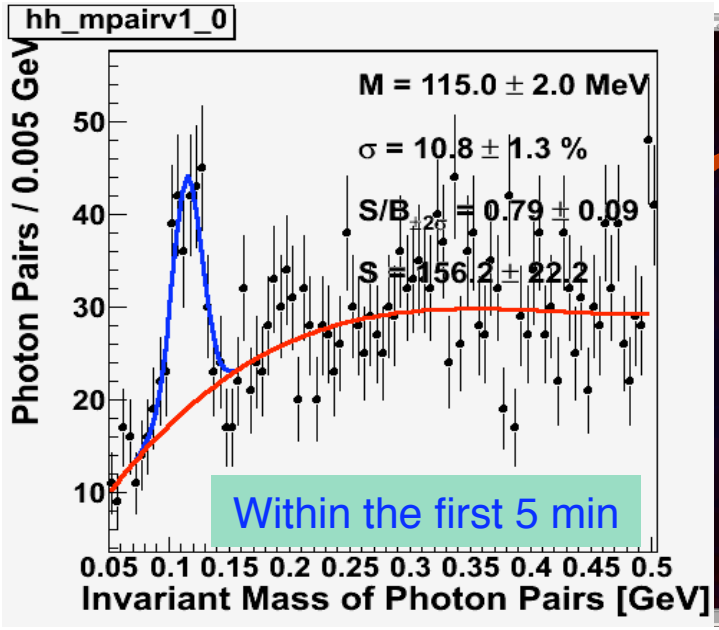
The full silicon tracker of CMS: 16.000 extremely sophisticated, radiation resistant, silicon devices capable to handle the harsh environment of the LHC collisions.

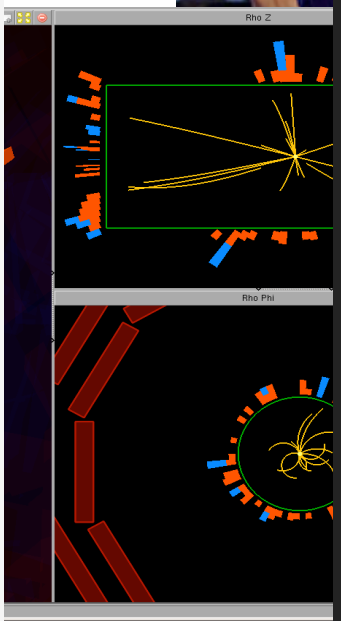

Another
“mission impossible”

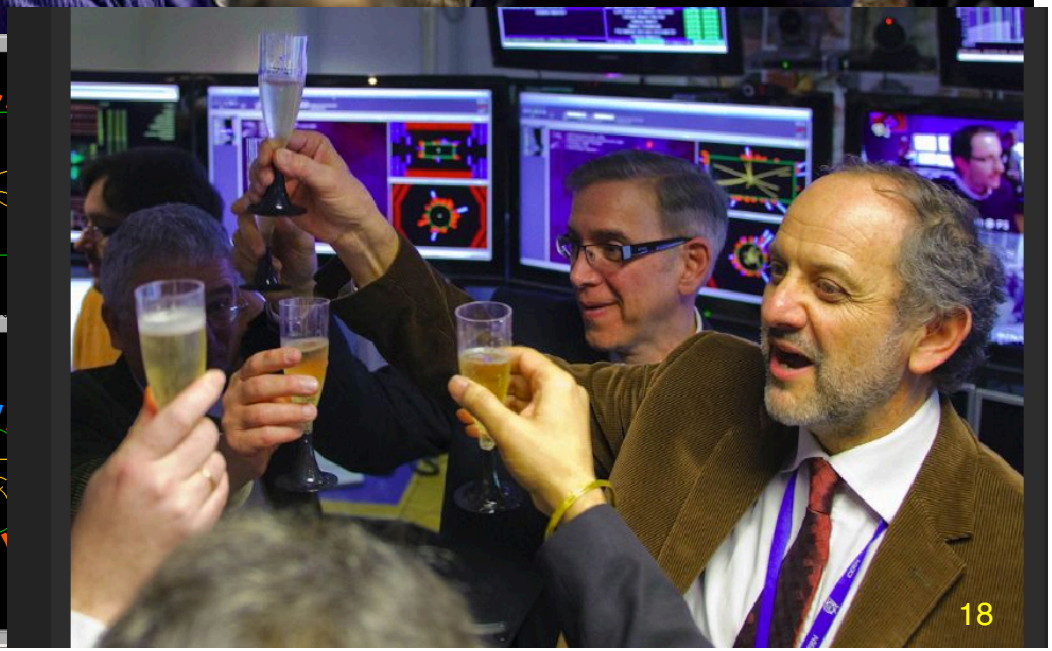
That led to a fantastic detector

The story of deep emotions

30/3/2010 12:58 : 7TeV Collisions



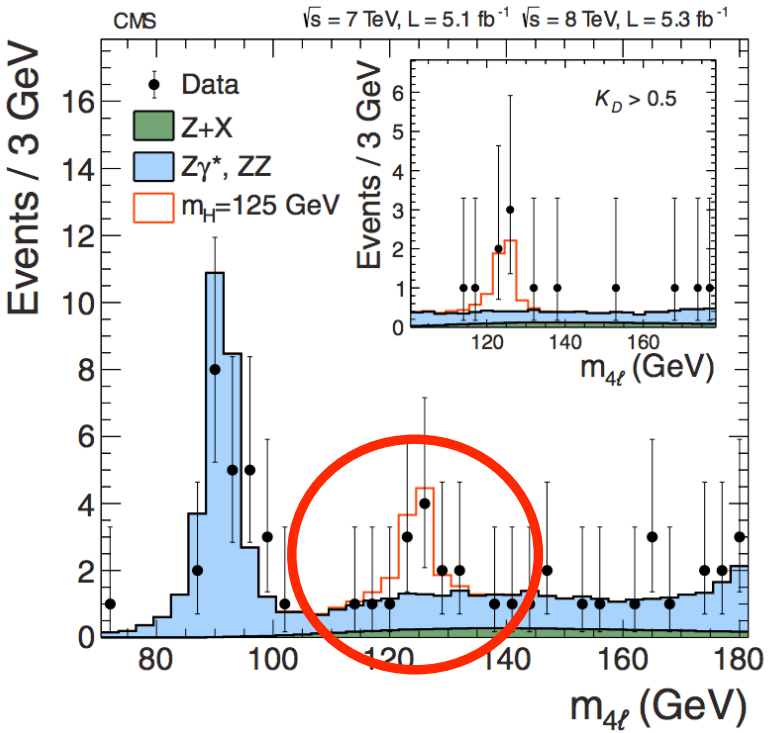




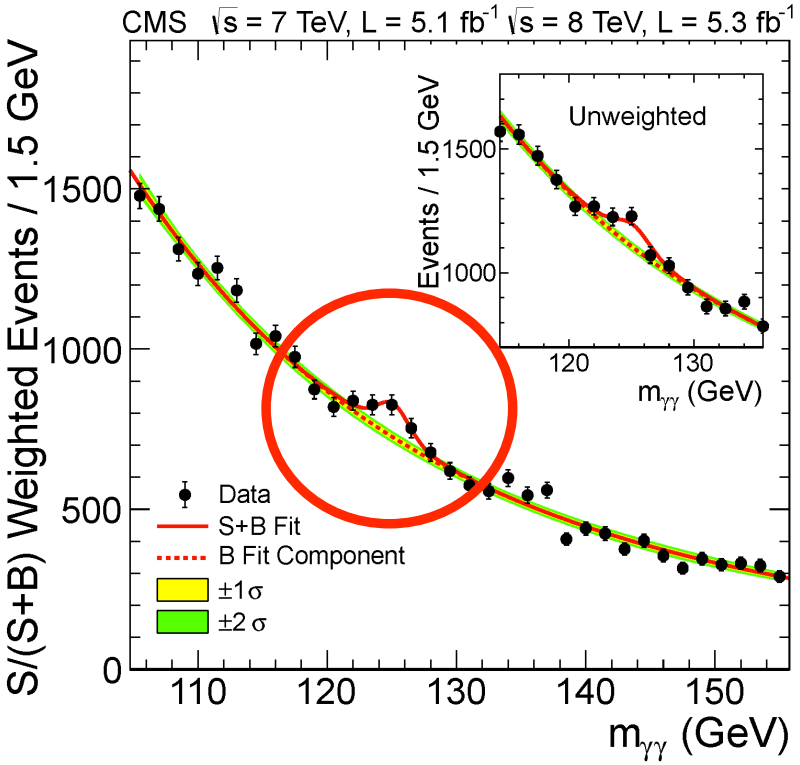

and of eyes that will be difficult to forget.

And just when everybody thought that this would have been another un-successful attempt.

H→ZZ→4leptons



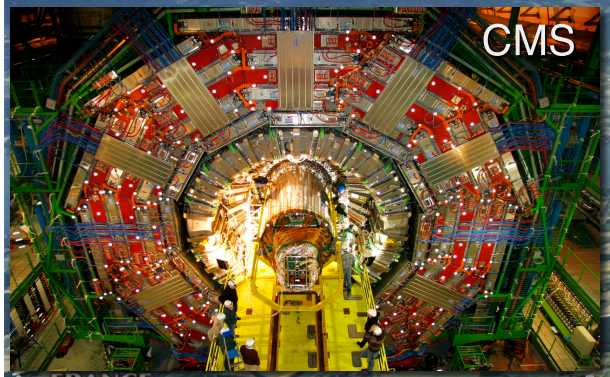
H→γγ



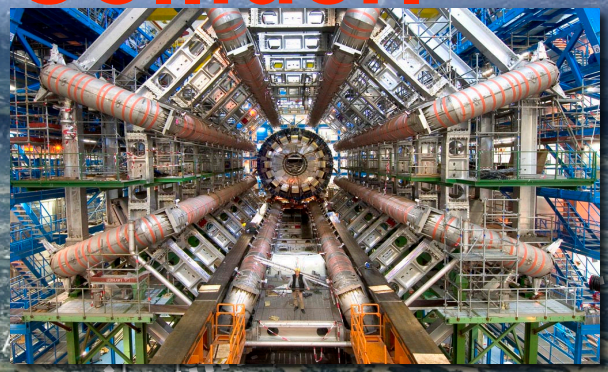
3.2σ excess (3.8 exp.)@ 125.6 GeV **4.1σ excess (2.8exp.) @ 125GeV**

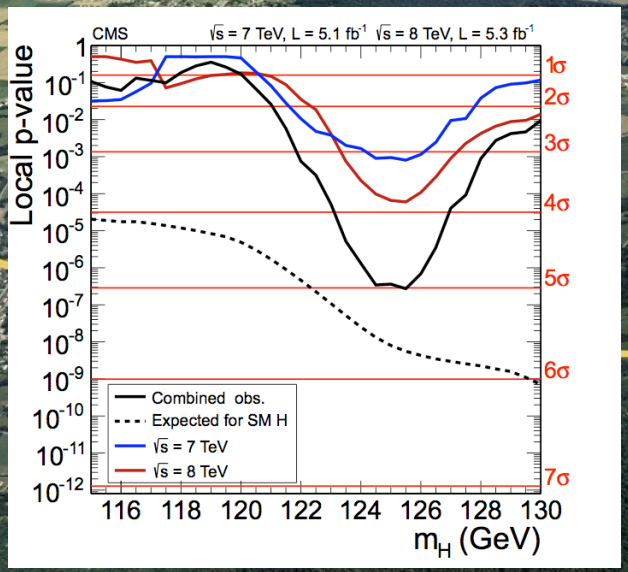
A coincidence of signals in two high resolution channels triggered an historical discovery.

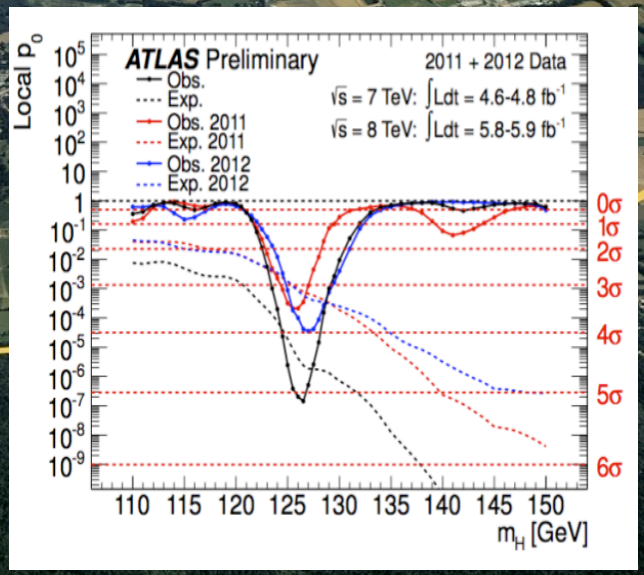
A new boson discovered by ATLAS and CMS at the Large Hadron Collider.



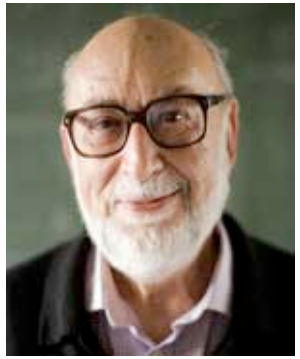
ATLAS



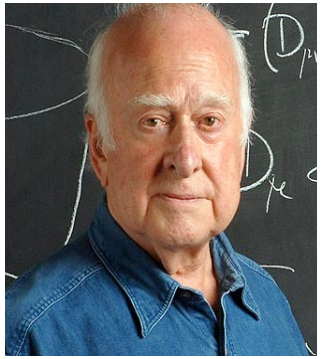




Nobel Prize for Physics 2013

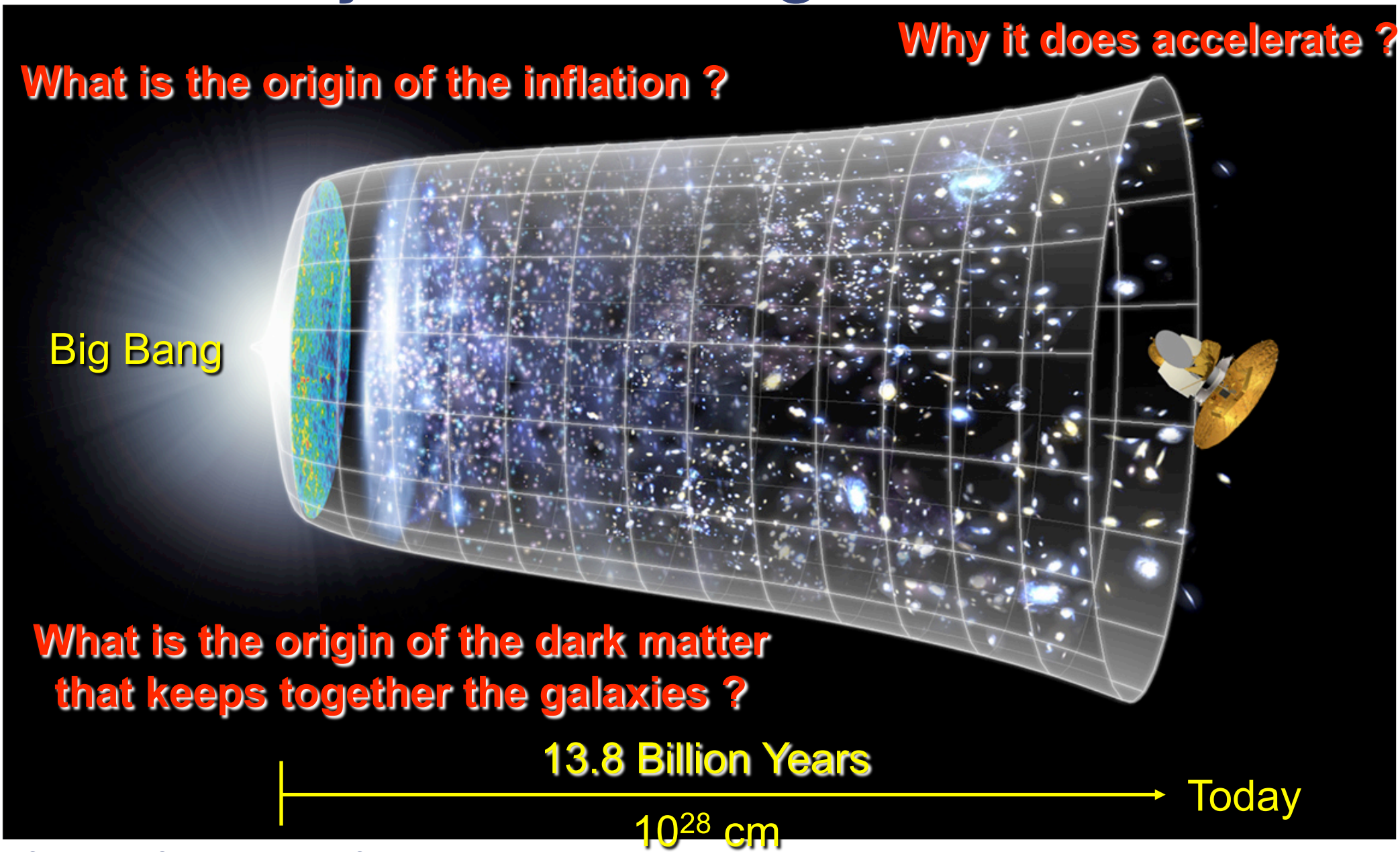


Francois Englert



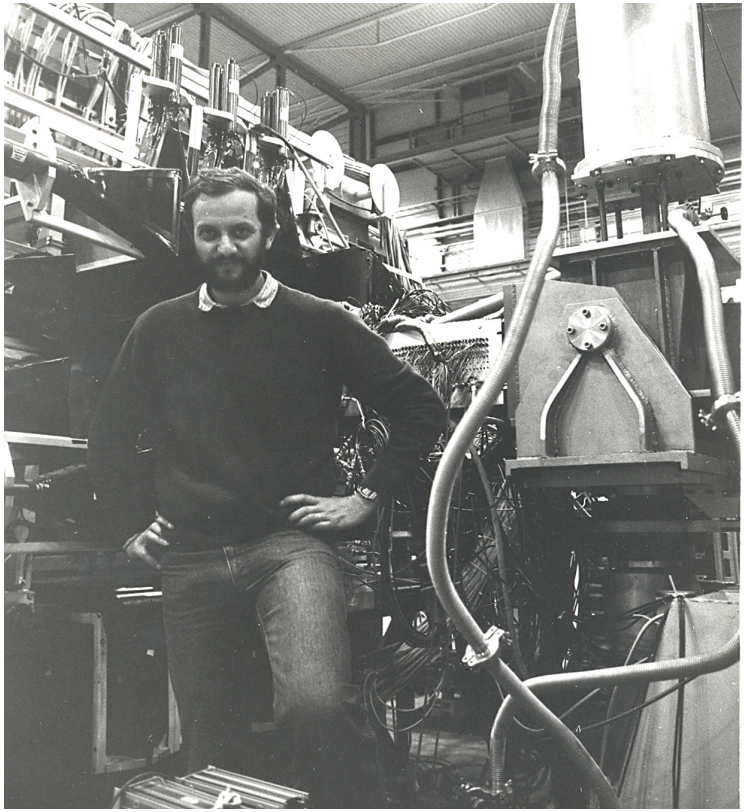
Peter Higgs

The story of a challenge that continues



The effects of all this.

Very elegant clothes (sometime) .....but no more hair.



Many thanks Alberto for having trained a young student to think “out of the box” and not to be afraid of any new challenge, in particular those considered “missions impossible”.