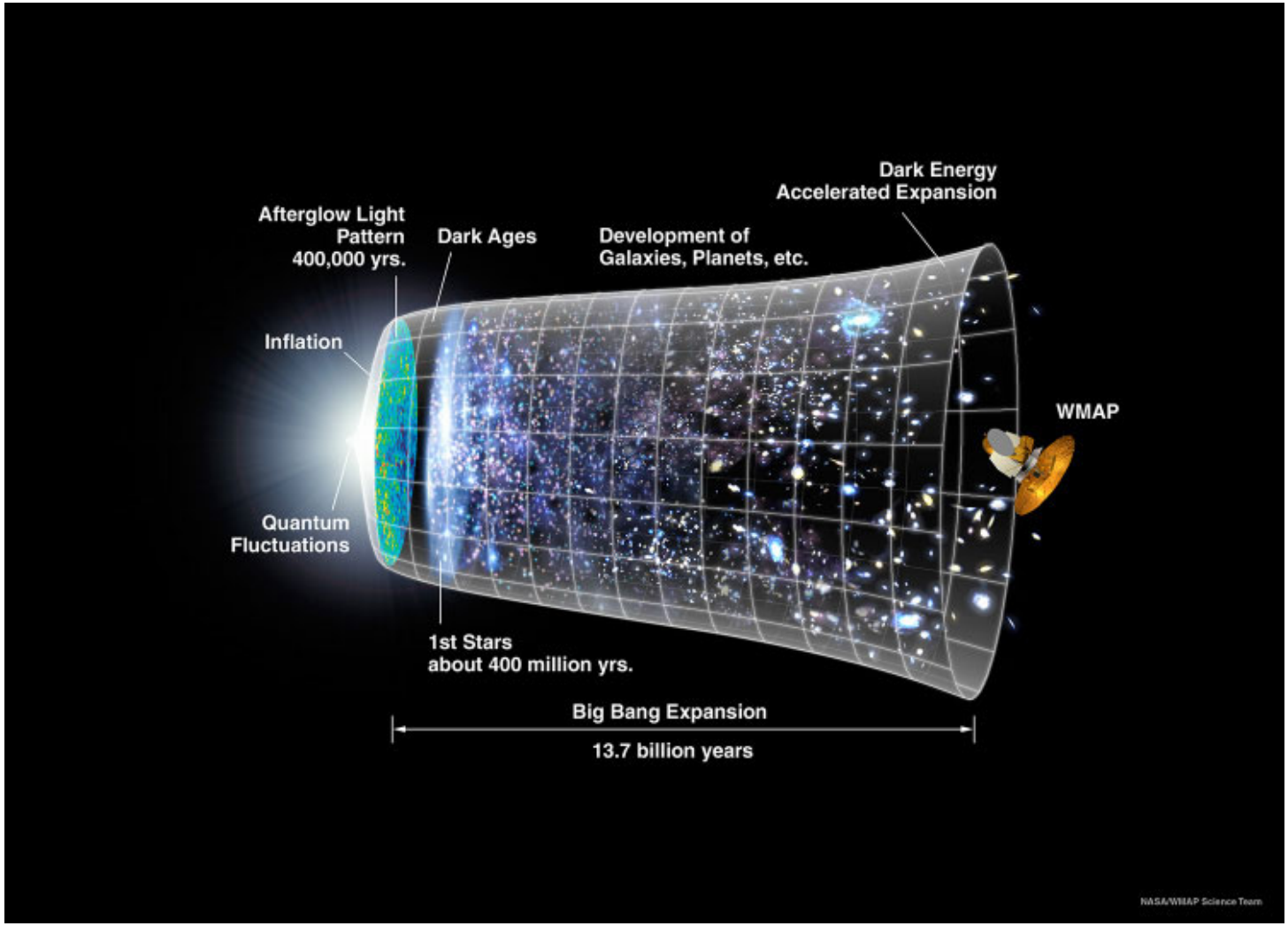
Exploring the frontiers of knowledge
Explorer les frontières du savoir

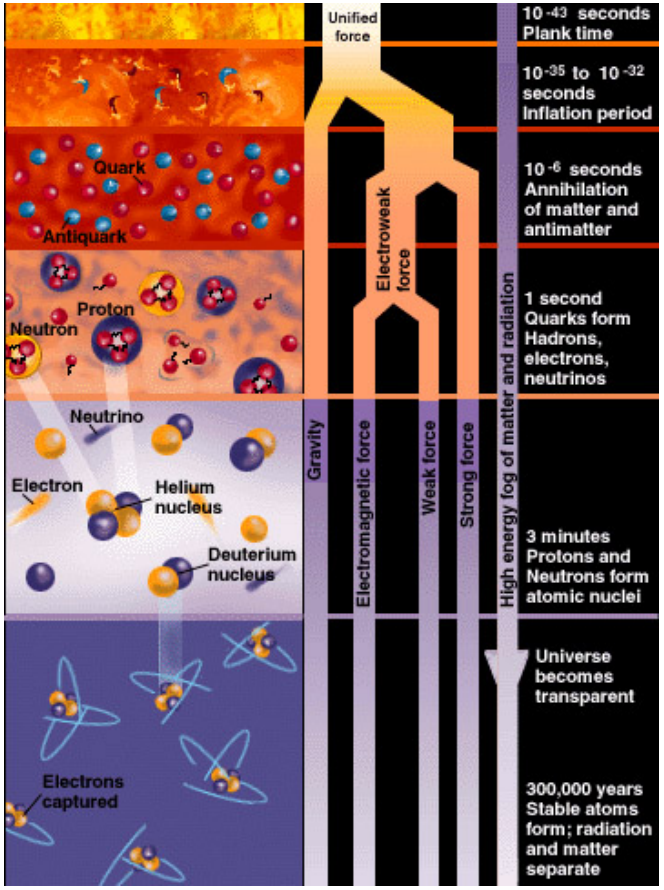
Hunting the Higgs boson

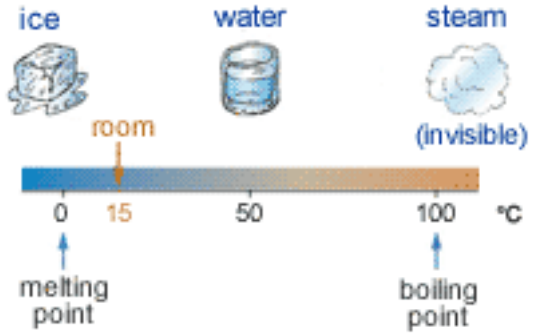
James Gillies, Head of communication, CERN

The Universe on a page



Symmetry breaking and the emergence of structure

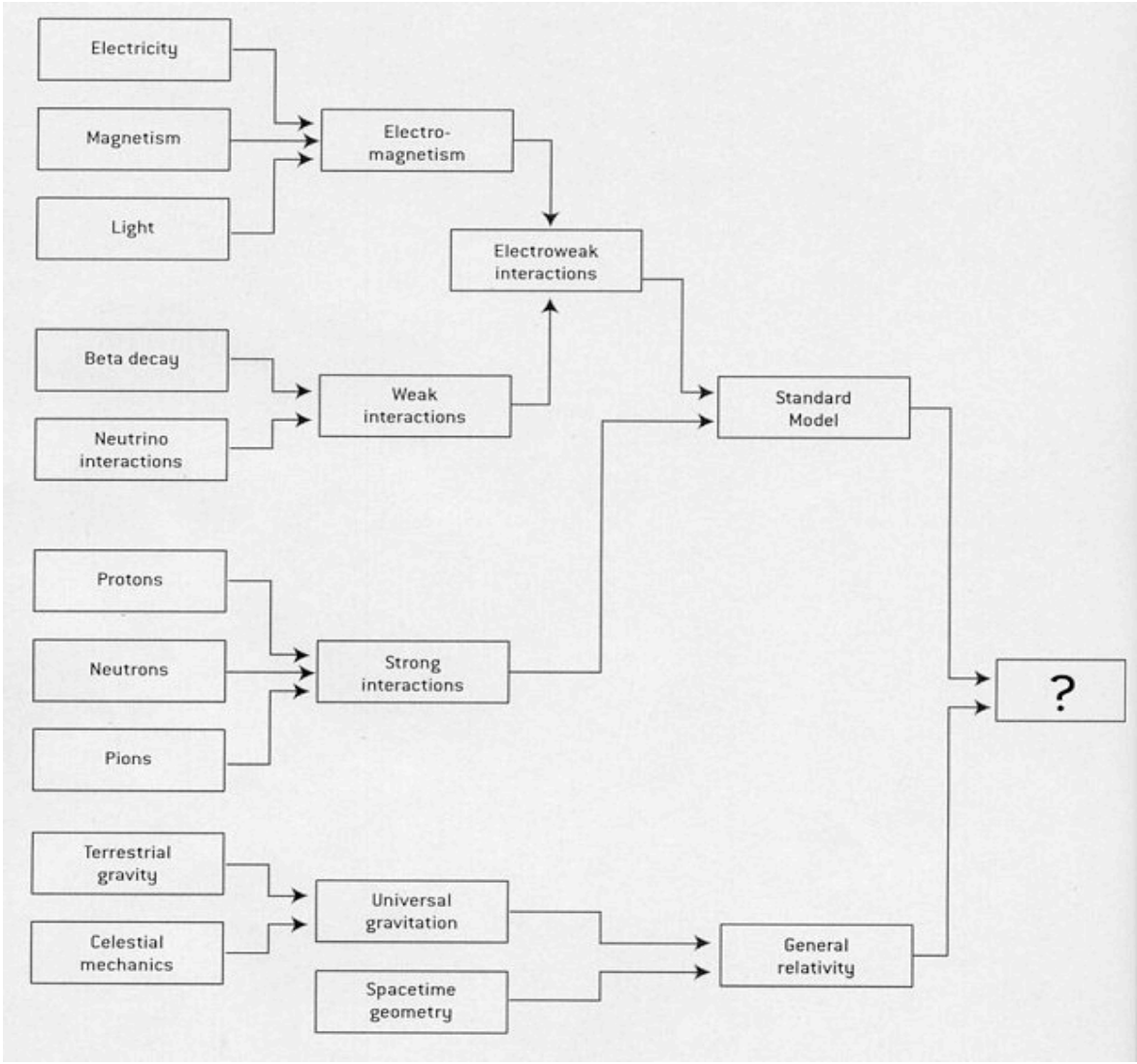




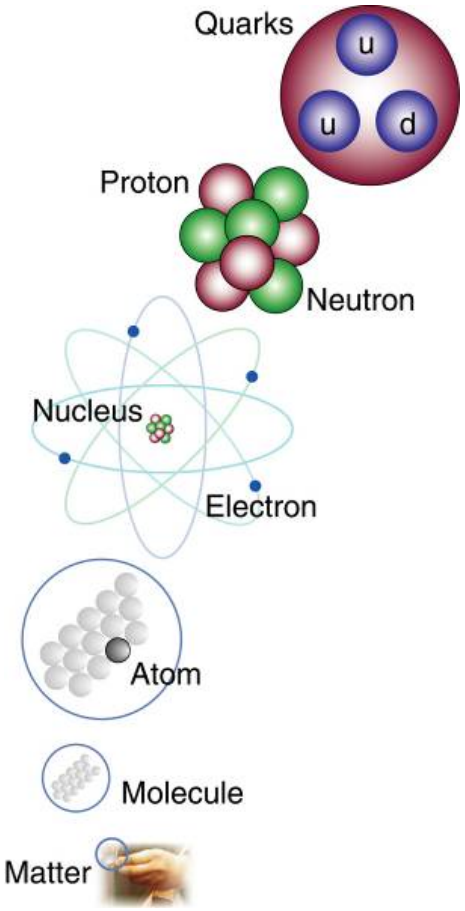
The longest ellipsis …

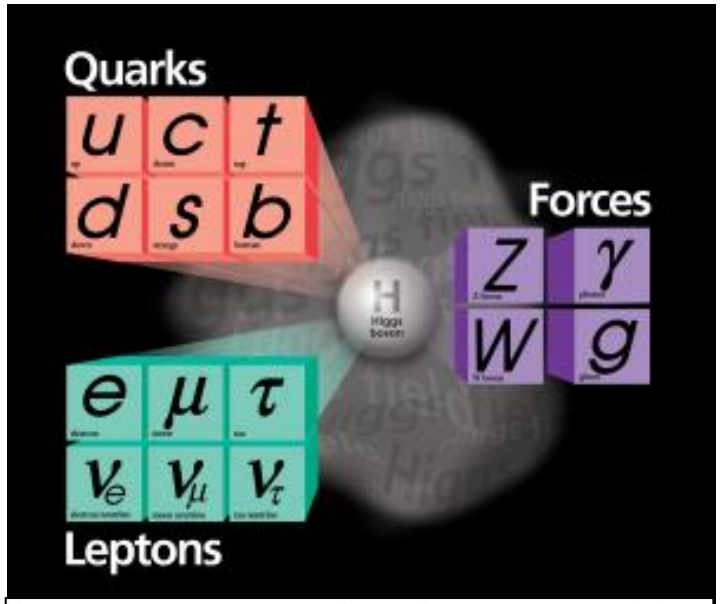
1687, Newton: Gravitational unification

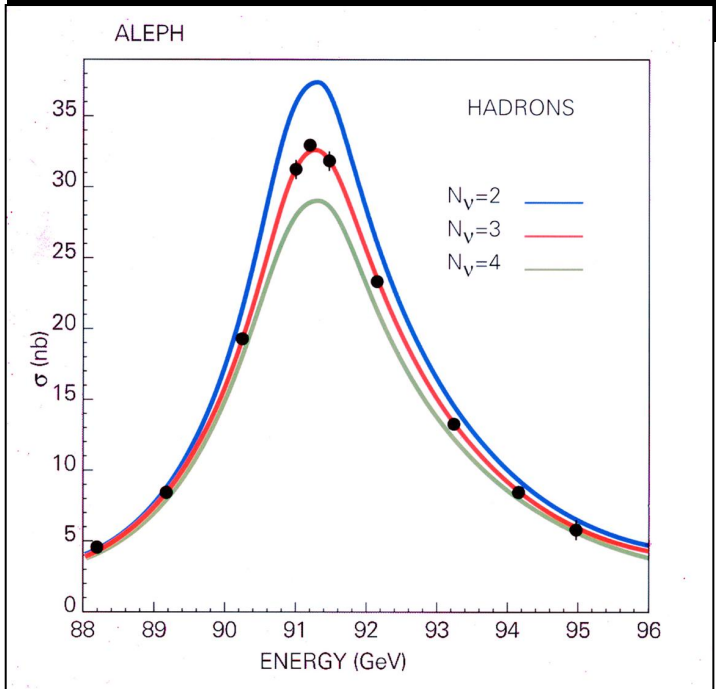
The dream of unification



The Standard Model



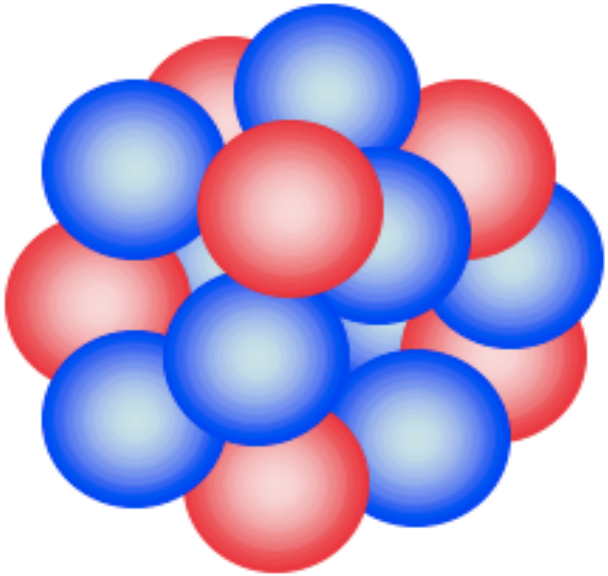




CERN

Exploring the frontiers of knowledge
Explorer les frontières du savoir

1960s, Glashow, Weinberg, Salam: Electroweak unification



Weak

Range – nuclear scale

Electromagnetic

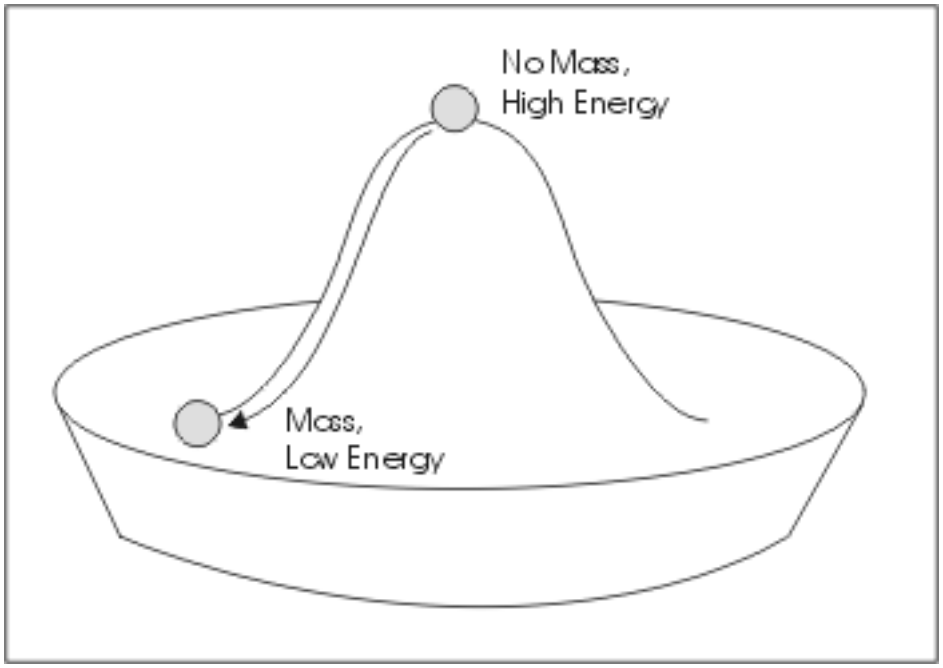
Range – infinite

Long range and short range…

Question? Why does electromagnetism have infinite range, whereas the weak interaction is short range?

Answer (1964-5, Brout, Englert, Higgs, Guralnik, Hagen, Kibble…): Because the carrier of the weak force is heavy. The symmetry that unifies electromagnetism and weak interactions is broken.

The BEH(iggs)GHK mechanism



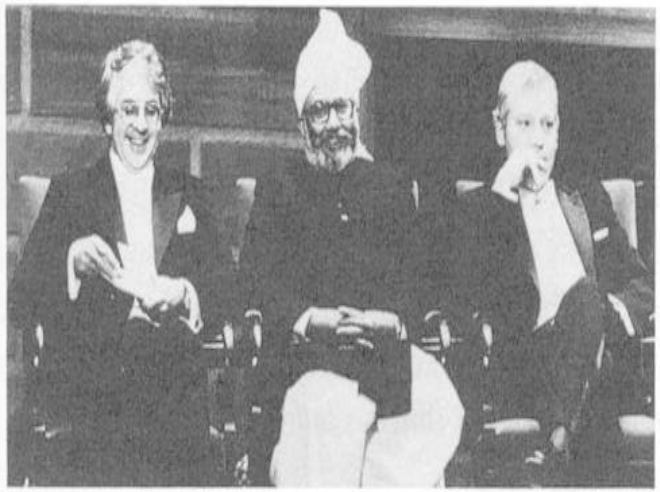
High energy – Weak force carriers have no mass. The symmetry is intact in the early universe.

Low energy – Weak force carriers have mass. The symmetry is now broken.

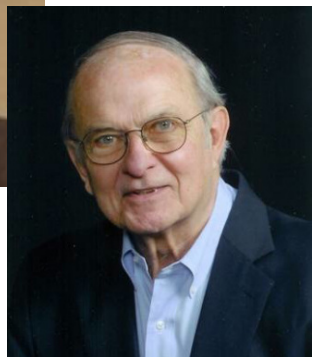
Exploring the frontiers of knowledge
Explorer les frontières du savoir

The Higgs field is a scalar field

To recap…



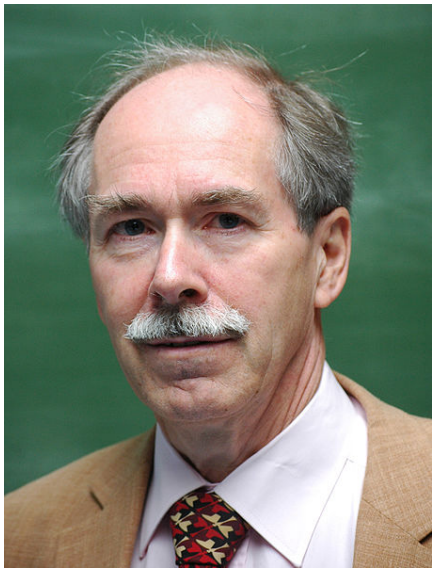
Sheldon Glashow, Abdus Salam, and Steven Weinberg sharing the Nobel Prize, 1979



End of the 1960s, Glashow, Salam, Weinberg – electroweak unification (W^+, W^-, Z^0, γ) …

Brout, Englert, Higgs, Hagen, Guralnik, Kibble – electroweak symmetry breaking: W, Z massive, γ massless

Slight hitch…



The theory produced infinities when used to calculate physical properties.

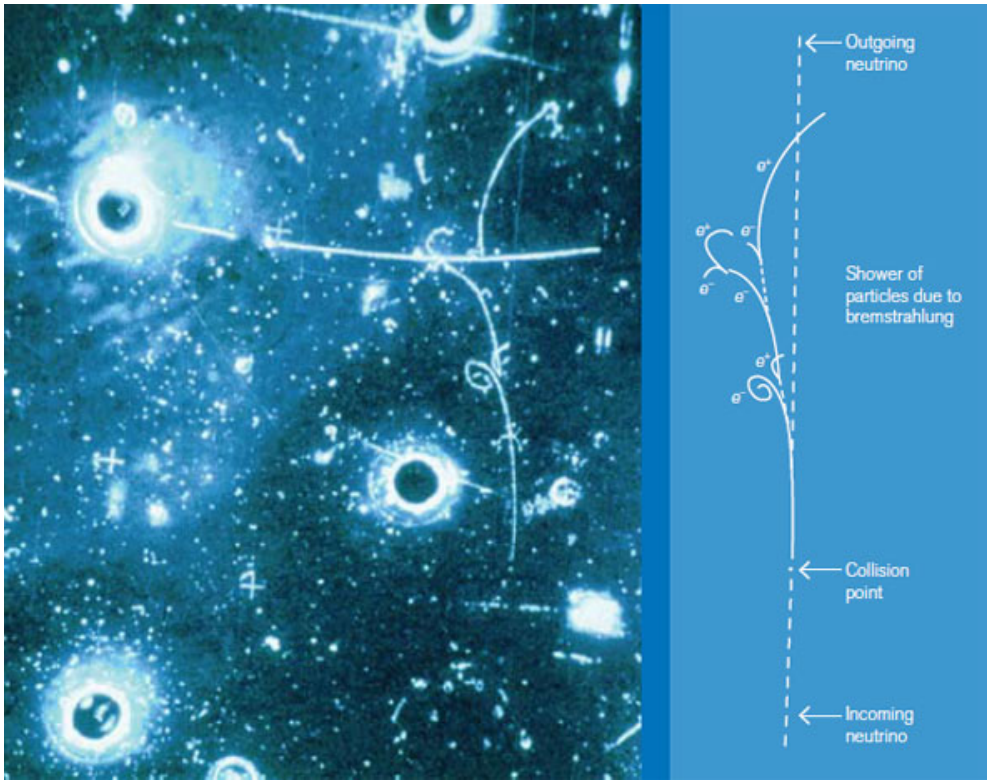
Resolved by ‘t Hooft and Veltman in 1972 (Nobel Prize 1999)

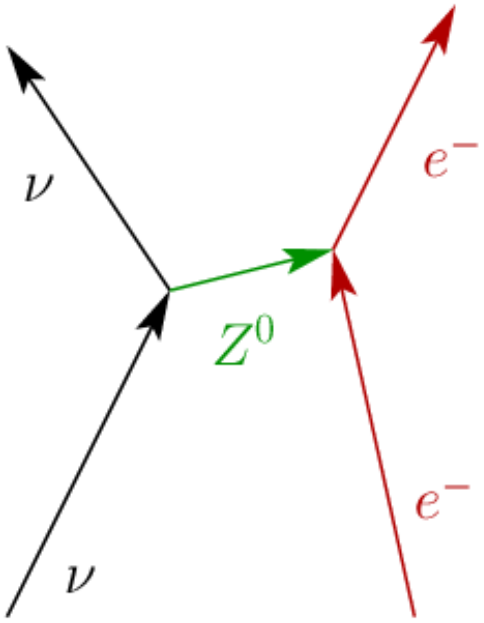
Why is the Higgs called Higgs?

Ben Lee called it that?

Steven Weinberg mis-cited papers?

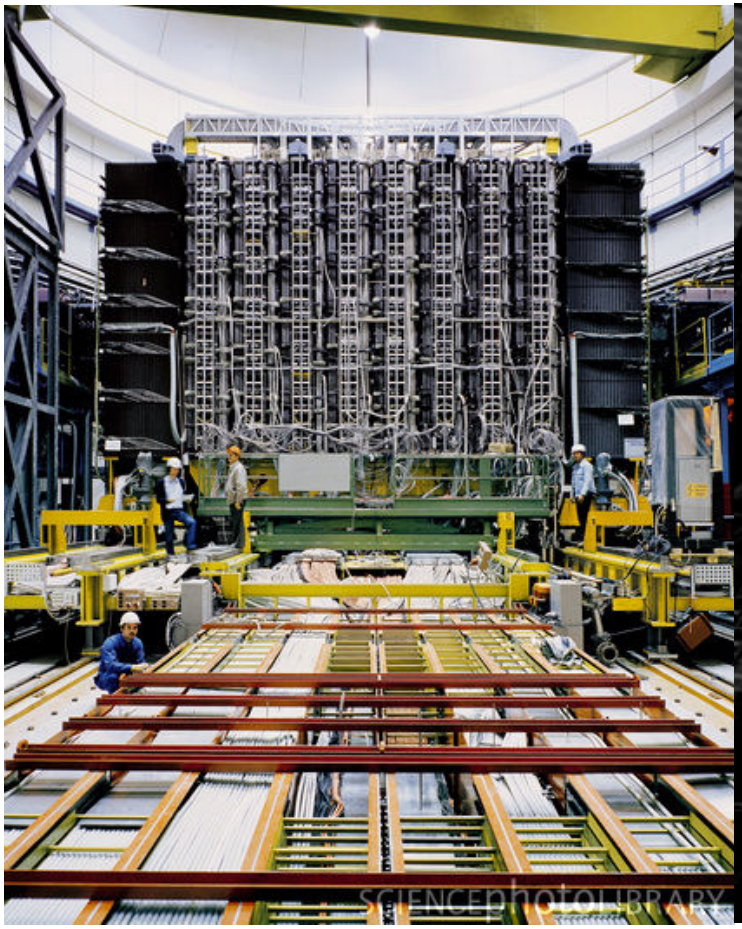
First experimental evidence

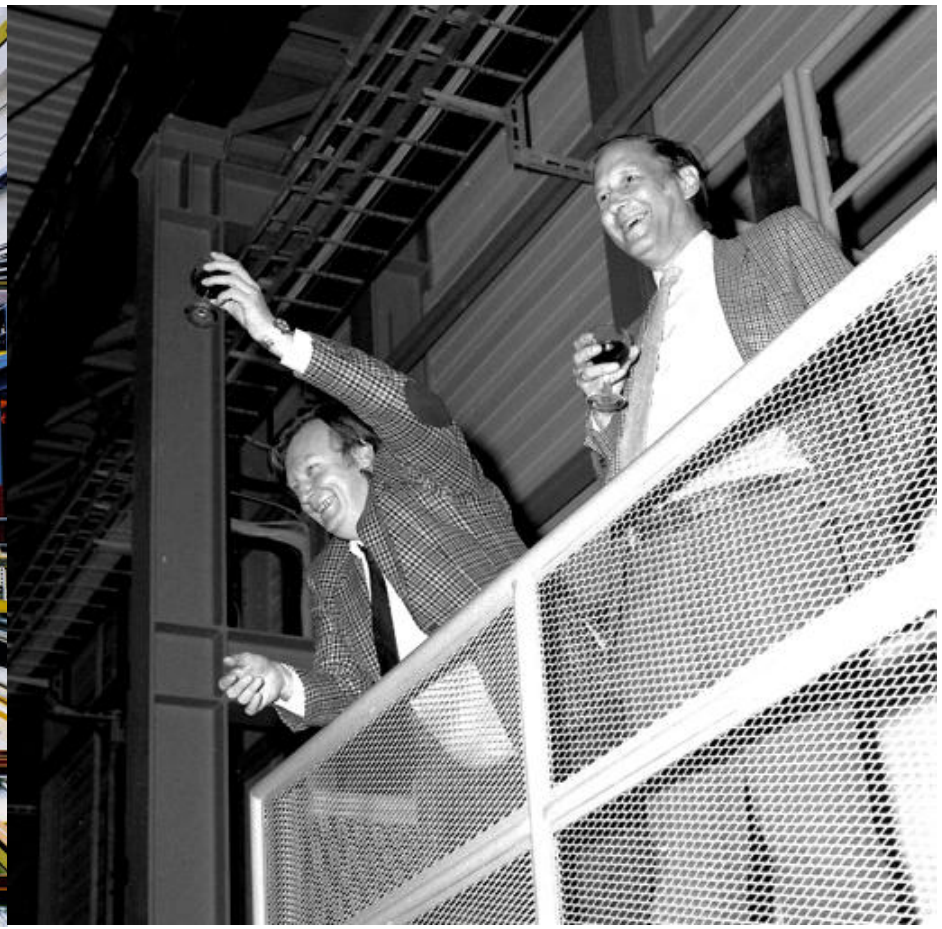




Neutral current

1983: UA1 and UA2 experiments detect W and Z bosons





The search is on…

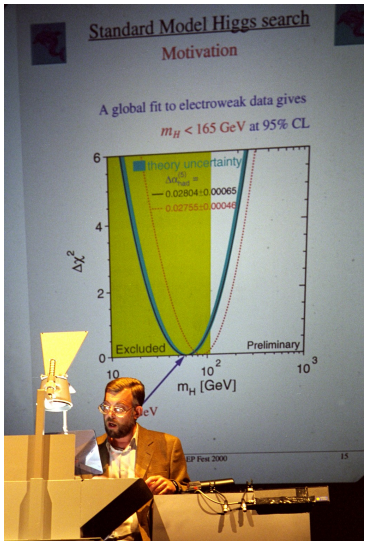
Tevatron, Fermilab

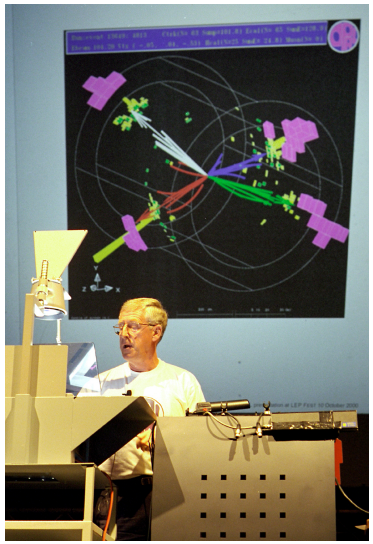
SLC, SLAC

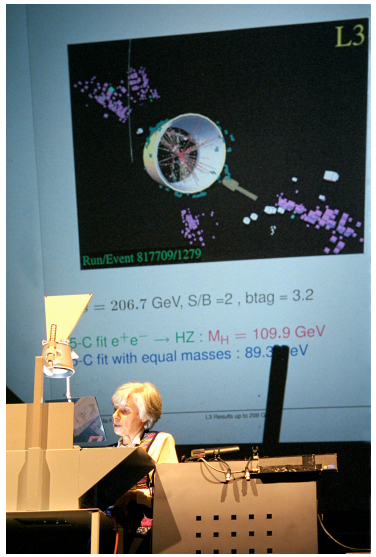
LEP, CERN

The year 2000….

- CERN's ageing LEP collider was pushed to the limit…
- …had the experiments seen a glimpse of the Higgs?





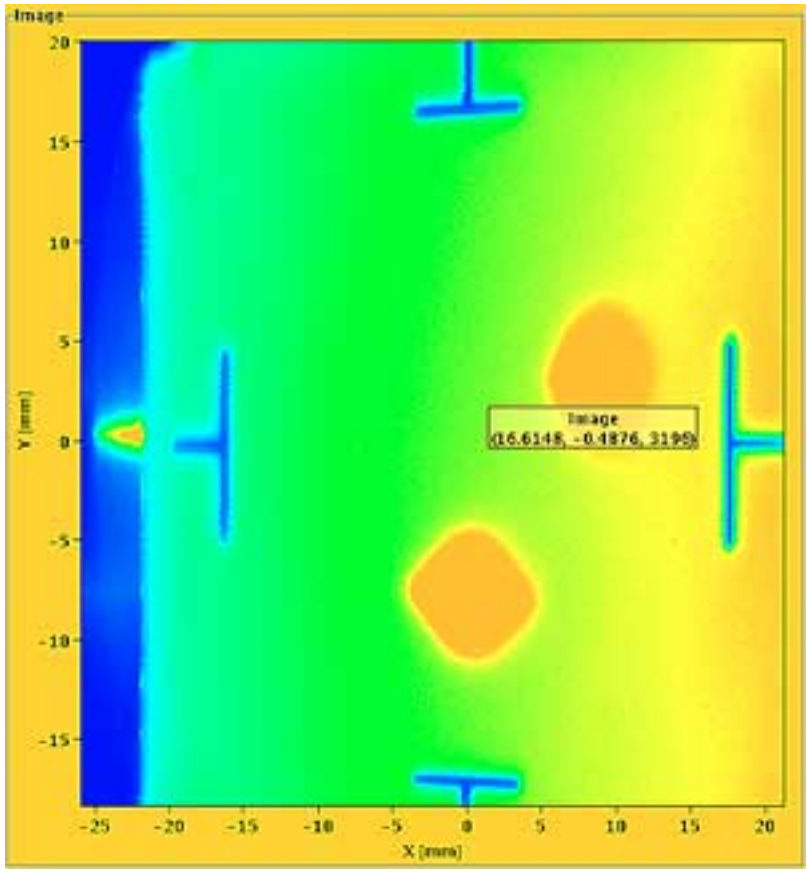


The drive to the LHC

- We'd have to wait and see
- Director General announces LEP to shut, as planned, in 2000 (the following year, he announced an 18% cost overrun for the LHC).
- All eyes turn towards Chicago…

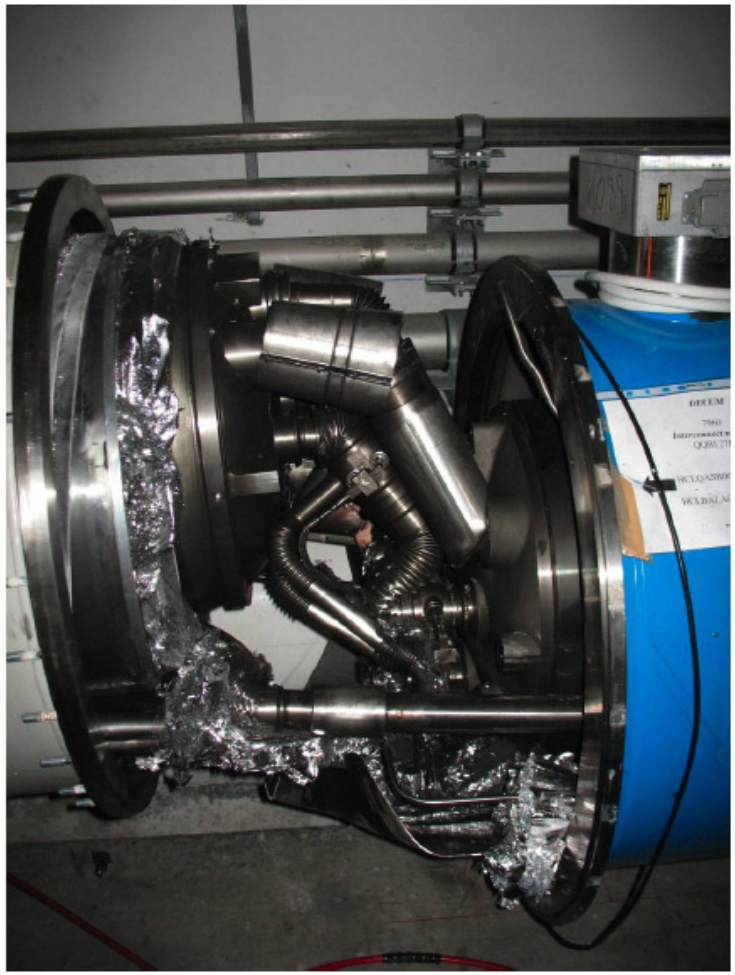
The Tevatron is back

2008: LHC first beam

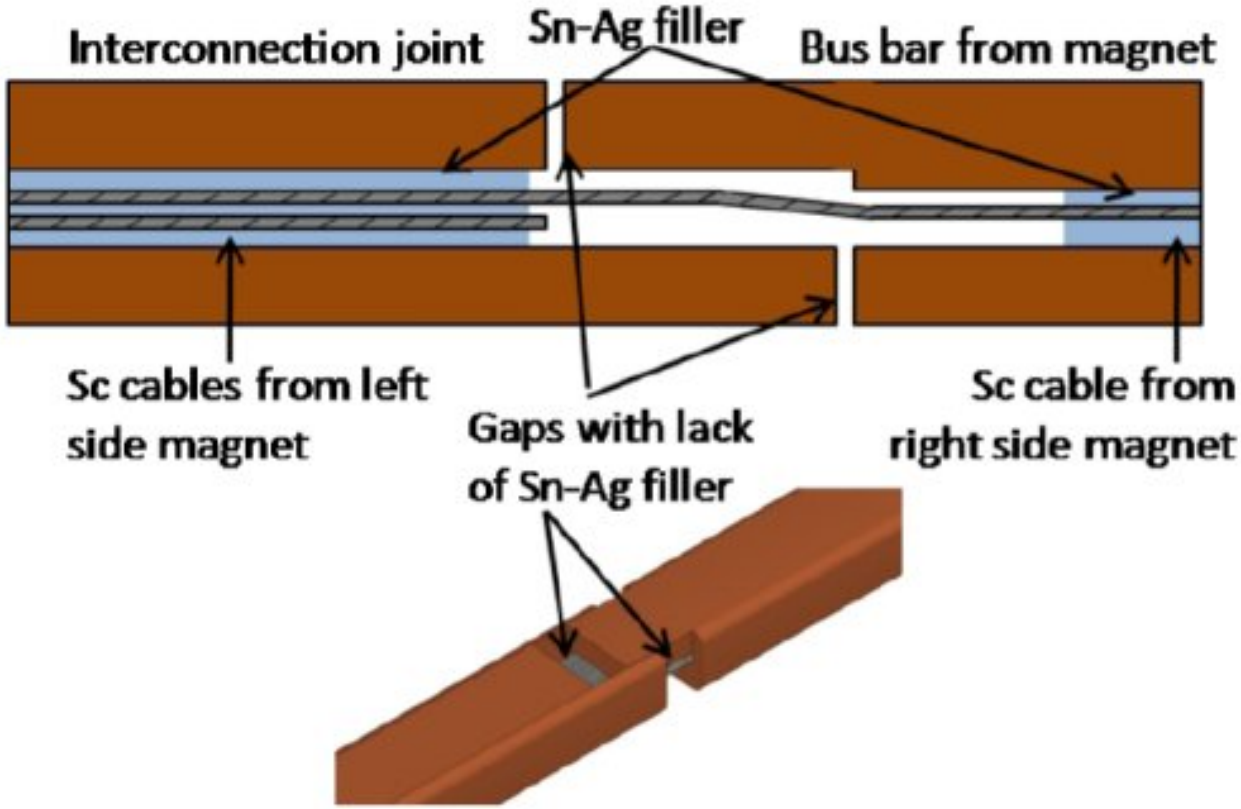


- Beam circulates in the LHC for the first time on 10 September 2008.
- One week later, the machine is broken, and off for a year…
- The race is still on!

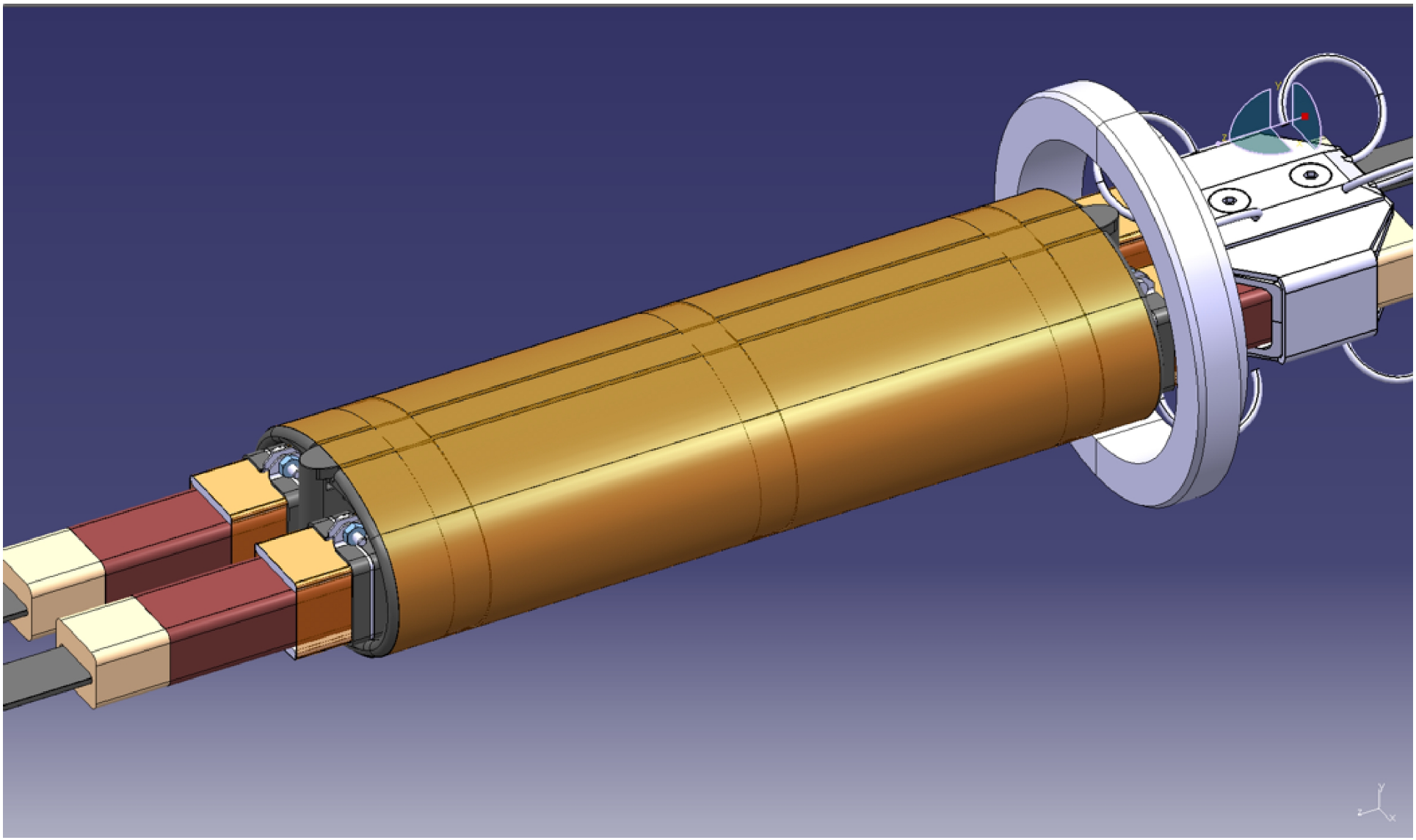
What went wrong in 2008?



What went wrong in 2008?



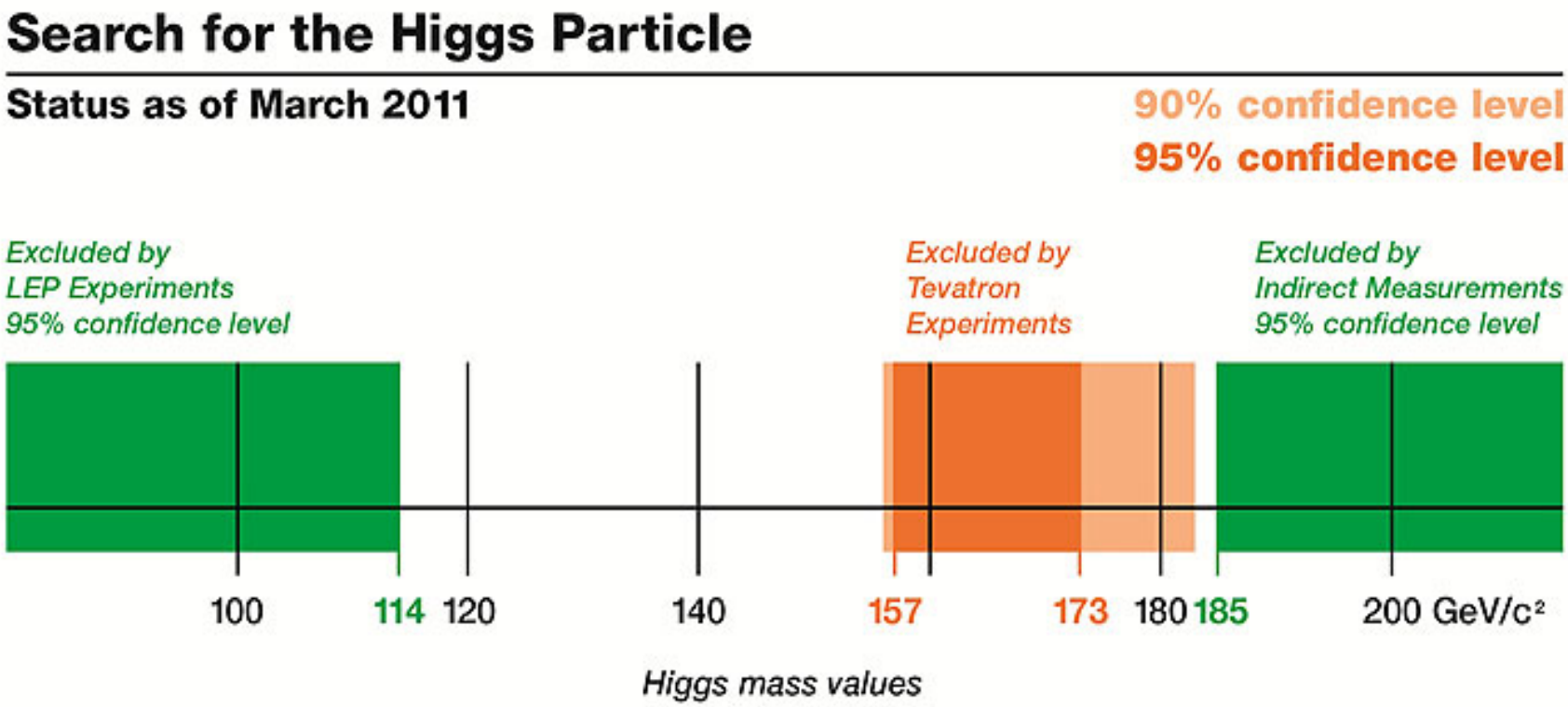
And what are we doing about it?



2009: The LHC is back…

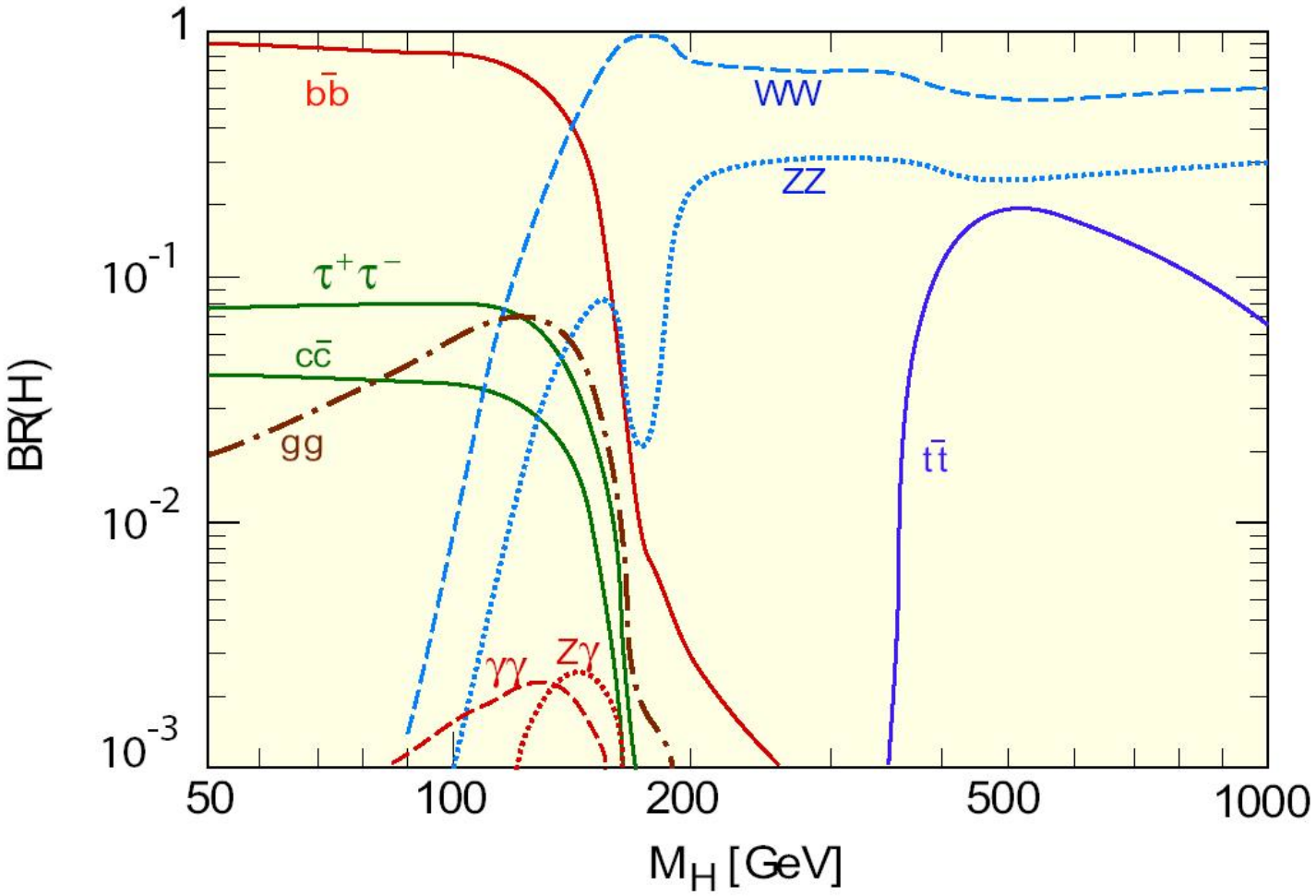
… and soon delivering data vastly more rapidly than the Tevatron

The status of the Higgs search at the beginning of 2011

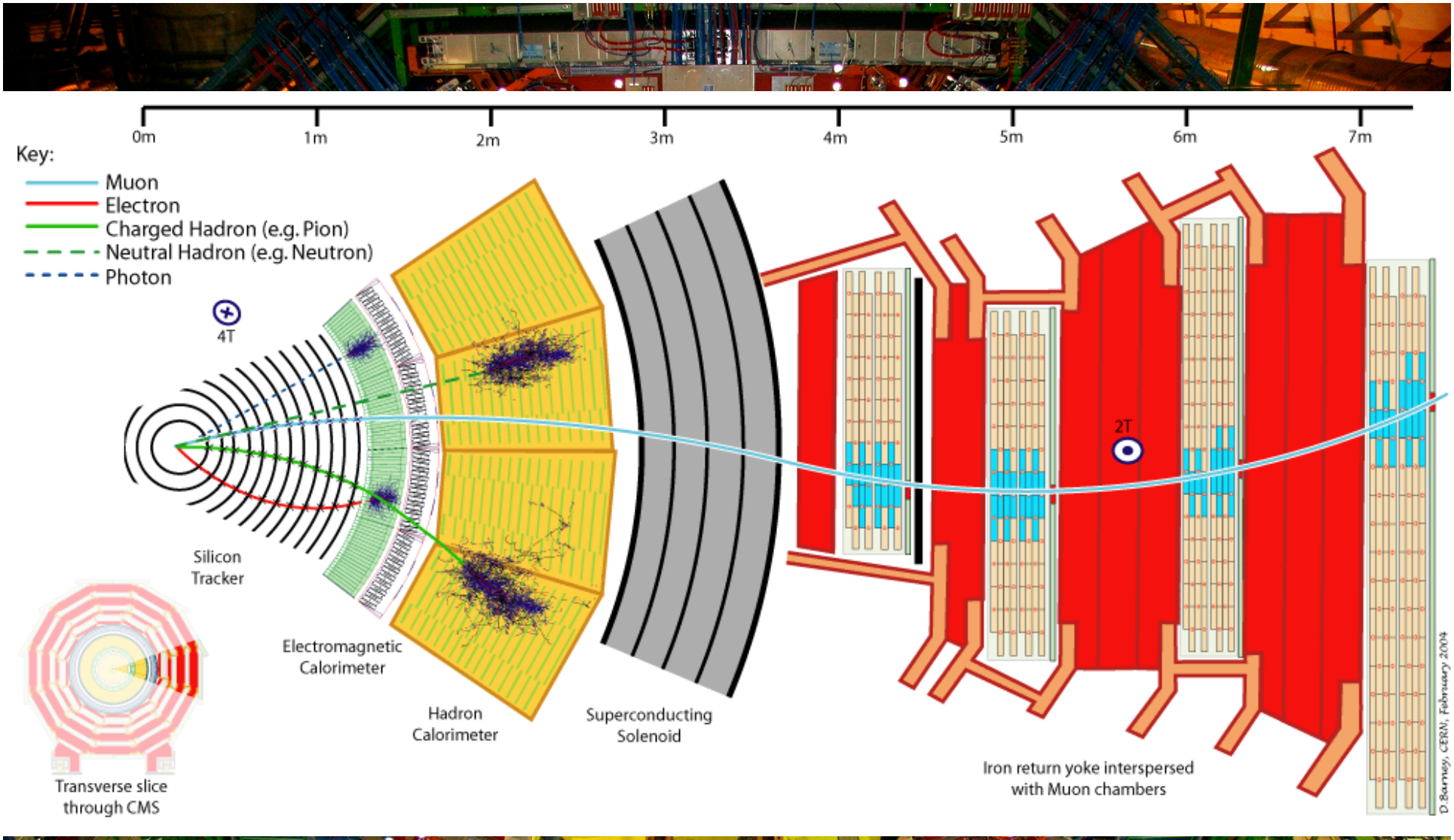


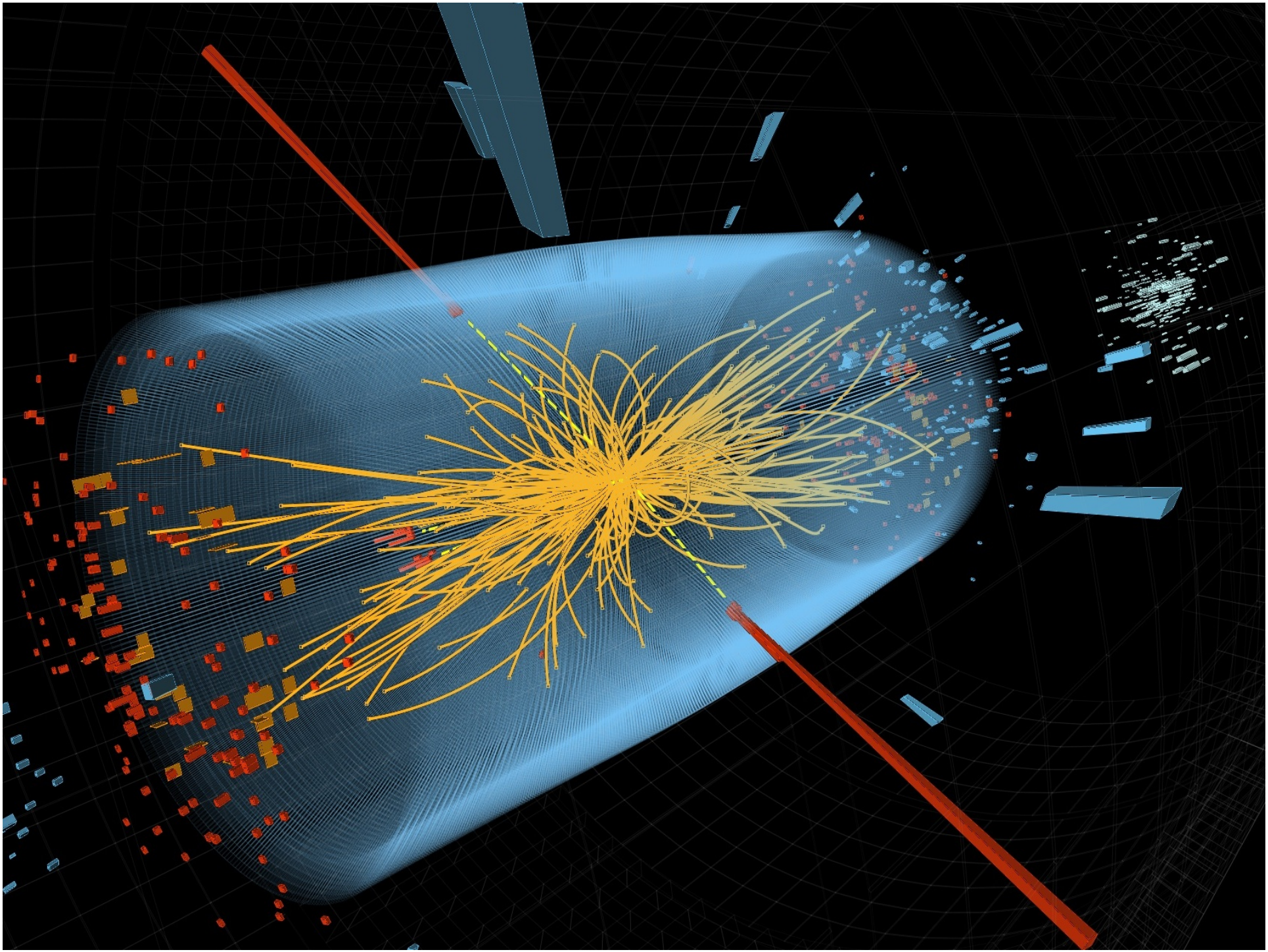
How do you search for a Higgs?

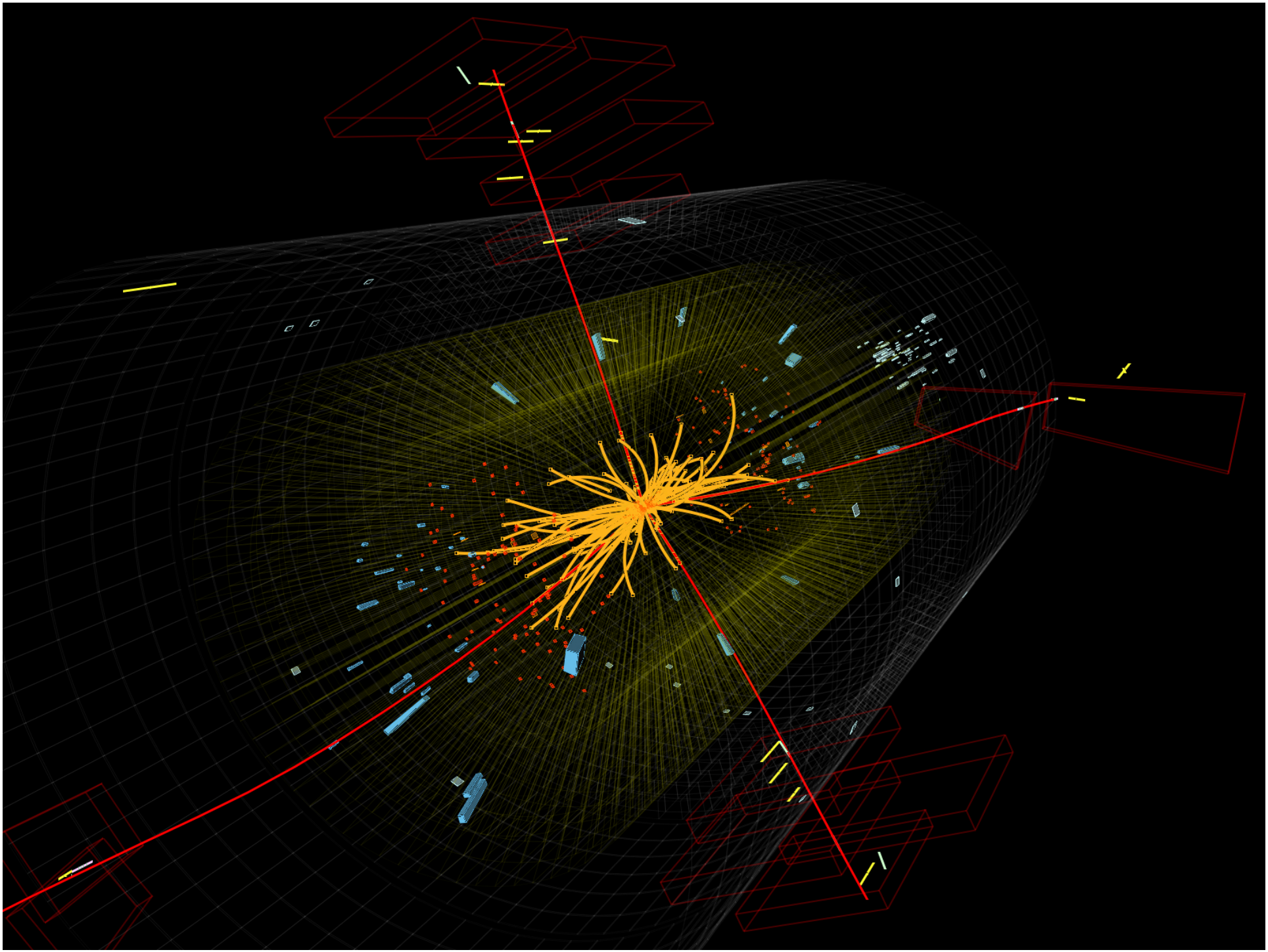
$E = mc^2$



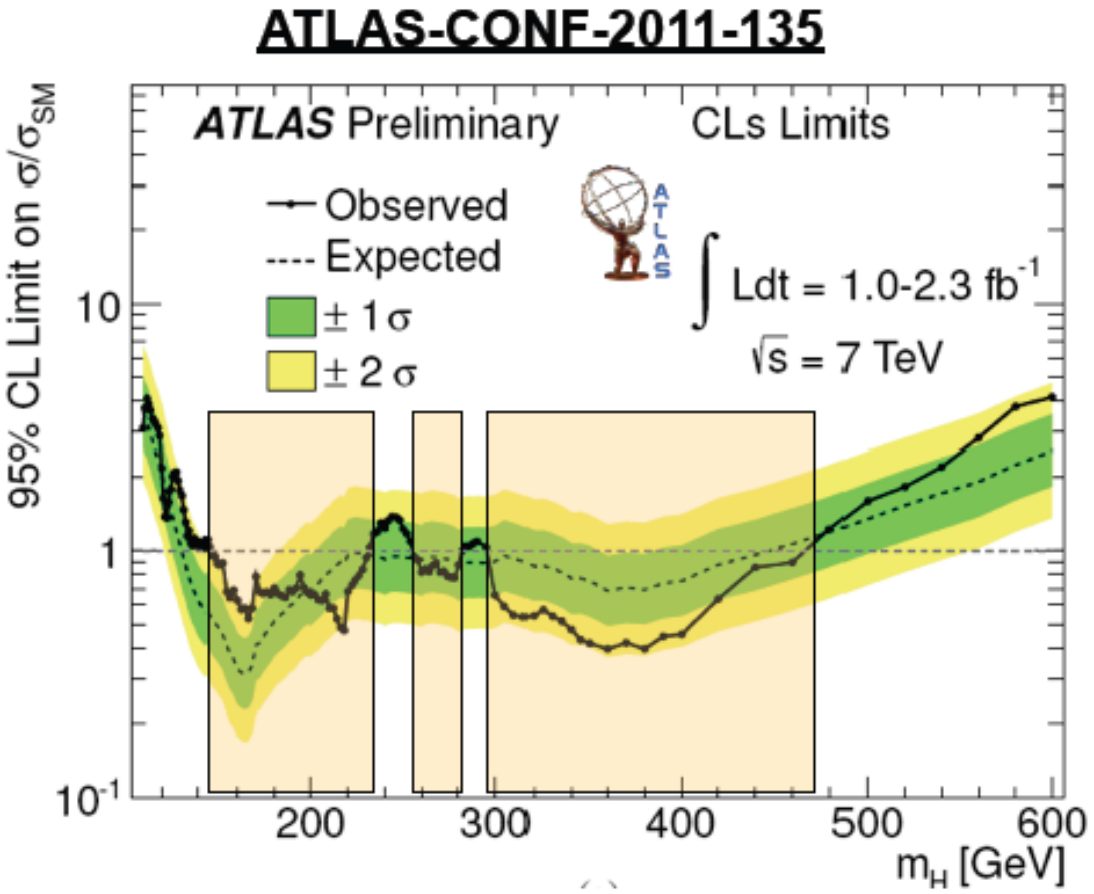
The CMS particle detector







Summer conferences 2011



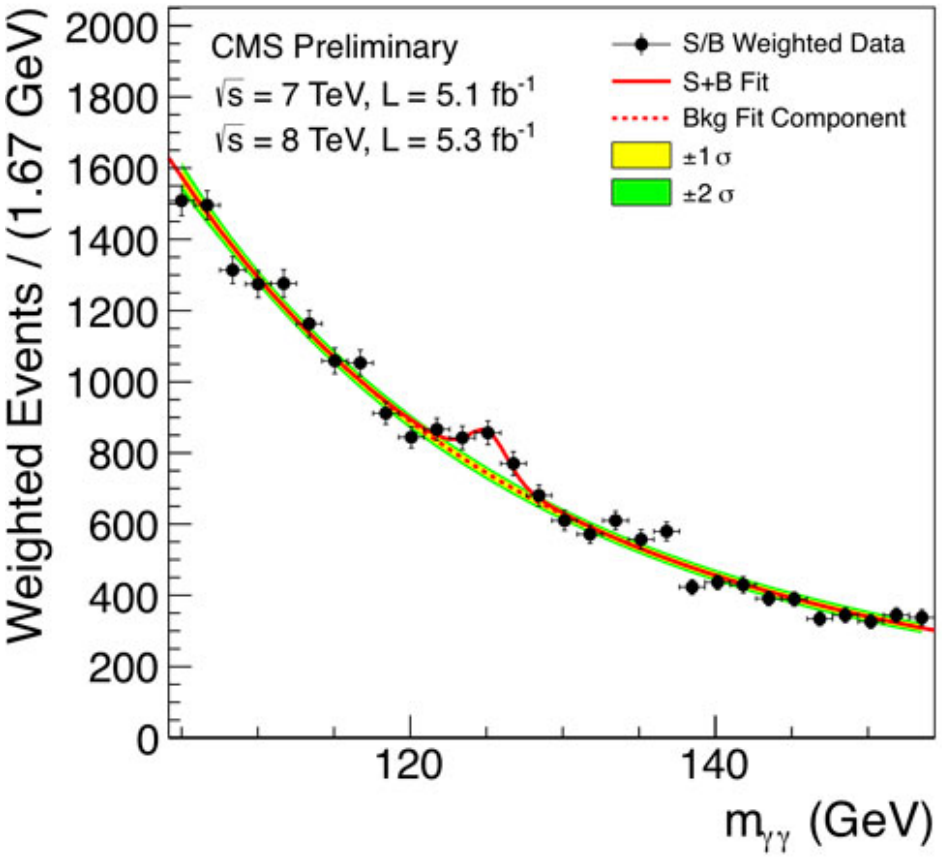
Higgs is 115 GeV – 145 GeV – or nowhere

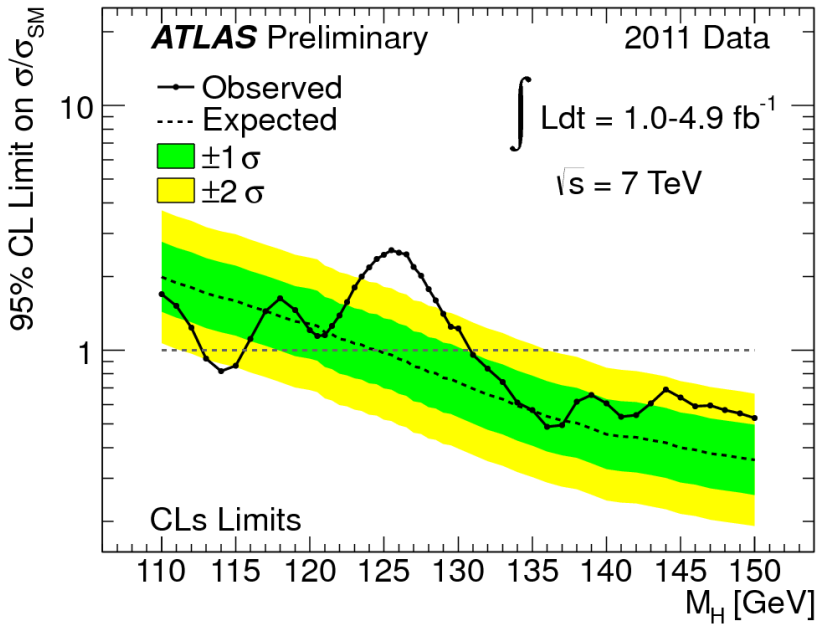
Higgs update seminar December 2011

Higgs update seminar July 2012

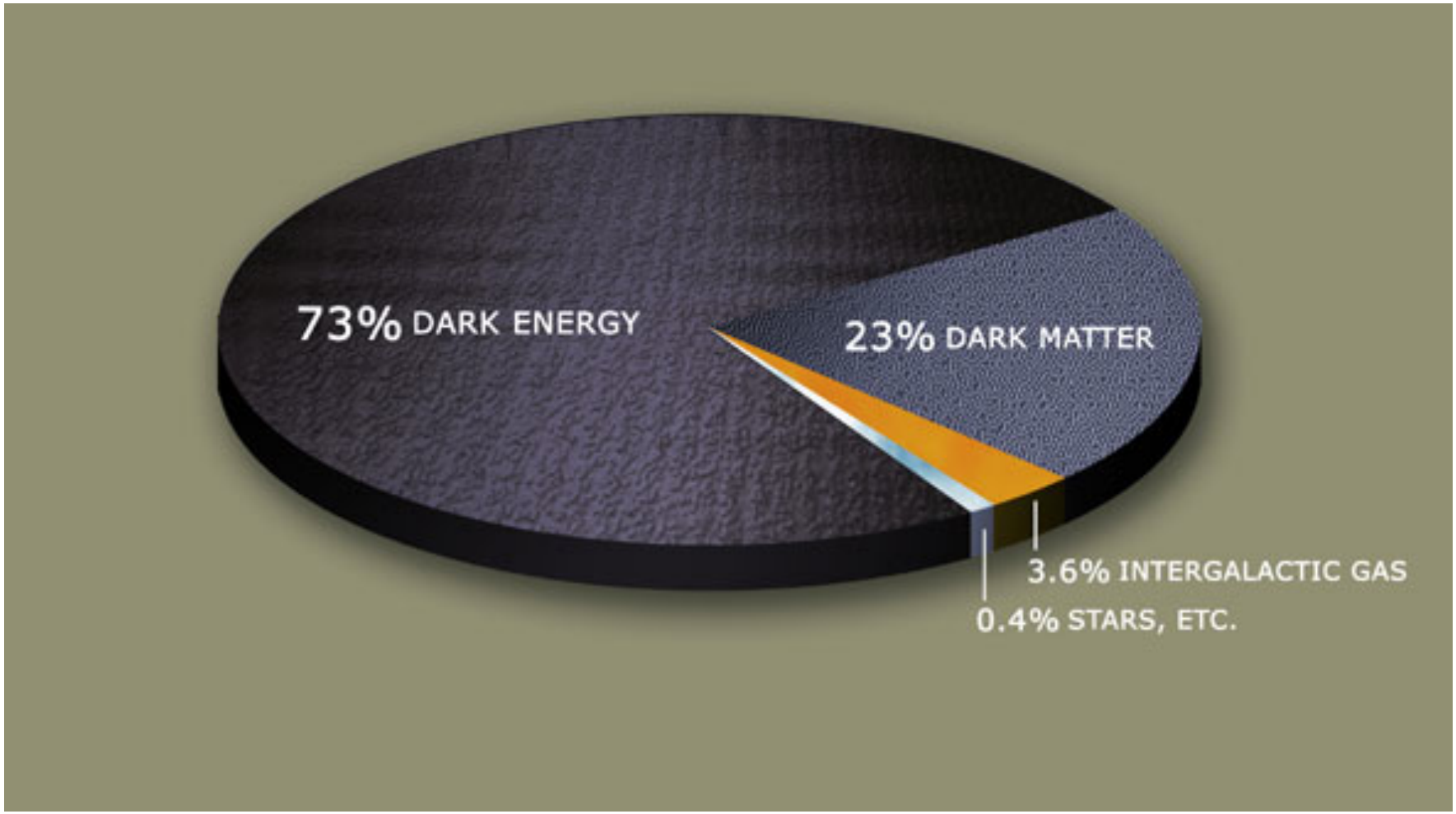
450,000 people watched it live!

The result…

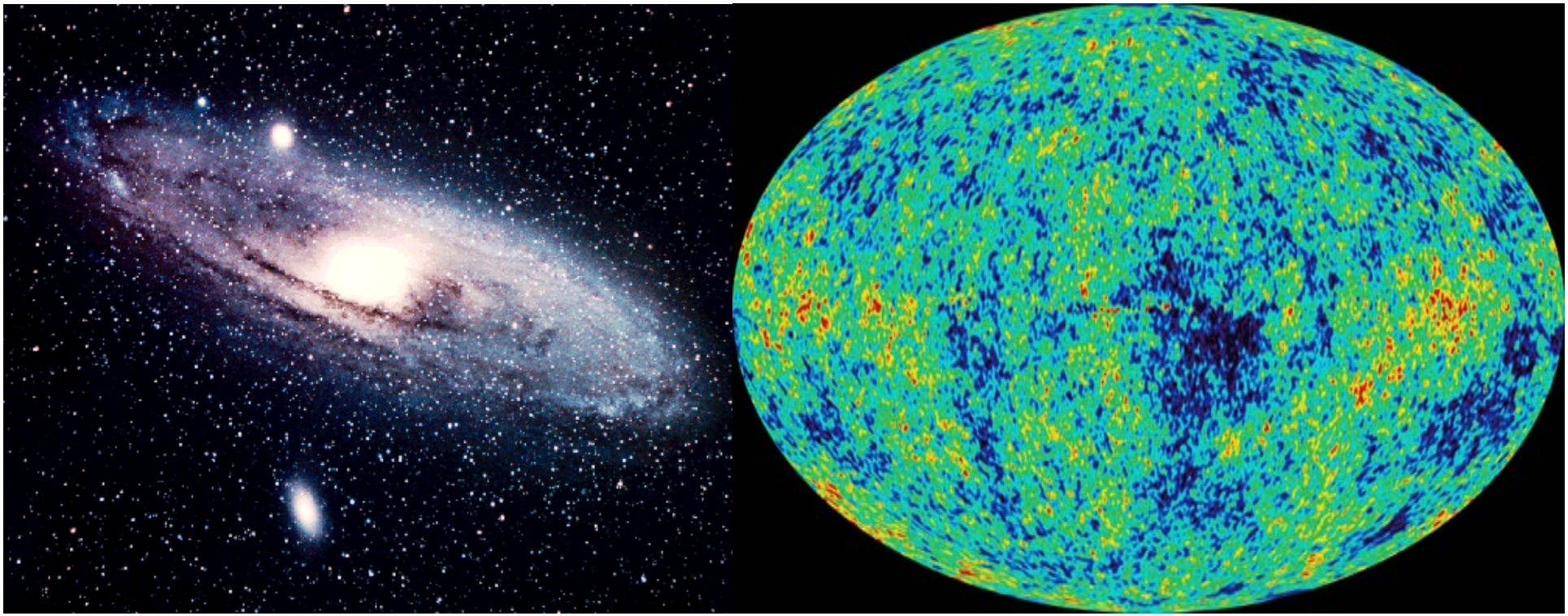

CMS Preliminary
√s = 7 TeV, L = 5.1 fb-1
√s = 8 TeV, L = 5.3 fb-1
S/B Weighted Data
S+B Fit
Bkg Fit Component
±1 σ
±2 σ
Weighted Events / (1.67 GeV)
2000
1800
1600
1400
1200
1000
800
600
400
200
0
120
140
mγγ (GeV)


ATLAS Preliminary
2011 Data
Observed
Expected
±1 σ
±2 σ
∫ Ldt = 1.0-4.9 fb-1
√s = 7 TeV
95% CL Limit on σ/σSM
10
1
CLs Limits
110 115 120 125 130 135 140 145 150
MH [GeV]

Next steps


73% DARK ENERGY
23% DARK MATTER
3.6% INTERGALACTIC GAS
0.4% STARS, ETC.

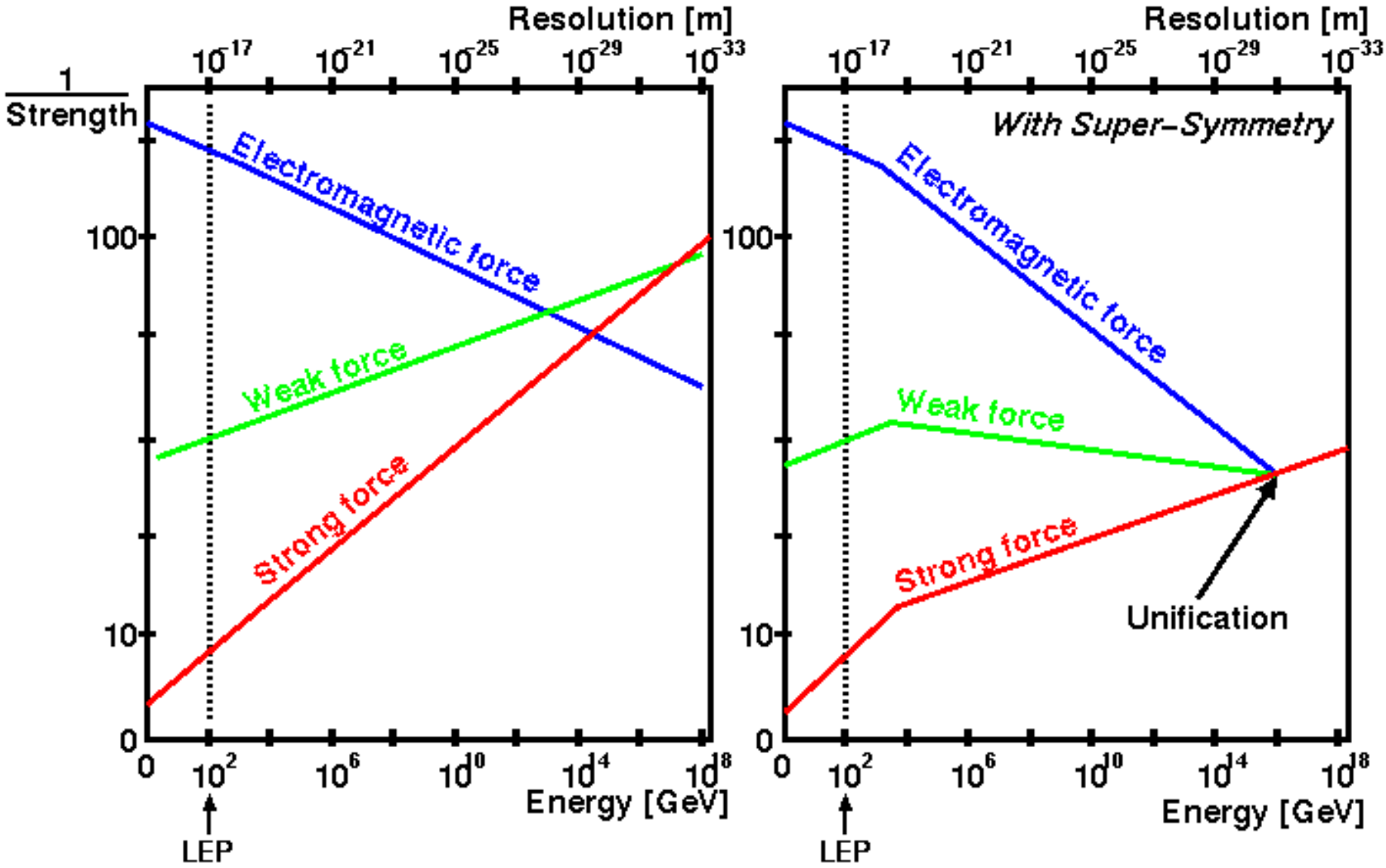
Next steps



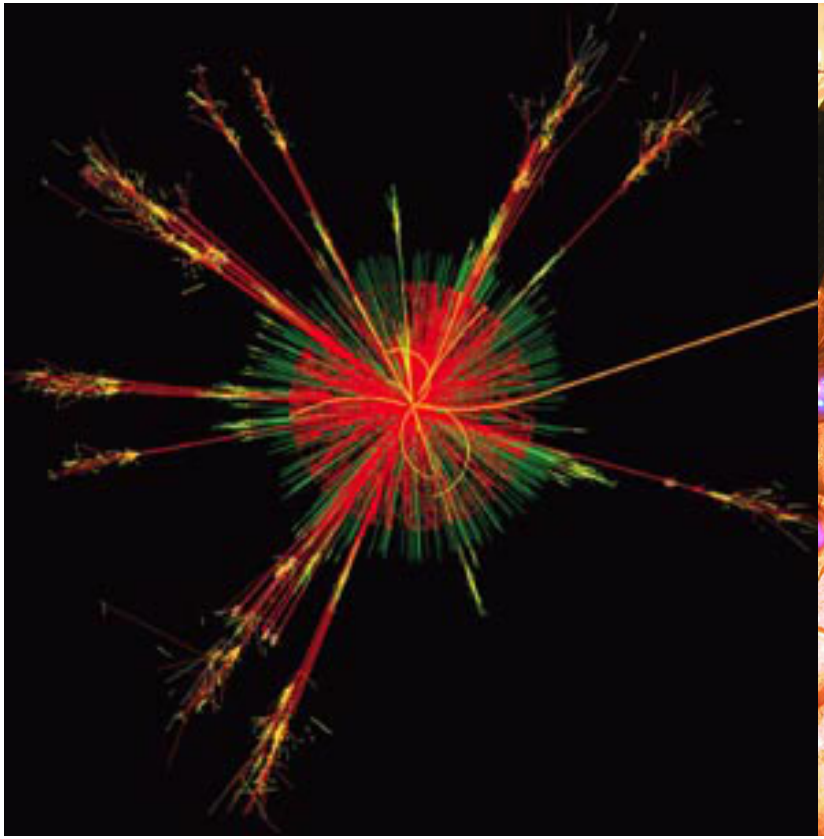
Dark Matter…

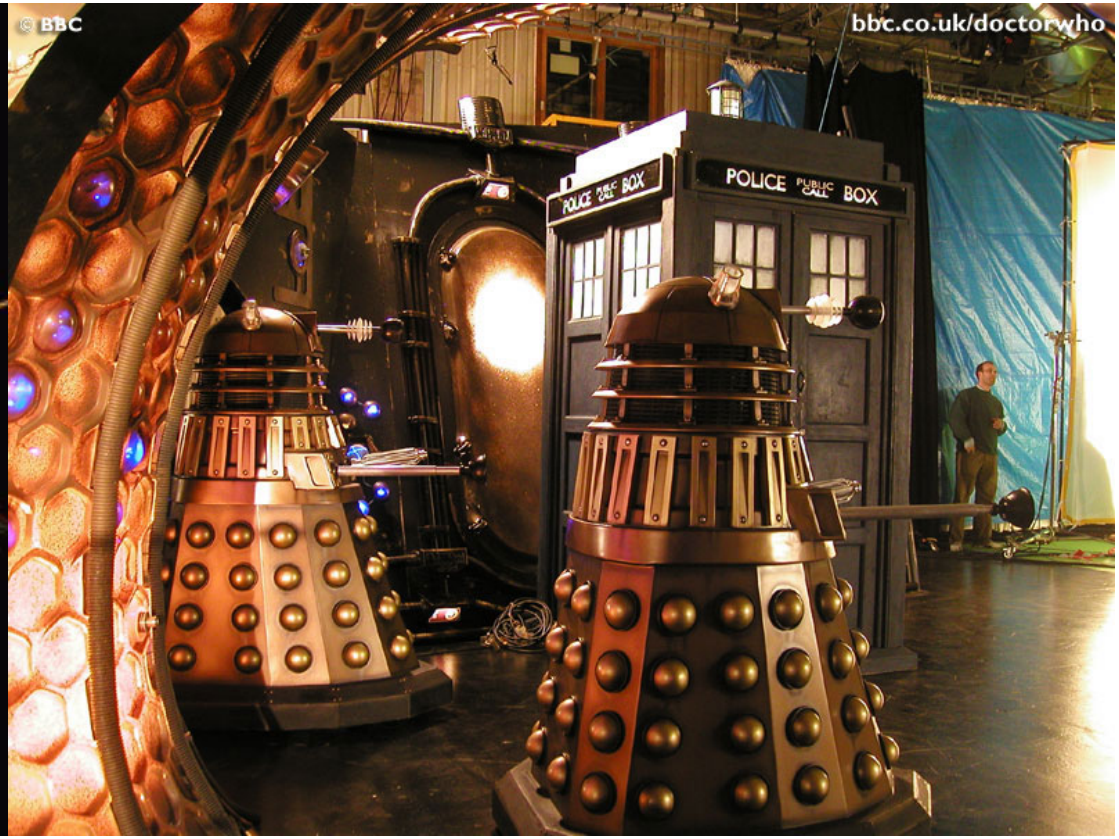
Dark Energy…

Bring on SUSY…


Resolution [m]
10^{-17}
10^{-21}
10^{-25}
10^{-29}
10^{-33}
1
Strength
100
10
0
Electromagnetic force
Weak force
Strong force
0
10^{2}
10^{6}
10^{10}
10^{14}
10^{18}
Energy [GeV]
LEP
Resolution [m]
With Super-Symmetry
Electromagnetic force
Weak force
Strong force
Unification
Energy [GeV]
LEP

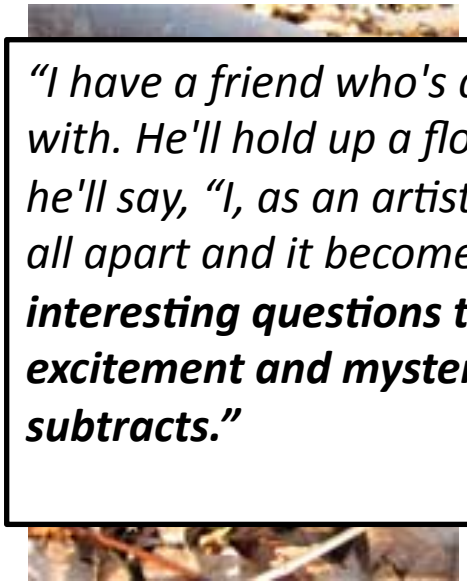
Next steps

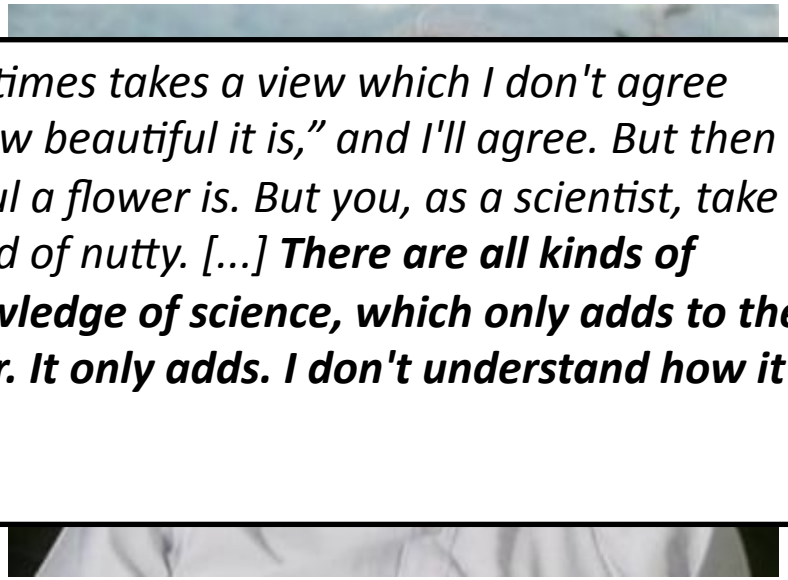




CERN: where science and science fiction meet…

Does all this make you feel small?





"I have a friend who's an artist, and he sometimes takes a view which I don't agree with. He'll hold up a flower and say, "Look how beautiful it is," and I'll agree. But then he'll say, "I, as an artist, can see how beautiful a flower is. But you, as a scientist, take it all apart and it becomes dull." I think he's kind of nutty. [...] ***There are all kinds of interesting questions that come from a knowledge of science, which only adds to the excitement and mystery and awe of a flower. It only adds. I don't understand how it subtracts."***

Exploring the frontiers of knowledge
Explorer les frontières du savoir

www.cern.ch

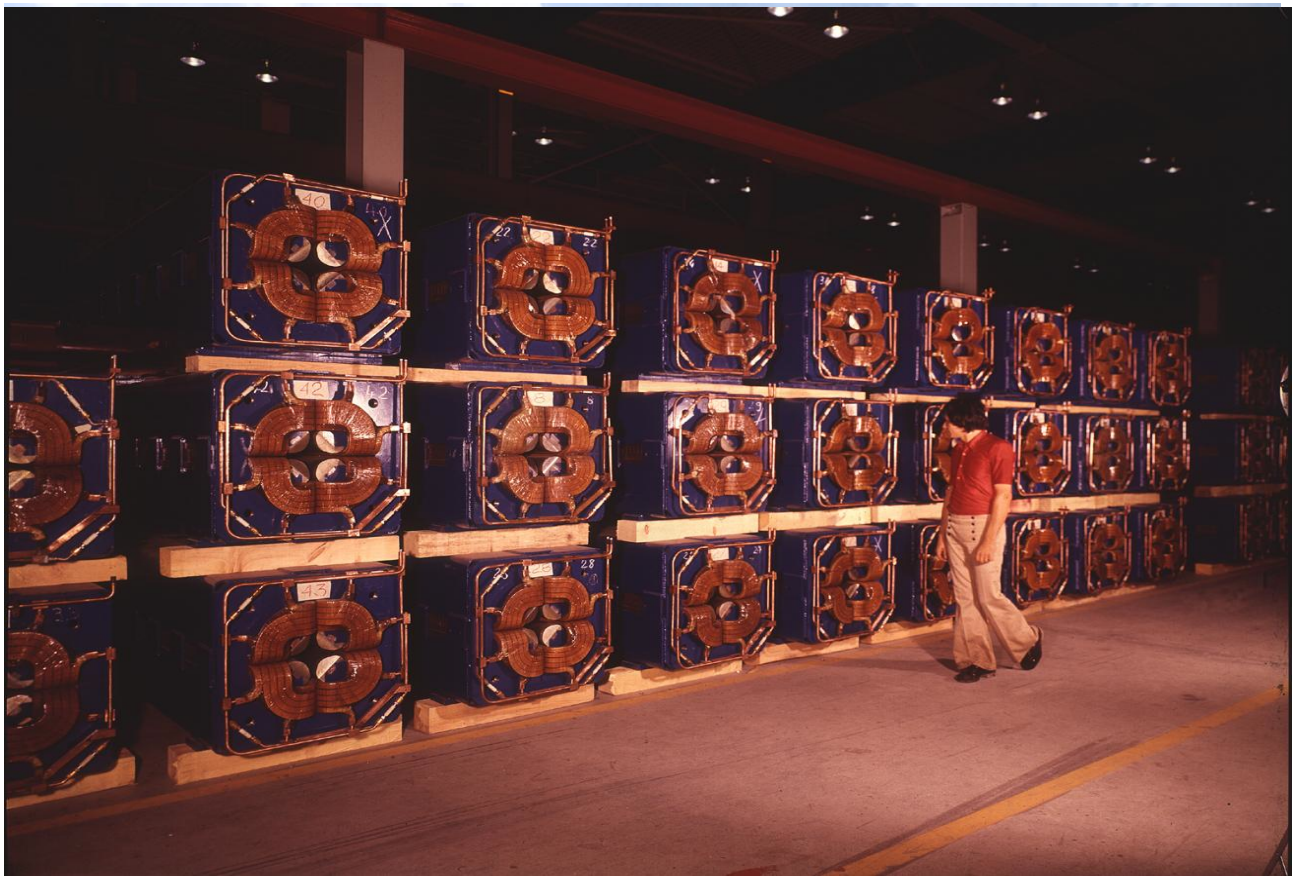
Further reading…

Ian Sample – Massive

Lisa Randall – Warped Passages, Knocking on Heaven's Door

Frank Close – The (new) Cosmic Onion

The after school physics quiz



In which decade did CERN use these magnets to build the SPS?