You know what I did this summer…

The Higgs Boson, Revealed!

Victoria Martin, ATLAS Edinburgh

In Memorium: Thomas Binoth

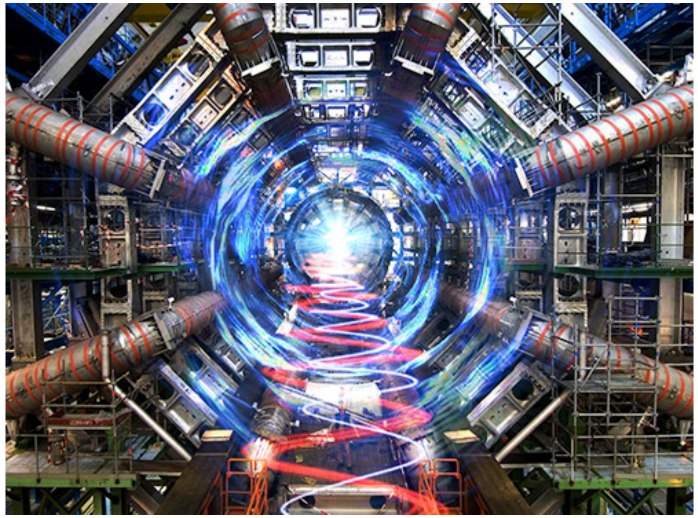
Dr Thomas Binoth died in an avalanche on Sunday 3rd January 2010, while skiing in the Diemtigtal Valley, 25 miles south of Bern, Switzerland.

Thomas was a Reader in Theoretical Particle Physics at the University of Edinburgh. His death comes at a critical moment in the history of our understanding of physics at the smallest scales, the world of elementary particles and their interactions. We have a theory, the Standard Model, established forty years ago, which describes in fantastic detail the wealth of experimental data from high energy particle colliders. However, a key ingredient of this theory, the Higgs boson, has so far remained elusive. The Large Hadron Collider (LHC), constructed over the last decade at CERN in Geneva, is the highest energy collider ever built, and is expected to discover the Higgs boson and the physics that underlies it. The first high energy collisions were seen in December 2009. This experiment was the focus of Thomas' theoretical work.

Contents

- What is this thing called Higgs?

- The Large Hadron Collider at CERN



- The ATLAS experiment
- How to find a Higgs

- The 4th July 2012 and Higgsteria!
- What's next

What is this thing called Higgs?

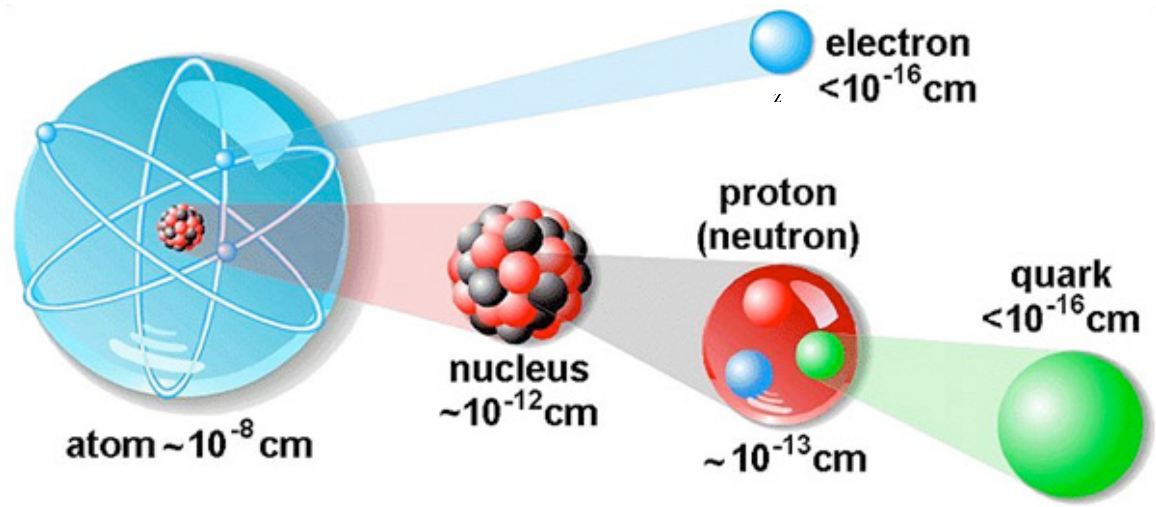
Energy and Mass Units

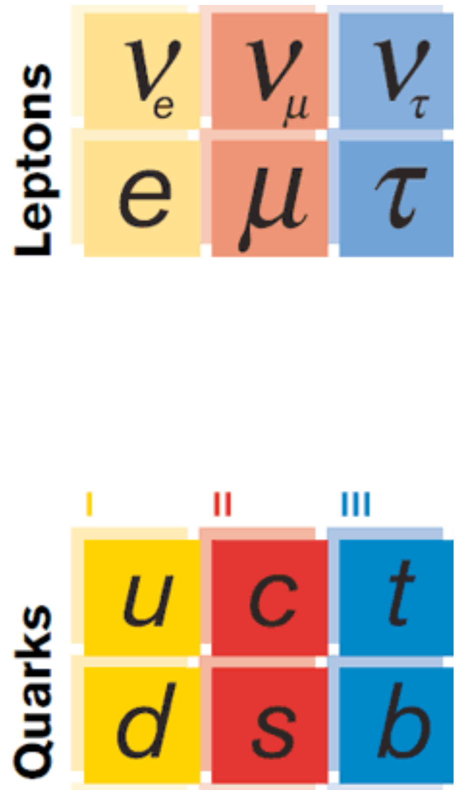
- Particle Physicists use units of electron-Volts, **eV**.
  - **1 eV** is the energy gained by a particle with the charge **e**, when accelerated through **1 V**.
  - $\mathbf{1\ eV = 1.60 \times 10^{-19}\ J}$
  - We often use $\mathbf{MeV \equiv 1.60 \times 10^{-13}\ J}$ or $\mathbf{GeV \equiv 1.60 \times 10^{-10}\ J}$

- Mass units: $\mathbf{MeV}/c^2$ or $\mathbf{GeV}/c^2$.
  - $\mathbf{1\ GeV}/c^2 = \mathbf{1.79\ x\ 10^{-27}\ kg}$
  - The mass of the proton, $\mathbf{m_p = 0.982\ GeV}/c^2$.
  - Occasionally we drop the c^2 from the notation (equivalent to setting c=1).

The World of Particle Physics

- Particle physics aims to understand the universe on the smallest length scales.





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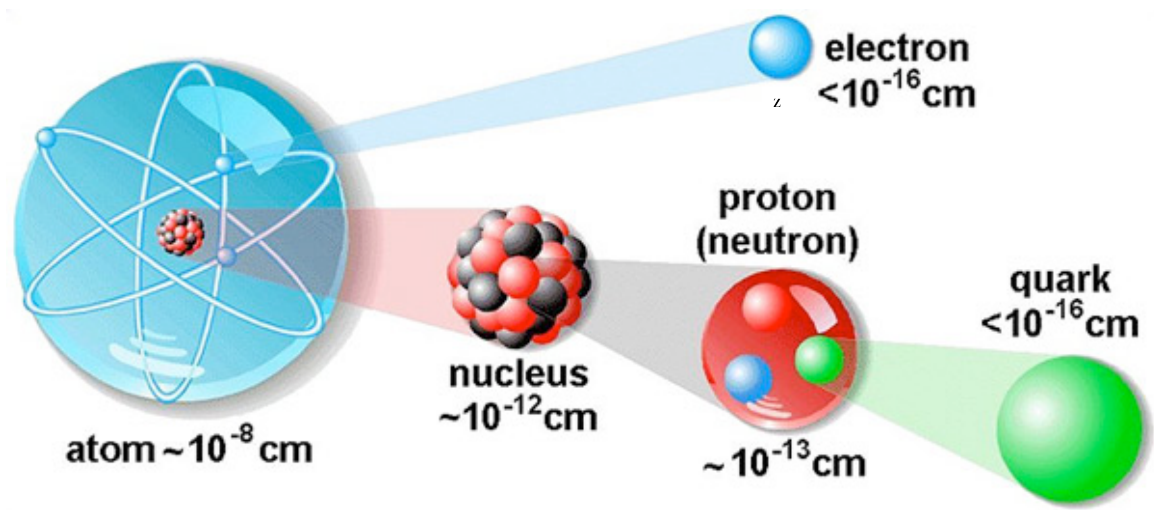

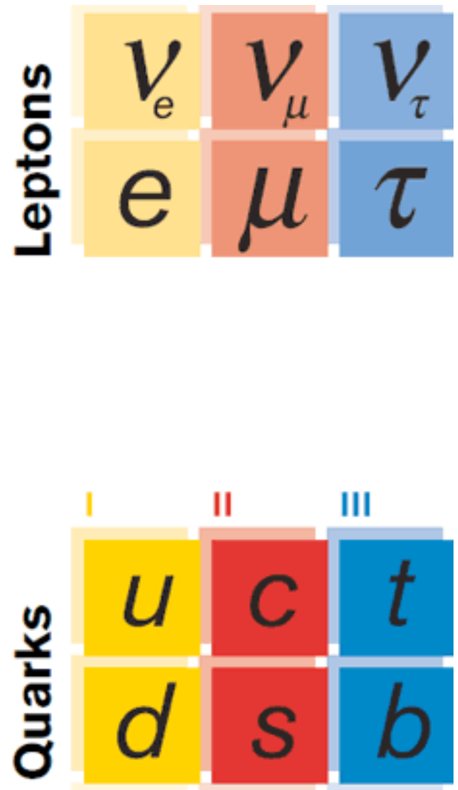

Quarks and leptons are observed to be ***fermions***, ***S*=½**.

Forces and Interactions

- We need to understand the **interactions** of the quarks and leptons.

- Four forces are observed in nature:

strongest to weakest

  - The strong nuclear force
  - The electromagnetic force
  - The weak nuclear force
  - Gravity

- Short distances: use quantum physics to describe interactions.
- Each individual interaction is caused the the exchange of a force carrying particle.
- We think of each of the force carriers as causing a ***field*** where the interaction can take place.

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All the force carriers are observed to be ***bosons*** with ***S=1***.

The “Standard Model” of Particle Physics

- The Standard Model of Particle Physics describes the quarks, leptons and the strong, weak and electromagnetic interactions between using **gauge theory**.

Three Generations of Matter

- Gauge theory marries:
  - **Einstein’s theory of special relativity** (physics of the very fast)
  - **Quantum physics** (physics of the very small)
  - **Symmetries** (observed in many areas of physics)

- The Standard Model was developed by Glashow, Weinburg, Salam. Essential contributions from Higgs, ‘t Hooft & Veltman, Yang & Mills.

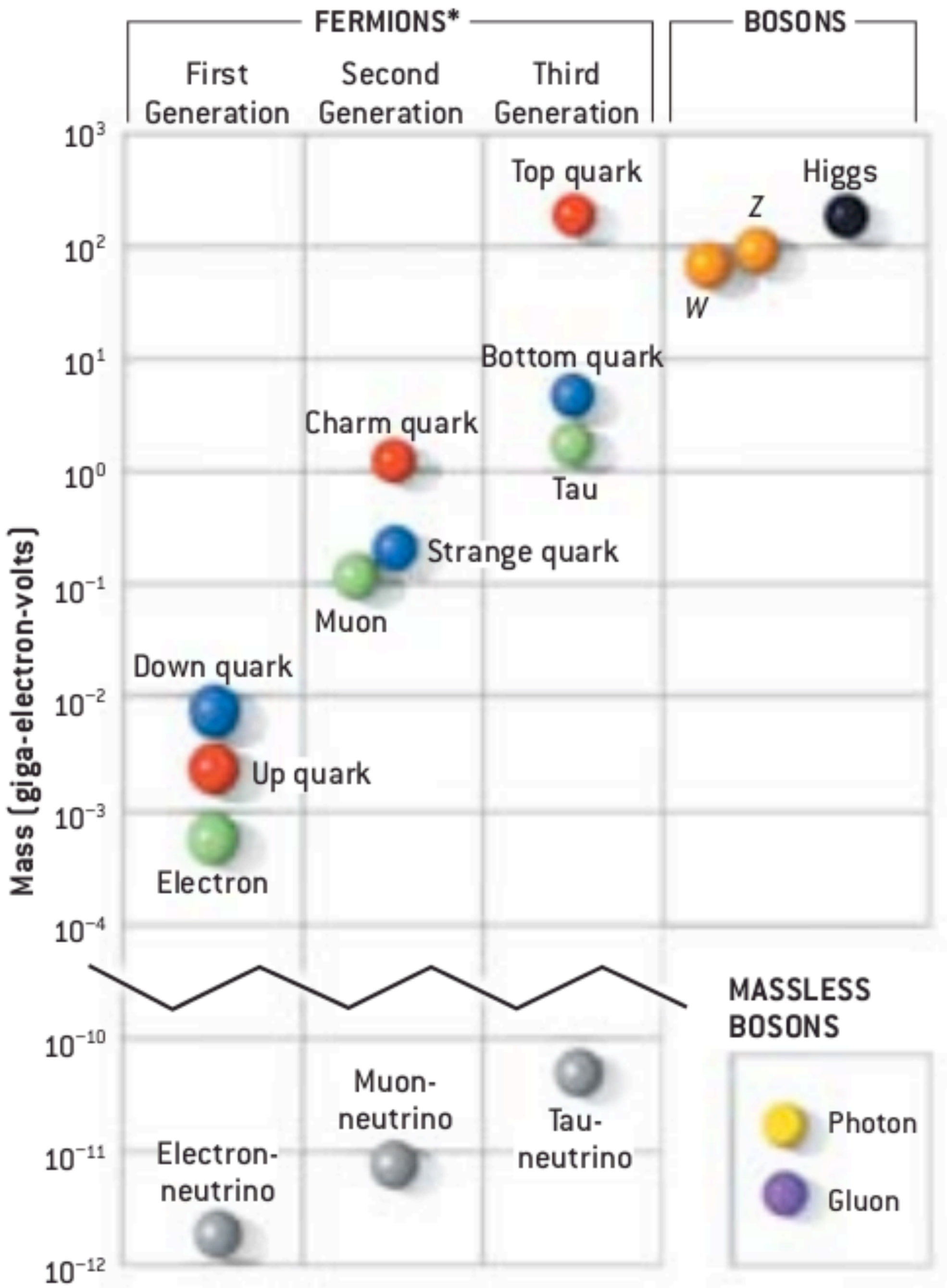
- Possibly the best tested theory in physics!

Each of the forces is described by a gauge group
- Electromagnetism: U(1)
- Strong: SU(3)
- Weak: SU(2)

The bosons are the generators of the groups

Particle Masses

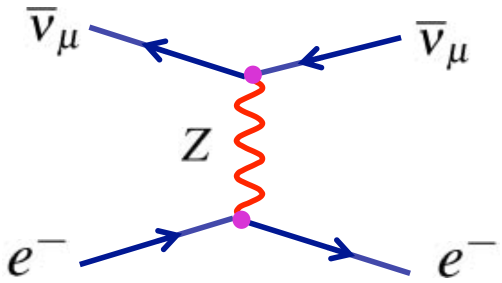
- The quark, lepton and boson masses are measured experimentally.

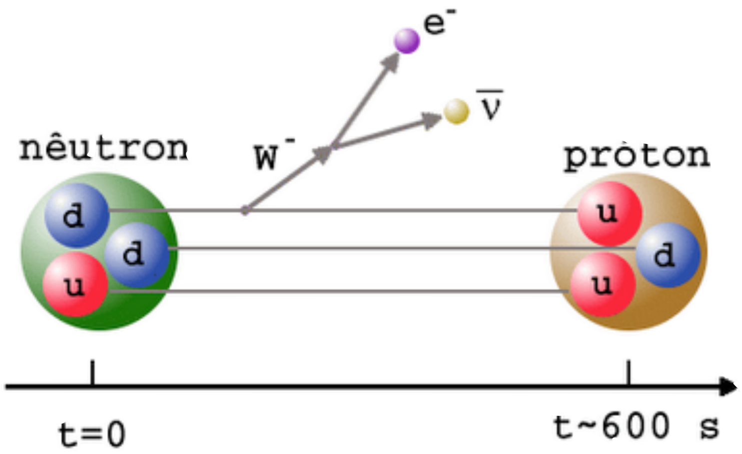


Gordon Kane, *The Dawn of Physics beyond the Standard Model*; Scientific American, May 2003.

W and *Z* bosons

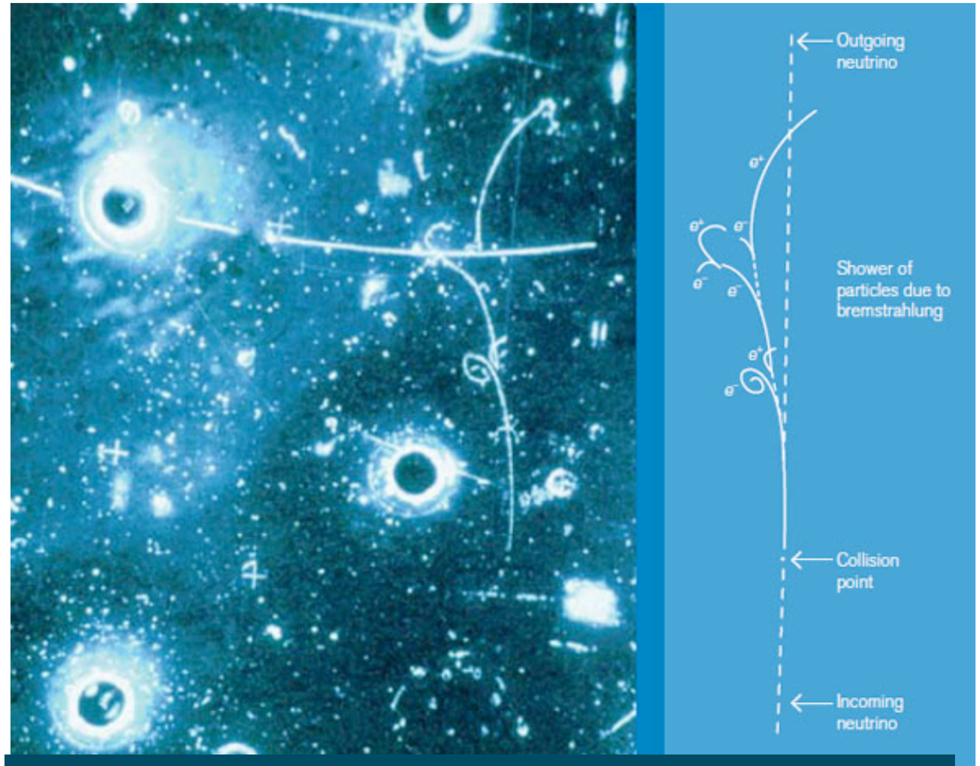
- The *W* and *Z* bosons transmit the weak force.
  - Forces cause particle decay: e.g. neutron decay.
  - Forces allow fermions to interact.



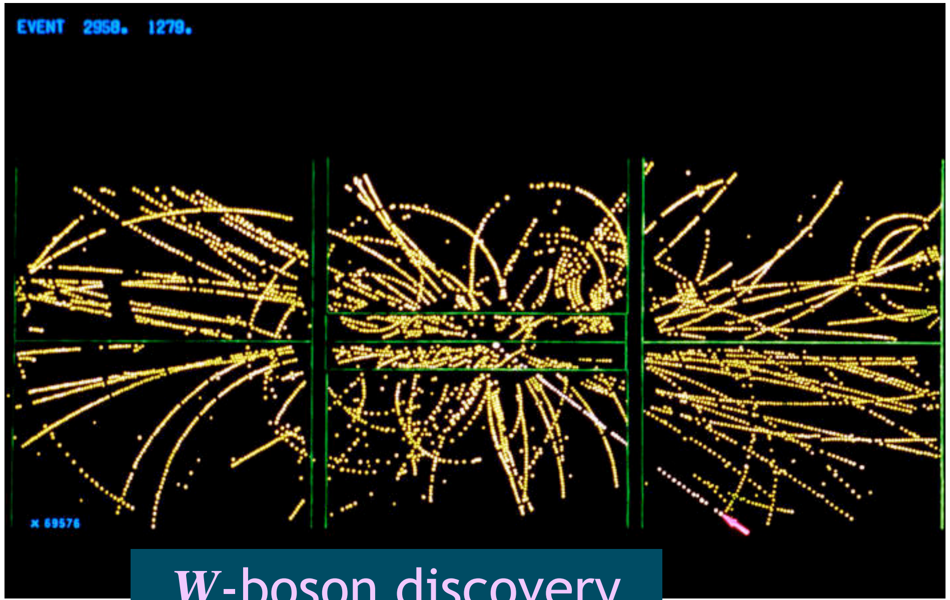


- *W* and *Z* bosons decay almost instantaneously.
- Never directly observed: we observe their consequences e.g. the decay products.
- *W* and *Z* bosons are massive:
  $m_W = 80.385 \pm 0.015$ GeV/c^2, $m_Z = 91.188 \pm 0.002$ GeV/c^2.

W and Z bosons



Z-boson interaction from Gargamelle experiment at CERN, 1973



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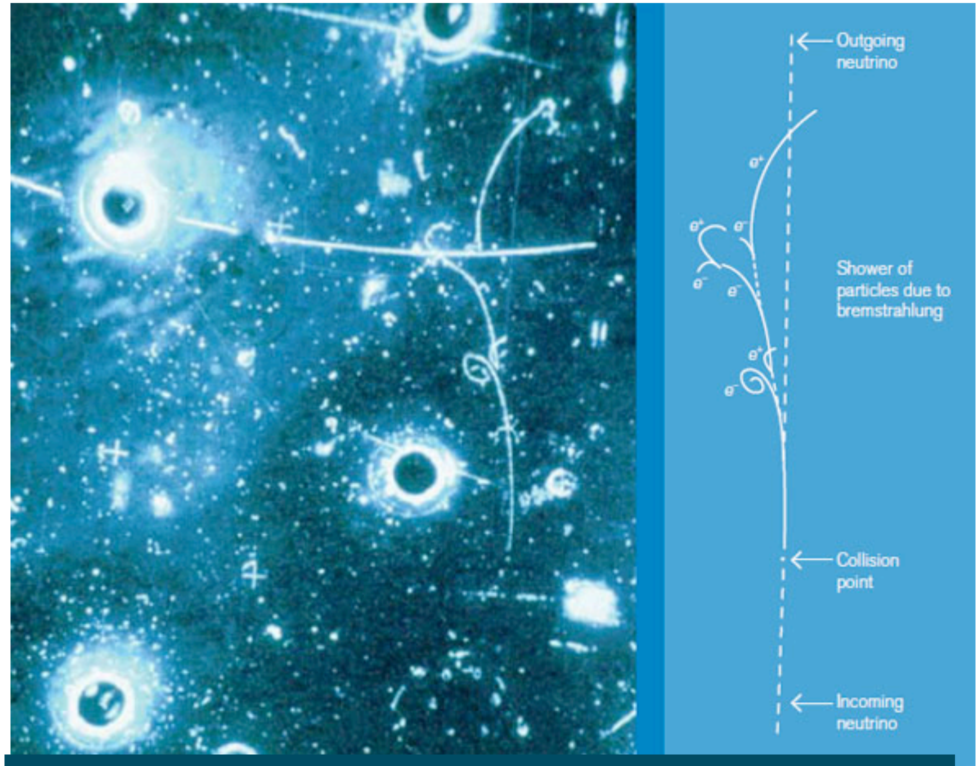
W and Z bosons



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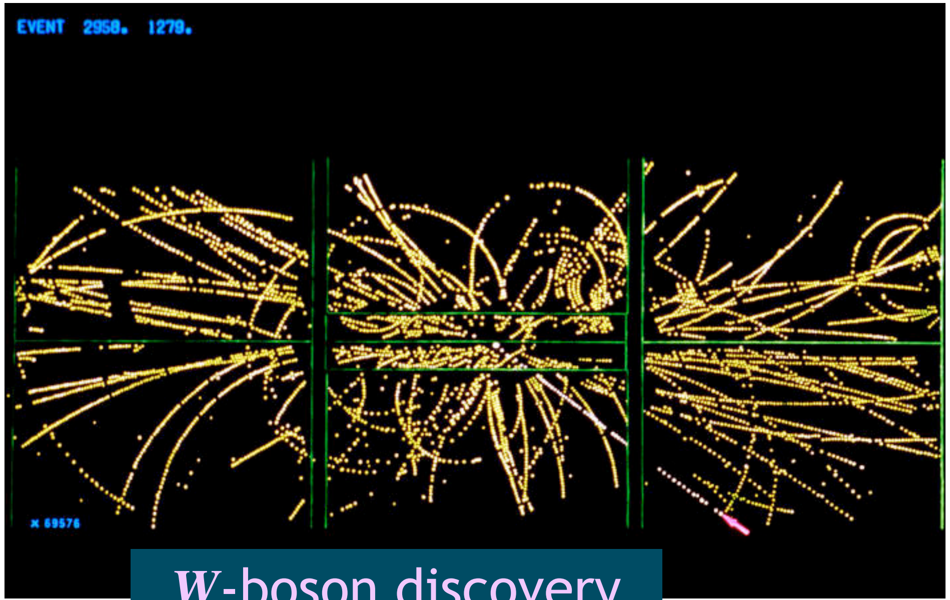


W-boson discovery from UA1 experiment at CERN, 1983

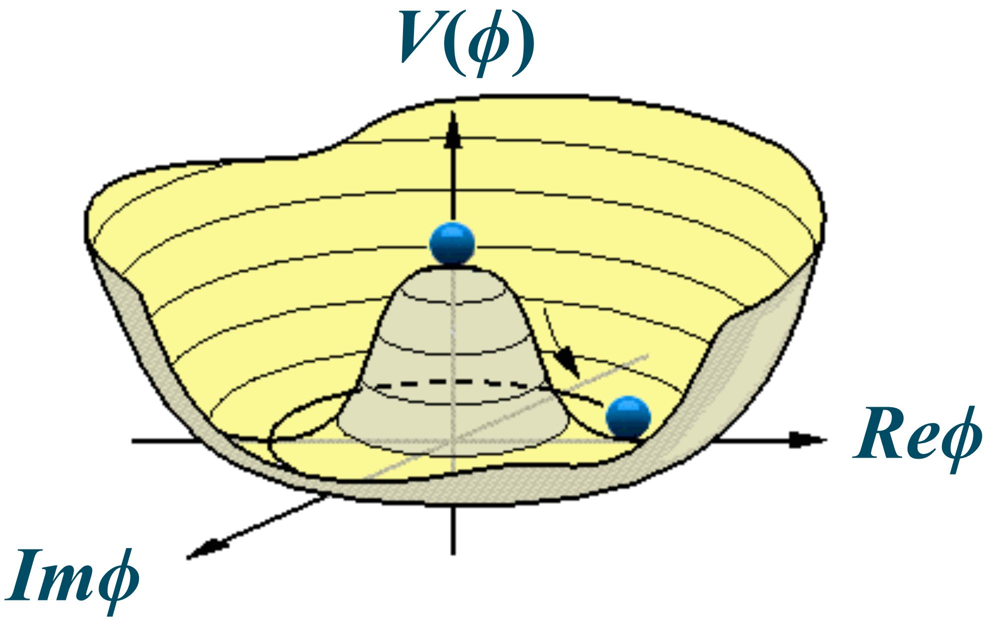
The crux of the Higgs problem: there is no way to satisfactorily include the mass of the W and Z bosons in the Standard Model without the Higgs mechanism!

The Higgs Mechanism

- Proposed The Higgs Mechanism was proposed in 1964 separately by Higgs; Brout & Englert; Guralnik, Hagen & Kibble.

- Proposes an extra field, ϕ, with potential:

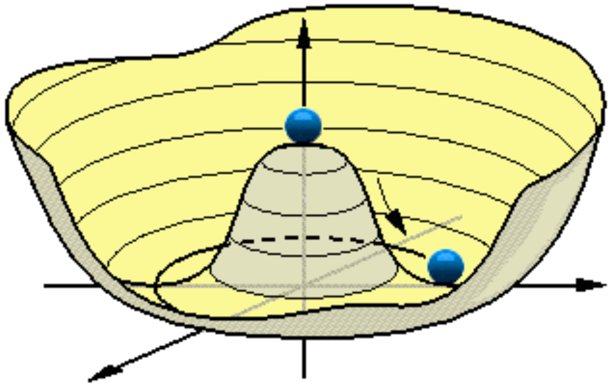
$$V(\phi) = -\mu^2\phi^\dagger\phi + \lambda(\phi^\dagger\phi)^2 \quad \text{with } \mu^2 > 0, \lambda > 0$$



- The minimum of the potential is a circle with

$$|\phi_0| \equiv -v = -\frac{\mu}{\sqrt{2\lambda}}$$

The Higgs Boson

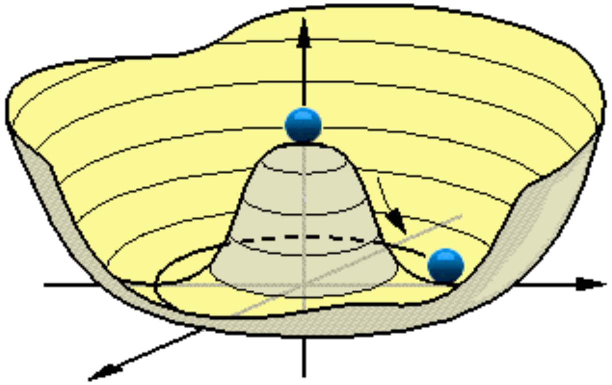


- Consider fluctuations of the ϕ field around the minimum:

$$\phi(x) = \frac{1}{\sqrt{2}}(v + h(x))$$

$$V(v+h) = V(v) + \lambda v^2 h^2 + 4\lambda v h^3 + \lambda h^4$$

The Higgs Boson



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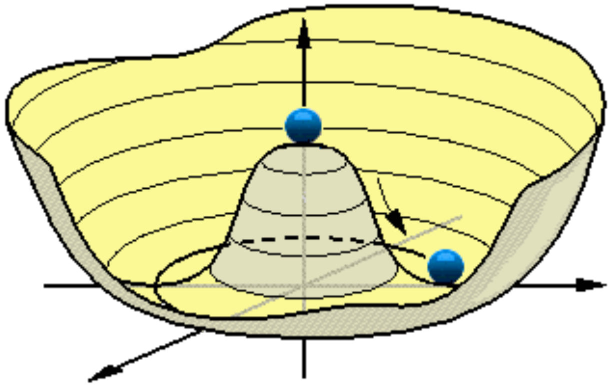

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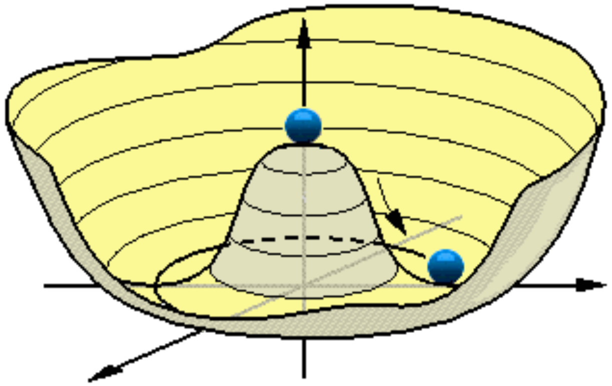

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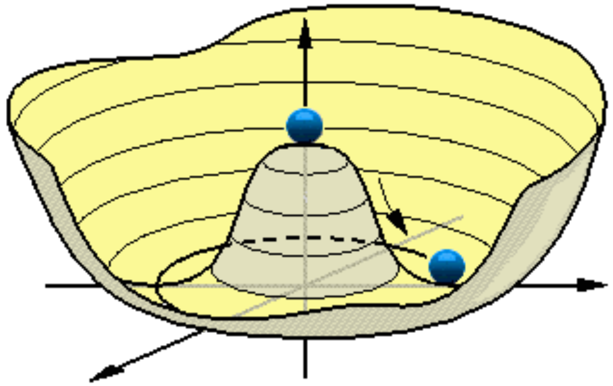

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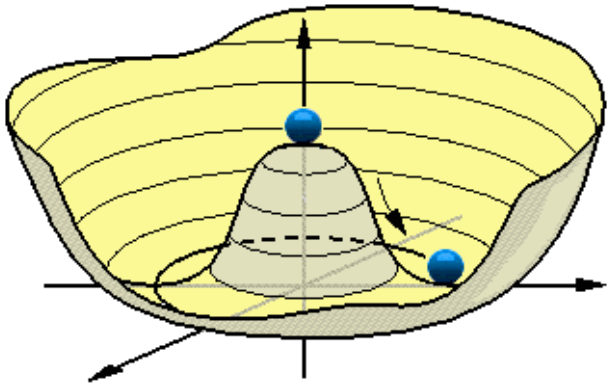

The Higgs boson has ***S=0***

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The excitations have a mass!

Higgs boson can
interact with itself

This is the Higgs boson!
it has mass $m_H = \sqrt{2\lambda} v$

Peter was the only one to observe this in 1964!

Particle Masses

- The Higgs mechanism explains the masses of the ***W*** and ***Z*** bosons.
- In terms of the minimum of the potential (***v***) and the strength of the weak force (g_W, g'_W):

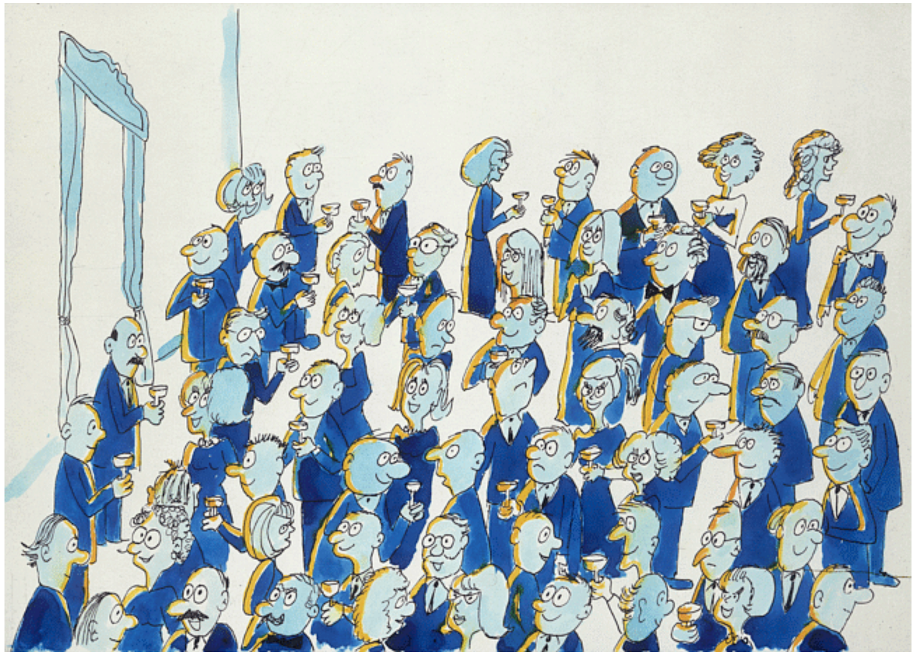
$$v = \frac{1}{2}\frac{m_W}{g_W} \qquad\qquad m_Z = m_W \frac{g'_W}{\sqrt{g'^2_W + g^2_W}}$$

- The Higgs mechanism also describe the masses of the quarks and leptons.
- The mass of each quark and lepton is proportional to how strongly the Higgs boson interacts with it.

- The mass of the Higgs boson is not predicted, λ is a free parameter:
- We must measure it! $m_H = \sqrt{2\lambda}v$

The Higgs Mechanism

1. Physicists at a conference reception; all free to move around the room.



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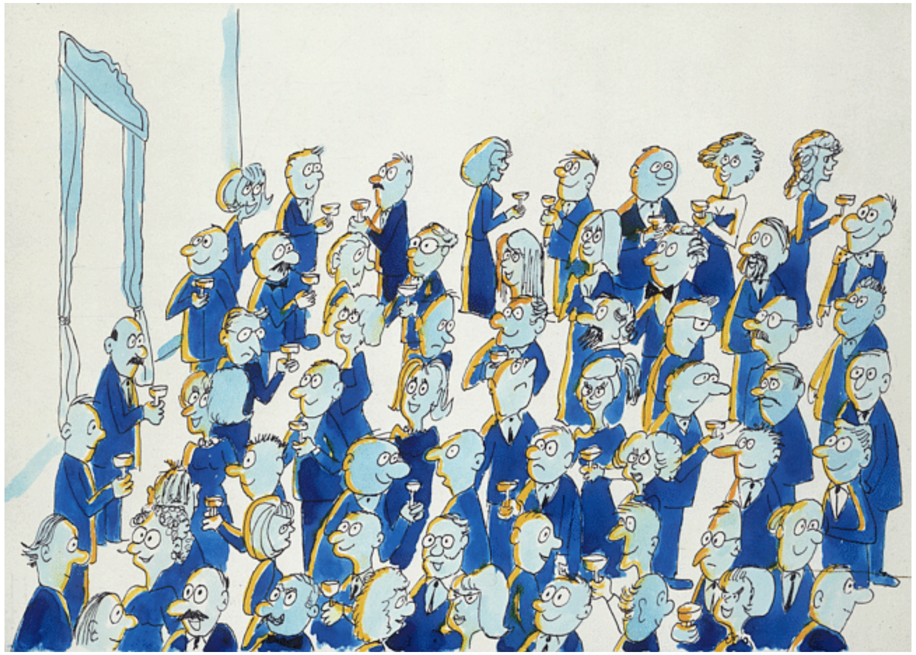

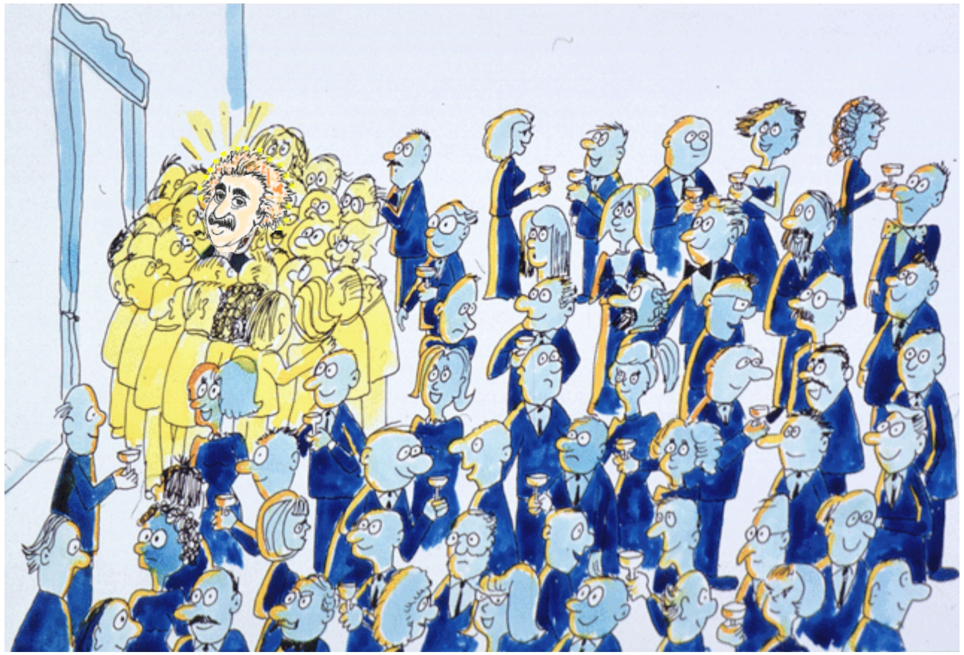

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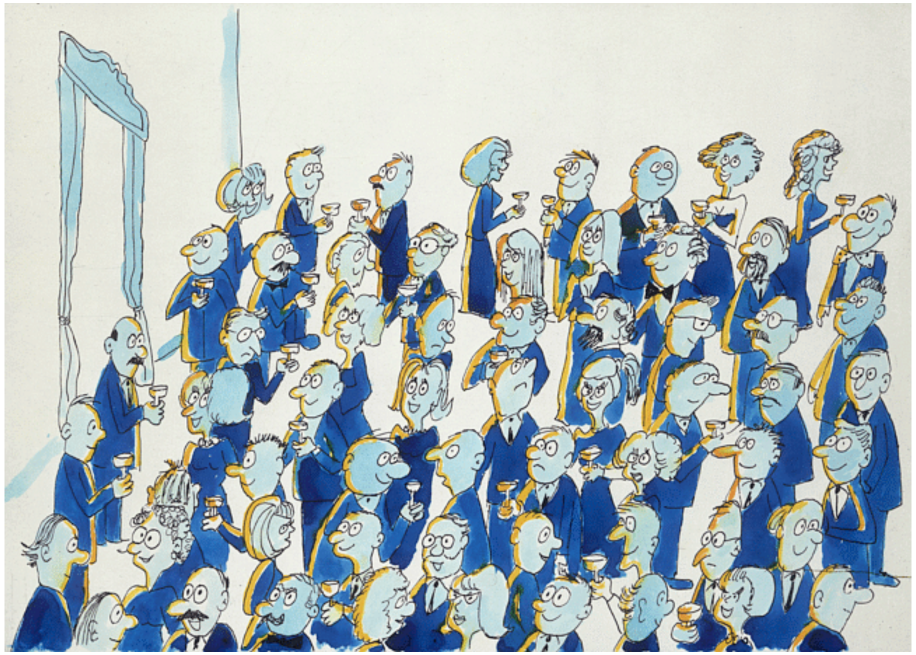
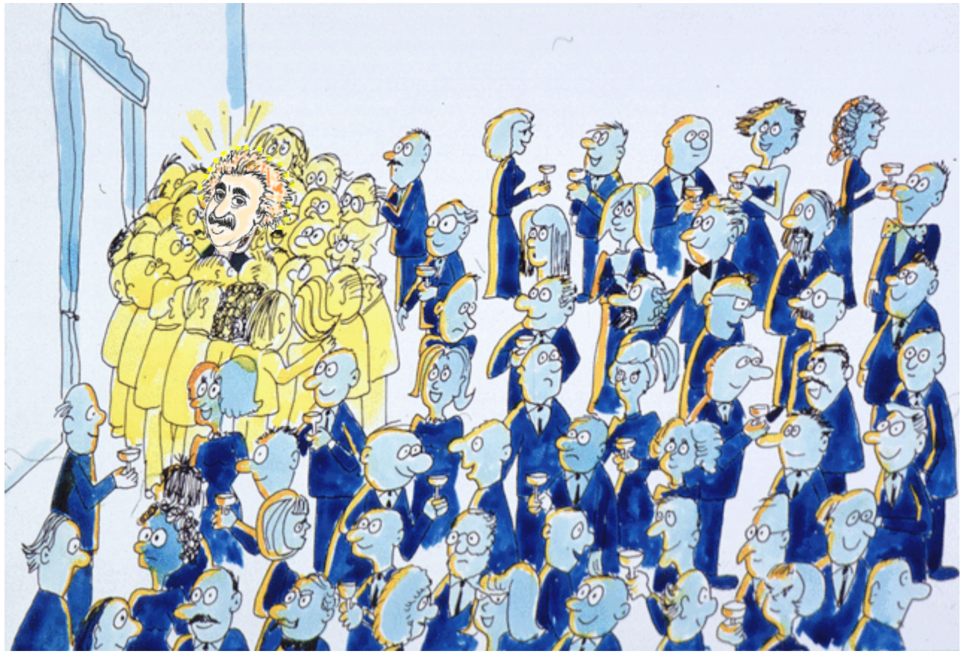


2. In comes a noble prize winner; everyone wants to speak to him.

The physicists crowd around him. The noble laureate is not free to move around; he has gained inertia by interacting with the crowd.



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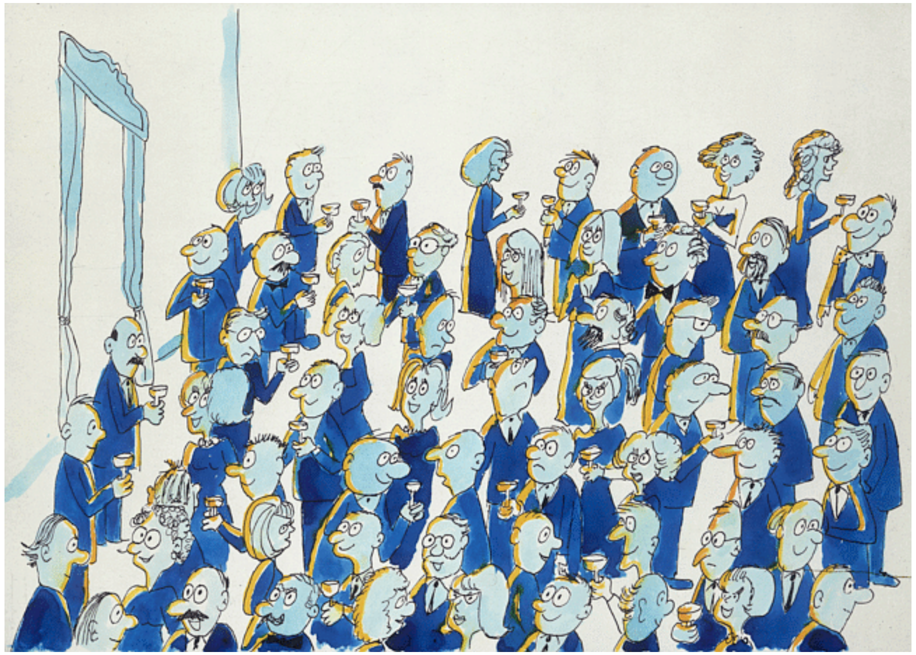

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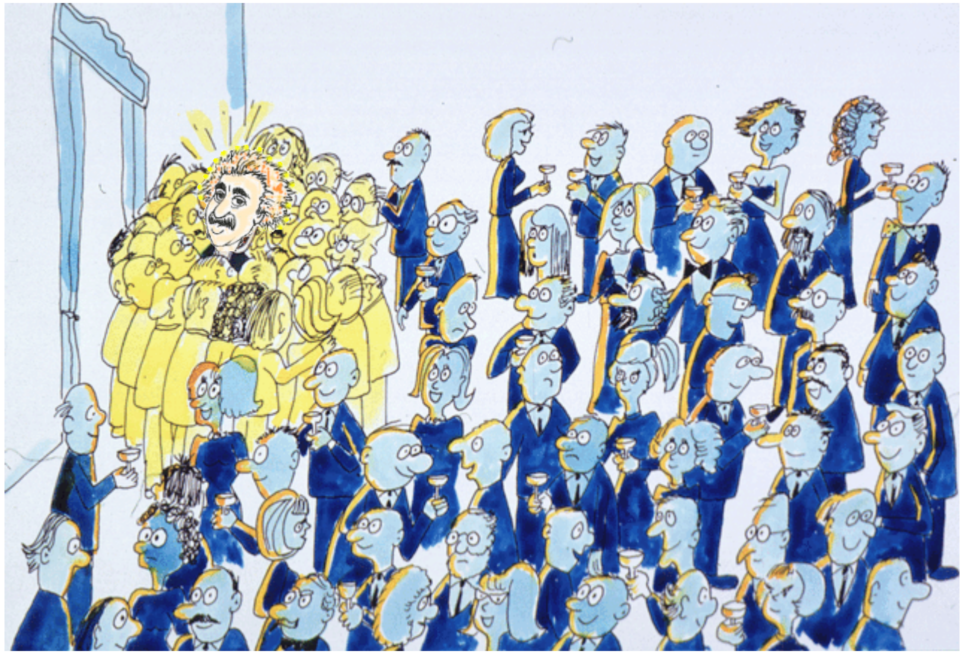
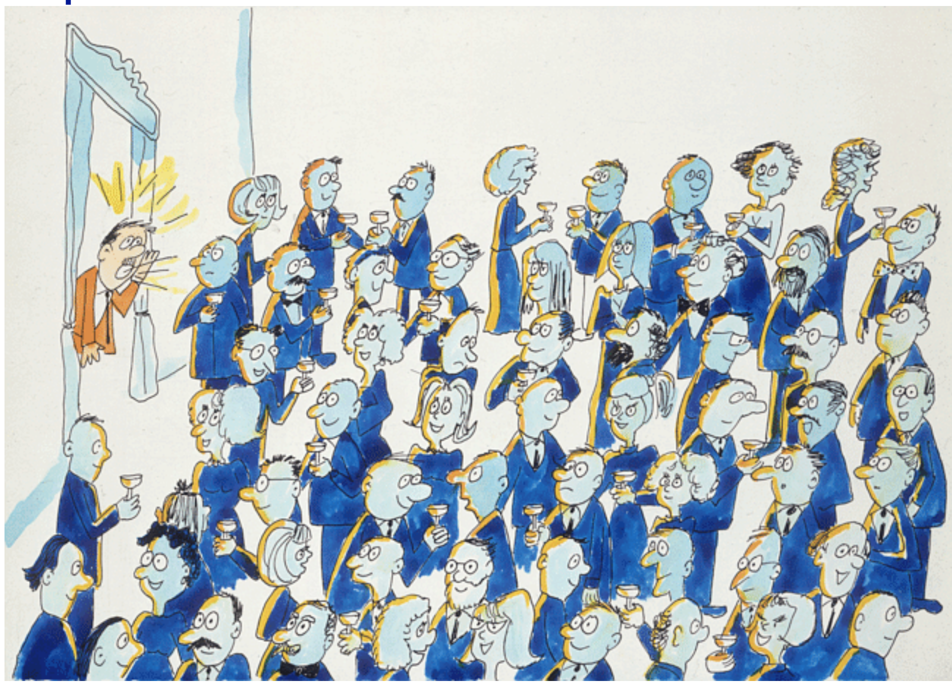


This is analogous to how the particles acquire mass: by interacting with the Higgs field. Laureates of different popularity gain different masses.

The Higgs Boson

3. The next evening; physicists enjoying another drink.

A rumour enters the room: the keynote speaker tomorrow will announce the discovery of a new particle!



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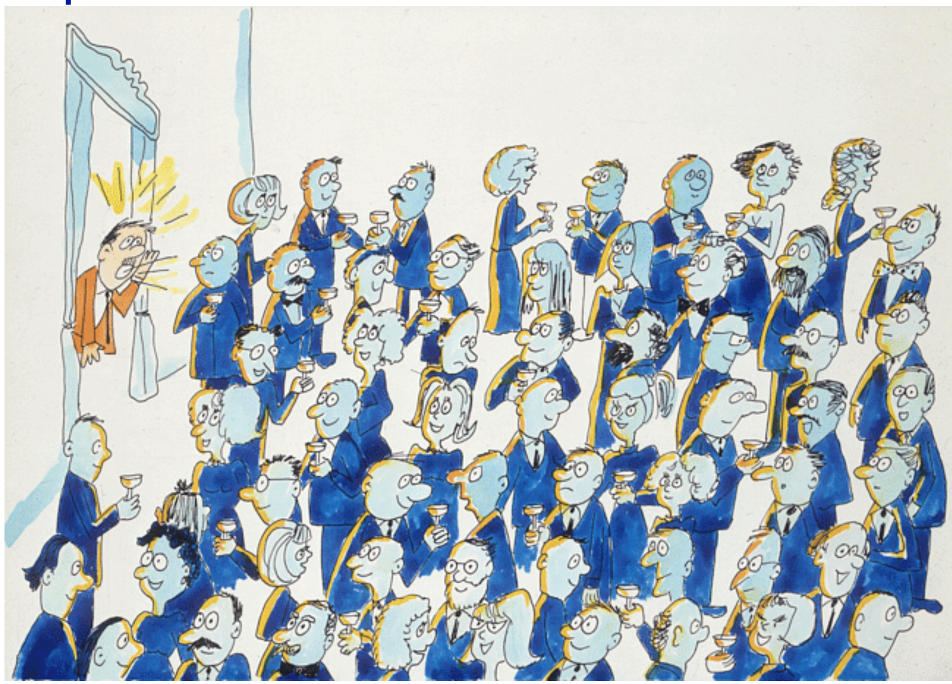

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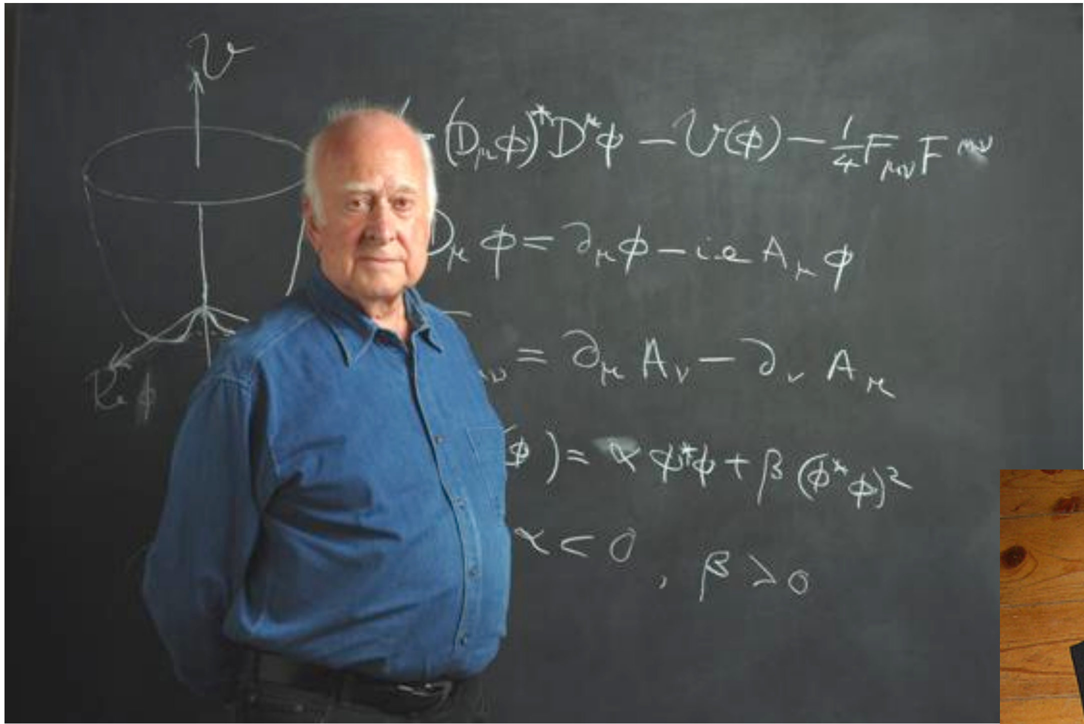
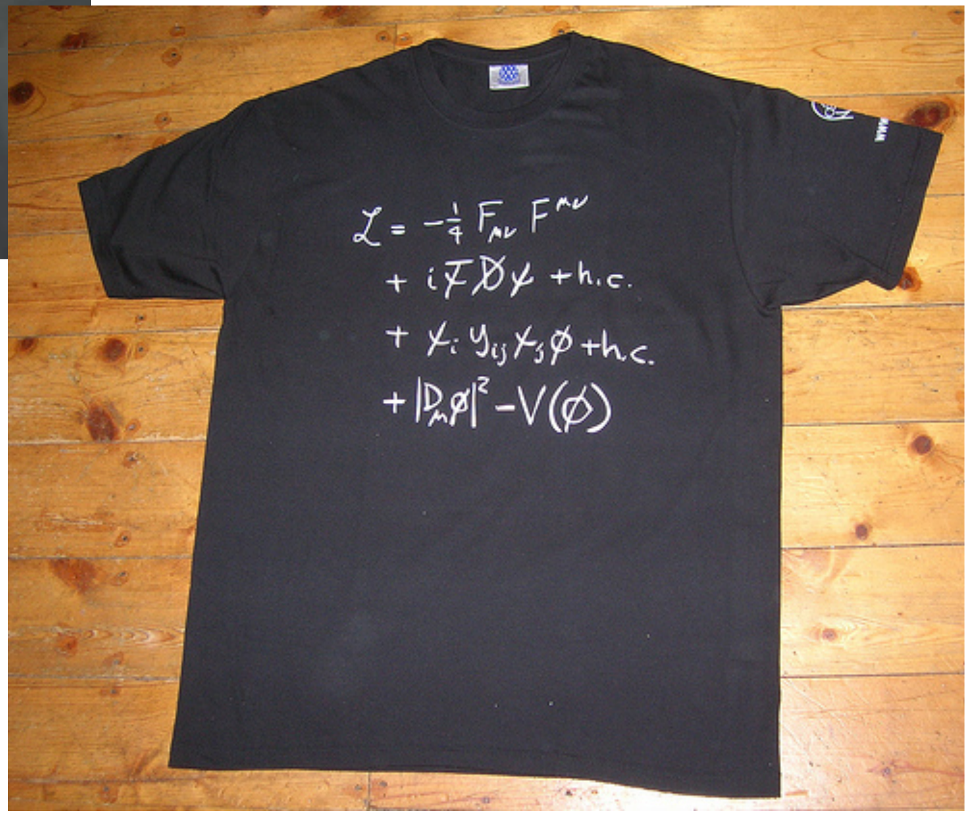
The clustering of the field of physicists is as if a new massive particle has formed. This is the Higgs boson.

For completeness...

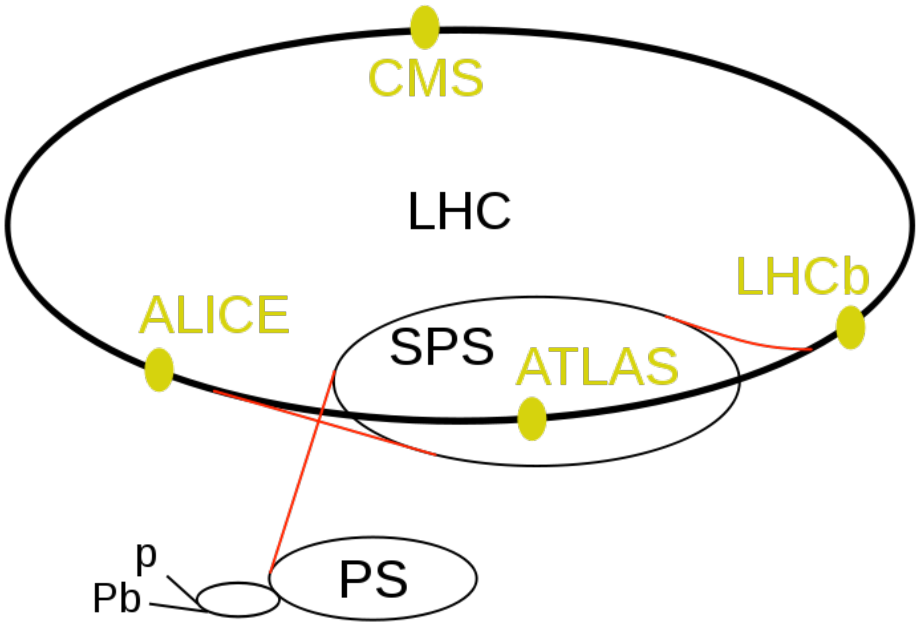




Searching for the Higgs Boson

My Collider

CERN uses a chain of accelerators, developed over decades, to accelerate protons from $\mathbf{KE = 0}$ to $\mathbf{4000\ GeV}$ in stages…



- Linear accelerator: up to 50 MeV
- Proton Synchroton Booster: 50 MeV → 1.4 GeV
- Proton Synchroton: 1.4 GeV → 26 GeV
- Super Proton Synchroton: 26 GeV → 450 GeV
- Large Hadron Collider: 450 GeV → 4 TeV

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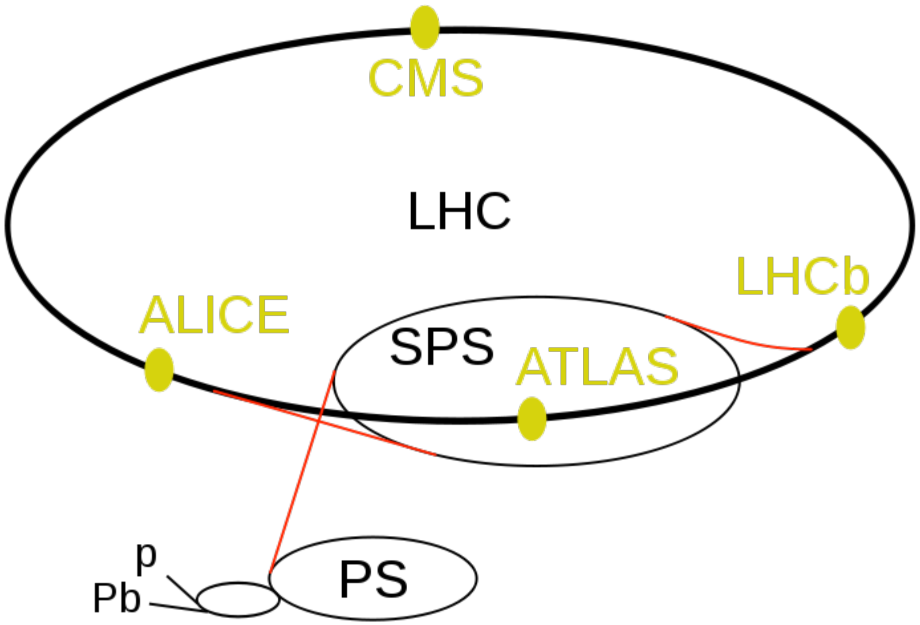

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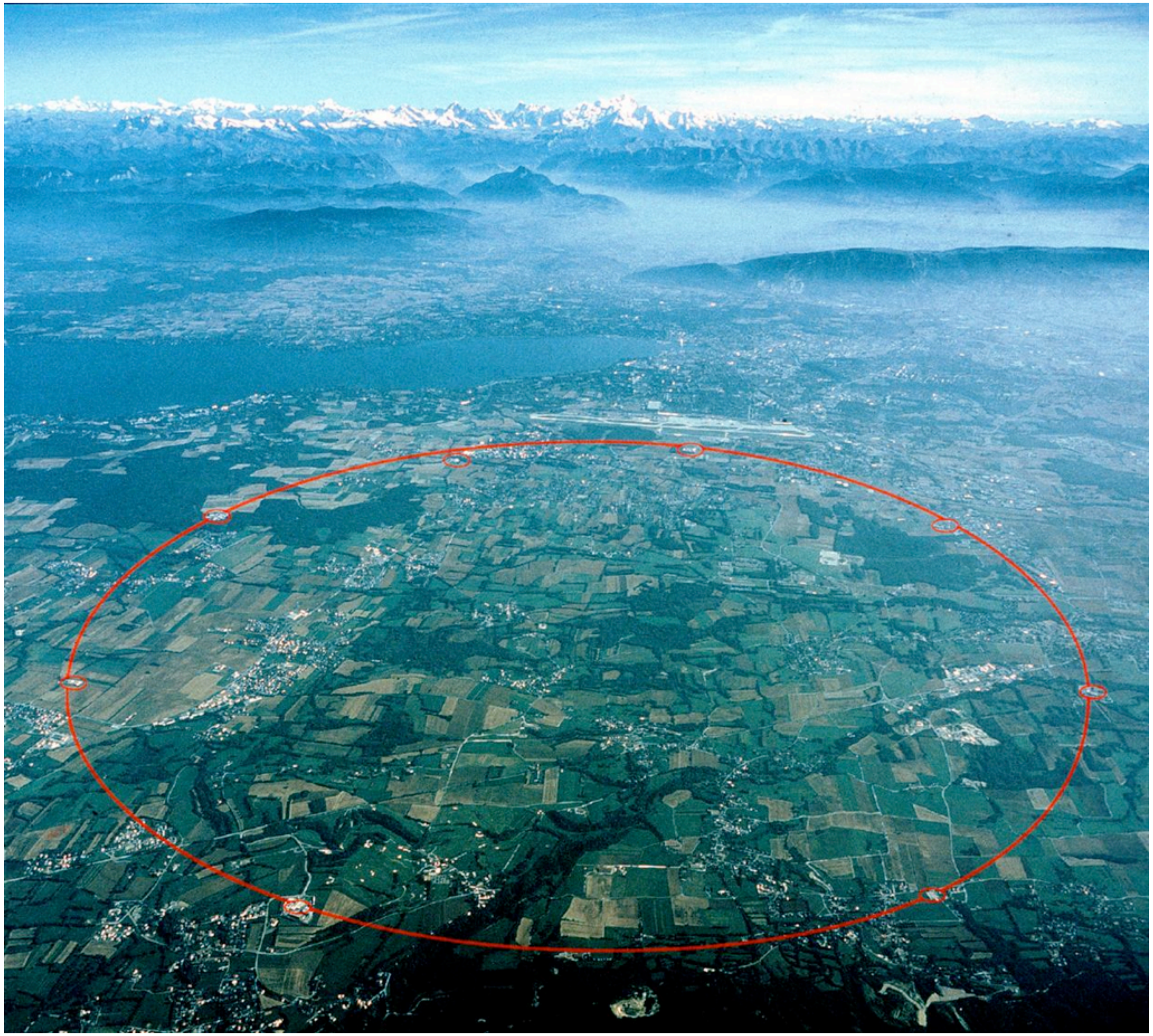
The Large Hadron Collider



- 27km circumference
- 50 to 175 m underground
- 9300 magnets used to keep the beam in orbit
- 1232 dipole magnets
- Ultra-high vacuum of 10^{-10} Torr, equivalent to 1,000 km above earth
- Each dipole magnet: 14.3 m long, runs at 1.9 K, provides 8.3 Tesla, cost 500 kCHF
- four 400 MHz power supplies accelerate the beams from 450 GeV to collision energy
- Design energy: 7 TeV per beam
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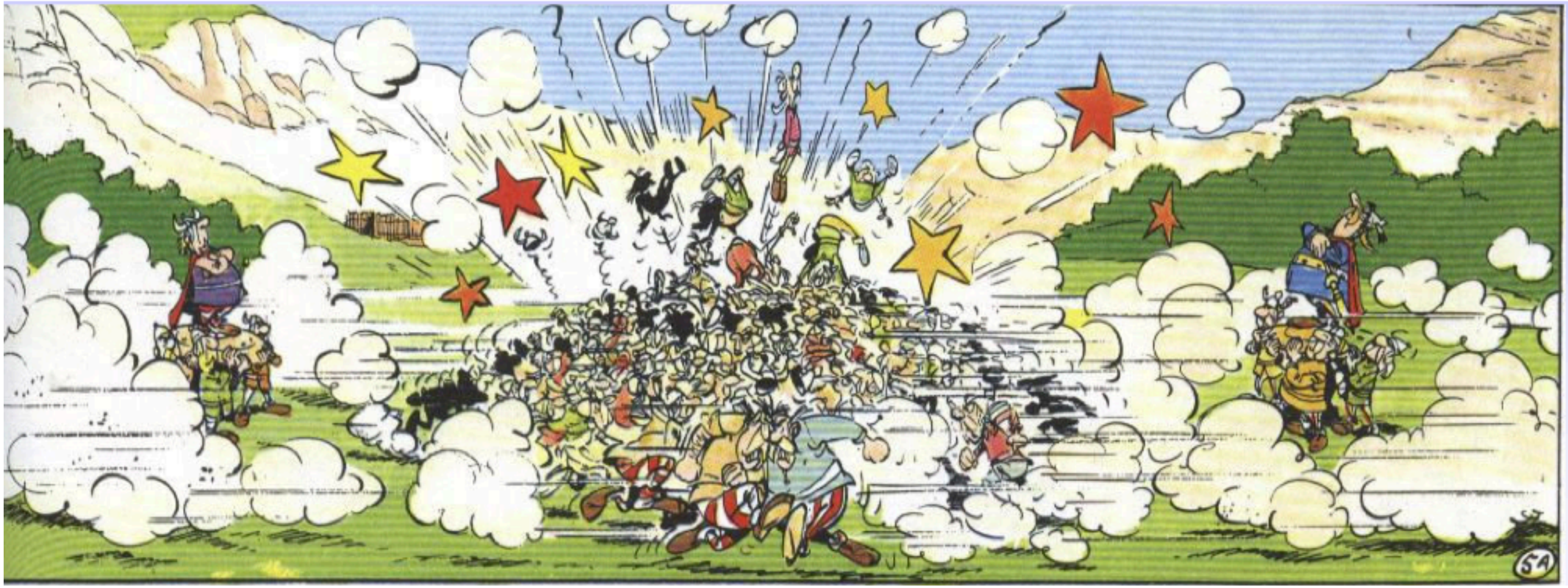

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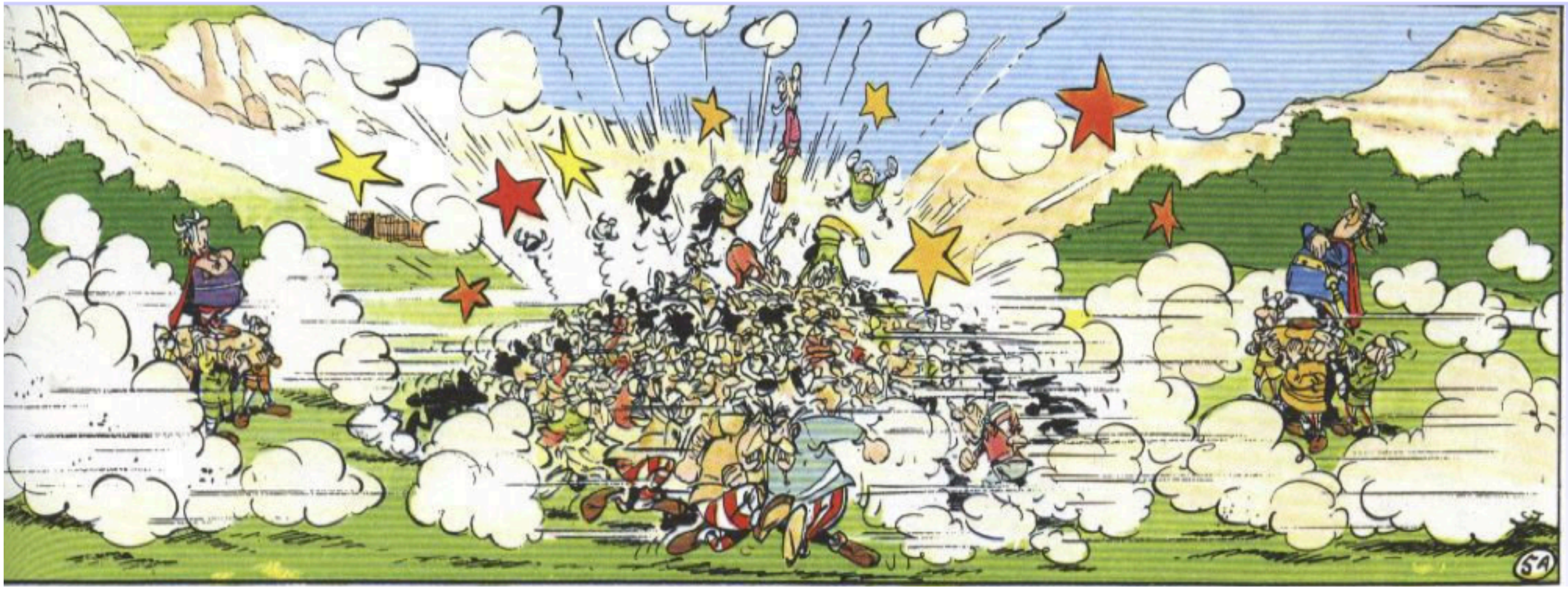
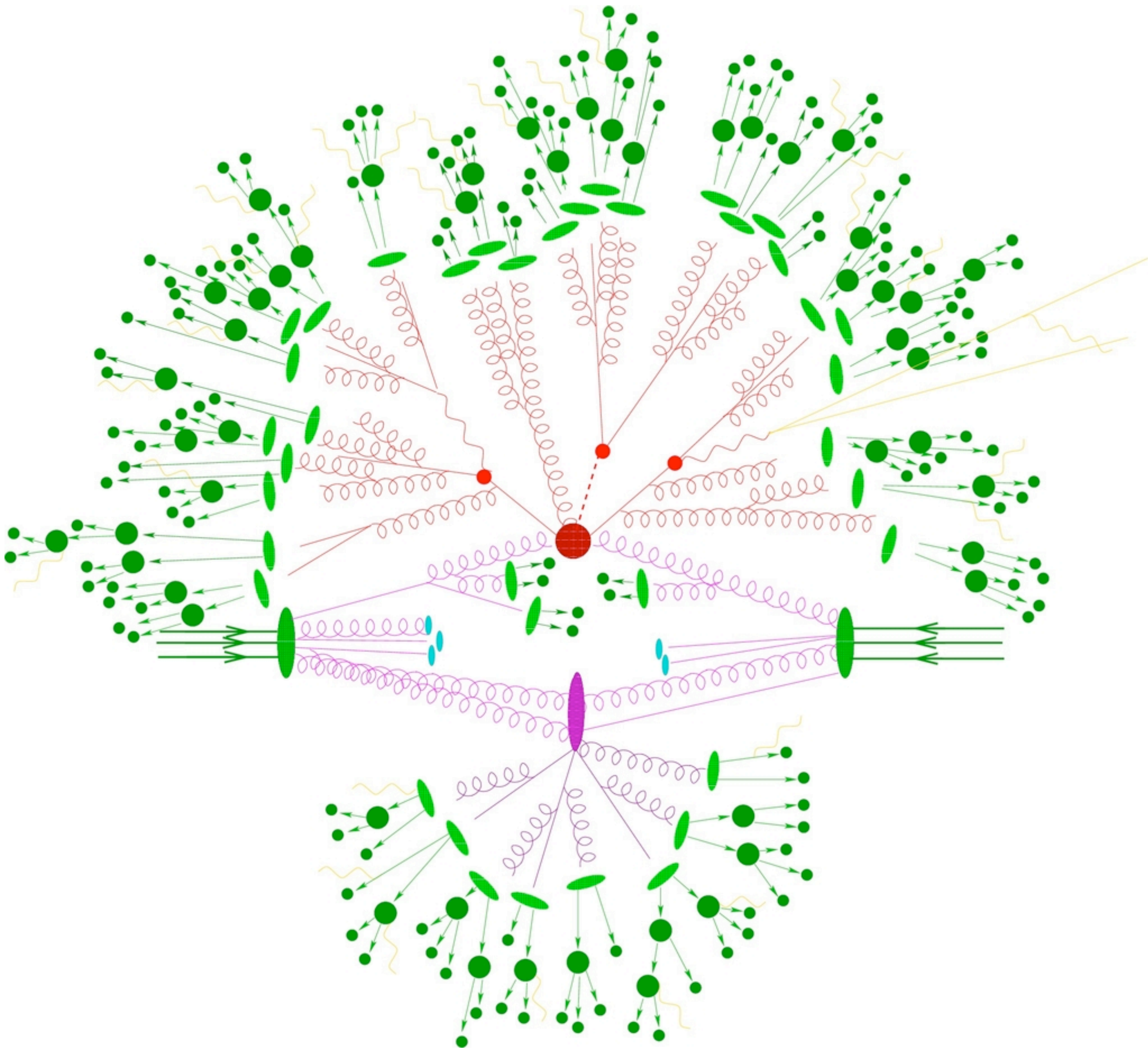


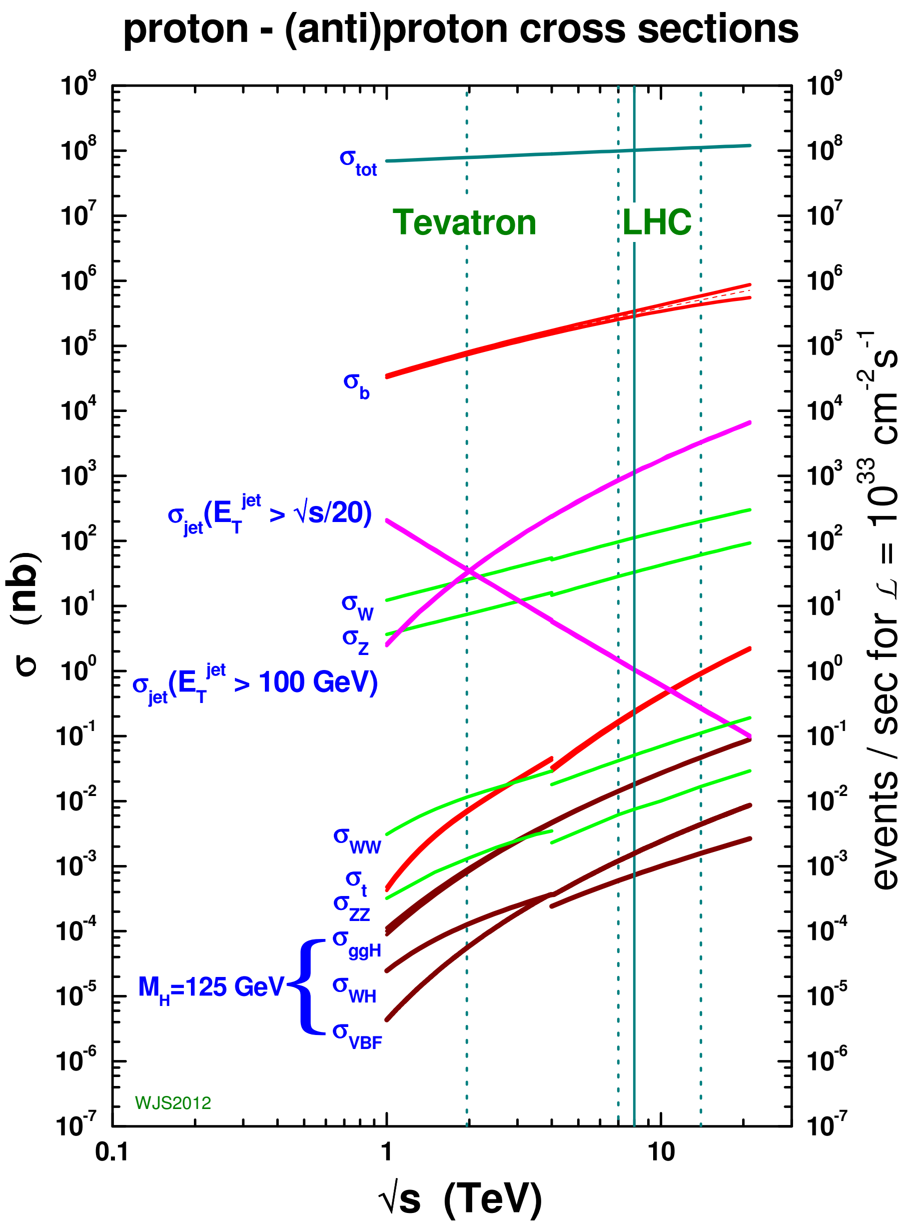
- A few challenges:
  - protons are composite objects (made of three quarks)
  - at LHC energies protons are even more complex: contain many interacting gluons



Making a Higgs boson at the LHC

- Most collisions don't make anything interesting
- Only one in 10^9 collisions creates a Higgs boson.
  - Higgs bosons are rare!

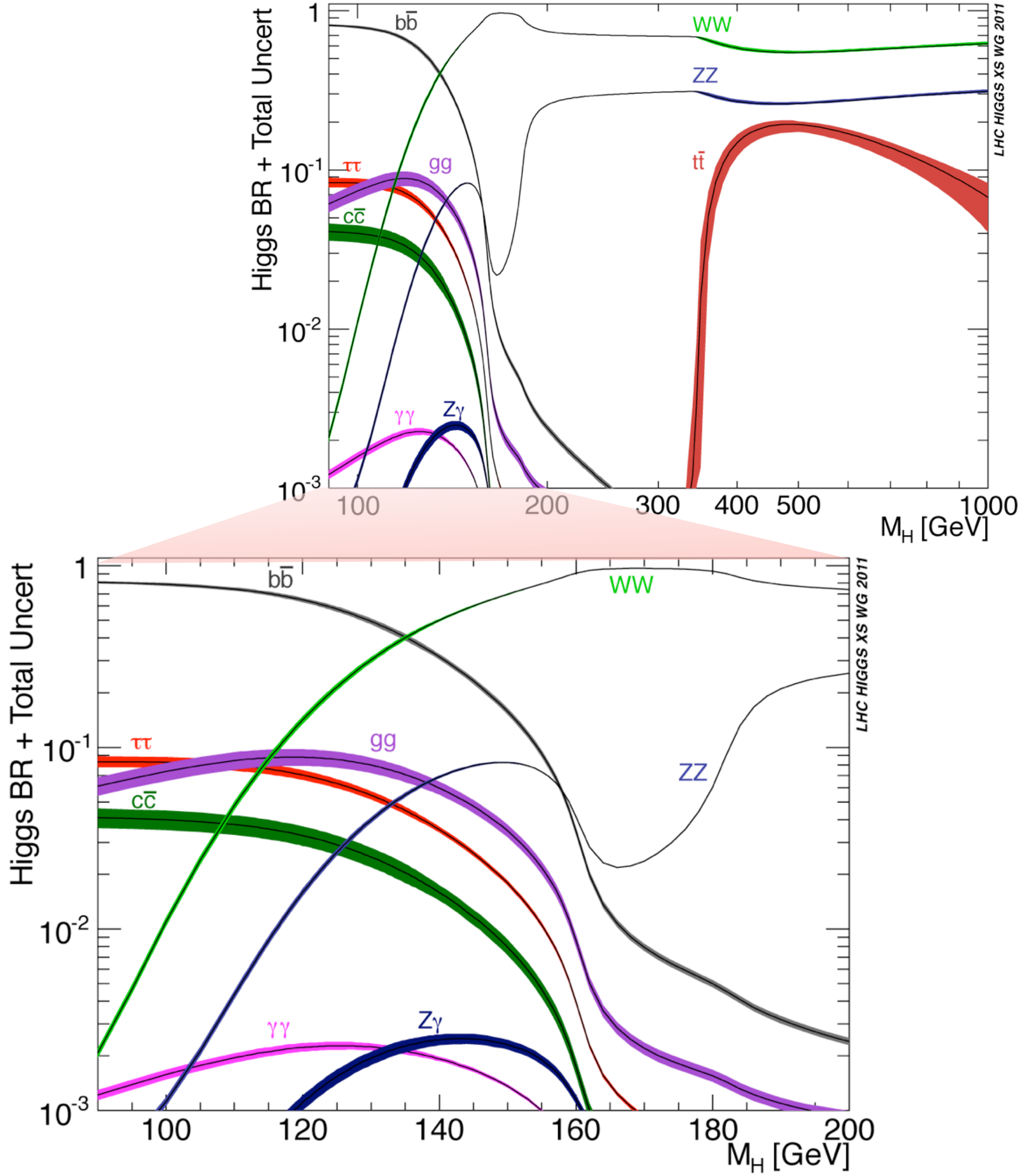
Another story altogether: what happens to all that data?



Identifying Higgs Bosons

- Higgs bosons decay almost instantaneously, into pairs of particles.
- Pairs of what … depends on Higgs boson mass, m_H.

- e.g. for $m_H = 125\ \mathrm{GeV}/c^2$
  - pairs of b-quarks: $H \to b\bar{b}$ 57.7%
  - pairs of Z-bosons: $H \to ZZ$ 2.6%
  - pairs of photons: $H \to \gamma\gamma$ 0.2%



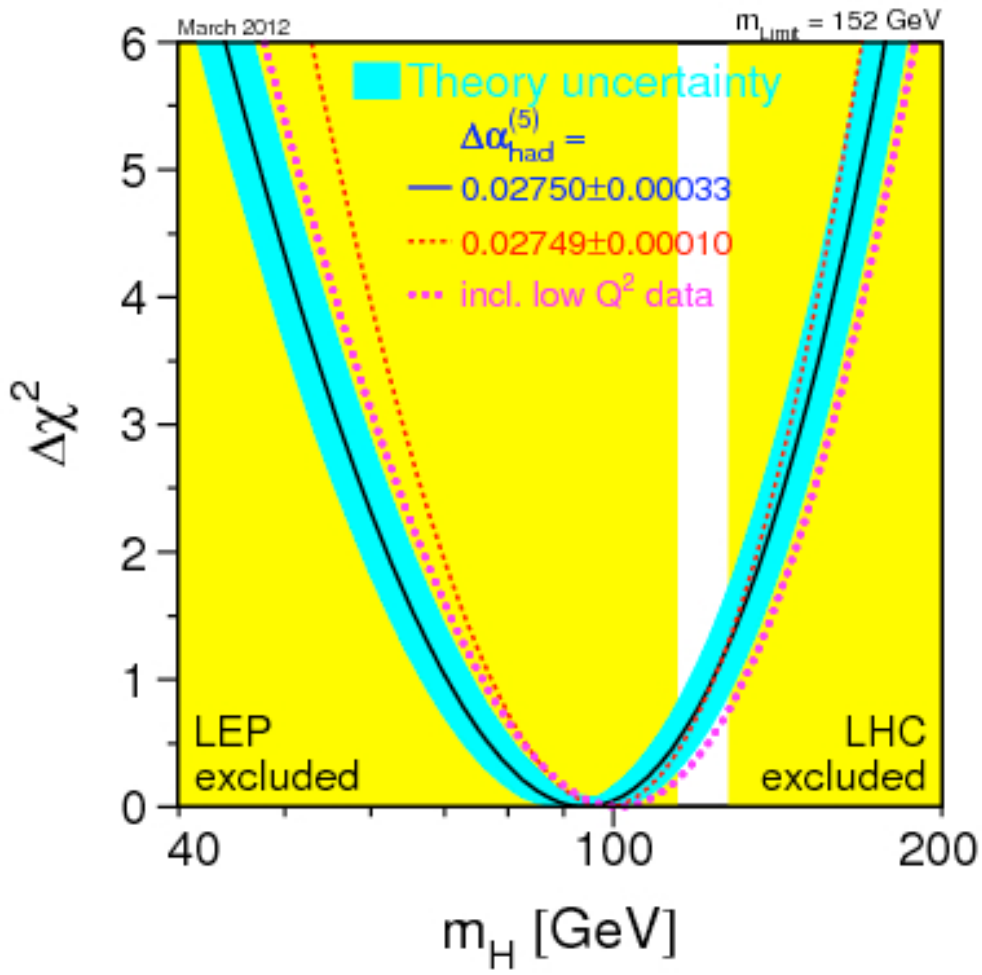
Before the 4th of July

- Before the LHC, earlier experiments ruled out:
- $m_H < 114.4$ GeV/c^2
- $147 < m_H < 180$ GeV/c^2

- Standard Model measurements are also sensitive to m_H

- "Best fit" value for the mass of the Higgs boson is $m_H = 94^{+29}_{-24}$ GeV/c^2

- LHC looks in the range $100 < m_H < 600$ GeV/c^2



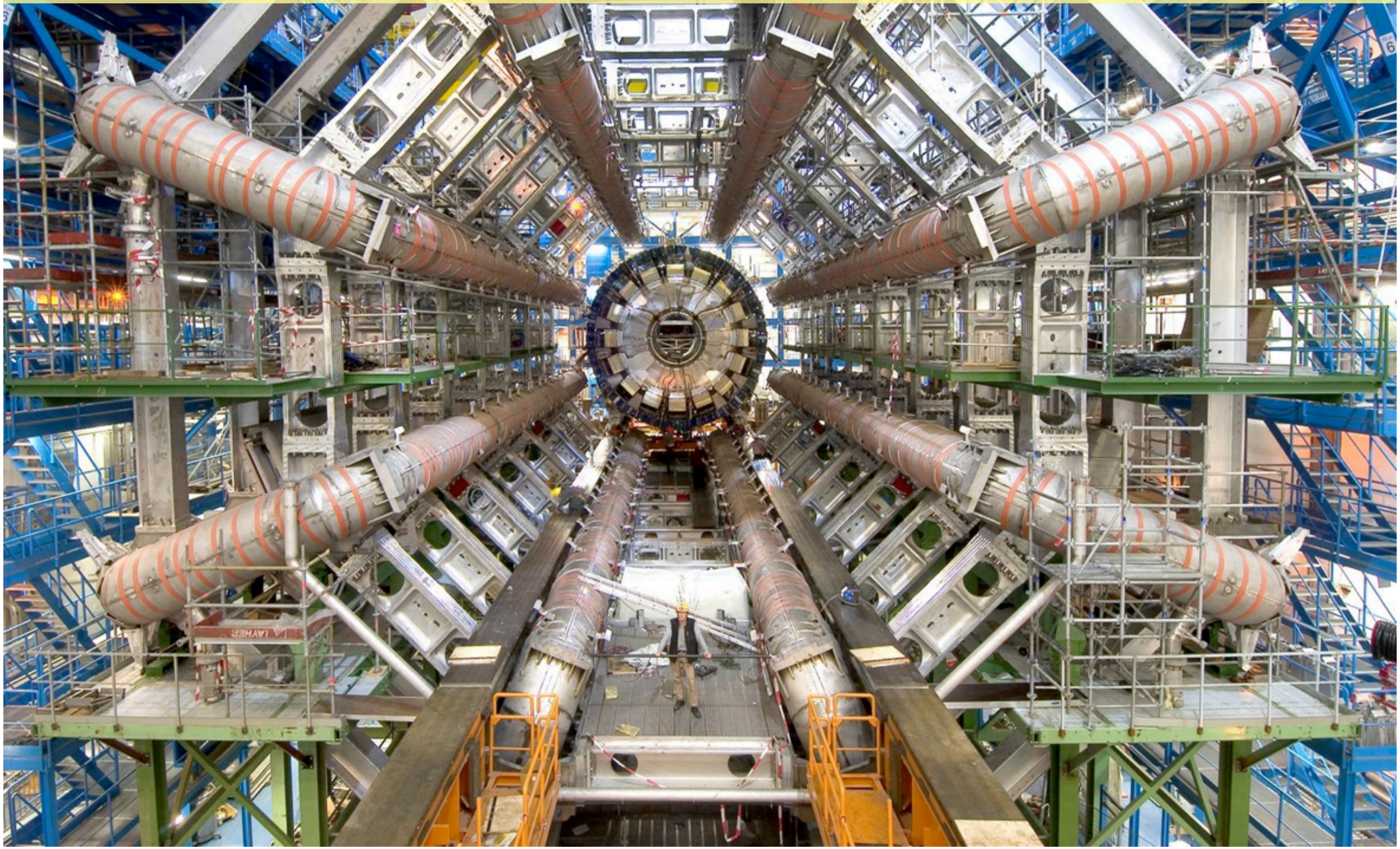
Detecting the Higgs boson...

Detecting the Higgs boson...

Remember we have to detect the decay products, not the boson itself

To detect the Higgs boson decays...

simply assembly the ATLAS detector at the proton collision point



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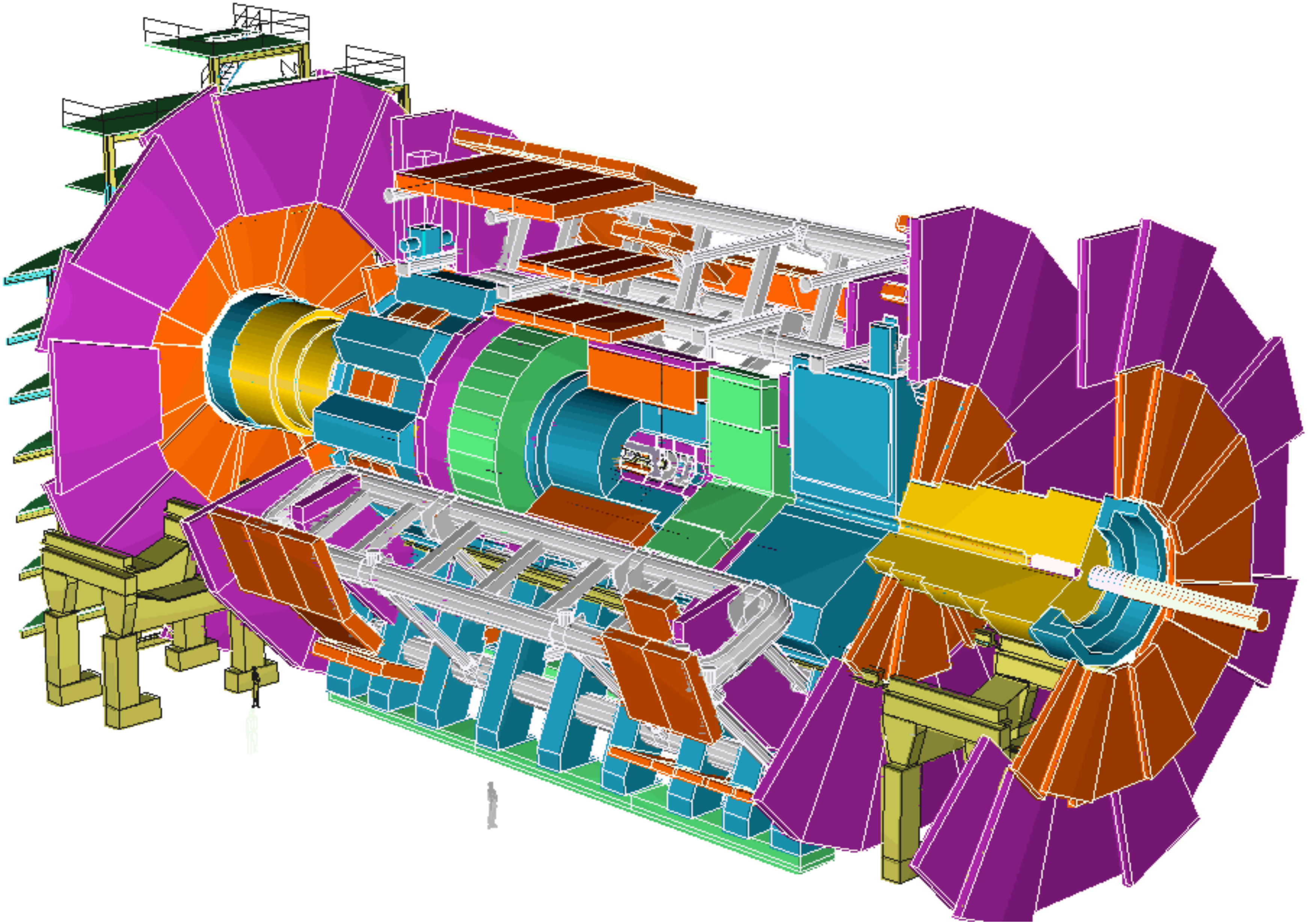

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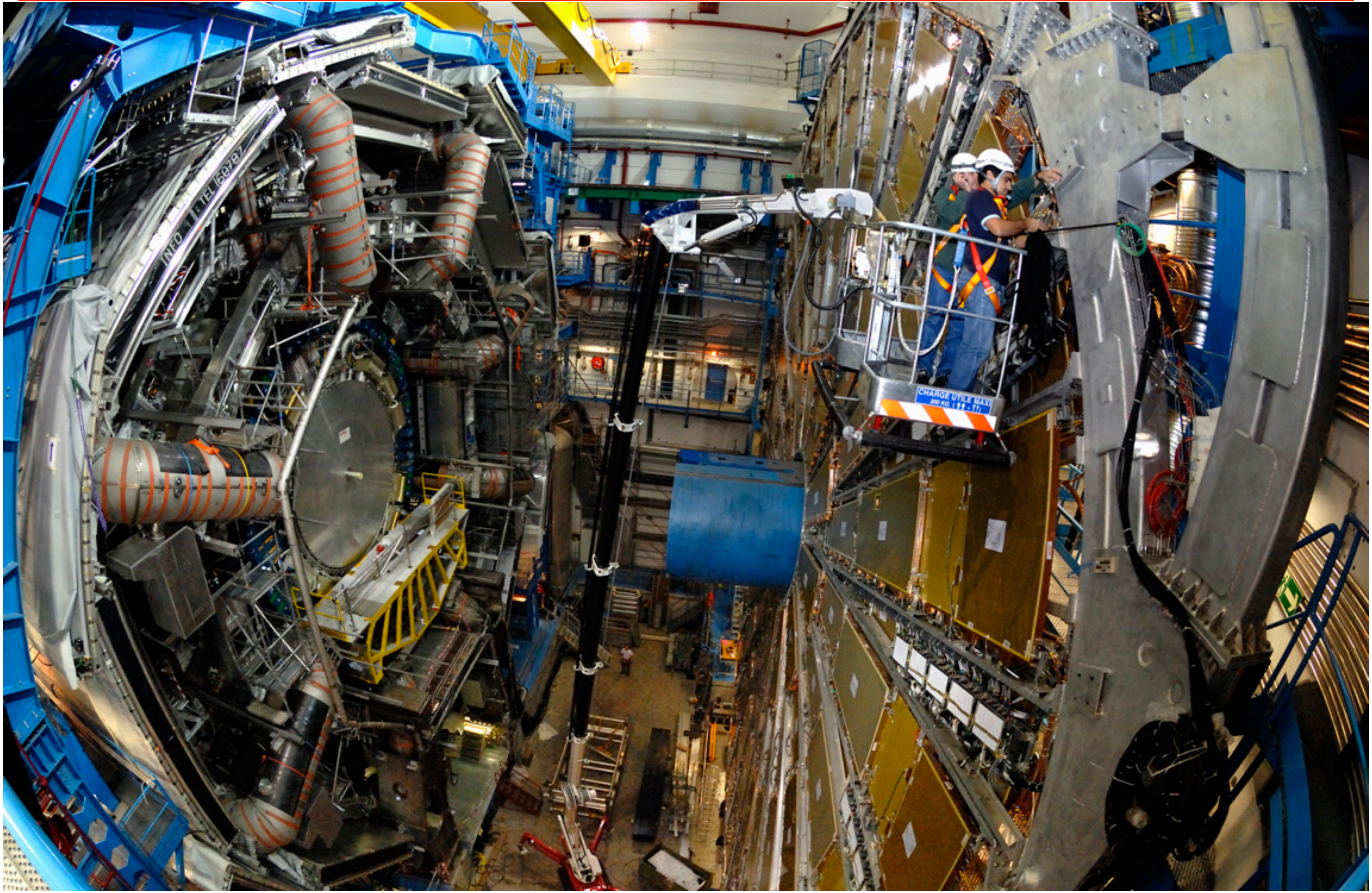


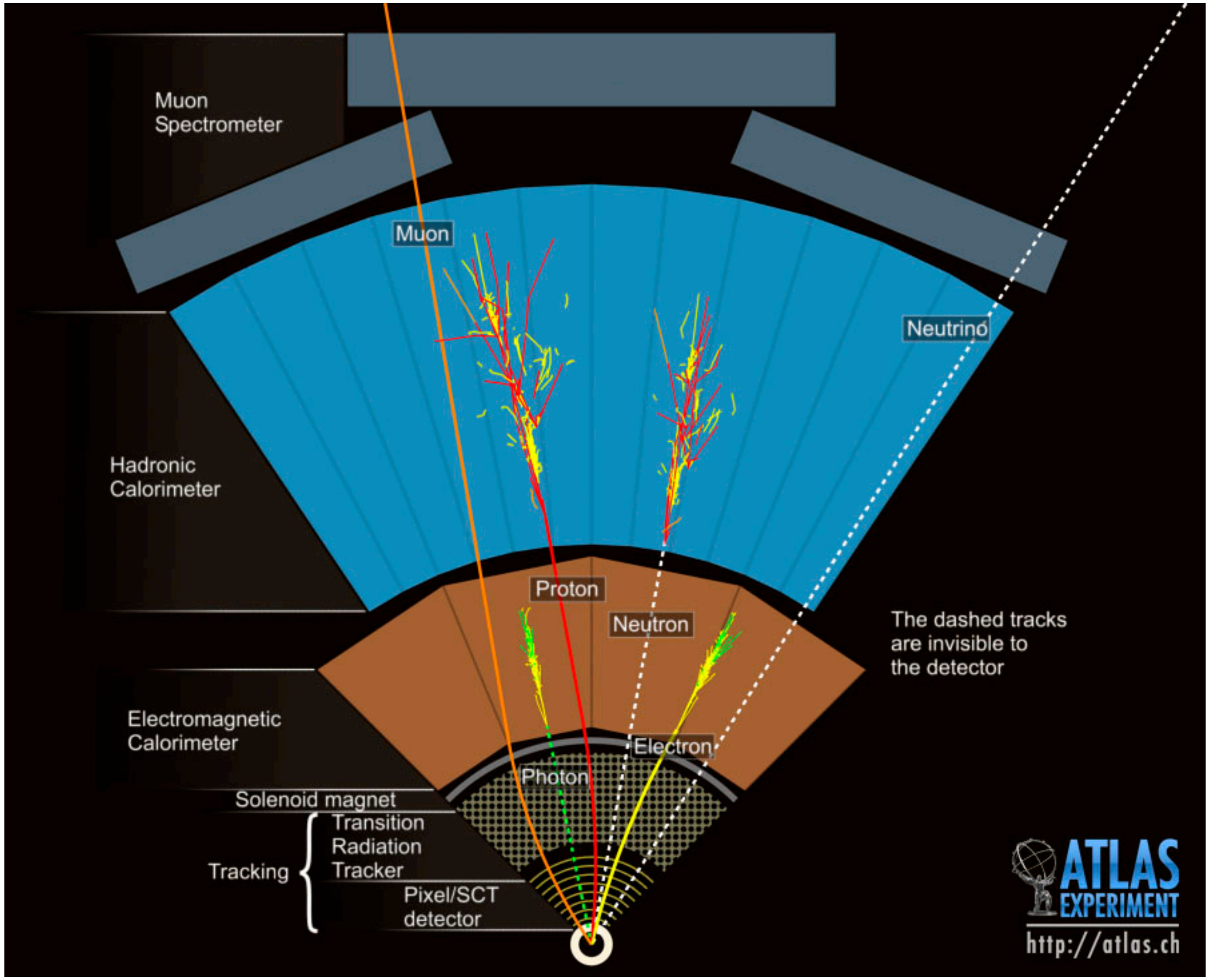
ATLAS detector

ATLAS is essentially the largest and most sophisticated digital camera ever built

- 45 meters long
- 25 meters diameter
- 7,000 tonnes

Observes and identifies all final state particles:

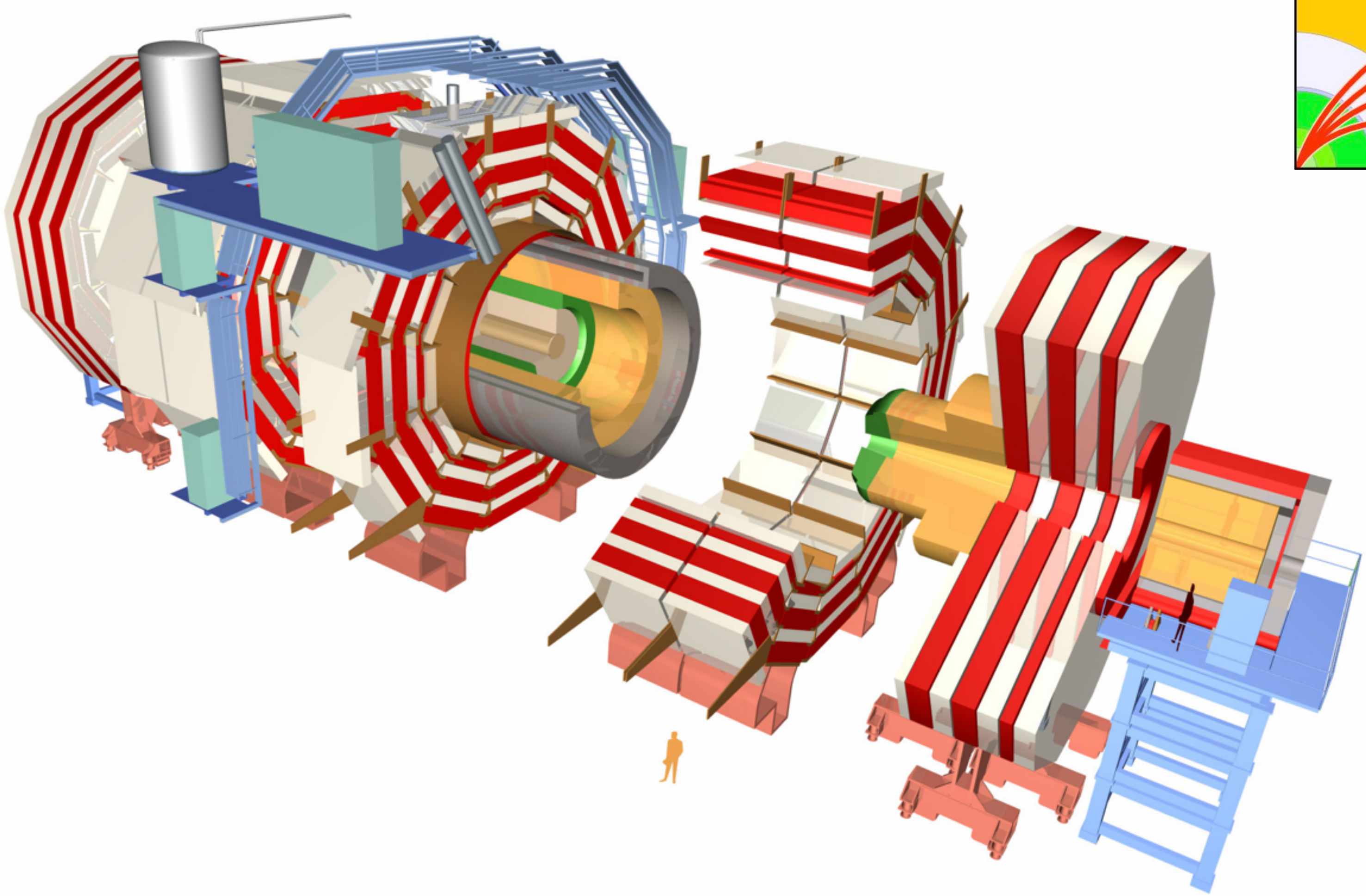
➡ those which live long enough to travel from the interaction point to the detector



ATLAS Collaboration

- 3,000 physicists at 175 institutions in 37 countries
- 20 from the University of Edinburgh

ATLAS is not alone in this endeavour. Our friendly rivals CMS (Compact Muon Solenoid) built this:



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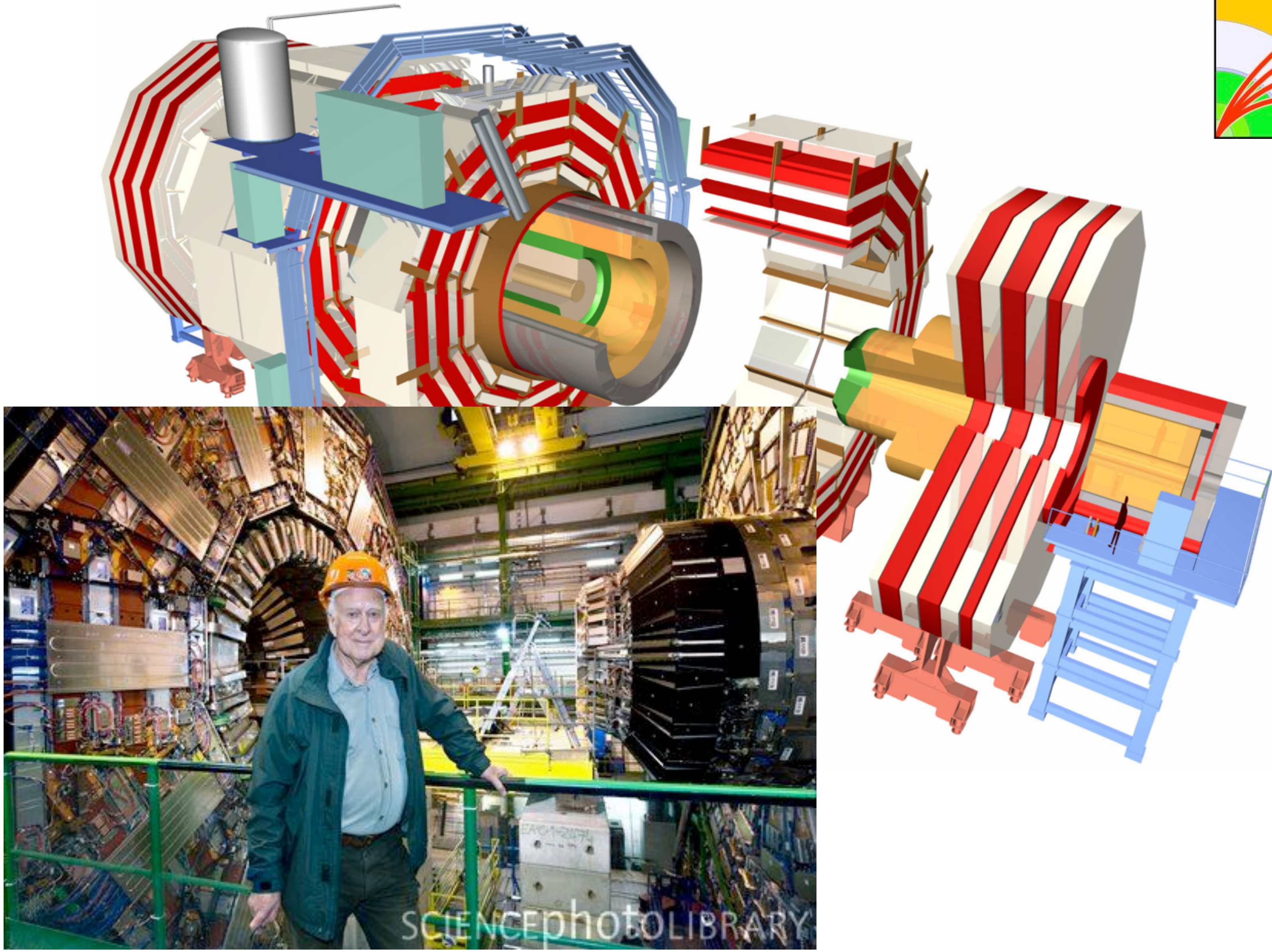

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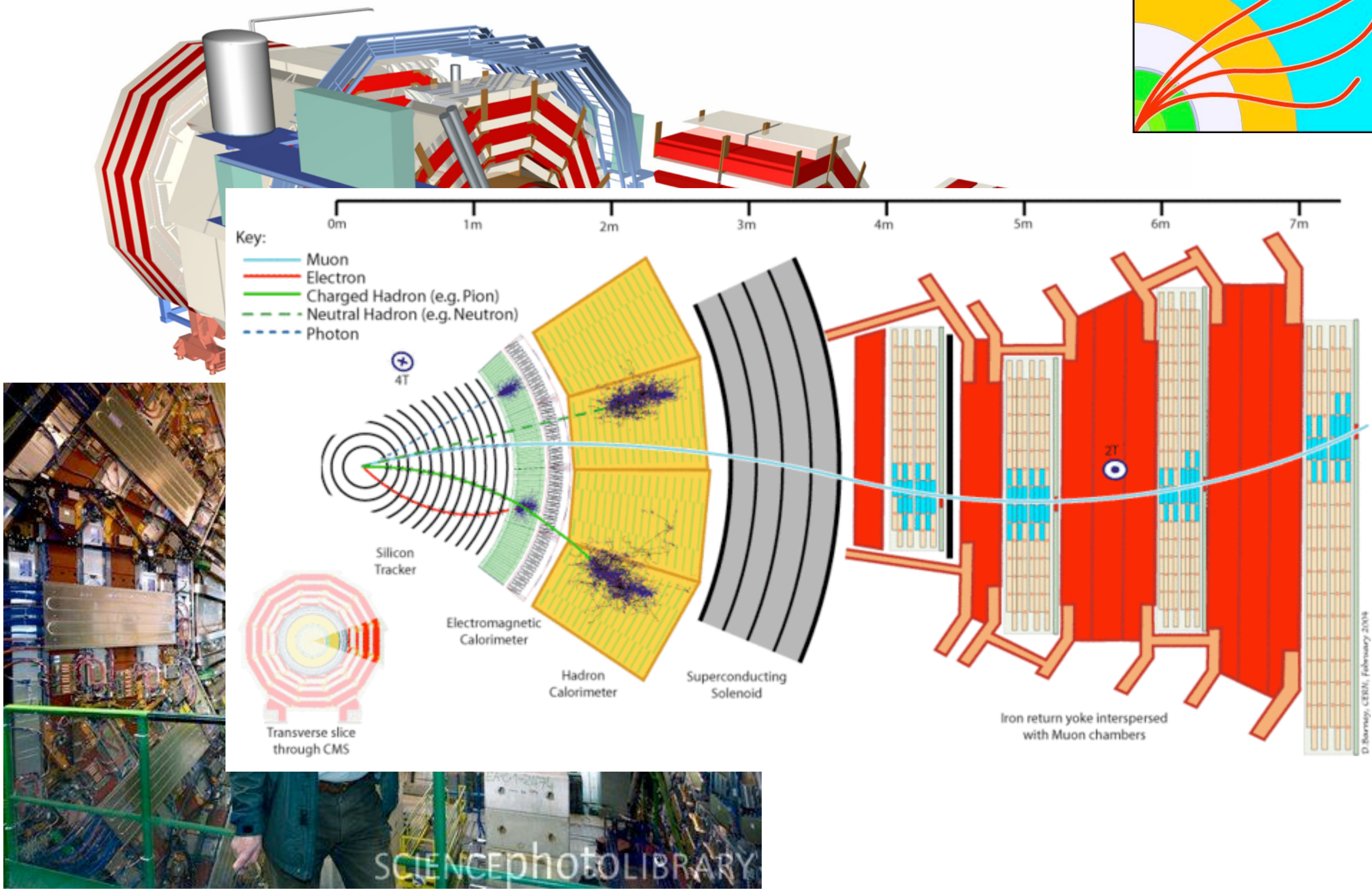
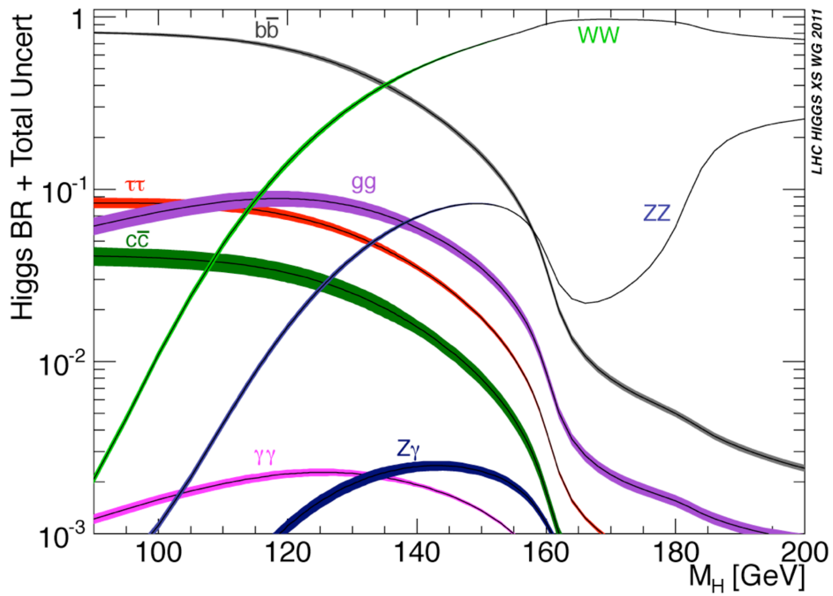
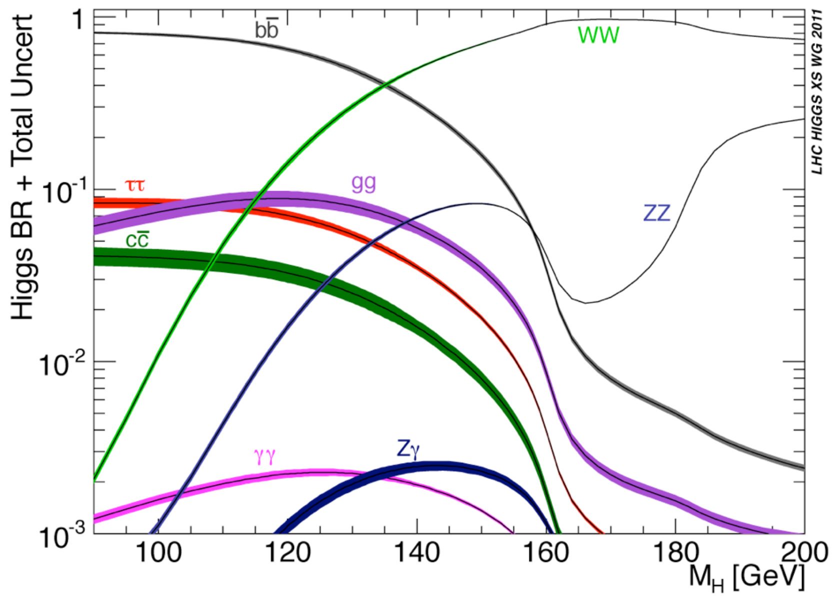


Analysing the Data



Analysing the Data

- ATLAS and CMS have collected and analysed data in 2011 and 2012.
  - 2011: proton collisions at **7 TeV, 4.8 fb^{-1}**
  - 2012: proton collisions at **8 TeV, 5.8 fb^{-1}**



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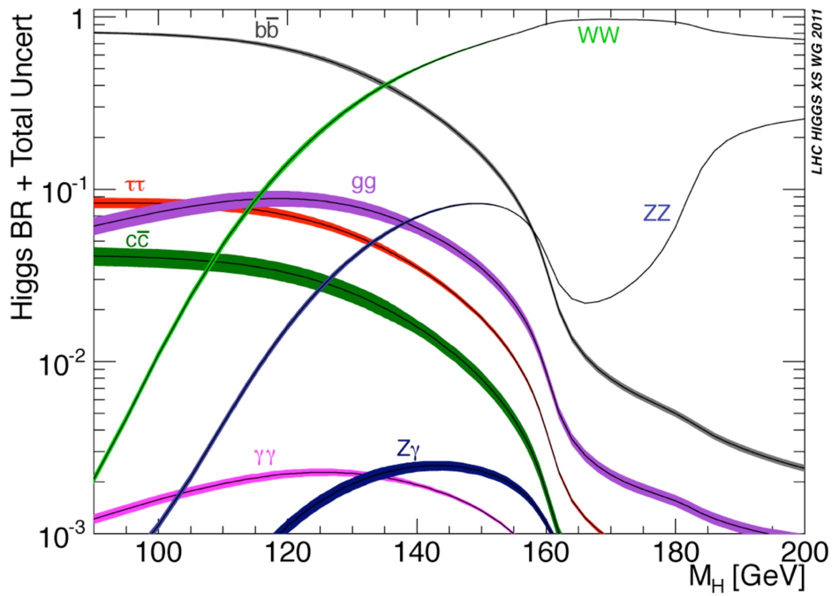
  - 2011: proton collisions at **7 TeV, 4.8 fb^{-1}**
  - 2012: proton collisions at **8 TeV, 5.8 fb^{-1}**

- We look for the pair of particles the Higgs boson is predicted to:
  - pairs of Z-bosons: $H \to ZZ$
  - pairs of W-bosons: $H \to WW$
  - pairs of photons: $H \to \gamma\gamma$
  - pairs of b-quarks: $H \to b\bar{b}$
  - pairs of τ-leptons: $H \to \tau^+\tau^-$



Looking for the Higgs

- Search in the data for collisions where the relevant pairs of particles are produced.
  - e.g. look for two photons.

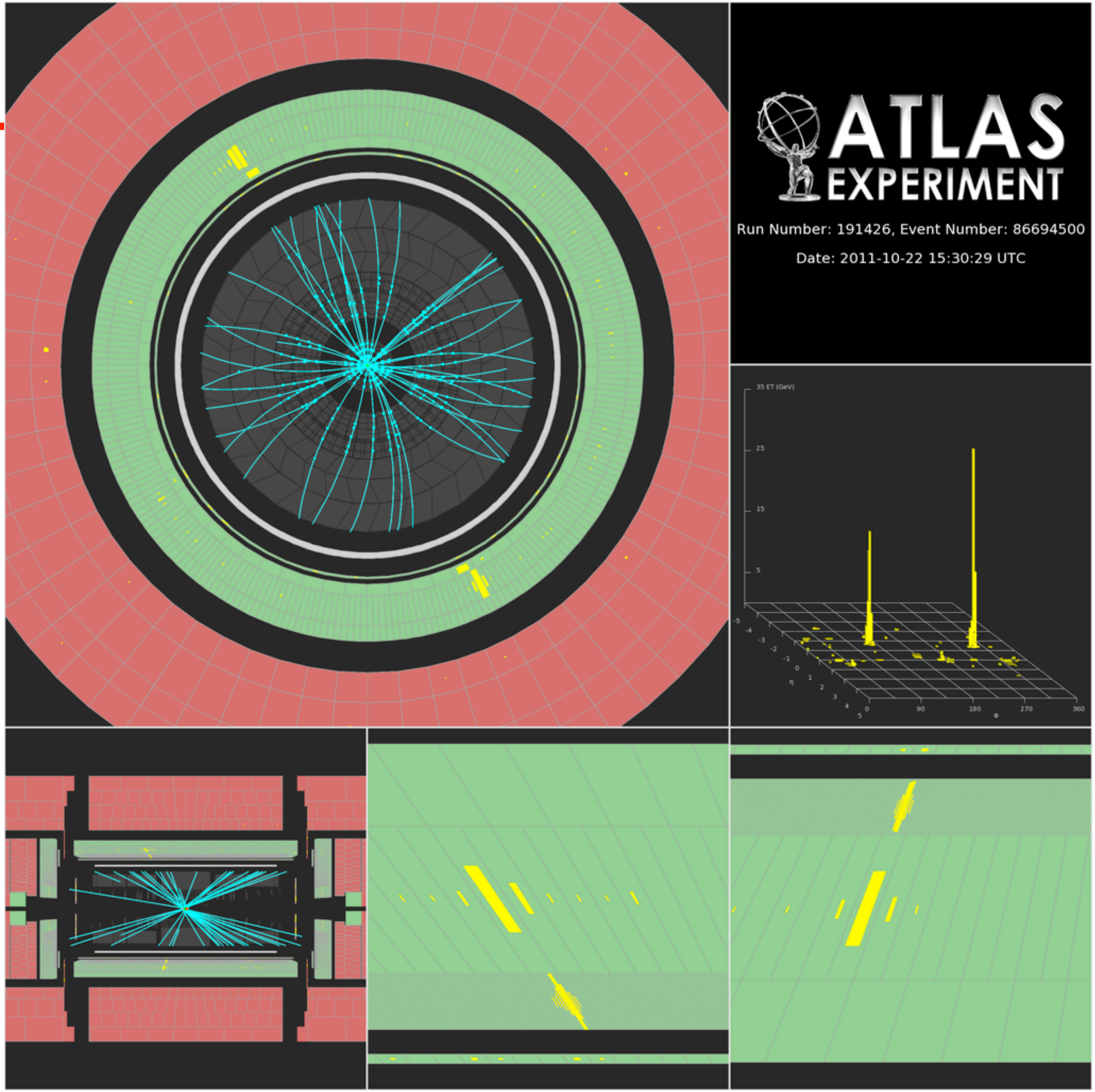
- Calculate the mass of the particle of the producing the pair of particles.

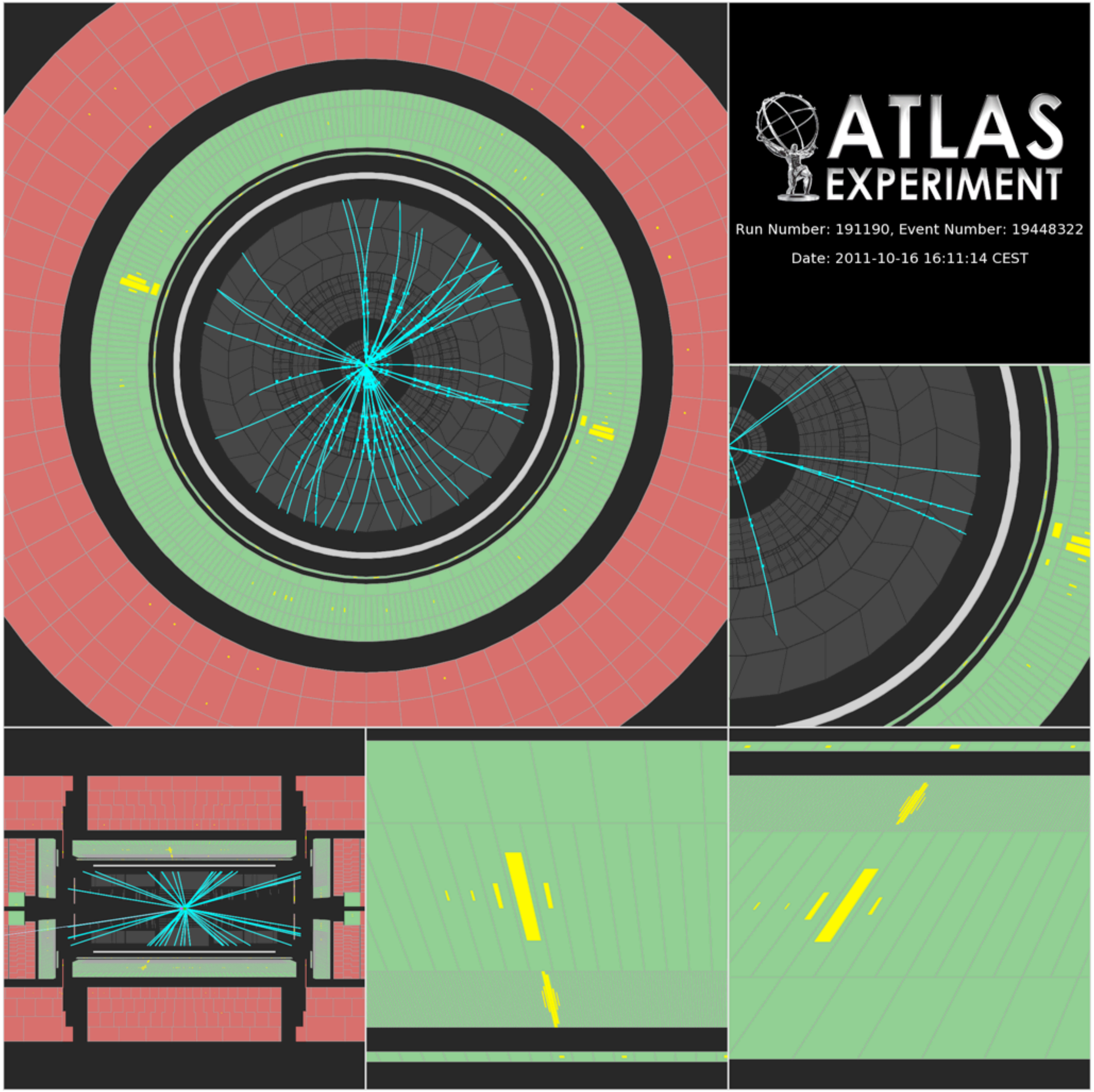
- Many other processes, nothing to do with the Higgs boson, can also produce two photons: known as **background processes**.

- Higgs boson decay will produce coherent pairs of photons with $m(\gamma\gamma)$ close to the mass of the Higgs, m_H.

- For discovery, we want to differentiate between the Higgs boson processes and the background processes at **5 standard deviations**.

$H \rightarrow \gamma\gamma$ Candidate

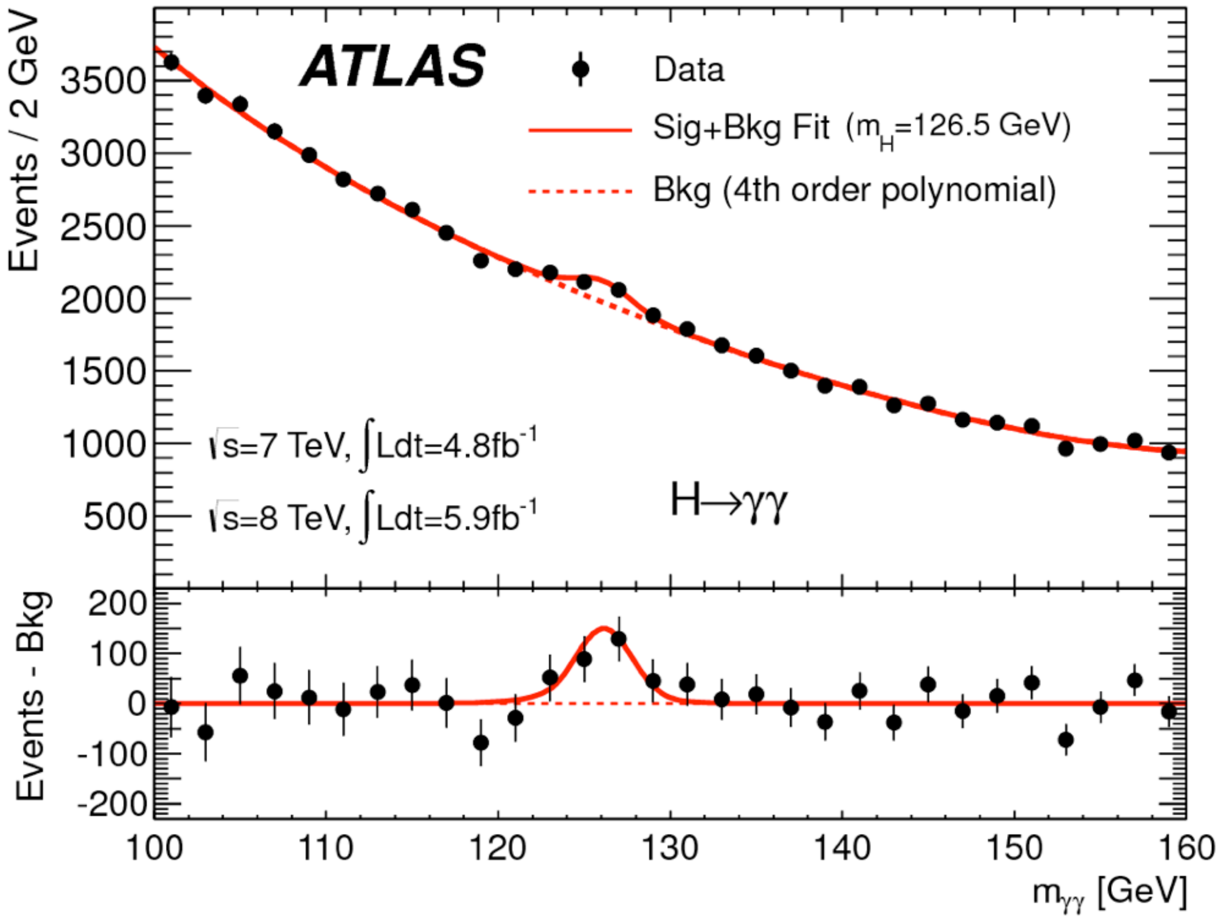




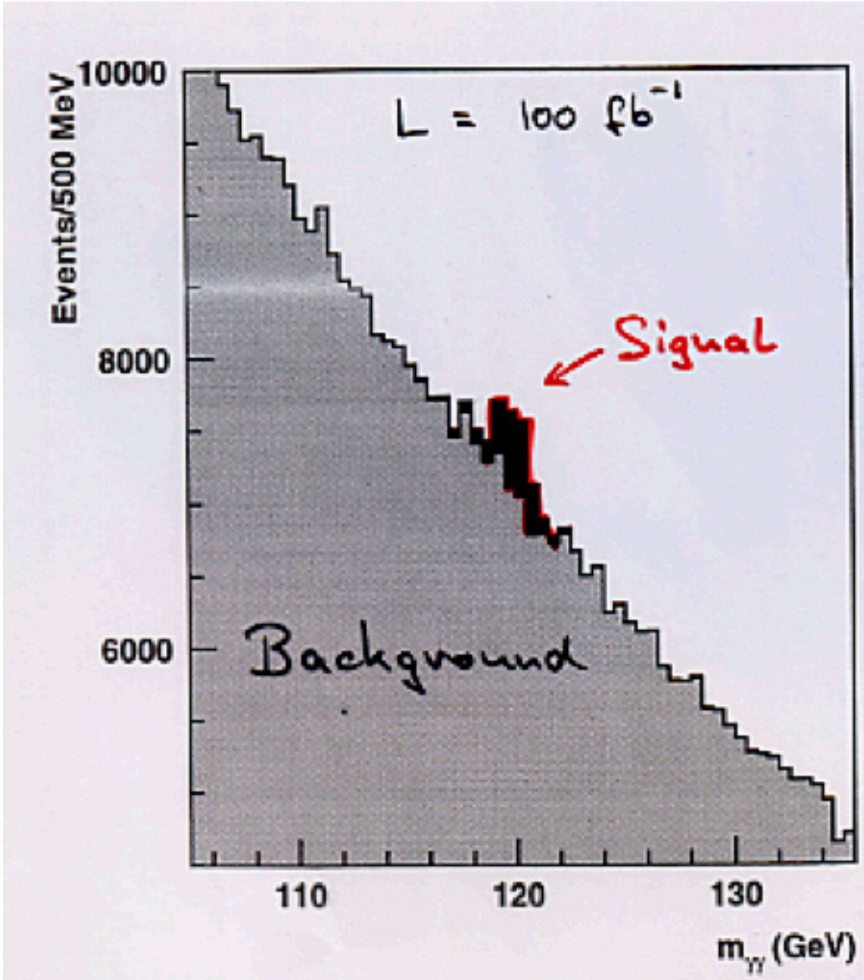
$H \rightarrow \gamma\gamma$ Candidate

$H \rightarrow \gamma\gamma$ Results

- Most photon pairs detected are due to background processes.
- Small excess of events at $m_{\gamma\gamma} \sim 125$ GeV/c^2
- Just as we'd expect if there's a Higgs boson which can decay into two photons.

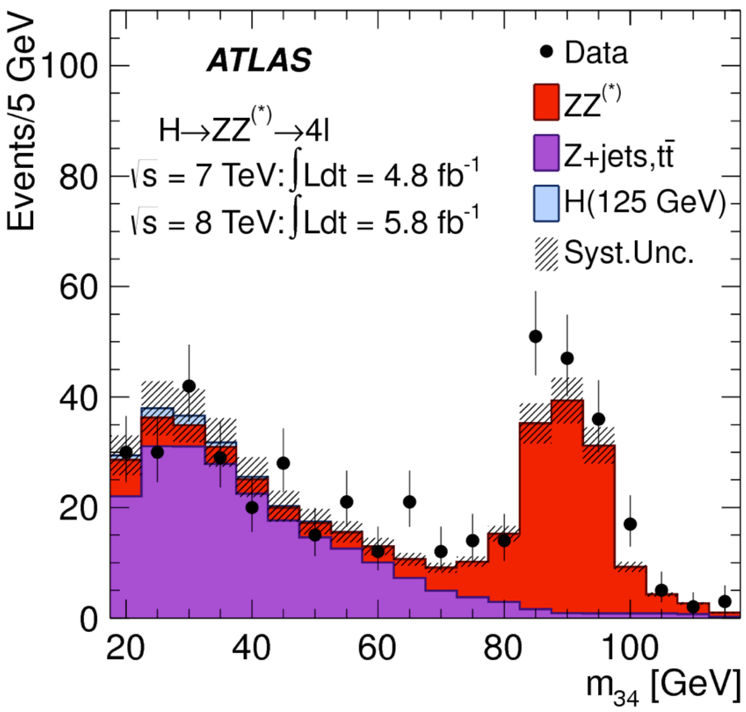


From Thomas' Door



Looking for $H \to ZZ$

- Z-bosons themselves decay
- Easiest to look for decays of Z-bosons into electrons or muons (leptons)
  $Z \to \mu^+\mu^-$, $Z \to e^+e^-$ ($H \to ZZ \to eeee$, $H \to ZZ \to ee\mu\mu$, $H \to ZZ \to \mu\mu\mu\mu$)
- Mass of two of the leptons should be close to m_Z
- Other collision events will also produce four leptons: challenge is to separate background and Higgs signal



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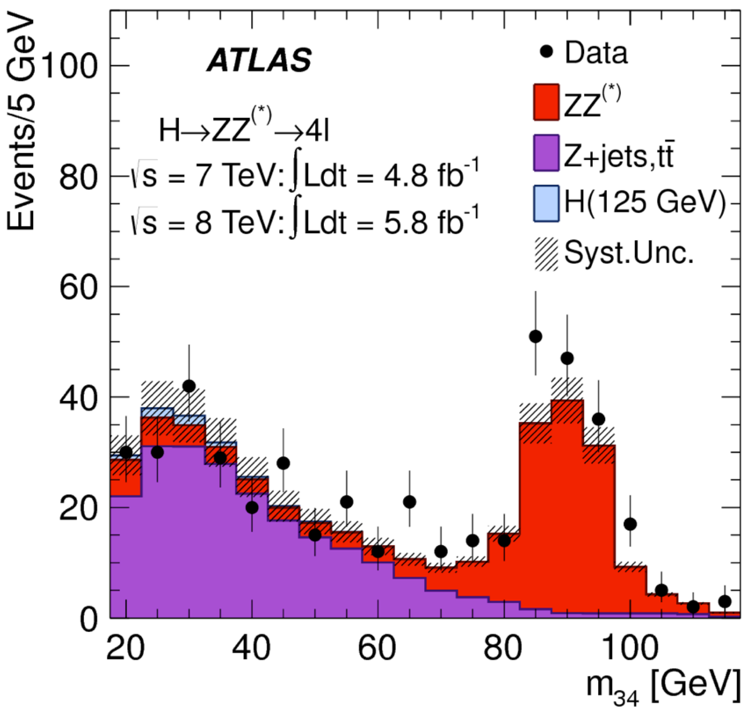
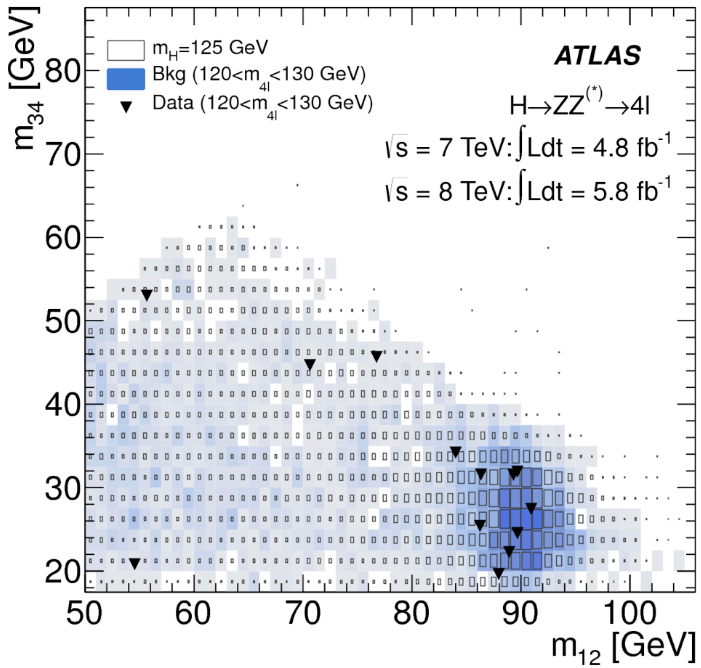
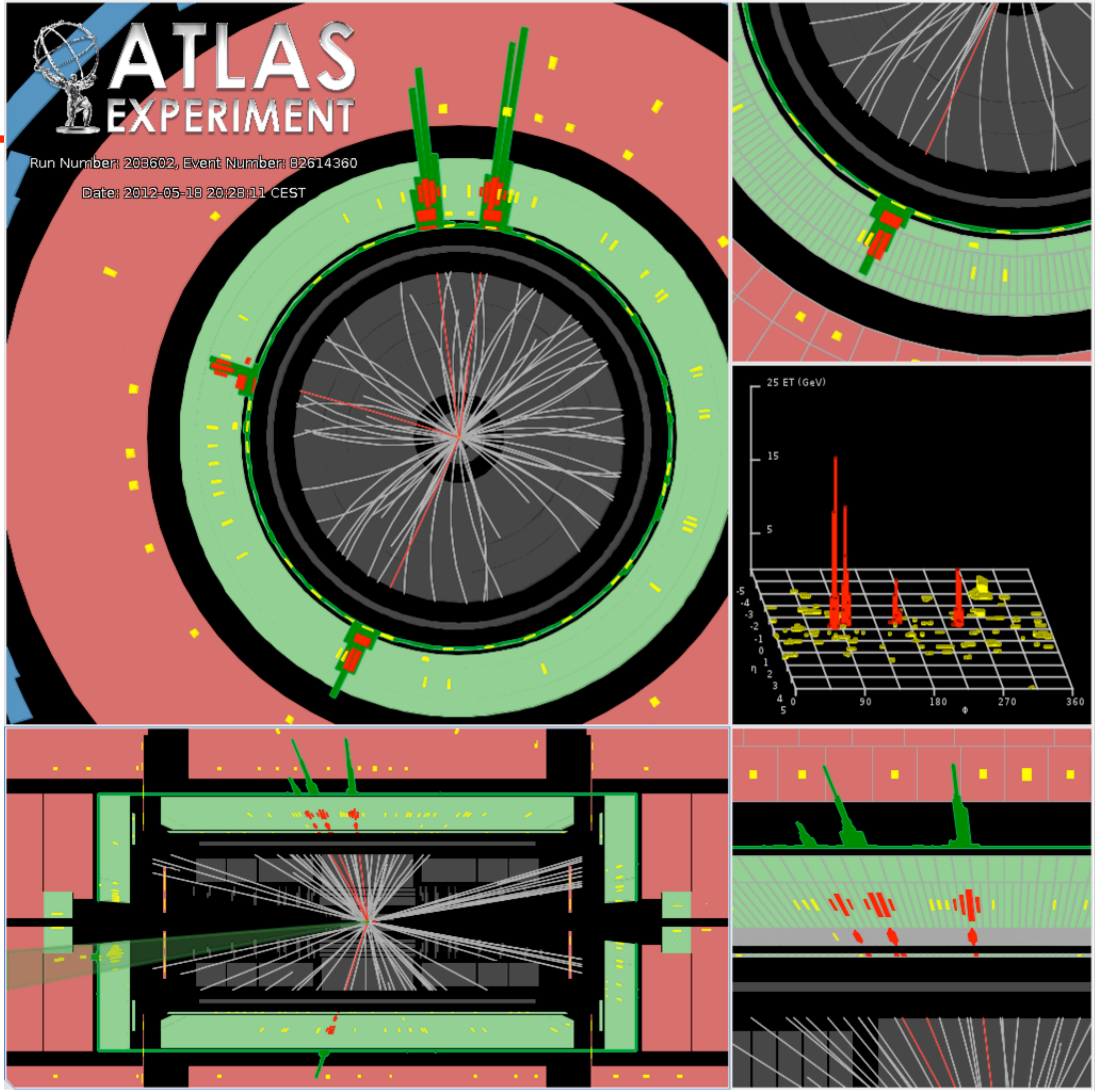


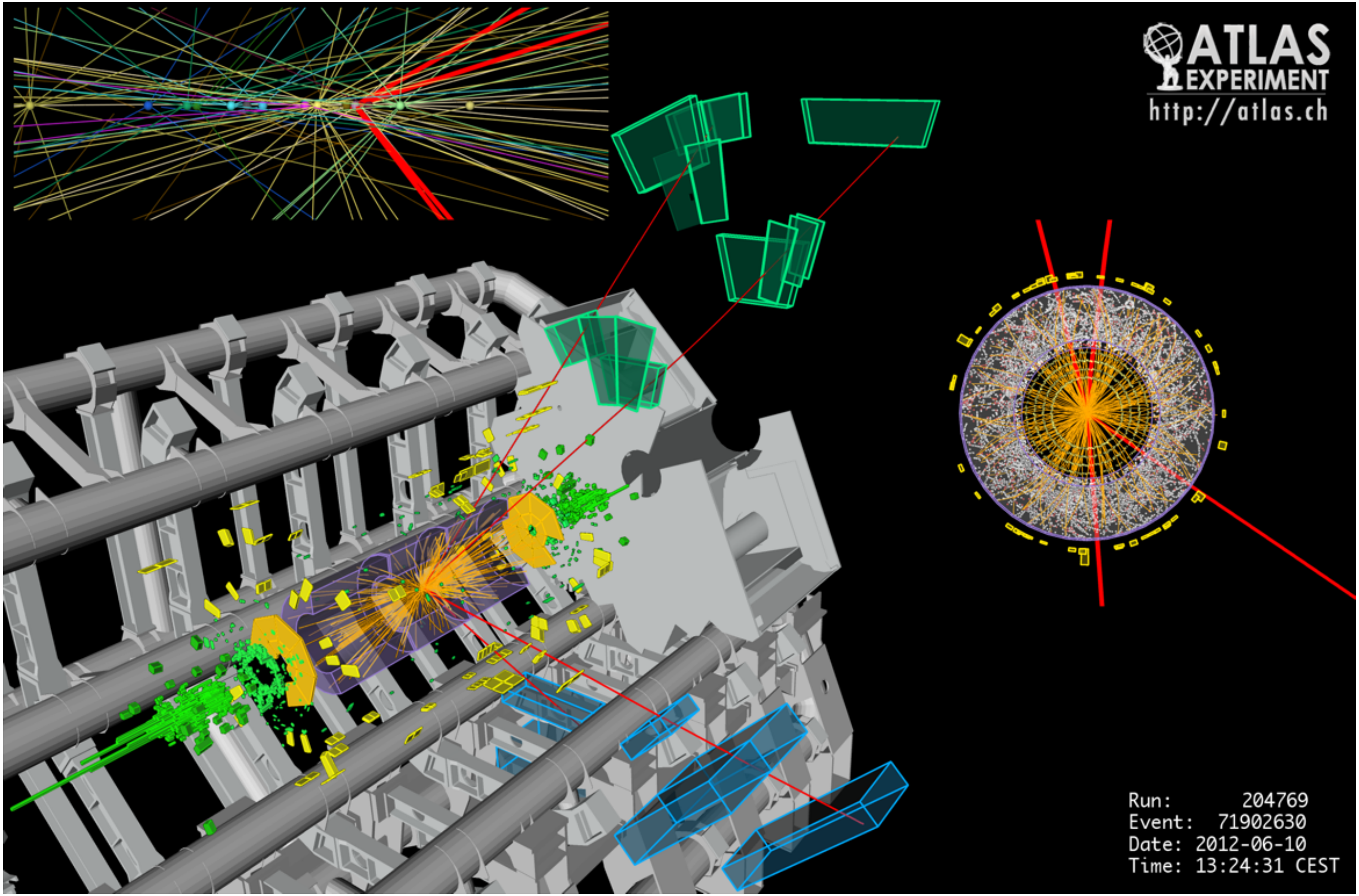


$H \to ZZ \to e^+e^-e^+e^-$

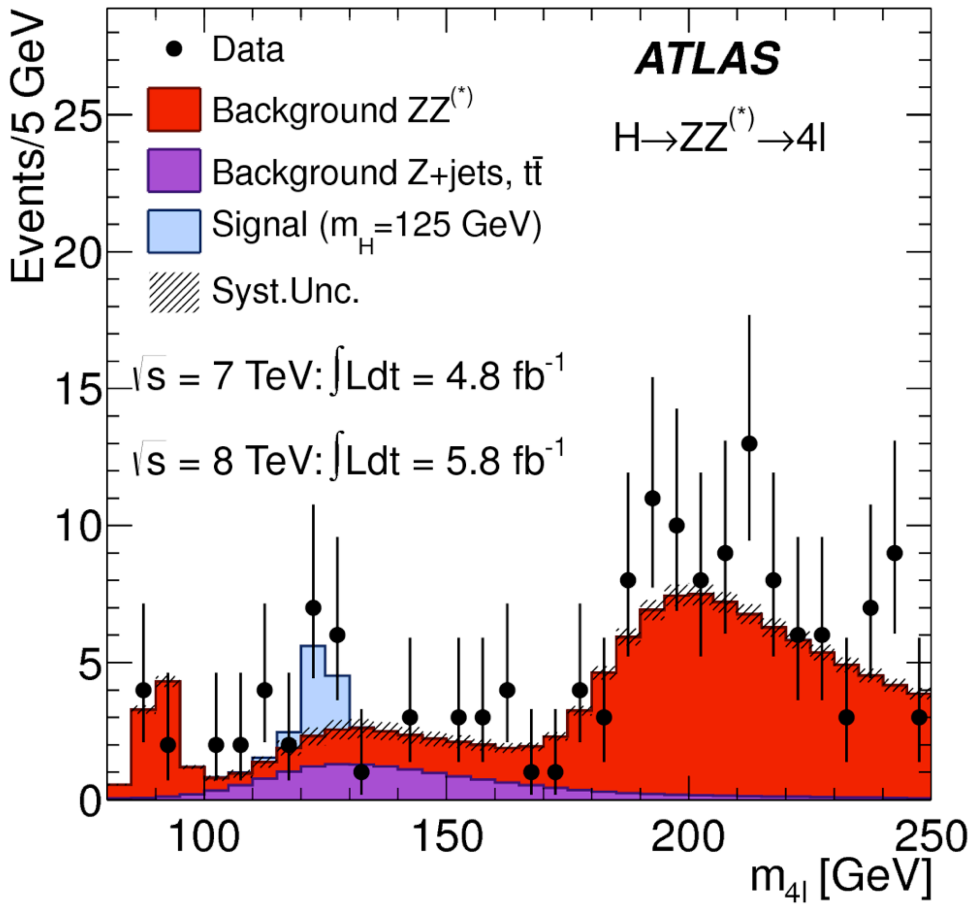
(probably!)



$H \to ZZ \to \mu^+\mu^-\mu^+\mu^-$ (maybe!)



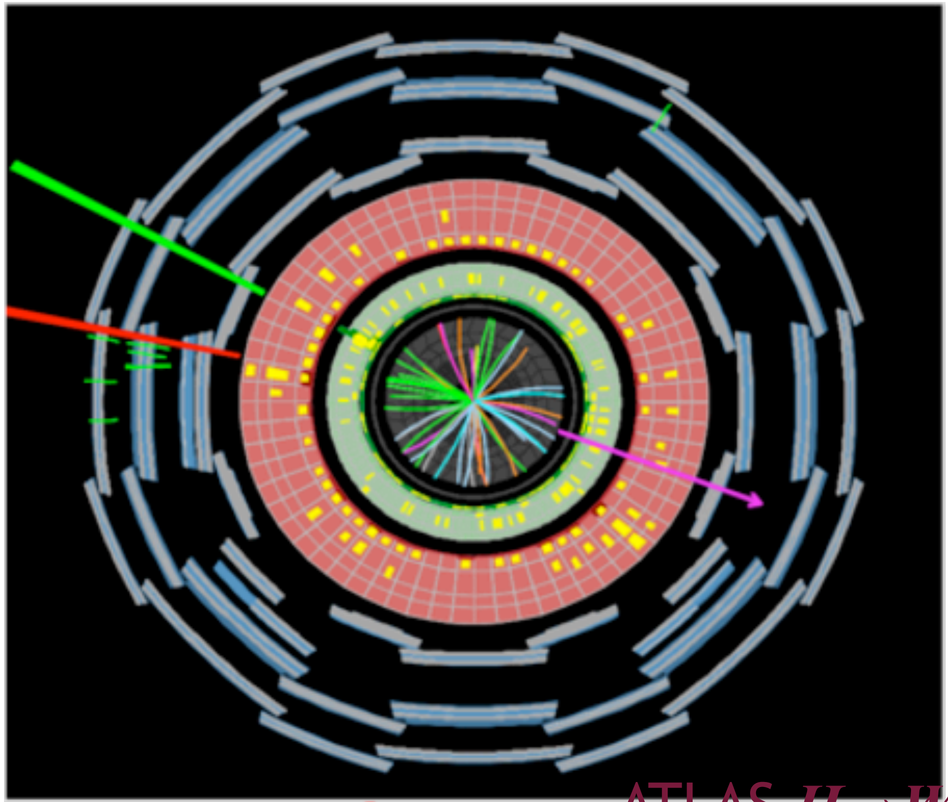
$H \to ZZ$ results

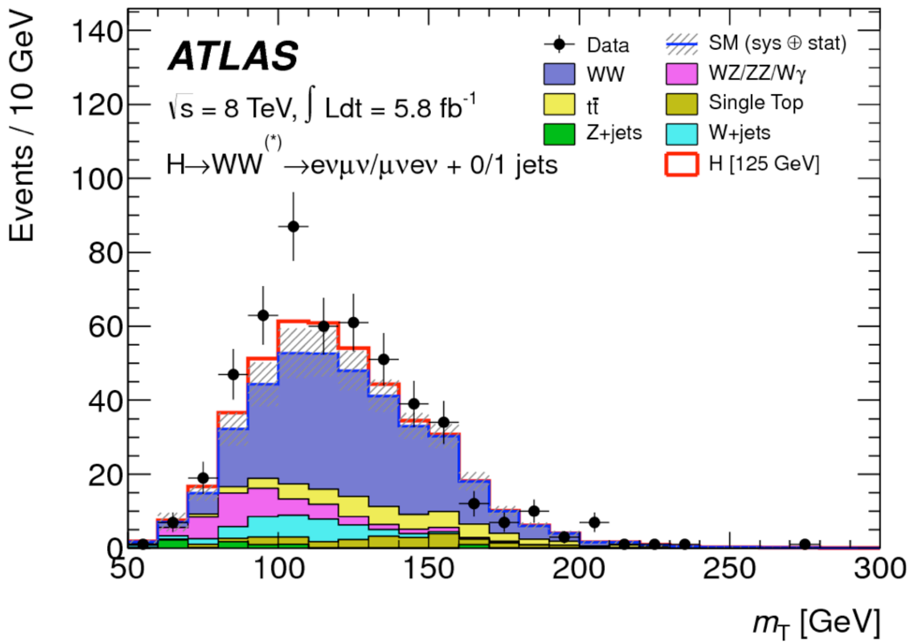


Compatible with a peak at $m_{\ell\ell\ell\ell} \sim 125$ GeV/c^2
in addition to background processes.

$H \rightarrow W^+W^-$

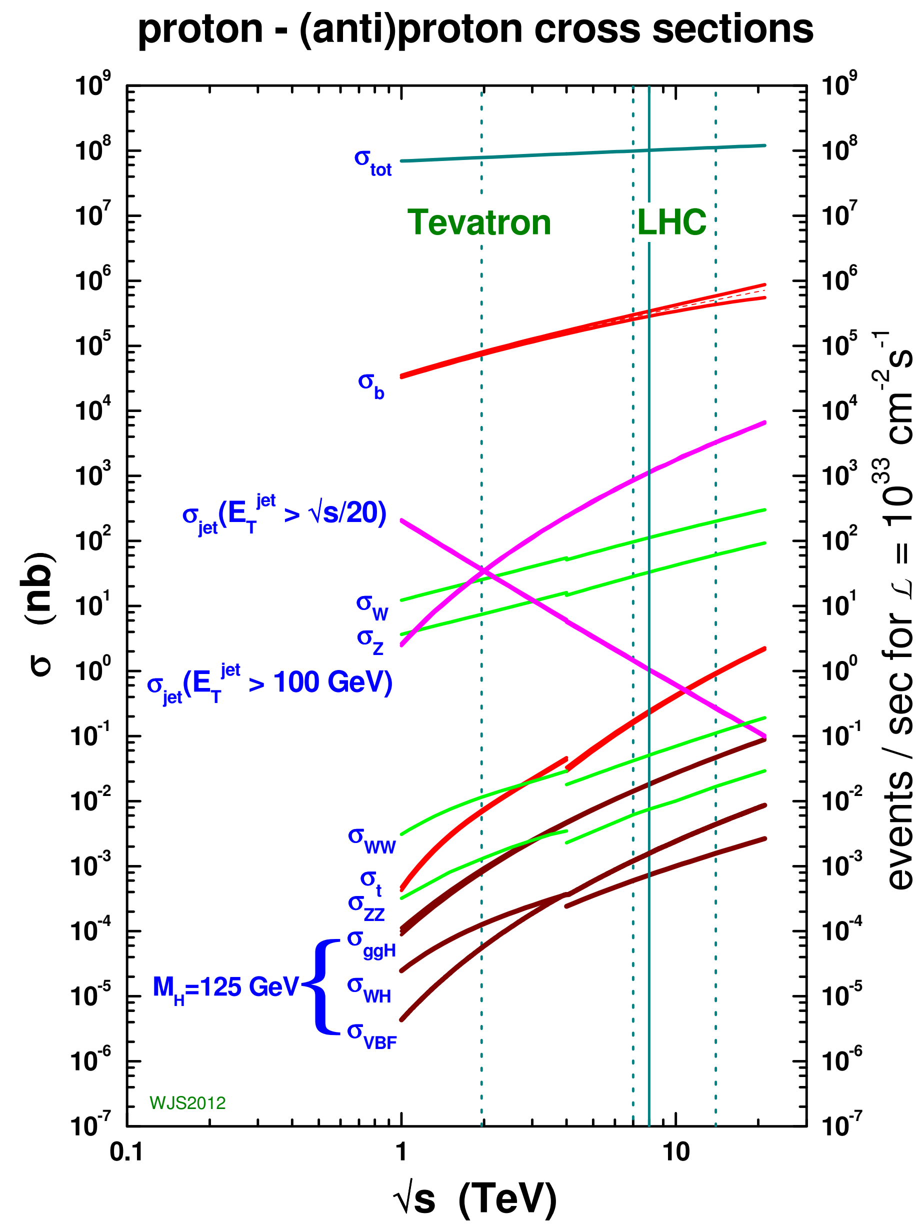
- W-bosons decay very quickly: easiest to look $W \rightarrow e\nu$, $W \rightarrow \mu\nu$
- Neutrinos (ν) don't appear in directly in ATLAS, but we can infer their presence.
- Data is compatible $m_H \sim 125$ GeV/c^2 Higgs boson being produced in addition to backgrounds.





ATLAS $H \rightarrow WW \rightarrow e\mu\nu\nu$ candidate event

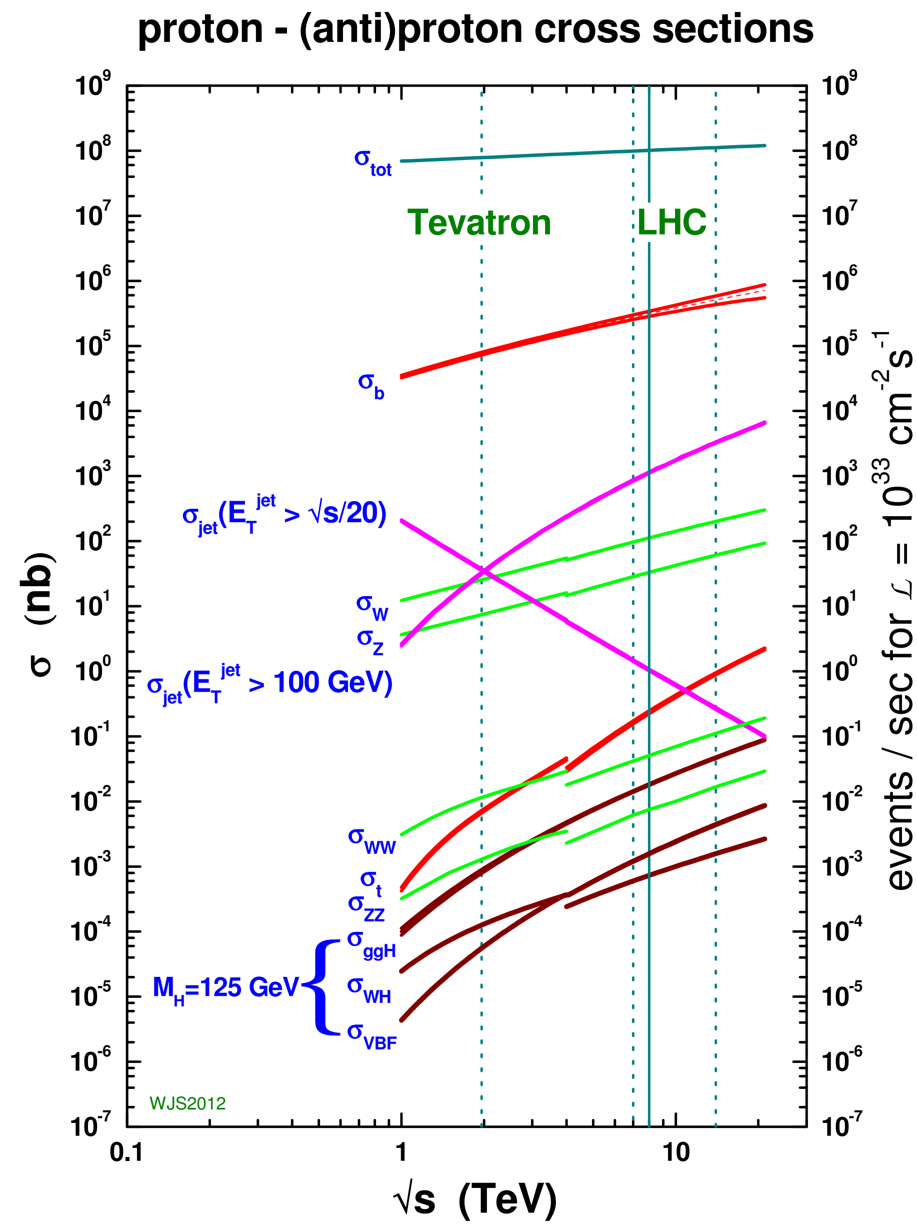
$H \to b\bar{b}$



proton - (anti)proton cross sections
σ (nb)
events / sec for ℒ = 10^33 cm^-2 s^-1
√s (TeV)
σtot
Tevatron
LHC
σb
σjet(ET jet > √s/20)
σW
σZ
σjet(ET jet > 100 GeV)
σWW
σt
σZZ
σggH
σWH
σVBF
MH=125 GeV
WJS2012

$H \rightarrow b\bar{b}$

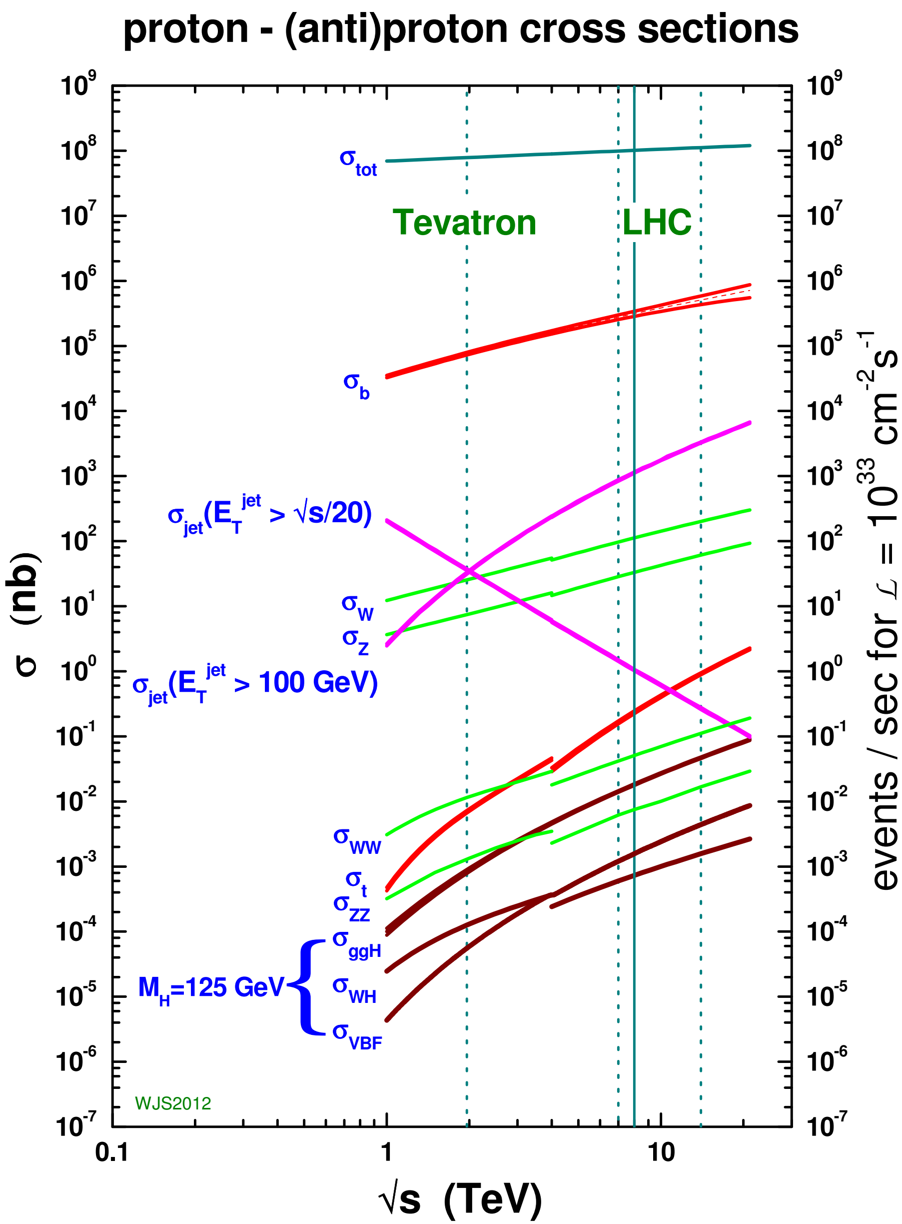
- Looking for pairs of b-quarks in the detector is very hard as b-quarks are ubiquitous.

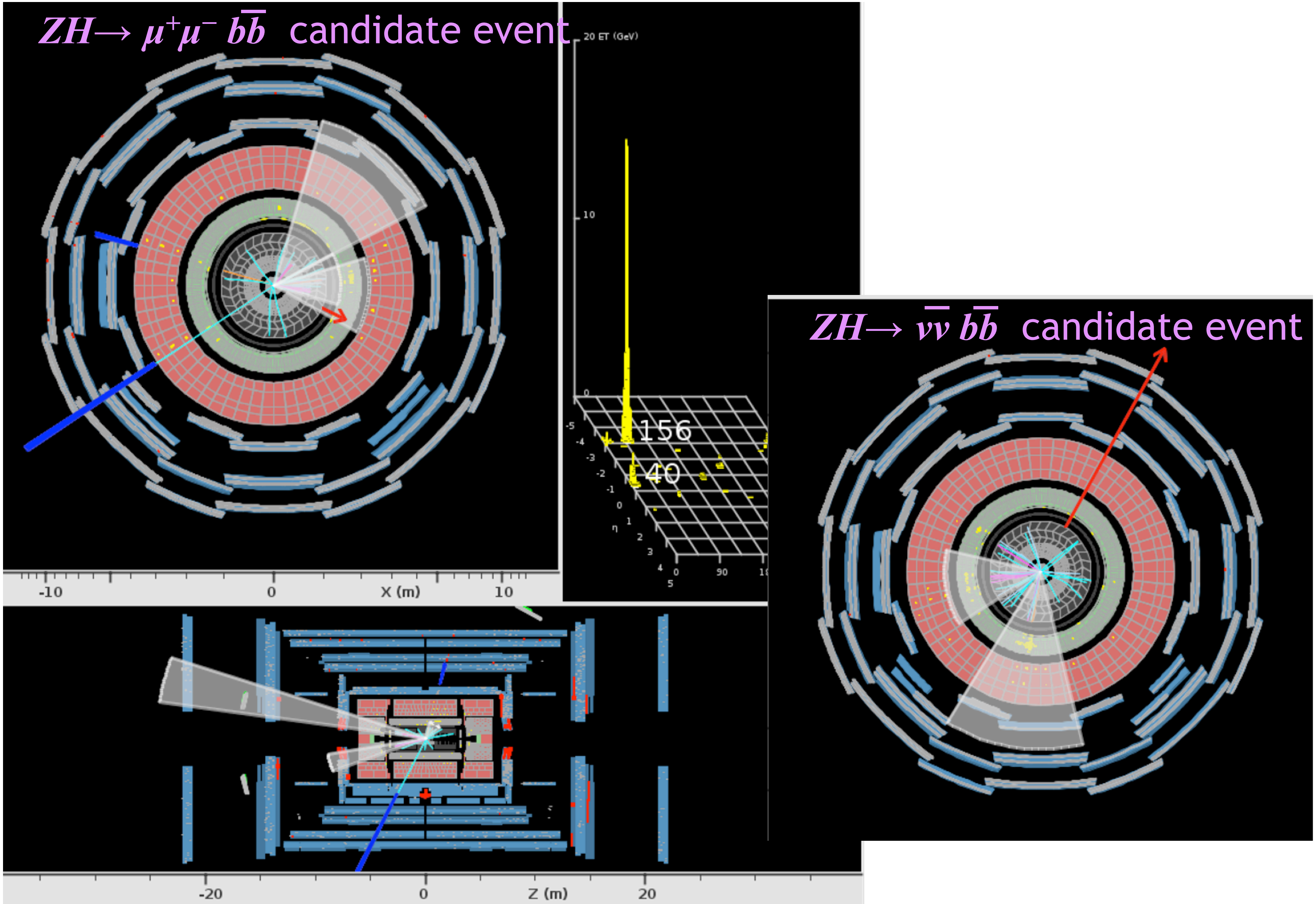


$H \rightarrow b\bar{b}$

- Looking for pairs of *b*-quarks in the detector is very hard as *b*-quarks are ubiquitous.

- Instead search for Higgs bosons produced along with a *W* or *Z* boson or top quarks:
  - $WH \rightarrow e\nu\, b\bar{b},\ \mu\nu\, b\bar{b}$
  - $ZH \rightarrow ee\, b\bar{b},\ \mu\mu\, b\bar{b},\ \nu\nu\, b\bar{b}$
  - $ttH \rightarrow t\,\bar{t}\,\, b\,\bar{b} \rightarrow e\,\nu\, q\bar{q}\, b\bar{b}$

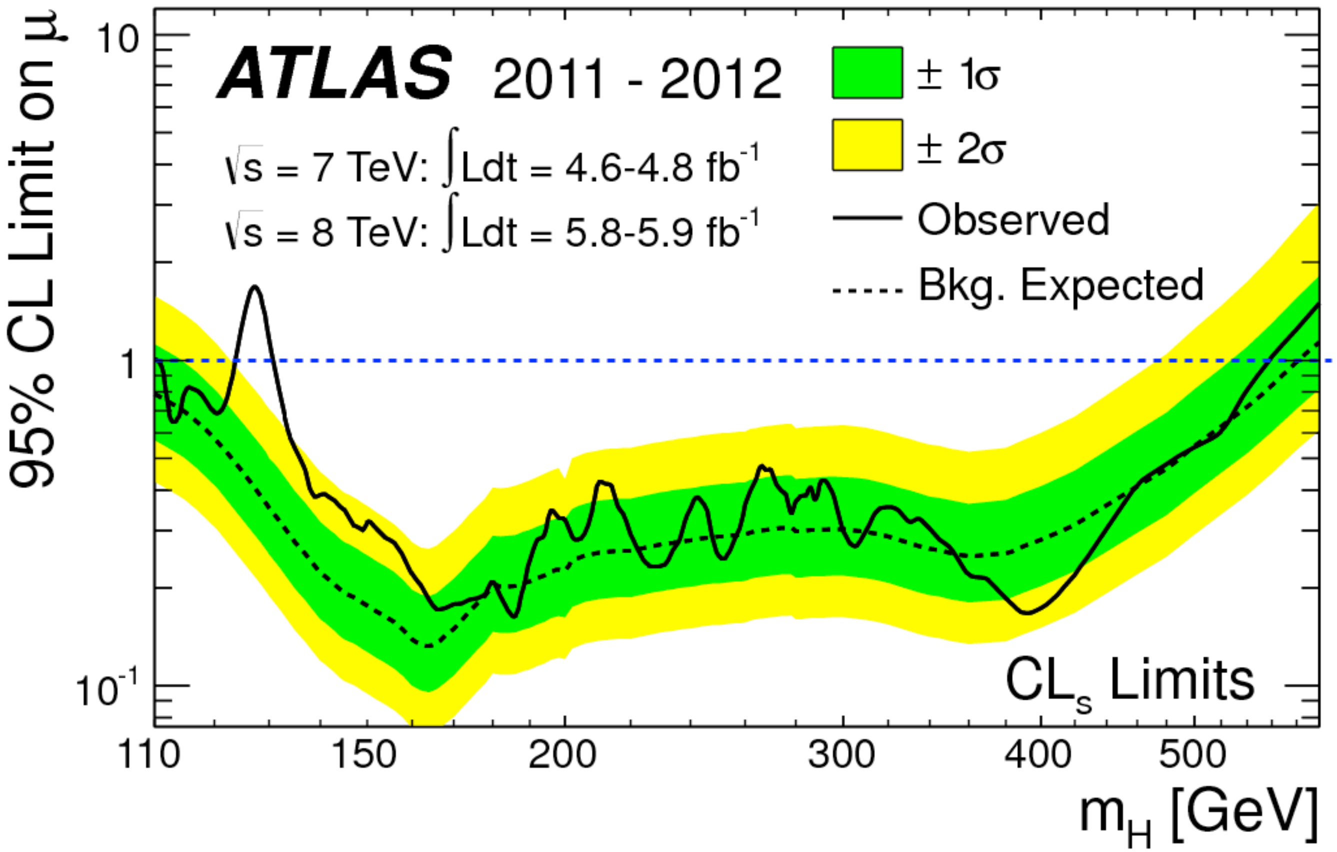




- No evidence for $H \to b\bar{b}$ in ATLAS, but we didn’t yet expect to see any.

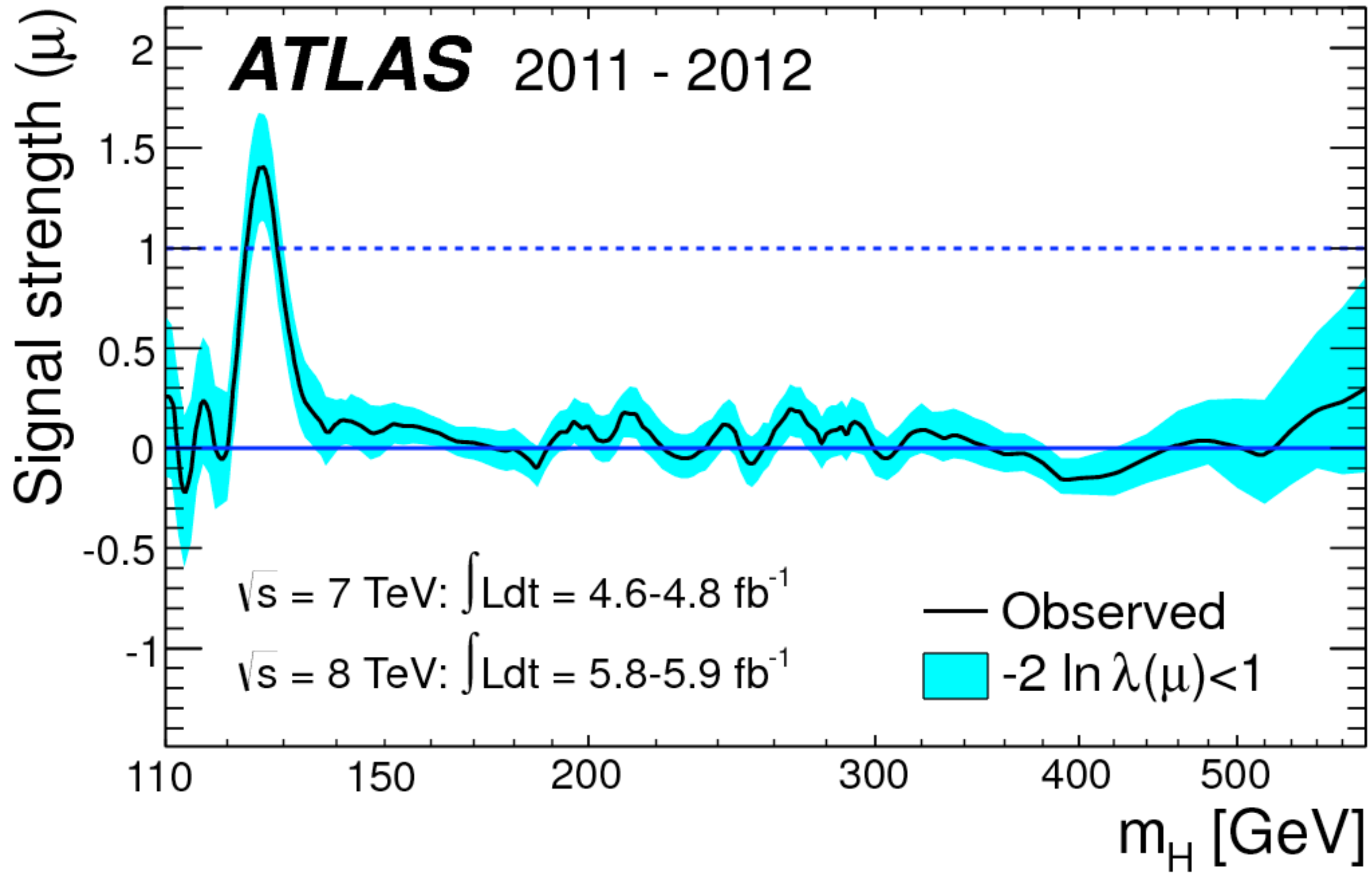
Combining the Searches

- Combining the analyses we've $H\to ZZ$, $H\to WW$, $H\to\gamma\gamma$ $H\to b\bar{b}$, $H\to\tau^+\tau^-$



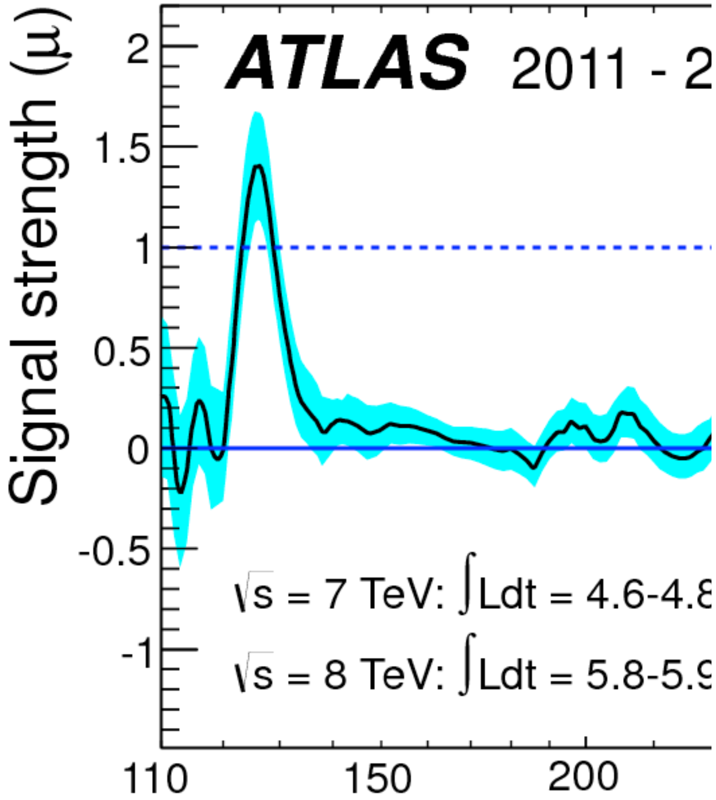
- This plot shows for what masses the Higgs boson can be excluded.
- ATLAS cannot exclude a Higgs between **122** and **131 GeV/c^2** at 95% confidence level.

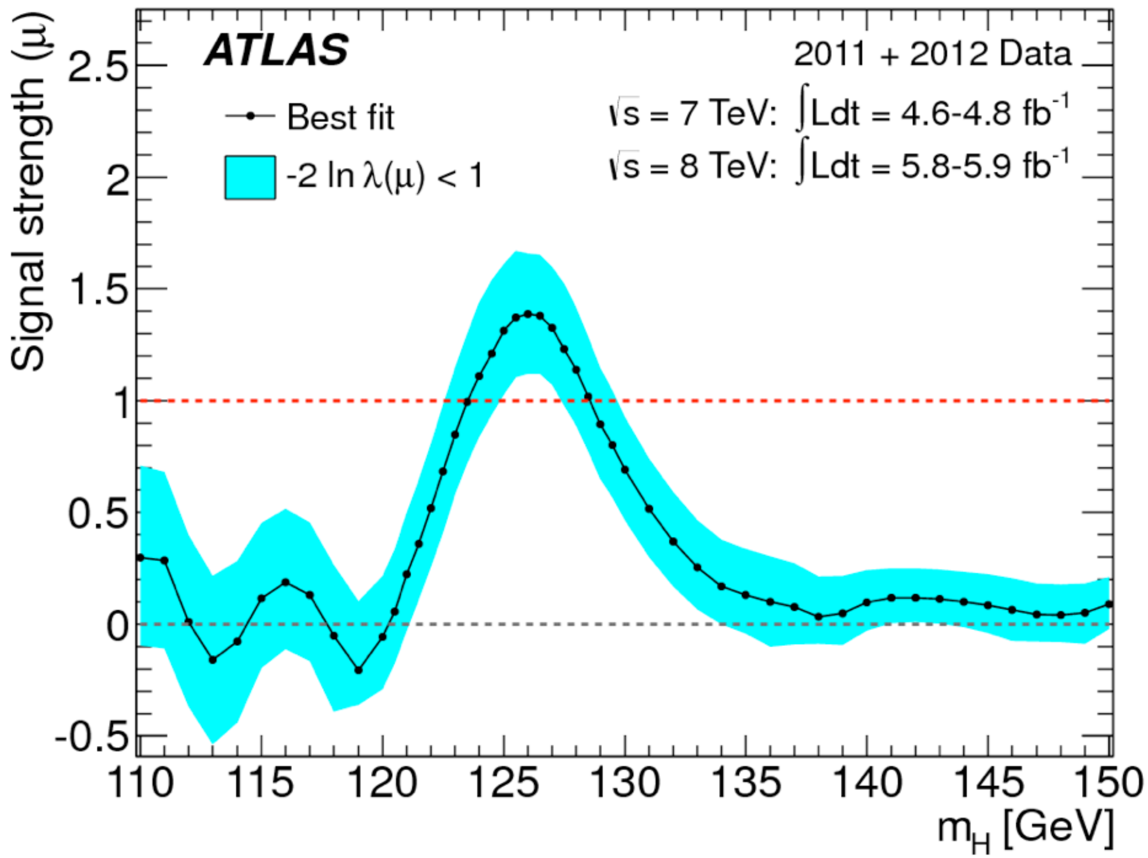
Combining the Searches



- μ compatible with $\mathbf{1}$ means the data is compatible with the hypotheses a Higgs boson is being created.
- Largest significance is at $m_H = \mathbf{126.5\ GeV}/c^2$

Combining the Searches





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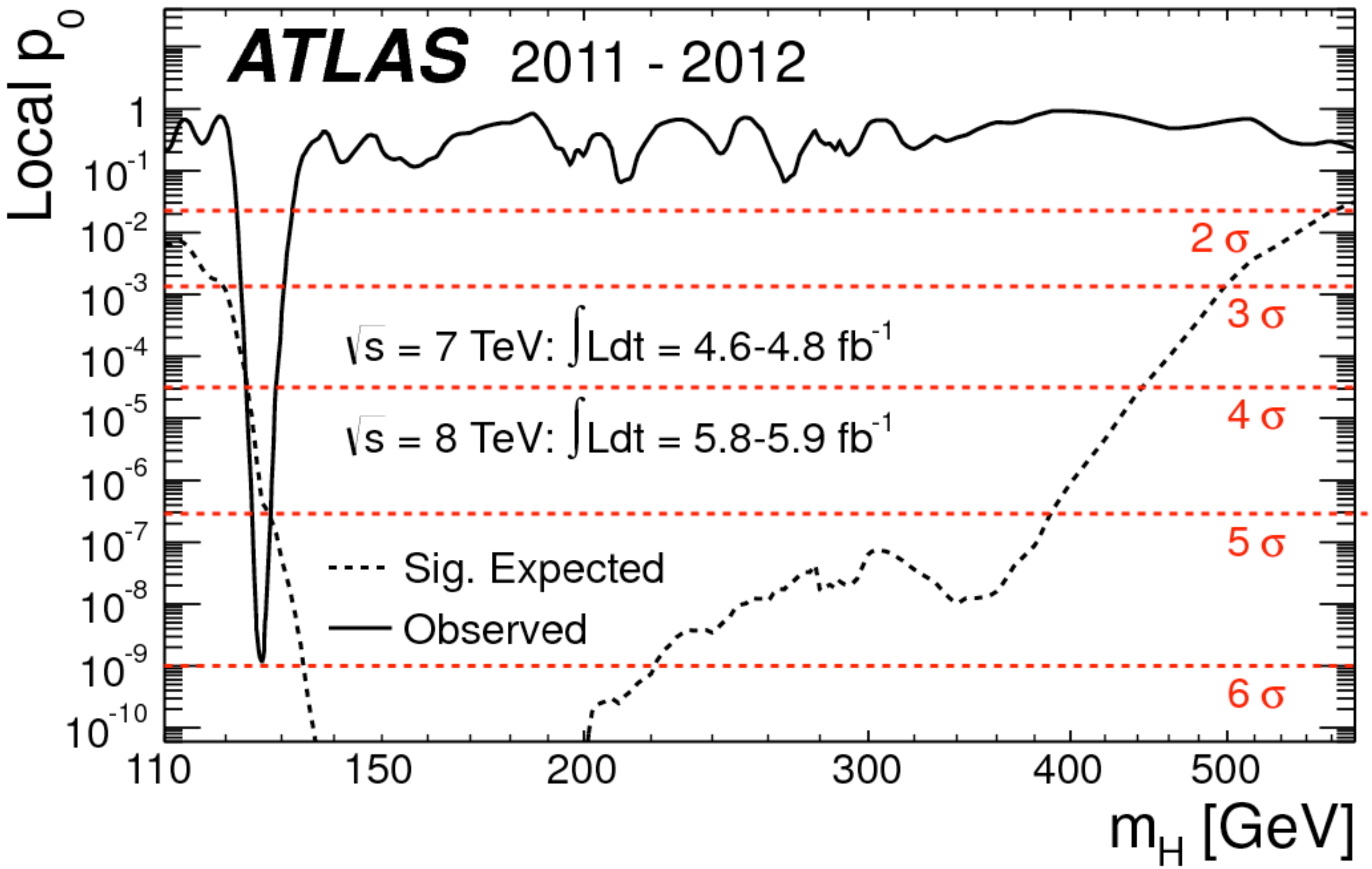


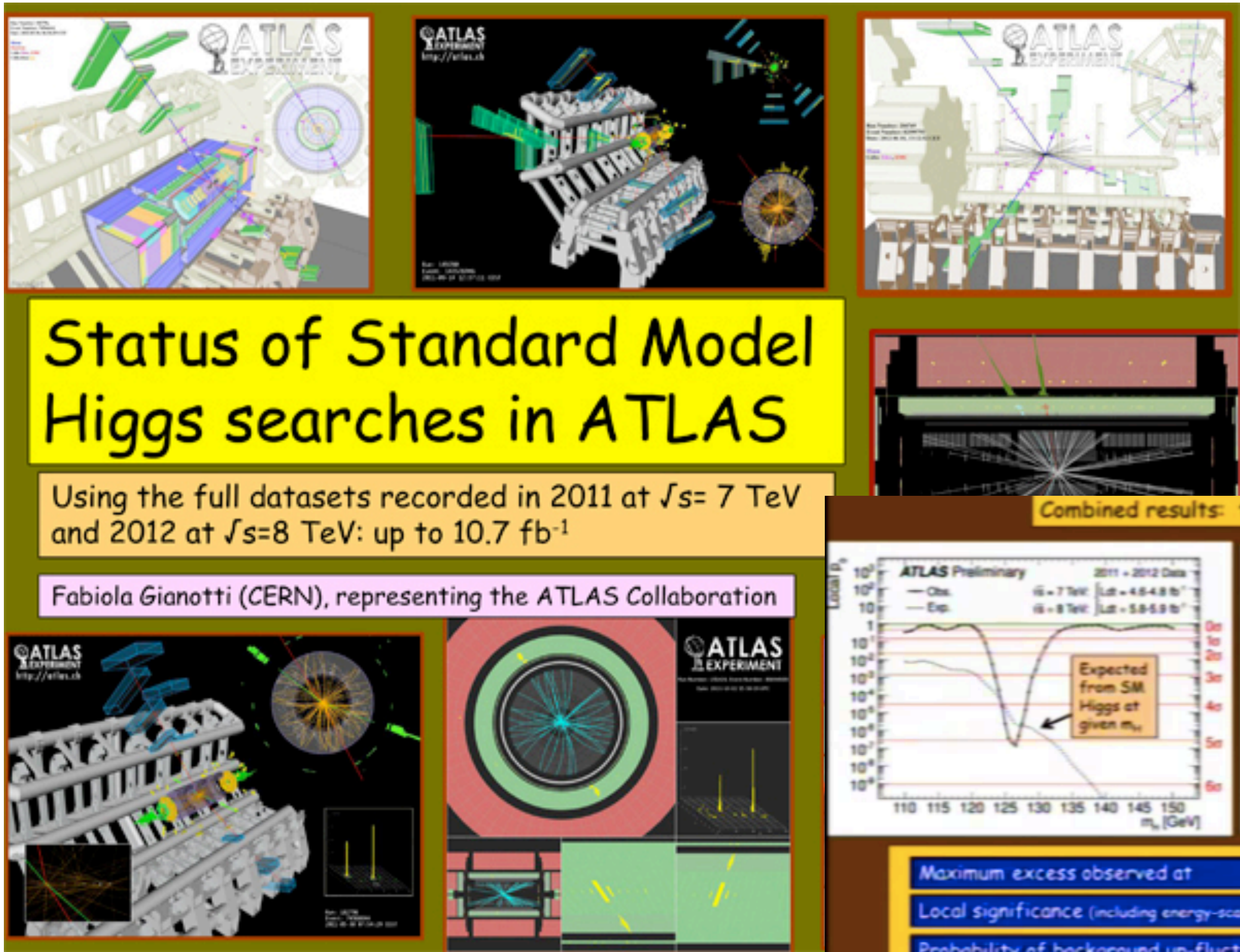
- The significance of the signal at **126.0 GeV/c^2** is 5.9 standard deviations!
- We have discovered something new!

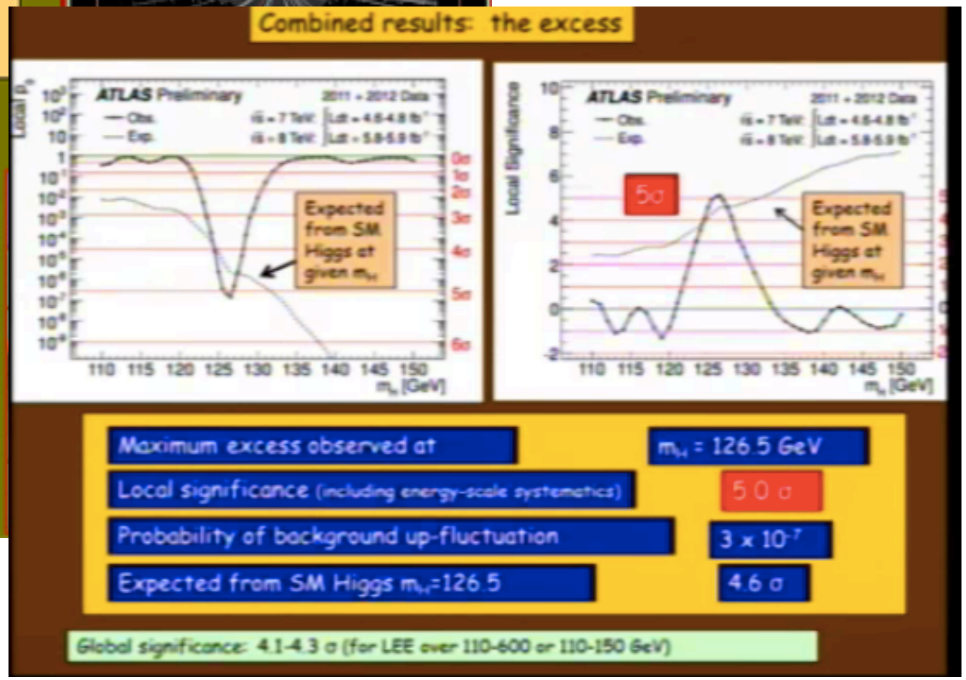
How we found out…

The 4th of July at CERN

The 4th of July at CERN

Fabiola's Talk





The 4th of July...

The 4th of July...

The 4th of July...

What happened next...

Higgsteria!


ELMUNDO.es
Descubren una nueva partícula que podría ser el bosón de Higgs
La policía identifica en Internet a cientos de pedófilos en 141 países
Competencia denuncia que la gasolina en España es de las más caras de la UE
María de Villota, operada por una fractura de cráneo


EL PAÍS
Hallada "la más sólida evidencia" de la existencia del bosón de Higgs


LAVANGUARDIA.com
Los científicos creen haber hallado la 'partícula de Dios'
Las farmacias avisan de que hay jubilados que no pueden pagar su medicina
¿Cuándo fluirá el crédito a las familias y empresas?
LA VANGUARDIA


Le Monde.fr
Le boson de Higgs découvert avec 99,9999 % de certitude


The New York Times
TRY A TIMES DIGITAL SUBSCRIPTION: 4 WEEKS FOR 99¢.
Rapid H.I.V. Home Test Wins Federal Approval
New Particle Could Be Physics' Holy Grail
As Bank Frames a Defense, Barclays' C.E.O. Resigns
INTRODUCING NEW YORK TIMES CORPORATE DIGITAL SUBSCRIPTIONS.
From insight comes inspiration.


rtve.es
Directo: Entrevista a Felipe González en 'Los Desayunos' de TVE
El CERN descubre una nueva partícula que podría ser el bosón de Higgs
RNE es la cadena de radio que más crece
Preguntas y respuestas
¿Qué es esta partícula?


theguardian
Diamond set to come out fighting as he faces MPs
The definite particle? Higgs boson discovered? Live coverage
Pakistan ends supply route dispute
Eurozone crisis: Troika talks begin


Tribune de Genève
Une nouvelle particule a été découverte
Genève au fil du temps
Cet été, bien informé rime avec mobilité

Me on the telly!

Some letters…

10 DOWNING STREET
LONDON SW1A 2AA

THE PRIME MINISTER

13 July 2012

Dear Professor Higgs,

I would like to take the opportunity of CERN's historic announcement last week to congratulate and thank you for all you have done for British physics.

Your research papers of 1964, despite their initial rejection as being 'of no obvious relevance to physics' have underpinned the theories of particle physicists for decades now and their recent validation was a great triumph for you and the other theorists, illustrating the real knowledge gains that can arise from the seemingly obscure puzzles and mental exercises that theoretical physics explores.

The work of the engineers, experimentalists, theorists and computer scientists, many of them British, that has made the Large Hadron Collider a successful research facility has captured the imagination of the public at all levels and ages. The lead taken by yourself and other UK researchers has inspired much of the nation and will stimulate more young people to pursue scientific enquiry and training, providing the skilled work force upon which a modern economy like ours depends for growth. I know just by looking at the number of hits my comments about the announcement have had on the No.10 website how much this has captured the public imagination and interest.

Your research will form part of the UK's rich heritage in scientific advances and on behalf of the nation, I wanted to express my sincere thanks.

Yours sincerely,

David Cameron

Professor Peter W Higgs

Ministear airson Ionnsachadh, Saidheans agus Cànain na h-Alba
Meinister for Lear, Science an Scotland's Leids
Minister for Learning, Science and Scotland's Languages
Alasdair Allan BPA/MSP

F/T: 0845 774 1741
E: scottish.ministers@scotland.gsi.gov.uk

The Scottish Government
Riaghaltas na h-Alba

Professor Peter Higgs, FInstP, FRSE, FRS

DELIVERING
A GAMES LEGACY FOR SCOTLAND

4 July 2012

Dear Professor Higgs

I was delighted to see the exciting announcement from CERN on the observation of a new particle consistent with Higgs boson. I can only imagine what you must be feeling.

I know these results are preliminary and are part of a huge and inspiring international collaborative effort, but I would like to offer my congratulations to both you personally, for inspiring the search, and the teams in Glasgow and Edinburgh involved in ATLAS, for helping to make this discovery happen.

I look forward to hearing more as the analysis continues.

Alasdair Allan

ALASDAIR ALLAN

Cidhe Bhictòria, Dùn Èideann, EH6 6QQ
Victoria Quay, Edinburgh EH6 6QQ
www.scotland.gov.uk

LEADER OF THE OPPOSITION

HOUSE OF COMMONS
LONDON SW1A 0AA

Mr Peter Higgs
c/o The University of Edinburgh
Old College
South Bridge
Edinburgh
EH8 9YL

28 August 2012

Dear Peter,

I wanted to offer my congratulations for the tremendous contribution you have made to the development of particle physics and to our understanding of the world in which we live.

It does not fall to many people in history to predict the theoretical existence of a sub-atomic particle which is then confirmed, mere decades later. The Higgs Boson will take its rightful place in the history of science.

Your work in the 1960s helped to inspire the very concept of the Large Hadron Collider which in turn has been an inspiring example of international scientific collaboration in which UK science has played a very prominent part.

The recent announcement by CERN (following the results of the ATLAS and CMS experiments) represents both the culmination of one scientific endeavour and the start of a new era in our continuous quest to understand our Universe.

Science is international but this country can be truly proud of the role you personally have played. Thank you and congratulations again.

Best wishes,

Ed Miliband

Rt Hon Ed Miliband MP

Received 5/9/12

Some emails...

Dear Sirs,

We are a craft beer micro company (Ca l'Arenys- GUINEU BEER), and we would like to make a Brewing Special Edition (10hl) as an Homage to Mr. Higgs

First of all we would like to know if there is any concern about it.

The idea is absolutely NON lucrative

-We would like to know, if possible, if Mr. Higgs likes beer and what styles does he prefer in order to adapt our receipt.

Best Regards

Xavier Serra

info@calarenys.com

Ca l'Arenys brewing Manager

Valls de Torruella (Barcelona)

Spain

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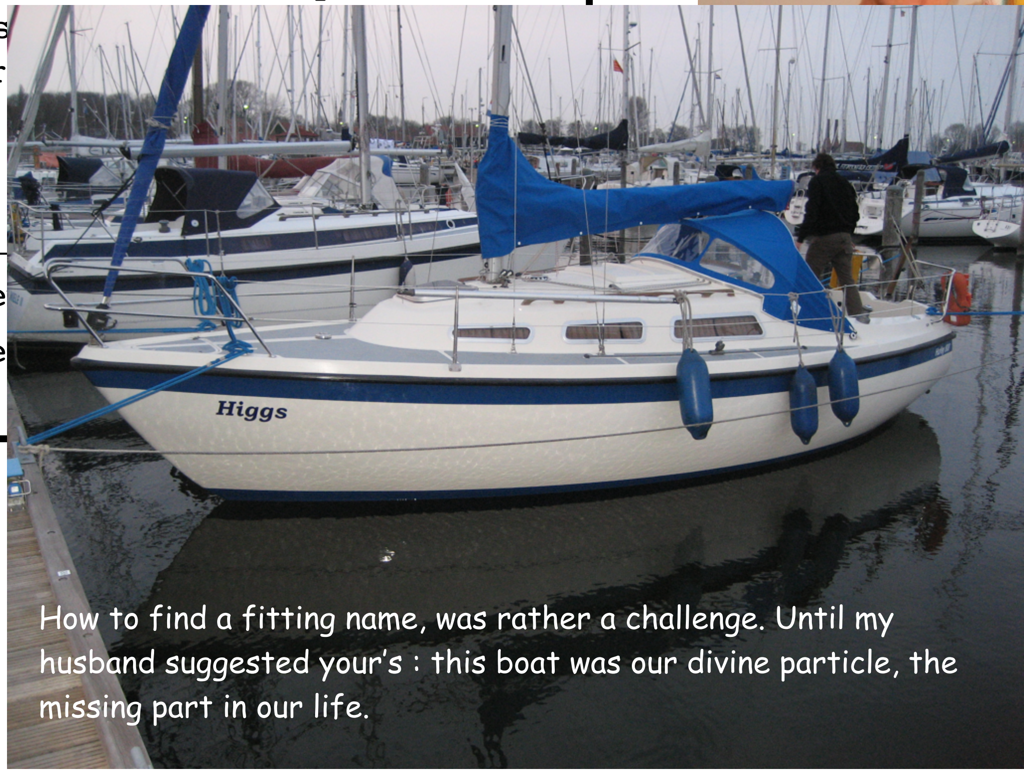
Xavier Serra

info@calarenys.

Ca l'Arenys bre

Valls de Torrue

Spain



ATLAS Collaborators celebrate at CERN

Published!

Observation of a New Particle in the Search for the Standard Model Higgs Boson with the ATLAS Detector at the LHC *Phys. Lett. B 716 (2012) 1-29*

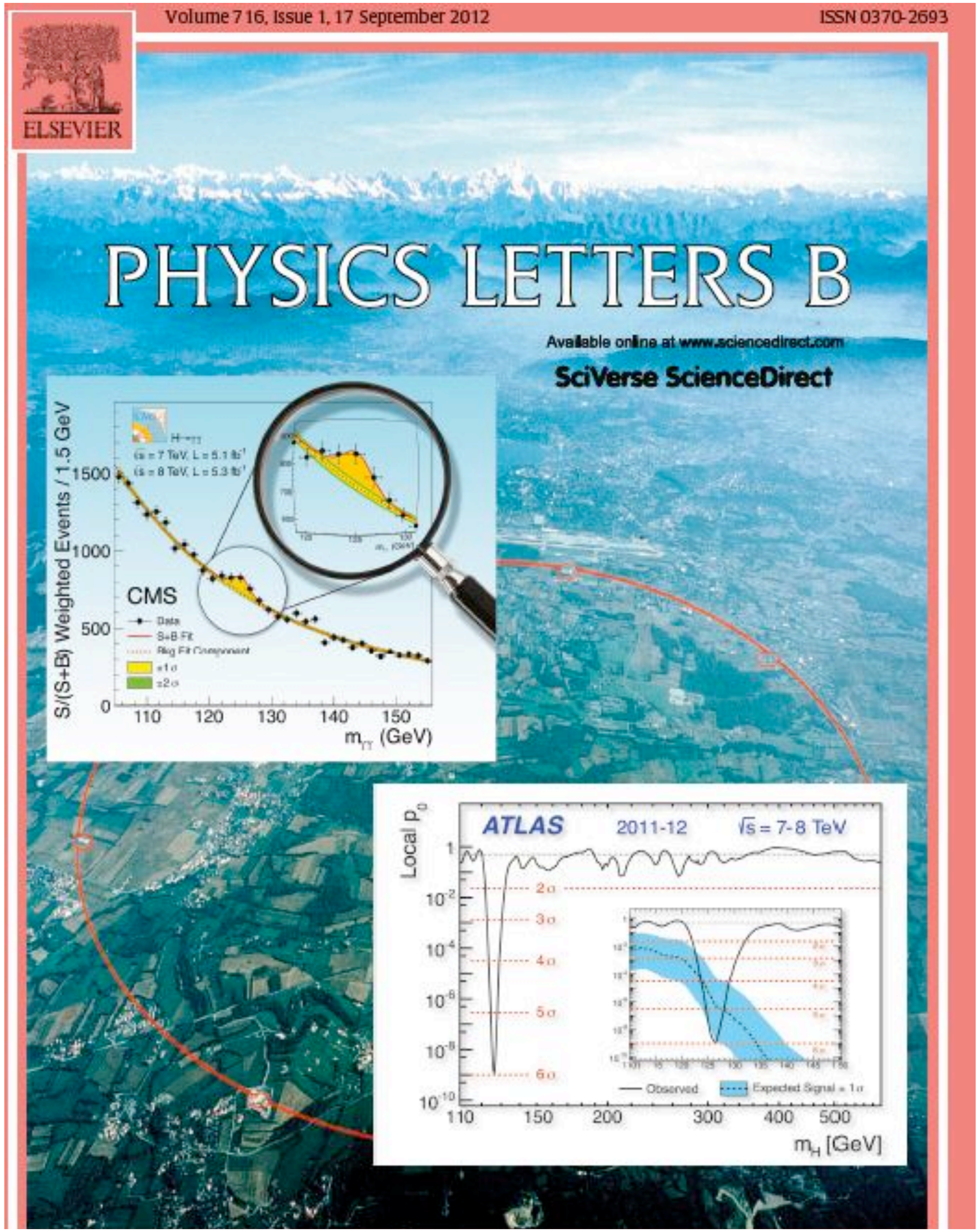
15 pages plus 14 page author list!

"Clear evidence for the production of a neutral boson with a measured mass of **126.0 ± 0.4(stat) ± 0.4(sys) GeV** is presented."

Observation of a new boson at a mass of 125 GeV with the CMS experiment at the LHC *Phys. Lett. B 716 (2012) 30–61*

15 pages plus 16 page author list!

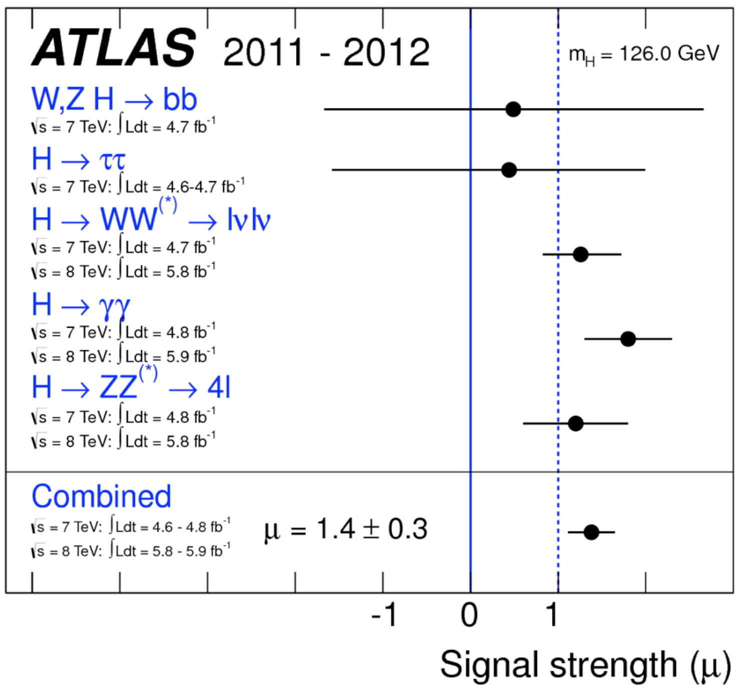
"An excess of events is observed [...] signalling the production of a new particle. [... with] a mass of **125.3 ± 0.4 (stat.) ± 0.5 (syst.) GeV**."

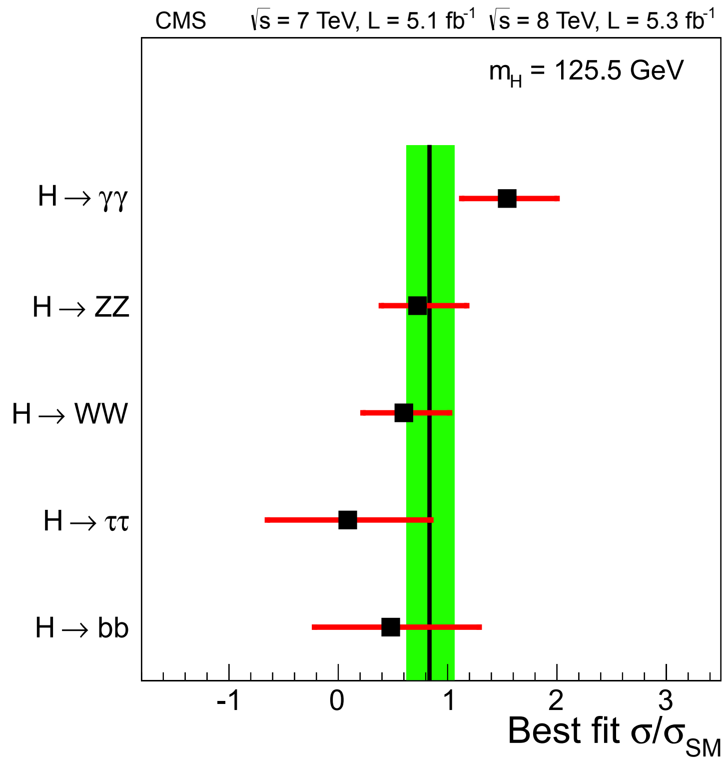


So is it the Higgs boson!?

Combining the Searches

- Recall, the Higgs boson is predicted to decay differently depending on m_H.
- Do our observations agree with the predictions? Look for μ or σ/σ_{SM} compatible with 1





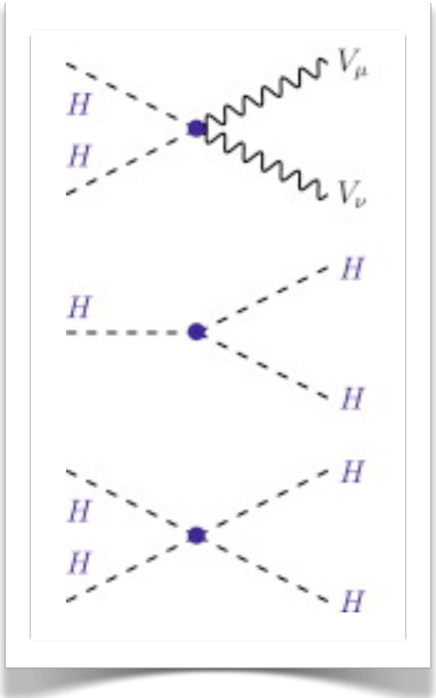
- So far, so good...

But is it the Higgs boson!?

- We don't know.
- So far, it certainly looks like the Higgs boson.

- e.g. for $m_H = 125\ \mathrm{GeV}/c^2$
  - pairs of b-quarks: $H \rightarrow b\bar{b}$ 57.7%
  - pairs of Z-bosons: $H \rightarrow ZZ$ 2.6%
  - pairs of photons: $H \rightarrow \gamma\gamma$ 0.2%

- The predictions for how the Higgs boson is produced and decays and interacts are very detailed.
- ATLAS and CMS need to take lots more data and analyse it carefully.
- Look for very rare decays, look for self-interactions of the Higgs.



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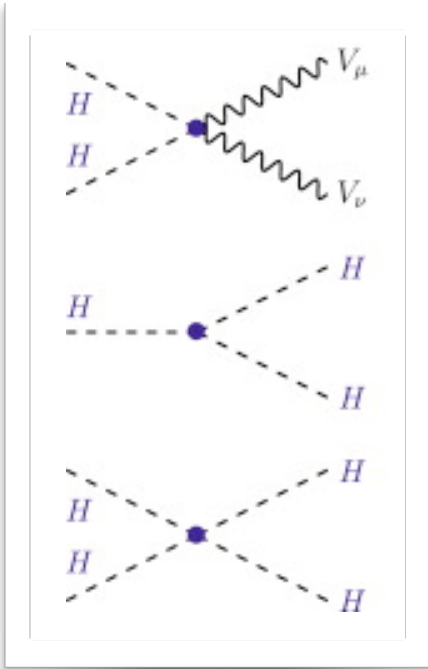

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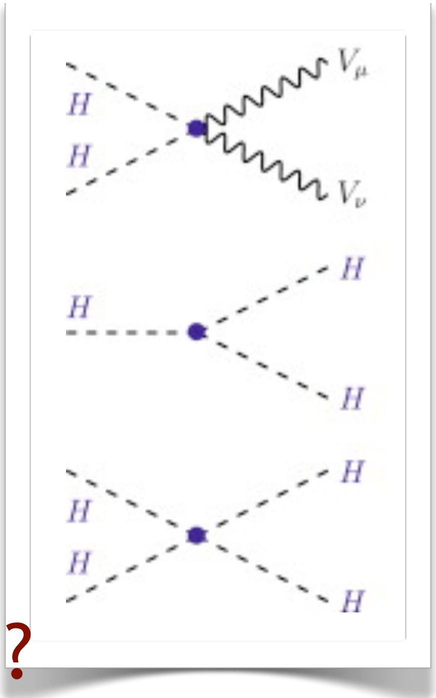

Do these happen?

What else could it be?

- It could be one of many Higgs bosons.
  - Some theories include e.g. **supersymmetry** include more Higgs bosons: h^0, H^0, A^0, H^+, H^-
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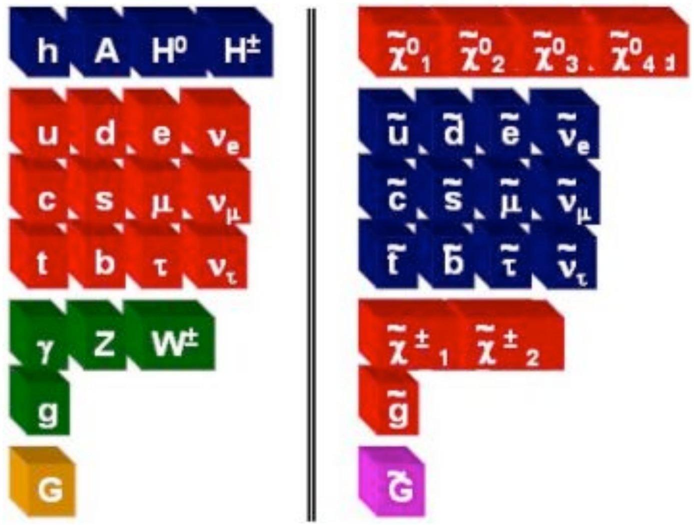

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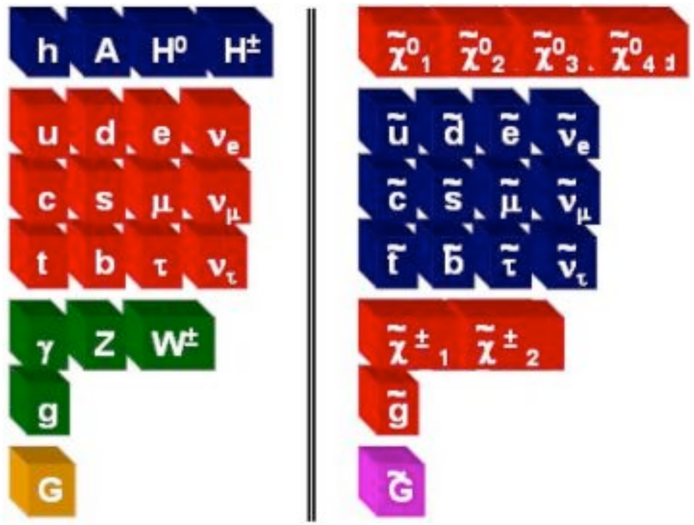

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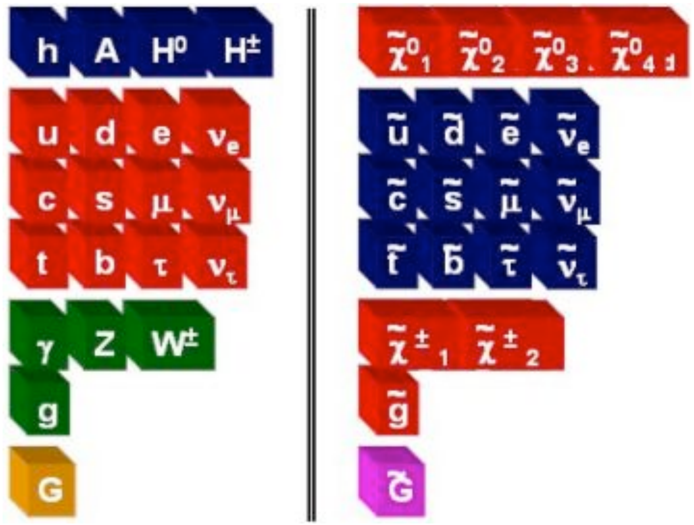

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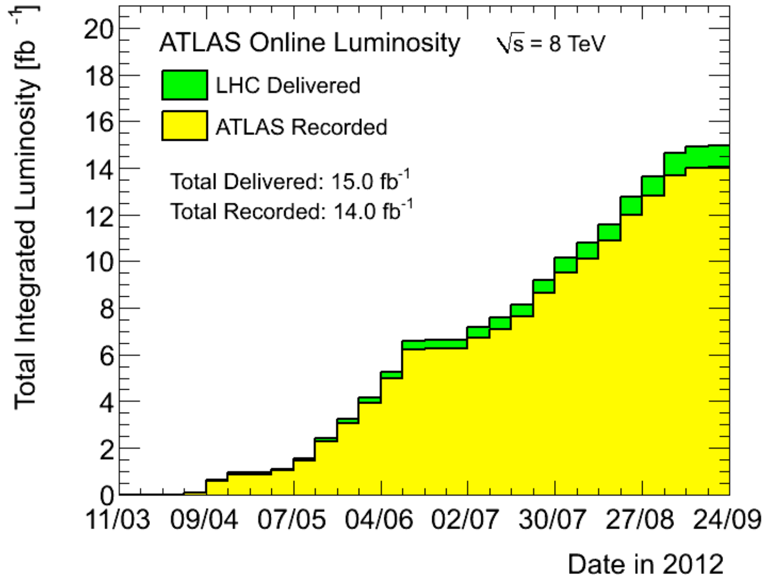
technicolor

- ATLAS and CMS can (and have) look(ed) for new particles associated with Supersymmetry and Technicolor

The Future

- The LHC is currently running at 8 TeV. More data on tape is already being analysed.



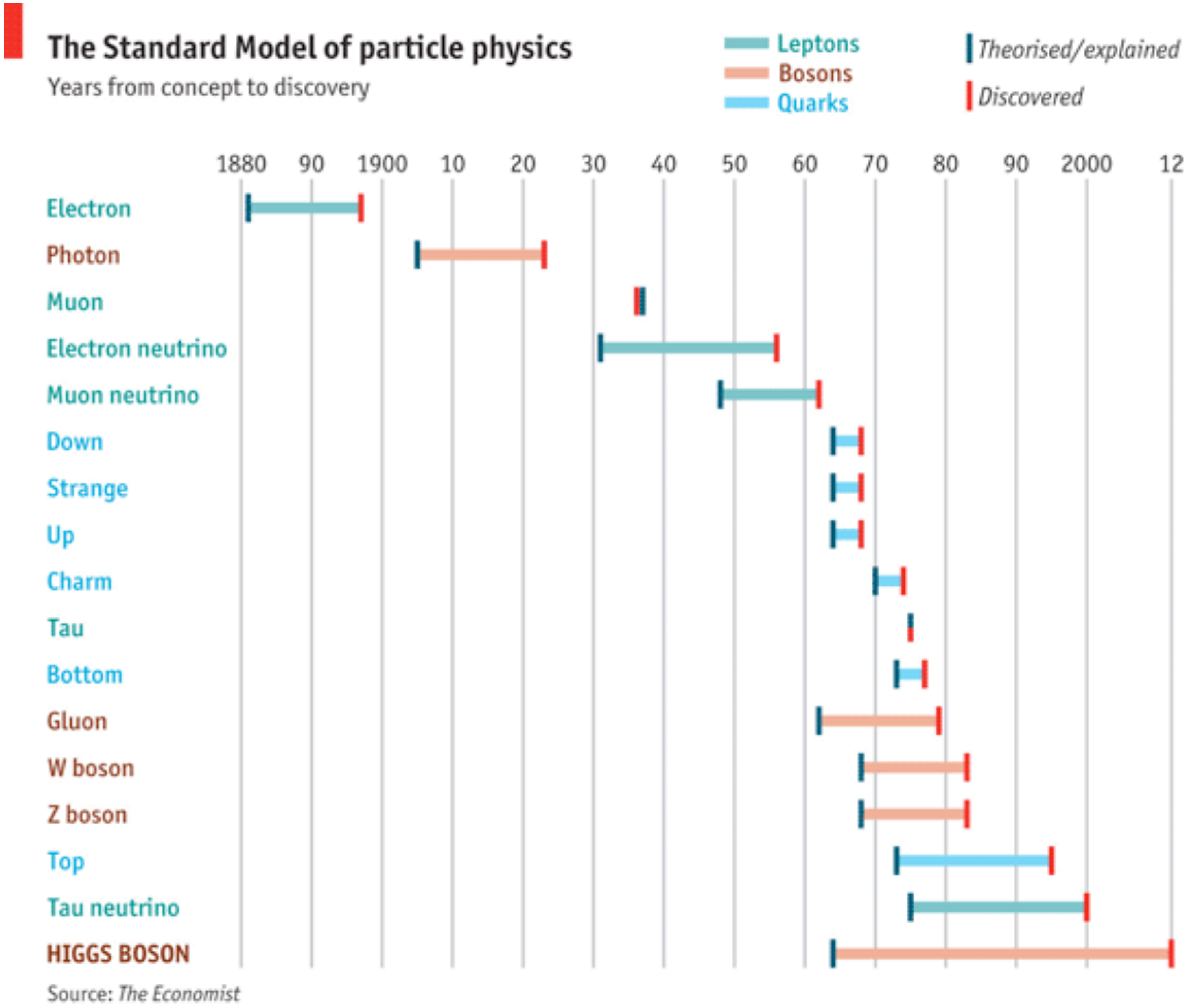
- In spring 2013 the LHC will shutdown for 18 month to upgrade accelerator

- 2015-2019 running at 13 or 14 TeV

- Post 2020, plans to keep running with higher intensity protons beams

- The ATLAS and CMS detectors will need to upgraded to fully exploit this extra data

- Lots more Higgs bosons physics, and maybe some further discoveries, to come from the LHC!



Economist,
http://www.economist.com/blogs/graphicdetail/2012/07/daily-chart-1

Conclusions

- The Higgs mechanism is required to explain why the W and Z bosons that transmit the weak force are massive.
- The Higgs mechanism predicts a new particle with an unknown mass: the Higgs boson, the missing particle in the Standard Model of particle physics.
- The ATLAS and CMS collaborations at CERN have discovered a new particle, compatible with the Higgs boson, with a mass of $m_H \sim 125$ GeV/c^2.
- We still don't know if it is ***the*** Higgs boson… lots more protons need to be collided, data collected and analysed.