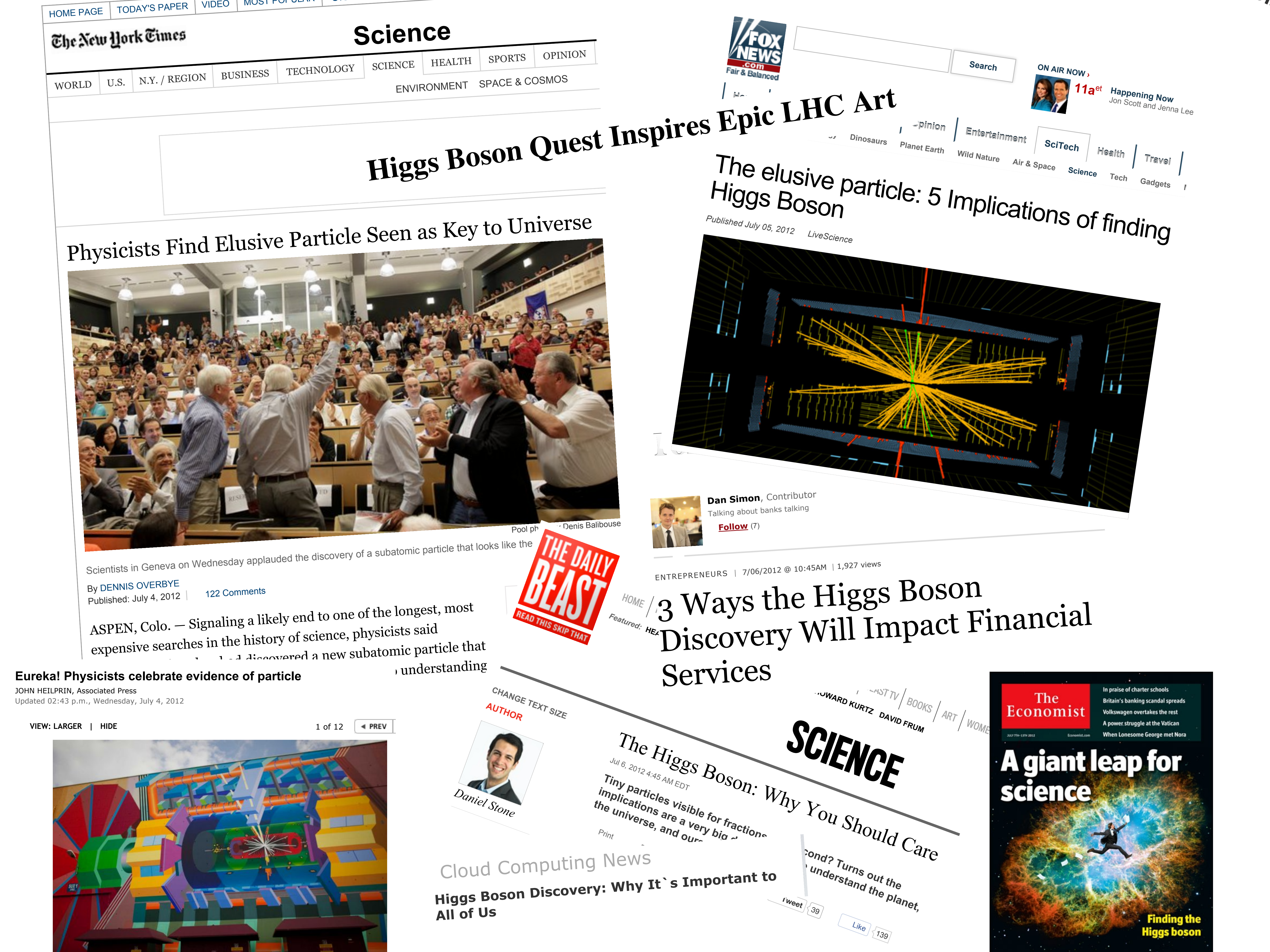

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Denis Balibouse
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By DENNIS OVERBYE
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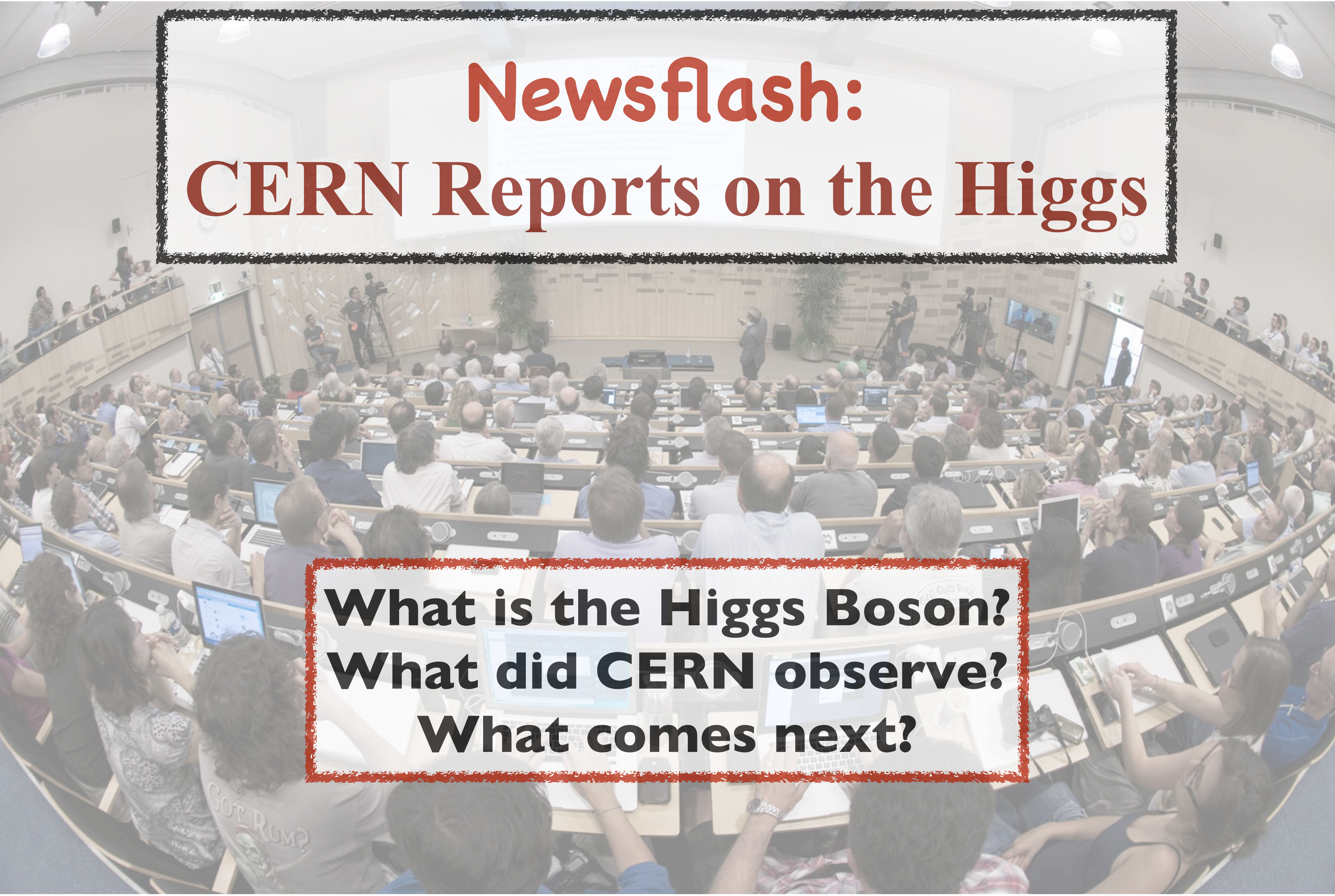
Finding the Higgs boson

Newsflash:
CERN Reports on the Higgs



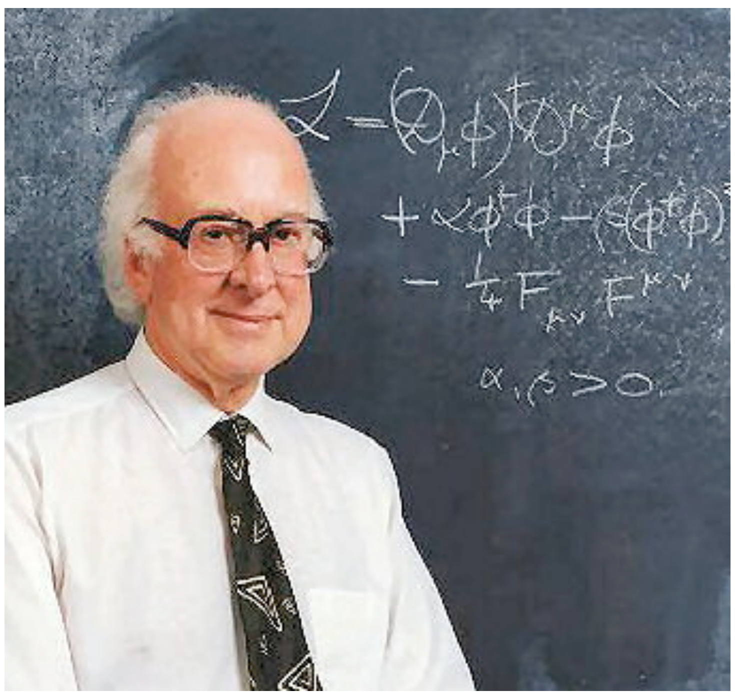
What is the Higgs Boson?
What did CERN observe?
What comes next?

July 6, 2012

Elizabeth H. Simmons
Michigan State University

50 ASPEN CENTER FOR PHYSICS

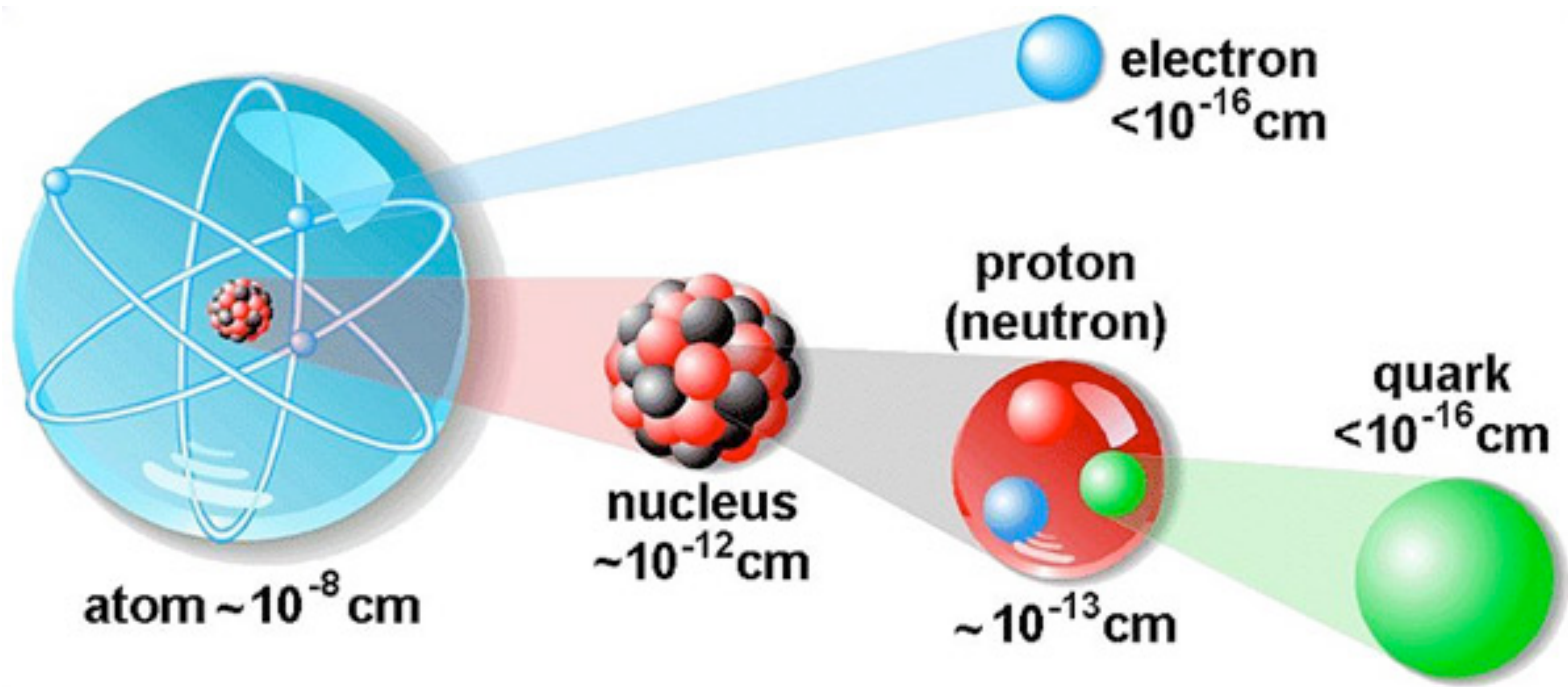
What is the Higgs Boson?



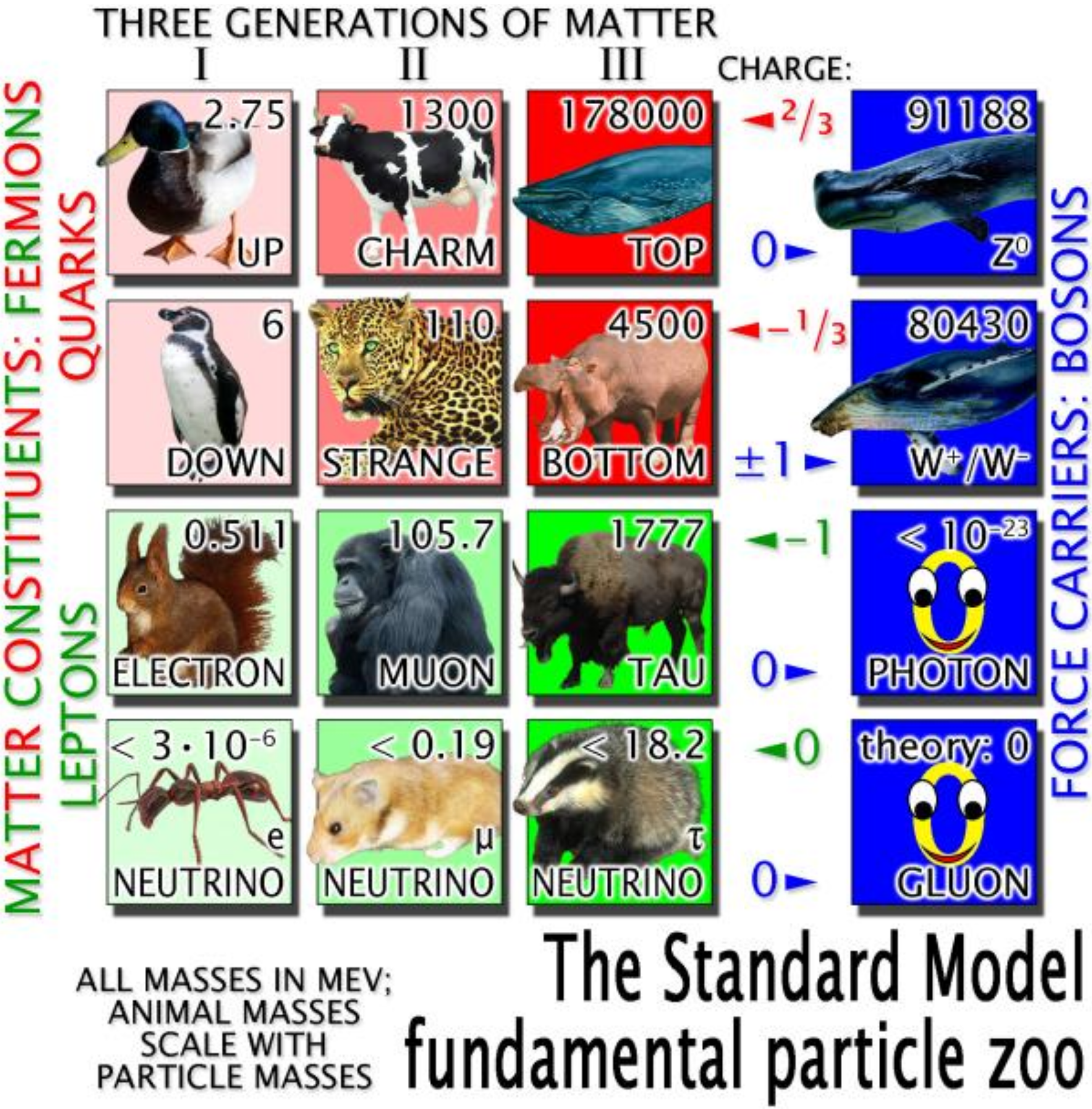
Peter Higgs

T. W. B. Kibble, Gerald S. Guralnik, Carl R. Hagen,
François Englert, and Robert Brout.

Subatomic Structure



ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich



e4.physik.uni-dortmund.de/bin/view/ATLAS/Bildergalerie

MYSTERIES

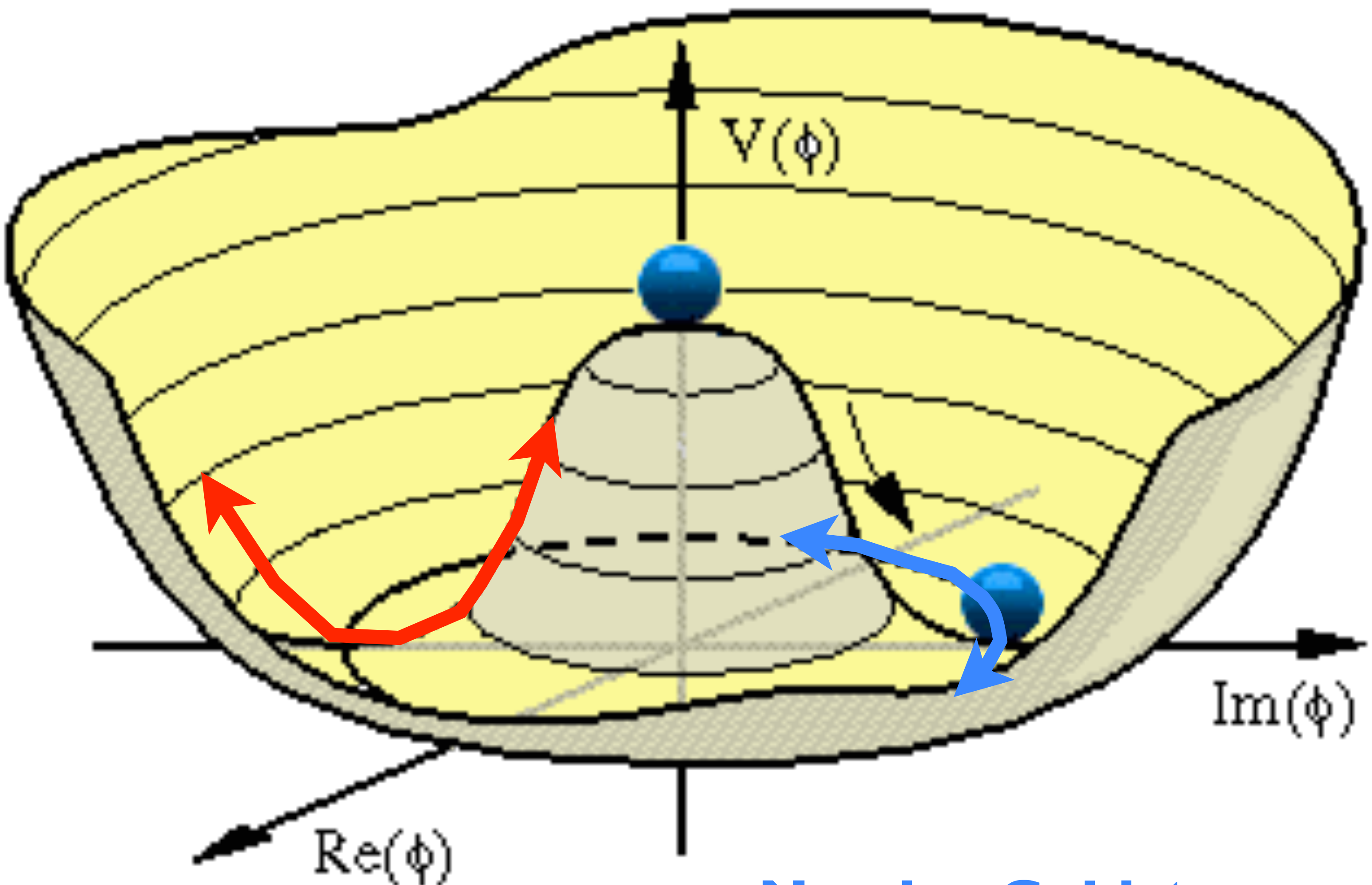
Flavor:

Why do similar fermions have different masses?

Electroweak:

Why are the W & Z bosons heavy while the photon is massless?

Higgs Field and Higgs Boson



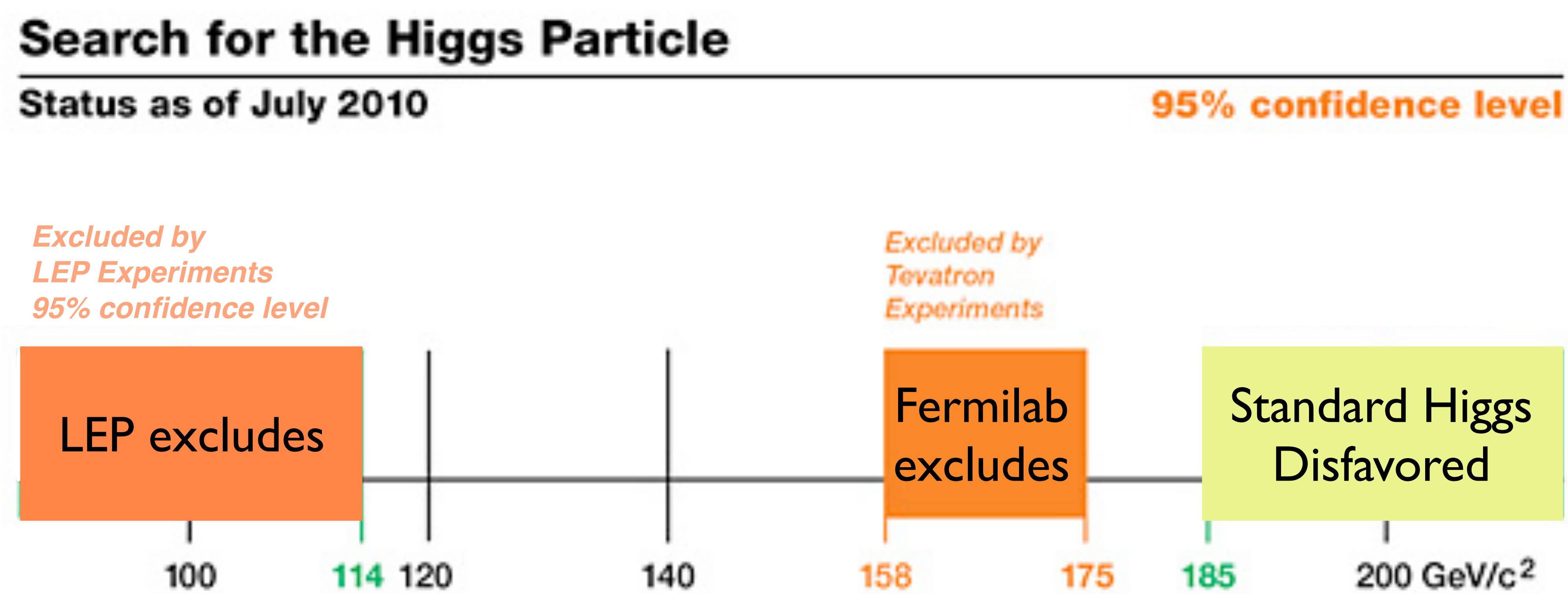
Nambu-Goldstone modes

A variety of masses:

The Higgs field would form a uniform background within the universe. Each particle would interact with the Higgs boson to a different degree.

The more strongly a particle interacted with the Higgs, the more mass it would gain and the more inertia it would display

Fermilab press room



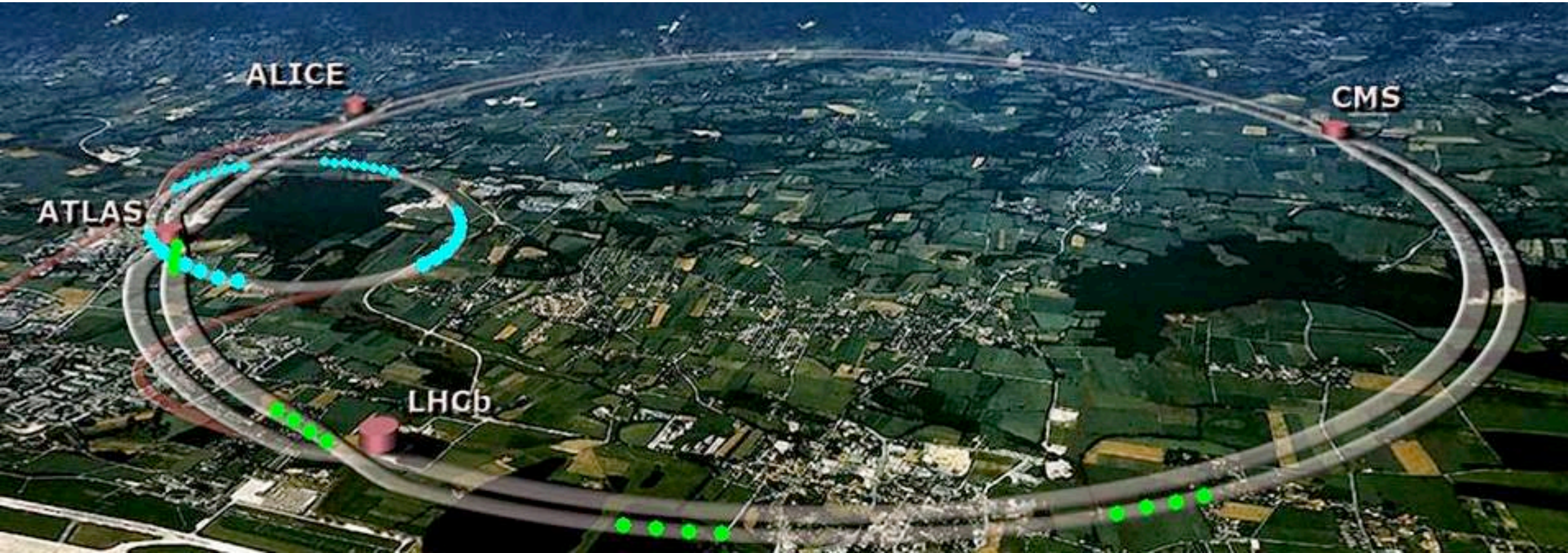
Higgs mass (GeV)

What did CERN observe?

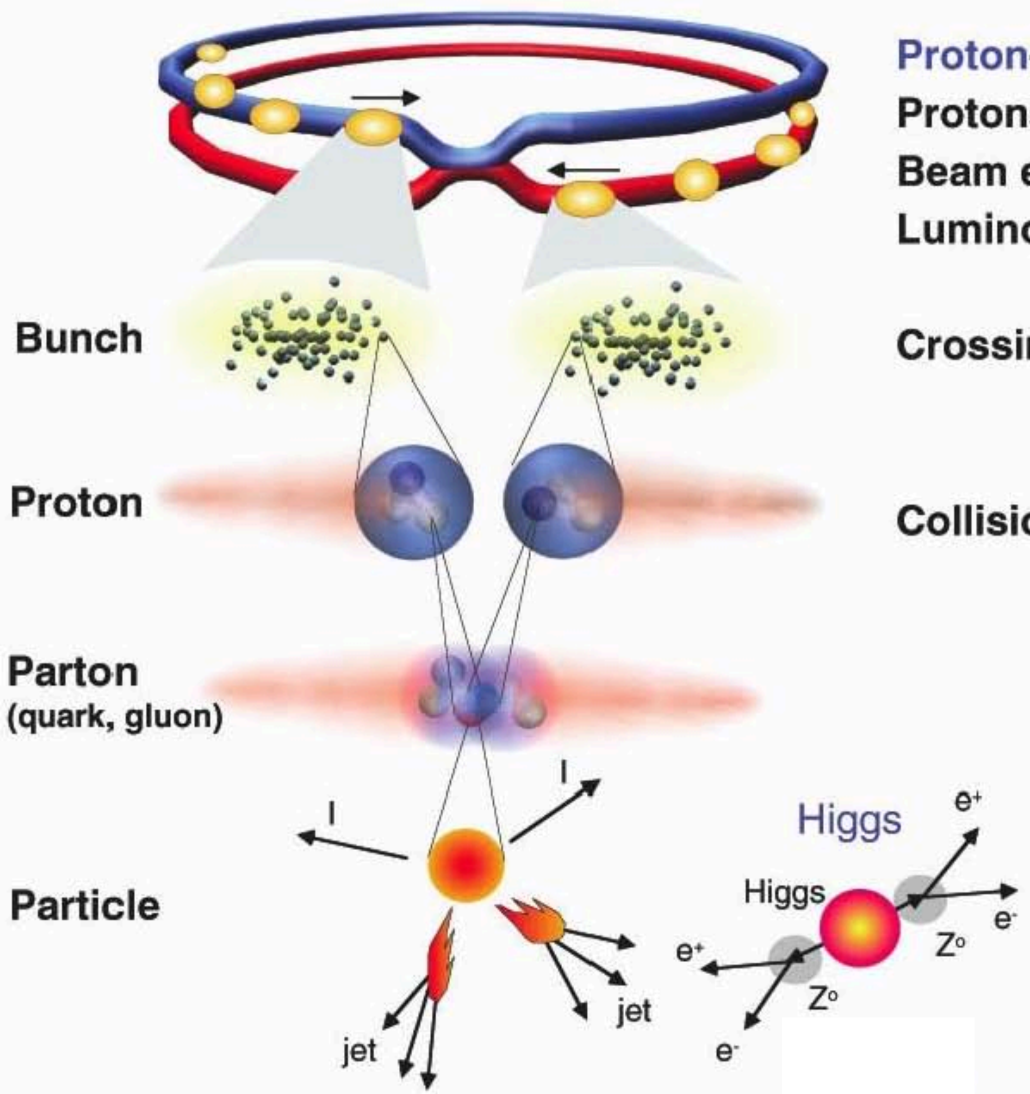
Colliders Seeking Answers

Fermilab
Tevatron
(1983-2011)

CERN LHC (2008 -)



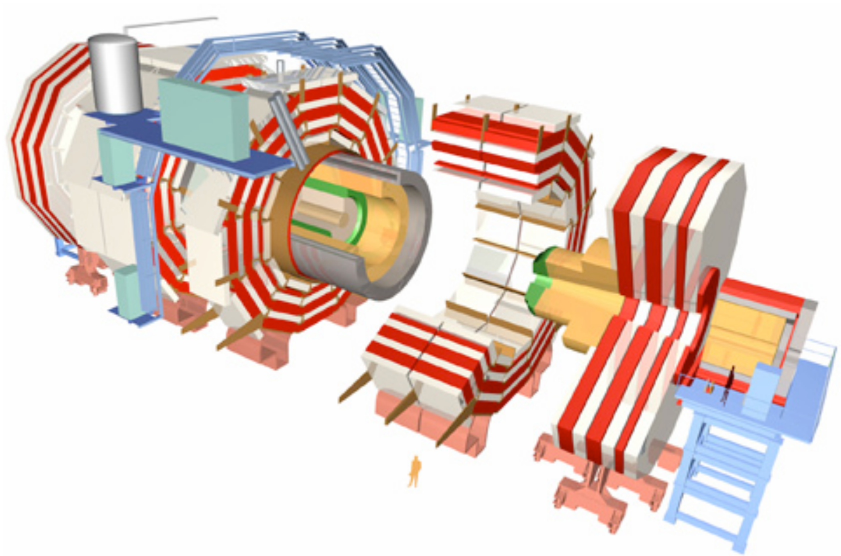
Proton-Proton Collissions

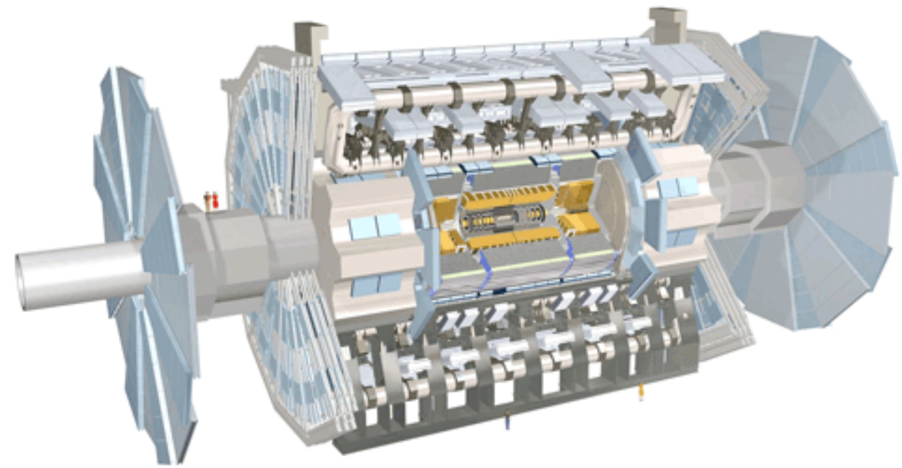


Proton-Proton	2835 bunch/beam
Protons/bunch	10^{11}
Beam energy	7 TeV (7×10^{12} eV)
Luminosity	10^{34} cm^{-2} s^{-1}
Crossing rate	40 MHz
Collisions ≈	10^{7} - 10^{9} Hz

Selection of 1 in 10,000,000,000,000

Results from Two Experiments





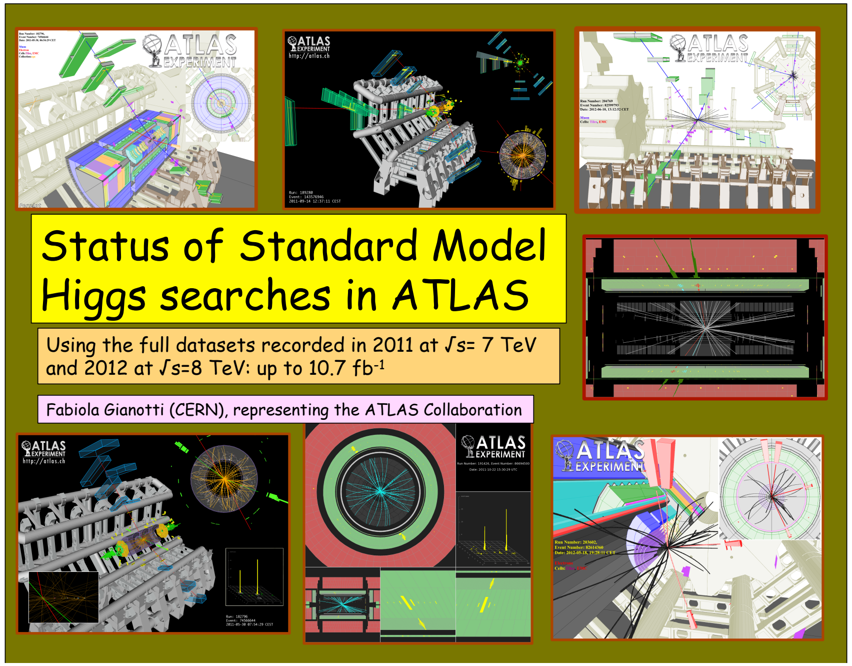
CMS

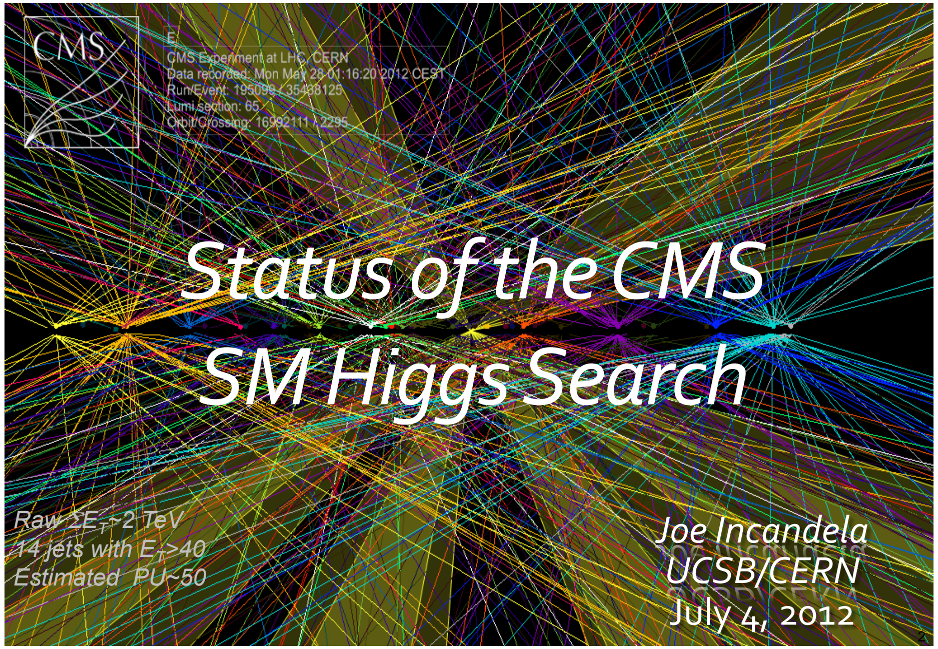
Spokesperson
Joe Incandela

ATLAS

Spokesperson
Fabiola Gianotti

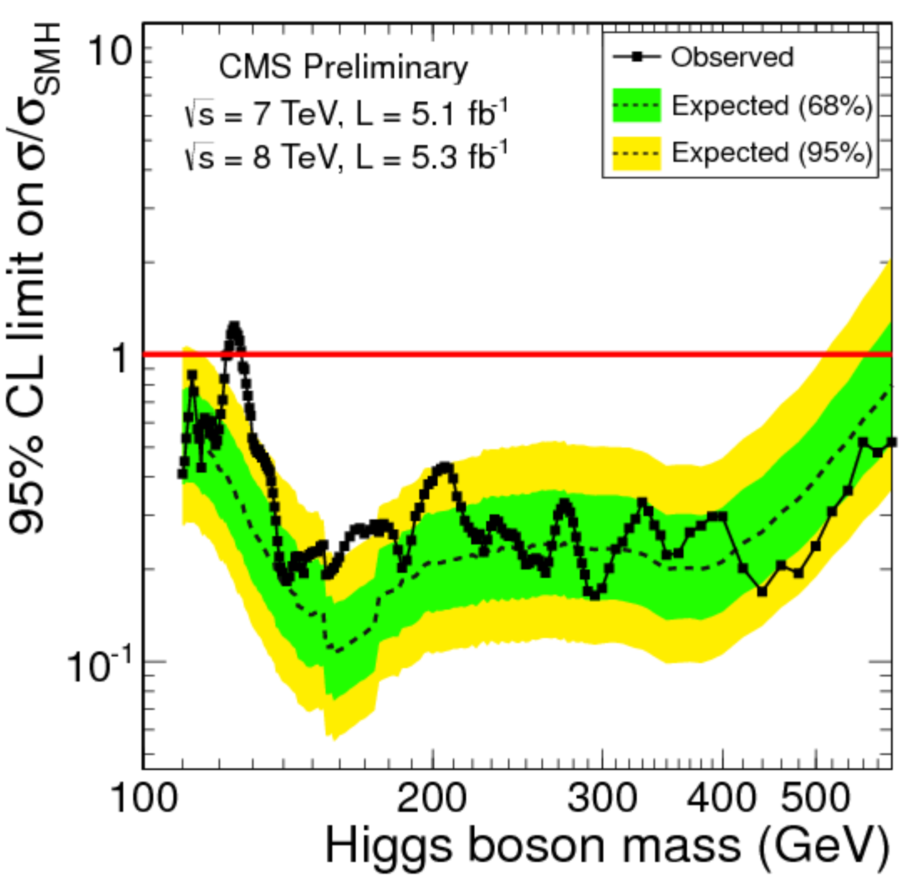
Slides from the Official Talks

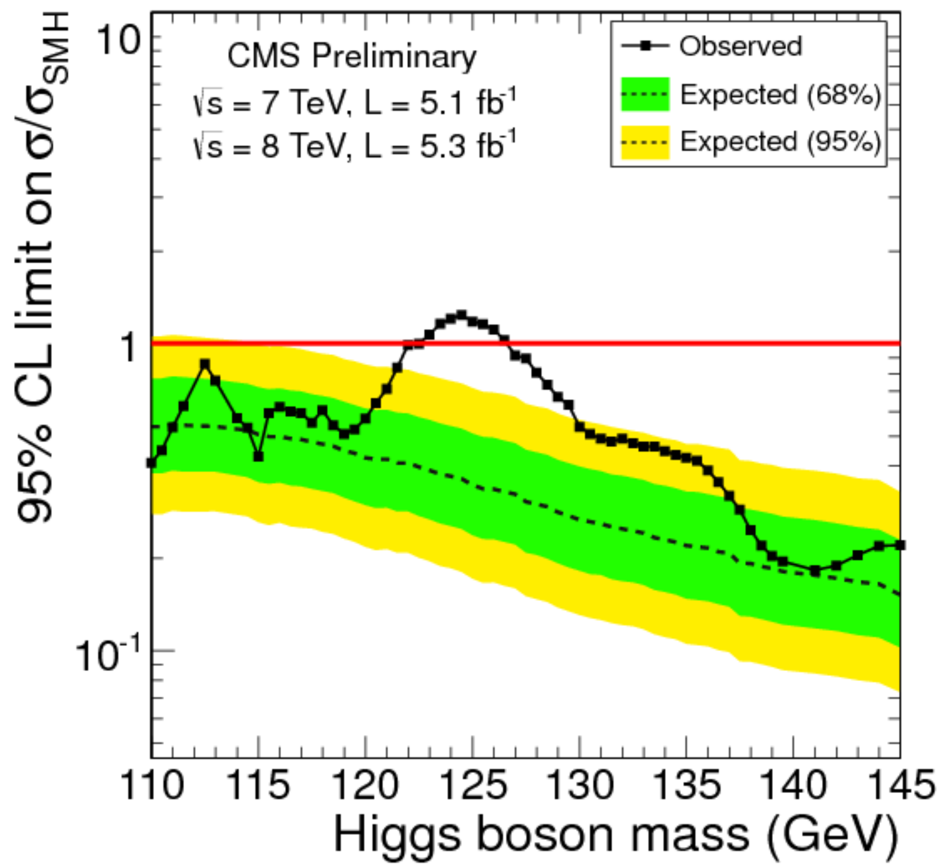




ACP Higgs-viewing
party 7-4-2012

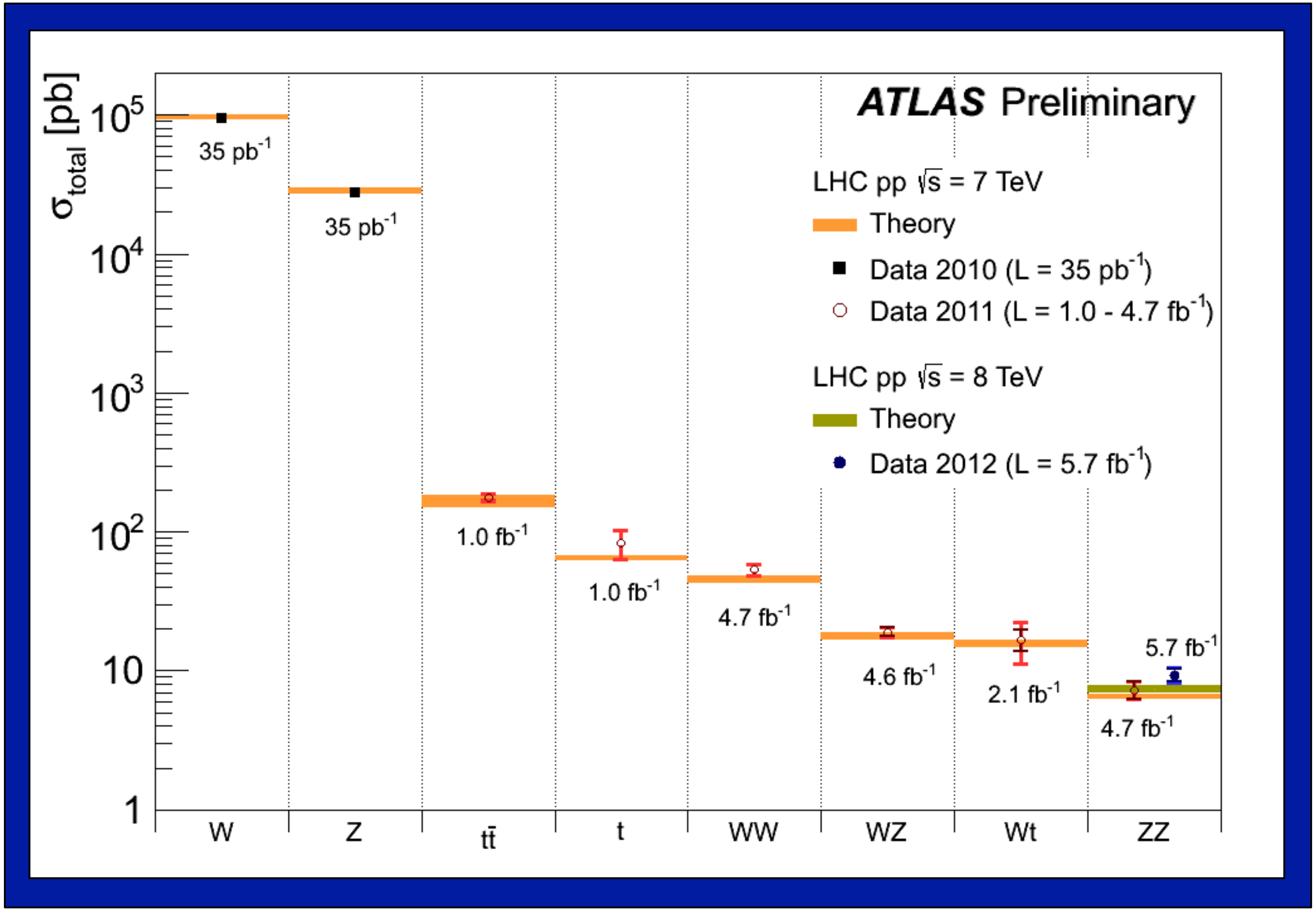
SM Higgs exclusion: signal strength





Observed: 110 – 122.5 .... 127 – 600 GeV at 95% CL

Most recent electroweak and top cross-section measurements



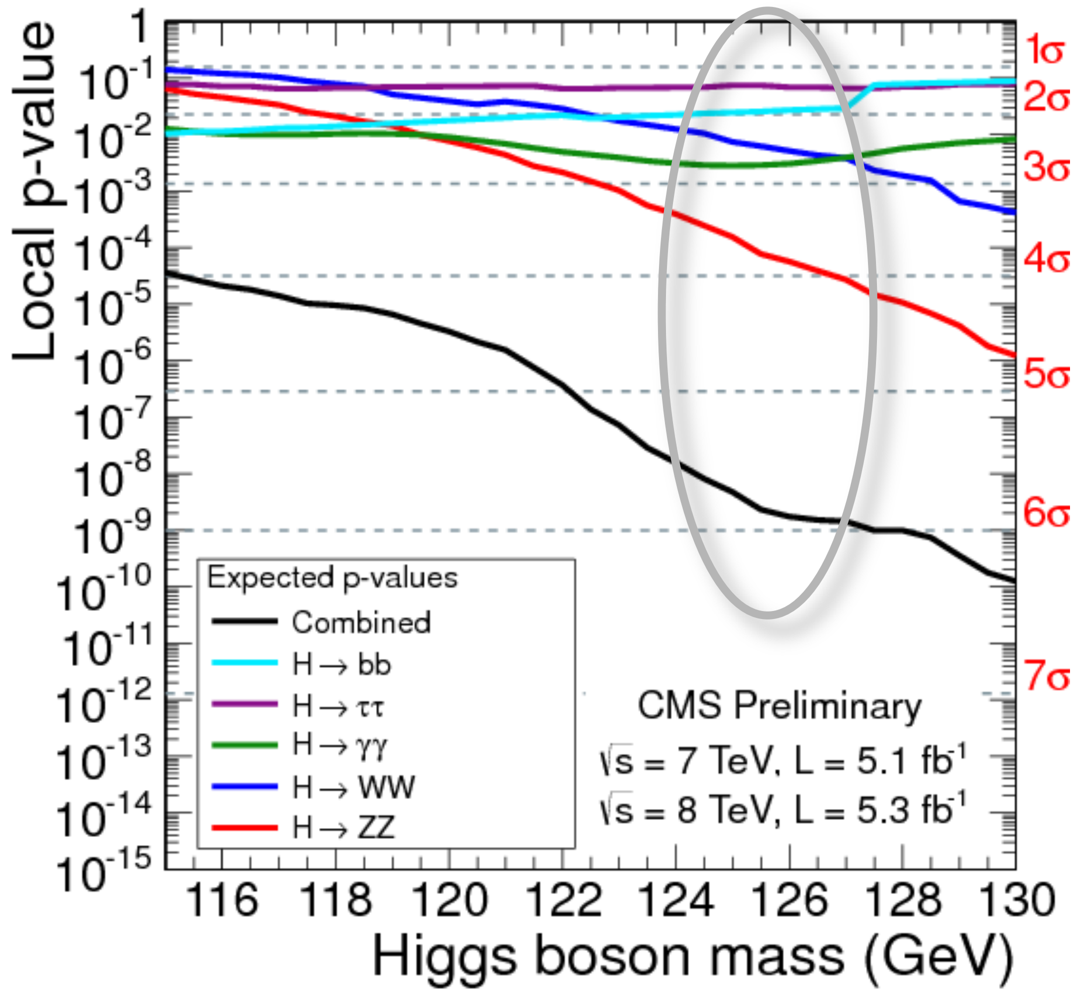
Inner error: statistical
Outer error: total

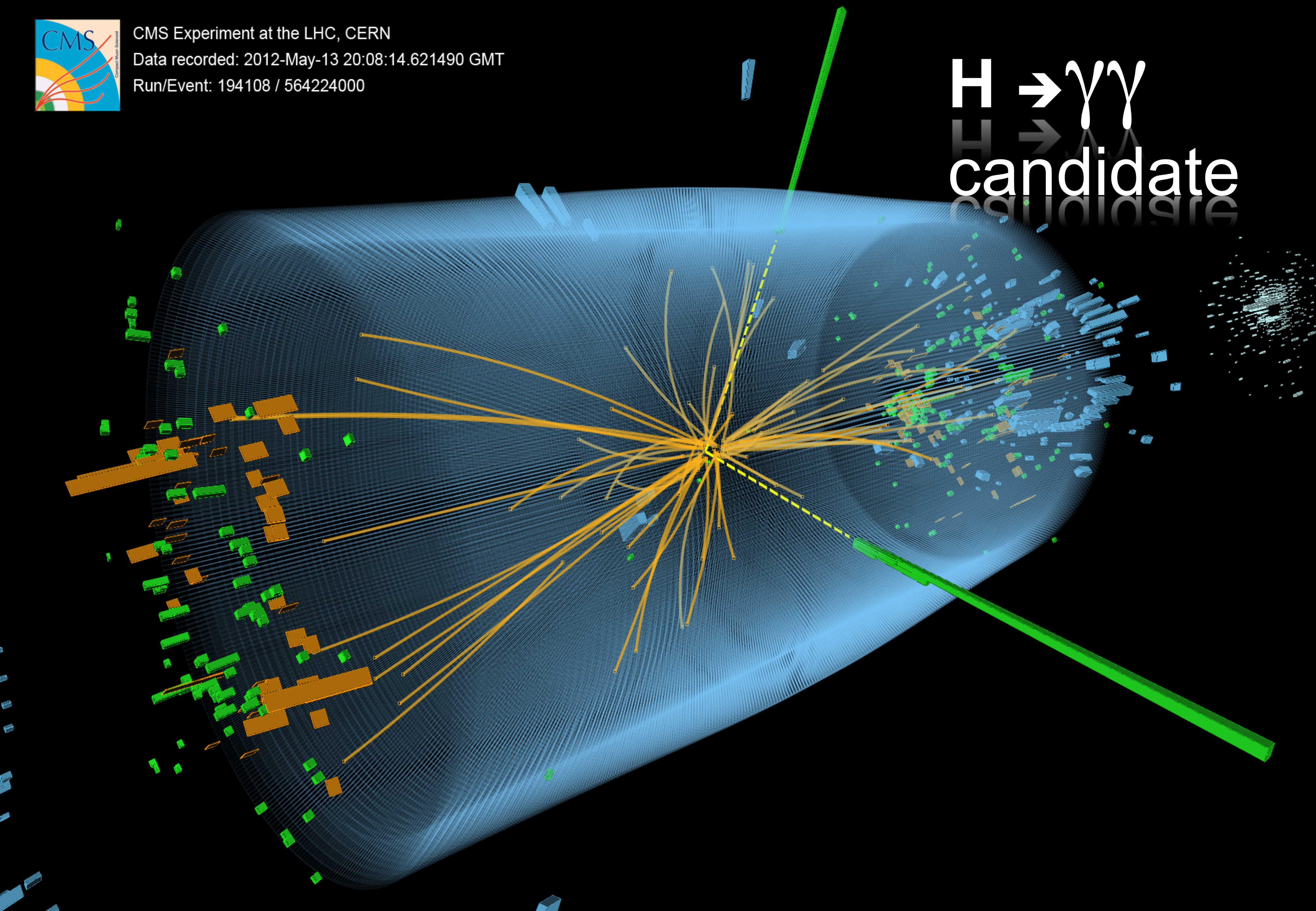
- Important on their own and as foundation for Higgs searches
- Most of these processes are reducible or irreducible backgrounds to Higgs
- Reconstruction and measurement of challenging processes (e.g. fully hadronic tt, single top, ..) are good training for some complex Higgs final states

CMS Discovery potential

p-values

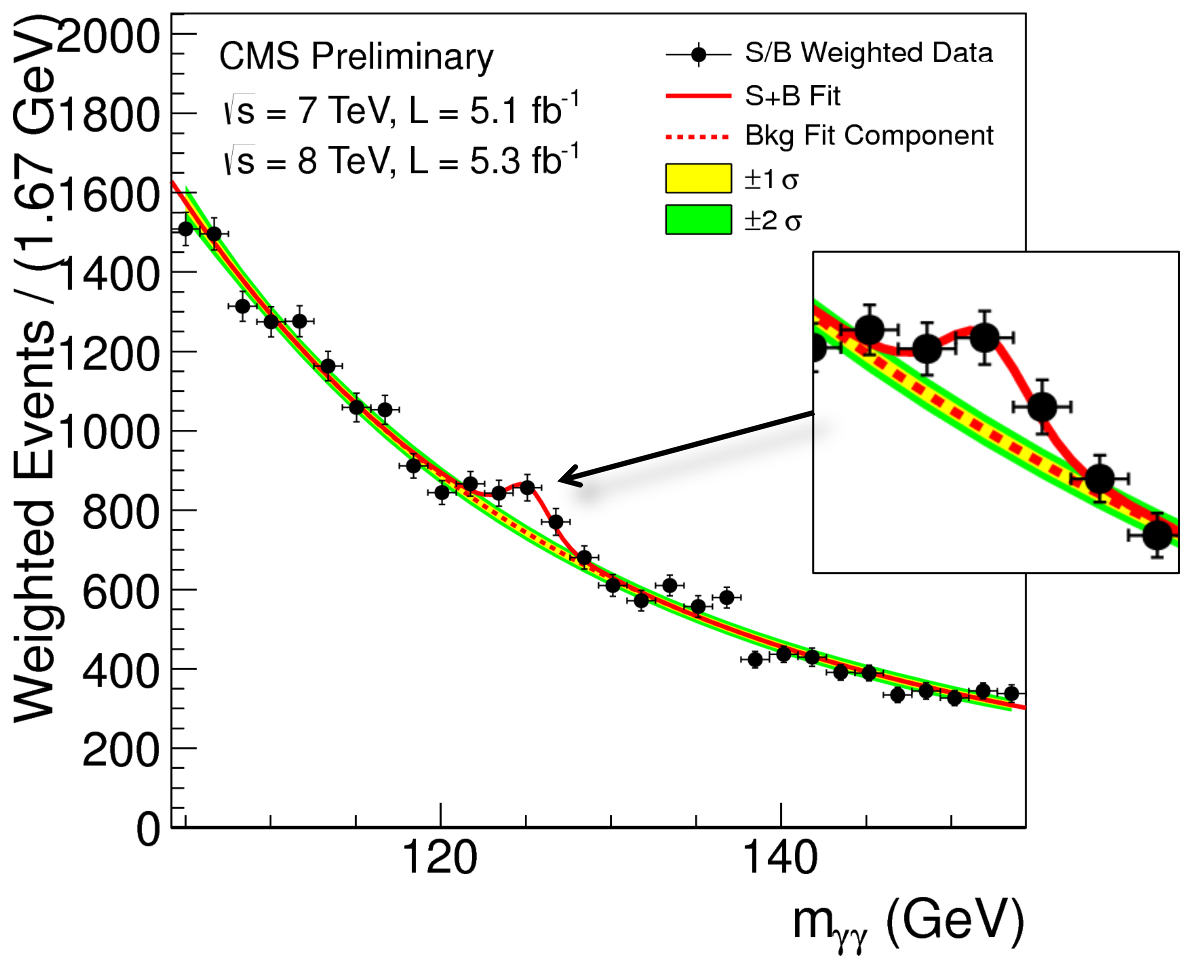
- Probability that background fluctuates to give an excess as large as the (average) signal size expected for a SM Higgs.
  - Takes into account all analysis steps, estimated backgrounds, etc. for the 5 search channels indicated.
- Excellent prospects for exploring properties




CMS Experiment at the LHC, CERN
Data recorded: 2012-May-13 20:08:14.621490 GMT
Run/Event: 194108 / 564224000
H → γγ
candidate

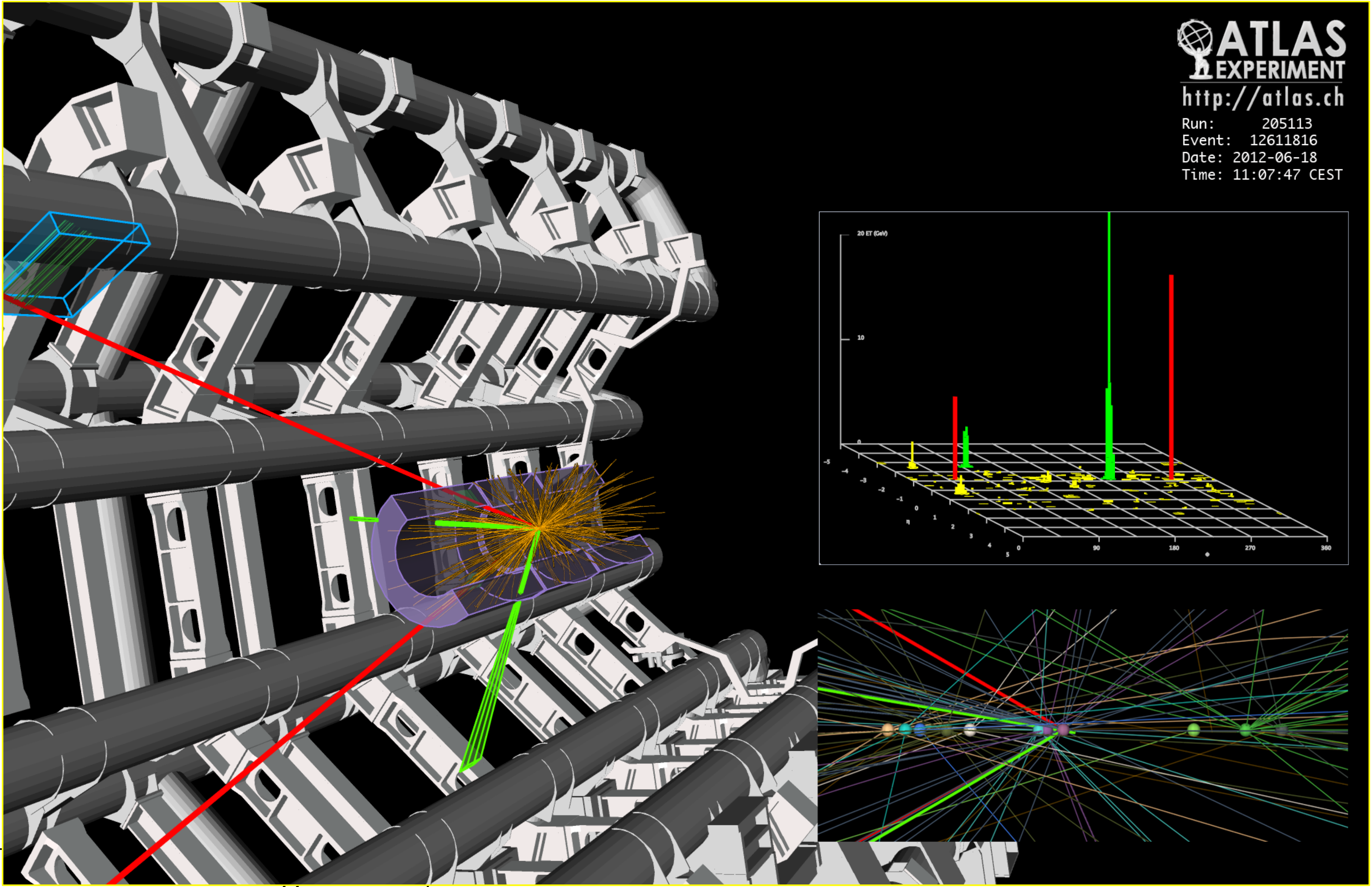
S/B Weighted Mass Distribution

- Sum of mass distributions for each event class, weighted by S/B
  - B is integral of background model over a constant signal fraction interval

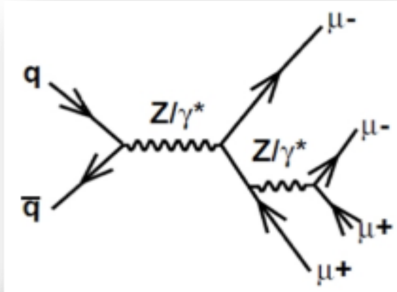


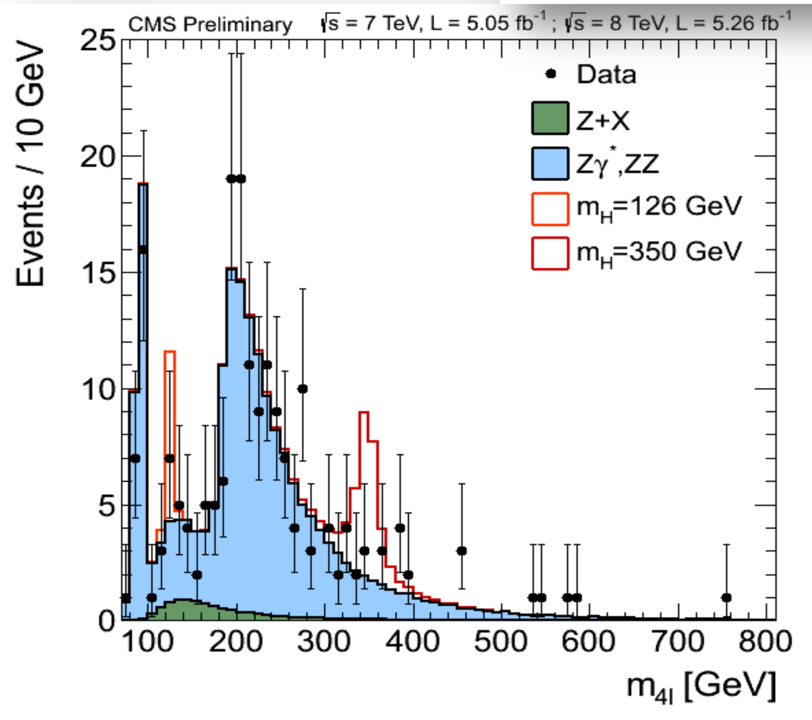
2e2μ candidate with $m_{2e2\mu}$ = 123.9 GeV

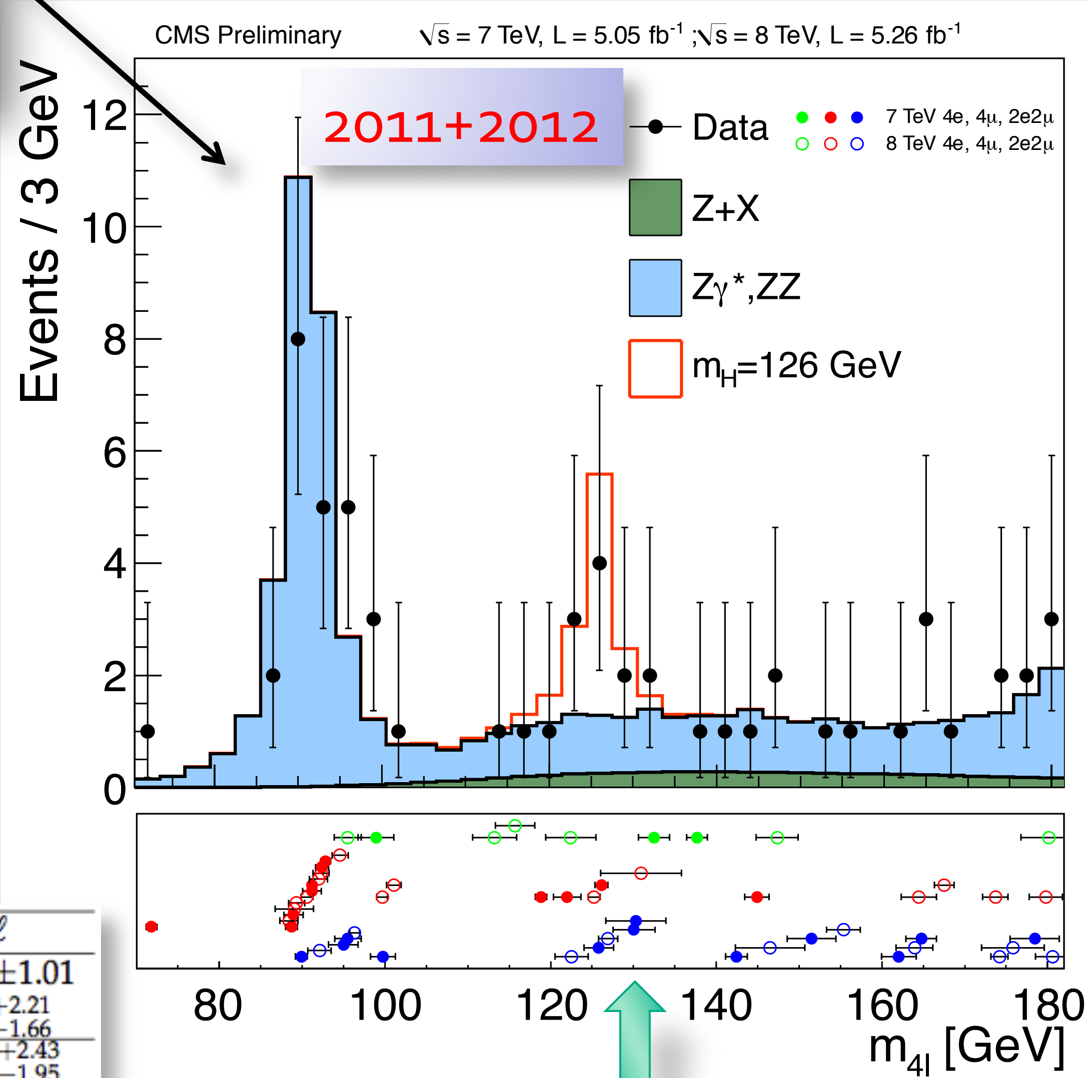
p_T (e,e,μ,μ) = 18.7, 76, 19.6, 7.9 GeV, m (e^+e^-) = 87.9 GeV, m($\mu^+\mu^-$) = 19.6 GeV
12 reconstructed vertices



Results: m(4l) spectrum







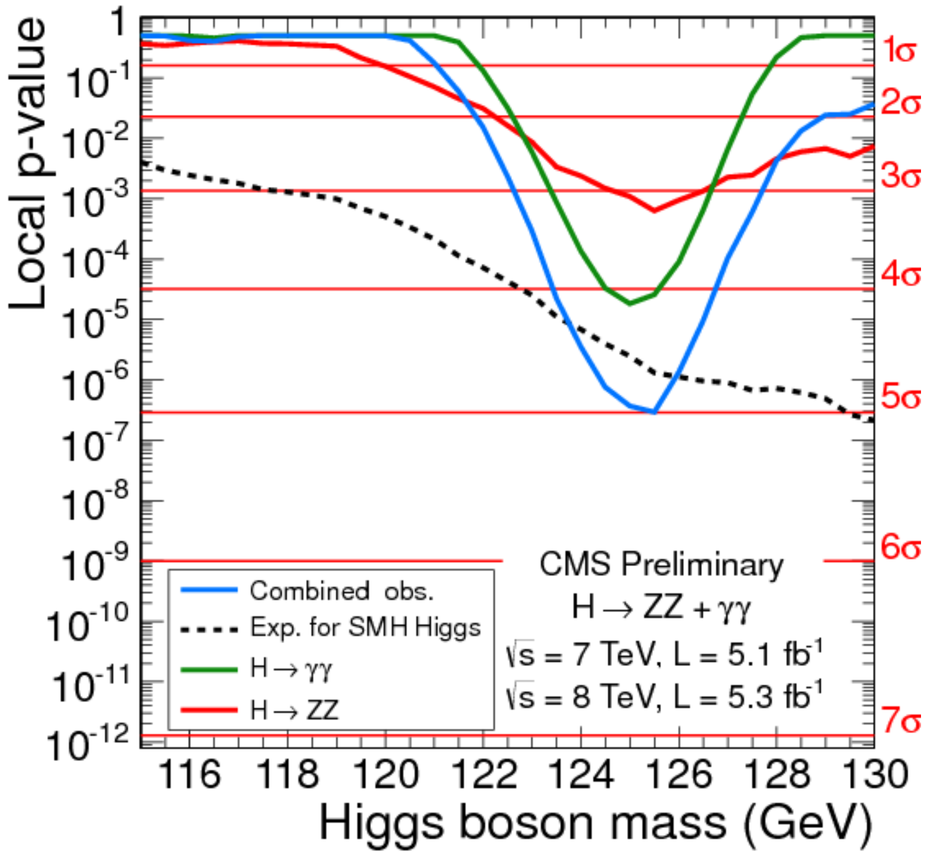
Event-by-event errors

Yields for m(4l)=110..160 GeV

Channel	4e	4μ	2e2μ	4ℓ
ZZ background	2.65 ±0.31	5.65 ±0.59	7.17 ±0.76	15.48 ±1.01
Z+X	$1.20^{+1.08}_{-0.78}$	$0.92^{+0.65}_{-0.55}$	$2.29^{+1.81}_{-1.36}$	$4.41^{+2.21}_{-1.66}$
All backgrounds	$3.85^{+1.12}_{-0.84}$	$6.58^{+0.88}_{-0.81}$	$9.46^{+1.96}_{-1.56}$	$19.88^{+2.43}_{-1.95}$
$m_H = 126$ GeV	1.51 ±0.48	2.99 ±0.60	3.81 ±0.89	8.31 ±1.18

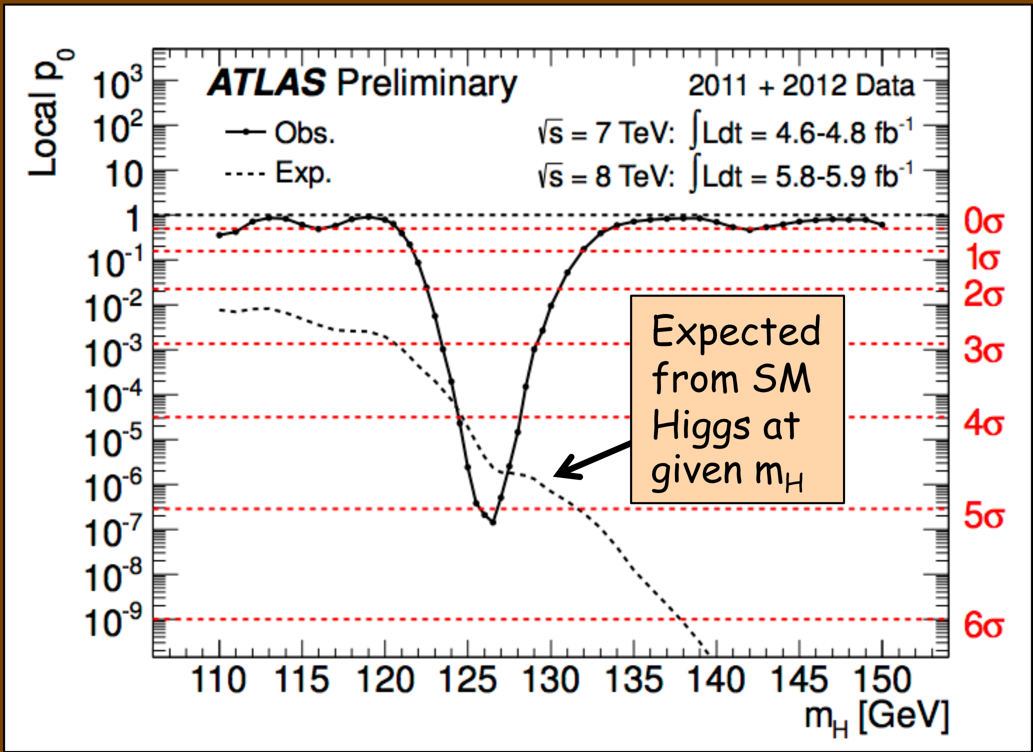
164 events expected in [100, 800 GeV]
172 events observed in [100, 800 GeV]

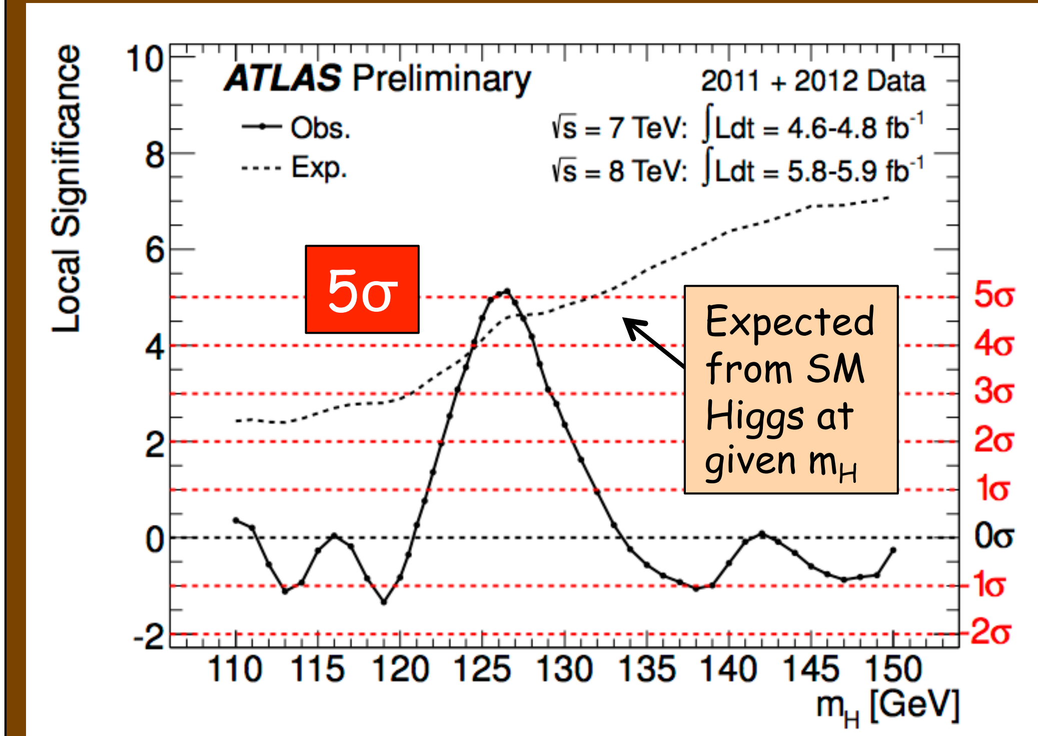
Characterization of excess near 125 GeV



- **high sensitivity, high mass resolution channels: γγ+4l**
  - **γγ: 4.1 σ excess**
  - **4 leptons: 3.2 σ excess**
  - **near the same mass 125 GeV**
- **comb. significance: 5.0 σ**
- **expected significance for SM Higgs: 4.7 σ**

Combined results: the excess



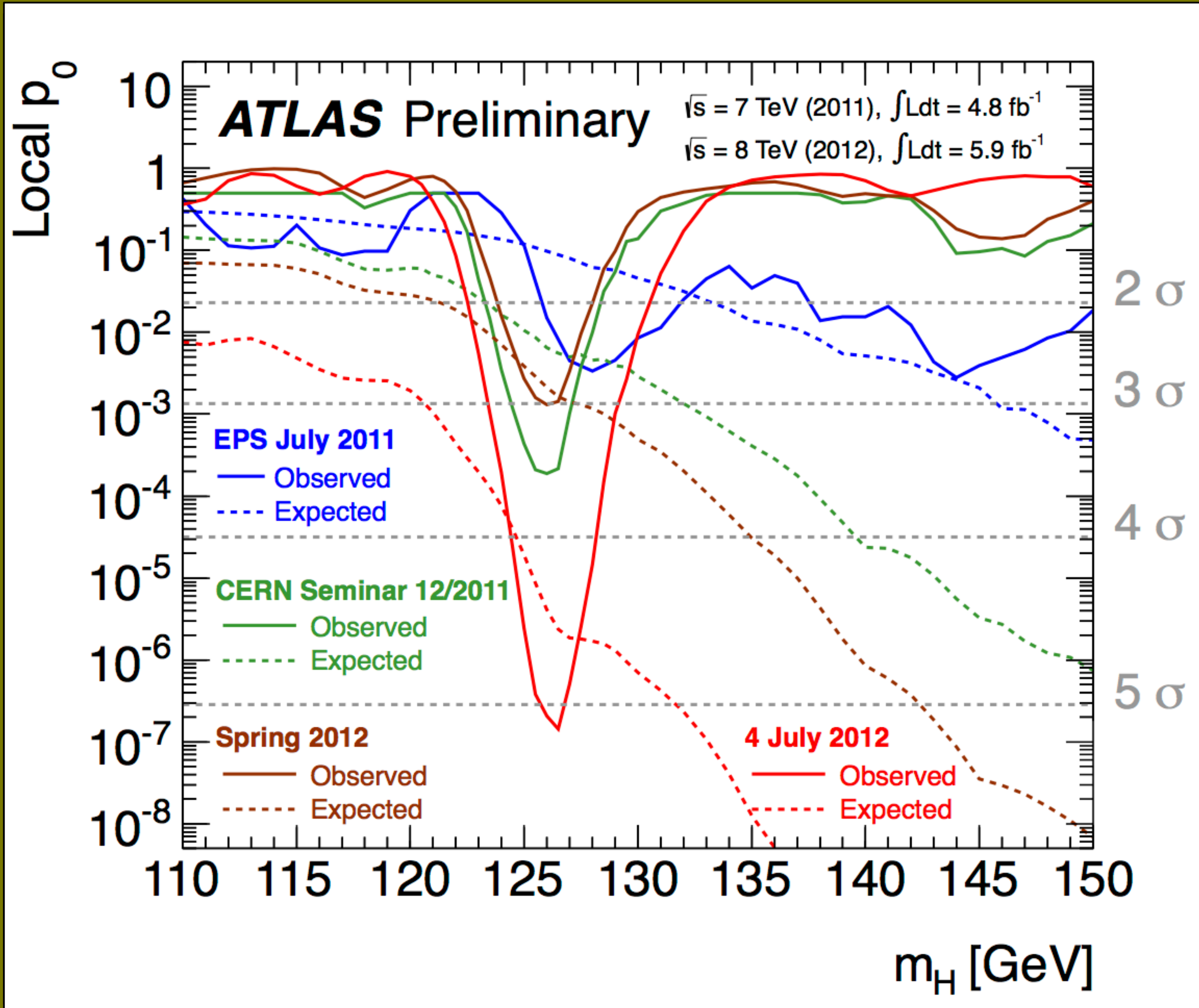


Maximum excess observed at	m_H = 126.5 GeV
Local significance (including energy-scale systematics)	5.0 σ
Probability of background up-fluctuation	3×10^{-7}
Expected from SM Higgs m_H=126.5	4.6 σ

Global significance: 4.1-4.3 σ (for LEE over 110-600 or 110-150 GeV)

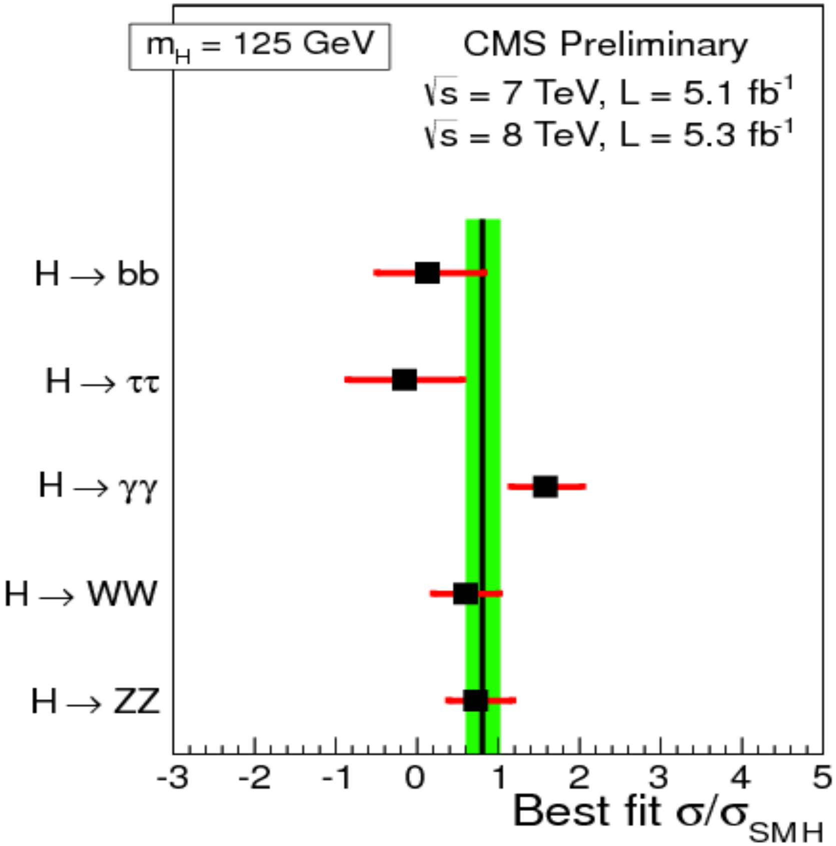
What Comes Next?

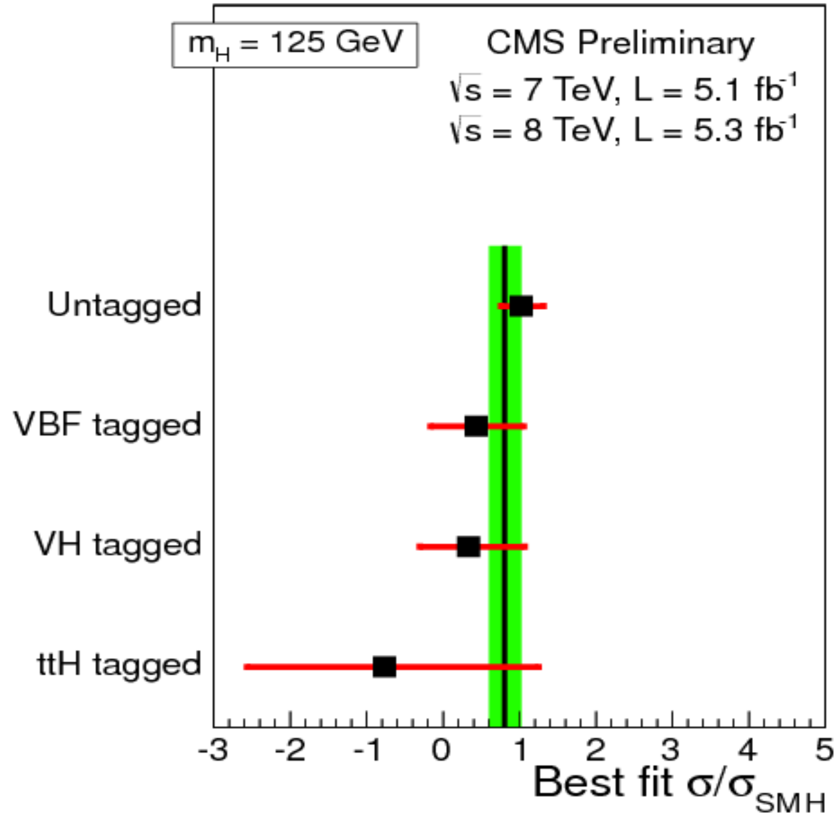
Evolution of the excess with time



Energy-scale systematics not included

Compatibility with SM Higgs boson
event yields in different modes (2)





- Event yields in different decay modes are self-consistent
- Event yields in different production topologies are self-consistent

What Comes Next?

- This data is our first tantalizing view of a new, exciting and long-awaited particle.

- LHC will take 2x more data in the rest of 2012 ... and then continue running through 2013.

- Priorities include measuring the Higgs in as many different decays and by as many methods as possible, to fill in the details.

- Above all, we want to know how "standard" the observed Higgs boson is and whether there are hints of exciting new particles yet to come.


theguardian

Higgs boson discovery: now the real work begins