LHC 2012 -
Beyond Moriond: Hunt for Multi-Higgs

by Frank Dodd (Tony) Smith Jr.

Abstract:

Nobel laureate Steven Weinberg (quoted in New Scientist 7 March 2012) said:

"One Higgs would be very sad ... If all we see at the LHC is one Higgs, it's not going to help us ... see clearly what the road ahead is ..." ...".

My view of the data from Tevatron and LHC presented at Moriond
(7 Mar 2012 and (in version 2 of this paper) 11 Mar 2012)
is that Steven Weinberg should be Very Happy. Instead of a single Standard Model Higgs at 125 GeV, I think the data indicates the following phenomena:

125 GeV - pion-type meson T0 (low-mass Tquark-antiUpquark);
126.5 GeV - pion-type meson T0c (low-mass Tquark-antiCharmquark);
136 GeV - SM Higgs (low state of 3-state Higgs);
195 GeV - SM Higgs (middle state of 3-state Higgs);
244 GeV - SM Higgs state near Higgs VEV (high state of 3-state Higgs).

Matt Strassler in his 6 Dec 2011 guest post on Cosmic Variance proposed
a flow chart for two phases in the LHC Hunt for Higgs:
Phase 1 being Search for a Single Standard Model Higgs;
Phase 2 including Search for 2 or more Higgs.

My view is that Phase 1 has failed to clearly find a Single Standard Model Higgs so that
the LHC should now in 2012 begin the Phase 2 Hunt for Multi-Higgs.

(References are included in the body of the paper and in linked material.)

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Beyond Moriond: Hunt for Multi-Higgs

Frank Dodd (Tony) Smith, Jr. - March 2012

The Moriond 2012 Electroweak Higgs session (7 March 2012) concluded with the presentation by Jean-Francois Grivaz who said:

Final remarks

- Interesting excess at 125 – 126 GeV seen by both ATLAS and CMS in the $\gamma\gamma$ channel.
- Backed by the ZZ channel in ATLAS, but the largest excess in this channel is at 119 GeV at CMS.
- WW does not contribute at the level expected

- Both CDF and D0 see a broad excess mostly in the bb channel, consistent with a signal around 125 GeV.

- If I dared combine ATLAS, CMS, and Tevatron's excesses, I would end up at ??? sigmas at 125 GeV...

The New York Times (Dennis Overbye on 7 Mar 20102) said: "... This is the first time in the long search for the particle that different groups, indeed different colliders, are in vague agreement. It has led to a joke in physics circles now: The Higgs boson has not been discovered yet, but its mass is 125 billion electron volts. ...".

The BBC (Jason Palmer on 7 Mar 2012) said: "... Scientists from the US Tevatron accelerator say they have spotted possible hints of the Higgs boson at a mass similar to that seen at the LHC. The findings add weight to the idea that the Higgs - purported to give all other particles their mass - exists near a mass of 125 gigaelectronvolts. ...".

Nature (Eugenie Samuel Reich on 7 Mar 2012) said: "... Boost for Higgs from Tevatron data Final analysis suggests the US collider saw signs of the elusive particle. ... indications announced on 7 March at ... Moriond ... are consistent with 2011 reports of a possible standard model Higgs particle with a mass of around 125 GeV from ... LHC ...".

Science AAAS (Adrian Cho on 7 March 2012) said: "... the Tevatron ... CDF and D0 ... see more candidate Higgs decays than one would expect from ... background ...
The excesses are in line with ... ATLAS and CMS ... excesses ... with a mass of about 125 ... GeV ...".

The Economist (J.P. on 7 Mar 2012) said: "... The latest "tantalising hint" ... from Fermilab ... neatly matches the more robust 3.6- and 3.1-sigma results from ATLAS and CMS ... They put the mass of the Higgs in a narrower band around 125 GeV.
A quick unofficial combination of the latest LHC and Tevatron results shows a signal in excess of 4 sigma, cutting the odds of a fluke to one in 15,000 or so. ...".

The Guardian (Alok Jha on 7 March 2012) said: "... Scientists at the Tevatron particle collider in the US have found the strongest evidence yet for the existence of the Higgs boson. Their results lend credence to the tentative glimpses of the subatomic particle reported at the end of last year by scientists at the Large Hadron Collider (LHC) ... suggesting that the particle is indeed real ...[and]... has a mass of around 120 GeV ...".

Wired Science (Adam Mann on 7 March 2012) said: "... two experiments from Fermi National Accelerator Laboratory in Illinois report hints of what may be the Higgs boson. The finding bolsters results announced last year from CERN's LHC experiments, which may have spotted the elusive particle at around 125 gigaelectronvolts (GeV).

"**A worldwide picture is starting to form that is making us excited** ..."
said Rob Roser, co-spokesperson for ... CDF ...".

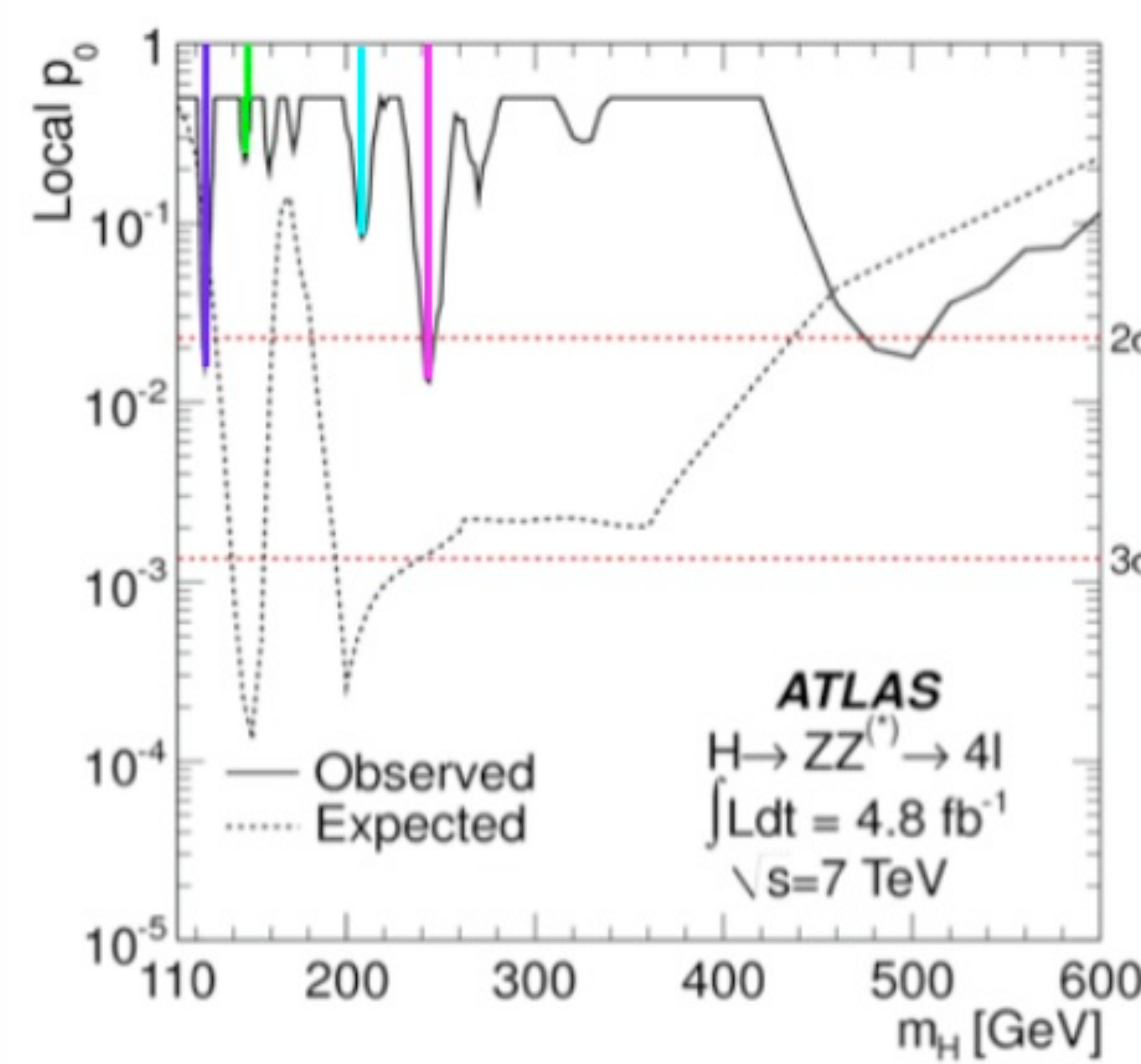
The WorldWide Consensus view of a 125 GeV Standard Model Higgs has a few dissenters:

New Scientist (Lisa Grossman on 7 March 2012) said: "... Conflicting Higgs results muddy particle hunt ... Physicists have been writing theories based on the assumption that there is only one Higgs boson for decades ... The LHC should have enough data to confirm or rule out the existence of the ... most basic type of Higgs that the standard model allows ... by the end of this year ... Nobel laureate Steven Weinberg ... says ...

"**One Higgs would be very sad … If all we see at the LHC is one Higgs, it's not going to help us … see clearly what the road ahead is** ..." ...".

My view is that if you look closely at the Tevatron/ATLAS/CMS data
you do in fact see more than one Sad Single Higgs:

ATLAS (Ralf Bernhard slide 35) for ZZ-4l Background Compatibility



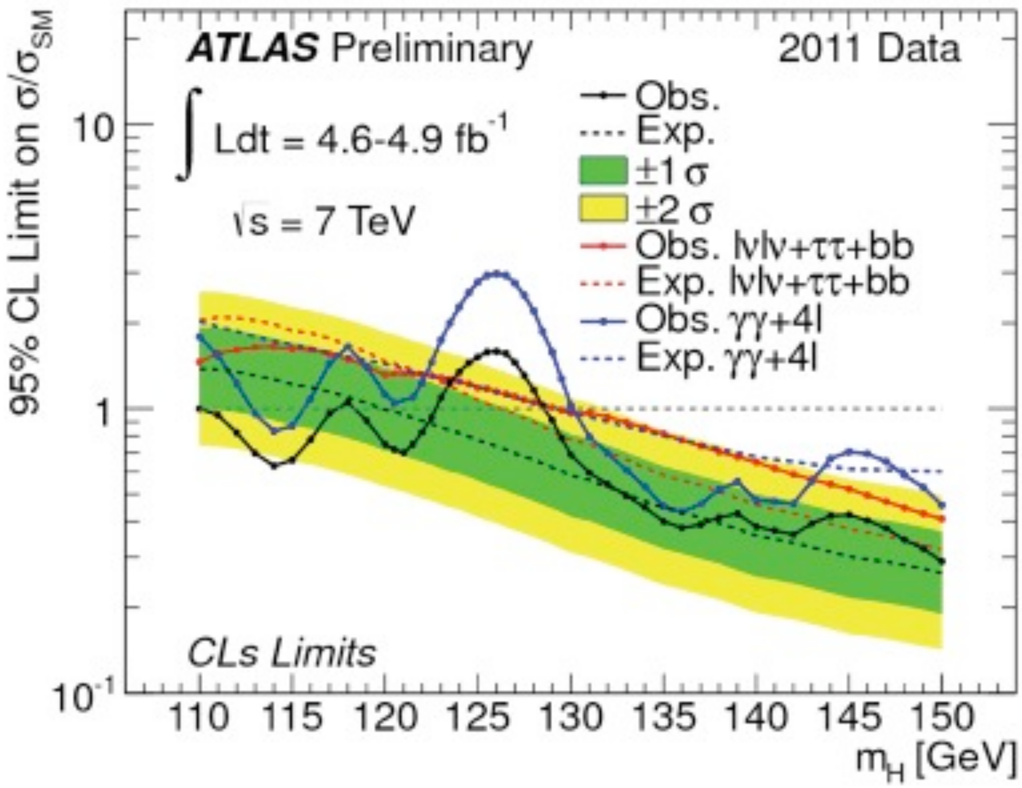
shows the strengths of peaks, some of which I have marked with color lines, and my physical interpretations of them:

around 126.5 GeV - purple line - T0 and T0c mesons with low-mass Tquark
around 145 GeV - green line - low-mass state of 3-state Higgs
around 210 GeV - cyan line - mid-mass state of 3-state Higgs
around 245 GeV - magenta line - high-mass state of 3-state Higgs

Peaks around 160 and 170 GeV are ignored as spurious background possibly related to W+/W- and mid-mass state Tquark phenomena.

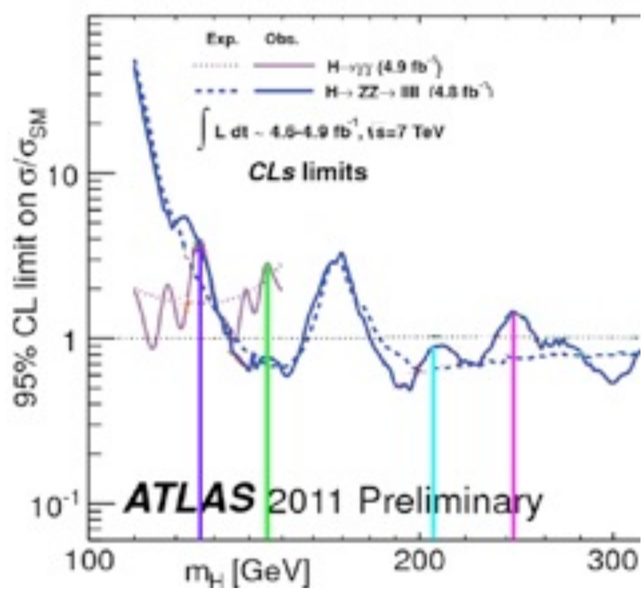
The peaks around 270, 320, and 500 GeV are ignored as background
(for example, in the ZZ-4l channel ATLAS has only 3 events in 475-525 GeV).

ATLAS (Ralf Bernhard slide 32)



shows that the high-resolution diphoton and ZZ-4l channels (blue line) give the clearest peaks around 125 GeV and 145 GeV.

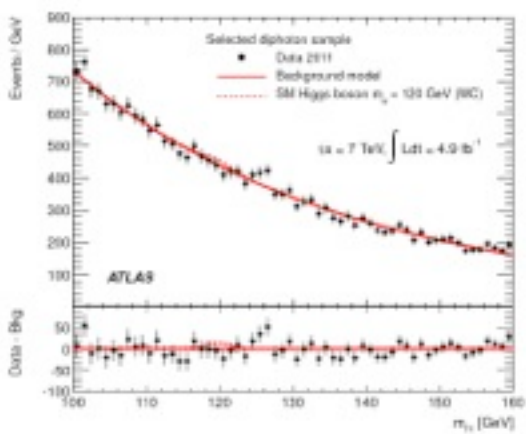
ATLAS ZZ-4l and diphoton (Ralf Bernhard slide 24) modified by me with color lines to indicate the peaks I find to be of interest shows:



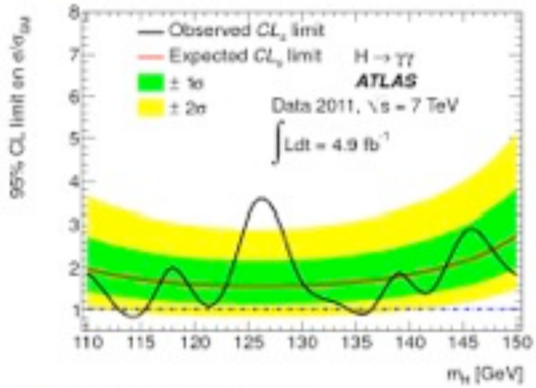
ATLAS (Sandra Kortner slides 15 and 11) shows details for diphoton and ZZ-4l:

Invariant $m_{\gamma\gamma}$ distribution,

summed over all categories:



Exclusion limit:

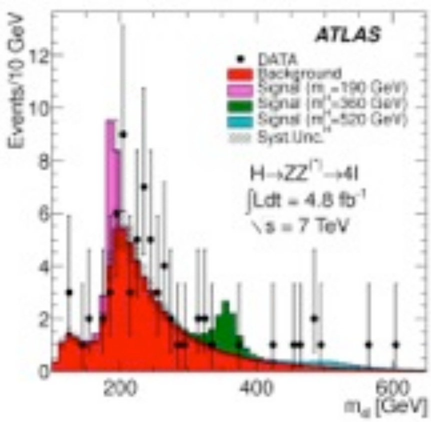


- Observed exclusion:

  113-115 GeV, 134.5-136 GeV.

Largest excess of events observed at 126.5 GeV.

- Local significance: 2.8σ (Global: 1.5σ for m_H =110-150 GeV).



Number of events in the full mass range:

	4μ	$2e2\mu$	$4e$
Expected	18.6±2.8	29.7±4.5	13.4±2.0
Observed	24	30	17

Small excesses observed around 3 mass values.

Local significance:

$m_{4\ell}$	125 GeV	244 GeV	500 GeV
Exp. w. signal	1.3σ	3.0σ	1.5σ
Observed	2.1σ	2.2σ	2.1σ

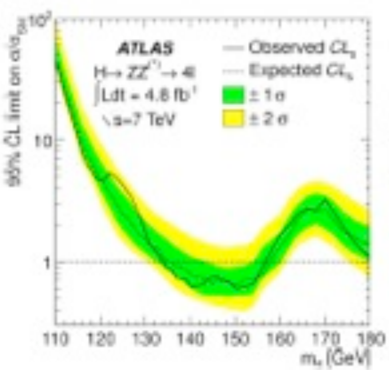
Expected limit:

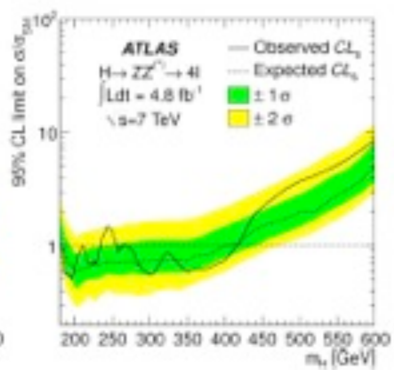
137-157, 184-400 GeV

Observed limit:

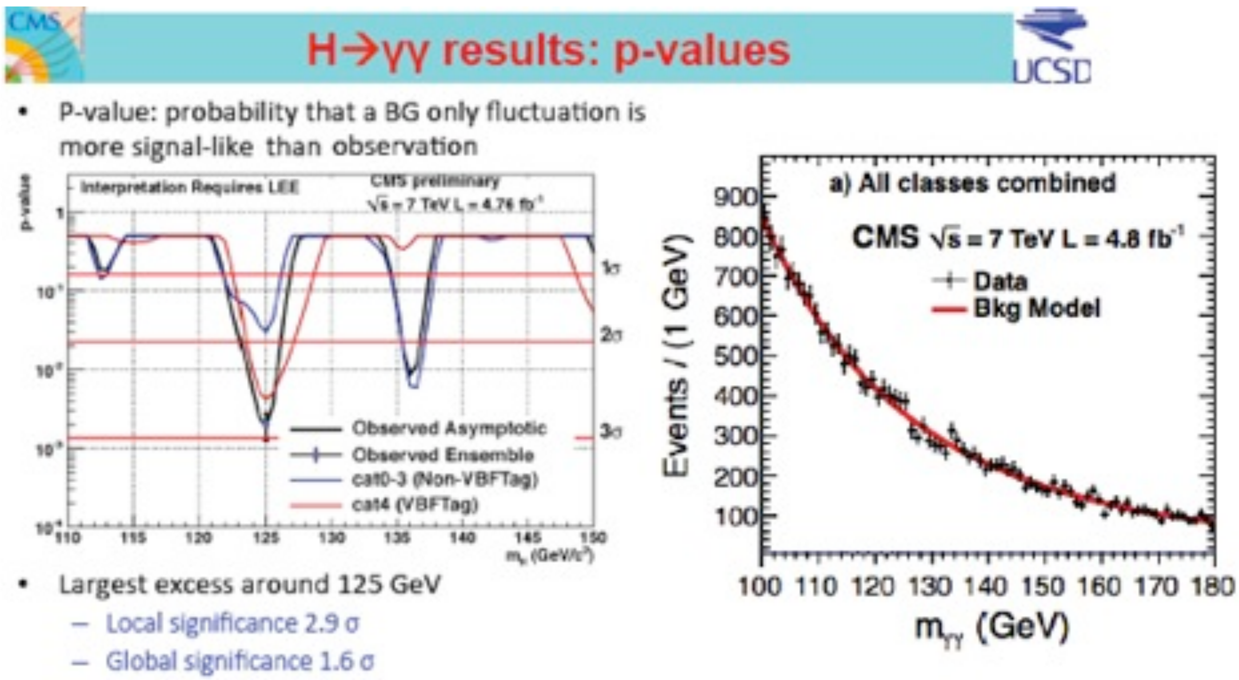
134-156, 182-233,

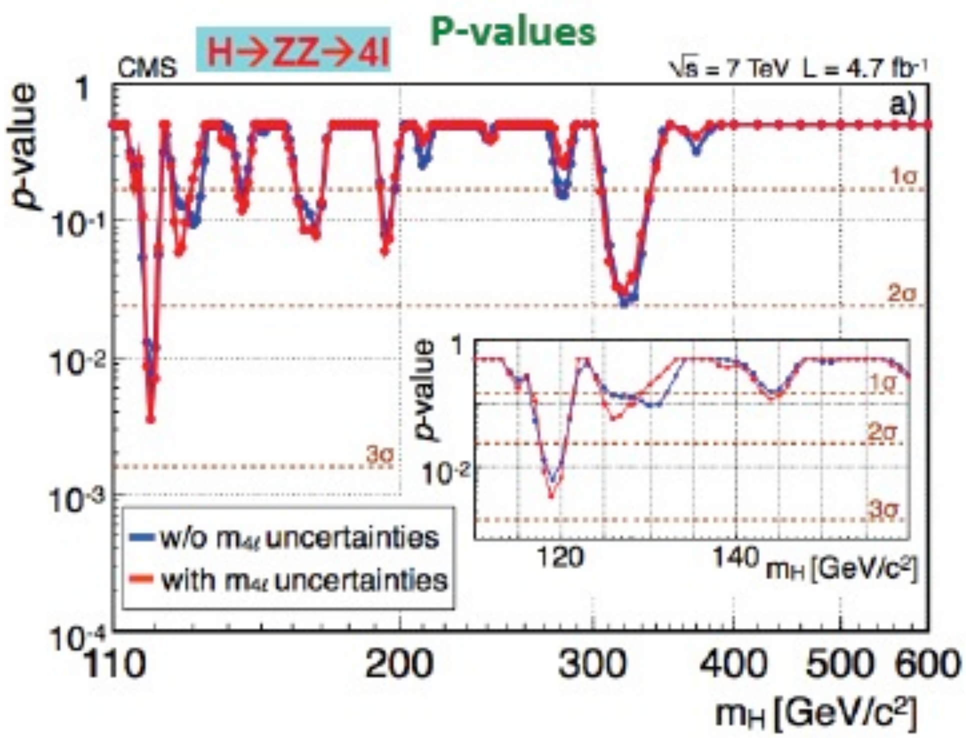
256-265, 268-415 GeV



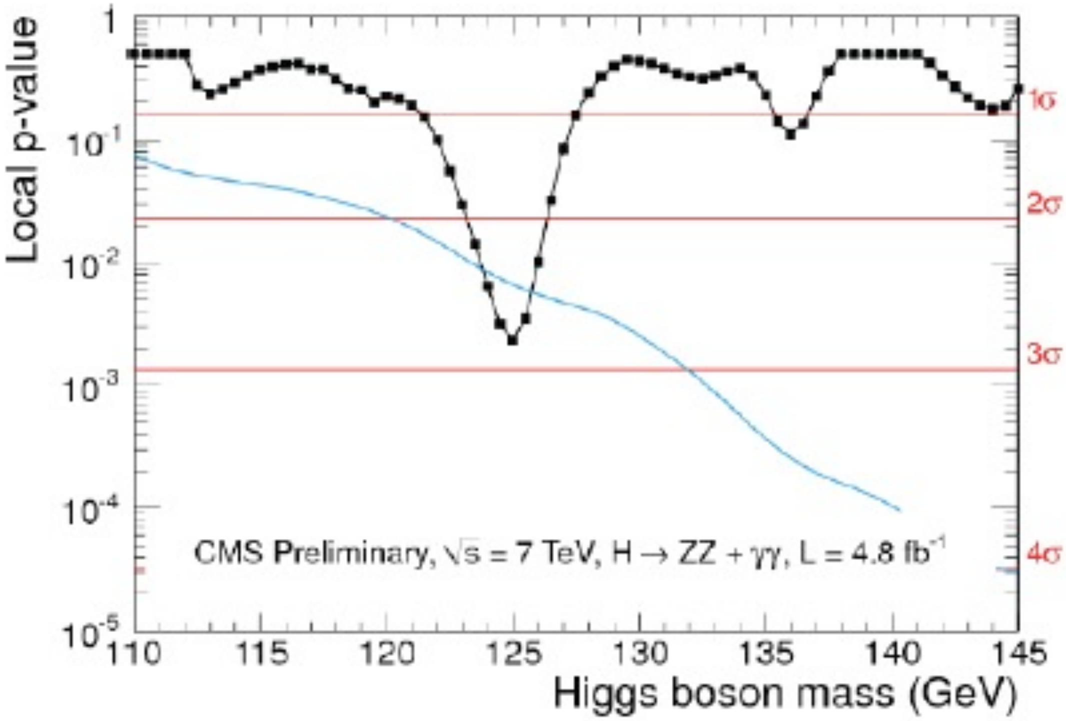


CMS (Marco Pieri slides 11 and 43 and 22) seems to show excesses
at 125 GeV (diphoton and ZZ-4l), 136 Gev (diphoton), 145 GeV (ZZ-4l),
and a small excess around 195 GeV (ZZ-4l):





CMS (Adi Bornheim slide 23)



shows that the high-resolution diphoton and ZZ-4l channels give the clearest peaks around 125 GeV and 136 GeV with a low peak at 145 GeV.

At CMS, the 125 GeV peak is clear in both diphoton and ZZ-4l channels,
but
the diphoton channel sees a peak at 136 GeV
and
the ZZ-4l channel sees a low peak at 145 GeV.

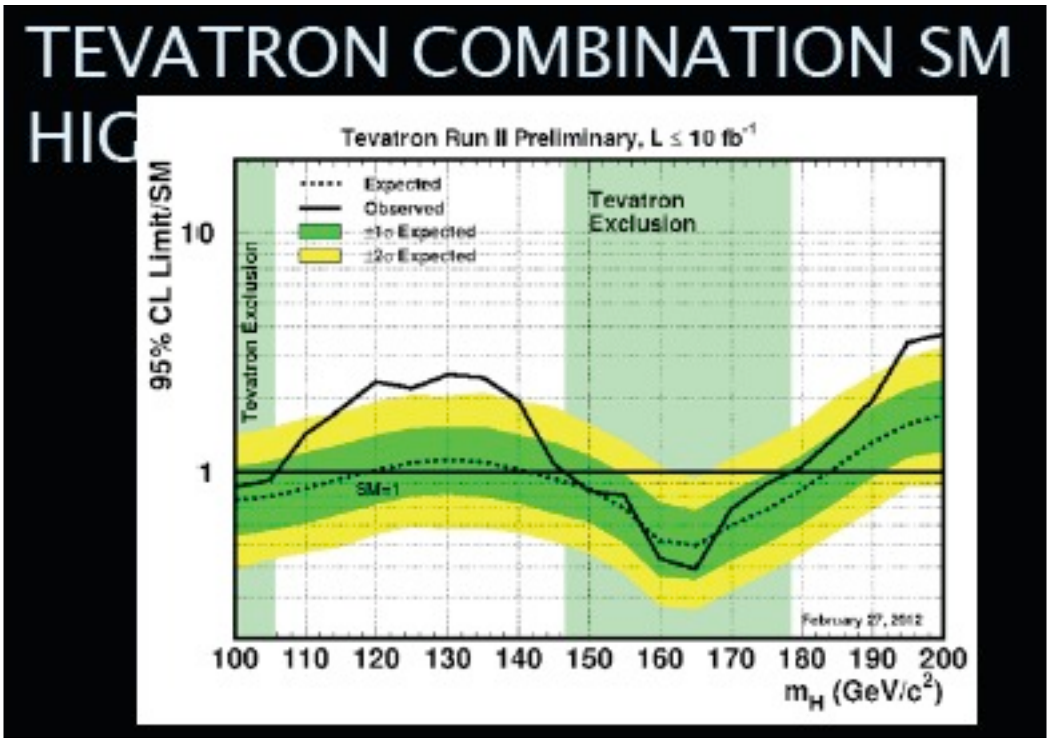
My view is that both the 136 and 145 correspond to the same physical phenomena as the ATLAS 145 GeV peak.

The Tevatron (Daniela Bortoletto slide 18) seems to show 3 peaks that are 2 sigma above expected at

120 GeV (a bit below 125-126.5 GeV)

135 GeV (a bit below 145 GeV)

195 GeV (a bit below 200 GeV)



If you just take the experimental results at face value
and do not view them from a particular model (SM or other) viewpoint,
and
ATLAS and CMS resolution distinguishes between 125 and 126.5
then my conclusion would be:

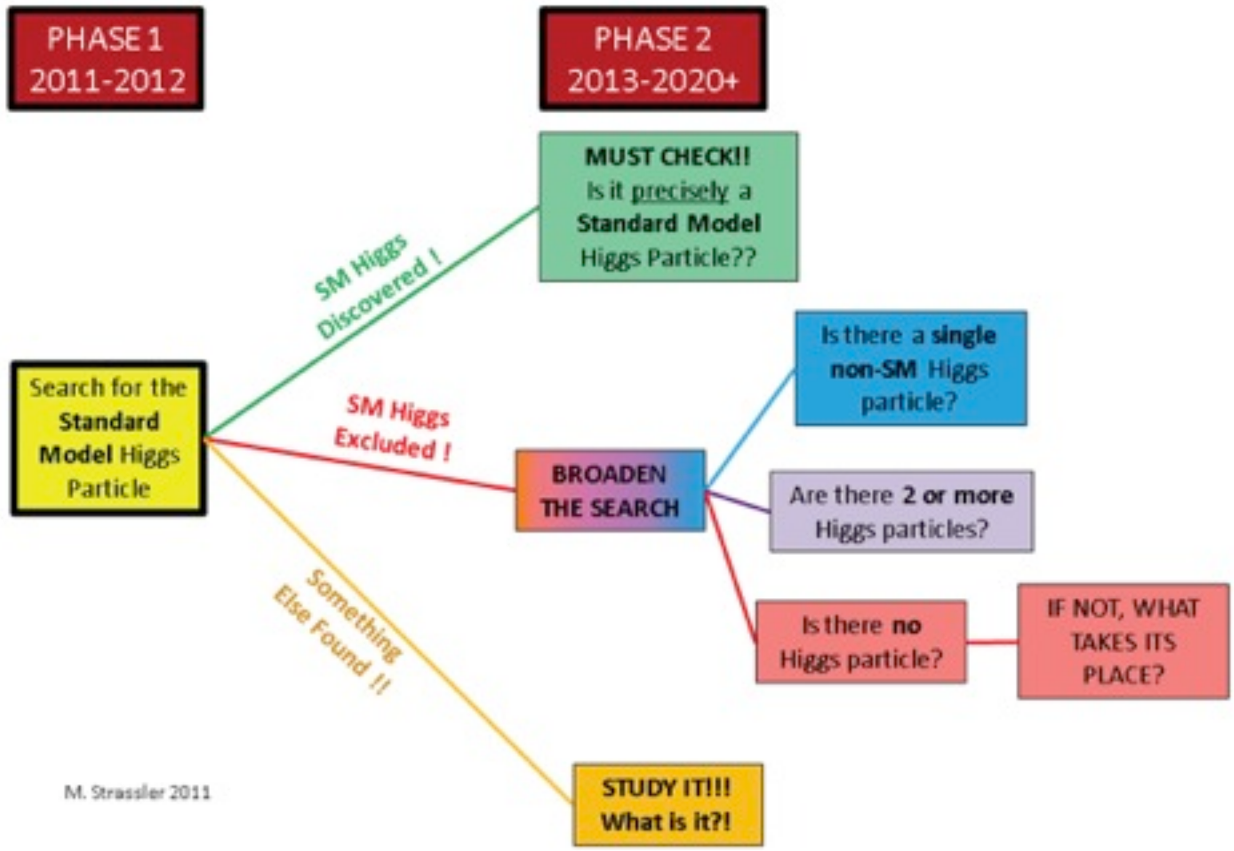
None of the results are evidence or discovery of anything,
but they are indications of interesting phenomena at
125 GeV (CMS value)
126.5 GeV (ATLAS value)
145 GeV (ATLAS and CMS ZZ-4l -
- CMS diphoton and Tevatron seeing 136 and 135 for that peak)
200 GeV (round number between CMS 195 and ATLAS 210)
245 GeV (ATLAS value)
that should be studied further.

My speculative model explanation would be

125 GeV - pion-type meson T0 (low-mass Tquark-antiUpquark)
126.5 GeV - pion-type meson T0c (low-mass Tquark-antiCharmquark)
145 GeV - SM Higgs (low state of 3-state Higgs)
200 GeV - SM Higgs (middle state of 3-state Higgs)
245 GeV - SM Higgs state near Higgs VEV (high state of 3-state Higgs)

(Note: I have no model interpreting the following:
CMS 300 GeV peak based on 9 ZZ-4l events from 290 to 360 GeV
ATLAS 500 GeV peak based on 3 ZZ-4l events from 475 to 525 GeV
My view is that they are not substantially different from background.)

Therefore, I think that the LHC Higgs search should now in 2012 go to what Matt Strassler calls Phase 2 as in his chart (from his 6 Dec 2011 guest post on Cosmic Variance) shown on the following page:



In particular,
I think that the data already taken by LHC indicates a faster approach than shown on the chart, in that

the Phase 2 LHC search "Are there 2 or more Higgs particles?" should begin in 2012

with respect to the 5/fb already taken by Halloween 2011
and whatever data is taken in 2012.

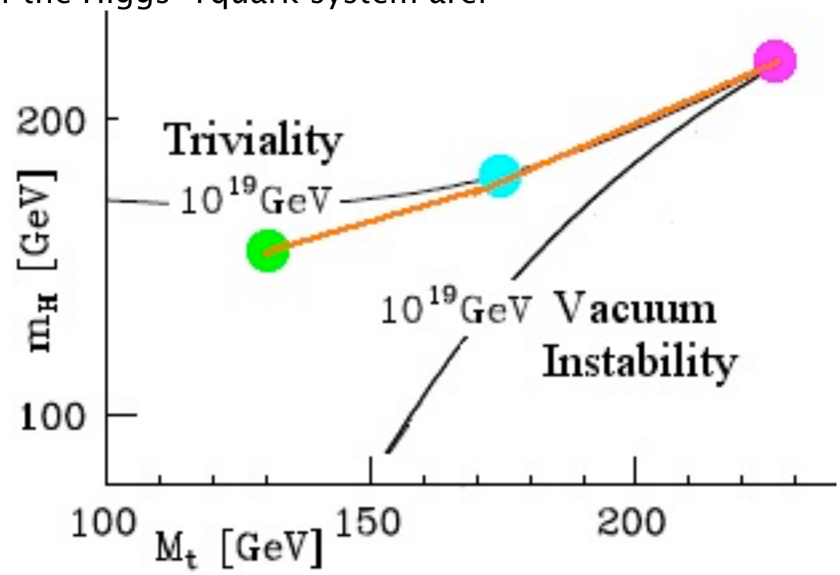
Such a search should be relatively easy to implement because,
as Matt Strassler explained in a "Quasi-Technical Section" on his blog entry "Awaiting Higgs News from the Tevatron Experiments" (6 Mar 2012):
"... suppose there were two Higgs fields ... and a Higgs particle for each one ... the production rate for either of the two Higgs particles is smaller than it is in the [single-Higgs] Standard Model ...". In other words,

**search for multi-state Higgs is like search for SM single-Higgs except only that
the SM Higgs cross-section is shared among multi Higgs states.**

What Might a Hunt for Multi-Higgs Find ?

For example, using my 3-state Higgs model (viXra 1108.0027):

The 3 states of the Higgs-Tquark system are:



The Magenta Dot  is the high-mass state: 220 GeV Tquark / 240 GeV Higgs.
The high-mass Higgs is near the observed excess around 245 GeV.
It is at the critical point of the Higgs-Tquark System
with respect to Vacuum Instability and Triviality, near the Higgs VEV.
It corresponds to the description in hep-ph/9603293 by Koichi Yamawaki
of **the Bardeen-Hill-Lindner model**.

The Gold Line leading down from the Critical Point goes roughly along
the Triviality Boundary line based on Renormalization Group calculations
described by Koichi Yamawaki in hep-ph/9603293 .

The Cyan Dot  where the Gold Line leaves the Triviality Boundary
is the middle-mass state of a 174 GeV Tquark and a 180 GeV Higgs.
It corresponds to the Higgs mass calculated by Hashimoto, Tanabashi,
and Yamawaki in hep-ph/0311165 where they show that for **8-dimensional Kaluza-Klein spacetime with the Higgs as a Tquark condensate**

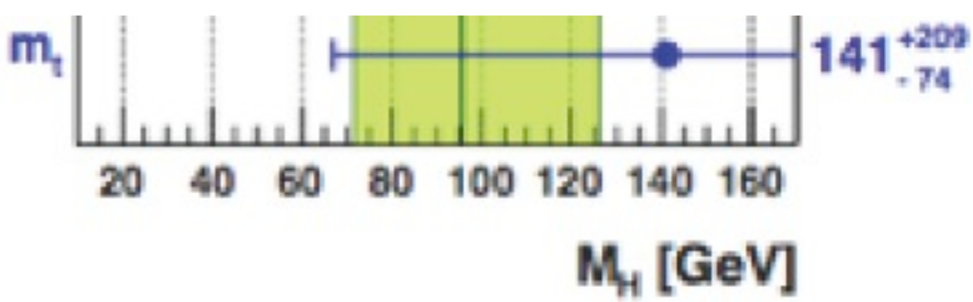
$172 < MT < 175$ GeV and $178 < MH < 188$ GeV.

The mid-mass Higgs is near the small observed excess around 200 GeV.
The physical meaning of the Triviality Bound is described by Pierre Ramond
in his book Journeys Beyond the Standard Model (Perseus Books 1999)

where he says at pages 175-176: "... for a ... (large) Higgs mass, we expect the standard model to enter a strong coupling regime ... losing ... our ability to calculate ... it is natural to think ... that **the Higgs actually is a composite** ... The resulting bound ... is sometimes called the triviality bound. The reason for this unfortunate name (the theory is anything but trivial) stems from lattice studies where the coupling is assumed to be finite everywhere; in that case the coupling is driven to zero, yielding in fact a trivial theory. In the standard model ... the coupling ... is certainly not zero. ...".

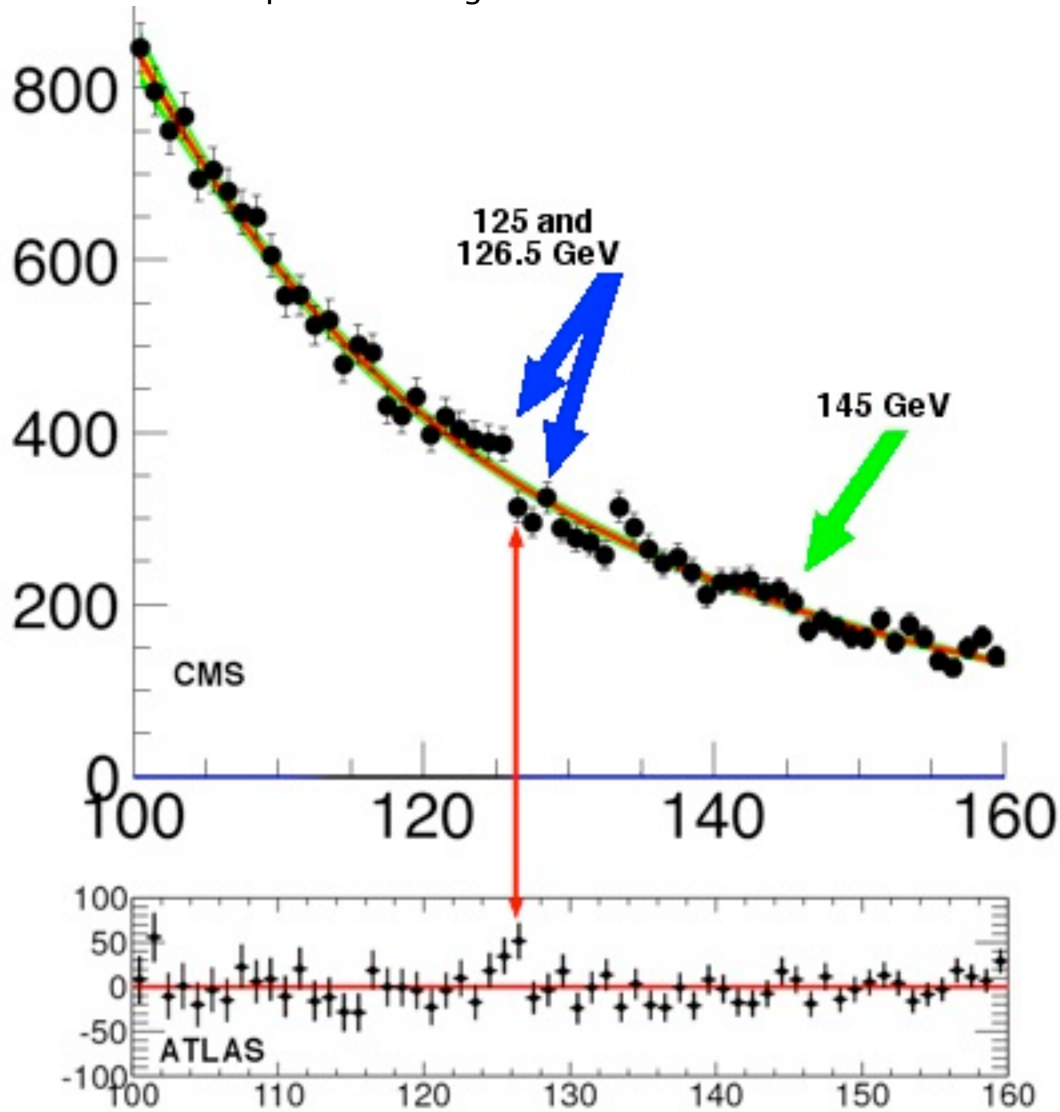
The Green Dot  where the Gold Line terminates in our Ordinary Phase
is the low-mass state of a 130 GeV Tquark and a 145 GeV Higgs.
Its location is determined by calculation of the basic Tquark and Higgs masses in an E8 physics model with mass calculations motivated by the techniques used by Armand Wyler based on mathematics of Hua Luogeng.
The **low-mass Higgs is the Higgs state that is necessary** for agreement with arXiv 0960.0954 by Ellis, Espinosa, Giudice, Hoecker and Riotto who require a Higgs with 135 < MH < 158 GeV **in order that**
"... the Standard Model may survive all the way to the Planck scale ...".
The low-mass Higgs range includes the observed excess around 145 GeV.

Since **in the 3-state system the Tquark mass is not fixed** a **Gfitter** chart



for **best fit with mt omitted** shows that the ElectroWeak data has a best fit **Higgs mass at 141 GeV (+209 -74)** which is in the low-mass Higgs range and
whose region of validity (error bars) includes also middle and high Higgs states.

The CMS and ATLAS diphoton histograms



show (blue arrows on CMS histogram) the 125 and 126.5 GeV observed peaks.
Since they are separated by about 1.5 GeV
which is about the mass difference between Charm and Up quarks,
it seems likely that they correspond to
a T0 meson (Tquark and Up antiquark) with low-mass-state Tquark
and
a T0c meson (Tquark and Charm antiquark) with low-mass-state Tquark.

The green arrow on the CMS histogram points to the 145 GeV low-mass Higgs region where CMS shows excess in both di-gamma and ZZ-4l channels
and where the Tevatron also shows excess.

The red arrow indicates a discrepancy noted by Matt Strassler on his blog on 9 Feb 2012 where he said:
"... ATLAS's largest excess (126-127) is at a point where CMS has a deficit ...
There are three possible reasons for this discrepancy.
1. There is no Higgs signal at all ...
2. There is a signal, but the shape and location of the signal are distorted because either ATLAS's or CMS's signal peak is sitting on top of a large background fluctuation. ... Were this true, by the way, then the excess at ATLAS would be a signal plus a background fluctuation, which combine to give an excess that seems too large for a Standard Model Higgs, but which will return toward the expected size as more data is gathered and the fluctuation in the background is smoothed away.
3. There is a signal, and either ATLAS or CMS has its photon energy measurement wrong by 1-2%. ...".

My view is that there is not a single-Higgs signal,

but

there are two signals (125 and 126.5 GeV) for mesons T0 and T0c

(Tquark components being low-mass Tquark states)

with

ATLAS seeing the 126.5 GeV peak

(which may be enlarged by background fluctuation (Matt Strassler's 2.)

that overwhelms the 125 GeV peak)

and

CMS seeing the 125 GeV peak

(and a very small bump at the right blue arrow near the 126.5 GeV peak).