Article

Higgs Combos, Global Fit, the Dead, the Alive & the New

Philip E. Gibbs*

Abstract

If we accept the combination uncertainty estimate and the statistical validity of combining all direct searches with electroweak fits:

- We indirectly rule out a lone standard model Higgs boson of any mass with no additional BSM physics at 90% confidence, i.e. a fair bit short of conclusively.
- We directly rule out any standard model Higgs boson at 95% confidence except in the mass ranges 114GeV to 144GeV or 240 GeV to 265 GeV or above 480 GeV.
- We do not rule out other BSM Higgs-type mechanisms including composite Higgs, technicolor Higgs, Higgs doublets, SUSY Higgs etc.
- We do not rule out high-mass Higgs bosons above 480 GeV in combination with other BSM physics that could explain electroweak fits and cure theoretical limitations of the SM at higher energies.
- We see excesses at around 130 GeV to around 160 GeV that could be between two and three sigma level. It might suggest some new physics such as some kind of Higgs particle(s) in this region. However, these are not high levels of statistical significance.

Key Words: Higgs combos, global fit, LHC, ATLAS, CMS, D0, CDF, ESP-HEPS, 2011.

Higgs Combo

Some people have been asking if confidence level plots can be combined now that we have the individual data from Dzero, CDF, ATLAS and CMS. The answer is of course not. You need to combine the underlying event data and all the backgrounds etc., and re-derive the levels from that.

On the other hand, confidence levels can sort of be combined by adding in inverse square, and there is no harm in trying so long as everyone realizes that the result is just a crude unofficial bootleg indicative approximation, right? So in that spirit here is my combined Tevatron plot

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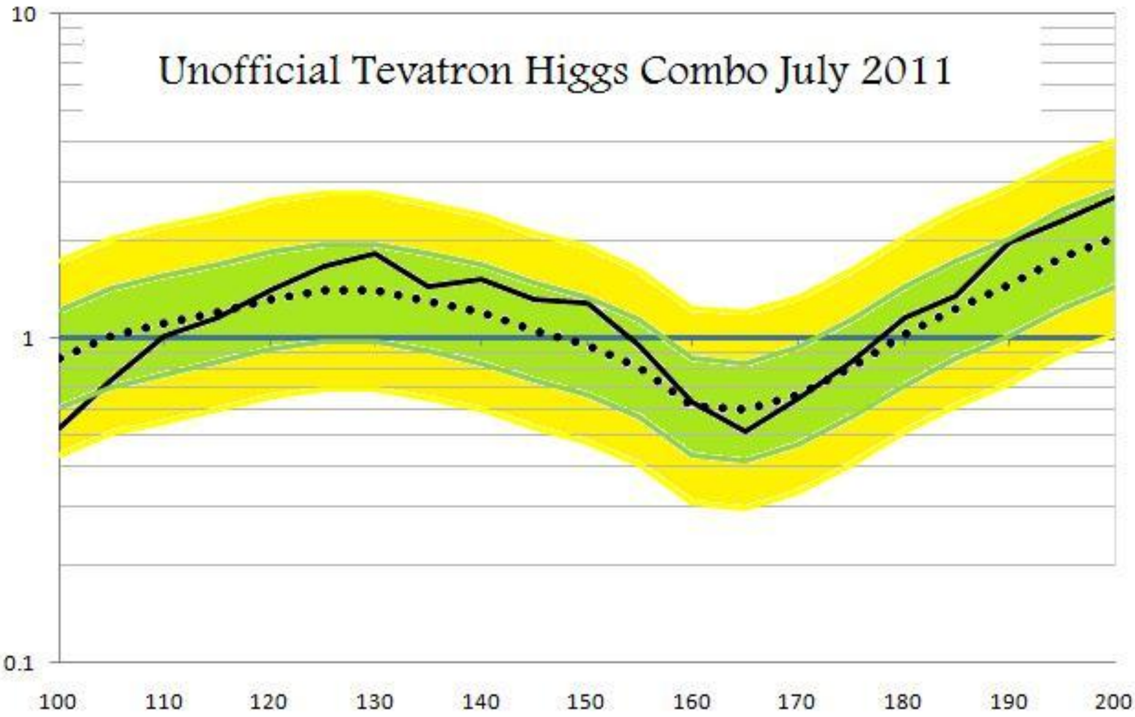
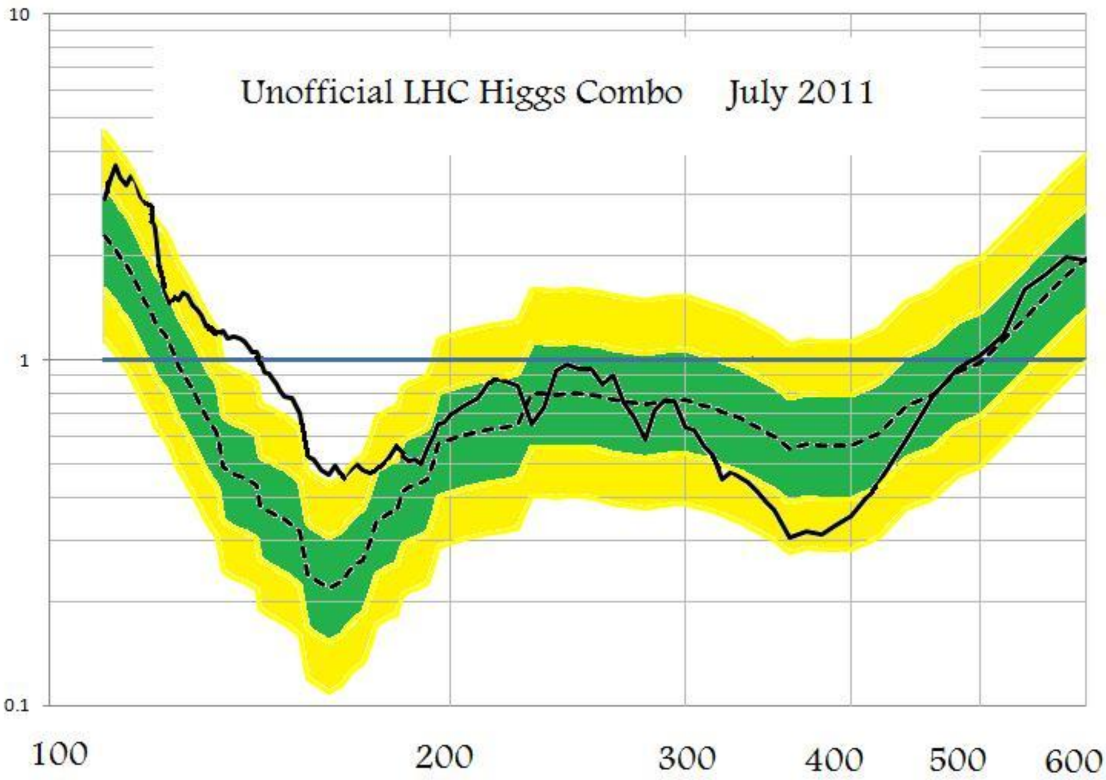
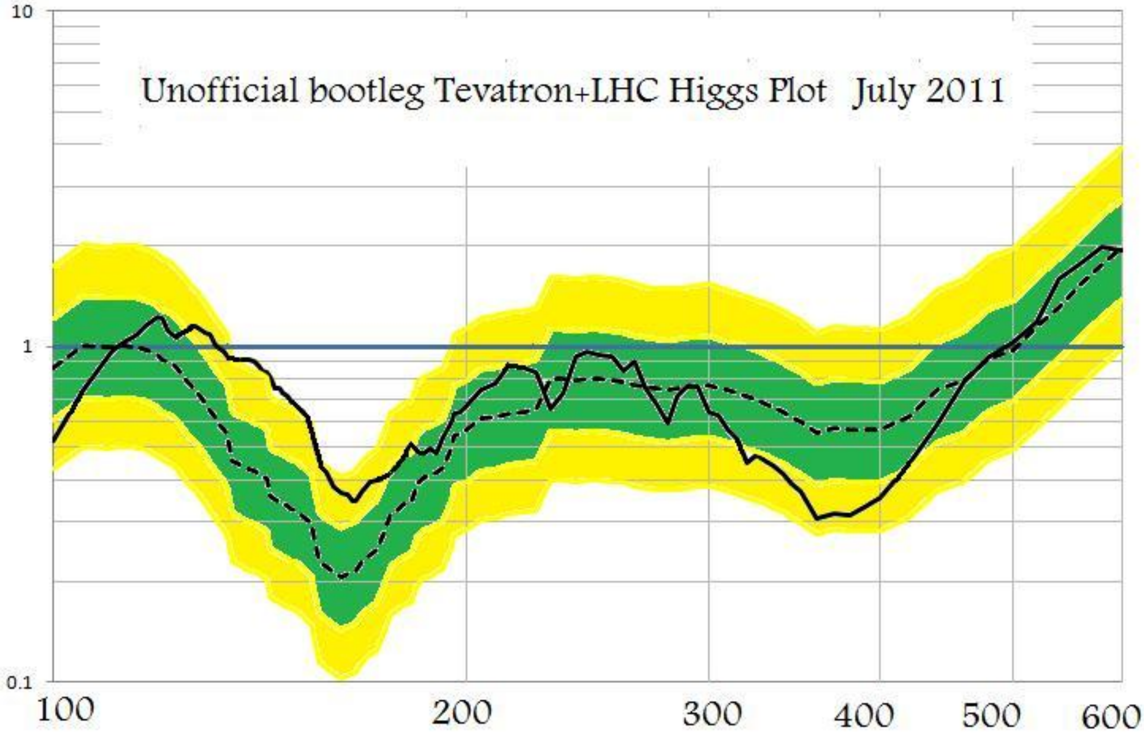
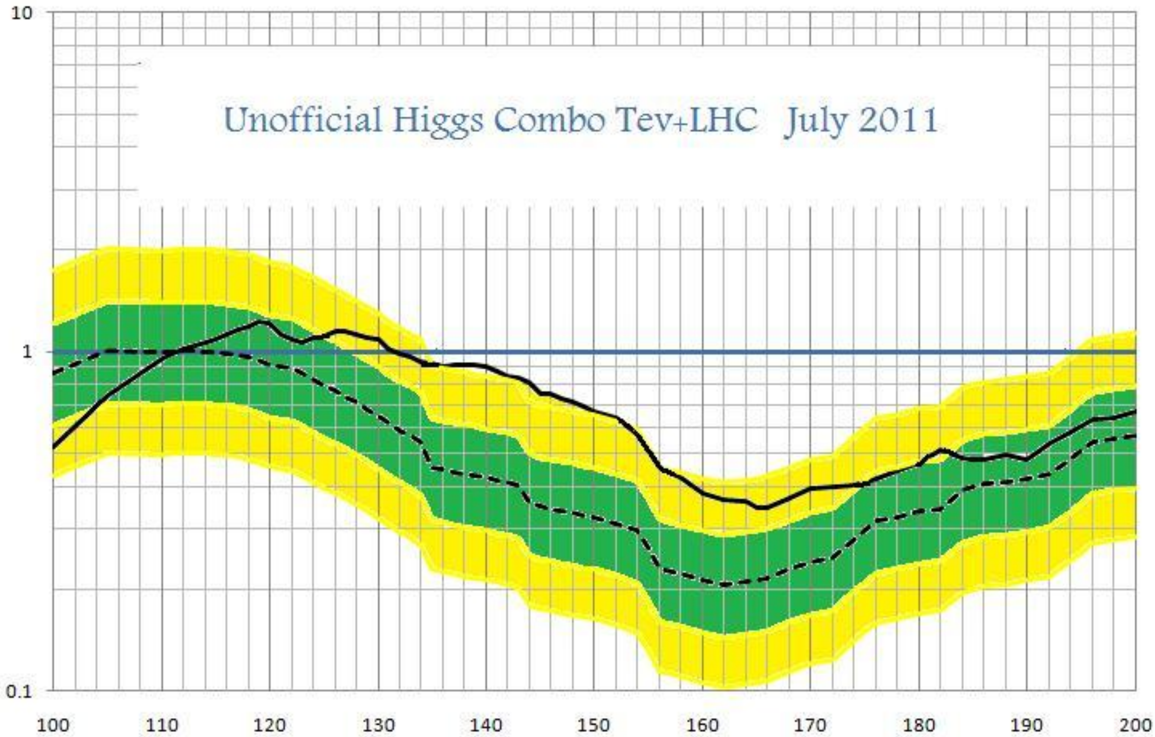


Using the same method, here is a combined LHC plot using the ATLAS and CMS plots published yesterday. It excludes all Higgs masses from 145 GeV to 480 GeV. This should be treated with skepticism, but if the Tevatron plot above matches the one that will be shown on Wednesday at EPS you will know that this one has some credibility too.



Finally, combine everything and what you get is this





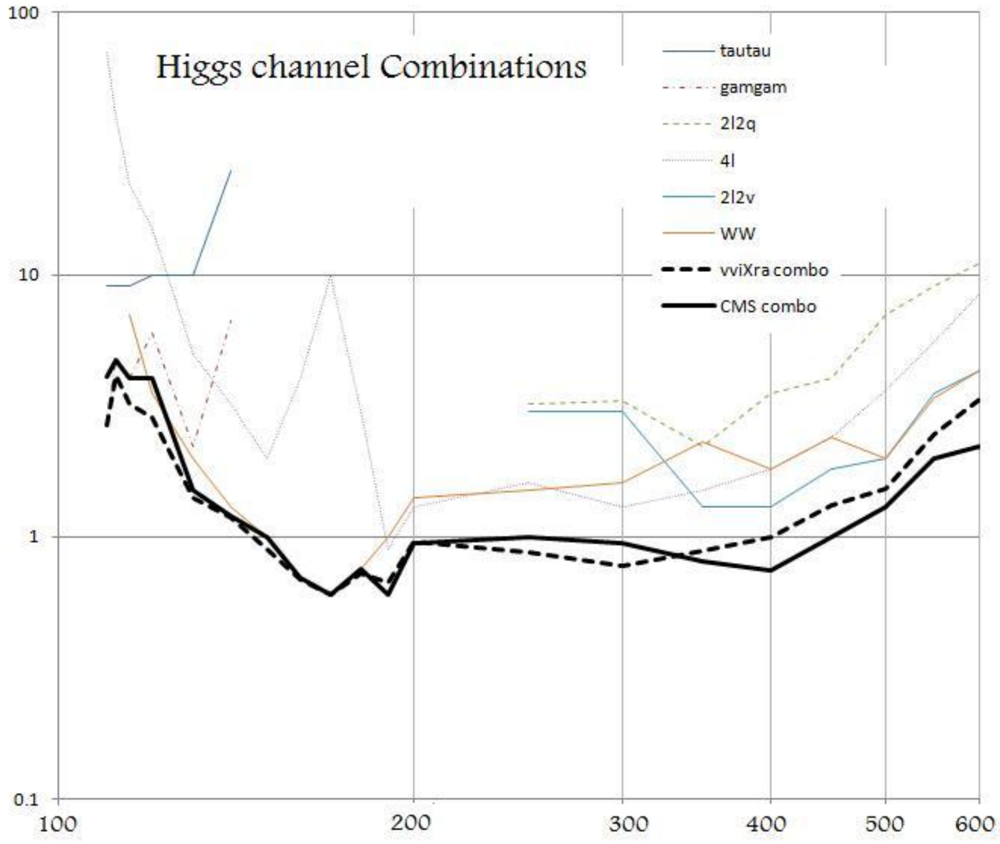
Yikes! Perhaps we shouldn't take this too seriously.

The formula used is

$$C_{combo} = (C_1^{-2} + C_2^{-2})^{-0.5}$$

This is used for the expected levels and the observed levels.

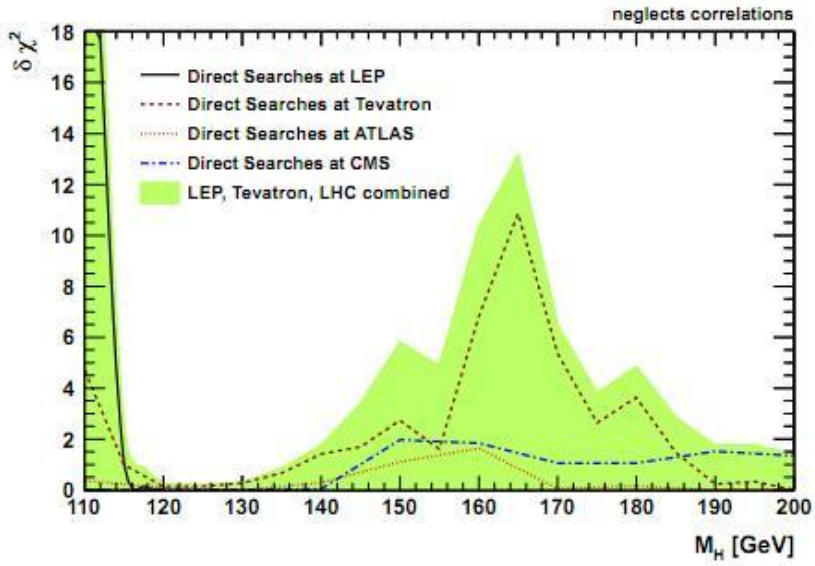
Update 25-July-2011: As an indication of how well this combination formula works here is a plot showing a combination test of the CMS decay channels using the same formula sampled at some mass points. The black dashed line is my estimated combination and the heavy black line is the official combination. It is not good enough to draw reliable conclusions about the size of any excesses but as a rough indication of what we can expect it seems very reasonable.



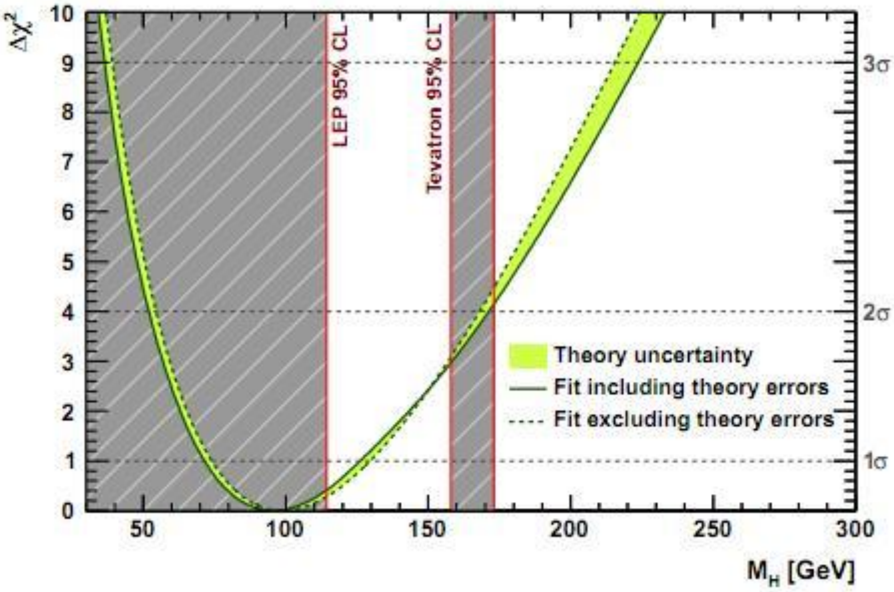
Global Fit Kills (or at least Wounds) the Standard Model

A few days ago I showed how to combine the Higgs confidence level plots by adding in inverse square. At the time I did not understand why this worked (I am a bit slow at statistics.) Since then I have looked again at the work on electroweak precision tests and the global fit where you can find the same calculation being done. The inverse square of the 95% confidence level limits is just one-quarter of the $\Delta\chi^2$ estimator. For independent variables these can be directly added to give an overall $\Delta\chi^2$ which can then be mapped back to an overall confidence level limit. This is exactly what I was doing in my combinations. So now I know that these combo plots are essentially correct, neglecting any correlations which should be zero.

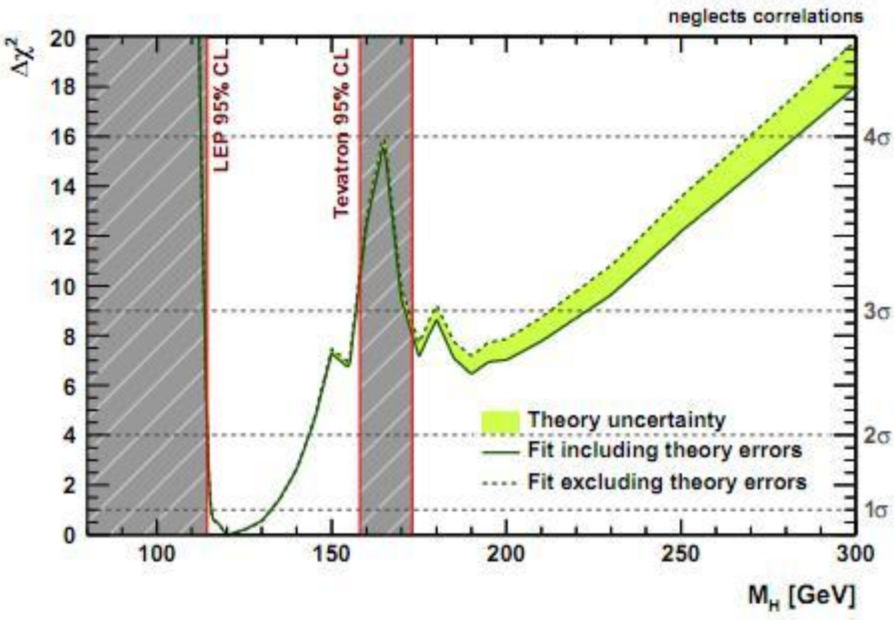
The latest update to the Global Electroweak Fit was submitted to arXiv earlier this month. There is a good plot showing the $\Delta\chi^2$ combination of the results from LEP, CMS, ATLAS and the Tevatron.



The global fit also takes into account the measurements of parameters such as the masses and widths of the W,Z and top particles. These can be fitted to the standard model to get another $\Delta\chi^2$ plot for the Higgs mass which looks like this



This can be combined with the direct searches to give an overall estimator plot

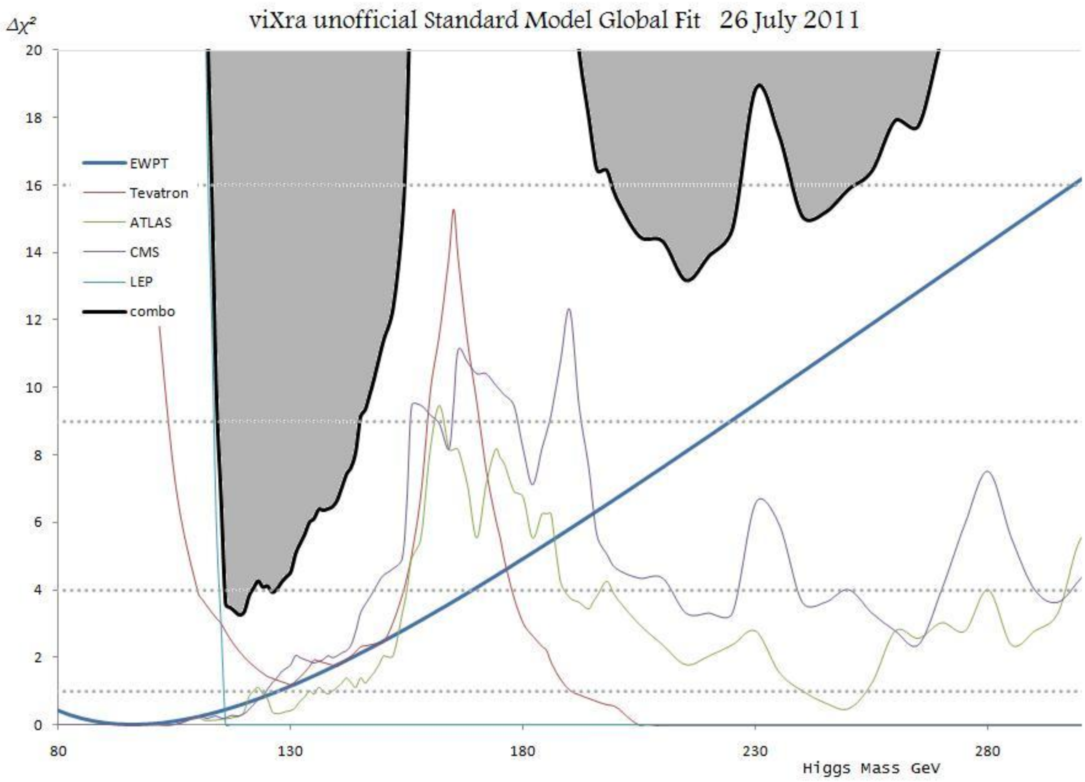


The way you read these plots is to look at the limits allowed below the horizontal dotted lines. The line at $\Delta\chi^2 = 1$ tells us the one standard deviation points so we estimate a value for the Higgs mass,

$M_H = 120^{+12}_{-5}$ GeV. (pre-EPS best fit)

The region below $\Delta\chi^2 = 4$ tells us what is allowed at 95% confidence level. Already this plot limits the Higgs mass to between 114 GeV and 143 GeV assuming that the standard model is correct.

These results were derived before the recent results of direct searches for Higgs announced at EPS HEP Now we just have to wait for the Gfitter group to update their charts using the new data. Of course you know that I am impatient and want to see this now so here is my unofficial reconstruction of the global fit using the recent direct searches and the electroweak fit from gfitter.



As you can see there is nothing in the gray region that survives at 1 sigma level. At 95% confidence everything is excluded except a small window between 115 GeV and 122 GeV. In this region the Standard Model vacuum is unstable.

In conclusion, the Standard Model is dead.

This does not kill the Higgs variants in other models such as MSSM but other fits can and will be made for these, not by me though.

What Is Dead, Alive or New?

There is a lot of interesting talk around the blogs about the fate of SUSY and even the whole field of phenomenology. It is a fascinating debate.

The CERN DG had some words of caution to give us during yesterday's press conference. These are early days for the LHC and we should not imagine that it has already given a definitive report, but it has made some good points along with the Tevatron.

The Higgs sector does not look like what the standard model predicts. There are hints of something in the light mass window but it does not look like the SM Higgs. It does not have sufficient cross-section and may be spread out over too wide a mass range. It is too early to say what that is, or even if anything is really there. Much more data must be collected so that each experiment can separately say what it sees. That could take until the end of next year, but we will certainly have more clues at the end of *this* year. If the Standard Model is out, then we cannot be sure that some heavier Higgs is not another possibility. It just wont be the SM Higgs.

SUSY predicts a light Higgs but all the searches for missing energy events predicted by SUSY have been negative so far. Does this mean SUSY is dead? Of course is doesn't. Some of the simpler SUSY models such as MSSM are looking very shaky, but there are other variants. We need some SUSY based fits using all the available data including the Higgs searches. Hopefully the phenomenologists will provide some updates for those soon to let us know what the conclusions are. I have explained in the past that SUSY is a well motivated theory. Many phenomenoligists have put a lot of work into it, but if the LHC rules it out I am sure they will be the first to give us the right reasons to think so.

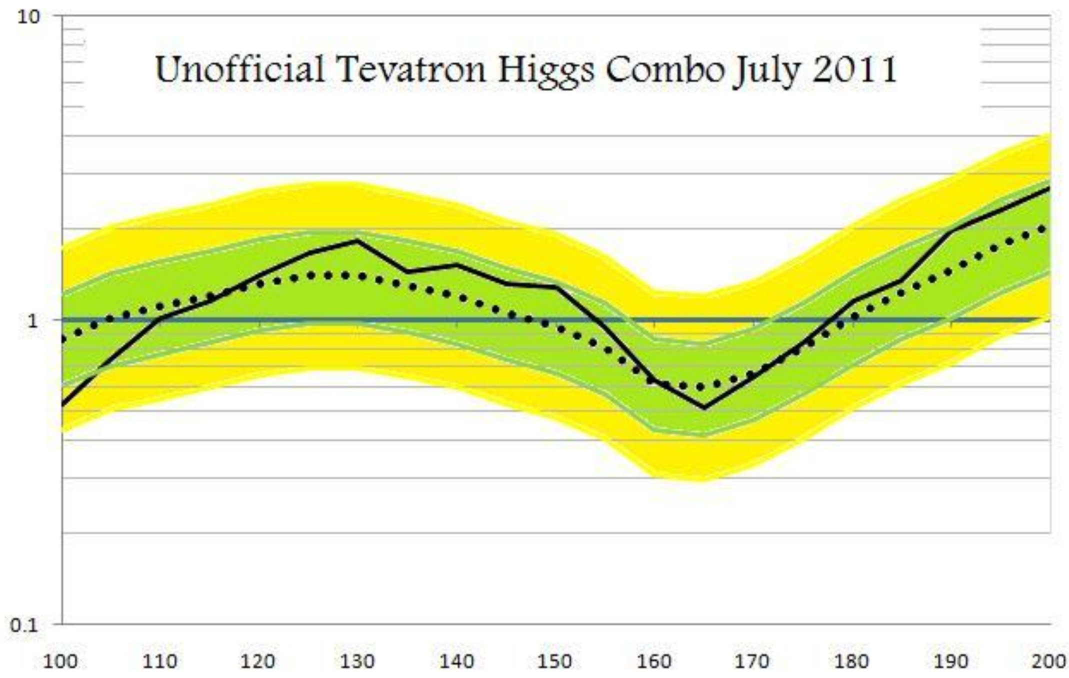
I don't agree that the work of phenomenologists has been a waste of time. Without their research the experiments would not have been able to set up the model based tests that have told us so much. A lot of different ideas apart from SUSY are being tested. They can't all be right. Following the EPS conference there will be a number of follow-up meetings to discuss the implications (see the Calendar). This will be the time for the theorists to come back and tell us what is left on the table. It will help the experimenters to prioritize the searches they want to put most effort into as more data becomes available.

The parameter space of SUSY is large and flexible but everywhere it describes a Higgs sector that is different from the standard model. That is why I think the Higgs sector is crucial to understanding whether SUSY at the electroweak scale will live or die. That part of the story is still at an early stage. The next chapters in this gripping tale will unfold in the next few months. There could be several unexpected twists on the way.

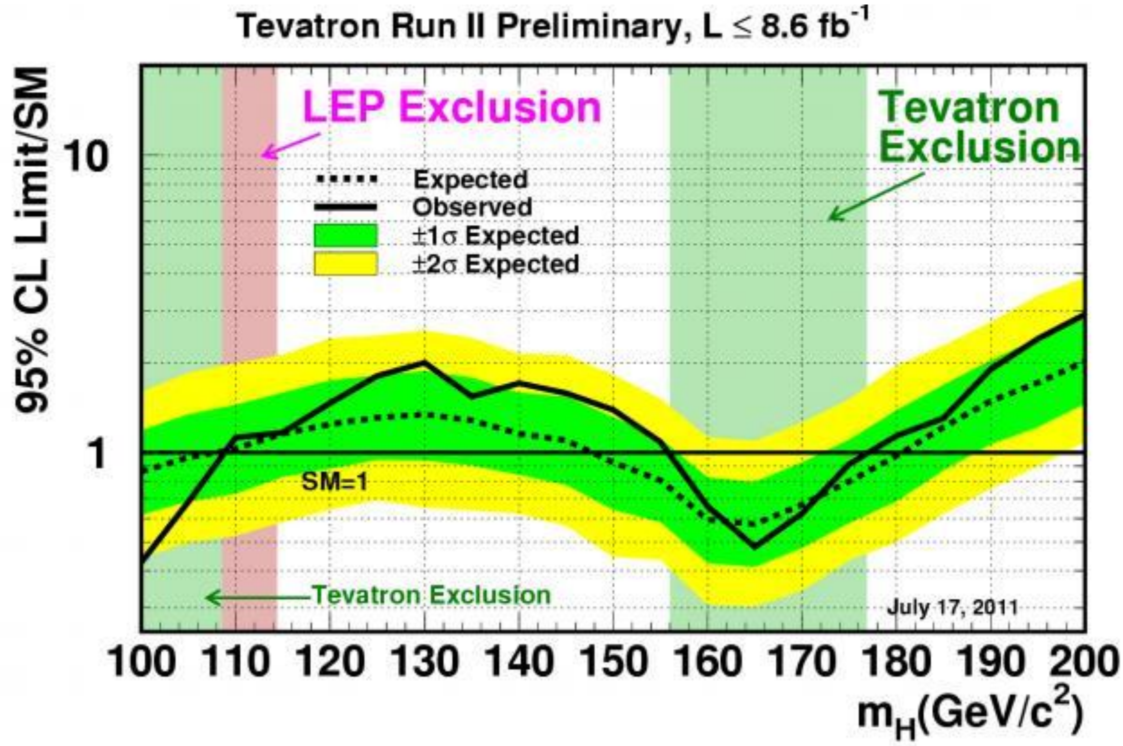
Comparing Combos

The Tevatron Higgs Combination is up, so time to compare with my prediction.

Here is mine from last week:



And now the official deal

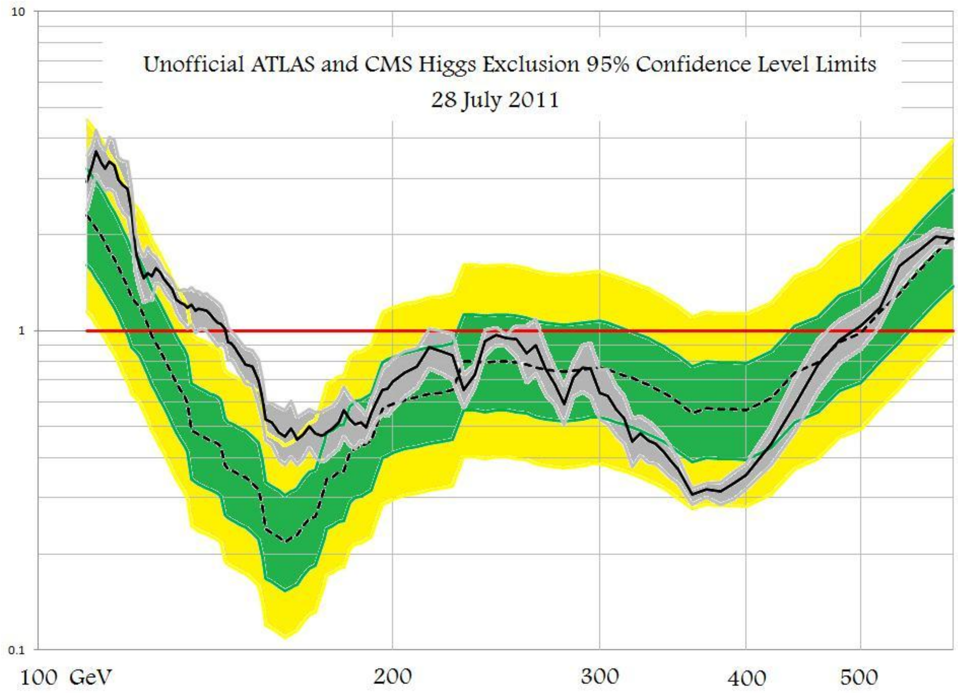


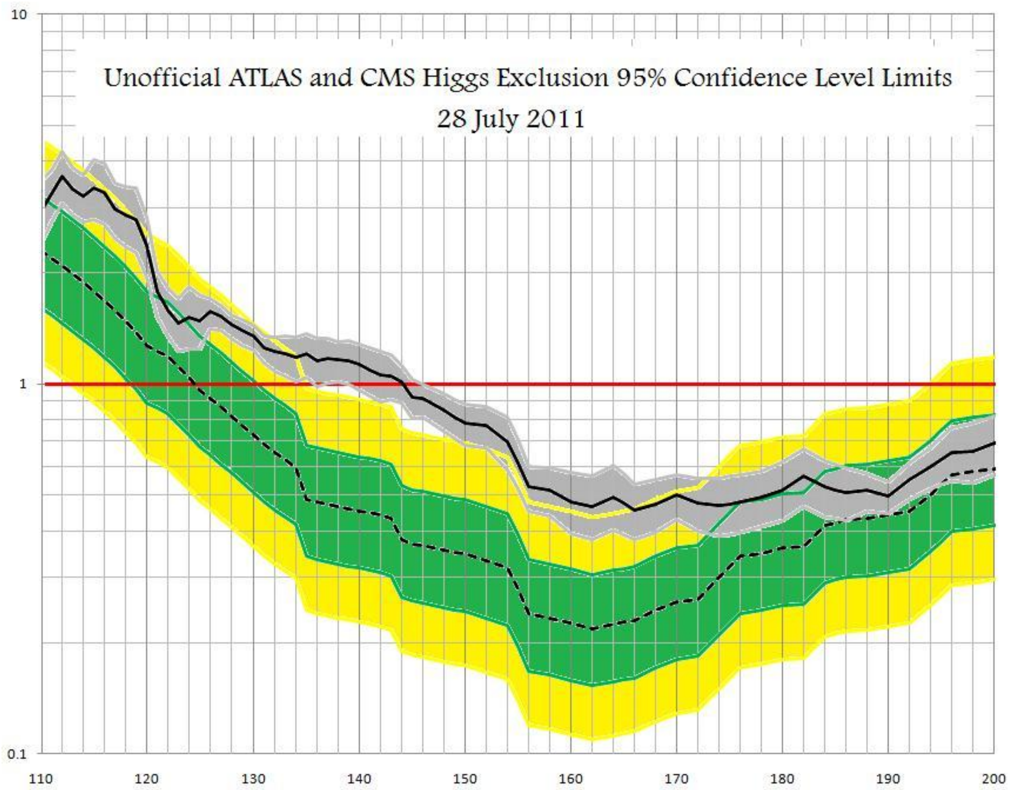
As you can see I got it pretty close. The main difference is that the peak excesses at 130 GeV and 140 GeV are a shade more pronounced on the official plot. The difference is about half a sigma. That is good news because it enhances the chance of new physics (such as a Higgs) in those regions.

Higgs Combination and Fits Revisited

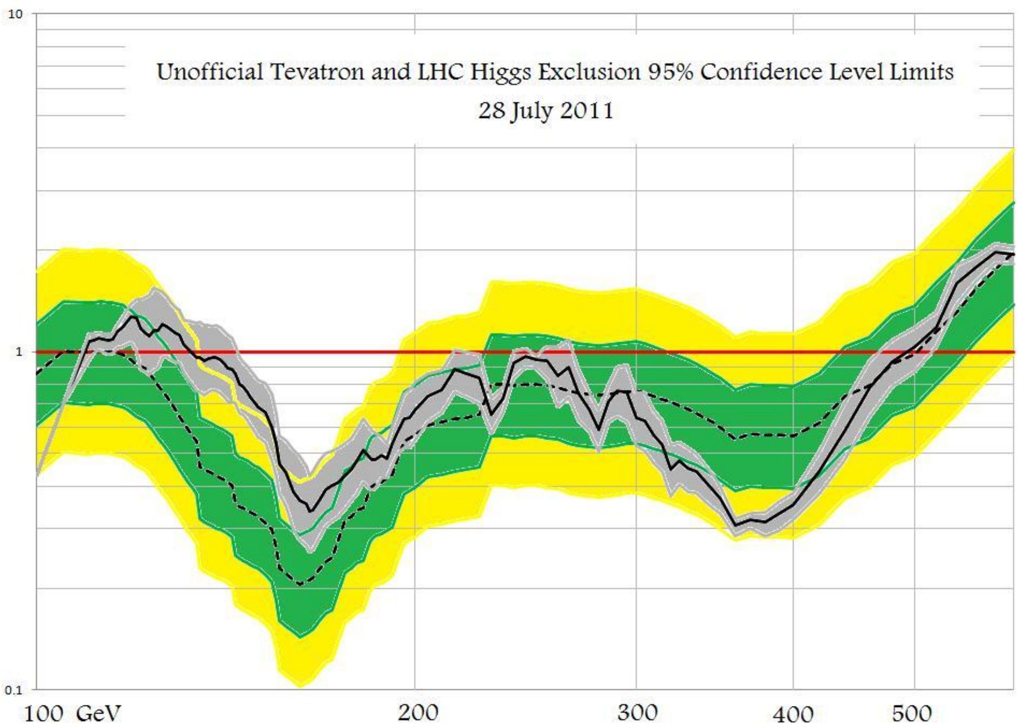
Now that the Tevatron Higgs combination is public and I can see how much error there is in the direct combination process, it seems like a good idea to redo my earlier combinations. I know lots of people are interested to see these now to give information about where we stand.

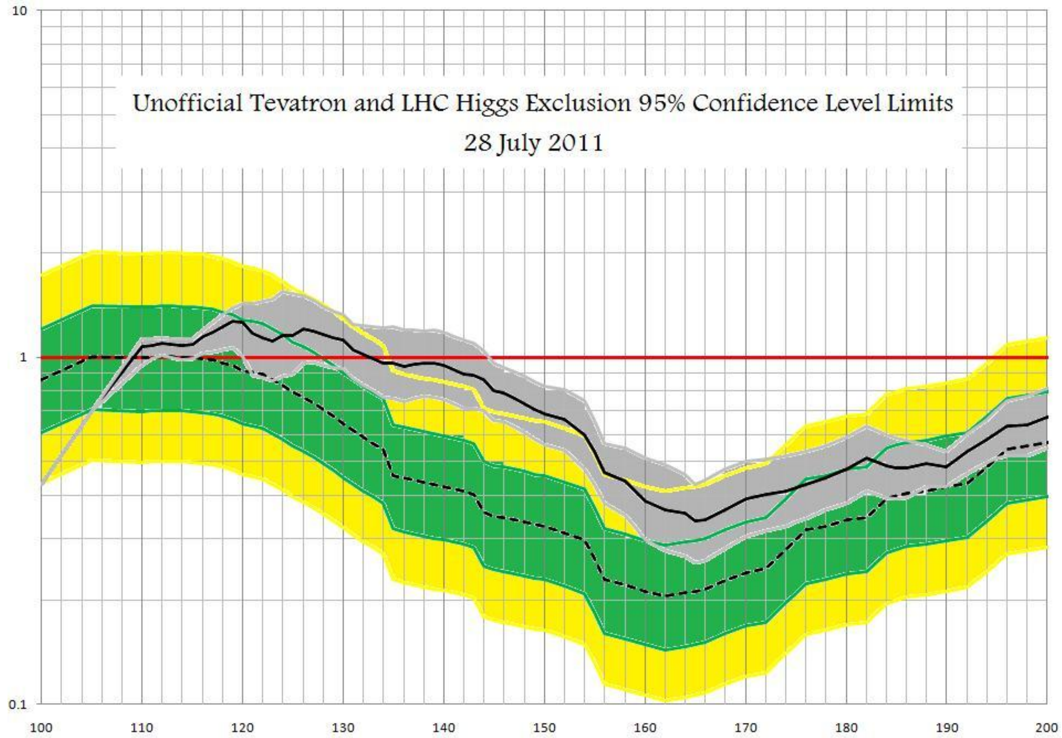
This first plot is the LHC Combination with a grey band to show the uncertainty in the combination process. This is based just on the observation that the Tevatron combination was up to half a sigma out in places and I am assuming that similar size errors can be expected for the LHC combination. Up to you to decide whether this is “Nonsense.”



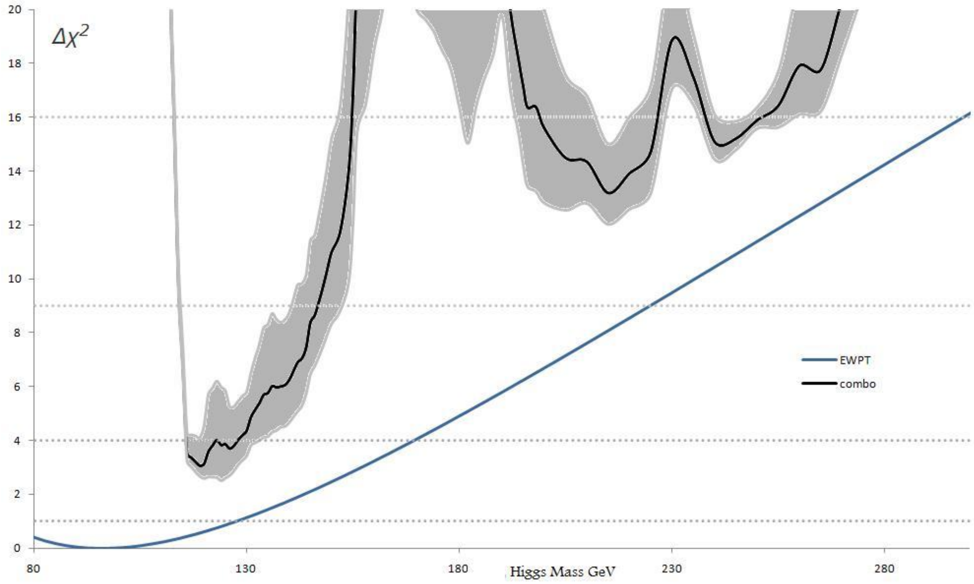


The Tevatron results are still best at the lowest masses so let's combine the new Tevatron combination with this one. there is most uncertainty in the regions where all experiments have similar limits.





What this is showing is that an excess around the 140 GeV area is possible but it is not likely to be consistent with a standard model Higgs because it is below or near the red line. We can strengthen this by doing the global fit with the combination uncertainty shown. The electroweak precision tests reduce the likelihood that a Standard Model Higgs Boson is at this mass.



If you compare this with my previous Standard Model Killer plot you will see that the black line is slightly lower at the minimum point because of the marginally less restrictive Tevatron combination. The combination uncertainty now added in grey shows that the $\Delta\chi^2$ could go as low as 2.5. Although this is not as dangerous for the Standard Model as before it still corresponds to a 90% or better exclusion for all Standard Model Higgs masses.

Some of the updated SUSY model fits only manage an 85% exclusion and other less restricted supersymmetry models would surely have a better chance. I think it is therefore reasonable to claim on this basis that Supersymmetry is in better shape than the Standard Model Higgs. This is contrary to the slant from the media and some other blogs who suggest that the excesses at 140 GeV are hints of the Higgs Boson while supersymmetry is in more trouble.

Of course many possibilities are still open and more data will certainly make a difference.

Update 29-July-2011: To be clear about what this does and does not rule out.

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References

1. http://blog.vixra.org/2011/07/23/higgs-combos/

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4. http://blog.vixra.org/2011/07/27/comparing-combos/

5. http://blog.vixra.org/2011/07/28/higgs-combination-and-fits-revisited/