Article

Did the Higgs Signal Fade? & The Best Higgs Plots Revealed

Philip E. Gibbs*

Abstract

The CMS excess did not fade at all, the difference was due to a change in the analysis from Cut-based to MVA-based for the dominant WW channel. The ATLAS combinations when reconstructed consistently only show a small decrease in the excesses. Not the large decrease advertised. Higgs boson hints are still alive. What is particularly interesting now is the bump at 140 GeV. Some people said that this excess came mostly from the WW channel, yet when the WW channel is removed the bump is still there with nearly 2-sigma significance. The two bumps peaking at 118 GeV and 128 GeV are also the right size for a Higgs signal but error bands are still too big. Any of these bumps could be statistical fluctuations but it is very unlikely that they all are. With current data available in the high-resolution channels it is not yet possible to draw robust conclusions, but I think I have demonstrated that this will be the best way to find the Higgs with future data. I hope the experimenters will take note and produce similar plots from the official data. Updated results with 2.5/fb could appear within weeks and we will see where the three candidate bumps are heading.

Key Words: Higgs combos, Higgs signal plot, LHC, ATLAS, CMS, Lepton-Photon 2011

Did the Higgs Signal Fade?

When the Lepton-Photon conference started 10 days ago there was a report in the Guardian that the signal for the Higgs boson reported at the earlier Europhysics conference had "faded". They even put figures on it saying that the excess observed by ATLAS had decreased from 2.8 to less than two and in CMS from 2.8 to 2.3. The message was echoed in other papers who picked up the story and was also reported at the conference by the collaborations themselves with CMS saying that "Excess in the low mass range seems to persist but with reduced significance."

The cause of this change was said to be the addition of some new data into the analysis, but I think this has to be looked at in more detail, so I have been doing some more combinations of the LHC data and am now working from the individual decay channel plots. The first clue that the story is not quite as straightforward as it seems comes when you look at what was said by CMS about the WW decay channels at the conferences. here first is the slide from Europhysics.

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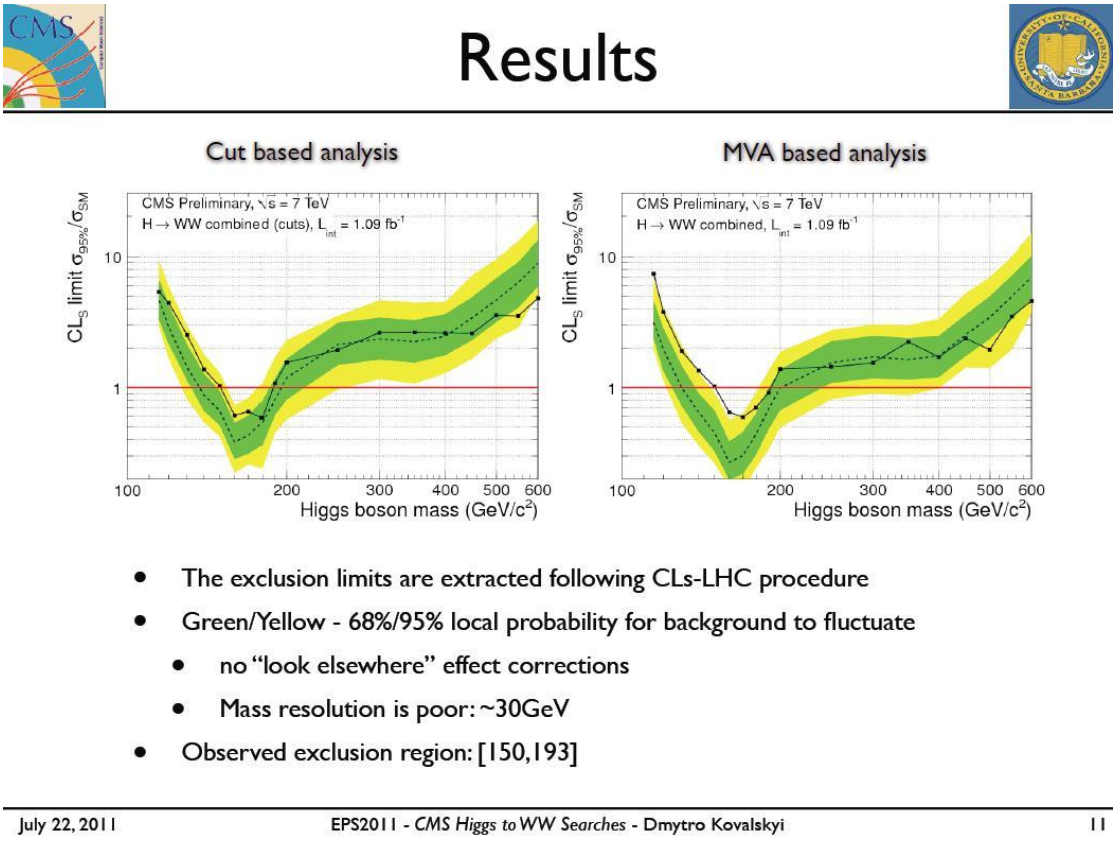
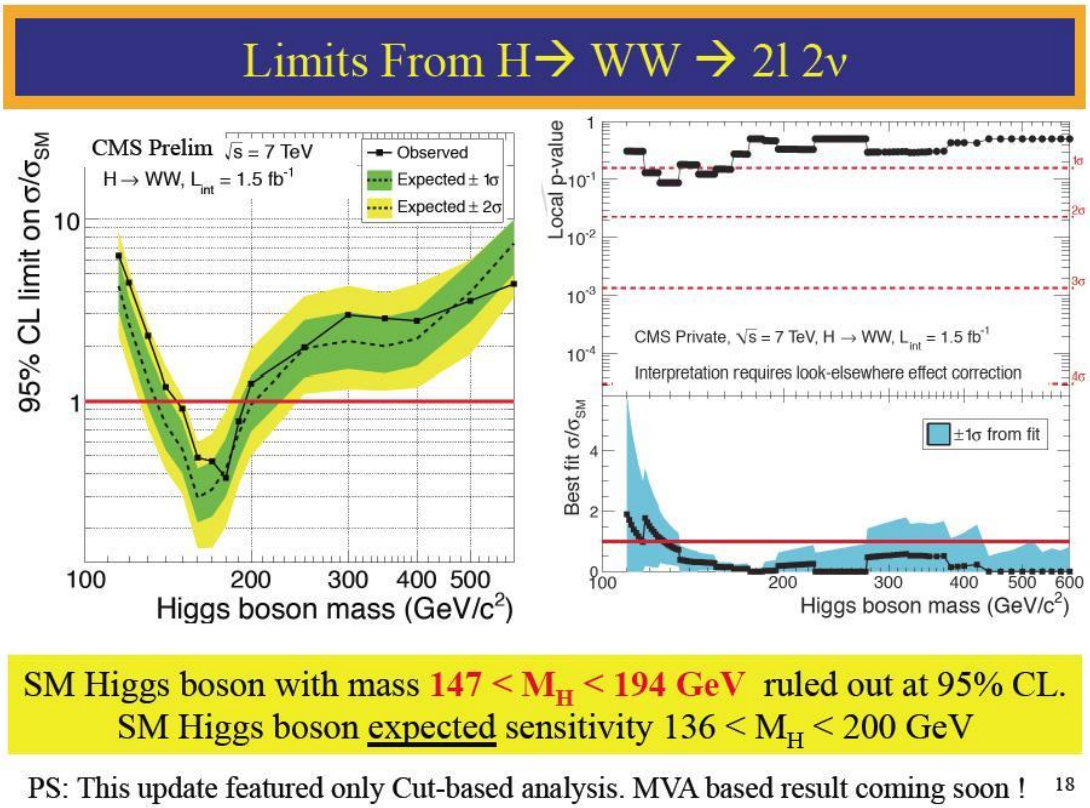


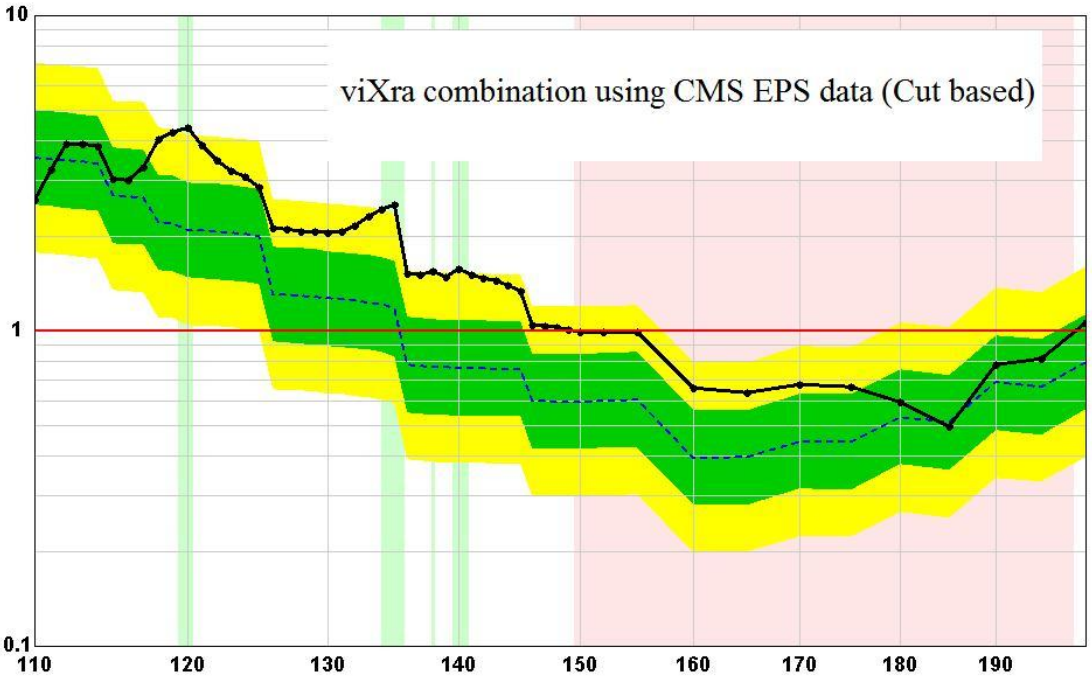
You may need to click to see full-sized. This slide shows that there are two distinct analysis methods available, "Cut based" and "MVA based". The MVA gives a much better result as shown by the lower expected CLs line. In fact it is about as good as twice as much data. You will also notice that the excess from the MVA analysis was bigger which is what you would expect if the signal is real. Indeed the MVA analysis was the one used in the final CMS combination for Europhysics.

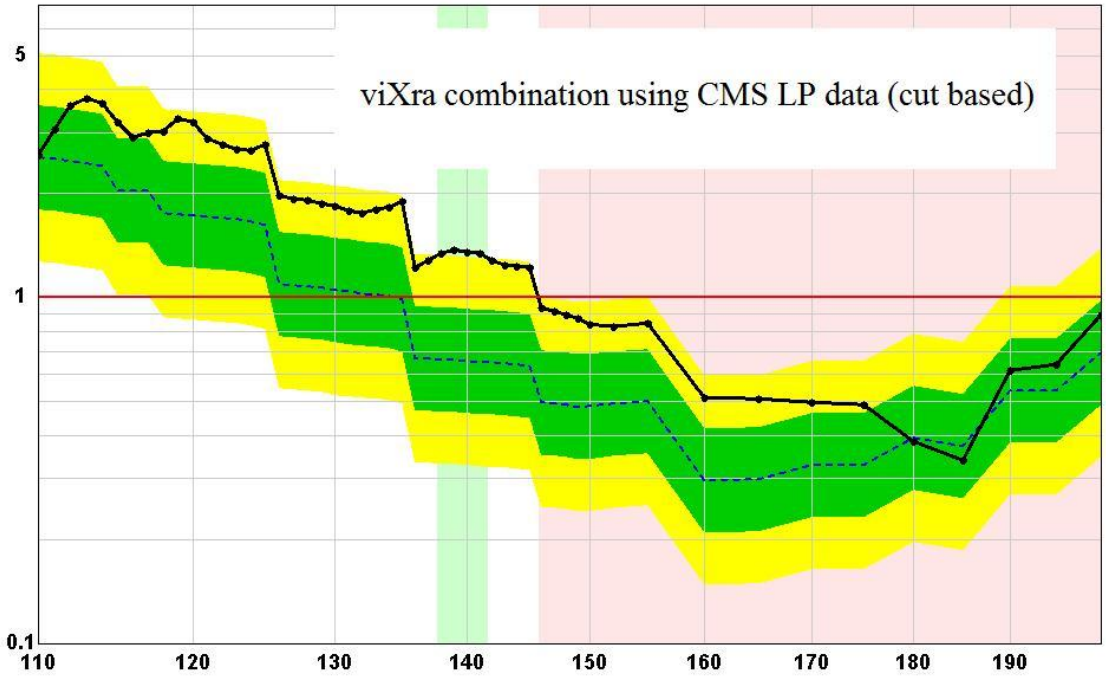
Now look at what they said at Lepton-Photon.

This shows just the Cut-based analysis with a note that the MVA-based result is coming soon! They have used 1.5/fb compared with 1.09/fb at EPS but remember that the MVA method is as good as twice as much data, so in fact the data used for WW at EPS was better and they took a backward step. The WW channel dominates the plot over the crucial range where the biggest excess was observed. You can even see directly that the expected CLs line went up higher in the LP plot compared to EPS, so really they took a step backward. A fading excess is therefore exactly what we should expect.



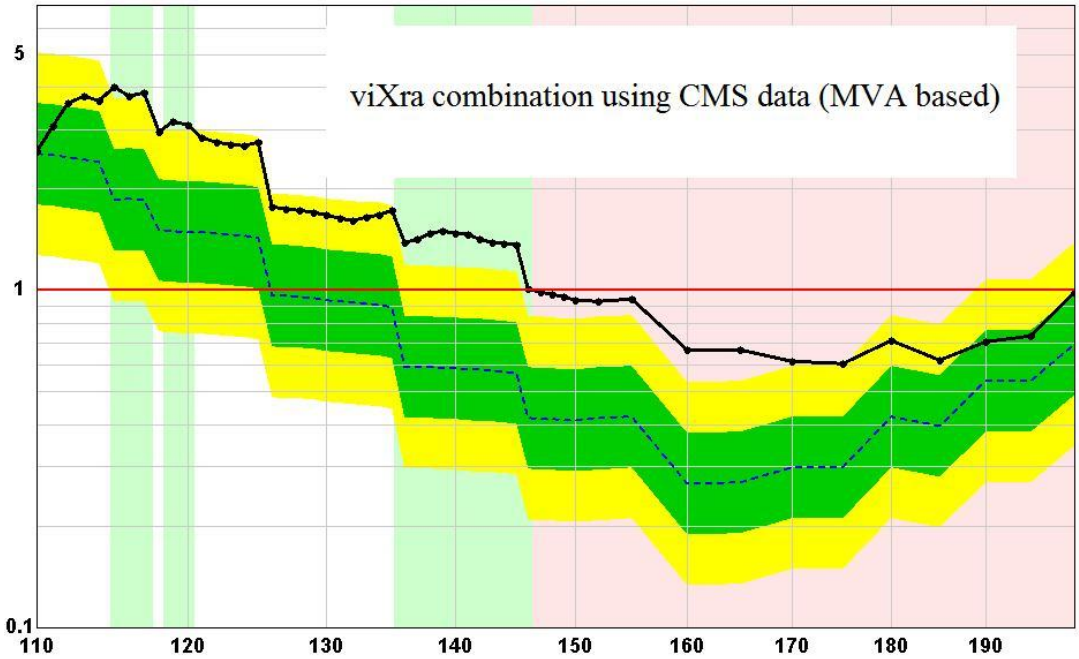
To see how much the excess actually changed we can reconstruct the EPS plot using the cut-based data and do the same thing for LP data. This is what we get





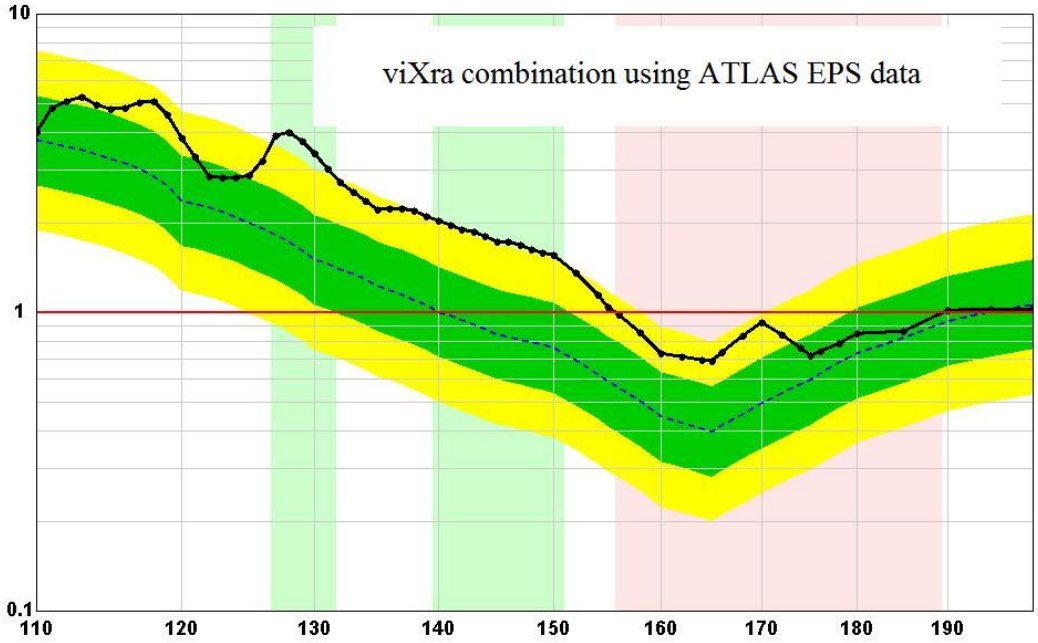
What we find is that there has been a small decrease in the excess in places, but not by much.

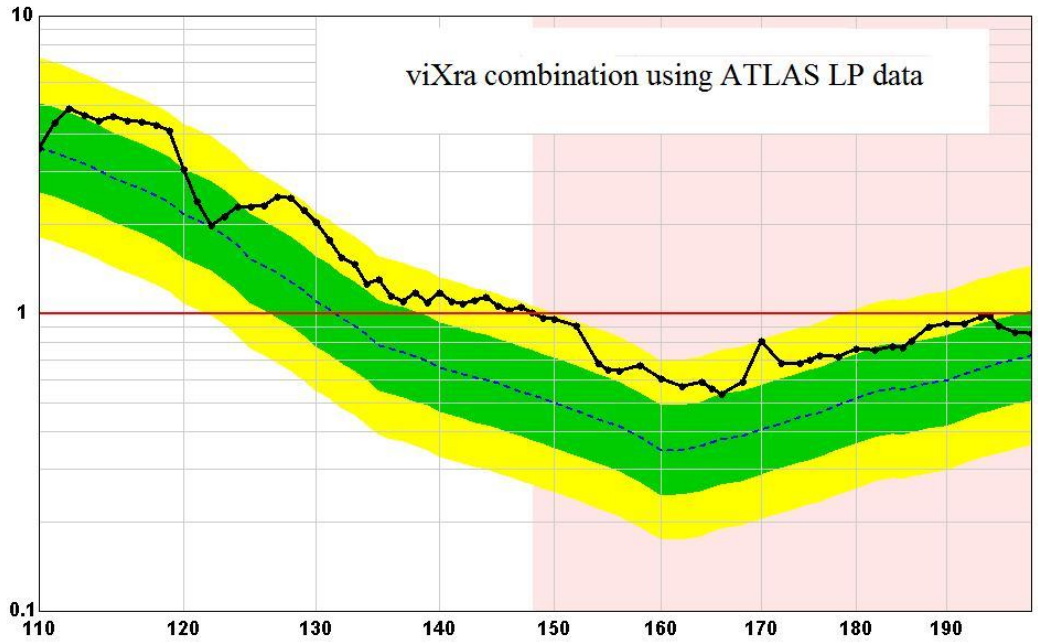
The natural thing to do next is to construct the plot using the MVA based data from EPS for the WW channel with the other channel data from LP. Since the EPS data was better for WW we should get the best possible results this way.



This brings back the broad excess previously seen with almost 3 sigma significance at 140 GeV. So what we can now say is that the observed decrease in the excess for CMS was mostly due to a change in the analysis rather than a statistical fluctuation as implied.

What about the ATLAS data? They were reported to have an even bigger decrease in the excess from 2.8 to less than 2 sigma. Here are my plots reconstructed from individual channel data.





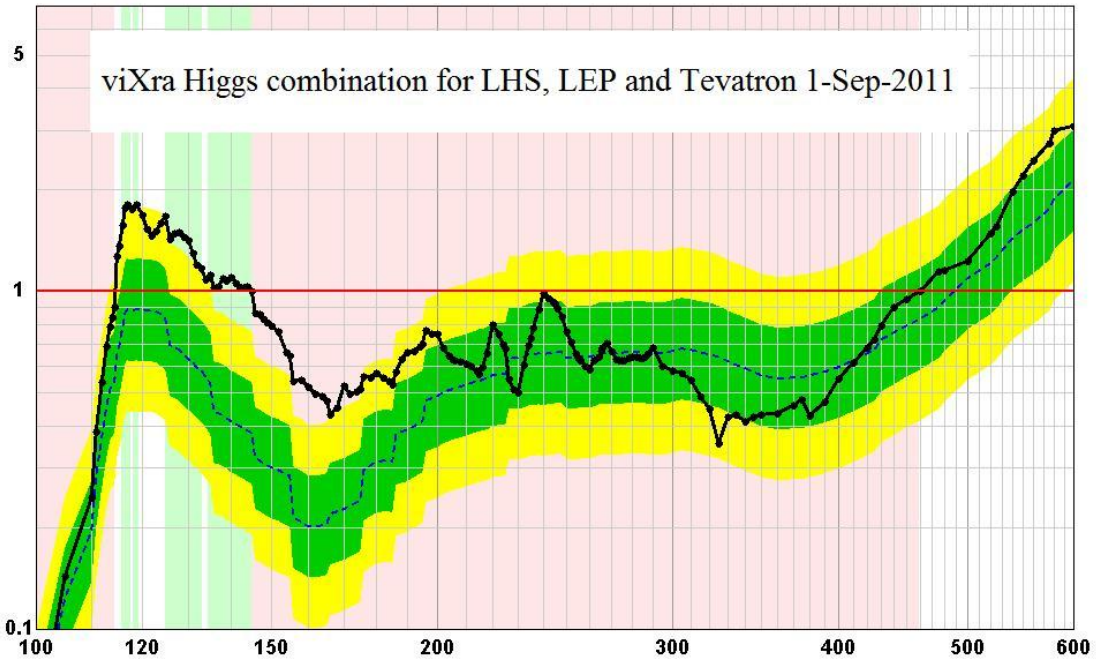
There is some decrease in the excess but not as much as advertised. In fact the signal does not appear to have been as strong as originally claimed in the first place. Of course my combinations may not be as accurate as the official ones, but at least I can be sure the analysis has not changed, just the data.

Conclusion: The CMS excess did not fade at all, the difference was due to a change in the analysis from Cut-based to MVA-based for the dominant WW channel. The ATLAS

combinations when reconstructed consistently only show a small decrease in the excesses. Not the large decrease advertised. Higgs boson hints are still alive.

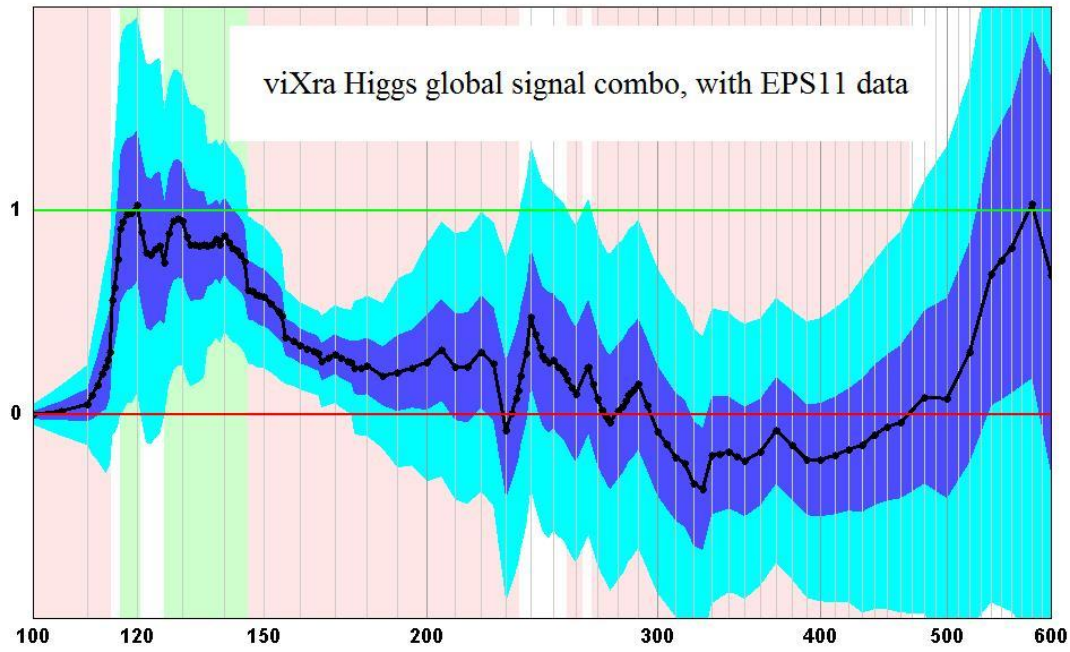
The Best Higgs Plots Revealed

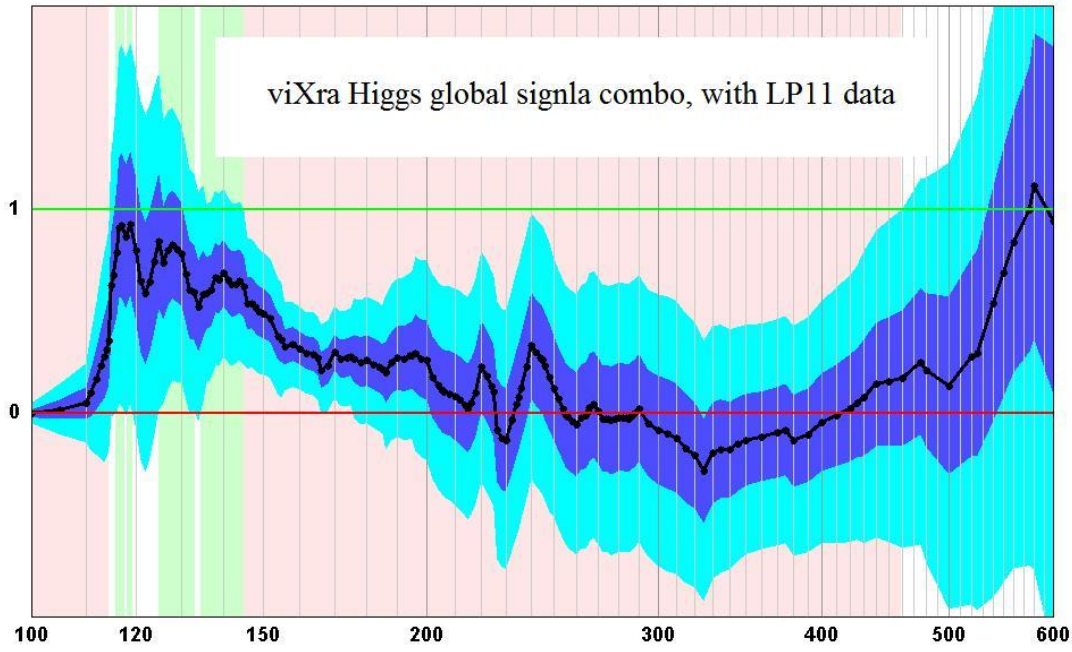
In the previous post I explained that the CMS Higgs plots shown at Lepton-Photon were not as good as they could have been because the MVA analysis for the WW channel was not ready. In fact the earlier MVA based analysis for WW shown at Europhys is better in theory than the Cut-based analysis shown at LP. The best combination plot should use all the best data from each channel over all the experiments and that means using the MVA WW channel from EPS for CMS. So here is the best possible plot (in theory) using all the best LHC data and the latest Tevatron data. I have even added in the LEP result for the first time.



This is a pretty nice result. Everything is excluded at 95% confidence in the mass range from 145 GeV to 460 GeV, but there are small excesses over the range from 115 GeV to 145 GeV. A good thing to notice about this plot is that the expected CLs line is below the 95% confidence limit all the way up to 500 GeV. If there were no Higgs boson in that range they would expect to have excluded it, but they haven't.

At this point I think that signal plots are more informative than the exclusion plots so here is how the signal changed between EPS and LP.



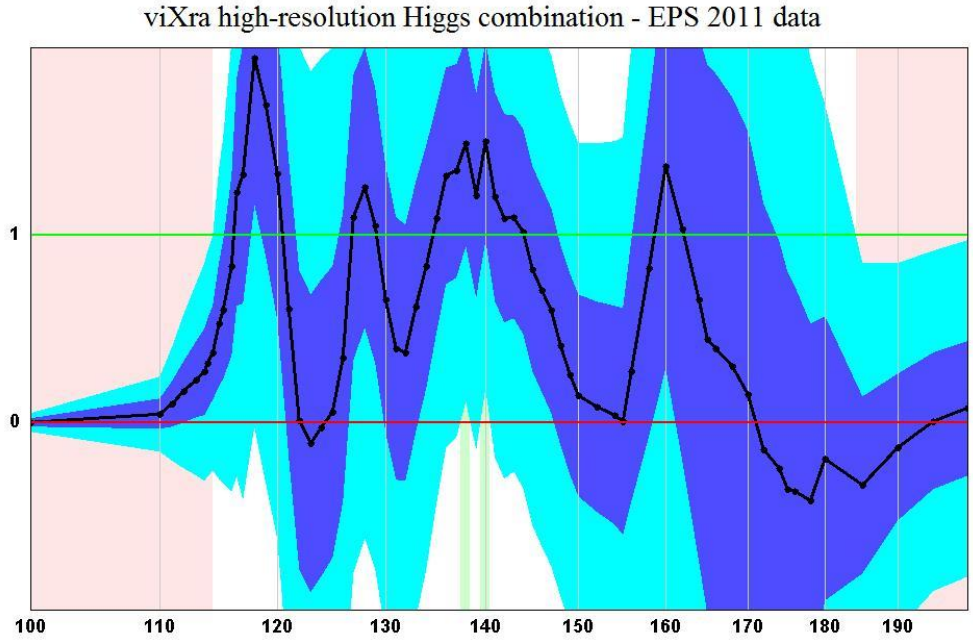


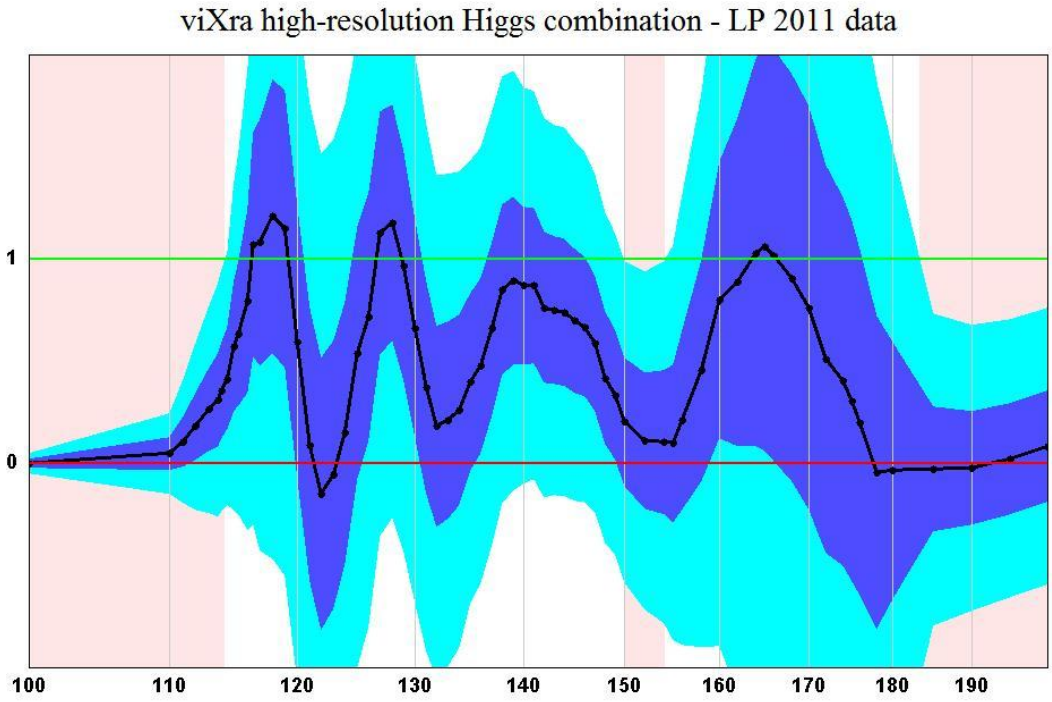
Remember that in these plots a level at zero indicates the absence of a Higgs Boson and a level at one indicates the presence of a Higgs boson. So the signal in the 115 GeV to 145 GeV is roughly the right strength for the Standard Model Higgs but it has dropped in the 140GeV area with the latest data as the error bands have tightened (though not as much as we previously thought). Now we should just wait for more data to resolve the low mass range, or should we?

I want to make the case that there is a big problem with these plots. Our expectation is that as more data comes in a sharp peak (or two) will emerge somewhere in the low mass region to reveal where the Higgs is. However, the plot is dominated by the WW channel over most of this range and the WW channel has low resolution. This is because it uses missing energy

observations to construct the underlying mass of the events. The W's decay into neutrinos which can never be detected directly. The result is that the Higgs appears as a broad excess in the WW channel and you can't locate it well. The WW channel is great for excluding large ranges of the mass spectrum, but it is not good for pinpointing a low mass Higgs that has a narrow width.

Furthermore, the situation will not improve as more data is added. The WW channel will always remain low resolution and it will always dominate the combination plot. Sadly the Tevatron data has the same problem. It is dominated by WW and bb channels with neutrinos in each case. In fact the detectors themselves have poorer resolution and even the digamma and ZZ channels are only ever plotted at 5 GeV intervals for the Tevatron. So what should we do? if some data could be making the plot worse the best thing is to remove it and see what we get. So here are the signal plots without WW channels and without Tevatron data.





These plots use mostly the digamma and ZZ channels from the LHC. The LEP data is also retained because it is high-resolution too. How many Higgs bosons do you see now? Above 160 GeV the Higgs is strongly excluded by WW data in the earlier plots. Without WW, the ZZ channel dominates but the background is high above 155 GeV which accounts for the large error bands. So the bump centred on 165 GeV can be safely ignored.

What is particularly interesting now is the bump at 140 GeV. Some people said that this excess came mostly from the WW channel, yet when the WW channel is removed the bump is still there with nearly 2-sigma significance. The two bumps peaking at 118 GeV and 128 GeV are also the right size for a Higgs signal but error bands are still too big. Any of these bumps could be statistical fluctuations but it is very unlikely that they all are.

With current data available in the high-resolution channels it is not yet possible to draw robust conclusions, but I think I have demonstrated that this will be the best way to find the Higgs with future data. I hope the experimenters will take note and produce similar plots from the official data.

Updated results with 2.5/fb could appear within weeks and we will see where the three candidate bumps are heading. With 5/fb or more by the end of the year these plots will be showing strong signals and with 10/fb or more by the end of 2012 the Higgs discovery should be conclusive from these plots, unless it isn't there.

References

1. http://blog.vixra.org/2011/08/31/did-the-higgs-signal-fade/
2. http://blog.vixra.org/2011/09/01/revealed-the-best-higgs-plots/