

Essay

Exciting New Era of Particle Physics

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Abstract

The editors of SGJ ask me to share with SGJ readers this article appeared in PSTJ V2(7) and I happily accept. I don't think there has ever been a moment quite like this in physics before. Within the next few months, weeks or even days we will learn something new about the universe that will change our thinking forever. I don't mean something like a little CP asymmetry or a new observation of neutrino physics. These things are great but they just pose questions that we cannot answer yet. What we are about to learn is going to generate so many new ideas in physics that the arXiv will run out of four digit numbers so that people have to start posting their papers in viXra. Am I exaggerating? Let us see take a look.

Key Words: LHC, Tevatron, new particle, Higgs, New Era.

I am of course talking about the Higgs sector and what it will tell us about the way particles interact. Given the mass exclusions we already know from the Tevatron it is already more likely that the Higgs sector will be described by something outside the standard model. With the exception of two small mass ranges either side of the presently excluded region, a Higgs boson that is consistent with the standard model is not now possible. The answer is probably going to be something else, perhaps a Higgs multiplet from some form of supersymmetry, or perhaps no Higgs at all. Whatever it is, it will lead to a new standard model with new physics that we don't yet know, but we probably will by the end of this year. There is a fair chance it will lead to an understanding of what dark matter is, how inflation worked and perhaps a lot more. This is a great year to be a physicist.

The fun has started at the Europhysics HEP conference (EPS2011). It might have even begun sooner if CERN would release all the results as conference notes before the start as they did for PLHC in June 2011. Personally I would rather it was announced at the conference. That would be more dramatic but if it would become public before you can be sure we will report it at viXra Log.

EPS 2011

So what have been shown at EPS2011, the main conference on particle physics this year? There was a list of 370 talks online and 130 posters. All are interesting in their own way, but at least 60 of them have included new results from LHC and the Tevatron that could contain new physics about the Higgs sector. These are the ones everybody has been looking out for.

The interest starts on day one, the 21st July. ATLAS will present some SUSY search results which may or may not go beyond the results from PLHC last month. Then CFD and D0 will give us all the details of their Higgs channels using 8.5/fb or 8.9/fb for each one. This will be

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covered in five talks in the space of a couple of hours. At moriond the Tevatron already gave results using up to 8.2/fb but not for all channels so there could be some very useful information here about lower mass Higgs. They are not likely to see a signal but they could limit further or even exclude those last few places where a standard model Higgs can live.

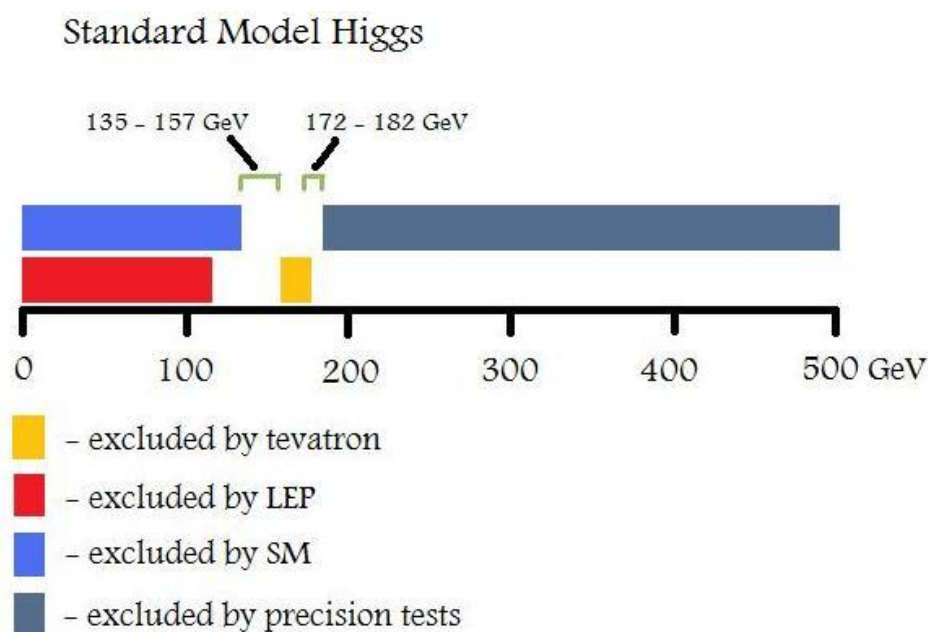
On the second day we will see the Higgs search results from CMS and ATLAS, including all the individual channels and the combined results for each experiment. Some new searches for charged Higgs will also be included. This is the day when we are most likely to see the first signs of something spectacular, (if the beans have not already been spilt by then). That is because most of these results will be using about 1/fb of data, five times what was shown last month for a few searches and thirty times what has been used in most of them before. Even some of the posters have new results about SUSY on offer with 2011 data. I'm going to assume that 1/fb of data will be the norm for these results, but if it is less for some we will just have slightly longer to wait.

On the fifth day the Plenary sessions will start. There will be an "opening" address days after all the interesting talks have sunk in, just like at ICHEP last year when President Sarkozy turned up to give a speech. We don't know who will appear this time. There will be a press conference but that will probably be just for the Main Stream Media and will not be broadcast. We don't care because we will already have all the best information.

The plenary talks will be webcast live and will make fascinating viewing. The opening talk will be by Smoot on cosmology. There will be summaries of the results of the Higgs searches and outlooks from each continent. The plenary talks will be spread over three days.

Let's now look in more detail at what the Higgs sector has to offer that could be so thrilling.

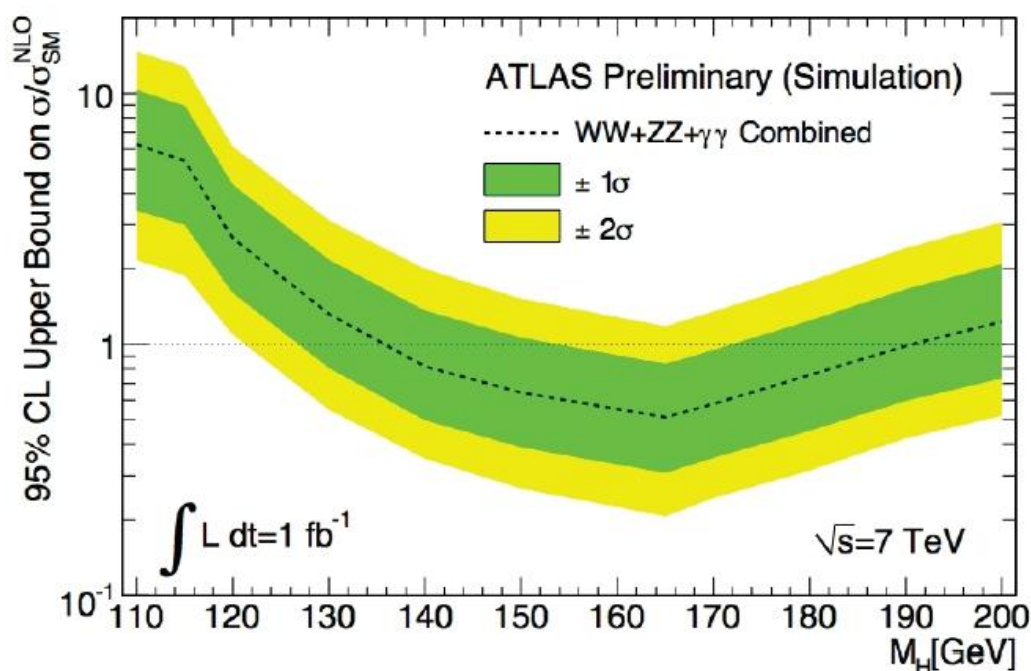
The Standard Model Higgs



What are the chances that the Higgs sector is described by a single standard model Higgs Boson? This is the least interesting result we could get because it would tell us nothing about Dark Matter or anything else beyond the standard model.

Most of the mass regions for a SM Higgs are already ruled out. From theory we know that a lone Higgs boson below 135 GeV would destabilise the vacuum. The Tevatron has excluded it in direct searches from 157 GeV to 172 GeV, and electroweak precision tests from LEP and the Tevatron rule out a standard model Higgs above 182 GeV. So there are just two small windows where it can still be hiding.

If it is not in these two mass regions then ATLAS will be able to show us a plot on the 22nd July that looks like this earlier simulation



This will exclude the possibility that a lone standard model Higgs is the answer. In case they are unlucky with the statistics, CMS have the same reach and the Tevatron combined analysis will too. If the Higgs is in those windows then the combined projected significance for the LHC is 3 to 5 sigmas depending on the exact mass. By combining the signals we should have a very good indication of where it is by next week, unless the standard model is not everything to be found.

Higgsless

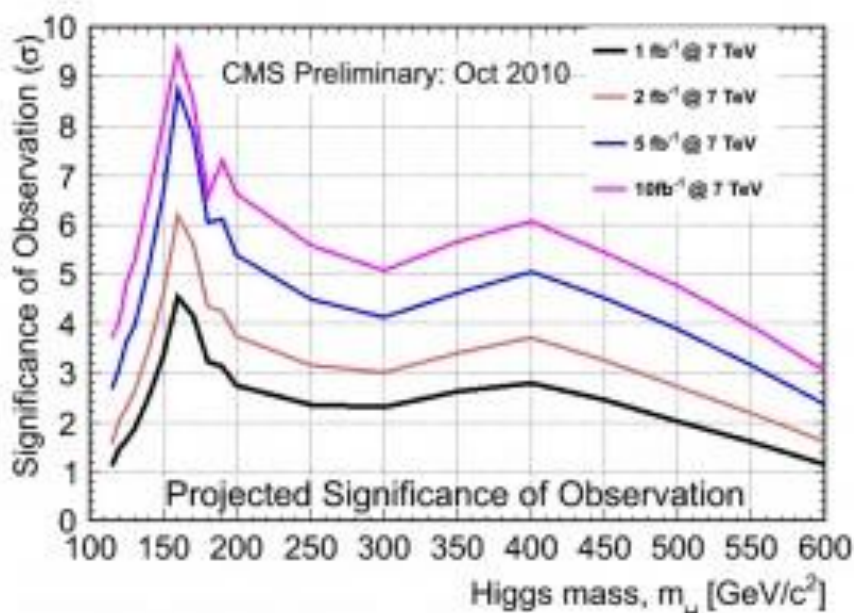
What if there is no Higgs signal to be found? Theories that propose this tend to use quite innovative ideas such as gravity induced symmetry breaking. Because these ideas are often quite outlandish it is right to say that a total exclusion of the Higgs would be the most revolutionary result the LHC could provide.

The combined 2/fb from ATLAS and CMS is sufficient to rule out the Higgs from about 120GeV to 535 GeV. Although a combined plot will not be presented at EPS-HEP, the

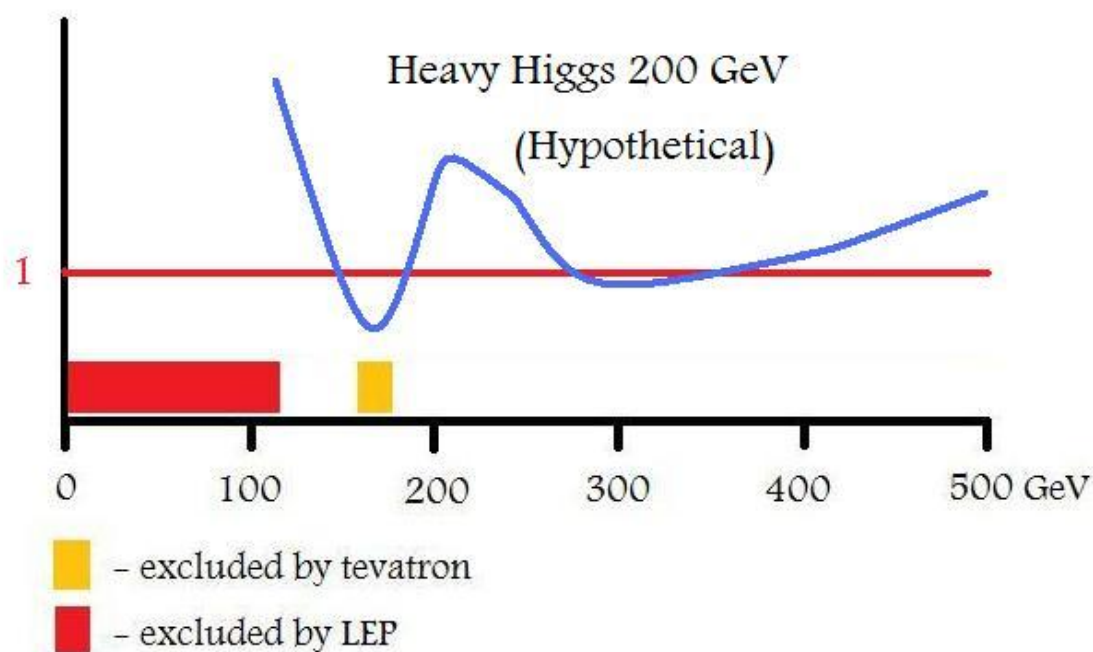
individual results will be. These can be crudely combined by comparing bumps to see if the combined plot is likely to produce anything of significance. The Tevatron will also add information especially for the remaining window between 114 GeV and 120 GeV. So if the Higgs sector is Higgsless up to 500 GeV we are going to have a good indication of that too next week. A much heavier Higgs might be possible but it would have to be accompanied by other heavy particles to account for the electroweak precision tests. Chances are there would be some other clue in the data about what is going on, and it might be revealed next week.

Heavy Higgs

Precision tests suggest that the Higgs cannot be heavy, but these tests assume there is no other physics. If we rule out the standard model they don't apply anymore and a Higgs boson above 182 GeV is perfectly possible. Using this plot of projected significance we can get an idea of what might be coming.



If there is a Higgs boson in the range 200 GeV to 500 GeV it should produce a signal with between 2 and 3 sigma significance from 1/fb. A signal of that size would be inconclusive, but if the same signal appears for both ATLAS and CMS it would be a different story. Here is a rough indication of what kind of shape we might expect to see if there is a heavy [Higgs at around 200GeV](#)



I have not included the expected significance but the peak at 200 GeV would have to be around 2 to 3 sigmas. An enlarged exclusion around the existing tevatron exclusion is to be expected and a new exclusion higher up is possible. This makes the signal an isolated peak, but the signal itself should be not more than about 20 GeV wide.

Finding a heavy Higgs signal would be a dramatic new result because there would have to be something else with it to account for precision tests. That might show up too, either as another peak on the same plot or in other searches.

Light Higgs and Multiplets

A light Higgs is harder to locate for CMS and ATLAS but if they present their full digamma results as 1/fb and the Tevatron present their results at 8.5/fb, then the combined signal could be promising. A light Higgs is the signature of SUSY and is usually accompanied by other bosons. The MSSM has a multiplet of five Higgs some of which are charged. The next model has seven of them. These extra bosons are likely to be in a range that could be seen as another heavy Higgs or in charged Higgs searches that are also being presented. A light Higgs on its own destabilises the vacuum so it is hard to see how it could not be accompanied by something else.

Whatever way you look at it the chances are we will have something positive to look at for EPS, and if we don't there will be more data for the next conference with between 5/fb and 10/fb by the end of this year for each of ATLAS and CMS. Whatever is found will tell us in quantitative detail about how the Higgs sector works and it will inspire many new lines of theoretical search to be tested in the years that follow.

I know that some people think the collaborations need to be still more open and fast with their data, but it is unprecedented for such large collaborations in particle physics to show so

many results so soon after the data has been collected. It is really an impressive achievement if they do.

Therefore, we should all be grateful about the data of these experiments being made available very quickly. With a lot of other big-science experiments the people running them keep the data to themselves for years so that they can analyse it in detail before anyone else has a chance (c.f. Planck). The collaborations here are making extraordinary efforts to get the data out as soon as possible giving the whole physics community a chance to go through it. Science will progress faster that way so we should applaud them and hope that the theorists take full advantage of the opportunity being offered.

References

1. <http://blog.vixra.org/2011/07/16/hold-your-breath/>