The Higgs boson is the only particle predicted by the Standard Model (SM) of particle physics that has not yet been experimentally observed. Its observation would be a major step forward in our understanding of how particles acquire mass. Conversely, not finding the SM Higgs boson at the LHC would be very significant and would lead to a greater focus on alternative theories that extend beyond the Standard Model, with associated Higgs-like particles.

Today the CMS Collaboration presented their latest results in the search for the Standard Model Higgs boson, using the entire data sample of proton-proton collisions collected up to the end of 2011. These data amount to 4.7 fb⁻¹ of integrated luminosity [REF: FB], meaning that CMS can study Higgs production in almost the entire mass range above the limit from CERN’s Large Electron Positron (LEP) collider of 114 GeV/c² (or 114 GeV in natural units [REF: GEV]) and up to 600 GeV. Our results were achieved by combining searches in a number of predicted Higgs “decays channels” including: pairs of W or Z bosons, which decay to four leptons; pairs of heavy quarks; pairs of tau leptons; and pairs of photons (Figure 1).

**Figure 1:** A typical candidate event including two high-energy photons whose energy (depicted by red towers) is measured in the CMS electromagnetic calorimeter. The yellow lines are the measured tracks of other particles produced in the collision.

Our preliminary results, for several statistical confidence levels [REF: CL], exclude the existence of the SM Higgs boson in a wide range of possible Higgs boson masses:

- 127 – 600 GeV at 95% confidence level, as shown in Figure 2a;
• 128 – 525 GeV at 99% confidence level.

A mass is said to be “excluded at 95% confidence level” if the Standard Model Higgs boson with that mass would yield more evidence than that observed in our data at least 95% of the time in a set of repeated experiments.

Figure 2a: Exclusion limit on the mass of the SM Higgs boson at 95% confidence level (below red line). The analysis is based on 4.7 fb⁻¹ of proton-proton data collected by CMS in 2010 and 2011. The hatched bands show the mass regions previously excluded by LEP, the Fermilab Tevatron, and now by CMS. The dashed line and the green and yellow bands show the average expected CMS sensitivity corresponding to the actual amount of data analysed.

We do not exclude a SM Higgs boson with a mass between 115 GeV and 127 GeV at 95% confidence level. Compared to the SM prediction there is an excess of events in this mass region (see Figure 2b), that appears, quite consistently, in five independent channels.
Figure 2b: SM Higgs exclusion limit at 95% confidence level for 4.7 fb$^{-1}$ proton-proton data collected by CMS in 2010 and 2011, showing the lower mass region.

With the amount of data collected so far, it is inherently difficult to distinguish between the two hypotheses of existence vs non-existence of a Higgs signal in this low mass region. The observed excess of events could be a statistical fluctuation of the known background processes, either with or without the existence of the SM Higgs boson in this mass range. The larger data samples to be collected in 2012 will reduce the statistical uncertainties, enabling us to make a clear statement on the possible existence, or not, of the SM Higgs boson in this mass region.

The excess is most compatible with an SM Higgs hypothesis in the vicinity of 124 GeV and below, but with a statistical significance of less than 2 standard deviations (2$\sigma$) from the known backgrounds, once the so-called Look-Elsewhere Effect [REF: LEE] has been taken into account. This is well below the significance level that traditionally has been associated with excesses that stand the test of time.

If we explore the hypothesis that our observed excesses could be the first hint of the presence of the SM Higgs boson, we find that the production rate (“cross section” relative to the SM, $\sigma/\sigma_{SM}$) for each decay channel is consistent with expectations, albeit with large uncertainties. However, the low statistical significances mean that these excesses can reasonably be interpreted as fluctuations of the background.

More data, to be collected in 2012, will help ascertain the origin of the excess.

References

The electron volt is a unit of energy. In particle physics, where mass and energy are often interchanged, it is common to use $eV/c^2$ as a unit of mass (from $E = mc^2$, where $c$ is the speed of light in vacuum). Even more common is to use a system of natural units with $c$ set to 1 (hence, $E = m$), and simply use $eV$ as a unit of mass.

Confidence level is a statistical measure of the percentage of test results that can be expected to be within a specified range. For example, a confidence level of 95% means that the result of an action will probably meet expectations 95% of the time.