CMS closes major chapter of Higgs measurements

The data reveal that the particle discovered at CERN continues to behave just like the Standard Model predicts

Since the discovery of a Higgs boson by the CMS and ATLAS Collaborations in 2012, physicists at the LHC have been making intense efforts to measure this new particle's properties. The Standard Model Higgs boson is the particle associated with an all-pervading field that is believed to impart mass to fundamental particles via the Brout-Englert-Higgs mechanism. Awaited for decades, the 2012 observation was a historical milestone for the LHC and led to the award of the 2013 Nobel Prize in Physics to Peter Higgs and François Englert. An open question arising from the discovery is whether the new particle is the one of the Standard Model -- or a different one, perhaps just one of many types of Higgs bosons waiting to be found. Since the particle's discovery, physicists at the LHC have been making intense efforts to answer this question.

This week, at the 37th International Conference on High Energy Physics , a bi-annual major stage for particle physics, which in 2014 is held in Valencia, Spain, the CMS Collaboration is presenting a broad set of results from new studies of the Higgs boson. The new results are based on the full Run 1 data from pp collisions at centre-of-mass energies of 7 and 8 TeV. The analysis includes the final calibration and alignment constants and contains about 25 fb^{-1} of data.

Decay to two photons

The Higgs boson is an ephemeral particle. It decays into pairs of lighter particles almost immediately after it is produced in LHC collisions. One such "decay channel" is the one in which the Higgs transforms into two photons. The latest CMS results in this decay channel show a peak in the data with a significance of 5σ, corresponding to a probability of less than one in 3,000,000 that the peak is caused by random fluctuations. Figure 1 shows the clear signal of the Higgs over the background in the data. CMS has also measured the mass of the Higgs boson with a precision of a few parts per thousand, with the systematic uncertainty of the measurement four times smaller than the previous preliminary value.

The precision of the new mass measurement - a few parts in a thousand - testifies to the inspired design and meticulous construction of the CMS detector, its efficient operation and calibration throughout Run 1 of the LHC, and the tireless efforts of the analysis teams in understanding all aspects of the detector performance.

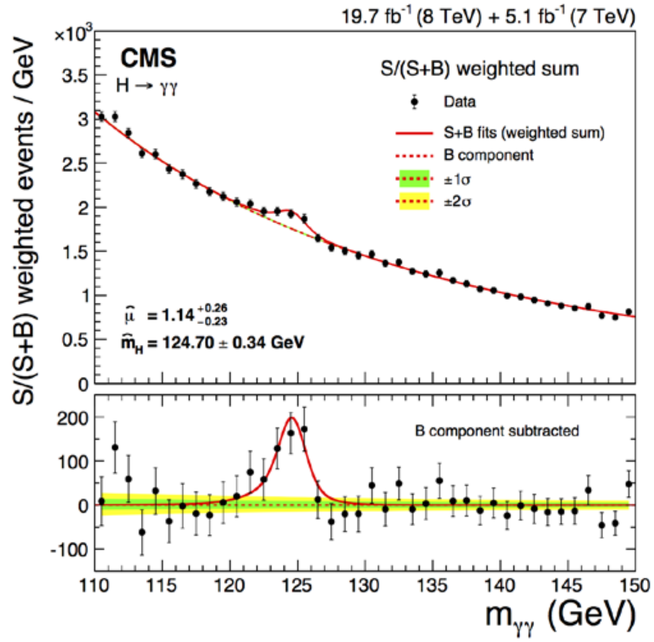

Figure 1 - Combined diphoton mass spectrum illustrating the significance of the observed excess, where events are weighted by the expected signal-to-background ratio. The corresponding background-subtracted distribution is shown in the lower panel.

Combining decay channels, production modes

The two-photon analysis completes the set of Run 1 measurements with final calibration and alignment, covering the five primary decay modes of the Higgs boson [2,3,4,5]. This paves the way for a preliminary combination of all the decay channels observed thus far [6], to extract the maximum possible information on the properties of the new boson, including its couplings to the fundamental particles. The combined best-fit ratio of the signal strength observed to that expected in the standard model, is found to be 1.00 ±0.13, in square agreement with state-of-the-art standard model calculations. Furthermore, when the data are dissected into the separate production and decay properties of the Higgs boson, no significant deviations from the expectations for the standard model are found (Fig. 2). In addition to the coupling results, the preliminary combination includes a combined measurement of the Higgs boson mass from the two-photon and $ZZ \to 4\ell$ channels: m_H = 125.03 ± 0.30 GeV. Taken together, the results represent an impressive tour de force, the culmination of four years of painstaking effort that began with the first CMS searches for the Higgs boson in 2010.

“After half a century of searching, it is exhilarating to piece together the Higgs puzzle, standing on the shoulders of giants, both those who built the experiments and those who carried out the standard model calculations.” says Prof Jim Olsen, who is currently convening the Higgs Analysis Group in CMS.

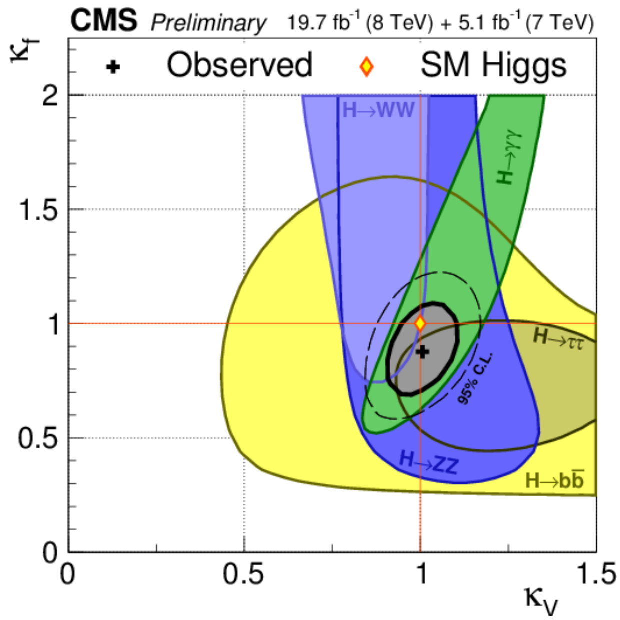

Figure 2 - Compatibility of Higgs boson couplings to vector bosons (V) and fermions (f) with the standard model expectation (diamond). The allowed regions by each group of decay modes analyzed (colored) combine into a much smaller region (grey) that is fully compatible with the standard model.

Finally, the spin structure of the Higgs boson has been probed with unprecedented detail in a new set of CMS results searching for anomalous couplings to vector bosons. If the new particle is indeed a Higgs boson it should be a scalar, a particle with zero spin and positive parity. The analyses include separate investigations of the WW→2ℓ2ν [7] and ZZ→4ℓ [8] decay channels to test alternative spin-parity assignments against the expected scalar nature of the standard model Higgs boson. For the first time, the possibility that the particle is an admixture of different parity states is also investigated. Results are combined for the two channels and all alternative hypotheses studied are found to be significantly disfavored with respect to the standard model hypothesis.

Along with the recent CMS publication in Nature Physics demonstrating strong evidence for the Higgs boson decay to fermions [9], the new results presented in Valencia provide further striking signs of its standard model nature. With the wrapping up of Run 1 results, the CMS experiment is now intensely focused on preparations for Run 2, where the centre-of-mass energy of the LHC will be raised to up to 13 TeV and the luminosity will be much increased. With a more powerful accelerator and the upgraded CMS detector, the collaboration looks forward to the promise of new and exciting results on the Higgs boson in Run 2.
Andre Tinoco Mendes, a researcher at CERN who reported the Higgs results from CMS at the conference, stressed that “It will take more data and better calculations to sharpen the picture further and exploit the full potential of the LHC.”

References

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