Exploring the structure of the Higgs sector

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Introduction

In the Standard Model of particle physics the masses of the $W^{\pm}$ and Z bosons are generated through the Englert-Brout-Higgs mechanism of spontaneous electroweak symmetry breaking, introduced in 1964. The Higgs boson is a massive elementary particle which appears in the most economic implementation of the mechanism. The masses of the fermions in the Standard Model are generated through direct Yukawa couplings to the Higgs field.
On 4^{th} July 2012, with strong involvement and leadership from our group, the ATLAS and CMS Collaborations announced the observation of a particle with a mass of about 125 GeV, consistent with the Standard Model Higgs boson.
Following the discovery, we now focus on measuring the properties of the Higgs boson, notably its mass and couplings to other particles, as well as searches for physics beyond the Standard Model through an extended Higgs sector or anomalous production/decays of the observed Higgs boson.

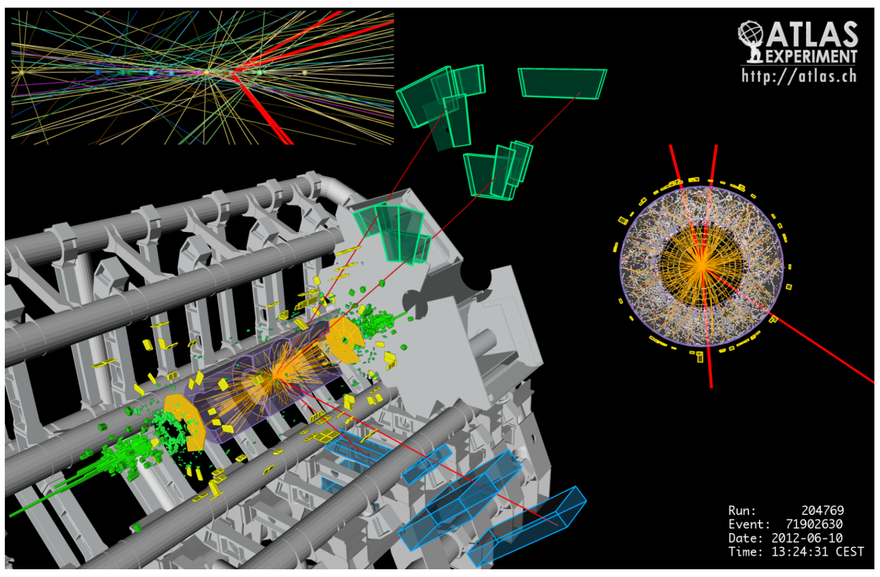
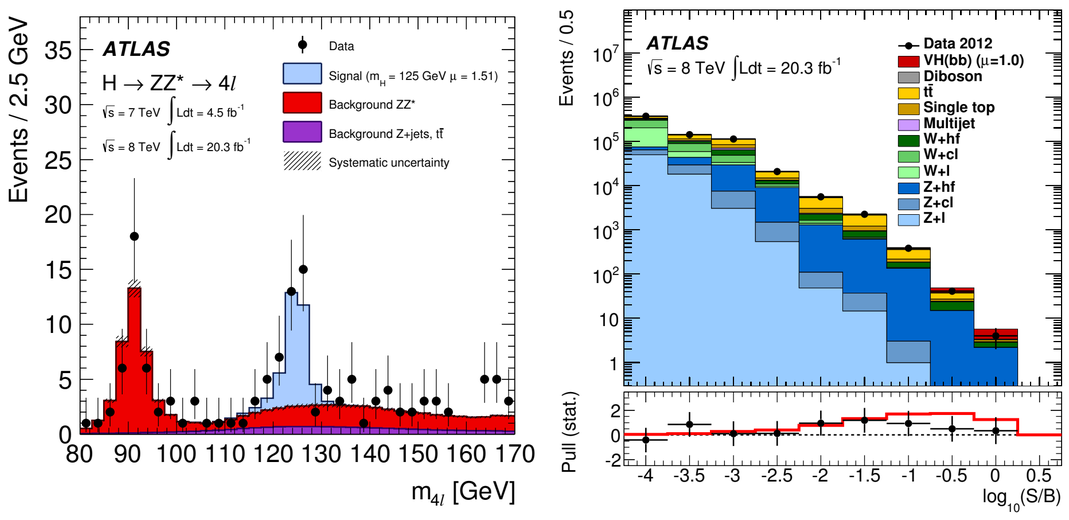


Figure 1: Event display of a $h \to ZZ^* \to 4\mu$ candidate event with a mass of 125.1 GeV. The masses of the lepton pairs are 86.3 GeV and 31.6 GeV.

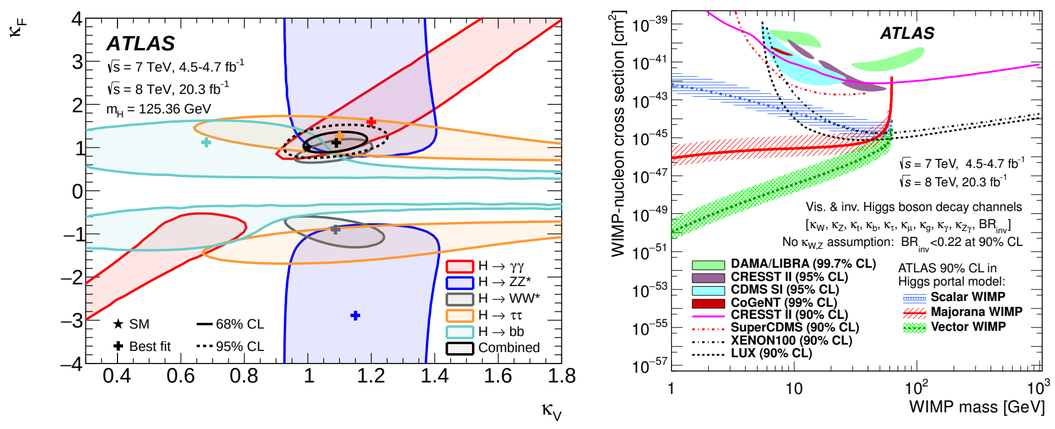
Measurement of the properties of the observed Higgs boson

The Birmingham group has a leading involvement in the analysis of ATLAS data, studying the Higgs boson mass and coupling properties using $h \to ZZ$ and $h \to b\bar{b}$ decays. We also contribute significantly to the combination of all ATLAS Higgs boson measurements, probing the predictions of the Standard Model.



(a) (b)

Figure 2: (a) The distribution of the four-lepton invariant mass, $m_{4\ell}$, for the selected candidates (filled circles) compared to the expected signal and background contributions (filled histograms). (b) Event yields as a function of $\log(S/B)$ for data, background and Higgs boson signal with m_H =125 GeV.



(a) (b)

Figure 3: (a) Results for the global coupling-strength scale factors for fermions (κ_F) and for vector bosons (κ_V), assuming only SM contributions to the total Higgs boson width. (b) ATLAS 90% confidence level upper limit on the WIMP–nucleon scattering cross section in a Higgs portal model as a function of the mass of the dark-matter particle, for a scalar, Majorana fermion, or vector-boson WIMP.

Study of the Yukawa sector

Our group is pioneering searches for rare Higgs boson decays to the exclusive final state $h \to \mathcal{Q}\gamma$, where $\mathcal{Q} = J/\psi$ or Υ. This is a unique probe to the first and second generation quark–Higgs boson couplings. The previously unobserved corresponding decays of the Z boson, are also studied.

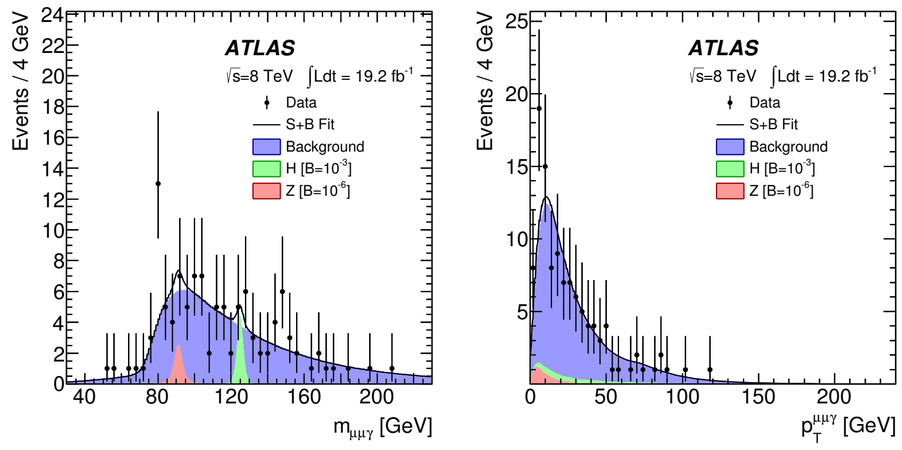
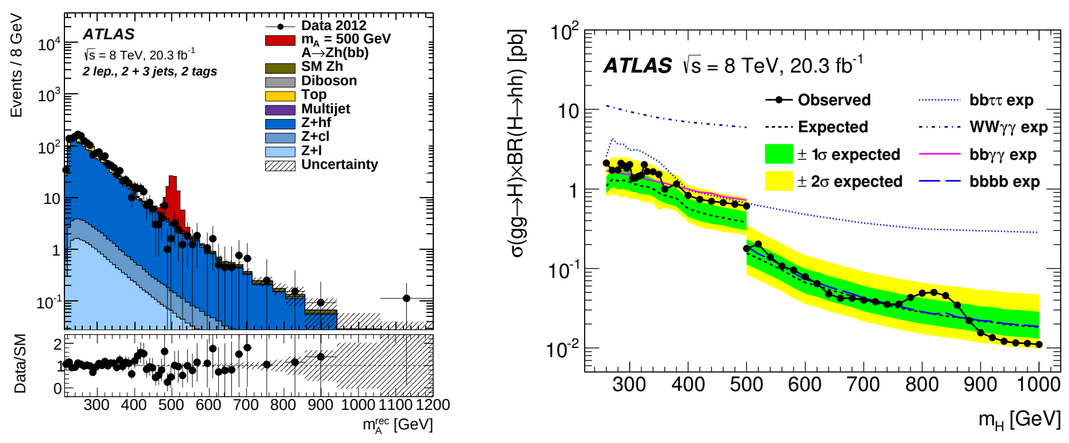


Figure 4: The $m_{\mu\mu\gamma}$ and $p^T_{\mu\mu\gamma}$ distributions of the selected $J/\psi\gamma$ candidates, along with the results of the unbinned maximum likelihood fit to the signal and background model (S+B fit).

Search for additional Higgs bosons

We are performing a comprehensive set of searches for additional Higgs bosons, including a possible pseudo-scalar Higgs boson A in its decay to Zh, heavy scalar H in its decay through ZZ and a charged Higgs boson decaying to WZ. We are also looking for beyond the Standard Model contributions to resonant and non-resonant di-Higgs boson production.



(a) (b)

Figure 5: (a) Mass distribution for the $A \to Zh \to \ell\ell b\bar{b}$ candidates. The signal shown corresponds to $\sigma(gg \to A) \times BR(A \to Zh) \times BR(h \to bb) = 500$ fb with $m_A = 500$ GeV. (b) The observed and expected 95% confidence level upper limits on $\sigma(gg \to H) \times BR(H \to hh)$, as a function of the heavy Higgs boson mass m_H, combining searches in $hh \to \gamma\gamma bb, bbbb, bb\tau\tau$ and $\gamma\gamma WW^*$ final states.

Future Perspectives

We are involved in the preparations for the LHC High Luminosity upgrade, and we are evaluating the physics potential of future facilities like the Future Circular Collider.

Figure 6: Expected 95% confidence level upper limits on the squared coupling, κ'^2, of a heavy Higgs boson arising through an additional electroweak singlet. Contours of the total width scale factor, $\Gamma_H/\Gamma_{H,SM}$, and κ'^2, of the heavy Higgs boson are also illustrated.

Acknowledgments

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References

More details, with list of publications, conferences talks and seminars/colloquia:
http://www.ep.ph.bham.ac.uk/index.php?page=exp/ATLAS/HiggsPhysics

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