Detection of the Standard Model Higgs Boson in the H->ZZ*->4l channel using relaxed cuts in event selection with ATLAS Detector

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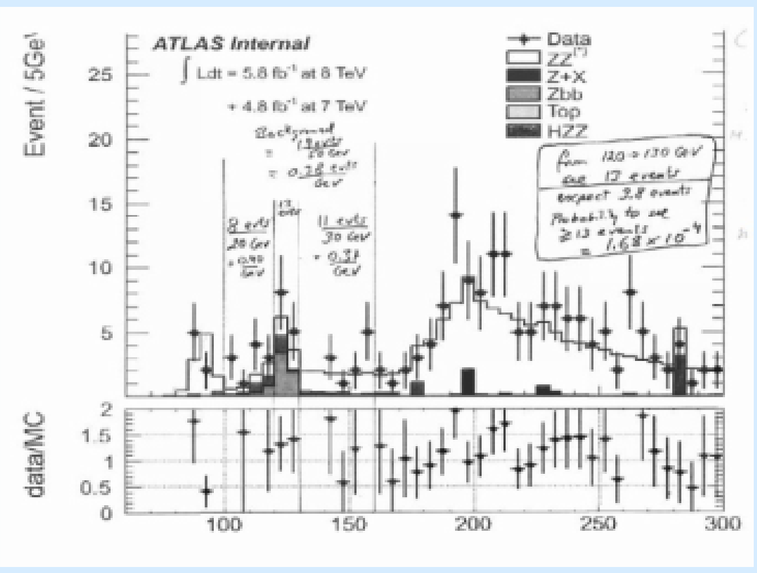
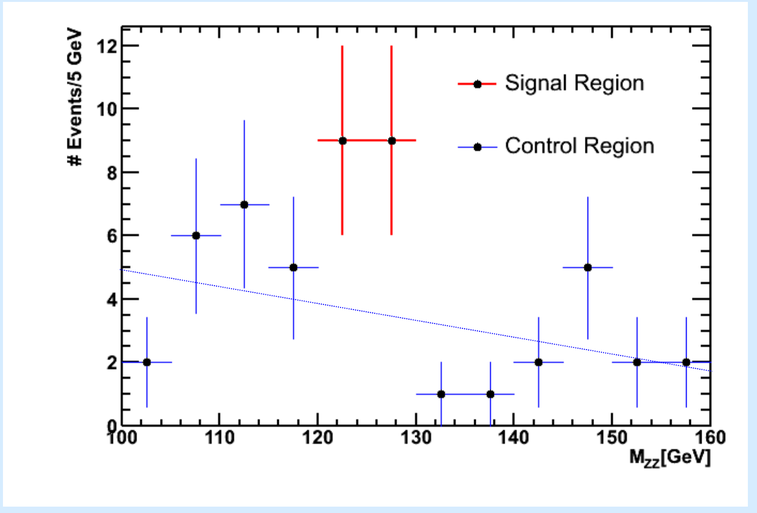
As announced at CERN on July 4th, a Standard Model(SM) Higgs-like particle has been discovered separately in the ATLAS and the CMS experiments at roughly 126 GeV, with a 5σ combined significance. The Large Hadron Collider(LHC) is running at record high center-of-mass energy of 8 TeV in 2012, producing roughly 1fb^{-1} collision data per week. With the extension of the run period to the end of this year, it is hoped that the signal significance can be further enhanced and the data can shed light on the properties of the SM Higgs-like particle. Among all the decay channels, the H->ZZ*->4l channel provides a good sensitivity and mass resolution (roughly 2 GeV at 126 GeV) and is therefore an important channel for studying the properties of the new particle. Here, we demonstrated a simple analysis with a data-driven background estimation.

Signal and Control Regions

As inspired by Professor Rudolf Thun, a signal region is defined for events with four lepton invariant mass between 120GeV and 130GeV. Assuming a roughly linear background (as shown in the plot below), the background can be estimated by data-driven method using two sidebands from 100GeV to 120GeV and from 130GeV to 160GeV.



Professor Thun's hand-writing on the four lepton invariant mass plot, suggesting the idea of using sidebands as control regions.



Four lepton invariant mass distribution for relaxed cuts. (The background is estimated by a linear fit to the control region as indicated by the blue dotted line.)

A total of **18 events** are observed in the signal region and **33 events** in the control region.

Signal Significance

The average number of background event in the signal region can roughly be estimated by integrating the fit line from 120GeV to 130GeV, which gives 7.2 events.

The likelihood for getting a total of more than or equal to 18 events as a fluctuation of the background can be computed by making use of the Poisson distribution as shown below:

P(NEvts ≥ 18 | Bkg = 7.2) = 0.05%

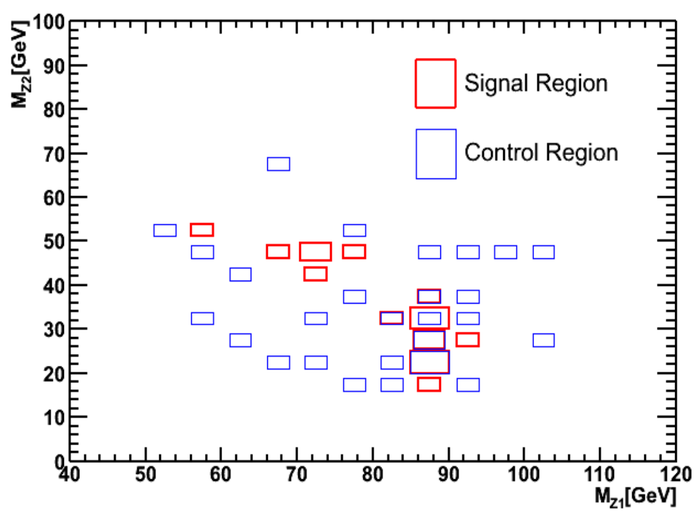
which corresponds to a signal significance of **3.3σ**. The local p_0 adapted from the ATLAS conference note [2] is 0.029% (3.4σ). Our simple estimation gave a similar signal significance, given looser cuts and more data.

Dataset and Event Selection

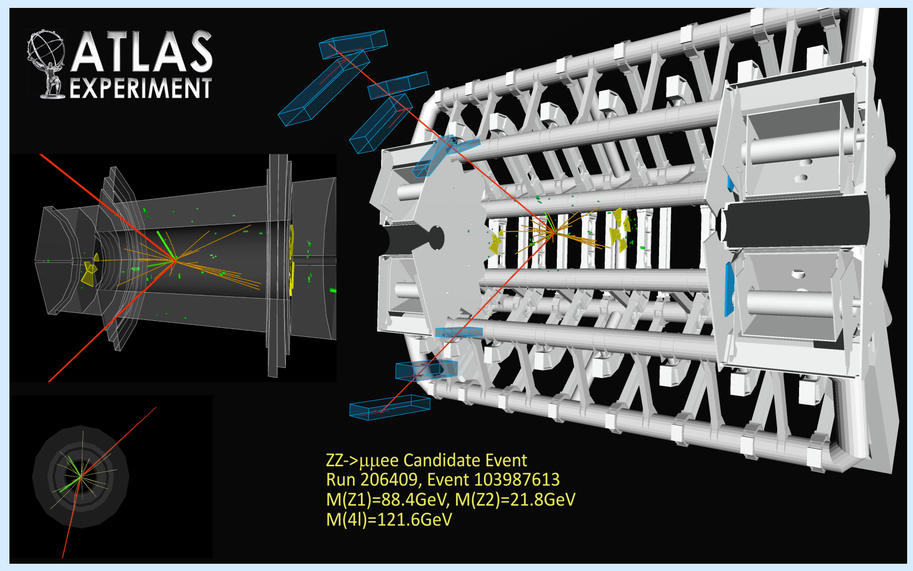
In this analysis, we used the 7 TeV collision data from 2011 corresponding to an integrated luminosity up to **4.8fb^{-1}**. For 8 TeV, we used data from run 200804 to run 207113. Data from run 200804 to run 205113 corresponds to an integrated luminosity up to **5.8fb^{-1}**. For data from run 206299 to run 207113, CoolRun Good Run List (GRL) is used instead of the official Higgs to four lepton GRL, with an integrated luminosity of **0.73fb^{-1}**.

The official summer 2012 selection [1] has been applied. In order to increase acceptance to cope with limited statistics, the electron(muon) P_T cut is loosened from 7(6) GeV to 5(4) GeV. Lepton P_T cut for Lep2(3) is relaxed from 15(10) GeV to 10(5) GeV. For dilepton mass, we require that 50 GeV<M_{Z1}<106 GeV and M_{Thres}<M_{Z2}<115 GeV where M_{Thres} ranges from 17.5 GeV to 50 GeV as a function of M_{ZZ}.

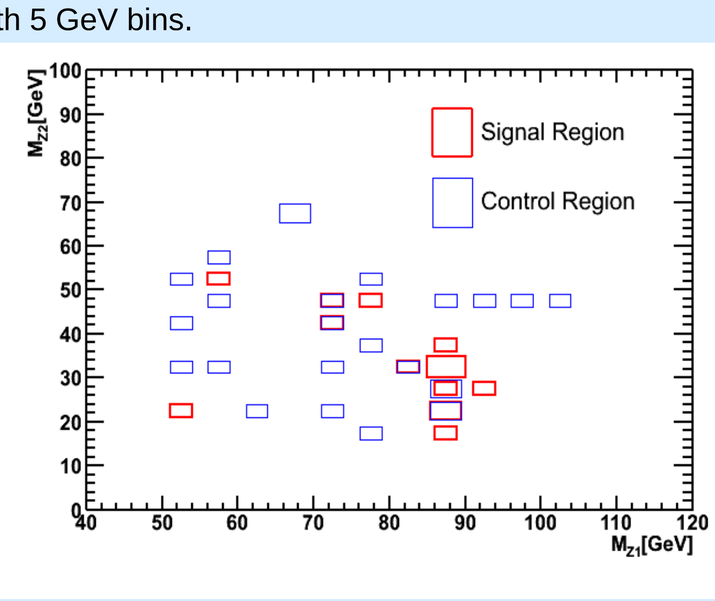
Kinematic Distributions



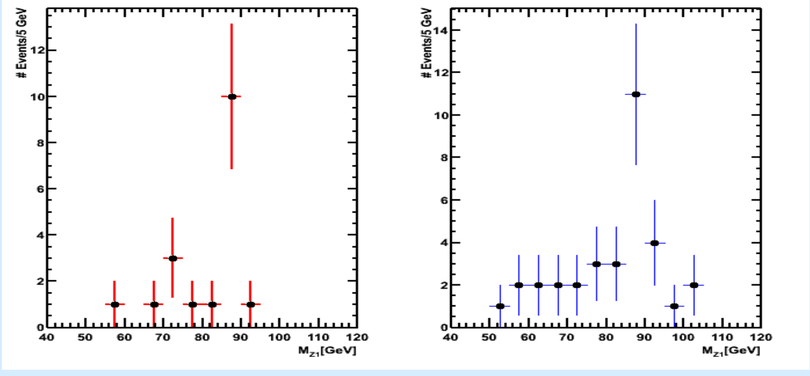
2D plot for Z2 invariant mass vs Z1 invariant mass for signal (Red) and sidebands (Blue) for **relaxed cuts** with 5 GeV bins.



Event display for the latest 2μ2e candidate in the 0.73fb^{-1} data.
EventNumber: 103987613 RunNumber: 206409
M_{ZZ} = 121.6 GeV M_{Z1} = 88.4 GeV M_{Z2} = 21.8 GeV

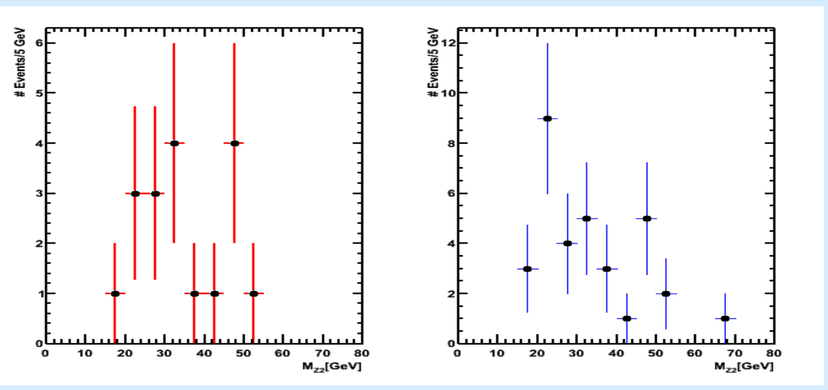


2D plot for Z2 invariant mass vs Z1 invariant mass for signal (Red) and sidebands (Blue) for **standard cuts** with 5 GeV.

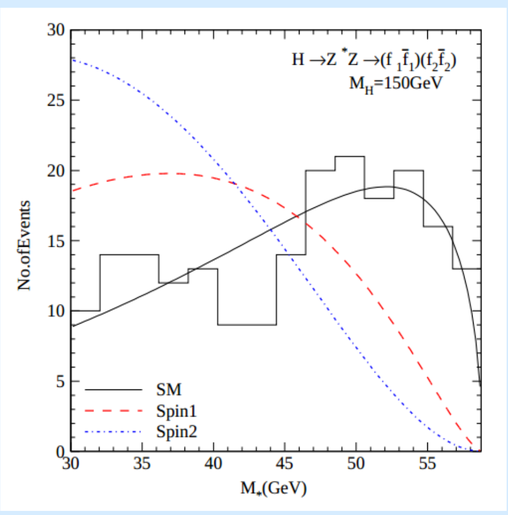


Z1 invariant mass distribution for signal (Red) and sidebands (Blue) separately.

What to do next?



Z2 invariant mass distribution for signal (Red) and sidebands (Blue) separately.



Z2 invariant mass distribution for spin-0 (SM), spin-1 and spin-2 Higgs boson with mass of 150GeV. [3].

It is hoped that with more data by the end of 2012, at least see some hints would be observed on the spin nature of the Higgs-like particle from the Z2 invariant mass distribution.

References

[1] The ATLAS Collaboration, *Search for the SM Higgs boson in the decay channel H->ZZ->llll Summer 2012, http://twiki.cern.ch/twiki/bin/viewauth/AtlasProtected/HiggsZZllllSummer2012*.
[2] The ATLAS Collaboration, *Observation of an excess of events in the search for the Standard Model Higgs boson in the H-> ZZ*-> 4l channel with the ATLAS detector, ATLAS-CONF-2012-092*.
[3] S.Y. Choi et. al., *Identifying the Higgs Spin and Parity in Decays to Z Pairs, CERN-TH-2002-231*.