Searches for the Standard Model Higgs boson decay $H \to ZZ^{(*)} \to 4\ell$ with the ATLAS detector

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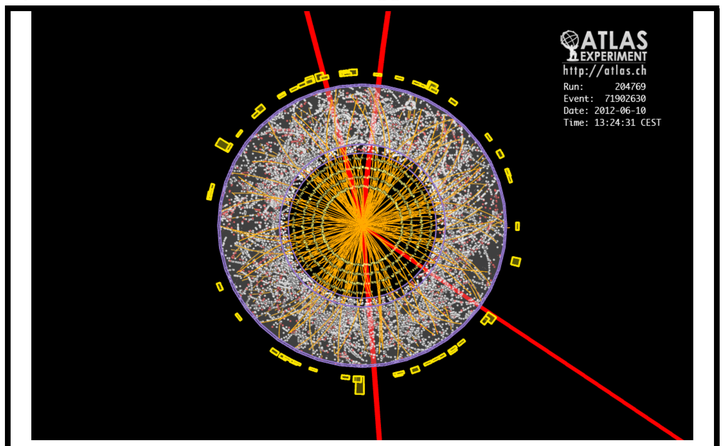
Abstract

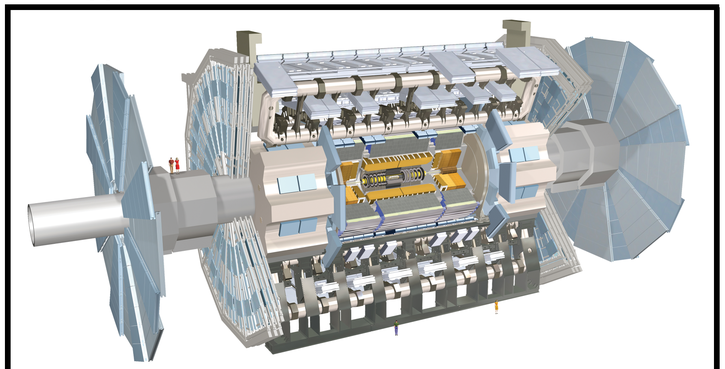
- The LHC was built to **explore physics beyond current knowledge**
- The ATLAS detector (A Toroidal LHC ApparatuS) is the largest experiment at the **proton-proton colliding LHC**
- **Precise electroweak fits predict a light SM Higgs boson**, most likely $m_H = 95^{+30}_{-24}$ GeV [1]
- In July 2012 a new particle was discovered at around 125 GeV hinting at a **possible discovery of the SM Higgs boson** [2]



Event display of a Higgs candidate decaying into $ZZ^{(*)} \to 4\mu$ zoomed into the tracking detector where the muon tracks are highlighted in red. This event 71902630 during run 204769 was recorded by ATLAS on 10-Jun-2012, 13:24:31 CEST. [3]

ATLAS Detector

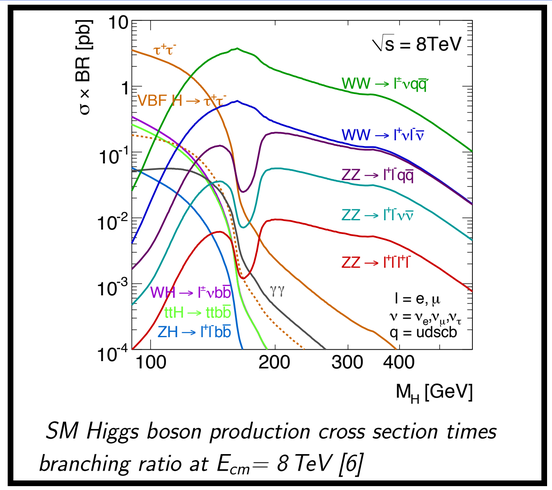
- Built to explore new physics up to a **design energy of 14 TeV** and a design luminosity of $10^{34} cm^{-2} s^{-1}$
- Consists of an **inner detector, calorimeters, a muon system and forward detectors** embedded in a **superconducting magnet-system**
- The **reconstruction efficiency depends on the detector region** e.g. barrel vs. crack ($1.37 < |\eta| < 1.52$, between barrel and endcap) region [4]



Schematic of the ATLAS detector. [5]

$H \to ZZ^{(*)} \to 4\ell$ analysis

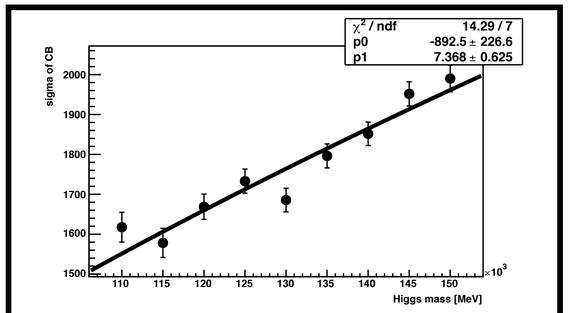
- **Channel with high potential** to discover the SM Higgs boson
- **Exploiting 110 GeV$<m_H<$600 GeV** as sensitive over large mass range
- The final state $\ell^+\ell^-\ell'^+\ell'^-$ abbreviated as 4ℓ denotes to electrons or muons
- Currently separated into **four final states**: 4μ, $2e2\mu$, 4e, $2\mu 2e$
- $2e2\mu$ and $2\mu 2e$ differ **for $m_H<$ 182 GeV** where the **second lepton pair originates from an off-shell Z boson**
- Even though many channels have higher $\sigma \times$BR, $H \to ZZ^{(*)} \to 4\ell$ has a **higher sensitivity due to its clean signature**



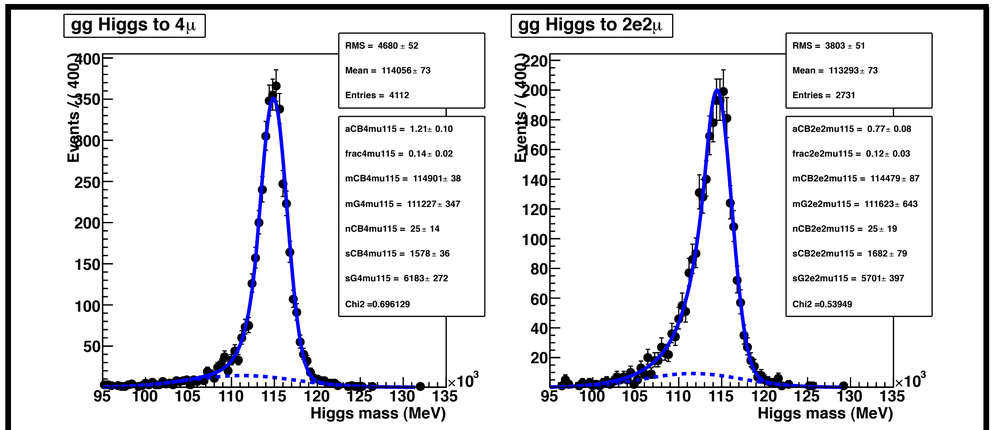
SM Higgs boson production cross section times branching ratio at E_{cm}= 8 TeV [6]

Statistical treatment of $H \to ZZ^{(*)} \to 4\ell$

- Improvements which are in progress:
  - Implementation of an **unbinned fit** to exploit the full potential of the limited statistics of the data
  - Event separation into **detector categories** of reconstruction efficiencies
  - Implementation of **per-event errors** as an alternative option where each event is allocated to its associated error
  - Developing **analytical models for background and signal**
- To apply these improvements a **new workspace is developed** which is part of RooStats containing projects with models and datasets to facilitate combinations



Resolution of simulated $H \to ZZ^* \to 4\mu$ produced by gg fusion. The resolution is obtained as the sigma of the Crystal ball (CB) when fitting the sum of a CB and a Gaussian distribution to $m_{4\ell}$.



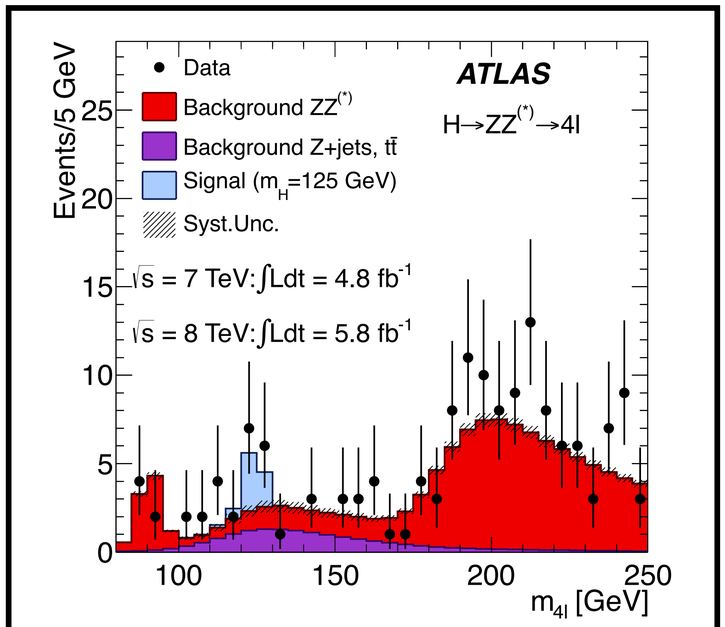
Simulated signal for m_H=115 GeV fitted by the sum of a CB and a Gaussian distribution to $m_{4\ell}$.

Background of $H \to ZZ^{(*)} \to 4\ell$

- The main background comes from the continuum $(Z^{(*)}/\gamma^*)(Z^{(*)}/\gamma^*)$
- In the **low mass range Z+jets and $t\bar{t}$** contribute to the background [2]

Results

- The datasets used have integrated luminosities of approximately 4.8 fb^{-1} collected at $\sqrt{s}$ = 7 TeV in 2011 and 5.8 fb^{-1} at $\sqrt{s}$ = 8 TeV in 2012
- The **$H \to ZZ^{(*)} \to 4\ell$ channel excluded** with 95 % confidence level the SM Higgs boson in the following mass regions: **131-162 GeV and 170-460 GeV**
- The **$H \to ZZ^{(*)} \to 4\ell$ channel** observed an excess of events around **m_H = 125 GeV** with **3.4 standard deviations** [7]



Selected candidates of the $H \to ZZ^{(*)} \to 4\ell$ analysis shown for the four-lepton invariant mass, $m_{4\ell}$. The data is compared to the background and signal expectation for a SM Higgs with m_H = 125 GeV. [7]

- The **discovery of a neutral boson** at 126.0± 0.4 (stat)±0.4 (sys) GeV was observed by the combined ATLAS Higgs analyses
- This observation with a significance of **5.9 standard deviations** is compatible with the SM Higgs boson [2]

References

- [1] Gfitter Group. Constraints on the electroweak symmetry breaking sector from global fits with Gfitter. 2011
- [2] arXiv:1207.7214v1
- [3] ATLAS-PHO-COLLAB-2012-008
- [4] The ATLAS Experiment at the CERN Large Hadron Collider. ATLAS Collaboration. JINST 3 (2008) S08003
- [5] CERN-GE-0803012
- [6] arXiv:1201.3084v1
- [7] ATLAS-COM-CONF-2012-106