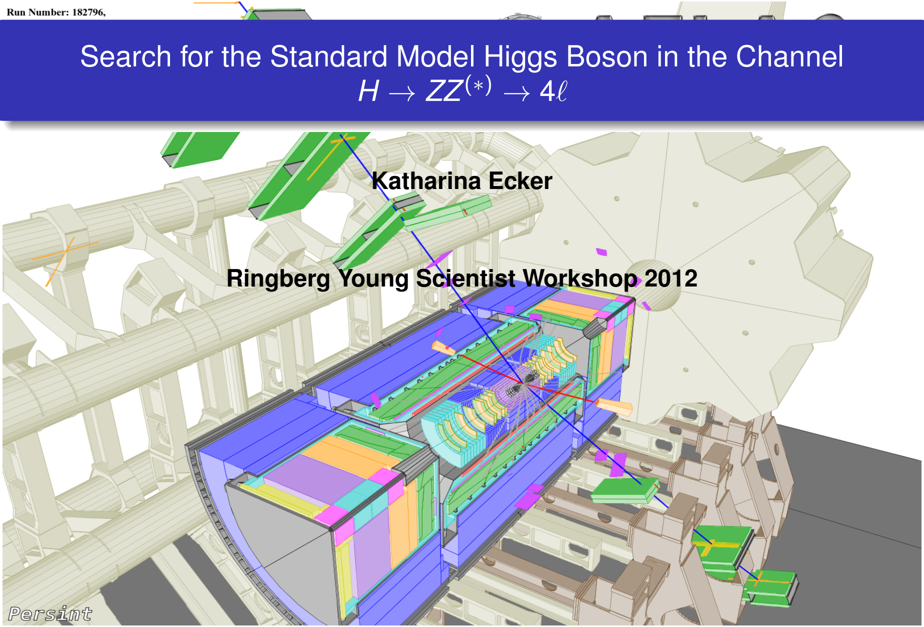


Search for the Standard Model Higgs Boson in the Channel $H \to ZZ^{(*)} \to 4\ell$

Katharina Ecker

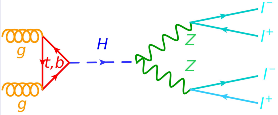
Ringberg Young Scientist Workshop 2012

Introduction: channel $H \to ZZ^{(*)} \to 4\ell$

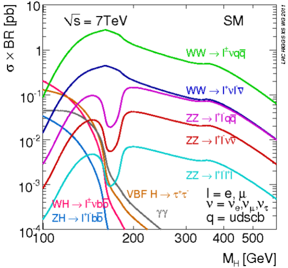
higgs decay channels $H \to ZZ^* \to 4l$, $H \to W^+W^- \to l\nu l\nu$, $H \to \gamma\gamma$, $H \to \tau^+\tau^-$, ...

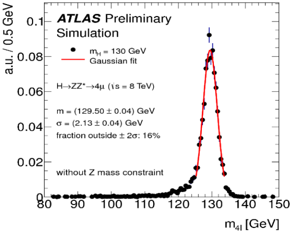
$H \to ZZ^{(*)} \to 4\ell \quad (l = e, \mu)$

- clean experimental signature
  four isolated leptons 4μ, $4e$, or $2\mu 2e$



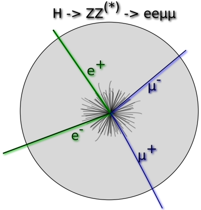
- but low branching ratio for $4l$ final state ($O(10^{-3} - 10^{-4})$)
- narrow resonance in $4l$ mass spectrum
- background: irreducible ZZ^*
  reducible $Z + jets$, $t\bar{t}$

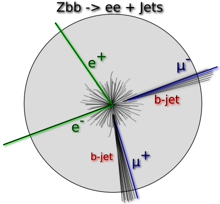




Lepton selection in channel $H \to ZZ^{(*)} \to 4\ell$

- 2 lepton pairs with same flavour and opposite sign e.g. $\mu^+\mu^-$ and e^+e^-
- sufficient energy, invariant mass of lepton pairs above thresholds
- lepton isolation: do we have an isolated lepton or a lepton from a jet?





two ways to decide:

draw cone with $\Delta R < 0.2$ around lepton and count...

1. $\sum$ *deposited energy* around lepton in the calorimeter

   $\to$ **"calorimeterisolation"**

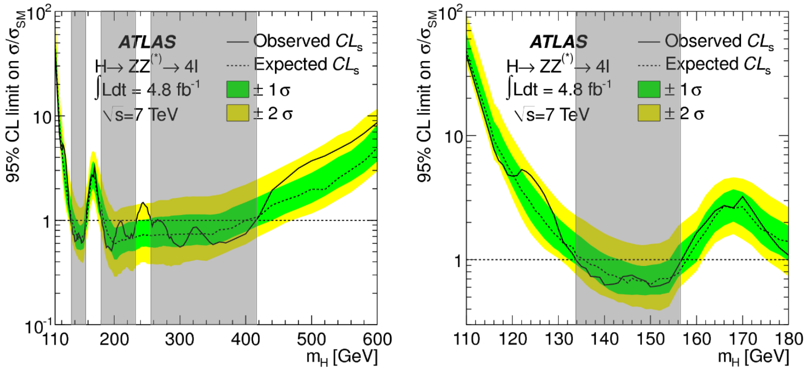
2. $\sum$ *tracks* around lepton in inner detector

   $\to$ **"trackisolation"**

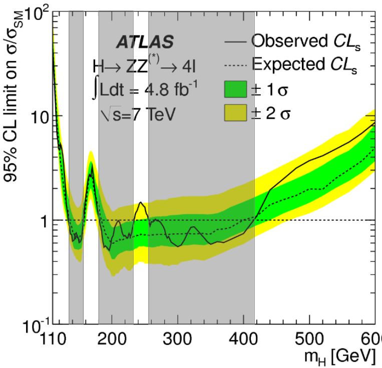
$\to$ exclude lepton if the sum of energy or tracks is above threshold!

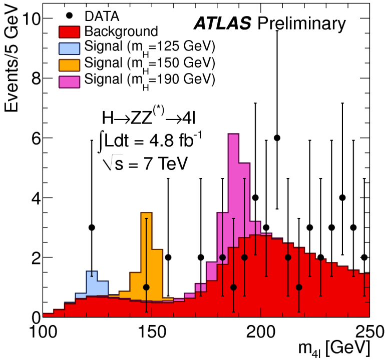
$\to$ reduction of background events $t\bar{t}$ and $Z + jets$

Results 2011 in the channel $H \to ZZ^{(*)} \to 4\ell$



- a slight excess in not yet excluded region 114.4 to 134 GeV
- $m_H \sim$ 125GeV with a local significance of 2.1σ
- all channels combined:
  exclusion restricts possible SM higgs to low mass region
  $\rightarrow$ important for 2012 analysis!





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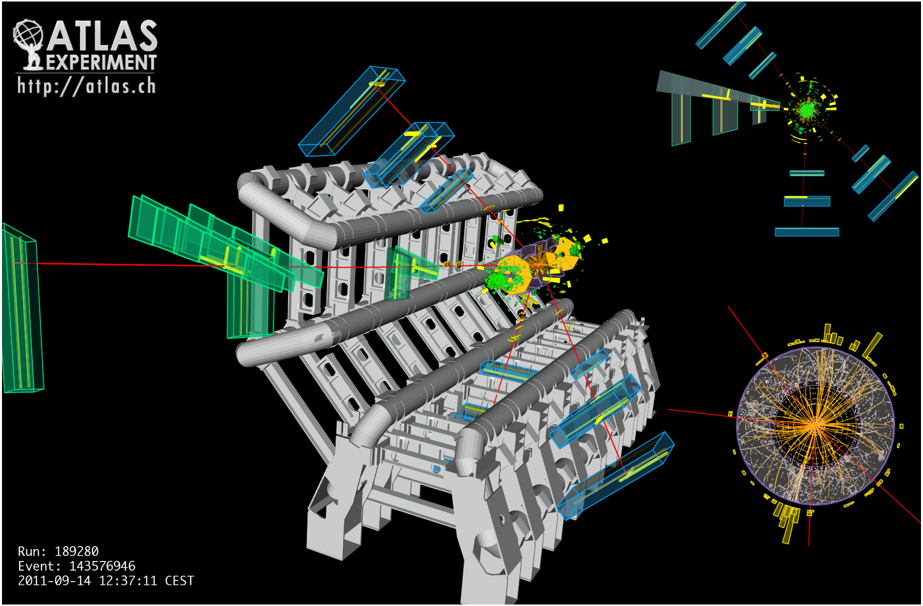
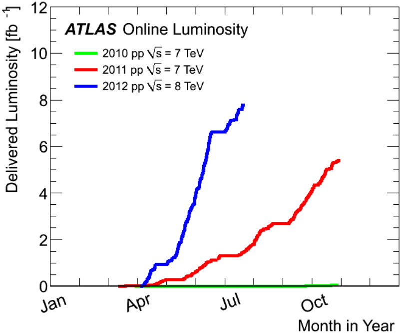
Results 2011 in channel $H \to ZZ^{(*)} \to 4\ell$

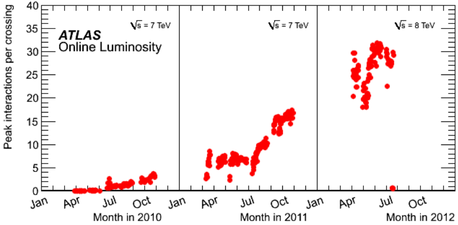
event display 2011 higgs candidate $H \to ZZ^{*} \to 4\mu$

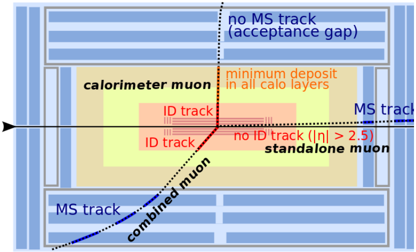


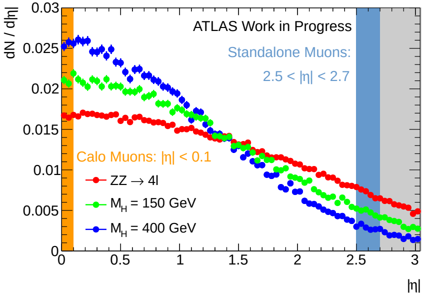
Changes for 2012 analysis

- $H \to 4l$ analysis improved to increase sensitivity
- improved fitting of electrons (Bremsstrahlung)
- increase of detector acceptance:
  inclusion of so called calorimeter muons and standalone muons
- **challenge 2012:** increased # of interactions per crossing "pile up"







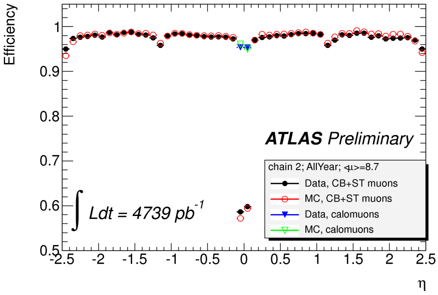


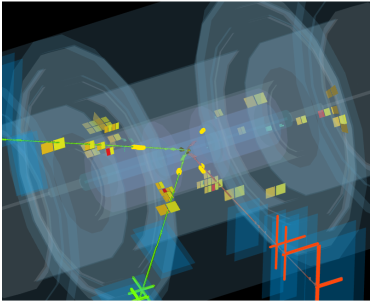
- **2011:**
  required for μ
  inner detector track and **muon spectrometer track**

  $\rightarrow$ lack in efficiency in central region

- **2012:**
  new calorimeter muon: inner detector track and **calorimeter track**

  $\rightarrow$ increase of efficiency in central region

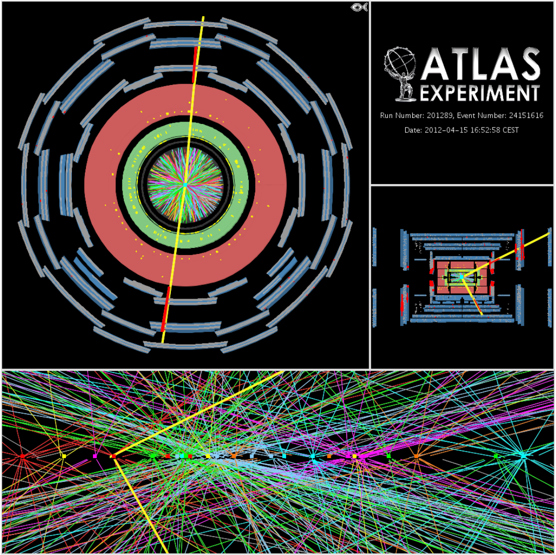




Inclusion of calorimeter μ into *H4l* Analysis

- increase of efficiency in central region
- additional events after final selection cuts:

H150:	4.1%
H200:	5.2%
ZZ:	4.2%

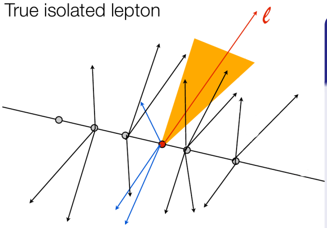


Pile up in 2012

$Z \rightarrow \mu^+\mu^-$ event in 2012 data with 25 reconstructed vertices

$\rightarrow$ new difficulties in reconstrucion

$\rightarrow$ example: μ isolation with pile up



Does the lepton isolation change with pile up?

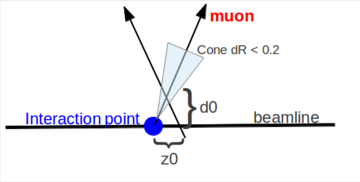
- calorimeterisolation=$\sum$ *deposited energy* around lepton in the calorimeter
- trackisolation=$\sum$ *tracks* around lepton in inner detector

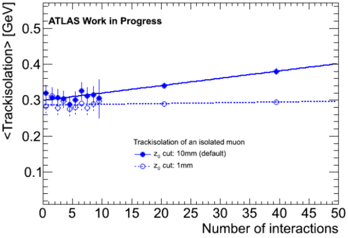
→ with pile up there is more energy and tracks around the lepton

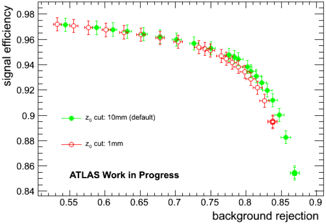
How do we decrease pile up dependency?

For our study we focused on:

- muons
- trackisolation
- idea: tighten d_0 and z_0 cuts of track selection





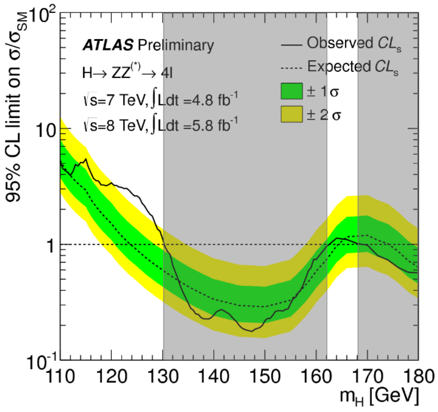


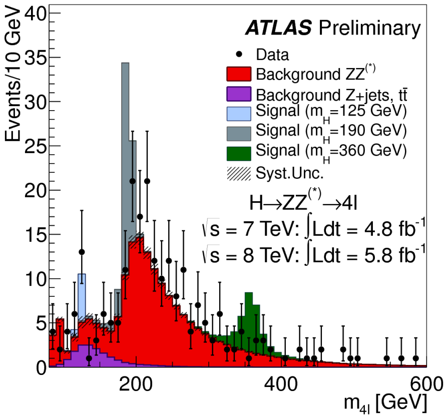
Trackisolation study

- new track selection
  remove all tracks with $z_0 > 1mm$
- comparison with default $z_0 > 10mm$
  using a $t\bar{t}$ MC sample
- very important:
- signal efficiency =
  $$\frac{\text{\# of signal } \mu \text{ that passed the cut}}{\text{\# of all signal } \mu}$$
- background rejection =
  $$\frac{\text{\# of bkg } \mu \text{ that did not pass the cut}}{\text{\# of all background } \mu}$$

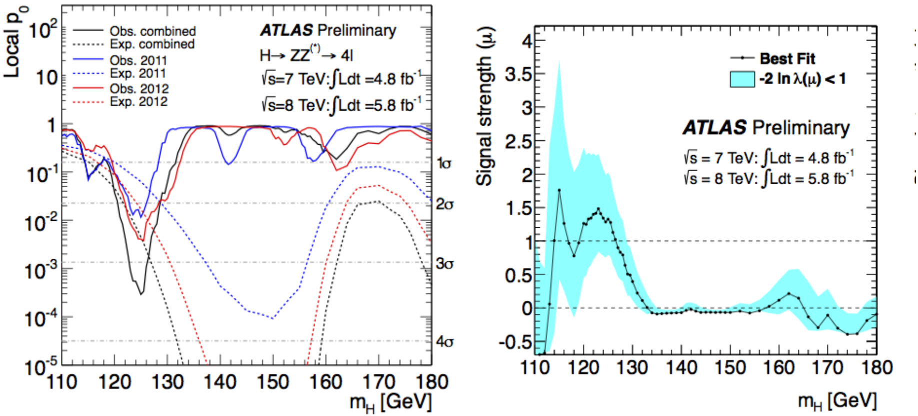
Result: strict z_0 cut removes pile up dependecy, but decreases rejection
$\rightarrow$ keep default method in flavor of better background rejection

Combined results 2011 and 2012 in the channel $H \to ZZ^{(*)} \to 4\ell$





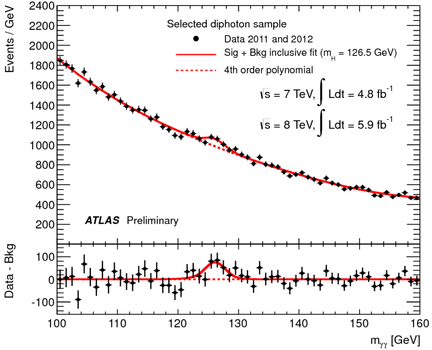
Combined results 2012 and 2011 in the channel $H \to ZZ^{(*)} \to 4\ell$



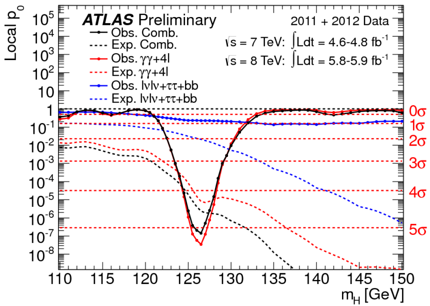
- p_0 value: probability that signal is caused by background fluctuation
- μ value: best fit signal strength normalized to SM expectation
- **H4l combination 2011 and 2012:**
  low mass excess around $m_H = 125\text{GeV}$ up to 3.4σ

Combined results 2012 and 2011 of all channels

$H \rightarrow \gamma\gamma$ combined result



p_0 value of all channels combined

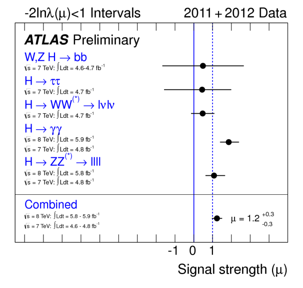


- full 2011 and 2012 datasets: $H \rightarrow \gamma\gamma$ $H \rightarrow ZZ^{(*)} \rightarrow 4\ell$
  full 2011 dataset: $VH \rightarrow b\bar{b}$, $H \rightarrow \tau\tau$, $H \rightarrow l\nu l\nu$
- observation of new boson with mass near 126.5 GeV with a 5σ significance

What needs to be done

Is the new boson compatible with a SM higgs boson?

best fit signal strength normalized to SM expectations for $m_H = 126.5$ GeV



$\mu \sim 1$, but value pulled down by channels which see no excess
$H \to \gamma\gamma : \mu > 1$ and $H \to 4l : \mu \sim 1$

we need to gather more data and measure properties of the new boson

- exact mass
- is it a spin 0 particle?
- coupling to $W, Z, b\bar{b}, \tau$...
- CP eigenvalue
- self-coupling

Conclusion and outlook

- we found a new boson with a mass of $\sim 126GeV$
- is it a SM higgs? time will tell...

http://www.fotocommunity.de/pc/pc/display/11692030

- **recorded luminosity** 2012: $\sim 5fb^{-1}$
- **expected luminosity** end of 2012: $\sim 25 - 30fb^{-1}$

  with this luminosity discovery in each channel is possible:
  $H \to ZZ^{(*)} \to 4\ell$
  $H \to W^+W^-$
  $H \to \gamma\gamma$

  and evidence possible for:
  $H \to \tau^+\tau^-$
  $H \to b\bar{b}$