LHCC Poster Session - CERN, 23 March 2011

Search for the SM and MSSM Higgs boson(s) with ATLAS 2010 data

Abstract

- The ATLAS experiment has searched for the SM Higgs boson in decays to ZZ, WW and $\gamma\gamma$ final states and the H/A of the MSSM in $\tau\tau$ states. No significant evidence for a signal is found in any search, and limits are presented either as a ratio of the Higgs boson production cross section to that of the standard model or in the m_A-tanβ plane.

Introduction

Why Higgs?

- The dynamics responsible for electroweak symmetry breaking are still unknown.
- In the SM, the Higgs mechanism is invoked to break the electroweak symmetry. A doublet of complex scalar fields is introduced, of which a single neutral scalar particle, the Higgs boson, remains after the symmetry breaking.
- In the MSSM, two complex Higgs doublets introduced, resulting in three neutral (h, H, A) and two charged ($H^{\pm}$) Higgs.
- The Higgs boson has not been discovered so far.

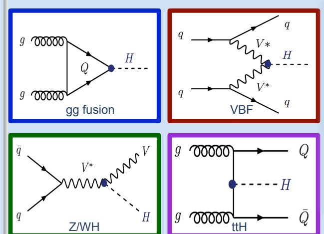
Higgs search at LEP and Tevatron

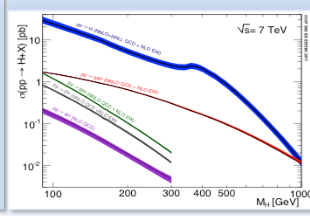
- Combined results from the four experiments at LEP have set a lower bound of 114.4 GeV/c².
- At the Tevatron, combined results from CDF and D0 have excluded the mass region 158 < m_H < 173 GeV/c² at 95% C.L.

Higgs search status at ATLAS

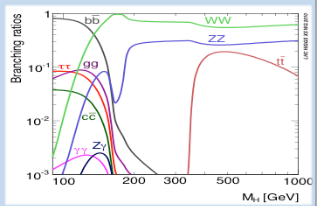
- The sensitivity to SM-like Higgs boson exceeds any experiment for mass above 250 GeV.
- Similar to the best existing results obtained in $\gamma\gamma$ channel and close in WW channel.
- The search for MSSM neutral Higgs using $\tau\tau$ channel surpasses existing constraint for a wide range of m_A.

SM Higgs Production in pp Collisions





Higgs decay modes



- All relevant Higgs mass regions in this plot can be scanned at LHC.

Low mass region:

- bb: large BR with mass peak, but poor resolution , large contamination from QCD bb events
- $\tau\tau$: low BR with mass peak, but poor resolution, large contamination from Z->$\tau\tau$
- $\gamma\gamma$: rather low BR, with mass peak of rather good resolution.

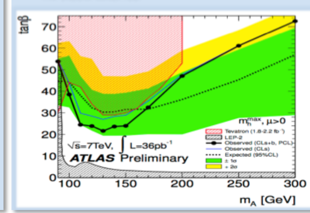
High mass region:

- WW: rather large BR but no mass peak
- ZZ: lower BR but mass peak with good resolution (H->ZZ->4l or llqq) or with large MET (H->ZZ->llνν)

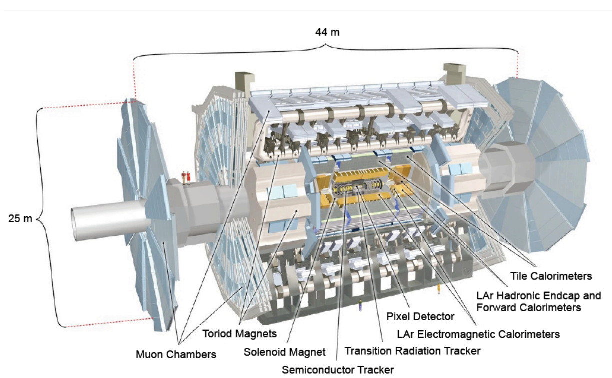
MSSM Higgs

- In MSSM, properties of the Higgs bosons are predicted at tree level by two parameters:
  1. CP-odd Higgs boson mass, m_A
  2. tangent of the ratio of vacuum expectations of the Higgs doublets, tan β
- Dominate production process for neutral Higgs:
  low tan β values (<10): gluon-gluon fusion
  larger tan β values: associated production with bb.
- Neutral Higgs decays:
  $\tau\tau$ final state is enhanced at high tan β.

ATLAS search neutral Higgs in $\tau\tau$ to lepton-hadron channel ($\tau\tau$ ->lh BR = 46%):
Observed events in data: 206
Expected background events: 195±33
No excess observed.



The ATLAS Detector

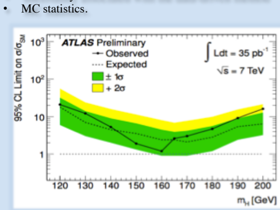


H-> WW->llνν

- This mode has strong sensitivity to the Higgs mass region [120, 200]. For much of the low mass region, at least one of the W boson has to be off the mass shell.
- Three disjoint analyses performed according to the jet multiplicity in the event.
  H+0 jet, H+1jet, H+2jets

Main systematic uncertainties:

- MC Q² scale
- jet energy scale
- b-tagging efficiency
- uncertainty associated with the data-driven method
- MC statistics.



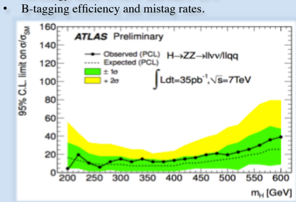
H-> ZZ

ATLAS sets limits using H-> ZZ->llνν/llqq

- Higher signal expectation than H->ZZ->4l due to the higher BR.
- Search mass range is [200, 600] GeV, extending beyond the sensitivities of LEP and Tevatron.
- Use M_{lljj} (llqq channel) and M_T (llνν channel) as the discriminant.

Main systematic uncertainties:

- Luminosity: ±11%
- Cross section of signal and background production
- Electron energy scale and efficiency: 4.6%
- Muon momentum scale , identification efficiency: 2%
- Jet energy scale: 5~12% and MET: 20%
- B-tagging efficiency and mistag rates.



H-> γγ

Inclusive analysis selection

- Trigger selection:
  - First 0.8 pb⁻¹ of data: one photon E_T > 14 GeV at the low level trigger
  - Later part of data: two photons E_T > 15 GeV
- At least two reconstructed photons: passing the acceptance cuts, tight identification and isolation requirement
- Kinematic cut: $p_T^{\gamma 1} > 40$ GeV, $p_T^{\gamma 2} > 25$ GeV
- Two photon invariant mass range: [100, 150] GeV

Trigger efficiency measurement

- Object-level efficiency: (bootstrap method)
  match the offline photon object with trigger object

$$\Delta R = \sqrt{\Delta\eta^2 + \Delta\varphi^2}$$

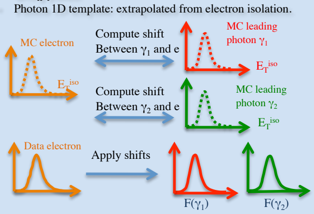
- First check on lower threshold trigger
- Check higher level and higher threshold trigger w.r.t lower one.

- Event-level efficiency: ($\varepsilon_1 \times \varepsilon_2$)
  1. object-level efficiency for photons E_T > 40 GeV: ε_1
  2. Events passing the kinematic cut, and leading photon matching with trigger object
  3. Check the event trigger efficiency on those events: ε_2

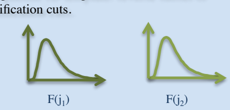
trigger item	L1_EM14	EF_2g15_loose
efficiency [%]	$100.0^{+0.0}_{-4.5} \pm 1$	$100.0^{+0.0}_{-5.0} \pm 1$

Data-driven background decomposition

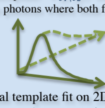
- Fit to the 2D isolation distribution to extract the $\gamma\gamma$, γj , $j\gamma$ and jj yields.
- Photon 1D template: extrapolated from electron isolation.



- Fake photon 1D template: reverse subset of identification cuts.

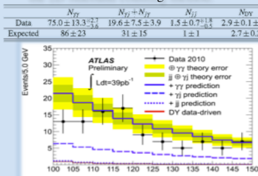


- Four 2D templates are summed together:
  - $\gamma\gamma$ template: $F(\gamma_1) \times F(\gamma_2)$
  - γj template: $F(\gamma_1) \times F(j_2)$
  - $j\gamma$ template: $F(j_1) \times F(\gamma_2)$
  - jj template: $F(j_1, j_2)$, 2D isolation distribution of the two photons where both fail tight identification.



- Total template fit on 2D isolation distribution of the two photons passing tight identification.
- Results derived from this method agree well with the 2D sideband counting method.

	$N_{\gamma\gamma}$	$N_{\gamma j}+N_{j\gamma}$	N_{jj}	N_{DY}
Data	$75.0 \pm 13.3^{+2.7}_{-3.6}$	$19.6 \pm 7.5 \pm 3.9$	$1.5 \pm 0.7^{+1.8}_{-0.5}$	$2.9 \pm 0.1 \pm 0.6$
Expected	86 ± 23	31 ± 15	1 ± 1	2.7 ± 0.2

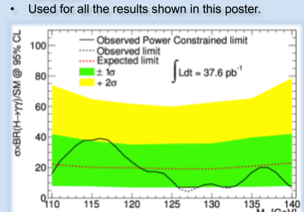


Power Constrained Limit

- Avoid excluding 0 or negative hypothesis.
  - Test statistic redefined as:

$$\tilde{q}_\mu = \begin{cases} -2\ln\frac{\mathcal{L}(\mu,\hat{\hat{\theta}})}{\mathcal{L}(0,\hat{\hat{\theta}})} & \hat{\mu} < 0, \\ -2\ln\frac{\mathcal{L}(\mu,\hat{\hat{\theta}})}{\mathcal{L}(\hat{\mu},\hat{\theta})} & 0 \le \hat{\mu} \le \mu, \\ 0 & \hat{\mu} > \mu \end{cases}$$

  - No stronger exclusions than the exclusion at -1σ from the median. It is the chosen limit in acceptable background fluctuations.
- Used for all the results shown in this poster.



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