Search for the Higgs Boson in the Channel $H \to ZZ^{(*)} \to 4l$ with the ATLAS Detector

Daniela Rebuzzi
on behalf of the ATLAS Collaboration
Pavia University and INFN

Physics in Collision
Kobe University, Japan, 30 August – 2 September 2009

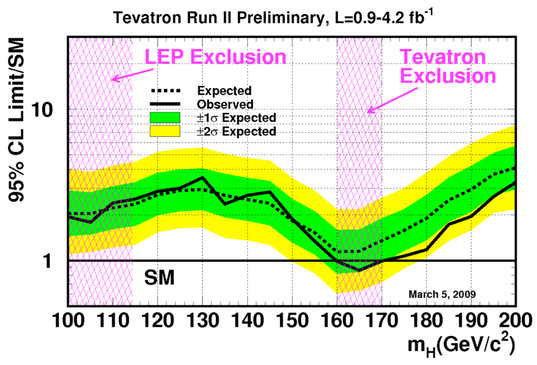
SM Higgs Boson Searches

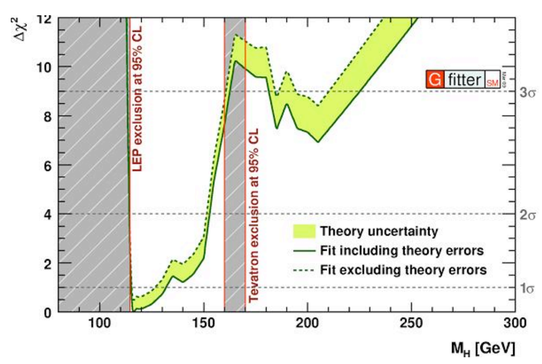
Theoretical limits: unitarity ($m_H < 1$ TeV/c^2), Higgs vacuum stability, Landau pole

EW precision data fit [1] : $m_H < 157$ GeV/c^2 @ 95% CL - $m_H < 186$ GeV /c^2 when including the LEP-2 direct search limit (August 2009)

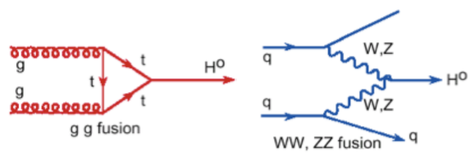
Direct searches :

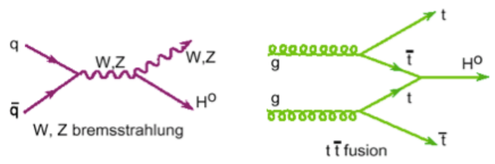
- LEP-2 : SM Higgs lighter than 114.4 GeV/c^2 excluded at 95% CL
- Tevatron [2] : SM Higgs with m_H = [160, 170] GeV/c^2 excluded at 95% CL



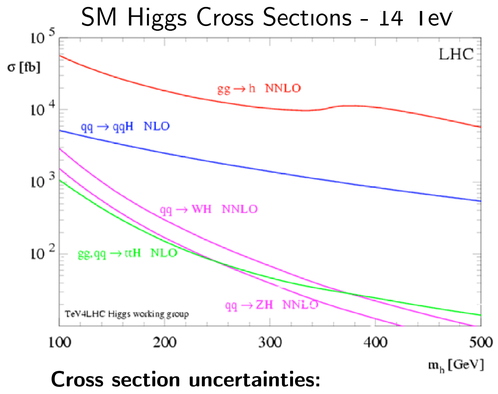


SM Higgs Boson at LHC





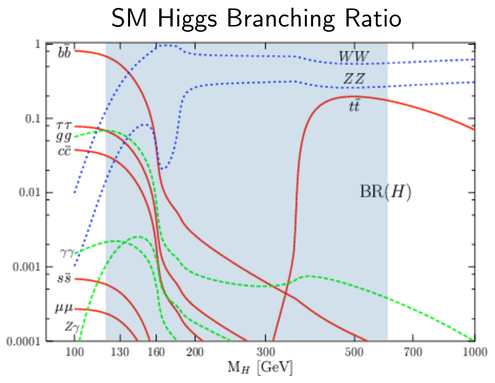
SM Higgs Cross Sections - 14 TeV



Cross section uncertainties:

gg fusion 10-20% (NNLO) tt fusion 10% (NLO)
W,Z bremss <5% (NNLO) WW,ZZ fusion <10% (NLO)

SM Higgs Branching Ratio



Branching ratios known to NLO

⇒ few % uncertainty

$H \to ZZ^{(*)} \to 4l$ Channel

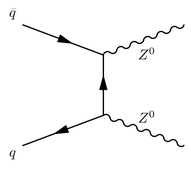
- two production channels considered: gg fusion and WW,ZZ fusion
- PYTHIA used to generate events
- $H \to ZZ^{(*)} \to 4l$ analysis: **three selections** 4e - 4μ - 2e2μ
- 12 mass points evaluated, from 120 to 600 GeV/c^2

Full detector simulation (Geant4) for signal and backgrounds

m_H [GeV]	σ_{LO}·BR [fb]	σ_{NLO}·BR [fb]
120	1.68	2.81
130	3.76	6.25
180	3.25	5.38
200	12.39	20.53
300	7.65	13.32
600	1.53	2.53

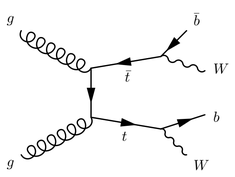
Signal Cross sections at 14 TeV

irreducible background

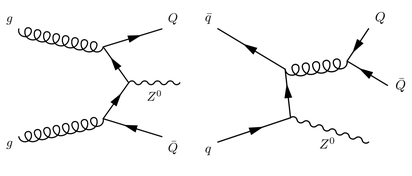


ZZ*/γ* →4l
PYTHIA rescaled to NLO (MCFM)
+30% for quark box diagram
$\sigma_{NLO} \times BR = 34.8$ (K[M_{ZZ}] + 0.3) fb

reducible background



ttbar →4l
MC@NLO
$\sigma_{NLO} \times BR = 6.1$ pb

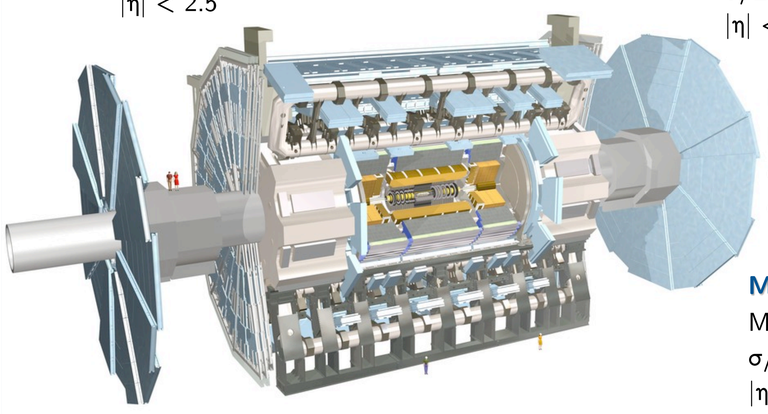


Zbbbar →4l
AcerMC rescaled to NLO (MCFM)
K-factor = 1.42
$\sigma_{NLO} \times BR = 812.1$ fb

ATLAS Detector [3]

TRACKER (ID)
Si pixels + strips -TRT → particle identification
$\sigma/p_T = 5 \times 10^{-4}\ p_T \oplus 0.01$
$|\eta| < 2.5$

EM CALO
Pb-liquid argon - uniform longitudinal segmentation
$\sigma/E = 10\%/\sqrt{E} \oplus 0.007$
$|\eta| < 3.2$



HAD CALO
Fe-scint. + Cu-liquid argon (≥ 10 λ)
$\sigma/E = 50\%/\sqrt{E} \oplus 0.03$ $|\eta| < 3.2$
$\sigma/E = 100\%/\sqrt{E} \oplus 0.1$ $3.1 < |\eta| < 4.9$

MUON SYSTEM (MS)
MDT, CSC, RPC, TGC
$\sigma/p_T = 10\%/p_T$ at $p_T = 1$ TeV/c
$|\eta| < 2.7$

$H \to ZZ^{(*)} \to 4l$ (l = e, μ) channel → electrons and muons involved only:

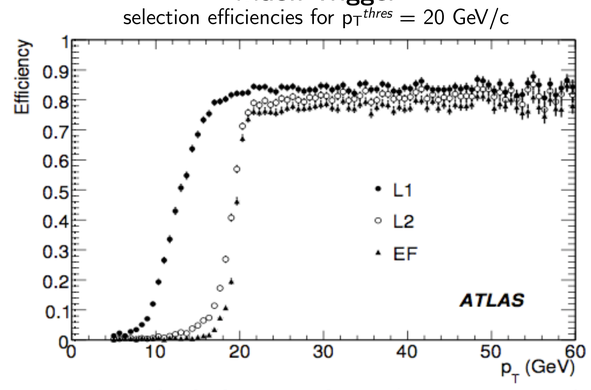
- *very good lepton trigger and identification needed*
- full event reconstruction - narrow mass peak for $m_H < 200$ GeV/c^2 (dominated by detector resolution)

Lepton-only final states are the cleanest at LHC

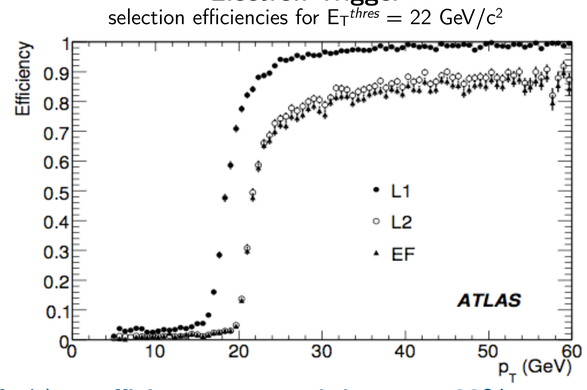
ATLAS Lepton Trigger and Reconstruction [4]

Impact of the *three-level ATLAS trigger chain* on $H \to ZZ^{(*)} \to 4l$ search evaluated - Only events fulfilling a given trigger selection are kept (electron and muon trigger slices) - *single or dilepton triggers*

Muon Trigger
selection efficiencies for $p_T^{thres} = 20$ GeV/c

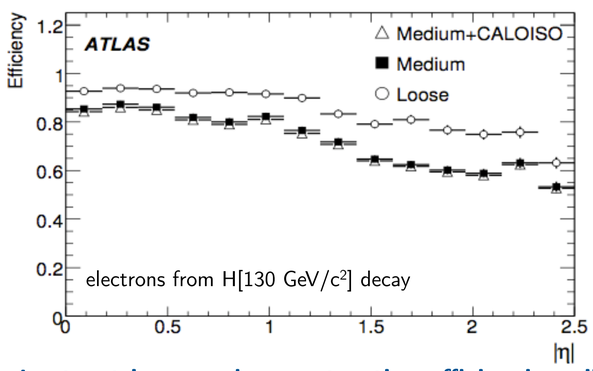


Electron Trigger
selection efficiencies for $E_T^{thres} = 22$ GeV/c^2

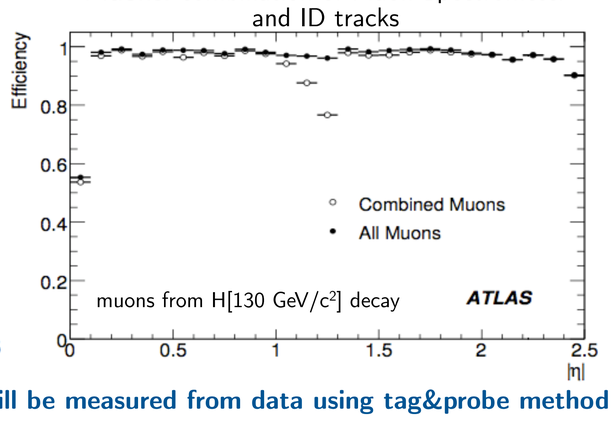


- **single lepton trigger** (1μ20 or 1e22i, default) → **efficiency on H→4l decays > 98%**
- **di-lepton trigger** (2μ10 or 2e15i or 1μ10 and 1e15i) → **efficiency higher than 97%**

Electrons: ID and EM Calo information



Muons: combination of Muon Spectrometer and ID tracks



Lepton trigger and reconstruction efficiencies will be measured from data using tag&probe method

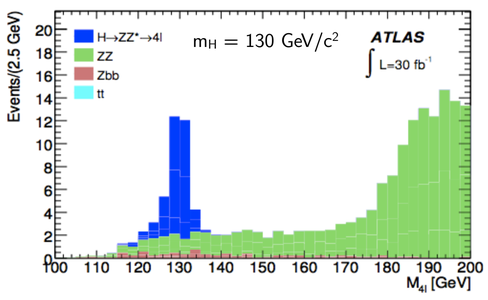
Event Selection and Results [4]

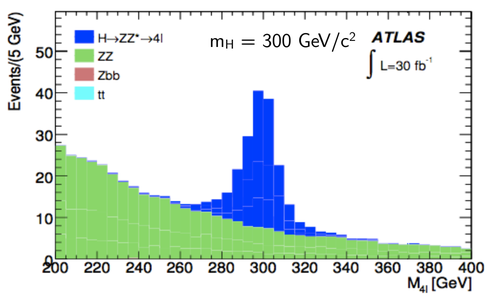
Event Preselection : creation of lepton pairs → $p_T > 7$ GeV/c and $|\eta| < 2.5$ - at least two leptons with $p_T > 20$ GeV/c

Event selection :

- four leptons (e,μ) in pairs of opposite charge and same flavor + additional lepton pair quality:
  - for $m_H > 200$ GeV/c^2 : *LooseElectrons* (= hadronic leakage, shower width, track match)
  - for $m_H < 200$ GeV/c^2 : *MediumElectrons* (= *LooseElectrons* + track quality and shower shape cuts + Calorimeter Isolation - CALOISO)
- Z mass constraint (i.e. Breit-Wigner + Gaussian, with σ equal to experimental resolution of Z mass) - on both Z's if $m_H > 200$ GeV/c^2 → *this improves H mass resolution by 10-17% for $m_H < 200$ GeV/c^2*
- Kinematic cuts on Z objects - Isolation and impact parameter cuts - Higgs mass window $m_H \pm 2\sigma_{MH}$

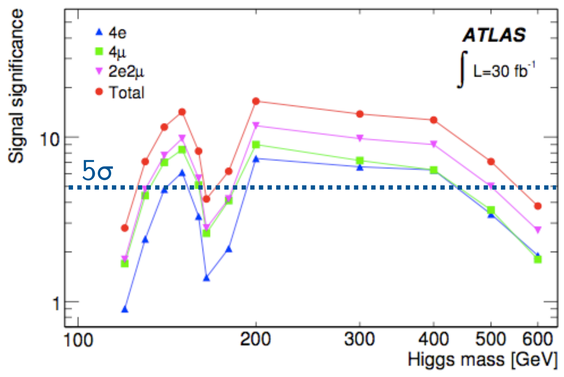
→ *Alignment of MS with ID crucial* - not only to measure with high precision the track transverse momentum and the primary vertex, but also to evaluate the track association to that vertex
→ *Calo isolation crucial* to reject leptons associated to jets



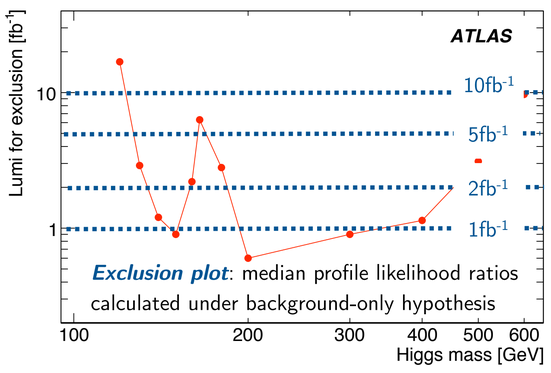


Results for integrated luminosity = 30 fb^{-1}
not including systematics and pileup (only statistical uncertainty)

- Events selected within a $\pm 2\sigma_{MH}$ window
- Significance calculated with Poisson statistics
- Effect of pileup (preliminary!): ~5% significance degradation



luminosity needed for the 95% CL exclusion of SM Higgs



Systematic uncertainties: theoretical (PDF, QCD scales), experimental (related to lepton reconstruction), uncertainty on LHC luminosity

➡ *Overall impact on the selection efficiencies: from 3.2% to 6.0% on the signal and from 3.1% to 5.4% on ZZ and Zbbbar backgrounds*
(ttbar contribution negligible)

References

[1] http://lepewwg.web.cern.ch/LEPEWWG/
[2] "Combined CDF and DZero Upper Limits on Standard Model Higgs-Boson Production with up to 4.2 fb^{-1} of Data ", FERMILAB-PUB-09-060-E
[3] "The ATLAS Experiment at the CERN Large Hadron Collider", J. Instrum. 3 (2008) S08003
[4] "Expected Performance of the ATLAS Experiment: Detector, Trigger and Physics", CERN-OPEN-2008-020