Measurement of the pp → Z→μμ+X cross section with the ATLAS detector at the LHC

IFAE 2010 - Incontri di Fisica delle Alte Energie
7-9 April 2010 Rome, Italy

R.Di Nardo on behalf of ATLAS collaboration
University of Roma Tor Vergata & INFN

Introduction

- In winter 2009 the LHC started to deliver proton proton collisions at the center of mass energy of 900 GeV
- After the winter shutdown the Collider has restarted the operation with the plan to deliver 1 fb^{-1} of integrated luminosity at 7 TeV in the center of mass in 2010-2011.

Process	Cross Section @ 7TeV(NLO)	Events for 200pb^{-1}
pp→Z→μμ+X	0.953 nb	~ 190000
pp→W→μν+X	9.86 nb	~ 1970000

- The ATLAS experiment physics plan for the coming two years is to "rediscover" SM physics (W , Z , top) with the aim to further improve the calibration of the detector since these processes are the main background to discover new physics

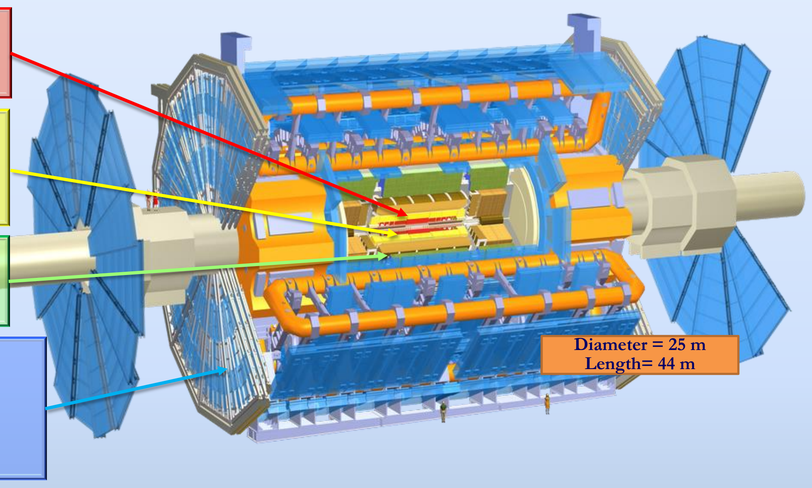
The ATLAS Experiment

INNER DETECTOR (|η|<2.5, B=2T)
Pixels+microstrips,+TRT(e/π separation)
$\sigma(p_T)/p_T \approx 5\times10^{-4} p_T \oplus 0.01$

EM CALORIMETER (|η|<3.2)
LAr + Pb uniform longitudinal segmentation
$\sigma(E)/E \sim 10\%/\sqrt{E} \oplus 0.007$

HADRONIC CALORIMETER (|η|<4.9)
Fe + scintillator / Cu+ Lar (10λ)
$\sigma(E)/E \sim 50\%/\sqrt{E} \oplus 0.03$

MUON SPECTROMETER (|η|<2.7)
Precision Chambers (MDT,CSC) + Trigger Chambers(RPC,TGC) in air core toroids
$\sigma(p_T)/p_T \sim 2\%$ @ 50GeV to 10% @ 1TeV (ID+MS)



Z production cross section at LHC

$$\sigma_Z \cdot BR(Z \to \mu\mu) = \frac{N_Z^{obs} - N_B}{A \times \varepsilon_r \times \varepsilon_t \times \int Ldt}$$

Fraction of MC events that passes kinematic and angular cuts

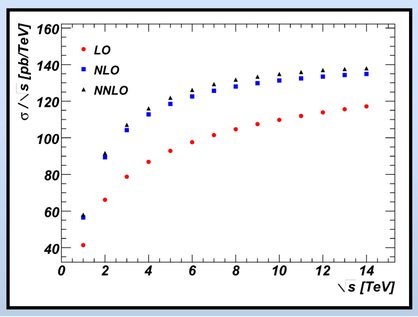
Reconstruction and trigger efficiency (Tag & Probe method from data)

Sum on all data of $\int L(t) l(t) p(t) f(t) dt$
Instant Luminosity, TDAQ lifetime, trigger prescale, failure and losses

- Systematic contributions from experimental and theoretical sources are carefully taken in to account

$$\frac{\delta\sigma}{\sigma} = \frac{\delta N \oplus \delta B}{N - B} \oplus \frac{\delta\varepsilon}{\varepsilon} \oplus \frac{\delta A}{A} \oplus \frac{\delta L}{L}$$

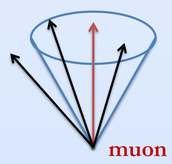
Z boson production inclusive cross-sections divided by proton-proton center-of-mass energy $\sqrt{s}$ as a function of $\sqrt{s}$. MSTW08 PDF sets are used.



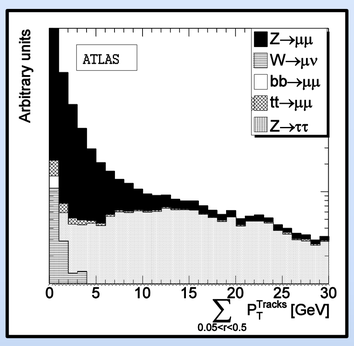
Background rejection

- Needed to minimize the impact of backgrounds in the analysis
- The background of the Z→$\mu^+\mu^-$ decay originates from:
  - $t\bar{t}$ events where muons come from the $t/\bar{t}$ quarks decay in t→Wb and W→μν
  - W→μν, where one muon come from W decay and the other one is a fake muon
  - Z→ττ due to possibility to have muons from τ decays
  - jet background (in particular muons coming from b-hadron decay)
- Track multiplicity and total transverse momentum of tracks within a cone around the selected muon are used as discriminating variables

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



Σp_T distribution of tracks within a cone ΔR=0.5 around the selected muon for the Z→$\mu^+\mu^-$ decay and for the other main backgrounds



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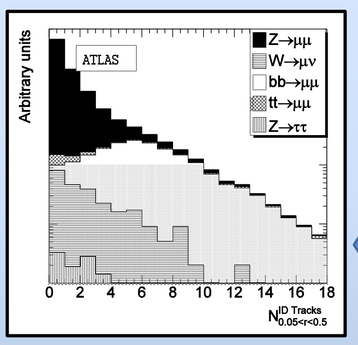
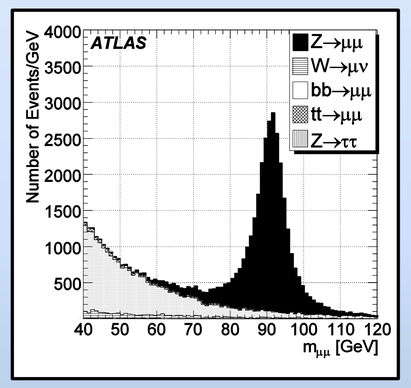


Event selection

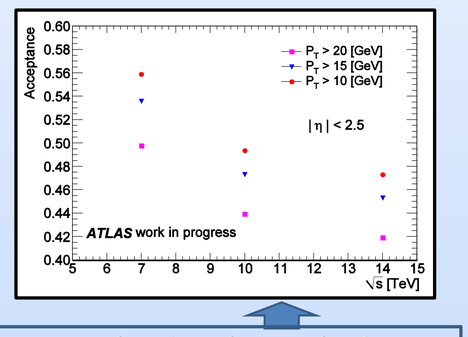
- A single lepton trigger requiring a muon (p_T>10GeV) is used in the analysis
- Events selection with two muons with p_T>20GeV and |η|<2.5 and opposite charge
  - Muons: are required to be either reconstructed by the *Combined* reconstruction algorithm (Muon Spectrometer + Inner detector muon track combination) or extrapolated from the inner detector
- Inner Detector track isolation cuts are applied for background rejection
  - Σp_T<5GeV and N^{ID}_{tracks} < 6 within a cone around the candidate muon with a size ΔR=0.5
- The invariant mass of the muon pair Mμμ should fulfill $|91.2GeV - M_{\mu\mu}| < 20$ GeV
- With this cuts ~70% of the Z→μμ events with muons in the acceptance are selected
- The residual background fraction is 0.004±0.001
  - dominant component comes form $t\bar{t}$ background (theoretical uncertainty of about 20% on the rate)

Reconstructed di-muon invariant mass distribution in the Z→$\mu^+\mu^-$ channel, for signal and background, for 50 pb^{-1} @ 14 TeV c.m.e. after all cuts, except the isolation and $M_{\mu\mu}$ cuts.



Acceptance

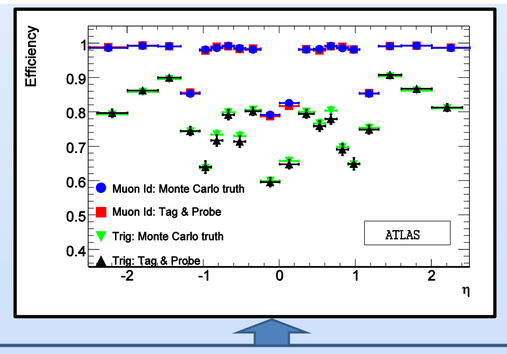
- Calculated through MC simulation (MC@NLO) imposing kinematical cuts (p_T and η) on outgoing muons from Z boson
- In the first stage of data taking the uncertainties on luminosity and acceptance will dominate the Z cross section measurement
- Systematic error in acceptance calculation depends on:
  - the different PDF error sets that can be used
  - the Initial State Radiation
  - Intrinsic p_T of incoming partons
  - QED corrections (computed with Photos tool)
  - Spin correlation between incoming partons and final leptons



Acceptance as function of c.m.e. for three different p_T cut on the muon coming from the Z boson decay and |η|<2.5 (only statistical errors are shown)

Reconstruction & trigger efficiency

- Tag & Probe method uses the independent muon measurement given by Inner Detector and Muon Spectrometer
- Requires two reconstructed track in ID and at least 1 in Muon Spectrometer. Invariant mass of two ID tracks close to Z mass. ID tracks isolated
- ID track + associated MS track form a tag muon
- The second track in the ID correspond to a probe muon and have the same role of the generated muon in the determination of efficiency with simulated data



The 20 GeV single muon trigger efficiency and the combined muon reconstruction efficiency vs η , as measured from the tag-and-probe method and compared to the truth, for 50 pb^{-1}.

Momentum scale and resolution

- The muon momentum measurement will be affected by: limited knowledge of the magnetic field, uncertainty in the energy loss of the muons, alignment of the muon spectrometer

ENERGY LOSS

- Muons with p_T<100 GeV lose on average ~3 GeV on their passage through the calorimeters almost independently of their energy.
- Material distribution knowledge better than a few percent → 5% uncertainty in material traversed correspond to a ±150 MeV uncertainty in energy loss.
- Using Z → μμ events, one computes the tower-dependent corrections

$$\chi^2 = \sum_{\mu\mu\ pairs\ k} \frac{\left[\left(p_{corr,+,k} + p_{corr,-,k}\right)^2 - M_Z^2\right]^2}{\sigma_k^2}$$

MS MISALIGNMENT

- Effect on momentum scale and resolution can be accounted by computing scale factors to correct the observed Z shape.
- An iterative procedure changes the MC p_T resolution function in width and scale, calculate the corresponding Z boson mass distribution and stops if the new distribution predicted agree within statistical error the measured distribution

References

1. "Expected Performance of the ATLAS Experiment : Detector, Trigger and Physics", CERN-OPEN-2008-020
2. "The Standard Model W and Z boson production cross-sections and their uncertainties", M. Simonyan , ATL-COM-PHYS-2009-289
3. "The ATLAS Experiment at the CERN Large Hadron Collider", The ATLAS Collaboration, 2008 JINST 3 S08003