Studies of Diboson Production (ZZ(*)→4l) with the ATLAS Detector

65th Scottish Universities Summer School in Physics - “LHC Physics”

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Introduction - Motivation

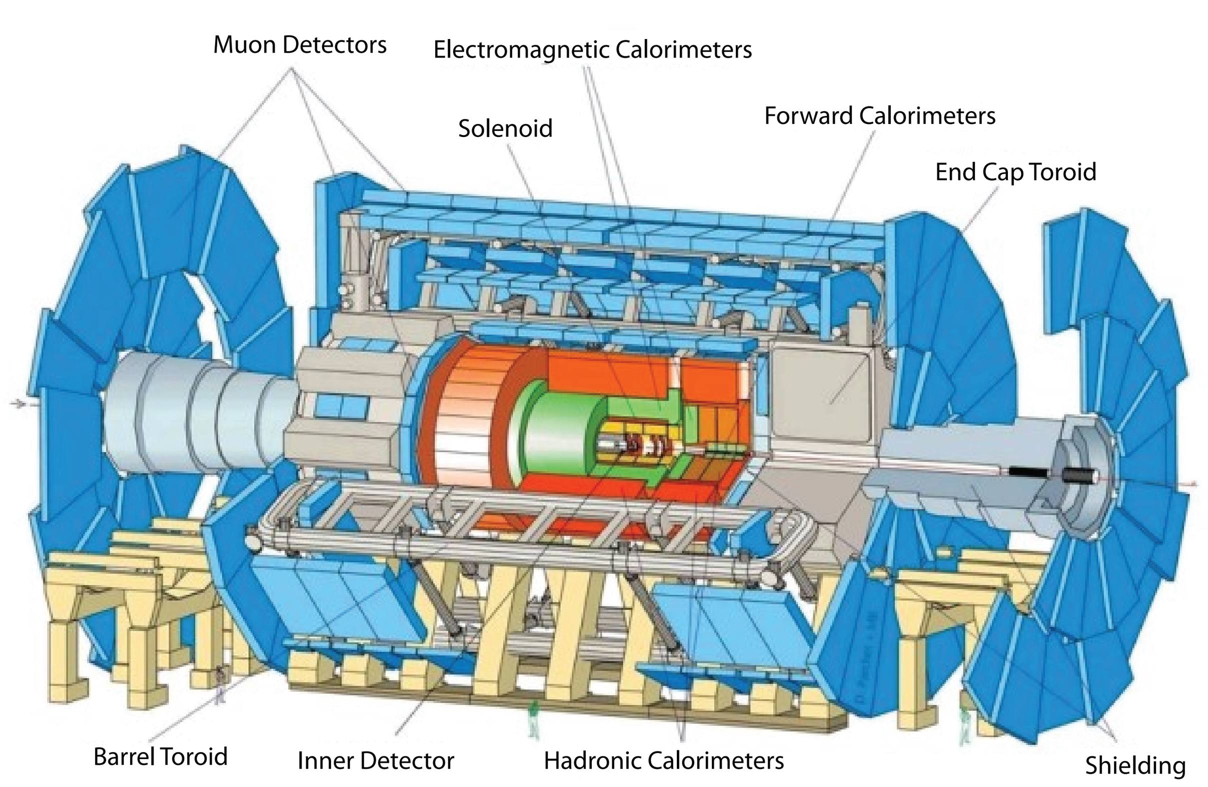
The ATLAS detector will give us the opportunity to study the physics process ZZ(*)→4l. In the current work the potential to observe at LHC the ZZ(*)→4l channel at 10 TeV with 200 pb^{-1} integrated luminosity is studied. Three different signatures have been examined: 4e, 4μ and 2e2μ. The physics process ZZ(*)→4l is of great interest because:

➡It provides an opportunity to measure this cross section and test the Standard Model prediction at the LHC energy scale.

➡ It constitutes the irreducible background to the Higgs in 4 leptons channel:H→ZZ*→4l, the “golden” decay channel of the Higgs boson. For that reason we have to be able to determine the shape of the 4 lepton invariant mass distribution of the diboson ZZ(*) decay from the data, in the search for the Higgs boson.

➡It is a probe to new physics through deviations of Triple Gauge Couplings (TGCs) from Standard Model predictions.

The ATLAS detector at the LHC



ATLAS is one of the four experiments which will detect the collision products of the LHC. The ATLAS detector is a general purpose HEP detector that consists of three main detection systems each with several detector technologies:

➡ The inner detector (ID) is located inside a solenoidal magnetic field of 2T. It will be used for tracking and momentum measurement of the charged particles.

➡ The Calorimetric System is divided in three parts: electromagnetic, hadronic and forward calorimeter. The e/m calorimeter uses LAr as active material and steel-coated lead (pb) as absorber and covers a range of |η| ≤ 3.2. The hadronic calorimeter is divided in one barrel, two end-cap (HEC) sections and the forward calorimeter (FCAL). The barrel hadronic calorimeter is made of steel which acts as absorber, while for active material tiles of plastic scintillator are used. The end-cap sections use copper as absorber material and LAr as the active medium. All of the hadronic calorimeter covers a range of |η| ≤ 4.9.

➡ The Muon Spectrometer (MS) is the outer part of the ATLAS detector and is using air core toroid magnet systems for both the barrel and end-cap regions (B=0.3-2T). Its purpose is to measure the trajectories of muons in order to determine their direction, their electric charge and their momentum in |η| < 2.7.

Analysis

➡ **Selection criteria**

✦ **Preselection**

e± i. Reconstructed by the electron finding algorithm ii. $p_T > 6$ GeV/c, |η| < 2.5

μ± i. MS track with an ID track associated to it unless in |η| > 2.5 where only MS track is required ii. χ^2 / DOF < 15 on match, χ^2 / DOF < 15 on fit iii. $p_T > 6$ GeV/c, |η| < 2.7

✦ **After Preselection:**

For both electrons and muons:

i. Create same flavor opposite charge pairs with lepton dR > 0.2 (where dR is the angle between the two leptons of the pair $dR=\sqrt{(\eta_1-\eta_2)^2+(\varphi_1-\varphi_2)^2}$).

ii. At least one lepton in each pair with $p_T > 20$ GeV/c.

iii. Isolation:

For electrons: Loose identification (Id) cuts have been applied to all electrons (Id cuts which refer to the shower shape in the calorimeter to discriminate signal from background) and Medium Id cuts to the Softer electrons (Id cuts which also include an isolation cut based on the E_T of the e/m shower inside a cone with radius 0.2, e/m cluster and inner detector matching and track quality cuts).

Loose cuts have been used in order to increase the statistics for the case of the backgrounds and study the shapes of the invariant mass distributions after every cut.

For muons: Isolation Ratio < 0.2 (Ratio is the energy in a cone of dR < 0.4 around the muon divided by E_T)

iv. Number of possible pairs which form a Z(*) ≥ 4

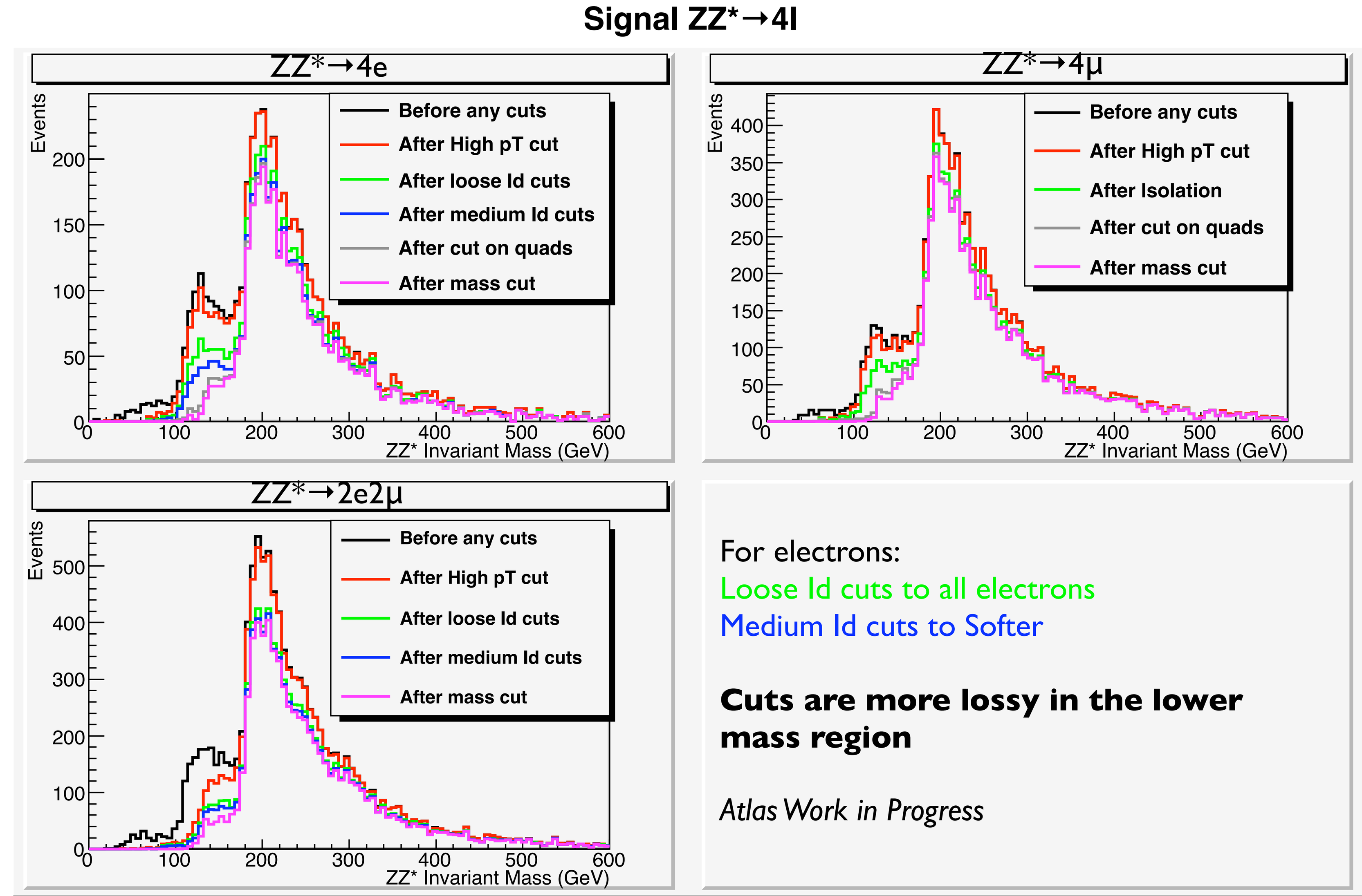
v. 2l invariant mass

- ZZ: 70 GeV/c < M_{ll}(pair1) < 110 GeV/c, 70GeV/c < M_{ll}(pair2) < 110 GeV/c
- ZZ*: 70 GeV/c < M_{ll}(pair1) < 110 GeV/c, M_{ll}(pair2) > 20 GeV/c

➡ **Invariant Mass Distributions**

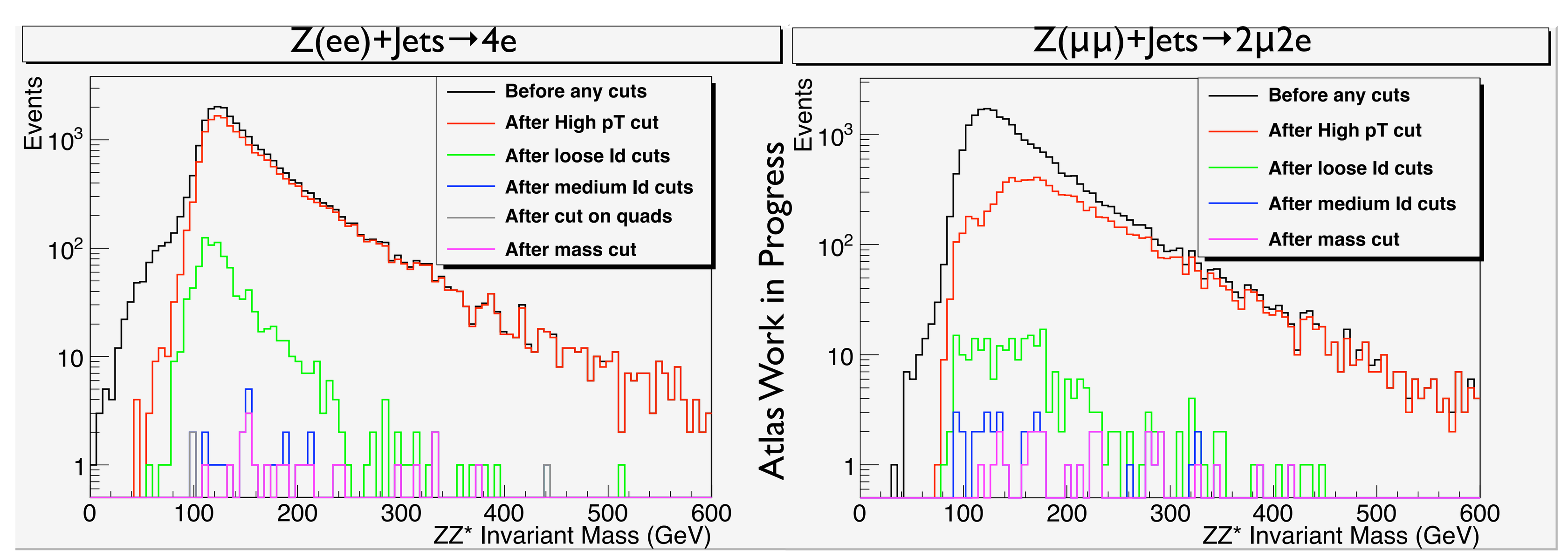
In order to study the ZZ(*)→4l channel and measure the production cross section we need to estimate the contribution from various background sources like Zbb(bar), Z+Jets and tt(bar).

Signal ZZ*→4l



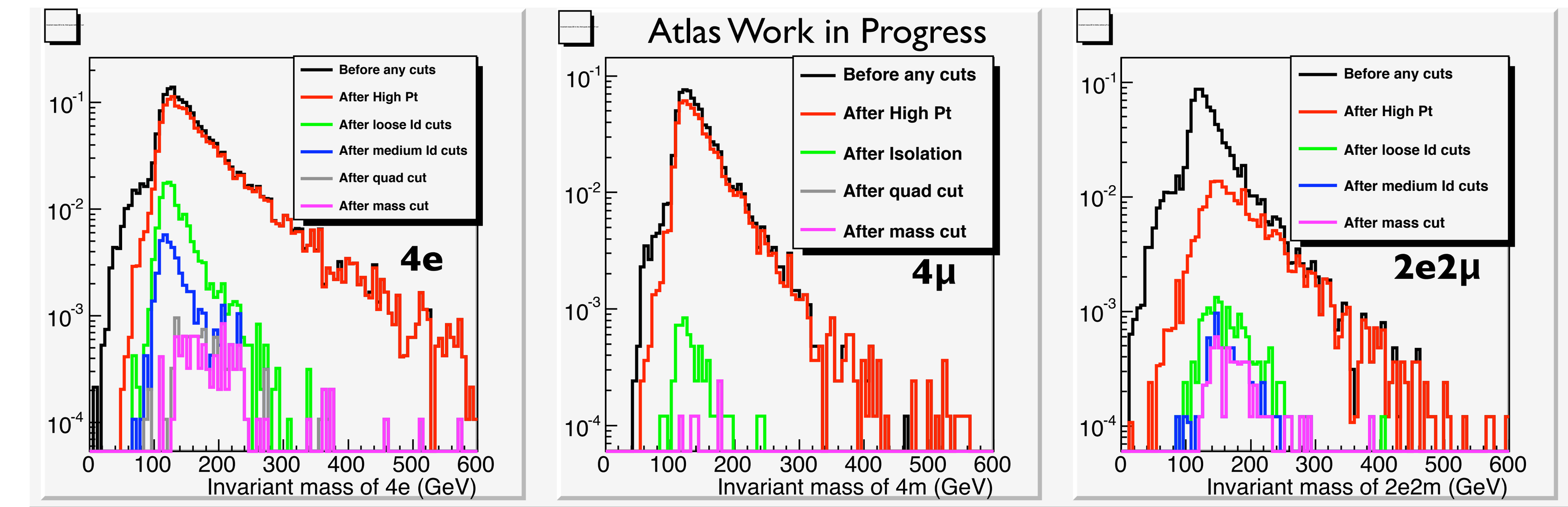
Invariant mass distributions after every cut for the case of Signal ZZ. The plots represent the three different signatures 4e, 4μ, 2e2μ.*

Backgrounds (all plots are in a log scale)



Invariant mass distributions after every cut for the Z(ee)+Jets and Z(μμ)+Jets backgrounds.

Zbb(bar)→4l (plots in log scale)



*Invariant mass distributions for the Zbb(bar) background. **Black** - Before any cuts, **Red** - After high p_T cut, **Green** - After loose Id cuts (for the case of 4e) - After Isolation (for the case of 4μ), **Blue** - After medium Id cuts to Softer, **Grey** - After quadruplets cut, **Pink** - After mass cut.*

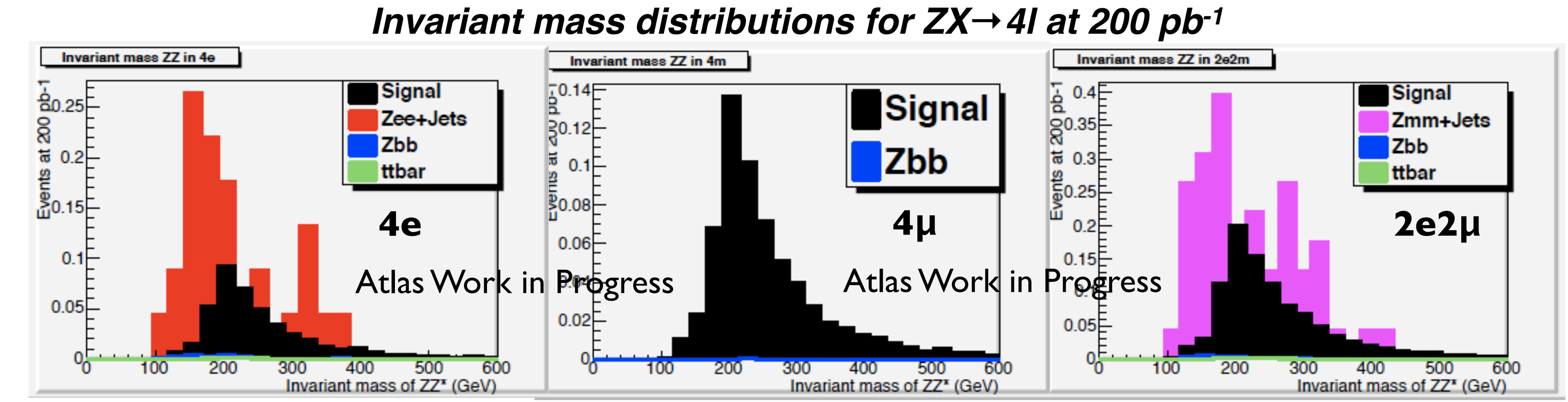
Results

Expected number of events at 200 pb^{-1}

Channel	Events “Loose” electrons	Events “Medium” electrons	Events “Loose” & “Medium” to Softer
ZZ*→4e	0.458	0.308	0.426
ZZ*→4μ	0.637	0.637	0.637
ZZ*→2e2μ	1.035	0.845	0.996
Total Signal	2.130	1.790	2.059
Z(ee)+Jets→4e	8.659	-	1.186
Z(μμ)+Jets→2μ2e	9.758	0.044	2.242
Zbb(bar)->4e	0.046	0.004	0.017
Zbb(bar)->4μ	0.0008	0.0008	0.0008
Zbb(bar)->2e2μ	0.0533	0.0052	0.0263
ttbar→4e	0.174	-	0.049
ttbar→2e2m	0.124	0.008	0.049
Total Background	18.715	0.052	3.526

A comparison between different definitions of ID cuts for the case of electrons.

Invariant mass distributions for ZX→4l at 200 pb^{-1}



Conclusions

- Higher rejection for the Z+Jets bg can be achieved by using the cut on quadruplets.
- Fake electrons is the main problem from Z+Jets.
- The contribution of the tt(bar) bg to our analysis is very small.
- Main goal is to measure the Z+Jets bg from real data using the shape of the invariant mass distributions of the pairs (Z, Z*).

Fully funded by the Research Training Network ARTEMIS (contract number MRTN-CT-2006-035657)