Study of ($pp \rightarrow Z/\gamma* \rightarrow \mu^+\mu^-$) at High Dimuon Masses with the ATLAS Detector

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The LHC will provide hitherto unreached center of mass energies, which allow testing new aspects of the standard model as well as searching for new physics. The Drell-Yan process ($pp \rightarrow Z/\gamma* \rightarrow \mu^+\mu^-$) offers a good channel for this, as the two resulting muons are a clear signal. Various theoretical extensions of the standard model predict changes in the Drell Yan spectrum, so a precise measurement can function as a model independent search for new physics.

The main background contributions stem from $t\bar{t}$ and $b\bar{b}$. Background from $W \rightarrow \mu\nu$ with one additional reconstructed muon has also been studied, but is neglegible. Due to the high cross section $b\bar{b}$ creates high background, but mainly with low dimuon masses. $t\bar{t}$ on the other hand has a much lower cross section, but is harder to distinguish from the signal, and results in larger dimuon masses than $b\bar{b}$ background.

To reduce background, a cut based analysis has been developed. The cuts have been chosen, to provide the best possible background reduction while keeping the systematic errors as low as possible. To reduce backgrounds various cuts on isolation, missing transverse energy ($\not{E}_T$) and event shape have been studied. The preselection of events is based on some quality cuts for the muons and requires two muons with a transverse momentum (p_T) above 20 GeV.

Isolation cuts are especially effective against $b\bar{b}$, due to the two nonisolated muons, that are typically close to jets. Due to the high top mass, top decay products are more separated from each other, which results in more isolated muons from top decays. On the other hand, the higher top mass results in more energy carried away in neutrinos. This results in a larger $\not{E}_T$, which can be used as cut. Muons from Drell Yan tend to be back to back, while in some $b\bar{b}$ events both muons are produced by the same jet. Therefore closely neighboured muons are rejected. $t\bar{t}$ also has a much higher jet activity, which leads to the idea of a cut on the scalar sum of all jets energies. It has been shown, that this cut reduces the $t\bar{t}$ background further, but introduces additional systematic errors that outweigh the lower background, therefore it is not applied in this analysis.

	$Z \rightarrow \mu^+\mu^-$	$t\bar{t}$	bb
Effective cross section	1808	450	4000
Preselection	817	13.2	438
Isolation	797	6.8	19.9
Muon distance	795	6.3	11.2
$\not{E}_T$	793	2.1	11.2

Table 1: Cutflow table normalized to 1 pb^{-1}. For $Z \rightarrow \mu^+\mu^-$ a Pythia sample with dimuon masses above 60 GeV was used. $t\bar{t}$ is a sample excluding fully hadronic decays produced by MC@NLO. The $b\bar{b}$ sample is also from Pythia, requiring two muons above 5 GeV.

Since a cut efficiency that is dependent on the dimuon mass would introduce a shift in the shape of the measured Drell Yan spectrum, special emphasize has been put on the behavior of all cuts at high dimuon masses.

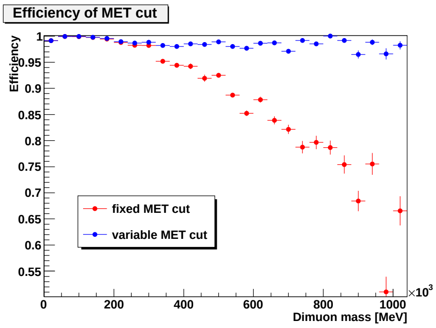

Fig. 1: Percentage of signal events surviving the cut on $\not{E}_T$. In red with a fixed cut, in blue with a cut dependent on the p_T of the muons.

A good example is $\not{E}_T$. A cut at a fixed value of e.g. $\not{E}_T < 50$ GeV is not feasible as $\not{E}_T$ depends on the transverse momenta (p_T) of the muons, which again depends on the dimuon mass. The reason for this is, that the biggest contribution to $\not{E}_T$ in high mass Drell Yan events is a wrongly measured muon p_T. Since the relative momentum resolution is proportional to p_T, the absolute resolution is proportional to ${p_T}^2$. This results in the steeply falling efficiency for a fixed cut on $\not{E}_T$ in Fig. 1.

Therefore the cut on $\not{E}_T$ is

$$\not{E}_T < \max\left(50\,GeV, \frac{\sqrt{{p_T}_1^4 + {p_T}_2^4}}{500\,GeV}\right),$$

where ${p_T}_i$ is the transverse momentum of the muon i=1,2. With this formula, the efficiency of the cut is nearly constant over a large dimuon mass range, as can be seen in Fig 1.

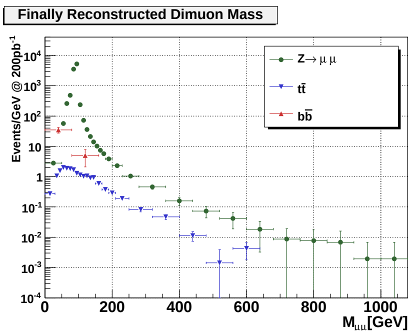

Fig. 2: Expected dimuon mass distribution for 200 pb^{-1}. The error bars on the signal are expected statistical errors, while the error bars on background represent the errors due to limited Monte Carlo statistics.

With the studied cuts a signal to background ratio of about 10 can be achieved. With 200 pb^{-1} the Drell Yan spectrum can be measured up to 600 GeV, as can be seen in Fig. 2. Furthermore the systematic effects of different Monte Carlo effects, including different hadronization schemes and next to leading order, have been studied. The cuts were optimized to reduce the impact of those systematics.