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Search for W' in Lepton+Missing E_T Final State With Early Data at ATLAS

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Extensions of the Standard Model gauge symmetries imply the existence of a new heavy charged gauge boson generically denoted as W'. Assuming Standard Model W like couplings, we evaluate the ATLAS discovery potential of such a boson in the lepton (electron and muon) plus missing transverse energy final state. The whole study is based on the full detector simulation data which include trigger performance and realistic detector calibration. Relevant systematic uncertainties are addressed. The study is focused at early stages of data taking with a centre of mass energy $\sqrt{s}$ =14 TeV.

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Despite the amazing experimental success of the Standard Model (SM) there are strong theoretical motivations for the existence of new particles that could be produced at the TeV scale. The existence of a new heavy charged gauge boson, W', arises in many extended gauge theories. The study presented here is based on predictions of a SM-like W' [1], which has the same couplings to fermions as the SM W, and whose decay to WZ is suppressed.

The DØ experiment has set the present lower limit for the W' boson mass to $m_{W'} > 1$ TeV at 95% C.L. [2]. According to several predictions there is at least one W' boson detectable at the LHC, and it is expected that the search reach will be increased even at early stages of data taking. Here, the study of ATLAS potential for W' search in electron or muon plus missing transverse energy final state is presented. This study is based on a recent realistic detector description, including a complete simulation of the trigger chain. A more detailed description of the study is given in [3].

For the signal simulation, samples of $W' \to l\nu$ ($l = e, \mu, \tau$) events are generated using `Pythia` [4], with the PDF CTEQ6. The W' boson masses range from 1 to 3.5 TeV, and the corresponding leading order cross sections from 9430 fb to 20 fb. The high-mass tail of SM $W \to l\nu$ production represents irreducible background, while $t\bar{t}$ and QCD multijet production are the main reducible backgrounds. `Pythia` is used for all signal and background generation, except for $t\bar{t}$ where the `MC@NLO` [5] event generator is used. Higher order corrections for W' and $W \to l\nu$ are evaluated with `MC@NLO`. For W' production, SM W boson production process is employed, with mass set to W' mass and width to the value calculated by `Pythia`. For a transverse mass[1], m_T above 700 GeV, the W' and the SM W leading order cross sections are multiplied by a factor of 1.37.

Muons are reconstructed using an algorithm which performs a statistical combination of a track reconstructed in the muon spectrometer with its corresponding track in the inner detector (ID). The reduction of fake and badly reconstructed muons is achieved by imposing quality criteria: $\chi^2_{match} < 100$, longitudinal impact parameter $<$200 mm and transverse impact parameter divided by its error $<$10. Electron candidates are built from clusters of calorimeter cells with energy deposition, which are matched to an ID track, with "medium" quality criteria applied for electron identification [3]. Missing E_T is calculated from energy deposits in calorimeter cells that survive a noise suppression procedure, with corrections applied for muon energy loss and for the energy deposition in the cryostat material; in a second step a refined calibration of calorimeter cells is done by using the association of calorimeter cells with reconstructed objects.

In order to extract signal over the background, events are required to have only one reconstructed lepton with $p_T(l) > 50$ GeV, $|\eta(l)| < 2.5$, and $E_T^{miss} > 50$ GeV. To suppress $t\bar{t}$ and QCD multijet backgrounds, selection criteria on lepton isolation and the lepton fraction are imposed. The lepton is considered isolated if the sum of the p_T of ID tracks in a cone $0.02 < \Delta R = \sqrt{(\Delta\phi)^2 + (\Delta\eta)^2} < 0.3$ around the lepton is less than 5% of the lepton p_T. The lepton fraction, which essentially measures the fraction of energy that can be attributed to leptons and neutrinos in an event, is defined as $(p_T(l) + E_T^{miss})/(p_T(l) + E_T^{miss} + \Sigma E_T)$. The events are required to have a lepton fraction > 0.5. Figure 1 presents the m_T distribution in the muon search mode after the selection. In order to minimize the integrated luminosity needed for a 5σ excess, an additional requirement on m_T is imposed. Cross sections for $m_{W'} = 1$ TeV and background in the electron

[1] $m_T = \sqrt{2p_T(l)E_T^{miss}(1 - cos\Phi_{\vec{p}_t(l),\vec{E}_T^{miss}})}$, where $p_T(l)$ and E_T^{miss} are the lepton transverse momentum, and the missing transverse energy.

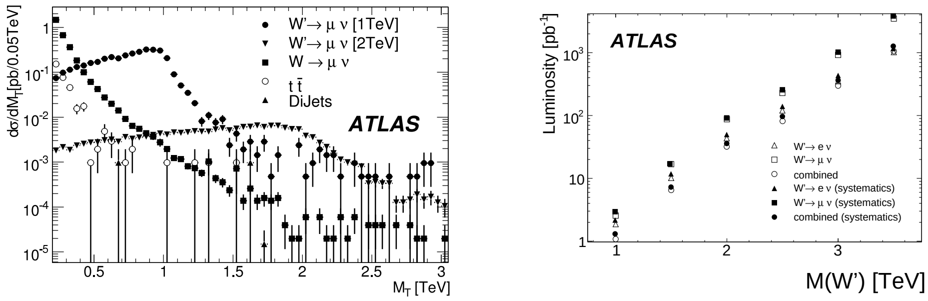

Figure 1: Expected m_T spectra after lepton fraction requirement in muon search mode (left). Integrated luminosity needed for 5σ discovery as a function of W' mass (right).

(muon) search mode for $m_T > 0.7$ TeV are 1.86 pb and 0.03 pb (2.20 pb and 0.05 pb) respectively. For $m_{W'} = 2$ TeV, the expected cross sections for the electron (muon) mode, for $m_T > 1.4$ TeV, are 0.074 pb and 0.001 pb (0.094 pb and 0.005 pb) respectively.

Relevant systematic uncertainties comprise generator and detector systematic uncertainties. The generator level uncertainty, which is estimated to be 8%, is mainly coming from PDF uncertainty, while higher order correction uncertainties and QED corrections are expected to be small. Detector systematic uncertainties comprise lepton identification efficiency, momentum scale and resolution, as well as jet energy scale and resolution and overall luminosity uncertainty. The largest effect is coming from luminosity (3%) and lepton identification efficiency uncertainties (5%), and from muon resolution uncertainty in the muon mode (5%). The significance for observing a W' signal is obtained from the expected number of signal (s) and background (b) events according to the formula $\sqrt{2((s+b)\ln(1+s/b)-s)}$, which gives a good approximation to the likelihood ratio based significance in the low statistics regime. With the systematic uncertainties taken into account, the required luminosity for a 5σ excess as a function of W' mass is shown on the Fig 1.

To summarize, the ATLAS detector potential to identify the decay of heavy, charged gauge boson with SM-like couplings to fermions, is studied in a lepton plus neutrino decay mode. It is shown that, even with an integrated luminosity of 10 pb^{-1} of well understood data, it would be possible to discover this type of boson should it exists not far from the current experimental limit.

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