PROCEEDINGS OF SCIENCE

Early Search for Supersymmetry at ATLAS

Xuai Zhuang on behalf of the ATLAS Collaboration[*] [†]
Ludwig-Maximilians-Universität, München, Germany
E-mail: Xuai.Zhuang@physik.uni-muenchen.de

The search for physics beyond the Standard Model (BSM) is one of the most important goals for the general purpose detector ATLAS at the Large Hadron Collider at CERN. Supersymmetry search strategies based on generic event signatures of high jet multiplicity and large missing transverse momentum, optionally including leptons in the final state with R-parity conservation are discussed in this document. We review the results for above SUSY search strategies with first data up to 305 nb^{-1} of integrated luminosity collected by ATLAS during 2010 at a centre-of-mass energy $\sqrt{s}$ = 7 TeV. [‡]

Workshop on Discovery Physics at the LHC -Kruger 2010
December 05-10, 2010
Kruger National Park, Mpumalanga, South Africa

[*]Speaker.

[†]The author would like to thank the organizing committee of the Workshop on Discovery Physics at the LHC -Kruger 2010 and everyone whose work contributed to this paper.

[‡]Since this talk was given, several results based on the larger integrated luminosity of 35 pb^{-1} collected by ATLAS during the 2010 have also been released[5].

PoS(Kruger 2010)051

1. Introduction

Supersymmetry (SUSY) is a theoretically favoured candidate for physics beyond the Standard Model. If strongly interacting supersymmetric particles are present at the TeV-scale, then such particles should be copiously produced in the 7 TeV collisions at the Large Hadron Collider (LHC) at CERN [1]. Therefore the search for the Supersymmetric particles is one of the most important aims of the ATLAS experiment at LHC.

This document presents a first comparison of data to Monte Carlo simulations for some of the most important kinematical variables that are expected to be employed in supersymmetry searches involving jets and missing transverse momentum and possibly including isolated leptons (electrons or muons) [2][3][4]. Selections based on these variables are expected to be sensitive not only to R-parity conserving SUSY particle production, but also to any model in which one or more strongly-interacting particles decay semi-invisibly producing leptons and jets. Three distinct signatures will be discussed in this document, which differ by the number of leptons in the final states (no-lepton and one-lepton channels) and by the application of a further b-tagging requirement (b-jet channel). The measurements in this document are based on data collected in the proton-proton collisions at $\sqrt{s}$ = 7 TeV at the LHC before August 2010. The no-lepton and one-lepton channels used a total integrated luminosity of 70 ± 8 nb^{-1} while the b-jet channel used 305 ± 17 nb^{-1}.

2. Inclusive SUSY search strategy and first measurements

2.1 Inclusive SUSY search strategy

High-energy jets, missing transverse energy ($E_{\mathrm{T}}^{\mathrm{miss}}$) and possibly leptons are the typical signature of R-parity conserved SUSY events at the LHC. The observation of deviations from the Standard Model may manifest the presence of SUSY. The discovery of new physics can only be claimed when Standard Model backgrounds are understood well and under control. Some of the most important SUSY sensitive variables have been measured and compared between data and Monte Carlo simulations to understand the Standard Model backgrounds. Due to the limited statistics of data taking considered here, the prediction of the Standard Model backgrounds is derived from Monte Carlo simulation directly.

One of the important SUSY sensitive variables is missing transverse momentum ($E_{\mathrm{T}}^{\mathrm{miss}}$), which is formed from two components. The first component is obtained from the vector sum of the transverse energies of all three-dimensional topological clusters in the calorimeter. The second component is obtained from the vector sum of the transverse momenta of isolated muons. The lepton isolation requirements is discussed later. The total missing transverse momentum is computed by a vector sum of these two components. Another important SUSY sensitive variable is the effective mass ($M_{\mathrm{eff}} = \sum_{i=1}^{N_{jets}} p_T^{jet,i} + \sum_{j=1}^{N_{leps}} p_T^{lep,j} + E_{\mathrm{T}}^{\mathrm{miss}}$), which is the scalar sum of the transverse momenta of N_{jets} leading jets, N_{leps} leading leptons and $E_{\mathrm{T}}^{\mathrm{miss}}$, where N_{jets} and N_{leps} are the number of jets and the number of leptons required in the analysis seperately. The transverse mass of the lepton and the $E_{\mathrm{T}}^{\mathrm{miss}}$ ($m_{\mathrm{T}} = \sqrt{2 \cdot p_{\mathrm{T}}^{\ell} \cdot E_{\mathrm{T}}^{\mathrm{miss}} \cdot (1 - \cos(\Delta\phi(\ell, E_{\mathrm{T}}^{\mathrm{miss}})))}$) is also used to suppress Standard Model backgrounds in the one-lepton channel.

2.2 Event selection and systematic uncertainty

After the good objects selection, the corresponding trigger requirement and a set of cleaning cuts to reject events containing jets which are consistent with calorimeter noise, cosmic rays or out-of-time energy deposits, the events are preselected by asking for at least two jets with transverse momentum $p_{\mathrm{T}} > 30$ GeV and one isolated lepton (electron or muon) with $p_{\mathrm{T}} > 20$ GeV in the one-lepton channel and in the b-jet channel, and by asking for at least two (2 jet channel), three (3 jet channel) or four (4 jet channel) jets with $p_{\mathrm{T}} > 30$ GeV, leading jet $p_{\mathrm{T}} > 70$ GeV and no lepton with $p_{\mathrm{T}} > 10$ GeV in the no-lepton channel. The signal region of the one-lepton channel is then defined by applying two further cuts: $E_{\mathrm{T}}^{\mathrm{miss}} > 30$ GeV and $m_{\mathrm{T}} > 100$ GeV. For the b-jet channel with one lepton, another two cuts are requiring: at least one b-tag with the decay length significance SV_0 $(= L/\sigma(L)$, L is the integrated luminosity) >6 and $E_{\mathrm{T}}^{\mathrm{miss}}$ significance $E_{\mathrm{T}}^{\mathrm{miss}}/\sqrt{\sum E_T} > 2\sqrt{GeV}$. The signal region of the no-lepton channel is defined by requiring: $E_{\mathrm{T}}^{\mathrm{miss}} > 40$ GeV, $\Delta\phi(\mathrm{jet}_i, \vec{E}_{\mathrm{T}}^{\mathrm{miss}}) > 0.2\,(i = 1,2,3)$ and $E_{\mathrm{T}}^{\mathrm{miss}}/M_{\mathrm{eff}} > 0.3$ (2 jet channel), 0.25 (3 jet channel) or 0.2 (4 jet channel), where $\Delta\phi(\mathrm{jet}_i, \vec{E}_{\mathrm{T}}^{\mathrm{miss}}), (i = 1,2,3)$ is the azimuthal angle between the three leading jets and $E_{\mathrm{T}}^{\mathrm{miss}}$.

The data is compared to the full-detector GEANT4 simulation which is reconstructed with the same algorithms as for the data. The Standard Model background processes considered in this analysis are QCD (PYTHIA), W/Z+jets (ALPGEN + HERWIG + Jimmy) and $t\bar{t}$ (MC@NLO + HERWIG + Jimmy). The PYTHIA QCD predictions were compared to a set of ALPGEN QCD samples; the differences were found to be well within the experimental uncertainties for the kinematic region explored. The QCD and W+jets backgrounds are normalized to the data in the control regions defined as $E_{\mathrm{T}}^{\mathrm{miss}} < 40$ GeV and $m_{\mathrm{T}} < 40$ GeV for the QCD background and $30 < E_{\mathrm{T}}^{\mathrm{miss}} < 50$ and $40 < m_{\mathrm{T}} < 80$ GeV for the W+jets background in the one-lepton channel. The QCD background is normalized to the data in a control region with at least two jets with $p_{\mathrm{T}} > 30$ GeV and leading jet $p_{\mathrm{T}} > 70$GeV in the no-lepton channel. As an example, the SU4 supersymmetric point (ISAJET+ HERWIG) is also shown in the plots with its cross section multiplied by 10; SU4 is a low-mass benchmark point close to the Tevatron limits and is defined as m_0 = 200 GeV, $m_{1/2}$ = 160 GeV, A_0 = -400 GeV, tanβ = 10 and $\mu > 0$.

The following most important sources of systematic uncertainties are considered: the uncertainty on the jet energy scale (which varies from 7-10% as a function of the jet p_{T} and η), the uncertainty on the W+jets and QCD normalizations (50%), the uncertainty on the Z+jets normalization (60%) and the uncertainty on the luminosity (11%).

2.3 Results

2.3.1 No-lepton channel

Fig. 1 shows the $E_{\mathrm{T}}^{\mathrm{miss}}$ and M_{eff} distributions for data and the different Standard Model contributions after the no lepton event selection in the different jet channels. All distributions are reasonably well described by the Monte Carlo predictions within the systematic uncertainties. In the signal region, four data events are found, which is consistent with the expectation of 6.6 ± 3.0 in the two-jet channel, no data events are found, which is consistent with the expectation of 1.9 ± 0.9 in the three-jet channel and one data event is found, which is consistent with the expectation of 1.0 ± 0.6 in the four-jet channel with 70 ± 8 nb^{-1} of integrated luminosity[2].

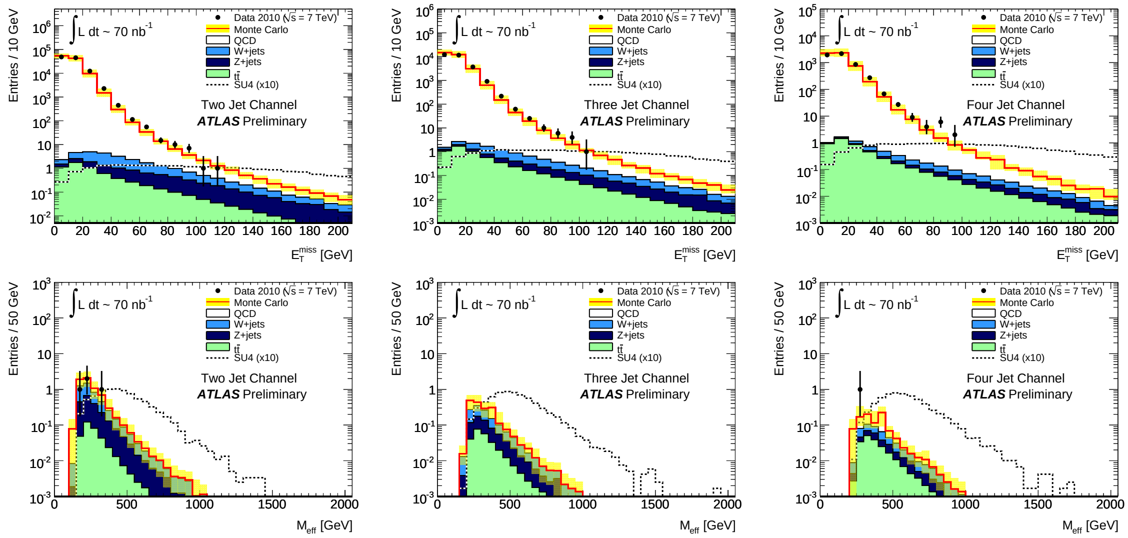

Figure 1: Distributions of $E_{\mathrm{T}}^{\mathrm{miss}}$ (upper) and M_{eff} (lower) for events in the two-jet channel (left), three-jet channel (medium) and four-jet channel (right) only with the jet selection cuts (upper) or after final selection cuts (lower) in the no-lepton channel.

2.3.2 One-lepton channel

Fig. 2 shows the $E_{\mathrm{T}}^{\mathrm{miss}}$ and M_{eff} distributions for data and the different Standard Model contributions after the electron channel event selection (left) and the muon channel event selection (right) in the one-lepton channel. All distributions are reasonably well described by the Monte Carlo predictions within the systematic uncertainties. Two events remain in the single electron channel and one event is found in the single muon channel. The Standard Model expectation is 3.6 ± 1.6 events in the electron channel and 2.8 ± 1.2 events in the muon channel with 70 ± 8 nb^{-1} of integrated luminosity[3].

2.3.3 b-jet channel with one lepton

In the framework of minimal supersymmetry (MSSM), the production of third generation squarks could be favoured. Direct pair production of sbottom or stop quarks can lead to a final state consisting of a pair of bottom-quark jets (b-jets) and significant $E_{\mathrm{T}}^{\mathrm{miss}}$. Leptons might also be present[4].

Fig. 3 shows the M_{eff} distributions for data and the different Standard Model contributions after the electron channel event selection (left) and muon channel event selection (right) in the b-jet channel. After applying all selections cuts, 4 events remain for the electron channel, with a Standard Model expectation of $4.8^{+1.7}_{-1.5}$, and 8 events remain for the muon channel, with a Standard Model expectation of $4.7^{+1.7}_{-1.5}$ with 305 ± 17 nb^{-1} of integrated luminosity. In both cases, data are in agreement with the Monte Carlo simulation within statistical and systematic uncertainties.

3. Conclusion and outlook

Measured distributions of missing transverse momentum, effective mass show agreement with

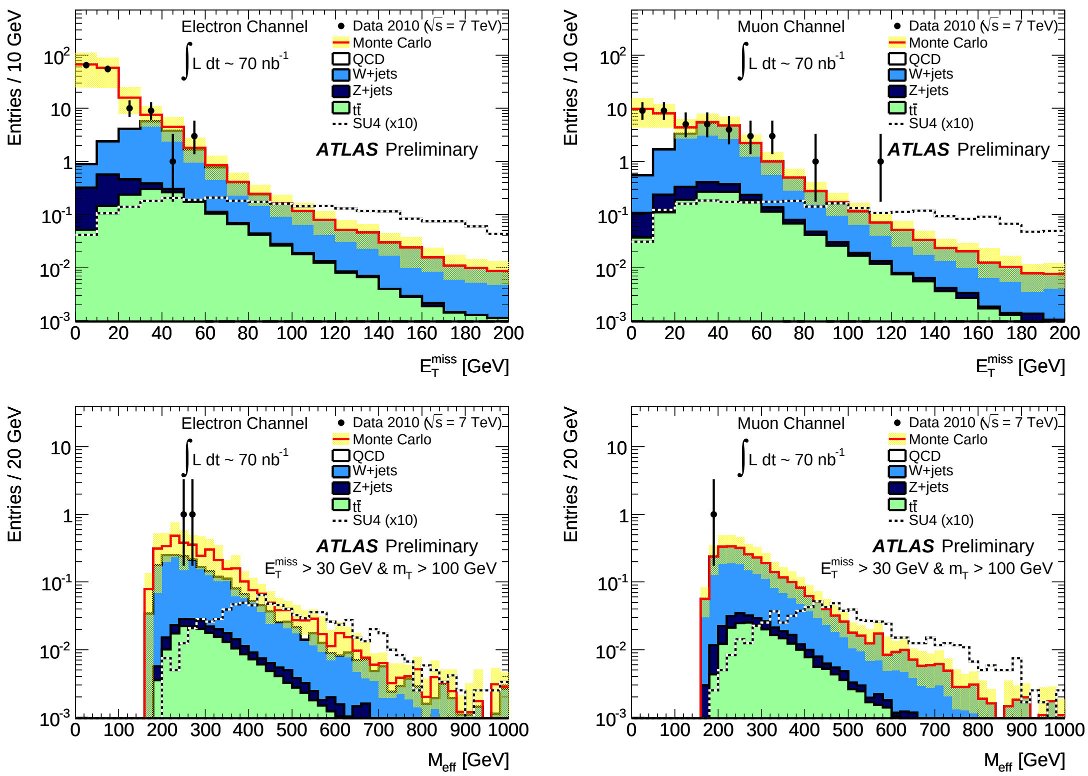

Figure 2: Distributions of the missing transverse momentum ($E_{\mathrm{T}}^{\mathrm{miss}}$) for events in the electron channel (upper left) and muon channel (upper right) only with the jet selection cuts requiring and distributions of the effective mass (M_{eff}) for events in the electron channel (left) and muon channel (right) after final selection cuts in the one-lepton channel.

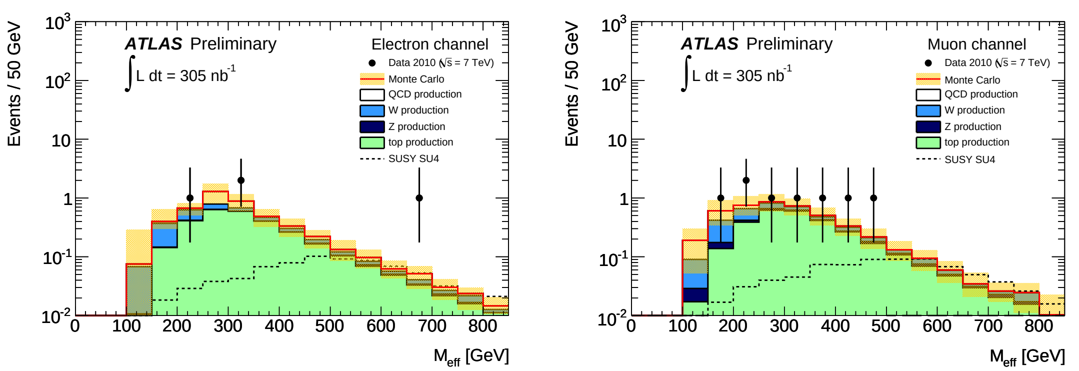

Figure 3: Effective Mass (M_{eff}) distributions for data and the different Standard Model contributions after the electron channel (left) and muon channel (right) event selections in the b-jet channel. The uncertainty band includes statistic and systematic uncertainties. The SU4 supersymmetry benchmark point is also shown.

the Standard Model predictions, which demonstrates that the ATLAS detector is performing well and that the Monte Carlo simulations describe both the underlying physics, and the detector response to jets and $E_{\mathrm{T}}^{\mathrm{miss}}$ within the systematic uncertainties achievable thus far.

References

[1] L. Evans and P. Bryant, JINST 3 (2008) S08001.

[2] Early supersymmetry searches in channels with jets and missing transverse momentum with the ATLAS detector, Atlas Collaboration, ATLAS-CONF-2010-065, 2010.

[3] Early supersymmetry searches with jets, missing transverse momentum and one or more leptons with the ATLAS Detector, Atlas Collaboration, ATLAS-CONF-2010-066, 2010.

[4] Early supersymmetry searches in events with missing transverse energy and b-jets with the ATLAS detector, Atlas Collaboration, ATLAS-CONF-2010-079, 2010.

[5] Search for squarks and gluinos using final states with jets and missing transverse momentum with the ATLAS detector in $\sqrt{s}$ = 7 TeV proton proton collisions, ATLAS collaboration, arXiv:1102.5290, accepted by Physics Letters B;
Search for supersymmetry using final states with one lepton, jets, and missing transverse momentum with the ATLAS detector in $\sqrt{s}$ = 7 TeV pp collisions, ATLAS collaboration, Phys. Rev. Lett. 106, 131802 (2011);
Search for supersymmetric particles in events with lepton pairs and large missing transverse momentum in $\sqrt{s}$ = 7 TeV proton-proton collisions with the ATLAS experiment, ATLAS collaboration, arXiv:1103.6214v1, submitted to EPJC Letters;
Search for supersymmetry in pp collisions at $\sqrt{s}$ = 7TeV in final states with missing transverse momentum and b-jets, ATLAS collaboration, arXiv:1103.4344v1, submitted to Phys. Lett. B.