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Discovery potential of Supersymmetry and Universal Extra Dimensions in the ATLAS experiment at the Large Hadron Collider at CERN

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This paper presents an evaluation of the discovery potential of Supersymmetry and Universal Extra Dimensions for channels with jets, leptons and missing transverse energy. The LHC running scenario at a center-of-mass energy of 10 TeV, delivering an integrated luminosity of 200 pb^{-1}, is investigated. This paper focuses on the discovery reach, and provides references to more detailed studies.

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Inclusive Searches for Supersymmetry and Universal Extra Dimensions

The search for new physics beyond the Standard Model (SM) is one of the most important goals in the scientific programme of the ATLAS experiment at the Large Hadron Collider (LHC), which started taking data at the end of 2009 at CERN, Geneva. Among the many candidate extensions of the Standard Model, Supersymmetry (SUSY) is one of the best motivated and studied theories; and many SUSY models predict the production of supersymmetric particles at LHC energy range. Universal Extra Dimensions (UED) is another theoretically favored candidate for Physics beyond the Standard Model.

Signals investigated in this study are from various SUSY scenarios with R-parity conservation and from a UED with Kaluza-Klein-parity conservation. In those scenarios new particles are produced by pair, mainly via $gg \to \tilde{g}\tilde{g}$, $qq \to \tilde{q}\tilde{q}$ or $gq \to \tilde{g}\tilde{q}$ processes. Final states contain the lightest UED or SUSY particle (LSP and LKP respectively)[1] which is suggested to be stable and weakly interacting by cosmological arguments, and so would escape the detection in ATLAS. For that reason this paper presents prospects for new phenomena searches in channels with a combination of jets, leptons and missing transverse energy (MET).

The ATLAS collaboration is studying the discovery reach of different models, looking for an excess of data from the SM in different channels with 2, 3 or 4 jets, and 0, 1 or 2 leptons. These inclusive channels explore a large variety of possible signals. The event selection cuts are set to be robust and efficient: hadronic jets, a certain amount of MET over a fixed threshold, sphericity of the space distribution of the final states and additional cuts on lepton p_{T} (> 20 GeV) where required. Details of the object selection and of the event selection are presented in [3].

These studies and the detailed ones presented in [3] extend the prospects for ATLAS results presented in [2]. To increase the number of studied points within the parameter space both pMSSM[2] [1] and mSUGRA supersymmetric models, beside to the UED SUSY-alike scenarios, are considered.

This work aims to show that cuts proposed in [2], slightly modified in transverse momentum and missing transverse energy to deal with the reduced $\sqrt{s}$, can lead to an early discovery with the ATLAS detector, assuming a center-of-mass energy of 10 TeVand an integrated luminosity of $\mathscr{L} = 200\ \mathrm{pb}^{-1}$.

Discovery reach with the ATLAS experiment

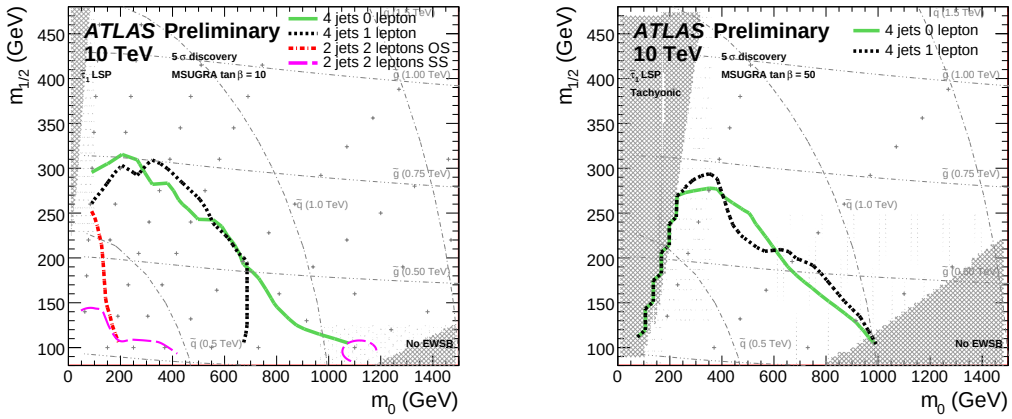
To explore the discovery reach of the strategy used in this analysis, a scan was performed over points in the parameter space of pMSSM, mSUGRA and UED grids. Each point identifies a particular model from the theoretical point of view. The variable used for this scan is the Effective Mass (M_{eff}), defined as the sum of the p_{T} of the jets and leptons in the event (according to the channel definition: 2 – 4 jets, 0 – 2 leptons), plus the missing transverse energy (MET); an example of M_{eff} distribution is showed in Fig. 3(b). The discovery reach has been calculated by finding the optimal M_{eff} cut (in step of 400 GeV) in order to maximize the significance Z_N, calculated using a convolution of a Poisson and Gaussian term to account for the systematic error. In this analysis a

[1] LSP and LKP stand for *Lightest Supersymmetric Particle* and *Lightest Kaluza-Klein Particle*, respectively.

[2] pMSSM stands for *phenomenological Minimal Supersymmetric Standard Model.*

systematic error of 50% on the SM background estimate was considered. Details of the statistical procedures can be found in [2].

The plots in the following will show the 5σ discovery reach lines in the parameter space for the various models, considering the channels with the highest discovery reach for each lepton multiplicity; the significance of different channels has not been combined. Fig. 1 shows the results for the mSUGRA model with $A_0 = 0$ GeV, $\mu > 0$, and $\tan\beta = 10$ (Fig. 1(a)) and 50 (Fig. 1(b)). Only the discovery reach of three channels are presented: 4 jets + 0 leptons, 4 jets + 1 lepton and 2 jets + 2 leptons with opposite charge (OS in the plot). The discovery reach line of the channel with 2 jets + 2 leptons with same sign (SS) was taken from [4] and integrated in the plot for comparison purpose. The discovery reach on the pMSSM is shown for a grid with constraints as a function of the total cross section in Fig. 2(a), and with constrains as a function of the minimal mass of the first and second generation squarks and gluino in Fig. 2(b). If the cross section is larger than 10 pb, most SUSY models (points on the grid) can be discovered for squark and gluino masses up to 600 GeV. A few points are only found with the 2/3 jets + 0/1 lepton channels. Since many models do not produce significant high p_{T} leptons, the 4 jets + 0 leptons channel is usually more effective. Fig. 3(a) shows the discovery reach for the UED model as a function of $1/R$ for different channels, where R is the radius which defines the size of the compactified extra dimension. The 3 jets + 0 leptons channel achieves the largest discovery reach, with a 5σ significance up to $1/R \approx 700$ GeV.

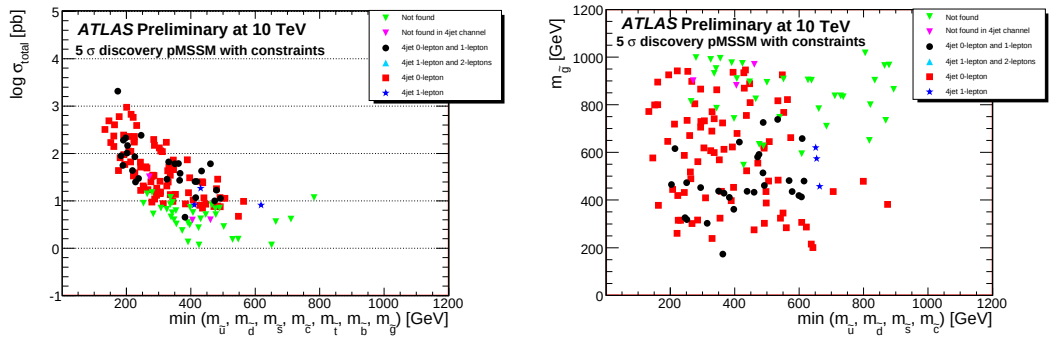


(a) mSUGRA $\tan\beta = 10$ (b) mSUGRA $\tan\beta = 10$

Figure 1: **(a):** 5σ discovery reach as a function of m_0 and $m_{1/2}$ for $\tan\beta = 10$ mSUGRA scan for channels with 0, 1 and 2 leptons. Only the channels with the largest discovery reach are shown for each lepton multiplicity. **(b):** 5σ discovery reach as a function of m_0 and $m_{1/2}$ for $\tan\beta = 50$ mSUGRA scan for channels with 0 and 1 lepton.

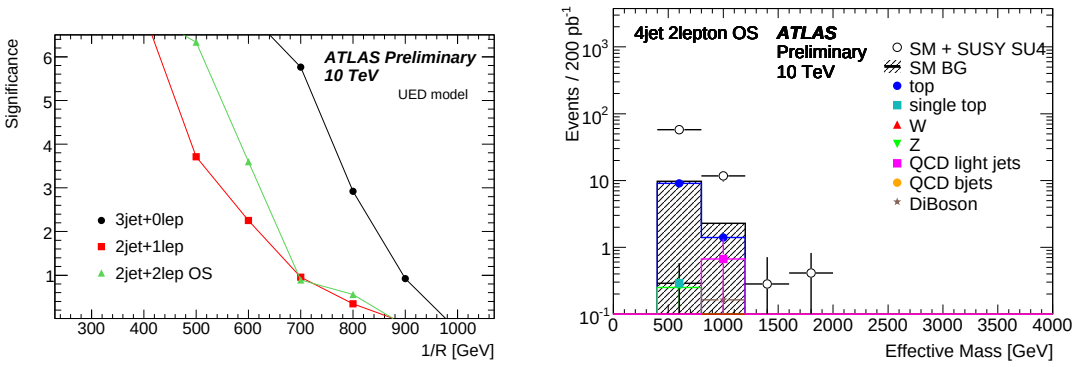
Conclusions

With an integrated luminosity of 200 pb^{-1}, running at $\sqrt{s} = 10$ TeV, the ATLAS experiment can discover signals of R-Parity conserving SUSY with squark and gluino masses less than 600-700 GeV in many scenarios. Signals of Universal Extra Dimensions can be discovered if $1/R < 700$ GeV.



(a) (b)

Figure 2: Points of the pMSSM grids with constraints as a function of the total cross section and the minimal SUSY mass ((**a**)) and as a function of the minimal mass of the light squarks (first and second generation) and the mass of the gluino ((**b**)).



(a) σ as a function of $1/R$ for UED scenario (b) Example of M_{eff} distribution

Figure 3: **(a):** Significance σ as a function of $1/R$ for the Universal Extra Dimensions (UED) scenario, taking into account channels with 0, 1 and 2 leptons. **(b):** Example of Effective mass distribution for the 4 jet channel with 2 leptons with opposite sign (OS) charge. M_{eff} definition and additional detailed distributions can be found in [3].

References

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