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Overview of searches for supersymmetry with the ATLAS detector

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ATLAS searches for supersymmetry in data from the 2010 and 2011 running of the LHC will be reviewed. These searches were performed in various channels containing different lepton and jet multiplicities in the final state. Although ATLAS searches for supersymmetry in channels both with and without missing transverse momentum, this talk will concentrate on the missing transverse momentum channels, in order to make the connection with dark matter.

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1. Introduction

Suspersymmetry (SUSY) [1] is one of the most popular extensions of the Standard Model (SM), postulating *superpartners* to each SM particles. However, the general MSSM Lagrangian violates leptonic and baryonic numbers in the superpotential, which requires to introduce a new symmetry, R-parity [2], in order to suppress proton decay. Under R-parity conserving scenarios sparticles are produced in pairs, and decay through cascades involving other sparticles down to the lightest supersymmetric particle (LSP), which is stable and provides a candidate for Dark Matter. Since the LSP is stable, it escapes detection thus leading to significant missing transverse momentum (whose magnitude will be referred as E_T^{miss}) in the event. This proceeding summarizes the search for SUSY in signatures with large E_T^{miss} with ATLAS at the LHC.

2. The ATLAS detector

The ATLAS detector is a multipurpose particle physics apparatus with a forward-backward symmetric cylindrical geometry and a nearly 4π coverage in solid angle. A full description can be found in Ref. [3]. The data used for the analyses summarized correspond to the data recorded in 2010 and during the first half of 2011 at $\sqrt{s}$ = 7 TeV. After application of the beam, detector and data quality requirements, they correspond to an integrated luminosity of 35 pb^{-1} for 2010 and 0.165 to 1.04 fb^{-1} for 2011. Signatures with no lepton use events triggered using a combination of a high p_T jet and large E_T^{miss}. This trigger is fully efficient for an offline leading jet p_T of 130 GeV and E_T^{miss} of 130 GeV. Signatures with lepton use events triggered using either a high p_T electron or muon. These triggers are fully efficient for offline electron p_T of 22 GeV and muon p_T of 20 GeV.

3. Search with zero-lepton, jets and missing transverse energy

If a squark pair is produced, and assuming $\tilde{q} \rightarrow q\tilde{\chi}_0^1$, two jets are expected in the final state. If a gluino pair is produced, and assuming $\tilde{g} \rightarrow qq\tilde{\chi}_0^1$, four jet are expected in the final state. The associated $\tilde{g}\tilde{q}$ production would lead to three jets in the final state. The search strategy defines five signal regions of different jet multiplicity and threshold to maximize the sensitivity for those three production modes and the coverage of $m_{\tilde{g}}, m_{\tilde{q}}$ plane [4]. The dominant QCD multi-jet production is reduced by requiring $\Delta\phi\left(jet, \vec{p}_T^{miss}\right) > 0.4$, defined as the minimum angle in the transverse plane between the between any of the three leading jets and the missing transverse momentum. Additional cuts on E_T^{miss} and m_{eff}, defined as the scalar sum of the p_T of all jets and E_T^{miss}, allow to enhance the signal. The background prediction is performed via a data-driven estimate. For each signal region, five control regions each enriched for a main background, namely QCD multi-jets, Z+jets, W+jets and top pair production, are used. The normalization of each background is obtained from a combined likelihood fit to all twenty-five control regions taking into account for mutual background contamination in the various control regions and correlated systematic uncertainties. The extrapolation to the signal region is performed using transfer factors for each background processed computed via a mix of data-driven and Monte Carlo techniques.

The number of observed data candidates is found to be consistent with the SM prediction for all five signal regions. The results are used to set a model independent 95% CL upper limit on the production cross section times acceptance. Additionally, two model specific interpretations are provided. The first one uses a phenomenological MSSM, where the LSP mass is set to zero and the masses of all SUSY particles, beside the gluino and the squark but including the third generation squarks, are set to 5 TeV. The result is presented as an exclusion contour in the $m_{\tilde{q}},m_{\tilde{g}}$ plane. Gluino and squark masses below 700 GeV and 875 GeV respectively are excluded in a dataset corresponding to 1.04 fb^{-1}. If $m_{\tilde{q}} = m_{\tilde{g}}$ is assumed, the exclusion increases to 1075 GeV.

4. Search with b-jets and missing transverse energy

Large mixing between $\tilde{q}_R$ and $\tilde{q}_L$ can yield to $\tilde{b}_1$ being significantly lighter than other squarks. Search for sbottom quark can be performed at the LHC via gluino decay [5]. The event selection for the analysis is similar to the previous search, but with the additional requirement of at least one b-jet. The sensitivity is maximized by defining four signal regions based on the number of b-tagged jets and m$_{\rm eff}$. The number of observed data candidates is found to be consistent with the SM prediction for all four signal regions. A 95% CL upper limit on the production cross-section times acceptance is obtained from those results. The results are interpreted using a phenomenological MSSM and simplified model scenarios, see Figure 1.

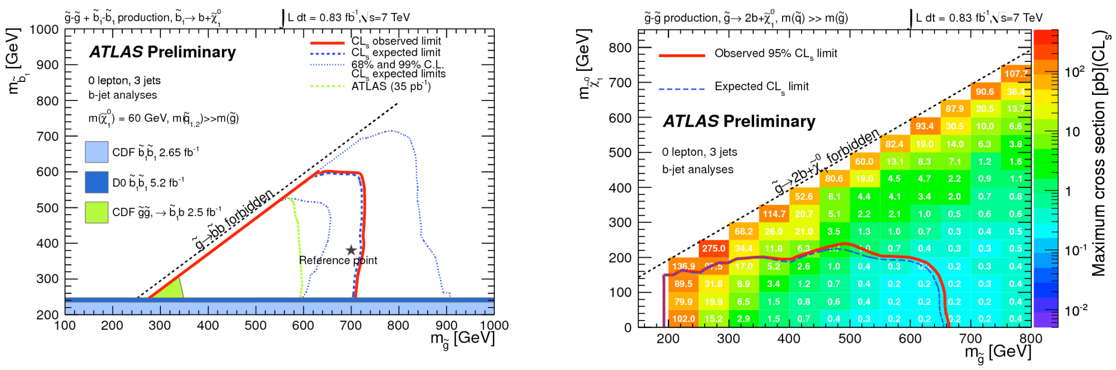

Figure 1: Left: Phenomenological MSSM observed and expected 95% CL exclusion limits in the $m_{\tilde{q}},m_{\tilde{g}}$ *plane. The LSP mass is assumed to be 60 GeV and 100% branching ratio is used for* $\tilde{g} \to \tilde{b}_1 b$ *and* $\tilde{b}_1 \to b\tilde{\chi}_1^0$*. Right: Simplified model gluino-gluino with three-body decay to* $b\bar{b}\tilde{\chi}_1^0$ *95% CL upper cross-section limits and expected and observed contours in the* $m_{\tilde{q}},m_{\tilde{g}}$ *plane [5].*

5. Search with one lepton, jets and missing transverse energy

Cascade decays including charginos and neutralinos can lead to final state with leptons. Leptonic final states allow suppressing the QCD multi-jets background and benefit from relatively low trigger threshold on single lepton trigger. The one-lepton analysis is designed to avoid overlapping with the zero, two, three or more lepton channels [6]. It is also not optimized for any particular SUSY model. The event selection consists of exactly one electron (muon) of p_T>25 (20) GeV, three leading jets of p_T>60, 25, 25 GeV respectively. QCD multi-jet background is suppressed by requiring $\Delta\phi\left(jet,\vec{p}_T^{\,miss}\right) > 0.2$. Additionally, the transverse mass[2], m_T, and the E_T^{miss} are required to be larger than 100 GeV and 125 GeV, respectively. Finally, E_T^{miss}/m_{eff} and m_{eff} are required to be greater than 0.25 and 500 GeV respectively. The dominant backgrounds after this selection are top pair production and W+jets which are estimated with a data-driven technique similar to the one used in the 0-lepton analysis. The fake-lepton background, arising from jets misidentified as leptons or leptons from heavy flavor jets, is estimated from a data-driven loose-tight lepton matrix method.

For both the electron and muon channels, the number of observed data candidates is found to be consistent with the SM prediction. The results are used to set a model independent 95% CL upper limit on the production cross section times acceptance. For the electron channel, this results on an upper limit of 41 fb and 53 fb for the muon channel for a dataset corresponding to 165 pb^{-1}. The results are also interpreted in terms of mSUGRA/CMSSM scenario as an exclusion contour in the m_0, $m_{½}$ plane.

6. Search with leptons, jets and missing transverse energy

6.1 Two-lepton Search

Weakino or strong production modes with cascade decays via charginos and neutralinos can lead to a final state of two leptons and E_T^{miss}. Three search strategies exploit the different combinations of the di-lepton charge and flavor to maximize the sensitivity [7][8]. Same-sign dilepton events are rare in the SM, but the production of gluinos, which decay with the same probability to $\tilde{q}\bar{q}$ and $\bar{\tilde{q}}q$, and $\tilde{q}\tilde{q}$ production yield same-sign dilepton events. The opposite sign dilepton signature has larger contribution from SM, but the signal yield also increase with the production of $\tilde{q}\bar{\tilde{q}}$ pairs. The third strategy uses events with two leptons of same flavor (e or μ) and opposite charge. This mode targets SUSY events where the leptons production is correlated (e.g $\tilde{\chi}_2^0 \to \tilde{l}^{\pm}l^{\mp} \to \tilde{\chi}_1^0 l^+ l^-$). Since the dominant SM backgrounds possess equal branching fractions to lepton pairs for identical and different flavor, they can be suppressed by subtracting the eμ contribution to the ee and μμ channels. This technique is referred as "flavor

[2] $m_T = \sqrt{p_T^l \cdot E_T^{miss} \cdot \left(1-\cos\left(\Delta\phi\left(\vec{l},\vec{p}_T^{\,miss}\right)\right)\right)}$

subtraction", and the quantity S[3] measures the excess of identical flavor events. In a dataset corresponding to 35 pb^{-1}, the number of observed data candidates is found to be consistent with the SM prediction across all channels. The flavor subtraction result is $S_{obv} = 1.98 \pm 0.15(\beta) \pm 0.06(\tau)$ with an expectation of $\bar{S}_{\exp} = 2.06 \pm 1.1$. The same-sign and opposite–sign results are interpreted as exclusion contour in the m_0, $m_{½}$ plane of the mSUGRA/CMSSM model. A phenomenological MSSM grid is used to set an exclusion region in the $m_{\tilde{q}}, m_{\tilde{g}}$ plane for a light neutralino and compress spectra scenarios. The same sign results are use to set an upper limit on the cross section times branching ratio for a simplified model for $\tilde{q}\tilde{q} \to q\tilde{\chi}_1^{\pm} q\tilde{\chi}_1^{\pm} \to qqW^{\pm}W^{\pm}\tilde{\chi}_1^0\tilde{\chi}_1^0$ [9].

6.2 Multileptons search

Charginos and neutralinos can be produced either directly or as intermediate states in long decay chains originating from pairs of coloured sparticles. They can then decay leptonically giving multileptons (three or more) SUSY signals. The search is performed for events with three or more leptons, two jets with p_T>59 GeV and E_T^{miss} >50 GeV [10]. Events including same-flavor and opposite-sign lepton pairs with m_{ll}<20 GeV or within 5 GeV of the Z-boson mass are discarded. In 35pb^{-1}, 19 three-lepton events are observed for 16.6±1.3 expected, and no data candidates are observed for four-leptons events, for a background prediction of $0.109 \pm 0.023^{+0.036}_{-0.025}$. The results are interpreted as exclusion contour in the m_0, $m_{½}$ plane using an mSUGRA/CMSSM.

7. Summary

The excellent performance of the LHC and the ATLAS detector in 2010 and 2011, has allowed to search for Supersymmetry. No deviation from the Standard Model is observed. and limits on various models are set, and several of them surpassed the Tevatron and LEP exclusions.

References

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[4] ATLAS Collaboration, arXiv:1109.6572 (2011), submitted to PLB.

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[3] $S = \frac{N(e^{\pm}e^{\mp})}{\beta\left(1-(1-\tau_e)^2\right)} + \frac{\beta N(\mu^{\pm}\mu^{\mp})}{1-(1-\tau_\mu)^2} - \frac{N(e^{\pm}\mu^{\mp})}{1-(1-\tau_e)(1-\tau_\mu)}$, where β is the ratio of electron to muon reconstruction efficiencies and acceptance and $\tau_{e/\mu}$ are the electron and muon trigger efficiencies respectively.

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[10] ATLAS Collaboration, ATL-CONF-2011-039, http://cdsweb.cern.ch/record/1338568.