PROCEEDINGS OF SCIENCE

Search for higgsinos with compressed spectra exploiting a low-momentum track with large transverse impact parameter

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Supersymmetry (SUSY) models with nearly mass-degenerate higgsinos could solve the hierarchy problem as well as offer a suitable dark matter candidate consistent with the observed thermal-relic dark matter density. However, the detection of SUSY higgsinos at the LHC remains challenging especially if their mass-splitting is $O(1\text{ GeV})$ or lower. A novel search using 140 fb^{-1} of proton-proton collision data collected by the ATLAS Detector at a center-of-mass energy $\sqrt{s} = 13$ TeV and targeting final states with an energetic jet, missing transverse momentum, and a low-momentum track with large transverse impact parameter is developed to face such challenge. Results are interpreted in terms of SUSY simplified models and, for the first time since the LEP era, a range of mass-splittings between the lightest charged and neutral higgsinos from 0.3 GeV to 0.9 GeV is excluded up to 170 GeV of higgsino mass.

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1. Introduction

Supersymmetry (SUSY) [1] is an extension of the Standard Model (SM) postulating the existence of a range of new particles differing from their SM counterparts by half a unit of spin. A subset of *R*-parity [2] conserving SUSY models that include new states with nearly degenerate masses can provide a Dark Matter candidate, while evading at the same time current high-energy collider constraints. Similarly to what happens to the gauge bosons within the SM, SUSY gauginos and higgsinos are allowed to mix together to create mass eigenstates called charginos, $\tilde{\chi}^{\pm}_{1,2}$, and neutralinos, $\tilde{\chi}^0_{1,2,3,4}$, where the lightest neutralino $\tilde{\chi}^0_1$ is stable. In the simplified models targeted in this proceedings, the wino and bino mass parameters are considered to be relatively large compared to the higgsino mass term μ, such that the two lightest neutralinos and the lightest chargino are mainly made of higgsinos and form a quasi-degenerate triplet of states, with masses close to the electroweak energy scale accessible at the LHC [3]. Whenever the mass splitting is larger than a few hundred MeV but still less than a couple of GeV the lifetime of the nearly mass-degenerate higgsinos is short enough that their decay takes place before the innermost pixel layer of the ATLAS detector [4] but long enough that the charged pions from the decay can be reconstructed as tracks with a finite displacement from the collision point. The displacement is measured via the transverse impact parameter d_0 and its significance $S(d_0) = d_0/\sigma(d_0)$. In the following, a brief summary of the results from a novel search using 140 fb^{-1} proton-proton collision data collected at $\sqrt{s} = 13$ TeV with the ATLAS detector and exploiting low momentum tracks with large transverse impact parameter to constrain compressed SUSY are presented. A comprehensive discussion can nevertheless be found in Ref. [5].

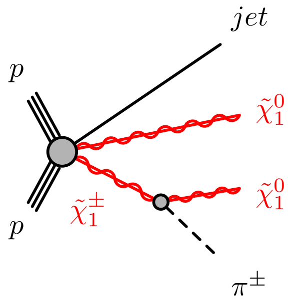
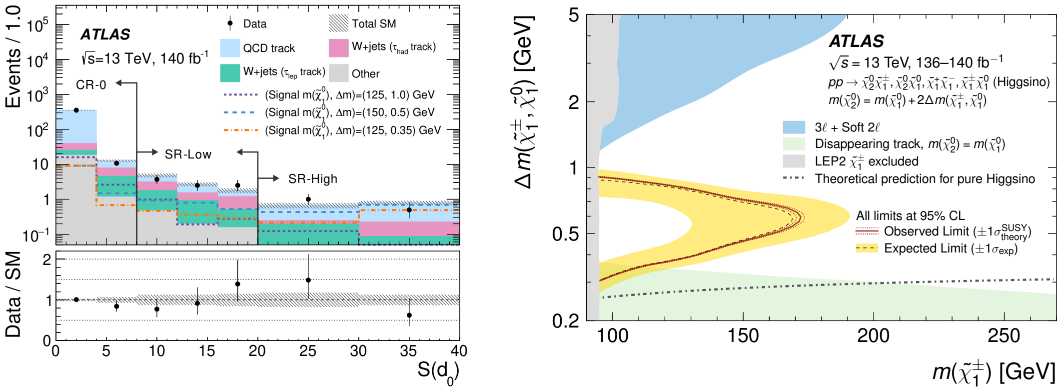


Figure 1: Representative Feynman diagram of $\tilde{\chi}^{\pm}_1\tilde{\chi}^0_1$ pair production, featuring a jet from the initial state radiation and the lightest chargino decaying to a soft pion. $\tilde{\chi}^+_1\tilde{\chi}^-_1$, $\tilde{\chi}^{\pm}_1\tilde{\chi}^0_2$, $\tilde{\chi}^0_2\tilde{\chi}^0_1$ processes are considered in the search as well.

2. Analysis strategy

The search described here and targeting the simplified models of Figure 1 is based on the proposal presented in Ref. [6]. The search identifies low-momentum charged particles that are consistent with the decay products of a $\tilde{\chi}^{\pm}_1$ by imposing a set of event- and track-level selections. The Signal Region (SR) is defined by selecting events with no leptons or photons and satisfying the missing transverse momentum ($E_{\mathrm{T}}^{\mathrm{miss}}$) trigger. Events must also contain at least one jet with $p_{\mathrm{T}} > 250$ GeV and $|\eta| < 2.4$, but no more than four jets, and have $E_{\mathrm{T}}^{\mathrm{miss}} > 600$ GeV. Finally, the presence of a signal candidate track with 2 GeV $\leq p_{\mathrm{T}} \leq$ 5 GeV and $S(d_0) > 8$ is required. The SR is split into two bins, labelled SR-Low [$8 < S(d_0) < 20$] and SR-High [$S(d_0) > 20$], to keep sensitivity to different mass splittings. The dominant background sources in the SR are hadronic and leptonic τ decay tracks in $W(\rightarrow \tau\nu)$ + jets events. The former is estimated by normalising Monte Carlo (MC) predictions to the data content of a Control Region (CR) with zero leptons, while the latter is constrained in the same way but using a CR requiring exactly one lepton. Both

CRs shift the track transverse momentum selection to 8 GeV $\leq p_{\mathrm{T}} \leq$ 20 GeV to keep orthogonality with respect to the SRs. The other relevant SM background consists of W/Z + jets events where tracks from long-lived hadrons, pileup jets or the underlying event are tagged as signal-like. A fully data-driven method is employed to estimate this background by first extracting the shape of the $S(d_0)$ distribution from the data events in a CR defined with the same selections of the SR but requiring exactly one muon ($W(\rightarrow \mu\nu)$ + jets), and then normalizing such shape to the data in a low-$S(d_0)$ CR ($S(d_0) < 8$) to obtain the estimate in the SR. Other minor backgrounds are estimated using directly the MC simulations.



(a) (b)

Figure 2: $S(d_0)$ distribution in the SRs and the adjacent control region CR-0ℓ (a), and 95% CL exclusion limits set on the considered higgsino simplified model (b). From Ref. [5].

3. Results and conclusion

No excess above the SM expectation is observed in the SR (Figure 2a). The results are interpreted in terms of exclusion limits set at 95% CL on higgsino simplified model masses of up to about 170 GeV (Figure 2b), exceeding the limit set by the LEP experiments for the first time and bridging a long-standing blind spot in the sensitivity of existing ATLAS higgsino searches.

References

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