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Searches for supersymmetric higgsinos with the ATLAS detector

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Summary. — A search for supersymmetric partners of the Higgs and gauge bosons (charginos and neutralinos) is presented in this work, using the data from the ATLAS experiment collected at LHC. Considerations on the naturalness of the Higgs boson mass suggest that the two lightest neutralinos might be a mix of the partners of the Higgs boson and could have a similar mass. Using this scenario as a reference, two analyses are presented. One has a final state with pairs of electrons or muons with low transverse momentums coming from the decay of the two lightest neutralinos, high missing transverse momentum generated by neutralinos which are non detectable, and an energetic jet coming from QCD initial state radiation. The second one is characterised by a final state with disappearing tracks, and high missing transverse momentum. Results are shown for the analysis obtained with 36 fb^{-1}, and limits are set on the mass parameter of the higgsinos.

1. – Introduction

Supersymmetry (SUSY) [1] predicts that for each Standard Model particle there exists a new state that differs just by half a unit of spin. Similar to the Standard Model, the superparteners of the gauge bosons mix together to give mass eigenstates called charginos ,$\tilde{\chi}^{\pm}_{1,2}$ and neutralinos, $\tilde{\chi}^{0}_{1,2,3,4}$ (where the subscripts indicate increasing mass) or collectively electroweakinos. The lightest neutralino is supposed to be stable due to R-parity conservation. If the mass parameters of the wino and bino are large with respect to the higgsino, the two lightest neutralinos and the lightest chargino are composed mainly of higgsinos and form a triplet of states with a mass close to the higgsino mass parameter μ [2]. The mass splitting between the three states is between few hundred MeV to a few tens of GeV, depending on how much the higgsinos are important in the mixture. If the difference in mass is of the order of few MeV, the lifetime of the chargino will be long enough to allow its detection through a track in the inner detector. Instead, if the mass difference is of the order of few GeV, the decays will be prompt, and with very soft decays products. Moreover, up until recently the only limits on this model were from the LEP experiments [3]. The analyses presented here were performed using the data collected by the ATLAS detector [4] during 2015 and 2016, at the LHC [5].

2. – Two-lepton analysis

The signal considered is the direct production of a pair of $\tilde{\chi}_2^0$ and $\tilde{\chi}_1^0$, or $\tilde{\chi}_2^0$ and $\tilde{\chi}_1^\pm$, where the $\tilde{\chi}_2^0$ decays into a $\tilde{\chi}_1^0$ and (through a virtual Z^0) two opposite-sign same-flavour leptons [6]. The signal is defined by the presence of large missing transverse momentum (denoted E_{T}^{miss}) due to the two neutralinos boosted against a very energetic jet from initial state radiation (ISR, it is required that $p_{\mathrm{T}}^{jet} > 100\,\mathrm{GeV}$). This topology allows to trigger on the E_{T}^{miss} and look at the two soft leptons from the decay. The invariant mass ($m_{\ell\ell}$) of the two leptons is bounded by the difference in mass of the two neutralinos, and its shape depends on whether they are higgsinos or wino-bino. The main strategy of the analysis is therefore to look at the invariant mass of two leptons and perform a shape fit in the region between 1 and 60 GeV of $m_{\ell\ell}$. This enhances the discovery potential and would also allow to characterize a new physics signal.

3. – Disappearing tracks analysis

In this scenario the direct production of a pair of $\tilde{\chi}_1^0\ \tilde{\chi}_1^\pm$,$\tilde{\chi}_1^+\ \tilde{\chi}_1^-$, and $\tilde{\chi}_2^0\ \tilde{\chi}_1^\pm$ is considered [7]. In this case the chargino is considered long lived, where the distance it can travel depends on the mass splitting. The mean lifetime can range from few ns for mass splitting of $\sim 150\,\mathrm{MeV}$, to few ps for differences in mass of $\sim 800\,\mathrm{MeV}$.

For long enough life time, the chargino will travel inside the detector, and leave a track inside the Inner Detector, before decaying into a neutralino and a charged pion. If the

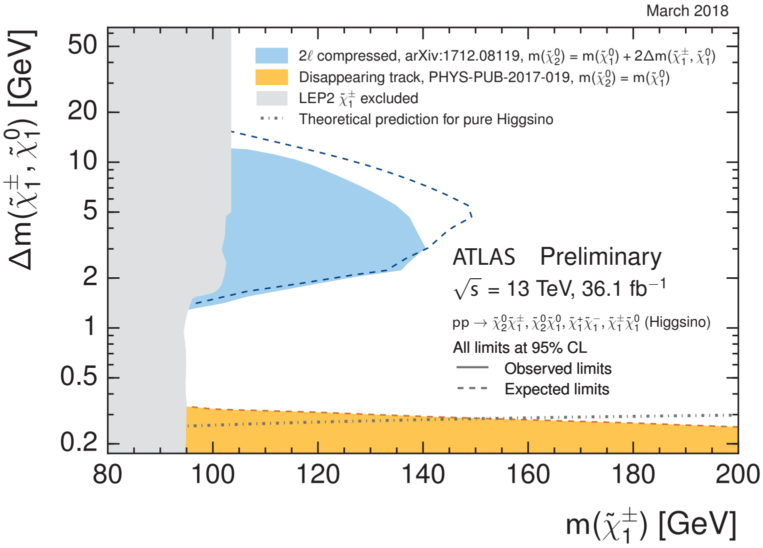

Fig. 1. – Exclusion limits at 95% confidence level for higgsino pair production of $\tilde{\chi}_1^0\ \tilde{\chi}_1^\pm$,$\tilde{\chi}_1^+\ \tilde{\chi}_1^-$, and $\tilde{\chi}_2^0\ \tilde{\chi}_1^\pm$ with off-shell SM-boson-mediated decays to the lightest neutralino, as a function of the $\tilde{\chi}_1^\pm$ and $\tilde{\chi}_1^0$ masses. In blue the limits for the two lepton analysis, in orange the ones for the disappearing tracks analysis. In grey the limits from LEP [8].

pion is not detected, then the distinctive signature of these models are called *disappearing tracks*, and these tracks are classified as tracklets.

In this analysis events are triggered by E_{T}^{miss}, and a high p_{T} jet is required . Events with leptons (electrons or muons) are vetoed. Tracklets are required to have four hits in the Pixel detector without holes and zero hits in the SCT detector. The distribution of the p_{T} of the tracklets it is then fitted.

4. – Results

Two analysis were presented in this article, using the data collected by the ATLAS experiment at the LHC during Run 2. No excesses have been observed with respect to the Standard Model predictions, therefore only limits on the particles masses have been set. The exclusion limits at 95% CL in the hypothesis of electroweakinos composed of mainly higgsinos are shown in fig. 1. Signals are excluded for masses of the chargino up to 140 GeV for a $\Delta m(\tilde{\chi}_1^{\pm}, \tilde{\chi}_1^0) \sim 3\,\mathrm{GeV}$, while signals with $\Delta m(\tilde{\chi}_1^{\pm}, \tilde{\chi}_1^0) < 300\,\mathrm{MeV}$ are also excluded.

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