Electroweakino Investigations

Ideas towards more general EW sector searches/interpretation

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Challenge: How to put together a tractable but comprehensive electroweakino sector search and interpretation that goes significantly beyond the SMS approach? A NTSMS (not too simplistic model spectrum - including couplings).

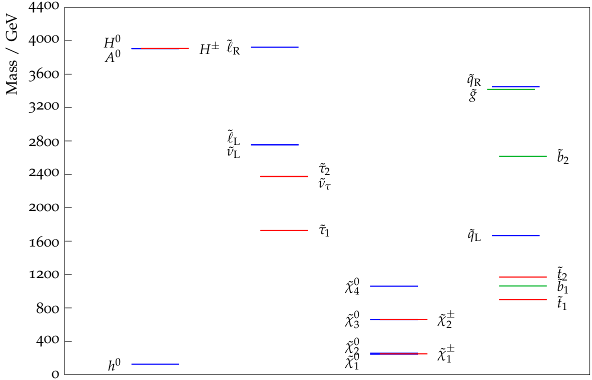
Introduction

At the Univ. of Kansas, the experimental HEP group on CMS, (A. Bean, C. Rogan, G.W Wilson), is currently working on a wide-ranging ISR-assisted compressed SUSY search with one or more leptons. Current targets are:

1. electroweakinos
2. stops
3. sleptons

- For the longer term, we have started to look into the feasibility of a more general search/interpretation focused on events with at least one lepton.
- Main target: comprehensive constraints on the electroweakino sector, naively parametrized by just 4 parameters, $(M_1, M_2, \mu, \tan\beta)$.
- Critical issue. How to efficiently cover all possibilities associated with the 3-particle ($\tilde{\chi}_1^{\pm}$, $\tilde{\chi}_2^0$, $\tilde{\chi}_1^0$) system of lowest-lying states.
- Ideally would like to leverage consistent cross-section, BR, kinematics predictions across many final state topologies and production modes without relying on pure Higgsino/pure Wino etc assumptions.
- Interested in also targeting cascade decays of heavier EWinos ($\tilde{\chi}_2^{\pm}$, $\tilde{\chi}_3^0$, $\tilde{\chi}_4^0$).
- SUSY may or may not exist. But it would be good to know answers to simple questions like: what is the lightest chargino mass allowed by LHC?

Triplet of low-mass EWinos (mostly Higgsino). In general, the masses and mass splittings are arbitrary. (for illustration - was not excluded then)

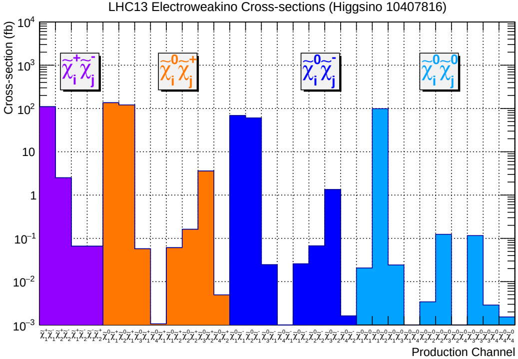


Masses (GeV)
$\widetilde{\chi}^0$ (1,2): 245.6, 257.4
$\widetilde{\chi}^0$ (3,4): 660.9, 1060
$\widetilde{\chi}^\pm$ (1,2): 250.5, 661.3

EWino sector defined by just 4 parameters ($M_1, M_2, \mu, \tan\beta$). Basically defines the 6 masses, cross-sections, differential cross-sections, branching fractions, decay ME, assuming other sparticles and heavy Higgs irrelevant.

EWino Pair NLO Cross-sections (Prospino2.1)

All 30 EWino pair processes (separating $\pm$) should be produced. Cross sections depend on (model dependent) EWino couplings to W, Z (if squarks heavy).



Note that all production channels are a coherent "SUSY signal", but if not treated this way, this "SUSY background" could pollute the search.

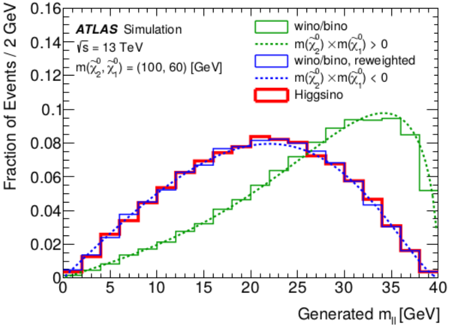
Most relevant for now are those involving the 3 lightest states.

$\tilde{\chi}_2^0\ \tilde{\chi}_1^{\pm}$, $\tilde{\chi}_1^+\ \tilde{\chi}_1^-$, $\tilde{\chi}_2^0\ \tilde{\chi}_1^0$, $\tilde{\chi}_1^0\ \tilde{\chi}_1^{\pm}$, $(\tilde{\chi}_2^0\ \tilde{\chi}_2^0)$.

With off-shell W, Z in the decays, these lead naturally to a mix of 1-lepton, 2-lepton, and 3-lepton final states. (4-lepton too). Kinematics requires **three** physical masses as parameters. Dynamics needs an additional parameter (at least).

Model Dependence Complications

See 1911.12606. $\tilde{\chi}_2^0 \rightarrow \tilde{\chi}_1^0\ \ell^+\ \ell^-$
3-body distribution of di-particle masses in the $\tilde{\chi}_2^0$ rest-frame depends on the signs of the eigenvalues associated with the diagonalization of the neutralino sector.



EWino pair cross-sections and differential cross-sections depend only on couplings of EWinos to W/Z. (assumes heavy squarks).

- But these are not straightforward in general for a given ($\tilde{\chi}_1^\pm$, $\tilde{\chi}_2^0$, $\tilde{\chi}_1^0$) - not being pure Higgsino or pure Wino.
- Example: $\tilde{\chi}_1^\pm\ \tilde{\chi}_2^0$. This depends on the W coupling to the pair, and is a function of the $\tilde{\chi}_1^\pm$ and $\tilde{\chi}_2^0$ couplings.
  See Eq 12.8 in Baer, Tata.

3/4 parameters?

- Have been looking at 3-physical mass experimental search / correspondence to 4-parameter model (see also Fuks, 1710.09941).
- No final conclusions yet, but there is certainly an additional and ambiguous degree of freedom that needs to be taken into account.
- It would help the poor experimentalist such as myself, if there was a well defined generic 4-parameter space that is unambiguous in terms of its predictions for the 6 electroweakino sparticle masses, branching fractions etc. (Maybe one just has to do things at tree level and forget about all this running and radiative corrections??) Good to also have this in the MCs of choice.

Longer Term

- Interested in targeting also cascade decays of heavier EWinos ($\tilde{\chi}_2^{\pm}$, $\tilde{\chi}_3^0$, $\tilde{\chi}_4^0$).
- Not yet clear how complementary this would be to the standard "3-EWino" search strategy.
- If the mass gaps are big, then signatures with additional on-shell W, Z, H in the decay may be the key to accessing compressed lower states.
- Suggest starting with a "simple" model with a mass-degenerate heavy pair (usually Wino) and allow all possible kinematic decays with equal branching fractions to cover the expected multitude of final states.
- (Maybe in the context of today's meeting is there much scope for the mass gaps of the higher mass states to be small too?)

Wrap-Up

1. I don't have the answers, but very much welcome collaboration towards figuring out how our community can search for something that might exist and be able to explain what progress has been made.
2. A more general approach is not computationally trivial!
3. The continued negative results shown in SMS plots are interpreted by many as real-model exclusions. This story then leads to the perception that this is not a fruitful area of research to be engaged in. We should do better.
4. It seems like electroweakinos are the last SUSY frontier at LHC, and we should do a good job of exploring this as thoroughly as possible.

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