Sneutrino DM signals as probe of neutrino seesaw dynamics

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Neutrino oscillation imply the neutrino is massive which means Standard Model(SM) need to be extended. Supersymmetry(SUSY) is one of the most studied frameworks to construct beyond SM model. The advantage of SUSY model is sneutrino, the superpartner of neutrino, can decay visibly in collider in some case. It gives chance to study neutrino dynamics at collider[1]. The minimal supersymmetric Standard Model (MSSM) still lacks a mechanism for neutrino mass generation, but it can be extended with various seesaw mechanisms. The SUSY and seesaw combination lead to nonstandard Dark Matter(DM) candidate, the Least supersymmetric particle(LSP). We shall investigate the possibility of estimating neutrino Yukawa couplings in the Next-to-minimal supersymmetric Standard Model(NMSSM) with right-handed neutrinos with a right-sneutrino DM candidate.

Motivation

- neutrino oscillation $\rightarrow$ seesaw is a natural way for (B-L)-violating[2].
- Type-I seesaw $\rightarrow$ right-hand majorana neutrino as intermediate heavy particle
- Extension of MSSM $\rightarrow$ μ problem and large left-right-handed mixing[3].

NMSSM with right hand neutrino

The superpotential is:

$$W = W_{NMSSM} + \lambda_N SNN + y_N L \cdot H_2 N \tag{1}$$

$$W_{NMSSM} = Y_u H_2 \cdot Q_u + Y_d H_1 \cdot Qd + Y_e H_1 \cdot Le - \lambda S H_1 \cdot H_2 + \frac{1}{3}\kappa S^3 \tag{2}$$

Consequences

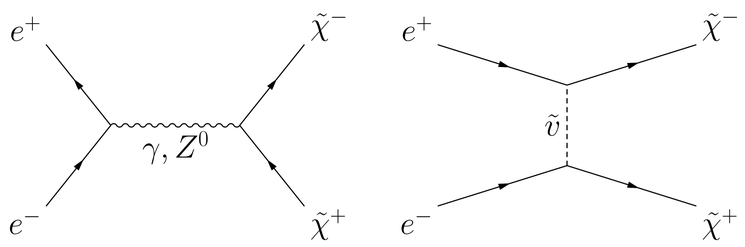
- Right-handed neutrino mass generation.
- Right-handed sneutrino (LSP) as DM candidate[4].

Simulation Platform

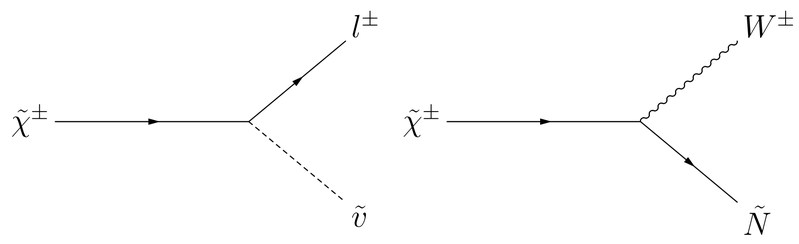
- SARAH-4.14.3: building and analysis model, generate spectrum source code.
- SPheno-4.0.3: calculate the SUSY spectrum.
- MadGraph5_aMC@NLO: A framework for computation of cross section and the use of a variety of tools to event manipulation and analysis.
- Madanalysis5: Simulation for particle collider and plot the result.
- MadDM-3.0: To check the relic density when right-hand sneutrino as LSP

Search for rare dacay mode

- We simulate electron-positron collision and use Delphes Silicon Detector for the International Linear Collider (ILC), known as DsiD[5].
- The process we generate is that the electron-positron collision produce chargino pair. The Feynman diagram is:

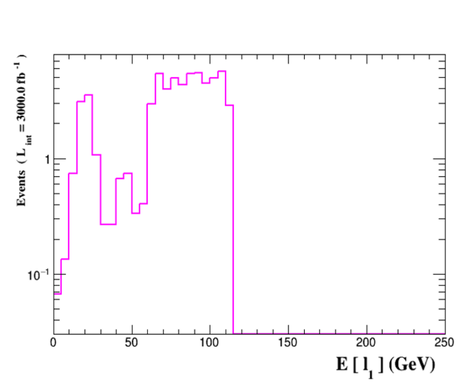


- The rare decay is chargino -> sneutrino + lepton(known as leading lepton) and chargino -> neutralino + W. The former depends on the neutrino Yukawa couplings, the latter on the gauge couplings and both on the spectrum.By measuring the branching ratio of chargino -> sneutrino + lepton, the neutrino Yukawa coupling can be deduced. The Feynman diagram is:



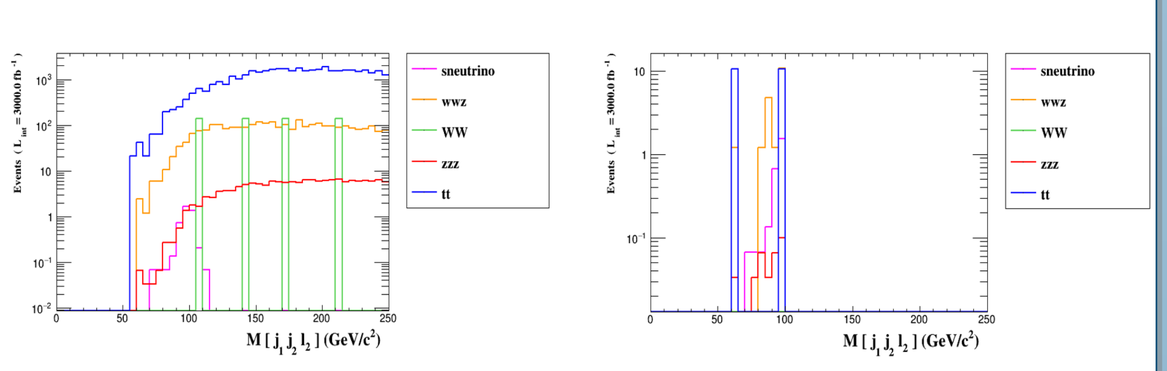
Simulation result and analysis

- The generation process is electron positron produces chargino pair, then constrain one of the chargino into right-hand sneutrino and charged lepton. The energy distribution of leading lepton is below:



Lepton concentrate around 100 GeV(hard lepton) and the end point are the signal of rare decay mode.

- Neutralino can decay into right-hand neutrino and right-hand sneutrino. The right-hand neutrino can decay into two jets and one lepton. In order to suppress background, the invariant mass of di-jet with one lepton is an observable which is a rare combination mode in the SM.



The left plot(without cut) shows the signal of right-hand neutrino, by adding cut, the SM background is suppressed much.

Summary and Outlook

- The chargino decay to a hard lepton and a LSP sneutrino is mediated by the neutrino Yukawa couplings.
- If the neutralino decays visibly to a RH neutrino + sneutrino, the final state can be distinguishable from backgrounds. We plan to check the effect of event topology with two jet and same sign dileptons.
- We may estimate the neutrino Yukawa coupling by estimating the branching ratio of the two-body decay.

References

References

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[4] David G Cerdeno and Osamu Seto. "Right-handed sneutrino dark matter in the NMSSM". In: *Journal of Cosmology and Astroparticle Physics* 2009.08 (2009), p. 032.

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