Slepton Discovery in Cascade Decays

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Motivation

- Plenty of work has been done on discovery of SUSY.
- Sensitivity to SUSY parameters has been explored largely only in benchmark scenarios.
  - Has this given us sufficient understanding of the entire parameter space?
- The most obvious method for discovery of sleptons is Drell-Yan production.
  - Suffers from small cross section and significant backgrounds.
- Can we do better?
Cascade Decays
Kinematic Shape in Slepton Decays

- Cascade Decays through on-shell sleptons have a characteristic triangular cutoff shape in dilepton invariant mass, with the cutoff appearing at

\[ M_{\text{max}} = \sqrt{\{(M_{\chi_2}^2 - M_{\ell}^2)(M_{\ell}^2 - M_{\chi_1}^2)\}/M_{\ell}^2} \]

- This is an unequivocal sign of the presence of a slepton-type state.
- This is most readily observed in the usual trilepton SUSY search channel.
The standard analysis of this signal shape generally assumes its dominance over all other decays.

This results in obvious-to-the-eye spectral shape, often enhanced by only having plotted the signal.

Bachacou, Hinchliffe, and Paige
Hep-ph/9907518
When have we actually seen this feature?

![Graphs showing events vs. m_{#nu#nu}](image-url)
SM Backgrounds

• We select only trilepton events to avoid large backgrounds from the Standard Model
  o WW, Z + jets, t tbar, …

• The only remaining backgrounds to consider with significant cross section are WZ and t tbar + V

• Cannot neglect fake leptons from t tbar
  o For fake rate of 5 per mil background from t tbar comparable to WZ

• Other processes either contain a Z boson or have very small rates
Multiple topologies can give rise to a trilepton signal in SUSY decays.

Most such signals arise with a Z boson in the final state and will have kinematics similar to those of the corresponding SM background.

Lepton flavor constraints indicate that any flavor mixing in the slepton sector must be small.

- Can reasonably use only same-flavor pairs in distributions.

At most two kinematic triangles in each channel.
Approach and Goals

- Model independent
  - Decay Topology
  - Spectrum
  - Production Mechanism
- Minimal cuts to maximize statistics
  - Only require 3 reconstructed leptons
  - No MET, Ht, or jet rejection cuts
- Exploit only kinematic shape of slepton decays
Pseudo-Experiment Generation

• Generate histogram with realistic errors by using MC as probability distribution
• Straightforward for signal and electroweak background
• Monte carlo for $t\bar{t}$ and a fake gives very poor statistics
  o Same-sign subtraction should still return a shape similar to the original dilepton spectrum
• Therefore plot one from 2-lepton sample and add noise to represent two wrong pairs (taken from 3-lepton same-sign pair in MC)
Background Fitting

- Backgrounds after same-sign subtraction have straightforward spectrum
- All backgrounds with Z boson give only the usual Z peak
- Continuous background from t tbar and fake has shape measurable in dilepton sample
- Usual data-driven method for understanding this background
  - Assume same spectral shape and fit for normalization
- 4 total parameters:
  - # of t tbar-type events
  - # of events in peak
  - Width of peak
  - Center of peak (can shift slightly due to binning effects)
Background Fitting

![Graph showing event distribution vs. mass](graph.png)
Signal Function

• Triangle exact at parton level for correct lepton pair
• Same-sign subtraction not perfect due to mass splitting of sneutrino and slepton
• Signal further distorted by brehmsstrahlung and detector smearing
• Nonetheless a triangle smeared by a gaussian response function is adequate to capture the cutoff well
• 3 parameters for signal function:
  o Cutoff position
  o Number of events
  o Strength of smearing effect
Signal + Background Fit

- Fit using chi-squared best-fit algorithm
- 3 GeV-wide bins
- Require that fit signal events be significant at 5-sigma level
  - Marginalize over all other parameters
- Generate multiple independent histograms for each case to avoid good or bad luck
Signal + Background Fit

- We simulated mass hierarchies which led to multiple values for the cutoff of the signal spectrum.
- The background was filled with a poisson-distributed number of events which corresponds to 100 /fb of luminosity.
Sensitivity

- For best model independence, we quote sensitivity as a function of cutoff in $\sigma \times BR \times A$ needed to discover the slepton in the decay chain
- Here we use an integrated luminosity of 100 /fb
Conclusions

• The classic triangle distribution of dilepton invariant mass is a certain indicator of the presence of a slepton
• Understanding the sensitivity of our current experiments to this signal is of great value
• We express the detectability of this signal in a model-independent way that allows application to a large set of topologies and spectra