Slepton Discovery in Cascade Decays

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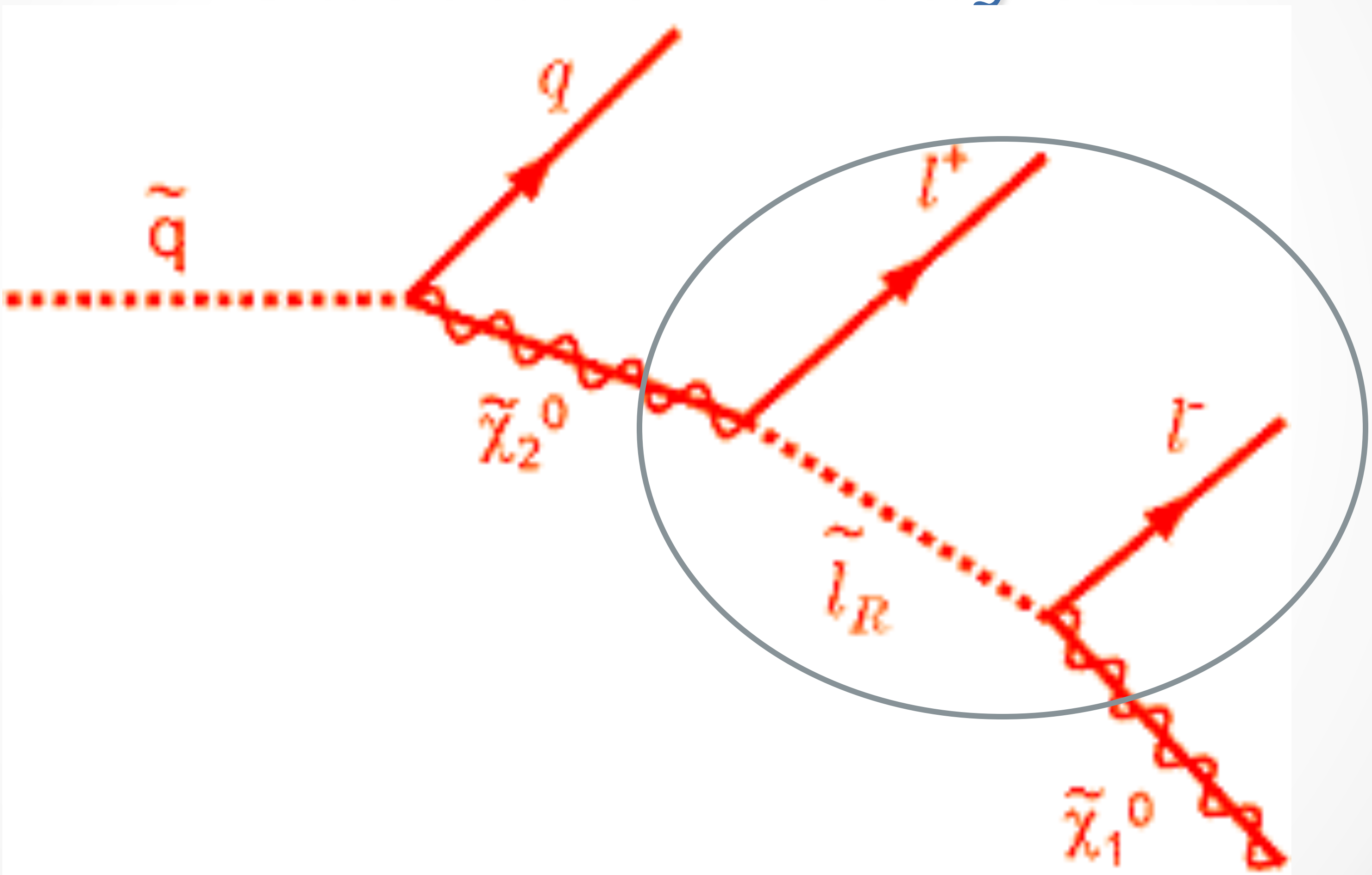
Motivation

- 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



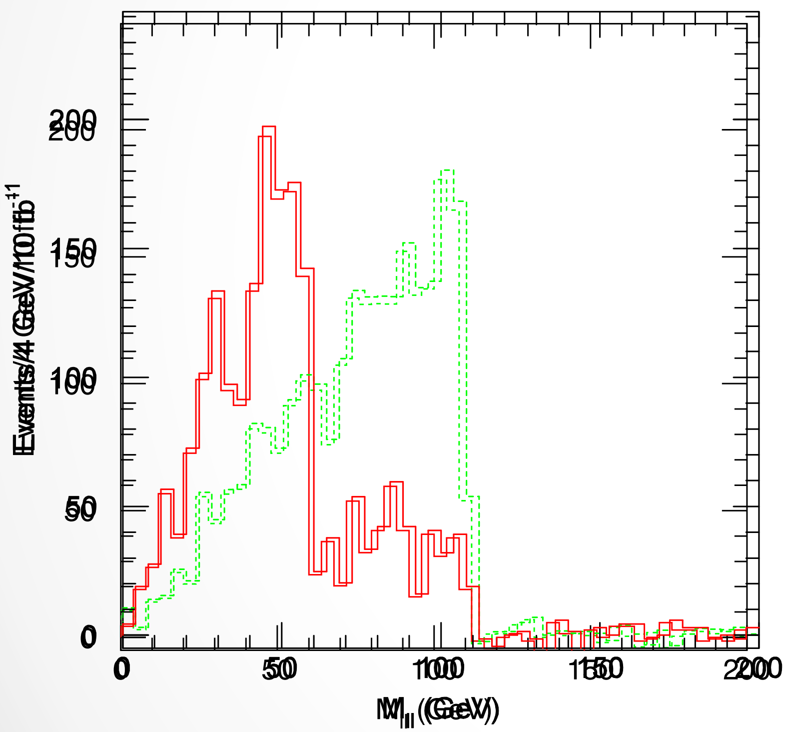
Kinematic Shape in Slepton Decays

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

$$M_{max} = \sqrt{\{(M_{\chi_2}^2 - M_{\tilde{\ell}}^2)(M_{\tilde{\ell}}^2 - M_{\chi_1}^2)\}/\{M_{\tilde{\ell}}^2\}}$$

- 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.

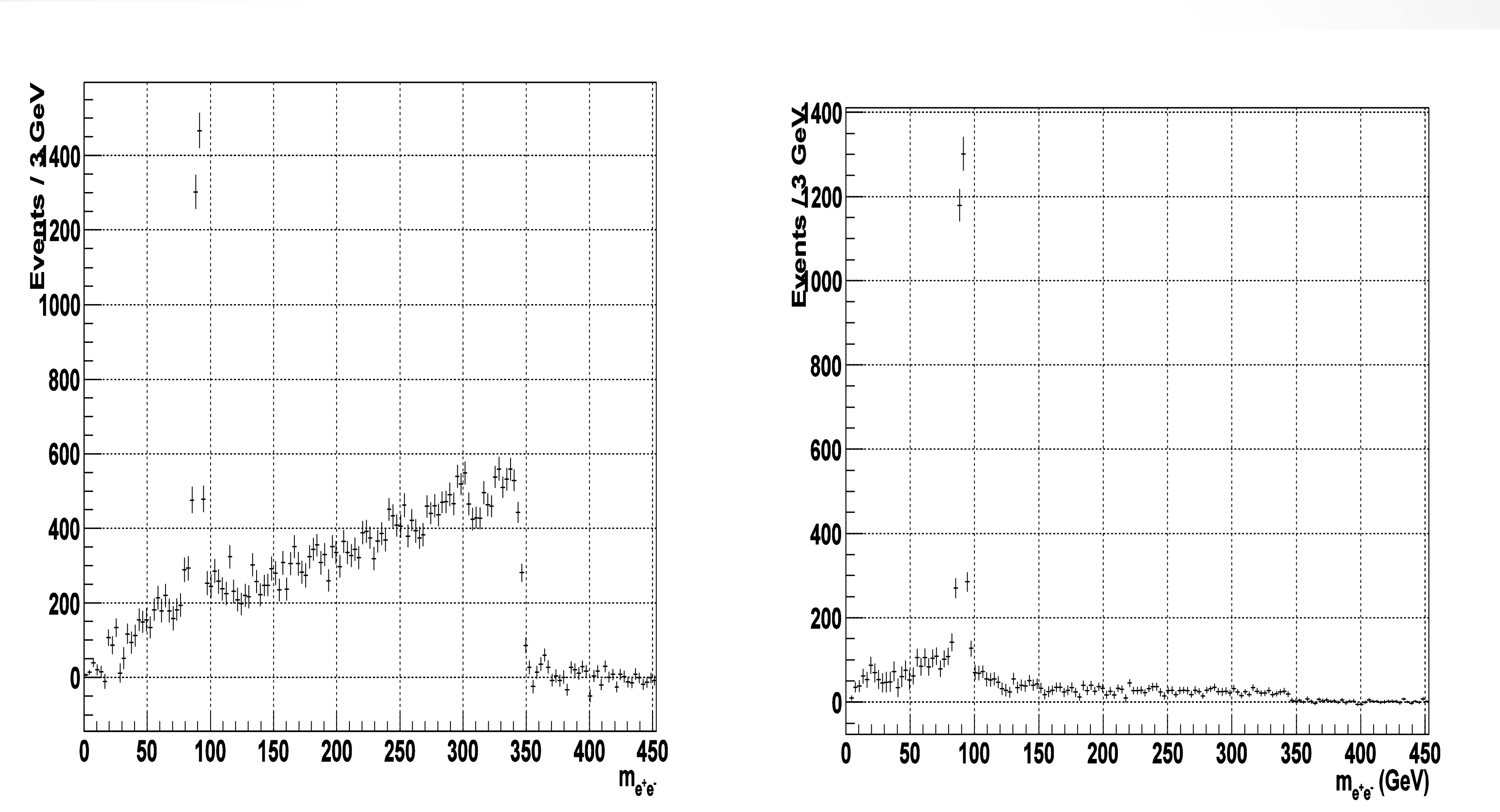
Kinematic Shape in Slepton Decays



Bachacou, Hinchliffe, and Paige
Hep-ph/9907518

- 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

When have we actually seen this feature?



SM Backgrounds

- We select only trilepton events to avoid large backgrounds from the Standard Model
  - 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
  - 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

SUSY Backgrounds

- 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

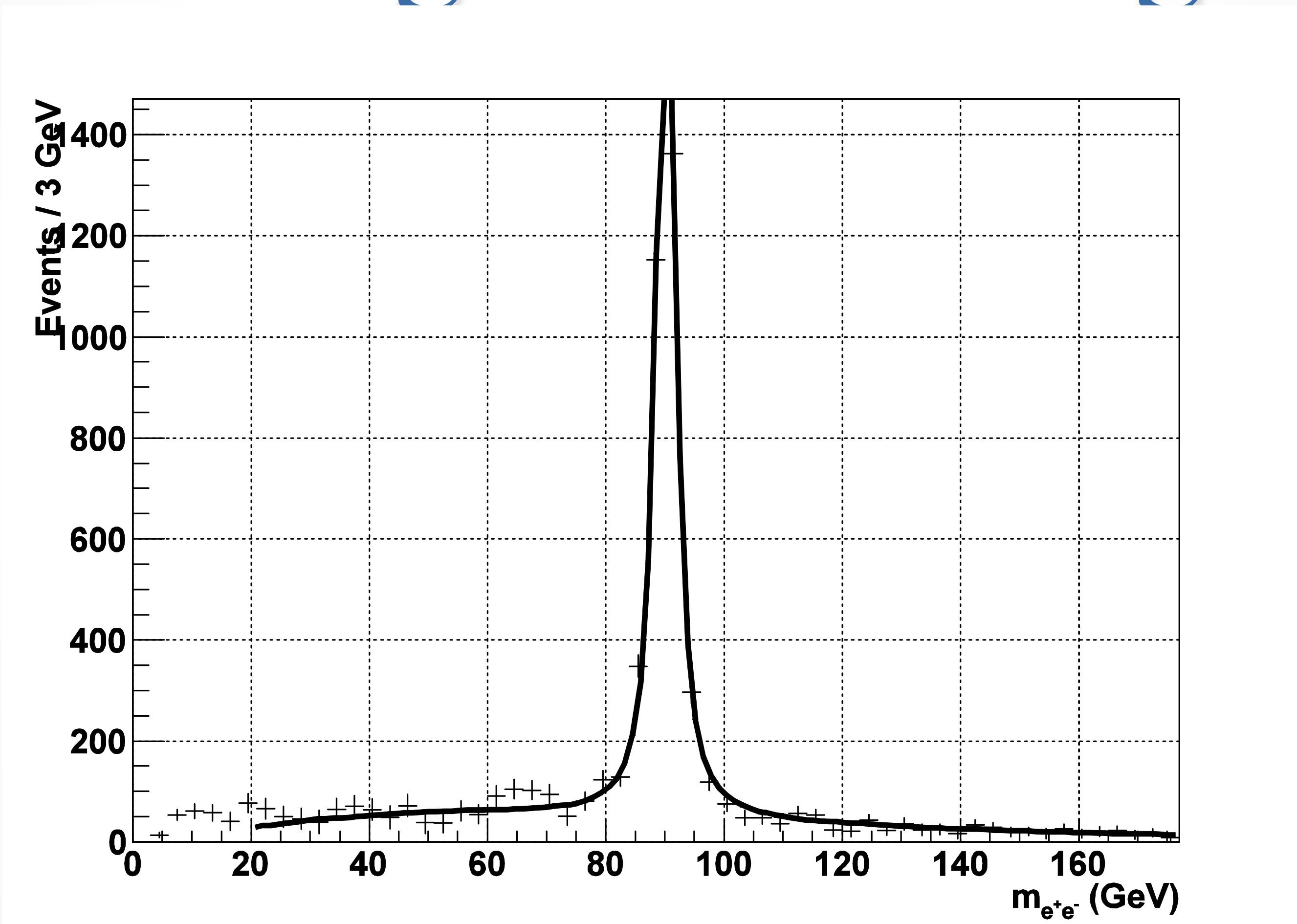
Pseudo-Experiment Generation

- Generate histogram with realistic errors by using MC as probability distribution
- Straightforward for signal and electroweak background
- Monte carlo for t tbar and a fake gives very poor statistics
    - 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)

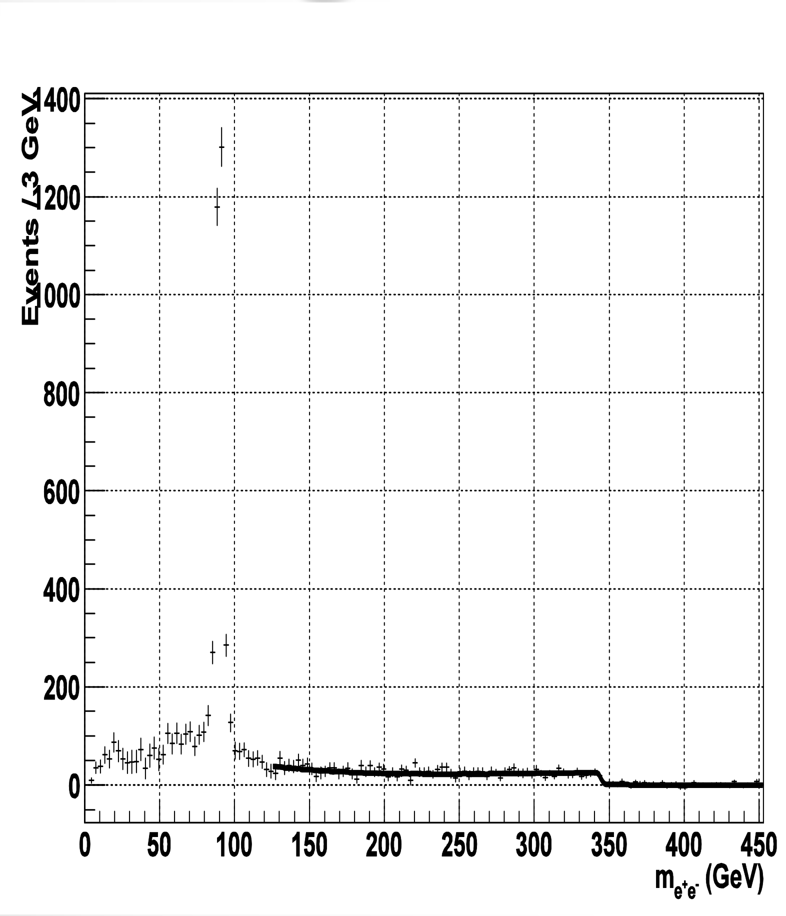
Background Fitting



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:
    - Cutoff position
    - Number of events
    - Strength of smearing effect

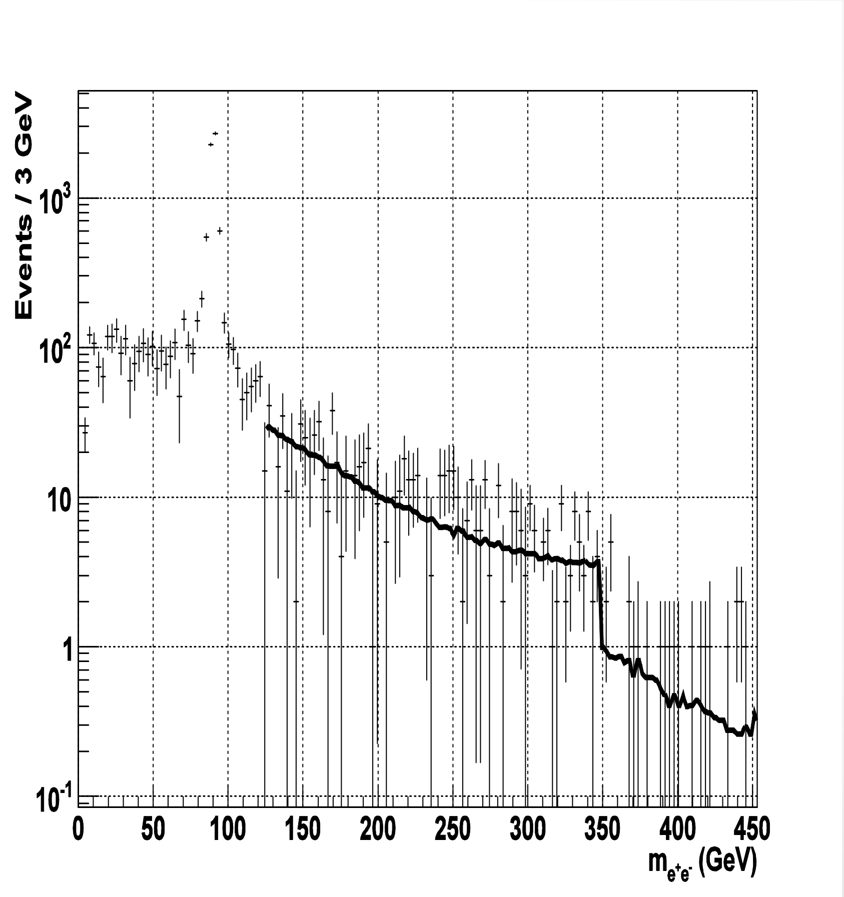
Signal + Background Fit



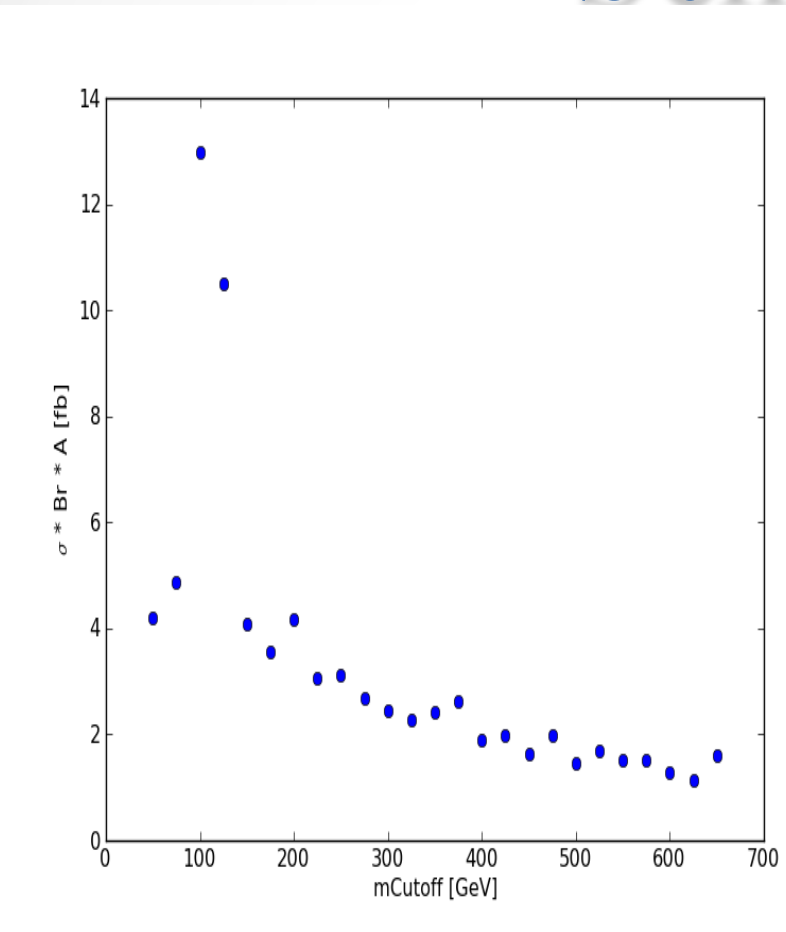
- Fit using chi-squared best-fit algorithm
- 3 GeV-wide bins
- Require that fit signal events be significant at 5-sigma level
    - Marginalize over all other parameters
- Generate multiple independent histograms for each case to avoid good or bad luck

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