General Features of SUSY Signals at the ILC:

Stable Charged Particle Searches

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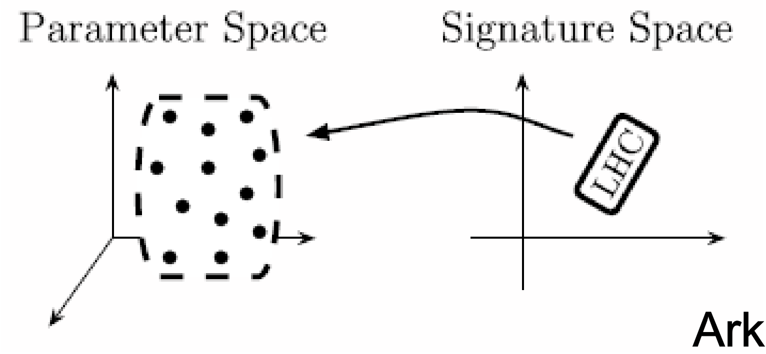
Why: The LHC Inverse Problem

If new physics is discovered at the LHC, can we uniquely determine what it is? Does a specific signature map back into a unique model with a fixed set of parameters? Many kinds of new physics can produce similar signatures…

Even within a very specific context, e.g., the MSSM, can we uniquely determine the values of, e.g., the weak scale Lagrangian parameters from LHC data alone?

The answer is, of course, `No!' →→The LHC Inverse Problem



This mapping is NOT unique !

Arkani-Hamed etal., hep-ph/0512190

What :

Can the ILC at 500 GeV distinguish all of the MSSM models (i.e., parameter space points) that were found to give degenerate signatures at the LHC ?? Can the SUSY particles in all these models be observed at ILC?

Along the way to answering these questions we needed to perform a general study of signals & backgrounds for hundreds of SUSY models providing a unique opportunity to examine, e.g., signatures, cuts, detector and simulation properties & our basic assumptions/prejudices about SUSY analyses at the ILC.

Sample: 242 models in 162 pairs c/o Nima & Friends

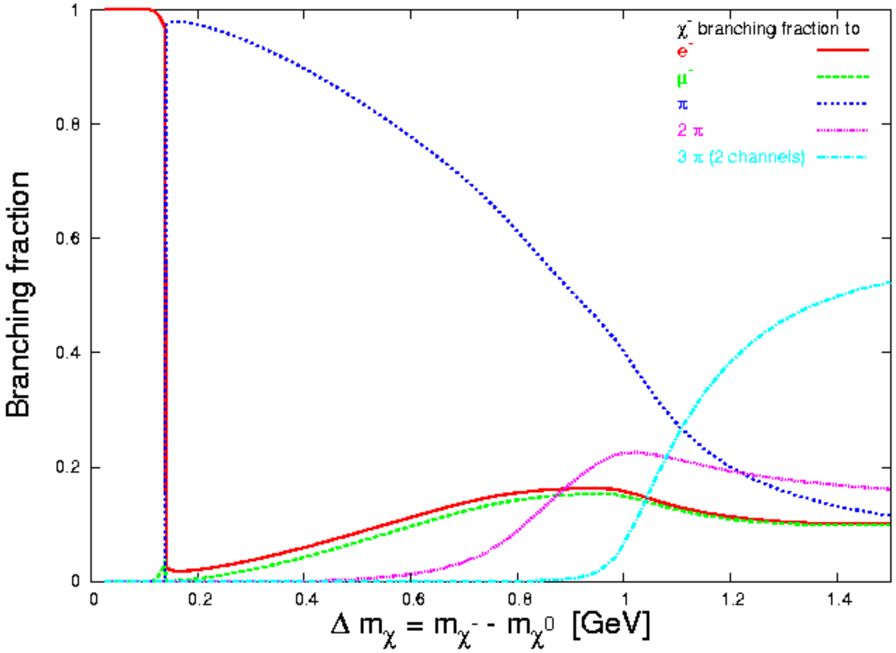
How :

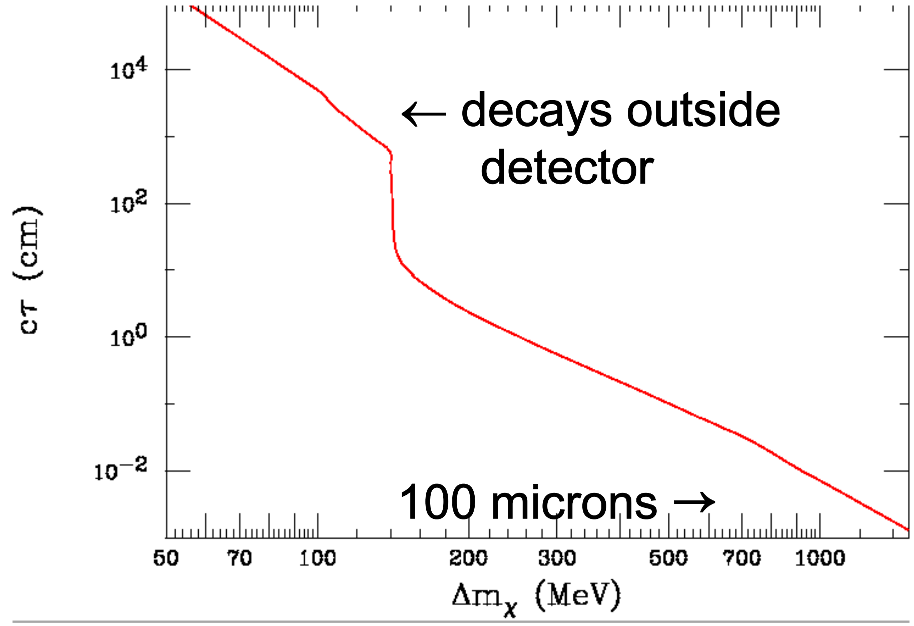
- Pick a model. Simulate signal events with PYTHIA and CompHEP feeding in Whizard/GuineaPig generated beamspectrum
- Add the SM backgrounds: all 2 -> 2, 4 & 6 ($e^+ e^-$, γe & $\gamma\gamma$) full matrix element processes (1016) produced by Tim Barklow
- Pipe this all through SiD fast detect simulation org.lcsim
- Assume L=500 fb^{-1} with P_{e-} =80% and analyze after appropriate generalized, i.e., *model-independent* cuts are applied.. this is highly non-trivial requiring many iterations

→→ ADD lots (and lots) of time…

Stable/Long-Lived Charged Particles :

- Charginos, staus or stops with small mass differences with the LSP (χ_1^0) can have quite long-lifetimes..



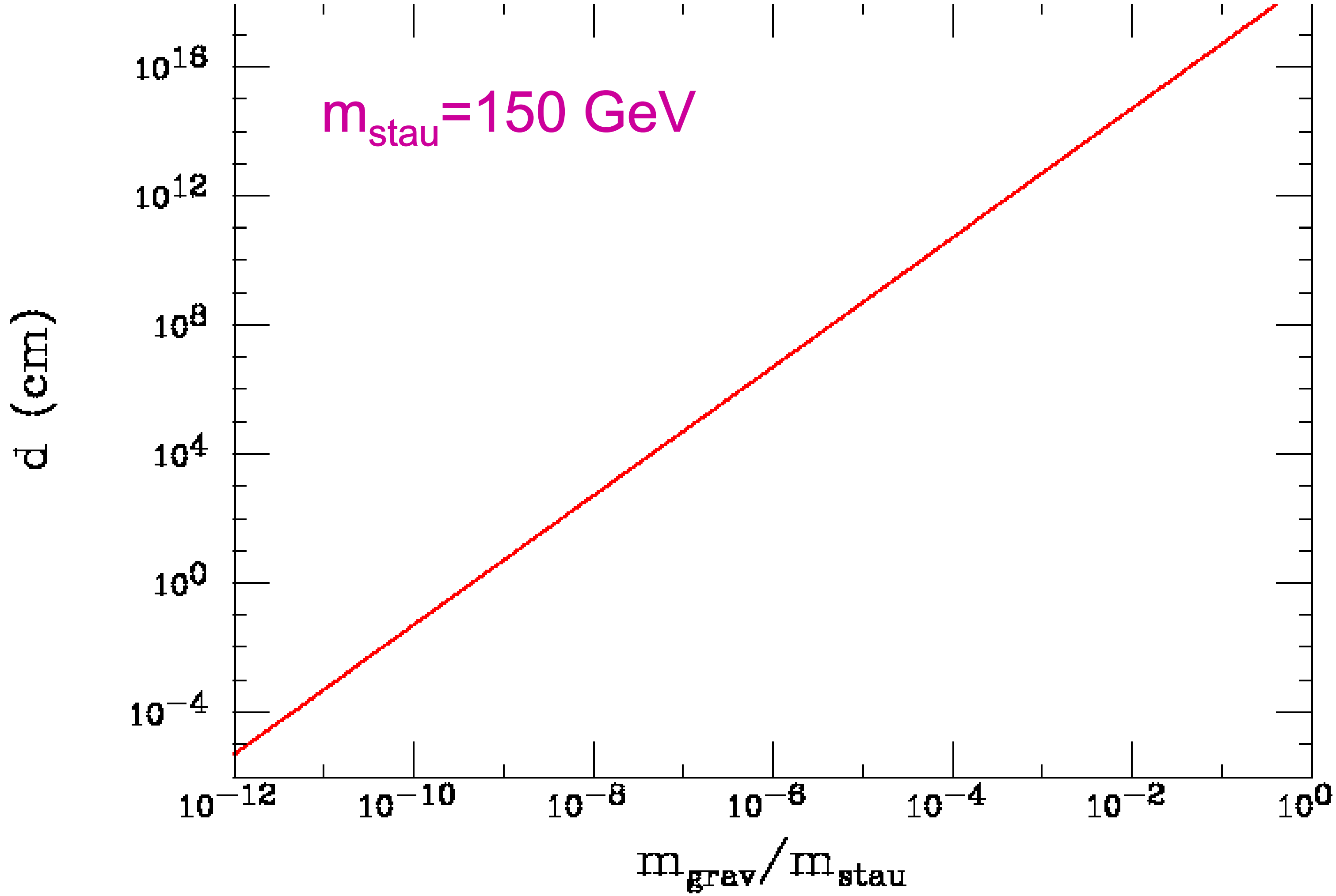


← decays outside detector

100 microns →

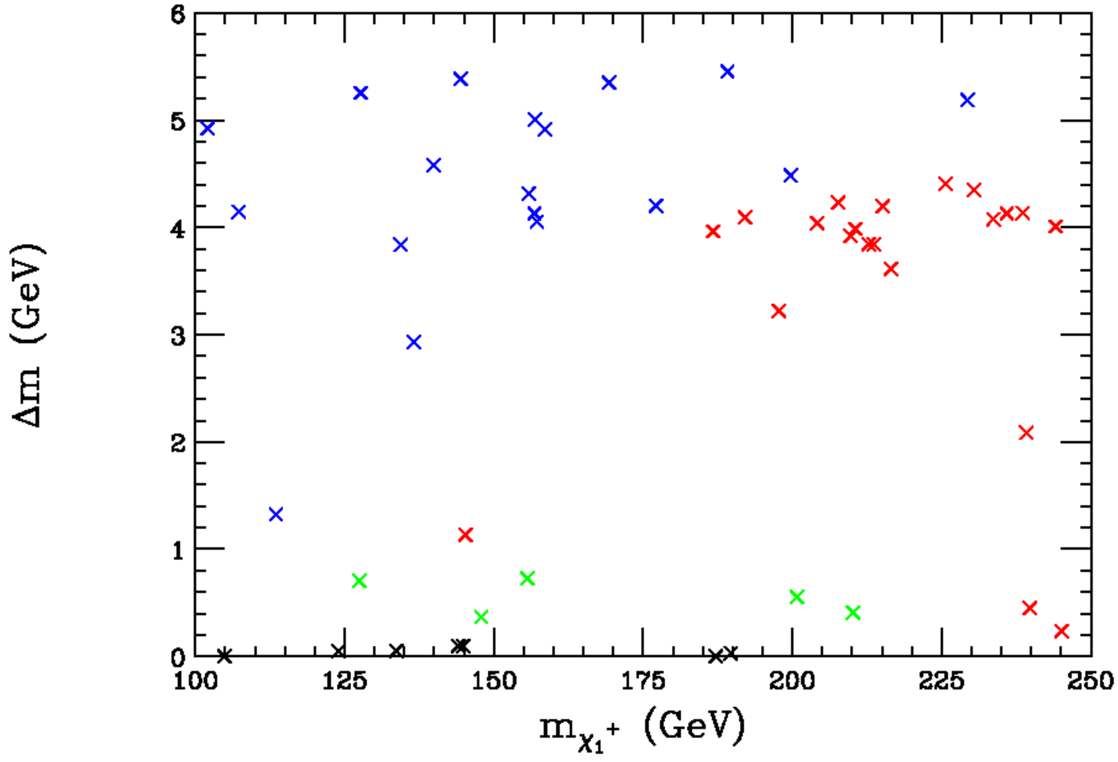
Note that we are *not* looking for decays inside the detector in this analysis…

•Staus lighter than χ_1^0 decaying via gravitinos…



→ at 500 GeV we find that

53/242 models have kinematically accessible χ_1^+ ... Seven are long-lived



7 models with very small **Δm**

←

28/242 models have kinematically accessible staus…three are long-lived…there are *no* accessible stops !

Comments & Features :

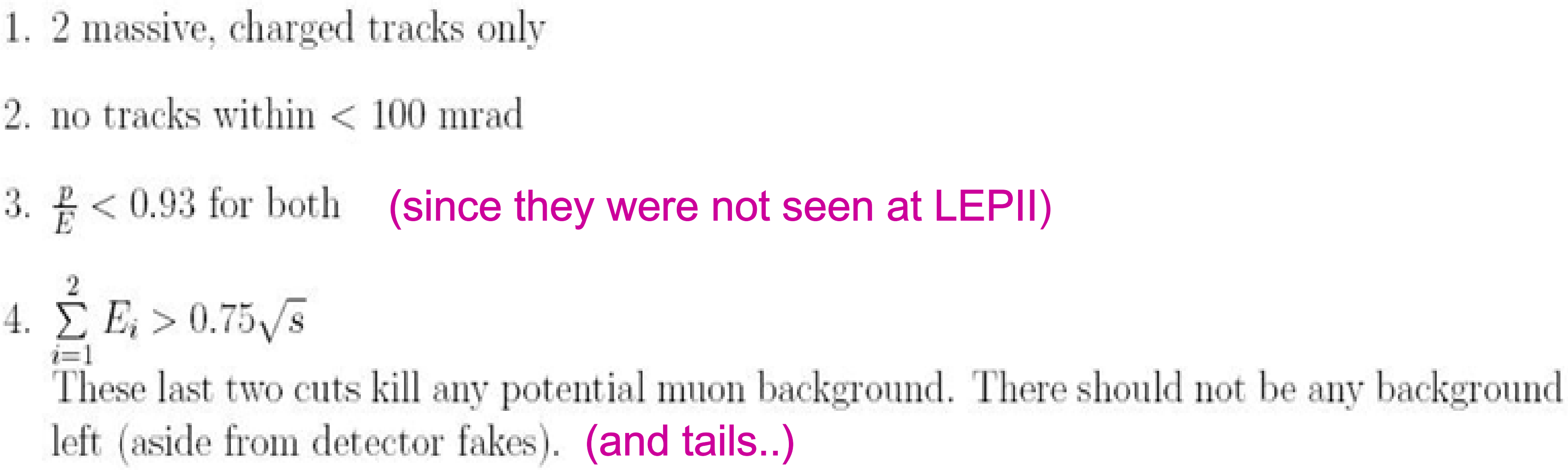
→ For these 10 models at ILC500, the long-lived states are the *only* SUSY particles that are observable

→ For the charginos, 6 of these models form 3 of the pairs not distinguished at the LHC. Thus we not only need to observe these states but we also need to tell them apart at the ILC.

→Note that these wino-like charginos have much larger cross sections at ILC than do staus.

Long-lived `Chargino’ Analysis

A surprisingly large number of our models have these particles



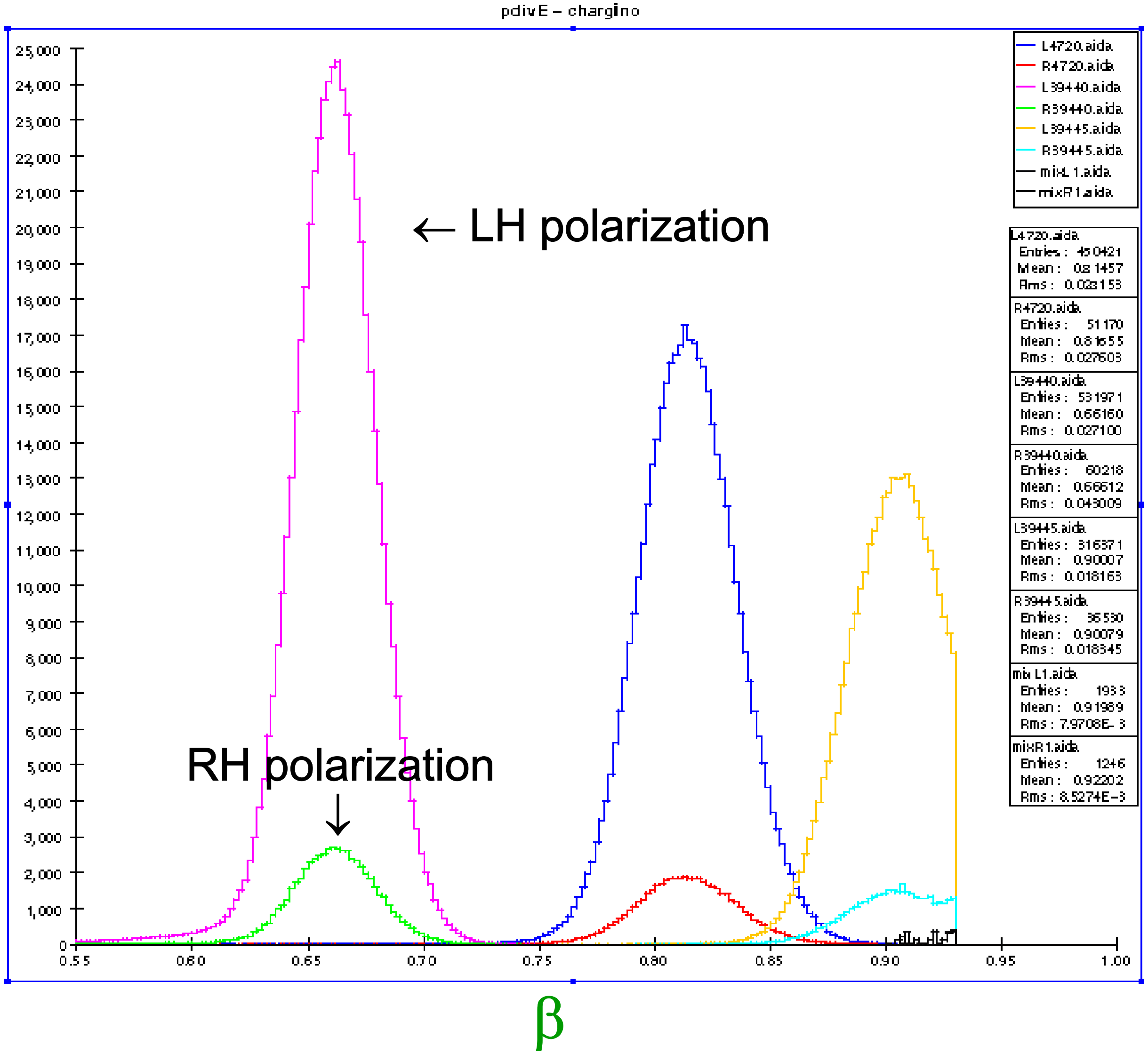
1. 2 massive, charged tracks only
2. no tracks within < 100 mrad
3. $\frac{p}{E} < 0.93$ for both (since they were not seen at LEPII)
4. $\sum_{i=1}^{2} E_i > 0.75\sqrt{s}$

These last two cuts kill any potential muon background. There should not be any background left (aside from detector fakes). (and tails..)

β=p/E : p is determined by track curvature in the B field while E is determined by some other method. Note TOF and/or dE/dx, is *not yet in the vanilla lcsim…*To mimic this we assume β is determined with a track E smearing of δE(→ δβ)=5 or 10% in our analysis before piping through lcsim, consistent with ILC detector models. (thanks to B. Schumm etal)

Small Δm charginos are mostly wino so have larger rates w/ LH beam polarization:

5% smearing

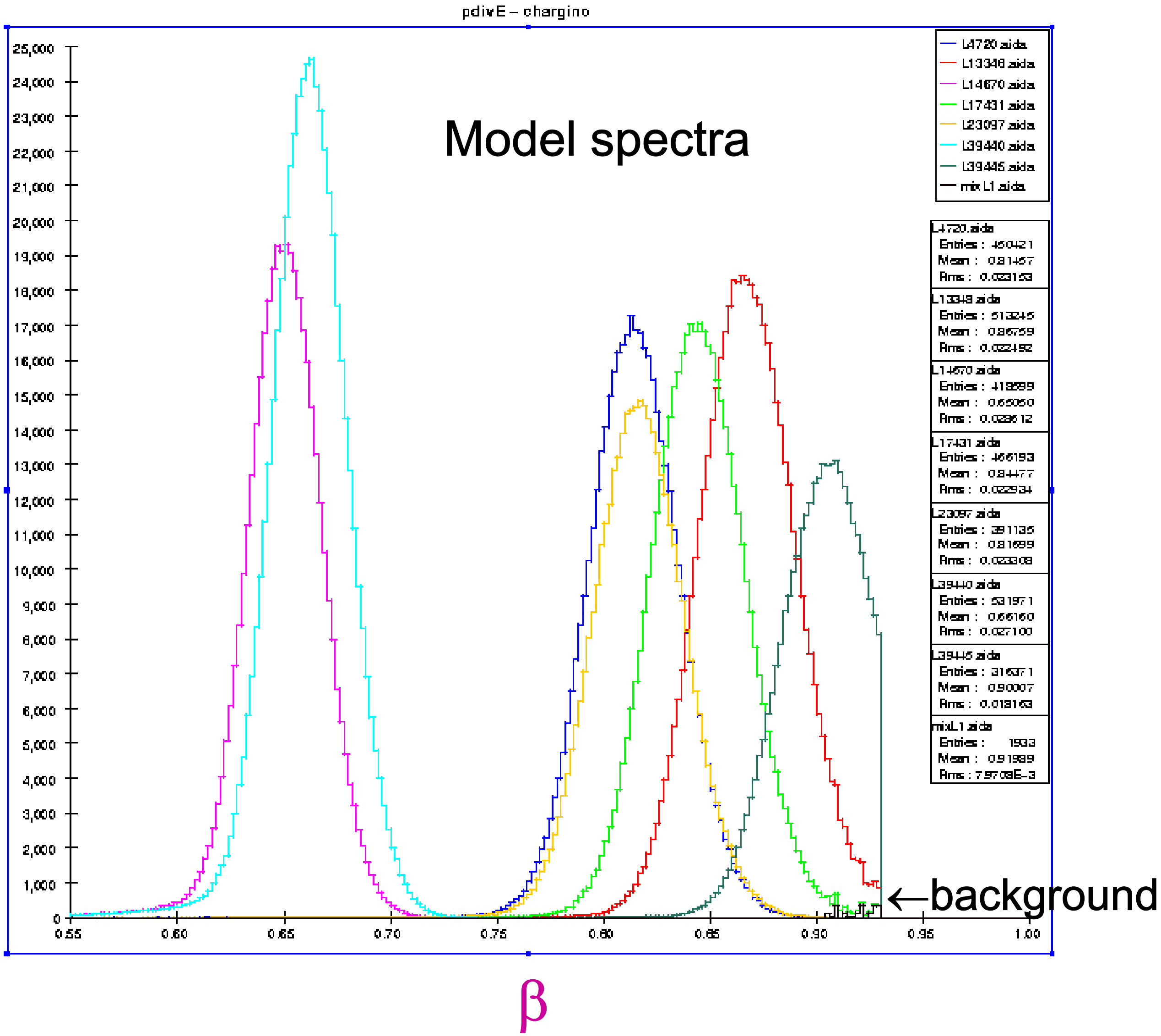


← LH polarization

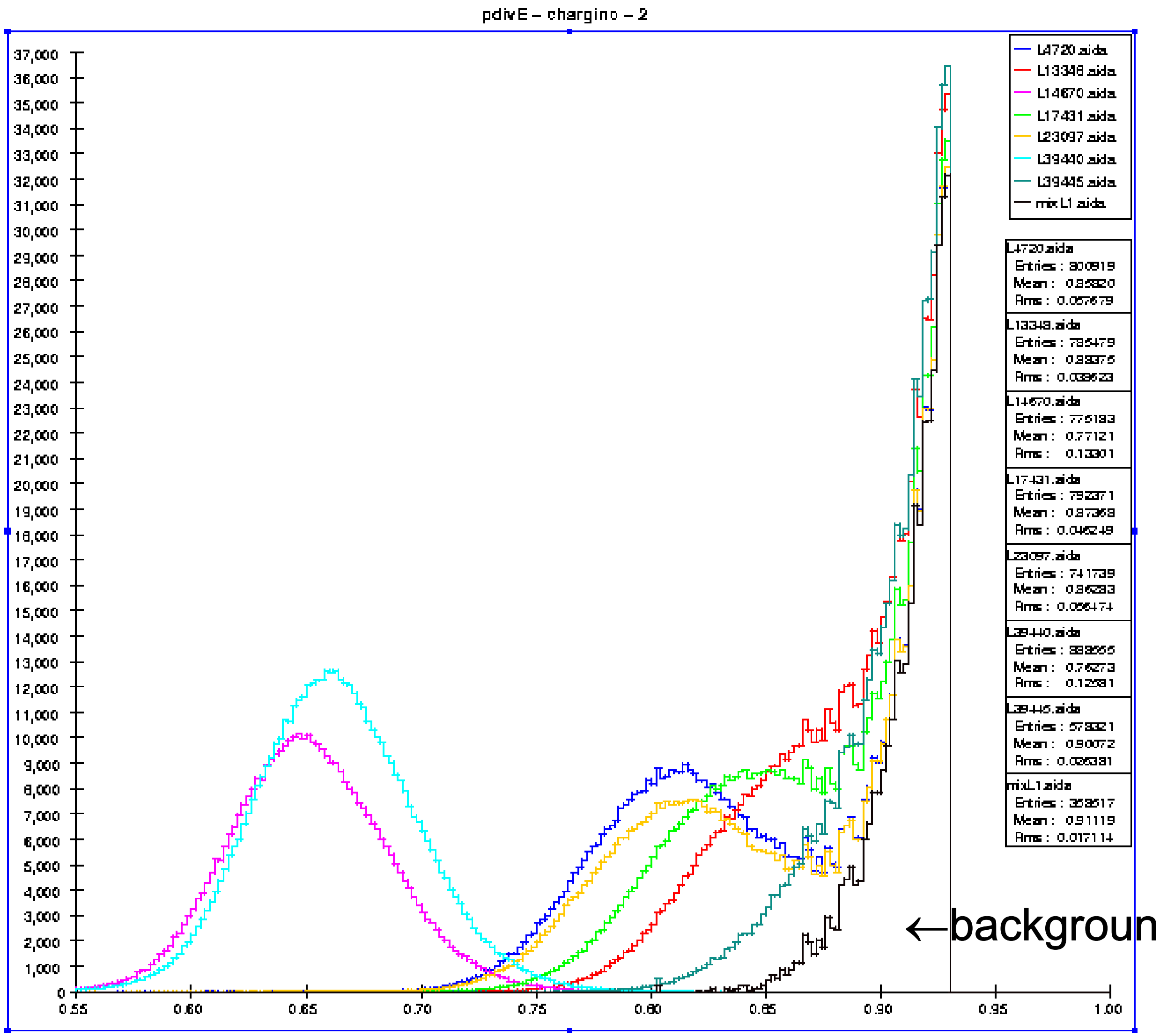
RH polarization ↓

Note that ATLAS(CMS) achieves a resolution on β better than 5(3)% so we should expect an ILC detector to do as well or better

The 7 chargino models are reasonably well separated w/ very little background and high statistics at 5% smearing….



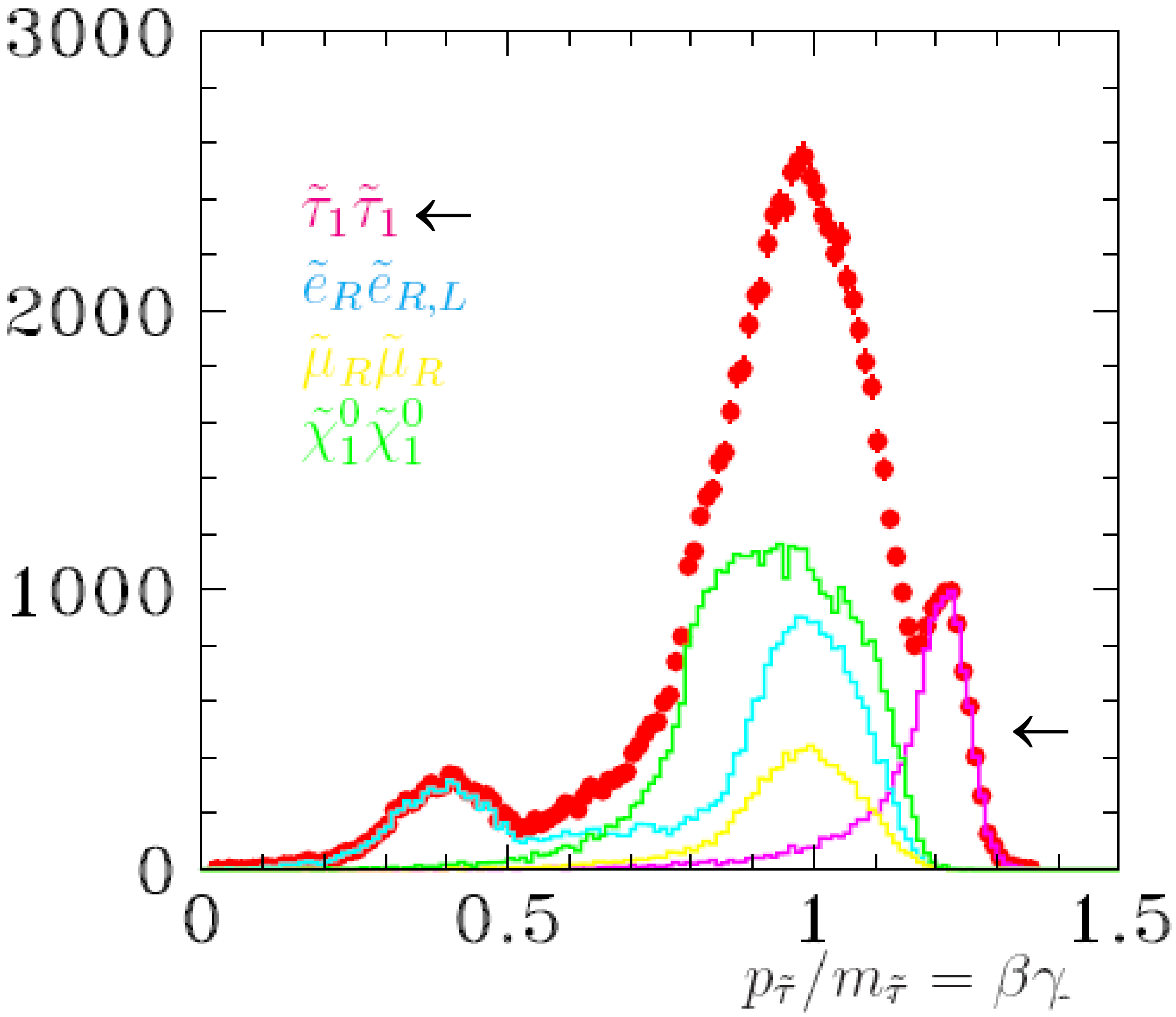
Going to 10% makes things a little harder….but still doable



←background

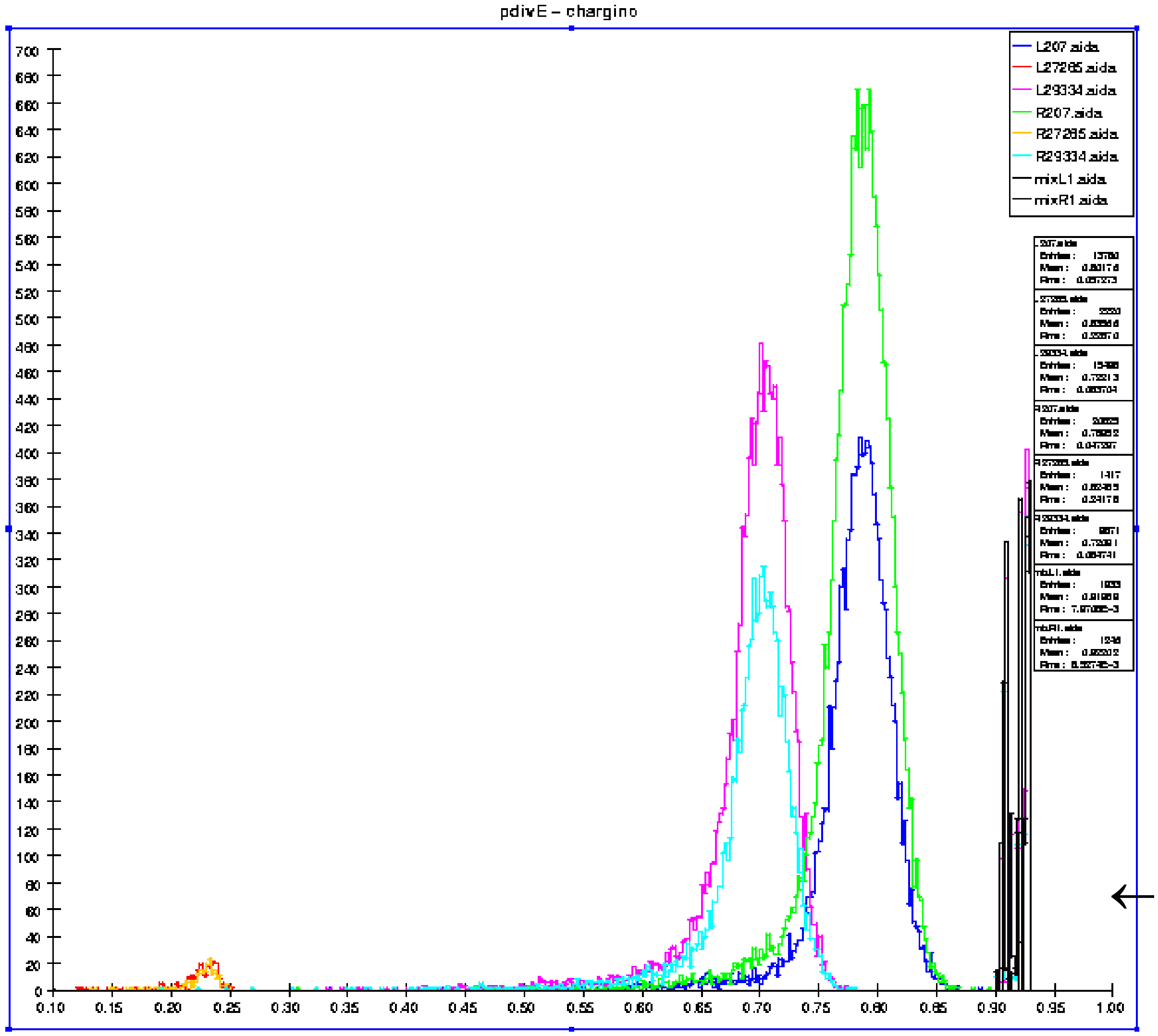
β

More sophisticated analyses show a distribution with a quite similar shape to the 5% case above…



e.g.,
H.U. Martyn
0709.1030

For staus the rates are lower so the backgrounds are more serious and polarization differences are less…

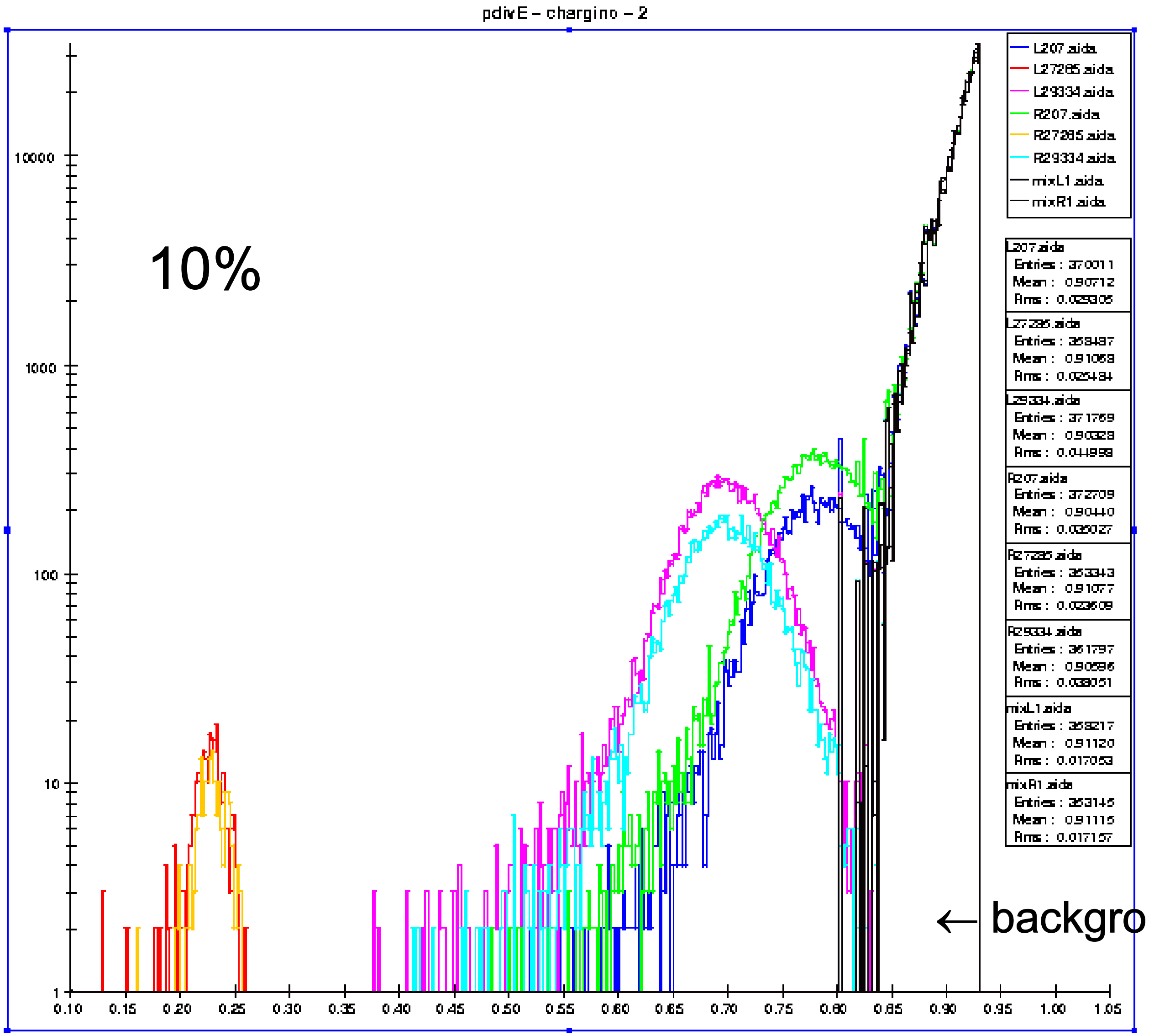


β

5%

← backgrounds

Backgrounds are far more important with the great smearing



10%

← backgrounds

β

- The ability to observe and, more importantly, to separate these model is quite dependent on the effective β resolution. Just going from 5->10% we observed a large difference in the background and the amount of model overlap--particularly more for the relatively light stable particles with masses near 100 GeV. Serious issues might arise if the effective resolution is much poorer than 10-15%...

- It is important to get a realistic ToF and/or dE/dx analysis into the vanilla public version of lcsim so a better SiD analysis can be done in the future than what we did here… It is critical to determine the effective β resolution.

- Stau vs chargino? Completely different angular distributions and beam polarization dependence as staus are scalars

Summary

- MSSM models which are `difficult’ at LHC seem to have a higher frequency of long-lived charged particles in them… these are usually either staus or charginos… our set of models contained both possibilities

- It is important to have good effective resolution in β in order to measure particle masses and distinguish models I would expect a β resolution better than 5%.

- It is important to get ToF and/or dE/dx fully implemented in lcsim so that we can do a better job with these types of analyses

BACKUP SLIDES

Final State	Number Accessible
$\tilde{e}_L^+\tilde{e}_L^-$	9
$\tilde{e}_R^+\tilde{e}_R^-$	15
$\tilde{e}_L^\pm\tilde{e}_R^\mp$	2
$\tilde{\mu}_L^+\tilde{\mu}_L^-$	9
$\tilde{\mu}_R^+\tilde{\mu}_R^-$	15
Any selectron or smuon	22
$\tilde{\tau}_1^+\tilde{\tau}_1^-$	28
$\tilde{\tau}_2^+\tilde{\tau}_2^-$	1
$\tilde{\tau}_1^\pm\tilde{\tau}_2^\mp$	4
$\tilde{\nu}_{e\mu}\tilde{\nu}^*_{e\mu}$	11
$\tilde{\nu}_\tau\tilde{\nu}^*_\tau$	18
$\tilde{\chi}_1^+\tilde{\chi}_1^-$	53
Any charged sparticle	85
$\tilde{\chi}_1^\pm\tilde{\chi}_2^\mp$	7
$\tilde{\chi}_1^0\tilde{\chi}_1^0$	181
$\tilde{\chi}_1^0\tilde{\chi}_1^0$ only	91
$\tilde{\chi}_1^0 + \tilde{\nu}$ only	5
$\tilde{\chi}_1^0\tilde{\chi}_2^0$	46
$\tilde{\chi}_1^0\tilde{\chi}_3^0$	10
$\tilde{\chi}_2^0\tilde{\chi}_2^0$	38
$\tilde{\chi}_2^0\tilde{\chi}_3^0$	4
$\tilde{\chi}_3^0\tilde{\chi}_3^0$	2
Nothing	61

Particle	Number Visible
$\tilde{e}_L$	8/9
$\tilde{e}_R$	12/15
$\tilde{\mu}_L$	9/9
$\tilde{\mu}_R$	12/15
$\tilde{\tau}_{1,2}$	21/28
$\tilde{\nu}_{e,\mu}$	0/11
$\tilde{\nu}_\tau$	0/18
$\tilde{\chi}_1^\pm$	49/53
$\tilde{\chi}_1^0$	17/180
$\tilde{\chi}_2^0$	5/46

242 Total Models

The Final Score

Visibility

78/85 models w/ at least one charged sparticle
82/161 models w/ an accessible sparticle
82/242 of all models

Distinguishable

57(63)/72 pairs w/ at least one charged sparticle at 5(3)σ
57(63)/162 of all pairs at 5(3)σ