Doubt about Veracity of Said Rule

IS HINCHLIFFE’S RULE TRUE?·

Boris Peon

Abstract

Hinchliffe has asserted that whenever the title of a paper is a question with a yes/no answer, the answer is always no. This paper demonstrates that Hinchliffe’s assertion is false, but only if it is true.
The LHC is Almost Ready to Go!

The entire community couldn’t be more excited! And is collectively holding its breath in anticipation...

Timeline for New Physics

1. New Physics will be discovered soon, HERE at the LHC!

2. We celebrate!

3. The next step is to measure model parameters and determine what theory the New Physics arises from
The “LHC Inverse Problem”:

• WHEN new physics is discovered at the LHC, how well can we determine what it is? Does a specific experimental signature map back into a unique theory with a fixed set of parameters? Many kinds of new physics can produce similar signatures…

• Even within a very specific context, e.g., the Minimal Supersymmetric Standard Model (the MSSM), can one uniquely determine the values of, e.g., the weak scale Lagrangian parameters from LHC data alone?

• Instead of starting with model parameters and determining experimental signatures, as theorists usually do, here we mimic real life and do the reverse…and find the mapping is NOT unique!
The Inverse Mapping of Data: there are many possible outcomes....

Much of the time a specific set of data maps back into many distinct islands/points in the model parameter space... → model degeneracy

What happens in the simple case of the MSSM??

LHC Inverse Problem

Generate blind SUSY data and map it back to parameters in the fundamental Lagrangian

- Generated 43,026 models within MSSM for 10 fb⁻¹ @ LHC (Pythia 6.324): model = point in MSSM parameter space
- For 15 parameters: (with flat priors)
  - Inos: \( M_1, M_2, M_3, \mu \)
  - Squarks: \( m_{q_1}, m_{q_2}, m_{u_1}, m_{u_2}, m_{d_1}, m_{d_2}, m_{t_1}, m_{t_2}, m_{b_1}, m_{b_2} \)
  - Sleptons: \( m_{\tilde{e}_1}, m_{\tilde{e}_2}, m_{\tilde{\mu}_1}, m_{\tilde{\mu}_2} \)

- Within the constraints:
  - \( 2 < \tan\beta < 50 \)
  - 1st two scalar generations kept degenerate

- Used ~1808 LHC MSSM Observables
  - Rate counting, kinematic distributions, ...
- NO SM Background! (so the real world is far worse)

Arkani-Hamed, Kane, Thaler, Wang, hep-ph/0512190
Essentials of MSSM Parameters...

\[
\left( \begin{array}{cc}
M_2 & M_W \sqrt{2} \sin \beta \\
M_W \sqrt{2} \cos \beta & \mu 
\end{array} \right)
\]

Wino + charged Higgsino \( \rightarrow \chi^+_{1,2} \)

bino + neutral wino and Higgsinos \( \rightarrow \chi^0_{1,2,3,4} \)

\[
M_f^2 = \left( \begin{array}{cc}
m_{fL}^2 & m_f X_f \\
m_{fR}^2 & M_{RR}^2
\end{array} \right),
\]

left- and right-sfermions \( \rightarrow \text{sfermions}_{1,2} \) ....mostly relevant for stops, sbottoms and staus.

LHC Inverse Problem: Results

- **Main result:** 283 pairs of models (383 distinct models\(^*\)) were found indistinguishable!
  - Many more than suggested by statistical analysis
- A signature maps back into a number of small islands in parameter space

* 242 models are physical

- Begs the question: Can the ILC resolve these degeneracies?  – We will address this issue
Characteristics of Degenerate Models

LHC: measure mass differences in cascade decays

- Flippers: Fixed mass eigenvalues, but flipped mixing components
- Sliders: Same mass differences, but different absolute masses
- Squeezers: Small mass differences

Sample Model Pairs

```plaintext
<table>
<thead>
<tr>
<th>Model</th>
<th>Mass (GeV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>d_L</td>
<td>6.0494365E+02</td>
</tr>
<tr>
<td>u_L</td>
<td>6.01141935E+02</td>
</tr>
<tr>
<td>s_L</td>
<td>6.0494365E+02</td>
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<td>c_L</td>
<td>6.0494365E+02</td>
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<tr>
<td>b_L</td>
<td>6.0494365E+02</td>
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<tr>
<td>d_R</td>
<td>6.10128617E+02</td>
</tr>
<tr>
<td>u_R</td>
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<tr>
<td>s_R</td>
<td>6.4766612E+02</td>
</tr>
<tr>
<td>c_R</td>
<td>6.4766612E+02</td>
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<td>b_R</td>
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<td>u_m</td>
<td>8.04764187E+02</td>
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<td>s_m</td>
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<td>c_R</td>
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</tr>
<tr>
<td>b_R</td>
<td>3.60866978E+02</td>
</tr>
</tbody>
</table>
```

MSSM: 34
Our Analysis

- We start with the AKTW degenerate pairs (242 distinct models)
- Simulate signal events with Pythia 6.324 & CompHEP, include ISR, ILC-design specific beamstrahlung (generated via WHIZARD/GuineaPig), beam energy spread
- Add SM background (1016 processes), produced by Tim Barklow via O’MEGA/WHIZARD – stored @ SLAC, size on disk = 1.7 Tb
  - All $2 \rightarrow 2$, $2 \rightarrow 4$, $2 \rightarrow 6$ processes with $e^+e^-$, $e^\pm\gamma$, $\gamma\gamma$ initial states with full matrix elements
  - We generate 2 complete, statistically independent sets of background
- Pipe through fast detector simulation: SiD detector concept, Java-based simulation, org.lcsim
  - 1st user analysis using SiD lcsim
- Analyze 500 fb$^{-1}$ “data” @ 500 GeV with 80% $P_e$- and appropriate kinematic cuts. Several iterations (seemingly endless) necessary to find the best cuts!
- We have stimulated much debugging of the various software
The present analysis is the first ILC study with

- 100’s of randomly generated MSSM models …
- Complete SM backgrounds calculated with full matrix elements
- Full ISR/beam spectrum including finite energy spread & beam crossing angle
- SiD fast detector simulation
- Over 20 simultaneous analyses using multiple observables

We have learned many lessons in the process

SM Background:

All ee, eγ, γγ → 2, 4, 6 processes w/ full matrix elements included

For example:

T. Barklow
SM Background: Example

Lesson: the use of full matrix elements is important!
- Sample background for selectron analysis
  \[ e^+e^- \rightarrow e^+e^- + \text{missing energy} \]

Full matrix elements produce a larger amplitude with a longer tail

Detector Simulation

- Use SiD Snowmass05 design via org.lcsim
  - 2 mrad crossing angle (checked that 20 mrad has negligible difference in analyses)
  - Particle tracking and ID only down to 150 mrad
  - Below 150 mrad, charged particles appear as neutral energy cluster. Coverage is tunable: we take \( \theta > 5 \) mrad
  - Low angle particles assigned \( \gamma \) or \( K^0 \) ID: causes problems in particle energy determination
  - Highly energetic \( \mu^+\)'s at low angles are not reconstructed: causes problems for stau analysis
  - Default jet finding algorithm is JADE with \( y_{\text{cut}} = 0.005 \). This is too low! Numerous soft gluons counted as jets: we take \( y_{\text{cut}} = 0.05 \)

Lesson: beware of blind use of fast detector simulations
Sparticle Counts

Kinematically accessible sparticles @ 500 GeV, 1 TeV

At 500 GeV:
- 20 models with selectrons & smuons.
- 28 models with staus
- 53 models with charginos
- 99 models have only $\chi_1^0$

Only 1 model inaccessible at 1 TeV

Sparticle mass spectrums
Breakdown of Kinematic Accessibility

<table>
<thead>
<tr>
<th>Final State</th>
<th>500 GeV</th>
<th>1 TeV</th>
</tr>
</thead>
<tbody>
<tr>
<td>e^+_Le^-_L</td>
<td>9</td>
<td>32</td>
</tr>
<tr>
<td>e^+_Le^-_R</td>
<td>15</td>
<td>86</td>
</tr>
<tr>
<td>e^+_R e^-_L</td>
<td>2</td>
<td>61</td>
</tr>
<tr>
<td>p^+_L p^-_L</td>
<td>9</td>
<td>52</td>
</tr>
<tr>
<td>p^+_R p^-_R</td>
<td>15</td>
<td>86</td>
</tr>
<tr>
<td>Any selectron or smuon</td>
<td>22</td>
<td>137</td>
</tr>
<tr>
<td>h^+_L h^-_L</td>
<td>28</td>
<td>145</td>
</tr>
<tr>
<td>h^+_R h^-_L</td>
<td>1</td>
<td>23</td>
</tr>
<tr>
<td>h^+_R h^-_R</td>
<td>4</td>
<td>61</td>
</tr>
<tr>
<td>h^+_L h^-_µ</td>
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<td>χ^+_1 χ^-_1</td>
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<td>88</td>
<td>224</td>
</tr>
<tr>
<td>χ^+_1 χ^-_1</td>
<td>7</td>
<td>33</td>
</tr>
<tr>
<td>χ^+_1 χ^-_1</td>
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<td>236</td>
</tr>
<tr>
<td>χ^+_1 χ^-_1 only</td>
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<td>χ^+_2 only</td>
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<td>38</td>
<td>91</td>
</tr>
<tr>
<td>χ^+_1 χ^+_2</td>
<td>4</td>
<td>41</td>
</tr>
<tr>
<td>χ^+_1 χ^+_2</td>
<td>2</td>
<td>23</td>
</tr>
<tr>
<td>Nothing</td>
<td>61</td>
<td>3</td>
</tr>
</tbody>
</table>

Out of 242 models, 61 + 91 + 5 = 157/242 ~ 65% have no obvious observable signal at the 500 GeV ILC...

This fraction reduces to 3/242 at 1 TeV!

This is a strong argument for upgrading to 1 TeV as soon as possible!

Analysis: Signal @ √s = 500 GeV

We simulate 15 channels:

- **Selectron**_{L,R}
- **Smuon**_{L,R}
- **Stau**
- **Sneutrino**
  - 4jet+lepton pair, 6jets + missing energy
- **Lightest Chargino**, χ^+_1, χ^-_1 mass splitting > 1 GeV
  - 6 channels: off- & on-shell W's decay to 4–jet, jj +µ, µ µ + missing energy final states
- **Lightest Chargino**, χ^+_1, χ^-_1 mass splitting < 1 GeV
  - tag on high–energy radiative γ associated production
  - stable charged particle search
- **Radiative LSP production**: χ^-_1, χ^-_1 + γ
- **χ^-_1, χ^-_2** associated production
Is it REALLY this easy??? Yes, with SPS1a’…

Previous ILC SUSY Studies

Selectrons
- Colorado Group Goodman et al.
- Bambade et al., hep-ph/0406019

Smuons
- Martyn, hep-ph/0408226

Staus
- Choi et al., hep-ph/0612301

Kinematic Cuts

Cuts adapted and expanded from:

- U. Nauenberg, et al., Colorado SUSY group,
  [arXiv:hep-ex/0401026]

We used these as a starting point and developed our own set of universal cuts, after iteration after iteration after iteration after iteration after …
Lesson: SPS1a’ is a special benchmark point

Looking at 100s of random MSSM models, we find that most have smaller rates than the SPS points commonly studied. Can be 50x smaller!

Some previously developed cuts tend to be too strong and completely wipe out the signal for our random models.

- Our cuts
- SM background for chargino production
- OPAL cuts

Selectron Analysis

\[ e^+e^- \rightarrow \bar{e}^+\bar{e}^- \rightarrow e^+ \chi_1^0 + e^- \chi_1^0 \]

Our kinematic cuts:

1. Exactly two leptons, identified as an electron and a positron, in the event. This cuts out SM background where for example both $\chi^0$s decay leptonically.
2. $E_{\text{miss}} < 1 \text{ GeV}$ for $|\cos \theta| > 0.9$.
   This is to cut down the main SM backgrounds from $W\nu$ and beam/beam interactions that produce leptons predominantly along the beam axis.
3. $E_{\text{miss}} < 0.4\sqrt{s}$ in the forward hemisphere. The forward hemisphere is defined as the hemisphere around the thrust axis that has more visible energy. (In this case we only have 2 visible particles, so this amounts to taking the highest energy of one of the particles.) The SUSY signal has missing energy in both hemispheres, whereas SM $e^+e^-$ production via $Z$-pair has missing energy only in one of the hemispheres, because the other $Z$ decays into neutrinos in the other hemisphere.
4. $|\cos \theta| > 0.96$ for the reconstructed electron-positron pair. Since SUSY has a lot of missing $E_T$, the SUSY-produced pair will not be back-to-back, in contrast to the SM background events.
5. We demand that the visible transverse momentum, or equivalently, the transverse momentum of the electron-positron pair, $p_{\text{vis}} = p_T^{e^+e^-} > 0.04\sqrt{s}$. This cut is to reduce the $\gamma\gamma$ and $e^+\gamma$ background which has nearly low $p_T$.
6. Acoplanarity angle $\Delta \phi^{e^+e^-} > 40$ degrees. Acoplanarity angle is equivalent to $\pi$ minus the angle between the electron $p_T$, $\Delta \phi^{e^+e^-} = \pi - \Delta \phi_P$, which translates the above requirement to a restriction of the transverse angle $\cos \theta_P > 0.94$.
   This cuts out a lot of $W$-pair and $\gamma\gamma$-background which tends to be more back-to-back.
7. $M_{\chi^0\chi^0} < M_W - 5 \text{ GeV}$ or $M_{\chi^0\chi^0} > M_Z + 5 \text{ GeV}$. This is to cut out events from $Z\chi^0\chi^0$, that is, $e^+e^- \rightarrow Z\chi^0\chi^0 \rightarrow \ell^+\ell^-\chi^0\chi^0$. 

$\ell = e,\mu$
Successive Effects of the Cuts

Background is reduced by several orders of magnitude!

Signal is reduced by a factor of 2

This canonical table-like structure is a result of the 2-body slepton decay mode

Results: Selectrons

Electron energy distribution

Left-handed electron beam

Right-handed electron beam
Results: Smuons

Muon energy distribution

Left-handed electron beam

Right-handed electron beam

Some Immediate Lessons

- SPS1a' production rates are significantly larger than for ALL of our random models
- The variation in rates is up to a factor of ~50! Clearly models with smaller rates will be challenging...
- The ratio of signals and backgrounds is very polarization dependent... usually one polarization choice is far better than another but the particular choice depends on the final state. For sleptons, RH polarization is the best choice.
Lesson: SUSY is a Background to SUSY

More signals in the $\mu \mu +$ missing channel

- Models that pass the smuon search criteria
- Actually chargino production!
- Note the different structure of the spectrum

More Distributions

Other observables can distinguish which sparticle is being produced

Smuons

$\mathbf{p_T^{vis}}$

Charginos

$\mathbf{p_T^{vis}}$
**Stau Analysis**

\[ e^+e^- \rightarrow \tilde{\tau}^+\tilde{\tau}^- \rightarrow \tau^+\chi_1^0 + \tau^-\chi_1^0 \]

1\textsuperscript{st} step: ID \(\tau\)'s
- 1–3-prong both hadronic decay
- 1 hadronic, 1 leptonic decay
- 1 e, 1 \(\mu\) decay

2\textsuperscript{nd} step: Apply cuts

- Essentially stable stau
- Close mass stau and LSP
- Well separated stau and LSP

**Results: Staus**

Tau energy distribution: very few of our models are observable above background from \(\gamma\gamma \rightarrow \tau\tau, \mu\mu\)

Left–handed electron beam

Right–handed electron beam
Case Study: $\gamma\gamma \rightarrow \mu\mu$ Background to Stau Production

Typical event:
- $e^{-}$: nearly full energy (244 GeV) goes down the beampipe with $p_T = 0$, not reconstructed for obvious reasons
- $e^{+}$: kicked out with decent $p_T$ and is reconstructed
  4–momentum $(E=51.665, -7.6473, -3.2886, -50.990)$
- $\mu^{-}$: is reconstructed and gives a cluster
  $(E = 5.9698, -4.7366, 0.11118, 3.6319)$
- $\mu^{+}$: very energetic, doesn't show up in the reconstructed particle list at all, leaves no cluster, and no track,
  $(E = 198.03, 12.384, 3.1775, -197.62)$ -- it's at ~65 mrad

Results: Staus, Alternate Analysis

Tau energy distribution: Remove electrons from tau ID
Cuts signal, but removes background from beam remnants

Left–handed electron beam

Right–handed electron beam

← our models

↓ background
Sneutrino pairs are kinematically accessible in 11/242 models

For the first two generations we have:

(i) sneutrino → ν + LSP is invisible, but generally dominates \( X \)

(ii) sneutrino → W + slepton → jj + lepton + LSP : not allowed on-shell \( X \)

(iii) sneutrino → \( \chi_1^+ + \text{lepton} \rightarrow jj + \text{lepton} + \text{LSP} \) : allowed in only one model and the resulting jets are rather soft..... \( X \)

(iv) sneutrino → ν + \( \chi_2^0 \rightarrow jj + \text{missing E} : \) allowed only in one model and the jets are again too soft... \( X \)

\[ \rightarrow \] sneutrinos are not observable at 500 GeV in any model.....

...and tagging the sneutrino final state with a γ doesn’t work either.

Results: Sneutrinos

Left-handed beam polarization

![Graph showing Missing E(4jll) with background and chargino & neutralino fakes indicated.]
Chargino Decays

\[ \Delta m = m_{\chi_1^\pm} - m_{\chi_1^0} \]

is a critical parameter in \( \chi_1^\pm \) analyses

Mass separation with LSP determines \( \chi_1^\pm \) decay modes

We perform analyses for 8 decay channels

Pythia Feature:

If the chargino mass is less than that of the LSP then PYTHIA resets the chargino mass to be that of the LSP +2m_\pi

A warning statement now appears in Pythia 6.410.

Chargino Analyses: Non–Close Mass Case

\[ \Delta m_{\chi} \equiv m_{\chi^\pm} - m_{\chi_1^0} > 1 \text{ GeV}. \]

1. Muon decay channel:

\[ \chi_1^\pm \rightarrow \mu^\pm \nu, \mu^\pm \bar{\nu} \rightarrow \mu E_{\text{miss}} \]
\[ \chi_1^\pm \rightarrow W(\pm) \chi_1^0 \rightarrow \mu + \chi_1^0 \]

2. Four–jet channel:

\[ \chi_1^\pm \chi_1^- \rightarrow W^+W^-\chi_1^0\chi_1^0, \quad W^\pm \rightarrow q\bar{q}. \]

3. Mixed channel:

\[ \chi_1^\pm \chi_1^- \rightarrow 2j + \mu^\pm + E_{\text{miss}} \]

Depending on the mass splitting the W can be real or virtual but in the latter case the W mass will not be reconstructed

Distinct analysis to cover cases with both real and virtual W's
Results: Charginos

4j + missing E analysis: Jet Pair Energy

Right-handed electron beam

\[ \Sigma E_j \]

2 real +1 fake (1822)

Results: Charginos

2\(\mu\) + missing E analysis: Muon Energy

Right-handed electron beam
Results: Charginos

2jet + μ + missing E analysis: Jet-pair Energy

Right-handed electron beam

On-shell W's  
Off-shell W's

Results: Charginos

2jet + μ + missing E analysis: Jet-pair Mass

Right-handed electron beam

On-shell W's  
Off-shell W's
Chargino Analyses: Close Mass Case

1. \( m_\pi \leq \Delta M_\chi < 1 \text{ GeV} \): Use \( \mu^+e^- \rightarrow \chi^+_1\chi^-_1 + \gamma \)

Tag on high \( P_T \) photon! Use CompHEP to generate hard matrix element

A surprisingly large number of our models have these particles

\( \Delta M_\chi < m_\pi \): Chargino decays into electron, neutrino, & LSP after traversing many meters – nearly back-to-back, stable, massive tracks \( \Rightarrow \) stable particle search

\( \beta = p/E \): \( p \) determined by track curvature in \( B \) field while \( E \) determined by some other method. Note TOF and/or \( dE/dx \), is not yet in the vanilla \textit{lcsim}...To mimic this we assume \( \beta \) is determined with a track \( E \) smearing of \( \delta E \rightarrow \delta \beta = 5 \) or 10% before piping through \textit{lcsim}, consistent with ILC detector models. (thanks to B. Schumm etal)
Stable charginos are quite easy to see with reasonable resolution

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

...other stable charged particles, in this case staus, are also captured by this analysis...

Summary of Chargino Analyses

Green = radiative only  Blue = off-shell W  Red = missed
Black = stable only    Magenta = off-shell & radiative
Radiative Neutralino Production

\[ e^+ e^- \rightarrow \chi_1^0 \chi_1^0 + \gamma \]

1. One \( \gamma \) and nothing else visible in the event
2. \( E_T^\gamma = E_\gamma \sin \theta_\gamma > 0.03 \sqrt{s}, \ \theta_\gamma \) is \( \gamma \) angle w/ beam axis
3. \( \sin \theta_\gamma > 0.1 \)
4. \( E_\gamma < 160.0 \text{ GeV} \) (removes radiative return to the Z)
5. Use CompHEP to generate hard matrix element

Signal significance of \( \sim 20 \) for SPS1a

Photon tagging is quite efficient.. This final state is visible for 17/242 models.

S/B can be substantially increased here by using positron polarization.

SPS1a' produces a rate far larger than all our models but is contaminated by sneutrino production
In most models the signal rate is so small there is no hope of observability... 

Right-handed beam polarization

\[ \chi_1^0 \chi_2^0 \text{ Associated Production} \]

most models have a small mass splitting and will be difficult: search for an on/off-shell Z in jj, ee, and \( \mu \mu \)
In the jj channel we see an excess at the Z (5 models) but also a huge W peak from both backgrounds and other sparticles. We also see the Higgs!

This signal can be cleaned up with better mass resolution and/or positron polarization.

In the ee channel we have mostly fakes.

**Grand Summary of Visibility**

Our goal is to collect the results and determine how many models lead to a visible signal at the 500 GeV ILC.

<table>
<thead>
<tr>
<th>Particle</th>
<th>Number Visible</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\tilde{e}_L$</td>
<td>8/9</td>
</tr>
<tr>
<td>$\tilde{e}_R$</td>
<td>12/15</td>
</tr>
<tr>
<td>$\tilde{\mu}_L$</td>
<td>9/9</td>
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<tr>
<td>$\tilde{\mu}_R$</td>
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<td>21/23</td>
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<td>$\tilde{\nu}_{e,\mu}$</td>
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<tr>
<td>$\tilde{\nu}_R$</td>
<td>0/18</td>
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<tr>
<td>$\tilde{\chi}_1^\pm$</td>
<td>49/53</td>
</tr>
<tr>
<td>$\tilde{\chi}_1^0$</td>
<td>17/180</td>
</tr>
<tr>
<td>$\tilde{\chi}_2^0$</td>
<td>5/46</td>
</tr>
</tbody>
</table>

We perform a likelihood ratio analysis based on Poisson statistics and require a significance $>5$ to claim observability.

$$R = \frac{L(S+B1,B2)}{L(B1,B2)}$$

$$\text{Sig} = (2 \log R)^{1/2} > 5$$

This is done individually for each of our analyses.
The Final Score

Visibility:

- 78/85 models w/ at least one charged sparticle
- 17/96 models w/ neutral sparticles only
- 82/161 models w/ any accessible sparticle
- 82/242 of all models

The ILC does well with charged sparticles. The ones missed are mostly due to phase space suppression producing small cross sections or inability to pass the kinematic cuts.

Models with only neutral sparticles are far more difficult

Model Comparisons

- We combine the results for each histogram for Models S1 and S2 with those obtained from our two independent full background samples, B1 & B2
- For each $e_{LR}$ beam we perform a $\chi^2$ comparison of the various distributions for (S1+B1) vs (S2+B2)
  $$\chi^2 = \chi^2 (S1+B1,S2+B2)$$
- We then ask if the 2 models are distinguishable at 5(3)$\sigma$
It is important to compare the two SM background samples to make sure the $\chi^2$ analysis procedures are correct... and no additional features are present. We pass this test with flying colors.

The Final Score (Part II)

Distinguishability:
- 57(63)/72 pairs with at least one charged sparticle at 5(3)$\sigma$
- 0/90 pairs where “neutral only” models are compared
- 57(63)/162 of all pairs at 5(3)$\sigma$

Some visible models are only “just so” and are thus hard to distinguish. This is especially true for the chargino vs chargino cases.

Again, “neutrals only” are very hard to observe.
Summary

1. This project has been a learning experience!
2. 1st ILC analysis of 100’s of random SUSY models (smaller rates than SPS1a)
3. $\sqrt{s} = 500$ GeV is not enough for this sample of models
4. Some cuts designed for specific models (SPS1a) kill random SUSY signal
5. SM Background with full matrix element is larger than that from Pythia
6. Forward detector coverage is critical
7. Some difficult cases:
   - close stau – LSP mass
   - $\chi_1^\pm \rightarrow W^*\chi_1^0 \rightarrow jj \chi_1^0$
8. 82/242 models have visible signatures at the 500 GeV ILC
9. 57/162 model pairs have distinguishable signatures at the 500 GeV ILC

Outlook

1. Study the 1 TeV case and the influence of positron polarization on both signals and backgrounds (+more channels to look at). Do threshold scans of some kind, include vertex detector analyses...
2. Explore using CompHEP to generate SUSY signal events for all analysis channels which allows for interference.
3. Study variations in the detector properties, in particular, the effect of introducing, e.g., low-angle muon ID below $\sim 140$ mr.
4. Begin a completely new analysis with a more realistic set of models which includes other constraints from, e.g., the Tevatron, LEP, WMAP, $g-2$, $b\rightarrow s\gamma$, dark matter searches, etc.