LHC^{-1} = ILC?

Carola F. Berger

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PHENO 07 – May 7th, 2007

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ƆH⅃$^{-1}$ = ILC ?

Yes, of course!

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Yes, ~~of course!~~

but

To appear, arXiv/0705.xxxx [hep-ph], featuring CFB, James Gainer, JoAnne L. Hewett, Ben Lillie, Thomas G. Rizzo

Outline

- **Summary of results of “The LHC Inverse Problem”, how to map from observables to a Lagrangian**
- **SUSY at the ILC**
  Standard Model background and analyses
- **Results (preliminary!)**
- **Summary and outlook**

Introduction

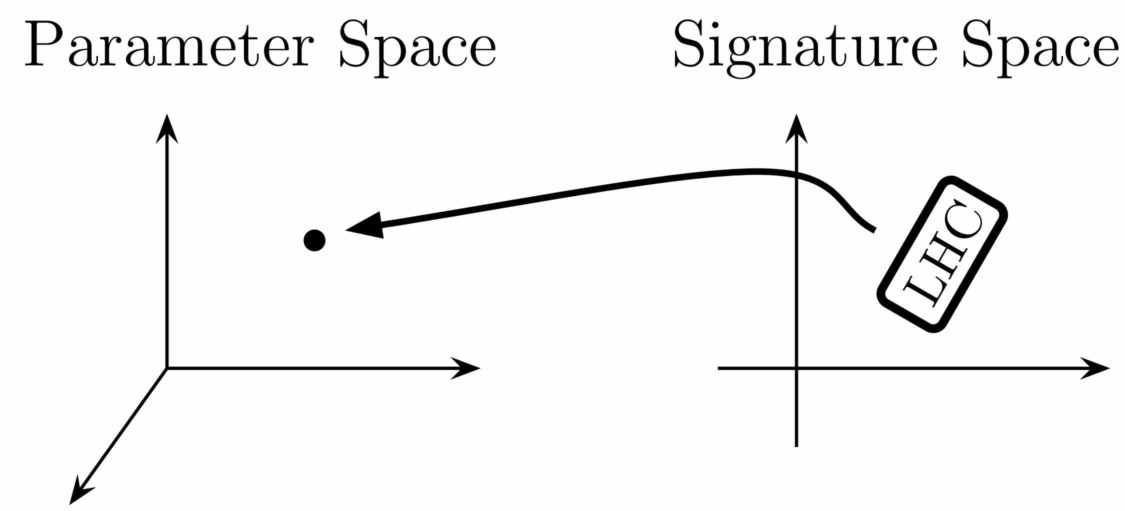
What's in a name?

Theorists: parameters ⇒ observables

Experimentalists: observables ⇒ parameters

N. Arkani-Hamed, G. L. Kane, J. Thaler, L.-T. Wang, *Supersymmetry and the LHC inverse problem*, JHEP 0608, 070 (2006) [hep-ph/0512190]

Question: parameters ⇔ observables – a one-to-one map?



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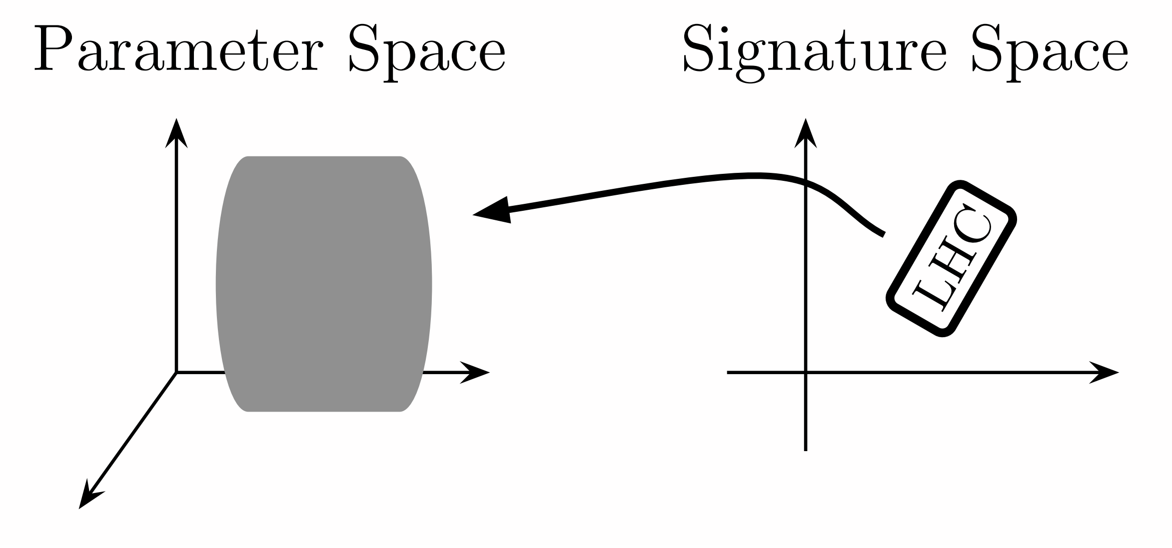

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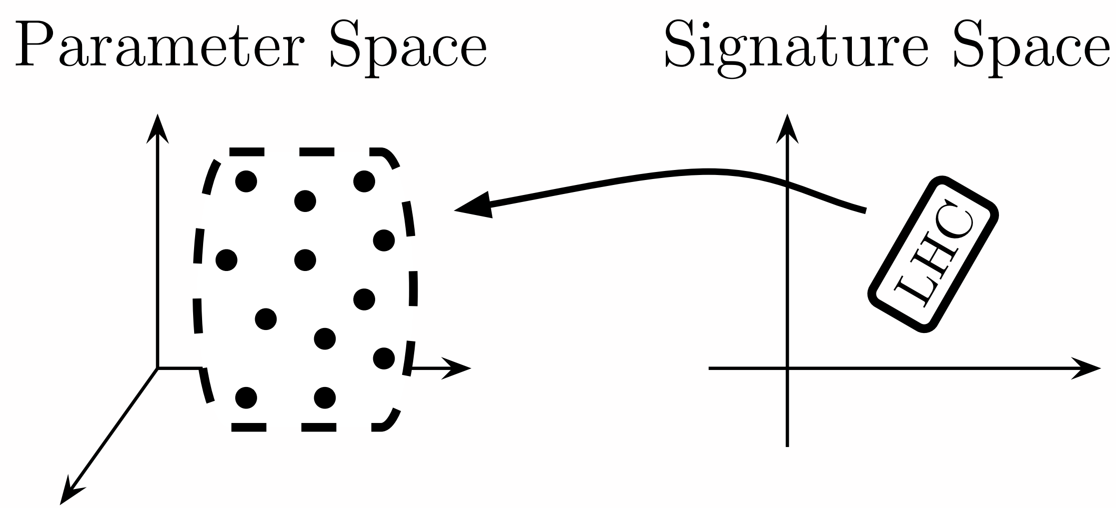

Introduction contd.

hep-ph/0512190: scan over (restricted) MSSM parameter space, simulation of different "models". Existence proof: there are distinct MSSM models that are indistinguishable at LHC with standard set of observables even without SM background.

The LHC can only measure mass differences accurately, initial state (= c.m. energy per collision) not well defined.
In addition, multiparton final states dominate. In general, "messy" final states $\Rightarrow$ soft particles not visible.

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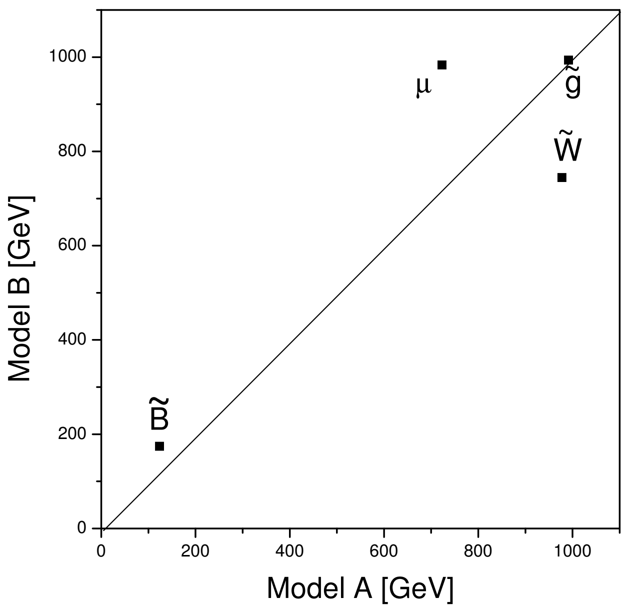
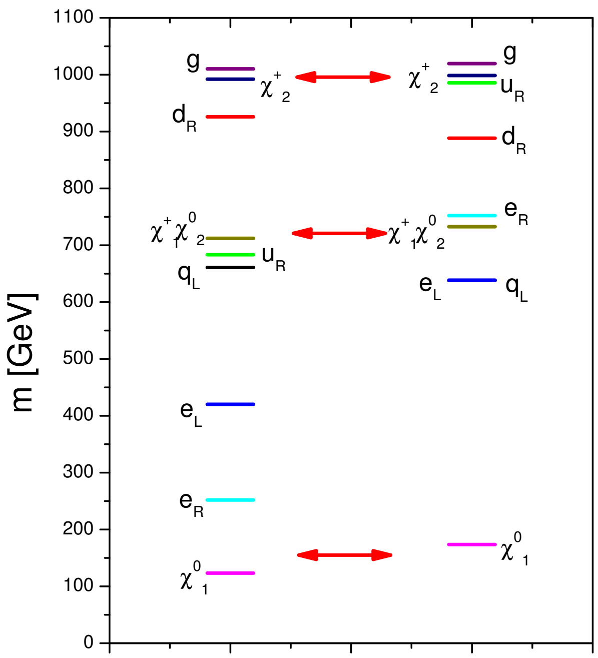
Question: given the list of MSSM "models" that turned out to be indistinguishable at the LHC in hep-ph/0512190, can the ILC distinguish them, using which observables?

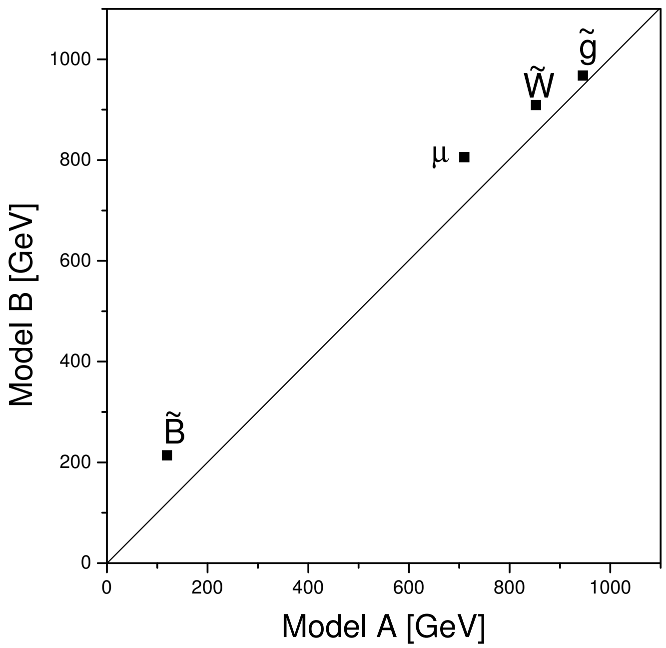
A Typical Degenerate Pair – Example 1

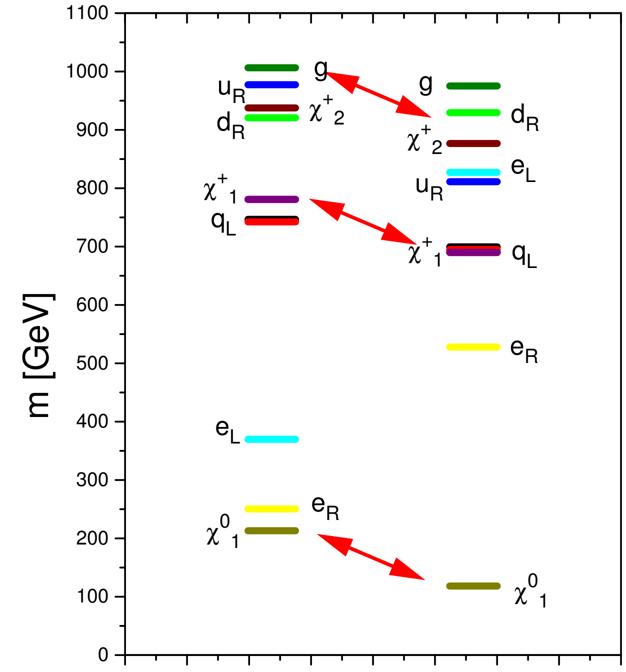




“Flipper”: mass of LSP fixed, but identity changes between mostly bino/wino and mostly Higgsino

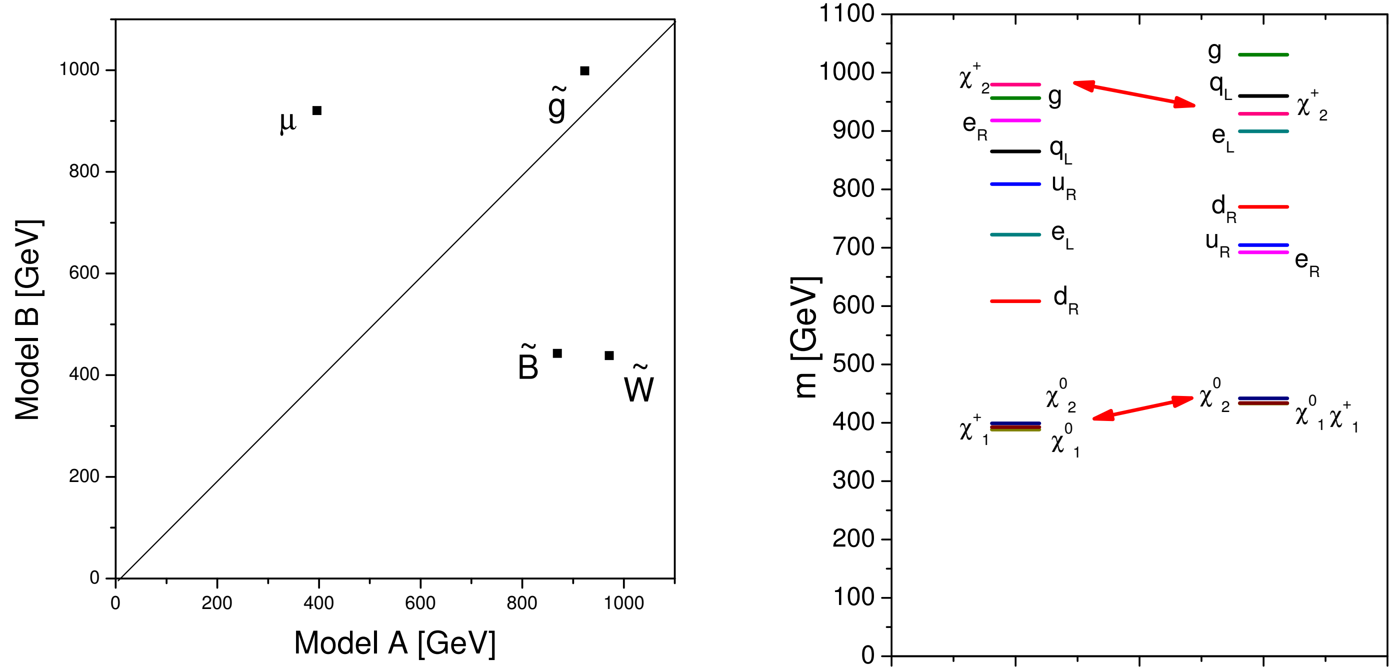
A Typical Degenerate Pair – Example 2





“Slider”: mass differences roughly the same, but shifted by about 100 GeV.

A Typical Degenerate Pair – Example 3

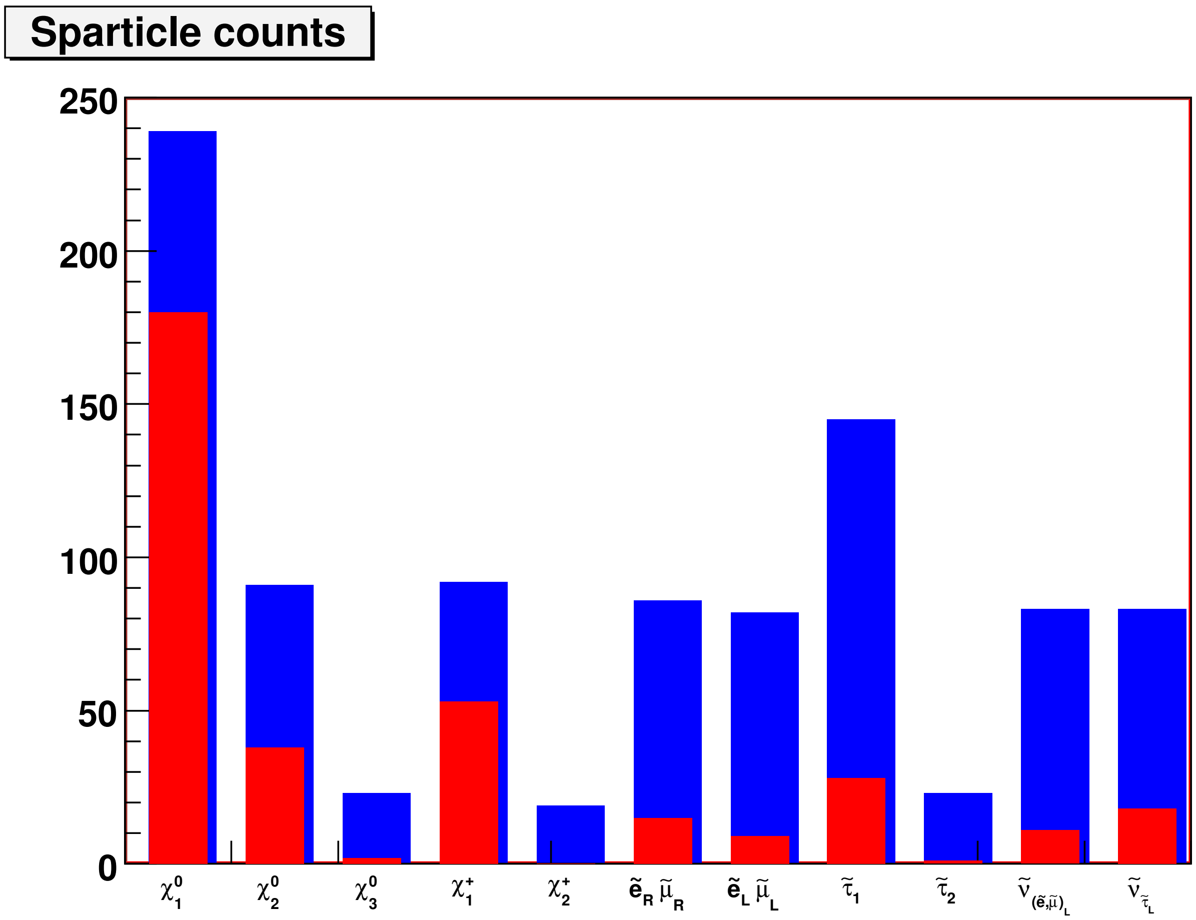


"Squeezer": mass differences between electroweakinos too similar – decay products too soft

Our Project – Overview

- **Simulate signal events with Pythia, and feed in appropriate beamspectrum generated via Whizard/GuineaPig, including ISR, beamstrahlung, beamspread**
- **Add SM background (1016 different processes), produced by Tim Barklow, stored on SLAC tape**
- **Pipe through detector simulation**
  Java-based detector simulation, code developed by SLAC ILC group: `org.lcsim`, SiD detector concept
- **Analyze 500 fb^{-1} of "data" with appropriate cuts**
  Several iterations necessary to find best cuts

Characteristics of Signal Models



Accessible at 500 GeV, 1 TeV c.m. energy

Analyses

- Selectrons – electron-positron pair plus LSPs (missing $\not{E}_T$)
- Smuons – muon-pair plus LSPs (missing $\not{E}_T$)
- Staus – tau-pair plus LSPs (missing $\not{E}_T$) - tau ID!
- Charginos – several sub-scenarios depending on $\Delta m_{\tilde{\chi}} = m_{\tilde{\chi}_1^\pm} - m_{\tilde{\chi}_1^0}$
  - $\Delta m_\chi > 1$ GeV – jets and/or μs plus LSPs
  - $m_\pi \leq \Delta m_{\tilde{\chi}} < 1$ GeV – radiative, tag on high-E photon
  - $\Delta m_{\tilde{\chi}} < m_\pi$ – massive, stable, charged track
- Radiative Neutralinos

Cuts

$\gamma\gamma$ and $e\gamma$ SM background nontrivial!
Need good particle ID and tracking down to low angles.

Cuts adapted and expanded from

- U. Nauenberg, *et al.*, Colorado SUSY group,
  `http://hep-www.colorado.edu/SUSY/susynlc.html`
- H. U. Martyn, arXiv:hep-ph/0408226
- P. Bambade, M. Berggren, F. Richard and Z. Zhang, arXiv:hep-ph/0406010
- G. Abbiendi *et al.* [OPAL Collaboration], Eur. Phys. J. C 35, 1 (2004) [arXiv:hep-ex/0401026]
- C. H. Chen, M. Drees and J. F. Gunion, Phys. Rev. Lett. 76, 2002 (1996) [arXiv:hep-ph/9512230]; J. F. Gunion and S. Mrenna, Phys. Rev. D 64, 075002 (2001) [arXiv:hep-ph/0103167]
- H. K. Dreiner, O. Kittel and U. Langenfeld, arXiv:hep-ph/0703009

SM Background

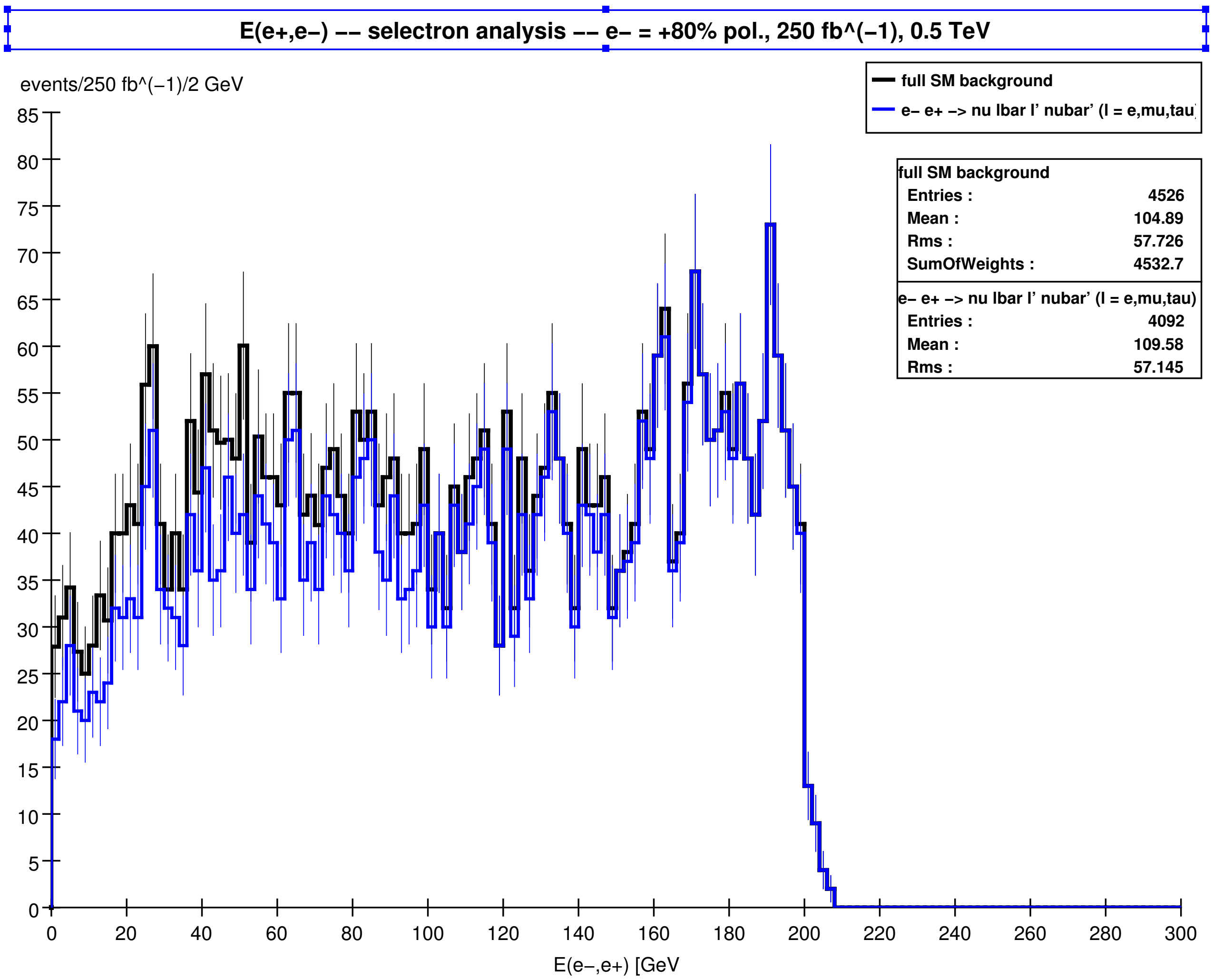
The LHC Inverse Problem – Summary

SUSY at the ILC

Sample Results – Selectron Analysis

- SM Background
- SM Background contd. – p_T
- Signal
- Signal + Background
- Sample Model Comparison

Summary and Outlook

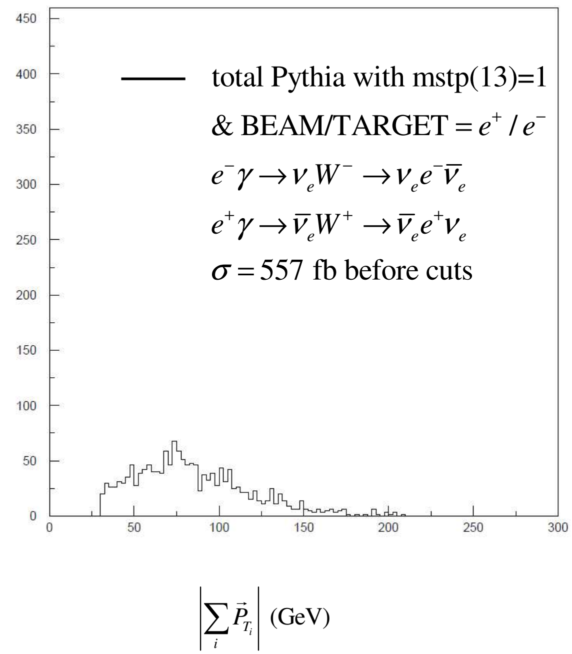


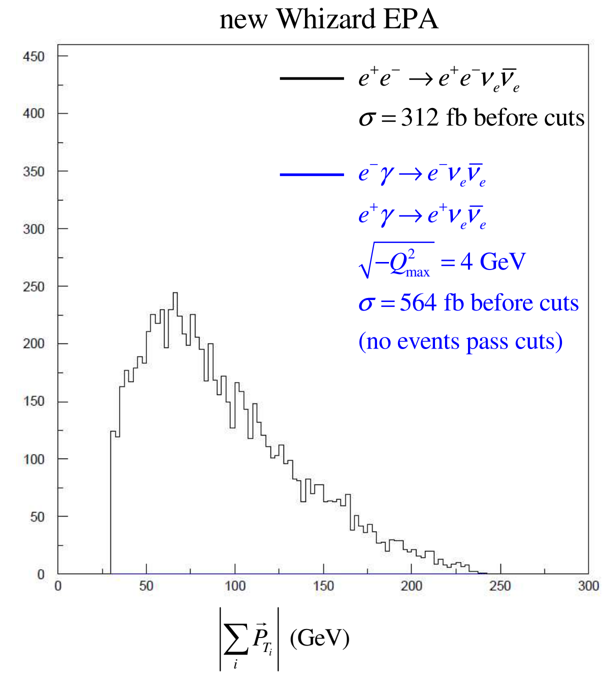
Bigger than "standard" background

SM Background contd. – p_T

Comparison Whizard $\Leftrightarrow$ PYTHIA:

$$e^-_{pol} = 0 \quad \sqrt{s} = 500\ \text{GeV} \quad 250\ \text{fb}^{-1}$$





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Thanks to Tim Barklow

SM Background contd. – p_T

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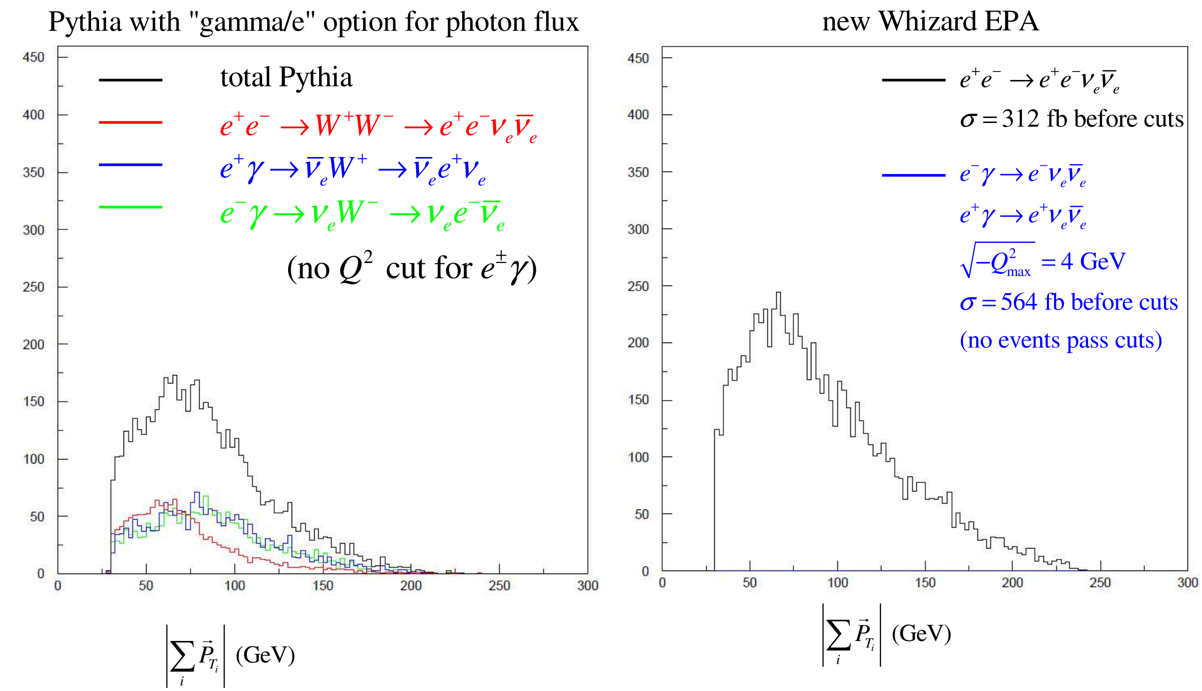

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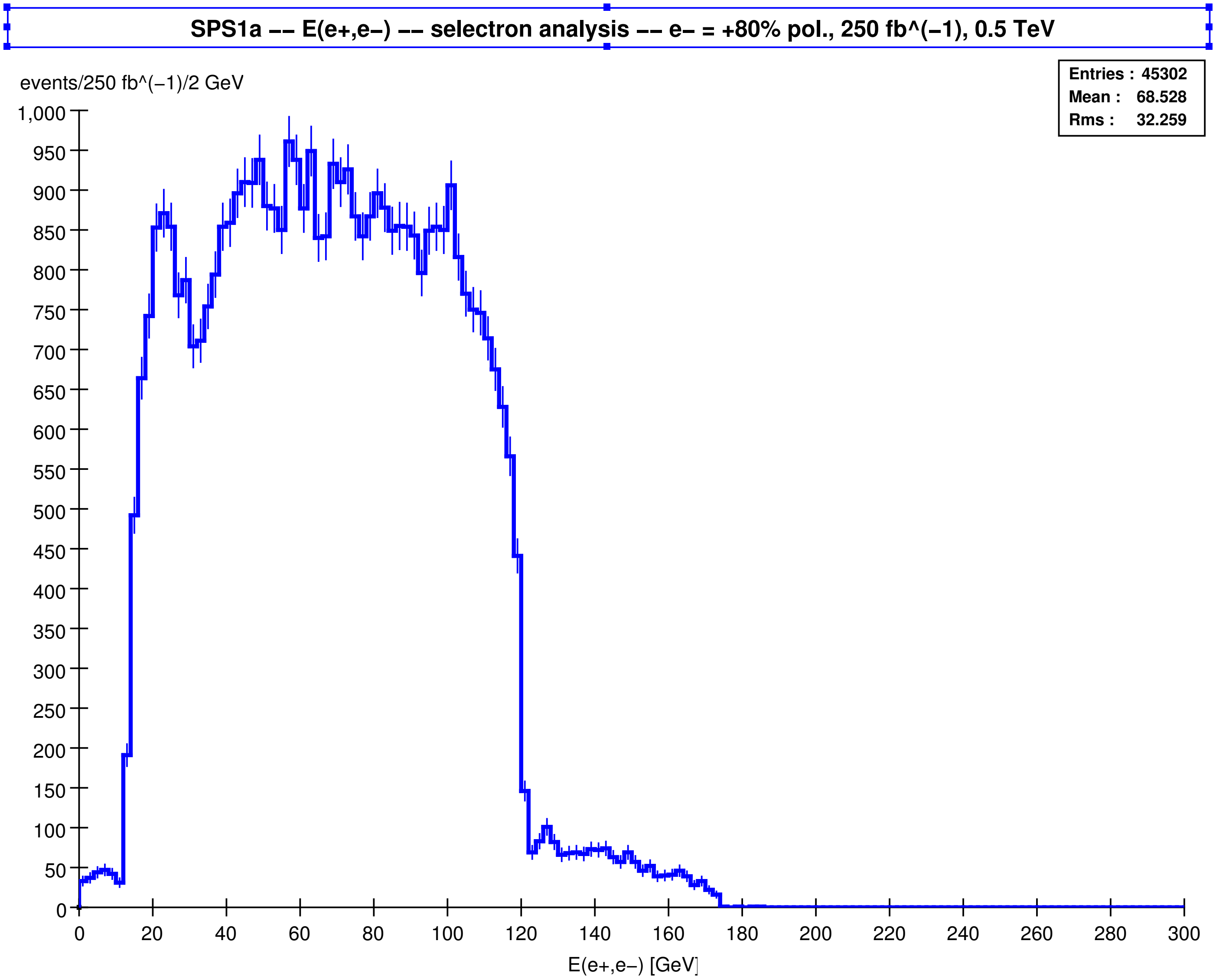
Signal



SPS1a –– E(e+,e–) –– selectron analysis –– e– = +80% pol., 250 fb^(–1), 0.5 TeV
Entries : 45302
Mean : 68.528
Rms : 32.259
events/250 fb^(–1)/2 GeV
1,000
950
900
850
800
750
700
650
600
550
500
450
400
350
300
250
200
150
100
50
0
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300
E(e+,e–) [GeV]

Signal

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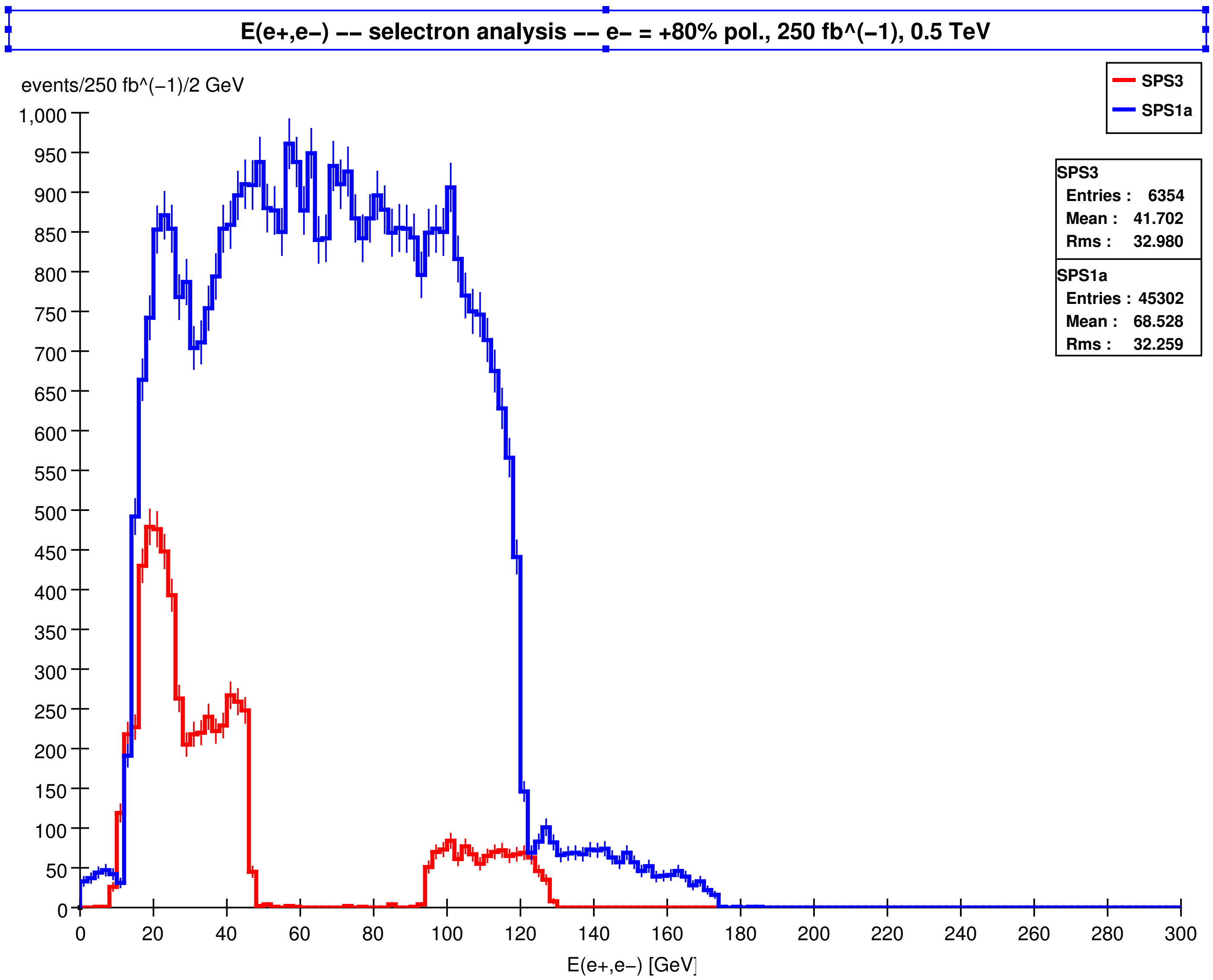

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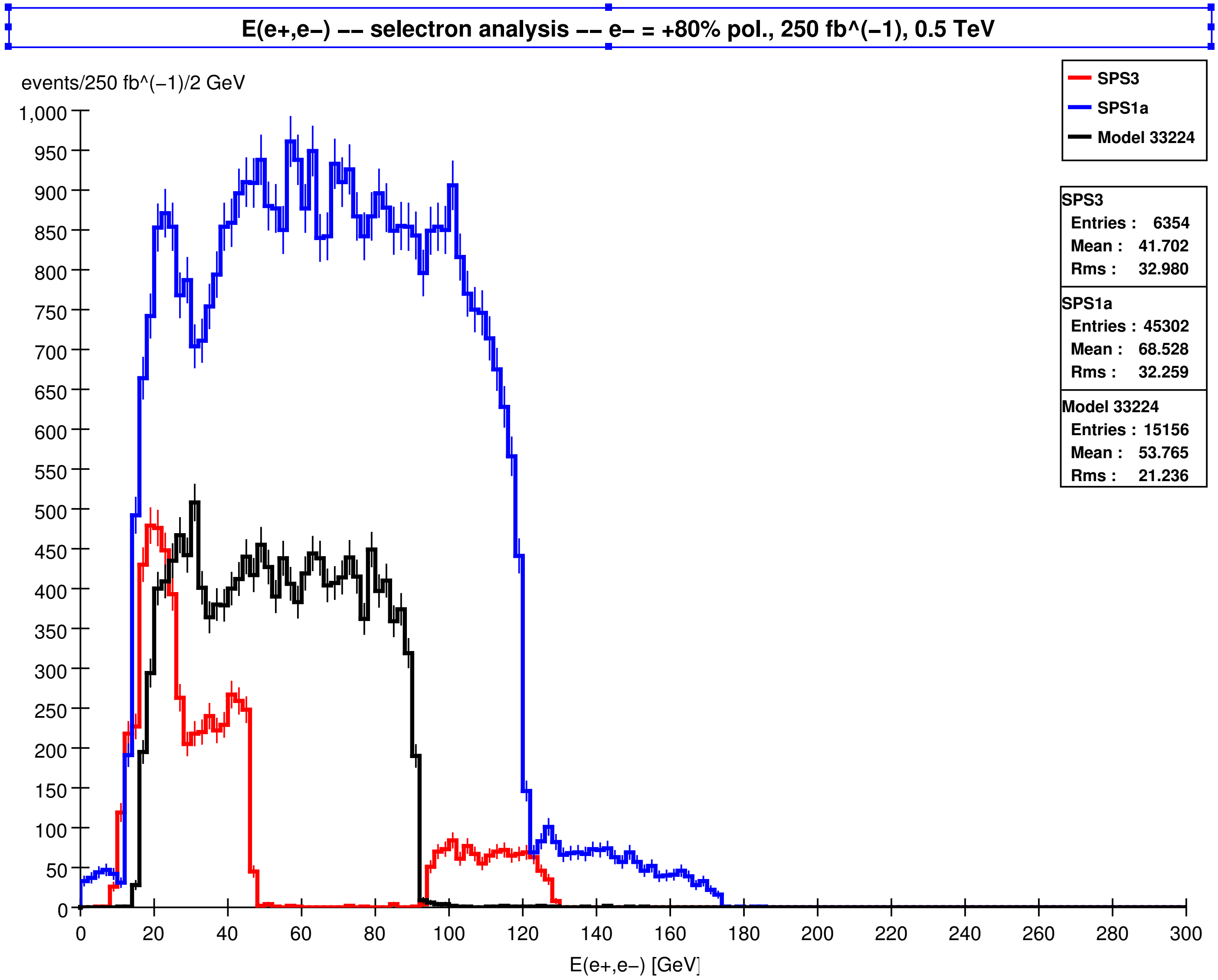

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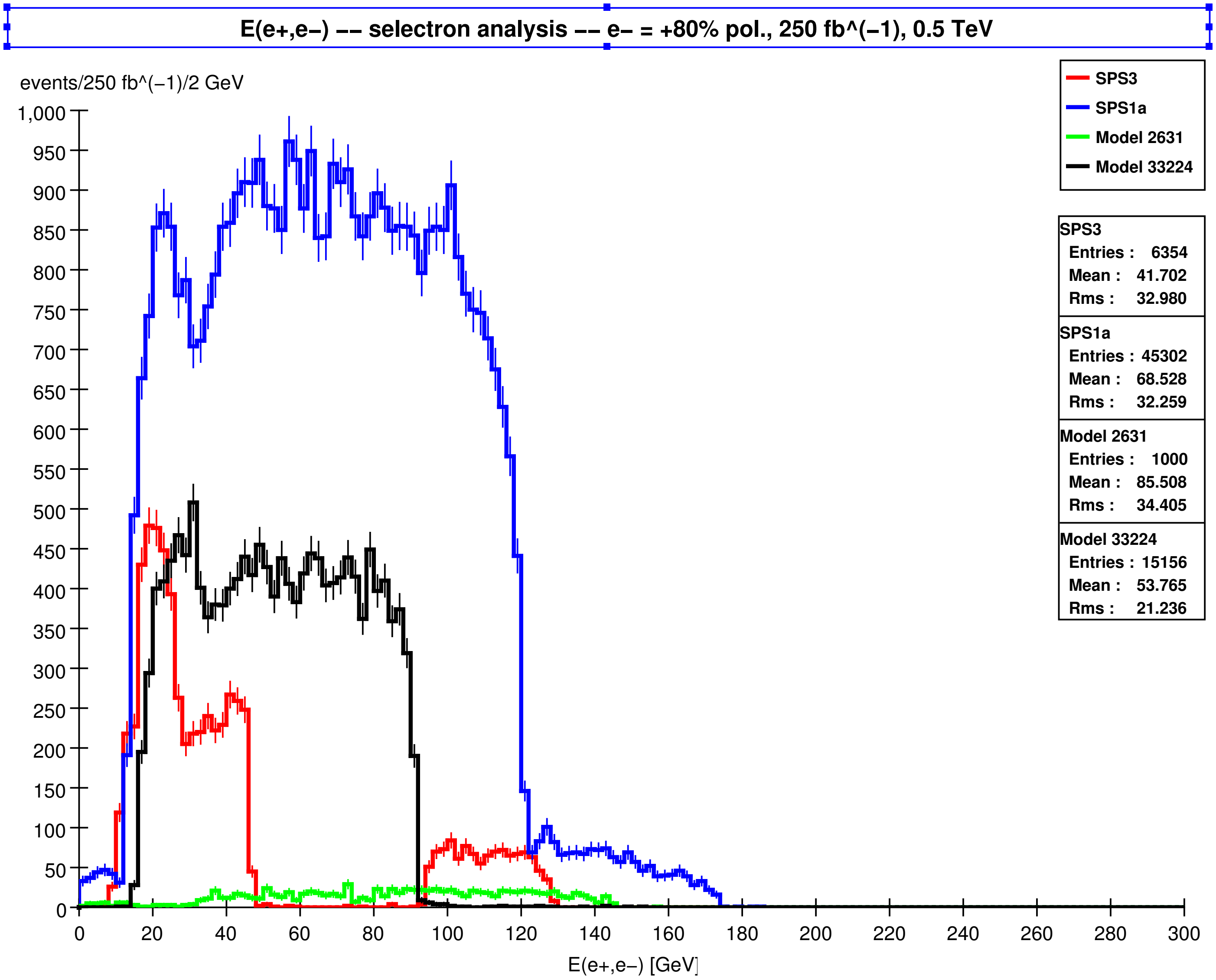
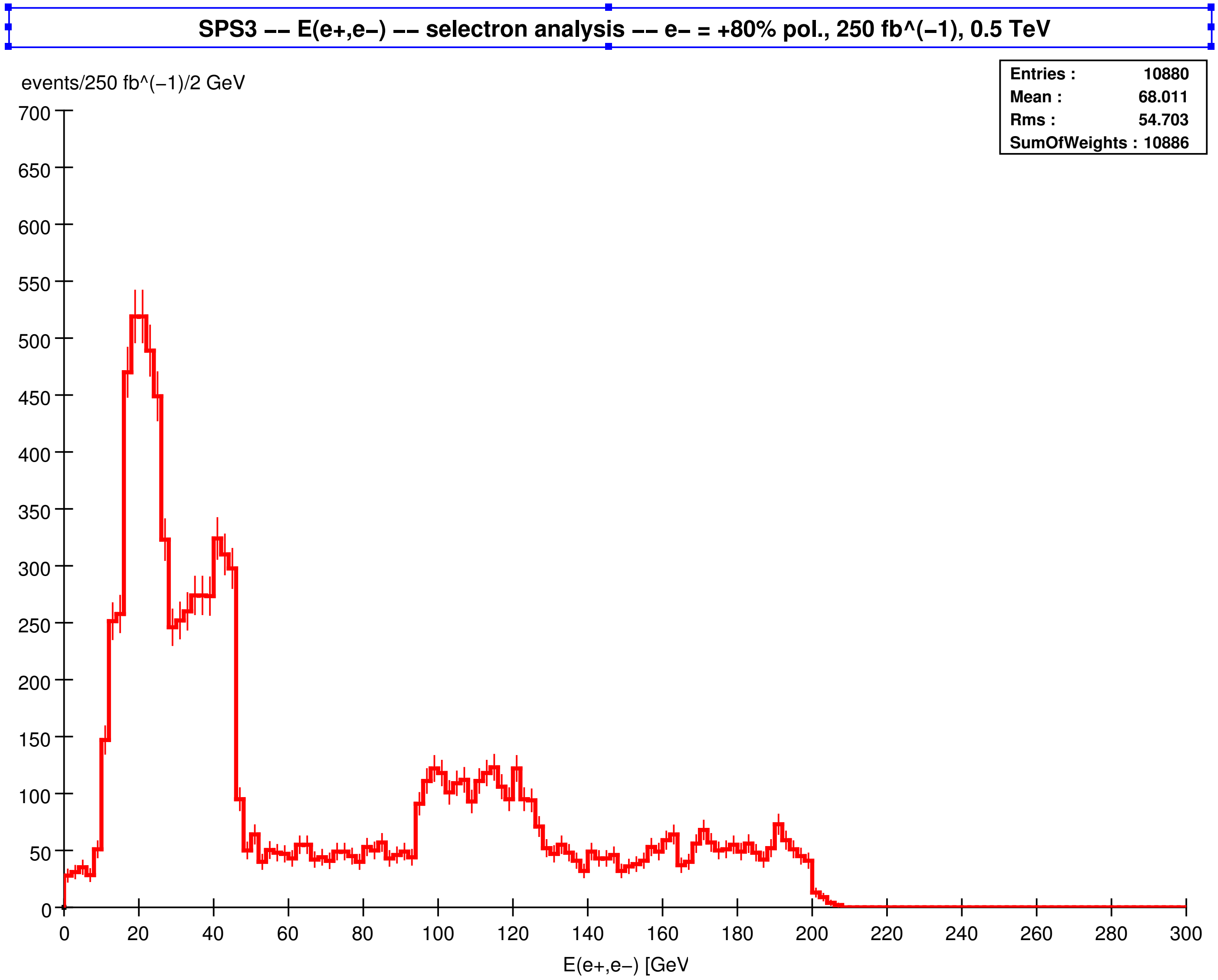


Signal + Background



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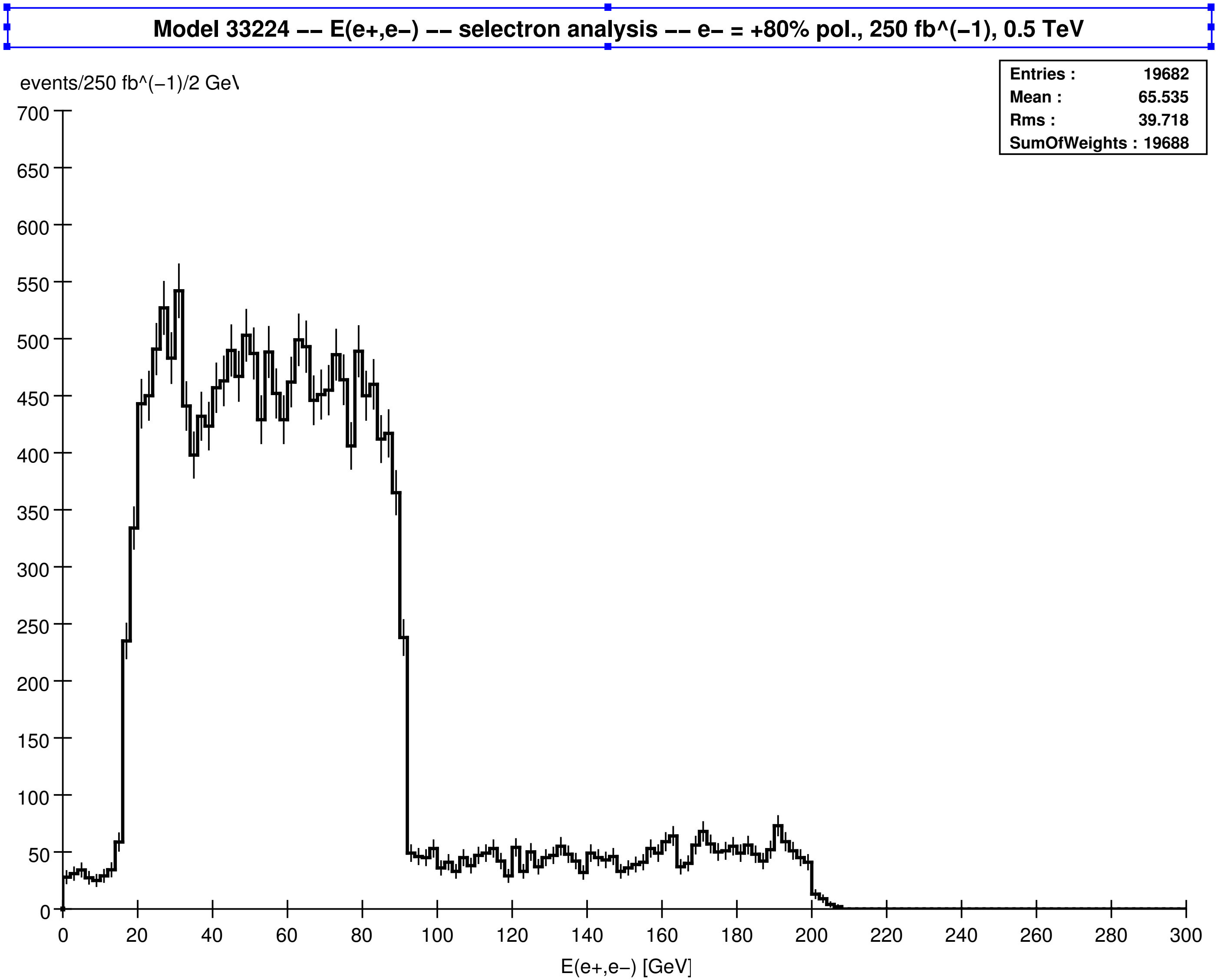

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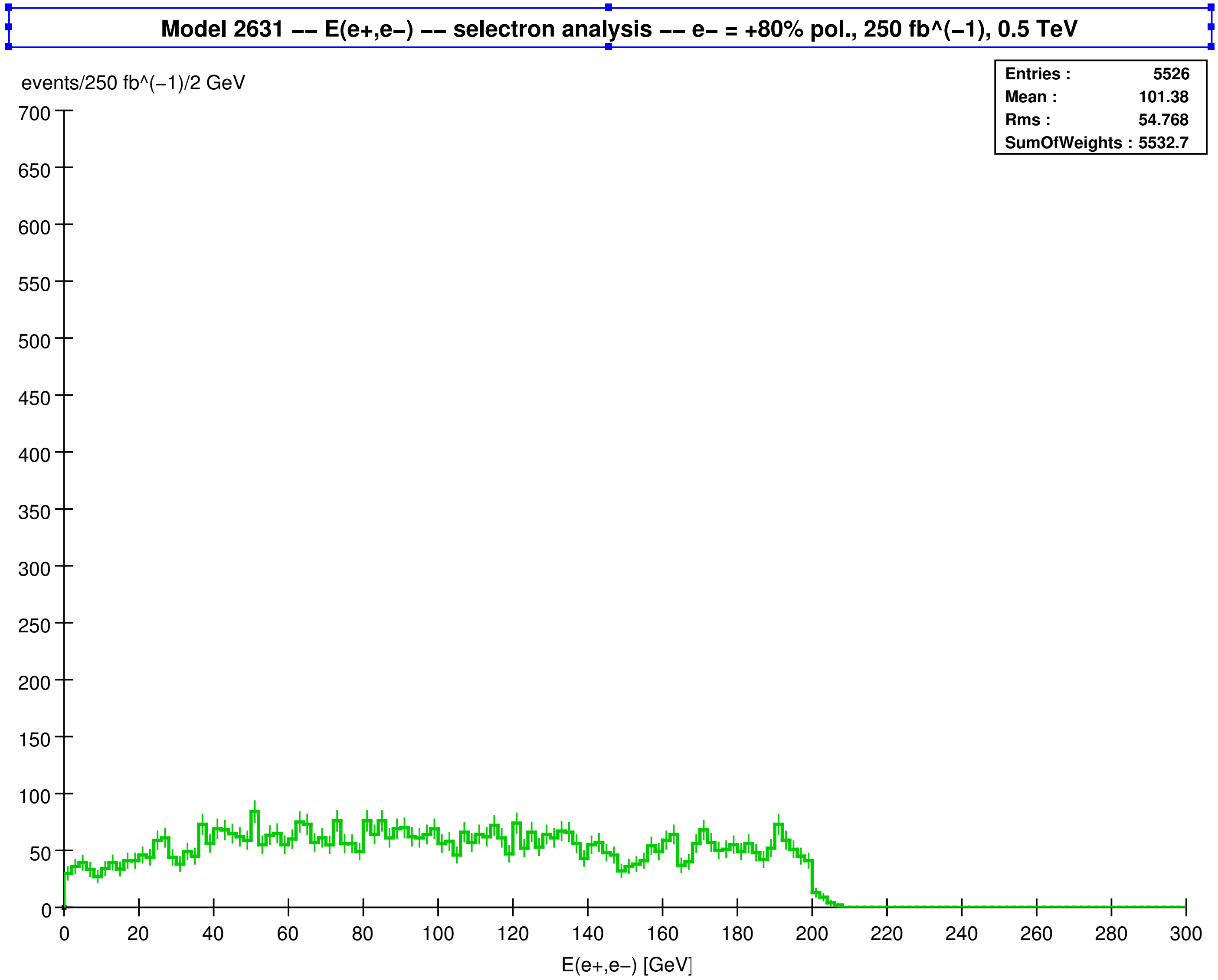
- **Signal + Background**
- Sample Model Comparison

Summary and Outlook

Signal + Background



Sample Model Comparison

Particle masses:

particle	Model 2631	Model 16195
$\tilde{e}_L, \tilde{\mu}_L$	190.2	459.1
$\tilde{e}_R, \tilde{\mu}_R$	759.8	708.7
$\tilde{\tau}_1$	177.4	528.9
$\tilde{\tau}_2$	842.2	552.5
$\tilde{\chi}_1^0$	102.7	151.3
$\tilde{\chi}_1^\pm$	759.9	767.6
$\tilde{q}_L$	750	655
$\tilde{d}_R, \tilde{s}_R$	630.5	984.3
$\tilde{u}_R, \tilde{c}_R$	700.4	787.1
$\tilde{g}$	1003.9	1014.8

Sample Model Comparison contd.

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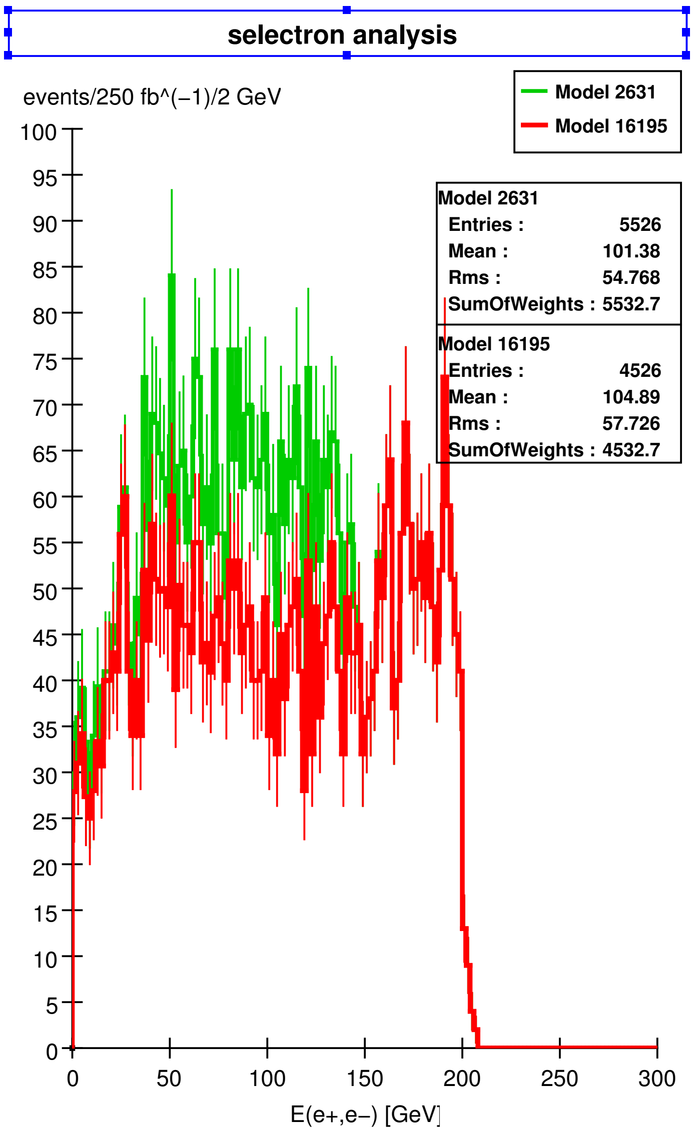

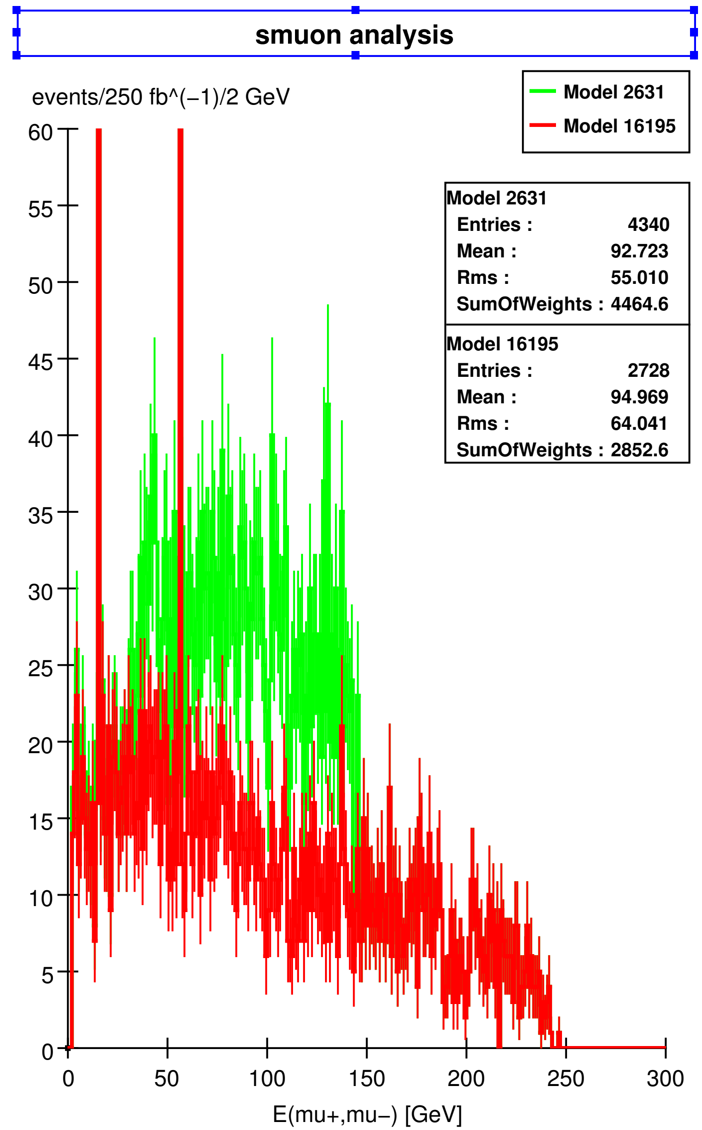

Summary

Work in progress!

- **First analysis of “random” points in SUSY parameter space looking at a variety of observables with full SM background.**
- **First “user” analysis with `org.lcsim` and SiD detector concept.**
  Low-angle tracking possibly very important
- **ILC can in principle distinguish between models that are degenerate at the LHC, by using polarized beams and due to accurate mass measurements.**
- **In practise cuts need to be optimized, and detector coverage as close to the beam direction as possible is very desirable.**
- **There are regions in SUSY parameter space that are challenging due to low number of signal events and SM background.**