Gaugino Property Determination in the Fully Hadronic Decay Mode at the ILC

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Particles, Strings, and the Early Universe
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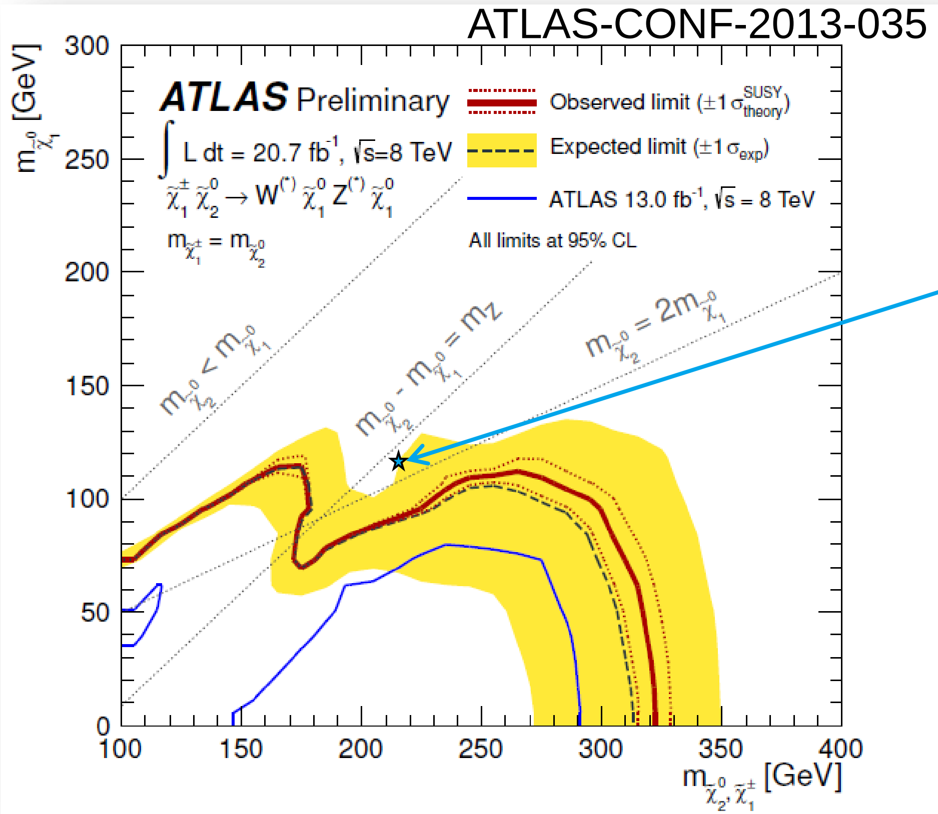
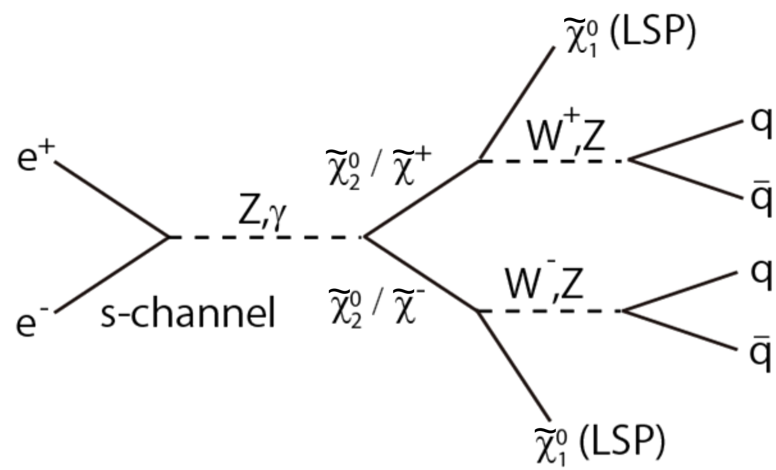
Status of LHC Searches for Direct Production of $\tilde{\chi}_1^{\pm}$ and $\tilde{\chi}_2^0$



"Point 5" benchmark : gaugino pair production at ILC

http://arxiv.org/pdf/1006.3396.pdf (ILD LoI)
http://arxiv.org/pdf/0911.0006v1.pdf (SiD LoI)

Particle	Mass [GeV]
$\tilde{\chi}_1^0$	115.7
$\tilde{\chi}_1^{\pm}$	216.5
$\tilde{\chi}_2^0$	216.7
$\tilde{\chi}_3^0$	380

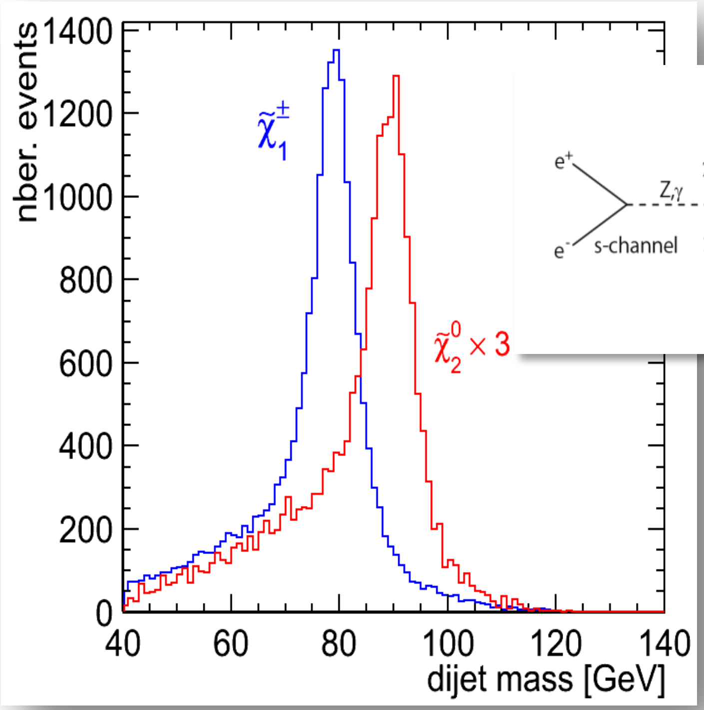


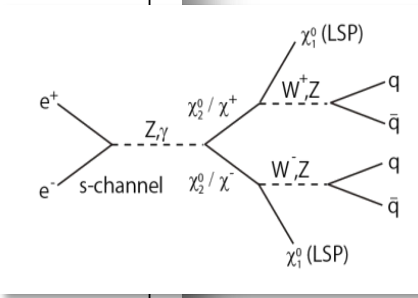
Motivation

> The „point 5“ scenario is a good case for:

> studying the detector and particle flow performance

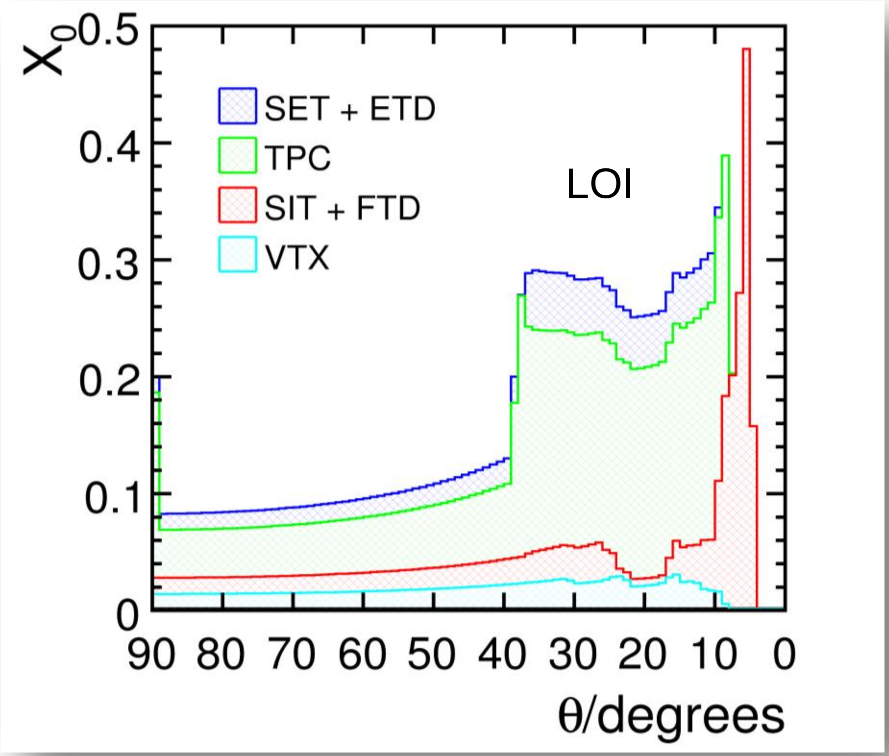
- 2 escaping LSP’s → missing energy
- hadronic decay of gauge bosons
- goal: clearly distinguish between W and Z pair events

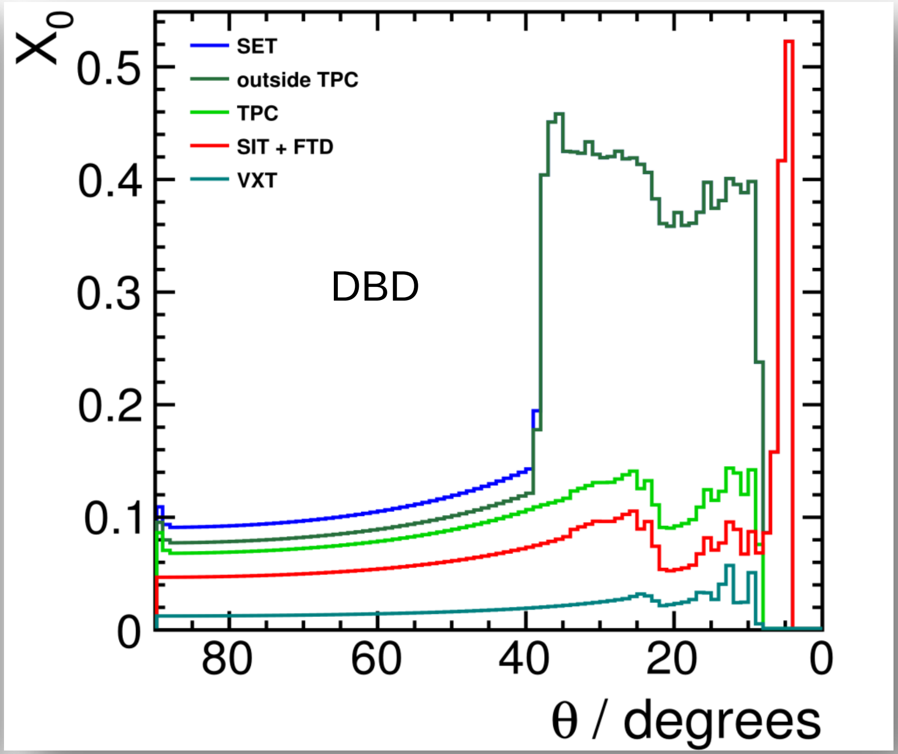




> **comparing and studying the performance of two versions of detector simulation (LOI and DBD)**

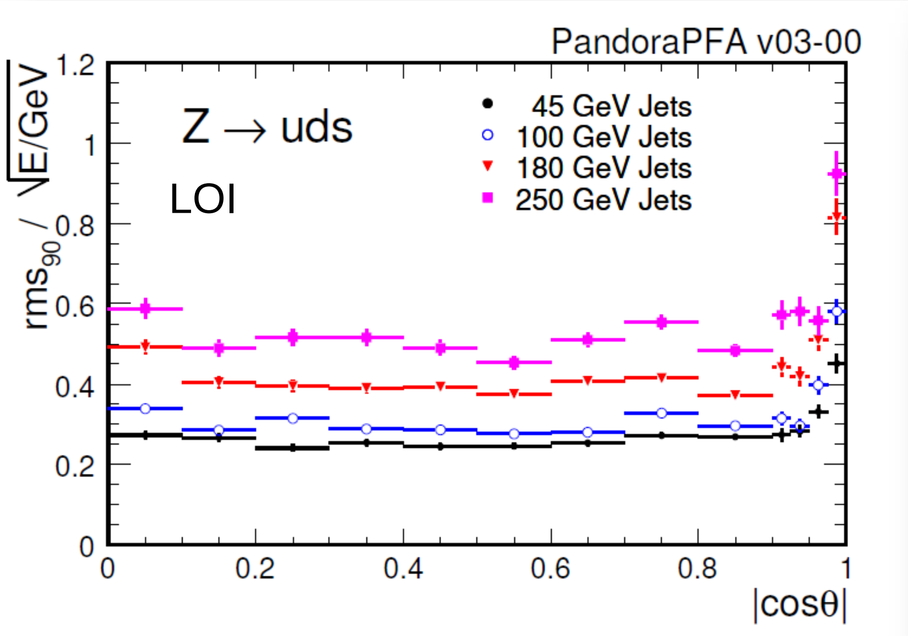
Changes Between LOI and DBD

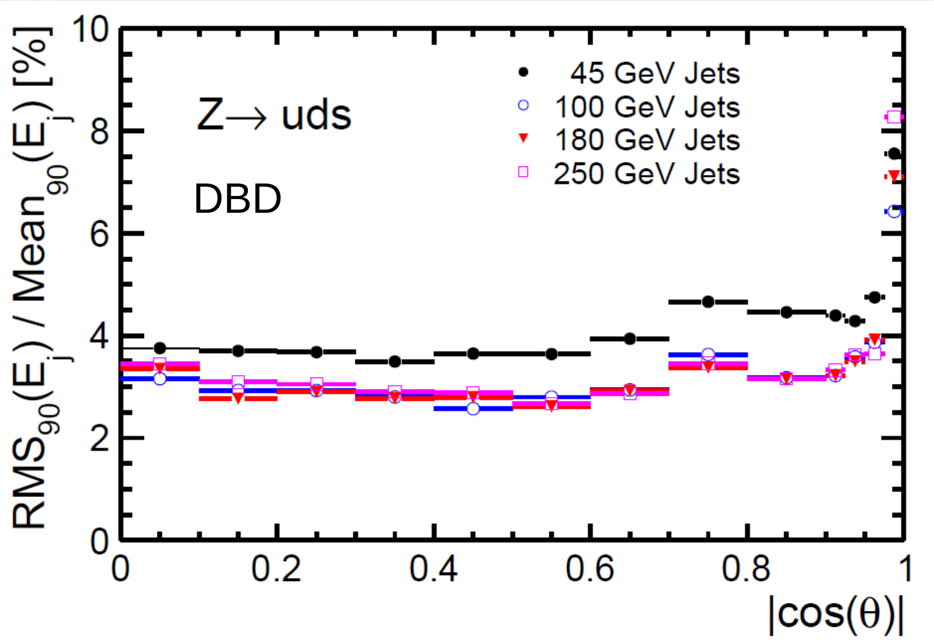




- The new simulation:
  - Improved detector realism: the vertexing, tracker and calorimeter components now include electronics and service materials
  - New forward tracking pattern recognition
  - New TPC pattern recognition

Changes Between LOI and DBD

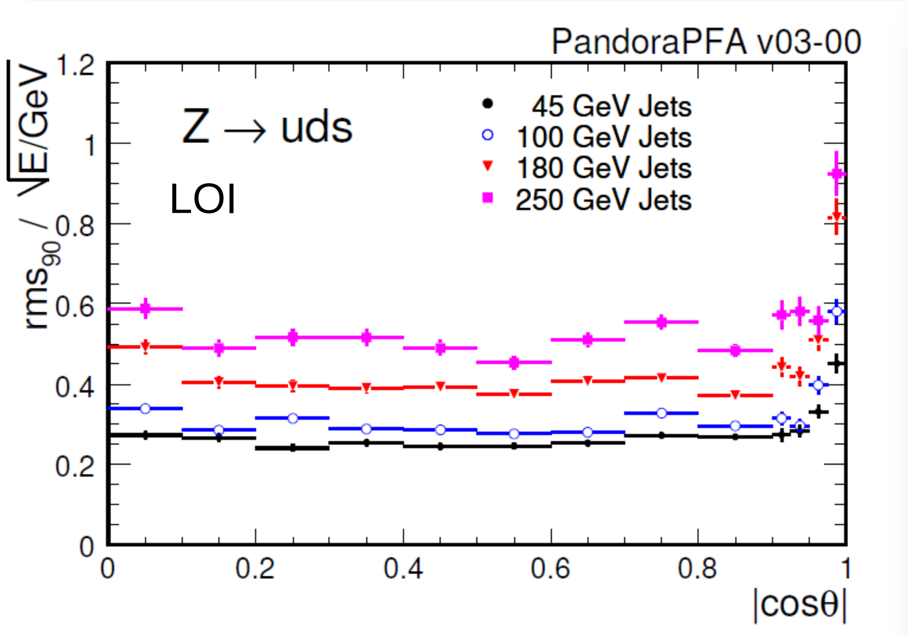


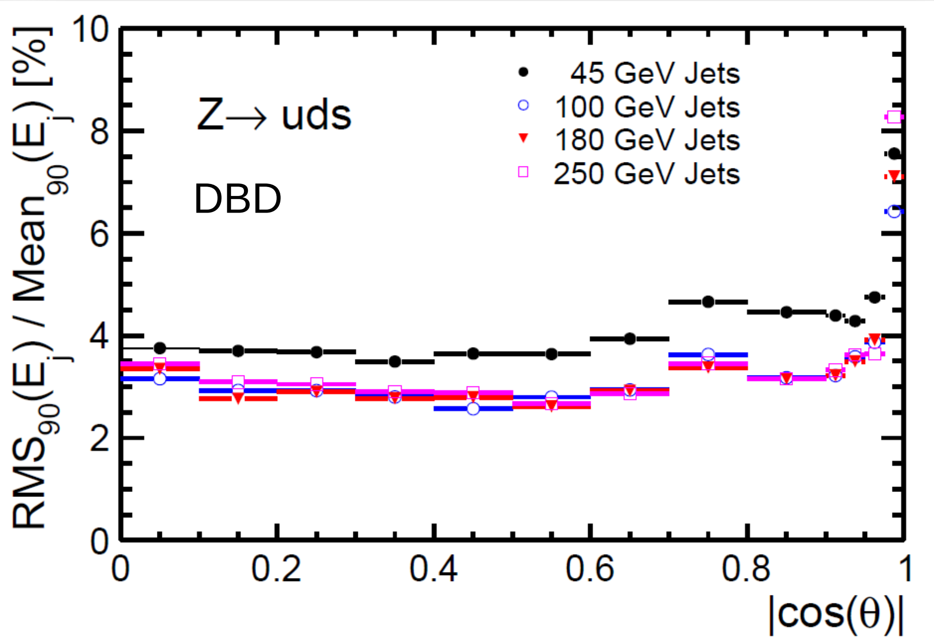


- Pandora PFANew: improved jet energy resolution

Jet Energy [GeV]	σ_{Ej}/E_j [LOI]	σ_{Ej}/E_j [DBD]
45	3.71±0.05 %	3.66±0.05 %
100	2.95±0.04 %	2.83±0.04 %
180	2.99±0.04 %	2.86±0.04 %
250	3.17±0.05 %	2.95±0.04 %

Changes Between LOI and DBD





Discuss gaugino mass and cross section measurements performed with both software versions!

Monte Carlo Sample

> Signal:

$$e^+e^- \rightarrow \tilde{\chi}_1{}^+\tilde{\chi}_1{}^- \Rightarrow \tilde{\chi}_1^\pm \rightarrow \tilde{\chi}_1^0 W^\pm \; [BR = 99.4\%] \qquad \sigma(\tilde{\chi}^\pm{}_1) = 132.16\, fb^{-1}$$

$$e^+e^- \rightarrow \tilde{\chi}_2{}^0\tilde{\chi}_2{}^0 \Rightarrow \tilde{\chi}_2^0 \rightarrow \tilde{\chi}_1^0 Z^0 \; [BR = 96.4\%] \qquad \sigma(\tilde{\chi}^0{}_2) = 23.29\, fb^{-1}$$

- ~ 34000 signal events ⟺ $\int \mathcal{L}$ = 500 fb^{-1} @ $\sqrt{s}$ = 500 GeV
  P(e+, e-) = (30%, - 80%)

> **LOI sample**:

- Redid the signal ntuples
- The jet energy scale was raised by 1%
- NO $\gamma\gamma$ background overlay

> **DBD sample:**

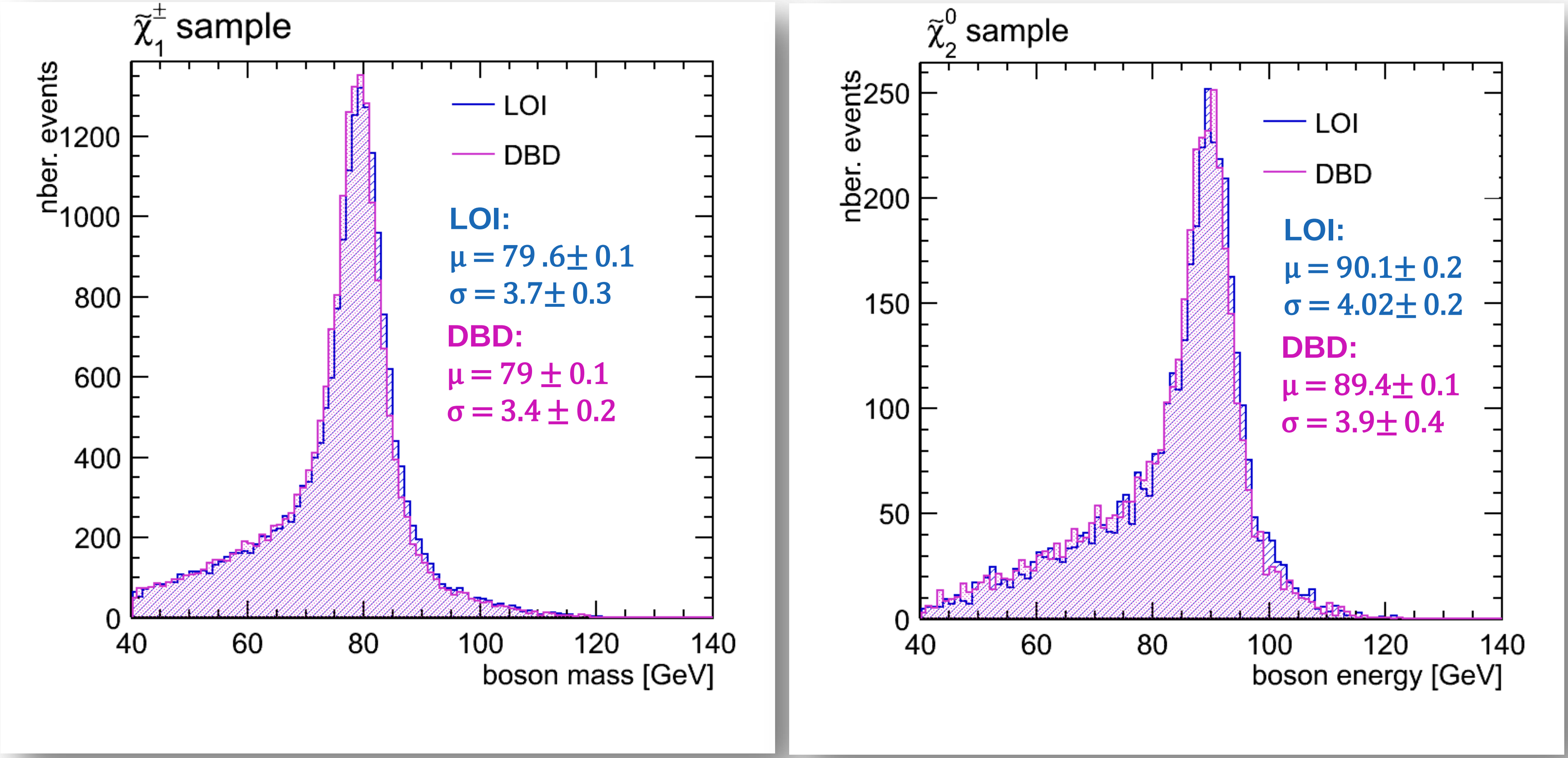
- Used the LOI generator files (signal only) in order to have the same beam spectrum
- Re-simulated and re-reconstructed the signal sample without $\gamma\gamma$ background overlay
- The jet energy scale was NOT increased
- Used the LOI SM background samples

$\tilde{\chi}_1^{\pm}$ and $\tilde{\chi}_2^0$ Pair Production at the ILC

- The **fully hadronic** decay modes of the on shell gauge bosons were chosen as **signal**
- **Signal topology**: 4 jets and missing energy
- **Background**:
  - SM 4f background is dominant
  - Each signal channel acts as background to the other!
- Event **preselection** – apply cuts on:
  - Number of tracks in event and per jet
  - Minimum number of PFOs per jet = 3
  - Minimum jet energy and $|\cos(\theta)_{jet}|$
  - $|\cos(\theta)_{pmiss}| < 0.99$
  - $100\ \mathrm{GeV} < E_{visible} < 300\ \mathrm{GeV}$
  - $M_{missing} > 220\ \mathrm{GeV}$
- Perform **kinematic fit** using Marlin KinFit: equal mass constraint (determine best jet pairing)
  - Apply cut on converged kinematic fit

$\tilde{\chi}_1^\pm$ and $\tilde{\chi}_2^0$ Cross Section Measurement

> **Use dijet mass to separate $\tilde{\chi}_1^\pm$ and $\tilde{\chi}_2^0$ events → measure cross section**

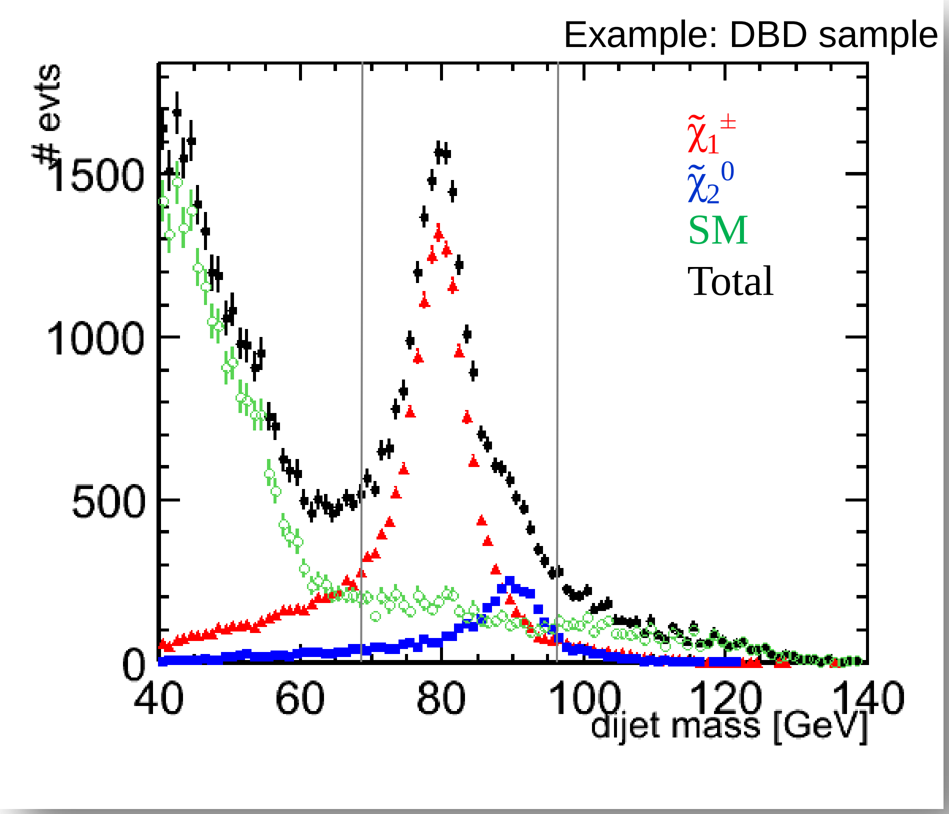


> The DBD distribution appears slightly narrower and shifted towards lower energy, however the DBD and LOI distributions are compatible with each other.

$\tilde{\chi}_1^\pm$ and $\tilde{\chi}_2^0$ Cross Section Measurement

- Use dijet mass to separate $\tilde{\chi}_1^\pm$ and $\tilde{\chi}_2^0$ events → measure cross section

Obs.	DBD		LOI	
	$\tilde{\chi}_1^\pm$	$\tilde{\chi}_2^0$	$\tilde{\chi}_1^\pm$	$\tilde{\chi}_2^0$
Efficiency	58%	64%	57%	65%
Purity	57%	12%	57%	13%

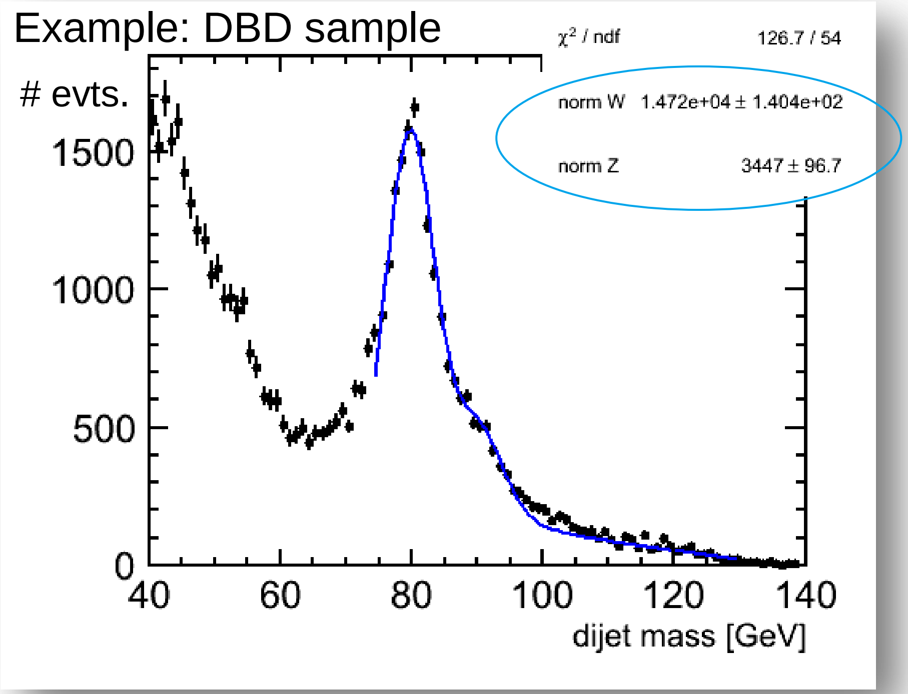


- Perform fit to disentangle chargino and neutralino candidates

$\tilde{\chi}_1^{\pm}$ and $\tilde{\chi}_2^0$ Cross Section Measurement

> Separating W and Z pairs candidates:

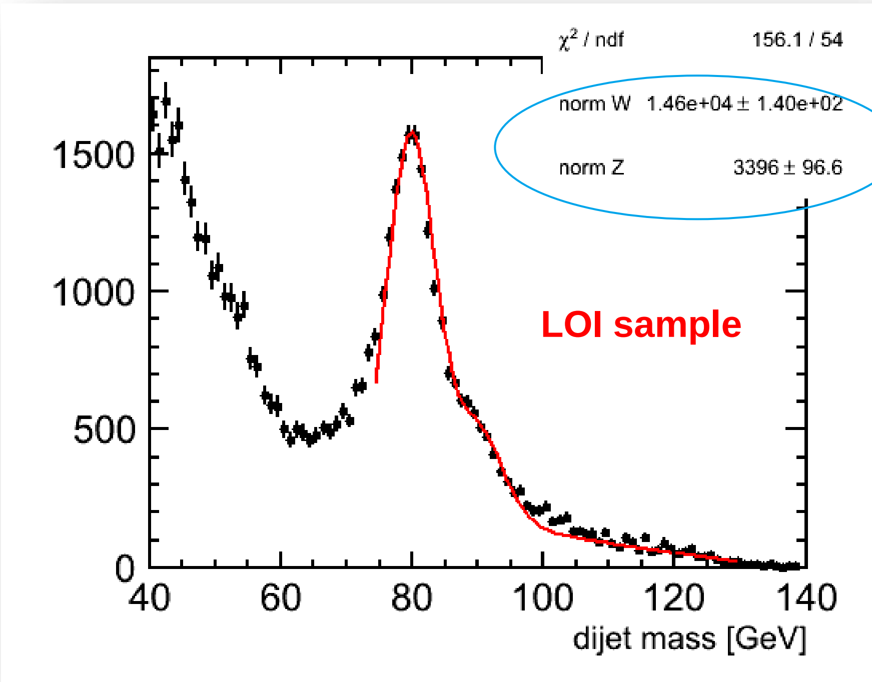
- SM background fitted with polynomial
- Signal distributions fitted with Voigt profile
  - Width (Γ) set to boson's natural width (2.11 GeV for W and 2.5 GeV for Z
  - Voigt $\sigma \simeq 3.5$ GeV detector resolution, deduced from a SM sample. The σ from the signal only sample is in the same ballpark!

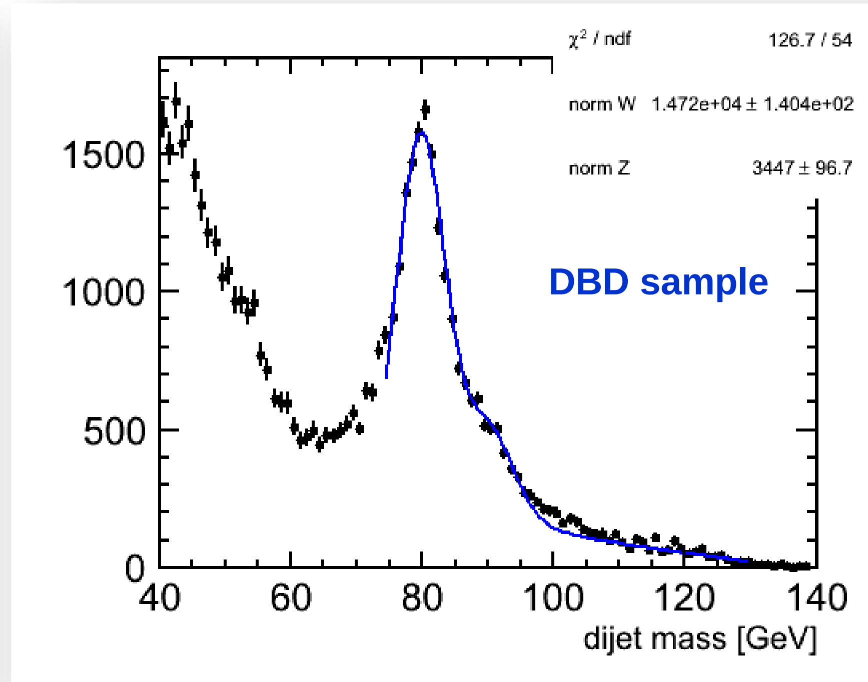


- Determine relative W/Z fractions from fit

$\tilde{\chi}_1^{\pm}$ and $\tilde{\chi}_2^0$ Cross Section Measurement

- Cross section calculation: determine the amount of W and Z pairs candidates.





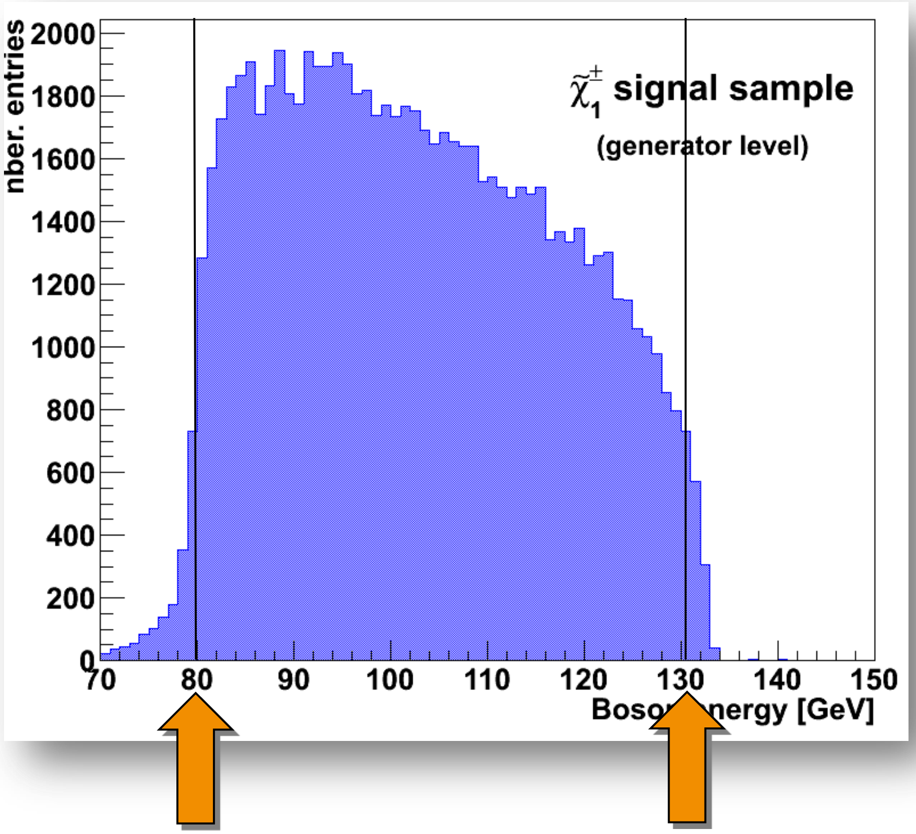
- $\sigma \backsim$ norm W / Z $\rightarrow$ check the statistical error on norm W/Z
- **For both LOI and DBD samples, the statistical errors are almost identical**:
  - In the case of $\tilde{\chi}_1^{\pm}$: $\simeq 1$ %
  - In the case of $\tilde{\chi}_2^{0}$: $\simeq 2.8$ %

$\tilde{\chi}_1^{\pm}$ and $\tilde{\chi}_2^0$ Mass Measurement

- Mass difference to LSP ($\tilde{\chi}_1^0$) is **larger** than
- Observe the decays of real gauge bosons M_Z
- 2 body decay → the edges of the energy spectrum are kinematically determined
- **Use dijet energy spectrum „end points“ in order to calculate masses**

$$\gamma = \frac{E_{beam}}{M_\chi}$$

$$E_\pm = \gamma \cdot EV^* \pm \gamma \cdot \beta \cdot \sqrt{E_V^{*2} - M_V^2}$$

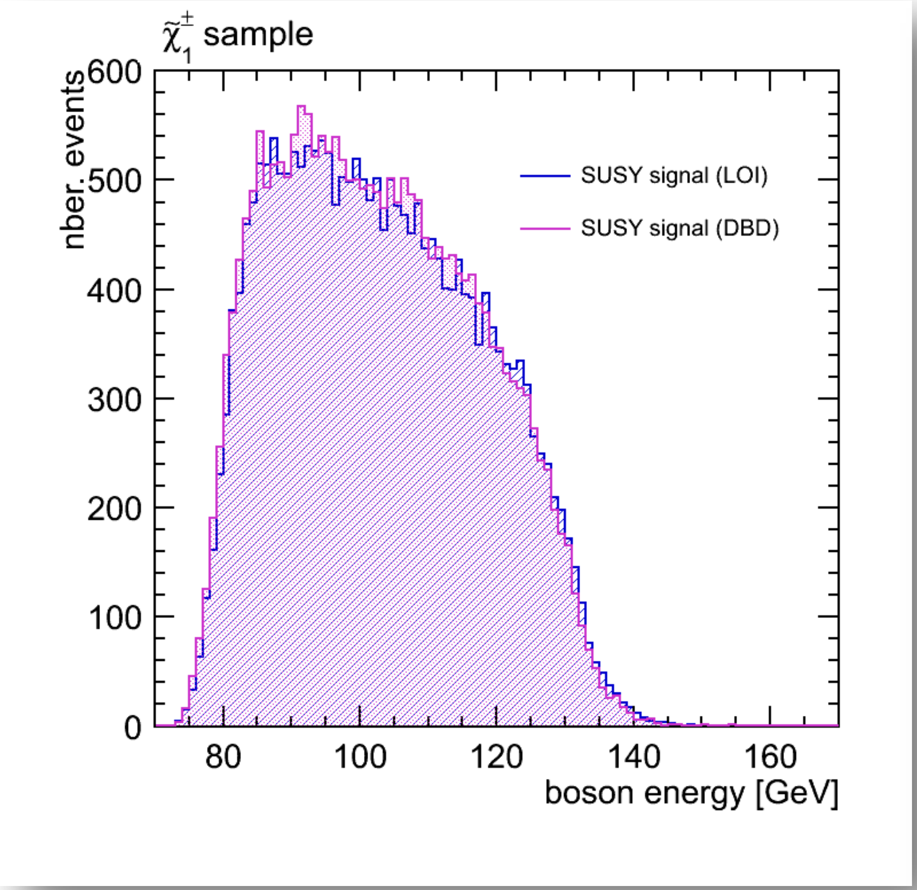


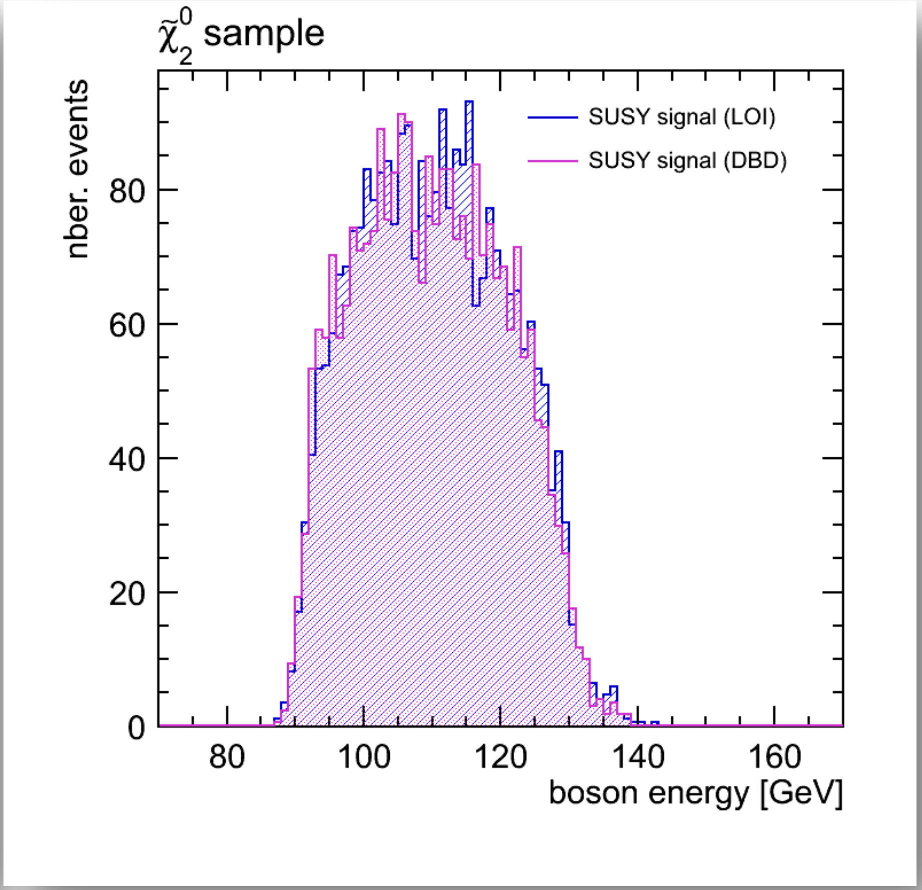
Real edge values [GeV]:

W_{low}	W_{high}	Z_{low}	Z_{high}
80.17	131.53	93.24	129.06

$\tilde{\chi}_1^\pm$ and $\tilde{\chi}_2^0$ Mass Measurement

- **Use dijet energy to measure $\tilde{\chi}_1^\pm$ and $\tilde{\chi}_2^0$ mass**





- The DBD distribution appears slightly narrower and shifted towards lower energies. Nevertheless, the two distributions agree very well.

$\tilde{\chi}_1^\pm$ and $\tilde{\chi}_2^0$ Mass Measurement

- Calculate χ^2 with respect to nominal W / Z mass

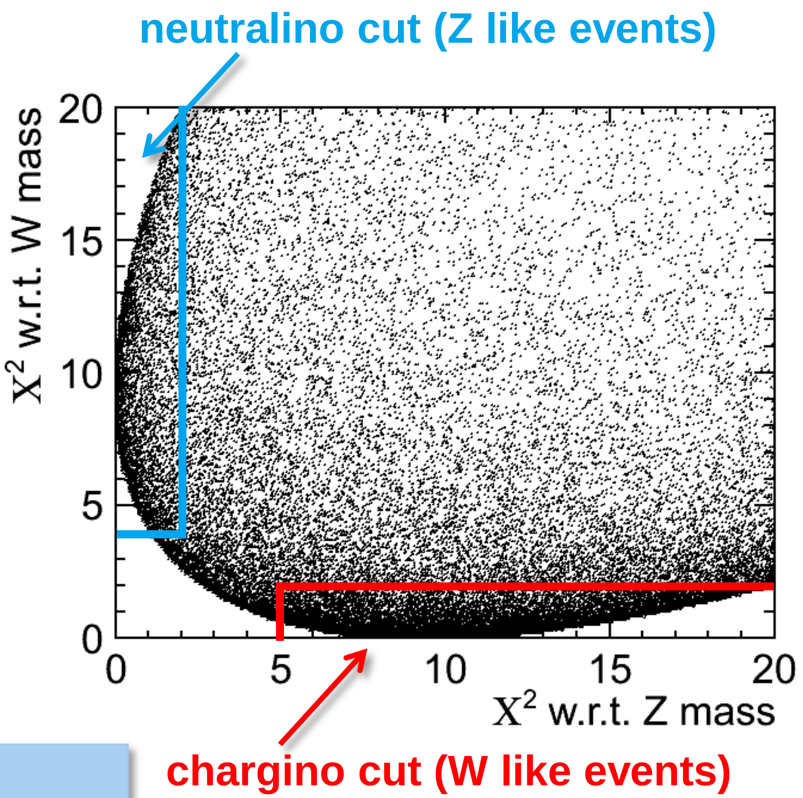
$$\chi^2(m_{j1}, m_{j2}) = \frac{(m_{j1} - m_V)^2 + (m_{j2} - m_V)^2}{\sigma^2}$$

⇩

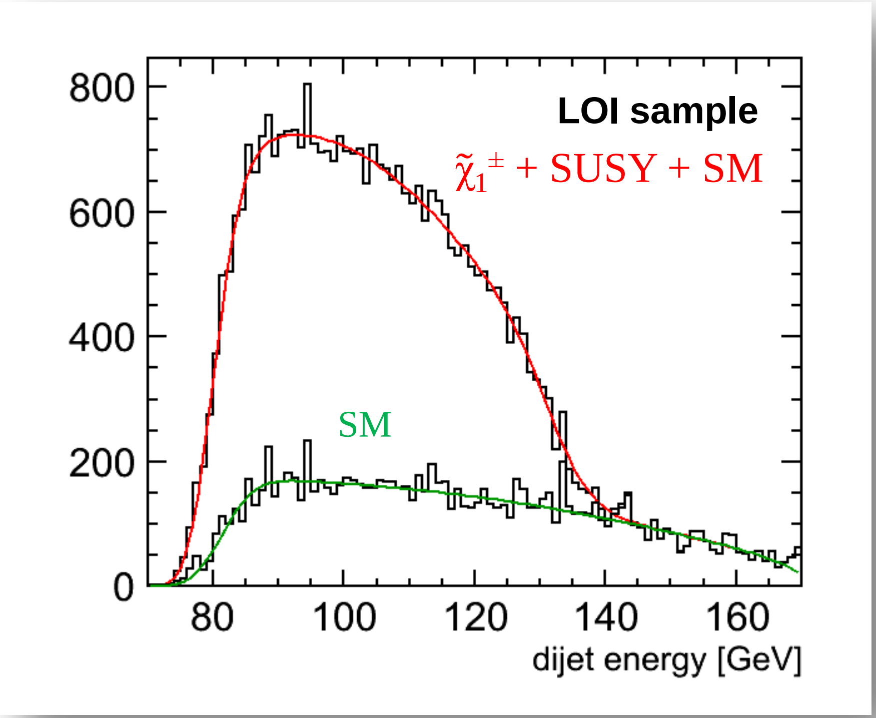
min $\chi^2 \rightarrow \tilde{\chi}_1^\pm$ and $\tilde{\chi}_2^0$ separation

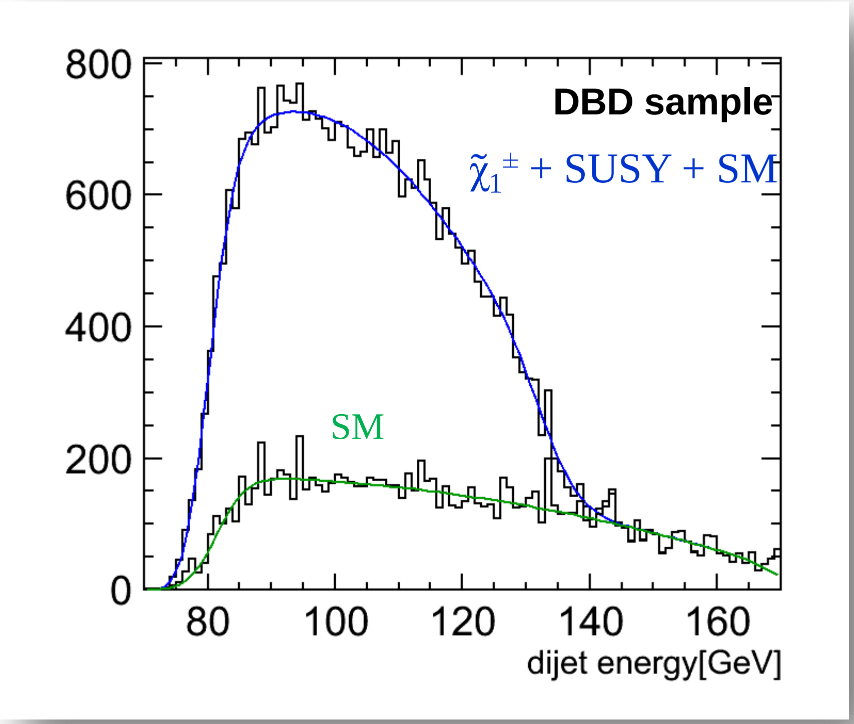
- Downside: lose statistics
  - Cut away 43% of $\tilde{\chi}_1^\pm$ surviving events
  - Cut away 68% of $\tilde{\chi}_2^0$ surviving events
- However, after the χ^2 cut, the separation is quite clear:

Obs.	DBD		LOI	
	$\tilde{\chi}_1^\pm$	$\tilde{\chi}_2^0$	$\tilde{\chi}_1^\pm$	$\tilde{\chi}_2^0$
Efficiency	57%	32%	56%	34%
Purity (total)	63%	35%	62%	35%
Purity (SUSY)	94%	68%	95%	66%



$\tilde{\chi}_1^{\pm}$ and $\tilde{\chi}_2^{0}$ Mass Measurement





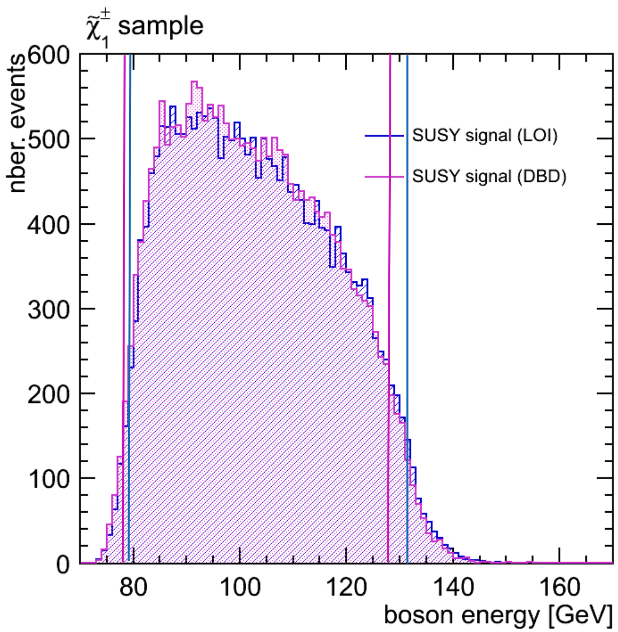
- Fit dijet energy spectrum and obtain edge positions:

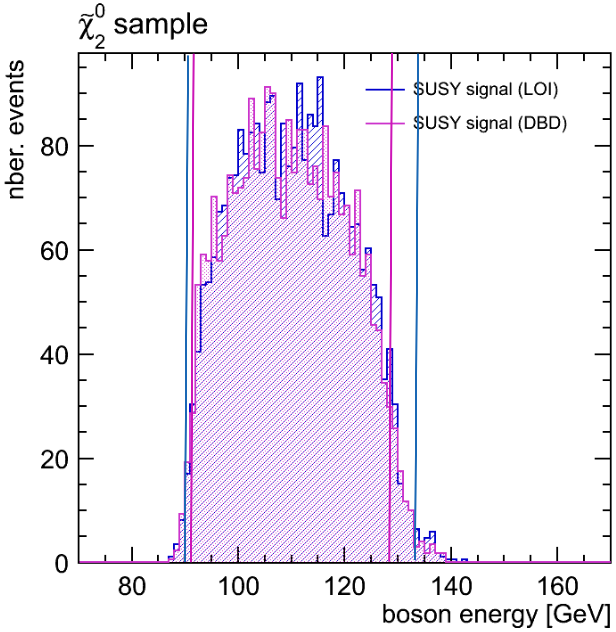
$$f(x; t_{0\_1}, b_{0\_2}, \sigma_{1\_2}, \gamma) = f_{SM} + \int_{t_0}^{t_1} (b_2 t^2 + b_1 t + b_0) V(x - t, \sigma(t), \gamma)\, dt$$

Where:

- The polynomial accounts for the top of the box spectrum
- The Voigt function accounts for the detector resolution and gauge boson width

$\tilde{\chi}_1^{\pm}$ and $\tilde{\chi}_2^0$ Mass Measurement





Sim.	Edge W_{low} [GeV]	Edge W_{high} [GeV]	Edge Z_{low} [GeV]	Edge Z_{high} [GeV]
DBD	79.5±1.7	128.3±1.2	91.9±0.8	127.9±0.7
LOI	79.7±0.3	131.9±0.9	91.0±0.7	133.6±0.5

The fitting method appears to be dependent on small changes in the fitted distribution.

Conclusions

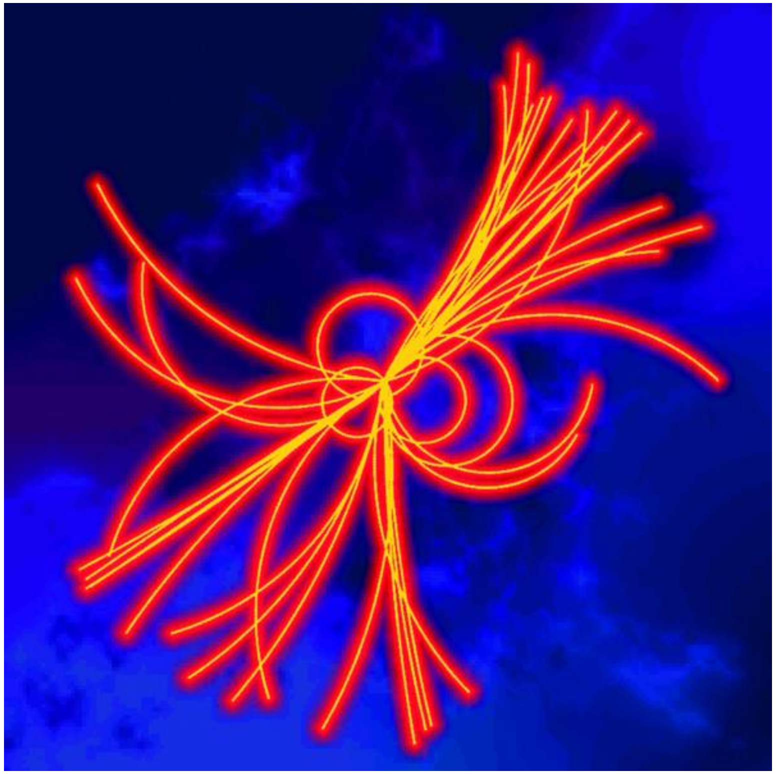
> Summary

- The $\tilde{\chi}_1^{\pm}$ and $\tilde{\chi}_2^0$ pair production in the framework of the "Point 5" benchmark has been presented.
- A preliminary comparison between the LOI and DBD simulation and reconstruction has been made;
  - The DBD reconstruction and selection efficiencies are similar to the LOI analysis
  - The cross section statistical error is ~ 1% for the $\tilde{\chi}_1^{\pm}$ case and ~ 3% in the $\tilde{\chi}_2^0$ case for both simulations.
  - The DBD reconstructed boson energy spectrum is very similar to the LOI spectrum
  - However the fitting method for the mass determination appears very sensitive to small changes. A more robust method is needed.

> Outlook:

- Perform 2D fit on the dijet mass plane for better accuracy in the cross section measurement.
- A mass calibration will be performed for the mass measurement.
- Consider new methods for extracting edge point positions (see talk by S. Caiazza).

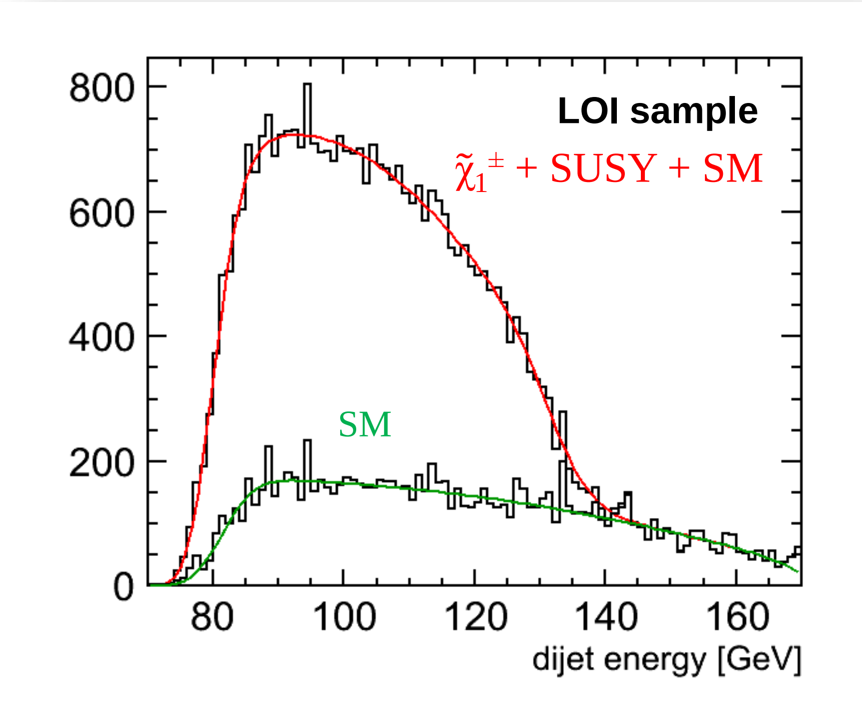
Thank You!

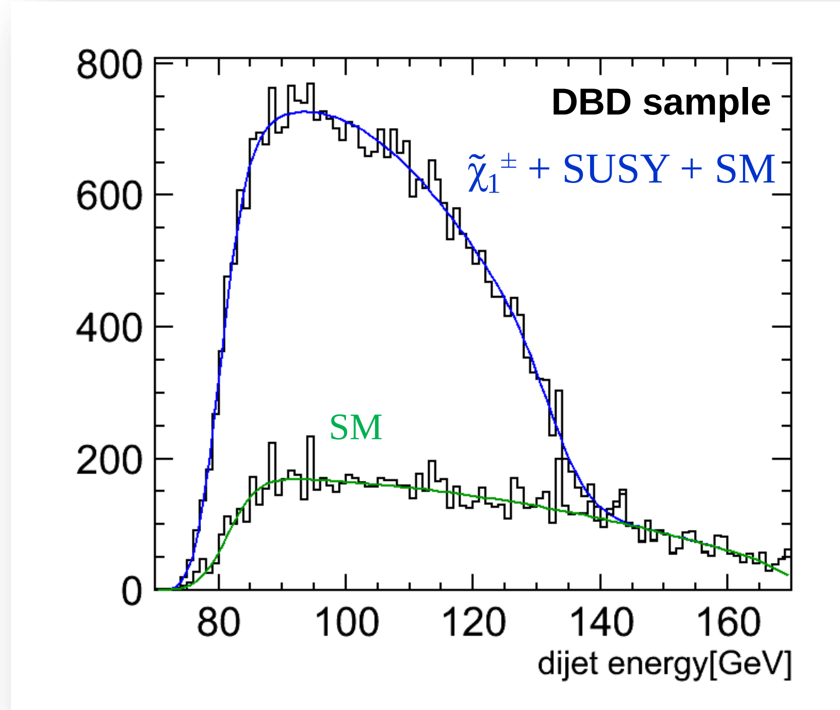


Cut flow:

Cut	$\tilde{\chi}_1^{\pm}$ had	$\tilde{\chi}_2^0$ had	Other SUSY	SMgg	SM 8f	SM 6f	SM4f	SM2f	SM other
No cut	28548	5488	74611	2.8 e+09	945	519242	1.3e+07	8.8e+08	4.8e+06
Total # tracks > 20	27914	5449	24318	3e+06	939	493257	6.7e+06	5.3e+06	0
100 < E_{vis} < 300 Gev	27912	5449	22518	1.1e+06	79	44435	949380	1.6e+06	0
E_{jet} > 5 GeV	27906	5446	20727	908393	79	44317	905894	1.5e+06	0
$\lvert\cos(\theta)_{jets}\rvert$ < 0.99	26572	5240	19205	350316	74	41130	668947	875094	0
Y_{34} > 0.001	26432	5218	15255	202462	74	38760	413787	166296	0
# tracks > 2/jet	25731	5146	9559	162161	56	22752	247160	145269	0
$\lvert\cos(\theta)_{miss}\rvert$ < 0.99	25476	5099	9487	25079	56	22322	185679	4039	0
E_l < 25 GeV	25135	4981	6463	23129	32	14409	146984	3533	0
N_{PFO} > 3	250411	4975	6102	23014	32	13697	139365	3518	0
$\lvert\cos(\theta)_{pmiss}\rvert$< 0.99	20148	4079	5179	681	26	9951	62676	529	0
M_{miss} > 220 GeV	20143	4079	5179	630	12	3687	45875	386	0
Kinfit converged	20085	4068	4999	626	12	3649	44577	341	0

$\tilde{\chi}_1^\pm$ and $\tilde{\chi}_2^0$ Mass Measurement





Obs.	Mass [GeV]	Error [GeV]	Diff. [GeV]
$\tilde{\chi}_1^\pm$	219.83	2.92	3.13
$\tilde{\chi}_2^0$	221.71	3.04	5.21
$\tilde{\chi}_1^0$	117.01	1.03	1.31

Obs.	Mass [GeV]	Error [GeV]	Diff. [GeV]
$\tilde{\chi}_1^\pm$	221.67	3.98	4.91
$\tilde{\chi}_2^0$	221.79	3.41	5.29
$\tilde{\chi}_1^0$	117.94	1.09	2.24