Chargino and Neutralino Cross-section Measurements

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ILD Software and Analysis Phone Meeting – 18.02.2015

Universität Hamburg
DER FORSCHUNG | DER LEHRE | DER BILDUNG

ilc

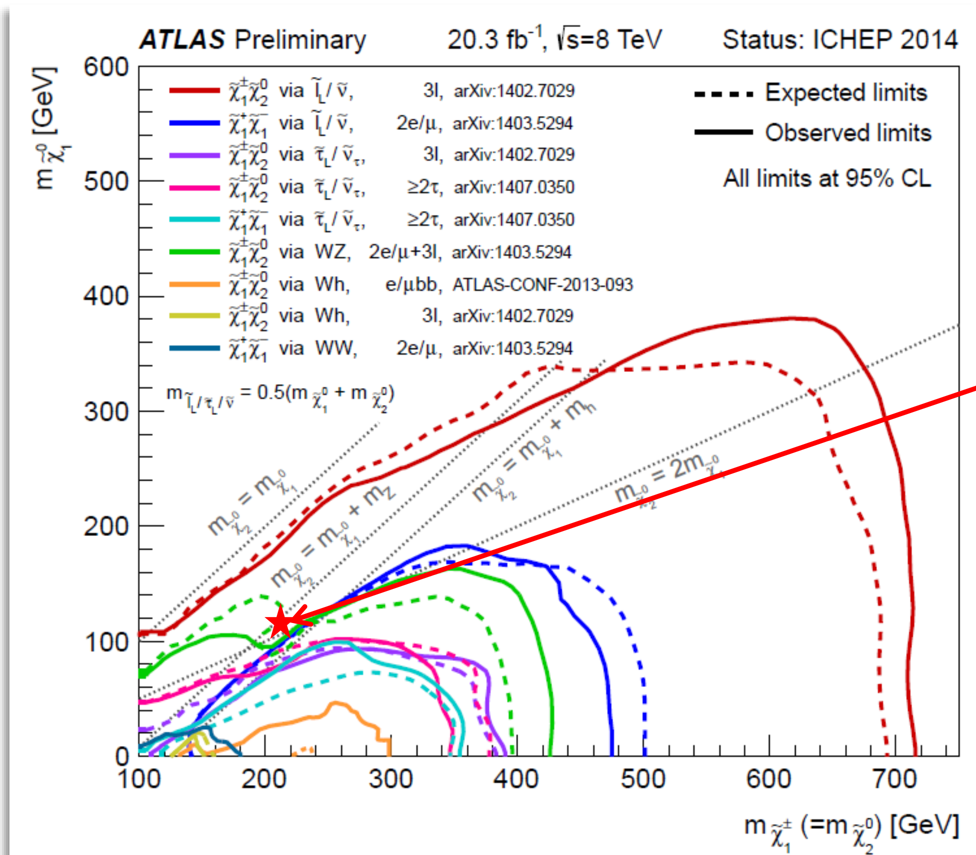
Particles, Strings, and the Early Universe
Collaborative Research Center SFB 676

DESY

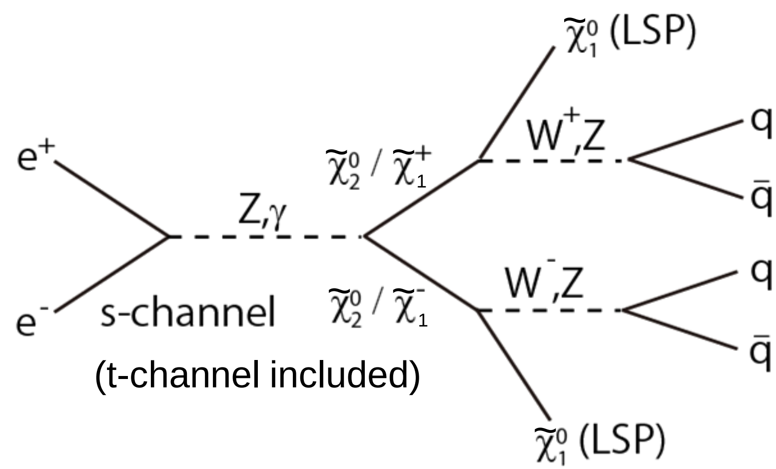
Study case: $\tilde{\chi}_1^{\pm}$ and $\tilde{\chi}_2^{0}$ Pair Production at the ILC

“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)



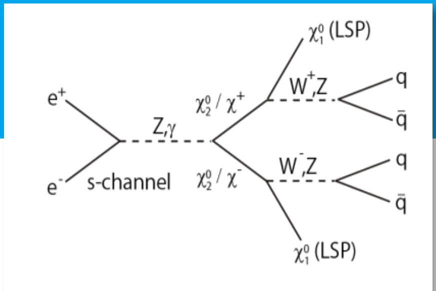
Particle	Mass [GeV]
$\tilde{\chi}_1^0$	115.7
$\tilde{\chi}_1^{\pm}$	216.5
$\tilde{\chi}_2^0$	216.7
$\tilde{\chi}_3^0$	380



$$\tilde{\chi}_1^{\pm} \rightarrow \tilde{\chi}_1^0 W^{\pm} \qquad BR = 99.4\%$$

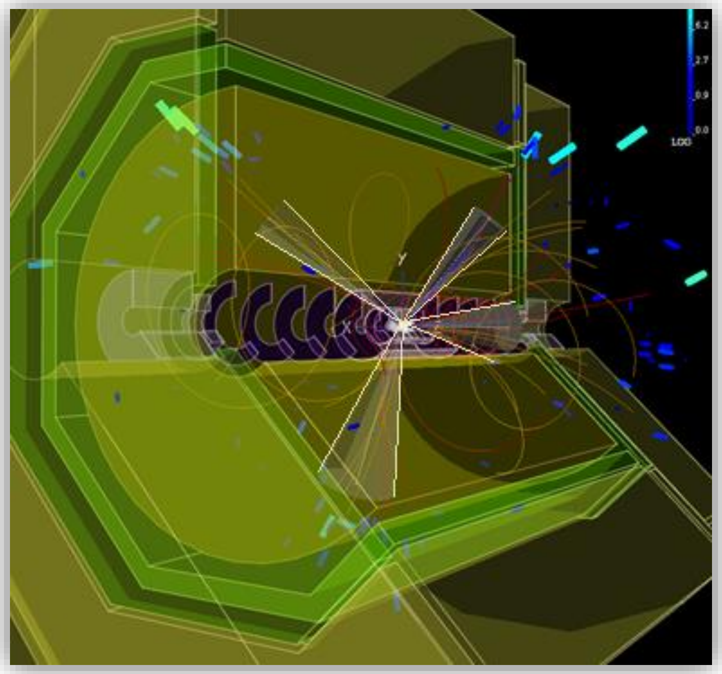
$$\tilde{\chi}_2^{0} \rightarrow \tilde{\chi}_1^0 Z^{0} \qquad BR = 96.4\%$$

Study Case - Motivation

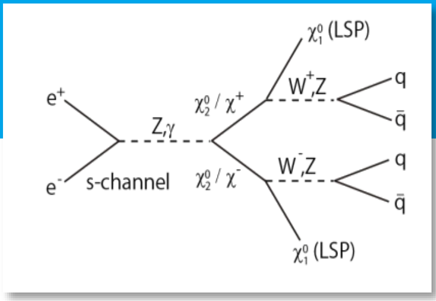


- Signal topology:
  - Four jets and missing energy (due to LSP)
  - Hadronic decay modes of gauge bosons chosen as signal
  - Both decay channels treated as signal in turn:

$$\tilde{\chi}_1^{\pm} \rightarrow \tilde{\chi}_1^0 W^{\pm} \quad \text{and} \quad \tilde{\chi}_2^0 \rightarrow \tilde{\chi}_1^0 Z^0$$



Study Case - Motivation



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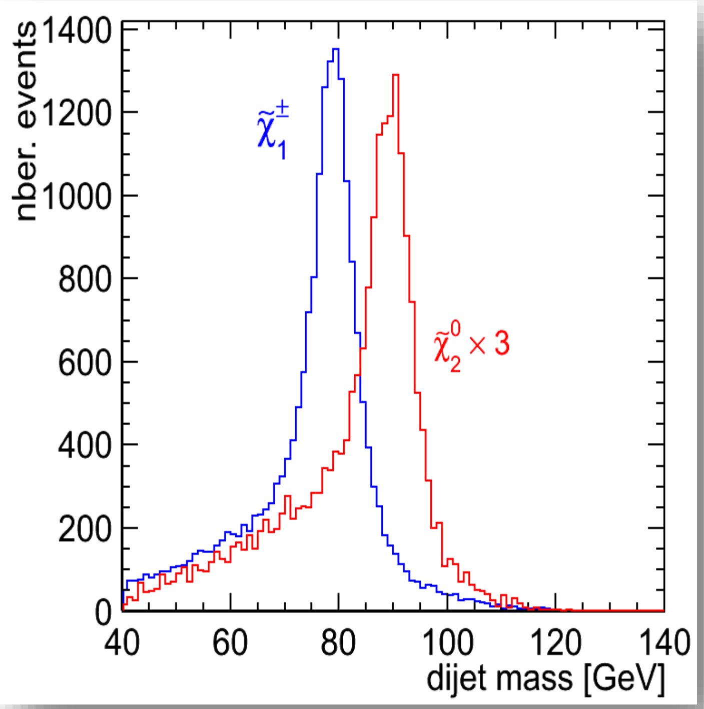
$$\tilde{\chi}_1^{\pm} \rightarrow \tilde{\chi}_1^0 W^{\pm} \quad \text{and} \quad \tilde{\chi}_2^0 \rightarrow \tilde{\chi}_1^0 Z^0$$

- $\tilde{\chi}_1^{\pm}$ and $\tilde{\chi}_2^0$ sample separation: essentially distinguish between W and Z pair events
- Good case for studying the detector and particle flow performance



Data Samples:

- Signal: 40000 $\tilde{\chi}_1^{\pm}$ events and 9000 $\tilde{\chi}_2^0$ events

LOI sample:

- Signal generated with `Whizard1.51`
  Background generated with `Whizard1.40`
- The RDR beam spectrum was used
- Signal + background were simulated and reconstructed with `ilcsoft v01-06`
- The jet energy scale was increased by 1%
- No $\gamma\gamma$ background overlay
- The analysis was run on existing data samples

DBD sample:

- Signal (as well as SM background) generated with `Whizard 1.95`
- The TDR beam spectrum was used
- Some processes could not be produced in Whizard 1.95
- Signal + background were simulated and reconstructed with `ilcsoft v01-16-02`
- The jet energy scale was **not** increased
- The $\gamma\gamma$ **background overlay** was taken into account
- The analysis was run

- **Note:** in the signal samples, the M_W was inadvertently lowered by Whizard to M_W = 79.8 GeV

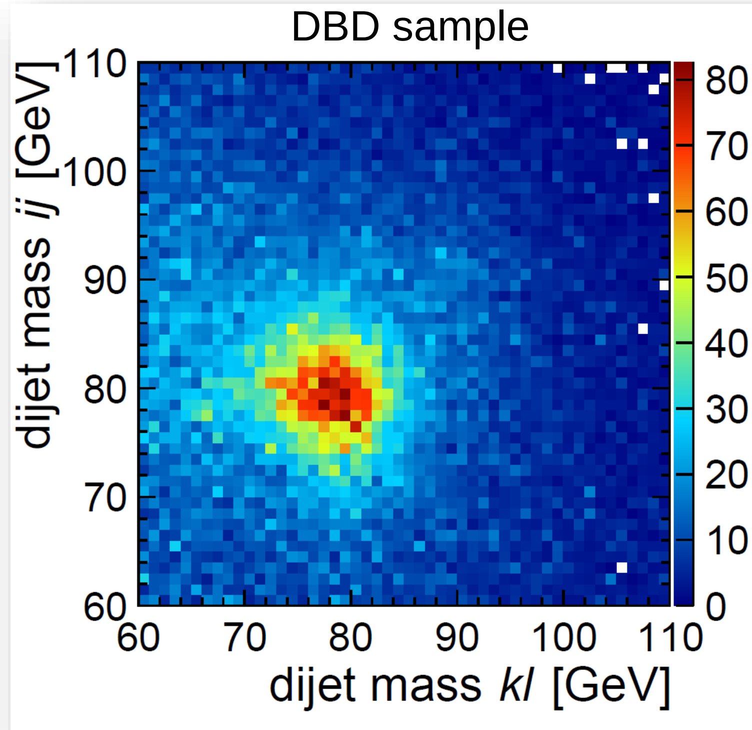
Analysis Strategy

- Remove $\gamma\gamma \rightarrow \mathrm{hadrons}$ background — **only for DBD**
- Cluster event into 4 jets (Durham)
- Run kinematic fit (equal mass constraint)
  - (Cluster event and kinematic fit: **common to both LOI and DBD**)
- Run isolated lepton finder (Junping) — **only for DBD**
- Perform SUSY preselection
- Perform cross section measurement
  - (SUSY preselection and cross section measurement: **common to both LOI and DBD**)

Note: Cross-section determination study exemplified with DBD samples only!
DBD – LOI comparison presented at the end of the talk.

Cross Section Determination Method

- Interested in: $\sigma(e^+e^- \to \tilde{\chi}_1^+\tilde{\chi}_1^-) \times \mathrm{B.R.}(\tilde{\chi}_1^+\tilde{\chi}_1^- \to \tilde{\chi}_1^0\tilde{\chi}_1^0 W^+W^-)$
  $\sigma(e^+e^- \to \tilde{\chi}_2^0\tilde{\chi}_2^0) \times \mathrm{B.R.}(\tilde{\chi}_2^0\tilde{\chi}_2^0 \to \tilde{\chi}_1^0\tilde{\chi}_1^0 Z^0Z^0)$
- Relevant observable: the reconstructed dijet [boson] mass
- Relevant distribution: the reconstructed mass of one dijet pair versus the other:
  - **AFTER** applying all selection cuts
  - Considering only those events for which the kinematic fit has converged
  - Including **all** possible dijet associations



The total distribution (SUSY + SM)

- Since $\sigma \propto \frac{Nr.events}{\varepsilon \cdot \int \mathcal{L}} \Rightarrow$ the goal is to identify the number of $\tilde{\chi}_1^\pm$ and $\tilde{\chi}_2^0$ events from the total distribution

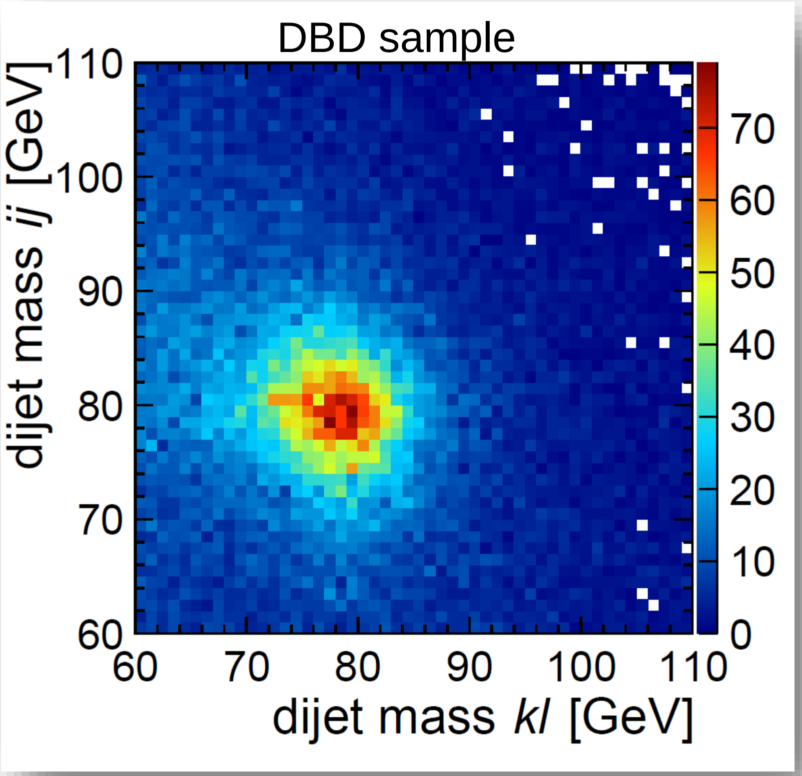
→ Perform 2D Template fit.

Cross Section: 2D Template Fit

> Use Monte Carlo data to produce:

- the chargino template

- After preselection
- Kinematic fit converged
- All dijet permutations included



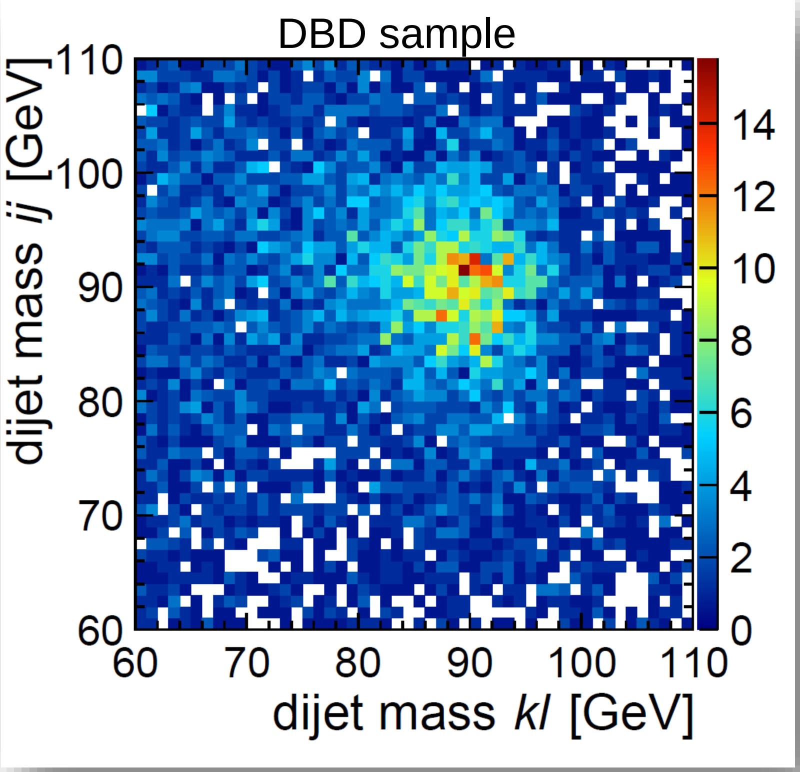
Chargino events only

Cross Section: 2D Template Fit

> Use Monte Carlo data to produce:

- the chargino template
- the neutralino template

- After preselection
- Kinematic fit converged
- All dijet permutations included

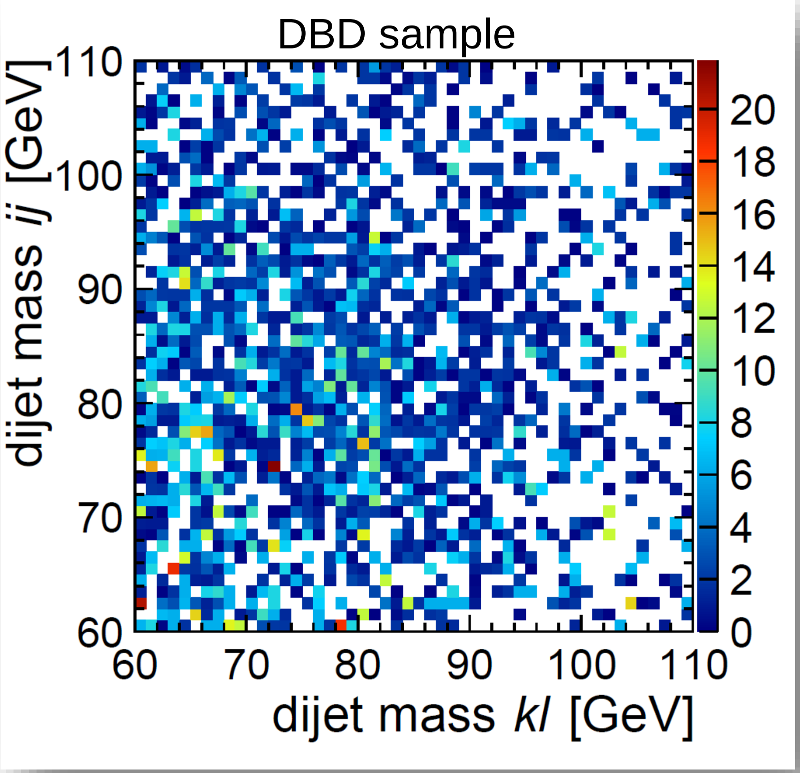


Neutralino events only

Cross Section: 2D Template Fit

> Use Monte Carlo data to produce:
  - the chargino template
  - the neutralino template
  - the SM background template

- After preselection
- Kinematic fit converged
- All dijet permutations included

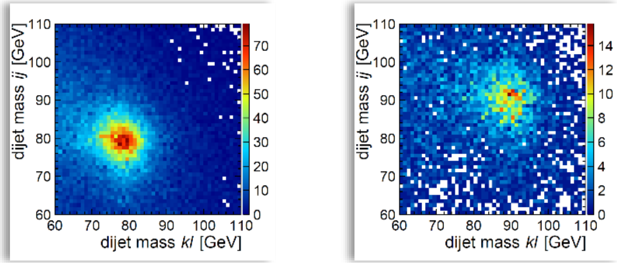


Standard Model events only

DESY

Cross Section: 2D Template Fit

> Defining the two-dimensional fitting function:

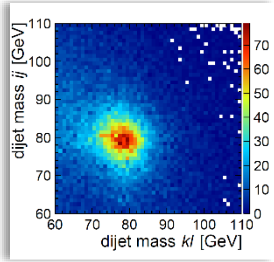


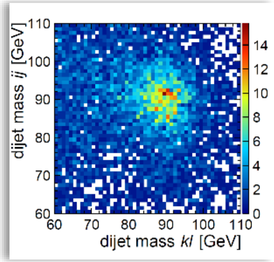
$$f_{Fit}(x,y) = a \times f_{\tilde{\chi}_1^{\mp}}(x,y) + b \times f_{\tilde{\chi}_2^0}(x,y)$$

- a and b → the only free parameters
- a and b = the fraction of template events found in the total data distribution
- in an ideal case, a = b =1

Cross Section: 2D Template Fit

- Defining the two-dimensional fitting function:

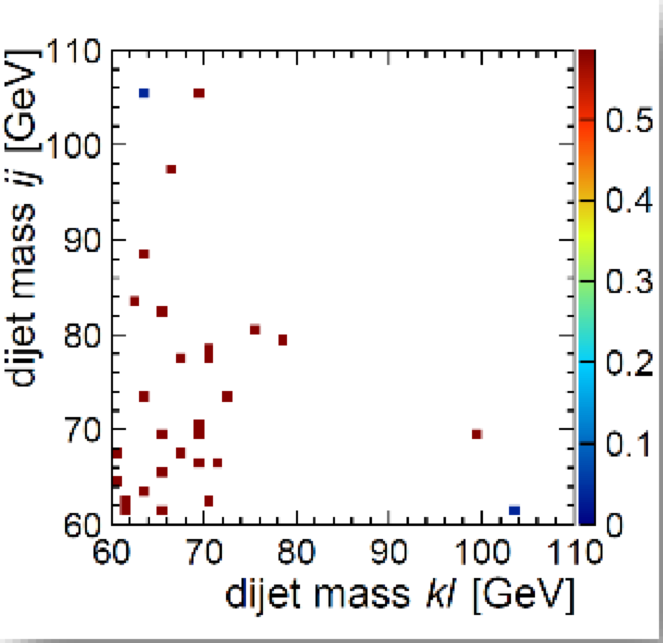




$$f_{Fit}(x,y) = a \times f_{\tilde{\chi}_1^{\mp}}(x,y) + b \times f_{\tilde{\chi}_2^0}(x,y)$$

- After preselection
- Kinematic fit converged
- All dijet permutations

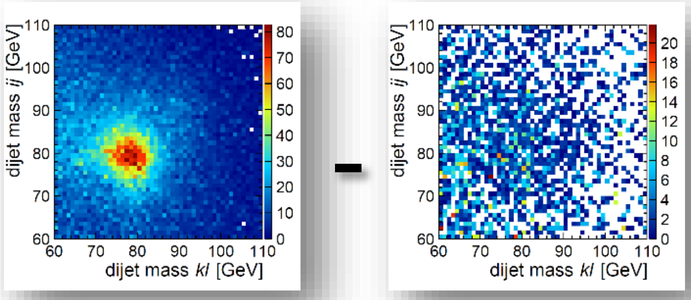
- a and b → the only free parameters
- a and b = the fraction of template events found in the total data distribution
- in an ideal case, a = b =1
- the **SUSY background is negligible** →



Applying the 2D Template Fit

> The fitting procedure:

- Subtract the SM background template from the total data distribution



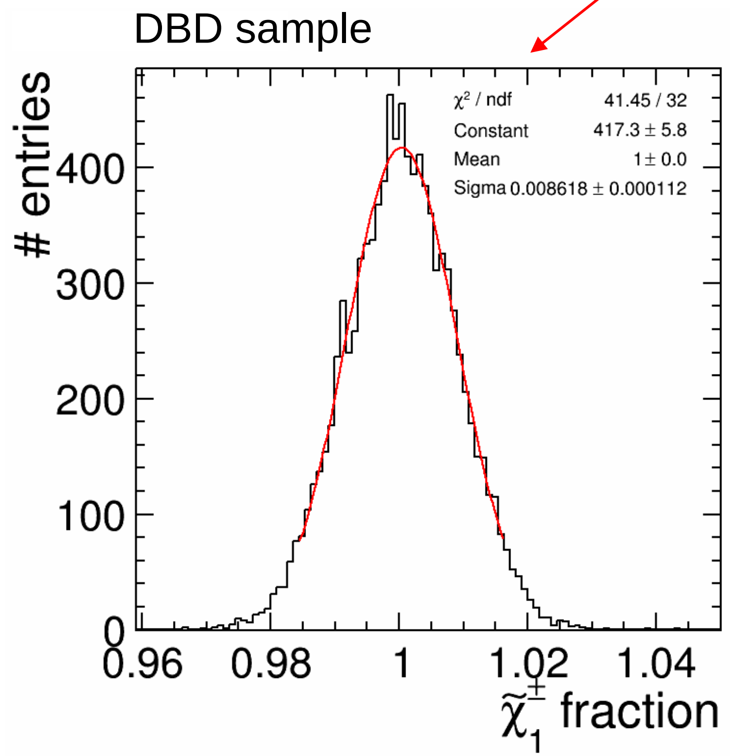
- Apply the template fit on the remaining data events
- **Note:** limited amount of Monte Carlo data available ⟶ do a **toy Monte Carlo study**

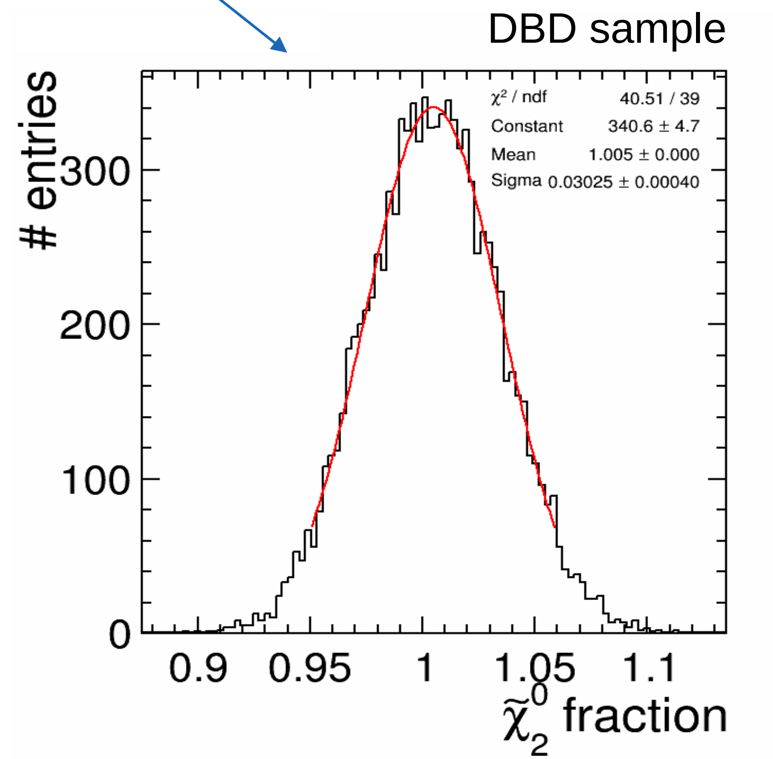
> Running the toy MC:

- Treat the total data distribution as a p.d.f
- Randomly sample the initial distribution N times: $N = N_{evts.}^{initial} \pm \sqrt{N_{evts.}^{initial}}$
- Subtract the SM template from the new distribution
- Apply the fitting function → obtain one value each for a and b
- Repeat procedure 10000 times

2D Template Fit: Results [DBD sample]

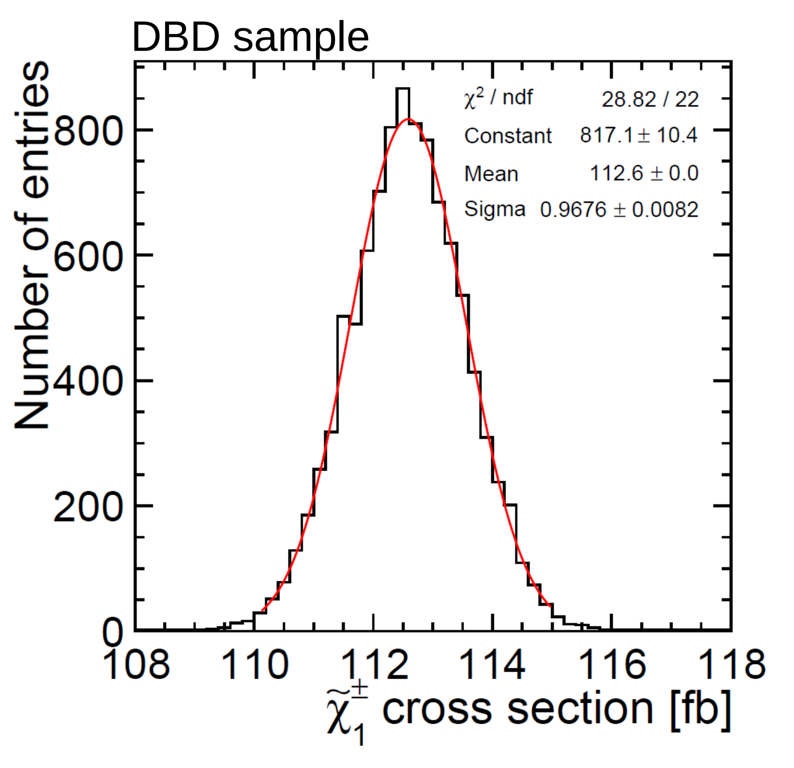
$$f_{Fit}(x,y) = a \times f_{\tilde{\chi}_1^{\mp}}(x,y) + b \times f_{\tilde{\chi}_2^0}(x,y)$$

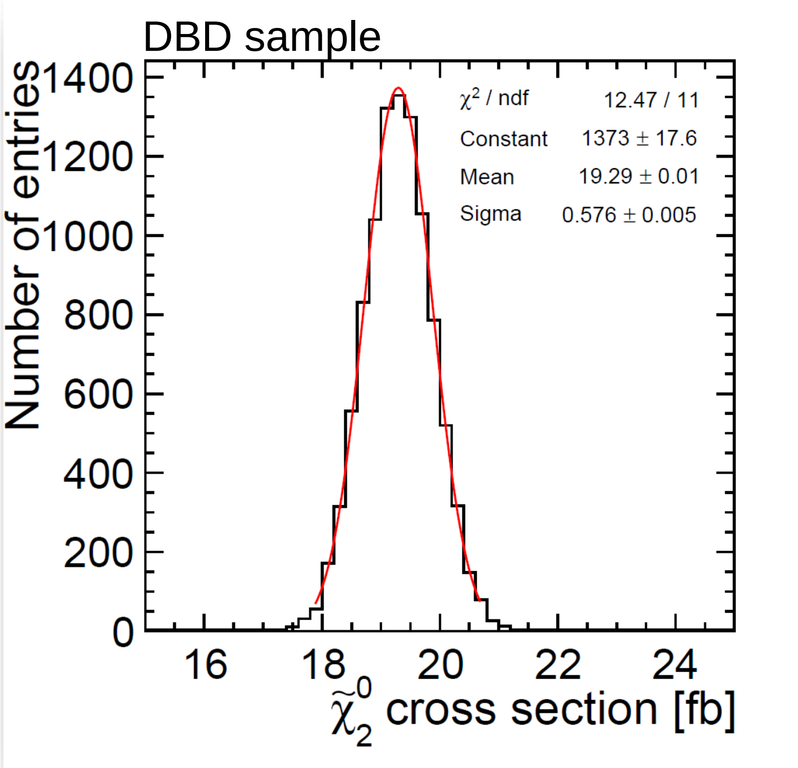




$$a_{mean} = 1.00 \pm 0.009$$
$$b_{mean} = 1.01 \pm 0.03$$

2D Template Fit: Results





Sample	$\tilde{\chi}_1^{\pm}$ x- section [fb]	$\tilde{\chi}_2^0$ x-section [fb]
Generator	112.54	19.2
DBD	112.6 ± 0.97	19.3 ± 0.58

Cross Section: 2D Template Fit – Comparison to LOI

> The same procedure has been applied to the LOI data:

Sample	$\tilde{\chi}_1^{\pm}$ x- section [fb]	$\tilde{\chi}_2^0$ x-section [fb]
Generator level	132.15	22.79
LOI	132.2 ± 1.14	23.17 ± 0.67
arXiv:0906.5508v2	132.9 ± 0.85	22.47 ± 0.48

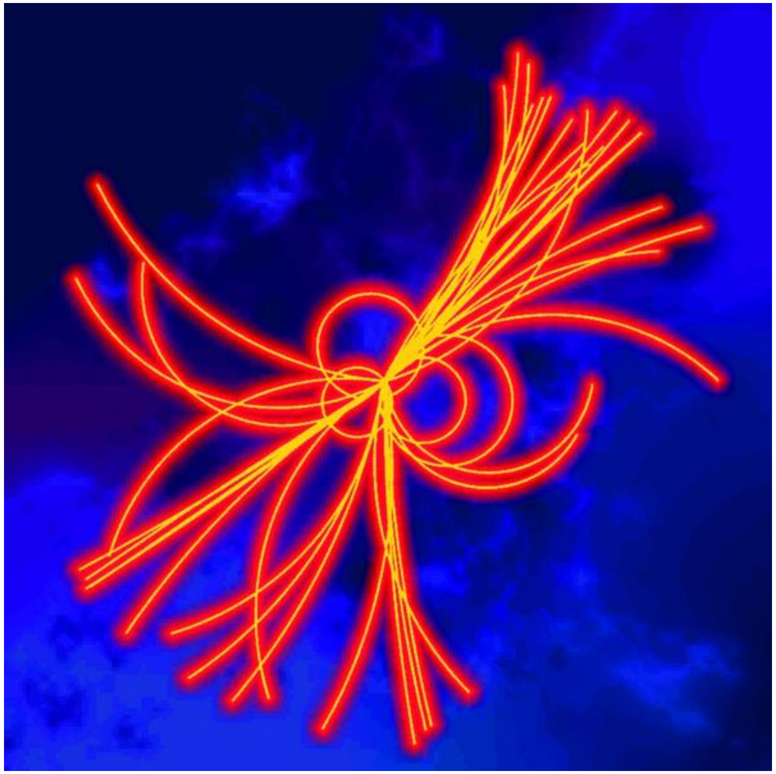
Sample	$\tilde{\chi}_1^{\pm}$ x- section [fb]	$\tilde{\chi}_2^0$ x-section [fb]
Generator level	112.54	19.2
DBD	112.6 ± 0.97	19.3 ± 0.58

- **Note** **-** the difference between cross sections at generator level
    - Difference in beam-spectrum
    - Missing processes - Whizard 1.95

Conclusions

- A 2D template fitting procedure for cross-section determination was presented.
- Due to limited amounts of available Monte Carlo data samples a toy Monte Carlo study was performed.
- The procedure was applied both on LOI as well as on DBD data:
  - The mean values of the determined cross-sections are very close to the model values in both cases → cross-check for the procedure performance.
  - Despite increased detector realism and addition of $\gamma\gamma$ background, the values of the determined statistical uncertainties are very similar for both data samples: ≈1% for $\tilde{\chi}_1^{\pm}$ and ≈ 3% for $\tilde{\chi}_2^0$.

Thank You!



Preselection

- Apply the following cuts to both samples:

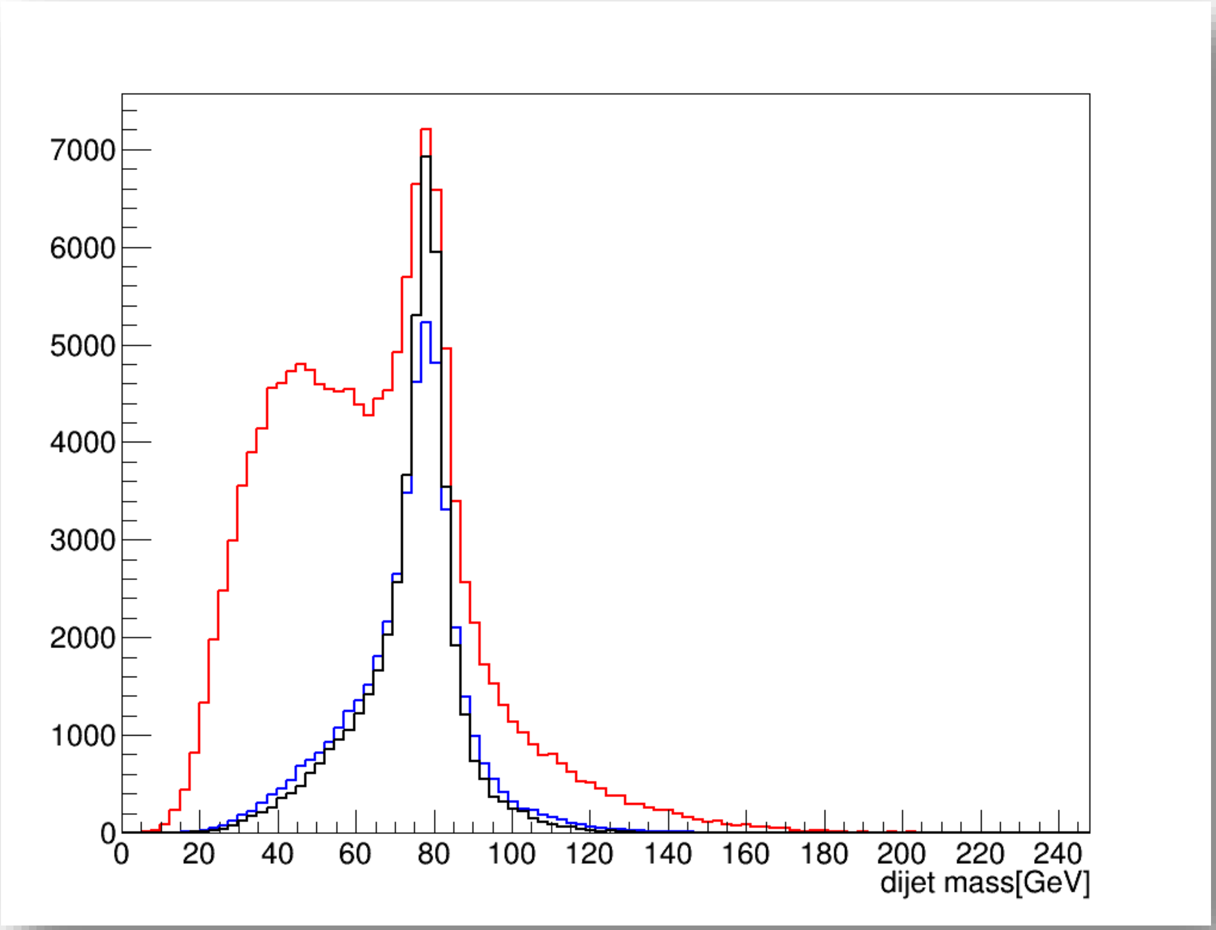
1. Number tracks in event > 20
2. 100 GeV < $E_{visible}$ < 300 GeV
3. E_{jet} > 5 GeV
4. $|\cos(\theta_{jets})| < 0.9$
5. $Y_{34} > 0.001$
6. Number tracks per jet > 2
7. $|\cos(\theta_{miss})| < 0.99$
8. E_{lepton} < 25 GeV
9. Number of PFOs per jet > 3
10. $|\cos(\theta_{miss})| < 0.8$
11. Mmiss > 220 GeV
12. Kinematic fit converged

LOI & DBD common (cuts 1–12)

13. No isolated lepton
14. 30 < Number PFOs in event < 150
15. 4 < Nr. Tracks with P_T > 1GeV < 50
16. Thrust < 0.98

DBD (cuts 13–16)

KinFit



Red, start mass

Blue, start mass – best comb.

Black, after kinfit – best comb.