Particle Flow and Gaugino Property Determination at the ILC.

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8th ANNUAL MEETING OF THE HELMHOLTZ ALLIANCE "PHYSICS AT THE TERASCALE“ – 02.12.2014

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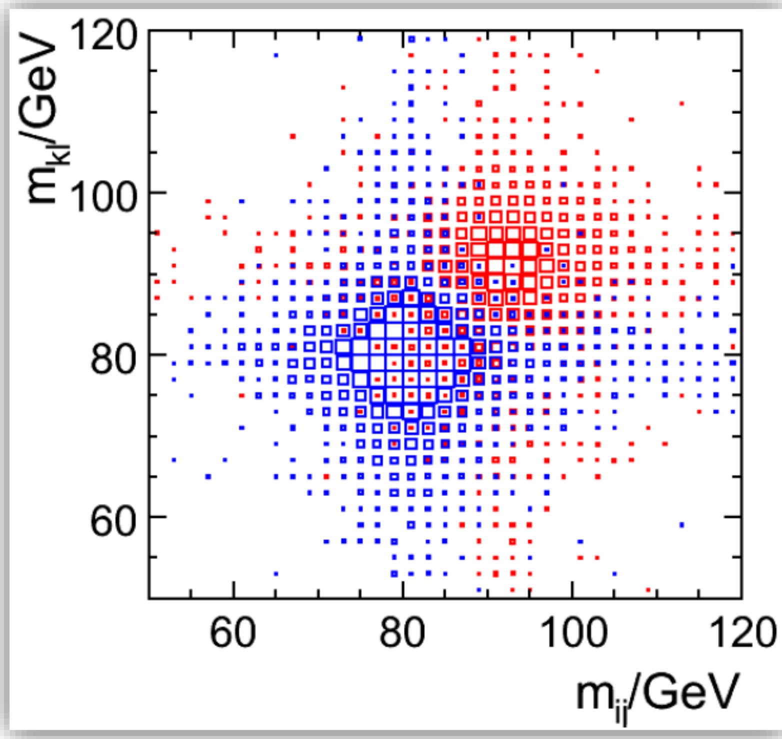
Particles, Strings, and the Early Universe
Collaborative Research Center SFB 676

Introduction

- ILC jet energy resolution goals

$$\frac{\sigma_E}{E} = \frac{0.3}{\sqrt{E\ [GeV]}} \rightarrow \sim 2 \text{ times better than LEP}$$

Example: W / Z boson separation



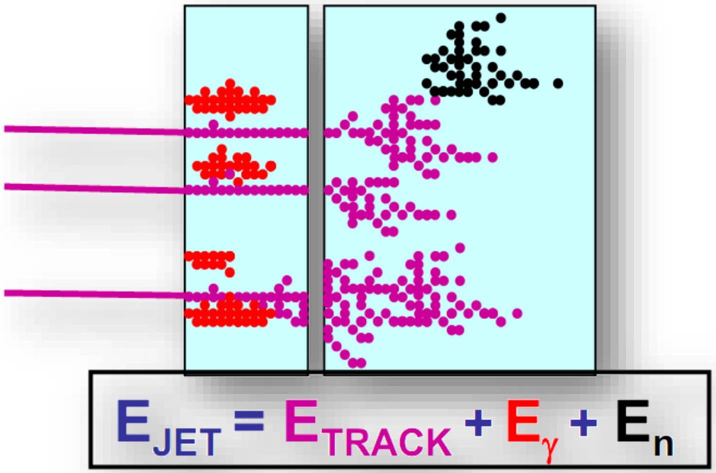
Introduction

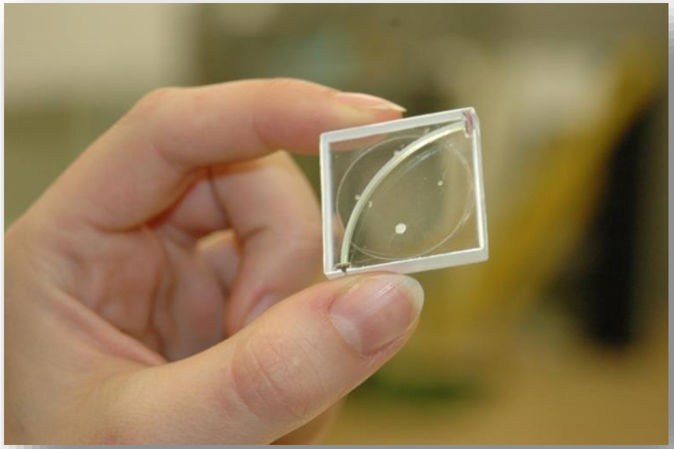
- ILC jet energy resolution goals

$$\frac{\sigma_E}{E} = \frac{0.3}{\sqrt{E\ [GeV]}} \rightarrow \sim 2 \text{ times better than LEP}$$

- A new type of calorimetry is needed: **Particle Flow**

Principle: measure each particle type in the most appropriate subdetector.





Introduction

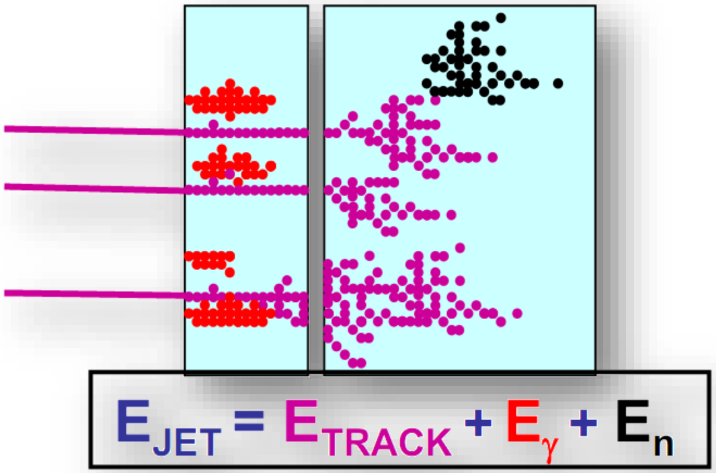
➢ ILC jet energy resolution goals

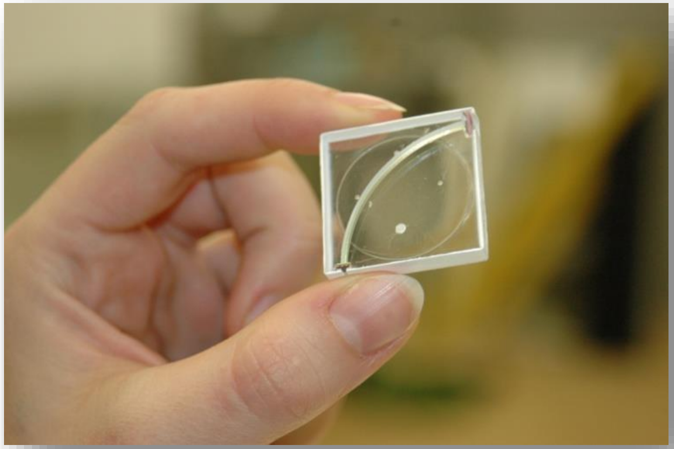
$$\frac{\sigma_E}{E} = \frac{0.3}{\sqrt{E\ [GeV]}}$$ $\rightarrow \sim$ 2 times better than LEP

➢ A new type of calorimetry is needed: **Particle Flow**

Principle: measure each particle type in the most appropriate subdetector.

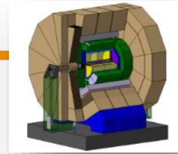
➢ There are currently three different software implementations of the Particle Flow reconstruction algorithm.





Current Detector Simulations

> Full Sim – „LOI“



EVENT GENERATOR
WHIZARD

↓

DETECTOR SIMULATION
MOKKA
- based on GEANT4

↓

RECONSTRUCTION
MARLINRECO
- track finding and fitting
- particle flow – **PandoraPFA**
- flavour tagging

↓

OUTPUT
DST

> Full Sim – „DBD“

EVENT GENERATOR
WHIZARD

↓

DETECTOR SIMULATION
MOKKA
- **Increased realism**

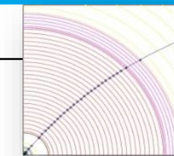
↓

RECONSTRUCTION
MARLINRECO
- track finding and fitting
- **PandoraPFANew - rewritten**
- flavour tagging

↓

OUTPUT
DST

> SGV



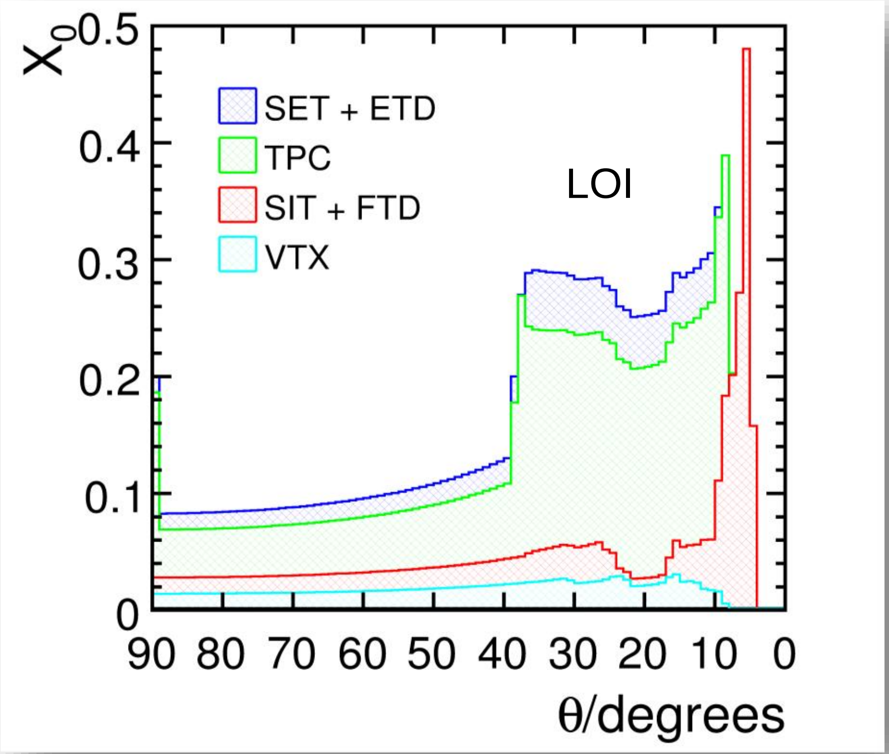
Simulation á Grande Vitesse

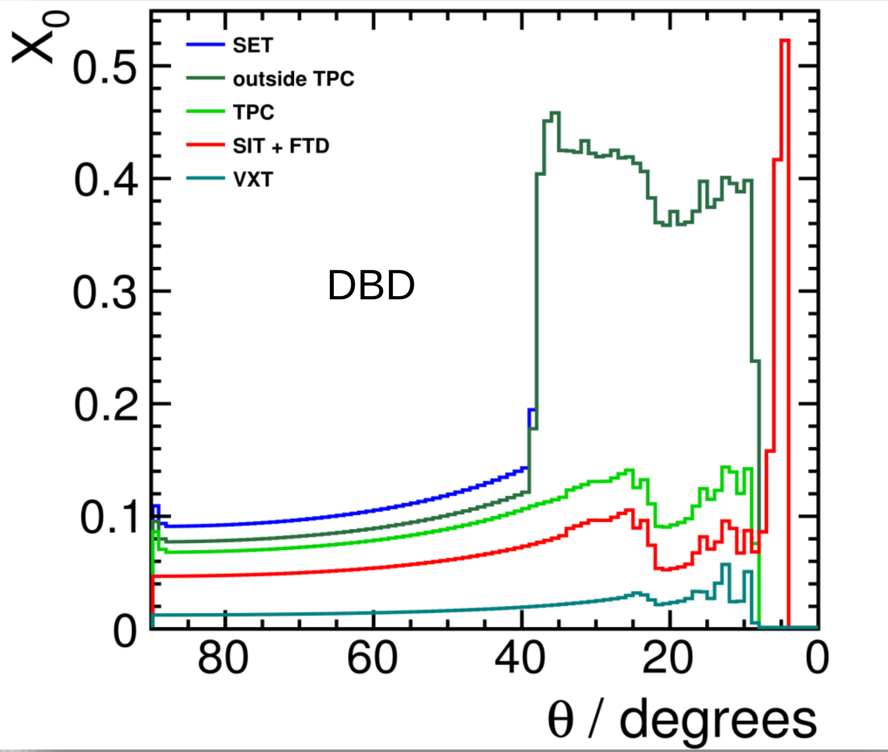
- SGV: 10 ms to simulate one event
- Full sim: O(min)

SGV is ~ 10^3 x faster than the full simulation!

- **Particle Flow in SGV:** emulate PandoraPFA´s behaviour by using parametrisations.

Changes Between LOI and DBD: Simulation Level





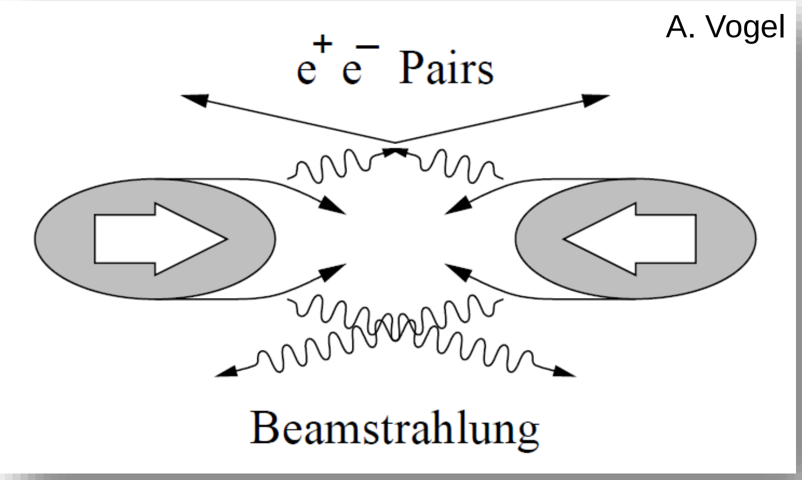
> The new simulation → **improved detector realism:**

- the vertexing
- the tracker (TPC)
- the calorimeter

now include electronics and service materials.

Changes Between LOI and DBD: $\gamma\gamma$ background

- The photons produced as beamstrahlung create hadrons
- The cross section for this process is high enough so that an average of <N> = 1.2 events occur per bunch crossing at 500 fb^{-1}
- The produced hadrons have low P_T
- These events act as pile-up for other processes
- In the DBD case (only) the $\gamma\gamma \rightarrow$ hadrons background was taken into account



- This background can be effectively removed such that it does not impact either the analysis or the LOI – DBD comparison

Changes Between LOI and DBD: Reconstruction Level

- New forward tracking pattern recognition
- New TPC pattern recognition
- Pandora PFA has been developed and rewritten → Pandora PFANew

For |cos(θ)| < 0.7

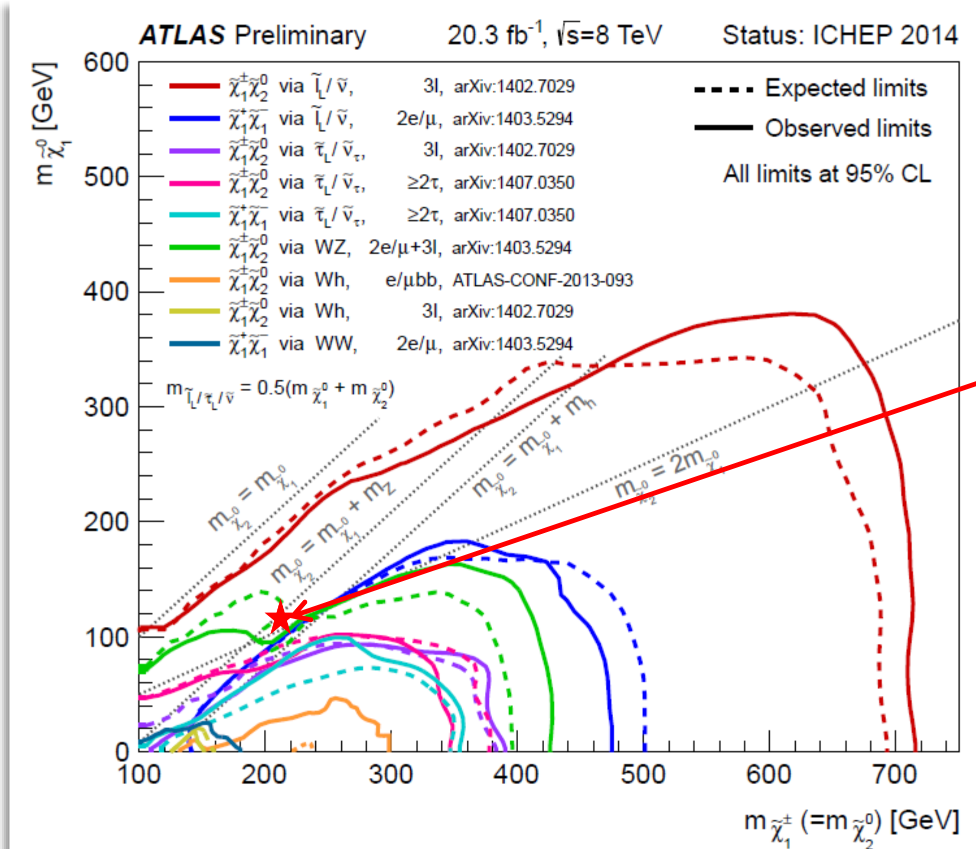
Jet Energy [GeV]	σ_{Ej}/E_j [LOI]	σ_{Ej}/E_j [DBD]
45	3.71±0.05 %	3.66±0.05 %
100	2.95±0.04 %	2.83±0.04 %
180	2.99±0.04 %	2.86±0.04 %
250	3.17±0.05 %	2.95±0.04 %

The jet energy resolution has actually improved despite the material addition.
Goal: **study what happens in a physics scenario!**

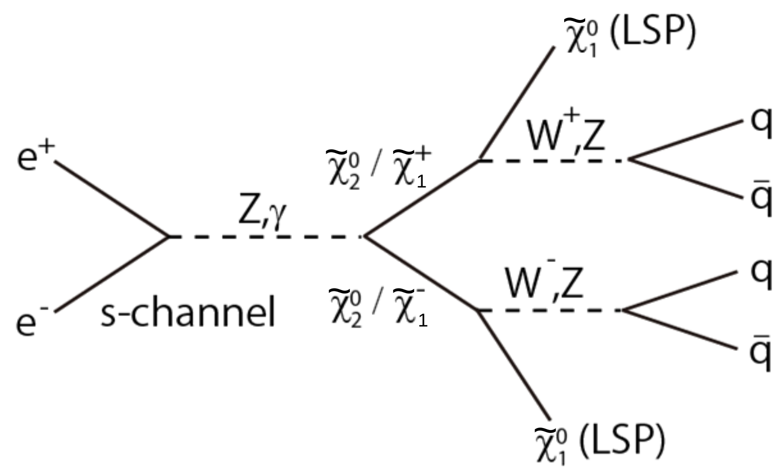
Study case: $\tilde{\chi}_1^{\pm}$ and $\tilde{\chi}_2^0$ Pair Production at the ILC

"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)



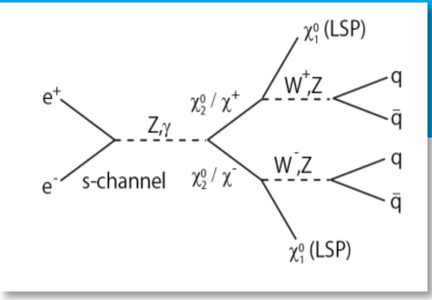
Particle	Mass [GeV]
$\tilde{\chi}_1^0$	115.7
$\tilde{\chi}_1^{\pm}$	216.5
$\tilde{\chi}_2^0$	216.7
$\tilde{\chi}_3^0$	380



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

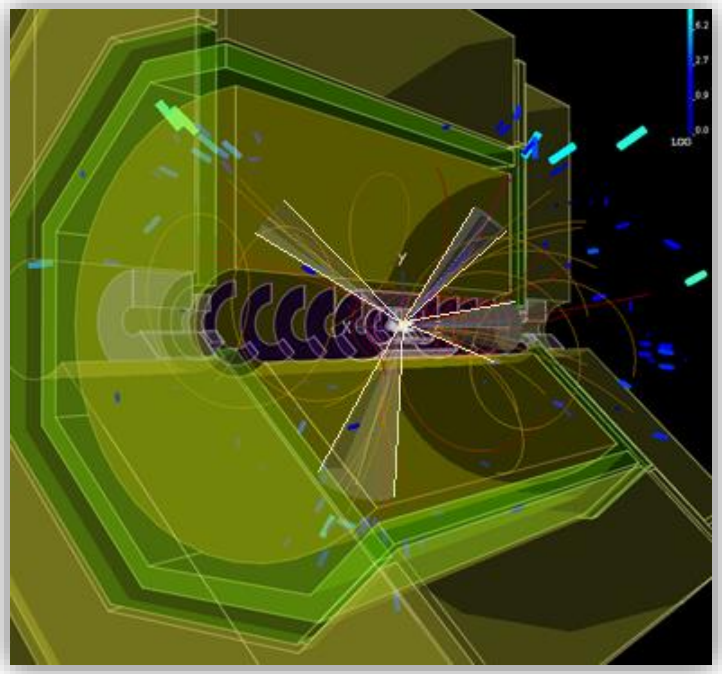
$$\tilde{\chi}_2^0 \rightarrow \tilde{\chi}_1^0 Z^0 \qquad BR = 96.4\%$$

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:

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



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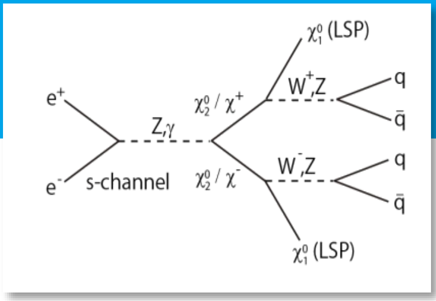

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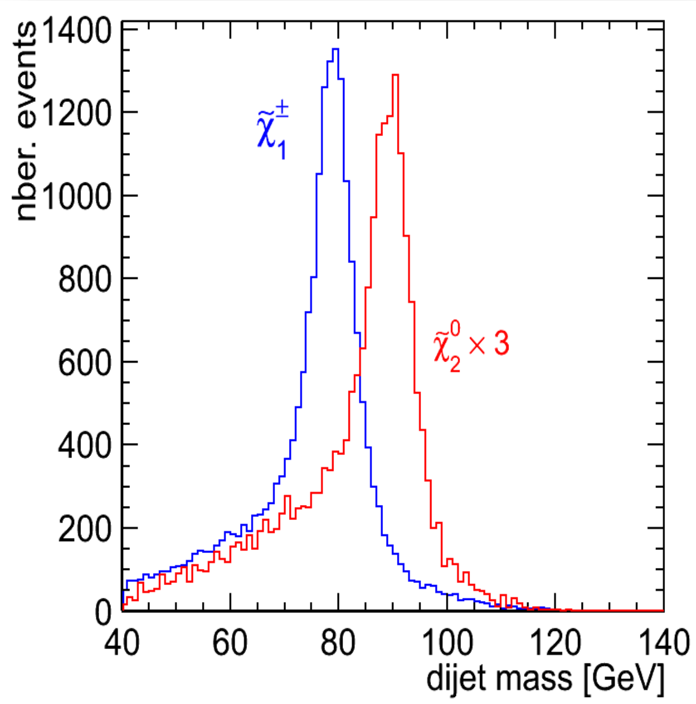
$$\tilde{\chi}_1^{\pm} \rightarrow \tilde{\chi}_1^0 W^{\pm} \quad \text{and} \quad \tilde{\chi}_2^0 \rightarrow \tilde{\chi}_1^0 Z^0$$

- $\tilde{\chi}_1^{\pm}$ 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



Analysis Strategy

- Remove $\gamma\gamma \rightarrow \text{hadrons}$ background — **only for DBD**
- Cluster event into 4 jets (Durham)
- Run kinematic fit (equal mass constraint)
- Run isolated lepton finder — **only for DBD**
- Perform SUSY preselection
- Separate $\tilde{\chi}_1^{\pm}$ and $\tilde{\chi}_2^0$ samples
- Perform mass measurement

common to both LOI and DBD (Cluster event into 4 jets; Run kinematic fit; Perform SUSY preselection; Separate samples; Perform mass measurement)

Analysis Strategy

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common to both LOI and DBD

Removing the γγ Background II

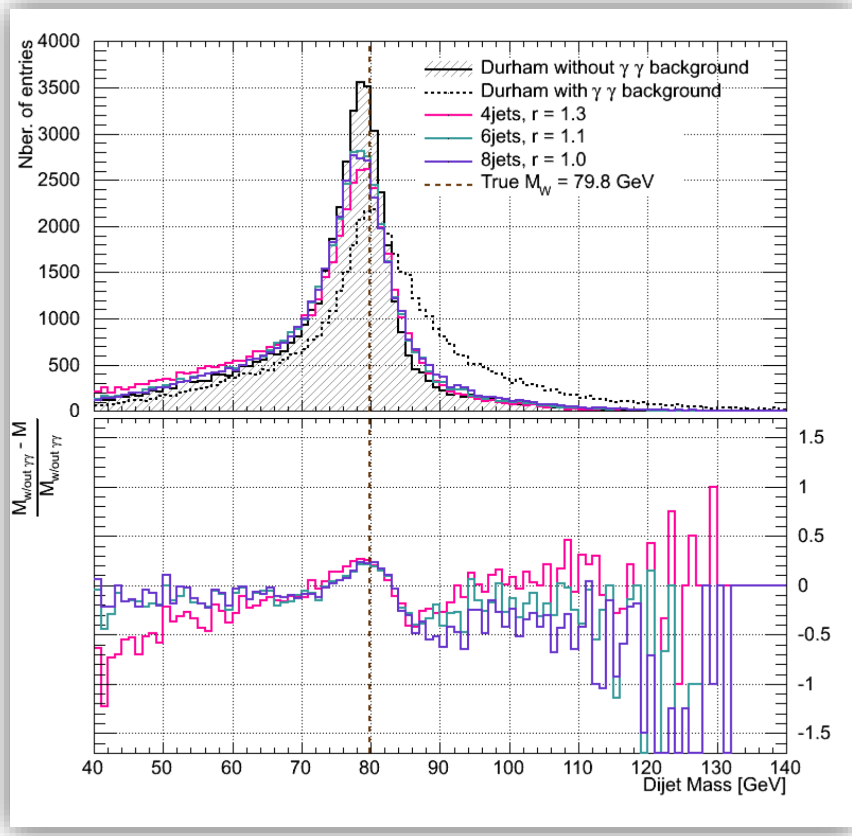
- Tested configurations:

Jets #	4 jets	6 jets	8 jets
	1.1	0.9	0.8
R value	**1.3**	**1.1**	**1.0**
	1.5	1.3	1.2

- Find the configuration most similar to the Durham distribution → χ^2 test :

Jets #	R val.	χ^2/ndf W	χ^2/ndf Z
4 jets	1.3	13.4	11.6
6 jets	**1.1**	**6.9**	**4.7**
8 jets	1.0	9.3	6.8

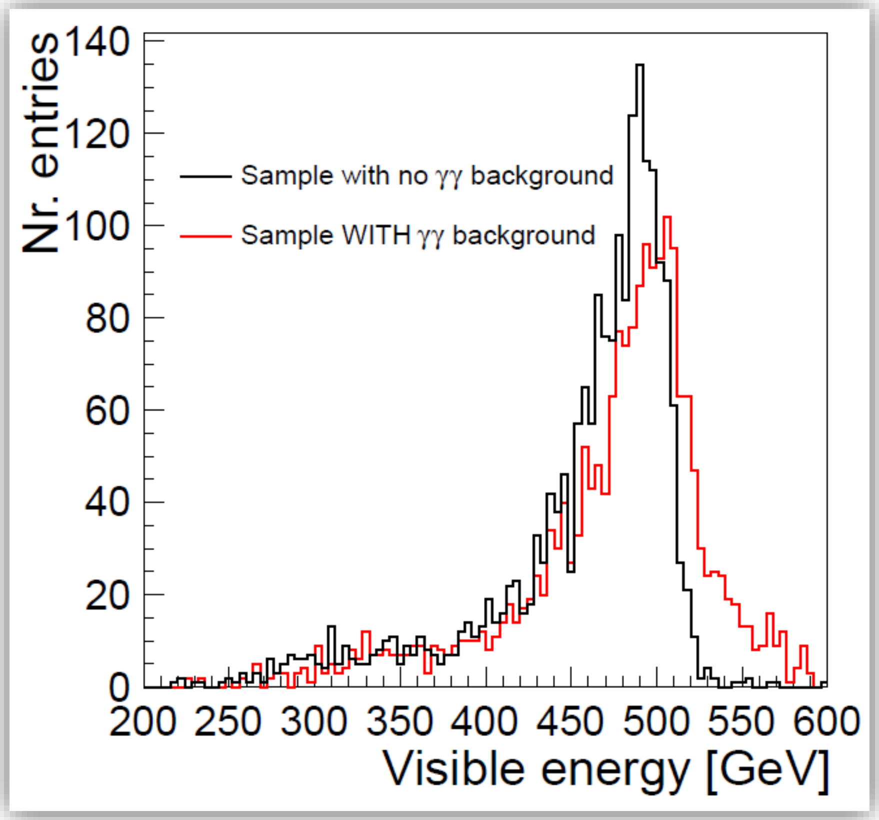
Used: **exclusive longitudinal k_T algorithm**

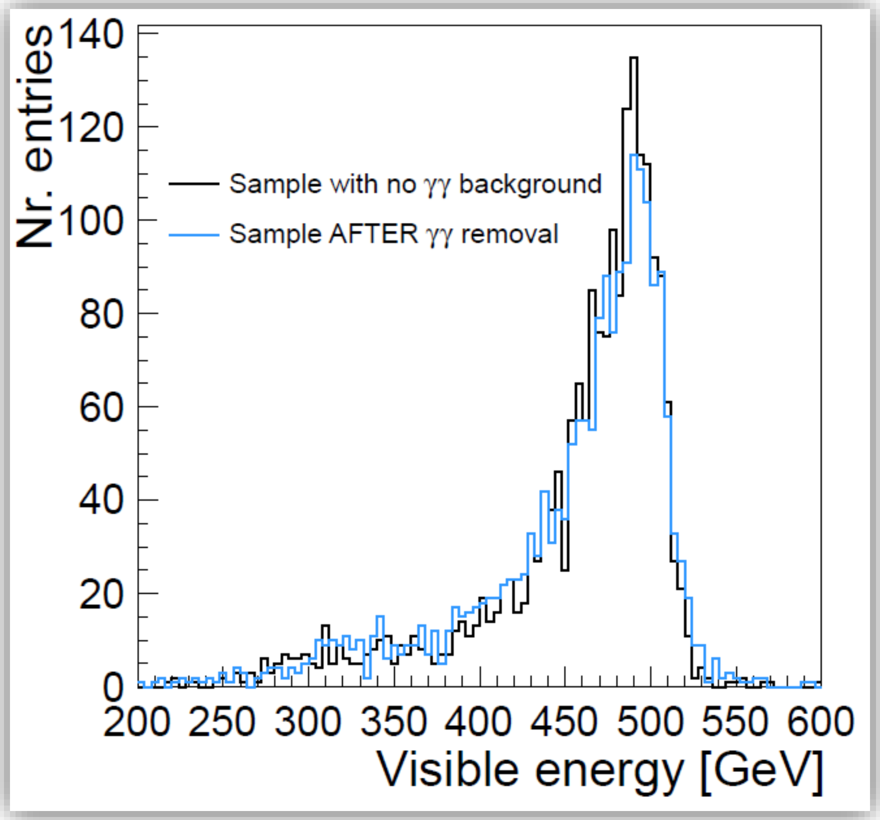


- **The 6 jets configuration with an R-value of 1.1 is best for γγ background removal !**

Removing the γγ Background III

➢ Checking the γγ background removal for the chosen configuration:





➢ After running the longitudinal exclusive k_T algorithm the visible energy is very similar to the no background case.

Analysis Strategy

- Remove $\gamma\gamma \rightarrow \text{hadrons}$ background — only for DBD
- Cluster event into 4 jets (Durham)
- Run kinematic fit (equal mass constraint)
- Run isolated lepton finder — only for DBD
- Perform SUSY preselection
- Separate $\tilde{\chi}_1^{\pm}$ and $\tilde{\chi}_2^0$ samples
- Perform mass measurement

(Cluster event into 4 jets, run kinematic fit, perform SUSY preselection, separate samples, perform mass measurement: **common to both LOI and DBD**)

$\tilde{\chi}_1^\pm$ and $\tilde{\chi}_2^0$ Signal Sample Further Separation

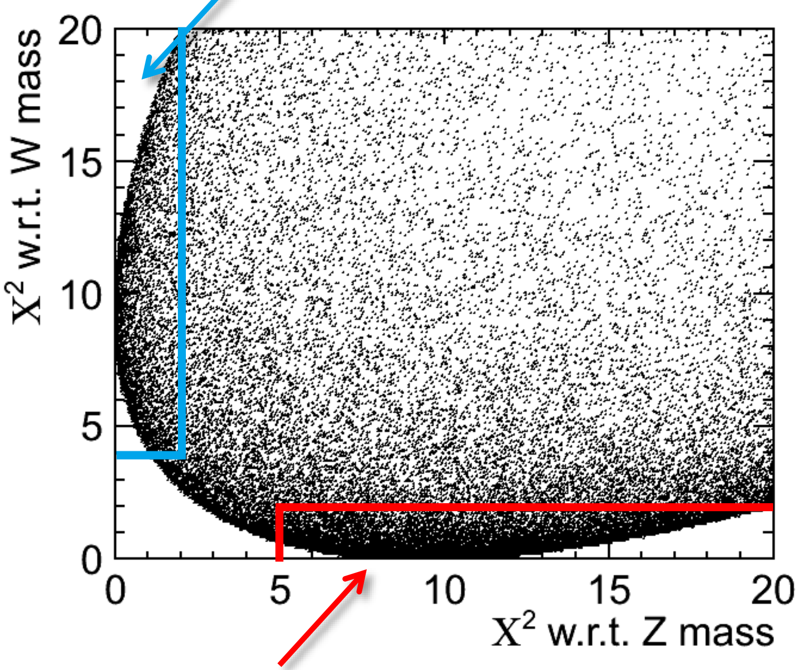
- Calculate χ^2 with respect to nominal W / Z mass

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

⇩

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:



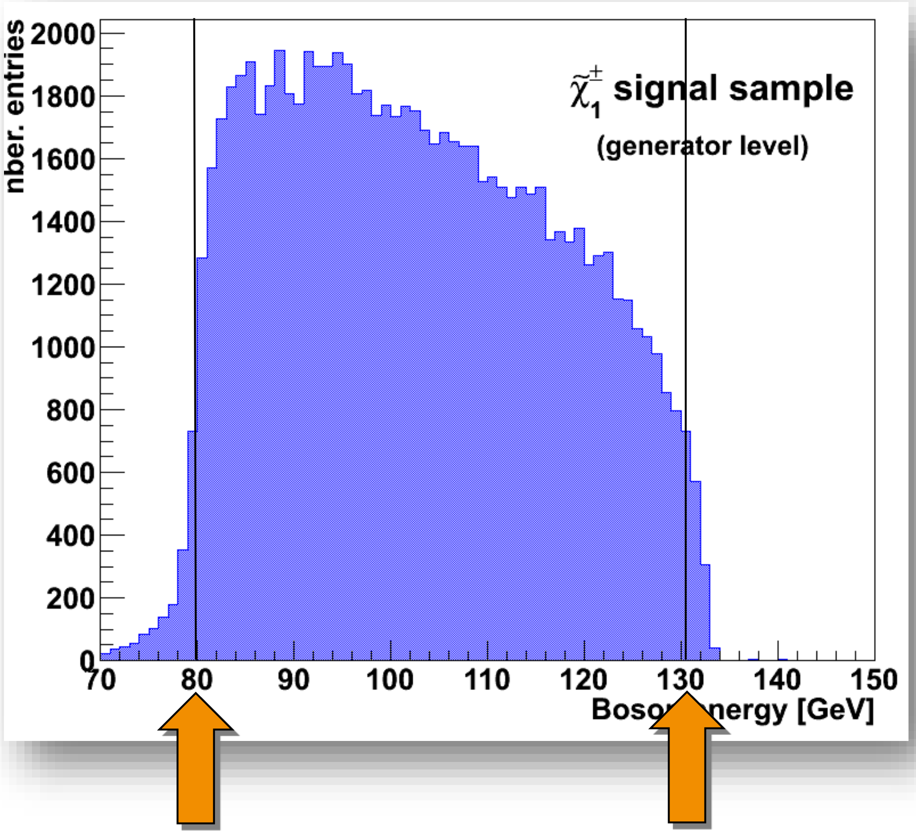
Obs.	DBD		LOI	
	$\tilde{\chi}_1^\pm$	$\tilde{\chi}_2^0$	$\tilde{\chi}_1^\pm$	$\tilde{\chi}_2^0$
Efficiency	53%	30%	56%	34%
Purity (total)	63%	38%	62%	35%
Purity (SUSY)	94%	62%	95%	66%

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

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

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

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



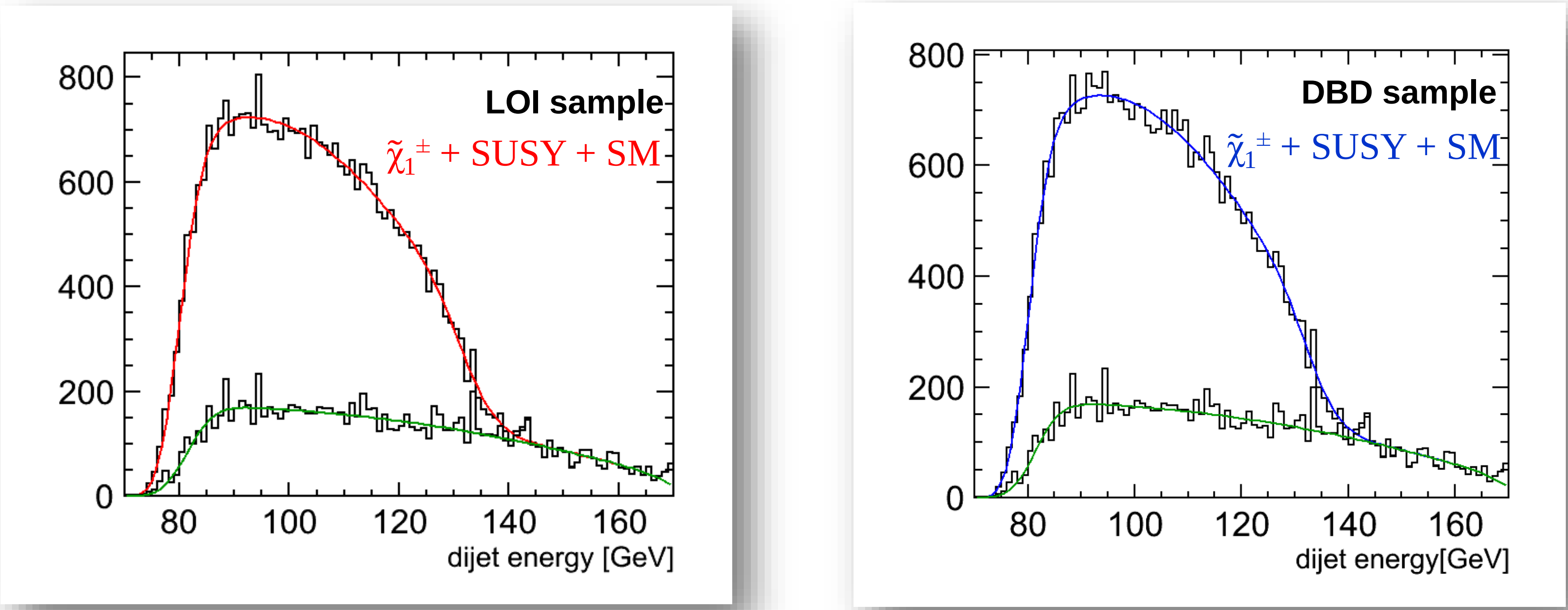
Real edge values [GeV]:

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 – "Endpoint" Method

- Fit dijet energy spectrum and obtain edge positions:

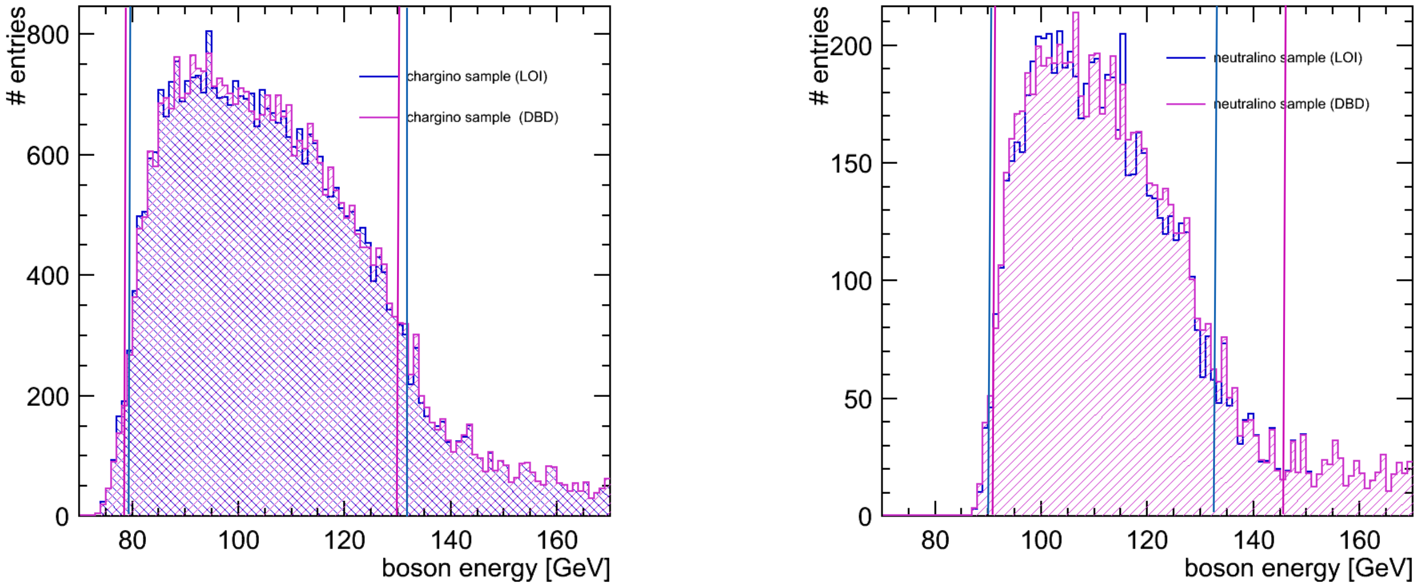
$$f(x; t_{0\_1}, b_{0\_2}, \sigma_{1\_2}, \gamma) = f_{SM} + \int_{t_0}^{t_1} (b_2 t^2 + b_1 t + b_0) V(x - t, \sigma(t), \gamma) dt$$



Where:

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

Issues of the „Endpoint Method“



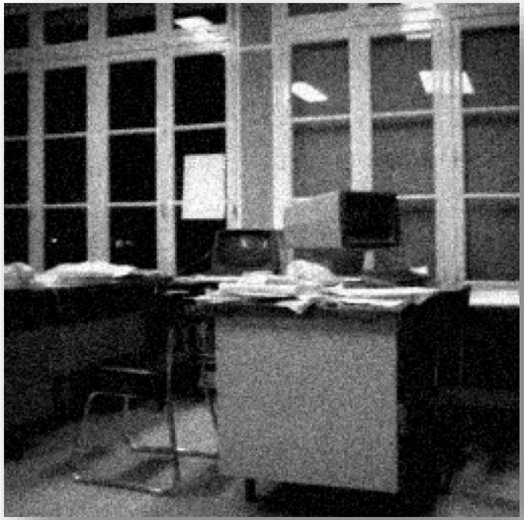
Sim.	Edge W_{low} [GeV]	Edge W_{high} [GeV]	Edge Z_{low} [GeV]	Edge Z_{high}[GeV]
DBD	79.5±0.5	130.2±1.1	91.3±0.6	146.1±4.8
LOI	79.7±0.3	131.9±0.9	91.0±0.7	133.6±0.5

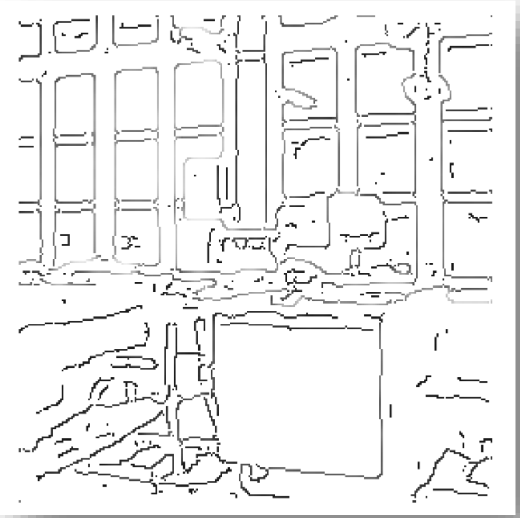
The fitting method appears to be highly dependent on small changes in the fitted distribution → it is NOT appropriate for comparing the two samples.

We need to apply a different edge extraction method!

Endpoint Extraction using an FIR Filter

- Finite Impulse Response (FIR) filters are digital filters used in signal processing, e.g. image processing:

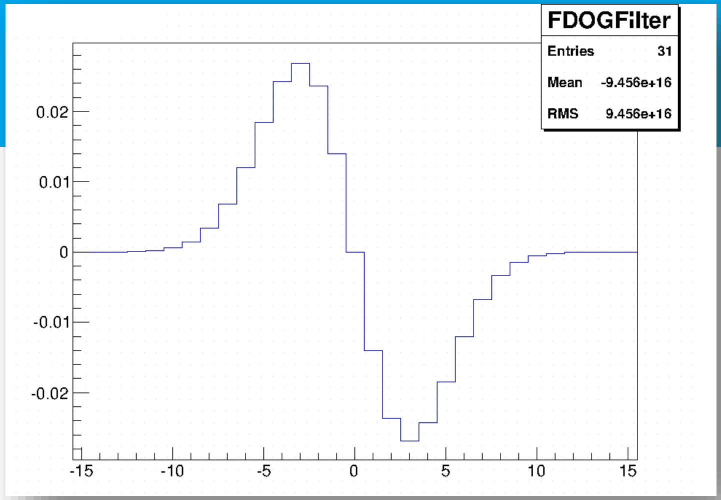




- Canny has suggested that an optimal filter is very similar to **the first derivative of a Gaussian**

  [J. F. Canny. **A computational approach to edge detection.** *IEEE Trans. Pattern Analysis and Machine Intelligence*, pages 679-698, 1986]

Applying an FIR Filter



- Goal: find edge positions in spectrum
- Strategy:
  - Choose an FIR filter
  - Note: filter length << signal histogram length
  - Treat both signal histogram as well as filter as arrays
  - Calculate dot product between Signal and Filter → obtain one value

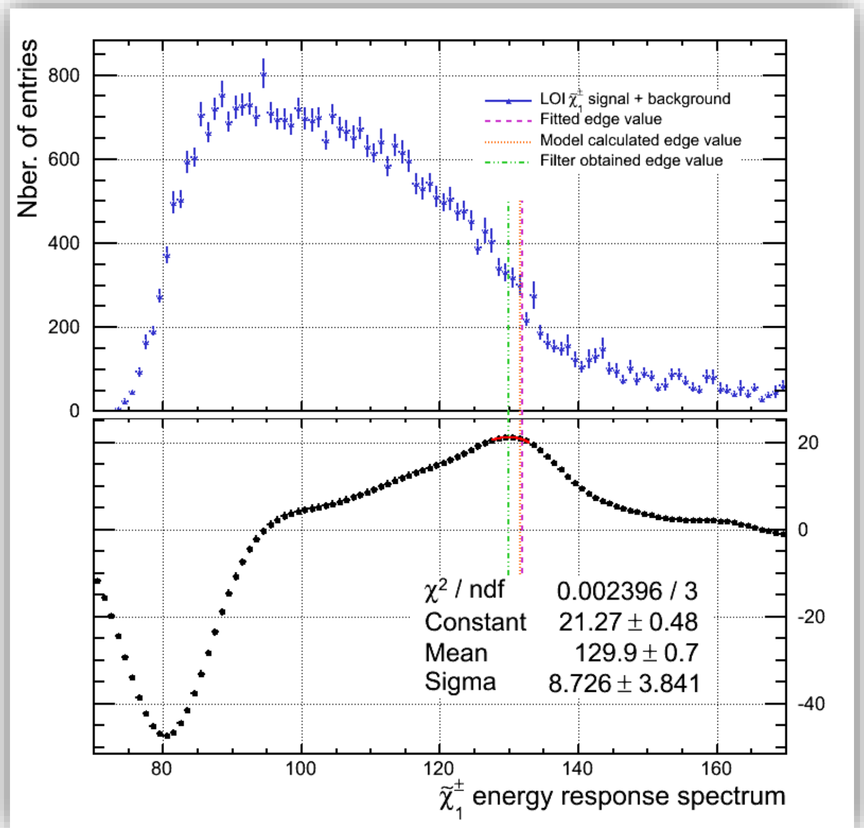
Bin #	1	2	3	...	98	99	100
Signal	0	15	28	...	34	22	4

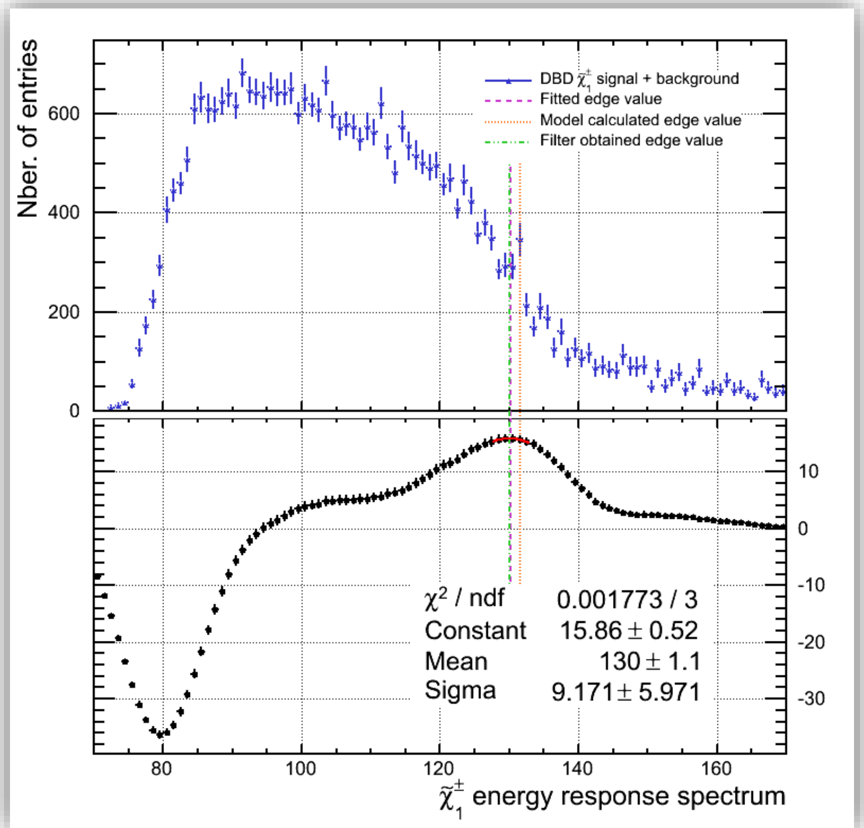
Bin #	1	2	3	...	28	29	30
Filter	0	0.01	0.02	...	-0.02	-0.01	0

$$0 \times 15 + 0.01 \times 28 + \ldots = \text{val2}$$

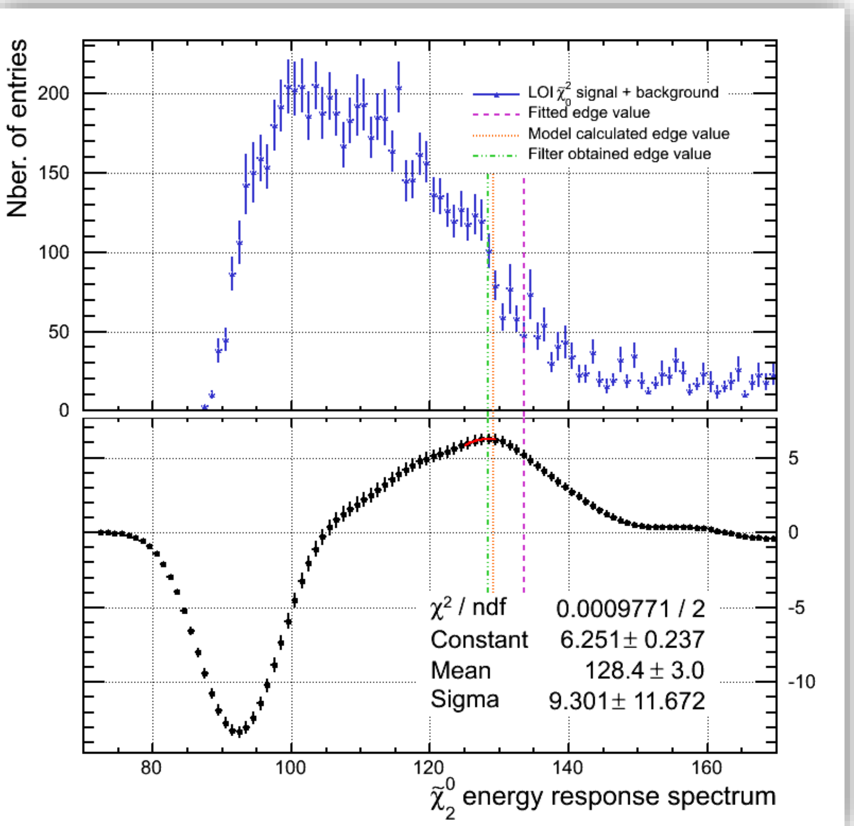
  - **“Move“ Filter along the (length) of the signal → obtain more values, which will form the total filter response**

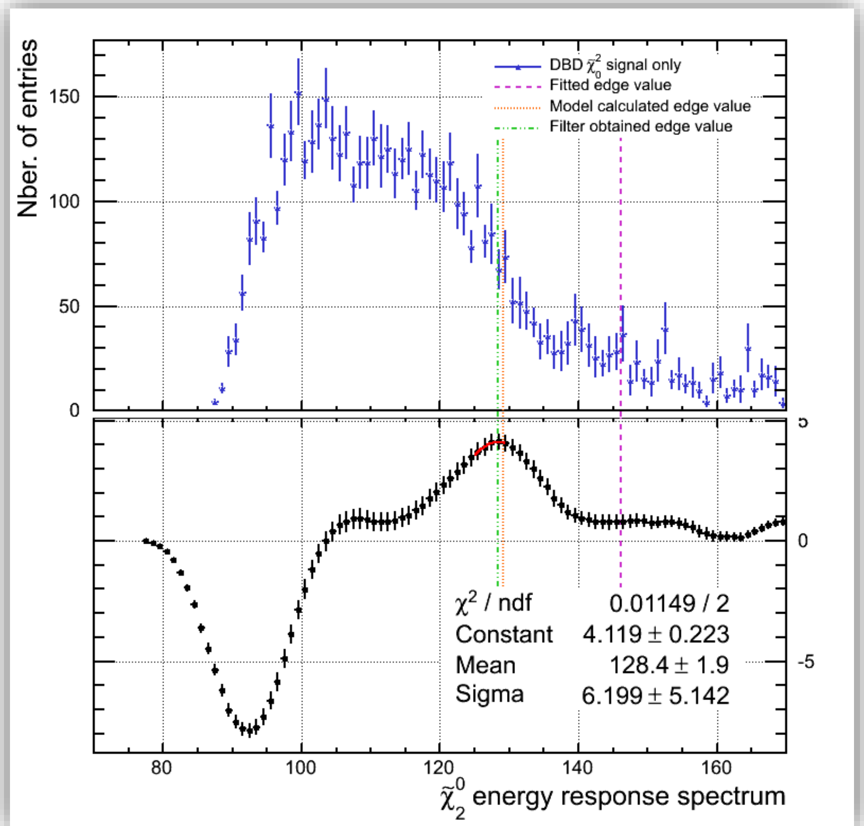
FIR Edge Extraction Comparison – LOI to DBD





FIR Edge Extraction Comparison – LOI to DBD





- On the chargino samples the filter appears to perform slightly worse than the fit in the LOI sample and just as well in the DBD case.
- However the filter performs considerably better in the case of the neutralino samples both for the LOI and the DBD case.

Edge Extraction Comparison

filter

True	80.17	131.53	93.24	129.06
Sim.	Edge W_{low} [GeV]	Edge W_{high} [GeV]	Edge Z_{low} [GeV]	Edge Z_{high} [GeV]
LOI	80.4±0.2	129.9±0.7	92.3±0.4	128.3±0.9
DBD	79.8±0.3	129.9±1.0	92.2±0.4	128.3±0.6

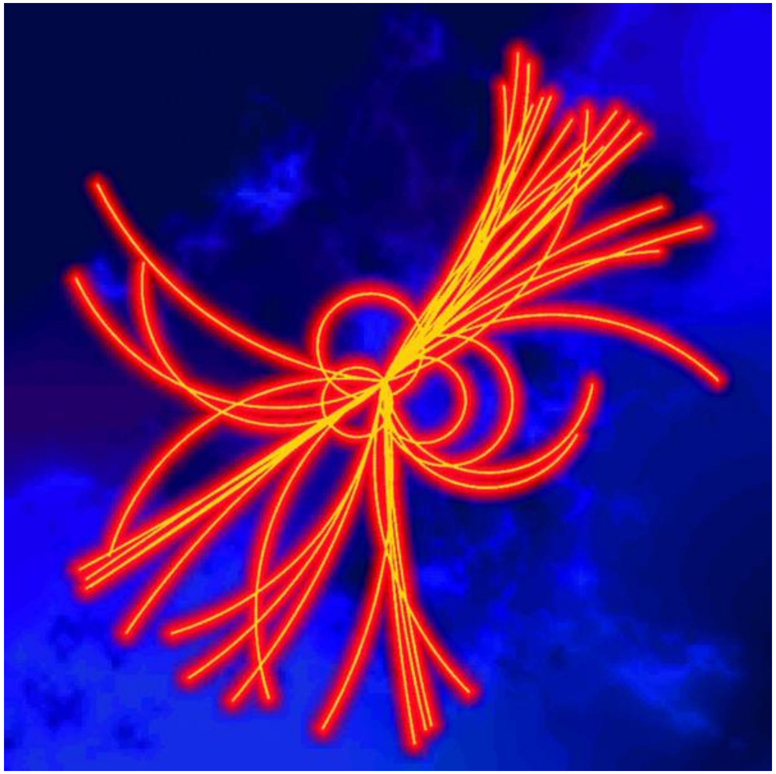
Sample	Mass $\tilde{\chi}_1^{\pm}$ [GeV]	Mass $\tilde{\chi}_2^0$ [GeV]	Mass $\tilde{\chi}_1^0$ [GeV]
TRUE	216.5	216.7	115.7
LOI	216.9±3.2	220.0±1.4	118.4±1.1
DBD	217.3±3.2	220.4±1.5	118.5±0.9

- The filter method is more stable in determining the edge position
- The mass values extracted from the LOI and DBD samples are compatibile within their statistical errors
- The systematic errors will be addressed by a mass calibration study [ongoing]

Conclusions

- In the last few years, the realism in the simulation of the ILC detectors has been significantly increased (e.g. leading to an 50% increase in the amount of material in front of the calorimeter endcaps due to the inclusion of electronics and service materials, etc.)
- The effect of this material addition has been studied in a physics scenario particularly sensitive to Particle Flow
  - No performance degradation has been observed
- The simulation realism has been further increased by adding the overlay of low P_T $\gamma\gamma \rightarrow$ hadrons
  - The overlay can be mitigated by exclusive jet clustering
- New methods to extract sparticle masses from kinematic edges have been studied: e.g. finite impulse response filters

Thank You!



Back up slides

Data Samples:

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

LOI sample:	**DBD sample:**
Signal generated with `Whizard1.51` Background generated with `Whizard1.40`	Signal (as well as SM background) generated with `Whizard 1.95`
The RDR beam spectrum was used	The TDR beam spectrum was used

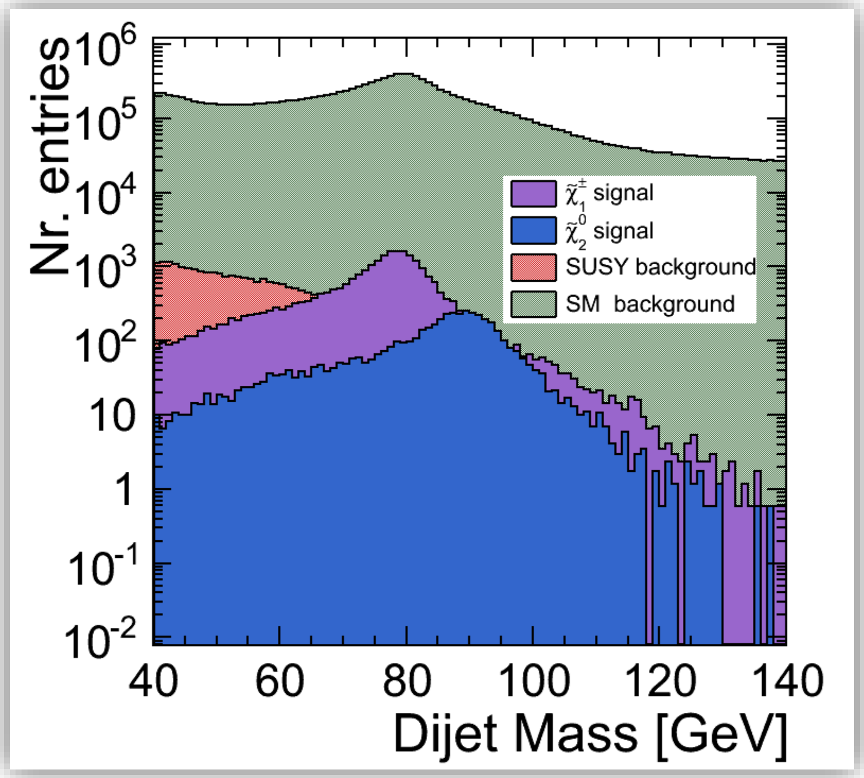
- **Note:** in the signal samples, the M_W was inadvertently lowered by Whizard to M_W = 79.8 GeV

Signal + background were simulated and reconstructed with `ilcsoft v01-06`	Signal + background were simulated and reconstructed with `ilcsoft v01-16-02`
The jet energy scale was increased by 1%	The jet energy scale was **not** increased
No $\gamma\gamma$ background overlay	The **$\gamma\gamma$ background overlay** was taken into account
The analysis was re-run on existing data samples	The analysis was re-run

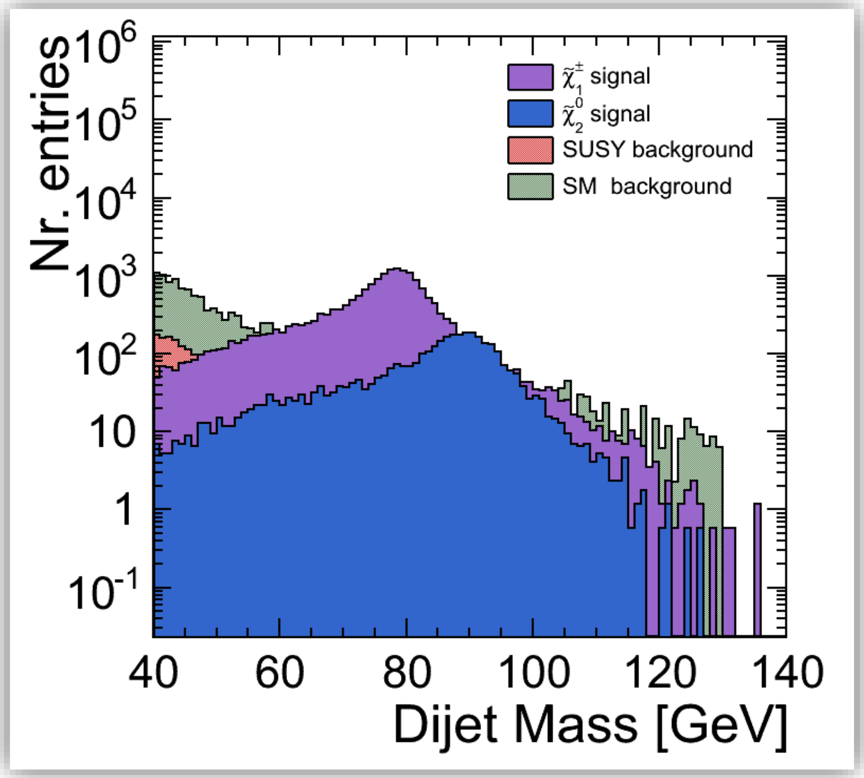
Preselection Outcome

Example: the DBD sample [LOI sample very similar]

Before preselection



After preselection



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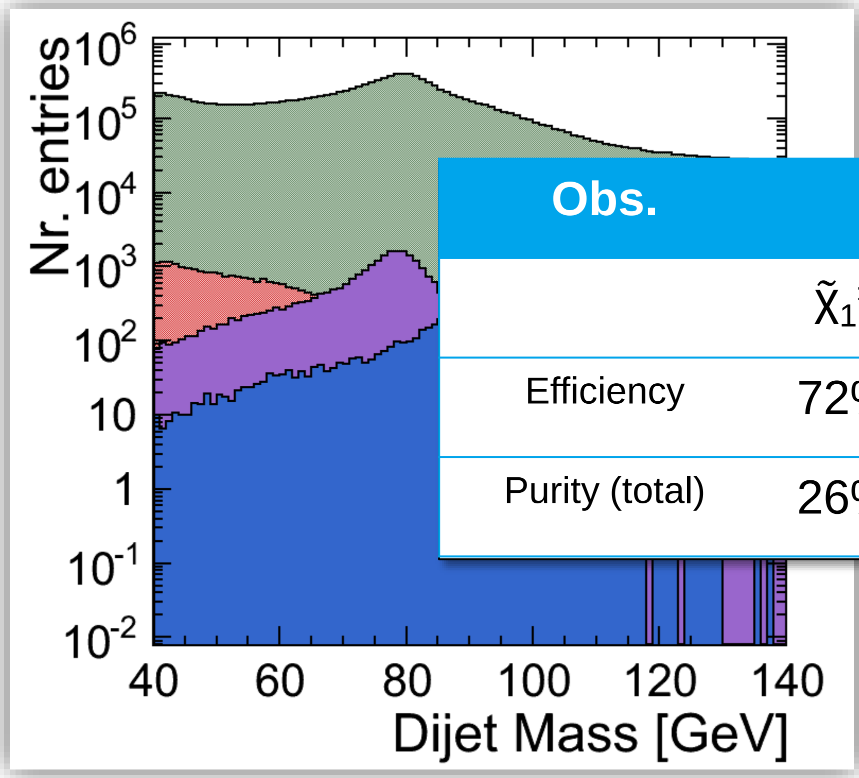
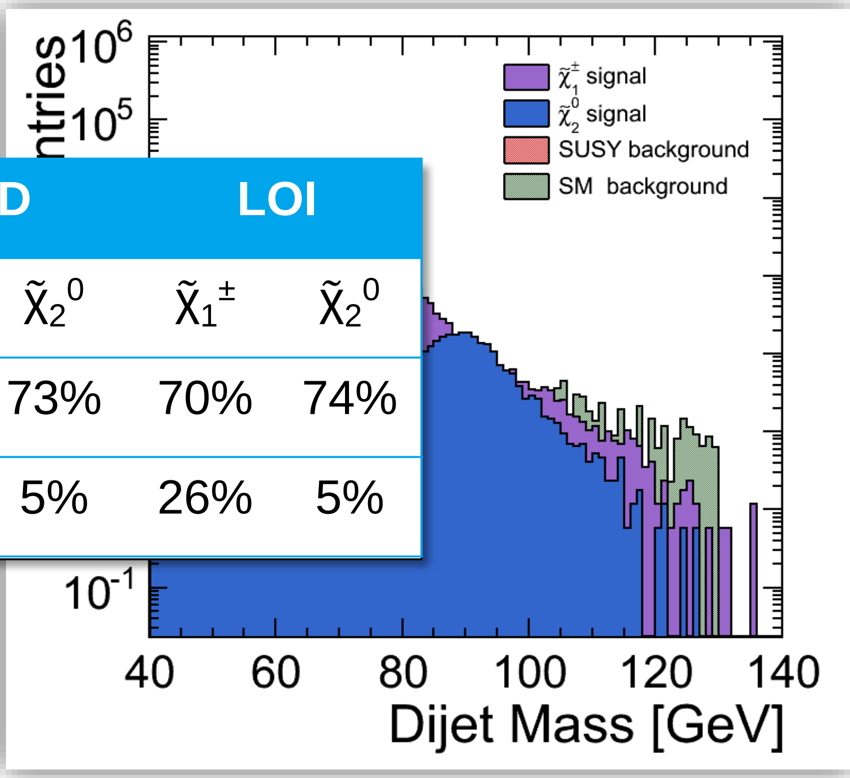


After preselection



Obs.	DBD		LOI	
	$\tilde{\chi}_1^\pm$	$\tilde{\chi}_2^0$	$\tilde{\chi}_1^\pm$	$\tilde{\chi}_2^0$
Efficiency	72%	73%	70%	74%
Purity (total)	26%	5%	26%	5%

Analysis Strategy

- Remove $\gamma\gamma \to \mathrm{hadrons}$ background — only for DBD
- Cluster event into 4 jets (Durham)
- Run kinematic fit (equal mass constraint)
- Run isolated lepton finder — only for DBD
- Perform SUSY preselection
- Separate $\tilde{\chi}_1^{\pm}$ and $\tilde{\chi}_2^0$ samples
- Perform mass measurement

Cluster event into 4 jets, run kinematic fit, perform SUSY preselection, separate samples, perform mass measurement: **common to both LOI and DBD**

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

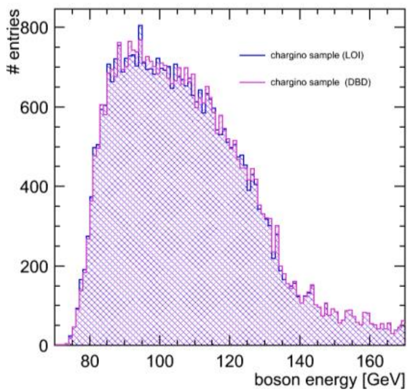
(1–12: LOI & DBD common)

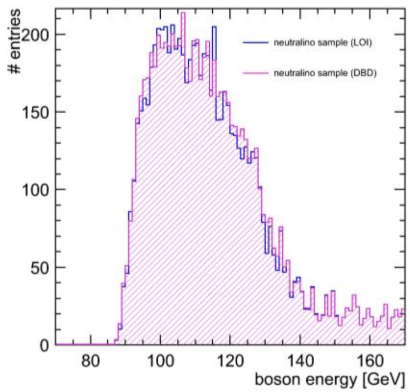
13. No isolated lepton
14. 30 < Number PFOs in event < 150
15. 4 < Nr. Tracks with P_T > 1GeV < 50
16. Thrust < 0.98

(13–16: DBD)

Obs.	DBD		LOI	
	$\tilde{\chi}_1^{\pm}$	$\tilde{\chi}_2^{0}$	$\tilde{\chi}_1^{\pm}$	$\tilde{\chi}_2^{0}$
Efficiency	72%	73%	70%	74%
Purity (total)	26%	5%	26%	5%

Edge Extraction Comparison





True	80.17	131.53	93.24	129.06
Sim.	**Edge W_{low} [GeV]**	**Edge W_{high} [GeV]**	**Edge Z_{low} [GeV]**	**Edge Z_{high}[GeV]**
LOI	79.7±0.3	131.9±0.9	91.0±0.7	133.6±0.5
DBD	79.5±0.5	130.2±1.1	91.3±0.6	146.1±4.8
filter LOI	80.4±0.2	129.9±0.7	92.3±0.4	128.3±0.9
filter DBD	79.8±0.3	129.9±1.0	92.2±0.4	128.3±0.6

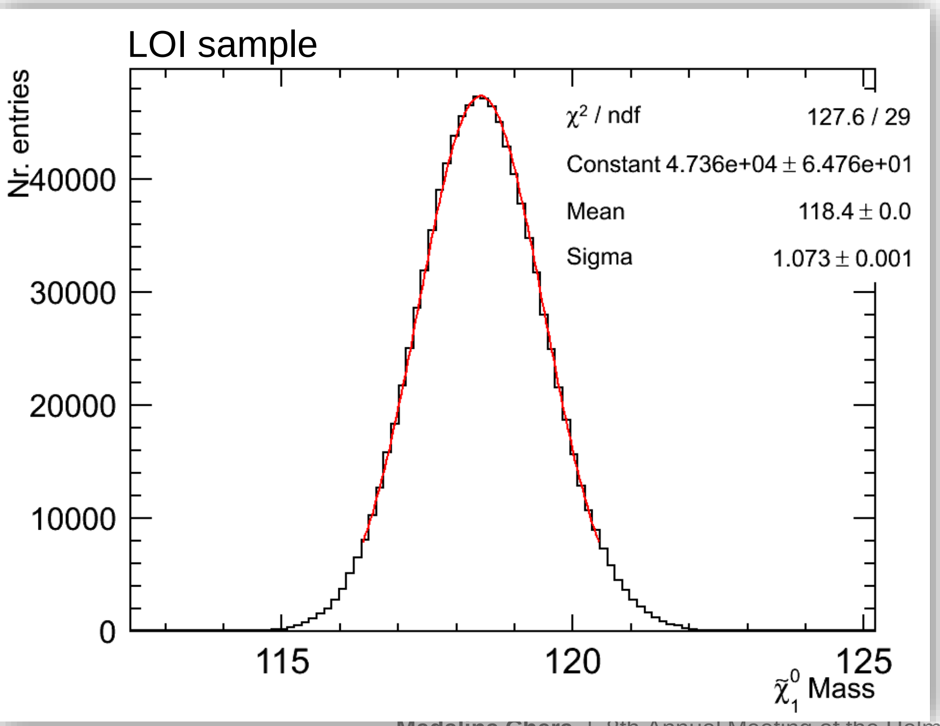
The filter extraction method is preferable:

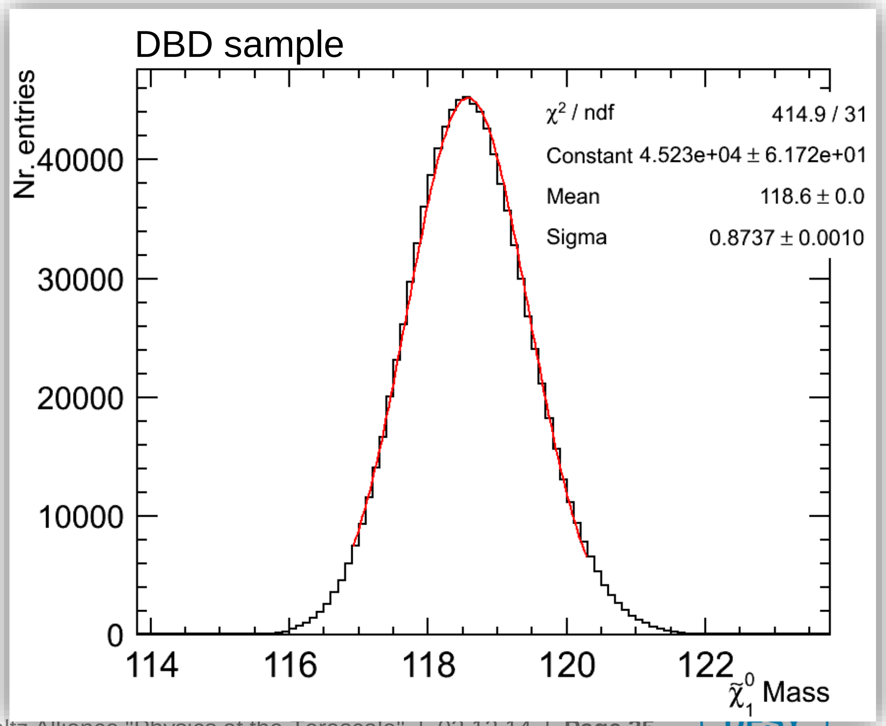
- it is more stable
- provides smaller uncertainties in determining the edge position.

DESY

Toy MC for the Mass Calculation

- To estimate the statistical precision of the mass measurement → toy MC
- Input: edge values + their fluctuations as obtained from the filter
- 1 000 000 values were generated within the edge fluctuations
- The mass calculations have been performed with the generated values 1 000 000 times





Removing the γγ Background

- Use the **longitudinal exclusive k_T** jet clustering algorithm:
- It calculates:
  - The “distance“ between each pair of reconstructed particles:

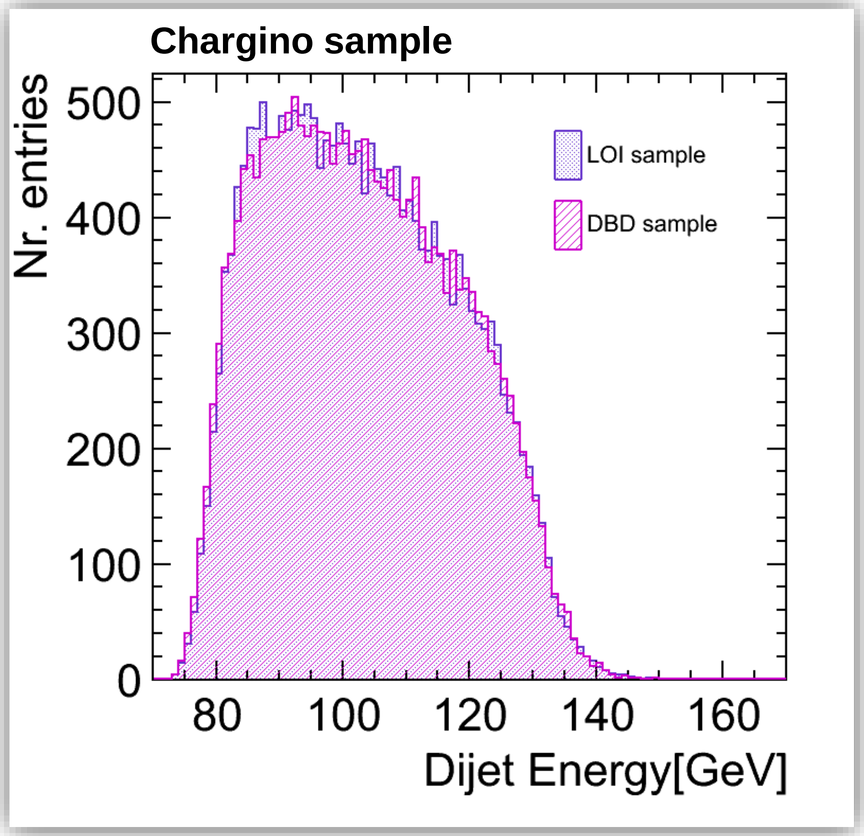
$$dist_{ij} = \frac{\min\left(p_{Ti}^2, p_{Tj}^2\right) \cdot \Delta \boldsymbol{R}_{ij}{}^2}{\boldsymbol{R}^2}$$

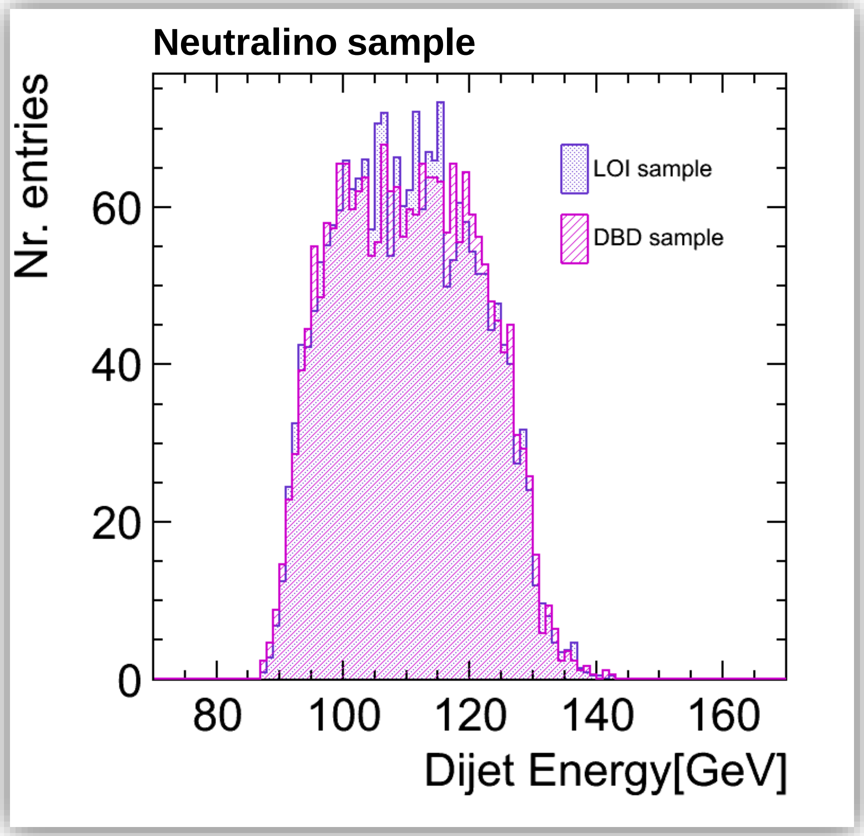
  - The distance between each reconstructed particle and the beam ($dist_{ij}^{Beam}$)
  - If the $dist_{ij}^{Beam}$ is minimum then the particle is discarded
- The number of required jets as well as the R parameter are free parameters.
- In order to increase performance:

optimise the number of requested jets and the R-value!

Dijet [Boson] Energy Comparison LOI - DBD

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

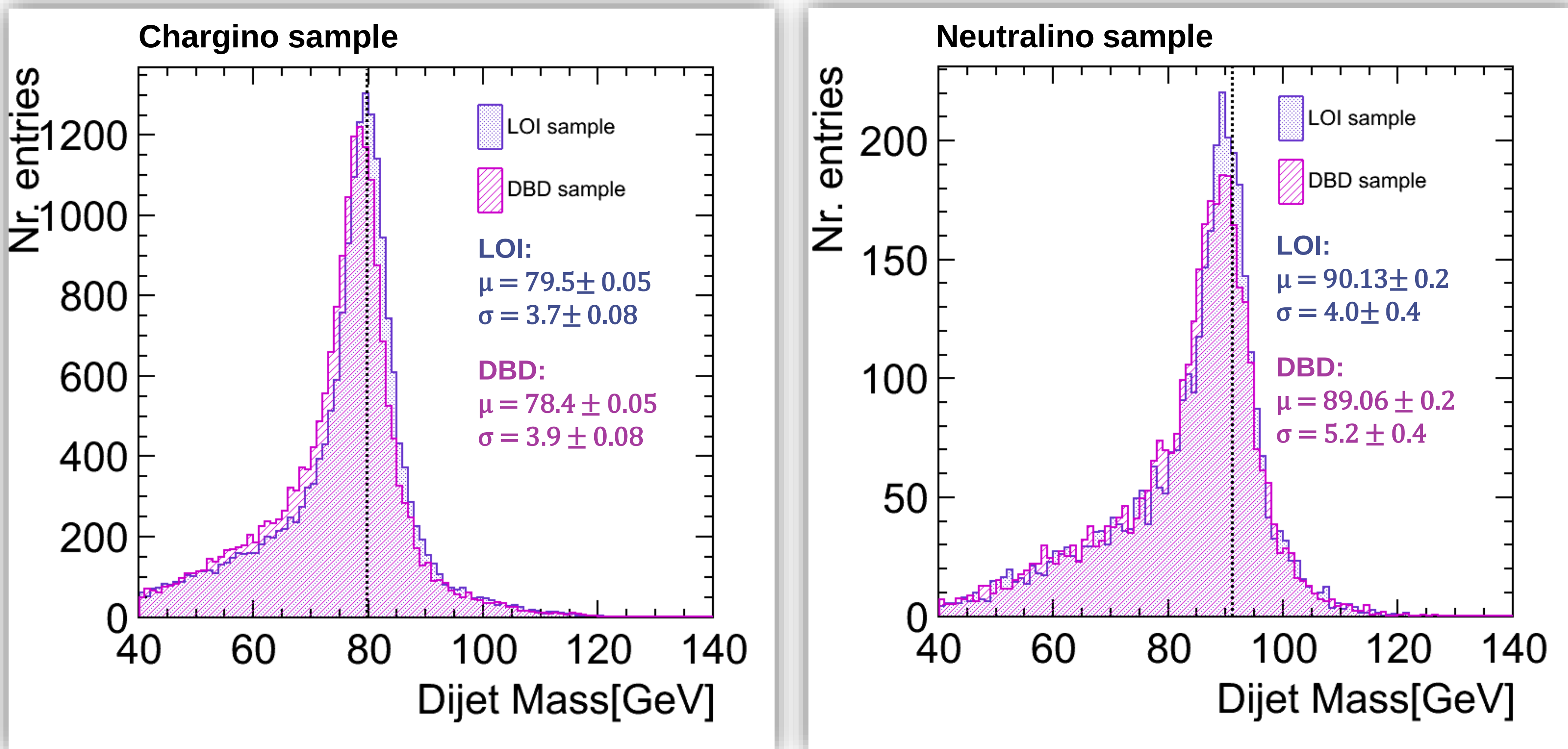




> The DBD distribution appears slightly shifted towards lower energies. Nevertheless, the two distributions agree very well.

Dijet [Boson] Mass Comparison – LOI to DBD

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

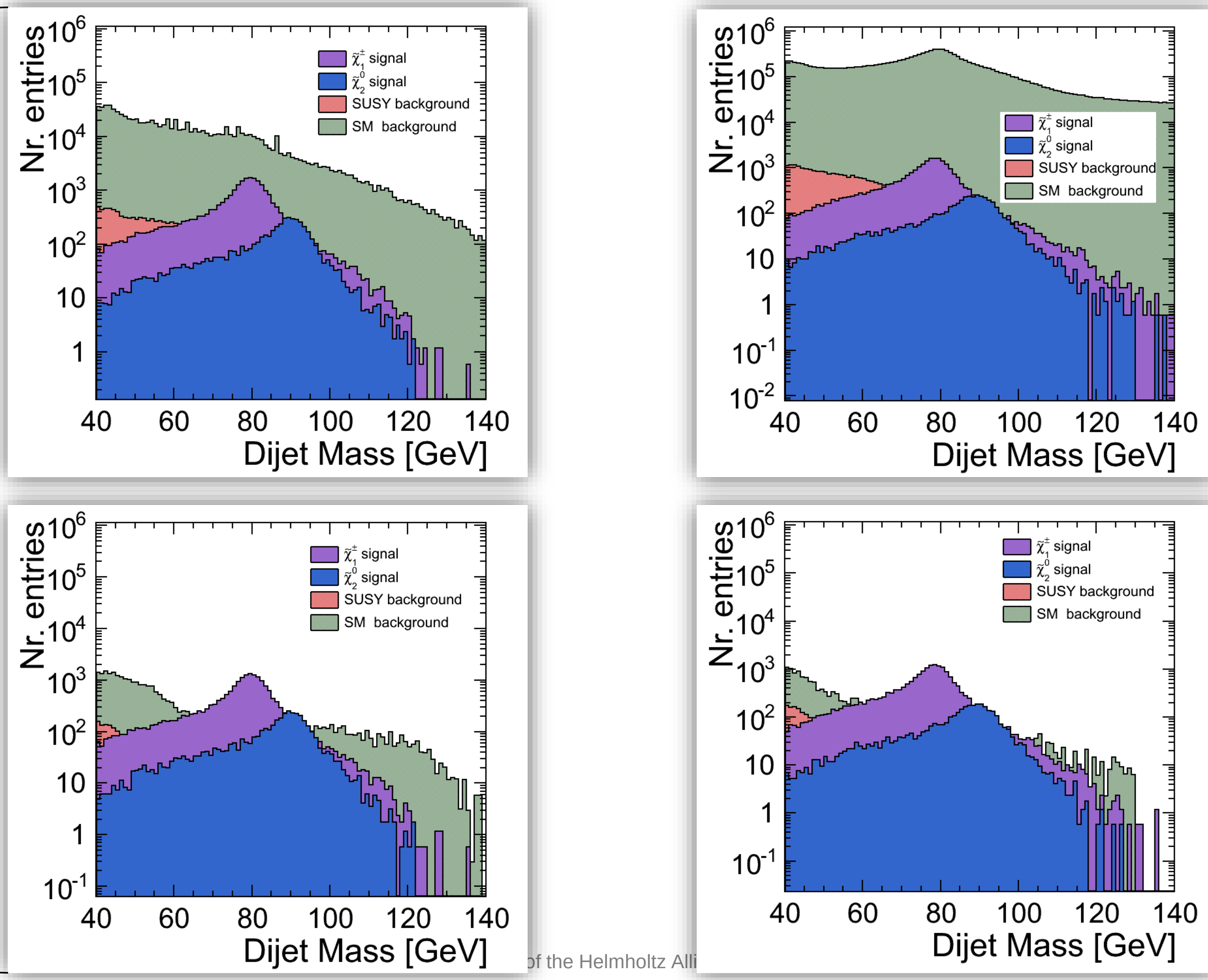


> The DBD distribution appears slightly narrower and shifted towards lower energy, however the DBD and LOI distributions are compatible with each other.

Preselection Outcome

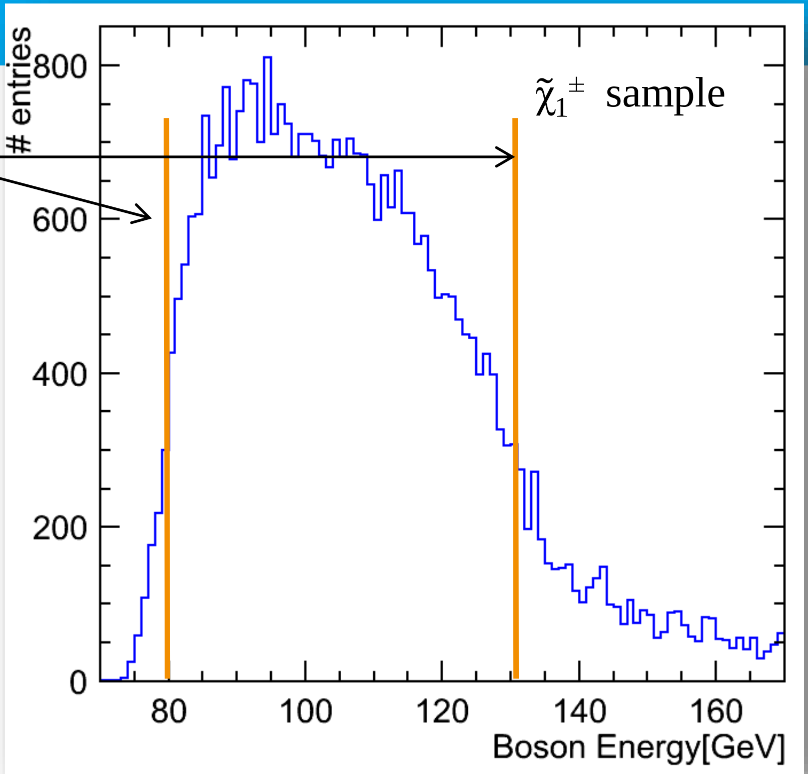
LOI

DBD



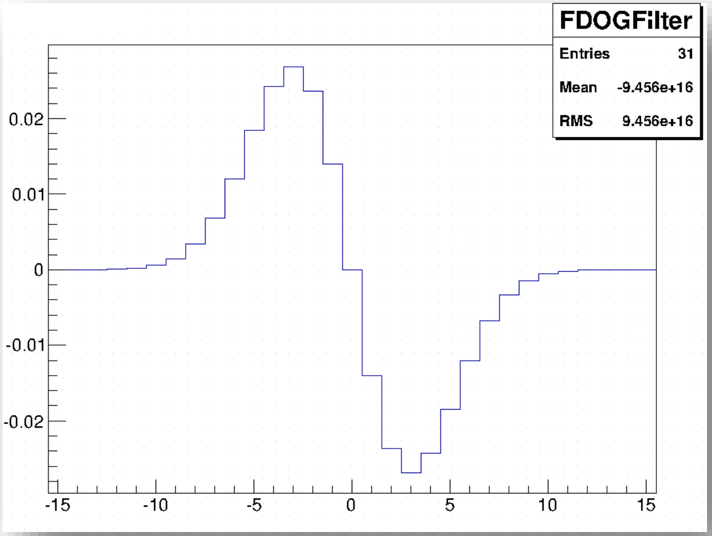
Applying an FIR Filter

- Goal: find edge positions in spectrum



Applying an FIR Filter

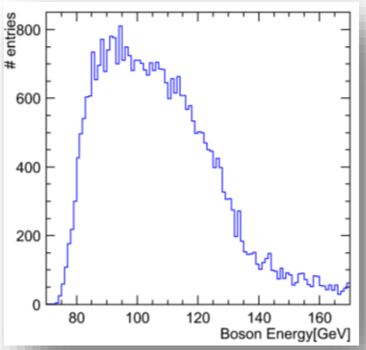
- Goal: find edge positions in spectrum
- Strategy:
  - Choose an FIR filter
  - Note: filter length << signal histogram length



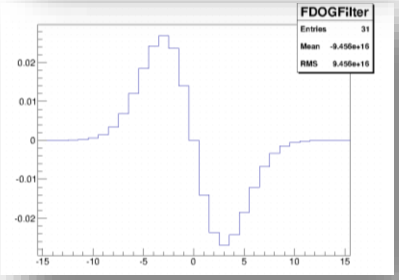
Applying an FIR Filter

- Goal: find edge positions in spectrum
- Strategy:
  - Choose an FIR filter
  - Note: filter length << signal histogram length
  - Treat both signal histogram as well as filter as **arrays**:

Bin #	1	2	3	...	98	99	100
Signal	0	15	28	...	34	22	4



Bin #	1	2	3	...	28	29	30
Filter	0	0.01	0.02	...	-0.02	-0.01	0



Applying an FIR Filter

- Goal: find edge positions in spectrum
- Strategy:
  - Choose an FIR filter
  - Note: filter length << signal histogram length
  - Treat both signal histogram as well as filter as **arrays**
  - Calculate dot product between **Signal** and **Filter → obtain one value**

Bin #	1	2	3	...	98	99	100
Signal	0	15	28	...	34	22	4

Bin #	1	2	3	...	28	29	30
Filter	0	0.01	0.02	...	-0.02	-0.01	0

$$0 \times 0 + 0.01 \times 15 + 0.02 \times 28 + \ldots = \text{val1}$$

Applying an FIR Filter

- Goal: find edge positions in spectrum
- Strategy:
  - Choose an FIR filter
  - Note: filter length << signal histogram length
  - Treat both signal histogram as well as filter as arrays
  - Calculate dot product between Signal and Filter → obtain one value

Bin #	1	2	3	...	98	99	100
Signal	0	15	28	...	34	22	4

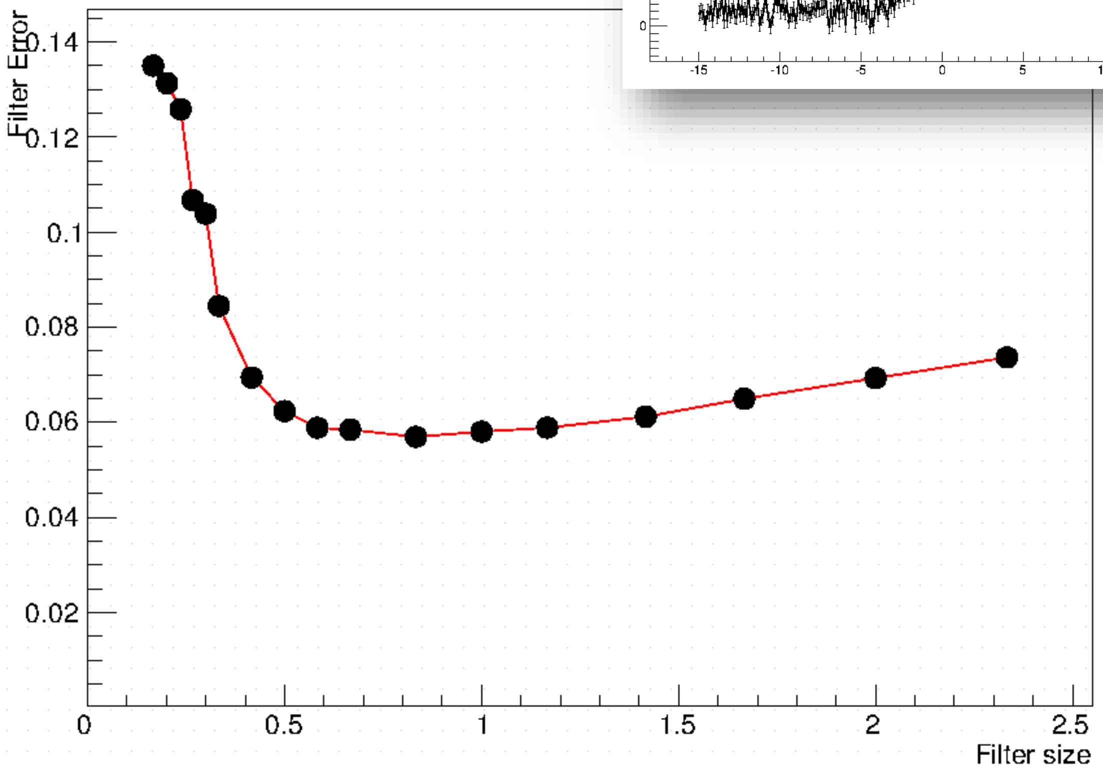
Bin #	1	2	3	...	28	29	30
Filter	0	0.01	0.02	...	-0.02	-0.01	0

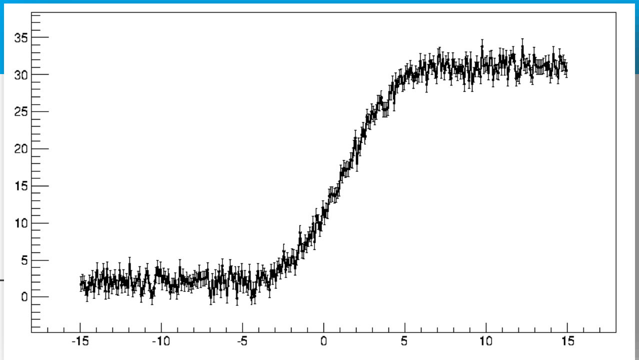
$$0 \times 15 + 0.01 \times 28 + \ldots = \mathrm{val2}$$

  - **“Move“ Filter along the (length) of the signal → obtain more values, which will form the total filter response**

Testing the FDOG Filter

Studied the effect of the filter size on a smeared step edge Monte Carlo data.

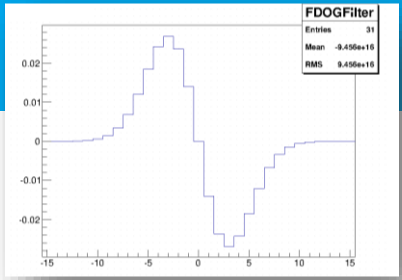


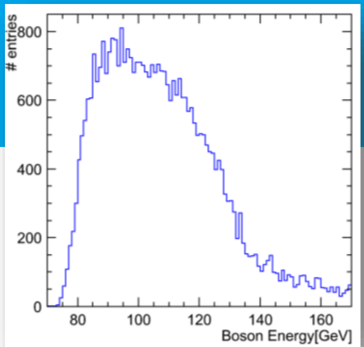


S. Caiazza

The FDOG filter does indeed perform best.
The filter size should be comparable to the size of the edge feature.
We chose $\sigma = 5$ bins.

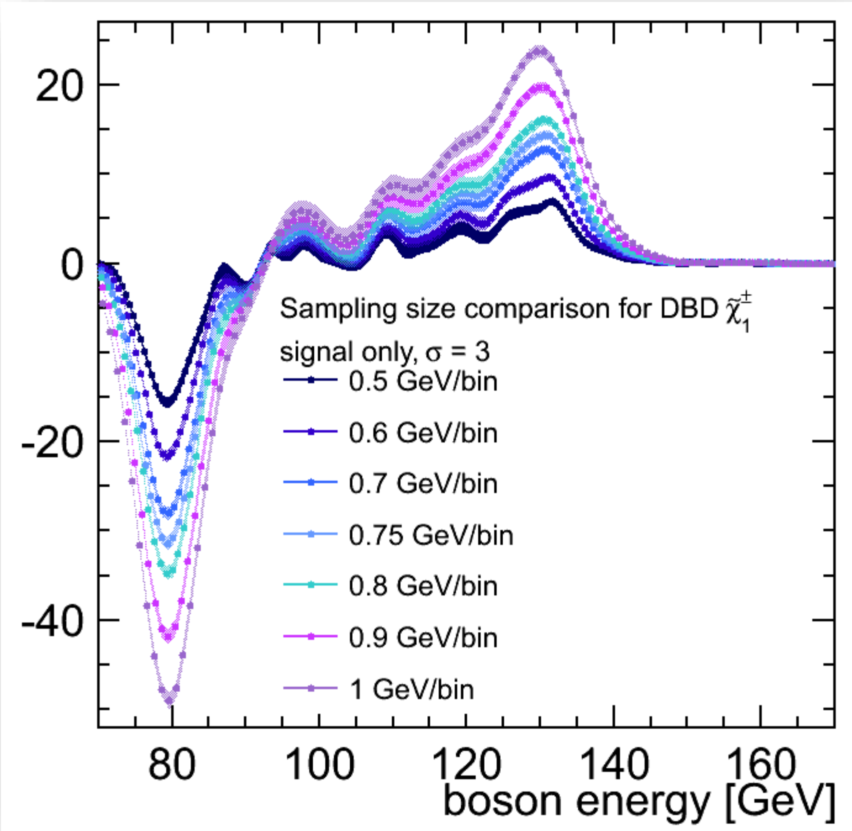
Testing the FDOG Filter

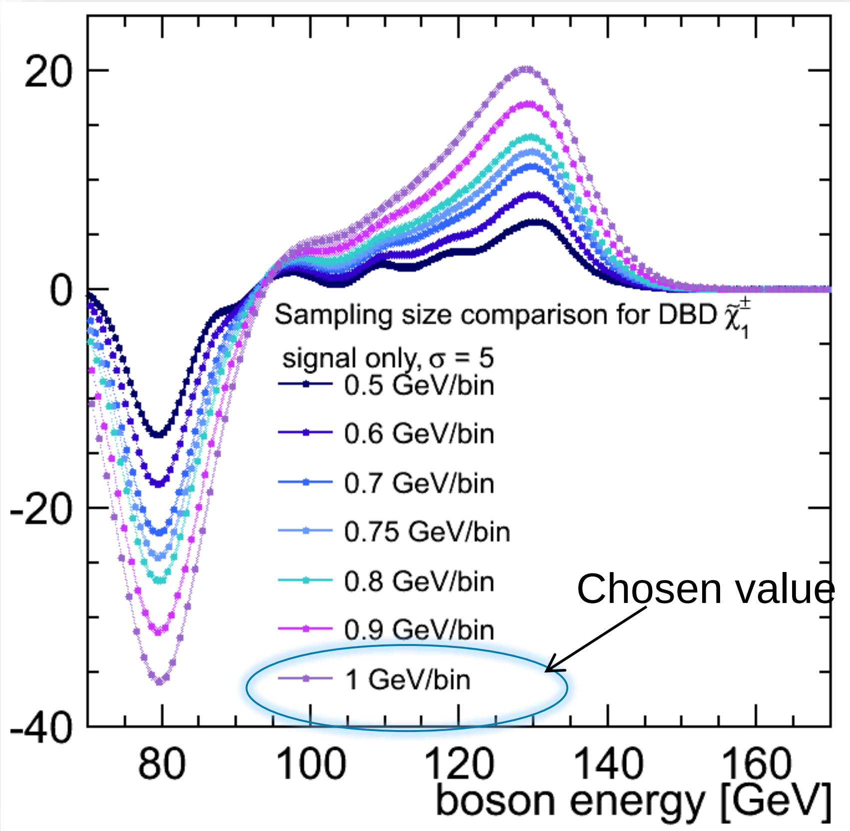




- There are two important filter characteristics that must be optimised: the bin size and the filter size.

Filter response after applying the FDOG Filter to the $\tilde{\chi}_1^{\pm}$ energy distribution:



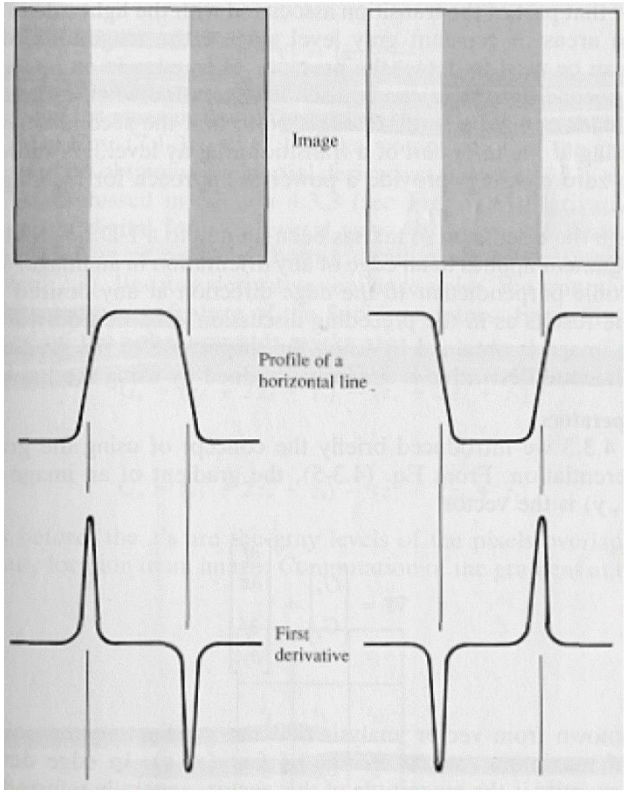


Applying an FIR Filter – Example: the box function

- The changes of a function can be described by the derivative → interpret the histogram as a 1D function
- The points that lie on the edge of the distribution → detected by local maxima and minima of the first derivative

$$f'(x) = \lim_{h \to 0} \frac{f(x+h) - f(x)}{h} \approx f(x+1) - f(x) \quad (h = 1)$$

- The first derivative is approximated by using the **kernel [-1, 0, 1]**



Applying an FIR Filter – Example: the box function

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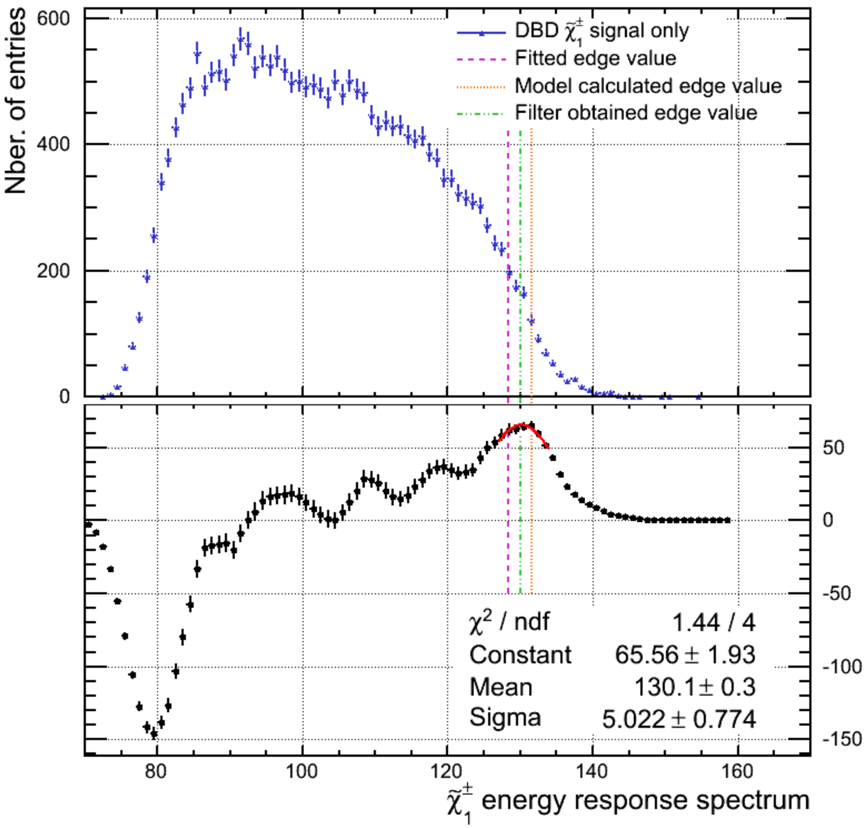
$$f'(x) = \lim_{h\to 0}\frac{f(x+h)-f(x)}{h} \approx f(x+1)-f(x) \quad (h=1)$$

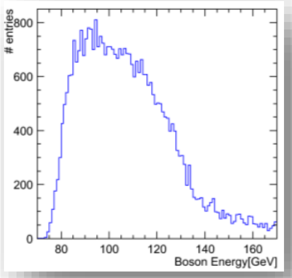
- The first derivative is approximated by using the **kernel [-1, 0, 1]**
- The kernel is convoluted with the histogram:

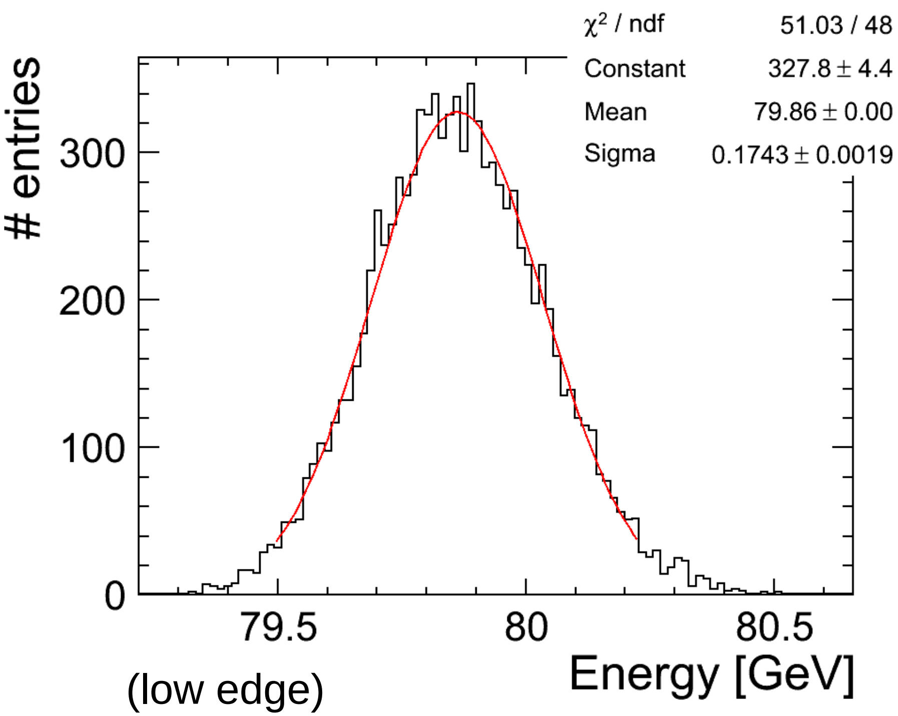
$$response_i = -1 \times bin_{i-1} + 0 \times bin_i + 1 \times bin_{i+1}$$

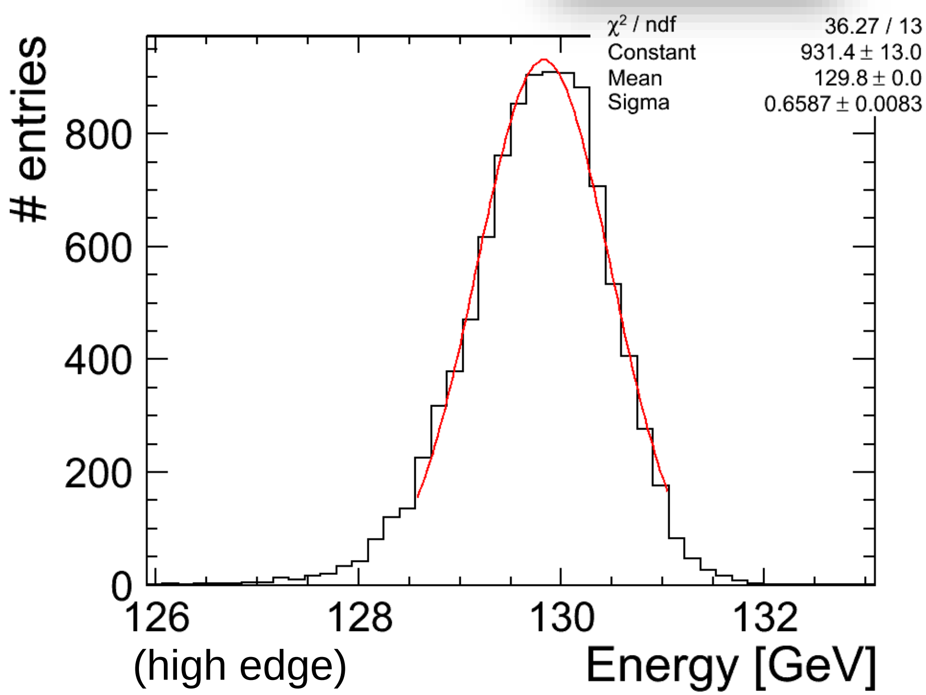


Toy MC for the Filter Edge Extraction

- To estimate the statistical precision of the edge extraction → toy MC
- 10000 $\tilde{\chi}_1^\pm$ and $\tilde{\chi}_2^0$ energy spectra have been produced
- The FDOG filter was then applied 10000 times
- Example: for the $\tilde{\chi}_1^\pm$ case:





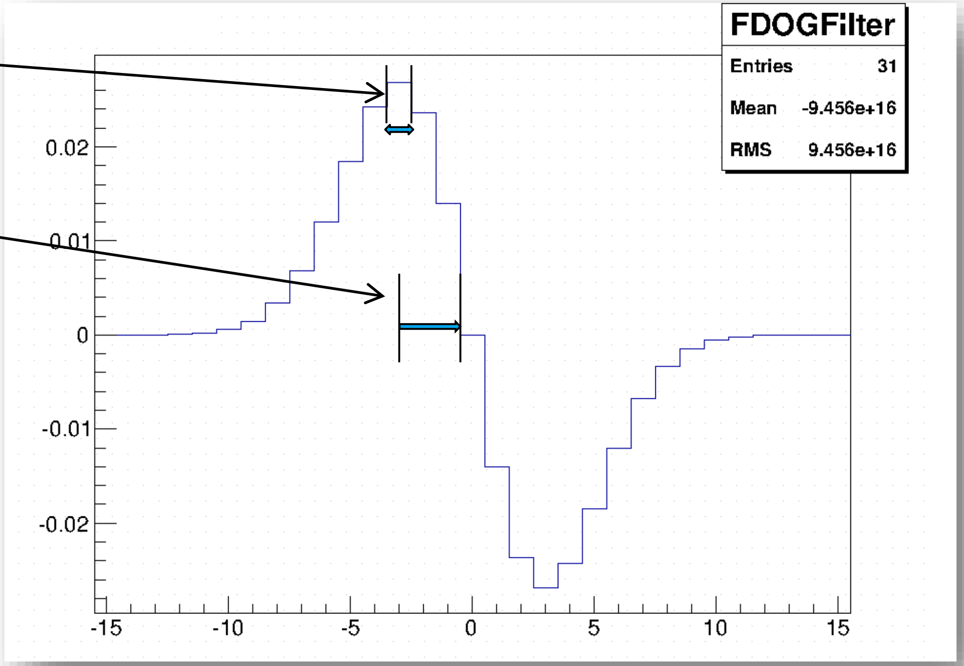


Testing the FDOG Filter

> There are two important filter characteristics that must be optimised:

the bin size

the filter size



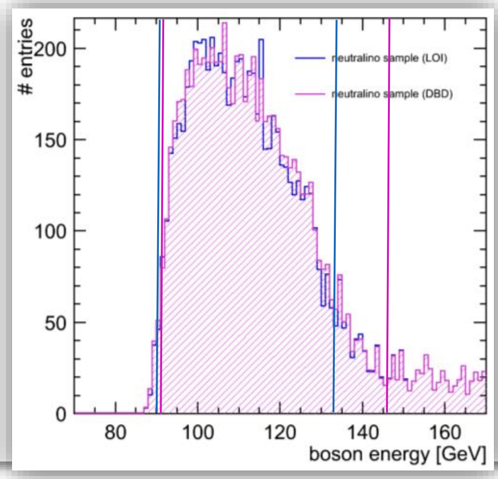
It is crucial to strike the right balance between the two:

- If the bin size is too small → the filter picks up a lot of statistical fluctuations
- If the filter size is too large → the edge position cannot be localised anymore

A toy MC study has been performed to optimise the filter and bin size.

Issues of the „Endpoint Method“

```
FCN=59.9958 FROM MIGRAD    STATUS=CONVERGED     813 CALLS       815 TOTAL
                     EDM=2.74963e-05    STRATEGY= 1  ERROR MATRIX UNCERTAINTY   1.5 per cent
 EXT PARAMETER                PARABOLIC        MINOS ERRORS
NO.   NAME      VALUE          ERROR      NEGATIVE      POSITIVE
1  p0        7.25426e+01   2.24546e+01
2  p1        2.13268e+01   1.04688e+01
3  p2        0.00000e+00    fixed
4  p3       -1.06699e+00   2.46836e-01
5  p4        9.12861e+01   6.03729e-01
6  p5        1.46148e+02   4.78189e+00
7  p6        3.49626e-01   1.53170e+00
8  p7        8.51573e+00   2.24546e+00
9  p8        3.41940e-01   1.25555e+00
10  p9        9.12000e+01    fixed
```



Sim.	Edge W_{low} [GeV]	Edge W_{high} [GeV]	Edge Z_{low} [GeV]	Edge Z_{high}[GeV]
DBD	79.5±0.5	130.2±1.1	91.3±0.6	146.1±4.8
LOI	79.7±0.3	131.9±0.9	91.0±0.7	133.6±0.5

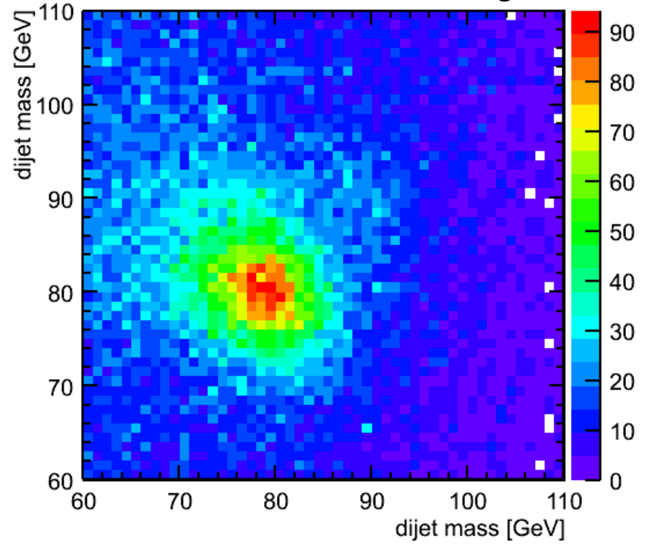
The fitting method appears to be highly dependent on small changes in the fitted distribution → it is clearly NOT appropriate for a comparing the simulation and reconstruction performance.

We need to apply a different edge extraction method!

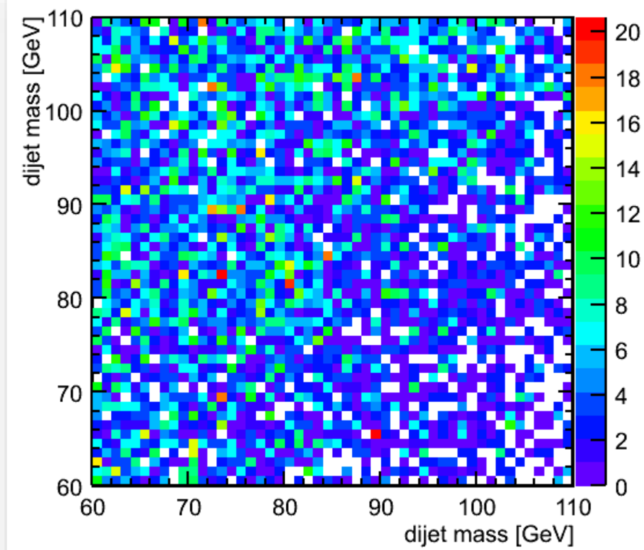
3.2. $\tilde{\chi}_1^\pm$ and $\tilde{\chi}_2^0$ Cross Section Measurement
3.2.2. 2D dijet mass fit

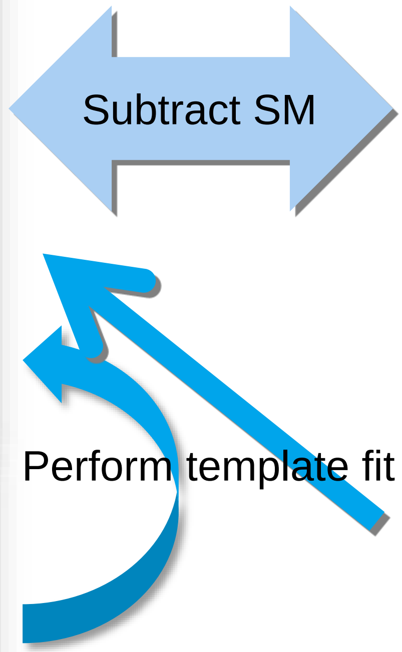
Example: DBD sample

Distribution for SM + all signal



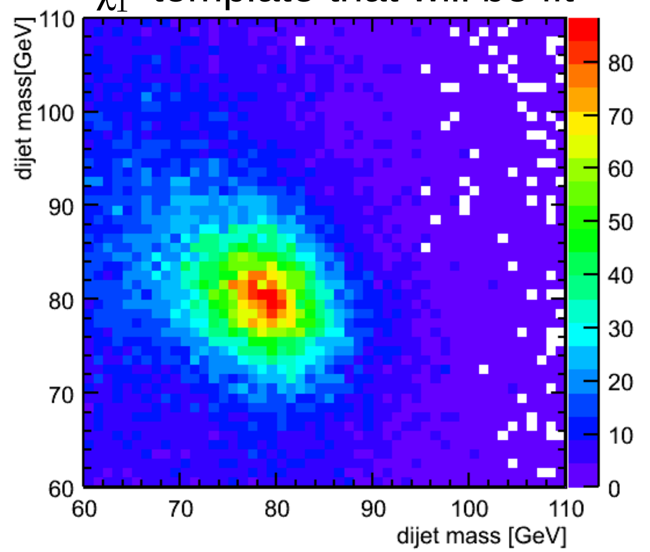
sm



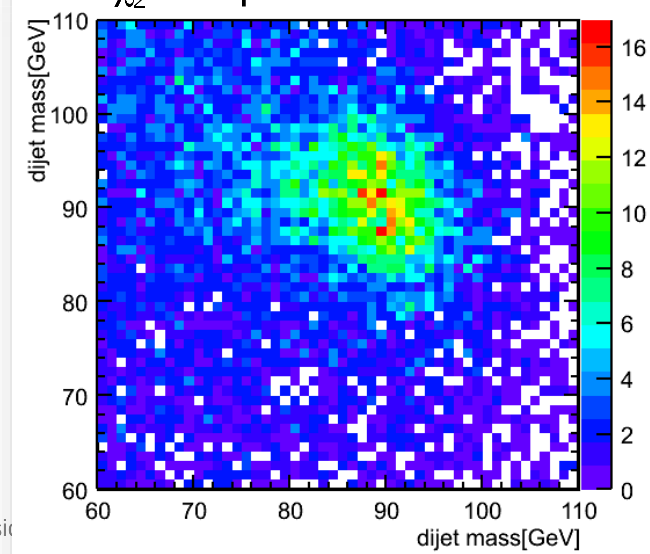


Perform template fit

$\tilde{\chi}_1^\pm$ template that will be fit



$\tilde{\chi}_2^0$ template that will be fit



Outline

1. Introduction – Particle Flow
2. Different implementations of PandoraPFA (`LOI` & `DBD`)
3. Gaugino Pair Production as Physics Study Case
4. Analysis Strategy
5. Treating the $\gamma\gamma$ Background
6. Mass Measurement Comparison
7. Conclusions & Outlook