ADVANCED DIFFERENTIAL METHODS FOR THE MEASUREMENT OF KINEMATIC EDGES

And their application to the lepton colliders SUSY measurement

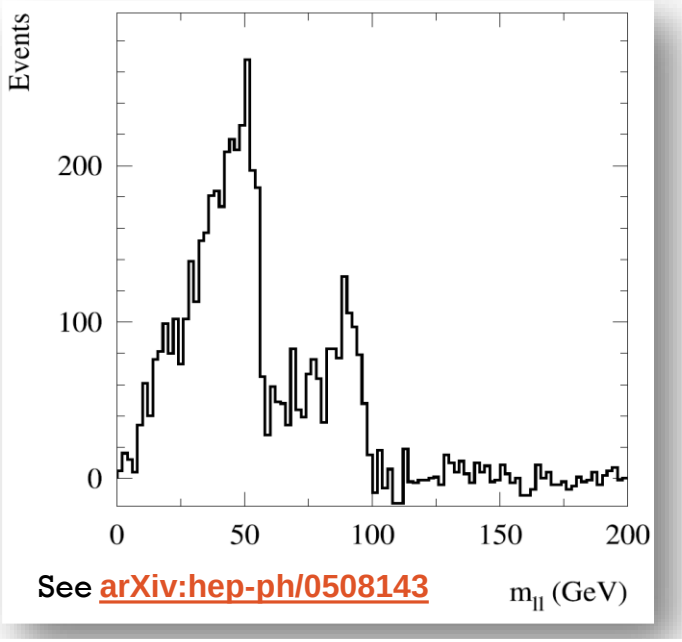
KINEMATIC EDGES

Model independent signature

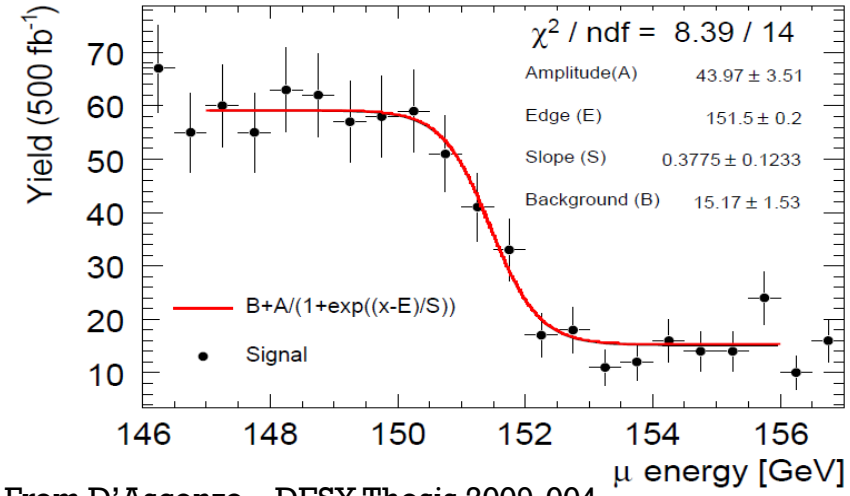
- Position depends only on kinematics (special relativity)
- Specific interaction irrelevant

BSM searches

- Many searches rely on the identification and measurement of kinematic edges



See arXiv:hep-ph/0508143



From D'Ascenzo – DESY Thesis 2009-004

KINEMATIC EDGES MEASUREMENT

Fitting an arbitrary function

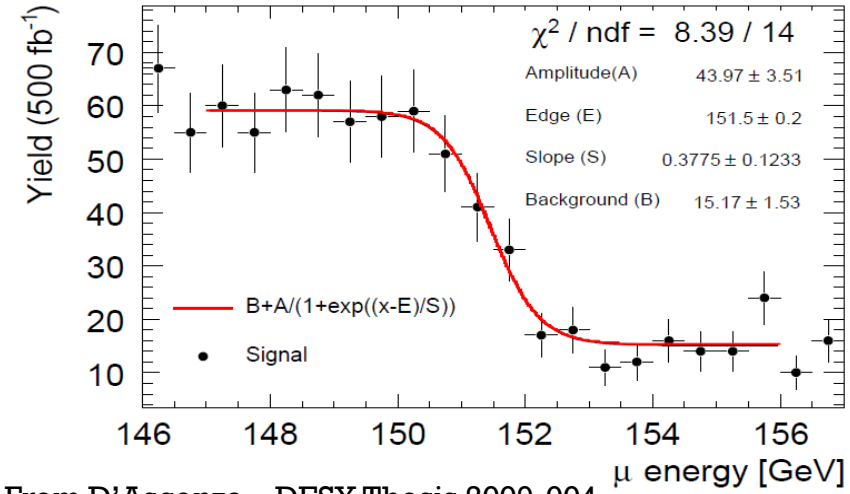
- Typically no physical reason behind the choice
- The function depends on the BG shape
- The function should depend on the "distortion sources"

End point detection

- Model independent
- Conceptually slightly different
- Important cross-check

What is an edge?

- Locus of the local maxima of the first derivative and 0 of the second derivative



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DIFFERENTIAL EDGE DETECTION

DIFFERENTIAL EDGE MEASUREMENT

Derivative regularization

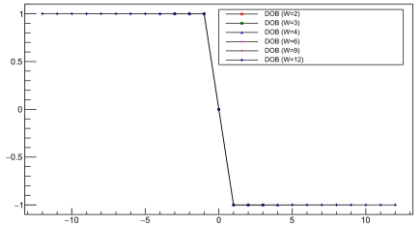
- The differential operator is not robust against noise
- Need some kind of preliminary smoothing
- Edge detection operator most used in image processing

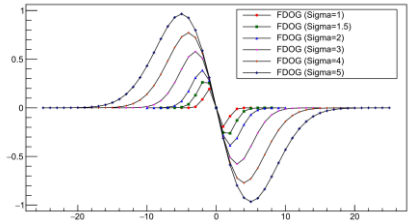
Implementation

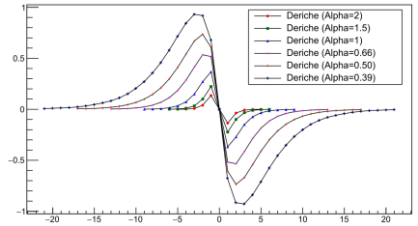
- Regularization and differential operator merged (filter)
- Convolution of the filter with the target function
- Measurement of the response peak position

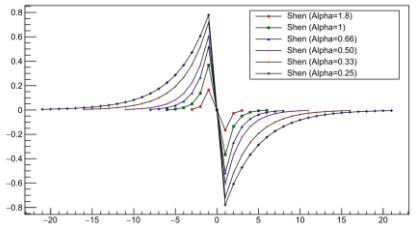
Implemented filters

- Difference of boxes: Moving average
- First derivative of a Gaussian: Gaussian smoothing
- Deriche: Continuous exponential smoothing
- Shen: Exponential smoothing with discontinuity at the origin









LOCALIZATION BENCHMARK PARAMETER

Definition

- The accuracy in the determination of the edge position in a noisy environment
- Measured with a toy MC by randomly fluctuating the template distribution within its errors

Bias

- The average distance between the true and measured position
- If different than 0 defines the calibration to apply to obtain the "true position"

Error

- RMS of the measured position
- Defines the measurement uncertainty

Depends on

- Peak interpolation algorithm
- Signal shape
- Filter size
- Signal to noise ratio

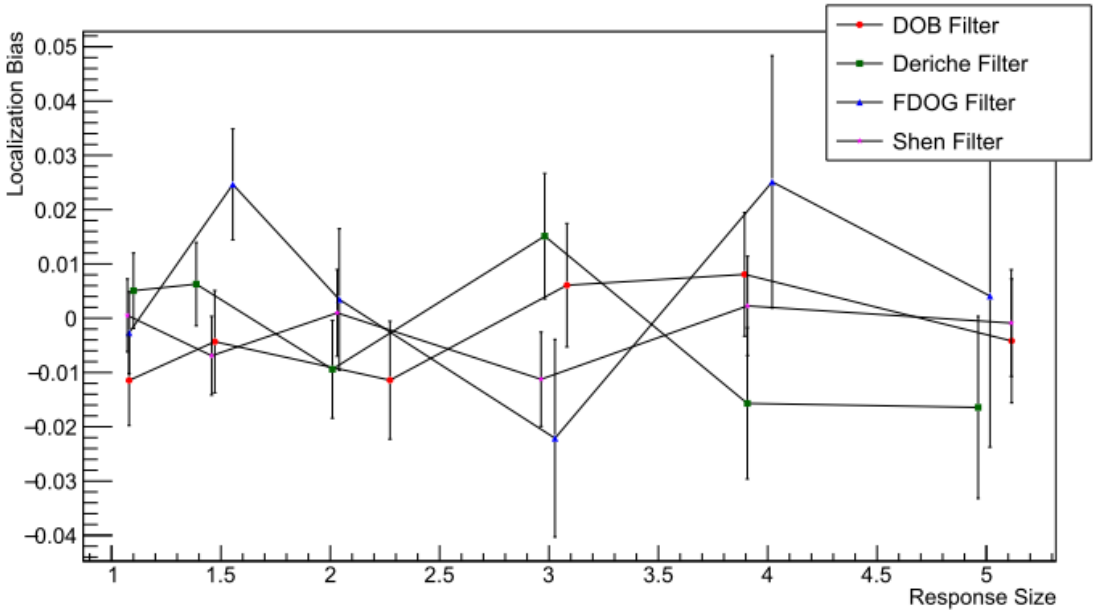
IDEAL STEP

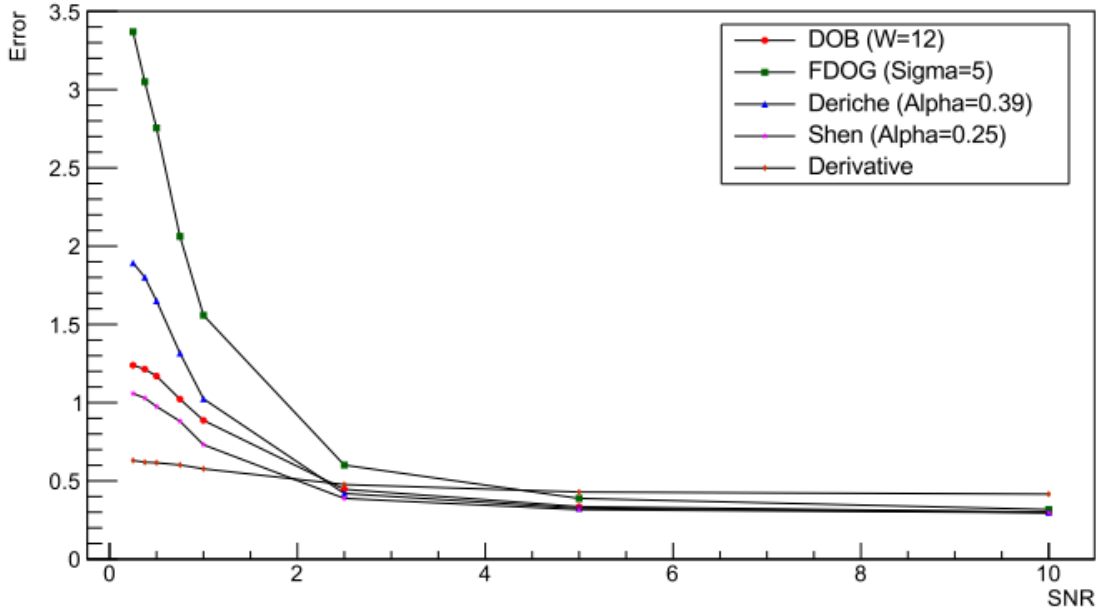
Bias compatible with 0

- Cross-check for the quality of the implementation

Asymptotic decrease

- Similar localization at high Signal-to-Noise ratio





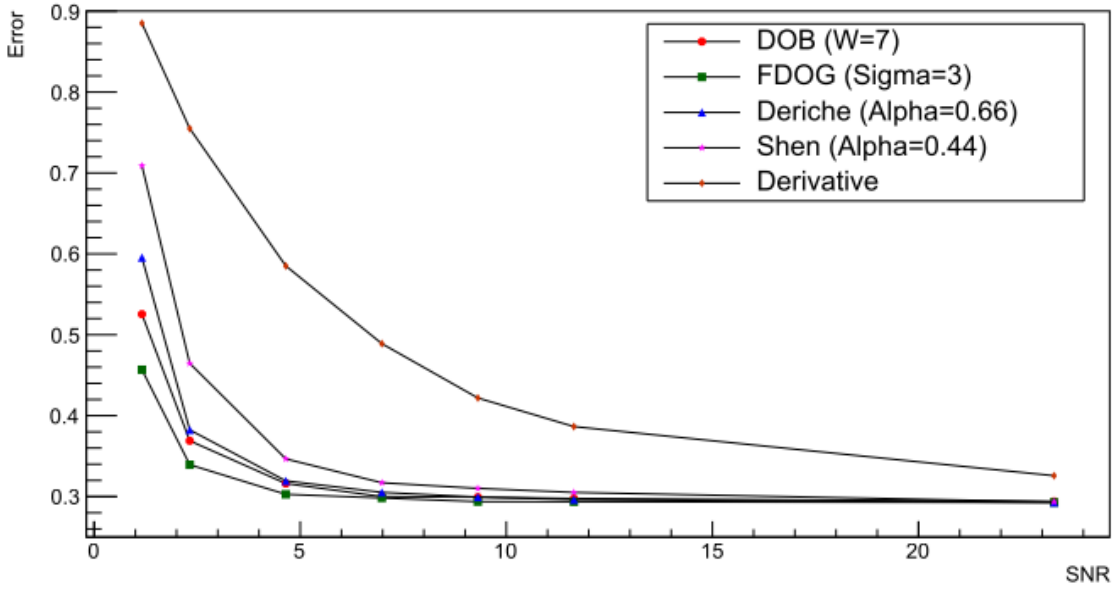
SMOOTH STEP

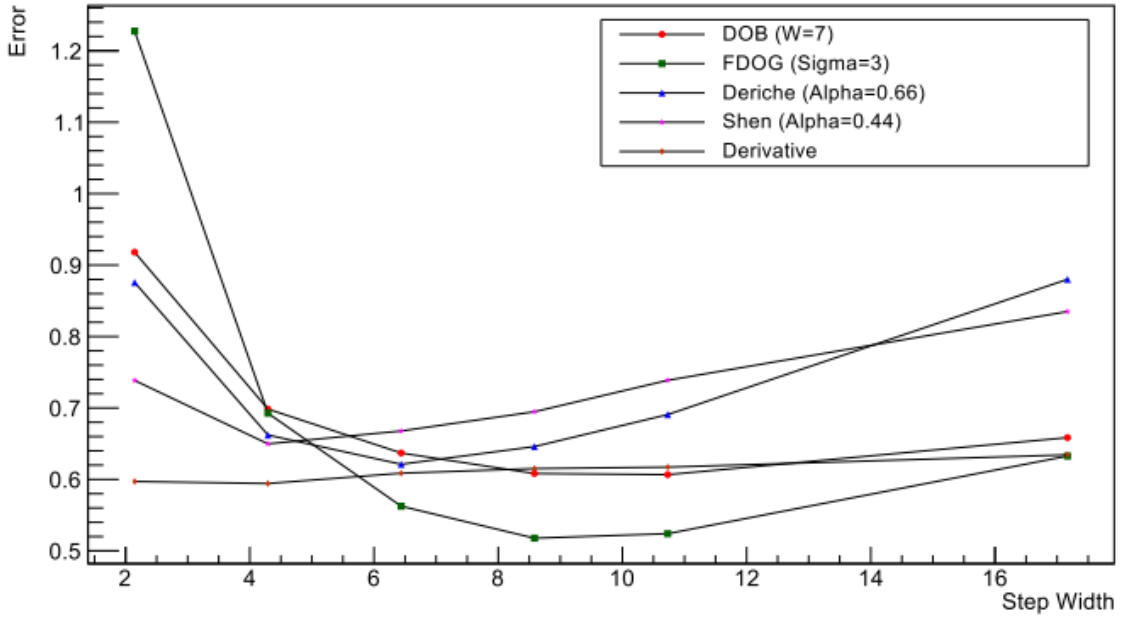
Asymptotic behavior

- Similar to the ideal case
- The common derivative now is much worse

Size optimization

- Error is minimized at fix width/size ratios
- Optimization depends on the filter type
- FDOG is typically the best at its optimal size.





SELECTRON-NEUTRALINO MASS MEASUREMENT

ILC SELECTRON PRODUCTION

Production processes

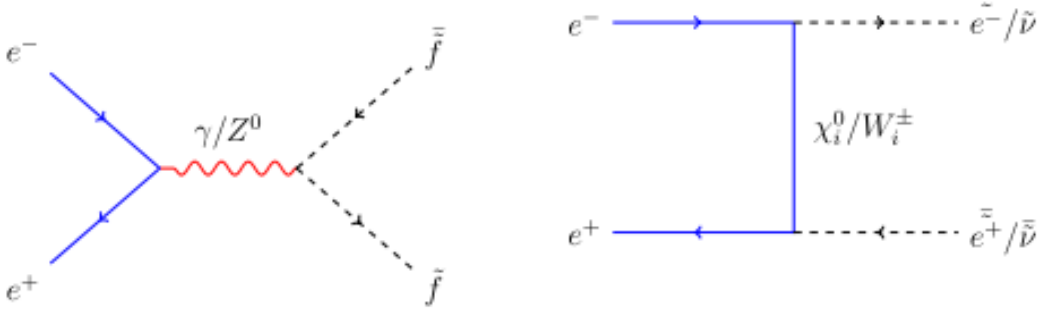
- Both s- and t- channel processes
- Constructive interference
- T-channel dominance

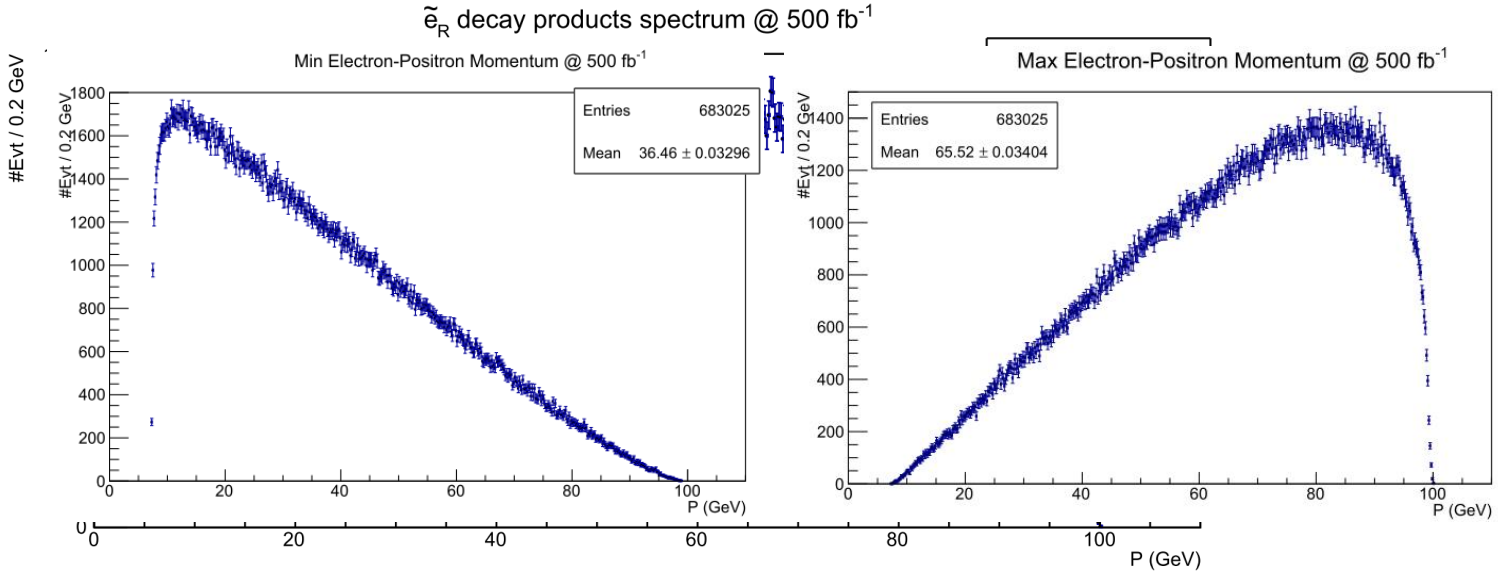
Kinematic edges

- Momentum edges depending on the SUSY masses
- 2 edges for 2 masses
- Separate measurement

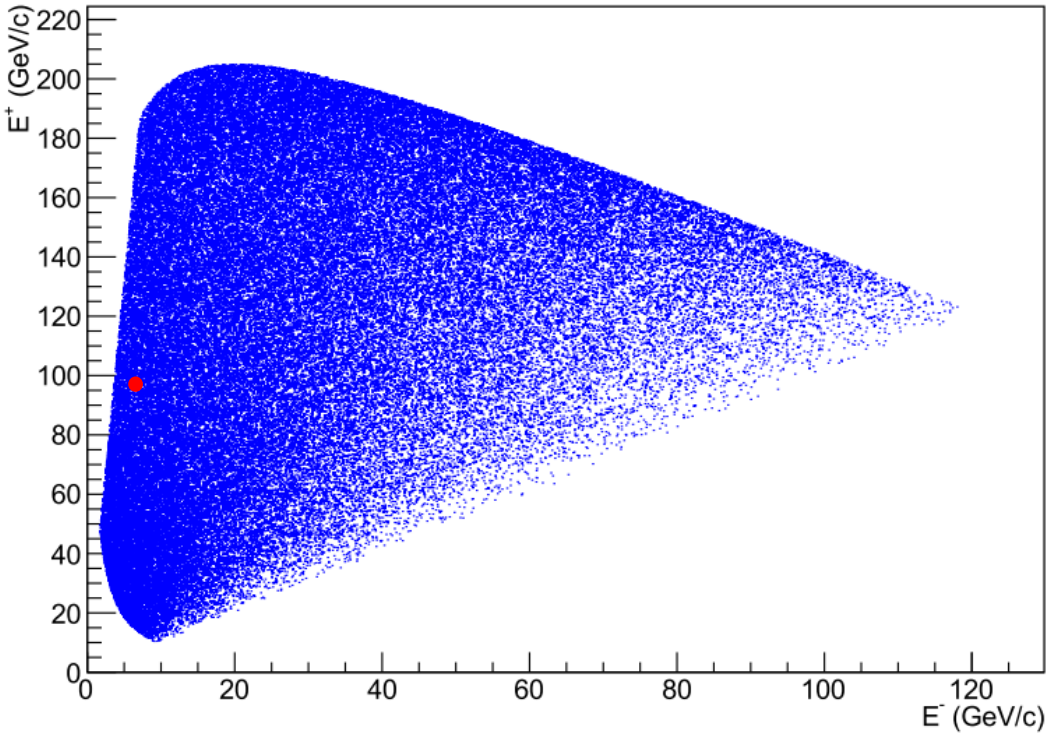
Experimental distortions

- Beamstrahlung
- ISR
- Detector reconstruction
- Selection





ANALYSIS LIMITS



LEP limits

- Neutralino mass > 46 GeV
- Selectron mass > 97.5 GeV
- Mass difference > 10 GeV

ILC parameters

- 500 GeV
- 500 fb^{-1}
- 80% right handed electrons
- 30% left handed positrons

Edge limits

- Max edge: 10-205 GeV
- Min edge: 2.5-120 GeV

STC4 SUSY Benchmark

- Selectron mass: 126.235 GeV
- Neutralino mass: 95.586 GeV

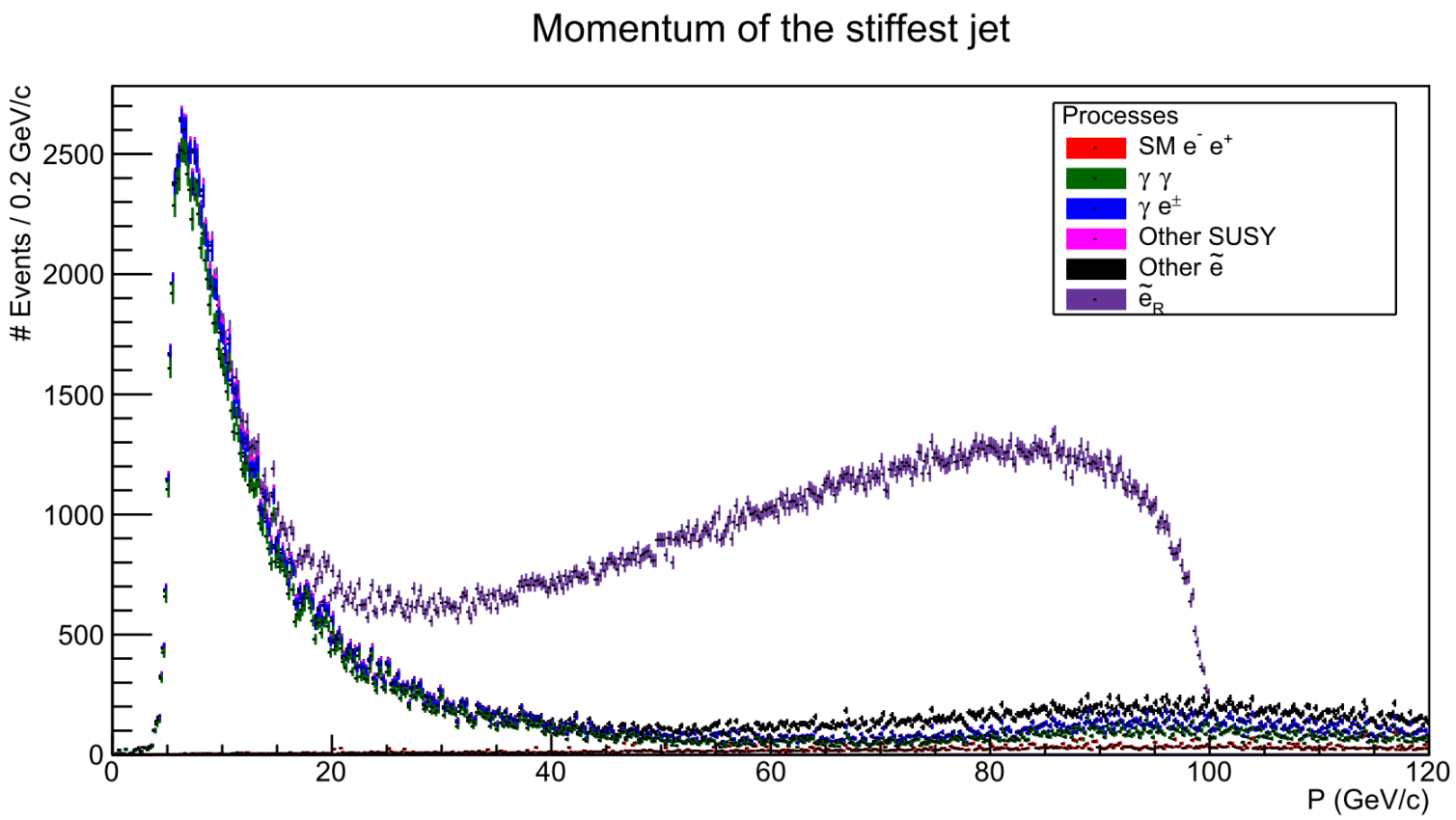
HIGH EDGE SELECTION

Optimized to reduce distortions of the high edge

- Low energy peak irrelevant
- Would work for almost all the available mass range
- About 82% acceptance of the signal sample

Edge position measurement

- Localization error: 42 MeV
- Localization bias: -605 MeV



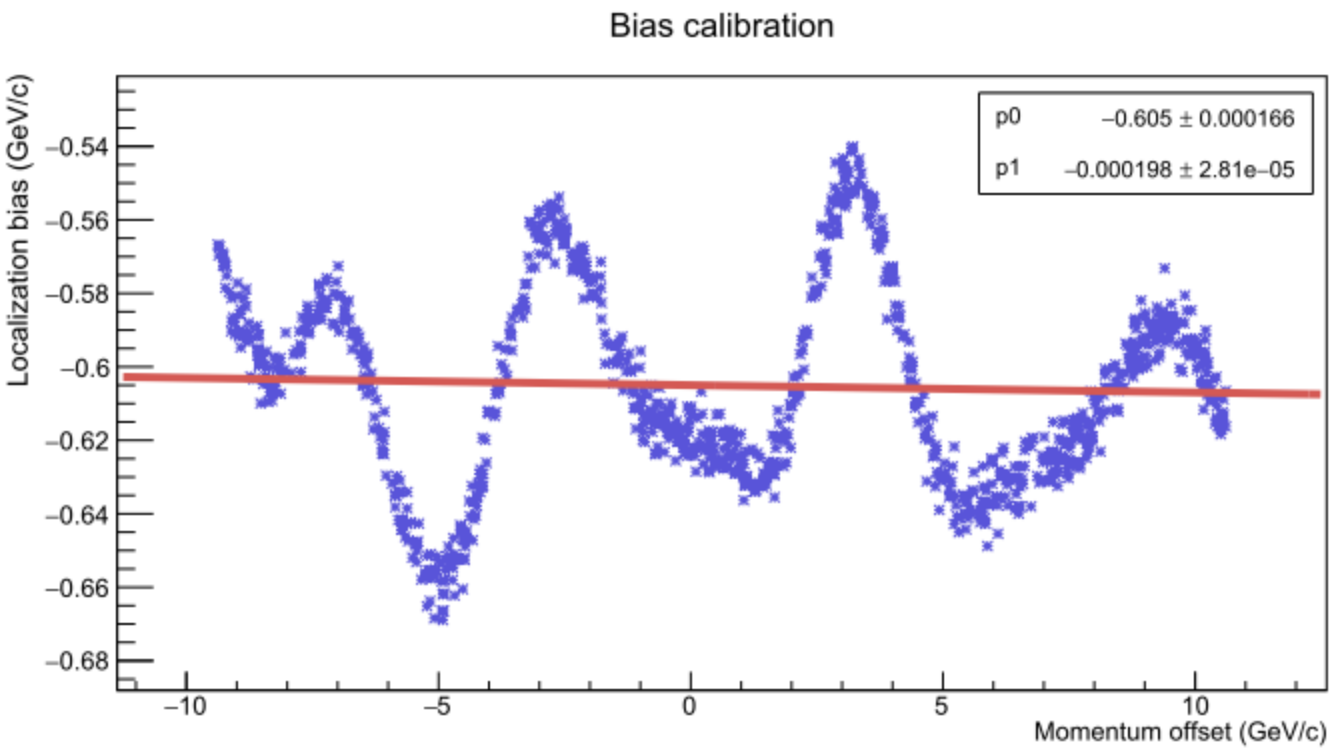
HIGH EDGE CALIBRATION

Technique

- Apply a random offset to the signal sample
- Adding the signal to a fixed background
- Using the new histogram as a template for the full edge measurement procedure

Result

- Flat calibration curve
- Fluctuation due to the background uncertainties
- Bias error (RMS of the results): 26 MeV



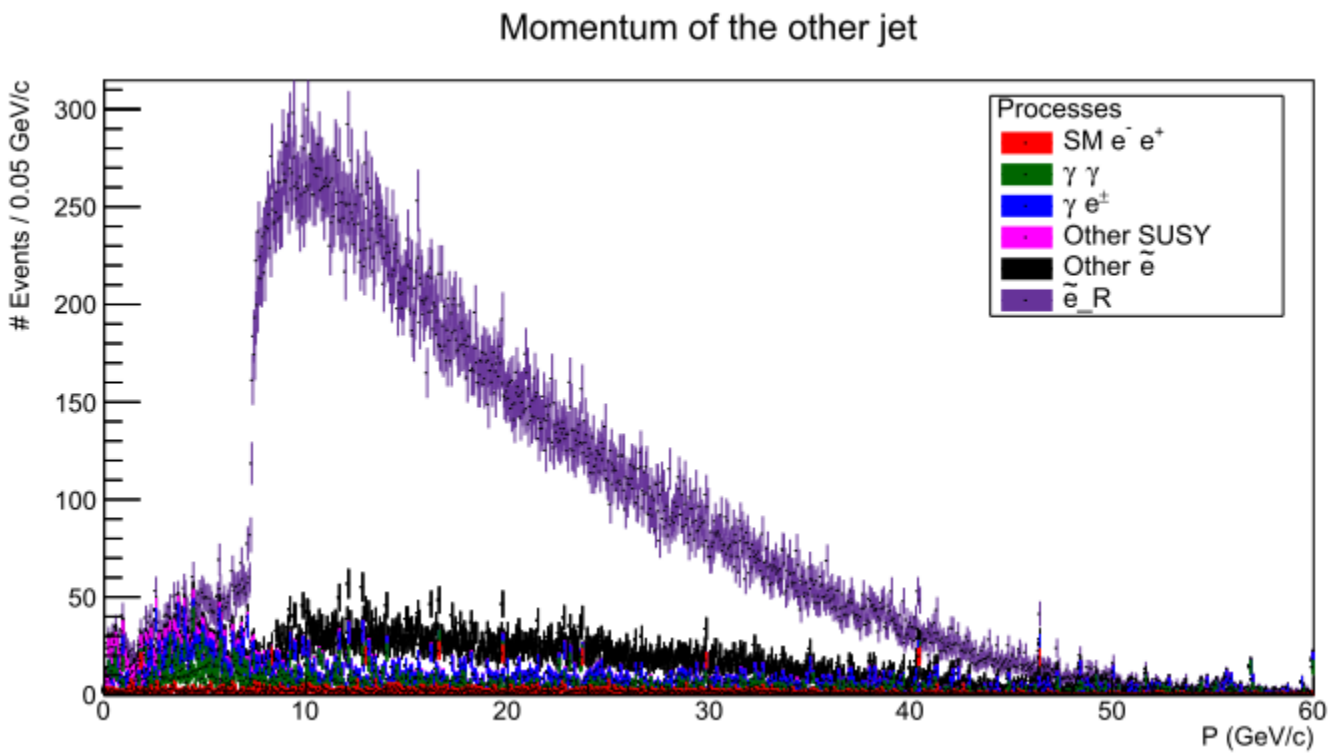
LOW EDGE SELECTION

Stricter analysis

- Removal of the low energy background
- Additional collinearity and coplanarity cuts
- 22% acceptance but 4.26 total signal purity

Edge position measurement

- Localization error: 14 MeV
- Localization bias: 94 MeV



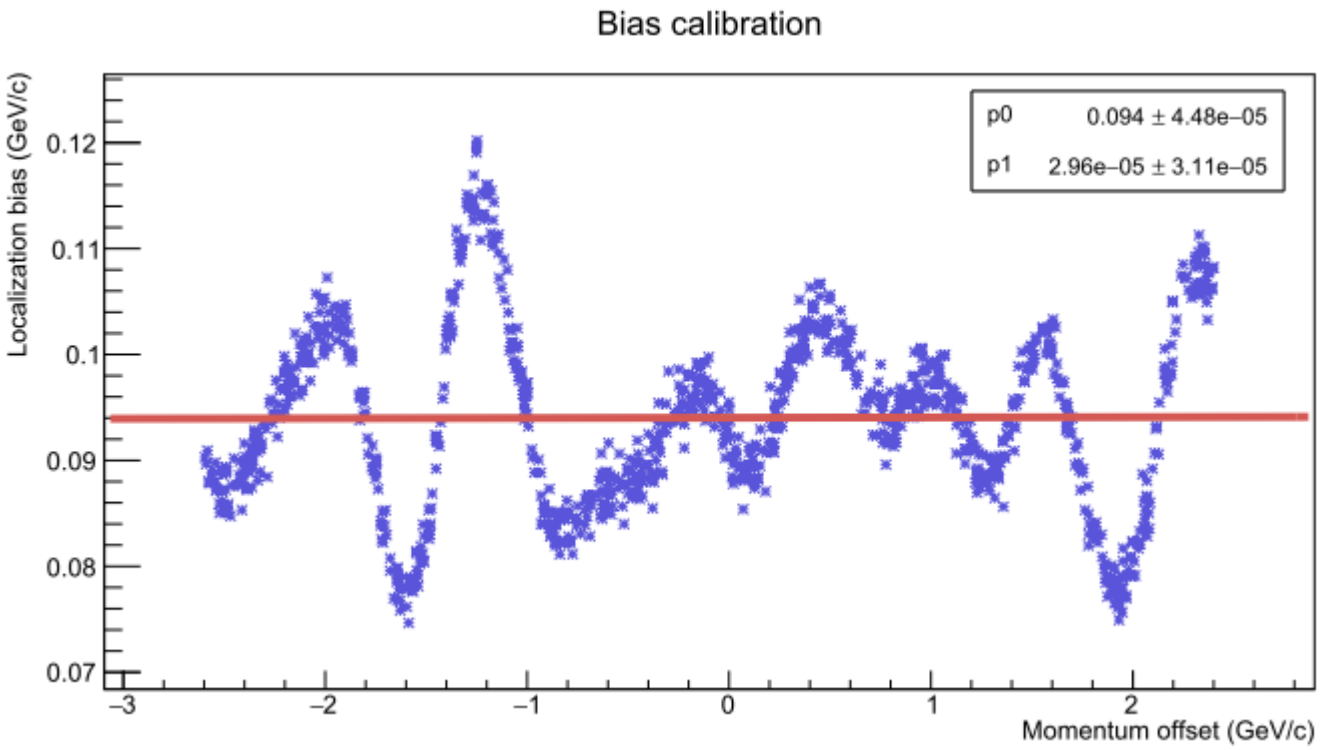
LOW EDGE CALIBRATION

Same technique as before

- Smaller range, proportional to the binning chosen

Results

- Flat calibration curve
- Bias error: 8.4 MeV



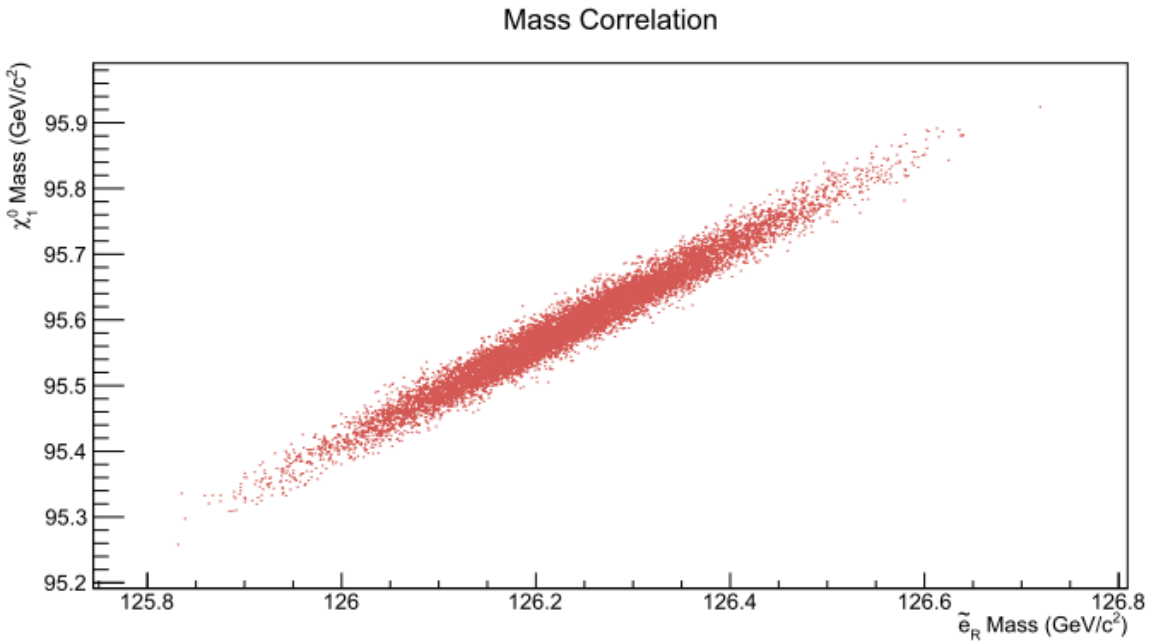
MASS MEASUREMENT

Procedure

- Use the final selection histograms as templates
- Generate a new pair for each data point and measure the edge position
- Subtract the bias, variable according to the calculated error
- Extract mass errors and correlations
- Consistent with analytic error propagation assuming edge positions as independent variables

Final results

- Measured selectron mass: 126.242 +- 0.119 GeV
- True selectron mass: 126.235 GeV
- Neutralino mass: 95.594 +- 0.091 GeV
- True neutralino mass: 95.586 GeV
- Covariance: 0.0106 GeV^2
- Correlation coefficient: 0.749



CONCLUSIONS

CONCLUSIVE SUMMARY

Differential operator is the most direct way to measure the position of an edge-like structure

- Differential operators must be made robust against noise to be applied to experimental distributions

Differential edge detection algorithm

- Robust differential operator
- Data-driven optimization procedure

Selectron-LSP mass measurement

- Applied to the STC4 SUSY benchmark point.
- Cut based analysis

Final results

- Selectron mass error: 119 GeV (was 210)
- Neutralino mass error: 91 GeV (was 160)

BACKUP

OPTIMIZATION PROCEDURE

MC Toy optimization

- Use the input distribution as a function template.
- Vary the input according to the template n times and measure the edge position to evaluate the localization error

Fixed binning

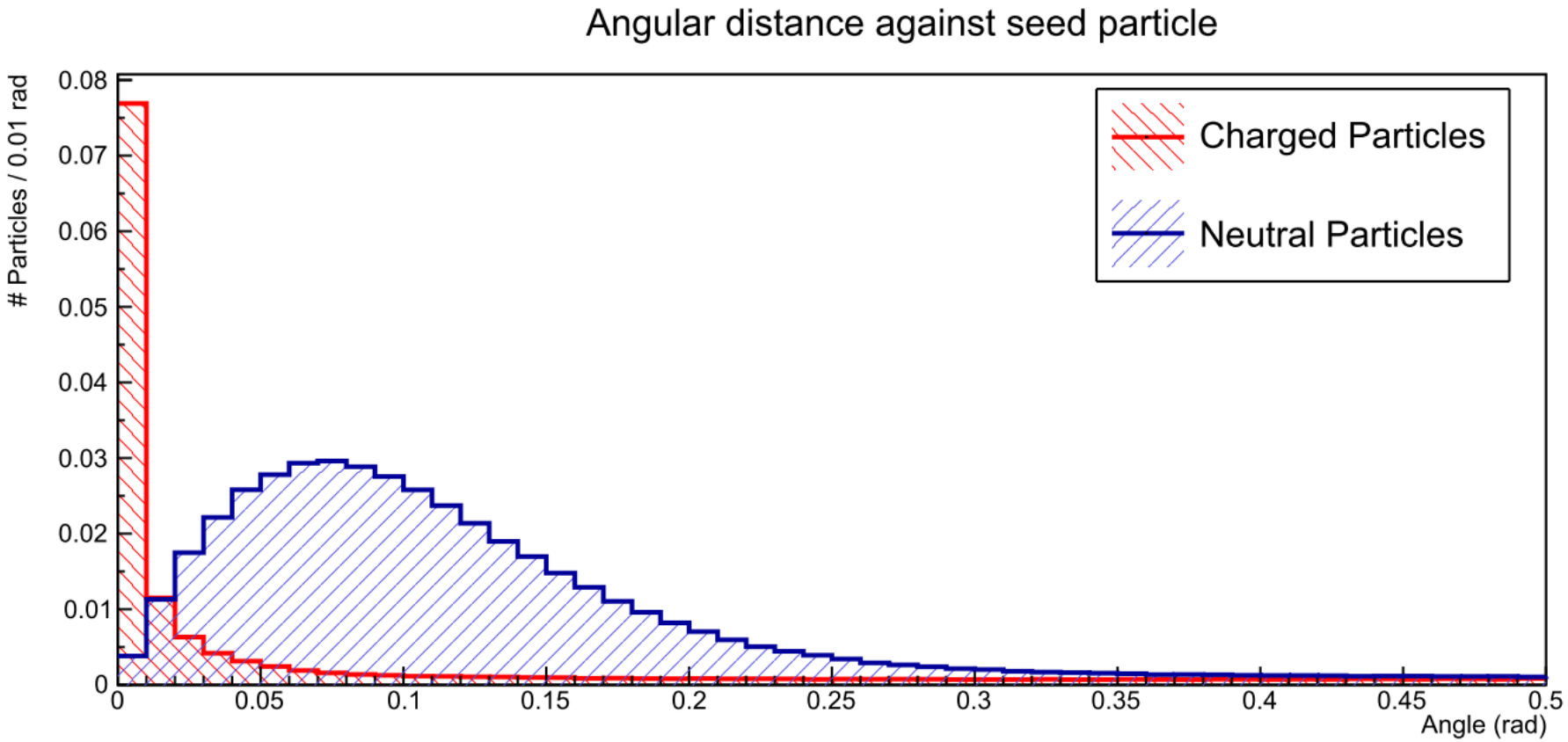
- Shen or Deriche for small features (depending on the noise amplitude)
- FDOG for extended edges

Variable binning (histograms)

- Optimize the binning to extend the edge size keeping the relative noise low enough
- Use the MC Toy optimization to minimize the error

ELECTRON MOMENTUM RECONSTRUCTION

ANGULAR DISTANCE – ZOOM IN



JET FINDER COMPARE