Energy Calibration for the $\mathcal{TWIST}$ Muon Decay Spectrum

Current Status and Future Directions

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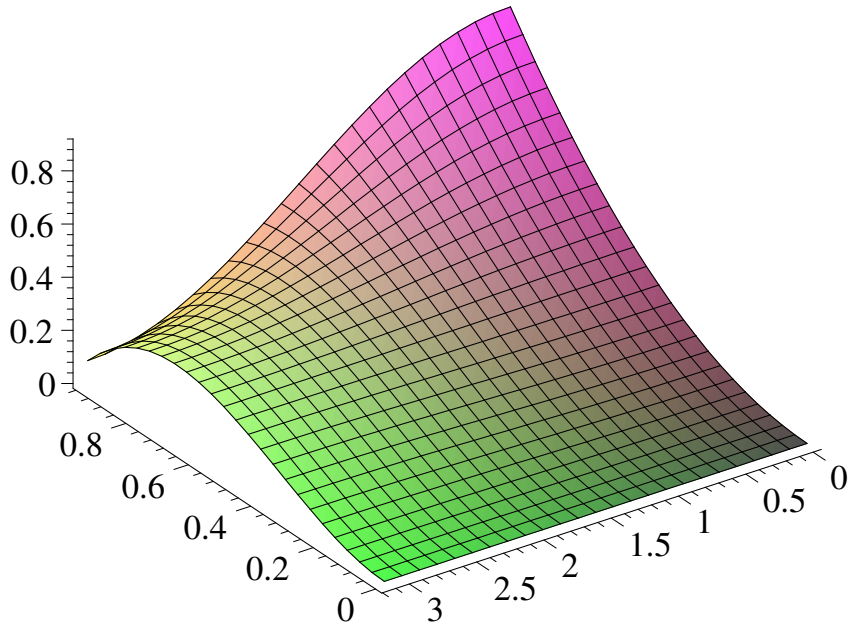
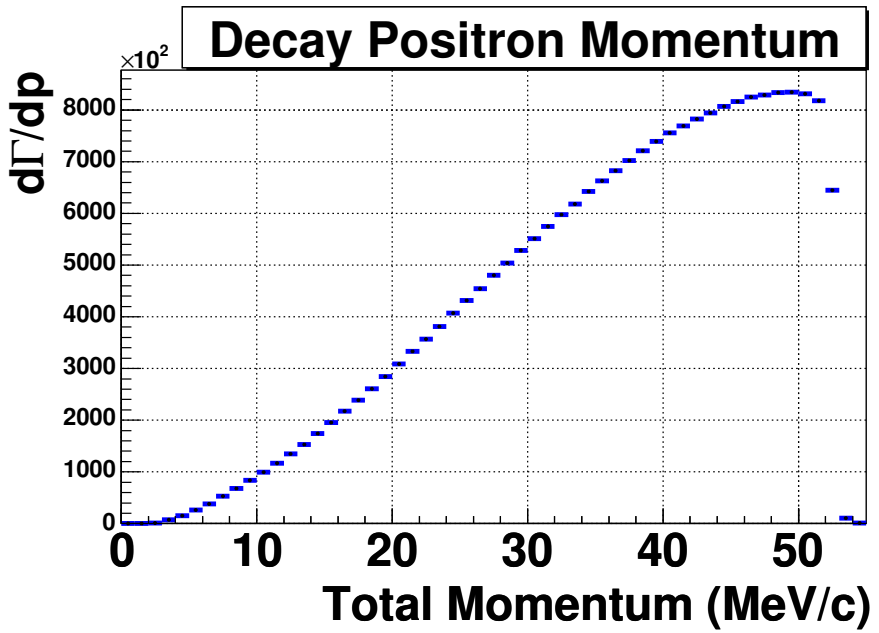
Introduction

- Brief description of $\mathcal{TWIST}$
- Analysis strategy in $\mathcal{TWIST}$: Role of energy calibration
- Measurement of energy calibration
- Issues and improvements

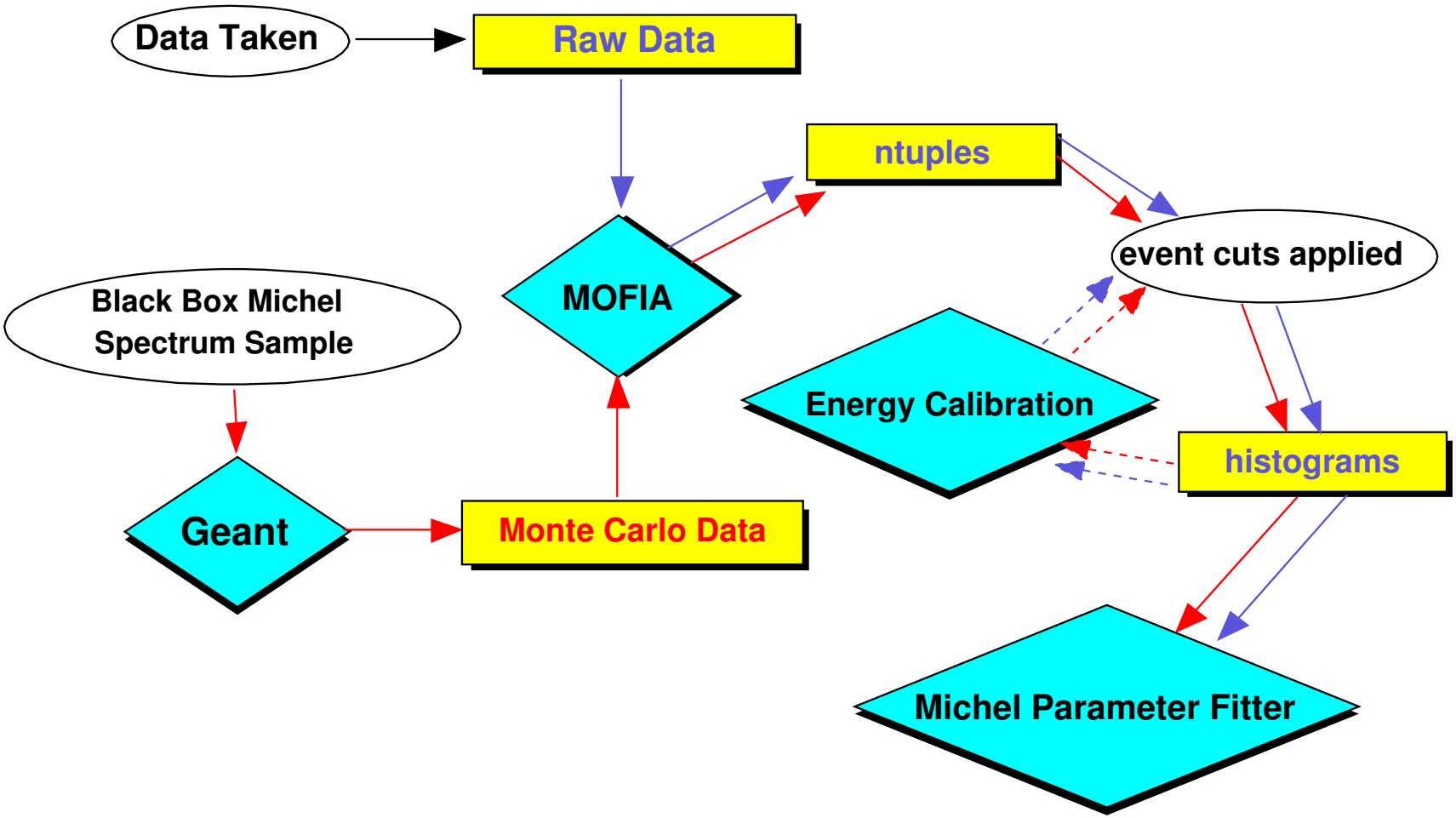
Brisf Description of $\mathcal{TWIST}$

- $\mathcal{T}$riumf $\mathcal{W}$eak $\mathcal{I}$nteraction $\mathcal{S}$ymmetry $\mathcal{T}$est
- High precision test of the Standard model weak interaction using muon decay
- Objective is to measure the Michel parameters ρ, δ, and $P_\mu\xi$ to unprecedented precision





Analysis Strategy in $\mathcal{TWIST}$



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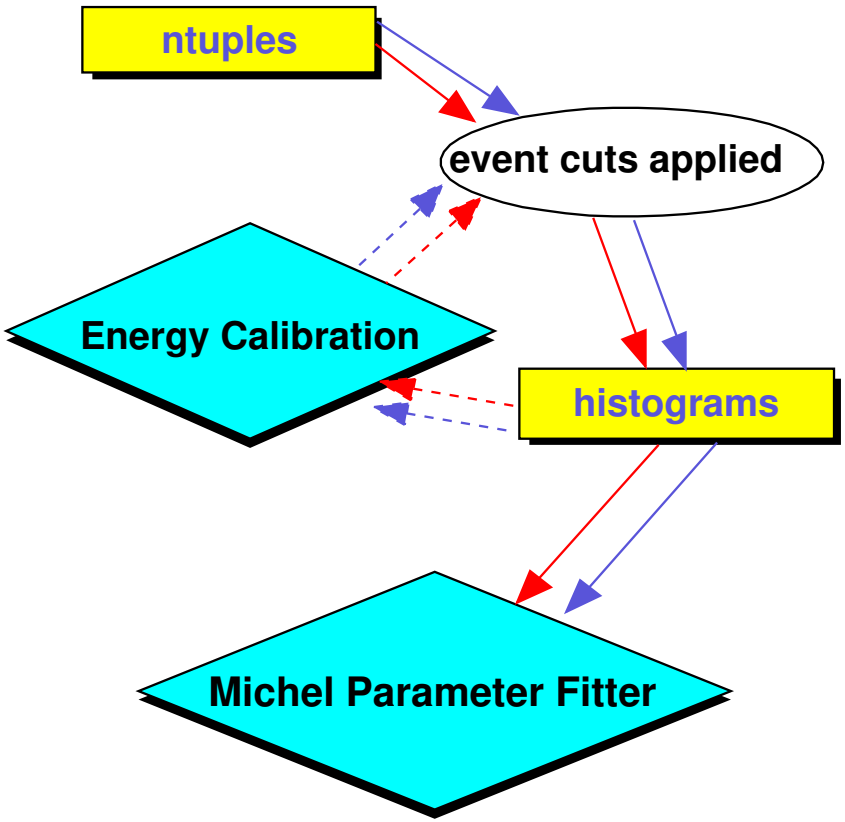
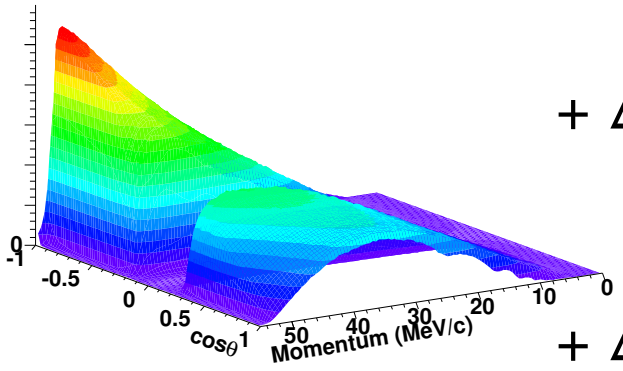


$TWIST$ Parameter Fitting

Monte Carlo $+ \Delta\rho$

Fit = 

$+ \Delta\xi\delta$

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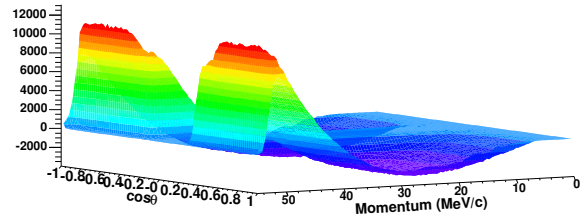
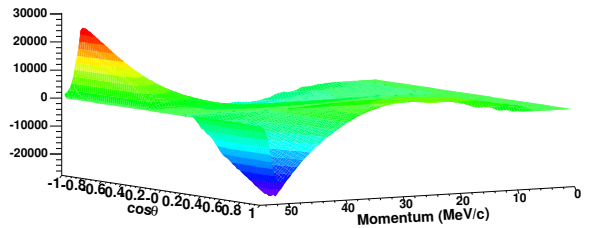
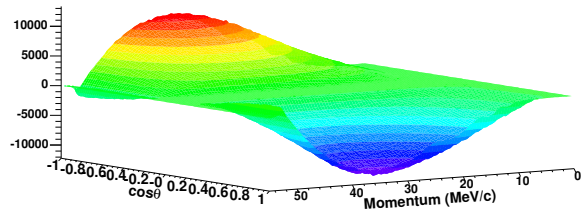
Simulated derivatives







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- Makes calibration of the energy scale imperative.

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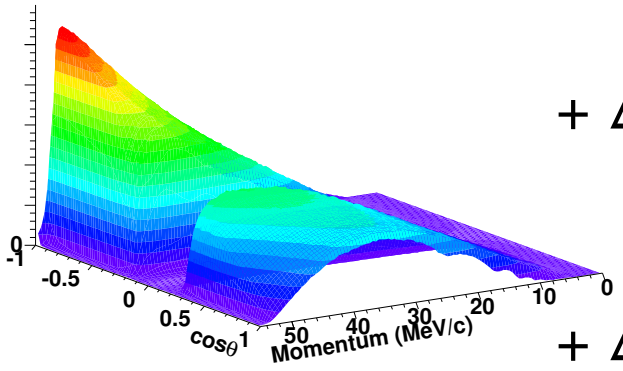
Fit =  $+ \Delta\xi\delta$

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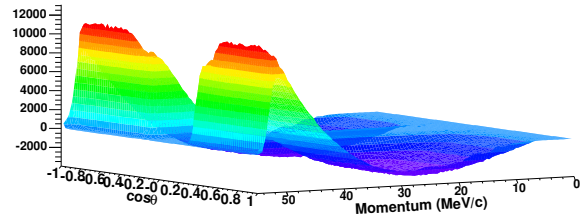

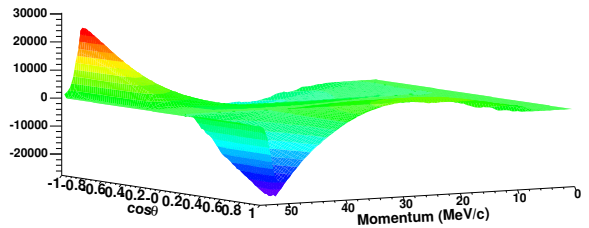

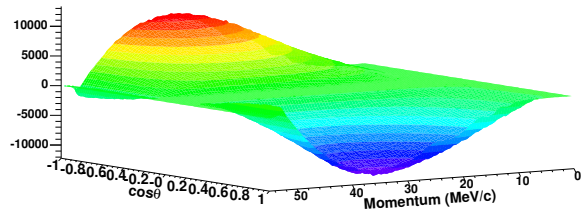

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Energy Calibration

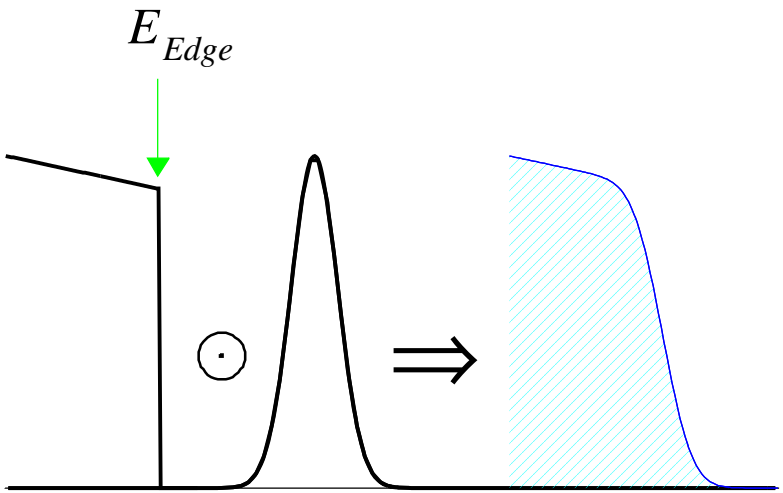
- We anticipate a correction to momentum of the form

$$p^{rec} = \left(1 + \frac{\beta}{p_0}\right)\left(p^{true} - \frac{\alpha}{|\cos\theta|}\right).$$

  - β represents a correction to the energy scaling
  - α represents the energy loss
  - p_0 is the endpoint of the Michel Spectrum
- The energy calibration can only be completed at the endpoint of the spectrum

Model of the Endpoint

Simple model of the Michel spectrum endpoint was devised



- Convolution of a Gaussian and a sloped step function
- Slope is dependant on momentum and angle

$$y = a_0 + a_1 \cos\theta + (b_0 + b_1 \cos\theta)p$$

- Binned log likelihood fit used to find edge

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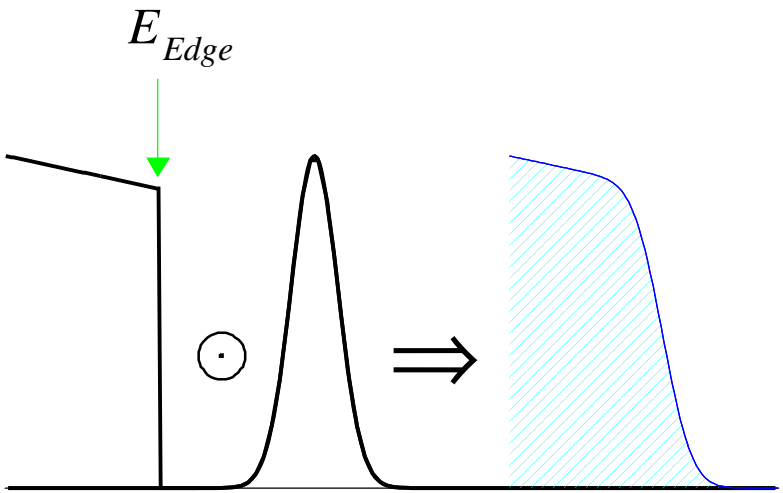

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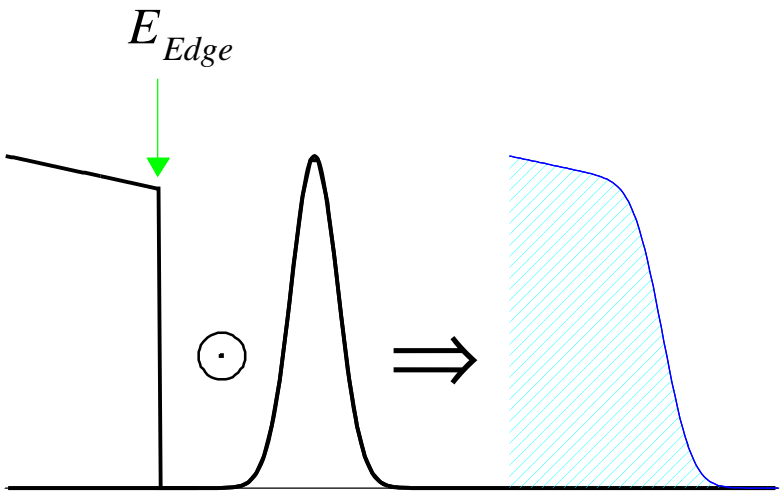

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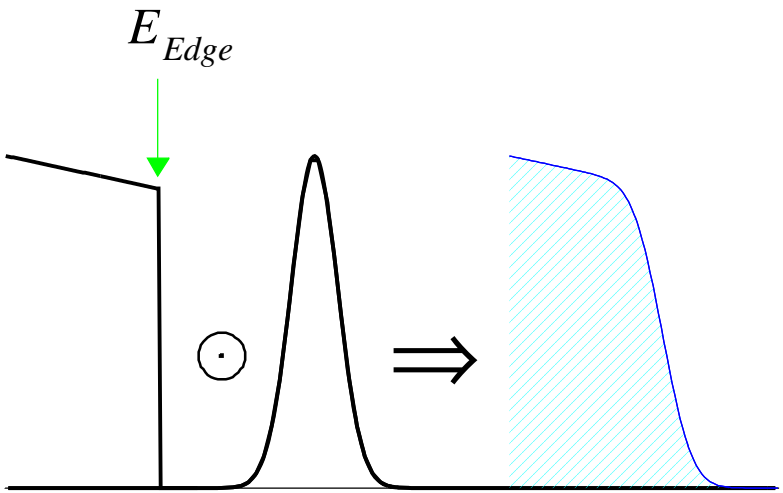

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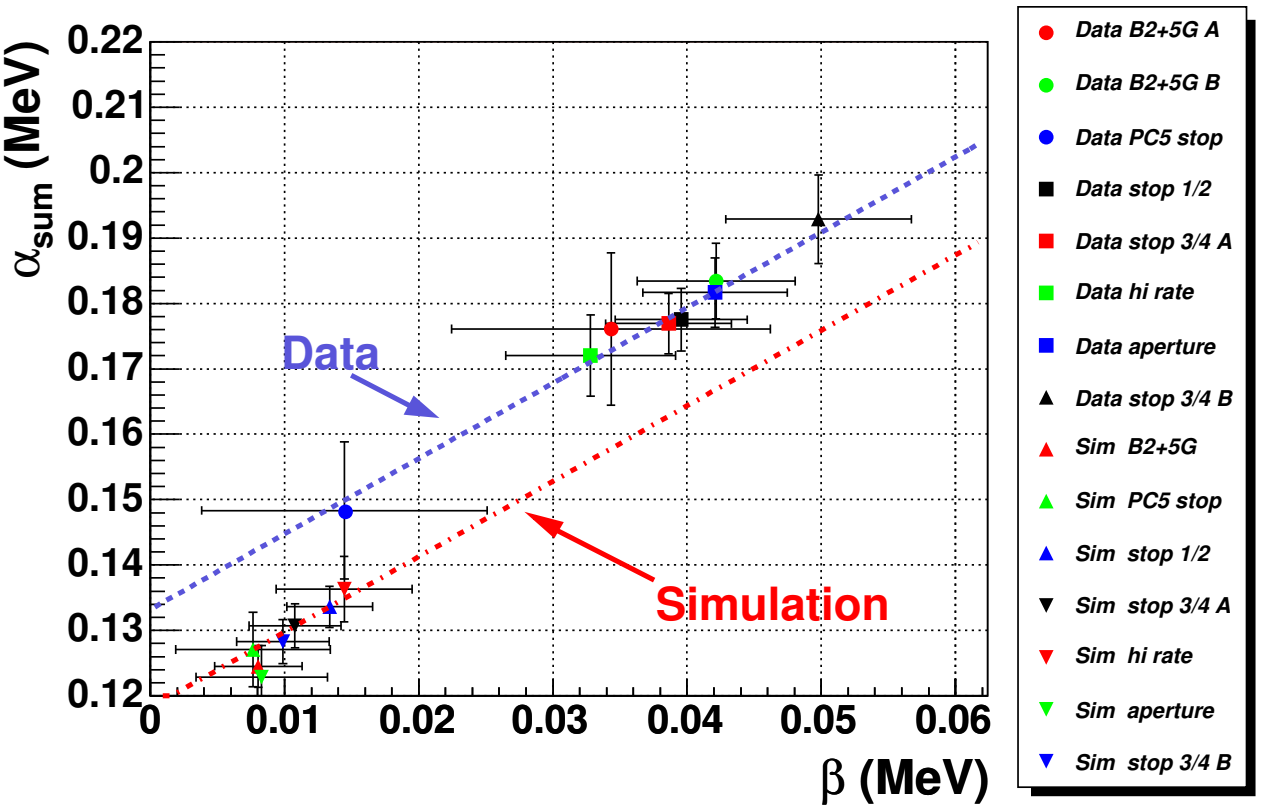
Room For Improvement

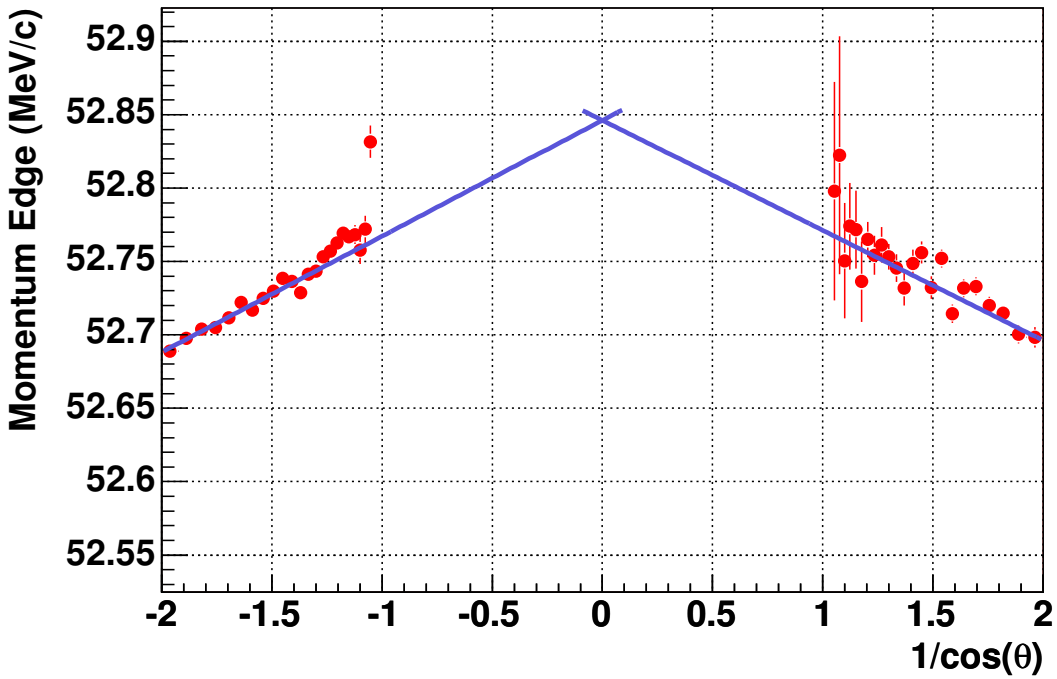
Current, accepted, energy calibration has a few problems



- Large correlations between fitting parameters
  - main example is a large correlation between $\alpha_{up} + \alpha_{down}$ and β

- Model of the endpoint allows for a dependence on the Michel parameters.
- Method is statistics intensive; requires a full data set

Fitting correlations



- Mostly due to fitting a straight line with a large lever arm
- Example: α_{sum} problem

- Problem can possibly corrected by adjusting the parameters to limit the lever arm.
- Some concern has been raised over the physical applicability of this method
- Current alternative is to fix the value of β

Michel Parameters and Energy Calibration

- Model of the endpoint measure the slope of the spectrum with respect to the momentum and angle of the positron.
- This is an implicit dependence of the energy calibration on the Michel parameters.
- Has been measured by checking the energy calibration of raw Monte Carlo + derivatives
  - test has produced changes of 4% in β, 0.5% in α
  - resulting change in Michel parameters after applying calibration is on the order of 10^{-5}

Conclusions

- Energy calibration has been an integral part of the $\mathcal{TWIST}$ analysis to date
- Issues exist within the energy calibration used in the analysis to date
- Correlation between α_{sum} and β seems to be the most significant (currently represents a large systematic effect)
- Relationship between edge parameters and Michel parameters seems to be small but should be checked on a fit by fit basis.
- Improvements pending.

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