Energy Calibration for the TWIST Muon Decay Spectrum
Current Status and Future Directions

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Introduction

- Brief description of TWIST
- Analysis strategy in TWIST: Role of energy calibration
- Measurement of energy calibration
- Issues and improvements
Brief Description of TWIST

- Triumf Weak Interaction Symmetry Test
- High precision test of the Standard model weak interaction using muon decay
- Objective is to measure the Michel parameters $\rho$, $\delta$, and $P_\mu \xi$ to unprecedented precision
Analysis Strategy in TWIST

1. Data Taken
2. Raw Data
3. ntuples
4. event cuts applied
5. Energy Calibration
6. histograms
7. Michel Parameter Fitter
8. Monte Carlo Data
9. Geant
10. Black Box Michel Spectrum Sample

-MOFIA-
Analysis Strategy in TWIST

- ntuples
- Energy Calibration
- Michel Parameter Fitter
- histograms
- event cuts applied
Monte Carlo

Fit =

+ $\Delta \rho$

+ $\Delta \xi \delta$

+ $\Delta \xi$

Comparisons of data and Monte Carlo without energy calibration produces a change in the Michel parameters on the order of $10^{-4}$

Makes calibration of the energy scale imperative.
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Energy Calibration

- We anticipate a correction to momentum of the form

\[ p_{\text{rec}} = \left(1 + \frac{\beta}{p_0}\right) \left(p_{\text{true}} - \frac{\alpha}{|\cos \theta|}\right). \]

- $\beta$ represents a correction to the energy scaling
- $\alpha$ 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

\[ E_{\text{Edge}} \]

Convolution of a Gaussian and a sloped step function

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

Slope is dependant on momentum and angle

Binned log likelihood fit used to find edge
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- Binned log likelihood fit used to find edge
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 $\beta$

- 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: $\alpha_{sum}$ 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 $\beta$. 

Entries 46
Mean 9.1e-05
RMS 1.443

Momentum Edge (MeV/c)

52.5 52.55 52.6 52.65 52.7 52.75 52.8 52.85 52.9
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 $\alpha$, 0.5% in $\beta$
- resulting change in Michel parameters after applying calibration is on the order of $10^{-5}$
Energy calibration has been an integral part of the TWIST analysis to date.

Issues exist within the energy calibration used in the analysis to date.

Correlation between $\alpha_{\text{sum}}$ and $\beta$ 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.

Thank you to Andrei Gaponenko and Blair Jamieson.
Conclusions

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