Evaluation and Simulation of the Response Function in the TWIST Experiment

Robert MacDonald
University of Alberta
for the TWIST Collaboration

CAP Congress, June 2005
The TWIST Collaboration

Canada
TRIUMF
University of Alberta*
University of British Columbia
University of Montréal
University of Regina
University of Victoria

United States
Texas A&M University
Valparaiso University

Russia
RRC "Kurchatov Institute"

with funding from NSERC and the US DOE.

TWIST Spokesperson: Glen Marshall (TRIUMF)
Supervisor: Art Olin (TRIUMF/UVic)

http://twist.triumf.ca
Outline

• Introduction to TWIST
• Overview of MC validation method
• Sample validation results
• Conclusions
The TWIST Experiment
TRIUMF Weak Interaction Symmetry Test

- Measure \((p, \cos \theta)\) spectrum of \(\mu^+\) decay
  \[
  \mu^+ \rightarrow e^+ \nu \bar{\nu} e \bar{\mu}
  \]
- High-precision test of the weak interaction

See also hep-ex/0409066 (NIM, in press)

Analysis made possible by the Westgrid computing facility.

Robert MacDonald  TWIST
The TWIST Detector

Tracking Chambers

Tracking Chambers

Target

muon

positron

Robert MacDonald

TWIST

5
The Michel Spectrum

A general description of muon decay spectrum

\[ N(p, \cos \theta) \propto F_{IS}(p; \rho, \eta) + P_{\mu \cos \theta} F_{AS}(p; \xi, \delta) \]
Extracting Michel Parameters

Measured vs Simulated

\[ \Delta \rho, \Delta \eta, \Delta \delta, \Delta \xi \]

\[ \Delta \rho + \rho_{MC} = \rho_{data} \text{ etc.} \]

Simulation Software is GEANT3.
Verify MC with Specialized Data

- Stop muons at one end of detector.
- Fit the same track twice: measure of response function in energy and angle.
- Results independent of Michel parameters.

*Focus of today's talk: energy response function.*
Sensitivity to MC Errors

(First Physics) \rightarrow (Final Goals)

(\sim 10^{-3}) \rightarrow (\text{few } \times 10^{-4}) \quad \text{Final MC Tolerances}

<table>
<thead>
<tr>
<th></th>
<th>$\rho$</th>
<th>$\delta$</th>
<th>$\xi$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hard Interactions</td>
<td>0.45$\rightarrow$0.15</td>
<td>0.53$\rightarrow$0.18</td>
<td>0.60$\rightarrow$0.20</td>
</tr>
<tr>
<td>Energy Smearing</td>
<td>0.18$\rightarrow$0.05</td>
<td>0.15$\rightarrow$0.05</td>
<td>0.07$\rightarrow$0.05</td>
</tr>
<tr>
<td>Energy Calibration</td>
<td>0.15$\rightarrow$0.05</td>
<td>0.22$\rightarrow$0.07</td>
<td>0.27$\rightarrow$0.09</td>
</tr>
</tbody>
</table>

(units of 1e-3)

- Inaccuracies in Monte Carlo simulation can result in systematic errors in reconstructed Michel parameters.
Energy Loss Distribution

• Compare energy loss in bins of $(p, \cos \theta)$. Example:

  \begin{align*}
  \text{Mean (keV)} \\
  \text{Data} & \quad -121.2 \pm 0.7 \\
  \text{MC} & \quad -129.6 \pm 0.7 \\
  \text{RMS (keV)} \\
  \text{Data} & \quad 138.6 \pm 0.5 \\
  \text{MC} & \quad 133.0 \pm 0.5
  \end{align*}
Energy Loss vs Energy

- Compare energy loss vs total energy. Example:

  Mean (keV)

  Data  -126.3±0.2
  MC    -131.7±0.1
Rate of "Hard" Energy Loss

- Compare rate of events with energy loss $> 1.1$ MeV.

Example:

Rate of "Hard" $\Delta \rho$

Data $(137.9 \pm 8)e^{-4}$

MC $(138.4 \pm 3)e^{-4}$

$\Delta \rho < -1.1$ MeV
Conclusion

• Method of testing GEANT3 simulation with high precision.
  - One of the strongest validations of GEANT3 at these energy levels (20 - 50 MeV/c positrons).

• Allows tuning of simulation to meet TWIST goals.

• Very little tuning will be required to meet TWIST's final requirements!

• Work in progress...
Continuing Work

- Study scattering (similar methods).
- Improve analysis.
- Check effects of DC foil thickness.
- Understand details of any remaining discrepancies.
Acceptance of US Stops Study

- Standard fiducial
- Beam positrons
- Target region