VLENF SuperBIND Analysis Update

R. Bayes

[1]School of Physics and Astronomy
University of Glasgow

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Outline

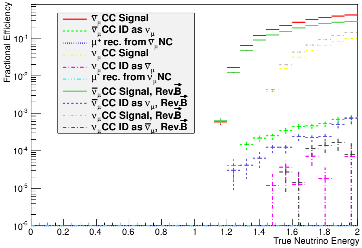
An Erratum

Single Particle Simulations

Reconstruction Rethink

Error in Reversed B-Field Analysis

- There was an inconsistency in the analysis of the reversed B-Field simulation.
- Charge selection used L_4 criteria, instead of L_1.
- Selection efficiency is lower than earlier reported.
- All other signals were the same.



- Reversing field polarity does not improve the result.
- Best efficiency from stored μ^- — $\bar{\nu}_\mu$ CC signal.
  - $\bar{\nu}_\mu$CC Eff — 0.1473(1)
  - ν_μCC μ^+ background — 1.2×10^{-5}
  - NC backgrounds negligable

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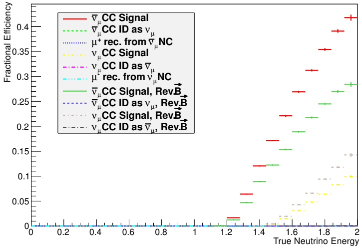

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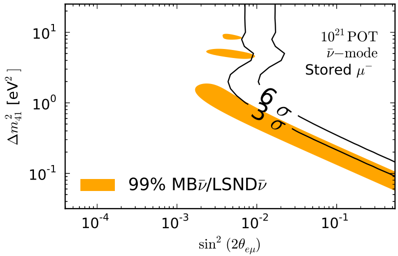

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Evaluation of Sources of Charge Mis-ID

Use simplified definitions for efficiency

- Charge ID efficiency:
  - Numerator: Number of events fit with correct reconstructed charge.
  - Denominator: Number of fitted events.
- Reconstruction Efficiency:
  - Numerator: Number of fitted events.
  - Denominator: All collected events.

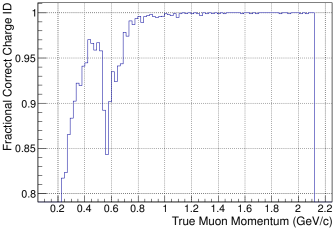
Consider Simplified Simulation

- Single particle simulations to test reconstruction.
- Compare the result to standard sim. to find failures.

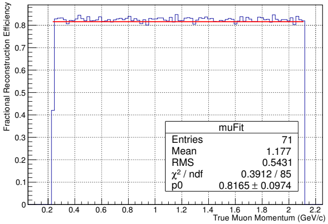
Single μ^+ simulation in SuperBind

- 10^5 μ^+ simulated.
- μ^+ start from random position.
- zero transverse momentum.
- Momenta uniformly distributed between 0.2 GeV/c and 2 GeV/c.
- Nearly 100% charge efficiency for $p_\mu > 1$ GeV/c.
- Uniform 81% reconstruction efficiency at all momenta.

Charge ID Efficiency



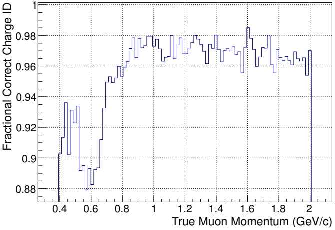
Reconstruction Efficiency



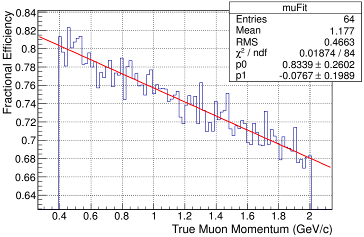
Single μ^- simulation in SuperBind

- 10^5 μ^- simulated.
- μ^- start from random position.
- zero transverse momentum.
- Momenta uniformly distributed between 0.2 GeV/c and 2 GeV/c.
- Charge efficiency $< 97\%$.
- Reconstruction efficiency decreases linearly with momentum

Charge ID Efficiency



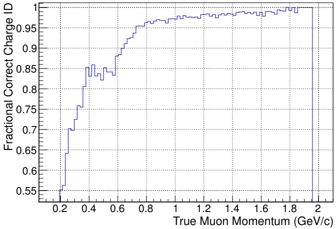
Reconstruction Efficiency



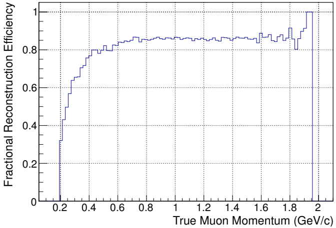
Efficiencies in Standard Simulations

- Consider GENIE based simulation.
- 10^5 $\bar{\nu}_\mu$ CC simulation.
- Signal events are μ^+
- Charge efficiency increases with momentum to 95%

Charge ID Efficiency



Reconstruction Efficiency



What has been learned?

Reconstruction of μ^+ very good for $p_\mu > 1$ GeV/c

- Charge ID almost perfect for single muons in this region
- Reconstruction efficiency uniform.
- (not shown) Majority of reconstruction failures due to lack of measurements either before pattern recognition or fitting.

Results from $\bar{\nu}_\mu$CC event reconstruction not as good.

- What is missing in single particle simulation?
  1. Muons generated off axis—Is multiple scattering a problem?
  2. Hadronization or other showers—No pions in single muon simulation.

Can the sources of mis-ID be tested?

Multiple scattering as a source of failure

- Single particle can be changed to simulate muons produced at $\pi/4$ angle to detector axis.
  - increase amount of multiple scattering in iron by factor of $\sqrt{2}$.
  - should increase threshold before optimal charge ID.

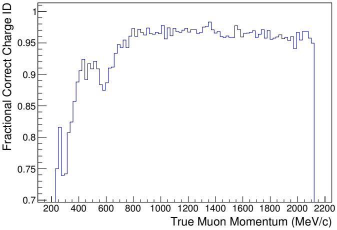
Hadronization as a source of charge mis-ID

- Run single particle simulation of pions.
  - Check the muon charge ID and reconstruction efficiency.
  - Is there a way to positively identify muons reconstructed from pions?

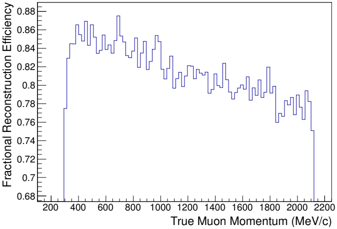
Offaxis single muon Simulation

- Simulated 10^5 μ^+ with momenta between 0.2 GeV/c and 2.0 GeV/c with $\cos\theta = 1/sqrt2$.
- There is a loss in charge ID and reconstruction efficiency for off-axis μ^+.

Charge ID Efficiency



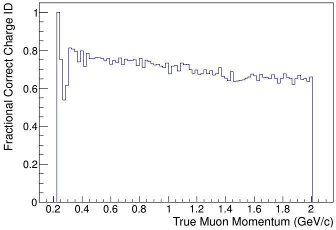
Reconstruction Efficiency



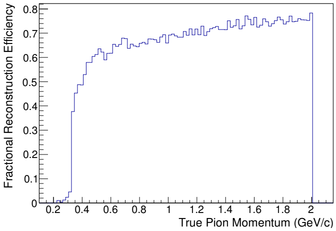
Single π^+ Simulation

- Run the simulation as before—no change in reconstruction.
- Select tracks with positive charge.
- Reconstruction efficiency lower than for muons—but the majority of events are being reconstructed.
- Charge ID decreases with pion momentum—could be inconsistancy of Eloss correction?

Charge ID Efficiency



Reconstruction Efficiency



Do We Have the Right Information at this Energy Range

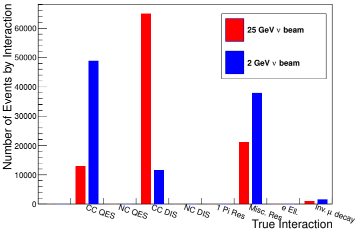
- Using the same analysis as that derived for 25 GeV MIND.
- Primary tool for background reduction is number of hits and track quality.
  - Number of hit is neutral current rejection.
  - Track quality serves as CC and NC background rejection.
- Lower energy $\rightarrow$ shorter tracks and fewer hits
  - Difference between N hits distribution not as great.
  - $\sigma_{q/p}/(q/p)$ distribution more broad and double peaked for correct charge ID.
- Other charge selection criteria do not do as well.
- Need to redevelop analysis and produce other criteria.

Why the Energy Range Matters

MIND was optimized for DIS events

- Majority of events are DIS.
- Typified by long track with localized activity.
- Only one muon track is identified in reconstruction.

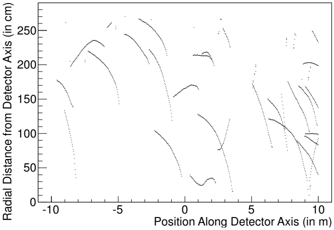
Most detector events generated by VLENF are QES



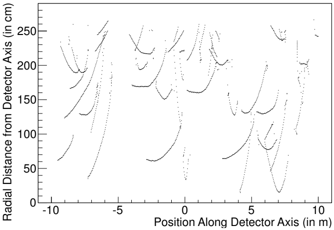
- $\nu_\mu + n \rightarrow \mu^- + p$
- $\bar{\nu} + p \rightarrow \mu^+ + n$
- Inherent asymmetry to events.
- More charged secondaries in ν_μ events.
- Is it possible to confuse tracks?

Viewing QES events as they appear in Detector.

$\bar{\nu}_\mu$ CC Events



ν_μ CC Events



- Selected QES interactions from first 100 Events of ν_μ and $\bar{\nu}_\mu$ GENIE simulations.
- Look at
  - All Selected Events.
  - All Fitted QES events.
  - QES with correct charge ID.
- There are two track events both simulations
  - In ν_μ events this is proton.
  - In $\bar{\nu}_\mu$ it is likely more complicated.
- All tracks should be fitted.
  - Topology can be used for CC selection.
  - What if most hits is not the longest track?

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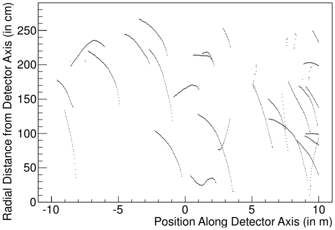

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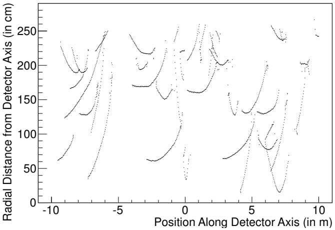

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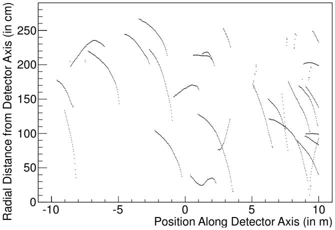

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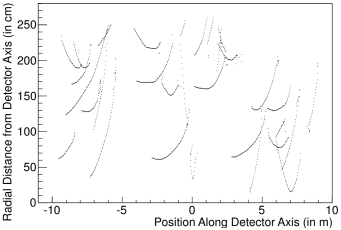

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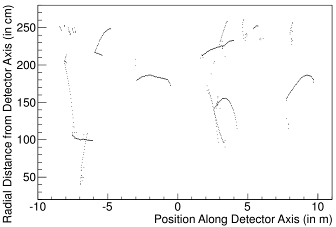
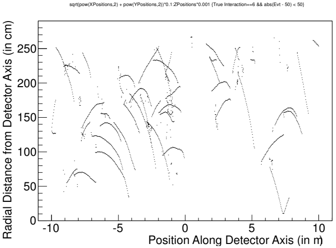
Viewing Other Events as they Appear in the Detector

$\bar{\nu}_\mu$ DIS CC Events



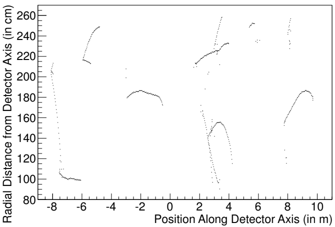
$\bar{\nu}_\mu$ RES CC Events



- Selected DIS and RES events from first 100 events of $\bar{\nu}_\mu$ GENIE simulation.
- Look at
  - All events.
  - Correct charge ID events.
  - Incorrect charge ID events.
- Similar problems occur.
  - Multiple tracks are not properly dealt with.
  - Most hits does not always mean the longest track.
- Similar solution — Fit all tracks.
- Reformulation of reconstruction in progress.

Viewing Other Events as they Appear in the Detector

$\bar{\nu}_\mu$ DIS CC Events



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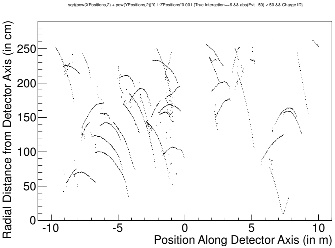

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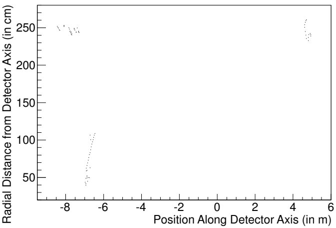

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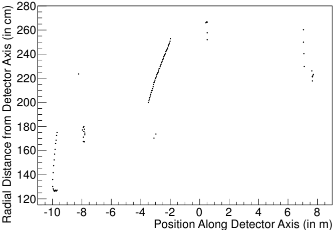

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Summary

- We have hit a limit with the existing reconstruction/analysis.
- Alterations to the analysis are necessary.
- Will have to address two weaknesses
  - Appearent sensitivity to scattering — can this be “fixed”?
  - Selection of longest set of single hits — need to fit everything.