Charm Production in a MIND-Type far detector as a Background to the Oscillation Signal

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Introduction

Interim Design Report, IDS-NF-020, Pg 201

"A Near Detector needs to measure the charm cross-section to validate the size of the charm background in the far detector, since this is the main background to the wrong sign muon signature"

- What is the magnitude of the charm background in the MIND simulation?
- Does this necessitate a near detector optimized for the charm cross-section?

Further Background

The interaction of interest

- $\nu_\mu N \rightarrow \mu^- D^+ X$ when $D^+ \rightarrow \mu^+ anything$
- if the μ^+ is selected then this will give the wrong result

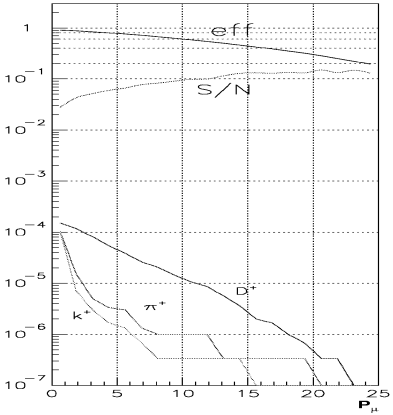
- Has been discussed in the context of early investigations in understanding the golden channel analysis. [1]
- suggests that a golden channel analysis should produce background on the order of between 10^{-7} and 10^{-5}
- These interactions exist in GENIE[2]

[1] Cervera *et.al.*, Nuc. Phys. B 579(2000) 17-55

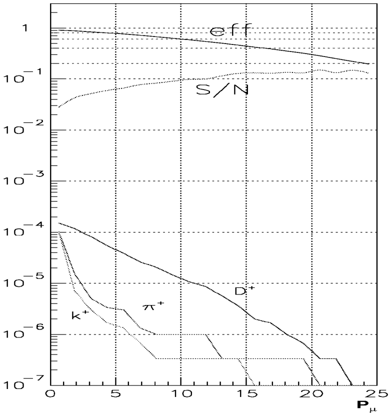
[2] C.Andreopoulos *et al.*, The GENIE Neutrino Monte Carlo Generator, Nucl.Instrum.Meth.A614:87-104,2010.

Previous Estimates[3]

ν_μ CC Limits



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



This assumed a very different design for a MIND.

[3]Cervera *et.al.*, Nuc. Phys. B 579(2000) 17-55

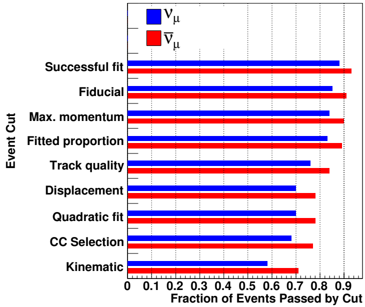
MIND Detector Simulation used for Study

- Using a detector with a square cross section.
- Dimensions: 14 m$\times$14 m$\times$40 m.
- Alternating 3 cm thick iron plates and 2 cm scintillator planes.
- Used a uniform 1 Tesla magnetic field.
- For the purpose of this study used GENIE event generator.
- Analysis nominally identical to that used for IDR studies.

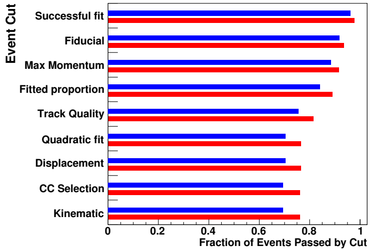
Changes from IDR

Differences in the Yield

From IDR



Current Study

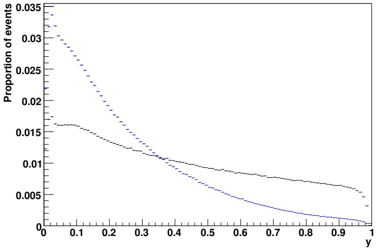


- Total survival fraction has increased.
- Purity of track fitting extremely high.

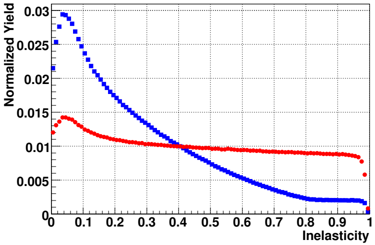
Changes From IDR

Differences in the physics due to GENIE

From IDR



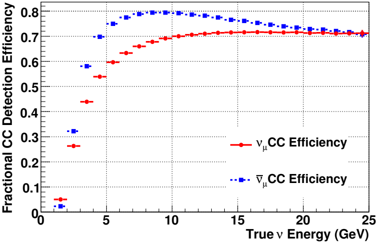
Current Study

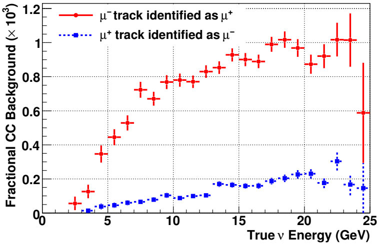


- GENIE produces a different inelasticity distribution compared to NUANCE.
- Caused by a different treatment of the PDF.

Efficiencies and Backgrounds

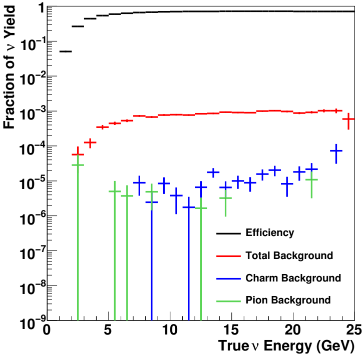
- To be counted a track must pass all cuts.
- Background events have the wrong charge.
- To isolate background sources MC truth consulted
  - Charm background in subset of events where there are charm mesons.
  - Probability of charm production in neutrino scatter:
    - $P(c|\bar{\nu}_\mu) \approx 1.1\%$
    - $P(c|\nu_\mu) \approx 2.4\%$
  - Pion background in coherent and resonant pion production events.



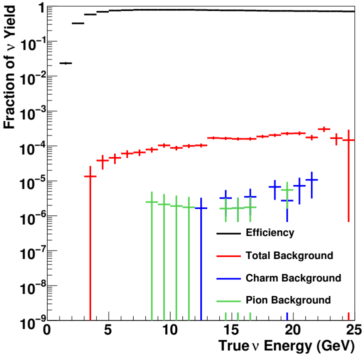


Charge Current Efficiencies and Backgrounds

ν_μ CC



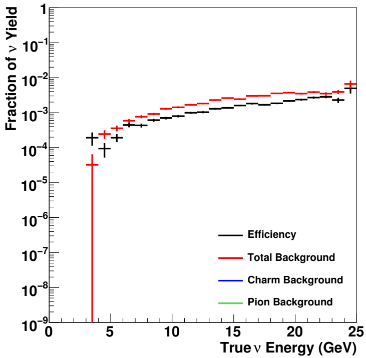
$\bar{\nu}_\mu$ CC



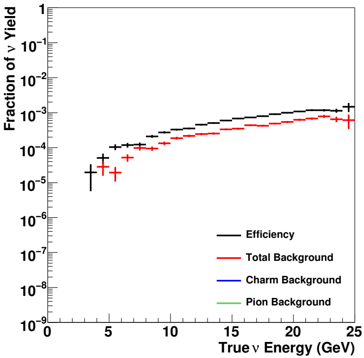
- Background is not dominated by charm backgrounds.
- Charm and pion backgrounds are at the limit of detection.

Neutral Current Efficiencies and Backgrounds

ν_μ NC



$\bar{\nu}_\mu$ NC



- Neutral current backgrounds of the same order as efficiency.
- Charm and pion backgrounds not apparent.

Conclusions

- Charm and pion backgrounds sampled using 8×10^6 charge current ν_μ and $\bar{\nu}_\mu$ events.
- Simplified MIND geometry assumed.
- Total backgrounds are;
  - ν_μ: $\sim 10^{-3}$
  - $\bar{\nu}_\mu$: $\sim 10^{-4}$
- Charm backgrounds are very small.
  - ν_μ: $\sim 10^{-5}$
  - $\bar{\nu}_\mu$: $< 10^{-5}$
- Pion background is of the same magnitude.
- Backgrounds are now dominated by false positive reconstructions.