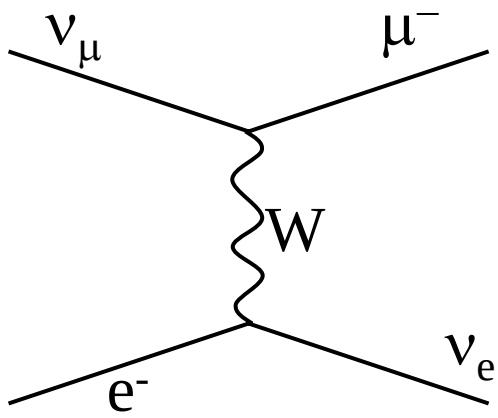
Inverse Muon Decay – Preliminary Report

- Introduction
- Kinematics/Cross Section (*with update*)
- Reconstruction Issues
- MC
- *Vicki Moeller (FNAL Summer Student) & P.S.*

Introduction



- Inverse Muon Decay
  - CC off Atomic Electrons
  - Pure Electroweak process
  - No Nuclear/Hadronic uncertainties
  - Measured by Charm-II, CCFR, NuTeV
    - Cross section, V-A test, LFV limits
- Value to MINOS
  - At a minimum, hopefully will be useful tool for independent measurement of neutrino flux above 11 GeV

IMD Kinematics

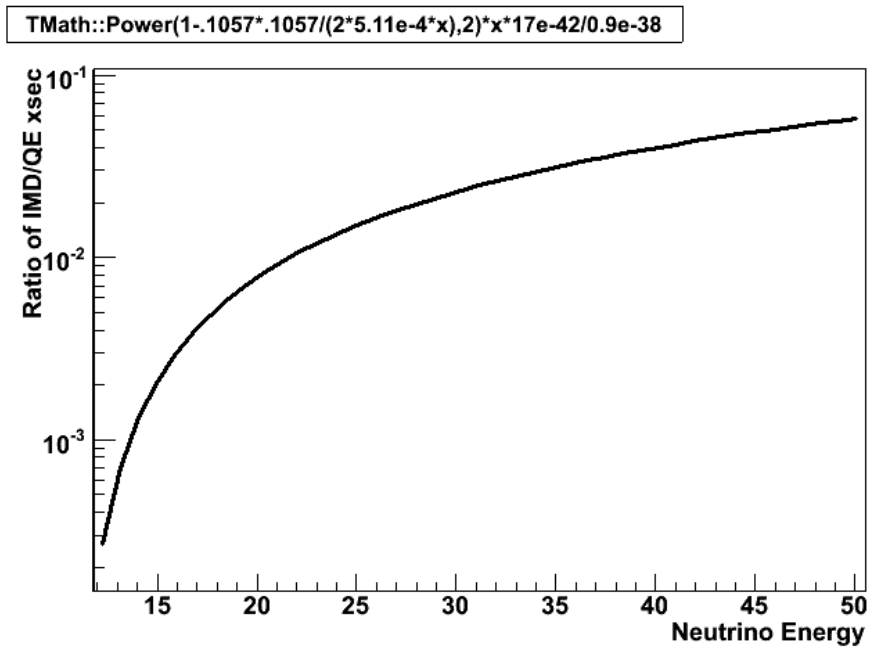
- Threshold
  - 11 GeV : $s=2E_\nu m_e$
- High Boost
  - $\gamma = \sqrt{E_\nu / 2m_e}$ = ~100 at threshold
- Highly forward μ
  - P_T < 100 MeV/c for E_ν<50 GeV

Cross Section

- Born Level:
  - $\sigma^B = \frac{G_F^2}{\pi}\frac{(s-m_\mu)^2}{s}$, isotropic in C.O.M.
  - P_μ(lab) flatly distributed between 11GeV and P_ν
  - $\sigma^B = \sigma_{as}^B E_\nu \left(1-\frac{m_\mu^2}{s}\right)$, $\sigma_{as}^B = \frac{2m_e G_F^2}{\pi}$ = 17.23 x 10^{-42} cm^2 GeV^{-1} (SM)
  - Compare QEL: ~10^{-38} cm^2 (flat in this range)

Comparison to QE Cross Section

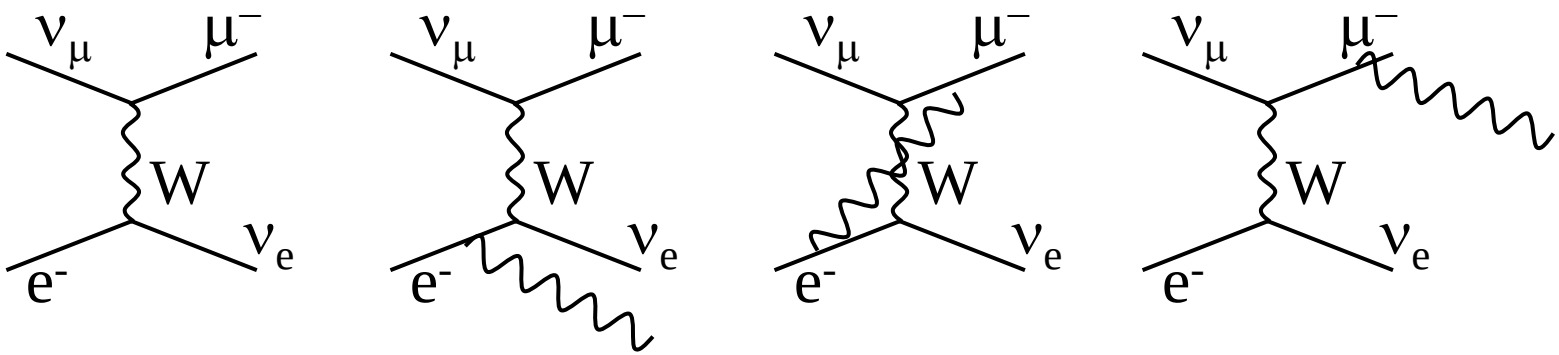
- IMD s grows linearly away from threshold
- QE is ~flat
- Approximate ratio:



Update slide

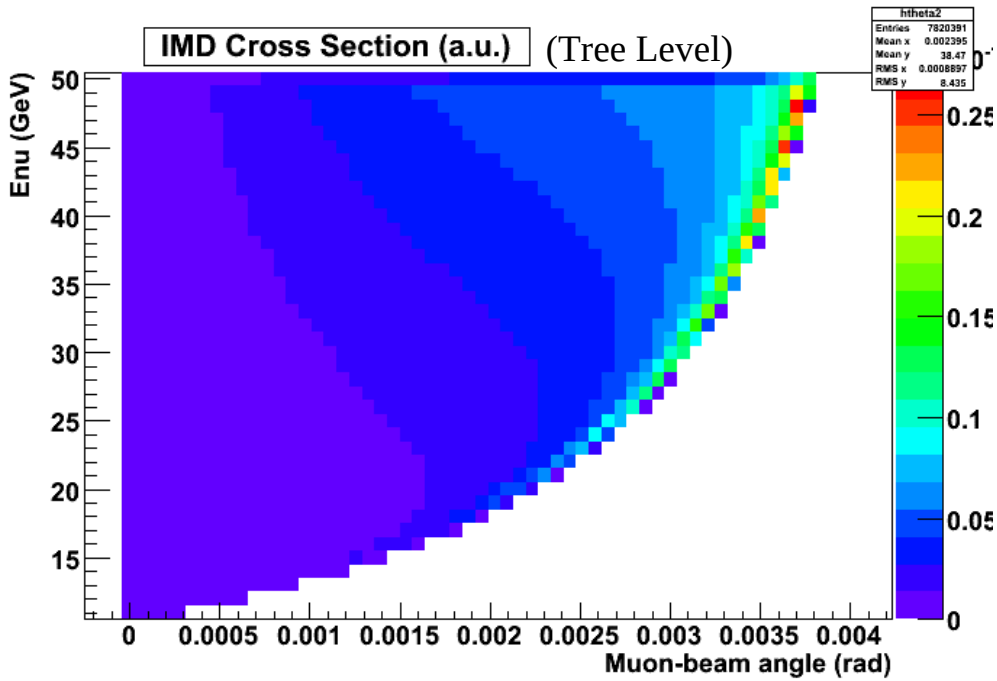
Radiative Corrections

- D.Yu. Bardin and V.A. Dokuchaeva, Nucl. Phys. B287 (1987) 839.
- Costas has incorporated totally inclusive correction into MC
- Non-inclusive probably negligible, but need to check



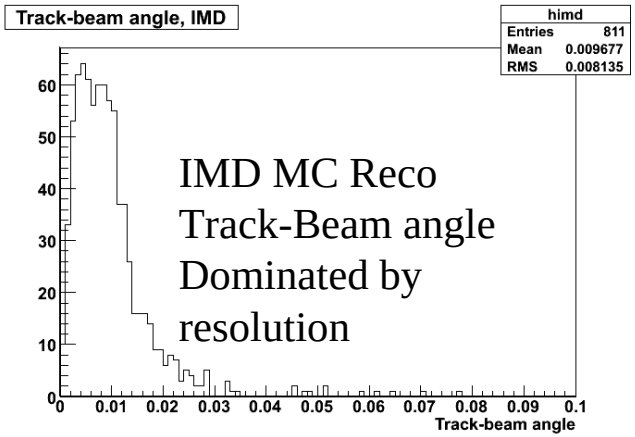
Signature

- Signature (in the ideal case):
  - No hadronic activity
  - Small angles
  - (E_μ>11GeV)
- Ideal Kinematics (in ideal case)
  - $E_\nu = f(P_\mu, \theta_\mu)$

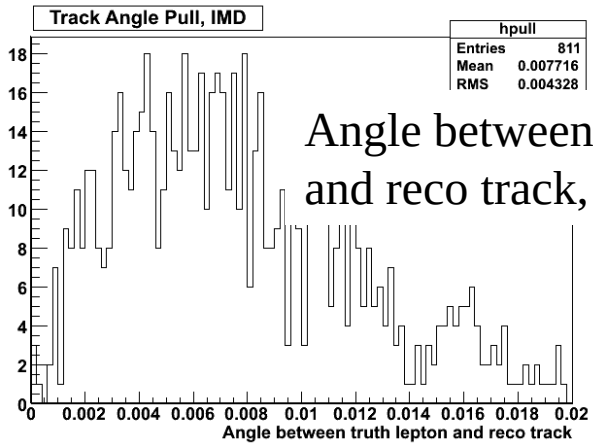


Angular Resolution

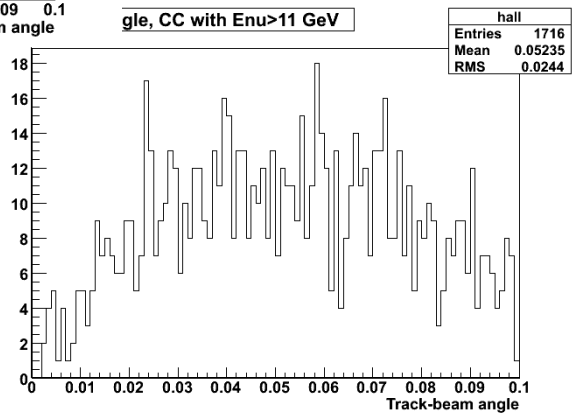
- For very forward tracks, angular resolution is not terrible:



IMD MC Reco Track-Beam angle Dominated by resolution



Angle between truth and reco track, IMD

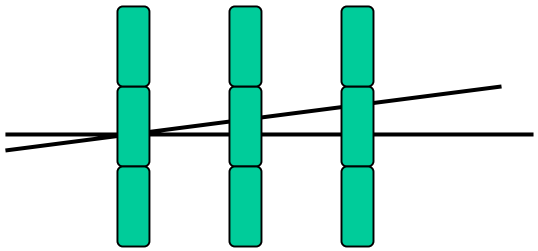


CC MC Track-Beam angle

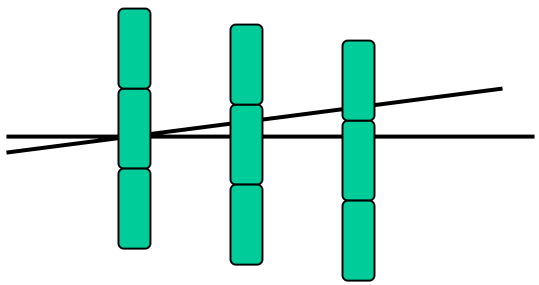
Just to guide the eye, not comparable samples!

Improved Angular Resolution?

- MC has perfect alignment across planes



- (Well Known) random alignment should be better

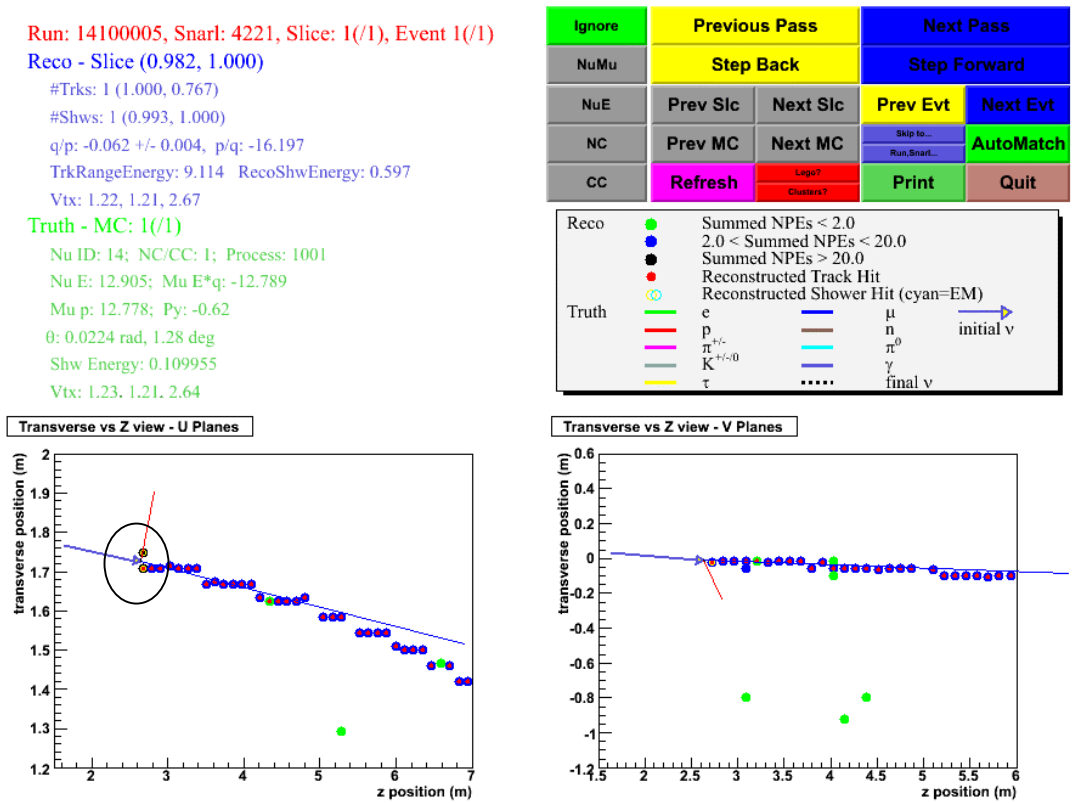


“Showers”

- Most IMD MC events have “showers”
  - ~1/2 are Brems (?)
  - ~1/2 are phantoms at start of track
  - May need lower level cut than “reco says there is a shower”
    - E.g., sum of activity near vertex
      - May also be needed for QE background:

QE Background

- QE with no proton track will probably be biggest background
  - ~500x larger cross section at 15 GeV
  - Look for extra hits near track vertex

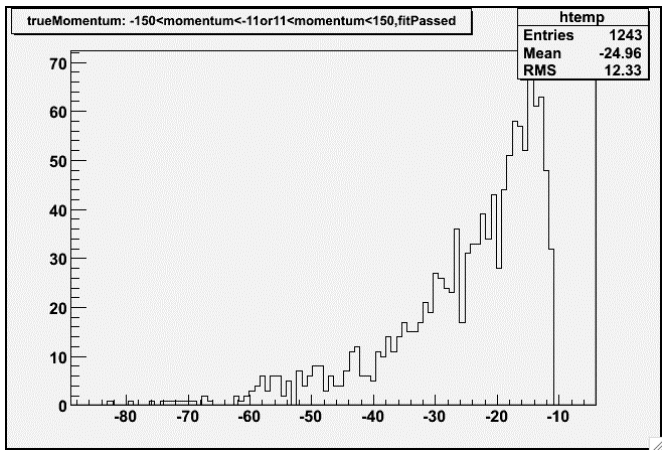


Real-life kinematics

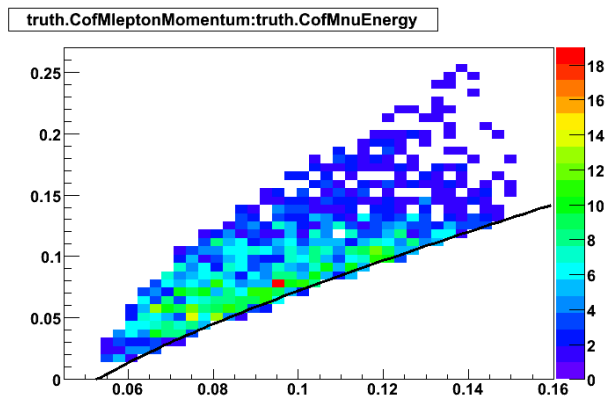
- Angular resolution doesn't permit E_ν reco
  - May just be good enough to ID IMD, but certainly not enough to do kinematics
- How to judge (beam) production models?
  - Data/MC comparisons of p_μ spectra
  - Unfolding technique to get $\phi_\nu(E)$?

First Look at IMD MC

- Model from Costas, implemented in Neugen by Hugh
  - Thanks Hugh for generating 2k events!
- Reasonable at first glance.



Anomaly: p_μ* vs. p_ν* doesn't obey 2-body constraint
Problem with MC? Or with Boost?



To Do

- Signal ID
  - Develop working cuts
    - Track quality, sanity
    - Showers
    - Extra non-reco activity (QE)?
- MC
  - Non-perfect alignment
  - Verify sensitivity to internal Brehmsstrahlung photons
- Flux Analysis
  - Efficiencies, acceptance, background, unfolding
- Not yet clear that this will work.