Oscillation Physics Chapter of Minerνa Proposal

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- Proposal Chapter Outline: see last meeting `http://minos.phy.tufts.edu/gallag/MinervaJune03.ppt`
- Current strategy of Off-Axis Group
- How Minerνa can contribute

Current Strategy of Off-Axis Group

At Far Detector, Backgrounds are from:

- Intrinsic ν_e
  - → This is single largest source
  - → Mostly from μ decay
- Neutral Current π^0 production
  - → This is the most poorly constrained by current data
- Charged Current π^0 production
  - → strongly Δm^2 dependent
  - → will change a lot between near and far detector

Overall Problem: Near Detector measurements have very different relative contributions of the three...

Current Strategy of Off-Axis Group, II

Relative contributions: (assuming same detector, same cuts)

- ND On Axis:
  - → mostly NC events fall in 2GeV "no μ" sample
- ND Off Axis:
  - → Events roughly split equally between all 3 contributions
- FD Off Axis:
  - → 50% are ν_e
  - → 25% are NC
  - → 25% are ν_μCC at high y (assuming $\Delta m^2 = 2.5 \times 10^{-3} eV^2$)

Intrinsic ν_e background

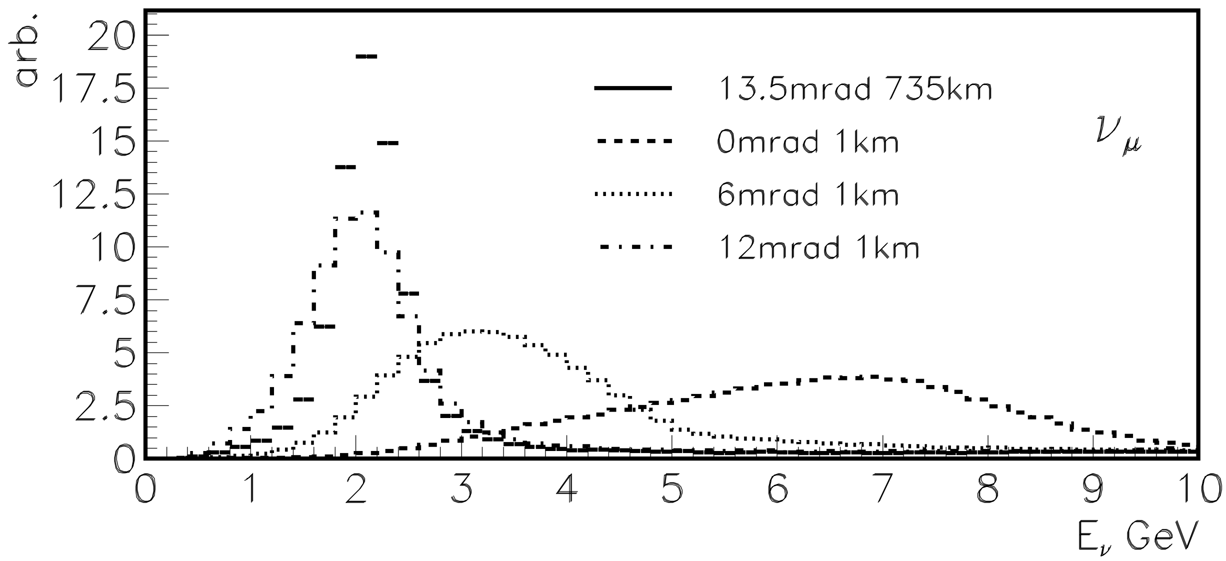
One idea to get to this:

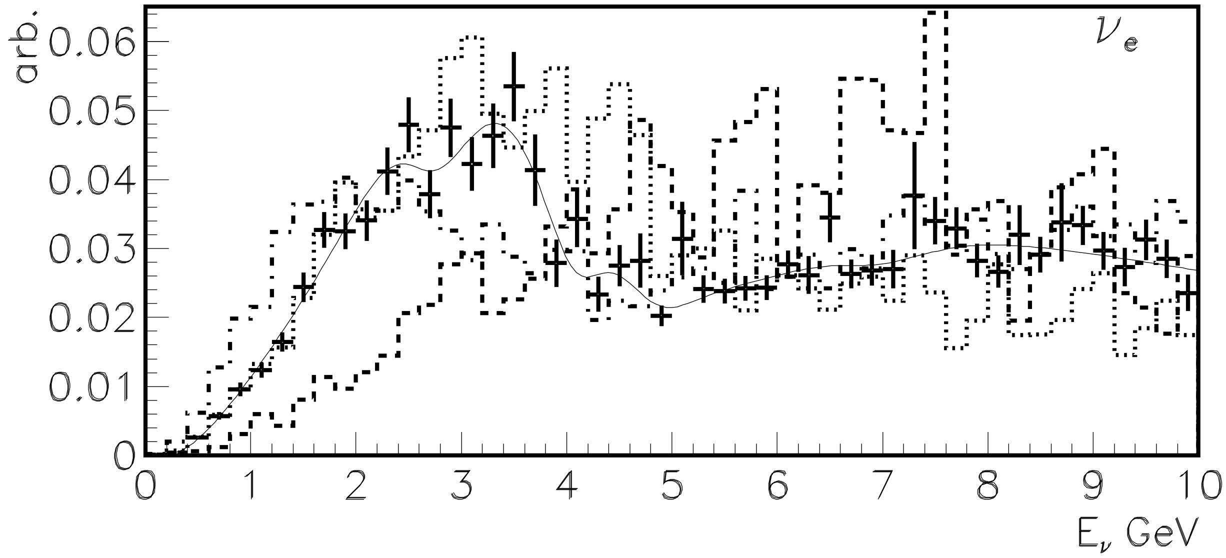
- measure ν_μ CC spectrum in MINOS ND
- infer $\pi \rightarrow \mu \rightarrow \nu_e$ chain
- use MIPP measurements to get kaon contributions
- maybe even measure ν_e's at high energy to limit K production of ν_e

Problems with this:

- need to extrapolate ν_μ cross sections at high energy to ν_e cross sections at low energy
- things can happen to muons which won't affect π^0's (i.e. more multiple scattering in decay pipe flanges, etc.)
- not clear at how high an energy MINOS detector can even see ν_e's
- FD beam ν_e's which survive all cuts are very different mix of QE, resonance and DIS than the beam ν_μ's.

ν_μ and ν_e fluxes vs angle





Obviously ν_μ changes much more quickly than ν_e...
all plots normalized to same area

What Minerνa could contribute to ν_e measurement:

- ν_e quasielastic event measurement (on and/or off axis)
- QE/resonance contributions (as function of simulated OA detector)
- uncertainty in extrapolations depend on where Minerνa is...

What we need to prove this:

- ability to reconstruct ν_e quasielastic events
- prediction of ultimate NC contamination in that sample
- π^0/e separation figure of merit: how many π^0's will ultimately be in the final sample?

Ultimately: a ν_e CC "event library" using fully reconstructed Minerνa events

NC Background Measurement

One Possible strategy:

- Look at all events in "no-μ", 2GeV visible Energy Window
- Apply same cuts as Far Detector
- Subtract off near ν_e contamination
- Resulting number is used to calculate ϵ

$$\epsilon = \frac{NC\ events\ passing\ all\ cuts}{NC\ Candidates\ in\ 1.5 - 2.5GeV\ window}$$

Assumption is that ϵ is a function only of the visible energy (for NC events), not a function of the incoming neutrino energy

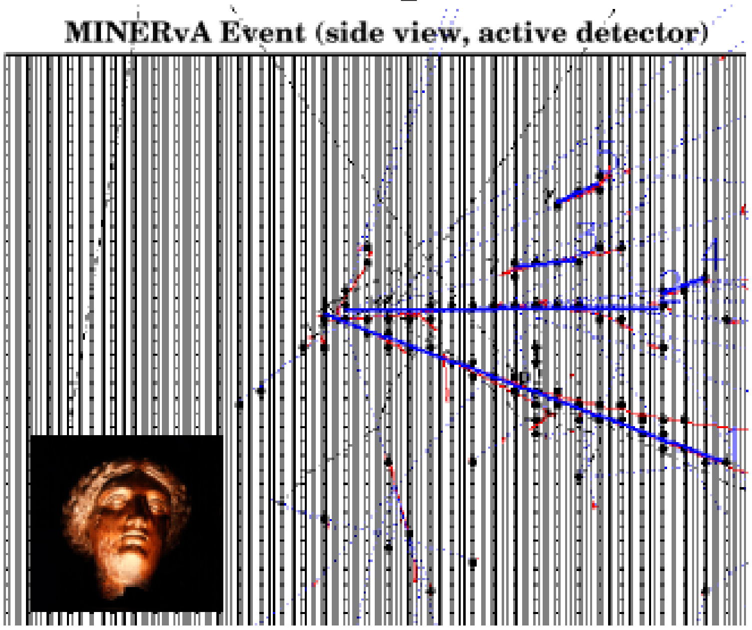
How can Minerνa Help with NC processes?

- better description of NC processes (coherent, resonance, etc)
- more clean sample of NC events
  - $\rightarrow \pi/\mu$ separation
  - $\rightarrow p_t$ measurement
- By measuring ϵ for several beam energies (by moving the target wrt to the horns)
- by measuring ϵ for several angles (?)

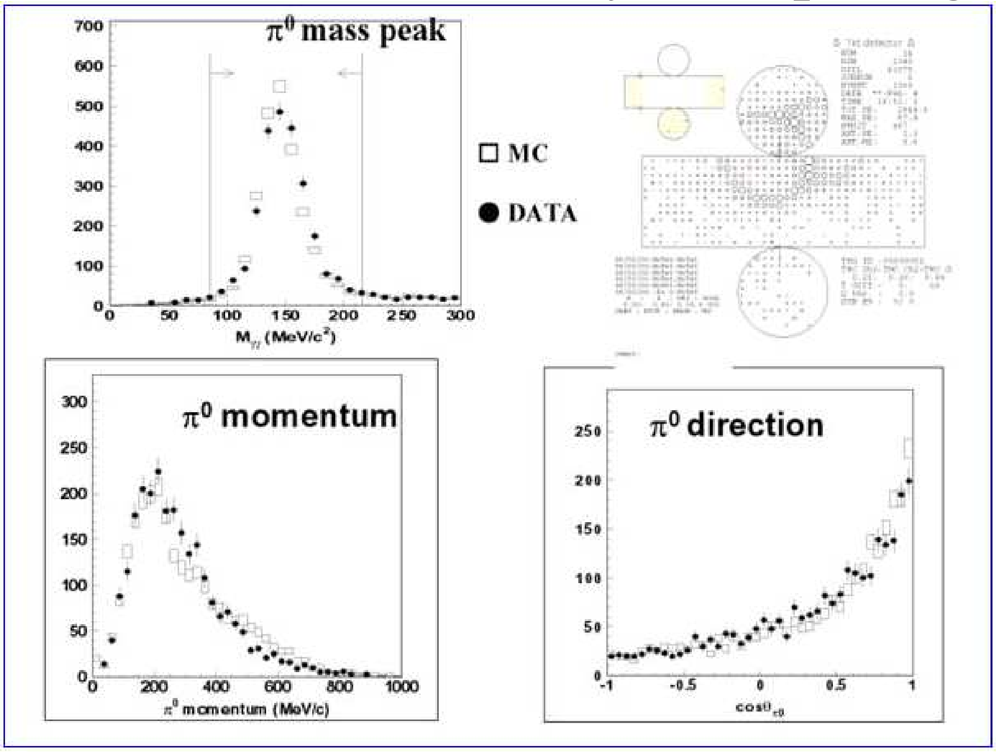
Intriguing possibility: also make "NC" event library

Detector Requirements for good NC ID

- look for both photons from π^0 interaction



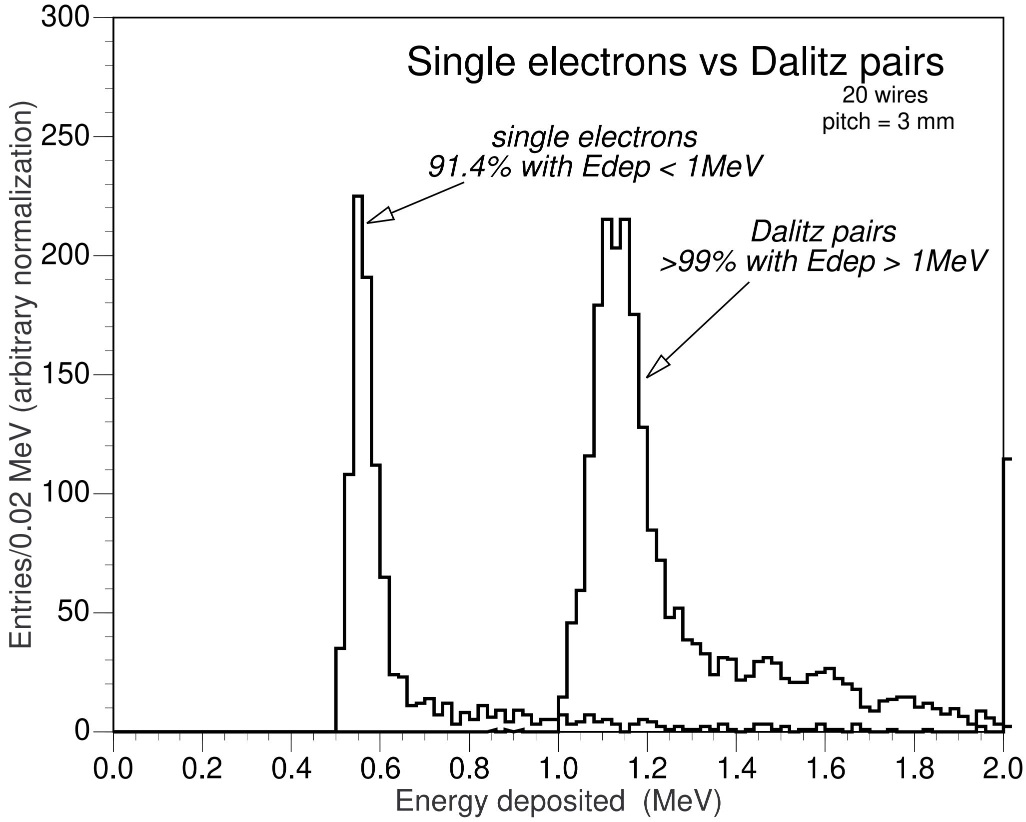
- measure π^0's for many 2γ opening angles



K2K, LP2003

Detector Requirements for good NC ID, cont'd

- dE/dx for first few radiation lengths



This is for: 3mm liquid argon spacing (2% X_o) will make MINERVA version (5% X_o?) of this to see how it looks

photostatistics will count here!

CC Background Measurement

One Possible strategy:

- Look at all events in "1 clean μ", 2GeV "Hadron Energy" Window
- Apply same cuts as Far Detector OA analysis
- Subtract off most of μ-induced activity contamination
- Resulting number is used to calculate efficiency ϵ_{CC}

$$\epsilon_{cc} = \frac{CC\ evts\ passing\ all\ cuts}{CC\ evts\ in\ 1.5 - 2.5GeV\ E_{had} window}$$

Assumption is that ϵ is a function only of the hadron energy (for CC events), not a function of the incoming neutrino energy

How can Minerνa Help with CC processes?

- better description of NC processes (coherent, resonance, etc)
- more clean sample of CC events (π/μ separation)
- By measuring ϵ for several beam energies (change target-horn separation)
- by measuring ϵ for several angles (?)

Here Minerνa should really clean up because we'll have very clean samples of CC π^0 events, should be able to measure out to a higher y than Off axis experiment.

Summary Slide

Plots/Numbers we need:

- How pure a ν_e CC sample can we measure?
- How pure a NC sample (π^0) can we measure?
  - $\rightarrow$ down to what 2γ angles can we see two EM showers?
- How pure a ν_μ CC sample at high y can we see
  - $\rightarrow$ down to what μ energy?

Figures of Merit

1. Measurement of the ν_e Flux vs E_ν to $\sim 5\%$ in each 1GeV bin.
   - a 90% pure sample of nue CC events
   - an understanding of the QE/RES components of that sample.
   - cuts to identify electrons should be at least 90% efficient (so we can allow a large uncertainty on that inefficiency)
2. Measurement of ν_e CC and single π^0 backgrounds
   - 99% containment of photons from π^0's
   - 90% separation of single π^0 from e^-
3. Low energy measurements:
   - Good NC/CC separation down to lowest possible visible energies
   - 80% separation at 1 GeV
4. Total energy measurements
   - Must be able to contain neutrons as least as well as MINOS - 95% ?