NuMI Offaxis

Near Detector and Backgrounds

Stanley Wojcicki
Stanford University

Cambridge Offaxis workshop

January 12, 2004

Topics

- Why Near Detector?
- Background Issues
- Normalization Question
- Some Simulation Results
- On or off axis

Potential Backgrounds

- Beam ν_e's (from μ and K decays)
  - At some level irreducible (energy resolution important)
- Neutral current (NC) interactions (ν_μ, ν_τ, ν_e)
  - Mainly due to asymmetric decay of π^0->$\gamma\gamma$
    - Identification of 2nd gamma (transverse granularity)
    - Origin separated from vertex (longitudinal granularity)
    - Double initial pulse height (pulse height measurement)
- Misidentified ν_μ CC interactions
  - Mechanisms for giving background
    - Misidentification of μ as electron
    - Missed μ (short) and misidentified (as e) asymmetric π^0
  - Due to oscillations background lower in FD than in ND
- Due to low energy τ->e background negligible

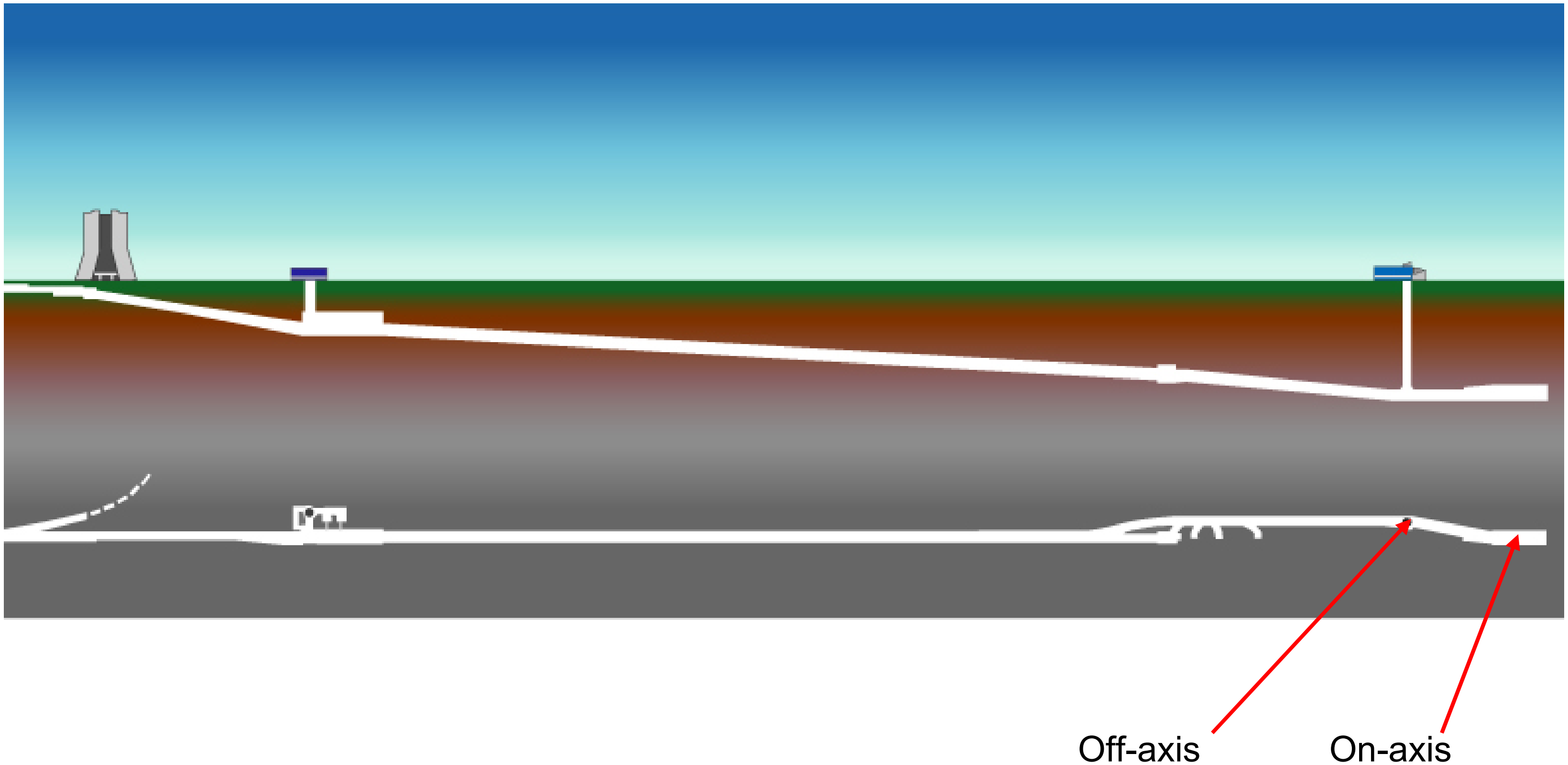
MINOS Near Detector

- MINOS Near Detector can contribute some information re backgrounds
- One can measure here ν_μ CC event spectrum (at 0^o) and from it derive muon spectrum at all angles
- This will give ν_e spectrum at all angles
- Uncertainties are:
  - Potential relative x-section uncertainties at 2 and 5 GeV
  - Response of low-Z off-axis detector

Background Issues

- Different backgrounds may not extrapolate the same way from Near to Far Detectors
- To get around this situation, one can:
  - Measure background contribution from each source
  - Choose conditions such that they will extrapolate similarly
  - Combination of the two
- To set the scale on required level of understanding the systematics; statistical fluctuation on background in FD will be about 15-20% for a 200 kt-yr run

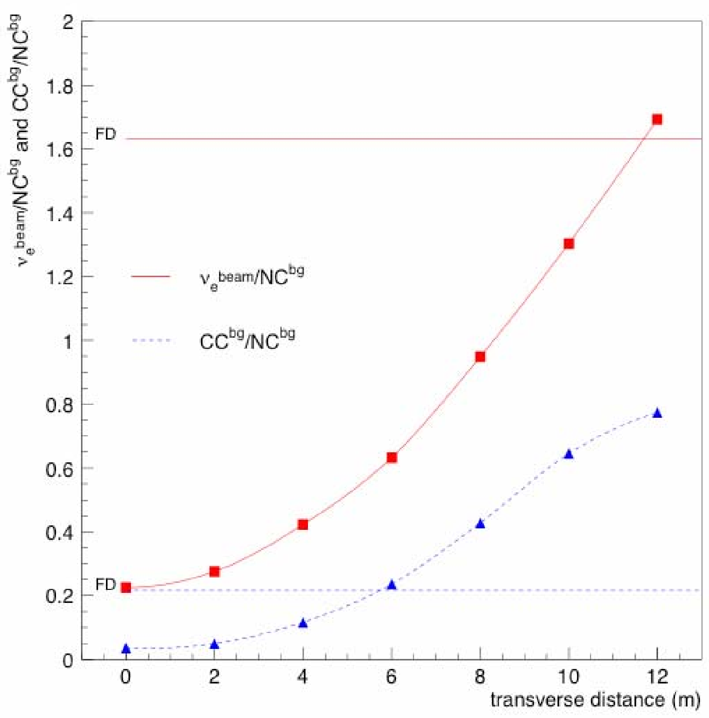
Near Detector Sites



Possible Near Detector Sites
(from MINERνA proposal)

Figure 89: Possible sites for off axis running in the NuMI Underground area

Dependence of different backgrounds



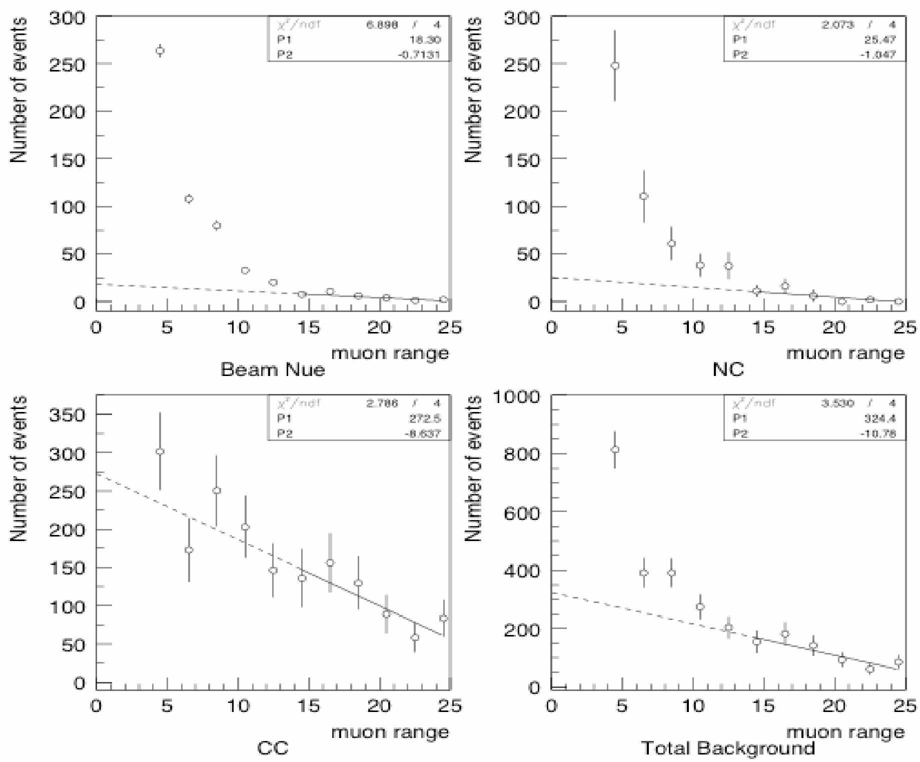
At 12m Near Detector:

- At ND, CC = 22.3 % and at FD = 7.6 %
- Underestimate of CC background by a factor of 2, gives overestimate of total background at FD of 8.7 %
- Statistical error on total background will be ~15%

CC Background Question

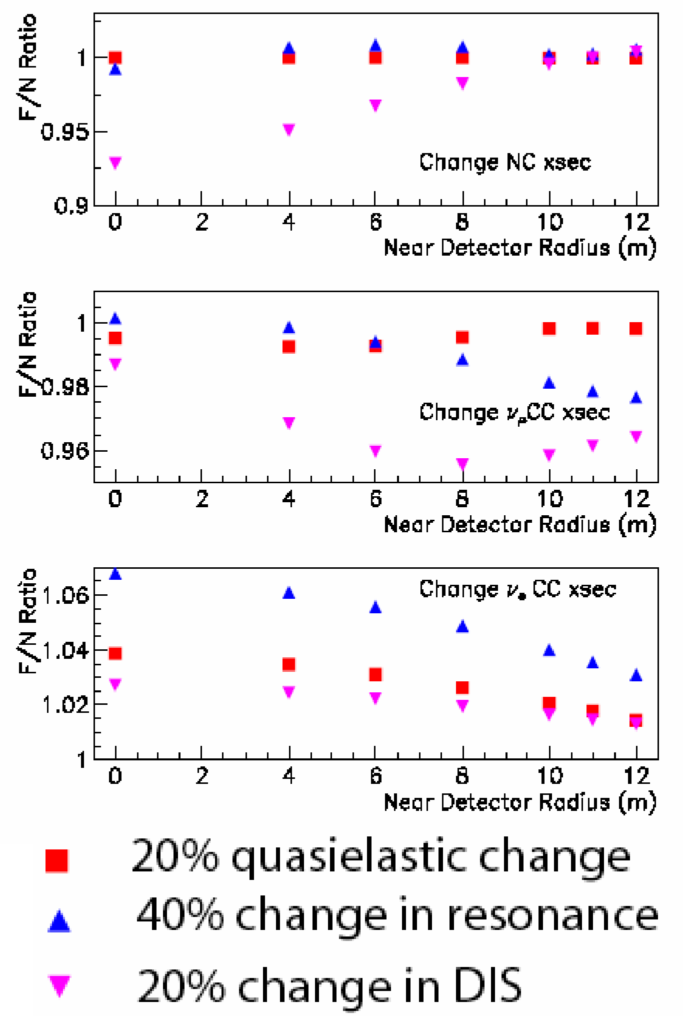
- Can one measure it independently in the Near Detector and if so how well?
- One way of approaching it:
  - Measure ν_e simulation probability for events with definite muon signature and E_{had} in the right range as a function of muon range; then extrapolate to short muon range events which are buried in NC events
- Results from simulations using RPC detector look very promising

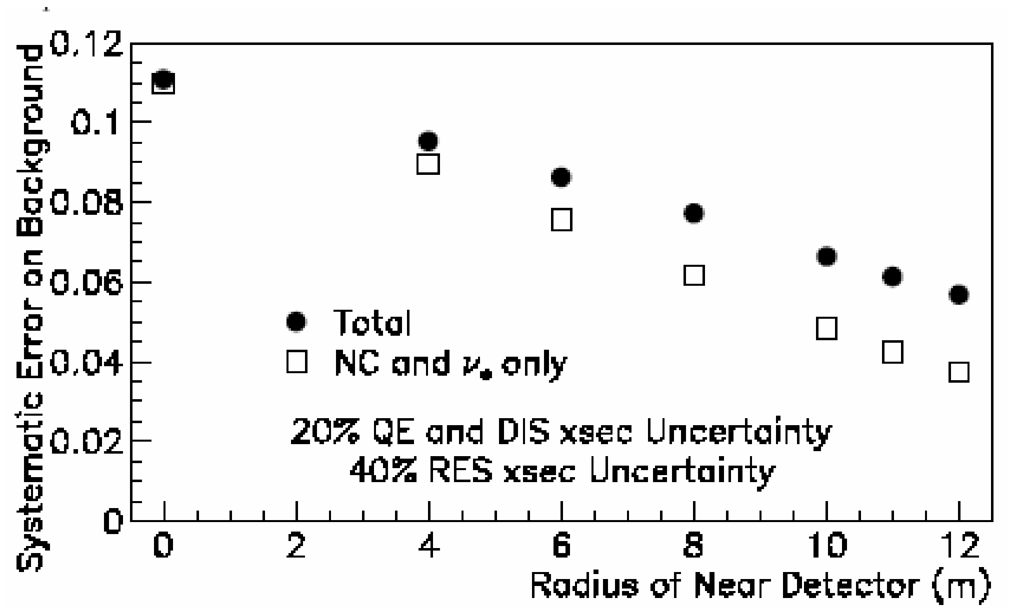
CC background estimate by extrapolation



The extrapolation in “muon” range for CC events gives a value very close to the one obtained from extrapolation of all background events

Cross section uncertainties





(From preliminary calculations by Debbie Harris)

Normalization Issue

- In principle, relative normalization between two detectors is determined by geometry ($1/z^2$), but:
  - Have to correct for line source nature of beam
  - Have to correct for different mean distance to ND for different backgrounds
  - Have to understand mass (fiducial volume) of each detector and relative flux exposure
- Internal normalization (on data) is potentially more bias free
  - NC events look like optimum means of normalization
  - Or maybe even better, NC with $1.5 < E_{had} < 2.5$ GeV or similar limits
  - Need to worry about high *y* CC contamination (?)

Issues to be studied

(for the proposal and eventually for the analysis)

- Sensitivity to variation of contribution from different channels (eg QE, res, DIS) and variation of internal distributions
- Required size, nature and possible location of ND
- What can we learn from auxiliary experiments
- How much better will we know nature of ν interactions at 2 GeV in 5 years; how can we optimize it with NuMI detectors
- + many more

On/off-axis Pros and Cons

- On-axis pros
  - Background dominated by only one source, NC
  - Other important background, ν_e^{beam}, can be calculated reliably
  - CC background absent like in Far Detector
  - NC normalization cleaner (less CC)
  - Fewer constraints on location
- On-axis cons
  - Need to rely on calculation or independent measurement of major background, ν_e^{beam}
  - Spectrum of source of NC events is quite different in the Near Detector than in Far Detector
- Off-axis pros
  - The two main backgrounds, NC and ν_e^{beam} can be made to extrapolate similarly from Near to Far Detector
  - The energy spectra of neutrinos in two detectors are rather similar
  - Near Detector provides useful cross section information on different channels
- Off-axis cons
  - Have to rely on separate determination of the CC background, which is very different in the two detectors

Personal view

- An offaxis detector is more straight forward from the point of view of analysis
- Estimate of CC background rate (biggest uncertainty) does not need to be very precise and should be feasible
- Relatively different contribution to normalization (low *y* events) can probably be understood - more work needed here
- To an outsider, an offaxis detector measurements will probably be more convincing