MINOS nue 1/14/2003

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nue meeting 1/14/2003

- Review of Numi-714
- What was NOT done in Numi-714
- Comments on more recent work
- List of analysis items for discussion
- List of items for further work on optimizing the beam.

What was done in NUMI-714

Cluster finding algorithm.

- Cut MC events with $P_\mu > 1GeV$.
- Fraction of energy in highest energy cluster $>$ 0.7.
- Number of strips in highest energy cluster ≥ 9.
- Neural net estimator $Y > 0$.

  Input to neural net was a 5 strip $\times$ 10 plane box around shower and two angles ($U - Z$, $V - Z$) of the shower.
- FINAL cut on Etot kept as a function of Δm^2.

What was NOT done in NUMI-714

- No examination of Monte Carlo accuracy.
- No study of multiplexing.
- No muon filter.
- No near detector study.
- No elucidation of requirements on calibration, calibration module, photo-electron counts, etc.
- Must perform detailed examination of remaining background. An eyescan suggested another factor of 2 improvement in background rejection possible.

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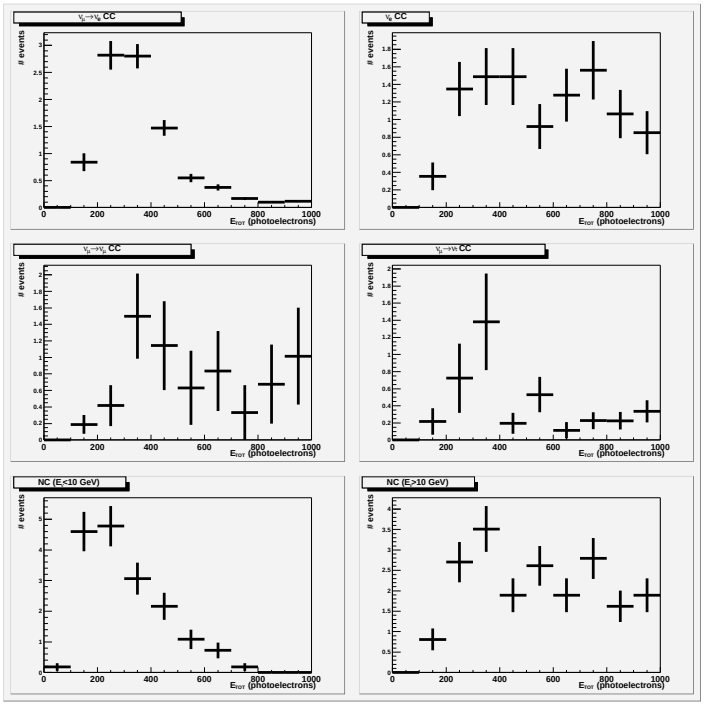
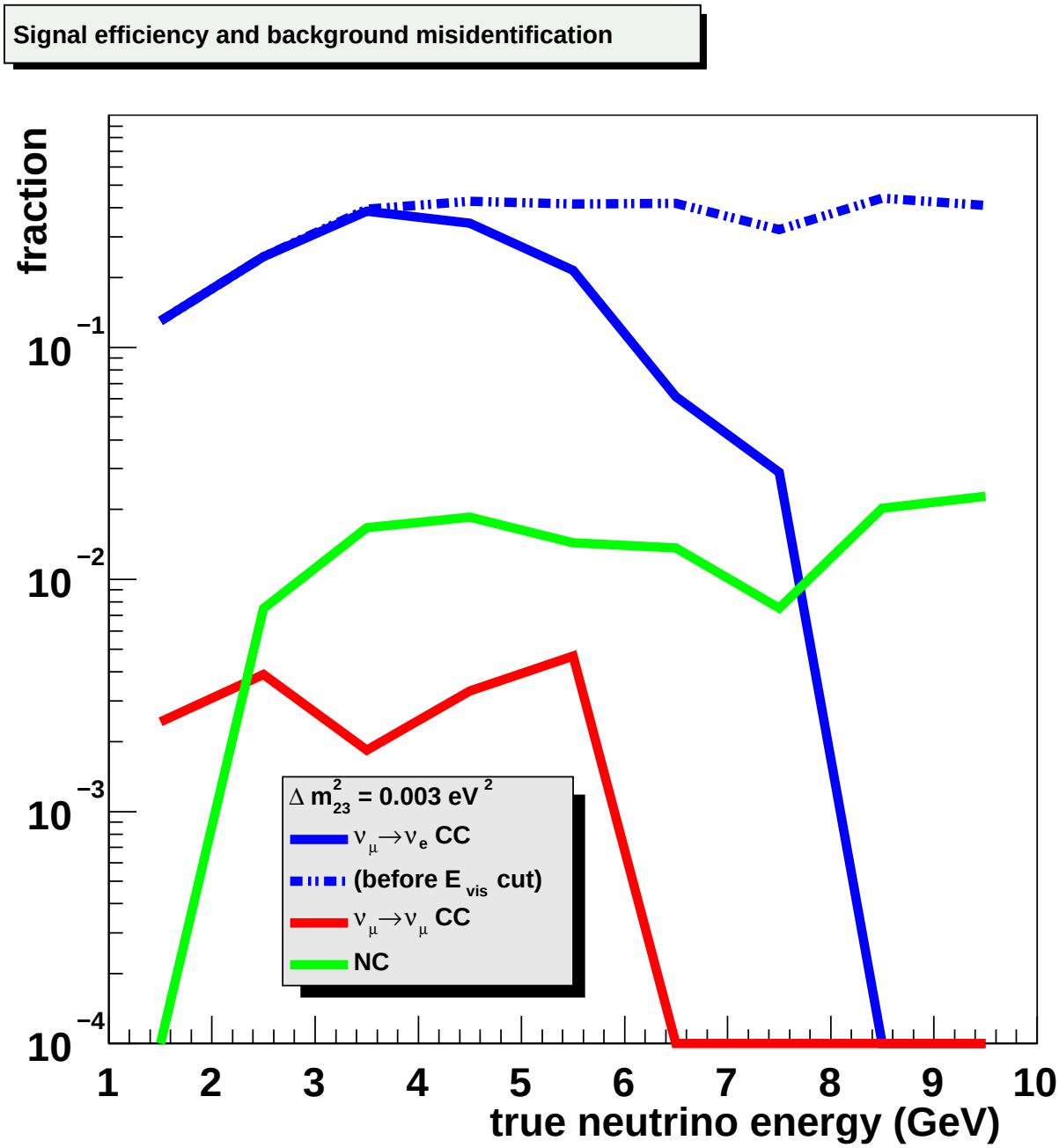


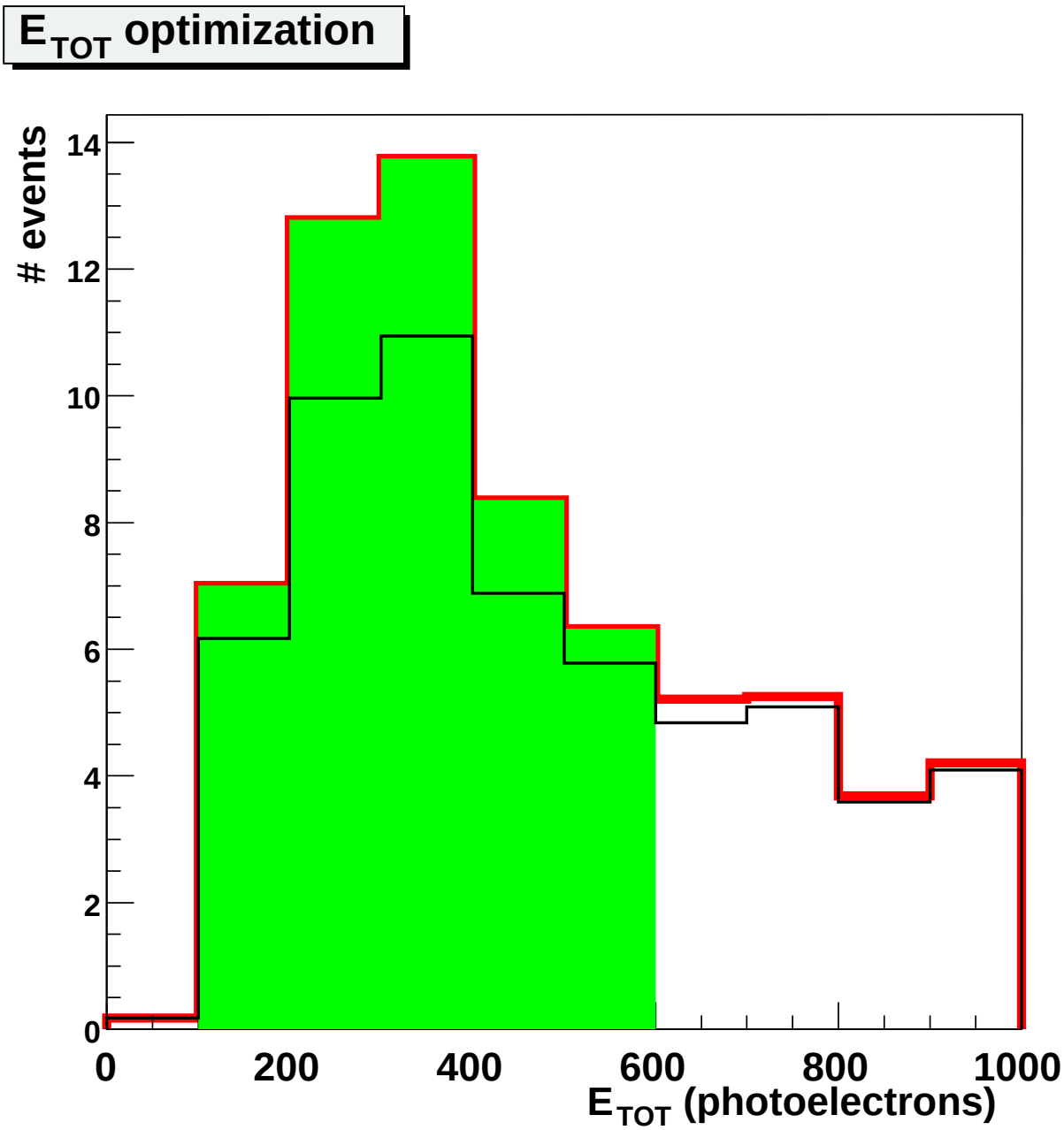
Figure 11: Event distributions for the total energy (E_{TOT}). We require 100 photoelectrons $< E_{TOT} <$ 600 photoelectons. The histograms are normalized to 10 kt-yr data samples. Three generation mixing has been applied with $U_{e3}^2 = 0.01$ ($\Theta_{13} = 5.7^0$), $\Delta m^2 = 0.003 eV^2$, and $U_{\mu 3}^2 = U_{\tau 3}^2$.

Expected Efficiency (ν_e appearance)



$$\delta m^2 = 0.003\mathrm{eV}^2$$

Expected Signal/Background (ν_e appearance)



10 kt-yr, $U_{e3}^2 = 0.01$, $\delta m^2 = 0.003\,\mathrm{eV}^2$, $U_{\mu 3}^2 = U_{\tau 4}^2$

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10 kt-yr exposure in PH2 low and $\Delta m^2 = 0.003eV^2$, $U_{e3}^2 = 0.01$						
	signal	background				
	CC	CC			NC	
sequential cuts:	$\nu_\mu \to \nu_e$	beam ν_e	$\nu_\mu \to \nu_\mu$	$\nu_\mu \to \nu_\tau$	$E_\nu < 10GeV$	$E_\nu > 10GeV$
all events	030	70.9	3906.2	46.0	1061.1	740.7
$P_\mu < 1GeV$	030	70.9	306.3	935	1061.1	740.7
$E_{CLUST}/E_{TOT} > 0.7$	13.9	36.7	23.4	7.8	28.1	114.8
cluster $N_{STRIPS} \geq 9$	12.0	34.8	16.9	6.0	34.1	58.7
$Y > 0$	9.8	036	12.7	5.3	16.8	41.1
$100pe < E_{TOT} < 600pe$	8.5	5.6	3.9	3.0	5.7	11.5
efficiency, bkgd fraction	0.28	0.079	0.001	0.066	0.015	0.016

Table 3: Summary of data reduction for $\Delta m^2 = 0.003eV^2$ and $U_{e3}^2 = 0.01$ (ie. $\theta_{13} = 5.7^o$) in 10 kt-yr of PH2 low.

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		CC bckg.			NC bckg.		Tot bckg.
	Signal	ν_e	ν_μ	ν_τ	$E_\nu < 10GeV$	$E_\nu > 10GeV$	
NHNP	8.5	5.6	3.9	3.0	15.7	11.5	39.7
HNP	10.3	10.4	5.1	4.2	20.3	15.4	55.4
NHP	8.3	5.4	3.7	2.1	13.8	3.7	28.7
HP	10.3	11.5	5.6	3.2	18.6	5.5	44.4

Table 9: Number of expected signal and background events for $\Delta m^2 = 0.003eV^2$ and $|U_{e3}|^2 = 0.01$ after all cuts. NHNP = no hose, no plug or baseline beam; HNP = with hose and no plug; NHP = no hose and with plug; HP = with hose and with plug. It should be noted that the cuts were optimized separately for each beam condition.

5 Studies of systematic errors

It is clear that to reach the desired sensitivity ($|U_{e3}|^2 \sim 0.01$) we must estimate and subtract the number of background events from the observed number of electron showers. Table 9 has a summary of final signal to background numbers for various beam configurations.

We need to understand the uncertainties on the background estimate shown in table 9. This could also be considered the error on the background if no use is made of the near detector data. This error has three components: the error on the neutrino spectrum simulation, the error on the cross sections, and the error on the simulation of the event pattern and the effect of the cuts. The main error on the ν_e beam contamination background is from the beam simulation. We will use the error of 20% from the E734 measurement of this contamination [16] in a similar 1 GeV wide band beam at the BNL-AGS. Another experiment, E776, assigned an error of 12% to the ν_e contamination after tuning of their Monte Carlo using the ν_μ spectrum measurement. Since the MINOS ν_μ far spectrum will be highly distorted due to oscillations this method cannot be used, therfore we will use the 20% number. We can also use the systematic error obtained in E776 for both the ν_μ charged current and the neutral current π^0 channels [17]. E776 assigned an overall error of 40% to the π^0 contamination; this includes both the cross section uncertainty as well as uncertainty on Monte Carlo simulations of the events. However, they assigned a much larger, 100%, error to the charged current component to their π^0 background [18]. Therefore we will assign as error of 100% to our ν_μ charged current rate and use 40% for the neutral current background. The error on the ν_τ charged current background will depend on the pattern recognition cuts; for the moment we will assume no error on this estimate. Using these numbers we obtain an error of 30% for the total background. Given this uncertainty, which is larger than the signal, it is clear that an accurate measurement of the background must be performed in the near detector. This measurement must then be extrapolated by Monte Carlo to the far detector.

The uncertainty in this procedure will come from two different sources: 1)

Problem for ν_e: background

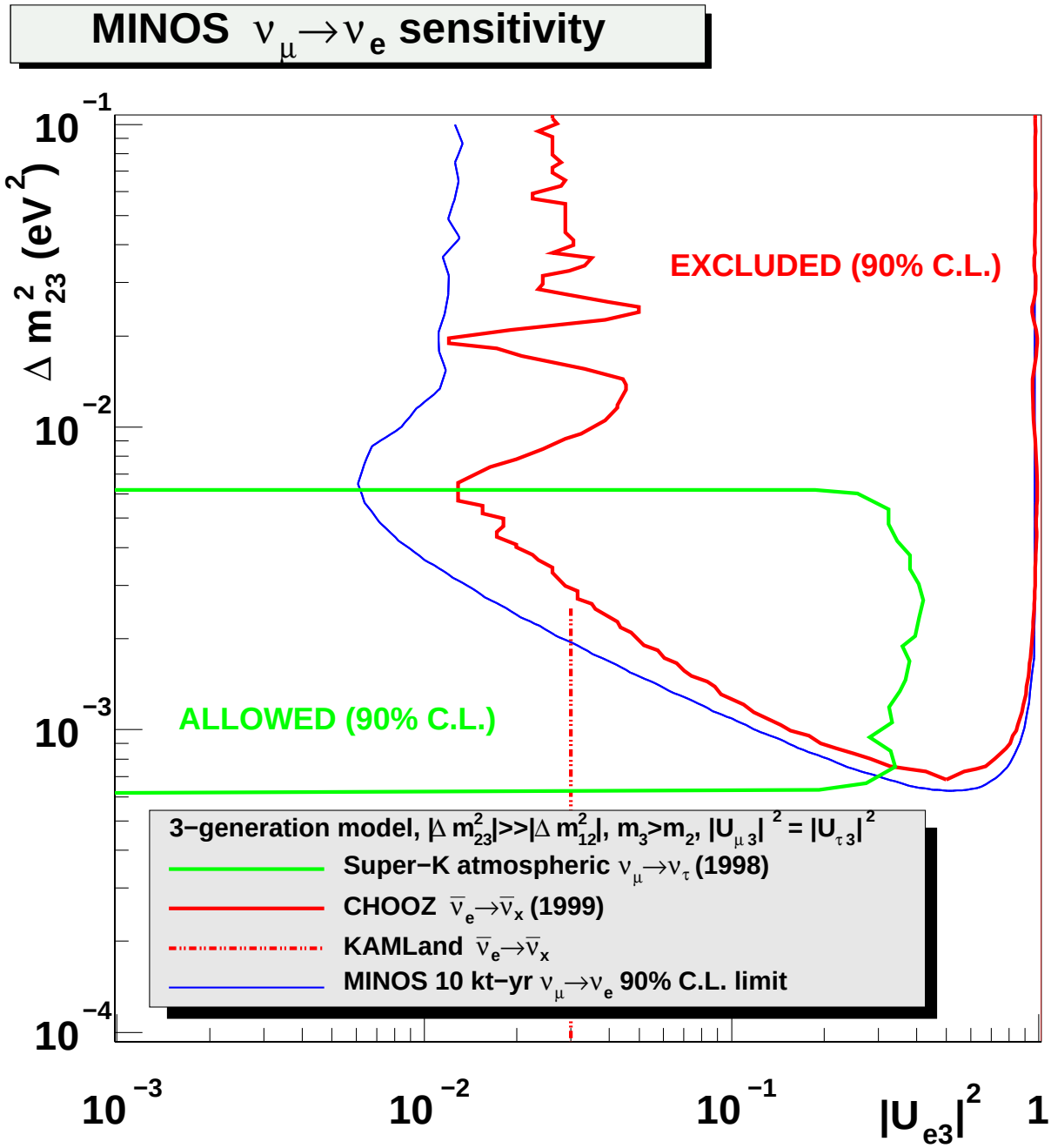
δm^2	signal	ν_e (intrinsic)	ν_μ CC	ν_τ CC	NC (E_ν <10 GeV)	NC (E_ν >10 GeV)
0.002	8	5.6	3.9	2	15.7	11.5
0.003	8.5	5.6	3.9	3	15.7	11.5
0.004	20	5.6	3.9	10	12.0	11.5

At $|U_{e3}|^2 = 0.01$

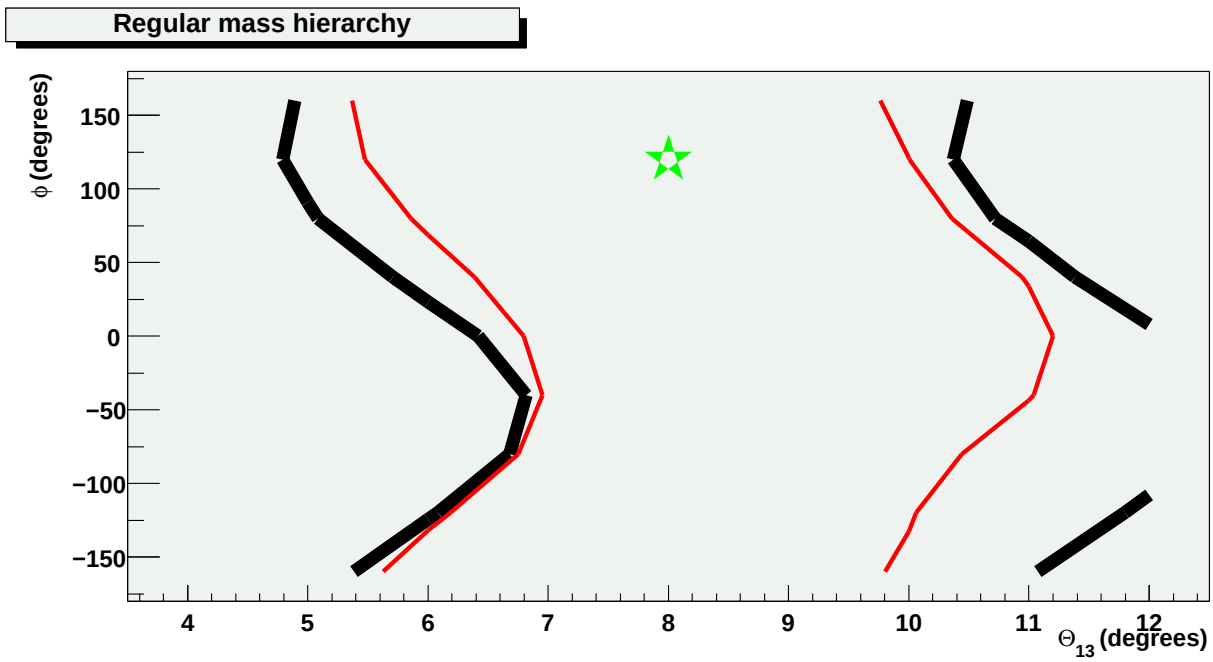
Baseline LE beam.

10 kton·years.

Expected Limits
(ν_e appearance)



Expected Sensitivities (ν_e appearance)

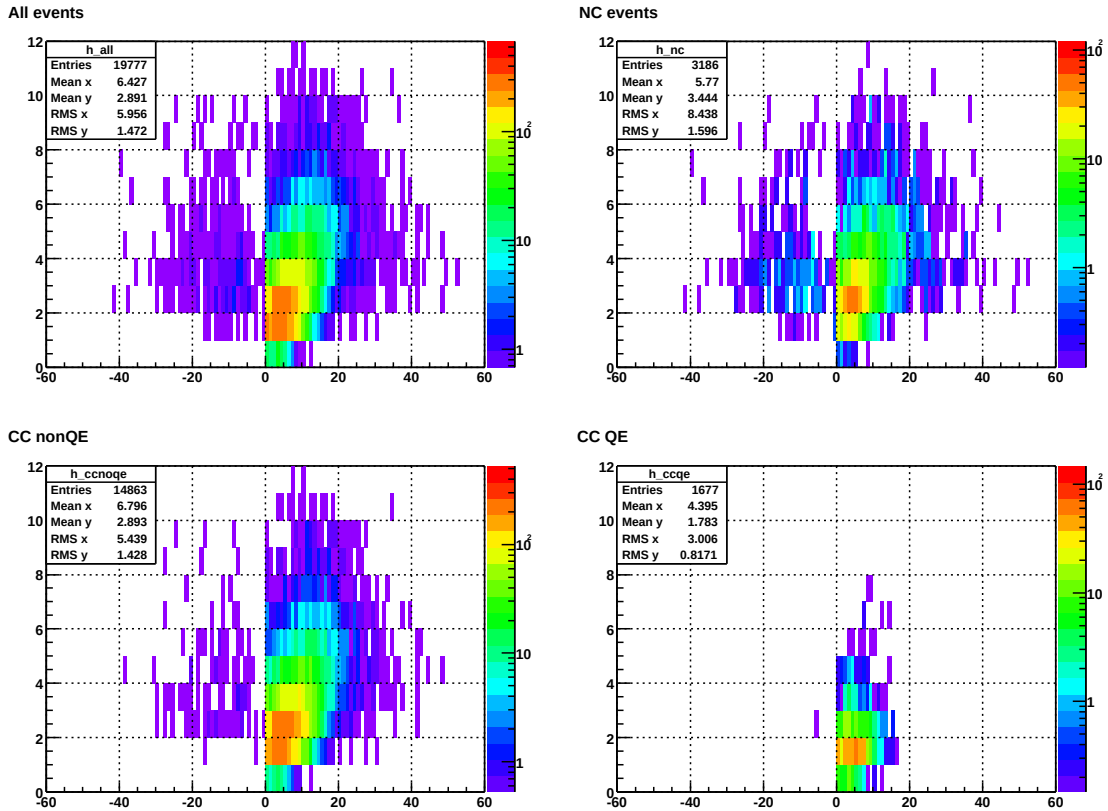


Green test point at $\theta_{13} = .14$, $\theta_{12} = \pi/4$, $\theta_{23} = \pi/4$, $\delta m^2_{12} = 0.0001\mathrm{eV}^2$, $\delta m^2_{23} = 0.003\mathrm{eV}^2$, $\phi = 2\pi/3$.

Black line is 1-σ, 10 kt-yr $\nu_\mu \rightarrow \nu_e$

Red line is 1-σ, 20 kt-yr $\bar{\nu}_\mu \rightarrow \bar{\nu}_e$

Some New Work



Brett: Run 25000 MC events assuming total $\nu_\mu \rightarrow \nu_e$ conversion. Run demultiplexing. New "standard" shower finder. Simple cut: 10 planes, 2 strips => 68% QE 14% NC.

Future Experimental Approach

- More flux at lower energy

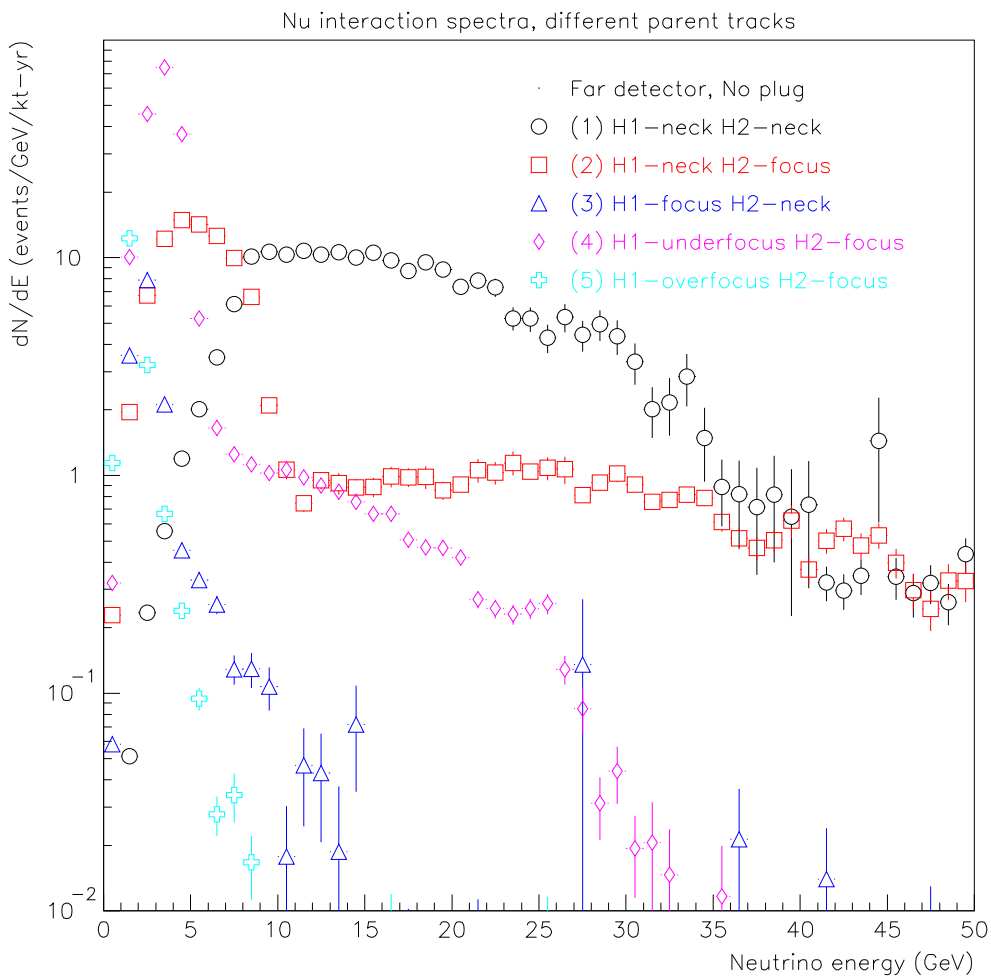
  Improve Δm^2 resolution. Observe a dip in the spectrum.

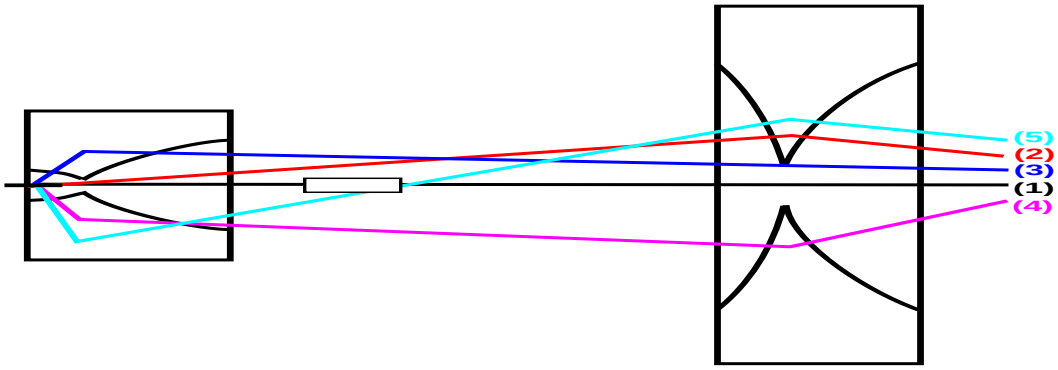
  - New target/horn design
  - Event rate
  - Muon detection threshold in detector ?

- Enhance sensitivity to ν_e
  - Reduce high energy flux (NC back.)
  - Make detector better ?
  - Build another detector ?

- Build a separate detector Off-axis.

Neutrino Beam Components





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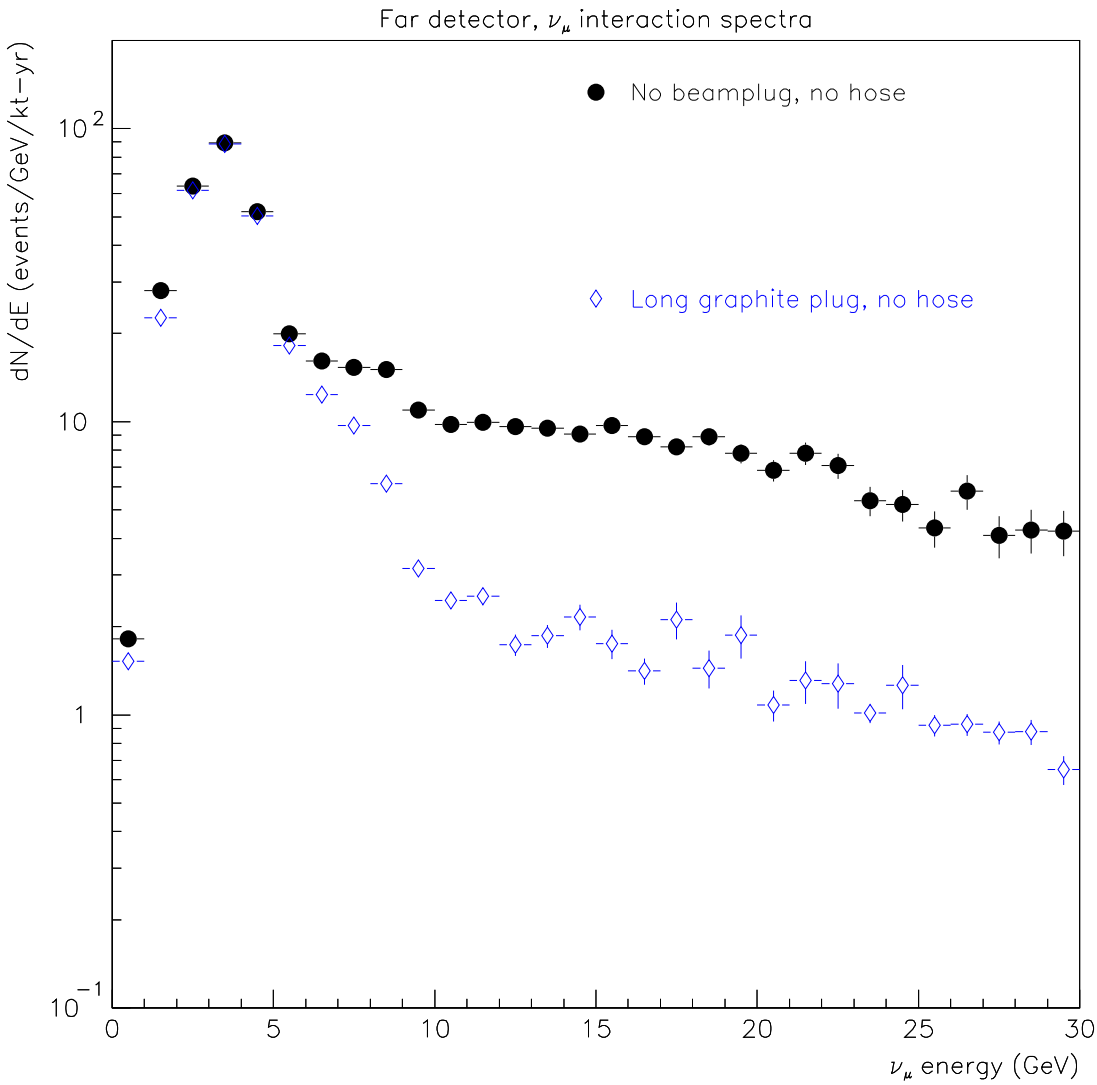
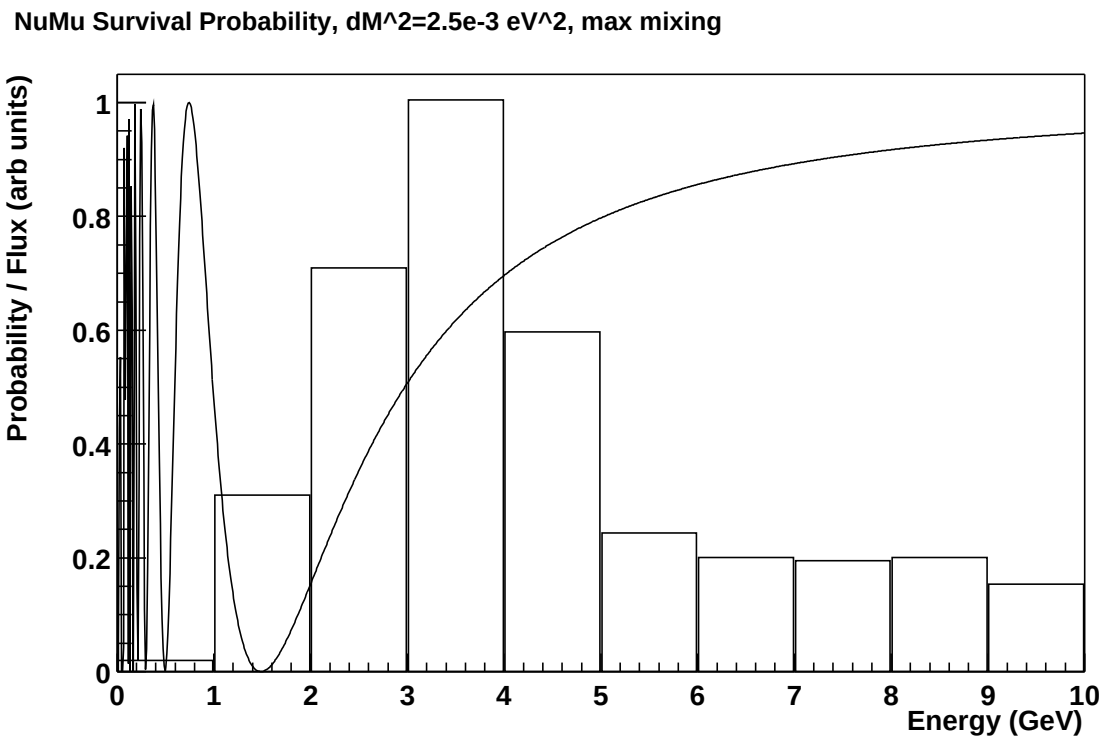
Effects of 2.5m Graphite plug



Energy (GeV) :	0 - 3	3 - 6	6 - 10	10 - 30
Reduction (%):	5	0.0	24	80

Oscillation Probabilities



List of analysis tasks for $\nu_\mu \rightarrow \nu_e$

- Re-evaluate the cross sections in the Monte Carlo.

  Steve Kahn will show some y-distributions that seem strange.

- Recalculate the physics reach for MINOS with new improved reconstruction software.

  1 Plot from Brett as a start.

  Is there a demultiplexing issue for showers ?

- Simulate and analyze the background spectrum in the near detector. Determine effects that will limit the systematic uncertainty on the background to the electron signal.

  We made no study of near detector in NUMI-714. Assumed 10% sys. error on background.

- Introduce calibration data from the recent calibration runs of a test module at CERN into the analysis.

  It is still unclear where the calibration detector data fits in the nue study.

- Blind Analysis

Blind Analysis 3 methods

- Analyze near detector data to determine cuts. Rely on Monte Carlo to predict far detector background. Apply cuts to far spectrum without prior examination of far data.

  Need to have faith that we understand all far detector hardware/software problems.

- Divide far data in two parts. e.g. 1/3 and 2/3 Develop cuts on 1/3 of the sample. Apply cuts to 2/3 that is left blind.

  We may not have enough statistics to divide the data samples in this way.

- Mix Monte Carlo ν_e signal into the data. Attach a crypto-number to each event with two keys kept with two separate people. Develop cuts and extract the signal in the normal way on the entire data set. When satisfied with your understanding of the background eliminate the Monte Carlo events with the cryto-graphic flag.

  Must have excellent simulation of the detector in every possible way.

  Need to know Δm^2 reasonably well.

List of items for $\nu_\mu \rightarrow \nu_e$ optimized running

- Redesign the first horn as well as the target in the NuMI beamline to produce a beam with more flux at 1.5 GeV.
- Eliminate the high energy tail which produces neutrinos of energy as high as 50 GeV.
- Calculate the improvement in signal to background ratio with the new beam. Identify potential new problems in systematics.
- Perform conceptual engineering design of the horn/target system; in particular, identify solutions to the problem of keeping the target cool and mechanically intact.
- Prepare a preliminary schedule and budget for the proposed NuMI beam upgrade. Can this be ready by 2006 ?
- Understand the performance of the new system for the off-axis neutrino spectrum.