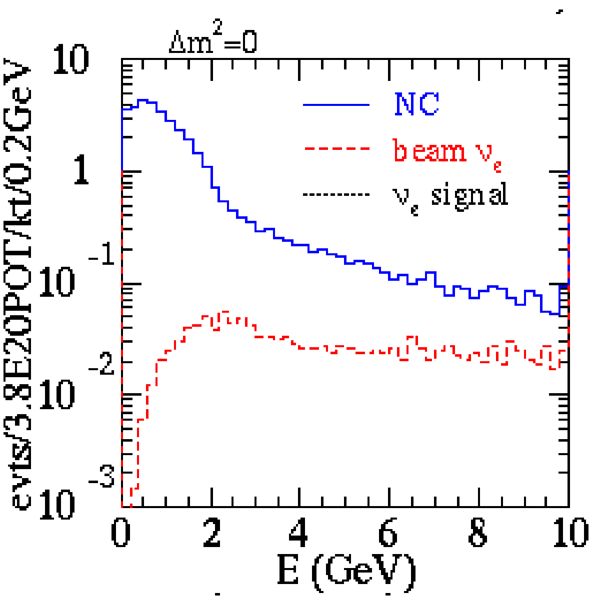
Far Detector Working Group Overview

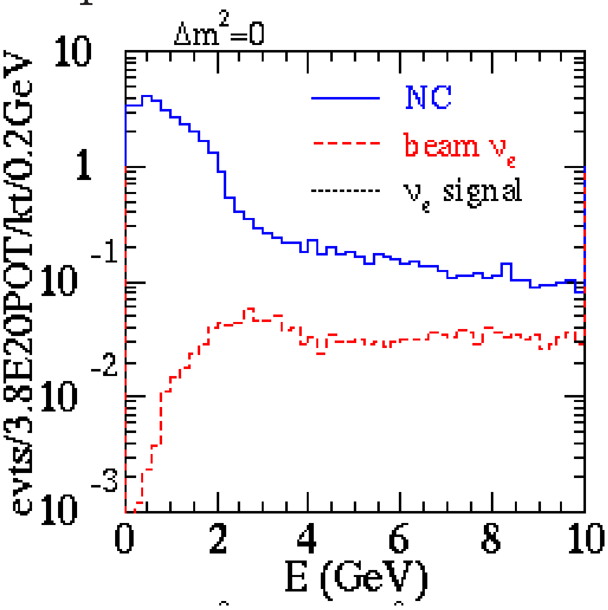
- Brief Reminder of Yesterday
- Description of Detectors
- Sensitivities vs Running Time
- A Word about Systematic Errors
- Sensitivities vs Baseline
- Goals for This Workshop

Deborah Harris
May 3, 2002
New Initiatives with the NUMI Beamline

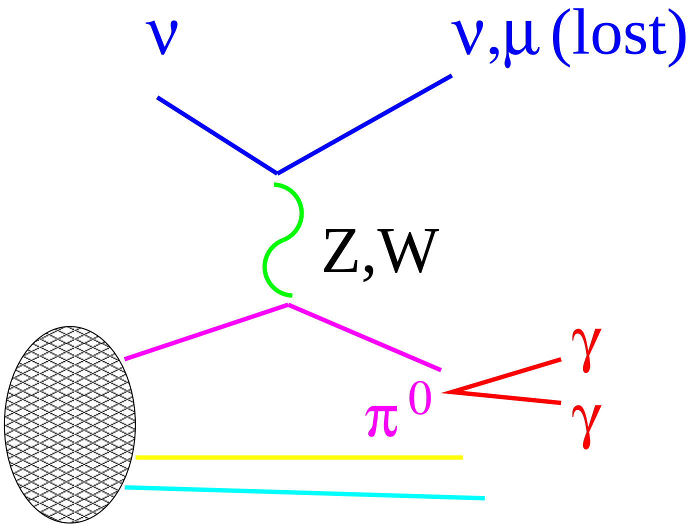
Bane of our Existence: Neutral Current Background

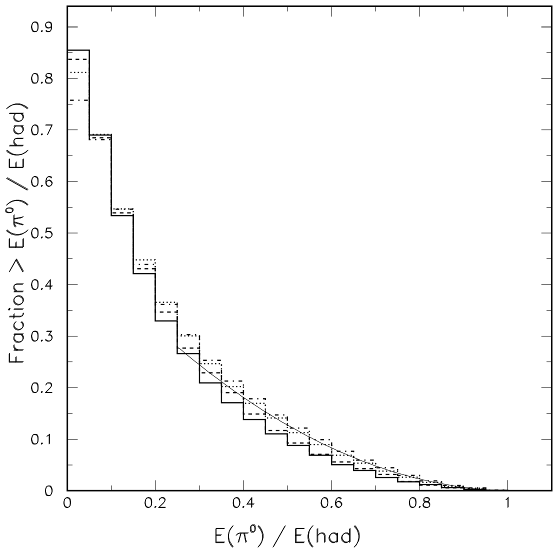
As Mark Messier is now Showing in the Beam Working Group:





Low Energy Medium Energy





from F.DeJongh

The problem with multi-variable problems....

Problem: Given a beam flux, your sensitivity depends on:

- Mass of Detector
- f_s Signal efficiency
- f_b Background efficiency
- ϵ_b Systematic uncertainty on f_b
- Δm^2 (maybe even the sign)
- Baseline..

How is a person to chose?
Argument we've all heard (made?) before:
$\Phi \sim 1/L^2, \sin^2(\Delta m^2 L/E) \sim L^2$ –not so fast!

Detectors to Consider

Requirements: Electron Appearance!

- Good Longitudinal and transverse segmentation
- Good Energy Resolution to remove NC and ν_e events
- Particle ID at the 10^{-2} level at least!

Vital Statistics of Detectors:
(as defined for this study)

- NC Background "Efficiency"

$$f_{NC} = \frac{\text{NC Events accepted after all cuts}}{\nu_\mu \text{ events in energy peak}}$$

- Detector Signal Efficiency

$$\epsilon_s = \frac{\text{NC Events accepted after all cuts}}{CC\nu_\mu \text{events in energy peak}}$$

- Mass

MINOS Detector

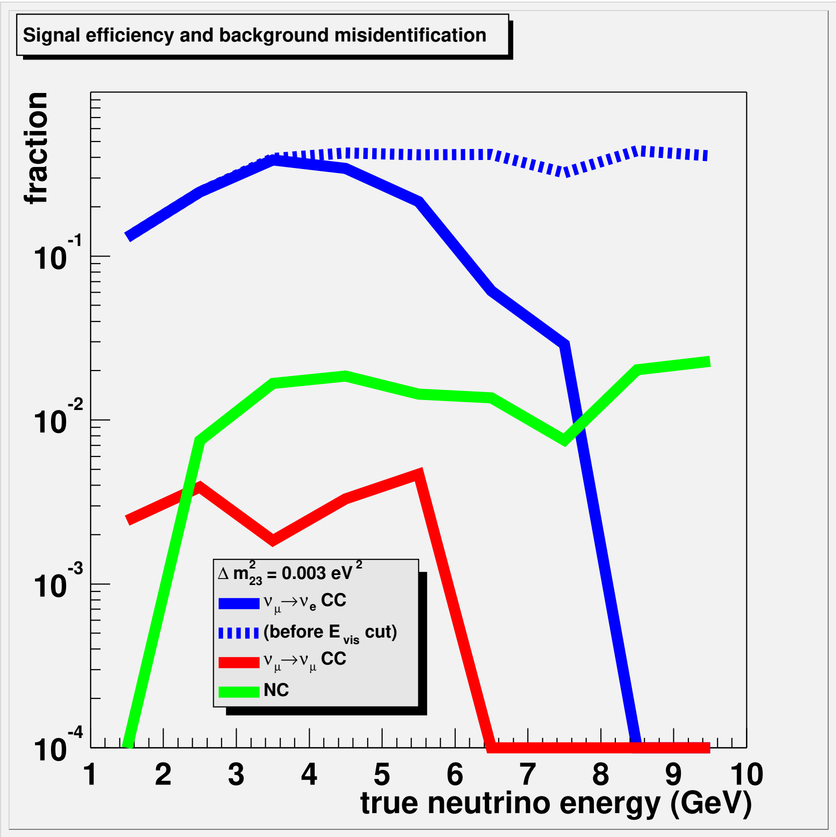


Figure 16: Signal efficiency and background misidentification versus true neutrino energy (for $\Delta m^2 = 0.003eV^2$).

NUMI-L-714: Diwan, Messier, Wai, Viren

Estimate from this plot:

Signal Acceptance at 2GeV could be

30

as good as it was tuned to be at 3GeV (40%)

NC Background Rejection at 2GeV:

1.5% "standard" so 1.5/(cc/nc)% or 0.6%.

Intrinsic ν_e would therefore be $.5\% * .4 = .2\%$, so NC is about 3 times larger than ν_e's in the beam

Water Cerenkov Detector

NC Background: About 2 times the ν_e background after cuts
Beam Background*acceptance= 0.125%
Acceptance 24%
See talk by Mark Messier

Comments:

- Instrumenting only surface, so channel count and probably cost $\propto (mass)^{2/3}$
- proof of principle exists
- performance not as good as at 1GeV but...
- Above analysis was with log likelihood functions and looking at many variables...but
- could different photocathode coverage help?
- Electronics, timing? (Bob Svoboda)
- What about AQUARICH technology? (Scott Menary)

Fine-Grained Calorimeter Detector

Two ideas for this technique: Sandwhiches of Thin steel, air, and scintillator, or Plastic, and RPC
Both achieve 35-42% signal efficiency
Both achieve NC background rejection to where it is about half or 2/3 the intrinsic ν_e

Comments:

- What segmentation is really needed?
- How will an experiment
  deal with the channel count?
- what is the cost/kton? (scales linearly with mass)
- .....

Most of Focus of Afternoon: Fine-Grained Calorimetry

See overview talks by:
Michal Szleper, Ken Heller, Adam Para, Jeff Nelson, Bruce King
Absorber Talks:
Ron Richards
Readout Talks:
Daniel Marlow, Caren Hagner, Eric Prebys
Engineering Issues:
Vic Guarino, Jeff Nelson

ICARUS Detector

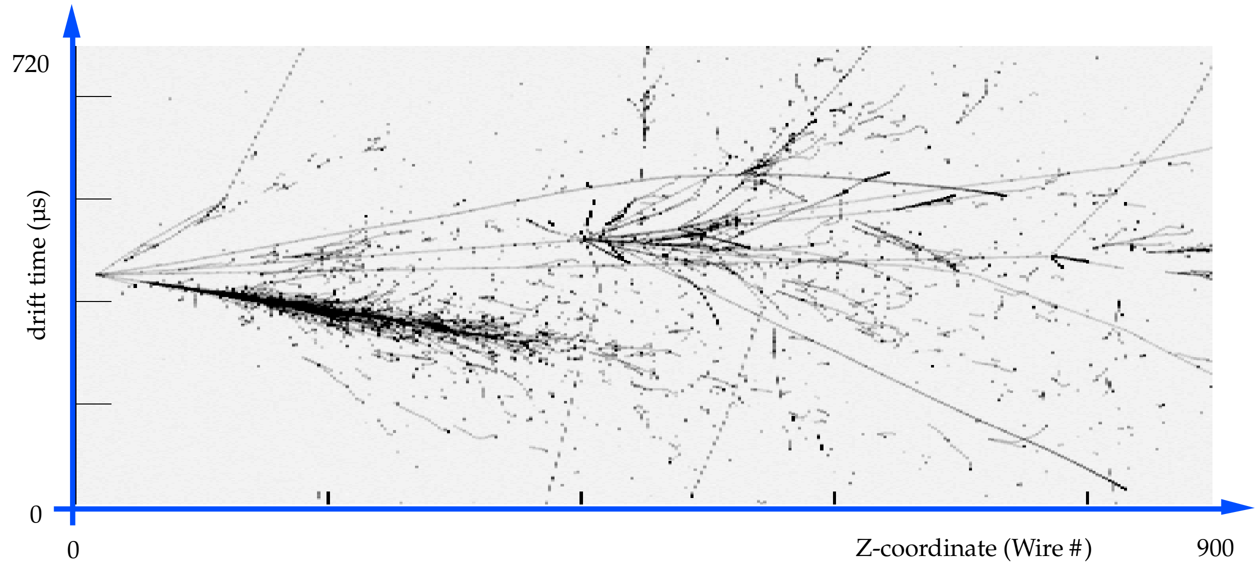
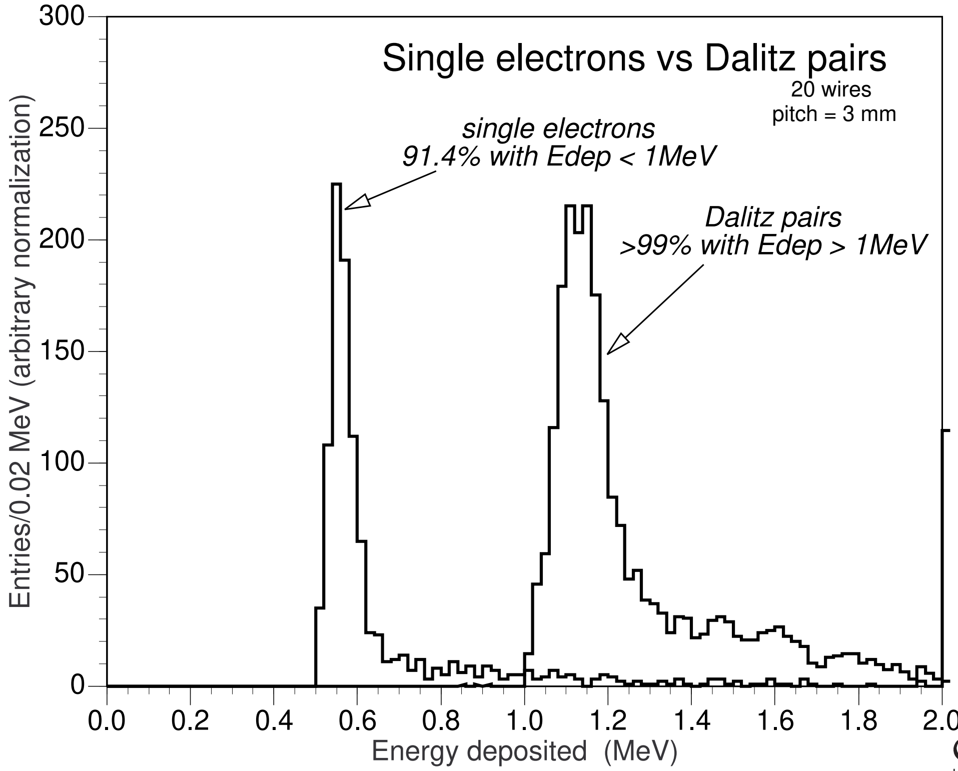


Figure 1



See talk by D. Cline in this session!

ICARUS Detector , Continued

Quoted Energy Resolution:

$$\sigma_{electron}/E = 3\% \oplus 1\%$$

$$\sigma_{hadron}/E = 20\% \oplus 5\%$$

So for a 2GeV neutrino, the energy resolution is at least 10% if not better, so it's more narrow than the width of the beam itself.

NC Background: 0.05%
Beam Background*acceptance= 0.45%
Acceptance 90%
M.Campanelli, and ICANOE proposal

Comments on ICARUS Detector

- in principle, instrumenting surface not volume...
- still a lot of channels
- 600Ton Module being commissioned now...
- MC is Gorgeous, how does this perform in real ν beam?
- If 600Ton is largest module, is cost prohibitively high?
- If not, what is the largest module size?

Detector Summary

Target	Readout	Segm.	ρ	ϵ_s	f_{NC}
MINOS[a]	Scint	$1.4X_0$	~ 4	40%	0.6 %
4.5mmSteel[b] + 3cm air	Scint	$0.25X_0$	$< 1!$	38%	0.15%
Plastic[c] Pellets	Glass RPC	$0.3X_0$	0.75	35 %	0.1%
ICARUS[d]	TPC	a lot	1.4	90%	0.01%
H_2O Č[e]	PMT's	n/a	1	24.0%	0.6%

References:

[a] M.Diwan, M.Messier, B.Viren, L.Wai, NUMI-L-714

[b] M. Szleper, M.Velasco

[c] A. Para

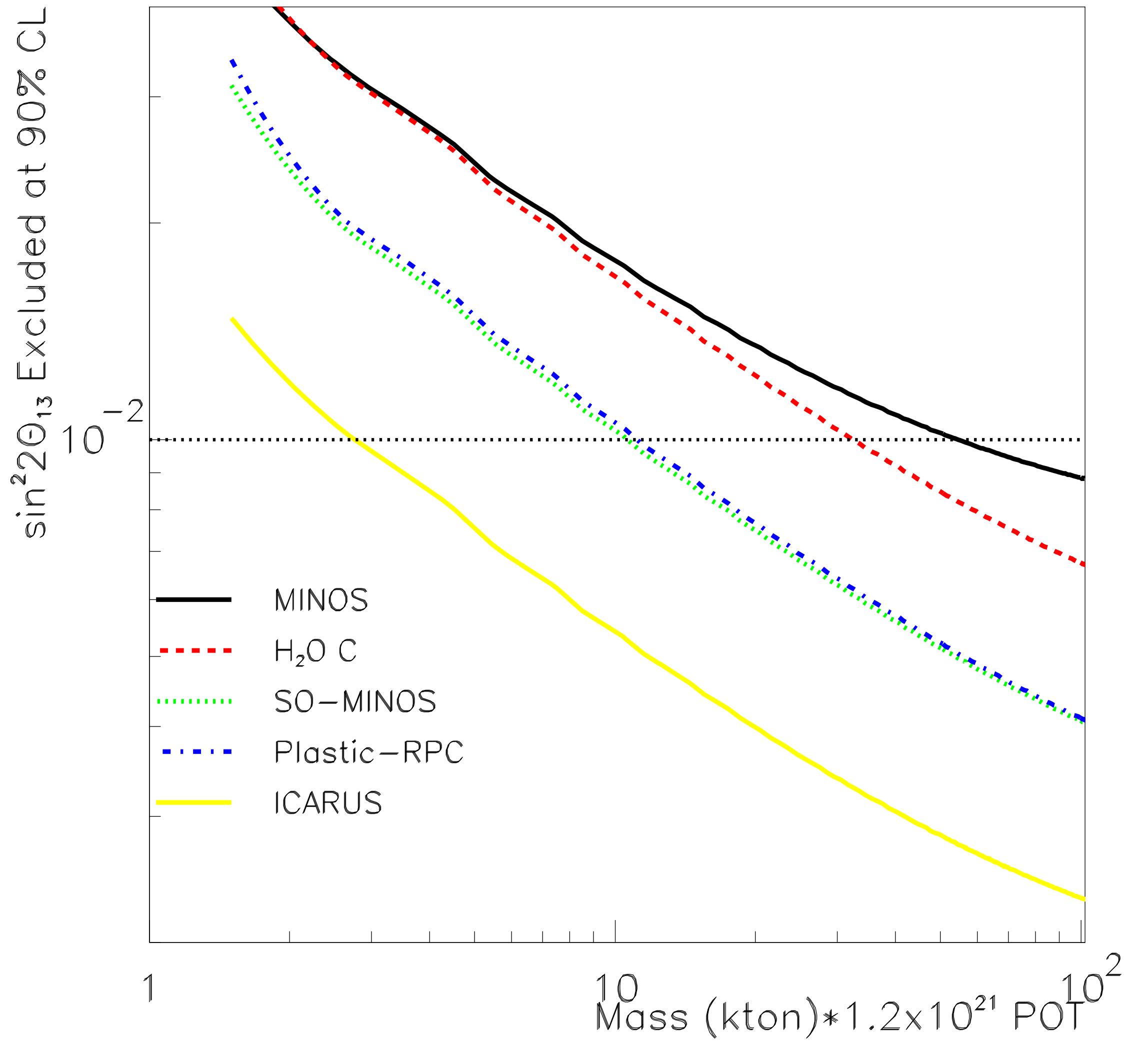
[d] M. Campanelli, and ICANOE Proposal

[e] Mark Messier, Dave Casper

Assumptions for remainder, unless otherwise stated:

- $\Delta m^2_{23} = 3 \times 10^{-3} eV^2, \theta_{23} = 45°$
- 10% Syst. error on NC+ν_e background
- Baseline=735km
- No Matter Effects
- monochromatic beam

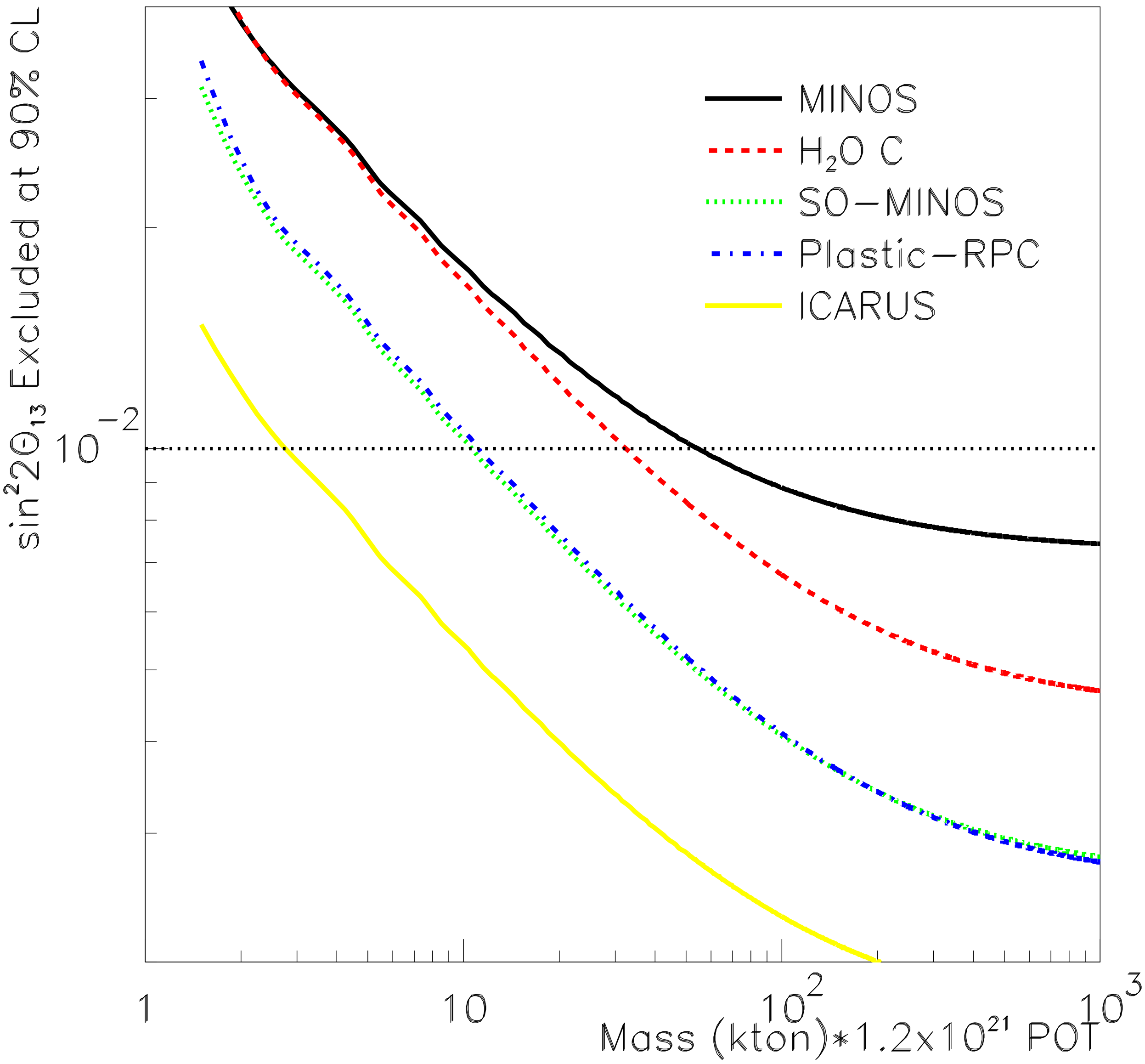
Sensitivity Versus Mass



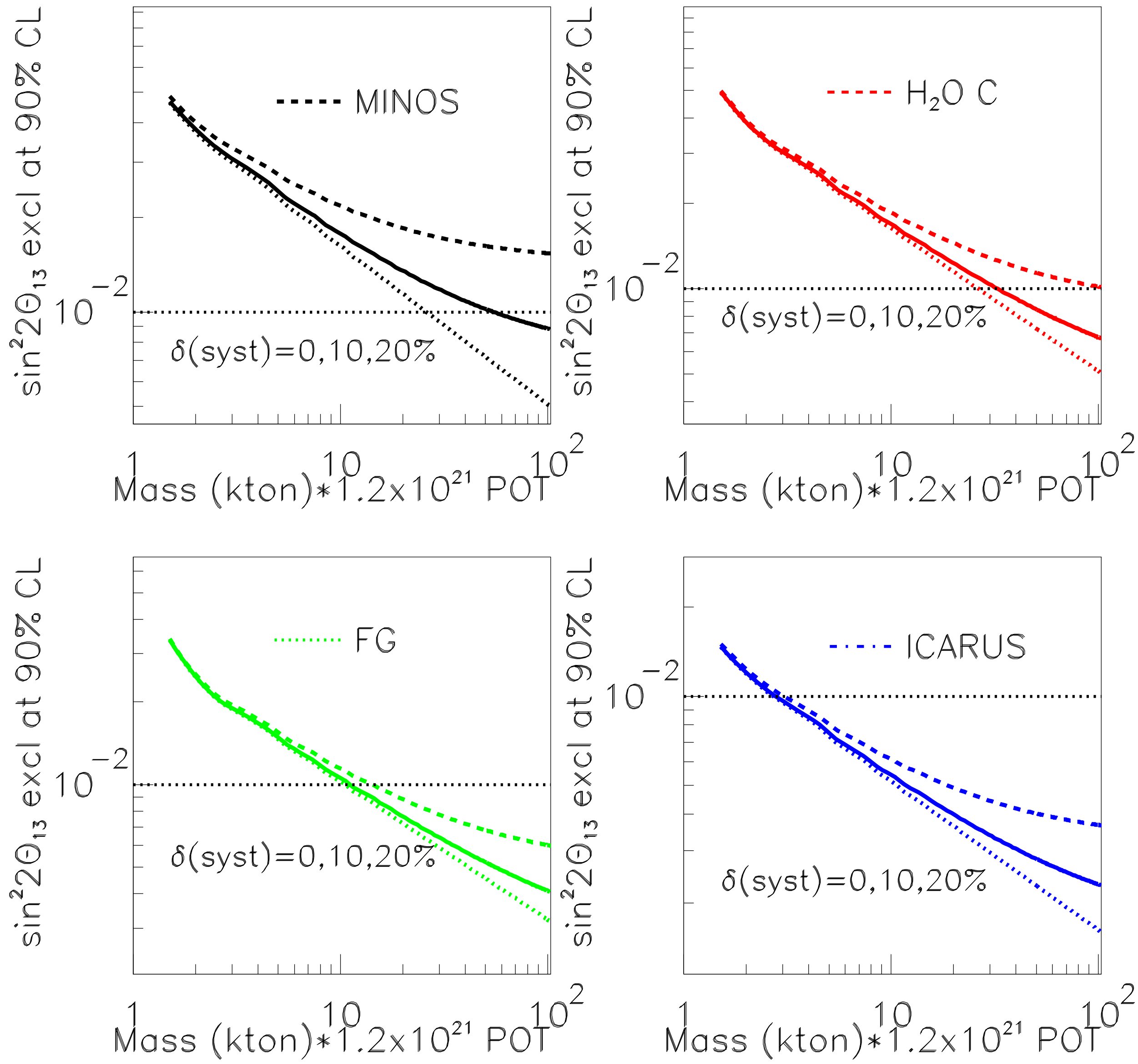
Rough Conclusion:

- ICARUS detector compared to Fine-Grained Calorimeter is about a factor of 3 more sensitive **per kton**
- Water Cerenkov compared to FG is ∼factor of 3 less sensitive **per kton**

Where do these Experiments run up against Systematics?



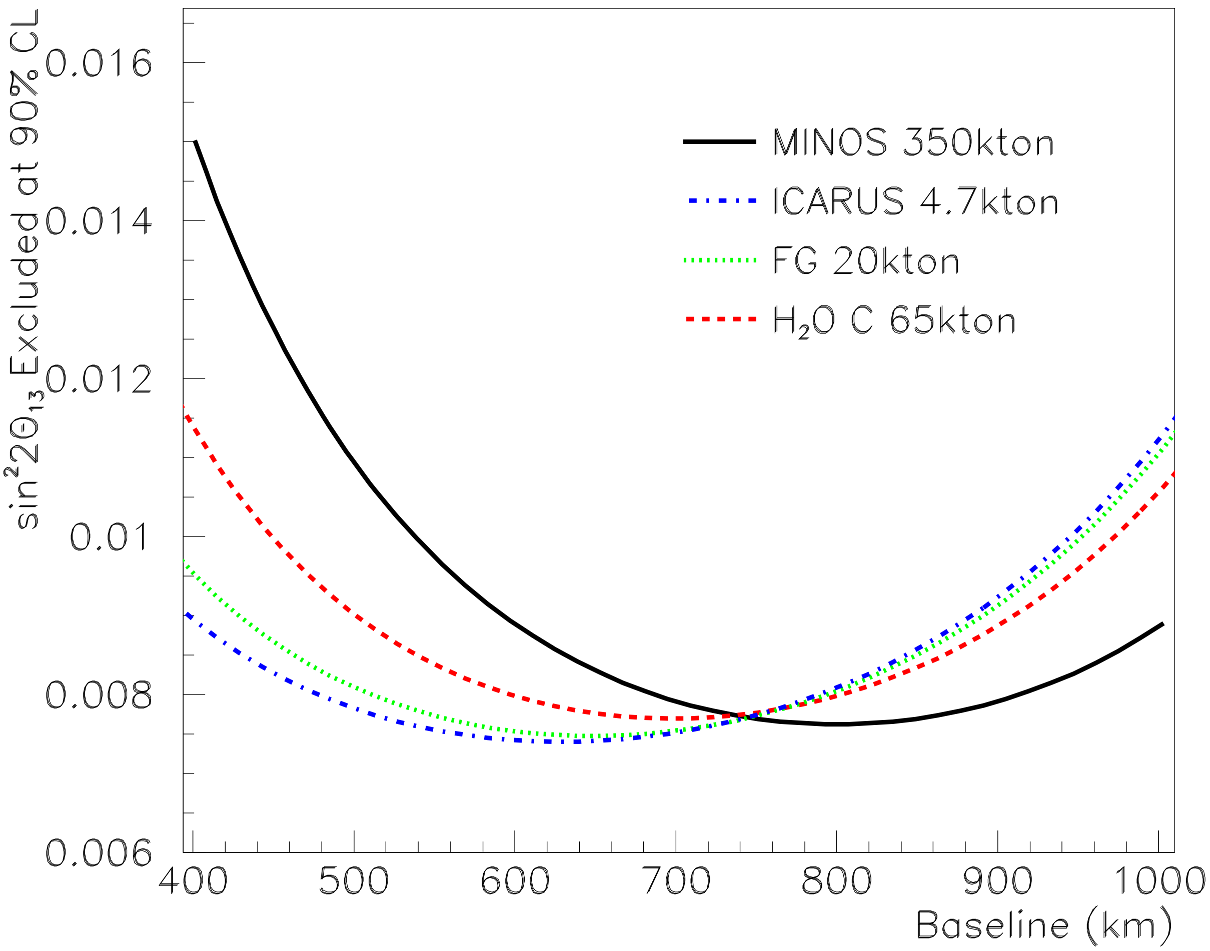
Effects of Systematics on Different Experiments



Where is the MINOS off-axis beam?

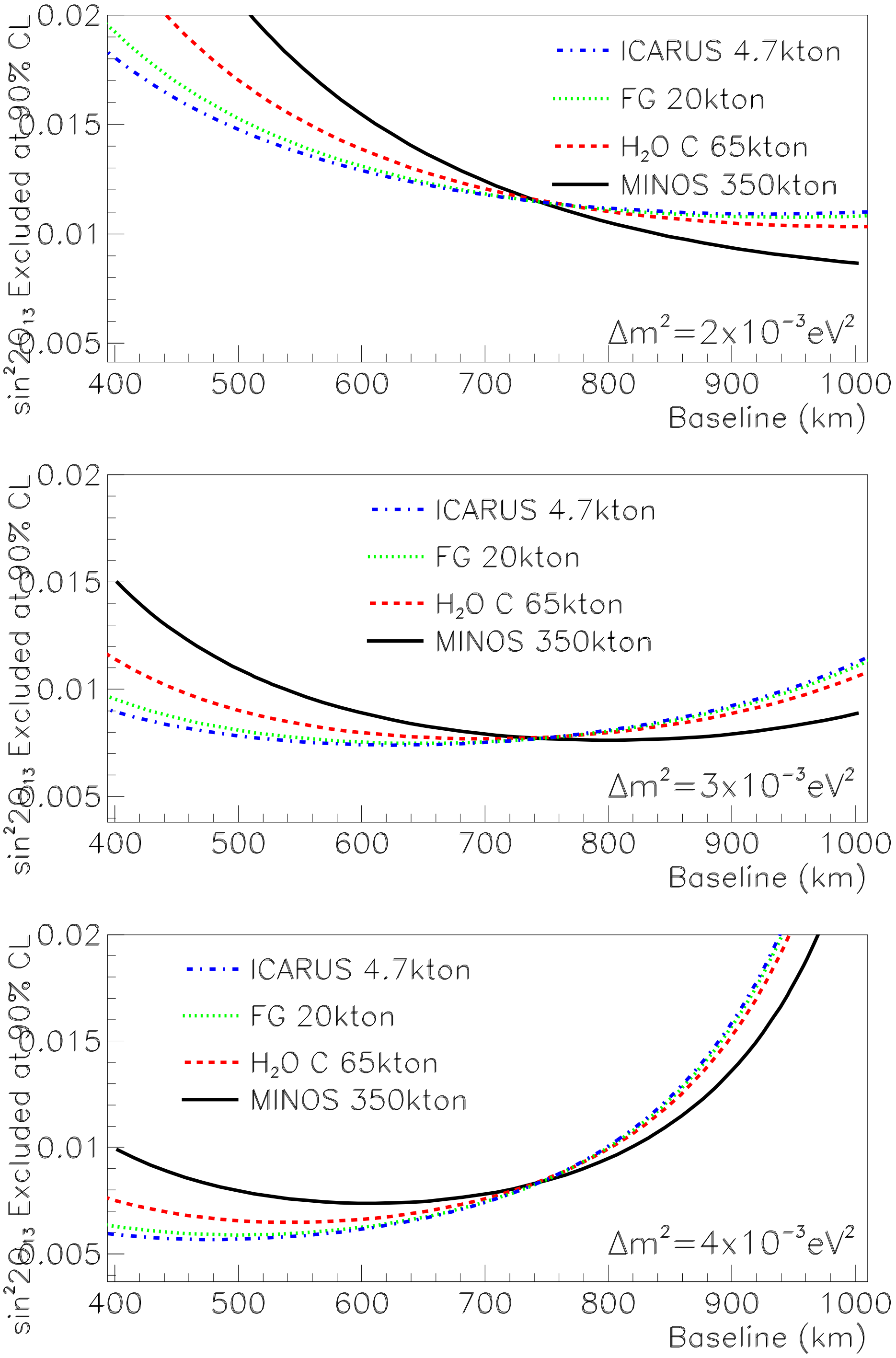
For 10km off, could be as far as 911m away!

Is Site Choice Independent of Detector Choice?



But what does baseline buy you?
Matter effects, which is
something unique to MINOS off-axis

Baseline/Δm^2_{23}/Detector Correlations



Goals for this Working Group

First of all: is this table correct?

Target	Readout	Segm.	ρ	ϵ_s	f_{NC}
MINOS[a]	Scint	$1.4X_0$	~ 4	40%	0.6 %
4.5mmSteel[b] + 3cm air	Scint	$0.25X_0$	$< 1!$	38%	0.15%
Plastic[c]	Glass	$0.3X_0$	0.75	35 %	0.1%
Pellets	RPC				
ICARUS[d]	TPC	a lot	1.4	90%	0.01%
H_2O Č[e]	PMT's	n/a	1	24.0%	0.6%

Second of all: Need to fill out a new table

Detector Technology	Cost /KTon	Cost Driver	KTon/$\|U_{e3}\|^2$ limit	KTon /year
Plastic/RPC				
4.5mm St/Sc				
ICARUS				
Water Cerenkov				

Comment: for fine grained calorimetry, absorber and readout can be considered separately!

Still other goals of working group

Are there sources of backgrounds we haven't considered?

Detector	ν_e CC $\delta(E)/E$	ν NC $\delta(yE_\nu)/yE_\nu$	High Eng. Feeddown	Cosmic Rays?
Plastic/RPC				
Steel/Scint				
ICARUS				
Water Č				

Schedule of Talks

Morning Session, WH 1E 9:00 - 12:30

	Chair: Scott Menary	
9:00	Overview	Debbie Harris (20)
9:20	Simulation/Analysis Tools	Robert Hatcher (25)
9:45	Liquid Argon TPC	David Cline (25)
10:10	Water Cerenkov	Mark Messier (25)
10:35	Break	
	Chair: Ken Heller	
10:55	AquaRich	Scott Menary (20)
11:15	Fine Grained Calorimetry	Michal Szleper (30)
11:45	Liquid Scintillator	Ken Heller (25)
12:10	Lunch	

Afternoon Session, WH15NW 1:25 - 6:15

	Chair: Ken Heller	
1:25	Low Density Calorimeter: Overview	Adam Para (20)
1:45	Engineering for Large Calorimeter	Vic Guarino (25)
2:10	Absorber construction	Ron Richards (20)
2:30	Extrapolating from MINOS	Jeff Nelson (30)
3:00	Options for a Steel/Scint. Detector	Bruce King (25)
3:25	Modular Detectors	John Cooper (15)
3:40	Cosmic Ray Backgrounds	Peter Shanahan (20)
4:00	Break (lab-wide party!)	
	Chair: Scott Menary	
4:30	RPC + gas system overview	Daniel Marlow (25)
4:55	RPC: Belle Experience	Caren Hagner (20)
5:15	Electronics Issues	Eric Prebys (20)
5:35	Discussion	