CC Disappearance in the Off-Axis Beam

R. Bernstein
FNAL
NuFact '02

Outline

- Physics and Detector Assumptions
- Correlations and the Physical Boundary
- Algorithms
- Results
- Future Work

Physics and Detector Assumptions

- Searching for $\nu_\mu \to \nu_\tau$
- Off-Axis Detector: 10 km at 735 km
- Un-magnetized Detector with Calorimetry from Hit Counting:

§1. $\sigma/E = 1.0/\sqrt{E}$ as in FMMF
(R. Hatcher, priv. comm.)

(Contrast to $0.8/\sqrt{E}$ CCFR and $0.55/\sqrt{E}$ NuMI)

§2. No μ Tracking or Pattern-Recognition

Two Points Above Imply
No Spectral Information, so

- Σ events from 1–3 GeV so total rate test, no spectral information

relies on δ-fcn beam:

– ν_μ at 2 GeV after oscillation won't reconstruct at 2 GeV

- Choices somewhat Arbitrary,
  Based On Notion that
  NC Contamination Dominates Error

Choice	Reason	Alternative
1–3 GeV Range	Around Peak and 1σ	Tune
Hit-Counting	No Calorimetry	Calorimeter
No Muon Tracking	π/μ's Look Identical	H_2O Ch.
Total Rate	No Spectral	Calorimetry

- Algorithm: ν_μ Oscillates to:

Channel	CC	NC
ν_τ	below threshold	Identical to ν_μ NC
ν_e	ignore	ignore

For now, ignore ν_τ NC interactions which pass cuts...

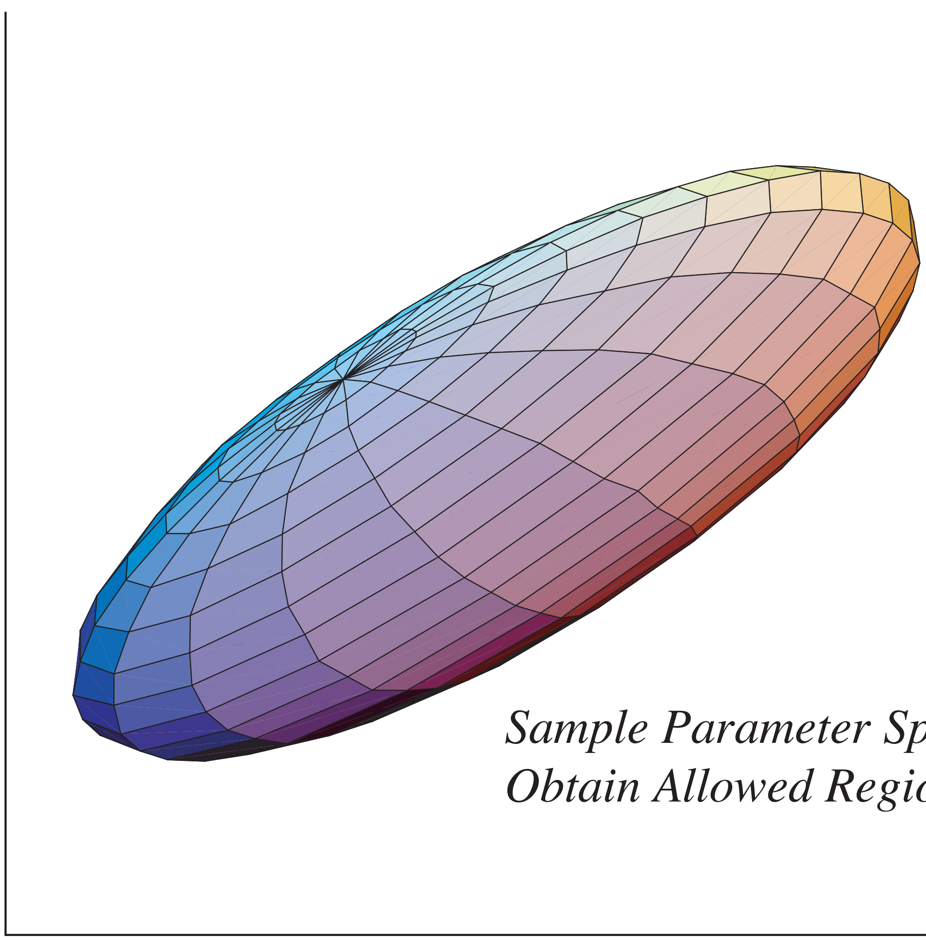
- Suggestion:

§1. Investigate Spectral Test

§2. Quasi-Elastics

Neyman-Pearson Hypothesis Test

- *aka* Feldman-Cousins
- "Most Powerful" Accept-Reject
- Constructs Confidence Levels
- Correctly Handles Physical Boundary and Correlated Errors



Generate $\Delta\chi^2$ Distribution Before Experiment Ever Runs

- Choose point in $\Delta m^2, \sin^2 2\theta$ space
- Run Many "Experiments"
  From that Point:
- Allow All Errors to Fluctuate
  Acccording to Hypothesized Error Dist

§1. Gaussian, Flat, Poisson, … *etc.*

§2. Throw Correlated Errors Together

- *e.g.*, correlated flux: affects entire data set
- Each "experiment" throw different
  correlated flux error
- End Up With Distirbution in Error Space With all Correlations Properly Handled and Weighted According to Probability Distribution for Each Error
- Get Distribution of χ^2 for that Point in Parameter Space

Compare Data to Distribution

- Are Data Consistent With Statistic for that $\Delta m^2, \sin^2 2\theta$ at 90% CL?
- Sensitivity is "Ensemble Average" of Data
- *Same* for Signal and Exclusion!

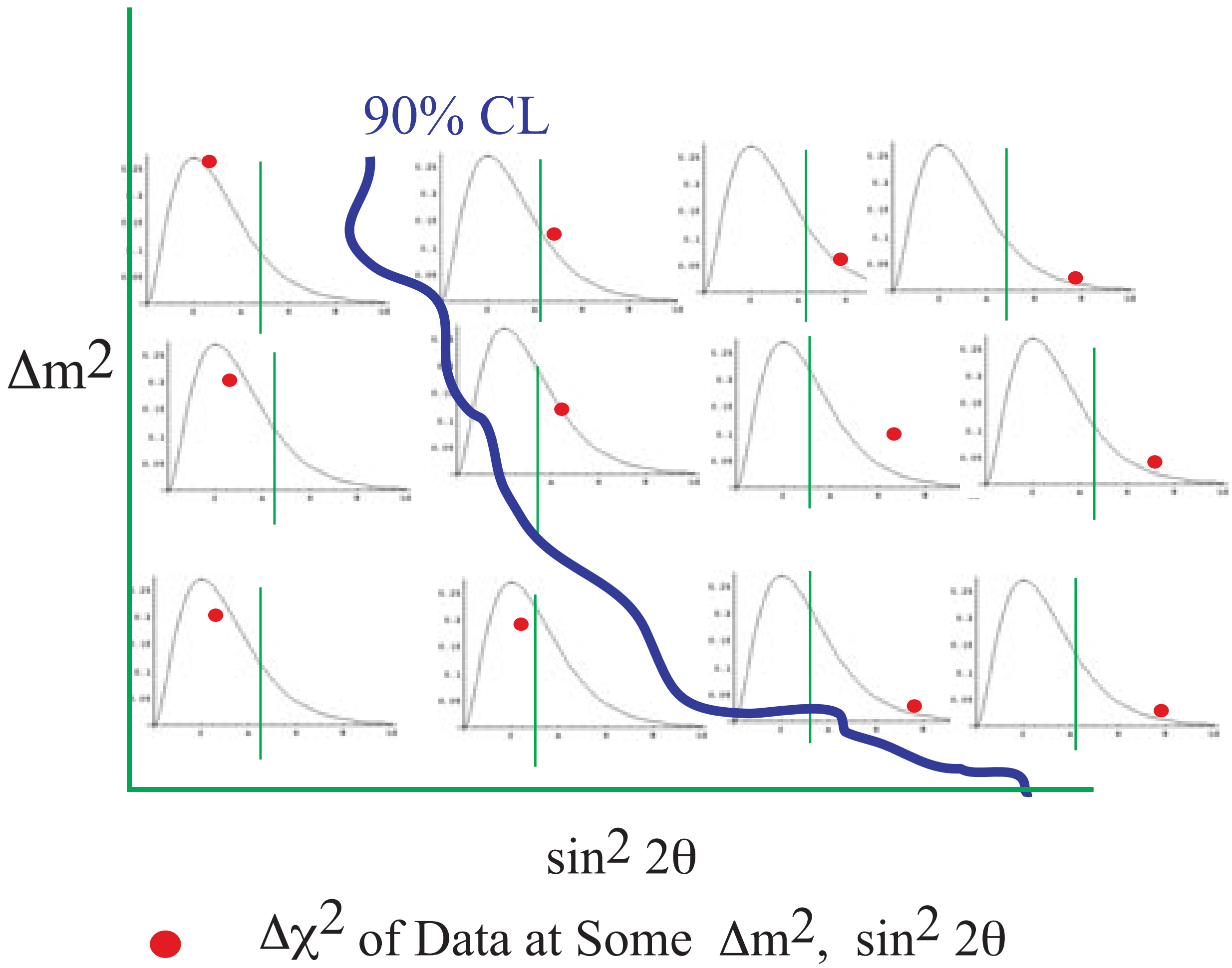
- Denote:
  - **O** as the number of events at some point in parameter space
  - **FO** as the number of events at the *same* point in parameter space with all errors allowed to fluctuate.
  - **D** as the number of data events.

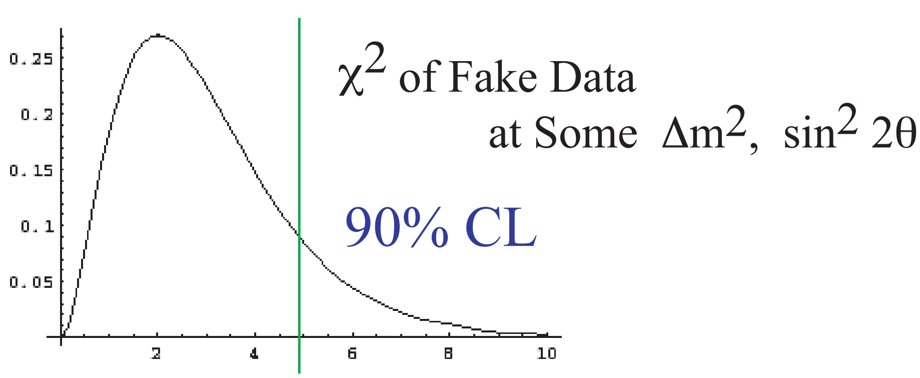
- Form:

$$\chi^2_{\text{rate}} = \frac{(\mathbf{D} - \mathbf{O})^2}{\mathbf{O}}$$

- $\Delta\chi^2$ is what is used to determinine confidence levels

$$\Delta\chi^2_{\text{rate}} = \chi^2 - \chi^2(\text{best fit})$$





- Errors:

Statistical	100 kt· years	

Beam		
Correlated Flux Random Flux Shape	3% 2% in any 1 GeV bin $A\sin(\lambda E_\nu/5. + \phi)$ $-.10 < A < .10$ flat $0 < \lambda < 2\pi \times 5$ flat $0 < \phi < 2\pi$ flat	From studying hep-ex/0110001, 0110032

Detector		
Hadronic Energy Muon Momentum	$1.0/\sqrt{E}$ not separately seen include with hadron shower energy	

- Shape Error from

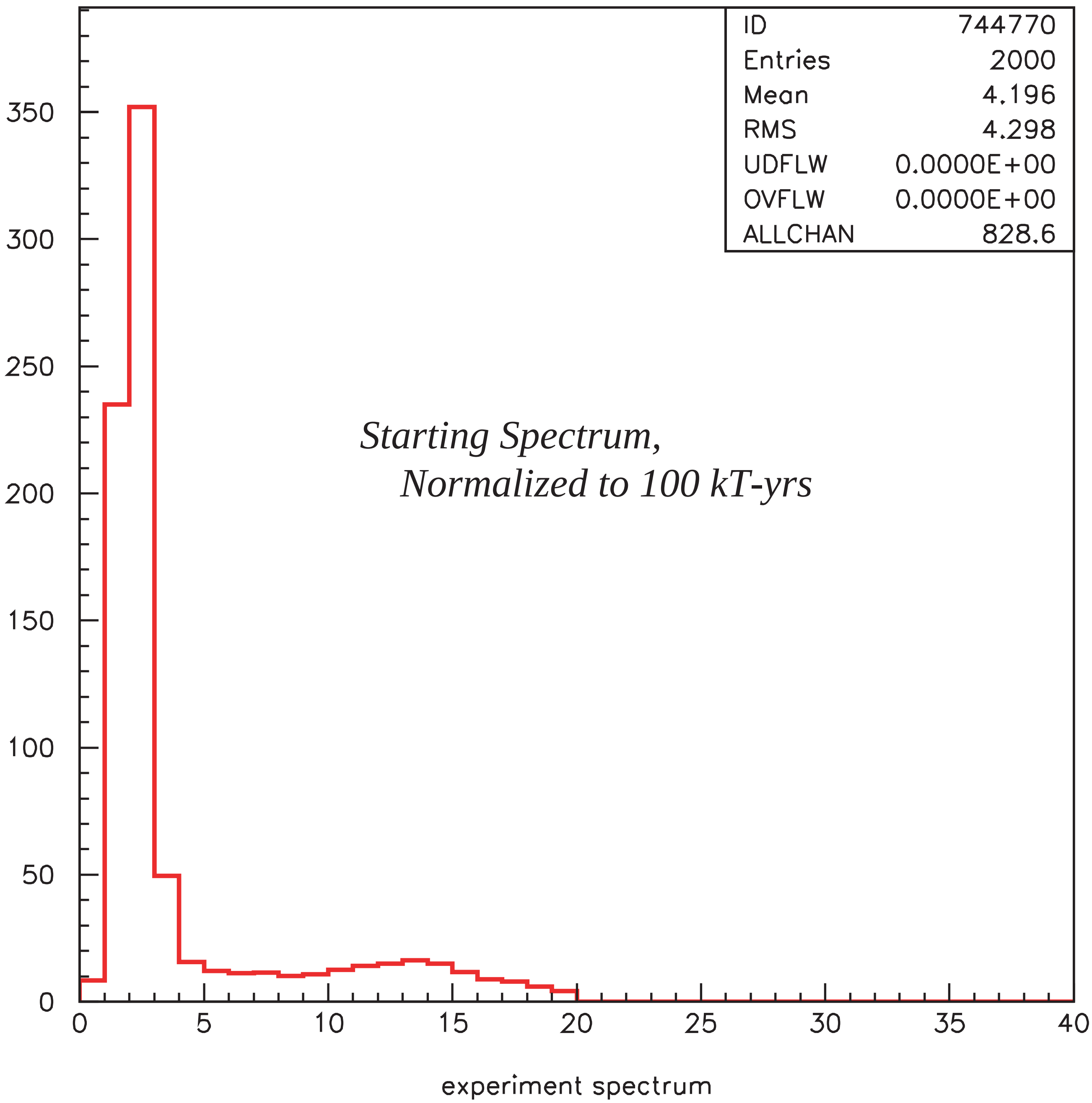
  §1. Extrapolation from near Detector to 2°

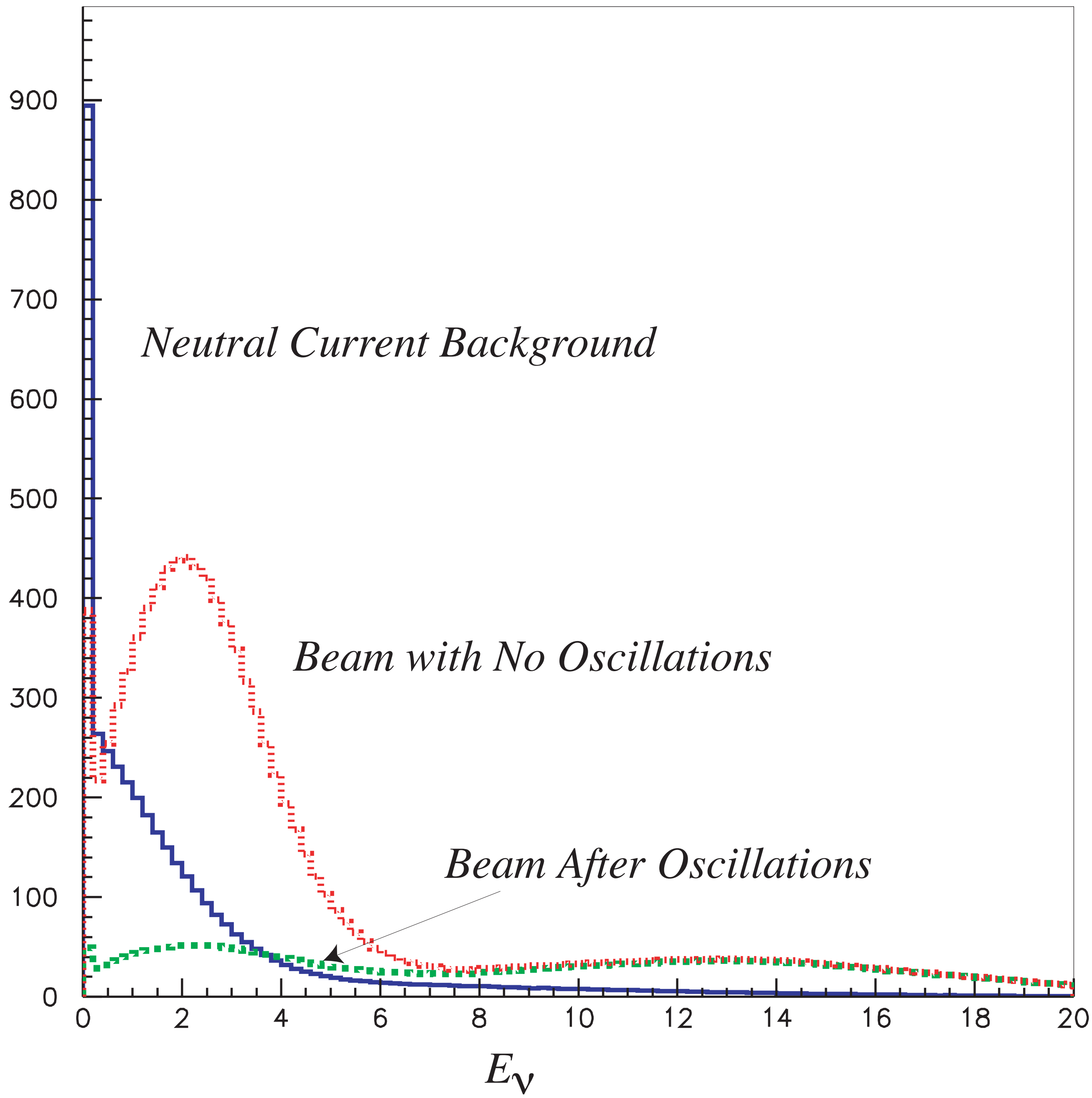
  §2. Magnetic Horn Elements

  §3. GEANT/FLUKA/...

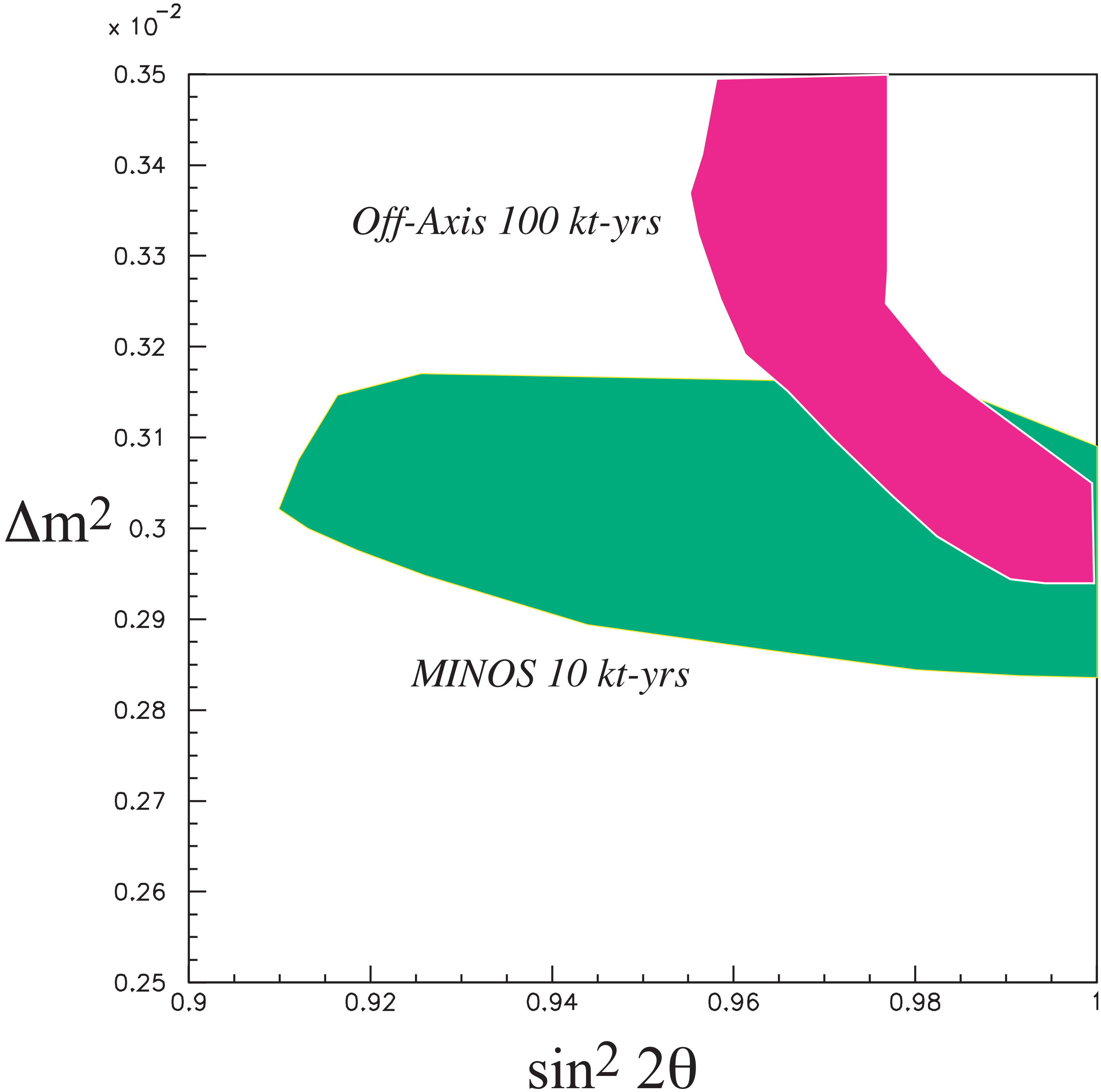
- Correlated Flux from

  §1. Fiducial Volume and Mass of Near, Far Detectors


ID 744770
Entries 2000
Mean 4.196
RMS 4.298
UDFLW 0.0000E+00
OVFLW 0.0000E+00
ALLCHAN 828.6
Starting Spectrum,
Normalized to 100 kT-yrs
0
50
100
150
200
250
300
350
0
5
10
15
20
25
30
35
40
experiment spectrum


Neutral Current Background
Beam with No Oscillations
Beam After Oscillations
900
800
700
600
500
400
300
200
100
0
0
2
4
6
8
10
12
14
16
18
20
E_ν

- $\nu_\mu \to \nu_\tau$ 90% CL
- Signal at $\Delta m^2 = .0030, \sin^2 2\theta = 1.0$



Future Work

§1. Can This Do Better than Total Rate Test

§2. Rigorous Combined MINOS signal
(tedious, time-consuming,
but straightforward)

§3. Move to $\nu_\mu \rightarrow \nu_e$