JHF ν_μ Disappearance Sensitivity

status report

- Goal: study sensitivity to Δm^2 as a function of Δm^2, compare with what was in LOI.
  - Use the K2K experiments error sets for a "realistic" baseline.
  - Use the full K2K analysis technique for realistic results
- Today:
  - Used new JHF/MC interaction in SK.
  - Use Chi2 instead of unbinned likelihood(high statistics)
  - Looked at range of Δm^2.
- Eventually -> Check effect of 2km detector.

What are the K2K Systematic Errors?

The oscillation analysis includes the full correlations between systematic errors, and cancellation between the near and far detectors.

Error matrices with energy corelations from near detector and pion monitor fits.

Flux/x-section (8 bins) + nonQE/QE ratio

Far/Near ratio (6 bins)

Flux and cross section partially cancel between KEK and SK.

Energy dependent numbers with no energy correllations:

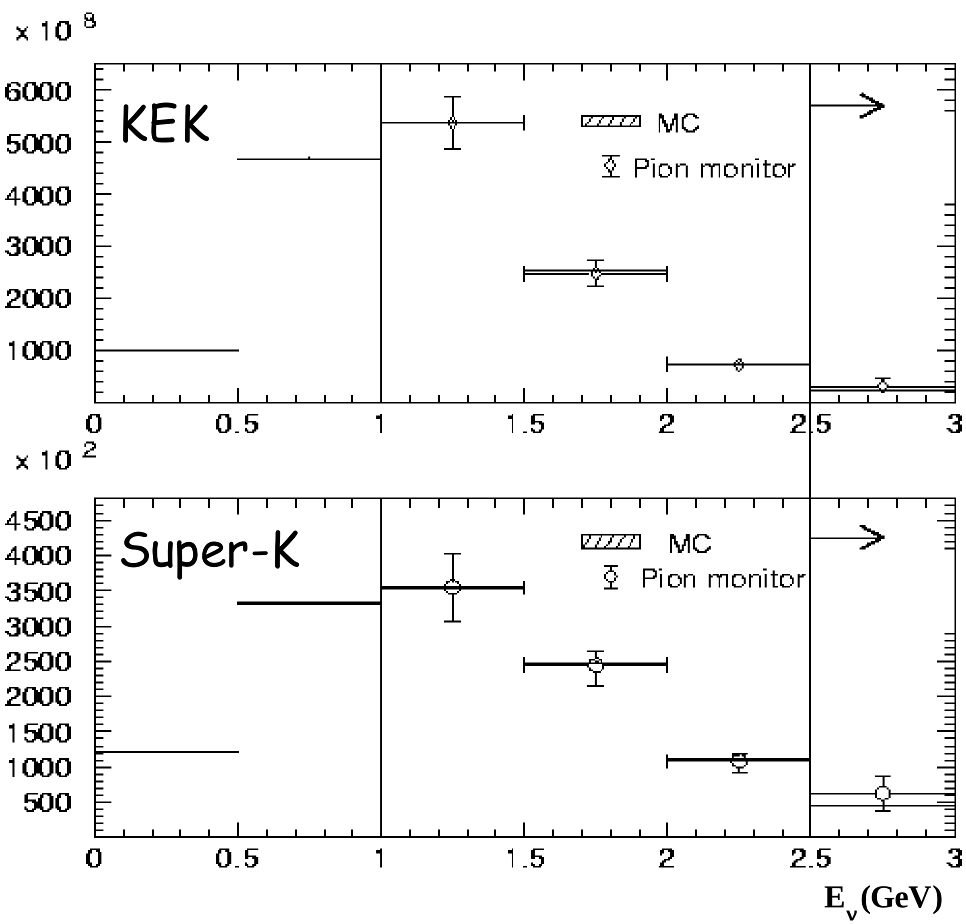
Vertex + PID + Ring-Counting for 1-ring sample (~10%)

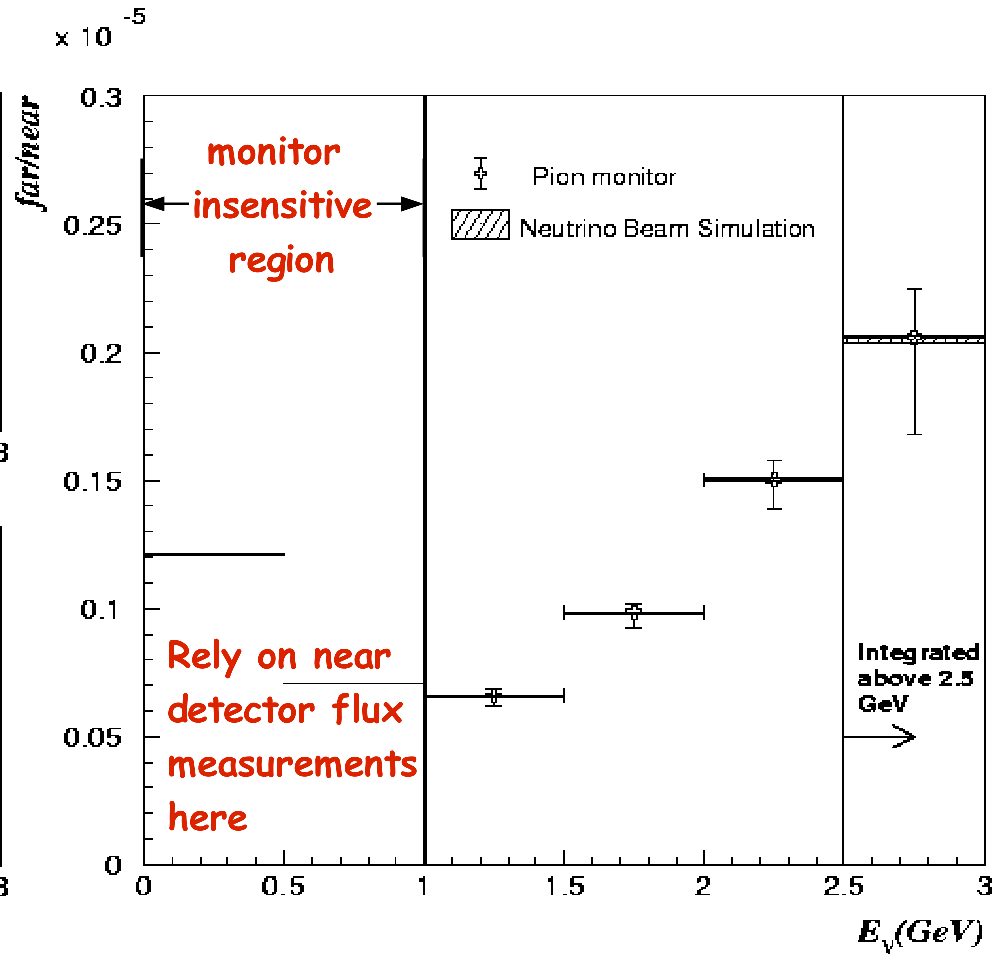
Errors on Normalization only [fiducial volume, POT] (~6%)

SK energy scale error (3%) ← Shift reconstructed energy in MC

K2K Neutrino Flux and F/N Ratio

Validating the Beam MC with the Pion Monitor

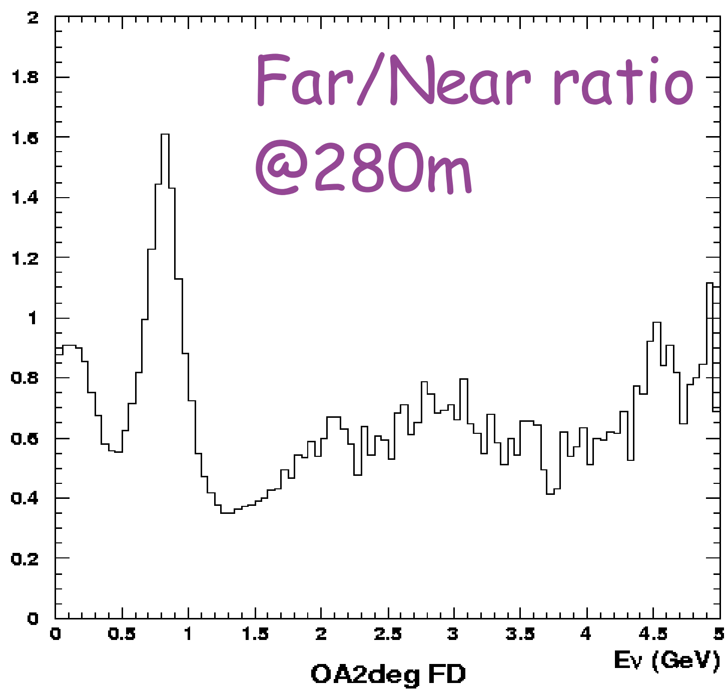


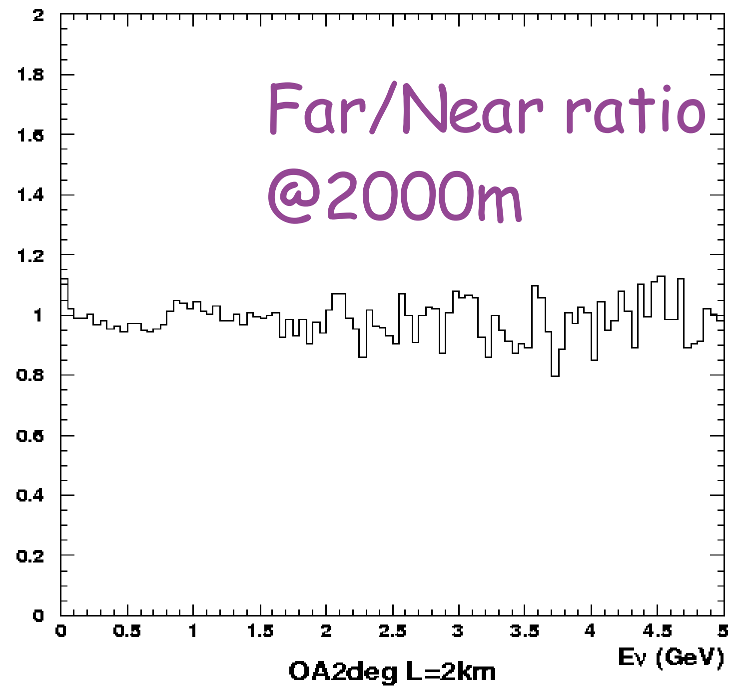


This comparison is used to choose the MC flux model and calculate the errors on the flux.

This ratio is used to predict the SK flux based on the measured near detector fluxes.

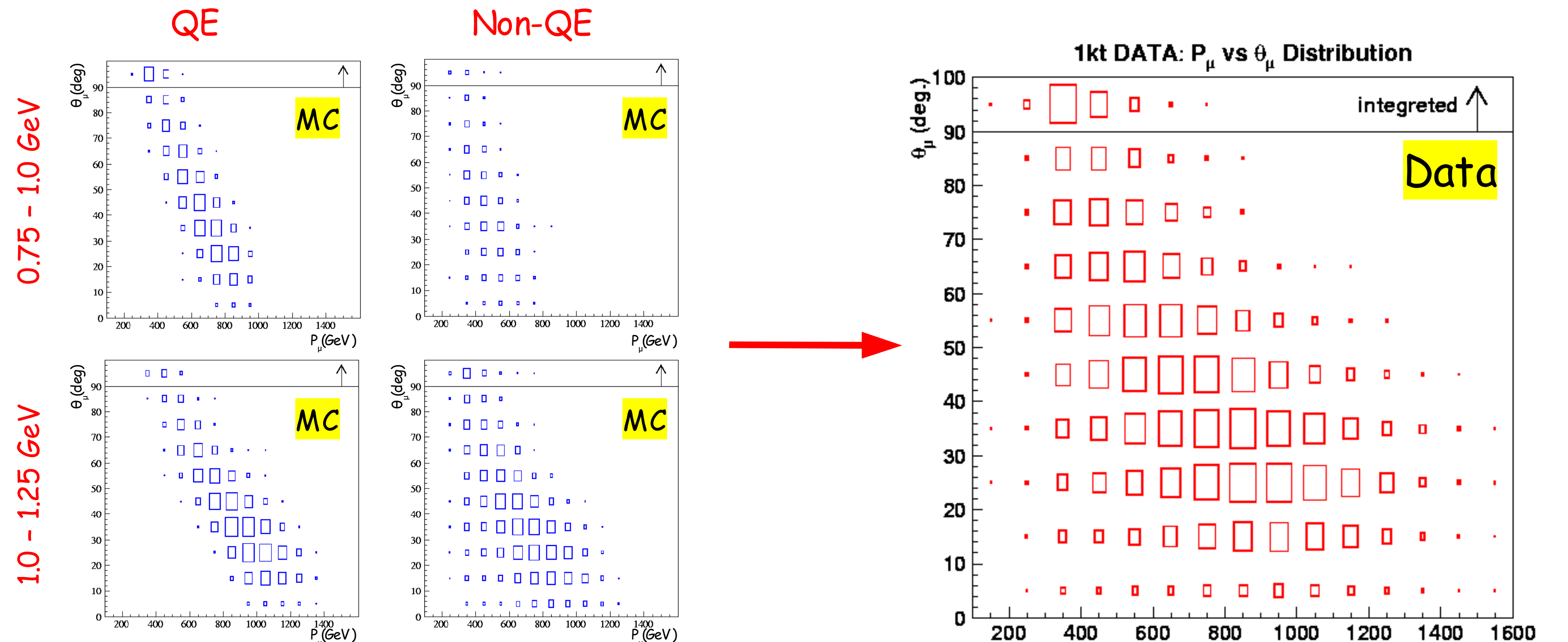
JHF Far/Near Ratios





Merged Near Detector Data Fit

We fit the near detector data for E_ν and nonQE/QE ratio.



Adjust relative weights of these MC templates to match real data.

subset of fit

Fit using data from:

1kton(1 track)

SciFi(1 track)

SciFi(2 track) (QE and nonQE)

Output of fit is:

Matrix of ν flux weights

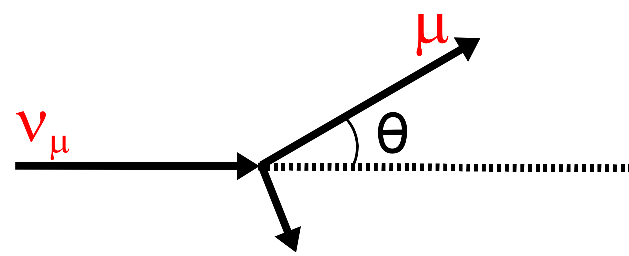
nonQE/QE ratio

X^2 = 227 for 197 dof

E_ν Reconstruction (assuming QE)

Luckily, in a Quasi-Elastic reaction, even if only the muon is visible we can reconstruct the neutrino energy!

If the interaction is non Quasi-Elastic then the reconstructed energy will be incorrect.



$$E_\nu = \frac{m_N E_\mu - m_\mu^2/2}{m_N - E_\mu + p_\mu \cos(}$$

m_N = Neutron mass

E_μ = Muon energy

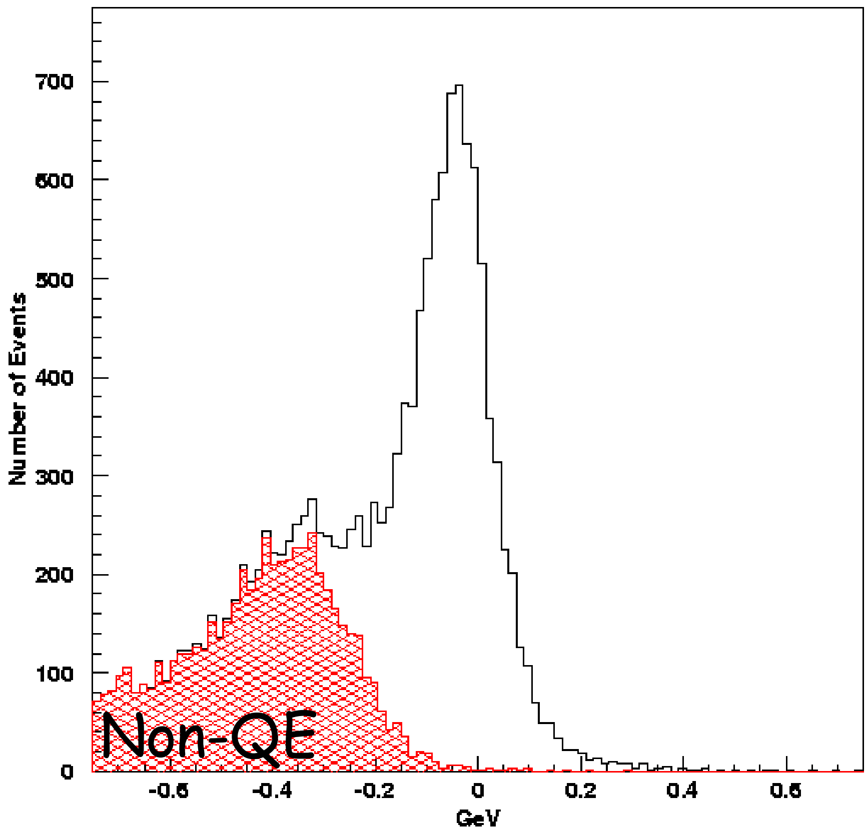
m_μ = Muon mass

p_μ = Muon momentum

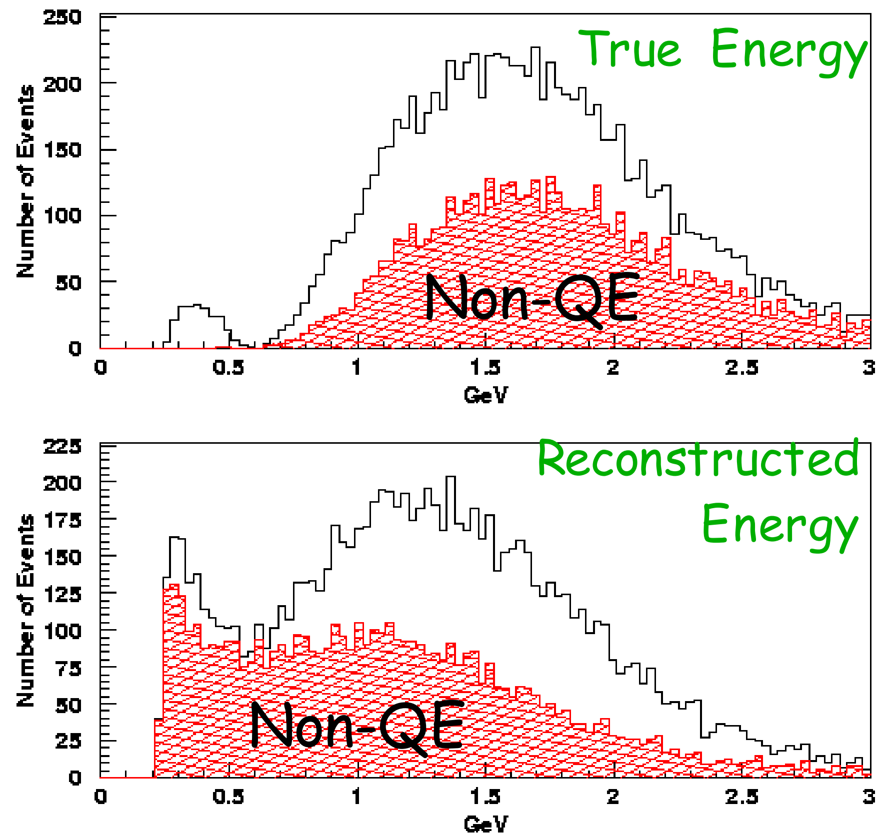
Θ_μ = Muon angle wrt beam

Non-QE interactions and E_ν Reconstruction

Example: K2K Flux MC



True – Reconstructed Energy



Non-QE reconstructs at low-energy in the oscillation dip!

Size of the K2K Errors

Diagonal error terms in %

Neutrino Energy E_ν	Flux Error $\Delta(\Phi_{ND})$	F/N Error $\Delta(F/N)$	SK Error $\Delta(\varepsilon_{SK})$
0 - 0.5	49	2.6	8.7
0.5 - 0.75	12	4.3	4.3
0.75 - 1.0	9.1	4.3	4.3
1.0 - 1.5	...	6.5	8.9
1.5 - 2.0	7.1	10.0	10.0
2.0 - 2.5	8.4	11.0	9.8
2.5 - 3.0	19	12.0	9.9
3.0 -	20	12.0	9.9

20% nonQE/QE error.

Errors are on the order of 10%

JHF MC sample(OA xx°)

Ntuple Mask File(Make almost same cuts as for K2K)

MCCUT Events: 49322 (file mccut.mask, read/write)

	# select	Description
bit 1:	49322	1
bit 5:	30105	potot>=200
bit 7:	29347	mccut(5)&&pomax/potot<=0.2
bit 10:	24731	mccut(7)&&nhitac<10
bit 12:	24676	mccut(10)&&agood>0
bit 14:	21842	mccut(12)&&evis>30
bit 15:	15340	mccut(14)&&wall>=200
bit 16:	10391	mccut(15)&&nring==1
bit 17:	9737	mccut(16)&&ms.f(1)>=0

Mu-like 1ring eff = 19%
(K2K also 19%)

I made K2K x 80 x 5 = K2K x 400 events =
~ 16600 before oscilllations (need more MC events)

Too Many? [Loi OA 2deg: 2200 CC interactions/yr]

Incorporating Systematic Errors

The K2K oscillation analysis includes the full correlations between systematic errors, and cancellation between the near and far detectors.

These errors are used in the likelihood analysis in two complementary ways.

Method 1: Generate random #s based on the errors (including correlations) and modify the prediction. Repeat many times, and average resulting likelihood.

Method 2: Add one constraint term to the likelihood for each systematic error number or matrix and minimize the resulting likelihood.

With Numerical Errors:

Use Random numbers generated by error matrices.

Generate many spectra using the correllated random numbers.

Don't allow any negative flux bins to be generated.

For each generated spectrum calculate X^2 for data.

Average the X^2 to obtain final value.

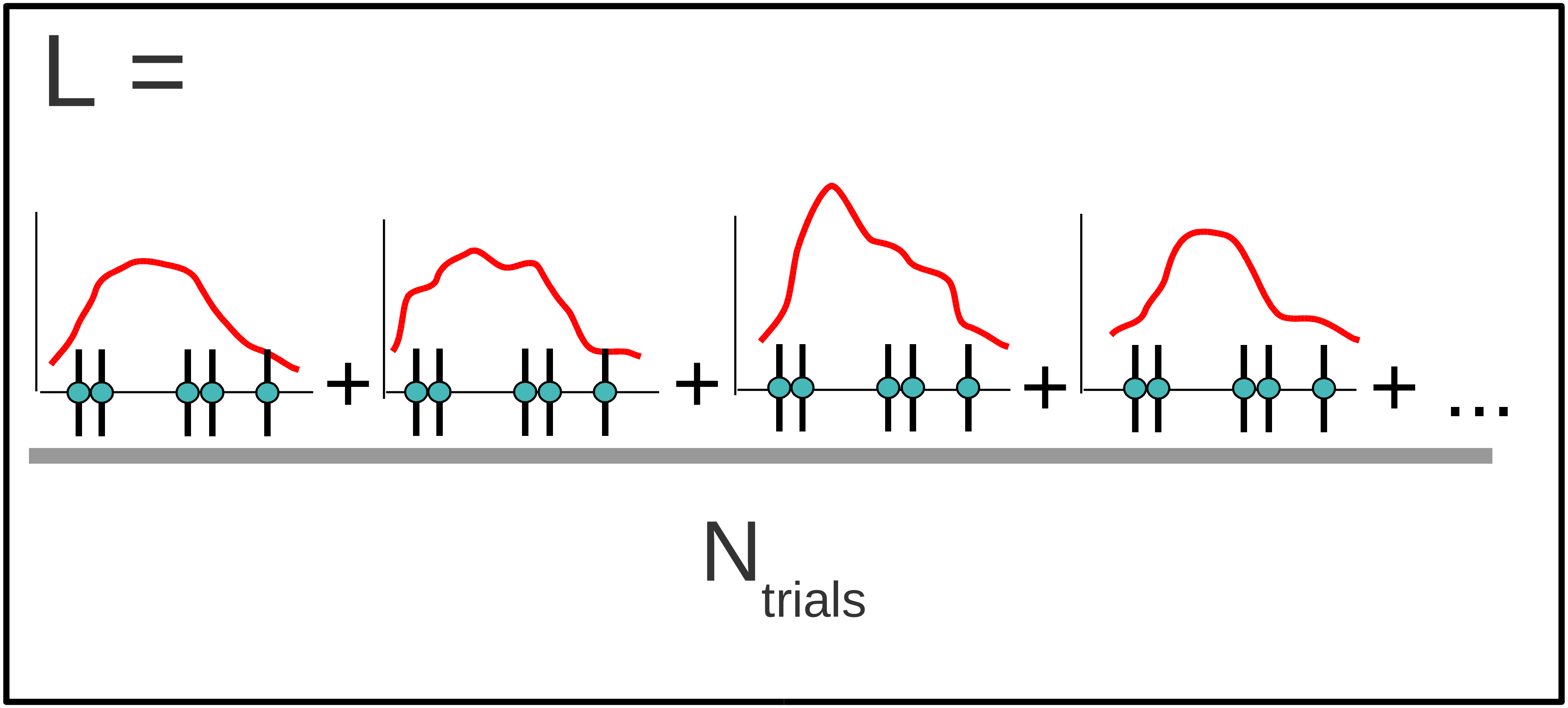
A numerical technique which has been used by other HEP experiments (L3/CLEO/PDF fitting).

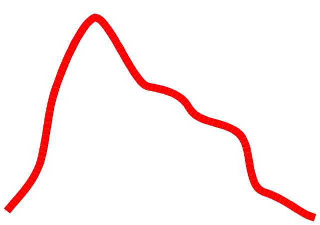
Swain/Taylor hep-ex/9712015 or NIM (for L3)

Advantages of method

- All correlation and errors are completely treated. Since it is a MC technique no assumptions are made about the shape of the minimum etc.
- Unlike constraint term method, non-Gaussian errors can be included.
  [already implemented for asymmetric Gaussian].

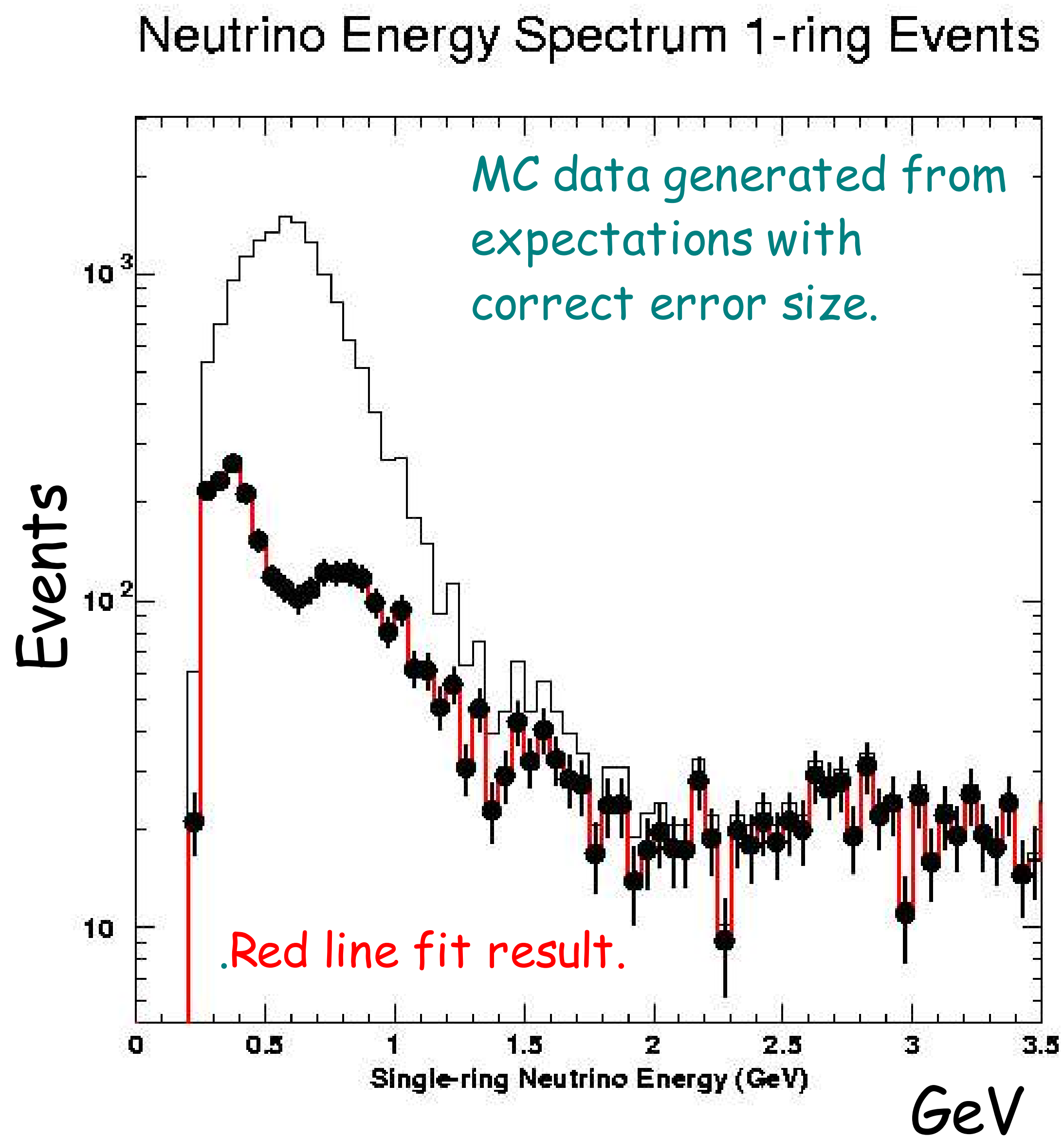
Graphical Picture of Technique



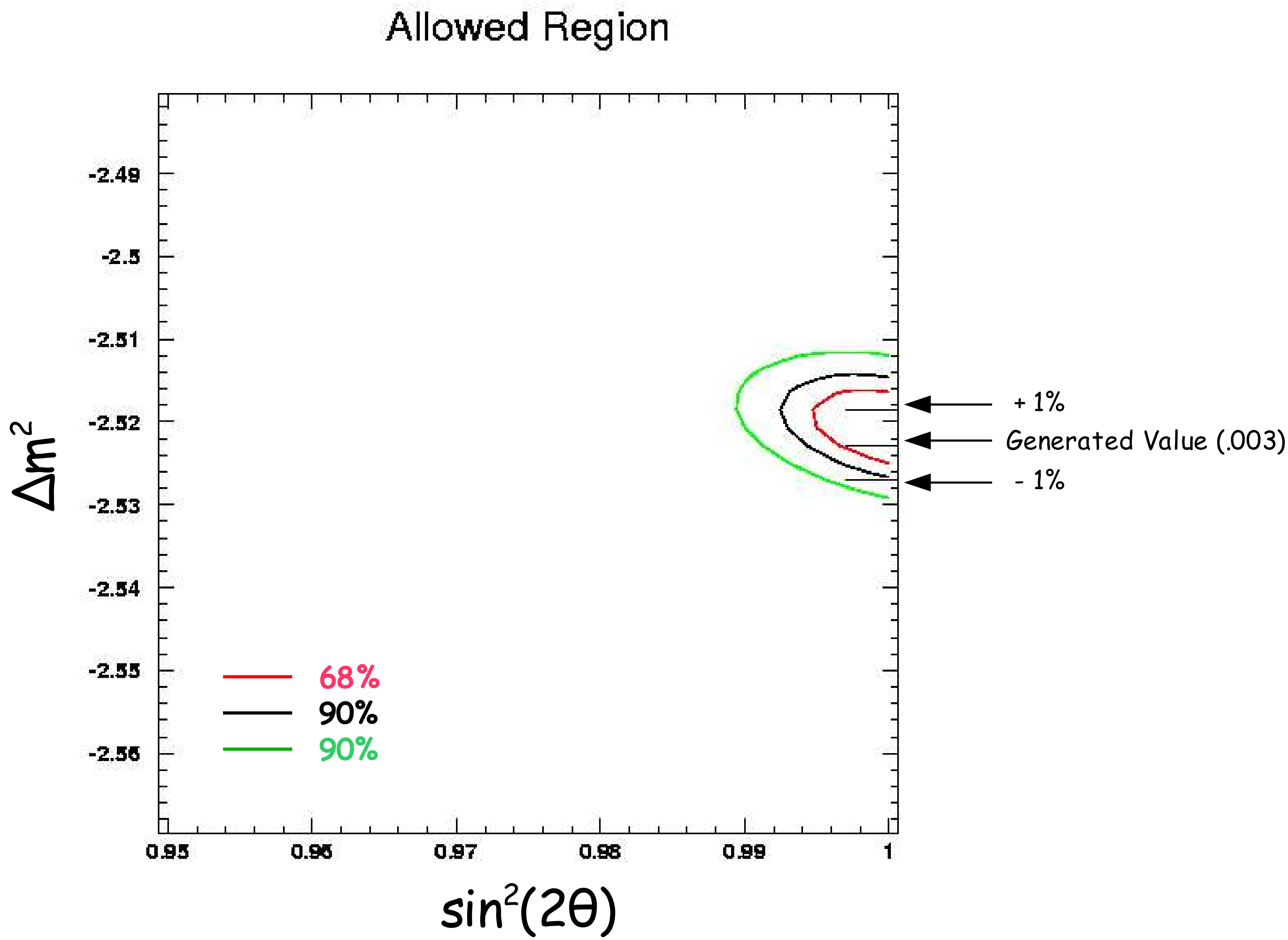


: Fluctuations in shape generated by correlation matrices.

Result of fit for 3.0 x 10^{-3}

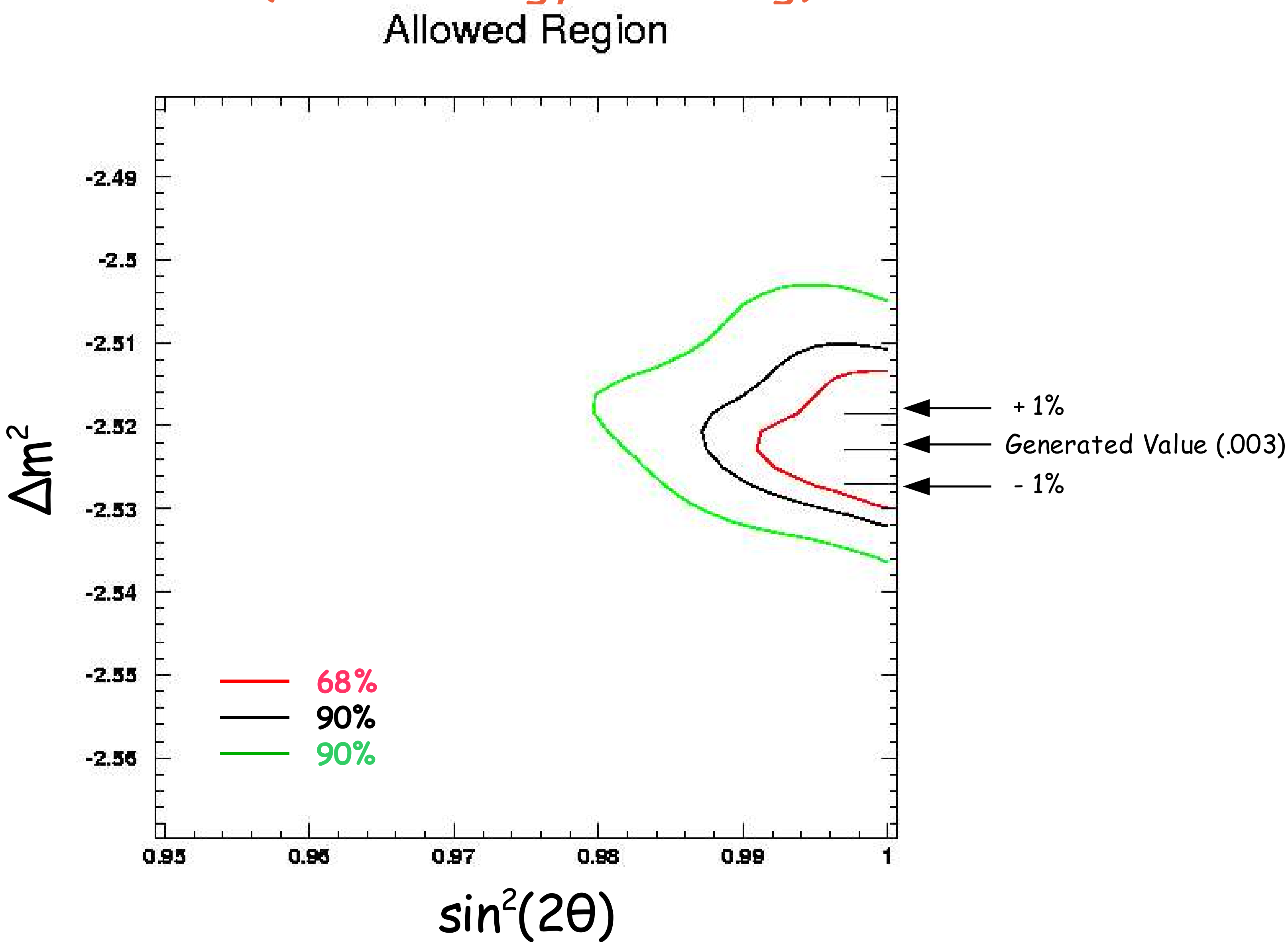


Allowed region $3x10^{-3}$ (no sys error)



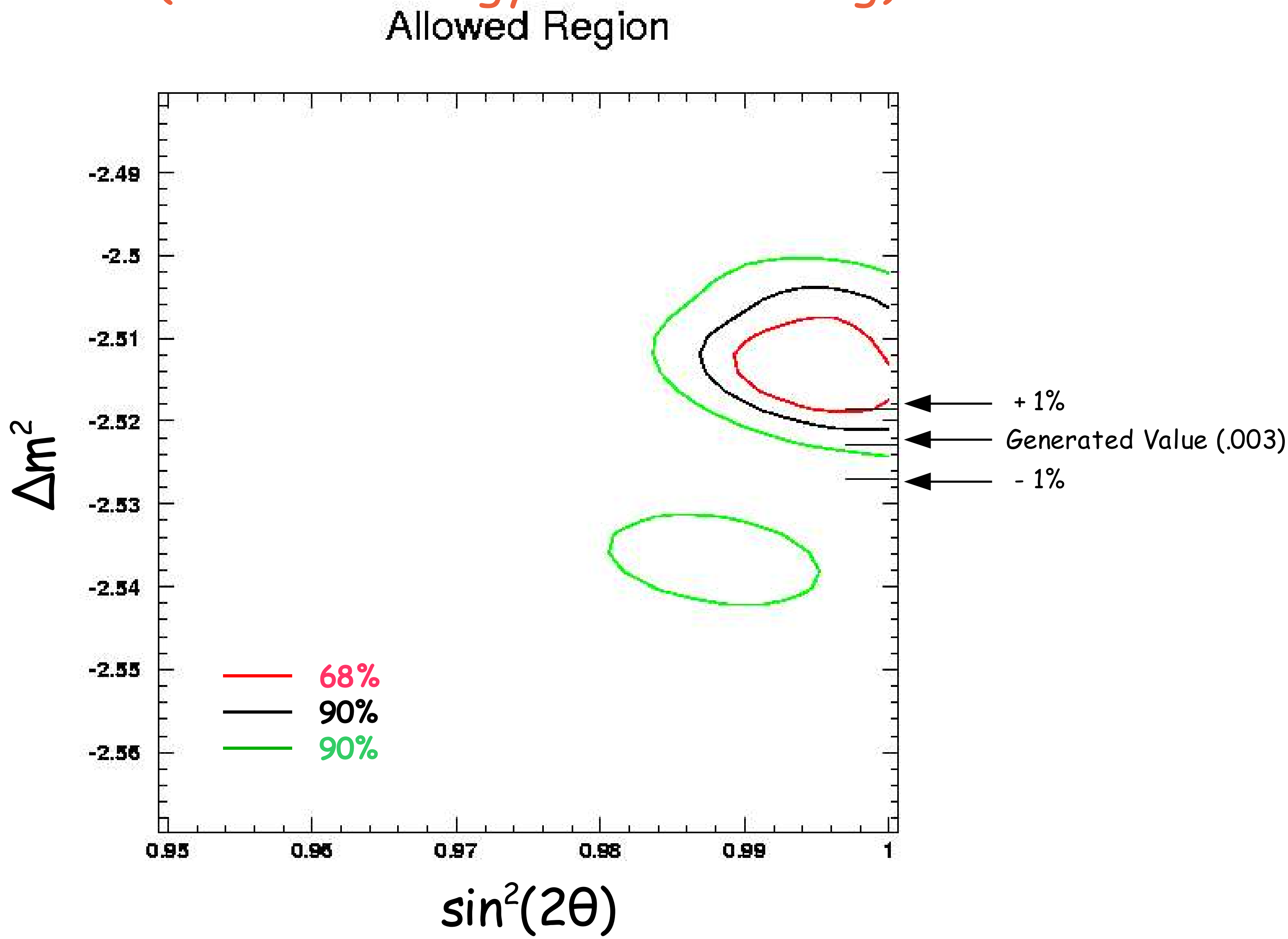
Allowed region $3x10^{-3}$

(no SK energy smearing)

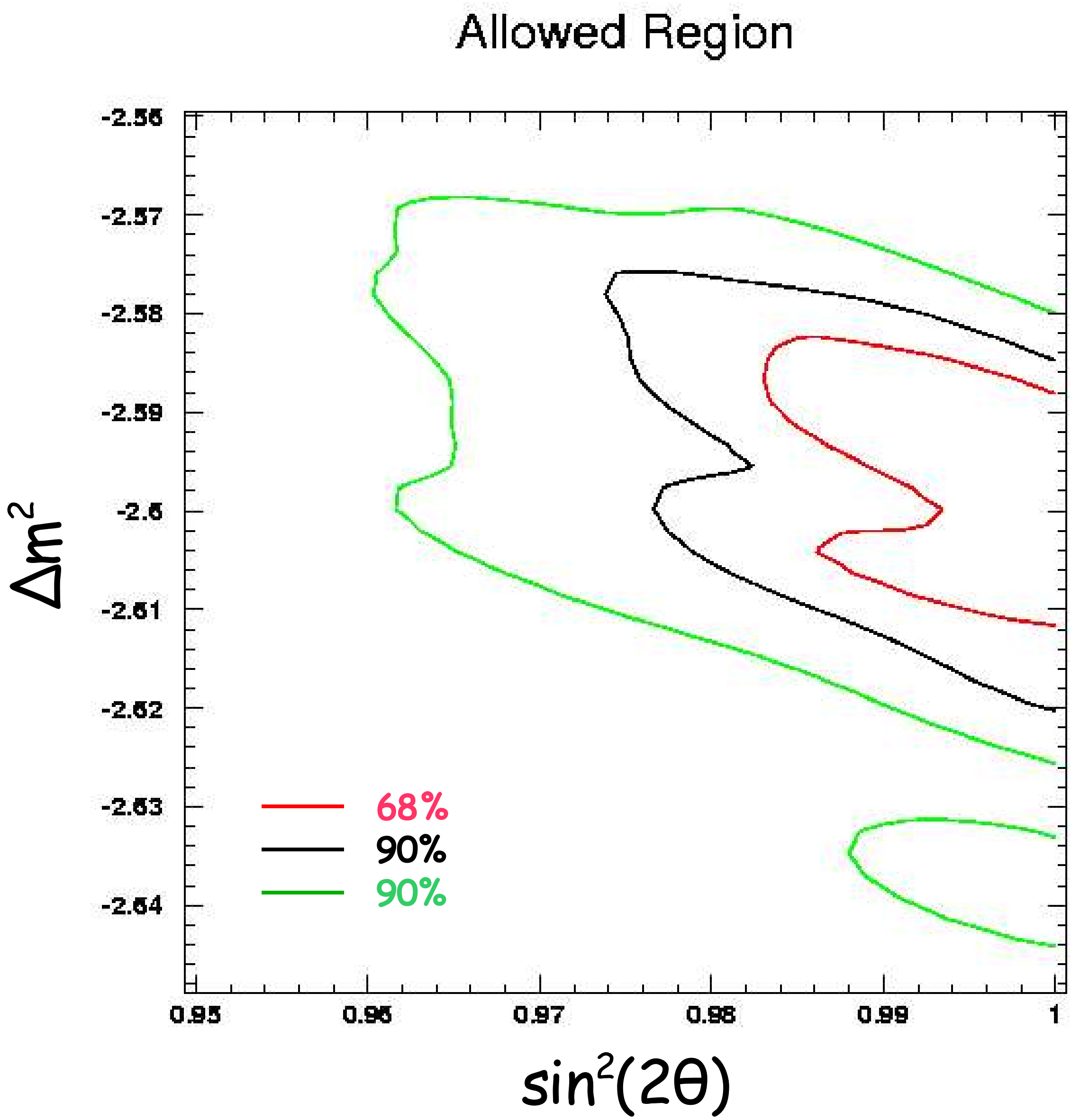


Allowed region $3x10^{-3}$

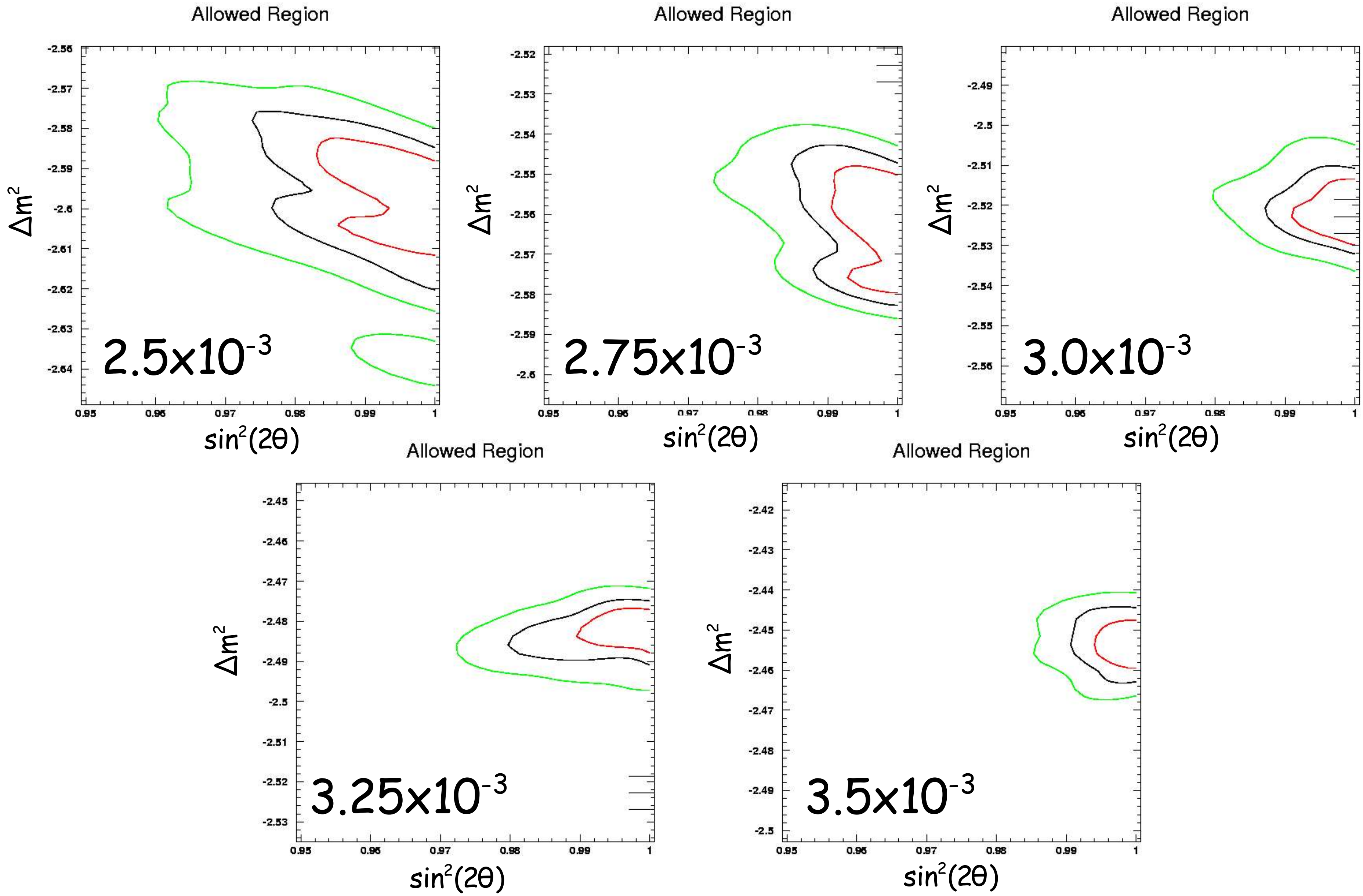
(with 3% energy scale smearing)



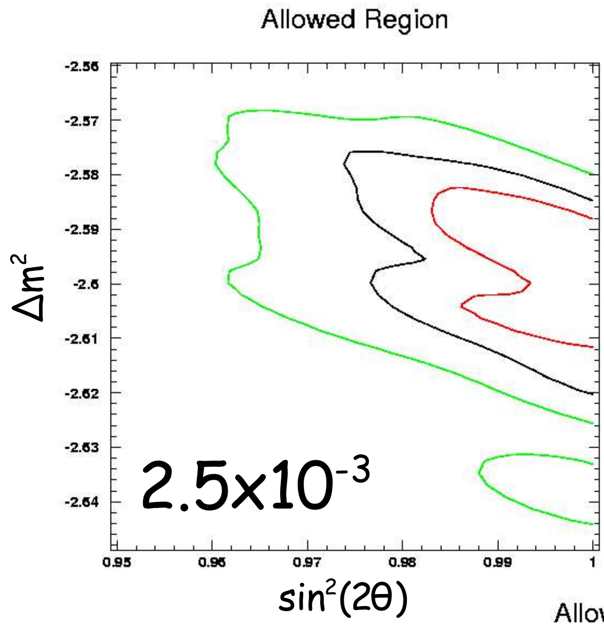
Allowed region 2.5x10^{-3} (no energy smearing)

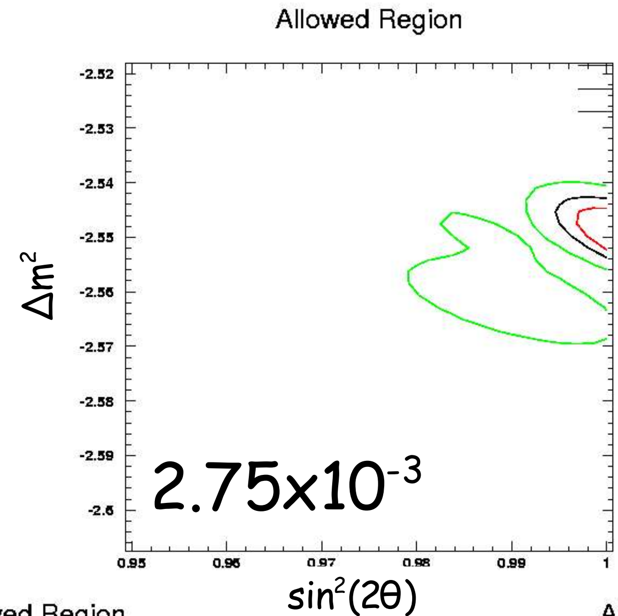


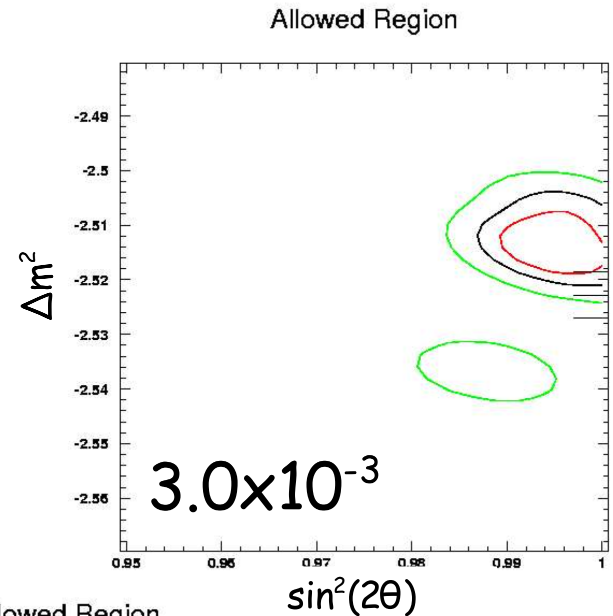
Allowed Regions (No Smearing)

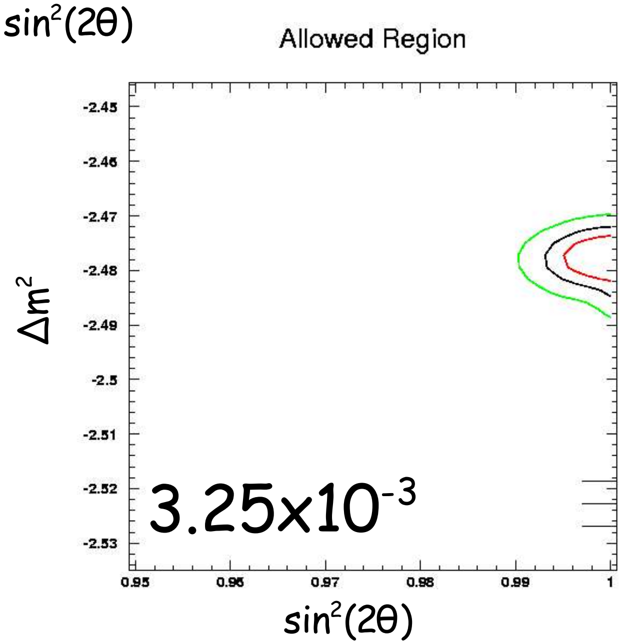


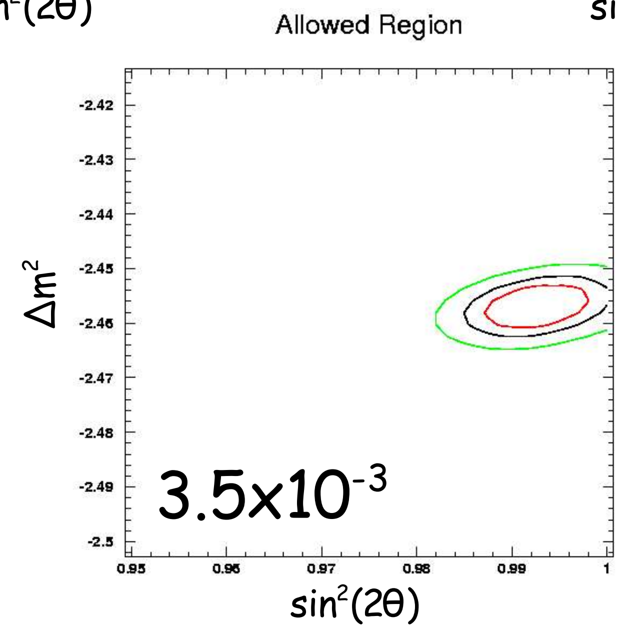
Allowed Regions (3% Energy Smearing)





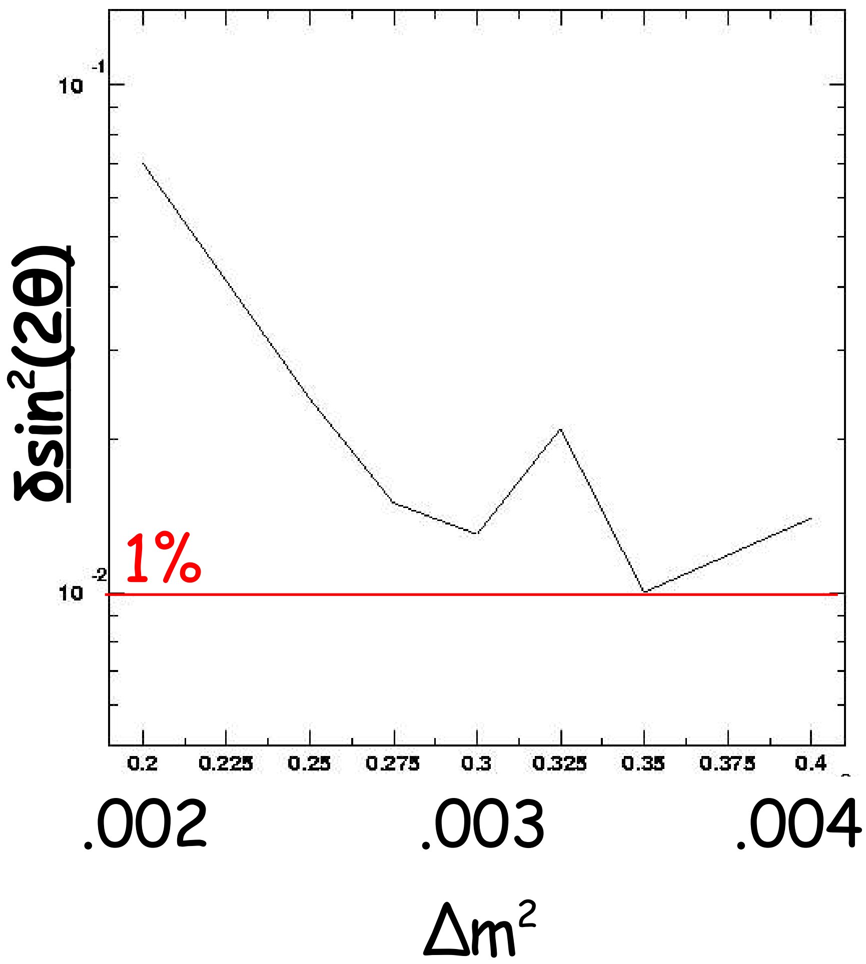




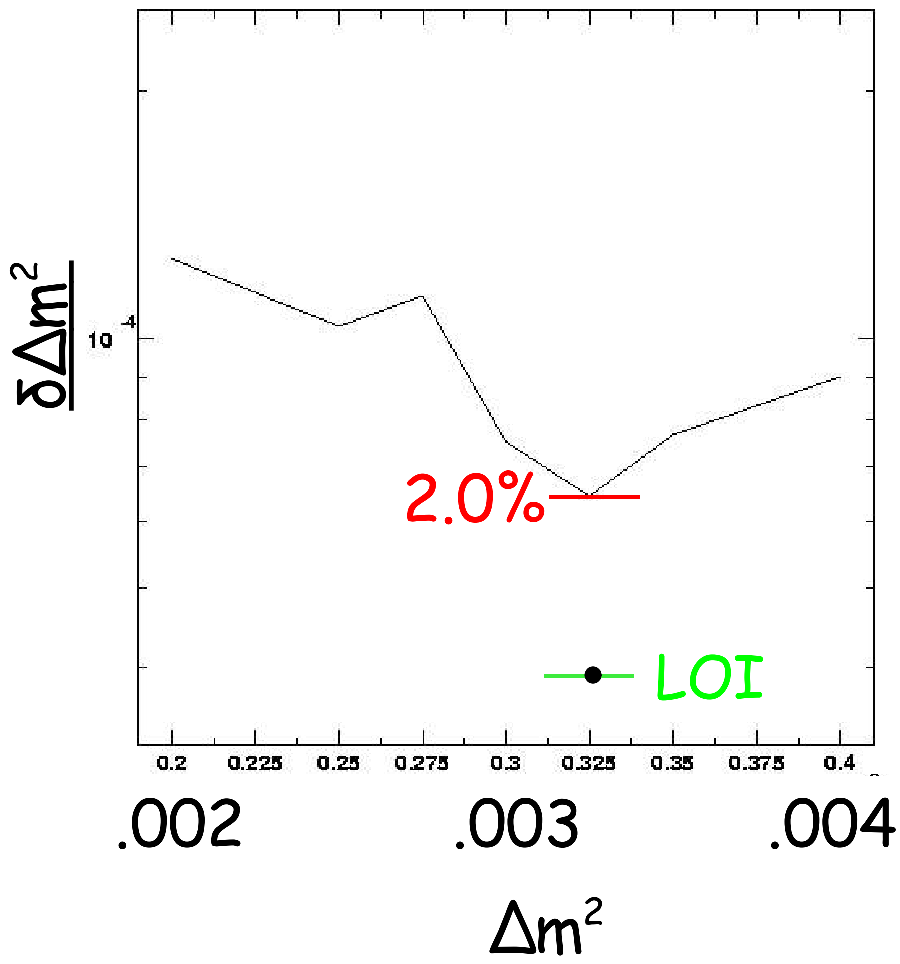


Sensitivity as function of Δm^2 (no energy smearing)

Use 90% line at Δm^2=value



Use 90% lines at $\sin^2(2\theta)$=1



Conclusions

- Used K2K tools to study sensitivity for disappearance
  - At deltaM2 tuned to OA angle, sensitivity is on the order of 1-2% (~agrees with LOI, but values are larger)
  - Need to understand effect of SK energy systematic error.
- Future
  - Generalize program to use arbitrary binning for N/F and flux error matrices[i.e. Not just 6 or 8 bins]
  - Modify error matrices for different detector configurations and see effect on oscillation result.
  - Check larger range of Δm^2.