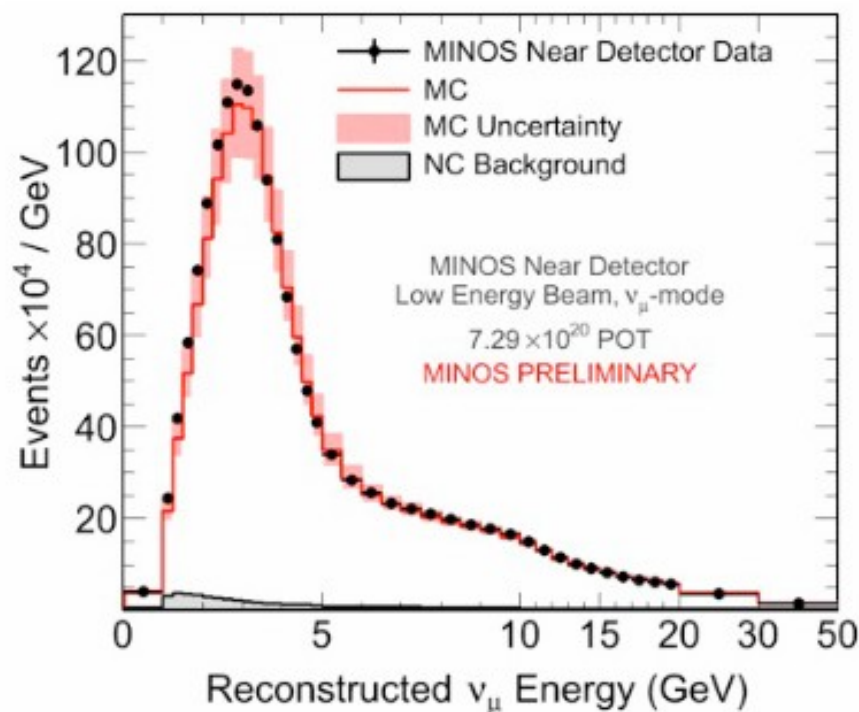
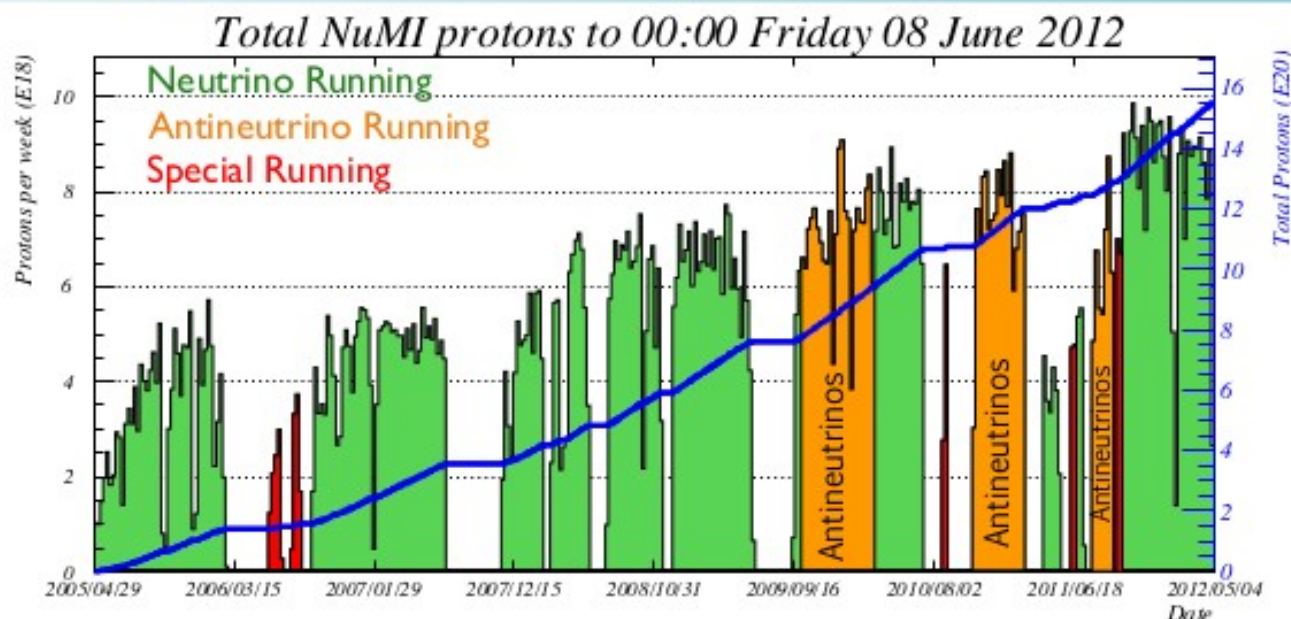




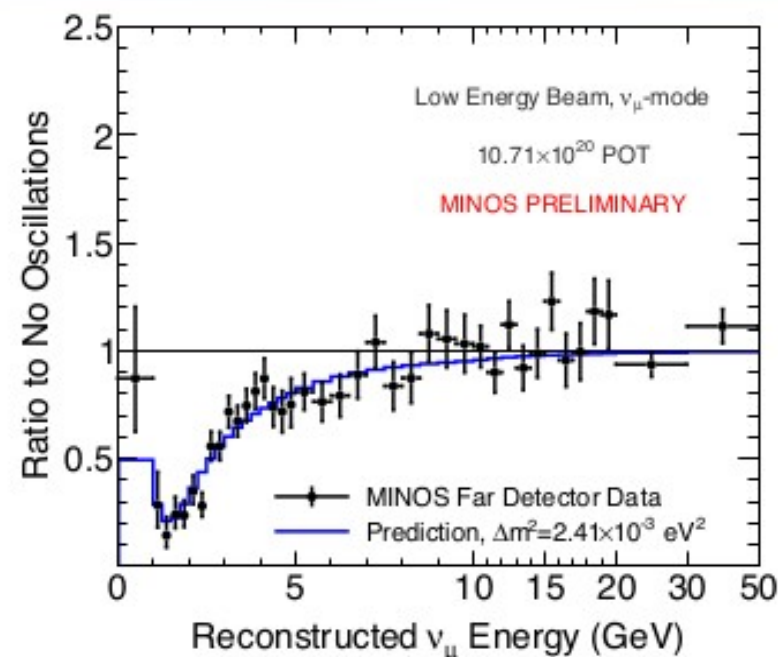
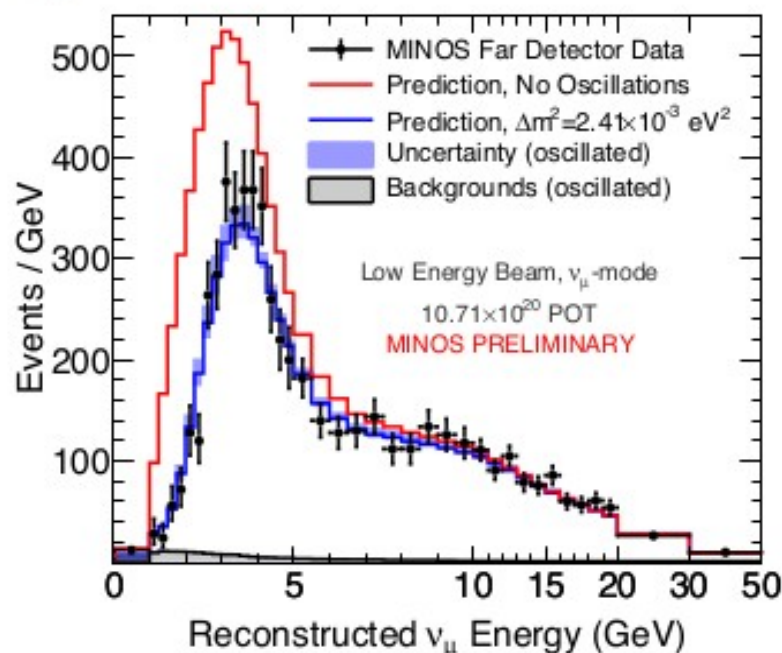
MINOS ν_μ and $\bar{\nu}_\mu$ Charged-Current Disappearance Analysis

- The results presented are obtained using the complete MINOS beam data sample collected between 2005 and 2012.
- A total of 10.71×10^{20} POT collected in neutrino mode and 3.36×10^{20} POT collected in antineutrino-enhanced mode are used in the analysis.
- Muons from ν_μ , $\bar{\nu}_\mu$ charged-current (CC) interactions are selected by multivariate algorithm based on a k-Nearest-Neighbor technique.
- The MINOS detectors are magnetized, enabling ν_μ and $\bar{\nu}_\mu$ to be separated on an event-by-event basis, by analyzing the muon curvature. $\bar{\nu}_\mu$ CC events are identified by a positive muon charge sign.
- The neutrino energy is reconstructed by summing the muon momentum and hadronic shower energy. The plot on the right shows the energy spectrum in the Near Detector (ND) for selected ν_μ CC events. The extrapolated ND spectrum is used to obtain the Far Detector unoscillated spectrum.





ν_μ Charged-Current Disappearance Results



For $0 < E_{\text{reco}} < 50 \text{ GeV}$

Prediction, No Oscillations: **3564 events**

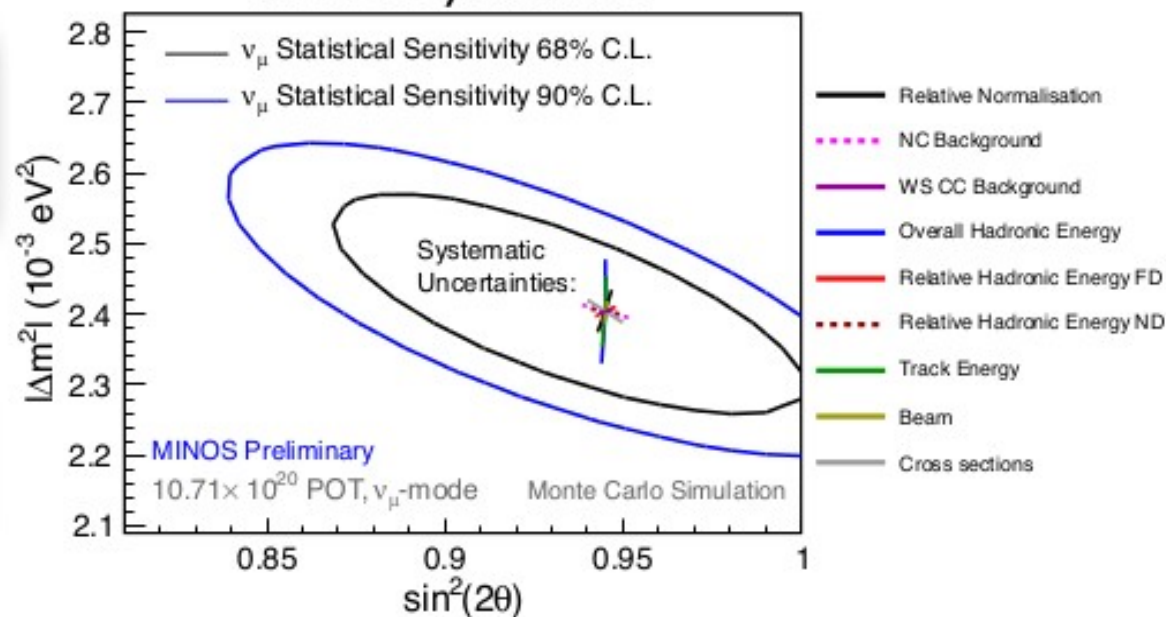
Observed: **2894 events**

ν_μ Oscillations Best Fit Parameters

$$|\Delta m_{\text{atm}}^2| = 2.41_{-0.10}^{+0.11} \times 10^{-3} \text{ eV}^2$$

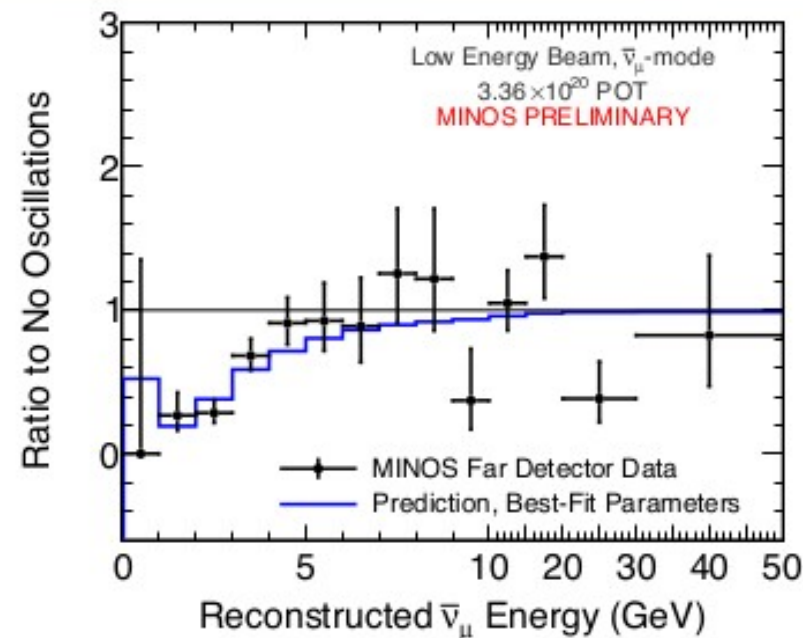
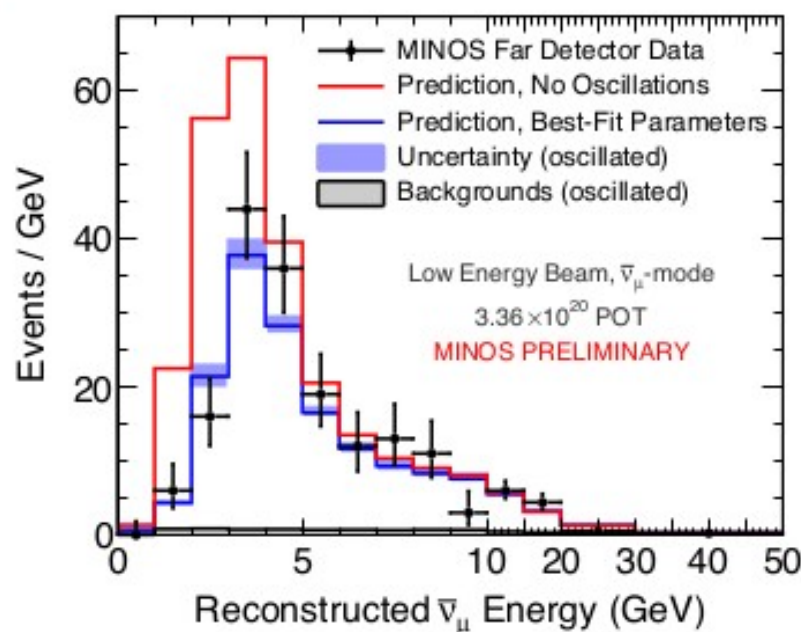
$$\sin^2(2\theta) = 0.94_{-0.05}^{+0.04}$$

Effect of Systematics





$\bar{\nu}_\mu$ Charged-Current Disappearance Results



For $0 < E_{\text{reco}} < 50$ GeV

Prediction, No Oscillations: **312 events**

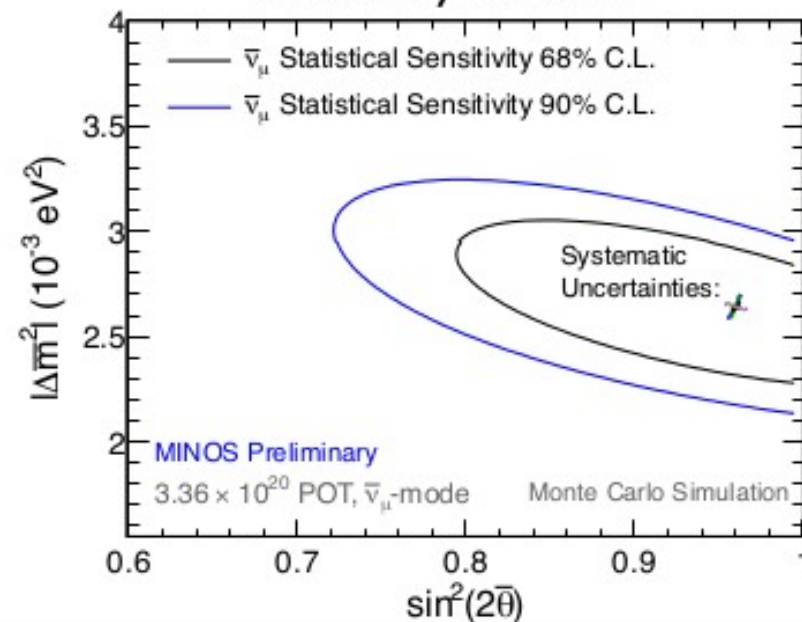
Observed: **226 events**

$\bar{\nu}_\mu$ Oscillations Best Fit Parameters

$$|\Delta \bar{m}_{\text{atm}}^2| = 2.64^{+0.28}_{-0.27} \times 10^{-3} \text{eV}^2$$

$$\sin^2(2\bar{\theta}) > 0.78 \text{ (90\% C.L.)}$$

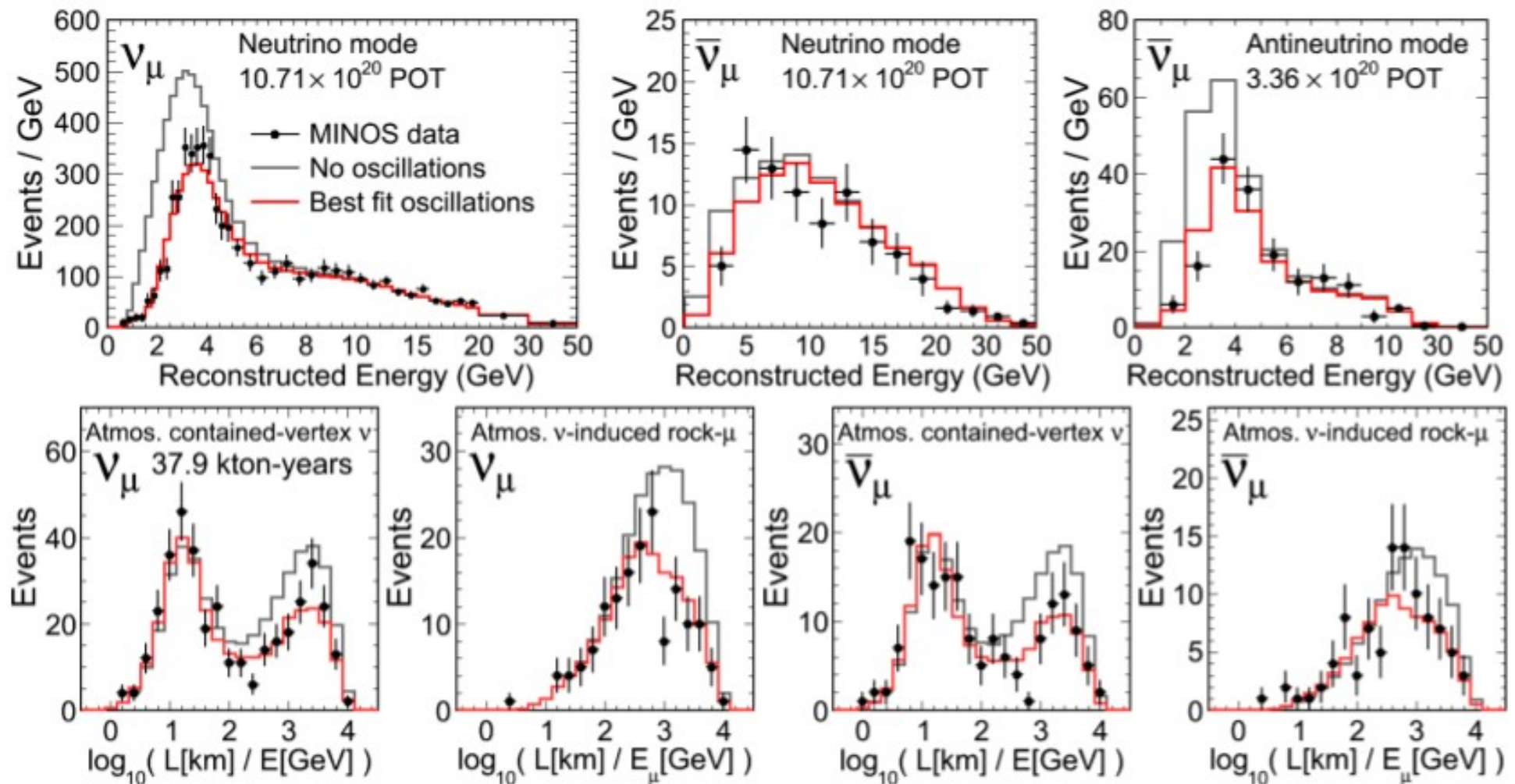
Effect of Systematics





Combined Beam+Atmospherics Disappearance Results

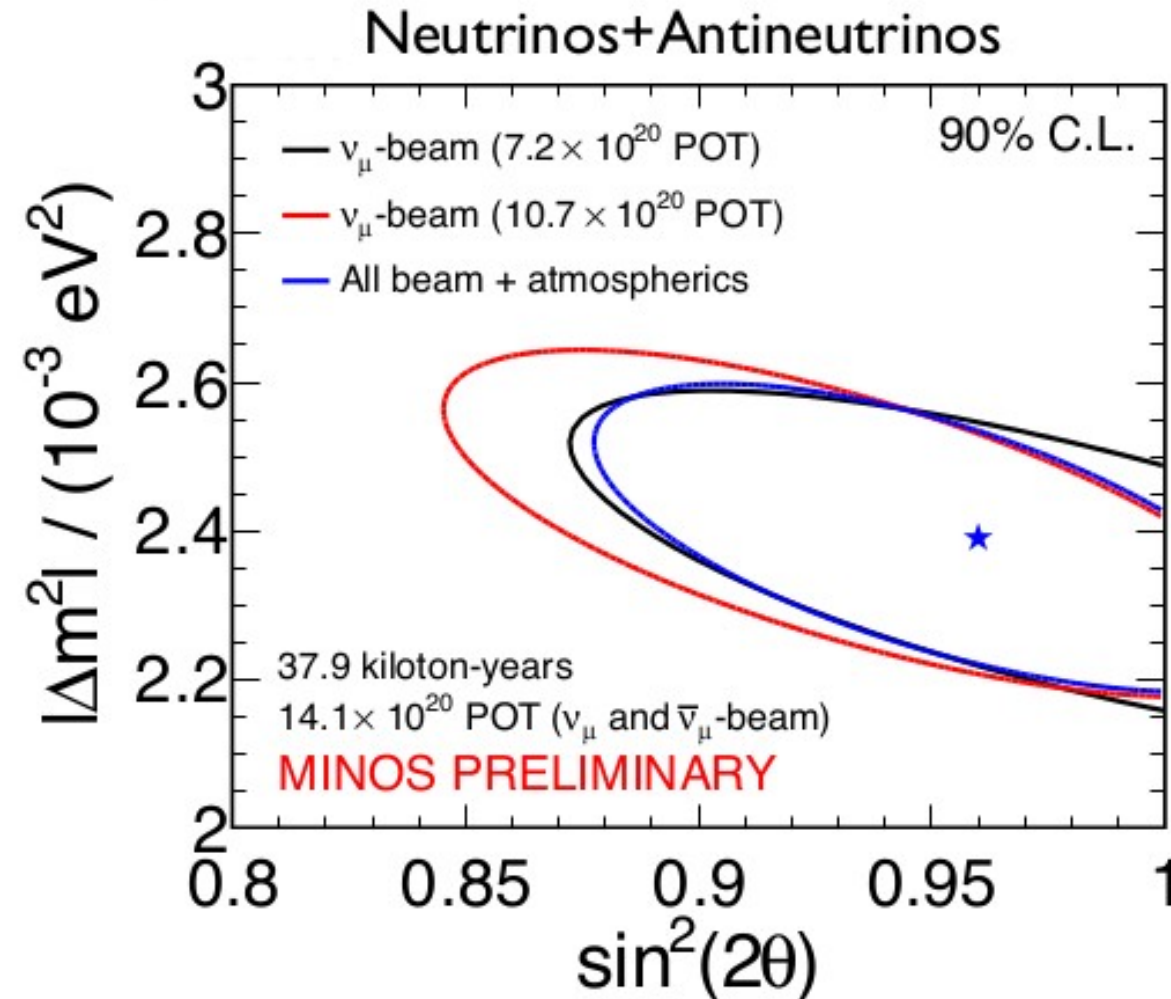
MINOS PRELIMINARY



- Red histogram shows the result from fitting a two-neutrino flavor oscillation scenario to the combined beam and atmospheric neutrino and antineutrino data samples. Fit includes 15 sources of systematic uncertainty as nuisance parameters.
- Oscillations are a good fit: 64% of pseudo-experiments have worse χ^2 .



Combined Beam+Atmospherics Disappearance Results

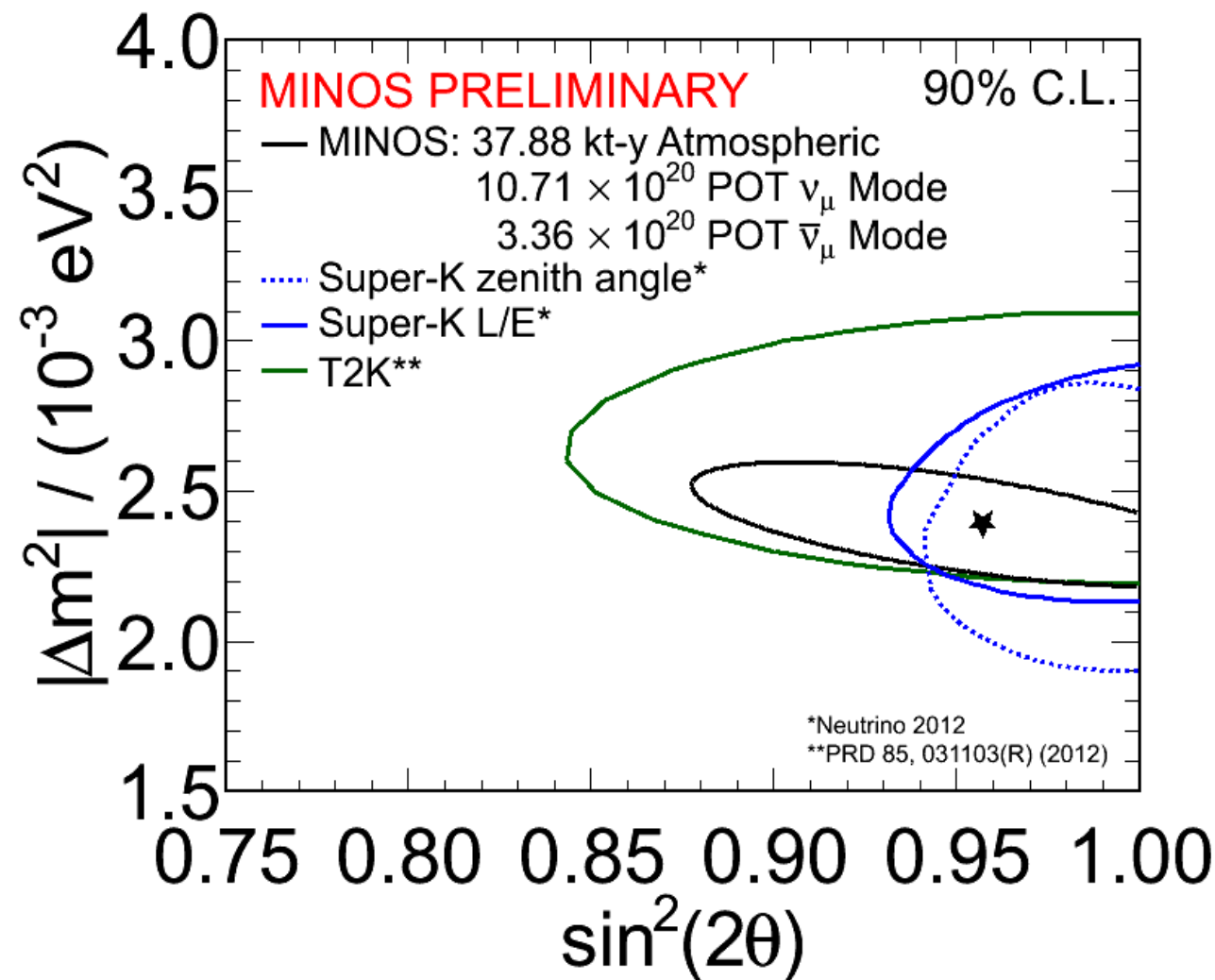


$$|\Delta m_{\text{atm}}^2| = 2.39_{-0.10}^{+0.09} \times 10^{-3} \text{ eV}^2$$
$$\sin^2(2\theta) = 0.96_{-0.04}^{+0.04}$$

- The MINOS beam and atmospheric neutrinos and antineutrinos are combined into a single oscillation analysis using an extended version of the fitting framework developed for the previous analysis.
- The analysis includes 15 sources of systematic uncertainty, fitted as nuisance parameters,
- A maximum-likelihood fit is used to determine the two-flavour oscillation parameters.
- An extension of the analysis from two to three-flavour oscillations is in progress



MINOS Allowed Regions Compared to Other Experiments



MINOS Best Fit Parameters

$$|\Delta m_{\text{atm}}^2| = 2.39_{-0.10}^{+0.09} \times 10^{-3} \text{ eV}^2$$

$$\sin^2(2\theta) = 0.96_{-0.04}^{+0.04}$$

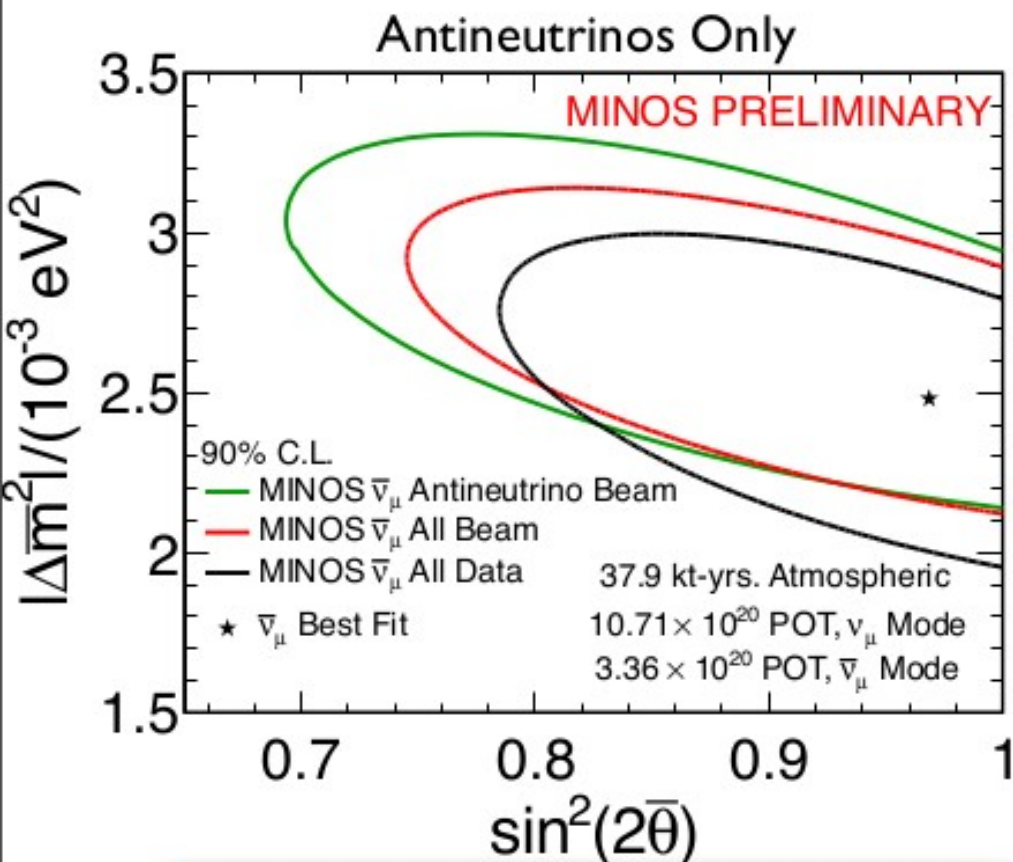
$$\sin^2(2\theta) > 0.90 \text{ (90\% C.L.)}$$

- MINOS makes the leading measurement of $|\Delta m_{\text{atm}}^2|$ with 4.2% precision.



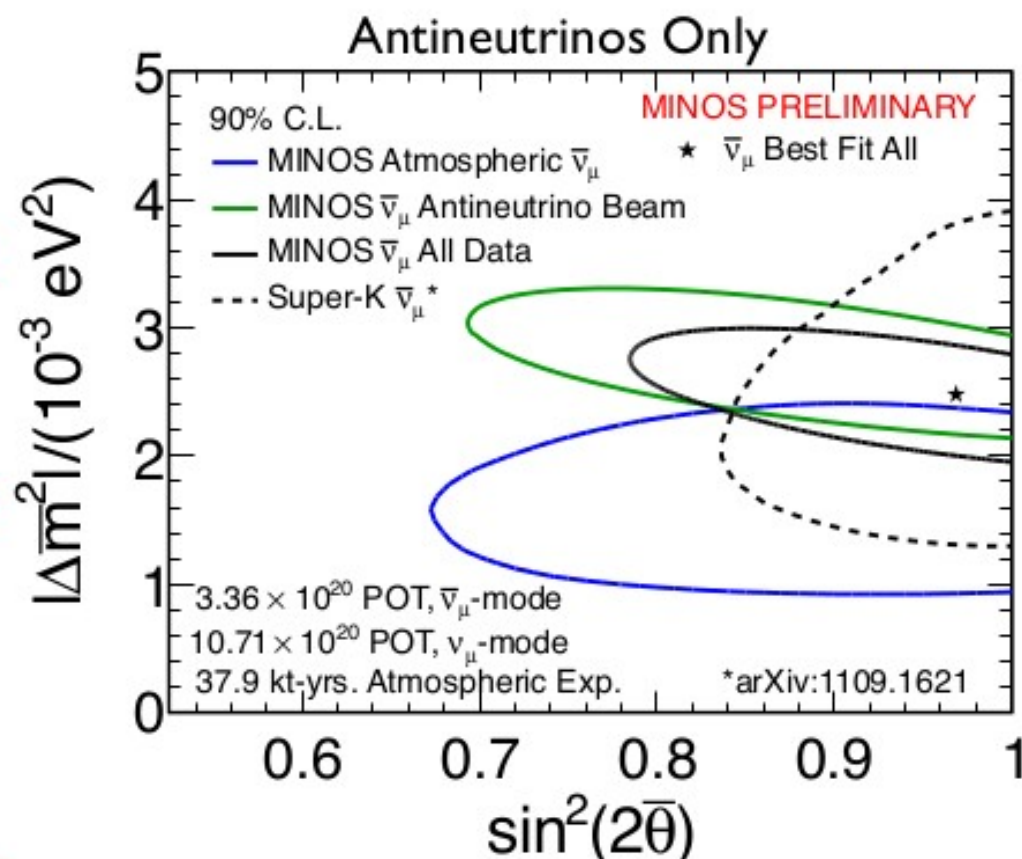
Combined Beam+Atmospherics Disappearance Results

- The MINOS oscillation fit is extended to allow different oscillation parameters for ν_μ and $\bar{\nu}_\mu$.
- The extended fit is used to determine confidence limits on the antineutrino oscillation parameters by marginalizing over the neutrino oscillation parameters.



$$|\Delta \bar{m}_{\text{atm}}^2| = 2.48_{-0.27}^{+0.22} \times 10^{-3} \text{ eV}^2$$

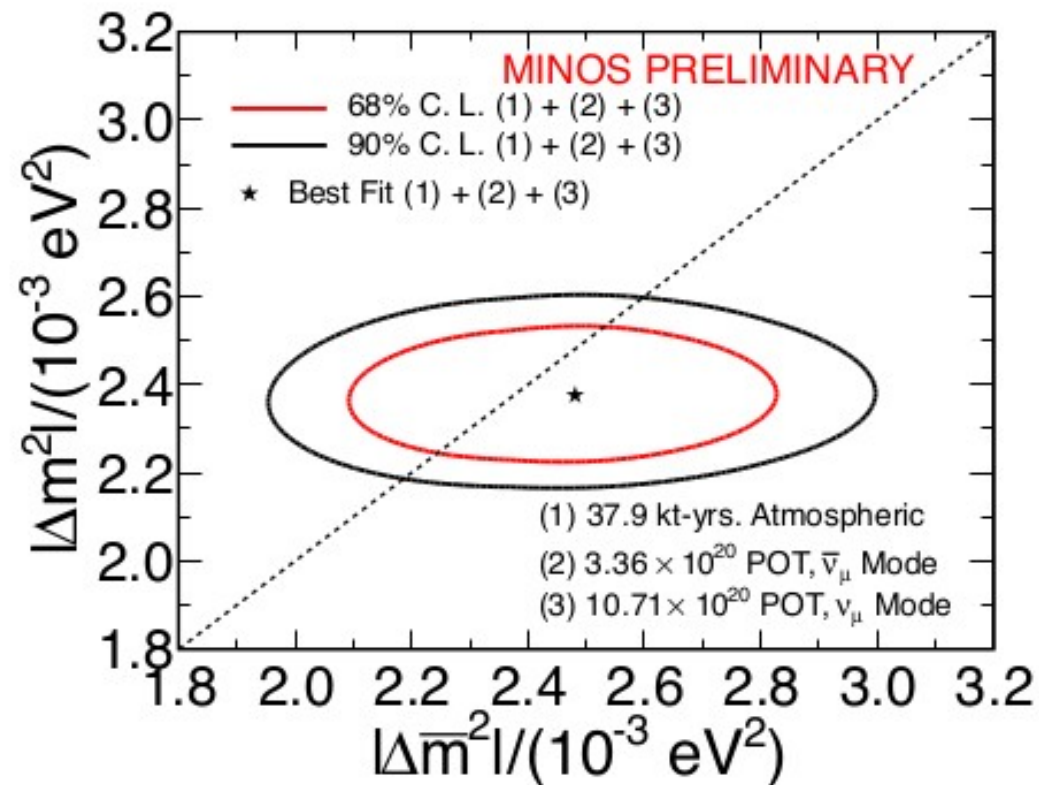
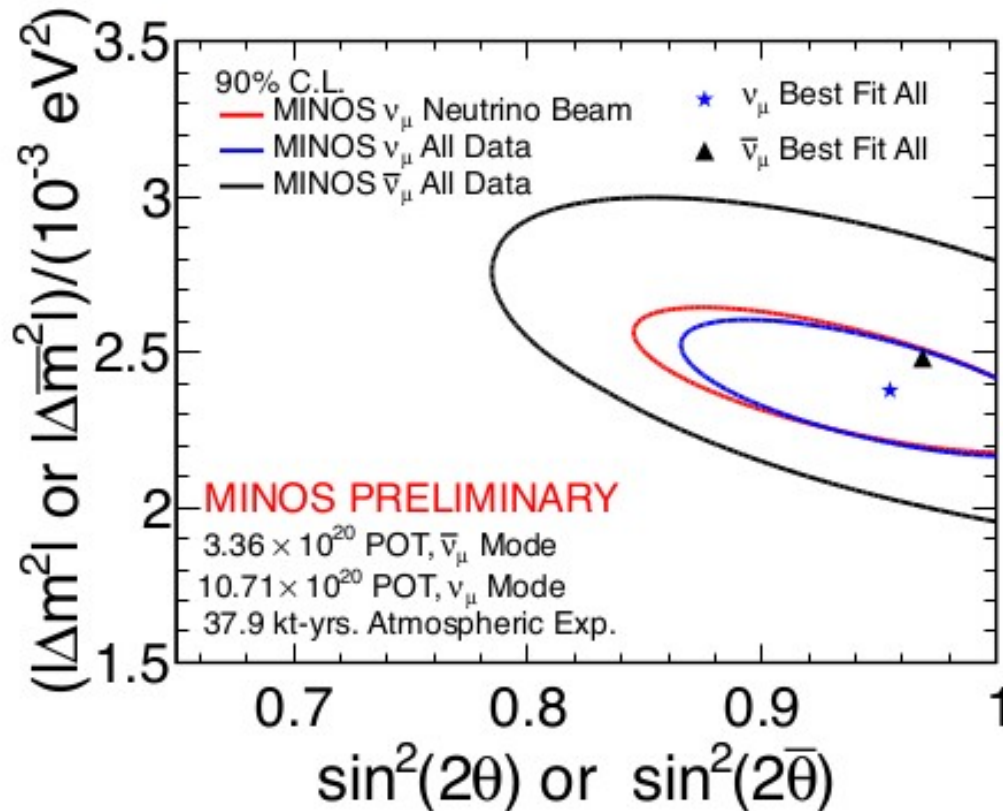
$$\sin^2(2\bar{\theta}) = 0.97_{-0.08}^{+0.03}$$



- Plot above shows a comparison of MINOS antineutrino results for beam, atmospheric and beam+atmospheric samples with results from the Super-Kamiokande experiment



Neutrino vs. Antineutrino Disappearance



$$|\Delta \bar{m}^2| - |\Delta m^2| = 1.0_{-2.8}^{+2.4} \times 10^{-4} \text{ eV}^2$$

- MINOS finds consistent values for neutrinos and antineutrino oscillation parameters measured via charged-current disappearance.