

Status of NuMI experiments MINOS+ and NOvA

Joao Coelho

For the MINOS+ and NOvA Collaborations



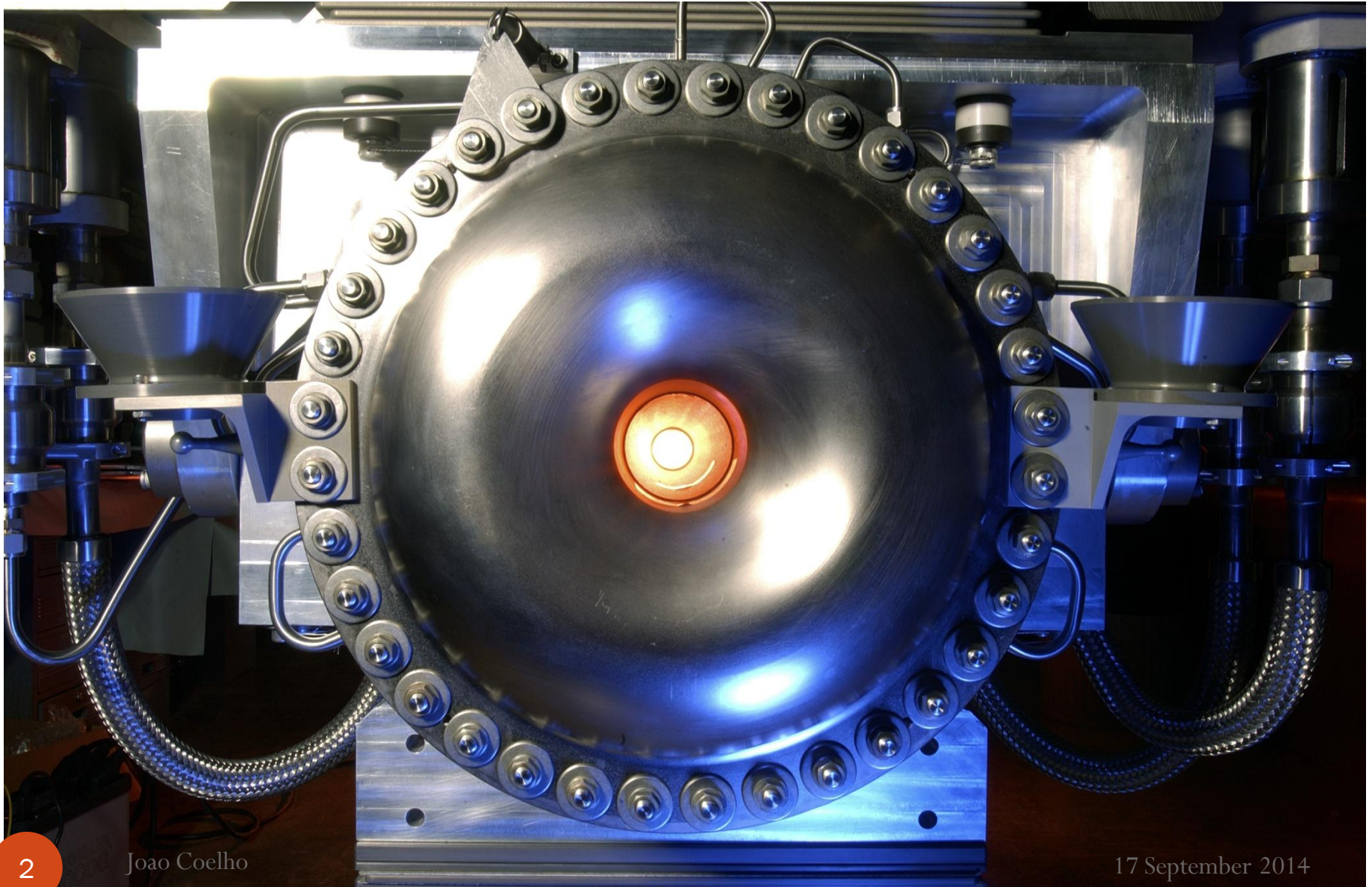
Tufts University



Tufts
UNIVERSITY

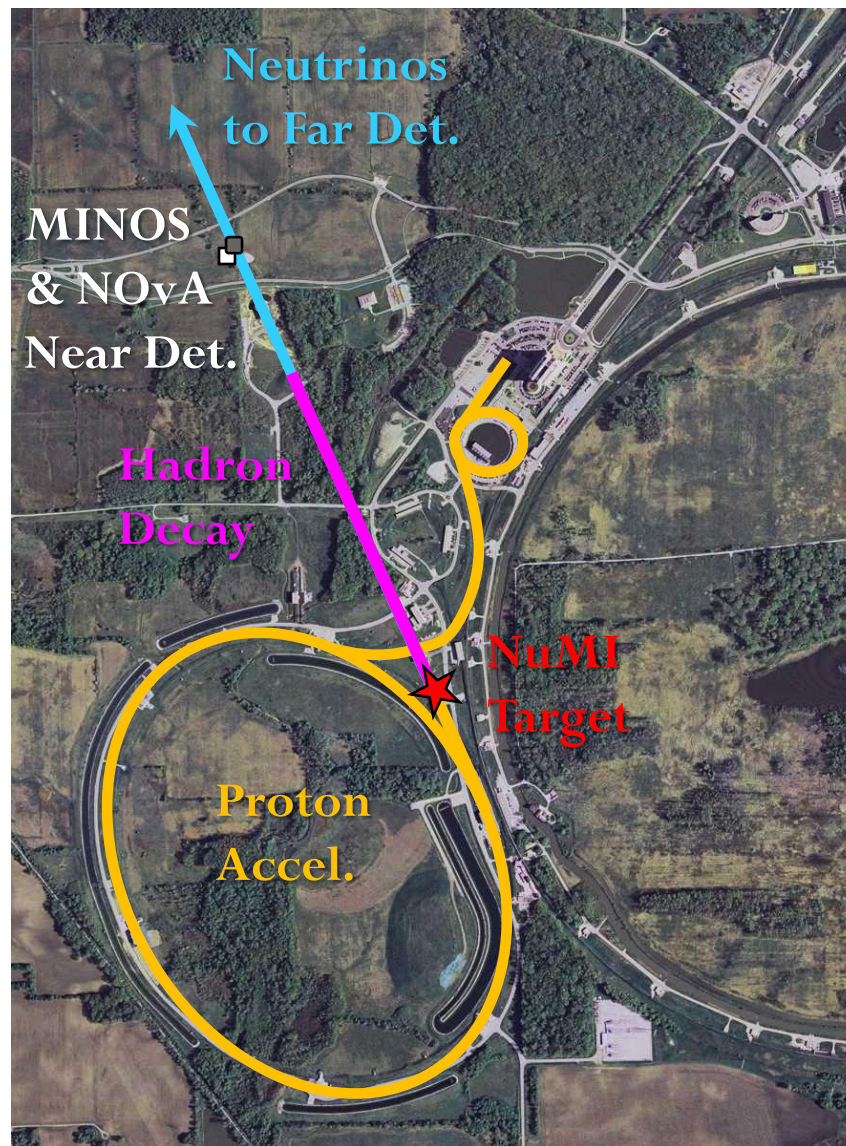
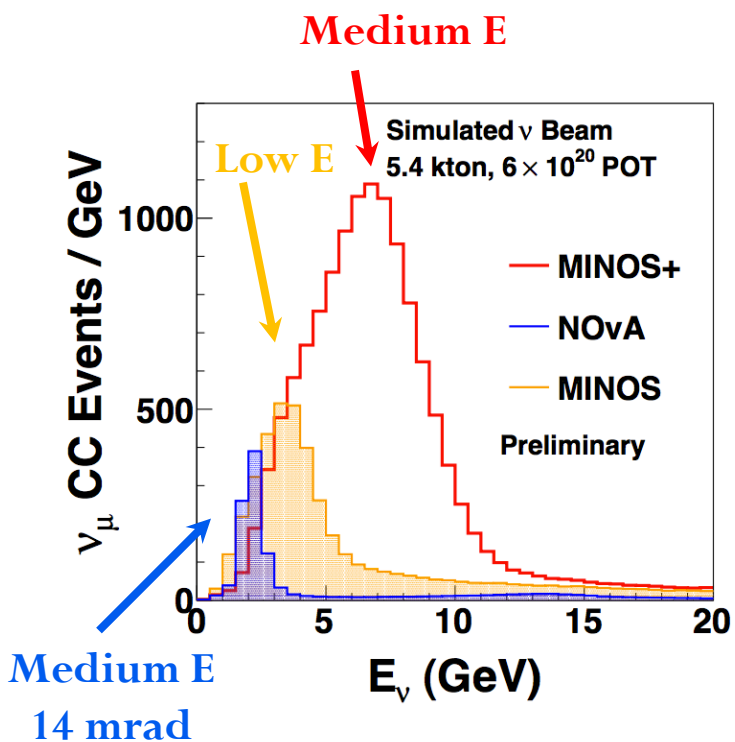


The NuMI Beam



NuMI Beam

- Currently at 320 kW
- Capable of 700 kW

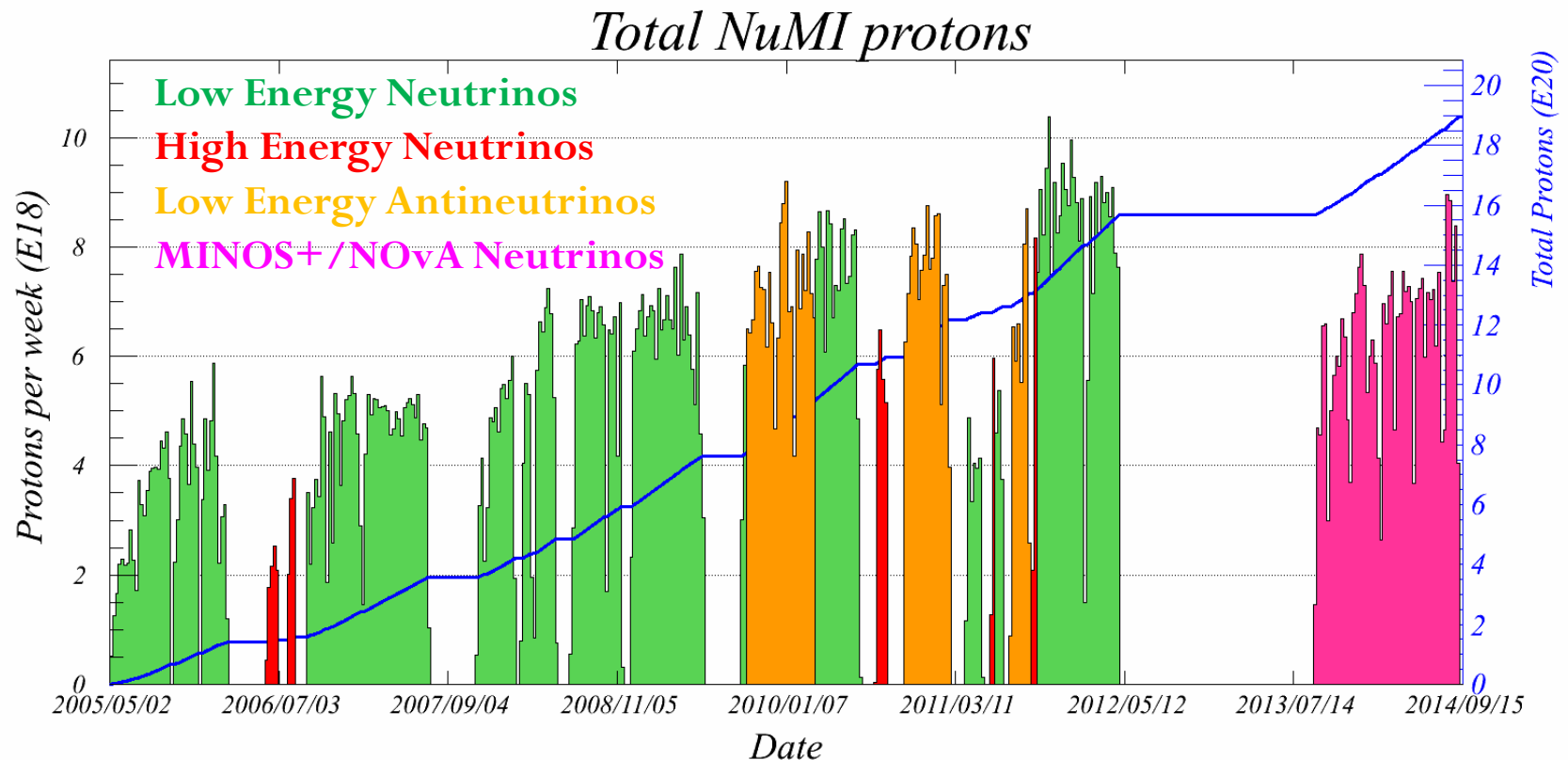


NuMI Beam



NuMI Beam

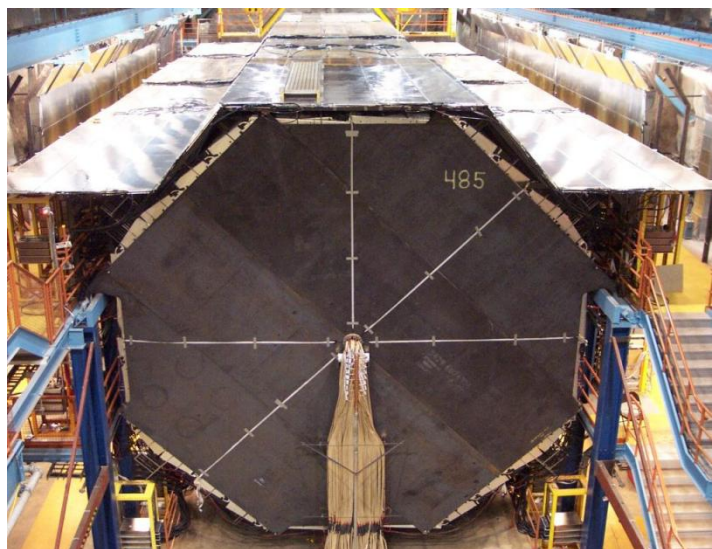
- 18.97×10^{20} Protons on Target (PoT) delivered to date
- 3.26×10^{20} PoT with the new beam for MINOS+ and NOvA
- Ran at 320 kW for a month before the shutdown on Sep. 5th



MINOS+



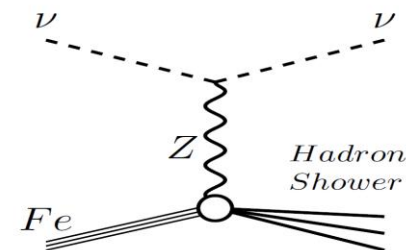
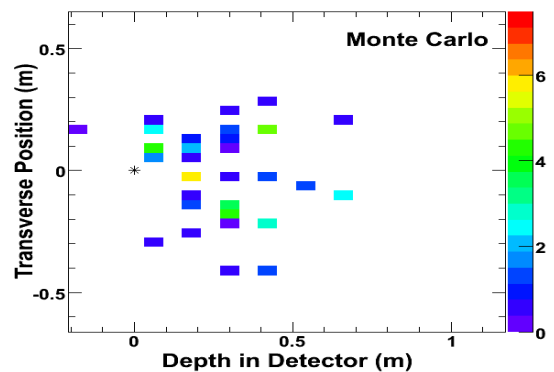
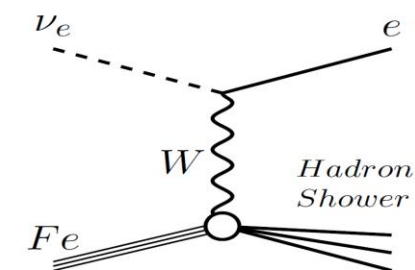
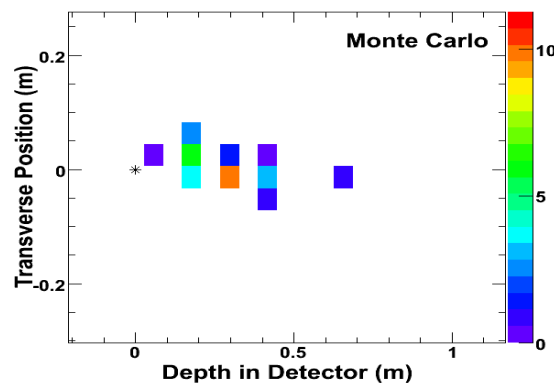
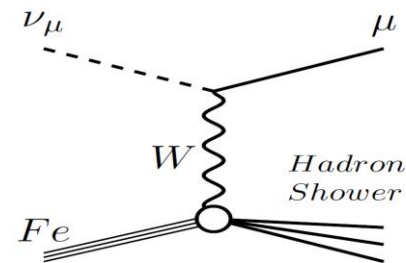
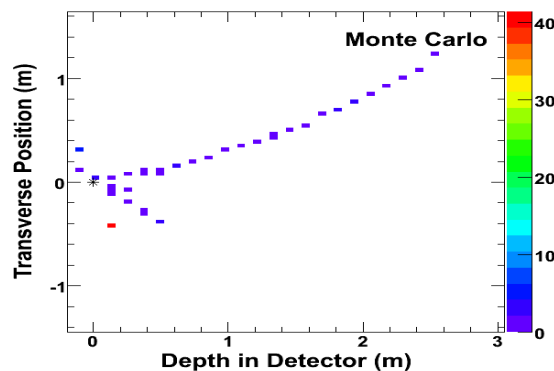
MINOS+



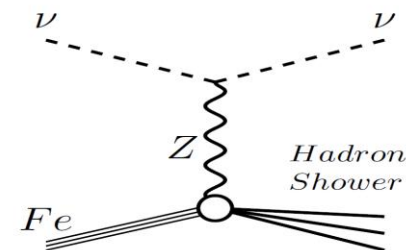
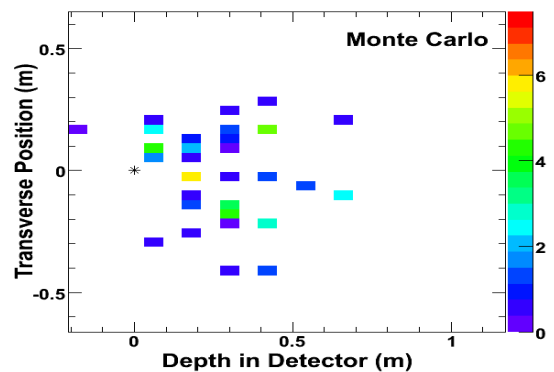
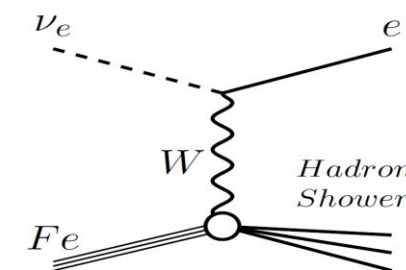
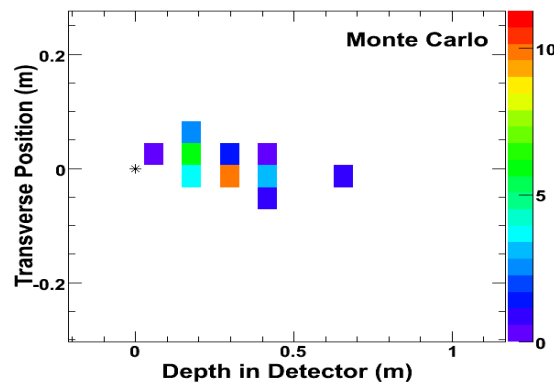
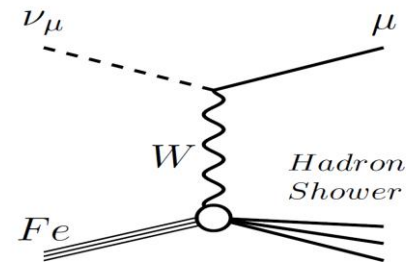
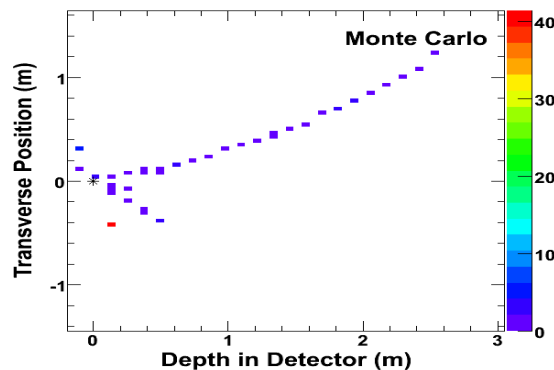
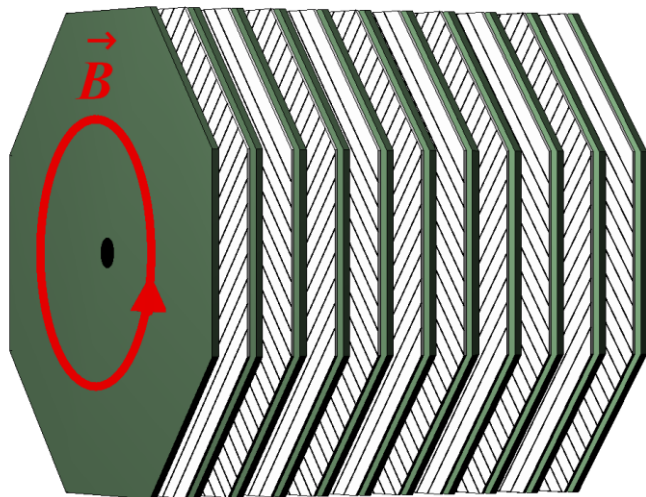
Magnetized steel-scintillator
tracking calorimeters

Far Detector: 5.4 kton

Near Detector: 0.98 kton



MINOS+



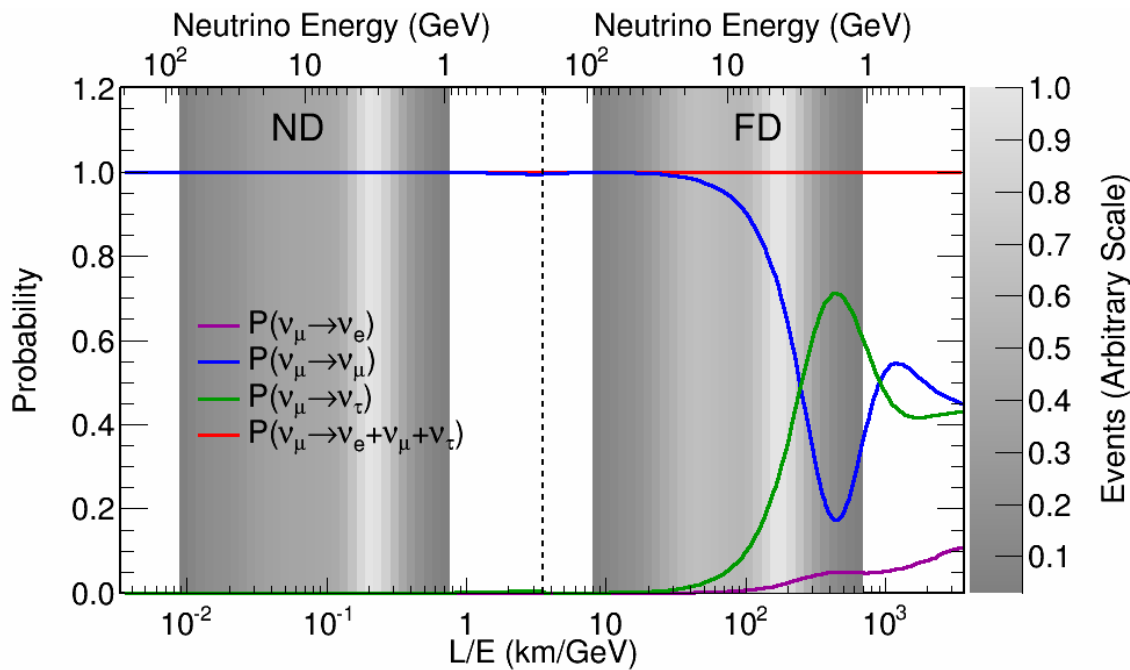
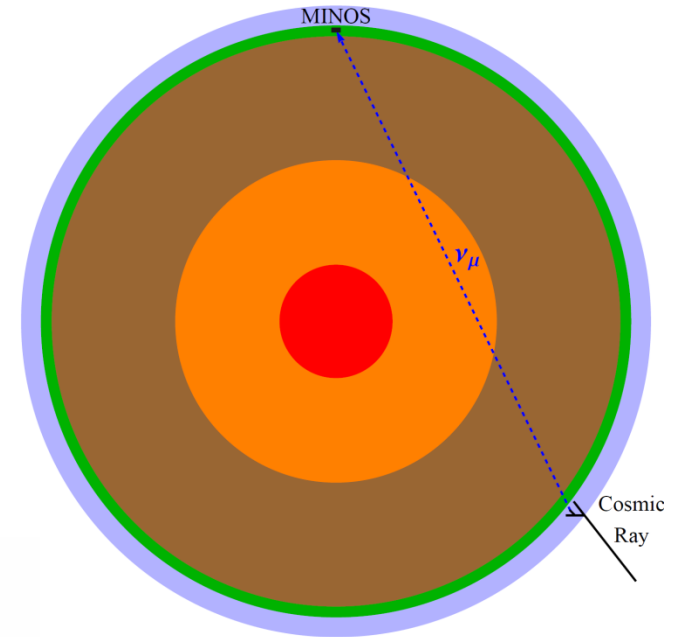
Magnetized steel-scintillator tracking calorimeters

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Neutrino Oscillation

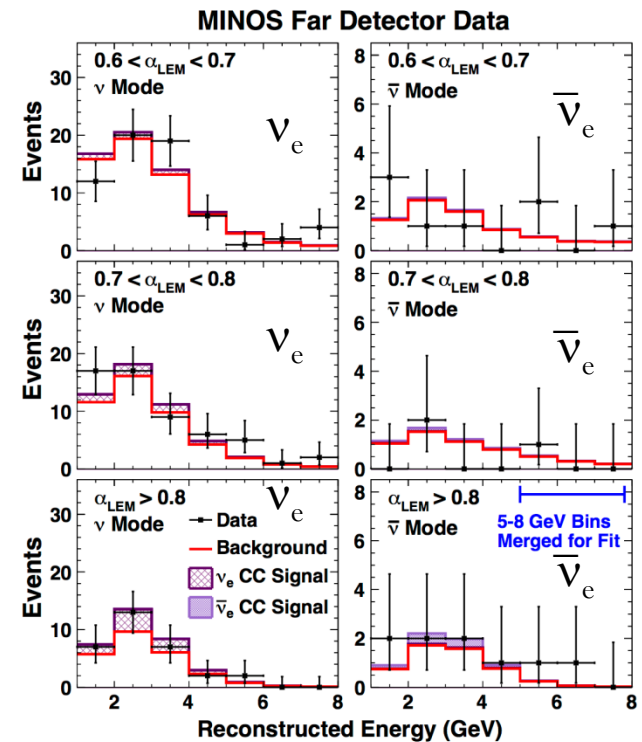
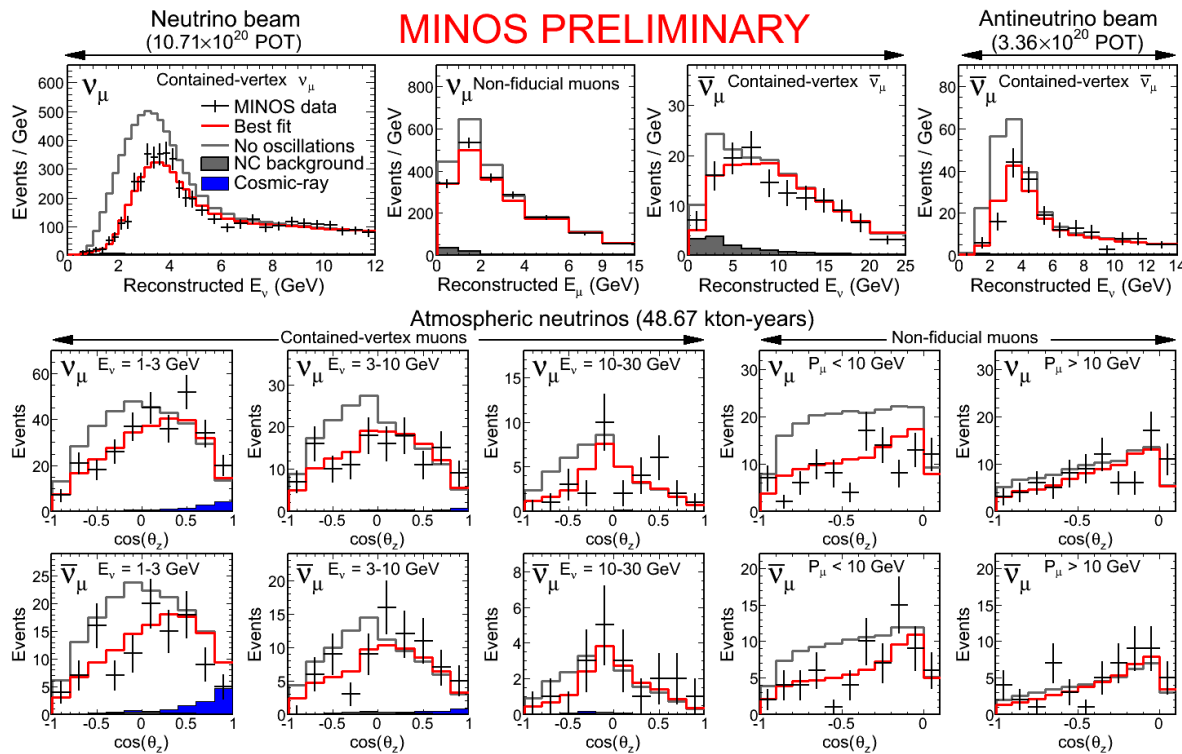
MINOS+



- ν_μ disappearance
 - ν_e appearance
 - NC to infer ν_τ
 - ν_τ appearance?
- Maybe in MINOS+

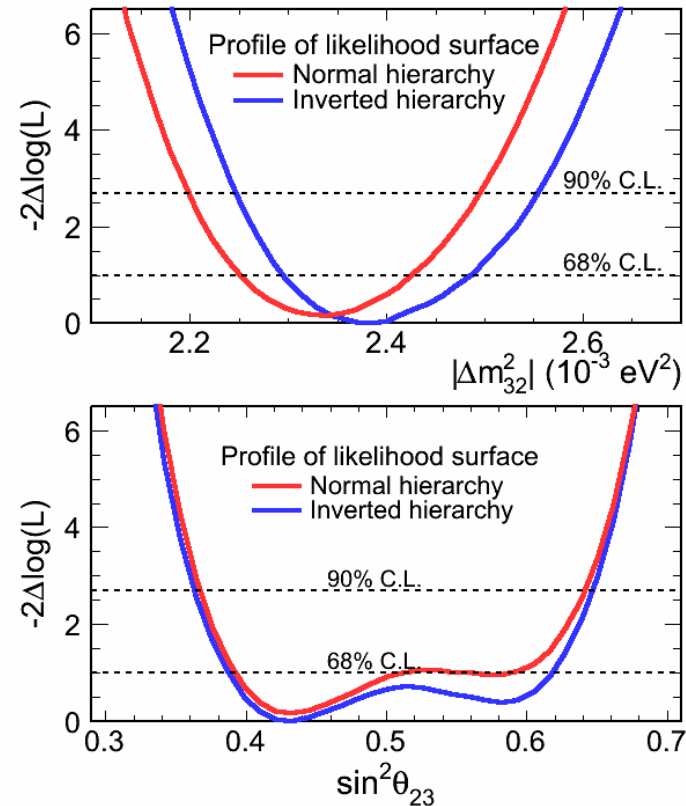
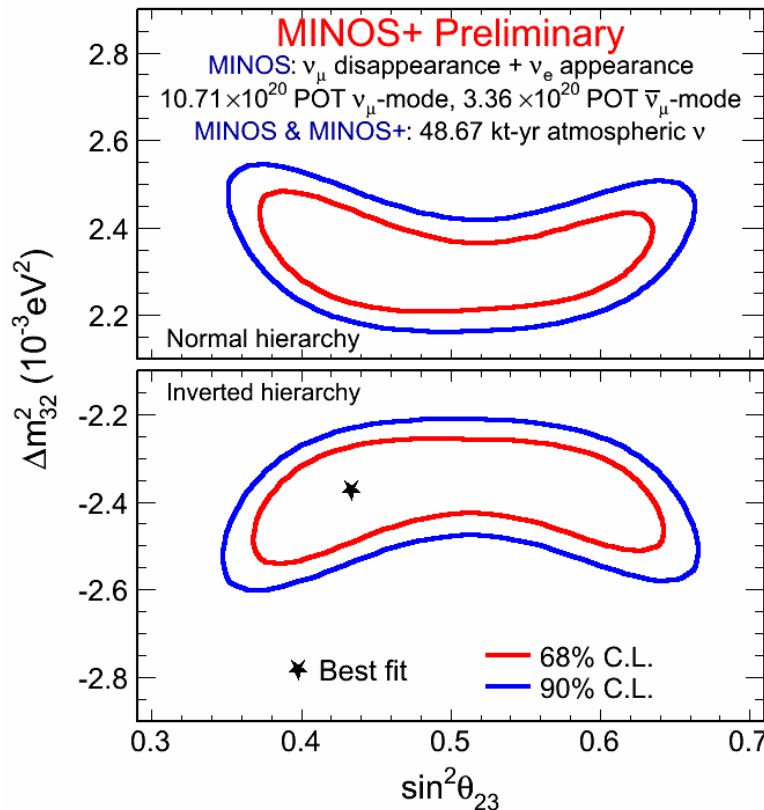
Results from MINOS

- Combine **ALL** neutrino data
- Neutrinos and antineutrinos
- +10.8 kton-years of atmospheric data in the MINOS+ era (28% increase)
- ν_μ disappearance and ν_e appearance
- Beam and atmospheric neutrinos



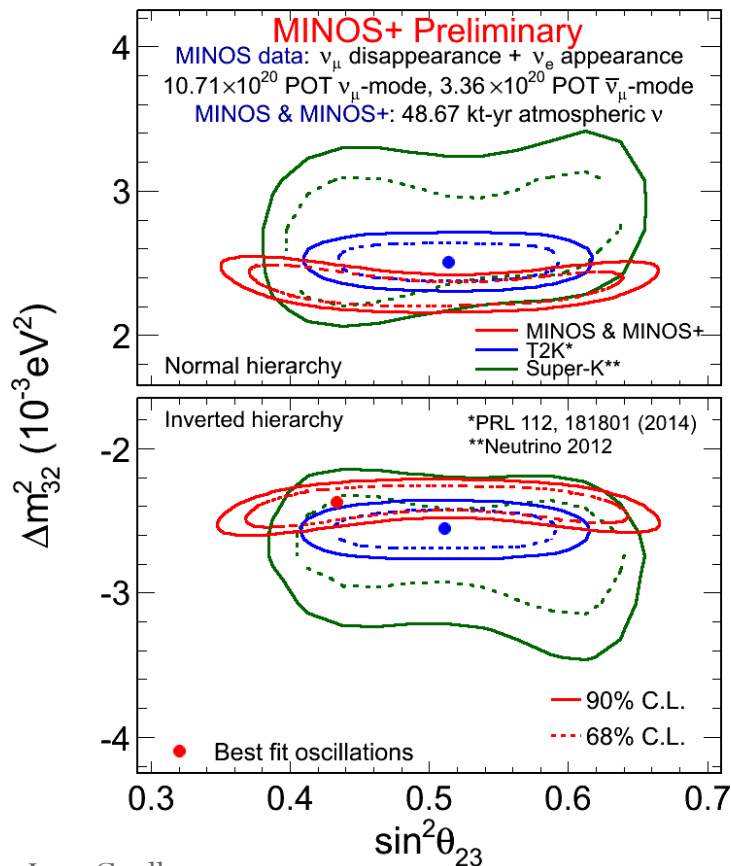
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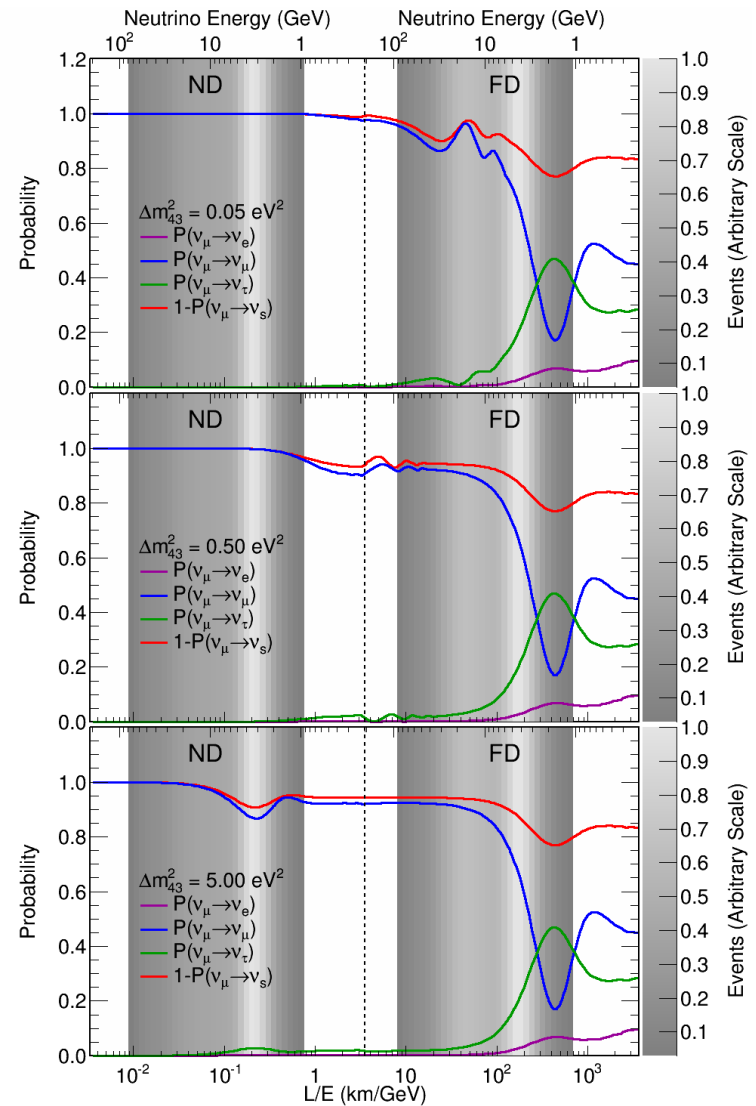
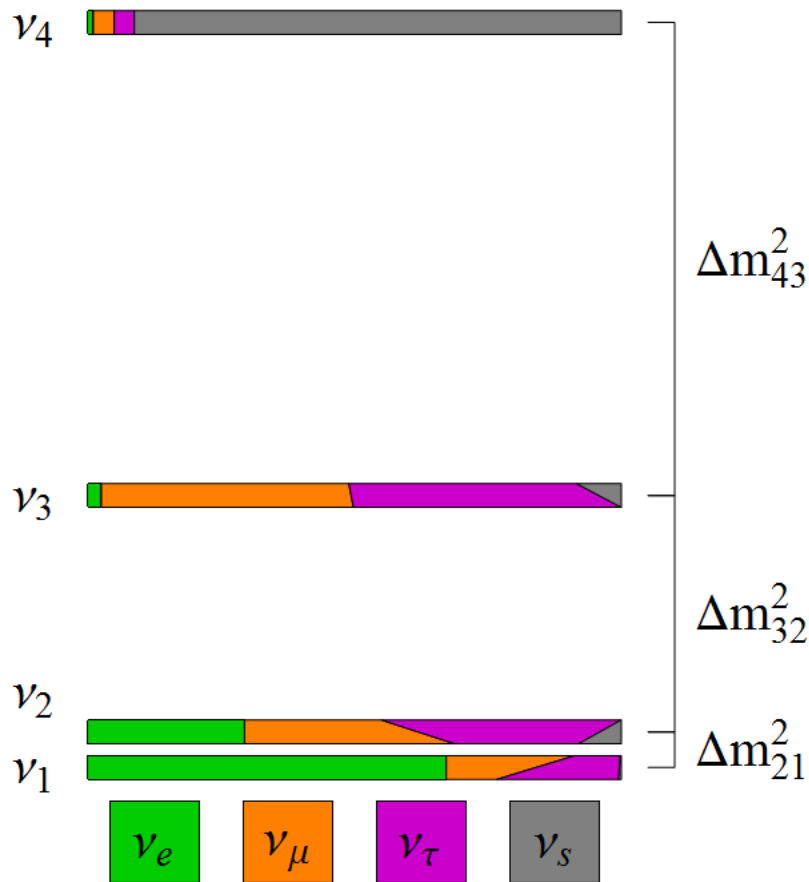
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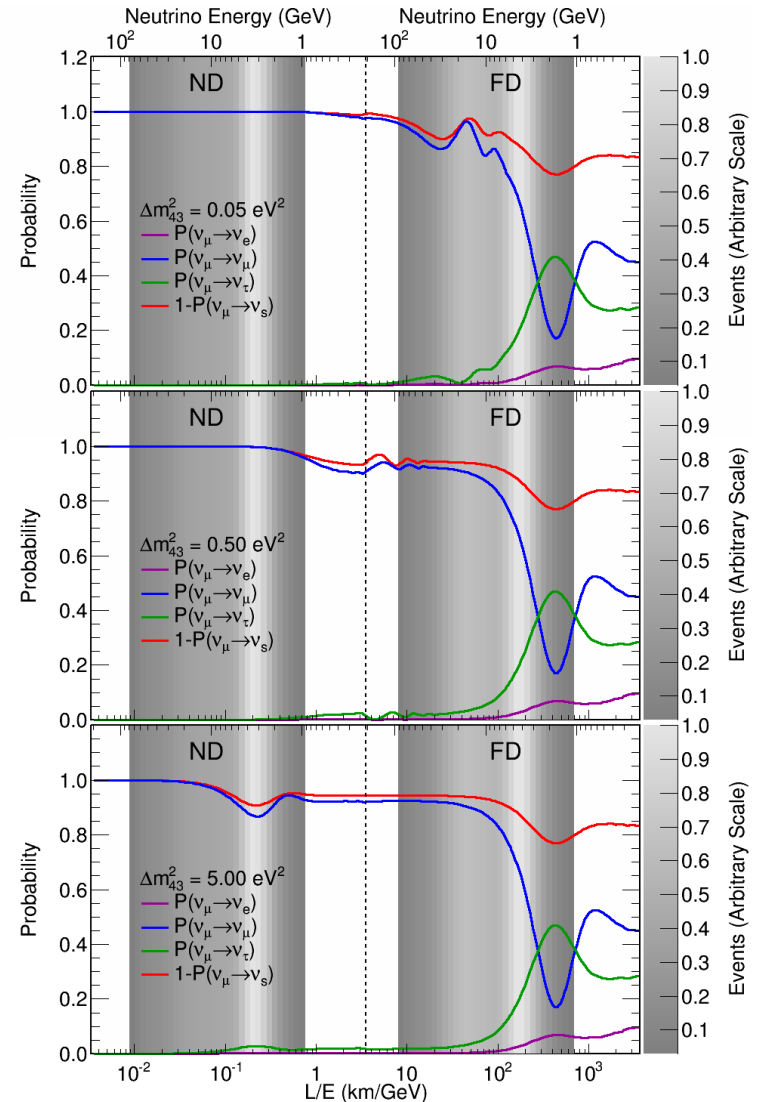
**Best
 measurement
 of Δm^2_{32}
 3.8% prec.**

Sterile Neutrinos



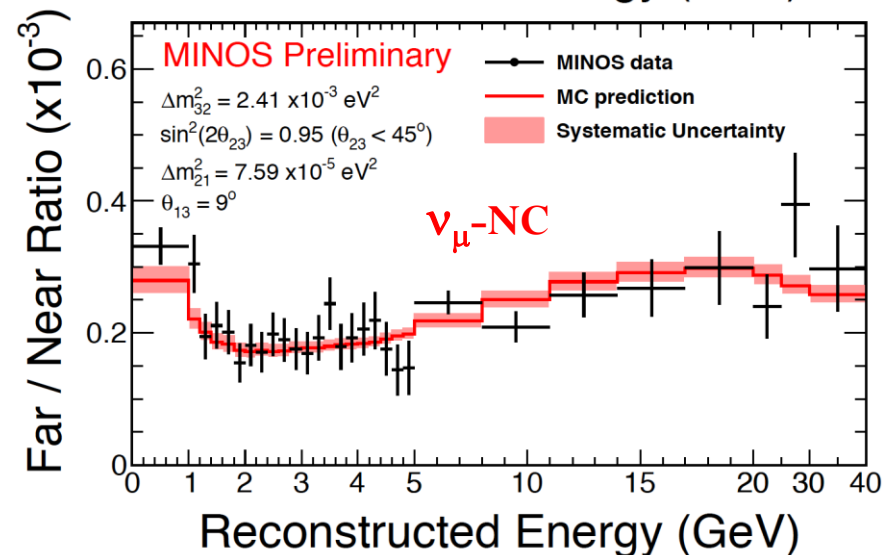
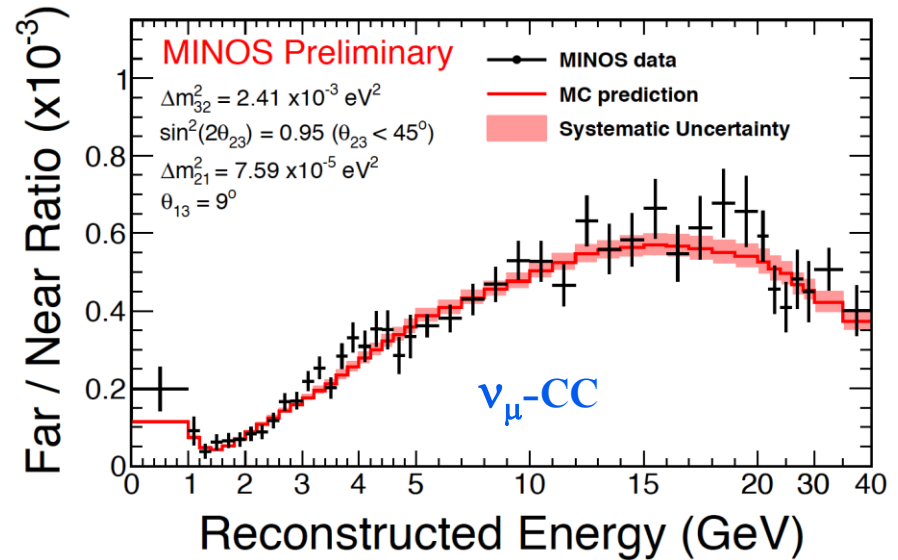
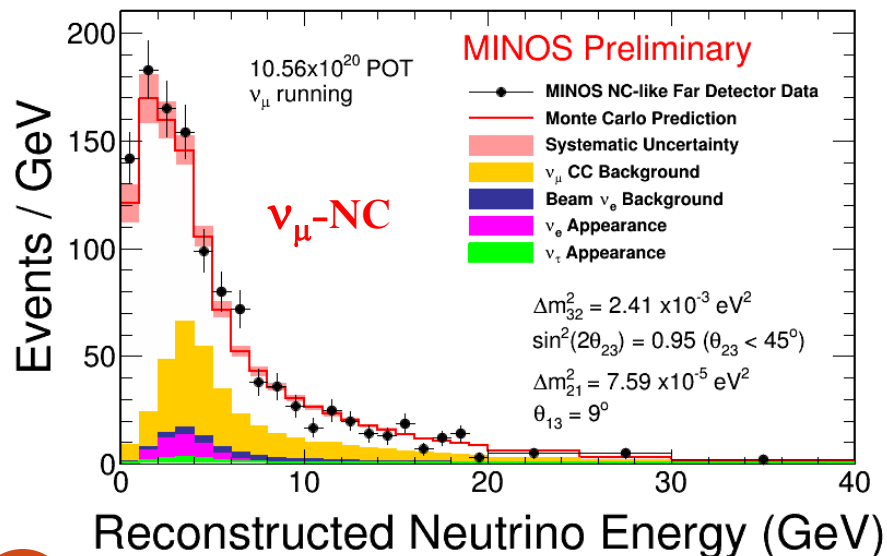
Sterile Neutrinos

- $\Delta m_{43}^2 \ll 0.5 \text{ eV}^2$:
 - Distortions at the FD
 - High energy tail
- $\Delta m_{43}^2 \sim 0.5 \text{ eV}^2$:
 - No distortions
 - Rate measurement
- $\Delta m_{43}^2 \gg 0.5 \text{ eV}^2$:
 - Distortions at ND
 - Most sensitive at low energies



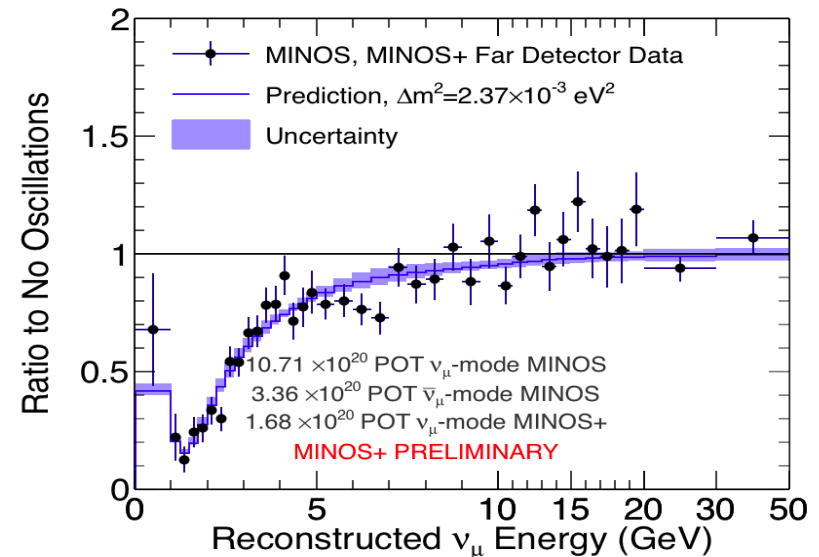
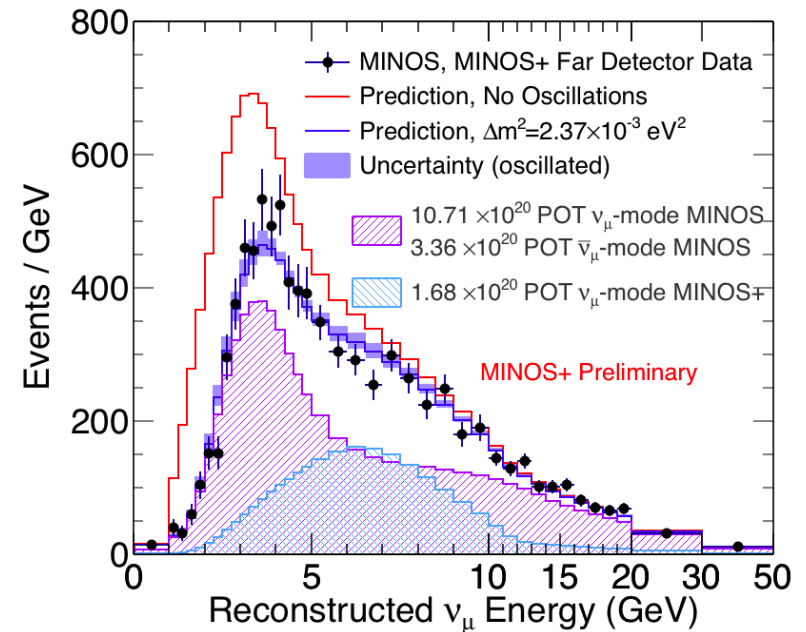
Sterile Neutrinos

- Ratios of Far and Near detectors consistent with no active-sterile mixing
- ν_μ must be transforming into ν_τ
- ν_e appearance is a background in the NC sample



MINOS+ Data

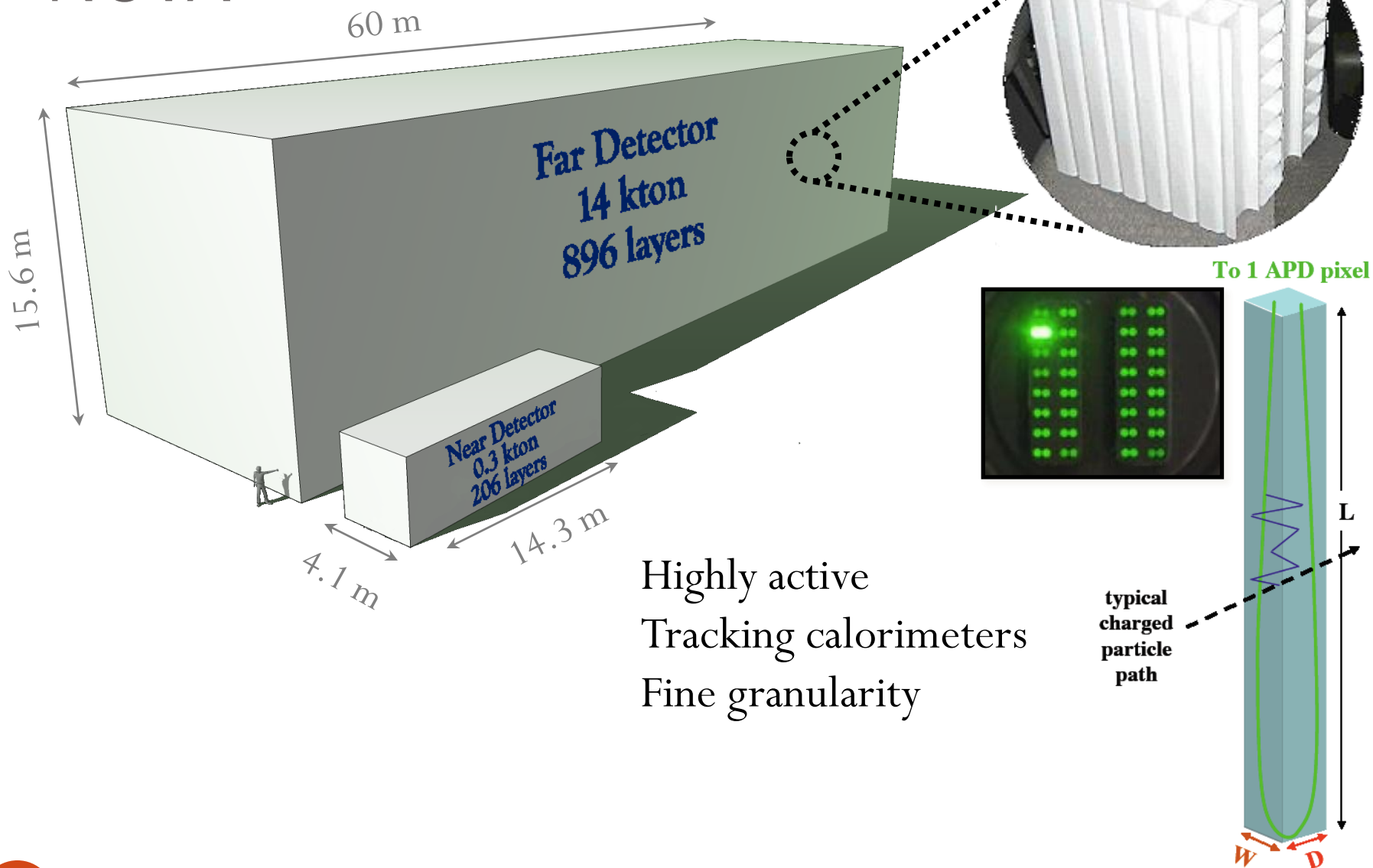
- More beam data from MINOS+
- Preliminary look agrees with expectations based on MINOS
- Already collected 23% more PoT
- Higher energy means even more events
- Improved sensitivity to sterile neutrinos



NOvA

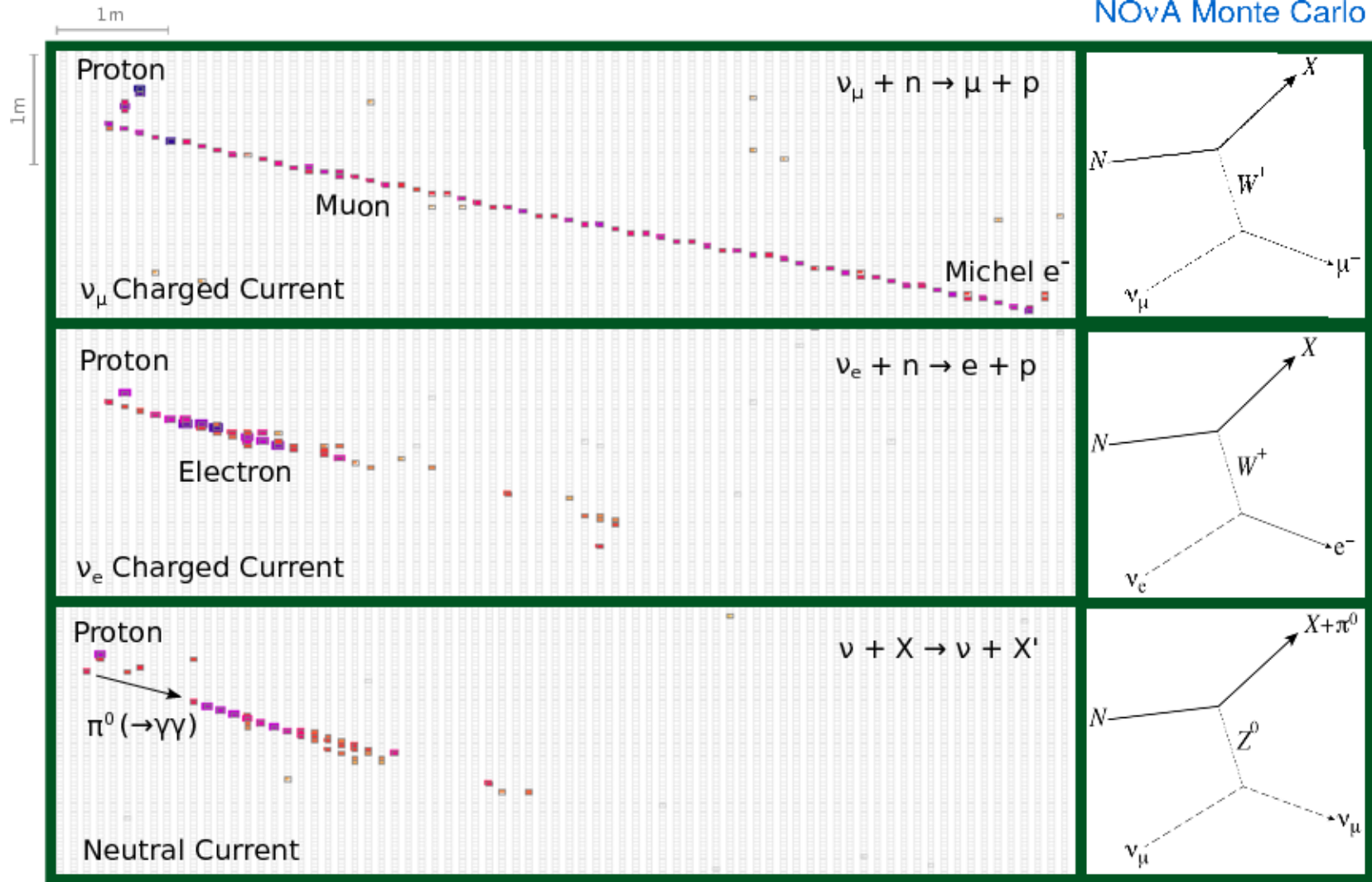


NOvA

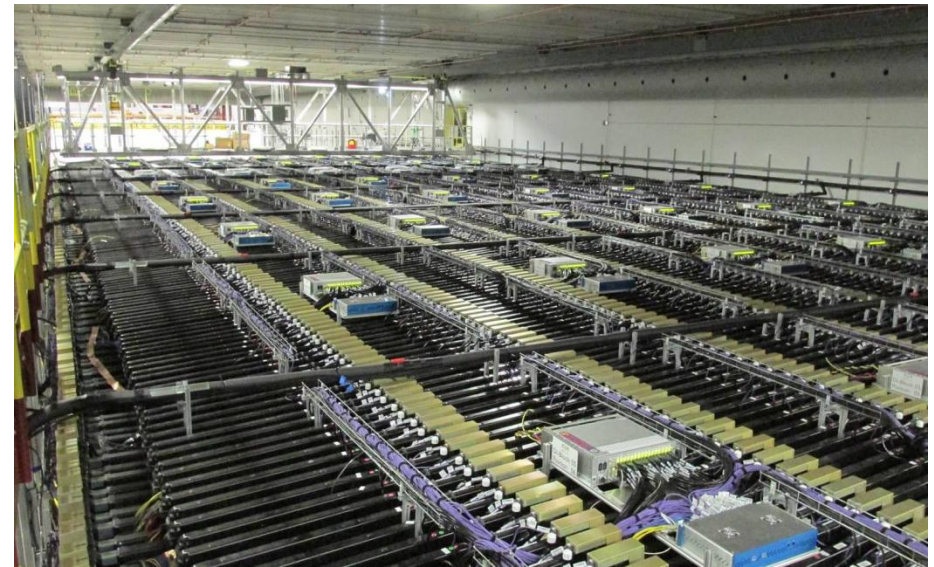
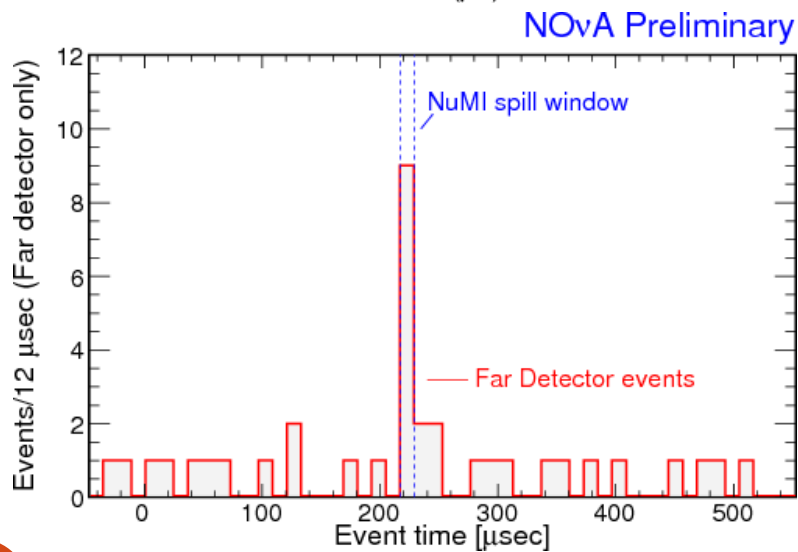
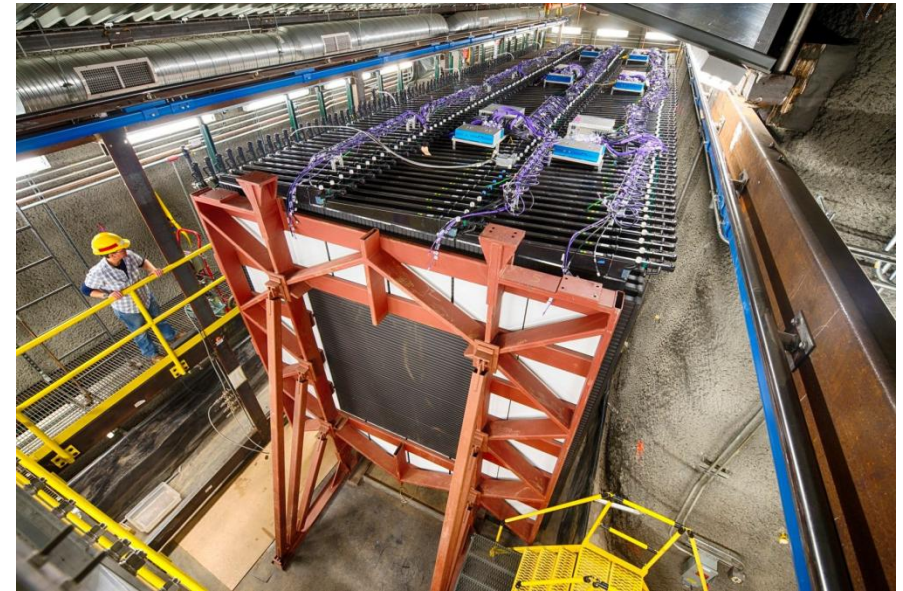
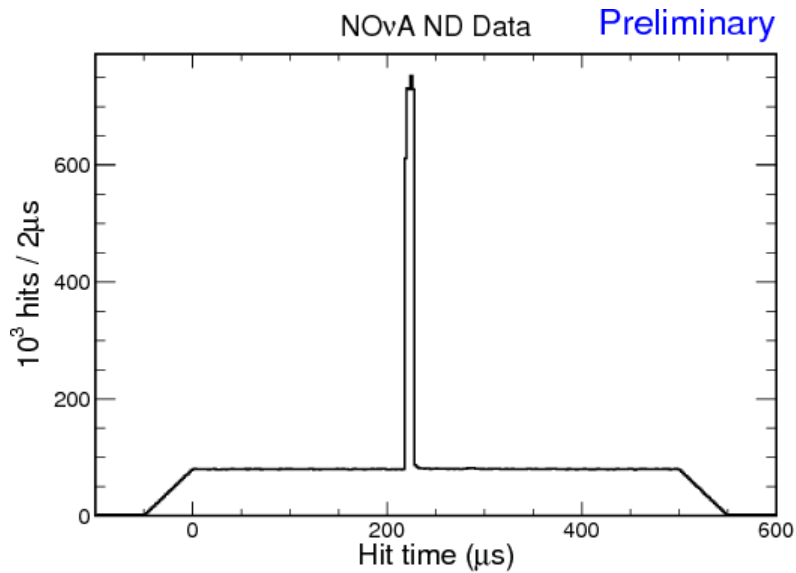


NOvA Topologies

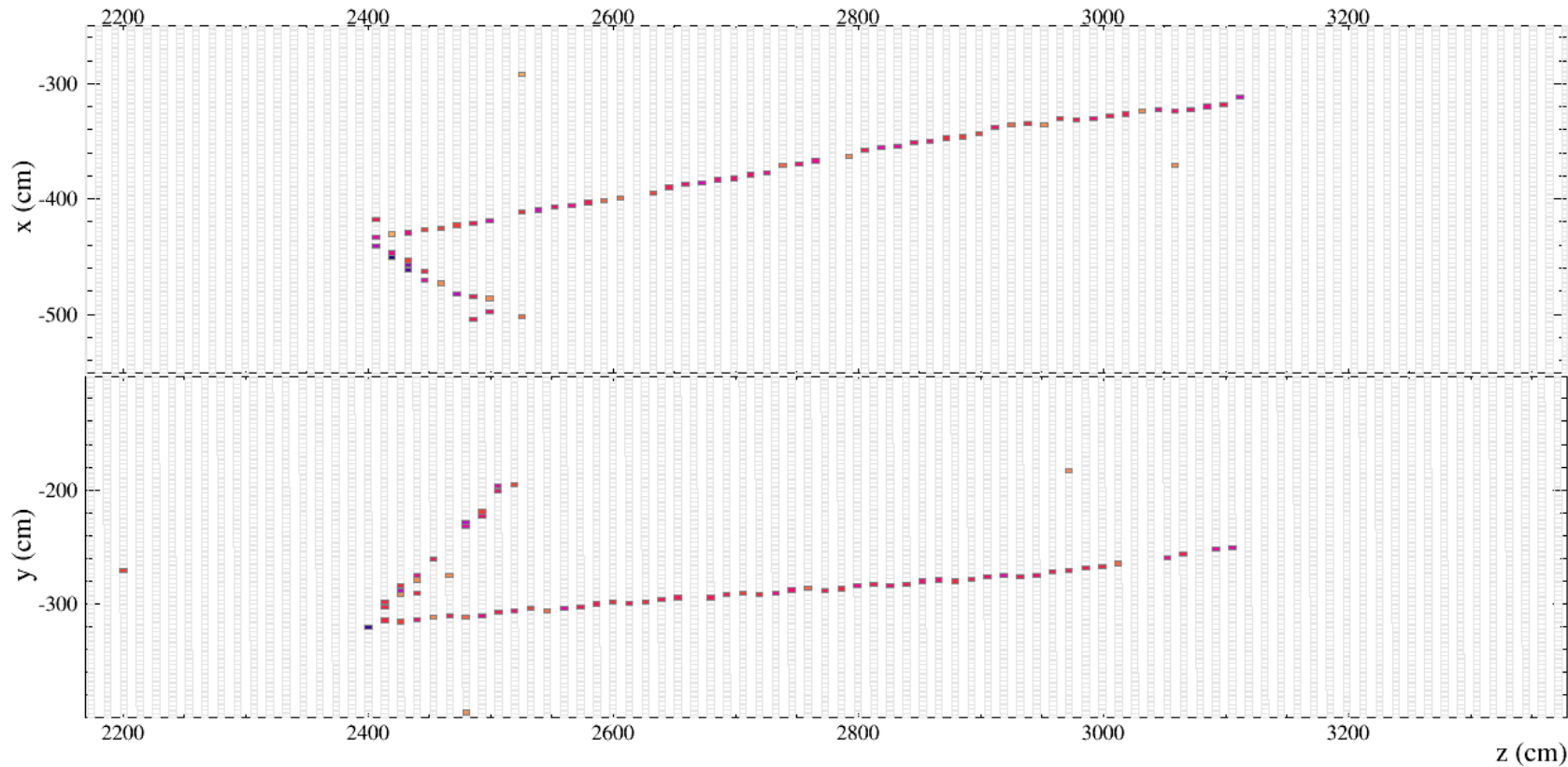
NOvA Monte Carlo



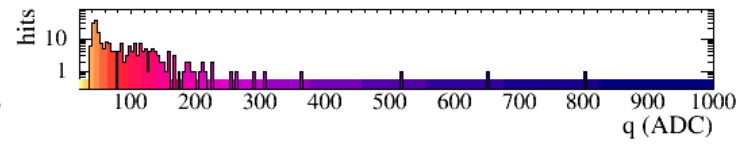
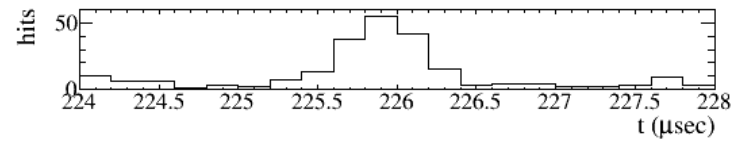
Detectors Complete



Neutrino Event



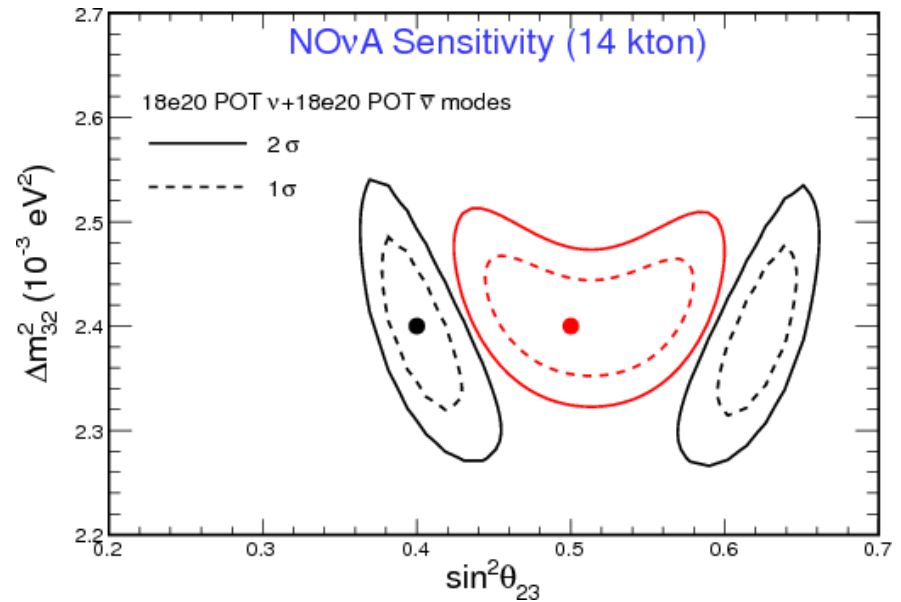
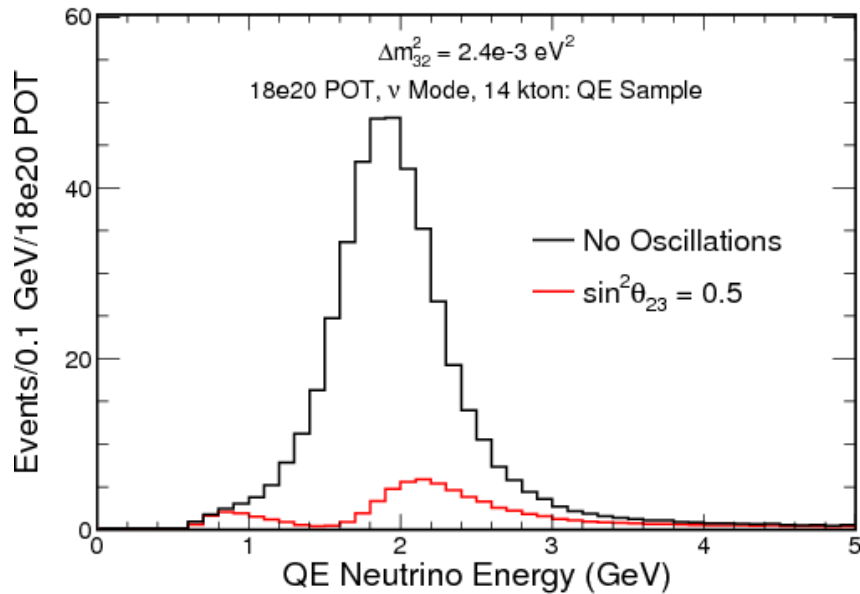
NOvA - FNAL E929
Run: 14828 / 38
Event: 192569 / NuMI
UTC Tue Apr 22, 2014
21:41:51.422846016



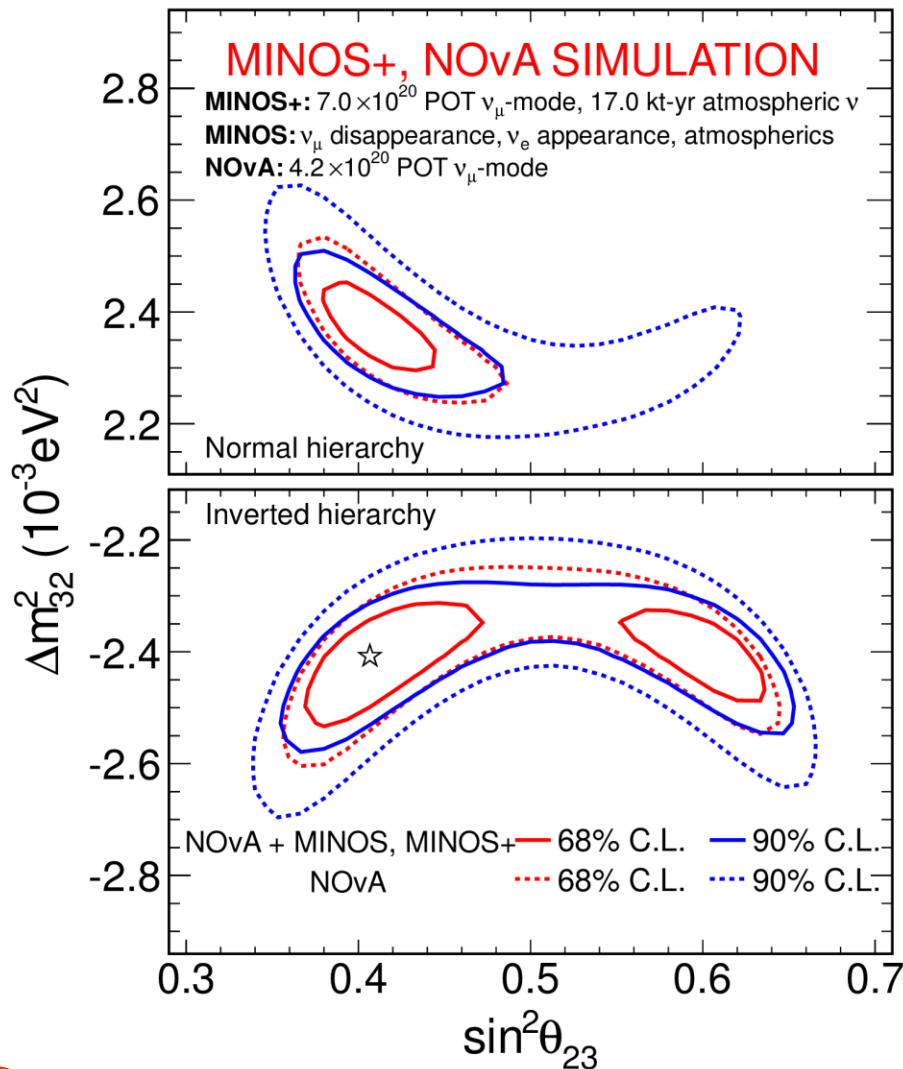
ν_μ Disappearance

- Clear oscillation signal
- Excellent resolution of oscillation dip
- $\sim 1\%$ precision on $\sin^2(2\theta_{23})$

NOvA Simulation



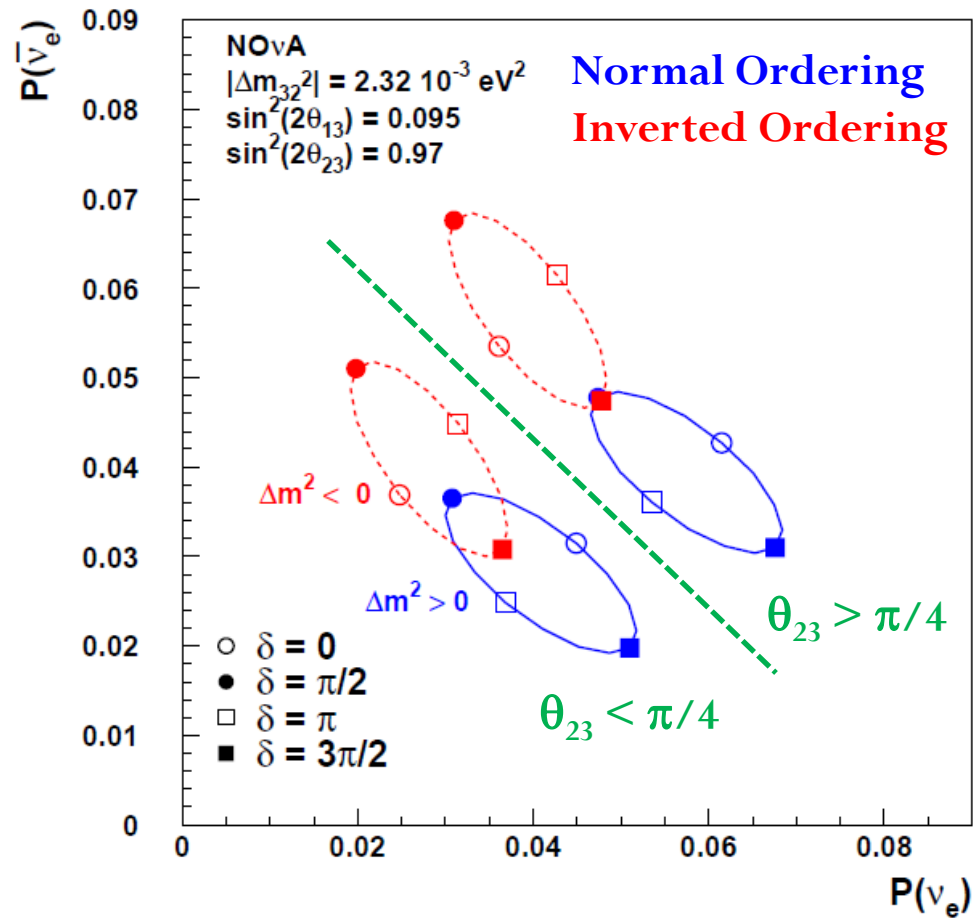
Early Sensitivity w/ MINOS+



- Expect this sensitivity by late 2015
- Enhanced with NOvA and MINOS+ combination

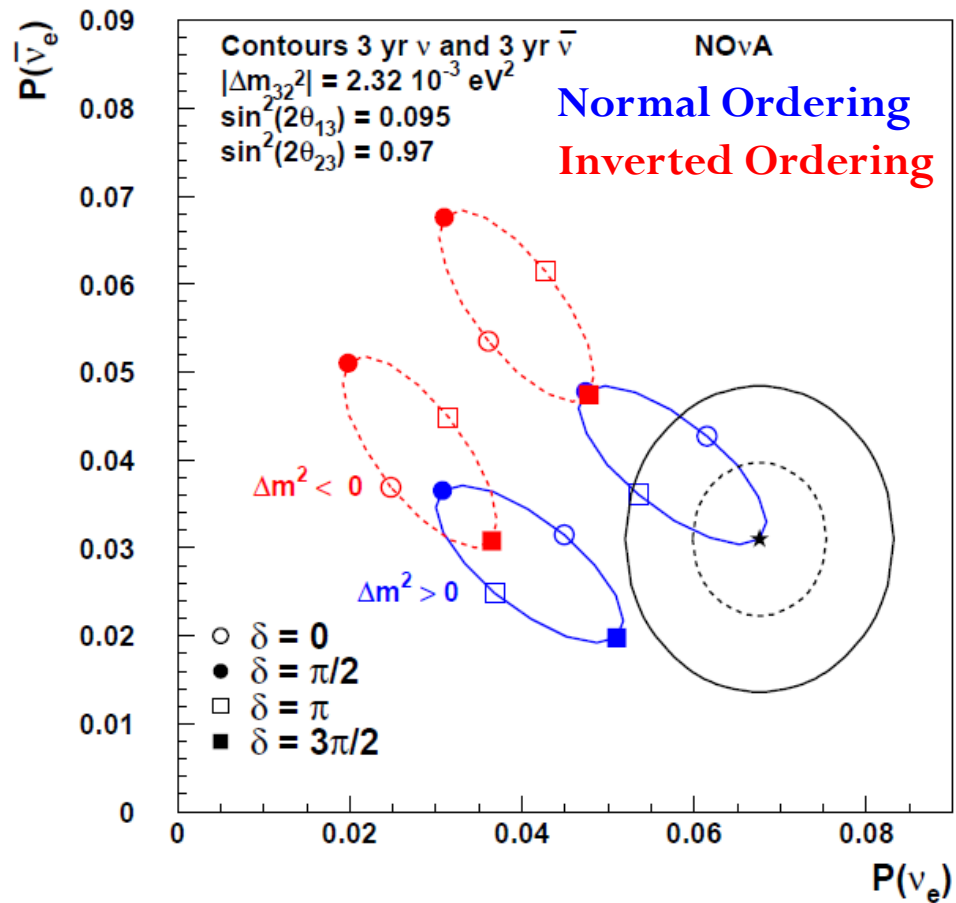
ν_e Appearance

$P(\bar{\nu}_e)$ vs. $P(\nu_e)$ for $\sin^2(2\theta_{23}) = 0.97$



ν_e Appearance

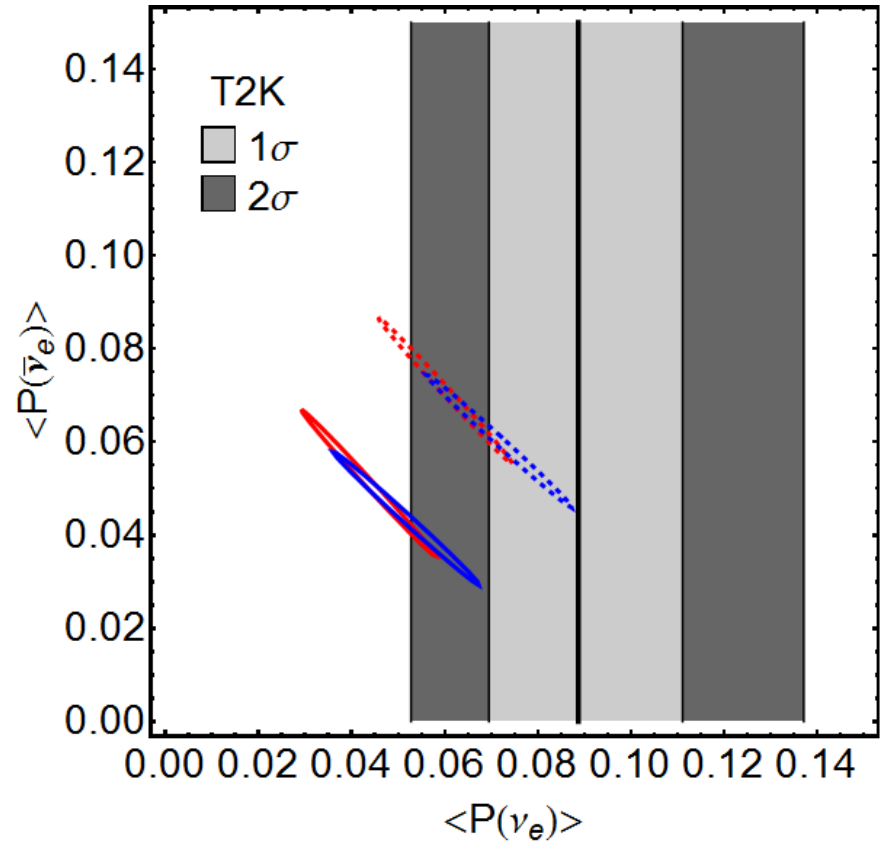
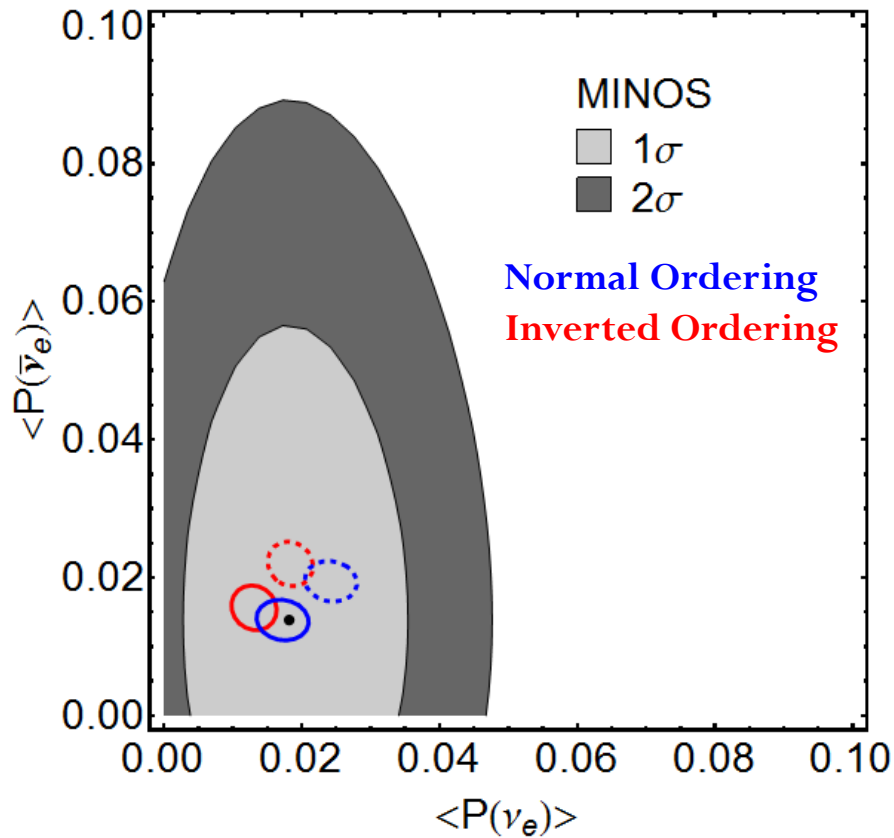
1 and 2 σ Contours for Starred Point



ν_e Appearance

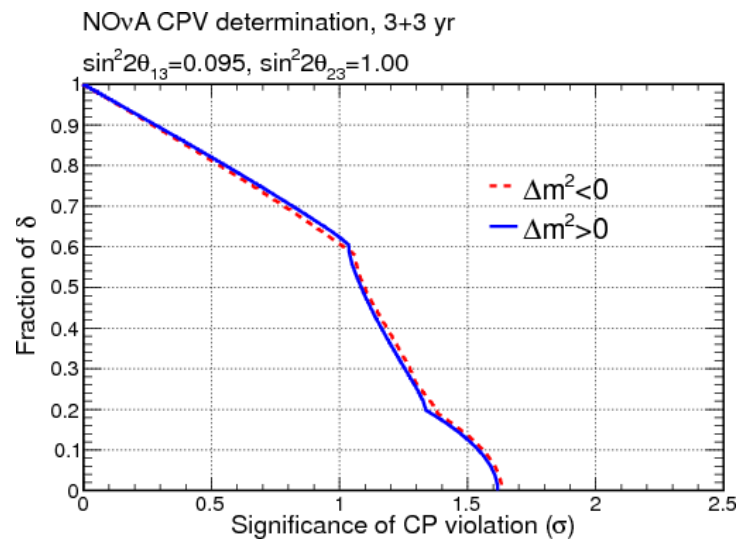
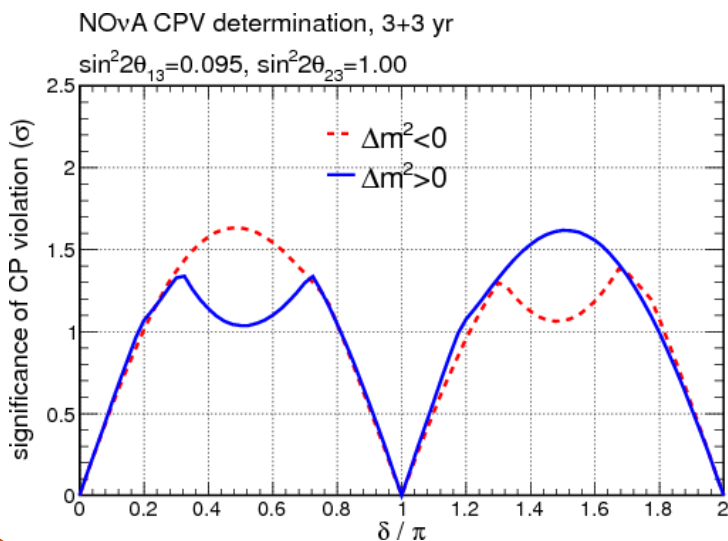
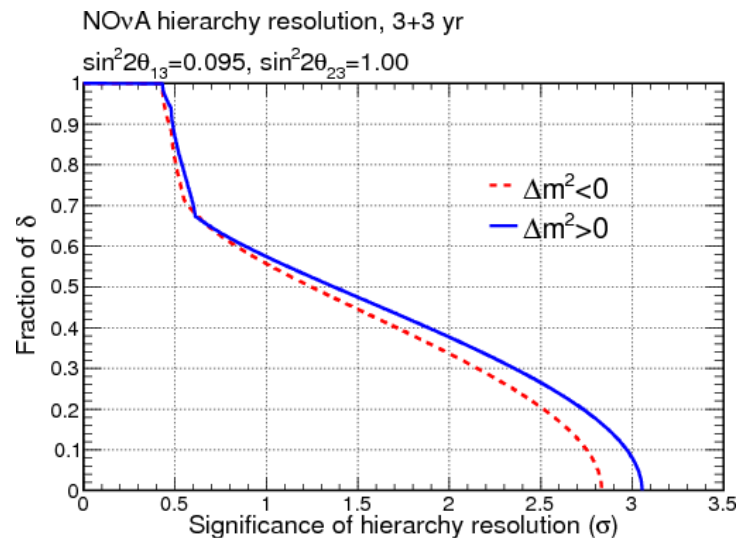
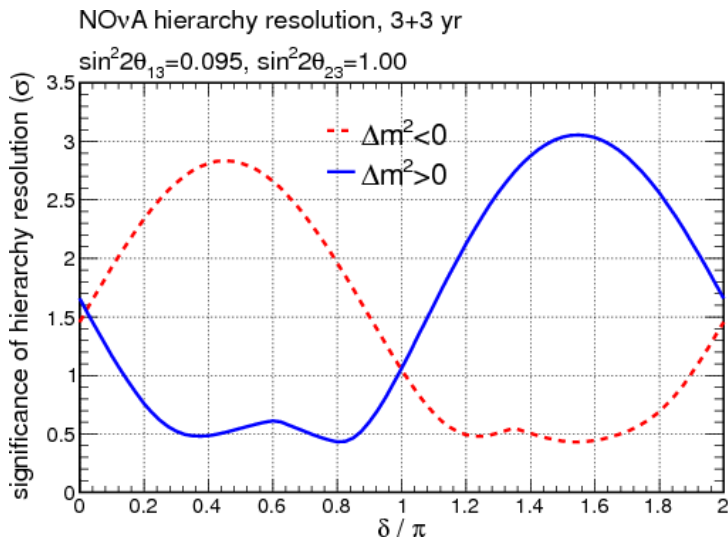
Current Knowledge

$$|\Delta m_{32}^2| = 2.32 \cdot 10^{-3} \text{ eV}^2$$
$$\sin^2(2\theta_{13}) = 0.095$$
$$\sin^2(2\theta_{23}) = 0.97$$



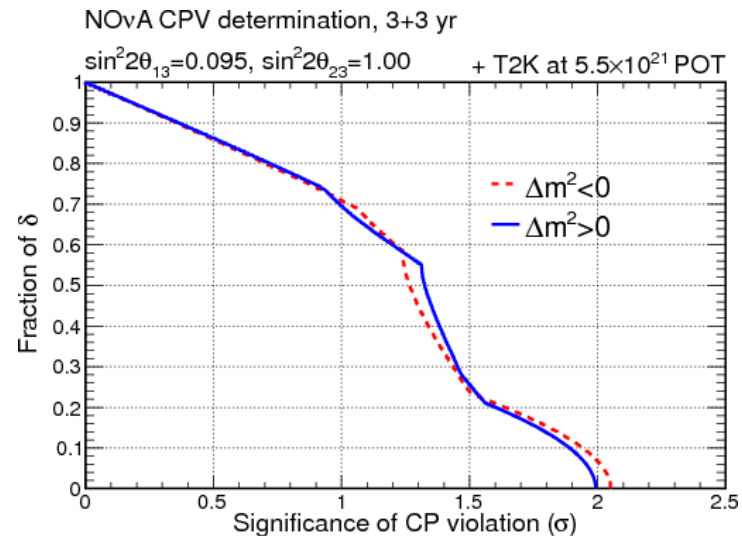
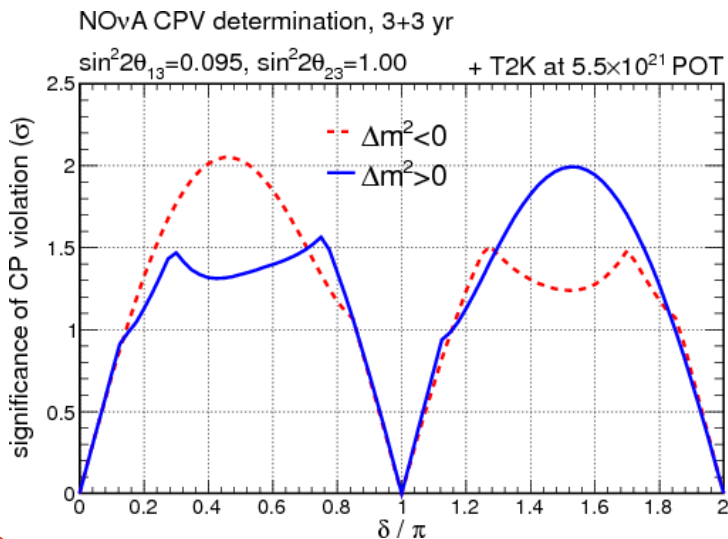
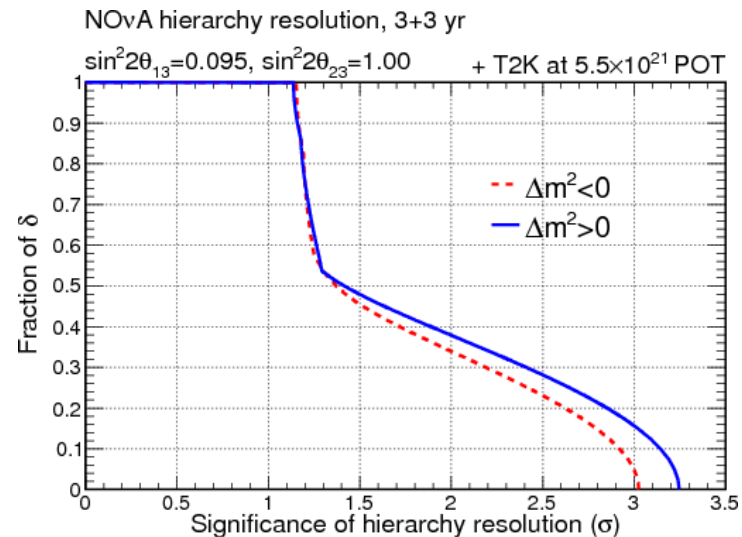
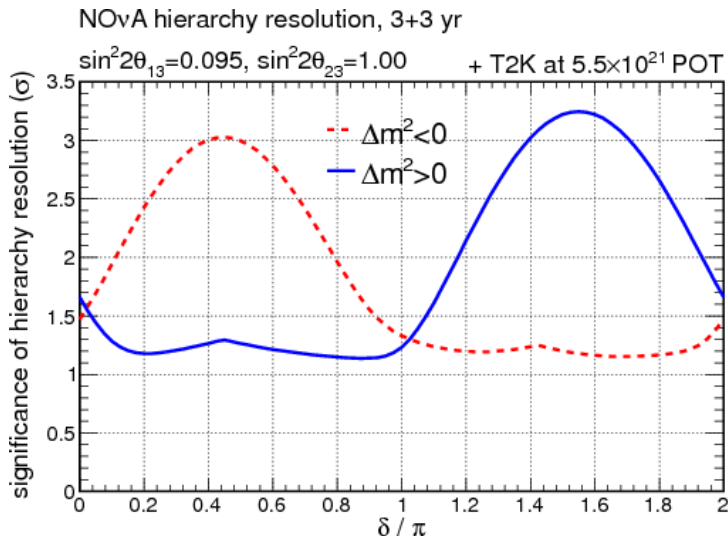
Sensitivities

Normal Ordering
Inverted Ordering



Sensitivities w/ T2K

Normal Ordering
Inverted Ordering



Summary

- MINOS has made world leading measurements of neutrino oscillations.
- MINOS+ and NOvA have just started and exciting results are coming soon.
- 3.26×10^{20} PoT already collected!
- Stay tuned.