Muon Neutrino Physics with NOvA

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Driven to Discover℠

Goals for the ν_μ Disappearance Analysis

- Precision measurement of $\sin^2(2\theta_{23})$
- Precision measurement of $|\Delta m^2_{32}|$
- Is $P(\nu_\mu \to \nu_\mu) = P(\bar{\nu}_\mu \to \bar{\nu}_\mu)$?

Oscillation Physics

- Measuring the energy spectrum of surviving muon-(anti)neutrinos yields precision measurements of $\sin^2(2\theta_{23})$ and $|\Delta m^2_{32}|$
  - If this analysis finds $\theta_{23} \neq \pi/4$, need another channel to determine whether $\theta_{23} > \pi/4$ or $\theta_{23} < \pi/4$

$$P\left(\overset{(-)}{\nu}_\mu \to \overset{(-)}{\nu}_\mu\right) \approx 1 - \sin^2(2\theta_{23})\sin^2(\Delta m^2_{32}\frac{L}{4E})$$

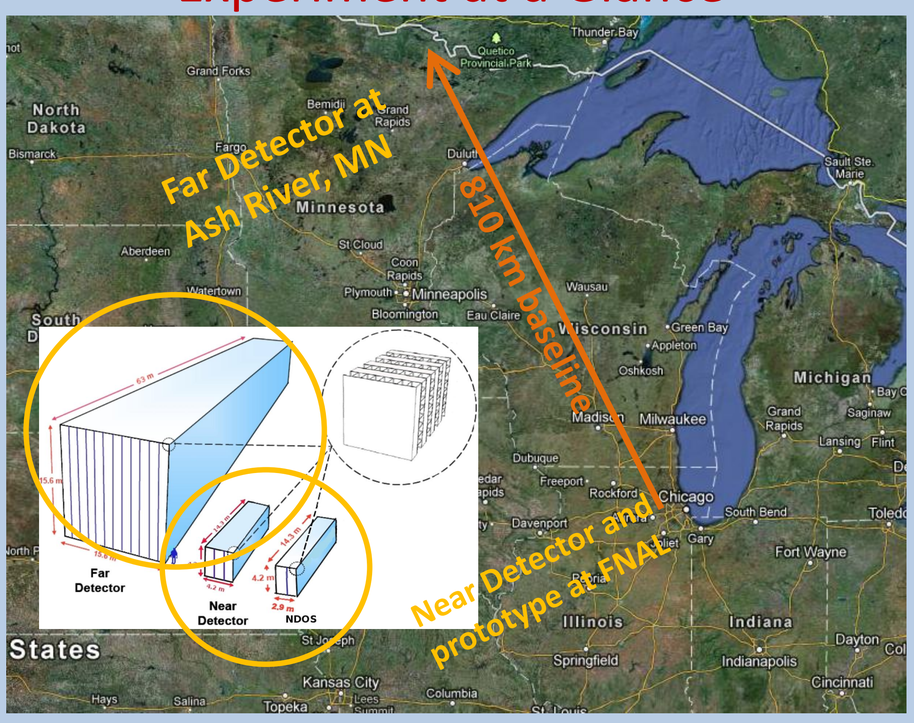
- Aid in the electron neutrino appearance analysis
  - Determine mass hierarchy and δ_{CP}

$$P\left(\overset{(-)}{\nu}_\mu \to \overset{(-)}{\nu}_e\right) \approx \sin^2 2\theta_{13}\sin^2\theta_{23}\frac{\sin^2(A-1)\Delta}{(A-1)^2}$$
$$\overset{(+)}{-}\ 2\alpha \sin\theta_{13}\sin\delta_{CP}\sin 2\theta_{12}\sin 2\theta_{23}\frac{\sin A\Delta}{A}\frac{\sin(A-1)\Delta}{A-1}\sin\Delta$$
$$+\ 2\alpha \sin\theta_{13}\cos\delta_{CP}\sin 2\theta_{12}\sin 2\theta_{23}\frac{\sin A\Delta}{A}\frac{\sin(A-1)\Delta}{A-1}\cos\Delta$$

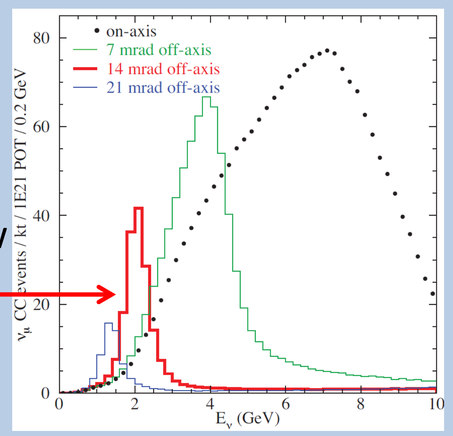
Where: $\alpha = \frac{\Delta m^2_{21}}{\Delta m^2_{31}}$ $\Delta = \Delta m^2_{31}\frac{L}{4E}$ $A = \overset{(-)}{+} G_f N_e \frac{L}{\sqrt{2}\Delta}$

- For more details on the electron neutrino appearance analysis, see E. Niner's poster

The NuMI Off-axis ν_e Appearance Experiment at a Glance



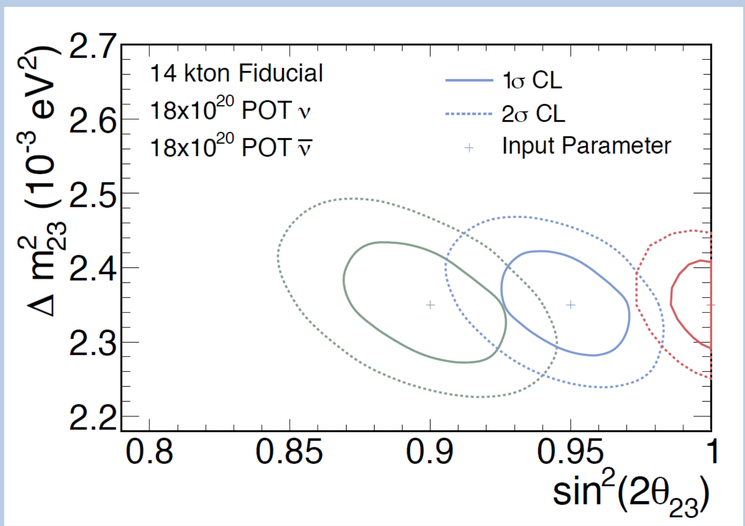
- Long-baseline ν oscillation experiment
- Near Detector and Far Detector
- 14 mrad off-axis location for narrow energy spectrum of neutrinos



- Study $\nu_\mu \to \nu_e$ and $\bar{\nu}_\mu \to \bar{\nu}_e$
- For a comprehensive overview of NOvA, see J. Liu's poster

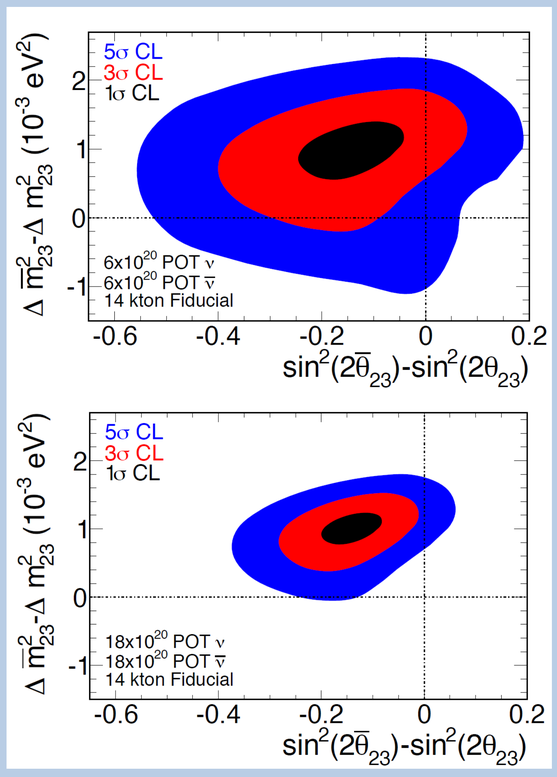
NOvA's Sensitivities Related to ν_μ Disappearance Measurement

Precision measurement θ_{23} and $|\Delta m^2_{32}|$



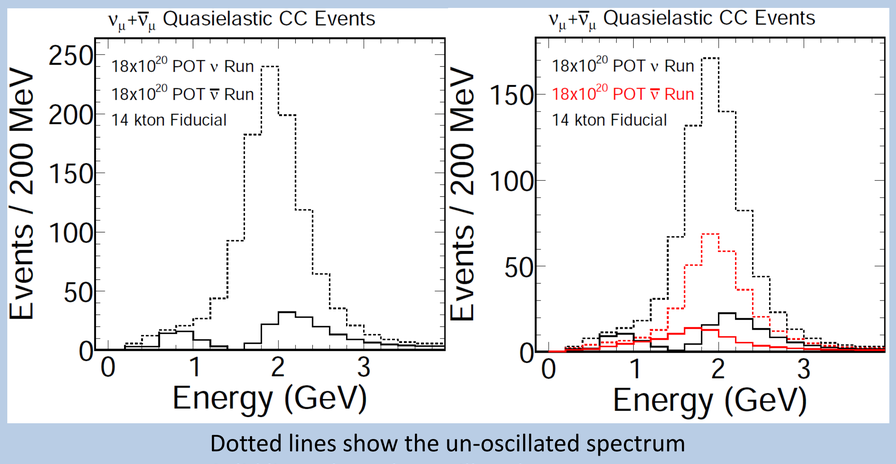
- These sensitivities correspond to:
  - Three different possible values of $\sin^2(2\theta_{23})$
  - A 14 kT Far Detector
  - Three years of running in neutrino mode
  - Three years of running in anti-neutrino mode

If $P(\nu_\mu \to \nu_\mu) \neq P(\bar{\nu}_\mu \to \bar{\nu}_\mu)$



- One year of data in each mode for the top plot
- Three years of data in each mode for the bottom plot
- Central value based on MINOS [PRL107,021801]

Expected QECC Spectra for Two Scenarios



Dotted lines show the un-oscillated spectrum
Solid lines show the oscillated spectrum

- Both plots show the Quasi-Elastic Charged Current (QECC) events' energy spectra for three years of data in each mode
- On the left, the survival probability is the same for muon neutrinos and muon antineutrinos and their spectra are summed
- On the right, the survival probability is different for muon neutrinos than for muon antineutrinos and their spectra are separated
- If survival probability is different
  - Is CPT violated?
  - Is there an exotic matter effect?