

NOvA Three Flavour Neutrino Oscillation results



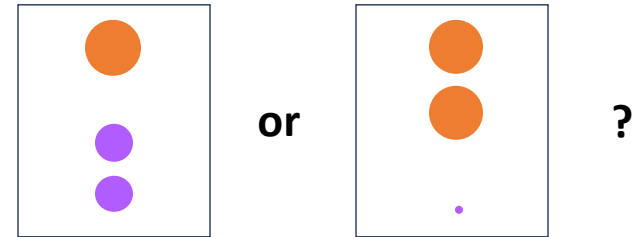
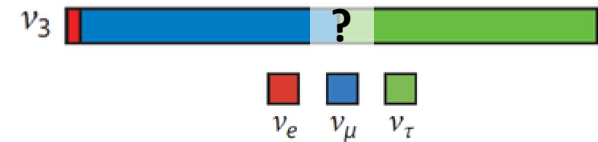
Thiago Bezerra, on behalf of the NOvA Collaboration
University of Sussex

10th June 2025

Neutrino oscillations in a nutshell



- ν flavour/interaction states (ν_e, ν_μ, ν_τ) as a mixing of mass/propagation states (ν_1, ν_2, ν_3)
 - Consequence is ν oscillations: $P(\nu_\mu \rightarrow \nu_e) \geq 0$
 - It's described by six independent parameters: $\theta_{12}, \theta_{13}, \theta_{23}, \Delta m^2_{21}, \Delta m^2_{32}, \delta_{CP}$
- Few open questions:
 - Octant: Is θ_{23} larger or lower than 45° ?
 - i.e.: does ν_3 mixing contain more ν_τ or ν_μ ?
 - Mass ordering: Is Δm^2_{32} positive or negative?
 - i.e.: do we have 2 light and 1 heavy neutrinos or the other way around?
 - CPV: is δ_{CP} different than 0 or π ?
 - i.e.: do neutrinos and antineutrinos behave in a different way?

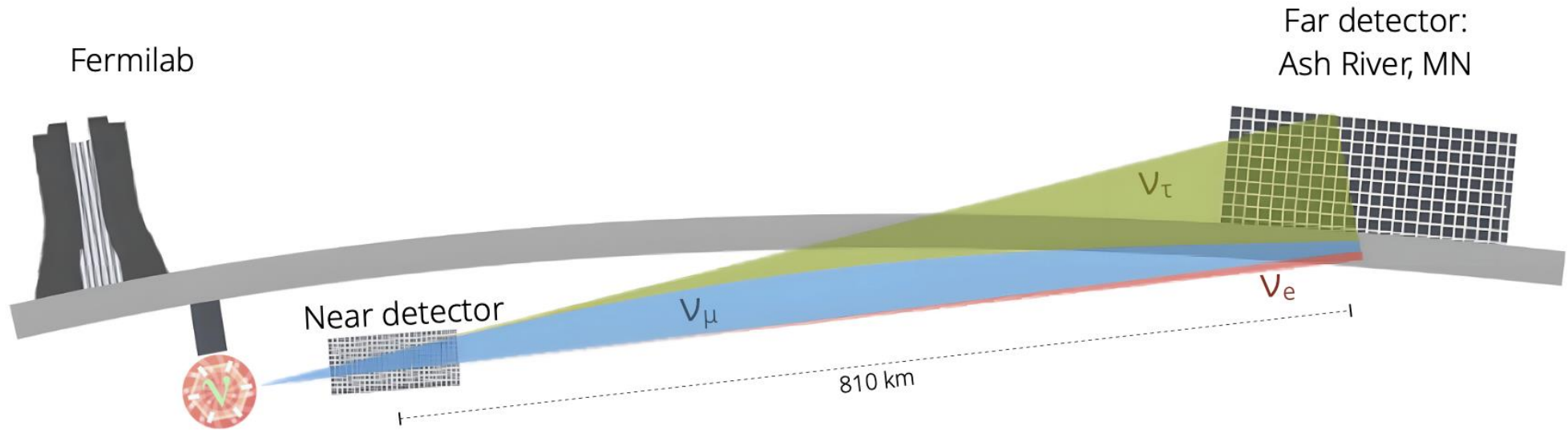


$$P(\nu_\mu \rightarrow \nu_e) = P(\bar{\nu}_\mu \rightarrow \bar{\nu}_e) \quad ?$$

The way we try to answer these questions



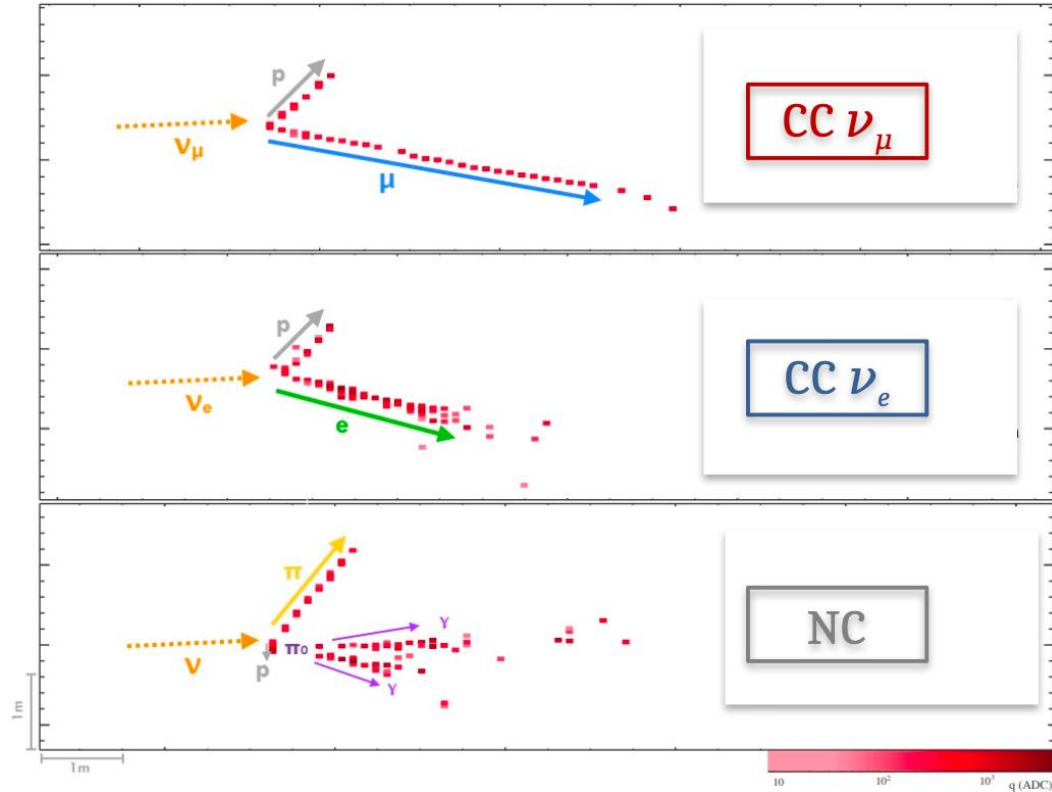
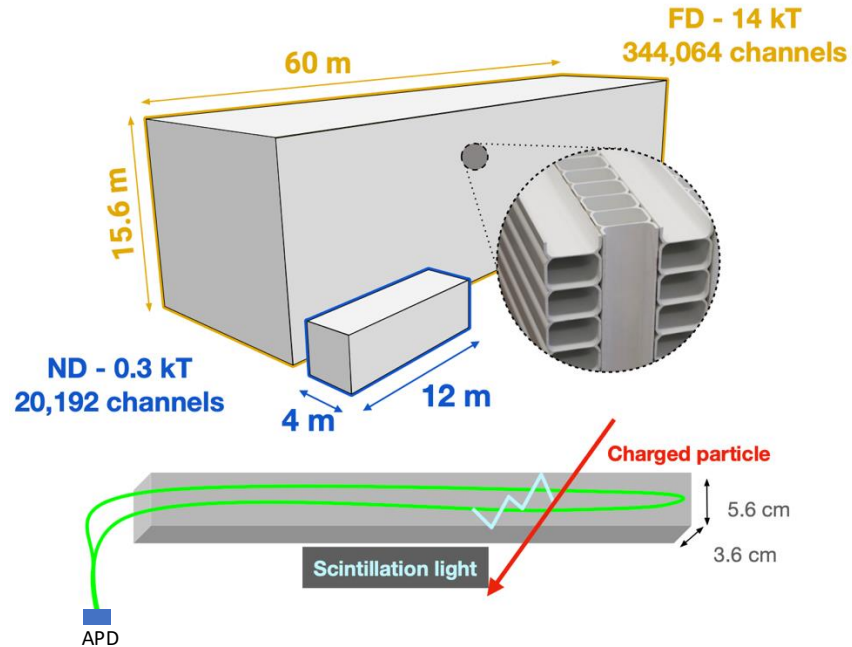
NuMI Off-Axis ν_e Appearance



The NOvA detectors



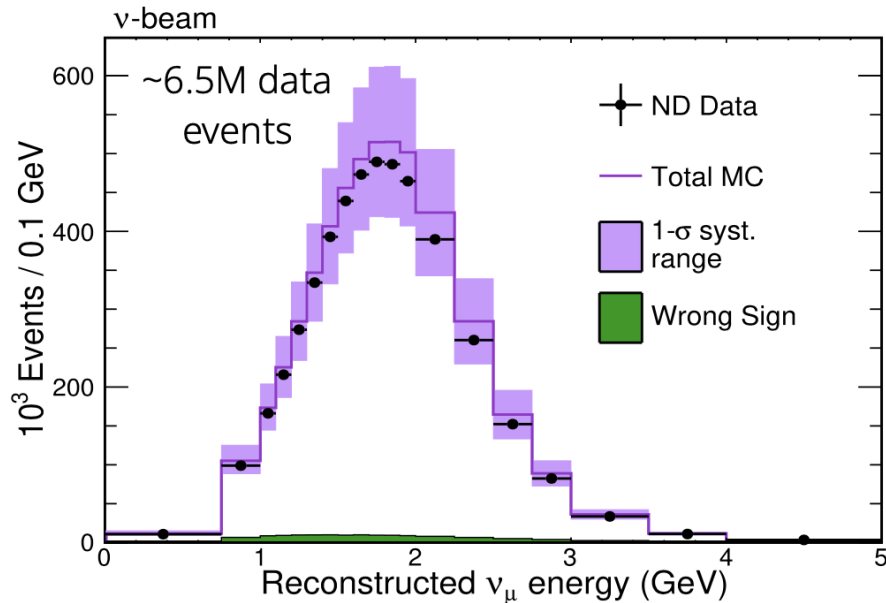
- Functionally identical Near and Far detectors
 - Extruded PVC cells filled with scintillator



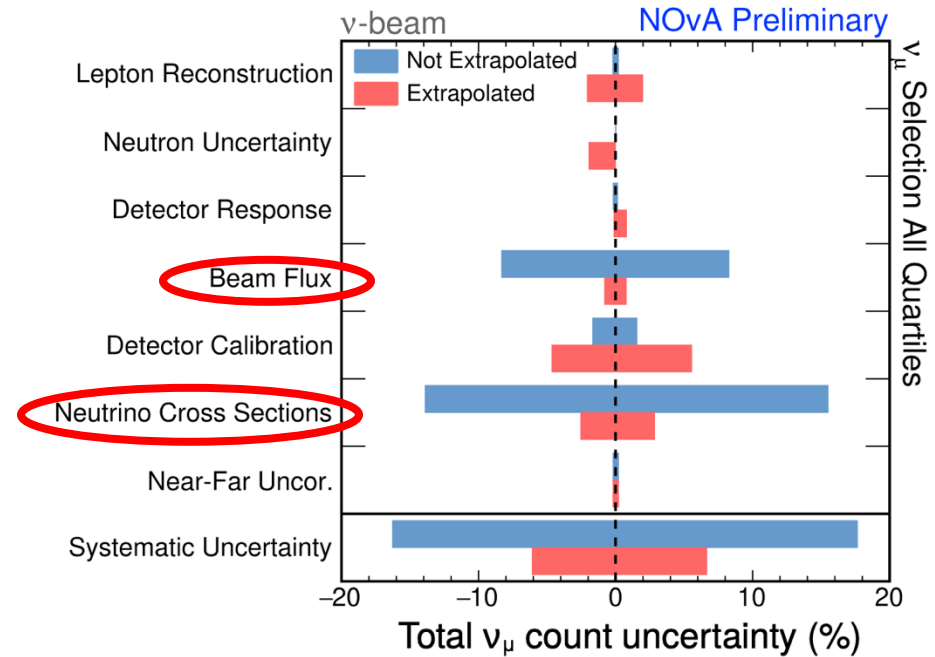
Near detector observations and systematic reduction

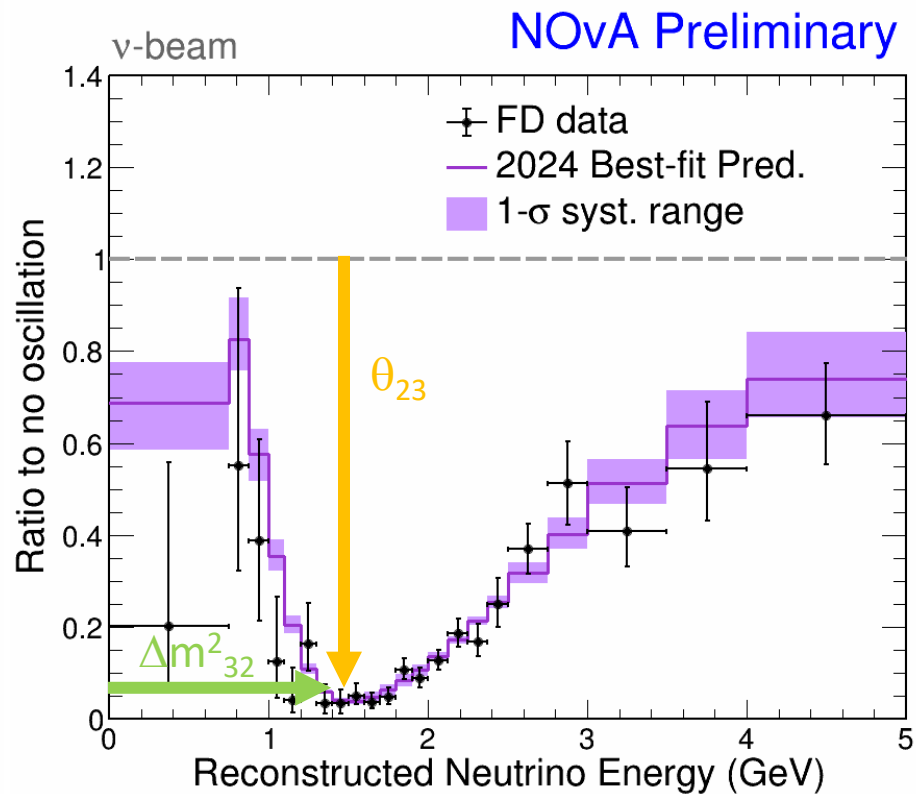
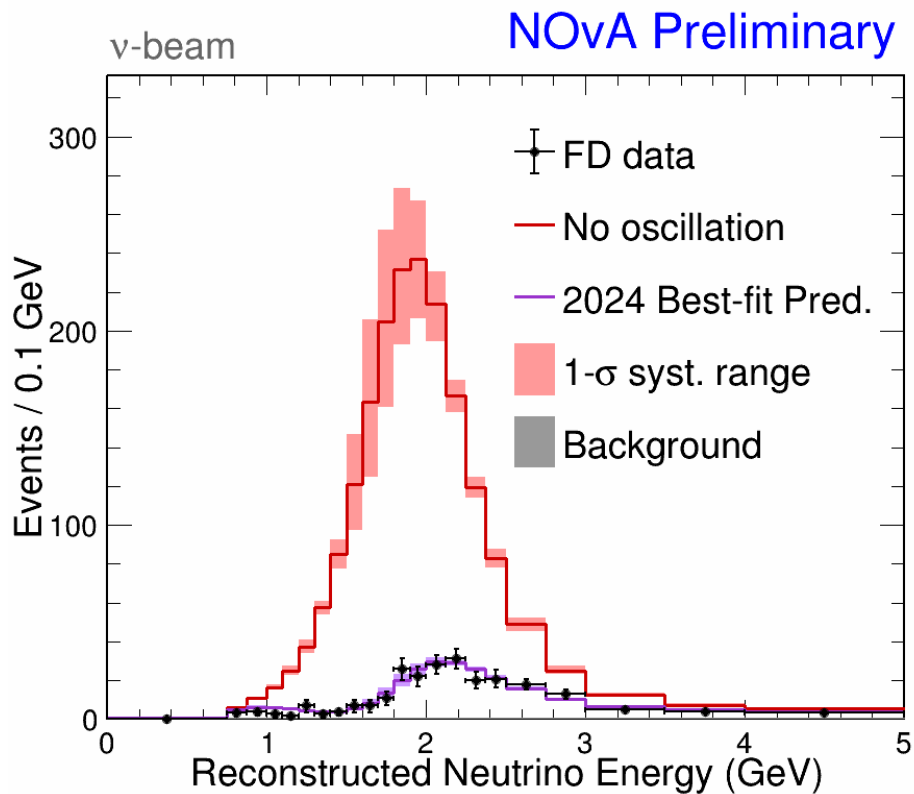


- 10 years (20014 – 2023) of NOvA beam!
 - neutrino: 26.61×10^{20} POT
 - antineutrino: 12.50×10^{20} POT



- Near detector reduces prediction uncertainty on the far detector



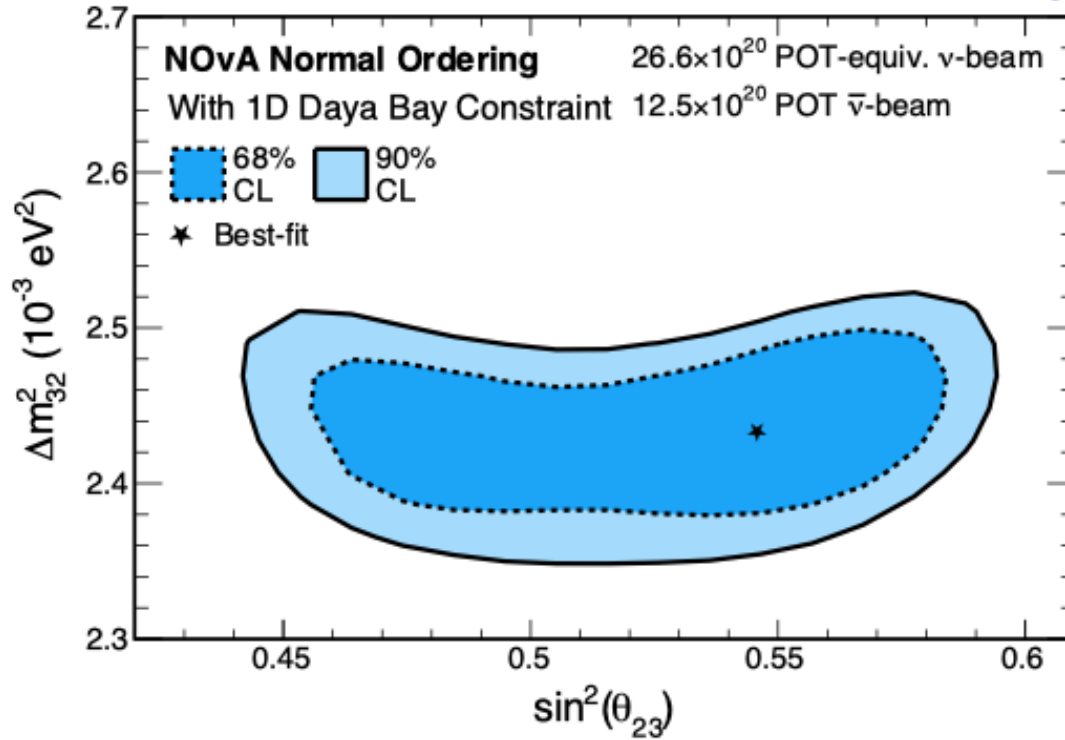


Latest NOvA measurements on oscillation parameters



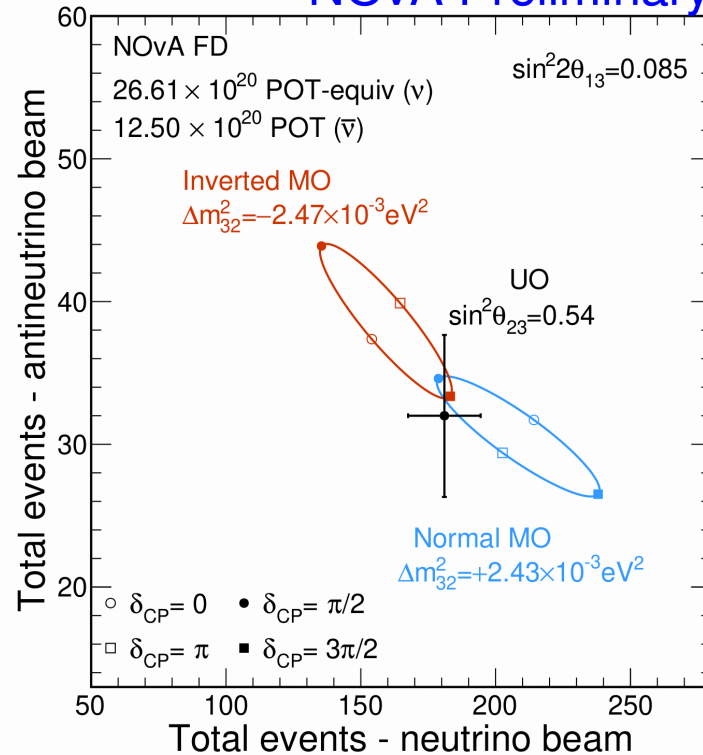
NOvA Preliminary

– Δm_{32}^2 and θ_{23}



	Best-fit
$\sin^2(\theta_{23})$	$0.546^{+0.032}_{-0.075}$
Δm_{32}^2 (10 ⁻³ eV ²)	$2.433^{+0.035}_{-0.036}$

NOvA Preliminary



Data favours region where matter & CP violation effects oppose on another

Future $\bar{\nu}$ data will be critical for disentangling.

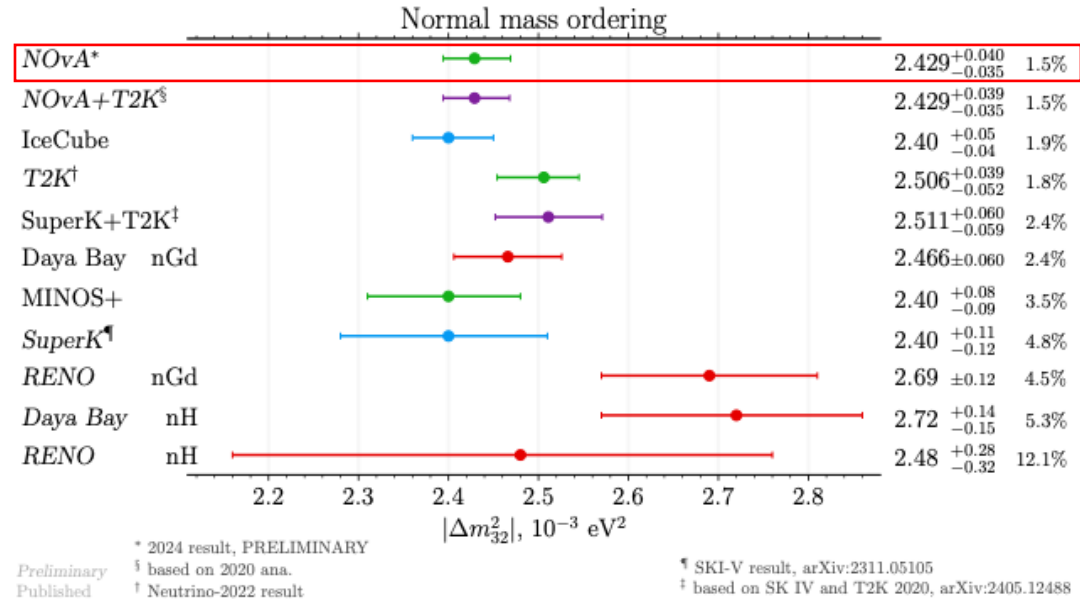
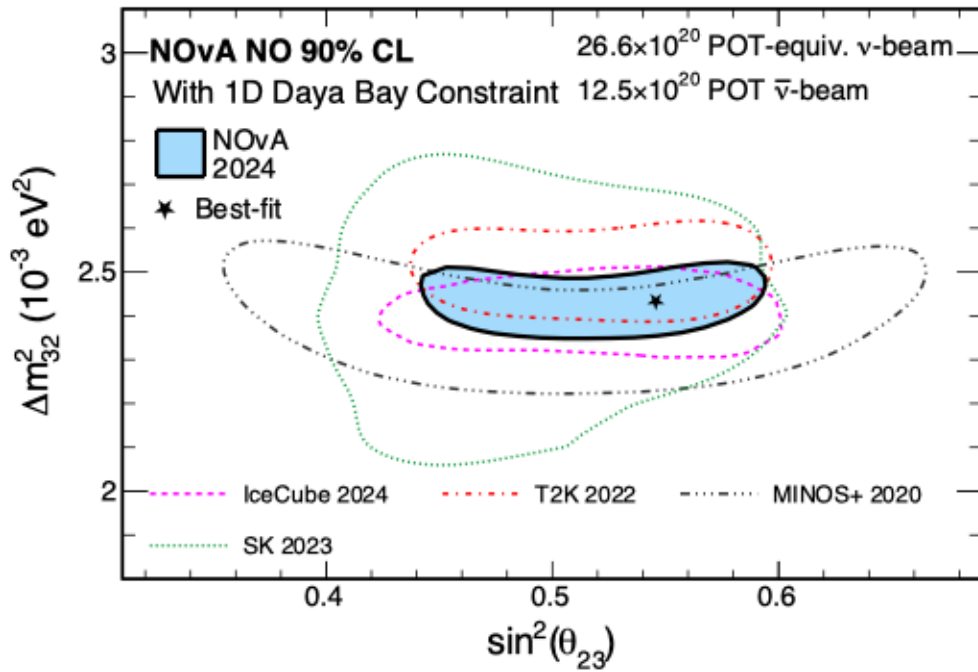
NOvA in perspective



Best Δm^2_{32} to date



NOvA Preliminary

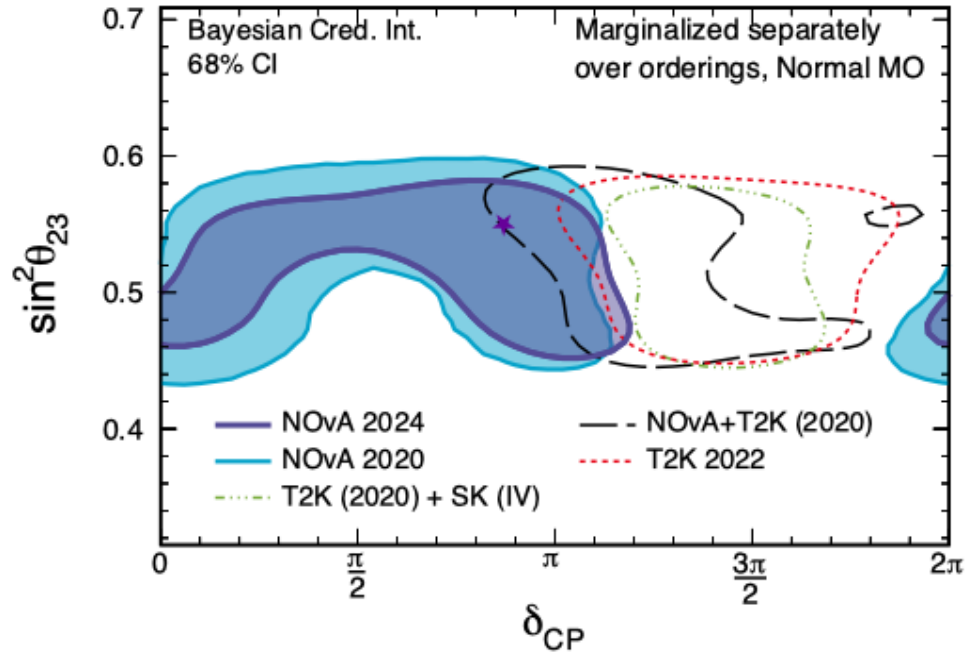


Most precise measured ν oscillation parameter!

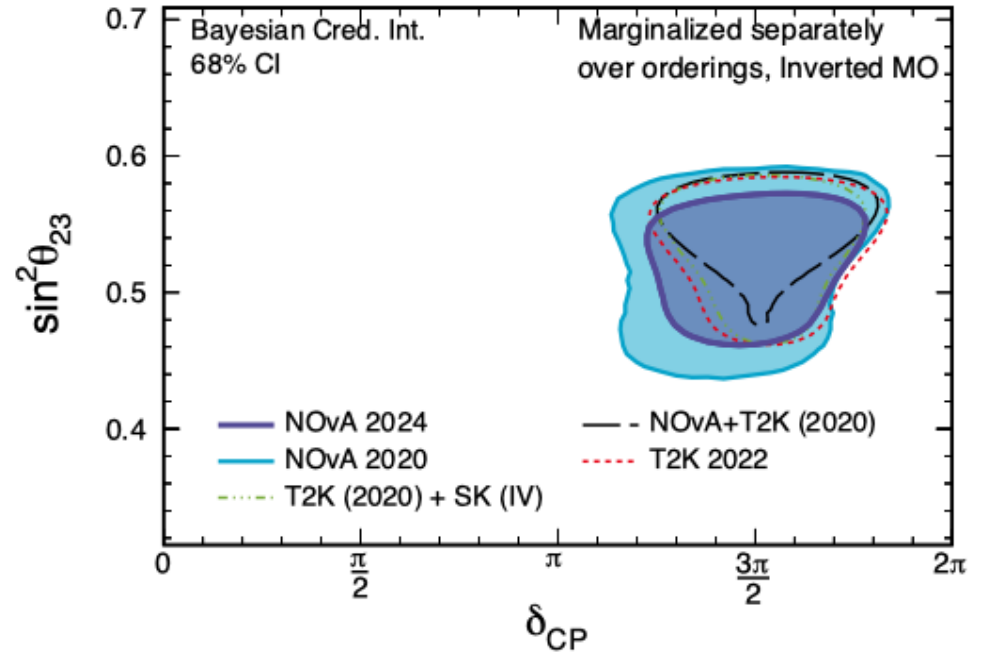
Mass ordering and CPV



NOvA Preliminary



NOvA Preliminary

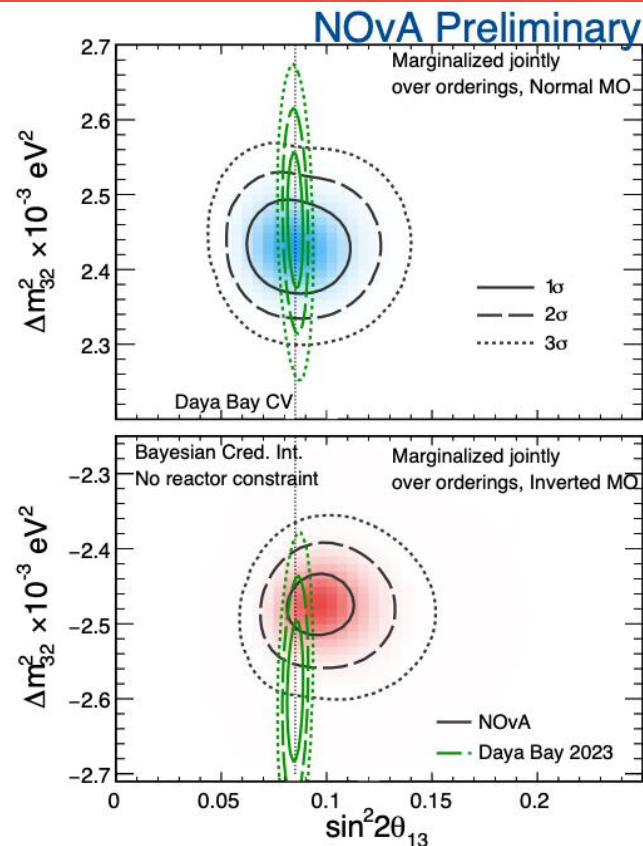
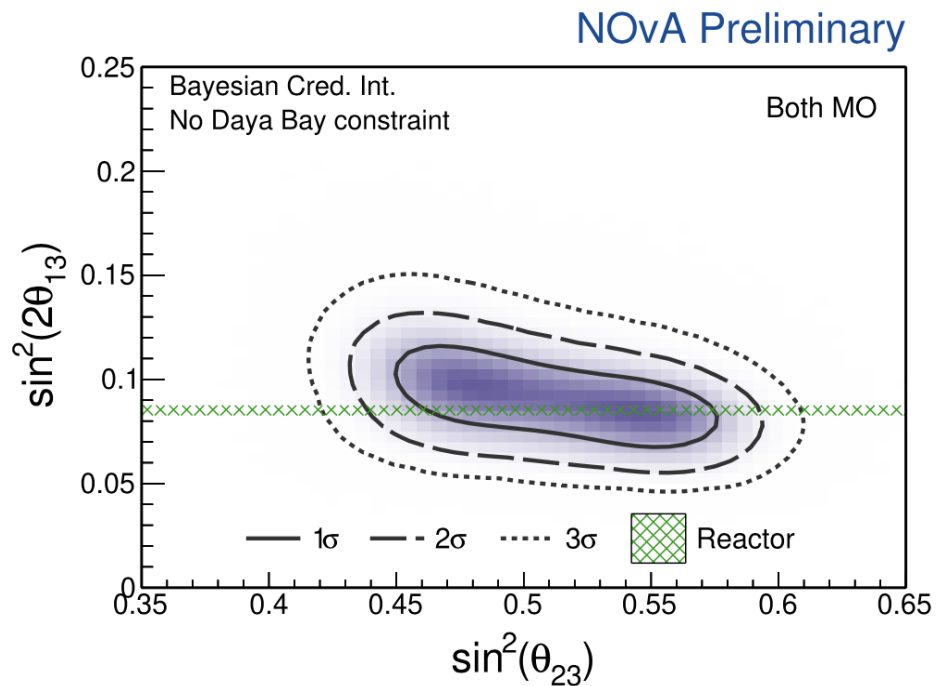


NOvA vs. other data favours different regions in NO, same region in IO

Synergy with reactor $\bar{\nu}_e$ experiments



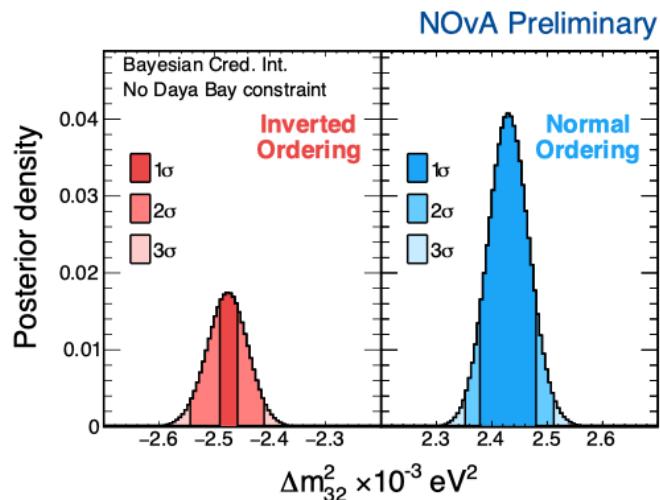
- θ_{13} measured with higher precision by reactor experiments



Synergy with reactor $\bar{\nu}_e$ experiments



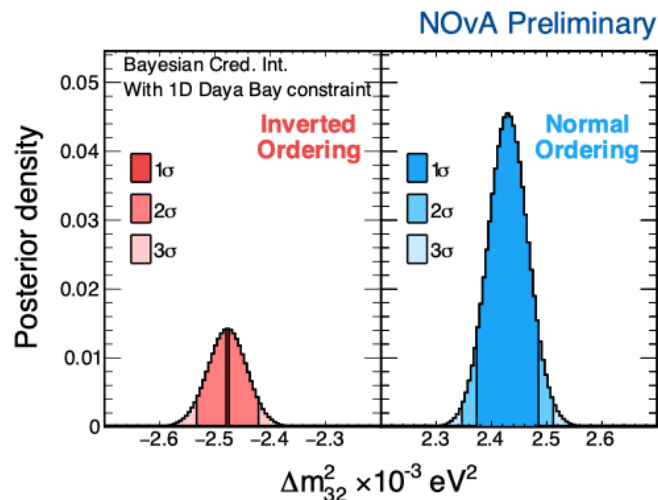
- Mass ordering (effect described first at: Phys. Rev. D 72: 013009, 2005)



No reactor constraint

N.O. preference:

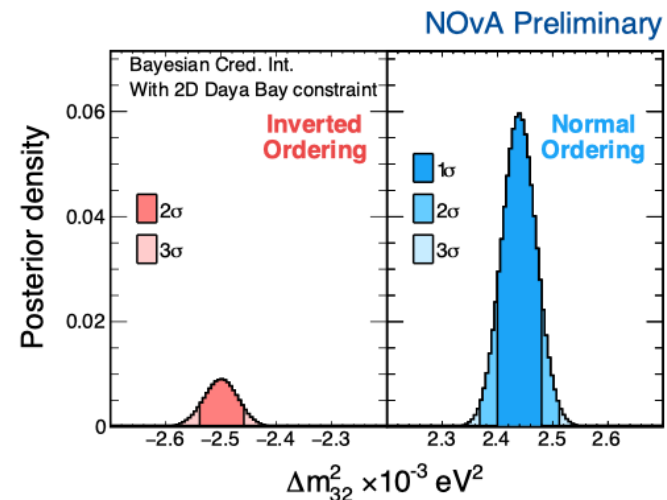
69% prob. (Bayes factor: 2.2)



Daya Bay $\sin^2 2\theta_{13}$

N.O. preference:

76% prob. (Bayes factor: 3.2)



Daya Bay $\sin^2 2\theta_{13}$ & Δm_{32}^2

N.O. preference:

87% prob. (Bayes factor: 6.8)

- Most recent of NOvA neutrino oscillation results
 - 10 years of neutrino and antineutrino data
 - Most precise single-experiment measurement of Δm^2_{32} (1.5%)
- Strong synergy with reactor experiments
 - Constraint on θ_{13} enhances upper octant preference (67% odds)
 - Constraint on Δm^2_{32} enhances Normal Ordering preference (87% odds)
- Compelling prospects from NOvA
 - Goal to doubling antineutrino data, crucial to clarify MO/CPV
 - Test beam to constraints detector systematics (see Emerson talk, [today 12:00](#))
 - Much more physics!
 - Adam on NSI and Steriles ([today 14:30](#))
 - Alex on ML and reconstruction ([today 16:00](#))
 - Tyler on BSM physics ([tomorrow 11:00](#))
 - Travis on cross-section measurements ([tomorrow 12:15](#))



<https://novaexperiment.fnal.gov>



Thank you!