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Latest Three Flavor Neutrino Oscillation Results from the NOvA Experiment

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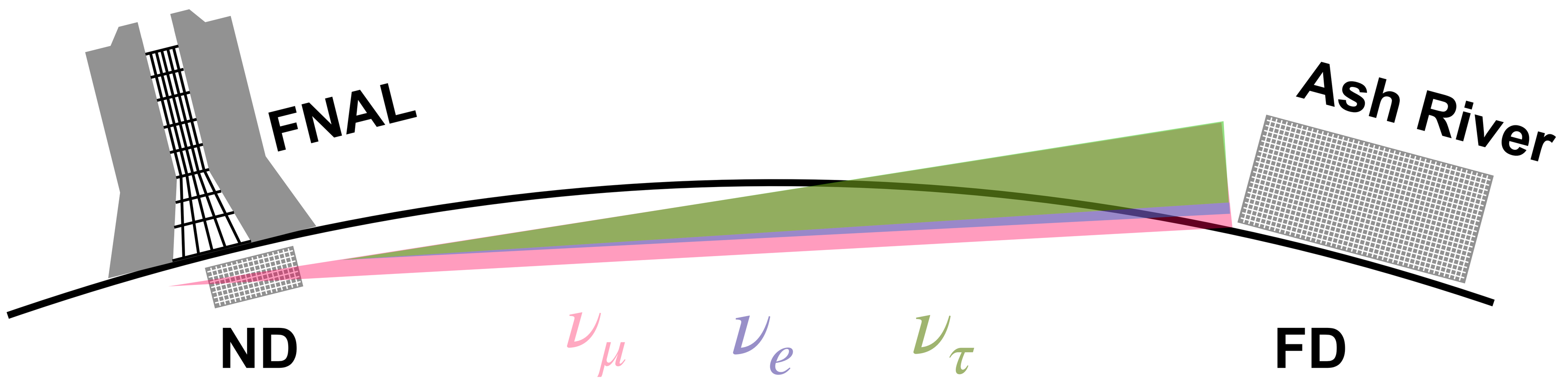
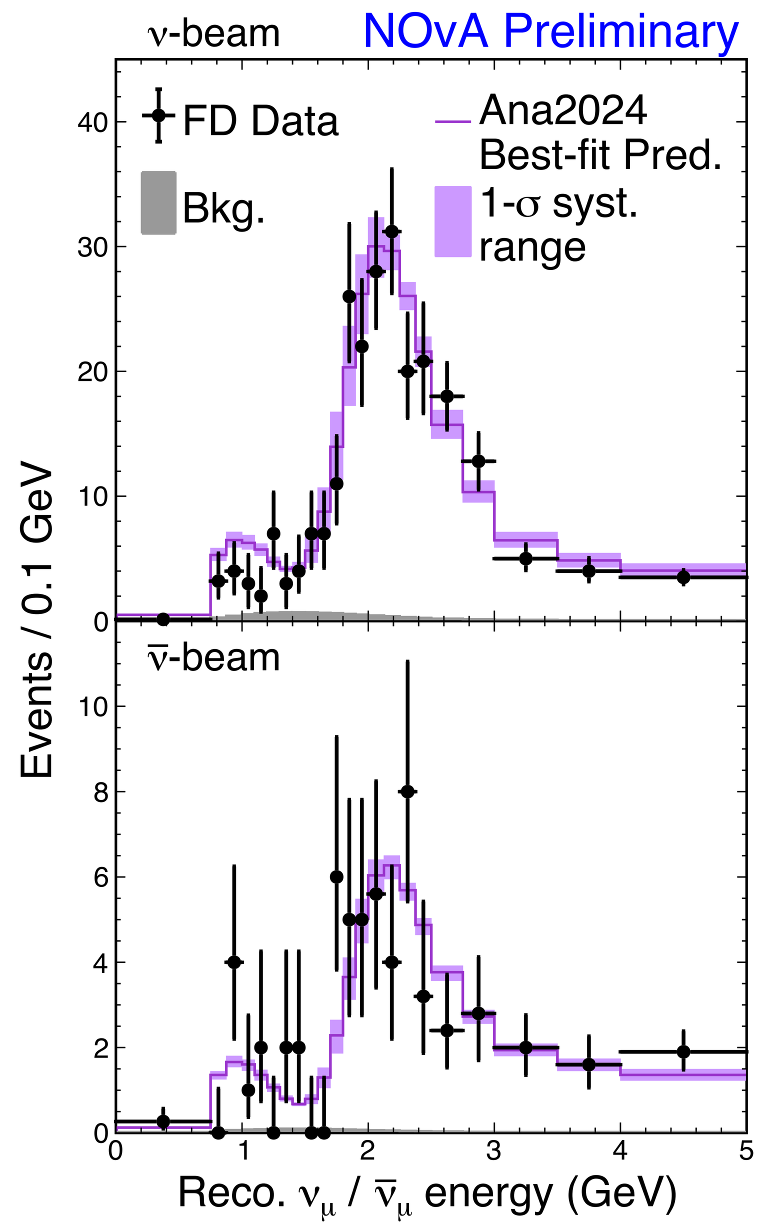
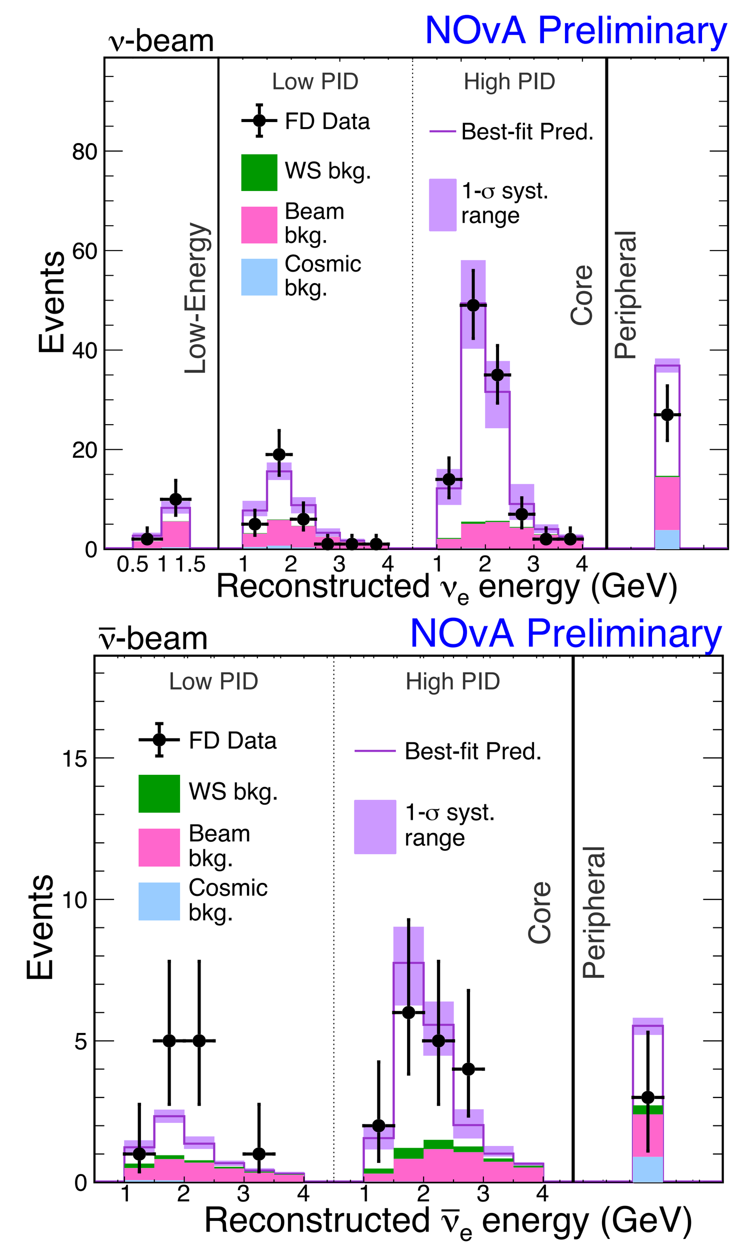
Introduction

- **N**uMI **O**ff-axis ν_e **A**ppearance Experiment (NOvA)
- A long-baseline Neutrino Oscillation Experiment
- Fermilab's NuMI beam line provides an intense ν_μ ($\bar{\nu}_\mu$) beam
- Two functionally identical liquid scintillaton detectors
  - Situated 809 km apart
  - 14.6 milli-radians Off-axis
- Primary Goal is to constraint parameters of 3-flavor neutrino oscillations
- Oscillation Channels:
  - ν_μ ($\bar{\nu}_\mu$) Disappearance
  - ν_e ($\bar{\nu}_e$) Appearance
- We present latest results of a frequentist fit to 10 years of NOvA oscillation data



Far Detector Observations

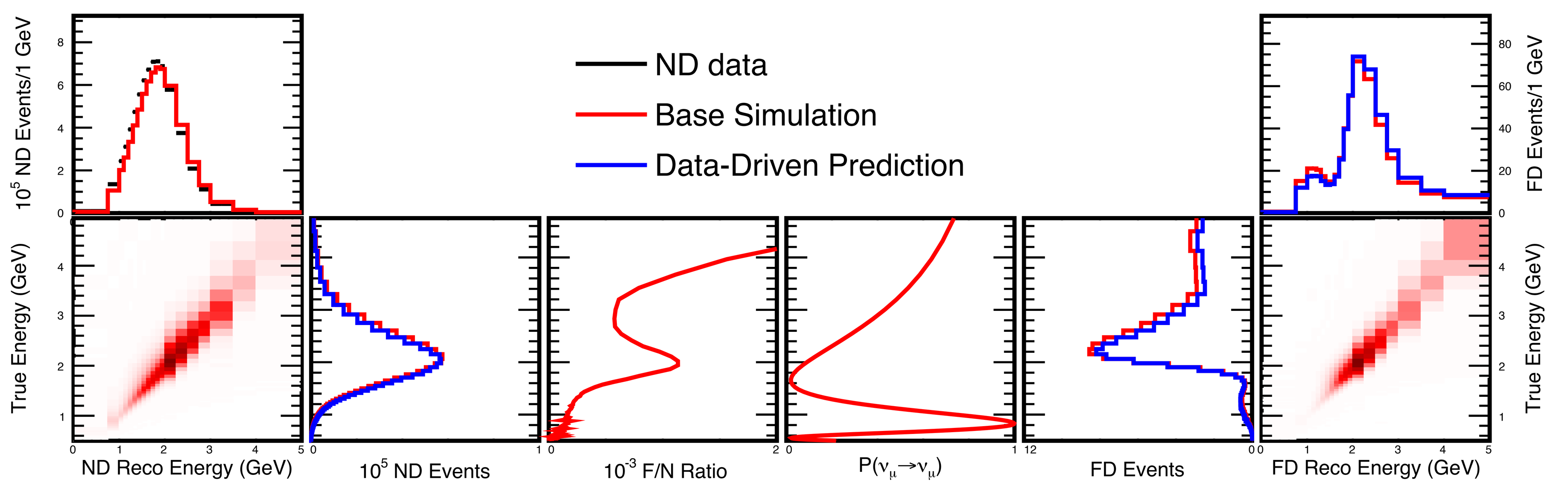




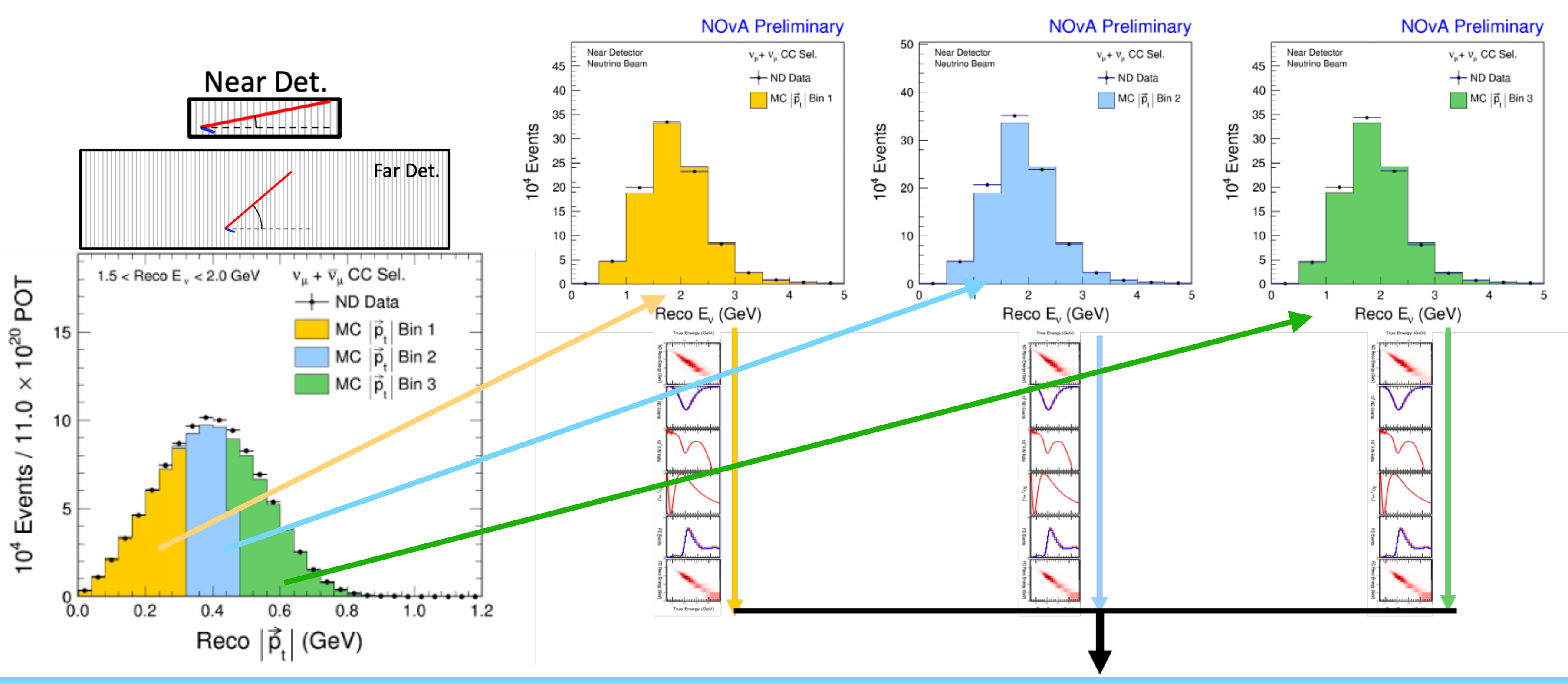
NOvA Data	ν_μ	$\bar{\nu}_\mu$	ν_e	$\bar{\nu}_e$	lowE ν_e
Observed Events	384	106	169	32	12
Background	11.3	1.7	54.9	12.2	6.8

Near-to-Far Extrapolation

- NOvA's functionally identical detectors help in reducing systematic uncertainties on the best fit neutrino oscillation parameters
- The near detector (ND) data-MC differences are extrapolated in true energy bins to provide data-driven predictions of un-oscillated ν_μ ($\bar{\nu}_\mu$) and oscillated ν_e ($\bar{\nu}_e$) events at the far detector (FD)



- The ν_μ ($\bar{\nu}_\mu$) extrapolation is divided into 4 hadronic energy fraction quartiles to improve the sensitivity of the experiment
- Extrapolation is further divided into 3 bins of final state lepton transverse momentum (p_t)



Frequentist Fit to Oscillation Data

- We perform a joint $\nu_\mu \to \nu_\mu$, $\bar{\nu}_\mu \to \bar{\nu}_\mu$, $\nu_\mu \to \nu_e$, and $\bar{\nu}_\mu \to \bar{\nu}_e$ fit to FD data to minimize the log-likelihood function
- Systematic uncertainties are incorporated as nuisance parameters

$$-2\ln\lambda(\vec{\theta}) = 2\sum_{i=1}^{\text{bins}}\left[\nu_i(\vec{\theta}) - n_i + n_i \ln\frac{n_i}{\nu_i(\vec{\theta})}\right] + \sum_i^{\text{systs}}\frac{s_i^2}{\sigma_i^2}$$

ν_i = predicted number of events

n_i = observed number of events

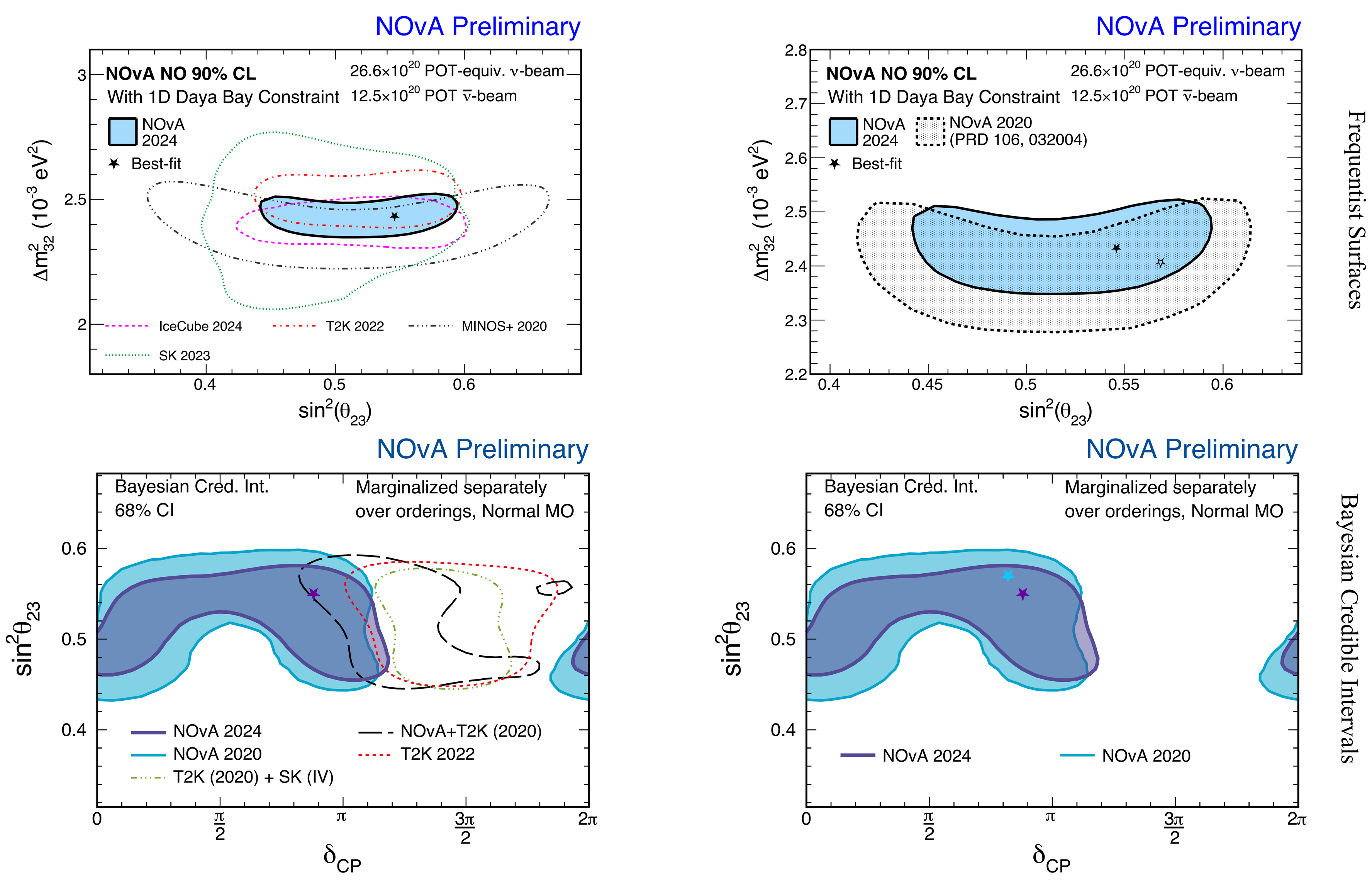
$\vec{\theta}$ = oscillation parameters

s_i = systematic shifts

σ_i = penalty term

- The profiled Feldman-Cousins method is used in calculating the confidence intervals [1]

Results



Parameters	$\sin^2(\theta_{23})$	$\Delta m^2_{32}(10^{-3}\ \text{eV}^2)$	δ_{CP} (π)
Best Fit	$0.546^{+0.032}_{-0.075}$	$2.433^{+0.035}_{-0.035}$	0.875

[1] Acero, M. A. et al. The profiled feldman-cousins technique for confidence interval construction in the presence of nuisance parameters (2022). 2207.14353.

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