Picture credit: Ximeng Wang

Latest Measurement of Muon Neutrino Disappearance with the IceCube Experiment

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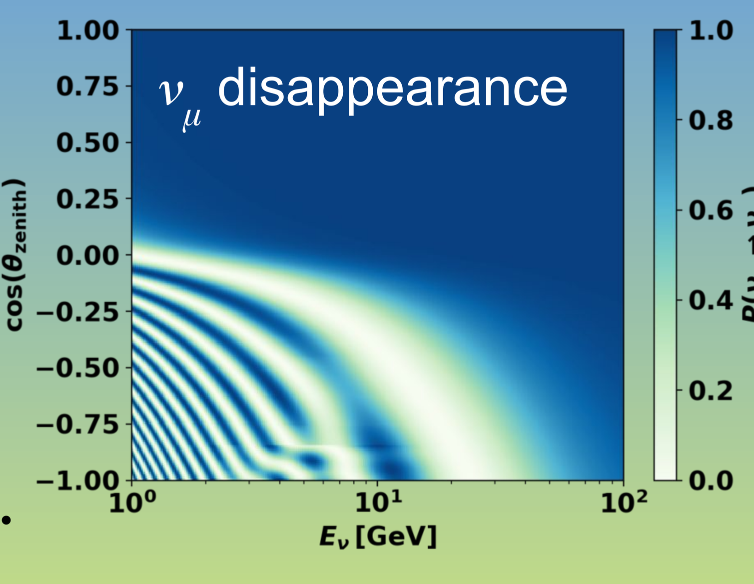
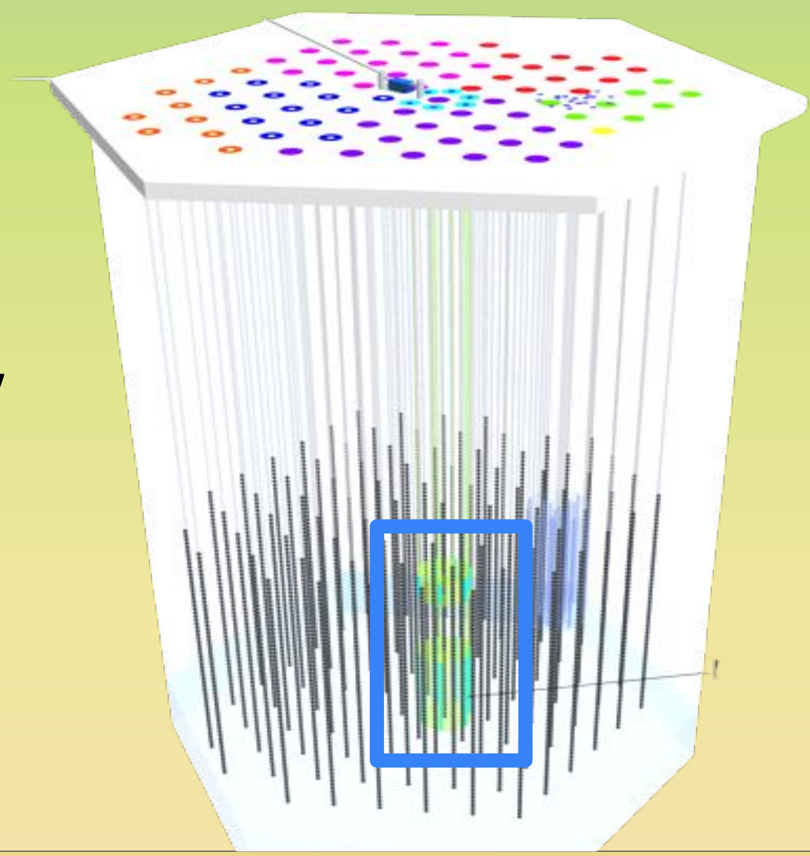
Abstract: The IceCube Neutrino Observatory is located at the geographic South Pole instrumenting a cubic kilometer of deep glacial ice with 5,160 digital optical modules on the main array to detect Cherenkov light. The DeepCore sub-detector is a denser in-fill array that gives a lower energy threshold where we can study neutrino oscillations using atmospheric neutrinos with energies of 5-100 GeV. Precisely reconstructing neutrino energy and arrival direction is critical to constraining oscillation parameters. Convolutional neural networks are employed for precise and fast event reconstructions. In this contribution, using IceCube data collected from 2012 to 2021, including latest improvements in reconstruction, selection, detector calibration, and treatment of systematic uncertainties, we present our most recent measurement of $\sin^2(\theta_{23})$ and Δm^2_{32}.

Background Introduction

Neutrinos have three flavor states. The oscillation probability depends on neutrino energy (E_ν) and travel distance ($L \propto \cos(\theta_{zenith})$).



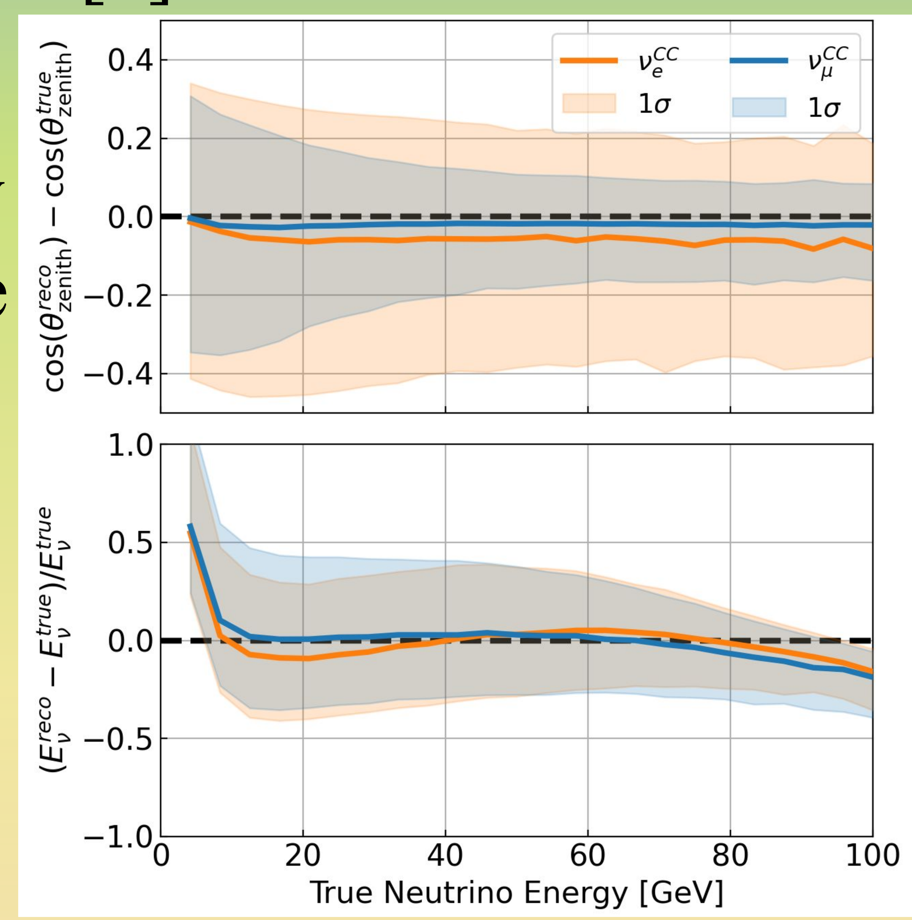
IceCube-DeepCore: ~15 MTon in bottom center, consisting of 8 denser and 7 standard strings, including 647 optical sensors with higher quantum efficiency than those on main array to enable GeV-scale neutrino detection.



Reconstruction & Selection

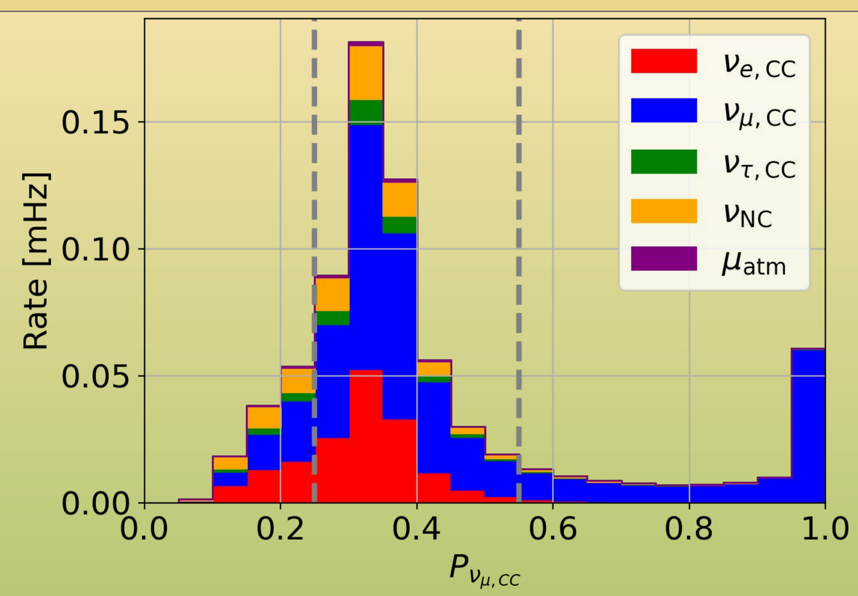
Reconstruction: Convolutional Neural Networks and boosted-decision tree are used to reconstruct neutrino energy (E), arrival direction (zenith angle, θ_{zenith}), interaction vertex, particle identification (PID), atmospheric muon classifier [1].

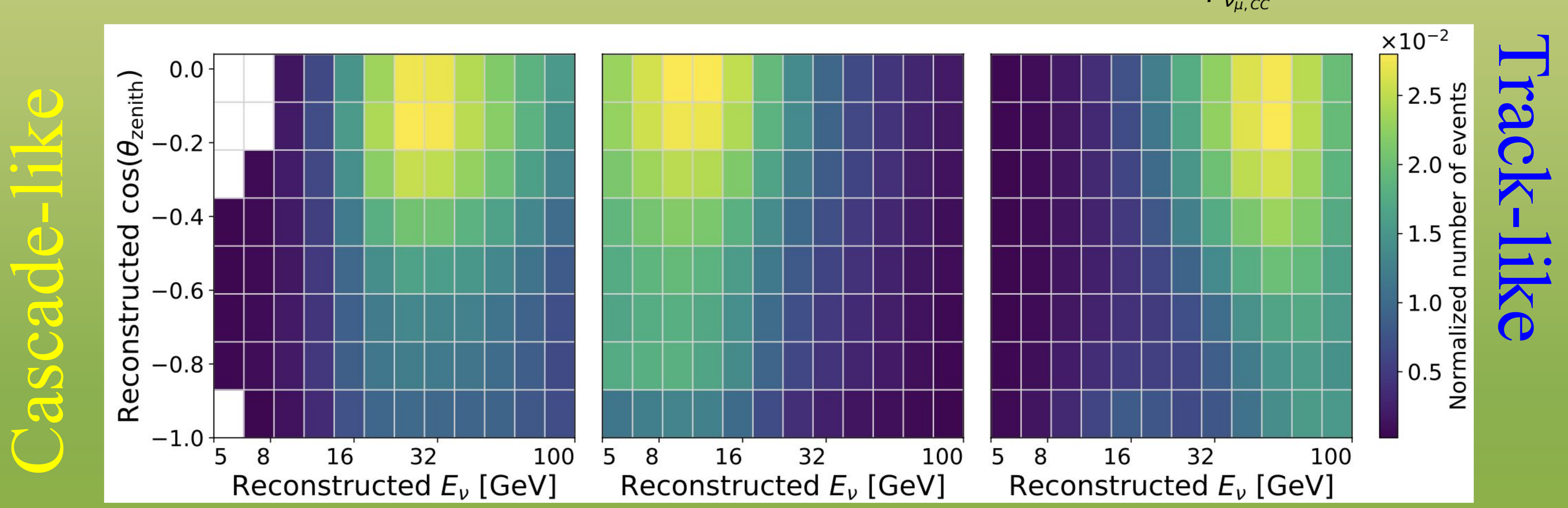
Selections: neutrino energy (5-100 GeV), arrival angle (below horizon), semi-contained (start in DeepCore), cosmic-ray muon background removal.



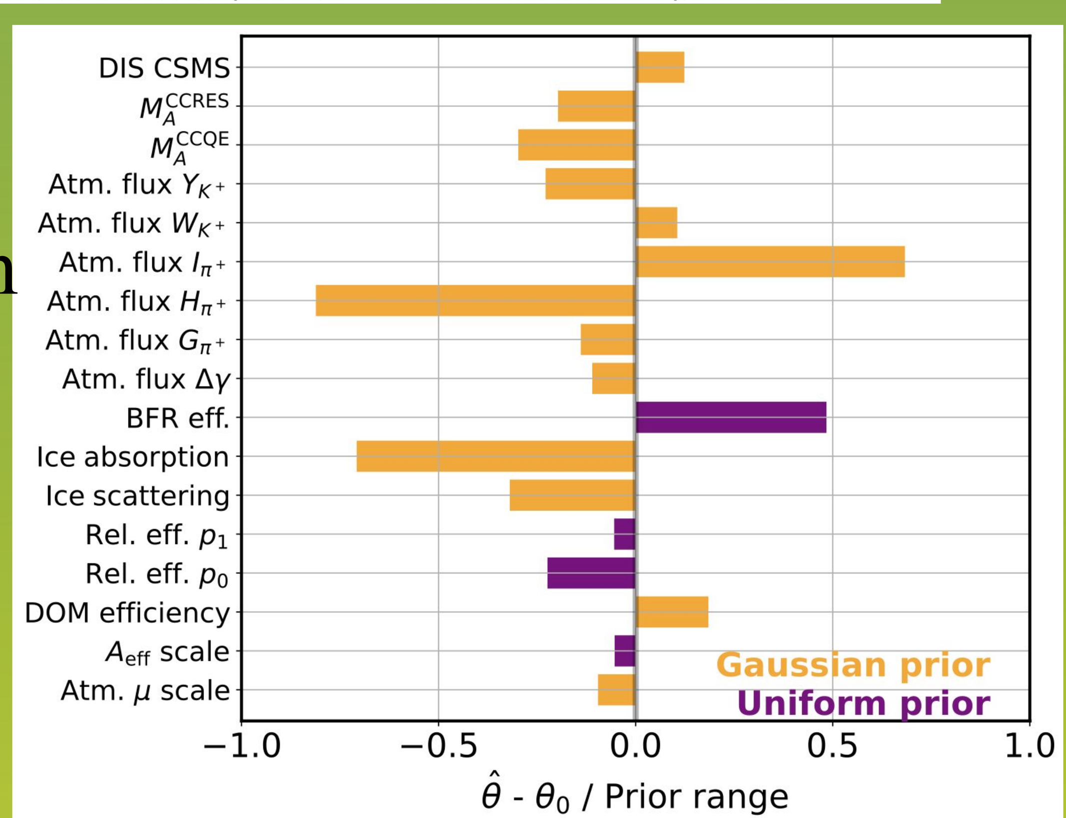
Analysis

3D Binning:
Energy: 10 log bins;
$\cos(\theta_{zenith})$: 8 linear bins;
PID: 3 bins





Systematics: Largely inherited from [2], nuisance parameters re-evaluated for this analysis.

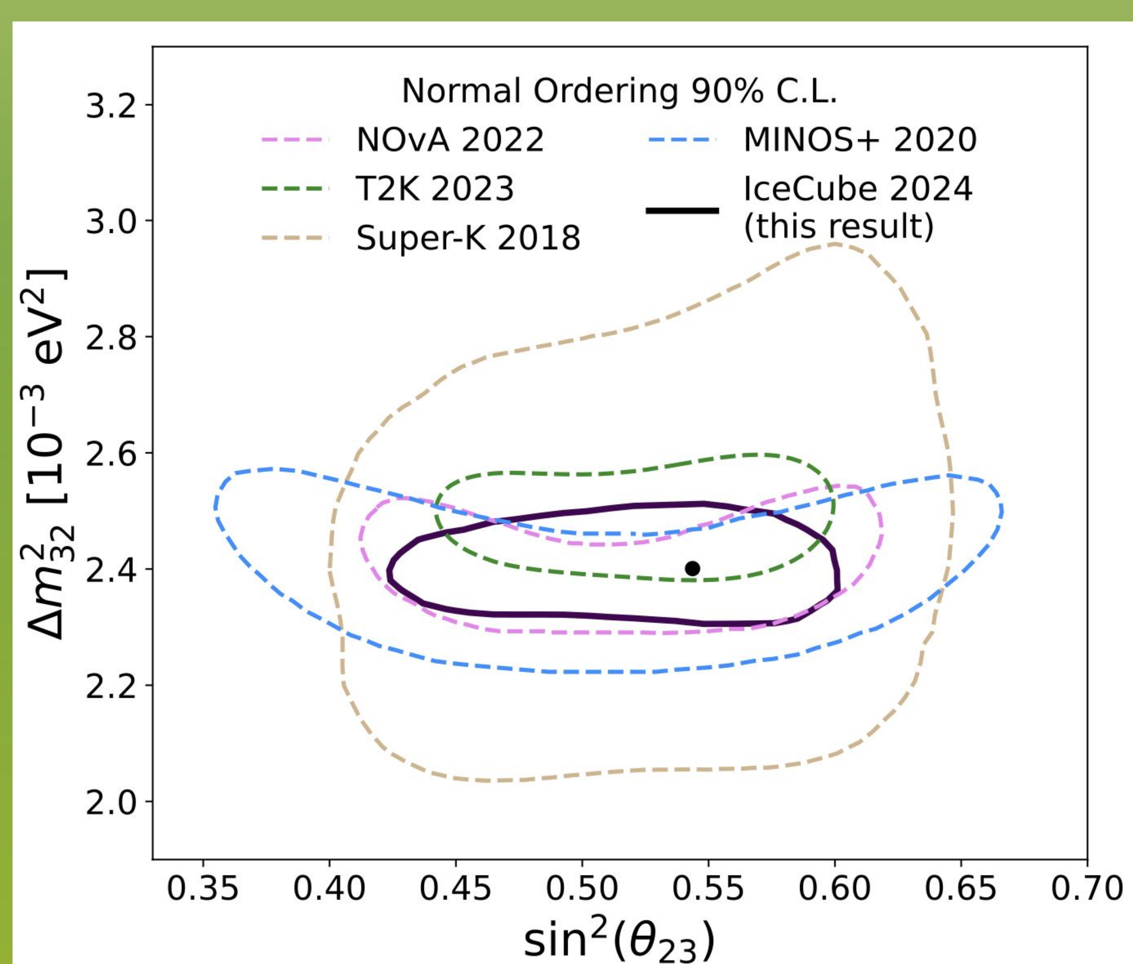


Result

Dataset: 2012-2021 (3,387 days) total of 150,257 neutrino candidates.

Highest-statistic atmospheric neutrino dataset for oscillation measurements.

	N_{events}(9.3yrs)	% of MC sample
ν_μ CC	88306	58.8
ν_e CC	35296	23.5
ν_τ CC	8772	5.8
ν NC	16981	11.3
atm. μ	917	0.6
Total MC	150272	-
data	150257	-



Compatible, complementary result with the existing measurements[3-6]

Competitive constraint on Δm^2_{32}.

Best-fit values & 1σ uncertainties:

$$\sin^2\theta_{23} = 0.54^{+0.04}_{-0.03}$$

$$\Delta m^2_{32} = 2.40^{+0.05}_{-0.04} \times 10^{-3} eV^2$$

Reference

[1] Phys. Sci. Forum 2023, 8(1), 62
[2] Phys. Rev. D 108, 012014 (2023)
[3] Phys. Rev. D 106, 032004 (2022)
[4] Eur. Phys. J. C 83(8), 782 (2023)
[5] Phys. Rev. L 125, 131802 (2020)
[6] 10.5281/zenodo.5779075 (2021)