Neutrino Oscillations in IceCube

- Neutrino oscillations constitute the only experimental evidence of non-conformity to the Standard Model (potential evidence for new physics).
- It describes transitions between flavor states to mass states.

Unitarity

- PMNS unitarity constraints are weakest for the third generation of neutrinos, an area where IceCube is highly sensitive [3].
- Non-unitarity could indicate that the 3x3 PMNS matrix is a subset of a larger N x N mixing matrix.
- IceCube operates in energy ranges where νₑₑ cross-section is much less kinematically suppressed than in accelerator experiments.

The IceCube and DeepCore Detectors

- Deployed to detect neutrinos of astrophysical origin.
- Consists of 86 strings of sensors buried underneath the South Pole.

Event Selection

- Consists of eight years of detector data (mid-2011 to mid-2019).
- Several cuts applied to eliminate atmospheric muons and self-triggered noise events (our main backgrounds).
- Use of new machine-learning classifiers (boosted decision trees to perform final-level muon rejection + PID classification).
- Yields a large statistics sample of neutrinos that well suited for νₑ disappearance (see poster #547), or for non-standard interactions (see poster # 364).

Sensitivity Projections

- Right: Expected change in the measured test-statistic for a range of injected tau normalization.
- In red: Variation expected from injecting the same nominal MC template (Asimov data challenge).
- In orange: Variation of the test statistic for multiple pseudo-experiments with poisson-fluctuated templates.

The Sample in Numbers

- Very good signal-to-background ratio in the key signal region (low-energy <50 GeV), upward-going events.

Analysis Principle

- We count the number of neutrinos detected per particle ID (ie flavor), energy and zenith bins.
- We then compare the result to our expectations from standard oscillation.
- Tau neutrino fraction is fit as a statistical excess of events in non-track events (we don’t identify individual tau neutrino events).

Cascade Like Events

- We perform a multi-dimensional fit of a Monte-Carlo template to our data. The fit includes both physical [ΔM²(2), θ23, τau normalization Nτ] and nuisance parameters to handle systematics.

Systematics Uncertainties:

- Neutrinos and muon spectral index.
- Atmospheric Neutrino Flux [4, 5].
- Quasielastic and resonant form factor.
- Deep Inelastic scattering cross section.
- Earth Model (neutrino propagation).
- Refractice Ice parametrization.
- Built Ice absorption & scattering.

Reconstruction of neutrino events:

- Change and time of hits from all DOMs are fed into a likelihood-based event reconstruction algorithm.
- νₑ→νₓ interactions have mostly track-like profiles, while νₓ→νₑ, νₑ→νₓ and all νₓ→νₐ interactions produce point-like (ie cascade) profiles.