Environmental decoherence in atmospheric neutrinos with IceCube

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1. Environmental ν decoherence

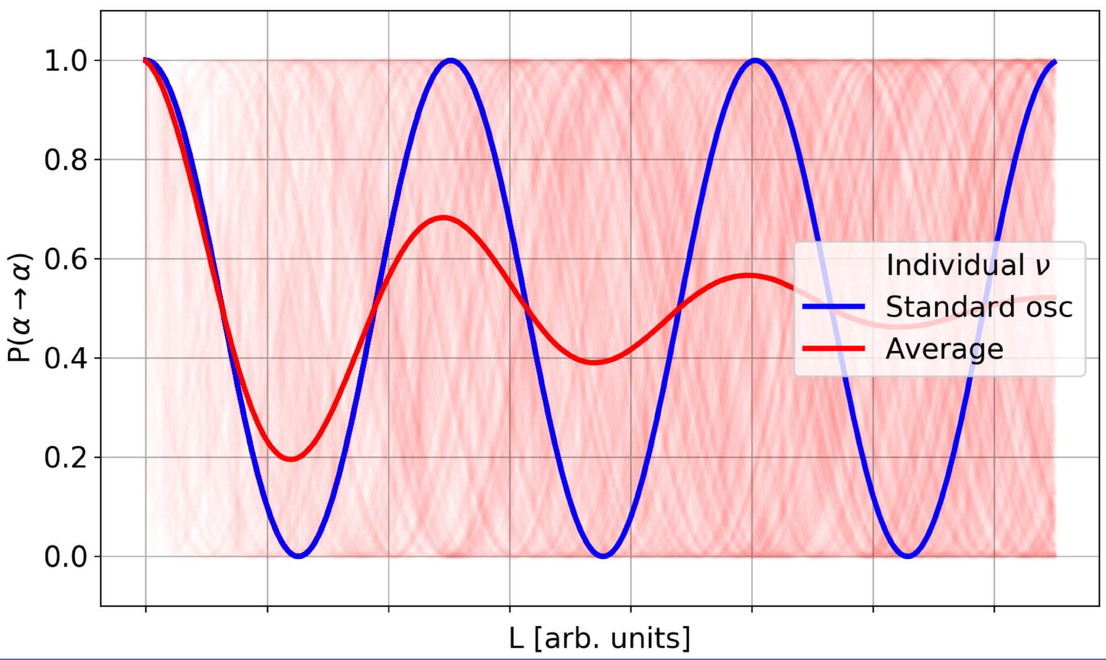
Constructive interference between ν states → oscillations

What if weak coupling between ν and environment?

→ Open quantum system

→ Decoherence → superposition degrades

→ Damping of oscillation probability over distance



2. Phenomenological model

Modelling decoherence in a microphysics-independent manner

Use density matrix, ρ, formalism (mixed states): $\rho = \sum_i p_i \left|\psi_i\right\rangle \left\langle\psi_i\right|$

Introduce decoherence operator: $\mathcal{D}[\rho]$

$$\dot{\rho} = -i[H, \rho] - \mathcal{D}[\rho]$$

General case: Lindblad form (open quantum system):

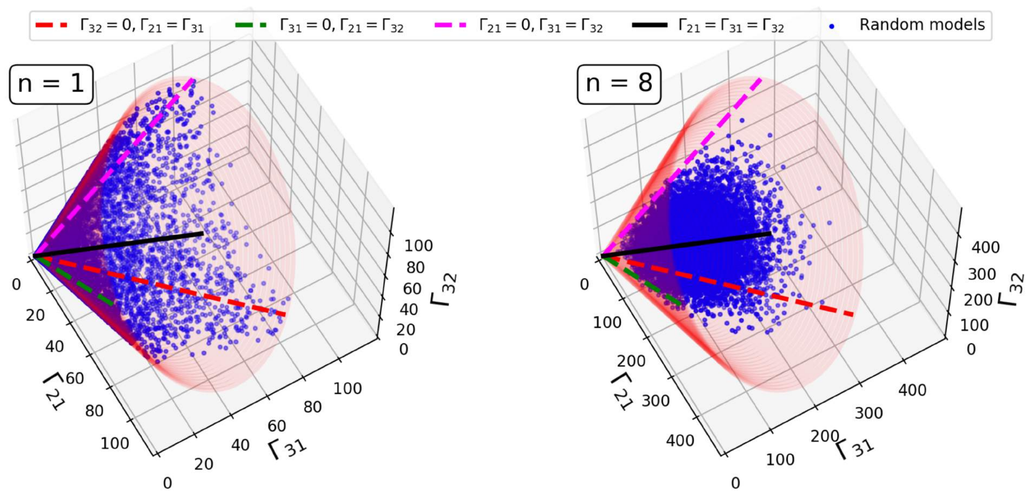
$$\mathcal{D}[\rho] = \sum_n^8 \left[\left\{\rho, D_n D_n^\dagger\right\} - 2 D_n \rho D_n^\dagger\right]$$

Assume unitarity, <E> conservation, increasing entropy:

$$\mathcal{D}[\rho] = \begin{pmatrix} 0 & \rho_{12}\Gamma_{21} & \rho_{13}\Gamma_{31} \\ \rho_{21}\Gamma_{21} & 0 & \rho_{23}\Gamma_{32} \\ \rho_{31}\Gamma_{31} & \rho_{32}\Gamma_{32} & 0 \end{pmatrix}$$

3 effective damping parameters in model: Γ_{ij}
Could be energy-dependent

Constraints from underlying form → conical bound



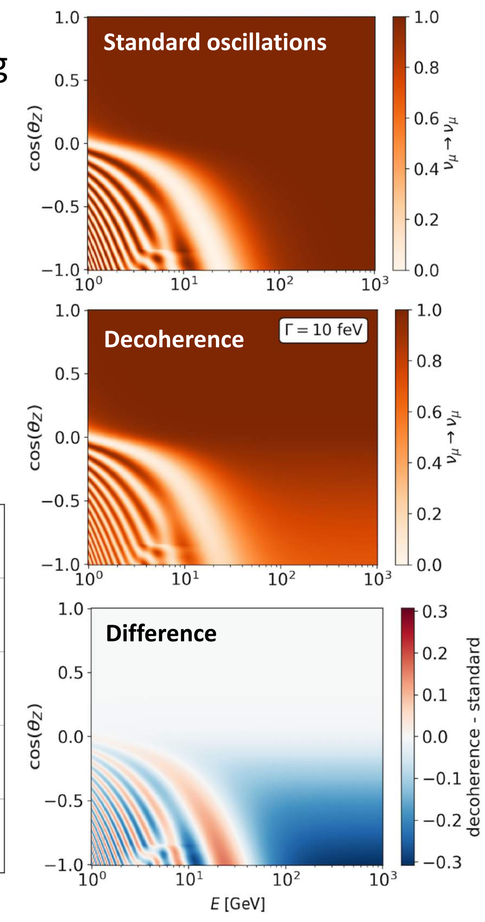
3. Decoherence in atmospheric ν

Strongest signal in atmospheric ν is damping of ν_μ disappearance

→ Weakens disappearance maxima

→ Introduces high energy disappearance

→ Zenith angle dependence



4. Sensitivity in DeepCore

DeepCore is densely instrumented region of IceCube detector

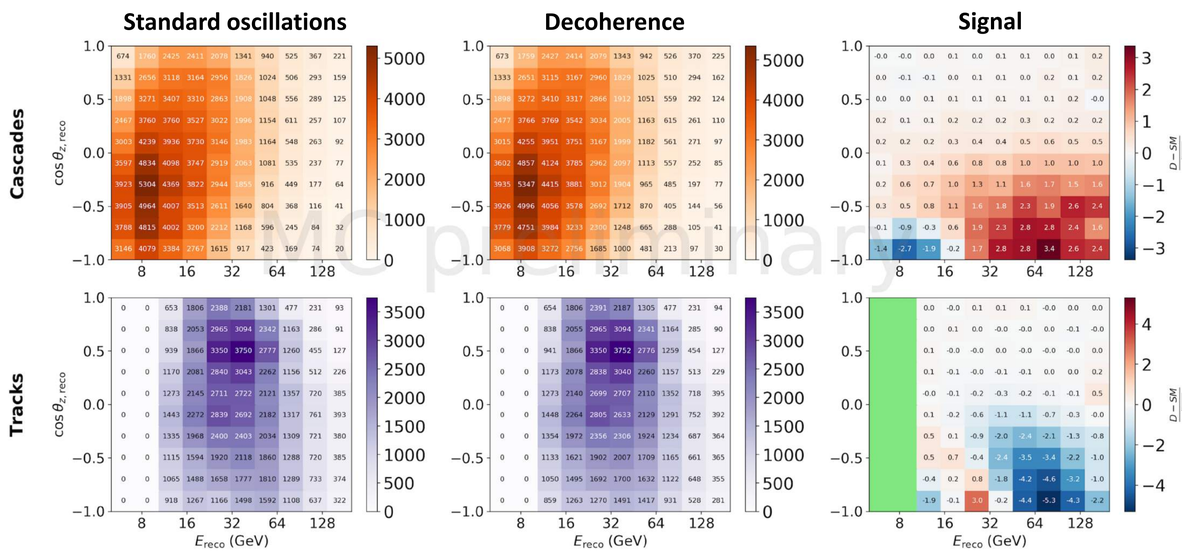
PMTs detect Cherenkov light from ν interactions in ice

Track-like ($\nu_{\mu,CC}$, μ_{atm}) and cascade-like ($\nu_{e,CC}$, $\nu_{\tau,CC}$, ν_{NC}) event topologies

Decoherence signal is 3D shape change in [E,cos(θ_{zenith}),PID] histogram

→ Fewer/more tracks/cascades at high energy

→ Reverse effect for standard ν_μ disappearance band

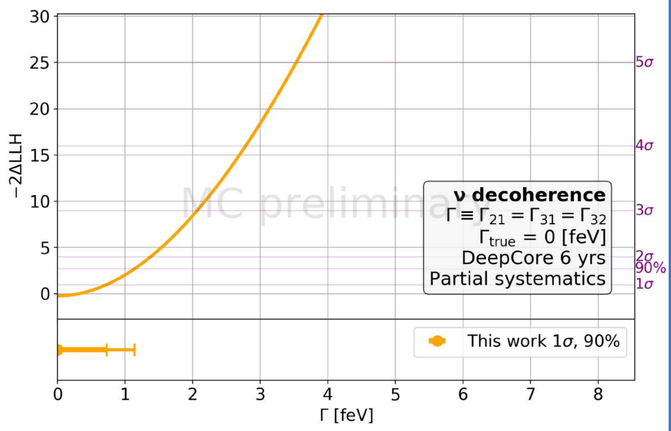


Preliminary sensitivity (6 years)

Assuming single Γ for simplicity

Included systematics:
Flux, cross-section

Still to implement:
Detector, ice systematics



References

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