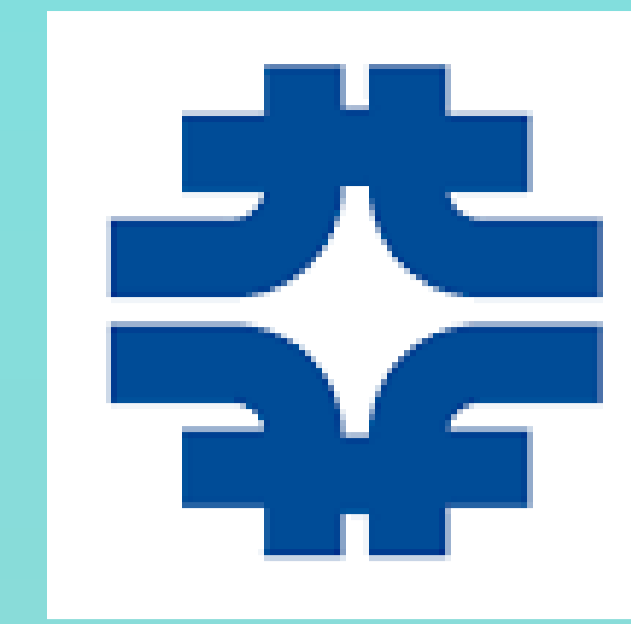


CP-violation measurement in DUNE with Sub-GeV Atmospheric Neutrinos

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Abstract

In this work, we study the **DUNE** sensitivity to the **CP-violation** phase using **sub-GeV atmospheric neutrinos**. LarTPCs would reconstruct with high accuracy the direction and the energy of incoming neutrinos. Combining the sensitivity of events with 0,1 and 2 observable protons in the final state, the results indicate that DUNE would be able to exclude several δ_{CP} values at more than 3σ of CL using only atmospheric neutrinos.

Atmospheric Neutrinos:

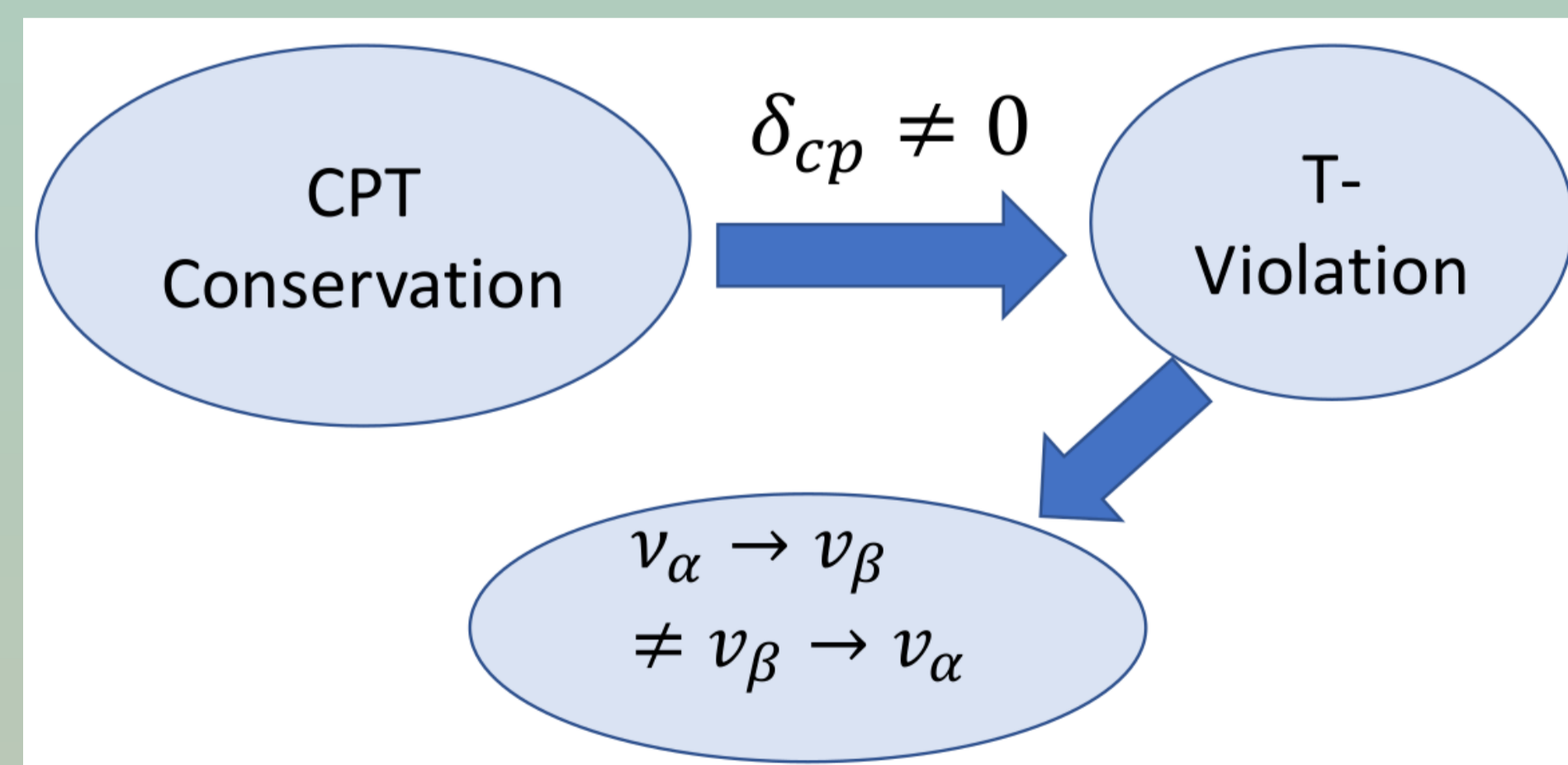
We consider the atmospheric flux in the energy range ($0.1 \leq E \leq 1$) GeV. The flux is parameterized as

$$\phi(E, c_\theta) = \phi_0 f(E, c_\theta) (E/E_0)^\gamma$$

The energy and zenith dependence ($f(E, c_\theta)$) is given by the Honda's table [1]. ϕ_0 and γ account for the systematic uncertainties.

For the neutrinos **crossing the Earth** with $E \sim 0.1$ GeV, the flavor oscillation is enhanced due to an **MSW resonance** in the solar sector.

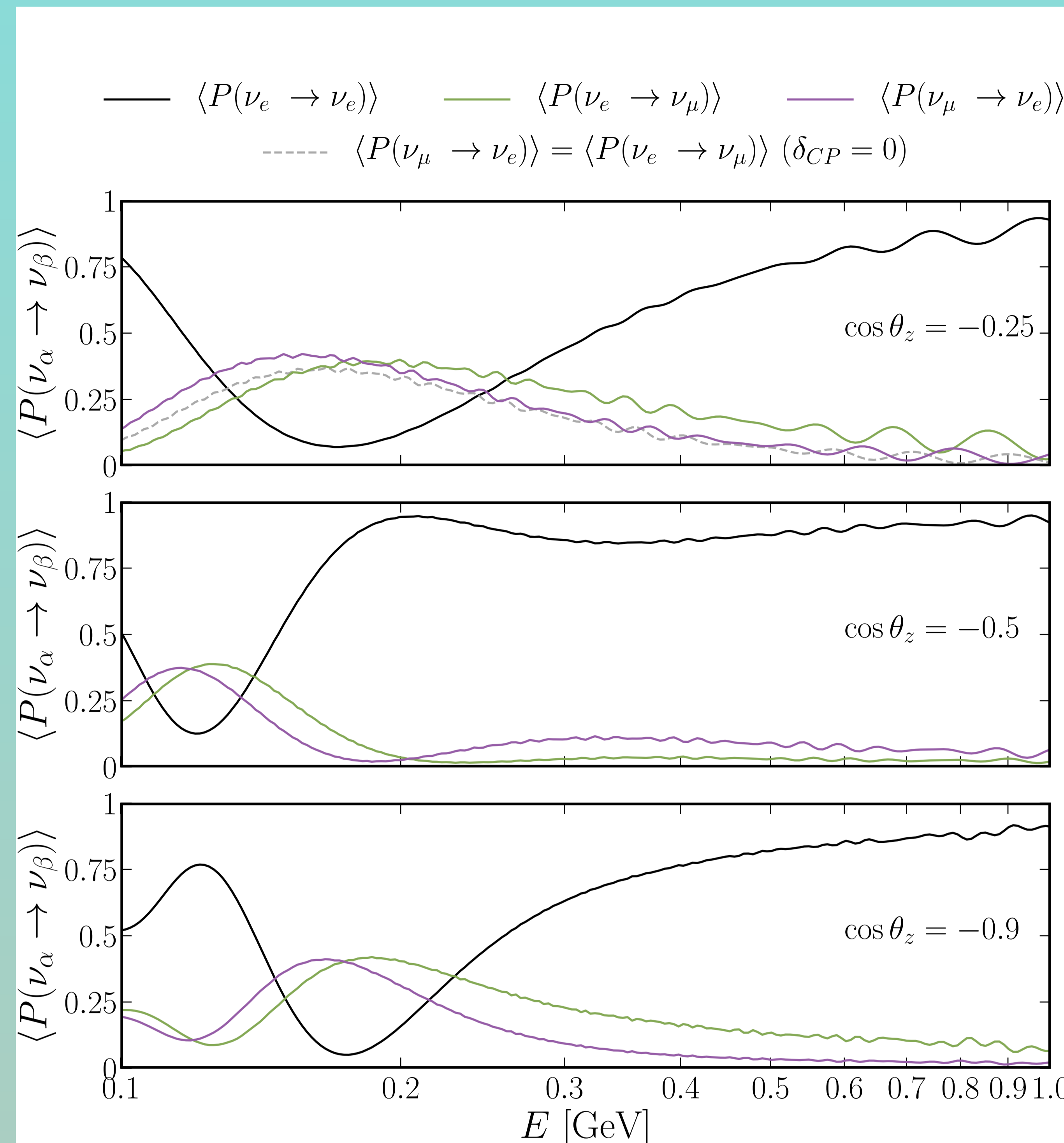
Can be measured δ_{cp} without a $\nu/\bar{\nu}$ discrimination?



The CP-violation term in the oscillation probability is

$$P_{CP} = -8J_r \sin \delta_{CP} \sin \Delta_{21} \sin \Delta_{31} \sin \Delta_{32}$$

At the sub-GeV scale, P_{CP} is enhanced due to the development of Δ_{21} .



DUNE Sensitivity

- LarTPCs reconstruct the incoming neutrino energy and direction from the full event topology.
- We consider CC events with up to two outgoing protons and no pions CC- $Np0\pi$

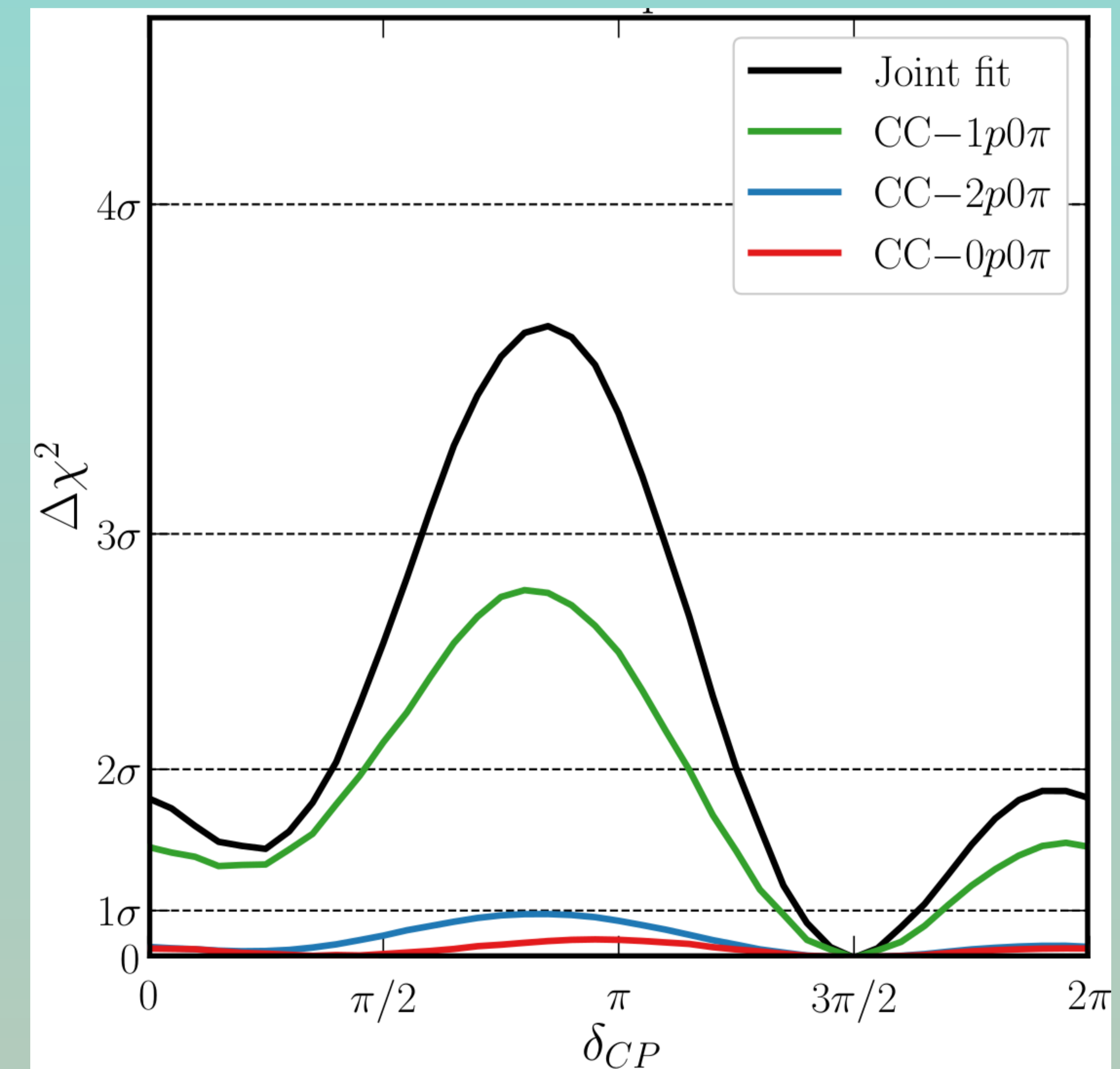
Np	Events/400 kton-year
CC-0p0 π	~ 5000
CC-1p0 π	~ 9000
CC-2p0 π	~ 250

- Each event sample is dominated by a neutrino type.
- Combining all samples, the impact of the systematics ($\phi_0, \gamma, \nu/\bar{\nu}, \nu_\mu/\nu_e$) is reduced to the percent level.

CC-1p0 π (ν -dominated)
CC-0p0 π ($\bar{\nu}$ -dominated)

$\phi_0 \sim 2\%$ $\gamma \sim 0.02$
 $\nu_\mu/\nu_e \sim 2\%$ $\bar{\nu}/\nu \sim 1\%$

- Fixing all the oscillation parameters and marginalizing over the flux systematics, we get the following sensitivity



Conclusions

- The **CP-violation** has a sizable impact on the **sub-GeV atmospheric neutrino** flux.
- Sub-GeV neutrinos can be reconstructed with a unique capability by **LarTPCs**.
- **DUNE's** sensitivity can rule out regions of allowed δ_{cp} parameter space at more than 3σ **CL**.

References

[1] M. Honda et al. *Phys. Rev. D*, 92(2):023004, 2015.