Search for anomalous tau neutrino appearance in the DUNE Near Detector

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Introduction
Objectives of the analysis

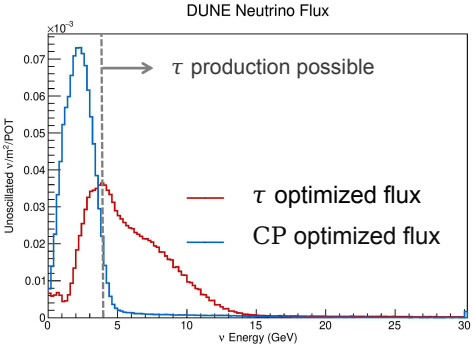
Objectives

- Main objective
  - Study of the eventual ν_τ that we may have in the DUNE ND that comes from short baseline oscillations, in a sterile neutrino framework.
  - Distance from neutrino source to DUNE ND is 574 m → no ν_τ should be present at the DUNE ND for 3-flavor oscillation model but ν_τ appearance possible for sterile-driven oscillations.
  - Evaluate the ν_τ appearance sensitivity of DUNE ND by studying ν_τ CC interactions for both leptonic and hadronic τ decay channels ($\tau \to e$, $\tau \to \mu$, $\tau \to \rho$).
- Oscillation probability

$$P(\nu_\mu \to \nu_\tau) \approx sin^2(2\theta_{\mu\tau}) sin^2\left(\frac{\Delta m^2_{41} L}{4E}\right)$$

$$sin^2(2\theta_{\mu\tau}) = 4|U_{\mu 4}|^2|U_{\tau 4}|^2 = cos^4\theta_{14} sin^2(2\theta_{24}) sin^2(\theta_{34})$$

- Simulation
  - Current analysis: events were generated using GENIE with Pythia 6 (analysis based on the truth infomation provided by GENIE).



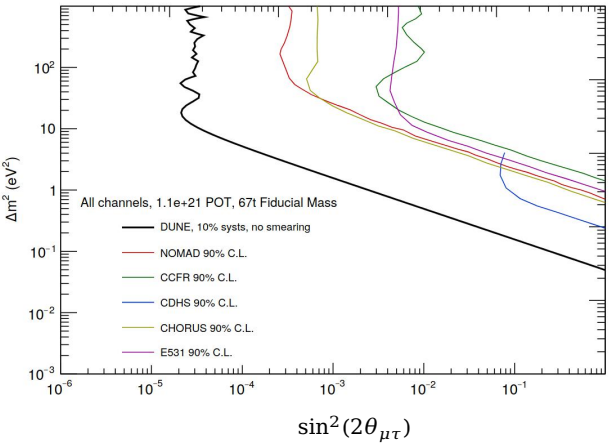
Beam configuration: higher energy neutrino beam optimized for ν_τ appearance in the DUNE Far Detector.

DUNE ND sensitivity to ν_τ appearance

Preliminary results

Sensitivity based on GENIE true information

- To evaluate sensitivity:
  - Separate the ν_τ events from corresponding backgrounds based on their transverse kinematic differences.
  - ROOT TMVA : Machine Learning algorithm (Boosted Decision Tree Gradient - BDTG) to separate ν_τ CC from their backgrounds.
- Sensitivity based on event counting where we considered a 67 tons fiducial mass for the ND-LAr and 1.1e+21 P.O.T.



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DUNE ND sensitivity to ν_τ appearance

Preliminary results

Smearing

- To evaluate selection efficiencies and sensitivity, the case where some smearing is applied to the final state particles 4-momentum was also considered.

- **Case 1 - without smearing** → In the first case, no smearing was applied to the particles four-momentum but only particles above a certain kinetic energy threshold were considered. :
  - protons : above 50 MeV.
  - photons : above 30 MeV.
  - pions : above 20 MeV.
  - no neutrons.

- **Case 2 - with smearing** → In addition to the kinetic energy thresholds above, energy and angular resolution smearing applied to particles 4-momentum.

Species	Threshold [MeV]	Energy Resolution	Angular Resolution [deg]
p	50	± 60 MeV	± 5
$\pi^{+/-}$	20	± 10%	± 2
γ	30	± 10%	± 5
e^-		± 10%	± 2
μ^-		± 10%	± 5

Table : Smearing values based on LArTPC performance in the MicroBooNE Experiment (arXiv:2012.09788v3)

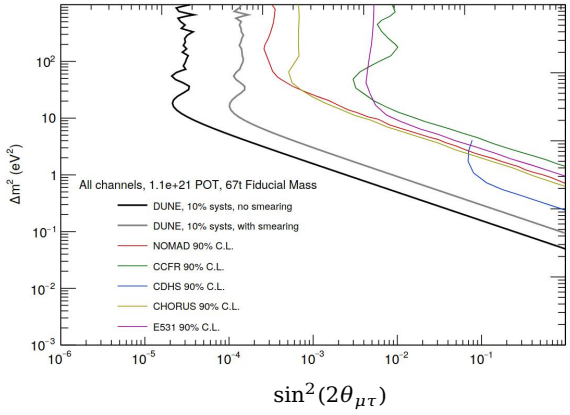
- **In both cases, a systematic uncertainty of 10% was taken into account.**

DUNE ND sensitivity to ν_τ appearance

Preliminary results

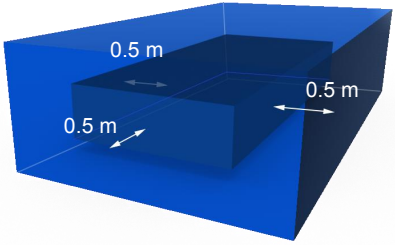
Sensitivity considering smearing

- Considering all three decay channels and smearing.



Feedback/Comments and current work

- Simulation tools: how the differences in GiBUU vs GENIE, especially in the final state hadrons will affect the sensitivity
- Tau decayer: need a decayer that effectively accounts for the polarization such as TAUOLA (currently use Pythia 6 which does not account for the polarization).
- Muon energy reconstruction:
  - ND-LAr lose acceptance for muons above ~0.7 GeV due to lack of containment.
  - Calculate the muon range in order to apply a muon containment cut and adjust smearing values accordingly.
- GENIE+Edep-sim simulation (det+reco):
  - Sent a request to the ND Production team to produce the required samples for the analysis, using Pythia 8 as a tau decayer, which takes into account the polarization (with reco if ever available).



ND LAr: used a 67 tons fiducial mass out of the 147 tons of the detector so as to leave about 1/2 m from the detector walls.

Thank you for your attention!