Studies of $\nu_{\tau}$ appearance in the DUNE Near Detector Complex

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DUNE PRIMARY PHYSICS GOALS:
- Measurements of the charge parity (CP) phase.
- Determination of the neutrino mass ordering ($\Delta m^2_{41}$).
- Measurement of the mixing angle $\theta_{23}$ and the determination of the octant in which it lies.
- Search for Physics Beyond the Standard Model.

DUNE EXPERIMENT:
- LBL experiment with a baseline of 1300 km (Fermilab to South Dakota).
- Uses a $\nu_{\tau}$ beam provided by the LBNF Facility (with a small $\nu_{\mu}$ contamination).

DUNE NEAR DETECTORS:
- Early phase of DUNE proposed detectors
- Full scope DUNE Experiment
- Scintillator tracking planes
- HgTPC (high-pressure gaseous argon)
- ECAL (electromagnetic calorimeter)

DUNE NEAR DETECTOR COMPLEX:
- The great resolution of the DUNE ND Complex, intense neutrino flux from LBNF and the short baseline of 574 makes the DUNE ND ideal for a sterile neutrino search.

OBJECTIVES OF THE ANALYSIS:
- Short baseline $\nu_{\mu} \rightarrow \nu_{\tau}$ oscillations could be evidence for a sterile neutrino:
  \[ P(\nu_{\mu} \rightarrow \nu_{\tau}) = \sin^2(2\theta_{23}) \sin^2 \left( \frac{\Delta m^2_{41}}{4E} \right) \]
- Objective: Study the eventful $\nu_{\tau}$ interactions in the DUNE ND Complex (574 m from neutrino source) driven by sterile neutrino mixing.
- Neutrino interactions were simulated using GENIE.

The electron and rho decay channel were added to the analysis (represented in the plot on the right) in which particles from interactions were supposed to be contained in ND LA:

- Momentum
- Angular
- Energy (GeV)
- Resolution

The signal and background separation is based on kinematic differences. A total of 18 variables was used.

The BDT was trained and tested with flat energy flux:

Background interaction products in the transverse plane

Signal interaction products in the transverse plane

Conclusion:
- DUNE’s near detectors are sensitive to short-baseline $\nu_{\tau}$ appearance for sterile neutrino searches.
- ND-GAr and ND-GAr Lite are key due to their muon resolution.
- A high-energy beam configuration could potentially give DUNE leading sensitivity to anomalous short-baseline $\nu_{\tau}$ appearance.

Next steps:
- Include SAND detector.
- Investigate other tau decay channels.