Phenomenological Study on DUNE's sensitivity to Atmospheric neutrinos

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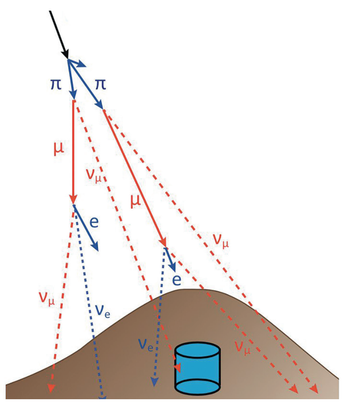
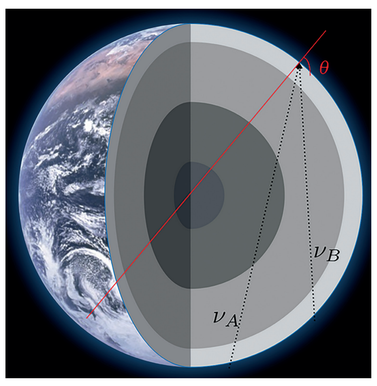
Presentation

Deep Underground Neutrino Experiment (DUNE) is a next-generation long baseline neutrino experiment that will provide a unique opportunity to study atmospheric neutrinos with precision. Due to their wide distribution in energy E and large distance travelled L, atmospheric neutrinos allow to probe a wide range of E/L values and therefore can provide invaluable insights into the different parameters of the PMNS matrix. Moreover, the results obtained with this source of neutrinos will be complementary to the accelerator neutrino program of DUNE and the joint analysis will improve sensitivity, or contrarily raise tensions hinting at new physics.

Atmospheric Neutrinos





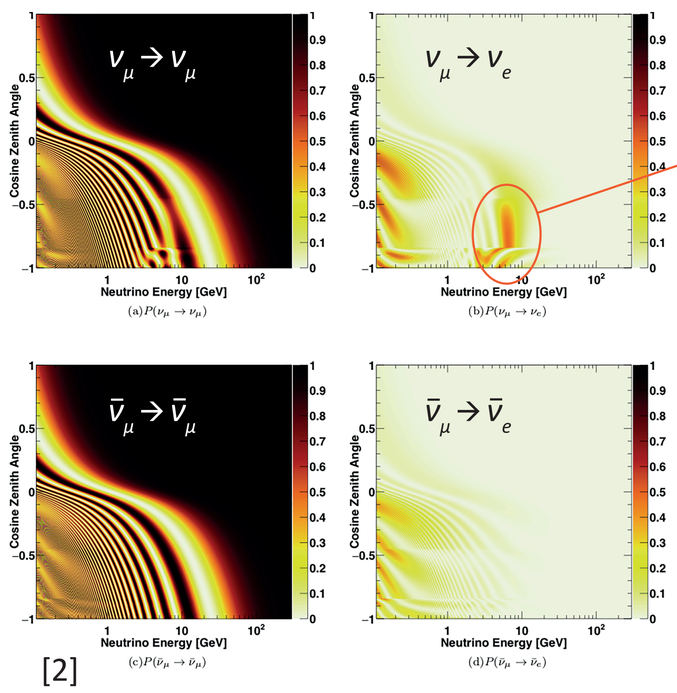
[2]

- Created in the atmosphere:

  cosmic rays interact with a nucleus
  ⇩
  produces pions
  ⇩
  neutrinos (2:1 ratio for ν_μ compared to ν_e)

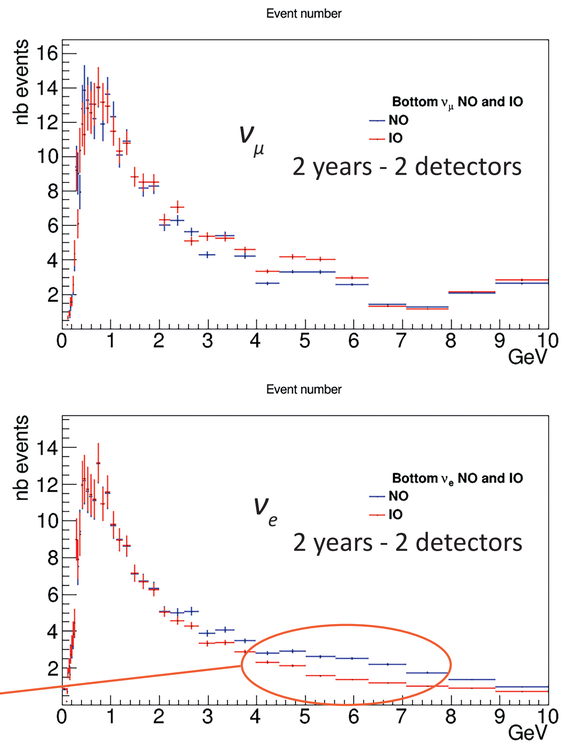
- Large distribution energies (MeV to TeV)
- Wide range of travelled distance depending only on θ (zenith angle, model of the earth used has 44 layers)
  ↳ Wide range of L/E
  ↳ Allows to explore different oscillation parameters (Mass hierarchy, θ_{23} etc.)

Oscillation Probabilities



[2]

- Calculated the oscillation probabilities with respect to cos(θ) and neutrino energy in normal mass ordering
- Oscillation peak



- $N_{evts} = \int_E \phi(E) \cdot \sigma(E) \cdot P_{osc}(E) \cdot t \cdot N_{target}$
- ν_μ et ν_e with $cos(\theta) < -0.7$
- DUNE incapable of separating $\nu/\bar{\nu}$ yet
- Can see the oscillation peak

Analysis Process

Generation

40M events GENIE
500x expected rate

⇨

Simulation

GEANT4 LAr TPC 17kt

⇩

Analysis

Analysed with MaCh3 with:

- Honda Flux [1]
- OscProb oscillation software
- No systematic errors (to be explored)
- Reconstructed energy is lepton energy
- Reconstructed angle is lepton angle

References & Acknowledgements

[1] M. Honda et al. *Atmospheric neutrino flux calculation using the nrlmsise-00 atmospheric model.* Phys. Rev. D,92 :023004, Jul 2015.
[2] K. Abe et al. *Atmospheric neutrino oscillation analysis with external constraintsin super-kamiokande i-iv.* Physical Review D, 97(7), April 2018.
[3] Jin, Seung-Seop et al. *Adaptive Markov chain Monte Carlo algorithms for Bayesian inference: recent advances and comparative study. Structure and Infrastructure Engineering.*

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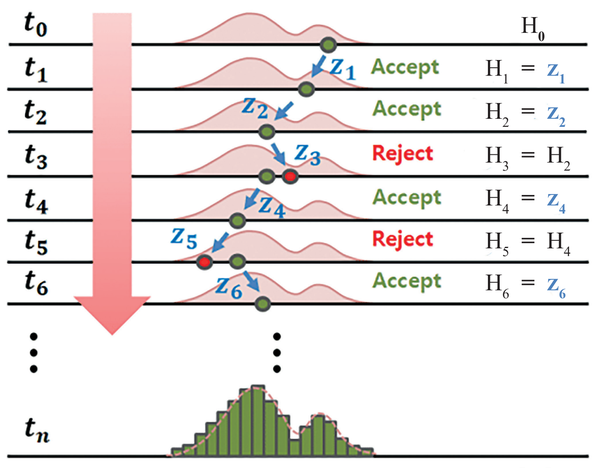
Current Work

1. Bayes' Theorem

$$P(H|D) = \frac{P(D|H)\,P(H)}{P(D)}$$

Posterior = $P(H|D)$; Likelihood = $P(D|H)$; Prior = $P(H)$; Evidence = $P(D)$

2. Markov Chain Monte Carlo

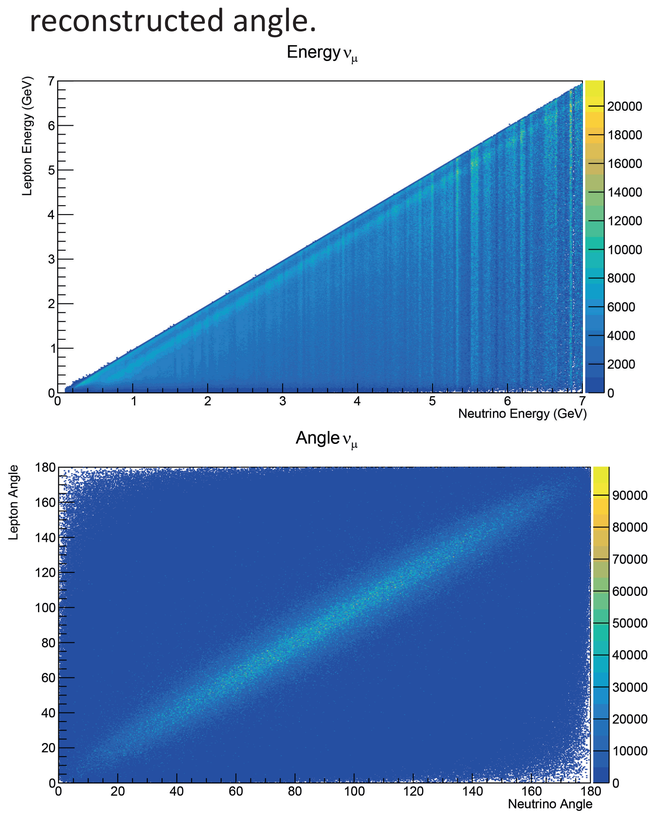


[3]

- Semi-random walk around the full parameter space
- Metropolis-Hastings algorithm for accepting or rejecting steps

3. Reconstruction

Similarly to what has been done in [2], I'm using the lepton energy (corrected from the Monte Carlo simulation) for the reconstructed energy and the lepton angle for the reconstructed angle.



4. Prospects

I will use MaCh3 to analyze our simulation and get an estimate of DUNE's sensivity and explore the effects of the different systematic errors for the flux, cross-sections, neutrino interactions, detector acceptance and efficiency etc... For that, I will compare the neutrinos from "above" and "below" and do a dual analysis similar to DUNE's with the near and far detectors.