Time Slicing of Neutrino Fluxes in Oscillation Experiments at Fermilab

Fermilab ACE Science Workshop

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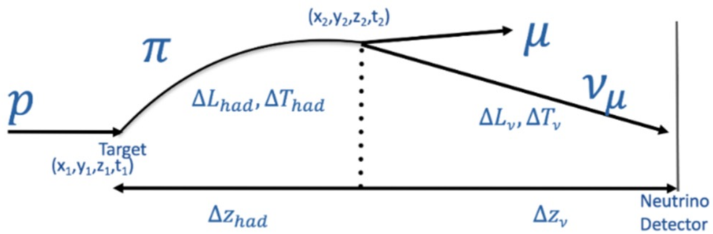
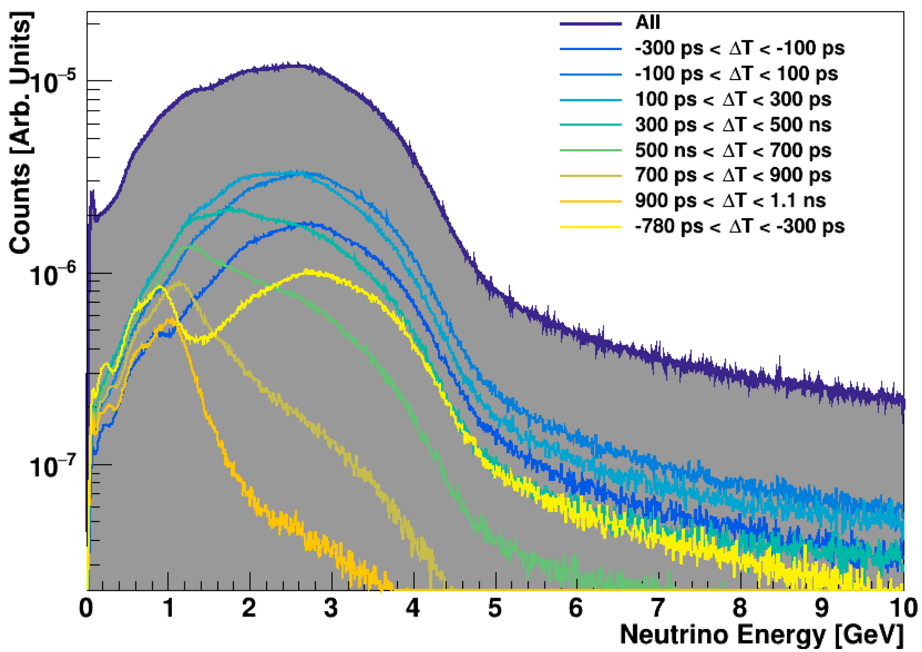
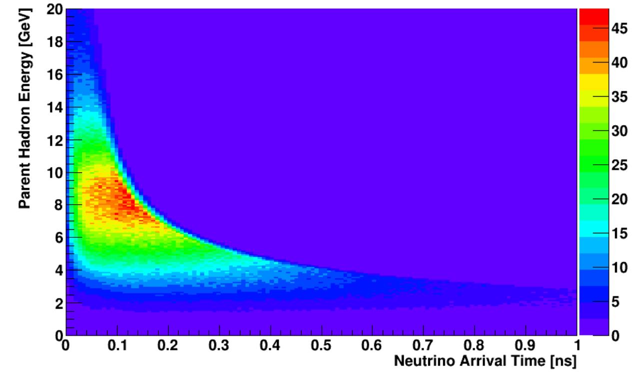
June 15, 2023

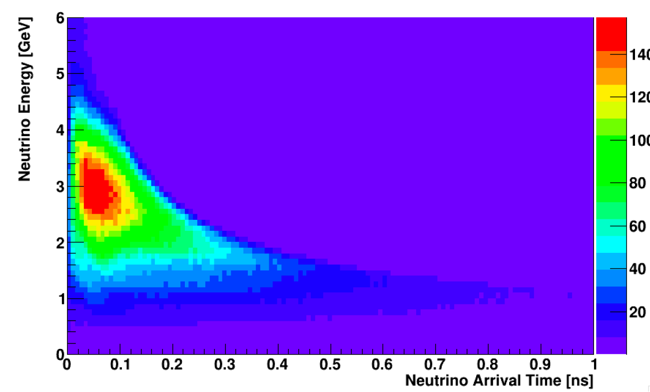
Neutrino Beam Timing – Stroboscopic Approach







Arrival time difference between neutrinos from relativistic hadrons and neutrino from hadron of energy E



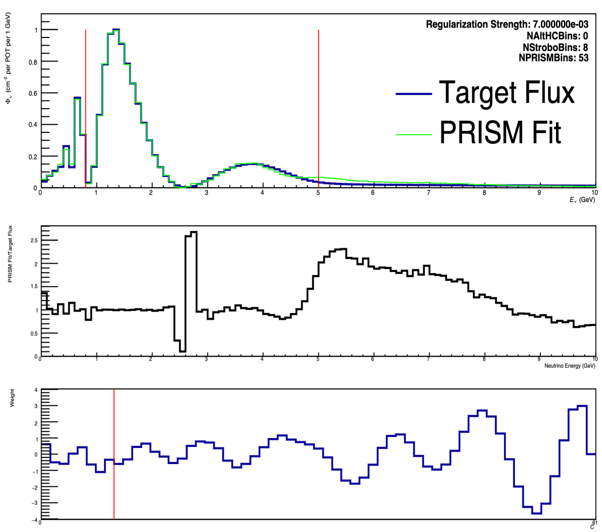
Relative neutrino arrival times versus neutrino energies for all neutrinos with simulated data of the LBNF beam

Motivation

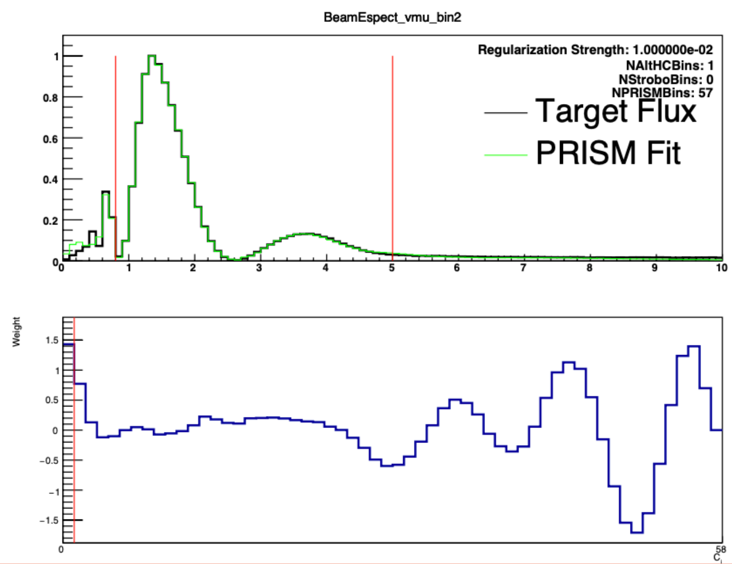
Number of Near Detector events = **Flux** · **Cross section** · **Detector effects**

Number of Far Detector events = **Flux** · **Oscillation probability** · **Cross section** · **Detector effects**

- If both flux and cross section have uncertainties, cannot unambiguously tell if we have both correct in models or both wrong in ways that result in approximately correct event rate prediction
- **Stroboscopic approach – can be applied to both Near & Far detectors**
  - Oscillated time integrated spectrum of Far Detector can be fitted to PRISM and Stroboscopic approaches in Near Detector
  - Can provide Far Detector oscillated time slices



PRISM fit with PRISM off-axis fluxes only + stroboscopic on-axis fluxes
No lower horn current flux



PRISM fits to oscillated Far Detector time bins

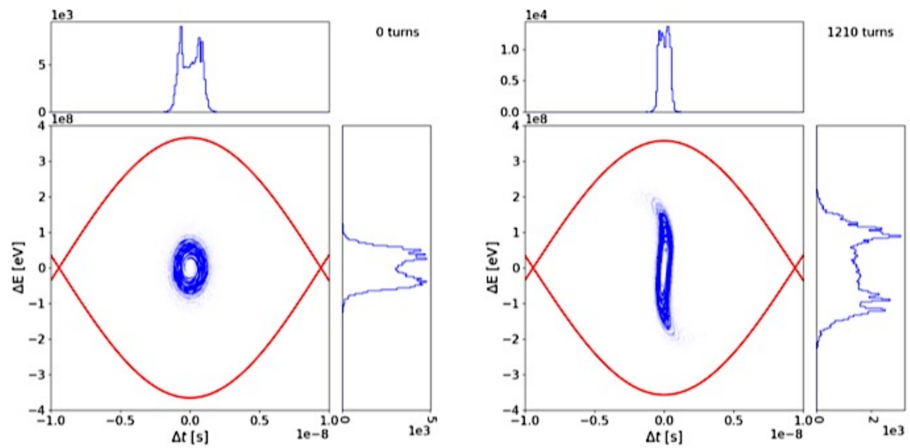
Application of Stroboscopic Approach

Application requires efforts in:

- Creation of short (O(100 ps)) proton bunch length
- Detectors with fast timing to get equivalent time resolution
- Synchronization b/w time at detector & time of bunch-by-bunch proton

Precision timing in DUNE ND – possible with minor upgrades, in FD later design modification possible

Use bunch rotation at MI to create Narrow Bunches:



Minimal bunch length of 330 ps occurs ~ 1210 revolution

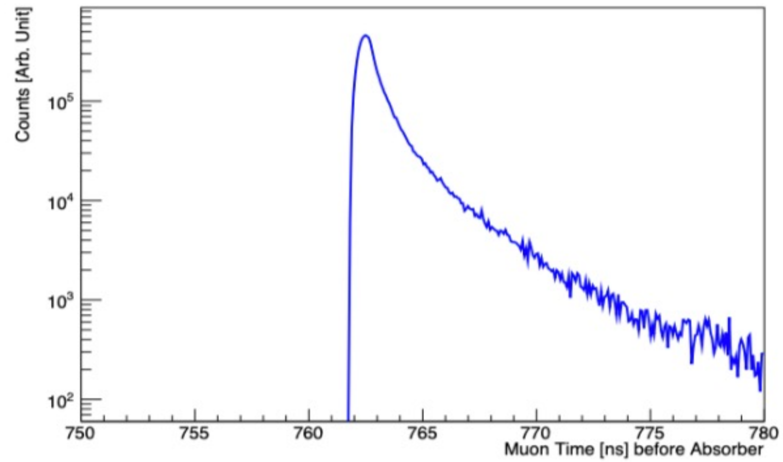
- ANNIE equipped with Large Area Picosecond Photodetectors (LAPPDs) → better vertex reconstruction, improved background rejection → together with precision timing in beam delivery and time synchronization tools developed, first proof of principle possible with ANNIE
- With tools developed for time synchronization, precision timing can be applied to future oscillation experiments with fast detectors - there is an excellent opportunity to think about fast timing for LAr-TPCs

Stroboscopic Muons

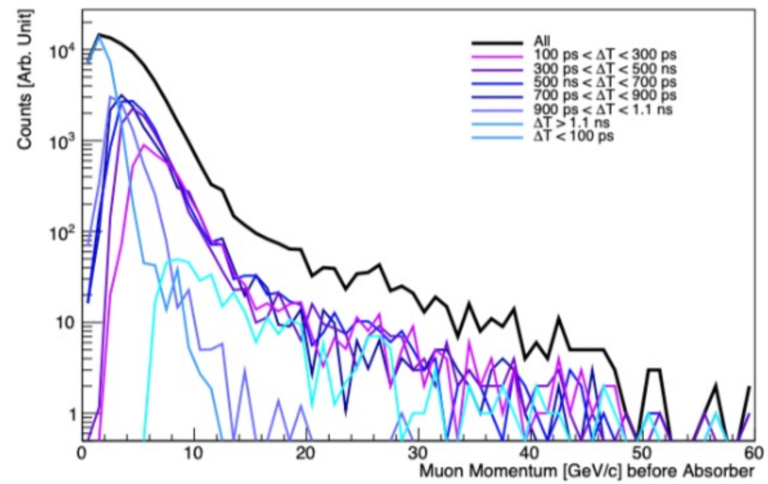
- Neutrinos & muons have a similar time-energy correlation from pion decay
- Muon momentum spectra can be measured stroboscopically
- Bin muons in same time intervals as neutrinos, create muon samples to normalize neutrino flux in each time bin
- By placing muon monitors before full absorbers installed, measure muon momentum spectrum during a low-intensity run on LBNF beamline – psec timing

Neutrinos & muons will play a key role in future neutrino experiments

Stroboscopic techniques allow us to exploit neutrino & muon beams to their fullest potential



Muon time before absorber



Muon momenta in each time bin after absorber

Reference

https://arxiv.org/pdf/1904.01611.pdf
https://indico.fnal.gov/event/58470/