Snowmass2021 - Letter of Interest

The Use of Precision Beam Timing in LBNF/DUNE

NF Topical Groups: (check all that apply □/■)

■ (NF1) Neutrino oscillations
■ (NF2) Sterile neutrinos
■ (NF3) Beyond the Standard Model
□ (NF4) Neutrinos from natural sources
□ (NF5) Neutrino properties
□ (NF6) Neutrino cross sections
□ (NF7) Applications
□ (TF11) Theory of neutrino physics
■ (NF9) Artificial neutrino sources
■ (NF10) Neutrino detectors
■ (Other) AF2 Accelerators for Neutrinos

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We propose to use a higher-frequency RF bunch structure for the primary proton beam on target and precision timing to select different energy and flavor spectra from a wide-band neutrino beam, based on the relative arrival times of the neutrinos with respect to the RF bunch structure. This 'stroboscopic' approach is complementary to techniques that select different neutrino energy spectra based on the angle with respect to the beam axis. A timing-based approach allows for the selection of varying energy spectra from the same on-axis detector, and applies equally to both the near and far detectors in an oscillation experiment. Energy and flavor discrimination of neutrinos produced by hadrons in-flight will require proton bunch lengths on the order of 100 ps and commensurate time resolution in the detector. Correlating neutrino events with the parent proton interaction is currently limited by the nanosecond-scale width of the proton bunches impinging on the target. We show that these limitations can be addressed by using a superconducting RF cavity to rebunch the present 53.1 MHz RF bunch structure with a factor of 10 higher RF frequency, thus attaining the required shorter bunch length.

The details of the approach are described in Ref [1]. Possible implementation of fast timing within the current parameters of LAr-TPC technology is described in a Snowmass Whitepaper [2]. Fast timing is also possible in water-based neutrino concepts such as Theia and could be demonstrated in the ANNIE experiment in the next several years.

References:

[1] E. Angelico, *et al.*, "Energy and flavor discrimination using precision time structure in on-axis neutrino beams," *Phys. Rev. D* **100** (Aug, 2019) 032008. https://link.aps.org/doi/10.1103/PhysRevD.100.032008.

[2] E. Angelico, A. Elagin, H. J. Frisch, and M. Wetstein, "Measuring the Neutrino Event Time in Liquid Argon by a Post-Reconstruction One-parameter Fit," *Snowmass Whitepaper, Neutrino Frontier* (4, 2020) , arXiv:2004.00580 [physics.ins-det].