Search for Heavy Neutral Leptons with SBND

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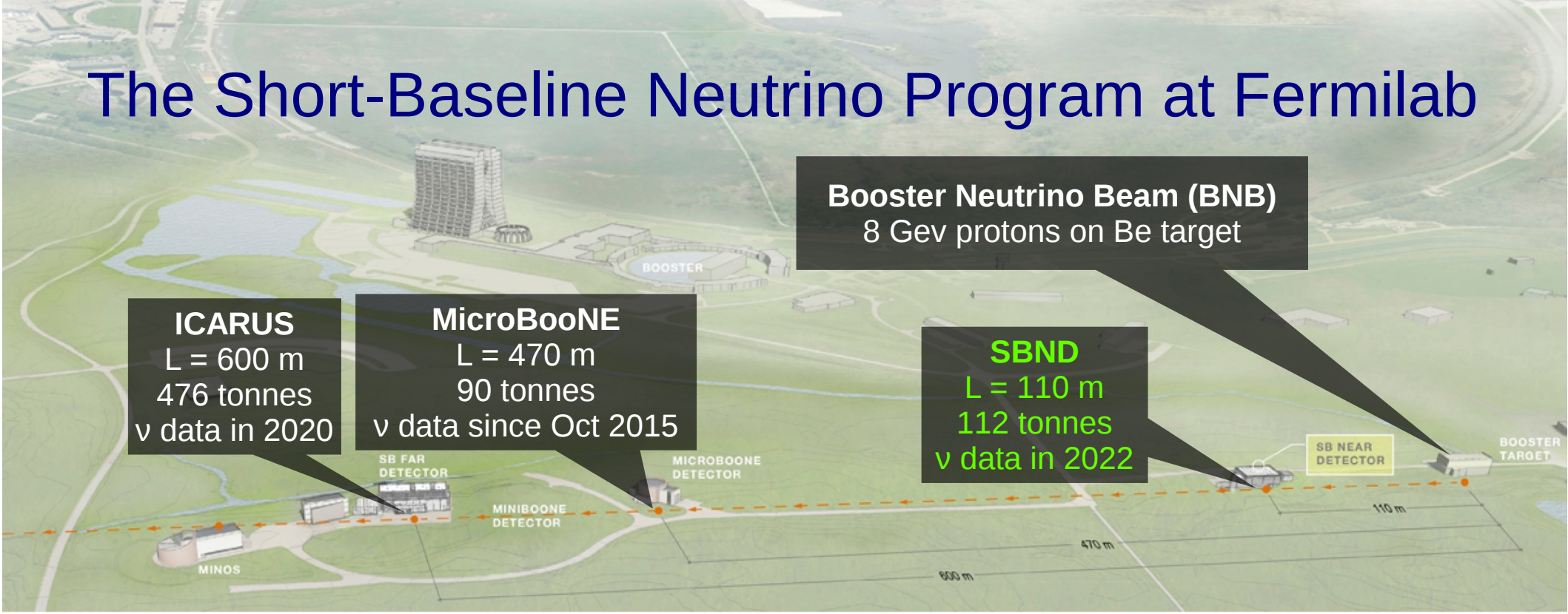
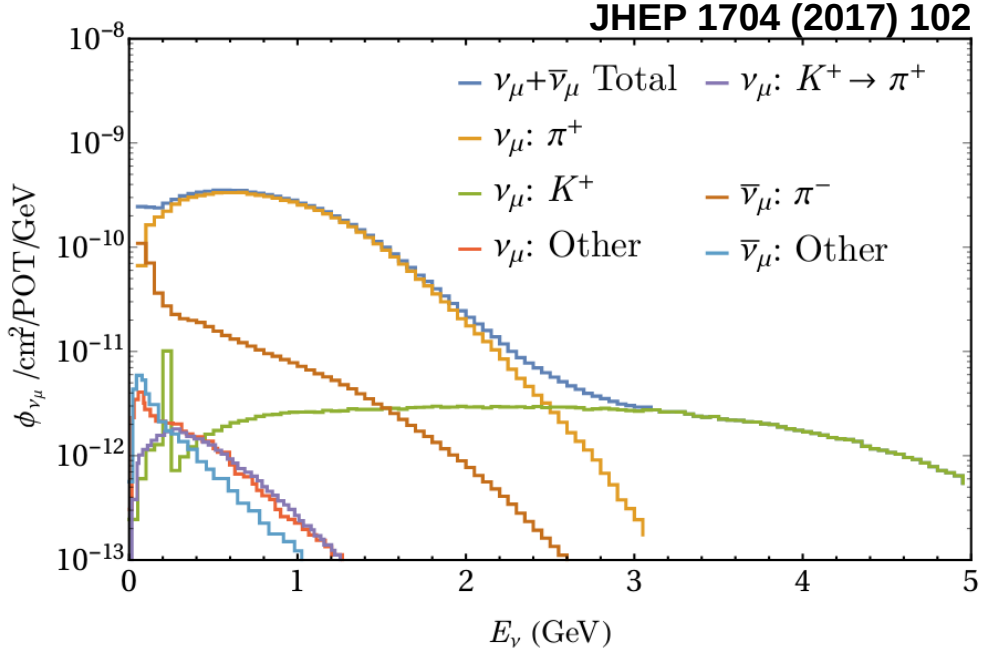
The Short-Baseline Neutrino Program at Fermilab

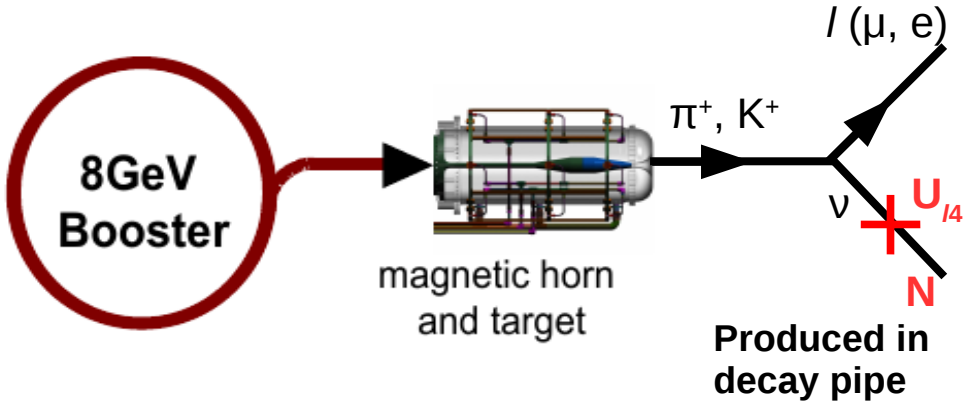


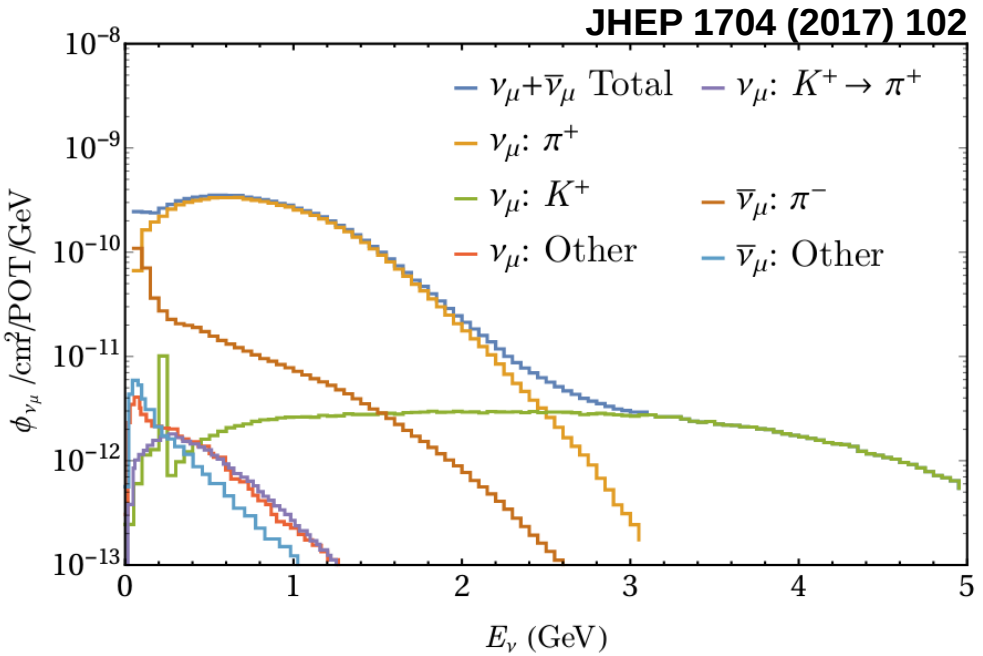
JHEP 1704 (2017) 102



- **Booster Neutrino Beam (BNB)** from pion decay-in-flight mostly (plus kaon and muon decay).
  - Single horn for focusing charged mesons.
  - Well-understood beam, same as MiniBooNE (**PRD 79, 072002**).

HNL Production in Fermilab SBN Program





- HNL may be **produced in BNB** secondary **meson decays** through mixing with Standard Model neutrinos.

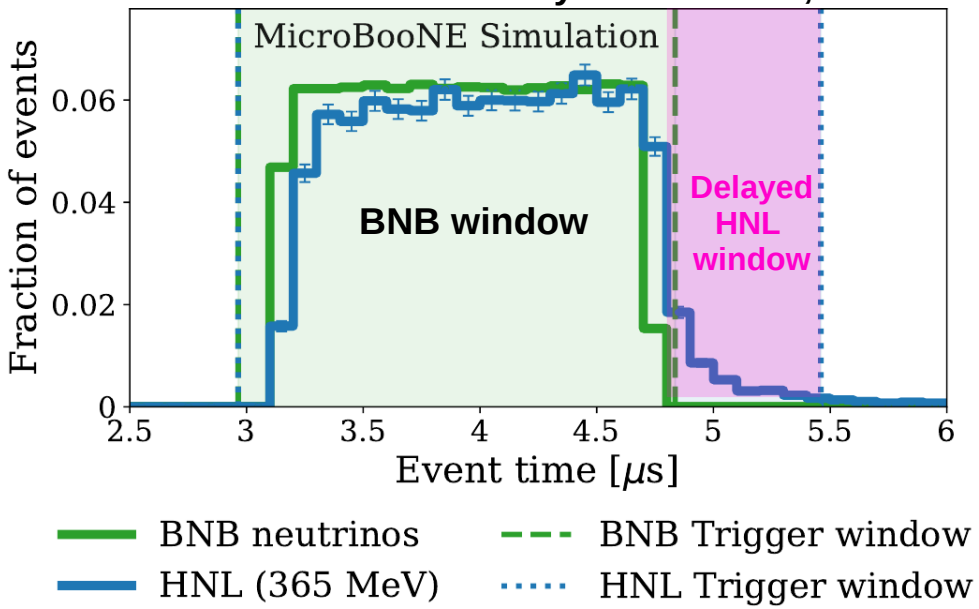
  Extended PMNS mixing matrix elements: U_{e4}, $U_{\mu4}$ (no τ production).

- **HNL mass range up to 493 MeV** (K-decay phase space).
- Full beam line simulation available: proton → meson/muon → SM neutrinos.
- HNL **decays in flight**.

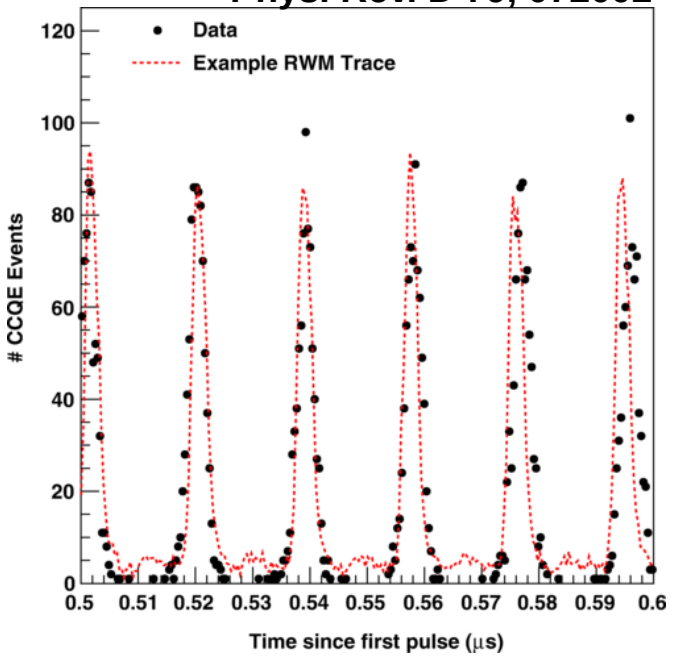
  Look for HNL decays within the detector.

HNL timing opportunities

Phys. Rev. D 101, 052001



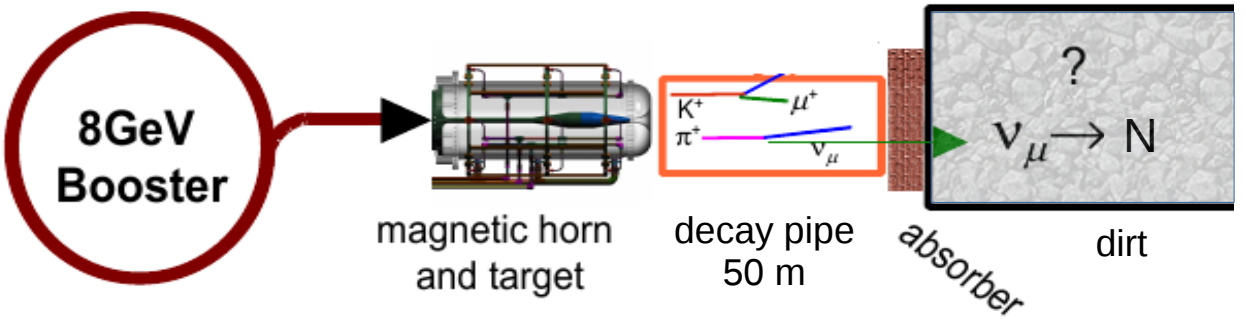
Phys. Rev. D 79, 072002



- **HNL travel slower than SM neutrinos.**
- Opportunity: extend neutrino trigger window to **capture HNL delayed events.**
- **MicroBooNE HNL search: focus on delayed HNL window.** No **SM neutrino background. Only cosmic ray background. Data-driven background measurement using an off-beam trigger** with same thresholds as the HNL trigger.
- SBND is closer to the target so difference in time-of-flight is not that useful.
- **MiniBooNE idea:** Use beam substructure to distinguish in-time SM events from off-time BSM events within the BNB window.

  It can be applied to HNL decays too. It requires a fine timing resolution, including detector effects is key to determine viability.

BNB flux files



- Simulation of the proton → meson (→ muon) → neutrino chain.
- Variables for each particle:
  - Initial position
  - Initial momentum
  - Initial energy
  - Initial time
  - Final momentum

CIEMAT Plan

- Marie Curie Fellowship awarded to search for HNL in the BNB with SBND.
- Interested in using the DUNE BSM HNL simulation to simulate the creation and decay of HNLs in the BNB.
  - Define interfaces between BNB flux simulation and DUNE BSM HNL simulation.
  - Define interfaces between DUNE BSM HNL simulation and LArSoft/sbndcode.
- First goal is studying the sensitivity of SBND to different decay channels using an MC-Truth-based reconstruction to determine viability (e.g. impact of SM neutrino background).
- Choose the best channel(s) and do a full simulation to define the search strategy.
- Search for HNL in SBND early data (2022 – 2023).