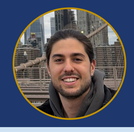
Towards searches for heavy neutral leptons with the Short-Baseline Near Detector experiment

Jorge Romeo Araujo and Nguyễn Vũ Chi Lan, on behalf of the SBND Collaboration



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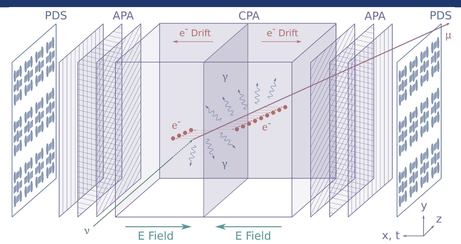
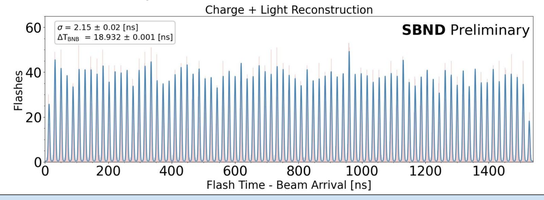
Short Baseline Near Detector (SBND)



SBND is a liquid argon time projection chamber (LArTPC) located just 110 m away from the target of the Booster Neutrino Beam (BNB). The proximity yields a potential high flux of potential BSM particles.

BNB's unique bunch structure

Advanced PDS achieves $\mathcal{O}$(ns) timing resolution → Search for BSM particles between neutrino bunches.

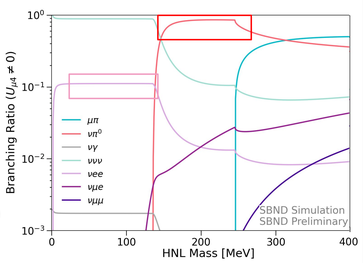


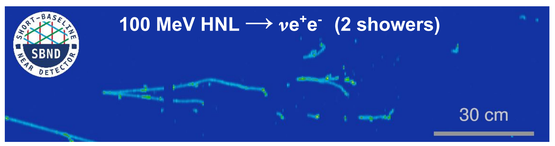
Heavy Neutral Leptons (HNLs)

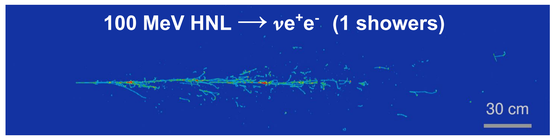
- HNLs explain neutrino lightness via the seesaw mechanism. HNLs mix with SM neutrino flavors via extended PMNS matrix
- Dominant production: BNB $K^+ \to \mu^+ N$ (HNL mass up to ~388 MeV)
- This analysis probes the muon-mixing parameter $|U_{\mu 4}|^2$ for Majorana HNLs through two channels:

  $N \to \nu e^+ e^-$ (35–140 MeV)

  $N \to \nu \pi^0$ (140–260 MeV)







Signal Selection

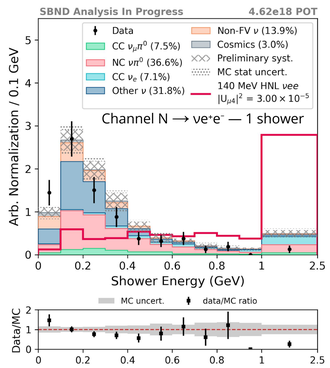
Pre-Selection
- Remove cosmic-like particles using Pandora's pattern recognition
- Vertex in fiducial volume (~71% of detector volume)

Charge-Light matching
- Scintillation light within the beam spill window
- Good match between charge in TPC and light in PMT systems

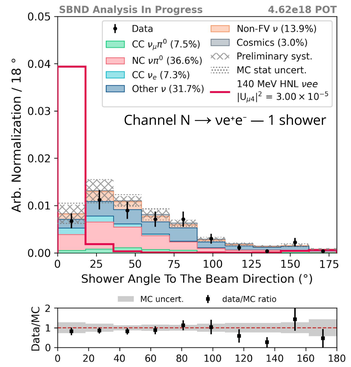
Topology Selection
- Number of tracks = 0
- Number of showers = 1 or 2

BDT
- Separates signal from background
- BDT score > 0.5

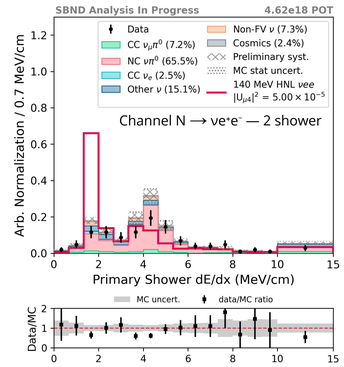
Shower Reconstruction



HNL decay products have higher energies than SM interactions



HNLs are highly boosted in the beam direction unlike SM background

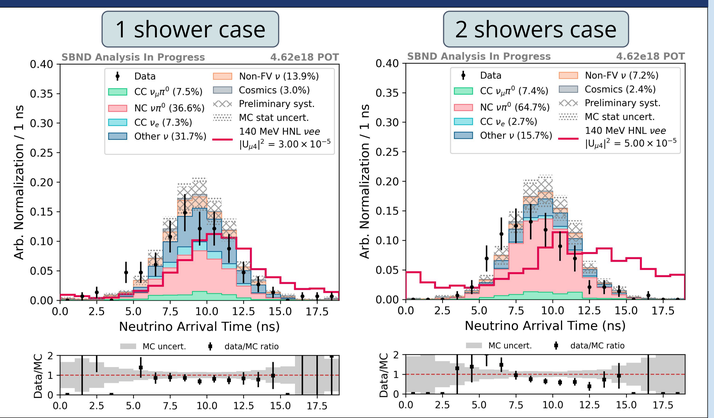


dE/dx used to distinguish electrons from photons

Good MC/Data agreement across all variables used in the BDT

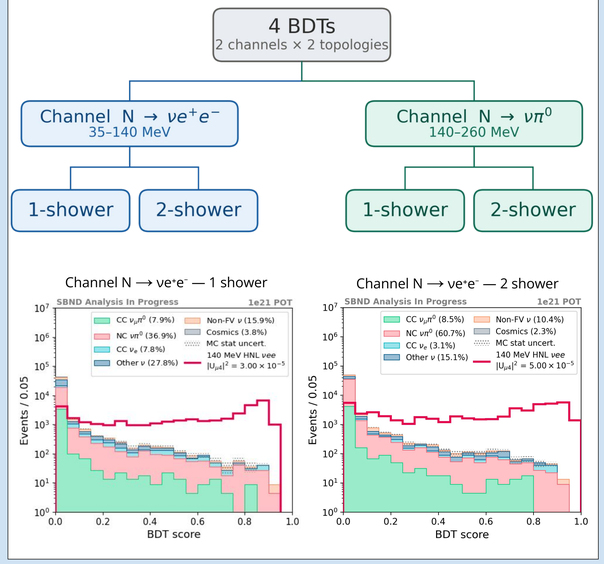
Timing Reconstruction

- Massive HNLs arrive a few ns delayed with respect to the SM neutrinos
- The 81 bunches of the BNB spill are collapsed into a single bunch
- First look at timing reconstruction for shower topologies
- Timing reconstruction is more challenging for 2 showers
- Active area of work within SBND



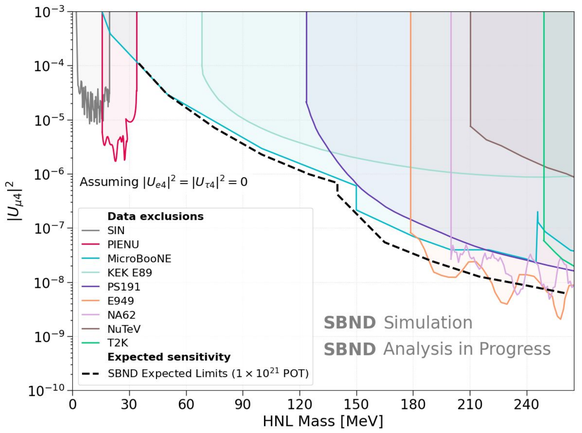
Boosted Decision Tree (BDT) Performance

BDTs use topological and calorimetry features.



Expected HNL Sensitivity

Sensitivity upper limits are extracted via a frequentist CL_s method based on a binned likelihood function over the beam bucket arrival time distribution.



SBND expected upper limits on the coupling $|U_{\mu 4}|^2$ at the 90% confidence level for Majorana HNLs.

SBND has the potential to explore uncharted space for heavy neutral leptons below the kaon mass!

U.S. DEPARTMENT of ENERGY

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