Towards a supernova-like neutrino cross-section measurement with muDAR in SBND

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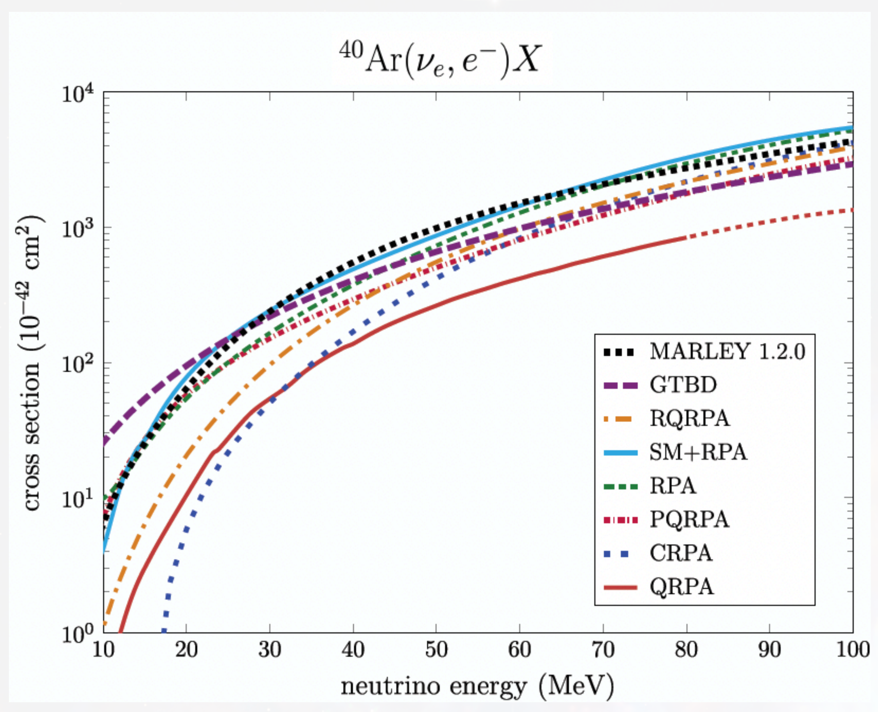
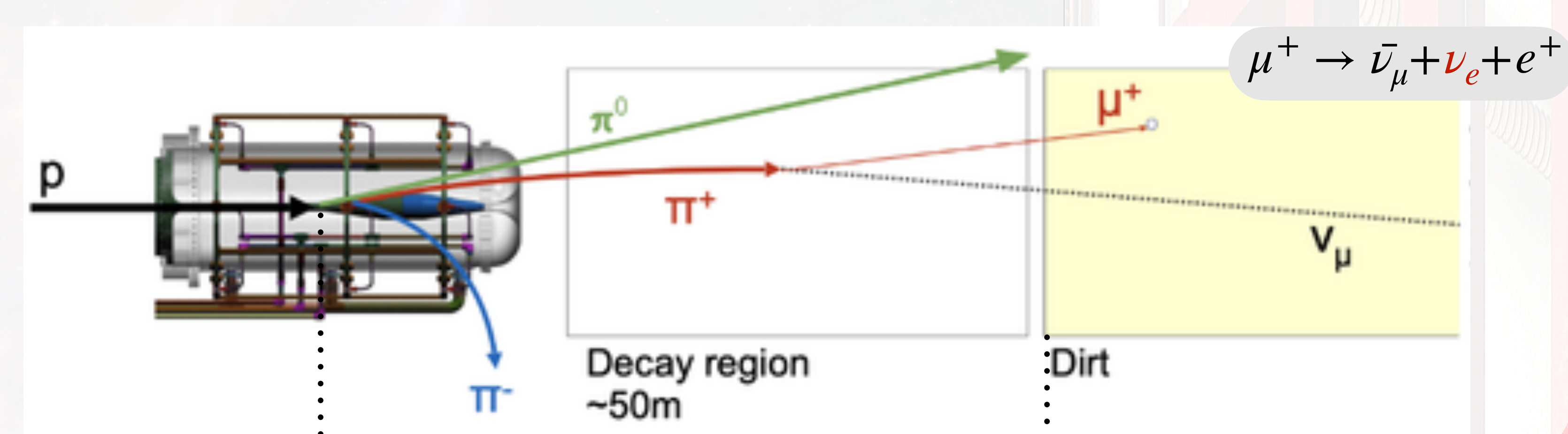
Astrophysical neutrinos

- Neutrinos are excellent cosmological messengers and can play a crucial role in answering some important questions at both the smallest and largest scales of the universe.
- DUNE will be a leading neutrino telescope with a rich programme of astroparticle physics. It will be uniquely sensitive to the **electron neutrino (ν_e)** forming the **supernova neutronization burst**.
- Current understanding of **σ(E_ν) is limited**. No ν_e-Ar measurements in the 10-50 MeV energy range [1].

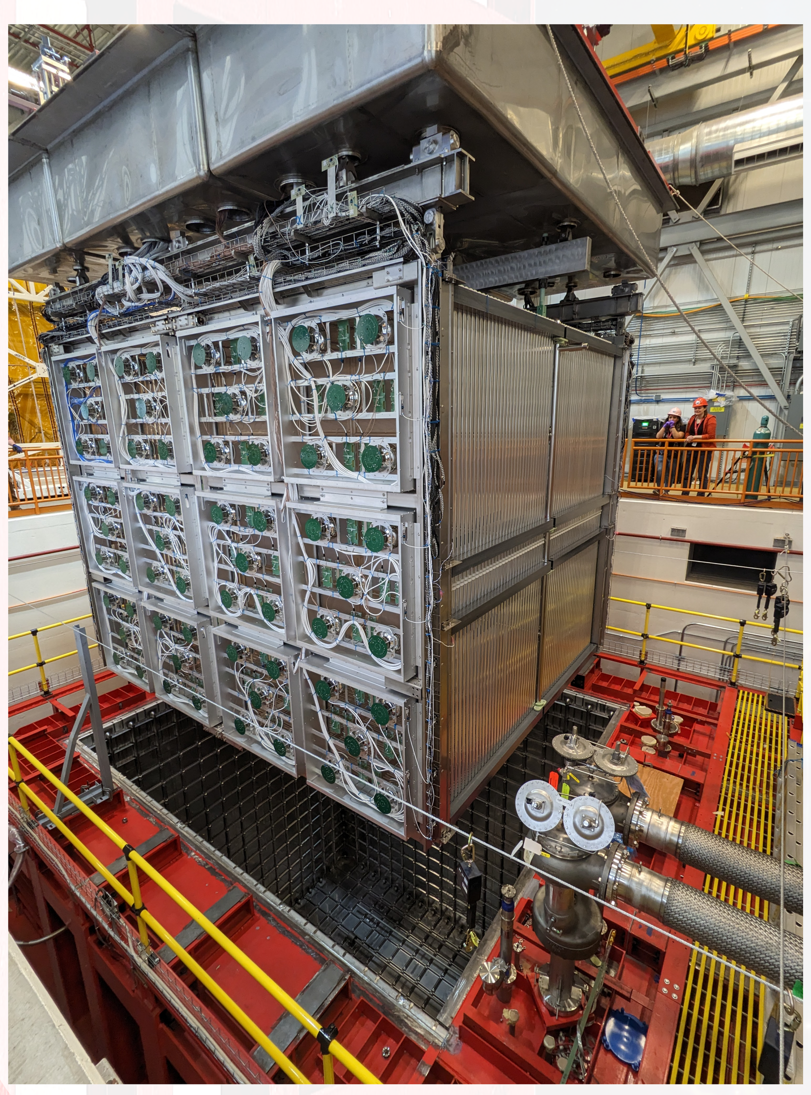


BNB

- The Booster Neutrino Beam (BNB) will provide over a million high-energy (~1 GeV) standard (mostly ν_μ) neutrinos per year (from decay-in-flight pions generated in proton-Beryllium collisions) to measure the un-oscillated content of the BNB with high statistics [2].
- **Muons** produced alongside these (ν_μ) neutrinos stop along the beamline in the hall and the absorber where they can later **decay at rest providing 10-50 MeV ν_e**.

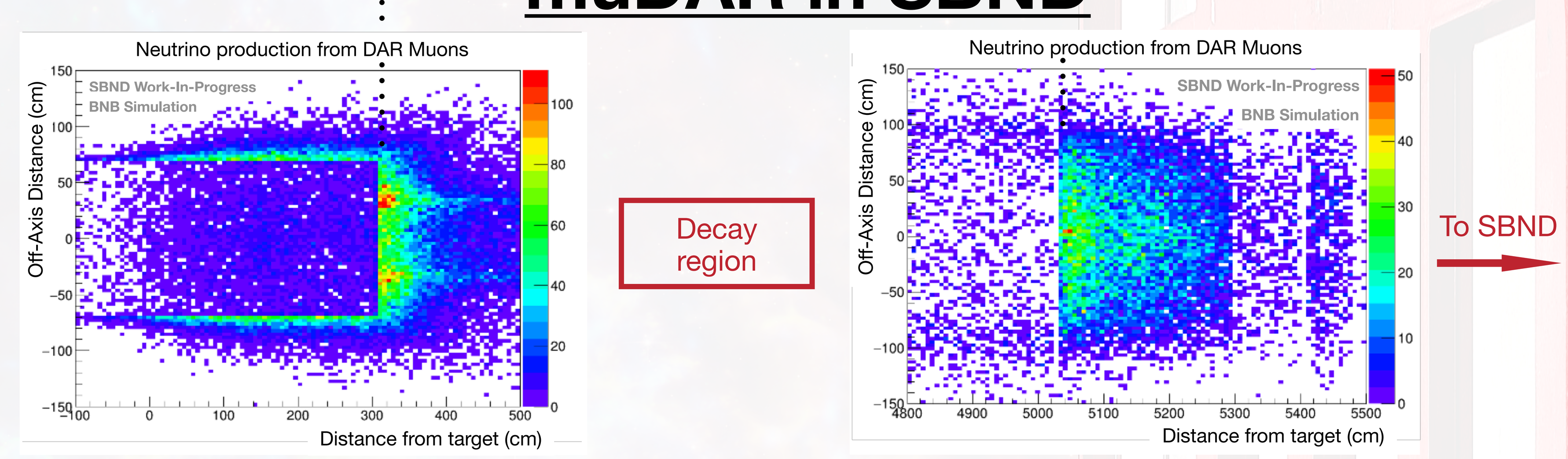


The SBND detector

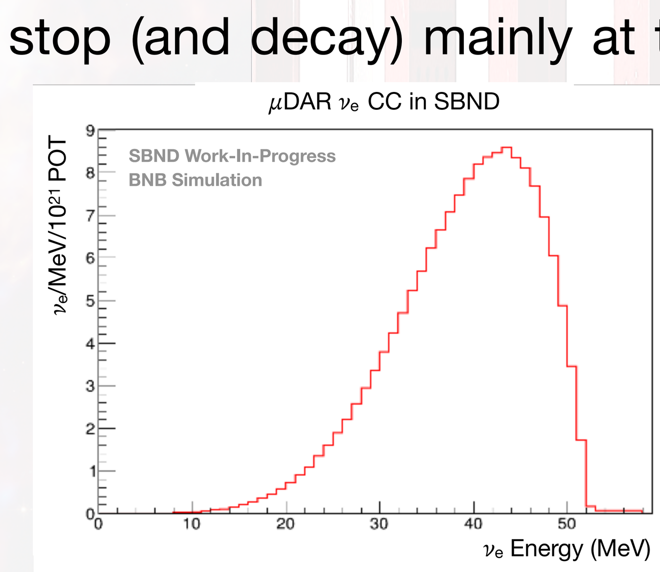


- Short-Baseline Near Detector (SBND) is located just **110 m** from the BNB target and has **112 tons** of liquid argon within the active volume of its detection systems [2].
- SBND has a broad science goal as part of SBN program.
- The combination of a highly capable LArTPC detector technology and its proximity to the BNB target, will enable precision studies of **neutrino-argon interactions**.

muDAR in SBND

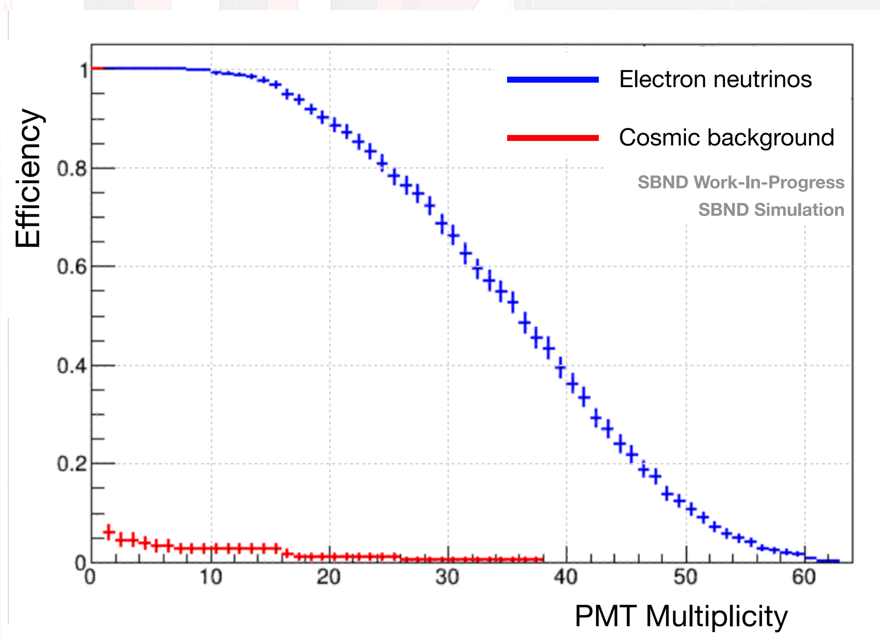


- G4BNB + MARLEY was used to evaluate the ν_e μDAR production.
- The ν_e μDAR come from muons that stop (and decay) mainly at the target hall and the absorber.
- BNB will deliver **~8x10^{15} μDAR ν_e/m^2**
- A total of **191 (per 10^{21} POT) ν_e** are expected in SBND.
- **161 ν_e CC** plus **30 ν_e - e** elastic scattering.



Triggering on muDAR neutrinos

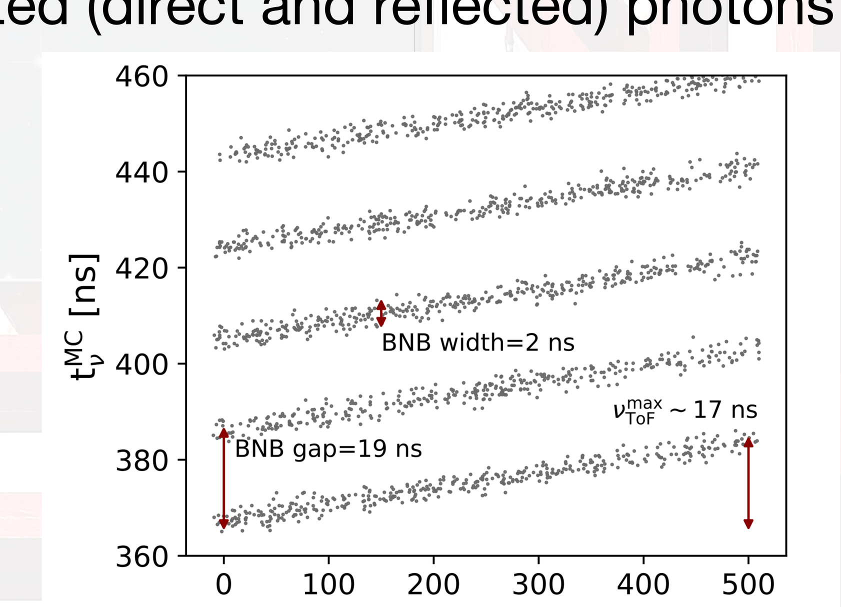
- The main background in a surface detector, as for "standard" ν_e, will be **cosmics**.
- Currently considered standard trigger schemes were evaluated showing similar performance for μDAR ν_e as for standard ν_μ (ν_e)



- The μDAR ν_e trigger efficiency for a **"OR" pairing scheme** that maximises neutrino efficiency is shown.
- A threshold of 5 PE for coated PMTs and 3 PE for uncoated PMTs is used.

Offline selection

- A preliminary selection using the Photon Detection System (PDS) to reject the large flux of cosmic background shows that requiring 500-1800 photons per ν_e interaction provides a signal selection efficiency of **87%** and a background rejection efficiency of **85%**.
- Further low-energy neutrino selection using the 5-9 (9-24) avereage number of reflected (direct and reflected) photons detected by the PMTs has shown potential increase to **94%** signal efficiency.
- Additional selection using the ns timing capabilities of SBND's PDS [3] and the μDAR ν_e delay by the muon lifetime is being explored.



[1] A. Abed Abud et al. (DUNE Collaboration). Impact of cross-section uncertainties on supernova neutrino spectral parameter fitting in the Deep Underground Neutrino Experiment. Phys.Rev.D 107 (2023) 11, 112012.
[2] P. A. Machado et al. The Short-Baseline Neutrino Program at Fermilab. Annual Review of Nuclear and Particle Science 69, 363-387 (2019)
[3] P. Abratenko et. al. (SBND Collaboration). Scintillation Light in SBND: Simulation, Reconstruction, and Expected Performance of the Photon Detection System. arXiv 2406.07514

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