Validating the Field Response Simulation of the Short-Baseline Near Detector (SBND)

Harry Scott on behalf of the SBND collaboration

Department of Physics and Astronomy, The University of Sheffield

1: Introduction

The Short-Baseline Near Detector (SBND) is a state-of-the-art liquid argon neutrino detector on the Short Baseline Neutrino programme at Fermilab, USA. SBND has developed a detailed simulation underpinning its rich measurement program with high statistics event samples. The simulation models the signals generated by energy depositions on the detector readout wires. The 'field response' signal is due to ionisation electrons drifting through the anode plane assemblies, inducing a current on the readout wires. The work presented in this poster validates the algorithms used in the simulation that emulate the detector reading out the field response signal.

2: The Short Baseline Neutrino (SBN) Programme

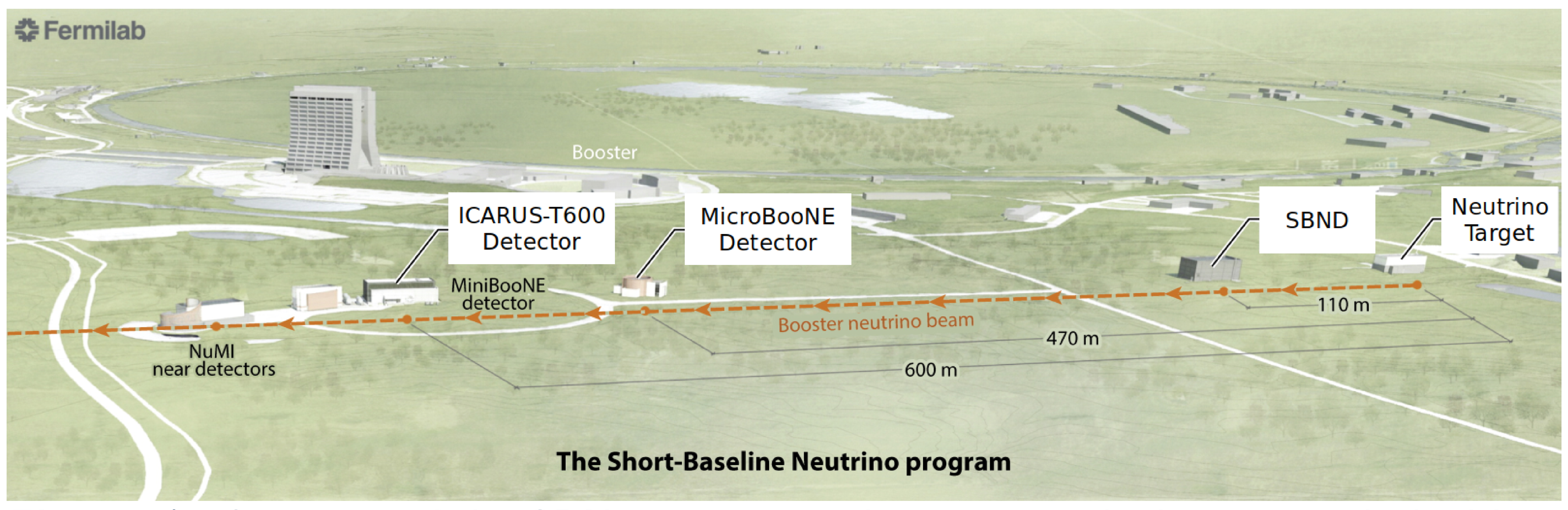

Figure 1: Overview of the SBN programme detectors, with the orange dashed line representing the Booster Neutrino Beam beamline [1].

- The SBN programme will measure interactions of neutrinos, from the Booster Neutrino Beam, with liquid argon in the ICARUS-T600 detector, MicroBooNE and SBND (600 m, 470 m and 110 m from the beam target respectively).
- It will determine if sterile neutrinos - a proposed 4th neutrino flavour which only couples to gravity - are the cause of neutrino oscillation data anomalies.
- It will also take precise measurements of ν-Ar cross-sections, and search for rare processes that could hint at physics beyond the standard model [2].

3: The Liquid Argon Time Projection Chamber (LArTPC)

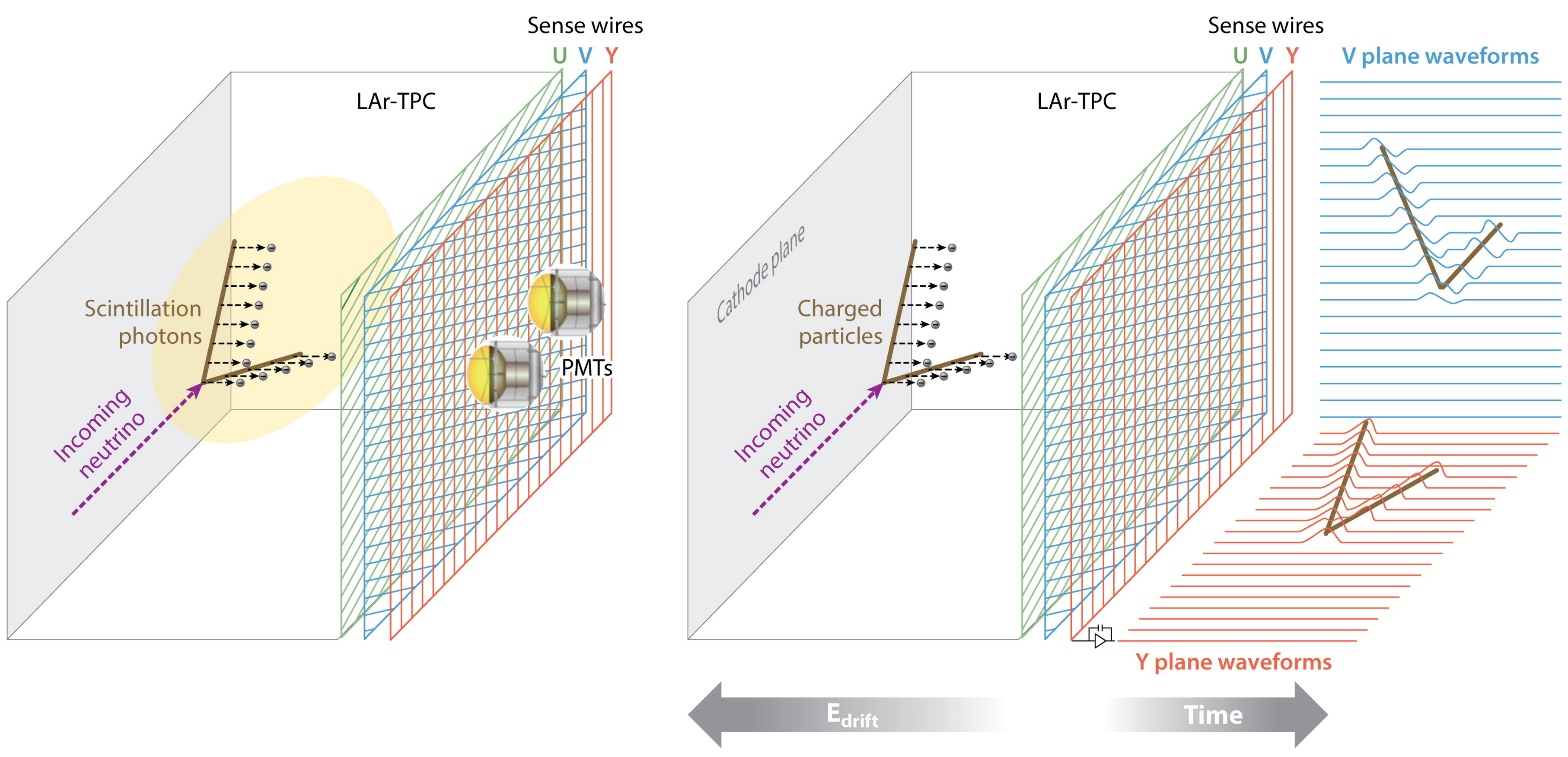

Figure 2: General setup and operation of a LArTPC [1].

- LArTPCs are particle detectors housing a large volume of liquid argon subject to a uniform electric field, allowing for full 3D imaging of particle interactions.
- Incoming neutrinos interact weakly with argon atoms, producing charged particles, which in turn excite and ionise argon atoms in their path.
- Ionisation electrons drift towards the anode plane assemblies - which consists of two induction wire planes (U and V) angled at $\pm 60°$ from the vertical, and one collection wire plane (Y) angled vertically - where the signal is read out.
- De-excitation photons are collected by photomultiplier tubes (PMTs) behind the APA, aiding in particle track reconstruction and event matching [2].

4: The Short Baseline Near Detector (SBND)

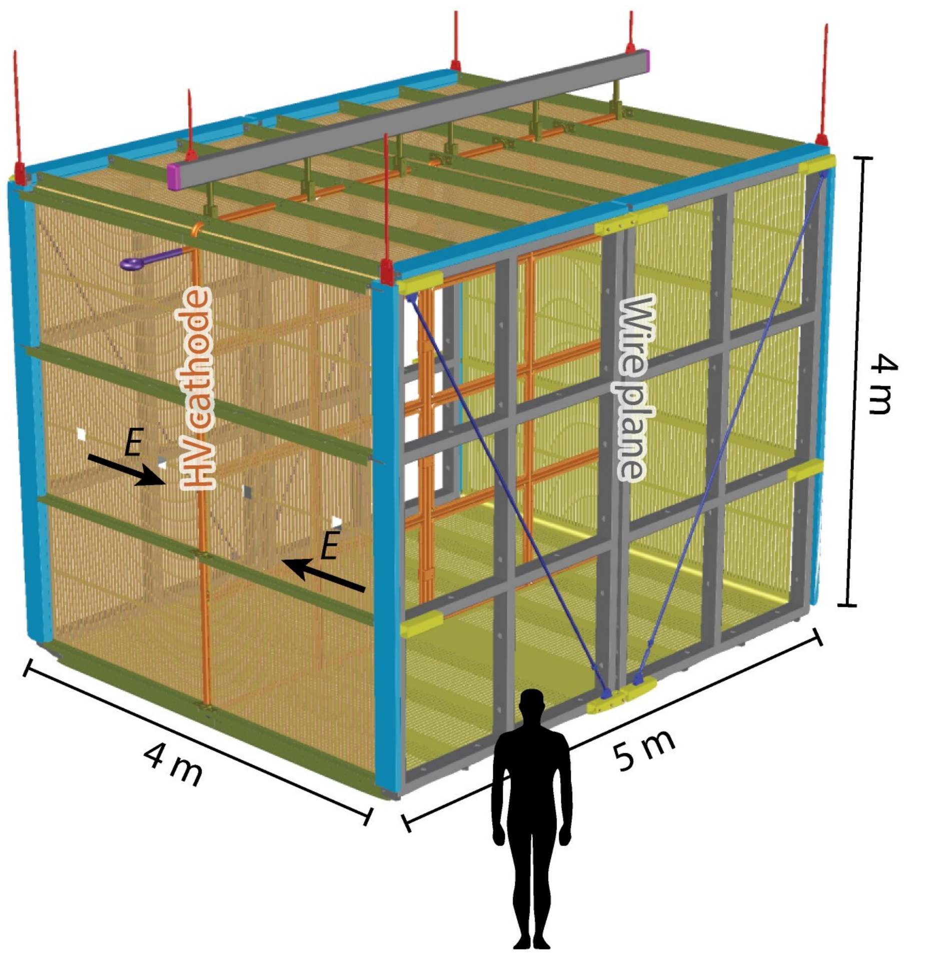

Figure 3: Detector design of SBND [1].

- SBND is the near-detector of the SBN programme, measuring the unoscillated flux of the BNB.
- The detector consists of two LArTPC modules, separated by a cathode, drifting any charges to the APA where the charge is read out.
- It has a total LAr mass of 220 tons, with an active mass of 112 tons, and is expected to observe over 7 million neutrino events in its lifetime.
- The high neutrino flux of SBND will also allow for the most precise ν_μ-Ar and ν_e-Ar scattering cross section measurements to date.

5: Field Response Signal

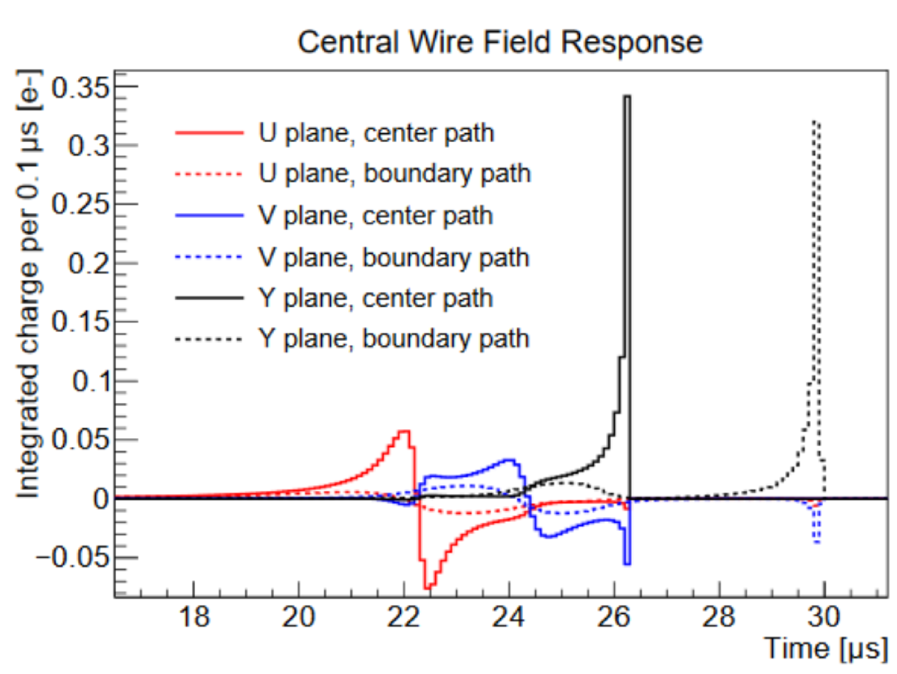

Figure 4: Simulated field response signal of MicroBooNE for each wire plane [3].

- SBND is under construction, so a simulation underpinning its measurement program with high statistics events has been developed.
- The simulation models the signals generated by energy depositions on the detector readout wires.
- The 'Field Response' is a signal due to electric fields from ionisation electrons inducing currents on wires.
- This work validates that the SBND simulation correctly models the field response signal.

6: SBND Signal Waveform Plots

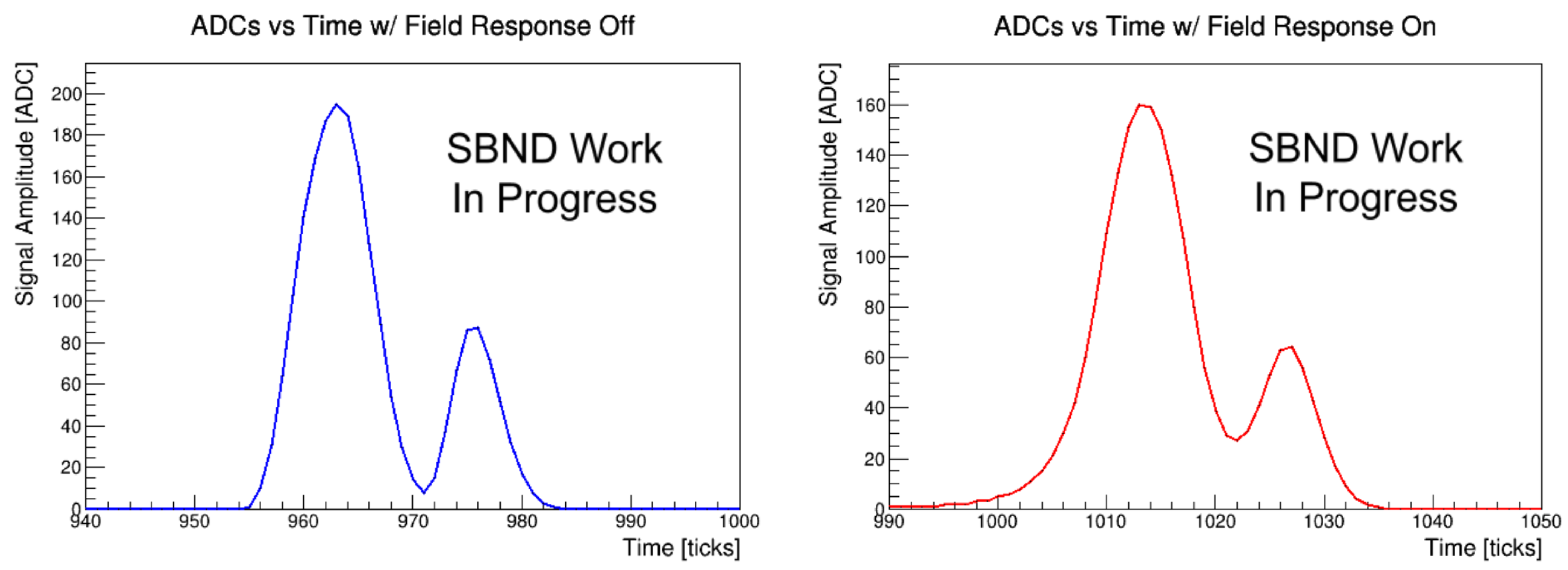

Figure 5: Simulated signal waveforms from a single wire with the field response turned off (left) and on (right). Time units are in ticks, where 1 tick $= 0.5$ μs.

- A single cosmic-ray muon crossing through the anode and cathode leaving an ionisation signal on the anode plane assemblies was simulated.
- Signal waveforms from a single anode wire are shown in figure 5.
- The left graph depicts the signal with zero impact from the field response; the right has the appropriate contribution from the field response.
- The full data readout window is 3400 ticks, equating to 1.8 ms.
- The field response broadens the signal waveforms; increasing the width from 28 ticks to 45 ticks and decreasing the amplitude from 200 ADC to 160 ADC.

7: Methodology for Validating the Field Response Simulation

- Simulate a large number of anode-cathode crossing cosmic-ray muon tracks.
- Run the simulation once with zero impact from the field response (truth data), and once with the expected contribution from the field response (reco data).
- Write an algorithm that finds the average shape of the waveform from all anode collection plane wires, using tracks close to the anode.
- Compare the truth data with the reco data by convolving the averaged 'field response off' waveform with the averaged 'field response on' waveform.
- Find the bias in the result of the convolution and correct for it.
- Repeat this method, finding the uncertainty after each iteration.

8: Conclusions and Further Work

- The field response signal of the SBND simulation is validated by modelling anode-cathode crossing cosmic muon tracks, then comparing the waveforms with and without the impact from the field response.
- Next step is to perform the methodology in section 7 in order to validate the simulation models the field response signal.

References

[1] Machado PAN, Palamara O, Schmitz DW. The Short-Baseline Neutrino Program at Fermilab. Annual Review of Nuclear and Particle Science. 2019, 69(1):P0363-87.

[2] Acciarri R, et al., A Proposal for a Three Detector Short-Baseline Neutrino Oscillation Program in the Fermilab Booster Neutrino Beam. arXiv. 2015.

[3] Adams C, et al., Ionization Electron Signal Processing in Single Phase LArTPCs I. Algorithm Description and Quantitative Evaluation with MicroBooNE Simulation. JOI. 2018, 13(07):P07006-6.