Status of Wire-Cell in the SBND experiment

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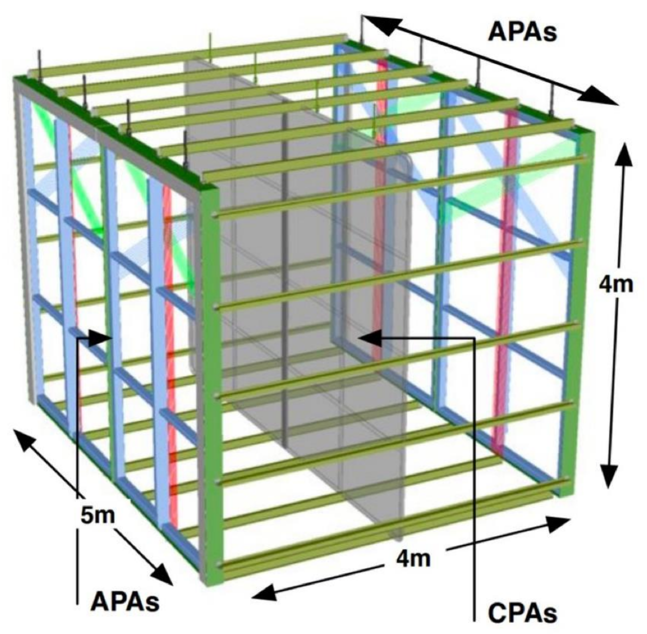
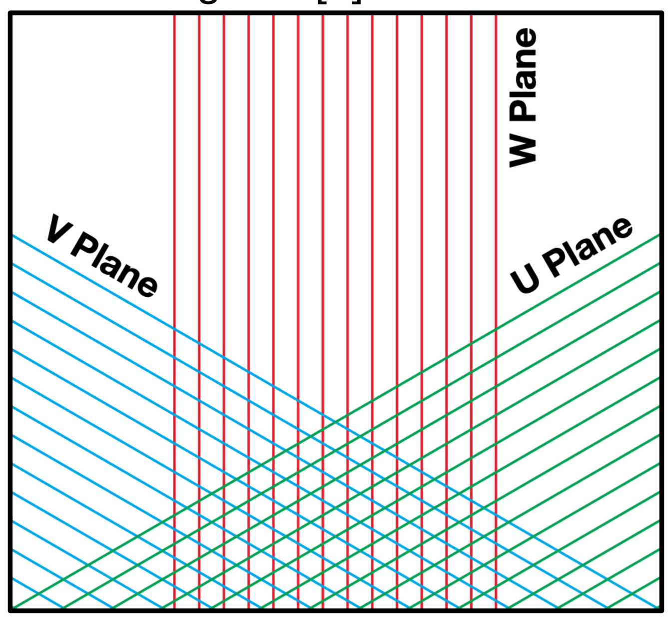
Short-Baseline Near Detector (SBND)

The Short-Baseline Near Detector (SBND), a 112 ton liquid argon time projection chamber (LArTPC), is the near detector of the Short-Baseline Neutrino Program [1]. In a LArTPC, ionization electrons from a charged particle interaction drift along electric field lines, inducing bipolar signals on induction wire planes and a unipolar signal on the collection wire plane. These measured signals undergo noise filtering, deconvolution, and signal processing to recover the original ionization signal. WireCell, a software package developed for LArTPCs, implements 2D deconvolution (in time and wire dimensions) to correct for the inter-wire induction field effects inherent to LArTPC signals [2].

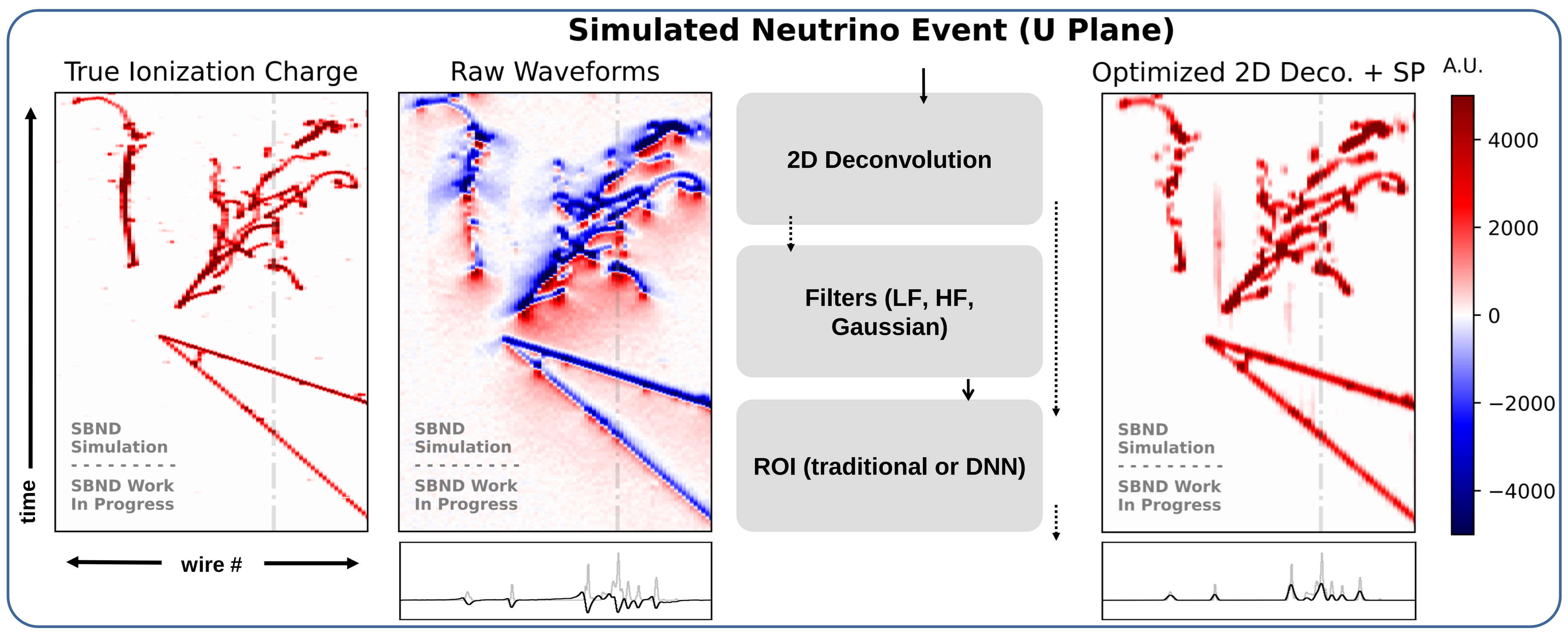


Model of the SBND detector [3], showing anode plane and cathode plane assemblies (APAs and CPAs). Wires are located on the APAs.

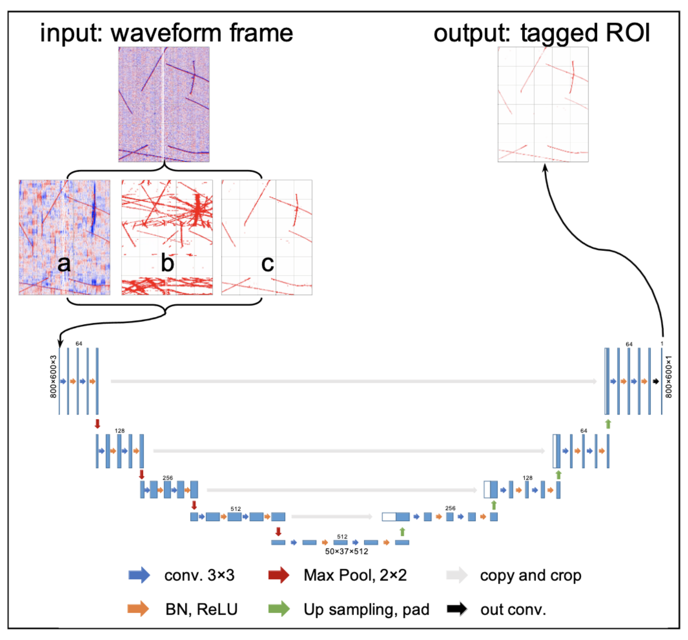


Layering of wires in SBND. U and V are the induction planes, rotated $\pm 60^\circ$ from the vertical. Wires are separated by 3mm in each plane.

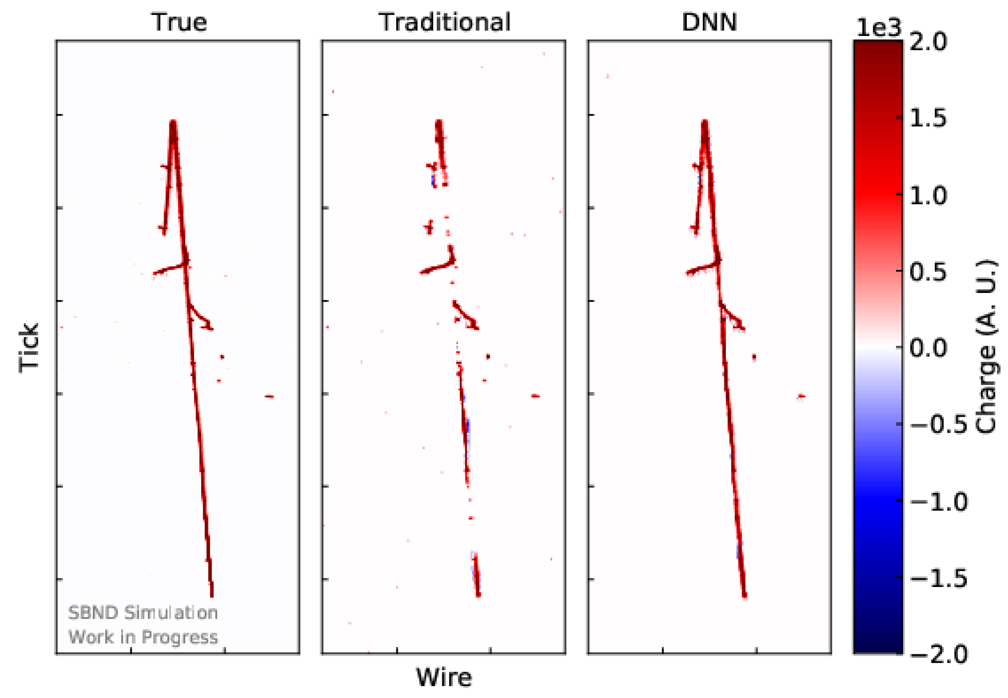
Simulated Neutrino Event (U Plane)



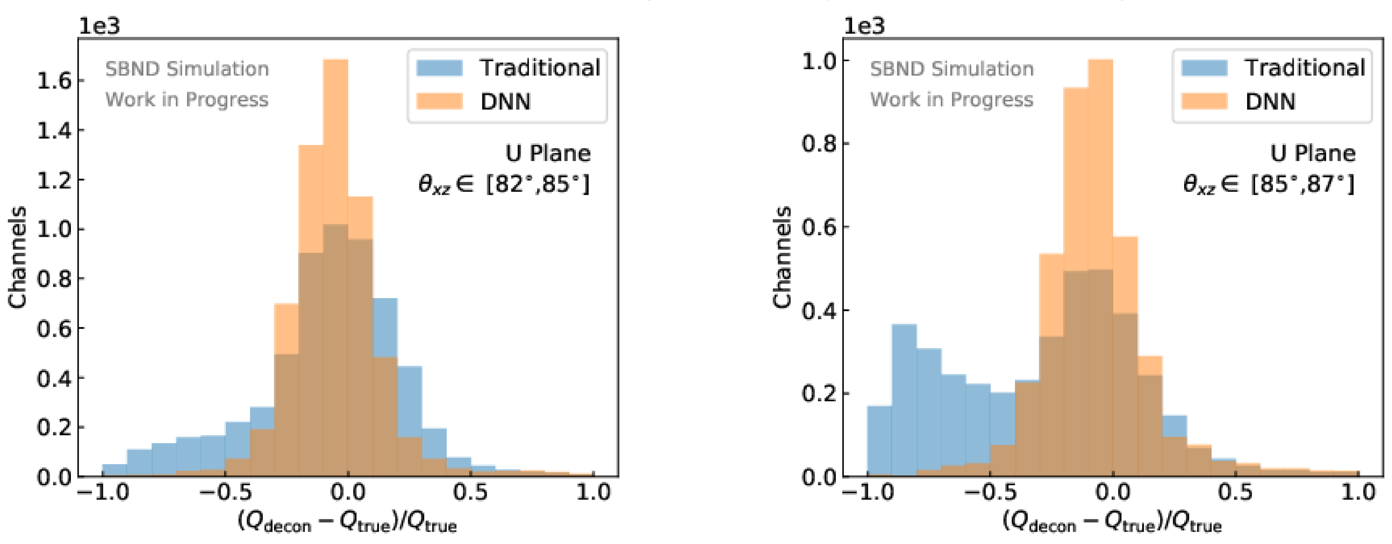
DNN Based ROI Finding in SBND



U-Net architecture used in the ROI detection for the DNN LArTPC signal processing



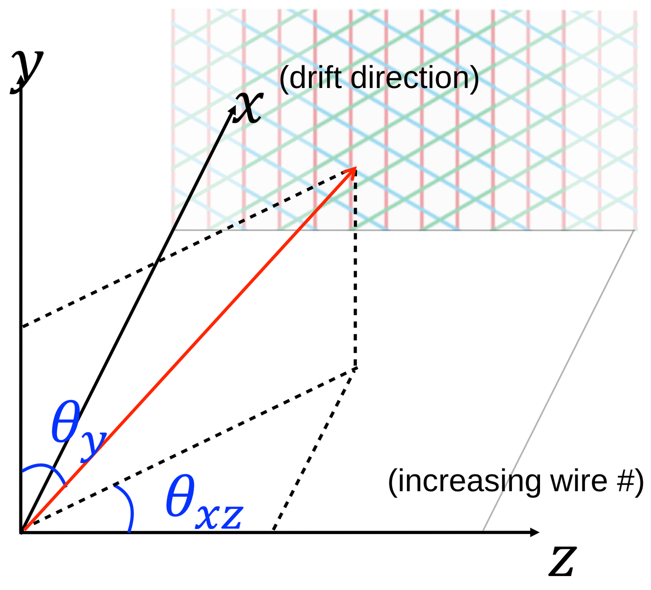
Comparison of the target (left), traditional ROI output (center) and DNN ROI prediction output (right) images.



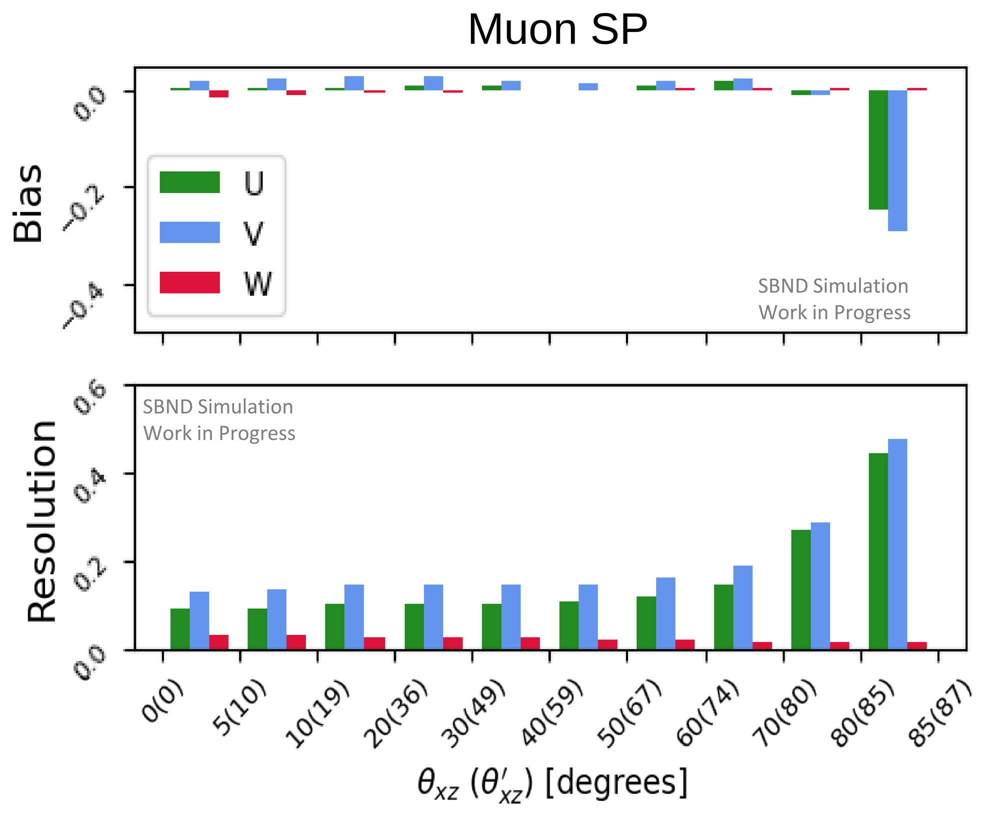
Charge bias and resolution in the ROI window predicted by the DNN as compared to the traditional ROI

1. Initial ROIs are formed by combining the deconvolved signals with tight and loose low-frequency software filters.
2. Across the channels, these initial signal ROIs are sliced into contemporaneous time slices of fixed duration
3. For a time slice, we determine a subset of channels from each plane consisting of those that are inside the initial ROIs.
4. For each induction-plane channel inside the subset, we determine if any of its wires overlap with two wires from the other two subsets (one from each). The successfully matched channels are the three-plane coincidence (MP3).
5. For each induction-plane channel outside of the subset, we determine if any of its wires overlap with two wires from the other two subsets (one from each). The successfully matched channels are the two-plane coincidence (MP2)

Signal Processing Optimization in SBND



Geometric coordinates and angles. The θ_{xz} angle of the track affects the signal shape on the wires. θ_y affects the signal amplitude only.

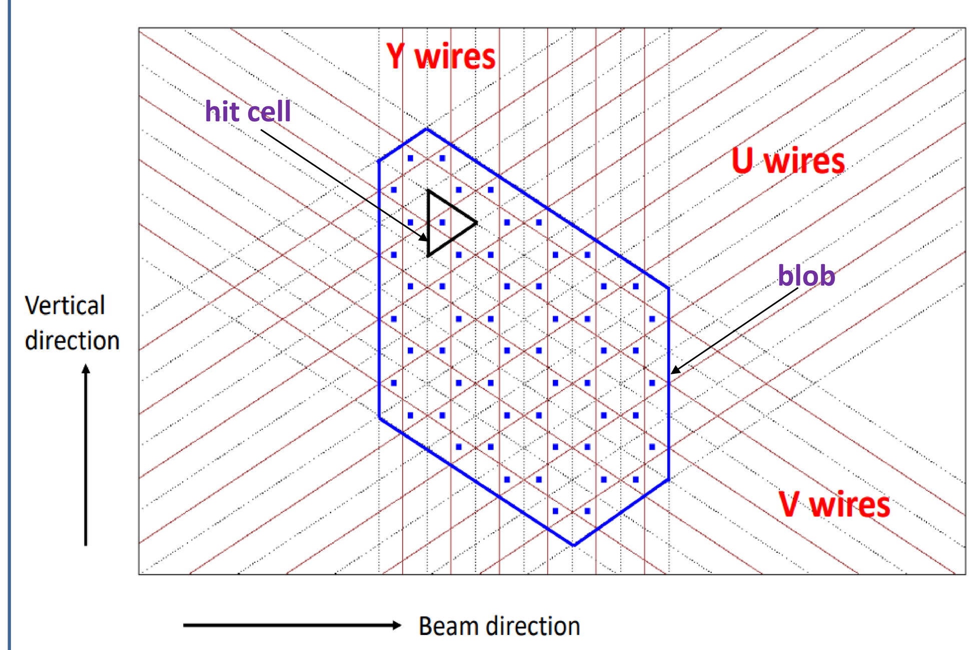


Percent bias and resolution of charge extraction using optimal SP filter values for all angular bins.

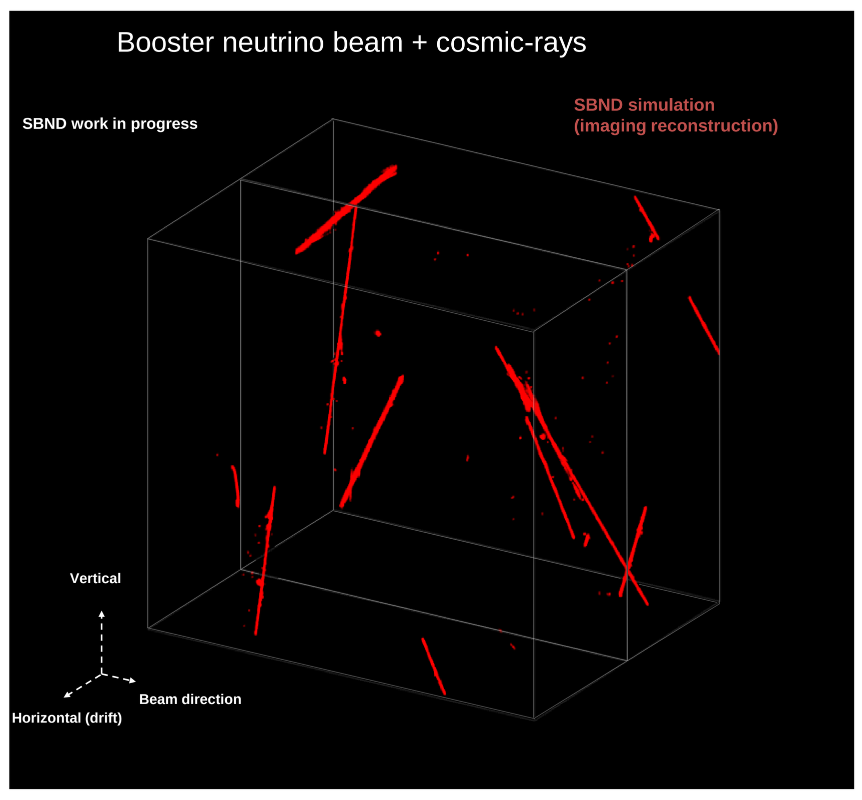
The main steps of SP are 2D deconvolution, high (HF) and low-frequency (LF) filters, and region-of-interest (ROI) finding. ROIs are implemented to limit LF noise and preserve charge extraction [2]. To optimize the SP chain, we simulated MIP particles in known θ_{xz} bins to maximize the charge extraction performance (bias, resolution, failure rate). We performed coordinate descent over SP filter (e.g. HF Wiener, LF, wire filters, etc.) values to determine optimum parameters.

WireCell 3-D Imaging Reconstruction in SBND

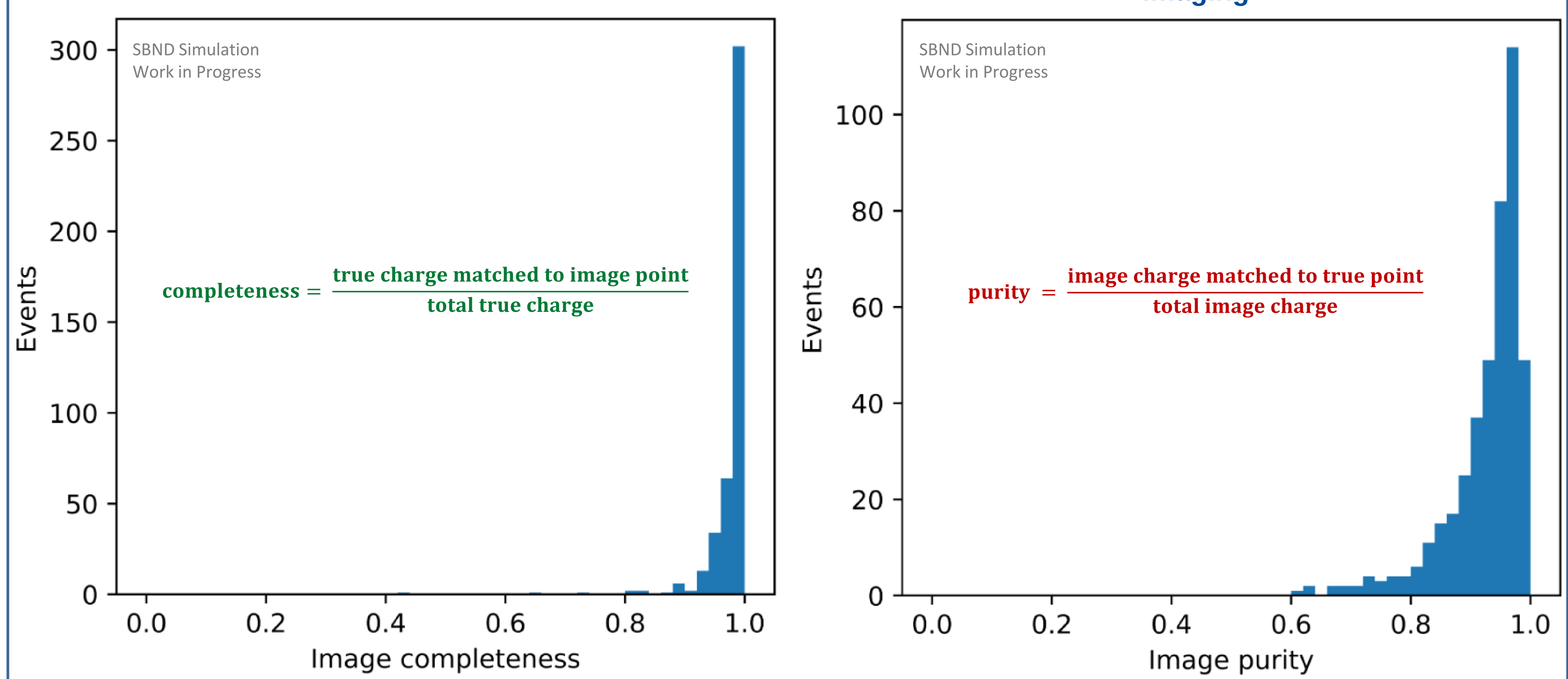
Tomographic event reconstruction [5] which creates a 3-D image of the electrons inside the TPC. Charge, time, geometry, connectivity and sparsity information are used to solve a minimization problem, which aims to relate the charge measured by a wire to the unknonwn charges of all possible hit cells along this wire. It uses charge from three wire planes (three 2D views) in a 2μs time slice window. A L1 regularization is used to speedup the minimization problem.



All possible hit cells that can be created by the hit wires.



Reconstructed cosmic-rays tracks using Wire-Cell imaging



Evaluation of imaging performance using neutrino events, overlayed with cosmic tracks. A KD-Tree query ball algorithm is used to match the nearest truth energy deposit to a given reconstructed imaging blob. Two metrics are defined to evaluate the 3-D imaging reconstruction performance, using 400 events. The good performance allows one to use imaging clusters as input to high-level reconstruction algorithms.

Acknowledgement

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References

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[2] C. Adams *et al* 2018 *JINST* **13** P07006
[3] R. Acciarri *et al* 2020 *JINST* **15** P0603
[4] H.W. Yu *et al* 2021*JINST* **16** P01036
[5] The MicroBooNE collaboration *et al* 2021 *JINST* **16** P06043