

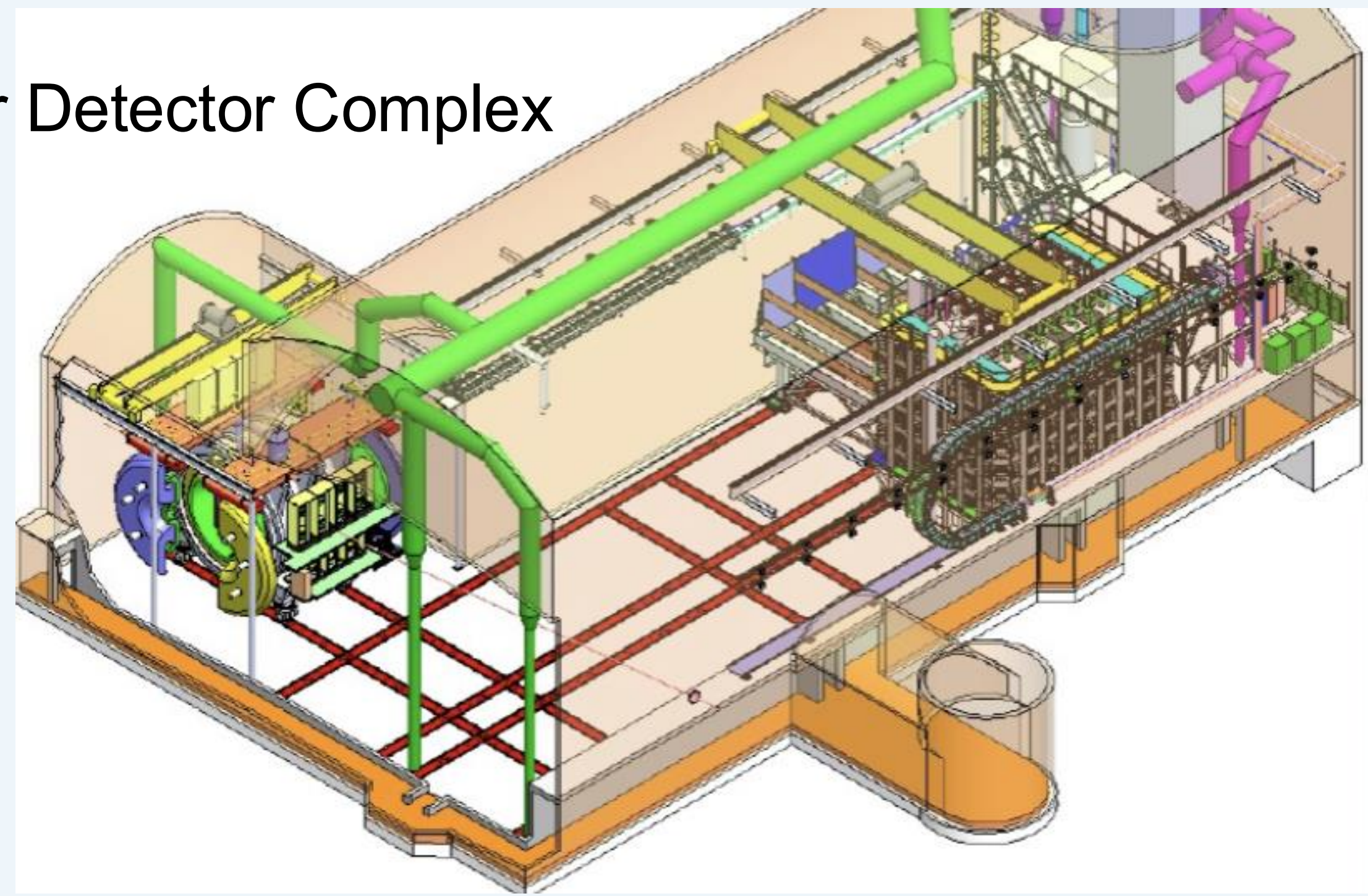
# GPU-Accelerated Simulation and Signal Unfolding for DUNE ND-LAr

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arXiv:2602.12052

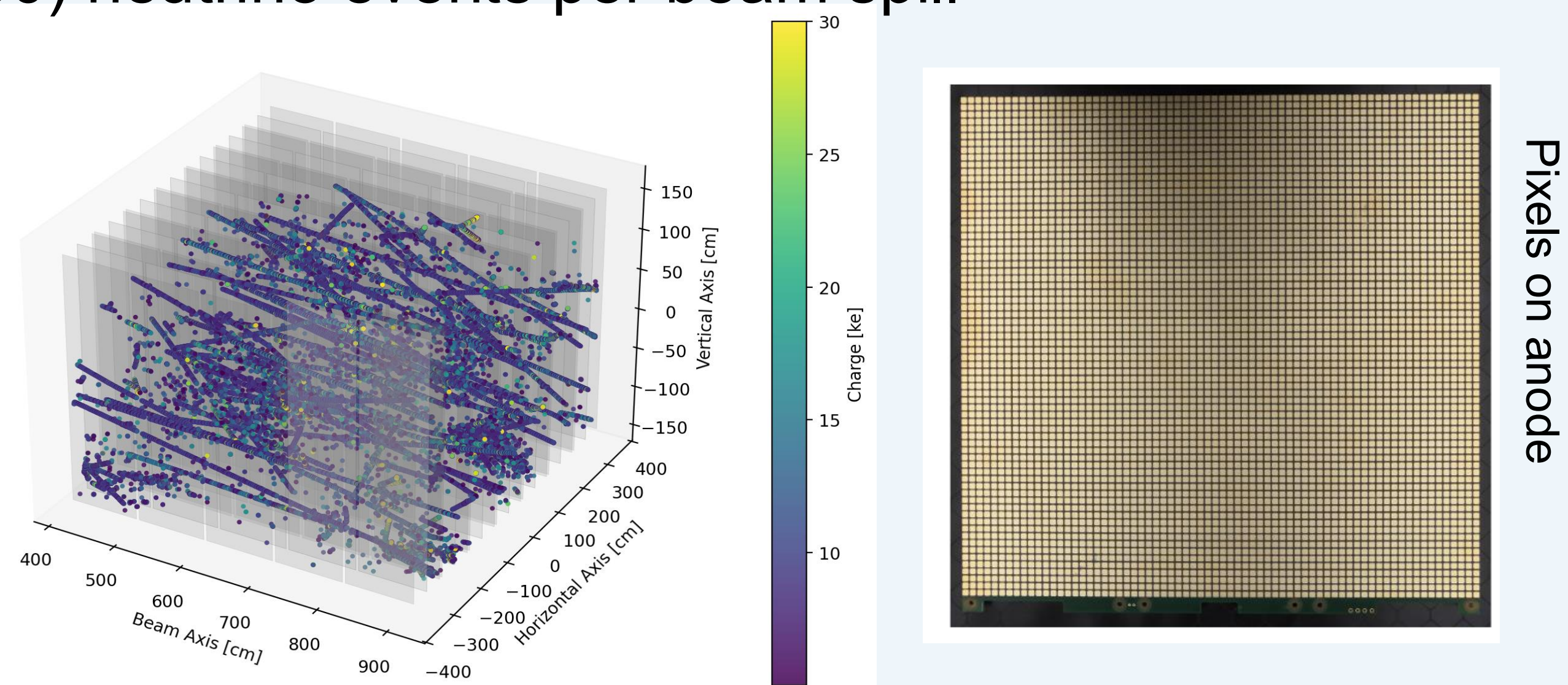
## DUNE & Scalable Simulation

**DUNE:** long-baseline neutrino oscillation experiment, with a near detector complex and far detectors located 1300 km away.

### Near Detector Complex



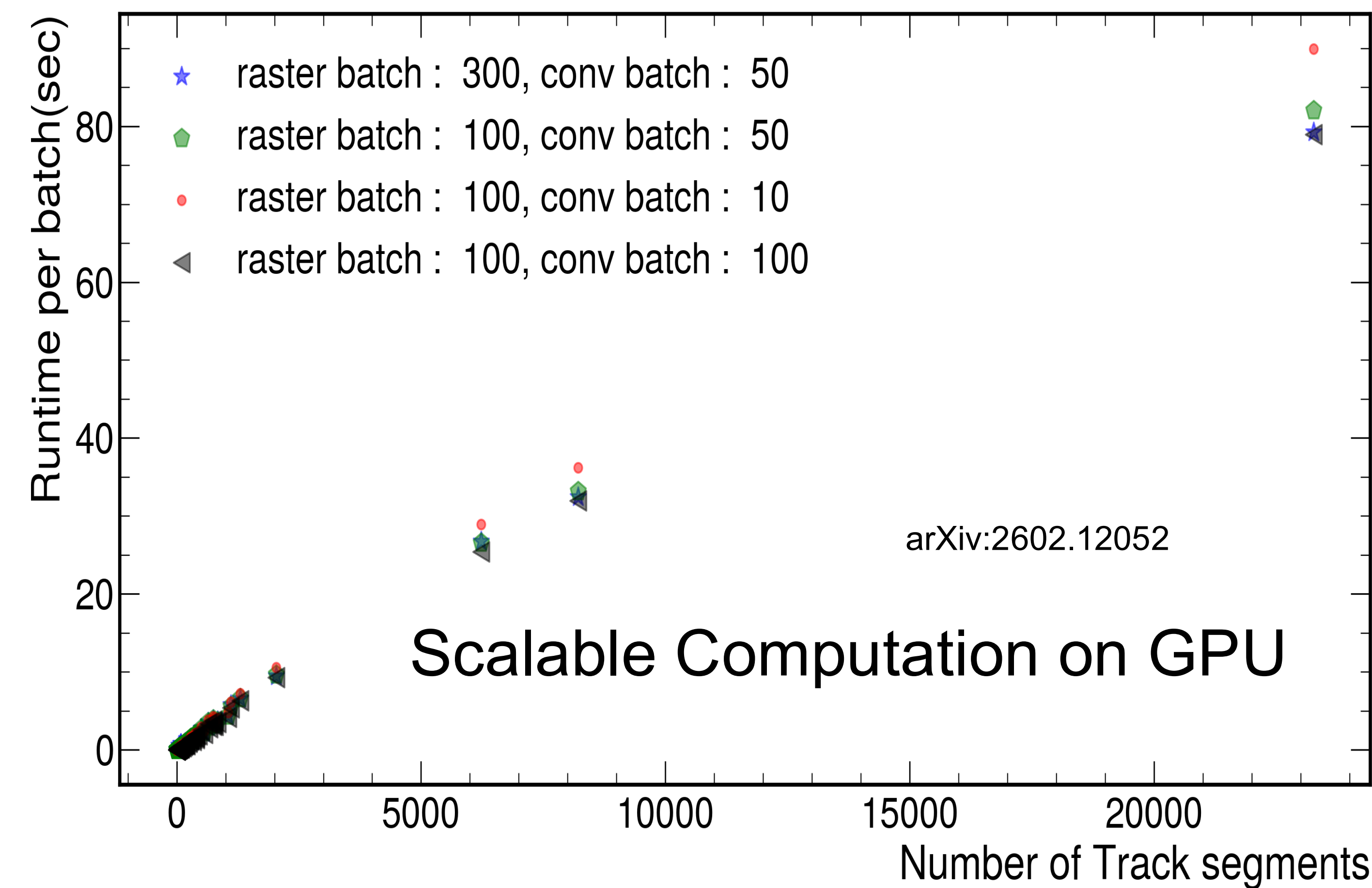
- ND-LAr: 70 modular pixelated liquid-Argon TPC at near detector complex ~14 million readout channels per module
- O(50) neutrino events per beam spill



## Factorized analytic solution + efficient implementation

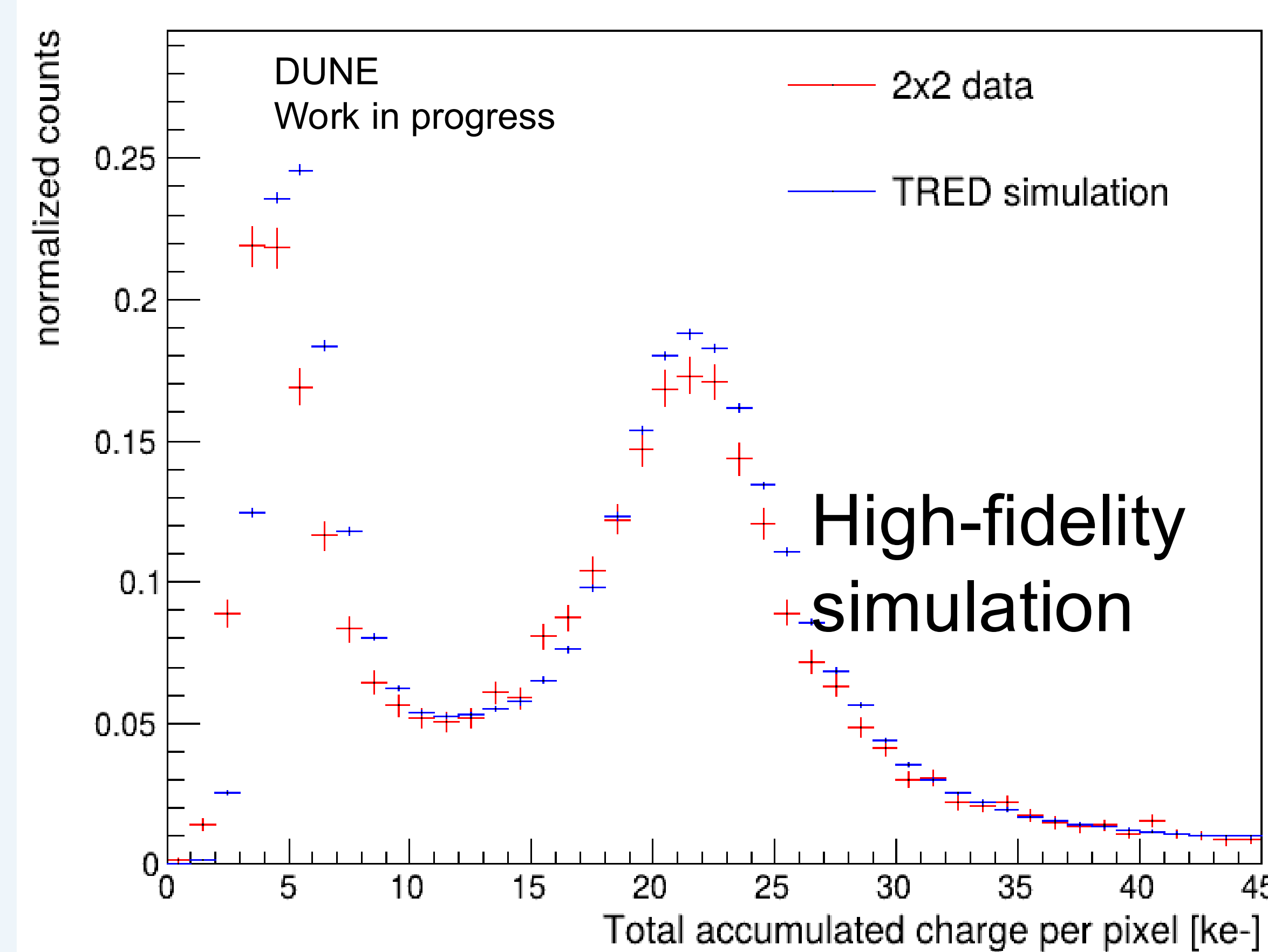
- Factorized and analytic solution for induced waveform = ionization charge \* field response.
- Hierarchy batching for controlling GPU memory consumptions.
- Novel abstract data class, Block Sparse Binned Tensor, to allow FFT on sparse data.

## Simulation and computing performance



## Preliminary Simulation/Data comparison

Isochronous through-going tracks to anodes are selected. Characteristic energy deposition from Minimum Ionization Particles are observed in both data and simulation.



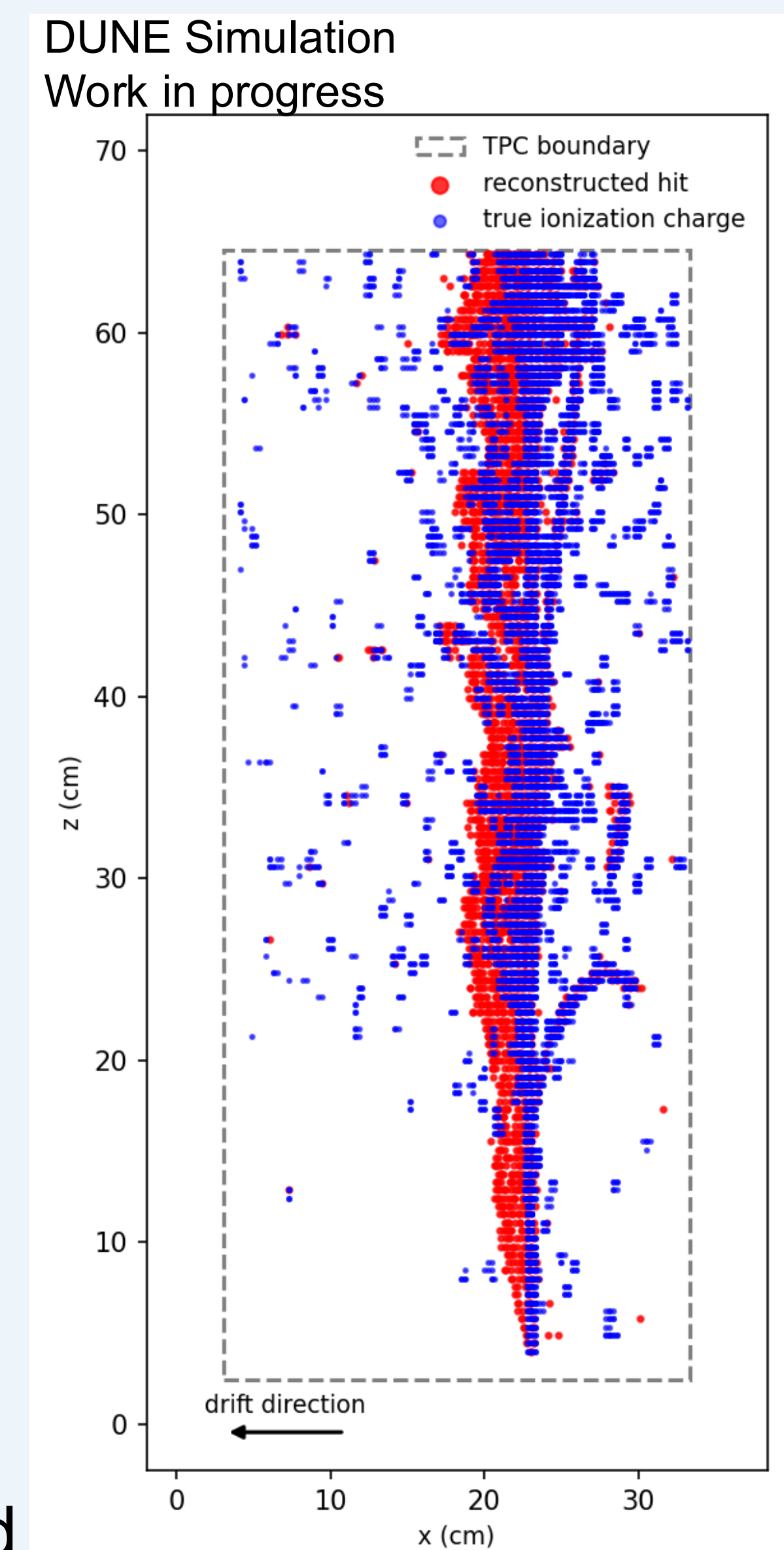
## Signal processing for re-triggering

**Issue:** Ionization charge signals are split into multiple hits due to long-range induced coherent signals.

**Limitation:** Full waveforms required by traditional signal processing are zero-suppressed, by threshold+self-triggering

**Solution:** LArPix continuously records integrated charge on pixels after triggering.

**Deconvolution approach:** Recover zero-suppressed waveforms using physics-guided signal templates.



## Preliminary Studies in Simulation

- Performance tested on simulated positron-shower in LArTPC.
- Regressed charge agrees well with the true ionization charge.

