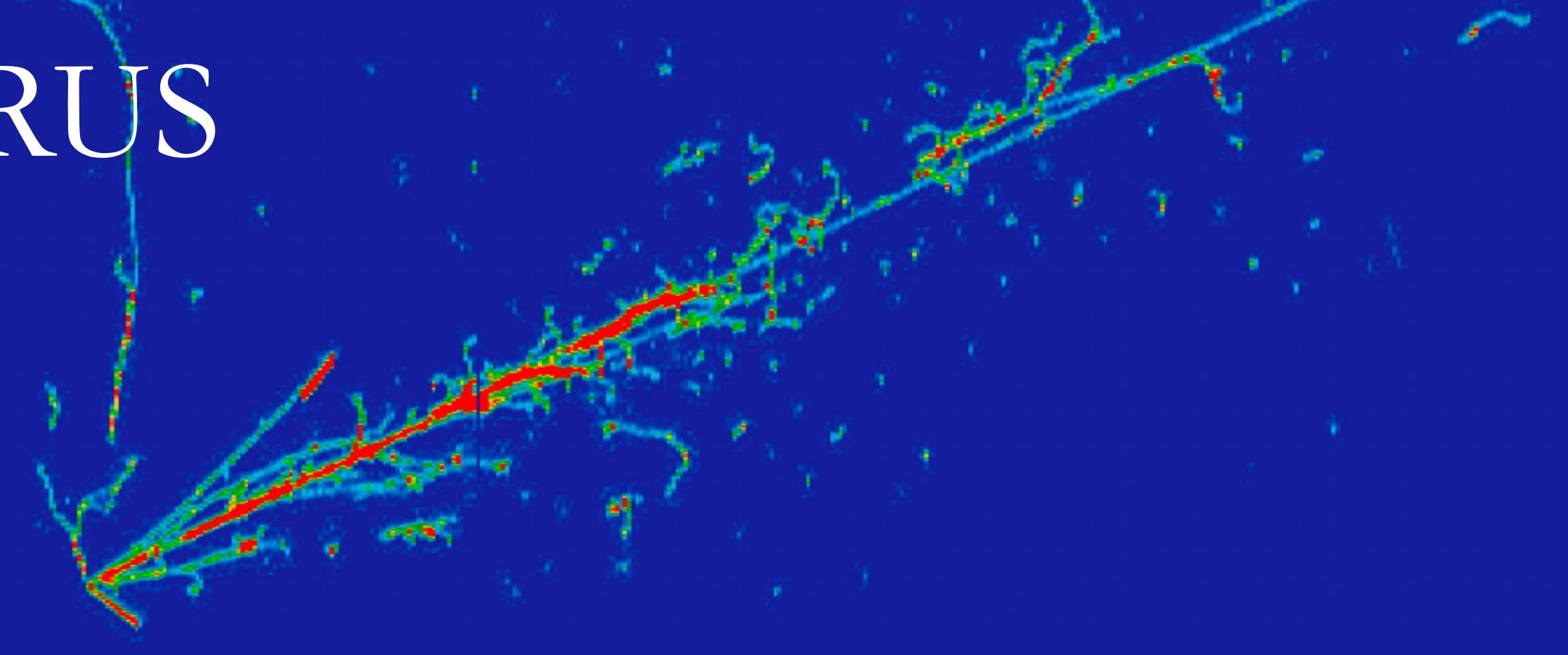


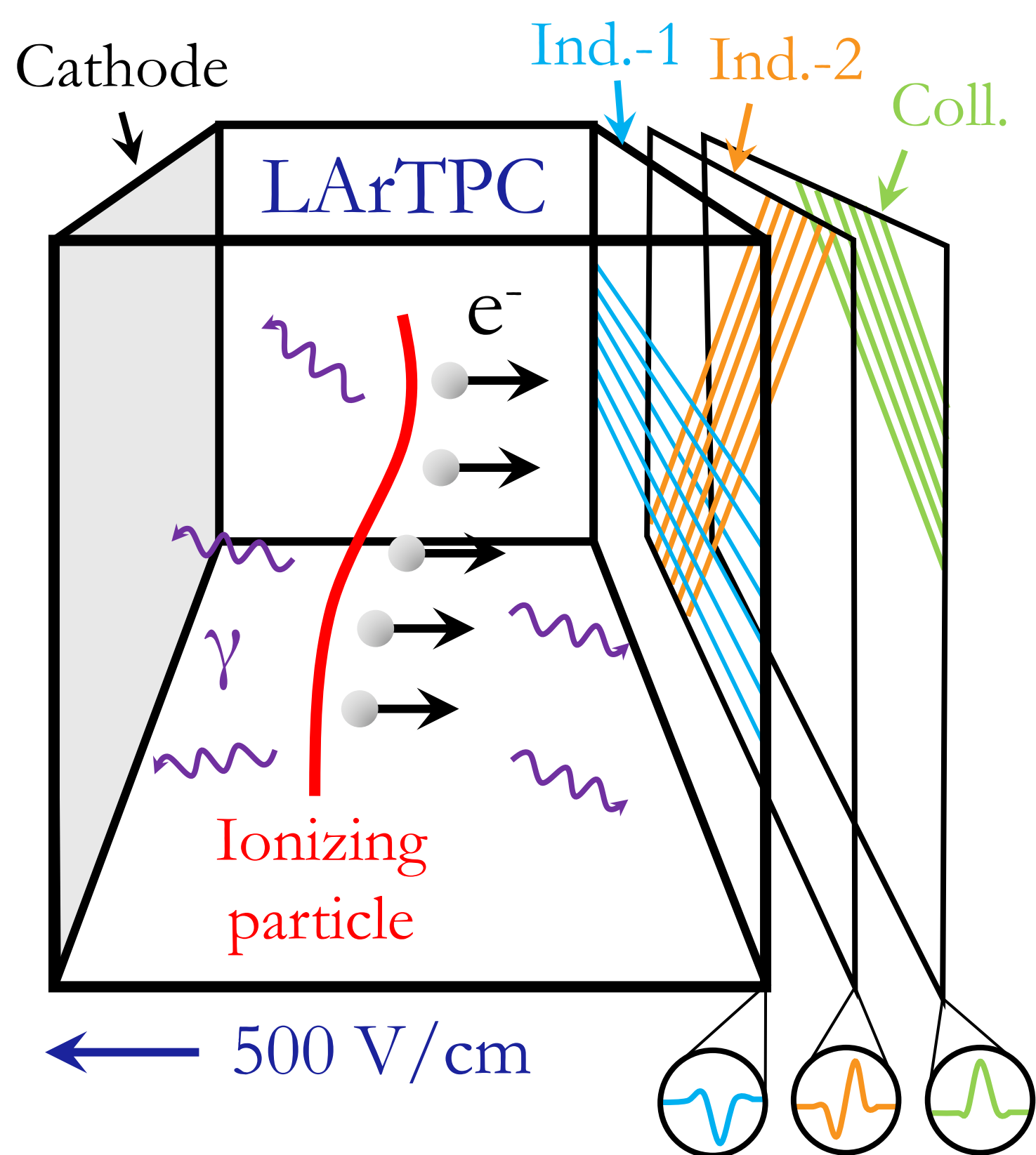
# Electromagnetic shower reconstruction in the ICARUS liquid argon time projection chamber detector

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on behalf of the ICARUS Collaboration



## ICARUS at Fermilab's SBN Program

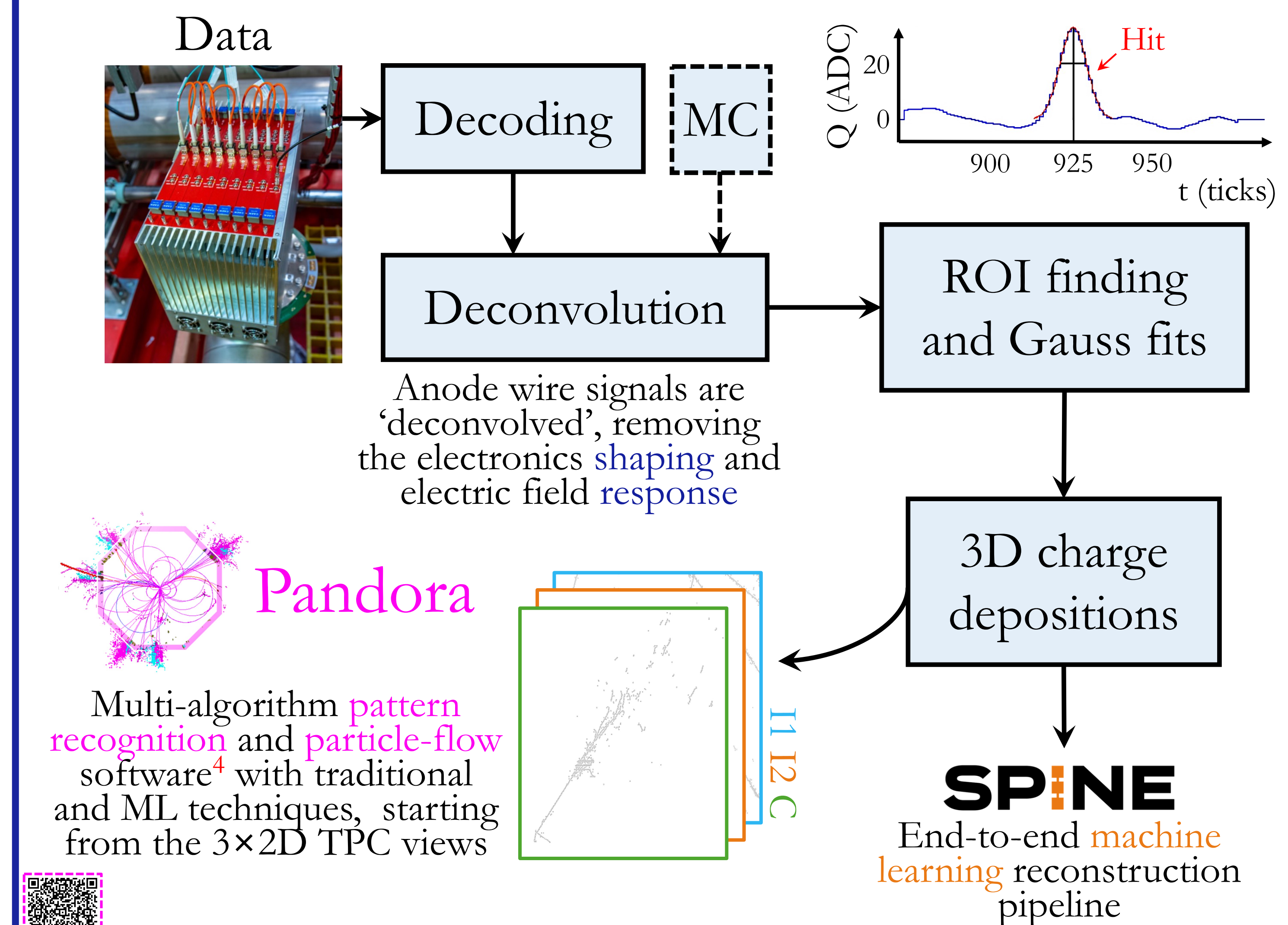
ICARUS is the first large-scale liquid argon TPC (LArTPC)<sup>1</sup>, operated deep-underground at Gran Sasso until 2013<sup>2</sup>. After refurbishing, ICARUS started taking data in 2020 at Fermilab's SBN program with the BNB and off-axis NuMI beams, looking for eV-scale sterile neutrinos<sup>3</sup>.



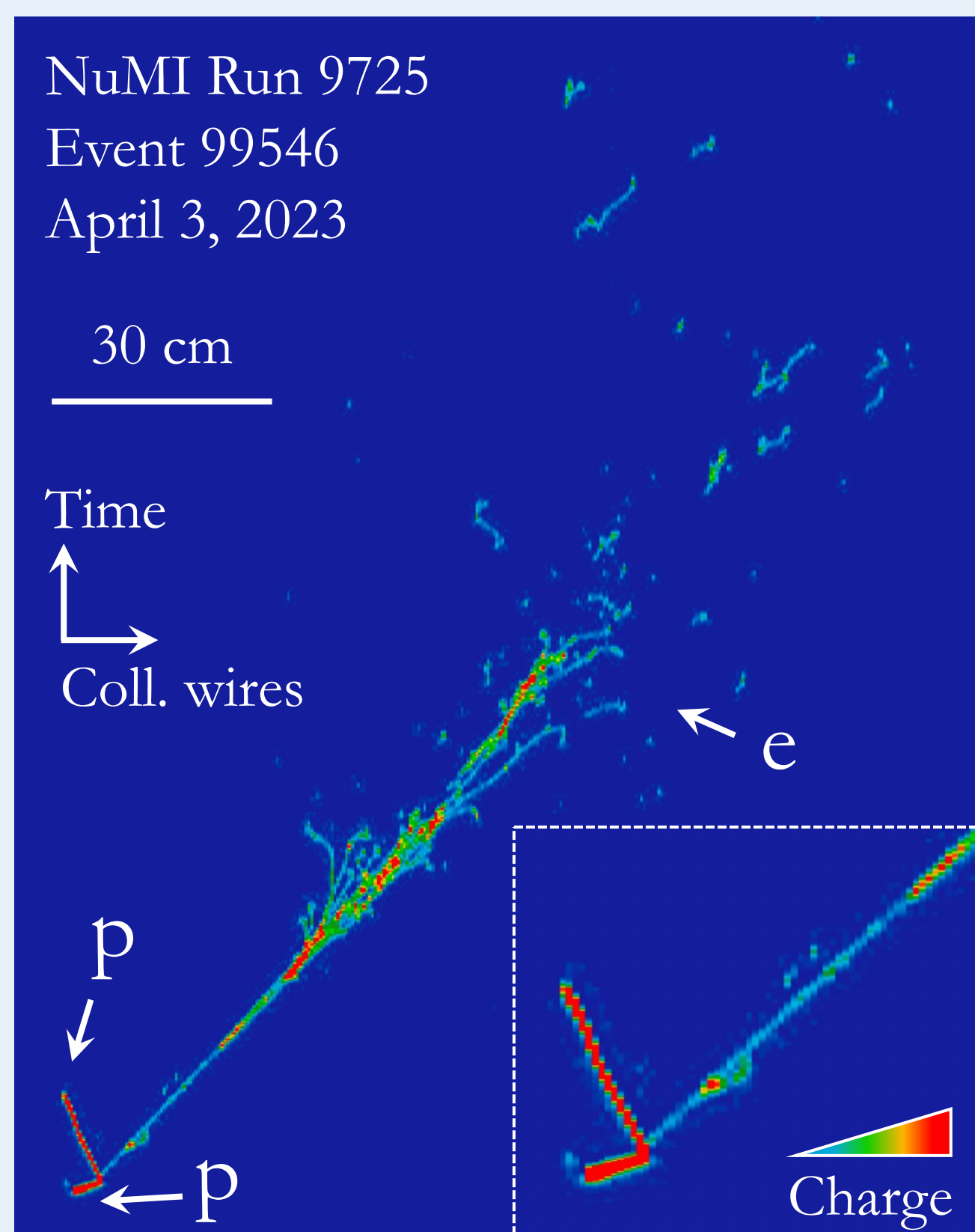
Two identical modules (760 t of ultra-pure LAr):

- ★ each hosting 2 TPCs sharing a common central cathode (1.5 m drift, 1 ms);
- ★ three TPC wire planes (Induction-1, Induction-2, Collection) for 3D tomographic reconstruction of charge;
- ★ 360 8" PMTs behind anodes to collect prompt scintillation light.

## Signal processing and reconstruction

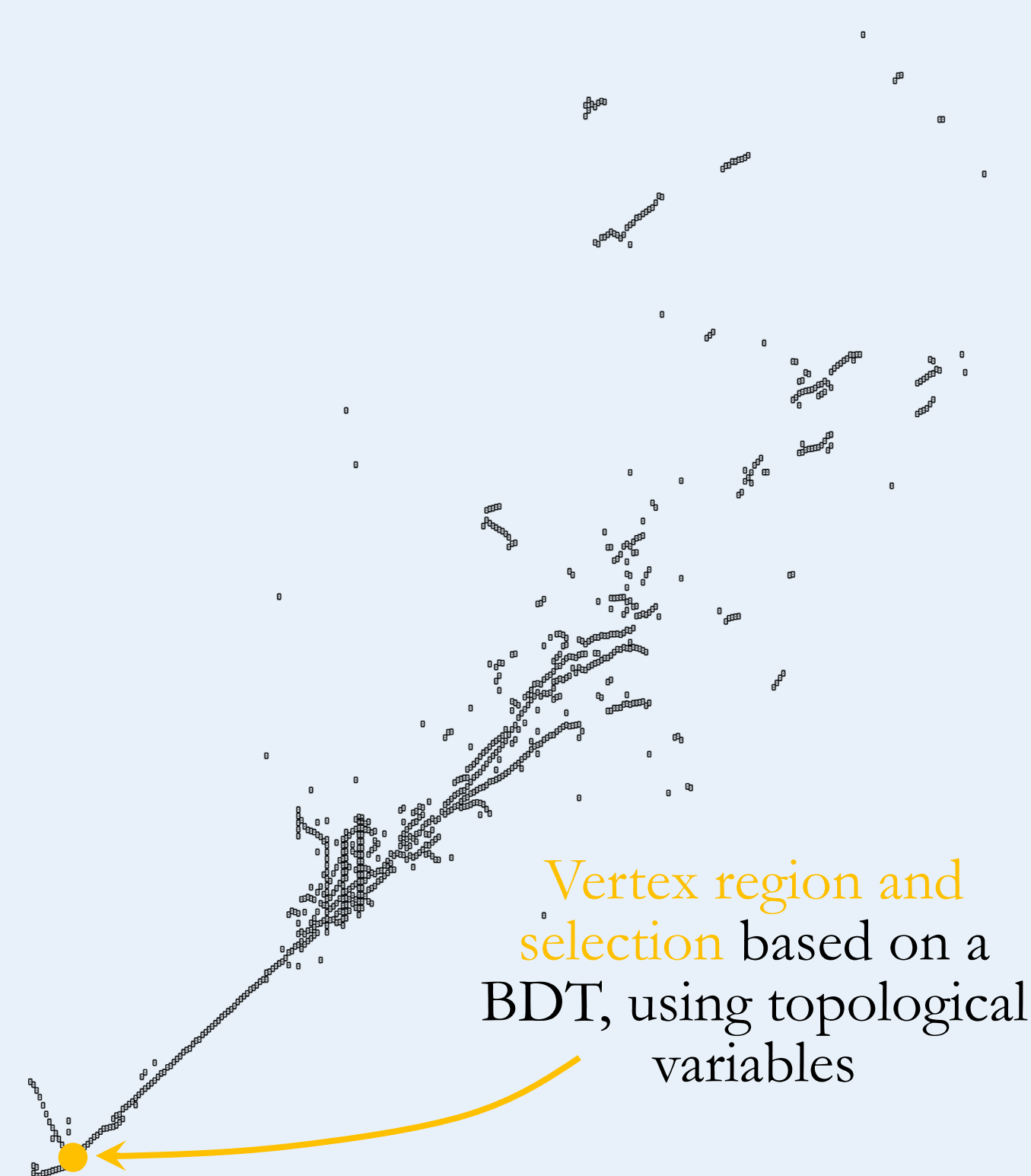


### Deconvolved wire signals



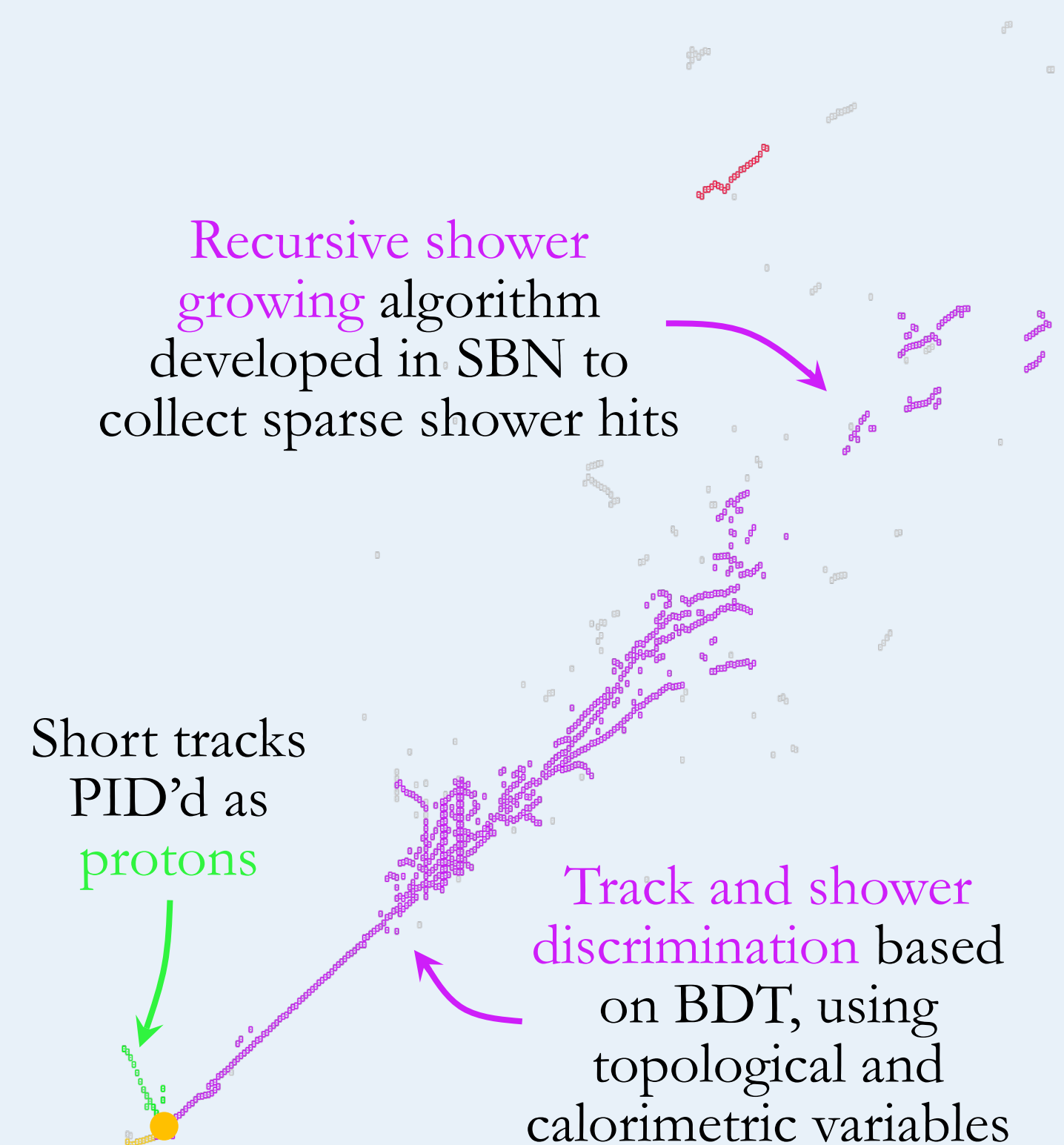
Electron shower in charged-current interactions recognized by absence of gap and MIP-like charge deposition at the start

### Identified hits

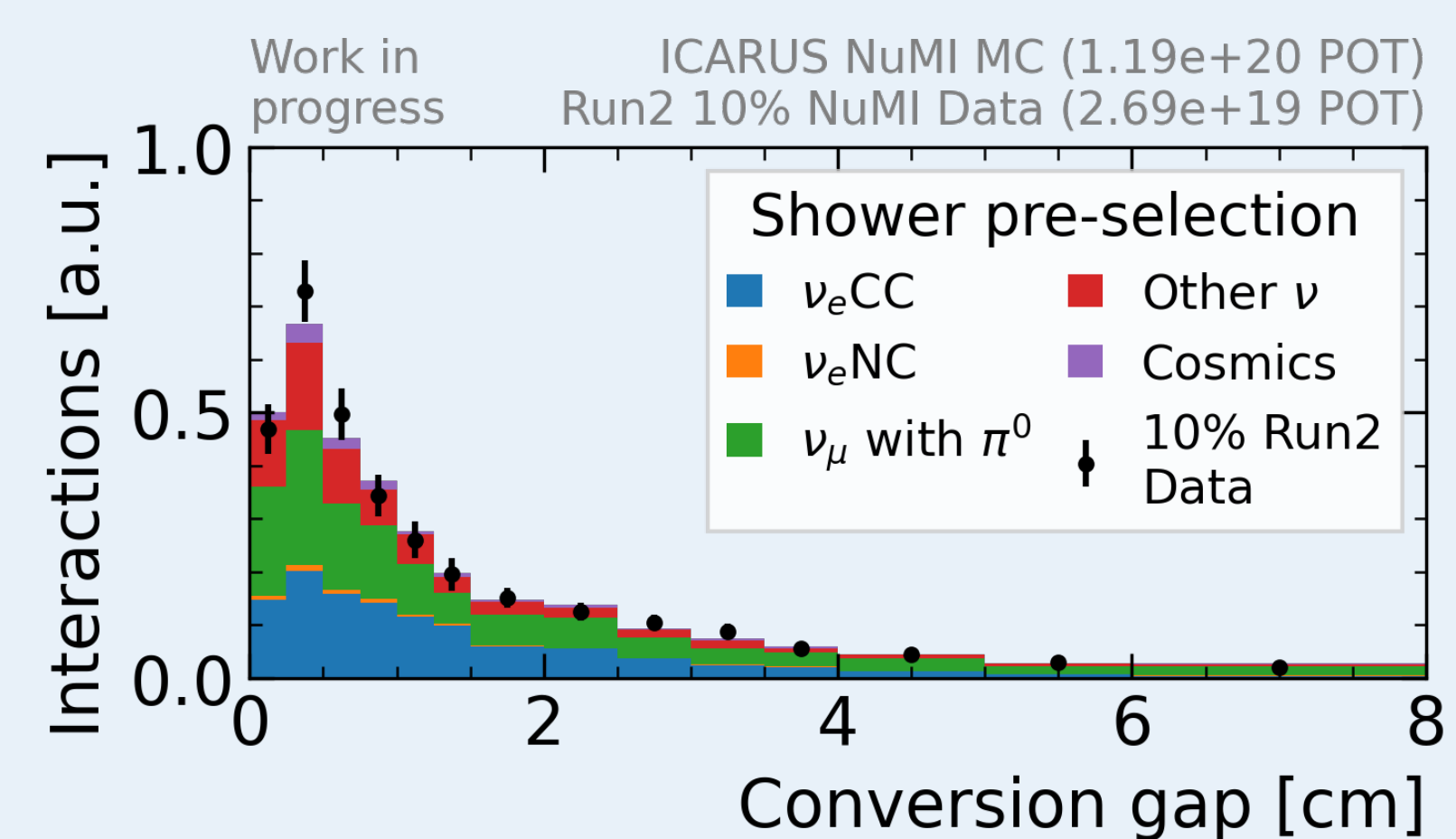
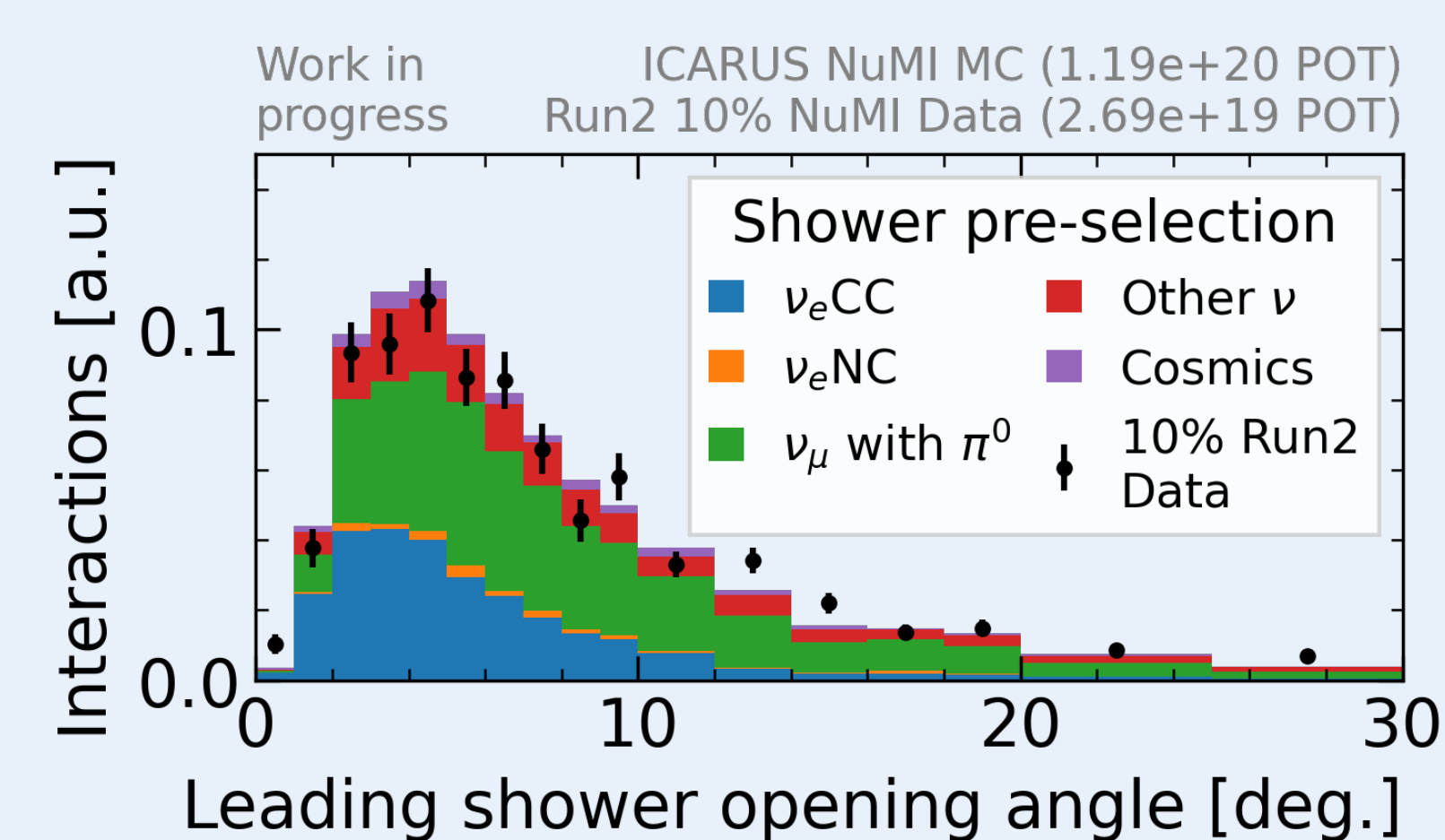


All neutrino-like interactions are processed with PandoraNu (vertexing, track and shower discrimination, particle flow)

### Reconstructed event



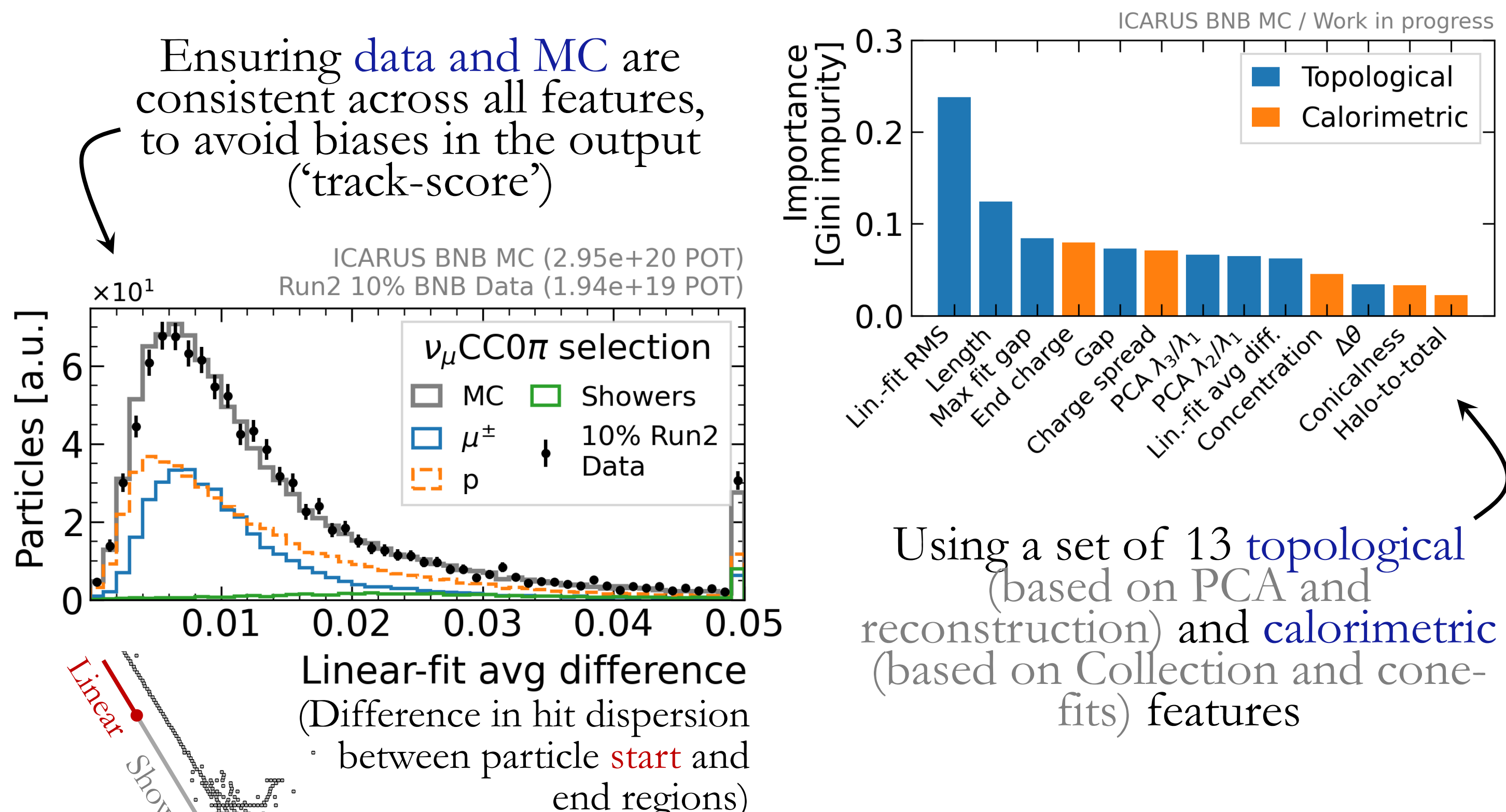
Performs clustering and particle flow: tracks and showers are discriminated, and showers are recursively 'grown' from vertex



Good data and MC agreement across topologic variables in generic shower selection, enabling progress on νeCC selections

## Track and shower discrimination

Track-like ( $\mu^\pm$ ,  $\pi^\pm$ , p) and shower-like ( $e^\pm$ ,  $\gamma$ ,  $\pi^0$ ) signatures are discriminated using a boosted decision tree (BDT), trained on ICARUS MC using AdaBoost with shallow trees and stratified 5-fold cross-validation:



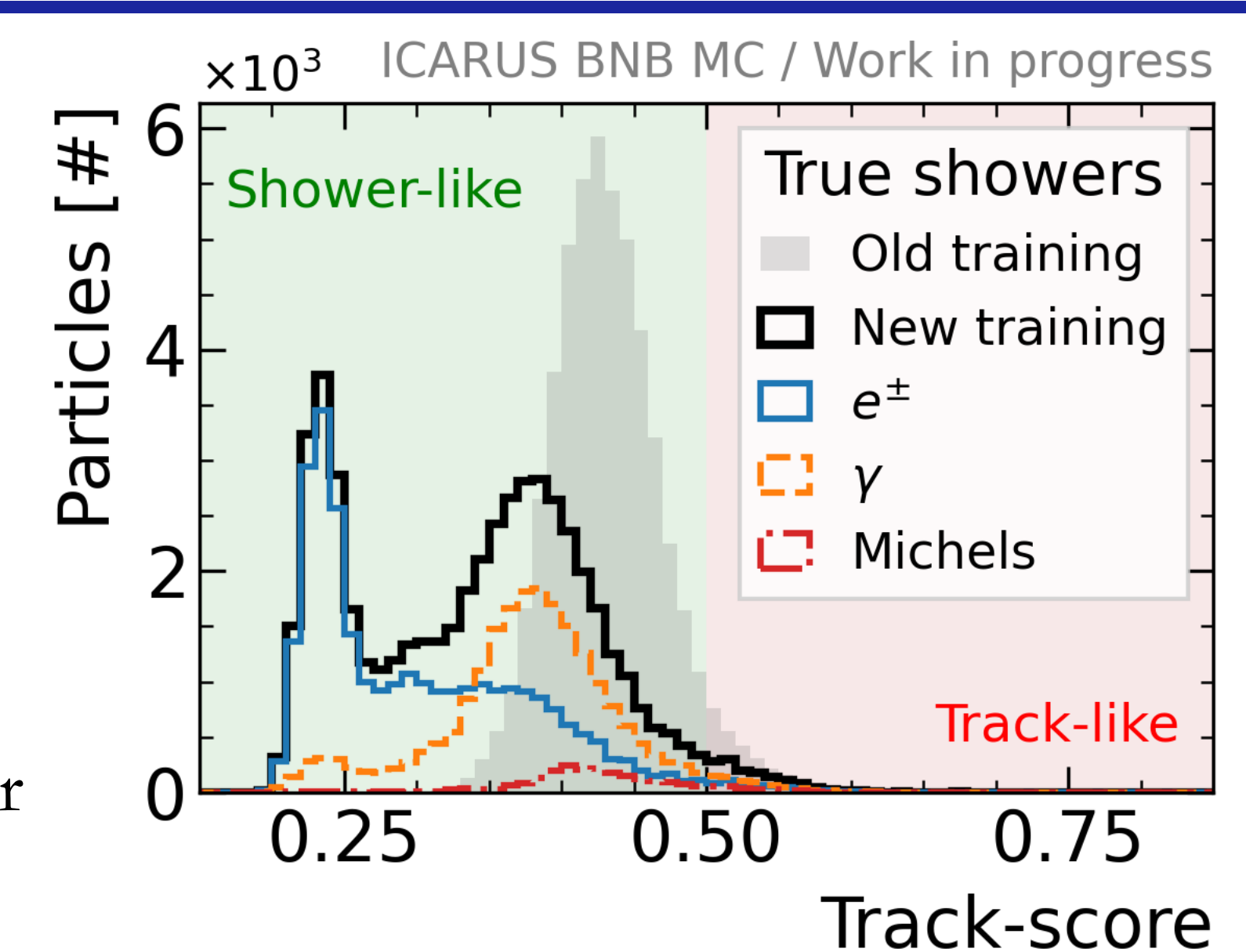
## Results

New ICARUS training predicts track and shower classes with high confidence:

- ★ accuracy improves to 97%;
- ★ relying more on calorimetry enhances performance and further discriminates  $e^\pm$  and  $\gamma$  ( $\pi^0$ );
- ★ leads to a >13% purity increase in on-going νeCC0π selections.

## Outlook

Electromagnetic shower reconstruction is being overhauled at ICARUS: progress on signal processing updates, energy extraction and calibration, and enhancements via an integrated graph neural network approach.



- [1] C. Rubbia, *CERN-EP 77-08* (1977)
- [2] ICARUS, *Eur. Phys. J. C* **73**, 2599 (2013)
- [3] ICARUS, *Eur. Phys. J. C* **83**, 467 (2023)
- [4] MicroBooNE, *Eur. Phys. J. C* **78**, 982 (2018)

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