

# Using Stopping Cosmic Muons for Calibrations at DUNE

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## 1. The Deep Underground Neutrino Experiment (DUNE)

- DUNE is a next-generation long-baseline neutrino experiment with a broad physics program.
  - Neutrino oscillations, supernova neutrinos, searches for rare processes, and more.
- It consists of a near and a far detector, set 1300 km apart.
- A key technology is the Liquid Argon Time Projection Chamber (LArTPC).

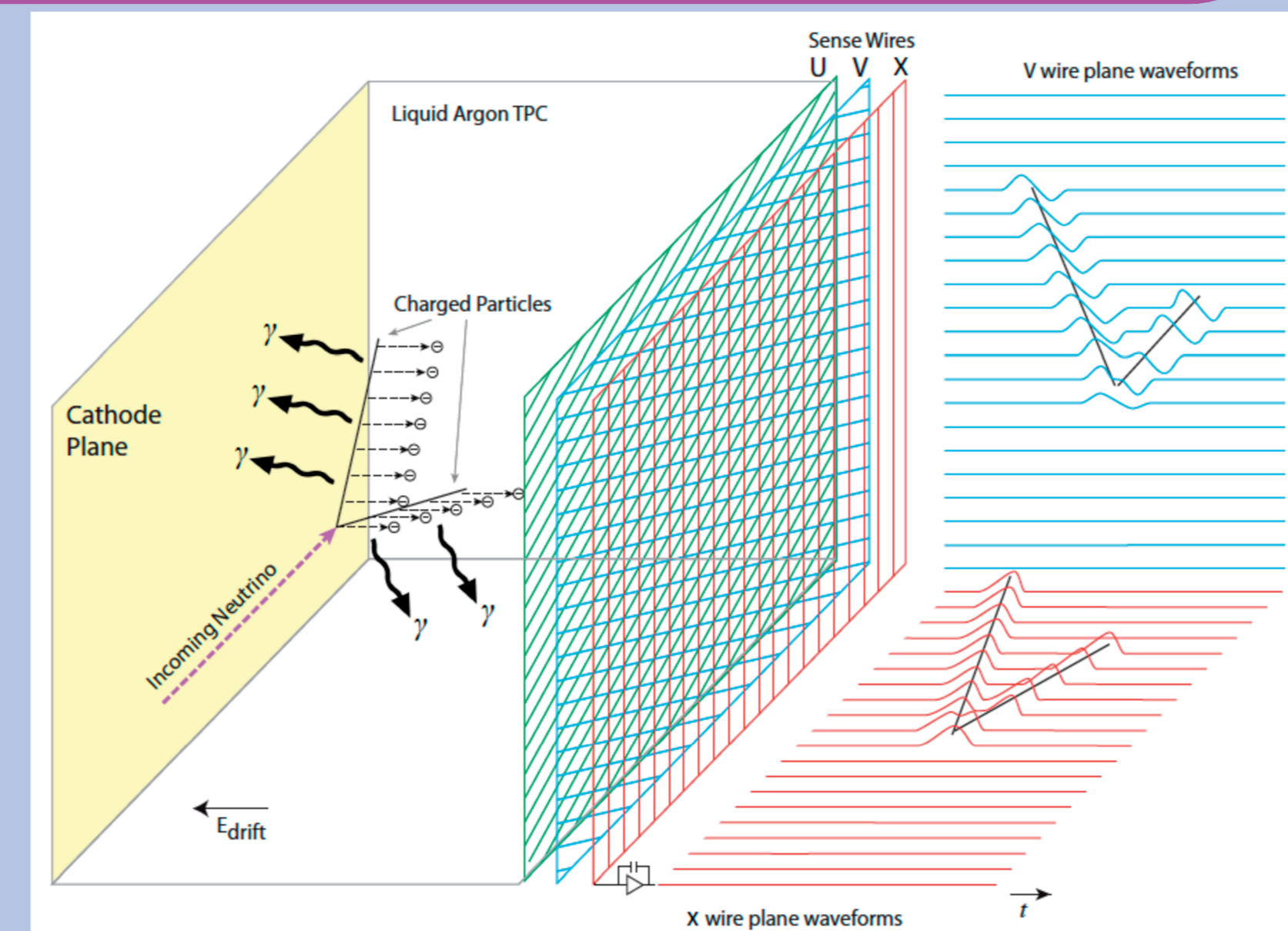


Figure 2: Schematic of a horizontal-drift LArTPC [1].

- Ionisation electrons produced by charged particles are drifted by an electric field to three wire readout planes.

## 2. Calibration Motivation

- Calibration is needed to quantify our understanding of...

**SYSTEMATIC UNCERTAINTIES**      **THE DETECTOR**      **THE RECONSTRUCTION**

- Particles with well known energy spectra act as standard candles.
  - Such as stopping cosmic muons.
- LArTPCs record charge per unit length.
  - This must become energy per unit length ( $dE/dx$ ).
- $dE/dx$  is essential for particle identification (PID).
  - Stopping particles show different energy depositions at the same residual ranges.

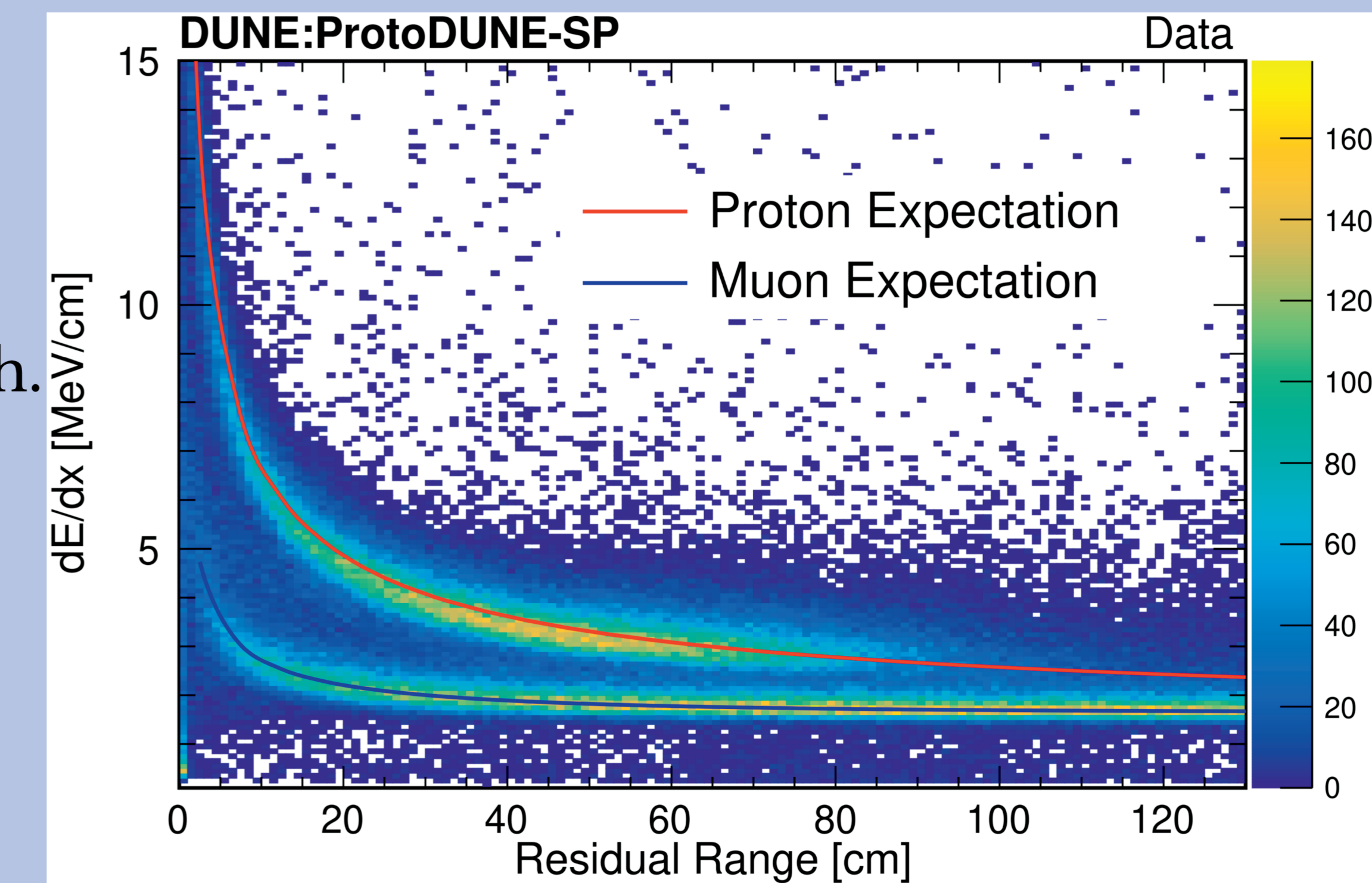
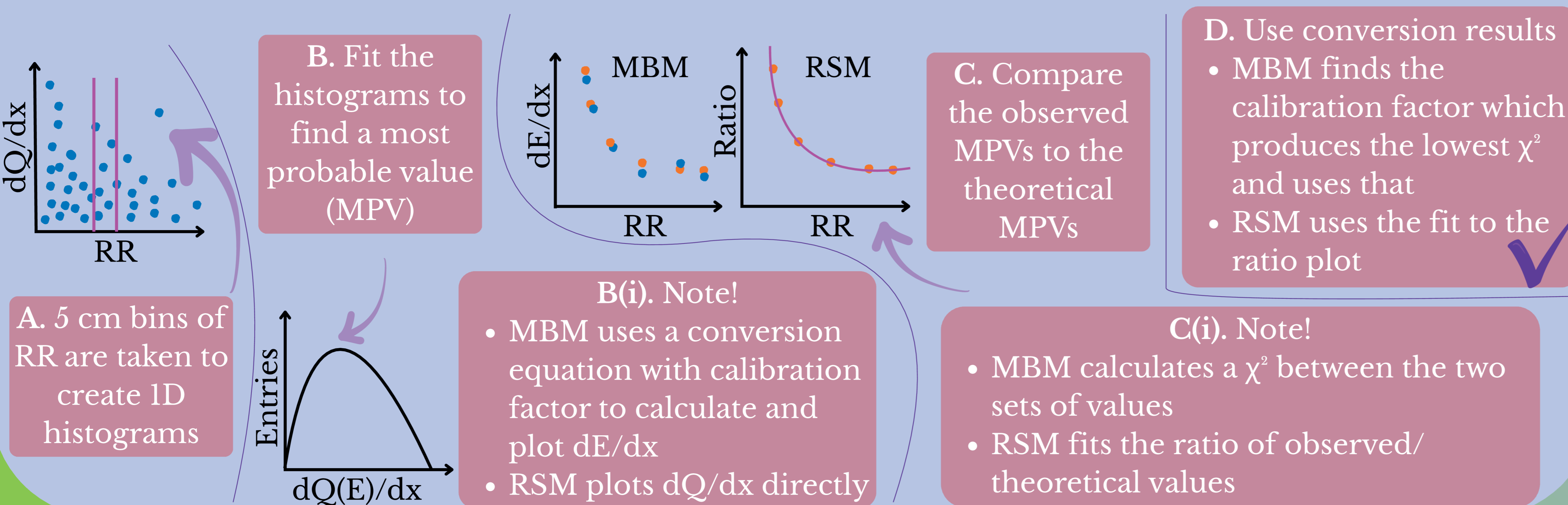


Figure 3: An example of using  $dE/dx$  for PID [2].

## 3. Method of Calibration

- Two methods were used and compared for consistency.
- The Modified Box Model (MBM) [2] is standard but relies on derived constants.
- The Recombination Scaling Model (RSM) was developed to reduce the model dependence of the calibration procedure.
- The track selection achieved 99% purity and 68% signal efficiency.



## 4. Performance

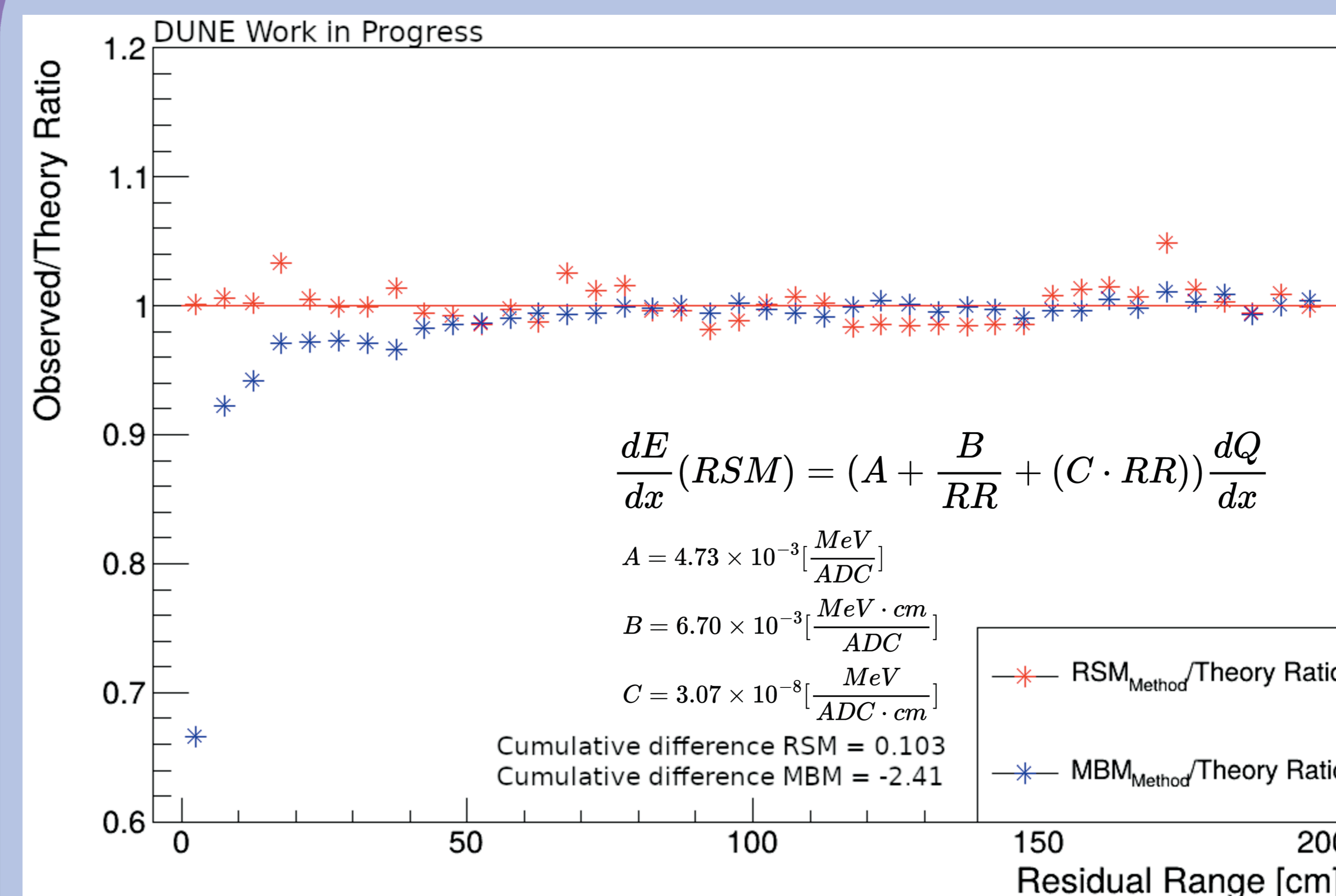


Figure 4: The RSM and MBM calibration methods as compared to theoretical values.

- Results from both methods are found to be consistent.
- The observed divergence of the MBM at low residual range values is a result of the binning procedure.
- These methods are ready to be tested with data.
- There is the potential to expand the RSM to other particle types.

### References

- [1] B. Abi et al., The DUNE Collaboration, arXiv preprint arXiv:2002.03005 (2020).
- [2] B. Abi et al., The DUNE Collaboration, JINST 15 P12004 (2020).

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