Data reconstruction and analysis for the 3×1×1 m^3 dual phase liquid argon time projection chamber prototype

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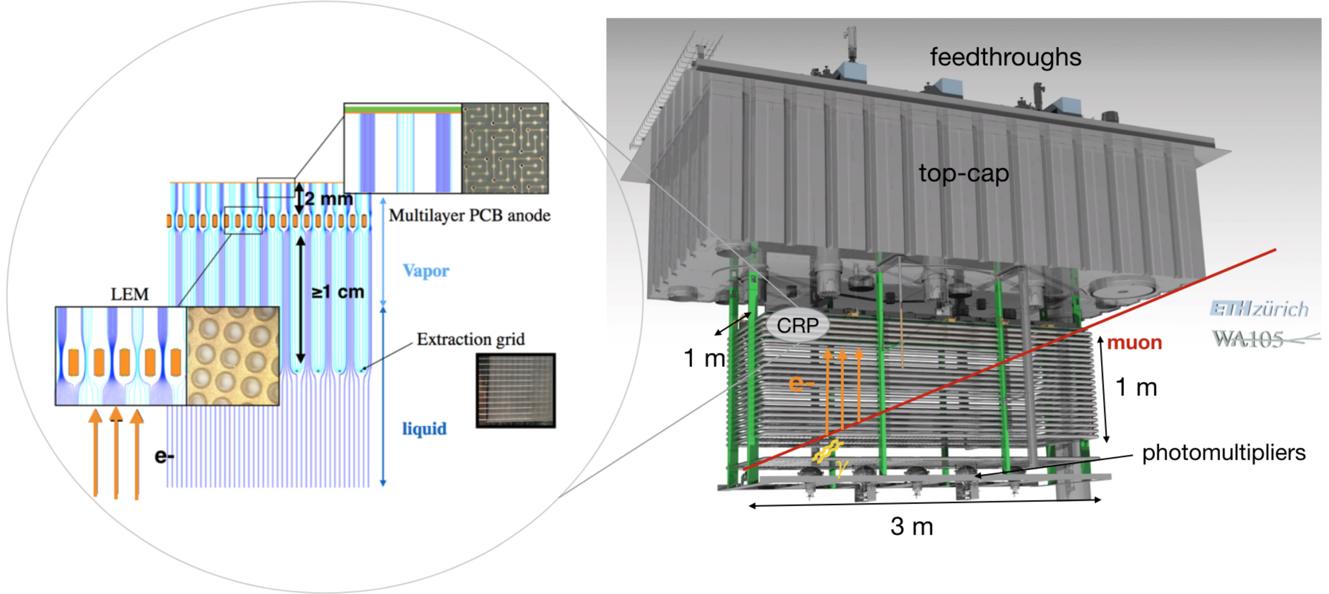
DUNE DEEP UNDERGROUND NEUTRINO EXPERIMENT

1. The dual phase liquid argon TPC

3×1×1 m^3 prototype at CERN:

1. Charged particles produce ionization charge and scintillation light inside the liquid argon
2. The drift field drifts the charge upwards, the light is collected by PMTs
3. The charge gets extracted into a gas argon layer and is amplified in Large Electron Multipliers
4. The charge is collected by the anode and shared equally between the two readout views

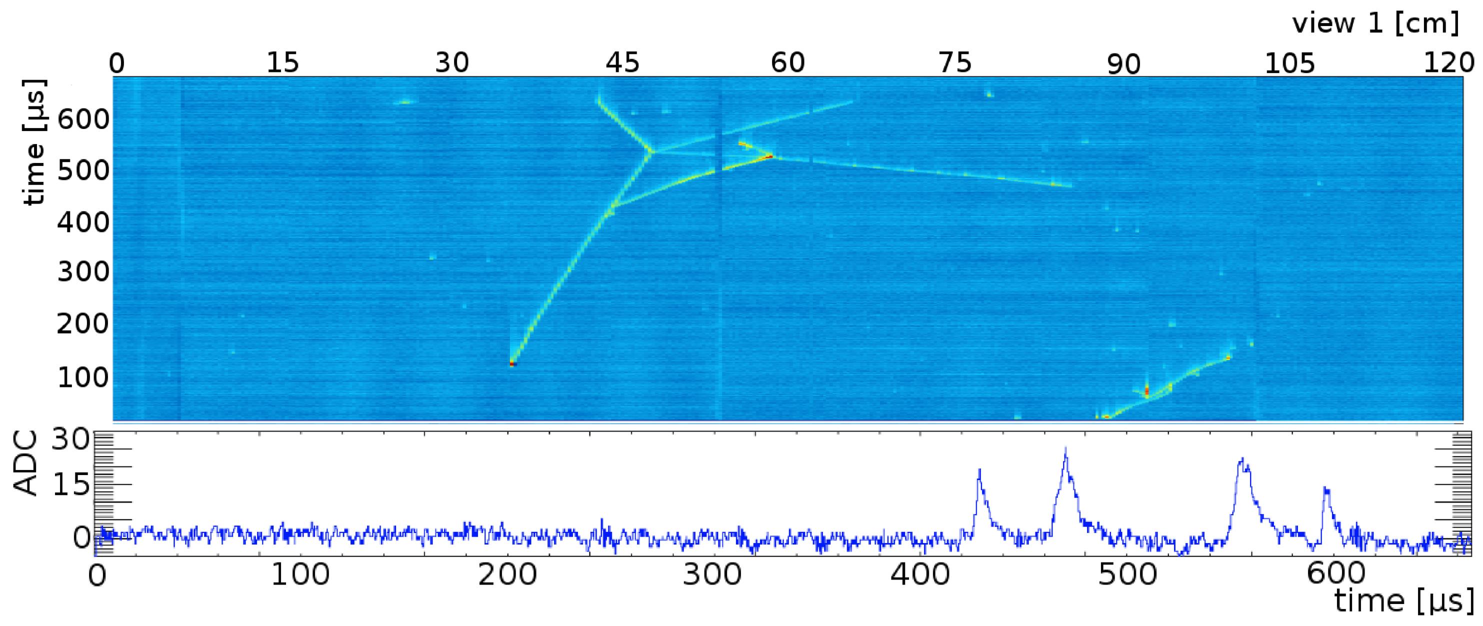


- 3×1×1 m^3: first ton scale dual phase liquid argon time projection chamber and part of an R&D program for multi-kiloton DP LAr TPCs in the context of DUNE. **Essential milestones are:**
  1. **high argon purity** to allow electron drift over a long distance (goal: 3 ms)
  2. a **uniform charge readout** to ensure a good energy resolution across the TPC
  3. a **good understanding of the light signal** to trigger rare events like supernovae or p-decay
  4. **understanding the impact of space charge** for surface-based DP LAr TPCs

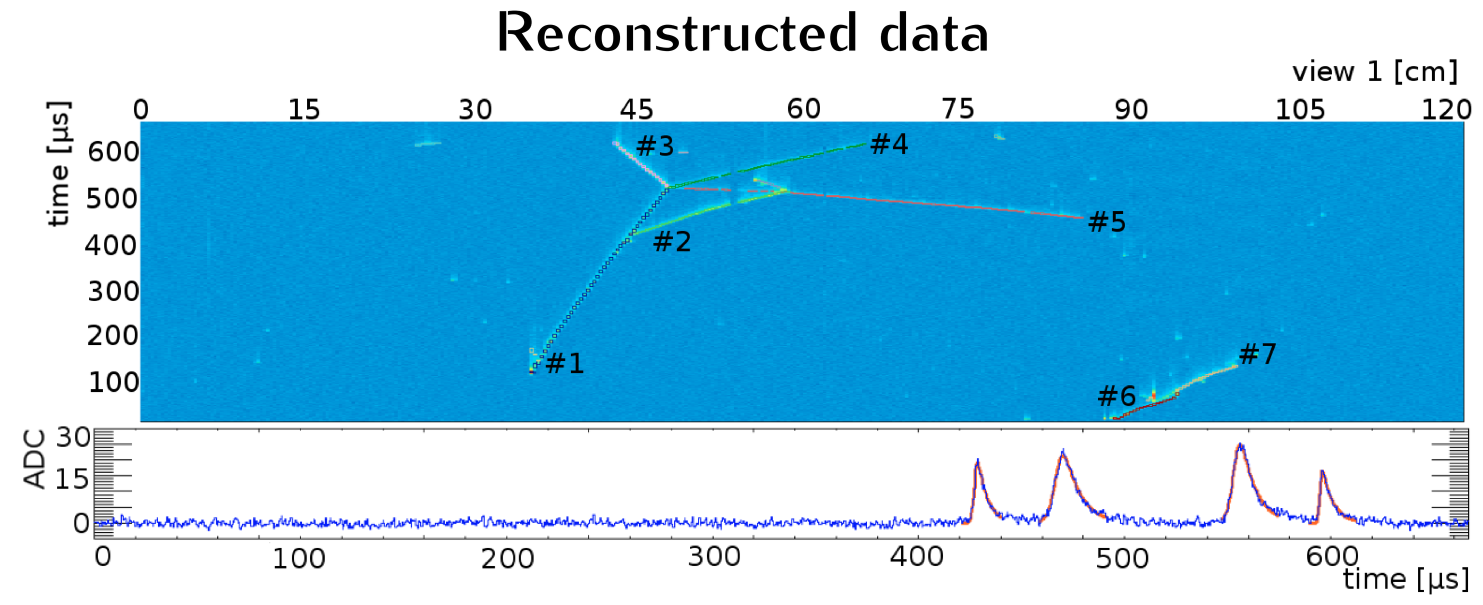
  → a good reconstruction is essential to evaluate the performance of the detector

2. Noise filter, hit finding and 2D pattern recognition

Raw data



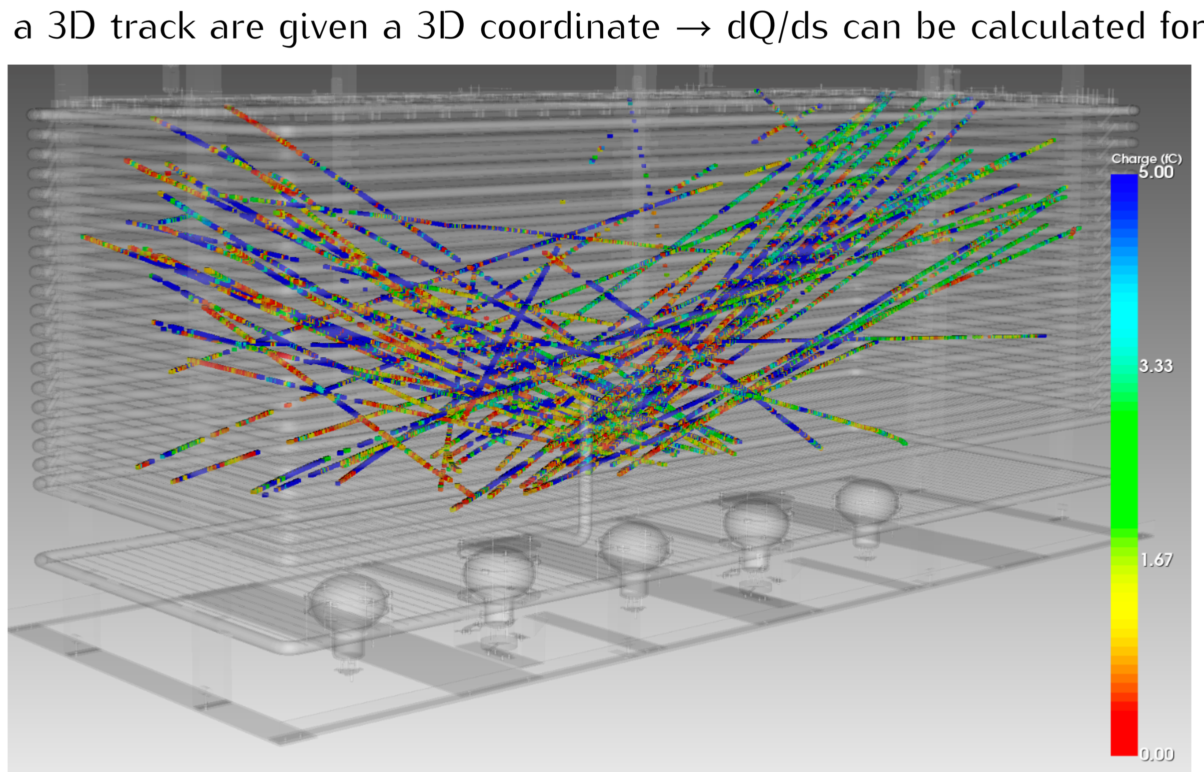
Reconstructed data



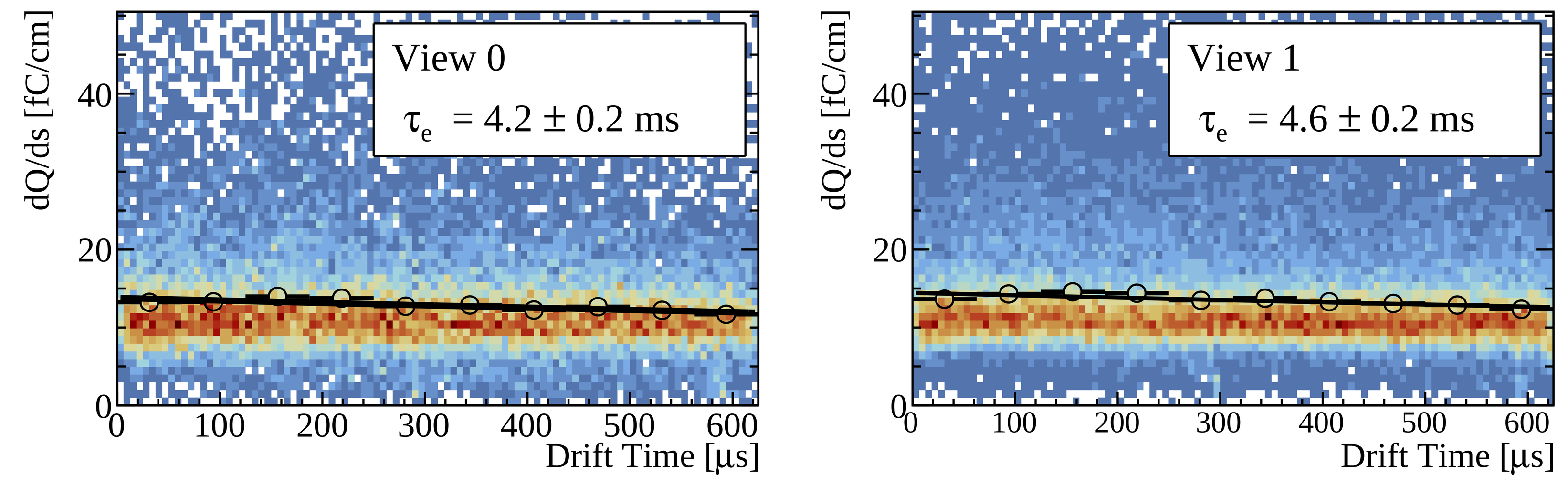
- **Noise filter:** flattening of slow baseline fluctuations and coherent noise removal
- **Hit finding:** peaks are fitted and filled into a 2D histogram
- **2D pattern recognition:** consecutive hits of similar size are added to a "cluster" (#1 - #7)

3. 3D reconstruction

- 3D reco matches two clusters from the two readout view with similar start and end times
- Hits inside a 3D track are given a 3D coordinate → dQ/ds can be calculated for each hit



4. Argon purity



Why?

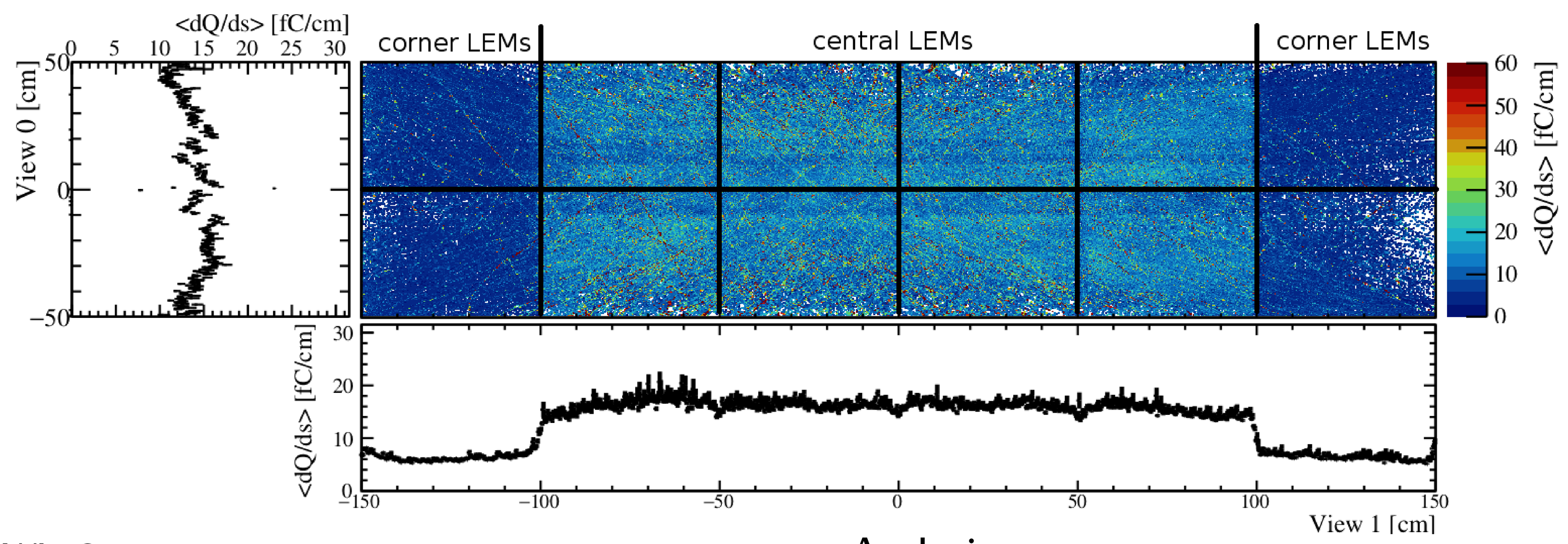
Impurities in LAr such as O_2 and H_2O capture drifting electrons:

$$N_{e^-}(t) = N_{e^-,0} \cdot e^{-t/\tau_{e^-}}, \text{ where } \tau_{e^-} \approx \frac{300\mu s}{\rho_{O_2}\,[\mathrm{ppb}]}$$

Analysis:

- Select top-to-bottom tracks and calculate the dQ/ds for each hit
- Calculate mean of dQ/ds distribution for each drift time and fit exponential

5. Charge readout uniformity



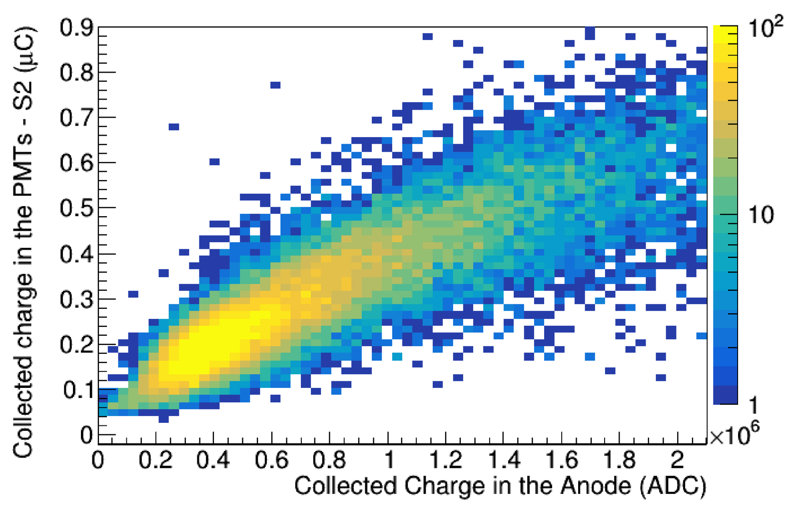
Why?

1. The uniformity of the charge readout affects the energy resolution of the TPC
2. The parameter which affects the most the effective gain is the LEM thickness

Analysis:

- Select through-going tracks
- Correct hit integral for purity and calculate dQ/ds for each hit
- Corner LEMs operated at lower fields

6. Charge-light matching



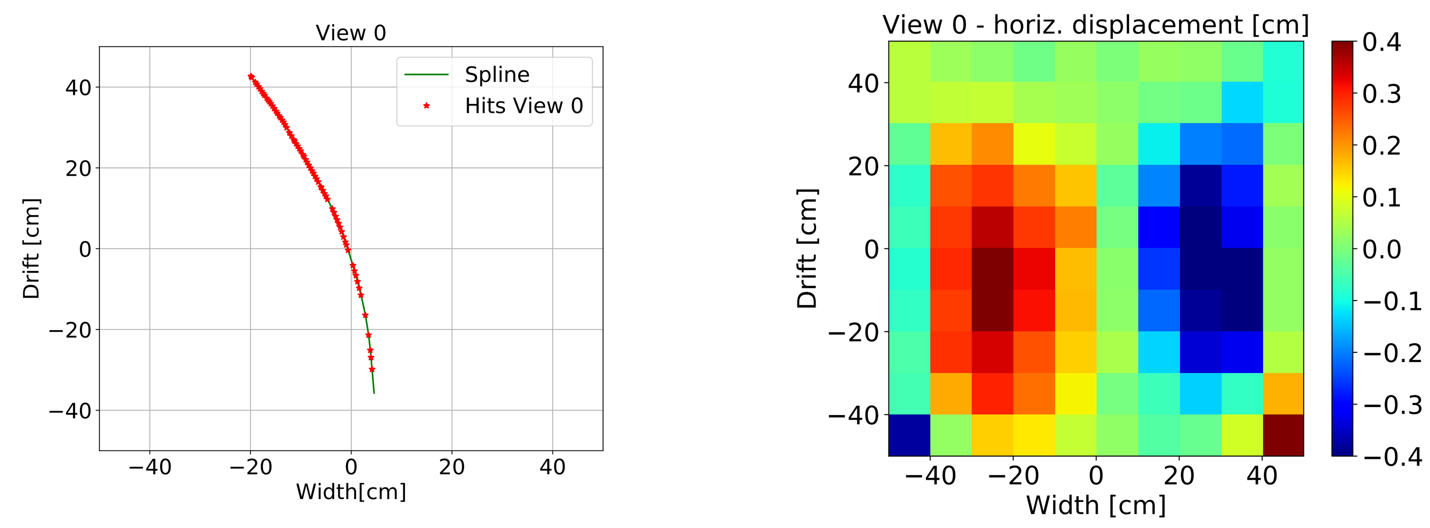
Why?

- The light signal can be used as trigger and to determine the t_0 of a reconstructed track → charge and light data need to be matched
- If charge and light are matched correctly, S2 signal and total charge should be correlated

Analysis:

- Match the timestamp difference Δt of timestamps of consecutive events
- Sum up recorded charge in whole anode and S2 signal in all PMTs

7. Track curvature and space charge



Why?

- Tracks can deviate from a straight line due to multiple scattering, or if the drift field is non-uniform because of edge effects or space charge
- 3×1×1 m^3 data ideal opportunity to study the impact of space charge in large volume detectors

Analysis:

- Select through-going tracks
- Fit a spline to the 3D hits and uniformly interpolate new points along the spline as well as along the line connecting start and end point of the track
- Calculate the "displacement": vector between a point on the spline and the corresponding point on the straight line