Automated Reconstruction, Signal Processing and Particle Identification in DUNE

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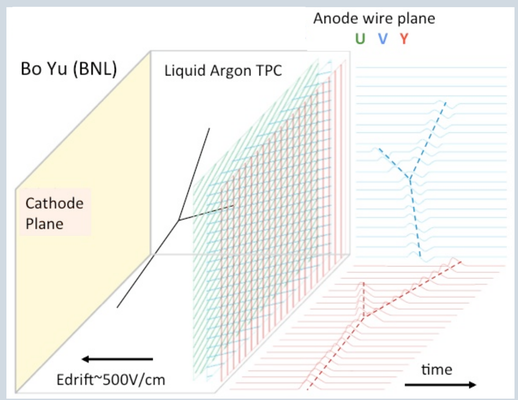
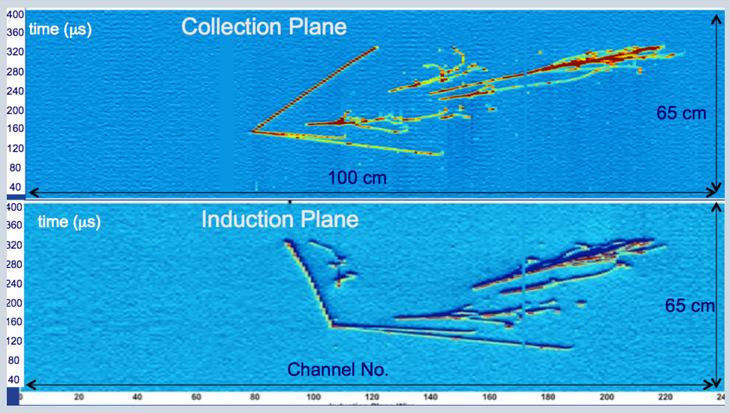
Introduction & Motivation

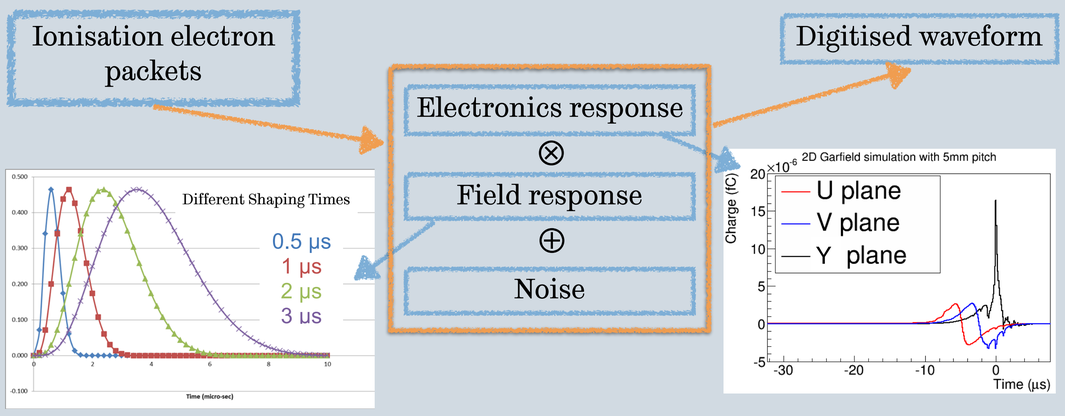


- LArTPCs provide 2D projections of a 3D event image with excellent spatial resolution.
- Reconstruction of events is challenging:
  - Large amount of information, tracks and showers overlap near neutrino vertex, wire readout loses information.
- DUNE requires [1]:
  - Beam neutrinos: vertex reconstruction, muon reconstruction and $\mu/\pi/p$ separation, electron reconstruction and e/γ separation.
  - Proton decays: track and vertex reconstruction, calorimetry, photon detector reconstruction.
  - Supernova: low-energy ν_e reconstruction, photon detector reconstruction.

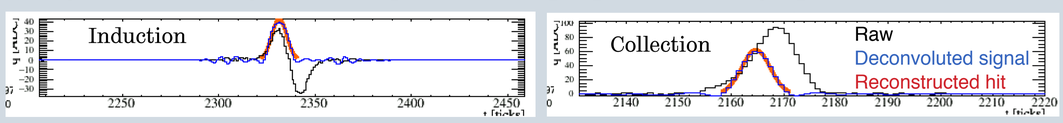


Real ArgoNeuT neutrino event [2] — three tracks, four photon showers

Signal Processing

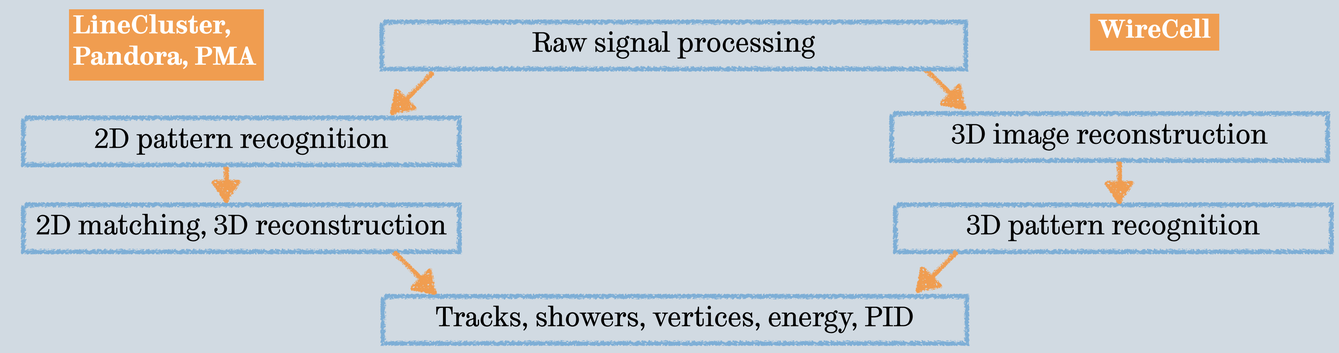


- Filter noise and remove effects of field response and electronics response through deconvolution [3].
- 'Hit finding' proceeds by finding 'pulses' above threshold in the deconvoluted signal and fitting Gaussian peak to find properties (charge, peak time, width).



Reconstruction Overview

- DUNE utilises and contributes to LArSoft [4], the shared software framework for LArTPC experiments at Fermilab.
- Two approaches, each use same information.

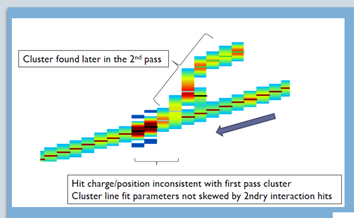


- **2D approach**: reconstruct clusters in each view by grouping hits from the same particle and match between the views to make 3D objects.
- Clusters: LineCluster (tracks), BlurredCluster (showers), Pandora.
- Tracks: Projection Matching Algorithm (PMA), Pandora.
- Showers: EMShower, Pandora.

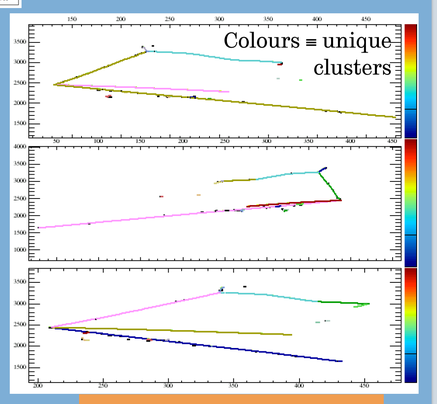
- **3D approach**: WireCell.
- Form 3D space points, with location and charge directly.
- Perform clustering and tracking on these 3D points.

Pattern Recognition

LineCluster

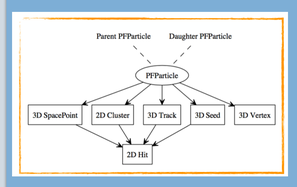


- Use cluster tracking information from low hit density regions downstream of primary vertex to extrapolate into (primary vertex) or through (δ-rays, showers) high density regions.

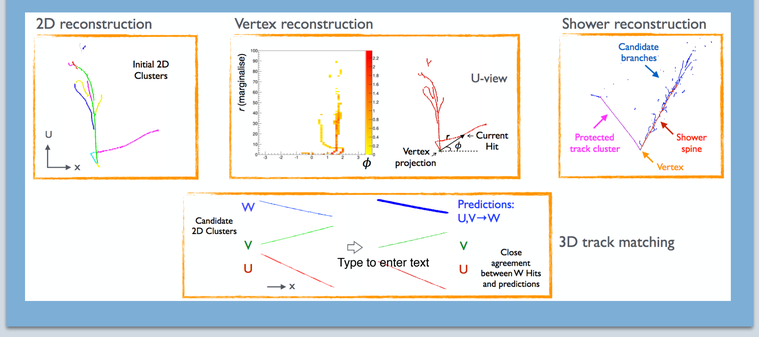


2.4 GeV ν_μ in DUNE

Pandora

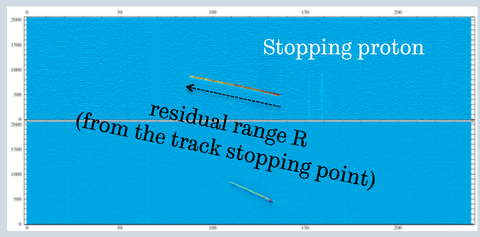


- Well-established tool for pattern recognition in fine-grained HEP detectors (future linear colliders, LHC, LArTPC) [6][7].
- Multi-algorithm approach for automated and optimised pattern recognition.
- Two specialised streams: cosmics and beam neutrino.

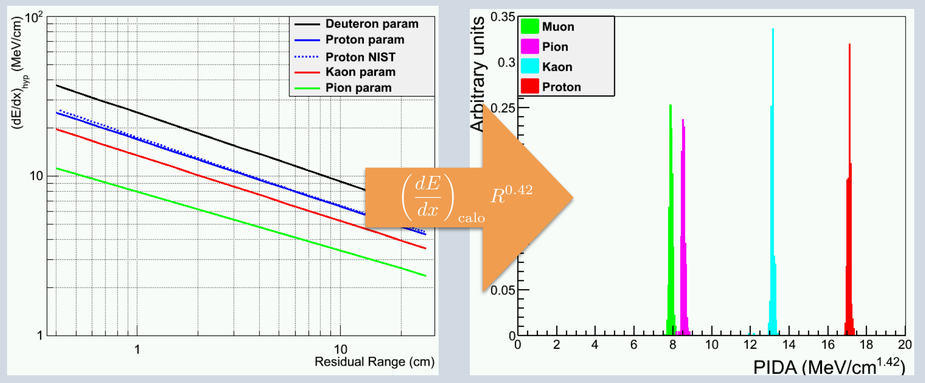


Particle Identification

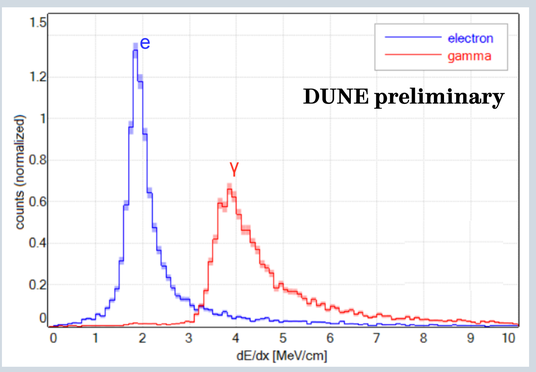
- The high quality spatial and calorimetric reconstruction capabilities of LArTPCs facilitate excellent particle identification.



- PIDA [12]: good separation in deposited energy as function of range.
- Similar slopes, different intercepts; use intercepts to perform PID.



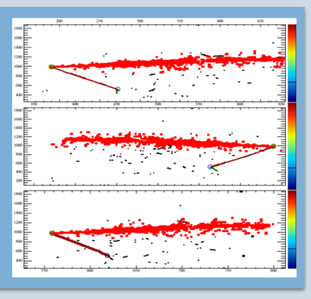
- Information at start of shower can give info about particle type.
- Electrons: 1 mip (~2.1 MeV/cm), photons: 2 mip (~4.2 MeV/cm).



- Particle ID demonstrations are strongly MC-based; work to emulate using reconstruction is progressing well but still ongoing.

Shower reconstruction

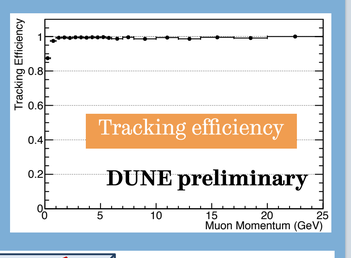
- BlurredCluster: uses Gaussian blurring on hit map image to produce more complete clusters [9].
- Match between views to make showers [10].

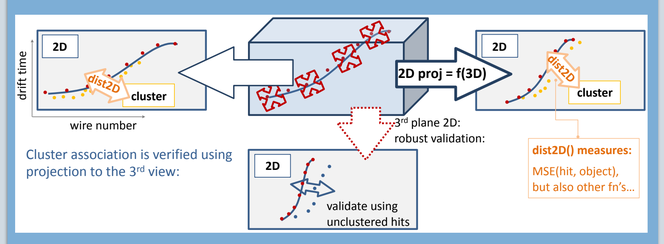


Shower and track in three views

Projection Matching Algorithm (PMA)

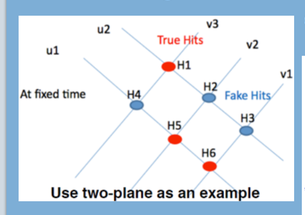
- Instead of building 3D objects by matching 2D hits between different views, build 3D objects by minimising distance from the object's 2D projection to 2D hits [8].
- Fit vertex and reoptimise tracks.

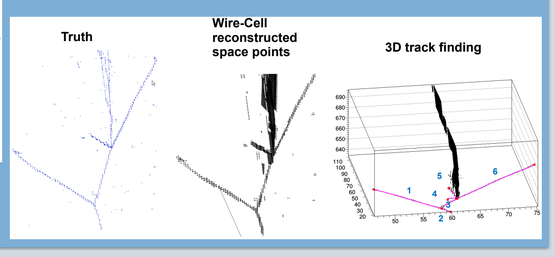




WireCell

- Use charge information to make 3D space point: same charge in voxel measured by 3 planes [11].





The Bottom Line

- After significant dedicated effort, event reconstruction in LArTPCs has reached an advanced level. DUNE has fully automatic reconstruction chain for signal processing, pattern recognition, track and shower reconstruction and particle identification.
- The shared LArSoft framework has been instrumental in developments and collaboration of expertise.

References

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[9] M. Wallbank, BlurredCluster Algorithm, http://larsoft.org/single-record/?pdb=110 (2015)
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