ProtoDUNE Physics Analysis

Tingjun Yang (Fermilab)

DUNE Collaboration Monthly Meeting
June 22, 2018

Outline

- ProtoDUNE analysis goals
- Updates on the ProtoDUNE DRA activities since the last collaboration meeting
  - Data quality monitoring
  - Detector calibration
  - Reconstruction
  - Analysis

ProtoDUNE Analysis Goals

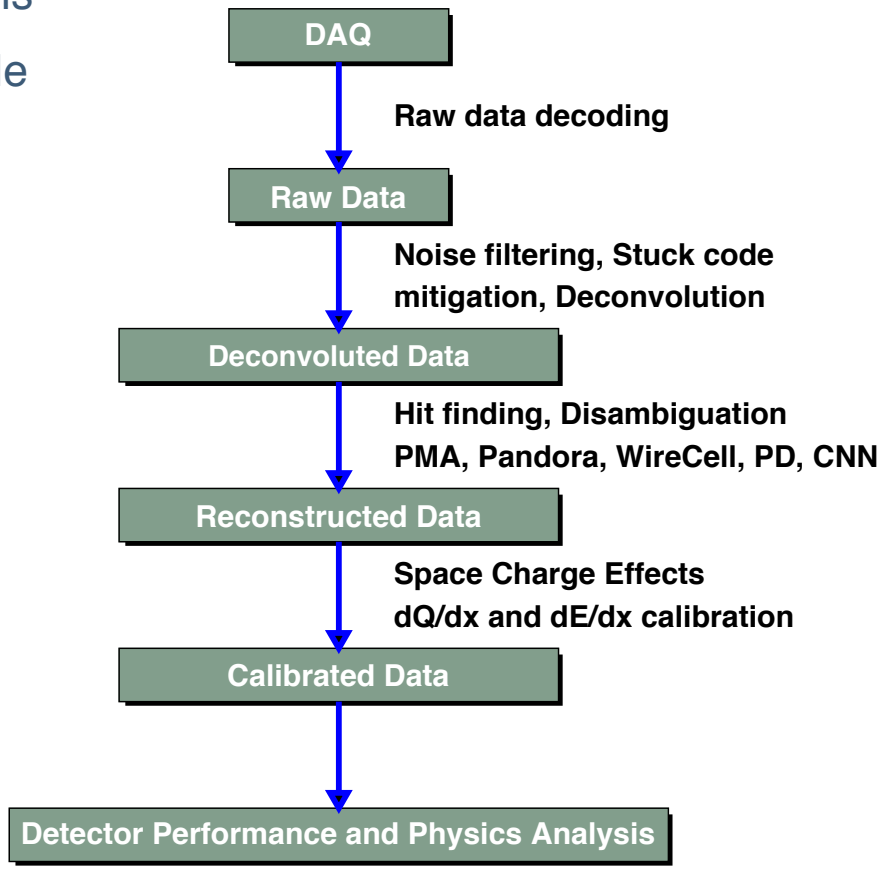
- **Short-term goals** – detector performance
  - Dead channels, noisy channels
  - Noise level, signal to noise ratio
  - Electron lifetime
- **Medium-term goals** – detector response
  - dE/dx of pions, protons, kaons, electrons
  - Energy and momentum resolutions
- **Long-term goals** – cross sections
  - Inclusive pion cross section
  - Exclusive channels – charge exchange, etc.

Information for DUNE physics TDR

Physics publications

The ProtoDUNE SP DRA Organization

- **DRA** – Detector Reconstruction and Analysis
- **DRA Level 1** – overall responsibility on code development and organizing analysis effort
  - T. Yang (FNAL)
  - G. Christodoulou (CERN)
- **DRA Level 2**
  - Reconstruction – L. Whitehead (CERN)
  - DQM – M. Potekhin (BNL)
  - Calibration – M. Mooney (CSU)
  - Analysis – S. Bordoni (CERN)



Weekly meeting on Wednesday 9:30 am Fermilab time, 4:30 pm CERN time
Mailing list: dune-proto-sp-dra@fnal.gov

https://web.fnal.gov/collaboration/DUNE/SitePages/ProtoDUNEs%20simulation%20and%20reconstruction%20activities.aspx

Monitor Data Transfer and Storage

Andrew Norman

https://landscape.fnal.gov/monitor/d/000000299/protodune?refresh=5m&orgId=1

Raw Data Decoding

Tom Junk

- Offline Raw Decoder Modules are based on those written for the Online Monitoring by Jingbo Wang, Tonino Sergi, Paolo Franchini, Patrick Tsang, and Philip Rodrigues. RCE unpacking code from JJ Russell. FELIX overlays by Milo Vermeulen.

Raw decoder: convert raw data to larsoft analyzable format
Channel map: convert online channel number to offline channel number

	Raw decoder	Channel map
TPC (RCE)	Exists	Verified by channel ID data
TPC (FELIX)	Exists	Verified by channel ID data
Photon detectors (SSP)	Exists	Initial version exists
Timing	In preparation	
Triggers (CTB, CRT)	In preparation	In preparation

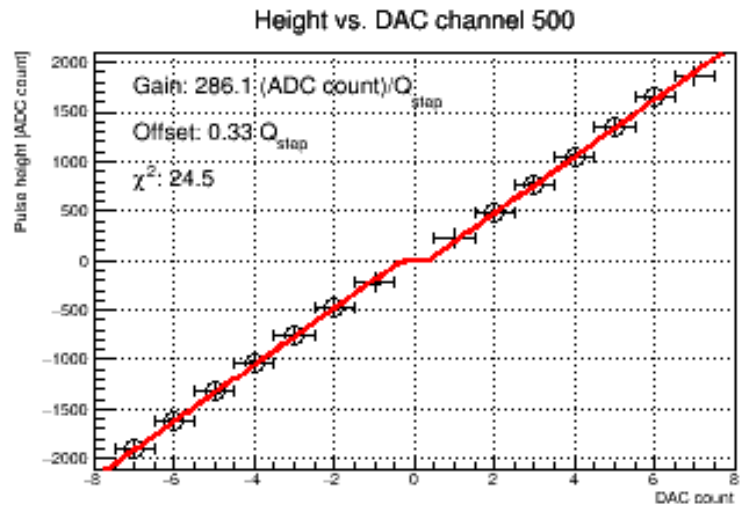
Data Quality Monitoring

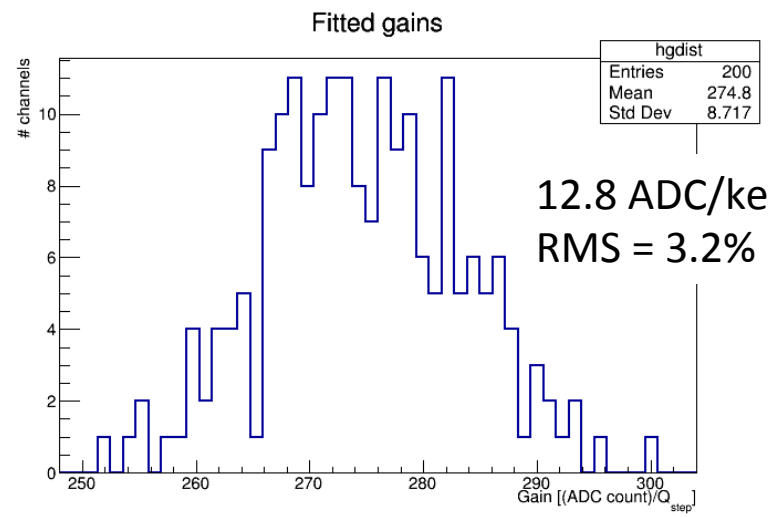
- Continue to develop DQM payloads - George Christodoulou, Tom Junk, Bruce Baller, David Adams
  - Already available: TPC monitor, hit monitor, SSP monitor, electron lifetime, signal to noise ratio, event display
  - In progress: CRT monitor, trigger monitor, beamline instrumentation monitor
- Continue to improve DQM infrastructure – Maxim Potekhin
  - Upgraded payload scripts for the "DQM monitor" to include XROOTD stage in, stage out and the ROOT macro to produce the graphics (PNGs).
  - Working to build the UI for efficient access to all the plots from the DQM web pages.

ADC Calibration

David Adams

- David Adams looked at the pulser data from the coldbox data at CERN.
- An average gain of 78 e/(ADC count) with σ = 3.2%.
- More work needed to correct for non-linearity or get response in the single MIP region.
- Xin and Wenqiang will have more information on ADC nonlinearity next week.

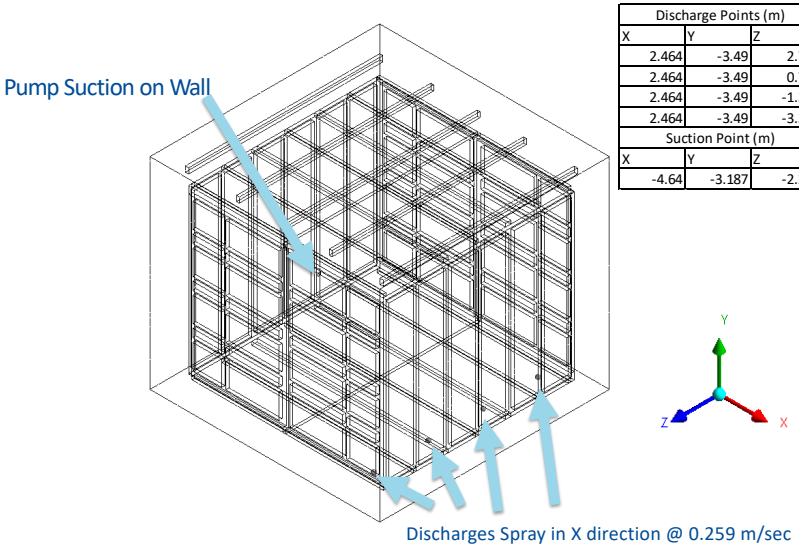




https://indico.fnal.gov/event/17410/contribution/1/material/slides/0.pdf

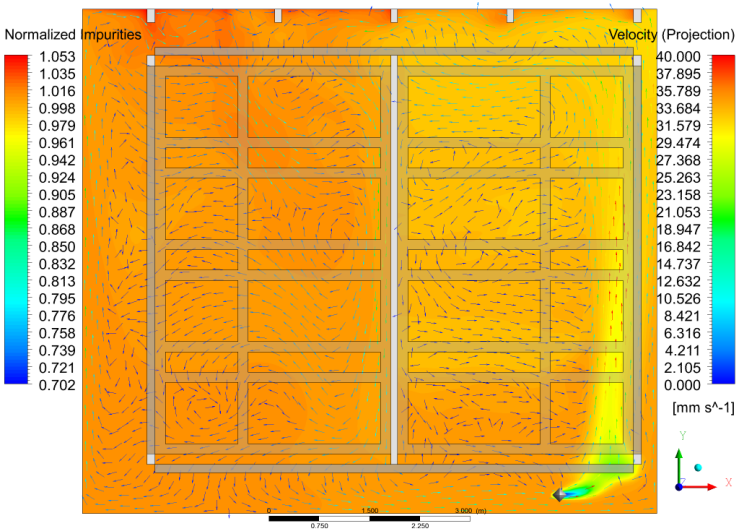
LAr Flow Simulation w/ Space Charge

Erik Voirin



Discharge Points (m)		
X	Y	Z
2.464	-3.49	2.753
2.464	-3.49	0.713
2.464	-3.49	-1.327
2.464	-3.49	-3.367
Suction Point (m)		
X	Y	Z
-4.64	-3.187	-2.243

Normalized Impurities @ Plane lined up with discharge port (z = 0.713m)



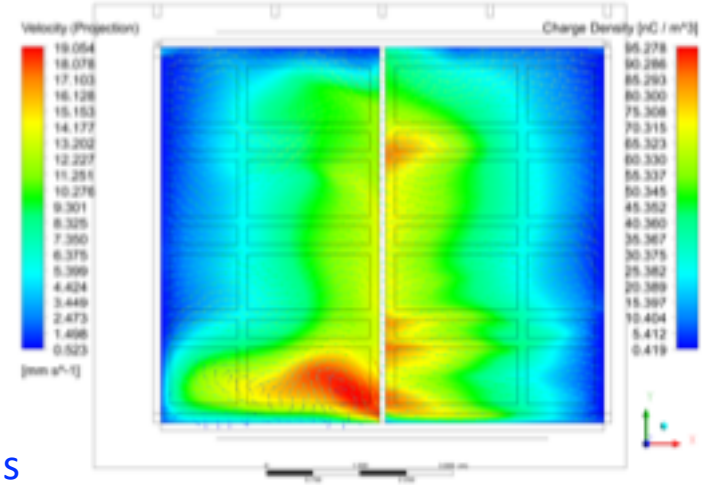
- Developed by Erik Voirin for ProtoDUNE-SP (previously produced for 35-ton) – see DUNE-doc-928
- 3D simulation of LAr flow, 8 mm/s ion drift @ 500 V/cm, uniform space charge deposition from cosmics
- Calculated velocity, temperature, and impurity fields inside ProtoDUNE cryostat using CFD methods.

https://indico.fnal.gov/event/17340/contribution/1/material/slides/0.pdf

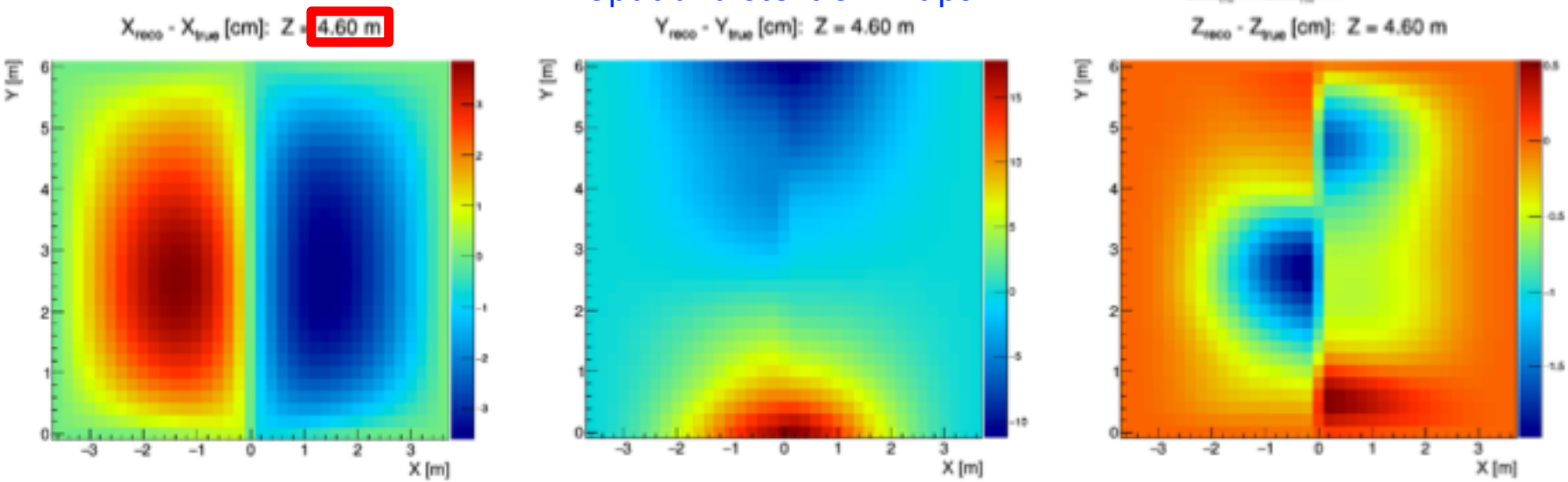
Space Charge Simulation with LAr Flow

Mike Mooney

- Mike Mooney simulated SCE using Erik's space charge density map - **first study of LAr flow on SCE**
- Very different distributions in the two drift volumes
- New maps are being added to simulation
- Essential to have **data-driven calibration**



Spatial distortion maps



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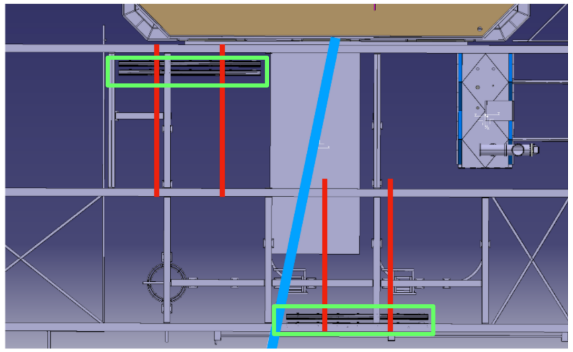
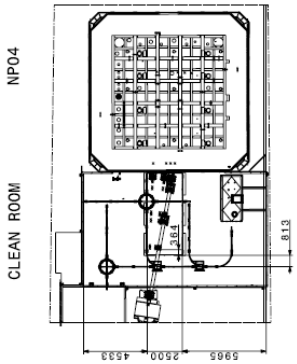
CRT Simulation

- CRT matched tracks will provide valuable information for detector calibration.
- Elzbieta Nowak studied the particle rates and spectra for different CRT frame positions.
- Next steps
  - Finalize CRT frame positions
  - Update geometry (Martin Tzanov)
  - Implement CRT simulation in LArSoft (Andrew Olivier)
  - Match TPC information with CRT information (Arbin Timilsina)

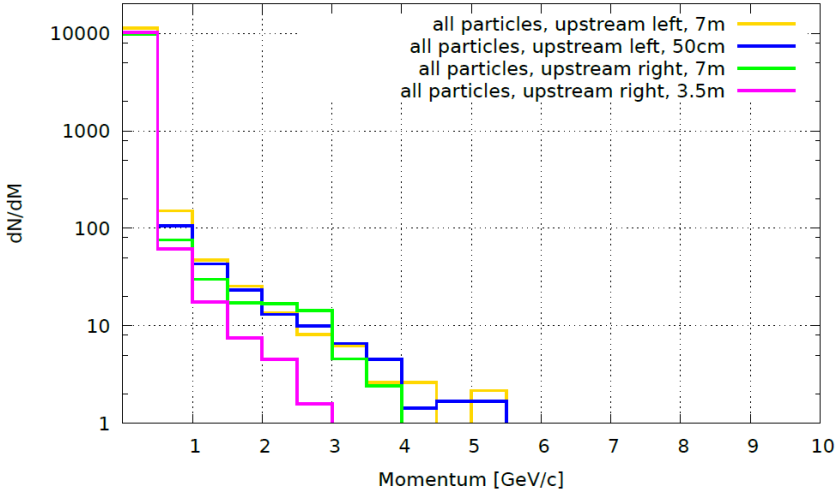
CRT Frame Positions





- 4 modules upstream; 4 downstream
- Upstream modules staggered: 3m and 7m?

By Camillo Mariani



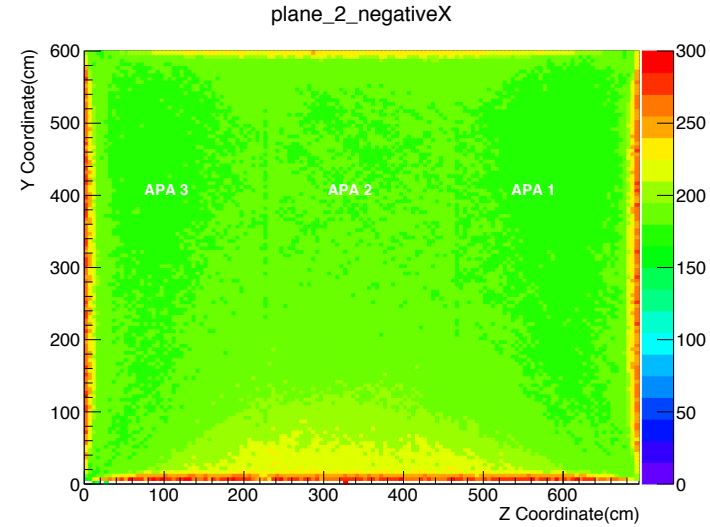
https://indico.fnal.gov/event/17220/contribution/0/material/slides/0.pdf
https://indico.fnal.gov/event/17410/contribution/3/material/slides/0.pdf

Detector Calibration with Muons

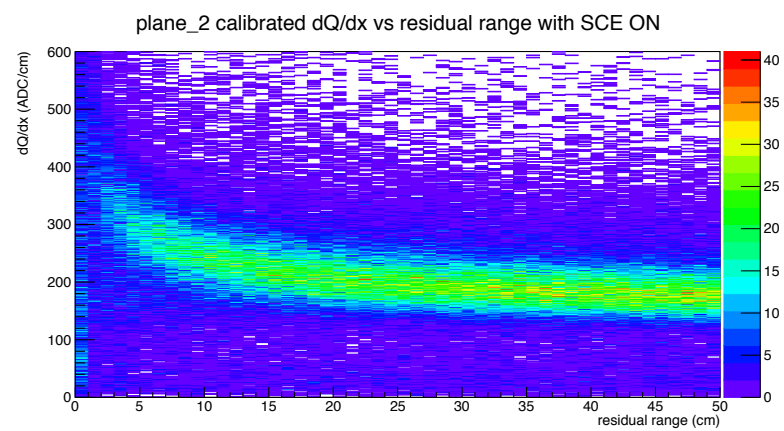
Ajib Paudel

- Similar procedure developed by MicroBooNE: MicroBooNE-NOTE-1048-PUB (2018).
- **dQ/dx calibration** using through-going muons – complete with MC
  - Remove **spatial** and **temporal** variations in detector response
  - Calibration constants are being uploaded to database by Jon Paley
- **dE/dx calibration** using stopping muons – in progress
  - Determine absolute energy scale using muon stopping power
  - More details in DRA meeting next week

dQ/dx calibration

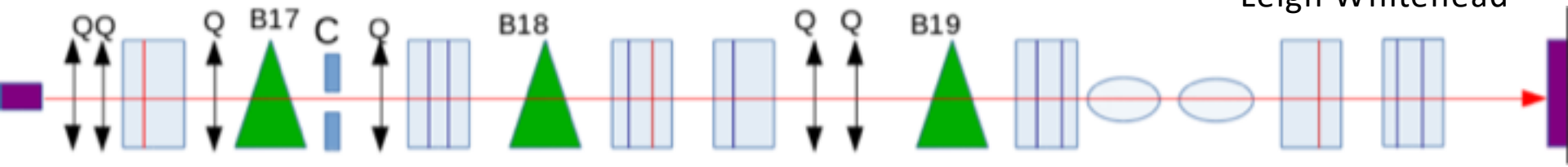


dE/dx calibration



Beamline Instrumentation

Pablo Fernandez
Leigh Whitehead

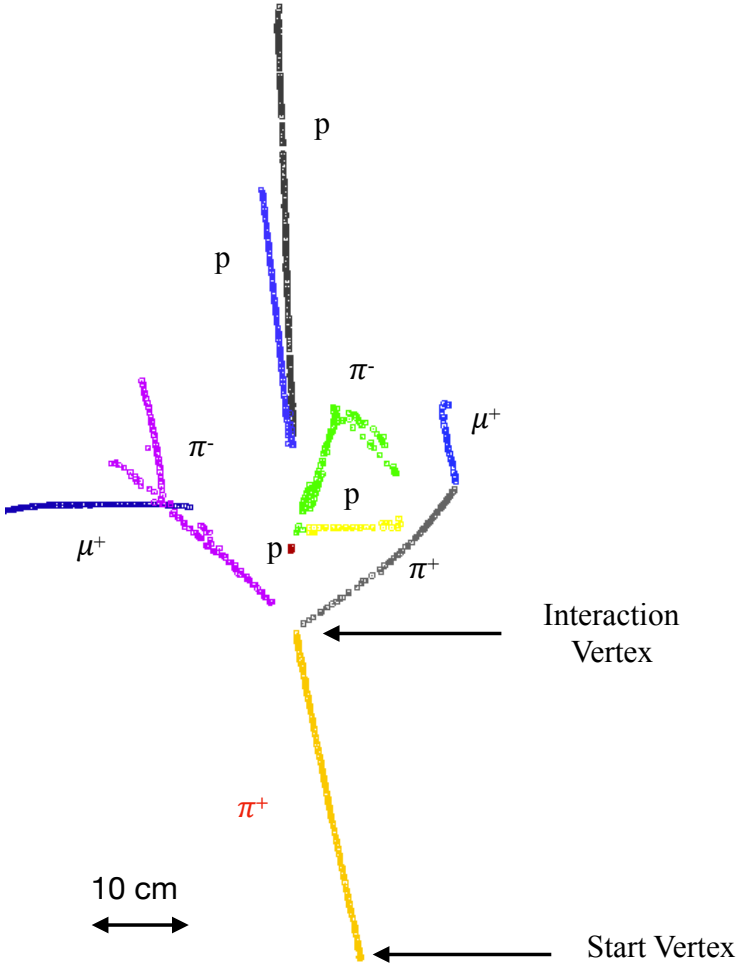


- Working with beamline instrumentation group to save beamline information and match TPC information with beamline information.
- Add the characteristic variable of each beam monitor, and smear according to the insights about the beam monitors given by Paola (from BI group). This is almost done.
- Building another module for the Beam-TPC matching variables. Waiting for the BI group to give us information about the coordinate systems they are using in the simulation.

Reconstruction

Steve Green

- The Pandora team continues to make amazing progress to improve reconstruction for ProtoDUNE.
- Adaptive Boost Decision Tree based Beam Particle ID:
  - Efficiencies: 72.3% for beam and 94.5% for cosmic muons
  - PFParticle hierarchy and tagging to facility analysis
- We recommend people use Pandora reconstruction for the analysis and give feedbacks.



Analysis Plans

- Currently preparing dE/dx measurements
  - Detector calibration
  - Beam-TPC matching
  - Reconstruction development
  - Preliminary results with MC soon
- Planning for cross section measurements is on-going
  - Learning lessons from LArIAT
- Photon detector analysis plans are being formed
  - First priority is to measure the detection efficiency for the 3 PD technologies and provide information to TDR
- Work on a common analysis and systematics framework has started

Conclusions

- Preparing for ProtoDUNE-SP data analysis is progressing very well.
- Will provide useful information to the DUNE physics TDR and publish physics results on cross sections.

Analysis

- Quick space charge studies (before calibration) - Jon Sensenig
- Pion analysis
  - Pion dE/dx - Owen Goodwin
  - Pion momentum resolution (range vs calorimetry vs MCS) -
  - Inclusive pion cross section - Stefania Bordoni, Linda Cremonesi, Jake Calcutt
  - Pion elastic scattering studies - Alex Dvornikov
  - Pion charge exchange cross section -Steve Green, Milo Vermeulen
- Proton analysis
  - Proton dE/dx, recombination - Heng-Ye Liao, George Christodoulou
  - Proton momentum resolution (range vs calorimetry) -
- Electron analysis
  - Electron dE/dx - James Pillow
  - Electron energy resolution - James Pillow
- Kaon analysis - Pablo Fernandez
- Multi-track analysis from secondary vertex -
- Photon detector analysis
  - Photon detector efficiencies - Bryan Ramson, Alex Himmel
  - Photon detectors (which analysis?) - Josh Thompson
- General analysis and systematics framework - All
  - Work started in dunetpc branch feature/lhw_protoAnalysis

https://web.fnal.gov/collaboration/DUNE/SitePages/ProtoDUNEs%20simulation%20and%20reconstruction%20activities.aspx