Update on ProtoDUNE-SP Data Analysis

Tingjun Yang

Collaboration Monthly Meeting

Dec 14, 2018

Introduction

- ProtoDUNE-SP analysis is progressing well.
- In this talk, I will summarize the current status of reconstruction and analysis efforts.
- In the end I will talk about the near-term and long-term plans.

Resources

- Wiki: how to look at ProtoDUNE-SP data:
  - https://wiki.dunescience.org/wiki/Look_at_ProtoDUNE_SP_data
- Protodune channel on SLACK.
- Weekly meeting on Wednesday.
- LArTPC reconstruction and calibration workshop:
  - https://indico.fnal.gov/event/18523/
- ProtoDUNE analysis workshop on Jan 27, 2019
  - https://indico.fnal.gov/event/19133/
  - The list of topics for physics analyses (with TPC, PD, CRT data) will be presented at this workshop.

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

Summary of known issues in data

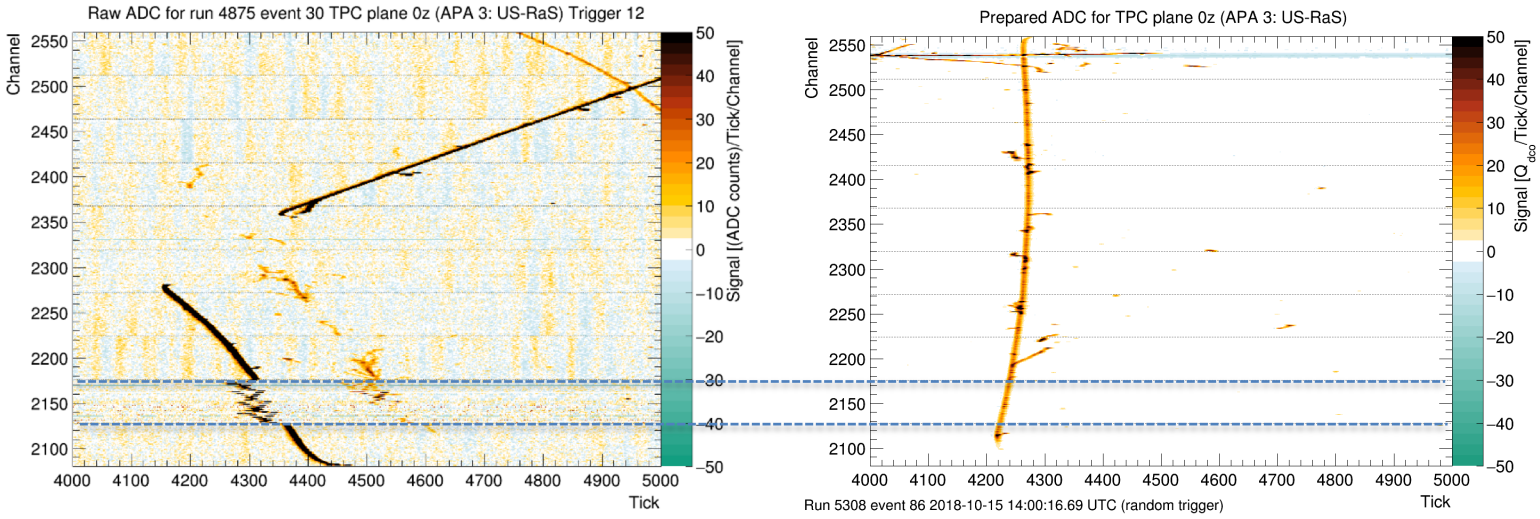
Tom Junk

- Sticky ADC codes - standard mitigation in place, and alternatives for doing it better are being explored. Not a problem.
- Coherent noise - being worked on.
- FEMB 302 loss of timing signals - mitigated.
- Undershoot - mitigated
- Nonuniformity of response near field cage - analyzers have to set fiducial cuts
- Distortion and loss of charge due to electron diverters - either cut out that region or interpolate missing information.
- Front-end saturation - affects cosmic rays. Still needs study to see if high-energy beam events are impacted.
- Ledge effect - with the new baseline, most data were taken with little ledge-effect signals seen.
- Dead and otherwise bad channels - very small fraction, not a problem. We are measuring the impact of disconnected wires on signals in neighboring planes.

FEMB 302 – time misalignment recovered

JJ Russell
Tom Junk
David Adams

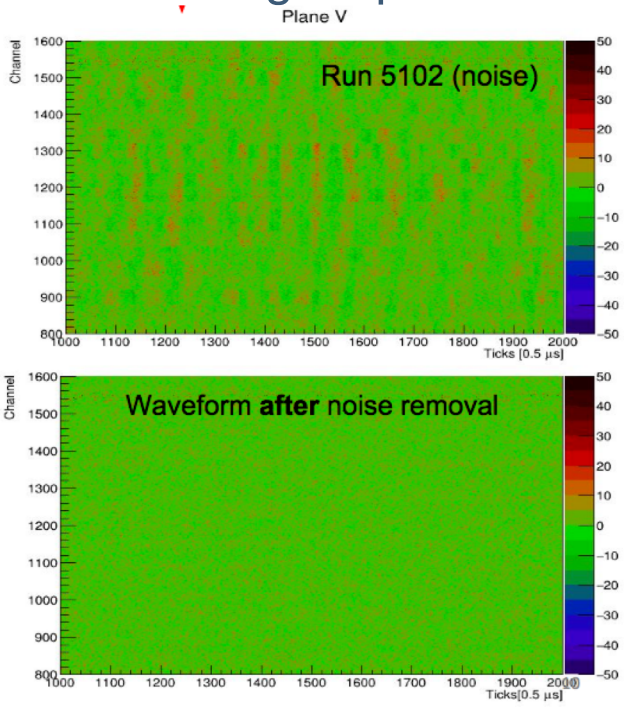
- FEMB 302 has lost both of the clock lines, likely due to a partially broken connector, which led to time offsets in the TPC data.
- JJ Russell improved the data unpacker to significantly improve timing alignment. David Adams further improved the time offset by stretching the waveform to correct for the slightly different sampling rate.
- Details in Tom Junk's talk: https://indico.fnal.gov/event/18800/contribution/6/material/slides/0.pdf

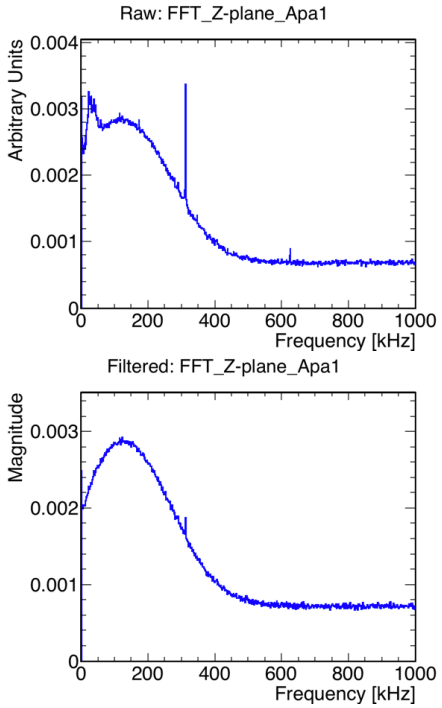


Coherent noise removed

Carlos Sarasty
Wenqiang Gu
Jingbo Wang

- The source of this coherent noise is the low voltage regulator that provides power to the cold electronics. It manifests at low frequencies ≈ 40 kHz.
  - The level is low in ProtoDUNE-SP.
  - Can be mitigated using median of waveforms from the same FEMB after signal protection.





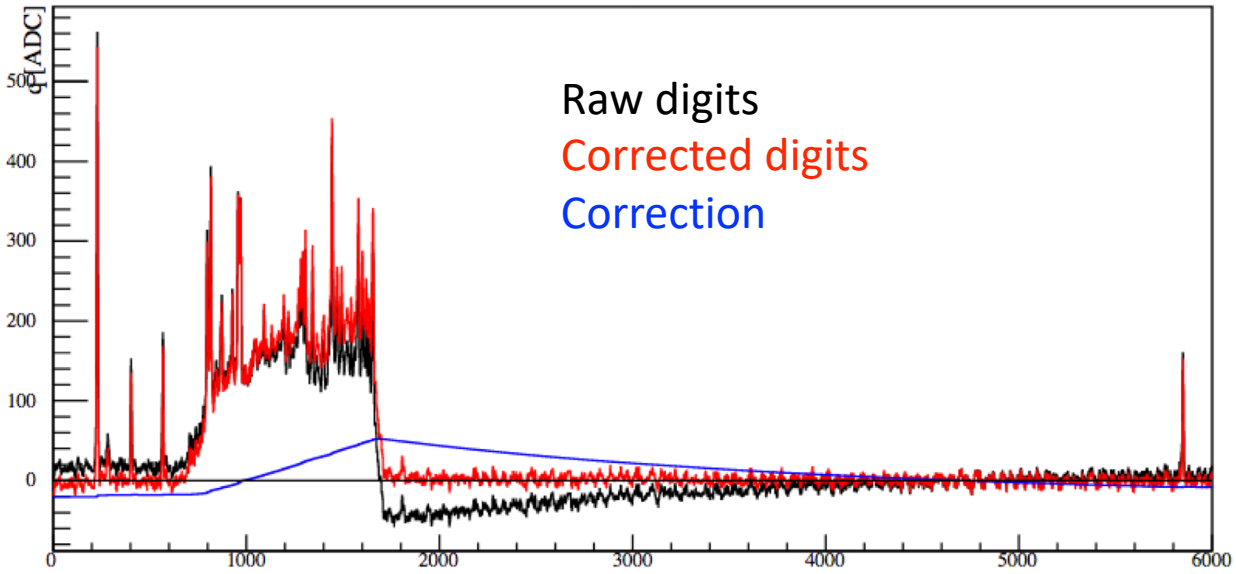
Carlos Sarasty, Wenqiang Gu: https://indico.fnal.gov/event/18925/contribution/1/material/slides/0.pdf

Jingbo Wang: https://indico.fnal.gov/event/19262/contribution/12/material/slides/0.pdf

Undershoot Correction

Tom Junk

- Undershoot caused by AC coupling in the front end.
  - Long time constant(s) (~milliseconds)
  - Most prominent in collection plane
- Tom developed a method to fix it in the time-domain
- https://indico.fnal.gov/event/19015/contribution/1/material/slides/0.pdf

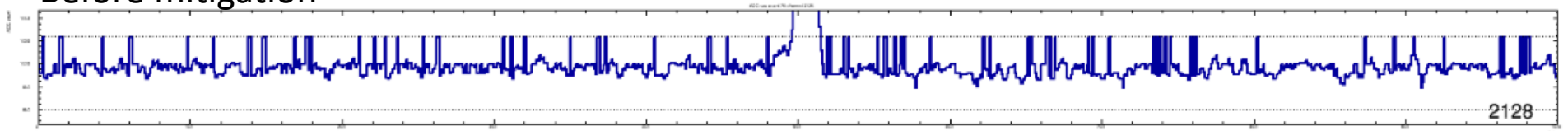


Sticky Code Mitigated

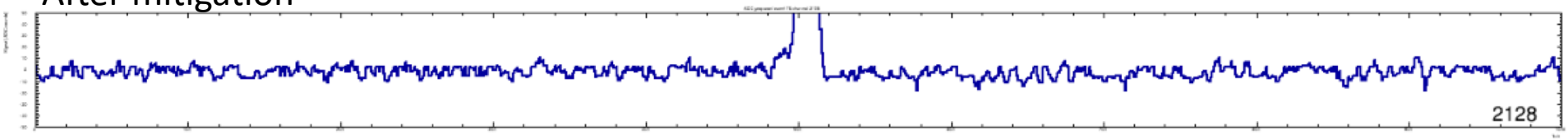
David Adams
Wenqiang Gu

- Sticky code - the 6 LSBs in ADC ASIC was found to be “sticky” around 000000 (0x00) or 111111 (0x3F).
- Can be mitigated through linear interpolation or constant-curvature interpolation.
- A new method is developed to interpolate through FT.

Before mitigation



After mitigation



https://indico.fnal.gov/event/19071/contribution/3/material/slides/0.pdf
https://indico.fnal.gov/event/18427/contribution/1/material/slides/0.pdf

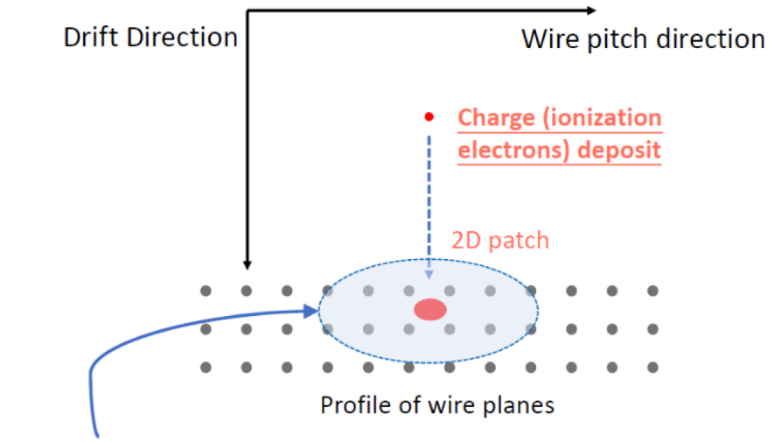
Reconstruction/analysis efforts

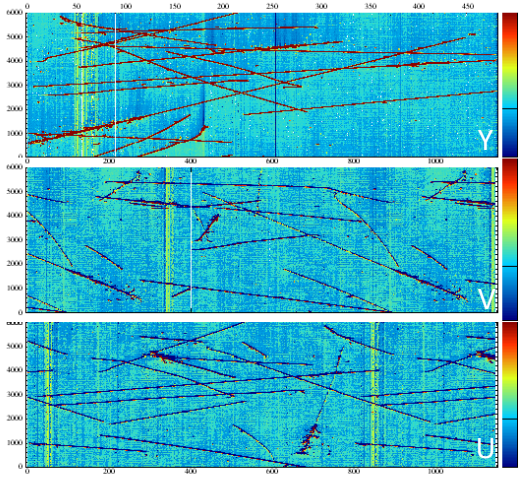
- Reconstruction
  - 2D deconvolution – first result looks promising
  - Tag anode crossing tracks with t0
    - https://indico.fnal.gov/event/19185/contribution/5/material/slides/0.pdf
  - CNN shower tagging – testing
- Calibration
  - Detector uniformity and energy scale
  - Space charge effects
- Analysis
  - Signal to noise ratio
    - https://indico.fnal.gov/event/19185/contribution/4/material/slides/0.pdf
  - Improved beamline-TPC matching
  - Evaluate beam particle reconstruction efficiency
    - https://indico.fnal.gov/event/19132/contribution/3/material/slides/0.pdf
  - Detector alignment
    - https://indico.fnal.gov/event/19071/contribution/5/material/slides/0.pdf

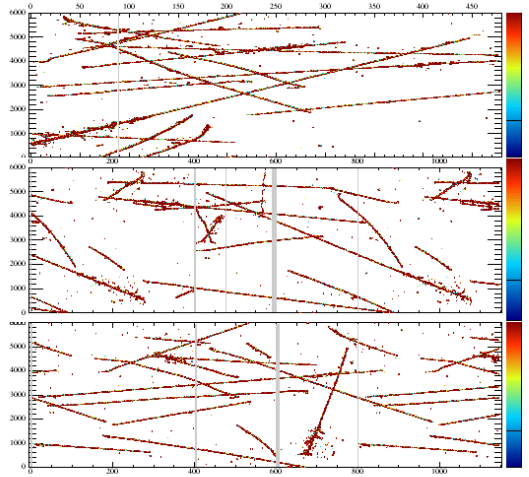
2D deconvolution

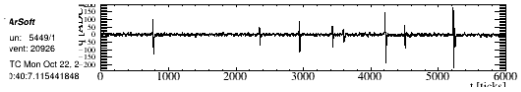
WireCell Team

- Induction from neighboring ionization electrons are important to recover the signal on the induction wires.
- 2D deconvolution tested on data.

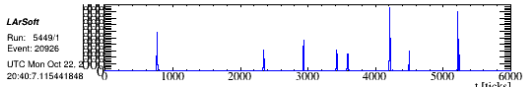




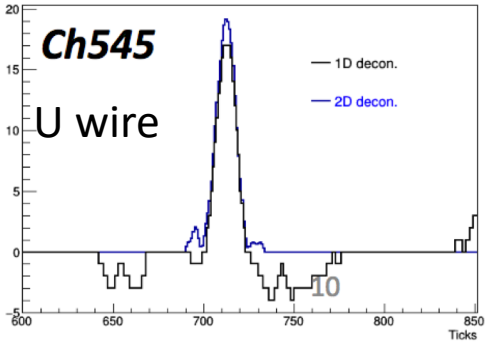




Raw signal



After undershoot correction, sticky code mitigation, 2D deconvolution and ROI finding.



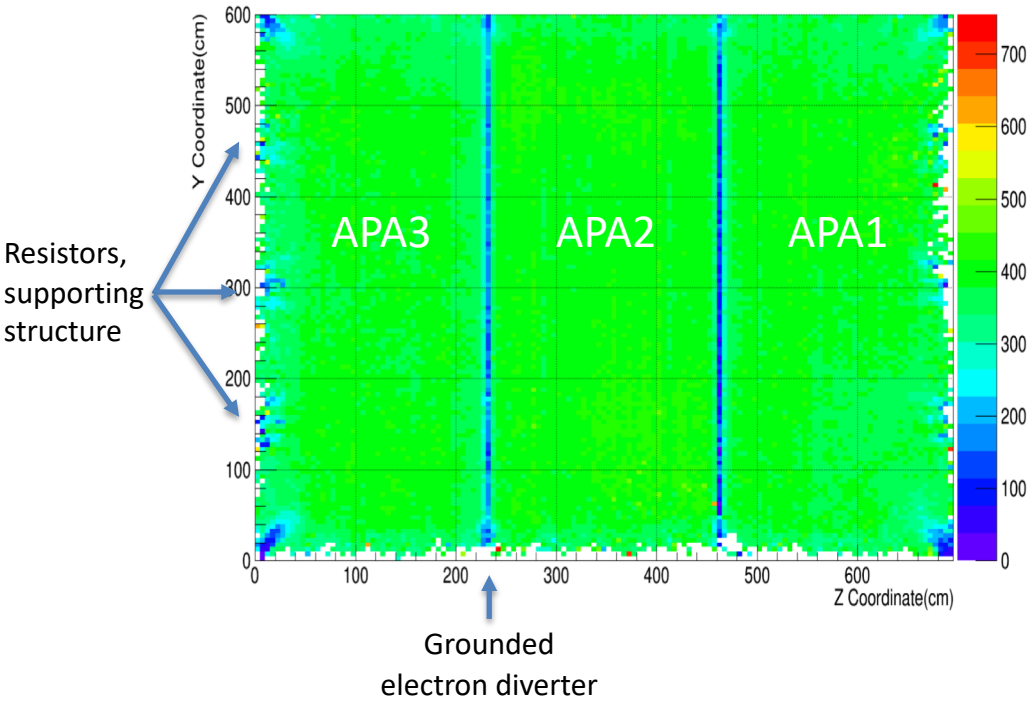
Wenqiang Gu:
https://indico.fnal.gov/event/19185/contribution/1/material/slides/0.pdf

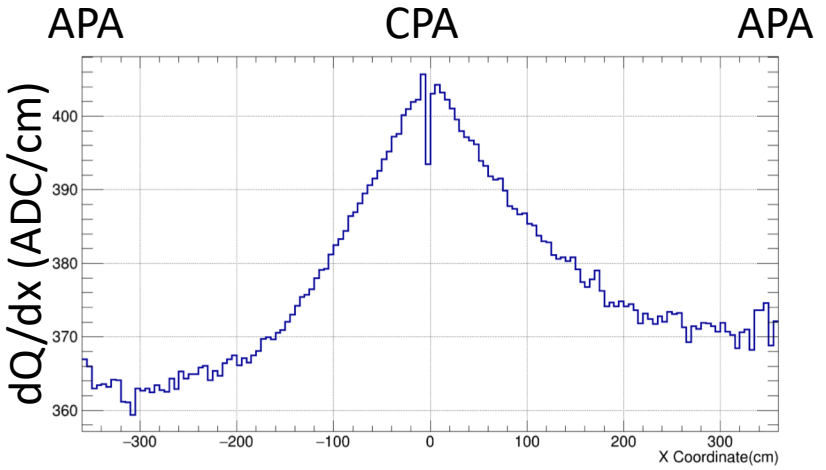
Detector Uniformity Studied

Ajib Paudel
Tom Junk

- Using cathode-crossing tracks (provides t_0 tag) to study detector uniformity.

Beam side collection planes





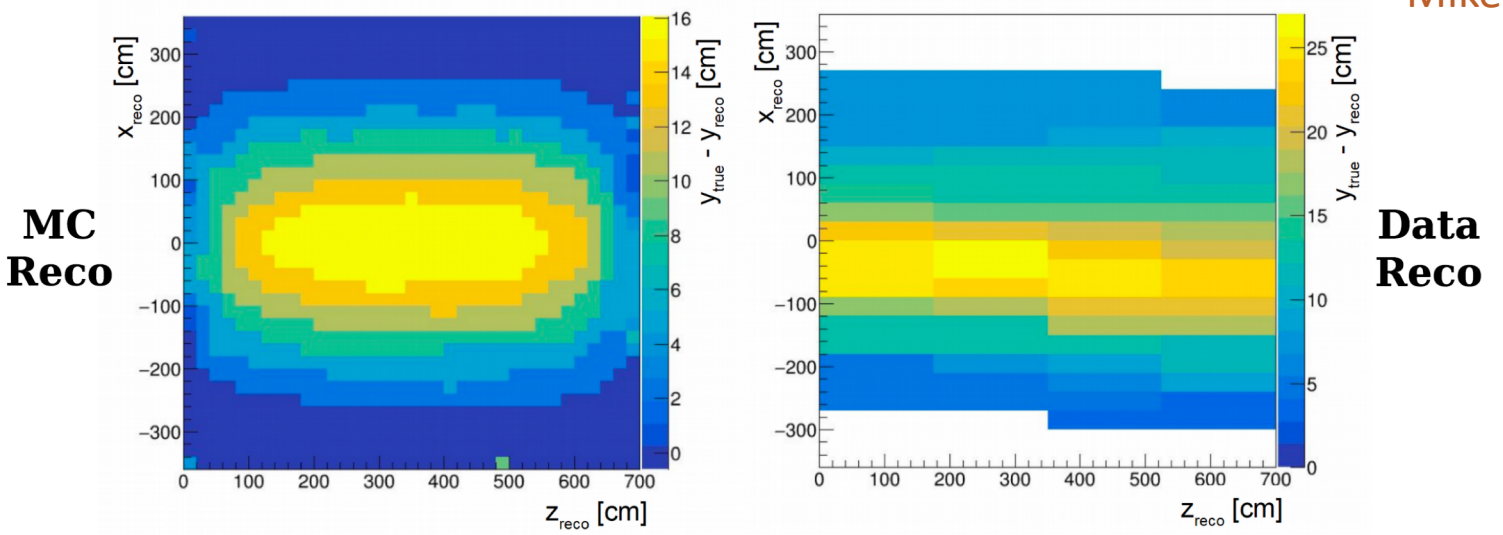
Q_C/Q_A ~ 1.1

Detector response looks uniform.

Ajib: https://indico.fnal.gov/event/19132/contribution/1/material/slides/0.pdf
Tom: https://indico.fnal.gov/event/19354/contribution/1/material/slides/0.pdf

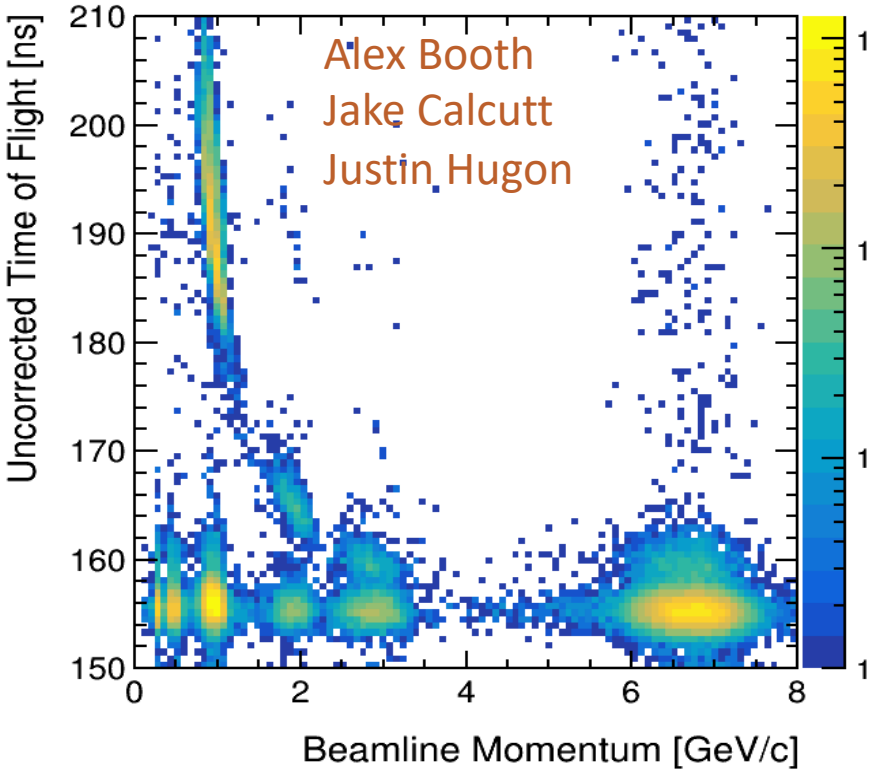
Space Charge Effects Studies in Progress

Hannah Rogers
Mike Mooney

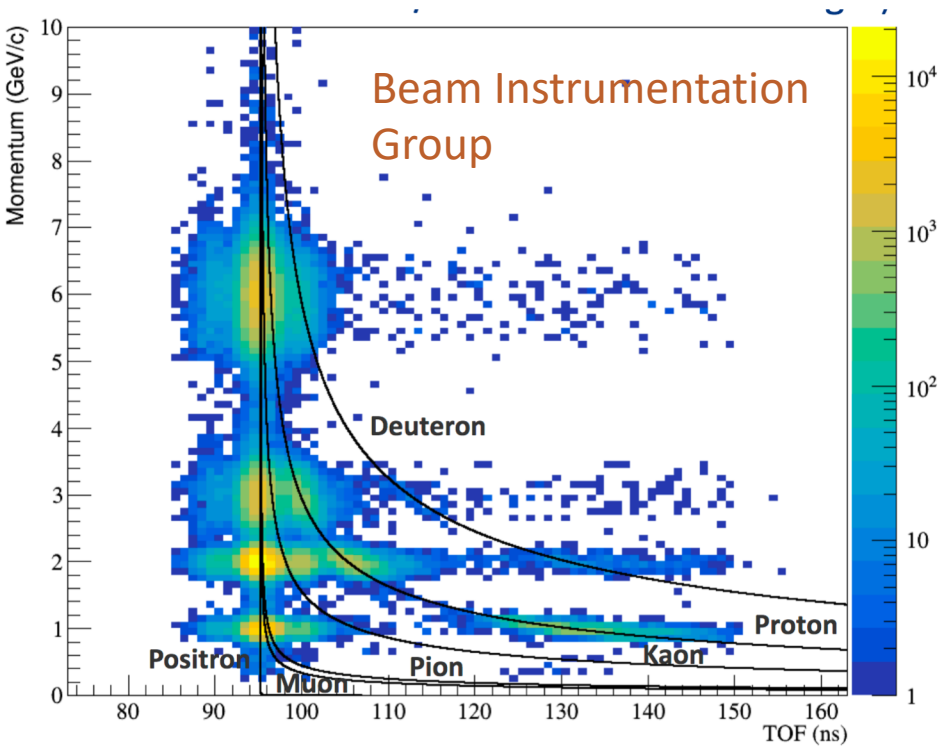


- Using cathode-crossing cosmic tracks (provides t_0 tag) in ProtoDUNE-SP data to study spatial offsets at TPC top
  - Coarse binning due to low statistics; processing more data, should have extensive study of TPC faces by end of year
  - Spatial offsets slightly larger than expected: **25+ cm**
  - Hints of correlation w/ electron lifetime... negative ions?
- https://indico.fnal.gov/event/18731/contribution/5/material/slides/0.pdf
- A task force is recently formed to address the need to use different samples.

Beamline information



Raw beamline information included in production files.



Calibrated beamline information

- https://indico.fnal.gov/event/19185/contribution/2/material/slides/0.pdf
- https://indico.fnal.gov/event/19270/contribution/1/material/slides/0.pdf

Photon detector system

Data

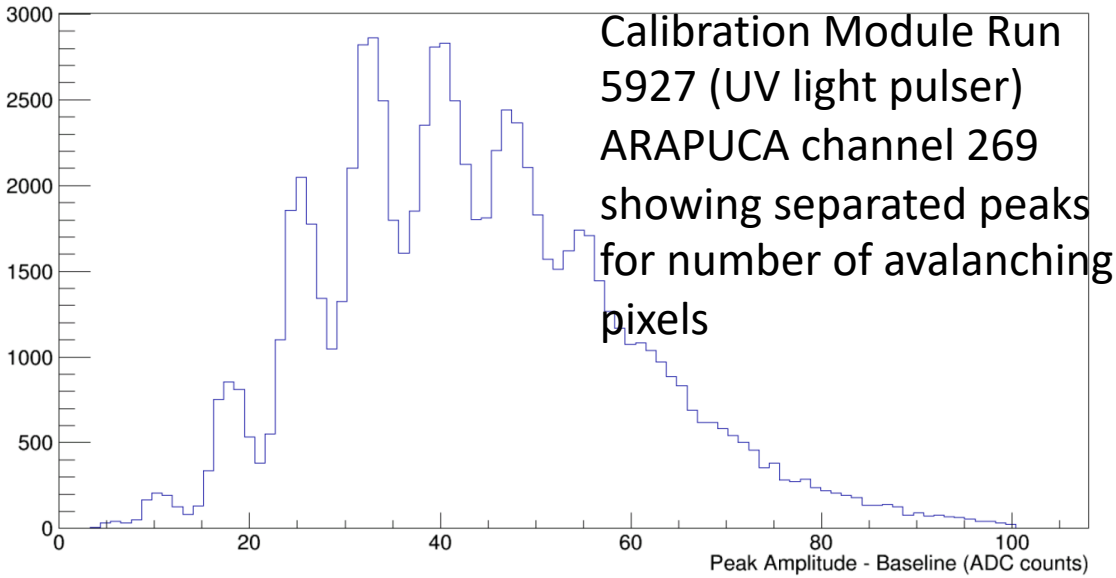
- Lots of data
  - Bias scans for all Sensors
  - Cosmics, lots of cosmic
  - Beam data
  - CRT
  - DCM Calibration Module

Calibrations

- SensL Bars
- MPPC Bars
- ARAPUCA (MPPC)
  - x12 & 2x6 (should be the same)
- Data sources:
  - Bias Scans
  - Quiet parts of external triggers
  - Calibration Module data

Future Plan

- Finish Calibration Measurements
  - Will probably require additional runs to optimize calibration
- Analyze event–by–event data integrating CRT/TPC/BI/PDS



Calibration Module Run 5927 (UV light pulser) ARAPUCA channel 269 showing separated peaks for number of avalanching pixels

Conclusions and future plan

- The ProtoDUNE-SP data analysis is progressing well.
  - Most of the data imperfection are understood and are largely mitigated - further improvements in progress.
  - Reconstruction is being improved (2D deconvolution, etc.)
  - Beamline information is helpful for particle ID and momentum measurement.
- Next steps
  - Finish detector calibration (need CRT information).
  - Measure dQ/dx and dE/dx of pions, protons and electrons.
  - Preliminary results on cross sections.