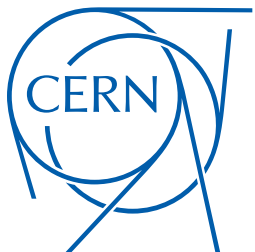


# ProtoDUNE-SP

## A First Look at Data

Leigh Whitehead  
(On behalf of the DRA)

19/10/18

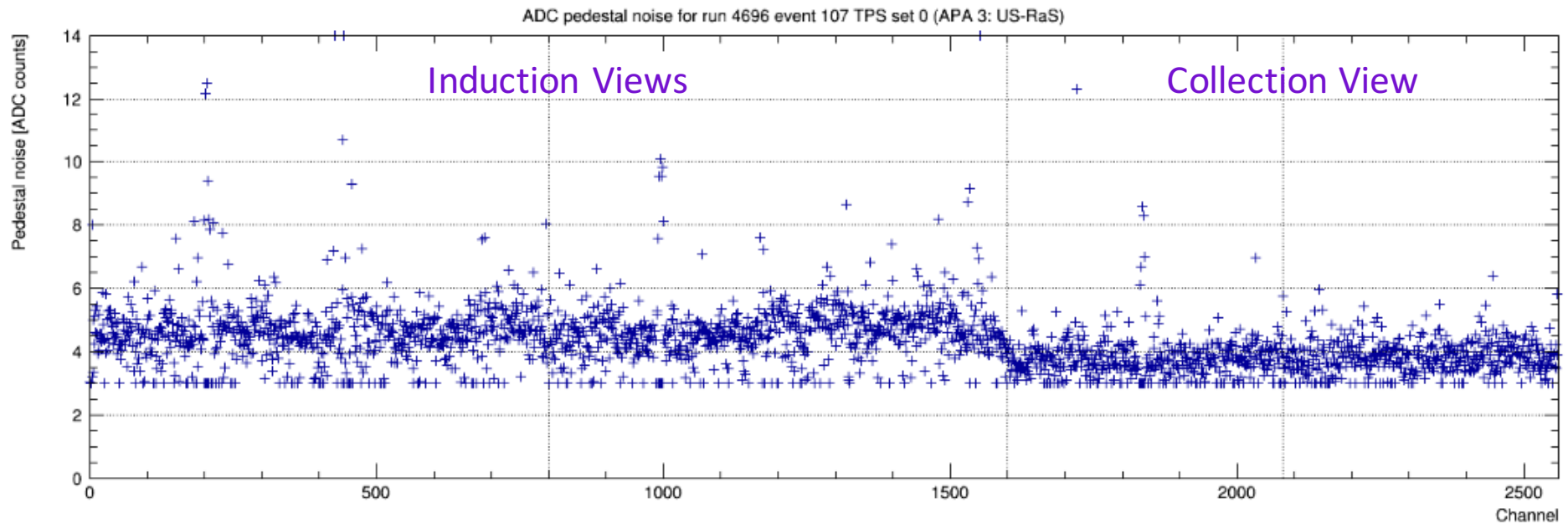


# Introduction

- I'll cover the main points from the protoDUNE data studies so far
- Low-level reconstruction
  - Noise level and signal-noise
  - Electron lifetime
- Calibrations
  - Sticky code mitigation and electronics calibration
  - Space-charge calibration
  - Muon-based calibrations
  - Beam-TPC information matching
- High-level reconstruction
  - Event displays using Pandora's track- and shower-finding capabilities

Thanks to Tingjun for his slides from the LBNC review

# Noise level



D. Adams, BNL

DUNE Collaboration: PD physics, sim reco

Looking at protoDUNE data

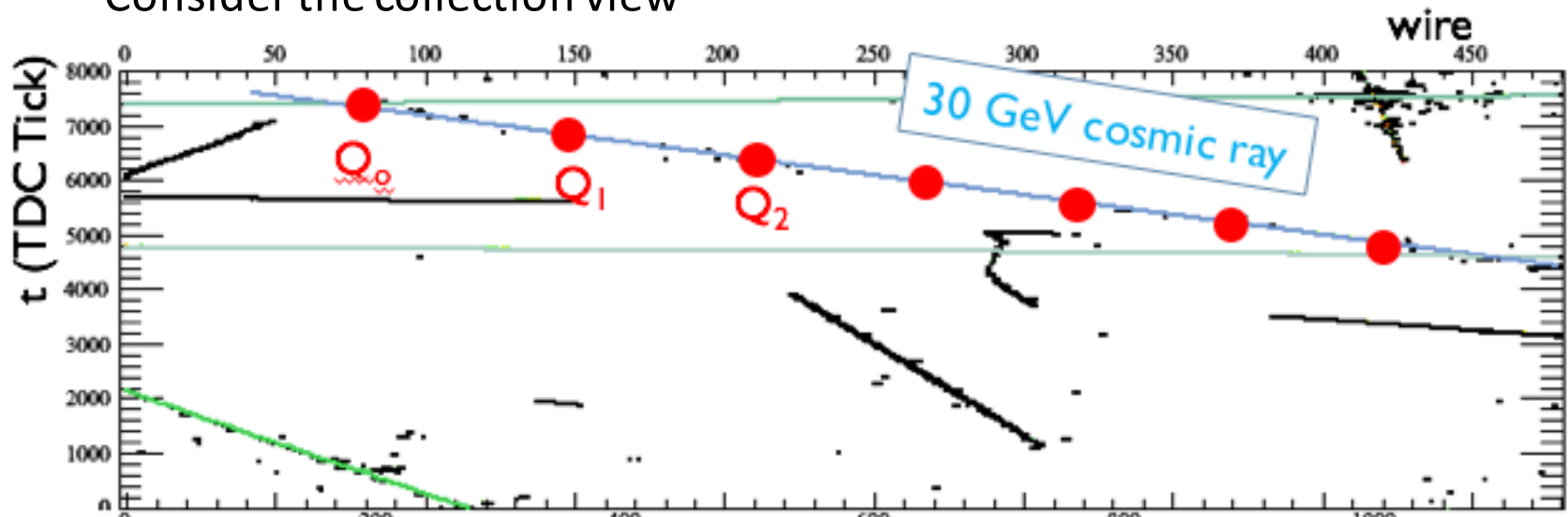
September 27, 2018

14

- Measured noise-level:
  - Collection plane: 3.5 ADC or 500  $e^-$
  - Induction plane: 4.5 ADC or 600  $e^-$
- Preliminary results show 99.7% of 15,360 channels are alive
- Masking of bad channels is underway

# Electron lifetime and S/N

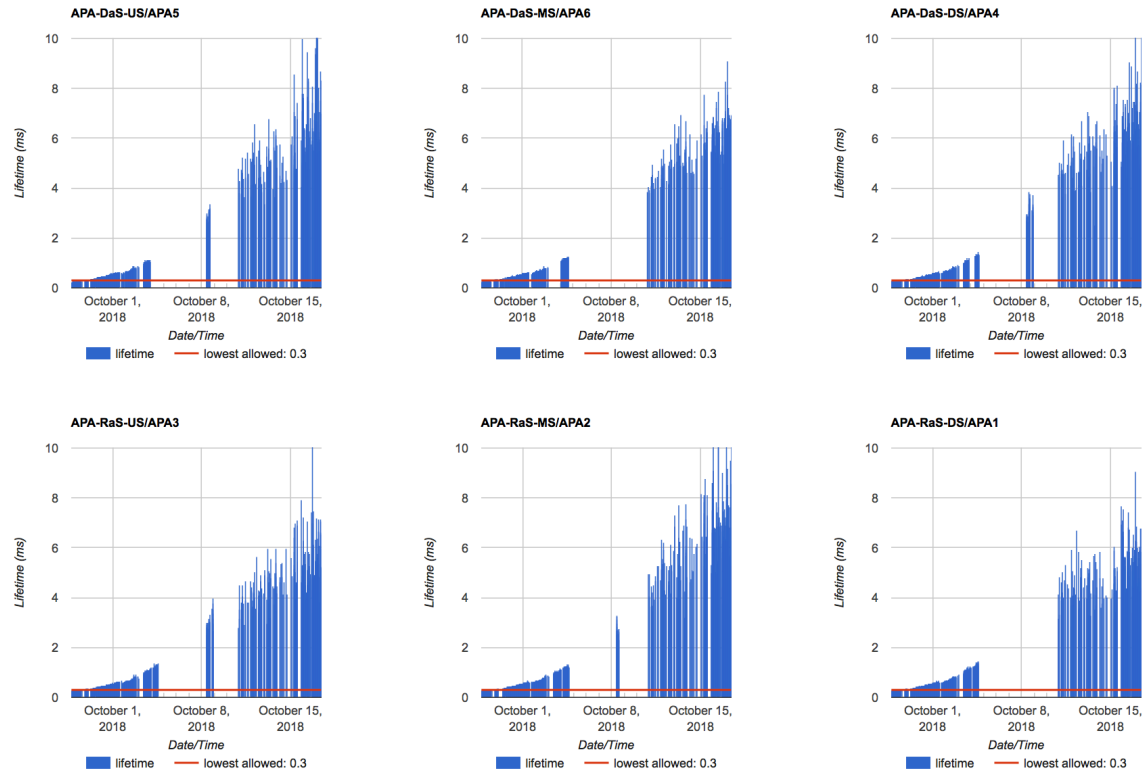
- Use reconstruction up to the “trajcluster” clustering step
  - Consider the collection view



$$Q_n = Q_0 \exp(-(t_n - t_0)/\tau) \quad \tau = \text{drift electron lifetime}$$

- S/N: Use low-angle cosmic rays and take the average of the peak pulse-height compared to the background wire noise

# Electron lifetime

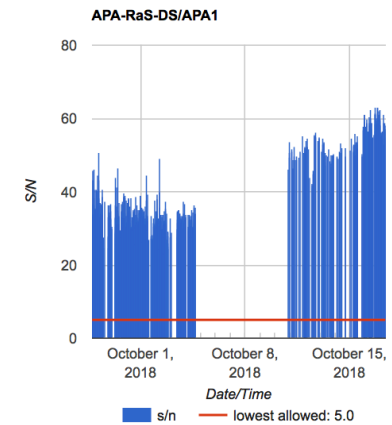
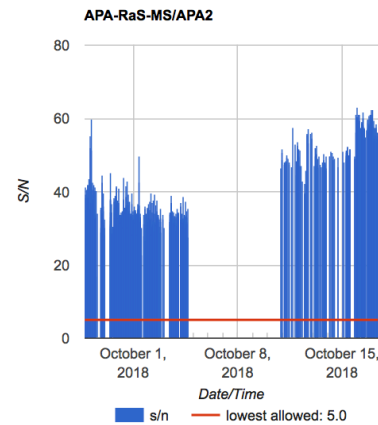
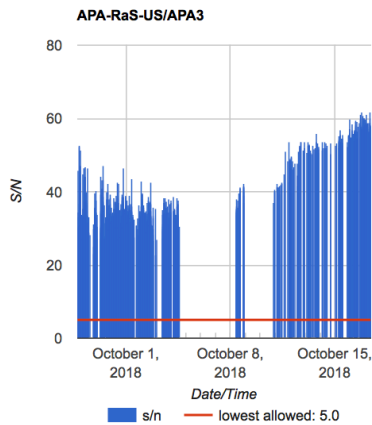
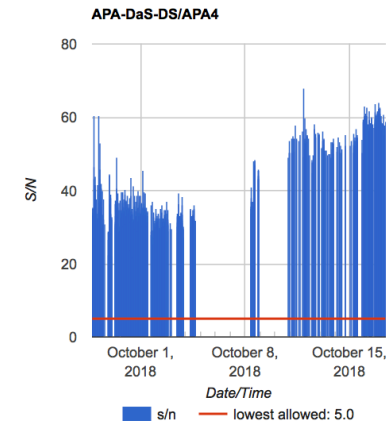
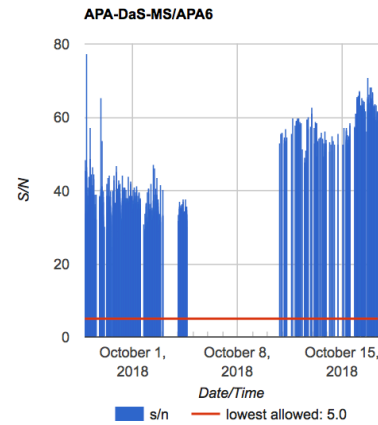
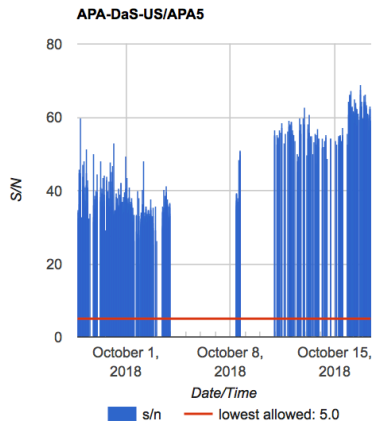


- Module running in DQM reports lifetime  $> 6\text{ms}$
- Purity monitors in the detector:  $> 4\text{ms}$

These values have some biases, so true value likely somewhere in the middle

See here: <http://p3s-content.cern.ch/monitor/puritychart>

# Signal-to-Noise



Beam

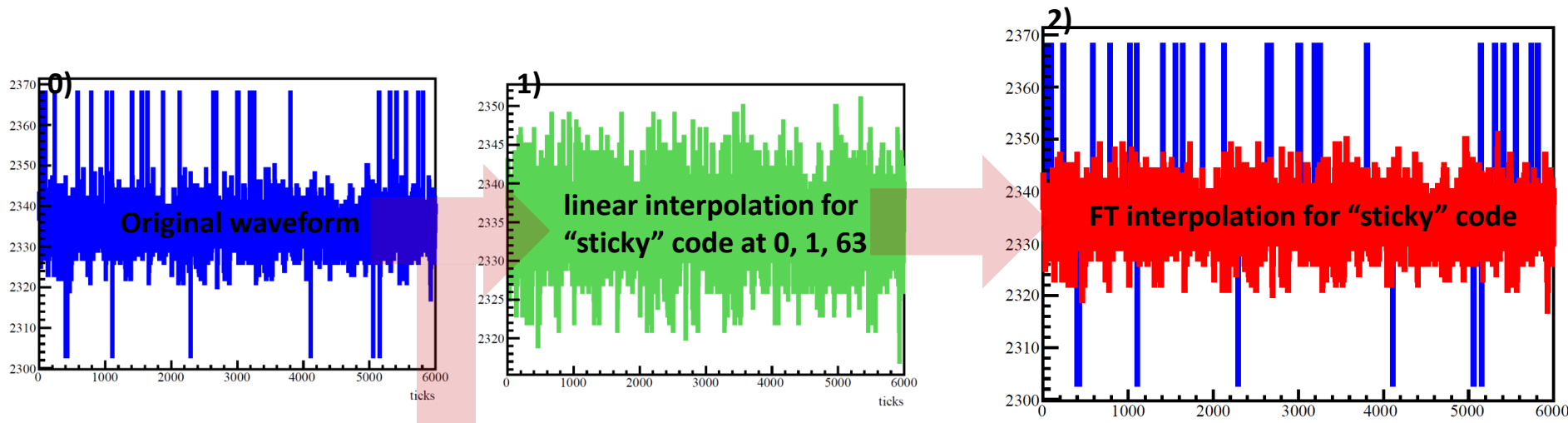


- Module running in DQM reports S/N of about 50 in all APAs

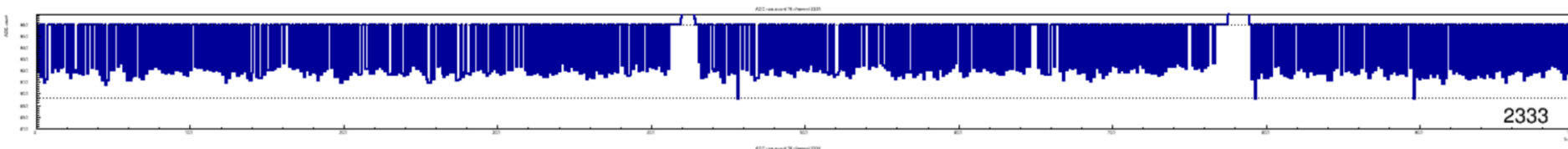
See here: <http://p3s-content.cern.ch/monitor/snchart>

# Sticky codes

- Sticky codes are a known problem with the ASICs
  - The six least significant bits can get stuck at all 0s or all 1s
  - Mitigation through linear or FT interpolation

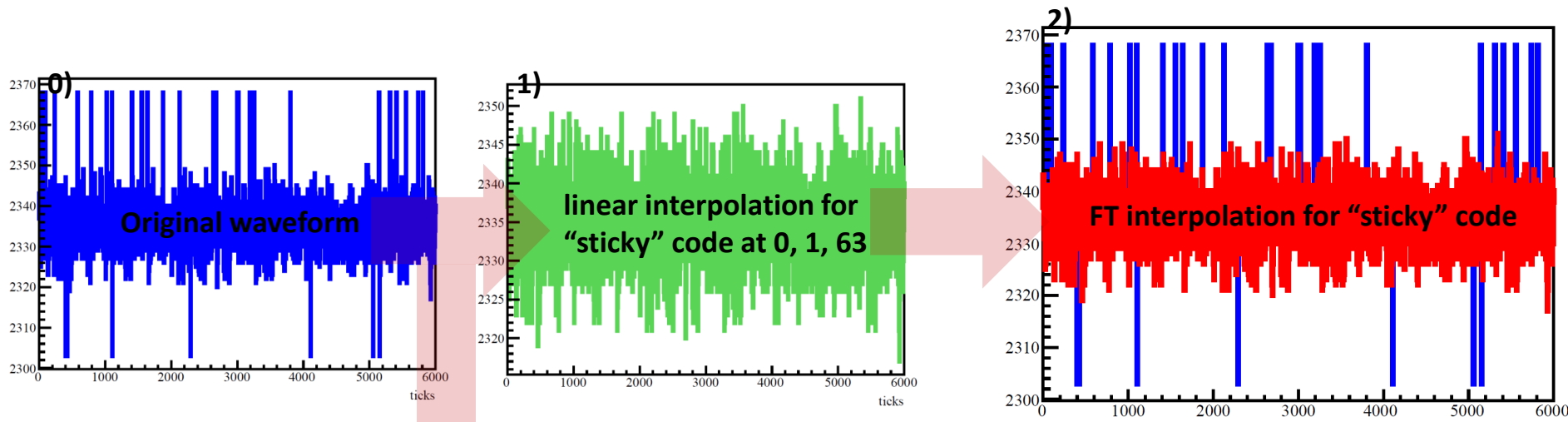


- Example of linear mitigation from data:

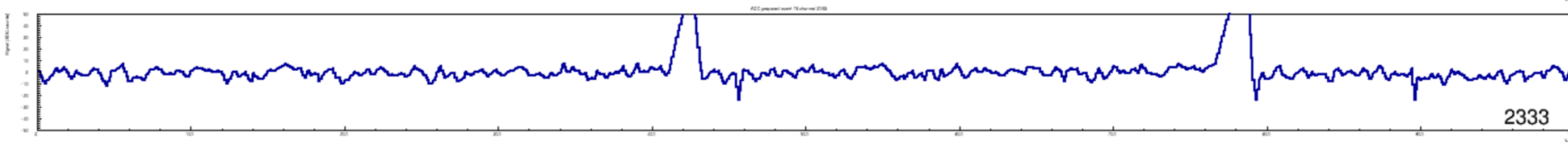


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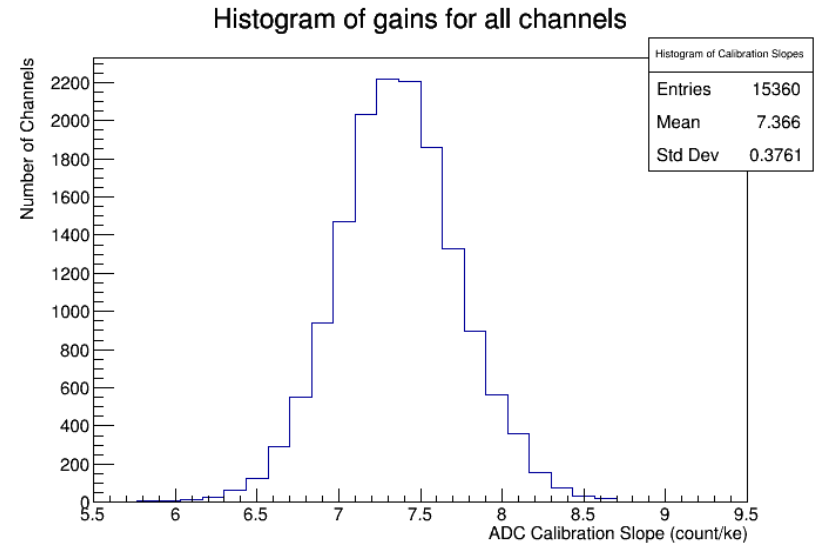
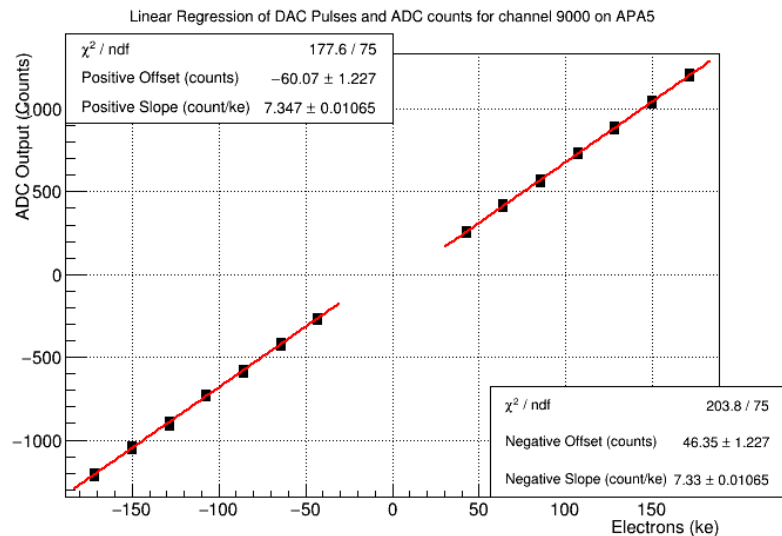
- Example of linear mitigation from data:





# ADC gain and linearity

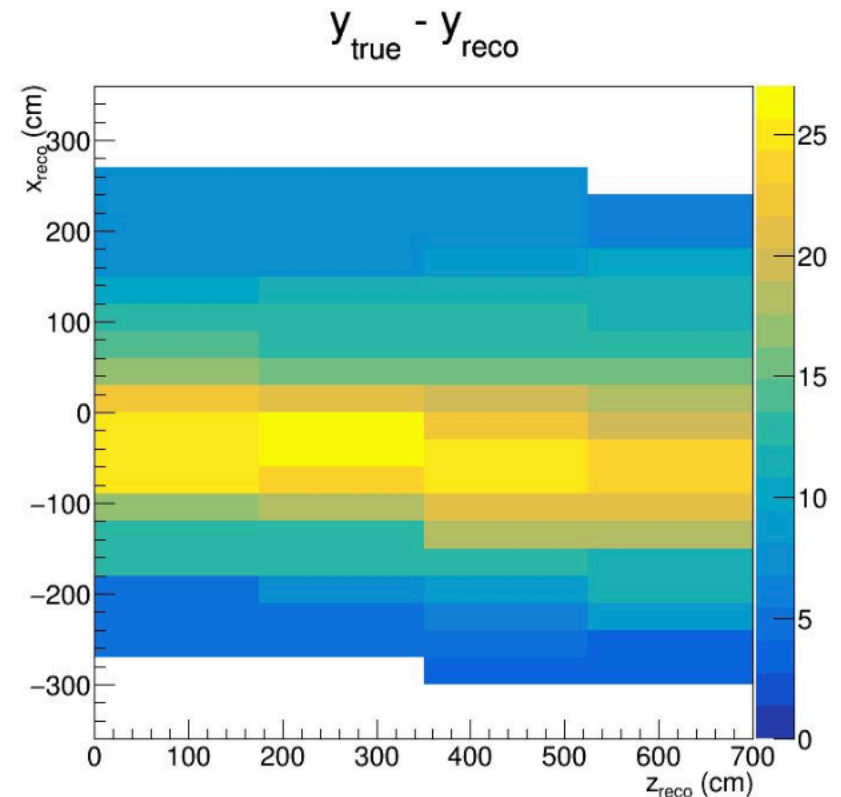
- Pulser data used to measure the ADC gain and linearity



- The gain variation is approximately 5% averaged across all channels

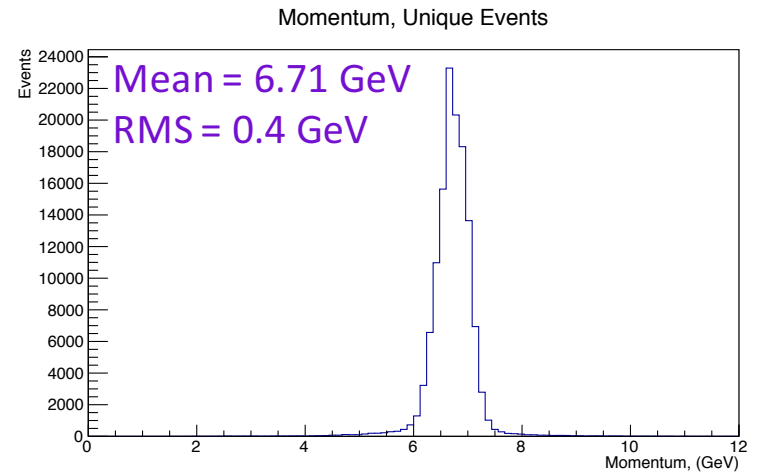
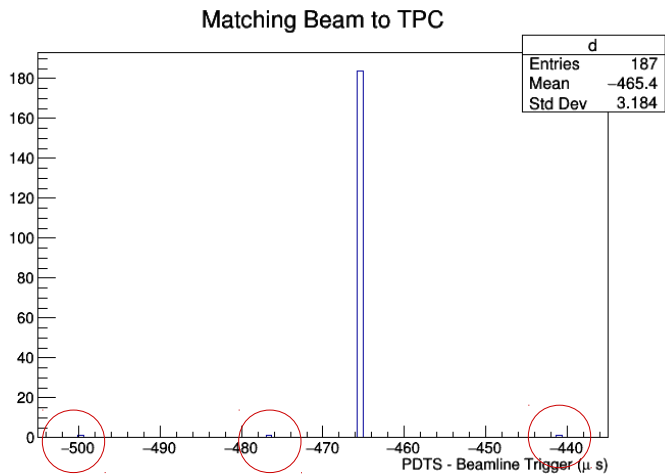
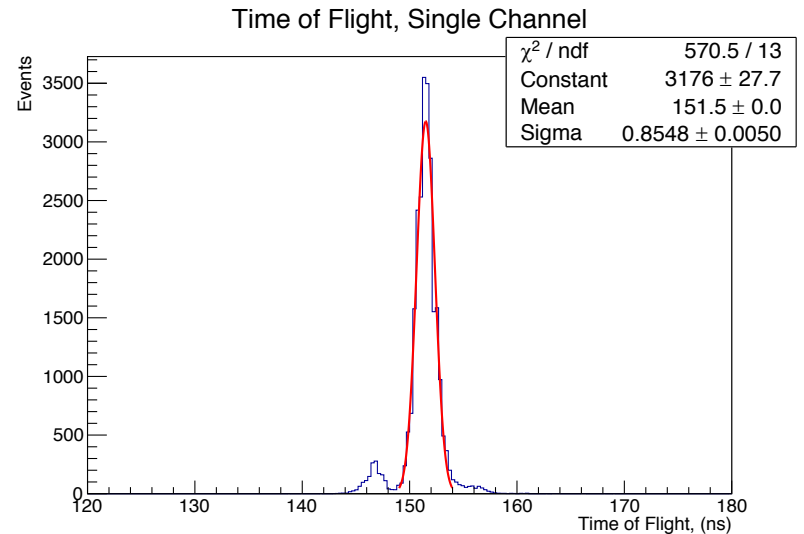
# Space charge

- Space charge calibration uses 3D reconstructed cosmic muons
  - This means we must know the T0 of the tracks! The two sources are cathode-crossing tracks and anode-piercing tracks (with matched optical flash)
- Very preliminary study using just a few hundred cathode-crossers
- See offsets at the top of the detector of the order of 25cm in y near the cathode



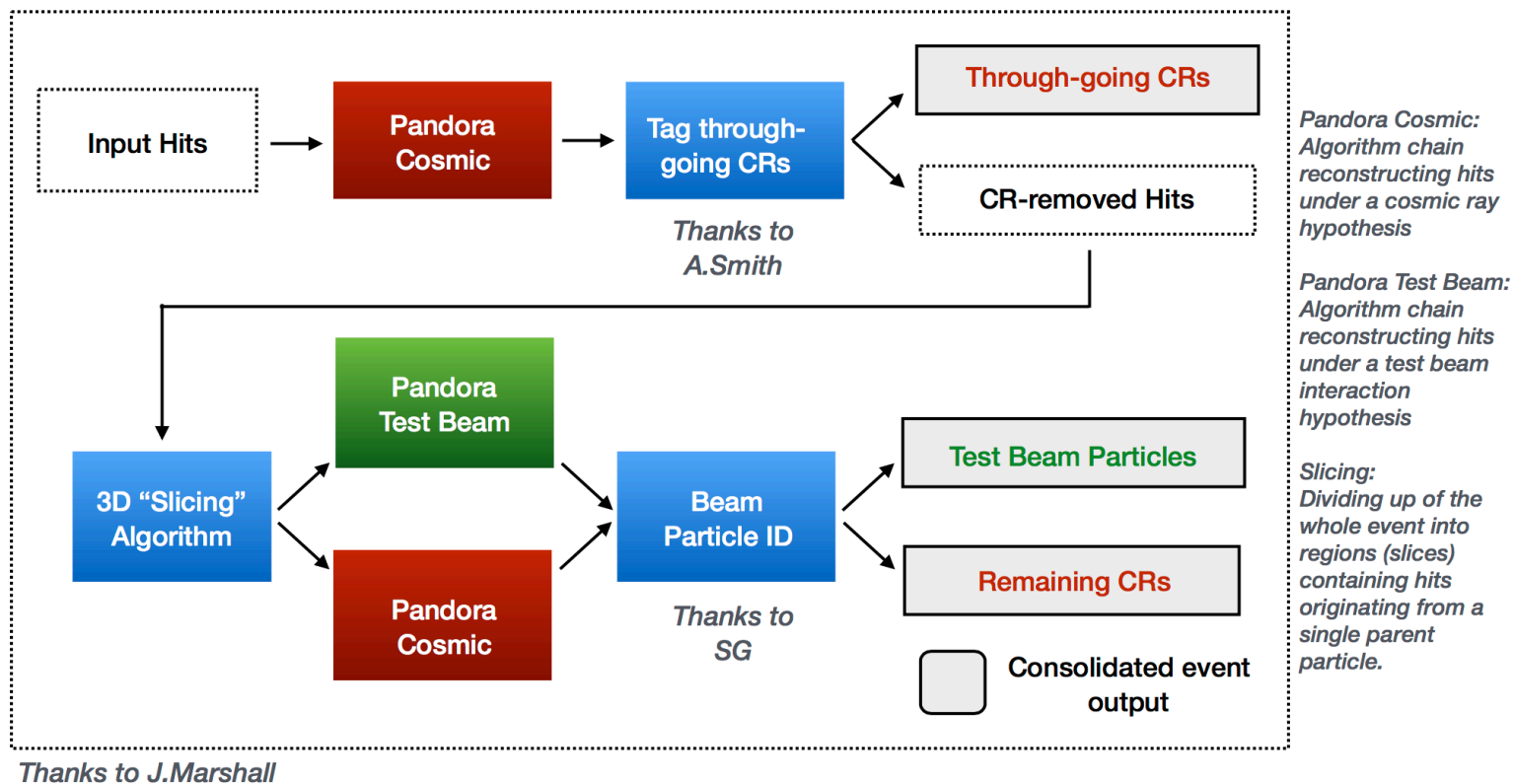
# Beamline information

- Beam information saved into DIP at CERN and copied to the IFBeam database at FNAL
  - Used by online monitoring and the offline reconstruction
  - Key to matching the TPC track back to the beam and PID



# Pandora reconstruction

- The reconstruction chain:



- The output is a particle hierarchy with daughter particles attached to the parents – very convenient for analysis!

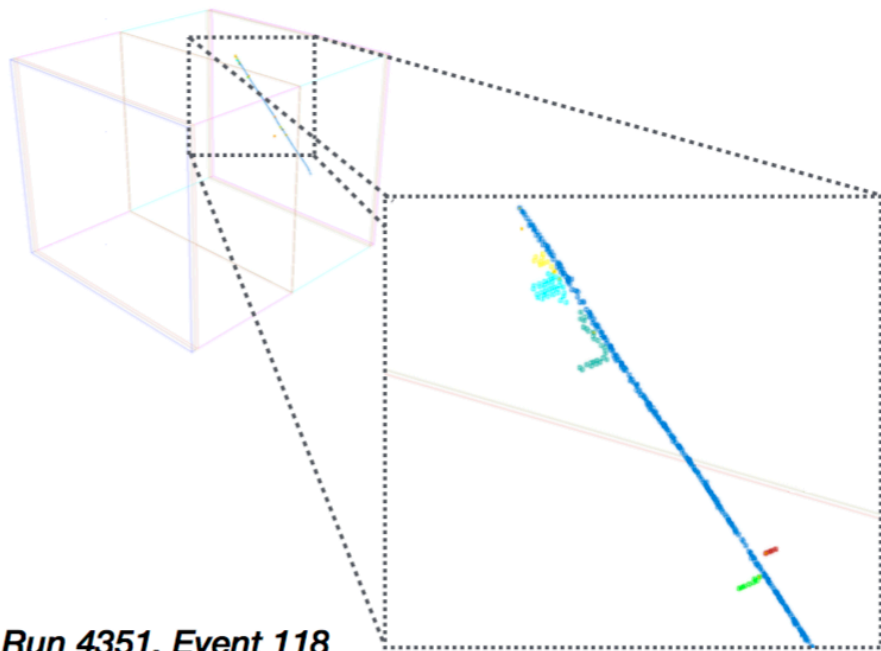
# Pandora reconstruction

- We have processed a small number of interesting events
- Only changes made compared to MC processing:
  - Slightly increased hit charge threshold to mitigate some noisy channels
  - Cut-off to remove some low frequency noise in induction planes
- This aside, the reconstruction was run normally
  - A few of the early examples needed to be forced to use the Pandora test-beam reconstruction mode
  - Those examples from the actual beam run are shown "out-of-the-box" meaning Pandora recognised them as beam interactions

# Early cosmic events

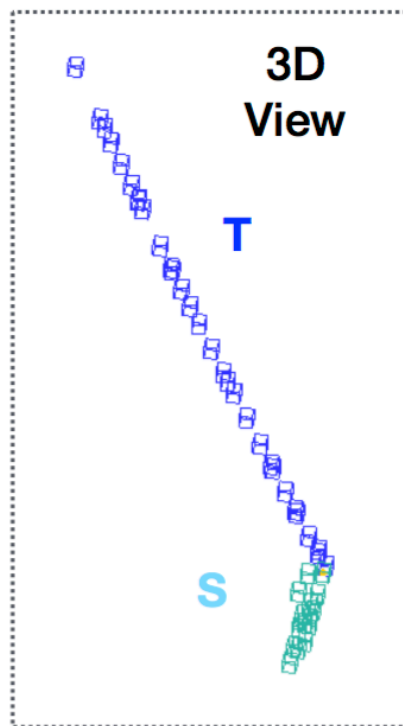
- The first tracks reconstructed were close to the APAs due to the initial low purity and ramping the HV

Event 1: One of the First Tracks

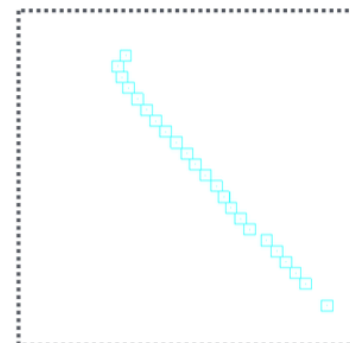


Run 4351, Event 118

Event 2: Michel Electron Candidate



W View



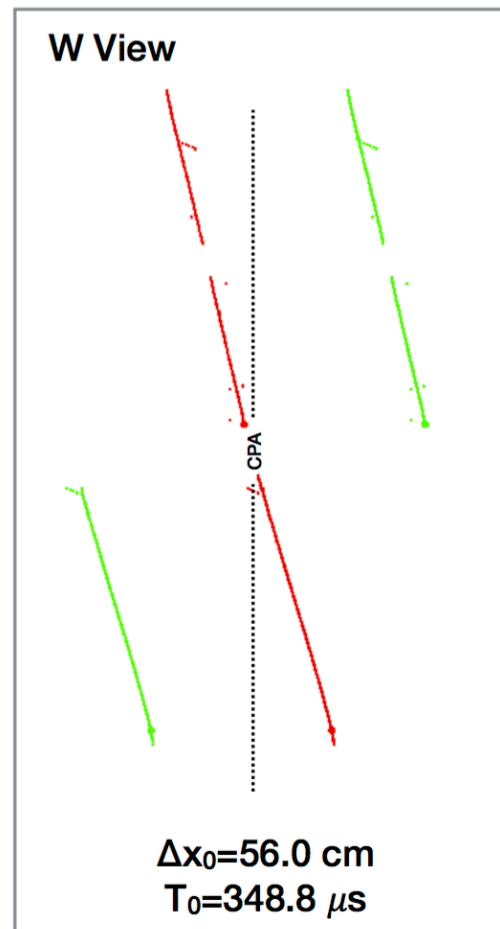
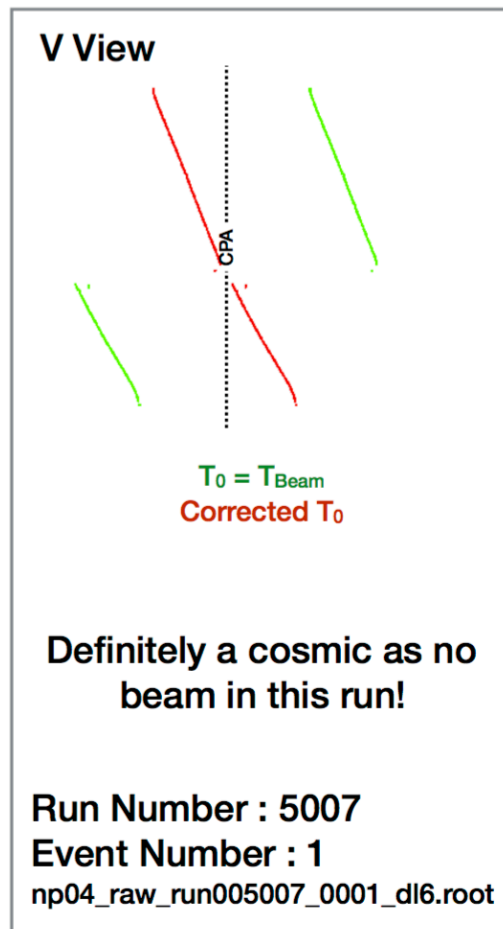
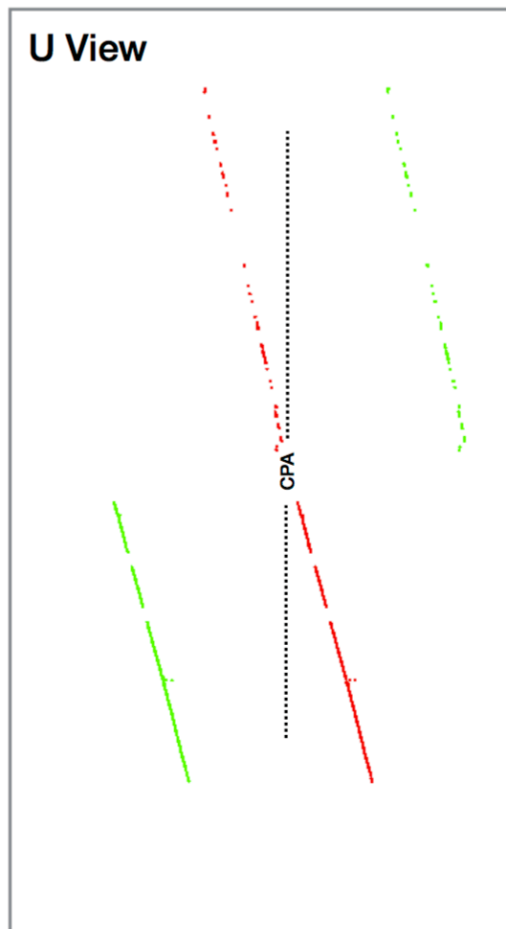
V View



Run 4517, Event 1558

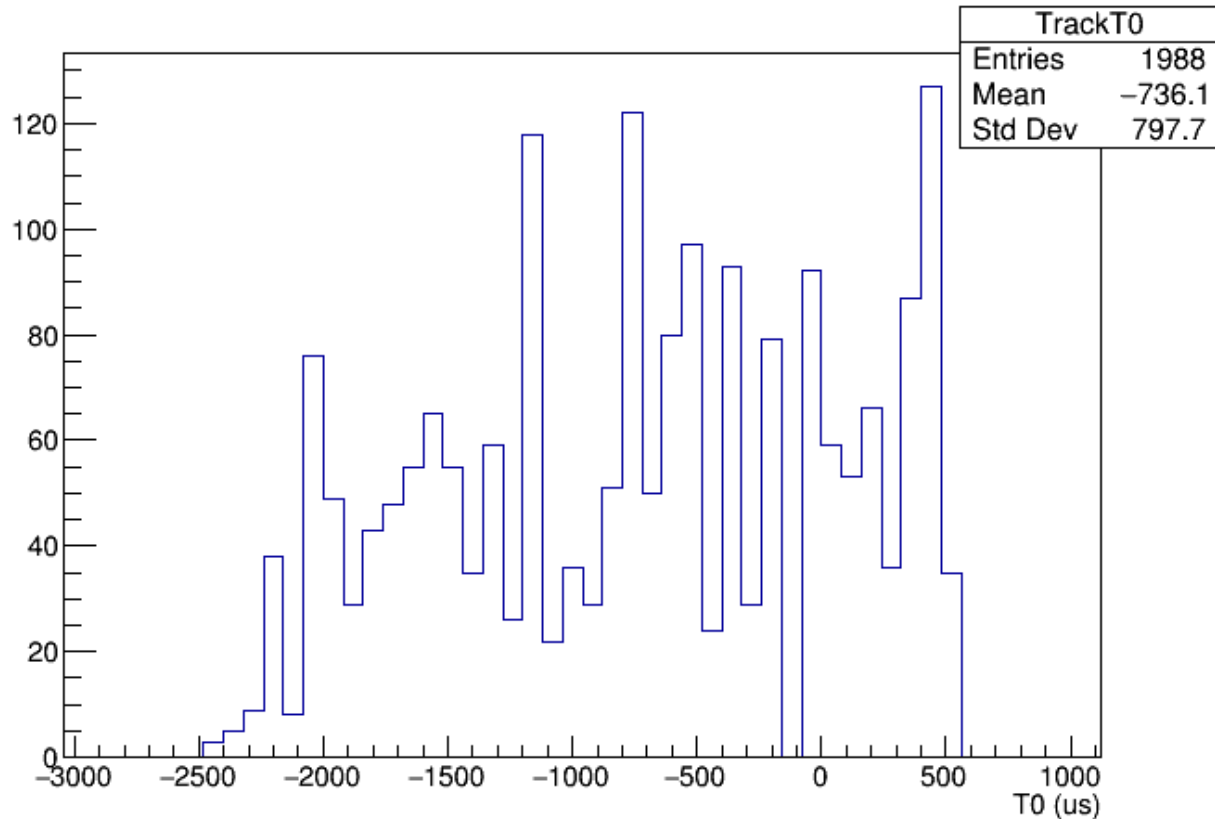
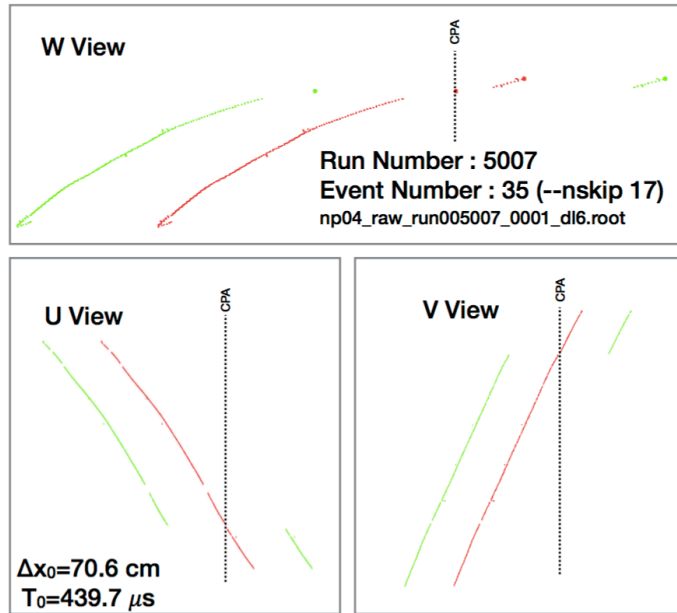
# Cathode-stitched cosmic

- First cathode-stitched track
  - First on data for Pandora too (no central cathode in MicroBooNE)



# Cathode-stitched cosmic

- Many others!

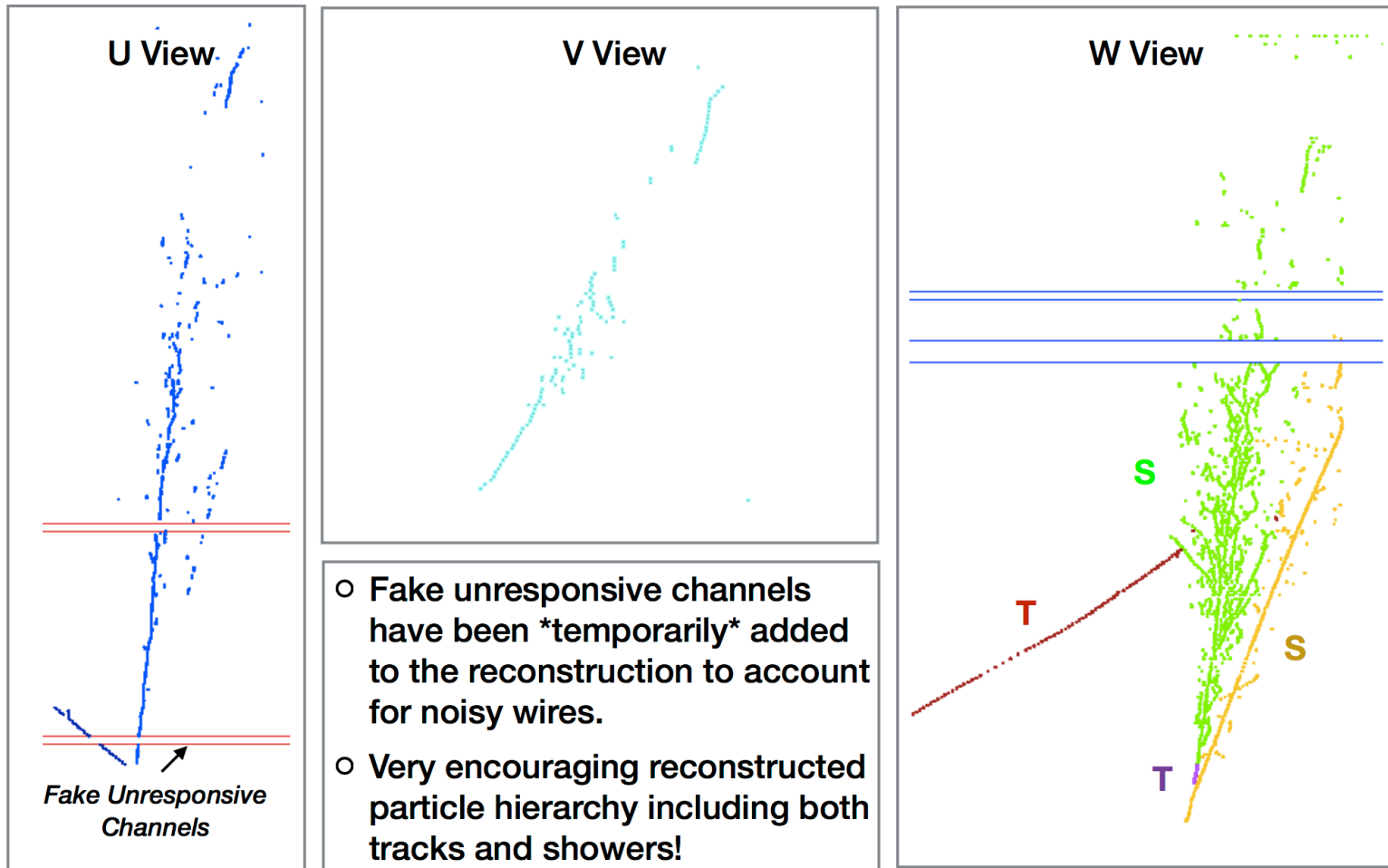


- Expect T0 range:
  - $250 \mu\text{s}$  pre-trigger,  $2750 \mu\text{s}$  post-trigger and  $2250 \mu\text{s}$  drift time
  - Lower limit =  $-(250+2250) = -2500 \mu\text{s}$
  - Upper limit =  $(2750-2250) = 500 \mu\text{s}$



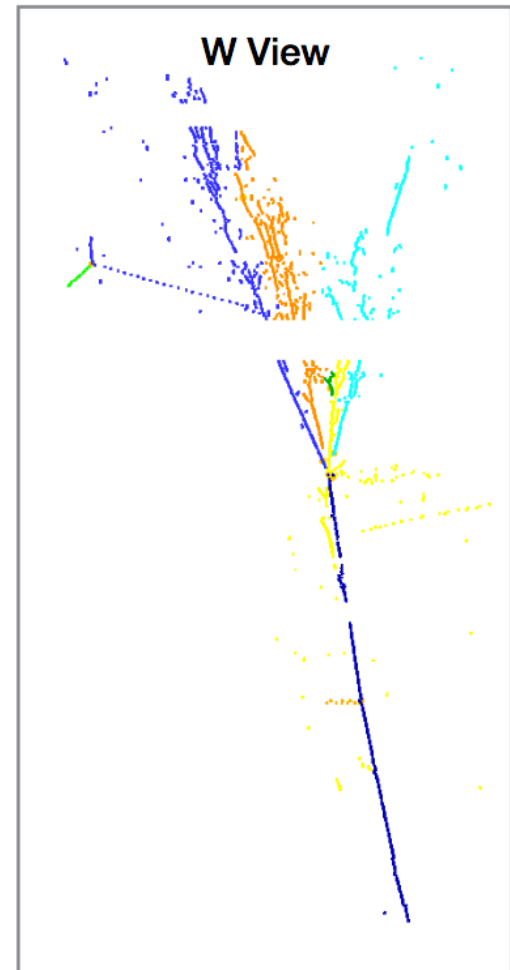
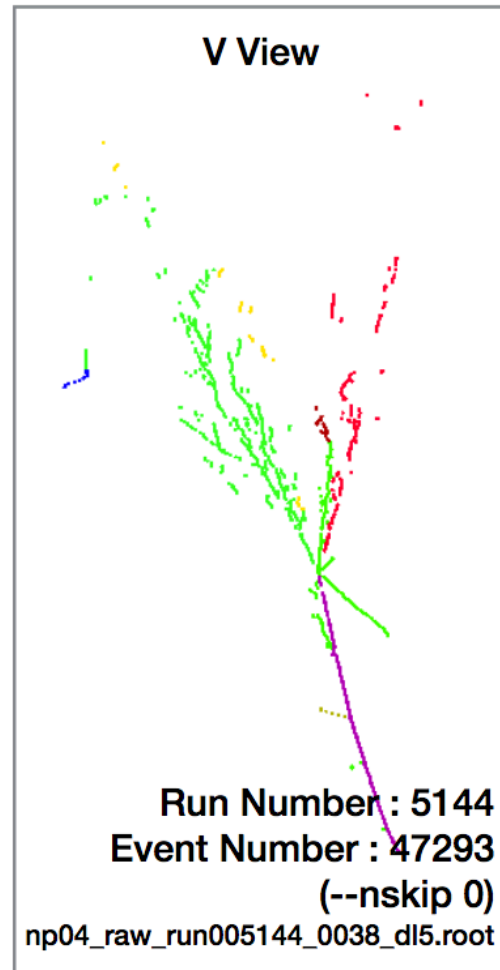
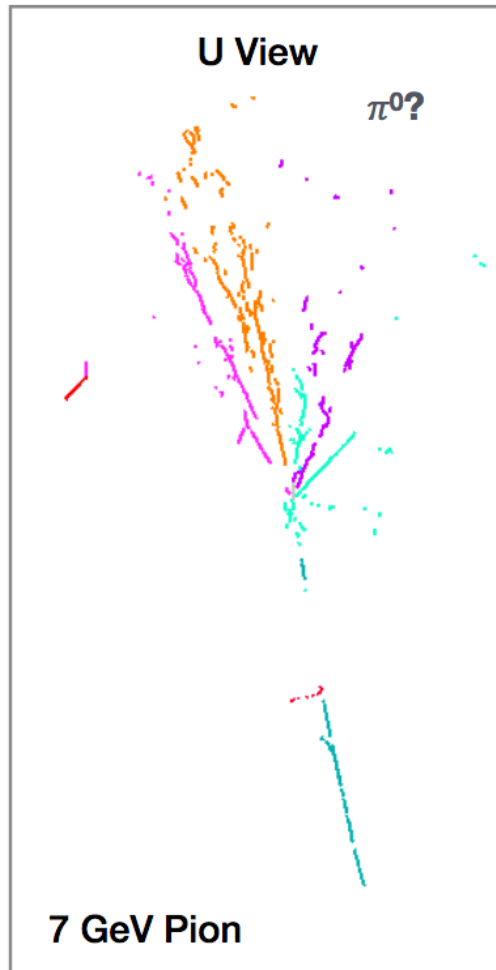
# Halo beam event

- This is an early beam halo interaction during parasitic beam



# 7 GeV beam interactions

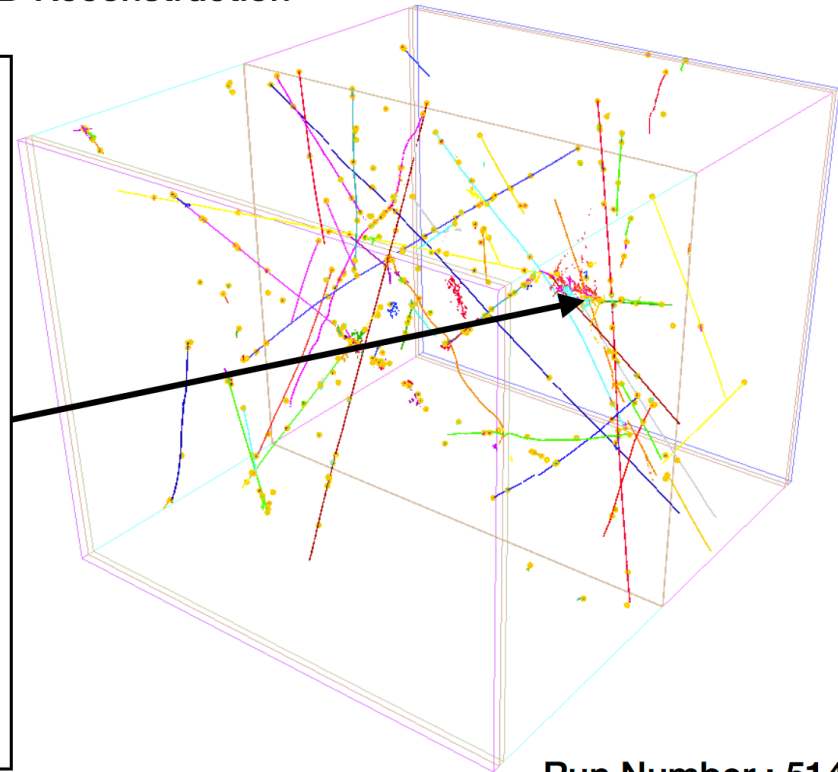
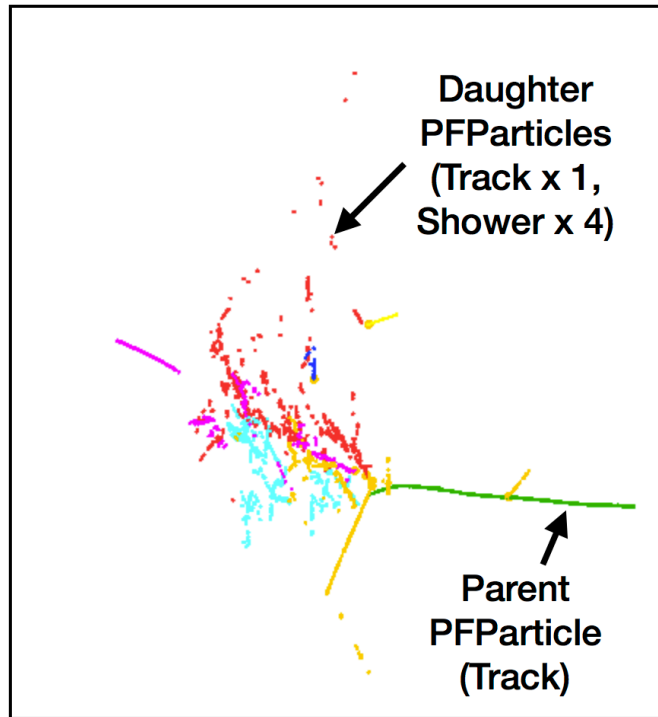
- One of the first!



# 7 GeV beam interactions

- One of the first!

Full 3D Reconstruction



Default Pandora beam particle ID identifies this particle as a test beam pion automatically.

Run Number : 5144  
Event Number : 47293  
(--nskip 0)  
np04\_raw\_run005141\_0016\_dl2.root

# Summary

- These slides represent a lot of work by a lot of people, from hardware up to software
- Impressive performance of the detector and software “out-of-the-box”
- Look forward to more results with many improvements!
  - Noise mitigation and bad channel masking
  - Reconstruction algorithm tuning
  - High level performance plots!
- Fast-paced changes – keep track at our meetings at the ProtoDUNE DRA meetings for full details
  - This week’s meeting: <https://indico.fnal.gov/event/18731/>