# ProtoDUNE-SP: First Look at Data

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LBNC review

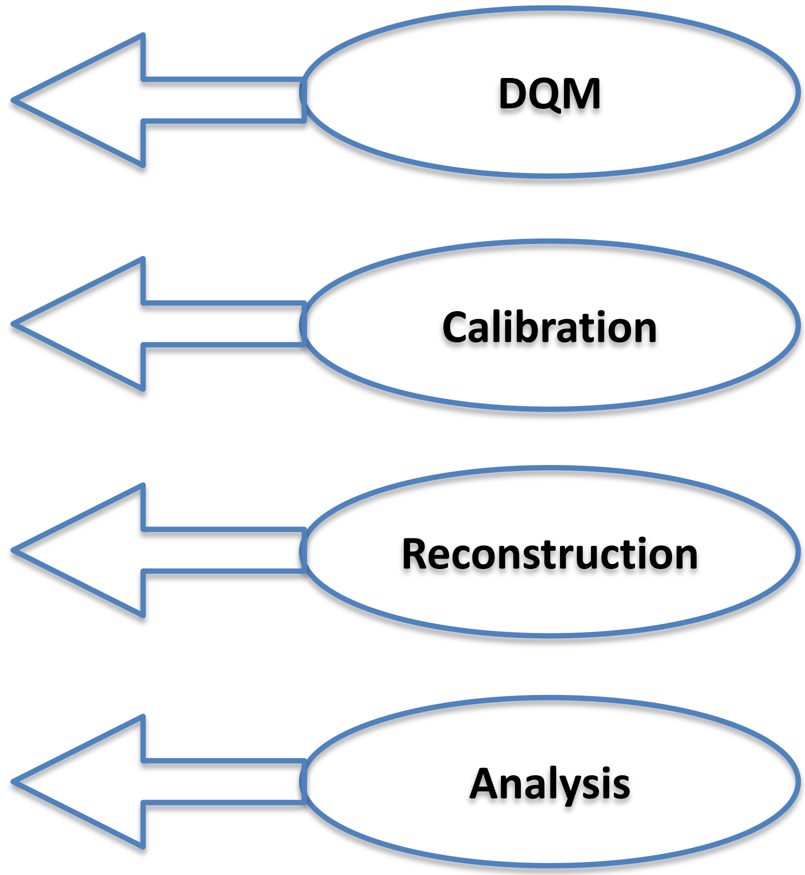
Oct 15, 2018

# What can we learn from ProtoDUNE?

DUNE FD

ProtoDUNE

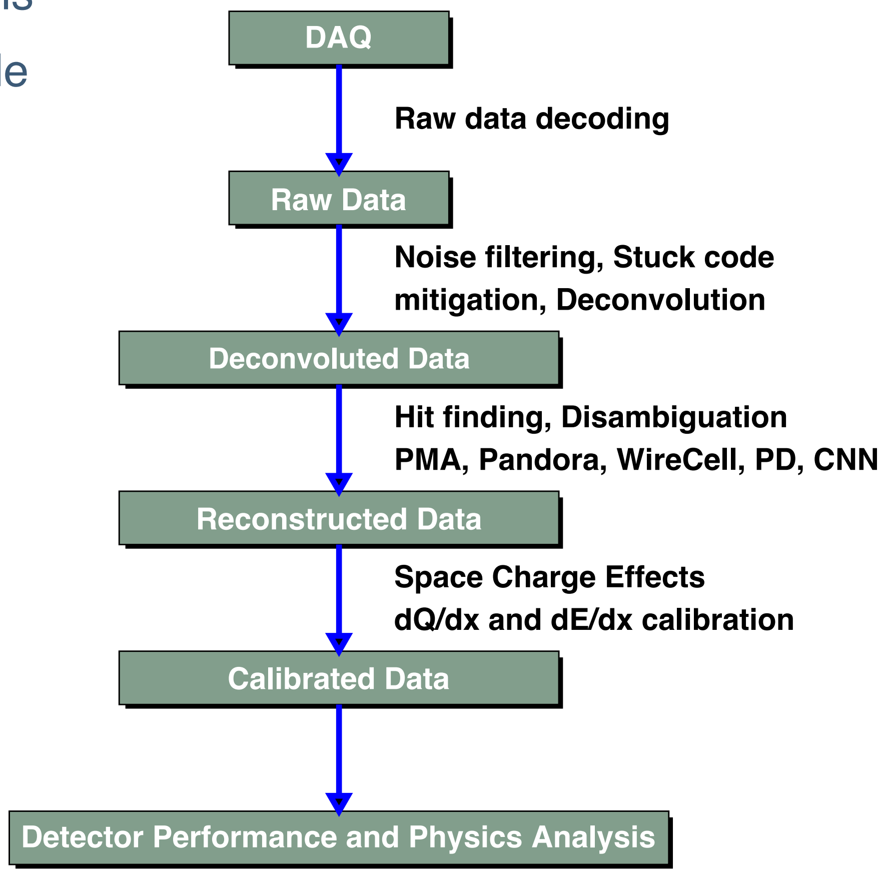
- **Detector Performance**
  - Signal-to-Noise ratio
  - Modeling of detector response
- **LBL Physics**
  - Electron energy reconstruction
  - Muon momentum reconstruction
- **Nucleon Decay Search**
  - Kaon reconstruction
- **Supernova Neutrino Search**
  - ~10 MeV electron reconstruction



# 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

# 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.

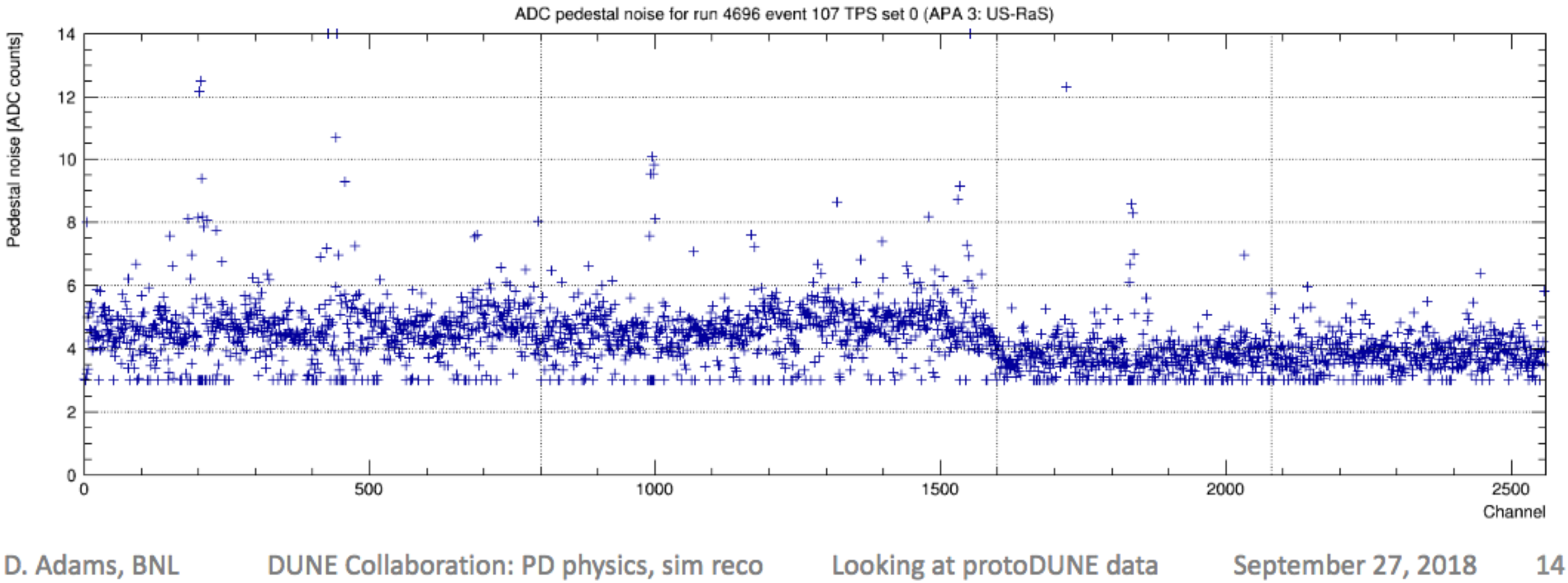
Information for DUNE physics TDR (short-term and medium-term goals)

Physics publications (long-term goals)

# Outline

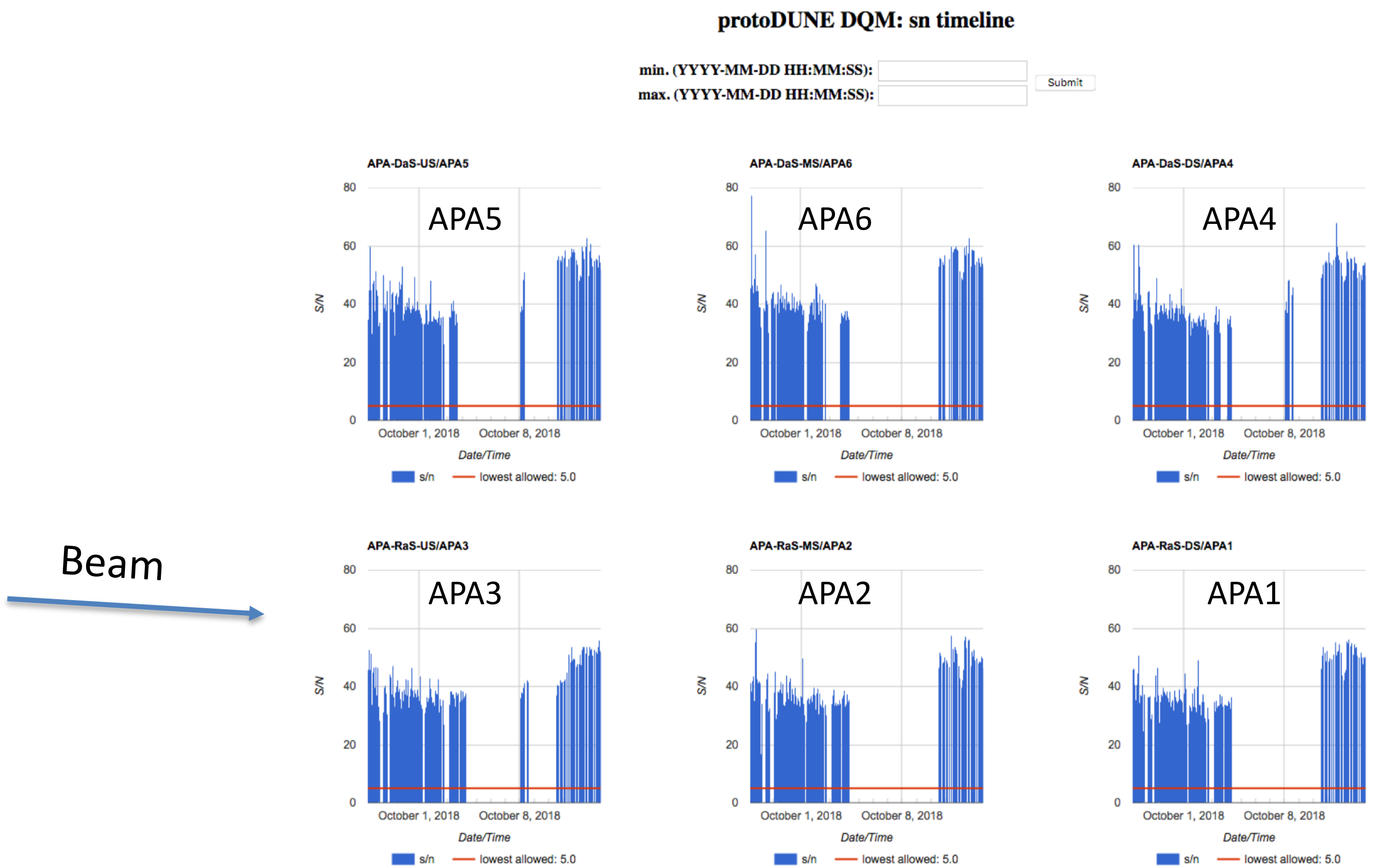
- Results of detector performance
  - Noise level, signal to noise ratio
  - Electron lifetime
- Preparation for data analysis
  - Beam-TPC information matching
  - Sticky code mitigation
  - Electronics calibration
  - Space Charge calibration
  - Muon based calibration
  - TPC reconstruction
  - Photon detector analysis
- Event displays

# Noise level



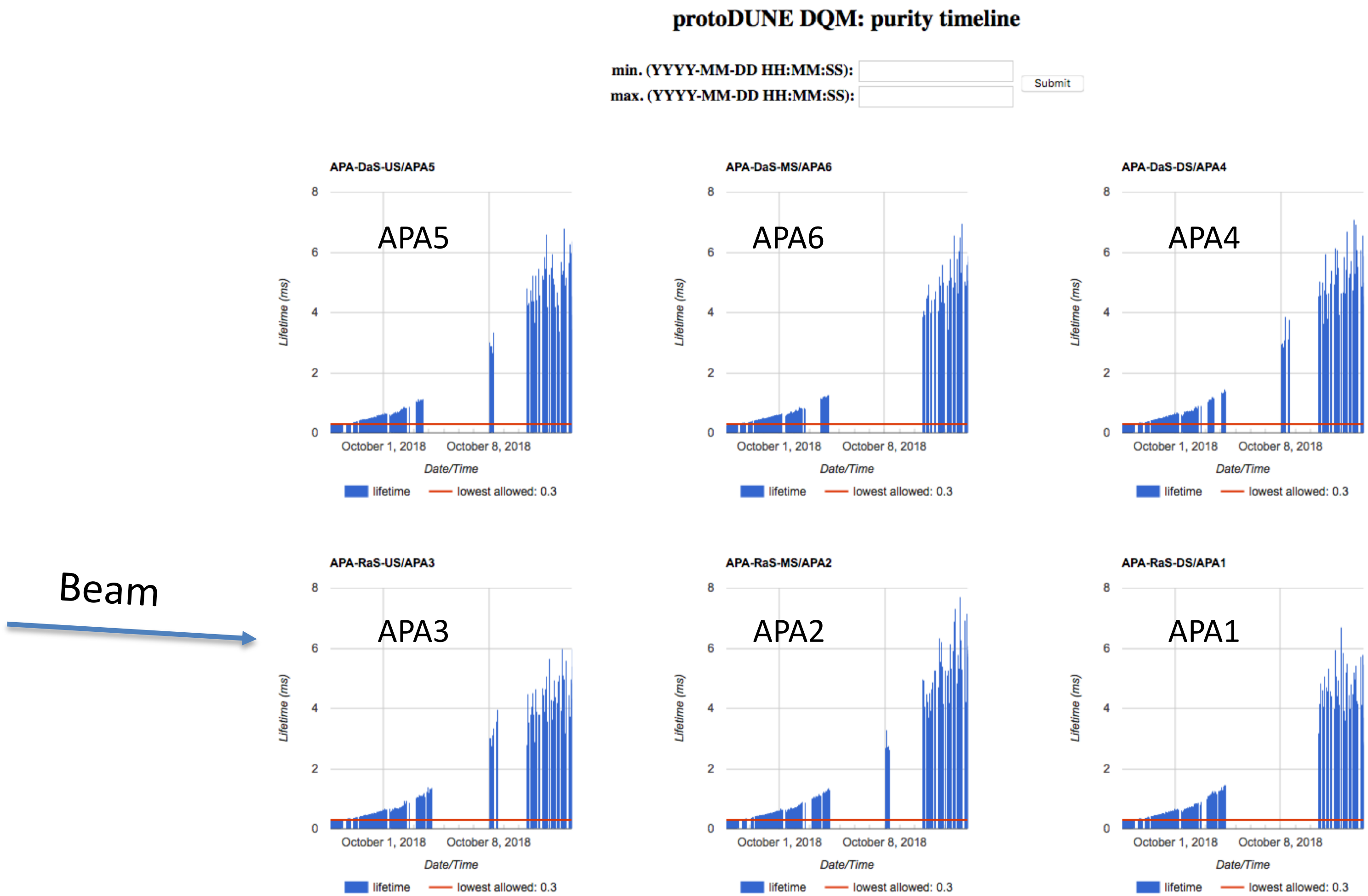

- Noise level
  - Collection: 3.5 ADC (500 e)
  - Induction: 4.5 ADC (600 e)
- Preliminary results show 99.7% of 15,360 channels are alive

# Signal-to-noise ratio




- Signal to noise ratio from DQM: ~50 in collection channels in all APAs

# Electron lifetime




- Purity monitored by both purity monitors and muons

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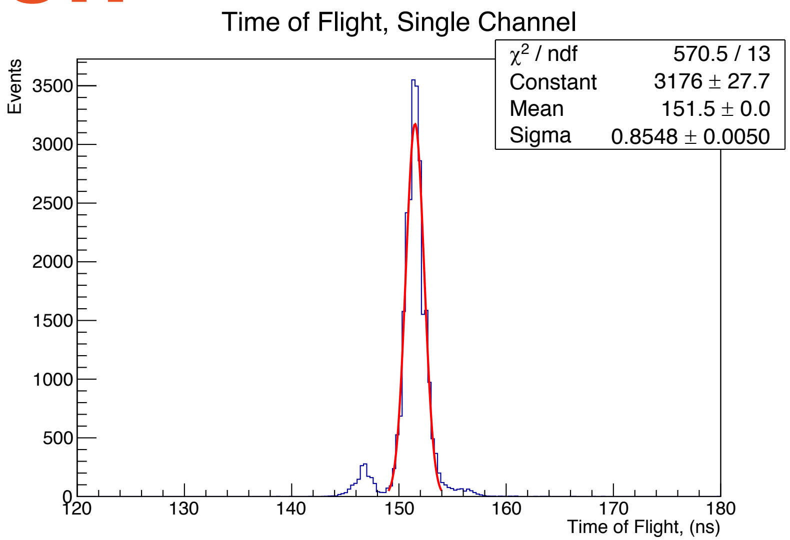
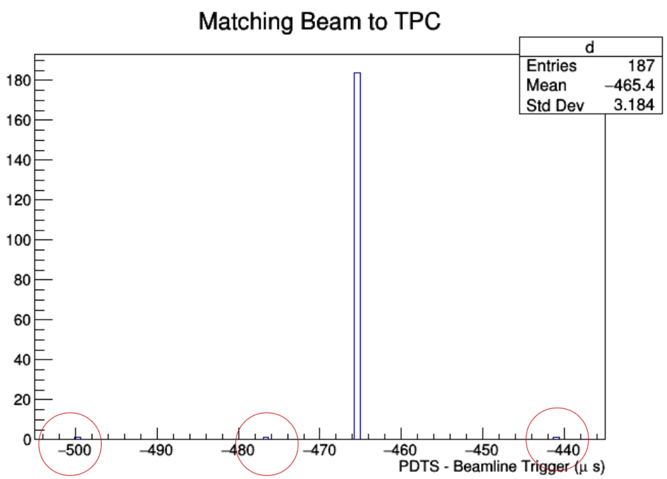
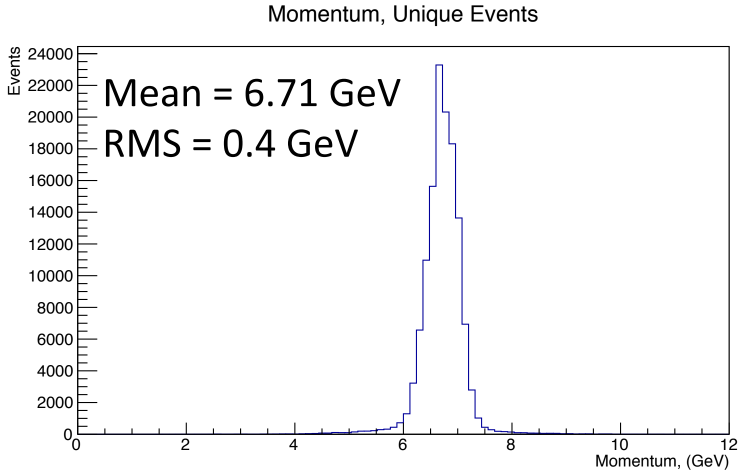
# Beamline Information

- Beamline information is saved to DIP database at CERN and then copied to IFBeam database at Fermilab.
  - Save beamline information for online monitoring and offline analysis: particle direction, momentum, PID with Cerenkov Detectors, Time of Flight Measurements.
  - Matching TPC beam events to tracks in beamline.



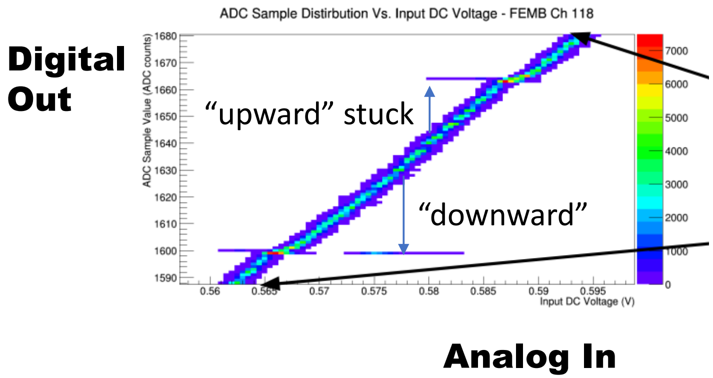



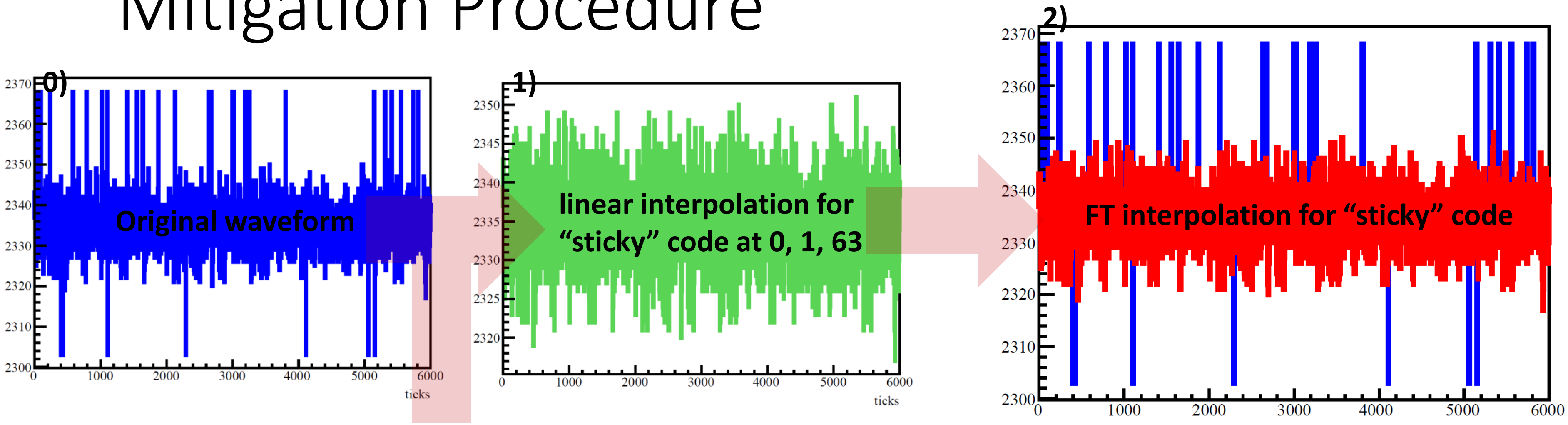

8 hrs of data taking at 7GeV.

# Sticky Code Mitigation

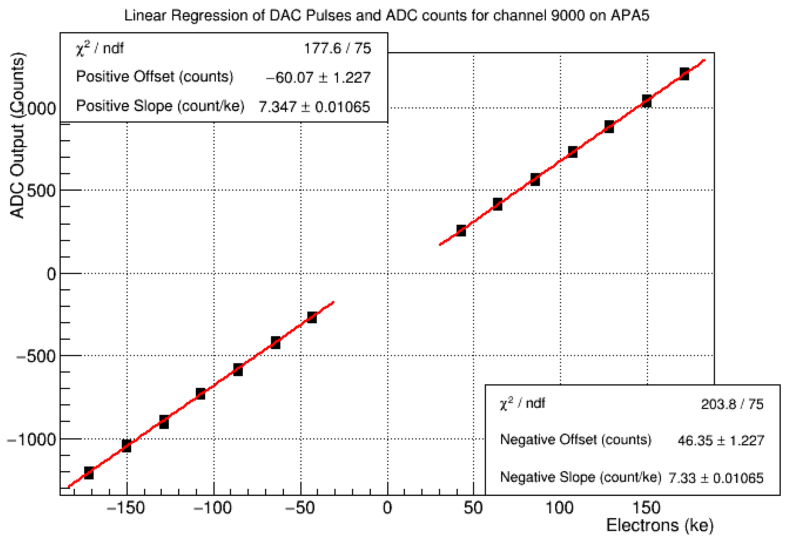
- Sticky code - the 6 LSBs in ADC ASIC was found to be “sticky” around 000000 (0x00) or 111111 (0x3F).
- Can be mitigated through linear interpolation.
- A new method is developed to interpolate through FT.
- The current focus is on noise mitigation and deconvolution.

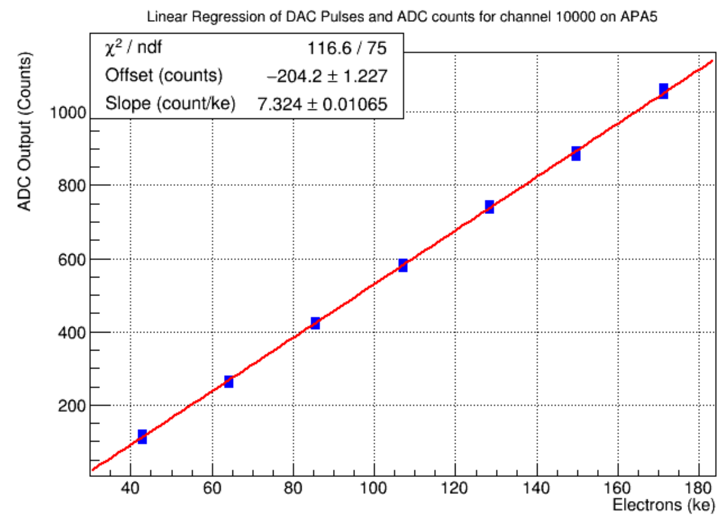


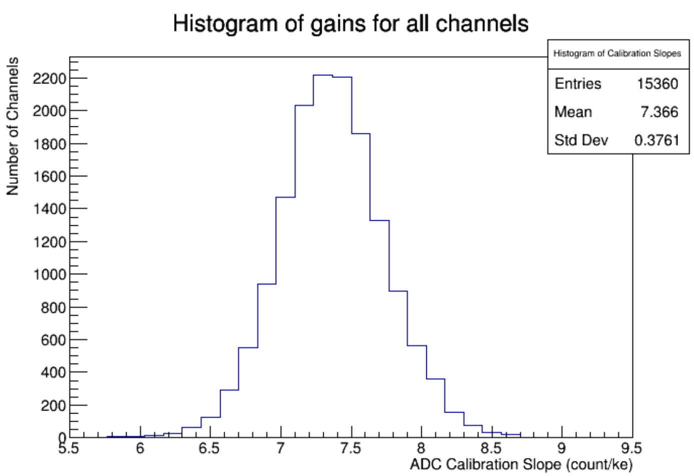

## Mitigation Procedure



# ADC gain and linearity



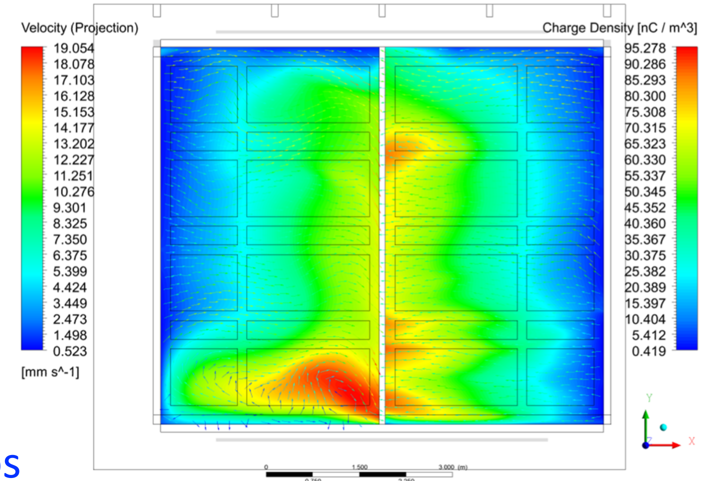



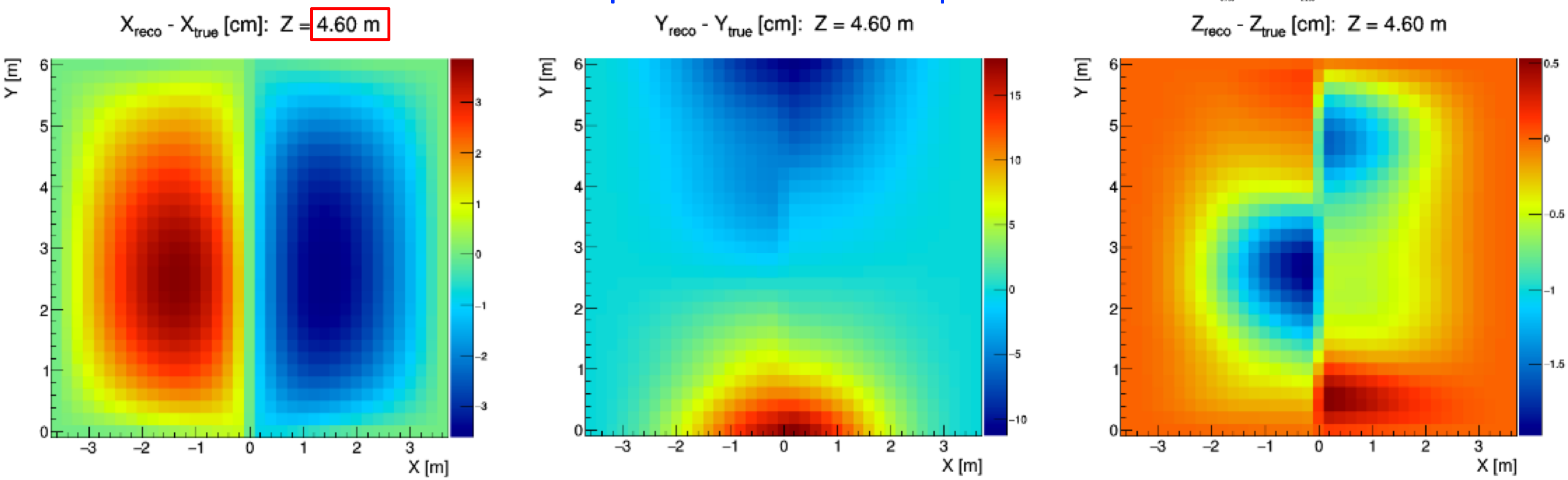

- Using pulser data to measure ADC gain and linearity.
- Analysis of a recent pulser run 4565.
- Gain variation is ~5% over all channels.

# Space Charge Simulation with LAr Flow

- We now simulate SCE using the space charge density map with LAr flow - **first study of LAr flow on SCE**
- Very different distributions in the two drift volumes
- Essential to have **data-driven calibration**



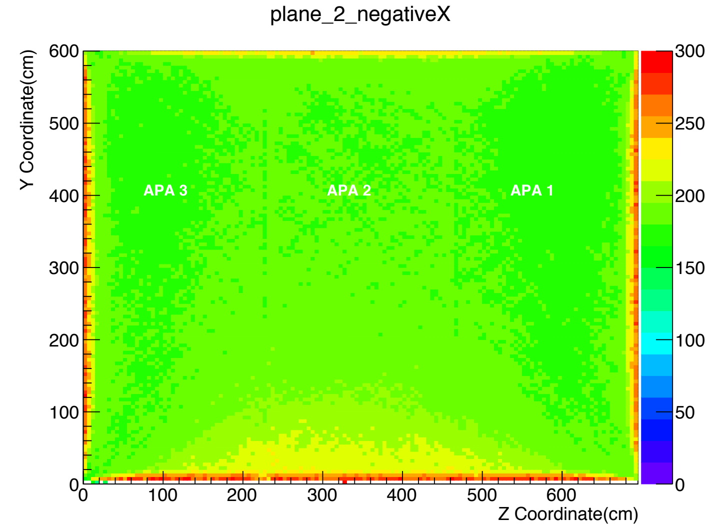

Spatial distortion maps



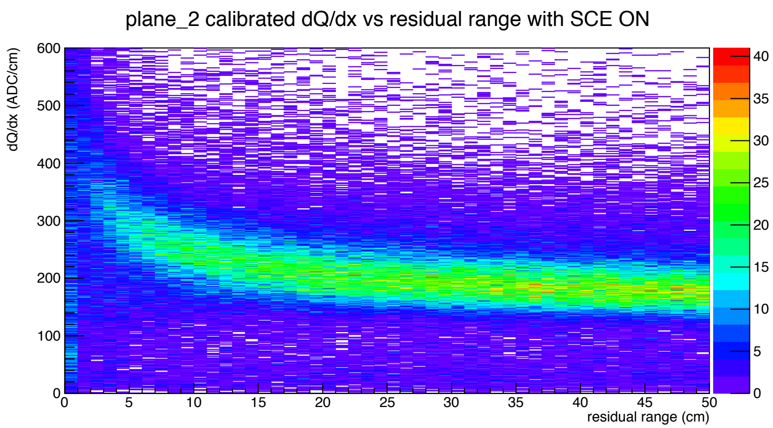
# Detector Calibration with Muons

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

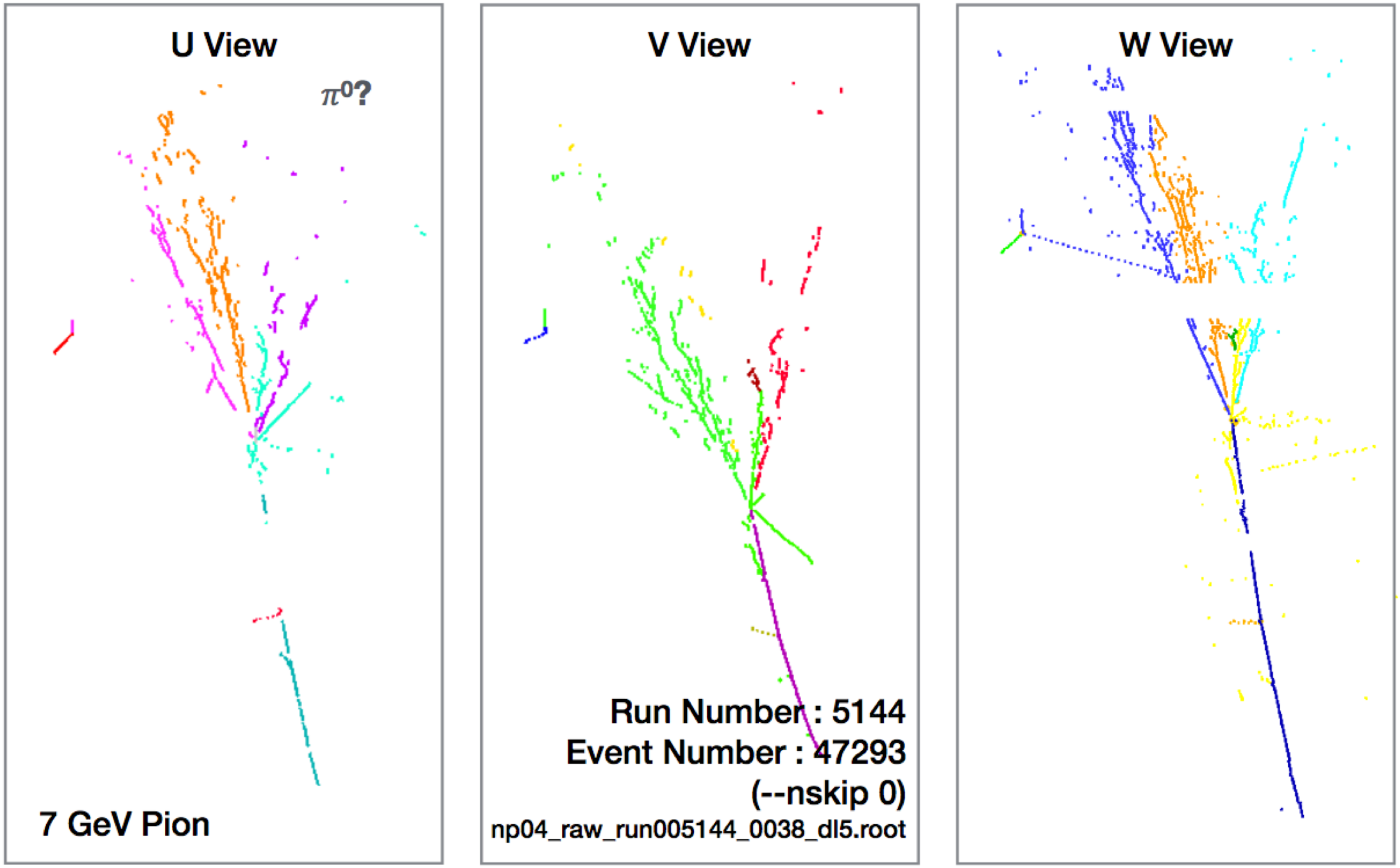
dQ/dx calibration




dE/dx calibration



# Pandora Reconstruction

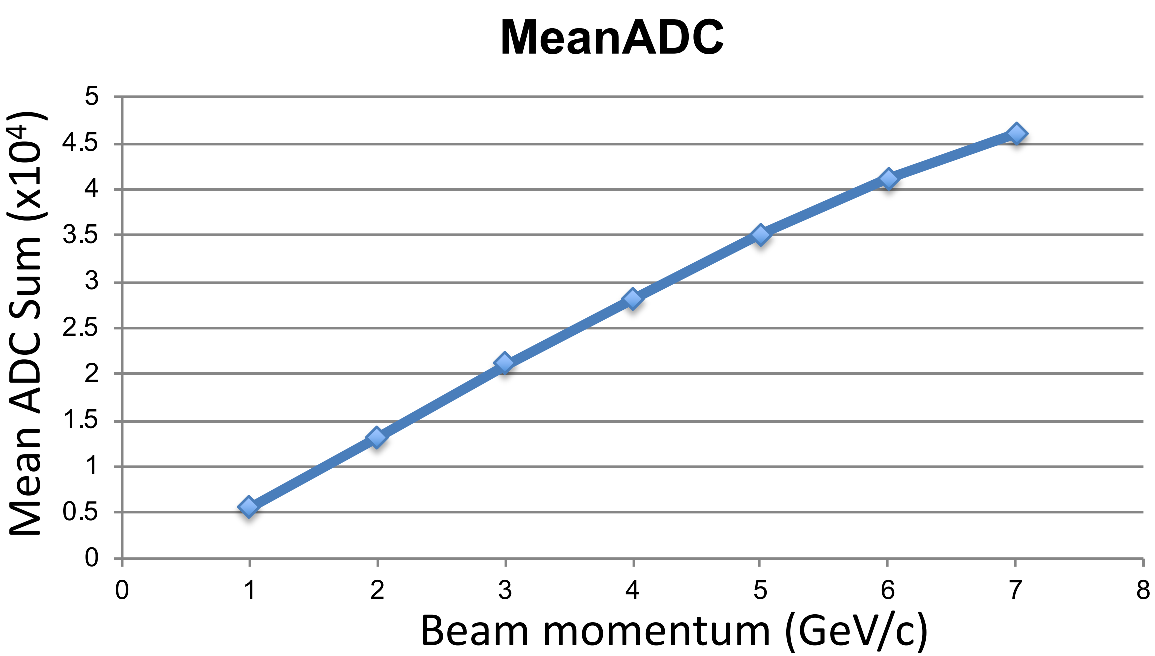



- Pandora pattern recognition algorithms are being optimized for data. Preliminary results look good.

# Photon Detector Analysis

- The PDS system is operational: we see both beam particles and cosmic-ray muons.
- All SSP modules are operational and reading back.
- Very few dead/noisy channels.

Mean ADC Sum vs. Energy APA3 Arapuca



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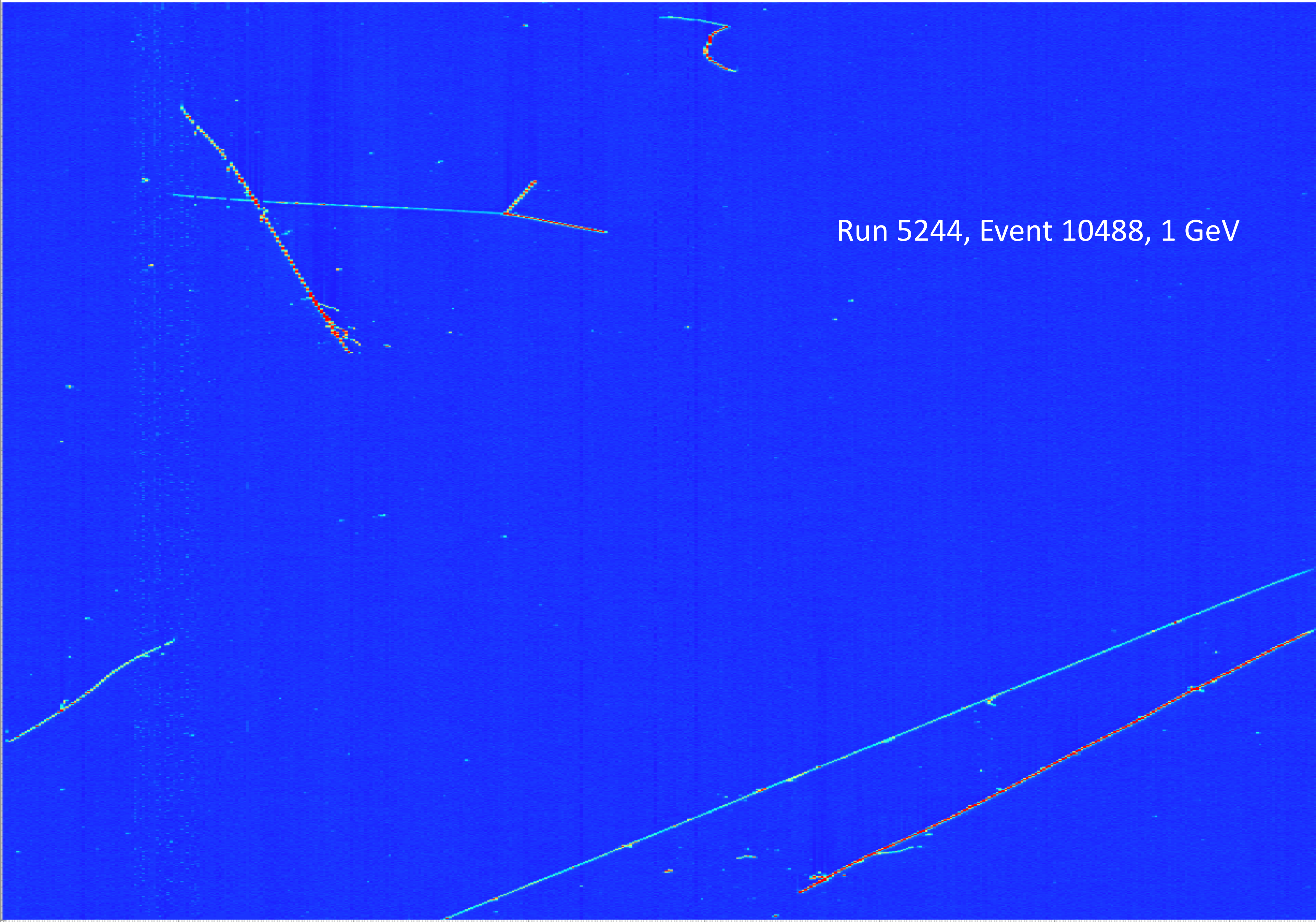
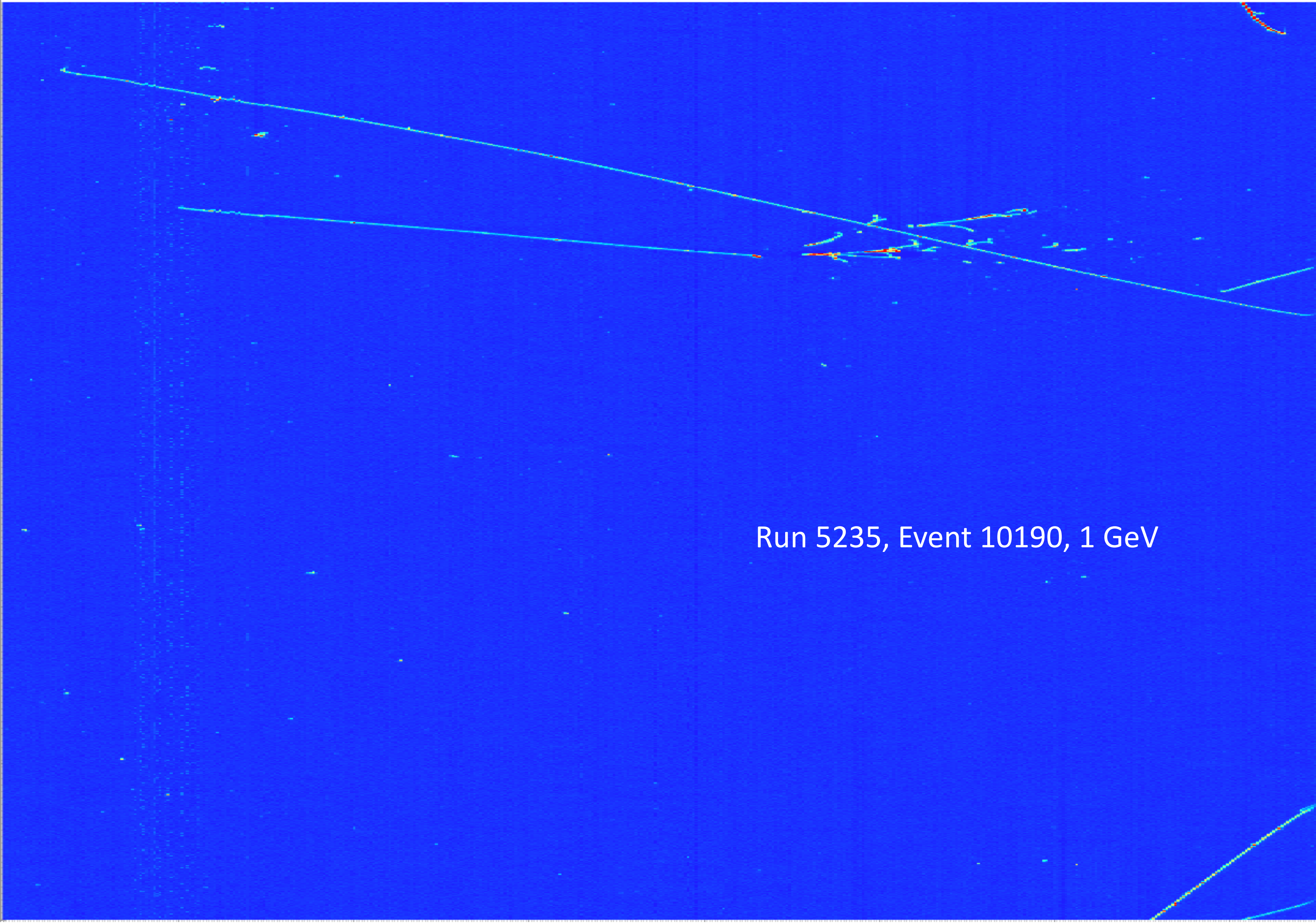
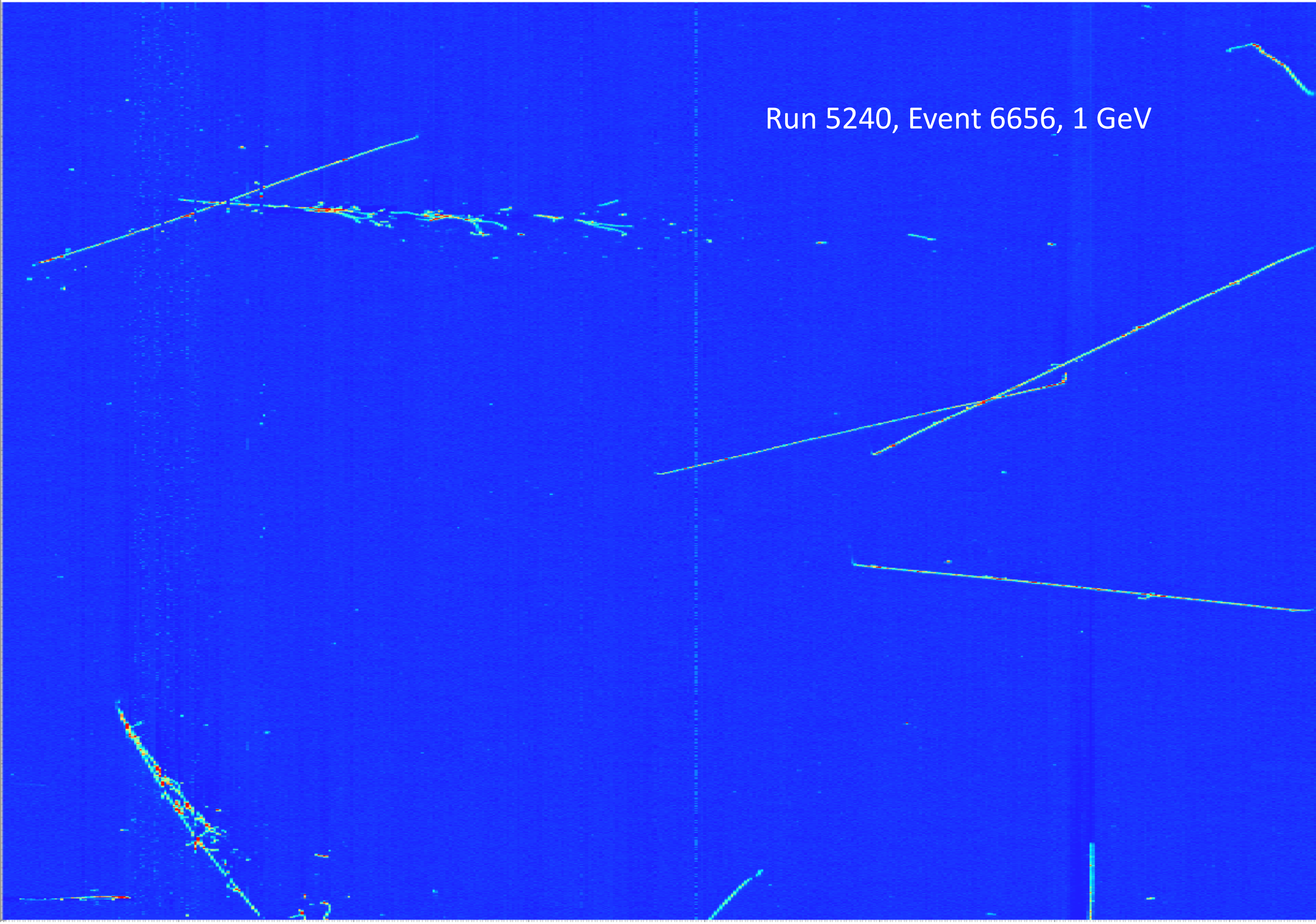
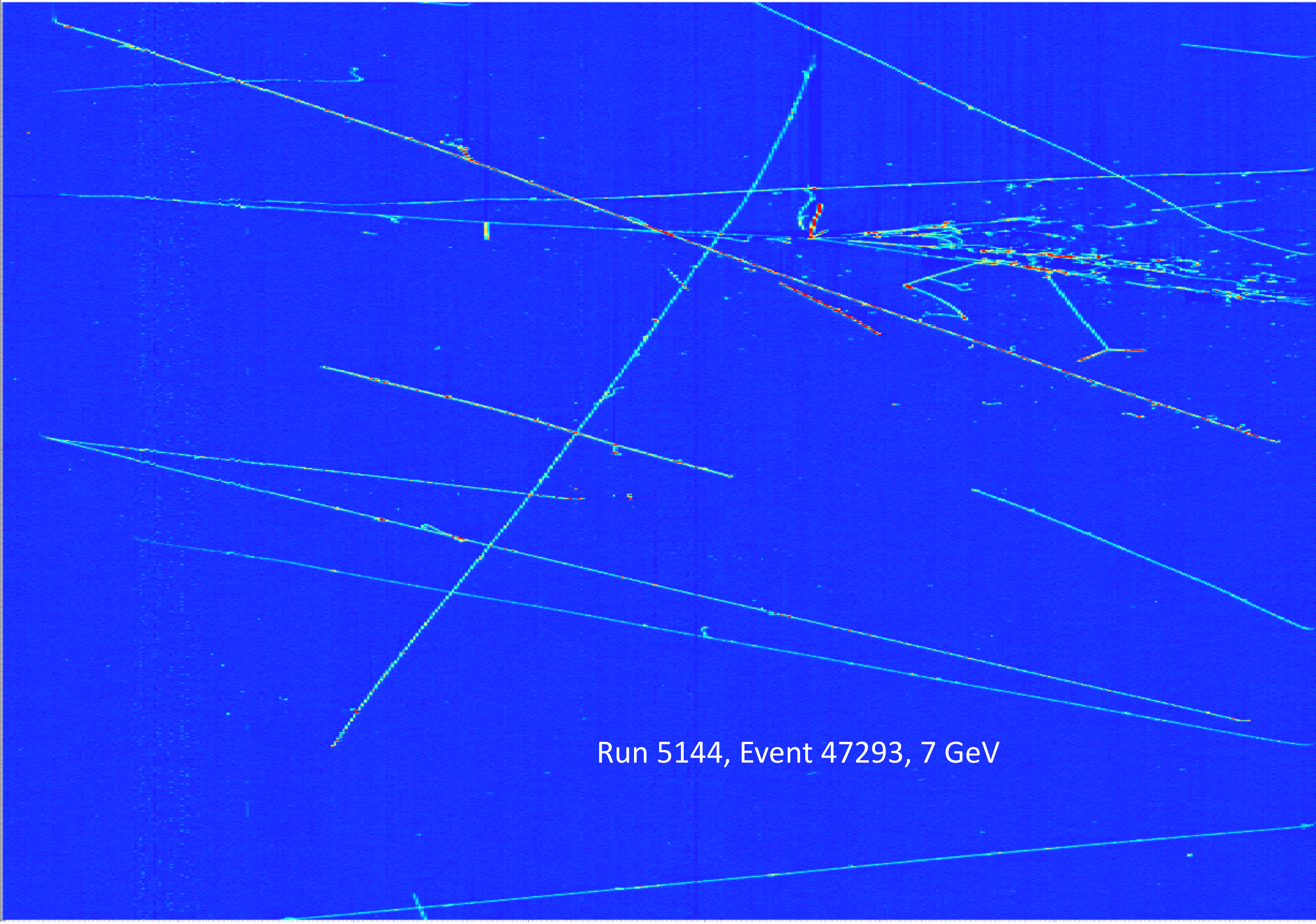
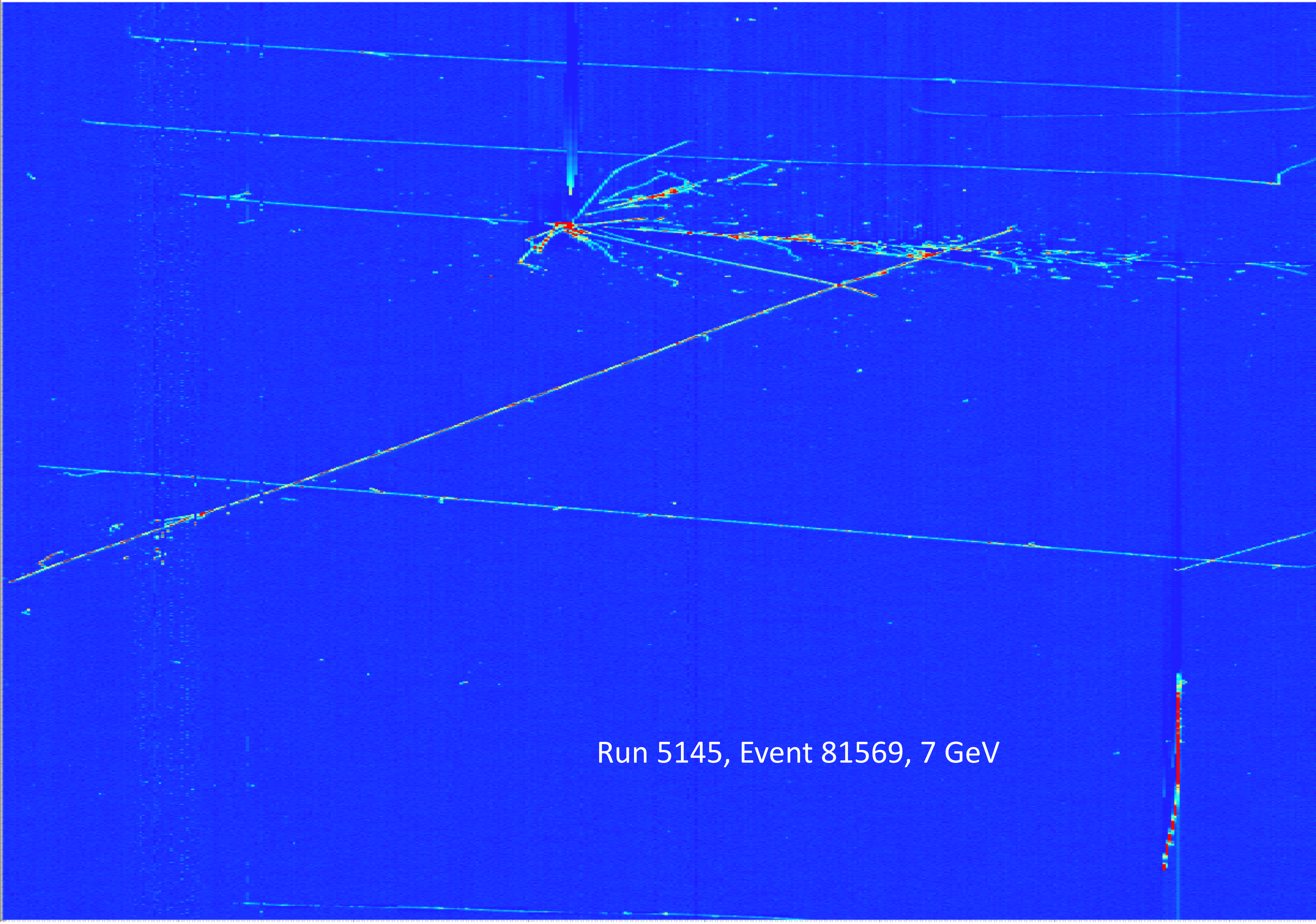

Run 5244, Event 10488, 1 GeV

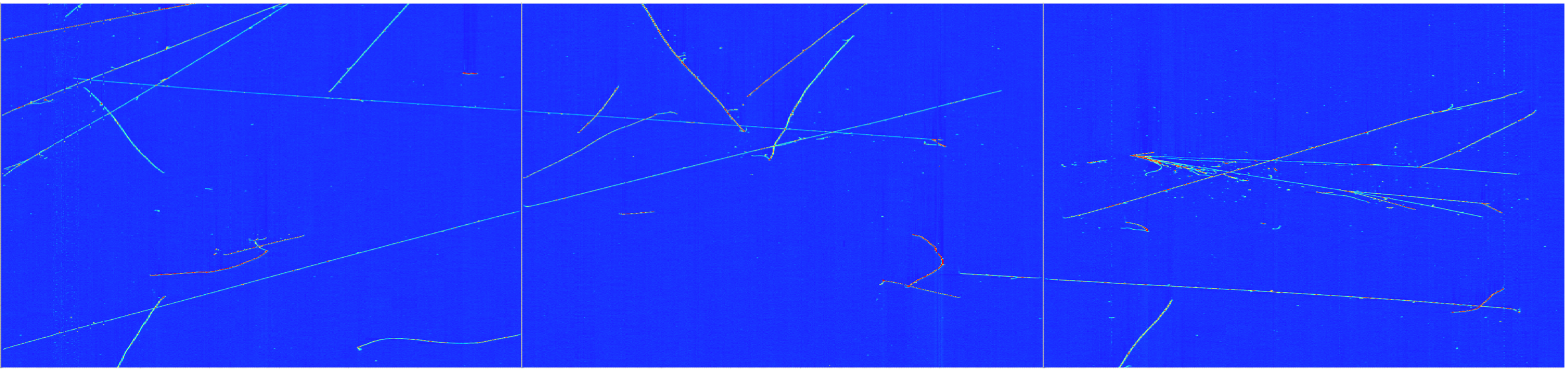

Run 5235, Event 10190, 1 GeV


Run 5240, Event 6656, 1 GeV


Run 5144, Event 47293, 7 GeV


Run 5145, Event 81569, 7 GeV

Run 5203, Event 1290, 7 GeV



# Conclusions

- The first look at data looks very promising
  - Very low noise level and very high signal-to-noise ratio
  - Very few dead/bad channels
- We are able to reconstruct tracks with just a few tweaks to the reconstruction algorithms.
  - Current focus is on low level reconstruction
- We have developed tools for detector calibration using MC.
- More results on calibration and cross sections will arrive.