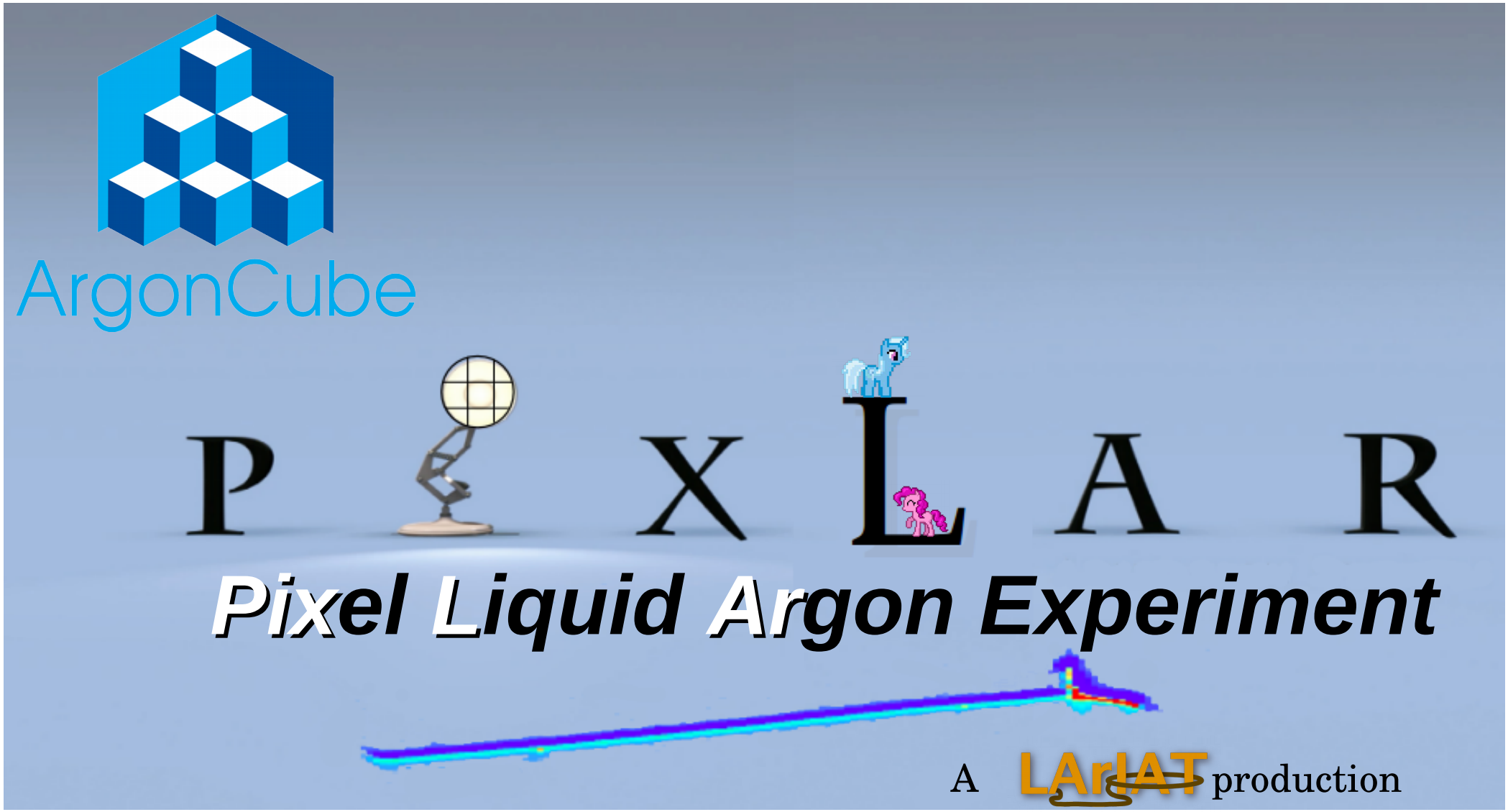
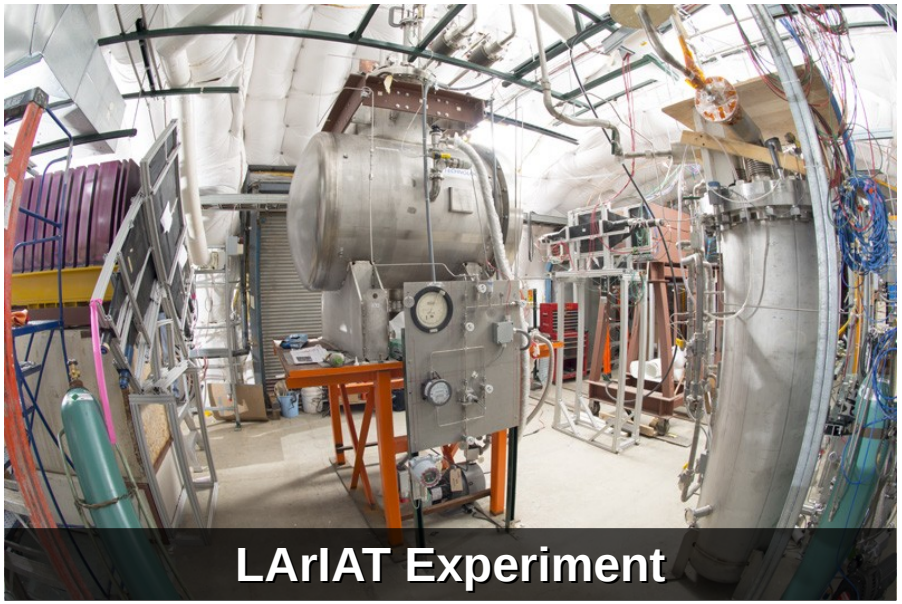


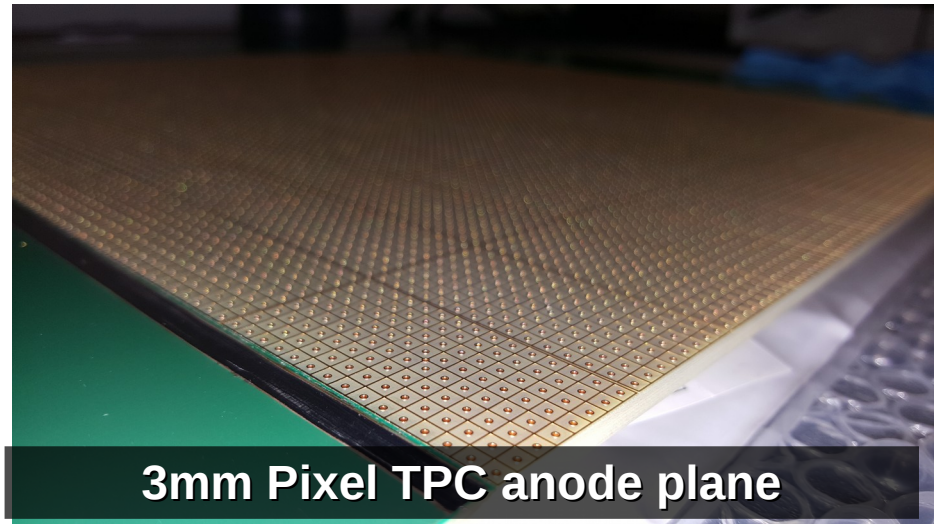
Jonathan Asaadi
UT Arlington
(On behalf of the PixLAr Collaboration)

What is PixLAr?

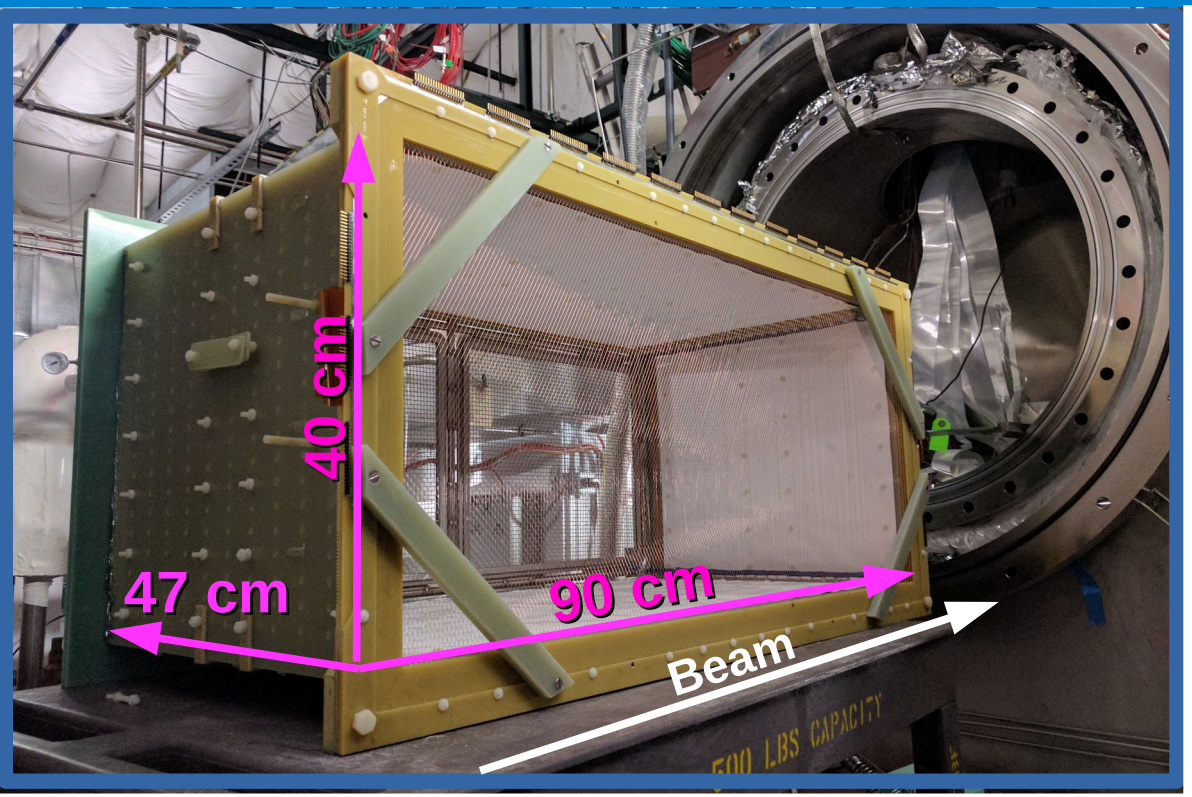
- **PixLAr is the use of the Liquid Argon in A Testbeam (LArIAT) setup, with a pixel based charge readout**
  - The setup utilized the existing cold electronics (LArASIC)
  - The pixel plane was a PCB based on the option being considered for the DUNE near detector
    - In order to accommodate the existing wire readout, some multiplexing had to be done


LArIAT Experiment

- **Main goals of the initial PixLAr setup**
  - Feasibility of pixel based LArTPC in an operating experiment
  - Demonstration of the ability to cope with a high multiplicity environment
  - Utilize the charge particle beam to perform physics measurements (dE/dX, pion interactions, etc...)
  - Explore additional light readout R&D

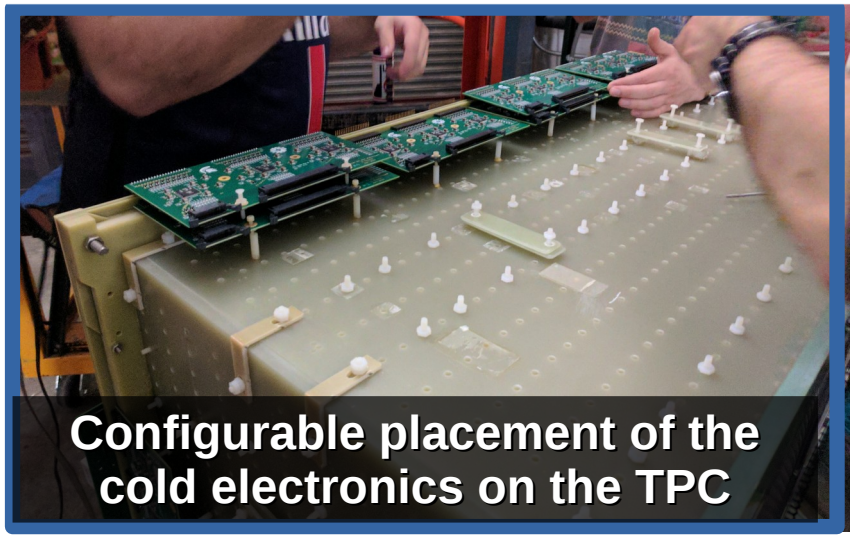

3mm Pixel TPC anode plane

Inside the LArIAT Cryostat (TPC)

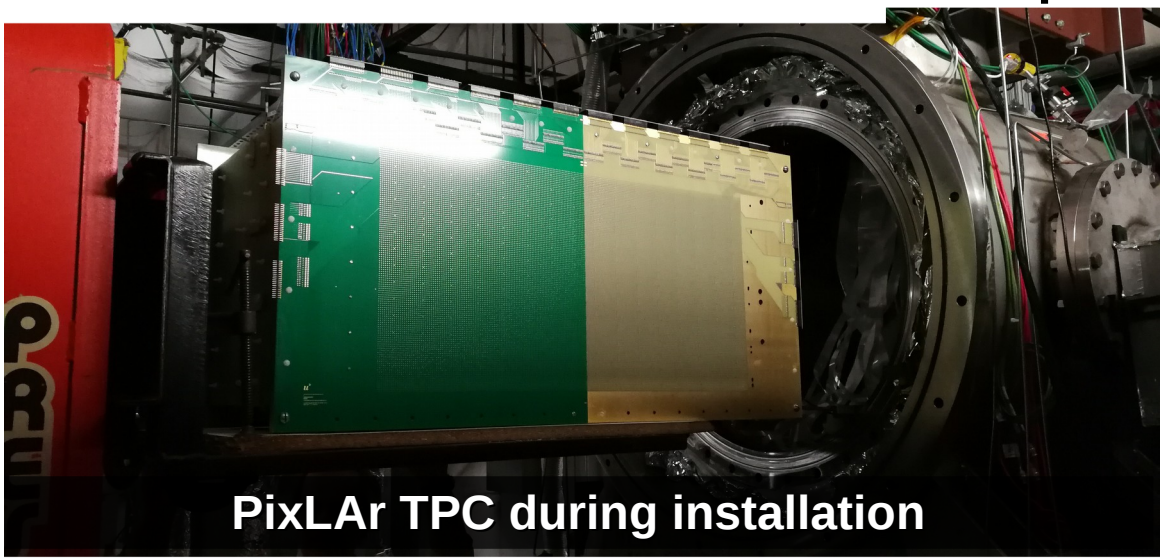


- **90 cm long (beam directions) 47 cm wide (drift direction) 40 cm tall TPC**
- **480 TPC channels available**
  - LArASIC's on custom motherboards (designed by MSU)
    - Same ASICs used by MicrBooNE
  - Output into CAEN 1740 digitizers
  - Great signal to noise achieved in previous wire readout runs
- **500 V/cm nominal field**
- **Ability to integrate various light**

e setup

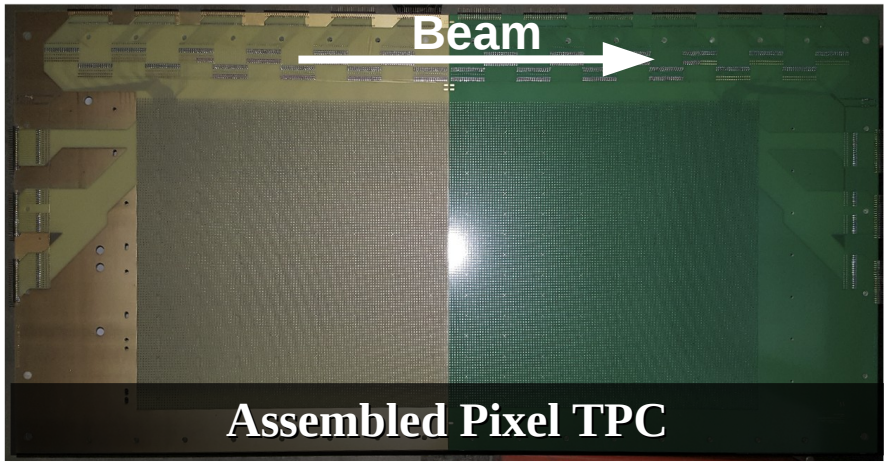


Configurable placement of the cold electronics on the TPC

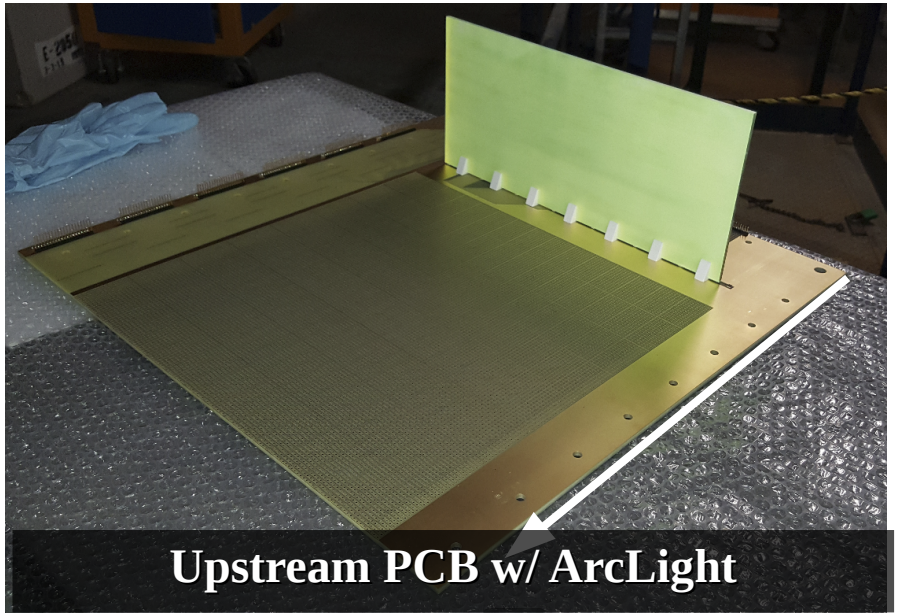


PixLAr TPC during installation

PixLAr Pixel Plane



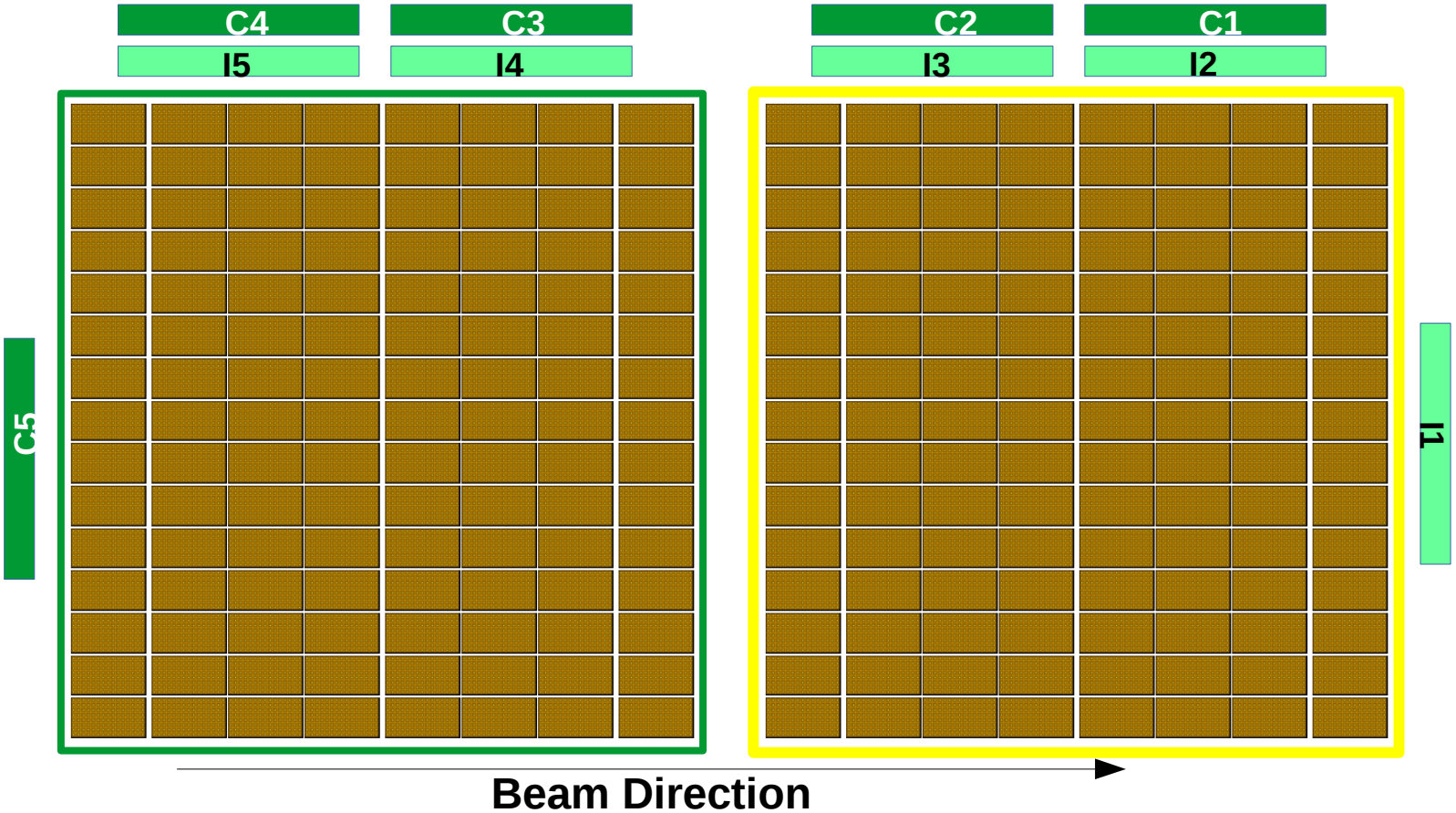
Assembled Pixel TPC


Upstream PCB w/ ArcLight

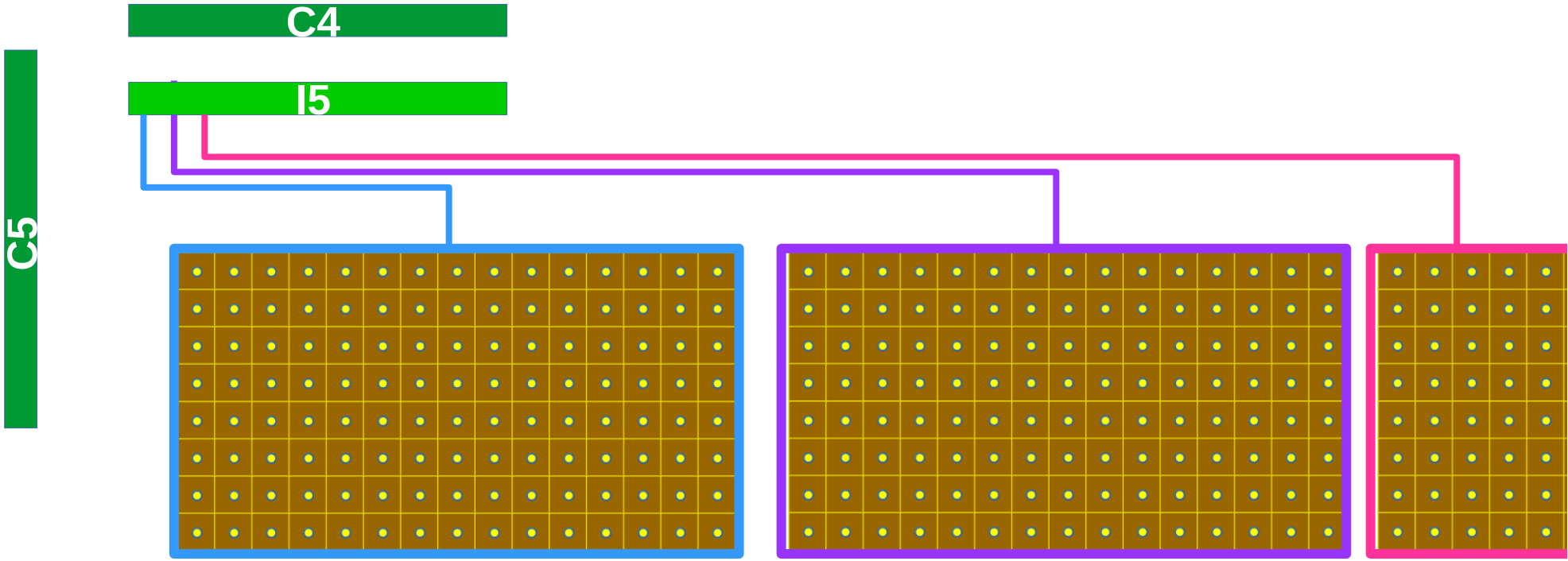
- **The PCB pixel plane was manufactured by the University of Bern**
  - Pixel plane broken into two halves and mounted on the TPC
  - Each plane had a 36 cm^2 active pixel area
  - 14,400 pixels per PCB
    - Total of 28,800 pixels
  - Light detection devices were mounted on the available space in the upstream and downstream portion of the detector

How to get 28k pixels with 480 channels

- **LArIAT's 480 channels are readout on 10 motherboards with 48 channels each**
- **The requires multiplexing the pixels across the TPC to an individual channel (many pixels = 1 readout channel**
  - This means you need a technique to break the ambiguities
    - Will use induction pulses to break this ambiguity
  - Important to note that the demonstration of a pixel ASIC reduces the necessity for such acrobatics
    - (See Dan's talk)
    - Good to have a proof of principle that the method works even with existing electronics

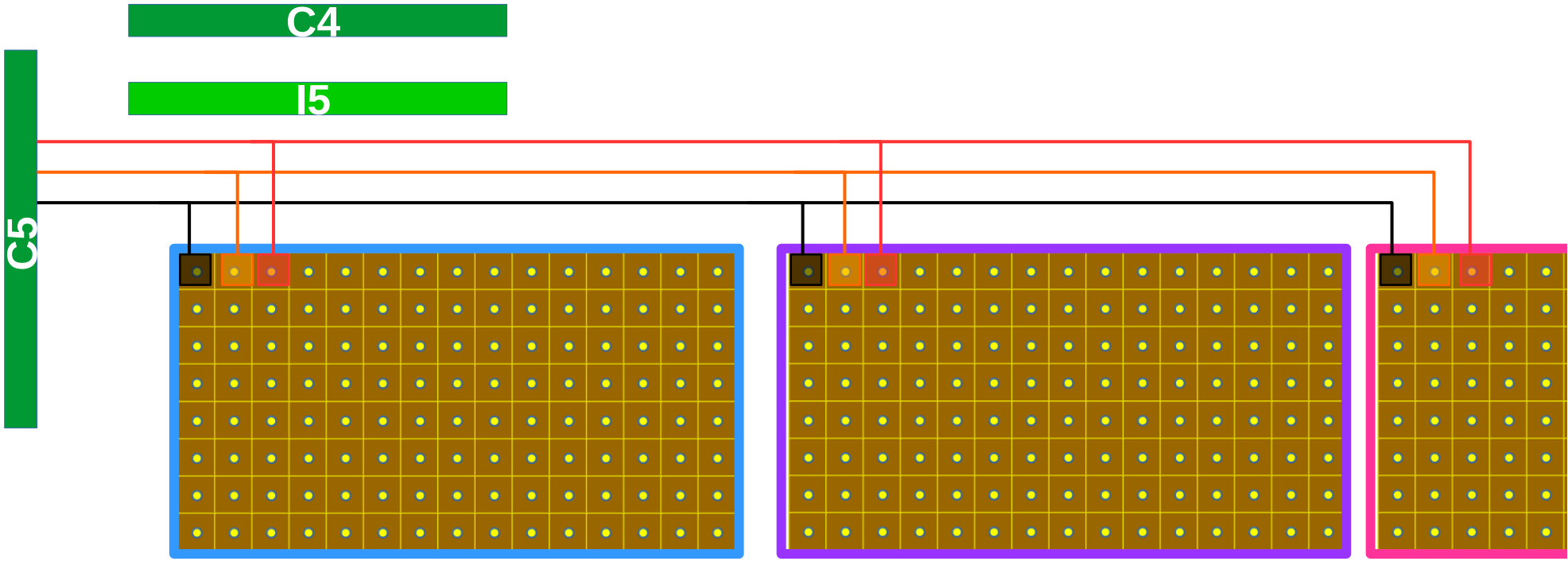


How to get 28k pixels with 480 channels

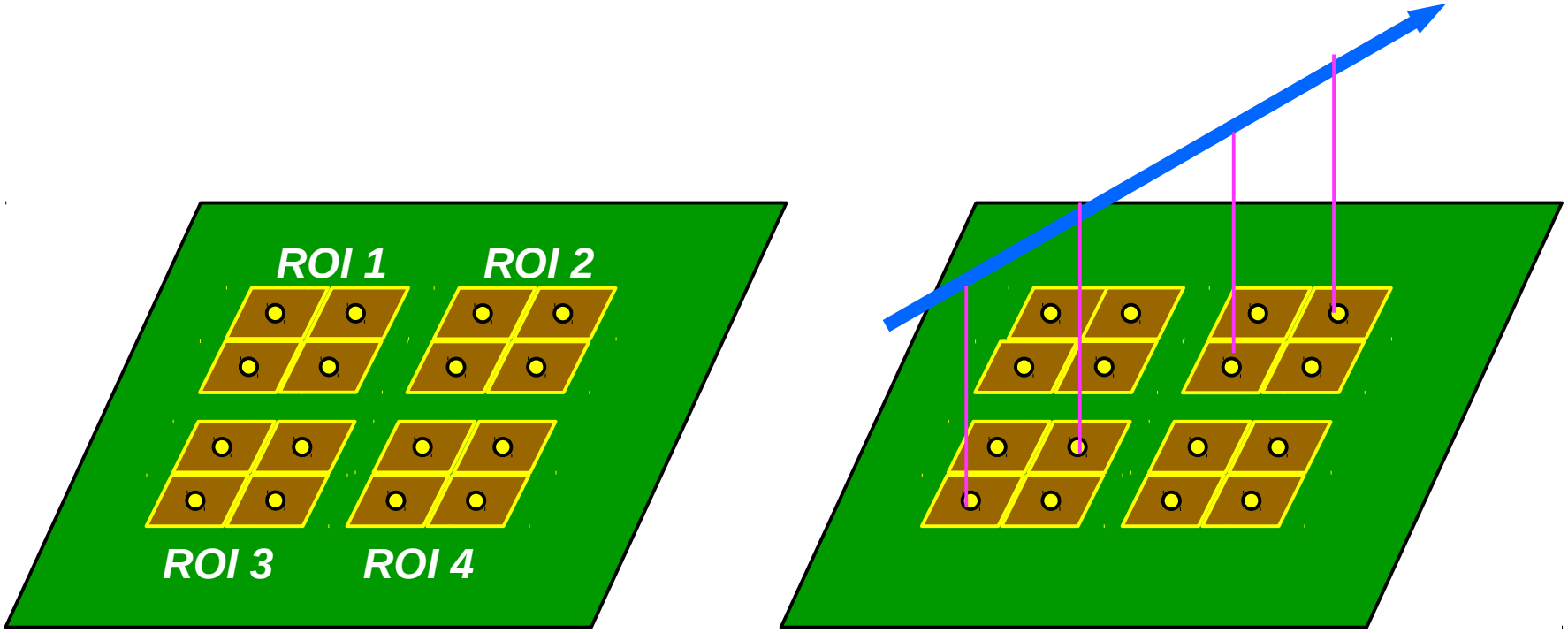


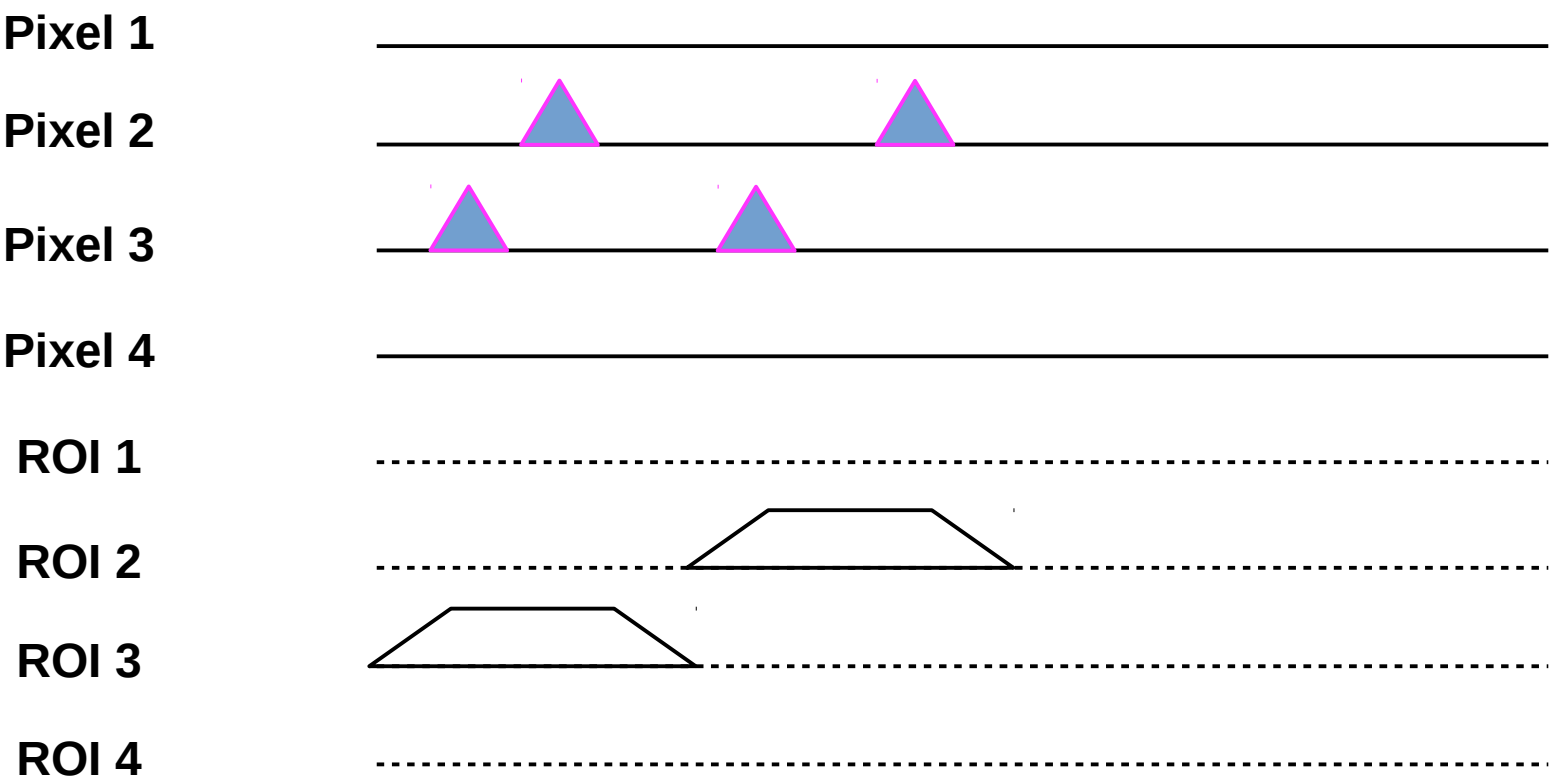
- **The way the multiplexing is done is to treat every 8x15 array of pixels (120) pixels as its own Region of Interest (ROI) which provides an induction pulse**
- **Each one of these ROI's is mapped to an individual channel in the readout**
- **For each PCB there are 120 ROI's arranged into the 36 cm^2 area**

How to get 28k pixels with 480 channels



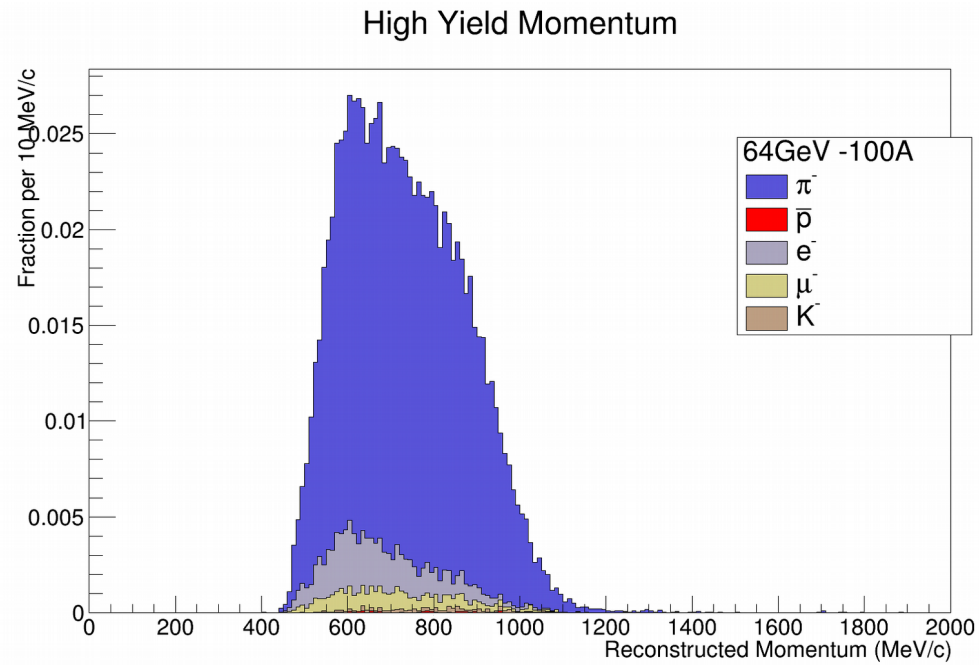
- **Each unique pixel from each ROI is ganged together to reduce the overall channel count**
  - e.g. **Pixel 01/ROI 01** is multiplexed with **Pixel 01/ROI 02**, **Pixel 01/ROI 03**, and **Pixel 02/ROI 01** is multiplexed with **Pixel 02/ROI 02**, etc...

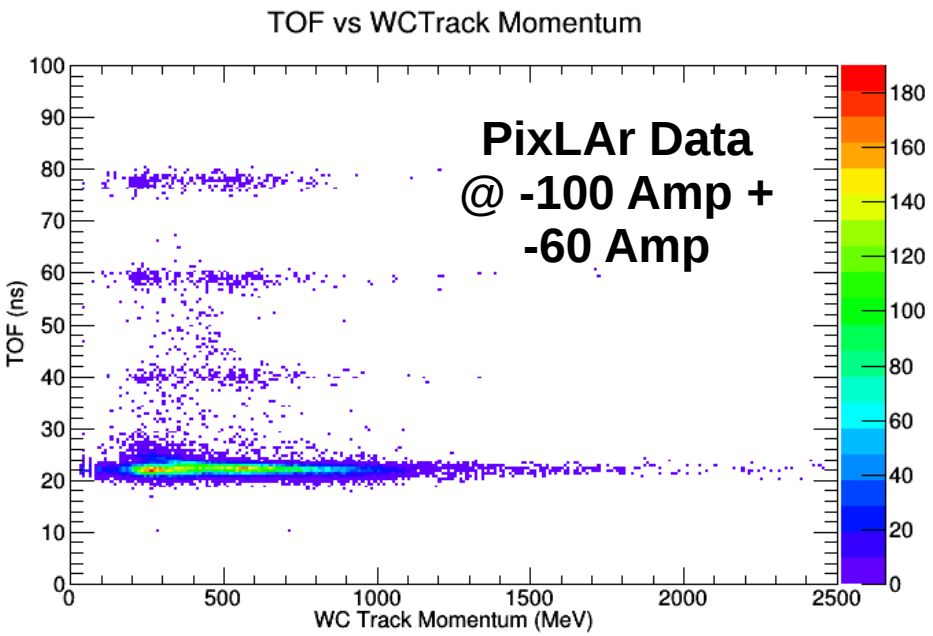

ROI 1
ROI 2
ROI 3
ROI 4


Pixel 1
Pixel 2
Pixel 3
Pixel 4
ROI 1
ROI 2
ROI 3
ROI 4

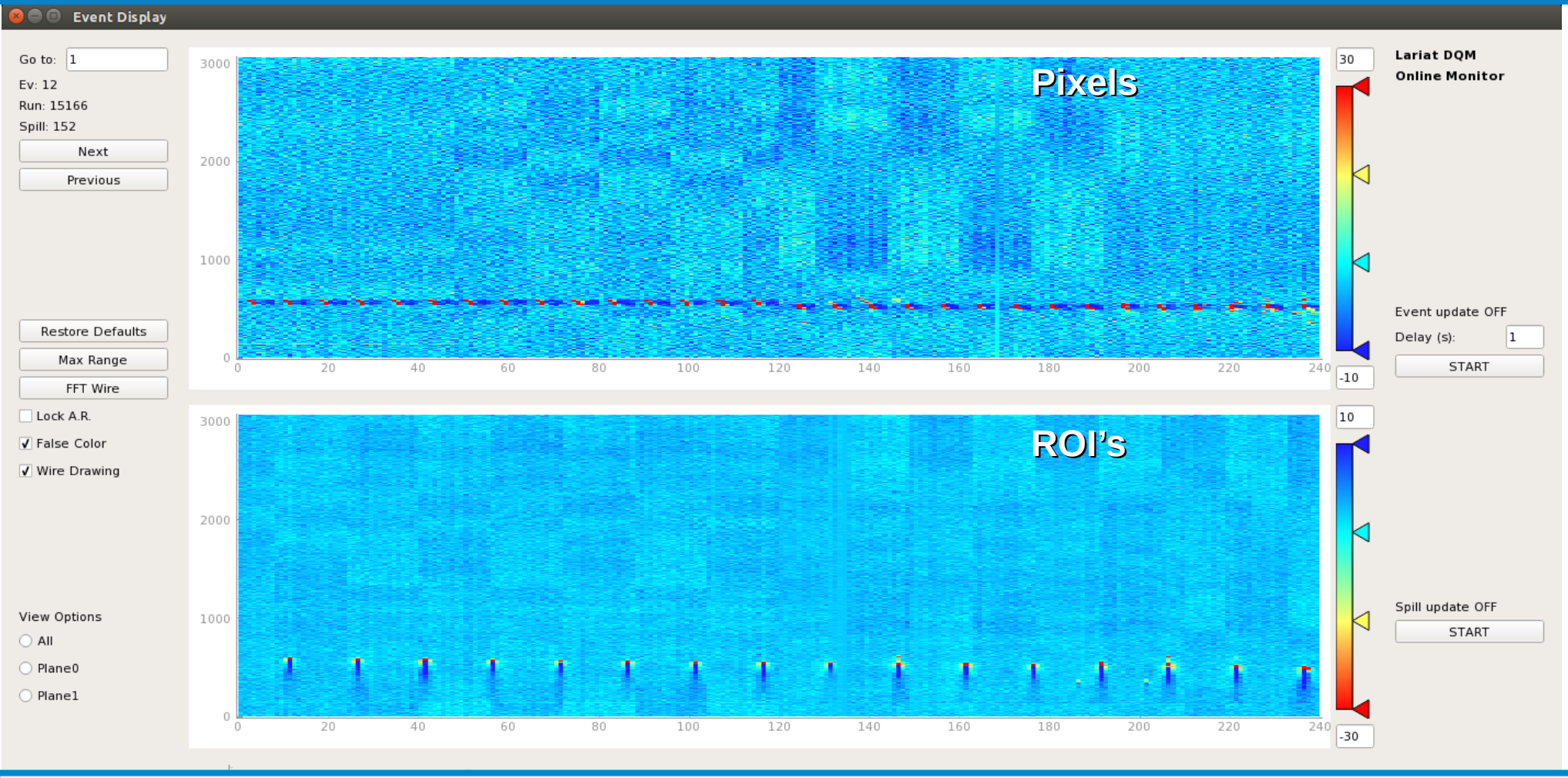
PixLAr Data Taking Campaign

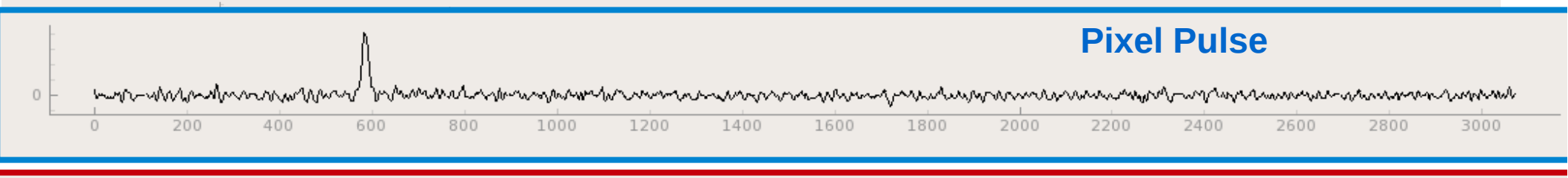
- **PixLAr took data from 12/1/17 – 1/25/18**
  - 7 weeks of data taking in a number of different beamline configurations
    - Both magnet polarities and at low and high momentum
  - Also triggered on cosmic rays using LArIAT cosmic paddles
    - Provides a nice sample of tracks which cross anode to cathode to help with calibrations and reconstruction

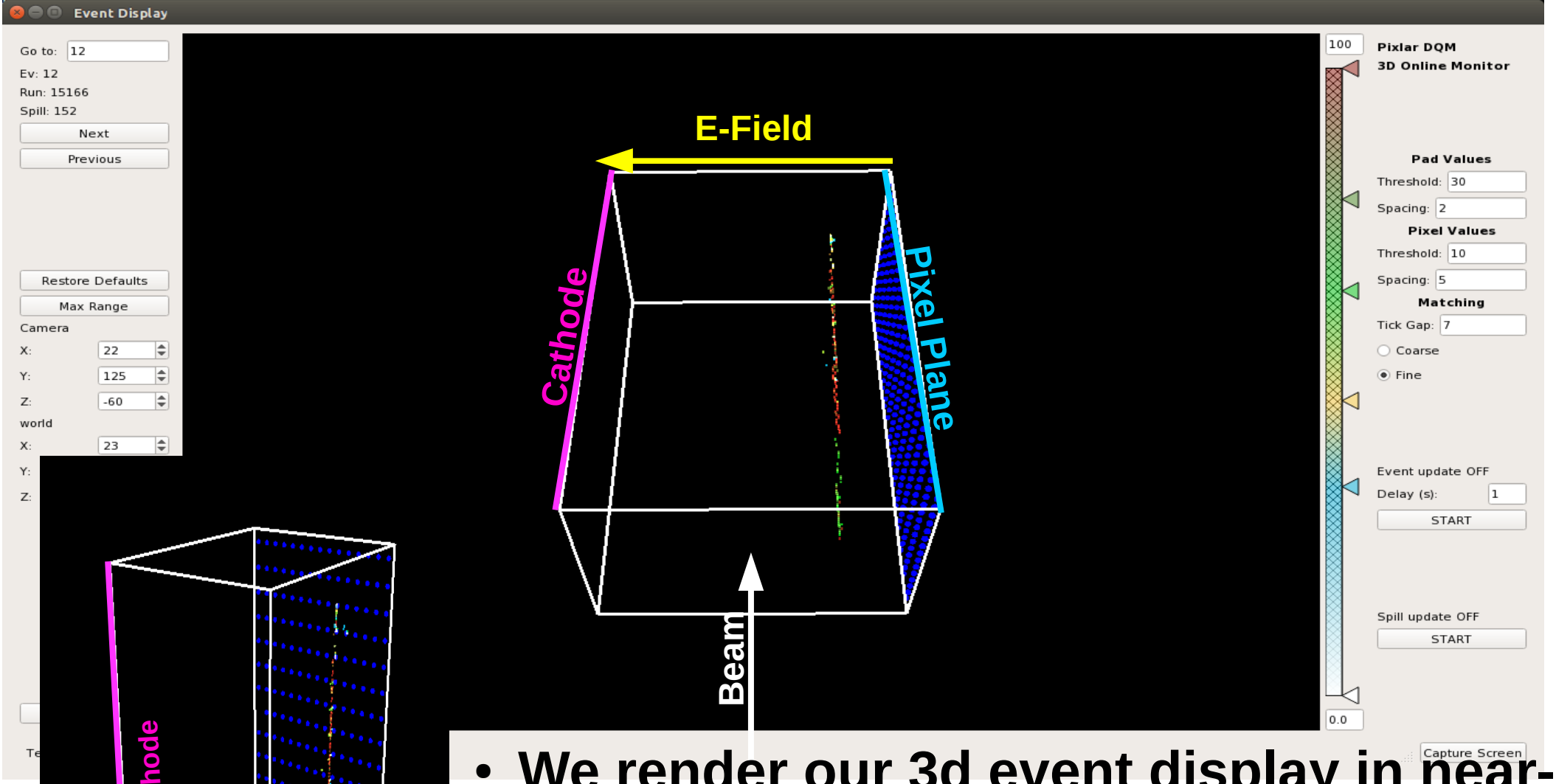


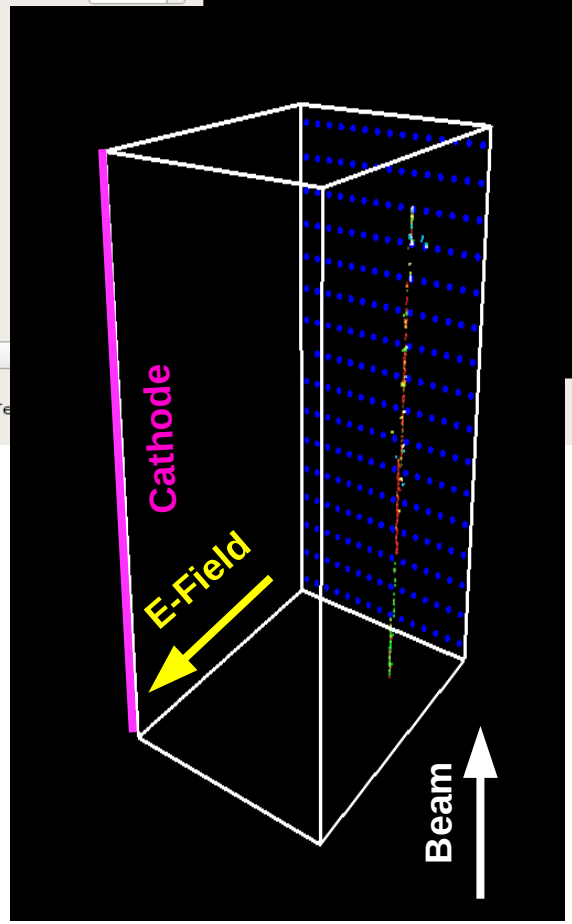


Pixel / ROI Event Display



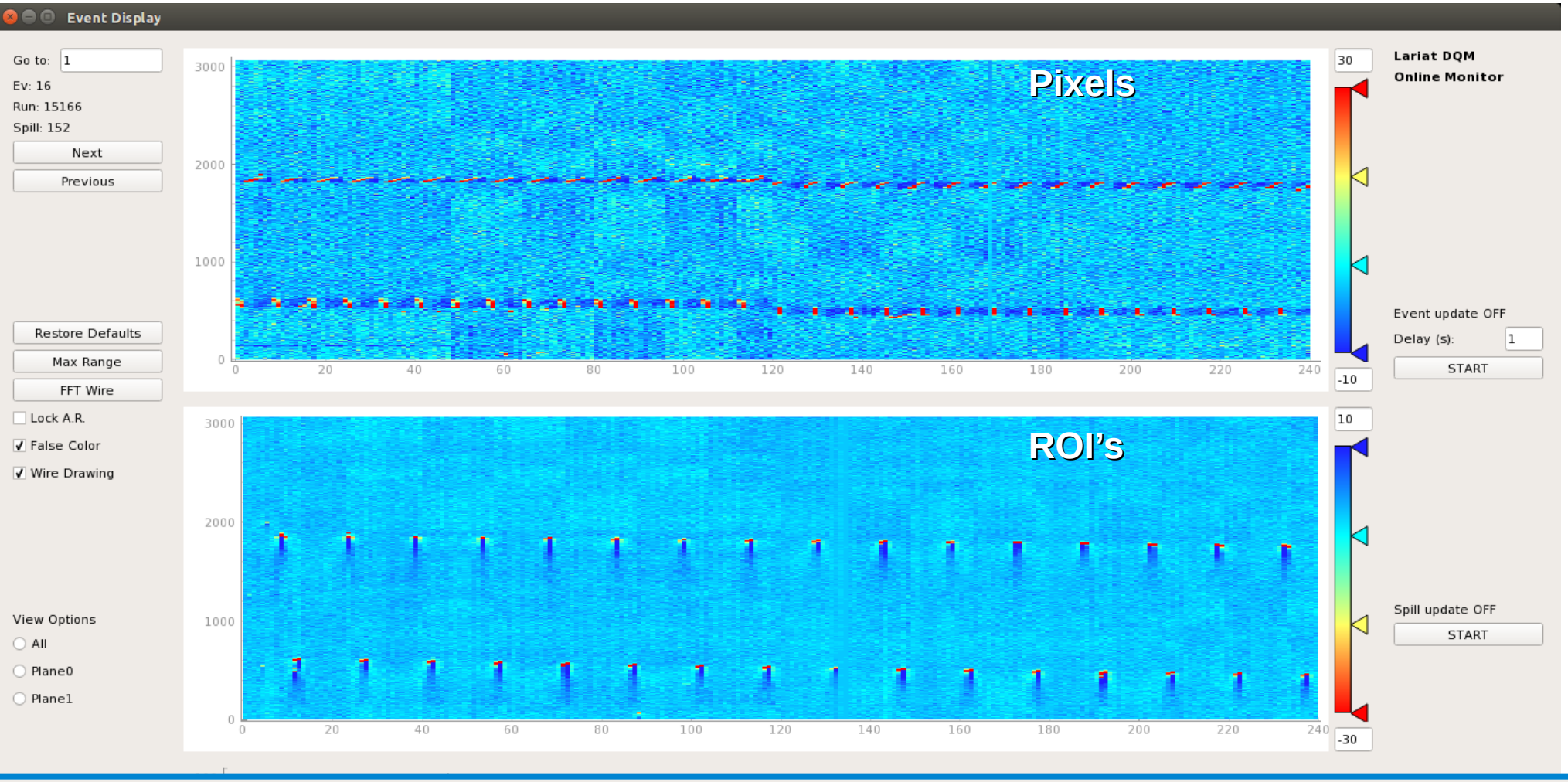


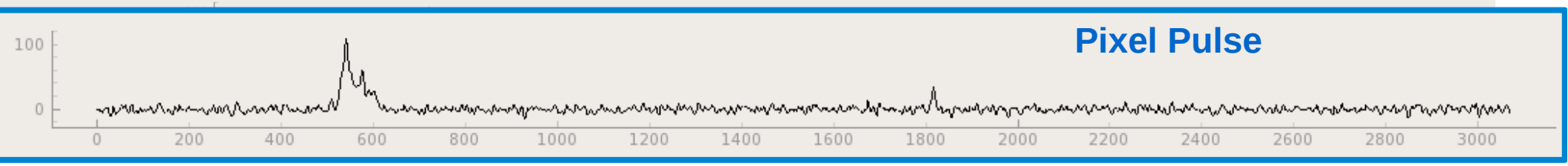


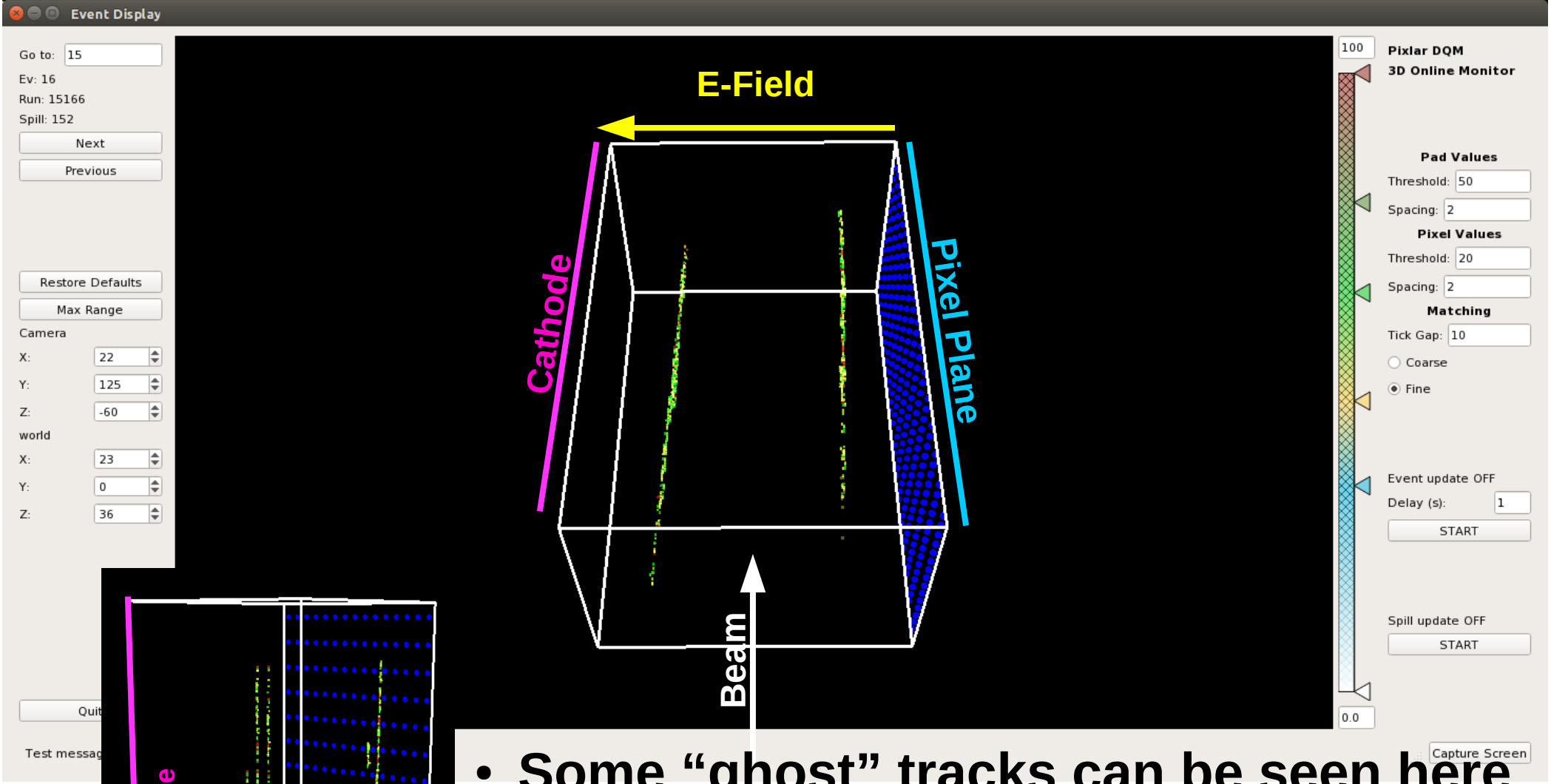


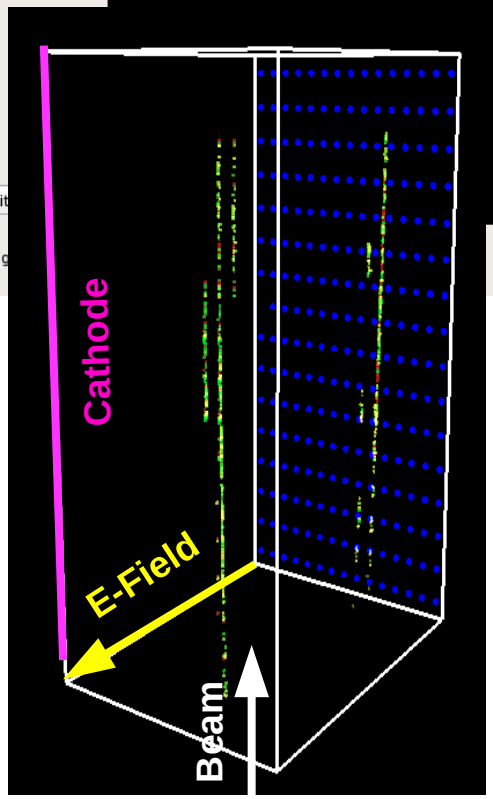
- **We render our 3d event display in near-real time (~1 min lag behind the DAQ to process the event)**
- **Here Pixel/ROI matching has been done**
  - For speed we typically only plot the ROI block

Pixel / ROI Event Display (Two track event)





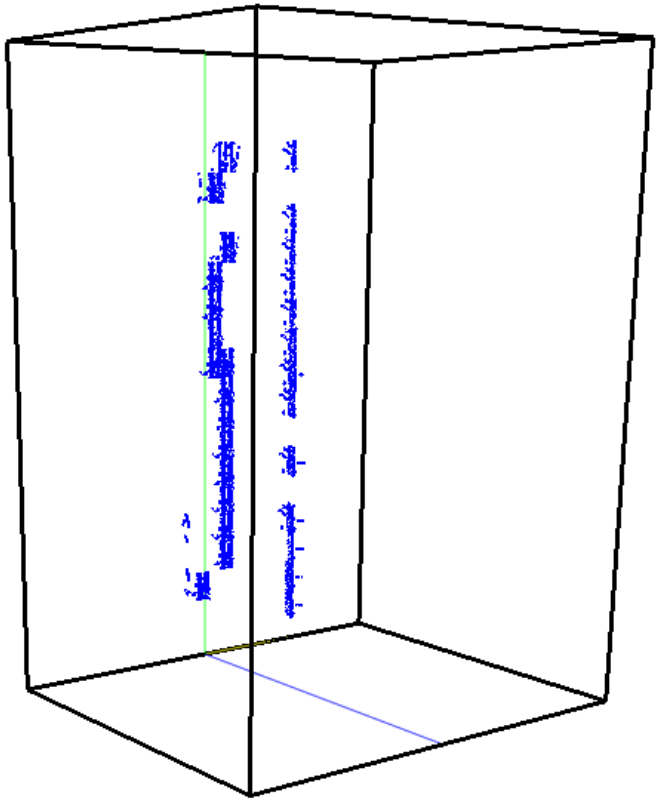




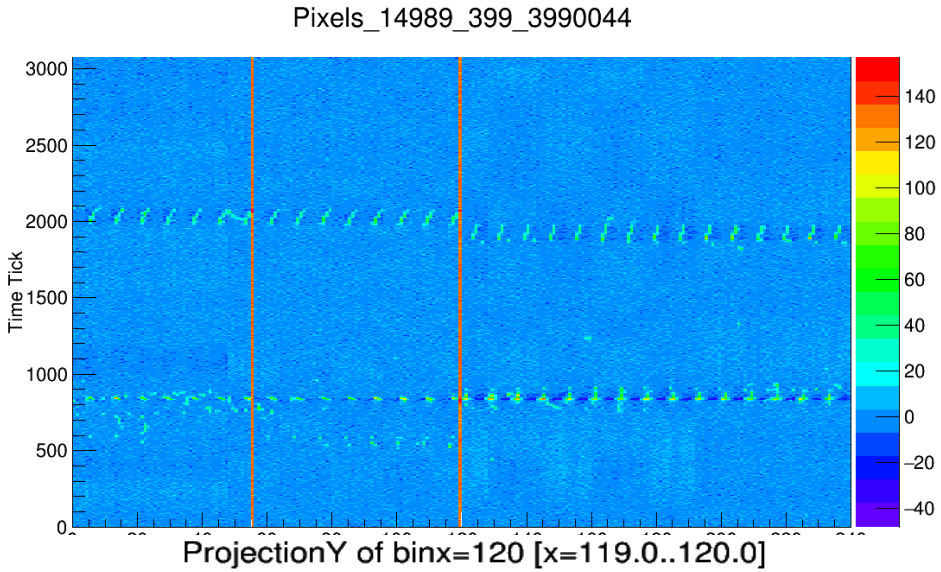
- **Some "ghost" tracks can be seen here**
  - Note: only the most rudimentary peak/hit finding is done "on the fly" to generate these events
  - More strict matching requirements tends to clean this up

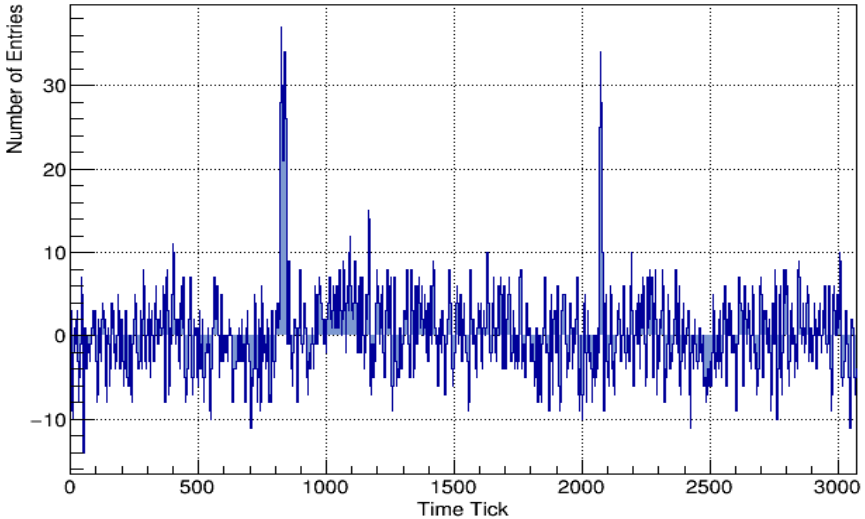
Simple Physics we can extract

- **We have implemented a version of this Pixel/ROI matching into LArSoft (LArIATsoft) and even managed to generate spacepoints (3d LArSoft objects)**



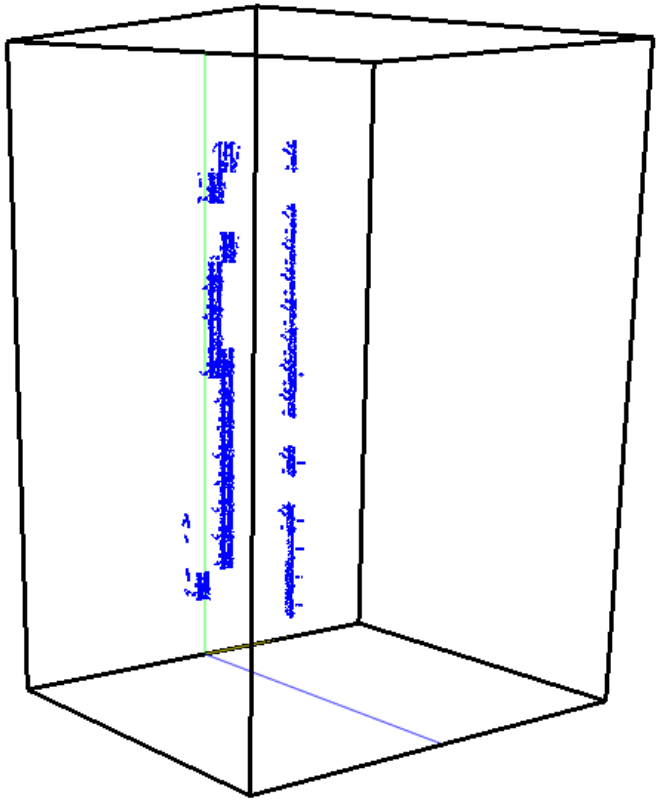
Generate all possible spacepoints



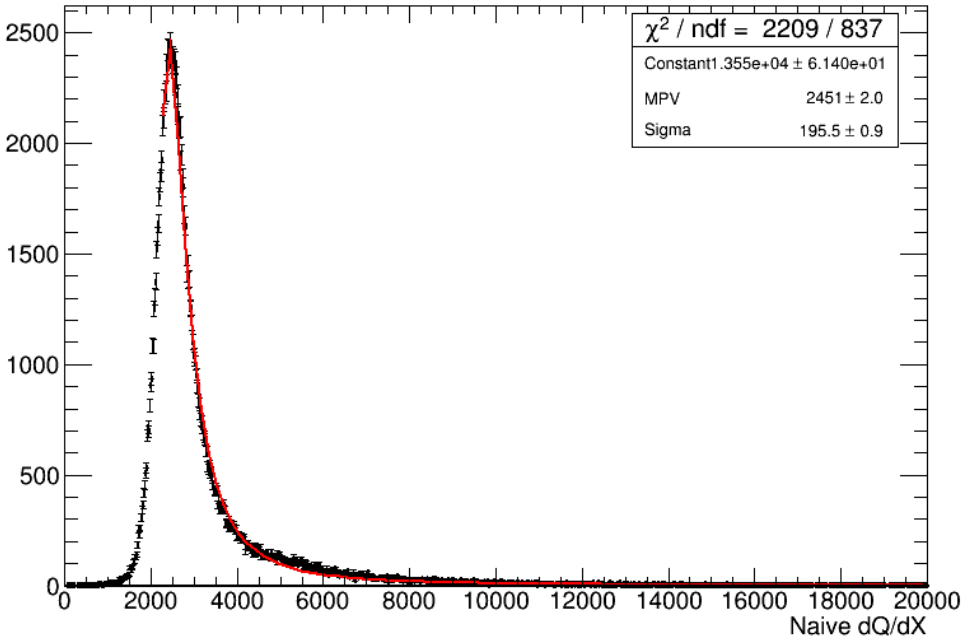


Simple Physics we can extract

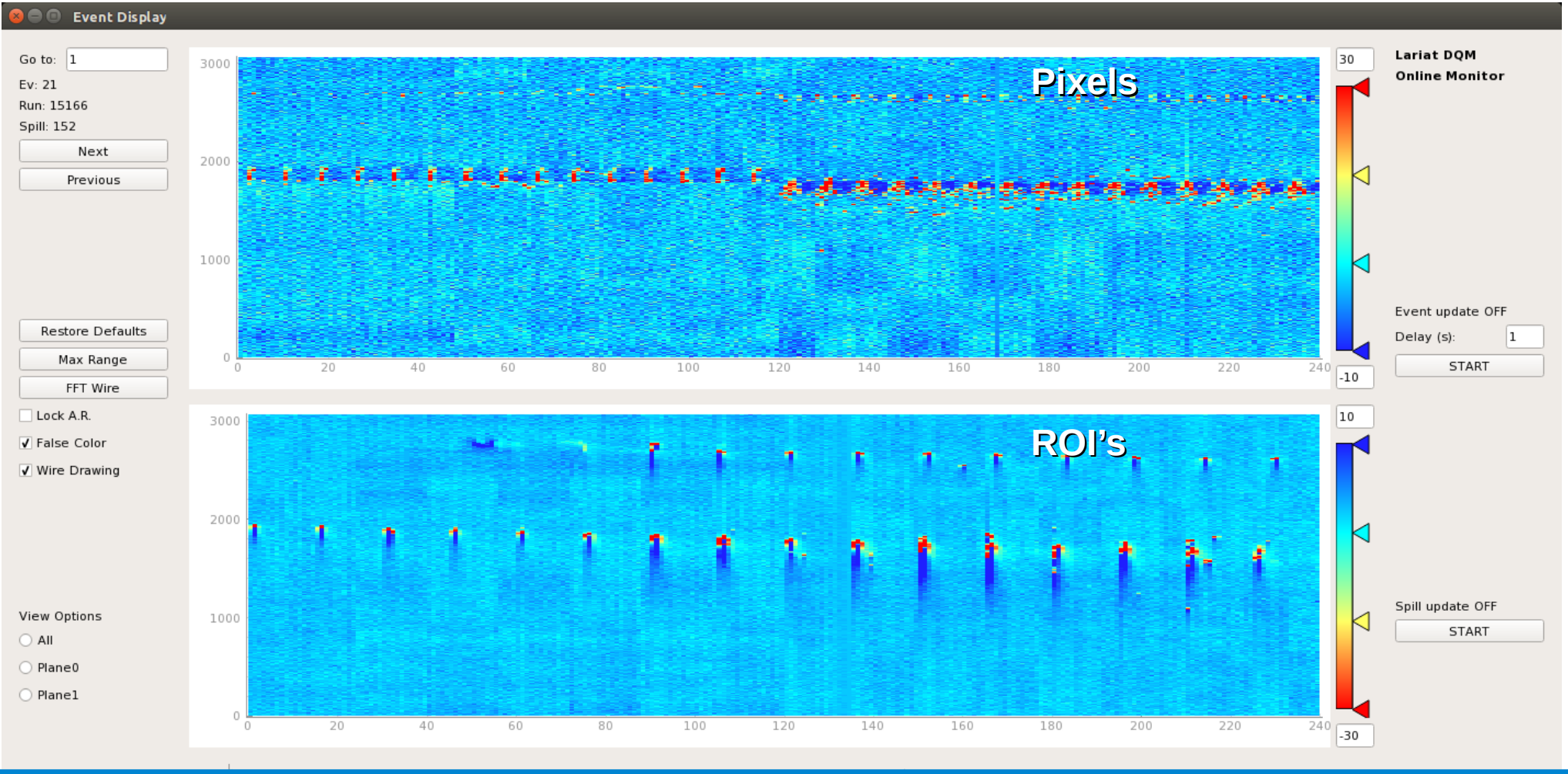
- **If we only take the contiguous space points from events where there is obvious straight lines through the TPC we can make a simple d'Q'/dX plot**
  - Note: I put “Q” in quotes because we haven't done any calibration of the signal yet...this is just converting pixel ADC using LArIAT constants
  - All that said, it shows we are on our way to extracting physics!

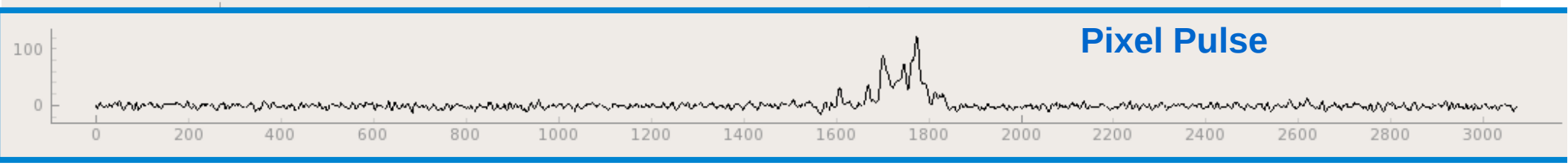


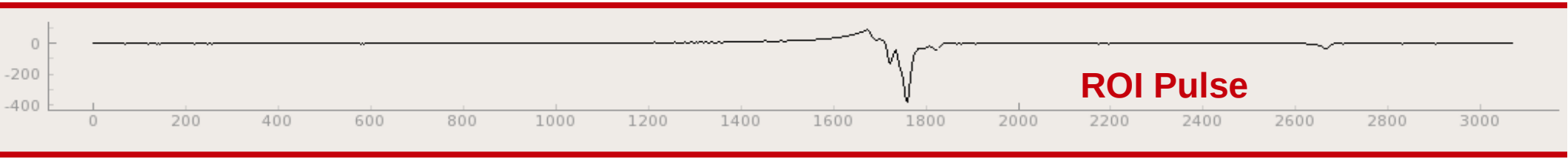
Generate all possible spacepoints

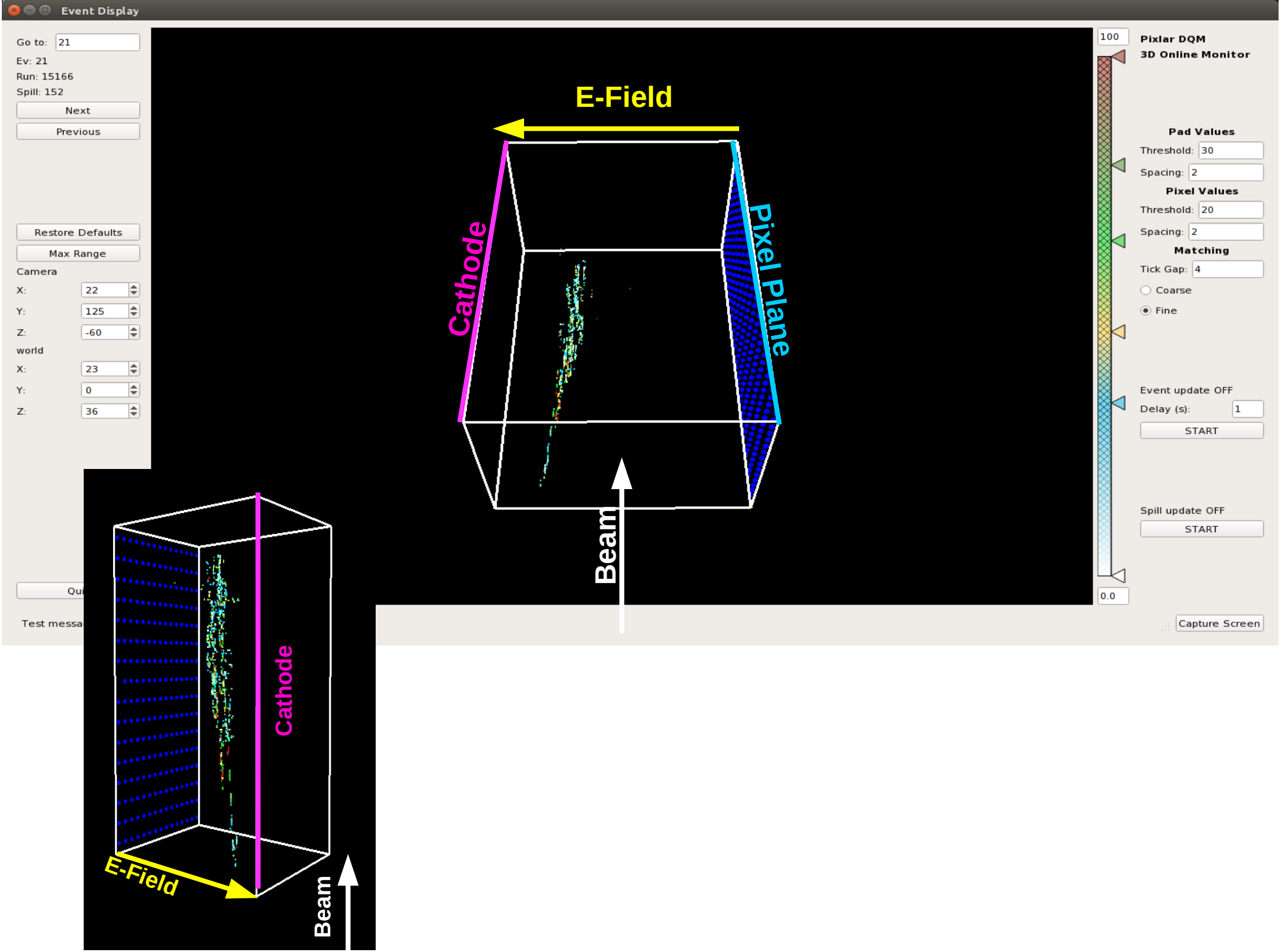


Pixel / ROI Event Display (EM-Shower)

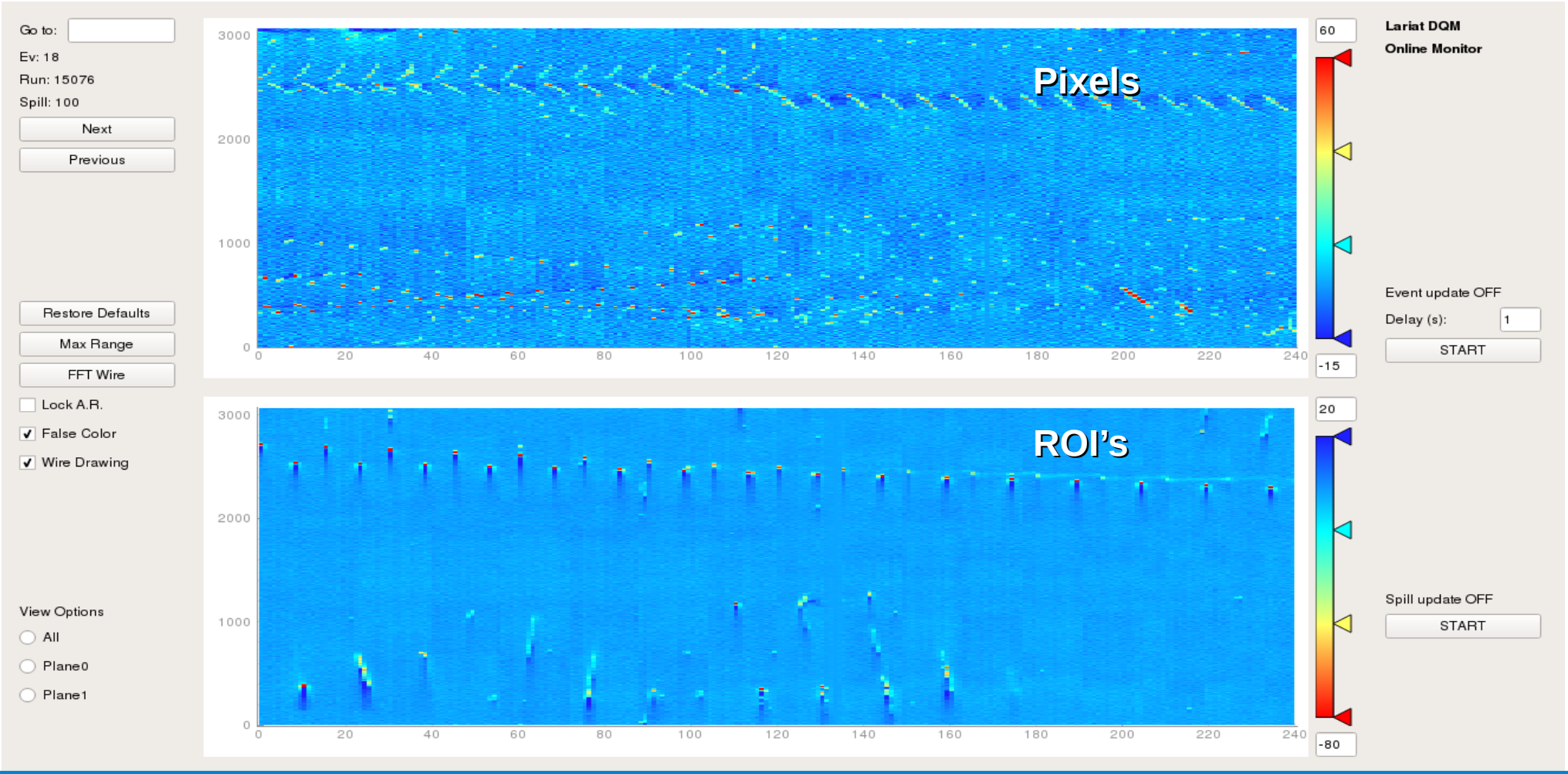


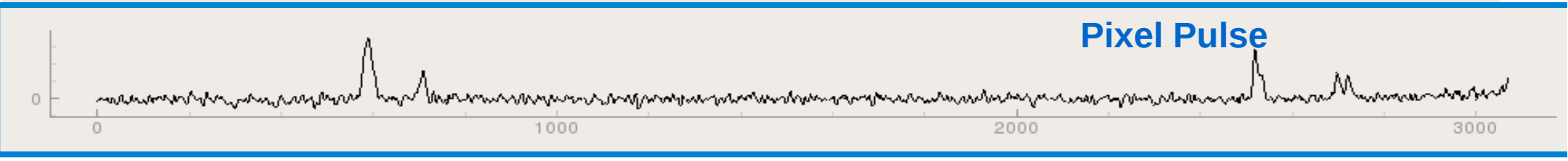


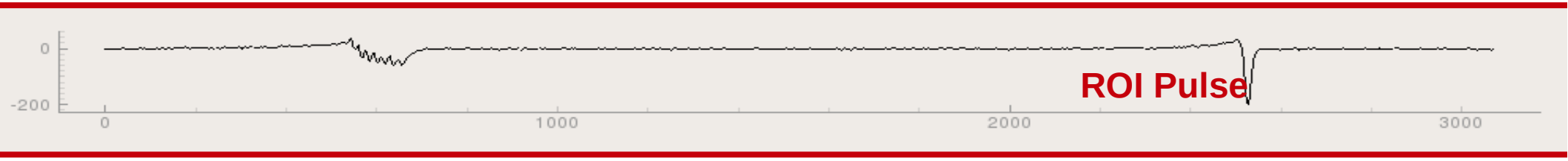


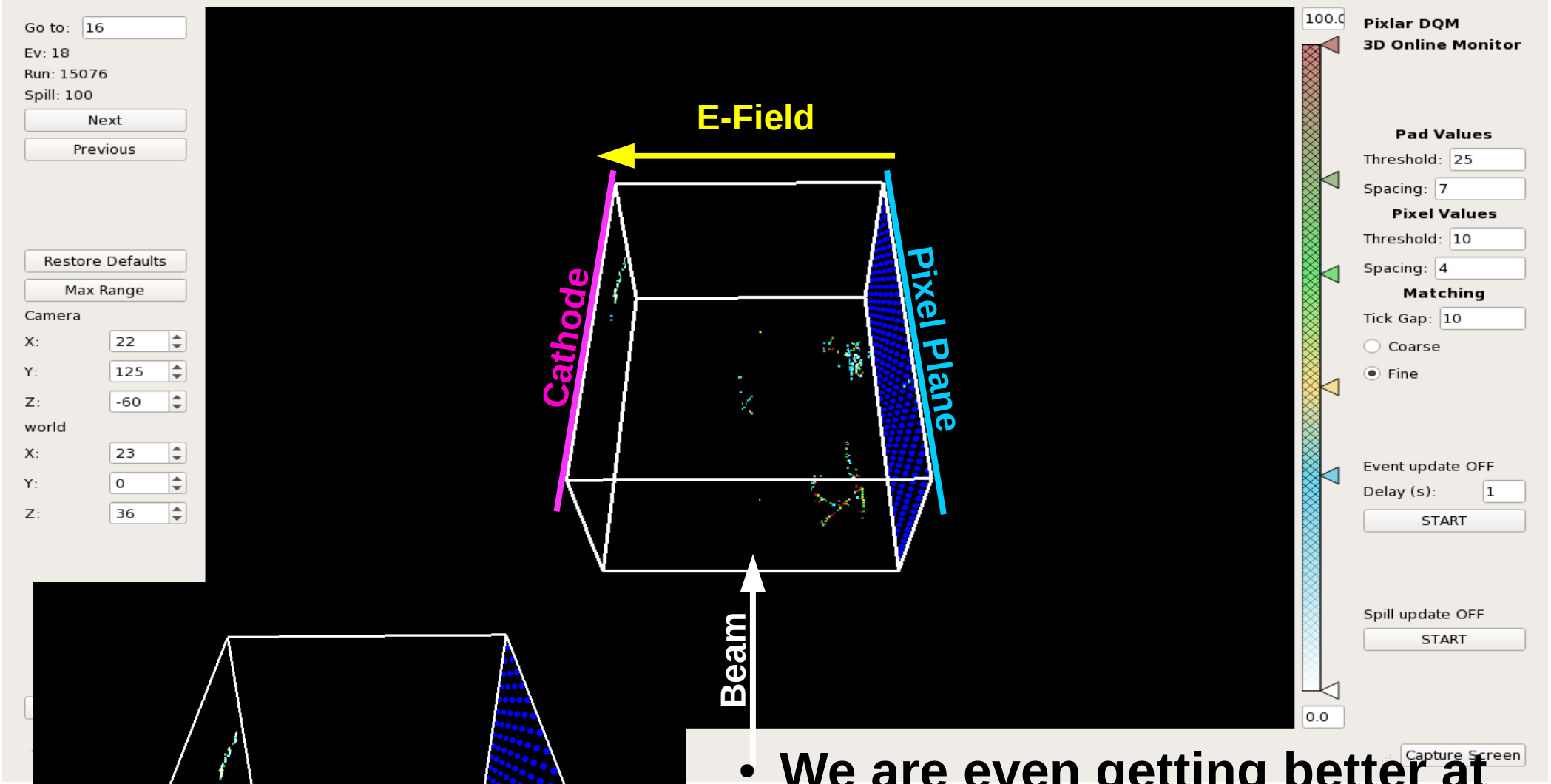

Event Display
Go to: 21
Ev: 21
Run: 15166
Spill: 152
Next
Previous
Restore Defaults
Max Range
Camera
X: 22
Y: 125
Z: -60
world
X: 23
Y: 0
Z: 36
Test messa
E-Field
Cathode
Pixel Plane
Beam
100
0.0
Pixlar DQM
3D Online Monitor
Pad Values
Threshold: 30
Spacing: 2
Pixel Values
Threshold: 20
Spacing: 2
Matching
Tick Gap: 4
Coarse
Fine
Event update OFF
Delay (s): 1
START
Spill update OFF
START
Capture Screen
Cathode
E-Field
Beam

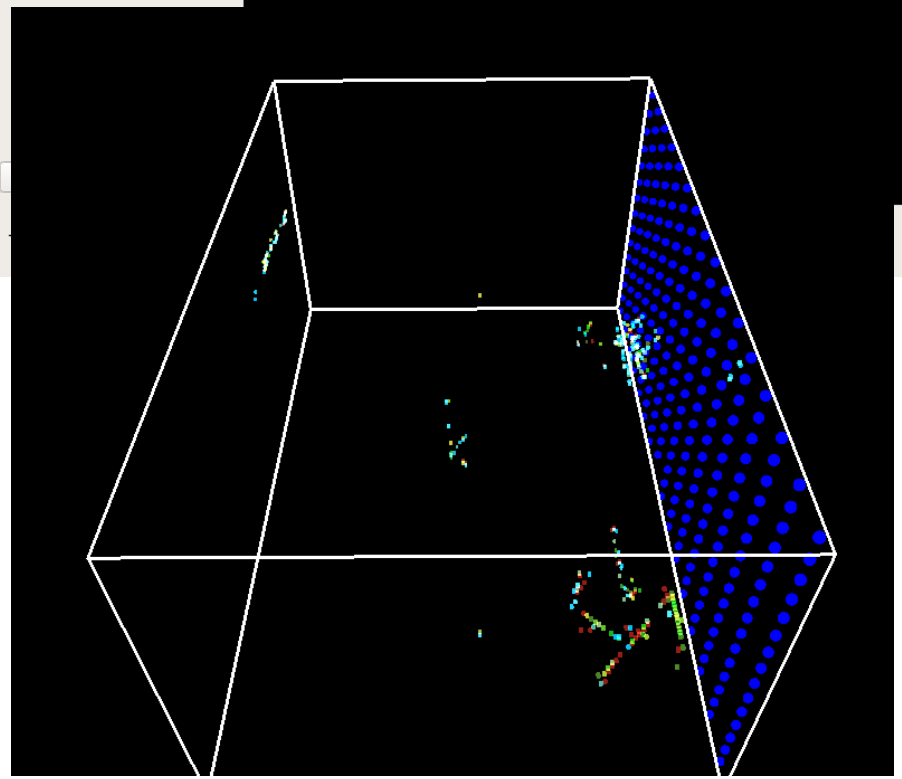
Pixel / ROI Event Display (Busy Event)







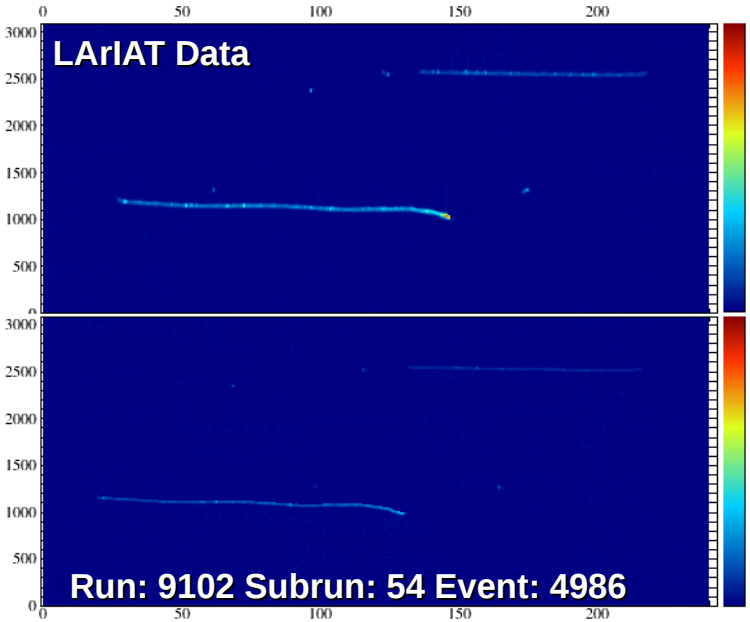


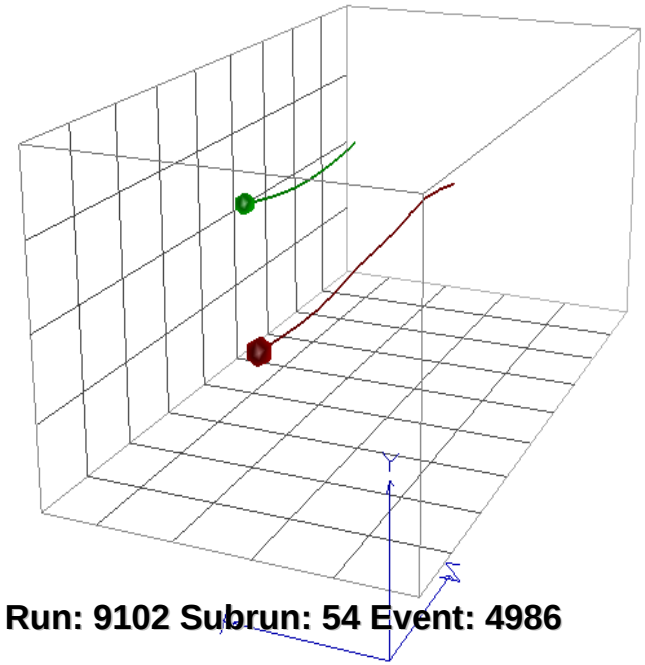


- **We are even getting better at complex topologies like the ones shown here with short tracks angled close to the pixel plane**
  - More work is still ongoing to fully understand the data

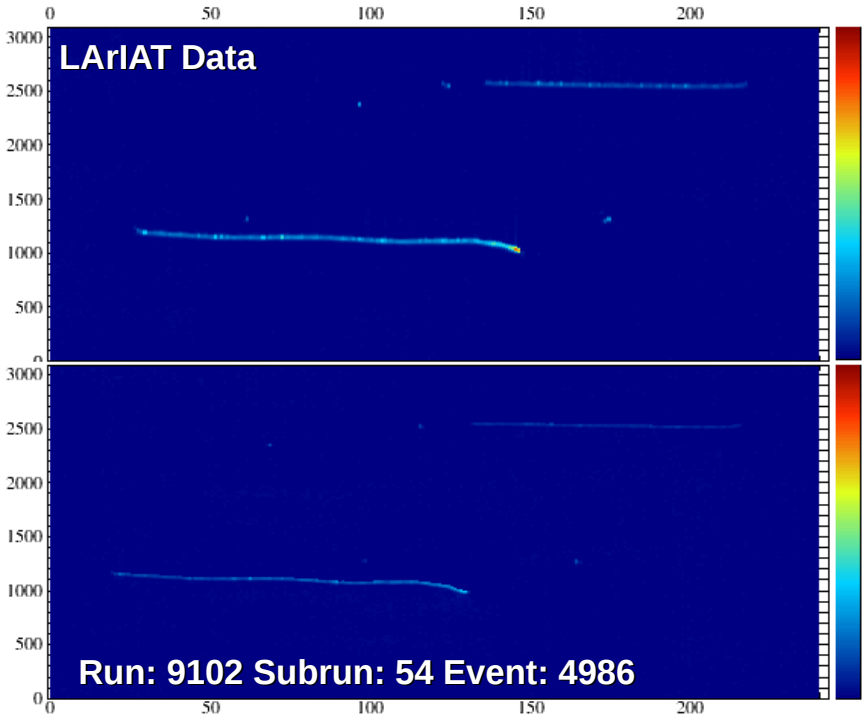
Creating Pixel Based Monte Carlo

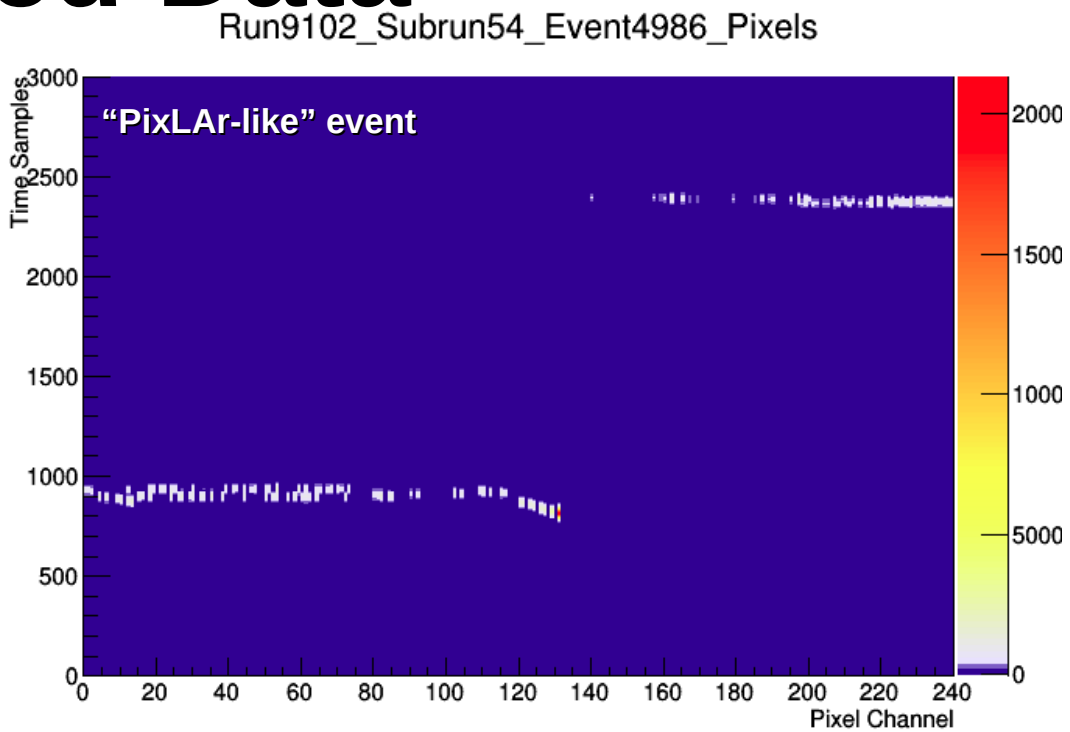
- **In order to best understand our data we want to use a simple pixel Monte Carlo which captures the multiplexing we did in PixLAr**
  - We hope that this will also be of broader use to the LArSoft/Pixel effort once we've tackled some of the practical bits for our own use
- **The methodology is simple**
  - Take each MC event and use the truth X, Y, Z position of the particle
  - Treat the charge that would be assoicated with a “hit” in the conventional wire readout as instead being associated with pixels
    - Use ADC in the collection plane for pixels
    - Use ADC in the induction plane for ROI's
  - Use the mapping of the PixLAr plane, the expected drift speed, and sampling time to turn this into a simulacrum of a PixLAr event
  - Implement the current Pixel reconstruction (originally developed by the Damian at the Bern group) to see if we can recover the input from the data
  - Tune to have MC match the data



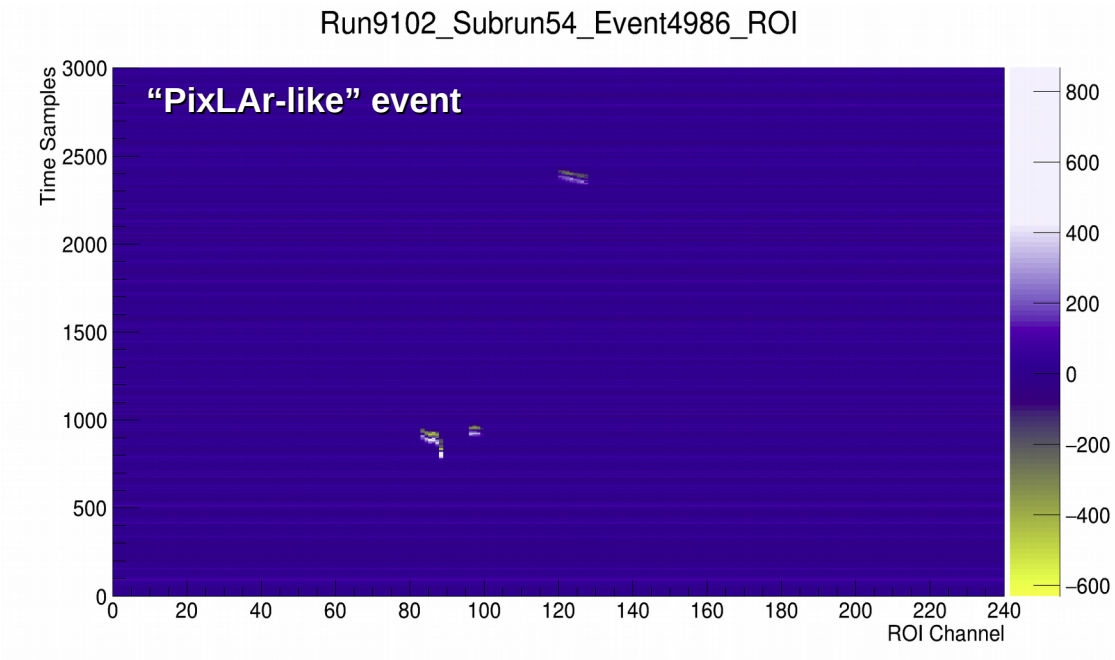


Pixelized Data

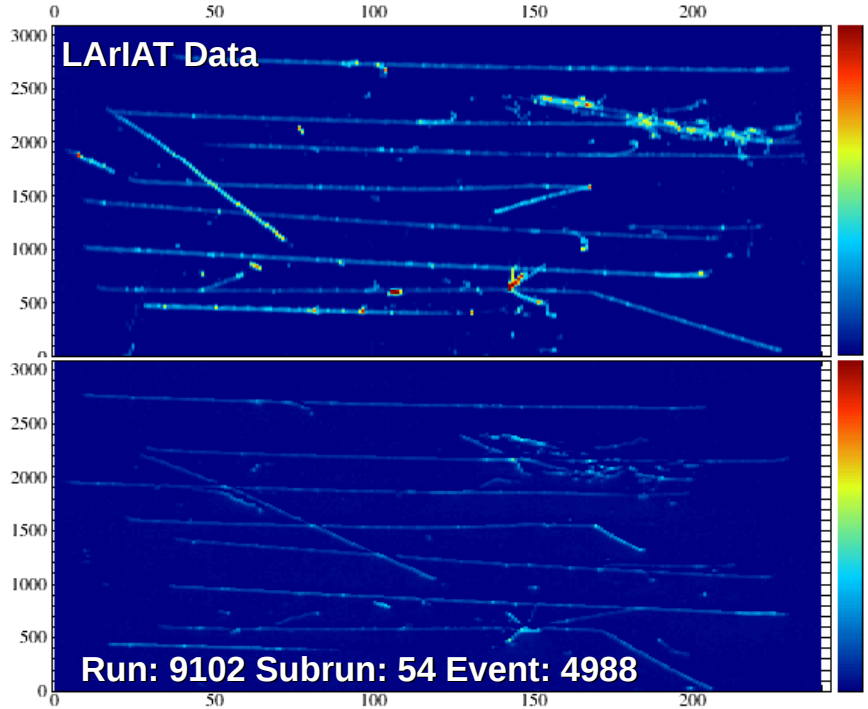


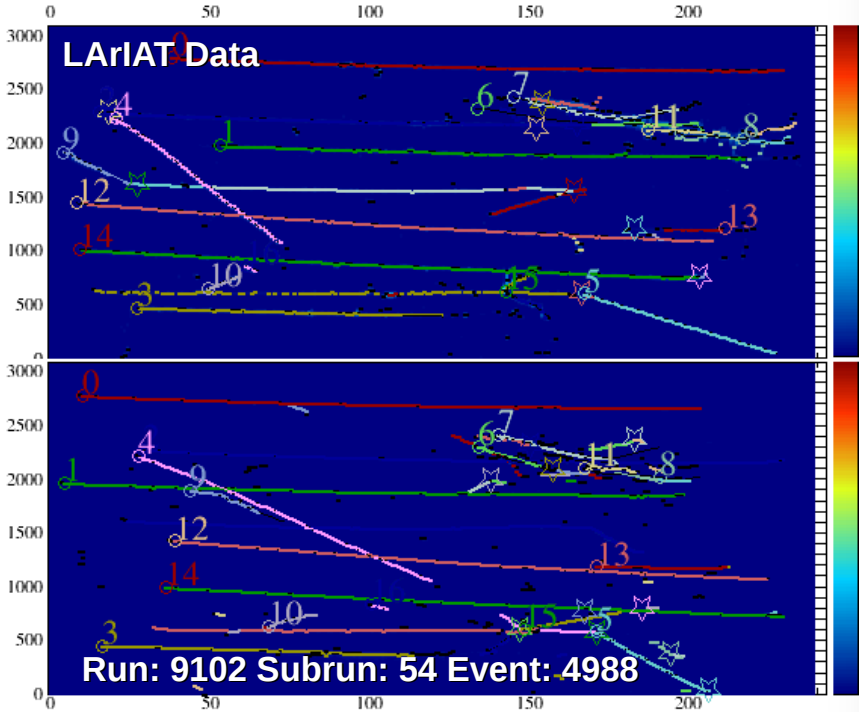


- **Pixel parameters chosen for the moment based visualization and needs to be updated to incorporate what we know from the actual PixLAr run**
- **Pixel Hits**
  - Height → 1000*ADC value
  - Width → 15 samples
- **ROI Hits**
  - Height → 100*ADC value
  - Width → 15 samples

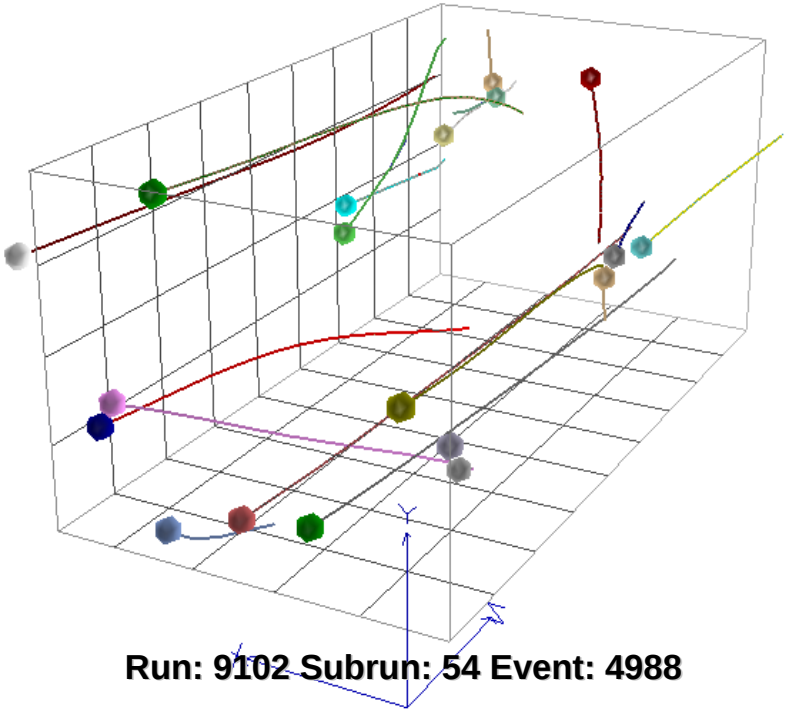


Run: 9102, Subrun: 54, Event: 4988

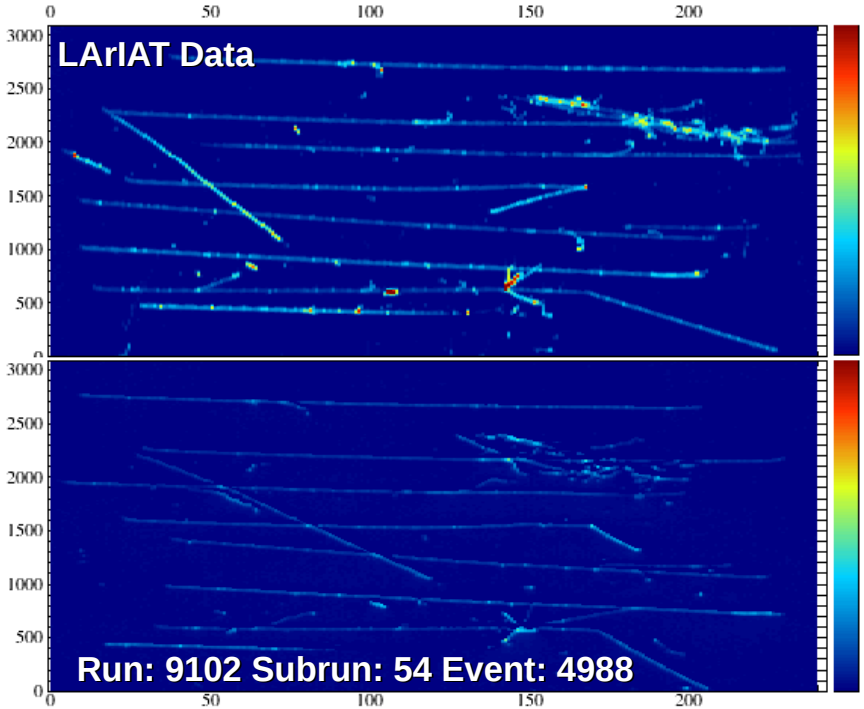


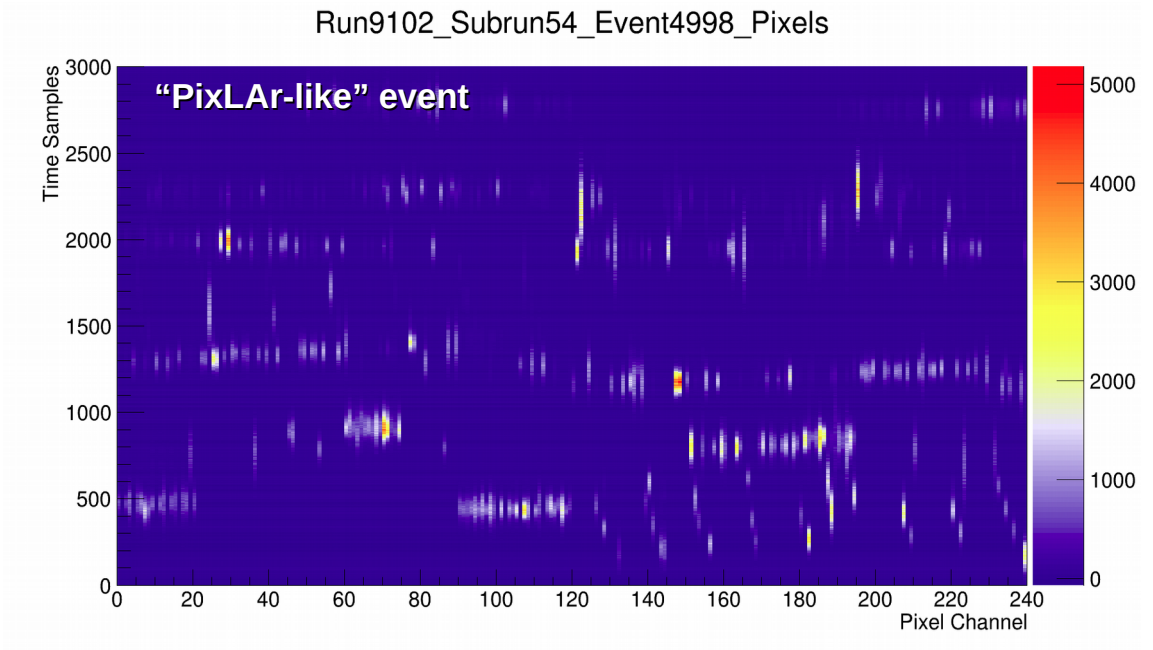


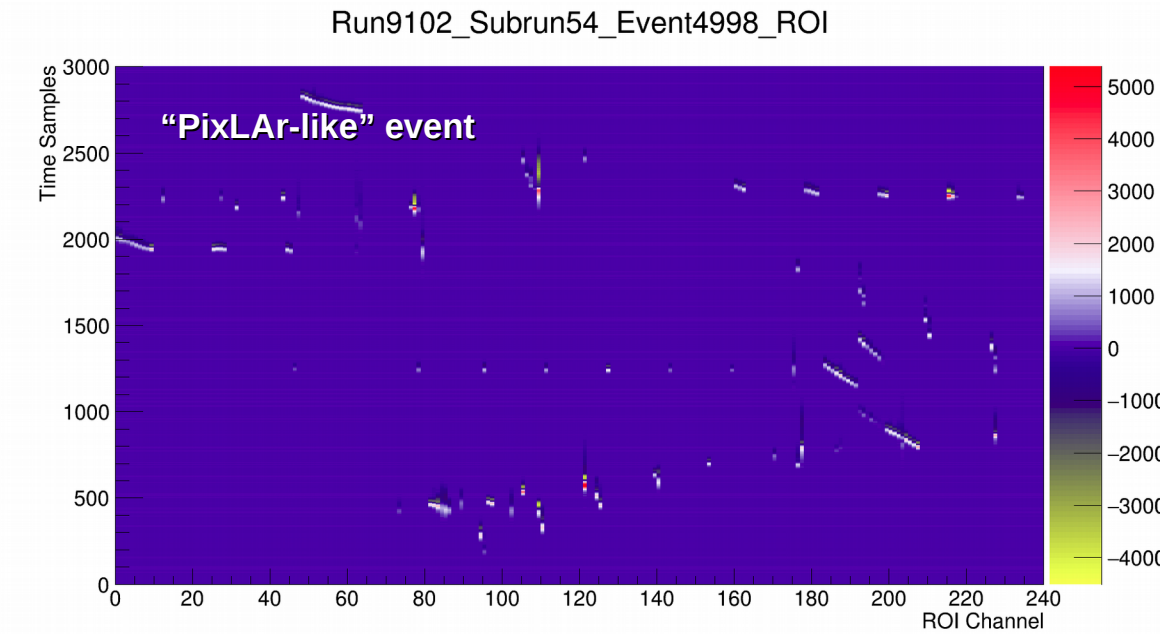
- **19 tracks reconstructed**
  - This is a typically “busy” pileup event in LArIAT and is a stretch for us to disentangle
    - although our existing reco does a pretty good job!
    - Note: not all the EM shower information gets turned into charge here



Pixelized Data



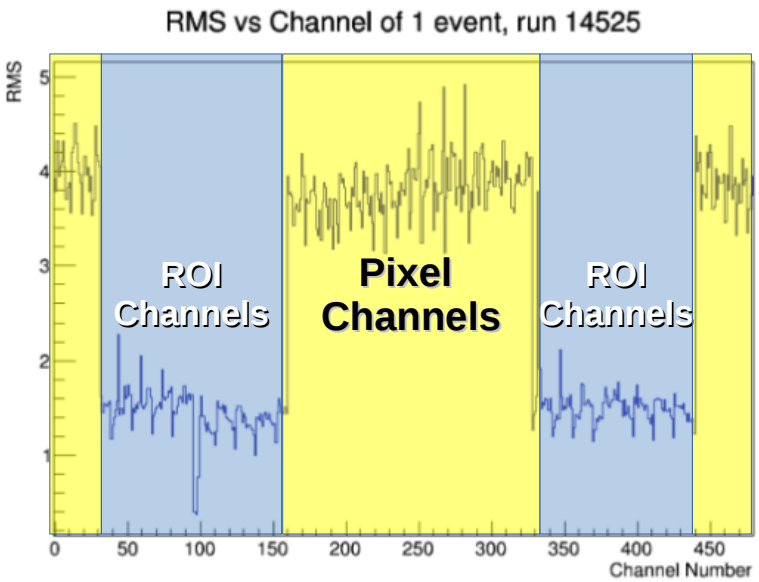


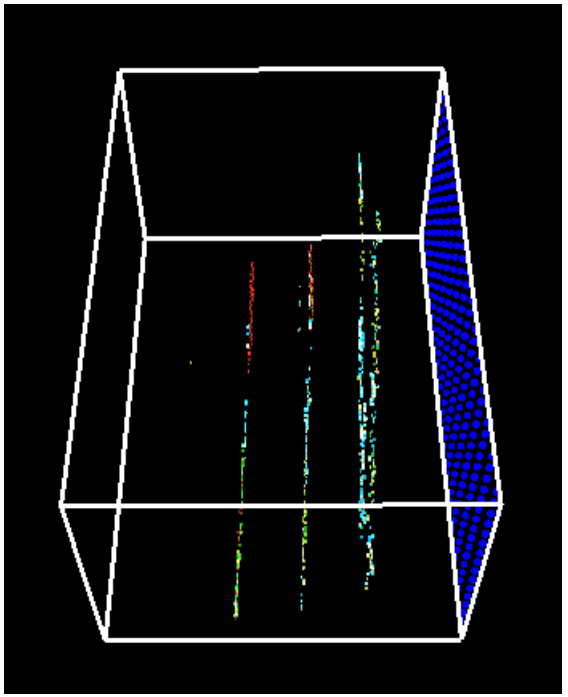


- **Here we assume some more realistic hit parameters and add some noise to the event**
  - This is much more noise then what we saw in the actual data run
- **Pixel Hits**
  - Height → 50*ADC value
  - Width from FWHM
- **ROI Hits**
  - Height → 50*ADC value
  - Width from FWHM

What we've learned so far

- **PixLAr was able to achieve resonable signal to noise even with the extensive multiplexing done for the pixels**
  - With no noise filtering we are seeing ~12:1 S:N
  - We expect this will improve slightly with some software noise filtering
- **High multiplicity events don't seem to pose a problem for this technology**
  - We can clearly disentangle 3-4 tracks per 45 cm drift region with no problems
  - I claim (without hard evidence yet) we will easily reconstruct 8+ tracks per 45 cm drift region
    - This work is ongoing to give solid performance numbers for minimum track distance and high multiplicity, but even simple event displays and rudimentary matching shows promise
    - Also, in the DUNE near detector we hope not to have to contend with the multiplexing we had to do here (again, See Dan's upcoming talk)

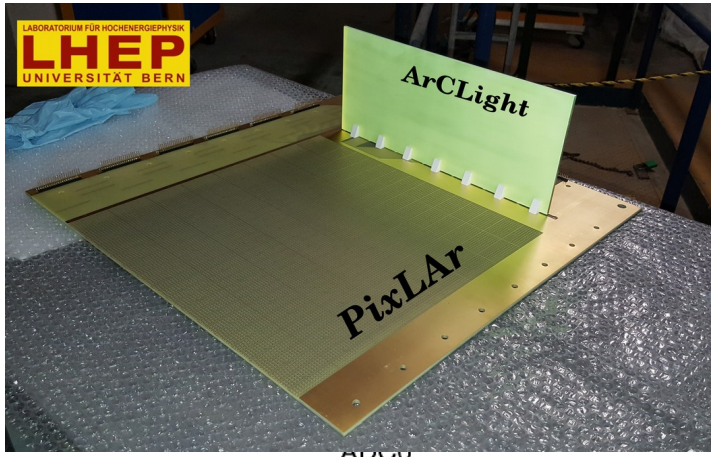


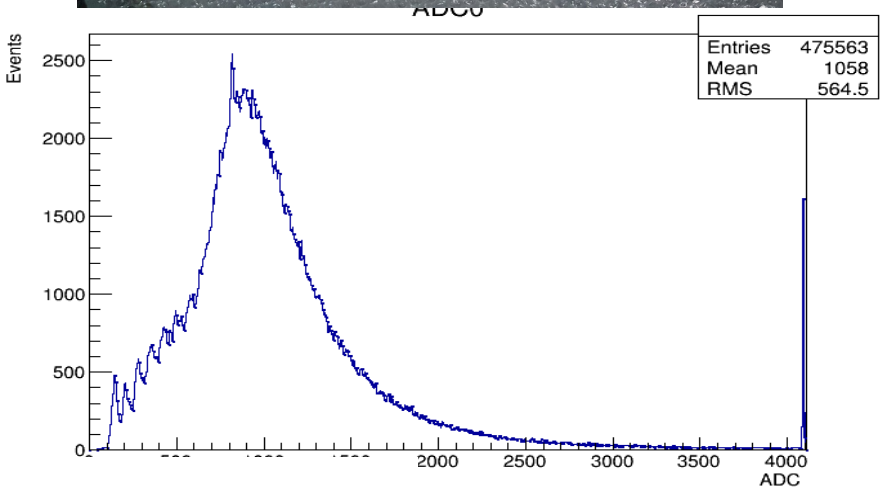


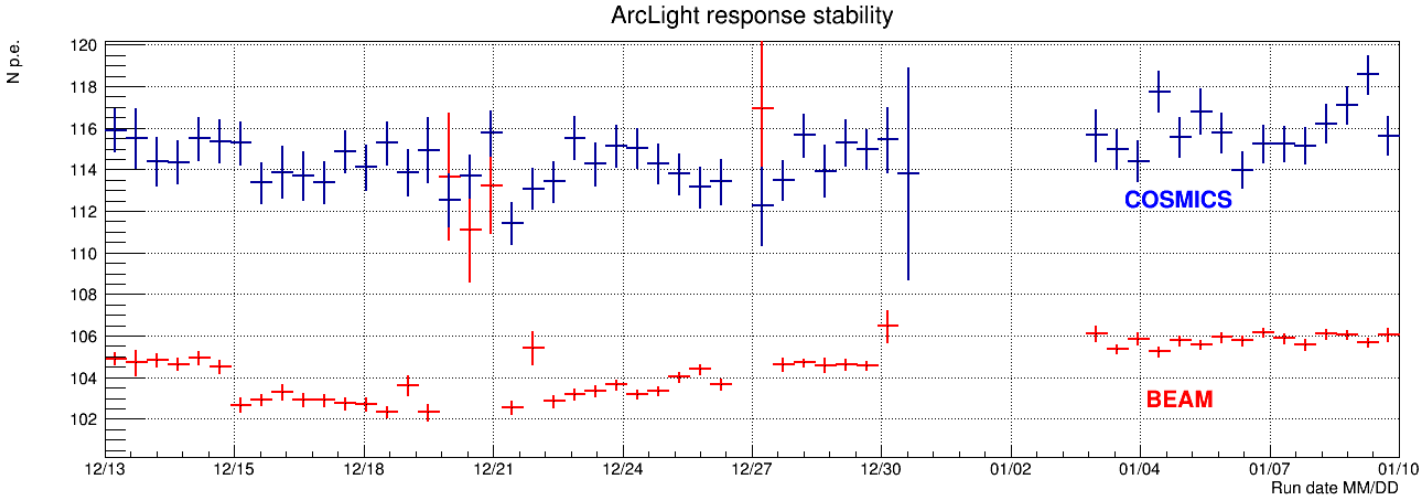
4 through going tracks

ArcLight Performance

- **4 out of 8 SiPM's worked**
  - Not clear what caused the other 4 to lose response
- **Single PE response seen in both beam and cosmics**
  - Very preliminary photon detection efficiency ~0.24%
    - Expected ~0.35%
    - Work still ongoing….
- **ArcLight response has been stable over the course of our run**

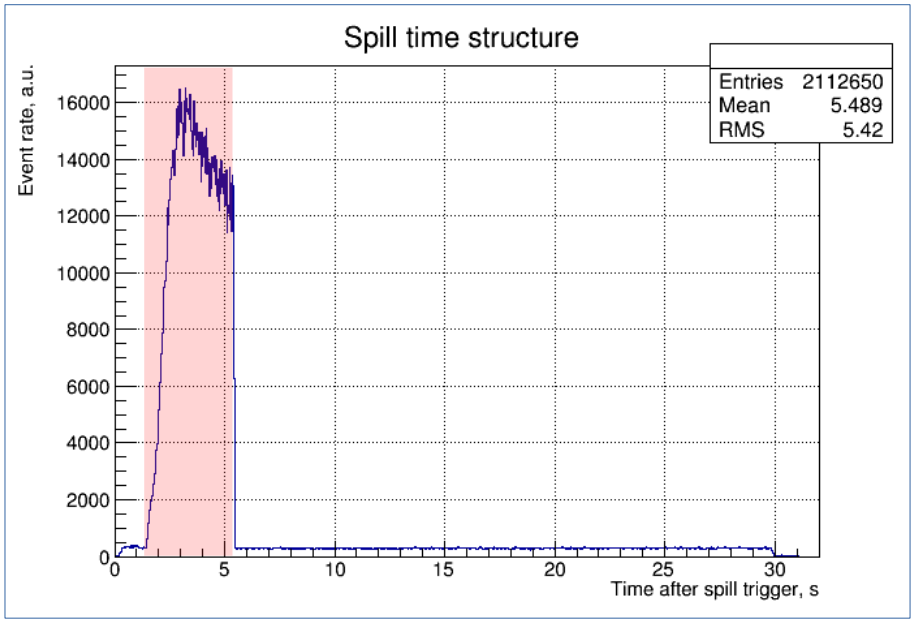


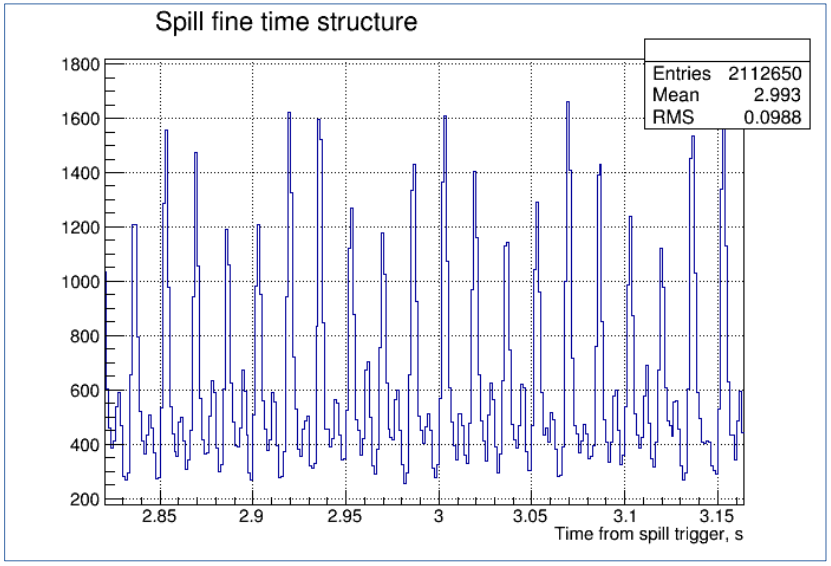


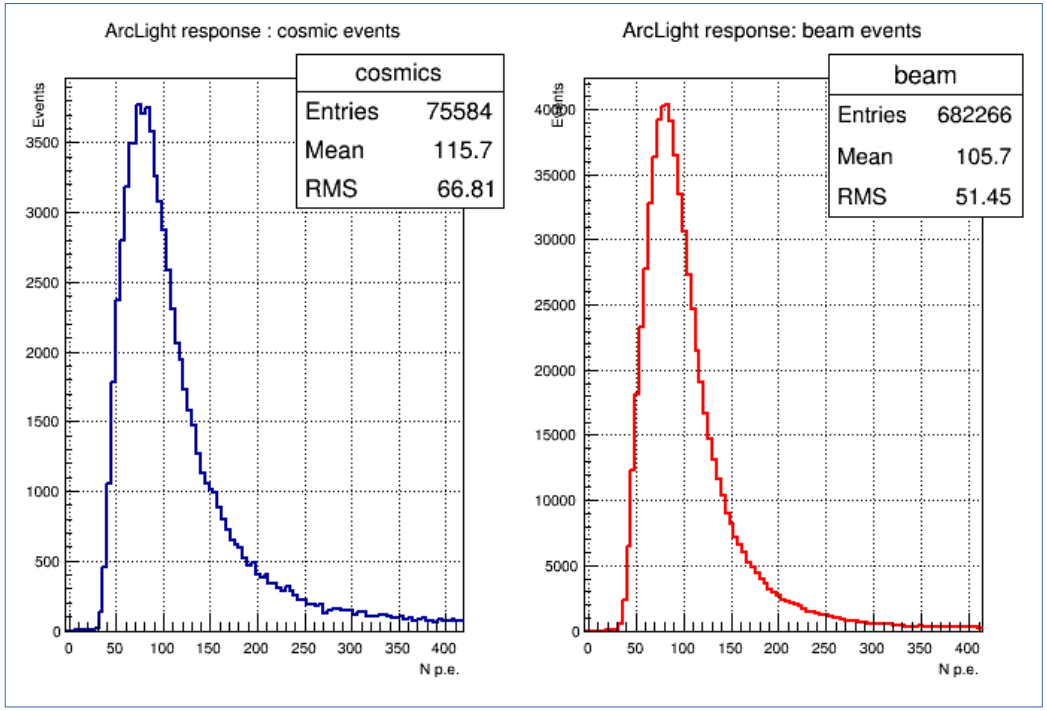


ArcLight Performance

- **Using the timing information from the ArcLight, the beam spill structure becomes apparent!**
- **Light Yield for both beam and cosmics is very consistent**

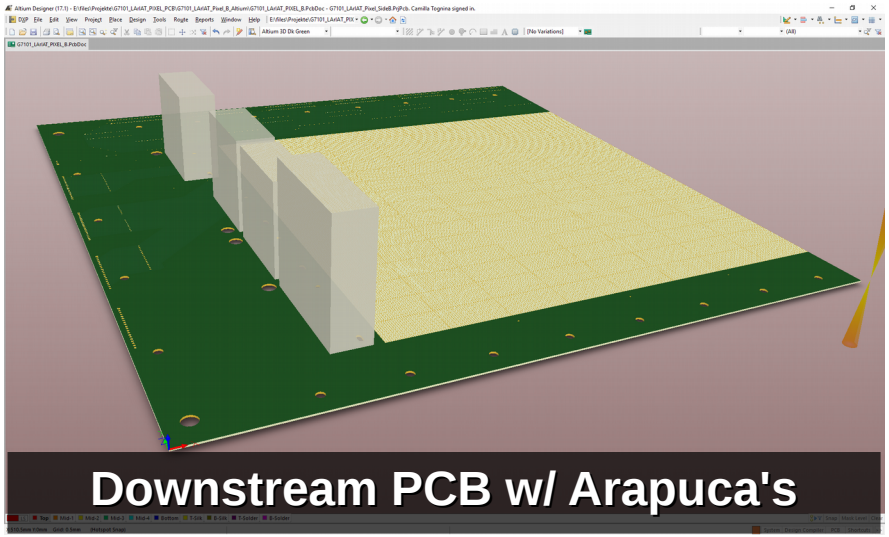






Arapuca's Performance

- **2 out of the 3 Arapuca's functioned very well during our run**
  - Coincident triggers clearly seen during cosmics run
  - For reasons not entirely clear, they were inducing an unusual amount of noise on the pixel plane, so we did not run with them on as much
- **Analysis is still underway, but will provide a nice cross-comparison with the ArcLight device**



Conclusions

- **PixLAr has just completed its test beam data taking**
  - We have a veritable treasure trove of interesting pixel LArTPC data in hand!
  - Will be working in collaboration with LArIAT to hopefully do some interesting cross-comparisions between the wire and pixel readout
    - Note: Since the hardware multiplexing was used for this setup, it isn't a true demonstration of the power of pixel readout...but a good step in that direction!
- **We continue to work toward the full 3d reconstruction of these events**
  - First results just starting to come to maturity
  - Nearline 3d rendering of the events shows the real power of these detectors
  - More detailed reconstruction still to be done
- **Both the Arapuca's and ArcLight successfully took beam data during the run**
  - Combining the output of both these detectors should provide useful input to the ongoing LAr-Light readout R&D

Special Thanks

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