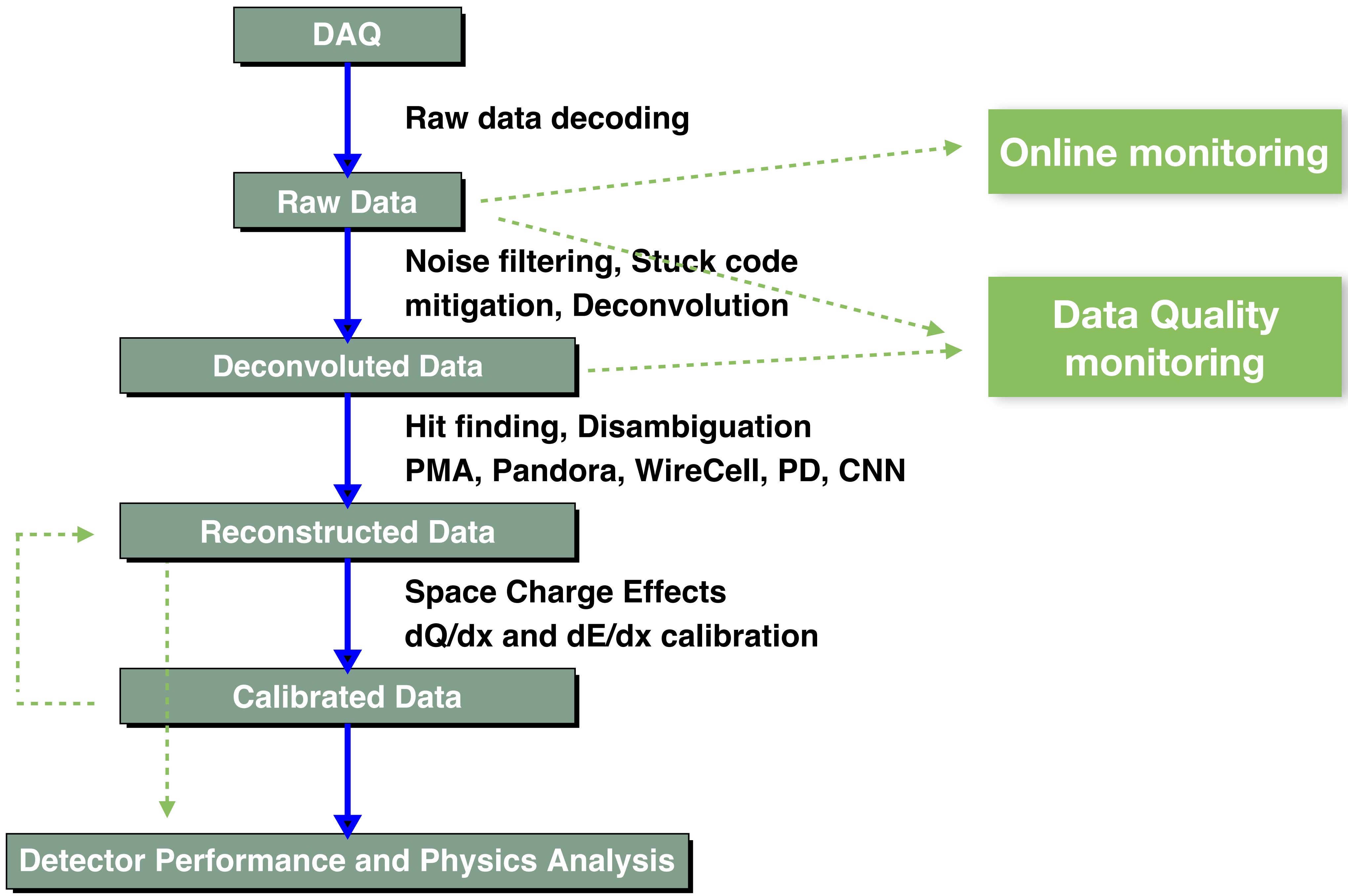
S. BORDONI *ON BEHALF OF THE DRA GROUP*

SUMMARY OF THE PROTODUNE-SP DATA READINESS SATUS

DATA FLOW CHART



OUTLINE OF THE TALK

- From raw data to reconstructed data
- Data Quality monitoring
- Detector calibration
- Physics measurements at protoDUNE
    - short term goals (inputs to TDR)
    - long term goals

FROM RAW DATA TO RECONSTRUCTED DATA

FROM DAQ TO RAW DATA

T. Junk

- DAQ systems will provide data from the TPC (RCE/FELIX), the PDS (SSPs), the Central Trigger Board (CTB), the CRT and the timing system
- The uncompressed data (artdaq fragments) are unpacked producing the data product (raw::RawDigit) used downstream. During the unpacking process, data integrity checks can be performed
- Similar procedure of raw decoders for the PDs

How it works:

- Raw Decoders apply the channel mapping : ~1s (TPC) and 0.1s (PDs) / APA / event
- A channel mapping is run to have a bidirectional correspondence between the DAQ map (crate:slot:fiber:chan_number) to the offiline map (chan_number from 0 to 15359).
- the channel map is saved in a file and remain available for posterior re-processing of data
- test of the correct mapping checks for failure (double, missing, mismatching chans) can be run

data product used downstream

raw::RawDigit | raw::OpDetWaveform | recob::OpHit

TPC DATA PREPARATION

- Raw ADC counts are converted in Region of Interest (ROI) which are used to build hits and tracks from the reconstruction

→Leigh's talk for detailed description on Reconstruction

- Several steps:
  - pedestal estimation and subtraction
  - ADC problem mitigation
  - calibration (non uniform gain, electronics readout)
  - signal deconvolution
  - noise filtering
  - ROI identification
- Data preparation handled by a series of tools which configuration can be easily changed
- Data describing a subset of channel is passed to each tool in turn. At today, protoDUNE will process 1 APA per time (likely to change)

STATUS

- **RawDecoders:** Not all of them are ready. We are still missing :
  - Trigger: communication started with CTB people. Design of the decoder and data product on going
  - CRT : work not started yet

- **Channel maps:** Not all of them are ready. We are still missing :
  - RCE: Channel-ID-mode data (instead of ADC values) providing a unique offline channel number. Tested with cold box data.
  - FELIX: Channel-ID-mode data available now. Work in progress
  - SSP: cabling still to be completed. Initial mapping draft but SSP team plan to have and maintain a database

DATA QUALITY MONITORING

DQM (OR NEAR LINE MONITORING)

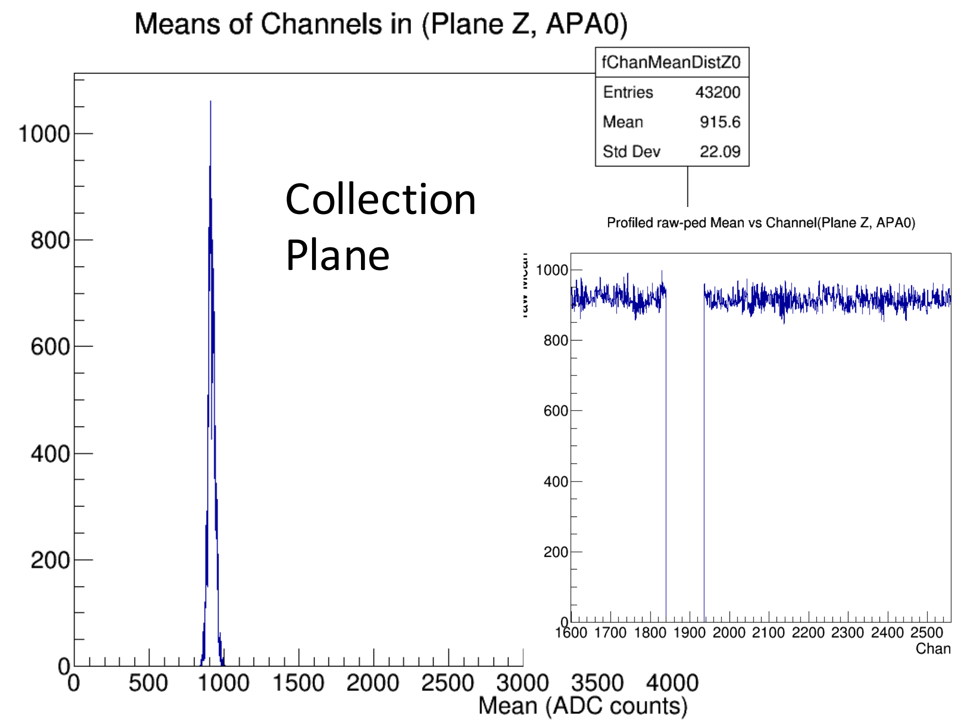
→*Maxim's talk for detailed description*

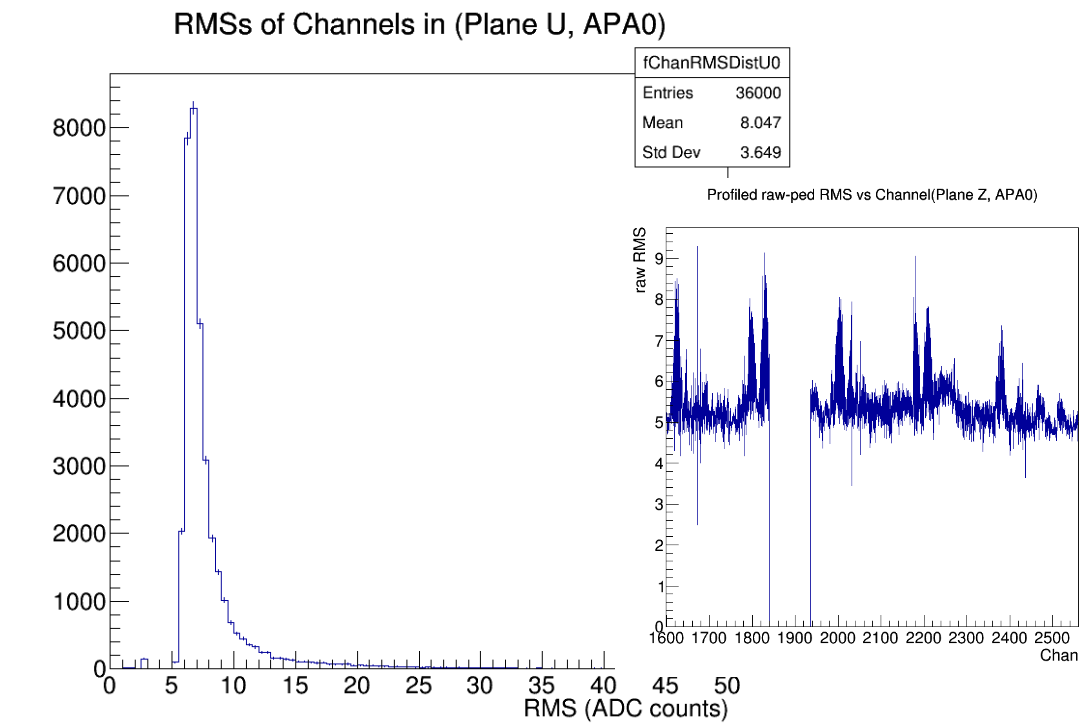
B. Baller, M. Potekhin, T. Junk, D. Adams

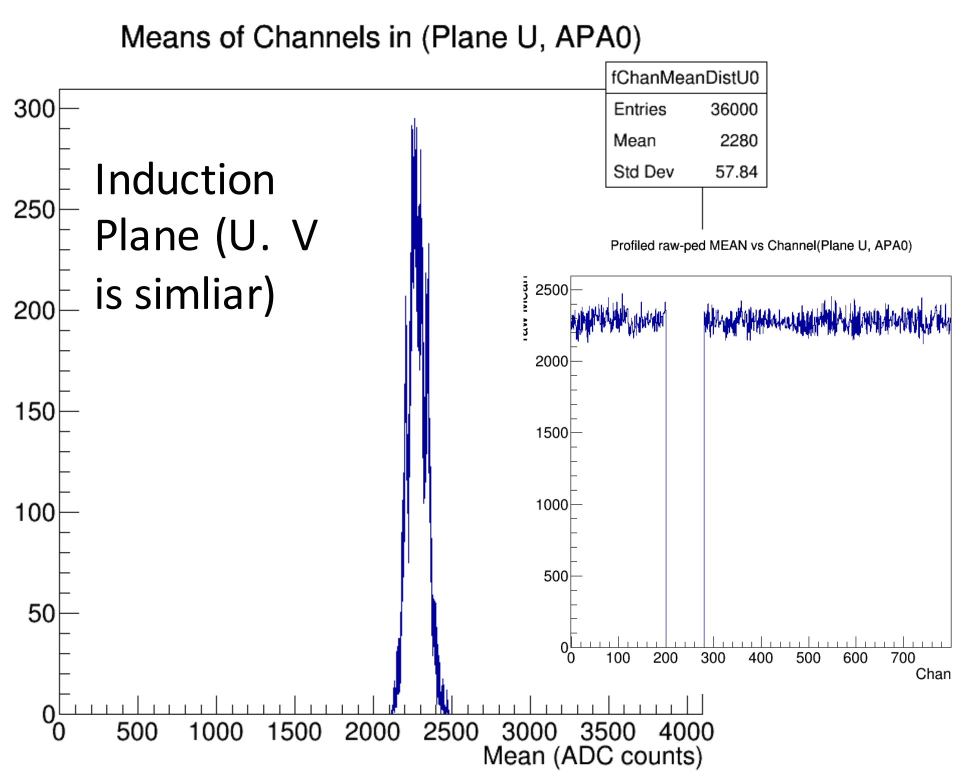
- DQM, relying on more relaxed requirements (latency of processing) is complementing the Online monitoring
- Developed by the OM team. Factored out into separate modules offline (don't always have to be run)
- Several quantities monitored:
  - **TPC :** channel ADC mean and RMS, frequency spectrum, stuck-code fraction by channel and aggregated
  - **PDs :** waveforms single and all events, peak times, heights, areas, Fourier transform

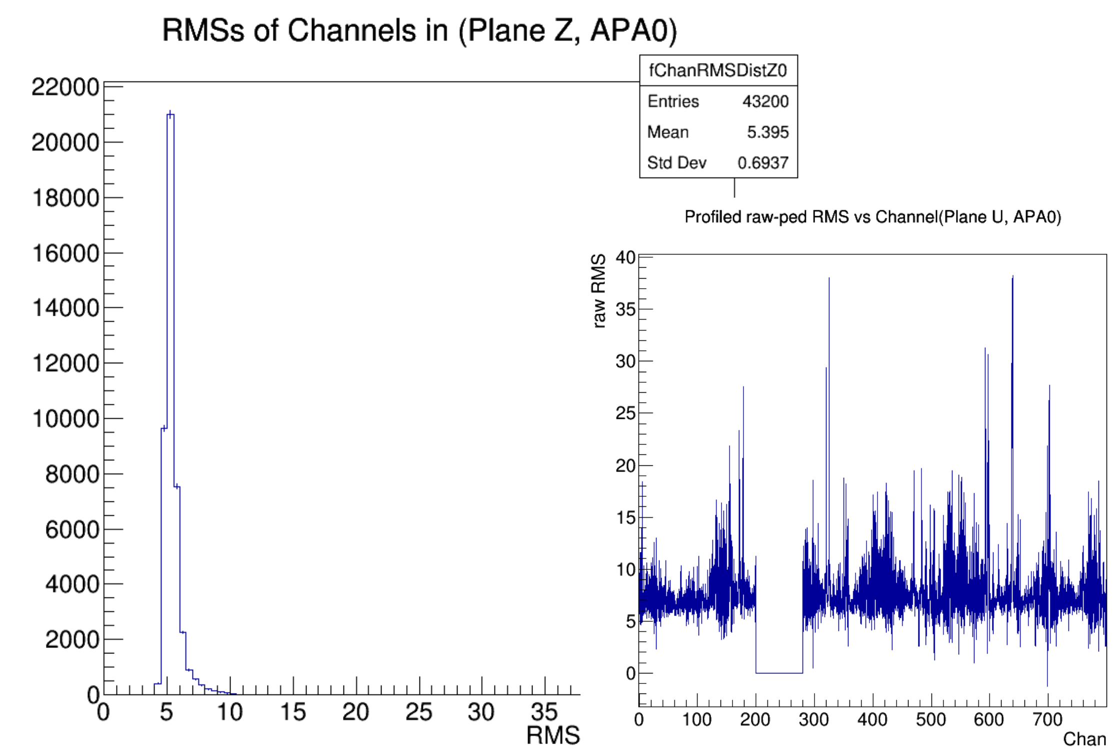
Run 973
Cold-box
test cold,
no bias voltages

DQM DURING COLD BOX TESTS

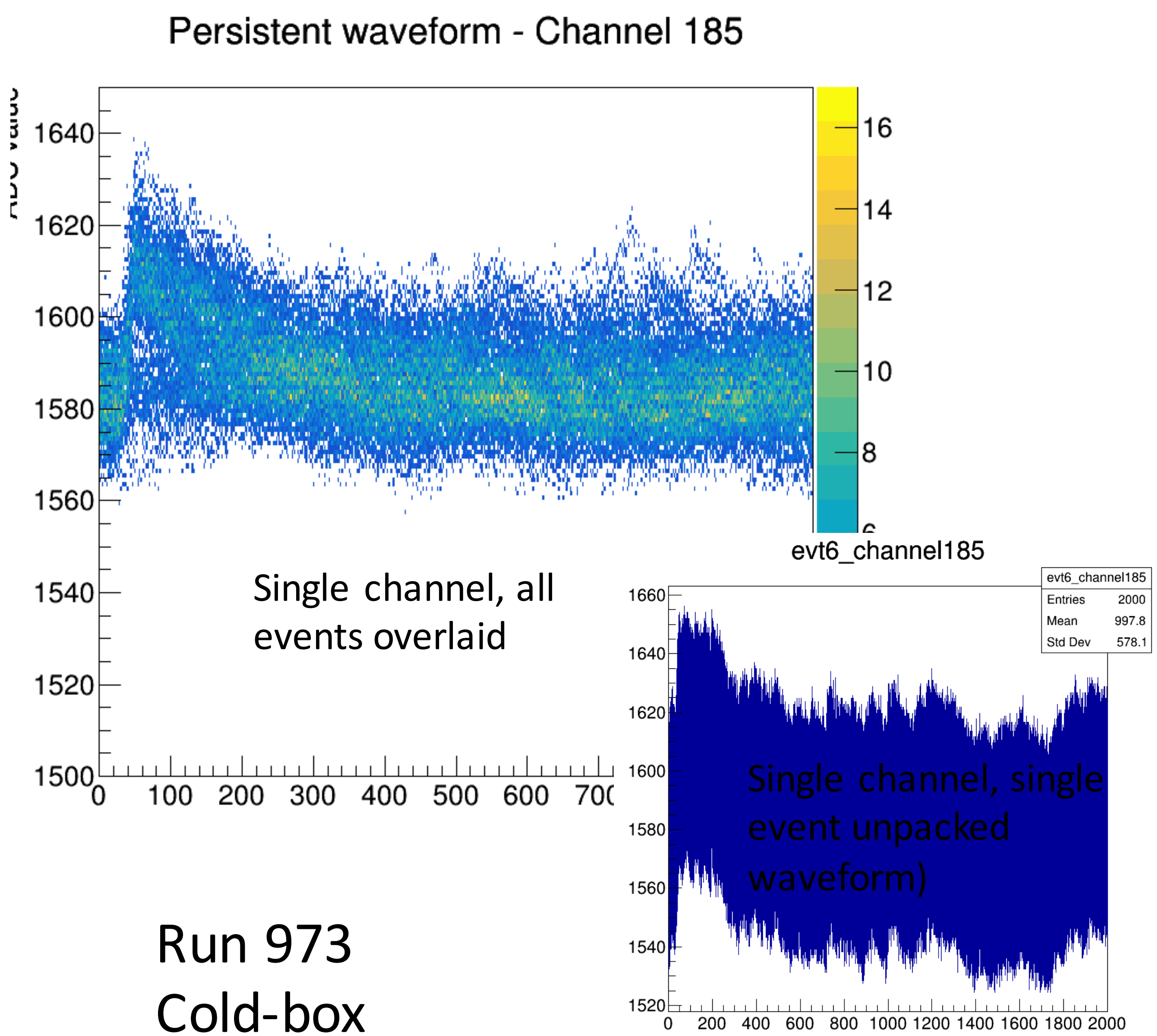






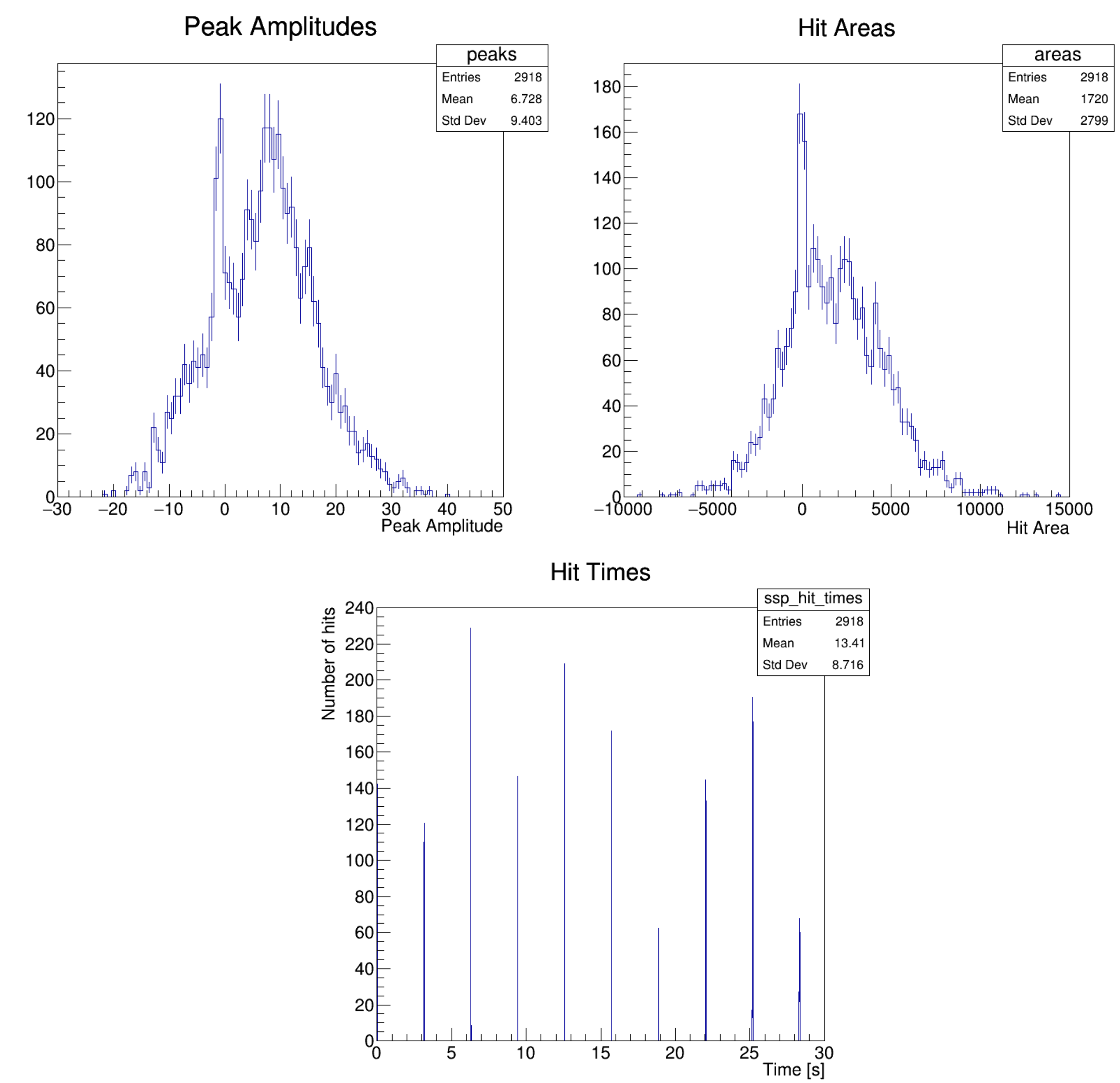


DQM DURING COLD BOX TESTS



Run 973
Cold-box
test cold,
no bias voltages

Run 1061, cold-box test run



pulses are from noise or dark rate

STATUS

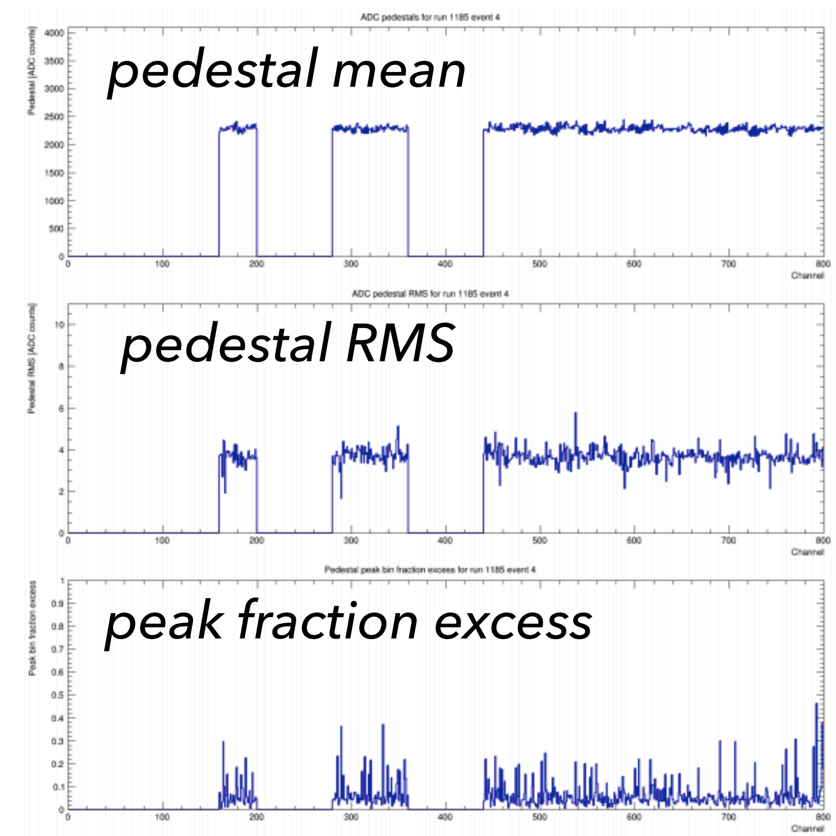
- At today DQM jobs produce a root file with histograms which are converted in png images and list them in a html file. Then access via web
- Tools tested for cold box data, improvements and extension of the monitoring plots ongoing
    - labeling of plots (run number, captions,..)
    - add more histograms and foreseen a separate list for expert checks
    - need to prepare a time-series plots (e.g. extract a small number of quantities and plots them vs time)

EVENT DISPLAY

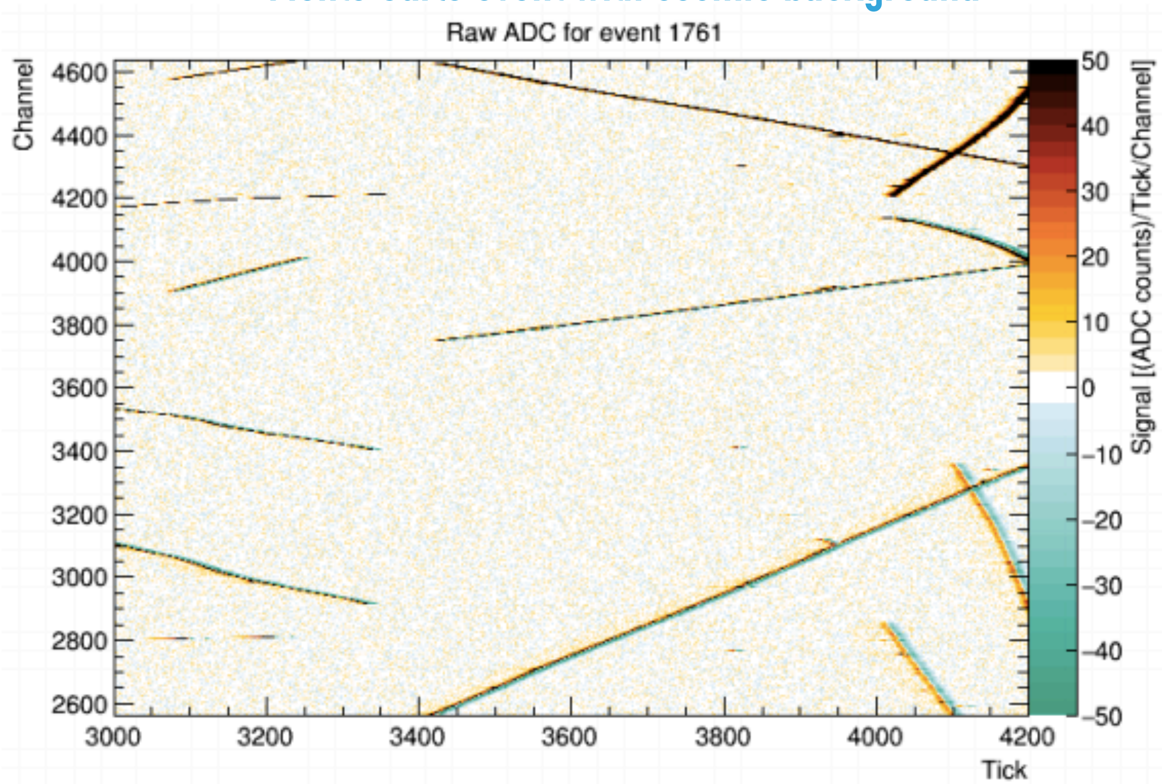
D. Adams

- Fast developments ongoing to have event display and monitoring during the data-taking.
- Example of the existing tools :e
  - evaluation of the simple quantity (e.g. pedestal) and determination of some simple metrics to monitor several channels rapidly
  - event display showing ADC vs channel vs time or wire vs drift

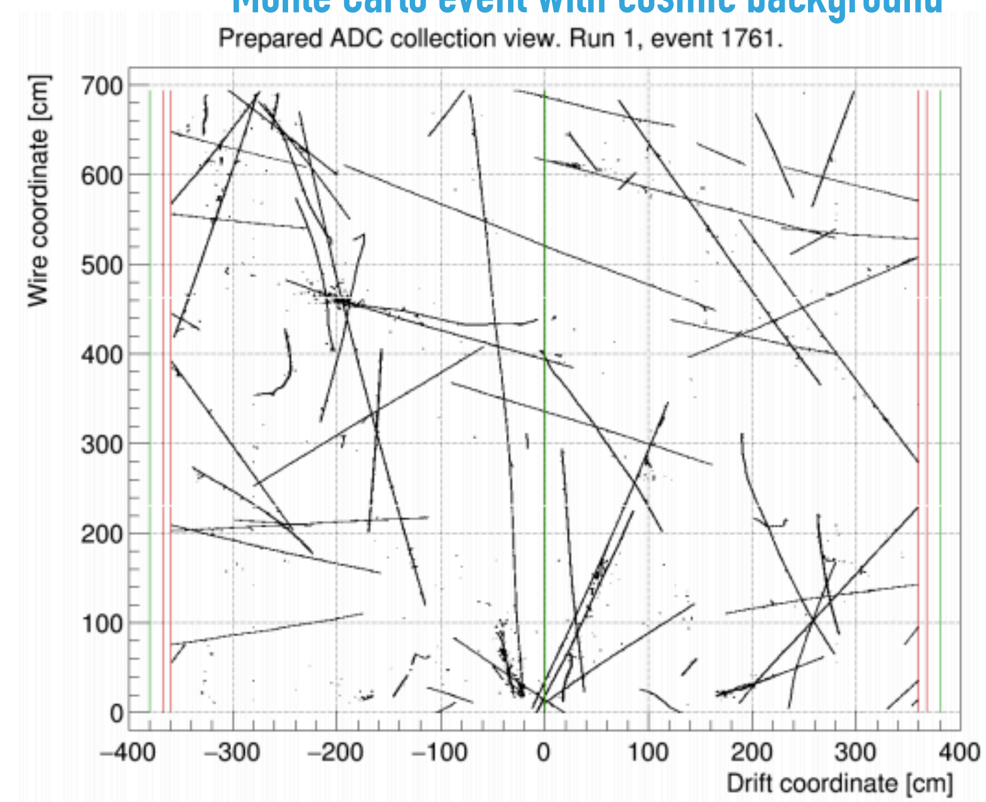
Cold box data, APA 5



Monte Carlo event with cosmic background

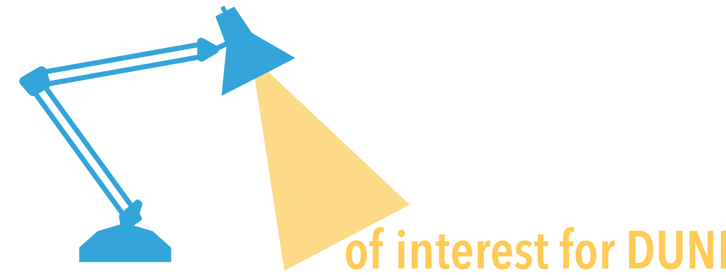


Monte Carlo event with cosmic background



ELECTRON LIFE TIME

B.Baller



- Independent measurement to the one performed using the purity monitor
- using cosmic ray tracks partially reconstructed —> offers the possibility to validate the early reconstruction chain in a timescale of hours

Strategy:

- Analyze clusters from cosmic muons with long extension in the drift direction
- Charge measured at the wire related to the one at the ionisation point by:

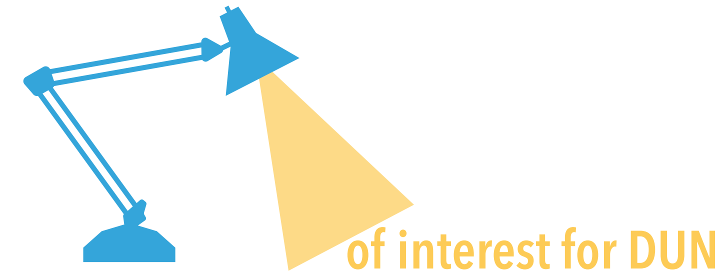
$$Q_{meas} = Q_0 \times e^{-(t_{arrive} - t_{ionize})/\tau_e}$$

$$\boxed{\ln Q = -t/\tau_e + C}$$

- Deposited charge is determined by the hit area and normalised. Cuts to reject delta-rays and spurious hits are applied
- lifetime (average and error) monitored per each run and each TPC

SIGNAL TO NOISE RATIO

B.Baller



- Alternative measurement wrt the one performed with raw data (pedestal + average pulse height)
- This method is based on reconstructed clusters (after noise removal, deconvolution and identification of RoI)
  - Selecting long and small angle clusters (>300 wires and TDC tick difference compatible with beam angle)
  - for each hit, signal and noise are computed and averaged for all hits in the clusters

$$S/N = \frac{\text{average amplitude of hits in the cluster}}{\text{pedestal RMS}}$$

TPC CALIBRATION

DETECTOR CALIBRATION – INTRODUCTION

- A detailed and full detector calibration is a crucial step to characterise the detector and ensure the "good quality" of data for physics measurements

- Calibration approach detailed have **two main purposes**:
  - define a strategy for DUNE
  - calibration specific to protoDUNE (surface detector)

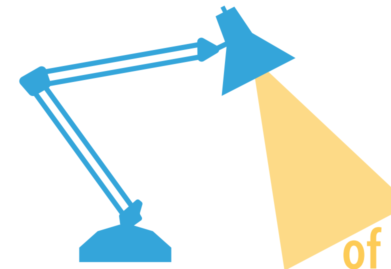
- The calibration strategy for protoDUNE profit of the **experience at MicroBooNE**

- **Three calibration categories** by the type of data needed:
  - calibration with noise data
  - calibration with pulser data
  - calibration with cosmic ray muons
  - calibration with ^{39}Ar beta decays

calibration sequence

CALIBRATIONS WITH NOISE DATA

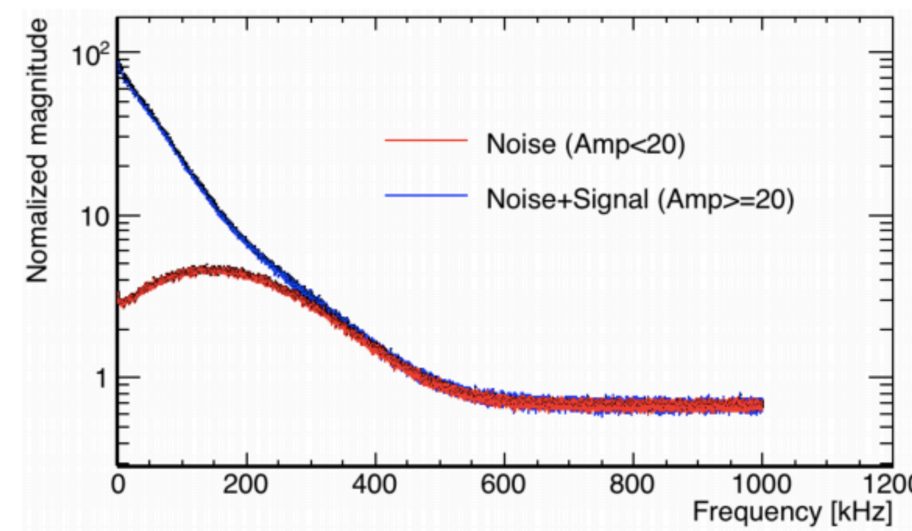
M. Mooney, J. Wang

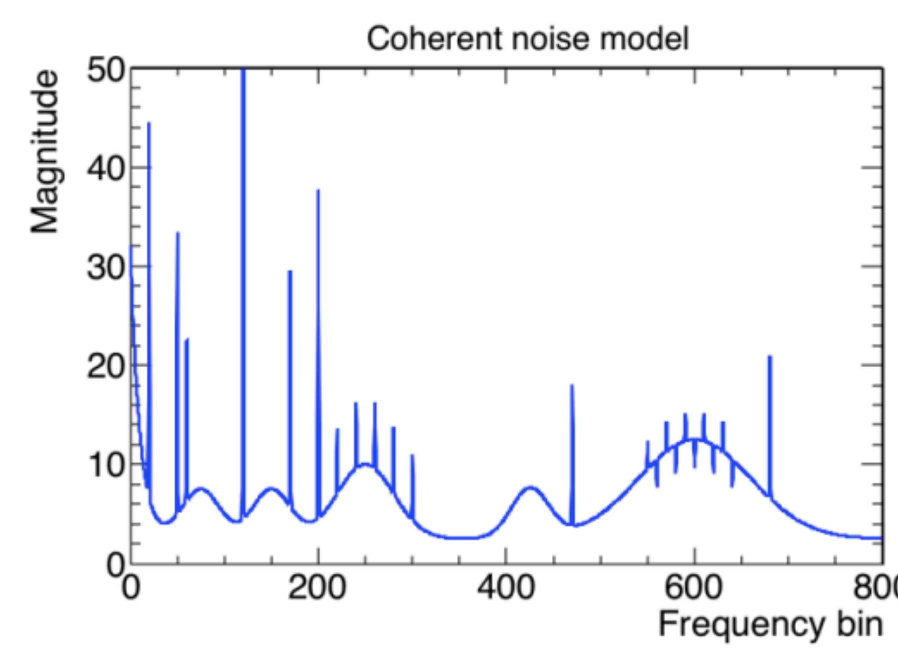


Dataset : ASIC LV on, cathode and wire bias HV off, external (pulser)triggers

With this calibration:

- measure the noise spectrum with characterisation of the coherent noise across the TPC
- construct a more realistic simulation of the noise (currently based on MicroBooNE data-driven spectrum)
- simulate pick-up noise
- determine a list of dead/noisy channels to be avoided by the reconstruction





CALIBRATIONS WITH PULSER DATA

M. Mooney, C. Alleman, D. Adams

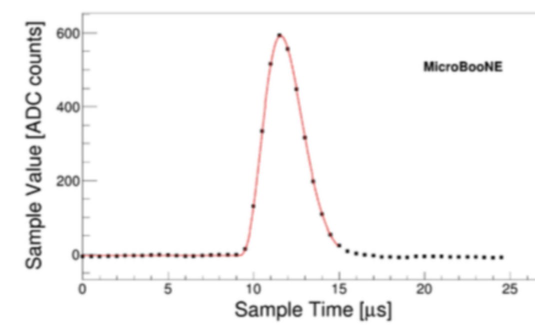
Dataset : ASIC LV on, cathode and wire bias HV off, external (pulser)triggers, electronics calibration signals enabled

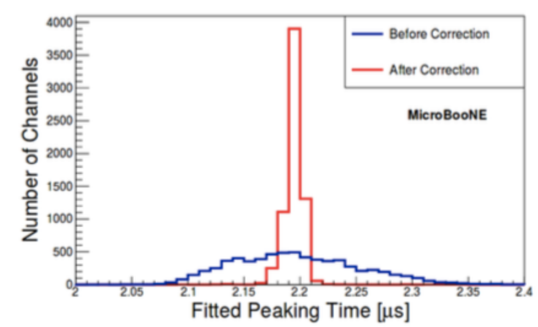
With this calibration:

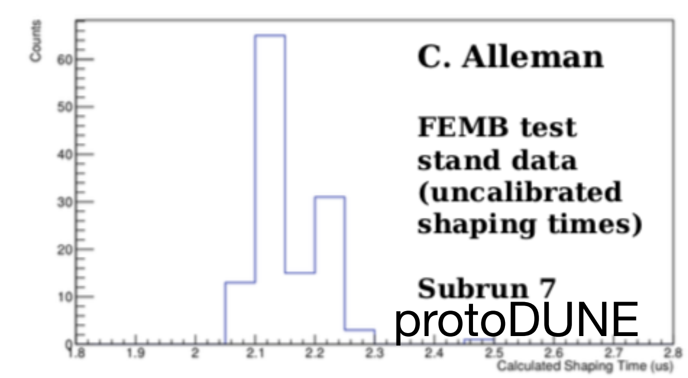
- Isolate the effects of the electronics and characterise them first before performing other LArTPC calibration in which they are folded
- FE ASIC: extract gain and shaping time channel by channel with known signals
- ADC ASIC: Including non linearity effects on-going and recovery of the information lost in the waveform due to stuck codes

Studied at BNL and can be included in calib. database but in-situ calibration are foreseen

FE ASIC calibration

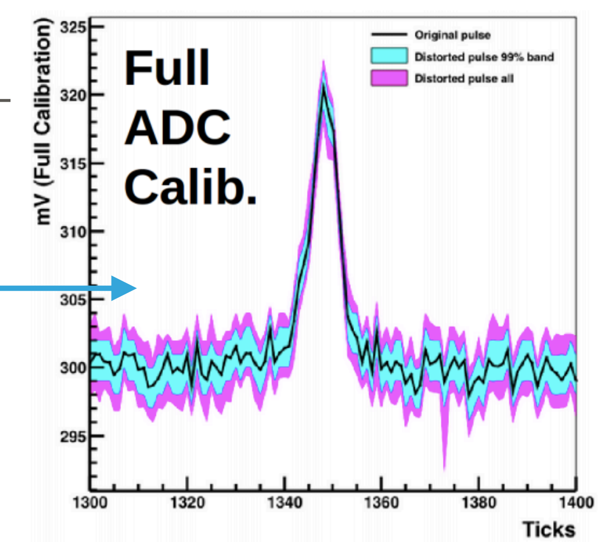






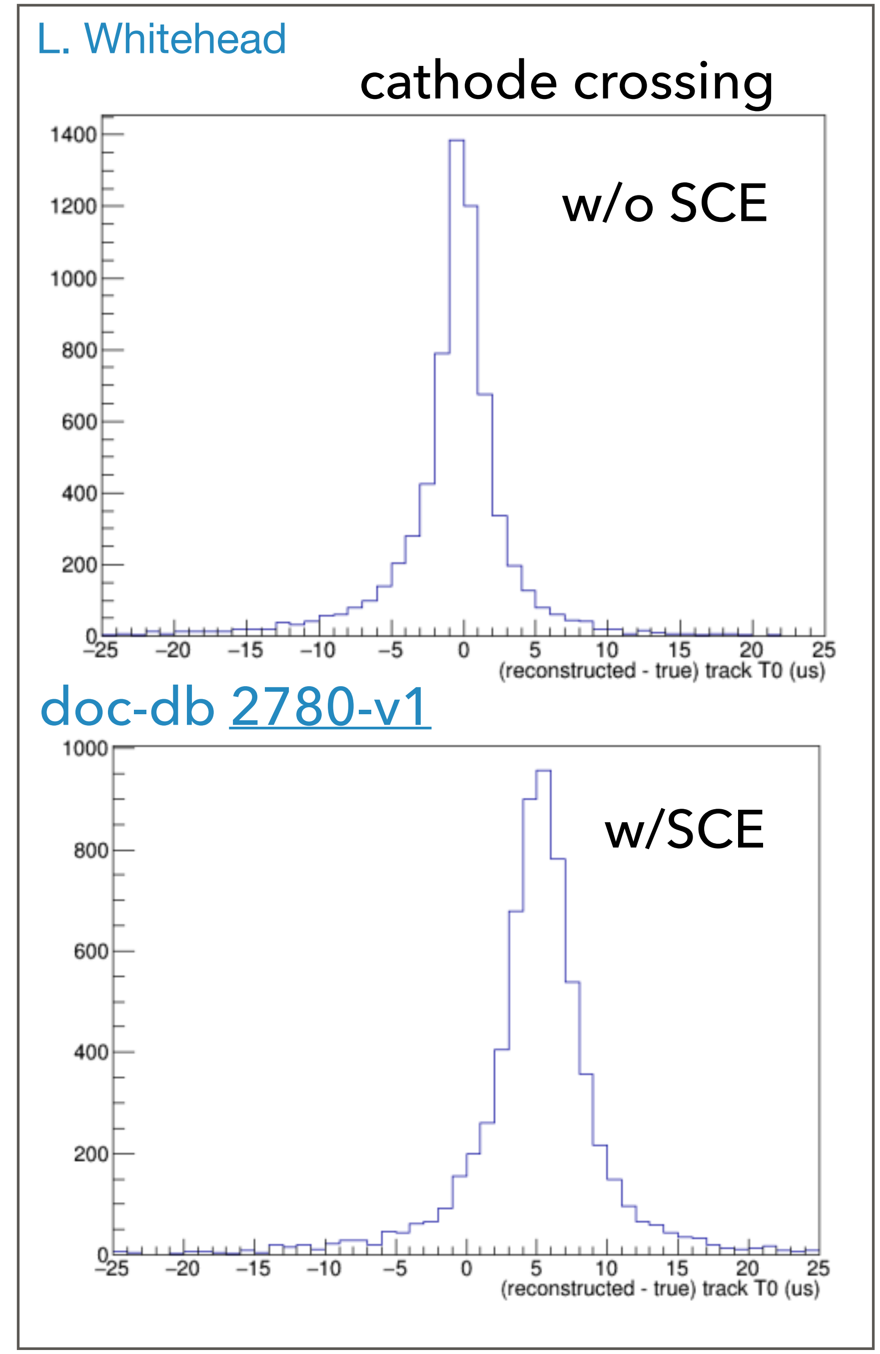
ADC ASIC calibration

ideal with non-linear voltage-to-ADC with arbitrary fine binning

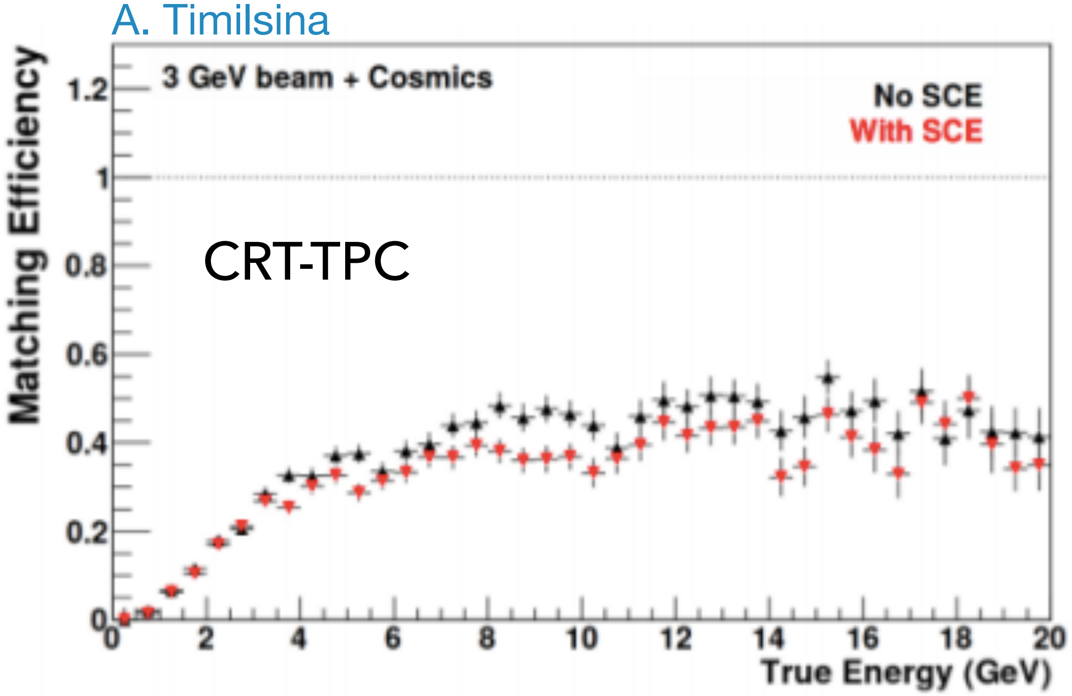


CALIBRATIONS WITH COSMIC MUONS (1)

- Several key calibrations need the knowledge of the track direction: Use of tagged -t0 tracks. Several possibilities available at protoDUNE
  - **cathode crossing muon through-going tracks** : from the stitching of the two segments the t0 is derived
  - **CRT-TPC:** to tag also muon halo tracks. Studies need to be updated with a more realistic CRT geometry



A. Timilsina

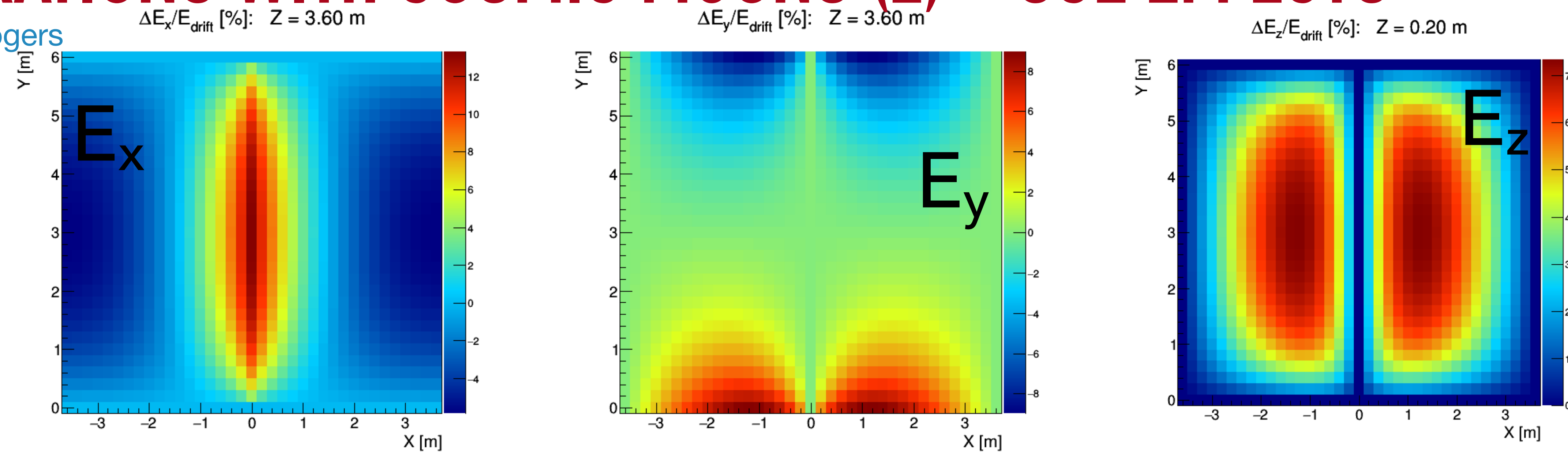


Progress to make a unique collection of all t0 tagged tracks in progress

CALIBRATIONS WITH COSMIC MUONS (2) - SCE EFFECTS

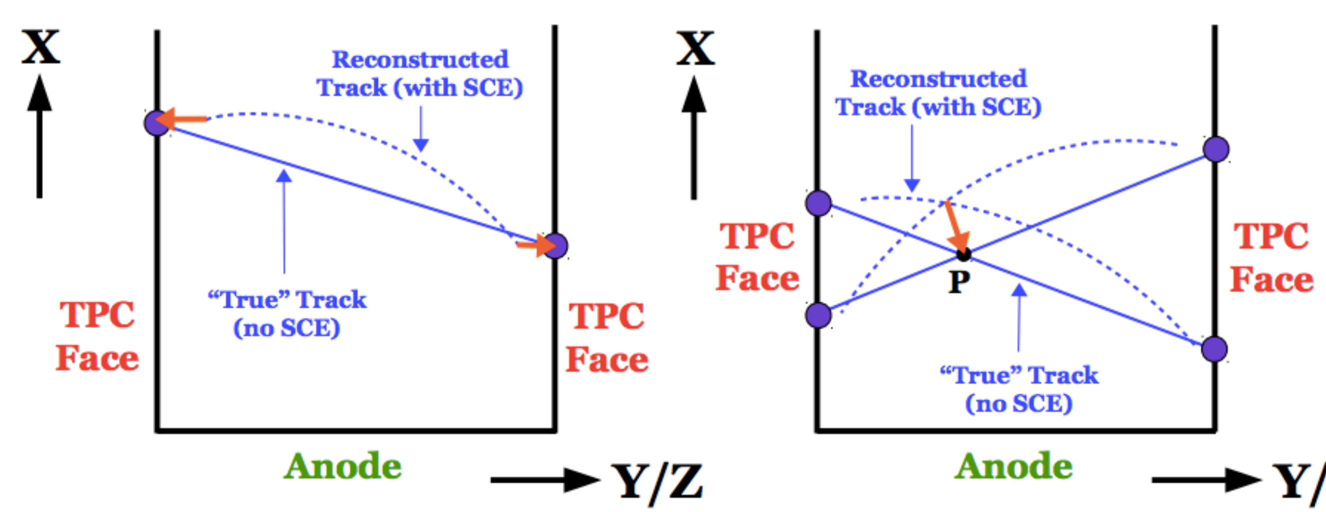
M. Mooney, H. Rogers

$E_{nominal}$ = 500 V/cm



SCE lead to distortions of the E-field (~15%) and therefore affect the reconstruction: reco-tracks shorten laterally (looks rotated) and bows towards the cathode

- Simulation based on MicroBooNE already included in the software and several studies
- Calibration using cosmic muons or CRT matched muons based on MicroBooNE experience:
  - **single tracks:** corrections at the TPC faces
  - **pairs of tracks:** point-to-point correction in the TPC bulk

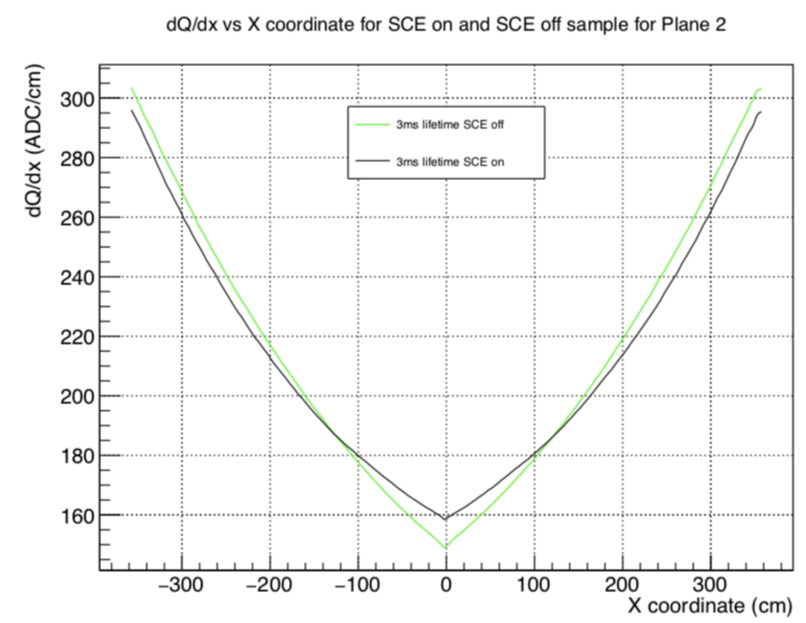


Effort in protoDUNE proceeding in lock-step with MicroBooNE

CALIBRATIONS WITH COSMIC MUONS (2) - DQDX

A. Pauldel, T. Yang

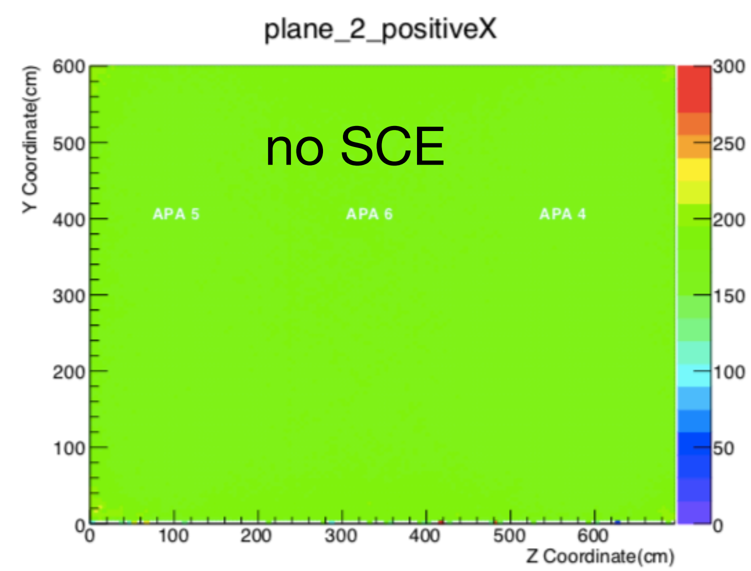
The goal is to convert ADC to MeV, removing effects due to e-attachment to impurities. Calibration done into two steps

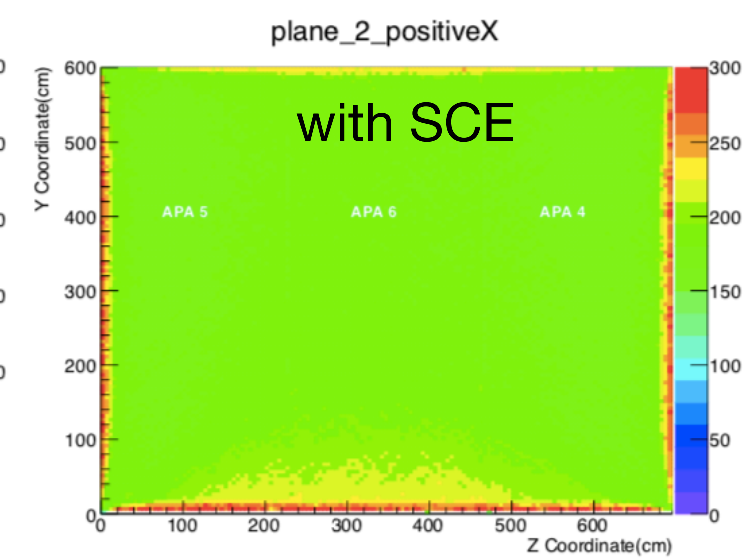


1. dQ/dx calibration using through-going cathode piercing cosmic muons
   - calibration on the y,z plane
   - calibration along the drift direction

$$(dQ/dx)_{calibrated} = (dQ/dx)_{reconstructed} \cdot C(x) \cdot C(y,z)$$

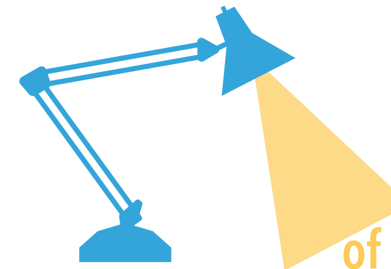
2. dE/dx calibration using stopping muons
   - identify and remove the Michel electron part
   - use the last 200cm residual range





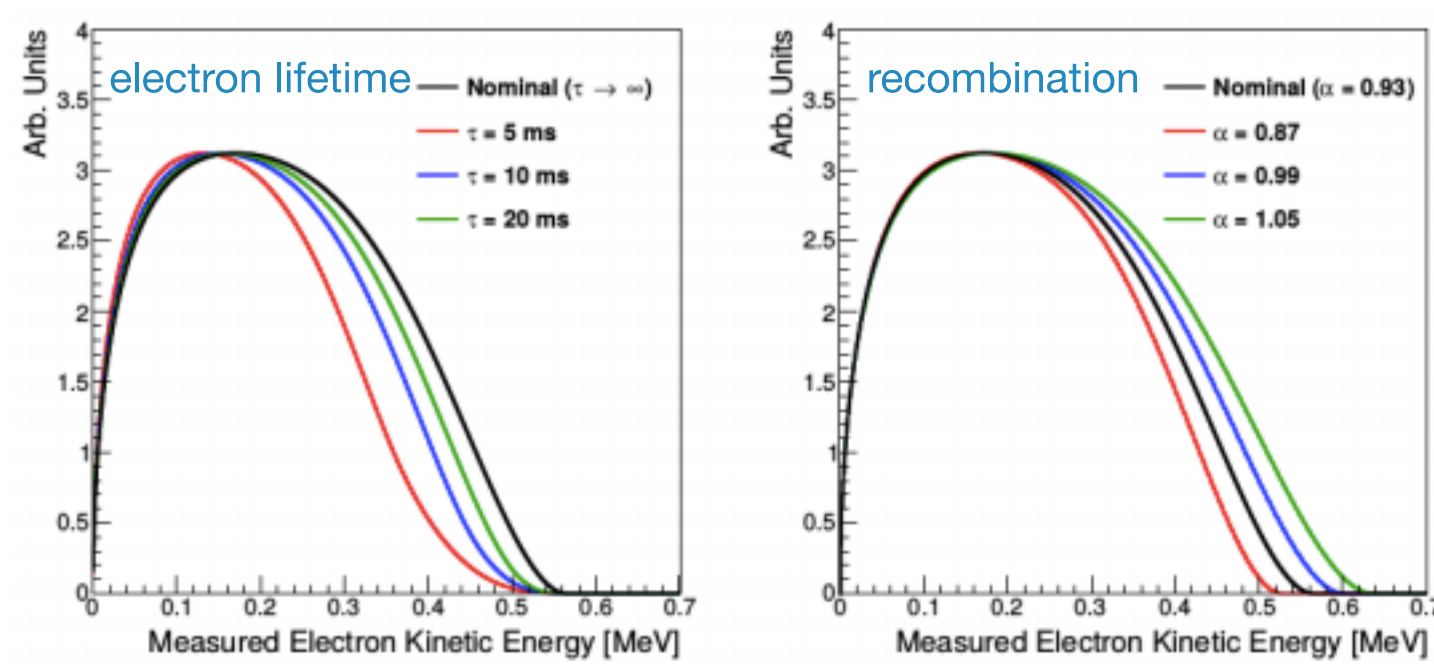
CALIBRATIONS WITH ^{39}AR BETA DECAYS

M. Mooney, A. Flesher



- **Dataset** : ASIC LV on, cathode and wire bias HV on, external (pulser)triggers,
- **Goal** : electrons lifetime, wire field response, recombination, diffusion

- Independent from previous calibration
- ^{39}Ar decays uniformly distributed in the drift direction, the expected energy spectra can be fully reconstructed with a given set of detector response parameters
- Based on MicroBooNE experience, provide the only way to have a fine-grained e-lifetime measurement in DUNE

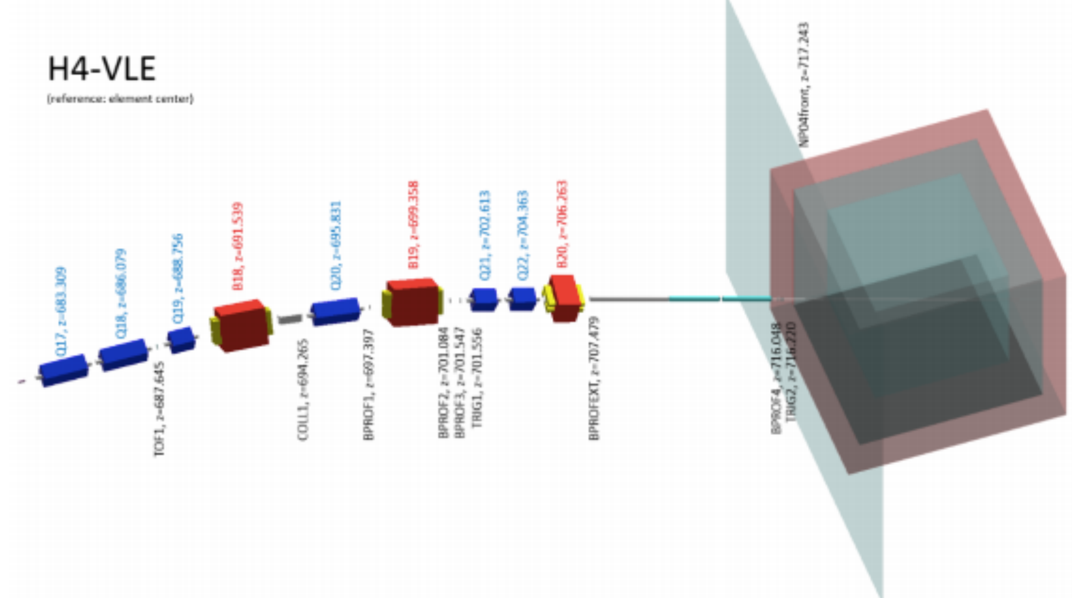


PHYSICS MEASUREMENTS

SHORT TERM GOALS

BEAM INTERFACE

P. Fernandez, C. Zhang



- To fully exploit the data from the H4 beam line, the line have been equipped of beam monitors and ToF and Cherenkov detectors allowing to tag the incoming particles
  → *Paola's talk for detailed description*

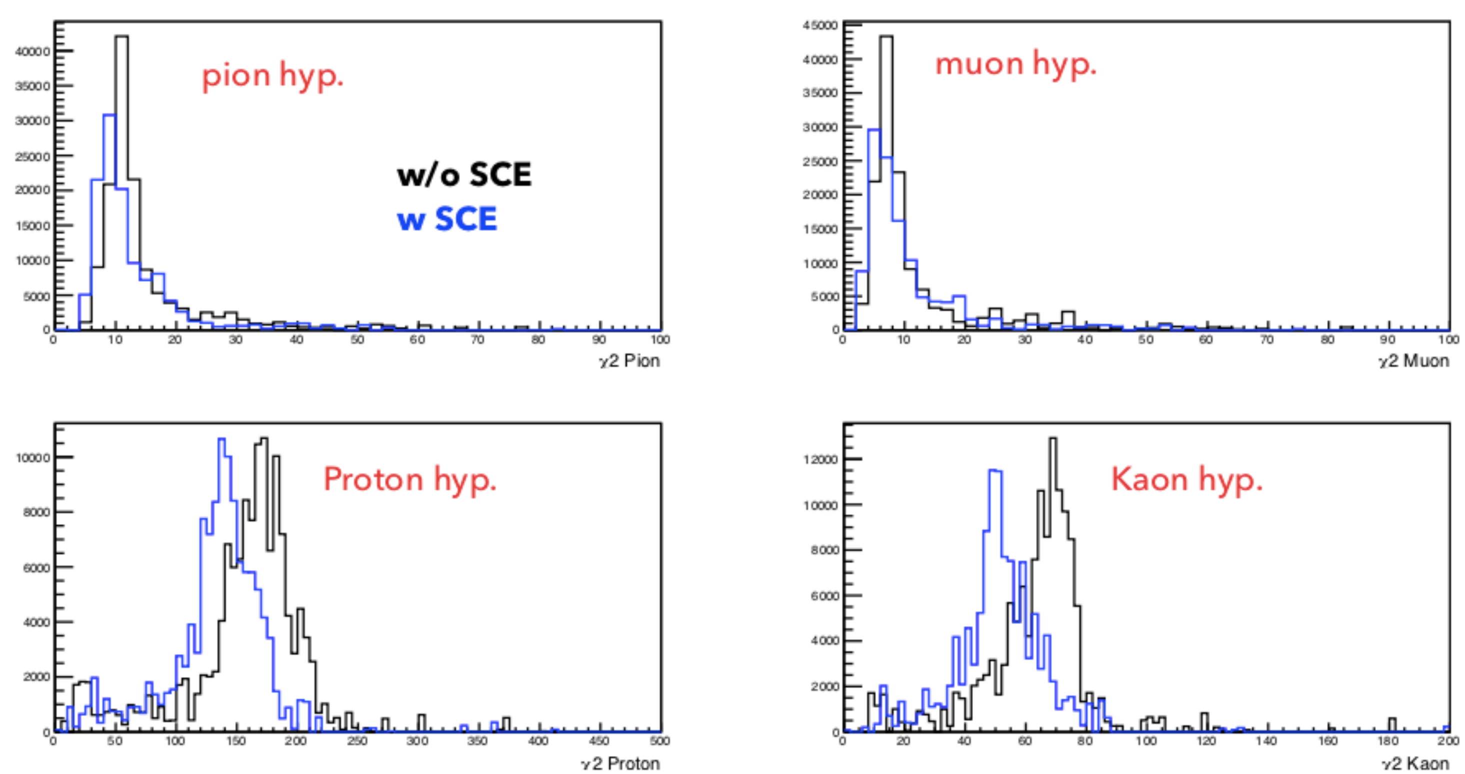
- Information from the beam instrumentation are crucial to perform beam-based data analysis (beam-TPC matching)

- Some work still to be done:
  - modify the existing interface to provide the same information in case of MC and data
  - simulate the response of the beam detectors using a simple smearing relying on their measured resolution
  - study events pile-up and beam background in case of high intensity as expected for high energy runs.

of interest for DUNE

PARTICLE ID FROM DEDX (PION, KAON, PROTON)

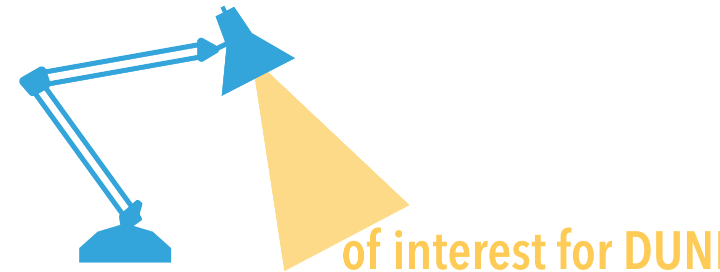
- Two approaches for Particle Identification based on dE/dx
  - $\chi 2$
  - PID-A
- dE/dx should be still carefully calibrated but first look seems promising
- PID-A performances and comparison of the two methods on-going



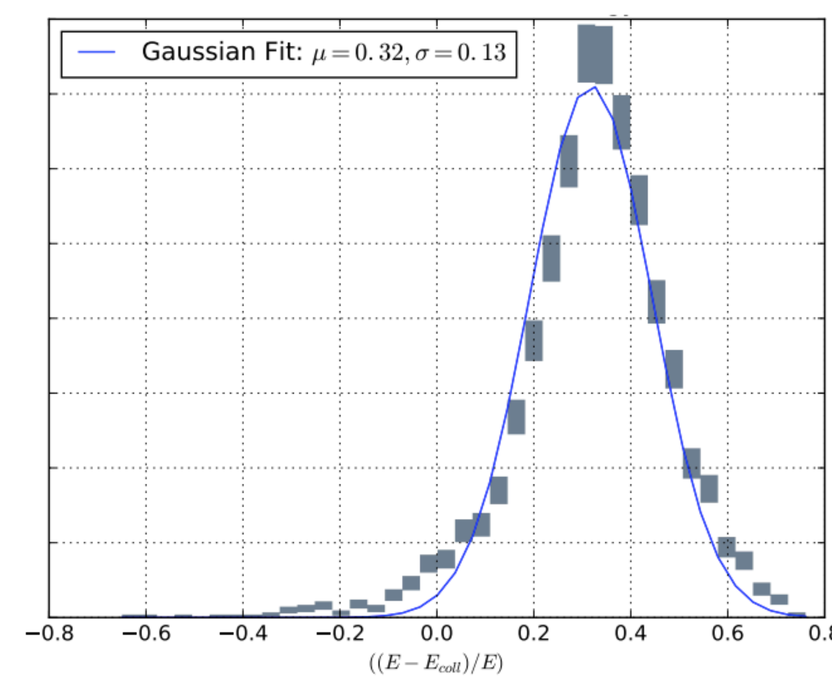
using MCC10 3GeV pions beam simulation

MICHEL ANALYSIS

A. Reynolds



- Identification of Michel electrons using CNN able to classify hits from EM, tracks, Michel and Empty
- Michel electrons are identified looking for Michel-like hits at the end of TPC tracks.
- Algorithm performed in each plane and lead to good energy collections (68% with a spread of 13%)

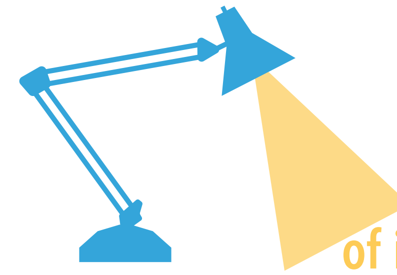


- Work on the energy reconstruction of Michel is on-going
- Using T0 tagged tracks, lifetime correction and recombination correction applied before converting the charge to energy
- The shape of the reconstructed spectra will be compared to the MC and if in good agreement the energy resolution will be studied based on the MC

PHYSICS MEASUREMENTS

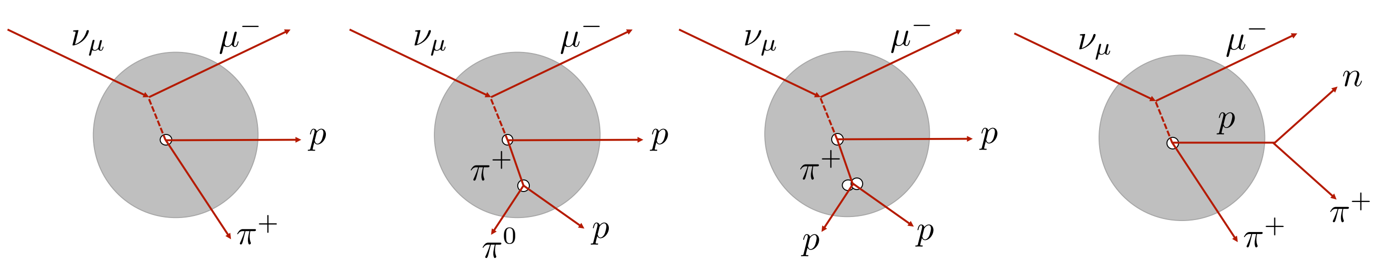
LONG TERM GOALS

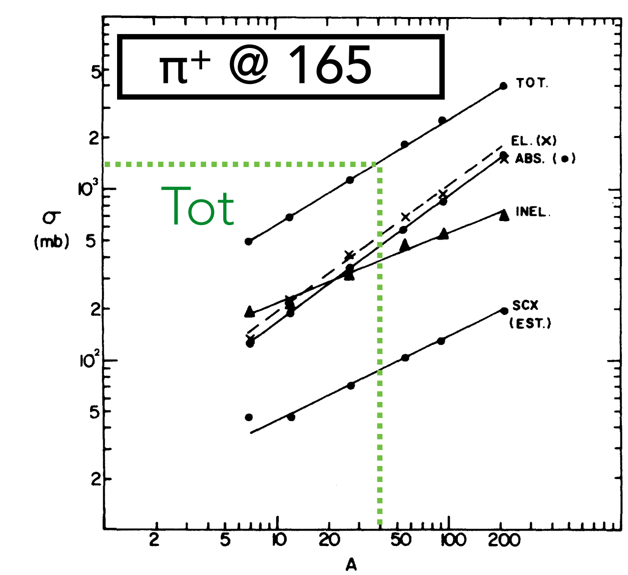
PION CROSS-SECTION MEASUREMENTS



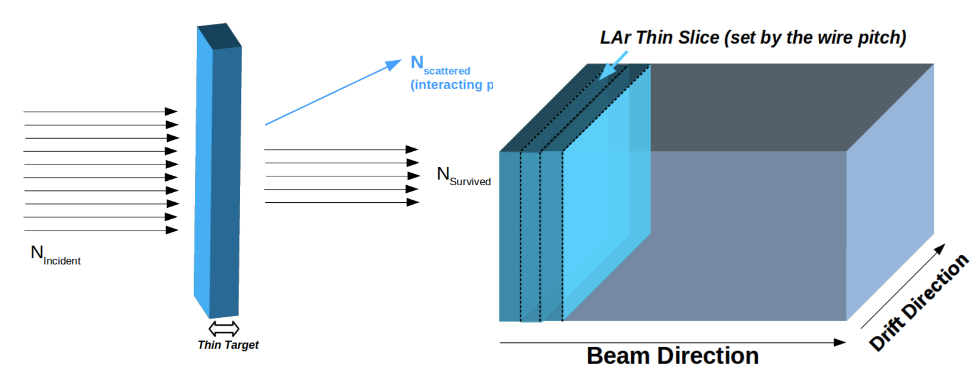
S.Bordoni, L. Cremonesi

- The knowledge of π-Ar interactions are key to control systematics for DUNE
- Measurements of interest for the entire LAr community (e.g. SBN)





- Almost no existing measurement of π-Ar cross-section
  - Old estimation from extrapolation from other nuclei (at very low p)
  - LArIAT recent measurement for $0.2 < p_\pi < 1.2$ GeV

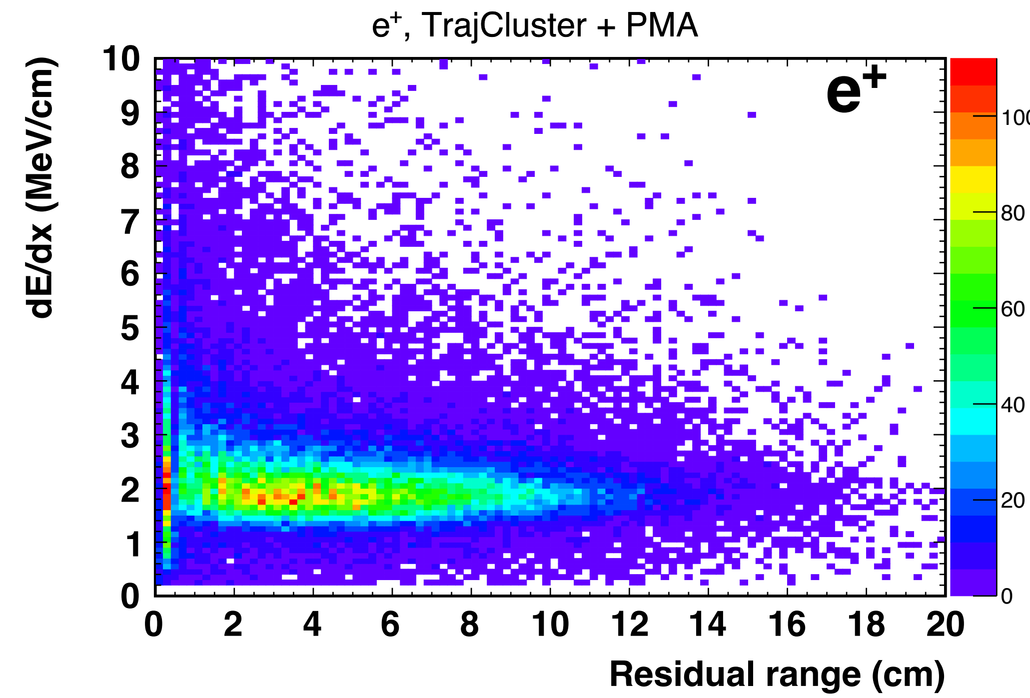


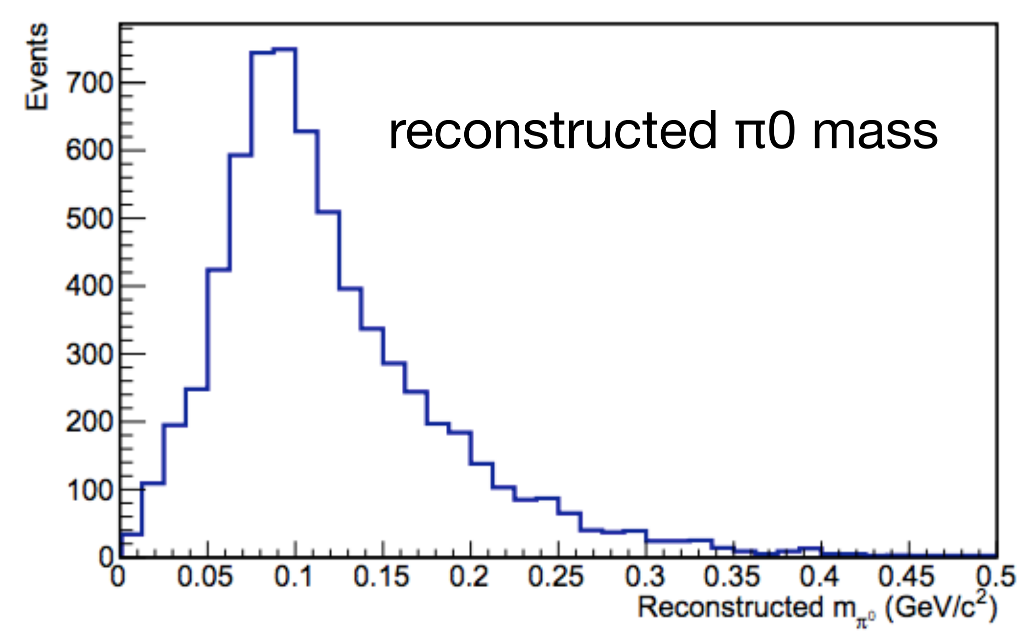
- ProtoDUNE aim to reproduce the measurement, enlarge the range, do a similar measurements for protons

OTHER GOALS

J.Pillow, A. Timislina, P. Fernandez, A. Izmaylov, …

- dEdx for electrons and EM energy calibration using e beam
- π^0 mass from $\pi^0 \rightarrow \gamma\gamma$ decays allow to for an in-situ EM energy calibration and check of the shower identification performances
- Studies of Kaons in LAr : primary particles limited at high energy but if secondaries can be identified protoDUNE can provide interesting results for proton decay searches
- MCS momentum measurement





PHOTON DETECTION SYSTEM ANALYSIS PLAN

A.Himmel, F. Cavanna, J. Thompson, Z. Djurcic, E. Kemp, C.Macias, N. Mcconkey

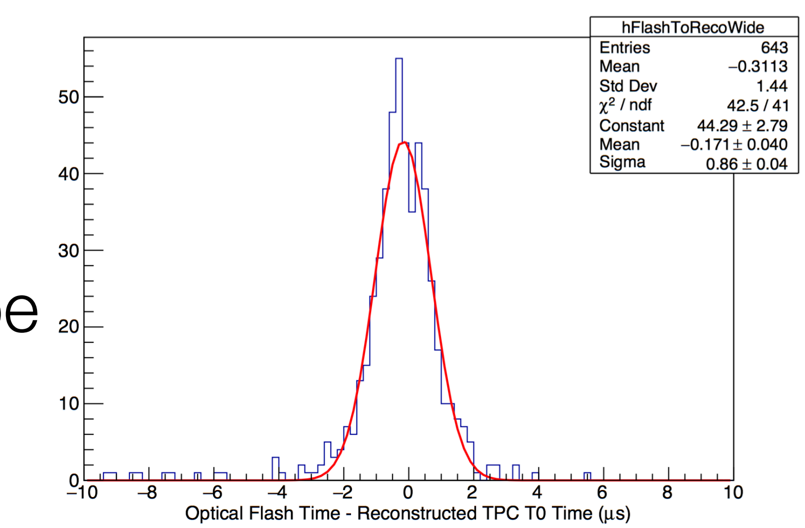
Short term goals (inputs to TDR)

- relative comparison of the performances of the 3 PDs
- Study of the light yield vs the distance to the PDs —> validation of the optical simulation and estimation of a detection efficiency (MC-based)

Such measurements will be done using cosmic tagged tracks (not relying on the TPC reconstruction)

Long term goals

- Characterisation of the electronics response and noise
- Light yield and pulse shape for a variety different particle type
- Michel electron identification by light information
- T0 tagging
- Calorimetry using charge and light informations



CONCLUSIONS

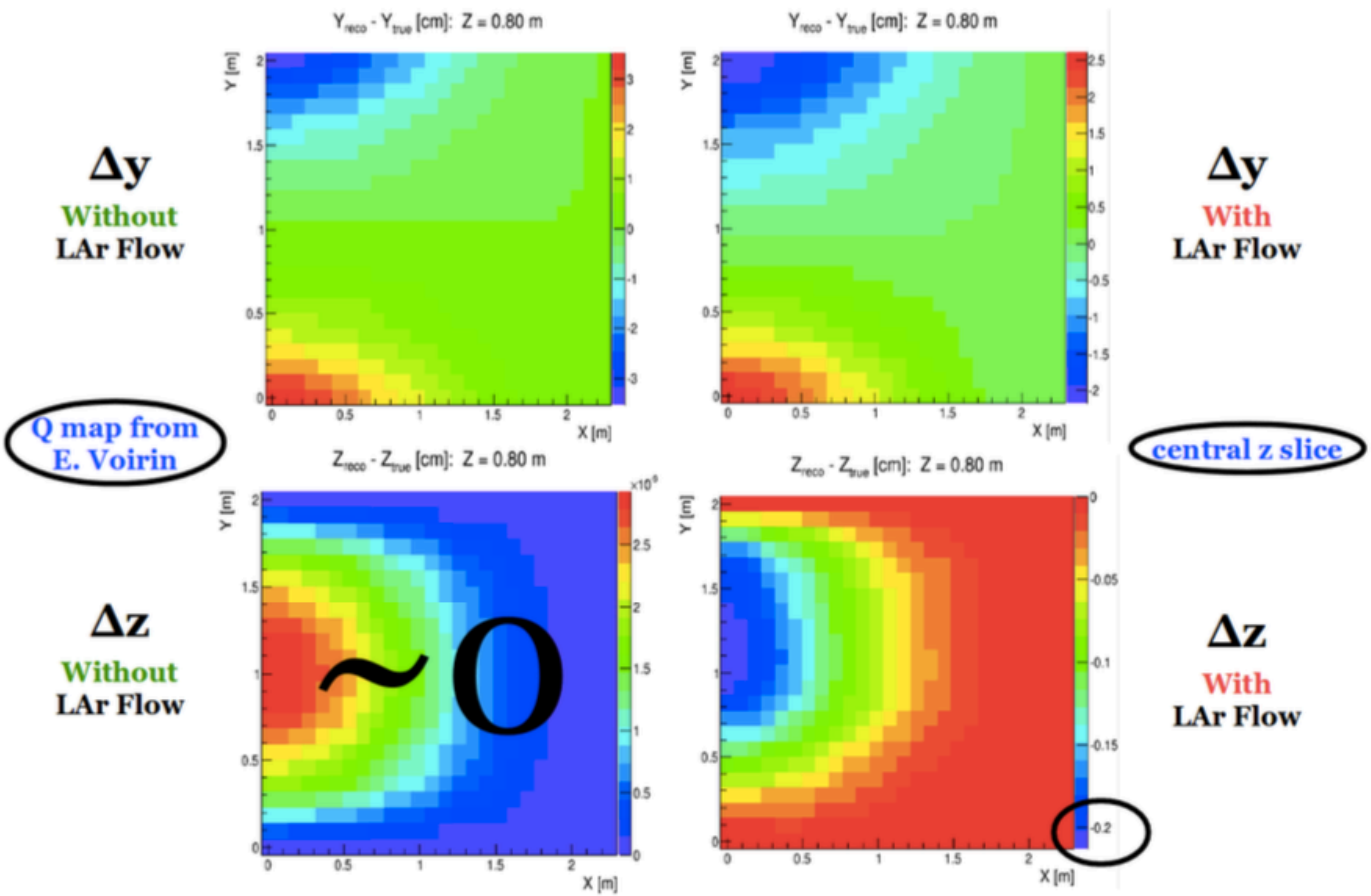
- Path from raw data to the reconstruction well defined.
- Tools in general in place, improvements/ extension are sometime needed but no points remain uncovered
- Data Quality Monitoring already in place and used for the cold box data
- Beam interface to ensure a good TPC-beam matching on-going
- Analysis plans to exploit the protoDUNE potential organised in short (inputs for TDR) and long term (possible physics measurements of interest for DUNE and LAr community)

SUPPLEMENTARY

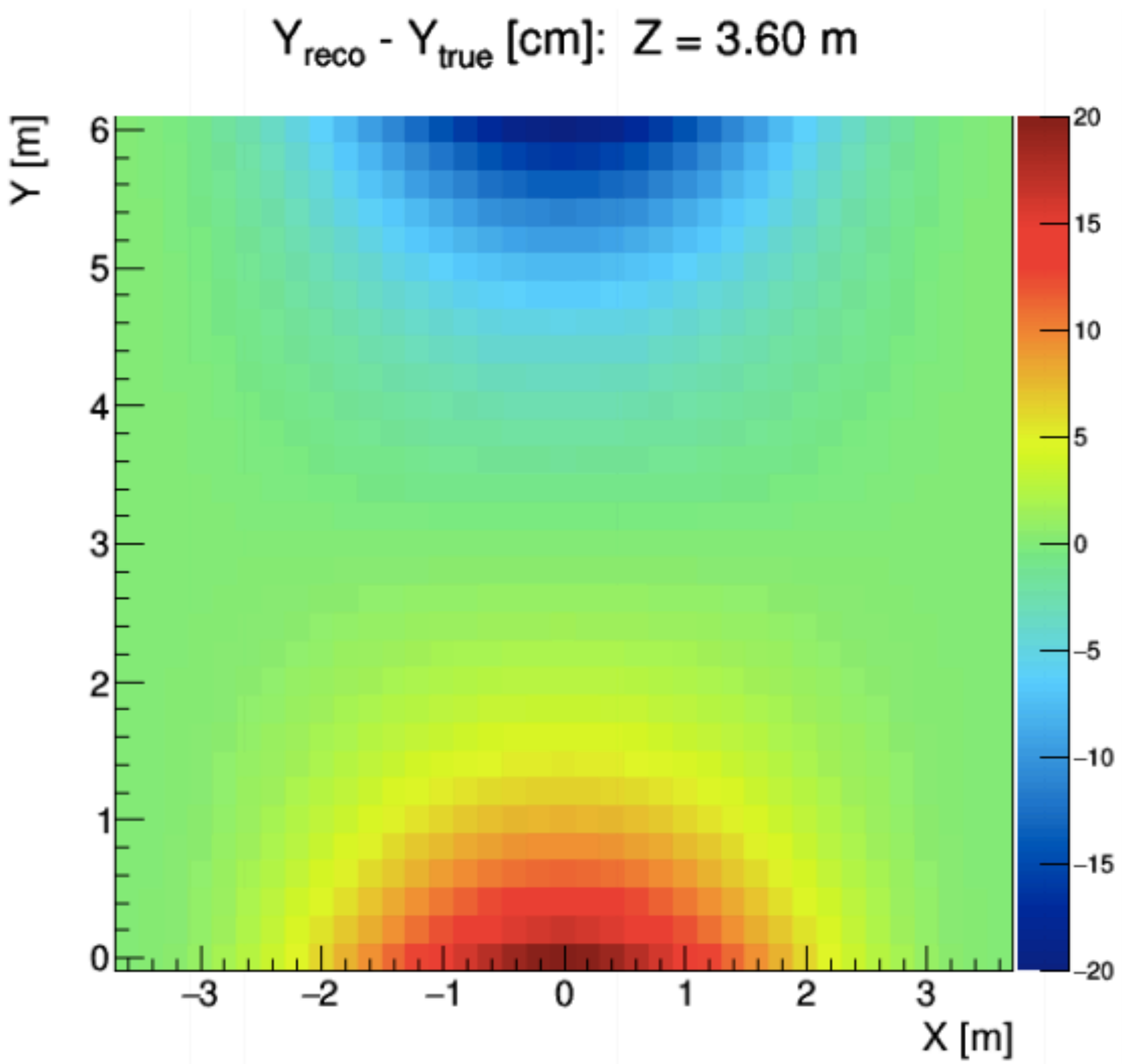
Raw Decoders: Future Work

- RCE unpacking: format and interface will not change when compressed RCE data come. New version of dunepdsprce (from JJ) will need to uncompress the data. Will require CPU as well.
- RCE: JJ has offered more detailed error reporting – will test it.
- FELIX raw decoder understands uncompressed FELIX data – will require updates in order to decompress.
- Also need Trigger and CRT raw decoders.
- Put the timing raw decoder info into a data product.
- Channel Maps need to be validated with data.
  - cosmic-ray tracks
  - beam particles
  - photon-detector pulsing

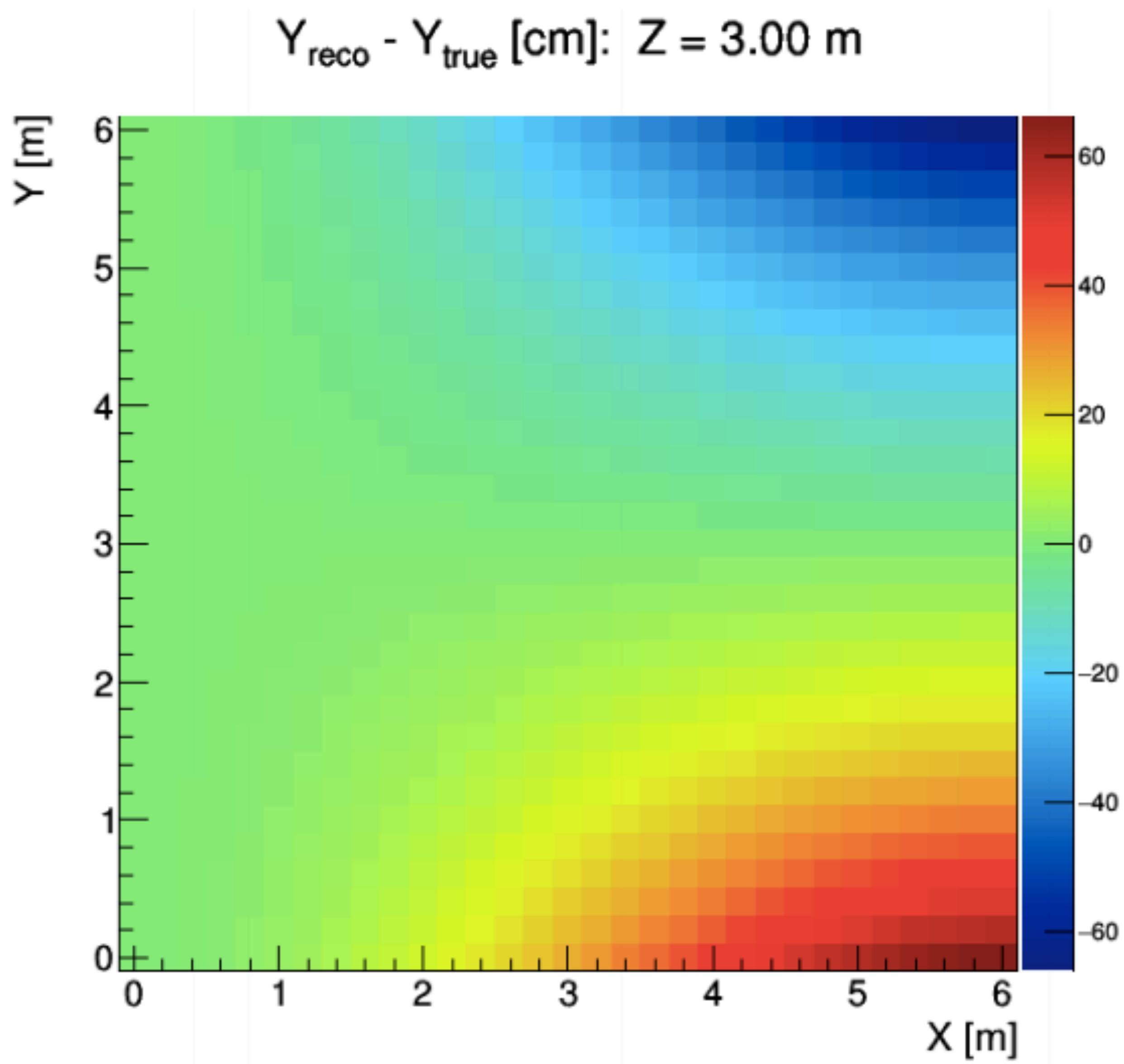
SCE w/ Fluid Flow (35 ton)



SCE – PREDICTION FOR SPATIAL DISTORTIONS



protoDUNE-SP



protoDUNE-DP

SCE – PREDICTION FOR SPATIAL DISTORTIONS