Update on ProtoDUNE-SP Calibration Plans

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ProtoDUNE-SP DRA Meeting – July 20th, 2017

Introduction

- Today: update on plans for calibrations effort at ProtoDUNE-SP, including feedback from meetings with individual analyzers/experts
- Reminder of ProtoDUNE-SP calibration tasks/goals:
  - **Per-channel calibrations (e.g. electronics gain)**
  - **Track-based calibrations (e.g. space charge effects)**
  - Perform auxiliary measurements of detector effects/response (e.g. diffusion)
  - Provide physics analysis groups with necessary inputs for study of systematics
  - Test calibration methodology to be used at the DUNE far detector
- Not included: online/nearline monitoring, metrics (Bruce)
- Before data comes: prepare simulation, test methodology

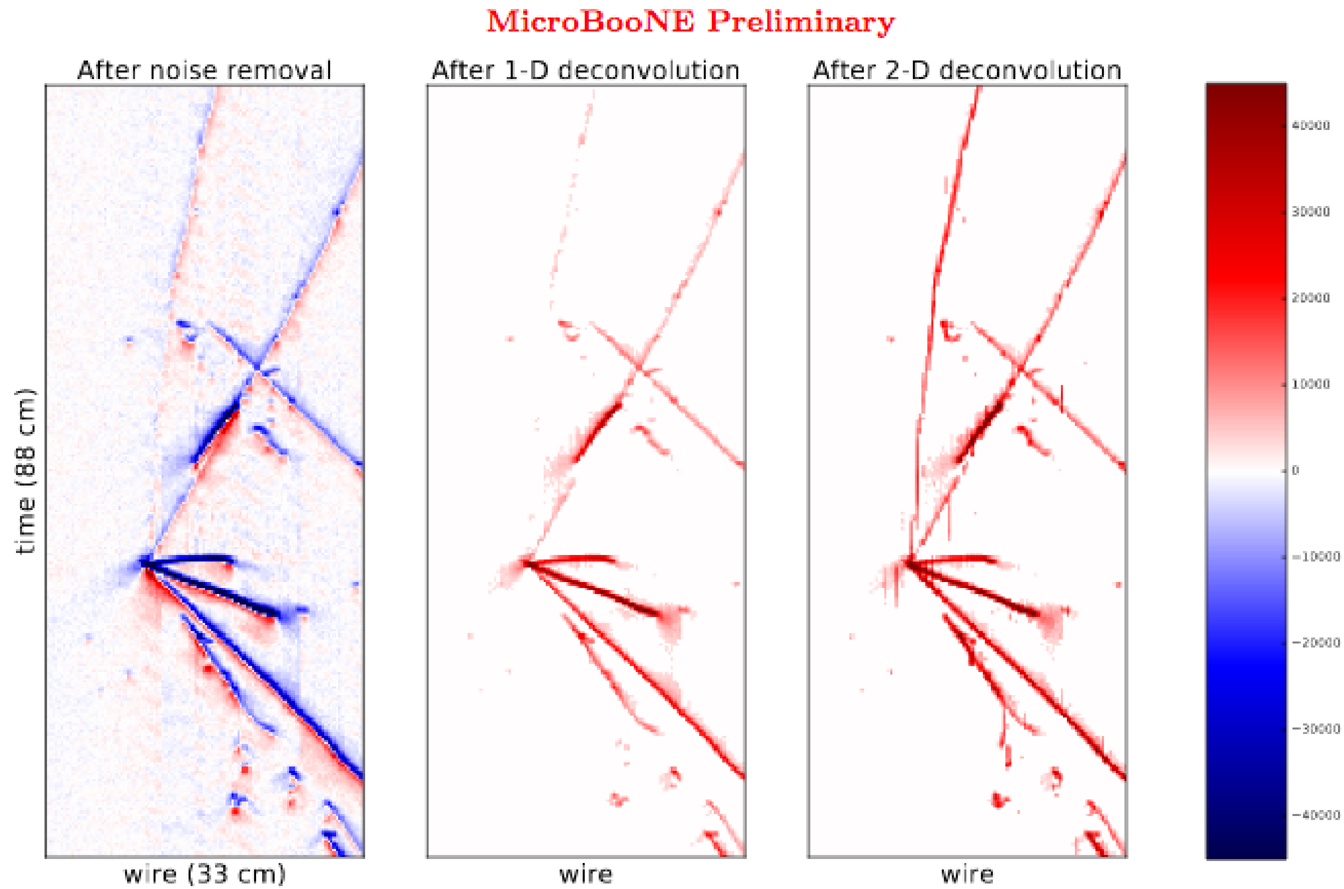
Per-Channel Calibrations

- First priority should be to simulate, to the best of our capabilities, expected noise and signal characteristics
  - Intrinsic FE noise: can simulate nearly perfectly
  - External noise features (e.g. pick-up noise): will be very hard to model – need to wait for data, and the hope is we can remove in either hardware or software (such that we need not simulate it)
  - ADC issues (non-linearity, stuck codes): can use bench measurements, but situation may change in-situ
  - Electronics gain, shaping-time: should be little variation in-situ, use nominal settings for now and also measure with data
  - Signal response: improved Garfield simulation exists, but may need to retune using 5 mm wire pitch data
- Then test calibration methods, evaluate impact on physics
- Go through some of these items in following slides

FE Noise and Signal Response

- Intrinsic FE noise modeled at MicroBooNE using data
  - Scale to expected capacitance at ProtoDUNE-SP
  - Later, check using ProtoDUNE-SP data
- Improved ionization signal response (Garfield) and associated deconvolution scheme
  - Simulate induced charge on neighboring wires
  - Deconvolution (reconstruction) important for recovering tracks at high angle w.r.t. anode plane in data, primarily for U/V planes
  - Less important at ProtoDUNE-SP than for MicroBooNE due to larger wire pitch (5 mm vs. 3 mm at MicroBooNE)
  - Use sim. tuned for MicroBooNE, later retune for ProtoDUNE-SP
- BNL group working on both items – **expected delivery by end of the year** (currently busy with MicroBooNE)

Example MicroBooNE Event



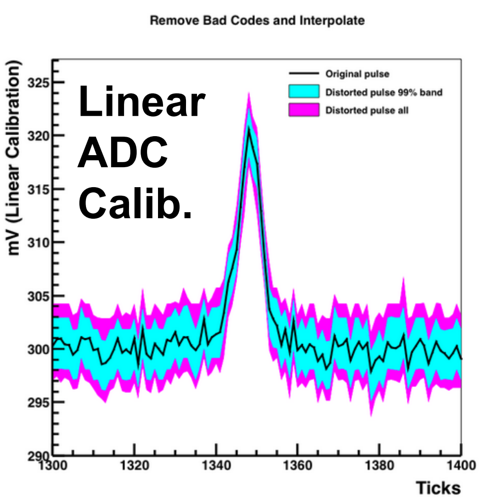
- Signal processing has improved since public note – streaks on 2D deconvolution image (right) now removed

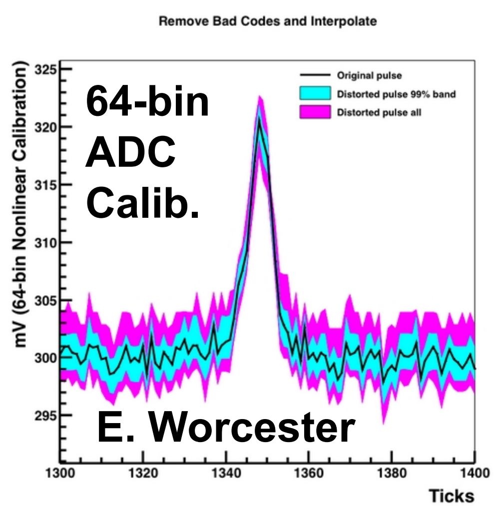
Simulating ADC Issues

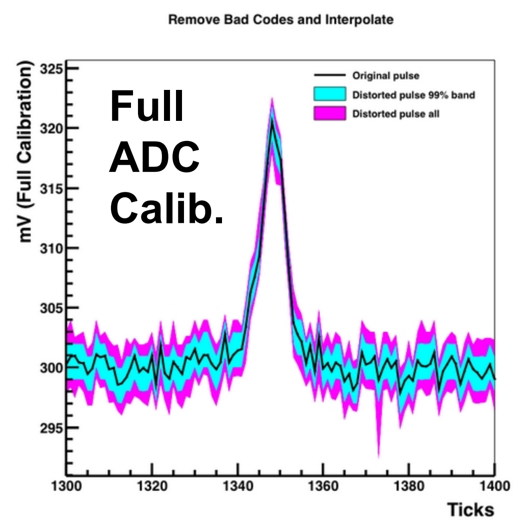
- Expert on this topic: David Adams (also Elizabeth Worcester)
- Principal things to simulate: non-linearity and stuck bits
  - Requires raw simulation of voltages, **then** utilize module to translate into number of ADCs
- Current simulation in LArSoft: 35-ton era (simplistic stuck bits model, no non-linearity issues)
- Production ADC ASICs currently being characterized at BNL – David will implement realistic simulation in LArSoft once this campaign is over (~**2 months** timescale)
- Small time-dependence of issue observed before, not expected to be primary concern for ProtoDUNE-SP

ADC Calibration

- May be case that ADCs have different characterstics in-situ w.r.t. bench measurements – need in-situ calibration
- One idea: shift pulser in time (using multiple gain settings) to sample wider range of ADC values, use for voltage-to-ADC calibration
- David (and Elizabeth or BNL postdoc) will help test calibration methodology once simulation is in





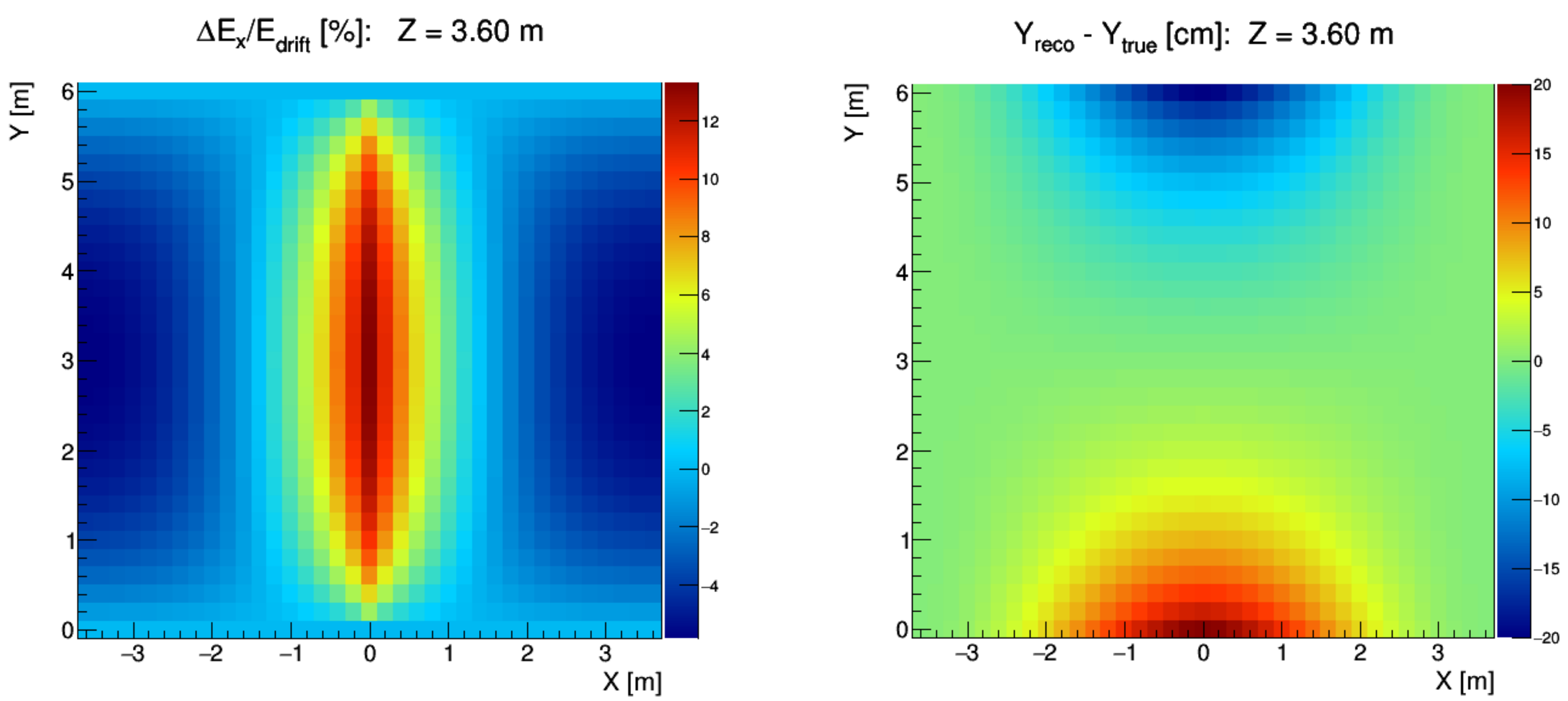


Track-Based Calibrations

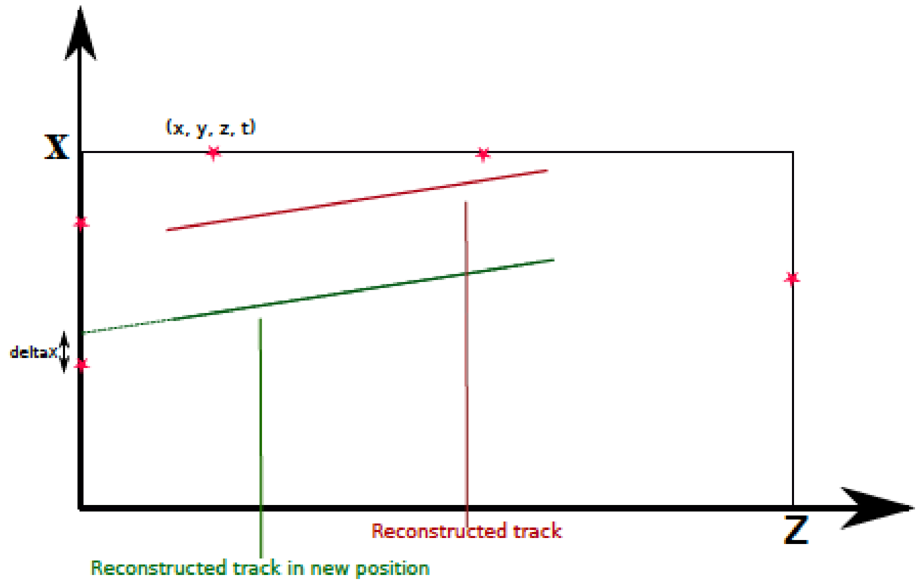
- Several calibrations and measurements rely on having reliable sample of t_o-tagged tracks on hand
  - Space charge effect calibration
  - Electron lifetime calibration
  - Auxiliary measurements such as diffusion, signal response, etc.
- First priority should be to establish full set of t_o-tagging algorithms and culminate set of t_o-tagged into common data product
  - CRT-tagged tracks
  - Tracks with t_o obtained using TPC/LCS information
- Then test calibration methodology, gauge impact on physics
- Also priority: simulation of detector effects

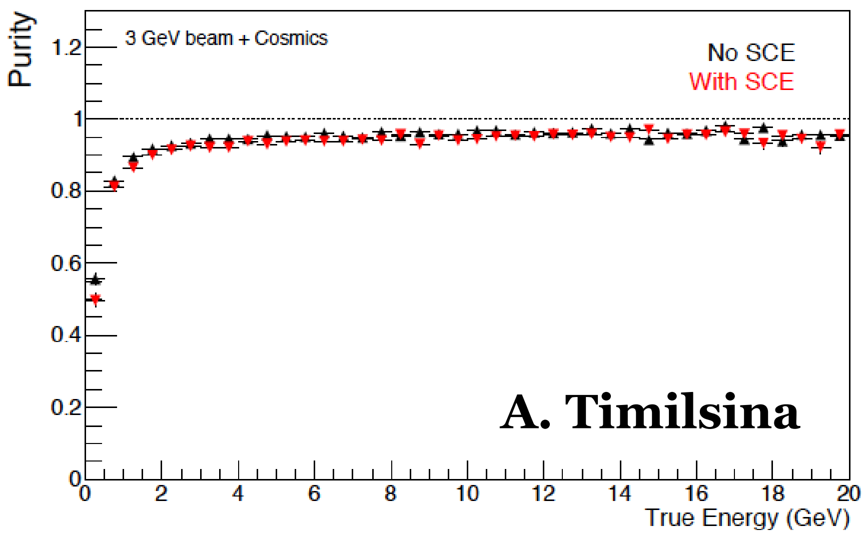
Simulation of Detector Effects

- Realistic simulation of detector effects important to test calibration methodology
  - E.g. electron lifetime, diffusion, space charge effects
- With space charge effect simulation in, basically done



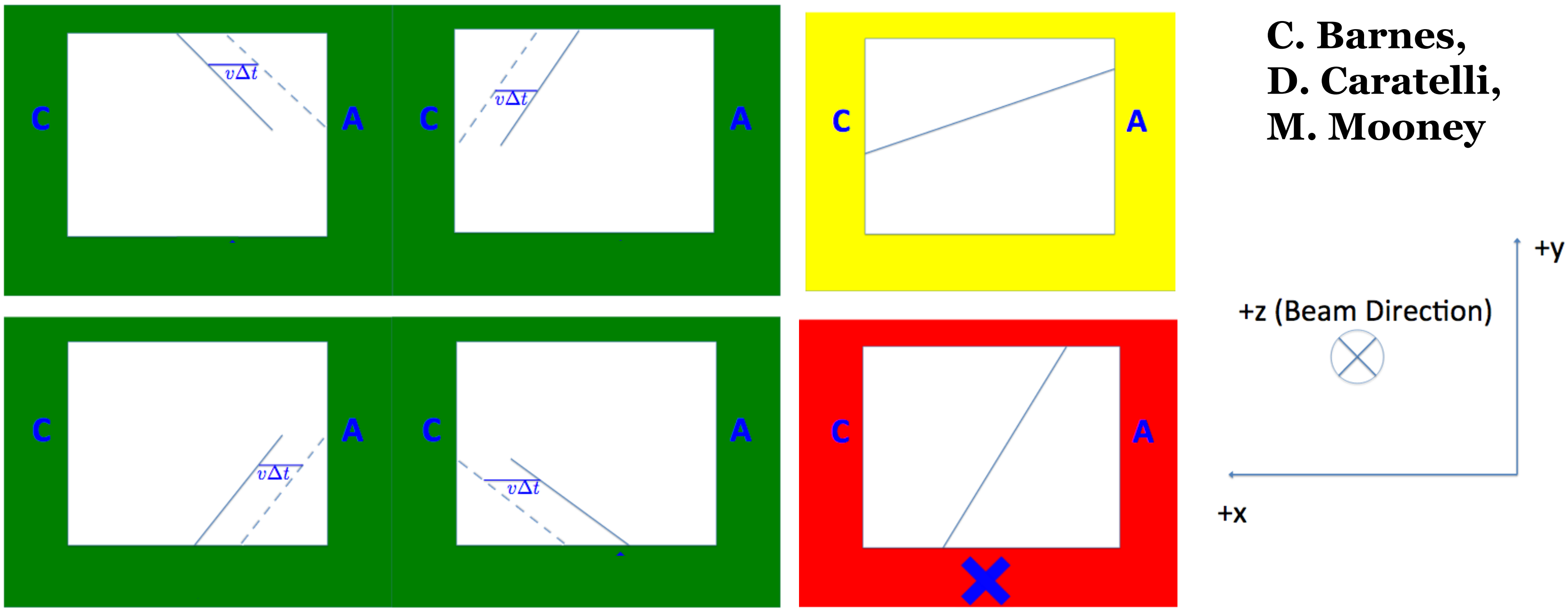
CRT-TPC Matching





- ProtoDUNE-SP CRT-TPC matching algorithm has been developed by Arbin
  - Robust against presence of space charge effects
  - Plan to tweak algorithm and utilize LCS to further improve purity
- No "proper" CRT geometry in simulation yet, so mocking CRT planes in simulation (w/ spatial smearing of hits)

Other t_0-Tagging Methods



C. Barnes,
D. Caratelli,
M. Mooney

- Can also tag track t_0 with strictly TPC info (purify with LCS)
  - Side-piercing tracks: assume through-going, use geometry
  - Cathode-anode crossers: projected *x* distance is full drift length
  - Not pictured: cathode crossers (ProtoDUNEs only)
- Public note from MicroBooNE coming out on this soon

Light Collection System

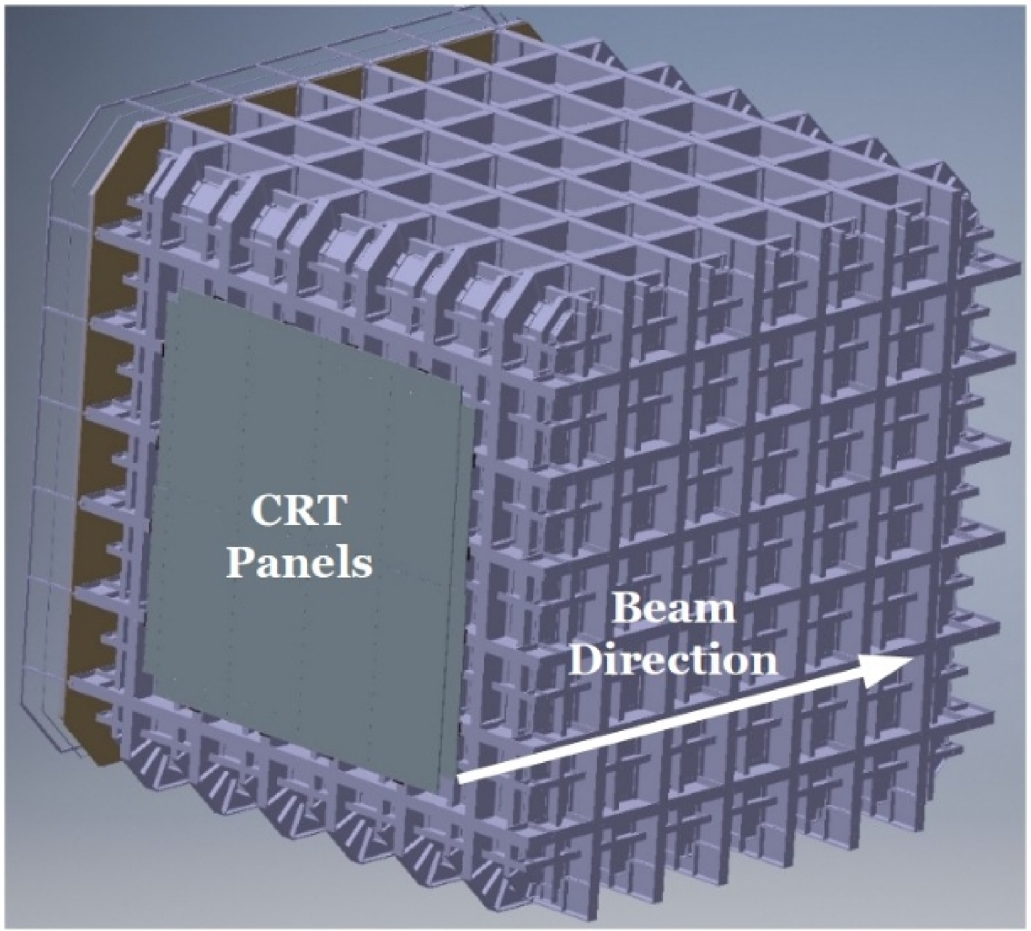
- Had a long discussion with Alex Himmel (the real expert) on the LCS at ProtoDUNE-SP
- Current simulation and reconstruction is borrowed from MicroBooNE
  - Simulate photons hitting light guides by using photon library, baking in effects of acceptance and quantum efficiency
  - Suitable photon library for ProtoDUNE-SP for variety of nitrogen levels
  - Reconstruction into OpHits (single LCS unit) then OpFlashes (several OpHits across multiple LCS units coincident in time)
- Feature: OpFlash reconstruction groups LCS units from both sides of cryostat – problematic for ProtoDUNE-SP?
- Needs someone to study to evaluate sim./reco. needs!

Summary

- Calibrations Group strategy:
  - 1) Simulate expected electronics state and detector effects as well as possible
  - 2) Prepare set of tools to do calibrations (e.g. t_0-tagged tracks)
  - 3) Test calibration methodology and evaluate residual impact on physics (e.g. dQ/dx, track/shower reconstruction efficiencies)
- Many simulation/reconstruction items in, others on way:
  - FE noise, signal response/deconv. by end of year (BNL group)
  - ADC issues simulation on ~2 months timescale (David Adams)
  - t_0-tagged track samples on ~2 months timescale (Arbin, others)
- Need **at least** two more people on these topics, one to help with electronics/noise calibrations, one for track-based calibrations – and more certainly very helpful!

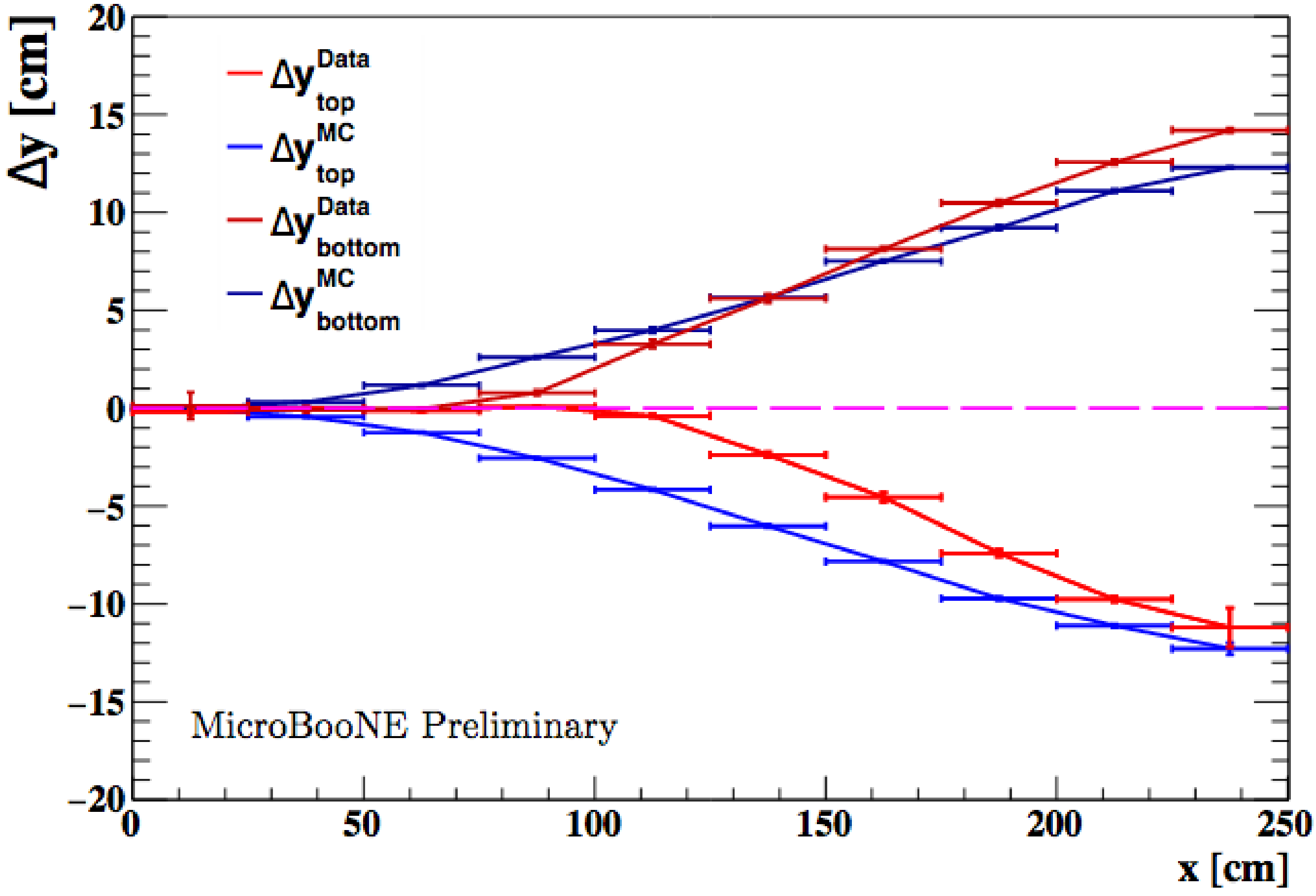
BACKUP SLIDES

ProtoDUNE-SP CRT



- 32 modules in total covering upstream and downstream faces of ProtoDUNE
- 8 H + 8 V modules on each side
  - 3.2 m × 1.6 m for each module
  - **2.5 × 2.5 cm pitch**
- Can tag:
  - Cosmics
  - Beam halo muons

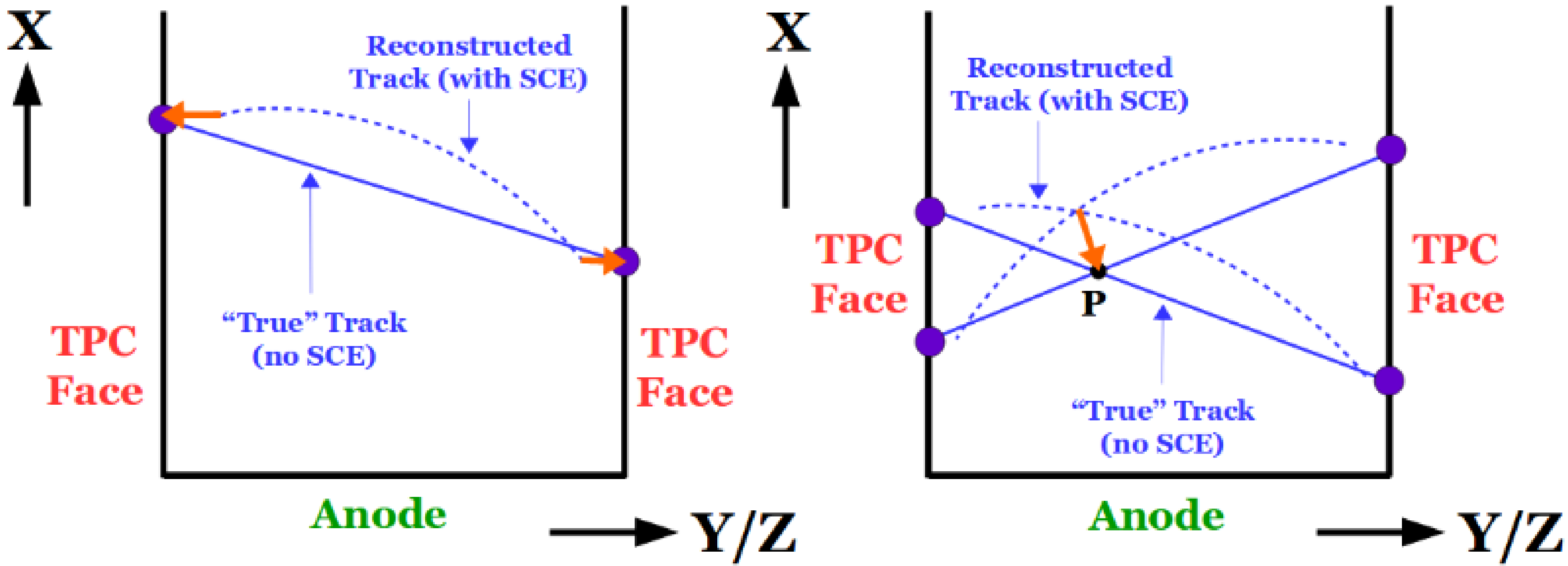
μBooNE SCE Data/MC Comp.



SCE Calibration Overview

- Basic need for space charge effect calibration: reconstructed space point (3D) with known true origin in 3D, covering entire active TPC volume
  - This requires knowing $\mathbf{t_o}$ of deposited charge
- Possibilities:
  - 1) Laser system (best option since true track truly known)
  - 2) Cosmic ray tagger (cosmic muons and/or beam muon halo)
  - 3) t_o-tagged tracks using TPC/LCS information
  - 4) Radioactive sources at fixed locations (inflexible)
  - 5) Radioactive sources moving about cryostat (hard to get t_o)
- ProtoDUNE-SP will utilize **#2/#3** (no #1, #4/#5 not planned)
- ProtoDUNE-DP: **#3** only?

SCE Calibration w/ Tracks



- Two samples of t_0-tagged tracks can provide SCE corrections:
  - Single tracks – enable corrections at TPC faces by utilizing endpoints of tracks (correction vector approximately orthonormal to TPC face)
  - Pairs of tracks – enables corrections in TPC bulk by utilizing unambiguous point-to-point correction looking at track crossing points
- Require high-momentum tracks (plenty from cosmics, beam halo)