protoDUNE MC: Intro to LArSoft Simulations and MC Samples

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protoDUNE Sim/Reco Meeting

protoDUNE LArSoft Details

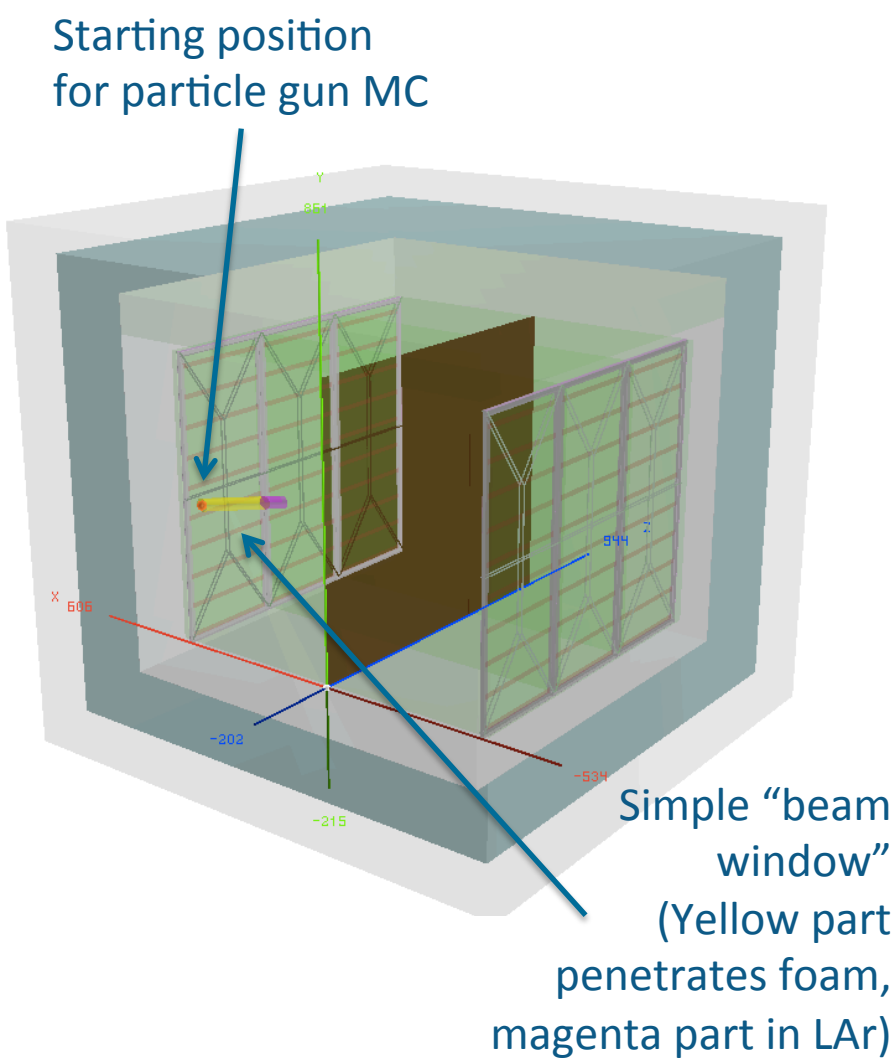
- protoDUNE code is part of dunetpc
- Most code is common with DUNE FD
- protoDUNE-specific details include:
  - Geometry (Martin Tsanov, Tyler Alion, ETW)
  - Optical library (Alex Himmel)
  - Cosmics library (Matt Bass)
  - Readout window (Dorota Stefan, ETW)

```
protodune_services: {
 ExptGeoHelperInterface:       @local::dune_geometry_helper
 Geometry:                     @local::protodune_geo
 DetectorClocksService:        @local::dunefd_detectorclocks
 DetectorPropertiesService:    @local::dunefd_detproperties
 LArPropertiesService:         @local::dunefd_properties
 LArFFT:                       @local::dunefd_larfft
 DatabaseUtil:                 @local::dunefd_database
 BackTracker:                  @local::dunefd_backtracker
 SpaceCharge:                  @local::protodune_spacecharge
 LArSeedService:               @local::dune_seedservice
 SignalShapingServiceDUNE:     @local::dunefd_signalshapingservice
 ChannelStatusService:         @local::dunefd_channel_status
}

protodune_simulation_services: {
 LArFFT:                       @local::dunefd_larfft
 LArG4Parameters:              @local::protodune_largeantparameters
 ExptGeoHelperInterface:       @local::dune_geometry_helper
 Geometry:                     @local::protodune_geo
 DetectorClocksService:        @local::dunefd_detectorclocks
 DetectorPropertiesService:    @local::dunefd_detproperties
 LArPropertiesService:         @local::dunefd_properties
 DatabaseUtil:                 @local::dunefd_database
 LArVoxelCalculator:           @local::dunefd_larvoxelcalculator
 MagneticField:                @local::no_mag
 BackTracker:                  @local::dunefd_backtracker
 SpaceCharge:                  @local::protodune_spacecharge
 LArSeedService:               @local::dune_seedservice
 SignalShapingServiceDUNE:     @local::dunefd_signalshapingservice
 PhotonVisibilityService:      @local::protodune_photonvisibilityservice
 OpDetResponseInterface:       @local::dunefd_opdetresponse
 ChannelStatusService:         @local::dunefd_channel_status
```

protoDUNE Geometry

- Developed by Martin Tzanov, starting from script to generate DUNE FD gdml written by Tyler Alion
- Active volume and wire planes are correctly implemented with sufficient detail
- Basic cryostat volume implemented based on Martin's reading of engineering drawings
- Includes basic implementation of field cage (needs work)
- Simple "beam window" implemented as nitrogen-filled steel pipe (needs work)
  - 25 cm outer diameter, 0.5 mm thick steel wall
  - Does not represent details of beam window design
  - Location somewhat arbitrary
- During development of cosmic simulation, had to correct material in outer volumes (foam, steel support)

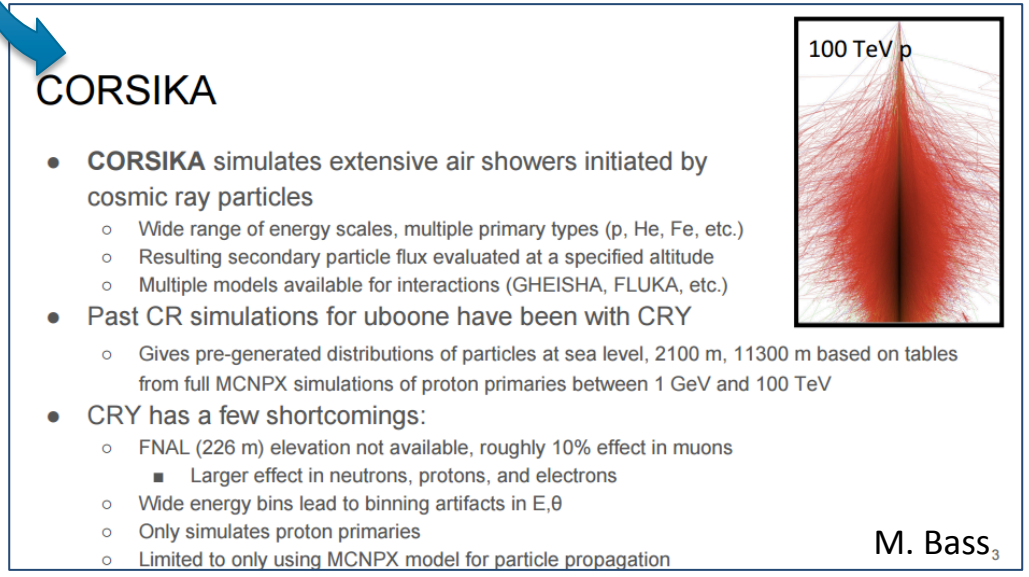


Optical Library

- Most recent library generation prior to MCC6 (no changes to geometry dimensions since then)
- Optical detectors in geometry not based on actual plan for protoDUNE (copied from FD script)
- Optical simulation runs (fcl files set up correctly)
- Results untested as far as I know

CORSIKA in LArSoft

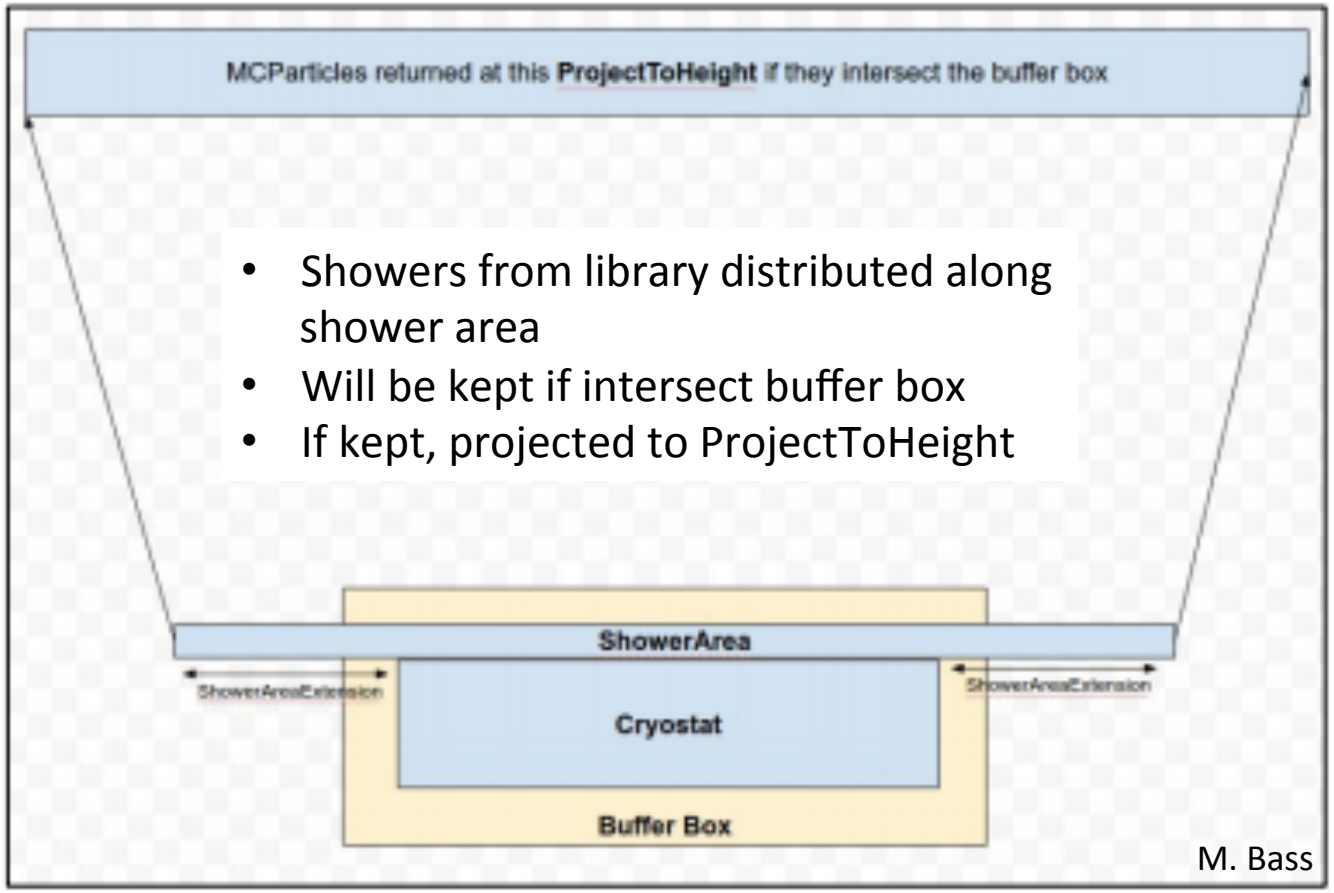
- CORSIKA cosmic ray simulation implemented in LArSoft by Matt Bass
  - Originally for uBooNE
  - See talk at LArSoft coordination meeting: indico.fnal.gov/conferenceDisplay.py?confId=10893
- CorsikaGen module in LArSoft samples from pre-generated library of CORSIKA samples
- Data files containing pre-generated samples produced on per-experiment basis – thanks to Matt for generating this library for protoDUNE



Quick check of muon rates:

- uBooNE: ~160 Hz/m^2
- protoDUNE: ~170 Hz/m^2
- Expected difference based on altitude ~6%
- This exercise uncovered issues with material in outer layers of DUNE/protoDUNE geometry – fix in progress.

CORSIKA in LArSoft (cont)



- Showers from library distributed along shower area
- Will be kept if intersect buffer box
- If kept, projected to ProjectToHeight

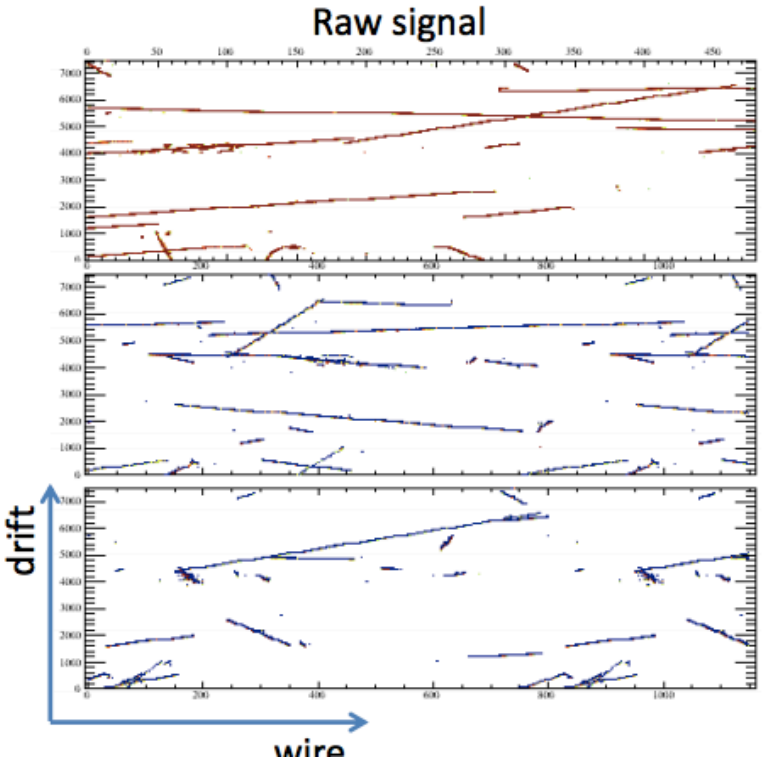
Cosmic Simulation in protoDUNE

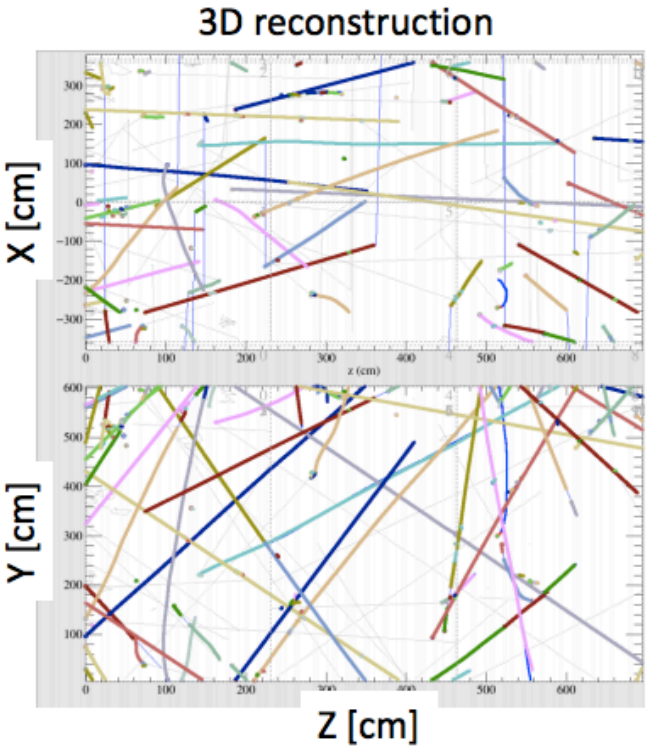
```
protodune_corsika_cmc:                @local::standard_CORSIKAGen_CMC
protodune_corsika_cmc.SampleTime:     6.45e-3   #0.2 ms (g4 rise time) + 2.25 ms
 (1 full drift window) + 4.0 ms (readout)
protodune_corsika_cmc.TimeOffset:     -3.325e-3 #4.0 ms readout should start at
-0.875 ms to match data
protodune_corsika_cmc.BufferBox:      [ -300.0,300.0,-300.0,300.0,-300.0,300.0 ]
protodune_corsika_cmc.ShowerAreaExtension: 2000
protodune_corsika_cmc.ProjectToHeight:  865  #height to which particles are projected in cm
protodune_corsika_cmc.ShowerInputFiles: [
            "/pnfs/dune/persistent/users/mibass/corsika/sqShowers/DAT2*.db",
            "/pnfs/dune/persistent/users/mibass/corsika/sqShowers/DAT3*.db",
            "/pnfs/dune/persistent/users/mibass/corsika/sqShowers/DAT4*.db",
            "/pnfs/dune/persistent/users/mibass/corsika/sqShowers/DAT5*.db",
            "/pnfs/dune/persistent/users/mibass/corsika/sqShowers/DAT6*.db"
          ]
```

- SampleTime = 1 full drift time + readout window
- TimeOffset adjusted for protoDUNE readout window (4 ms)
- BufferBox and ShowerAreaExtension enlarged relative to nominal CorsikaGen parameters
- ProjectToHeight (showers start here): z=865 cm is just above the cryostat volume in the existing geometry; no building in simulation
- ShowerInputFiles: files in dCache persistent
- Fcl file in dunetpc/dune/EventGenerator/corsika_protodune.fcl
- At g4 stage, recommend setting: physics.producers.largeant.KeepParticlesInVolumes: [“volCryostat”]

Example

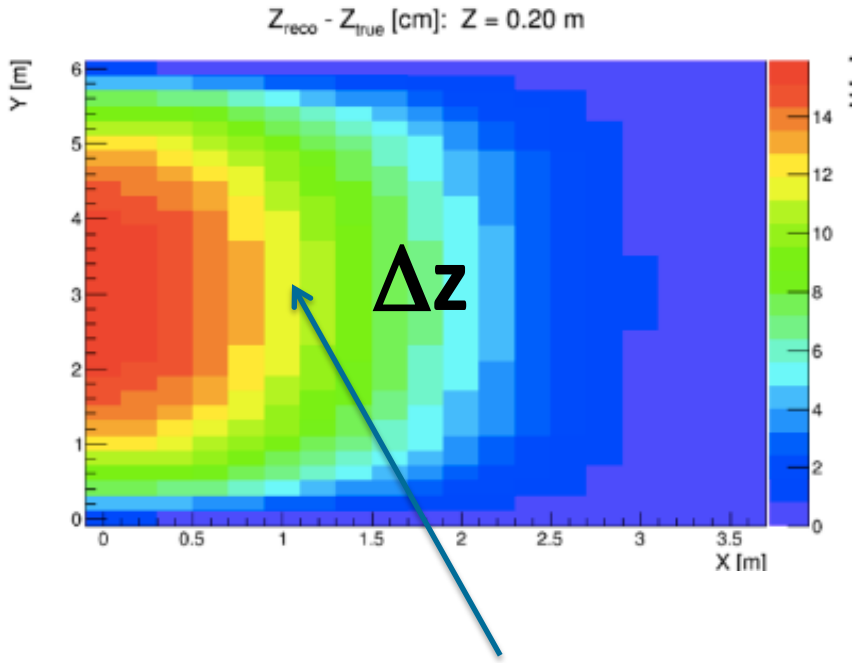
- See Dorota's talk later for details
- Expect something on the order of 40 events per readout window





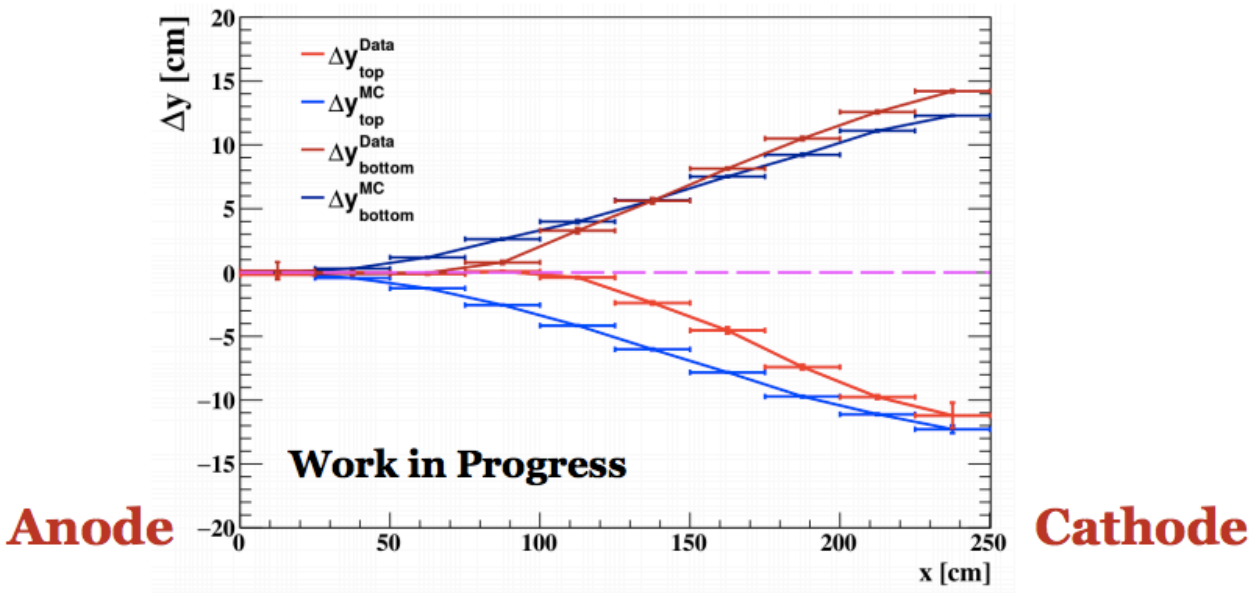
protoDUNE SCE Simulation

- Mike Mooney has standalone code to calculate expected field distortion based on assumption of uniform space charge distribution
- Position distortions based on calculated variation in E-field implemented in LArSoft (LArG4/ LArVoxelReadout)
- Adjustment to E-field used to calculate recombination factor in process of being implemented in LArSoft (LArG4/ IonizationAndScintillation)
- See M.M. talk at protoDUNE science workshop and September collaboration meeting
- Neither effect currently in default protoDUNE MC



Typical location of particle gun particles in current geometry

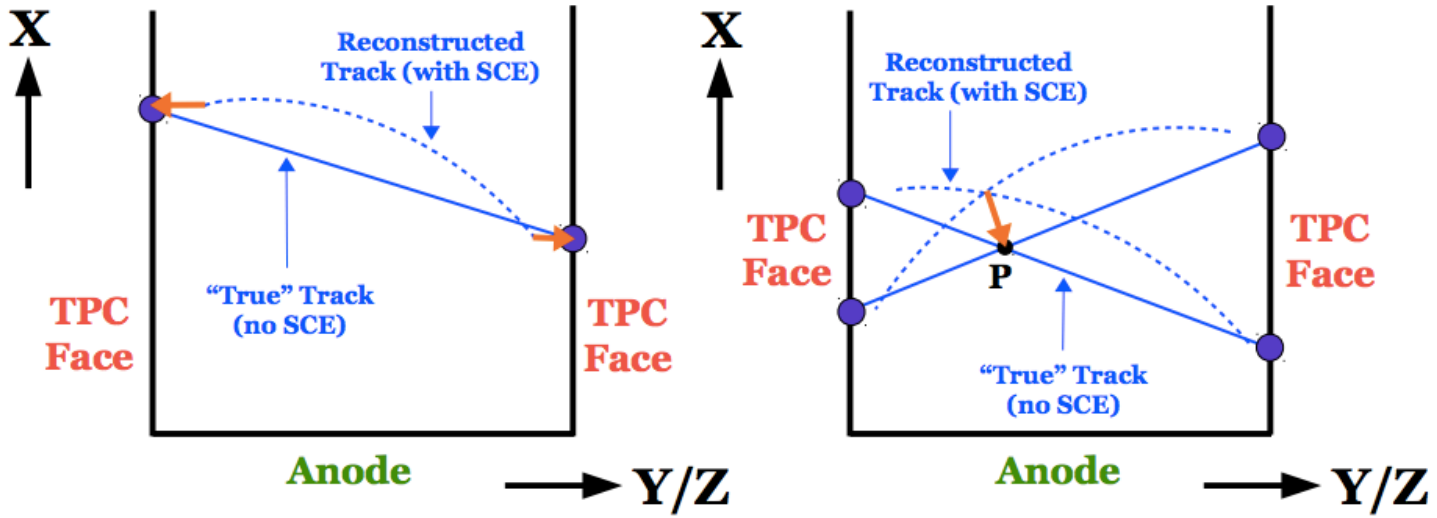
MicroBooNE SCE



- Comparison of data to simulation shows **overall agreement** of SCE in terms of both **magnitude** and **shape** in drift direction
- Some deviations near anode: effect seems to turn on further along in drift direction in data… impact of LAr flow?

M. Mooney

SCE Calibration Scheme



Current simulation effort to identify rate of events that can be used for this calibration (cosmics, beam halo)

- 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)

M. Mooney

Existing MC Samples

- MCC6 samples:
  - No SCE
  - Particle gun injected at front face of "beam window"
  - Both mono-energetic and $\Delta p/p$-5%
  - Positrons (1 GeV)
  - Kaons (1 GeV)
  - Protons (1 GeV)
  - Pions (200 MeV)
  - Muons (200 MeV)
  - Samples chosen based on needs of reconstruction effort (Robert/Dorota) and to for first exercise of MCC machinery with protoDUNE
- Privately generated samples:
  - Mono-energetic MCC samples with SCE position effect
  - Additional particle momenta using mono-energetic MCC setup w/ and w/o SCE position effect (BNL summer students J. Larkin and A. Depoian)
    - Positrons (300 MeV, 500 MeV, 1 GeV, 5 GeV)
    - Protons (700 GeV, 1 GeV, 2 GeV, 3 GeV)
    - Pions (300 MeV, 500 MeV, 1 GeV, 5 GeV)
    - Muons (500 MeV, 1 GeV, 5 GeV)
  - Cosmic ray events and cosmics overlayed on beam muons

Existing MC Samples (cont)

- MCC7 samples:
  - 2 GeV protons
  - 1 GeV kaons
  - 2 GeV pions
  - 1 GeV muons
  - 200, 500, 1000, 2000, 5000, 7000 MeV electrons
- Extra (MCC7 era) privately generated samples:
  - 1.5, 2, 3 GeV kaons
- All samples stored on FNAL DUNE disks
  - /dune/data
  - /pfns/dune/scratch
- MCC7 samples in:
  - /pnfs/dune/scratch/dunepro/v06_05_00
- Others scattered in private areas – ask Elizabeth or Dorota

Summary

- Work on protoDUNE-specific simulation began fall 2015
  - LArSoft protoDUNE services defined
  - Geometry with many details implemented
    - Improvements ongoing
  - Space charge effect simulation
    - Position distortion implemented
    - Recombination effect in progress
  - Cosmic simulation
    - CorsikaGen implemented
  - Continued addition of features and improvements to existing features will be driven by analysis needs
- Many MC samples exist – please start to analyze them!
- Additional MC samples available on request – please ask!