DEEP UNDERGROUND NEUTRINO EXPERIMENT

UNIVERSITY of HOUSTON
YOU ARE THE PRIDE
DEPARTMENT OF PHYSICS

First Results on ProtoDUNE-SP

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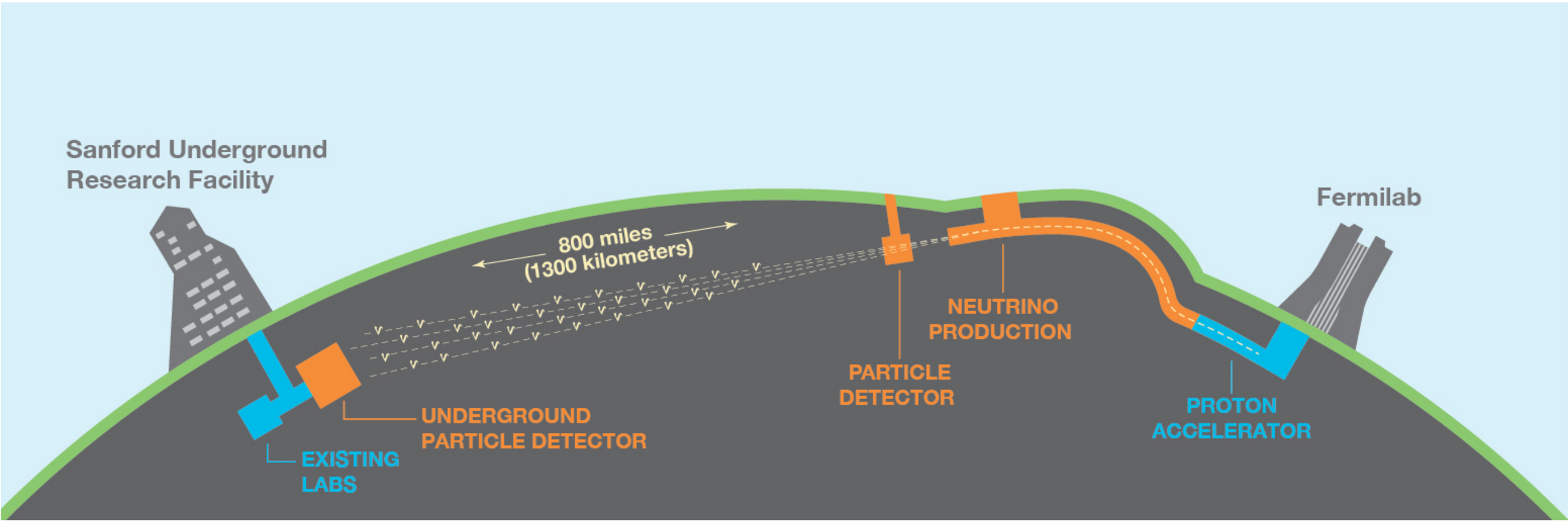
University of Houston
On behalf of the DUNE Collaboration

20th International Workshop on Next Generation Nucleon Decay and Neutrinos Detectors

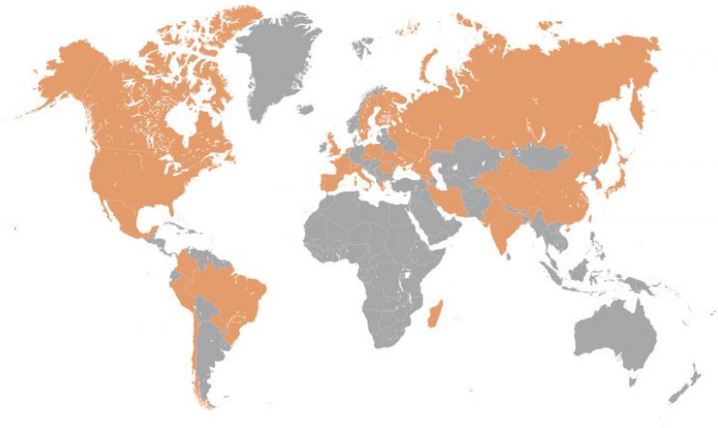
Deep Underground Neutrino Experiment (DUNE)



DUNE will be a world-class neutrino observatory

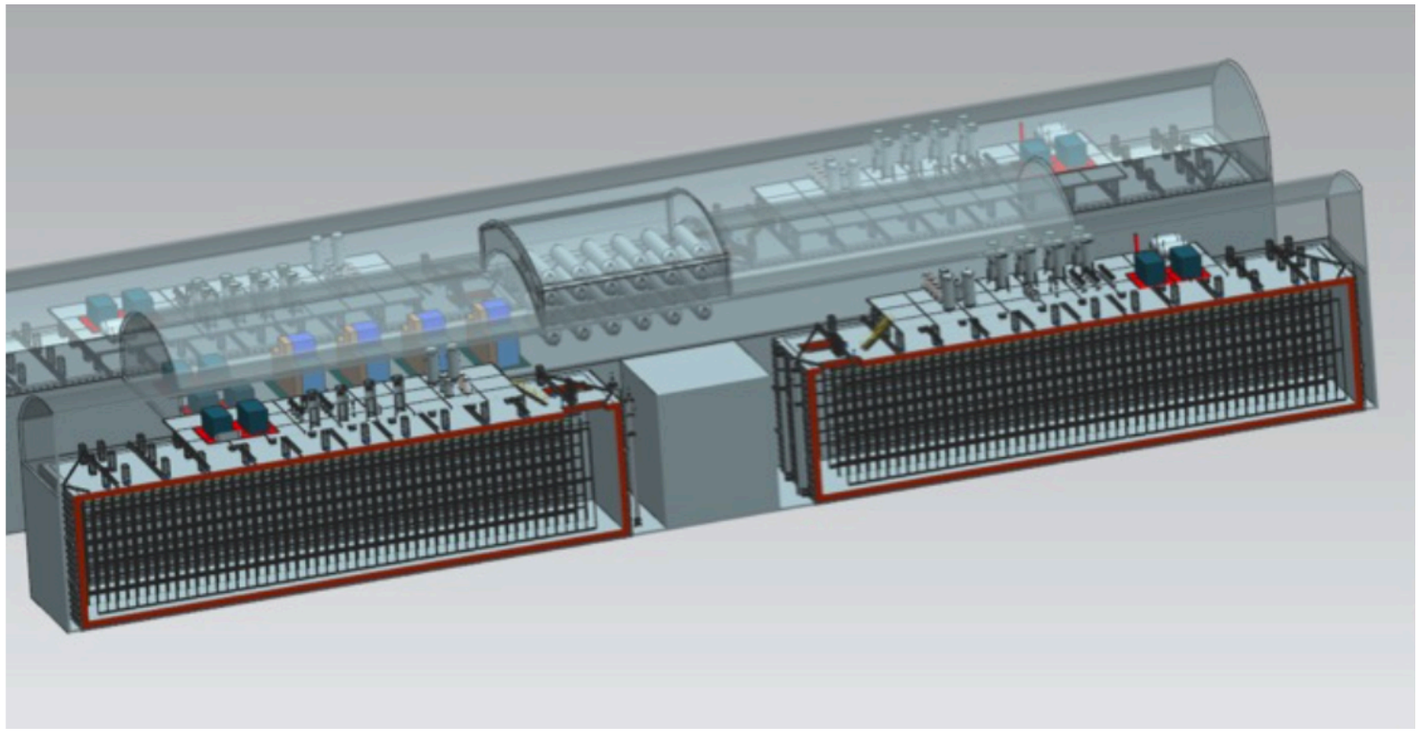
- A broad and rich physics program: CP violation searches in the neutrino sector, neutrino mass hierarchy, supernova neutrinos, baryon number violation searches
- The world's most intense neutrino beam from Fermilab
- A deep underground site, massive liquid argon detectors, and a precision near detector

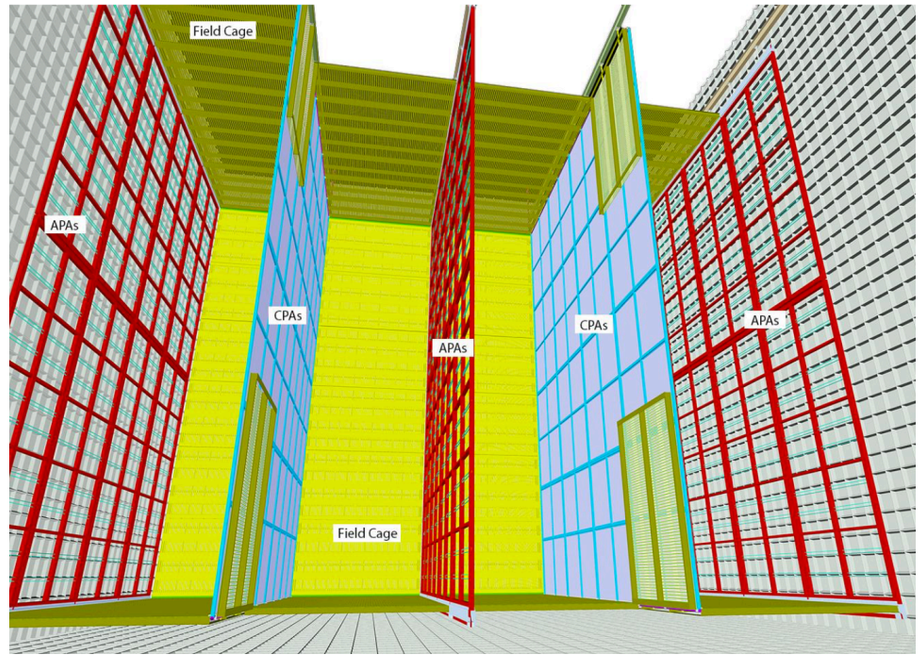
DUNE Collaboration



Over 1000 collaborators from 180+ institutions in 30+ countries

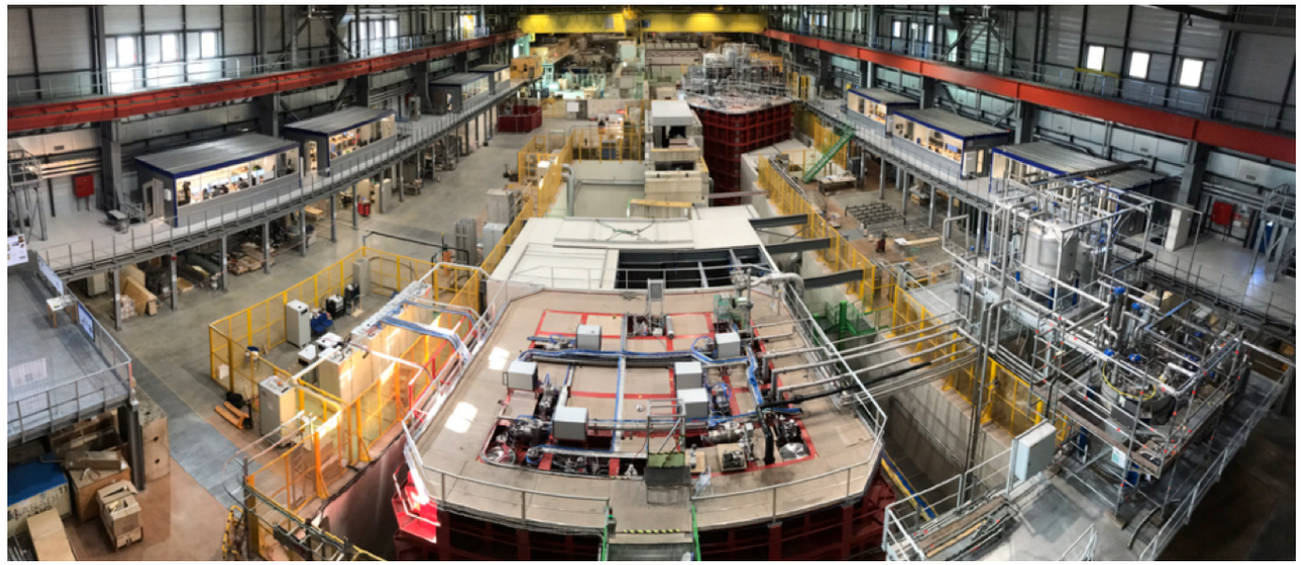
DUNE Far Detector: Single Phase LArTPC





- On-Axis 40 kton Far Detector at Sanford Underground Research Facility, South Dakota
- Four modules
- First module a single phase Liquid Argon Time Projection Chamber (LArTPC)
- Second module a double phase Time Projection Chamber
- To demonstrated the viability and technology of such detectors, prototype detectors are being tested

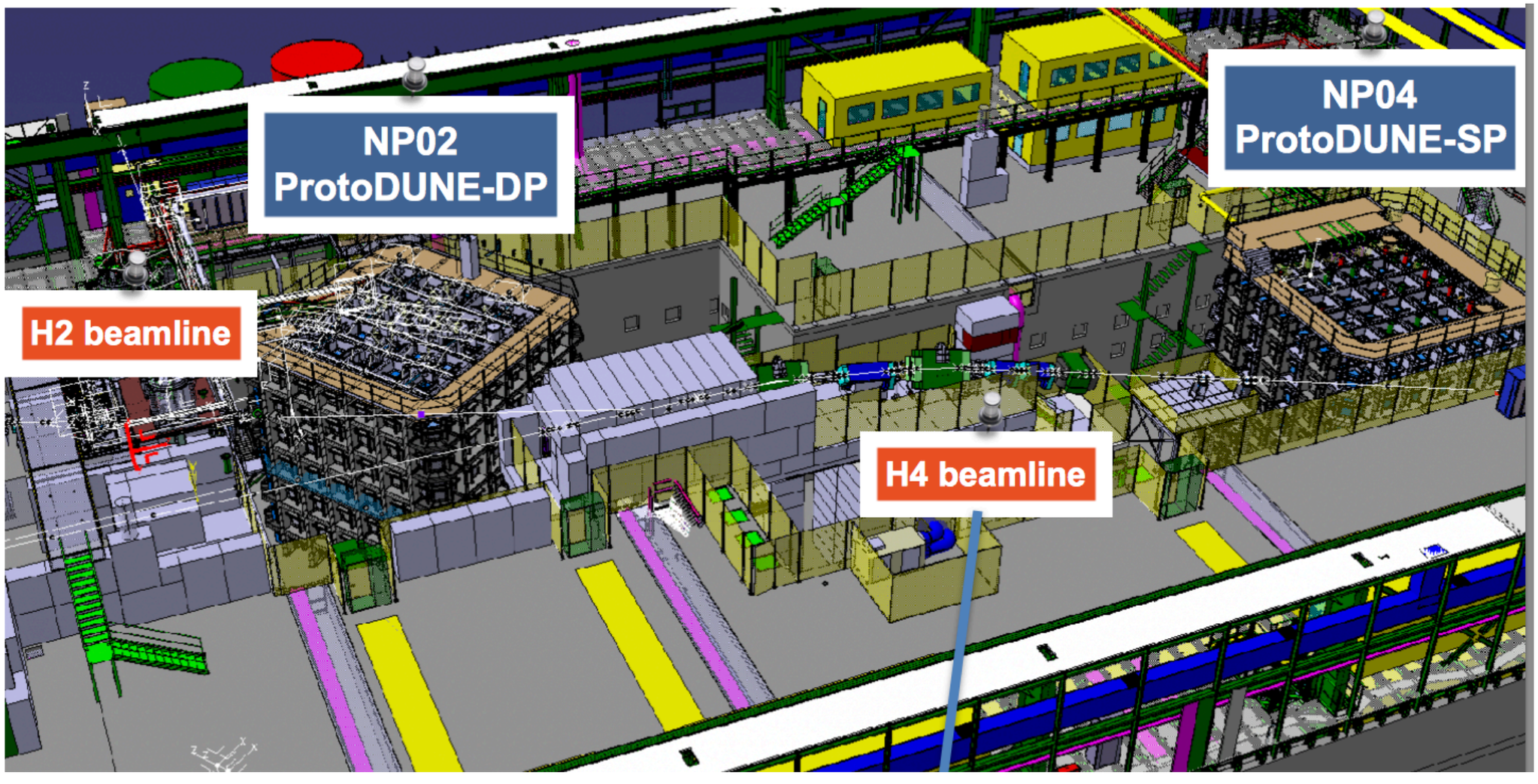
ProtoDUNE-SP at CERN Neutrino Plataform



- Prototyping production and installation procedures for DUNE Far Detector Design
- Validating design from perspective of basic detector performance
- Accumulating test-beam data to understand/calibrate response of detector to different particle species
- Demonstrating long term operational stability of the detector

ProtoDUNE at CERN Neutrino Plataform

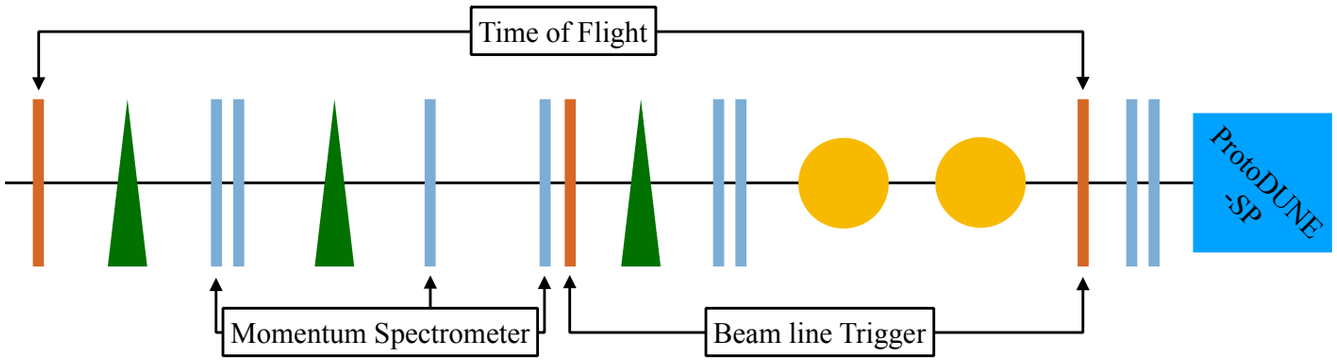
The ProtoDUNE-SP is located in a tertiary extension branch of the H4 beamline in the CERN EH1N extension

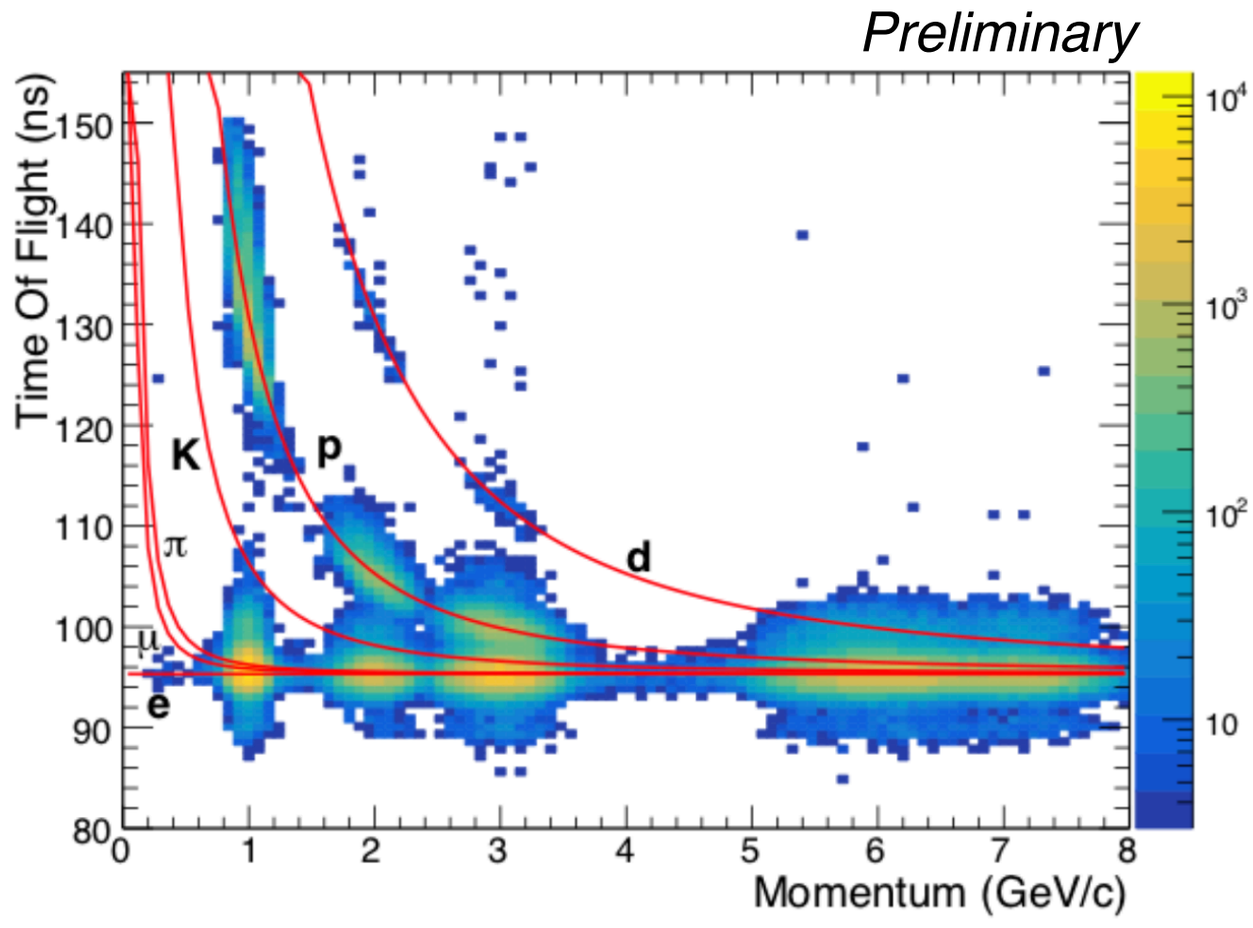


ProtoDUNE at CERN Neutrino Plataform

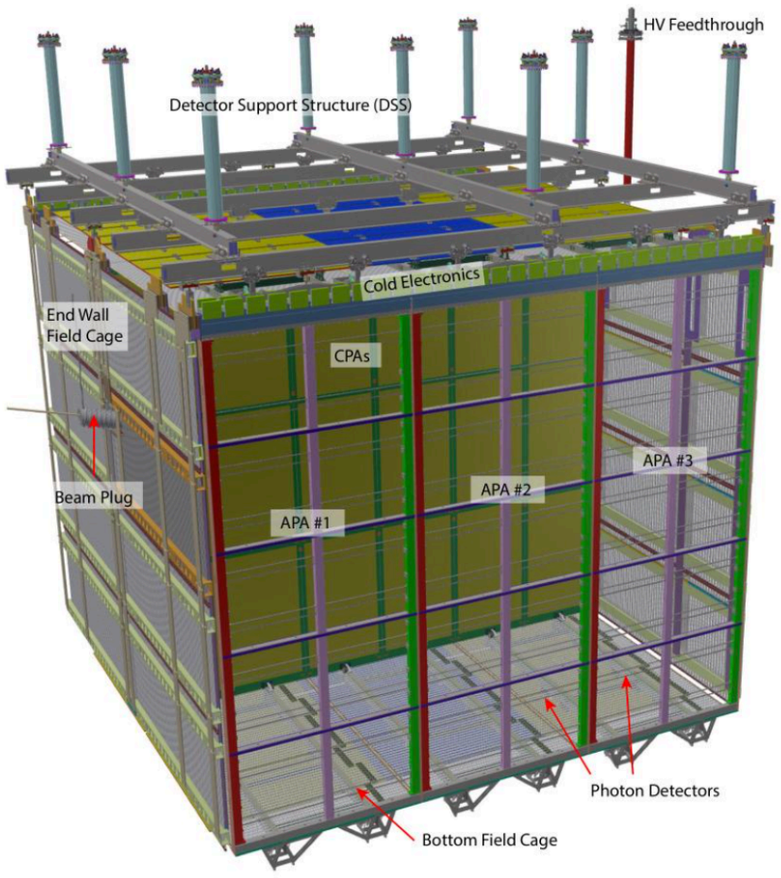
ProtoDUNE-SP at CERN Neutrino Plataform

- Tertiary beam
- Spectrometer to measure the particle momenta
- Particle ID from time of flight and two Cherenkov detectors
- Over 4 million triggers over the momentum range 0.3 to 7.0 GeV/c (positrons, pions, kaons and protons)



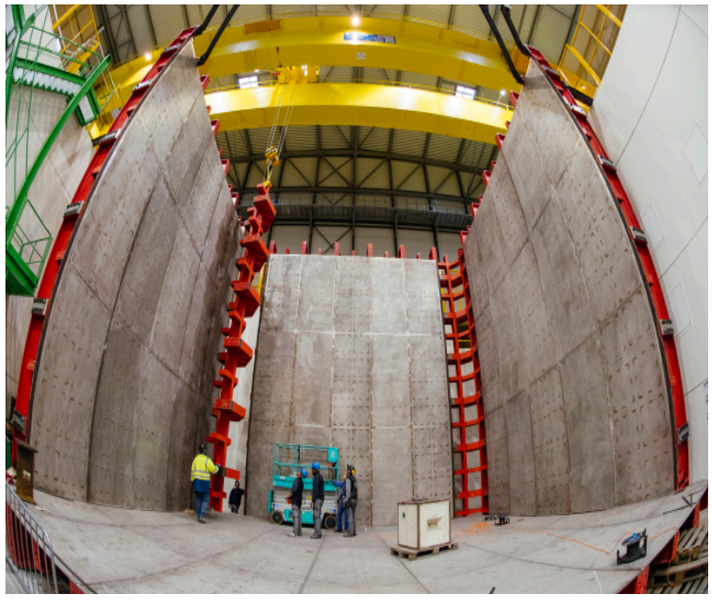


ProtoDUNE-SP

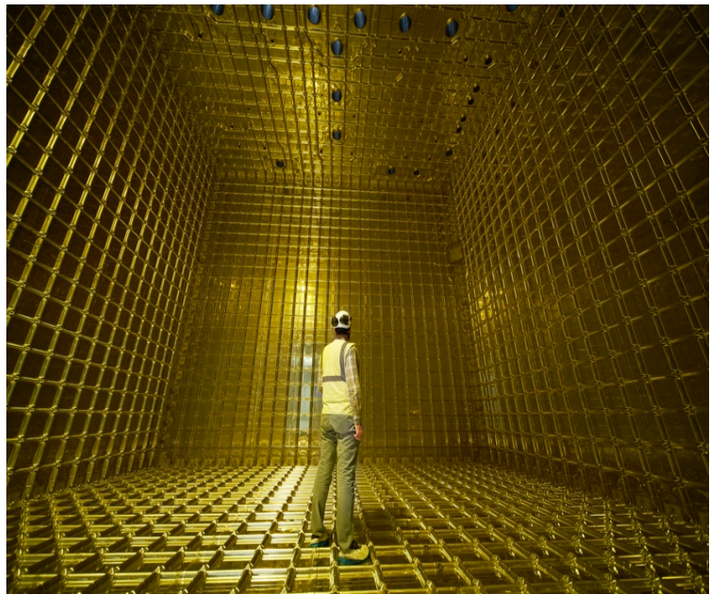


- 770 t of LAr mass
- Active Volume: 6m (H) x 7m (L) x 2x3.6m (W)
- Central Cathode Plane Assembly (CPA)
- Anode Plane Assembly (APA)
- 3.6 m drift distance @180 kV
- 500 V/cm field in drift volume
- Photodetectors integrated in APA
- Field cage: surrounds the open sides of the drift region, ensuring uniform electric field
- Cold electronics: directly attached to the top of the APA (2560 wires/APA, 15360 total wires)

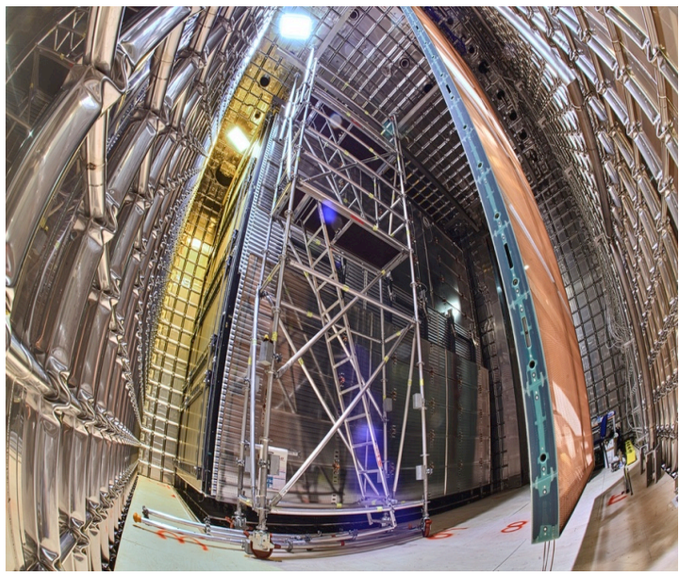
ProtoDUNE-SP at CERN Neutrino Plataform



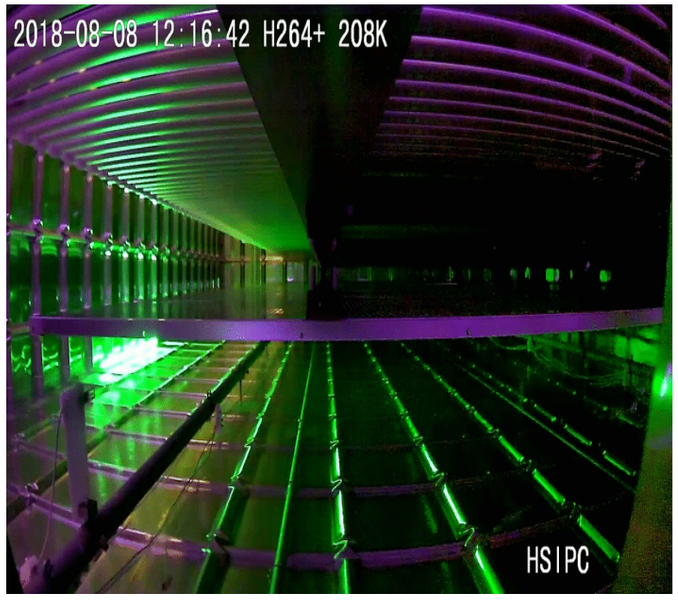
November 2016, cryostat structure assembly



September 2017, cryostat completion

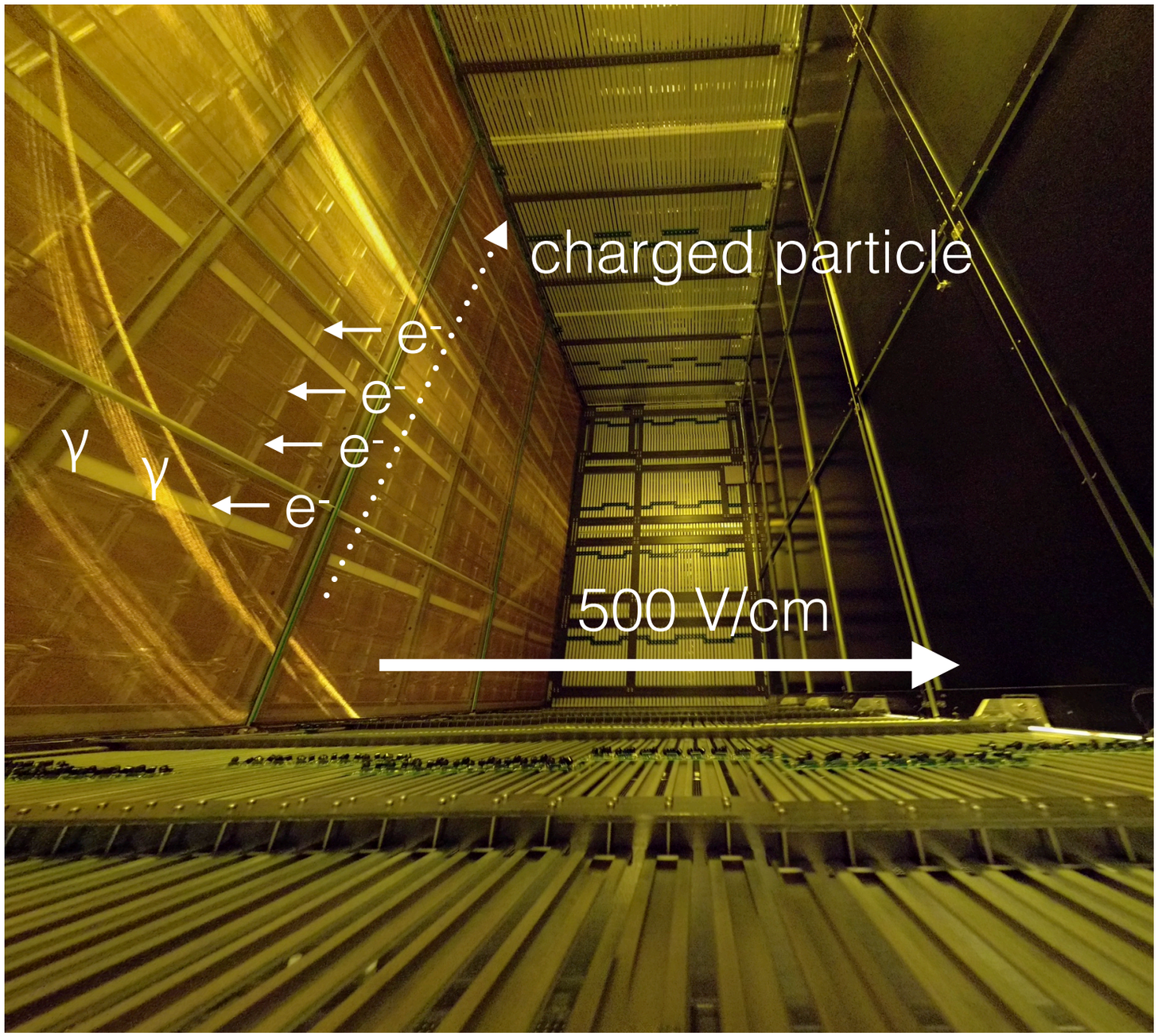


February 2018, detector assembly



August 2018, LAr Filling

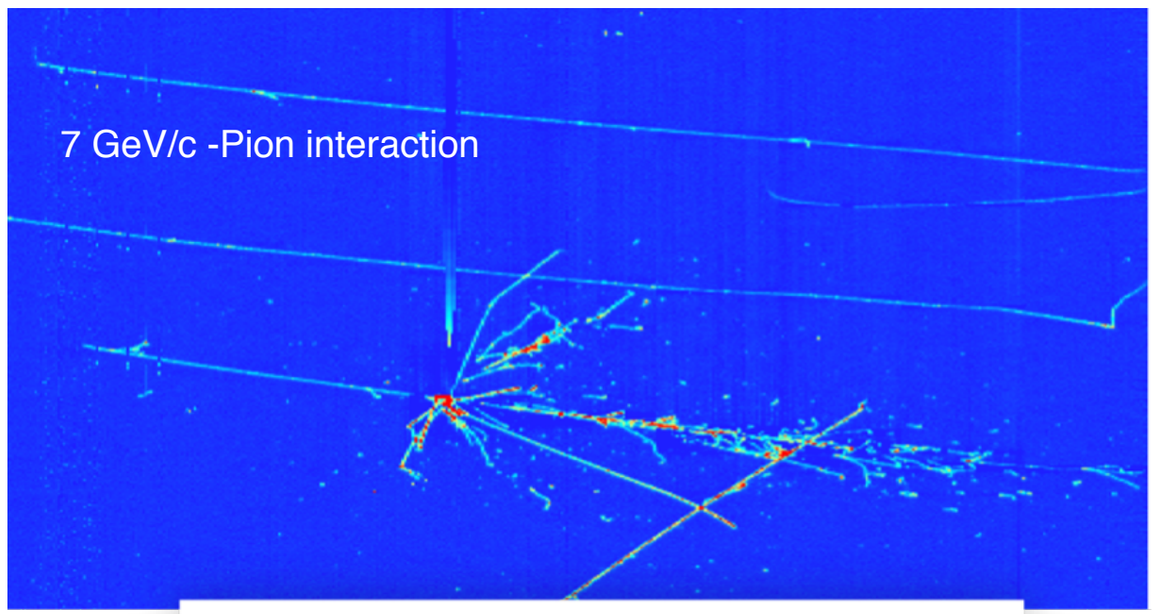
ProtoDUNE-SP

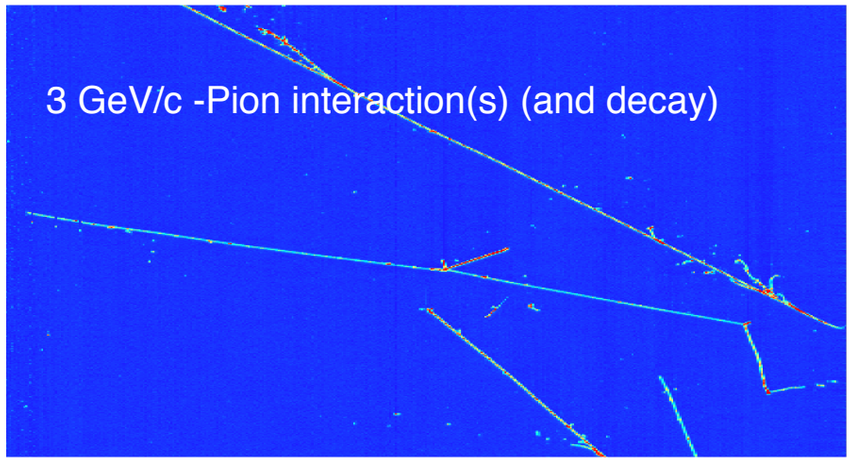


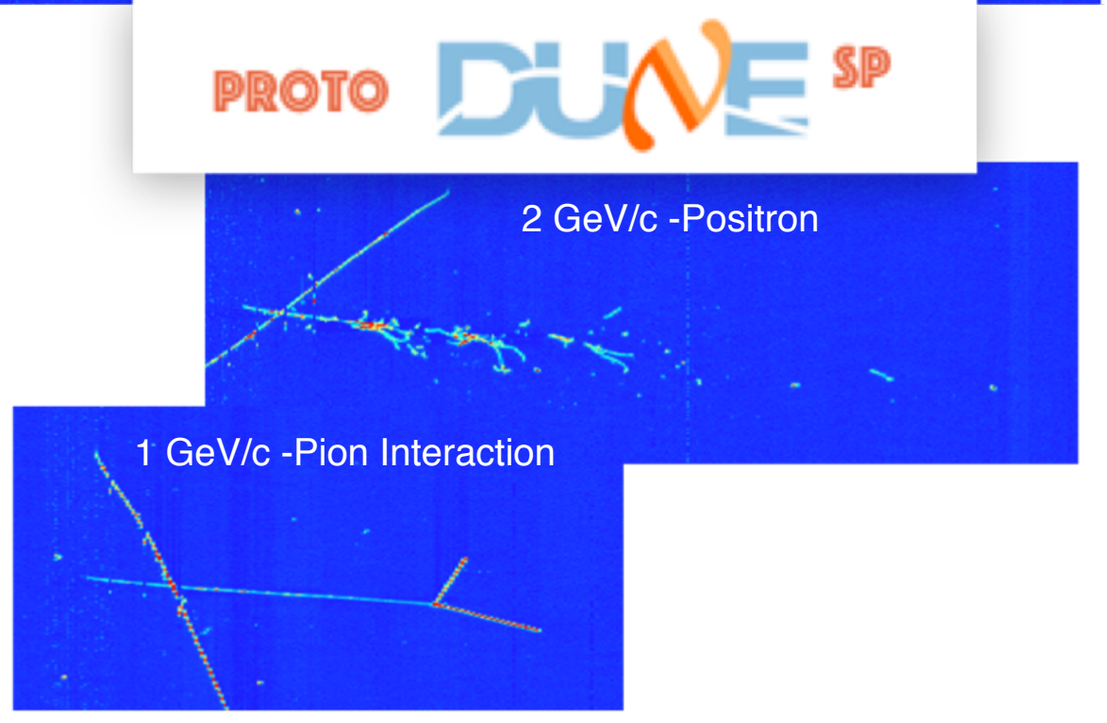
- Charged particles ionize Ar;
  liberated e^-
  are drifted to wire planes
  where their 2D
  location can be reconstructed;
  drift time gives 3rd dimension

ProtoDUNE-SP

- Test beam data taken during fall 2018
- Our first look showed very high quality data
- More than 99.5% of the 15360 wires are active

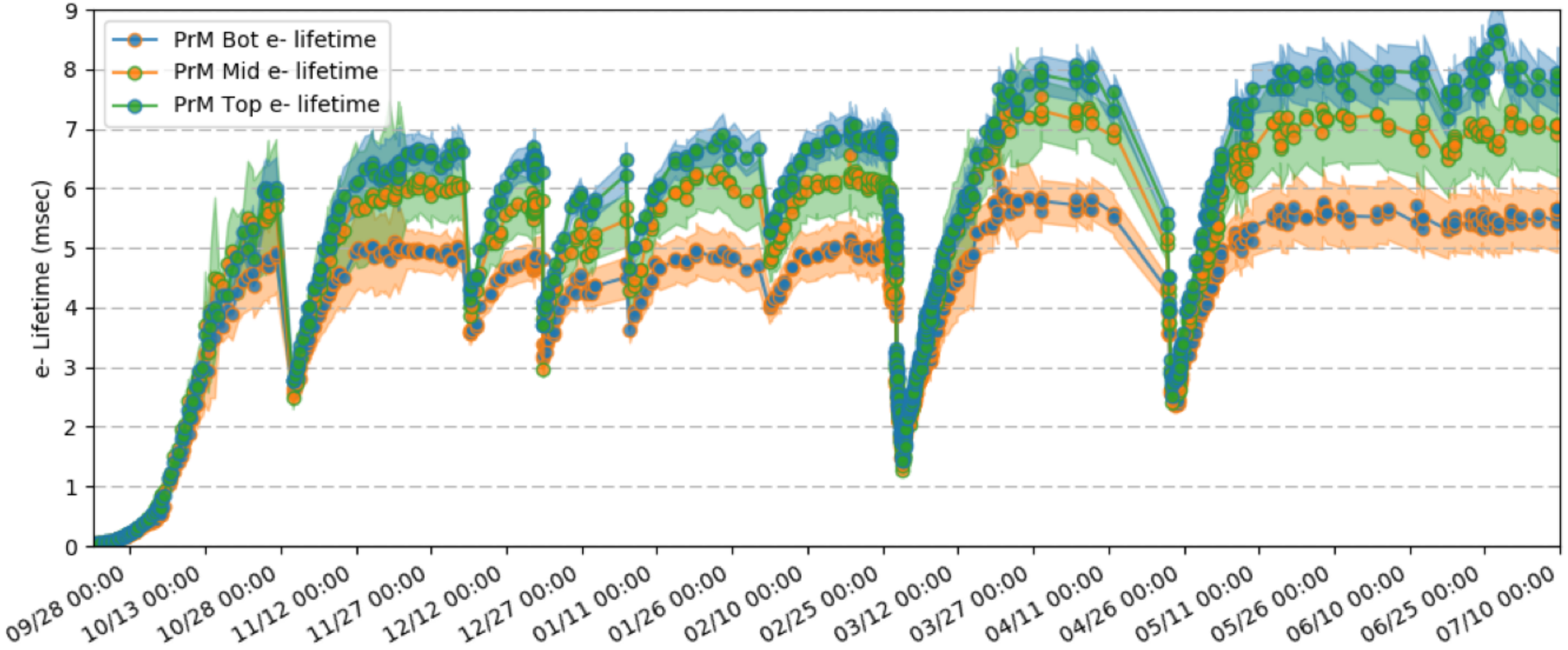






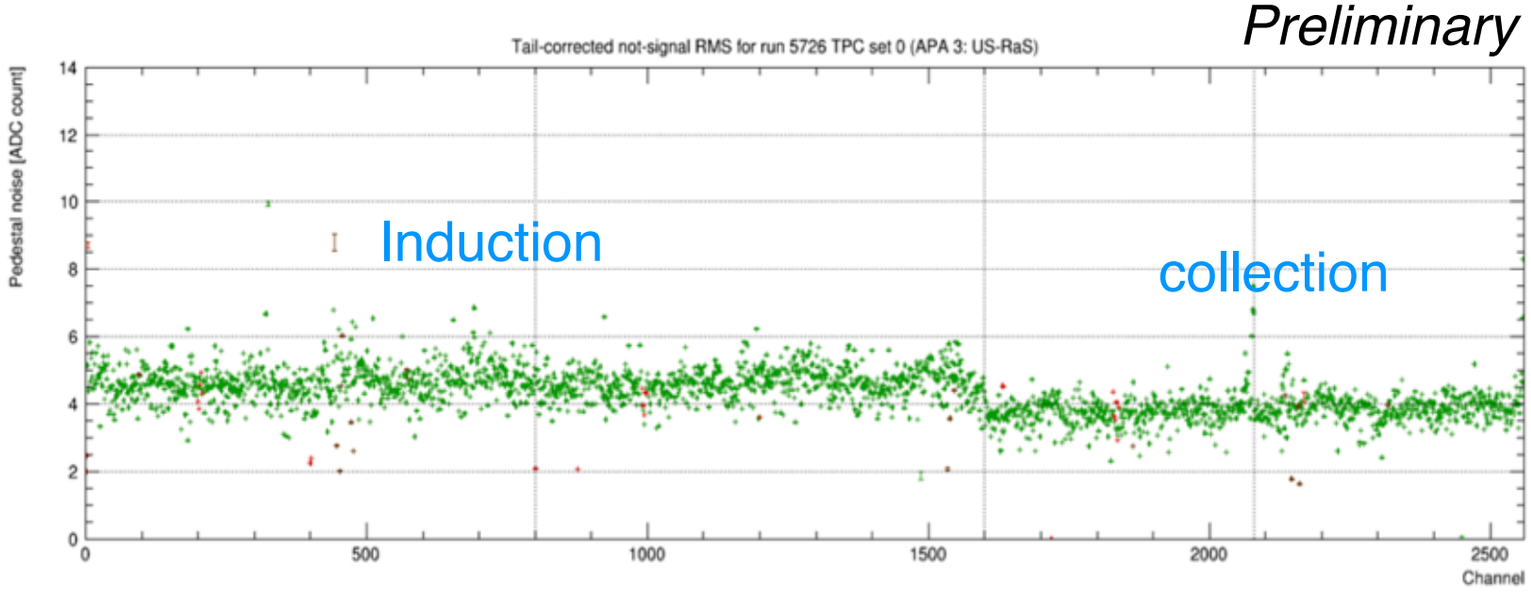
ProtoDUNE-SP, Detector Performance

Preliminary



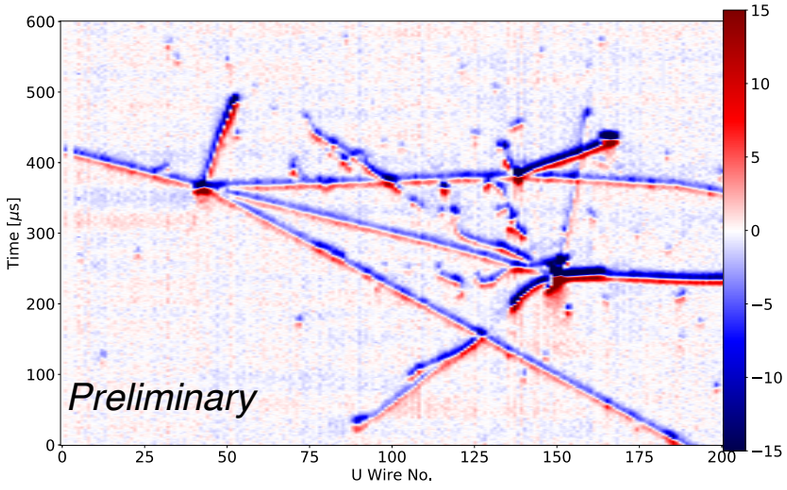
- Liquid Argon purity was routinely measured by the three Purity Monitors at 1.8 m, 3.7 m, and 5.6 m from the bottom of the cryostat
- High purity reached thanks to the gas/liquid recirculation and filtering systems

ProtoDUNE-SP, Detector Performance

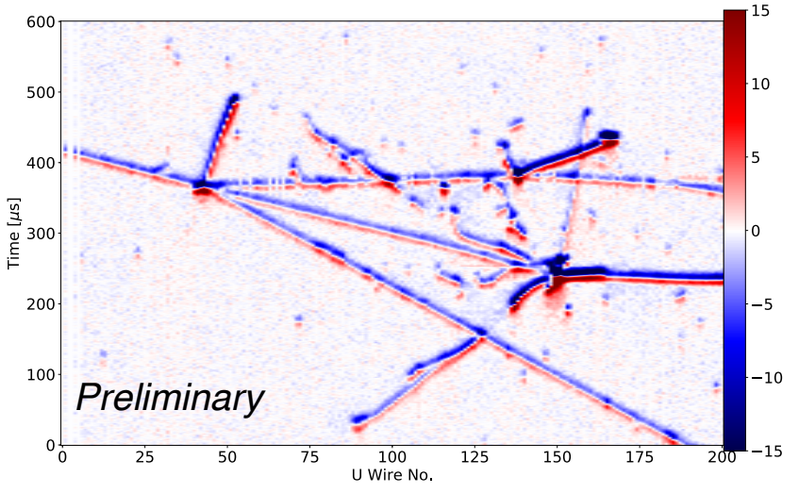


•Noise level measured by pedestal RMS before noise filtering
-Collection: 550 e^-
-Induction: 650 e^-
-Noise filter reduces both by 100 e^-

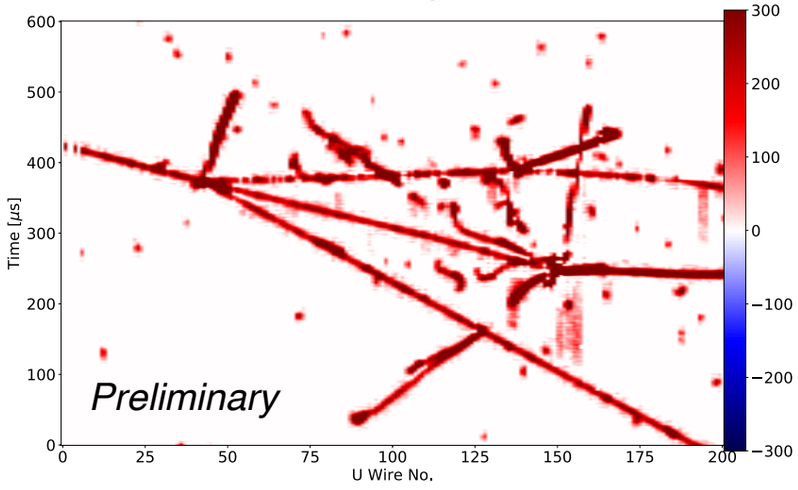
Raw waveform



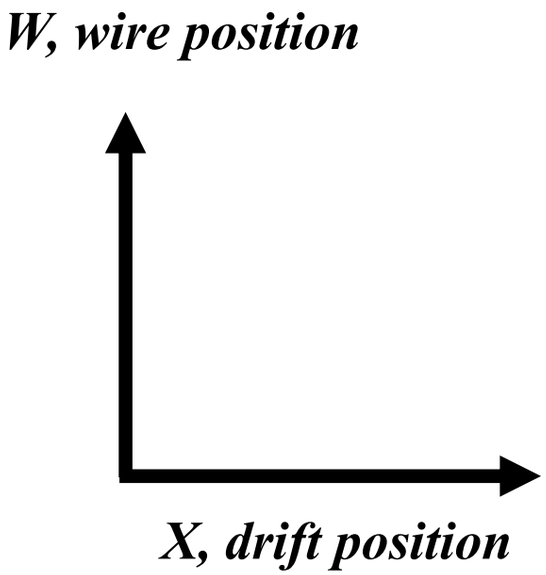
Raw waveform after CNR

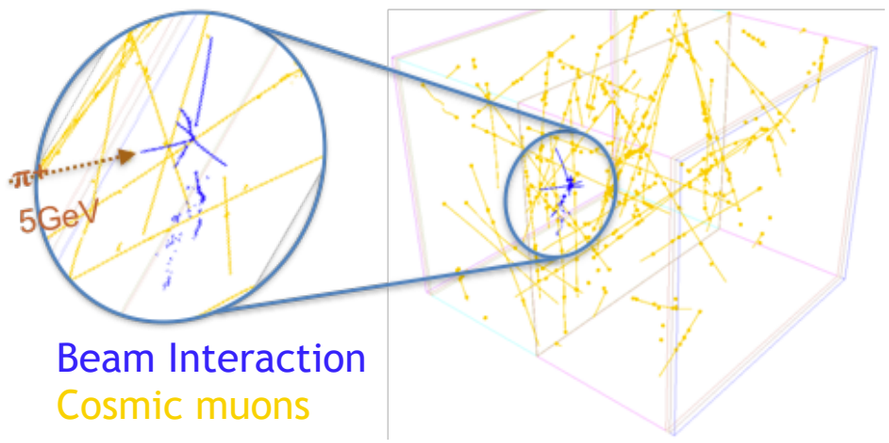


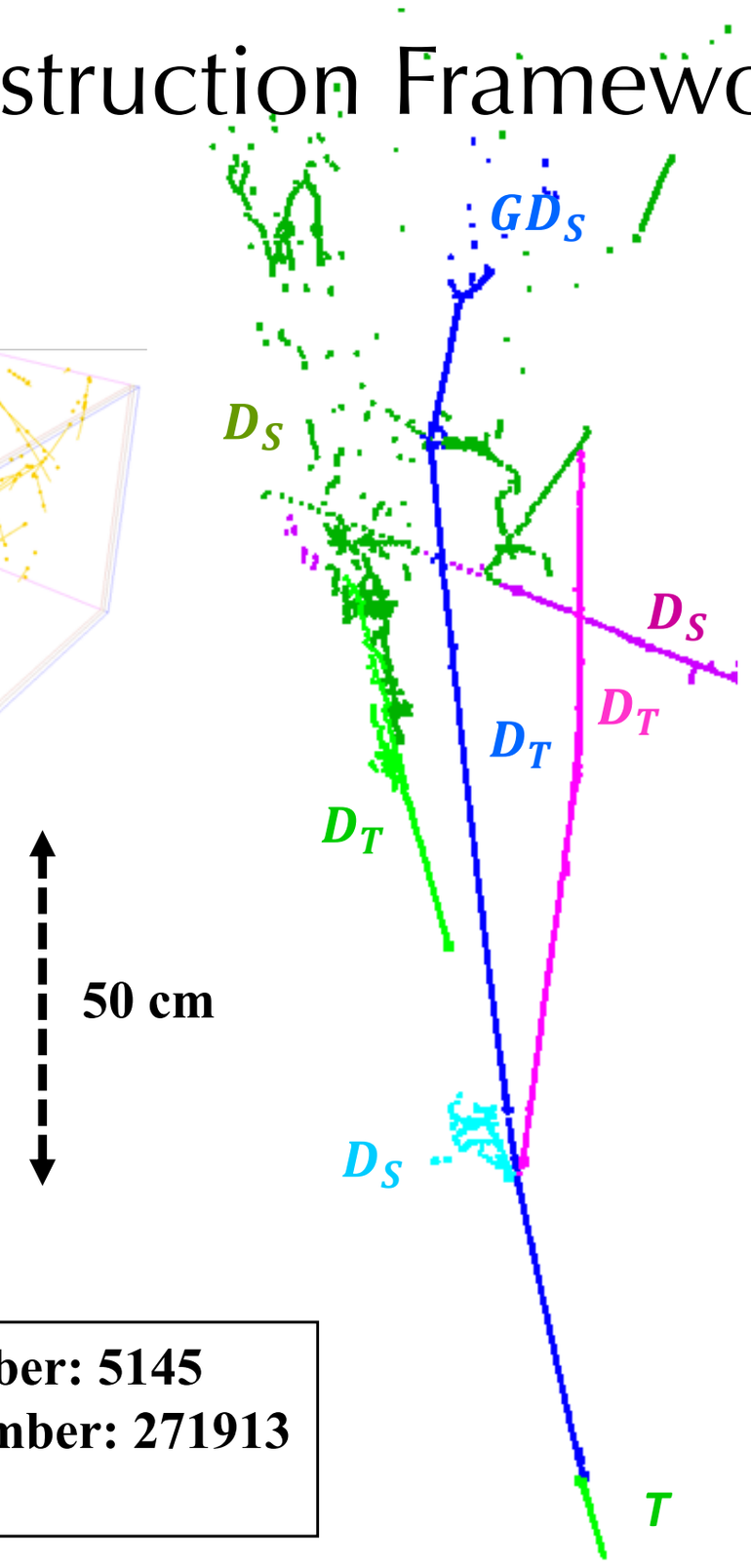
Ionization charge extracted



ProtoDUNE-SP, PANDORA Reconstruction Framework







D_T = Daughter Track
D_S = Daughter Shower
GD_T = Granddaughter Track
GD_S = Granddaughter Shower
T = Trigger Parent Particle (π^+)

Pandora: Eur. Phys. J., C75(9):439, 2015, and Eur. Phys. J., C78(1):82, 2018.

Run Number: 5145
Event Number: 271913
7 GeV

ProtoDUNE-SP – Data

ProtoDUNE-SP, Detector Calibration

- Remove any non-uniformity in the detector response

  Space charge effects (SCE) – removed using E-field map

  Attenuation caused by impurities – removed using muon MIP map

  Variations in electronics gain – removed using pulser data

  Other effects (grounded electron diverters, floating grid plane, etc.) – removed using muon MIP map

- Determine the absolute energy scale

  Using stopping muons

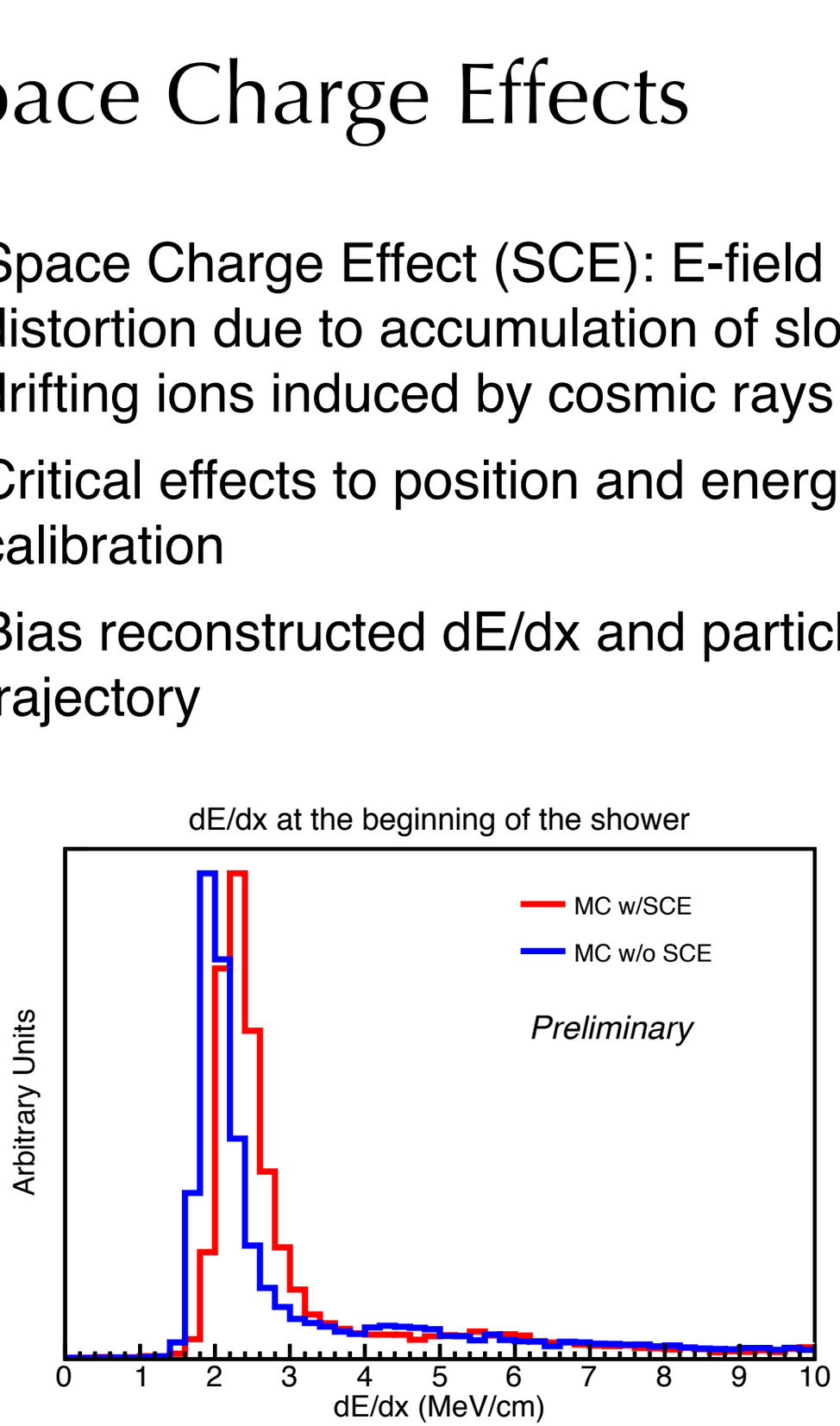
  dE/dx in the MIP region is very well understood theoretically to better than 1%

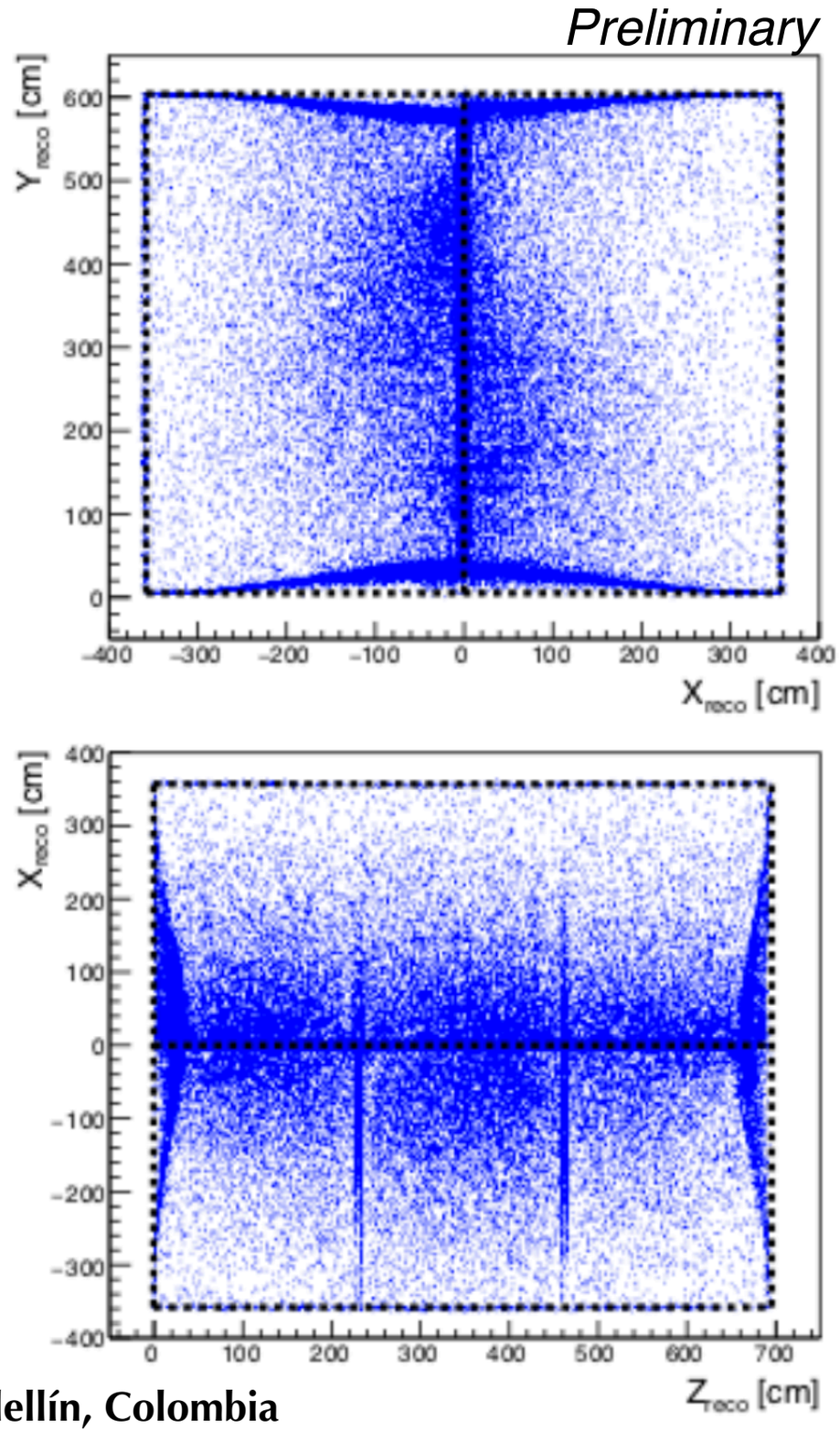
Space Charge Effects

Space Charge Effect (SCE): E-field distortion due to accumulation of slow drifting ions induced by cosmic rays

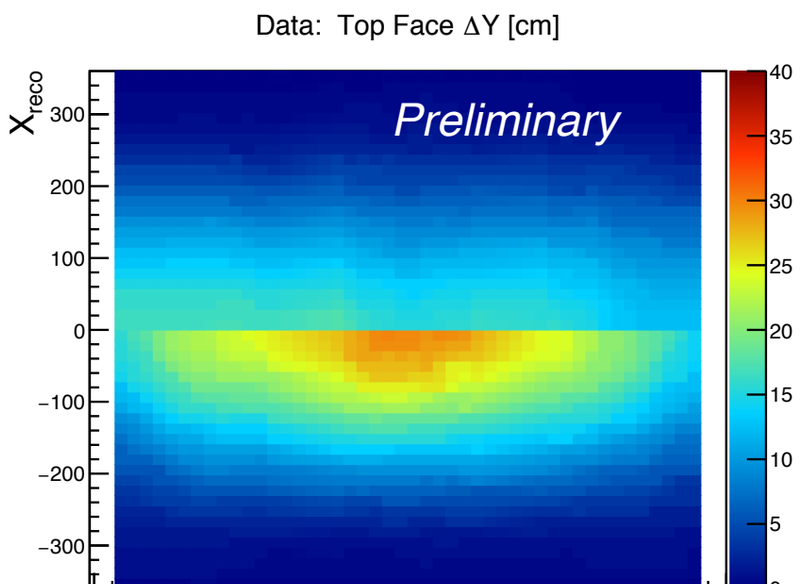
Critical effects to position and energy calibration

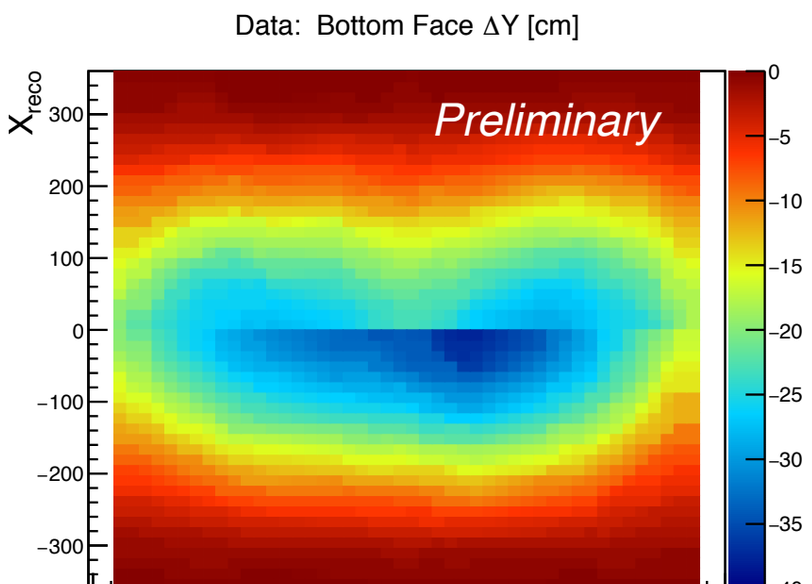
Bias reconstructed dE/dx and particle trajectory

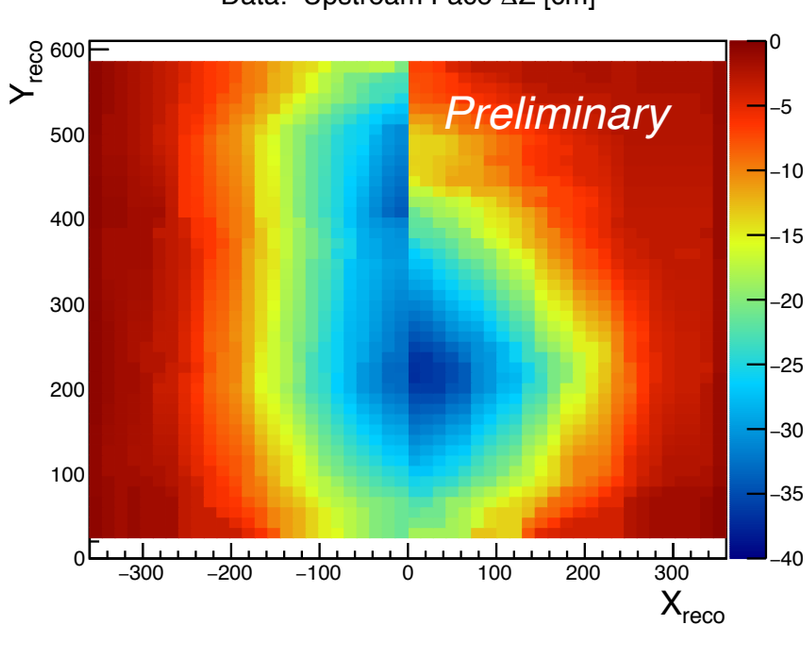


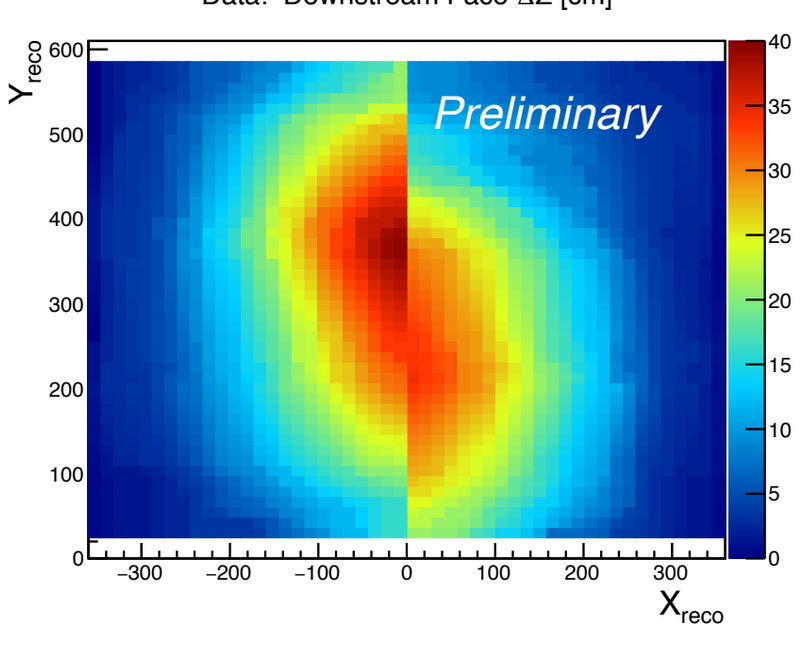


Space Charge Effects



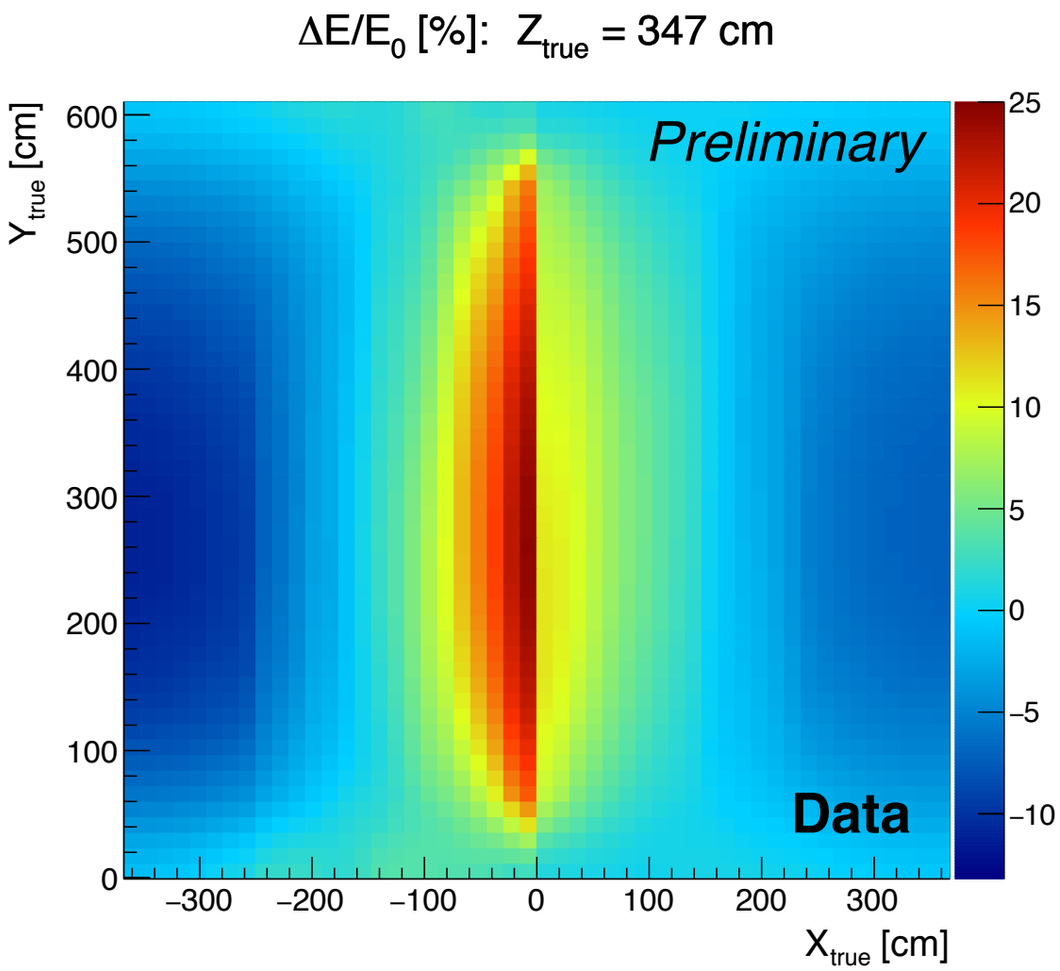






Look at spatial offsets of TPC in data

Space Charge Effects

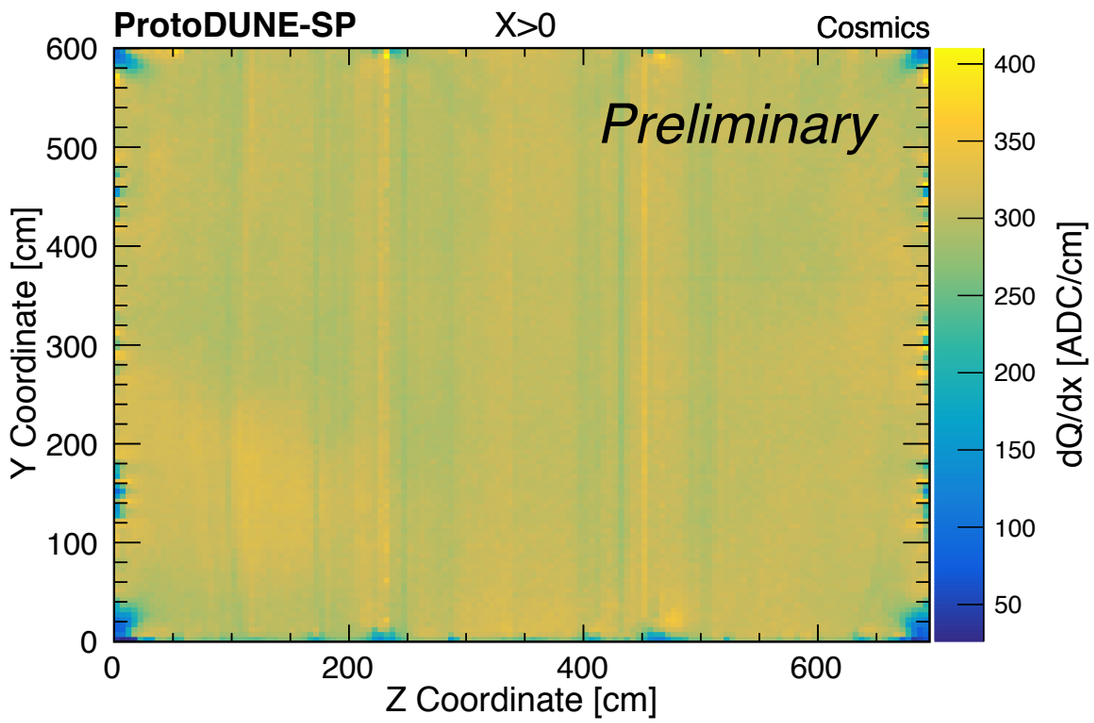


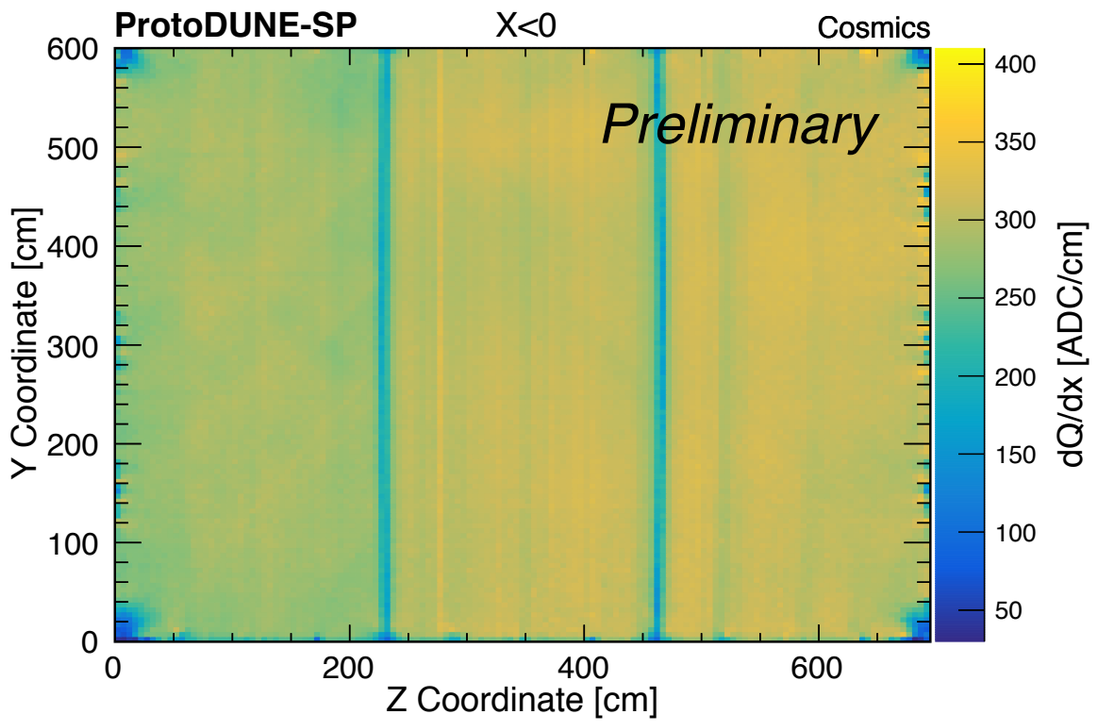
Straightforward to calculate E field distortions everywhere in detector with measured spatial offsets

Nearly 25% higher E field near cathode than nominal E field

Finally once we taking into account SCE we can correct them and continue with the calibration procedure

ProtoDUNE-SP, Detector Calibration





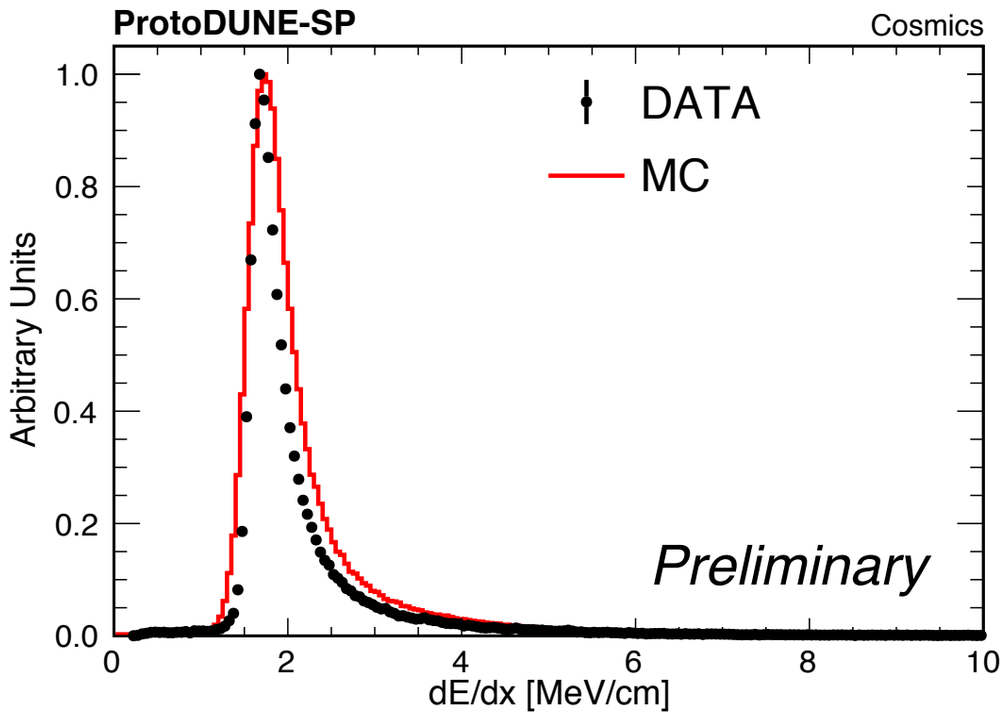
Attenuation caused by impurities – removed using muon MIP map

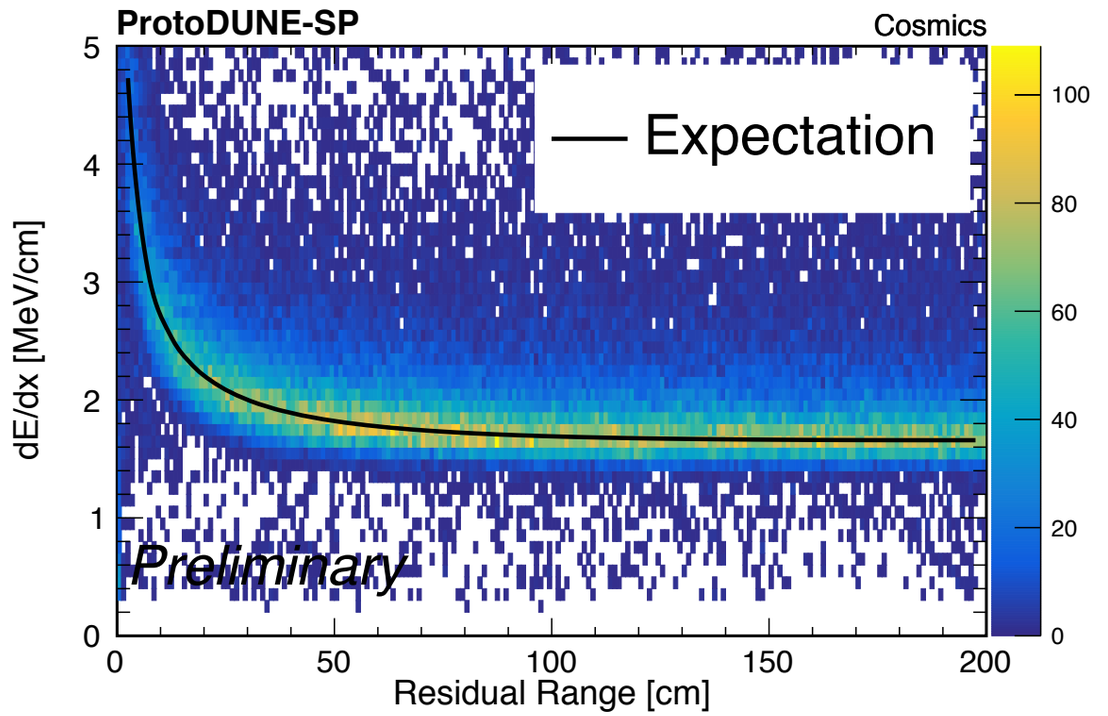
Variations in electronics gain – removed using pulser data

Other effects – removed using muon MIP map

Determine the absolute energy scale

ProtoDUNE-SP, dE/dx Reconstruction

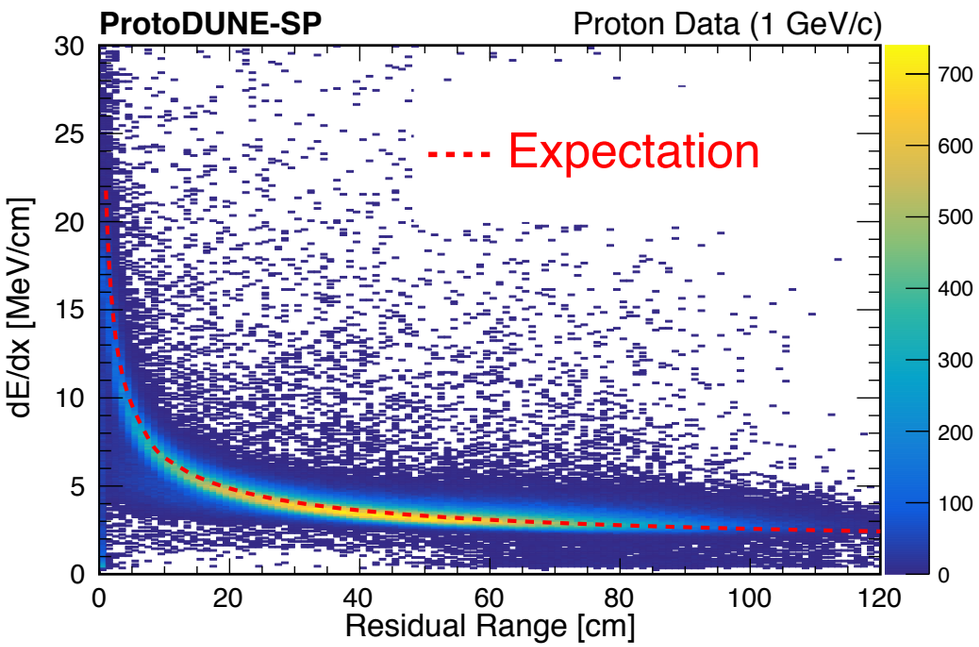


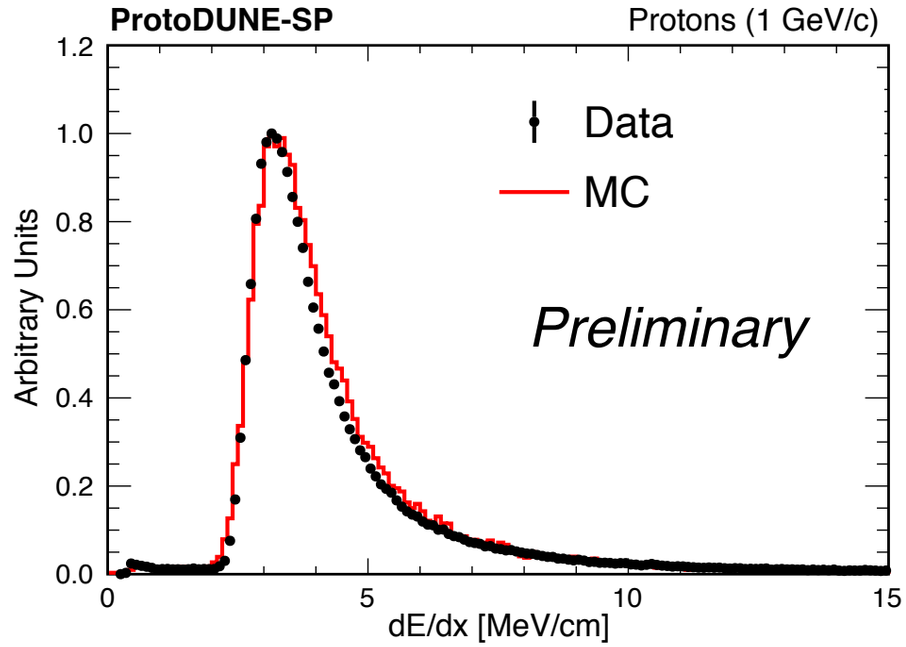


Use muon dE/dx at high residual range for absolute energy scale

After calibration, good agreement between data and simulation for cosmic muon dE/dx

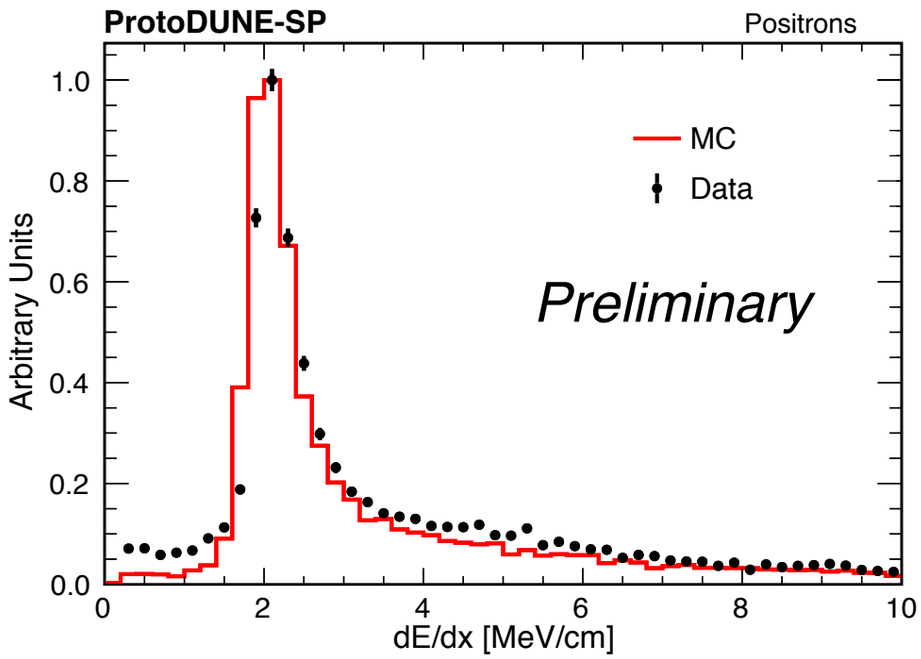
ProtoDUNE-SP, dE/dx Reconstruction





Same calibration applied to beam positrons and protons

dE/dx distribution sees very good agreement between data and simulation

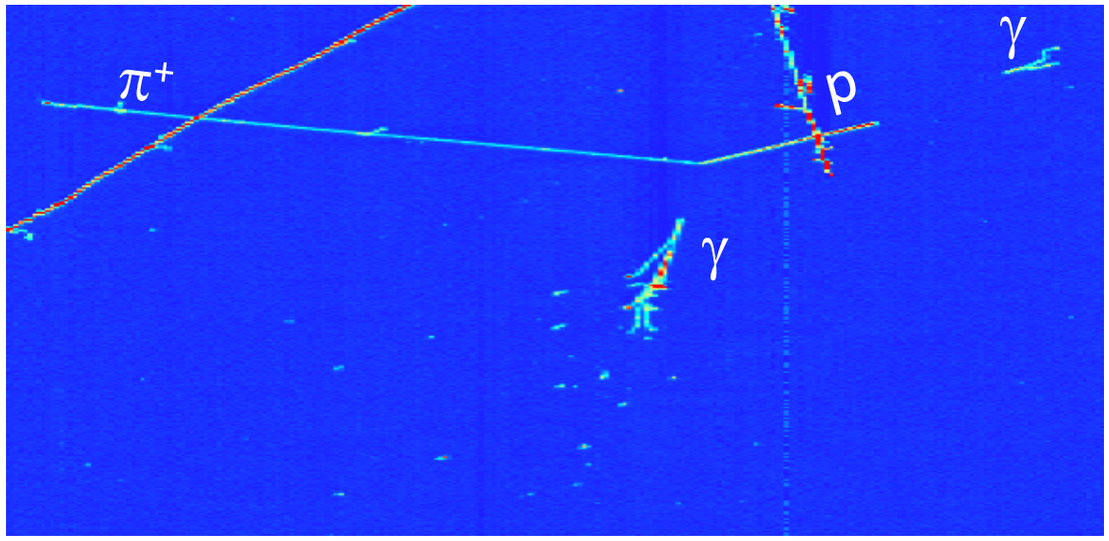


ProtoDUNE-SP, Future Analyses

-Provide input to DUNE to improve the final state interaction models

Inclusive and exclusive cross section measurements 1-7 GeV/c

E.g. the charge exchange process $\pi^+ + Ar \rightarrow Ar^* + p + \pi^0$ is an important background to the ν_e signals



Validate the GEANT simulation of hadron interactions in LAr

EM-Shower characterization using positrons and gammas from pi-zeros

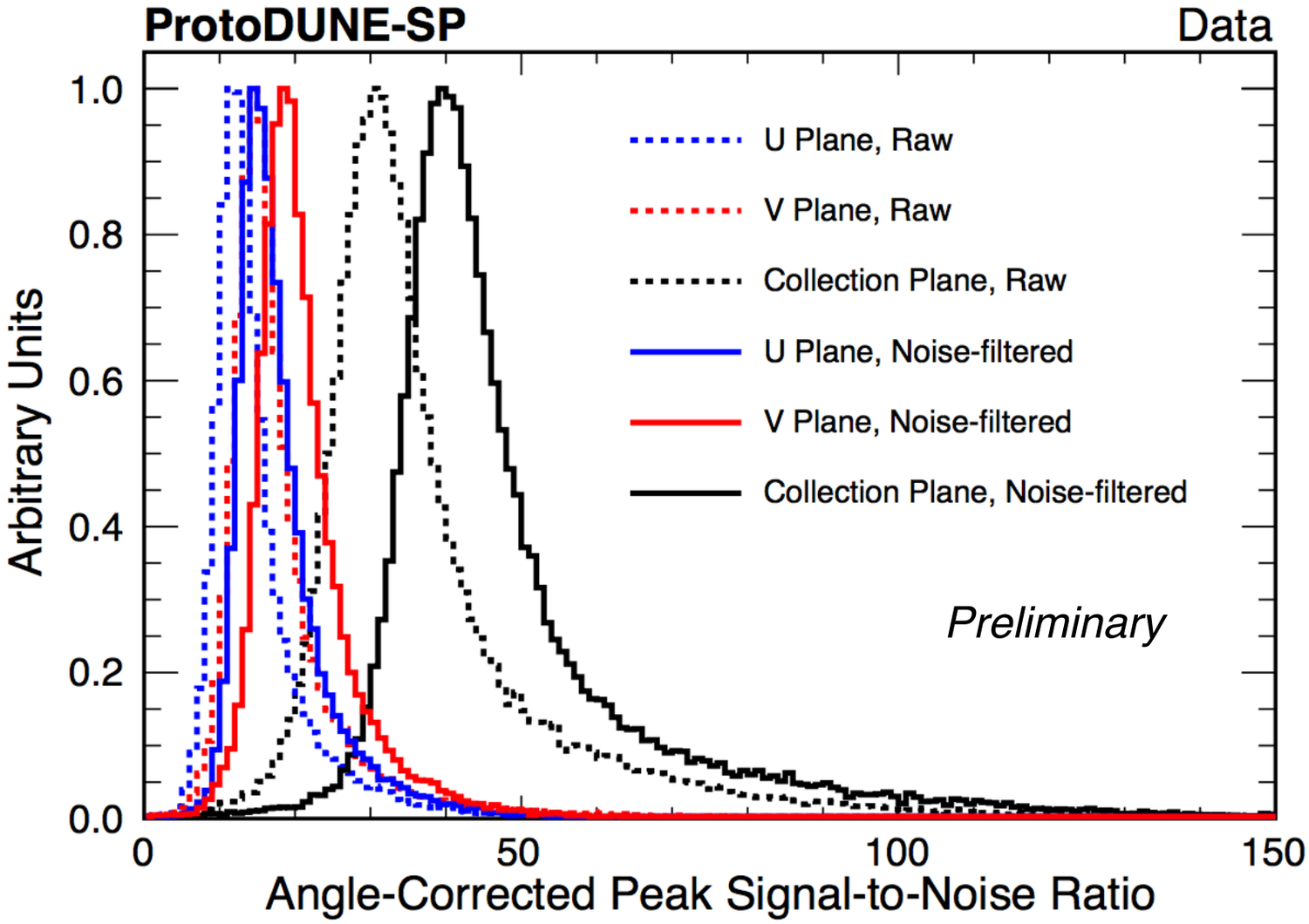
Summary

- ProtoDUNE-SP program a step forward to the success of 1st far detector module in DUNE
- ProtoDUNE-SP data quality demonstrates excellent detector understanding and performance
- Technical detector performance papers under preparation
- Working on physics measurements, which will provide valuable information to DUNE
- ProtoDUNE-SP continues to take cosmic data
- ProtoDUNE-DP operations begun on August 2019, it will take beam data following commissioning run

Thanks for listening

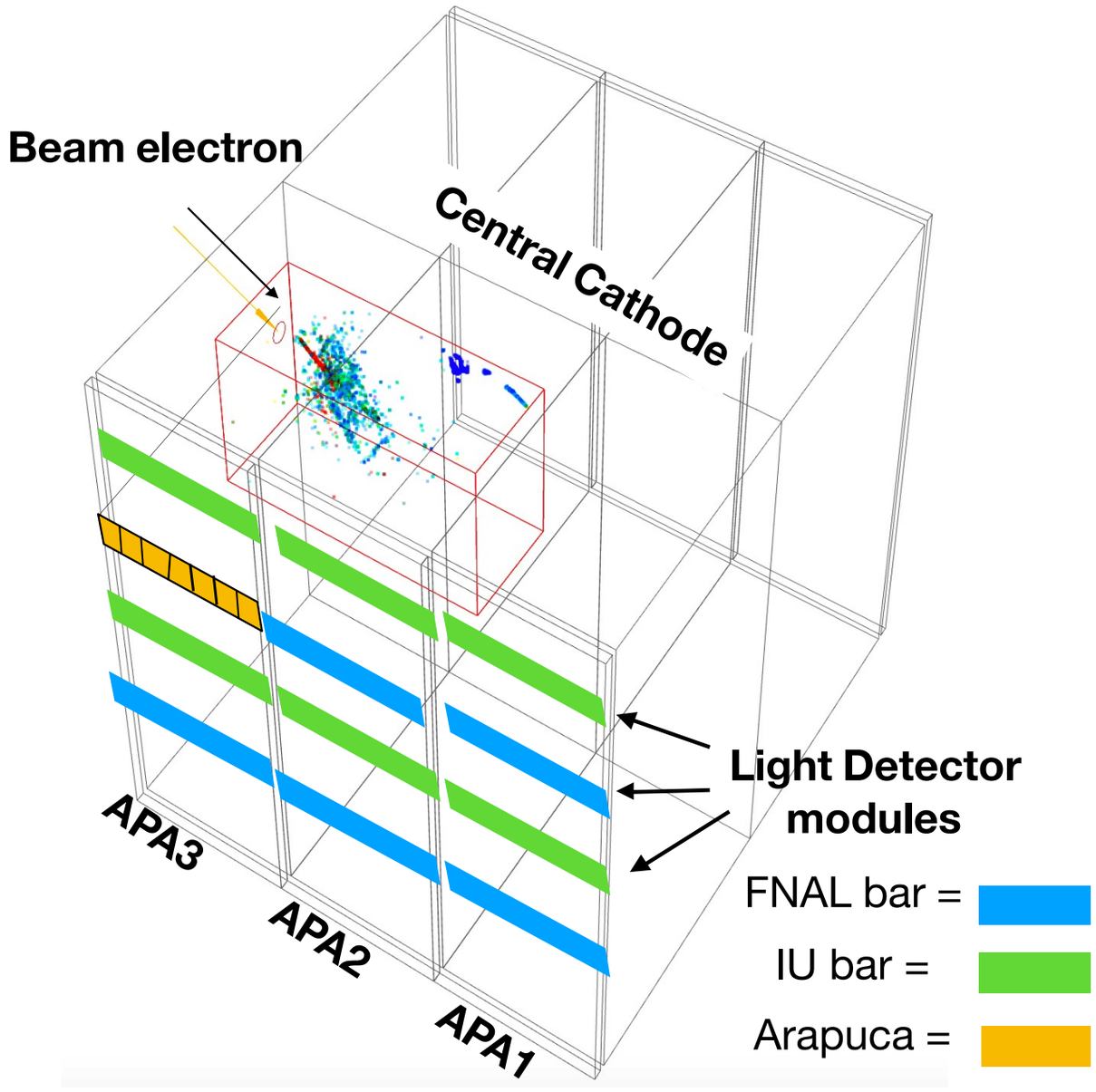
Extras

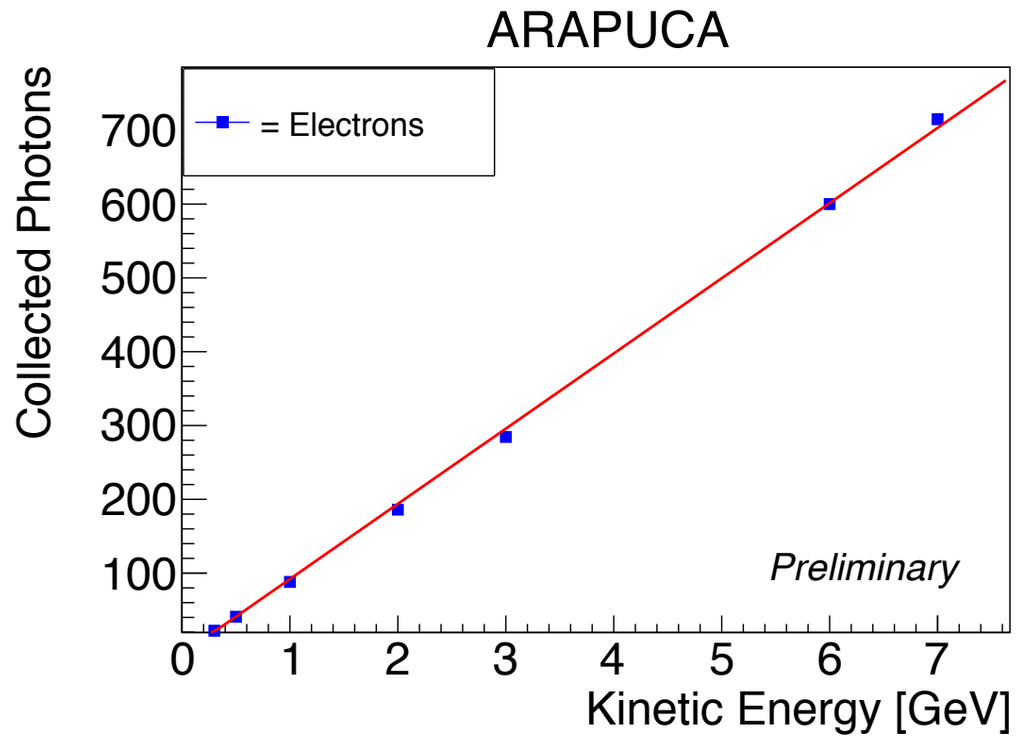
ProtoDUNE-SP, Photon Detector Response



Signal-to-noise ratio measured by cosmic muons

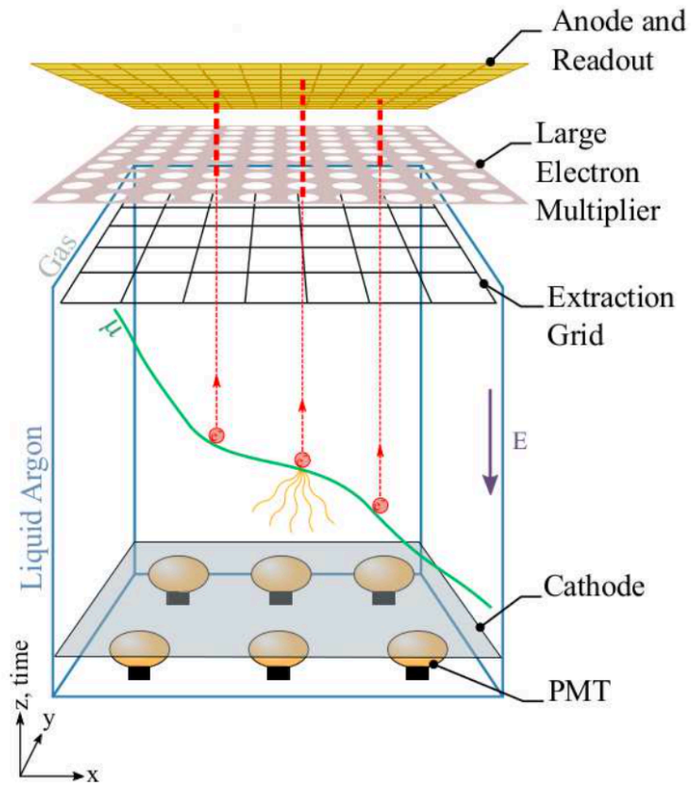
ProtoDUNE-SP, Photon Detector Response

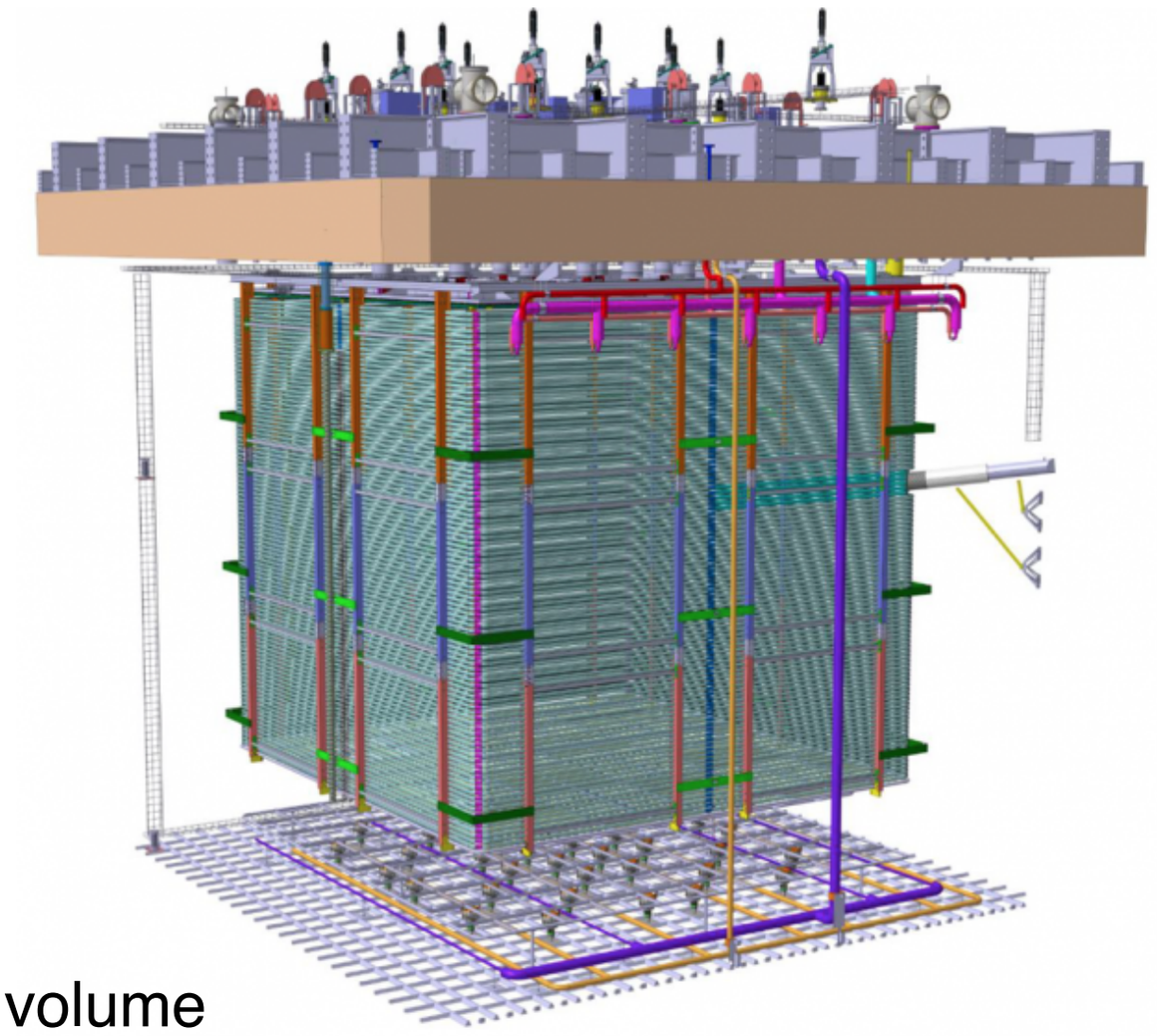




- Achieve energy linearity for beam electrons contained in the detector
- Not corrected for geometry and detection efficiency

ProtoDUNE-DP

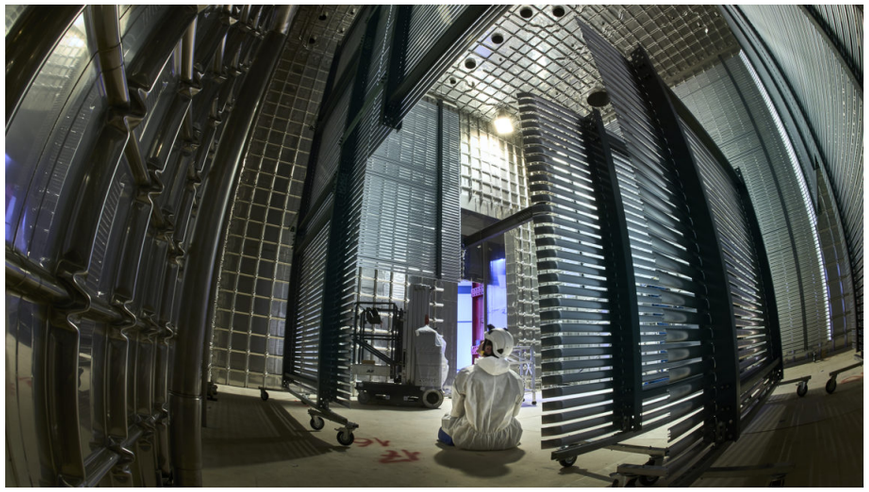


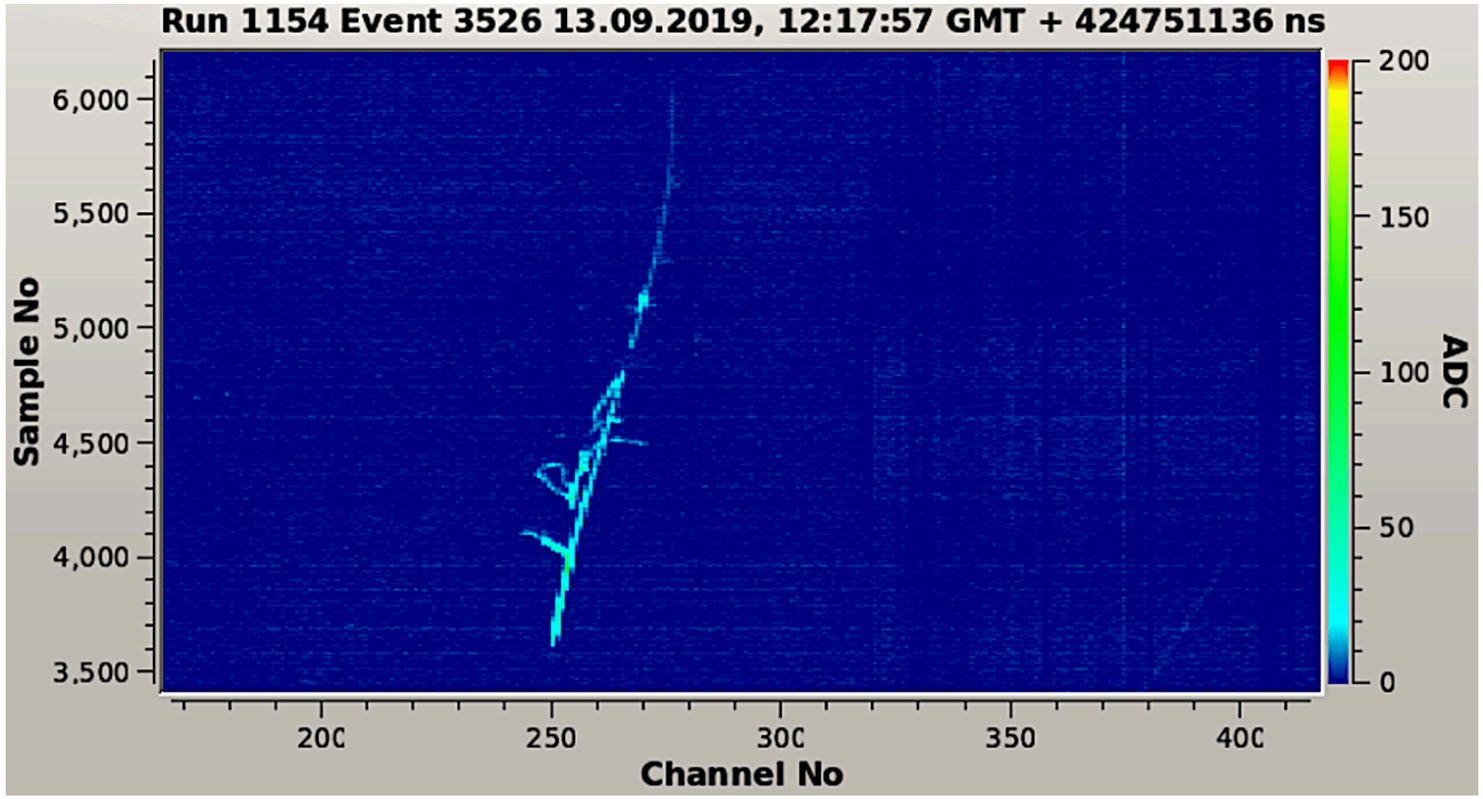


Electrons extracted from LAr to gaseous volume

- Signal amplified by Large Electron Multiplier (LEM) in gas phase
- Charge collected and recorded on 2-D segmented anode
- Drift distance: 6 m (vertical)
- Accessible electronics, better Signal/Noise
- Photon detectors: PMT below cathode

ProtoDUNE-DP





Track made by a cosmic-ray muon observed in the dual-phase ProtoDUNE detector. The ionization released by the muon track in liquid argon