A Journey of LArTPC Technology

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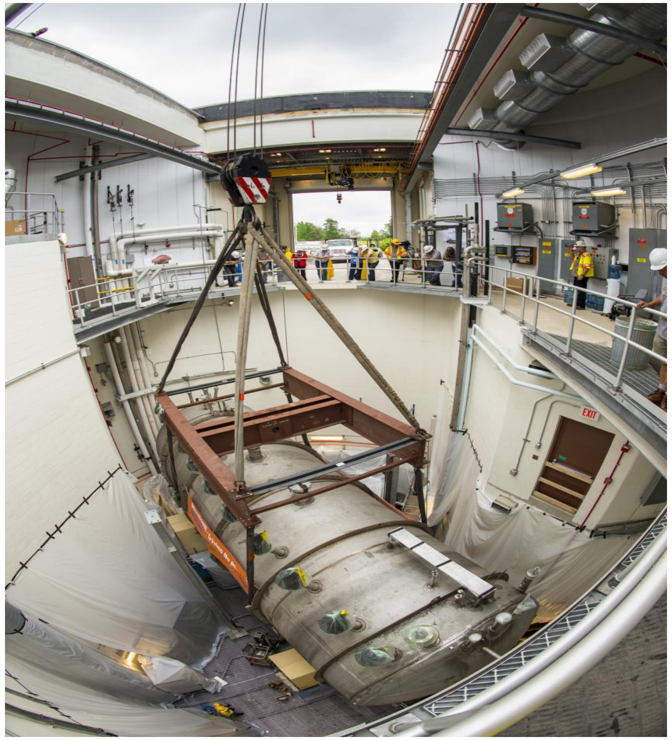
December 4, 2018

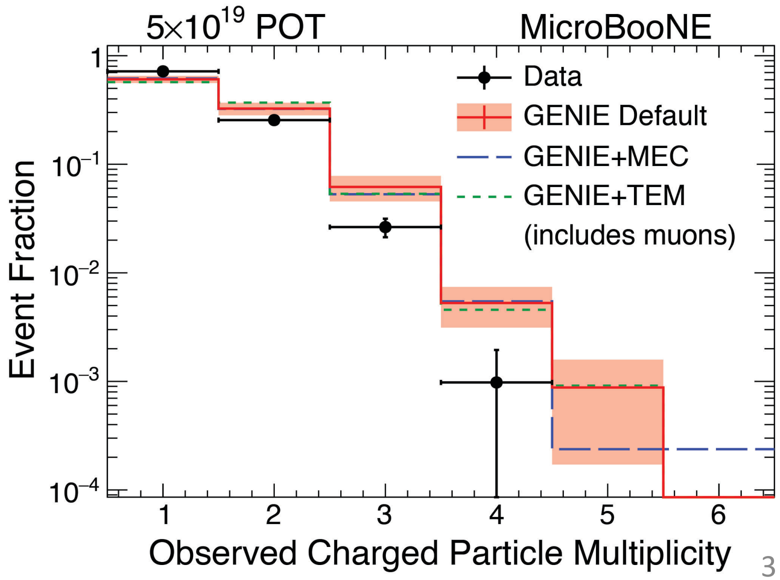
Accelerator based neutrino experiments

- Mostly ν_μ from accelerators
- Long and short baseline experiments
  - **Long baseline:** Detectors located far away from the source, assisted by a similar detector at a short distance (e.g DUNE: 1300km, NOvA: 810km)
    - Compare the flux measured in the near detector with that in the far detector
  - **Short baseline:** Detectors located at a close distance from the source (MicroBooNE: 470m, SBND: 110m)
    - Require a good understanding of the beam flux. Better if only one neutrino specie is present

A bit about my work history

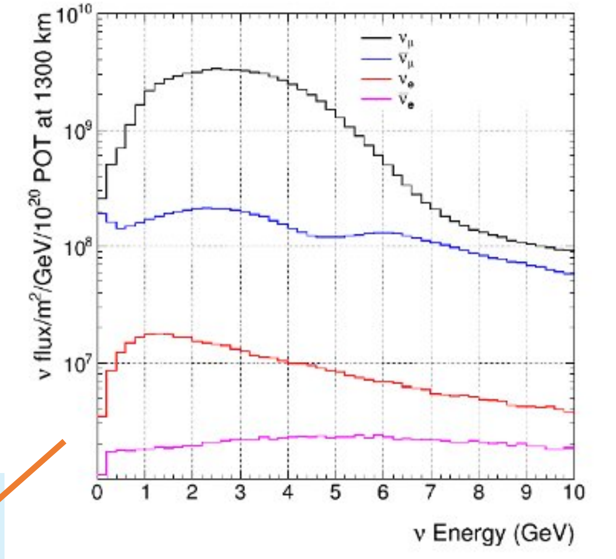
- PhD from Kansas State university, worked on MicroBooNE a LArTPC detector
- MicroBooNE:
  - 1st large scale operational LArTPC in the US
  - Studies short baseline neutrino oscillations
  - Worked on detector monitoring and stability
  - Also wrote the first physics paper from the collaboration
    - Charged particle multiplicity: http://news.fnal.gov/2018/05/microboone-measures-charged-particle-multiplicity-in-first-neutrino-beam-based-result/
- Started as Argonne neutrino group postdoc on Aug 6th, 2018
  - Working on DUNE, ProtoDUNE, and NOvA





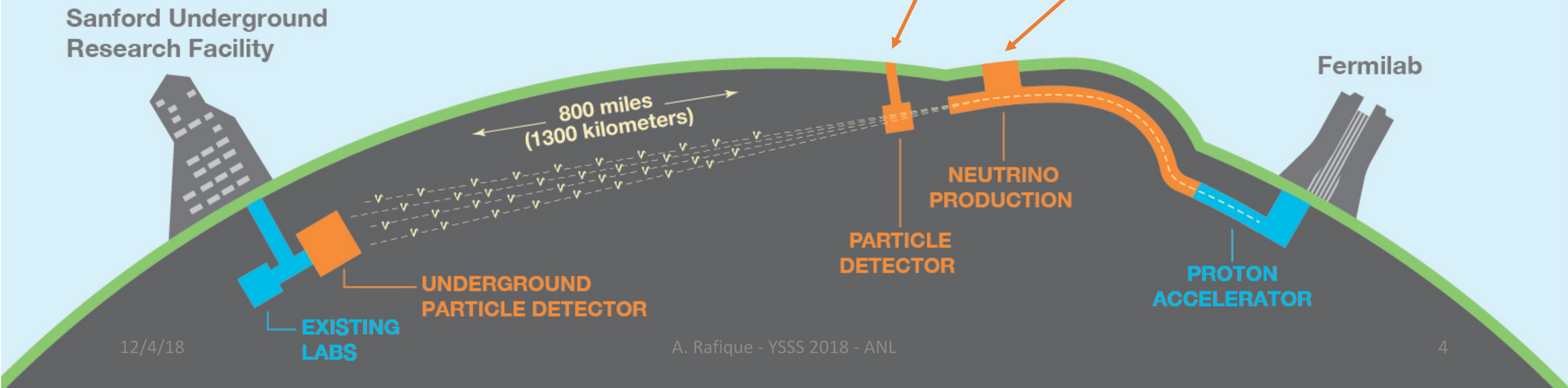
To the future: DUNE

- Leading-edge, international experiment for neutrino physics and proton decays studies
- 1100+ collaborators, 178 institutions, 32 countries
- Begin taking data in 2024
- 1300 km baseline
- FD: 4 LArTPCs, 40 kton fiducial volume



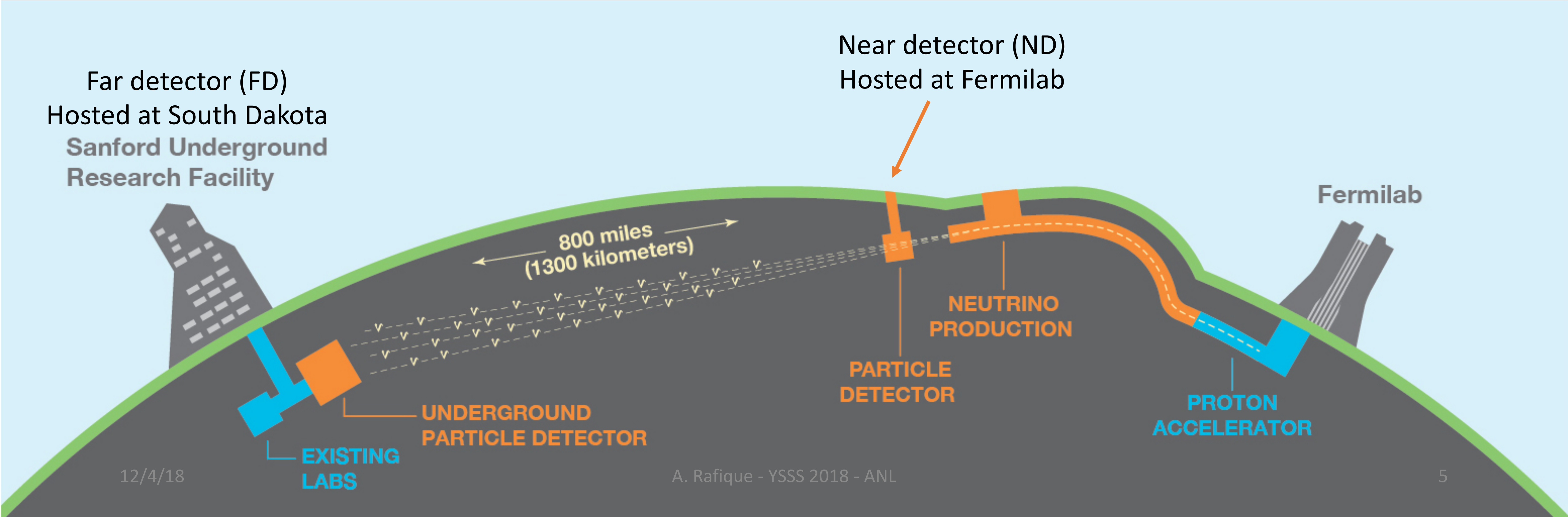
Far detector (FD)
Hosted at South Dakota

Near detector (ND)
Hosted at Fermilab



DUNE physics goals

- Precise measurement of neutrino oscillations parameters (ν_μ/ν_μ disappearance, ν_e/ν_e appearance), in particular δ_{CP} violation phase
- Detection of galactic-core supernovae neutrinos
- Proton decay, especially in the K-production modes ($p \rightarrow K^+\nu$; $p \rightarrow K^0\mu^+$; $p \rightarrow K^+\mu^-\pi^+$)
- Search for NSI (Non Standard Interactions)



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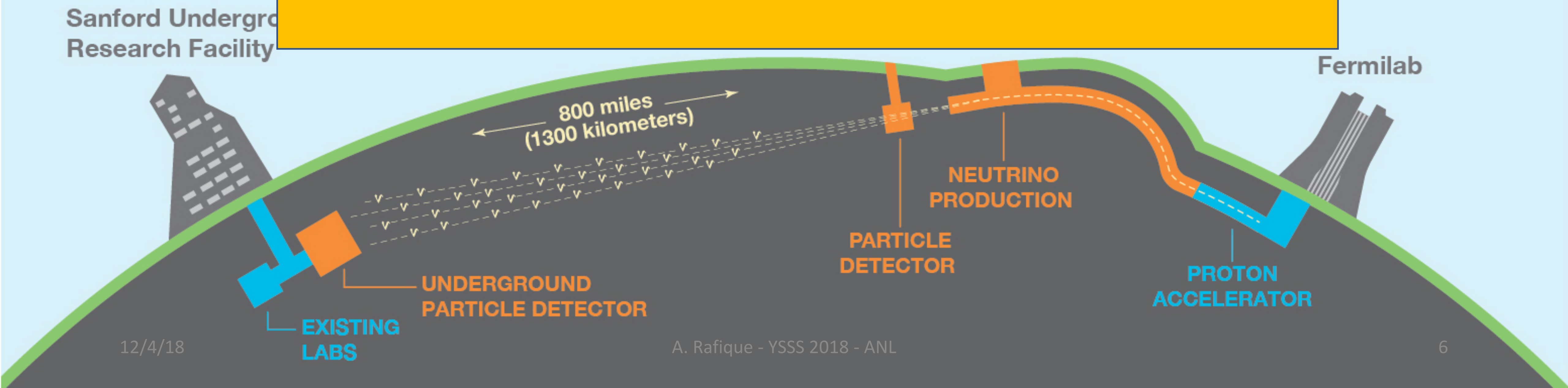
These goals require

- An excellent understanding of LArTPC technology
- Careful characterization, calibration, and reconstruction of the physics measurements
- Development of people expertise and analysis software framework

ProtoDUNE does the job!!!

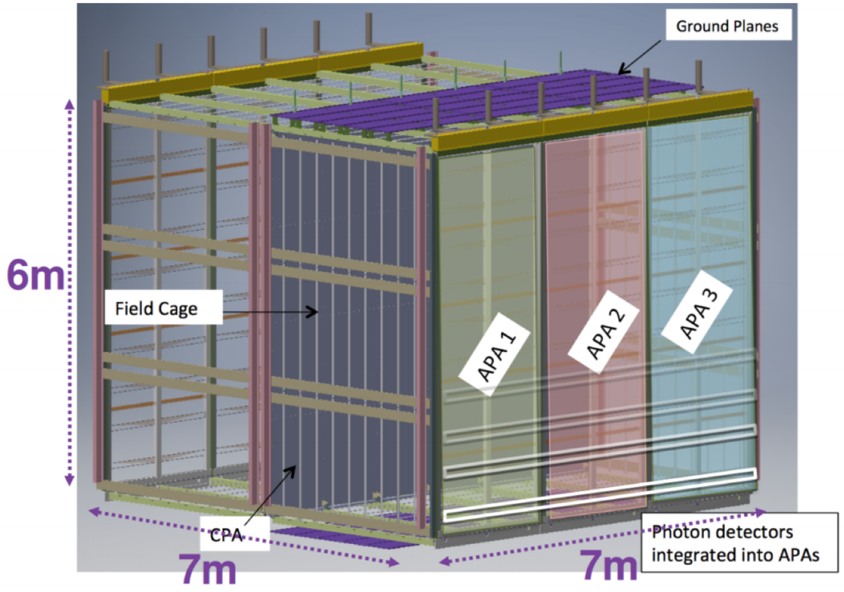
Far detector (FD

Hosted at South Da

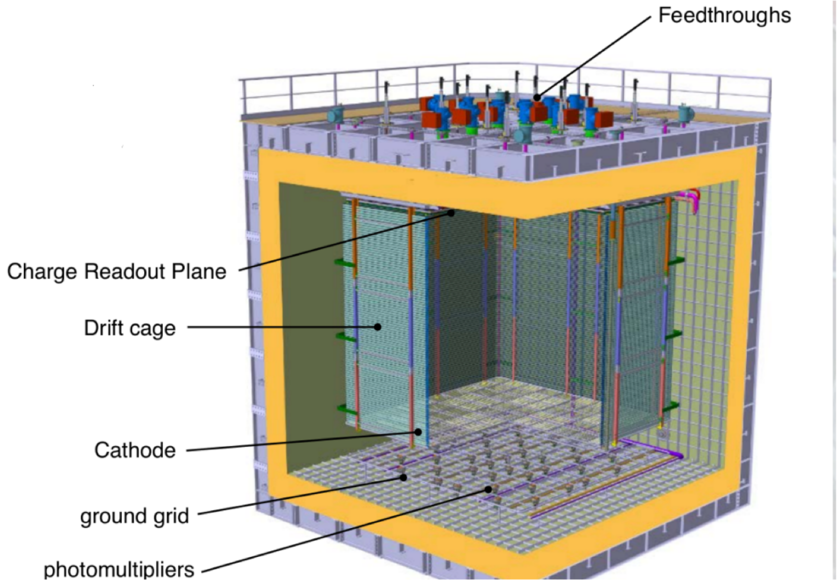


ProtoDUNE

- Two identical cryostats ~12m x 12m x 11m dimensions, holding ~800 to of LAr each operated at the CERN Neutrino Platform facility
- Two similar technologies
  - "single-phase (SP)" LArTPC – planned for the first DUNE FD module
  - "dual-phase (DP)" LArTPC – for the later modules
- Exposed to two independent low energy charged particles beams (1 - few GeVs)



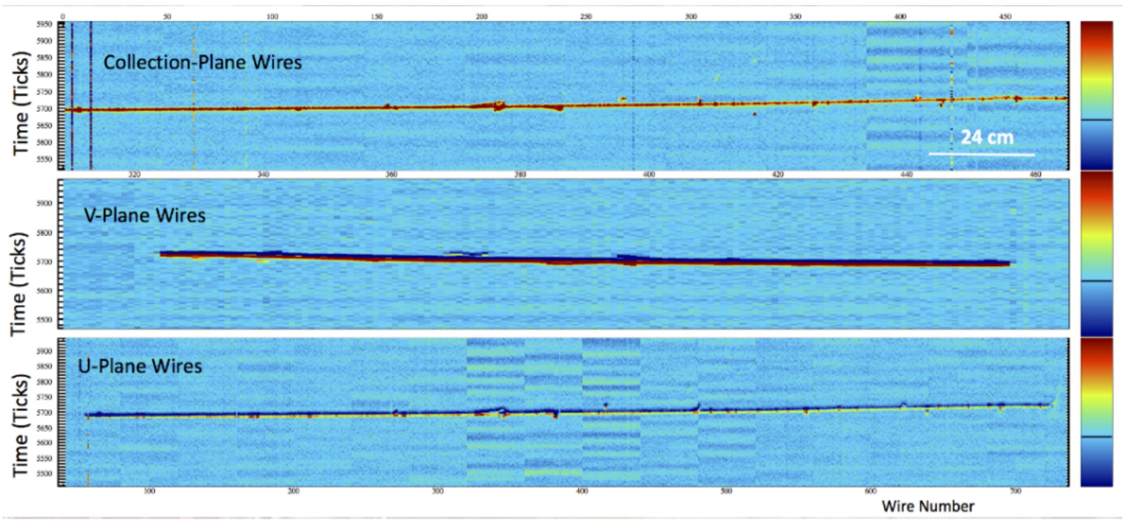
Single phase LArTPC: No signal amplification in liquid

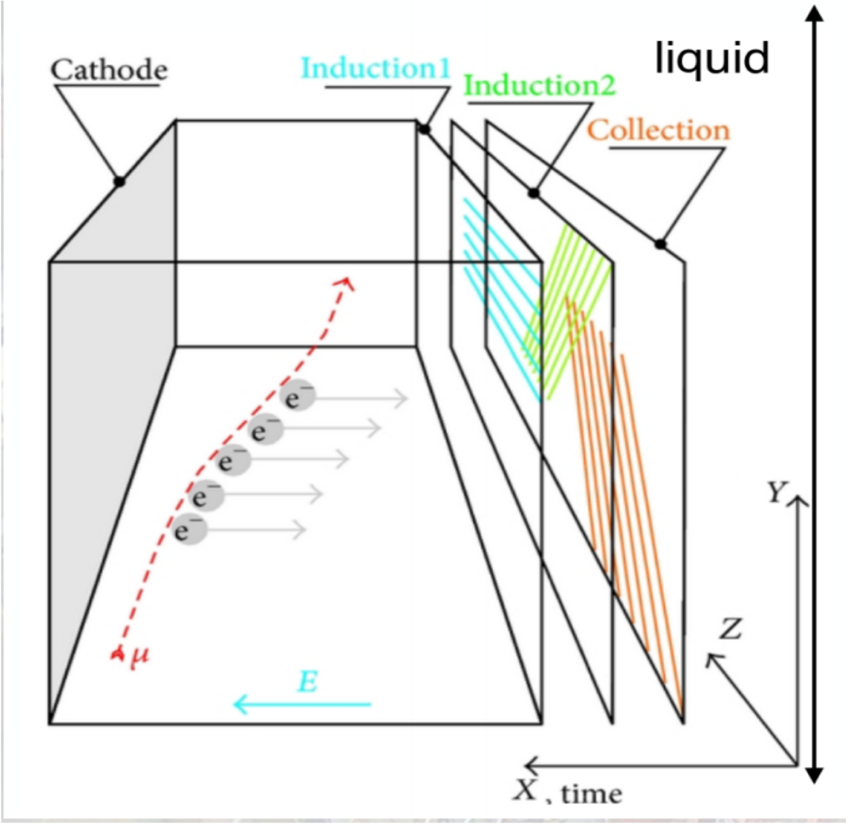


Dual phase LArTPC: drift in liquid, amplification in gas

How ProtoDUNE- SP works

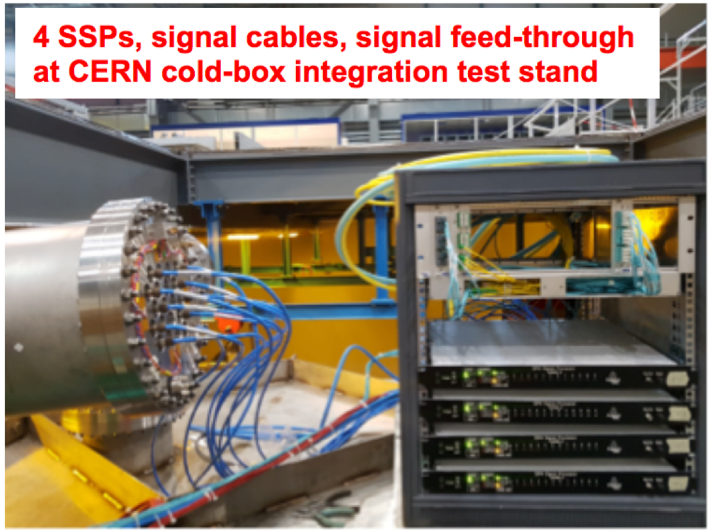
- Ionization charges drifted horizontally and read out by a set of 3 wire planes for 3D reconstruction and calorimetry
- LAr scintillation light collected by photon detection system behind wire planes for event triggering
- No signal amplification in liquid

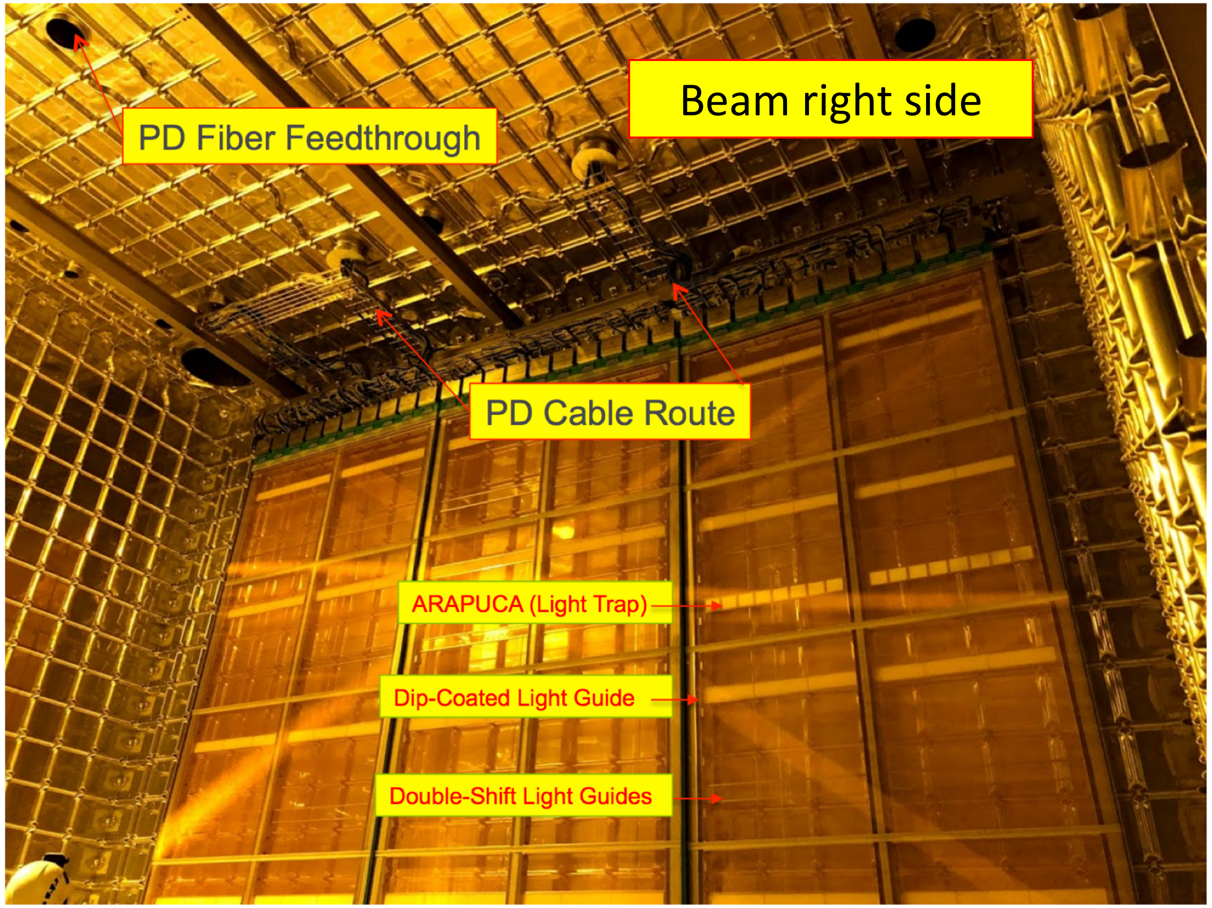




Photon Detector Modules inside APA

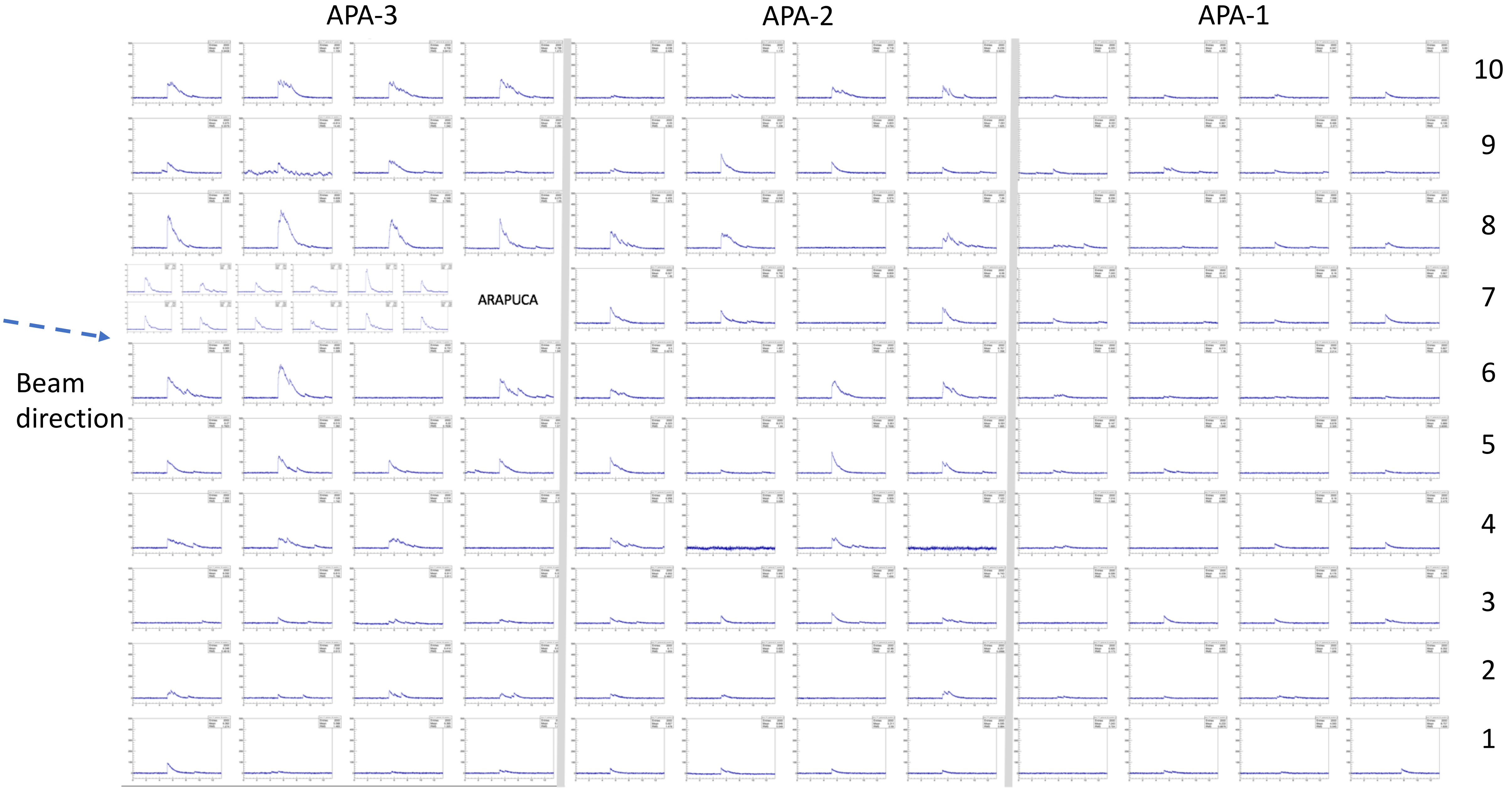
- For photon-detector readout system, 24 SiPM Signal Processor (SSP) units were produced at ANL to read out the 58 light guide and 2 ARAPUCAs photon collectors in final ProtoDUNE
  - 4 SSPs per APA





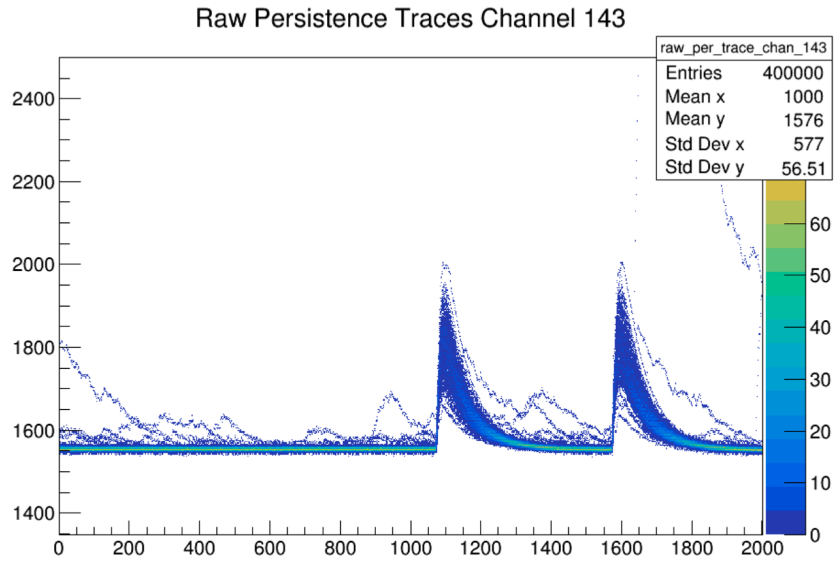
arXiv:1807.10327

Photon Detector Event



PD Calibration

- 5 diffusers on each side of the CPA
- UV-light system fabricated and installed to monitor health of the system, and to calibrate PDS gain and time resolution
- Calibration light pulses set by amplitude and pulse width, as a single pulse or as pulse pair
- We are now able to trigger the calibration modules
    - Soon going to integrate calibration module into the detector system



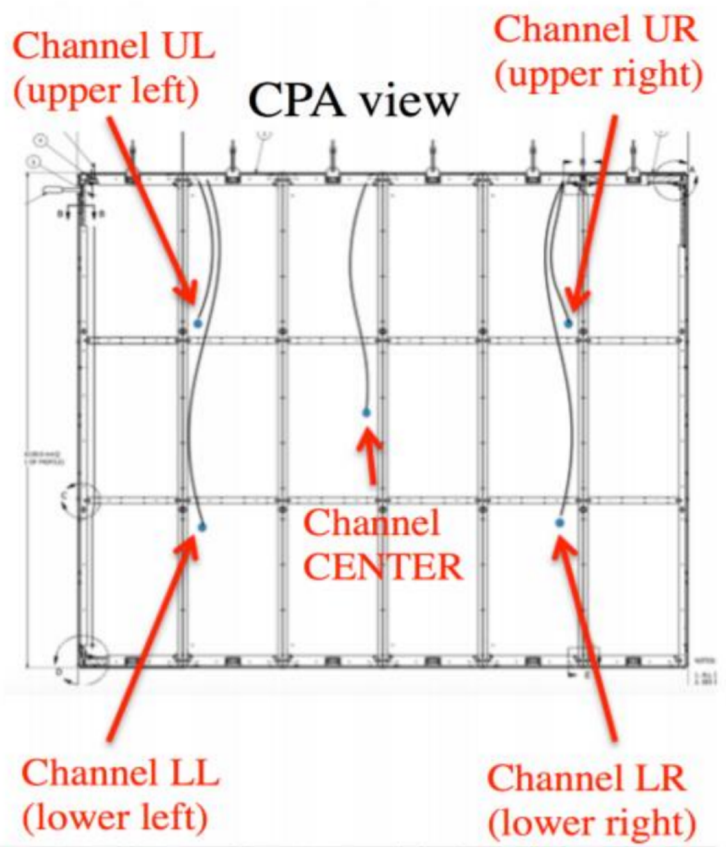


Figure 2: An CPA view from APA, with five light diffuser locations.

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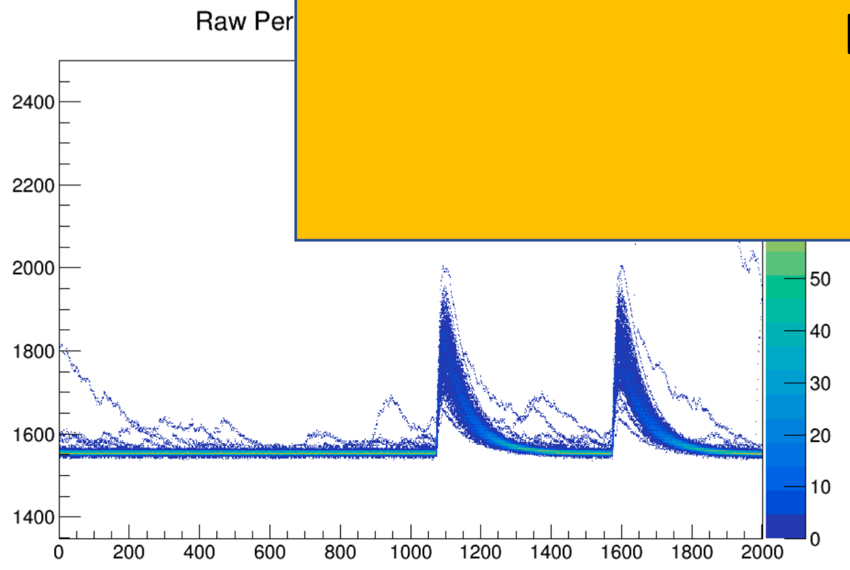
We are able to observe the calibration pulses in ARAPUCA (PD modules that will be used in DUNE)



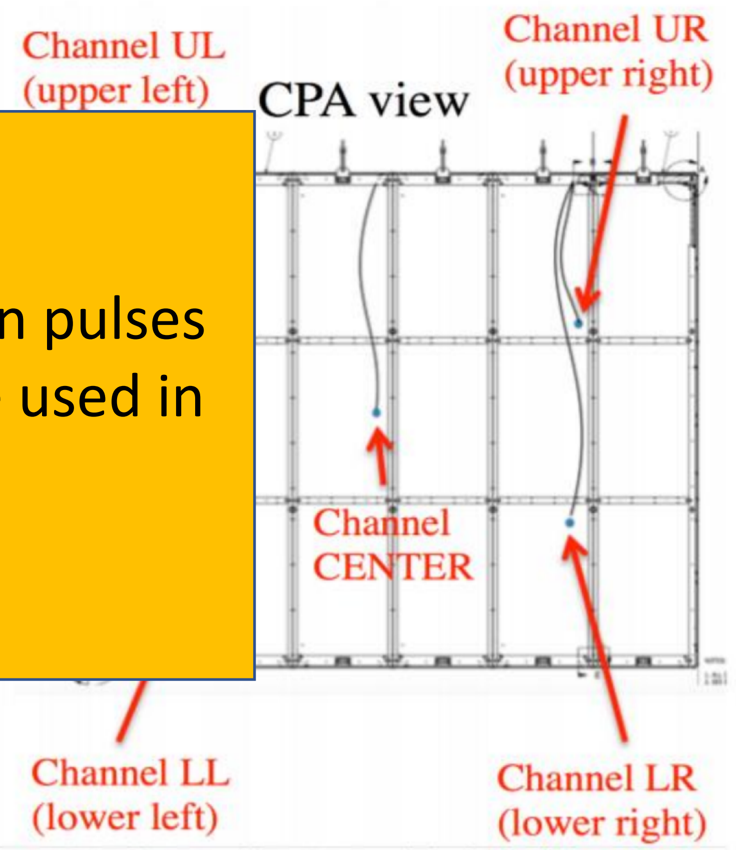
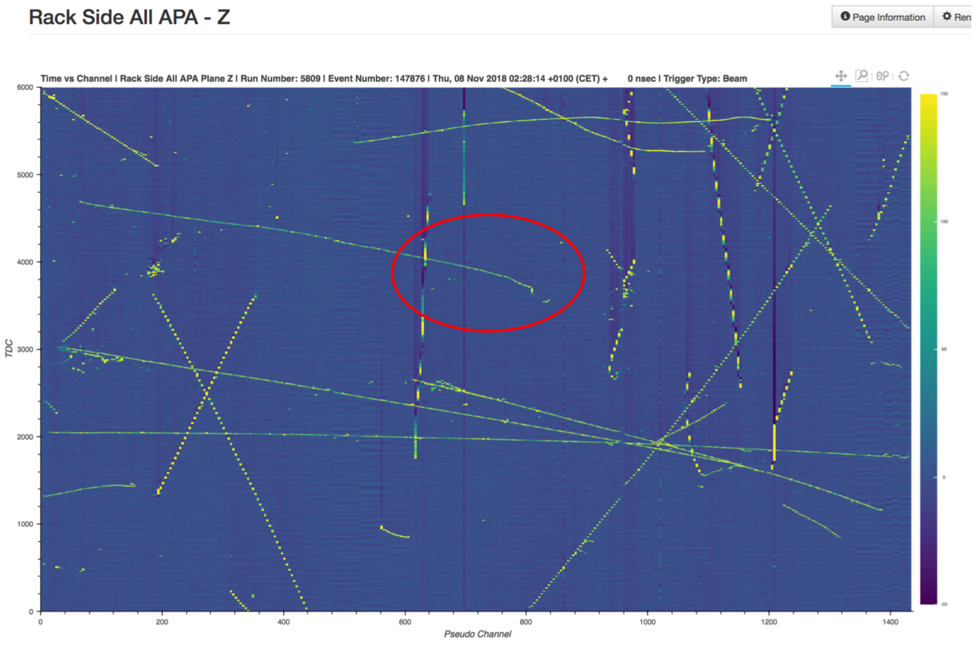


Figure 2: An CPA view from APA, with five light diffuser locations.

Future Plans

- Physics analysis: Look for michel electrons in ProtoDUNE
  - Michel electrons are produced by the decay-at-rest of cosmic-ray muons that come to a stop in the LArTPC
  - This will help us understand the electron low energy reconstruction
  - Help us distinguishing CCQE from non-CCQE interactions



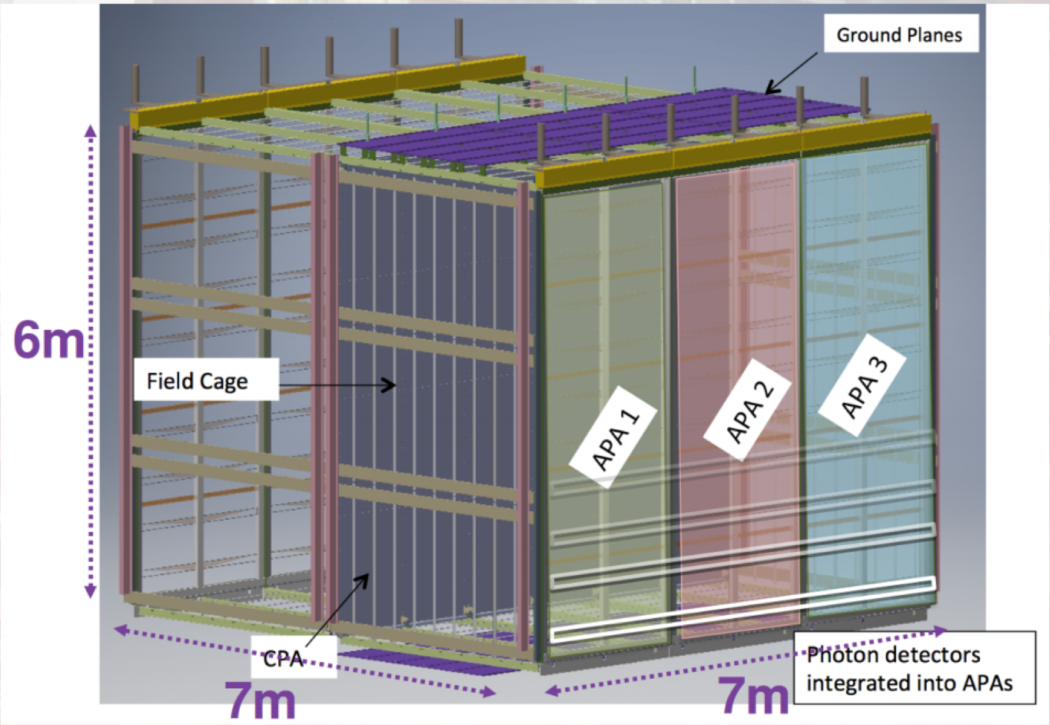
Thank you

Backup Slides

ProtoDUNE-SP overview

2 TPCs 6 m high, 7 m wide, 3.6 m deep, sharing the cathode

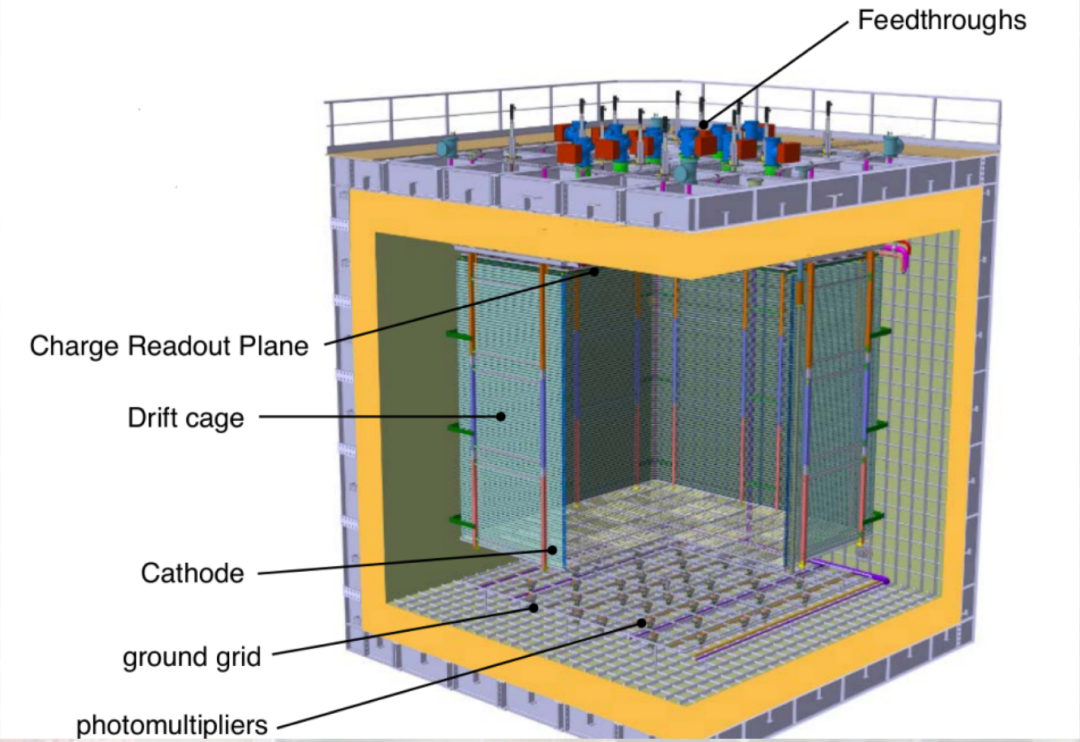
- ***6 Anode Plane Assembly***
  - ✔ 4 wire planes installed on SS frame
  - ✔ Cold electronics (preamplifier+digitizer) installed on the APA top
- ***3 Cathode Plane Assembly***
  - ✔ Resistive Kapton laminated on dielectric panels
  - ✔ 180 kV nominal (3.6 m drift @ 500 V/cm): **same as for DUNE FD**



- ***16 Field Cages***
  - ✔ Aluminum profiles on dielectric frame, provides constant 500 V/ cm electric field
  - ✔ Top and bottom elements equipped with perforated SS ground planes to ensure null field outside active volume
- ***60 Photon Detectors***
  - ✔ Light collecting bars read out by SiPMs installed in the APA frame (10 detectors/APA)
  - ✔ high coverage with small number of channels, no HV needed
  - ✔ 3 distinct versions installed → testing solutions for DUNE

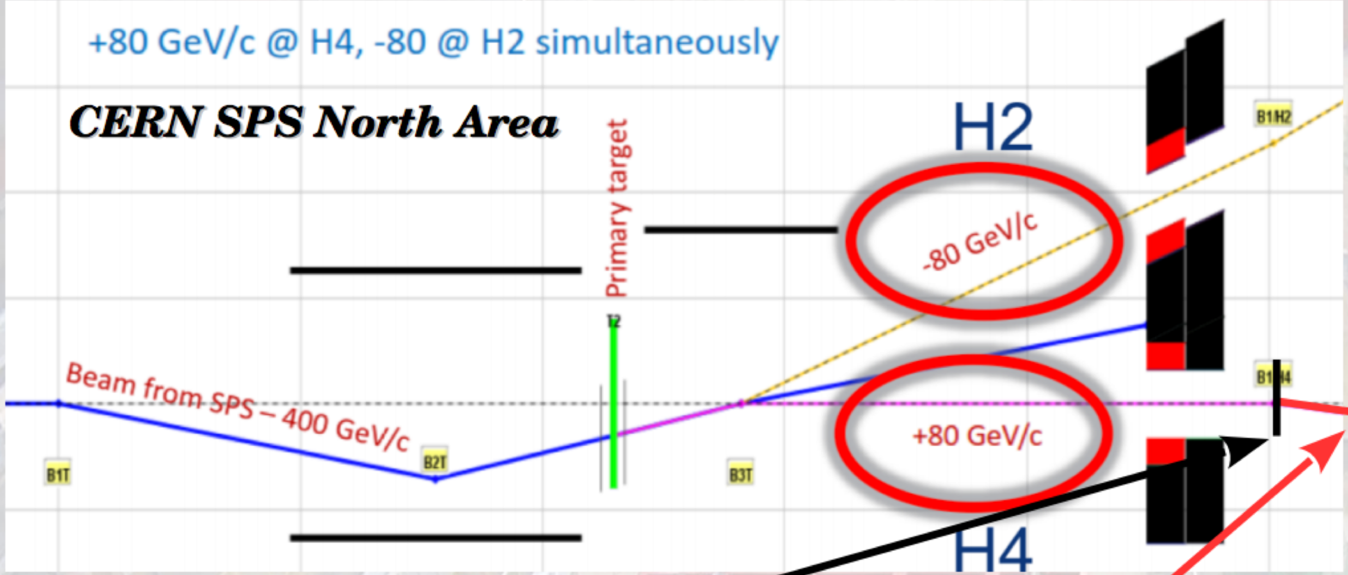
ProtoDUNE-DP overview

1 TPC 6 m high, 6 m wide, 6 m deep



- ***4 Charge Readout Plane***
  - ✔ Readout plane containing extraction grid, LEM and anode
- ***Cathode***
  - ✔ Grid of SS tubes to allow collection of light by PMTs placed below
  - ✔ 300 kV nominal (6 m drift @ 500 V/cm): **half as for DUNE FD**
- ***8 Drift Cages***
  - ✔ Similar design to single phase field cages, covers vertical sides of the detector
  - ✔ No ground planes protecting HV region
- ***36 Photon Detectors***
  - ✔ 8” PMTs, photocathode evaporate with TPB (Tetraphenyl Butadiene) to convert VUV LAr scintillation light into visible spectrum

The H2/H4 VLE beam line @ the Neutrino Platform



400 GeV/c P beam from SPS

80 GeV/c secondary π^+ beam

~0.5 – 7 GeV/c tertiary e^-,p,μ^+,π^+ beam

ProtoDUNE-SP (secondary) target

H4 VLE beam line