The status and results from ProtoDUNE Single Phase

Maura Spanu, Brookhaven National Laboratory

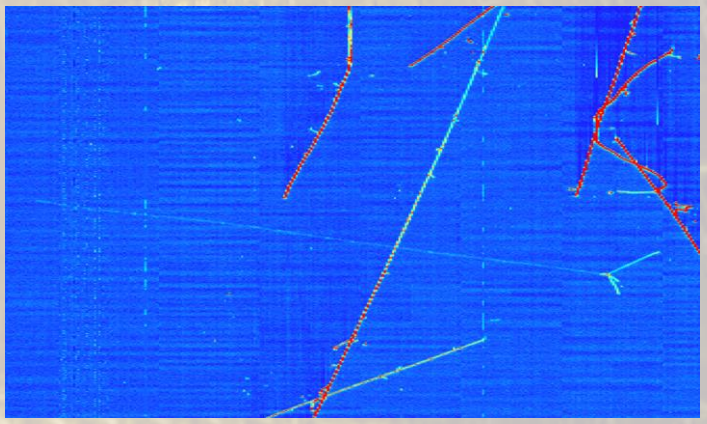
***on behalf of* DUNE collaboration**

9th international symposium on Large TPCs for low-energy rare event detection
12-14 December 2018

ProtoDUNE-SP – An incredible challenge!

Can you go from this…

to this...

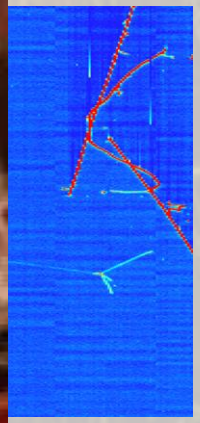


In less than two years?

ProtoDUNE-SP – An incredible challenge!

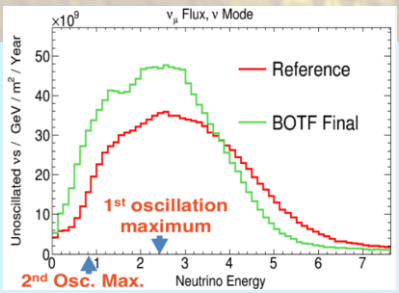
Can you go fro

to thi



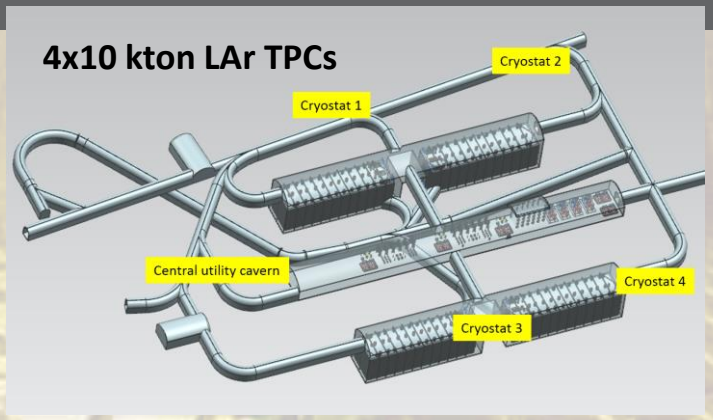
In less than two years?

Deep Underground Neutrino Experiment (DUNE)



$\nu_\mu/\bar{\nu}_\mu$ beam
1300 km baseline, from Fermilab to SURF
1.2 MW power (2026), up to 2.4 MW (phase II, 2032)

Far Detector at 1.5km underground: 4x10 kton fiducial Liquid Argon Time Projection Chambers (TPCs)



Near Detector
(Hosted at Fermilab)

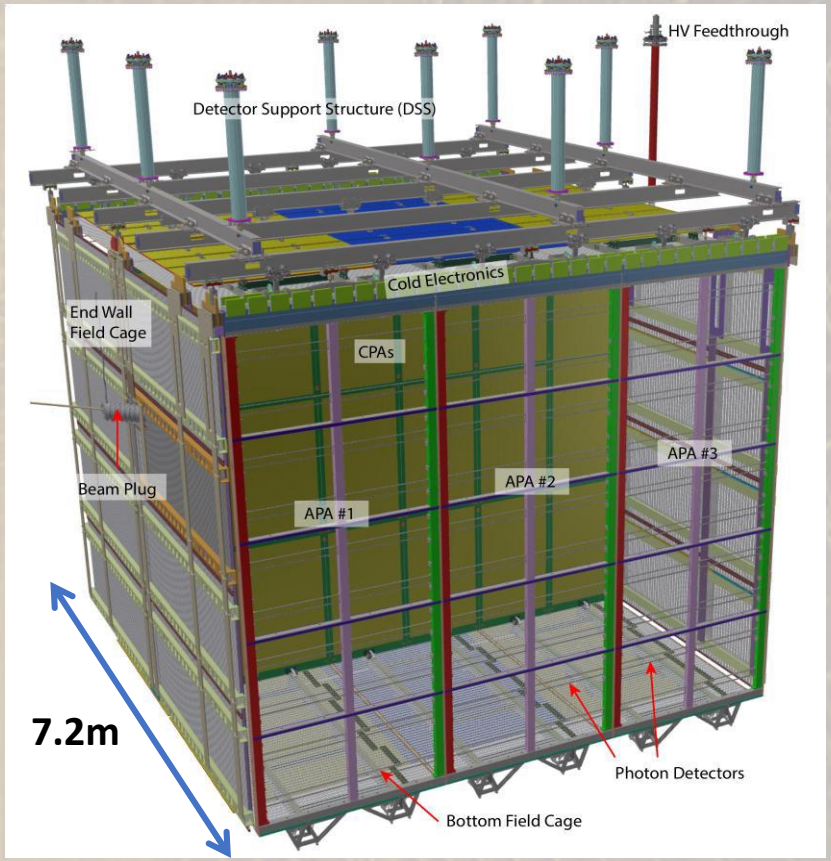
Two TPC concepts:
- Single Phase (LAr)
- Dual Phase (Ar gas+LAr)

Strong International Collaboration!

1100+ collaborators / 178+ institutions / 32+ countries
"LHC – size" neutrino experiment!

A huge small prototype – ProtoDUNE Single Phase

- **Single-Phase** LAr TPC prototype:
  - **6 Anode Plane Assemblies (APAs)**
    - Full-size APAs (6x2.5 m^2)
    - Total of **15,360** TPC sense wires and electronic channels
  - 3 **Cathode Plane Assemblies** (CPA)
    - Resistive Kapton laminated on dielectric panels
    - 180 kV nominal (2 x 3.6 m drift @ 500 V/cm)
  - ***16 Field Cage profiles***
    - Aluminum profiles on dielectric frame, provides constant 500 V/ cm electric field
    - Top and bottom elements equipped with perforated SS ground planes to ensure no field outside the active volume



Key test of design concepts and construction:

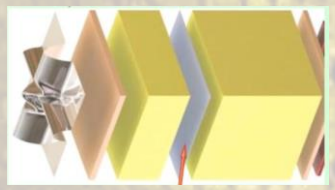
- TPC sense wire planes
- **Cold electronics** integral to wire planes
- **Cryostat feedtroughs** to integral warm interface (WIEC)
- **Scintillator SiPM** Photon Detectors (PD)
- **HV system**, field cage and cathode, for long drift (3.6m)

ProtoDUNE-SP Goals

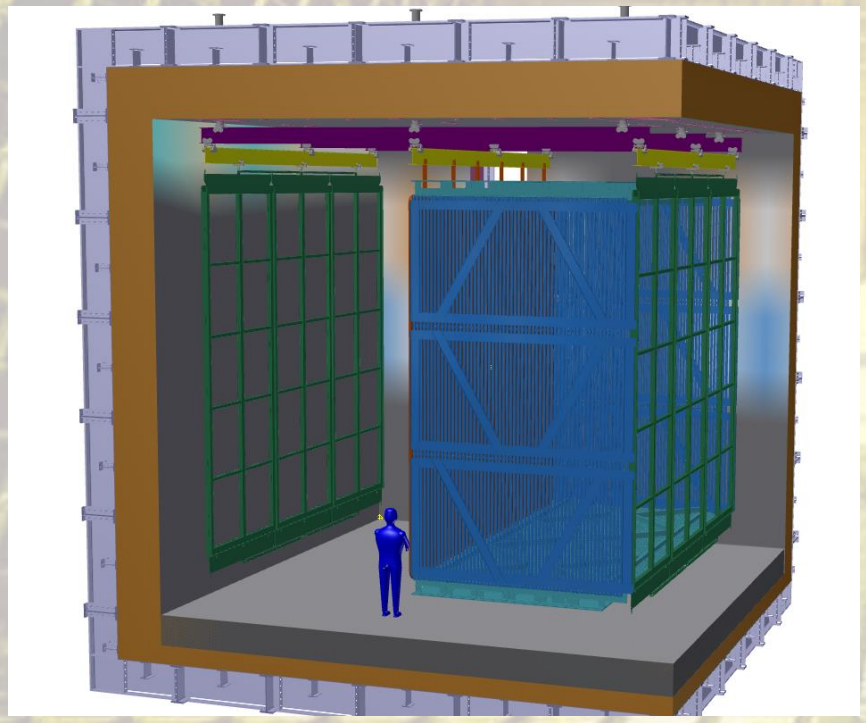
- Prototyping production and installation procedures for DUNE Far Detector design
- Validate design from perspective of basic detector performance
- Accumulate test-beam data to understand/calibrate response of the detector to different particle species
- Demonstrate the long term operational stability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

Ship in a Bottle: Detector Assembly inside the Cryostat

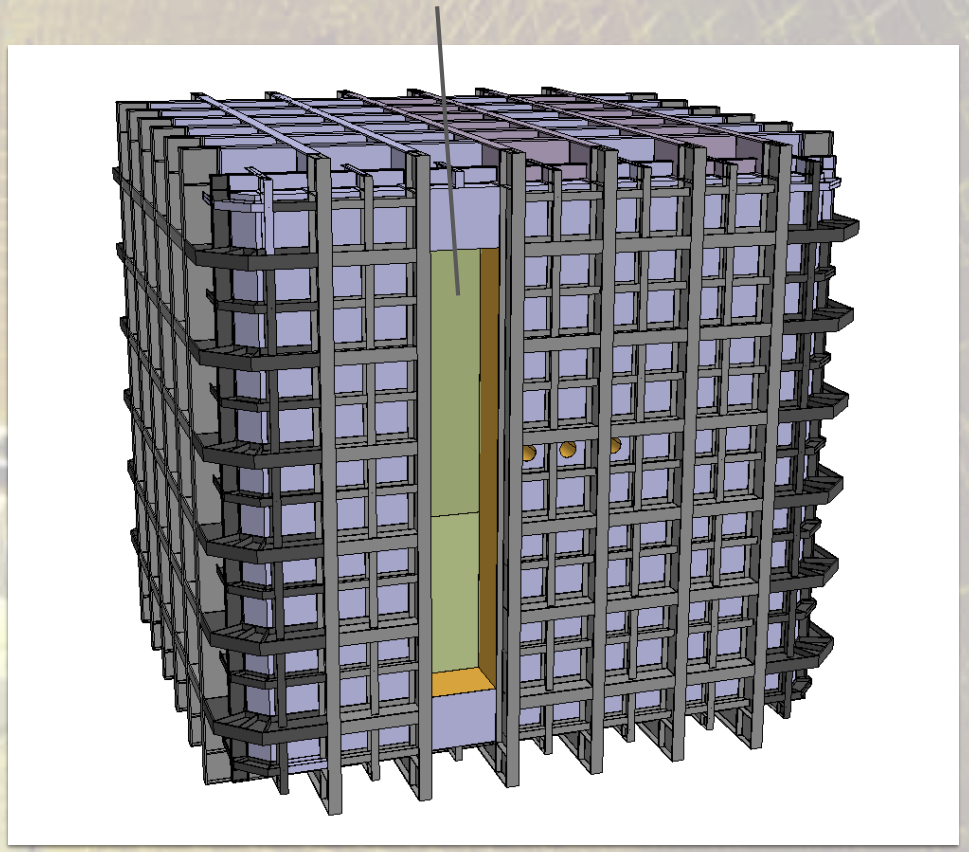
- Install membrane
- Leak test on cold vessel



- Installation of the TPC detector
- Close the TCO



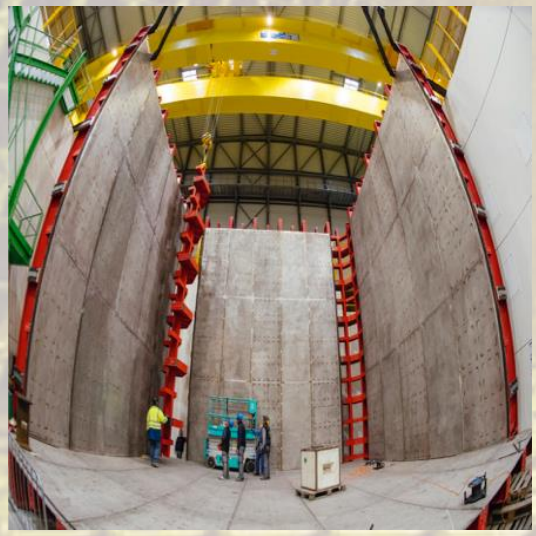
TECHNICAL CONSTRUCTION OPENING



TCO: *opening of 1372mm x 7900 mm on a side wall for inner detector installation*

ProtoDUNE-SP photo-story

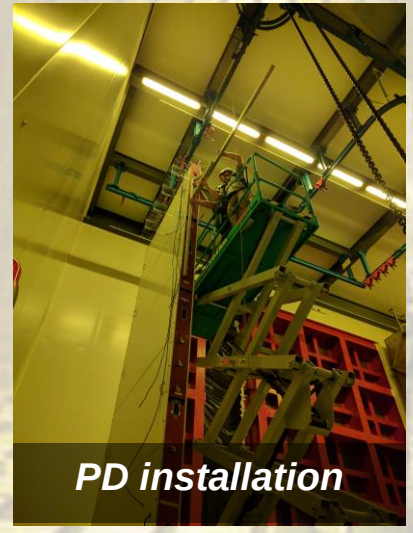
Oct 2016 – May 2017: Cryostat construction



ProtoDUNE-SP photo-story

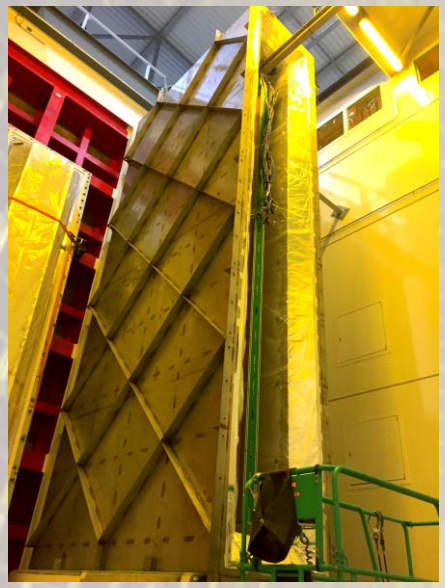
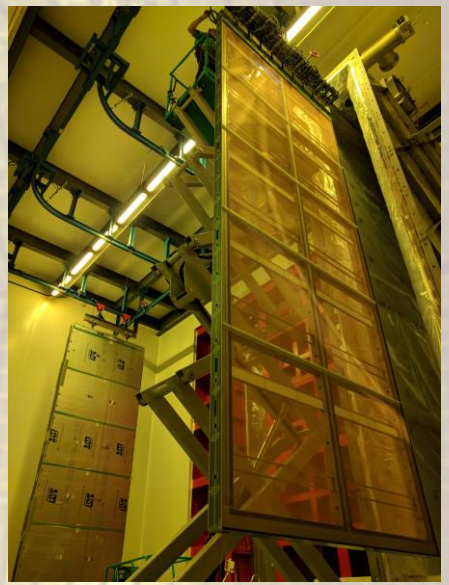
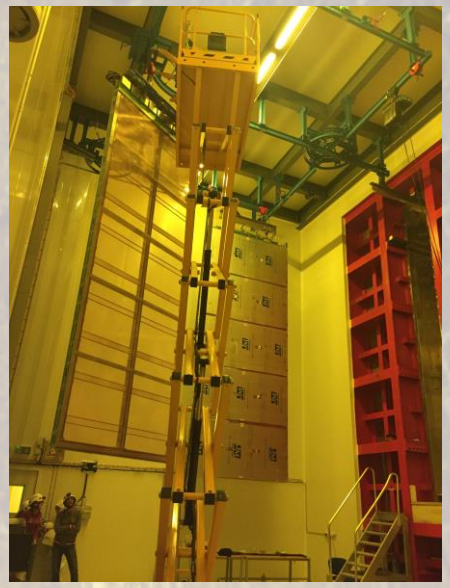
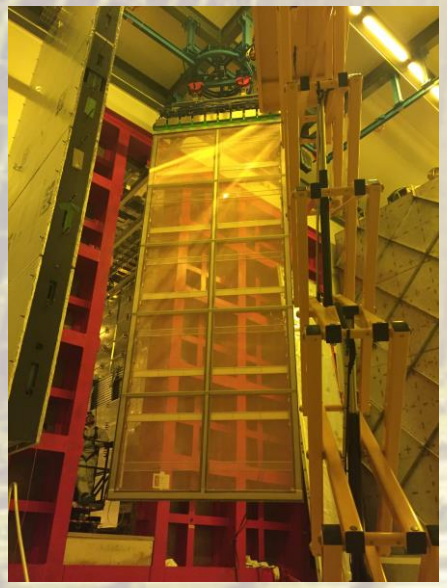
Aug 2017 – April 2018: APAs integration and test

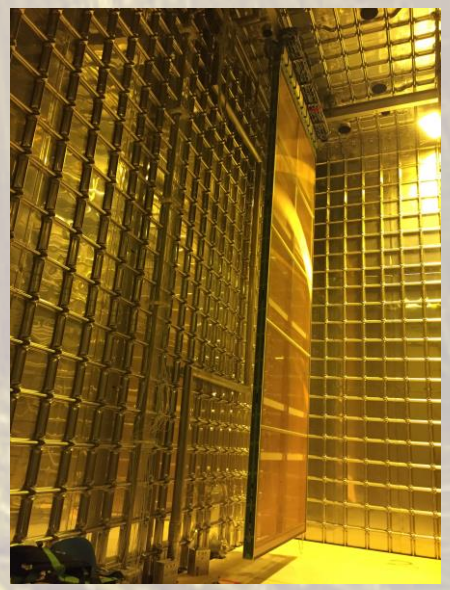
Wire tension measurement and visual inspection



Cold Electronics installation

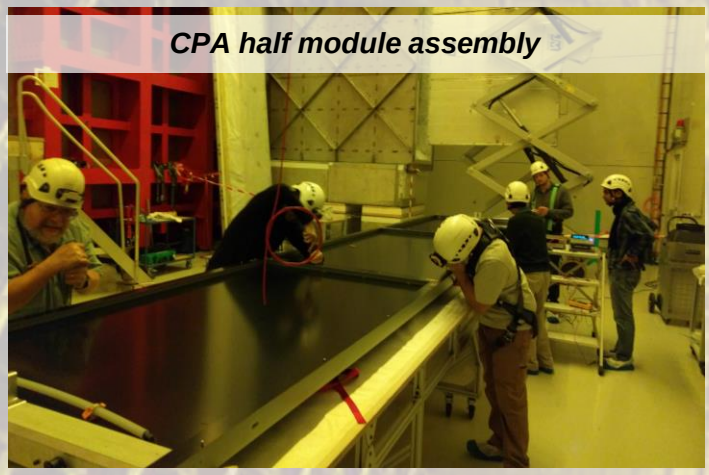
ProtoDUNE-SP photo-story

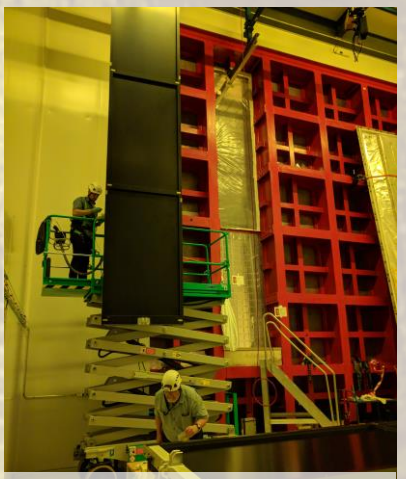





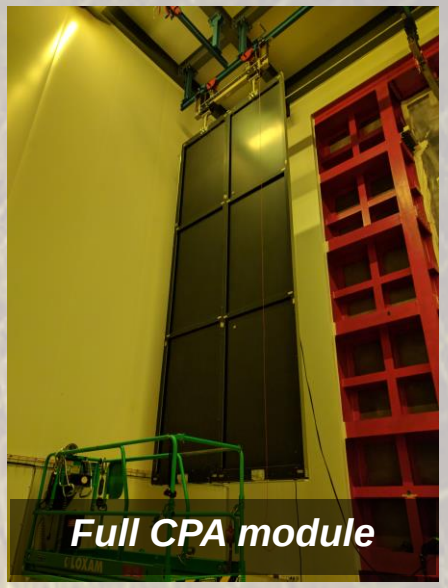


Moving APAs around

ProtoDUNE-SP photo-story

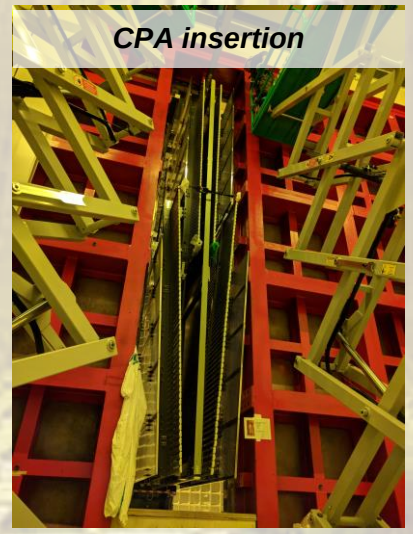

CPA half module assembly

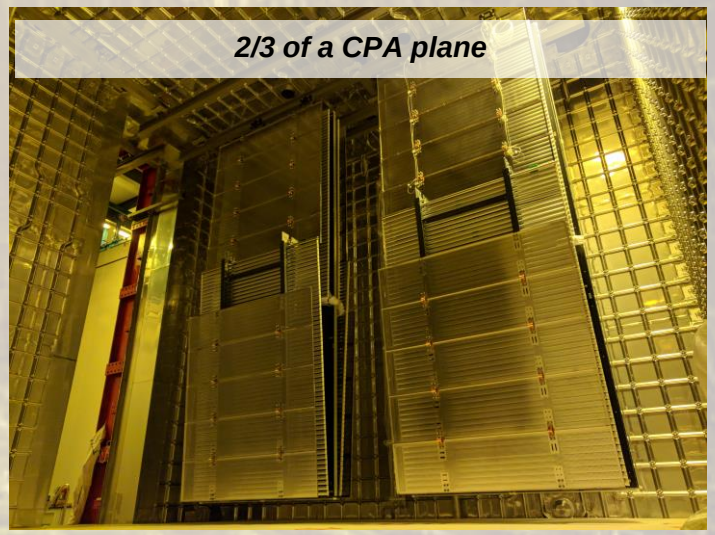

CPA continuity test


Full CPA module

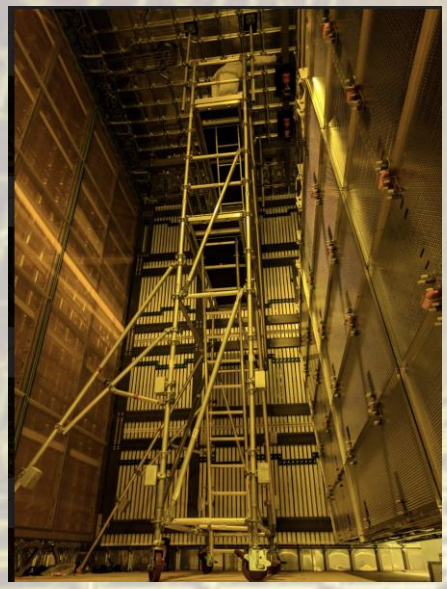
Jan 2017 – Apr 2018: CPA assembly and installation


Field cage installation


CPA insertion

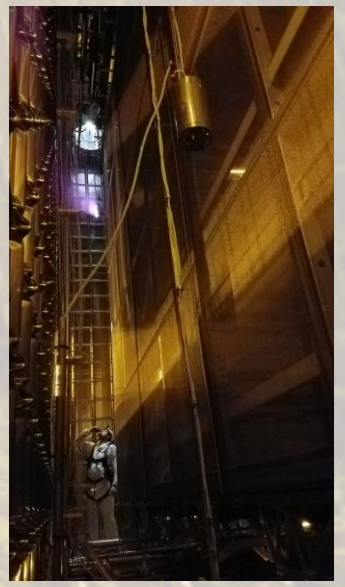

2/3 of a CPA plane

ProtoDUNE-SP photo-story



From

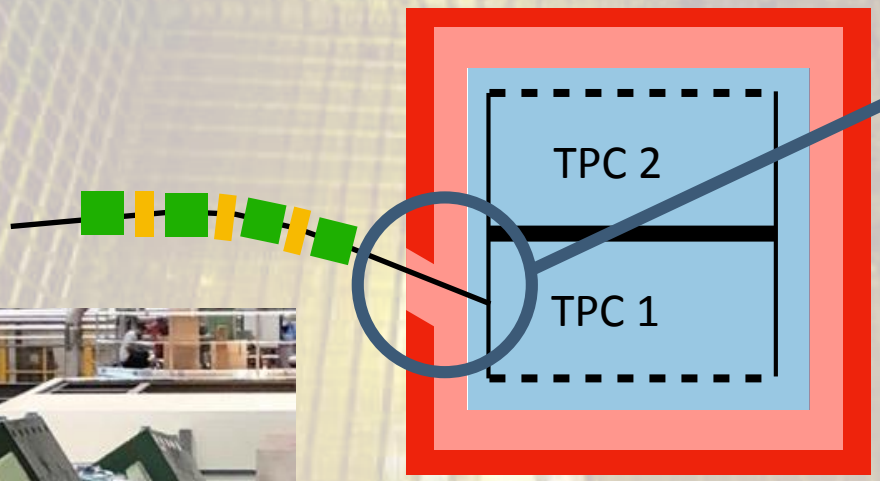
the inside

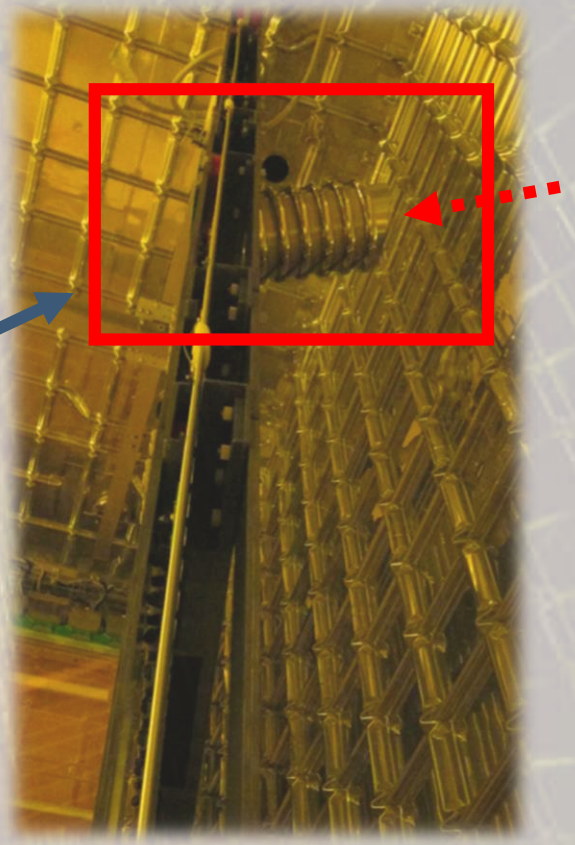


ProtoDUNE-SP Test Beam

Beamline

400 GeV/c p beam from SPS → 80 GeV/c secondary π^+
→ 0.5 – 7 GeV/c tertiary e^-, p, μ^+, π^+





EHN1 extension, H4 beamline

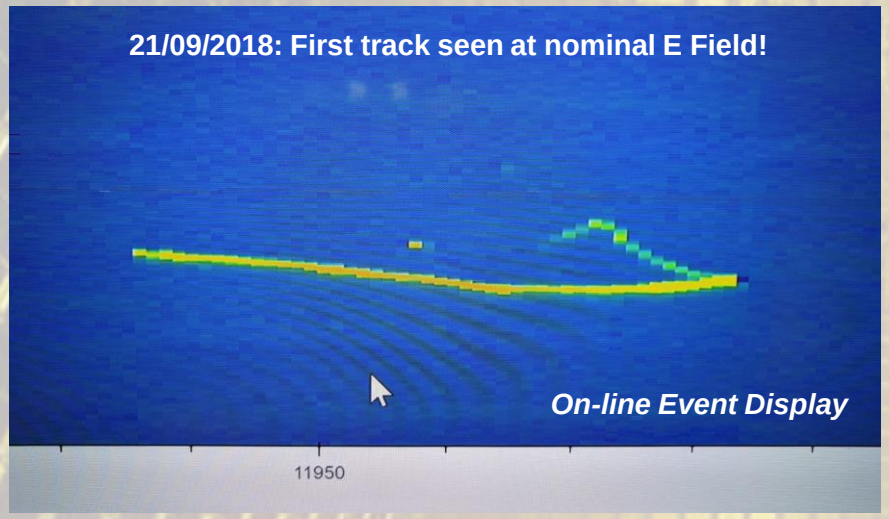
Beam plug = END of beamline to get electron showers inside TPC, filled with N2

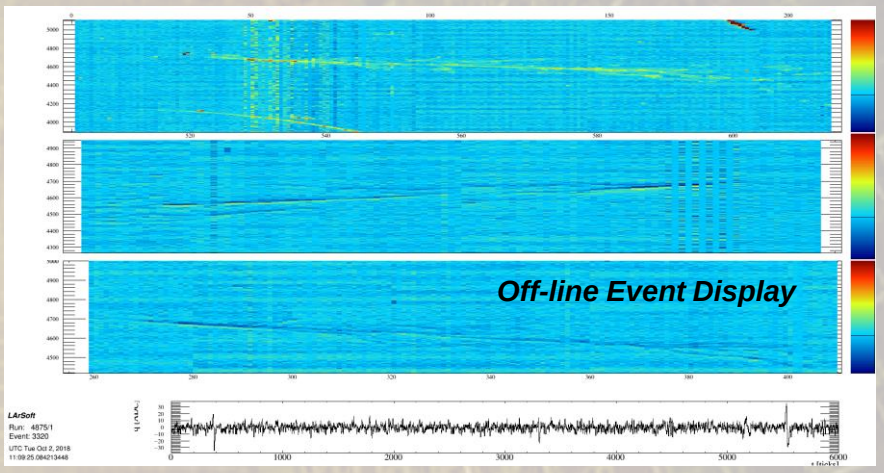
*PHYS. REV. ACCEL. BEAMS **20**, 111001 (2017)*

ProtoDUNE-SP summary and status

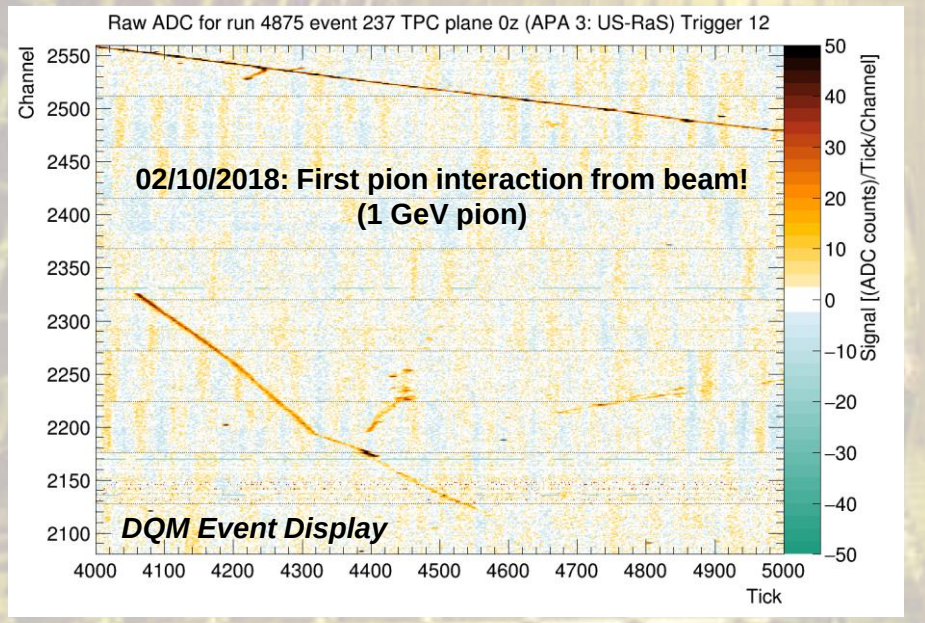
- ProtoDUNE-SP project has been approved on December 2015
- The cryostat construction started on October 2016 and was completed on May 2017
- TPC installation was completed at the end of April 2018, followed by an intense period of commissioning activities
- ProtoDUNE-SP detector was completed at the end of June 2018, filling of the cryostat completed on September 13th, TPC activated and on data taking since September 21th
- ProtoDUNE-SP took beam data until November 12th, followed by an endurance run with cosmics to assess the stability and performances of the detector
- Debugging activities on different detector components are now ongoing

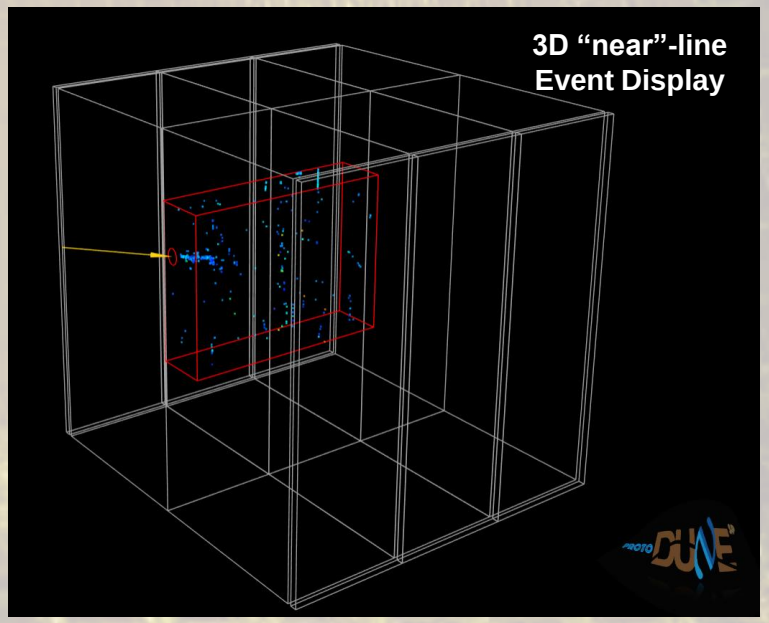
ProtoDUNE-SP first events



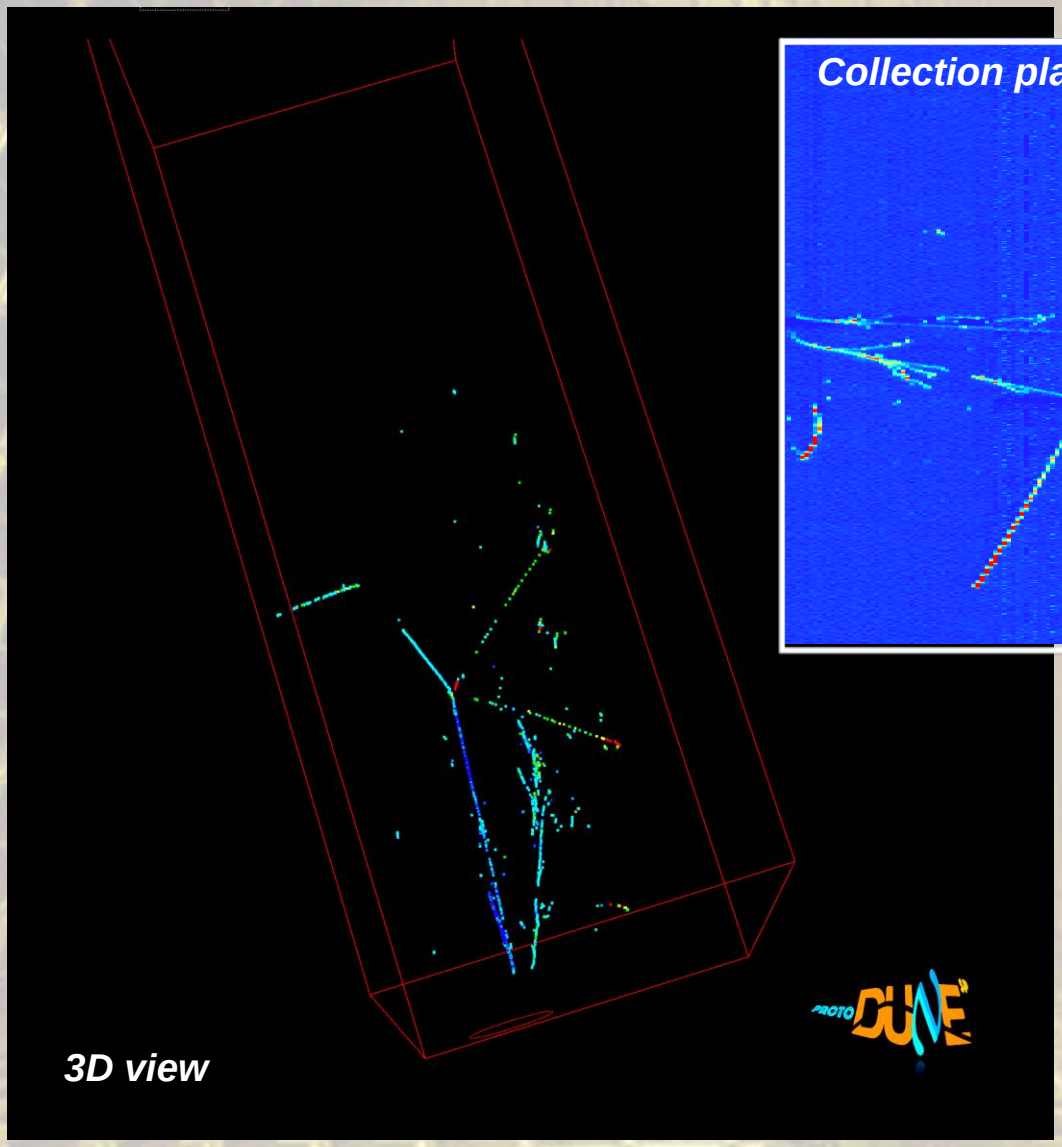


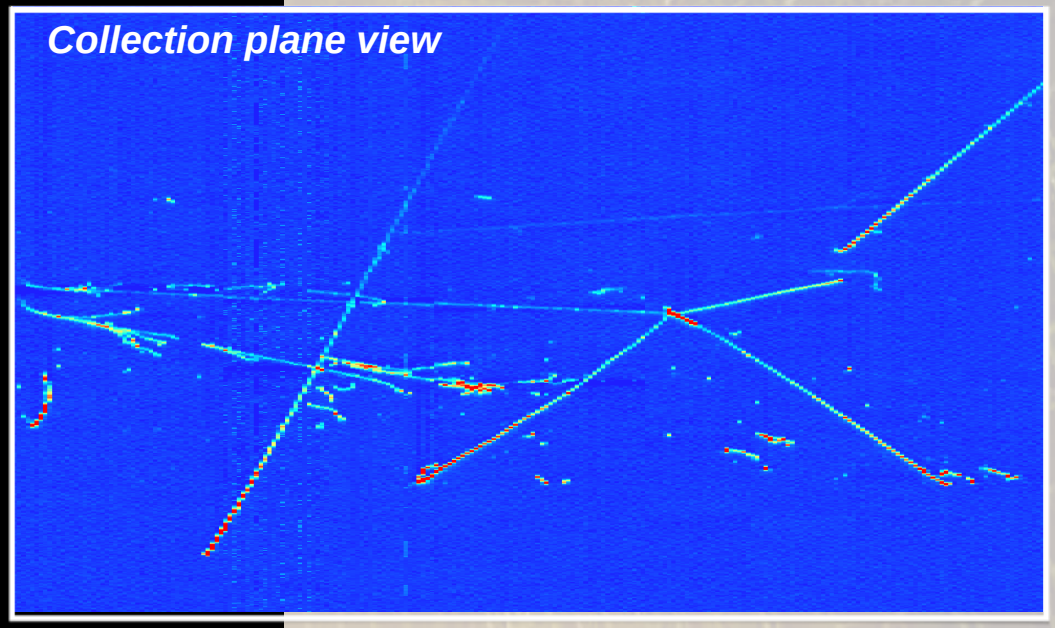
02/10/2018: First event seen from beam!
(1 GeV electron)





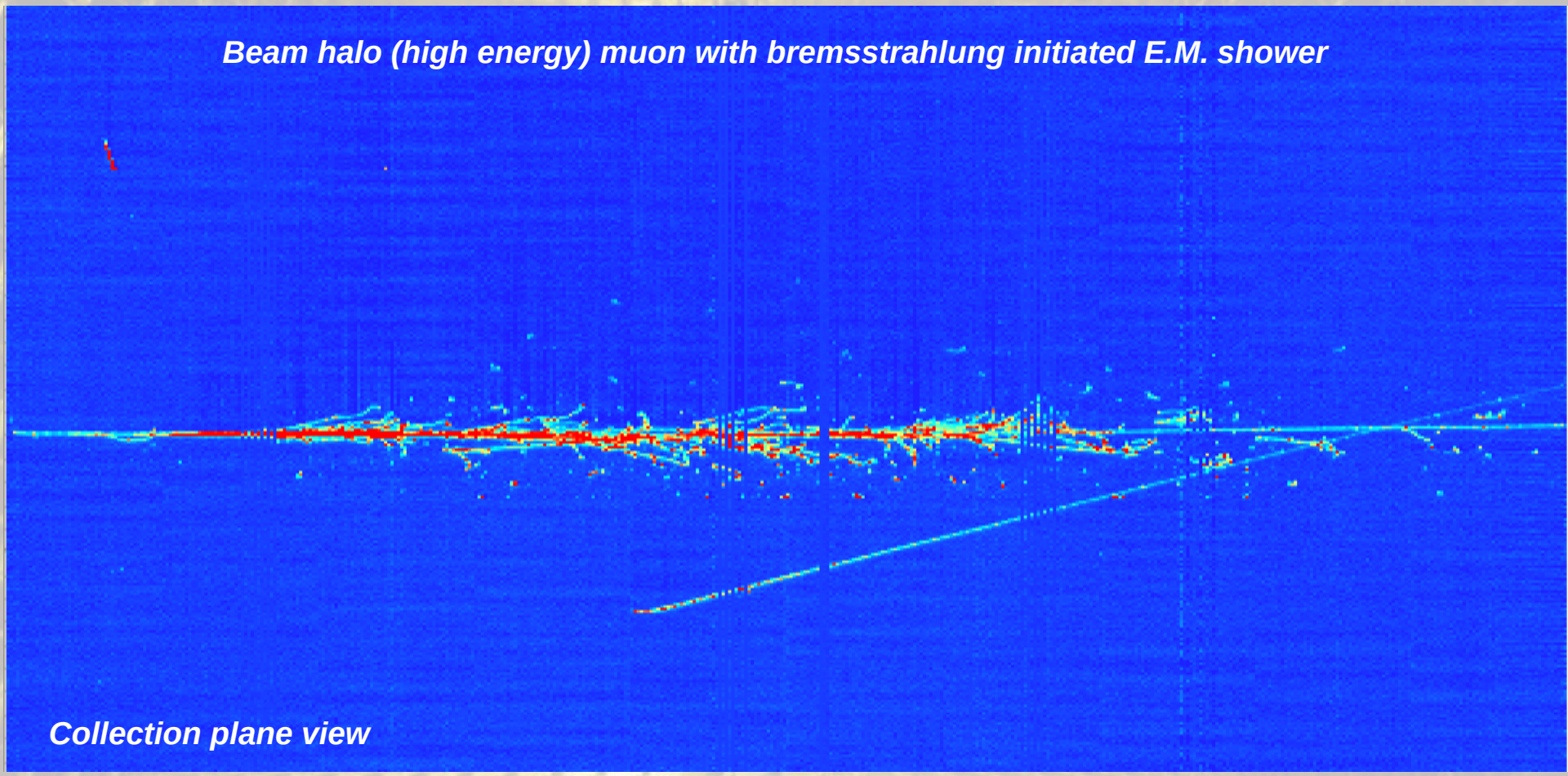
More events…



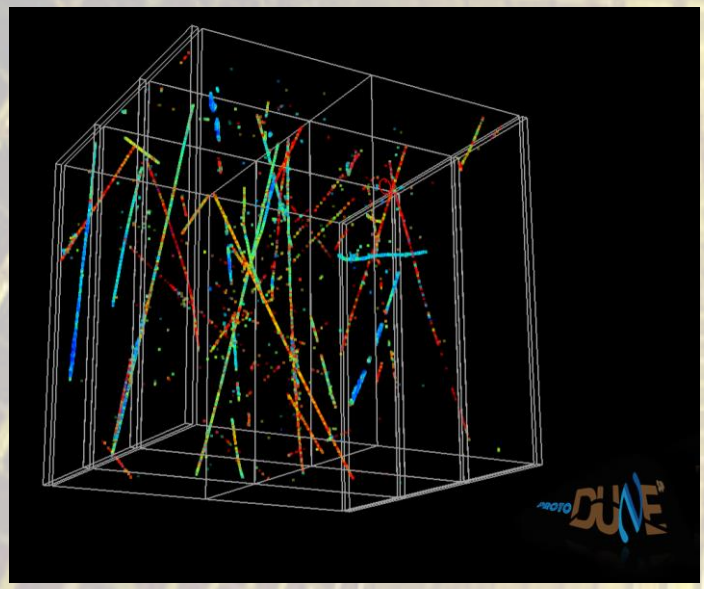


Run 4696, Ev 103:
2 EM showers and a pion interaction with 4 outcoming particles

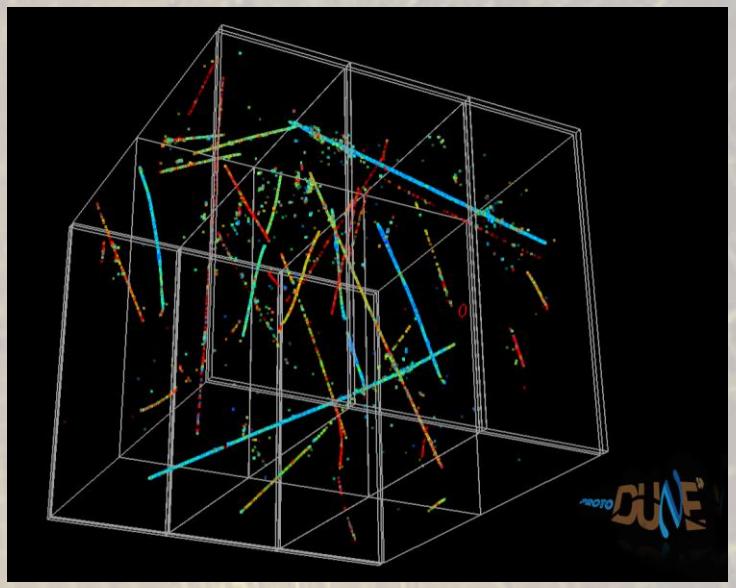
More events…

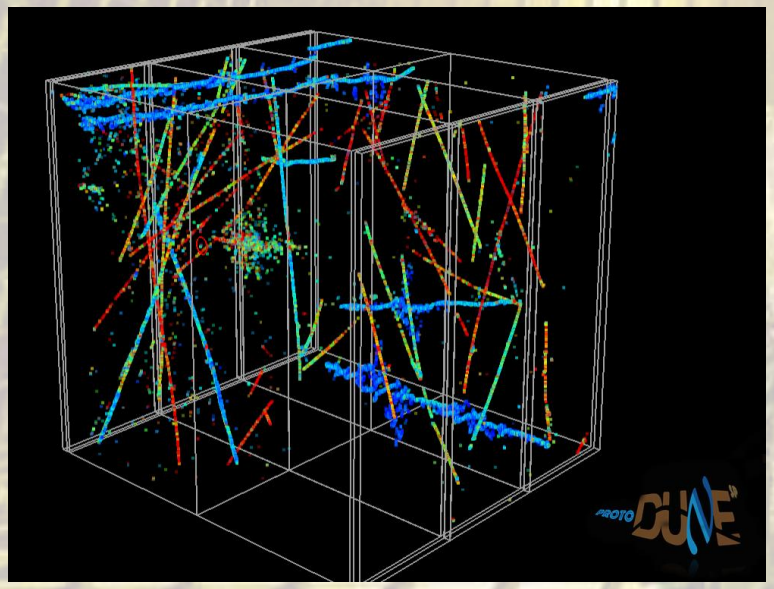

Beam halo (high energy) muon with bremsstrahlung initiated E.M. shower
Collection plane view

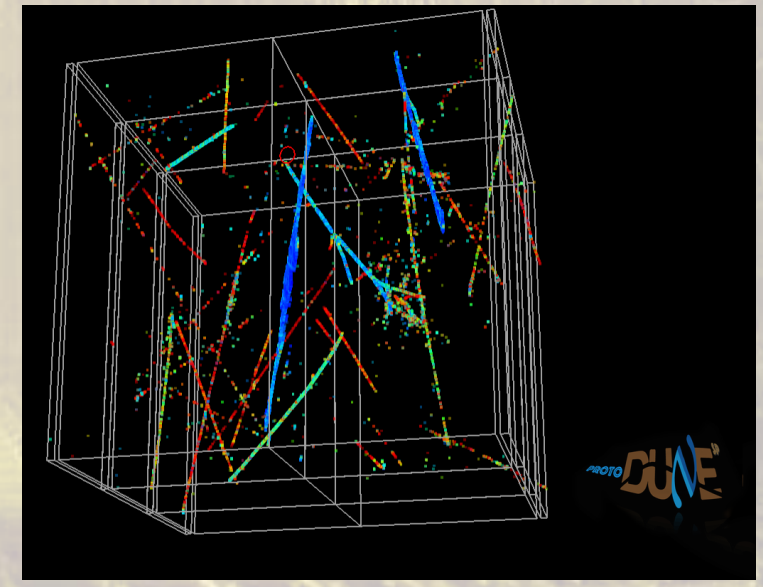
More events…



3D cosmic ray and beam events



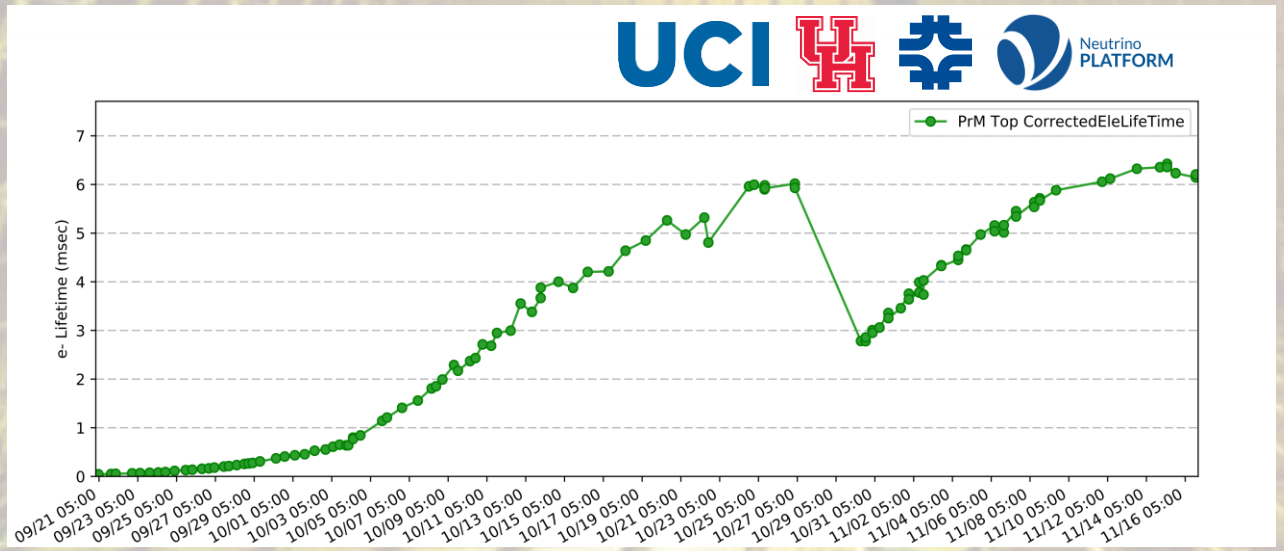




ProtoDUNE-SP - Test Beam Summary

- Summary of the estimated (from beam simulation) amount of pion, proton, positron and kaon events collected at each momentum during the beam run…

Momentum	Total Triggers	Expected Pi trig.	Expected Proton trig.	Expected Electr. trig.	Expected Kaon trig.
0.3 GeV/c	269K	0	0	242K	0
0.5 GeV/c	340K	1.5K	1.5K	296K	0
1 GeV/c	1089K	382K	420K	262K	0
2 GeV/c	728K	333K	128K	173K	5K
3 GeV/c	568K	284K	107K	113K	15K
6 GeV/c	702K	394K	70K	197K	28K
7 GeV/c	477K	299K	51K	98K	24K
All momenta	**4175K**	**1694K**	**779K**	**1384K**	**73K**



… and the electron drift-lifetime

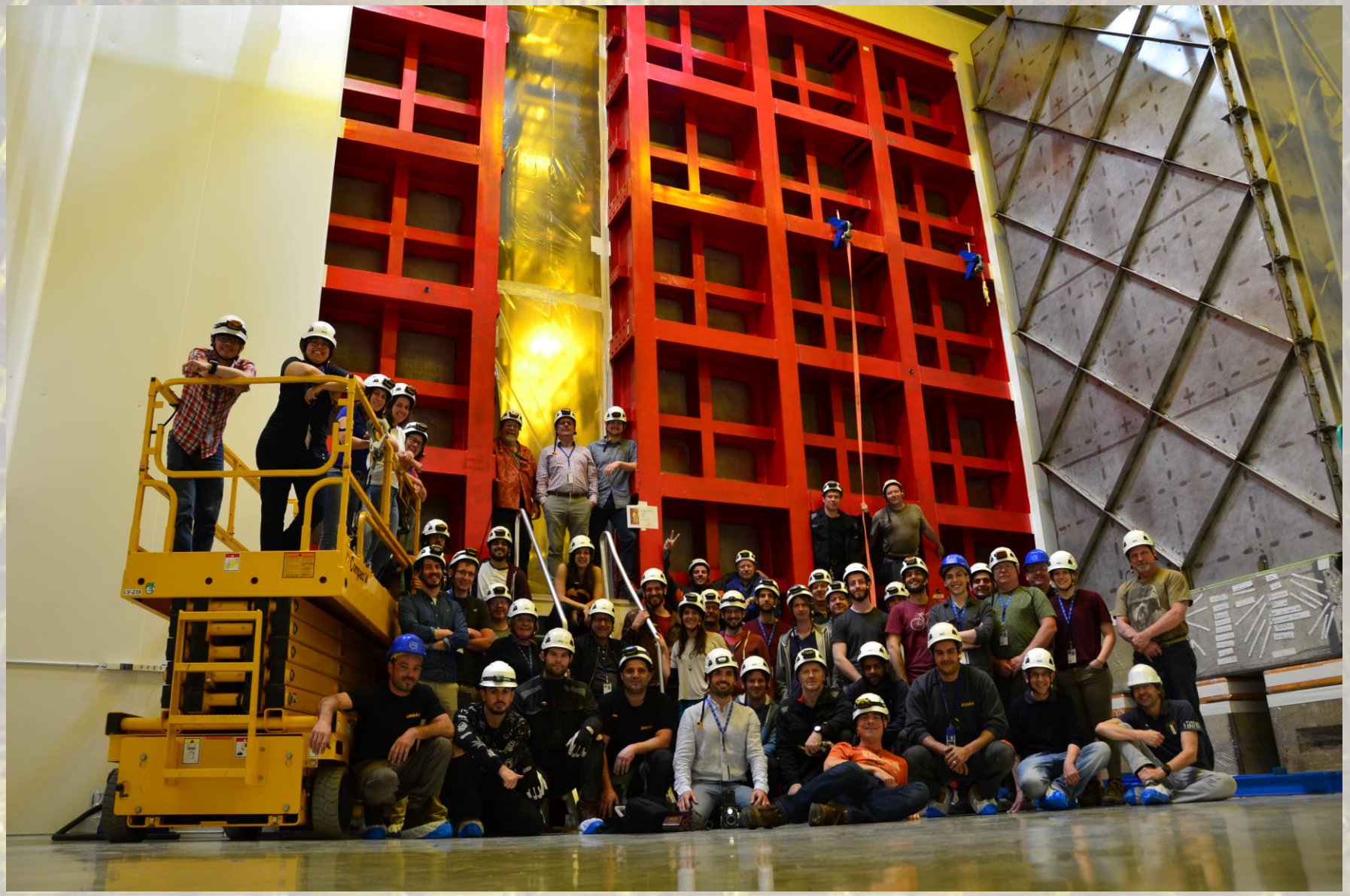
In conclusion…

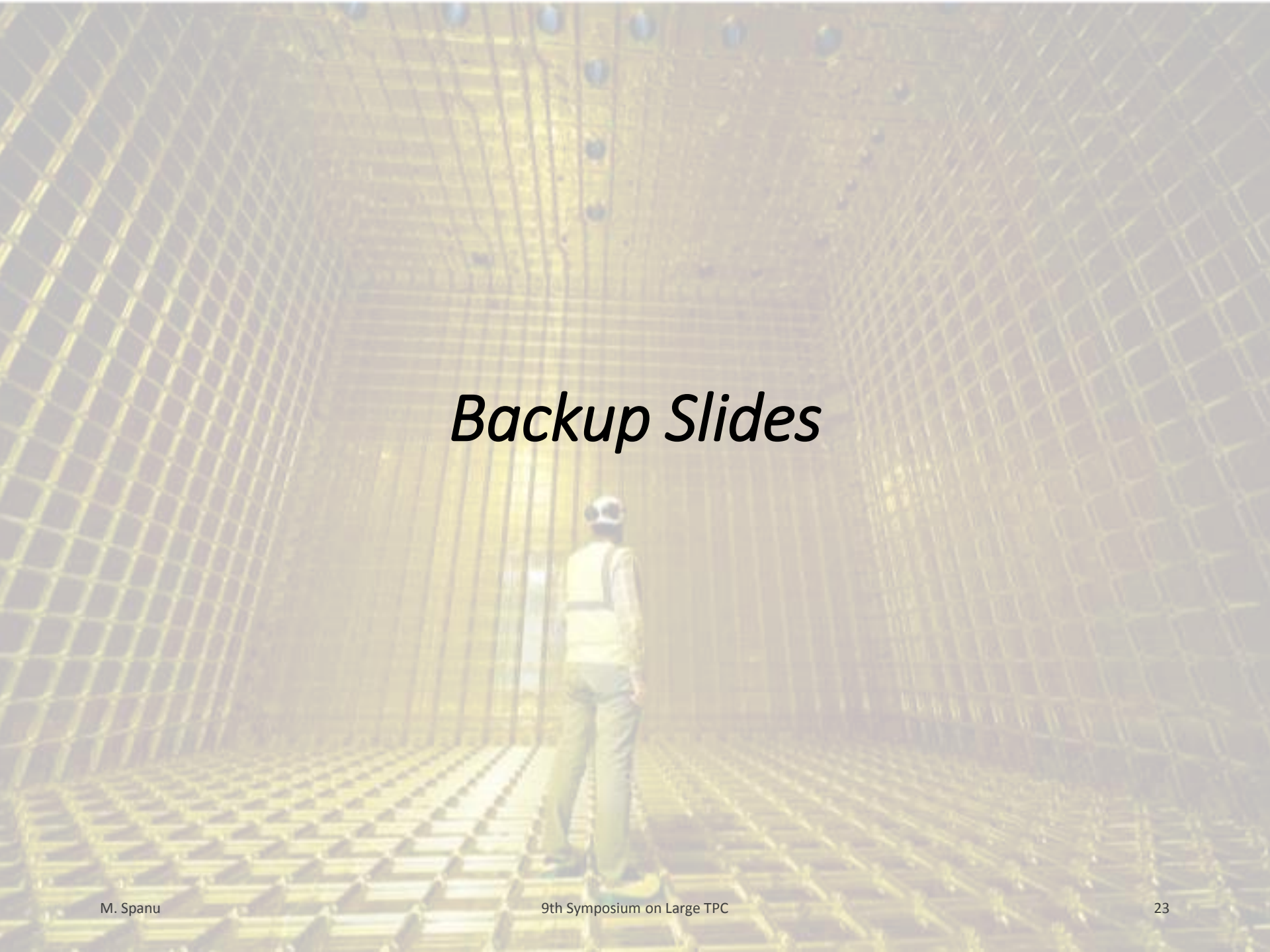
- DUNE is a leading-edge, international experiment for neutrino science and proton decay. Its ambitious physics program requires a careful prototyping of the engineering solutions envisaged for the scale-up of the LArTPC technology, as well as a careful control of the systematics through the acquisition of a deep knowledge of the detector response and performances: ProtoDUNE.

- ProtoDUNE-SP at CERN is a perfect example of making the impossible possible!
  - Assemble an entire LAr Detector inside the cryostat confined space in less than 2 yrs
  - Build a new, dedicated Charged Beam Line
  - Fill the cryostat with pure LAr and activate the detector in time for a Physics Run, before CERN LS2
  - … and collect data of unprecedented quality from the LArTPC.

- The beam and cosmic data collected by the detectors will be extremely important to address and define the systematic uncertainties of DUNE measurements

Thank you!

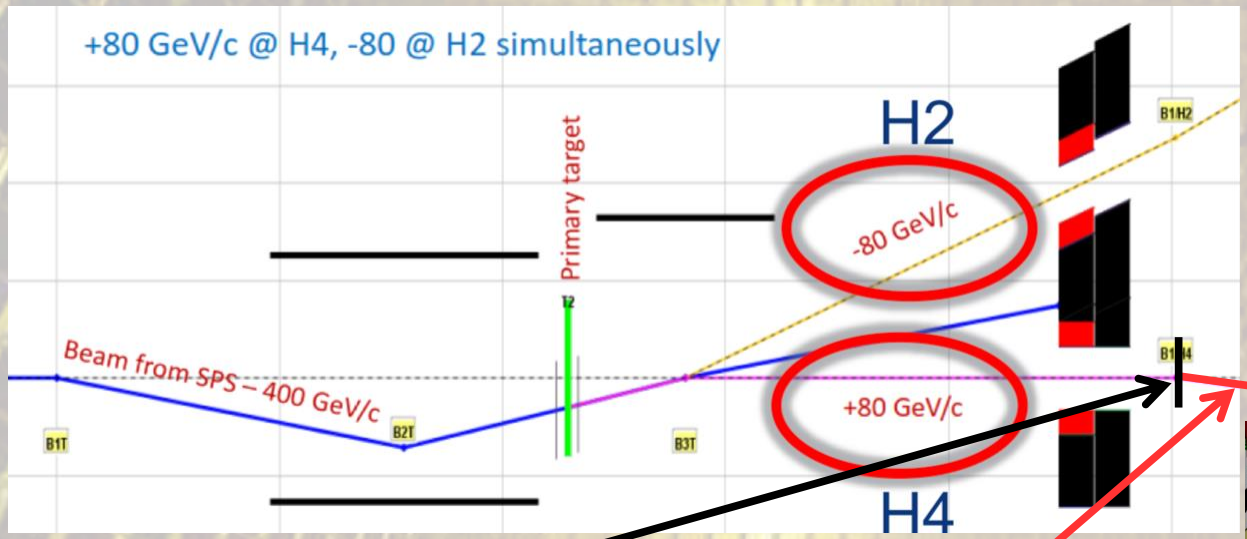



Backup Slides

DUNE Physics

- Precise measurement of neutrino oscillations parameters (ν_μ/ $\bar{\nu}_\mu$ disappearance, ν_e/ $\bar{\nu}_e$ appearance), in particular δ_{CP} violation phase and mass hierarchy at the 5σ level
- Detection of galactic-core supernovae neutrinos
- Proton decay, especially in the K-production modes ($p \rightarrow K^+ \bar{\nu}$; $p \rightarrow K^0 \mu^+$; $p \rightarrow K^+ \mu^- \pi^+$)
- Search for NSI (Non Standard Interactions)

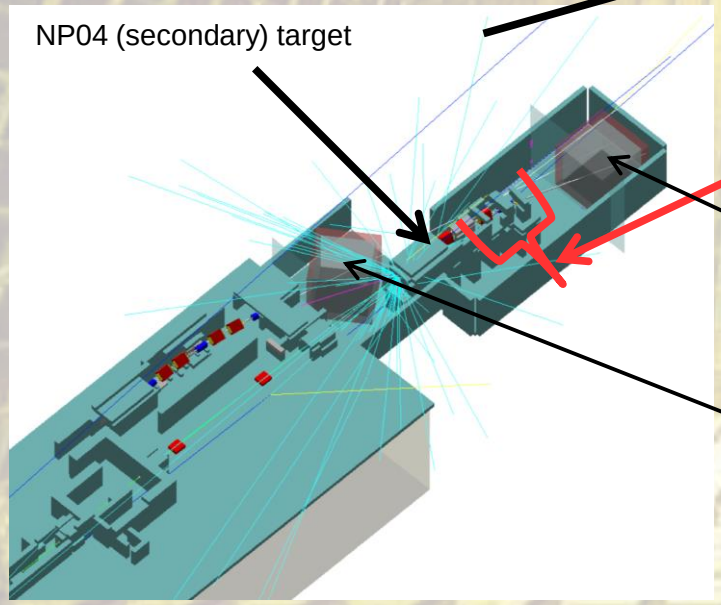
H4 VLE Beam line @ Neutrino Platform



400 GeV/c P beam from SPS

80 GeV/c secondary □⁺ beam

~0.5 – 7 GeV/c tertiary e⁻,p,μ⁺,□⁺ beam



H4 VLE beam line under construction

ProtoDUNE-SP cryostat

ProtoDUNE-DP cryostat