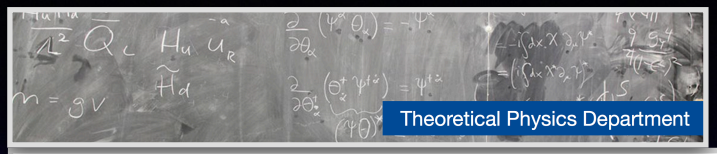
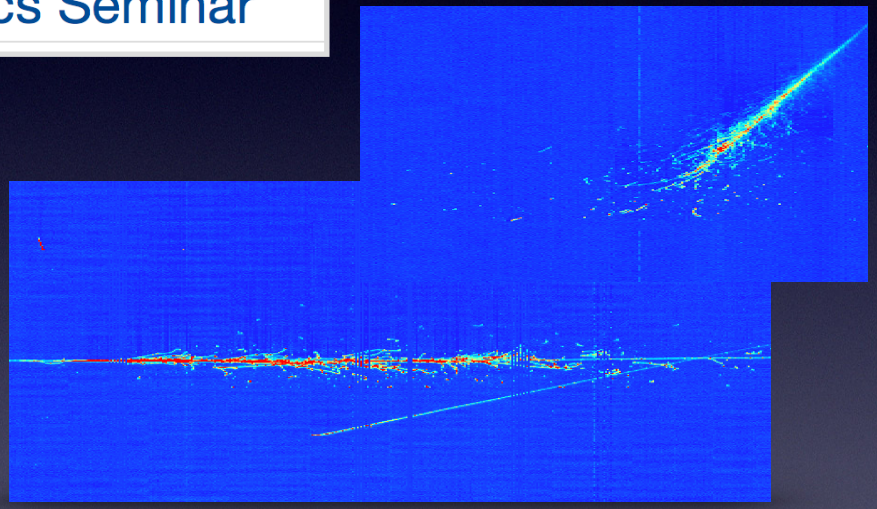
DEEP UNDERGROUND NEUTRINO EXPERIMENT



Joint Experimental-Theoretical Physics Seminar

Wine and Cheese from DUNE

Sept. 28, 2018, 4:00 pm



ProtoDUNE:

Chronicles of an endeavor

on behalf of DUNE Collaboration

Flavio Cavanna | Fermilab

PROTO DUNE SP

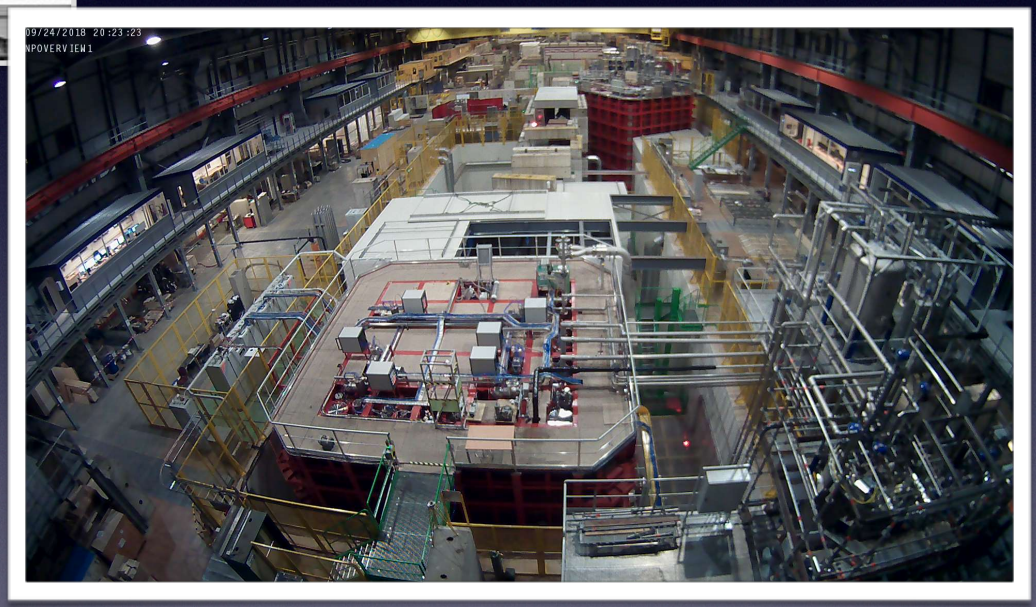
Outline:

DEEP UNDERGROUND NEUTRINO EXPERIMENT

PROTO DUNE SP

- **Introduction:** *what is this ? what is for ?*
- to there [Dec. 12, 2015]

from here [h. 2:32 am - Sept. 21, 2018]



- from first tracks [h. 2:33 am - Sept. 21, 2018]

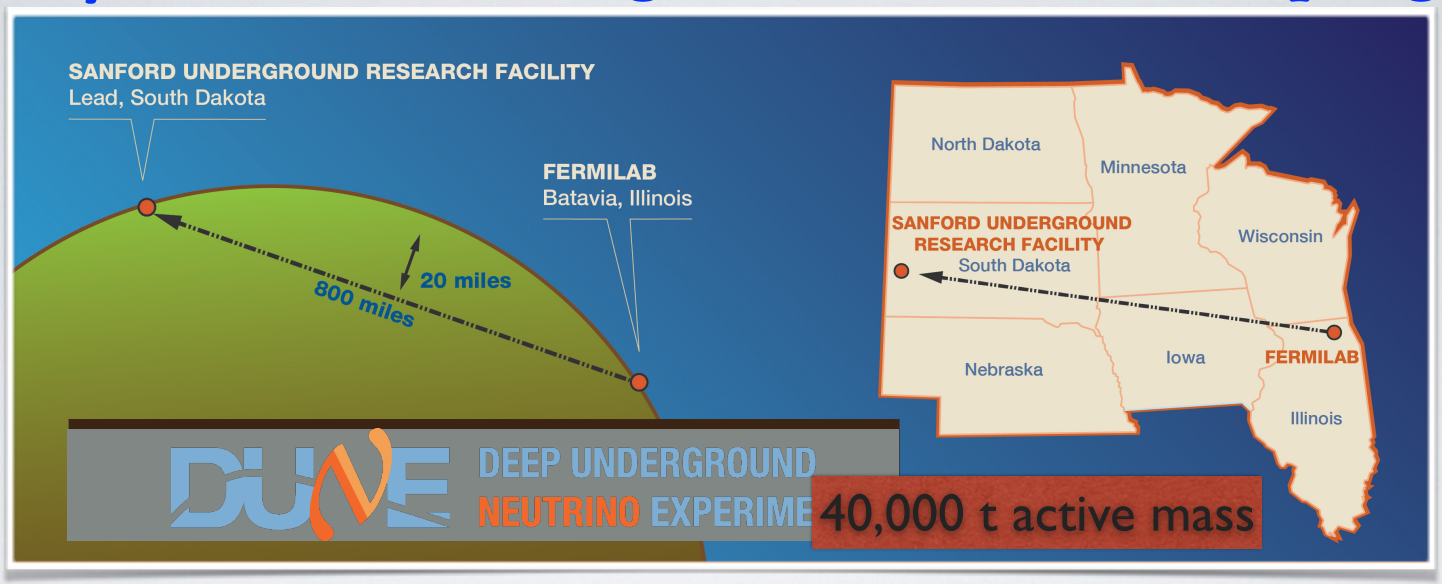
to first (preliminary) results from data analysis

Fermilab PROTO DUNE SP

PROTO DUNE SP

- what it is, what it's for

DUNE/LBNF: the Long Baseline Neutrino program



DUNE Highest Level Strategic Goals 2016 - 2019 *["DUNE Strategy for CD-2" document]*

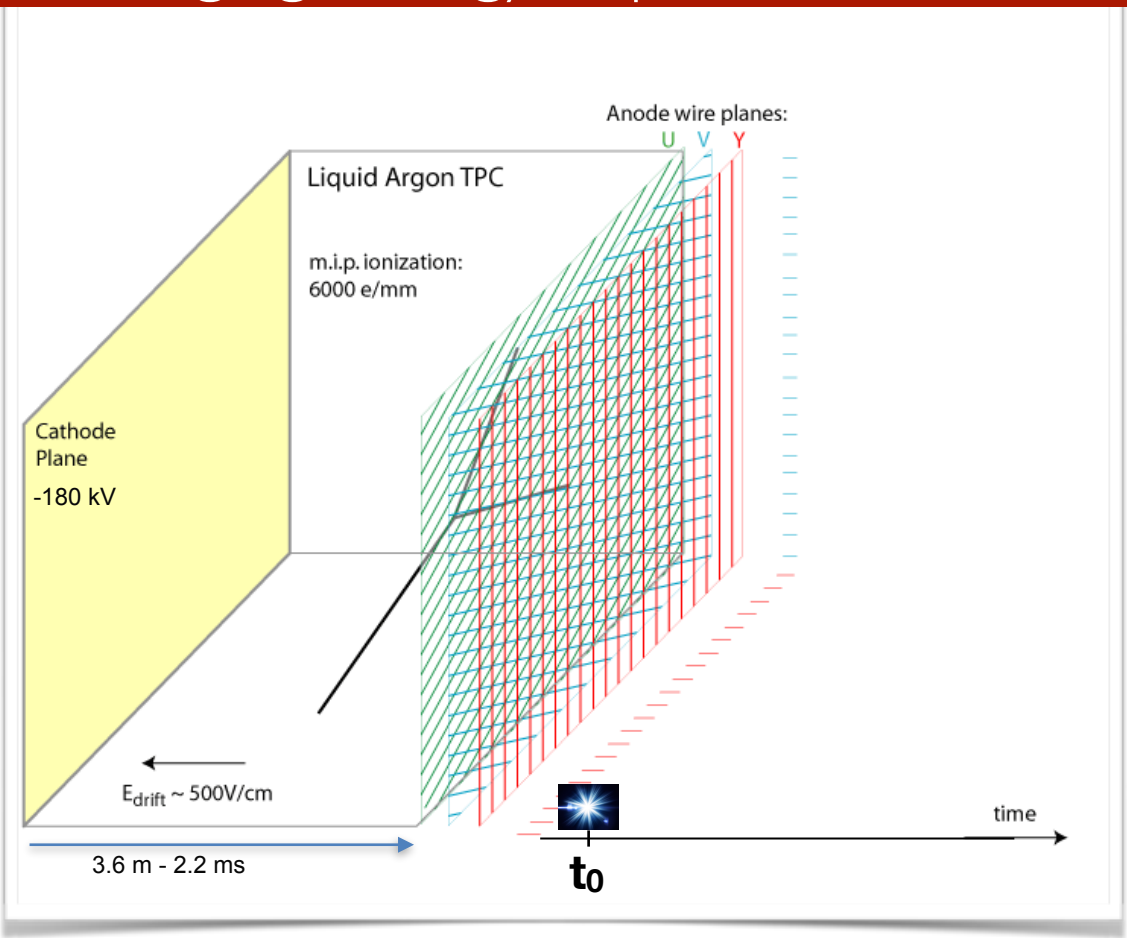
- **2 x 10-kt (fiducial mass) LArTPC Far Detector operating by 2026**
- **DUNE TDR for CD-2 Review in 2019**
- **Construction and operation of large-scale prototypes at CERN in 2018** Critical for demonstrating the ability of the DUNE collaboration to implement a major construction activity

LArTPC: Imaging, Energy deposited measurement and PId

DUNE Technology Choice

Energy release from charged particles in LAr:

- *free electron charge (TPC)*
- *scintillation light (PD)*



TPC Critical features:

- LAr ultra-high purity
- E Field: *uniformity and stability*

Photo-Detector for Triggering and t0 determination

protoDUNE in the DUNE Organizational Challenges *["DUNE Management and Organization" document]*

ProtoDUNE Single Phase is a crucial part the DUNE effort towards the construction of the first 10 kton far detector module,
prototyping at 1:1 scale the designs of many of the components for the far detector.

ProtoDUNE SP was first proposed to CERN SPSC in **June 2015** (SPSC-P-351).
It was approved at CERN as experiment NP-04 (protoDUNE), to operate at the **CERN Neutrino Platform** (a new, dedicated extension of the NorthArea TestBeam Facility)

A Memorandum of Understanding (MoU) was signed in **December 2015** by the Fermilab Director and the CERN Director of Research and Scientific Computing.

protoDUNE Endeavor

ProtoDUNE with its 7× 7 × 6 m^3 (active volume) LAr-TPC, 770 t tot. LAr volume, is a significant experiment in its own right (similar in scale to ICARUS)

The ProtoDUNE organizational structure is predicated on identifying a well-defined team within the DUNE collaboration that takes ownership of (and responsibility for) ProtoDUNE.

The goal is to collect test beam data before LHC LS2 (the CERN accelerator complex Long ShutDown starting on Nov.2018)

High-Level Time Schedule at protoDUNE SP approval

	Activity	FY16 Q1	FY16 Q2	FY16 Q3	FY16 Q4	FY17 Q1	FY17 Q2	FY17 Q3	FY17 Q4	FY18 Q1	FY18 Q2	FY18 Q3	FY18 Q4	FY19 Q1
	Installation Activities:													
1	Installation/Infrastructure Planning													
2	Facility Preparation													
3	Infrastructure installation (racks, crates, etc)													
4	Cryostat Installation													
5	Pre-Installation tasks inside Cryostat													
6	Installation of Detector in Cryostat													
7	Detector Commissioning													
8	Detector Operation													

Dec.15,ProtoDUNE Approved

Sept.16, Neutrino Platform ready

May 17, Cryostat ready

Jun.18, Detector in Cryostat

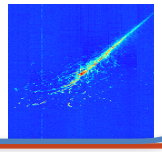
Jul-Nov, 18 Commissioning and Run

CERN Accelerator Long Shutdown

Neutrino PLATFORM

DUNE

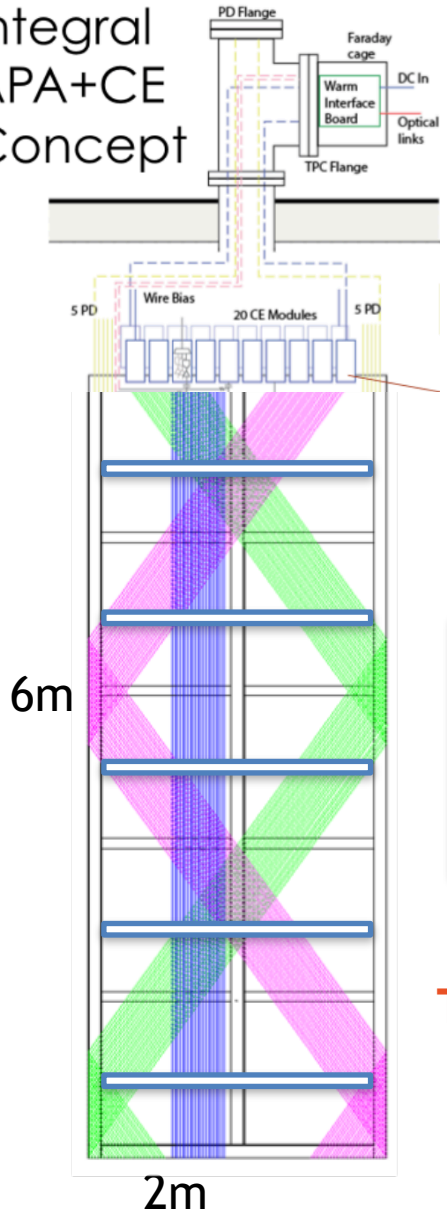
From digging the pit to data taking in 2.5 yr



ProtoDUNE SP High Level Strategic Goals

- 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

Integral APA+CE Concept



Core detector element: Anode Plane Assemblies (APA) with integrated Cold Electronics Boards and Ph.Detector modules

Each APA : 960 X, 800 V, 800 U, 960 G (un-instrumented) wires

10 Photon Detectors are installed into each APA frame

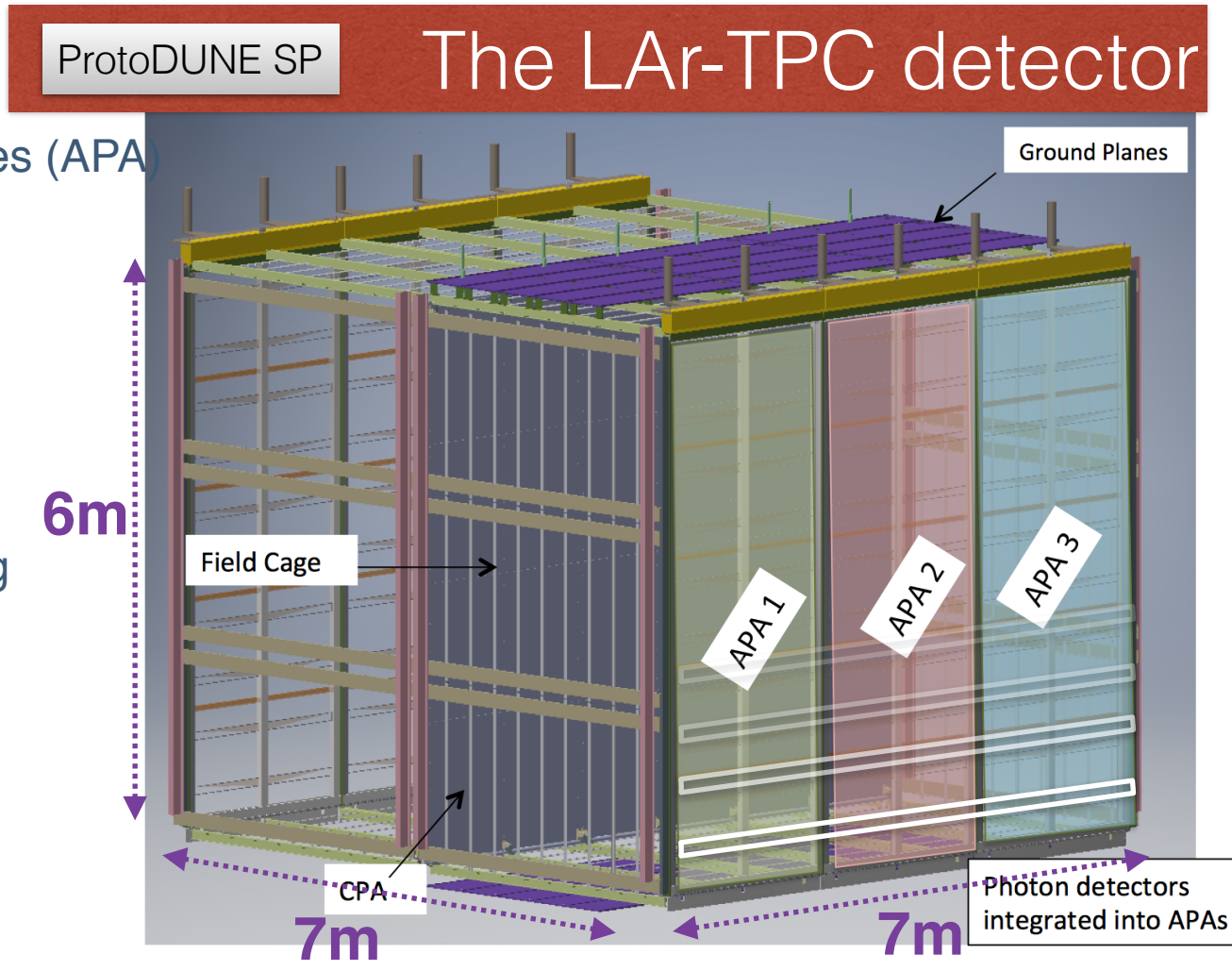
20 ColdElectronics Boxes mounted onto the APA frame and connected to the wires - 2560 Channels-Wire

The modular approach to detector construction enables the construction of detector elements to take place in parallel and at multiple sites.

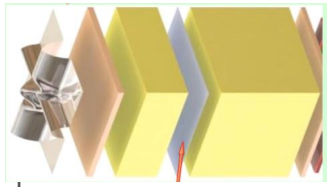
This will be an essential approach for the DUNE Far Detector

The ProtoDUNE SP Detector

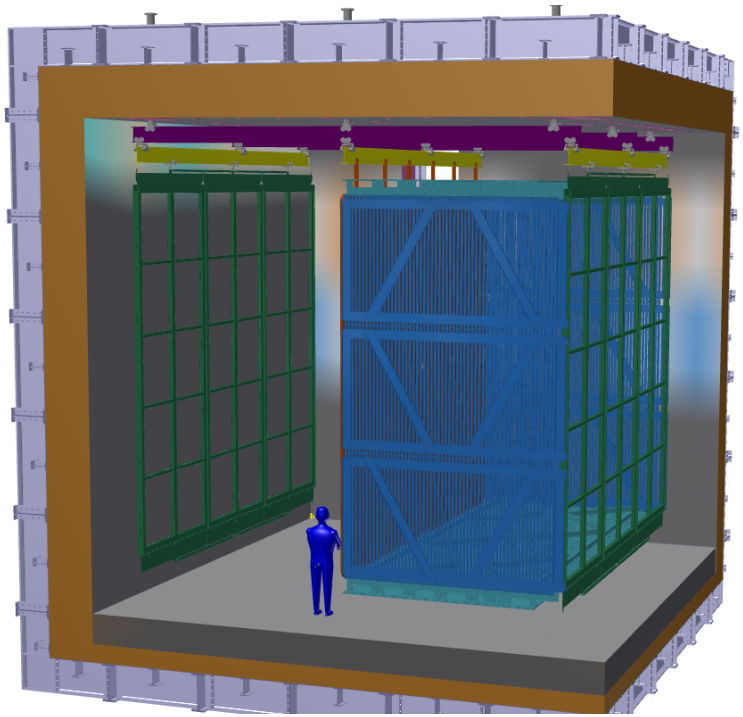
- Six Anode Plane Assemblies (APA)
  - 3 APAs on each side
- Central cathode plane
  - -180 kV nominal
- Field Cage for field shaping
  - shaped profiles / G-10 I-Beam
  - Constructed in panels
- Ground Planes



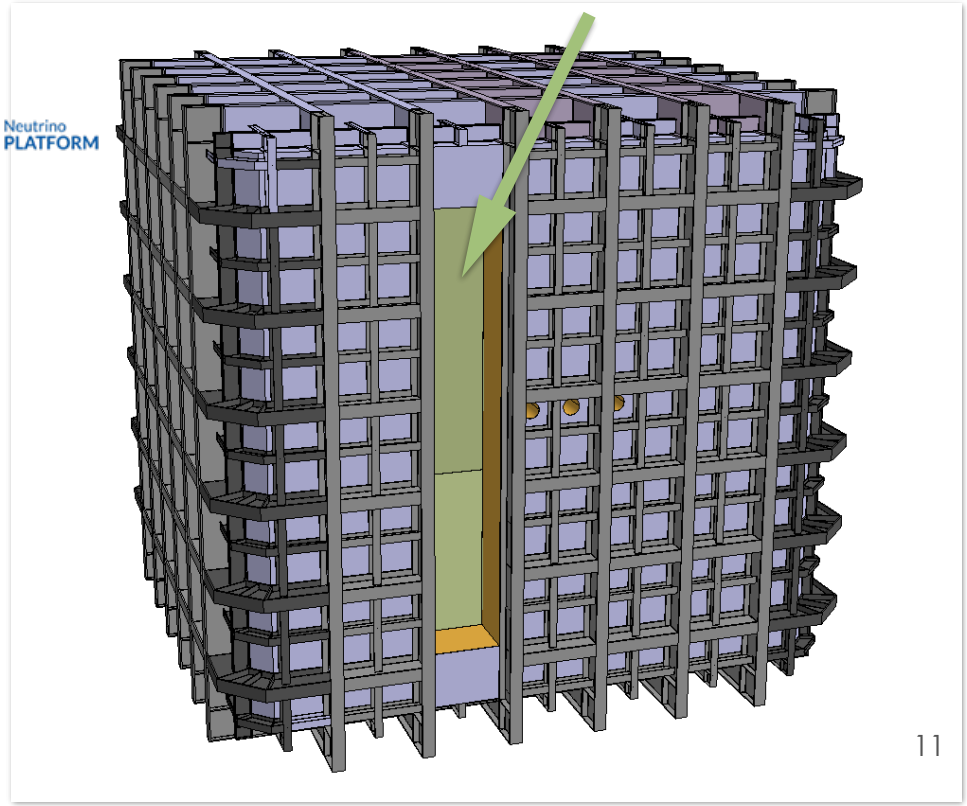
Ship in a Bottle: Detector Assembly inside the Cryostat



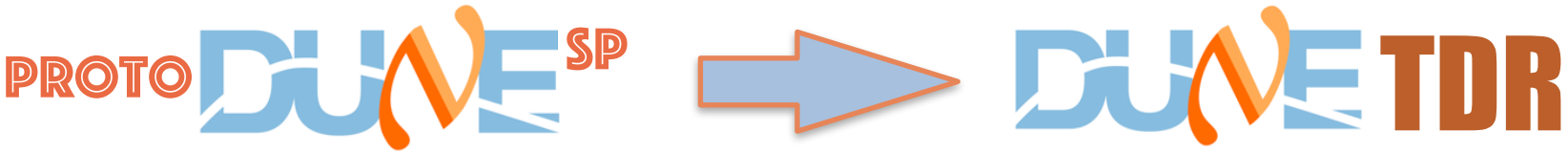
- Install membrane
- Leak test cold vessel
- Installation of the TPC detector
- Close TCO



TECHNICAL CONSTRUCTION OPENING



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



New/Innovative elements of the *DUNE Single Phase Far Detector Design* implemented in protoDUNE-SP:

- CRYOSTAT: Membrane Cryostat (non evacuable, based on LNG container technology)

- APA (TPC wire planes assembly with wrapped wire geometry)
- Cold Electronics (FE and ADC stages both in cold)
- PhotoDetector (3 options implemented)

- 3.6 m drift distance

- Resistive Cathode + HV bus
- Field Cage (based on Al profile assemblies) + Ground planes

- Cryo Instrumentation and Slow Control for monitoring LAr properties (high resolution Vertical T-Profiler, VideoCameras, Purity Monitors,..)

PROTO DUNE SP chronicles

from here *[h. 2:32 am - Sept. 21, 2018]*

to there [Dec. 12, 2015]

Detector Status - Checklist:

- ☑ - LAr filling Completed (LAr at Nominal level)
- ☑ - LAr recirculation ON
- ☑ - HV chain (from Pwr Supply to HV FeedThrough, from Cathode to the end of field Cage resistor divider) "tested"
- ☑ - grounding checked
- ☑ - CE electronic powered ON
- ☑ - Detector Control System active
- ☑ - DAQ ready for data taking
- ☑ - On-line monitor active
- ☑ - Computing for data transfer and first evt./data reconstruction operational
- ☑ - near-line Data Quality Monitor ready
- ☑ - full off-line analysis and reconstruction ready for real events
- ☑ - Beam ON (and beam instrumentation responding)

NP-04/ProtoDUNE-SP Control Room

Sept. 19, h. 15:32: start Detector Activation Procedure

Detector Status - Checklist:

- ☑ - LAr filling Completed (LAr at Nominal level)
- ☑ - LAr recirculation ON
- ☑ - HV chain (from Pwr Supply to HV FeedThrough, from Cathode to the end of field Cage resistor divider) "tested"
- ☑ - grounding checked
- ☑ - CE electronic powered ON
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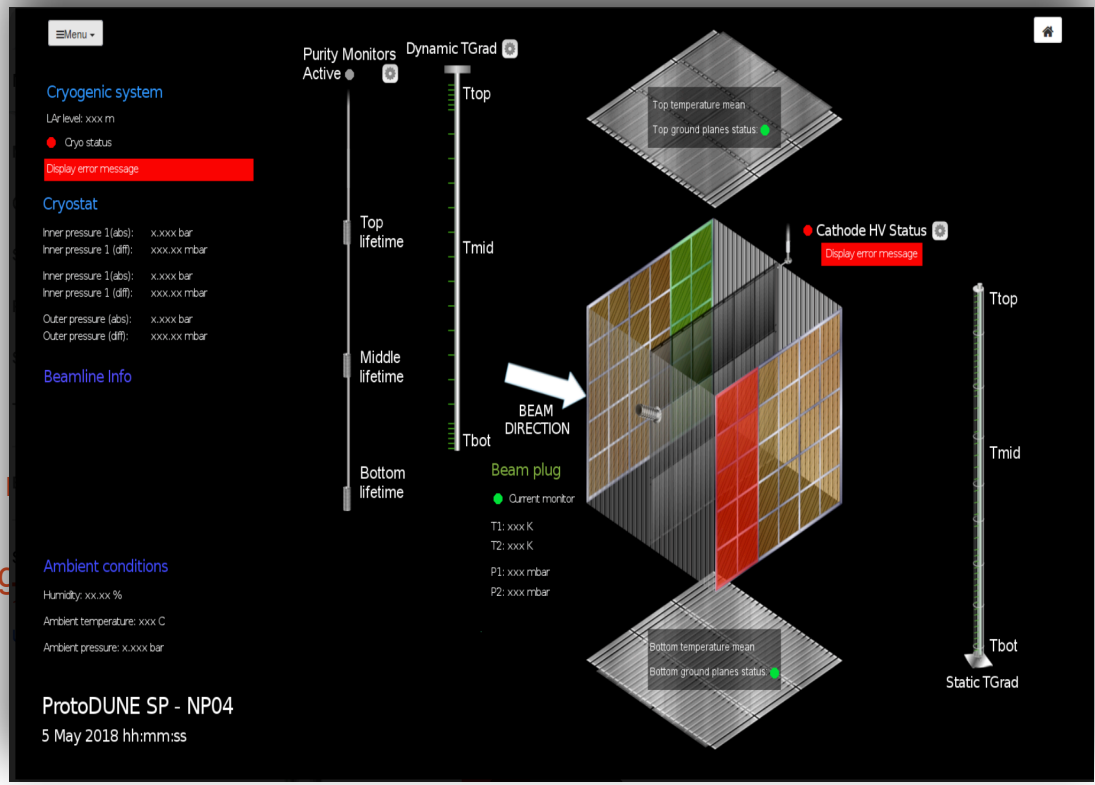
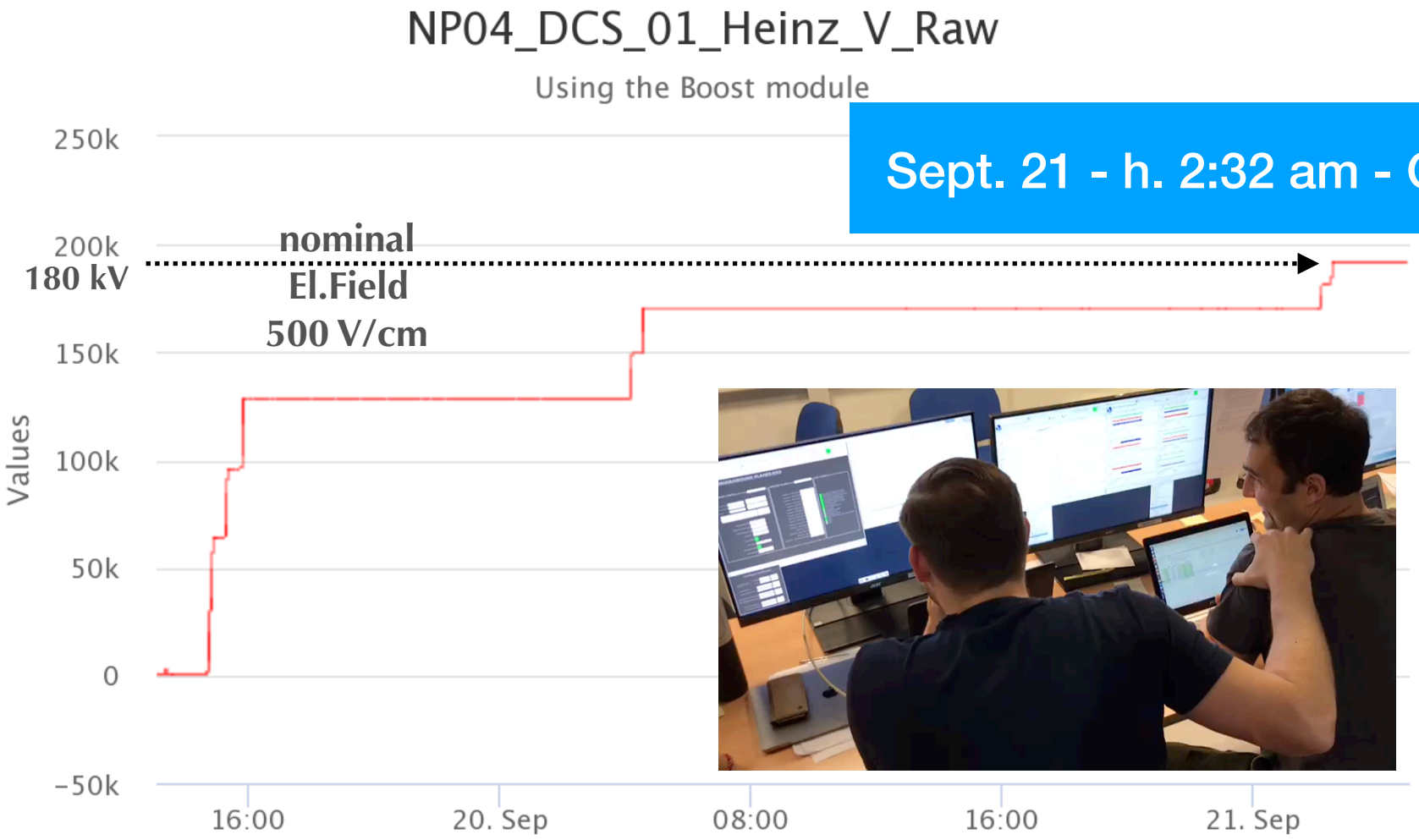
- ☑ - full off-line analysis and reconstruction ready for events
- ☑ - Beam ON (and beam instrumentation responding

NP-04/ProtoDUNE-SP Detector Control System



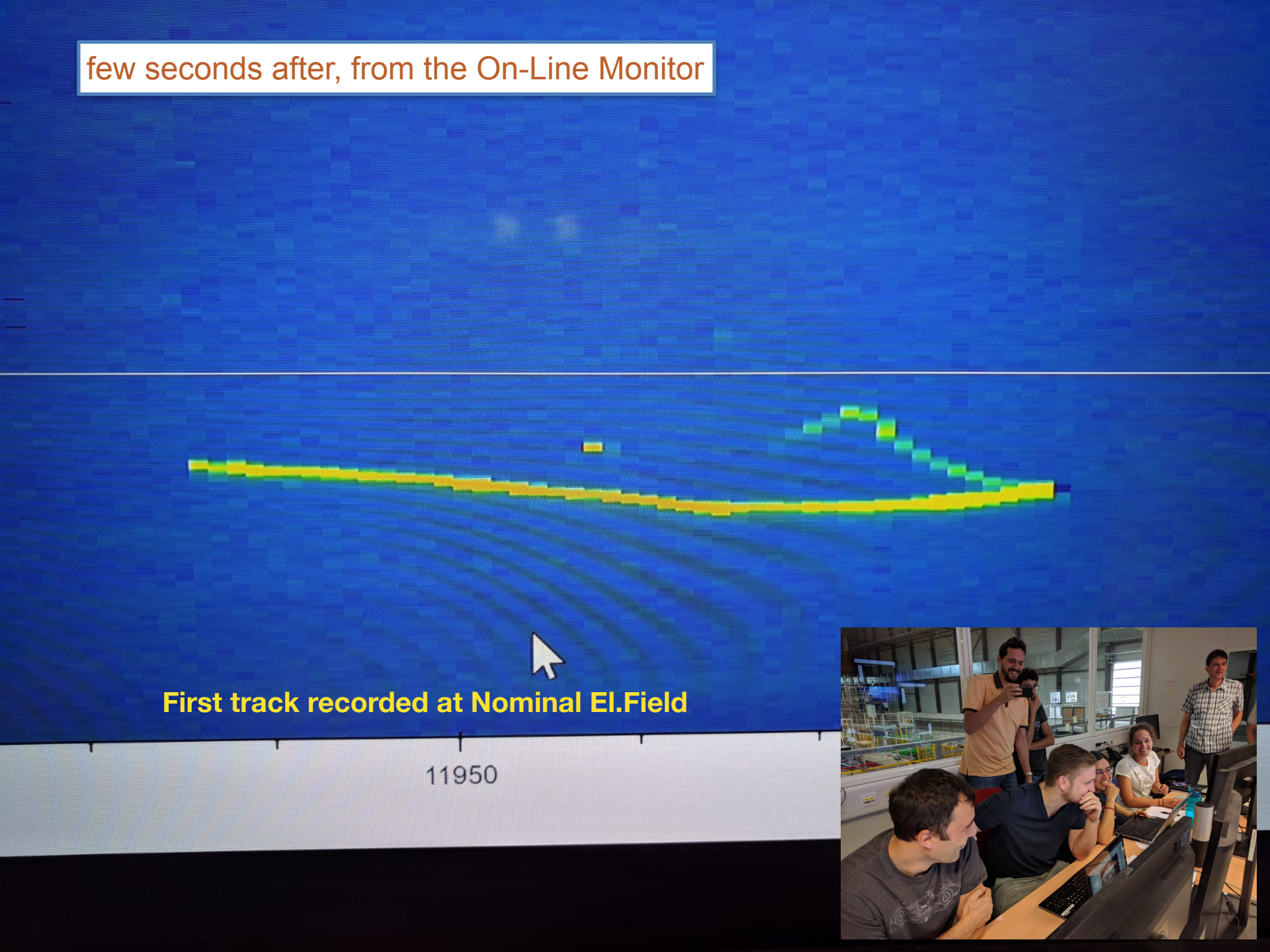
Sept. 19, h. 15:32: start Detector Activation Procedure



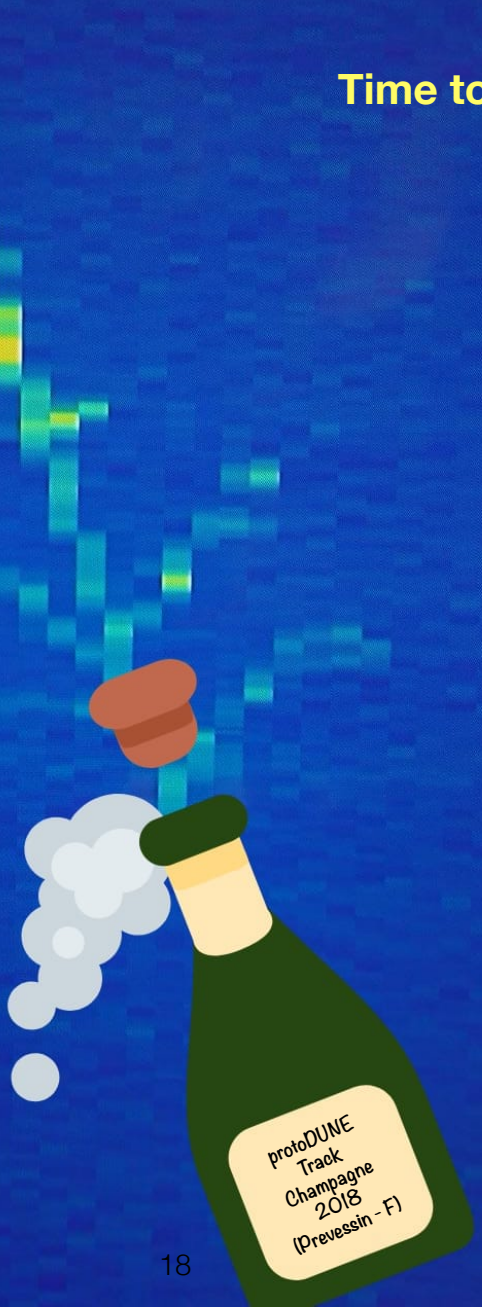
Sept. 21 - h. 2:32 am - CDT

HV Ramp from 0 to 180 kV (Nominal)

few seconds after, from the On-Line Monitor



Time to Celebrate

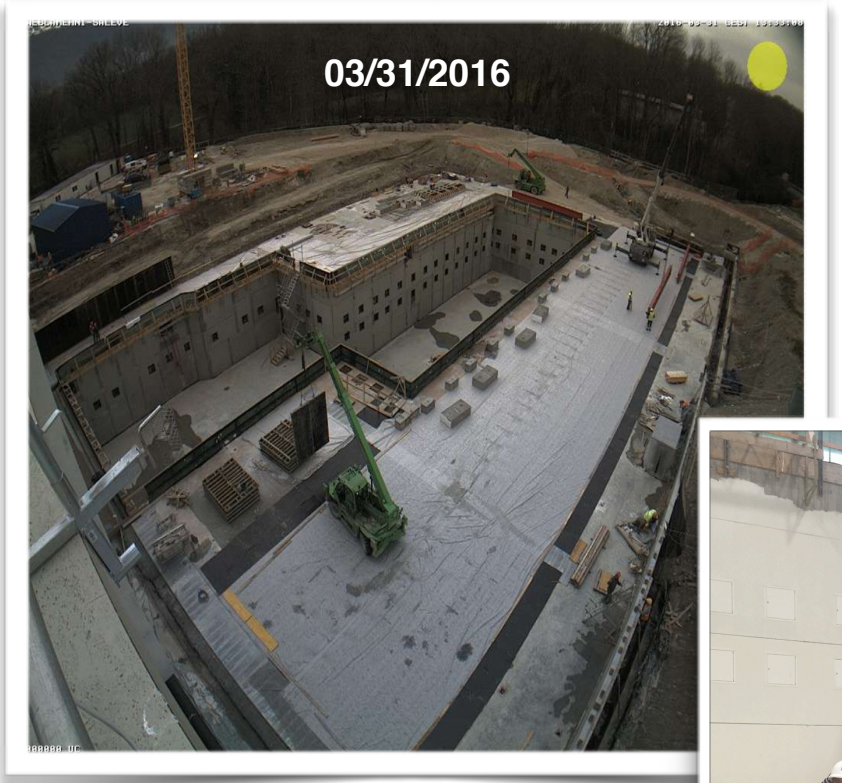


PROTO DUNE SP chronicles

&

Realization of the Neutrino Platform

the first step: Late 2015 - Oct. 2016

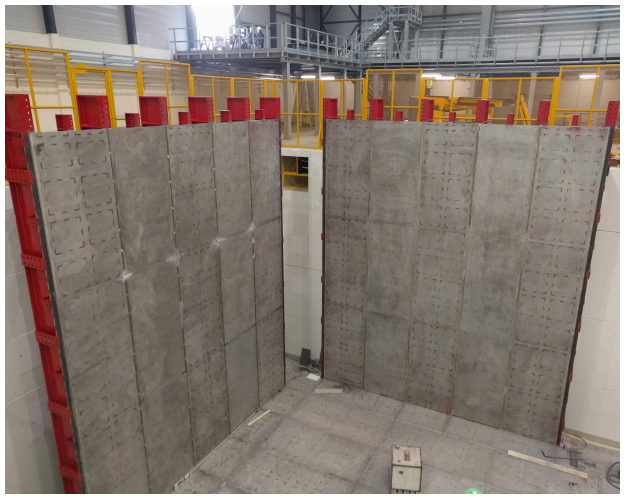
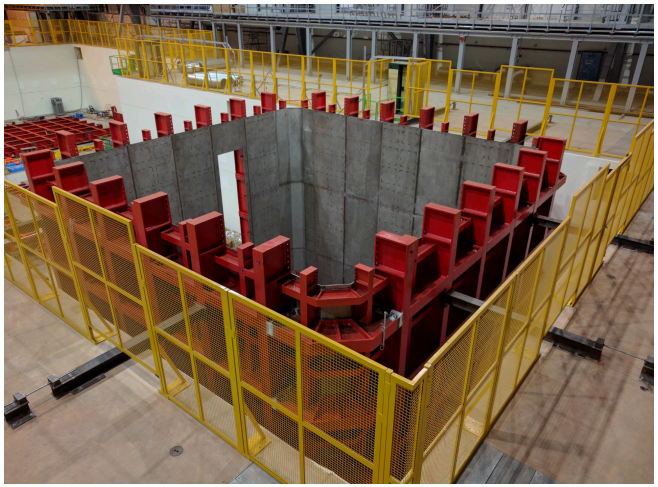


EHN1 extension

beneficial occupancy - September 2016

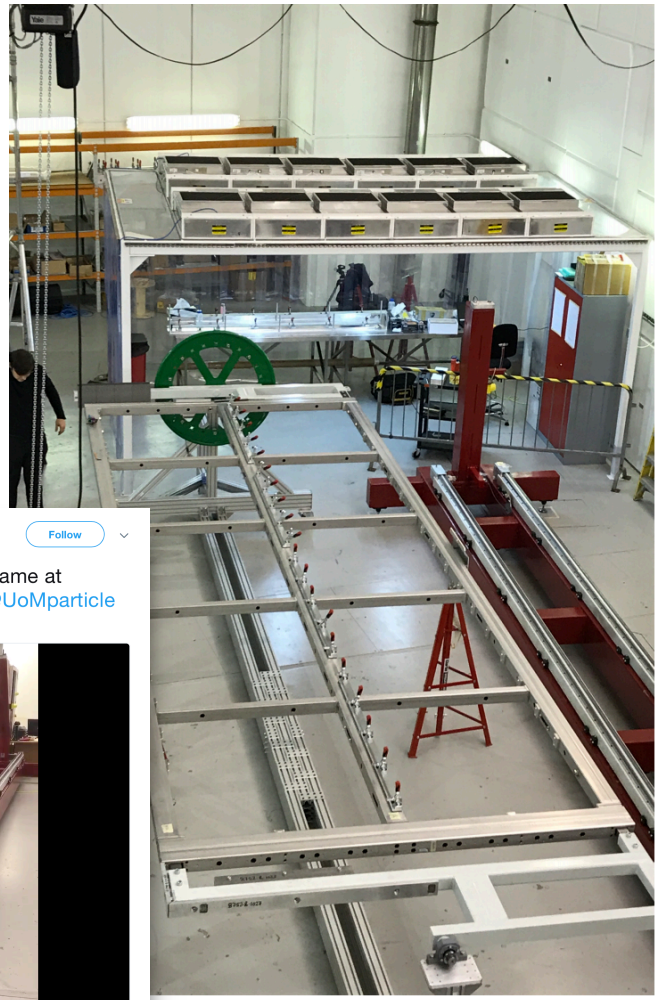
Cryostat construction

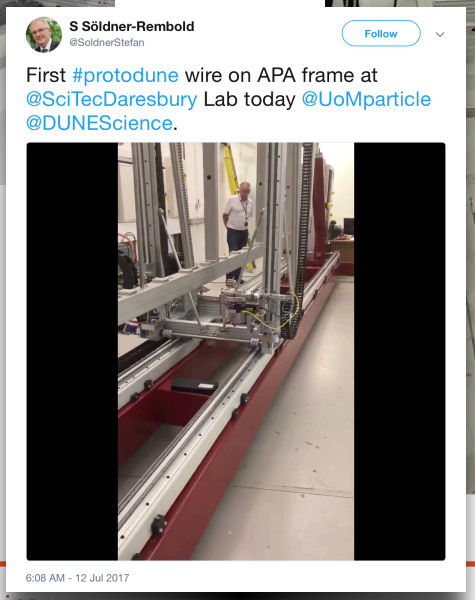
the second step: Oct. 2016 - May 2017

TPC - Cold Electronics - PhDetector

Fabrication of Detector components: Dec. 2016 to Mar. 2018





Cold electronics directly attached to APA (2560 wires):

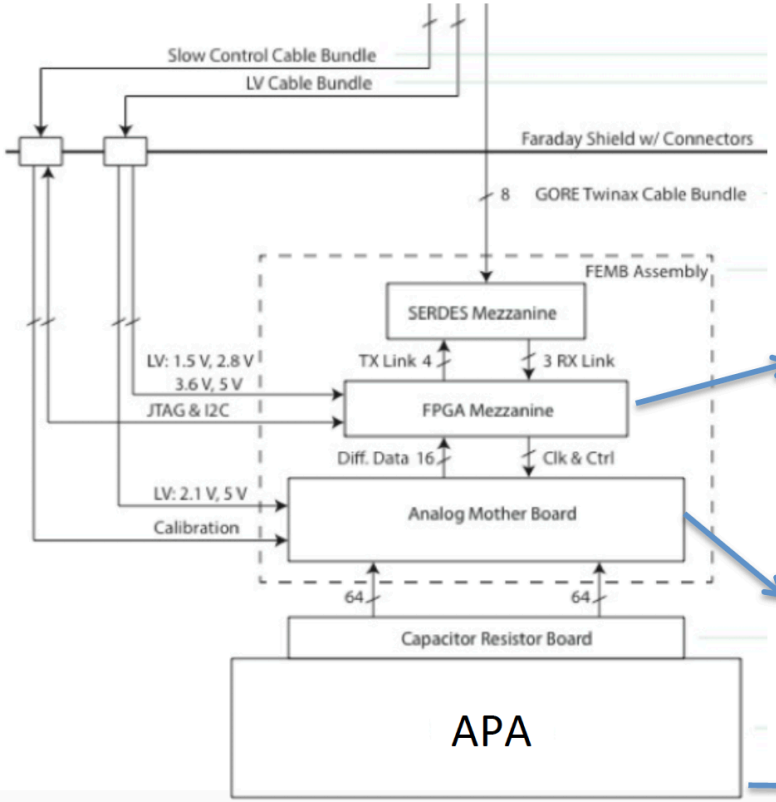
1 APA → 20 FEMB (2560 ch/20 = 128 ch)

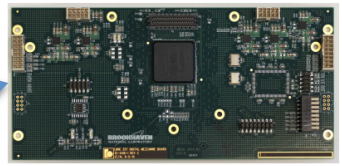
- Analog Mother board with 8 FE (16ch) and ADC ASICs (16ch) → 128 wires IN

→ **Multiplexed** to 4 OUTputs: 128 / 8 (ADC ASIC) / 4 (FPGA) = 4 outputs

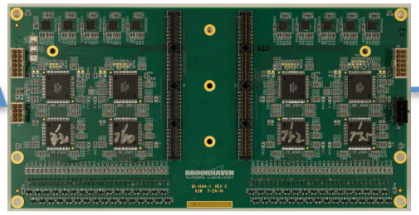
- 16 ch FE ASIC: Preamplifiers with shaping circuit

→ No zero suppression; no data compression

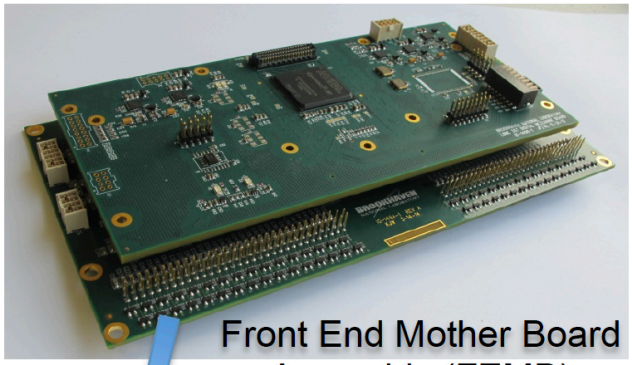




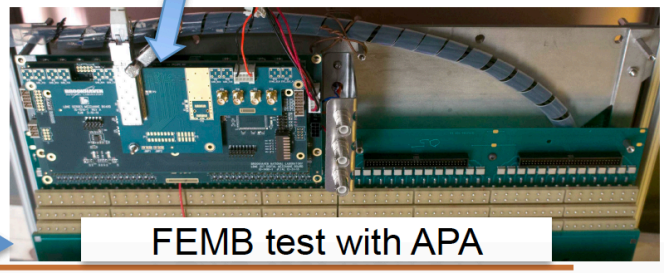
FPGA Mezzanine



Analog Mother Board



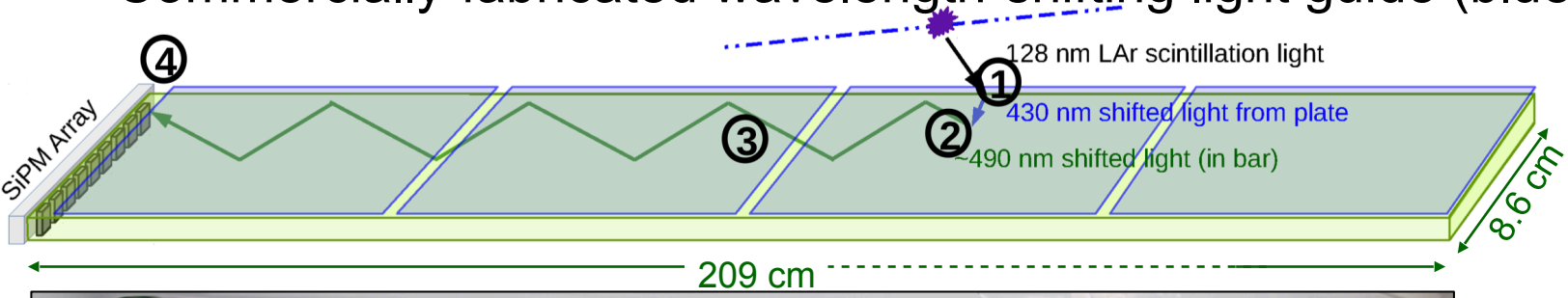
Front End Mother Board Assembly (FEMB)



FEMB test with APA

DOUBLE-SHIFT LIGHT GUIDE

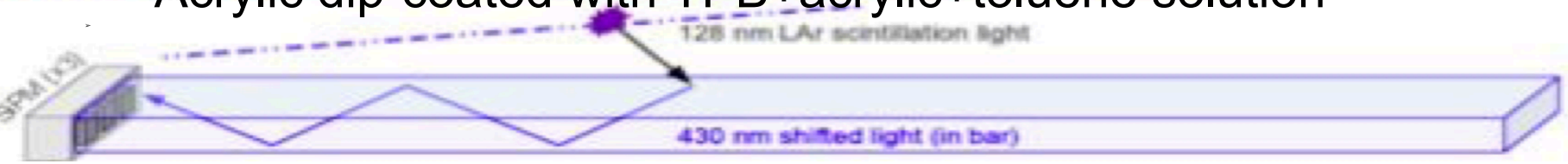
- Spray-coated wavelength-shifting plates (VUV to blue)
- Commercially-fabricated wavelength-shifting light guide (blue to green)



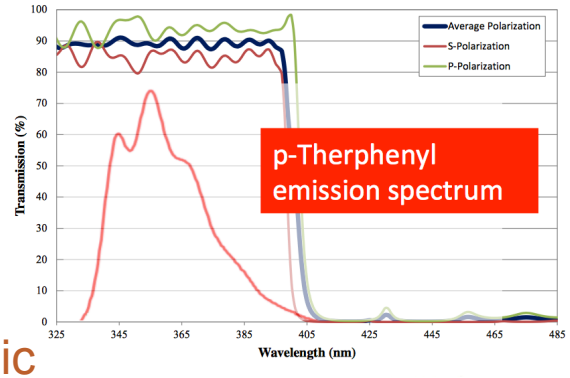
Transport shifted light via total internal reflection to readout (SiPM array)

DIP-COATED LIGHT GUIDE

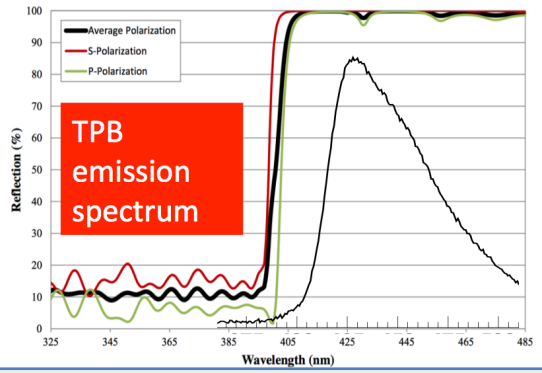
- Pre-treated commercially-cut acrylic
- Acrylic dip-coated with TPB+acrylic+toluene solution



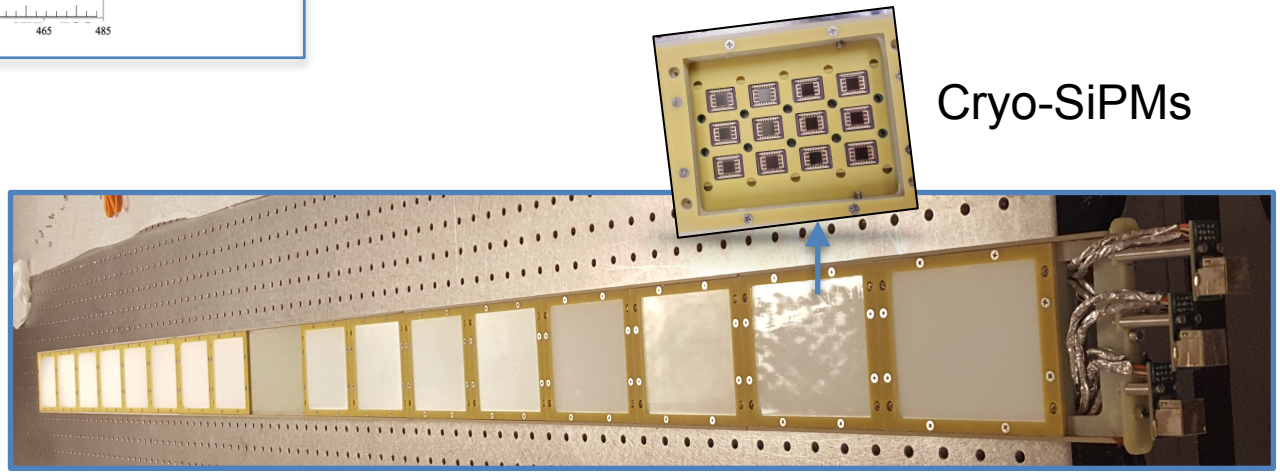
ARAPUCA LIGHT TRAP



Dichroic Glass



- Dichroic (short-pass) filter to trap w.l.-shifted light inside ARAPUCA reflective cell
- p-TerPhenyl on outer surface
- TPB on inner surface (trapped)
- Segmentation along beam direction
- Possibility to detect converted light by shifter on the cathode



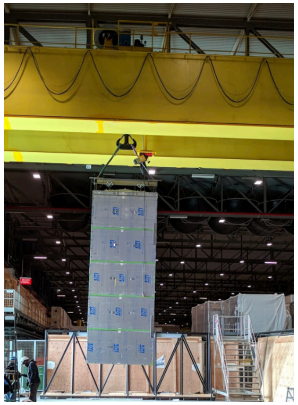
Cryo-SiPMs

TPC - Cold Electronics - PhDetector Delivery, Integration, Test and Installation

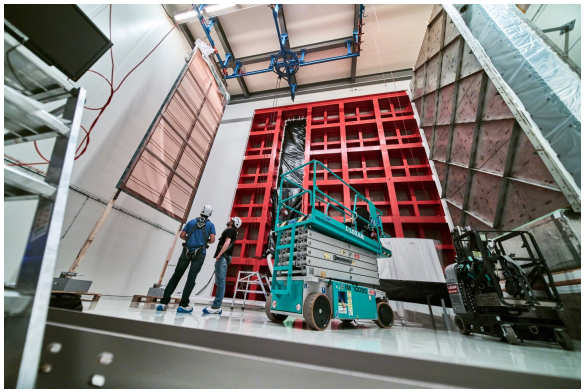
The long "ITI period": July 14, 2017 to Apr. 30, 2018

a very busy time !

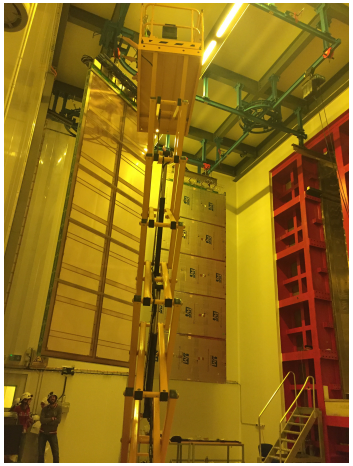
		Winding		Transport			Cold Box Test Time		In Cryostat	
		Start Winding	Finish Winding	Crate	Ship	Arrival at CERN	Start	Finish		
APA#1	PSL#1	2/1/17 A	6/30/17 A	7/7/17 A	7/11/17 A	7/14/2017 A	10/9/2017 A	11/26/2017 A	11/28/17 A	10 months
APA#2	PSL#2	8/9/17 A	10/23/17 A	11/10/2017 A	11/14/2017 A	11/17/2017 A	11/29/2017 A	1/17/2018 A	1/26/18 A	5 months
APA#3	UK#1	8/9/2017 A	12/01/2017 A	1/10/2018 A	1/12/2018 A	1/16/2018 A	1/31/2018 A	2/8/2018 A	2/9/2018 A	5 months
APA#4	PSL#3	11/20/2017 A	1/17/2018 A	2/9/2018 A	2/15/2018 A	2/20/2018 A	3/12/2018 A	3/27/2018 A	4/23/2018 A	5 months
APA#5	UK#2	1/23/2018 A	2/28/18 A	3/9/2018 A	3/13/2018 A	3/16/2018 A	4/18/2018 A	4/23/2018 A	4/24/2018 A	3 months
APA#6	PSL#4	2/8/2018 A	3/12/2018 A	3/23/2018 A	4/3/2018 A	4/6/2018 A	N/A	N/A	4/20/2018 A	2.5 months

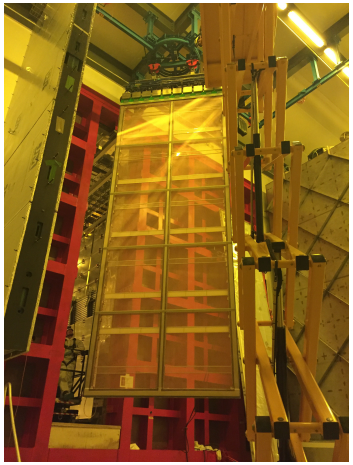


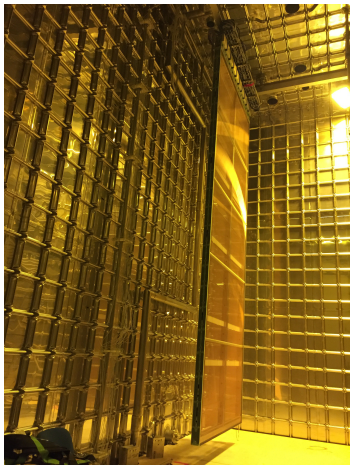
from outside
to inside



Detector Integration &
Cold Box test
in the Clean Room

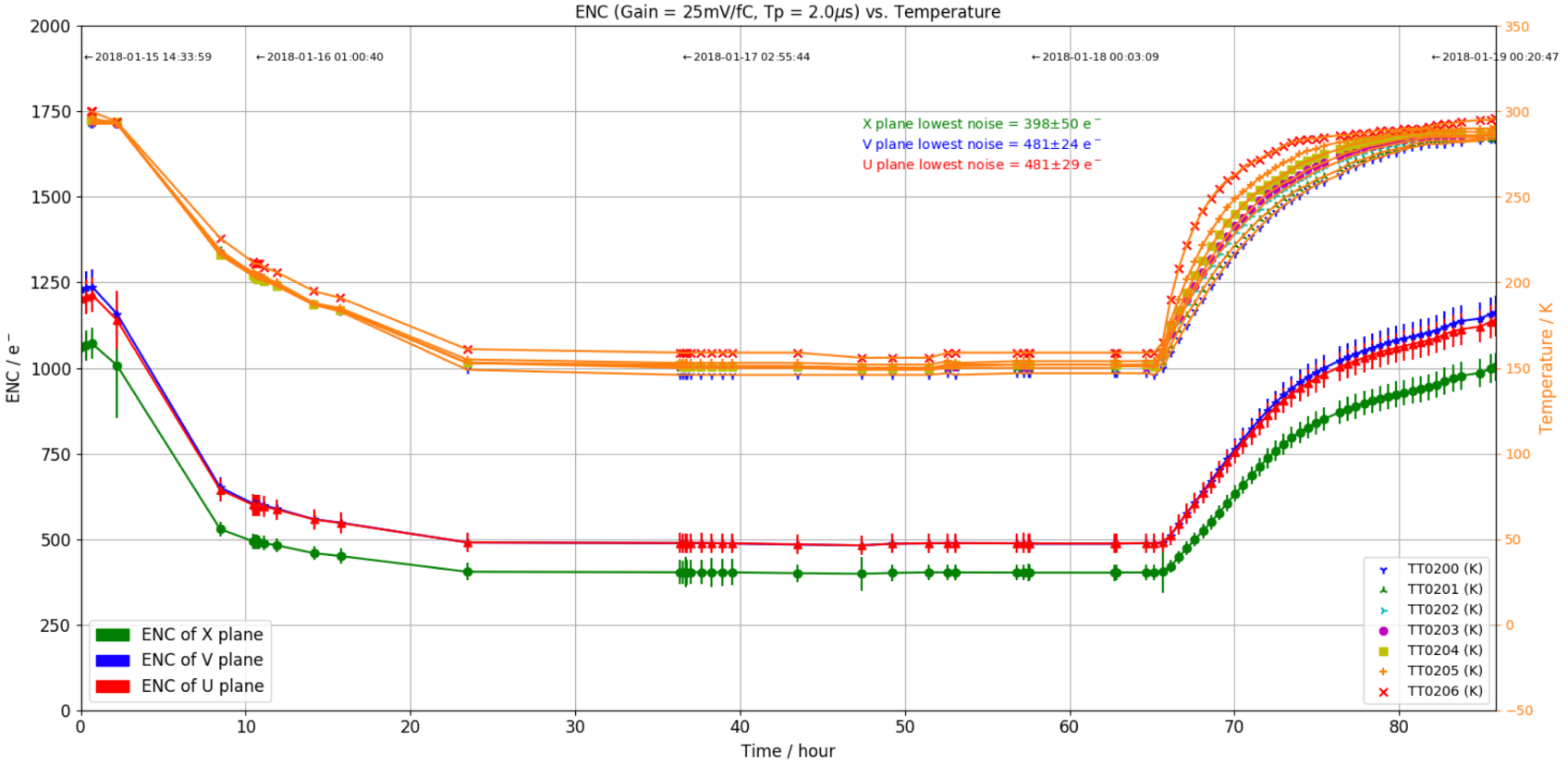




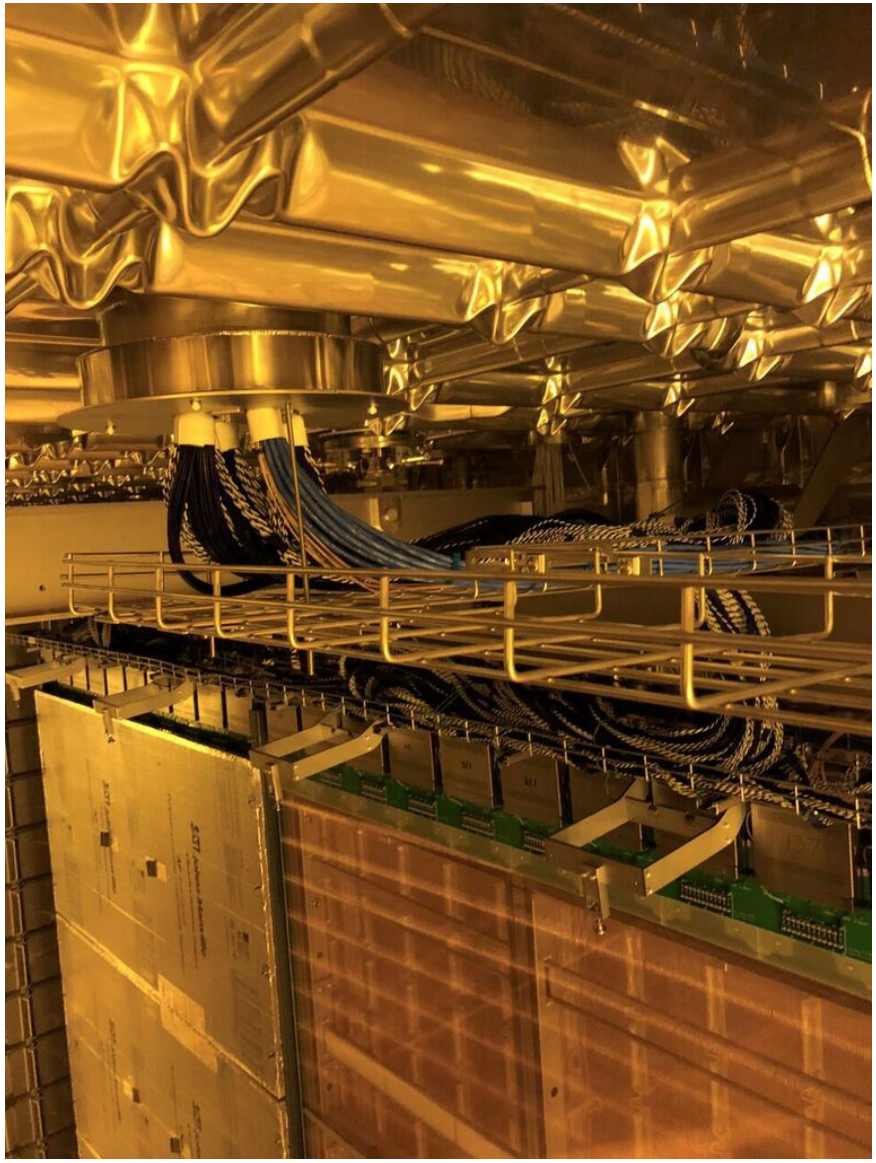


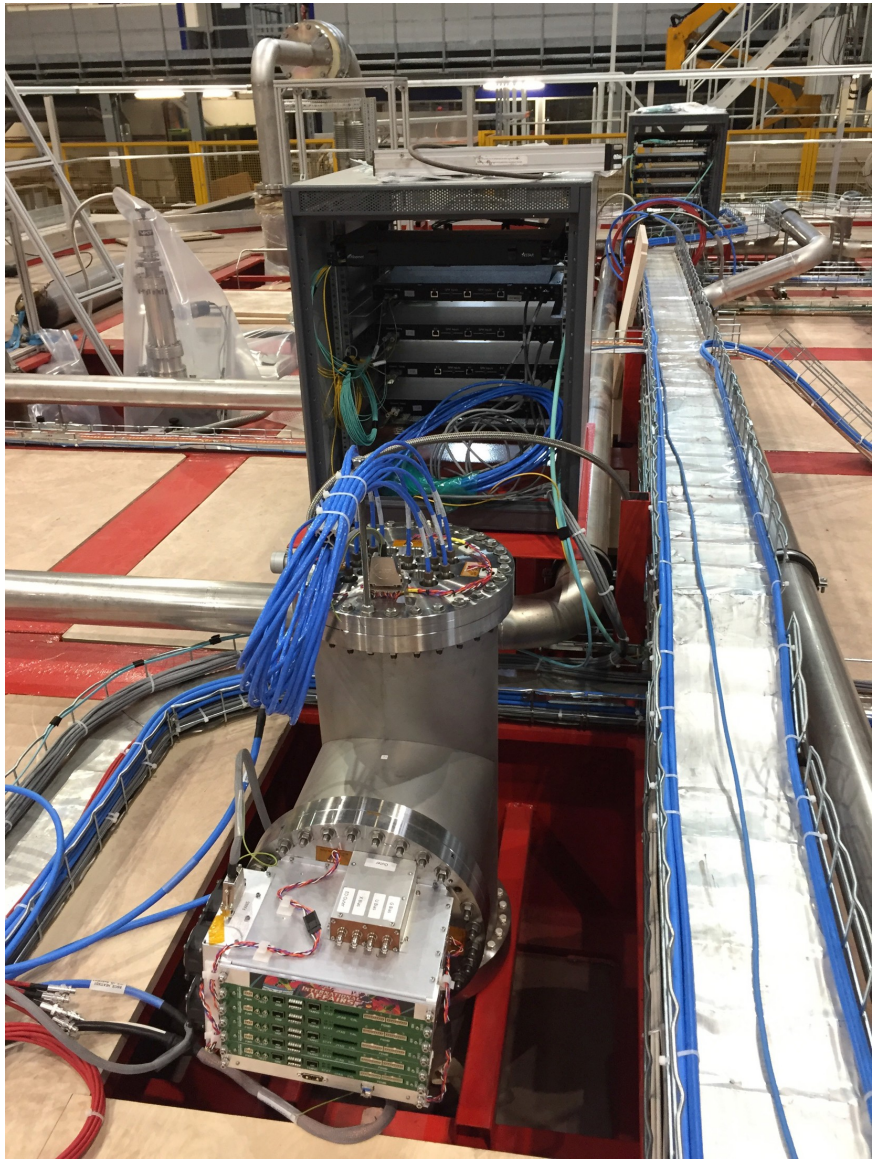
APA cold tests (GN_2)

ENC @ 150K:
380 e (X), 460 e (U, V)

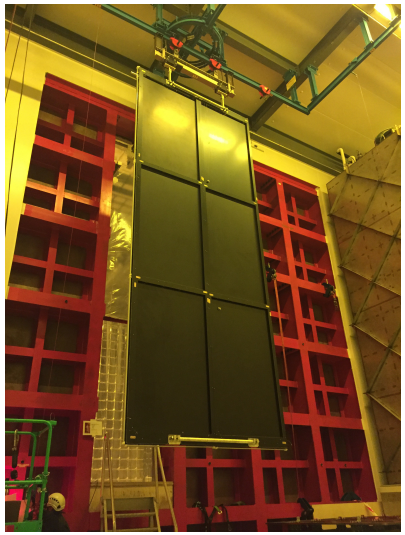


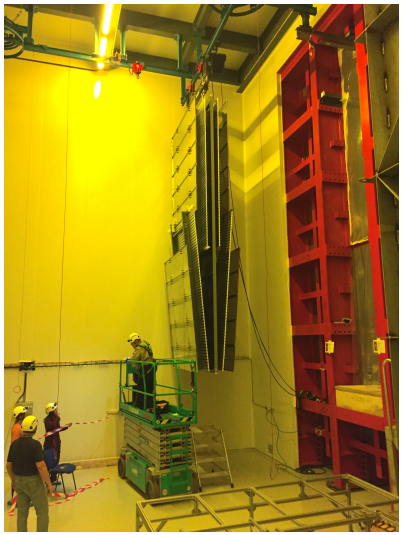
from inside to outside

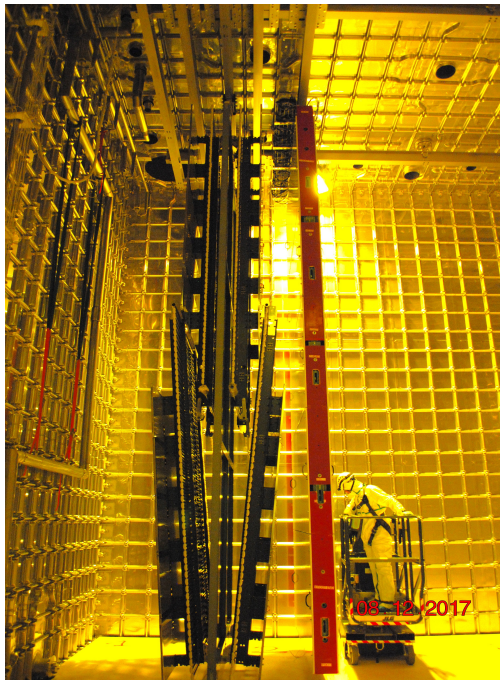


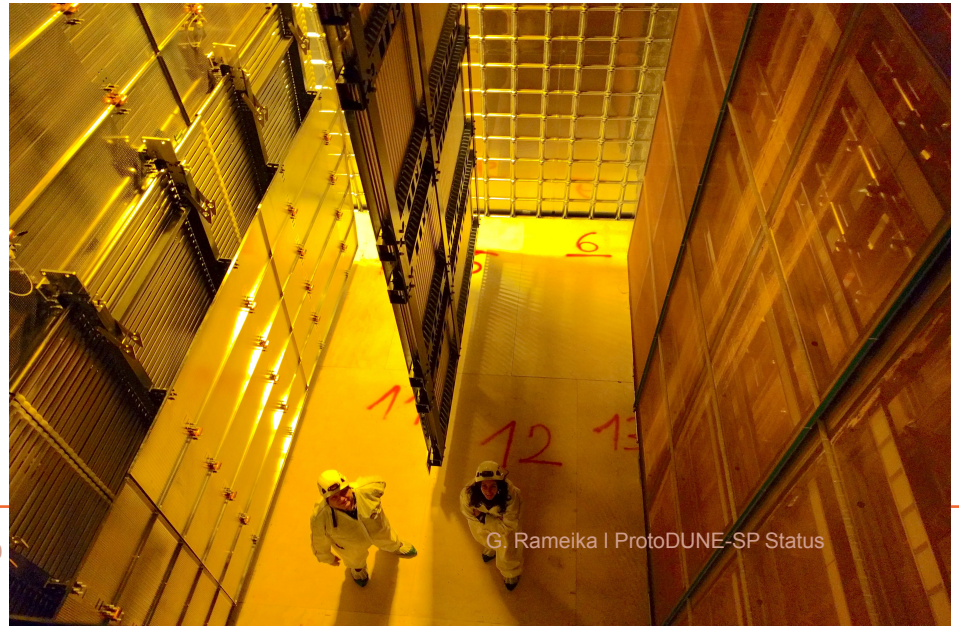


Cathode & Field Cage assembly



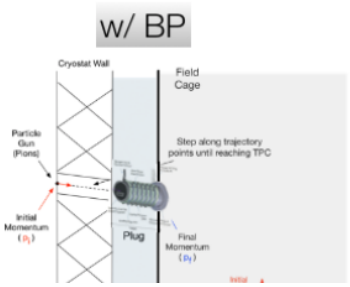




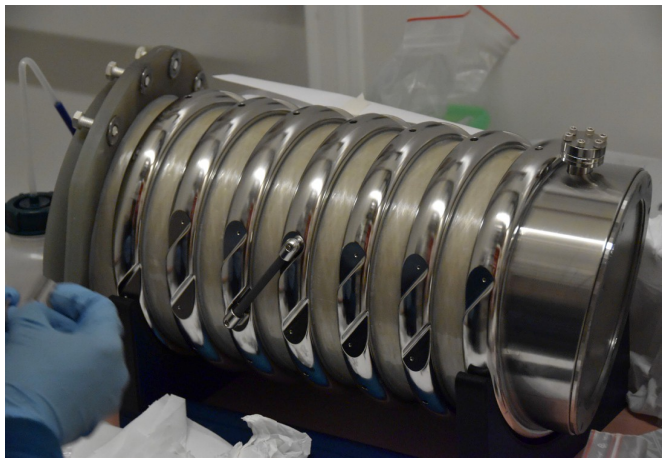


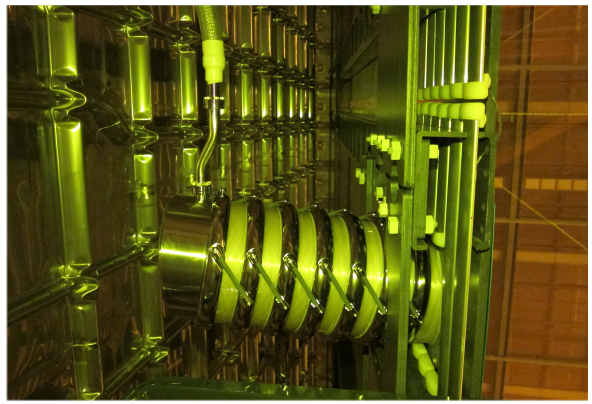
Full Scale Trial Assembly at Ash River

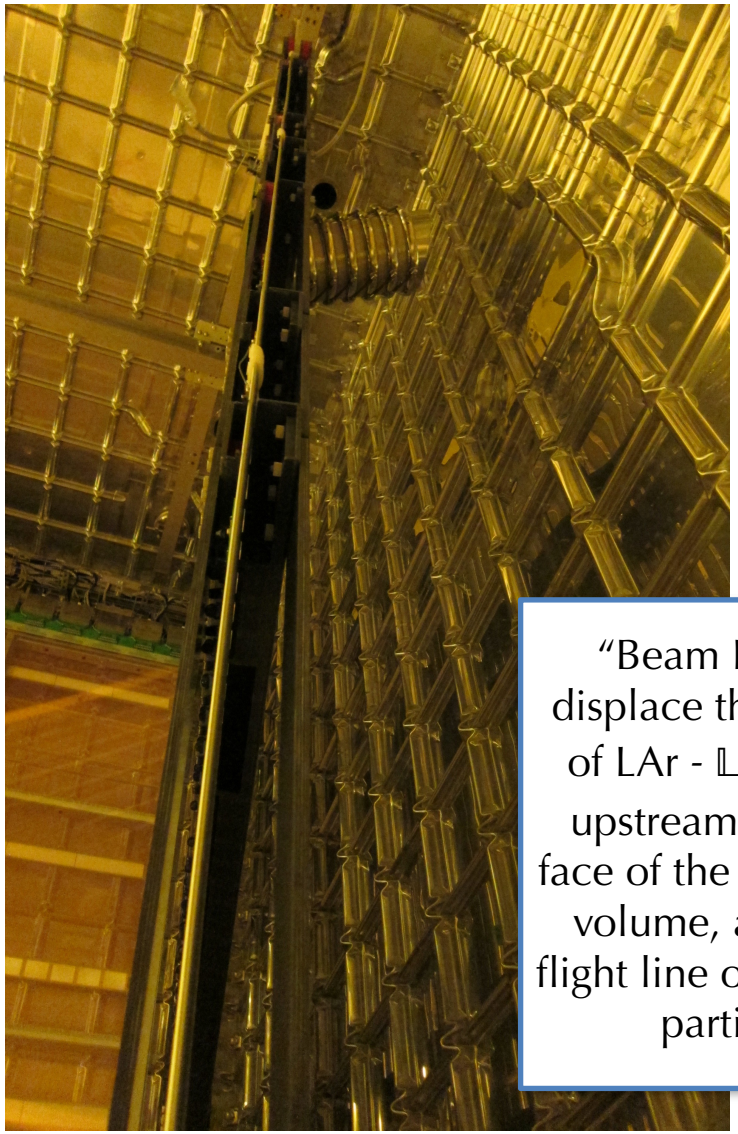
Beam Plug



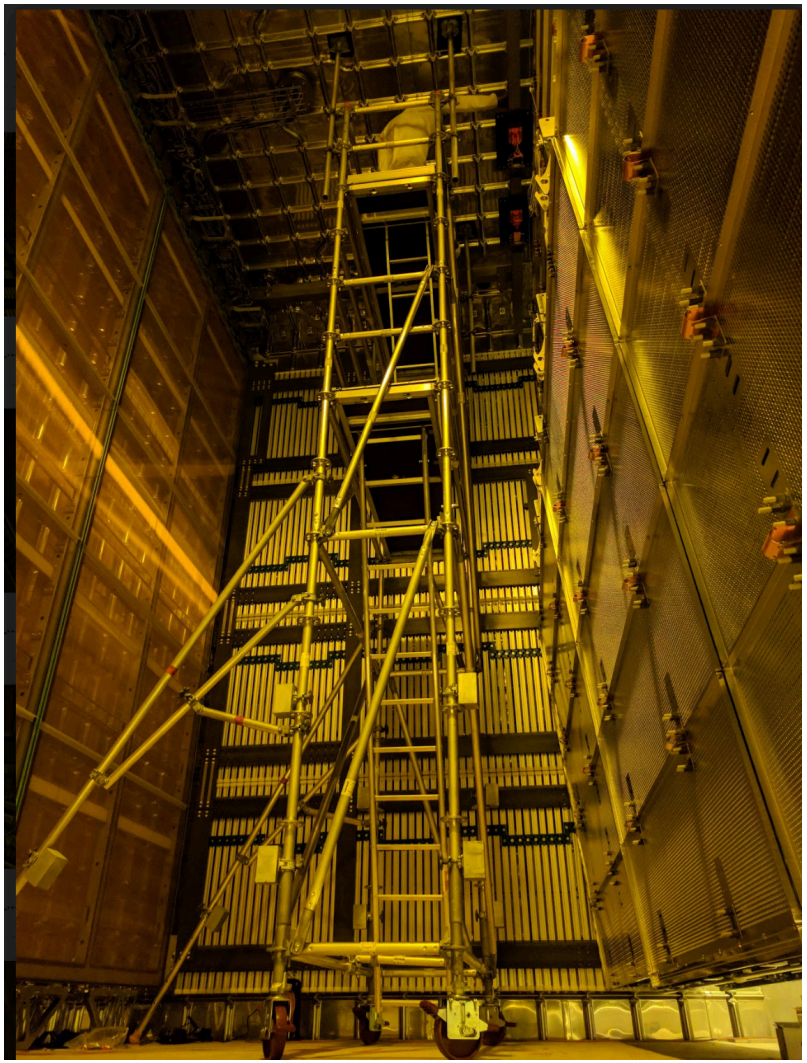
	w/ BP	w/out BP
Material Budget	$0.1X_0$, 0.01λ	$3.5X_0$, 0.9λ

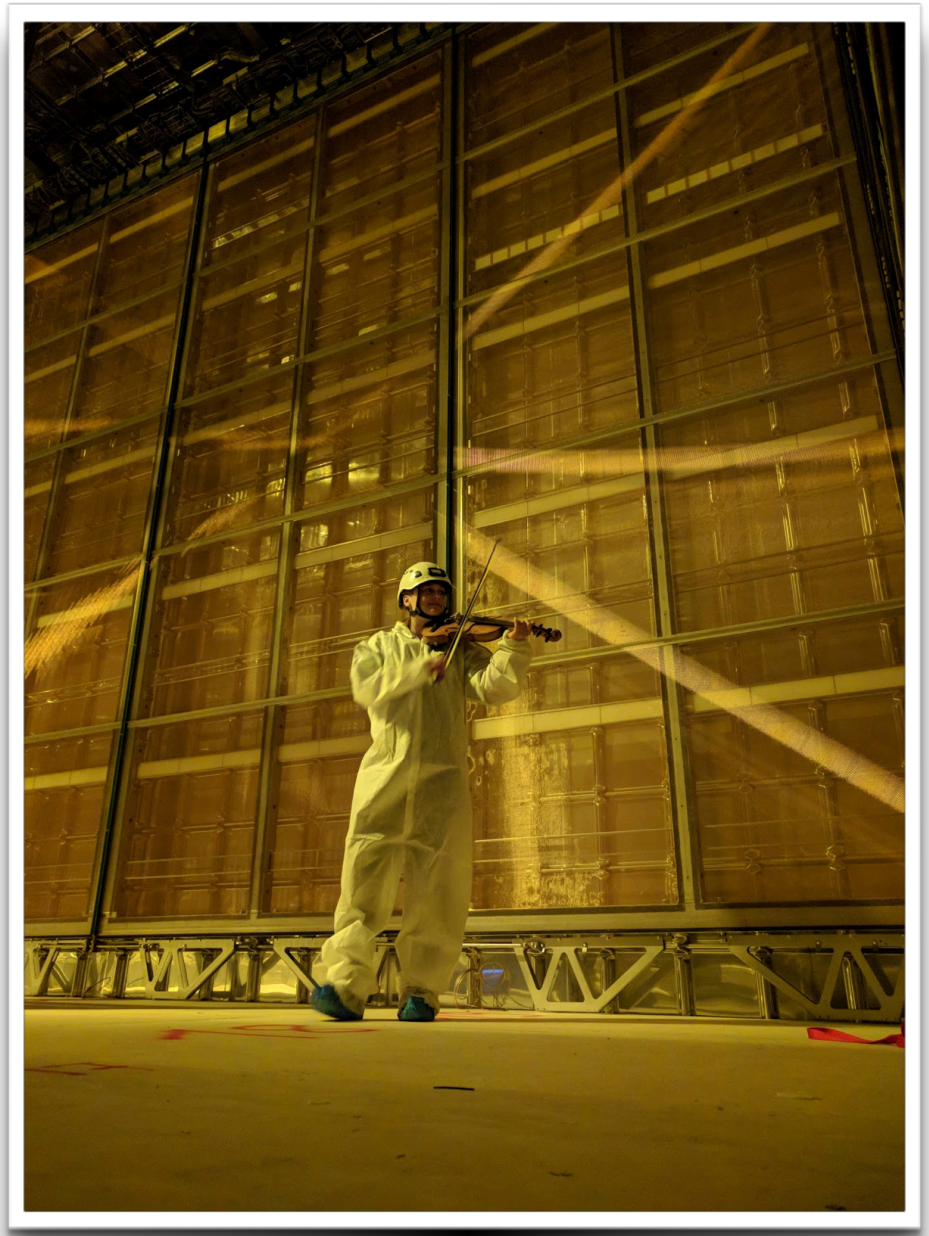






"Beam Plug" to displace the amount of LAr - $\mathbb{L}\sim 50\ cm$ - upstream the front face of the TPC active volume, along the flight line of the beam particles

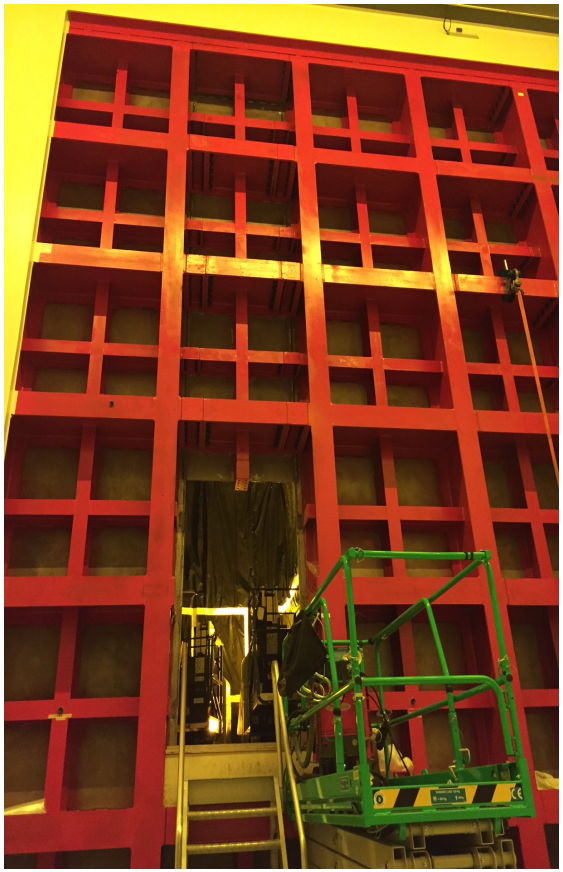


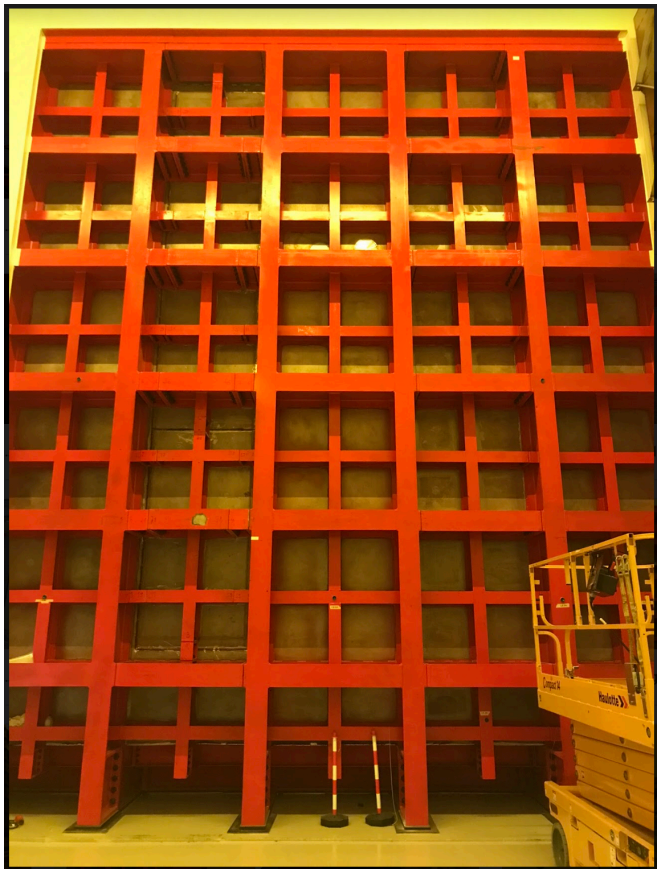


click here if you want to listen

Closing the Temporary Construction Opening

a hard deadline: May 1 to June 13 - 2018





… and assembly of the external cryogenics for LAr recirculation (re-condensation and filtration)

TPC mounting completed and LAr detector installation inside the Cryostat

one more step forward: June 14 to July 15 - 2018

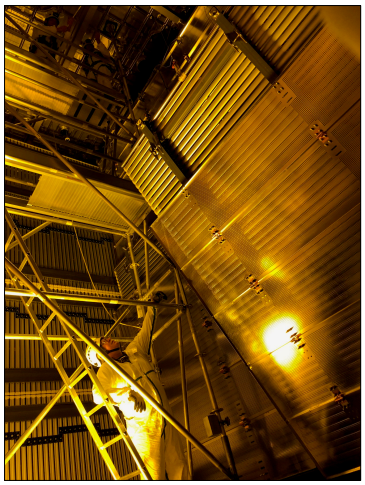
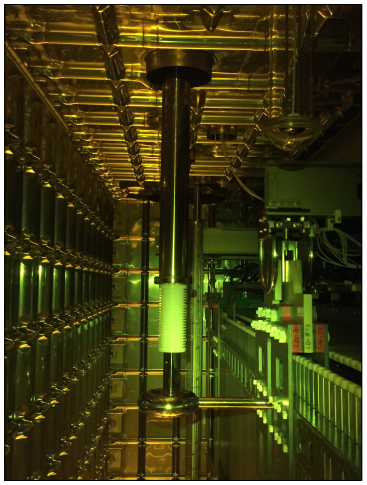
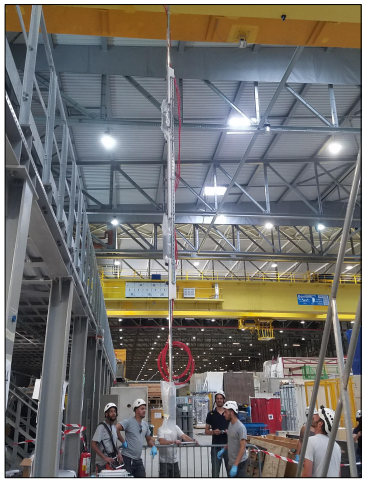
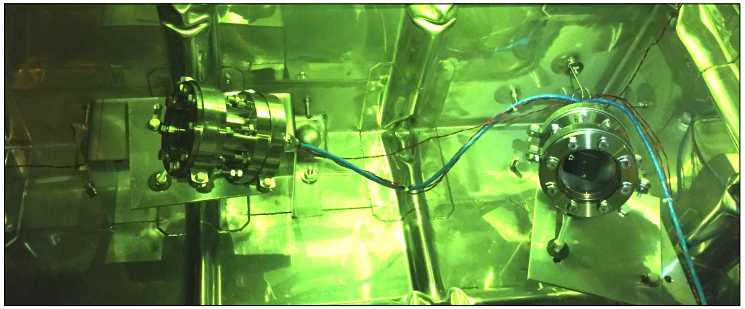
Regained access to the cryostat June 14th after the Temporary Construction Opening was sealed

Completed the beam left drift

- Fixed APAs and end walls into final position
- Deployed top/bottom field cage units
- Installed high voltage cup and feedthrough

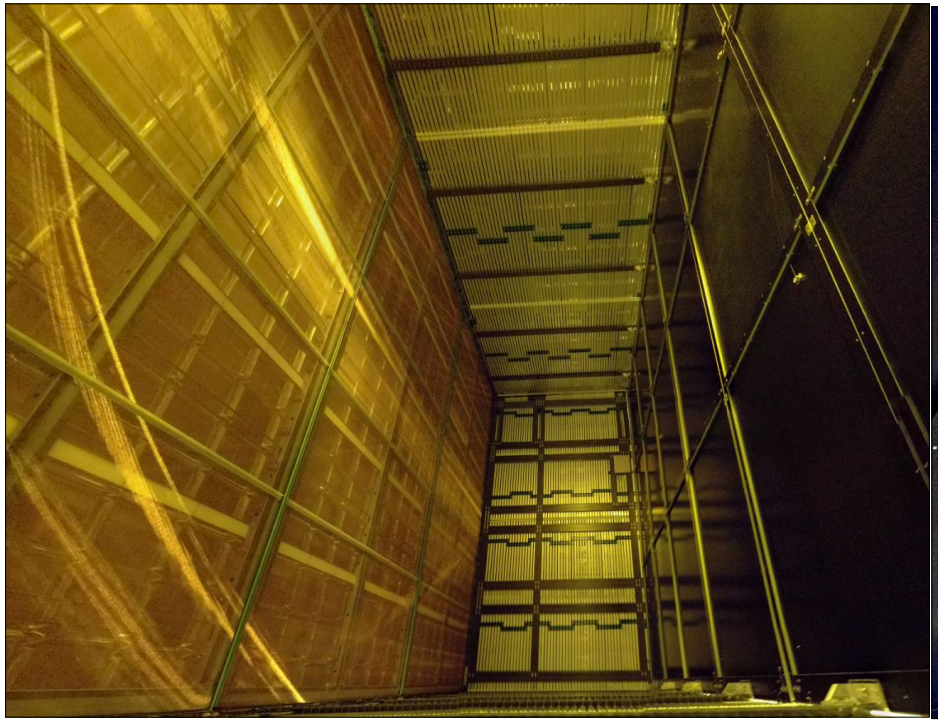
Installed Cryo-Instrumentation

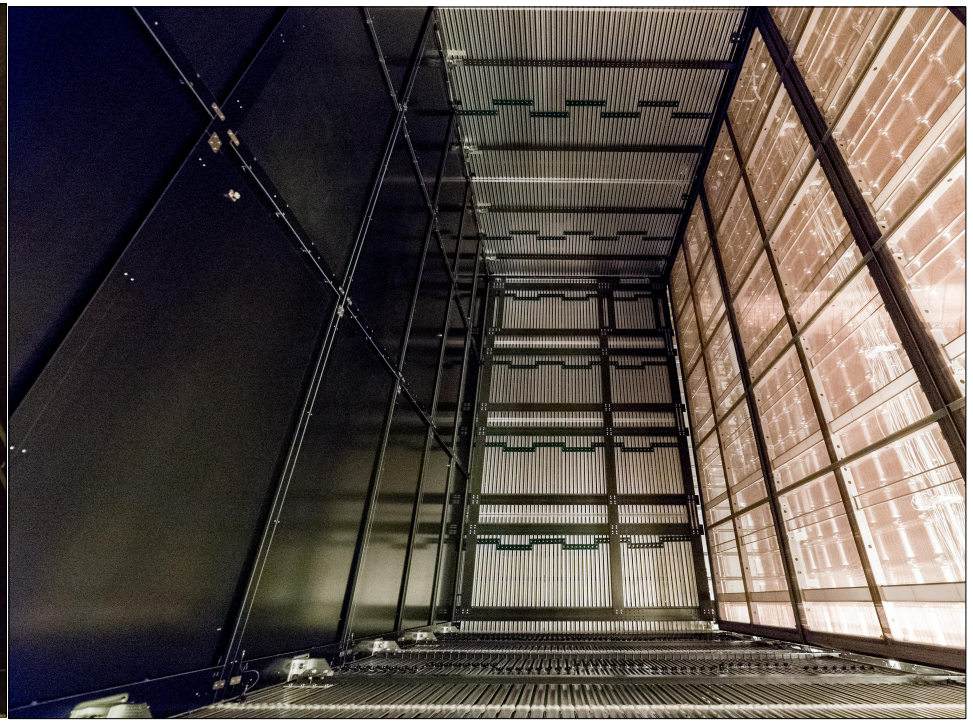
- Cameras
- LEDs (visible and IR)
- Temperature sensors/profilers
- Purity monitors

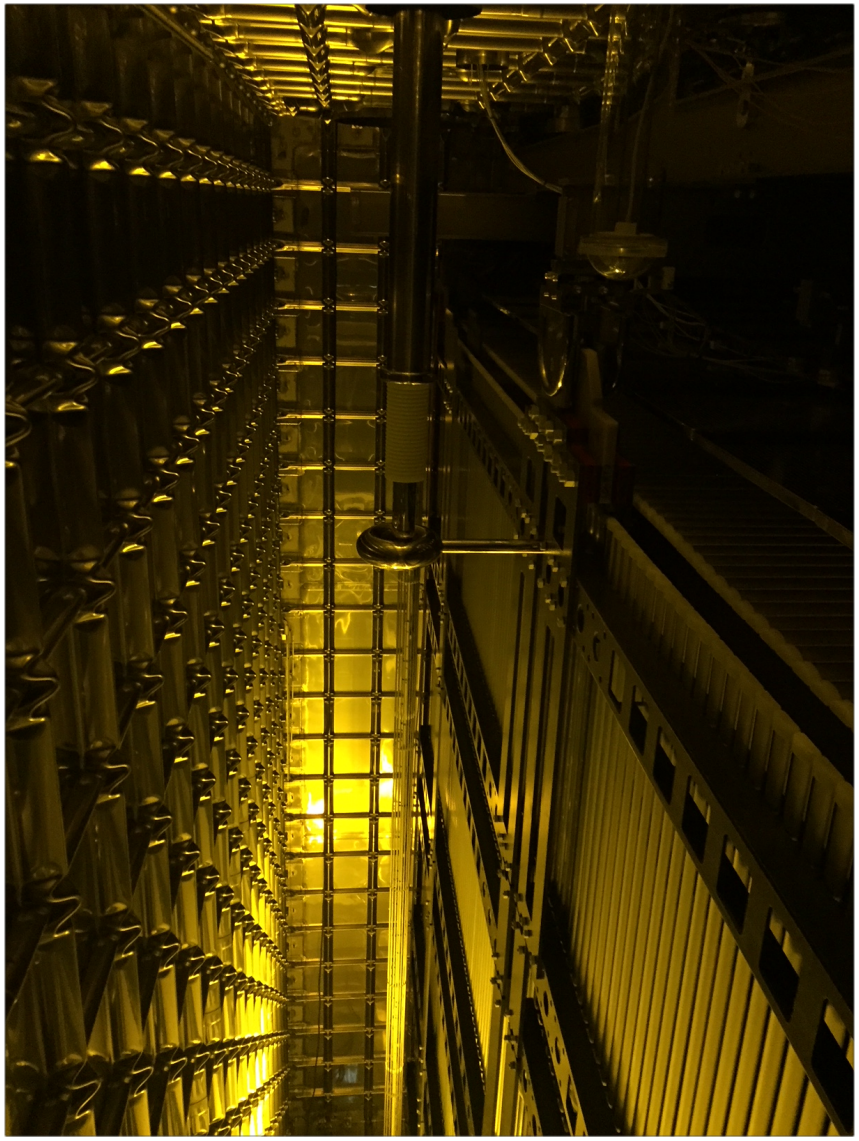
Final exit, June 28th

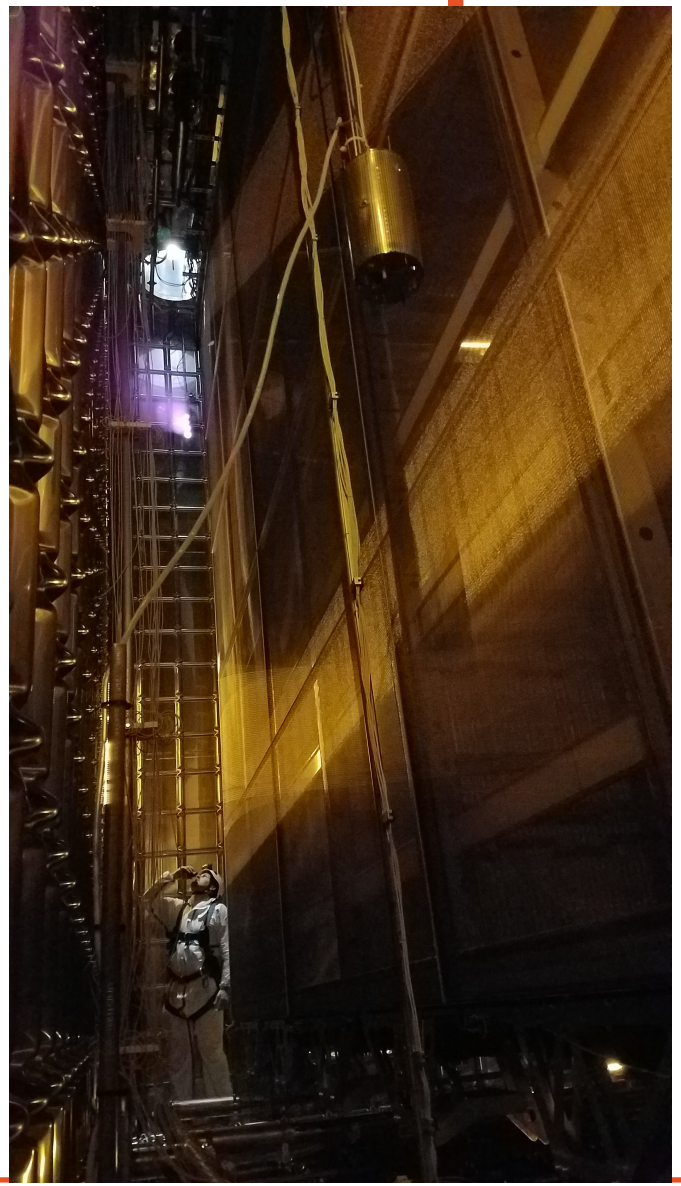
TPC Installation Completed





Detector Completed



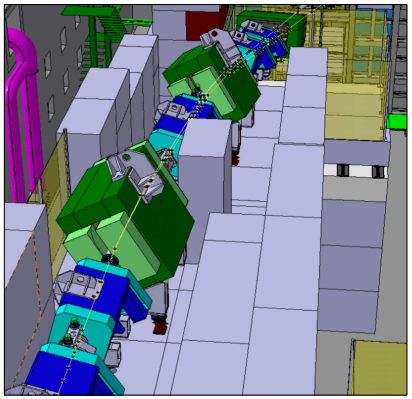


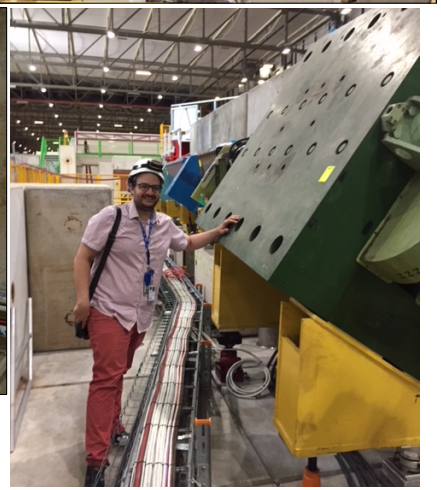
Installation of Beamline and Beam Instrumentation

at the same time outside the cryostat: June 14 to Aug 31 -

H4 extension:The new Tertiary, low-Mom Beam line bending sideway-down to point to the entry face of the TPC

- 2 secondary targets
  - W for lower momenta (0-3 GeV/c)
  - Cu for higher momenta (4-7 GeV/c)
- 3 dipoles for bending and momentum selection
- Quadruples for focusing the beam
- Collimator for increasing the momentum resolution
- 3 scintillators for trigger
  - 2 for TOF
- 8 beam profilers (scintillating fibers)
  - 5 profile the X (drift) coordinate
  - 3 profile the Y (vertical) coordinate
- 2 Cherenkov detectors for particle tagging (along with TOF)

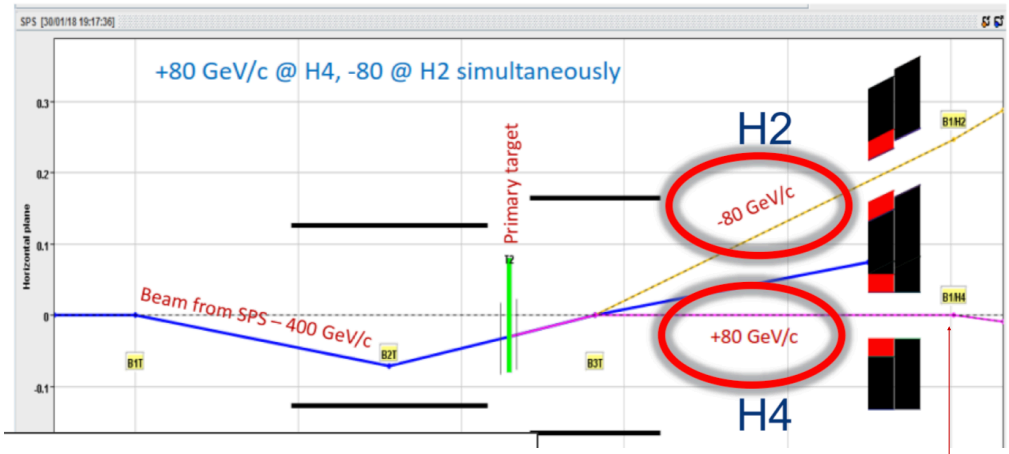


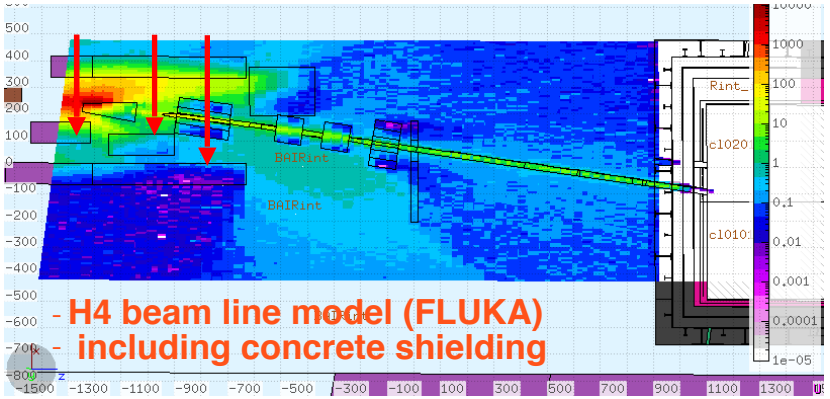


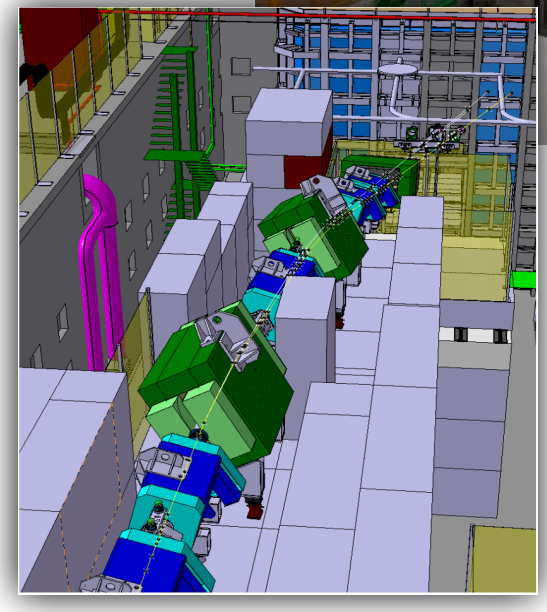
PHYS. REV. ACCEL. BEAMS **20**, 111001 (2017)

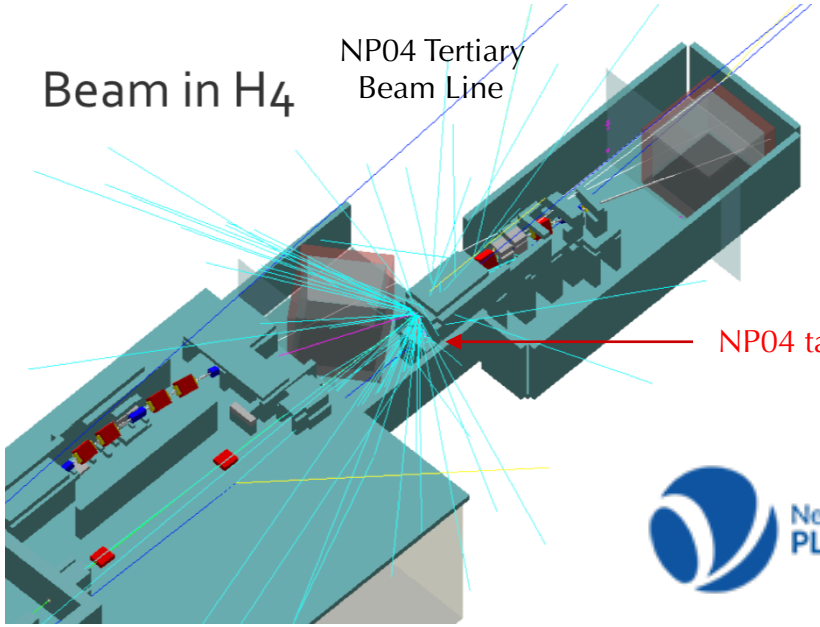
H4 (Tertiary) Beam Line

CERN SPS - North Area









Neutrino PLATFORM

Muon Tagger assembly, mounting, read-out

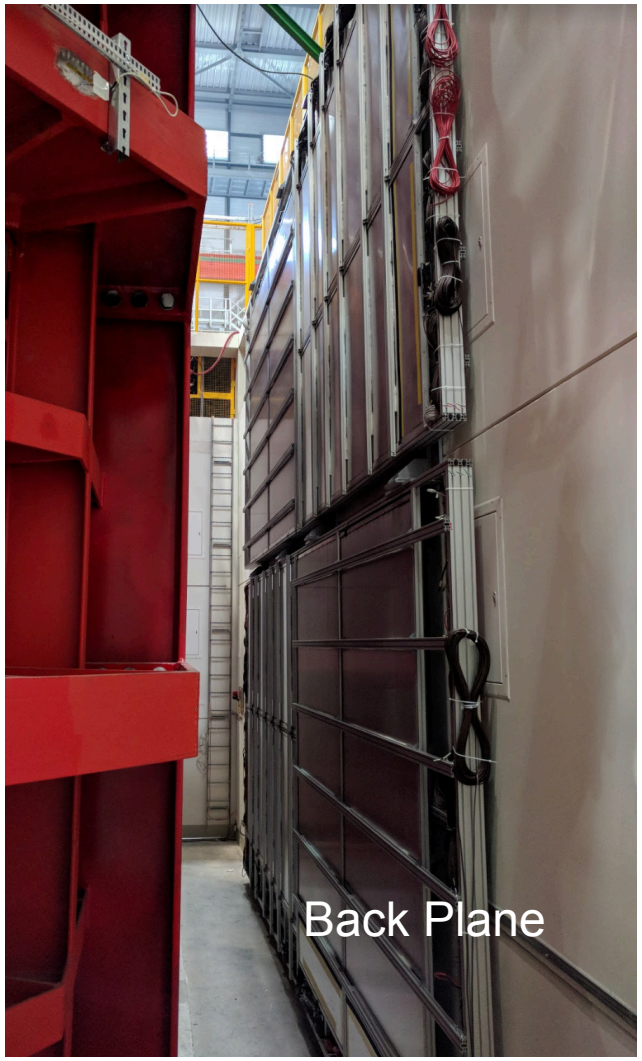
May 15 to Aug 31 - 2018

~6.8 m x 6.8 m
scintillator panels
upstream
and downstream

Trigger TPC on through-going muons
- *Cosmics*
- *Beam halo*

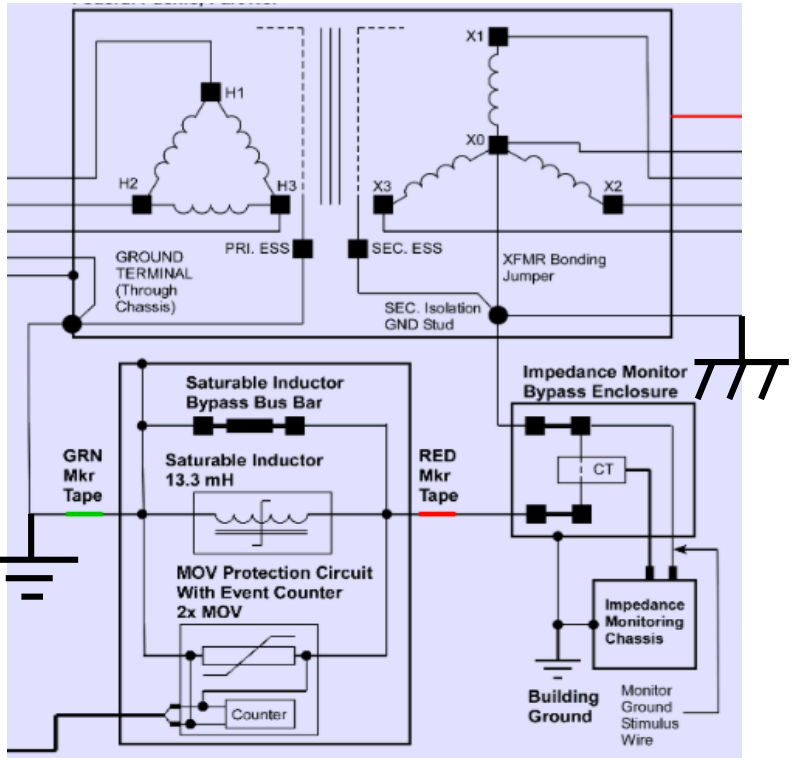
Tag muon tracks
provides T0
constraints Space Charge

Muon Tagger Modules



Implementation of the Grounding and Shielding Layout

May 15 to Aug 31 - 2018



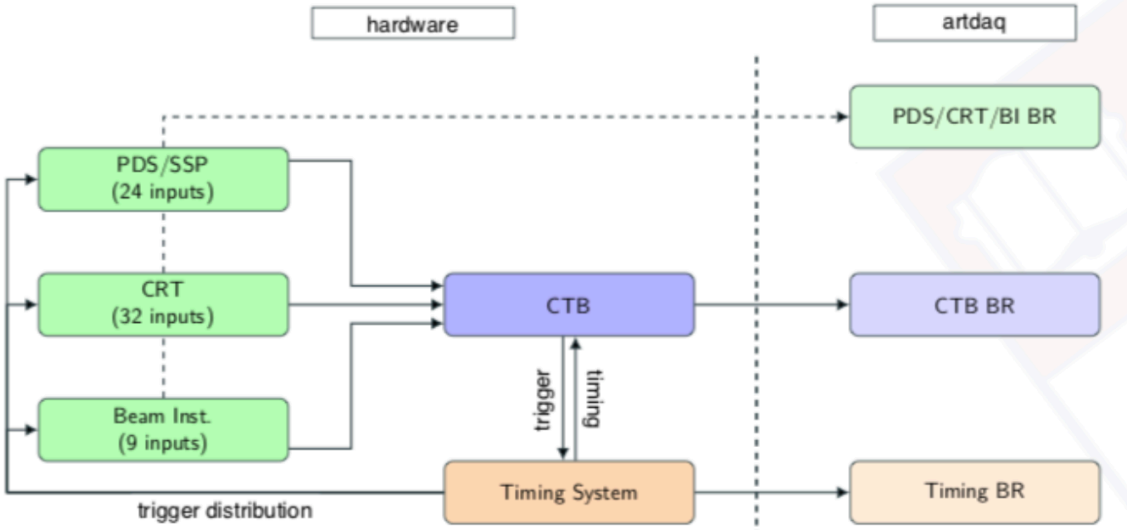
Data Acquisition System

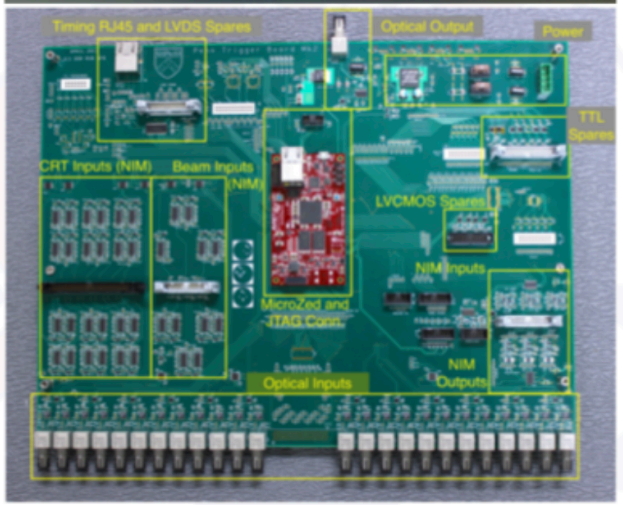
- Full readout of cold electronics equates to ~450 Gbit/s
  - Aiming for maximum 20 Gbit/s of storage
  - Almost 1PB of local storage available
- Readout systems tested successfully to sustain full readout and up to 60 Hz triggered output

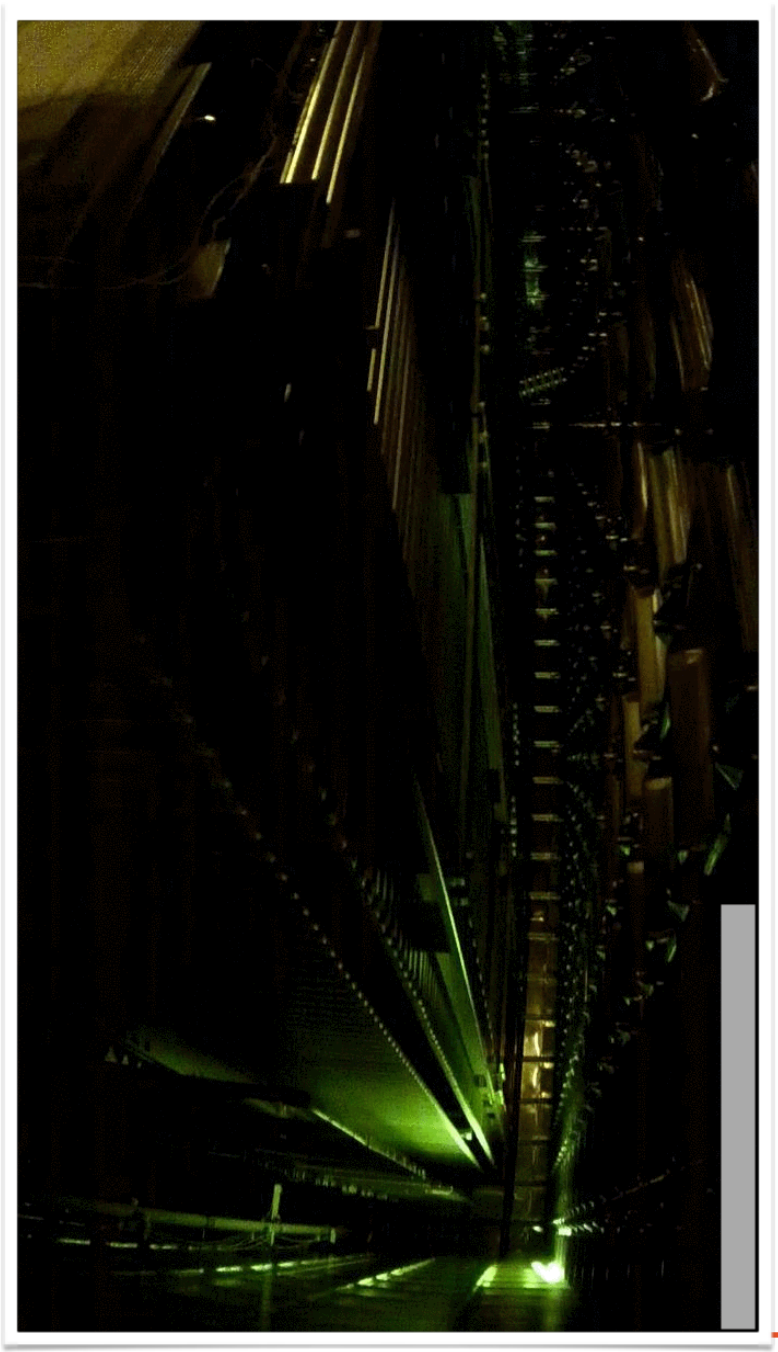
in between the Beam Line and the Detector

The Central Trigger Board (CTB)

- Hardware electronics with an embedded system with FPGA and CPU for trigger decision and data streaming







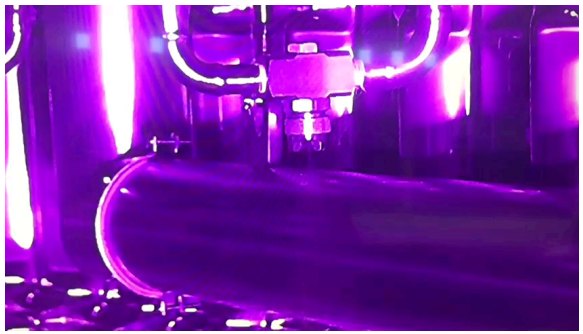
Cryogenic Commissioning
Purging, Cooling and LAr Filling

Neutrino PLATFORM

one last step: July 15
to Sept. 13 - 2018

LAr Filling:

LAr level going up as seen by a camera from Bottom of the Cryostat



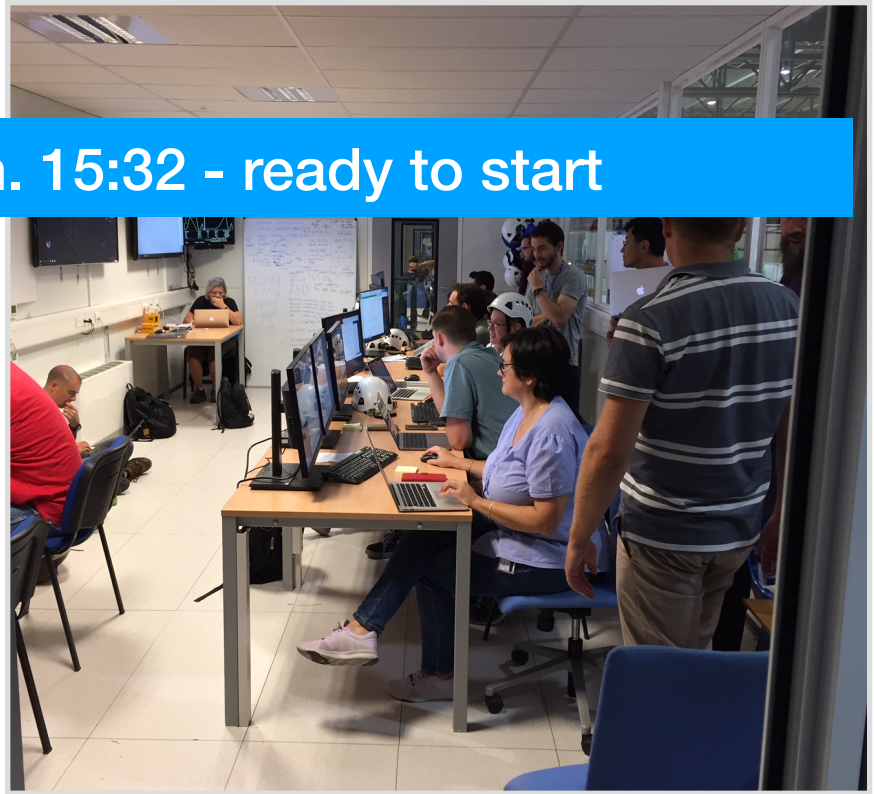
and Cooling:

spraying cold Ar from top of the Cryostat for cooling

- Kept the LAr level below the APA until the temperature gradient across its height was no more than 50K
- August 13th, increased fill rate
- September 13th, reached nominal level

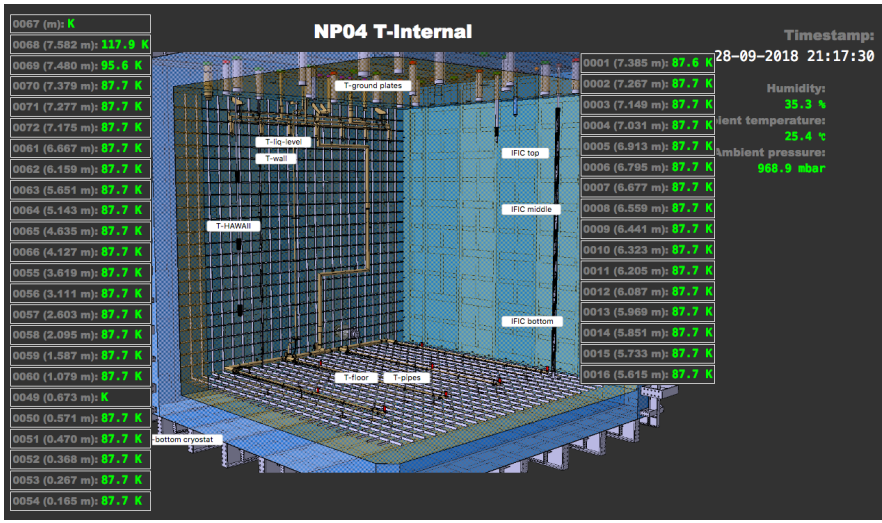
Start Detector Activation Procedure

and now back to Sept. 19, h. 15:32 - ready to start



Detector Status - Checklist:

- ☑ - LAr filling Completed (LAr at Nominal level)
- ☑ - LAr recirculation ON
- ☑ - HV chain (from Pwr Supply to HV FeedThrough, from Cathode to the end of field Cage resistor divider) "tested"
- ☑ - grounding checked
- ☑ - CE electronic powered ON
- ☑ - Detector Control System active
- ☑ - DAQ ready for data taking
- ☑ - On-line monitor active
- ☑ - Computing for data transfer and first evt./data reconstruction operational
- ☑ - near-line Data Quality Monitor ready
- ☑ - full off-line analysis and reconstruction ready for real events
- ☑ - Beam ON (and beam instrumentation responding)

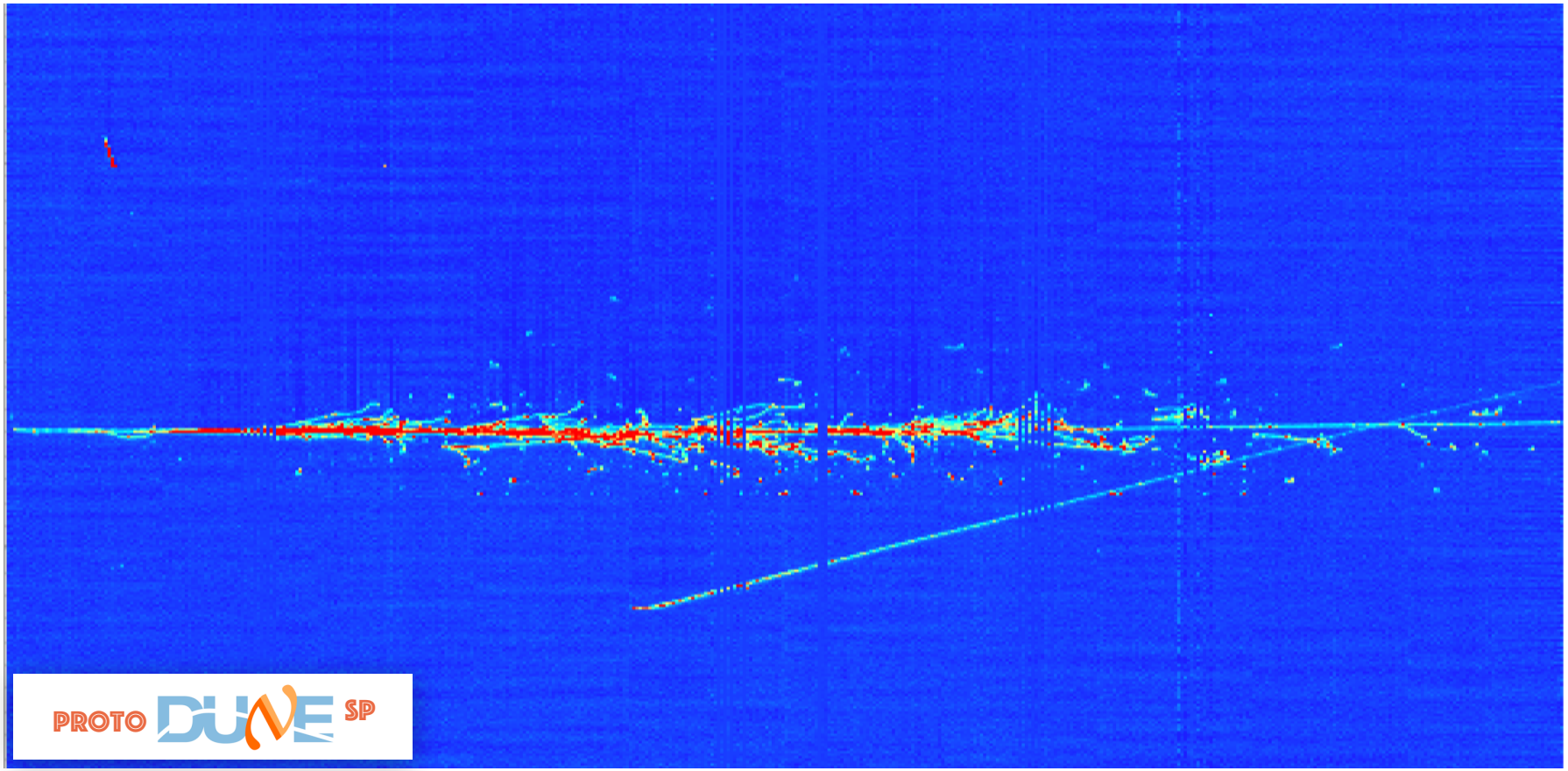


Outline:

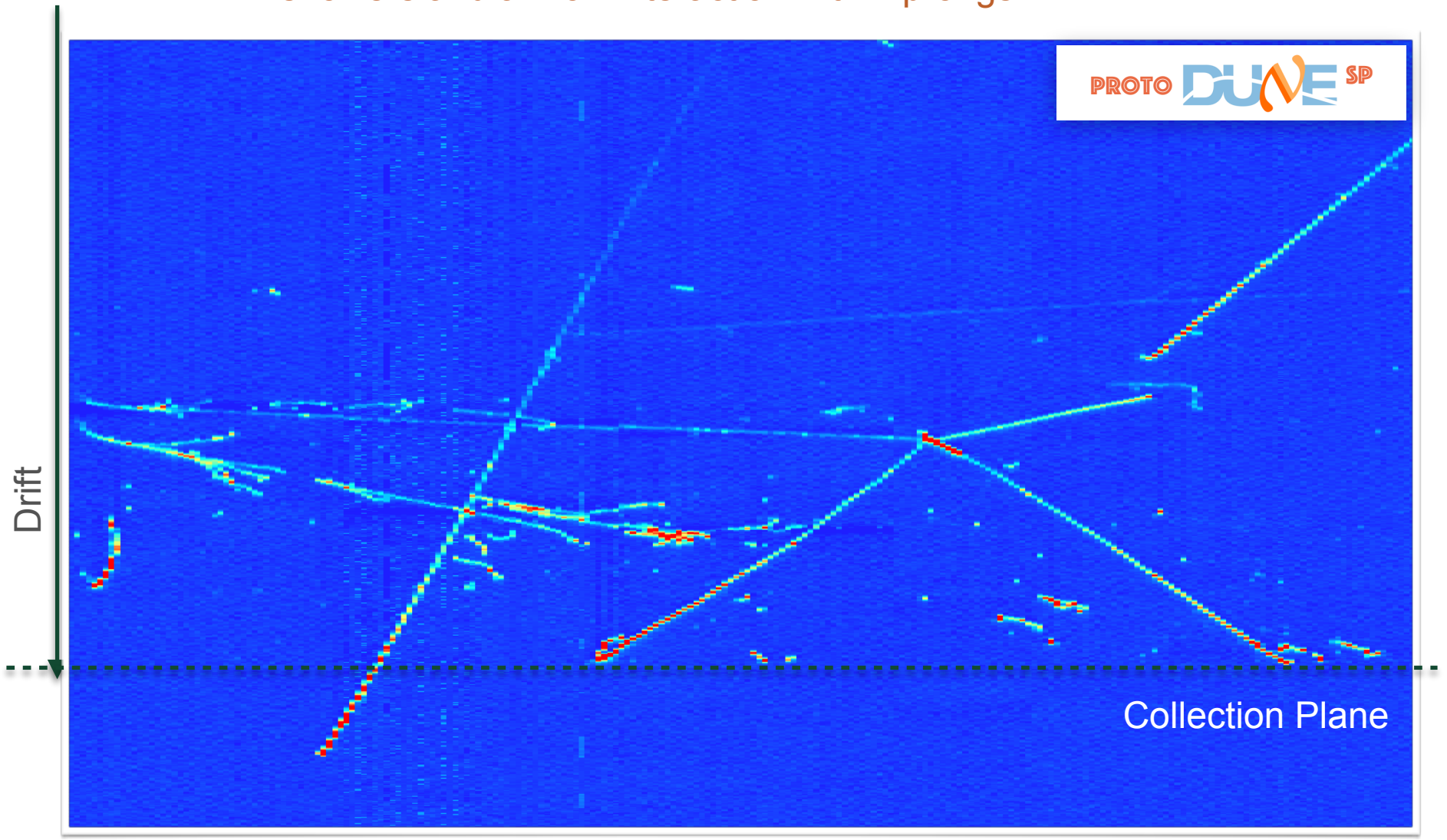
from first tracks [h. 2:33 am - Sept. 21, 2018]

to first (preliminary) results from data analysis

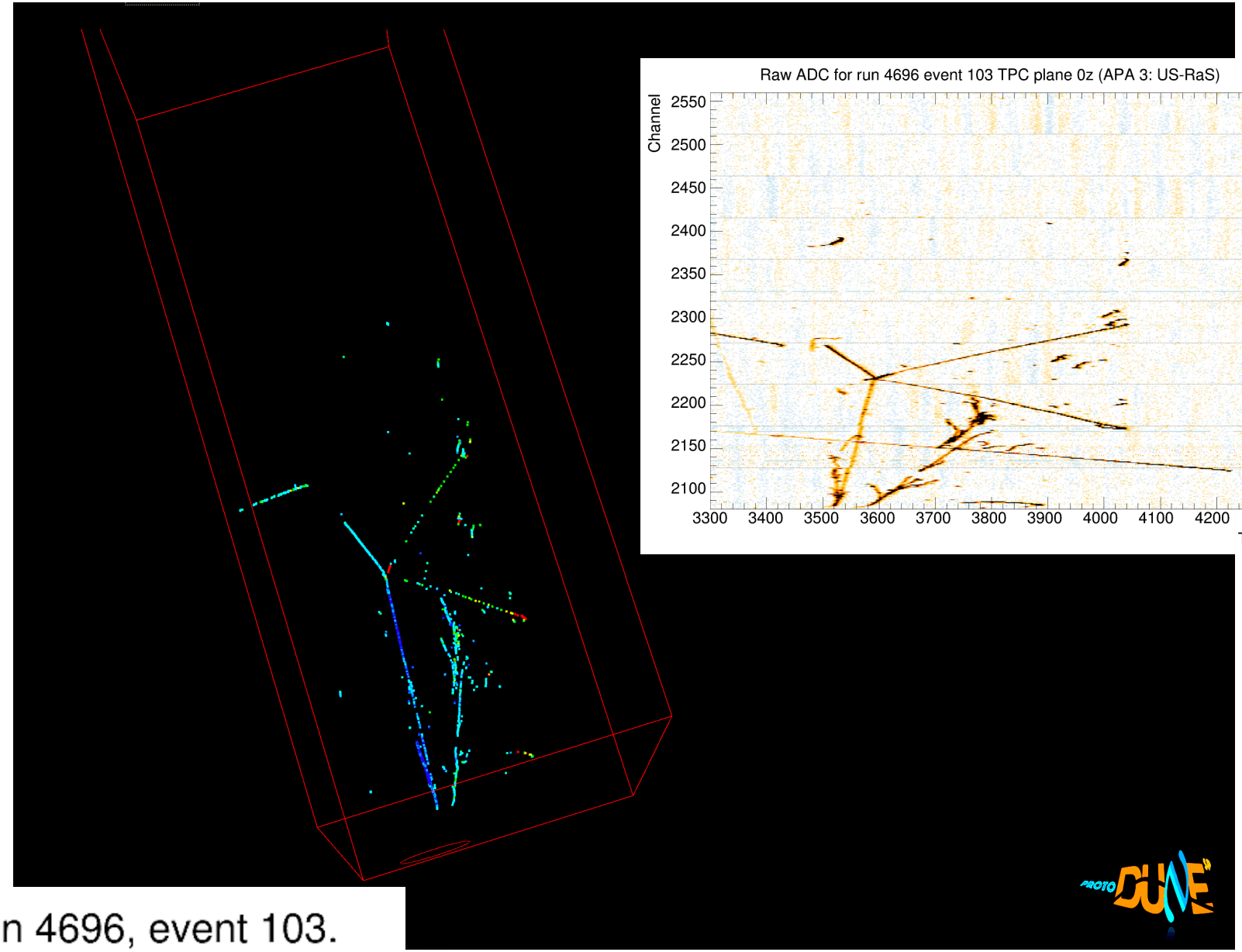
Halo (high energy) muon with bremsstrahlung initiated E.M. shower



2 EM showers and a Pion Interaction with 4 prongs

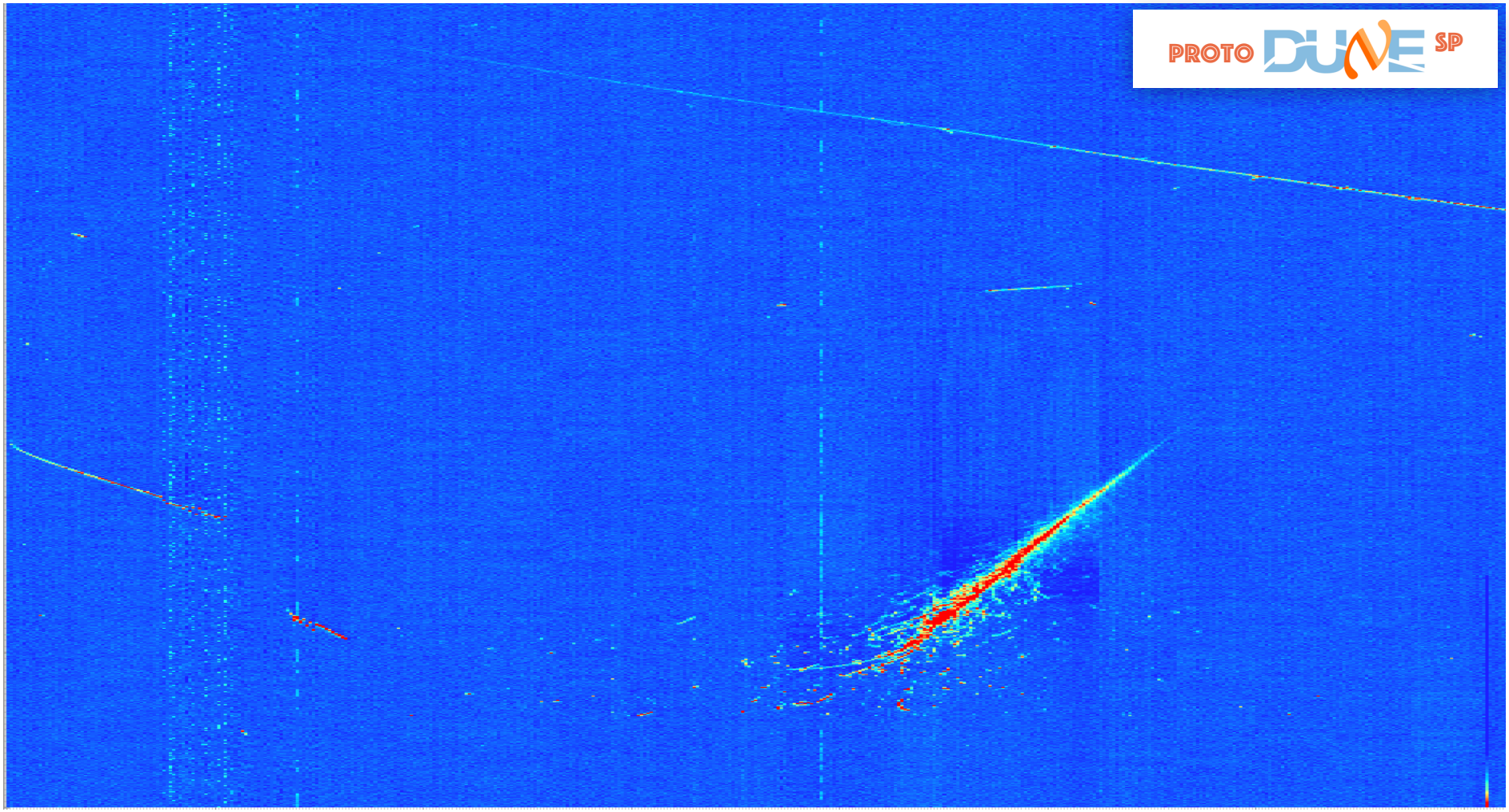


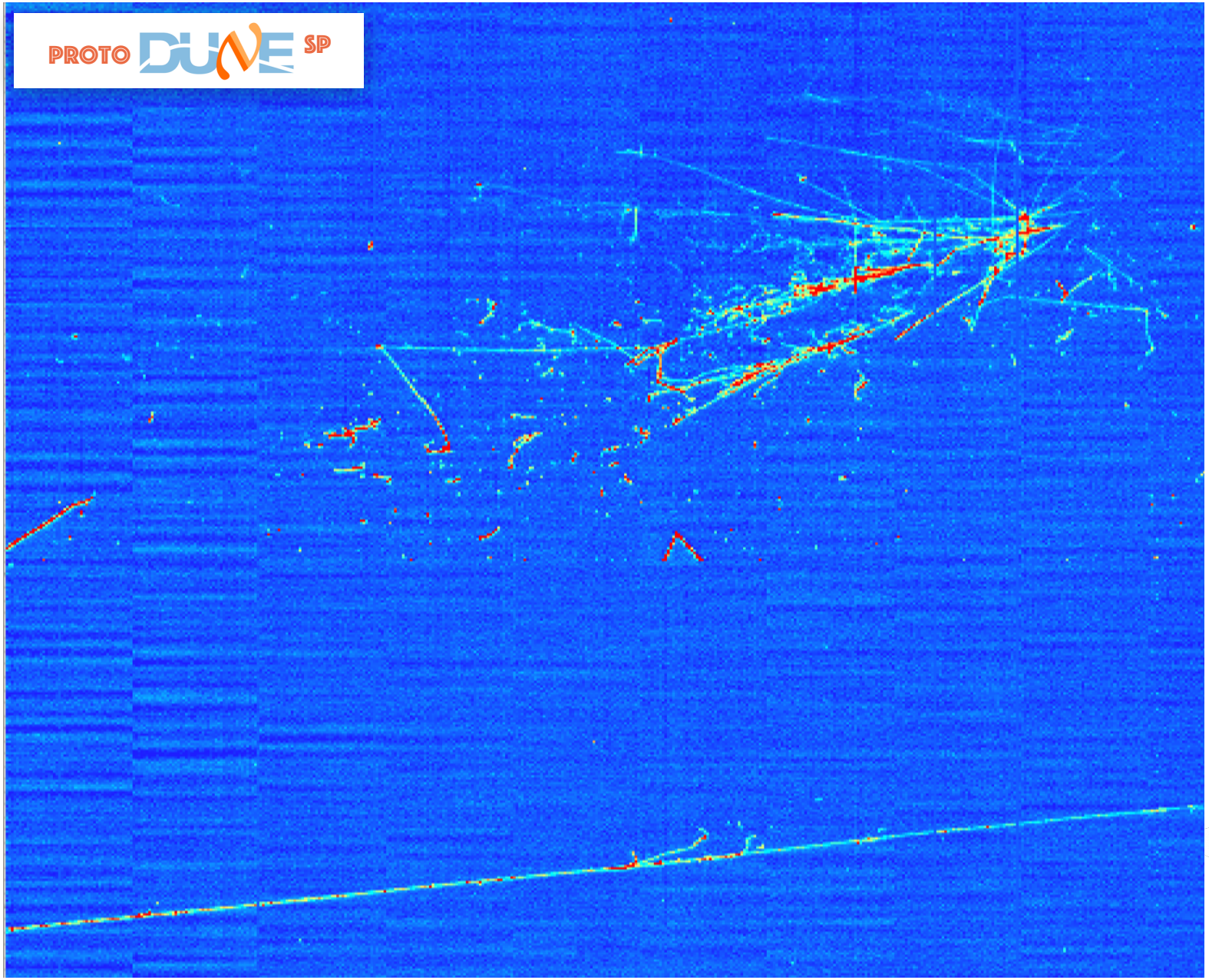
collection view. Run 4696, event 103.



Run 4696, event 103.

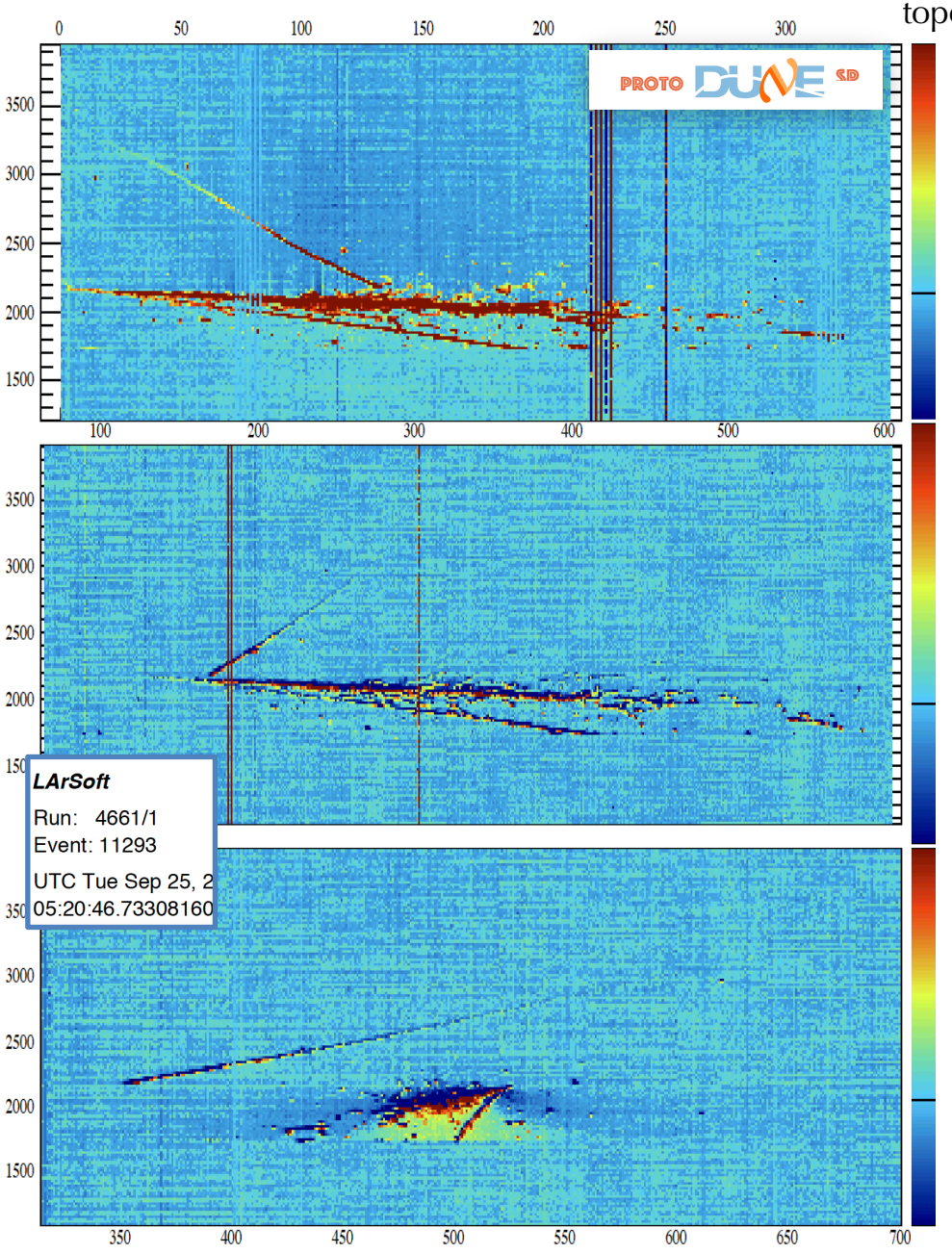
E.M. shower initiated by cosmic interaction in the top of cryostat

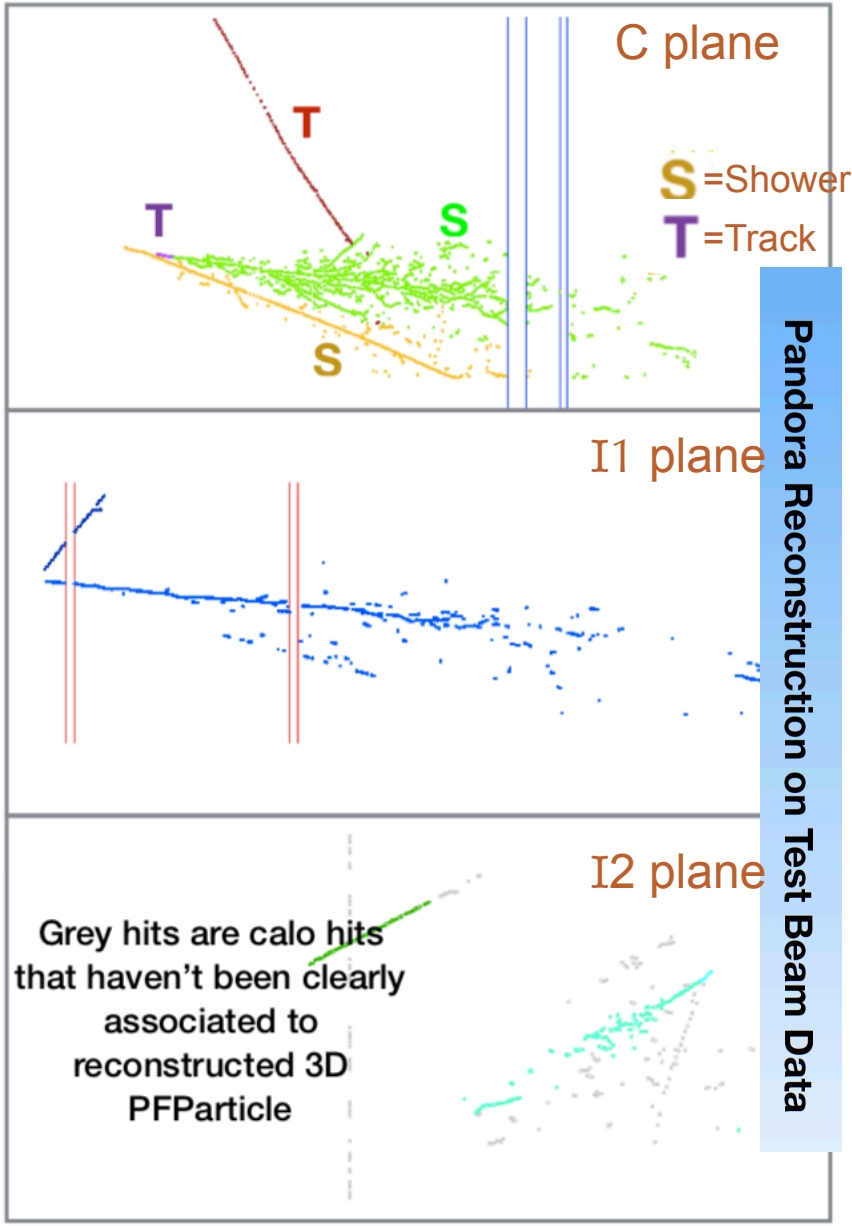




hadronic shower from cosmic ray interaction

topology looks consistent with $\pi^0 \rightarrow \gamma\gamma$ (S,S from Pandora)





TPC Wire Readout Performance

Preliminary results show **99.7% of 15,360 channels are alive**

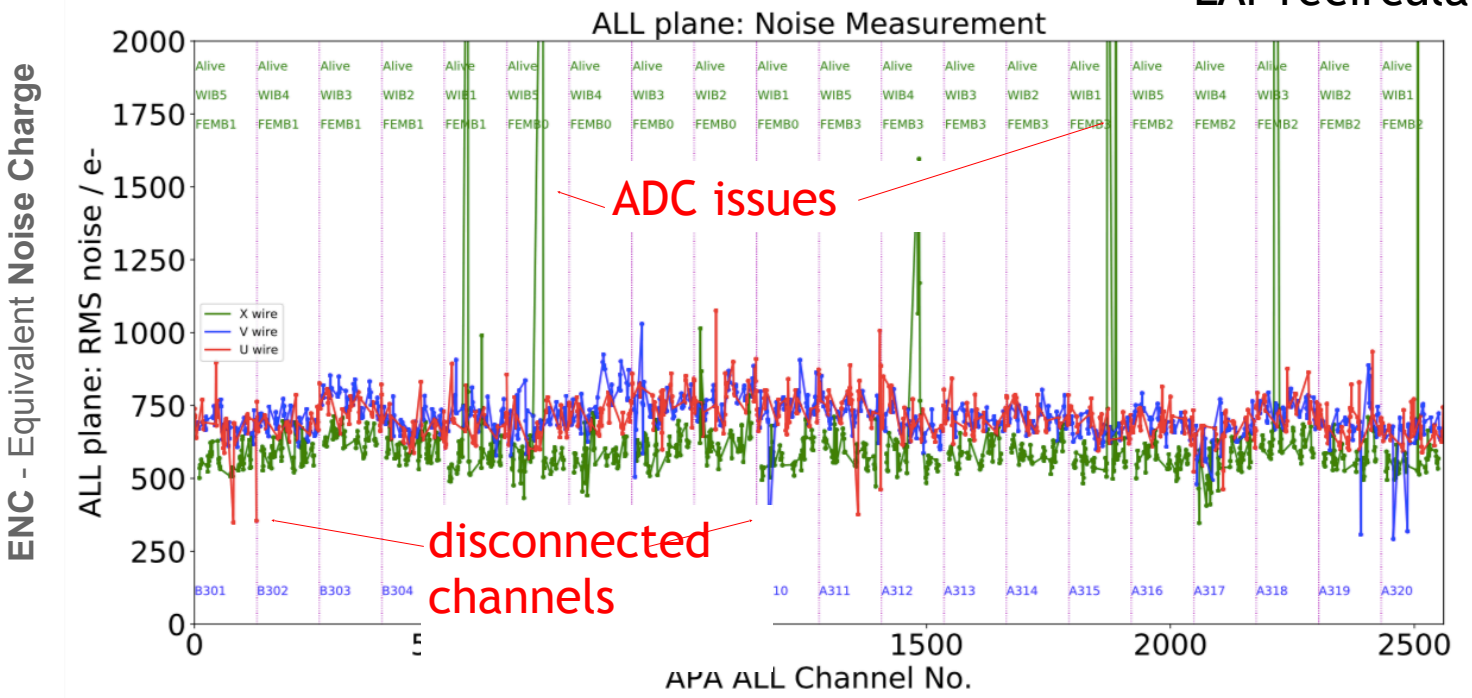
- 4 channels are non-responsive to the internal Front-End calibration circuit
- Noise on ~40 channels is consistent with an open wire in front of FE pre-amplifier
  - Randomly spread across all wire planes and APAs
  - Consistent with open channels observed in Cold Box pre-screening

At τ_s~2 μsec **collection/induction wire ENC ~550/750 e$^-$** estimated from preliminary analysis

- Several spatially localized “hot spots” with higher ENC
  - Ongoing effort to understand and mitigate noise contributions
  - No significant impact from full drift and wire bias HV and LAr filtering

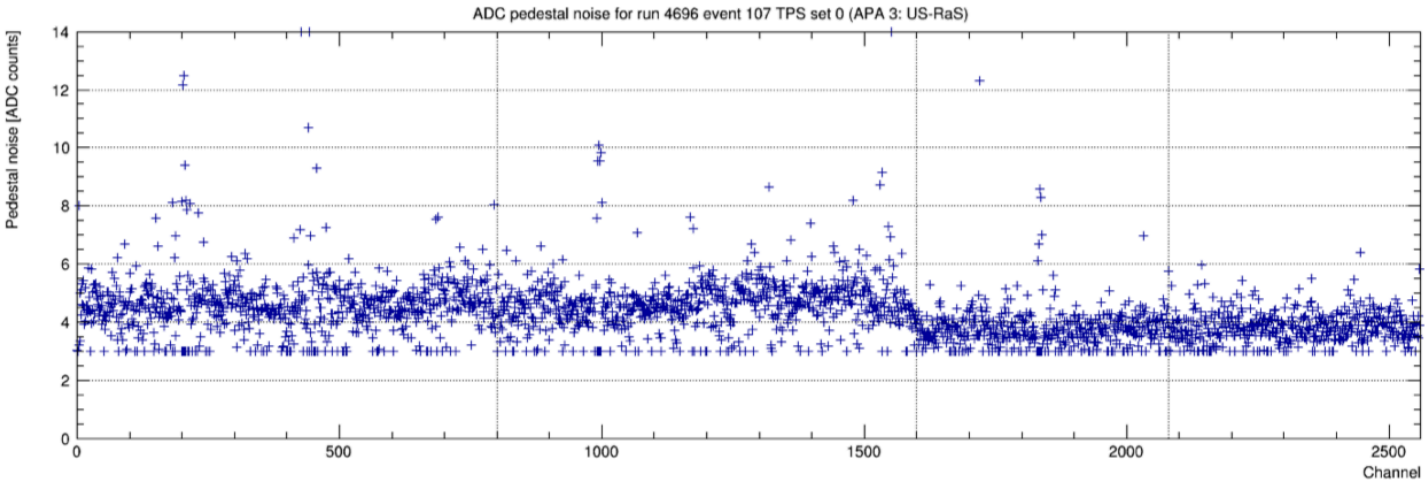
(e.g)APA3 Noise at -180kV

Nominal wire bias voltages
LAr recirculation on



from CE Expert data&analysis

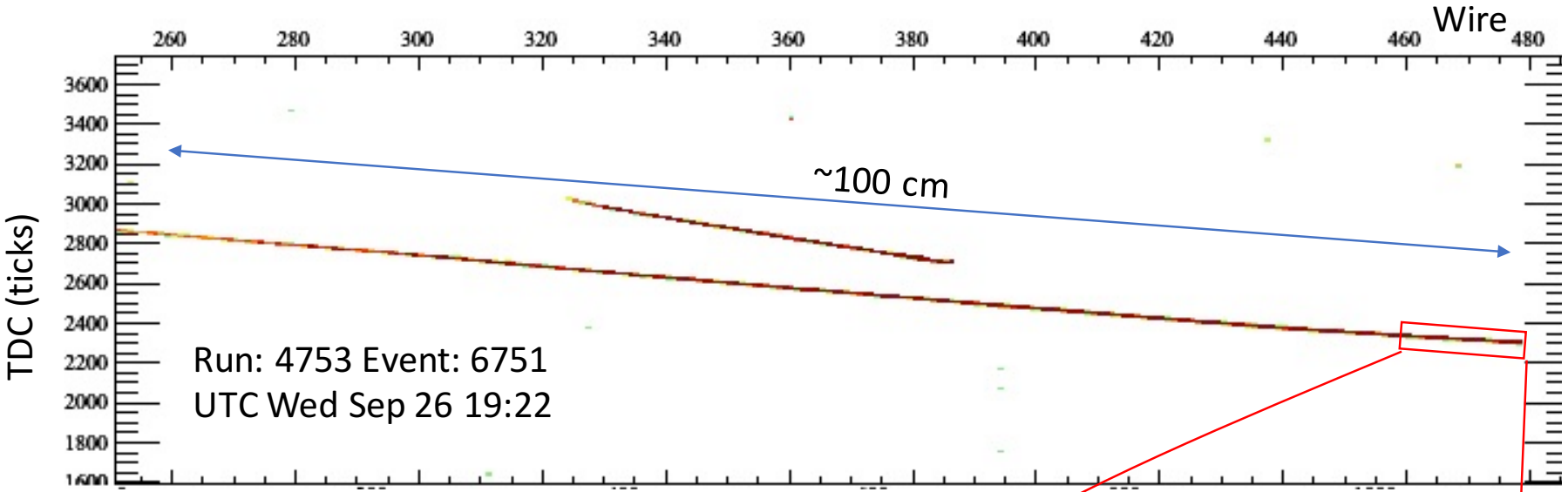
Gain = 14 mV/fC
(140 e/ADC)
Shaping time = 2 us



from Data Quality Monitor

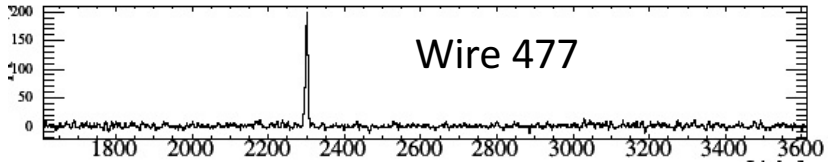
Over much of detector, noise level is

- Collection: 3.5 ADC (500 e)
- Induction: 4.5 ADC (600 e)
- Nice!

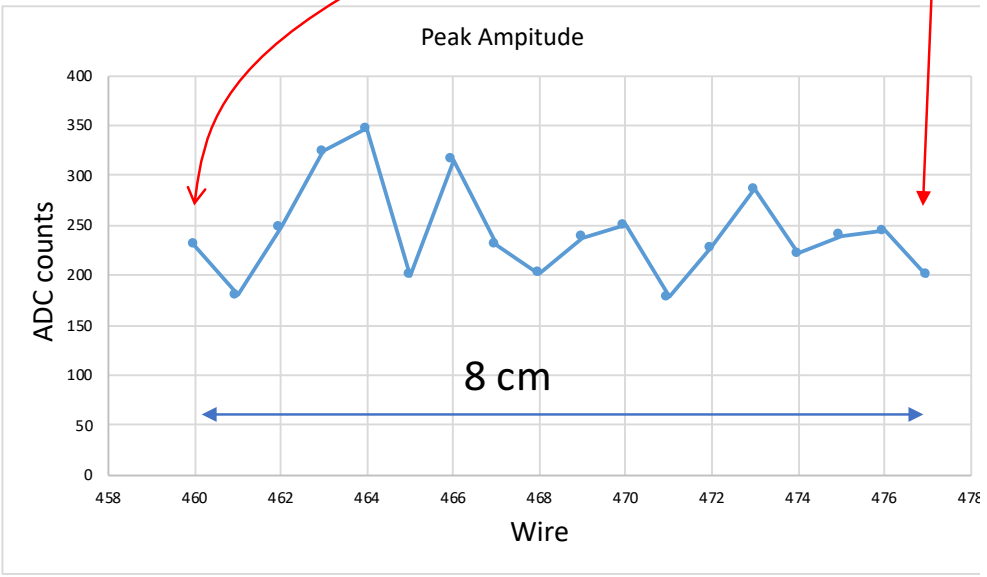


Average peak Amplitude = 242 ADC counts
rms = 47 ADC counts (19%)

ADC Counts



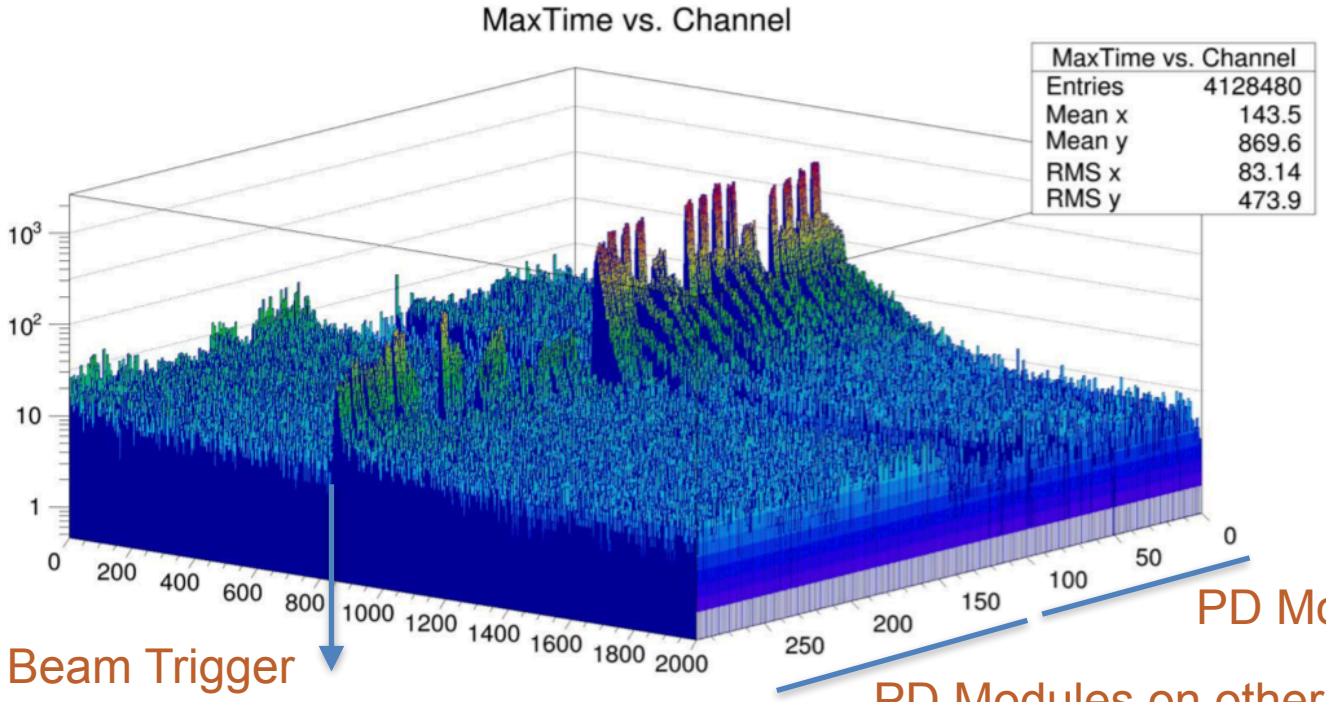
TDC (ticks)



PhDetector ReadOut Performance

Preliminary results show **96% of 256 r/o channels are alive**
(3 channel not responding, the other noisy)

and see signals from beam and cosmics!

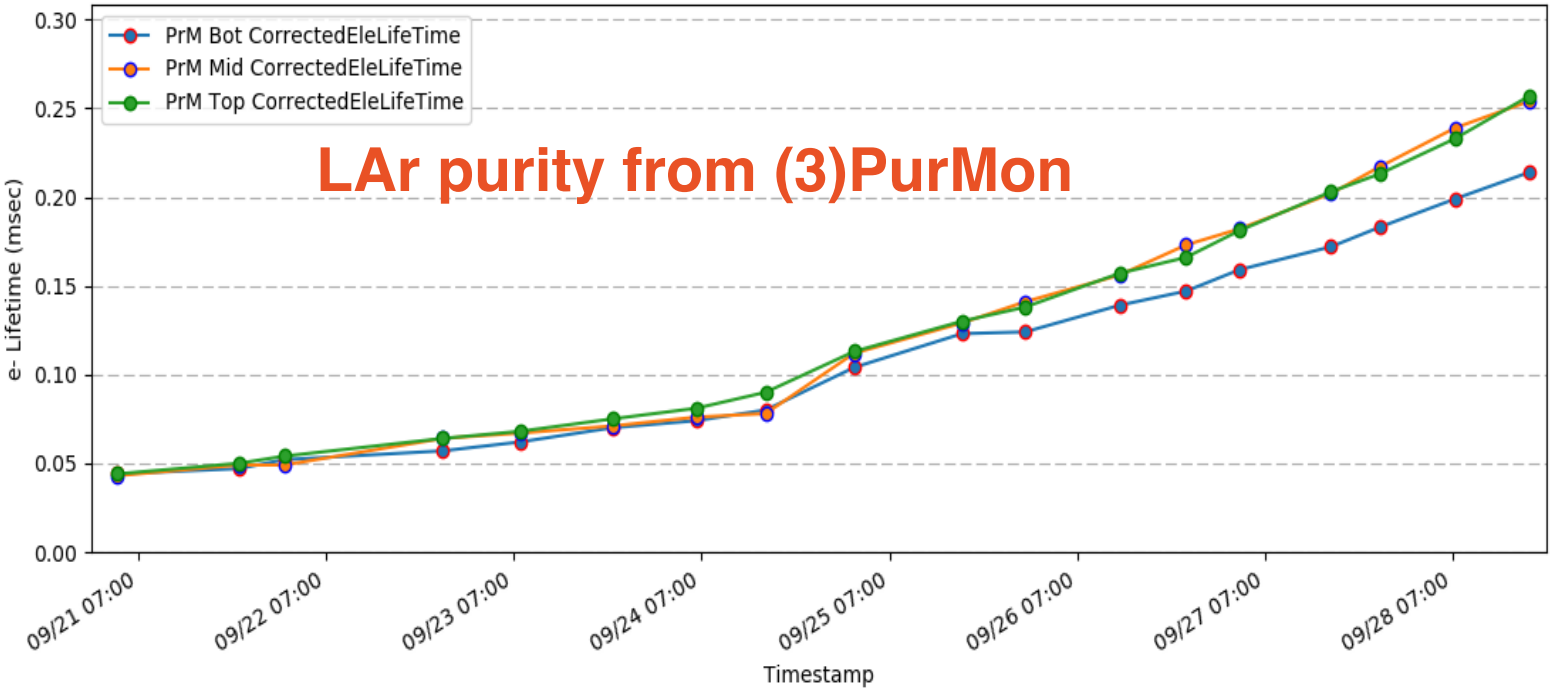


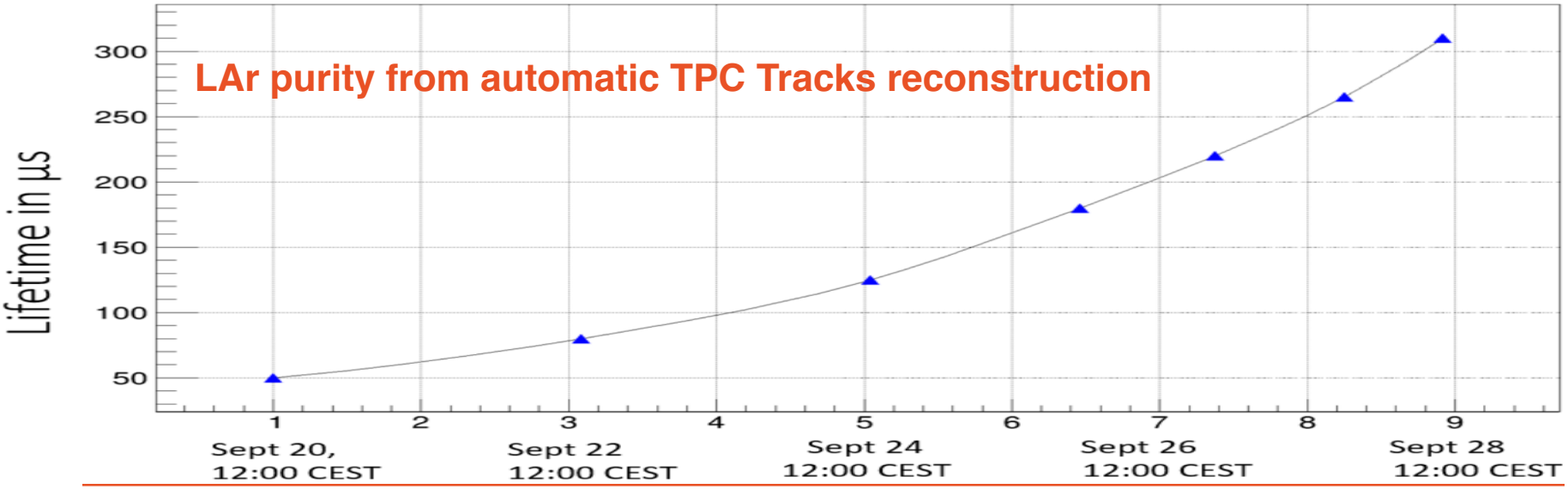
single PE peaks
calibration in progress
for gain calculation

PD Modules on the beam Side

PD Modules on other side Side of Cathode

Beam Trigger
Light from PD detected in time


PrM Bot CorrectedEleLifeTime
PrM Mid CorrectedEleLifeTime
PrM Top CorrectedEleLifeTime
LAr purity from (3)PurMon
e- Lifetime (msec)
0.30
0.25
0.20
0.15
0.10
0.05
0.00
09/21 07:00
09/22 07:00
09/23 07:00
09/24 07:00
09/25 07:00
09/26 07:00
09/27 07:00
09/28 07:00
Timestamp


LAr purity from automatic TPC Tracks reconstruction
Lifetime in µs
300
250
200
150
100
50
1
2
3
4
5
6
7
8
9
Sept 20, 12:00 CEST
Sept 22 12:00 CEST
Sept 24 12:00 CEST
Sept 26 12:00 CEST
Sept 28 12:00 CEST

Summary

DEEP UNDERGROUND NEUTRINO EXPERIMENT

Neutrino Platform at CERN perfect environment for making possible what appeared "impossible":

- Complete the LAr Detector Construction and assembly inside the confined space of a 1kT large Membrane Cryostat in less than 2 yrs
- Realize a new, dedicated Charged Particle Beam Line
- Fill the Cryostat with pure LAr and activate the detector at Nominal EF level in time for a Physics Run, before CERN LS2
- … and collect Data of unprecedented quality from the LArTPC

- Data taking proceeds - LAr purity is increasing rapidly, beam events will appear soon, stability of detector under continuous monitoring

Fermilab PROTO DUNE SP

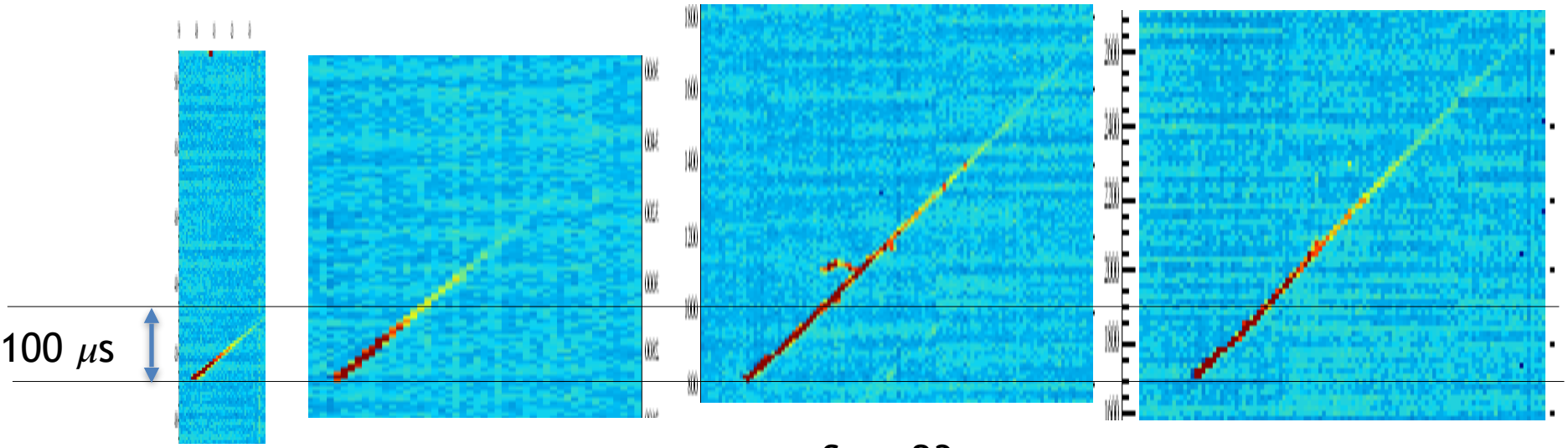
These achievements would never been made possible without the full dedication and outstanding skills and contagious enthusiasm of the many **DUNE Collaborators** and their supporting **Institutions** in US, in EU and Worldwide that contributed to the construction, assembly, test, commissioning and activation of ProtoDUNE-SP.

The partnership of the CERN Neutrino Platform and the CERN [TE-CRG, EN-EA, BE-BI, EP-DT-DI and TI] contributions were integral and fundamental part of the effort

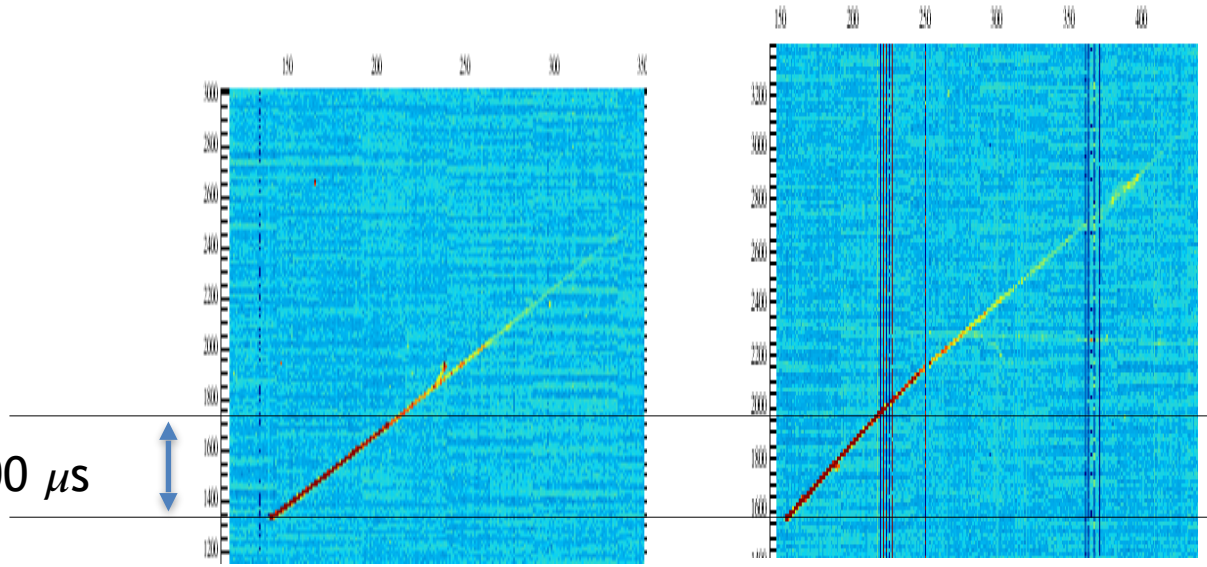
Look forward to see ProtoDUNE DP coming on-line in 2019

what we see now from the DQM - 3D Event display

Back Up slides



Sep. 20 Sep. 21 Sep. 23 Sep. 24



Sep. 25 Sep. 26

Tasks and Sub-system Teams on the ground at CERN

CERN Neutrino Platform

ProtoDUNE-Single Phase

Commissioning Leader, Run Coordinator

Computing
CERN
IT

DUNE
SW&Computing

Computing
FNAL-SCD

DAQ
&
on-line Monitor

APA Wire Bias
Cold and Warm
Electronics

Beam
Line
CERN
EN-EA

Beam
Instrumentation
CERN
BE-BI

Beam
Instrumentation

Trigger

DQM Infrastructure
(Data Quality Monitor)

Muon Tagger

DRA
(Data Reco and
Analysis)

Photon Detectors &
PD R/O Electronics

Cryogenics
CERN
TE-CRG

Cryo
Intrumentation

SlowCtrl/
DCS
CERN EP-
DT-DI

High Voltage
System
Beam Plug

Grounding and Shielding

1 - protoDUNE informing DUNE TDR

From the completed phase of detector components Construction and Integration, Cold Test procedures and Assembly in confined space (inside Cryostat):

- ✓ validated basic principles of the DUNE APA modular design
- ✓ developed APA factory model for production, based on Wisconsin-PSL and Daresbury-UK experience and production tooling and methods
- ✓ validated Photo-detector design concept (slots and connections)
- ▸ to be revised Cable routing for PDS and TPC electronics
- ✓ developed design for Integration and Test Facility at SURF, based on CERN-EHN1 experience [APA, CE and PD Integration Procedures and **Test full-size Detector Unit** in cold nitrogen gas - Cold Box]
- ✓ provided input to Quality Assurance for all systems and for planning Quality Control procedures

2 - protoDUNE informing DUNE TDR

From the currently under-way protoDUNE Commissioning phase:

- information about **Membrane Cryostat performance**:
  - Mechanical design
    - ✓ *overpressure test (successfully passed - July 9)*
  - ultimate level of impurity concentration in LAr:
    - ✓ air evacuation by GAr piston purging *(successfully accomplished - July 23-27)*
    - ➡ Ar recirculation/filtration circuit *(expected by end of Aug)*
  - Heat Load and cryogens consumption for cooling
- validation of internal cryo-instrumentation and detector components monitoring system [thousand variables/parameters are simultaneously and continuously logged by the DCS/SlwCtrl fully automated system]
- **validation of HV system design vs Goal (Drift EF = 500 V/cm)**

(most critical step, relevant for DUNE detector design)

3 - protoDUNE informing DUNE TDR *(continued)*

The physics performance of a LArTPC is a function of many intertwined detector parameters: *Argon purity, drift distance, Electric Field strength, wire pitch, wire length and noise levels in the readout electronics.*

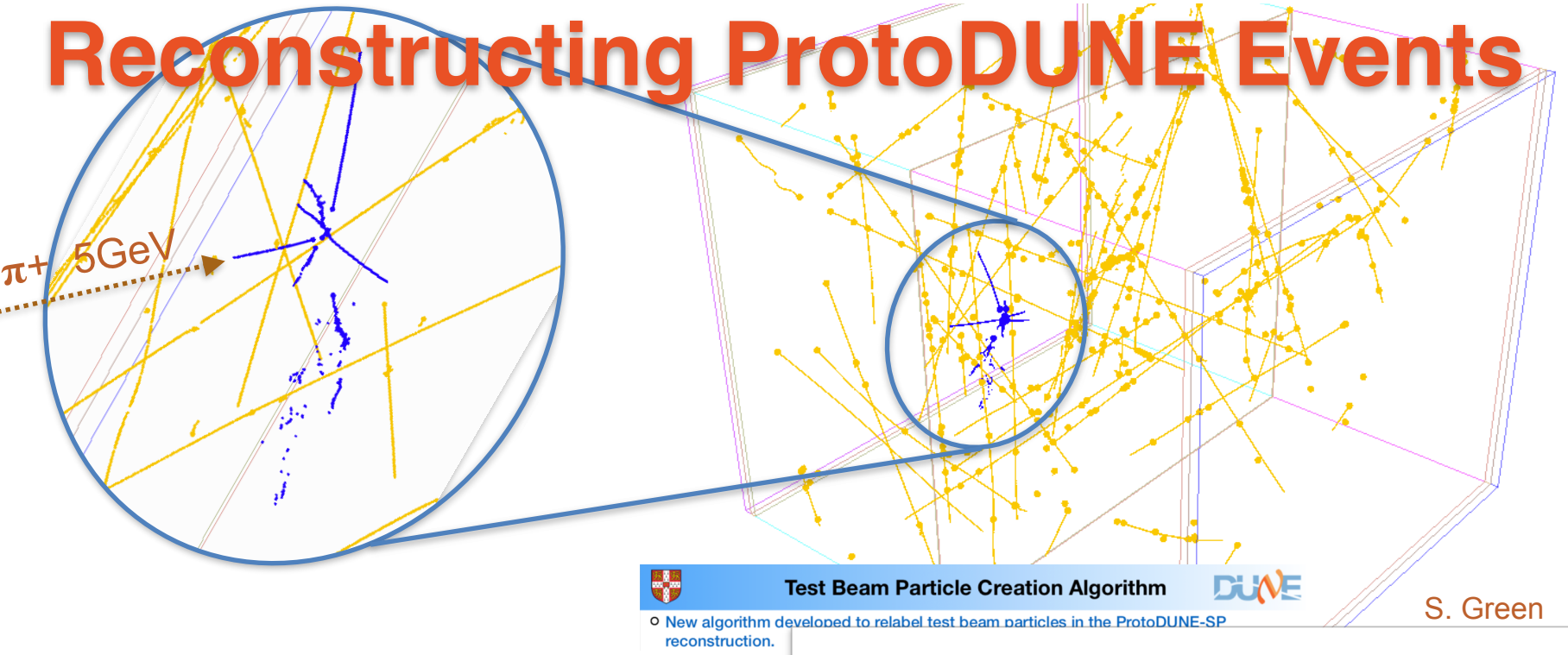
For a LArTPC on surface, ***space charge effects*** (SCE) is another leading detector effect on Physics Performance

- **Core calibration:** *from detected Charge to deposited Energy*
  converting dQ/dx (ADC/cm) to dE/dx (MeV/cm)

  includes
  - ➡ Electronics calibration
  - ➡ **Space charge effects**
  - ➡ Electron lifetime
  - ➡ Recombination effects
  - ➡ Muon/Pion based calibrations

Core Calibration is the basic Detector performance measurement fundamental to inform DUNE design

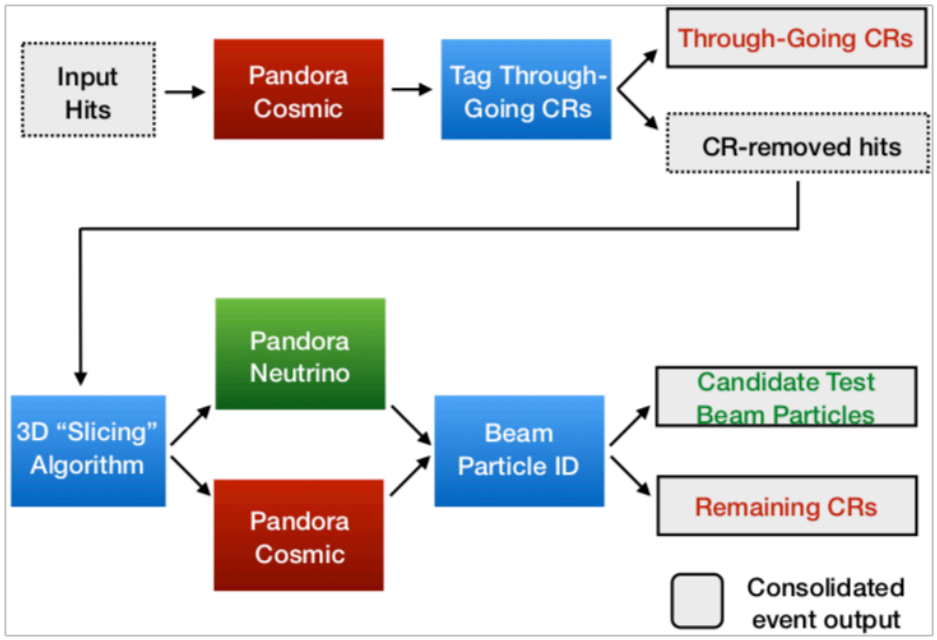
Reconstructing ProtoDUNE Events



Test Beam Particle Creation Algorithm

- New algorithm developed to relabel test beam particles in the ProtoDUNE-SP reconstruction.

S. Green

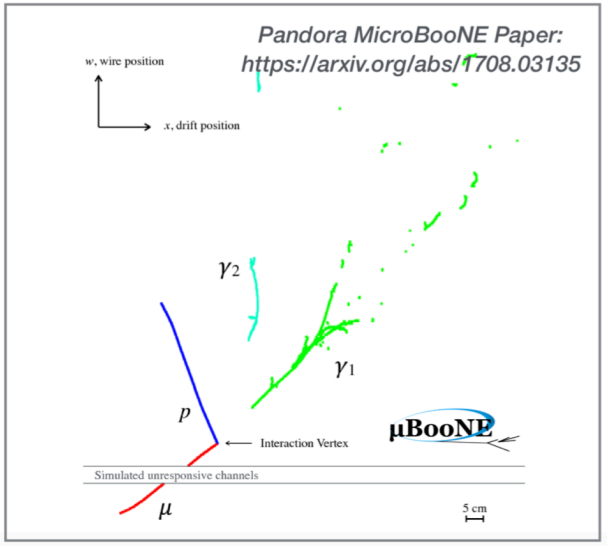


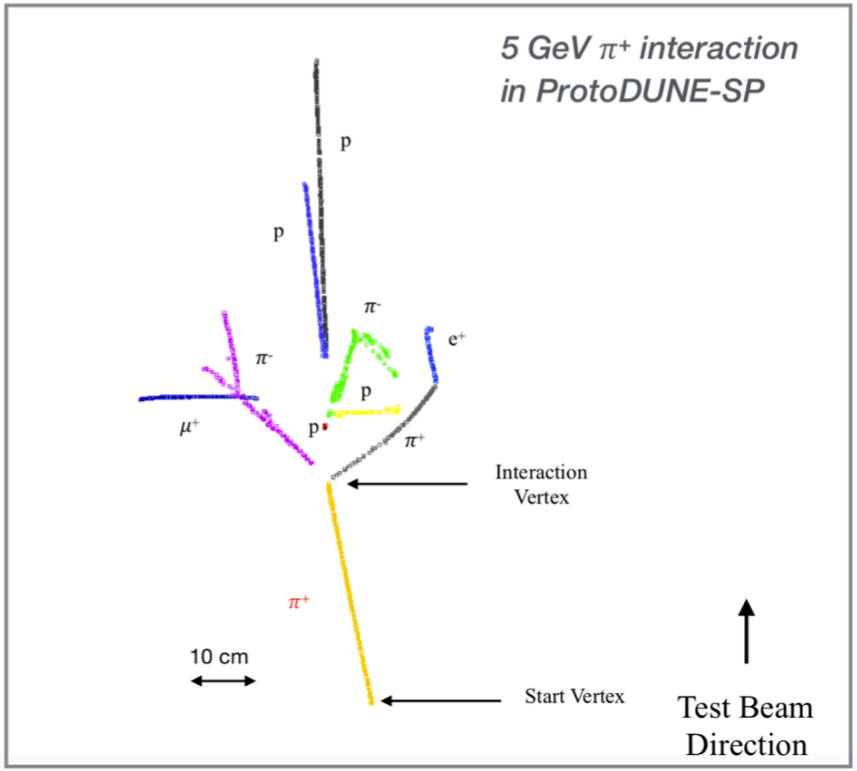
>70 cosmic muons expected in 5ms r/o window

- large statistics sample for calibration
- Space Charge Effect for LArTPC on surface
- Need Id Beam Event from surrounding crowd

Reconstruction

- Pandora progress to improve reconstruction specifically for ProtoDUNE.
- Adaptive Boost Decision Tree based Beam Particle ID:
  - Efficiencies: 72.3% for beam and 94.5% for cosmic muons
  - PFParticle hierarchy and tagging to facility analysis

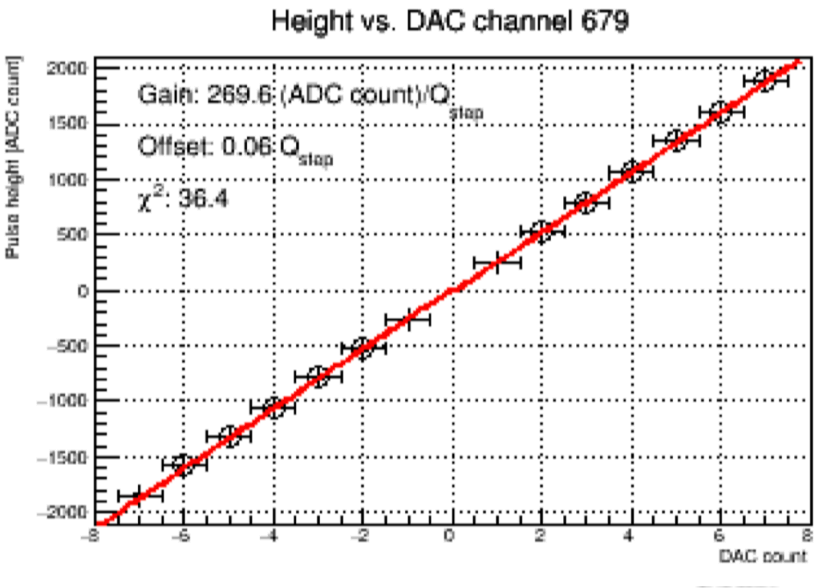


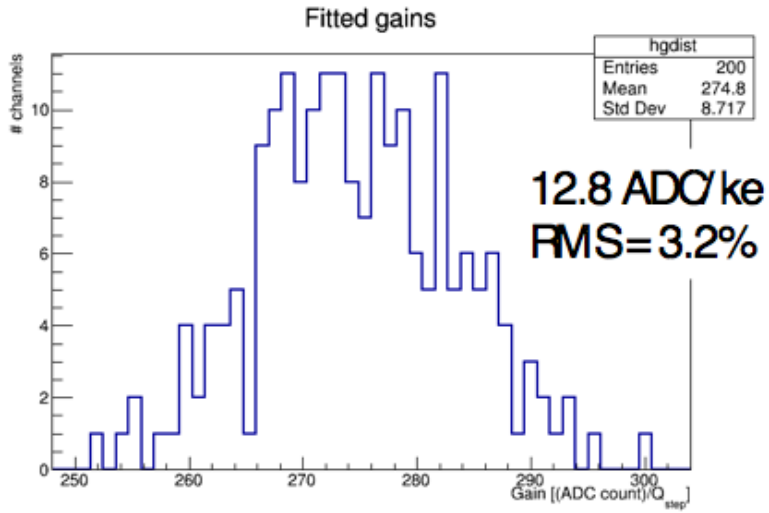


Steve Green

ADC Calibration

- data from the coldbox data at CERN.
- An average gain of 78 e/(ADC count) with σ = 3.2%.
- More work needed to correct for non-linearity or get response in the single MIP region.





https://indico.fnal.gov/event/17410/contribution/1/material/slides/0.pdf

and the Programme:

- 2018: Detector activation, **Test-Beam Run** + Cosmics
- 2019: (**) endurance Run with Cosmics [“long term stability”]
- 2020: continuing Operation (Cosmics) if desired
- 2021: keep open the option of recording Test Beam data after CERN LS2
- 2022: *no Operation is foreseen in and beyond 2022*.

(**) Note about the Long-Term Stability Run 2019

The long term stability Run with Cosmic
- 6 to 12 months extending in 2019 -
has been communicated to CERN SPSC on April 20

Plan for the long term stability Run under development

- minimal goal: maintain detector active and
  acquire short Cosmic Run every day
- *dedicated tests at different cryogenic system settings and detector operating parameters to be defined and included in the plan*
- additional inputs for specific tasks from DUNE Consortia to be collected

The CERN Experimental Programme

Grey Book database

» NP04

Welcome | Experiments & Projec

RESEARCH PROGRAMME

- LHC
- SPS
- PS
- AD
- ISOLDE Facility
- Irradiation Facility
- Neutrino Platform
- GRADE
- CTF3
- R&D
- Non-accelerator experiments

RESEARCH ACTIVITIES

- Experiments and Projects under Study
- Recognized Experiments
- Completed Experiments

RELATED LINKS

- EP Department
- Users' Office

NP04/ProtoDUNE-SP

Prototype of a Single-Phase Liquid Argon TPC for DUNE

SYNONYM:	ProtoDUNE-SP
RESEARCH PROGRAMME:	Neutrino Platform
APPROVED:	28-09-2016
BEAM:	
STATUS:	Preparation

Overview | Institutes | Participants

SPOKESPERSON:	Flavio CAVANNA
	Christofas TOURAMANIS
DEPUTY SPOKEPERSON(S):	
CONTACT PERSON:	Simona KRIVA
TECHNICAL COORDINATOR:	
RESOURCES COORDINATOR:	
GROUP LEADER IN MATTERS OF SAFETY (GLIMOS):	
DEPUTY GLIMOS:	
DEPARTMENTAL FLAMMABLE GAS SAFETY OFFICER (FGSO):	
DEPARTMENTAL CRYOGENICS OFFICER (CSO):	
EXPERIMENT SECRETARIAT E-MAIL:	cenf.secretariat@cern.ch
EXPERIMENT SECRETARIAT WEB SITE:	

NUMBER OF INSTITUTES:	49
NUMBER OF AUTHORS:	18
NUMBER OF PARTICIPANTS:	214
NUMBER OF COUNTRIES:	7

TODAY

Status history

Status	Start date	En
Preparation	22-02-2016	

Fermilab DUNE

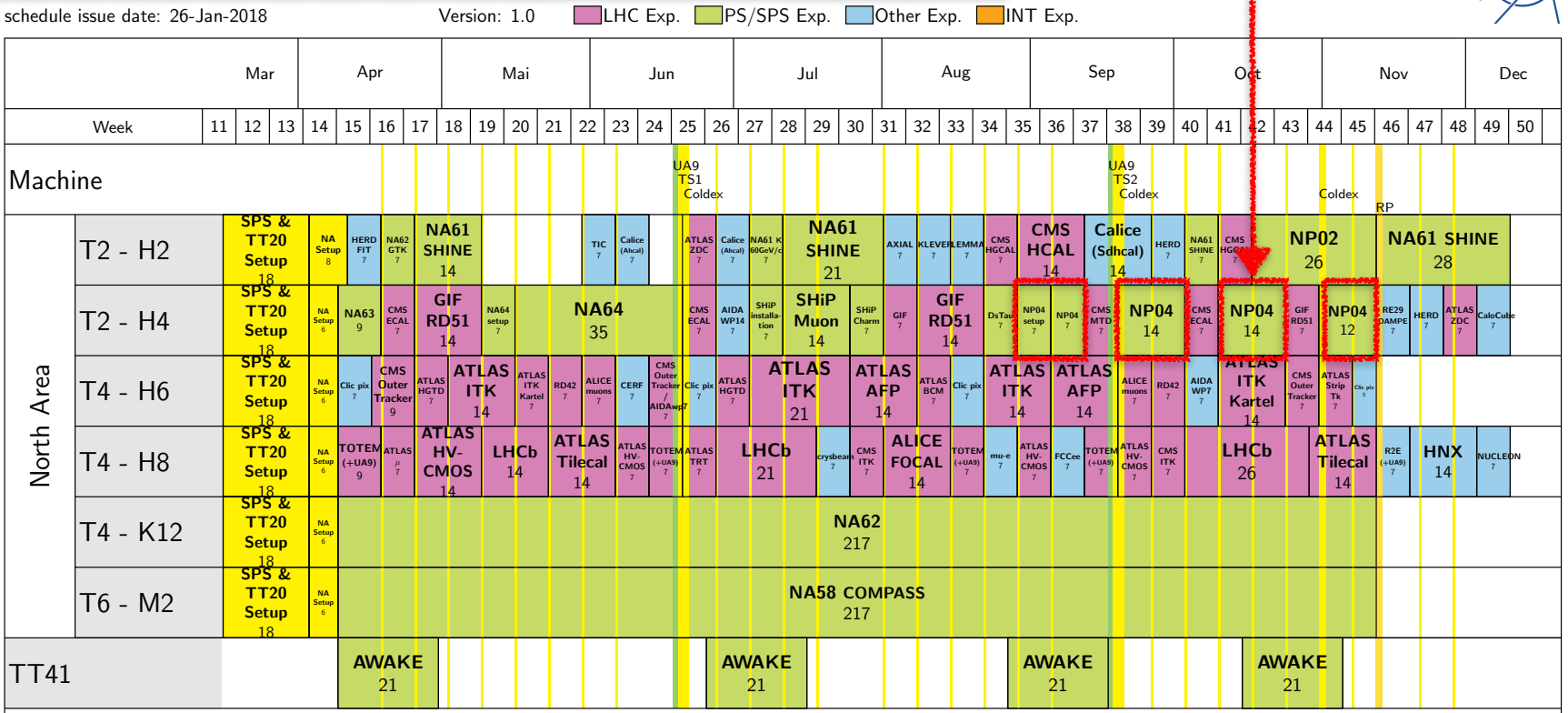
Next Step: ProtoDUNE-SP Beam Run

August 29, 2018 (Start)

November 11, 2018 (End)

H4 Beam Time Allocation to NP04 by SPS-C:

7.5 weeks (including Beam Commissioning Time) *in 4 blocks (2w + 2w + 2w + 1.5w)*



Data taking Plan

- **Engineering Run:**
  - Beam-line detectors activation and DAQ sync,
  - Beam Trigger activation/test/debug,
  - Secondary (Pion) Beam Intensity Tuning (measure/mitigation Muon Halo in LArTPC) ⇨ StartUp Physics Run

Beam Setting (Mom, Sign)	Beam Rate		Beam Time
2 GeV/c – Negative	27 Hz	50% π-, 50% e-	**1 week**

- **Physics Run**

[expected 3000 spill/day]:

➡Hadron Beam - Goals:
≥ 500 k Pion evt per momentum setting
≥ 100 k Proton evt per momentum setting

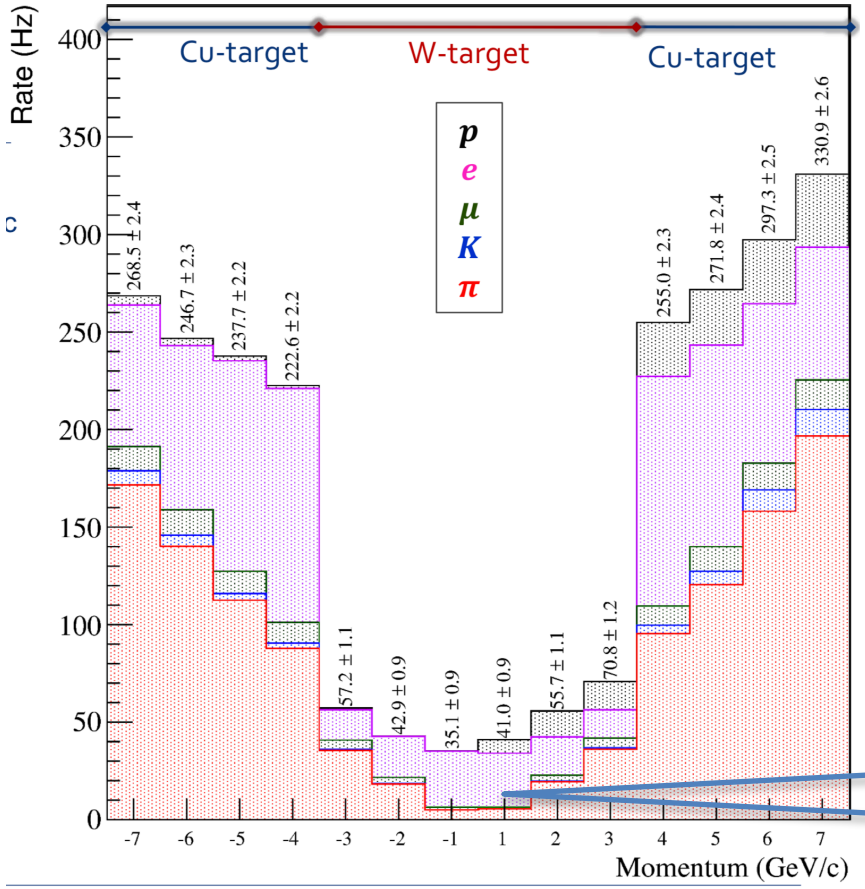
➡Electron Beam - Goal:

≥ 75 k Electron evt per energy setting

Tentative Plan - to be revised	**Hadron Beam** *Cu Target*		
Beam Setting (Mom, Sign)	**Accumul. Stat. (goal)**	**Trig. Rate/Beam Rate**	**Beam Time**
2 GeV/c - Positive	750 k [500 k π]	25 Hz / 38 Hz	**1 week**
3 GeV/c - Positive	750 k [500 k π]	25 Hz / 56 Hz	
no beam	-	-	1 week
1 GeV/c - Positive	1 M [500 k π]	25 Hz / 27 Hz	**2 week**
no beam	-	-	1 week
4 GeV/c - Positive	600 k [500 k π]	25 Hz / 196 Hz	
5 GeV/c - Positive	600 k [500 k π]	25 Hz / 200 Hz	**2 week**
6 GeV/c - Positive	600 k [500 k π]	25 Hz / 226 Hz	
7 GeV/c - Positive	600 k [500 k π]	25 Hz / 252 Hz	
no beam	-	-	1 week
	Electron Beam *Pb Target*		
Energy Ramp: 0.5, 0.6, 0.7, 0.8, 0.9, 1., 2., 3., 4., 5., 6., 7. GeV	75 k per En. setting 900 k Tot.	25 Hz / 60 Hz	**1.5 week**

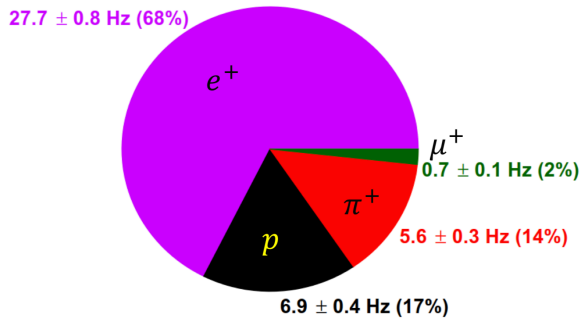
ProtoDUNE-SP TestBeam Run

Expected Rates (H4 beam line MC Calculation):
normalized to 10^6 pions on target per spill (4.8 s)



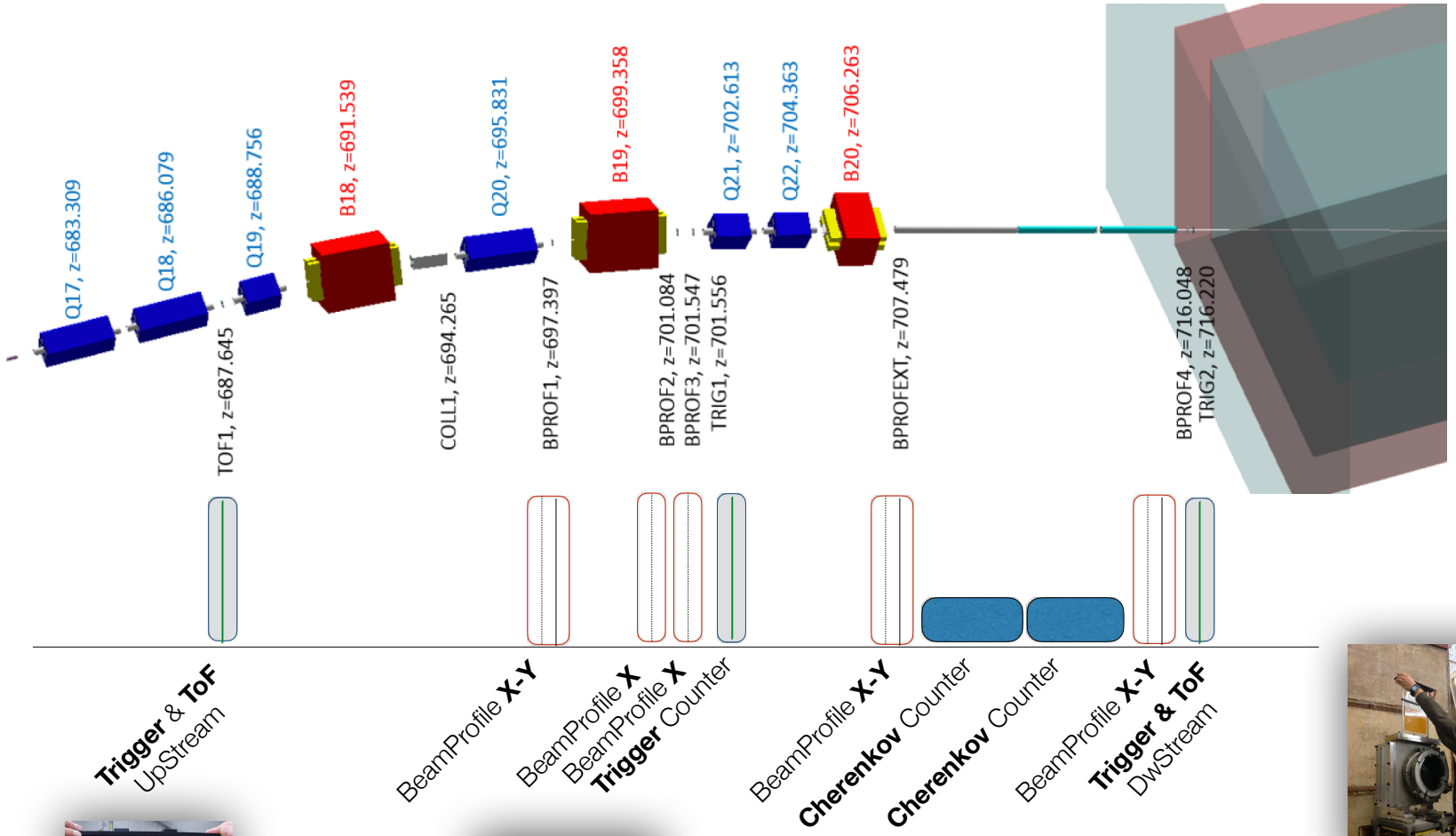
Rates at 1 GeV/c

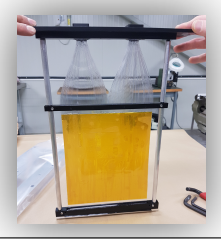
Rate with Collimator

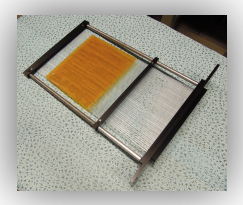


Neutrino PLATFORM

Fermilab DUNE







Blue: quadrupoles.
Red: bending magnets

Boxes: Beam detector supports
Beam Profile X,Y = Scint. Fibre Tracker
Trigger & Time-of-Flight detector =
= Scint. Fibre paddle

Cherenkov counters

NP04/H4 Beam Line & Beamline Detectors

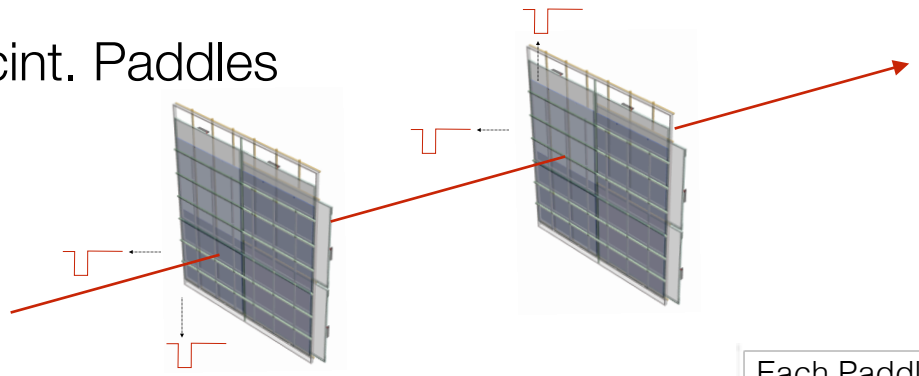
Neutrino PLATFORM

External Muon Tagger

Trigger logic using coincidence signals from upstream and downstream modules

A FAST NIM signal is generated when a coincidence is found btw the two layers of the hit paddle

2 Hor Scint. Paddles

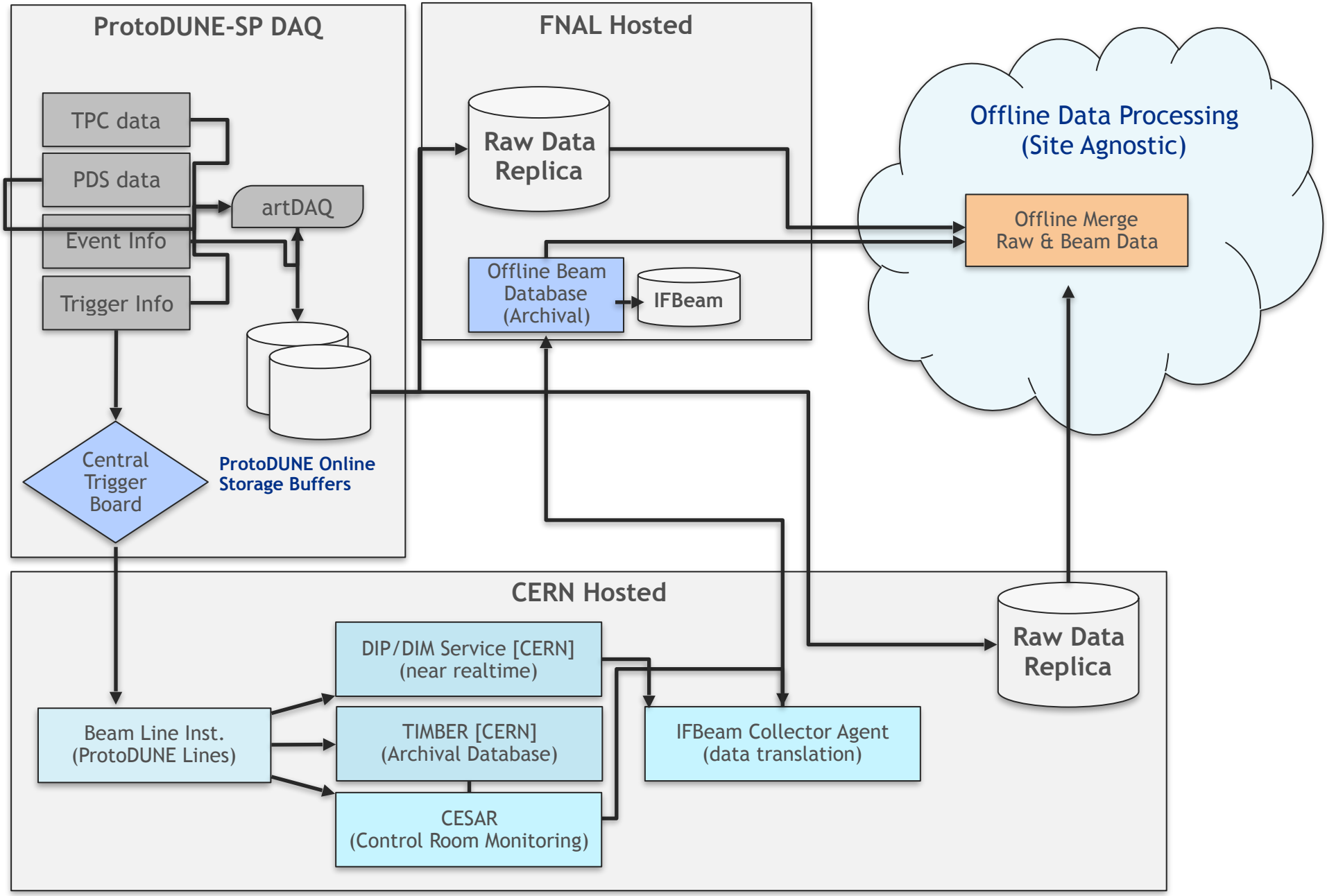


2 Vert

CRT Module

Each Paddle is made by TWO scintillator planes segmented in 5 cm wide strips (staggered).

- **during beam spill (BeamOn):**
  - ➡ Muon Tagger stand-alone trigger ⇨ ***hor-muon halo*** *trigger* for LAr TPC Calibration (e-lifetime, SCE)
  - ➡ in "anti-combination" w/ beam counter trigger ⇨ ***veto*** TPC readout in case of pile-up or halo/punch-through
- **out of beam spill (CosmicOn):**
  - ➡ Muon Tagger stand-alone trigger ⇨ ***hor-muon cosmic trigger*** for LAr TPC Calibration (e-lifetime, SCE)
  - ➡ in combination w/ internal PhDet trigger ⇨ *special* ***cosmic event trigger*** (cosmic ray induced muon bundles or electromagnetic cascades in atmosphere)


ProtoDUNE-SP DAQ
FNAL Hosted
TPC data
PDS data
Event Info
Trigger Info
artDAQ
Raw Data Replica
Offline Beam Database (Archival)
IFBeam
Offline Data Processing (Site Agnostic)
Offline Merge Raw & Beam Data
Central Trigger Board
ProtoDUNE Online Storage Buffers
CERN Hosted
DIP/DIM Service [CERN] (near realtime)
Beam Line Inst. (ProtoDUNE Lines)
TIMBER [CERN] (Archival Database)
IFBeam Collector Agent (data translation)
CESAR (Control Room Monitoring)
Raw Data Replica