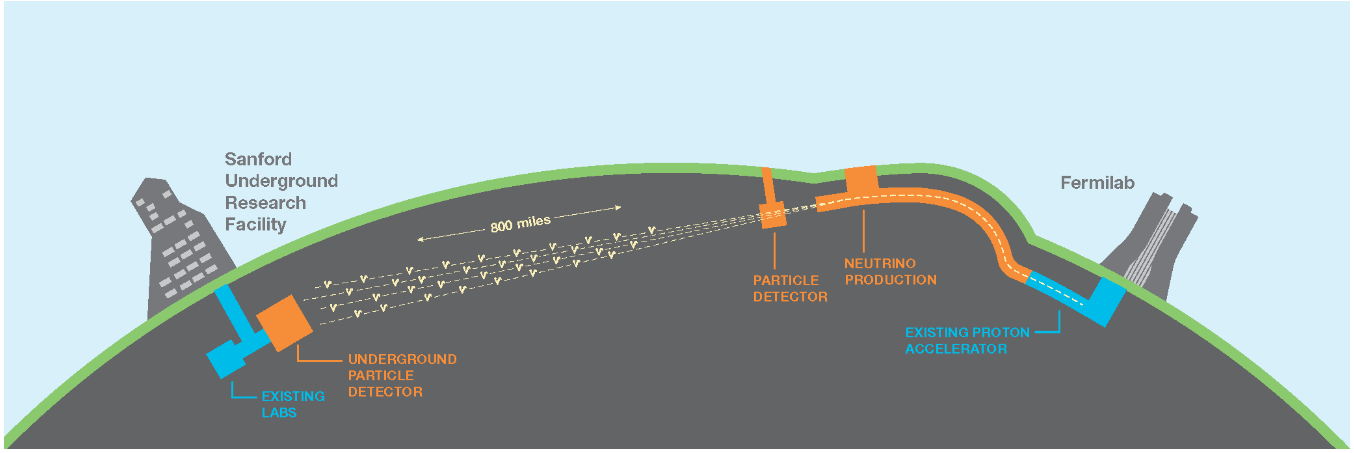


ProtoDUNE-SP Construction Status

Gina Rameika
LBNC Meeting
March 23 – 25, 2017

Outline

- Detector Overview
- Design and Construction Status
- Time Projection Chamber
  - Cathode/Field Cage /High Voltage
  - Anode Plane Assemblies
  - Front-end Amplifiers and Digitization
- Photon Detectors and Readout

- Prototyping and Installation Planning
  - High Voltage testing at PC4 (35-ton)
  - Full scale integration testing at Ash River
  - Electronics test stations at FNAL and BNL

- Summary

Watch my expression

🙂 Under control

🤔 New, unknown

😟 Concern

Major Milestones

Q3/2016: design reviews for ProtoDUNE-SP ✅ (complete Q4/2016)

Q3/2016: TDR for ProtoDUNE-SP ✅

BNL Cold Electronics Integration Test-stand Operational : 3/8/17 ✅

Submission of Production FEMB Fabrication : 4/19/17 on track

35ton HV Test (Phase 1) Complete : 5/3/17 on track

First 10 PD modules ready to ship to CERN : 5/9/17 will be @ CERN when needed

Ship APA#1 Electronics to CERN : 5/24/17

Ash River Trial Assembly Complete : 6/9/17 on track

PSL APA #1 Arrives @ CERN : 6/9/17 pushing very hard to keep to this date

PSL APA #2 Arrives @ CERN : 9/8/17

UK APA#1 Arrives @ CERN : 9/18/17

Decision to fabricate APA #7 : 8/18/17

35ton HV Test (Phase 2) Complete : 8/24/17

PSL APA #3 Arrives @ CERN: 11/9/17

UK APA #2 Arrives @ CERN : 11/27/17

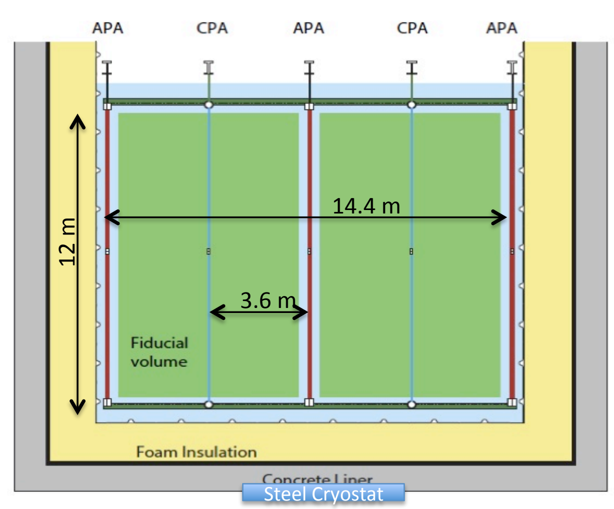
UK APA #3 Arrives @ CERN : 1/19/17

Main Goals of ProtoDUNE-SP

In progress

- Engineering validation of the full-scale DUNE detector components
- Develop the construction and quality control process
- Validate the interfaces between the detector elements and identify any revisions needed in the final design
- Validate the detector operation using cosmic rays
- Study the detector response to known charged particles
- Improve event reconstruction and detector response models

DUNE Dimensions



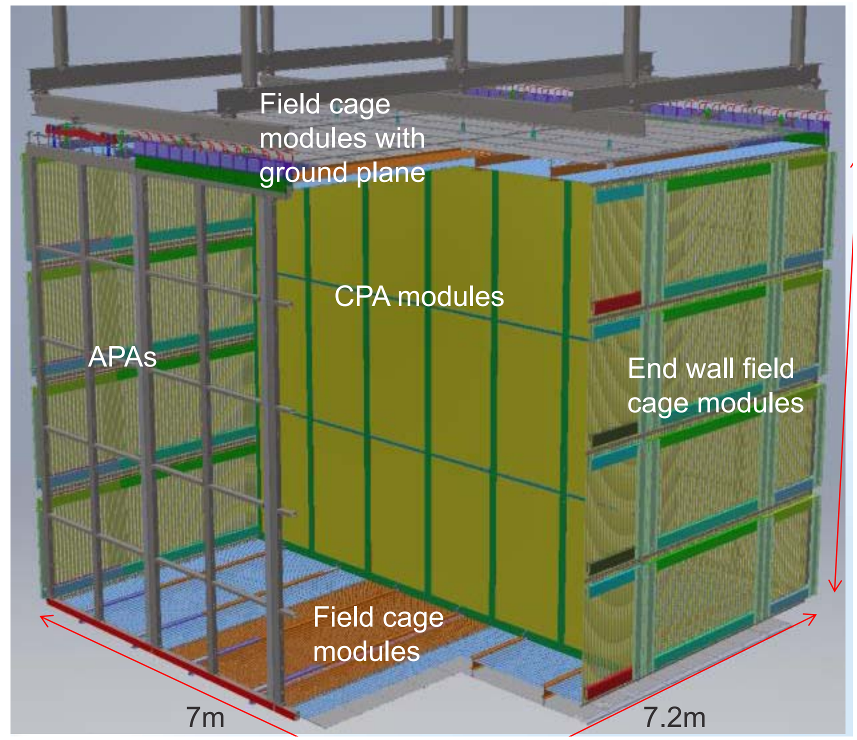
PD-SP Detector Overview

Main Detector Elements include :
Time Projection Chamber (TPC) ,
Front-end and digitizing electronics, a Photon Detector System (PDS) and Data Acquisition (DAQ)

Prototype of the single phase DUNE far detector. Full scale modules, but only half height of DUNE FD (single layer of APAs).

TPC has 6 units of anode wire planes (APAs), a high voltage cathode plane (18 "units"), 28 field cage modules, 15K readout channels

Dimensions - W: 3.6m (x2), H: 6m, L (along beam direction) : 7m ; 300 ton active mass



Detector Elements – a modular approach

Table 2.1: TPC detection components, dimensions and quantities

Detection Element	Approx Dimensions	Quantity
APA	6 m H by 2.4 m W	3 per anode plane, 6 total
CPA module	2 m H by 1.2 m W	3 per CPA column, 18 total in cathode plane
Top FC module	2.4 m W by 3.6 m along drift	3 per top FC assembly, 6 total
Bottom FC module	2.4 m W by 3.6 m along drift	3 per bottom FC assembly, 6 total
End-wall FC module	1.5 m H by 3.6 m along drift	4 per end-wall assembly (vertical drift volume edge), 16 total
PD module	2.2 m $\times$ 86 mm $\times$ 6 mm	10 per APA, 60 total

From ProtoDUNE Technical Design Report

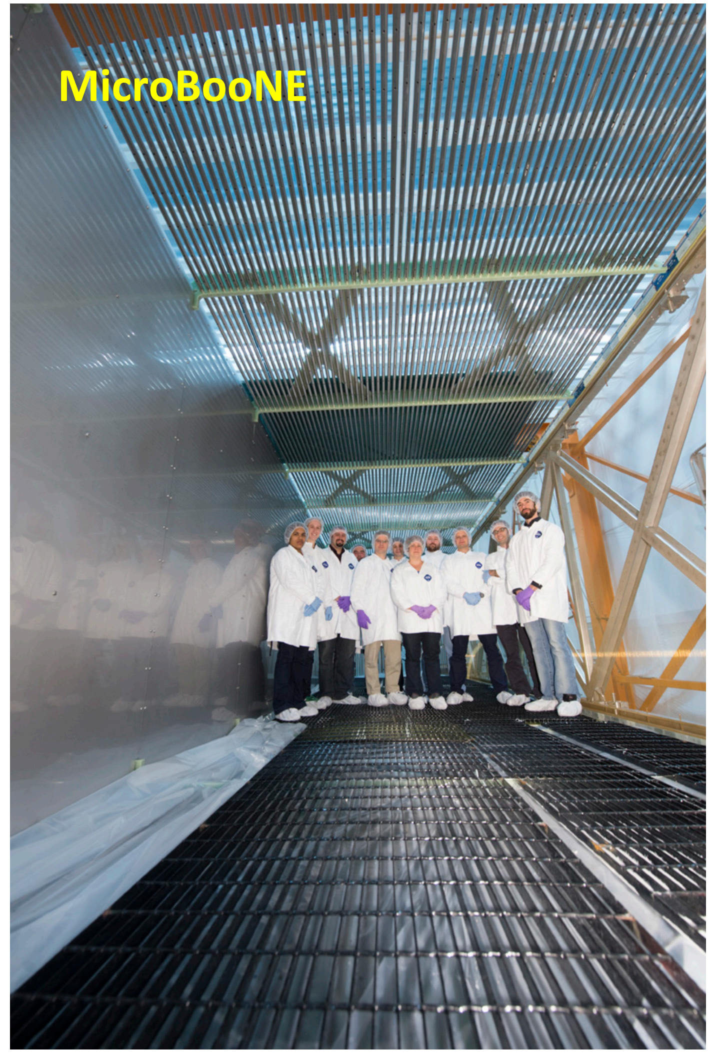
This modular approach to detector construction enables the construction of detector elements to take place in parallel and at multiple sites.

This will be an essential approach for the DUNE Far Detector.

Design Evolution from previous LArTPC Field Cages

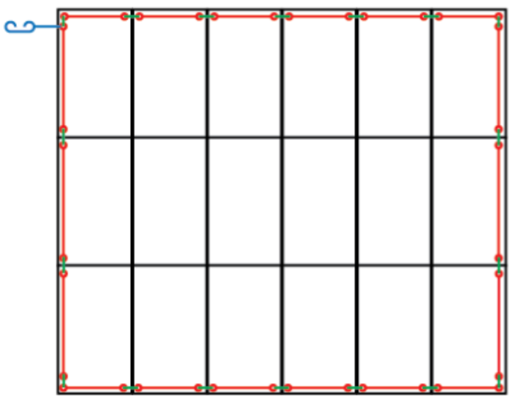
"Racetrack" Field Cage with metallic cathode

- not easily scalable
- tremendous stored energy

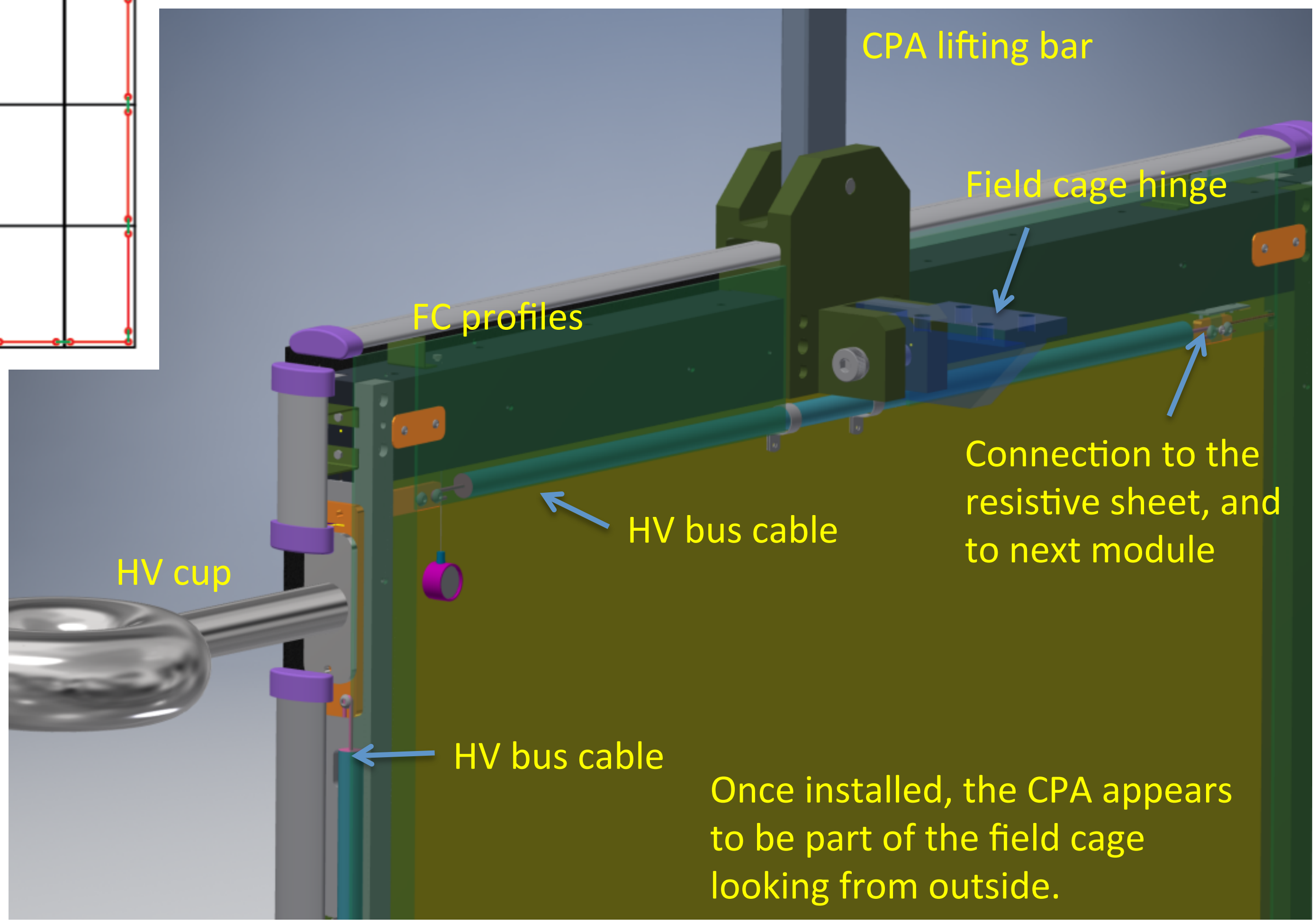


HV Bus distribution to cathode plane

New design



A HV bus cable to distributes the cathode voltage to all of the cathode panels



Two new elements of the TPC design

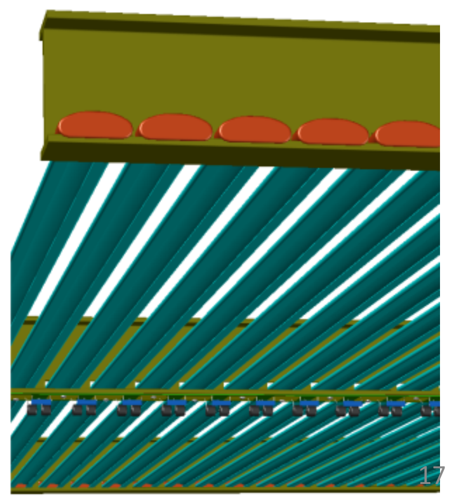
Resistive Cathode

CERN, BNL

- At full voltage (180kV) there is almost 100J of energy stored in the cathode plane
- In the event of a discharge from a cathode edge to the cryostat wall, there is a risk of physical damage to either the cathode or the membrane wall; the voltage on the an all metal cathode will collapse very quickly, injecting high current into the cold electronics, through the APA wires, risking damage to the front end ASICs
- To mitigate this risk a new all resistive cathode has been developed using a commercial resistive film
- Several types of resistive surfaces have been investigated and the preferred solution is Dupont Kapton film laminated on FR4 substrate

Modular Field Cage

- A new design of a modular field cage using extruded, open aluminum profiles held together by pultruded fiberglass beams has been developed
  - Panels are of manageable size and weight
  - Each panel has its own resistor chain to degrade the voltage and is electrically insulated from the adjacent panels which will minimize the peak energy dump in case of sparks



Stony Brook,
Louisiana State,
William & Mary,
CERN

Cathode Plane (CPA)

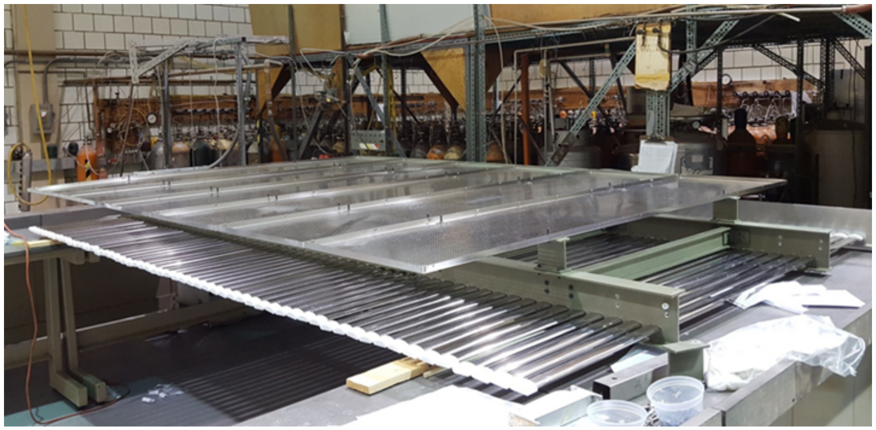
Argonne National Lab, BNL, CERN

18 individual “panels” assembled into units of 3 and assemblies of 2 panels; 3 total panels needed

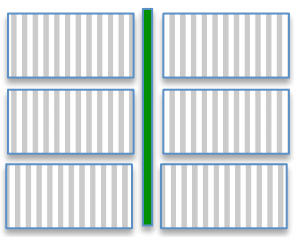
Field Cage Module Construction

Top and Bottom

Stony Brook University



Need 12 of these
6-top, 6-bottom



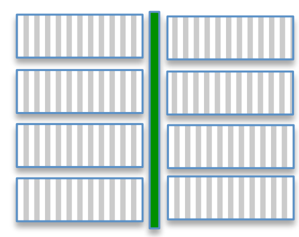
58 profiles in each module;
Profiles being procured by CERN and will be installed at CERN in the summer;

CERN, William & Mary

Endwalls

Louisiana State University

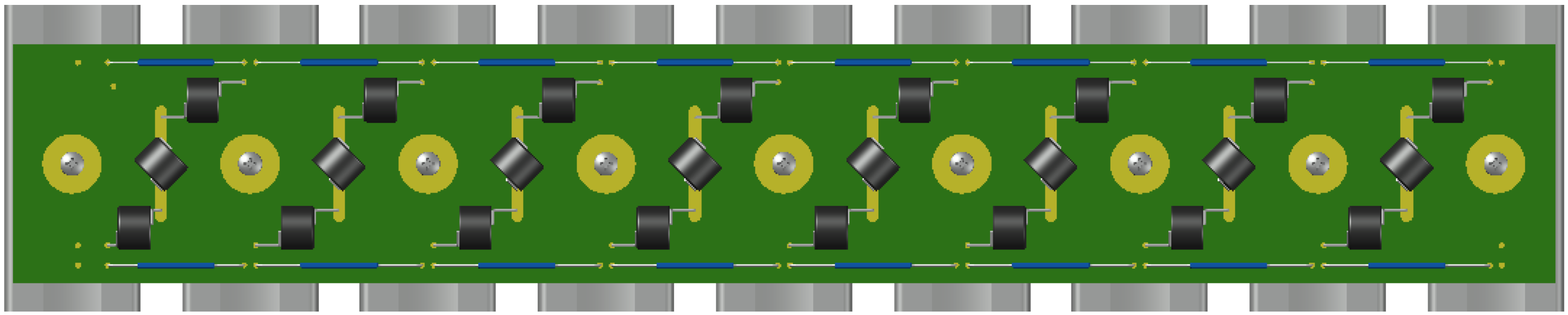
Need 16 of these
8 upstream
8 downstream
(1 us has the beam plug)

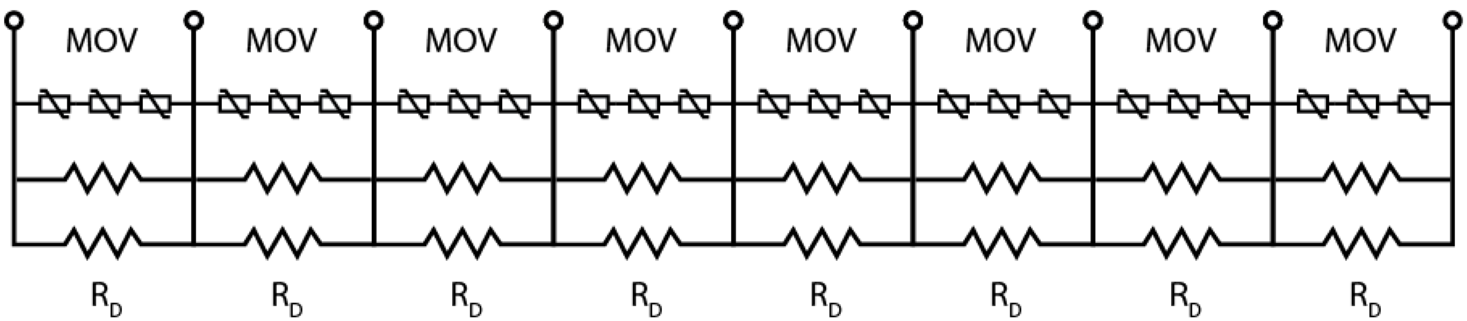


Field Cage Resistor Divider Boards

Create the field gradient (500V/cm nominal)
from the cathode to the anode plane

Louisiana State University





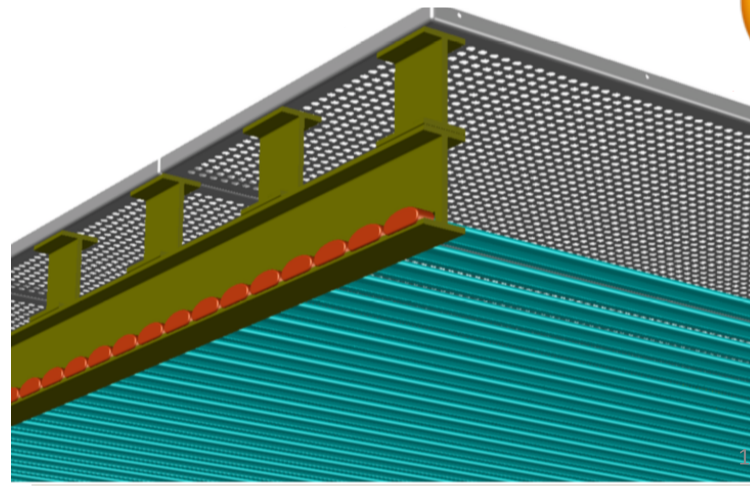
RD: SM104FE-1000M, MOV: ERZ-V14D182

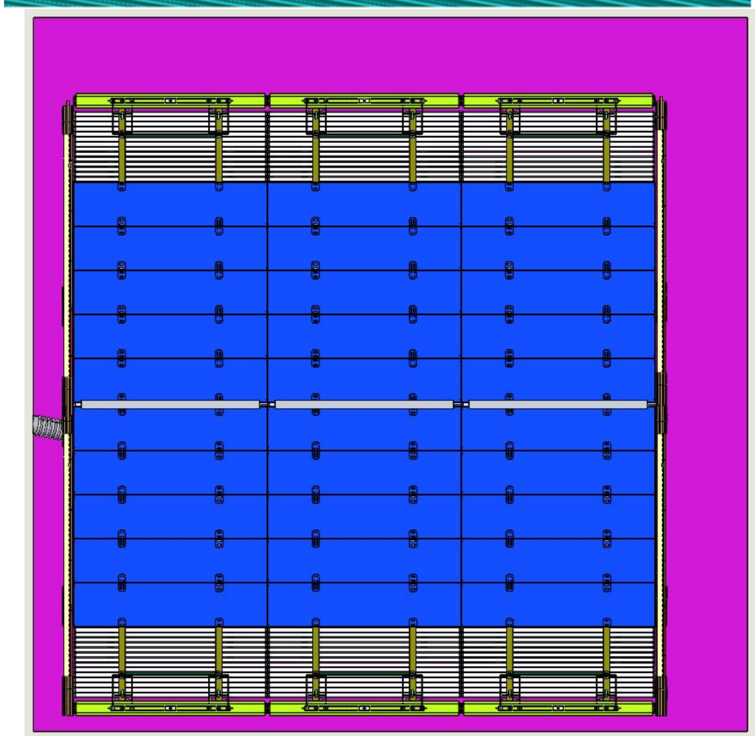
3 varistors
2 1GOhm resistors
per connection

One board connects 8 field cage profiles
Need 7 of these per field cage module -> 196 total boards needed
Will be installed on the field cage profiles at CERN

Ground Planes

CERN





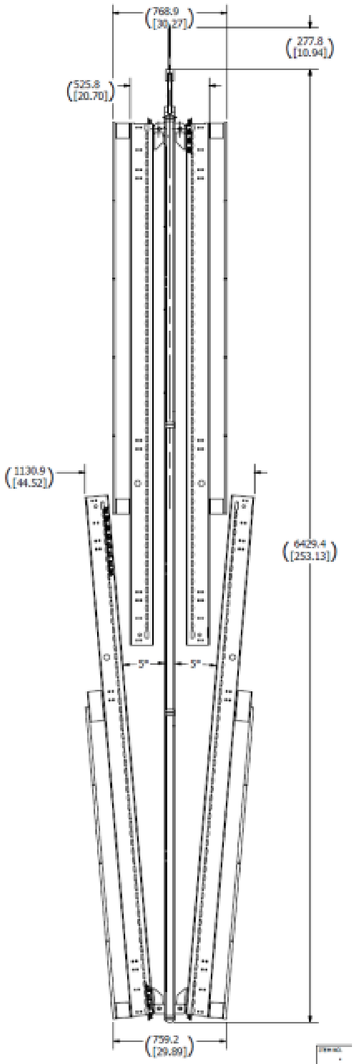
The purpose of the ground plane above the field cage is to shield the fringe field created by the CPA/FC from entering the gas ullage and cause breakdown

The ground planes are stamped from 1 mm thick stainless steel

The ground plane on each T/B field cage panel is composed of 5 panels.

Since the top and bottom field cages are designed to be symmetric, there is a ground plane by default on the bottom.

CPA-FC Assemblies



END VIEW 2

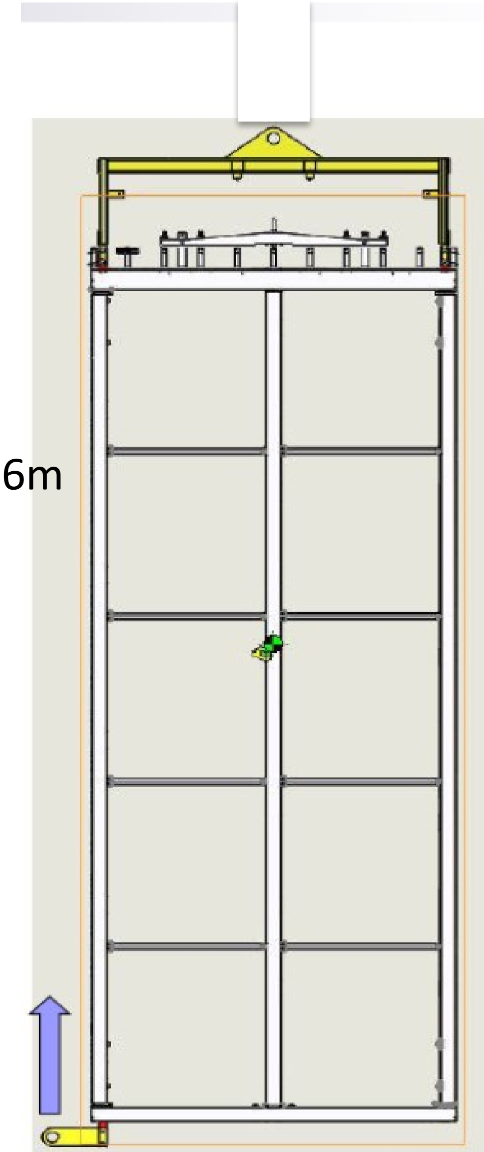
Each composed of a

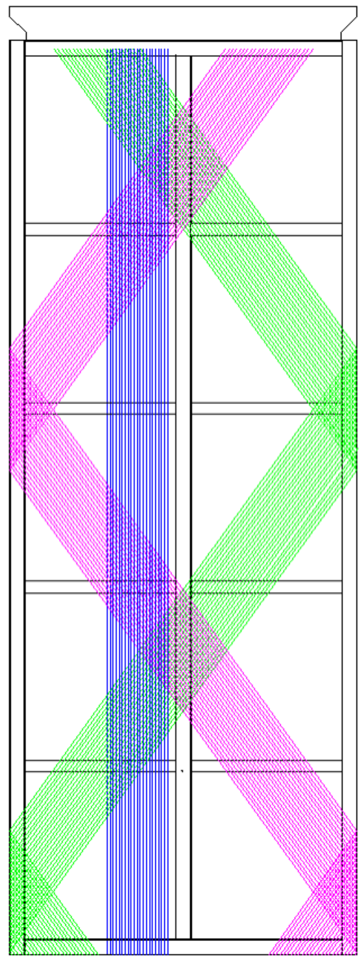
- CPA (2 columns, 6 units)
- 4 Field Cage Modules (w Ground Planes)
  - Beam Right
    - Top and Bottom
  - Beam Left
    - Top and Bottom

Units are assemble outside of the cryostat and moved into the cryostat through the TCO
Need 3 Assembled Units :

- Upstream
- Midstream
- Downstream

Anode Plane Assemblies (APA)





PD-SP will have 6 APAs

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

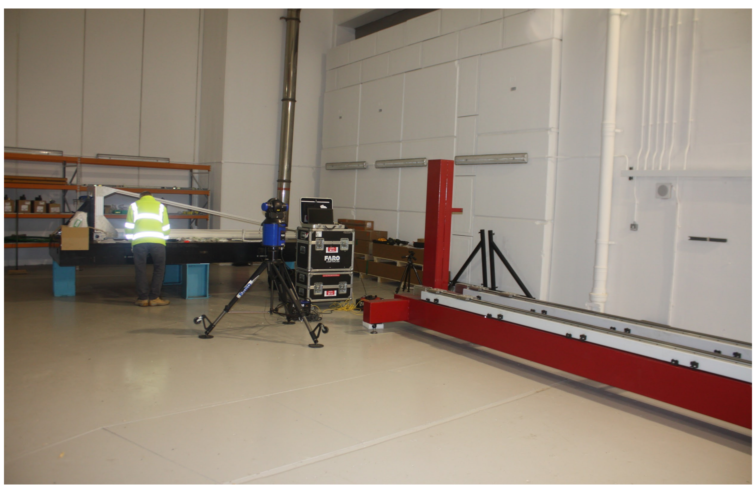
10 Photon Detectors are installed into each APA frame

APA Construction at UW-PSL and Daresbury, UK

schedule

UW - PSL
X-plane wires complete;
U-plane wire winding in progress

US APAs (1-3)
UW-PSL – Lead Lab
QA/QC support from Syracuse
UT-Arlington
Yale



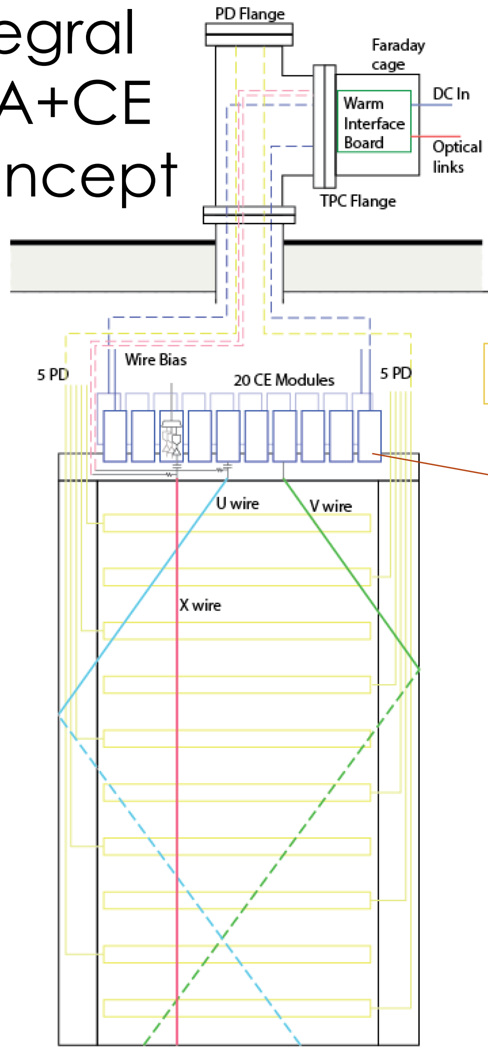
U.K. winder under construction at Daresbury

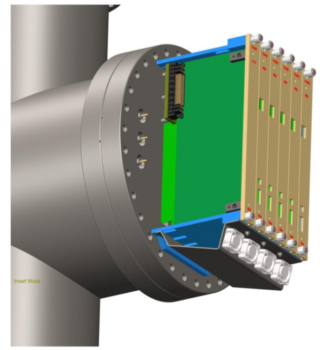
1st frame under construction

UK APAs (4–6)
Daresbury
Manchester,
Lancaster,
Sheffield,
Liverpool

TPC Readout – Cold Electronics with a warm interface

Integral APA+CE Concept

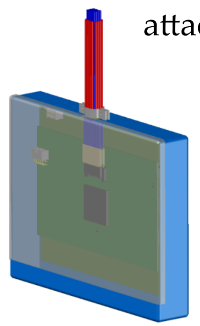


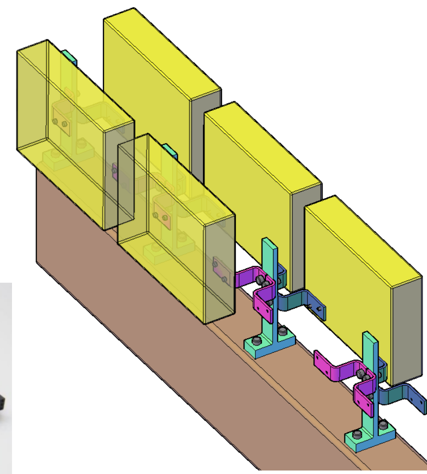


ProtoDUNE-SP

Keep eye on schedule for delivery and testing of ASICs and FEMBs

Cold electronics module and its attachment to the APA frame





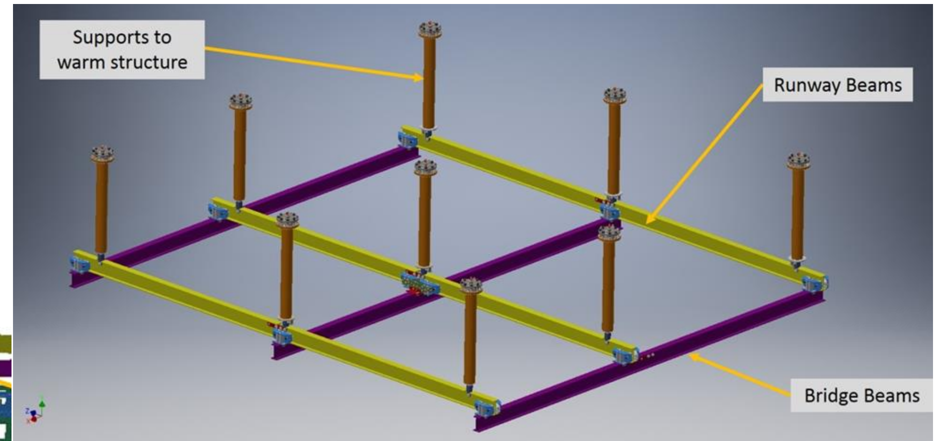
BNL - lead
UC Davis
Boston
Michigan State
U Penn
LSU
U of Florida
Fermilab

10/12/2016 H. Chen - Cold Electronics Review 23

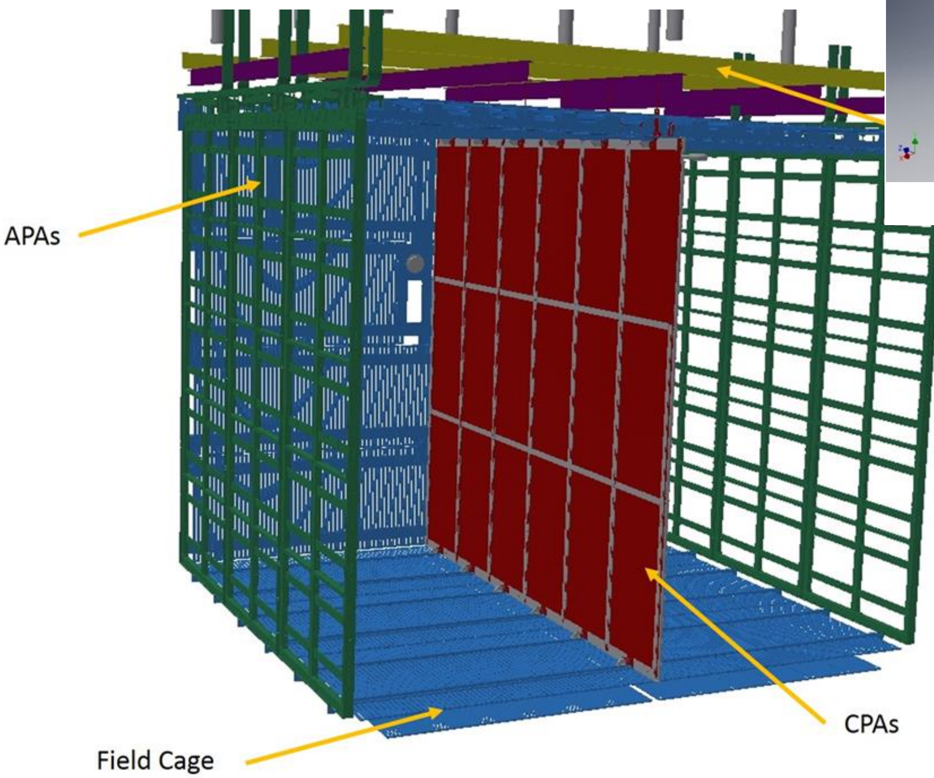
Detector Support Structure

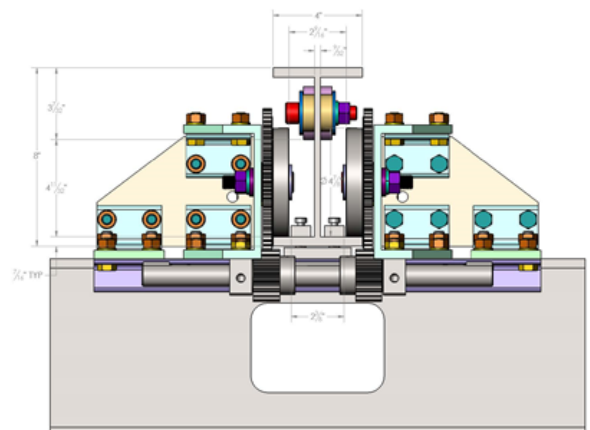
Design, schedule

Looks simple, but is a complicated structure which needs to support and enable positioning of the components during installation as well as in final position



Only three bridge beams are shown. Five will be used for installation.





Custom trolley design to enable positioning the elements

Fermilab DUNE

Full Scale Trial Assembly at Ash River

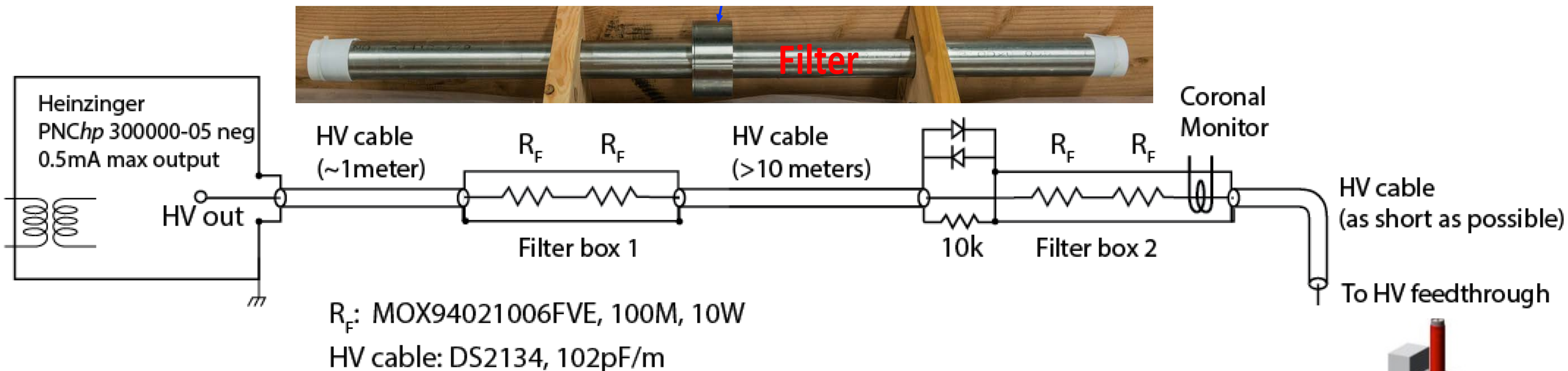
New,
Not exactly
same as CERN

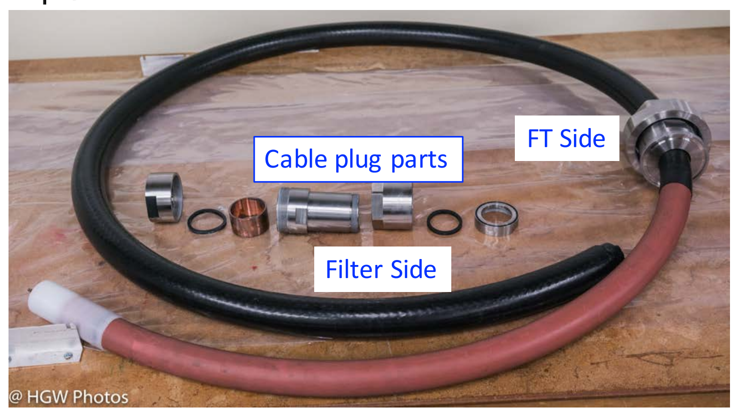
1/6 mock-up of PD
Learn how to deploy field cages
Latch into place
Develop installation procedures – including ES&H + QC

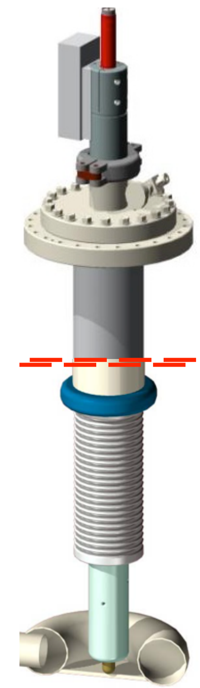
Developing installation tooling and procedures

Note – lifting devices and fixtures NEED TO BE REMOVED after construction is complete

High Voltage System







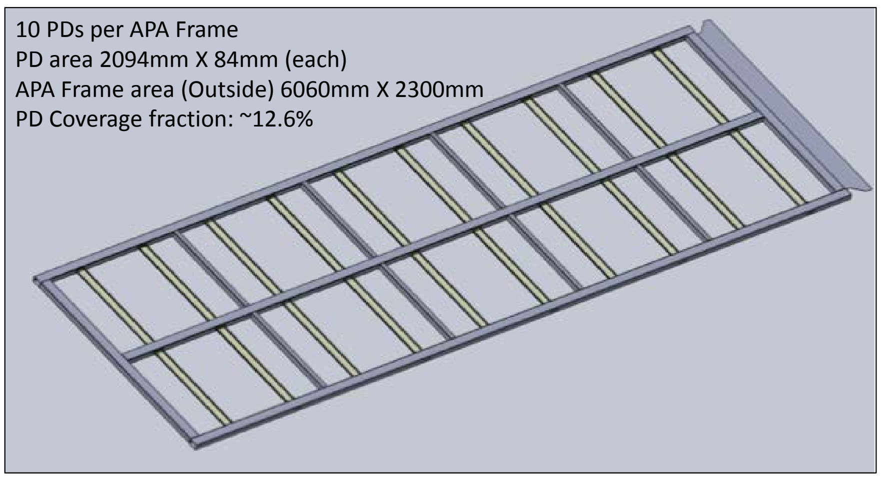
CERN, FNAL, BNL, Kansas State,
U of Houston, UC Davis

Fermilab DUNE

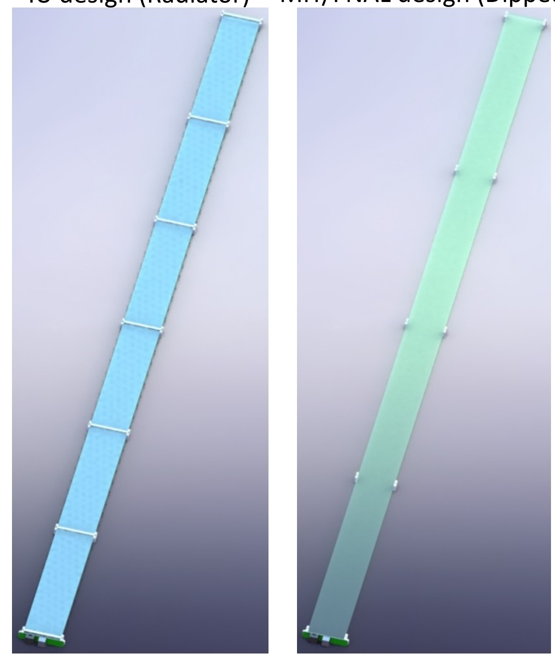
Photon Detection System

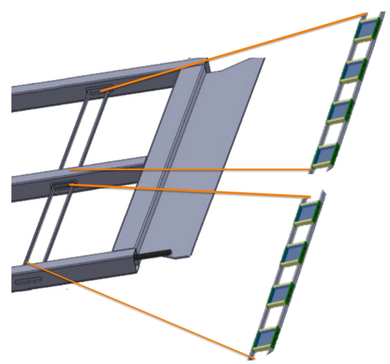
Indiana, FNAL, MIT, Northern Illinois,
Caltech, Colorado State, ANL, UNICAMP

10 Photon Detector bars per APA -> 60 total bars needed
3 types of “bars” being tested and fabricated



IU design (Radiator)   MIT/FNAL design (Dipped)



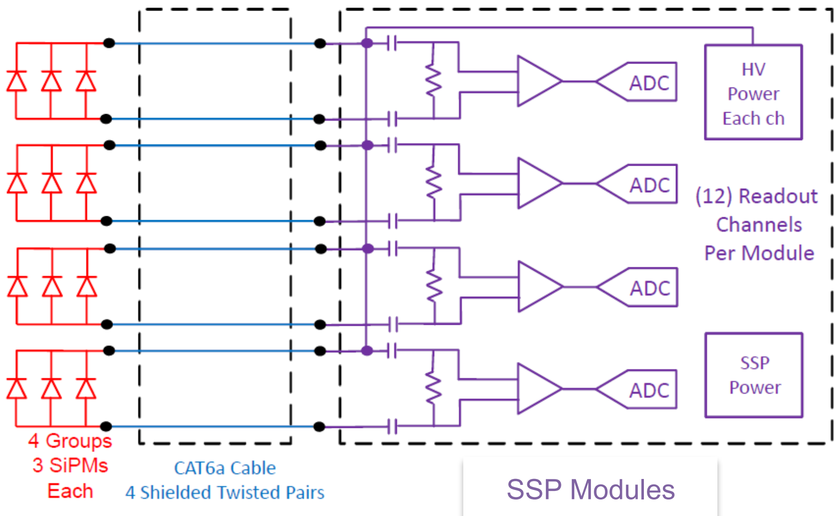


Arrapuca arrays
FNAL, UNICAMP

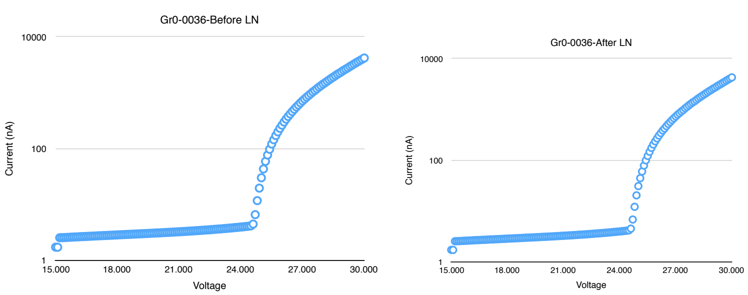
SiPM Readout

Each bar read out by an array of 12 SiPMs -> 720 SiPMs needed

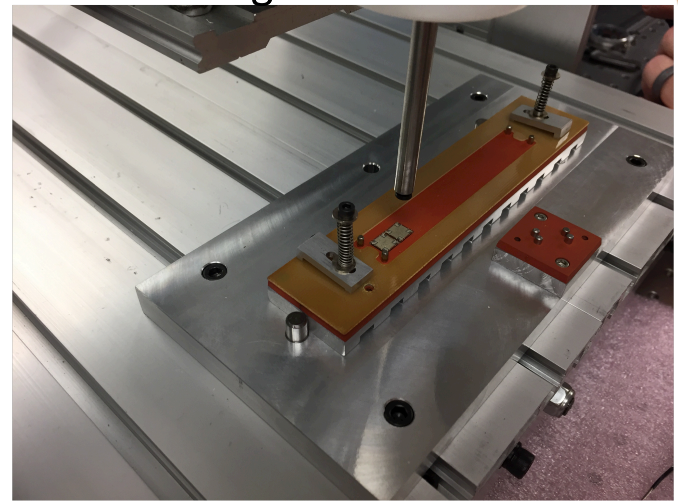
- Signals go into a 12 channel waveform digitizer with a 14-bit 150MSPS ADC

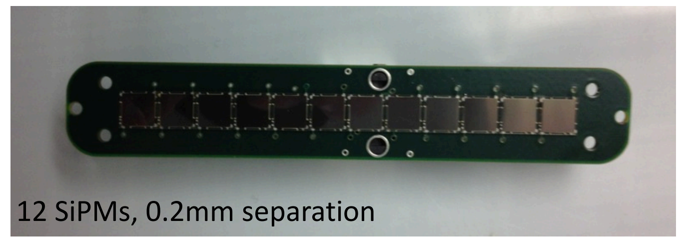


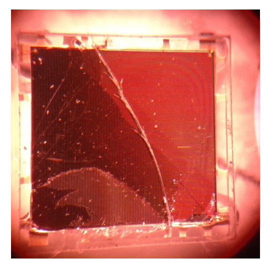
I-V curves warm and cold



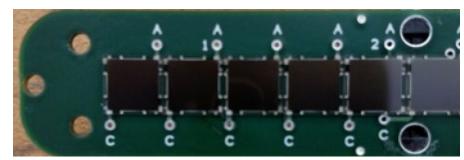
Mounting machine at CSU







Recent damage on a new batch
Not rated for cryogenic operation; but OK experience up until now

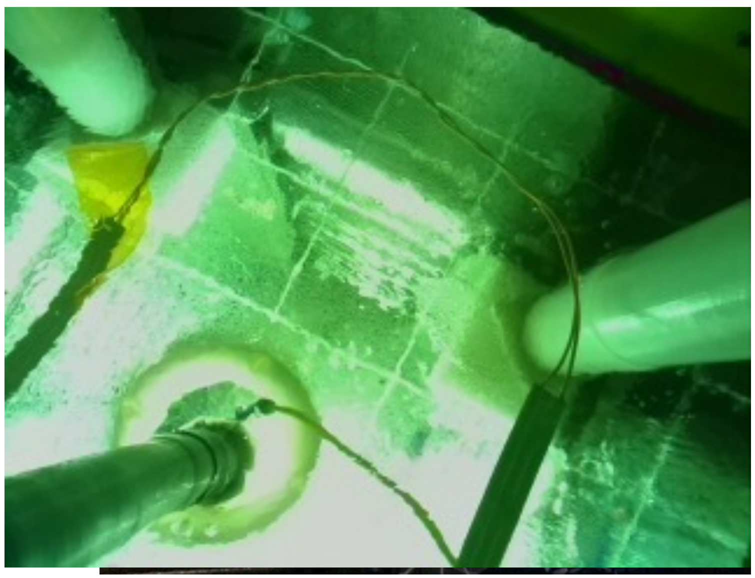


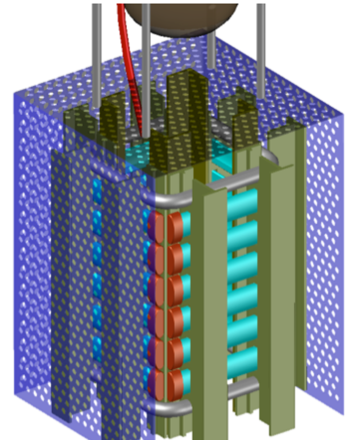
But indications that they are generally OK when properly mounted

Small field cage test

CERN

Designed to fit in the ICARUS 50 liter cryostat
Roll-formed Al and SS profiles with UHMW PE caps
All profiles a same potential
Applied -100kV without discharge



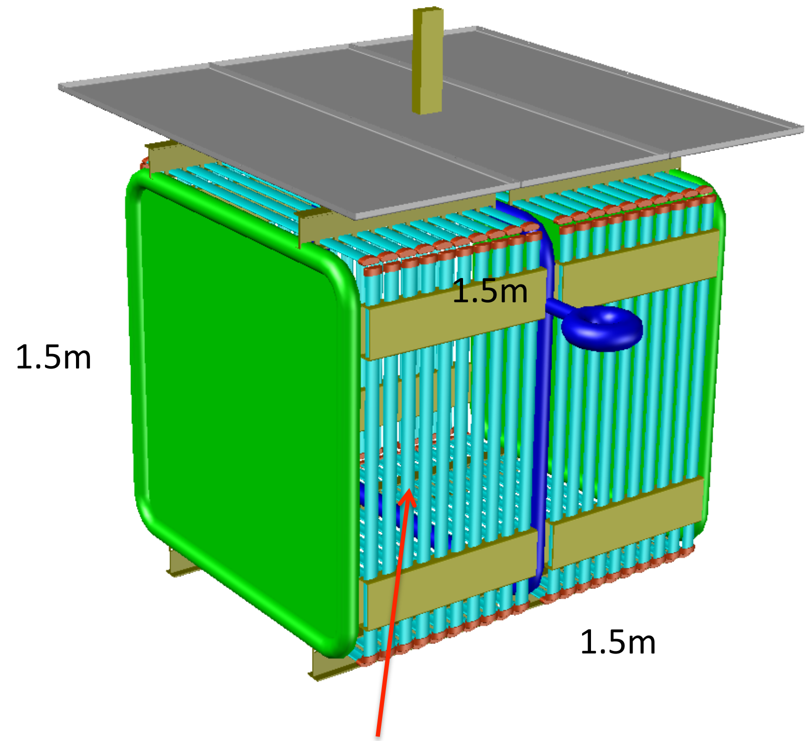


CPA/FC/HV test setup

Fermilab, ANL, BNL, William & Mary, Kansas State, LSU, UC Davis, University of Houston

- This setup will be able to test the following features at full scale for E field purpose:
  - CPA lifting fixture
  - Ground plane
  - Ground plane overhang
  - Field cage support structure
  - CPA edges
  - Field cage profiles
  - Profile caps
  - End wall FC box beams
  - HV cup

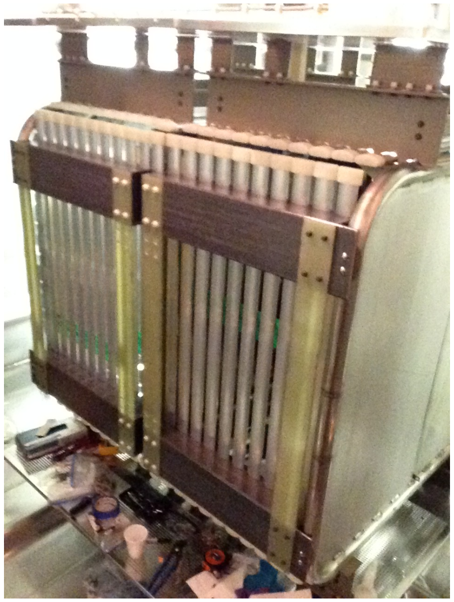
In the 35 ton facility at FNAL



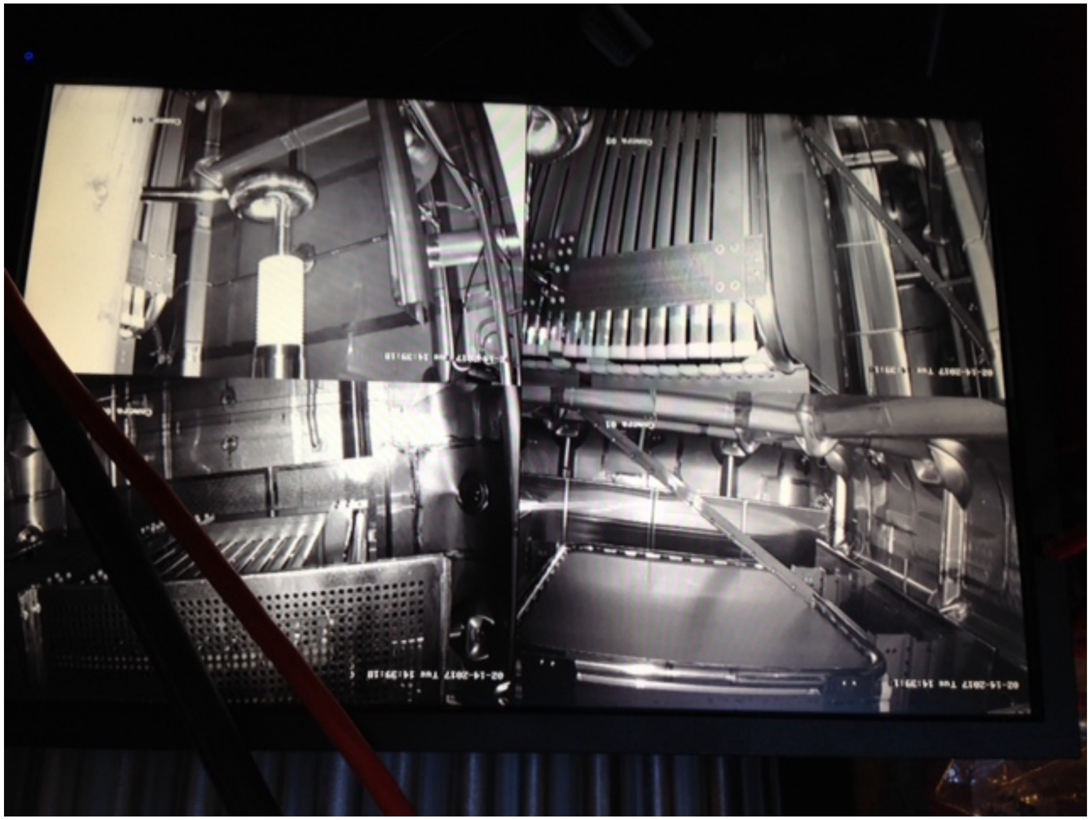
- Aluminum profiles with conductive coating have now mounted in the Field Cage panels:

37

High Voltage Test at the 35t



Instrumented with cameras and PMTs
Monitoring current draw as voltage is ramped up
Have ramped to 40kV in air with no sign of breakdown



Status :
Cool down
Filling
Ramp to voltage
Purify
Ramp to voltage

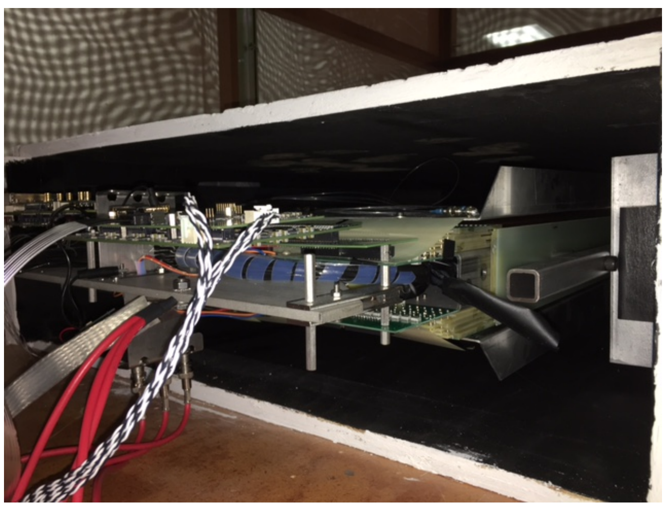
Electronics Testing – FNAL and BNL

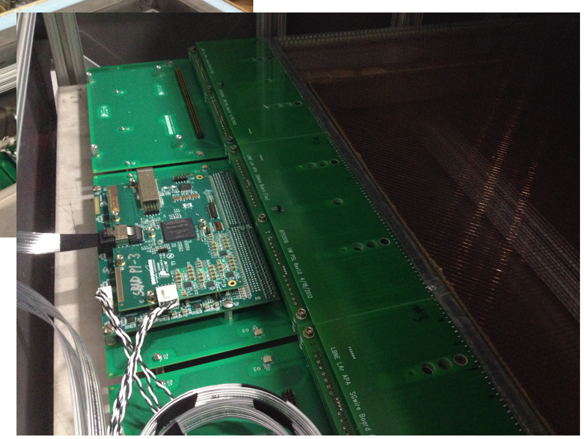
FNAL

- RF Shielded room with isolation transformer
- Warm test
- Will test full electronics chain (with small APA)

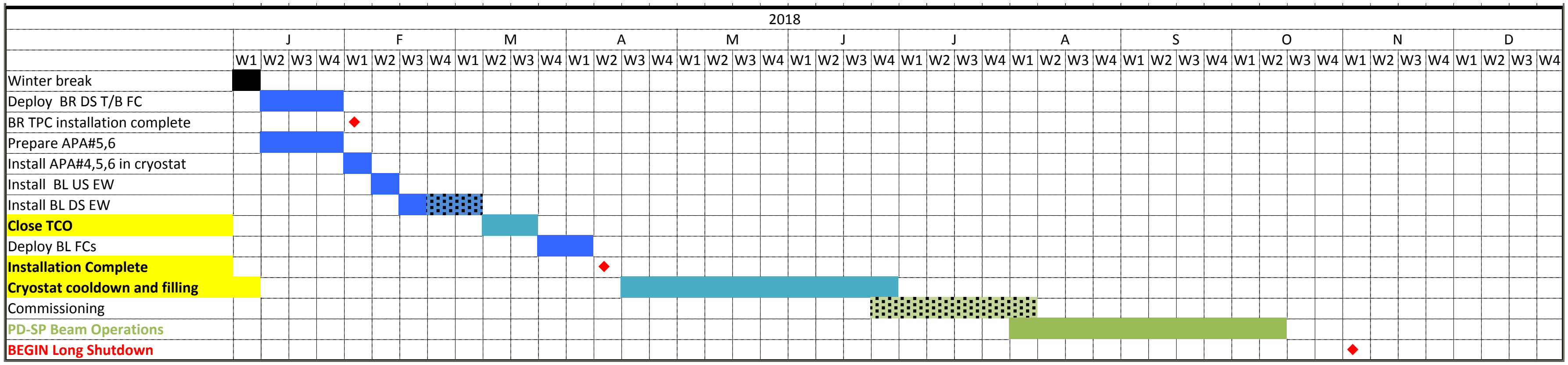
BNL

- Cold test (LN2)
- Also tests full chain with “40%” APA



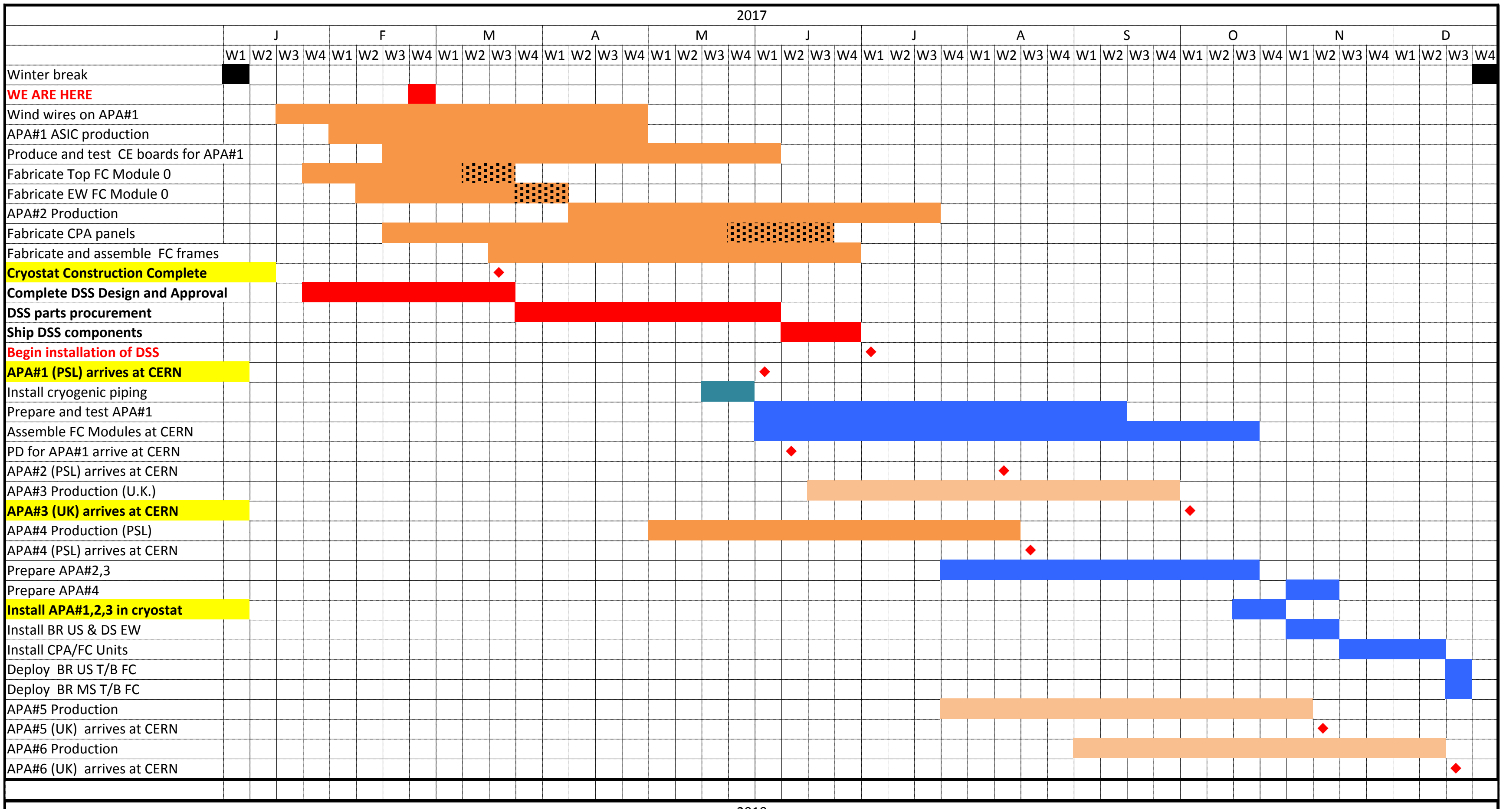


What keeps us awake at night : Schedule Driver



End of beam to EHN1

What we need to accomplish this year



Risk Updates

- Held a PD-SP Risk Workshop in early February
- Re-evaluated risks to protoDUNE-SP
  - 13 in Construction phase
  - 10 in Installation phase
  - 6 in Operations phase
  - 1 in Analysis phase
- Highest ranked risks
  - Schedule
    - APA delivery
    - Cold Electronics delivery
  - High Voltage
- Update :
  - closed 1 (FC production sites are ready)
  - realized 2 (APA behind schedule, SiPM yield unknown)

Response to LBNC Recommendations

Review Date	Item Description	Due Date	Status	Actions
12-Jun-16	Work with the funding agencies, including DOE, to make sure support for operations and the hiring of key personnel is realized in a timely fashion	1-Jun-17	in process	This has been highlighted at visits DOE in Germantown. Discussions with DOE continue. Fermilab have provided key hires.
23-Oct-16	The collaboration should review the goals of the test beam run taking into account the trade-off between meeting the current schedule versus the risk of the detector not performing as required	19-May-17	in process	A list of deliverables was provided to the DOE IPR March 1, 2017.
23-Oct-16	At the next LBNC, present the response plan from the Final Design Reviews and their outcomes	23-Mar-17	in process	Yes. We will. (Need high level response based on individual L3 responses)
23-Oct-16	Investigation of the variable high frequency noise problem should continue to be pursued with high priority to understand the root cause, which may not reside in the LV power supply.	22-Jun-17	in process	This is ongoing at both the FNAL screen room facility and the BNL cold 40% APA test stand.

Summary

- All detector elements are either in production or nearly ready to start (final versions of 1st elements)
- Most significant issue is meeting the schedule
  - Currently we have challenges in delivery of DSS, APAs and Cold Electronics
  - All equipment delivered to CERN needs to have acceptance reviews for safety before it can be installed
- Significant effort is going into the trial assembly so that the installation phase at CERN is efficient