SBND / NP04 Cold Cables & Feedthroughs for the Cold Electronics

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Outline

- Requirements
- Overall cable routing schemes
- Feedthrough port design
- Signal feedthrough flange design
- Cable routing from the APA to the feedthrough
- Summary

Charge Questions:

- Does the conceptual design for the CE systems meet the requirements?
- Are justifications for each of the specific technical design choices sufficiently documented?

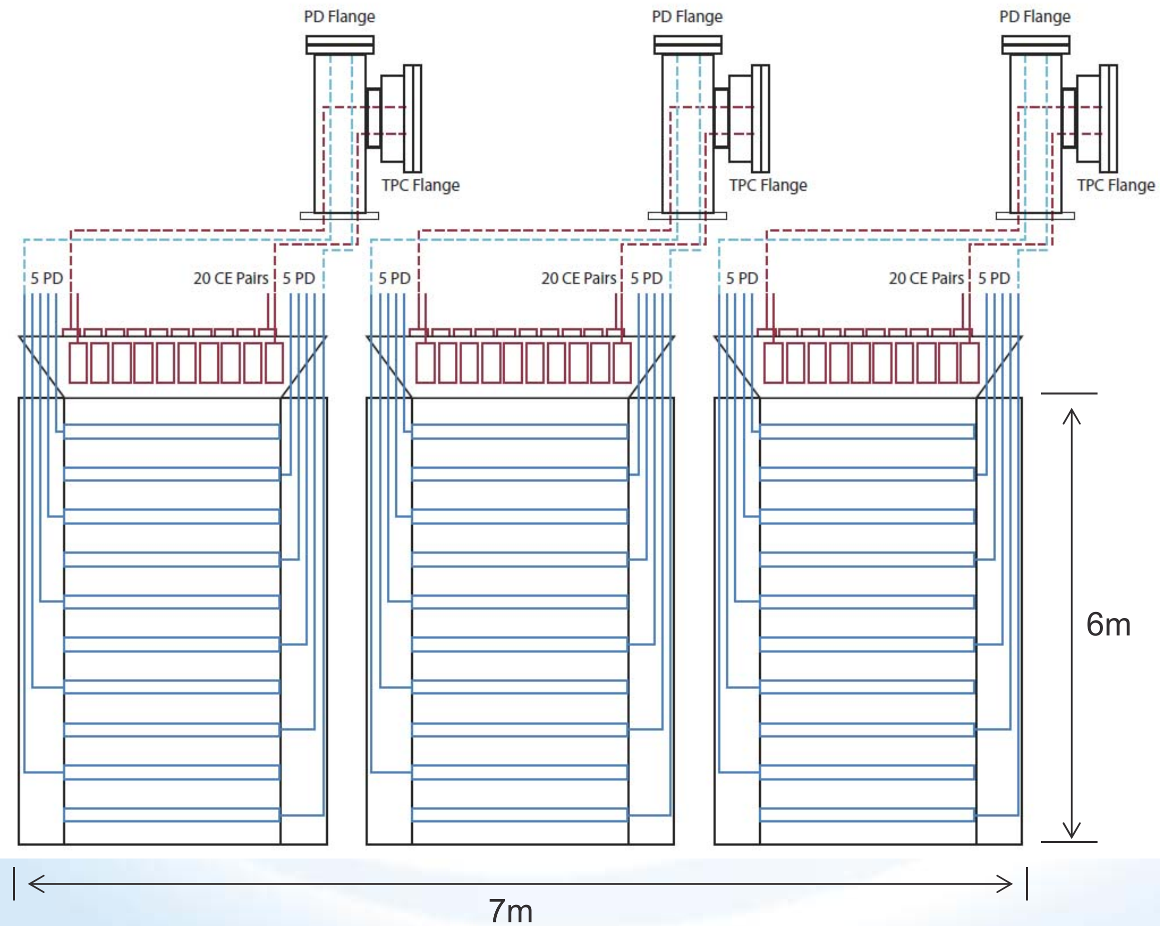
Requirements

- Signal Feedthroughs (SBND docdb 1158)
  - MAWP must ≥ cryostat MAWP (350 mbarg)
  - A proof test at 4x cryostat MAWP (1400 mbarg) to establish the feedthrough MAWP
  - Maintain a leak rate < 10^{-9} mbar·liter/sec under all thermal conditions*
  - Implement a purge port (minimum ¼" tubing) on the feedthrough flange
  - Avoid moisture condensation
- Cables
  - Use PTFE based cable for best LAr purity compatibility
  - Must be halogen free for use at CERN
  - Maintain signal integrity/voltage stability at room temperature for up to 25m in length (more in backup slides)
- Cable Routing
  - All electrical connections (power and signal) from an APA shall lead to a single feedthrough.
  - APA Power line return leads and any shields shall be connected to the common plane of the cold FE module at one end and to the flange of the feedthrough at the other end. This shall be the only connection of the APA frame to the cryostat.
- Feedthrough Port
  - Exert no mechanical stress to the crossing tube in the insulation space

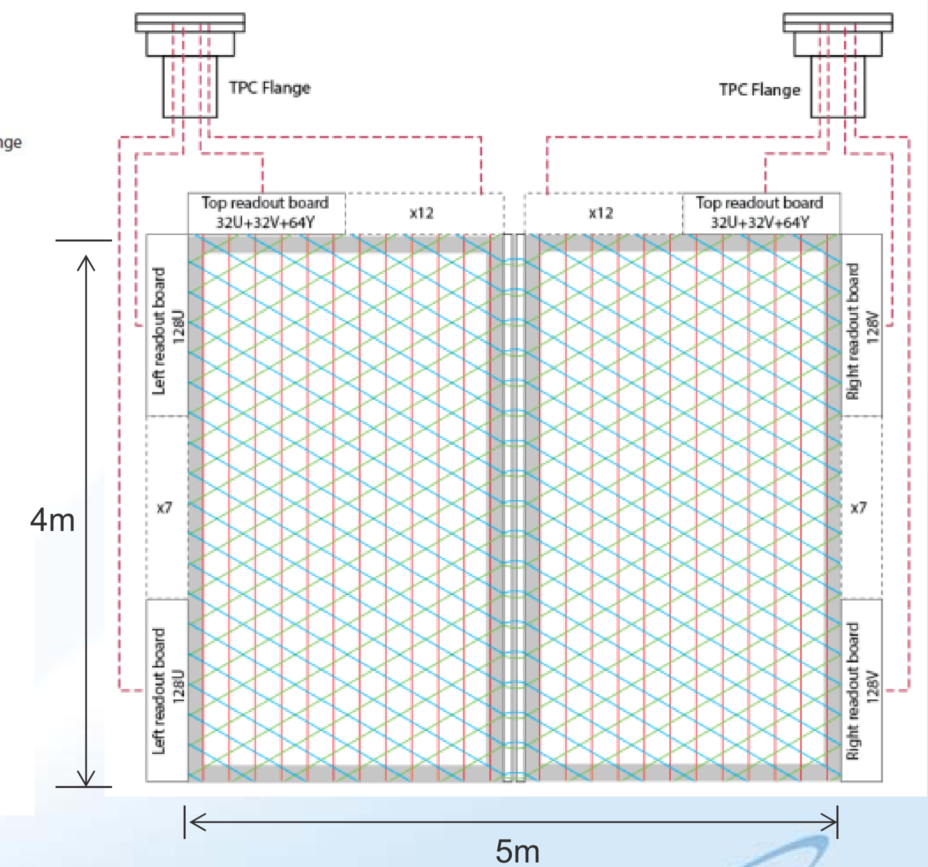
*Upon special situations, the SBND Technical Coordinator will consider granting an exception to this leak tightness requirement on a case-by-case basis.

NP04 and SBND APA Cable Routing Scheme

NP04



SBND



The SBND TPC

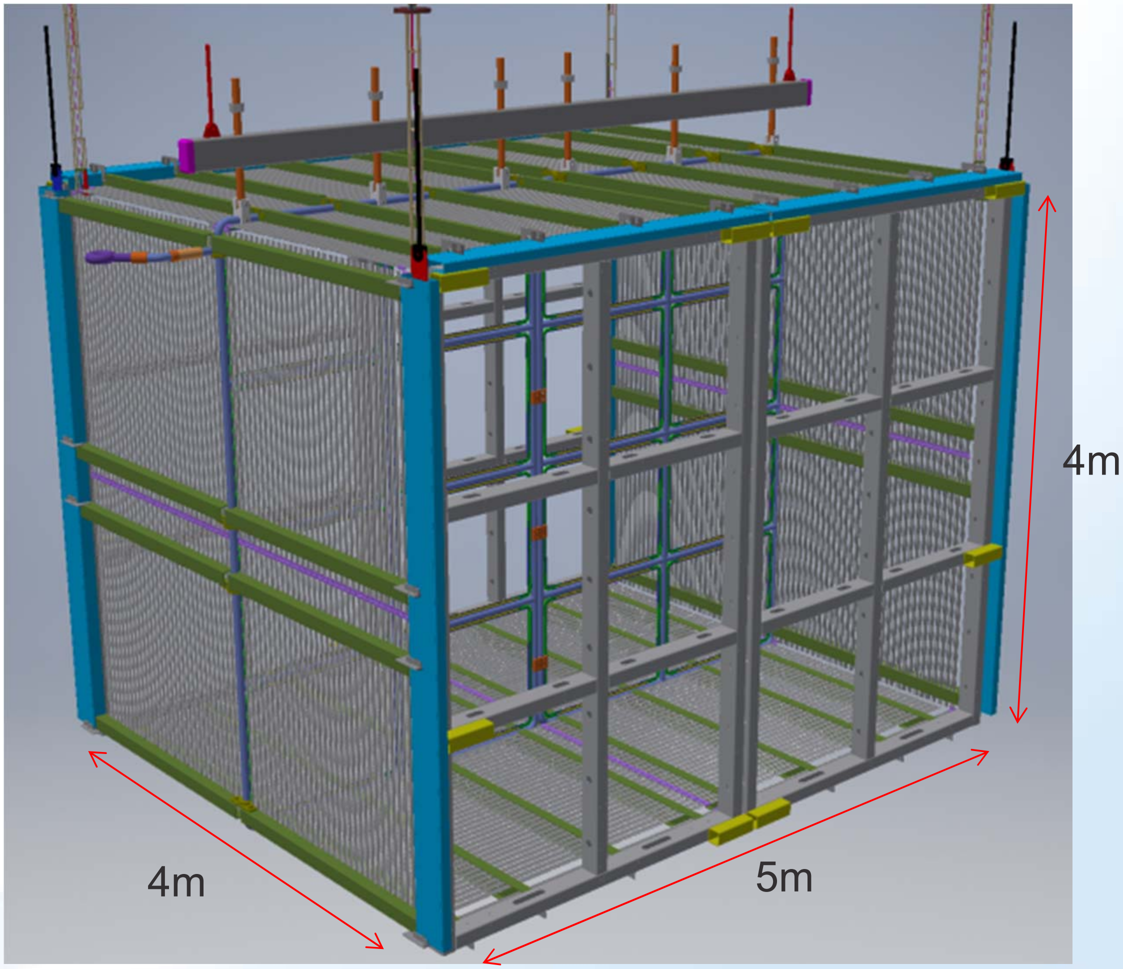
4 APAs, 11k readout channels

TPC readout feedthrough ports: 4, one on each top corner of the TPC

On each FT port:
22 sets of data and power cables
8 bias cables

Data cable:
3M mini SAS (twinax 8 pair + 8 sideband wires, 30 awg)
Power cable:
16x 22 awg wires in twisted pairs
Bias cable:
RG316 with SHV connectors

TPC cable length: equal length @ 6m



ProtoDUNE SP TPC

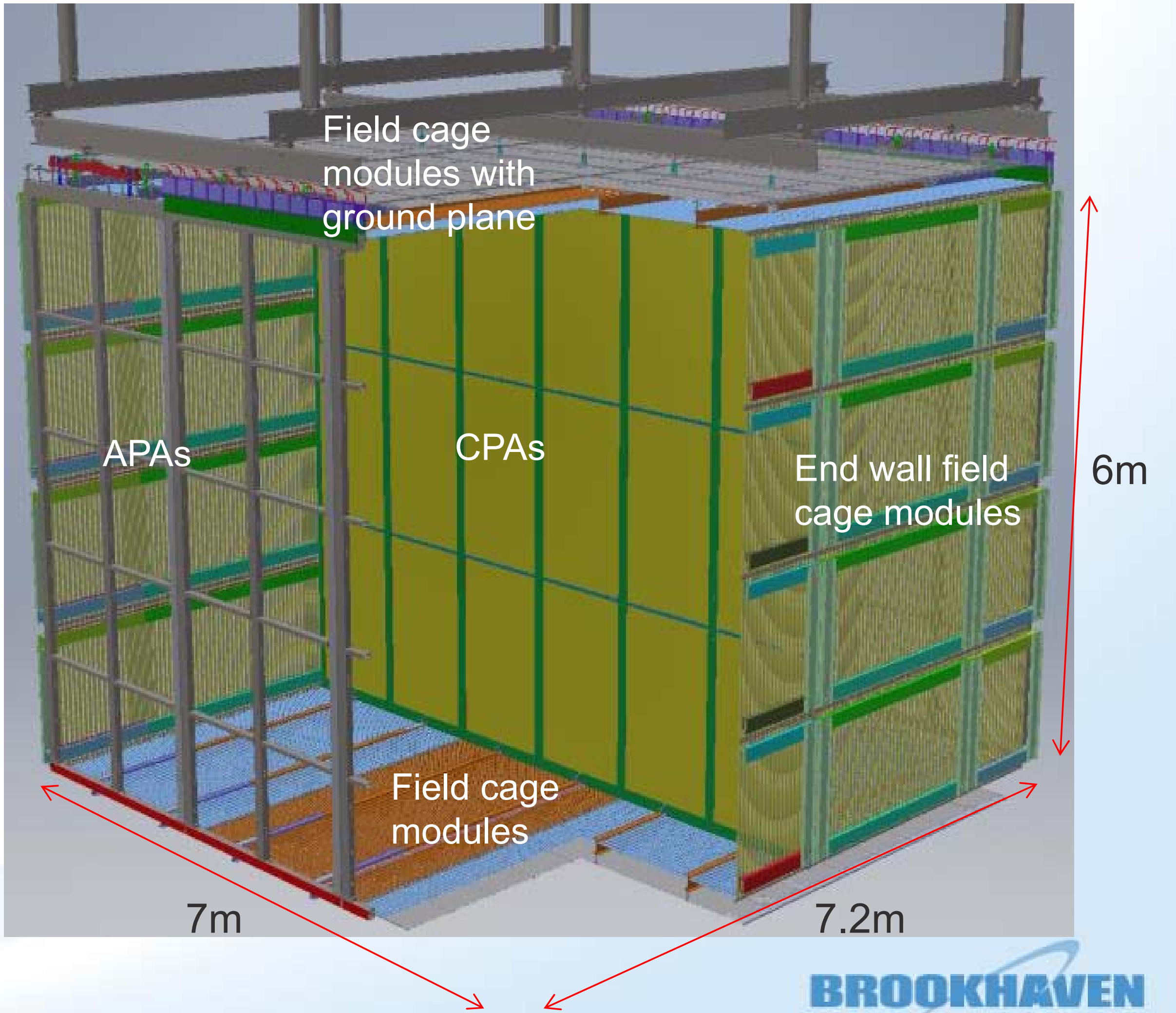
6 APAs, 15k readout channels

TPC readout feedthrough ports: 6, one per APA

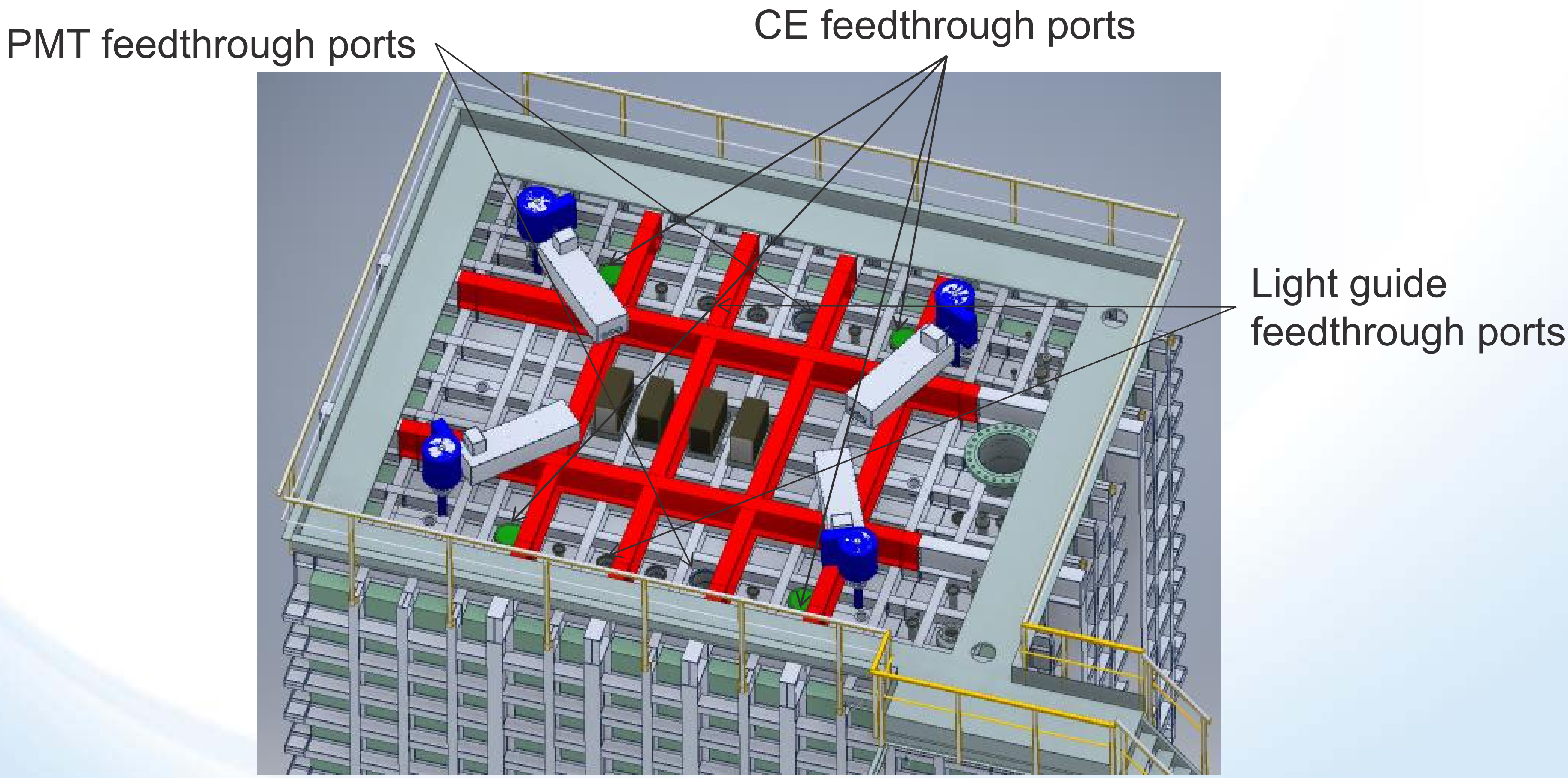
On each FT port:
20 sets of data and power cables from CE
10 PD cables
8 bias cables

Data cable:
Samtec twinax, 26 awg, 12 pairs
Power cable:
18x 20 awg wires in twisted pairs
Bias cable:
RG316 with SHV connectors
PD cable:
Cat 6

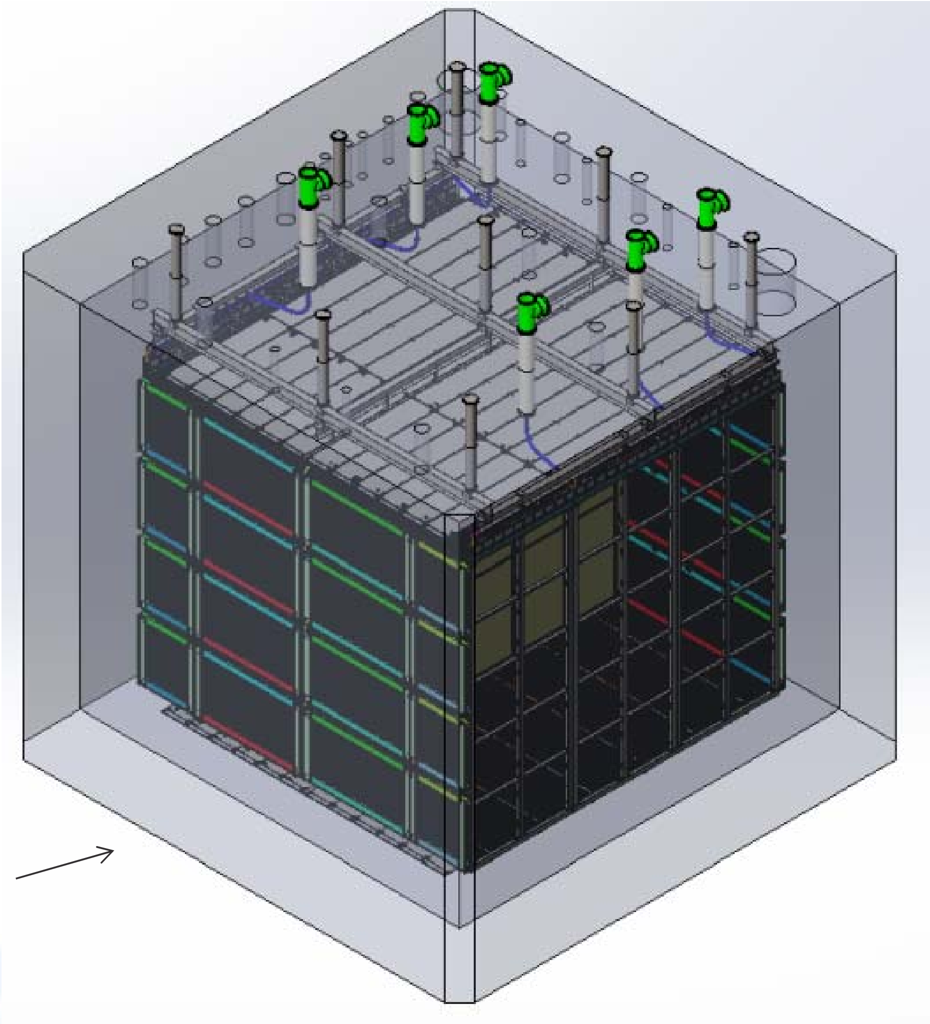
TPC cable length: equal length @ 7m



SBND Cryostat Top Arrangement



NP04 Cryostat Top Arrangement

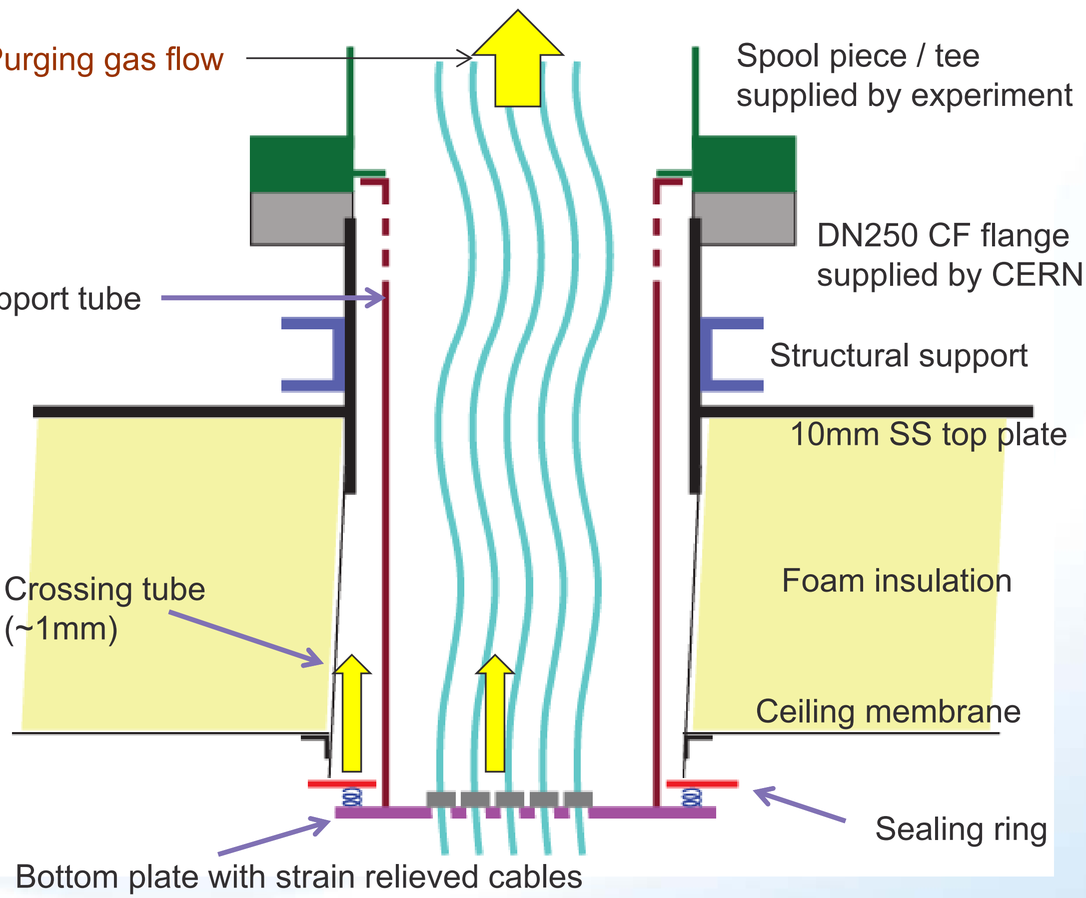


Beam

Both CE and PD cables from each APA share a feedthrough port

Feedthrough Port Design Concept

GTT/CERN will provide the feedthrough ports in the form of DN250 CF flanges on the top of the cryostat. The precise dimensions of these ports have not been finalized by CERN.

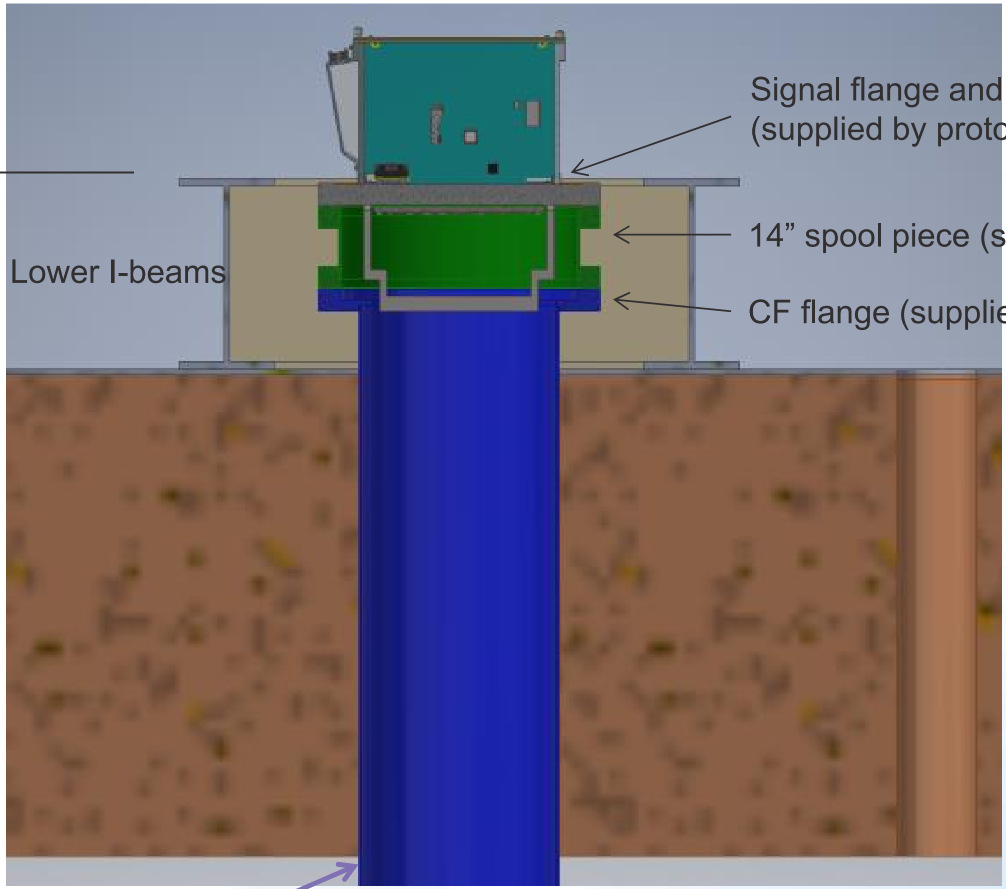


The bottom portion of the crossing tube is very thin therefore we must avoid transferring load to it.

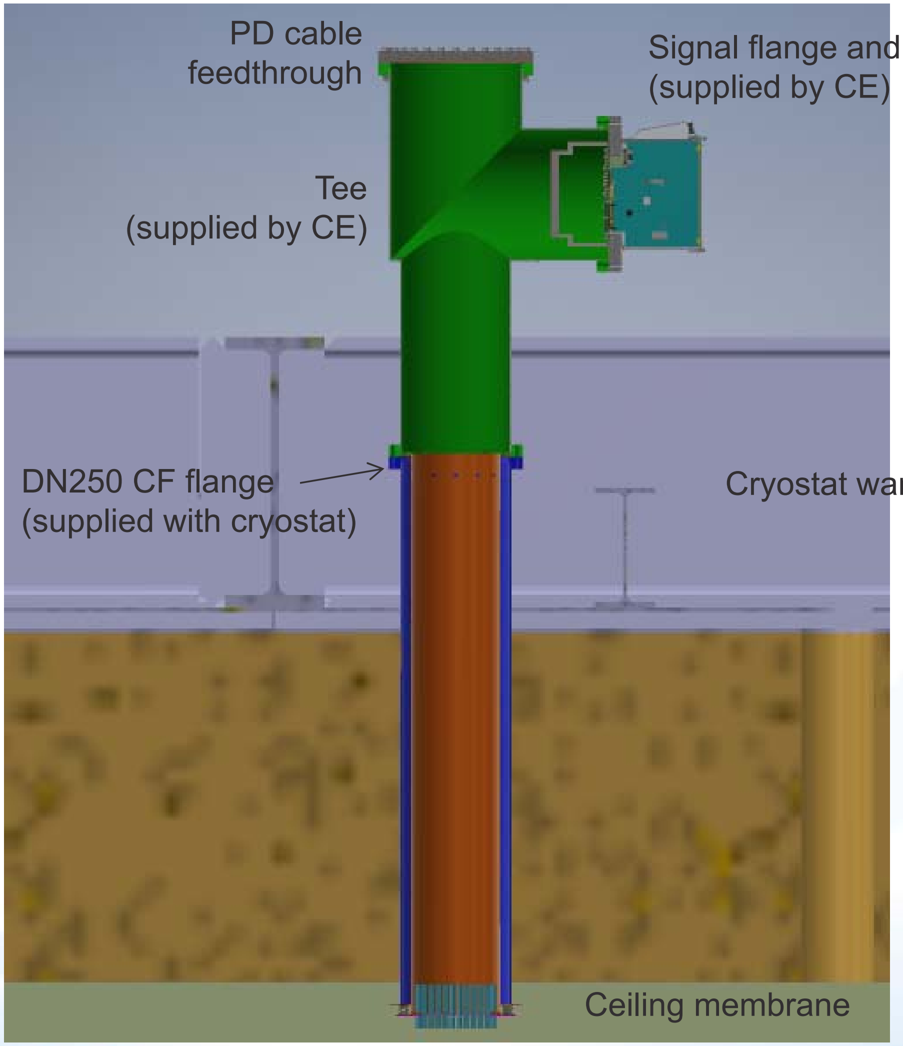
By blocking most of the openings at the bottom of this chimney, a small amount of gas argon purging will result in high velocity flow through the gaps at the bottom of the chimney, preventing the outgassing of the warm cables from diffusing back into the cryostat.

SBND Signal Feedthrough Port

Signal feedthrough flange must stay below the lower I-beams in order to get out of the TPC assembly building (DAB)

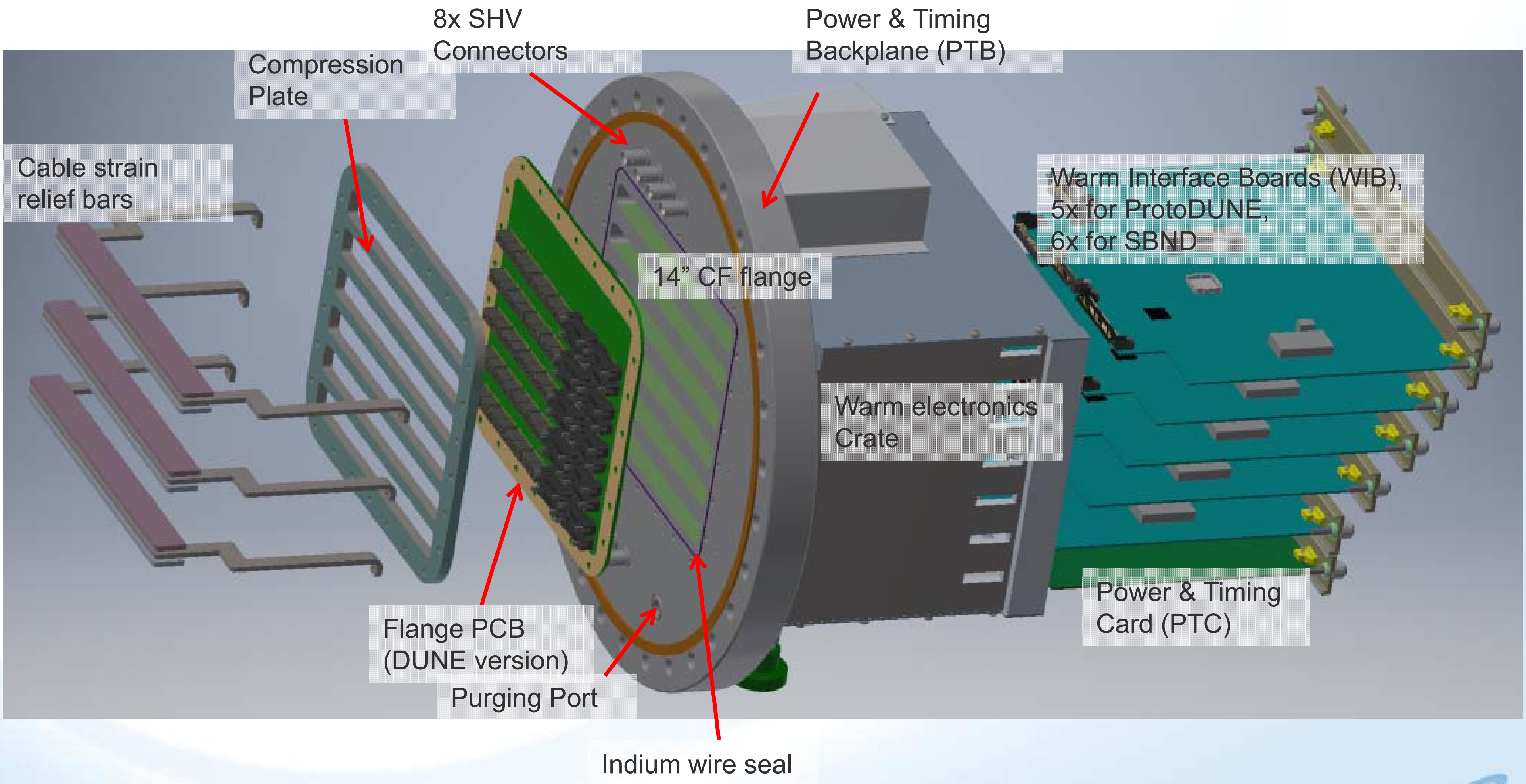


NP04 Signal Feedthrough Port

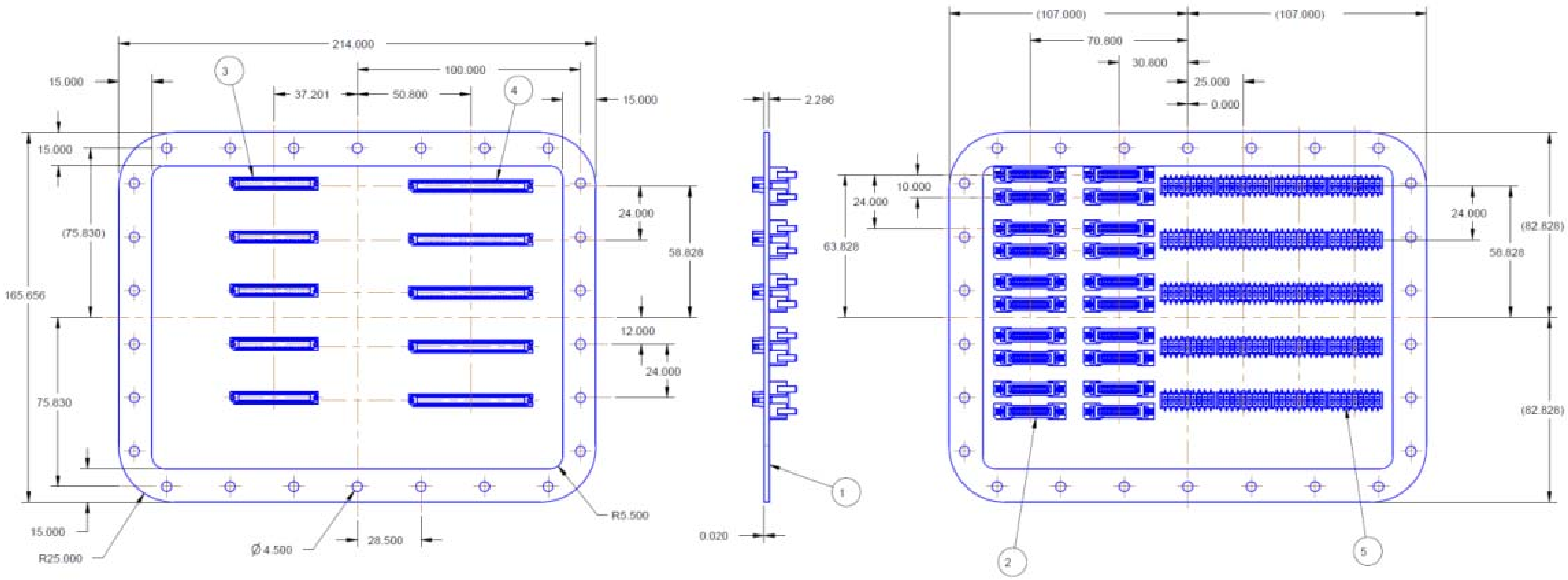


Both CE and PD cables pass through the same port. In the DUNE FD, we have twice as many cables. So a 4 way cross will be used: two CE flanges and one PD flange.

Exploded View of the Flange and Warm Interface Boards



Layout of the Flange PCB



Air Side

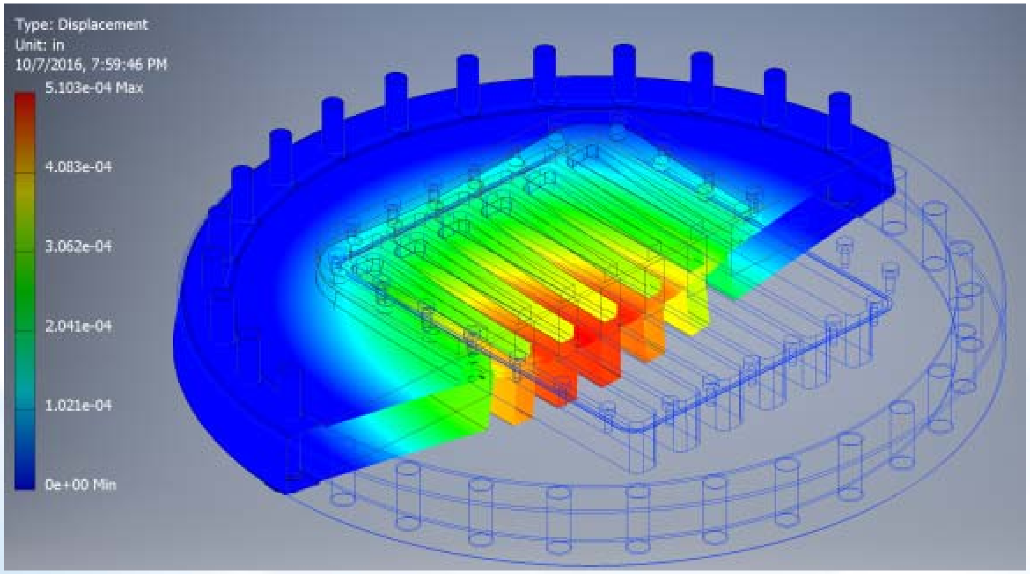
Argon Side

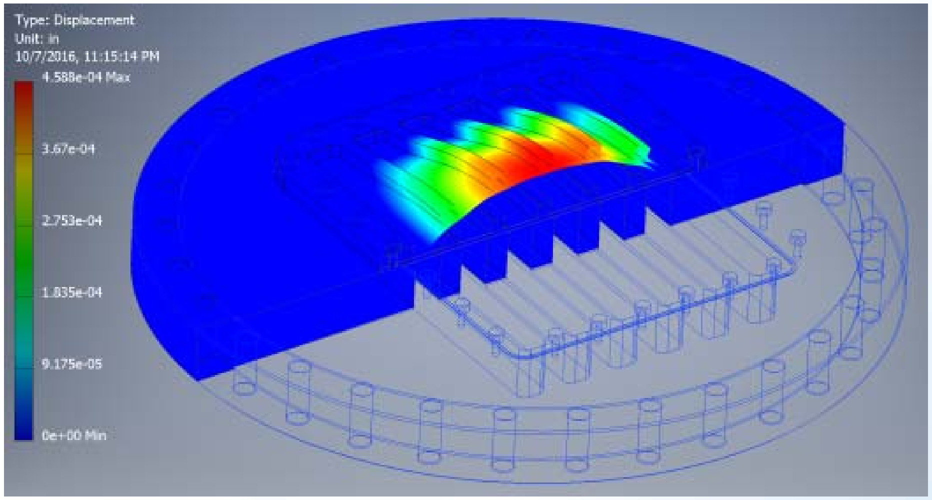
5	20	SAMTEC_IPL1-110-02-X-D-K
4	5	SAMTEC PN ERF8-060-05_0-X-DV-L
3	5	SAMTEC PN ERF8-040-05_0-X-DV-L-K
2	20	HSEC8-120-01-L-DV-A-BL
1	1	DUNE_CF13-25_FLANGE_PCB
ITEM	QTY	PART NAME / DESCRIPTION

Deflection Under Pressure

Cryostat design pressure range: 950 – 1350 mbar

5 psi from inside cryostat: ~13μm max deflection
Max stress: ~ 2000 psi





1 psi from outside cryostat: ~12μm
Max stress: ~ 900 psi

Leak Test of a Prototype Flange

Cryostat design pressure range: 950 – 1350 mbar (-0.7 – 5.1 psig)

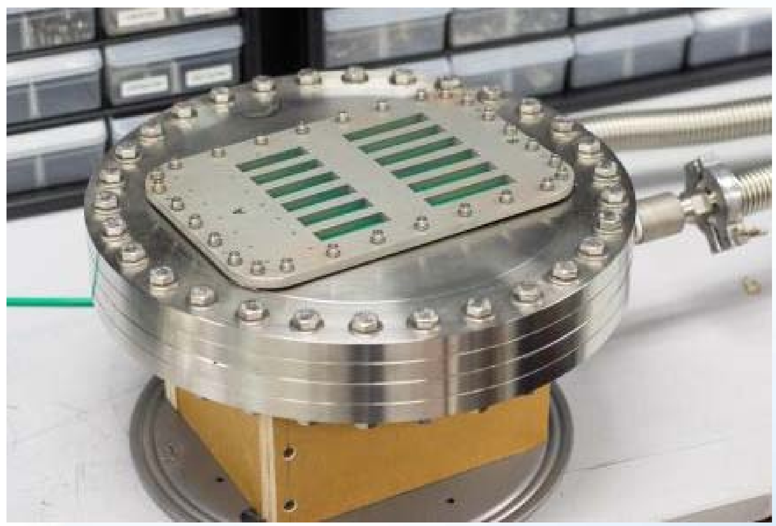
A special chamber was built to perform helium leak check of the signal flange under those two pressure extremes.

Both indium wire and spring energized metal seals were tested, including cold tests with indium seal.

The leak rate of the metal O-ring is 10^{-4} mbar.l/s

The leak rate of the indium wire seal is 1.6×10^{-9} mbar.l/s

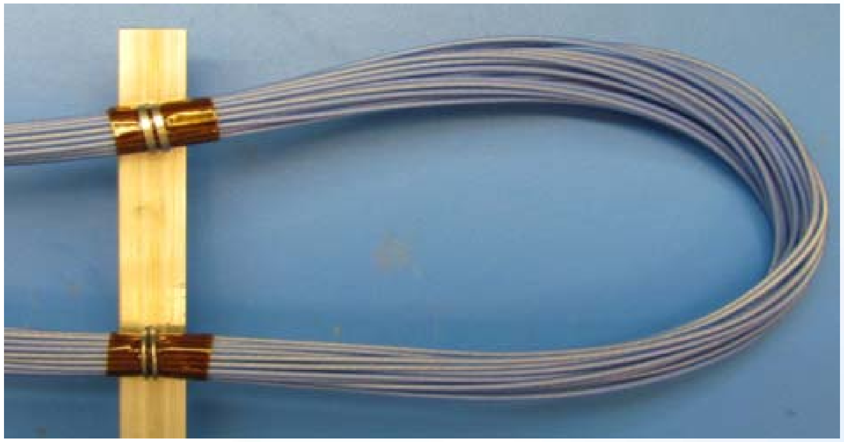
We expect lower leak rate with hard plated gold surfaces on the flange PCB.

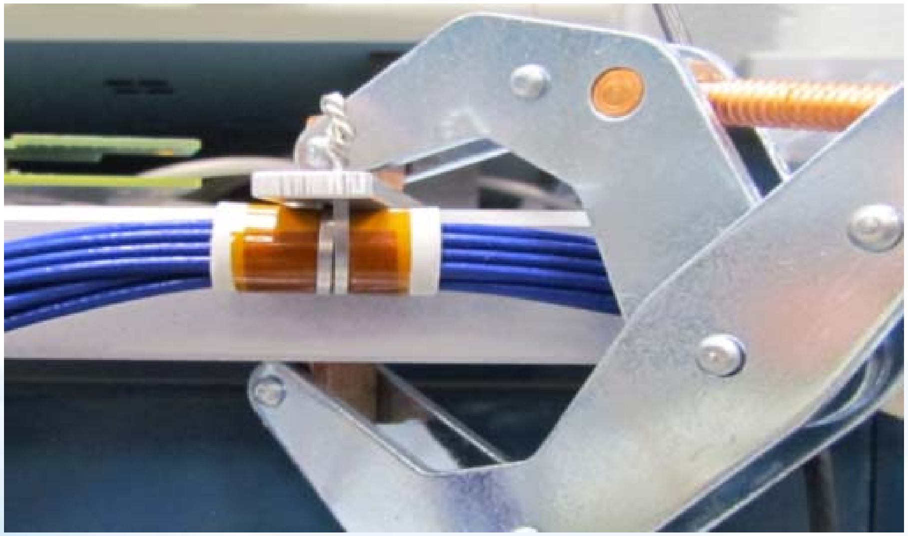


Cable Strain Relief

Examples of tests to hold cables against slippage (all Teflon jacketed cables)
Lock wires, commercial hose clamps, custom clamps

The cable clamps will be different between the DUNE and SBND versions of the cables

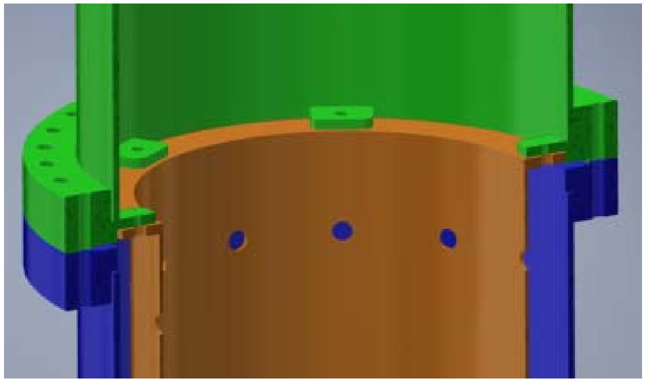




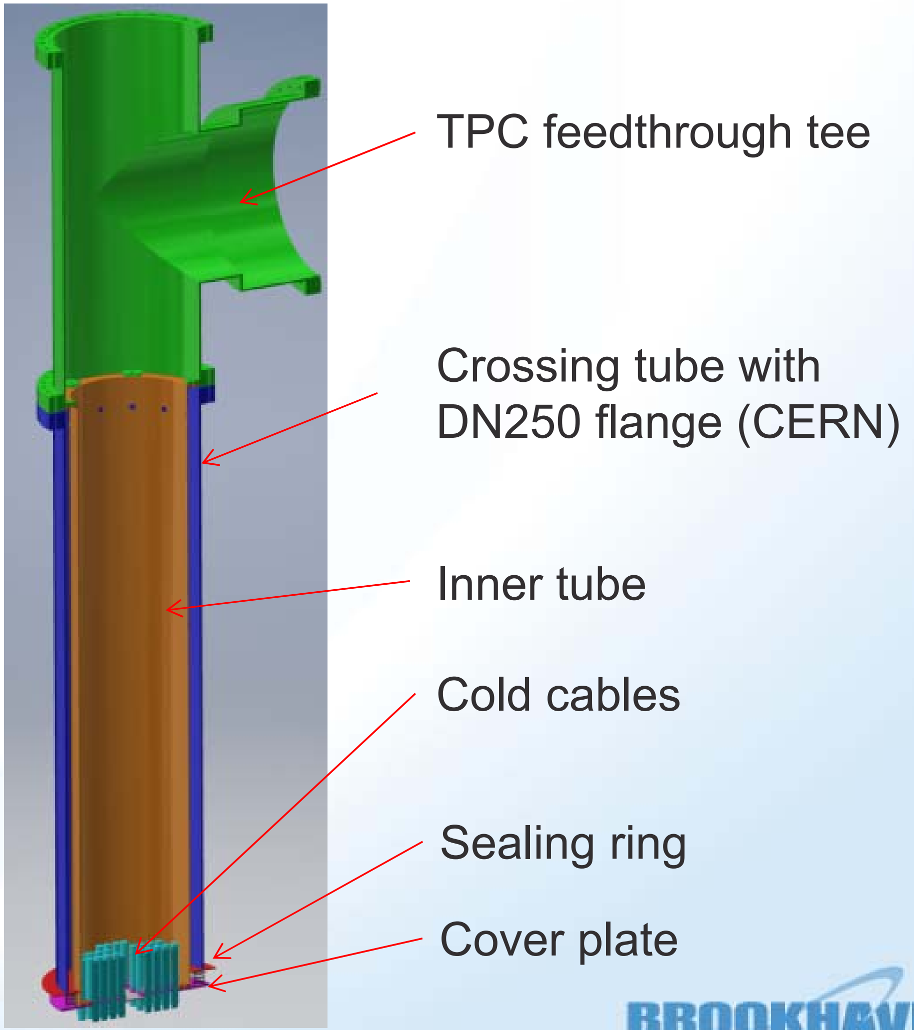
A Load Bearing Chimney Design

Assumptions:

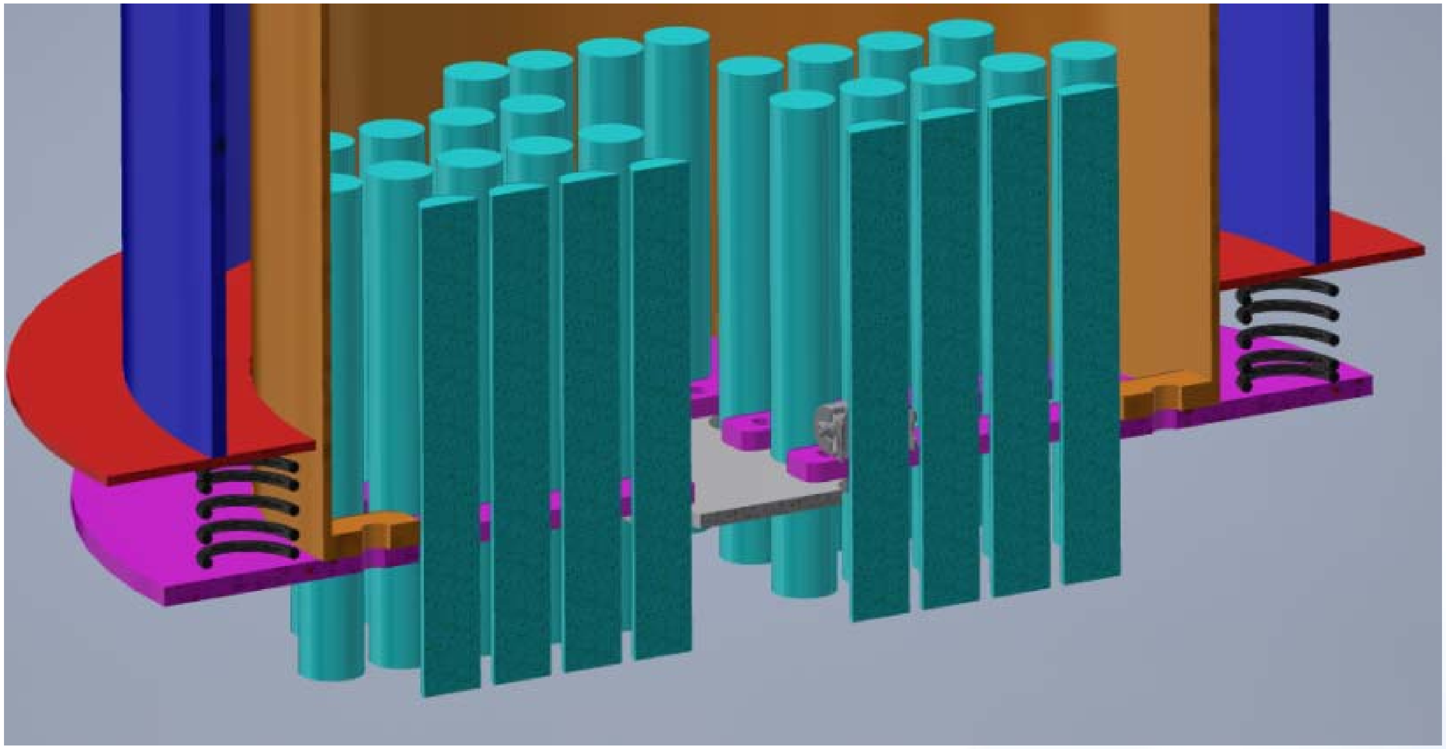
- CERN provide DN250 CF flanges above the cryostat top plate
- The crossing tube may have some angular tolerance wrt. the CF flange (~2cm clearance needed)
- No load on the crossing tube



The inner tube is a perforated SS tube ~ 8” OD. It has a thin flange on the top which is screwed into a few welded mounting tabs on the large tee.



Details of the Bottom of the Port



The bottom cover plate has many slots to capture the cable bundles (use hose clamps as stops on each cable). It has a large opening in the middle to ease the threading of cables. This opening is blocked by a plate (gray) when all cables are in place.

The inner tube has a few tabs on the inside bottom edge to hold a bottom cover plate (magenta). A sealing ring (red) is pushed up to the bottom opening of the crossing tube by compression springs. Except for a small axial force from this sealing ring, no other load is applied to the crossing tube.

The number of cables in ProtoDUNE is about half of what's shown here.

Argon Gas Purging Rate

LArTPC docdb 1983

Fermi National Accelerator Laboratory
PPD / Mechanical Support / Engineering Analysis

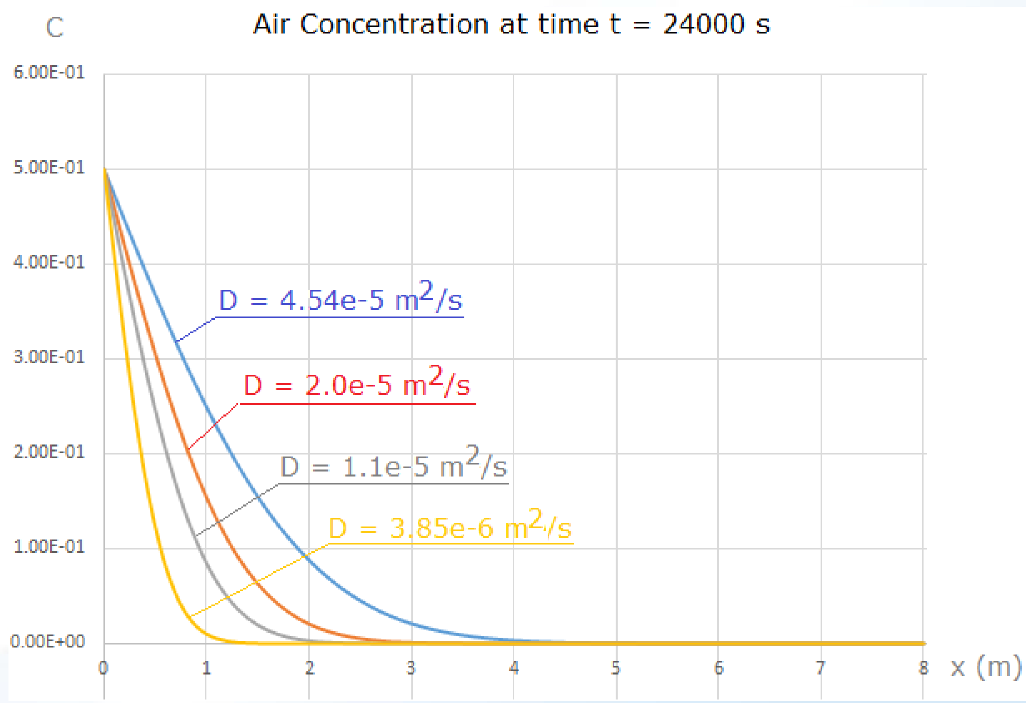
Simulation of Filling Tank with Argon

Zhijing Tang

April 11, 2016

This study is a justification of the gas argon piston purge method used to efficiently remove air from inside the cryostat. It seems to equally applicable to gas purging inside the feedthrough chimneys.

The model: a vertical tube, filled with air on top and argon on bottom, separated by a thin film at $x = 0$. The tube is large enough, so that we don't have to consider its boundary. At time $t = 0$, the film is removed. We calculate the air concentration for $t > 0$ and $x > 0$ (x direction pointing downward).



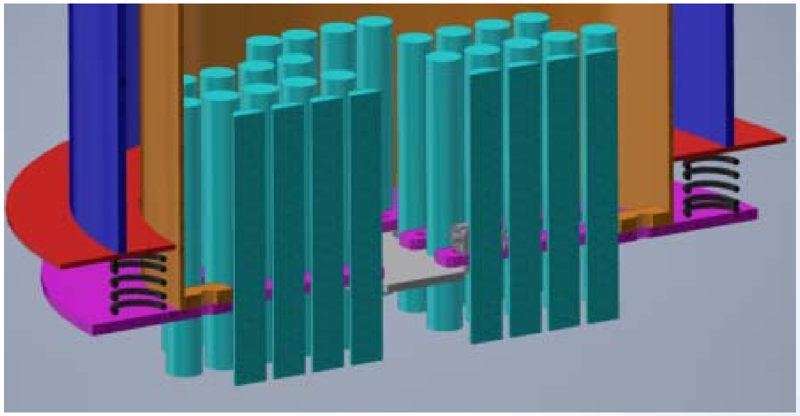
$D = 4.54\times10^{-5}$ m²/s ---- our calculated value;
$D = 2.0\times10^{-5}$ m²/s ---- experimentally measured value;
$D = 1.1\times10^{-5}$ m²/s ---- scaled to 200 K from experiment value;
$D = 0.395\times10^{-5}$ m²/s ---- scaled to 100 K from experiment value.

Diffusion coefficient (m^2/s)	Front 100 ppm position (m)	Front 100 ppm velocity (m/s)
4.54e-5	5.49	0.114e-3
2.0e-5	3.64	0.759e-4
1.1e-5	2.70	0.563e-4
0.385e-5	0.608	0.127e-4

We need mm/s scale argon purging velocity in the bottom of the FT chimney.

100ppm to 1ppb is a factor of 1.6 higher velocity

Gas Flow in the Chimney



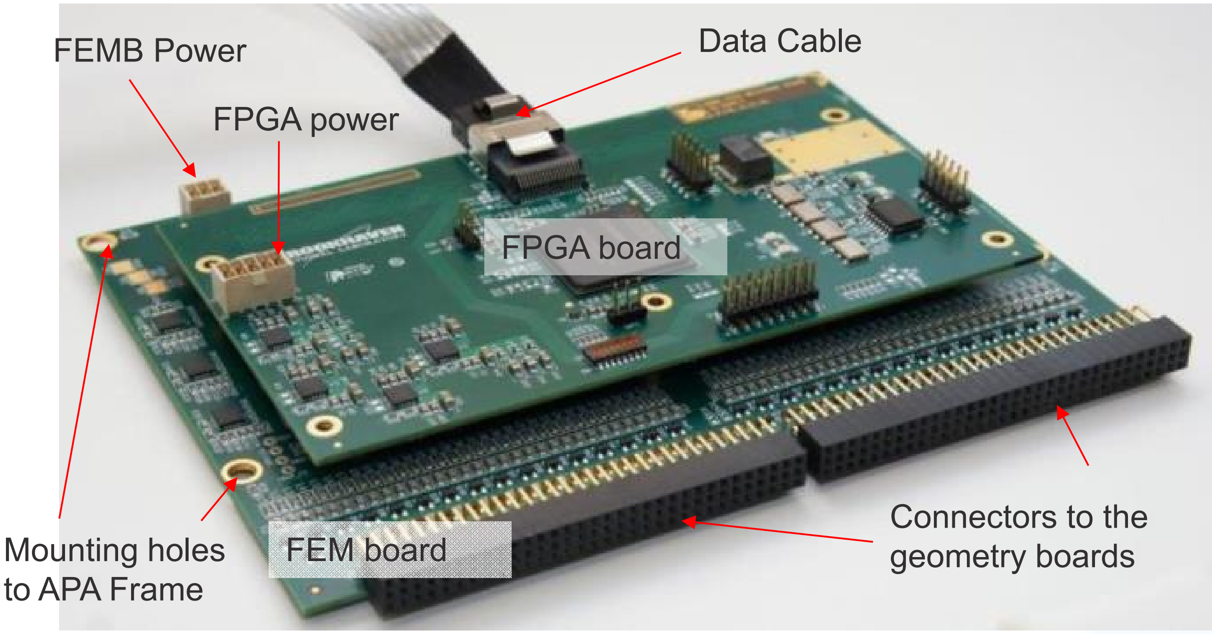
Assumptions:

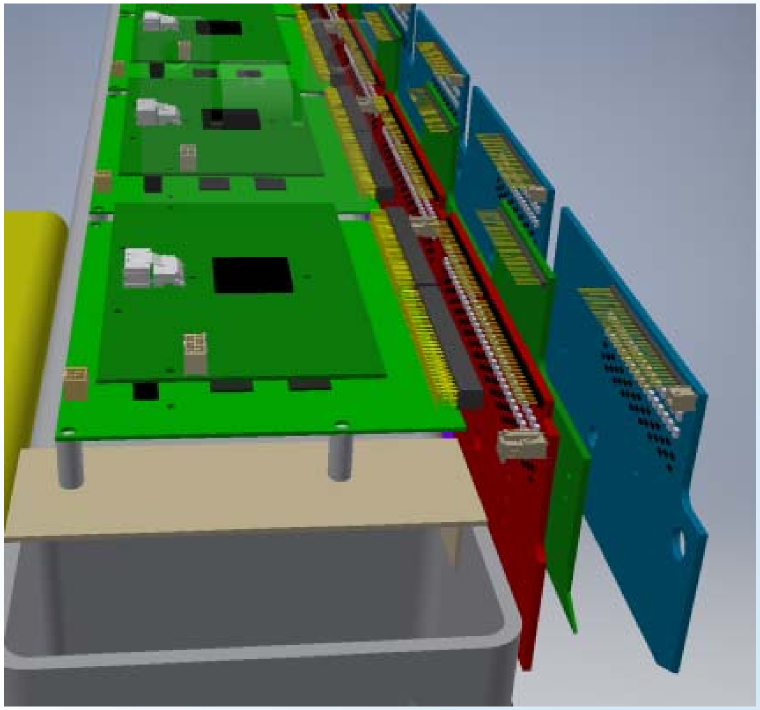
- 250mm ID cross section, 490cm^2
- Gas velocity: 1mm/s @ 87K at the bottom

- GAr density @ 87K: 5.8mg/cc
- Mass flow: 490*0.1*5.8=0.28 g/s
- GAr heat capacity: 0.52 kJ/kg/K
- Heat flow: 0.28 * 0.52 *(293-87) = 30 Watt

- The flow velocity at the bottom plate is much higher due to the restricted openings
- As the gas warms up, its volume increase and so is the flow velocity; partially compensating for the higher diffusion constant
- Additional baffles can be added in the inner tube to make the high flow velocity path longer; tricky to do so for the outer tube due to unknown alignment.

SBND Cold Electronics Boards and APA Connection (top bank)

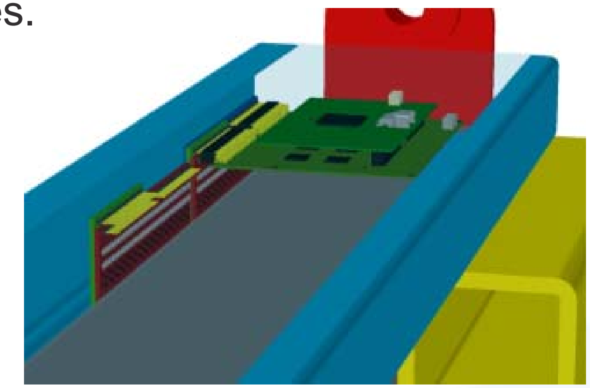


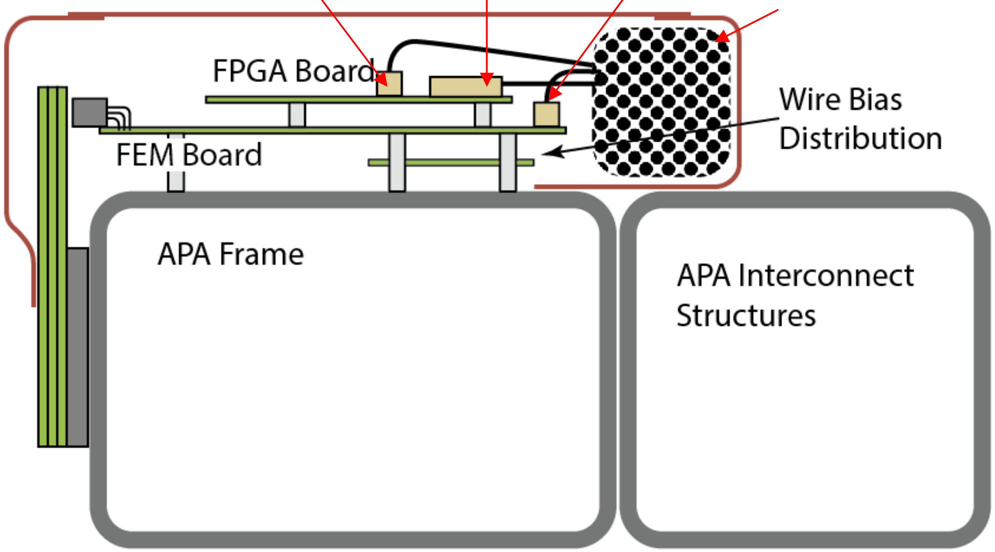


SBND geometry board stack and cold electronics board stack

SBND Cable Routing along the APAs

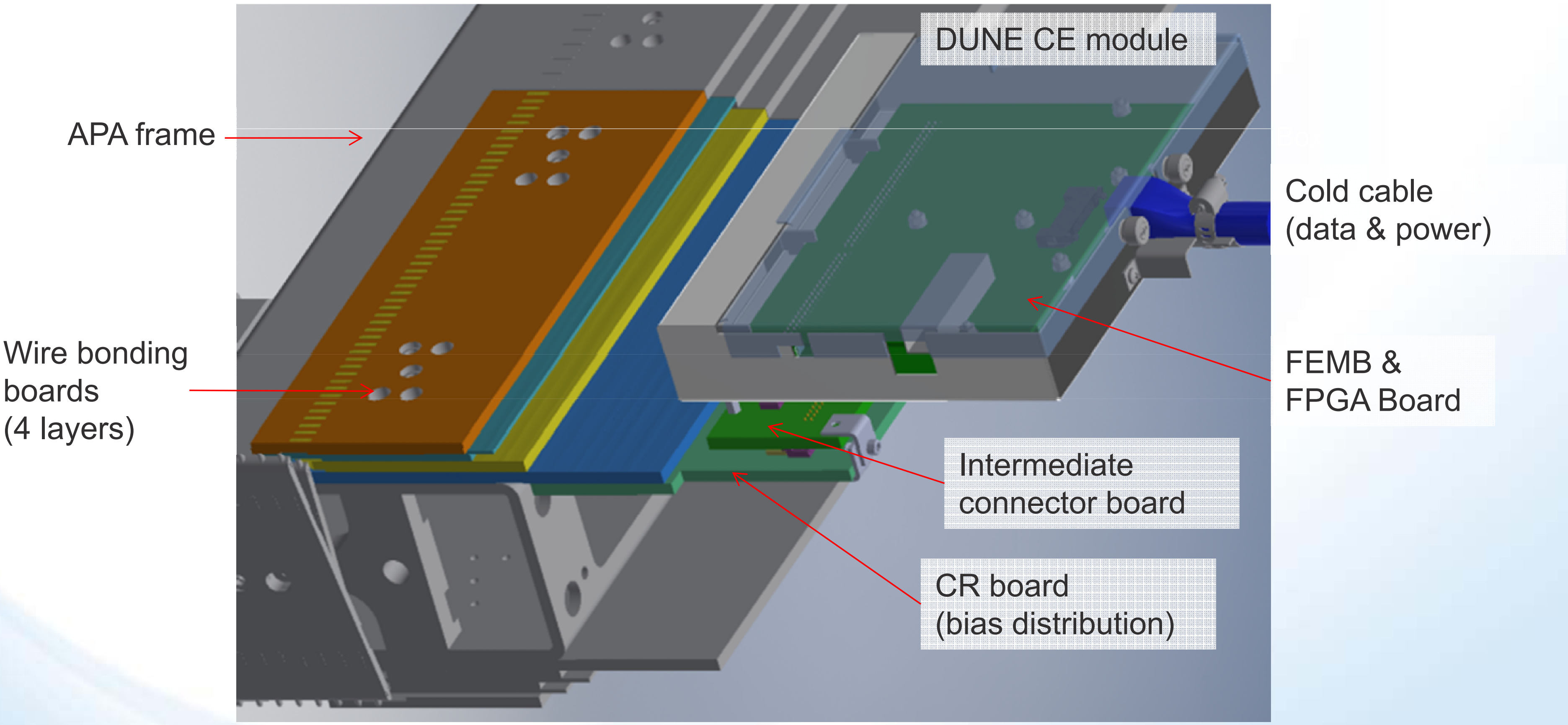
- 3 faraday cages are installed over the cold electronics boards.
- The top one has the outer cover perforated to allow gas escape.
- The side ones have solid covers to direct the gas up.
- Cables are routed inside the enclosure and exit at the top two corners of the APAs.
- FEM boards are grounded to the APA frame through their mounting hardware (screws and standoffs): ~ 2 per 10cm along the three APA sides.





A full scale mockup of the cable routing is underway

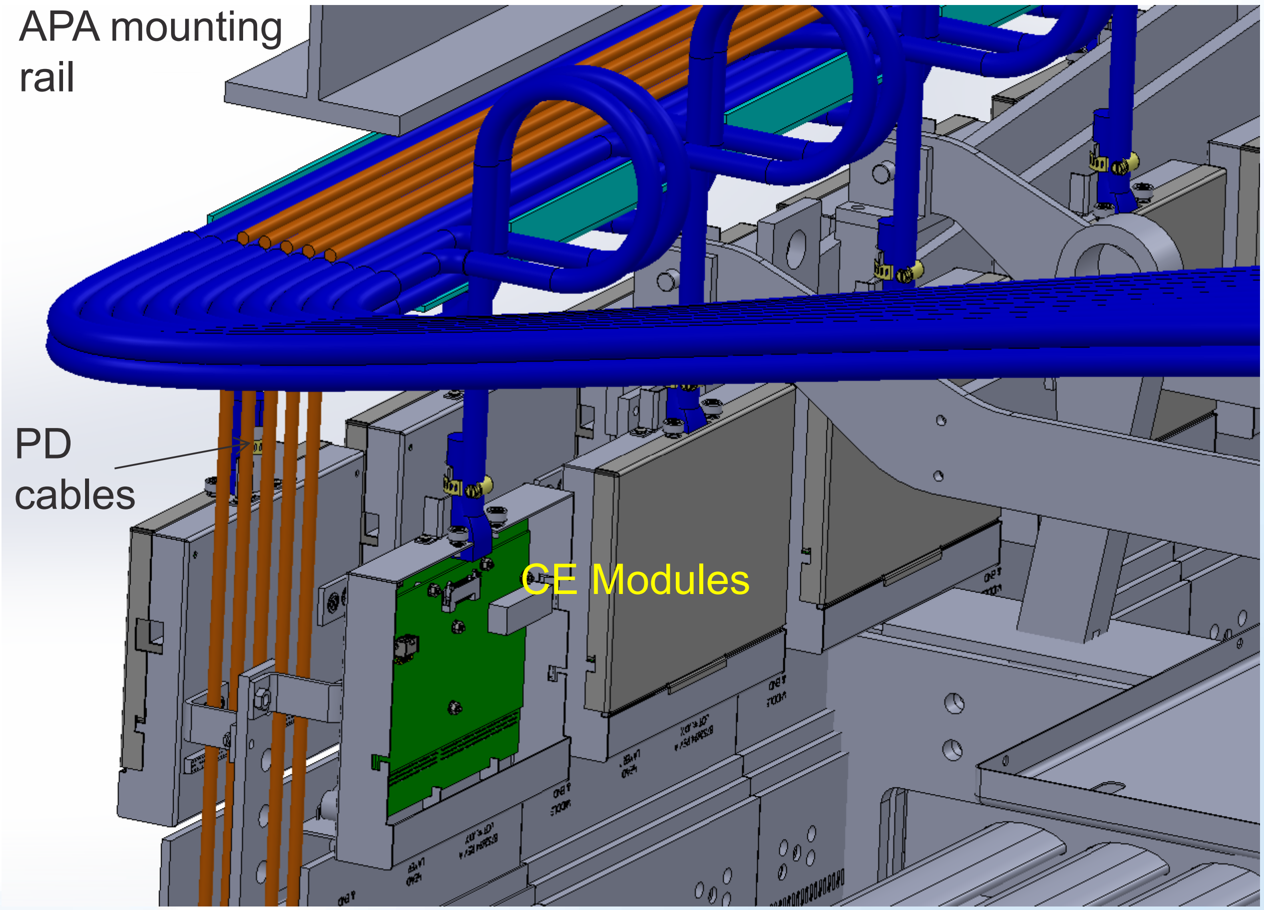
NP04 CE to APA Connection



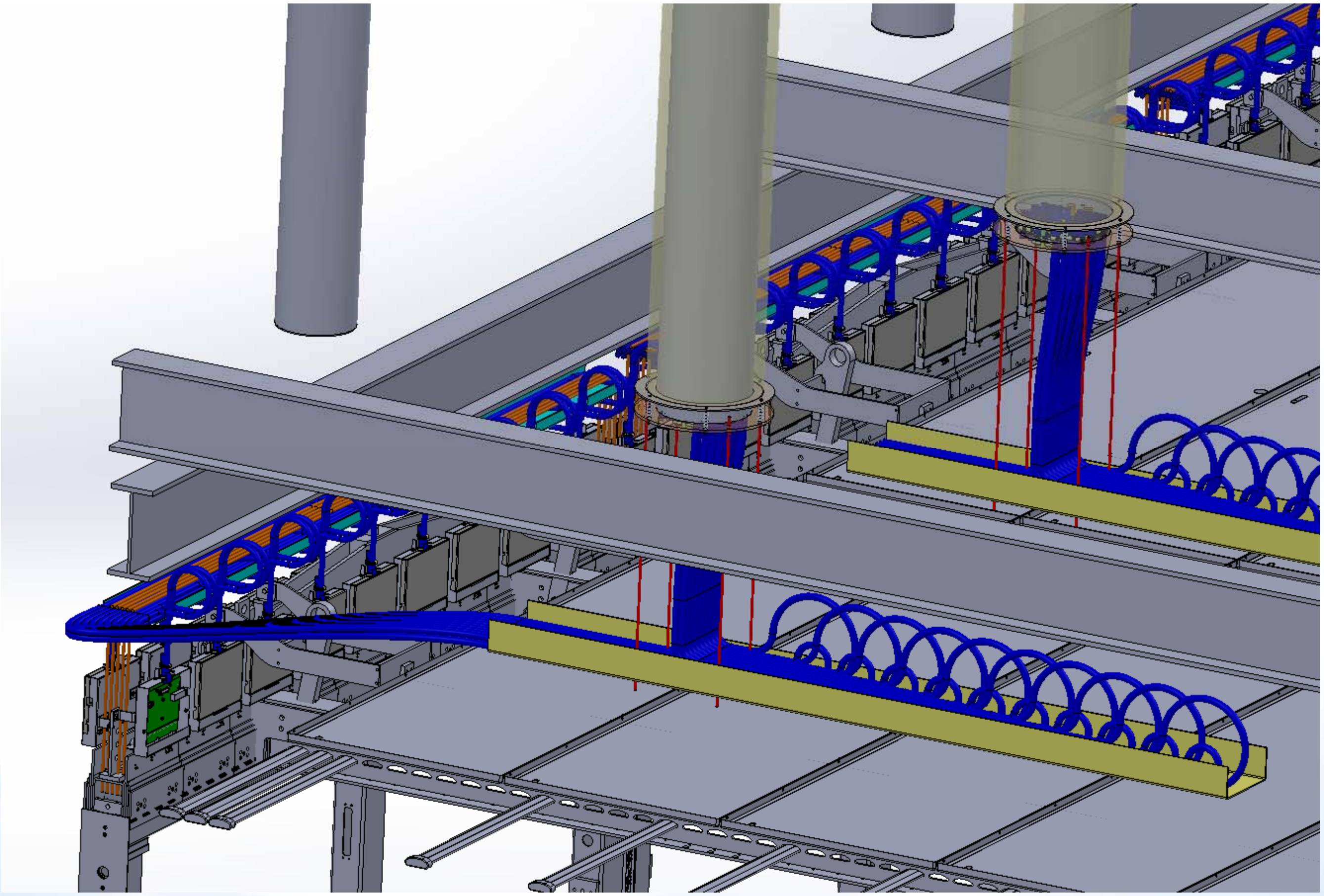
Concept of a Cable Tray Attached to an APA

A cable tray is planned on the APA between the cold electronics modules and the APA mounting rail to hold and direct the cables toward the feedthrough port.

Since the CE boxed are distributed over a 2.3m width but with cables of equal length, we have to store excess cables of various lengths somewhere.
We are working with the APA and integration teams to determine if all excess cables can be fit on this cable tray.



Concept of a Cable Tray under the Chimney



Since the CE boxed are distributed over a 2.3m width but with cables of equal length, we have to store excess cables of various lengths inside the cryostat. One concept is to store them on a tray under each chimney.

Summary

- A common CE signal feedthrough design has been developed for both DUNE and SBND. It is based on a multi-layer printed circuit board with blind vias and all surface mount components. Indium wire seal is used between the PCB and a 14” CF flange to make it leak tight and ensure good electrical contact (grounding). Minor differences exist between the two versions due to data cable connector choices. Second round of prototyping is underway.
- A low outgassing feedthrough chimney design concept is being developed and its detailed design awaits final design of the cryostat port. This concept uses minimal purging of the boil-off argon to sweep the impurities from the cables out of the cryostat. This concept should benefit both NP04 and SBND with tailored implementation details.
- The installation of the DUNE cold electronics boards is distinctively different from that of the SBND. The DUNE scheme is meant to ease large scale assembly, testing and installation with limited access.
- Cable routing scheme inside the cryostat for NP04 is evolving in connection with the development of the TPC installation process. The SBND design remains conceptual, but will be fleshed out soon.
- Use of PTFE based cables in NP04/DUNE needs to be resolved.

Backup Slides

DUNE Cold Cable Specification

- Cold cable development for DUNE has been progressing with SBND in parallel for the past few months
- Shown is a draft specification matrix for DUNE
- For SBND the maximum cable length is about 7 meters which allowed a cable gauge of 30 in a 3M cable with a miniSAS connector
- In DUNE the maximum length is 18-25 meters which requires a different solution
- Some of the companies which have provided cable, connectors or other information to date are:

  - 3M
  - Gore
  - Amphenol
  - Glenair
  - Hitachi
  - Huber+Suhner
  - Samtec
  - ANTA

Specification Matrix

Table A : Cable Requirements

Item	Cable parameters	DUNE
1	**Length (meters)**	25 m (maximum)
2	**Frequency**	600 MHz or 1.2 Gb/sec
3	**Temperature Range**	77 K (LN_2) to 325 K
4	**Attenuation Limit**	9.5 dB
5	**Number of Twinax Pairs**	12 twinaxial pairs,100 ohm
6	**Number of conductors**	Total 24 (both twinax and single)
7	**MiniSAS Connector on Feed-through Board**	Molex 75784-0126 (miniSAS)
8	**Total Area for Molex headers or other solution**	126mm x 88mm
9	**Area per header**	21 mm x 22 mm
10	**Header type**	Surface mount
11	**Known Acceptable Cable Insulation Polymers in Liquid Argon**	Teflon, FEP, PTFE, Tetzel, PFA
12	**Acceptable Connector Polymers**	Liquid Crystal Polymer(LCP)
13	**Unusable Polymers (all applications)**	Nylon, PVC
14	**Cable Schedule**	Test Cable September 2015 - 2 pieces Prototype March 2016 - 5 pieces Production1 Dec 2016 - 150 pieces Production2 Dec 2018 - 3500 pieces
15	**Websites for information on Detectors**	http://www.dunescience.org/ http://lbnf.fnal.gov/files/LBNF-DUNE-4pager.pdf

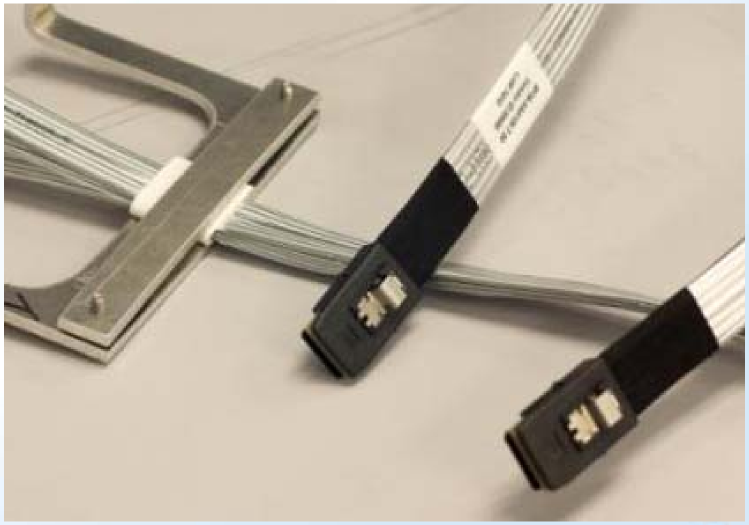
DRAFT

Cables

ProtoDUNE data cable

Power cable

DUNE

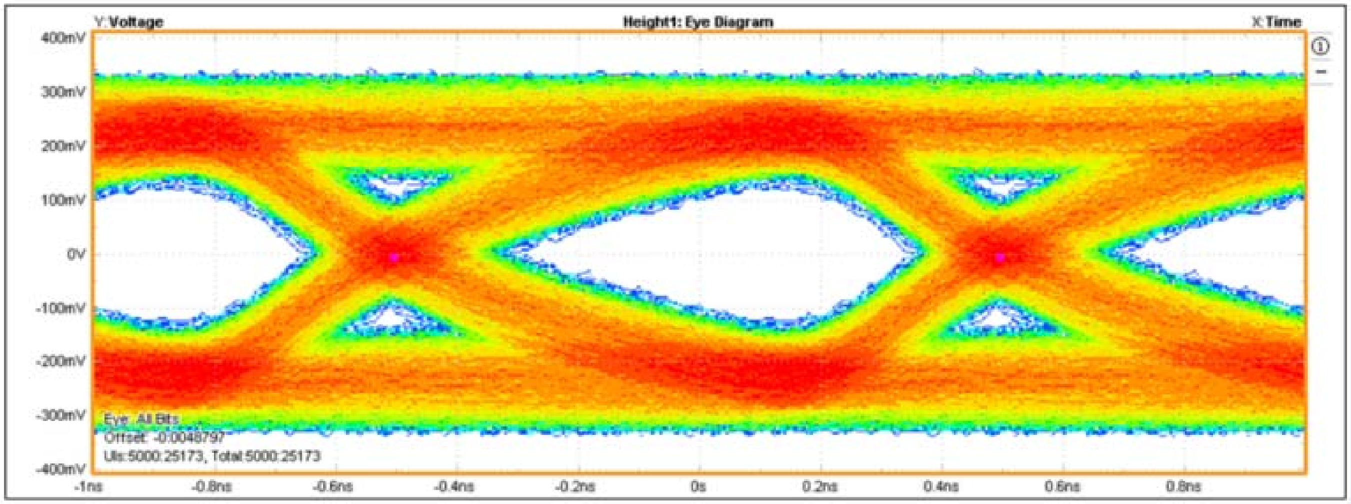


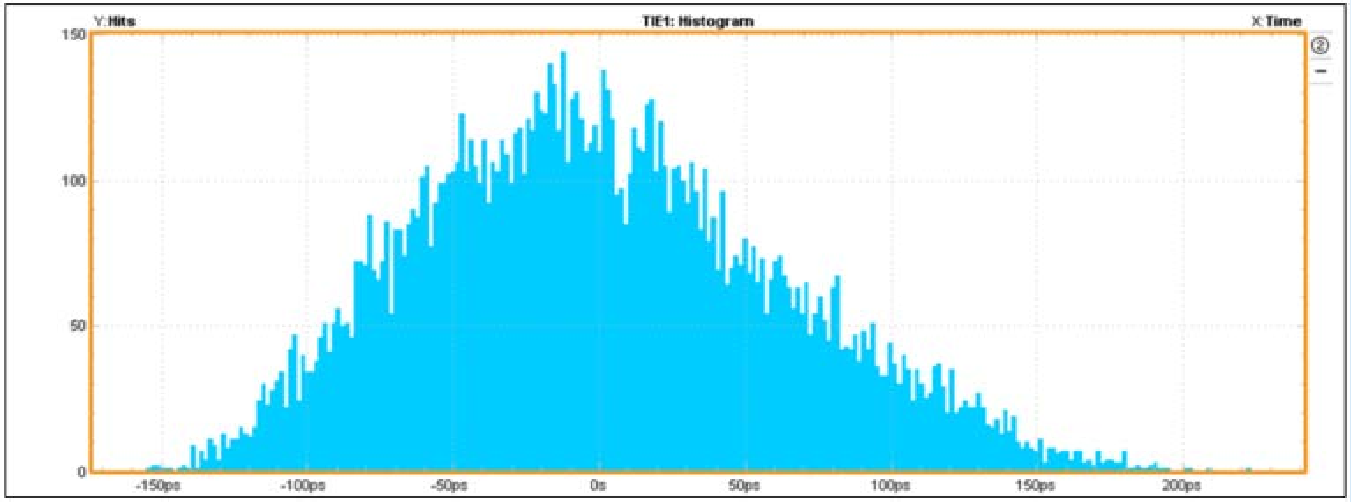
SBND data cable

Samtec 26 AWG Cable

- 1.3GHz
- Room Temperature
- 18m long

- @ 25m length, need equalizers on the WIBs

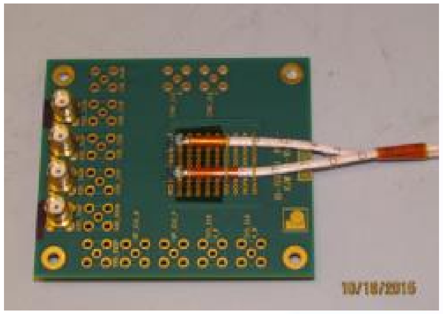




Cold Cable Setup, Samples and Terminations

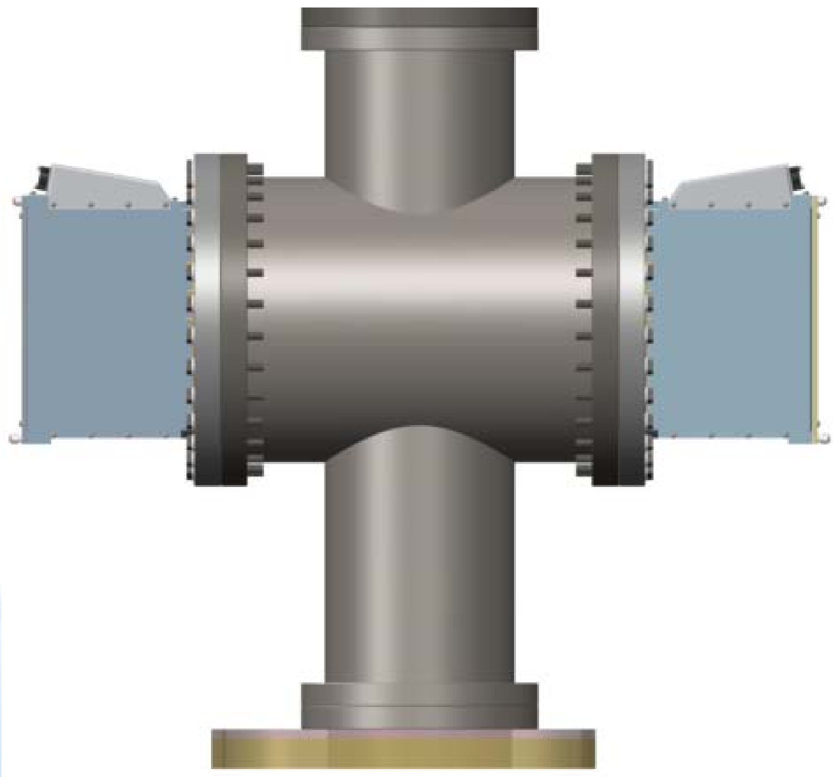
25 meter test samples

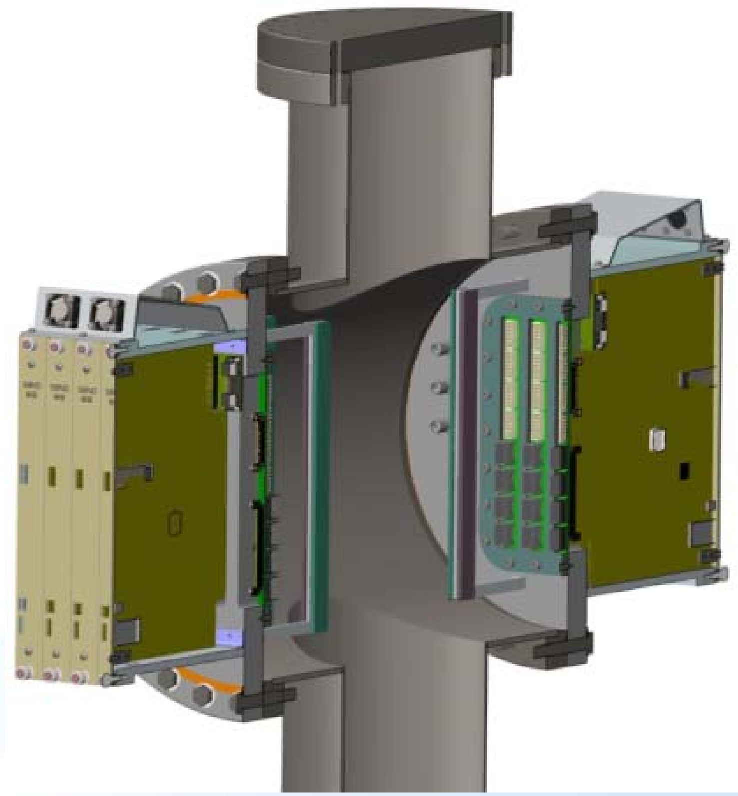
Eye Diagram Test Setup

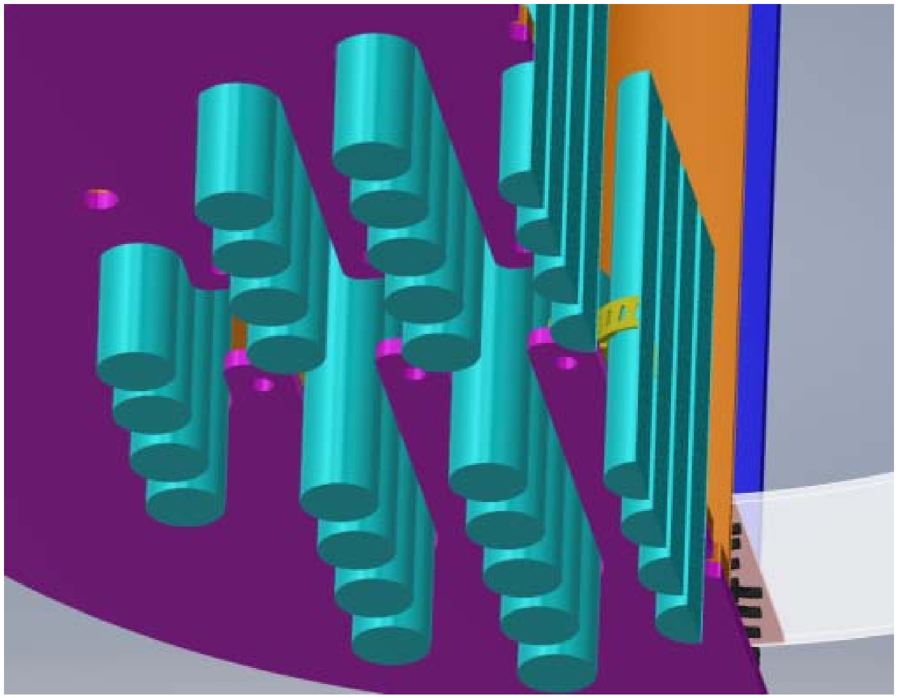


Terminations

DUNE Version of the Flanges/Crates







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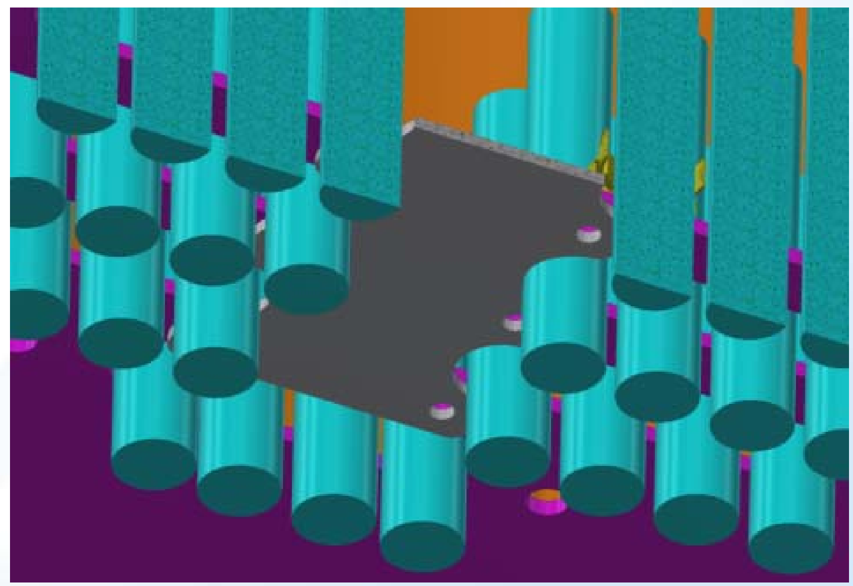

The cables can be pre-installed onto the bottom cover plate in the clean room.