

Calibration & Cryogenic Instrumentation (CALCI)

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DUNE FD I&I workshop
02/04/2020

CALCI Consortium

- Cryogenics Instrumentation and Calibration recently merged — Slow Controls no longer part of our scope, talk to DAQ-SC consortium
- **Calibration**
 - Ionization Laser; Photoelectron laser; Laser beam location system;
 - Pulsed neutron source system; Radioactive source system (leading to ProtoDUNE-2)
- **Cryogenic Instrumentation**
 - Purity monitors, cameras & light system, level meters, pressure meters, gas analyzers, all temperature sensors in the cryostat
- Unlike any other consortia, CALCI contains multiple systems each with their own requirements and installation needs — all providing valuable input to physics and/or experiment operations

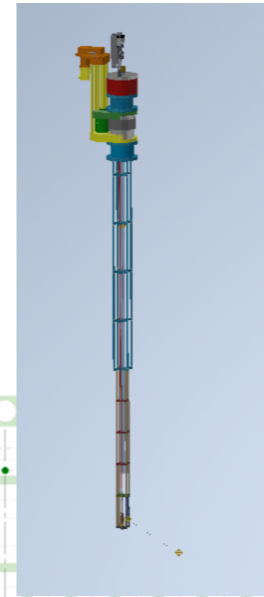
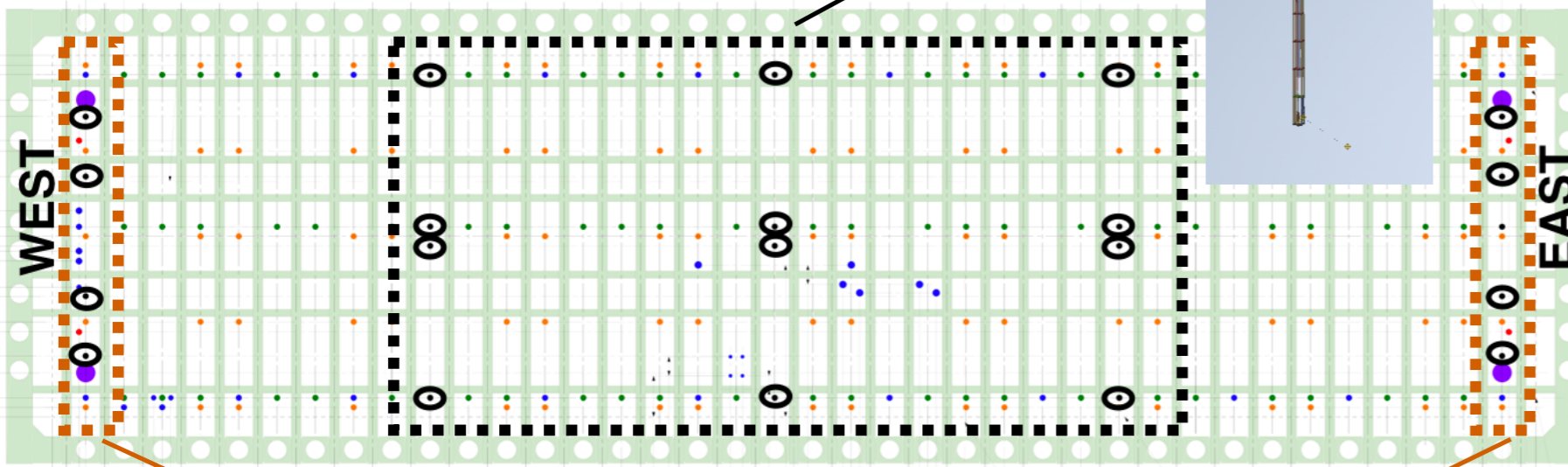
Ionization Laser (1/5)

- **New Baseline & Alternative**

Start from SBND design — thanks to Bern!

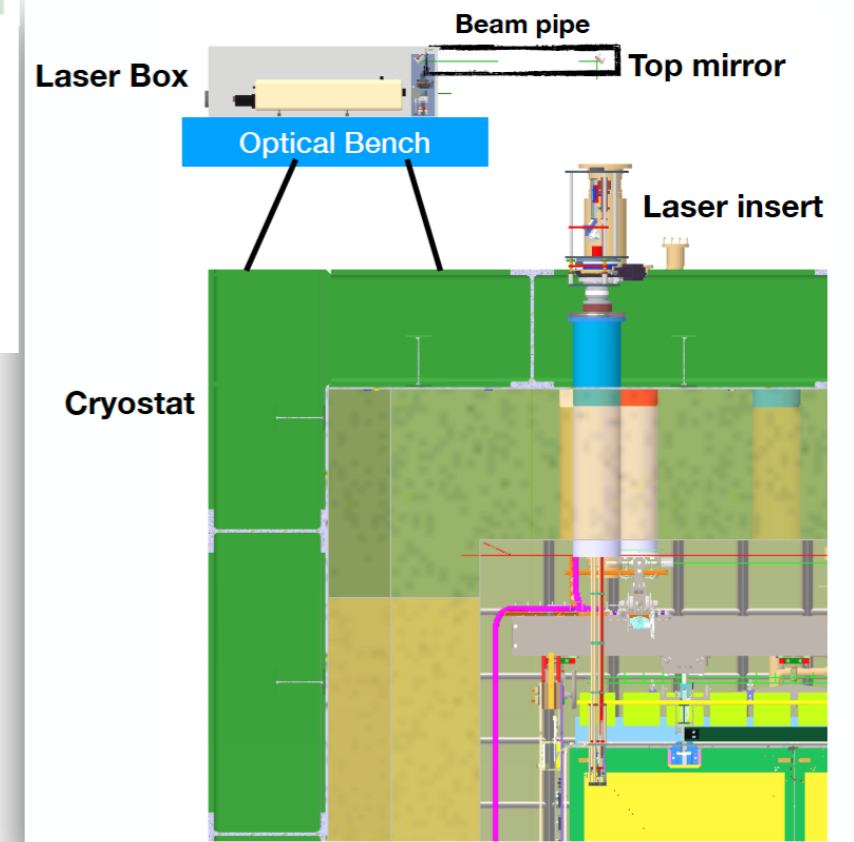
Baseline
Design 1; FC penetration
9 lasers, 12 periscopes
Periscope retraction

**Jan Boissevain
(LANL)**



Alternative
Design 2
dual-rotary system, No FC penetration

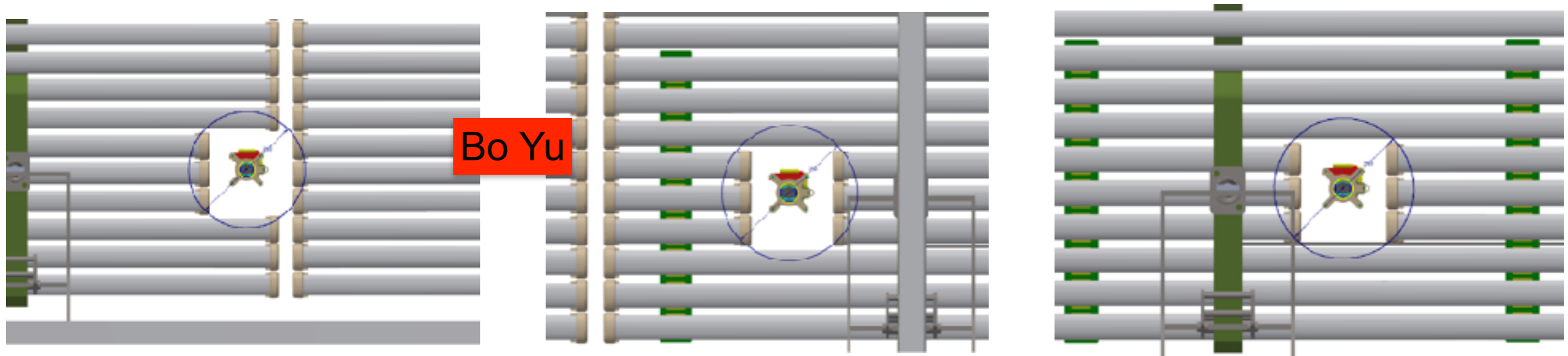
**Rui Alves
(LIP)**



Ionization Laser (2/5)

HV interfaces

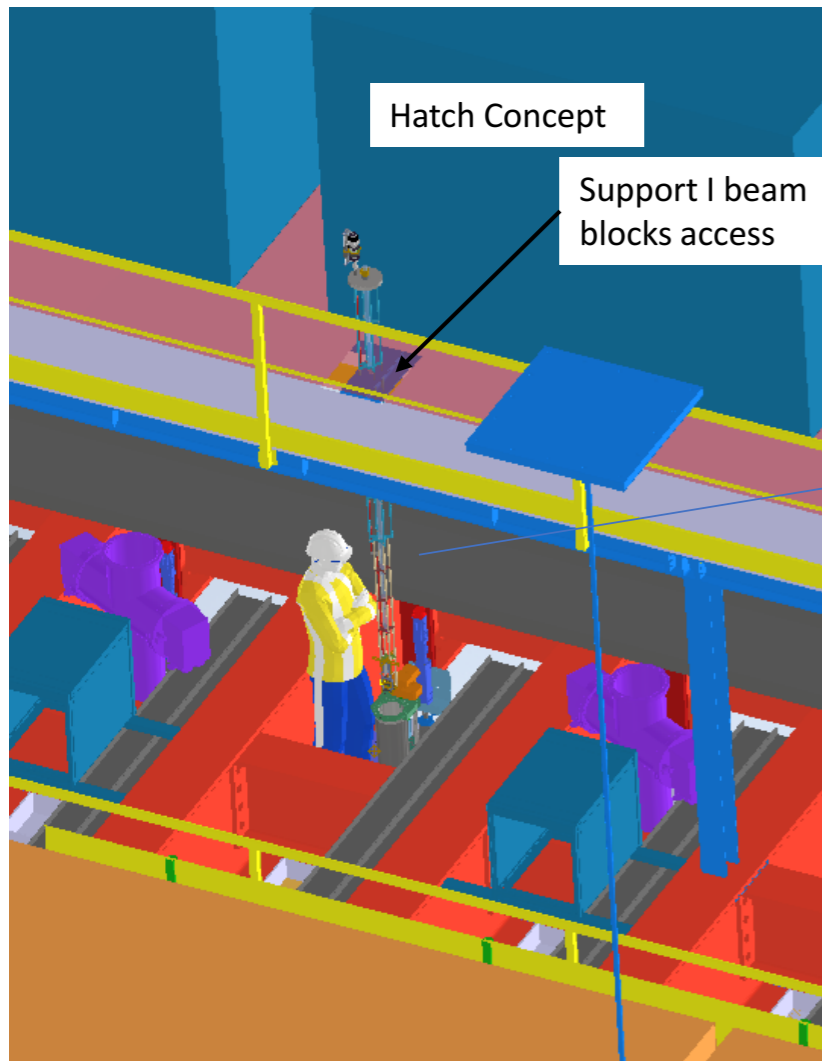
- Three types of FC penetrations needed for laser; small increase in cost for last two
- Plan is to assemble all FC modules underground. A special set of FC profiles with non-standard lengths will be fabricated by the “factory” and shipped to SURF. These special modules will be clearly marked in storage.
- CALCI-HV ICD on EDMS has detailed drawings



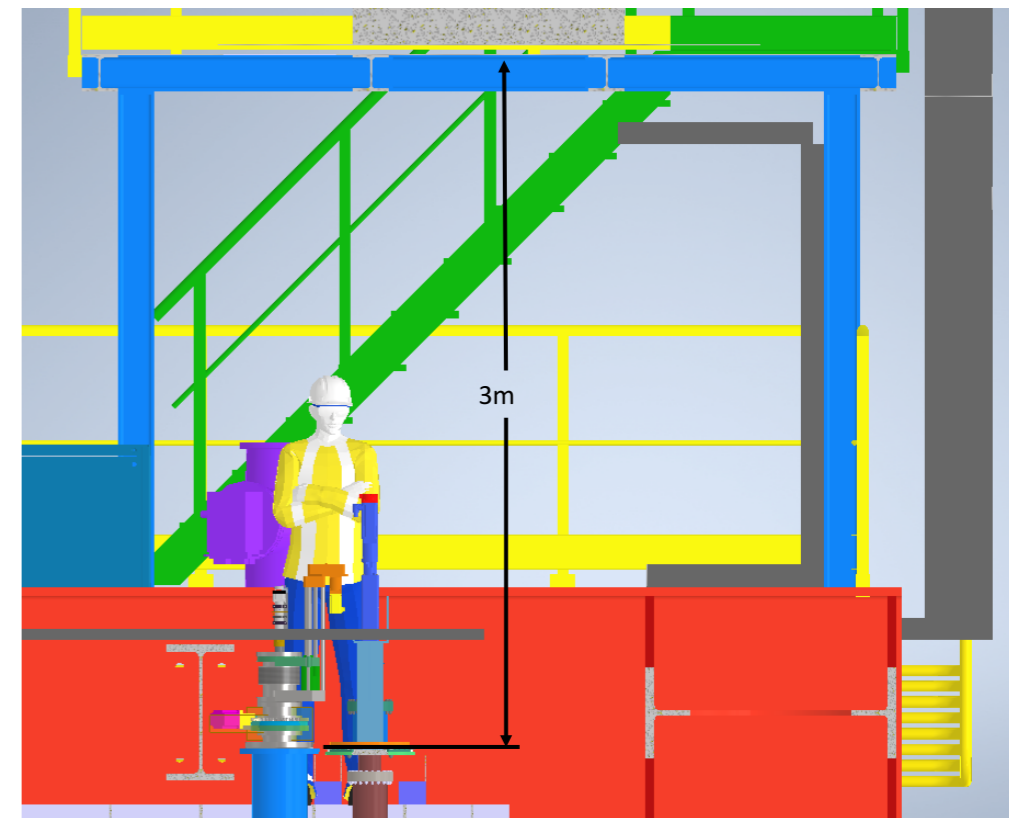
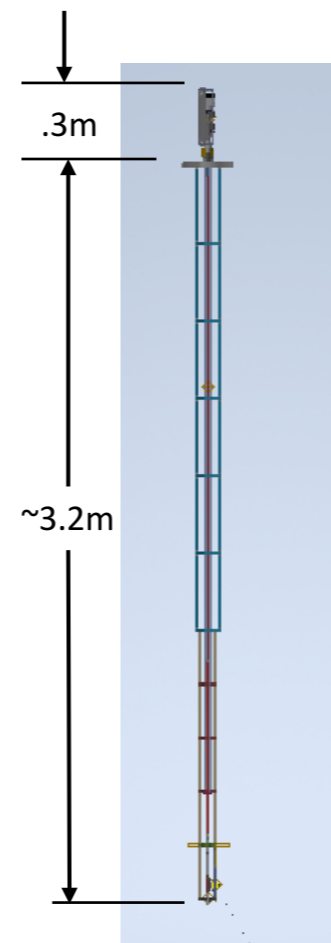
- Once the periscope length is finalized, understand E-field in both normal/retracted positions
- How much to penetrate into the FC? — shadowing effects from FC I-beams
- How much to retract above the FC to be considered safe?

Ionization Laser (3/5)

DUNE Laser Periscope Insert



DUNE Laser Periscope Insert

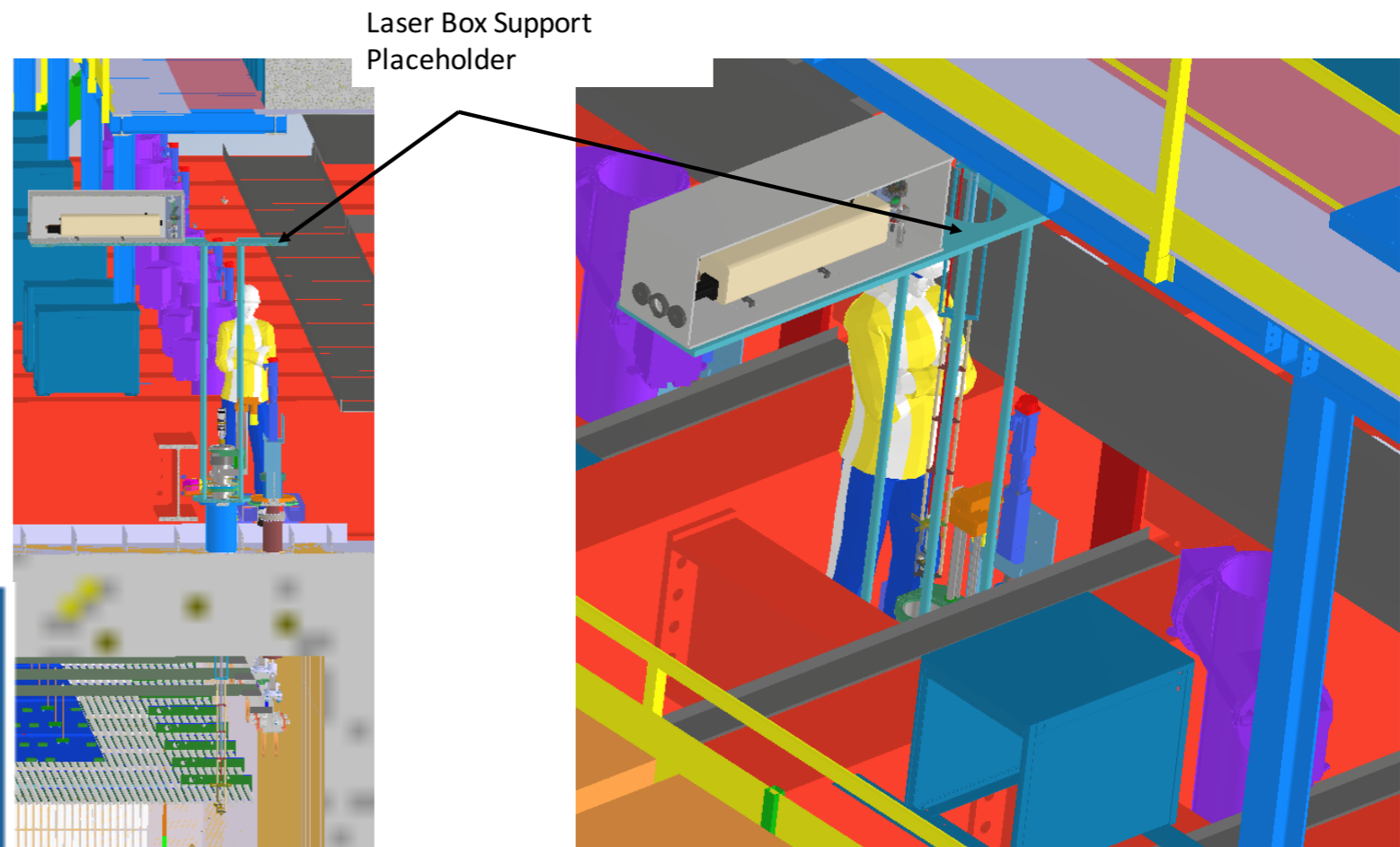
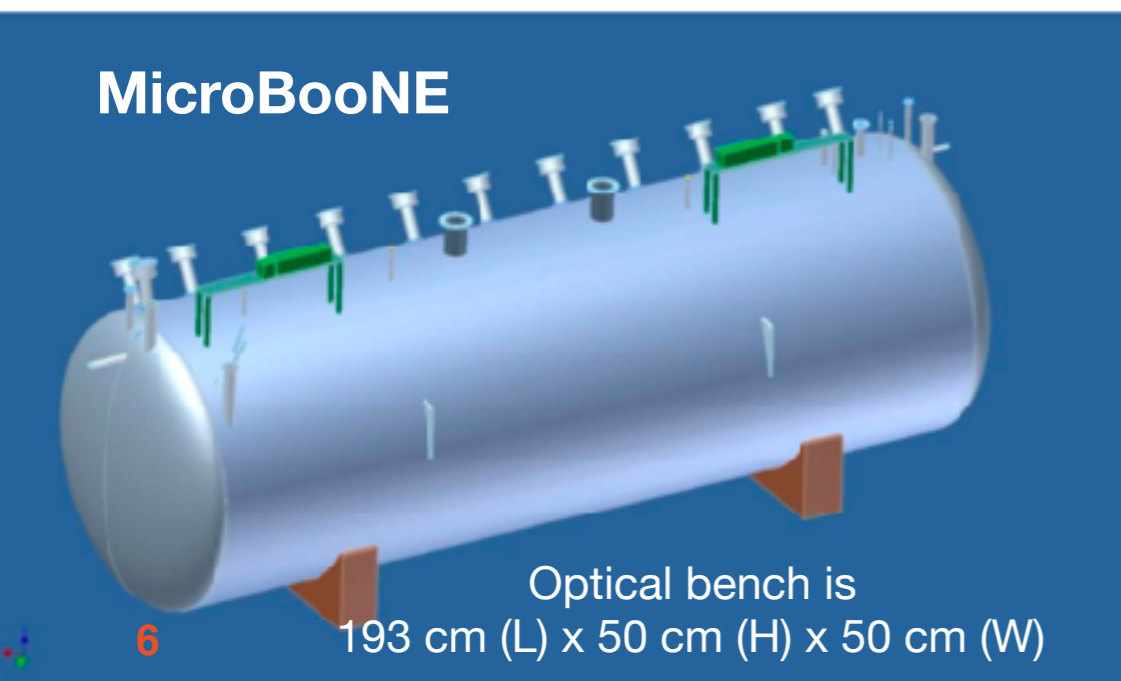


- May need a hatch for insertion/removal during installation — may not work for some locations
- Study split laser periscope concept to see if hatch requirement can be eliminated
- Replace Torlon on the chimney part with stainless steel — ensure proper electrical insulation

Ionization Laser (4/5)

Space on the cryostat roof

- Each laser will require an optical bench with the laser box and a laser beam pipe feeding into the port — need clear sight of path from the laser box to the feedthrough
- Exploring options for the design of the laser table and support system
- Going by the MicroBooNE model, about 2m (L) x 0.5 m (H) x 0.5 m (W) will be needed on top of the cryostat per laser
- Clearance around the table is also needed for a person to move around and align the laser carefully

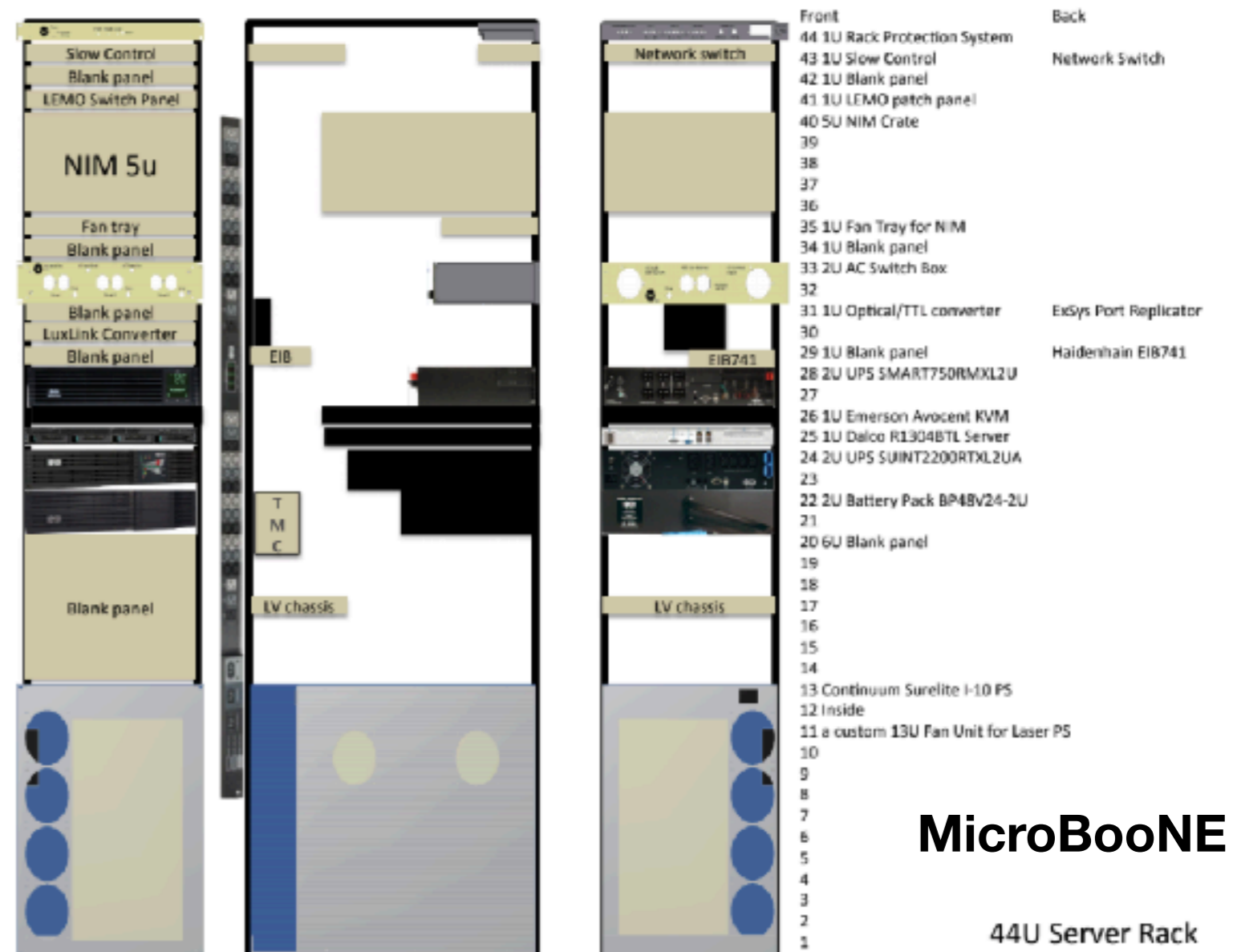


With 12 lasers, this requirement will be demanding on the cryostat real estate, additionally the proximity of the lasers to the laser racks is also important

Ionization Laser (5/5)

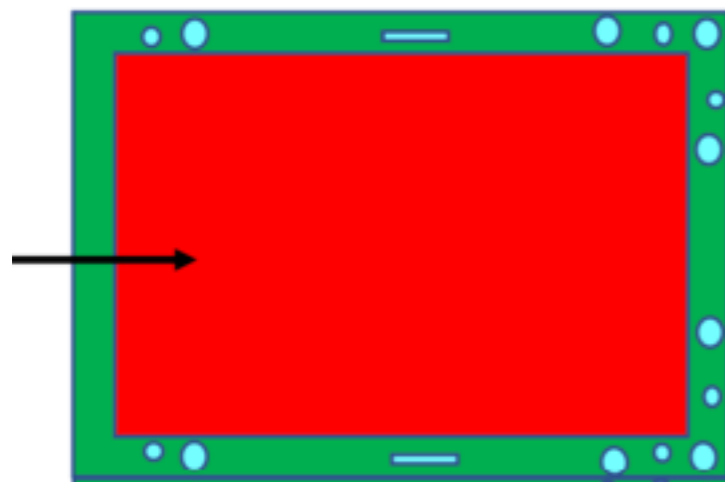
Electrical and other needs

- 1 rack per laser needed; 5kW power load per laser rack — too much ask but note that not all lasers run at the same time so we are okay
 - Laser power: 208-240 VAC, single phase, 10 A, heat dissipation from the power unit is 2 kW
 - MicroBooNE design also has UPS, cooling and fans in the rack — redo the laser rack packaging for DUNE
 - **Laser rack cannot be more than 5 m from the laser** — since not only HV, cooling and flash signal timing goes through the cable
 - Exploring with the manufacturer if there is anymore flexibility here
 - Grounding
 - Lasers are in general noisy; on MicroBooNE laser was kept on building ground
 - Discussing with Linda/Terri on plans for DUNE?
-
- The diagram illustrates the layout of a laser rack, showing the front, back, and side views. The front view lists components from top to bottom: Slow Control, Blank panel, LEMO Switch Panel, NIM 5u, Fan tray, Blank panel, LuxLink Converter, Blank panel, Network switch, EIB, LV chassis, and a custom 13U Fan Unit for Laser PS. The back view lists components: Network Switch, ExSys Port Replicator, Haldenhein E18741, and LV chassis. The side view shows the rack structure with labels for EIB, T M C, and LV chassis.



Photoelectron laser (1/2)

- Goal
 - create electrons at a definite point and time in the cathode to monitor the drift time and collected charge
- Method
 - UV light on photoelectric (PE) targets
 - 72 fibers on APA frames (3 /location * 6 locations/volume * 4 volumes)
 - targets on CPA frames



Jelena Maricic

Ranjan Dharmapalan

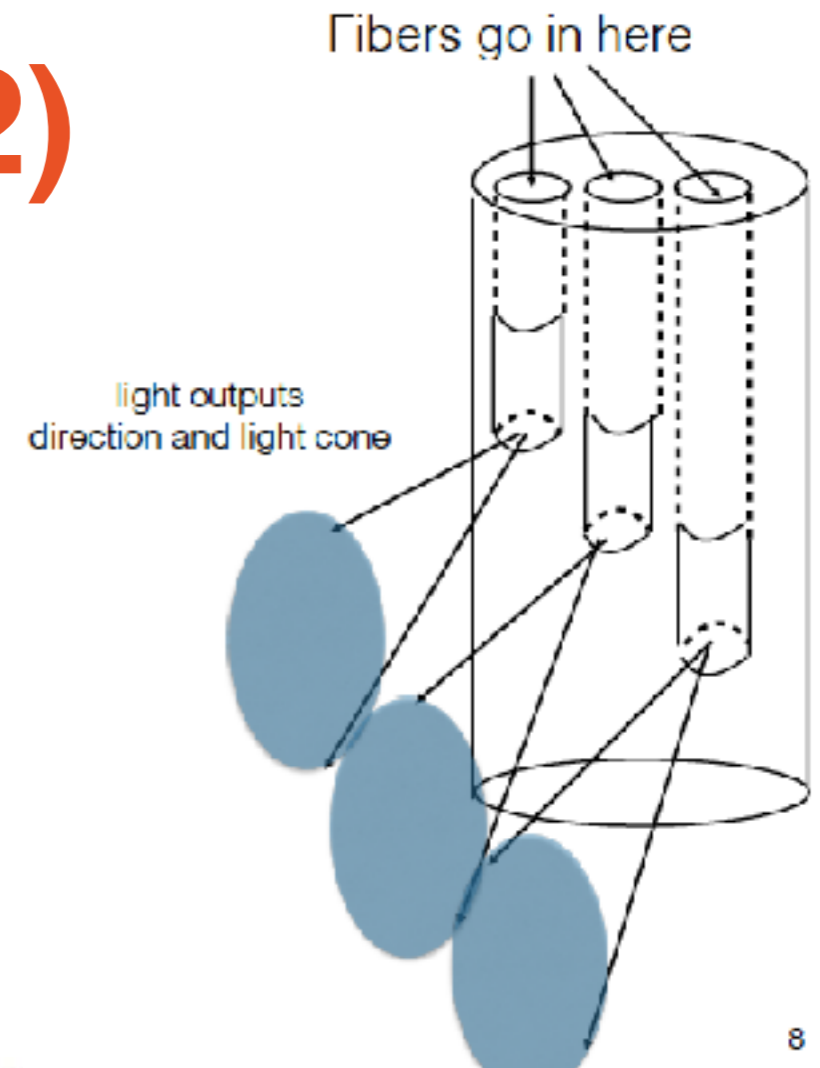
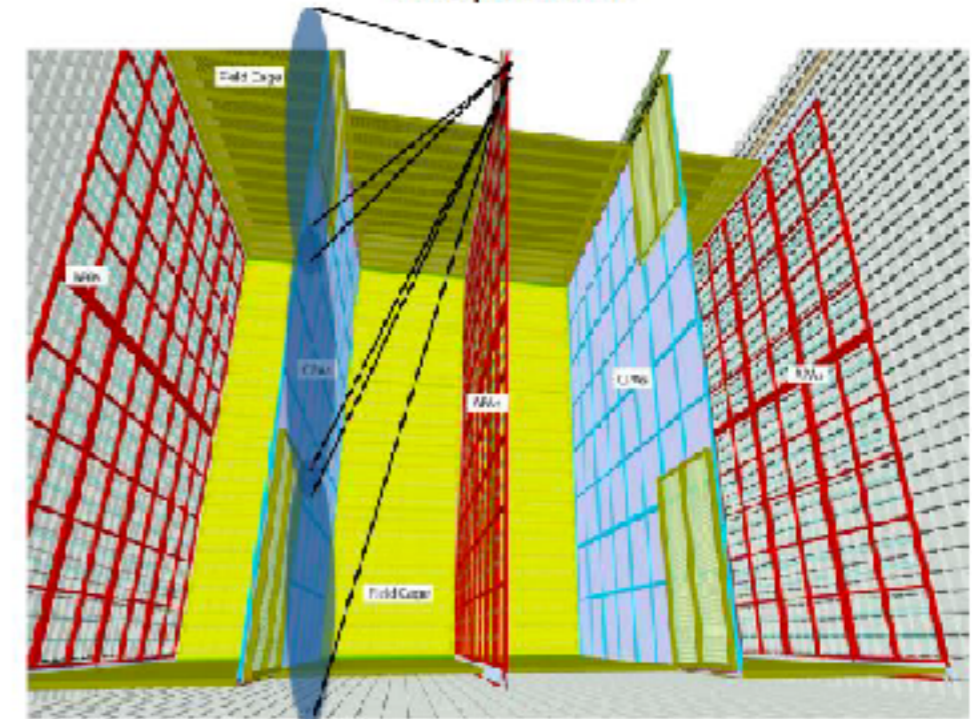


Photo-Electron Laser System: New

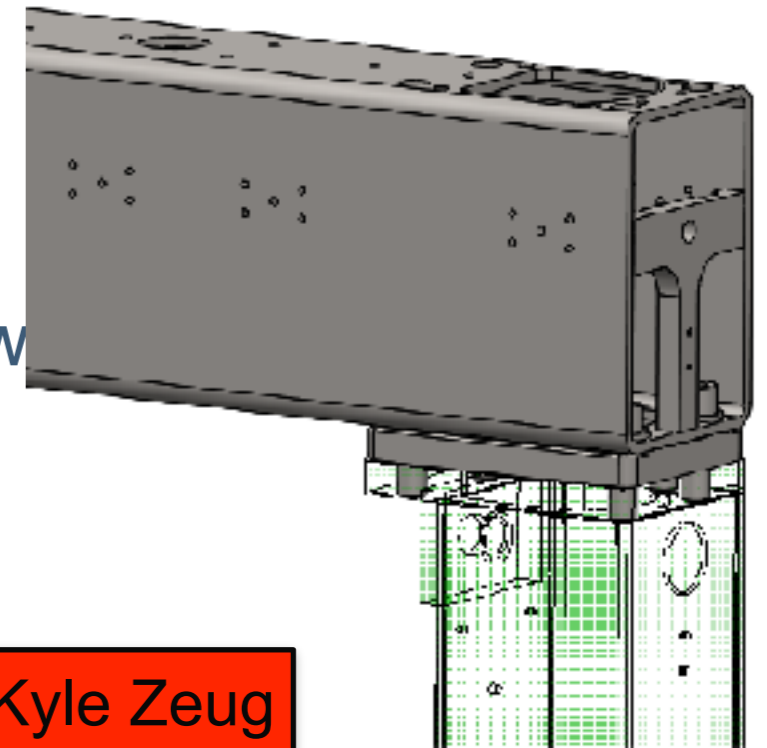
Concept for DUNE



Fibers on top, angled illumination on the CPA surface.

Photoelectron laser status (2/2)

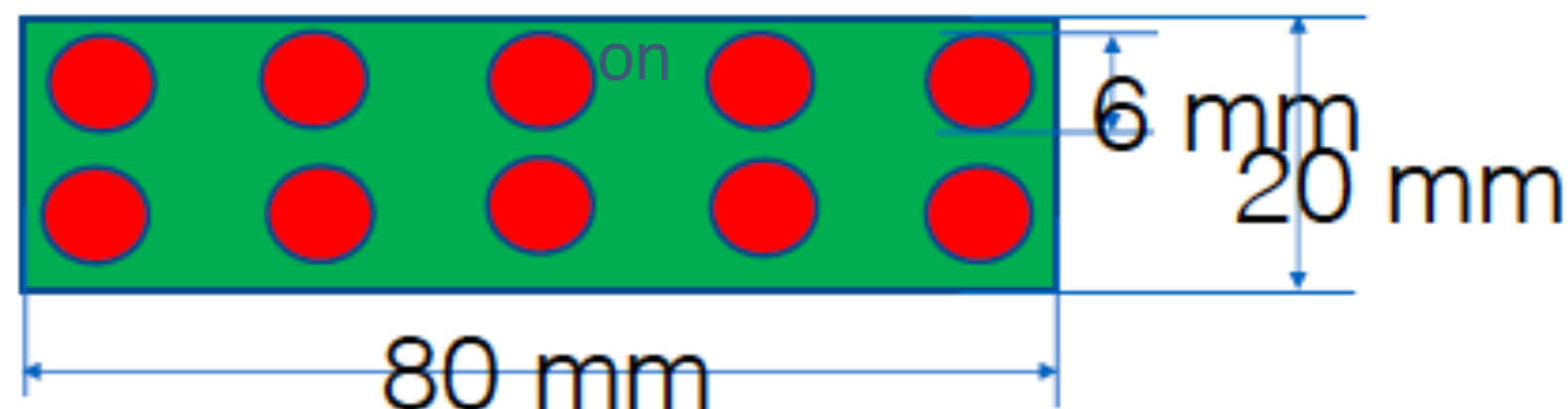
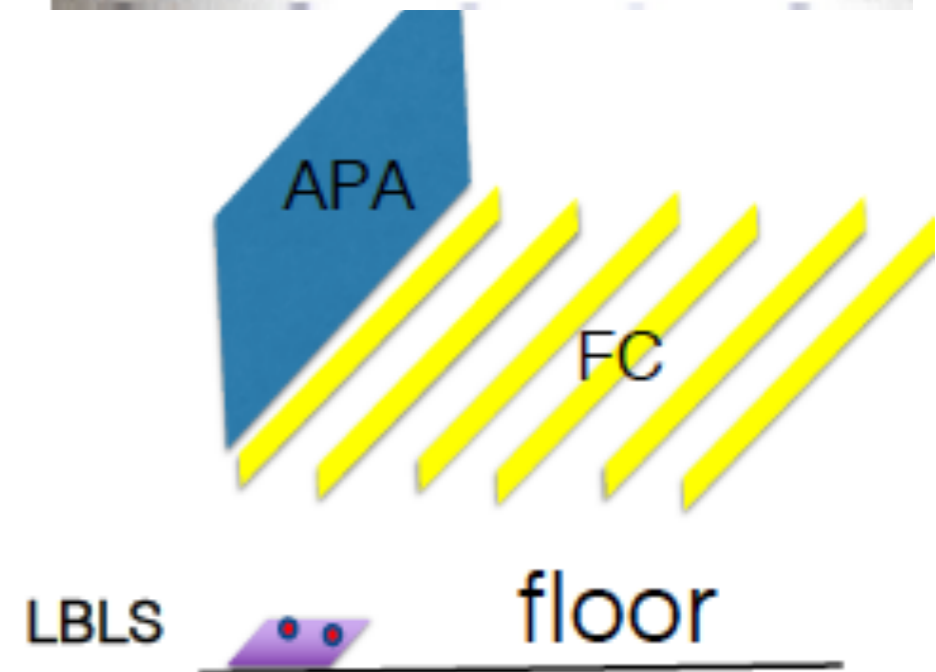
- Design open question: do we get enough light?
 - transmittance of full optical chain: laser/mirror/coupler/fibers/connections/opening angle
 - efficiency of photoelectric targets
 - background from kapton emission
 - Tests ongoing or very soon (Feb/Mar) at U. of Hawaii
- Recent technical decision (TB) on fixation
 - drill tapped holes on APA head frame T-piece
- Technical open questions
 - Routing of fibers along cable trays, onto CE ports?
 - Best way to attach targets to CPA frame



Laser beam location system(s) 1/2

PIN diode system

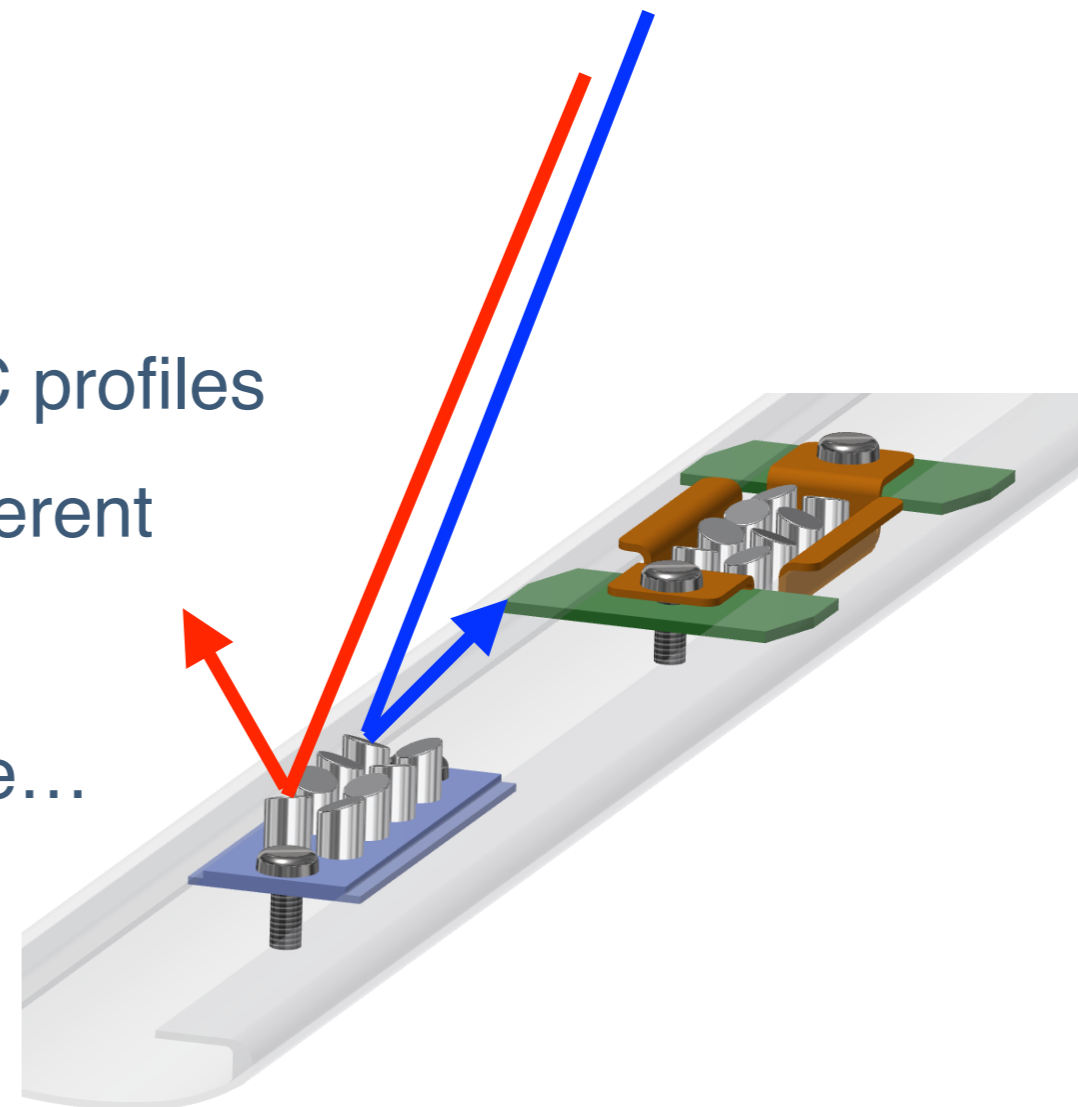
- Goal
 - measurement of the position hit by the laser, independent from its mechanical system
 - independent from TPC
- Method
 - passive PIN diodes give pulse when hit by laser
 - each diode needs a twisted pair cable
 - best location: floor below FC
 - 32 pads (8 pads/DV)
 - How to attach pin diodes to the floor? epoxy?
 - Cable routing from floor?



Laser beam location system(s) 2/2

Mirror system

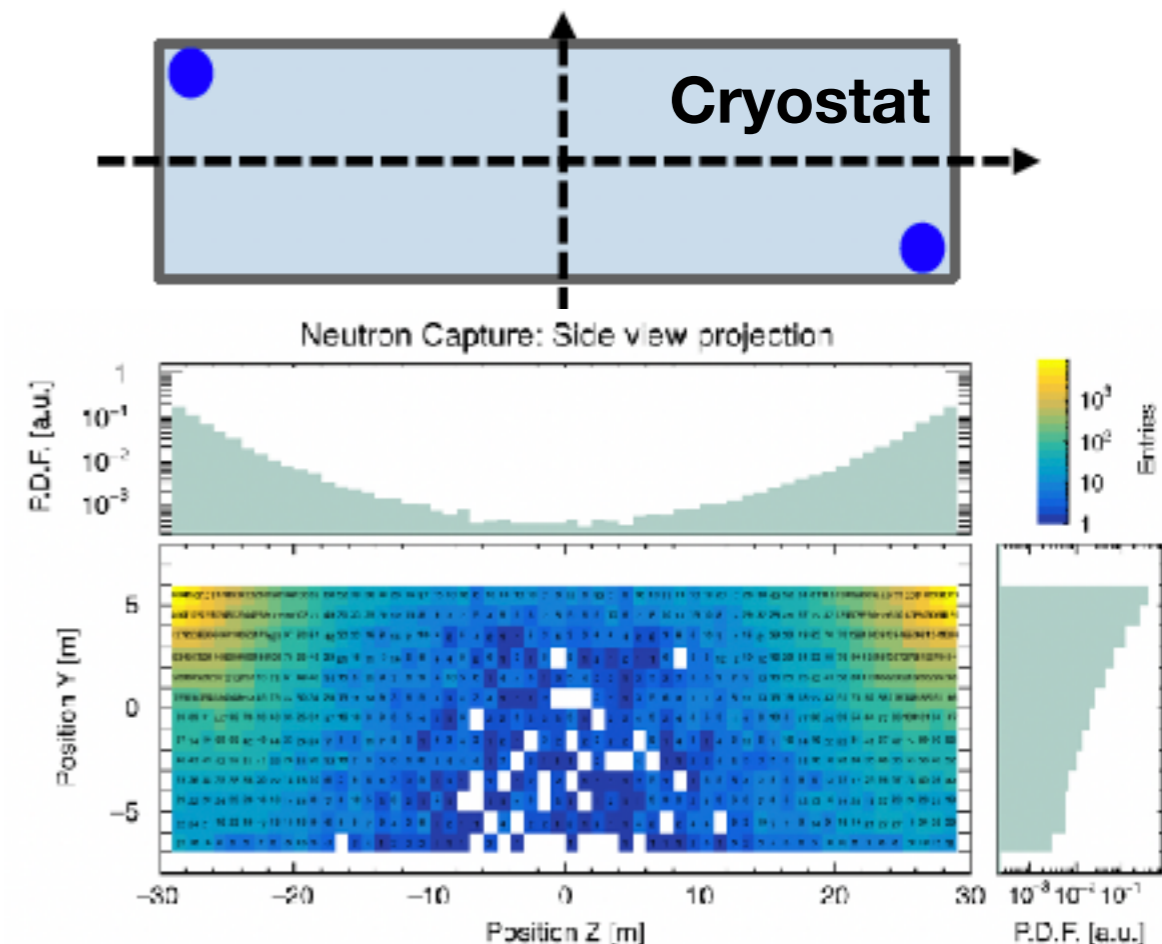
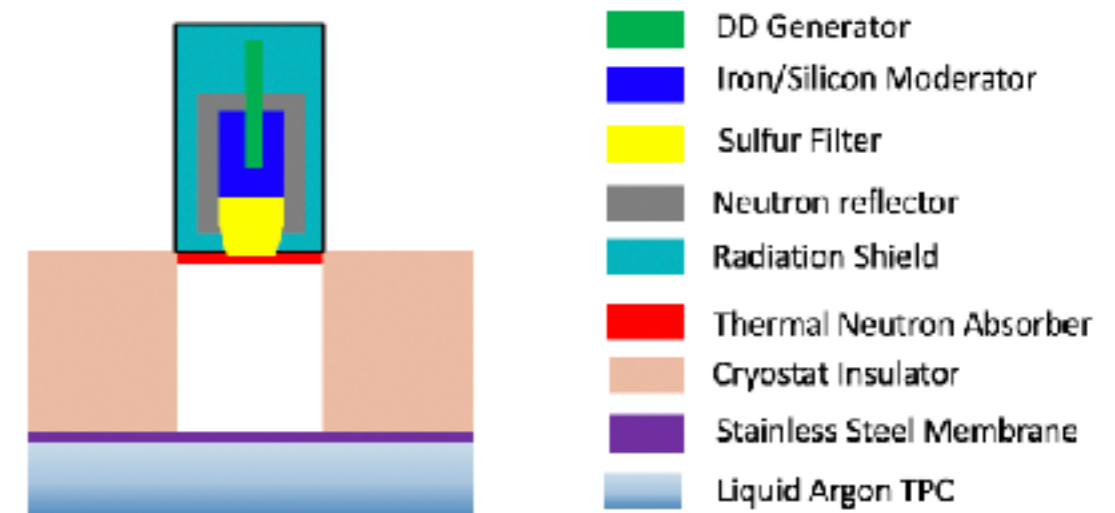
- Goal
 - measurement of the position hit by the laser, independent from its mechanical system
 - electrically passive, no cables
- Method
 - pad with mirror w/ different angles inside FC profiles
 - depending on the mirror hit, reflection is different
 - 32 pads (8 pads/DV), possibly more
 - needs pre-assembly in FC, know well where...
 - plan to test two versions in PD2
 - dielectric mirrors, polished Aluminum



Pulsed Neutron Source (PNS) 1/2

J. Wang, R. Svoboda

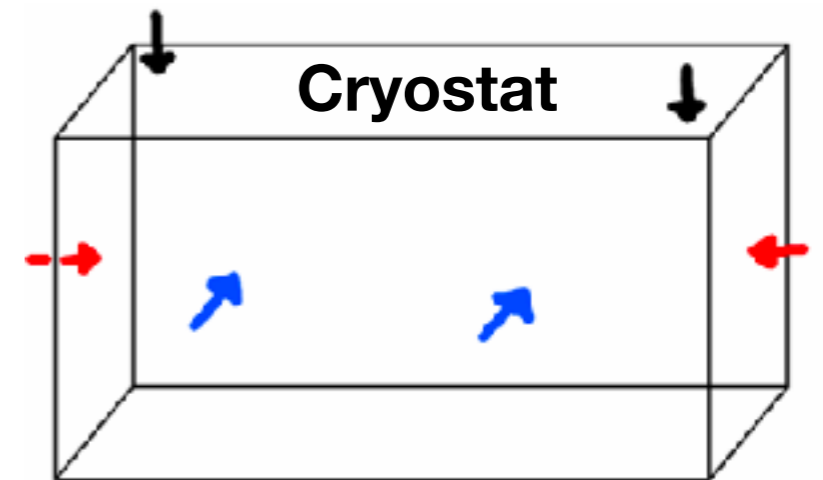
- Goal: Provide low energy calibration relevant to supernova and solar neutrinos
- Based on 57 keV neutron anti-resonance — ongoing work to confirm the concept with ARTIE experiment
- Baseline design: deployment in human access ports on opposite sides of the cryostat
 - 80 OD x 105 H
 - reduced coverage at the center, long run times, reduce lifetime of DD etc.
 - weighs about 1.5 tons, can it be supported by the cryostat I-beams?
 - Crane access on the mezzanine side human access port?
 - It is likely DD generator will be deployed in ProtoDUNE run 1 in April 2020



Pulsed Neutron Source (PNS) 2/2

J. Wang, R. Svoboda

- Possible side deployment an option?
 - Almost full coverage
 - Will need a platform; installation easier
 - Still need to remove insulation foam but a vacuum chamber to provide thermal insulation?
- Electrical and Other Needs
 - 0.5 rack per generator; 400 W power per generator
 - Integrated HV (150 kV) enclosed in the generator, but a cable needs to run from generator to control box — constraints on the cable length to be understood from manufacturer
 - Control box doesn't need to sit near the generator
 - Remote operation a must for safety and real estate considerations on top of cryostat

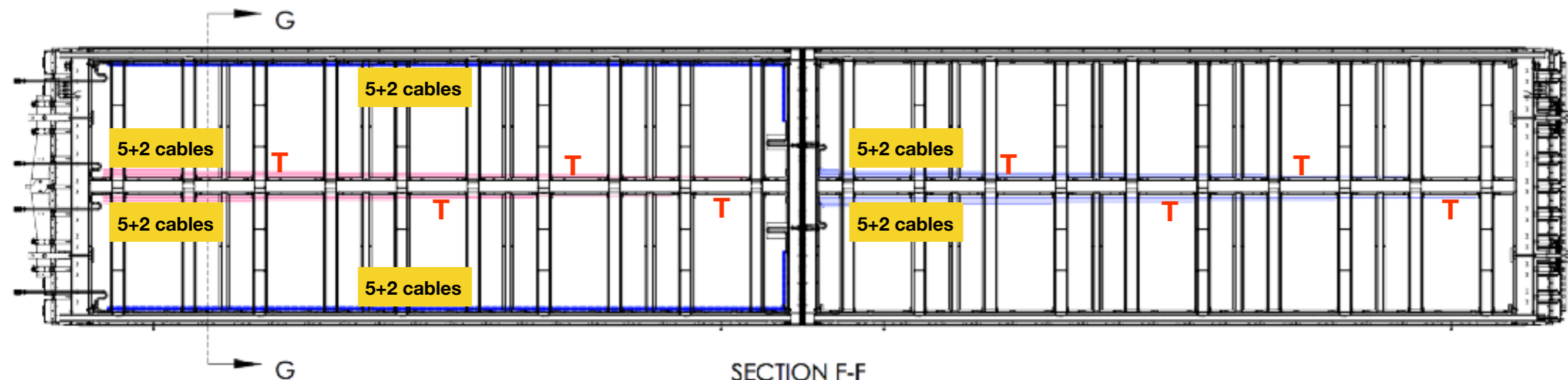


Installation sequence — Calibration

- Ionization laser
 - Install laser boxes as soon as cryostat space becomes available
 - Laser periscope installed from top of the cryostat once relevant structural elements are in place (FC modules with penetrations); start from farthest from TCO
- LBLS
 - Attachment of mirrors done during FC assembly underground and installed with FC
 - Pin diodes are attached to the cryostat floor so before detector elements are installed
- PE Laser
 - Targets can be attached to CPA after assembly but before they are installed in cryostat
 - Once CPAs are in place, need a high precision survey of locations
- PNS
 - System assembled in a radiation safe area underground and lifted by crane to the cryostat
 - Installed after human access ports are closed

Temperature sensors on APAs (1/4)

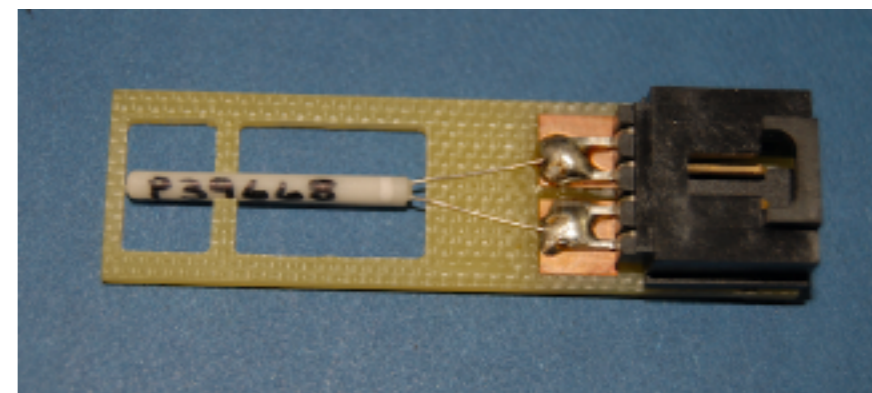
Anselmo



- The current configuration assumes 4 sensors/APA with two specialized (< 3 mm OD) cables in each of the PDS cable bundles
- RTD and PDS cables will use the same routing path up to the flange, and installation will be done simultaneously
- RTDs should be plugged in as late as possible in the production process to avoid damage
- Bookkeeping:

RTD serial number \iff #APA + position

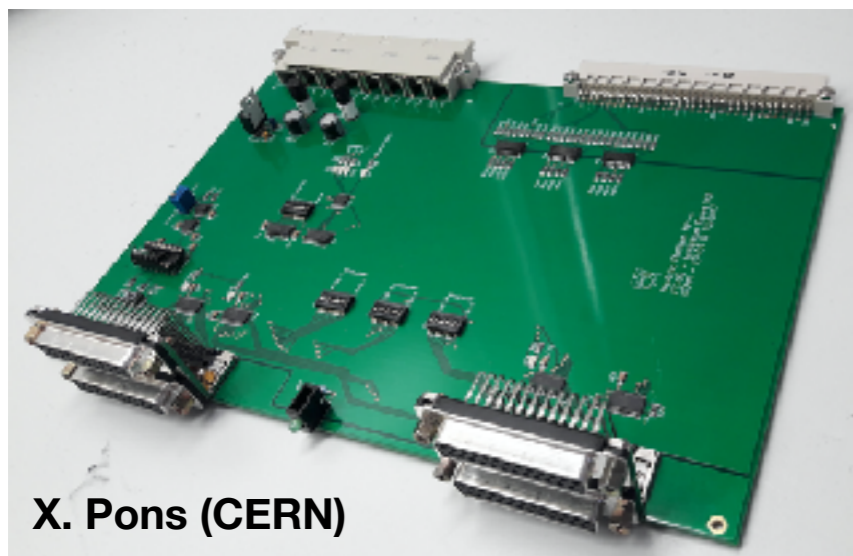
PCB + sensor + connector
used in ProtoDUNE-SP



Temperature sensors on APAs (2/4)

Outside the Cryostat

- In principle, direct cables from PDS flange to racks, where the multiplexing board for the 24 sensors would be
- Needs to understand what is the best grouping scheme for several MUX cards (to minimize cable lengths and noise)
- In terms of rack space, this results in 25U rack space total — easily accommodated in PDS racks?

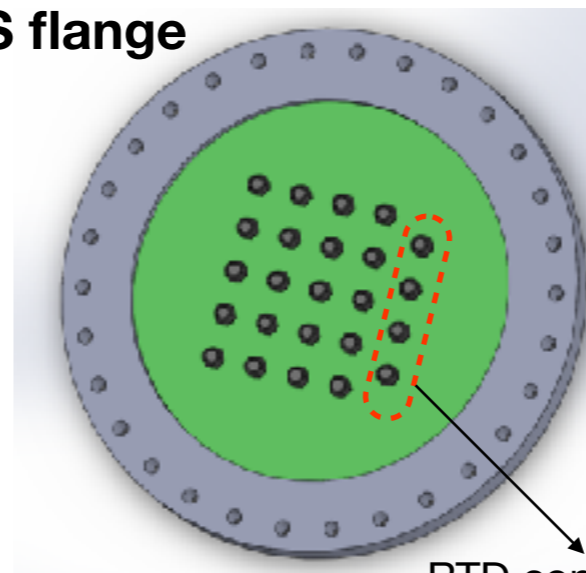


X. Pons (CERN)

1U Multiplexing board for 24 sensors

four 25 pins connectors —> three 37 pins connectors

PDS flange



RTD connectors

1 connector for 2 sensors

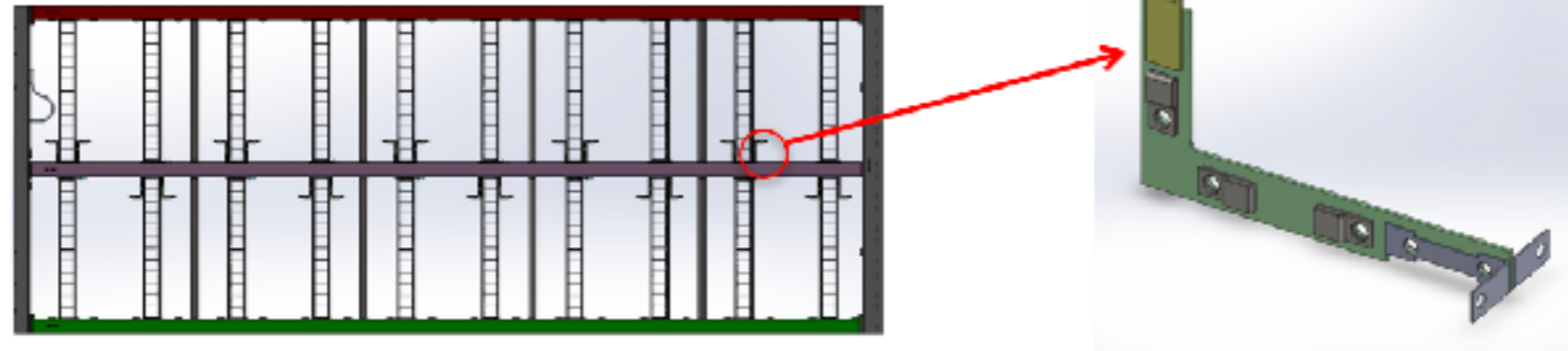


Temperature sensors on APAs (3/4)

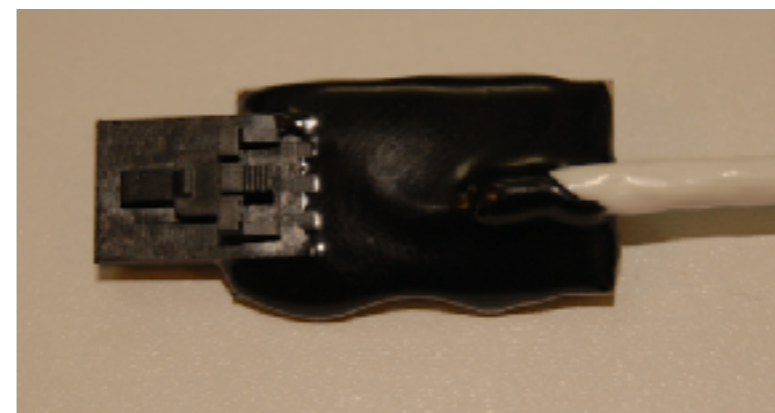
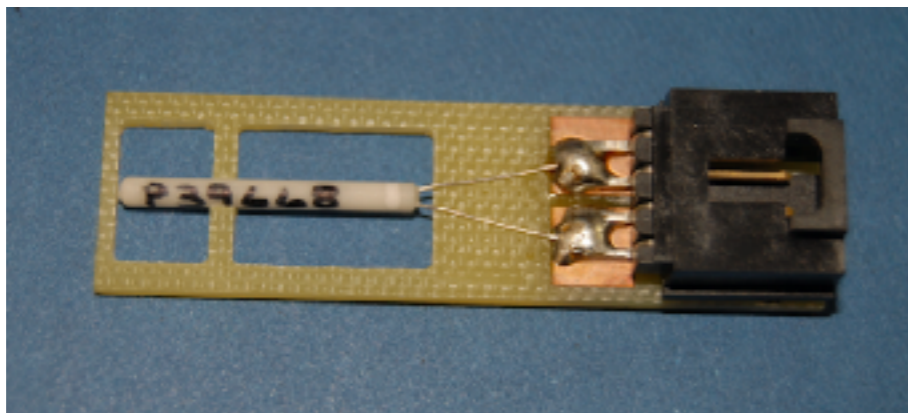
Action items

- Design of the interface between sensor/cable and APA frame will be done in the next few weeks (D. Warner, D. Wenman).
- Mechanical structure that holds the sensor away from the frame or in contact with it

“Away from the frame” design (D. Warner)

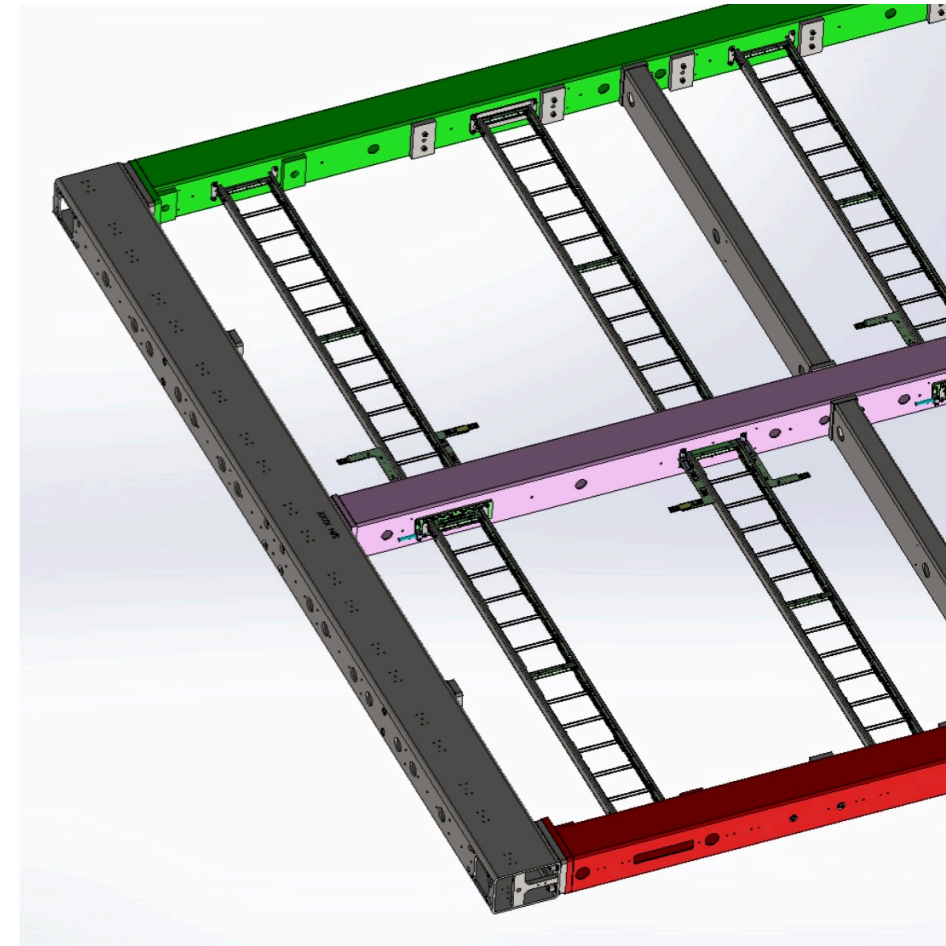
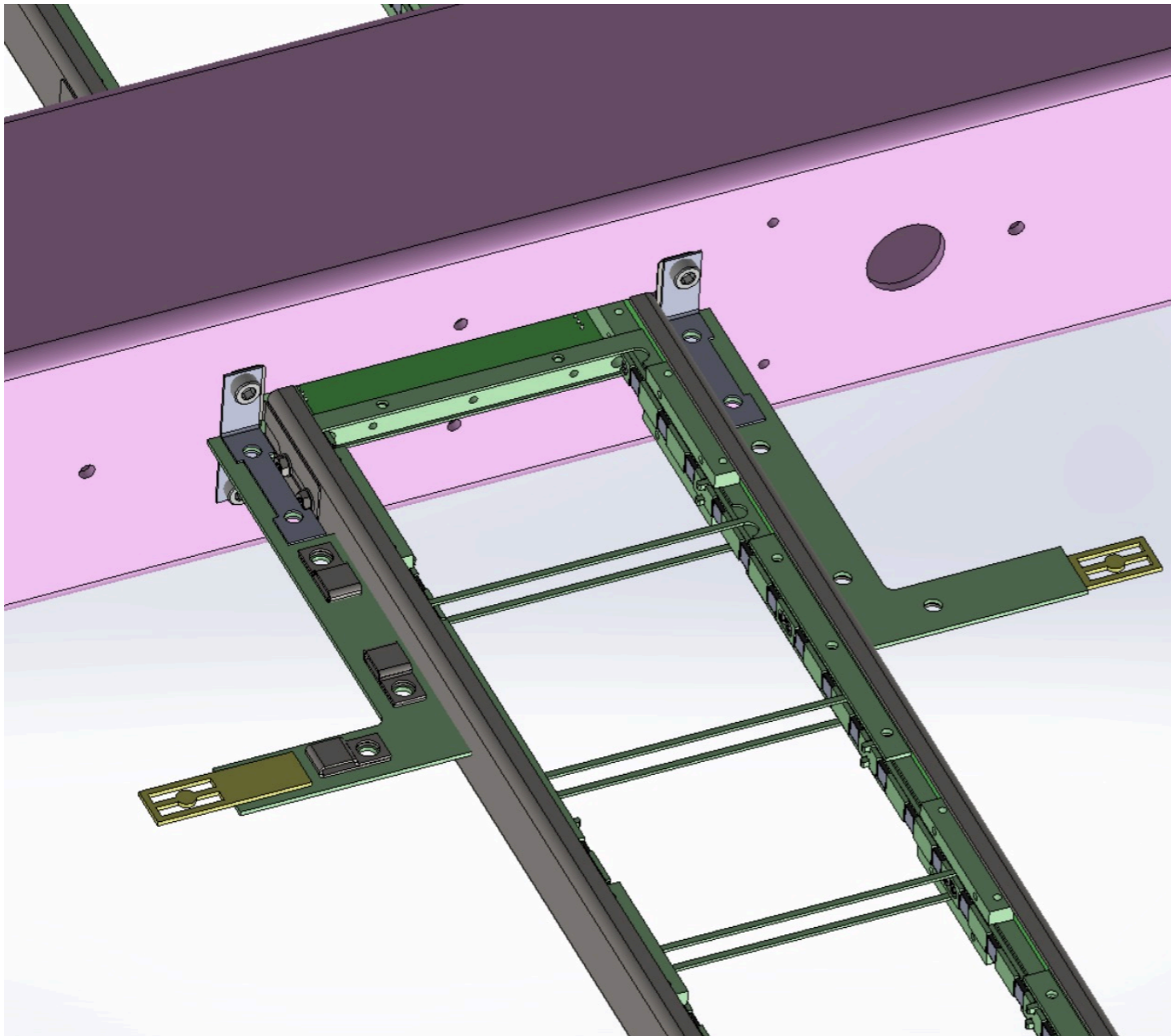


- Cable, connector and sensor to be sent to PSL at the end of this week. Prototype to be tested in the cold box at PSL for mechanical interfaces and electronics noise



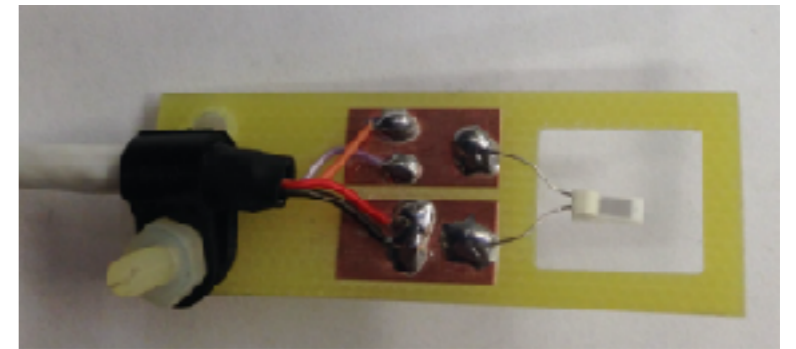
Temperature sensors on APAs (4/4)

Temperature sensor mount details



Other temperature sensors (1/3)

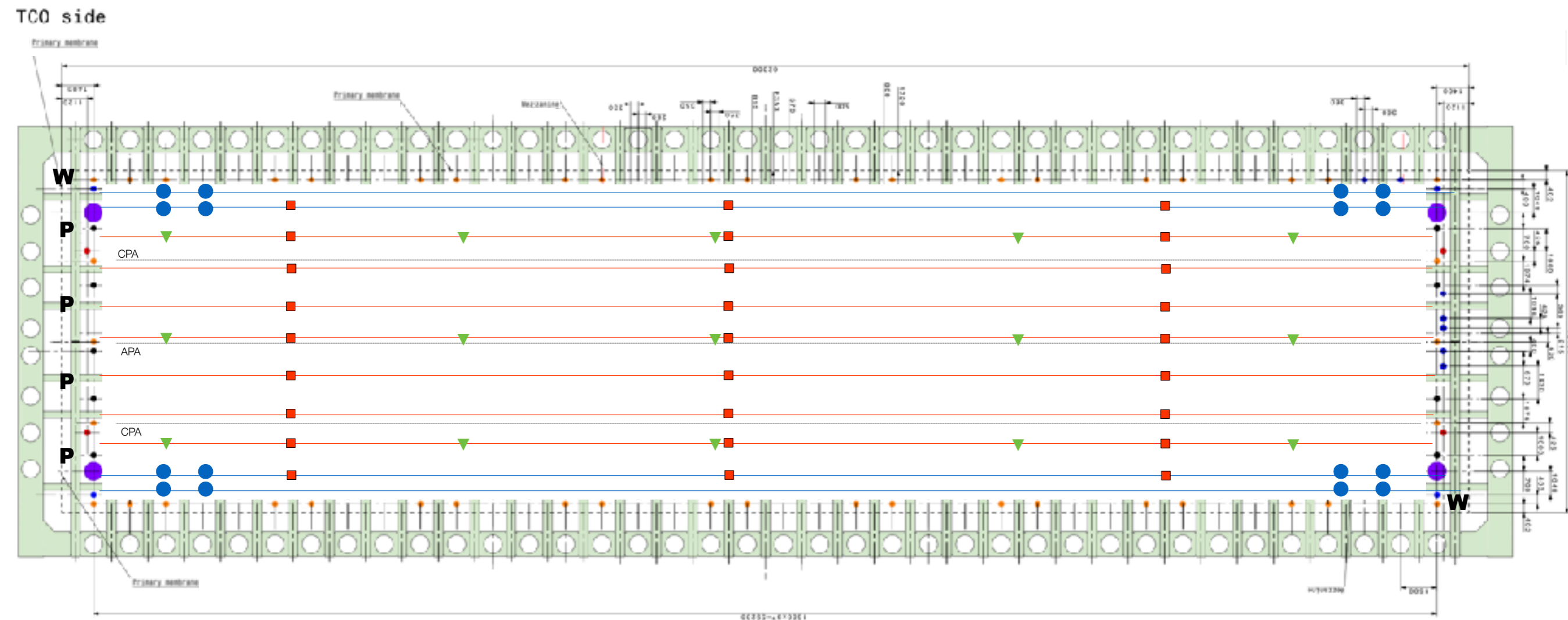
- Since bottom GPs have been removed, sensors would have to be very close to the pipes (even below) and far from the active volume. Then it is probably not worth to have them.
- **LAr pumps and inlets:** Important input for CFD simulations
- **Top GP sensors:** Several transverse arrays of sensors to better know what happens between two APA rows
- **Floor sensors:** Standard sensors epoxied to the floor for detecting the presence of LAr when filling starts
- **Wall sensors:** Standard sensors to measure the vertical gradient of the cryostat membrane during cool-down



We still assume DSS ports can be used to extract the signals
Since most sensors will be on the APAs we just need few (10?) localized ports

Other temperature sensors (2/3)

Sensor Map



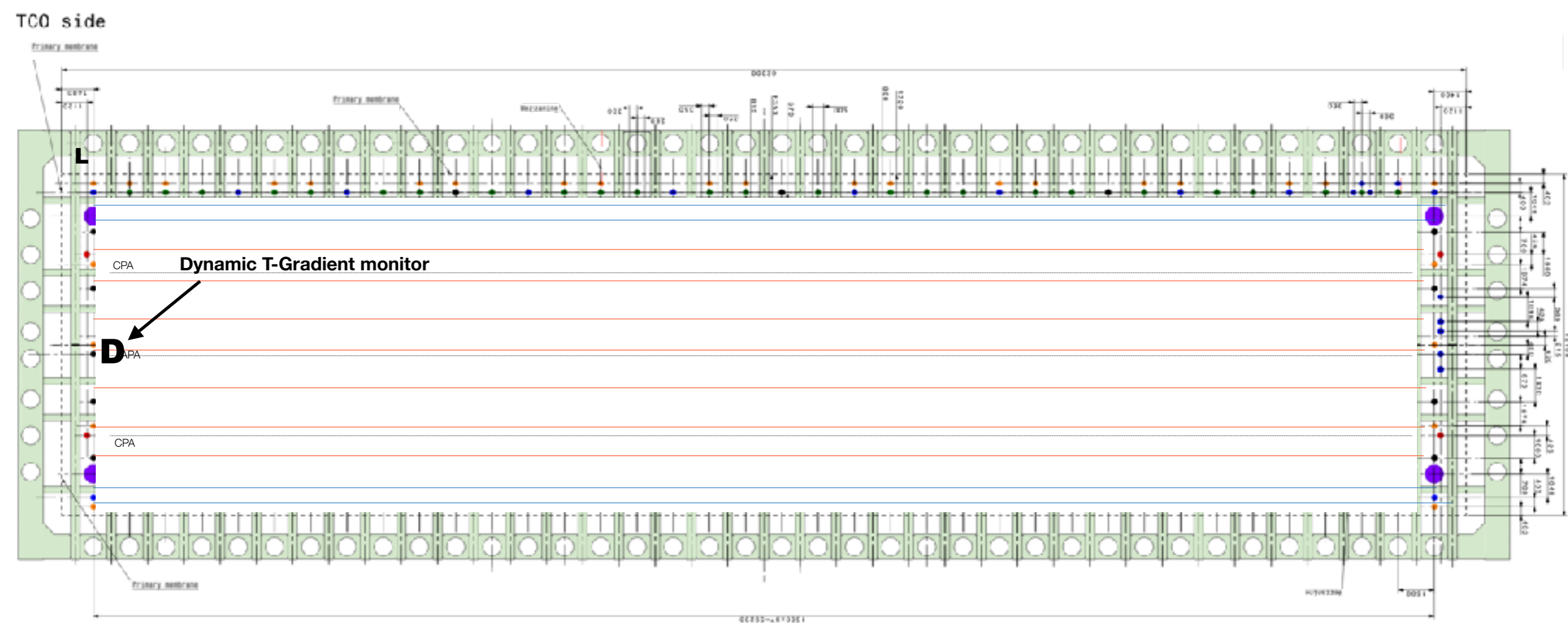
- Top/bottom (?) individual temperature sensors
- ▼ Floor individual temperature sensor (15 sensors in total)
- W** Wall sensor array with 13 sensors, one every three corrugations (26 sensors in total)
- P** Sensors near LAr pumps (4 sensors)
- Sensors in LAr inlets (LAr return pipes, 16 sensors)
- Gas purge pipes
- Liquid argon return pipes

Other temperature sensors (2/3)

Action Items

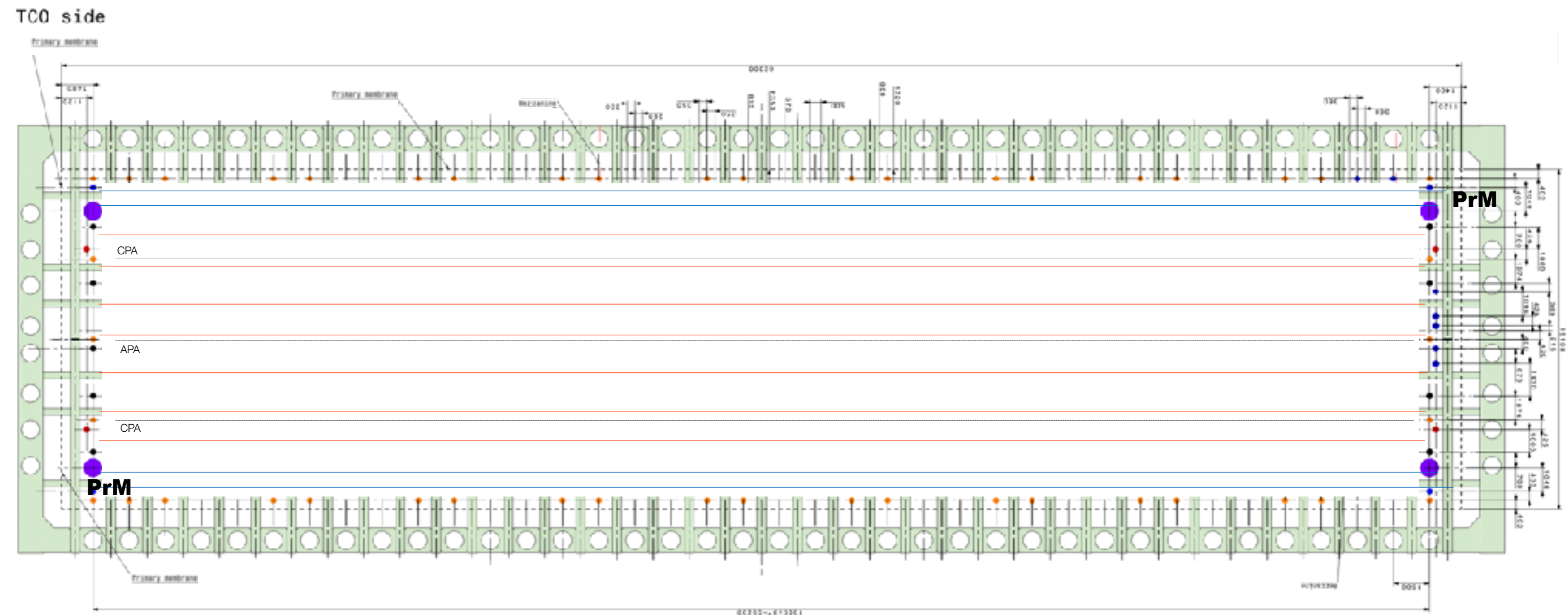
- Finalize sensor map. Recent changes (APA sensors, no bottom GPs) prevented us to converge earlier
- Identify suitable ports (DSS?) for extracting signals and work out the details with the owner of those ports
- Design mechanism to route cables from the bottom of the cryostat (also for cameras, LBLs pin diodes). Two options:
 - Bring all cables to the four vertical corners
 - Have a bottom-top cable routing mechanism in the middle of the cryostat (a SS string attached to bolts in top/bottom corners?)
- Installation plan depends very much on the above. All this to be finalized for the May review
- But most of this is expected to be installed at the very beginning

Dynamic T-gradient Thermometer



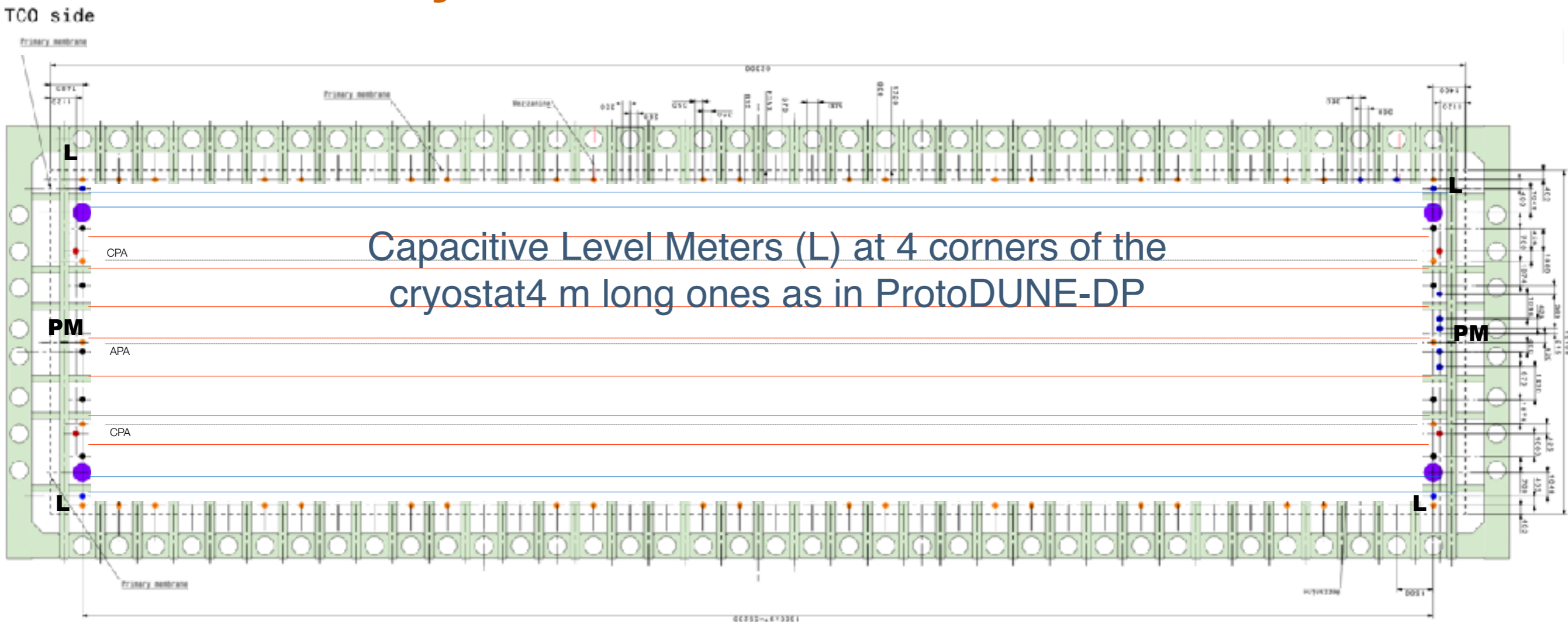
- Based on the input from last scope review and given the new plans on RTDs on APAs, the movable thermometer system design is being revised
 - Design greatly simplified especially on the warm side
 - May result in additional interfaces with the cryostat wall for anchor points
- One dedicated port for this system on the TCO side
- Route cables from the port to the specified rack (same as Sensors on APAs)
- About 50 sensors, 2-3U rack space needs for MUX cards

Purity Monitors

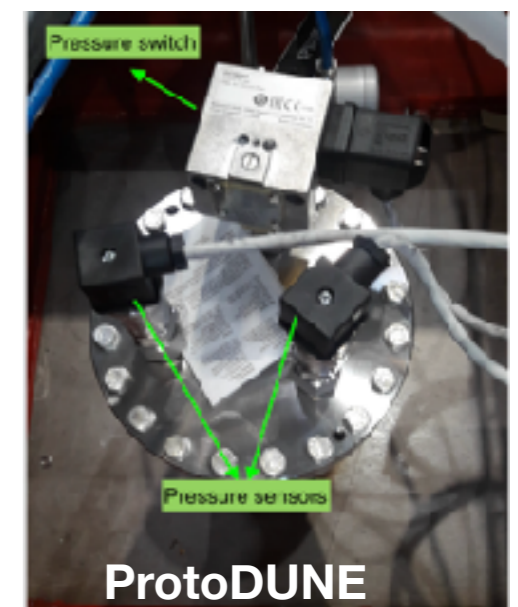


- Two purity monitor (PrM) arrays on opposite sides of the cryostat
 - exact scope on no. of PrMs e.g. inline to be defined at the May 2020 CALCI workshop
- Typically best to do straight deployment but no ports assigned, so propose to use human access ports
- Each purity monitor array will require a dedicated rack: total 2 racks
- Significant experience from ProtoDUNE to DUNE

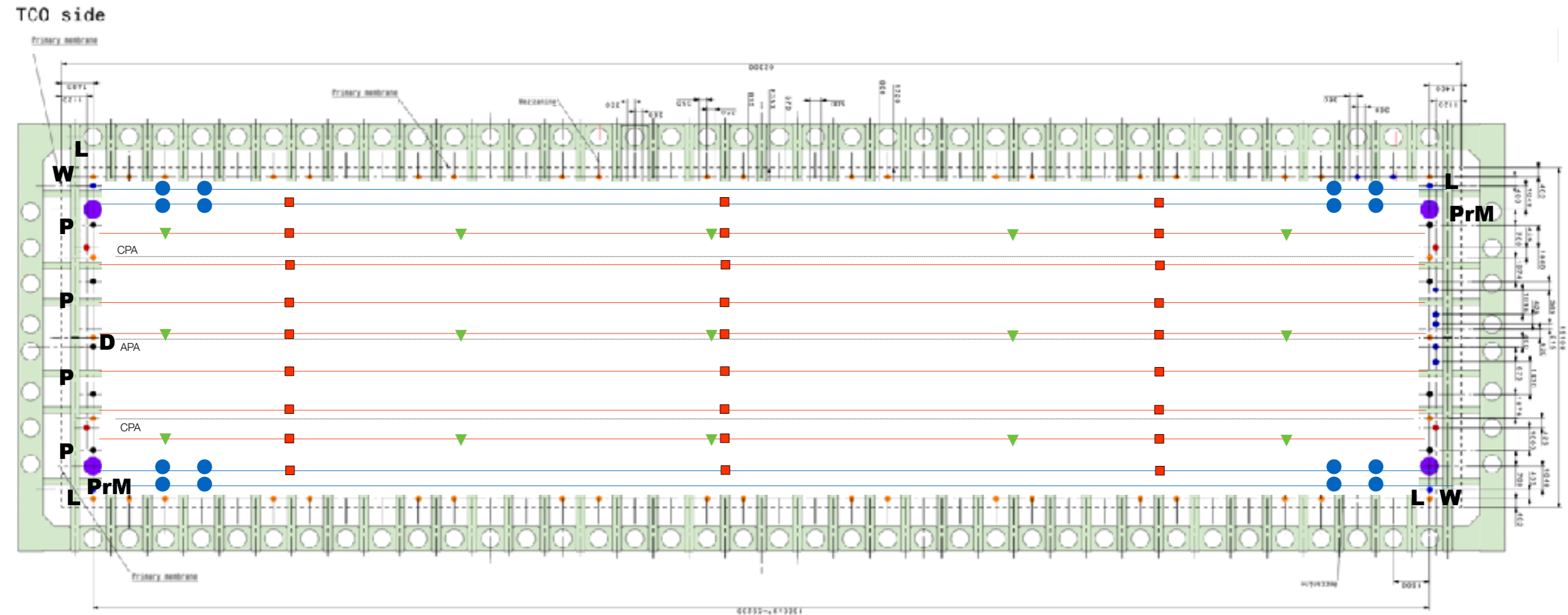
Other CI systems



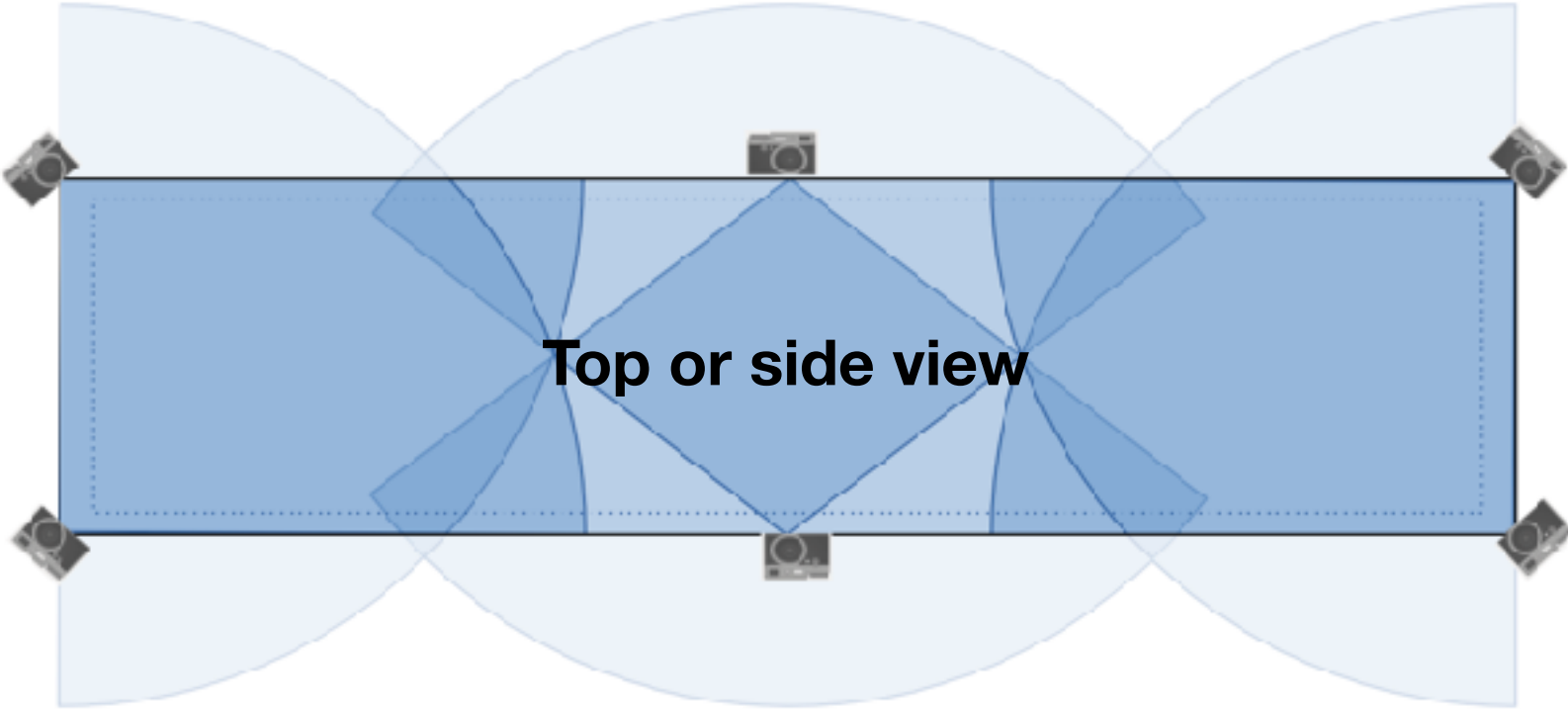
- **Level Meters (L)**
 - Support using bolts on the cryostat corners? — detailed design yet to be defined
 - No dedicated port needed; cables need to be routed (DSS?)
- **Pressure Meters (PM)**
 - Two pressure meters in opposite sides of the cryostat
 - Requires a flange, none assigned yet
 - ProtoDUNE installed two pressure sensors and a switch in a dedicated flange
- No institute signed up for both systems yet, done by CERN for ProtoDUNE



All CI devices together (except cameras)



- Top/bottom (?) individual temperature sensors
- ▼ Floor individual temperature sensor (15 sensors in total)
- W** Wall sensor array with 13 sensors, one every three corrugations (26 sensors in total)
- D** Dynamic T-Gradient monitor
- P** Sensors near LAr pumps (4 sensors)
- Sensors in LAr inlets (LAr return pipes, 16 sensors)
- PrM** Vertical array of three purity monitors
- L** Capacitive level meters
- Gas purge pipes
- Liquid argon return pipes

- Current plan: 3 warm and 12 cold cameras
 - Exact locations/ports yet to be finalized
 - Full Coverage with 12 cold cameras in the FD (8 in corners 4 in long edge centers)
- 
- The diagram shows a rectangular detector with a central diamond-shaped region. Eight camera icons are positioned at the corners and midpoints of the long edges. Light blue semi-circular fields of view emanate from each camera. A darker blue shaded area covers the central diamond and extends towards the corners. The text "Top or side view" is centered over the diamond.
- Top or side view**
- Active ongoing discussion to integrate camera(s) into the periscope design both to 1. help image the clearance of the periscope from FC profiles and 2. help with laser alignment — needs more discussion
 - <https://indico.fnal.gov/event/20144/session/11/contribution/219/material/slides/0.pdf>
 - Also discussions about HV consortium taking charge of cameras for HV related monitoring (either under CALCI or HV scope)
 - Need to understand camera needs from other groups and converge on locations
 - Port assignments for cameras is an open question

Installation sequence

- For cryogenic instrumentation, installation happens in several phases. Most systems will be installed in well defined periods (before or after TPC installation)

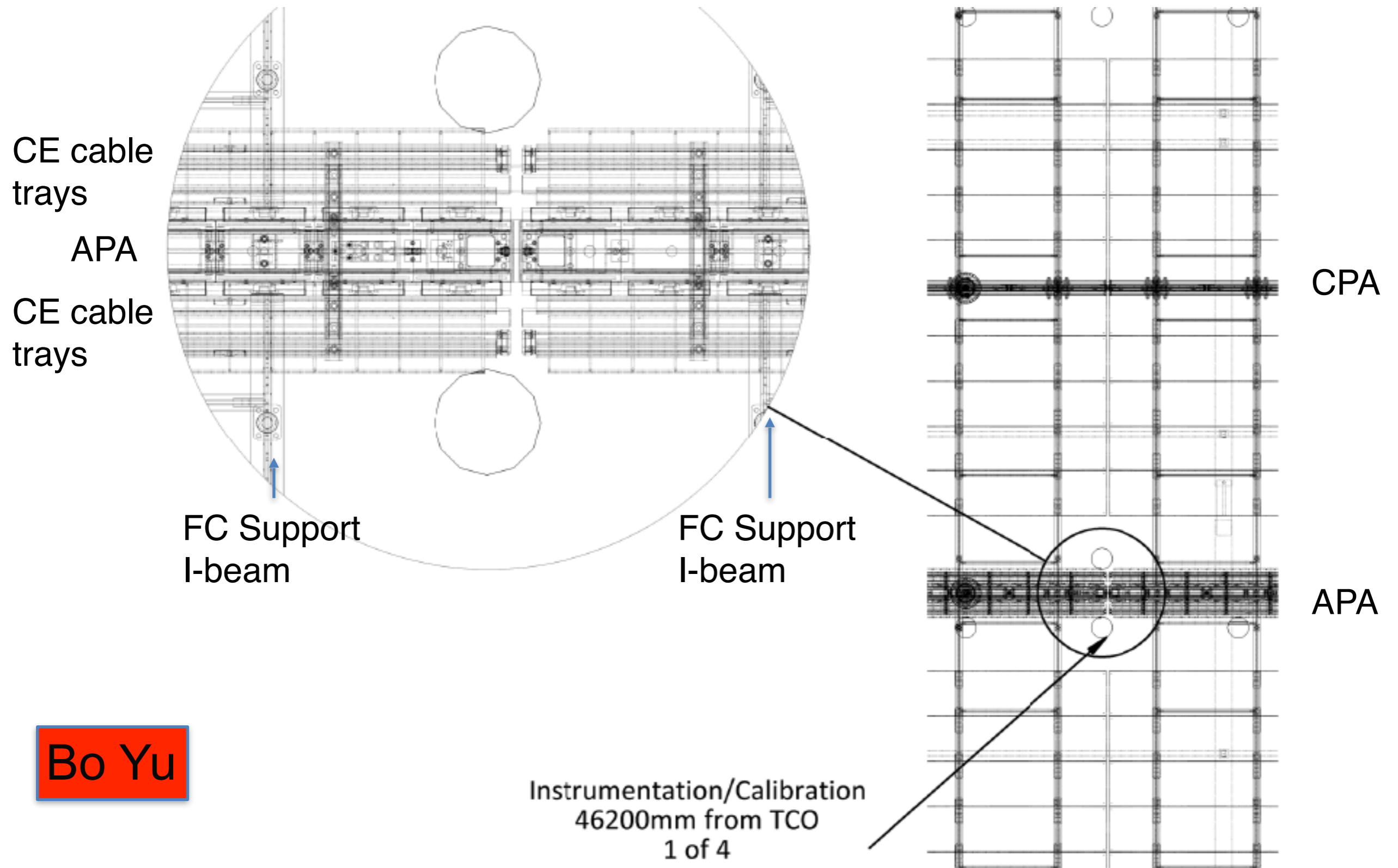
	Before TPC	During TPC	After TPC
Static T-Gradient monitors	X		
Top/bottom Individual sensors	X	X	
Dynamic T-Gradient monitors			X
Purity Monitors			X
Cameras & light emitting system	X	X	X
Gas Analyzers			X
Capacitive Level Meters(DUNE side)			X
GAr Pressure meters (DUNE side)			X
Sensors on APAs	X	X	

Summary

- Following the merger, all documents are being reorganized, especially the interface control documents
- Exact scope of CALCI yet to be defined — upcoming workshop in May 2020 at CERN
- **Biggest open issue is assignment of ports for systems and irrespective of what the exact scope will be (e.g. 12 vs 10 lasers) making needed accommodations for full scope before FD designs are frozen**
- Significant plans for Calibration in ProtoDUNE Run 2 involving all planned calibration systems — assigning ports in ProtoDUNE-II for calibration also forms an important step
- CALCI office space needs presented here: <https://indico.fnal.gov/event/21733/>
- Lot of other logistics not presented here but available on Doc-db, EDMS and Indico

Extra Slides

Laser Point Position 1

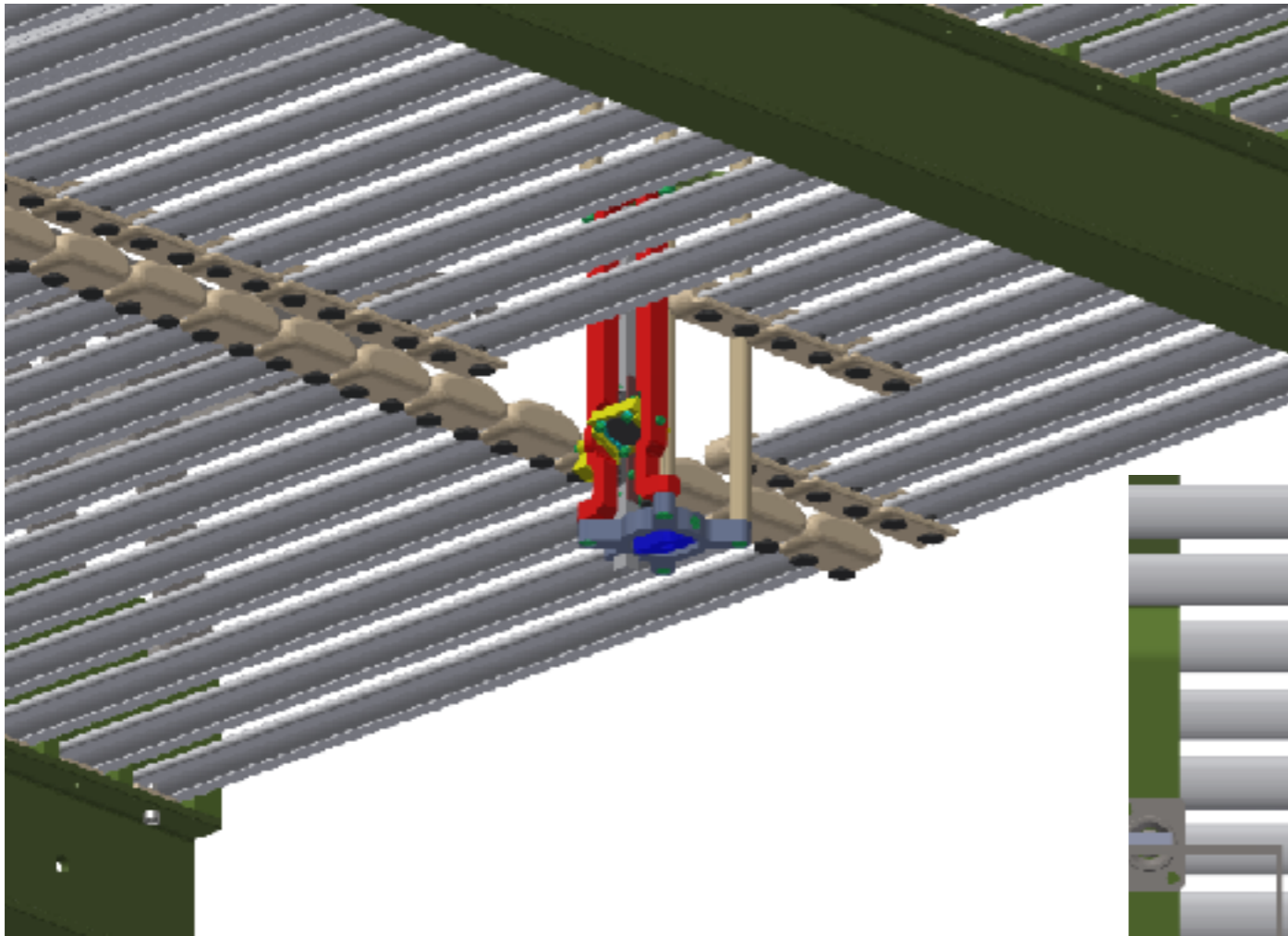


https://edms.cern.ch/file/2060543/1/Detector_Views_Center_2060543.pdf

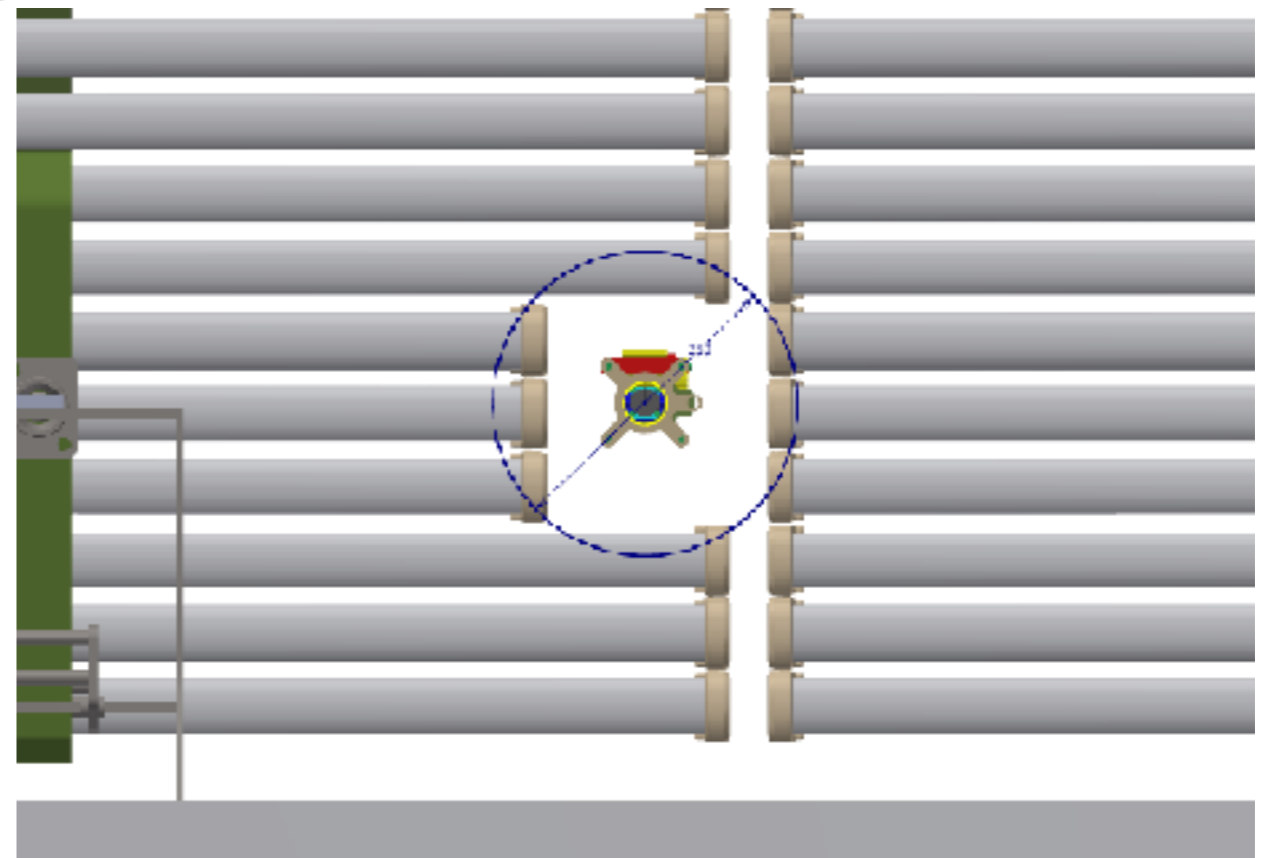
Laser Point Position 1

This is the easiest location to create an opening in the FC: simple shortening a few profiles on one side of the field cage module. No other changes are needed.

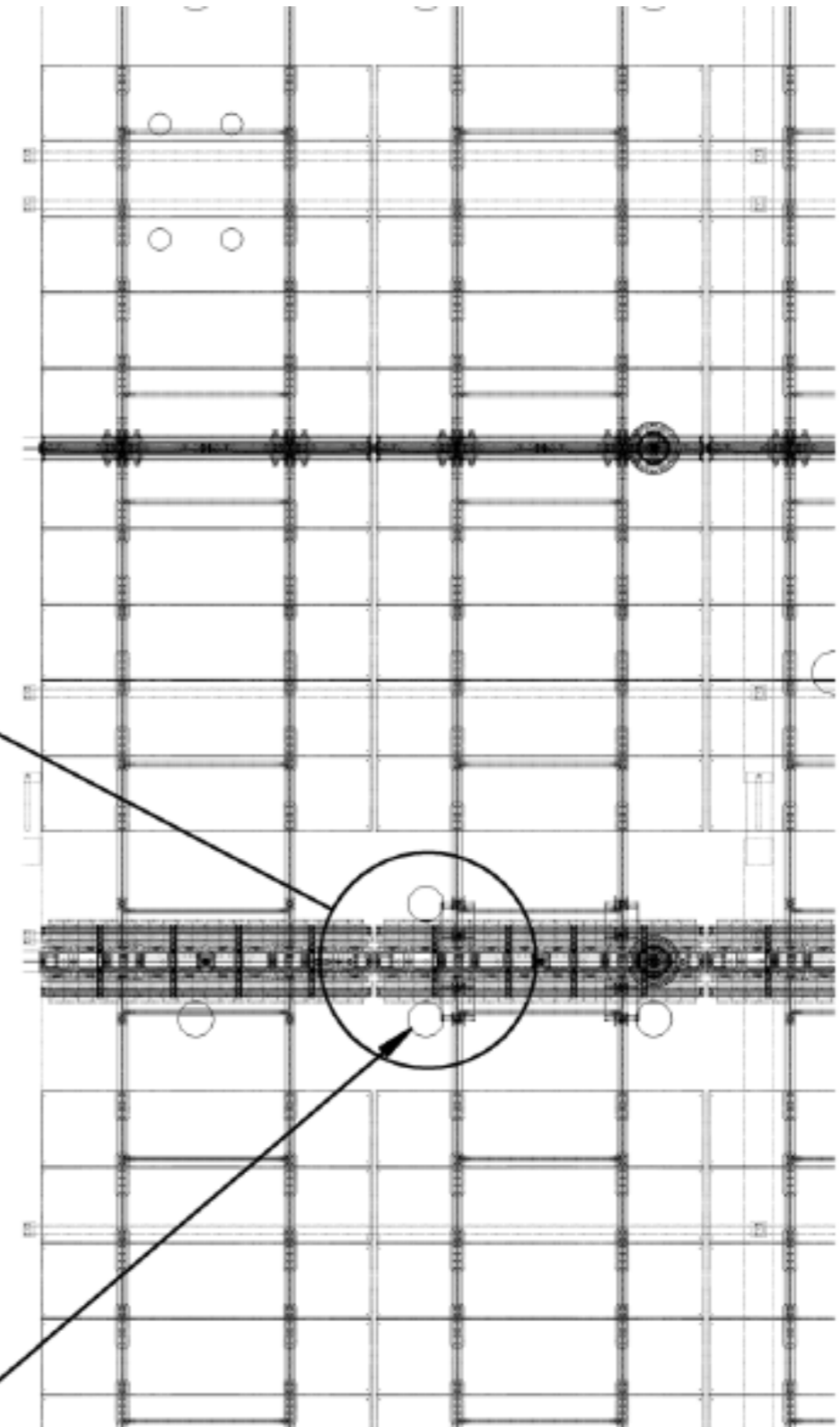
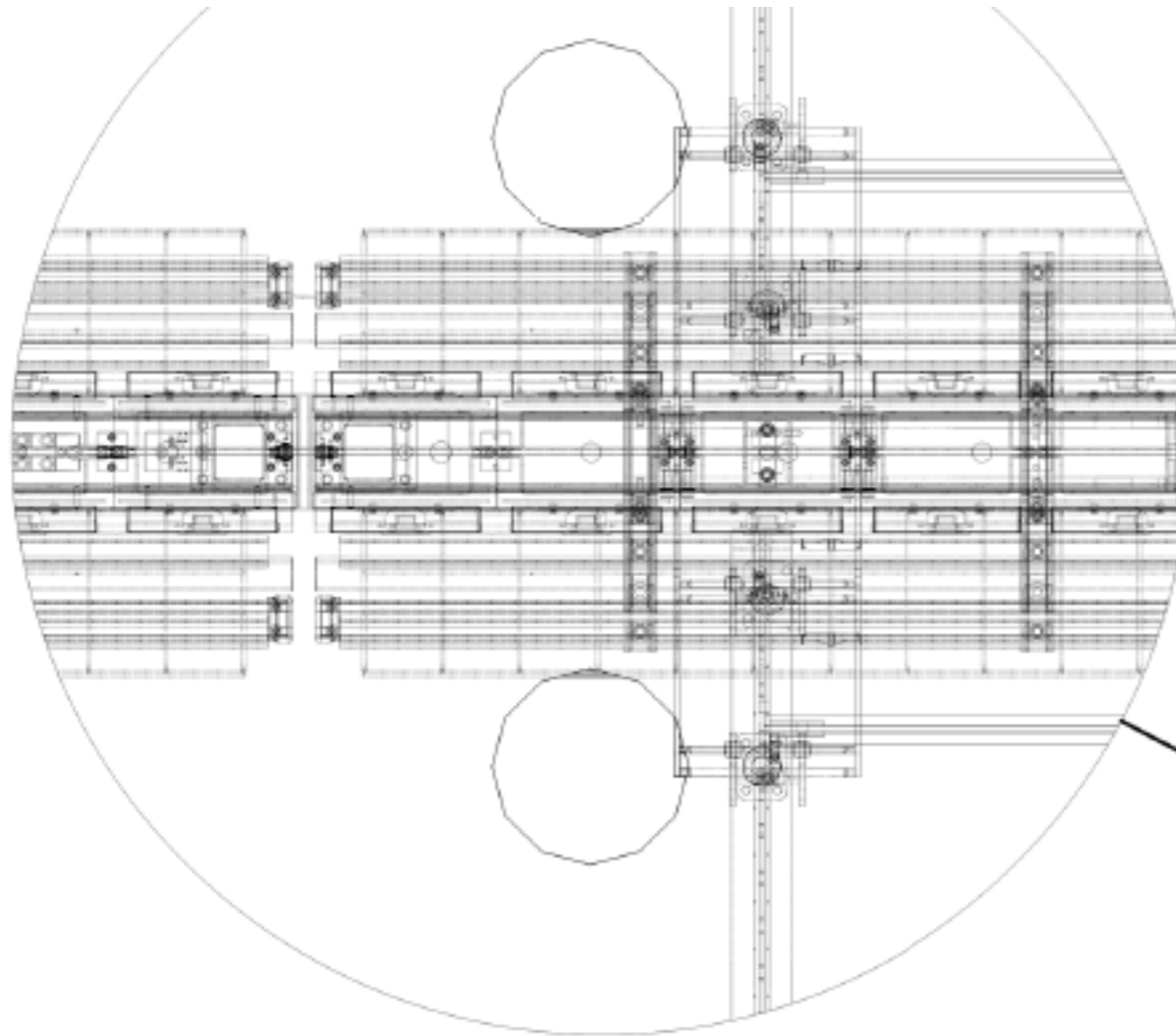
We are planning to assemble all FC modules underground. A special set of FC profiles with non-standard lengths will be fabricated by the “factory” and shipped to SURF. These special modules will be clearly marked in storage.



Bo Yu



Laser Point Position 2



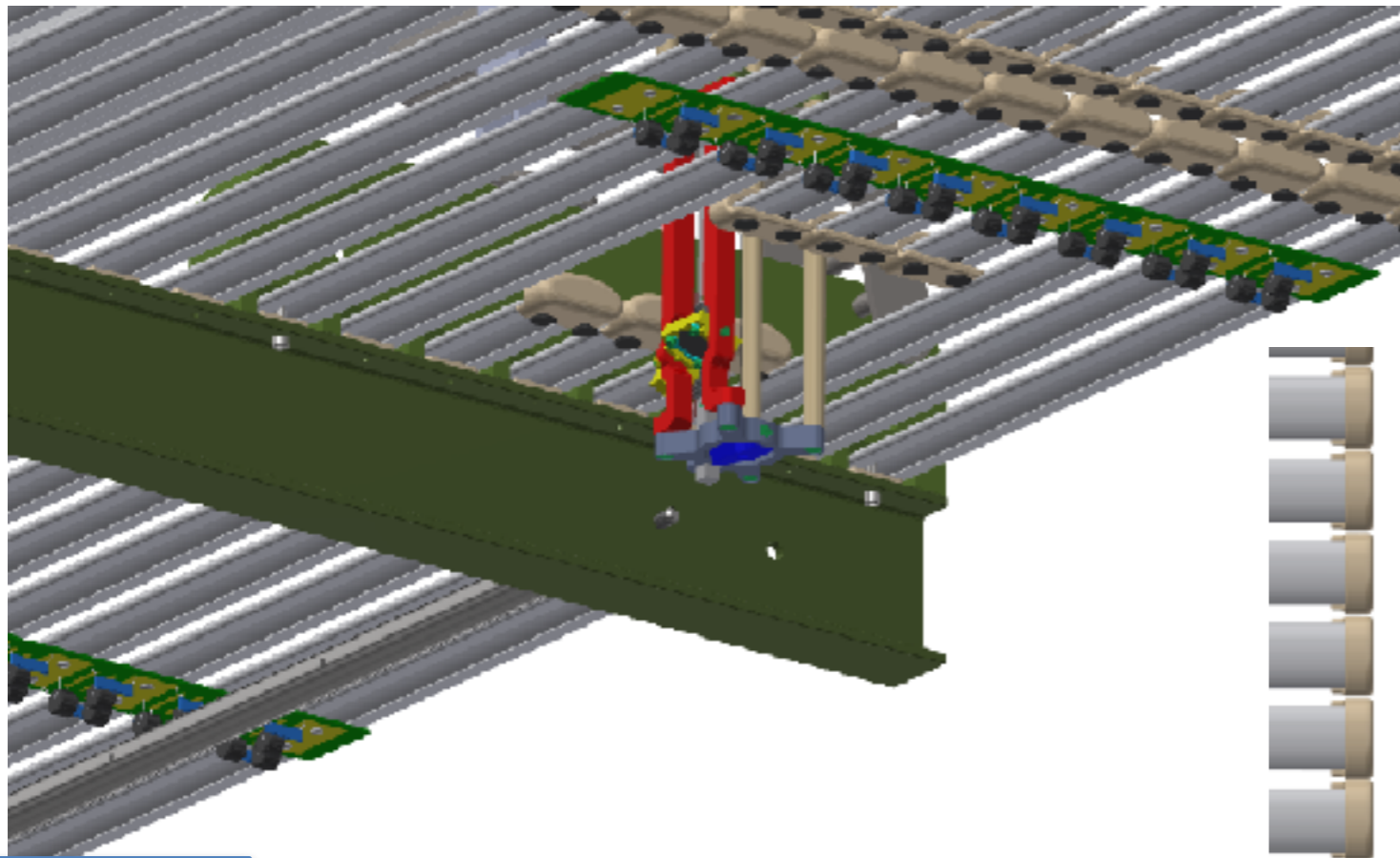
Instrumentation/Calibration
31800mm from TCO
1 of 4

Bo Yu

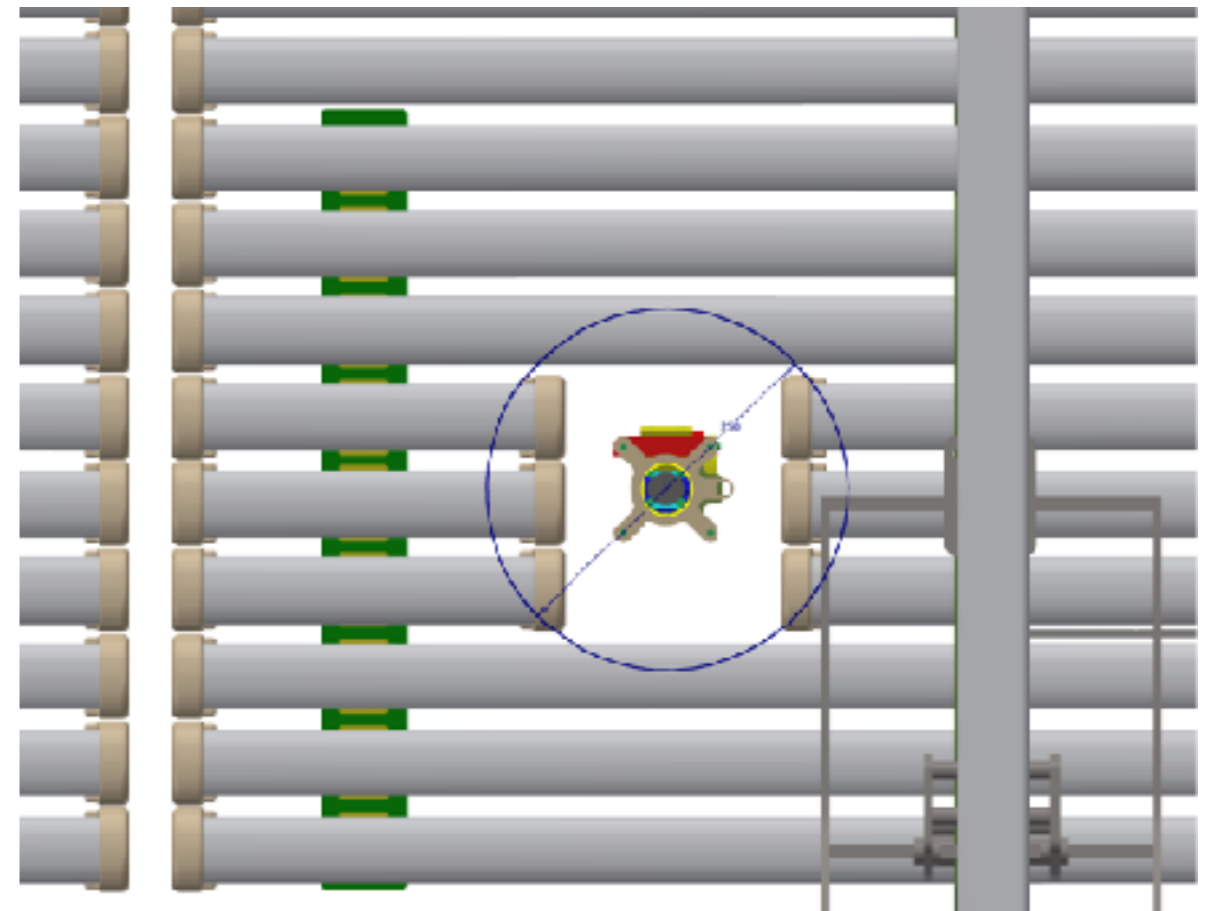
https://edms.cern.ch/file/2060543/1/Detector_Views_Center_2060543.pdf

Laser Point Position 2

Cut the profiles on FC module into a long, and a short sections. The long pieces are mounted on the I-beams as usually. The short pieces are supported locally by the uncut profiles. In fact, a special R divider board could be used for both the mechanical support and electrical connections. This divider, and the one it is connected to in parallel must have double per tap resistance. No change to the neighboring module.

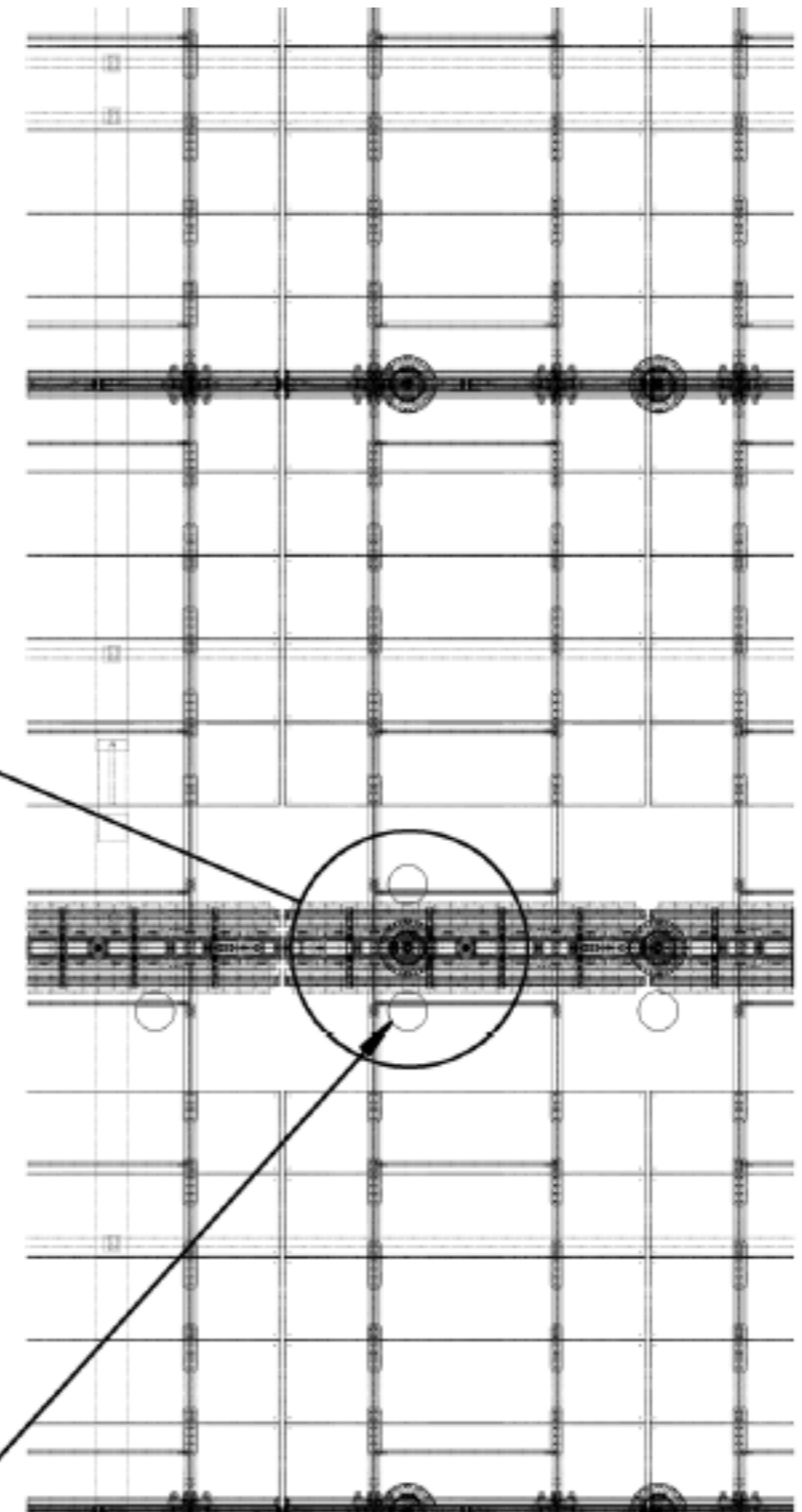
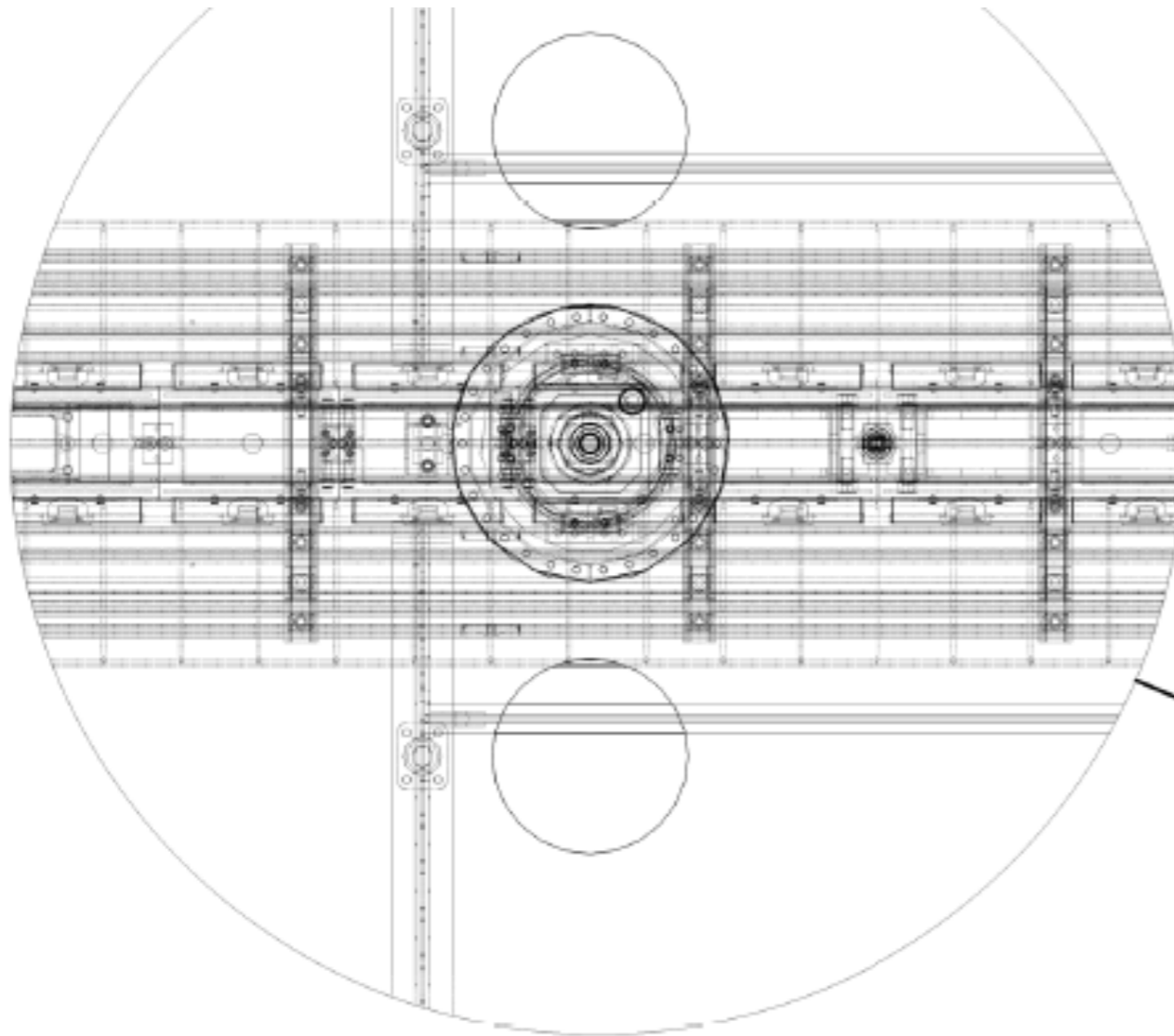


Compared to a standard module, this type will have a slight cost increase in M&S and labor.



Bo Yu

Laser Point Position 3



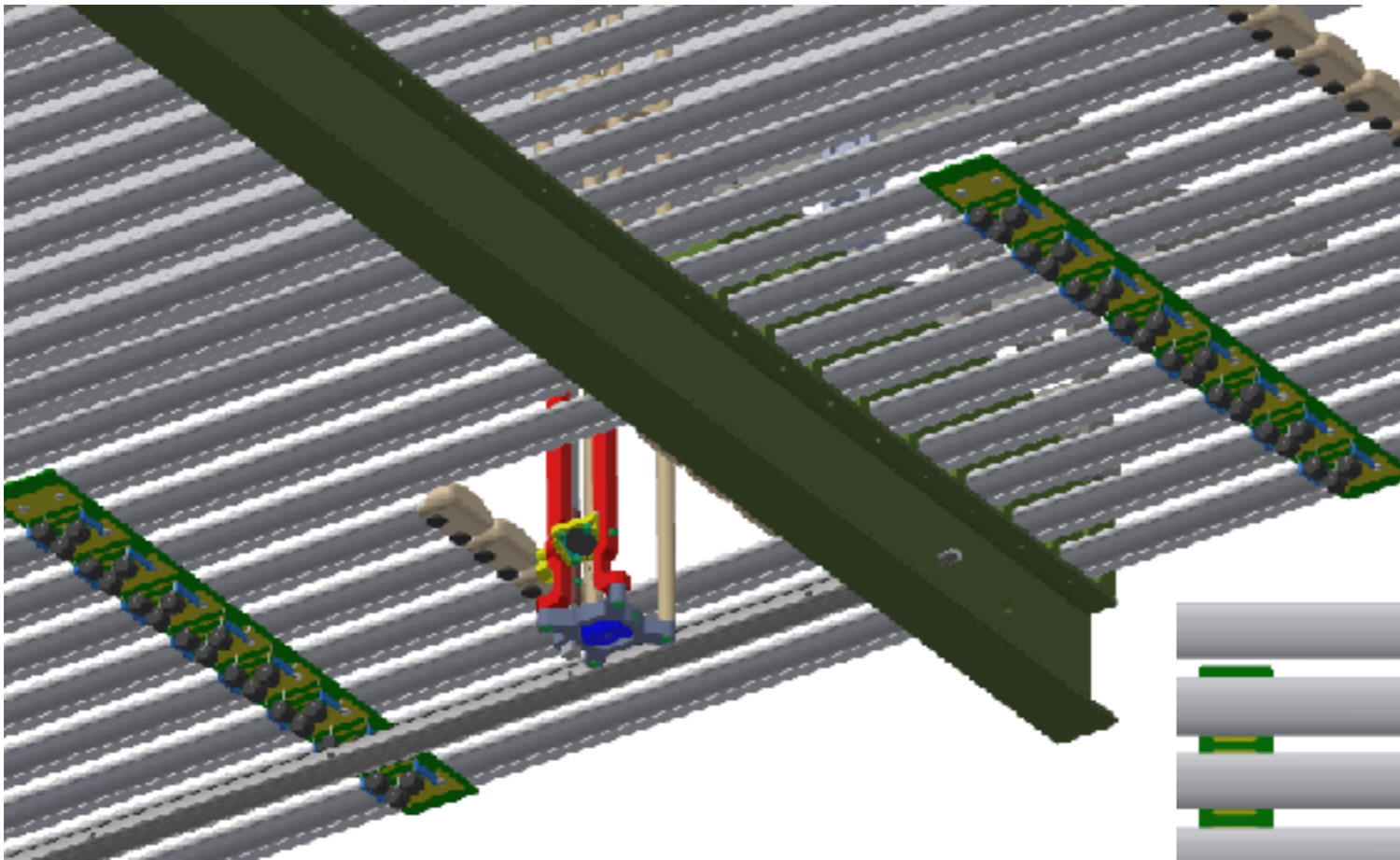
Bo Yu

Instrumentation/Calibration
17400mm from TCO
1 of 4

https://edms.cern.ch/file/2060543/1/Detector_Views_Center_2060543.pdf

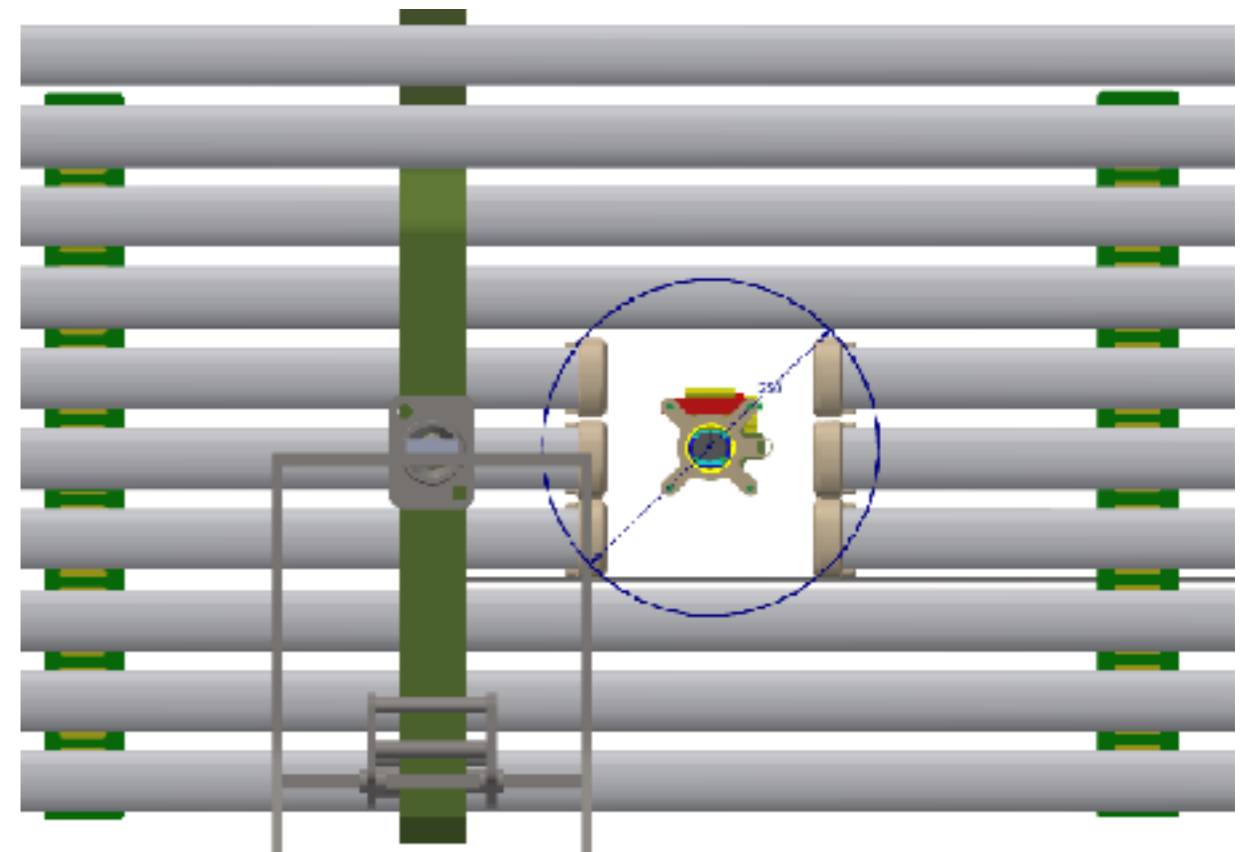
Laser Point Position 3

Cut the profiles on FC module into two sections. Both sections are mounted on one I-beam, and stabilized by special double value R divider boards.



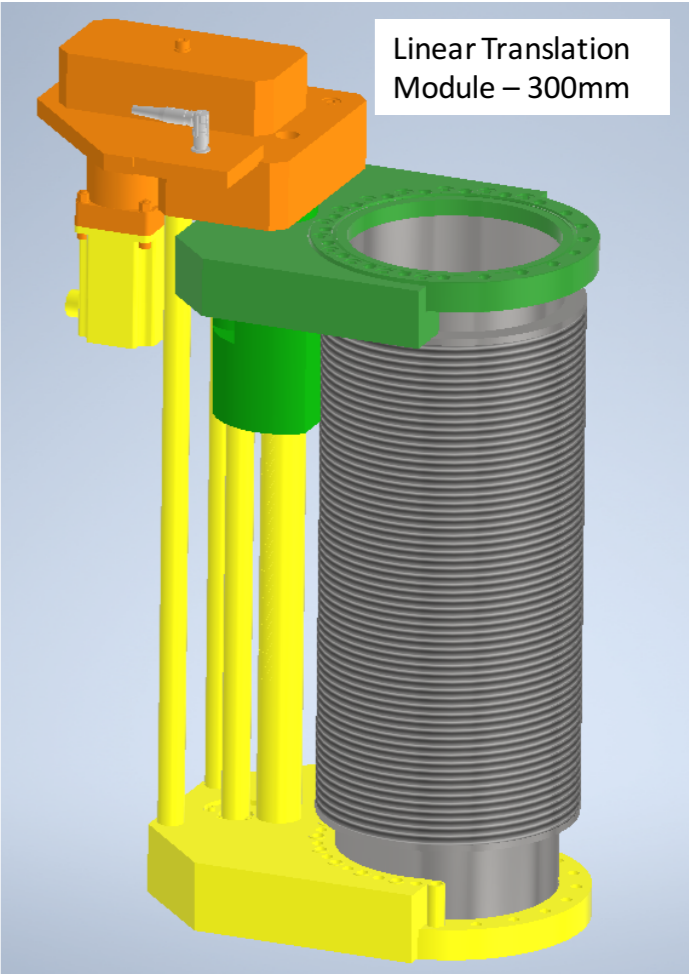
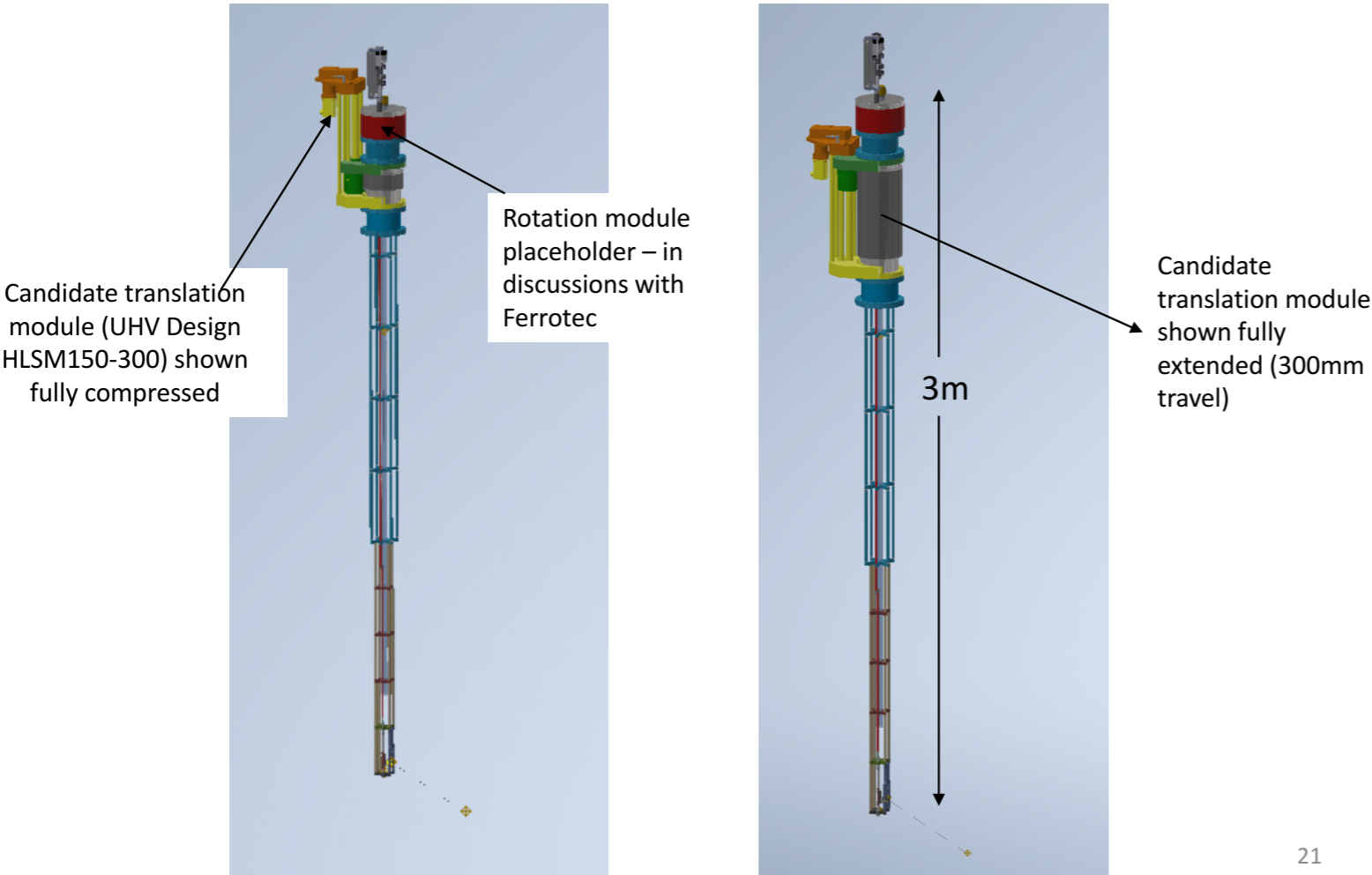
A small cost increase similar to the previous design is expected.

Bo Yu

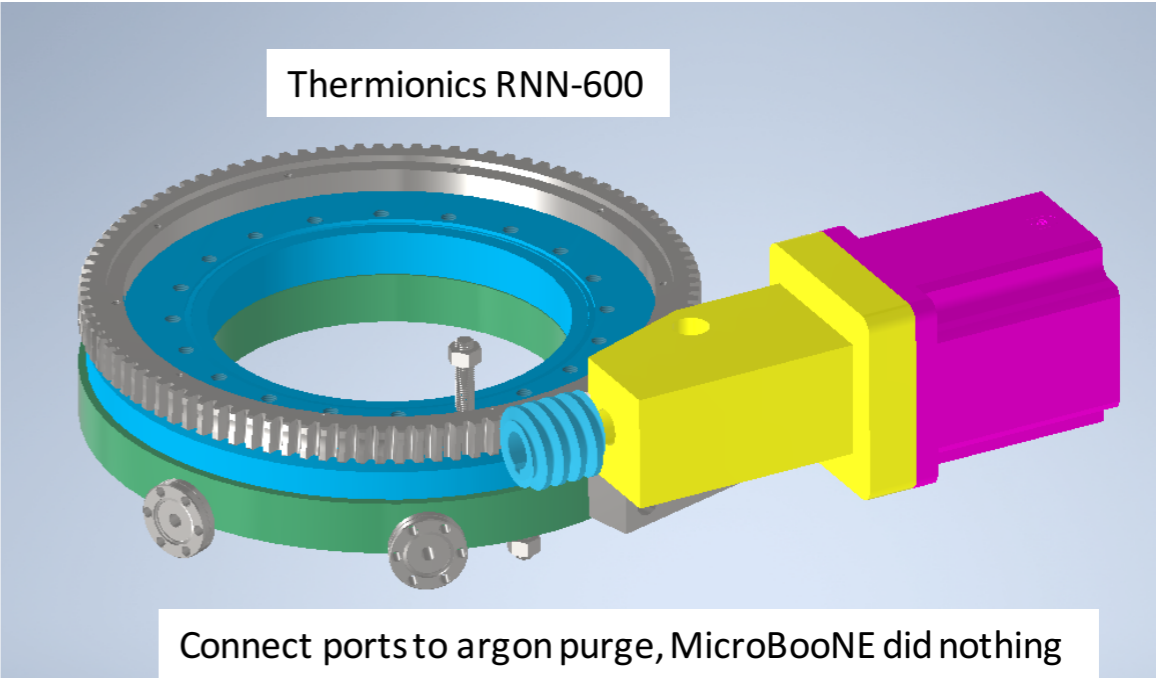
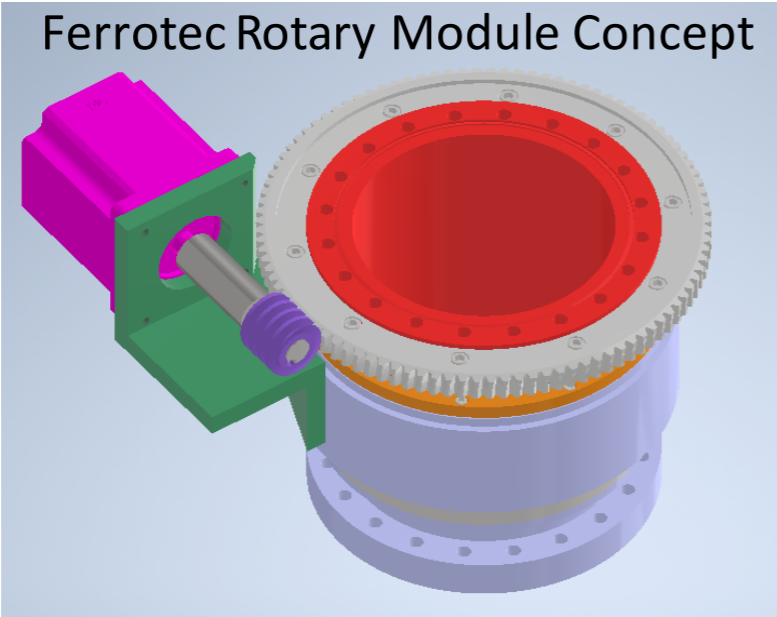


Periscope Retraction

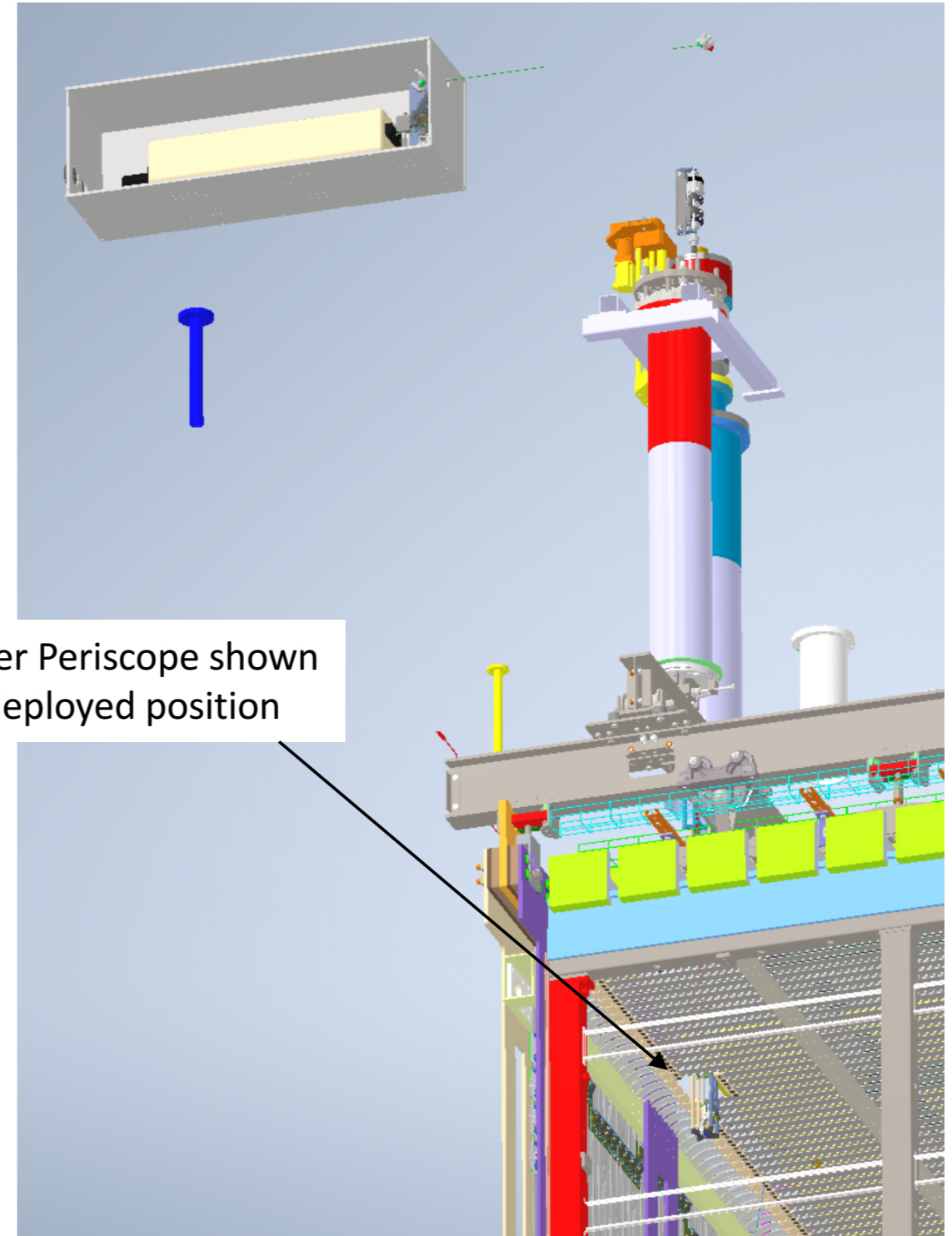
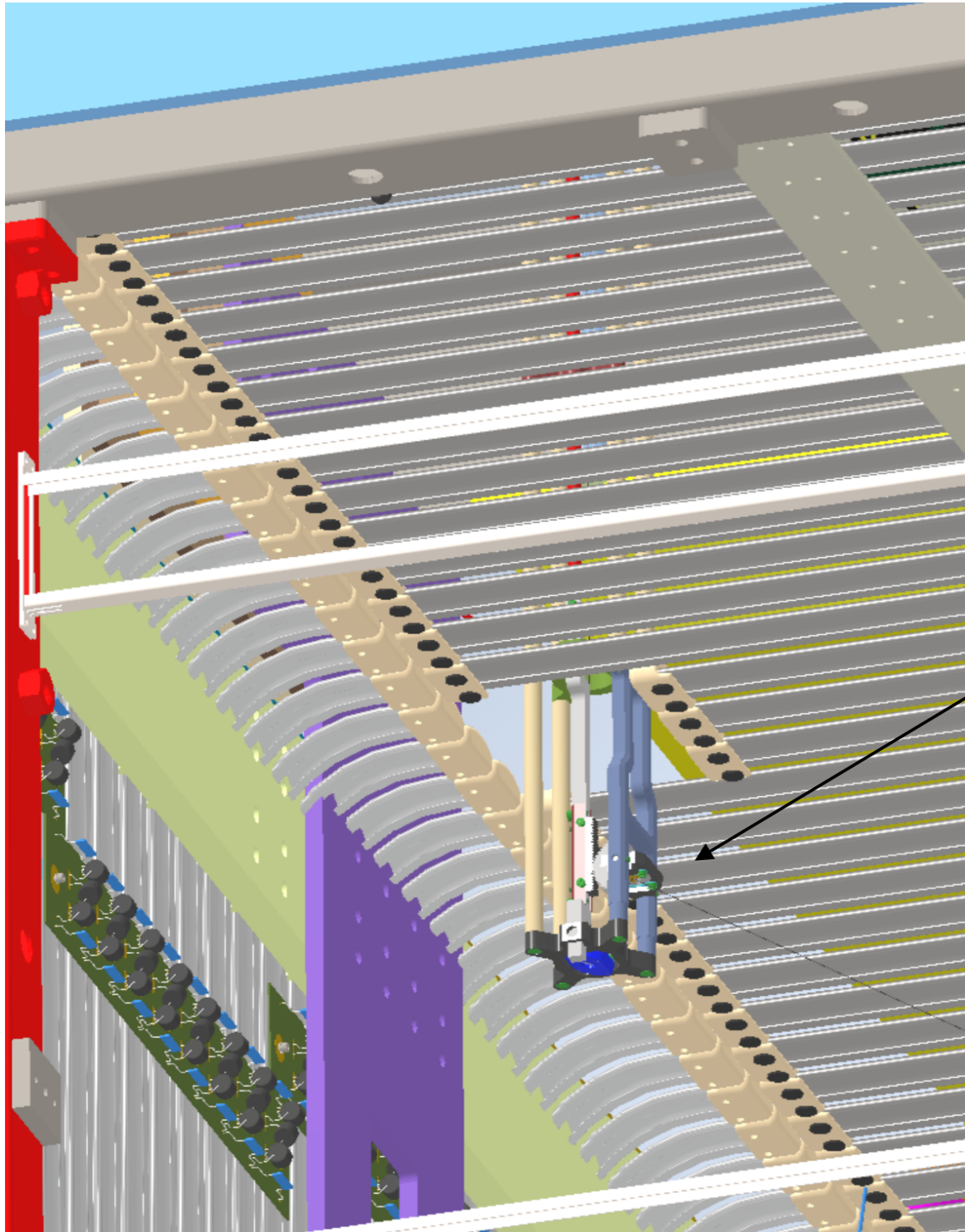
Laser periscope with rotation and translation (periscope for ProtoDUNE-SP)



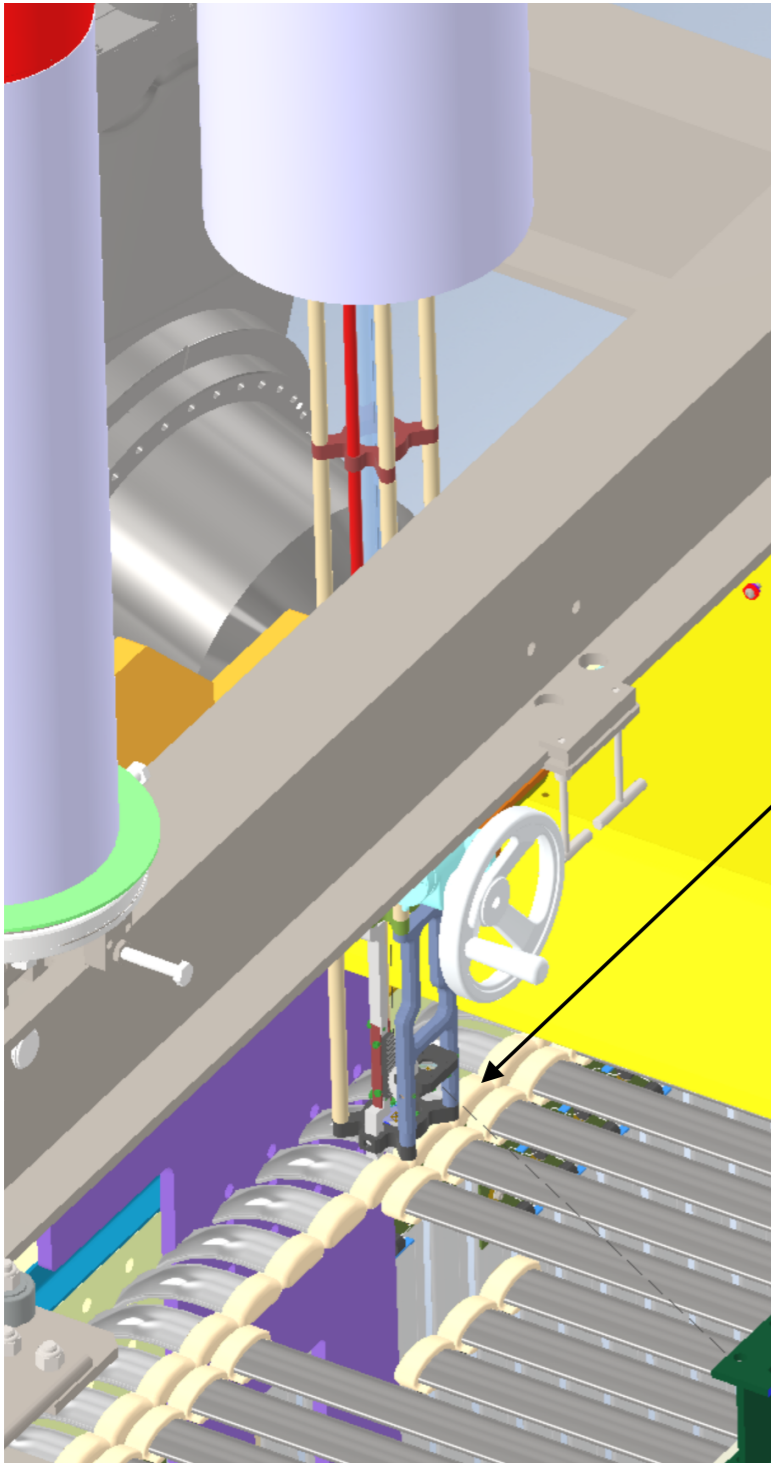
21



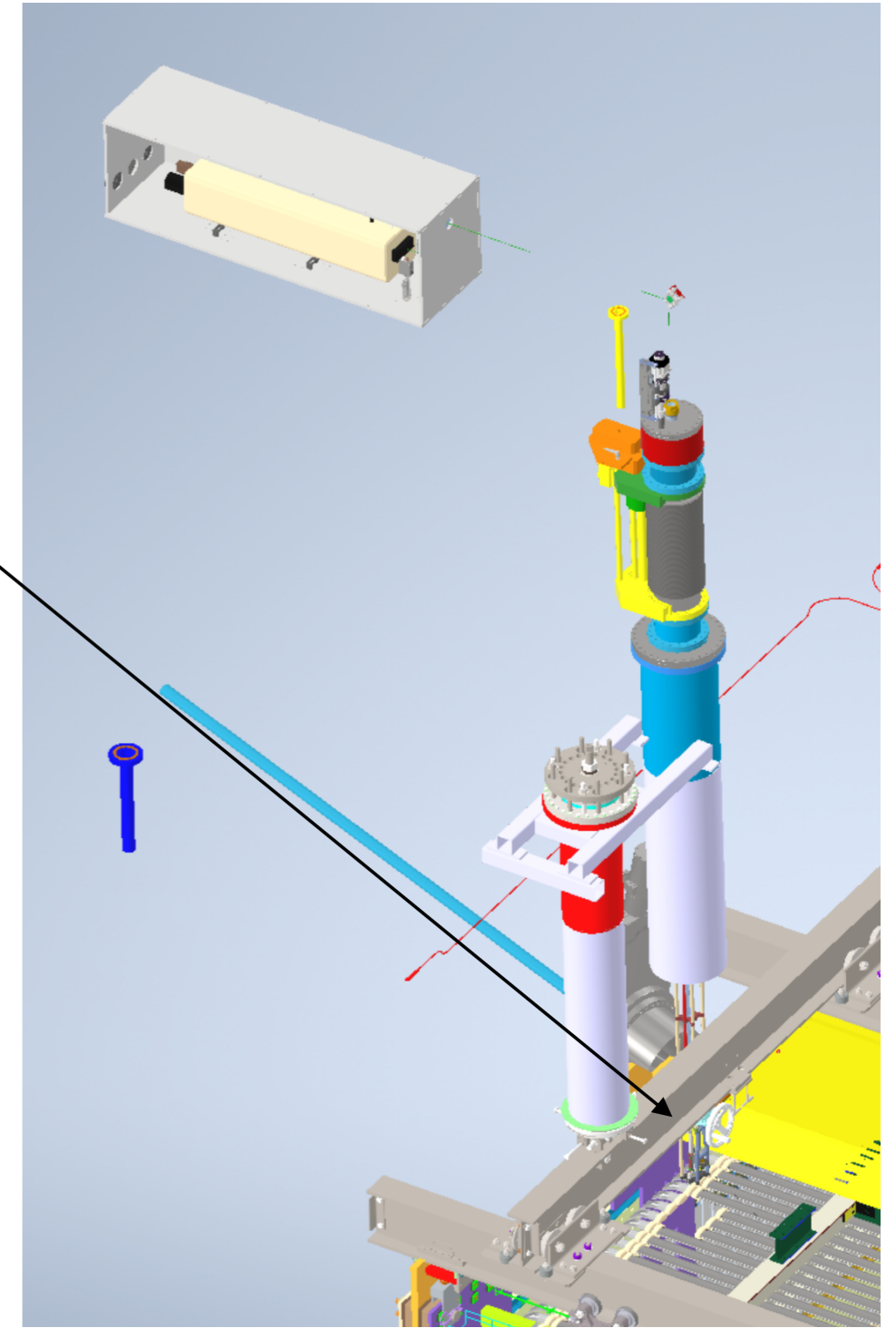
Laser Periscope in ProtoDUNE



Laser Periscope in ProtoDUNE



Laser Periscope in retracted position

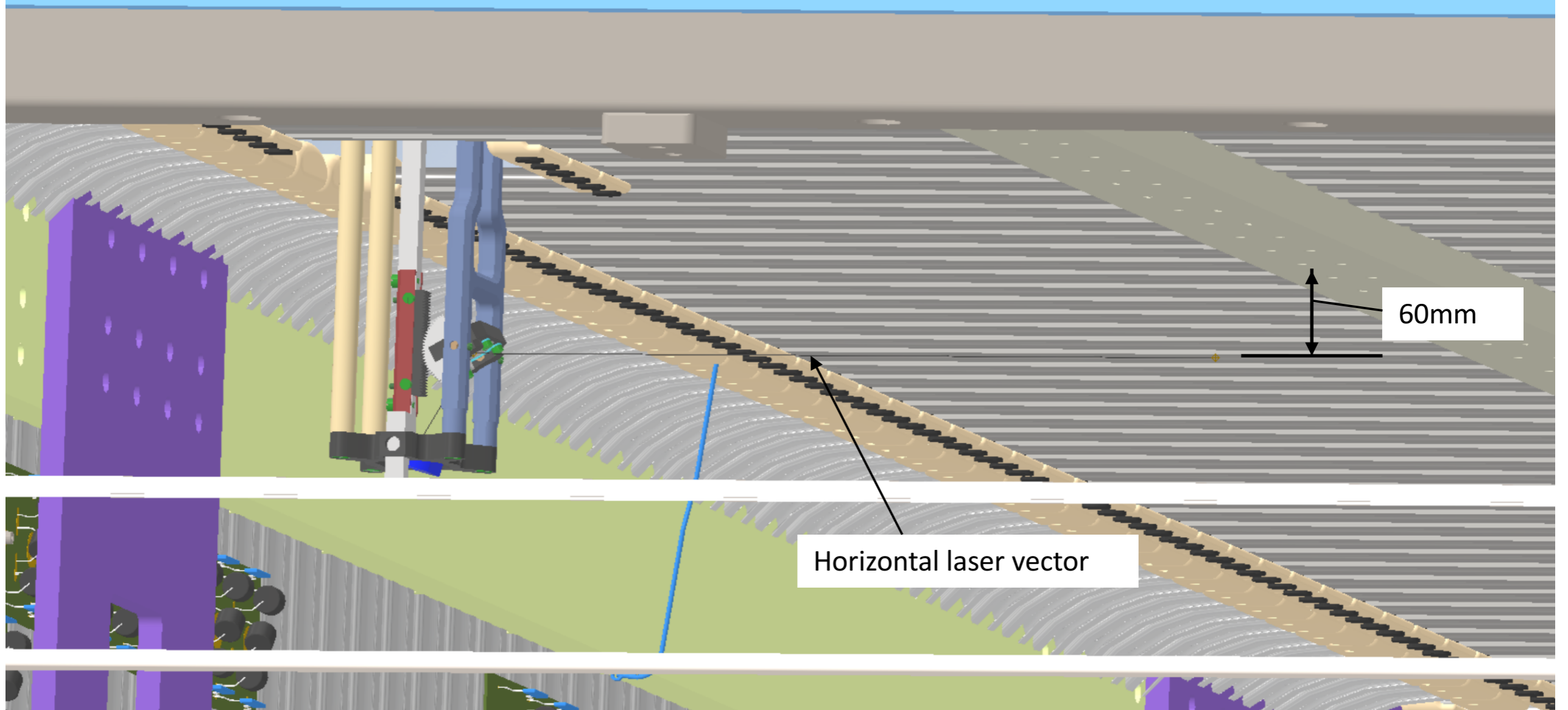


Laser Periscope in ProtoDUNE

How much to go into the FC?

Need to get the bottom mirror below the I-beam

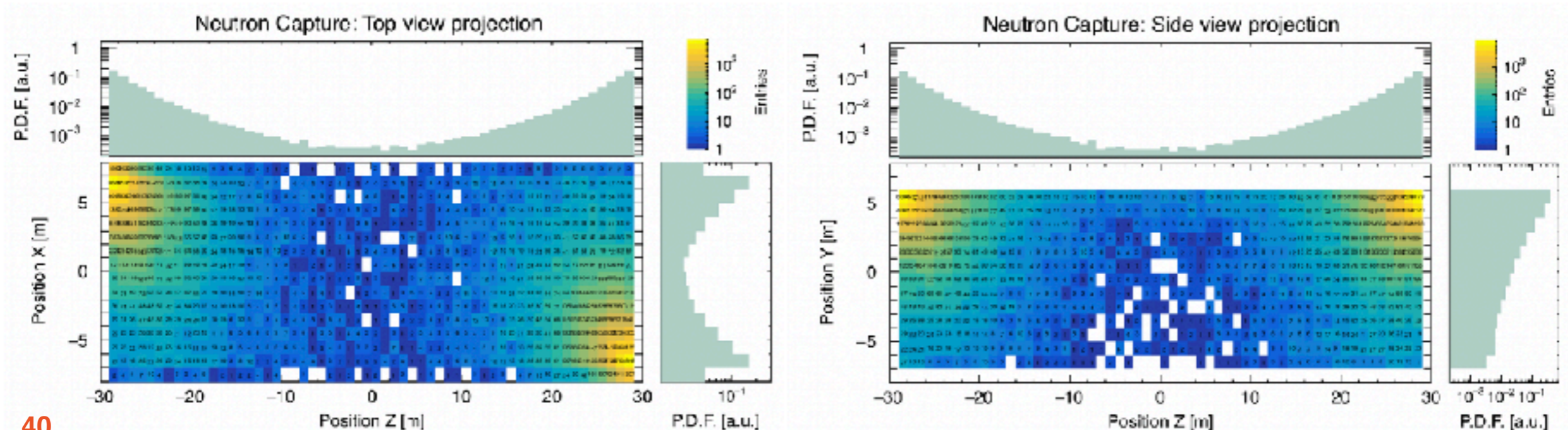
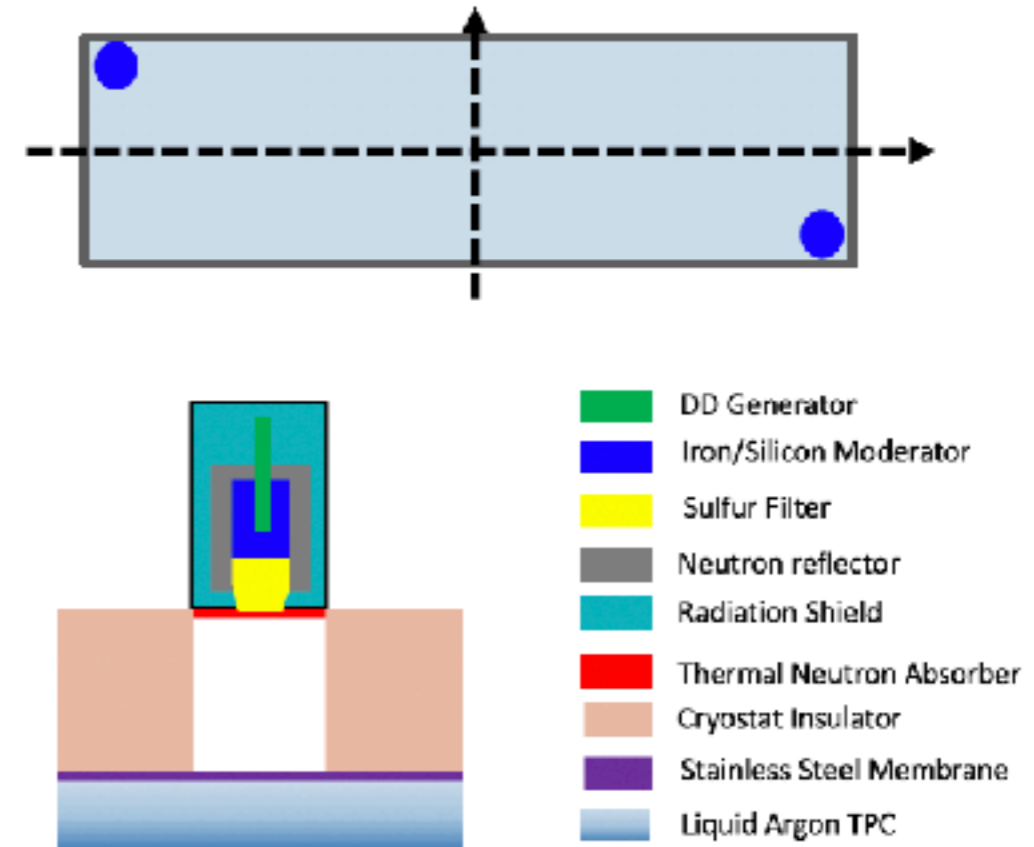
In DUNE, it penetrates more as the I-beam is longer



PNS Baseline Design

J. Wang, R. Svoboda

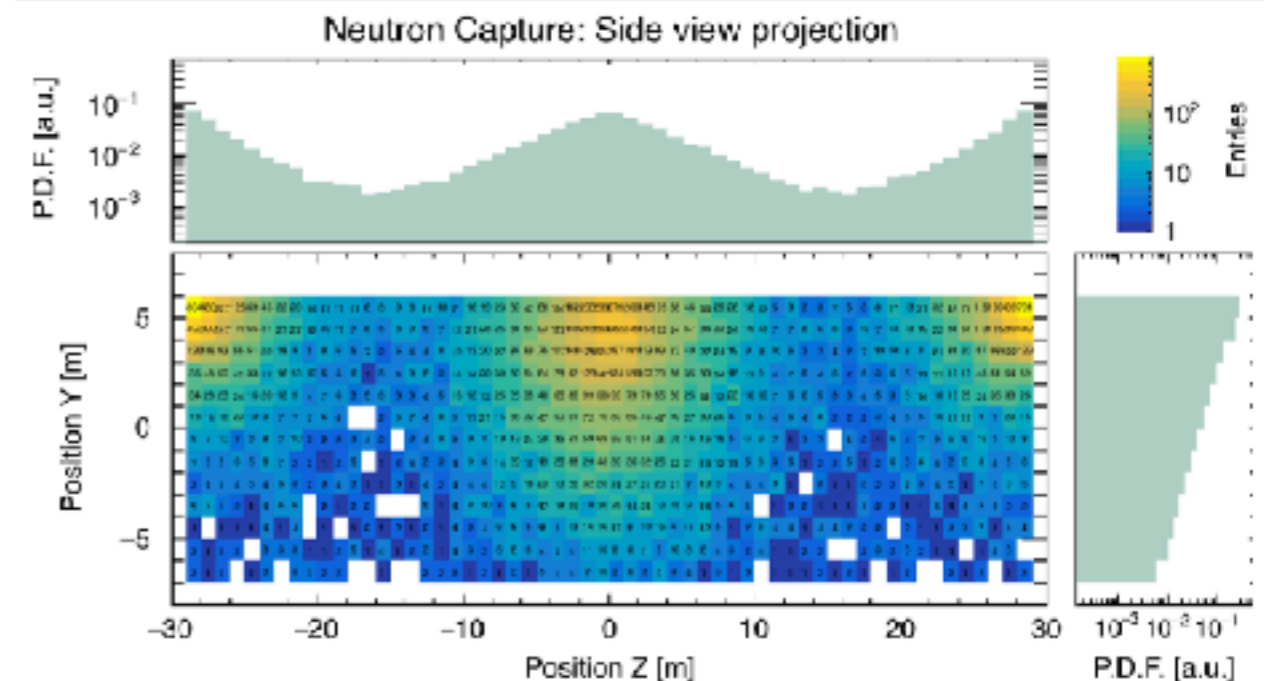
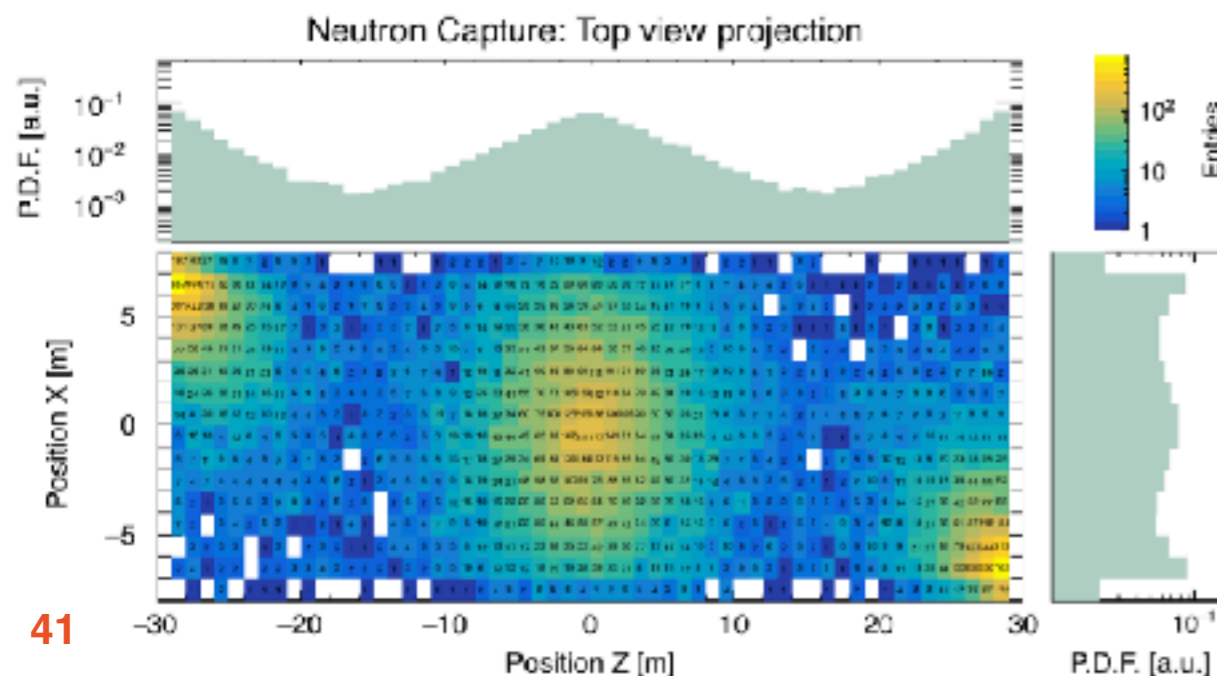
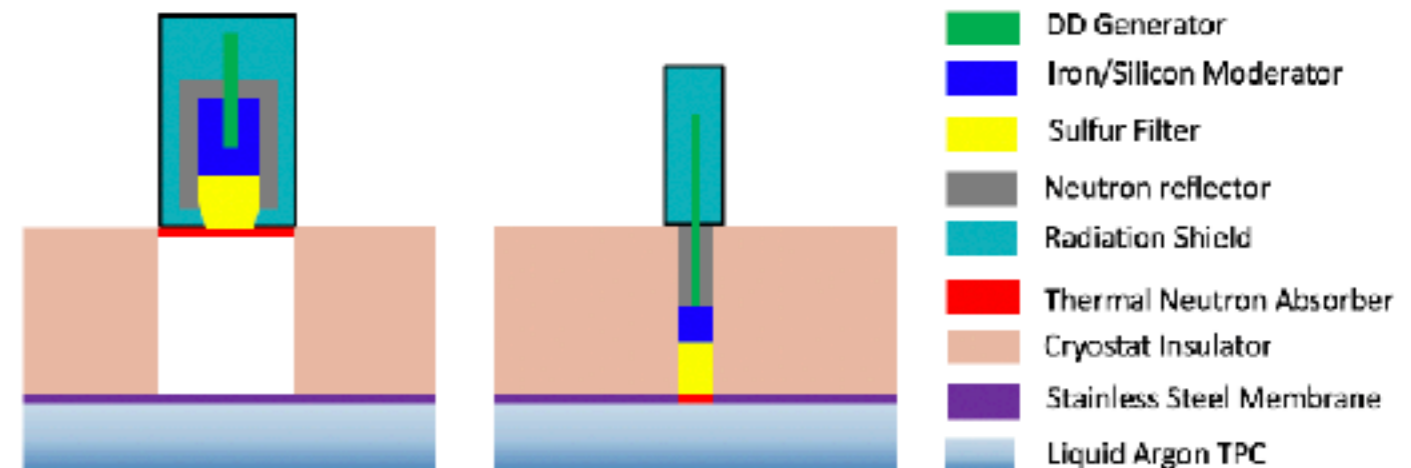
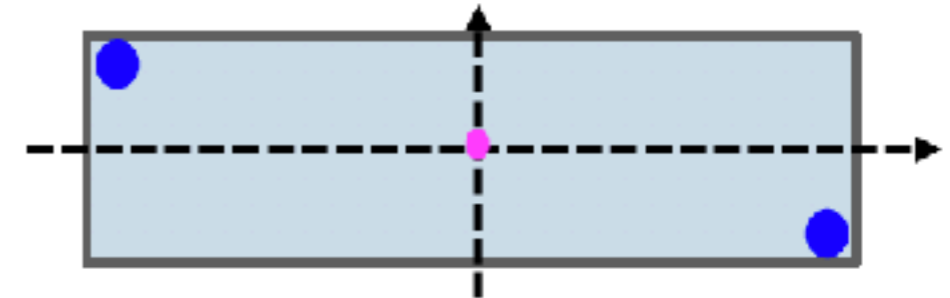
- Two PNS systems are deployed at the human access port locations on opposite sides of the cryostat
- This configuration provides high neutron capture yield at the edges but low coverage at the center



PNS Alternative Design

J. Wang, R. Svoboda

- Two PNS systems are deployed at the human access port locations on opposite sides of the cryostat
- One small format PNS system at the center using one of the 25 cm feedthrough ports
- Better coverage

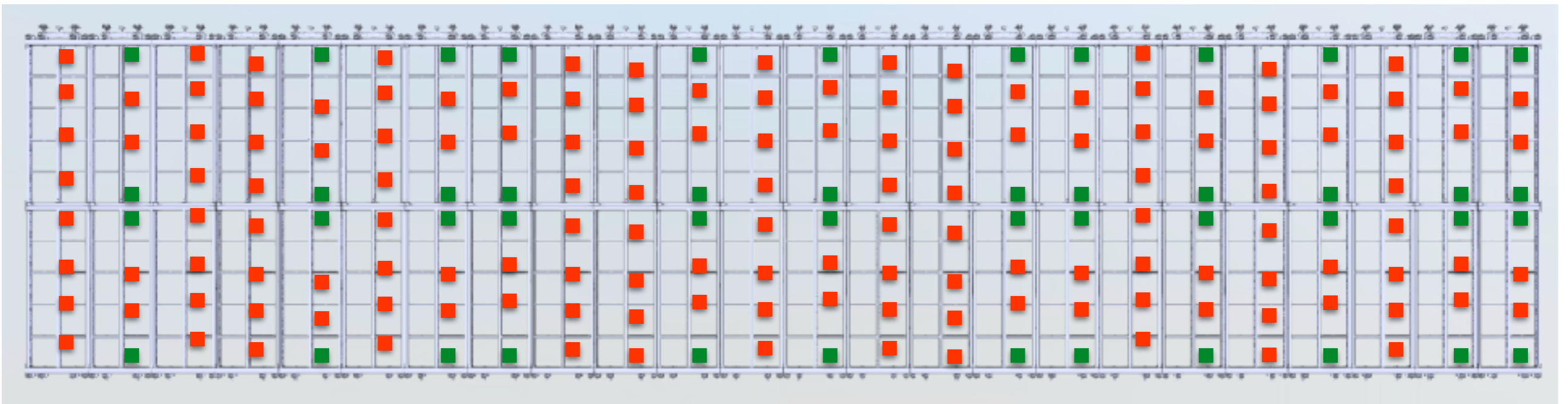


Proposed distribution

- The proposed distribution is half of the APA doublets with 8 precision sensors in LAr and the other half with 4 precision sensors in LAr and 4 standard sensors for APA frame measurement

- standard sensor touching APA frame (148)
- precision sensor in LAr (452 sensors)

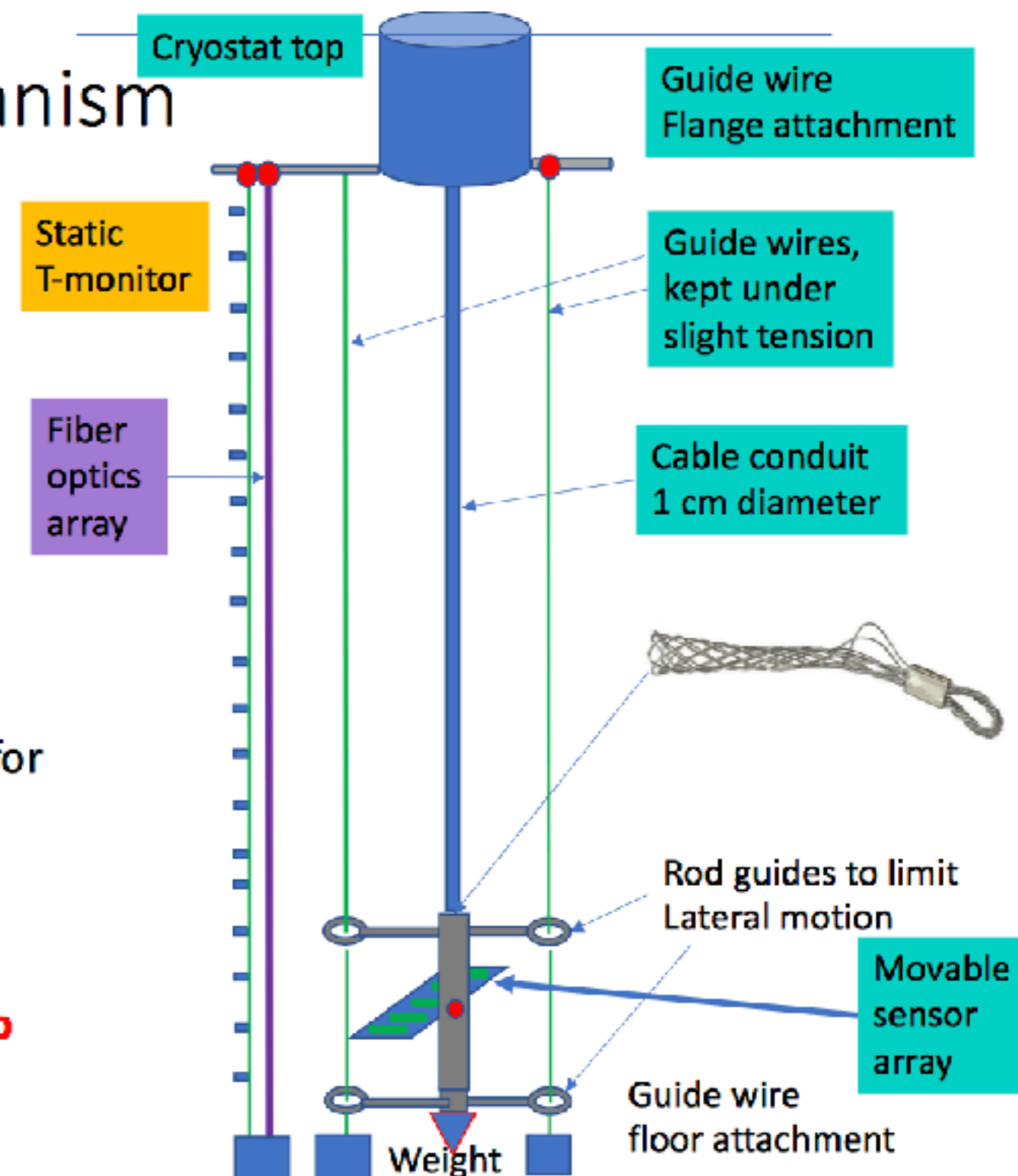
side view of an APA row



Dynamic Thermometer re-design

Sensor rod motion mechanism

- 5 sensor cables grouped together inside cable conduit
- Cable conduit has 1 cm diameter
- Cable conduit contains thin (1.5 mm diameter) stainless steel cable to avoid cable sagging
- Cable conduit and the stainless steel cable is attached to the top of the sensor rod to eliminate stress on the cables
- Cable conduit flexible; perforated to eliminate gas pockets.
- Weight on the bottom of the sensor rod keeps the cable conduit under tension (also account for buoyancy in LAr).
- Guide wires limits the upward motion of the sensors. Motor current is limited.
- Guide wire anchored on the static array.
- **Fiber optics design should be relatively easy to integrate with static monitor array sitting alongside the movable sensor array.**



Dynamic Thermometer re-design

Motion mechanism

- *Reuse motion mechanism from the current system as much as possible*
- Stepper motor drive
- Ferrofluidic seal to transfer the rotary motion to the spool
- Extra cable slack wind up on a spool. Spool will introduce additional uncertainty in z on the order of a few cm – not an issue
- 10 cm diameter spool, 10 cm height – 4 layers of cable conduit on the spool

