Photon Detector Design Overview

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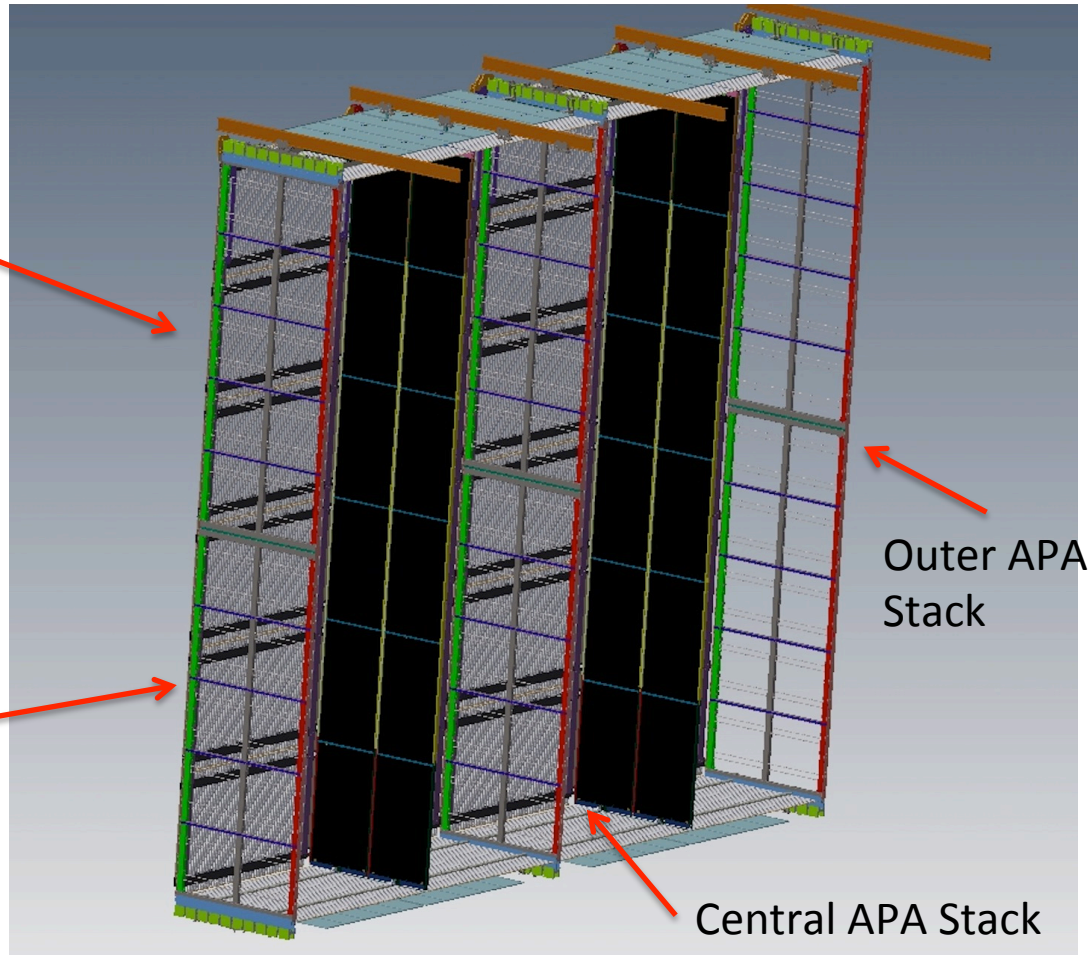
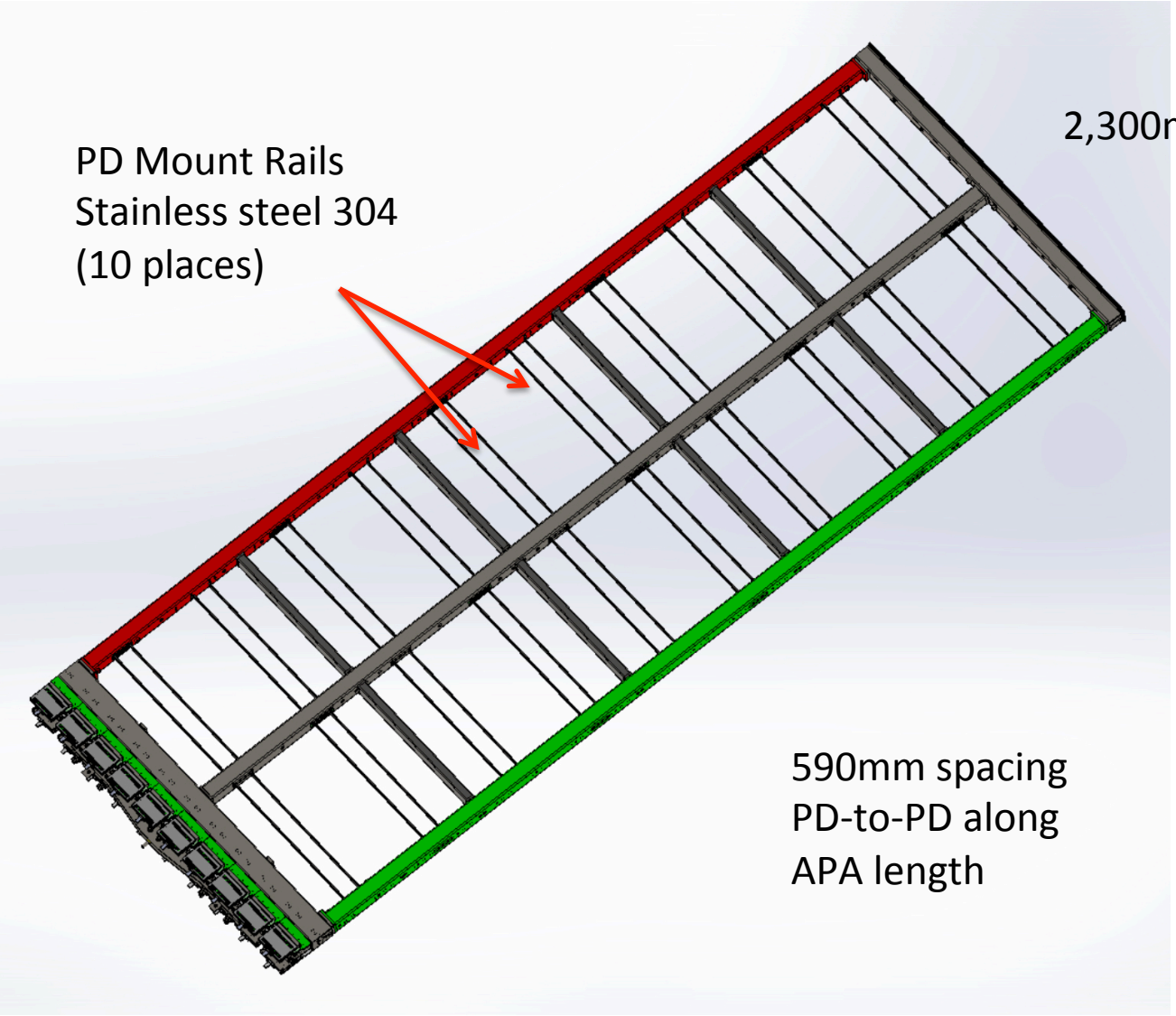
Single-Phase Photon Detector Consortium
November 12, 2018

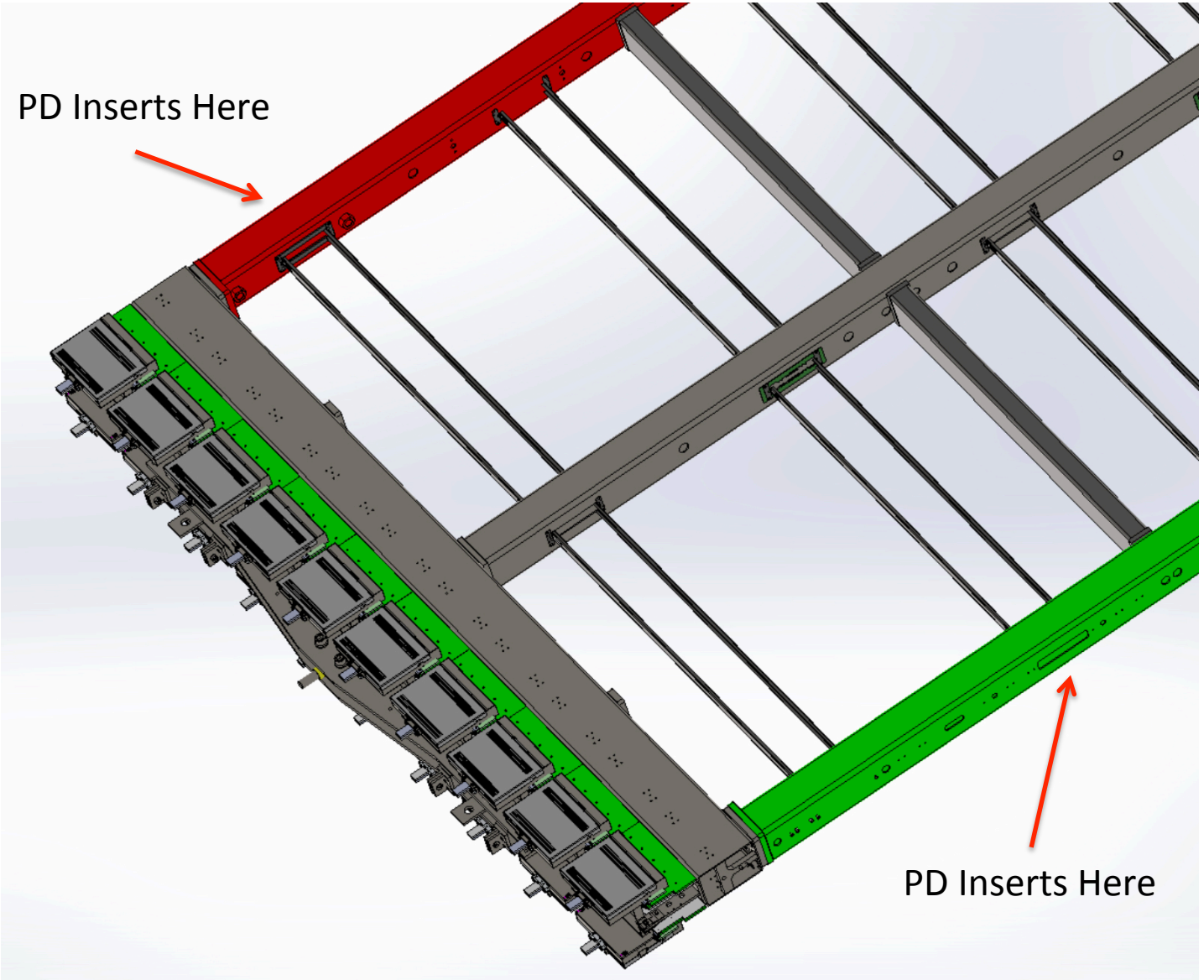
One Row of TPC in DUNE (1 of 25)



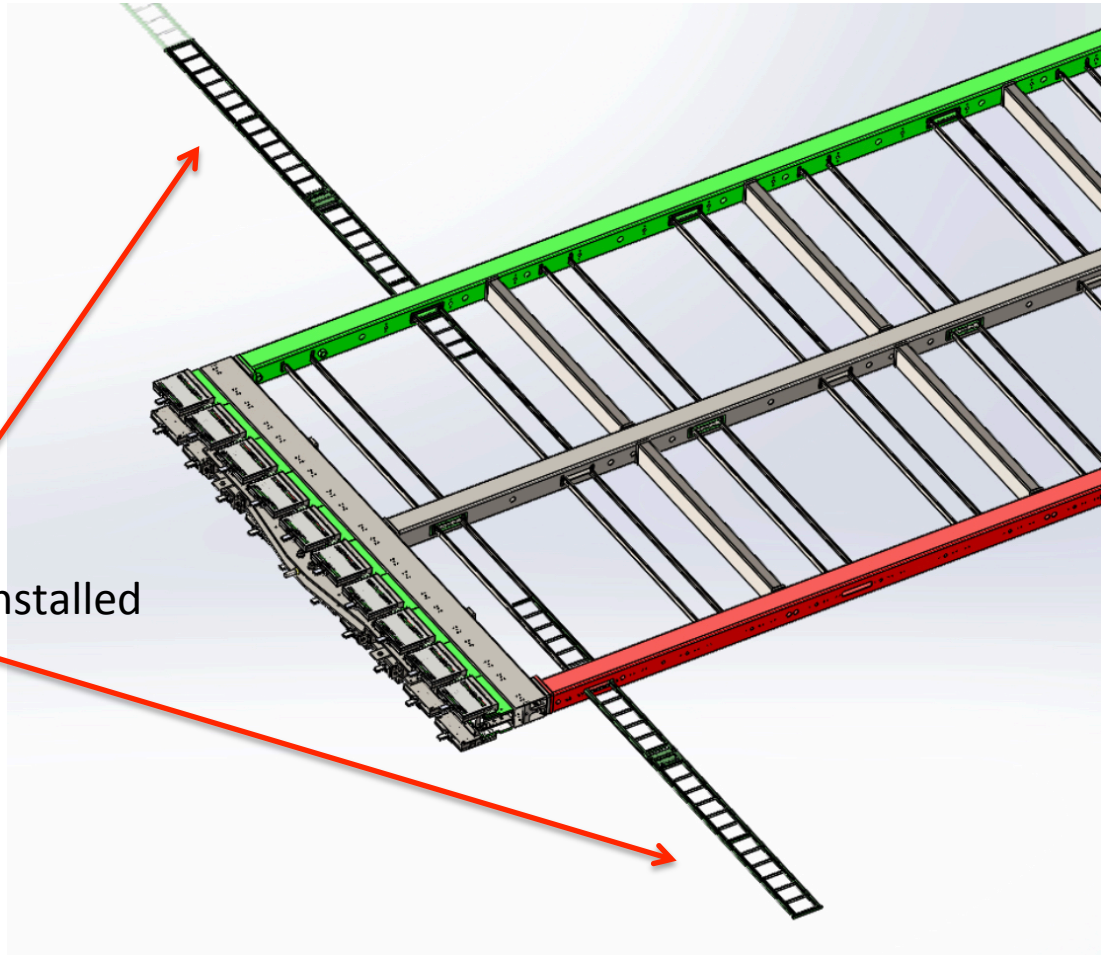
APA Frame with PD Mount Rails



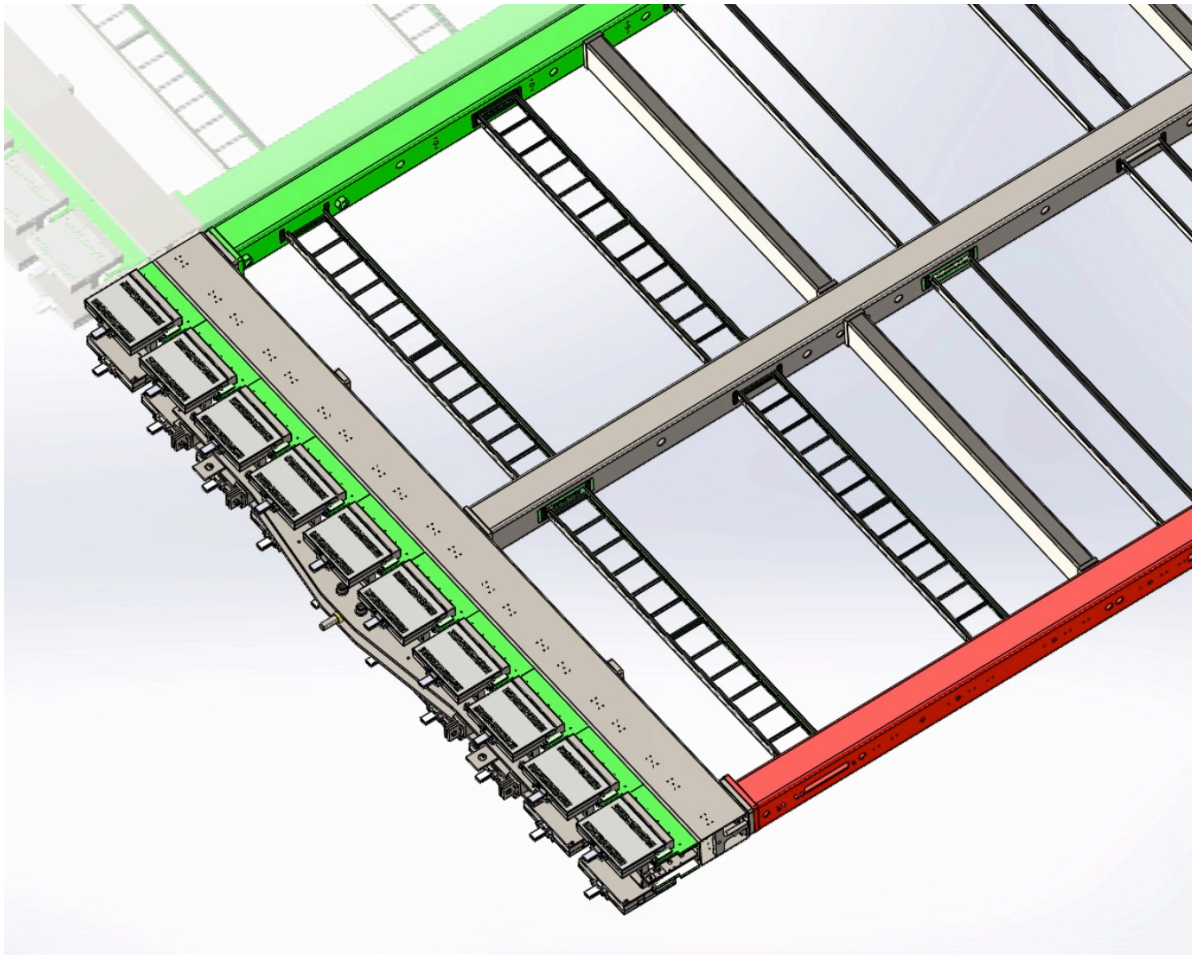
Rail Detail (1 Bay)



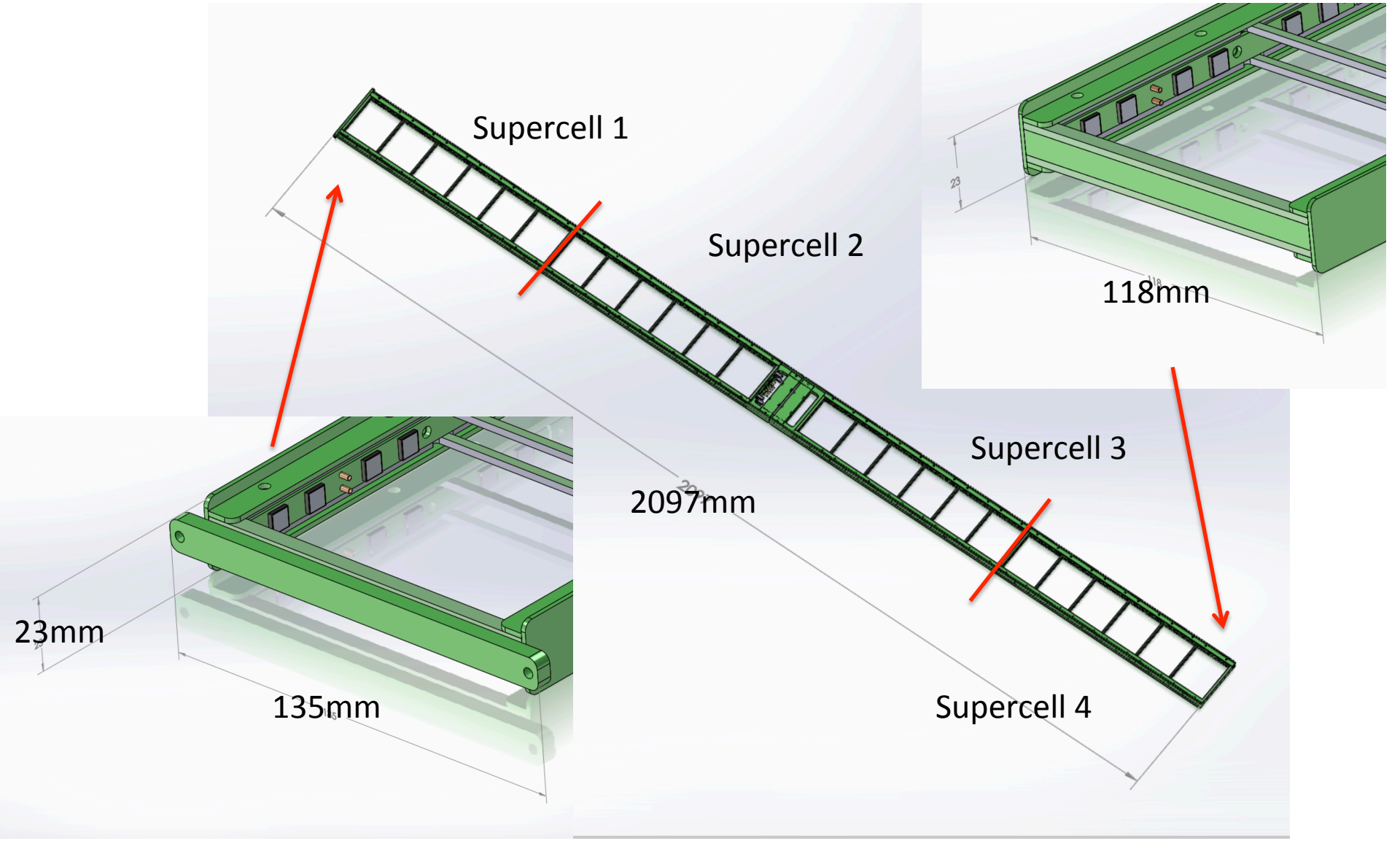
PD/APA Mounting Scheme



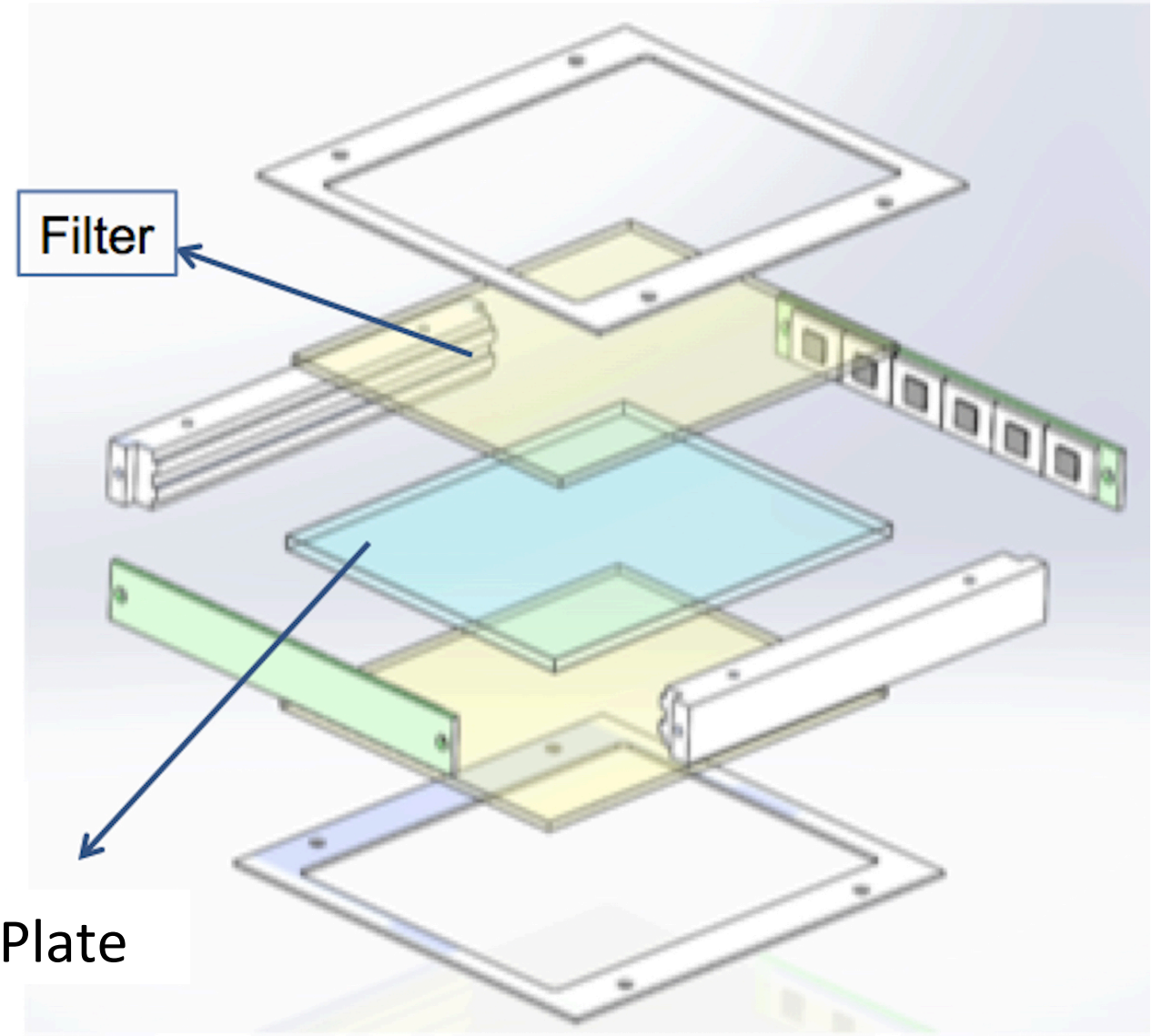
2 PDs installed in APA frame



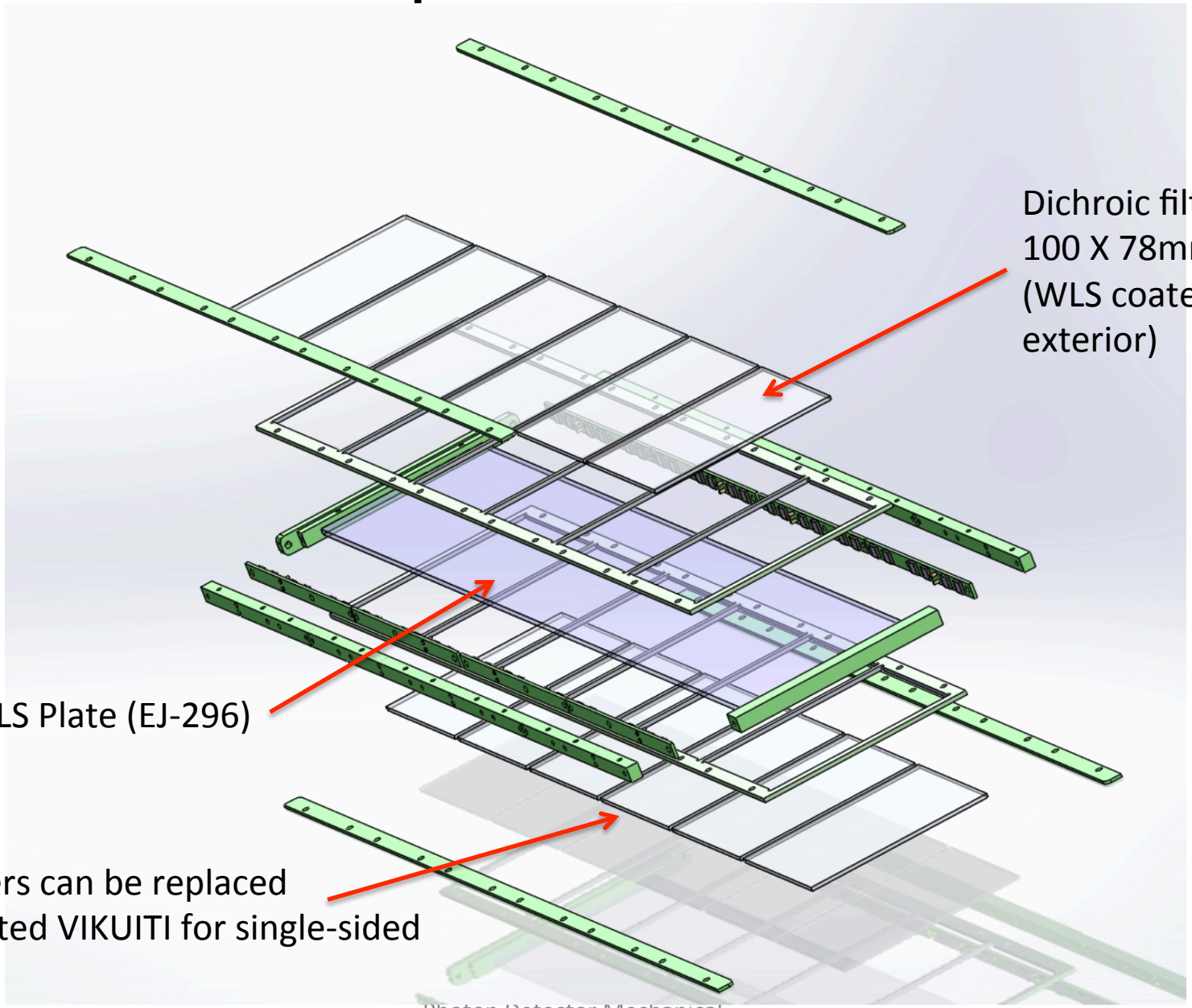
Current DUNE design-- X-ARAPUCA



Simplified Concept X-ARAPUCA



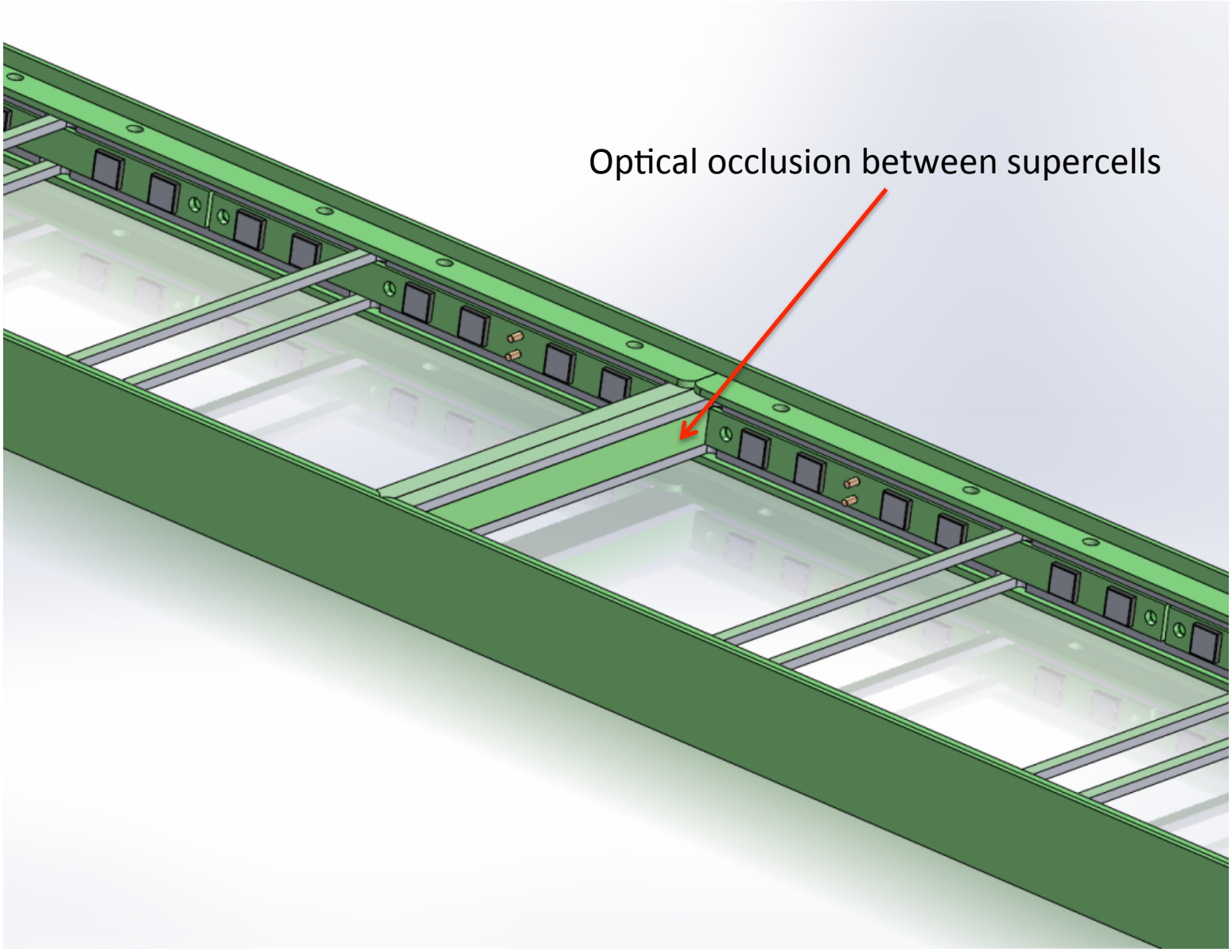
X-ARAPUCA Supercell Detail



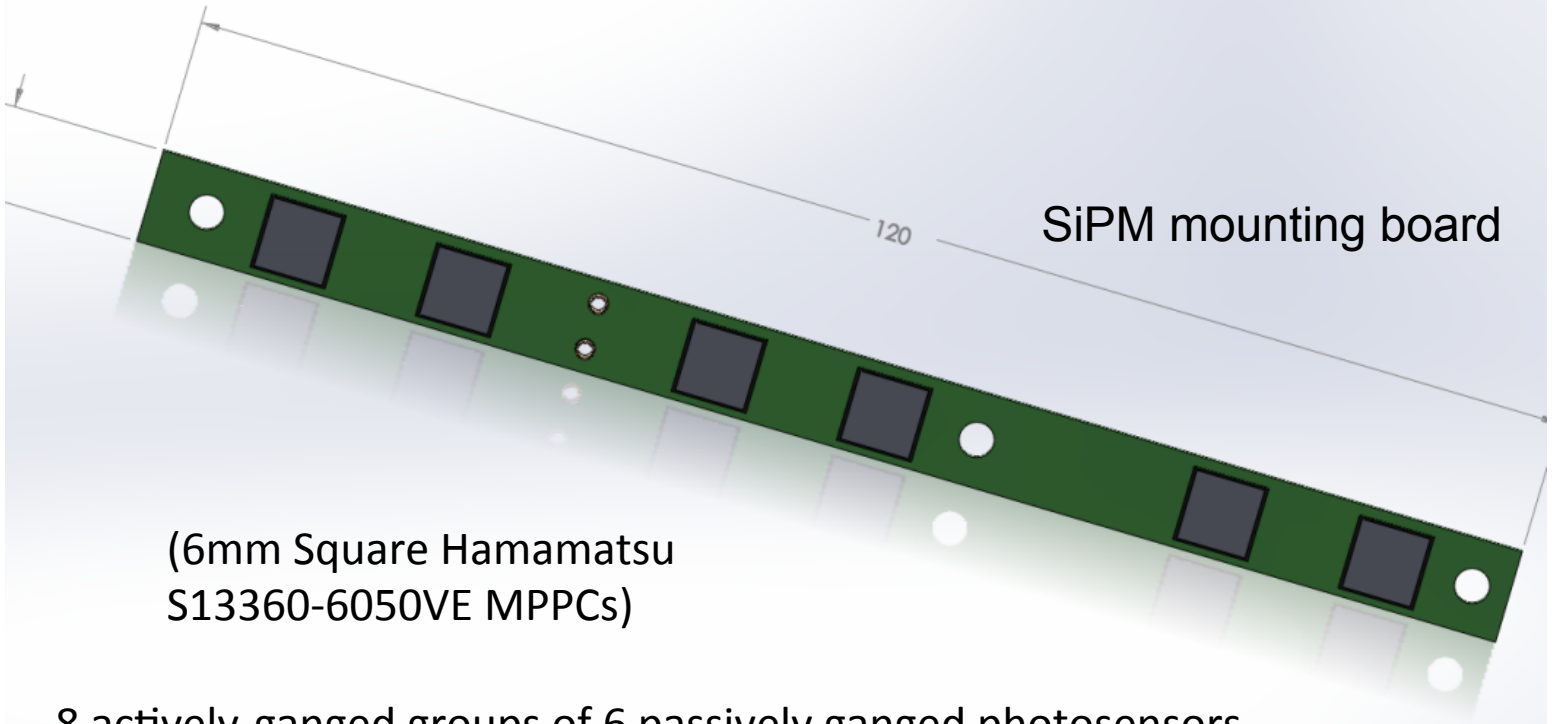
X-ARAPUCA Design
By the Numbers-Mechanical

- Per 10-kt module
  - 10 PDs per APA (150 APAs total-- 50 central, 100 wall APAs)
  - 500 double-active face (central) PDs
  - 1,000 single-active face (wall) PDs
  - 1,835 cm^2 collection area (each active face)
    - Compare to 1,224cm^2 collection area (one face only) for ProtoDUNE
- Overall dimensions 2,092mm long X 135mm width (max-- 118mm for most of length) X 23mm thick
- FR-4 G-10 framing materials
- Utilizes new 136 X 25mm APA slot
- Module extends < 10mm into APA side tube

X-ARAPUCA-- Photosensor Mounting



Side-readout Photosensor mount boards



(6mm Square Hamamatsu
S13360-6050VE MPPCs)

8 actively-ganged groups of 6 passively ganged photosensors
8 boards per supercell
48 photosensors per channel
4-fold readout segmentation still achieved

X-ARAPUCA Design
By the Numbers- Optical Components

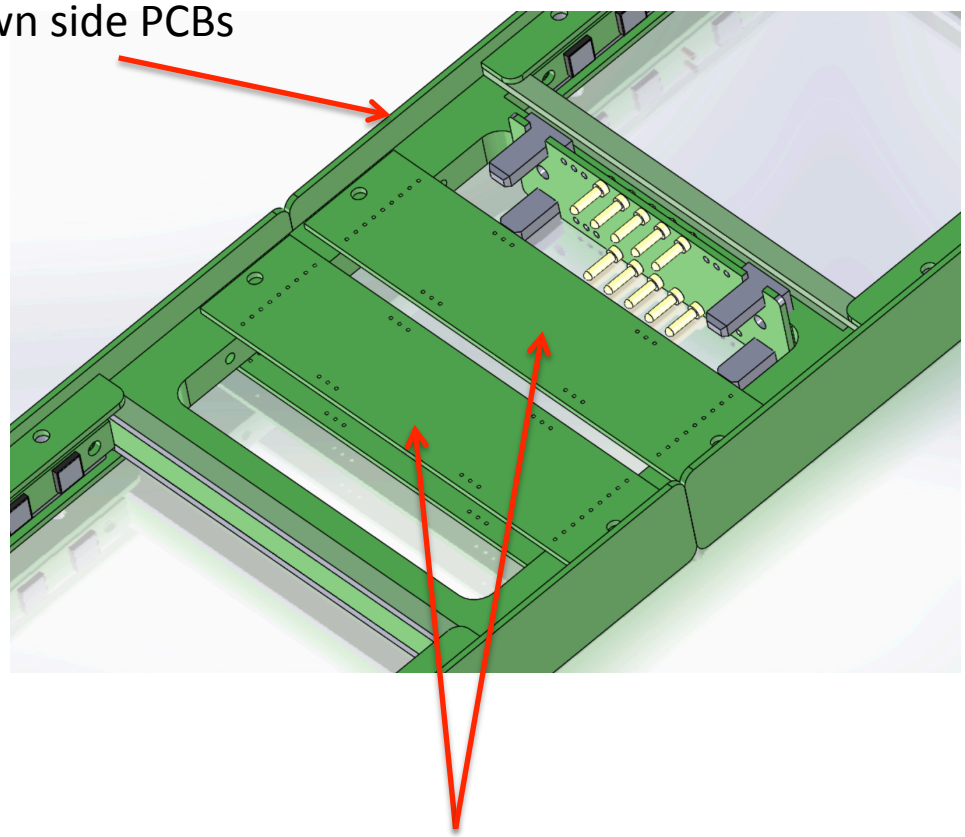
- 4 Optically-separate “Supercells”
- Each Supercell has 6 dichroic filter plates per side
  - WLS coated
  - Double-sided modules have filter plates on each side
  - Single-sided modules
- 1 Wavelength-shifting plate per supercell (4 total per module
  - Currently Eljen EJ-296 WLS plate, 92mm X 3mm X 484mm)
- Each supercell has 48 MPPCs
  - Current design: Hamamatsu S13360-6050VE MPPCs (6mm Sq.)
  - Other candidates possible
- 6 MPPCs mounted to passive-ganging PCB
- Signals routed down sides of ARAPUCA on side PCB
- 8 passive-ganging PCBs actively-ganged at center of module to 1 readout channel

PD Cabling Plans-Summary

- Photosensor Active Ganging PCBs in center of module
- Custom electrical connections automatically mate with PD insertion
- Cables pre-mounted into APA frames prior to APA wire wrapping
- Cable routing past APA frames closely follows ProtoDUNE experience
  - PD cables follow CE electronics routing path (in separated cable trays)
  - Current plan to duplicate ProtoDUNE PD cable flanges for DUNE
  - PD FE electronics mounted in mini-crates near flange Tees.

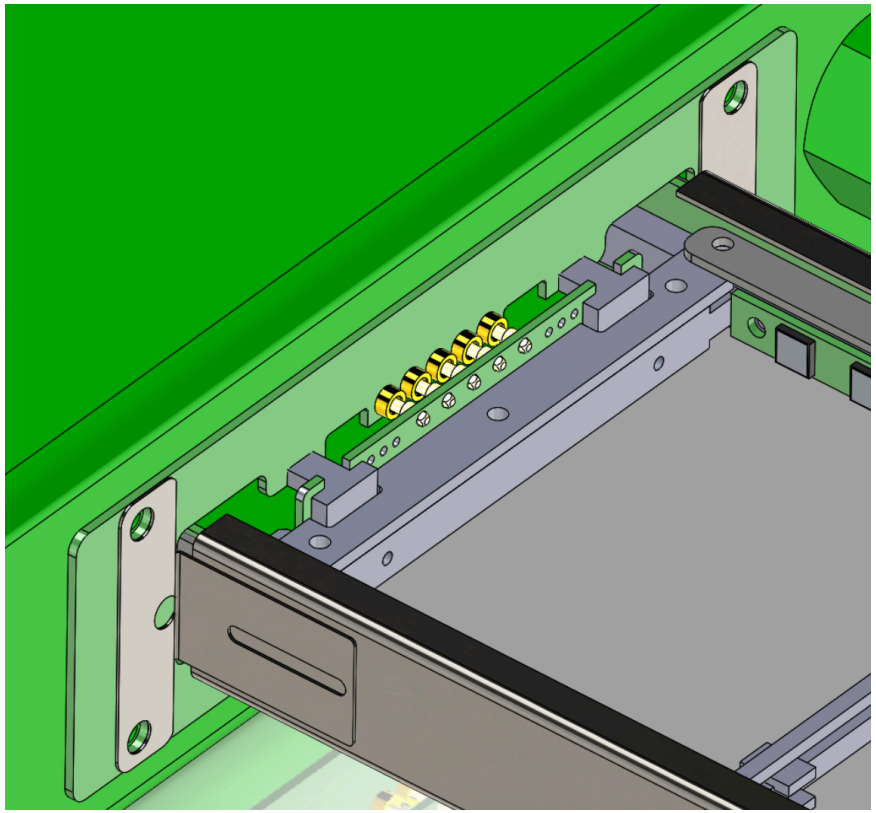
Photosensor Active Ganging

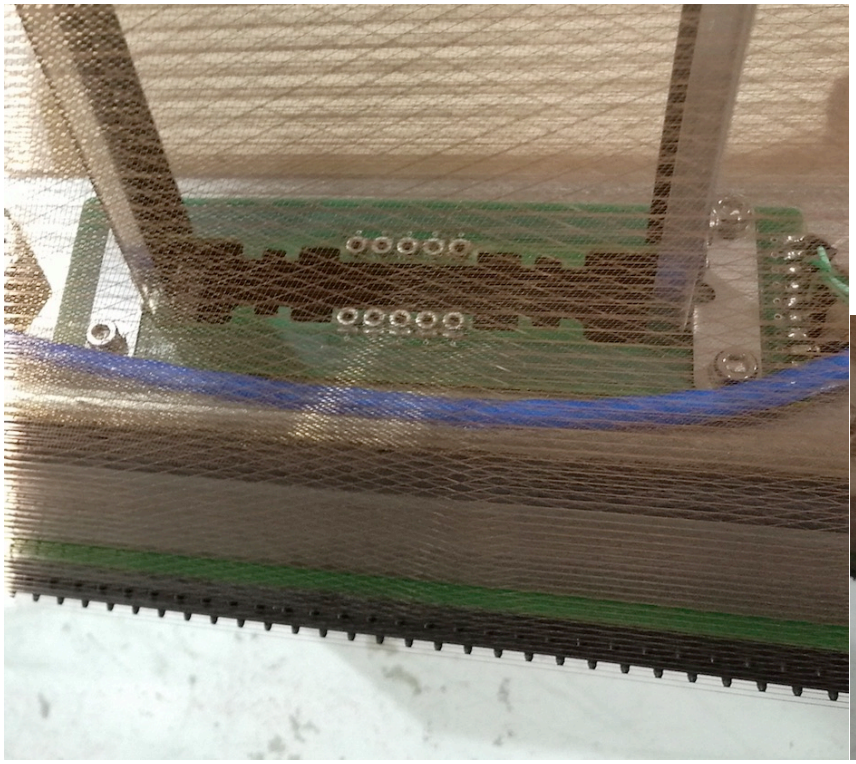
- Mounted to PCBs in center of PD module
- Positioned to lie within APA central tube (no additional lost active area)
- Large PCB area maximizes heat dissipation area (no LAr boiling)

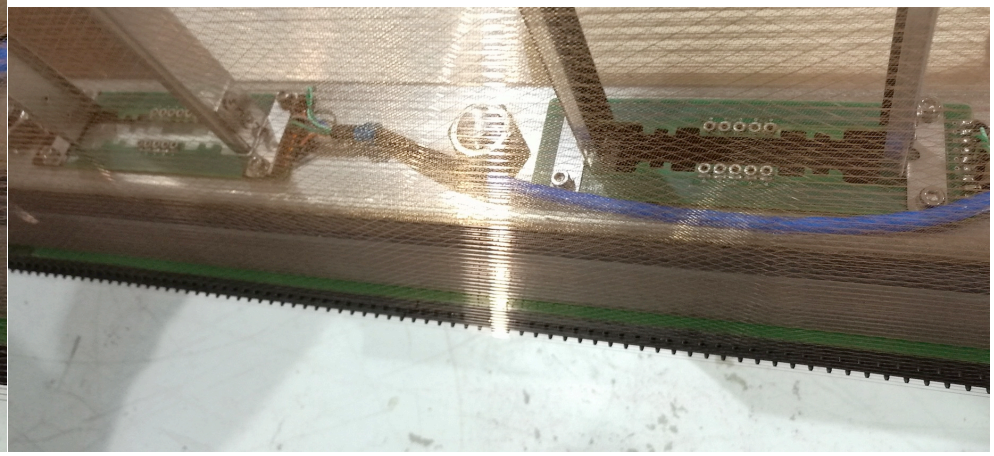


PD/APA Connector Concept

- Connector mounted to central rail of APA
- Automatically connects when module is inserted
- Cables run up inside APA frame
  - Outside APA side tubes
  - PD cables installed prior to APA wrapping

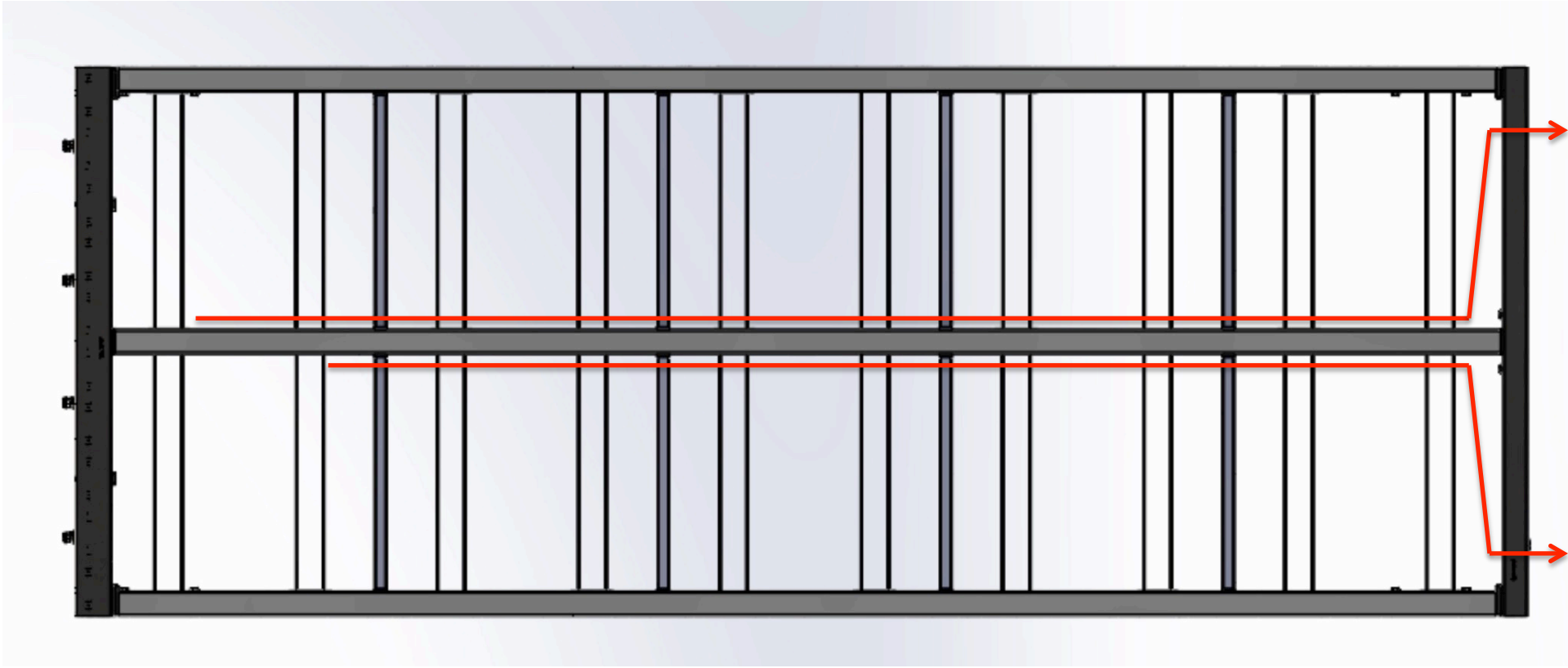






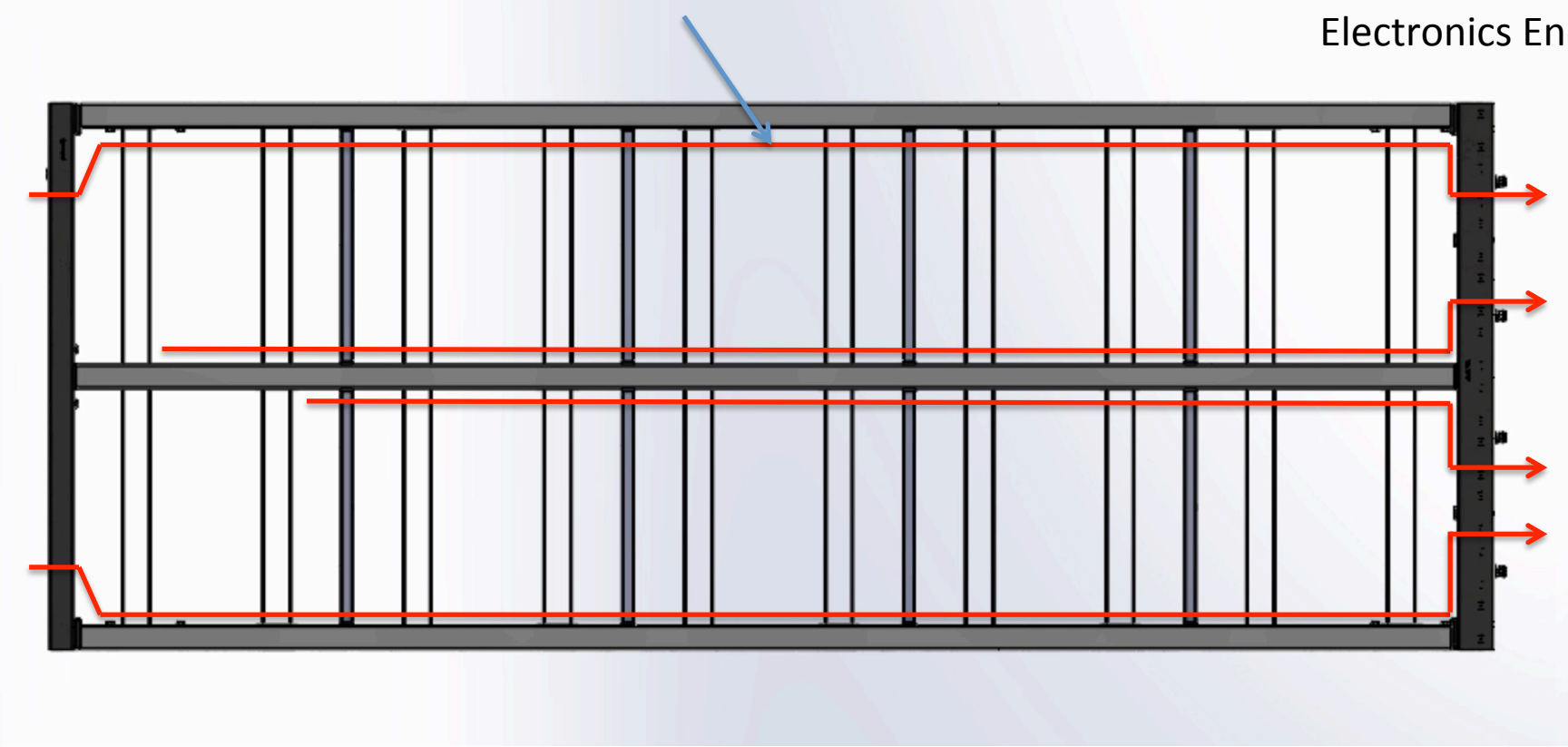
Bottom APA PD Cables

Electronics End



Top APA Cable Routing

Each outer red line represents 5 cables from lower APA

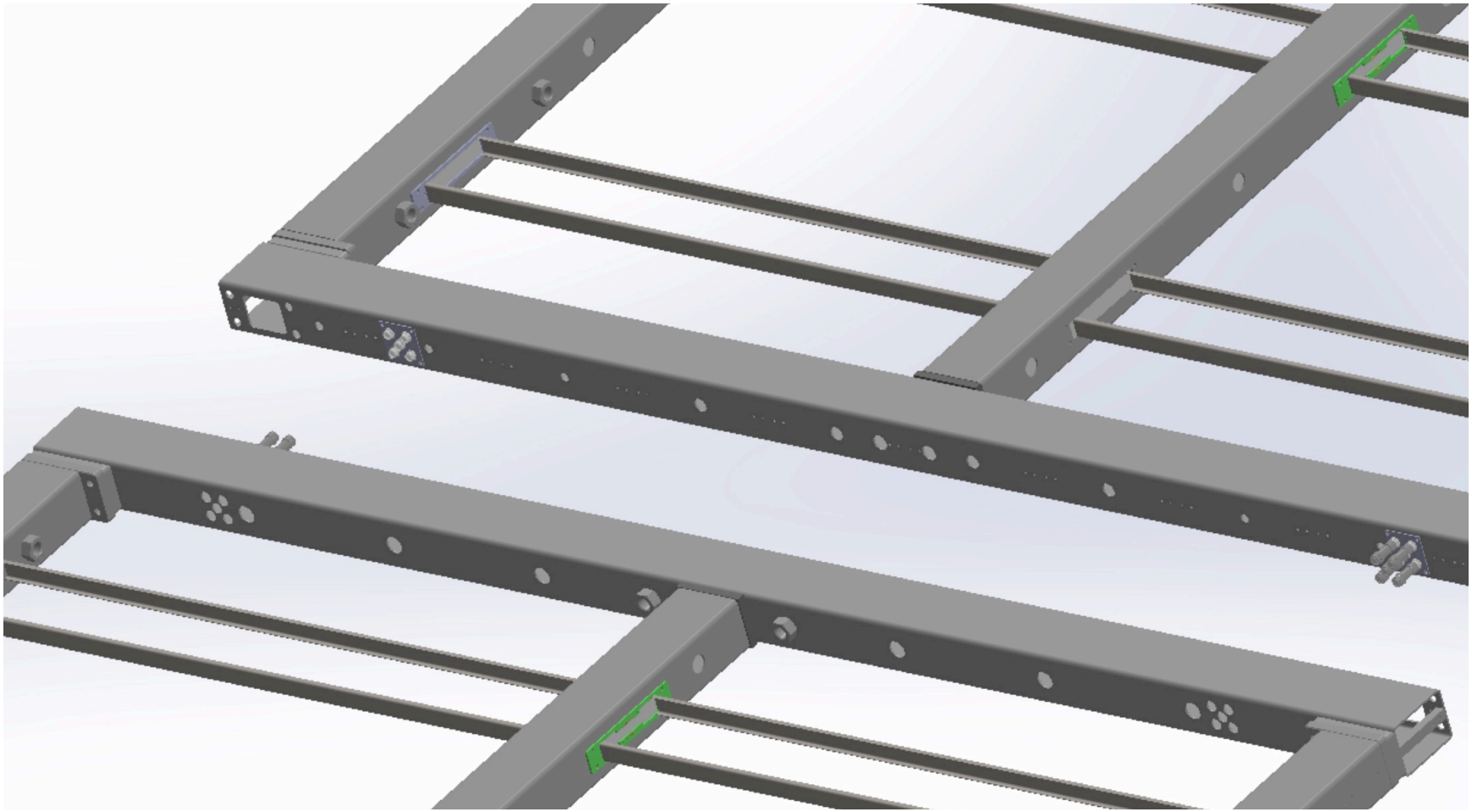


Inline Connector Candidate

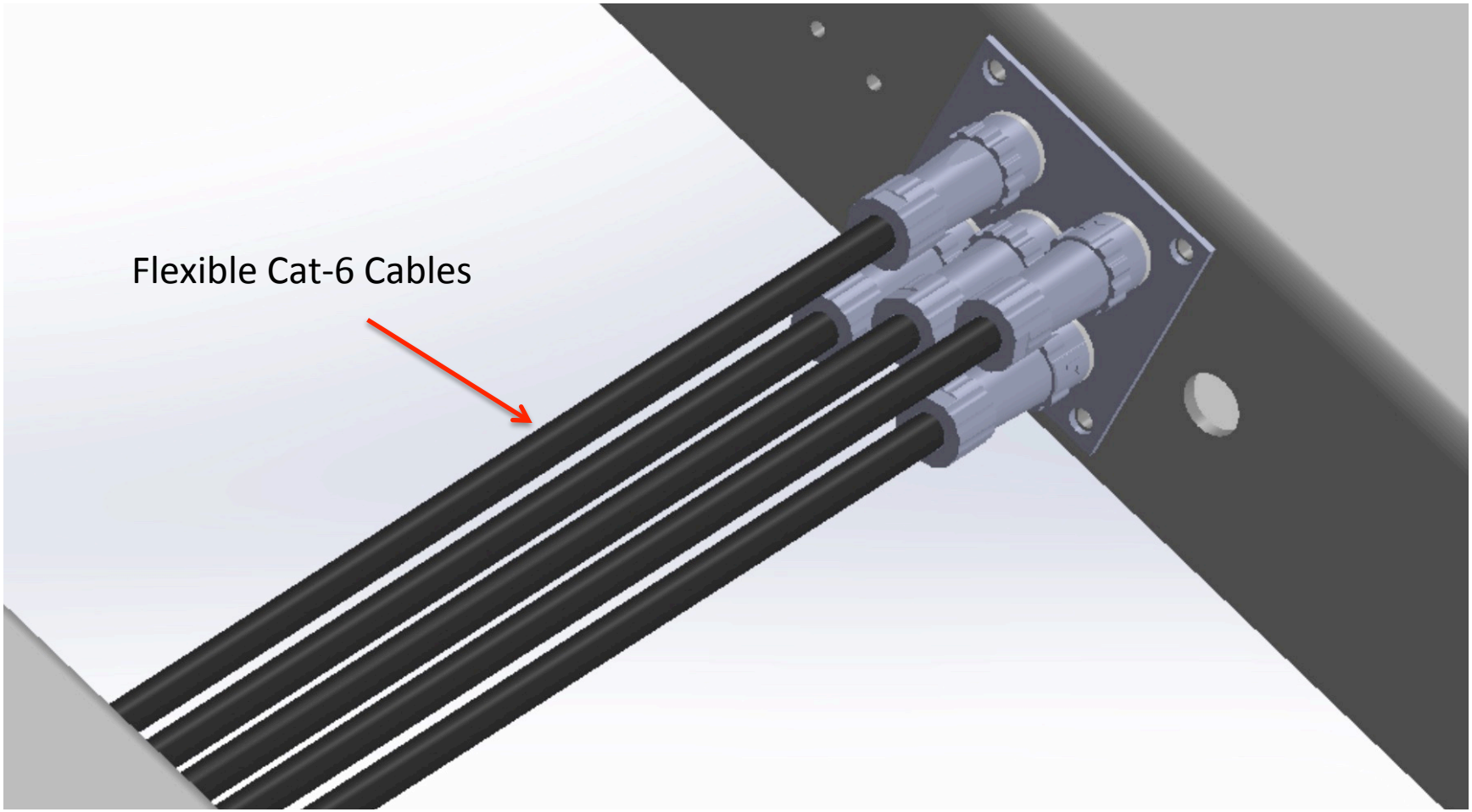
- Inline connectors will connect upper and lower APA PD cables
- Inline connectors will also connect long haul cables to PD cables inside APAs (at top of top APA)
- Hirose LF-series connectors are a primary candidate (same as ProtoDUNE)
- Still need to figure out where to put connectors between top and bottom

Hirose LF-series connectors

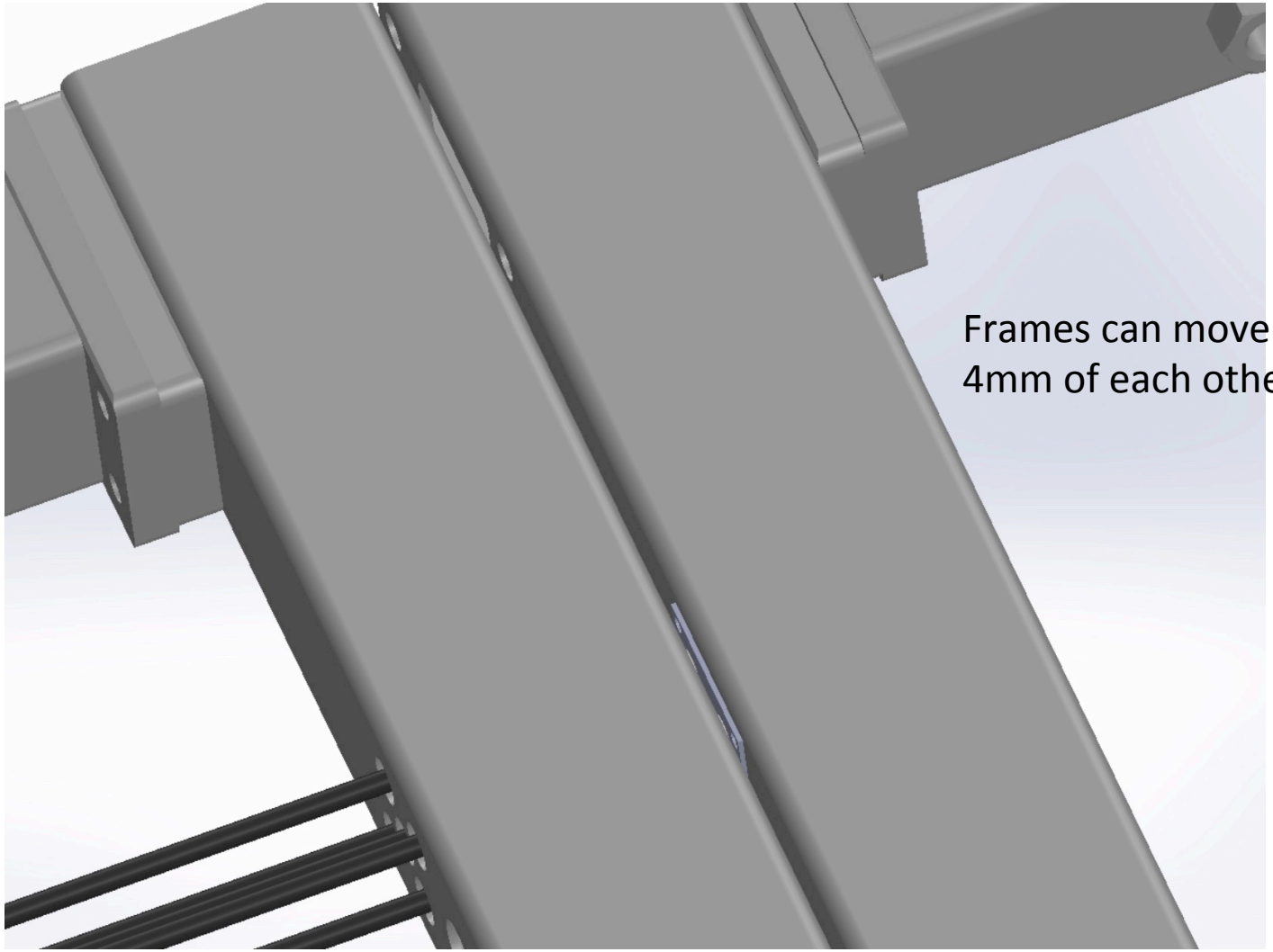
APA Joining (lower to upper APA)



Lower/Upper APA connected

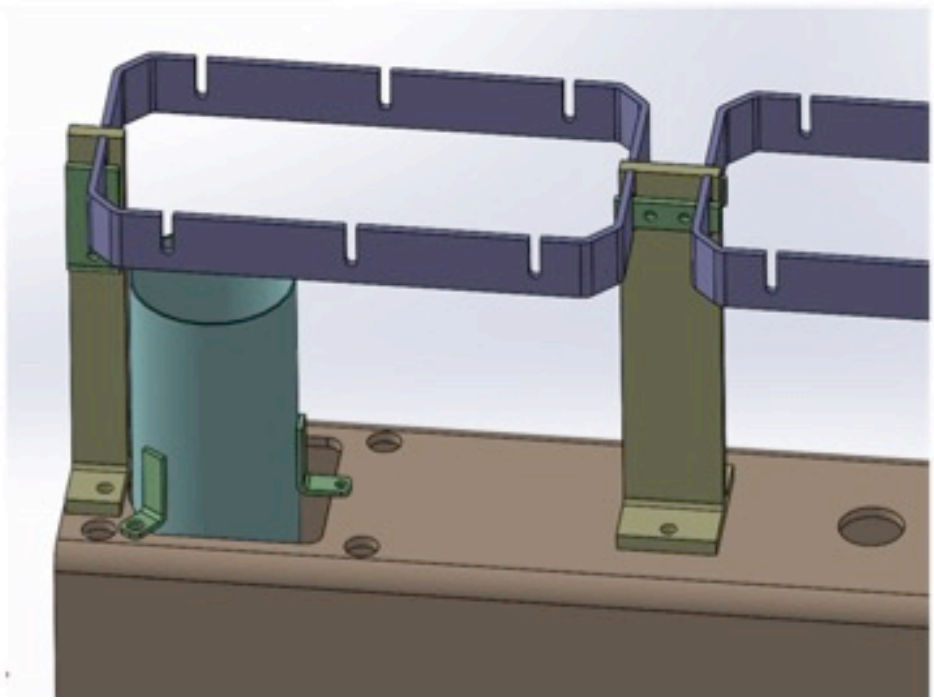


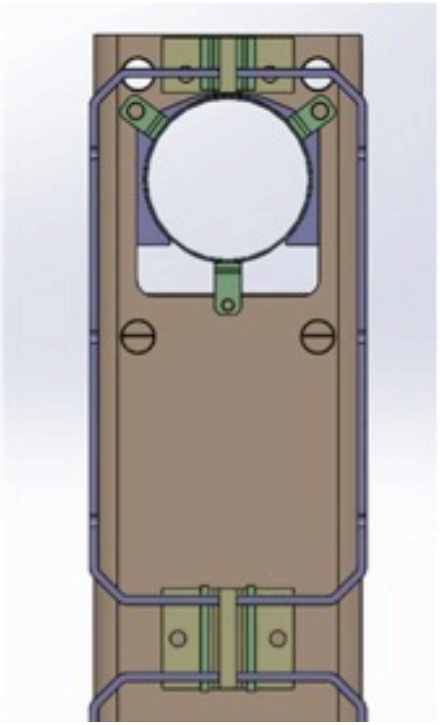
Upper and lower APA joined



Cable Routing-CE Cable Interactions

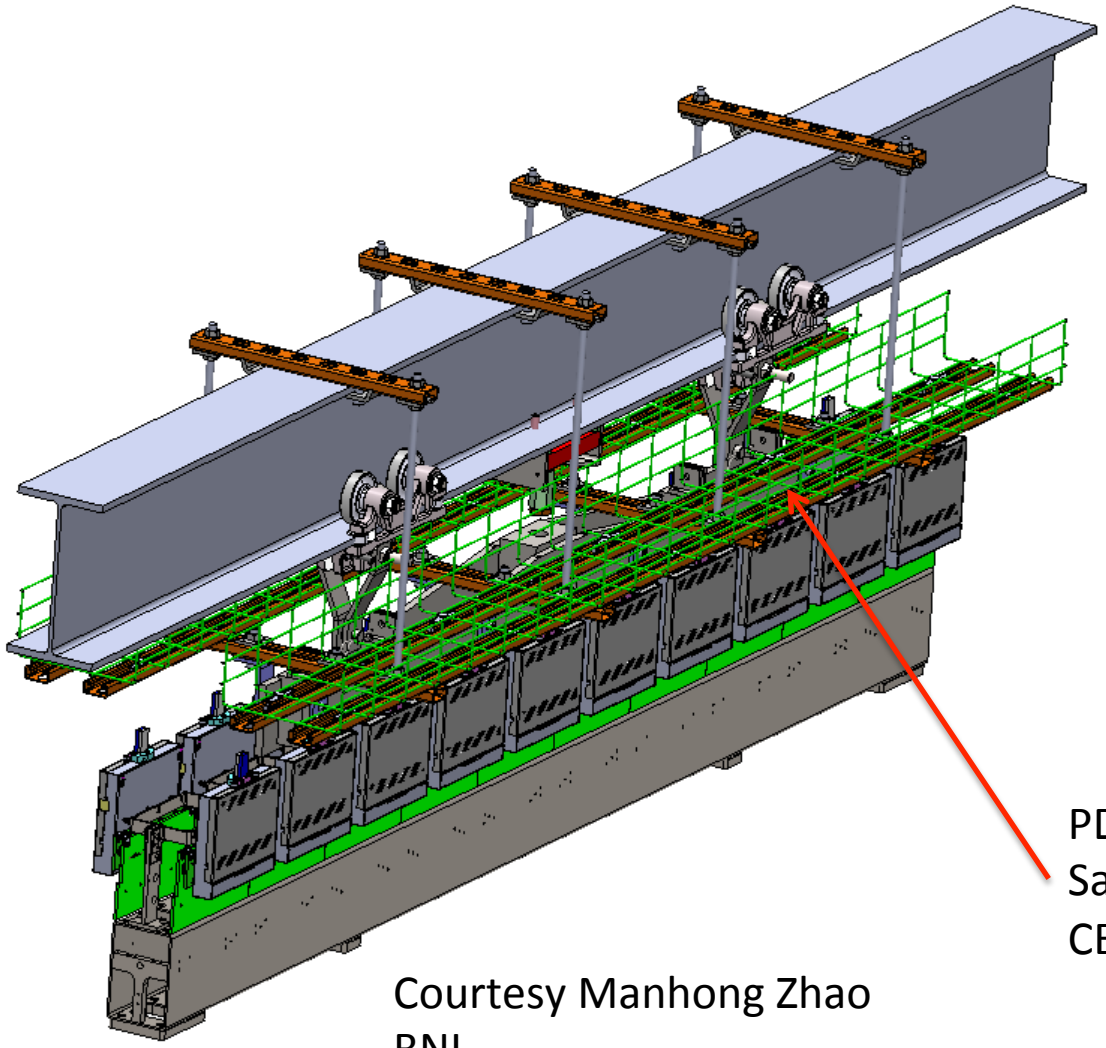
- A 2.5 inch OD conduit will be installed in each of the side tubes of both top and bottom APAs
- It is done at the ITF after the photon detectors are installed





Courtesy Manhong Zhao
BNL

Cable Routing Inside Cryostat



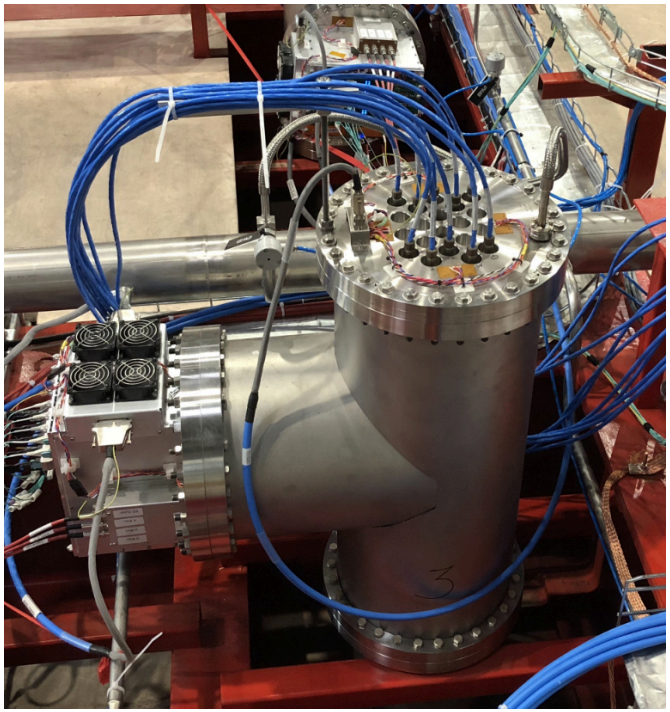
PD Cables route in the
Same cable trays with
CE cables (no separation)

Courtesy Manhong Zhao
BNL

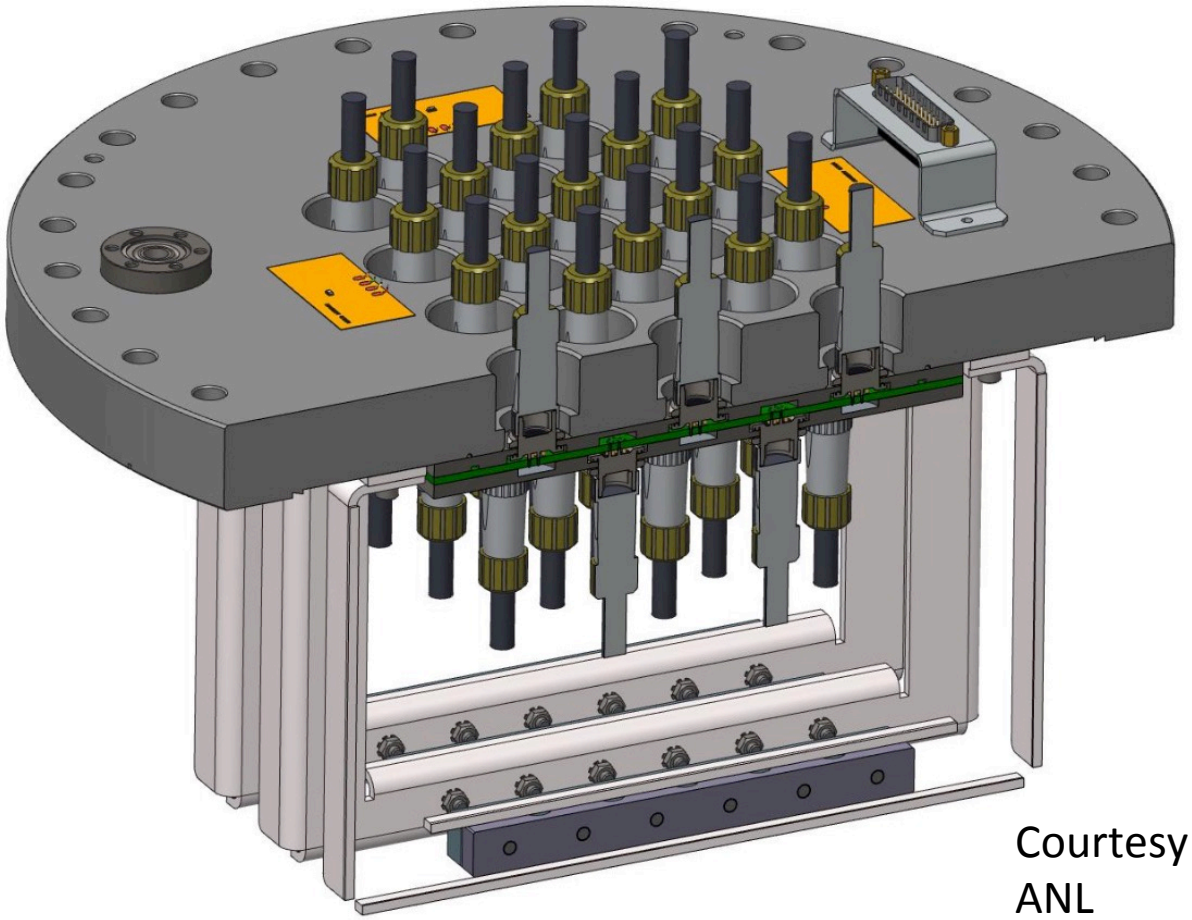
Cable penetrations

Photos Courtesy
Chris Macier IU

- PD cables penetrate cryostat through Tee
- Same design as ProtoDUNE

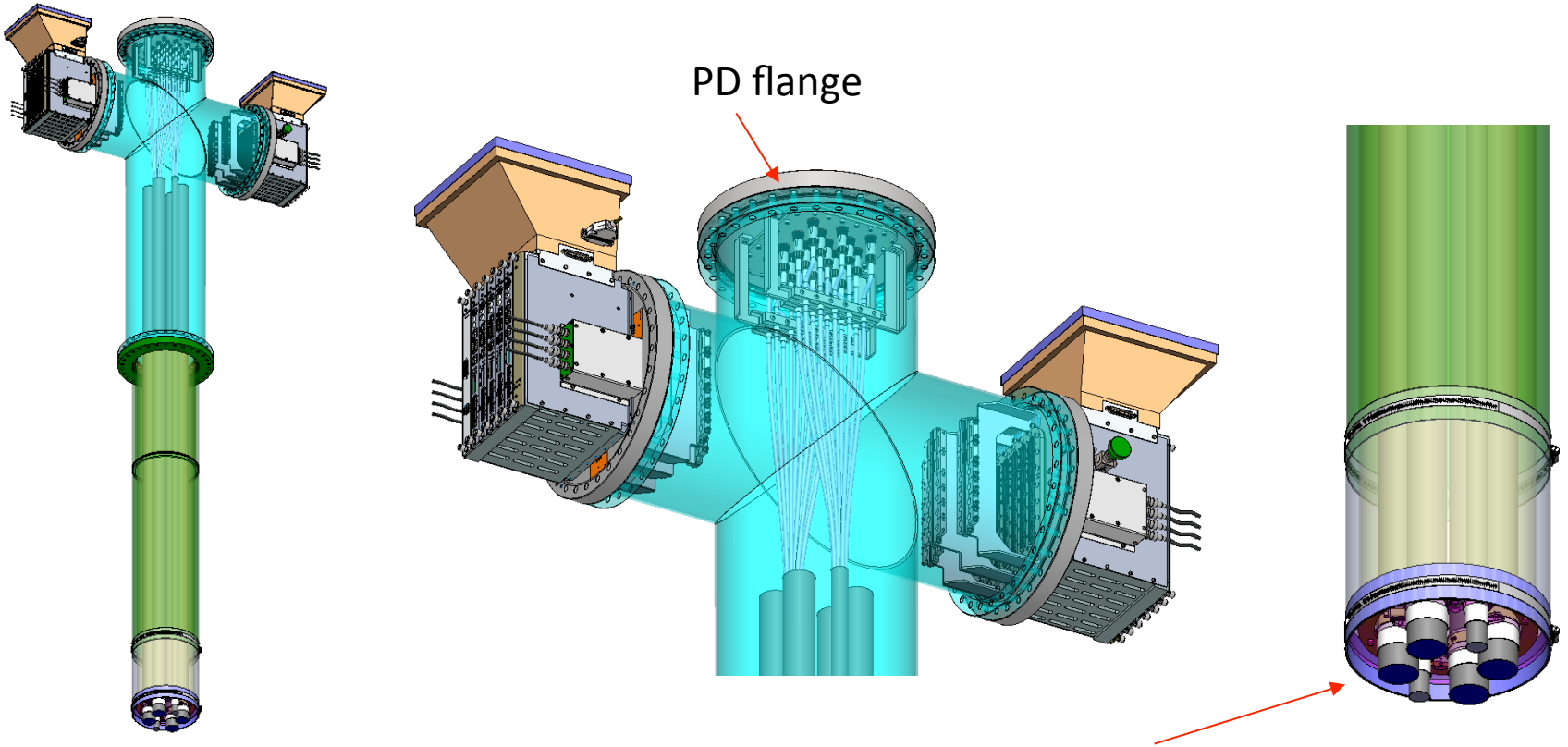


ProtoDUNE PD Signal Flange



Courtesy Todd Hayden
ANL

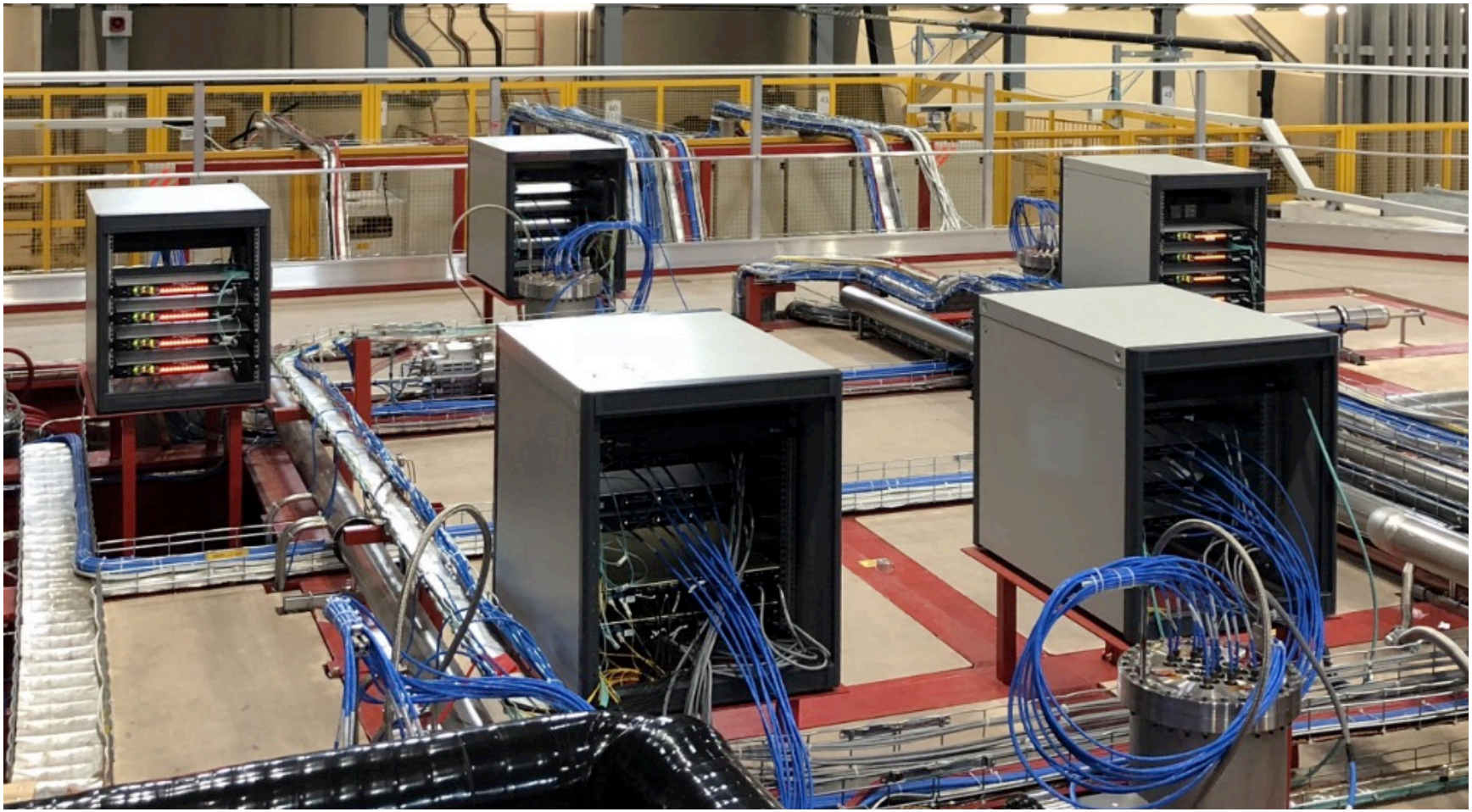
PD/CE Cable Routing Through Tee



Courtesy Manhong Zhao
BNL

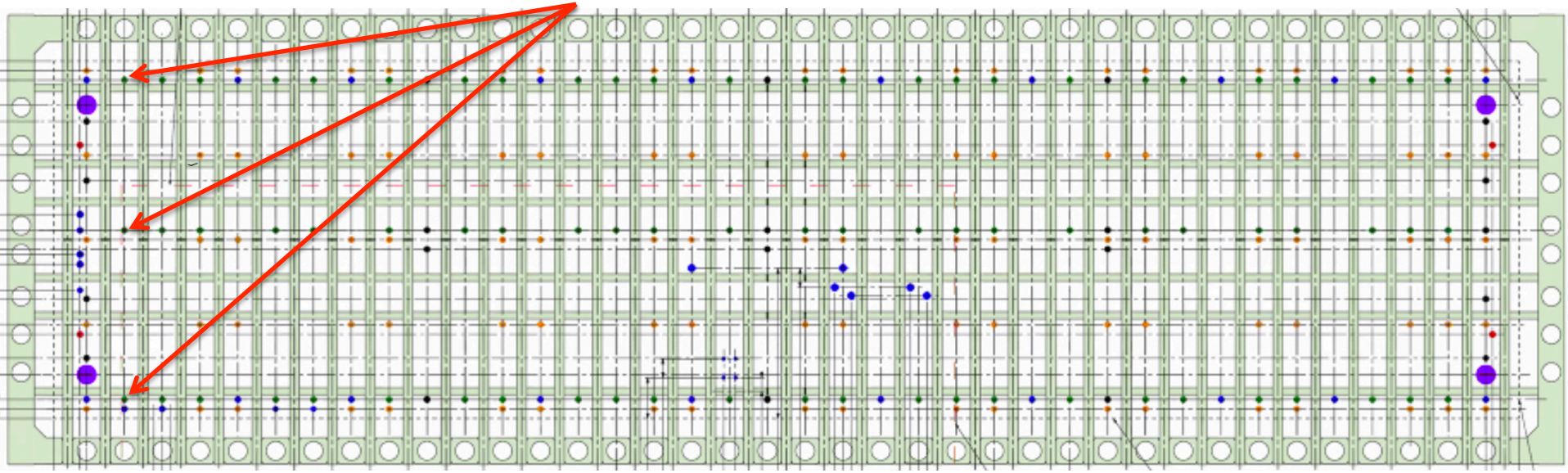
Mini-racks in ProtoDUNE (similar planned for DUNE)

Photos Courtesy
Chris Macier IU



Positions of Penetration Tees on top of Cryostat

PD/APA “T” positions on Cryostat (25 rows)



Electrical/Cabling plan -- By the numbers

- Central electrical connector block
  - Automatically connects with module insertion
  - Cables installed in APA prior to wire wrapping
  - Replaces
- Internal connections made using connectors and cables tested in ProtoDUNE
- 20 PD cable penetrations per cryostat flange
- 75 mini-crates for FE electronics module mounting

Main Engineering Risks

- Relative thermal contraction of APA and PD modules
  - Calculated-- <3mm relative contraction over 2m length
  - Main risk-- separating electrical connection
  - Mitigation-- Accounted for in length of contact pins
  - Tests-- Mechanical model tested in full-scale cryostat at CSU-- no connector failure

Main Engineering Risks-- 2

- Relative contraction of cables inside APA frame
  - Measured– (ProtoDUNE) 2% relative contraction of cables to APA frame
  - Mitigation– Planned >5% “Slack” cable loops left while anchoring cables inside APA frame
  - Tests–Will be checked with full-scale prototype inside CSU cryostat

Main Engineering Risks-- 3

- Deflection of PD modules inside APA frame damages APA wire grid during handling
  - PD deflection specified to <5mm in both directions under static and specified dynamic loads
  - Mitigation− PD modules engineered to meet specification
  - Tests− Prototype module testing suggests modules well within specifications. FEA will be conducted when design finalized

Assembly and Testing Plan

- PD production assumes a target production and testing rate of approximately 20 PD modules per week (average over 18 months)
- Actual throughput of our assembly and testing facilities will be determined once PD designs finalized.
- This task includes:
  - Module component fabrication
  - Incoming materials inspection/certification
  - Assembly of modules
  - QC testing of completed assemblies
- Additional post-assembly QC/QA will be discussed in separate presentations
- Location of assembly and testing facilities to be determined.

Materials Testing/Certification

- All PD module components will be tested and certified for use in DUNE by the FNAL materials test stand (as required in global requirements)
- Most materials already checked:
  - FR-4 G-10
  - PCBs
  - Solder
  - Vikuiti reflectors
  - Filter plates (coated-- n.b. long-term testing ongoing)
  - 304 SS
  - Signal cable
  - Connectors
- Still remaining to check: WLS plates
- Radiological testing ongoing at SDSM.
- Process supervised by PD integration working group

Future Development

- Future testing and development plans include:
  - Confirmation of mechanical design
  - Confirmation of WLS plate performance
  - Optimization of photosensor number, positions
  - Extensive testing of cabling/connector
  - Testing/verification of APA stack joining procedure

Safety

- Our safety plan is based largely on the ProtoDUNE experience
- Procedures will be established for all manufacturing, assembly and testing operations
- Safety requirements from each institution will provide the basis of the procedural controls
  - However, all safety plans will need to be approved by the consortium technical lead
- We plan to request assistance from the Fermilab safety team in developing and implementing safety plans
  - Probably including site visits by consortium leads and FNAL safety representatives.

Summary

- The X-ARAPUCA photon detector design as made a great deal of progress since ProtoDUNE
- Both double-sided (central APAs) and single-sided (outer APAs) are designed
- Extensive use of ProtoDUNE experience informed the designs
- Major improvements (Since protoDUNE) include:
  - Increased slot size in APA (nearly 50% increase in collection area)
  - WLS doped plates eliminate need for coating Vikuity sheets (as in ProtoDUNE ARAPUCA design)
  - Pre-installed cabling in APA frame eliminates interference between CE and PD cables.
- Plans for continuing testing/development will be covered in a later talk!

Backup Slides

ProtoDUNE ARAPUCA Design