

# Photon Detector System: Module, Support Structure, APA Interface System Design

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SP Photon Detector System Preliminary Design Review

18-19 June, 2020

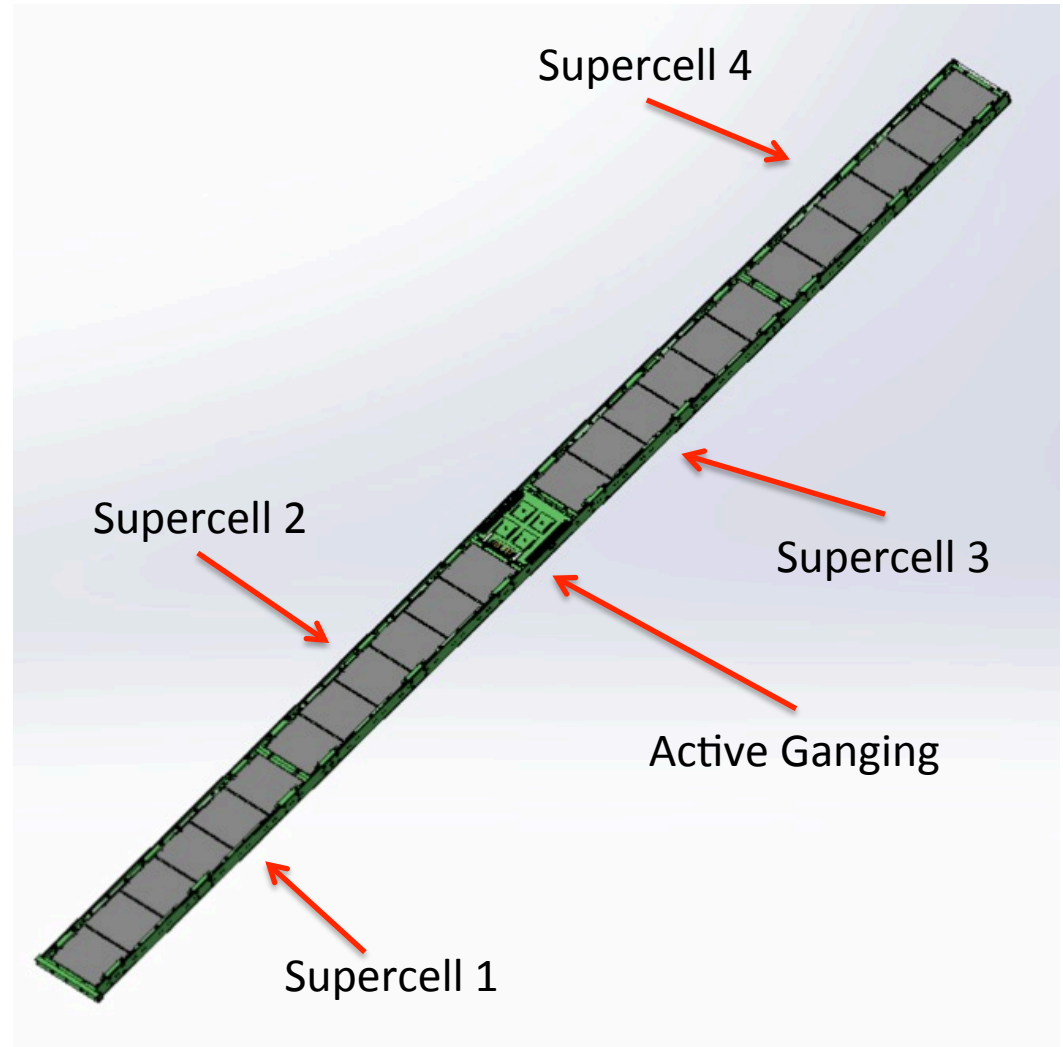


# Outline

- Light collector system design concept
- PD module design
  - Supercell
  - Module
- Rail support system
- Electrical connections
- Cable routing
  - Through APA frame
  - Between upper and lower APAs
  - Cable trays & crossing tube
  - Cryostat flange
- Summary

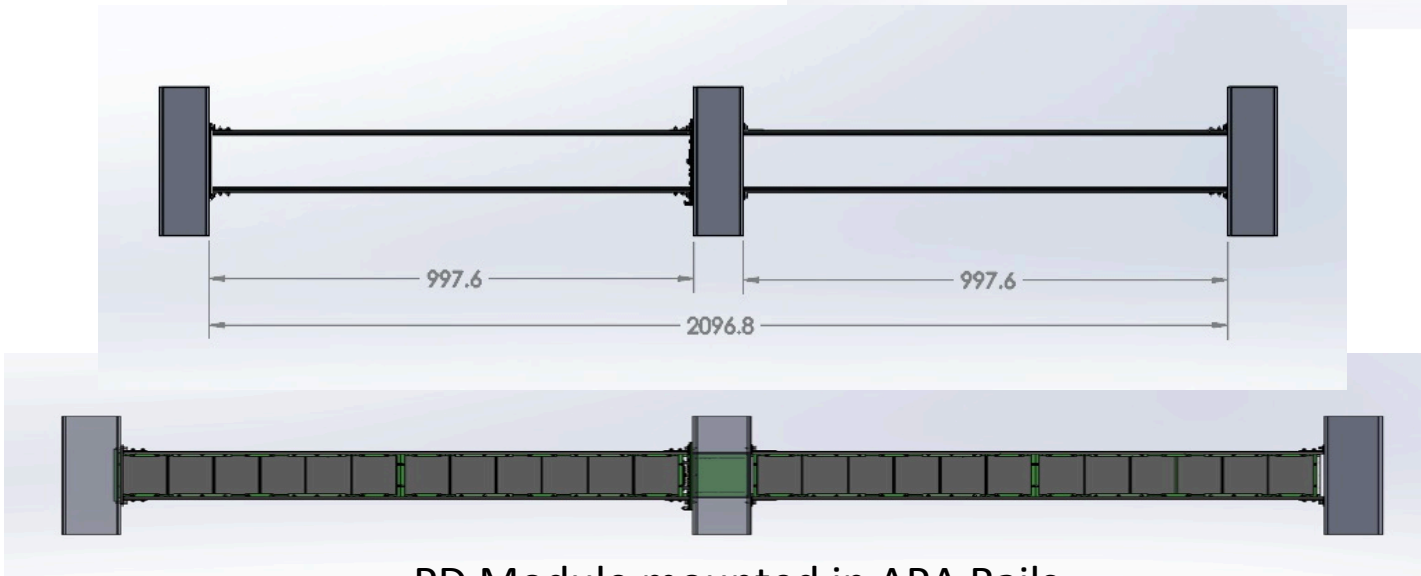
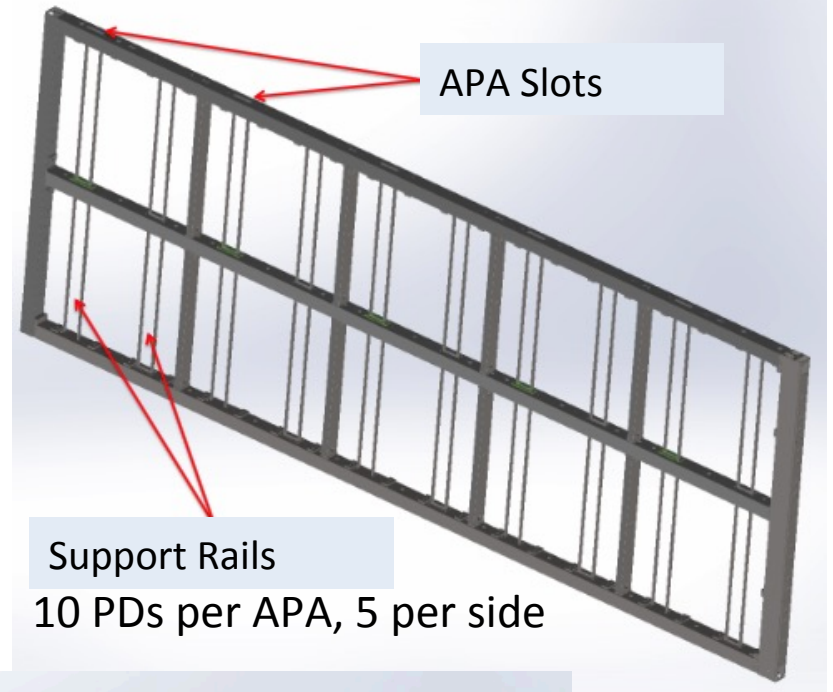
# Photon Detector Module– Basically unchanged since TDR

- Photon light detectors come in bar-shaped modules.
  - 2090mm X 118mm X 23.5mm
- Each bar consists of 4 optically-isolated readout channels called “Supercells”.
- Module form factor was selected to allow for installation into APA frame after wire wrapping.



# Photon Detector Mounting

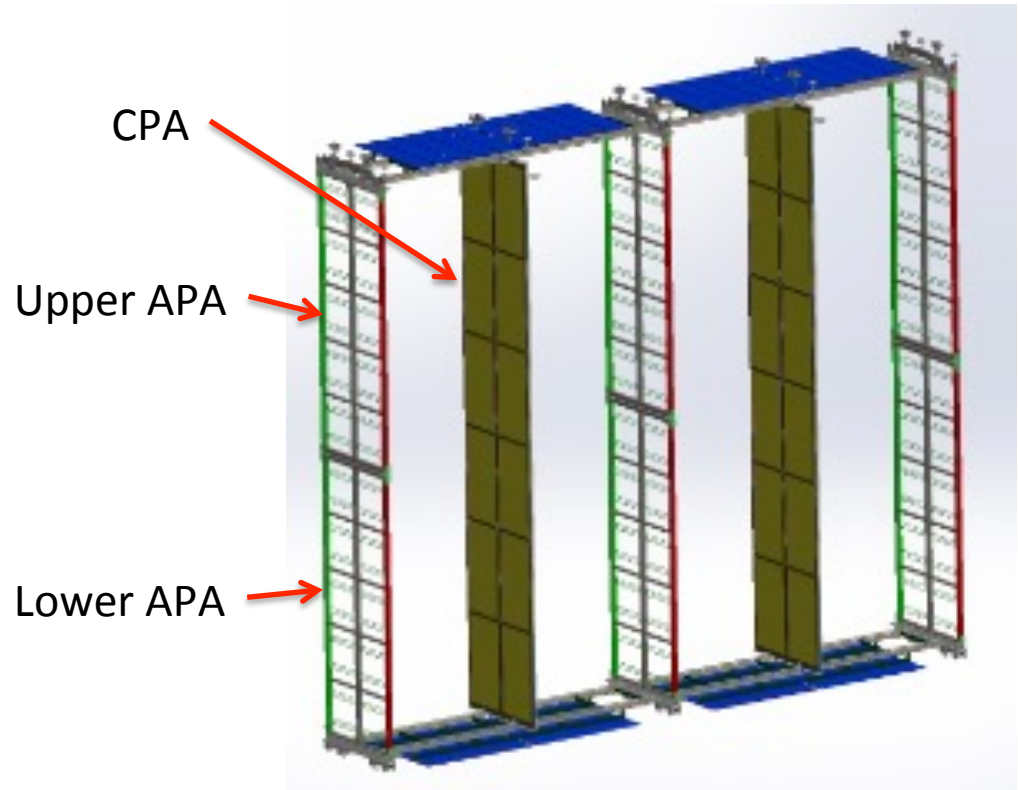
- Photon detectors are supported in APA frames.
- Mounted in stainless steel rails.
- Sail systems provided by PD consortium.



PD Module mounted in APA Rails

## APAs mounted in TPC slices

- In the DUNE FD, the APAs are stacked in pairs, and arranged in slices as in the figure.
- Note that this implies central APA PD modules must collect light from both directions.
- Also has implications for cable routing.

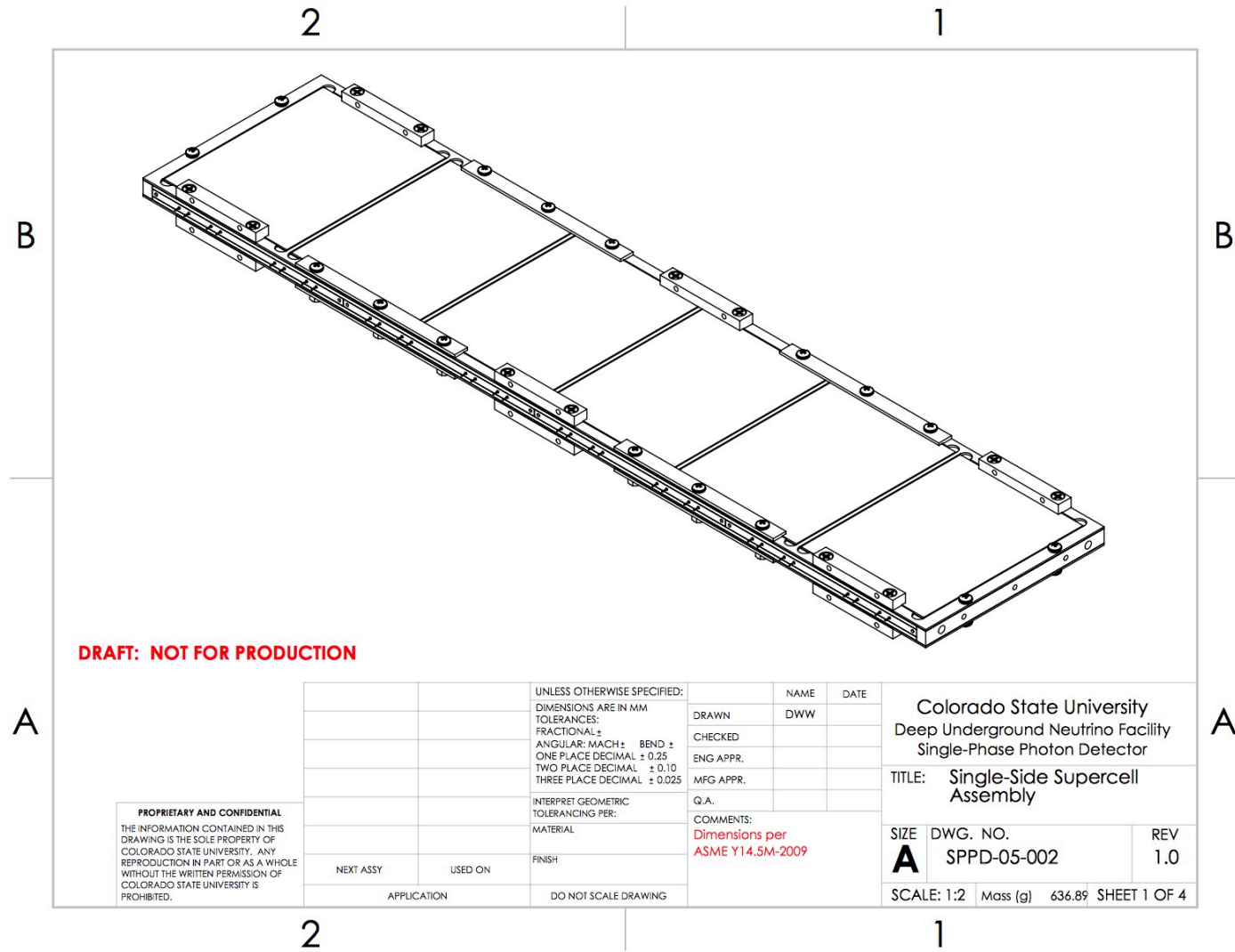


# System Summary (By the numbers)

| Item                     | Number (value)         |
|--------------------------|------------------------|
| Per Module               |                        |
| Readout channels         | 4                      |
| Photosensors             | 192                    |
| Dichroic Filters         | 24 (48)                |
| WLS plates               | 4                      |
| Readout Cables           | 1                      |
| Mass                     | 3.2kg                  |
| Per APA                  |                        |
| PD modules               | 10                     |
| Readout cables           | 10 (lower), 20 (upper) |
| Per 10kt detector module |                        |
| PD modules               | 1,500                  |
| Readout channels         | 6,000                  |
| DAPHNE modules           | 150                    |

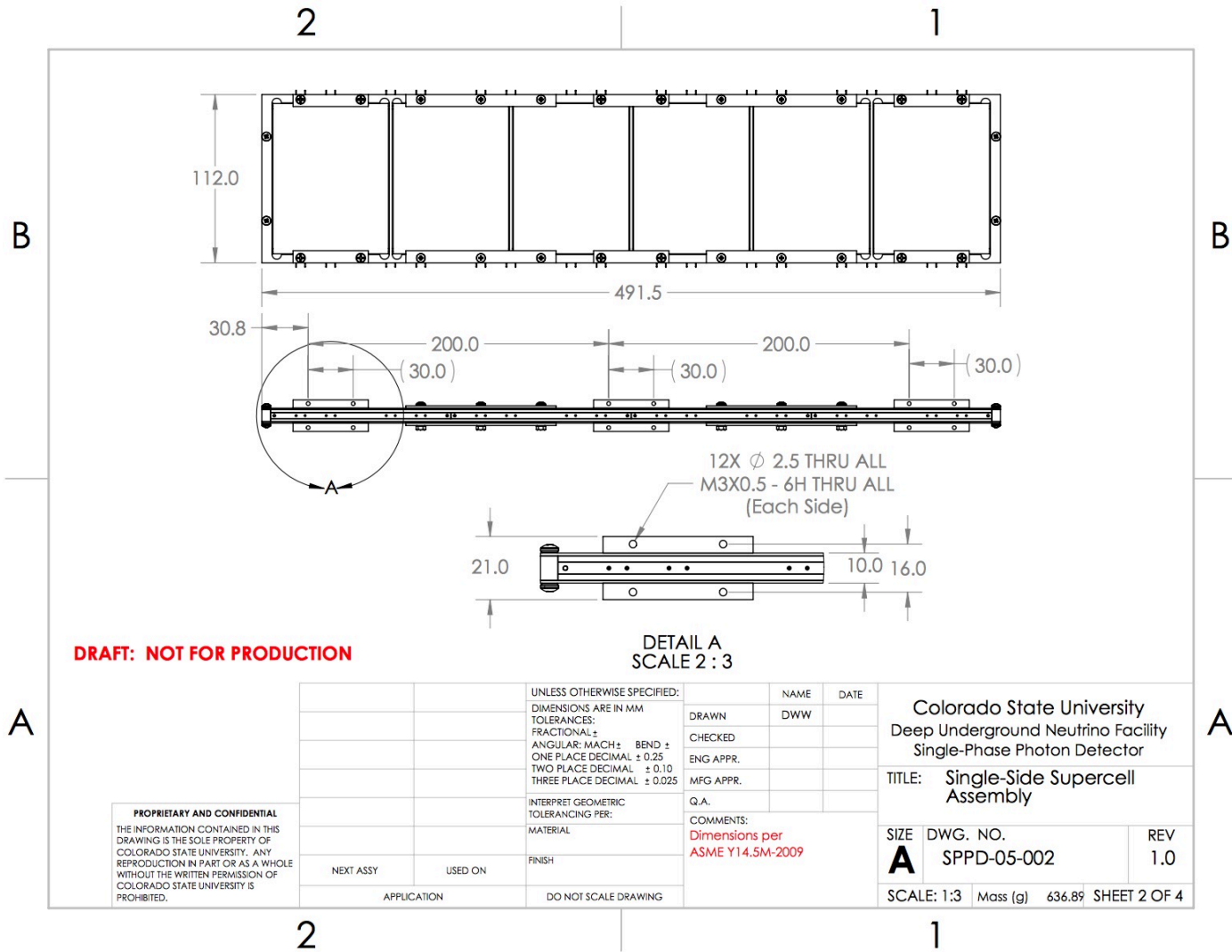
# PD Module Design: Supercell (i)

- A photon detector contains 4 independent readout channels called “Supercells.”
- Each supercell has 6 (12) dichroic filter windows, 1 WLS bar, and 48 photosensors.
- They come in single-direction and 2-direction flavors.



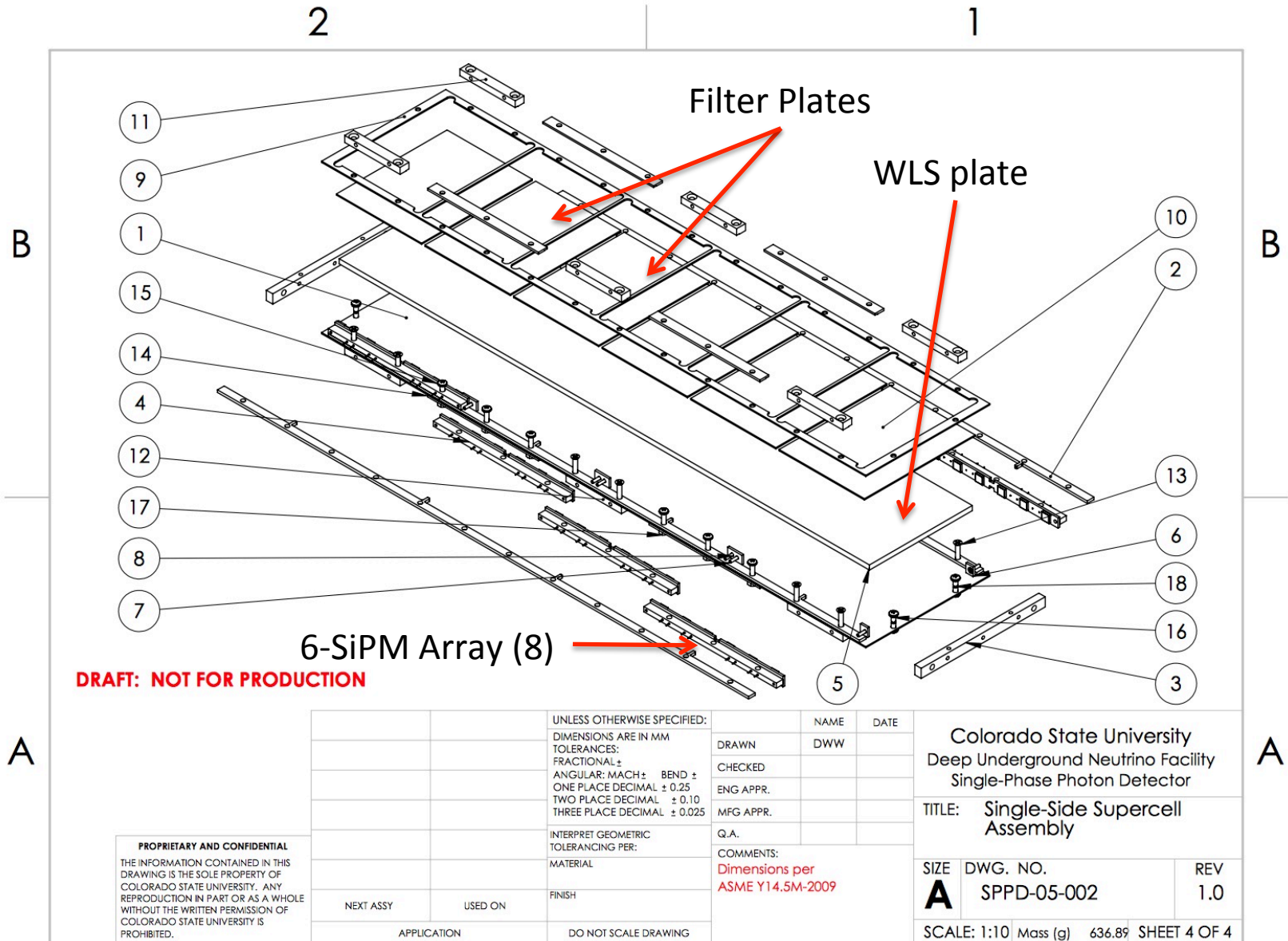
# PD Module Design: Supercell (ii)

- A supercell is approximately 490cm long and 12 cm wide.
- Each supercell is read out as an independent readout channel.
- This, and the spacing of bars in the APA frame (approximately 1/2 meter apart) defines the granularity of the PD readout.





# PD Module Design: Supercell (iii)



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|             |         |   |   |      |      |
|-------------|---------|---|---|------|------|
|             |         | UNLESS OTHERWISE SPECIFIED:<br>DIMENSIONS ARE IN MM<br>TOLERANCES:<br>FRACTIONAL ±<br>ANGULAR: MACH ± BEND ±<br>ONE PLACE DECIMAL ± 0.25<br>TWO PLACE DECIMAL ± 0.10<br>THREE PLACE DECIMAL ± 0.025 | DRAWN<br>DWW                                    | NAME | DATE |
|             |         | INTERPRET GEOMETRIC TOLERANCING PER:  | CHECKED   |      |      |
|             |         | MATERIAL  | ENG APPR.                                       |      |      |
|             |         | FINISH  | MFG APPR.                                       |      |      |
| NEXT ASSY   | USED ON |   | Q.A.  |      |      |
|             |         |   | COMMENTS:<br>Dimensions per<br>ASME Y14.5M-2009 |      |      |
| APPLICATION |         | DO NOT SCALE DRAWING  |   |      |      |

Colorado State University  
 Deep Underground Neutrino Facility  
 Single-Phase Photon Detector

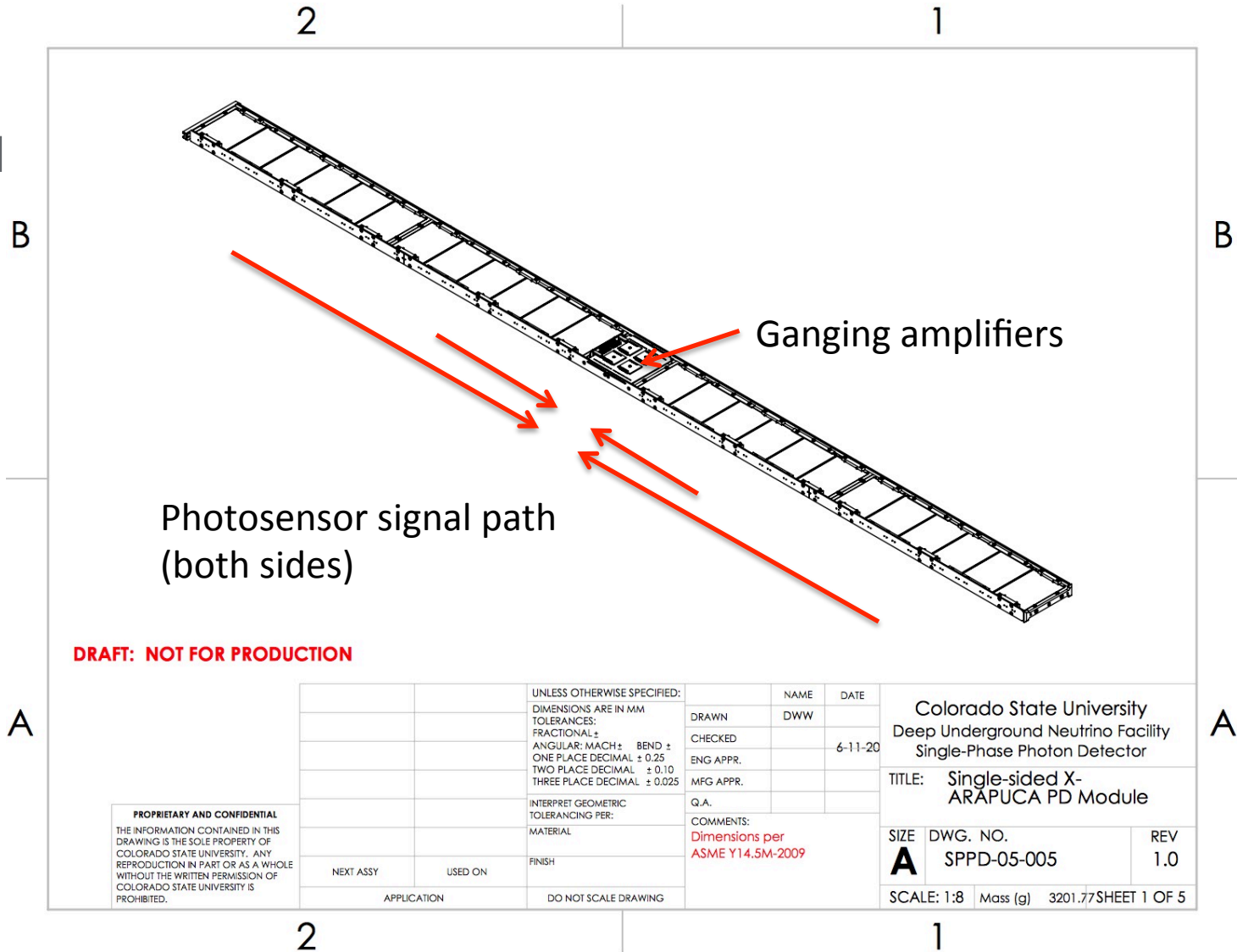
TITLE: Single-Side Supercell Assembly

SIZE DWG. NO. REV  
**A** SPPD-05-002 1.0

SCALE: 1:10 Mass (g) 636.89 SHEET 4 OF 4

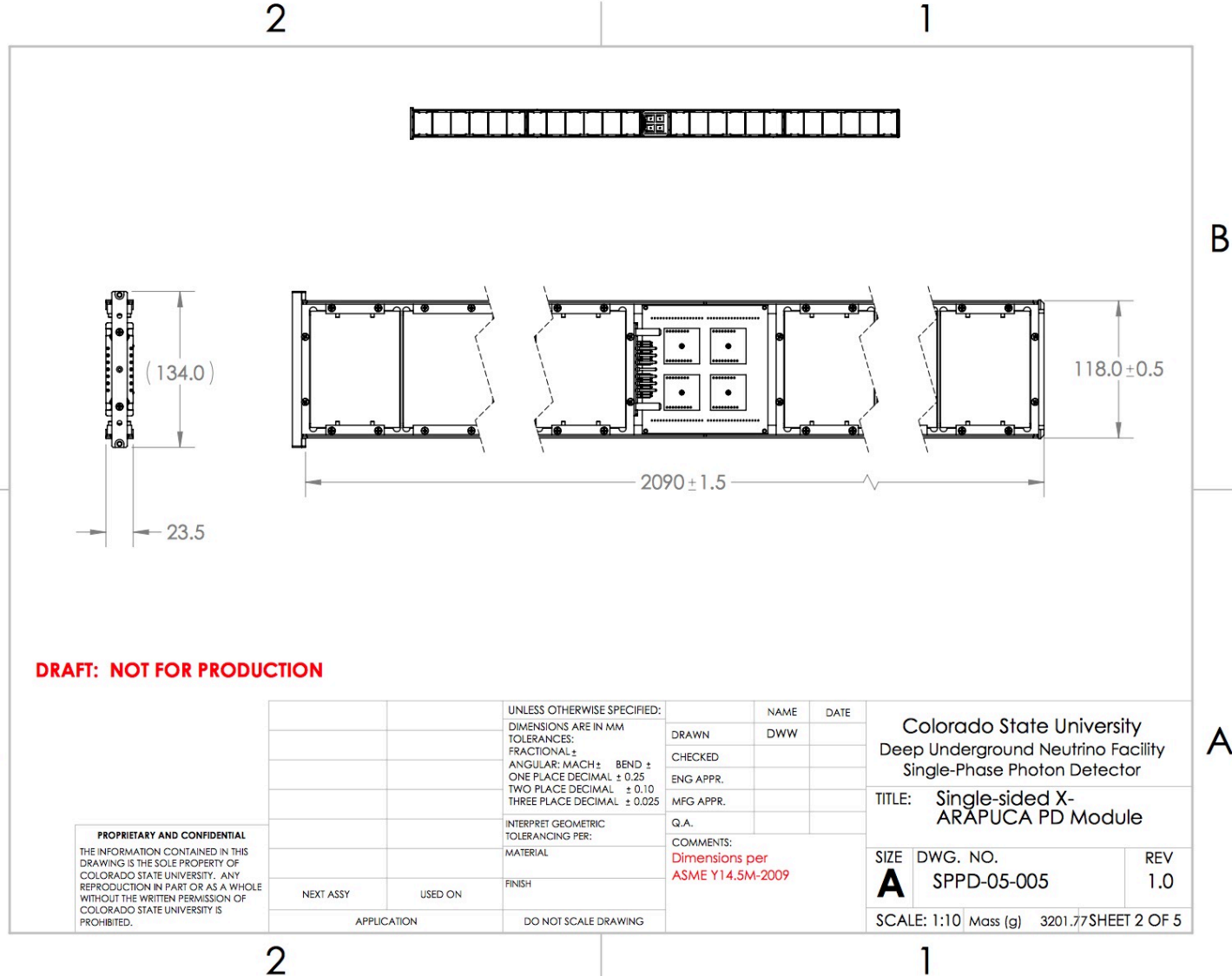
# PD Module Design: Module Assembly (i)

- 4 supercells are assembled into 1 module.
- Each module has 4 readout channels.
- Signals routed through PCBs on module sides (collected in center).



# PD Module Design: Module Assembly (ii)

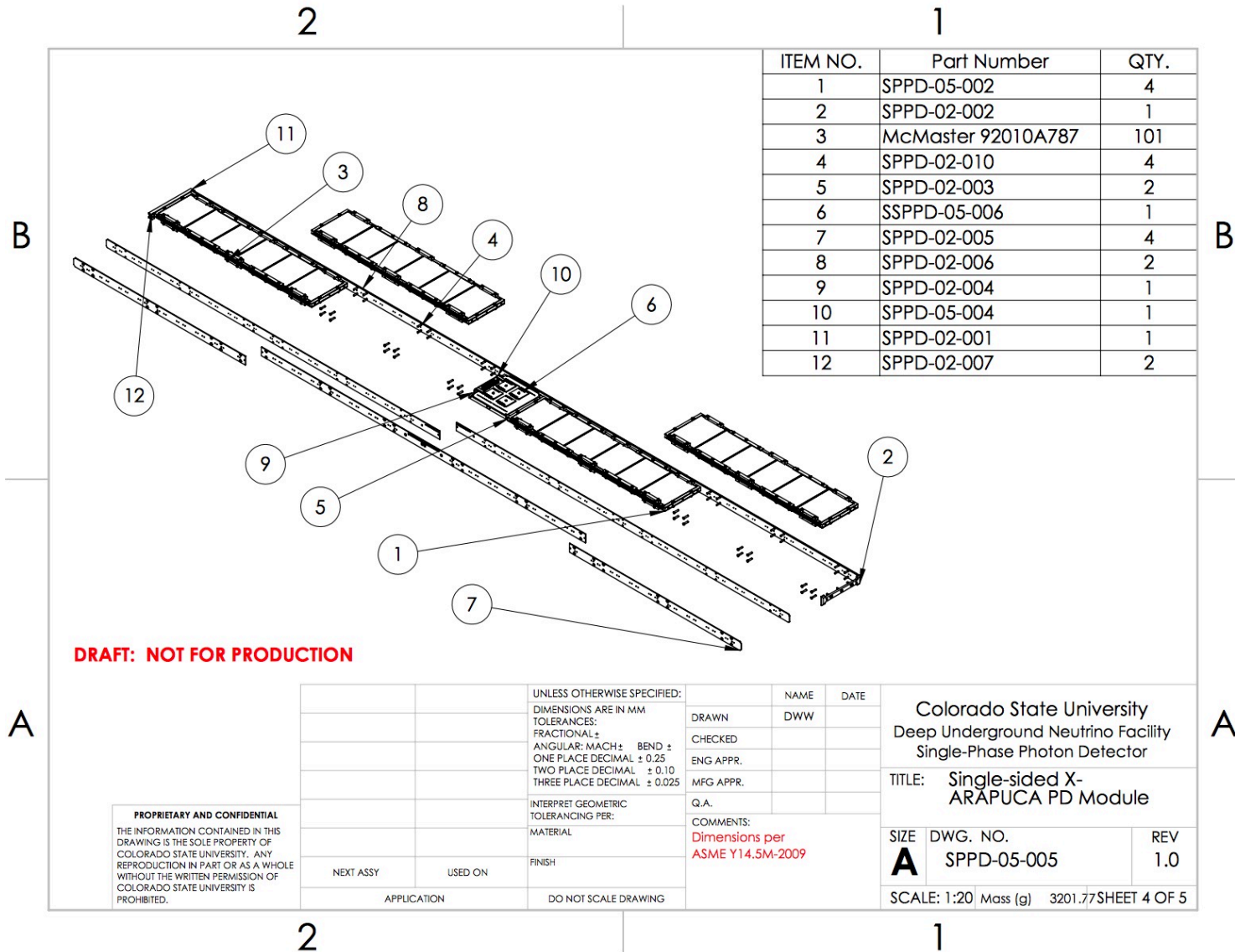
- Maximum (inc. tolerance) cross section 134.25 X 23.75mm, This fits into SPS side tube slot (134.75 X 24.75 inc. tol.)



- Module active length 2090 +/- 1.5mm.

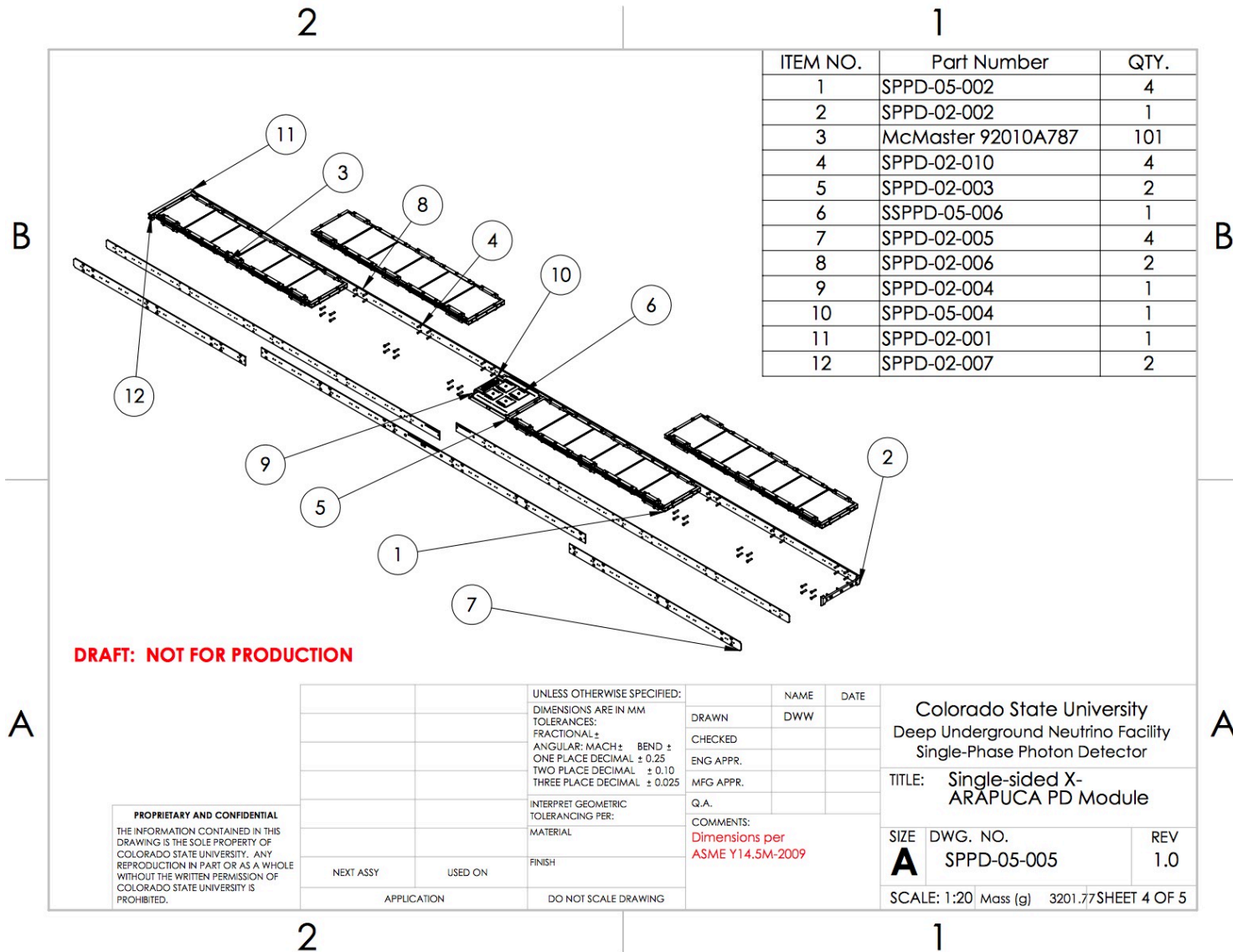
# PD Module Design: Module Assembly (iii)

- 4 supercells
- Central readout
- 4 routing PCBs along sides
- Outer strengthening ribs (support flex)



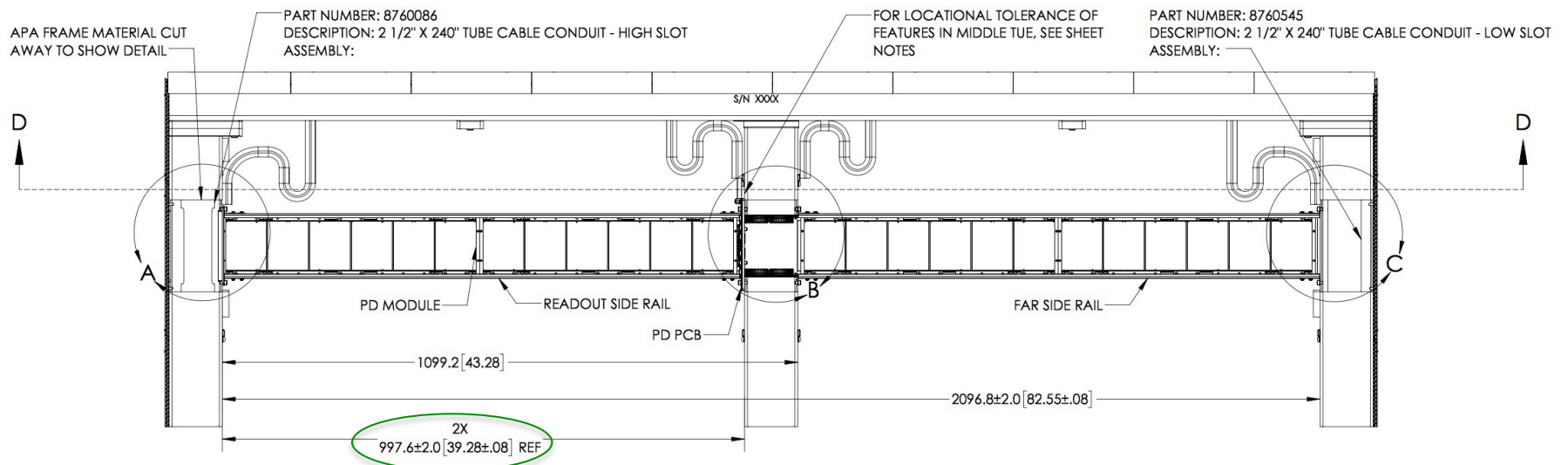
# PD Module Design: Module Assembly (iii)

- 4 Supercells
- Central readout
- 4 routing PCBs along sides
- Outer strengthening ribs
  - Support
  - Isolation



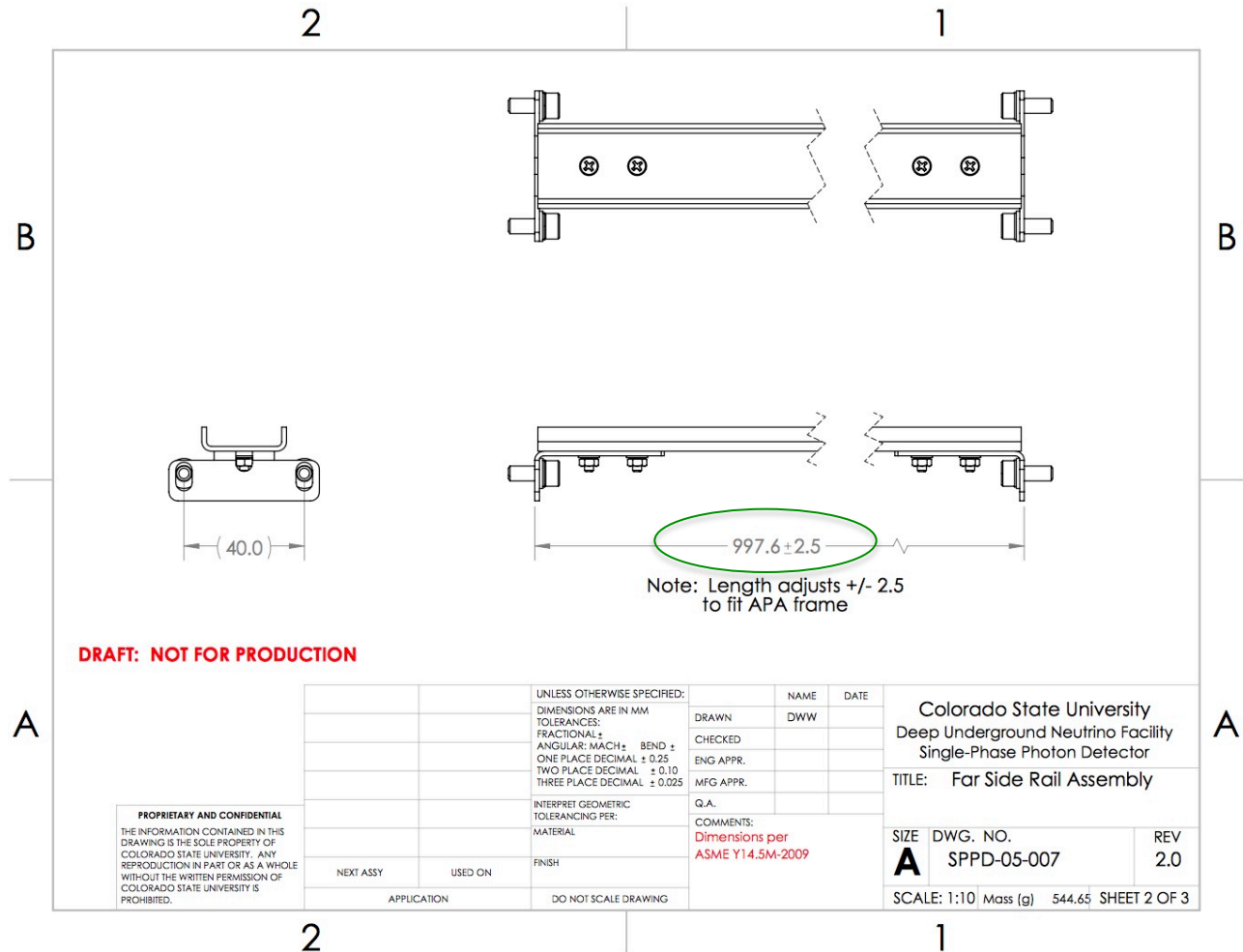
## Rail System (i)

- PD modules are supported in APAs in support rails.
- There are two types of PD rail assemblies:
  - Readout Side Rails
  - Far Side Rails
- Rails are supported between APA side and middle tubes.
- Rails are designed to accommodate +/- 2mm tolerance of APA tube position.



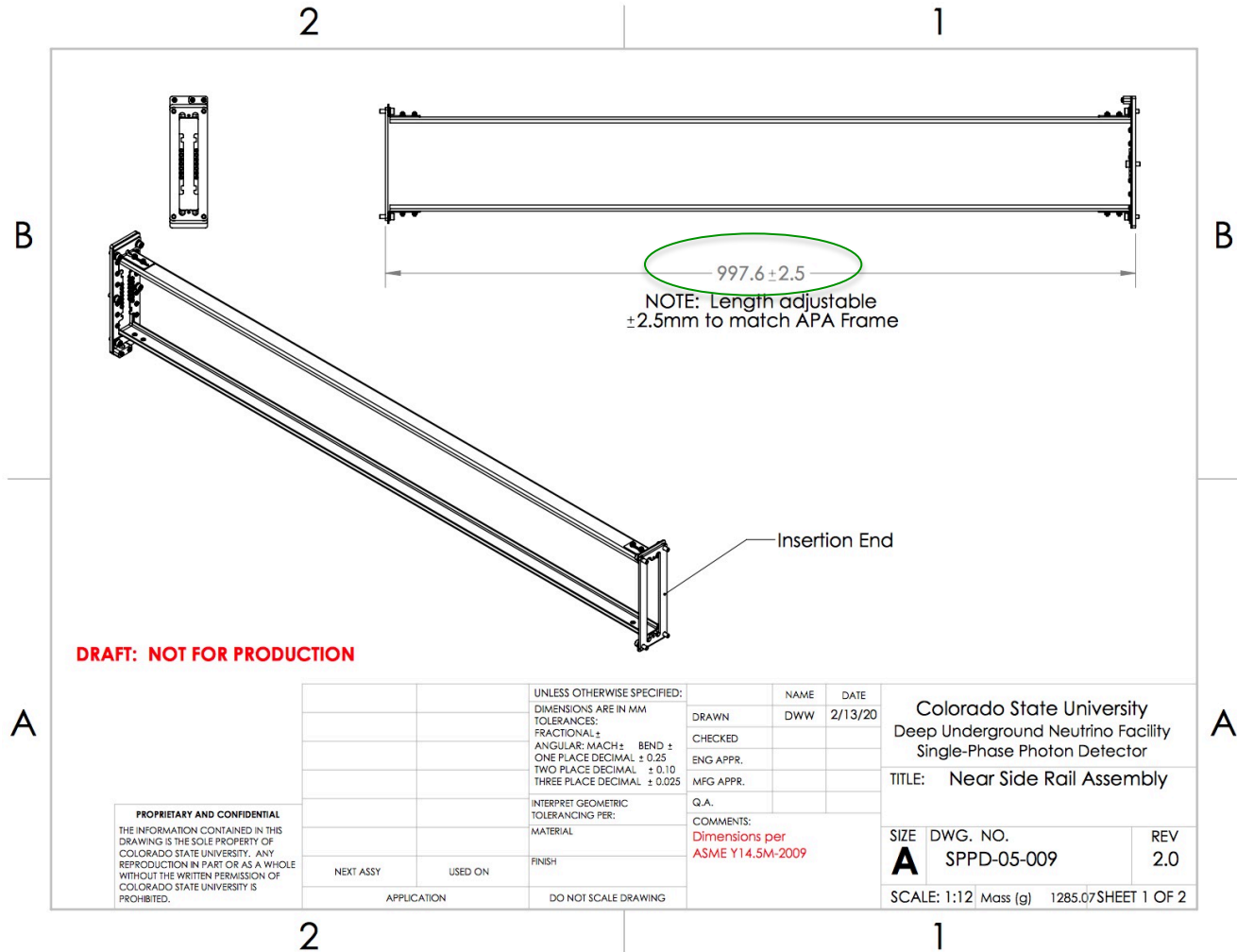
# Rail System (ii)

- Far side rail assembly
- Two assemblies per far side APA bay
- Adjustable length to match APA tolerances



# Rail System (iii)

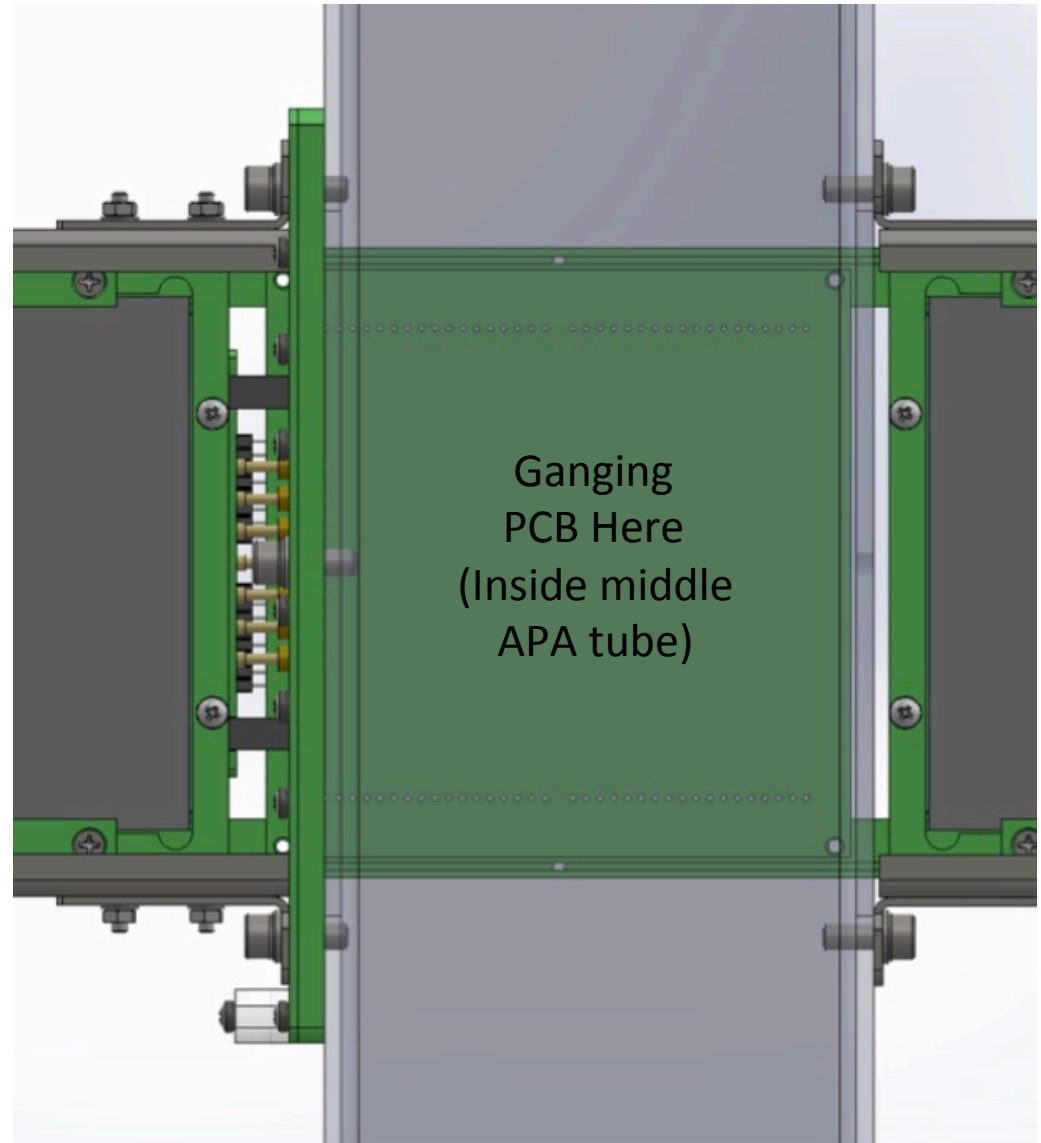
- Near side rail assembly.
- One assembly per insertion-side APA bay.
- Adjustable length to match APA tolerances.
- Includes electrical connector assembly.





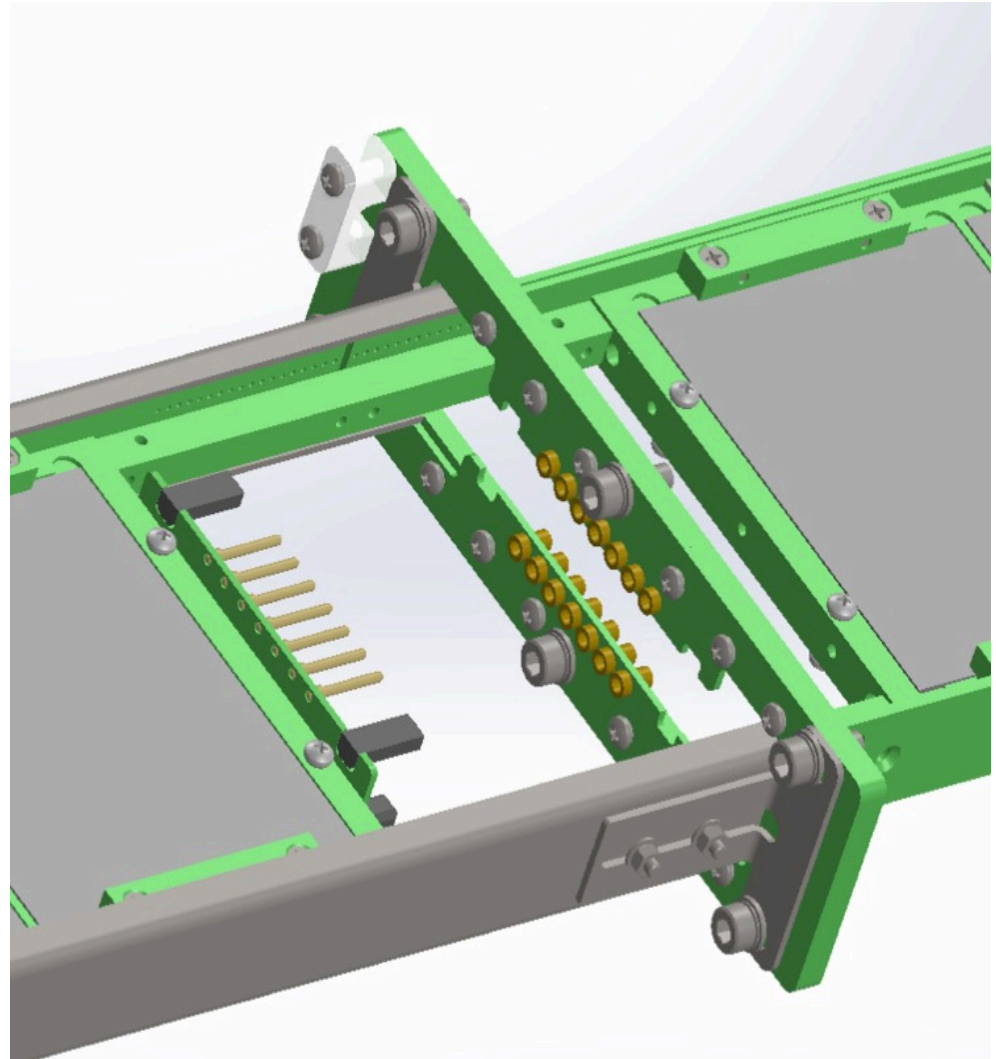
## Electrical Connections (i)

- Connections made at central tube. Connections occur automatically with module insertion.
- Socket board mounted to APA middle tube.
- Pin board mounted to module.



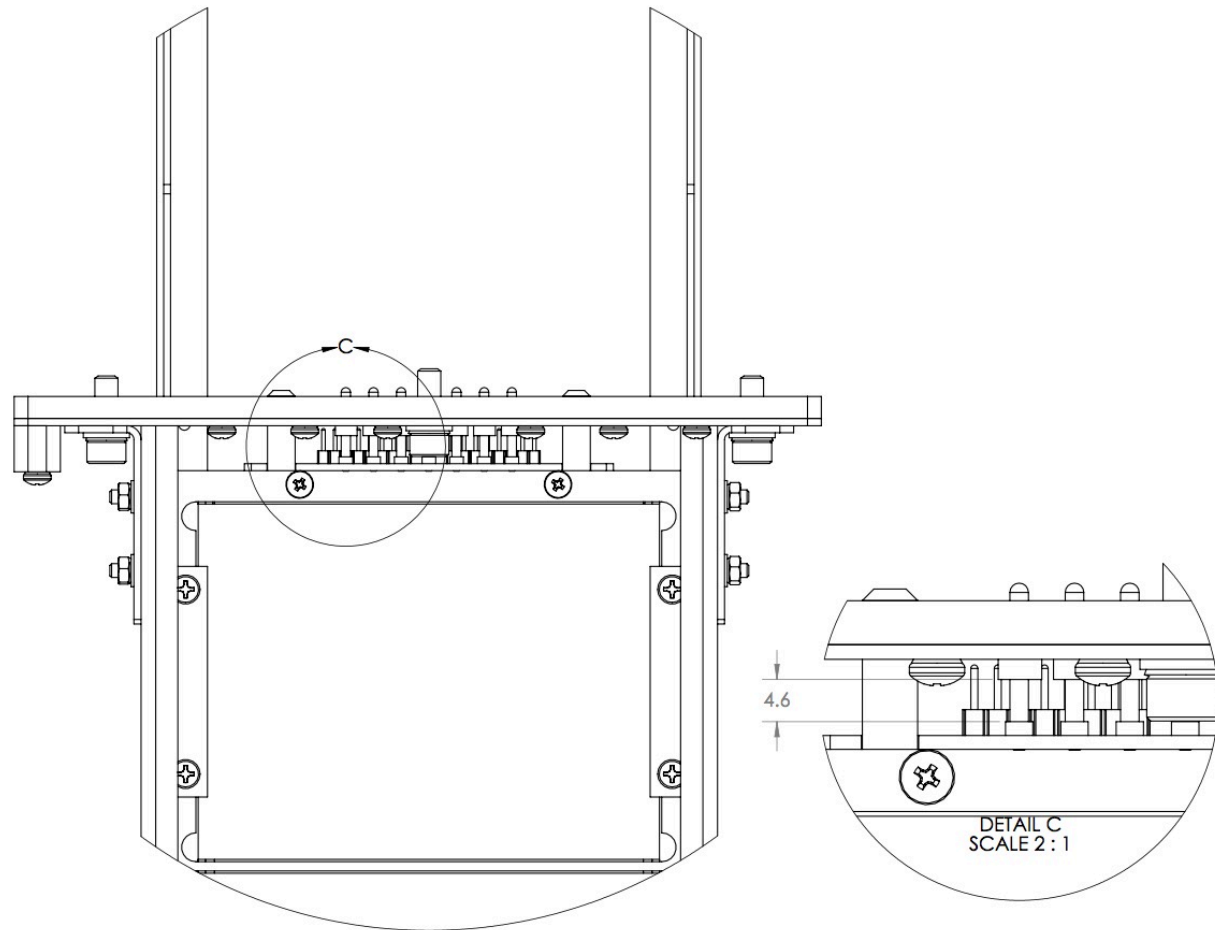
## Electrical Connections (ii)

- Module being inserted.
- Socket board mounted to APA.
- Pin board mounted to module.



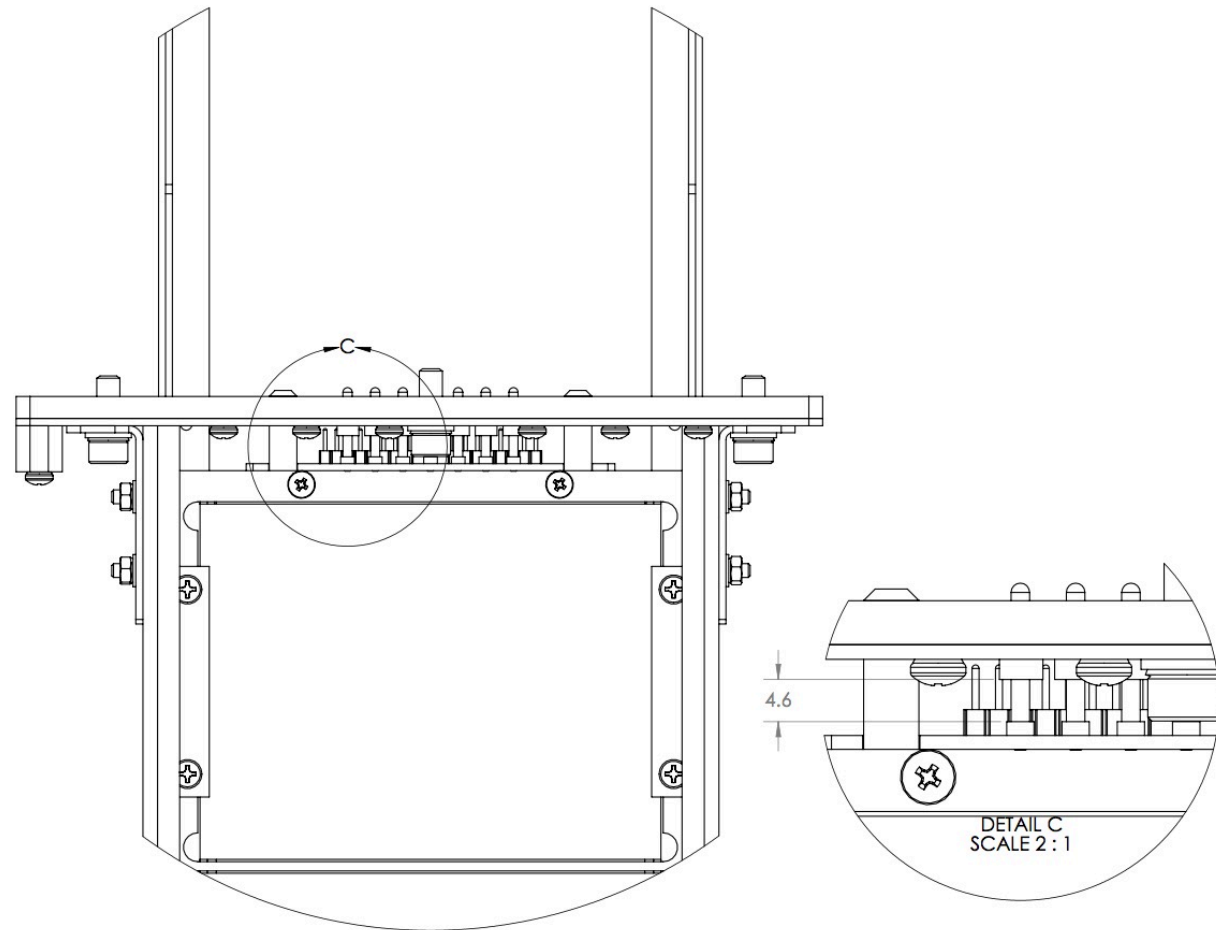
## Electrical Connections (iii)

- 4.6mm nominal gap left between pins and sockets when engaged.
- Additional 5mm of engagement length beyond nominal insertion.
- Checked to satisfy tolerance stackup and thermal variations .
- Pin-socket connections checked during multiple cycles in test dewar.



## Electrical Connections (iii)

- 4.6mm nominal gap left between pins and sockets when engaged
- Additional 5mm of engagement length beyond nominal insertion
- Checked to satisfy tolerance stack-up and thermal variations
- Pin-socket connections checked during multiple thermal cycles in test dewar



# PD System Engineering (i)

- PD frame constructed from FR-4 G-10.
  - Module dimensions in all 3 directions are controlled by in-plane (warp direction) FR-4. Warp direction indicated on component fabrication drawings.
  - This allows a close match between PD and APA frame thermal expansion.

Table 2 - Mechanical properties of PD system materials

| Material | Density<br>(g/cm <sup>3</sup> ) | Modulus of<br>Elasticity<br>(GPa) | CTE @ 87K<br>$\Delta T = 87K-298K =$<br>-211<br>(1/K x K) | Yield<br>Strength<br>(MPa) | Ultimate<br>strength (MPa)                       |
|----------|---------------------------------|-----------------------------------|---|----------------------------|--|
| FR4-G10  | 1.8                             | 16.6                              | -6.2E-03 (normal)<br>-2.1E-03 (warp)                      | NA                         | 165.4 (weak)<br>200 (strong)<br>64.7 (thickness) |
| SS 304   | 8.0                             | 193                               | -2.7E-03  | 215                        | 505  |

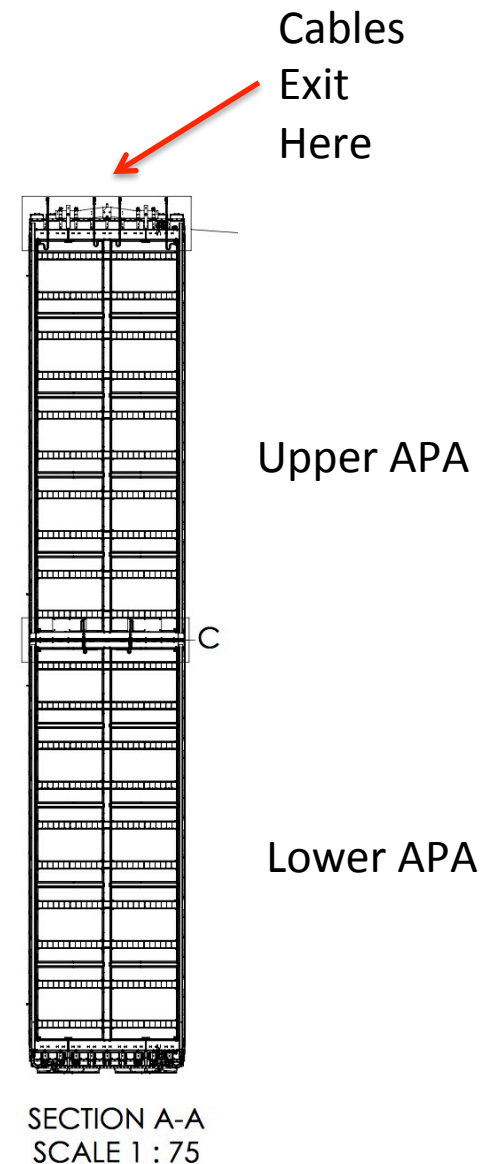
- Validated as part of Compliance Office design evaluation.
- Still awaiting final checkout in APA frame assembly at PSL.

## PD System Engineering (ii)

- PD modules are installed into APA frames in their final orientation, underground at SURF, immediately prior to insertion into the cryostat.
  - This limits the stresses seen by PD modules due to APA handling.
  - Evaluations limited to rails in APA frames.
- Additional engineering calculations still required prior to FDR:
  - Dynamic analysis of rails in APA during shipping.
  - Static analysis of rails in APA worst load cases for APA frame due to known handling/wire wrapping positions.
- Calculations ongoing at PSL and Fermilab.

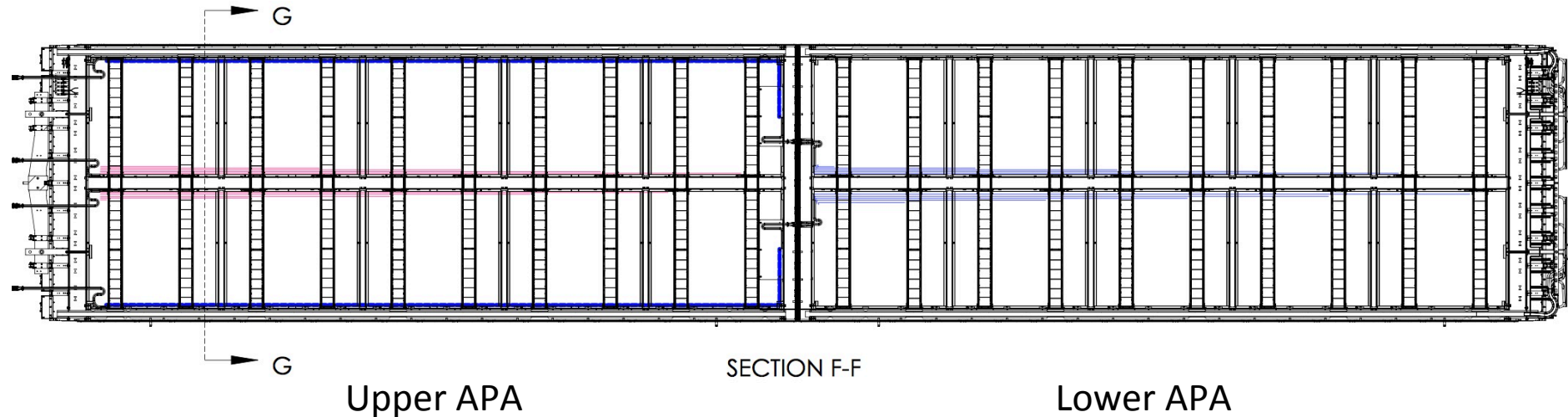
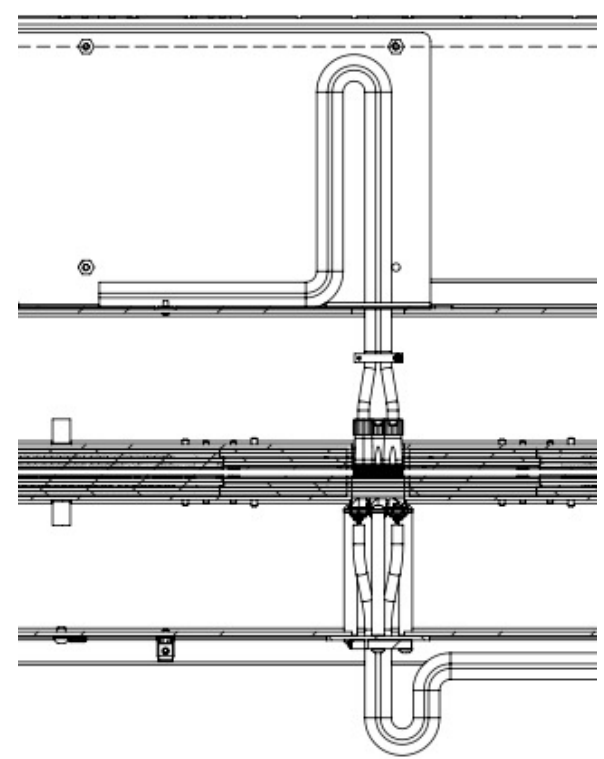
## Cable Routing (i): Through APA Frame

- APA frames joined vertically prior to insertion into cryostat.
- Cables from lower APA must route through upper APA.
- Requires two varieties of APA: Upper and lower.
- PD cable routing shared with CALCI temperature sensor cables. **NOT ADDRESSED SPECIFICALLY IN THIS PRESENTATION.**



## Cable Routing (ii): Through APA Frame

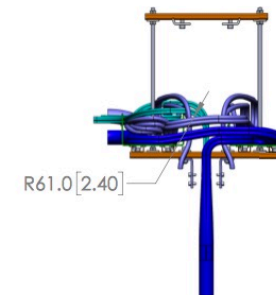
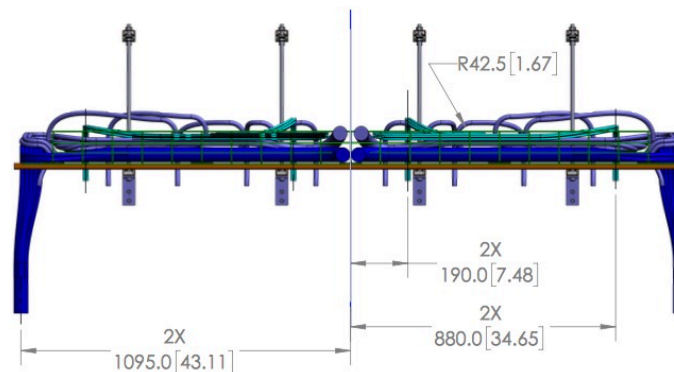
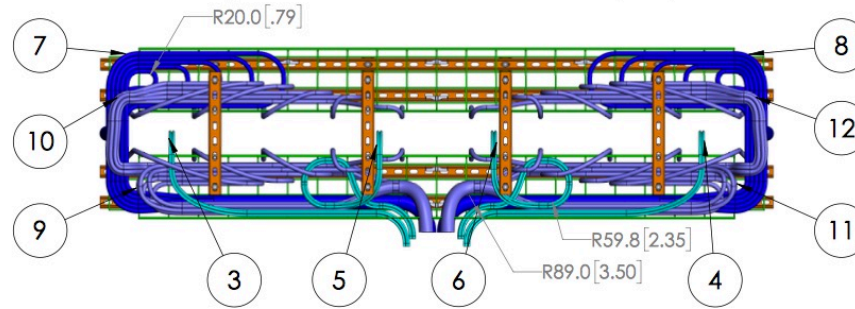
- Upper and lower APAs are joined using a custom interface block. Does not limit APA separation. Tested at PSL
- Cables mounted in APA frames prior to wire wrapping.
- Clearance for 2% relative thermal contraction (cable/APA frame) allowed.
- Full cable routing awaiting cryogenic testing at PSL (Covid delay).





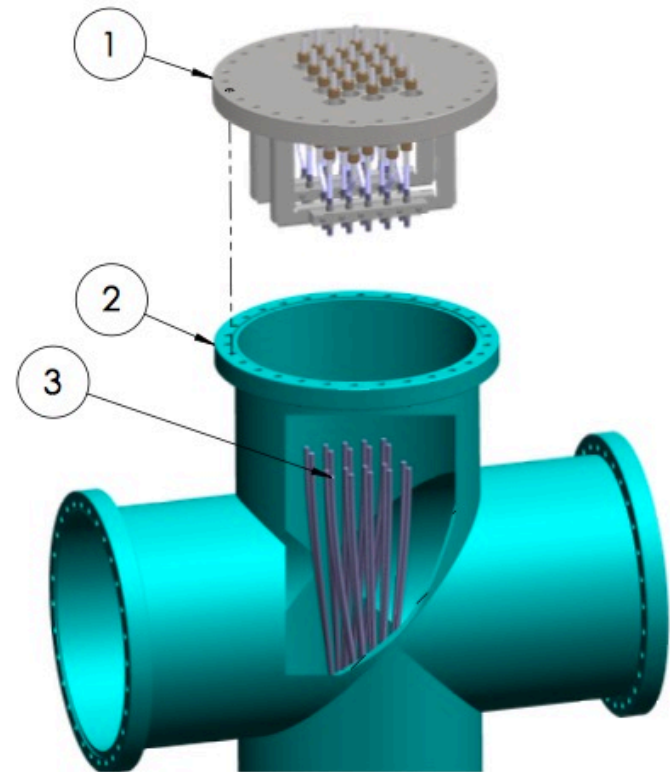
# Cable Routing (ii3): Shared Cable Tray

| ITEM NO. | FILE NAME                    | DESCRIPTION                                | QTY. | DESIGN MIN BEND RADIUS (MM) | MIN ALLOWABL |
|----------|------------------------------|--|------|-----------------------------|--------------|
| 1        | CE CABLE TRAY ON CHANNEL     | CABLE TRAY ON CHANNEL                      | 1    |                             |              |
| 2        | CE HANGER KIT                | HANGER KIT                                 | 4    |                             |              |
| 3        | PD BUNDLE IN TRAY LOWER - A  | PD CABLE BUNDLE IN TPC TRAY FROM LOWER APA | 1    | 100                         |              |
| 4        | PD BUNDLE IN TRAY LOWER - B  | PD CABLE BUNDLE IN TPC TRAY FROM LOWER APA | 1    | 100                         |              |
| 5        | PD BUNDLE IN TRAY UPPER - A  | PD CABLE BUNDLE IN TPC TRAY FROM UPPER APA | 1    | 100                         |              |
| 6        | PD BUNDLE IN TRAY UPPER - B  | PD CABLE BUNDLE IN TPC TRAY FROM UPPER APA | 1    | 100                         |              |
| 7        | CE CABLES IN TRAY LOWER - A  | CE CABLES IN TRAY FROM LOWER APA           | 1    | 55                          |              |
| 8        | CE CABLES IN TRAY LOWER - B  | CE CABLES IN TRAY FROM LOWER APA           | 1    | 55                          |              |
| 9        | CE CABLES IN TRAY UPPER - A1 | CE CABLES IN TRAY FROM UPPER APA           | 1    | 50                          |              |
| 10       | CE CABLES IN TRAY UPPER - A2 | CE CABLES IN TRAY FROM UPPER APA           | 1    | 50                          |              |
| 11       | CE CABLES IN TRAY UPPER - B1 | CE CABLES IN TRAY FROM UPPER APA           | 1    | 50                          |              |
| 12       | CE CABLES IN TRAY UPPER - B2 | CE CABLES IN TRAY FROM UPPER APA           | 1    | 50                          |              |



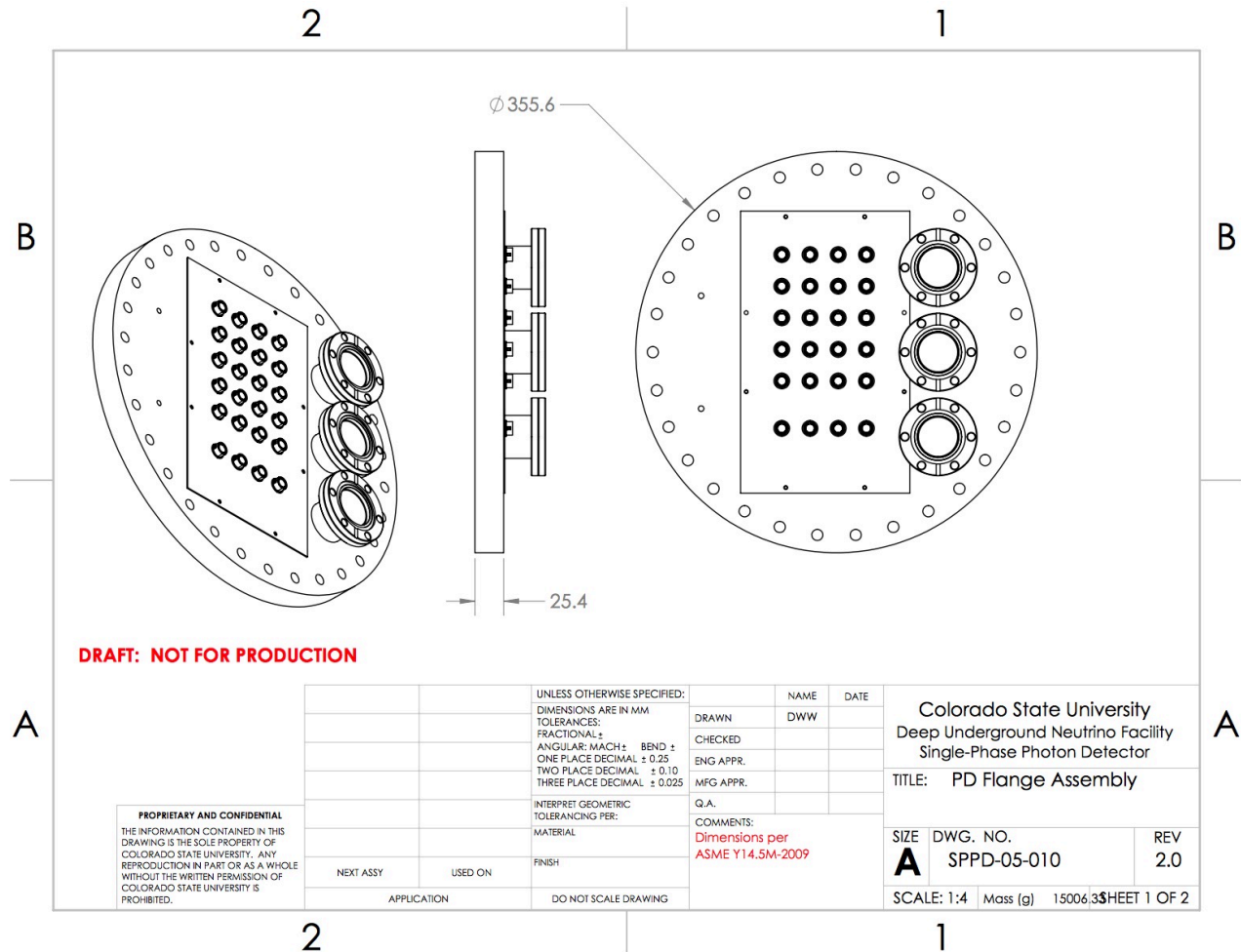
## Cable Routing (iv): Crossing tube

- Photon detectors share cable space in cable trays on top of APA and in crossing tube through cryostat insulation.
- PD custom flange shown in figure.
- Will be tested at Brookhaven test bed once Covid delays resolved.



# Cable Routing (v): Flange assembly

- Based on ProtoDUNE 1 design.
- Provided ports for signal cables (Gotti talk) and monitoring system fibers (Martinez talk).
- Provides grounding nexus (detector ground reference).
- Provides CALCI temperature sensor connectors.



## Design Documents: Where to find them!

- Modules described in TRD ([EDMS 2383194](#) ) and TDR update document ([EDMS 2383195](#) ).
- Full set of mechanical specifications
  - Component CAD models (.step) and drawings (.pdf)
  - Assembly CAD models (.step) and drawings (.pdf)
  - Bill of materials (Workbook and assembly drawing BOMs, including fasteners in most cases)

# Mechanical BOM/Drawing/Model Guide ([EDMS 2384656](#))

| SPPD Part Number                         | System           | Title  | Material            | Mass (g) | No/system | Model EDMS              | Drawing EDMS            |
|--|------------------|--|---------------------|----------|-----------|-------------------------|-------------------------|
| <b>SPPD-01-XXX Supercell Parts</b>       |                  |  |                     |          |           |                         |                         |
| SPPD-01-001                              | Supercell        | Side Rail Filter Plate Clamp Top             | FR-4 G-10           | 3.63     | 6         | <a href="#">2380160</a> | <a href="#">2383677</a> |
| SPPD-01-002                              | Supercell        | Side Rail Filter Plate Clamp Bottom          | FR-4 G-10           | 3.77     | 6         | <a href="#">2380160</a> | <a href="#">2383677</a> |
| SPPD-01-003                              | Supercell        | Central Filter Clamp                         | FR-4 G-10           | 2.17     | 4         | <a href="#">2380160</a> | <a href="#">2383677</a> |
| SPPD-01-004                              | Supercell        | Supercell Filter Locating Plate              | FR-4 G-10           | 13.24    | 1         | <a href="#">2380160</a> | <a href="#">2383677</a> |
| SPPD-01-005                              | Supercell        | Supercell Center End Rail                    | FR-4 G-10           | 8.96     | 2         | <a href="#">2380160</a> | <a href="#">2383677</a> |
| SPPD-01-006                              | Supercell        | Supercell 2mm top rail                       | FR-4 G-10           | 10.4     | 2         | <a href="#">2380160</a> | <a href="#">2383677</a> |
| SPPD-01-007                              | Supercell        | SiPM PCB Mounting Block                      | FR-4 G-10           | 4.96     | 8         | <a href="#">2380160</a> | <a href="#">2383677</a> |
| SPPD-01-008                              | Supercell        | Photosensor Mount Screw Shim Block           | FR-4 G-10           | 0.24     | 6         | <a href="#">2380160</a> | <a href="#">2383677</a> |
| SPPD-01-009                              | Supercell        | Photosensor End Mount Screw Shim Block       | FR-4 G-10           | 0.12     | 4         | <a href="#">2380160</a> | <a href="#">2383677</a> |
| SPPD-01-010                              |                  | OBSOLETE                                     | OBSOLETE            |          |           |                         |                         |
| SPPD-01-011                              | Supercell        | Dichroic Filter Plate                        | Fused Silica        | 16.94    | 6         | <a href="#">2380160</a> | <a href="#">2383677</a> |
| SPPD-01-012                              | Supercell        | WLS Plate (Blue Polystyrene)                 | Polystyrene         | 190.66   | 1         | <a href="#">2380160</a> | <a href="#">2383677</a> |
| SPPD-01-013                              | Supercell        | One Direction Supercell Backing Plate        | FR-4 G-10           | 101.37   | 1         | <a href="#">2380160</a> | <a href="#">2383677</a> |
| <b>SPPD-02-XXX Module Parts</b>          |                  |  |                     |          |           |                         |                         |
| SPPD-02-001                              | PD Module        | Module End Stop Block                        | FR-4 G-10           | 24.33    | 1         | <a href="#">2384229</a> | <a href="#">2384230</a> |
| SPPD-02-002                              | PD Module        | Front Guide Bar (molded polycarbonate)       | Polycarbonate       | 7.48     | 1         | <a href="#">2384229</a> | <a href="#">2384230</a> |
| SPPD-02-003                              | PD Module        | Active Ganging Support Rail                  | FR-4 G-10           | 14.01    | 2         | <a href="#">2384229</a> | <a href="#">2384230</a> |
| SPPD-02-004                              | PD Module        | Contact Block Spacer Block                   | FR-4 G-10           | 2.41     | 1         | <a href="#">2384229</a> | <a href="#">2384230</a> |
| SPPD-02-005                              | PD Module        | End Module Side Support Bar                  | FR-4 G-10           | 33.84    | 4         | <a href="#">2384229</a> | <a href="#">2384230</a> |
| SPPD-02-006                              | PD Module        | Center Module Side Support Bar               | FR-4 G-10           | 63.44    | 2         | <a href="#">2384229</a> | <a href="#">2384230</a> |
| SPPD-02-007                              | PD Module        | Module End Captive Screw Block               | FR-4 G-10           | 9.69     | 2         | <a href="#">2384229</a> | <a href="#">2384230</a> |
| SPPD-02-010                              | PD Module        | Side Readout Bar                             | FR-4 G-10           | 62.61    | 4         | <a href="#">2384229</a> | <a href="#">2384230</a> |
| <b>SPPD-03-XXX Guide Rail Parts</b>      |                  |  |                     |          |           |                         |                         |
| SPPD-03-001                              | APA Slot         | PD Rail Mount Angle                          | Stainless Steel 304 | 15.51    | 8         | <a href="#">2384650</a> | <a href="#">2384651</a> |
| SPPD-03-002                              | APA Slot         | PD Guide Rail-Far Side                       | Stainless Steel 304 | 491.64   | 2         | <a href="#">2384650</a> | <a href="#">2384651</a> |
| SPPD-03-003                              | APA Slot         | PD Rail Mount Plate- Insertion End           | Stainless Steel 304 | 104.85   | 1         | <a href="#">2384650</a> | <a href="#">2384651</a> |
| SPPD-03-004                              | APA Slot         | PD Readout PCB Backing Plate                 | FR-4                | 48.28    | 1         | <a href="#">2384650</a> | <a href="#">2384651</a> |
| SPPD-03-005                              | APA Slot         | PD Readout PCB                               | FR-4                | 17.02    | 1         | <a href="#">2384650</a> | <a href="#">2384651</a> |
| SPPD-03-006                              | APA Slot         | Signal Cable Clamp                           | Polycarbonate       | 2.03     | 1         | <a href="#">2384650</a> | <a href="#">2384651</a> |
| SPPD-03-007                              | APA Slot         | PD Guide Rail-Readout Side                   | Stainless Steel 304 | 487.39   | 2         | <a href="#">2384650</a> | <a href="#">2384651</a> |
| <b>SPPD-04-XXX-Cryostat Flange Parts</b> |                  |  |                     |          |           |                         |                         |
| SPPD-04-001                              | PD Flange        | PD Flange Blank                              | Stainless Steel 304 | 14467.58 | 1         | <a href="#">2384689</a> | <a href="#">2384690</a> |
| SPPD-04-002                              | PD Flange        | Flange Connector Cover Plate                 | Stainless Steel 304 | 277.7    | 1         | <a href="#">2384689</a> | <a href="#">2384690</a> |
| <b>SPPD-05-XXX Assemblies</b>            |                  |  |                     |          |           |                         |                         |
| SPPD-05-001                              | Supercell        | Hamamatsu Photosensor 8-pin PCB Sub-Assembly |                     | 3.52     | 8         | <a href="#">2384654</a> | <a href="#">2384655</a> |
| SPPD-05-002                              | PD Module        | Single-Side Supercell Assembly               |                     | 636.89   | 4         | <a href="#">2383678</a> | <a href="#">2383679</a> |
| SPPD-05-003                              | Supercell        | Photosensor Sub-Assembly                     |                     | 8.48     | 8         | <a href="#">2384654</a> | <a href="#">2384655</a> |
| SPPD-05-004                              | PD Module        | ARAPUCA electrical connector Assembly        |                     | 16.08    | 1         | <a href="#">2384654</a> | <a href="#">2384655</a> |
| SPPD-05-005                              | N/A              | Single Sided PD Module                       |                     | 3201.77  | N/A       | <a href="#">2383678</a> | <a href="#">2383679</a> |
| SPPD-05-006                              | PD Module        | Cold Amplifier Motherboard Assembly          |                     | 51.73    | 1         | <a href="#">2384654</a> |                         |
| SPPD-05-007                              | PD Rail Assembly | Far Side Rail Assembly                       |                     | 524.54   | 2         | <a href="#">2384649</a> | <a href="#">2384652</a> |
| SPPD-05-008                              | PD Rail Assembly | Connector PCB Assembly                       |                     | 87.37    | 1         | <a href="#">2384649</a> | <a href="#">2384652</a> |
| SPPD-05-009                              | PD Rail Assembly | Near Side Rail Assembly                      |                     | 1285.07  | 1         | <a href="#">2384649</a> | <a href="#">2384652</a> |
| SPPD-05-010                              | Flange Assembly  | PD Flange Assembly                           |                     | 15006.33 | 1         | <a href="#">2384688</a> | <a href="#">2384691</a> |
| SPPD-05-011                              | Flange Assembly  | Flange PCB Assembly                          |                     | 139.72   | 1         | <a href="#">2384688</a> | <a href="#">2384691</a> |

# Engineering Analysis Documents (Compliance Office)

- Analysis plan [EDMS 2380161](#)
- Structural analysis note [EDMS 2380229](#)
- Independent Review Reports

## **7. Conclusion for the 60 % design review:**

The status of the design of the PD is in a status acceptable for the PD 60 % design review. The analysis plan is validated and can be used for the structural analysis required for the Final Design review.

- Additional analysis of PD rail structure in APA frame required
  - Developing static and dynamic model input with APA
  - Will be complete prior to FDR

# Summary

- The baseline Photon Detector system design is complete at the PDR level and documented in EDMS.
- The design is significantly unchanged since the TDR
- Critical design tolerances have been specified and confirmed with APA and TPC consortia.
  - Included in Interface Control Documents
- While delays due to the COVID 19 crisis have slowed our prototyping plans, validation efforts are re-starting now.
- We are prepared to proceed to validation and analysis for the Final Design Review!