

# High Voltage System Interconnects for DUNE-SP

Glenn Horton-Smith

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Review of DUNE-SP High Voltage System

# There are many kinds of connections on the path from the HV cup arm to the APA

- Connections along the HV bus
- IntraCPA connections: panel to panel, RP to RP, bus to frame, frame to edge profiles
- CPA to FC (top, bottom, end walls)
- End of FC to APA.
- All of these interconnections were tested in ProtoDUNE-SP.

# Summary

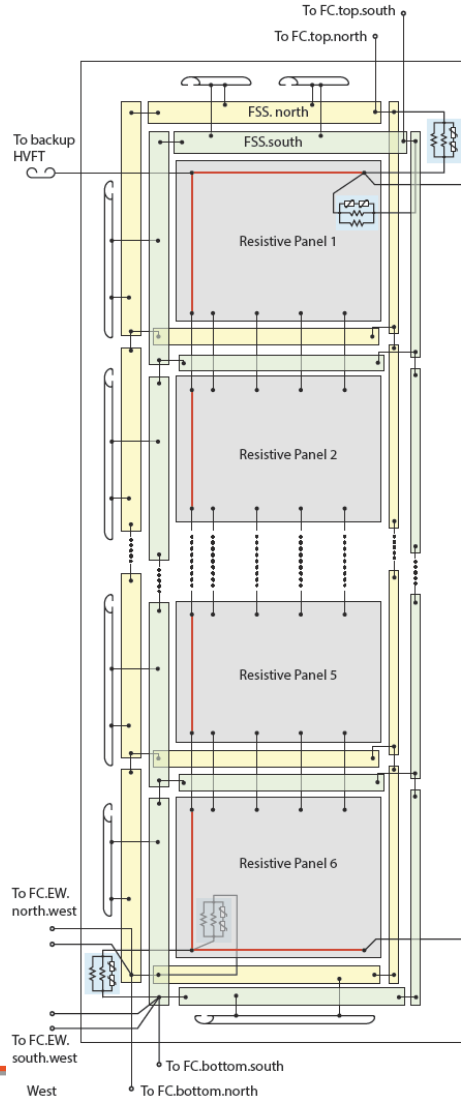
- There are essentially no changed or added interconnection designs in DUNE FD SP compared to ProtoDUNE SP.
  - Quantity of connections is increased compared to PD SP.
  - Vertical HV bus segment lengths adjusted.
- Some minor changes in connection sequence and logistics due to assembly procedure.

The rest of the presentation goes through each interconnect.

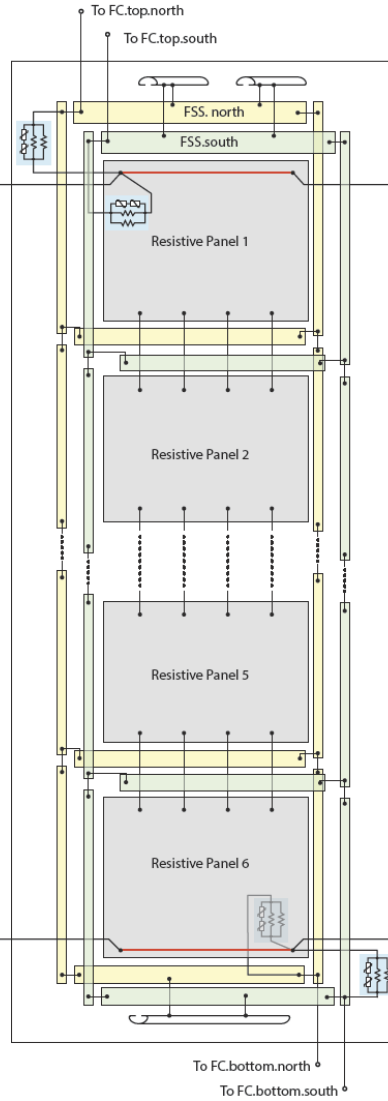
- Mechanical drawings and electrical schematics are in DUNE-doc-10452, and also in EDMS project CERN-0000195415.
- All part numbers in the following slides refer to drawings CPA\_051519\_part\_1.pdf and CPA\_051519\_part\_2.pdf.

# On CPA

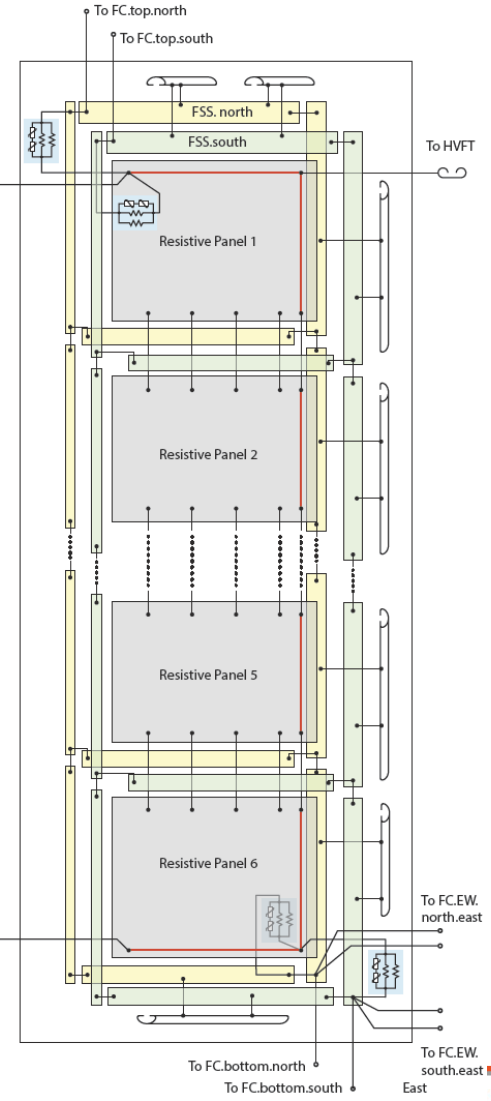
CPA. Panel 50



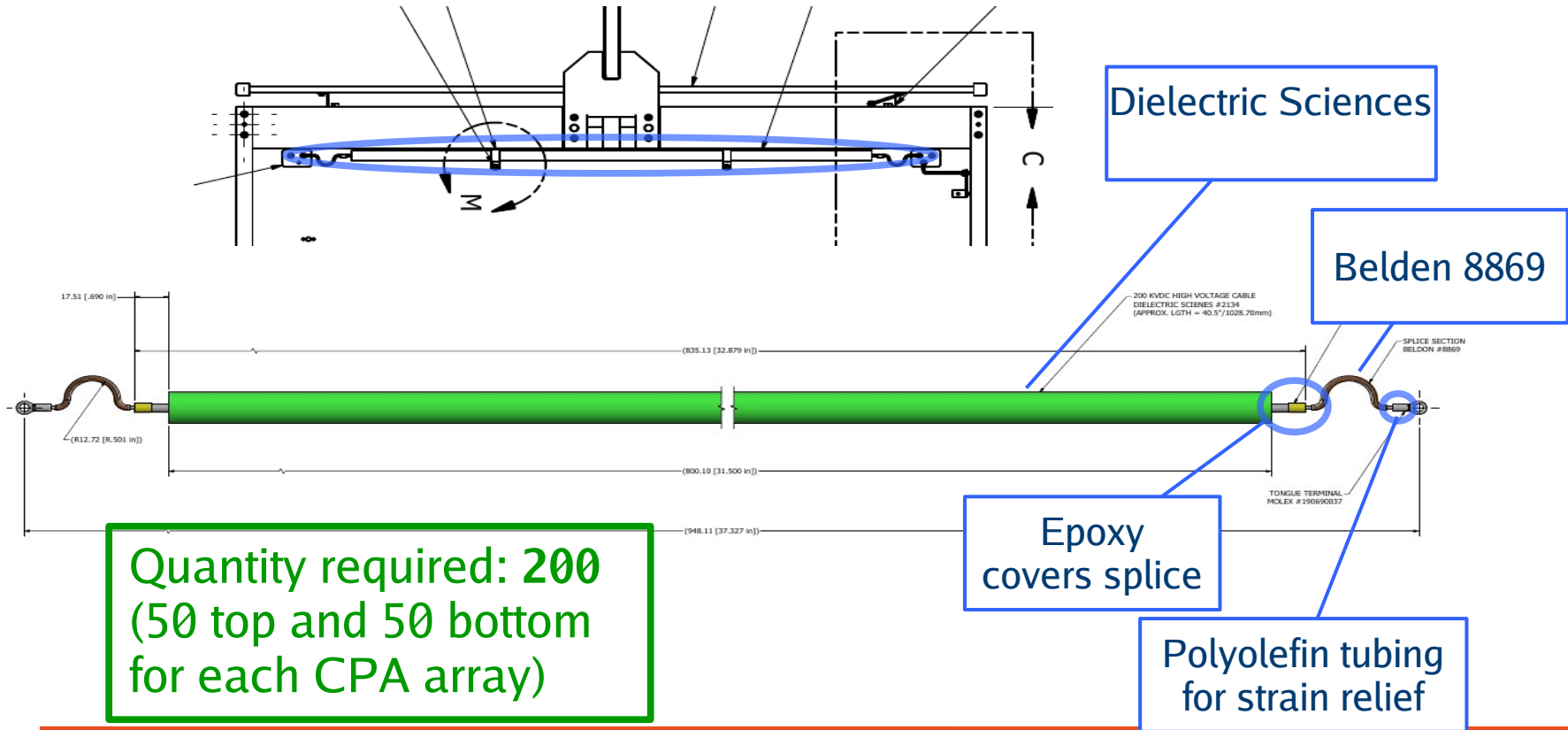
CPA. Panel 2 - 49



CPA. Panel 1

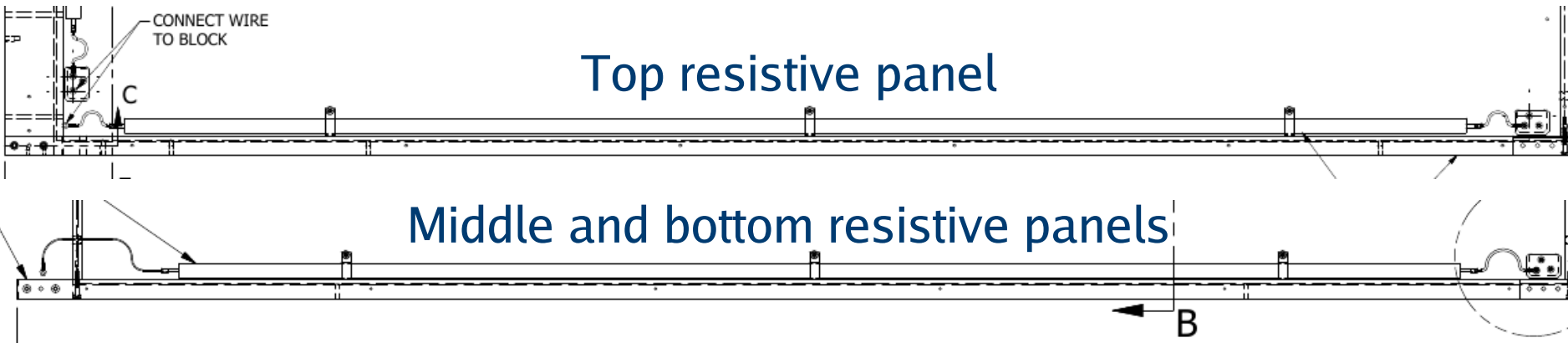


# Horizontal HV bus segments (DFD-20-A409 in CPA\_051519\_part\_2.pdf)



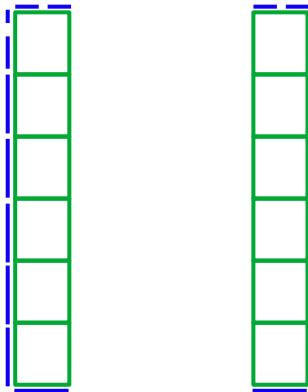
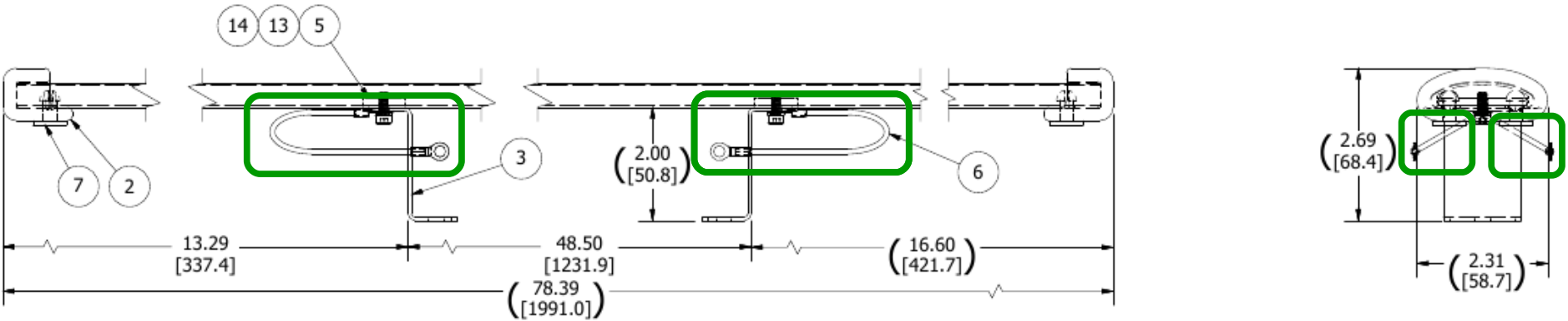
# Vertical HV bus segments, shown rotated 90 degrees to fit on slide (DFD-20-A411 and DFD-20-A505)

Up



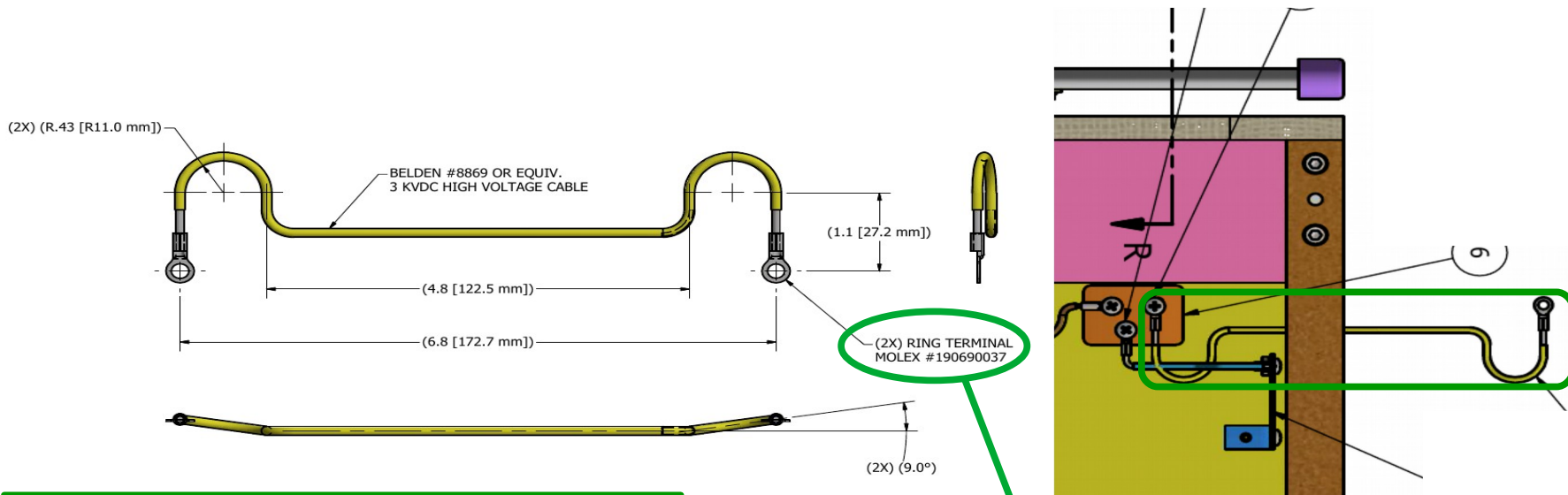
Quantity required:  
4 top panel style  
44 middle/bottom style

# CPA profile jumper – connects profiles to frame strip (DFD-20-A115)



Quantity required:  
 $2 \times 3 = 6$  for each middle CPA panel  
 $2 \times 10 = 20$  for each end CPA panel  
 $2 \times (6 \times 48 + 2 \times 20) = 656$  total

# CPA “panel-to-panel” wire – connects from one CPA to the next (DFD-20-A046)



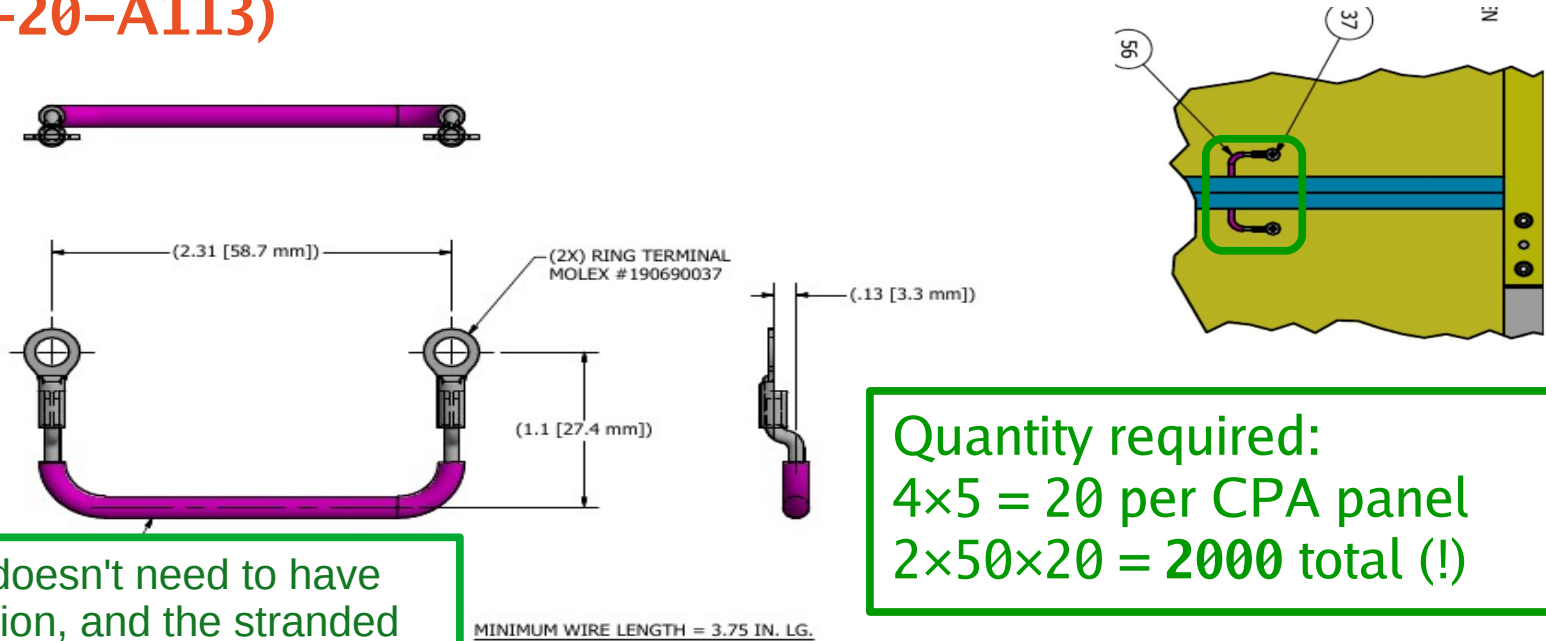
Quantity required:  
2 for each middle CPA panel  
1 for each end CPA panel  
 $2 \times (2 \times 48 + 1 \times 2) = 196$  total

Changed to fork terminals,  
3M part number #MU18-10FLK to  
ease installation.





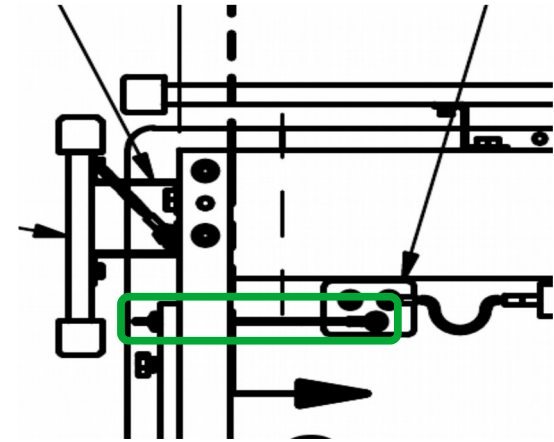
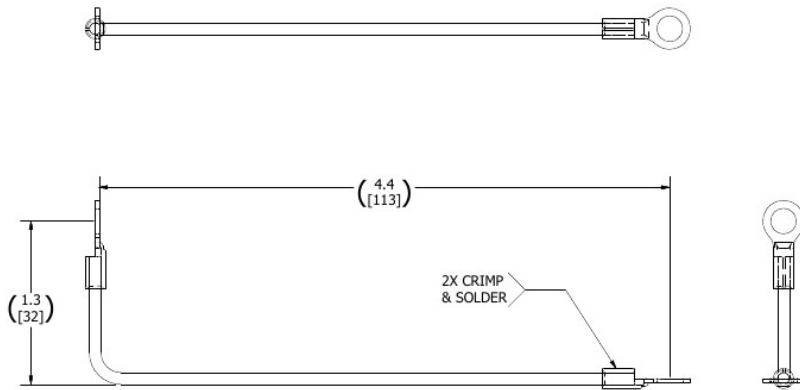
# CPA “section-to-section” wire: connects cathode RPs in CPA panel (DFD-20-A113)



This wire doesn't need to have HV insulation, and the stranded 22 AWG Belden 8869 is slightly mechanically weaker than solid wire. Solid 22AWG tinned copper wire is our choice here.

Quantity required:  
 $4 \times 5 = 20$  per CPA panel  
 $2 \times 50 \times 20 = 2000$  total (!)

# “Donut jumper”: connects HV cup arm to HV bus (DFD-20-A114)



Quantity required:  
1 per HV cup  
4 total

# Notes on HV bus

- A lesson learned from 35t HV assembly was to prefer fork connectors anywhere “in situ” installation is necessary.
- Polyolefin heat-shrink at crimp to ring terminals protects against twisting stranded wire at terminal, addresses another concern from 35t HV installation.
- HV bus assemblies for ProtoDUNE made were made and tested at Kansas State, cleaned in clean room, double-bagged in cleanroom bags, packed for shipping to ANL.
- No problems traced to HV bus at ProtoDUNE → no eagerness to change HV bus design.

# Notes on interconnect wires

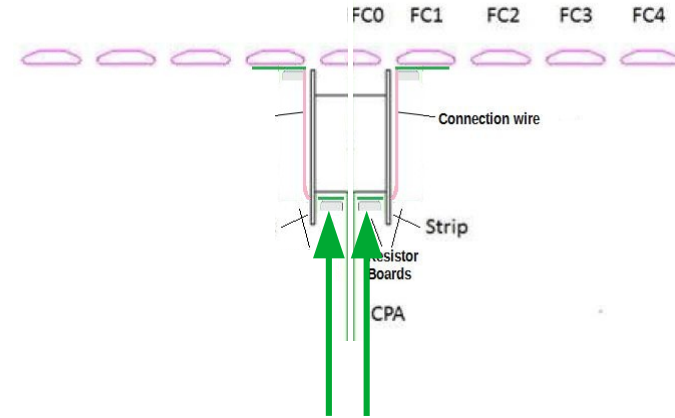
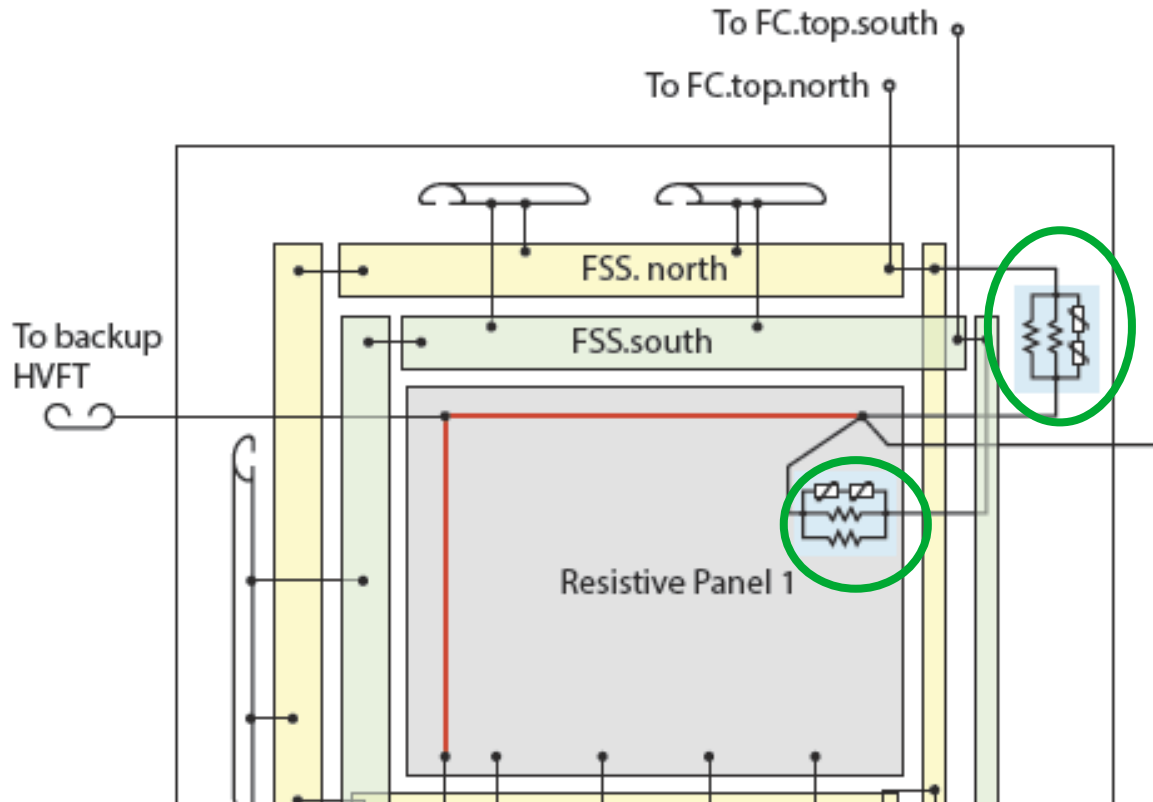
- Fork terminals were substituted for ring terminals on the frame–penetrating wires to allow for making connections during integration without completely removing a screw, based on 35t HV assembly experience.
- Solid, uninsulated wire was used for RP connections in ProtoDUNE, flexible HV wire with fork terminals elsewhere.
- For ProtoDUNE, all these wires were made, continuity tested, cleaned, and bagged at K–State.
- No problems traced to interconnect wires at ProtoDUNE → no eagerness to change interconnect wire design.

# Made at Kansas State U.

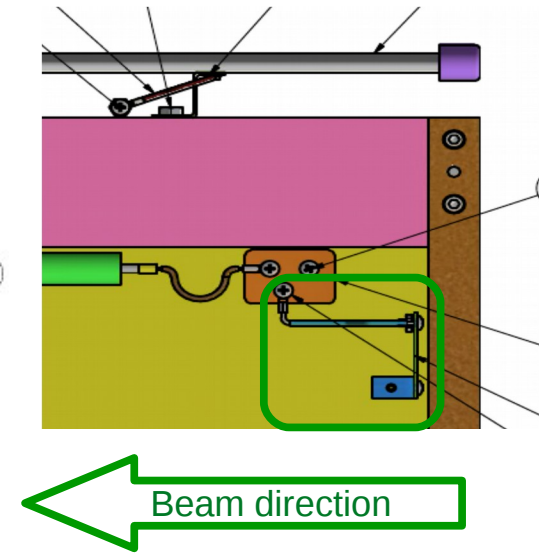
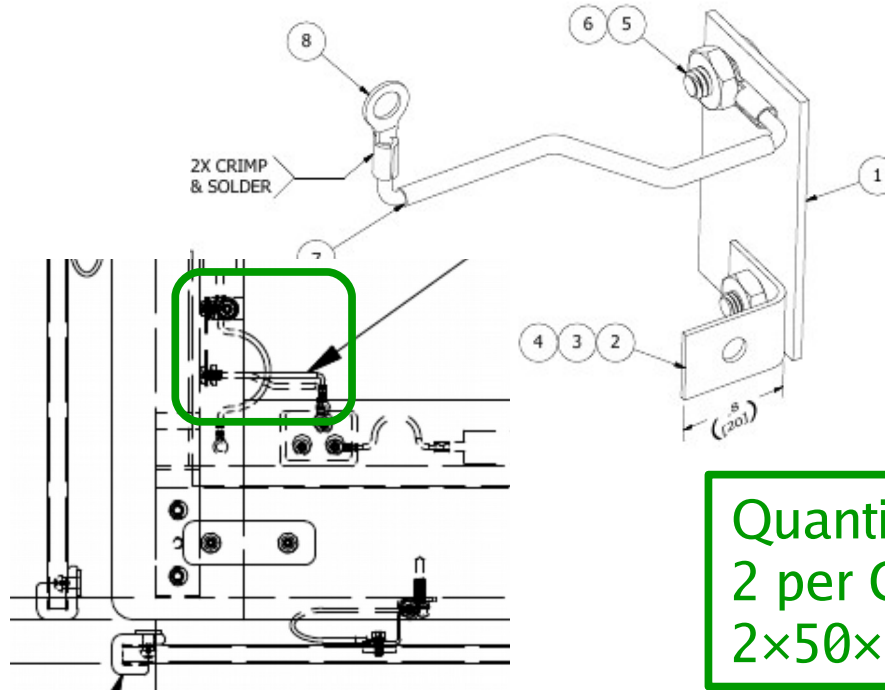
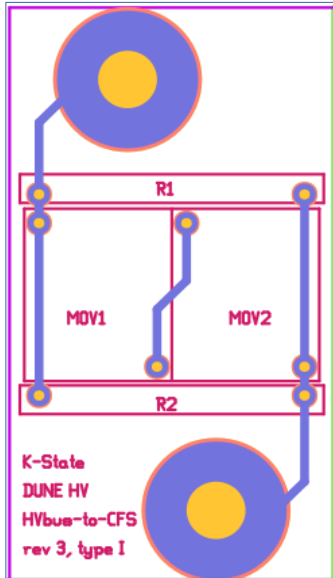
- All of the standalone HV cable and wire assemblies for ProtoDUNE were made in a few weeks in 2017 by one graduate student (Ajib Paudel).
- Quantity needed is about 12 times larger for DUNE.



# Connections to field strips and field cage

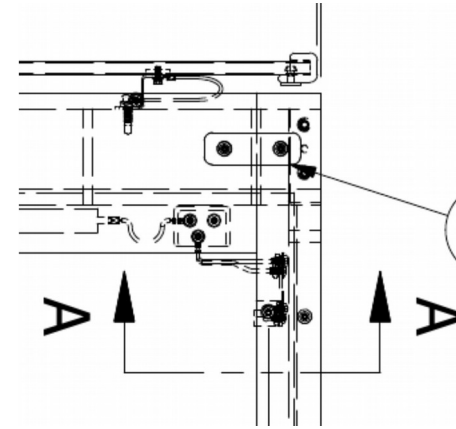
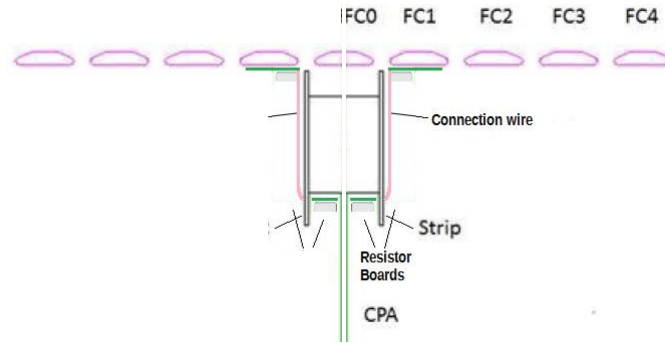
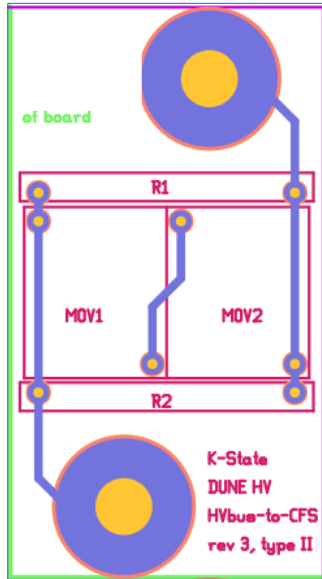


# Mini-electrical board for connecting HV to cathode frame field shaping strips, beam *left (south)* side, top and bottom (DUNE-1-10, DFD-20-A040)



Quantity required:  
2 per CPA panel  
 $2 \times 50 \times 2 = 200$  total

# Mini-electrical board for connecting HV to cathode frame field shaping strips, beam *right (north)* side, top/bottom (DUNE-1-36, DFD-20-A021)right



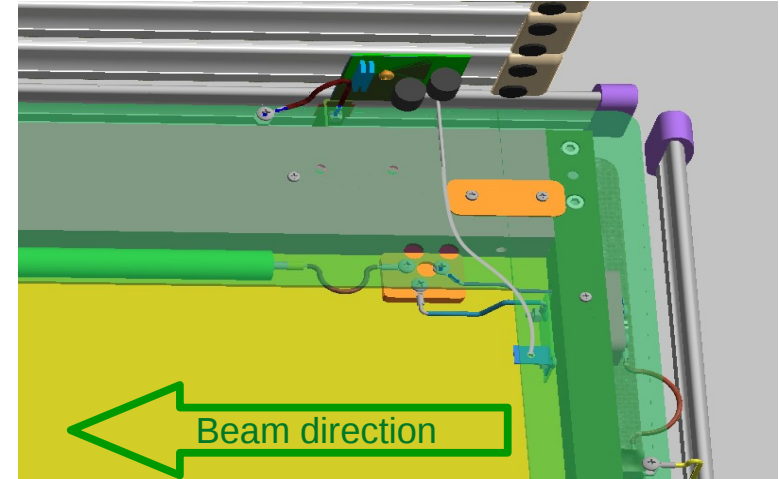
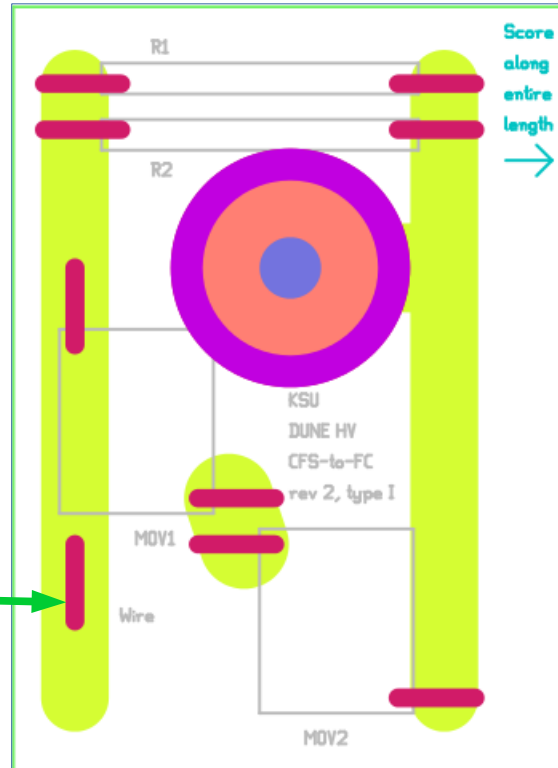
Quantity required:  
2 per CPA panel  
 $2 \times 50 \times 2 = 200$  total



# Electrical board for frame strip to FC connection, beam left side, top/bottom

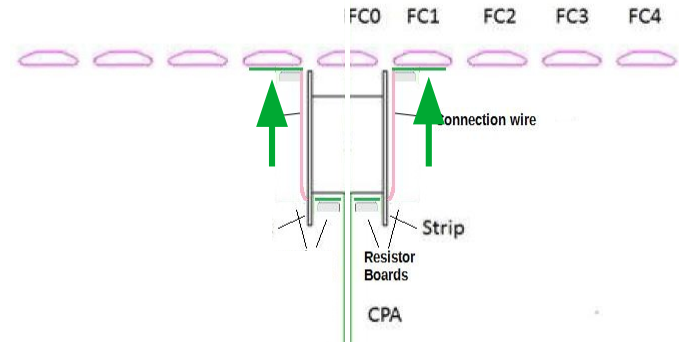
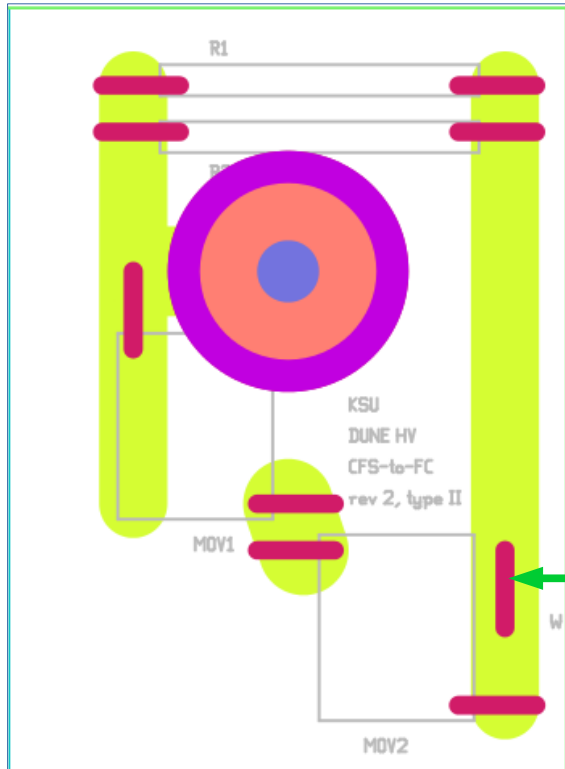
All components are surface-mounted to avoid pointy conductors on or between field cage profiles.

Wire connector with strain relief surface-mounted here



Quantity required:  
2 per CPA panel  
 $2 \times 50 \times 2 = 200$  total

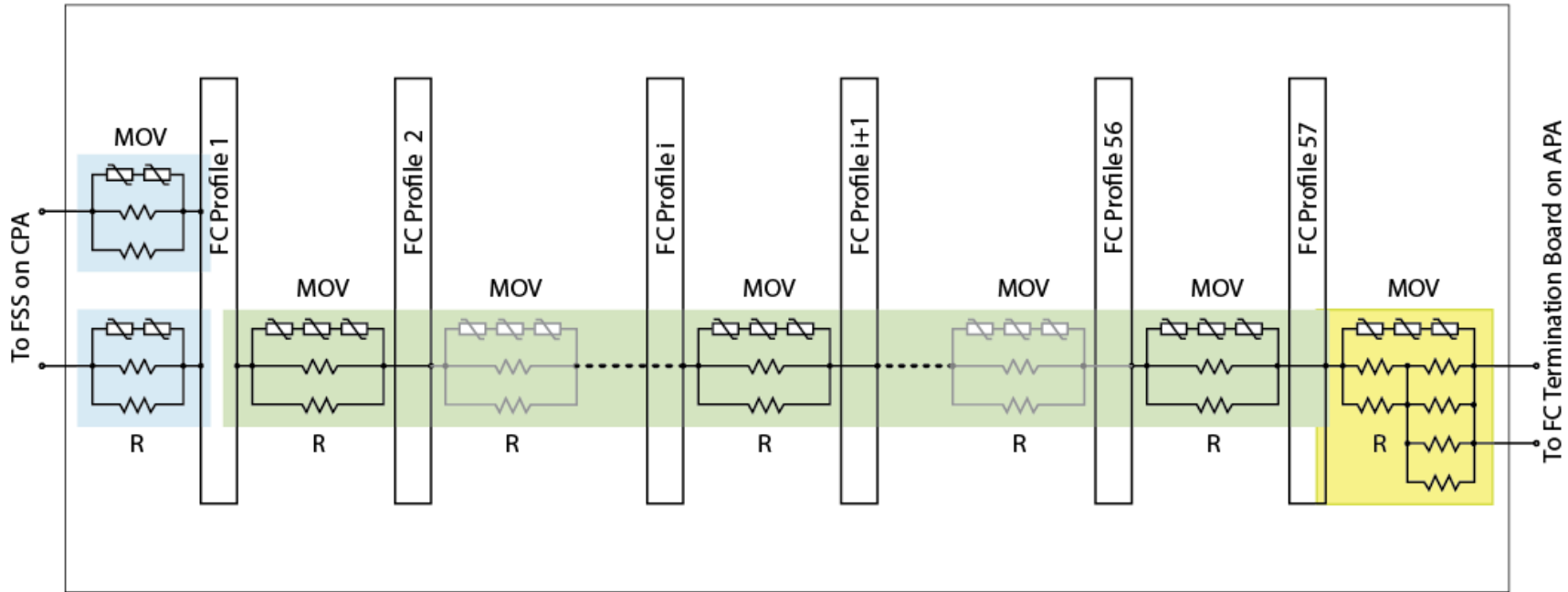
# Electrical board for frame strip to FC connection, beam right side, top/bottom



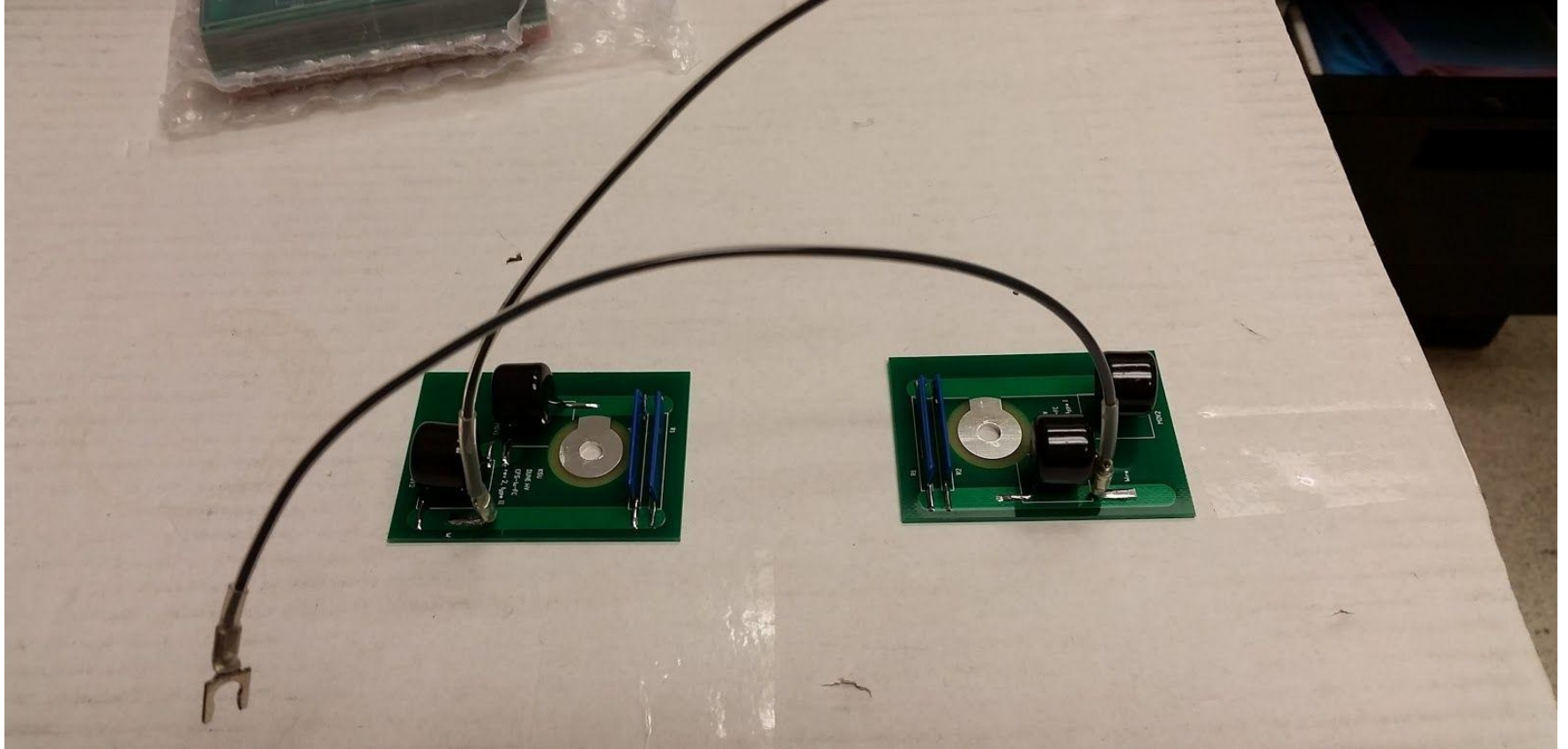
Wire connector with strain relief surface-mounted here

Quantity required:  
2 per CPA panel  
 $2 \times 50 \times 2 = 200$  total

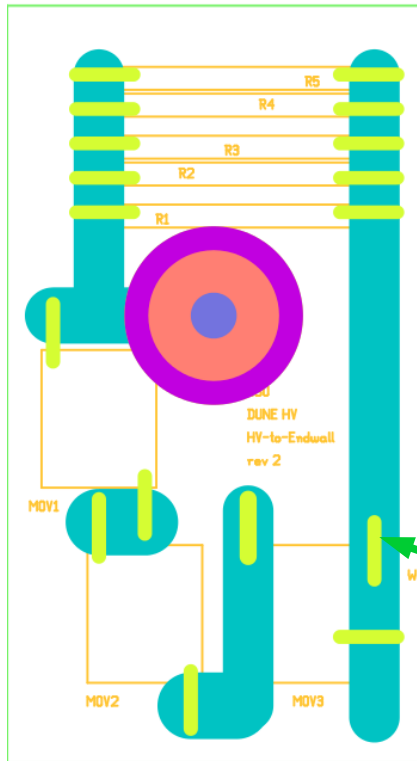
# Two frame strip to FC boards per top/bottom FC module



# Two field strip to FC boards made for ProtoDUNE-SP (one left, one right)



# Electrical board for HV bus to endwall connection

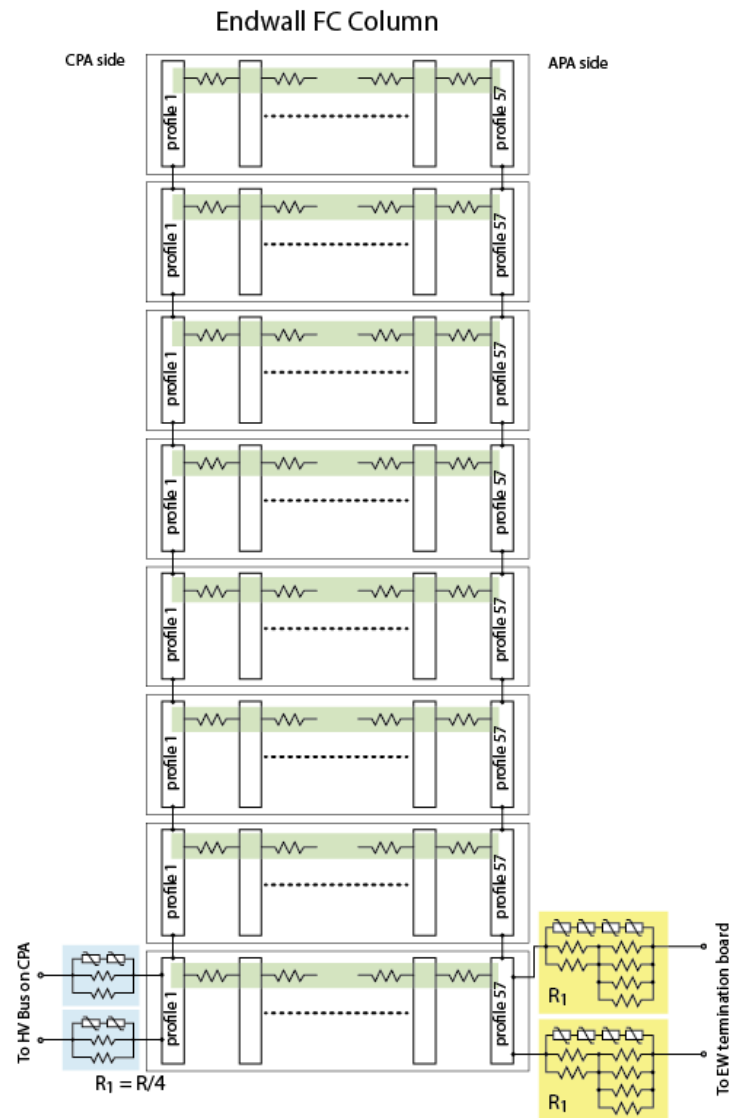
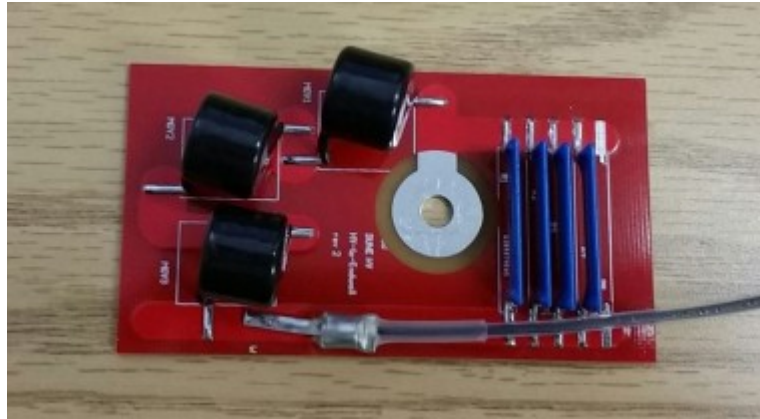


Wire connector with strain relief surface-mounted here

Quantity required:  
8 per CPA array  
(or 2 per endwall)

**$2 \times 8 = 16$  total**

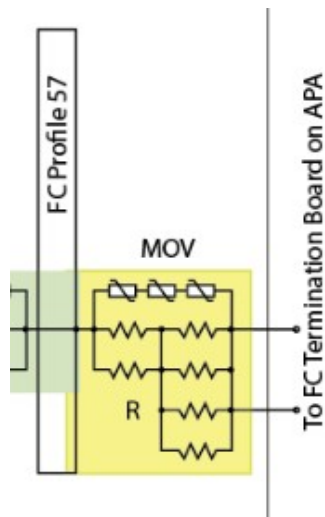
# Two HV bus to endwall boards per endwall, connected at bottom



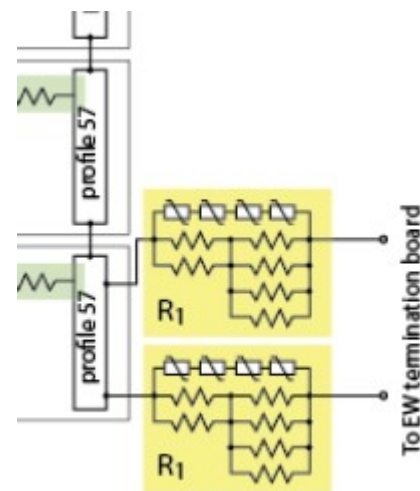
# Notes and status on various small boards

- All of the small boards and attached wire assemblies were made for ProtoDUNE in a few weeks by an EE student at KSU's Electronic Design Lab.
- Tested at 1.5 kV and 3.6 kV for expected resistor and varistor operation at room temperature. Results manually recorded; no automated system, unlike FC testing.
- Cleaned, bagged, shipped.
- About 17 times more boards needed for DUNE FD SP than for ProtoDUNE SP.

# Final step from profile 57 to termination



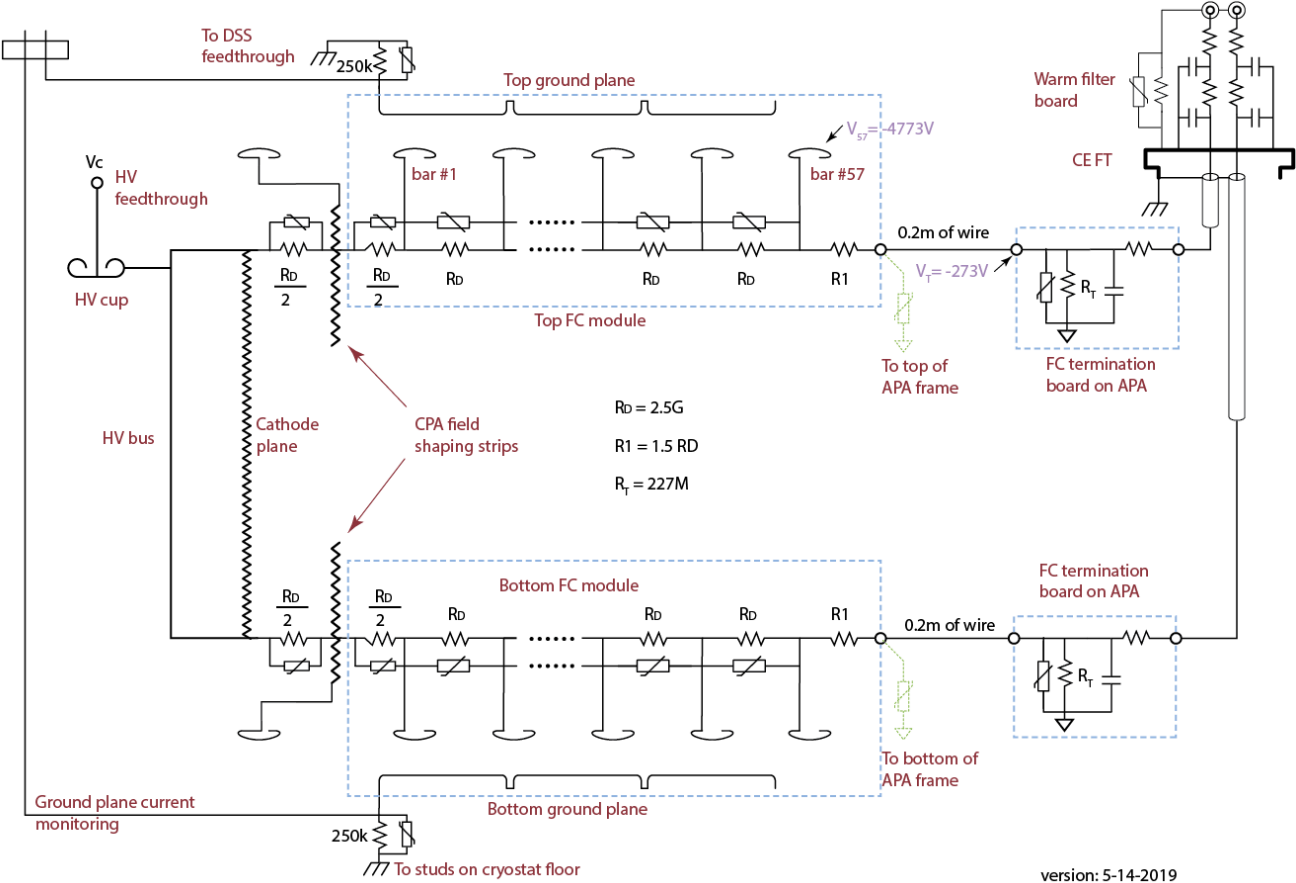
Quantity required:  
1 per T/B field cage  
 $1 \times 200 = 200$  total



Quantity required:  
2 per endwall  
 $2 \times 8 = 16$  total



# Final terminations



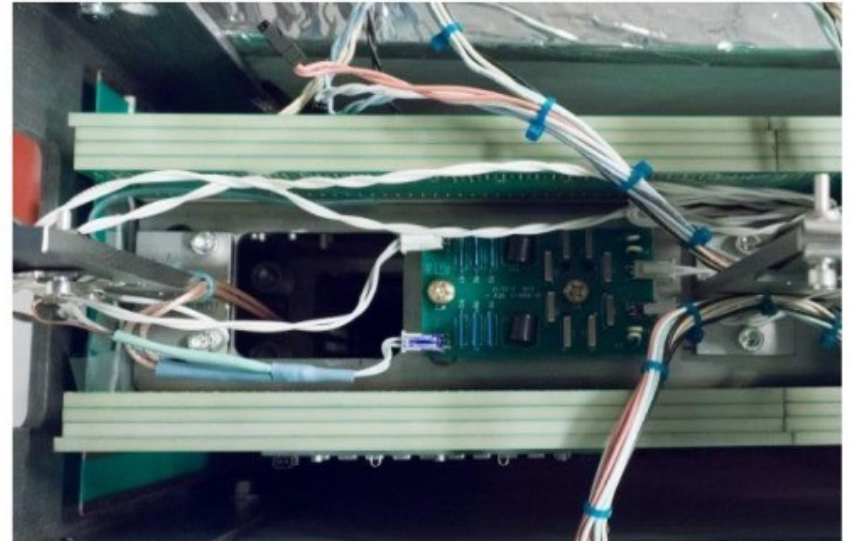
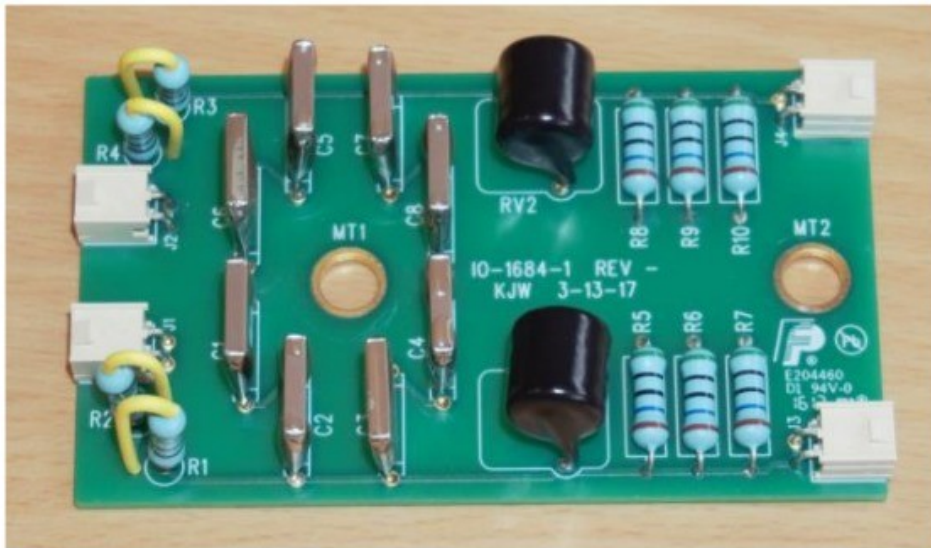


Figure 103 NP04 version of the FC termination board (left), and its mounting location on the APA.

# Summary

- There are essentially no changed or added interconnection designs in DUNE FD SP compared to ProtoDUNE SP.
  - Quantity of connections is increased compared to PD SP.
  - Vertical HV bus segment lengths adjusted.
- Some minor changes may be needed in connection sequence and logistics due to assembly procedure.

# Extras

# CPA terminology sheet

- **CPA array** = 1 cathode, full detector height and length; 25 CPA planes.
- **CPA plane** = full detector height, APA long; 2 adjacent CPA panels.
- **CPA panel** = full detector height, 1/2 APA long; stack of 3 CPA units.
- **CPA unit** = 1/3 detector height, 1/2 APA long; stack of 2 framed RPs
- **RP** = Resistive Panel, approximately 2 m (vert.) by 1.2 m (horiz.)
- Alternate terminology:
  - In the TDR SP HV chapter, the phrase "cathode plane" is used once in the introduction to describe the geometry of a CPA array.
  - In some older documents, a set of two side-by-side CPA panels (a CPA "plane") is referred to as a "CPA pair." (Also slide 36 in a draft of Vic's June 4 talk.)
  - In the April 2019 CPA assembly drawings, a vertical stack of 2 framed RPs (CPA unit) is called a "panel pair."

# FSS to FC board with FC folded, Ash River test

