

# CPA AND CONNECTIONS TO FCS, ENDWALLS, HV CUP

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- ❑ Procedures for making electrical connections
- ❑ Connection tests and measurements
- ❑ Documentation

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ANL

# Outline

- CPA Electrical Systems
  - ✓ HV Input, Bus and Resistive Panels
  - ✓ FSS/Profiles
- Procedures for electrical connections (Q1 mostly)
- Connection tests and measurements (answers Q1, Q2):
  - ✓ Cold tests at BNL
  - ✓ Connection tests at Ash River
  - ✓ Resistance measurements
- Checklists
- Connections Documentation
  - ✓ Unique connection designations
  - ✓ CPA/FC/EW connection key
- Summary

# CPA Production



Panel "A" Beam Left side

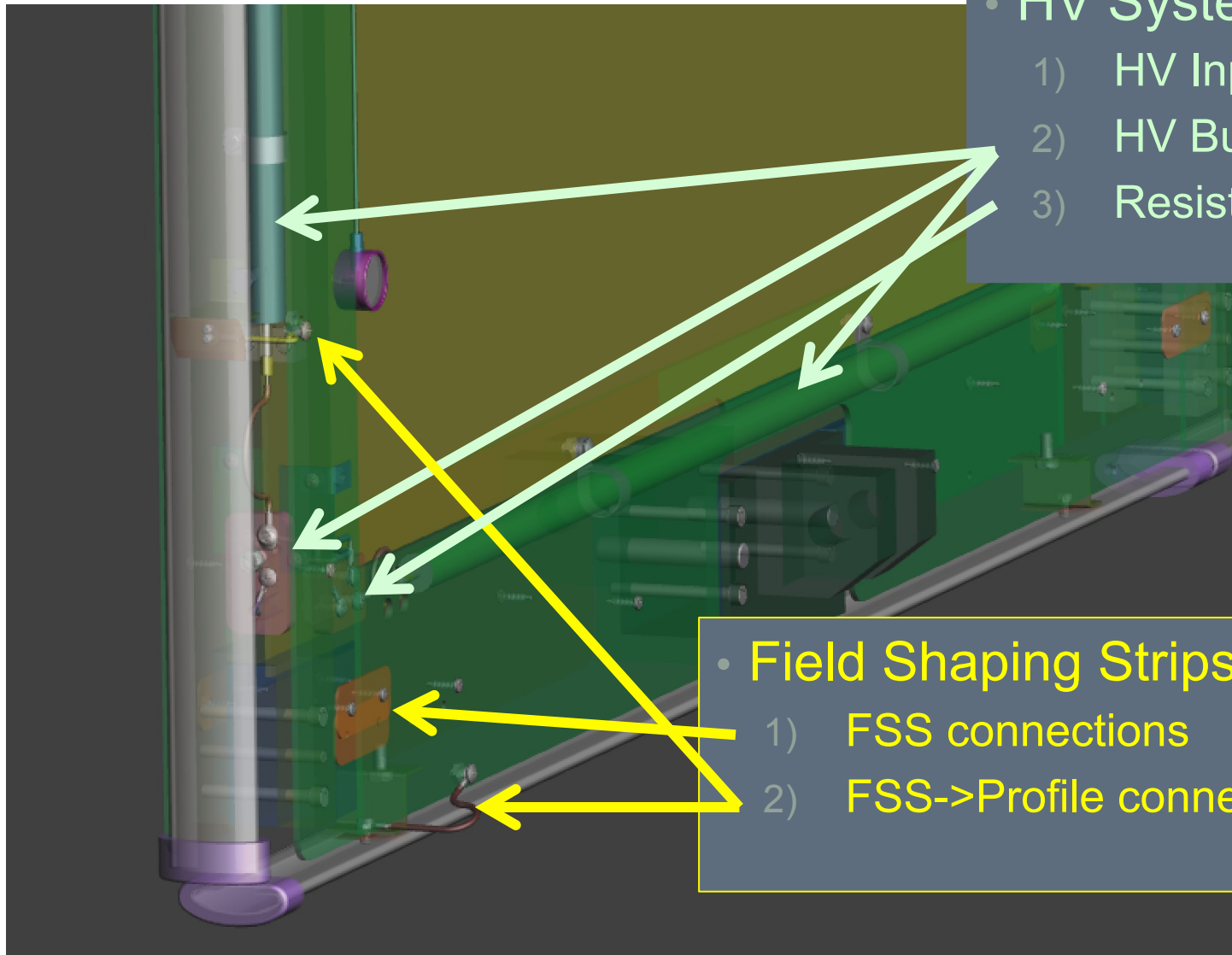


Panel "A" Beam Right side

# CPA Production



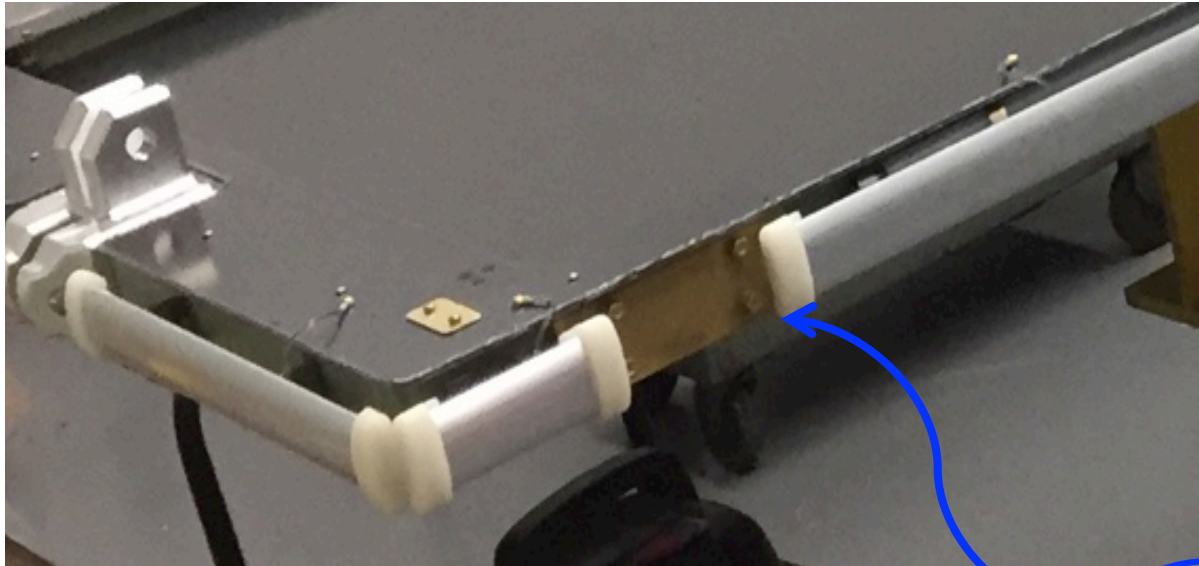
# CPA Electrical Systems



- HV System
  - 1) HV Input (Top)
  - 2) HV Bus
  - 3) Resistive Panels

- Field Shaping Strips/Profiles
  - 1) FSS connections
  - 2) FSS->Profile connections

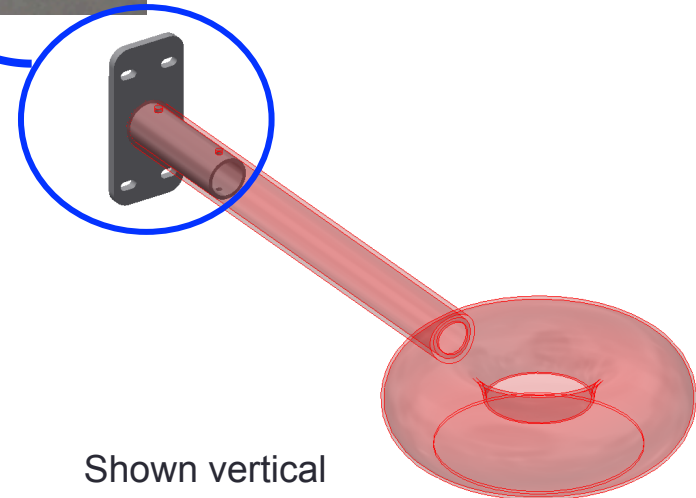
# HV Input



Two-piece (adjustable) connection between donut and CPA HV Bus  
- Dark piece (SS) plate with tube welded to face connects to brass plate on side of CPA

Connection made with 4 - 1/4-20 X 1" SS Hex Head screws with 1/4" split ring washers.

Thru hole (behind short Profile) with jumper to brass tab on resistive panel.



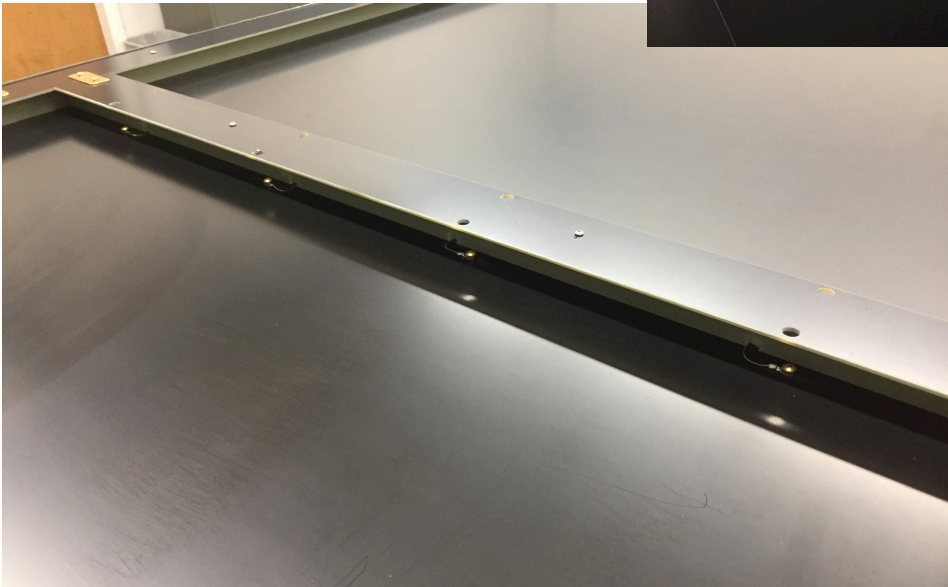
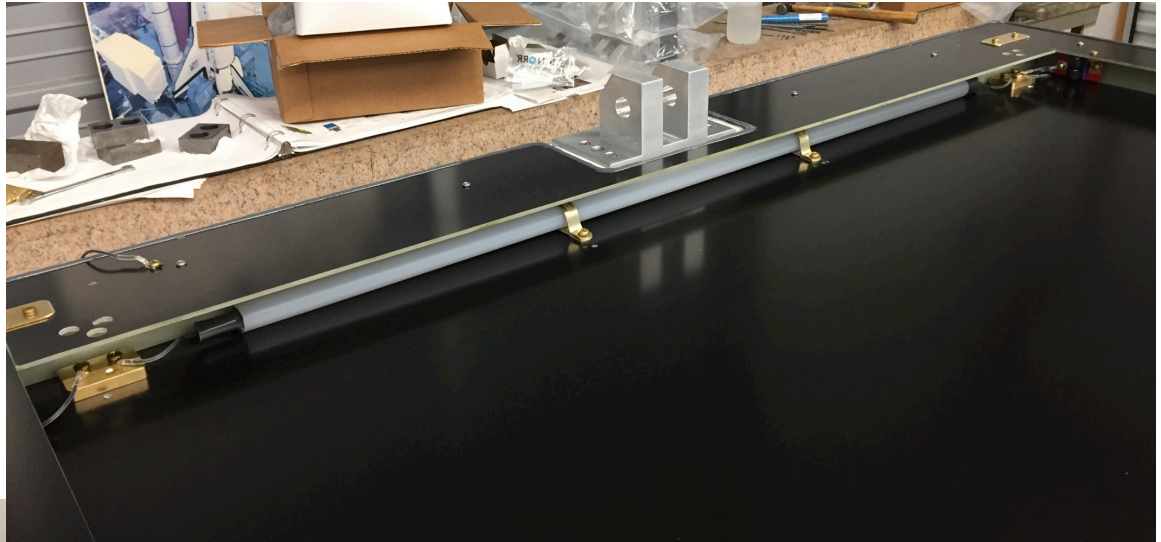
Shown vertical

# HV Bus and Resistive Panels (RPs)

## HV Bus connections

8-32 screws with Belleville washers thru tabs on front/back side – ring lug to HV cable

*Shown is HV Bus at Panel A bottom*

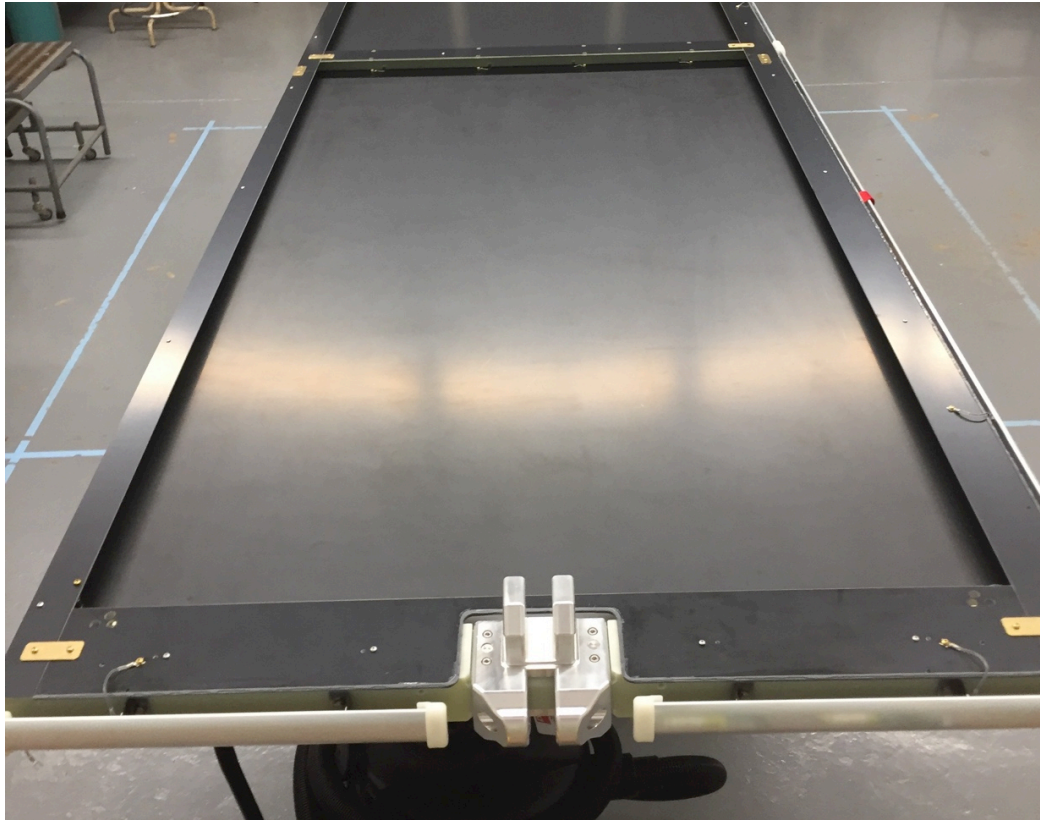


## RP connections

8-32 screws with Belleville washers on front side thru holes to flat washer and nut on back side – ring lugs to jumpers

*Shown are 4 jumpers at a panel-to-panel interface*

# Field Shaping Strips (FSS) and Profiles



FSS->Profile connections

8-32 screws with Belleville washers on FSS thru jumper to 8-32 screws with split ring washers to Profile nut

FSS connections

8-32 screws thru brass tabs with Belleville washers



Belleville washer and 8-32 screw



# CPA connections procedures

**DUNE-doc-2103**  
**SRM**

Following are excerpts from CPA Manufacturing Procedures document:

Attach 4 Section-to-Section wires (DUNE-1-42) to RPs at Upper/Middle and Middle/Lower Module interfaces using **#10-24 x .375" brass machine screws with brass lock washers and #10-24 brass hex nuts (DUNE-1A)**.

Attach components to the Upper Module (DUNE-1-1A) :

- a. The Upper Corner Electrical Connection Bracket (DUNE-1-11) is mounted on the L.H. side frame (DUNE-1A) using **1/4-20 x 1.0" hex head screws with 1/4" lock washers** (long to allow for eventual inclusion of HV Input plate).
- b. Drill #10 holes in the RP at the top according to DUNE-1-1-4 for the Section-to-Section wire jumper connections.
- c. Attach the Front (DUNE-1-7) and Rear (DUNE-1-8) Electrical Tab Plates according to DUNE-1A on L.H. and R.H. sides at the top using **#10-24 brass Phillips head screws with lock washers**, attaching electrical wire from DUNE-1-11 to DUNE-1-7 on the left side.
- d. The HV cable (DUNE-1-5) is mounted on the RP across the top of the module (DUNE-1A). **#10-24 x 0.75" machine screws with lock washers** are hand-tightened through mounting tabs. A Panel-to-Panel Wire (DUNE-1-41) is attached to the Front Electrical Tab Plate (DUNE-1-7) on the R.H. side.
- e. The resistor board (DUNE-1-10) is mounted on the RP (DUNE-1A) and eventually attached to the FSS thru the L-bracket with a **screw, lock washer, and nut according to drawing instructions**. See DUNE-1-36 for rear resistor board assembly instructions.
- f. Install Long Z-brackets (DUNE-1-27, -28, and -29) for Profiles on exterior side of Panel.
- g. Mount HV cables (DUNE-1-6 : DUNE-1-6-01, DUNE-1-6-02, DUNE-1-6-03) on exterior side according to DUNE-1A including Brass Tabs and Cable Stops (DUNE-1-38).
- h. Mount profiles on top (DUNE-1-31) using short Z brackets (DUNE-1-25), exterior side (DUNE-1-30, DUNE-1-32, DUNE-1-33, DUNE-1-34) using long Z brackets (DUNE-1-27, -28, -29 according to drawing).

***All electrical connections on CPA require threaded screws and lock washers***

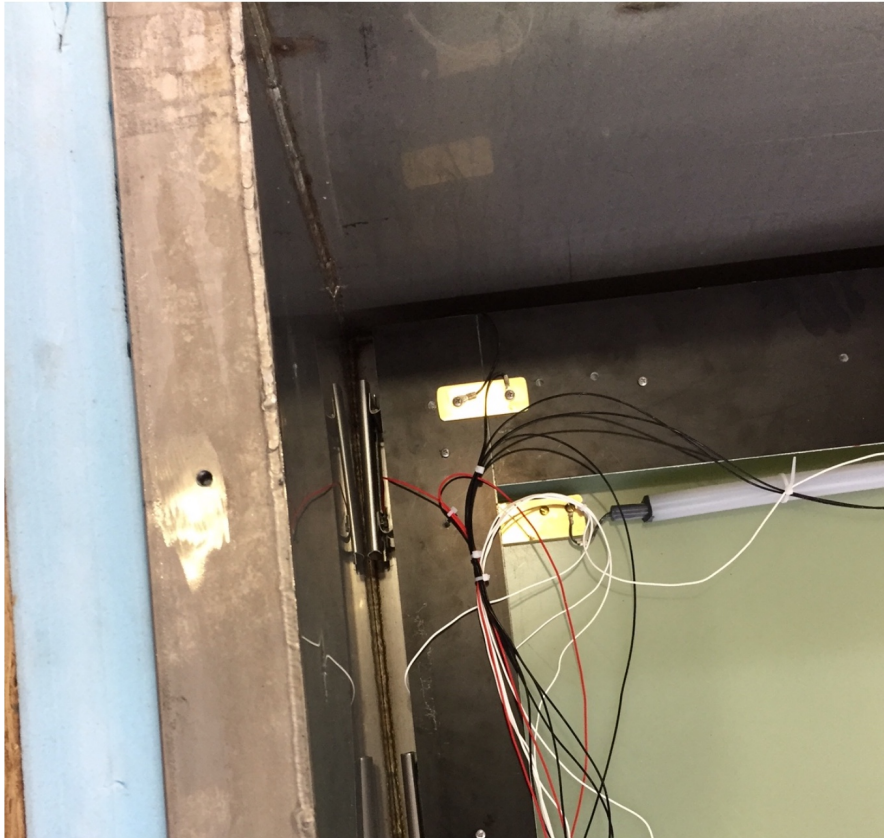
# Cold Tests at BNL

**DUNE-doc-2338**  
**SRM**

- Teflon-coated wires attached to connection points on the CPA modules
- Positions 1-4 are white wires and correspond to test points on the HV Bus
- HV input point is represented by position 3
  - 3 -> 4 and 3 -> 2 consist of a brass screw, a brass plate, a HV cable, and another brass plate
  - 3 -> 1 is 3 -> 2 plus an additional brass plate and a longer HV cable
  - 1 -> 4 is the whole length of the HV Bus, and 1 -> 3 and 1 -> 2 are shorter subsets of this circuit
- At position 4, HV Bus is connected to FSS through a resistor board
- Positions 5 and 6 are red wires and are connected to Profiles which are connected by jumper wires to the FSS
- Positions 7 - 10 are black wires and correspond to test points on the FSS
  - 5 -> 7 and 6 -> 8 are FSS -> Profile
  - 7 -> 8, 8 -> 9, and 9 -> 10 are connections thru FSSs

# Cold Test Connections

DUNE-doc-2338  
SRM



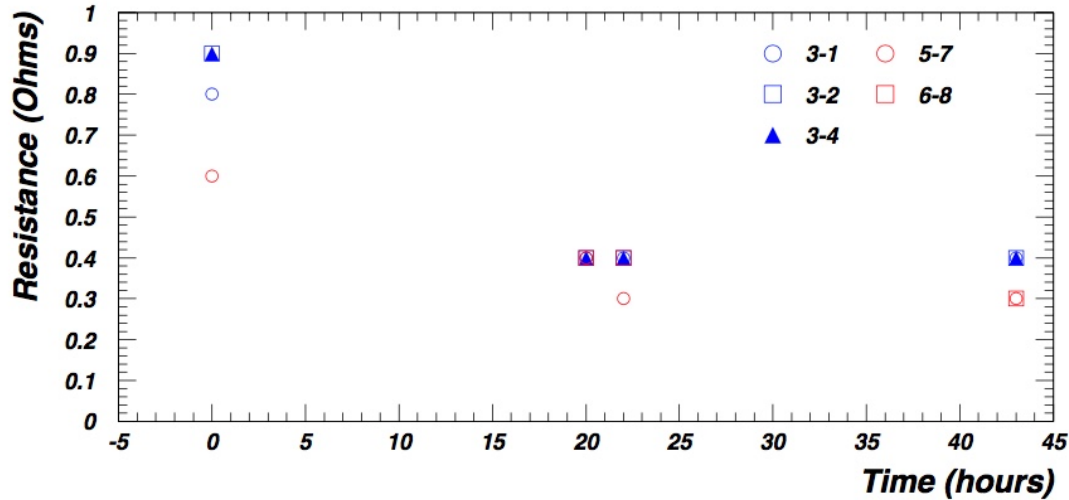
In Cold Box before cooling:  
White – HV connections  
Black – FSS connections  
Red – Profile connections



In Cold Box immersed in  
liquid nitrogen

# Cold Test Results

**DUNE-doc-2338**  
**SRM**



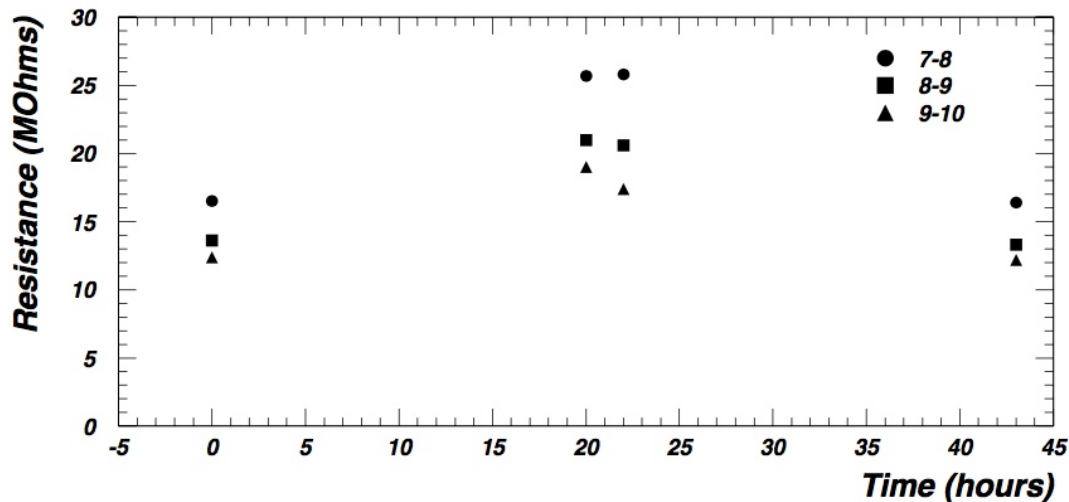
Low resistance measurements:

Blue – HV connections

Red – Profile connections

All connections remained tight

Warm | Cooling | Cold | Warming | Warm



High resistance measurements:

Black – FSS connections

All connections remained tight

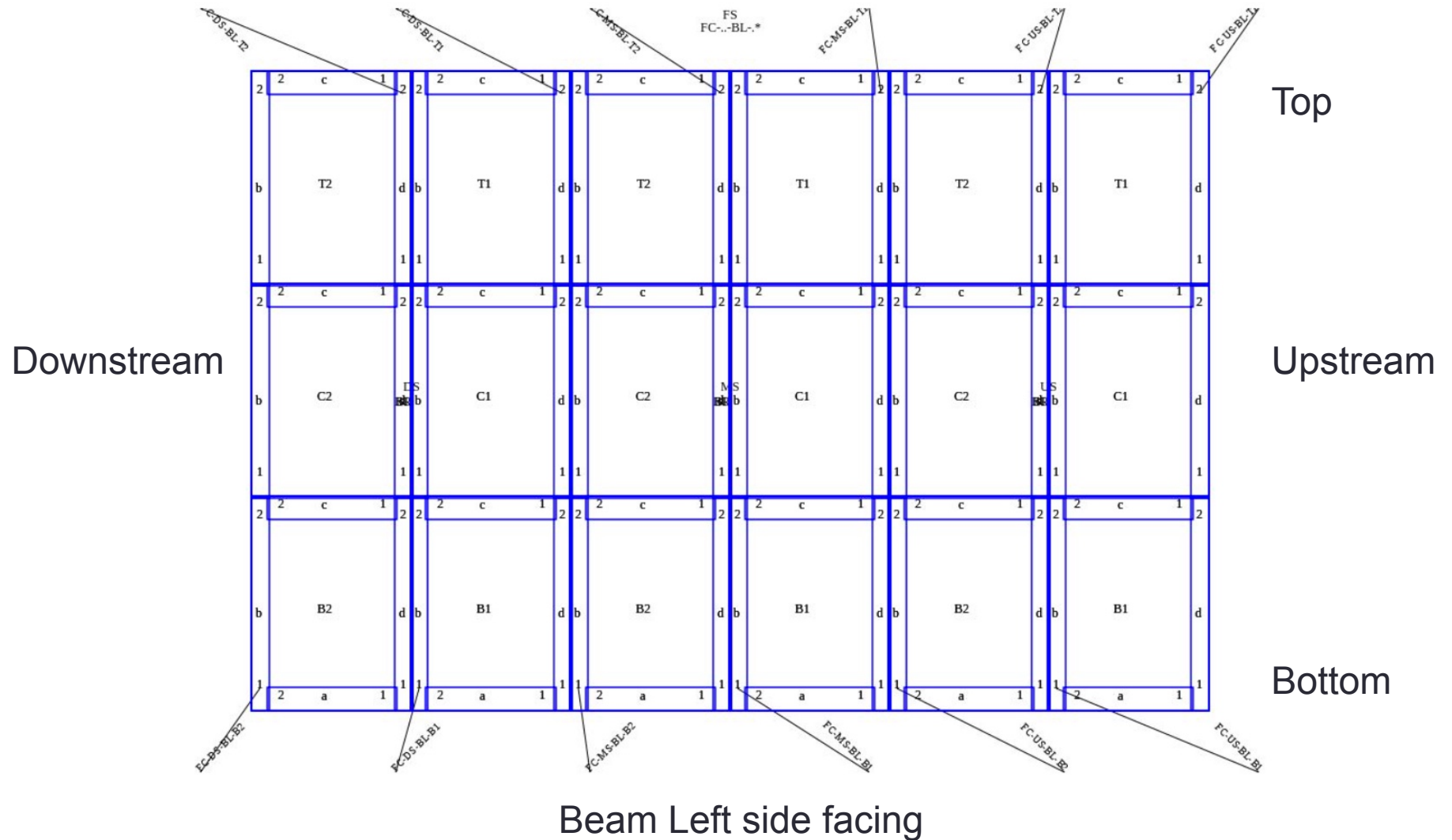
# Tests at Ash River

DUNE-doc-1870  
Glenn Horton-Smith

- Used mock CPAs, FCs, and EndWalls at Ash River to test connection positions and feasibility during installation
- CPA -> FC connections
  - ✓ 24 total connections from CPA FSS to 1<sup>st</sup> profile on FC units top and bottom, beam left and beam right – 4 connection per CPA Panel thru resistor boards
  - ✓ All done in Clean Room in folded configuration prior to insertion into cryostat
- CPA -> EndWall connections
  - ✓ 8 total connections from CPA HV Bus to 1<sup>st</sup> profile on EndWalls – 2 connections from CPA to each Endwall section - downstream beam left and right and upstream beam left and right thru resistor boards
  - ✓ All done in cryostat

# CPA -> FC Connections

DUNE-doc-1870  
Glenn Horton-Smith



# CPA -> FC Connections

DUNE-doc-1870  
Glenn Horton-Smith

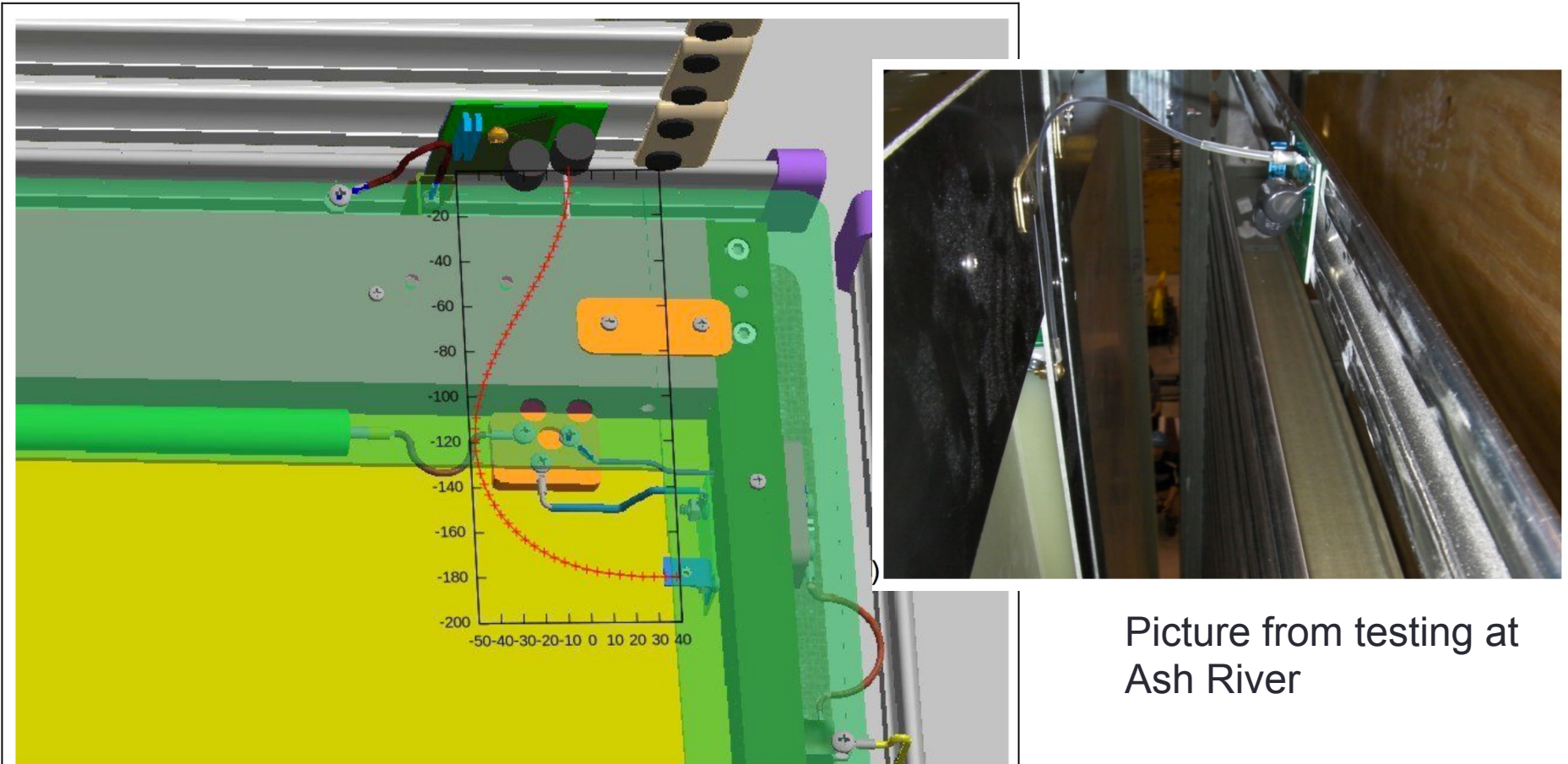
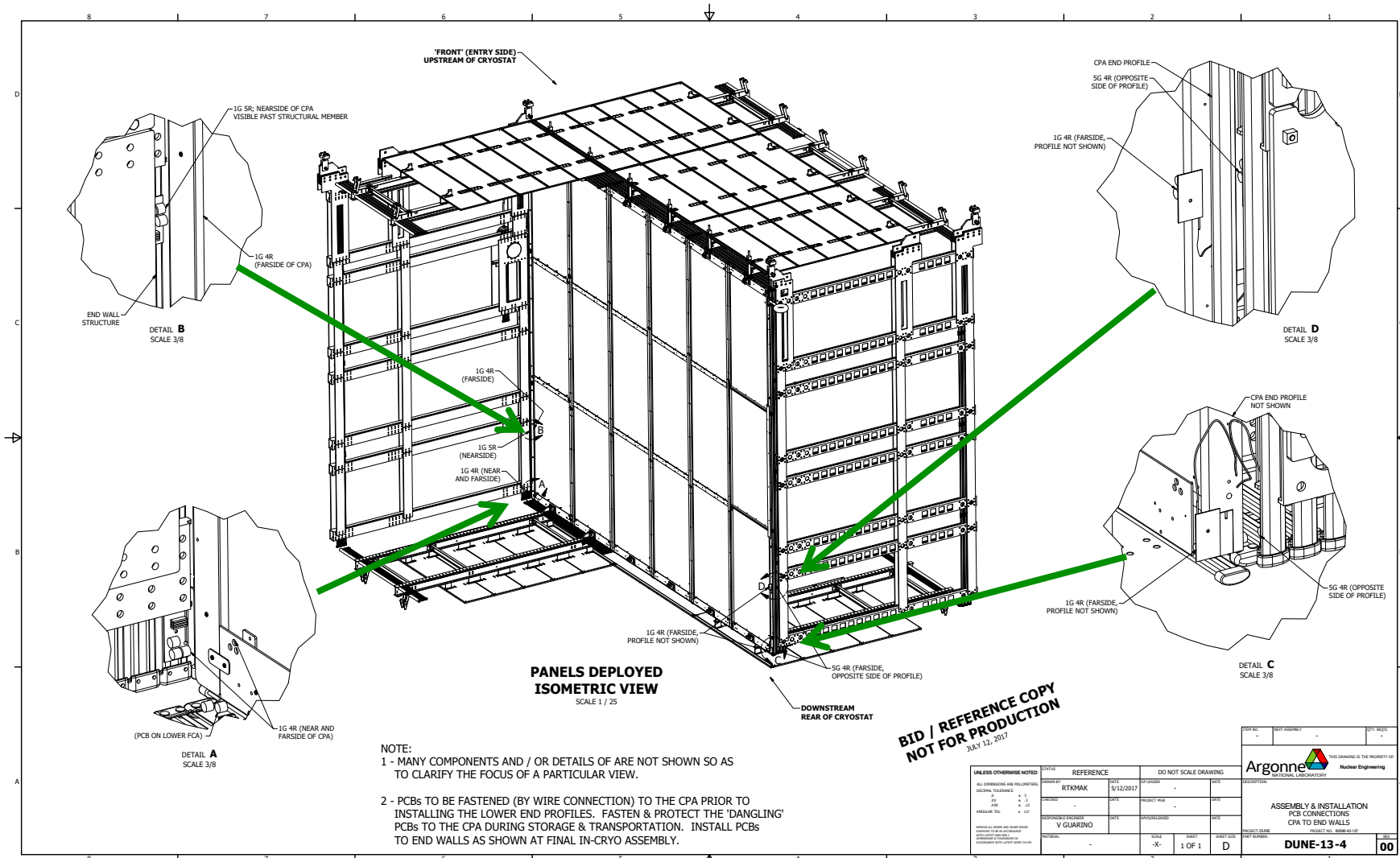


Figure 4: Perspective view of top upstream corner of upstream CPA on beam left side, with CFS-to-FC board and a calculated path of the wire (red curve). The wire is 250 mm long. Note the CPA to field strip connection screw (CFS) is missing in this rendering.

Picture from testing at  
Ash River

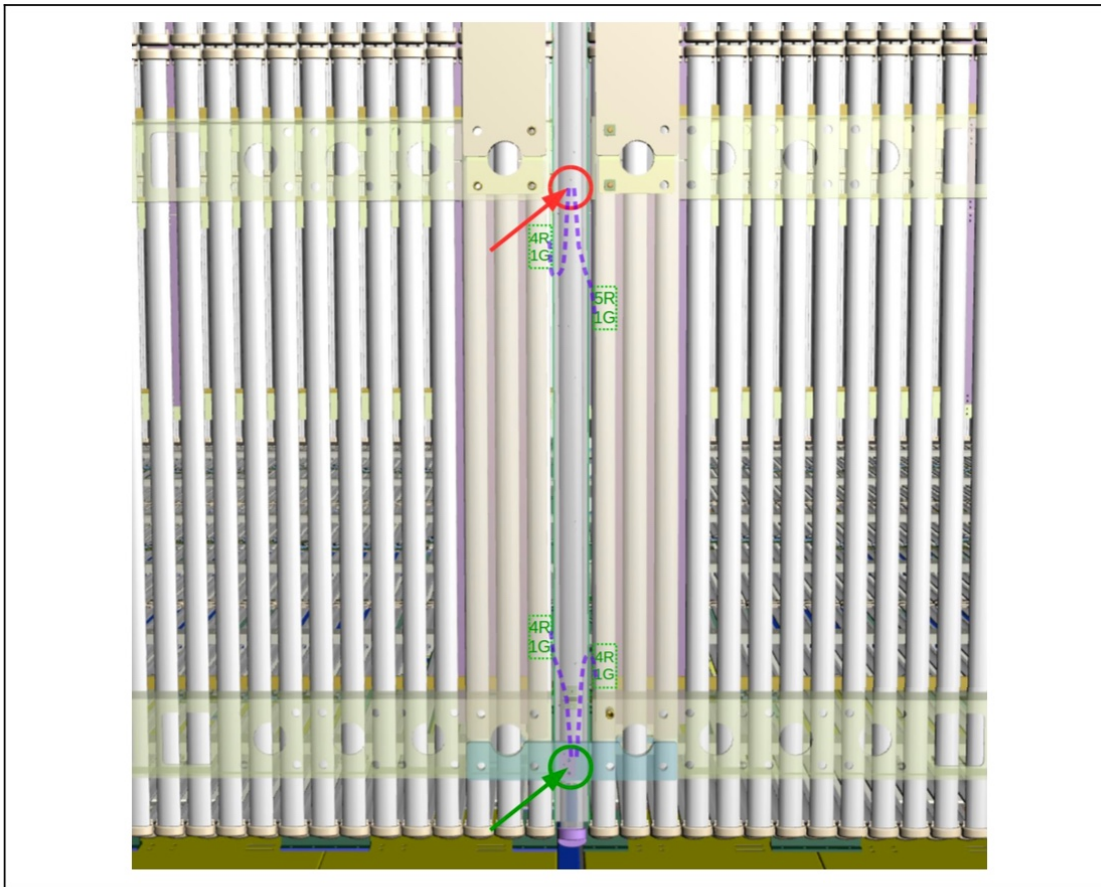
# CPA -> EndWall connections





# CPA -> EndWall Connections

**DUNE-doc-1870**  
**Glenn Horton-Smith**



Upstream EndWalls (BL, BR) showing location of CPA -> EW connections

Red/green circles indicate position of HV Bus tab mounted on the side of the CPA (underneath Profile in this view)

Figure 9: Perspective view of lower part of upstream endwalls, from DUNE-13 as found in DUNE-doc-1870-v5, viewed from outside looking downstream. The CPA edge profile and some endwall structures have been made semi-transparent to allow the CPA frame and adjacent endwall profiles to be seen. A circle and arrow mark the locations where the HV bus connector blocks should be, and dashed purple lines show possible paths of the wires to the HV-to-EW boards. The wires must be totally contained inside the field cage.

# Checklists

- CPA Production Checklists (DUNE-doc-2103)
  - R/□ measurements – resistive panels(RPs), FSSs (DUNE-doc-3962)
  - Continuity tests – HV Input, Bus, FSS->Profile
  - MΩ resistance measurements – RP->RP, FSS->FSS
  - CPA Resistor Board measurements – 9V battery, picoammeter (GΩ)
- CPA Installation Checklists (DUNE-doc-3992, 3998)
  - Continuity tests – HV Input, Bus (panel->panel)
  - Resistor Board measurements – CPA->FC, CPA->EW Keithley 6517B High Resistance Meter

# Checklists for CPA Connections

## CPA Panel HV Bus and RPs Connections Checklist

CPA Panel Type, # \_\_\_\_\_ Name \_\_\_\_\_

Date \_\_\_\_\_

Name	Drawing #	Connections designation	Continuity	Resistance (MOhms)
Top input wire to Tab	DUNE-1			
Top LH Tab to Top RH Tab	DUNE-1			
HV Input plate to Top Side Tab	DUNE-1			
Top Side Tab to Middle Side Tab	DUNE-1			
Middle Side Tab to Lower Side Tab	DUNE-1			
Lower Side Tab to Bottom Tab	DUNE-1			
Bottom Tab to Bottom LH Tab				
Bottom LH Tab to Bottom RH Tab				

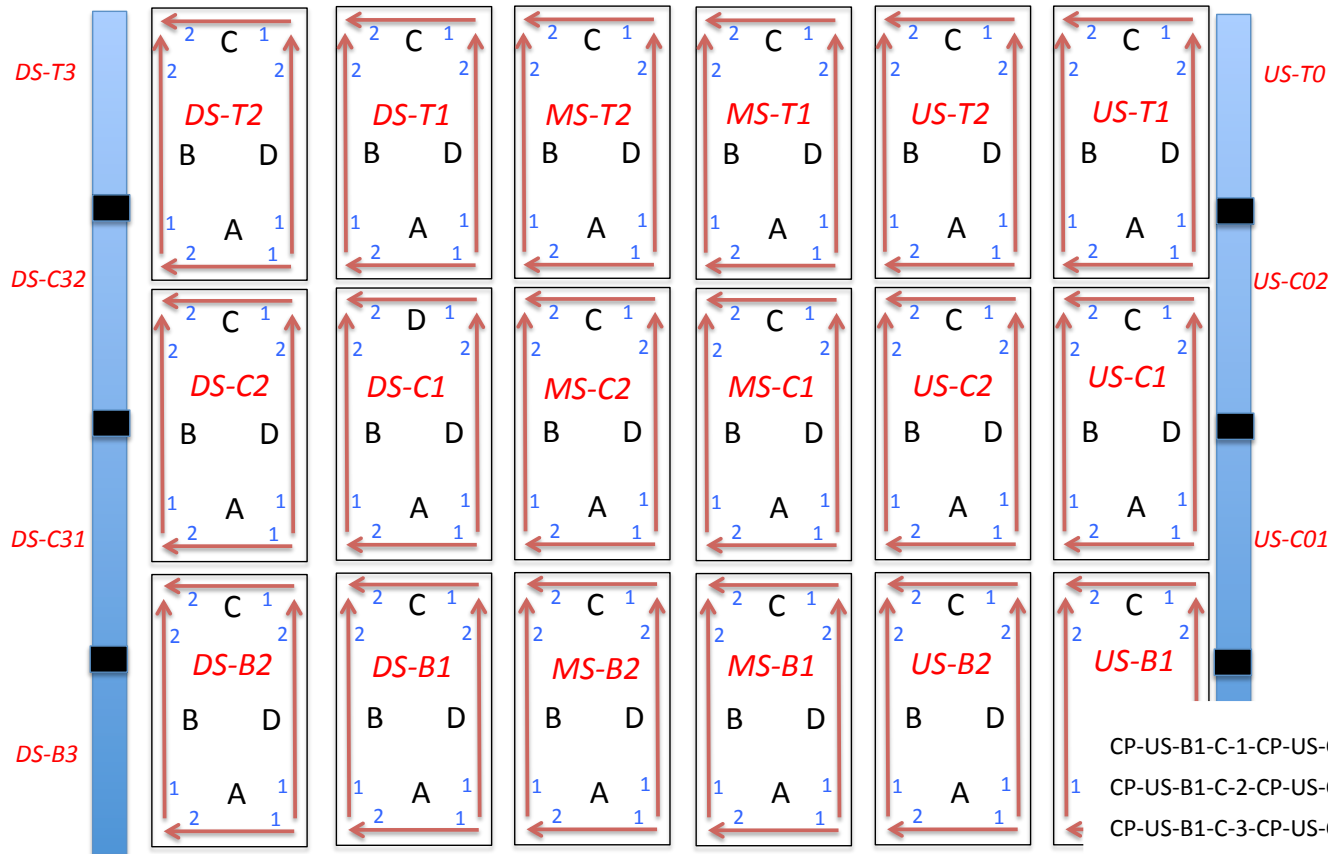
Example of production checklist for HV Bus and RP->RP connections

# Documentation

- DUNE-docs for connection procedures during production, installation
- Traveling checklists
- DUNE-docs for cold testing, test of connection positions and feasibility at Ash River
- Drawings (including 3D) of connections (also DUNE-docs)
- Documentation of connections for eventual database ->

# Unique Connection designation

CPA Coordinates viewed from BL side



**DUNE-doc-2326**  
**Rob Plunkett**

Example of some CPA connections from spreadsheet

- CP-US-B1-C-1-CP-US-C1-A-1
- CP-US-B1-C-2-CP-US-C1-A-2
- CP-US-B1-C-3-CP-US-C1-A-3
- CP-US-B1-C-4-CP-US-C1-A-4

**Panel Interconnects**

- CP-US-B1-A-1-HV-US-B1-1
- CP-US-B1-A-2-HV-US-B1-2

**Panel to HV**

# CPA/FC/EW Connection Key

Key linking CPA/FC/EW electrical connection configurations

**DUNE-doc-4676**  
**SRM**  
**Glenn Horton-Smith**  
**Rob Plunkett**

Description*	Rob's String	K-State RB SN	Conn #
CPA/FC Upp A BL	FS-DS-BL-T2-D-2-FC-DS-BL-T2	CFS-FC type ii green** 24 <input type="checkbox"/>	1
CPA/FC Upp B1 BL	FS-DS-BL-T1-D-2-FC-DS-BL-T1	25 <input type="checkbox"/>	5
CPA/FC Upp B2 BL	FS-MS-BL-T2-D-2-FC-MS-BL-T2	26 <input type="checkbox"/>	9
CPA/FC Upp B3 BL	FS-MS-BL-T1-D-2-FC-MS-BL-T1	27 <input type="checkbox"/>	13
CPA/FC Upp B4 BL	FS-US-BL-T2-D-2-FC-US-BL-T2	28 <input type="checkbox"/>	17
CPA/FC Upp C BL	FS-US-BL-T1-D-2-FC-US-BL-T1	29 <input type="checkbox"/>	21
		CFS-FC type i green**	
CPA/FC Upp A BR	FS-DS-BR-T2-D-2-FC-DS-BR-T2	1 <input type="checkbox"/>	3
CPA/FC Upp B1 BR	FS-DS-BR-T1-D-2-FC-DS-BR-T1	2 <input type="checkbox"/>	7

Donut      \*Looking at CPA face from Beam Left (BL)      ← Beam

A Upper	B1 Upper	B2 Upper	B3 Upper	B4 Upper	C Upper
A Middle	B1 Middle	B2 Middle	B3 Middle	B4 Middle	C Middle
A Lower	B1 Lower	B2 Lower	B3 Lower	B4 Lower	C Lower

1,3    5,7    9,11    13,15    17,19    21,23  
m 2,8    2,4    6,8    10,12    14,16    18,20    22,24  
b 1,7    m 4,6    b 3,5

- 1) Description according to diagram
- 2) Rob's designation
- 3) Glenn's CPA RB serial #
- 4) Connection # (CPA construction)
- 5) Used as checklist

# Summary

- Procedures for making consistent electrical connections on the CPA and between CPA and FCs, EWs are documented (and followed) in the work plan.
- Cold testing of all connection types on the CPA has been done
- CPA/FC/EW interconnection plan was devised and tested at Ash River
- Checklists are completed during CPA construction and installation for all connection types
- Extensive documentation including a unique connection diagram, a key which links drawings, connection diagram, serial numbers of boards (for database), and a connection description exists