Reception and Quality Control

DUNE PRR: Far Detector TPC and BD Electronics Cold Cables

12/13/2024

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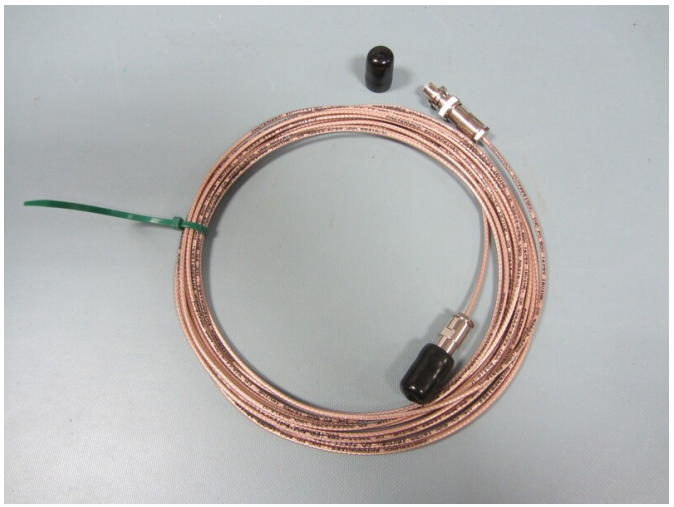
Documentation on EDMS

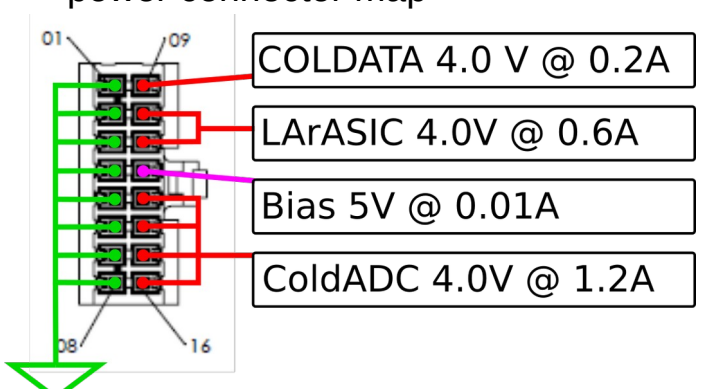
- CE QC plan: EDMS:2815079.
- Electrical safety note for Cold cables: EDMS:3205268.
- Quality Control of Cold Data cables for FEMBs: EDMS:3207305.

Cold Cables

power	data	HV bias
		
		

Power cables

power connector map

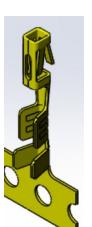


Requirements

	FD1-HD	FD2-VD
Length	9m, 22m	27m, 2.5m
Number of lines	4	
Max voltage	5 V	
Max current	1.2 A	
Operating temperature	70 K	
Mechanical strength	self-support over 12 m; rugged jacket	
misc.	must meet DUNE purity requirements; keep diameter small	

Final Design

- 8 pairs of AWG 20 silver plated copper wires (see the mapping) (rating: 3 *A*, 300 *V*)
- Samtec IPD1-08-D-K locking connectors (rating: 275 VAC, 4.8 A/pin)
- wire insulation: teflon



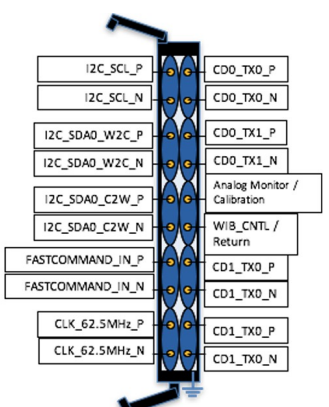
Data cables

Requirements

	FD1-HD	FD2-VD
Length	9m, 22m	27m, 2.5m
Number of lines	10 LVDS pairs (see the map);	
Max voltage / current	1.8 V	
Max current	3 mA	
Operating temperature	70 K	
Mechanical strength	self-support over 12 m, rugged jacket	
misc.	must meet DUNE purity test requirements; keep diameter small	
Data transmission	four 1.25 Gbps links	

data connector map

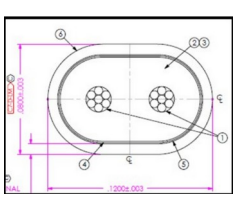
Signal name	Type	# of pairs	IO Standard
Data link	Differential	4	LVDS
I2C_SCL	Differential	1	LVDS
I2C_SDA0_C2W	Differential	1	LVDS
FASTCOMMAND	Differential	1	LVDS
CLK_62.5MHz	Differential	1	LVDS
Analog monitor/calibration	Single Ended	1/2	Analog 1.8 *V*
WIB_CNTL_GND	Single Ended	1/2	Analog 1.8 *V* or Return



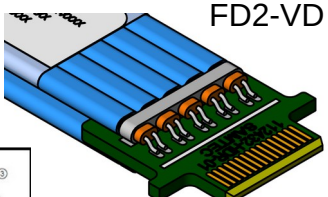
Final Design

- 10 pairs of AWG 26 twinax cables a
  (rating: 3.4 A, 575 V).
  (driven by mechanical strength requirements)
- Samtec PCB-type connectors
- insulation: Dyneon fluorothermoplastics THV 500G.

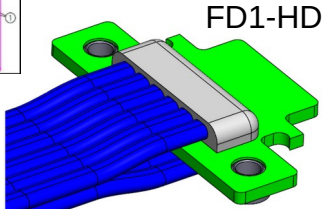
patch cable: see next slide



FD2-VD



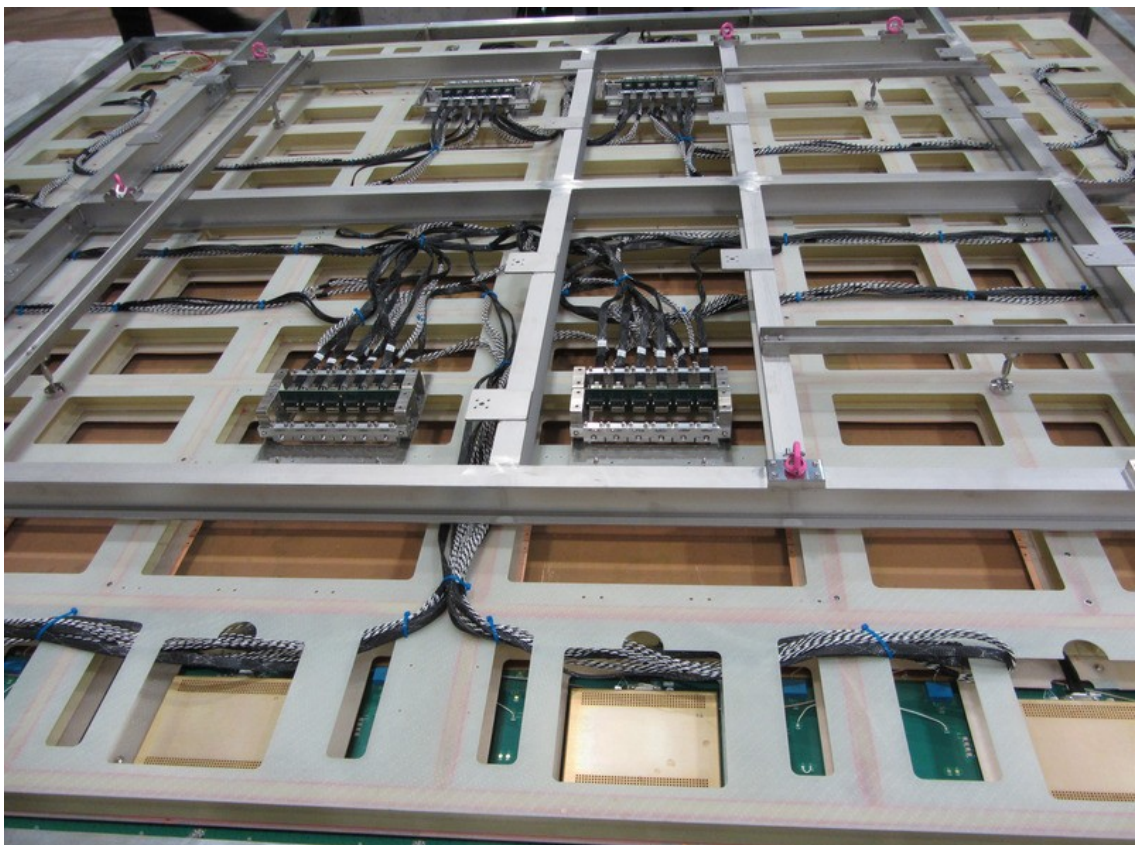
FD1-HD



Data patch cable

Final Design

- COTS 2.5-m-long miniSAS cable.
  Customization: mesh sleeve jacketing (for improved mechanical protection and maintain proper isolation following DUNE grounding and shielding rules).



HV bias cable

RG316

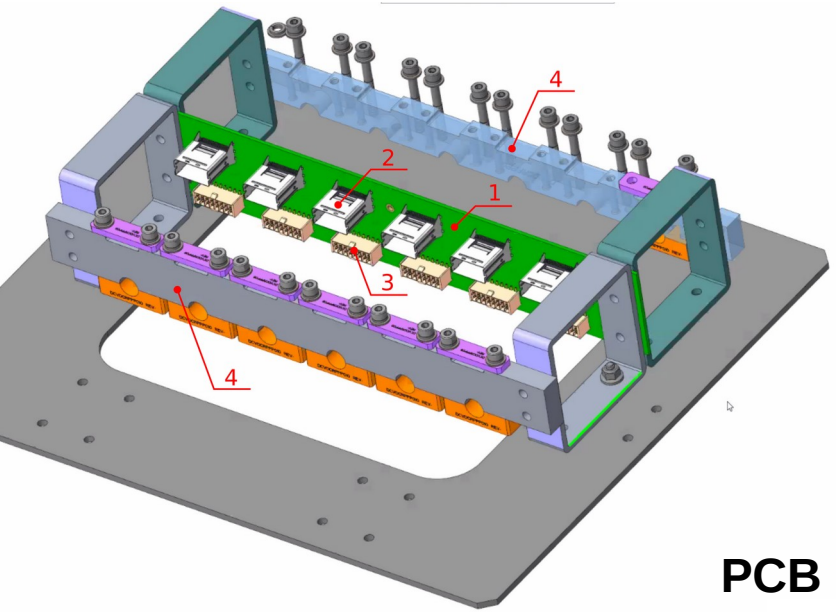
Requirements

	FD1-HD	FD2-VD
Length	9m, 22m	27m
Number of lines	1	
Max voltage	1.5 (may increase to 2) kV **DC** in pure Ar gas	
Max current	4 mA DC	
Operating temperature	70 K	
Mechanical strength	self-support over 12 m, rugged jacket	
misc.	must meet DUNE purity test requirements; keep diameter small	

Final Design

- COTS RG316 RF cables (0.02”-diameter inner conductor is a 7-strand silver-covered copper-clad steel (SCCS) wire (1) is enclosed by a Polytetrafluoroethylene (PTFE) insulation layer (2), one silver-covered copper braid shield (3) and 0.102”-diameter Fluorinated Ethylene Propylene (FEP) jacket (4)), terminated by PE4498 SHV connectors.
- Voltage rating of the cable:
  - AC: 2.0 kVrms (manufacturer)
  - DC: 20 kV (calculated); tested up to 8 kV per engineering note EDMS:2086112.
- Voltage rating of SHV connector:
  - AC: 1.1 kVrms (manufacturer)
  - DC: 5 kV – standard for SHV connectors
- Current ampacity estimate based on wire gauge: at least 1 A.

CRP patch panel (FD2-VD)



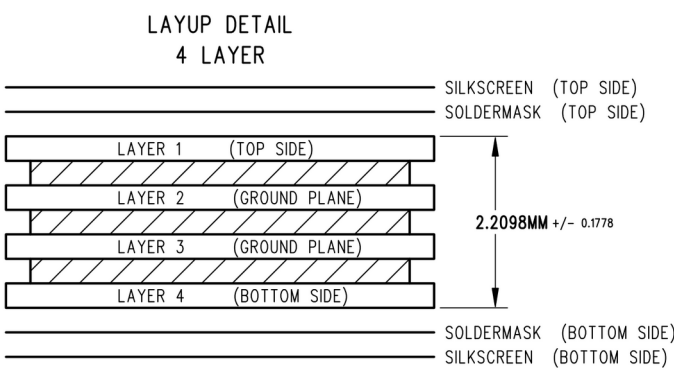
Requirements

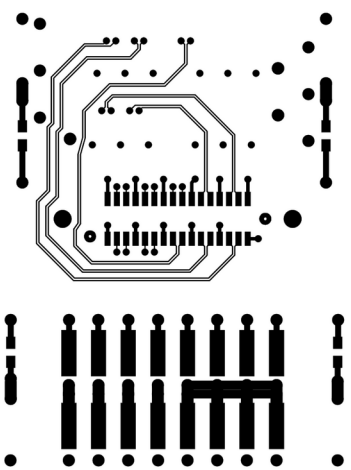
- Patch long (27m) cold power and data cables to short CRP cables.
- Currents and voltages – see previous slides.

Design

- PCB with soldered mating connectors.
- Metal structure for PCB support.

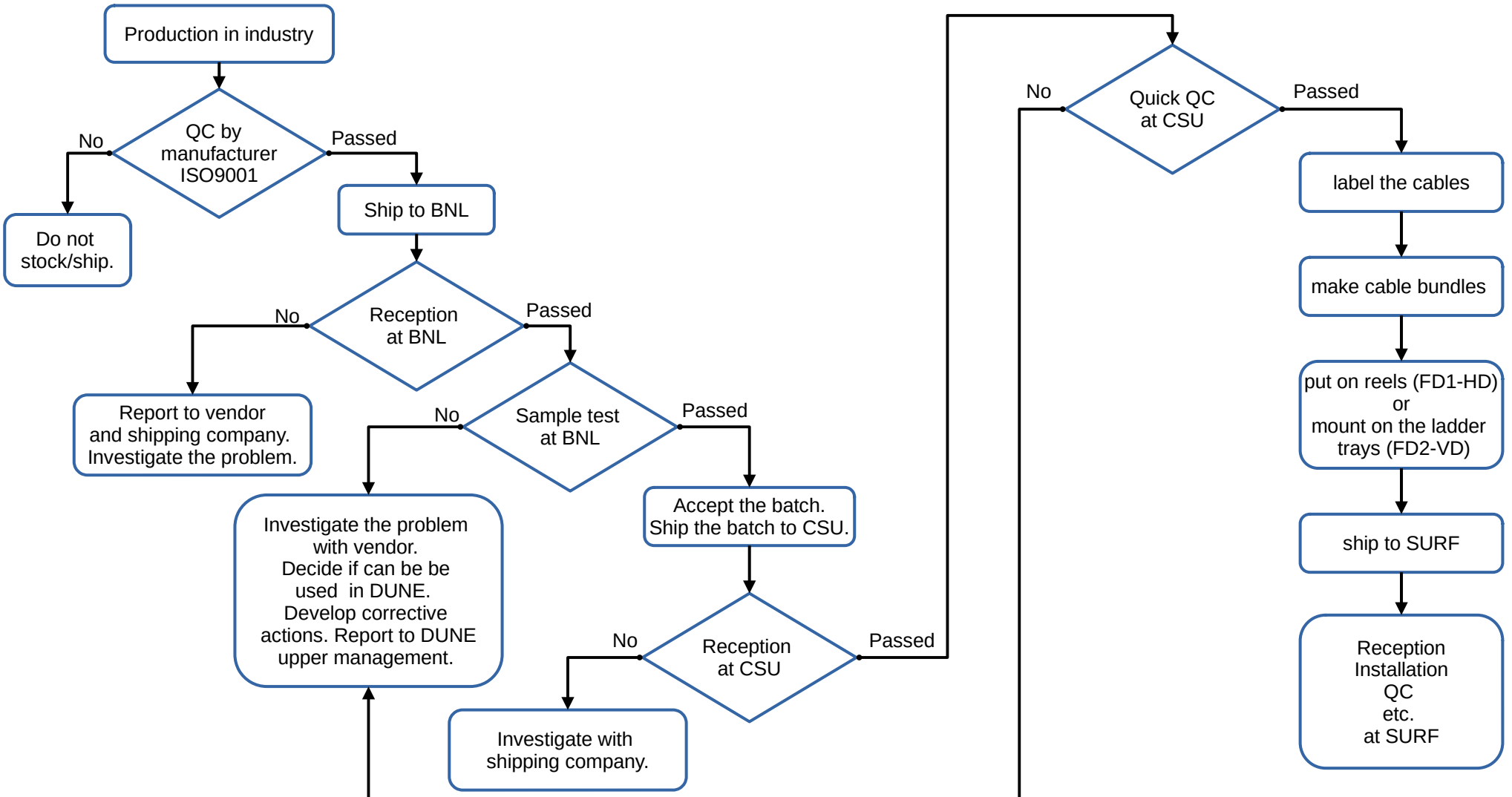
PCB





- 4-layer PCB with 1oz copper layers
- Inner layers – ground planes
- Outer layers – surface-mounted connectors
- Power traces:
  - width: 1 mm
  - length: 8.5 mm
  - calculated min. width required for 2 A current: 0.78 mm
- via: 0.457-mm-diameter
  - calculated ampacity: 3.25 A

Logistic and QC flow

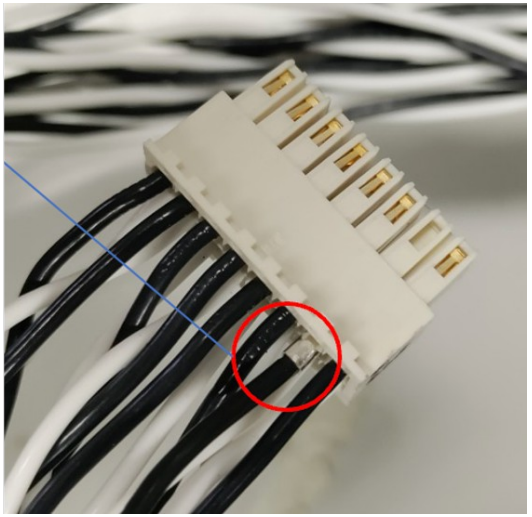


Sample testing at BNL

1. Visual inspection of cold power cables (Appendix A)
   (look for manufacturing defects on the wires and terminations)
2. Visual inspection of cold data cables (Appendix B)
   (look for manufacturing defects on the wires and terminations)
3. Cryo cycling of cold cables and visual inspection (Appendix E)
   (monitor compatibility of materials with cryogenic environment)
4. Continuity test of cold power cables (Appendix C)
5. Continuity test of cold data cables (Appendix D)
   (sanity check to test vendor's QC process)
6. Functionality test of cold cables (Appendix F)
   (to test for and intercept hidden problems early)

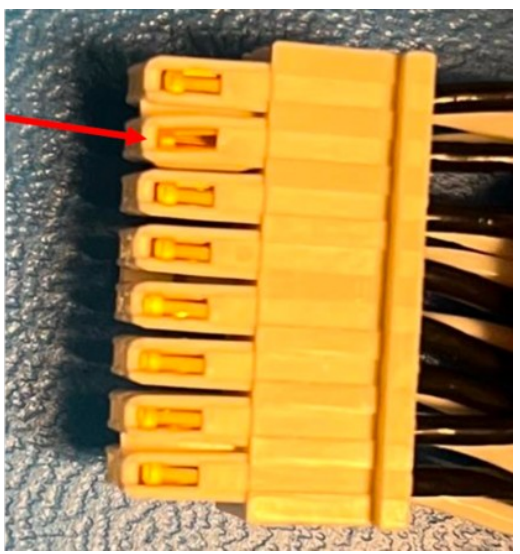
(See EDMS:3207305)

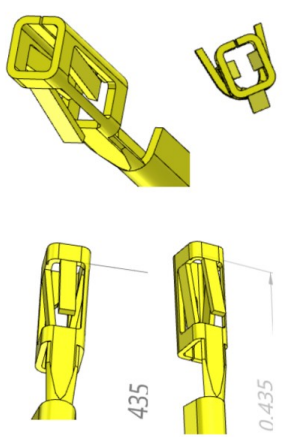
Visual inspection of cold power cables

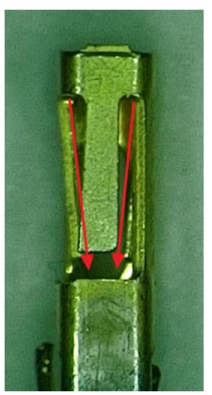


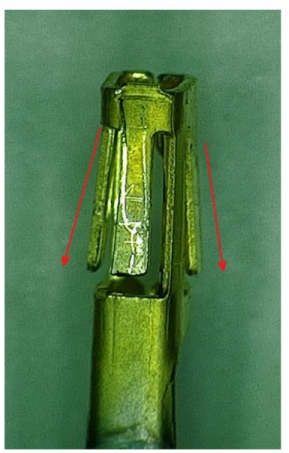
Potential problems:
1) Excessive stripping of insulation
2) Not fully inserted (not latched) pin
3) Wrongly inserted (rotated) pin
4) Bent contact wings
5) Bent latch pin
6) Defects in wire insulation
7) Loose cloth wrap

+ perform a pull test





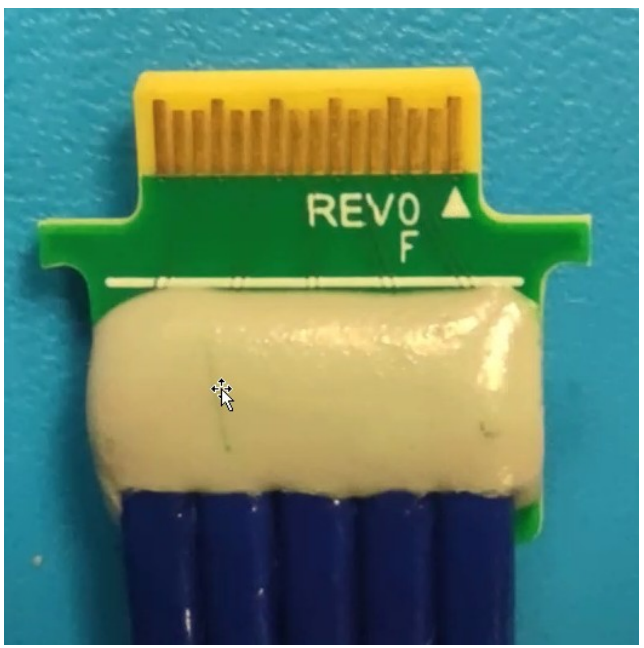

Good


Defective

Visual inspection of cold data cables

Potential problems

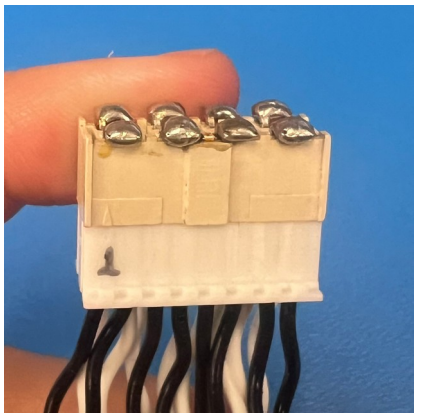
1) Excessive stripping of insulation
2) Excessive or insufficient application of gray epoxy
3) Defects in wire insulation

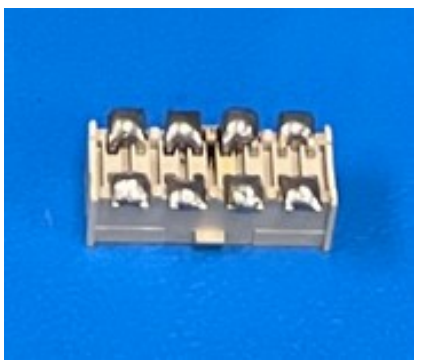


Cryo cycling of cold cables and visual inspection

1) Submerge cables into LN2 for ~10 minutes
2) Remove from LN2
3) Dry
4) Inspect for cables and connectors for cracking, degradation, etc.
5) Repeat the cryo cycle

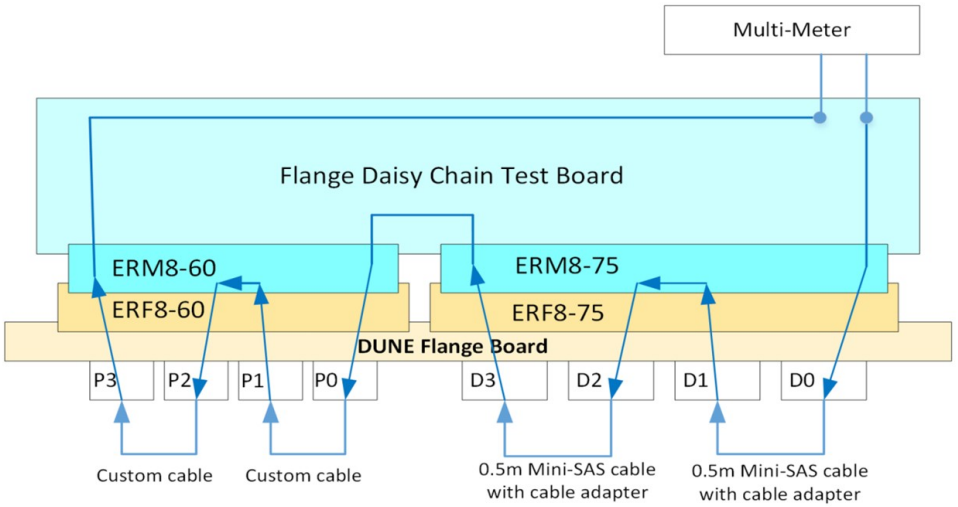
Continuity test of cold power cables

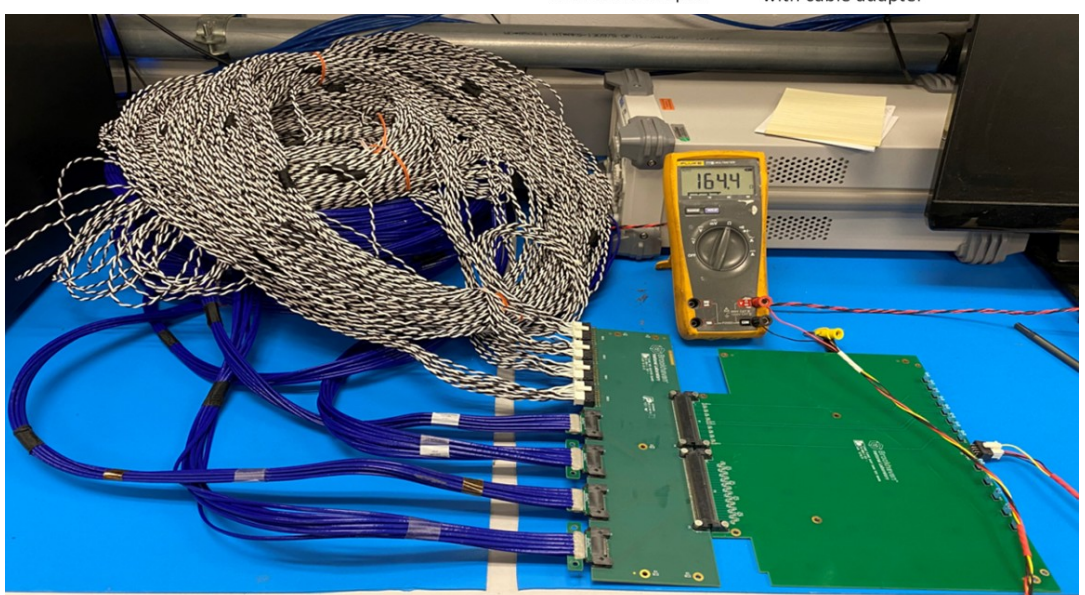




Custom-made connectors for daisy-chaining individual wires (black and white wires separately).
Expected measured resistance: 33 *mΩ/m* x cable length x 8 (number of wires) for AWG 20 wires.

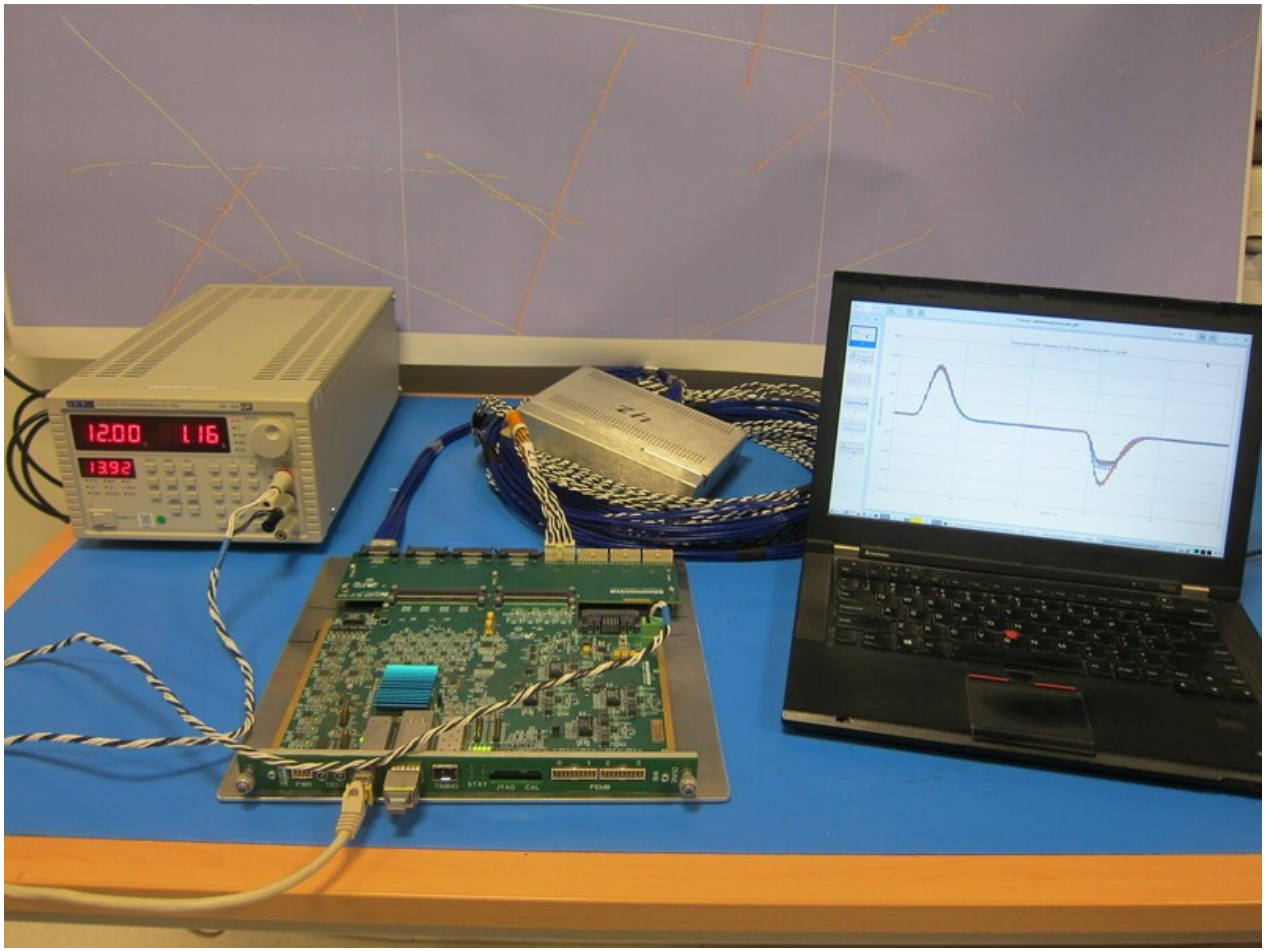
Continuity test of cold data cables





- Custom-made board for daisy-chaining individual wires of data cable.
- Can also be used for continuity testing of white power cables at the same time.
- Expected resistance of 22-m-long data cables is 164 *mΩ*.
- Acceptance criteria will be defined for all cable types.

Functionality test of cold cables



Example of a typical test stand for reception testing of FEMBs or functionality testing of CE cables.

- Up to 4 CE data and 4 power cables (and 4 FEMBs) can be tested simultaneously
- Simple acceptance creterion: pass/fail reported by the test

PART 02 Initial Test < Pass >

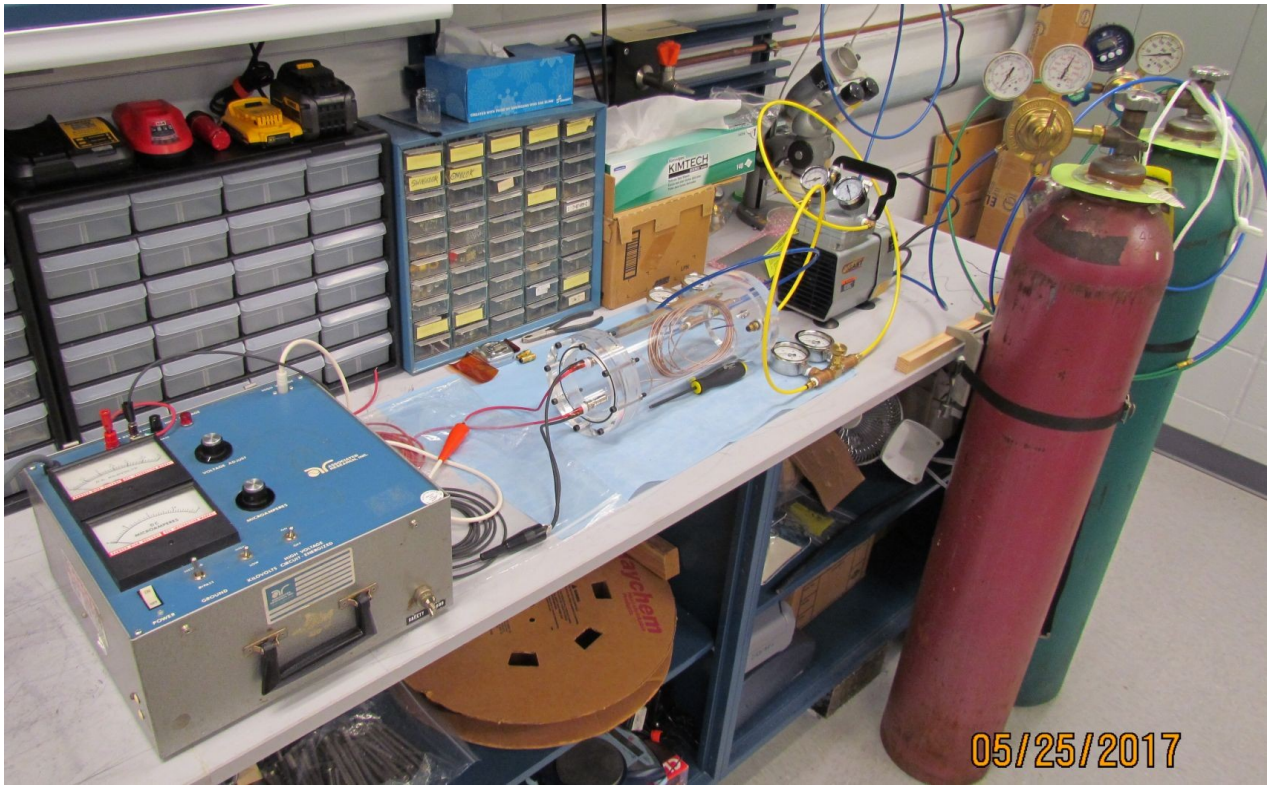
2.1 Initial Current Measurement

Initial Current Measurement				
Measure Object	BIAS	LArASIC	ColdDATA	ColdADC
V_set/V	5	3	3	3.5
V_meas/V	4.999	2.923	2.962	3.425
I_meas/V	0.003	0.439	0.168	1.648
P_meas/V	0.015	1.283	0.498	5.644
Total Power	7.44			

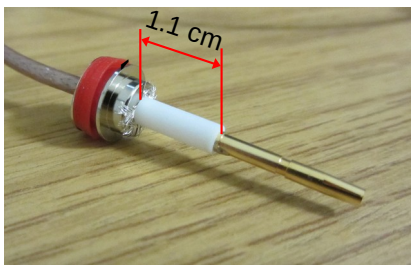
2.2 Check FEMB Registers

COLDATA_REG_1	ColdADC_REG_1	COLDATA_REG_2	ColdADC_REG_2	Result
Pass	Pass	Pass	Pass	True

Hipotting of HV bias cables



Test stand at BNL for characterization of HV cables for operation in Ar gas: Air-tight test chamber, vacuum pump, Ar cylinder, gas/vacuum lines, HV power supply. It can be used for QC testing (hipotting of HV cables for DUNE) as well.
We are planning to replace the test chamber with a larger one assembled from available DUNE parts (next slide).



Typical DC rating of SHV connectors: 5 kV

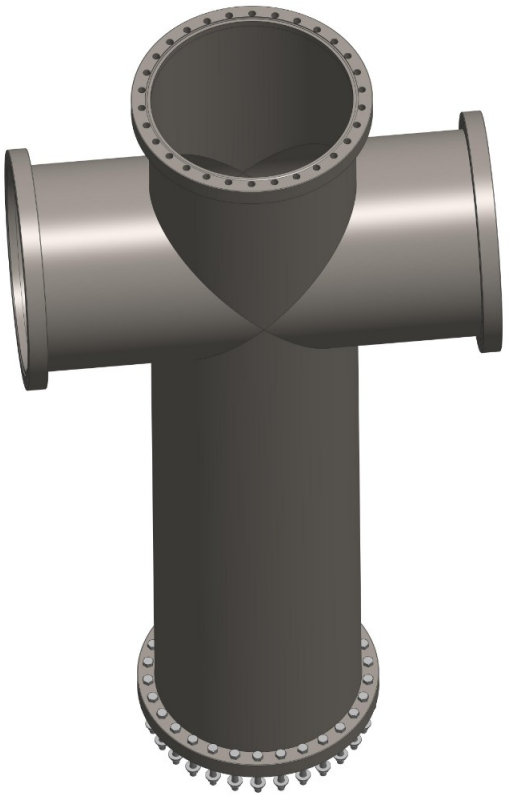
Dielectric strength of air: ε~30 kV/cm.

Dielectric strength of pure Ar: ~αε, α=0.2-0.5

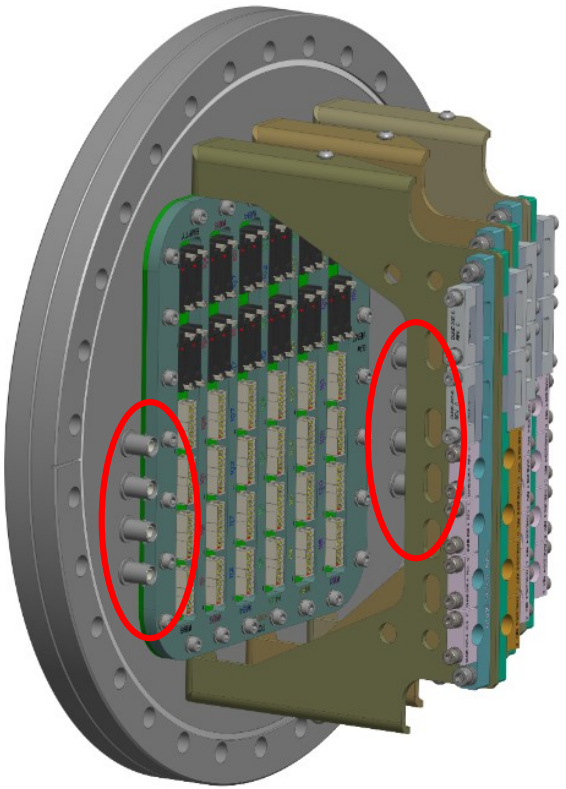
Safest approach: test HV cables in Ar.

Hi-capacity test chamber option

CE cross



CE flange



- 8 feedthrough SHV connectors for simultaneous testing of HV cables.
- The number of test cables can be further increased by daisy-chaining the cables.
- Can be used for continuity testing of HV cables.