Purity Monitor Final Design Review

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Motivation of Purity Monitors

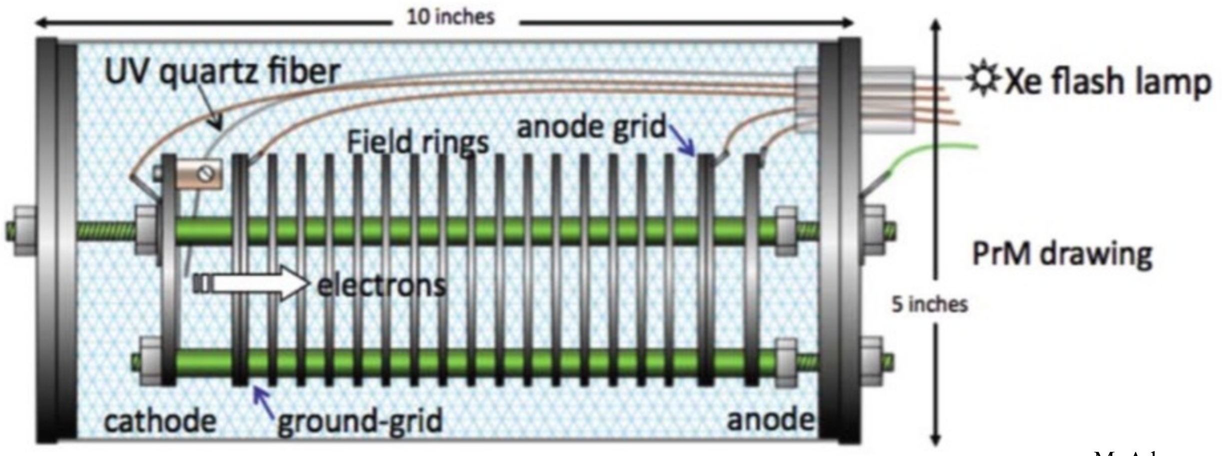
- Detector and cryogenic operation: Argon filling to cryostat during commissioning, alert pump and cryogenic accidents during operation, alert unexpected contamination in cryostat. Incidents alerted by PrMs in ProtoDUNE-SP include filter saturation, level gauge fake measurements, pump stoppages, etc.
- Provide benchmarks LAr purities for recirculation studies and TPC calibration
- Measure e-lifetime for data quality, calibration and analysis. Impurity measured by purity monitors and TPC/CRT in good agreement at ProtoDUNE-I. Provided PrM lifetime to ProtoDUNE-SP analysis group for run-by-run lifetime calibration.
- Measure purity stratification and verify Computational Fluid Dynamics (CFD)

Purity Monitors

PrM – miniature TPC to measure LAr purity and electron drift lifetime

- Use UV light on photocathode to produce photoelectrons
- Measure lifetime τ based on:

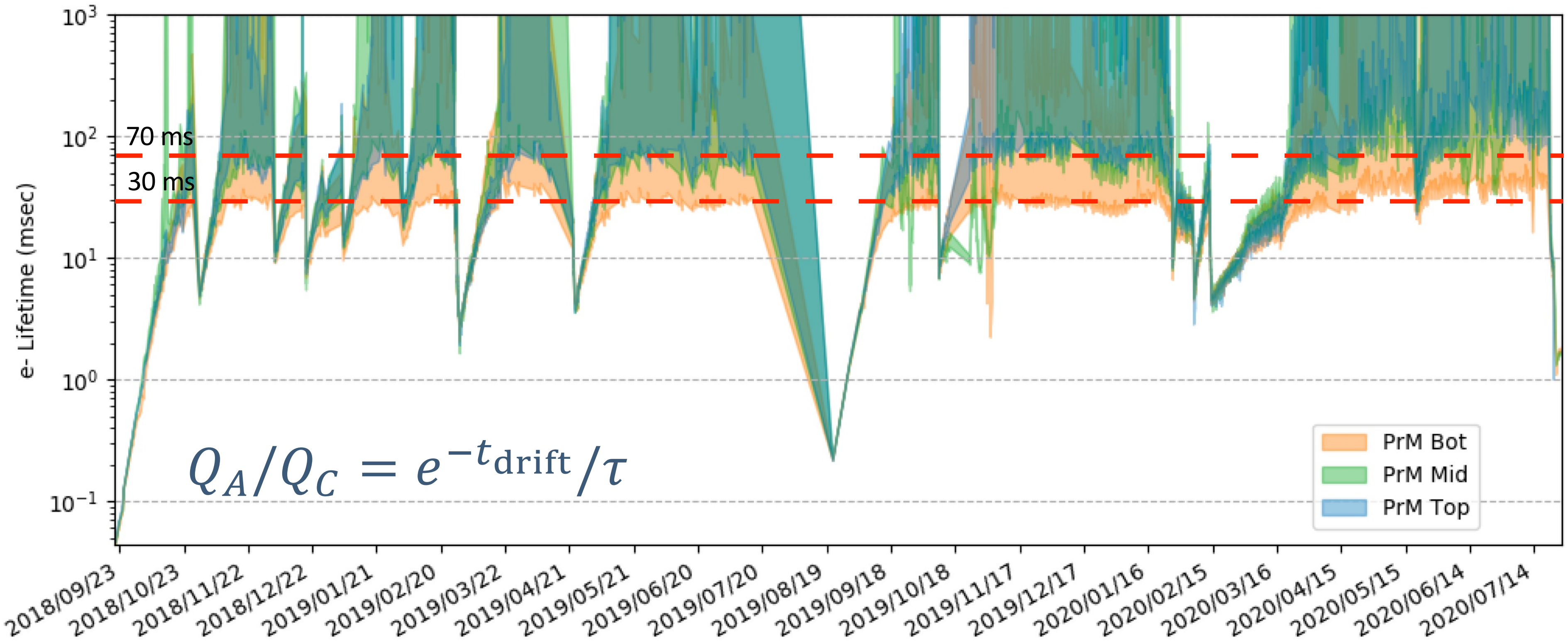
$$Q_{anode}/Q_{cathode} = e^{-t_{drift}/\tau}$$



M. Adamowski et al., JINST 9, P07005 (2014).

- Measuring the attenuation of charge from cathode to anode.
  - Many Flashes per measurement → Small statistical error
  - Small active volume → Small space charge effect
- A longer drift time will have better sensitivity at high purity, and a shorter drift time will have better sensitivity at low purity.

Purity monitoring for ProtoDUNE-SP-I



- Purity monitors successfully run in ProtonDUNE-SP
- Caught filter saturation during LAr filling, recirculation pump outages - preventing situations with potentially serious consequences for data taking
- High LAr purity and electron lifetime (> 30 ms) achieved at ProtoDUNE-SP.
- Key component of LArTPC calibration - corrects charge loss caused by LAr impurities.

DUNE Purity Monitors: Baseline Design and Scope

- Will build DUNE purity monitors in two different lengths: The standard purity monitor will have length of 25 cm with a drift distance of 16 cm, and the long purity monitor will have a length of 75 cm with a drift distance of 64 cm.
- Build 4 PrMs in each DUNE FD cryostat, 2 standard and 2 long
- Build 1 standard PrMs within recirculation (inline), after LAr filter

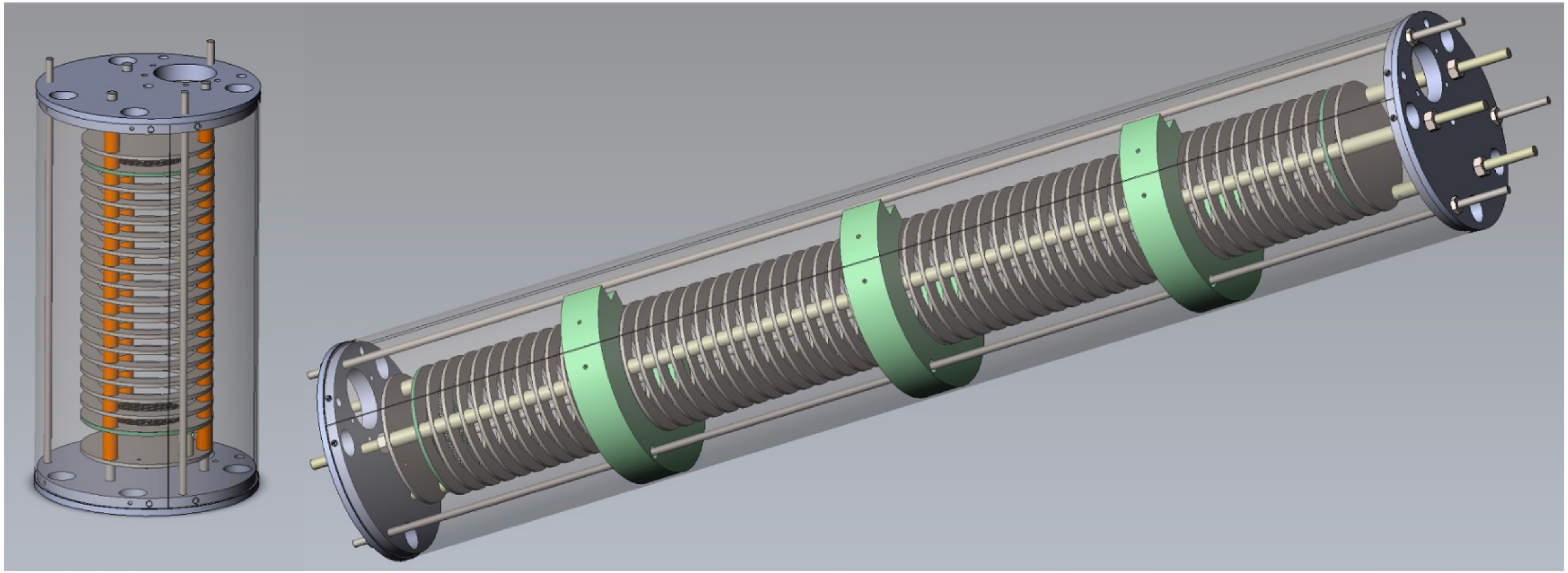
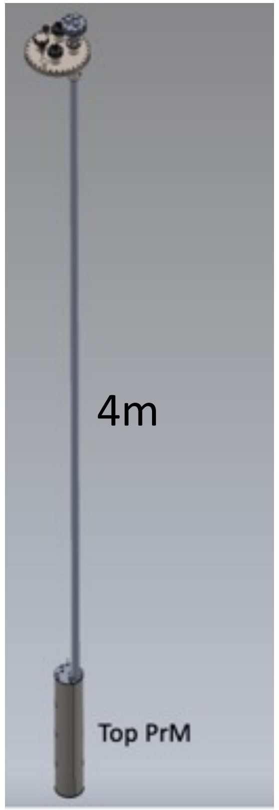


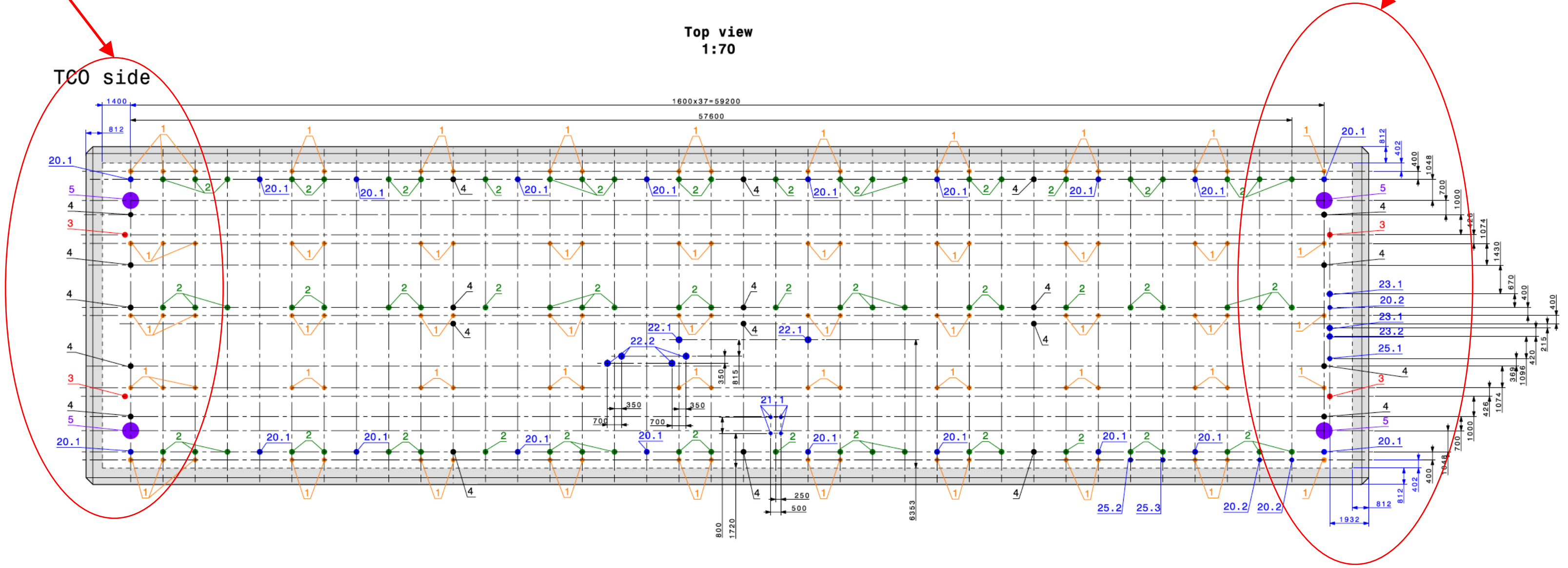
Figure 1.2: (left) standard purity monitor (right) long purity monitor

DUNE Cryostat Purity Monitors



4m

In the baseline design, each DUNE FD cryostat will deploy 4 purity monitors (2 standard and 2 long purity monitors). 2 purity monitors (1 long and 1 standard) will be installed on the east side in the same port at different heights (top, bottom), and the other 2 will be installed on the west side in the same way.

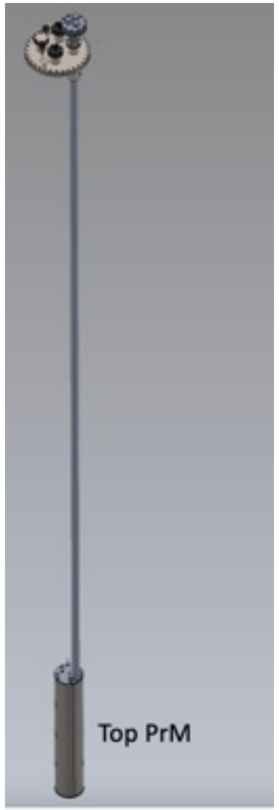


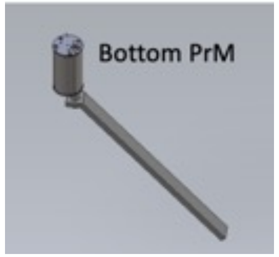
Possible ports

Detector penetrations

Pos.	Diameter [mm]	Quantity	Description
1	Ø200	100	Support
2	Ø250	75	Cable
3	Ø250	4	High voltage
4	Ø250	21	Instrumentation
5	Ø800	4	Manholes
7	2680x13428	1	Temporary Construction Opening

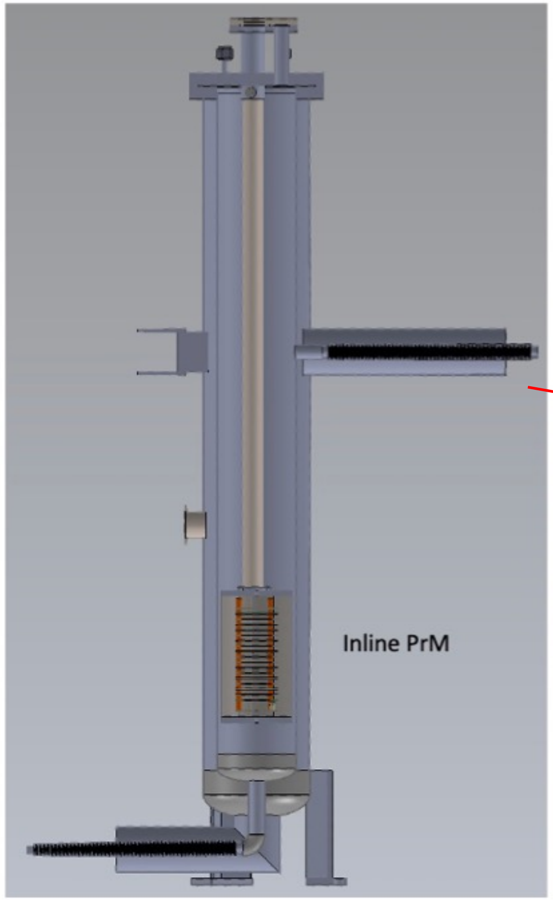
- Feasibility issues have been solved in ProtoDUNE-SP-I
- DUNE PrM mounting rod is only~4m long, prevent a long, rigid structure that could affect other system

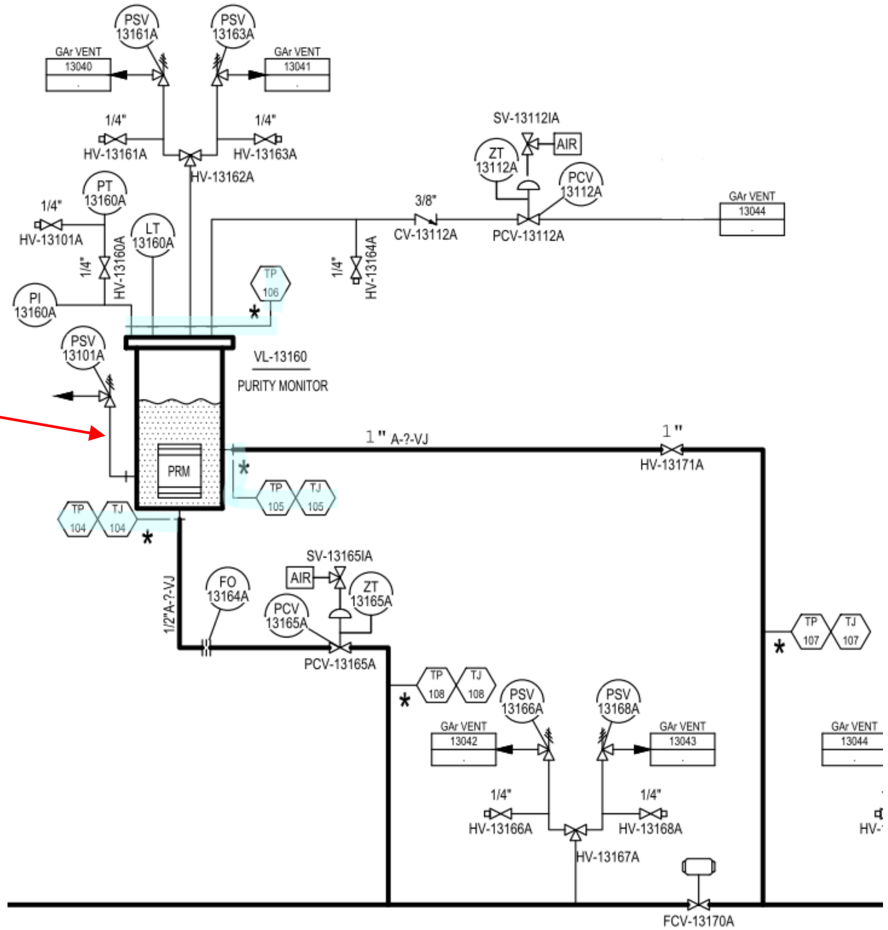




DUNE Inline Purity Monitor

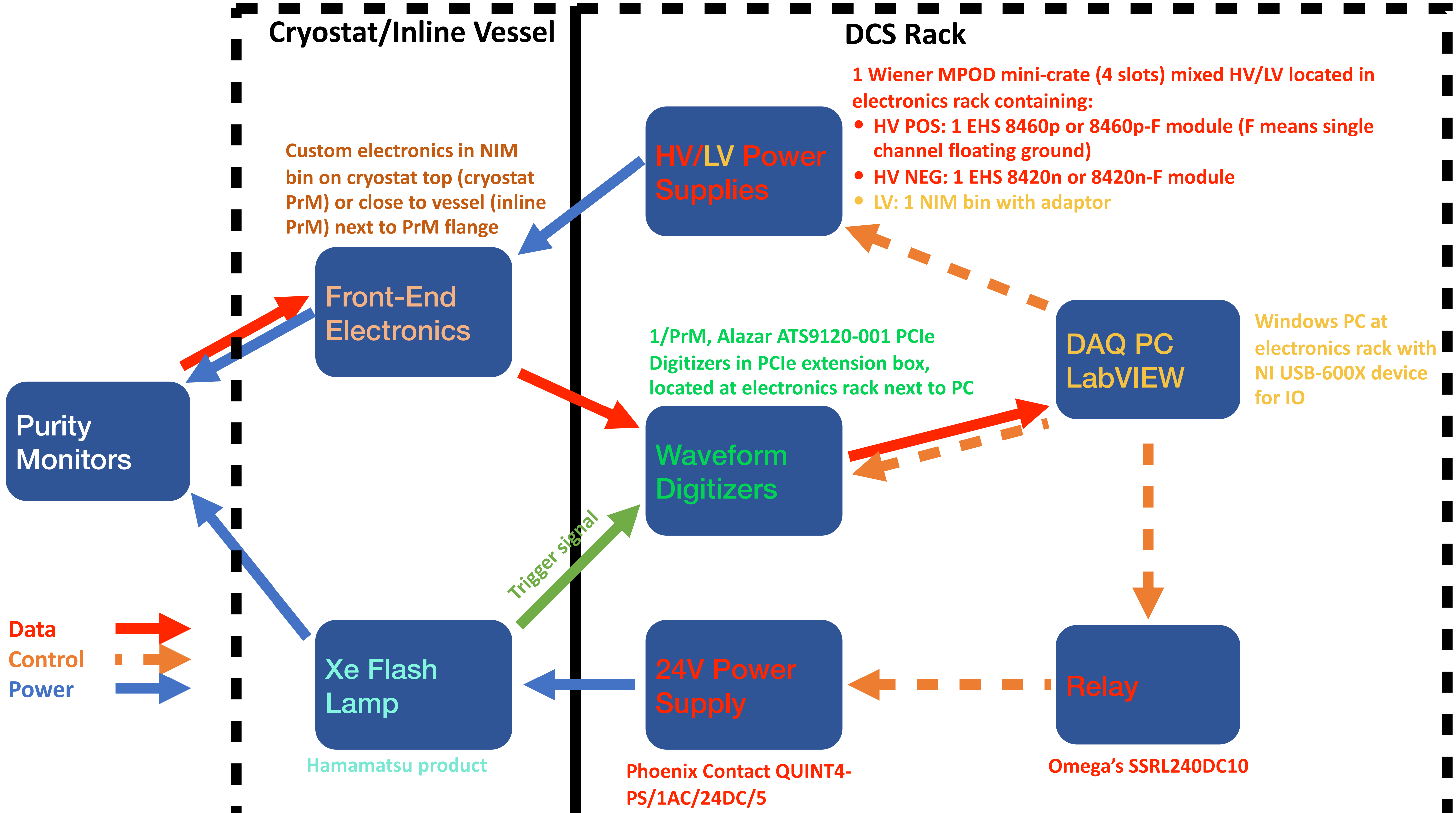
For each FD, there will be one purity monitor installed within the liquid argon recirculation system (inline purity monitor) after the liquid argon filter. The inline purity monitor will be mounted in a vacuum-insulated vessel. The vessel design is the same as that used in the MicroBooNE and SBND inline purity monitors. The vessel will have the same pipe size to connect with the process pipe and vacuum jacket in the LBNF cryogenic system.





- Interface document with LBNF produced
- DUNE will provide purity monitor and vessel
- LBNF will provide valves and pipes

Electrical Schematics: Components



Cryogenic Instrumentation Final Design Review

Purity Monitor Documentation

Design Documents:
(https://edms.cern.ch/project/CERN-0000237160)

1) Design Report: https://edms.cern.ch/document/2811711/1
2) Mechanical Models and Drawings: https://edms.cern.ch/document/2811307/1
3) Board Schematics and Layouts: https://edms.cern.ch/document/2811309/1
4) Board Bill of Materials (BOMs): https://edms.cern.ch/document/2811716/1
5) Grounding & Shielding Plan: https://edms.cern.ch/document/2811311/1
6) Electrical Connections Specification: https://edms.cern.ch/document/2811310/1
7) Commercial Electronic Component Specs: https://edms.cern.ch/document/2811308/1

Requirements Documents:
(https://edms.cern.ch/project/CERN-0000237161)

Installation Documents:
(https://edms.cern.ch/project/CERN-0000237162)

1) ProtoDUNE-II Installation plan: https://edms.cern.ch/document/2812003/1

Interface Documents:
(https://edms.cern.ch/project/CERN-0000237163)

1) CALCI/APA Interface: https://edms.cern.ch/document/2145136/5
2) CALCI/PDS Interface: https://edms.cern.ch/document/2145137/3
3) CALCI/TPC-ELEC Interface: https://edms.cern.ch/document/2145138/3
4) CALCI/HV Interface: https://edms.cern.ch/document/2145142/2
5) CALCI/DAQ Interface: https://edms.cern.ch/document/2088741/2
6) CALCI/Computing Interface: https://edms.cern.ch/document/2145159/2

QA/QC Documents:
(https://edms.cern.ch/project/CERN-0000237164)

1) QA/QC plan: https://edms.cern.ch/document/2811775/1

Cost/Schedule Documents:
(https://edms.cern.ch/project/CERN-0000237165)

1) Basis of Estimate (BOE) Report: https://edms.cern.ch/document/2811717/1

Previous Review Documentation:
(https://edms.cern.ch/project/CERN-0000237166)

1) Preliminary Design Review Closeout: https://edms.cern.ch/document/2796075/1

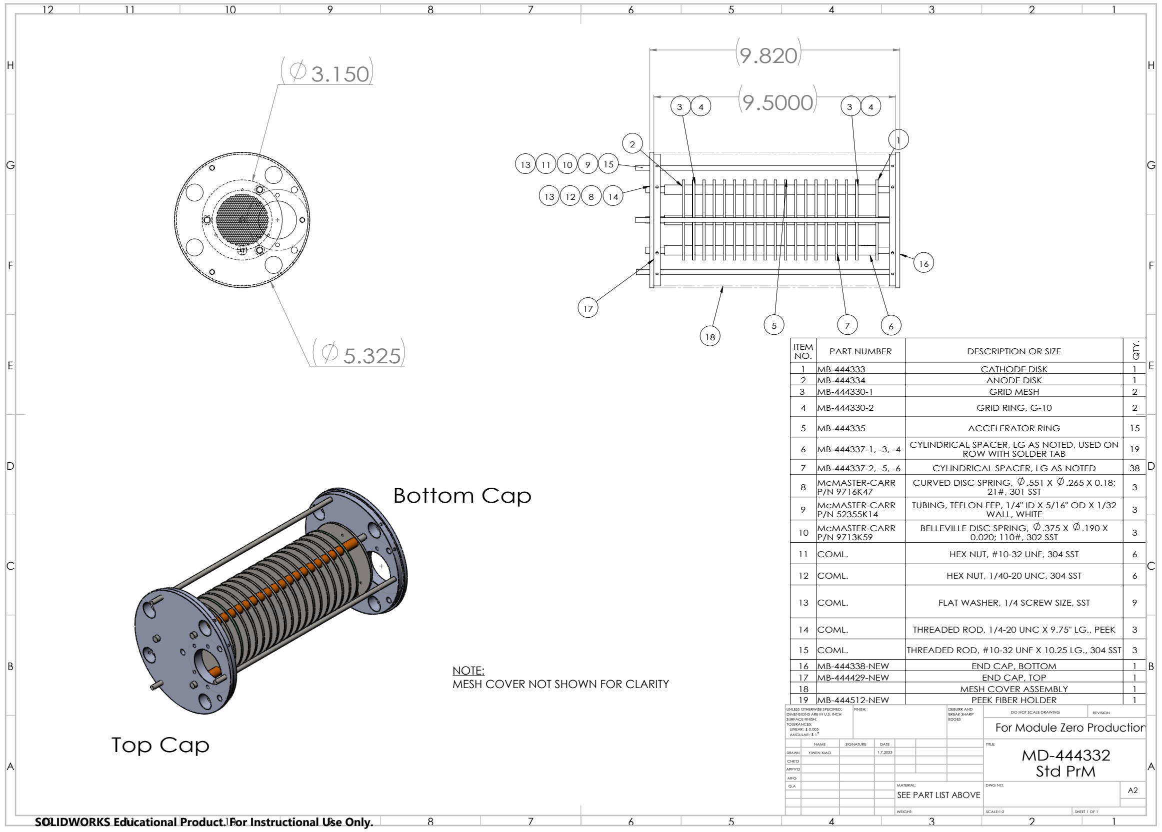
Mechanical Models and Drawings

Mechanical CAD Model for Sub-system
Mechanical Engineering Drawings and Assembly Drawing and Parts List:

Mechanical CAD Model for Sub-system:
(Directory: Assembly file)
CryoStatPrMAssembly: PrMSystem_DUNE.SLDASM
CryoStatPrMFlangeDrawing: CryoFlange_DUNE.SLDASM
InlinePrMAssemblyDrawing: InlinePrM_LArPiping.SLDASM
InlinePrMFlangeDrawing: Flange_10OD.SLDASM
InlinePrMVesselDrawing: LAr_piping.SLDASM
LongPrMDrawing: 3942.330-MD-444332-long-large cap_CENTER.SLDASM
StdPrMDrawing: 3942.330-MD-444332.SLDASM

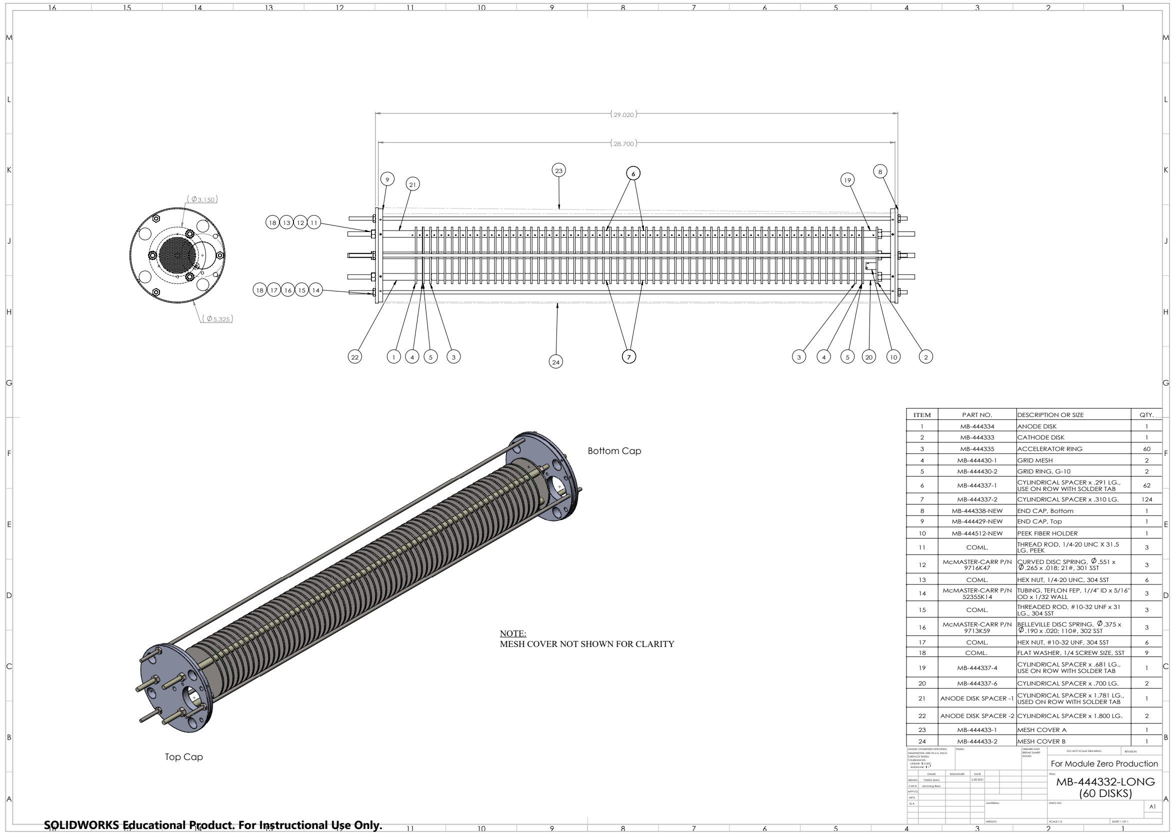
Mechanical Engineering Drawings and Assembly Drawing and Parts List:
(Directory: Assembly file)
CryostatPrMFlangeInstruction: CryoFlange_DUNE.pdf
CryoStatPrMAssemblyInstruction: PrMSystem_DUNE.pdf
InlinePrMAssemblyInstruction: INLINE_PrM_ASSEMBLY.pdf
InlinePrMFlangeInstruction: INLINE_PrM_FLANGE.pdf
InlinePrMVesselInstruction: LAr_piping_note_v21_run_2 OnePage68.pdf
LongPrMInstruction: LongPrMAssebly-MD-444332-large cap-CENTER.pdf
StdPrMInstruction: StdPrMAssembly-MD-444332.pdf

StdPrMInstruction



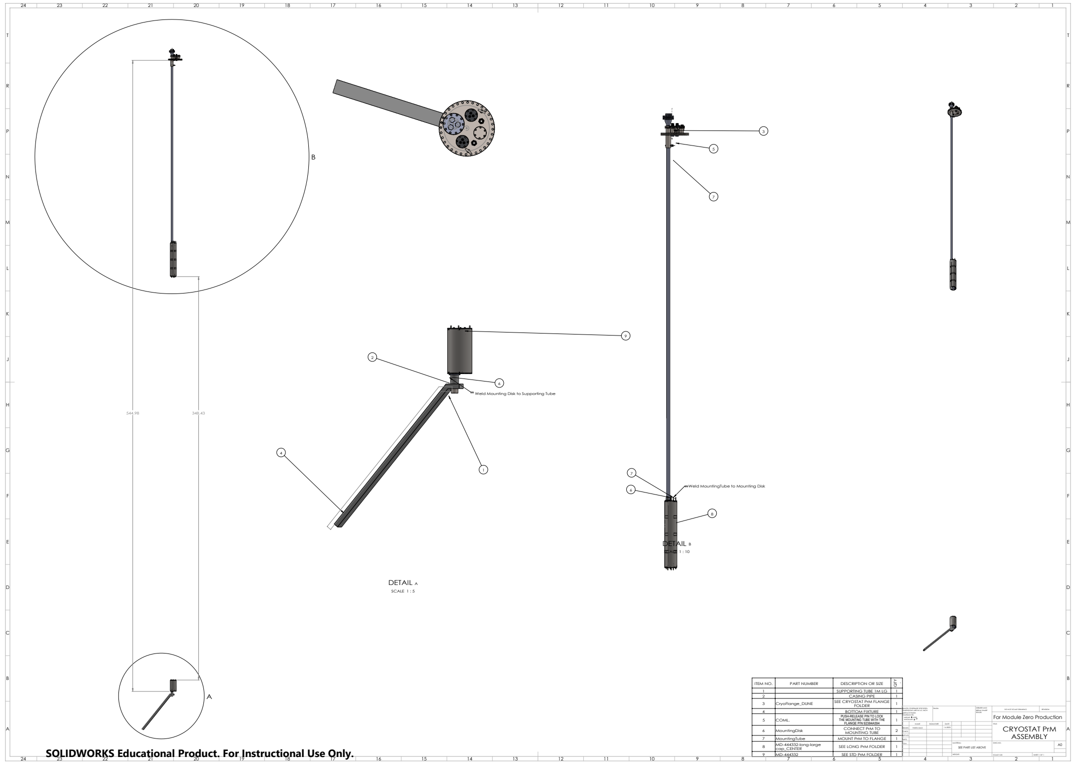
ITEM NO.	PART NUMBER	DESCRIPTION OR SIZE	QTY.
1	MB-444333	CATHODE DISK	1
2	MB-444334	ANODE DISK	1
3	MB-444330-1	GRID MESH	2
4	MB-444330-2	GRID RING, G-10	2
5	MB-444335	ACCELERATOR RING	15
6	MB-444337-1, -3, -4	CYLINDRICAL SPACER, LG AS NOTED, USED ON ROW WITH SOLDER TAB	19
7	MB-444337-2, -5, -6	CYLINDRICAL SPACER, LG AS NOTED	38
8	McMASTER-CARR P/N 9716K47	CURVED DISC SPRING, Ø.551 X Ø.265 X 0.18; 21#, 301 SST	3
9	McMASTER-CARR P/N 52355K14	TUBING, TEFLON FEP, 1/4" ID X 5/16" OD X 1/32 WALL, WHITE	3
10	McMASTER-CARR P/N 9713K59	BELLEVILLE DISC SPRING, Ø.375 X Ø.190 X 0.020; 110#, 302 SST	3
11	COML.	HEX NUT, #10-32 UNF, 304 SST	6
12	COML.	HEX NUT, 1/40-20 UNC, 304 SST	6
13	COML.	FLAT WASHER, 1/4 SCREW SIZE, SST	9
14	COML.	THREADED ROD, 1/4-20 UNC X 9.75" LG., PEEK	3
15	COML.	THREADED ROD, #10-32 UNF X 10.25 LG., 304 SST	3
16	MB-444338-NEW	END CAP, BOTTOM	1
17	MB-444429-NEW	END CAP, TOP	1
18		MESH COVER ASSEMBLY	1
19	MB-444512-NEW	PEEK FIBER HOLDER	1

LongPrMInstruction

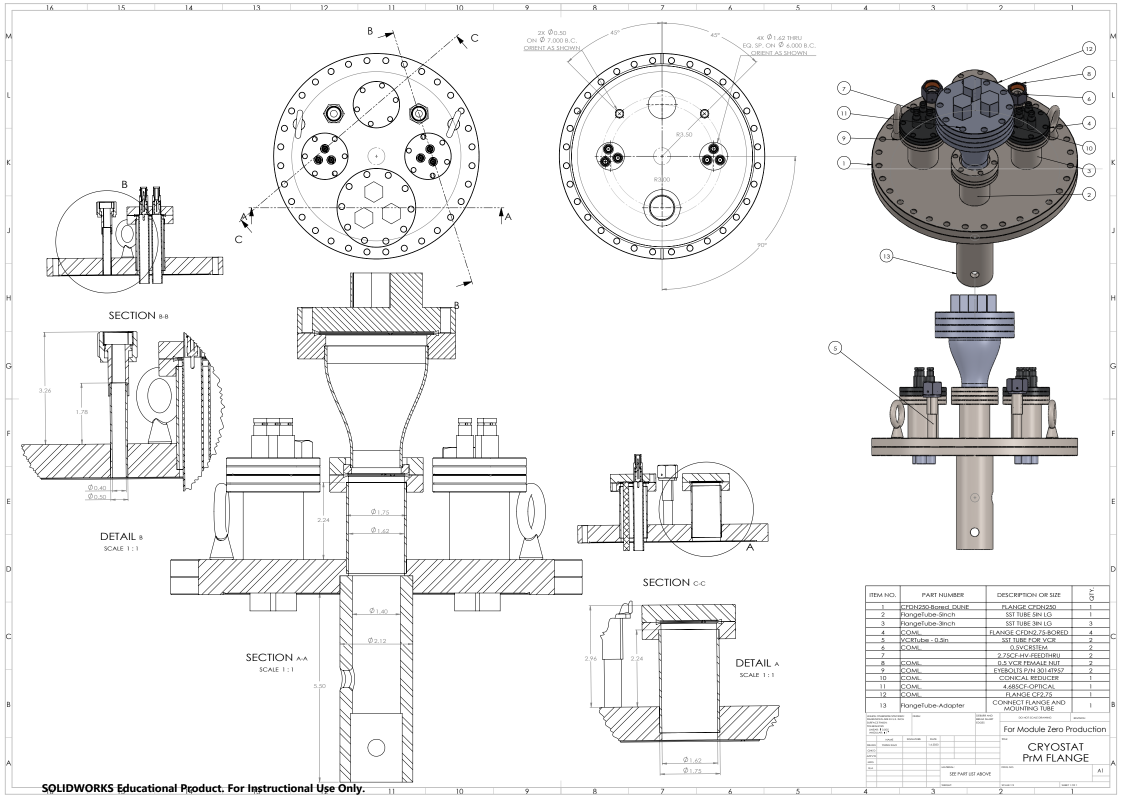


ITEM	PART NO.	DESCRIPTION OR SIZE	QTY.
1	MB-444334	ANODE DISK	1
2	MB-444333	CATHODE DISK	1
3	MB-444335	ACCELERATOR RING	60
4	MB-444430-1	GRID MESH	2
5	MB-444430-2	GRID RING, G-10	2
6	MB-444337-1	CYLINDRICAL SPACER x .291 LG., USE ON ROW WITH SOLDER TAB	62
7	MB-444337-2	CYLINDRICAL SPACER x .310 LG.	124
8	MB-444338-NEW	END CAP, Bottom	1
9	MB-444429-NEW	END CAP, Top	1
10	MB-444512-NEW	PEEK FIBER HOLDER	1
11	COML.	THREAD ROD, 1/4-20 UNC X 31.5 LG. PEEK	3
12	McMASTER-CARR P/N 9716K47	CURVED DISC SPRING, Ø.551 x Ø.265 x .018; 21#, 301 SST	3
13	COML.	HEX NUT, 1/4-20 UNC, 304 SST	6
14	McMASTER-CARR P/N 52355K14	TUBING, TEFLON FEP, 1//4" ID x 5/16" OD x 1/32 WALL	3
15	COML.	THREADED ROD, #10-32 UNF x 31 LG., 304 SST	3
16	McMASTER-CARR P/N 9713K59	BELLEVILLE DISC SPRING, Ø.375 x Ø.190 x .020; 110#, 302 SST	3
17	COML.	HEX NUT, #10-32 UNF, 304 SST	6
18	COML.	FLAT WASHER, 1/4 SCREW SIZE, SST	9
19	MB-444337-4	CYLINDRICAL SPACER x .681 LG., USE ON ROW WITH SOLDER TAB	1
20	MB-444337-6	CYLINDRICAL SPACER x .700 LG.	2
21	ANODE DISK SPACER -1	CYLINDRICAL SPACER x 1.781 LG., USED ON ROW WITH SOLDER TAB	1
22	ANODE DISK SPACER -2	CYLINDRICAL SPACER x 1.800 LG.	2
23	MB-444433-1	MESH COVER A	1
24	MB-444433-2	MESH COVER B	1

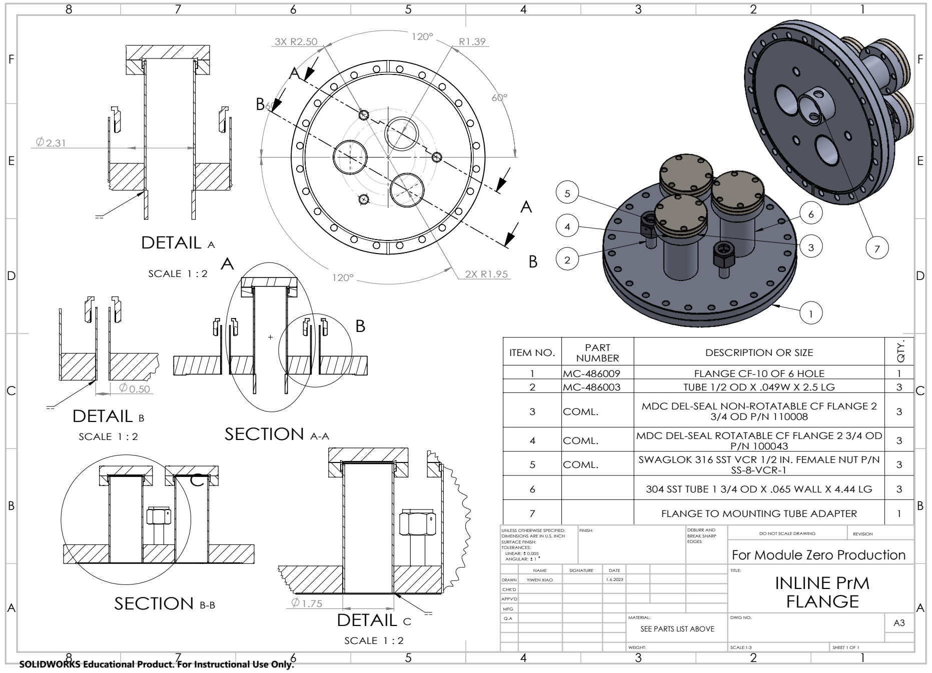
CryoStatPrMAssemblyInstruction



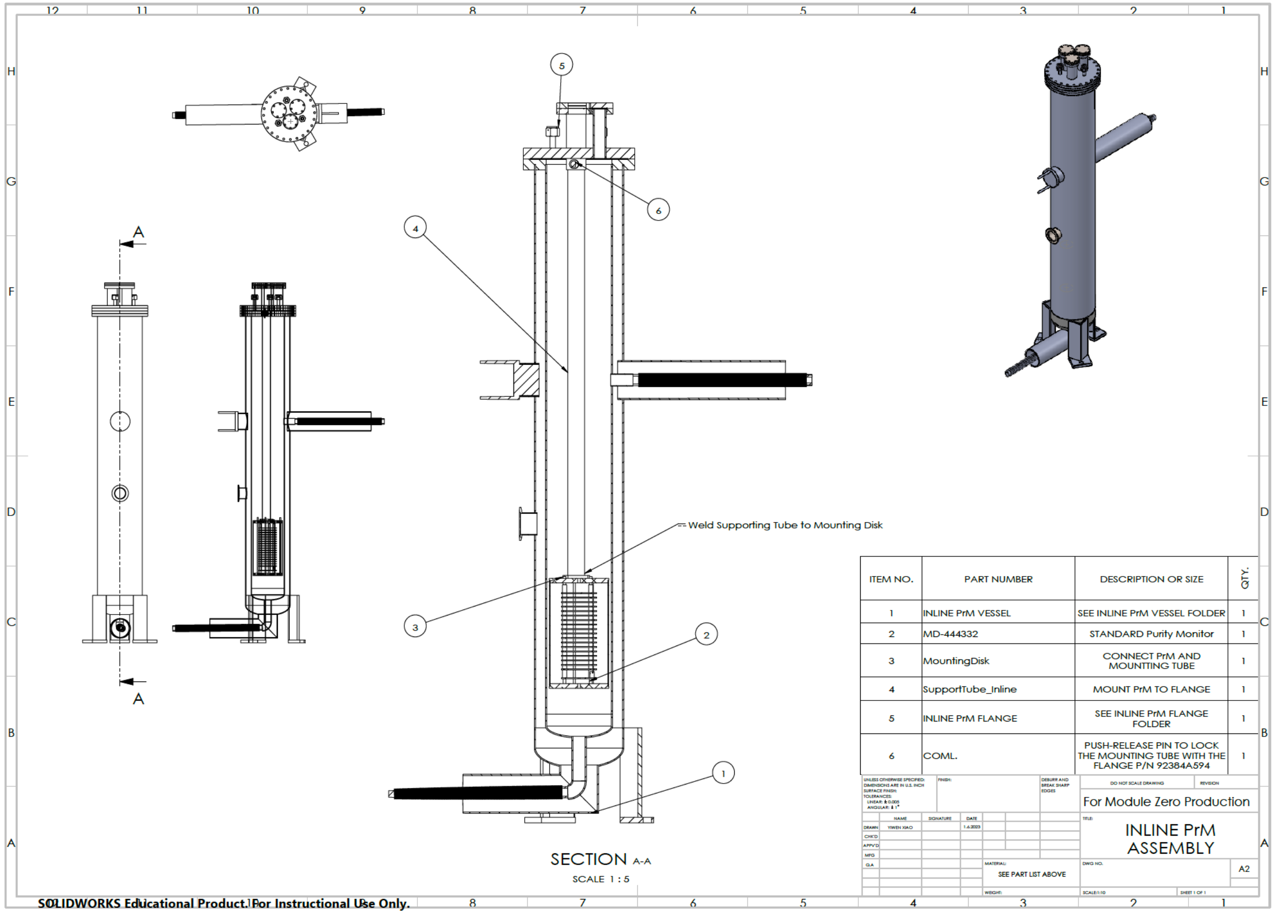
CryostatPrMFlangeInstruction



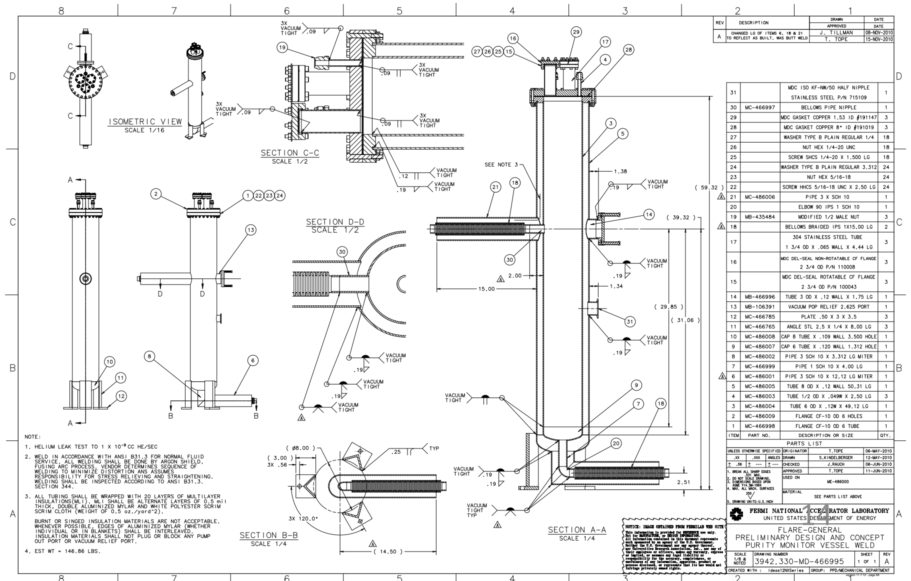
InlinePrMFlangeInstruction



InlinePrMAssemblyInstruction

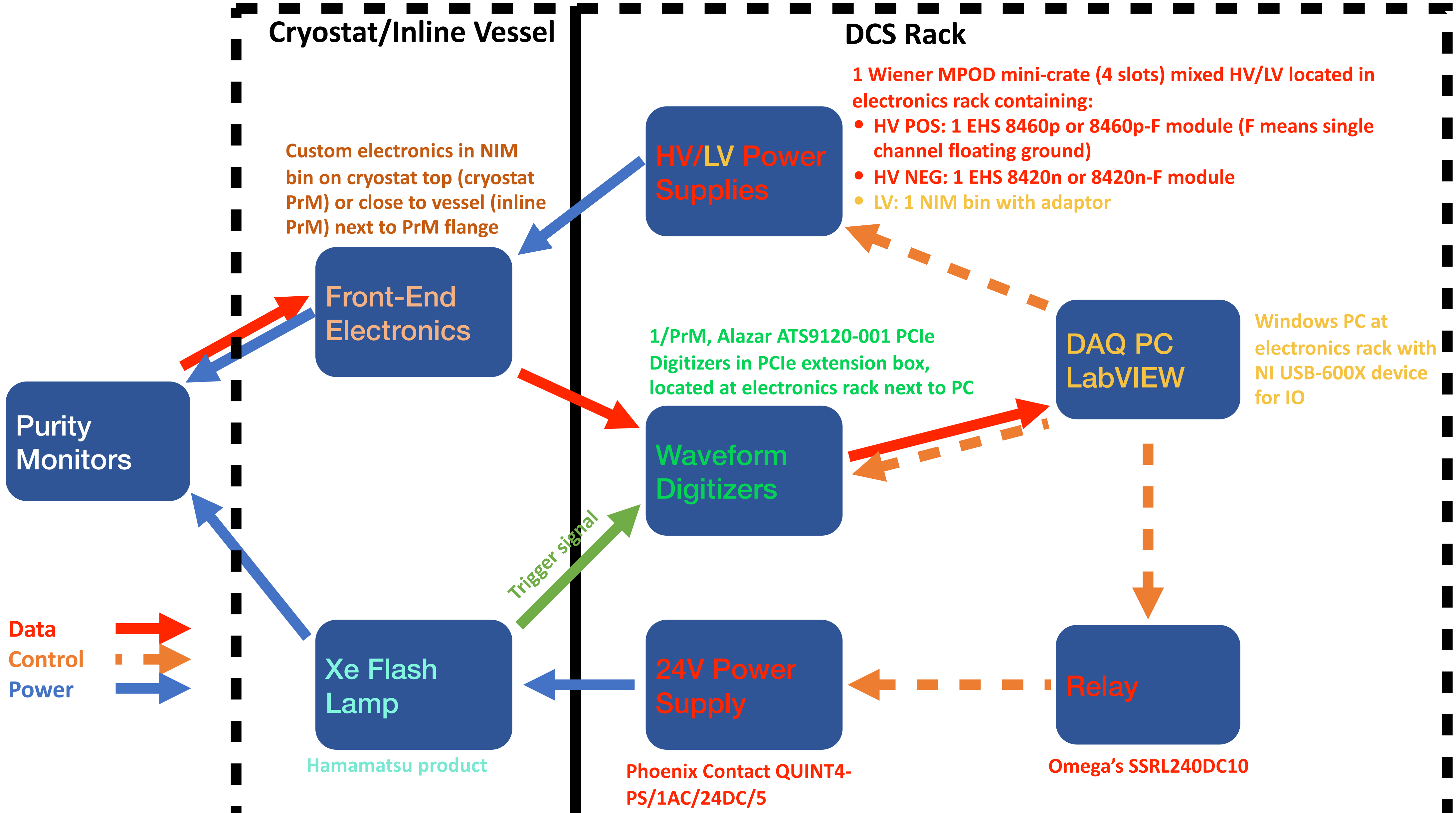


InlinePrMVesselInstruction



Purity Monitor Electrical Schematics & Board Layouts

Electrical Schematics: Components



Electrical Schematics: Cables

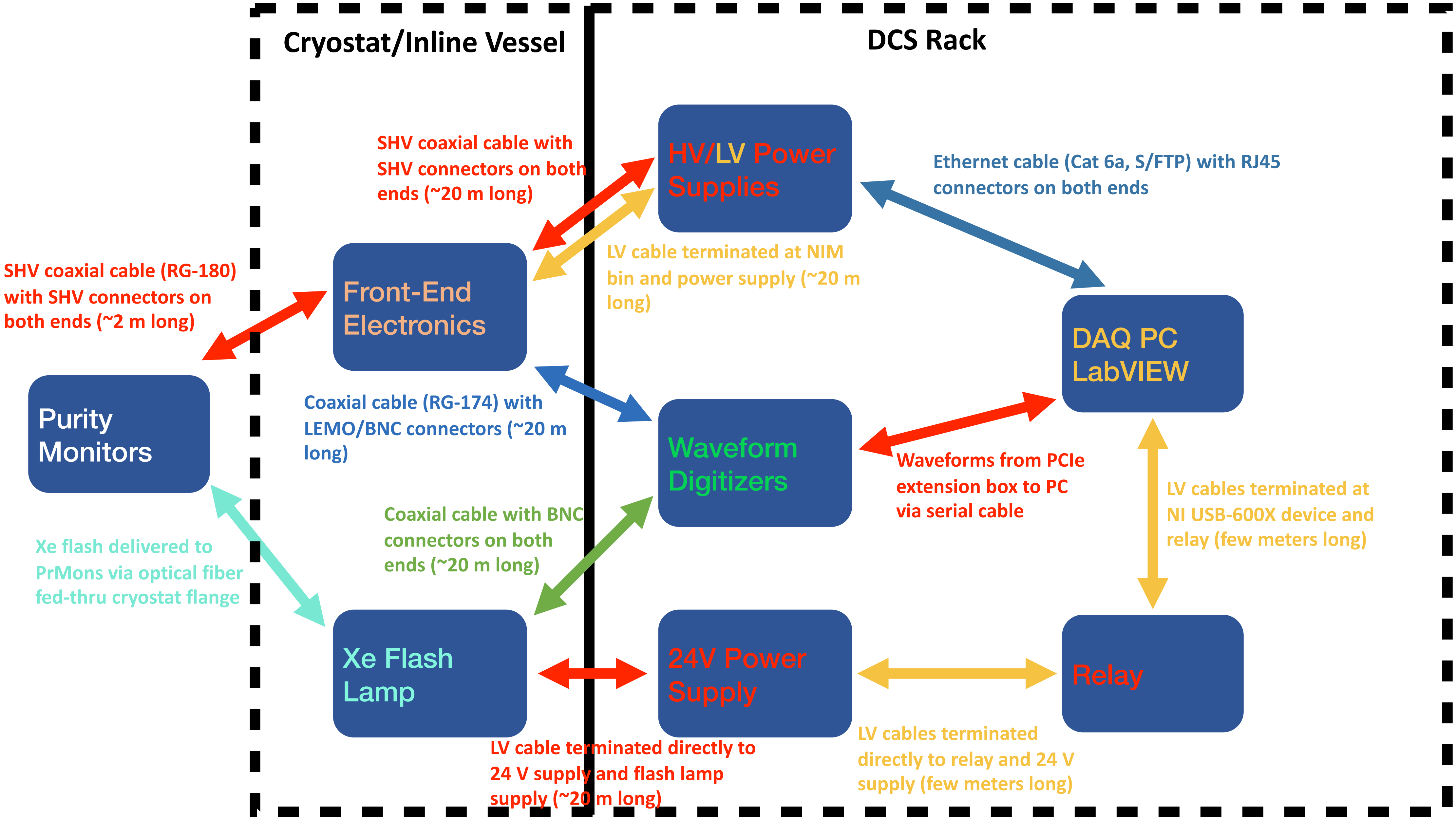
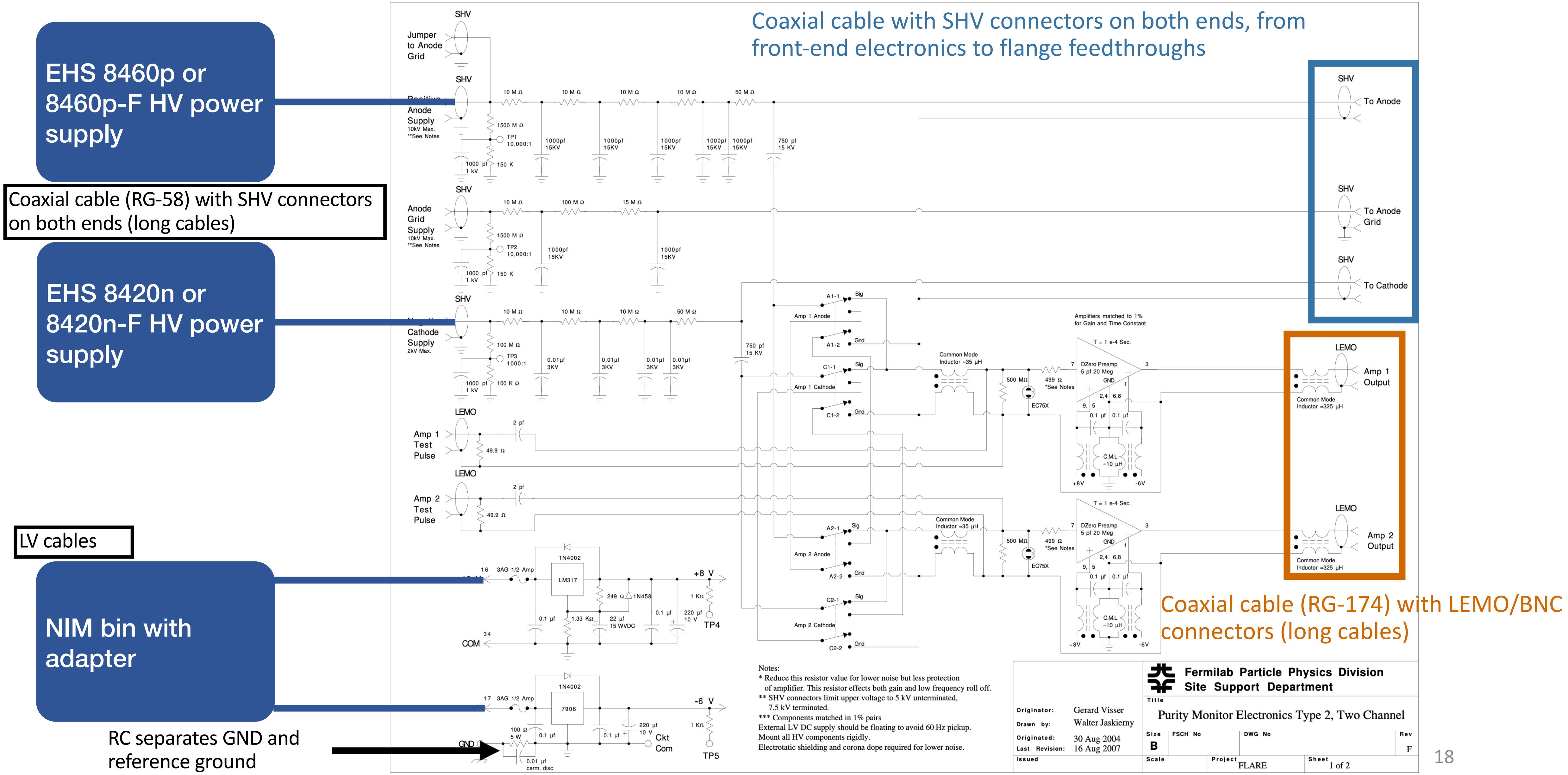


Diagram: Front-End Electronics



Front-End Electronics Photo

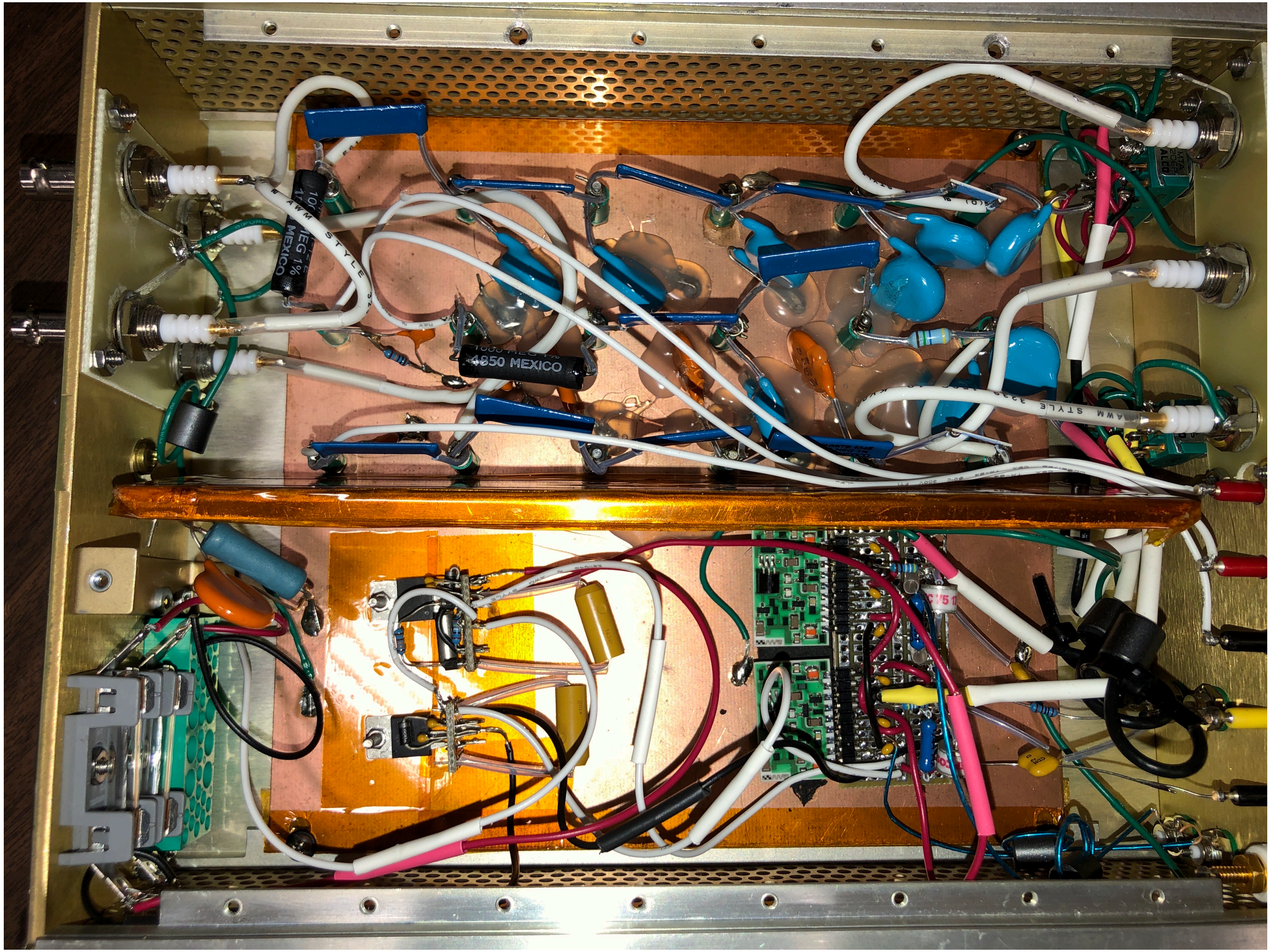
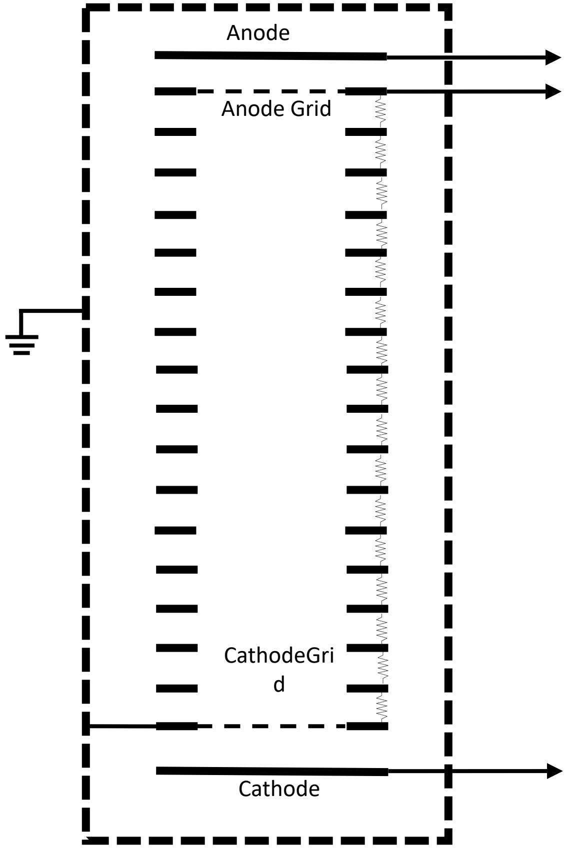


Diagram: Purity Monitor

Cable Ties to hold cables together, so the cables do not hang loosely in the cryostat

Connected to cryostat, Grounding details see Grounding Scheme



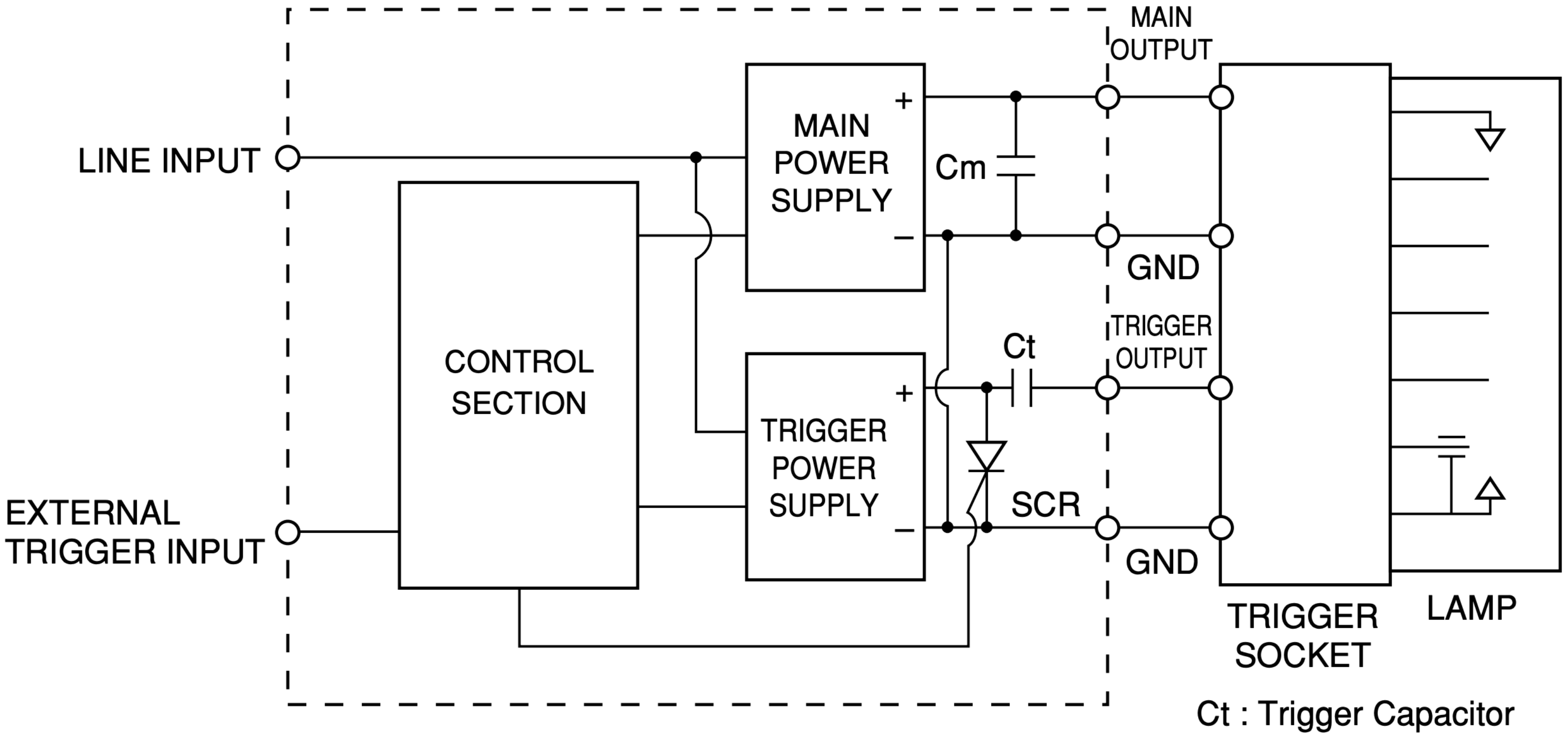
To separate SHV feedthrus (center pin)

Jaguar M17/95-RG180 Coaxial Cables used inside cryostat

To SHV feedthru (center pin)

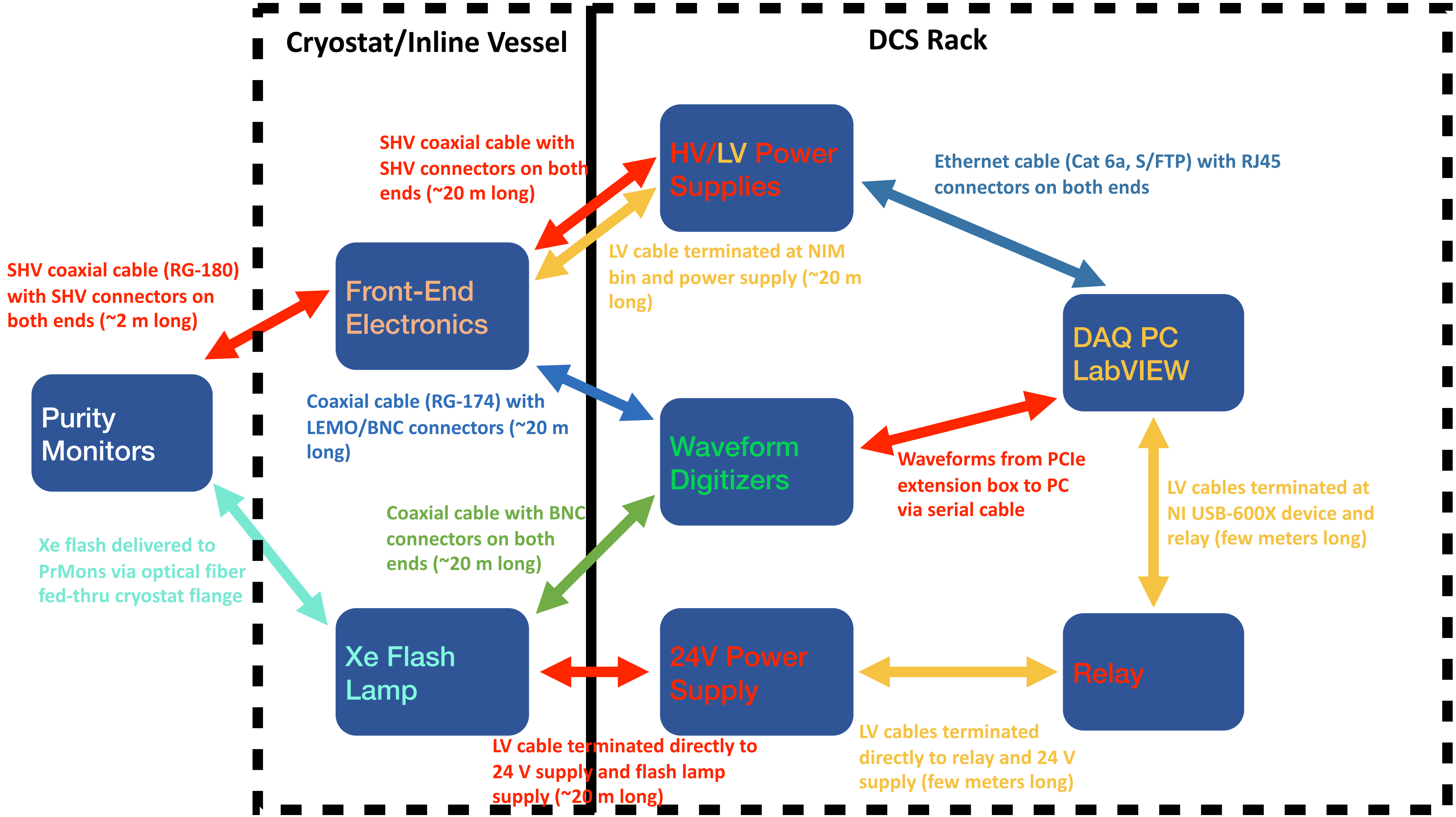
Diagram: Flash lamp system

- Flash lamp (L7684), Cooling jacket (E6611), Trigger socket (E6647), Discharge capacitor (E7289-02), Power supply (C6096-02)



Purity Monitor Specification of Electrical Cabling and Wiring Connections

Electrical Schematics: Cables



Cables and connectors

RG-58	Anode and Cathode HV	2	SHV	< 6 kV
RG-58	Anode grid HV jumper	1	SHV	< 6 kV
RG-174	Anode and Cathode Signal	2	LEMO to BNC	
RG-174	Trigger	1	BNC	
Wire	LV for FEE	4	42 pin NIM connector	+/- 12 V @ < 0.5 A
Wire	Xe flash lamp	3	Screw terminal at both ends	+24 V @ 3A
Cat6a S/FTP	Wiener MPOD mini-crate	1	RJ45	

Diagram: Front-End Electronics

EHS 8460p or 8460p-F HV power supply

Coaxial cable (RG-58) with SHV connectors on both ends (long cables)

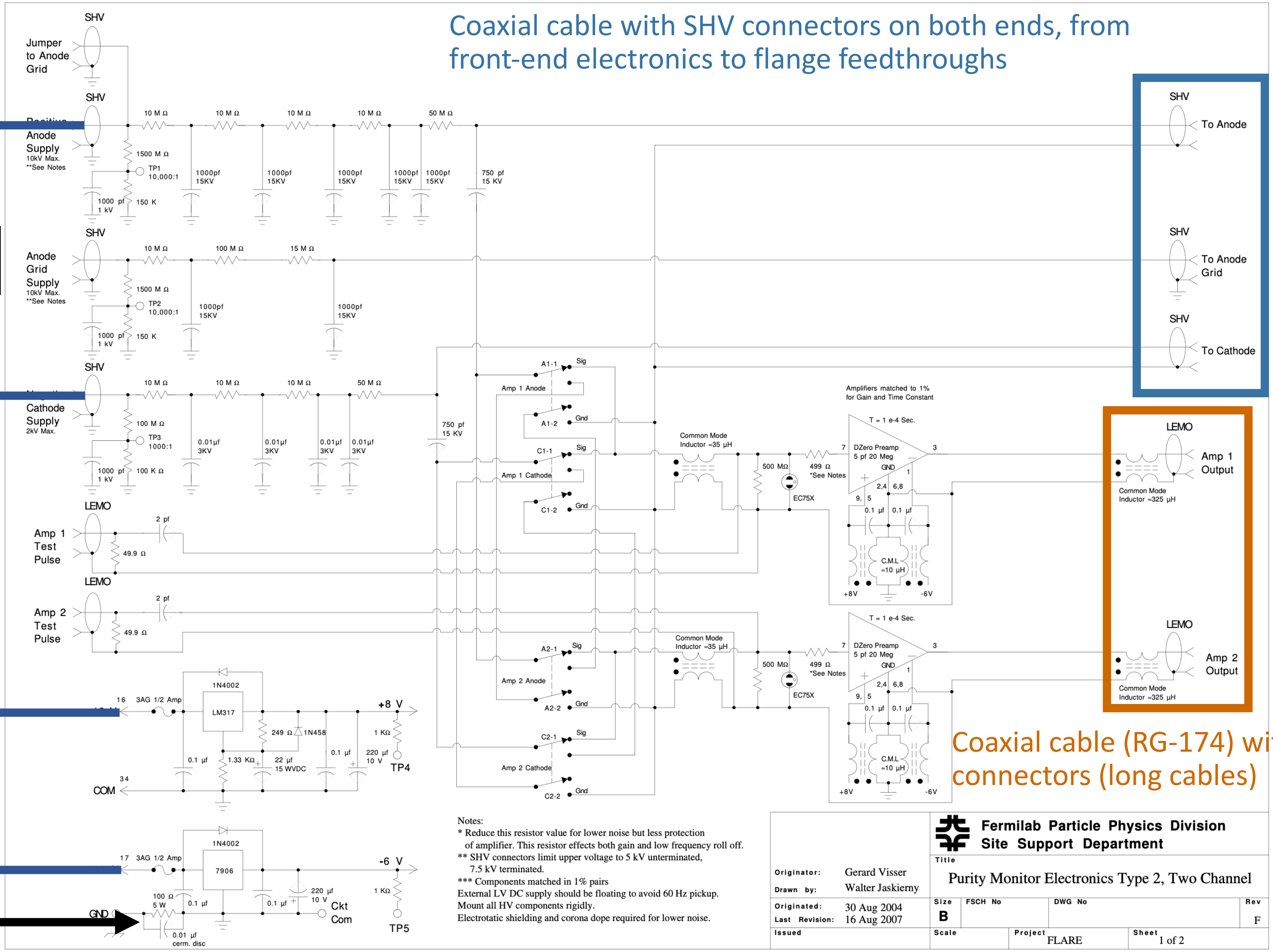
EHS 8420n or 8420n-F HV power supply

LV cables

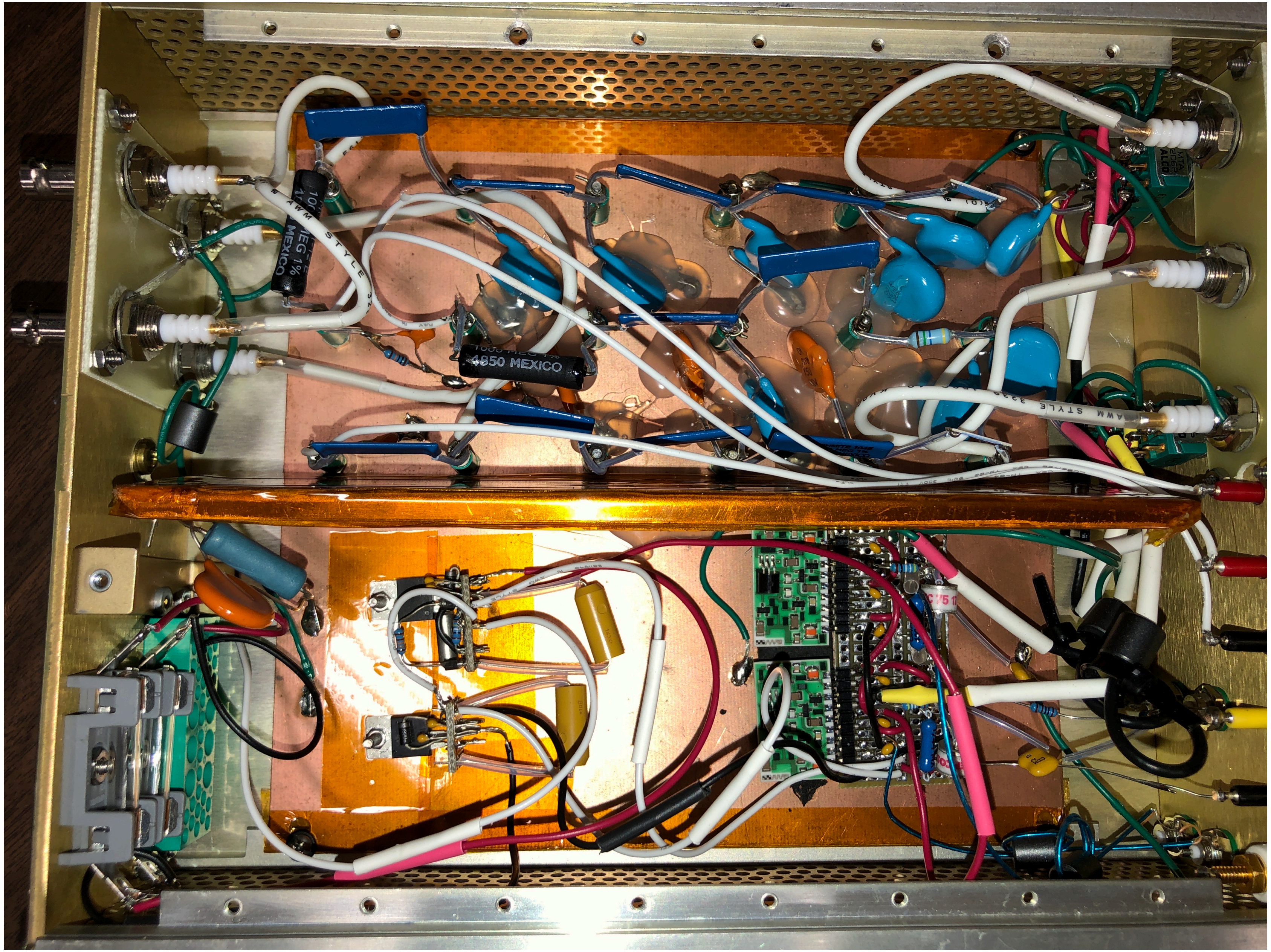
NIM bin with adapter

RC separates GND and reference ground

Coaxial cable with SHV connectors on both ends, from front-end electronics to flange feedthroughs



Coaxial cable (RG-174) with LEMO/BNC connectors (long cables)



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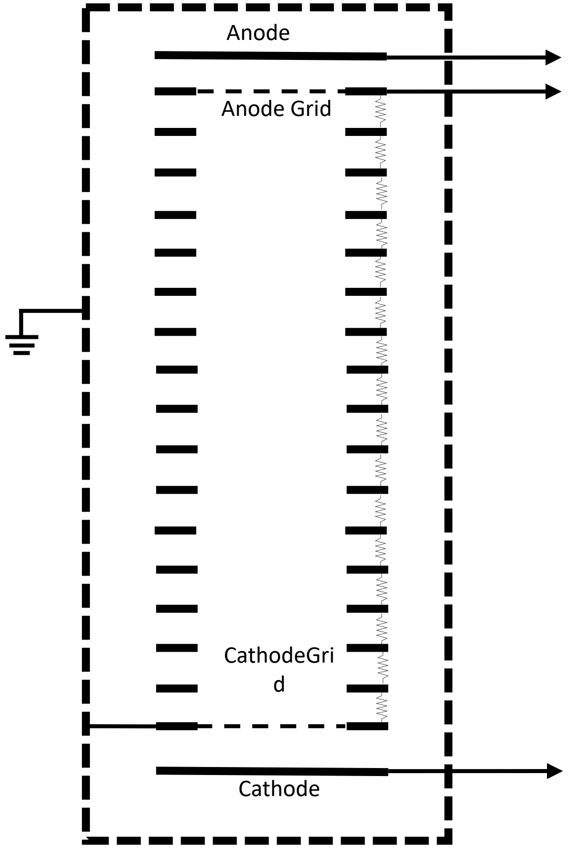


Connected to cryostat, Grounding details see Grounding Scheme

To separate SHV feedthrus (center pin)

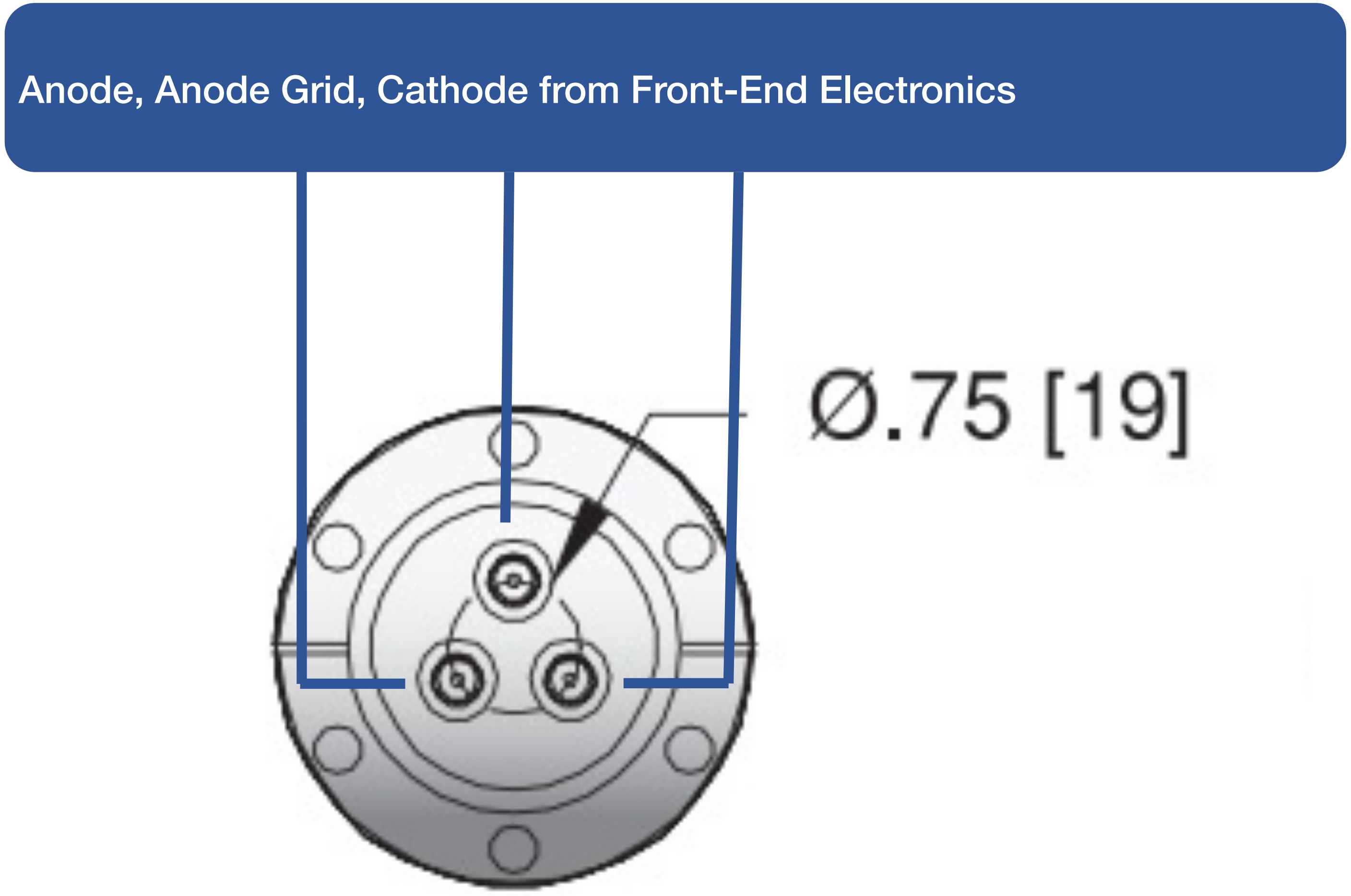
Jaguar M17/95-RG180 Coaxial Cables used inside cryostat

To SHV feedthru (center pin)

Cable Ties to hold cables together, so the cables do not hang loosely in the cryostat

HV Feedthrough

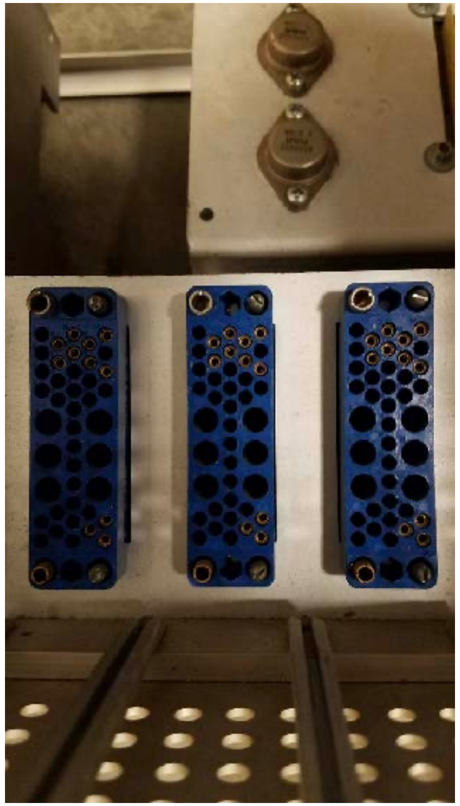
- Each PrM needs a SHV feedthrough with conflat flange (3 pins)



LV power supply cables to FEE

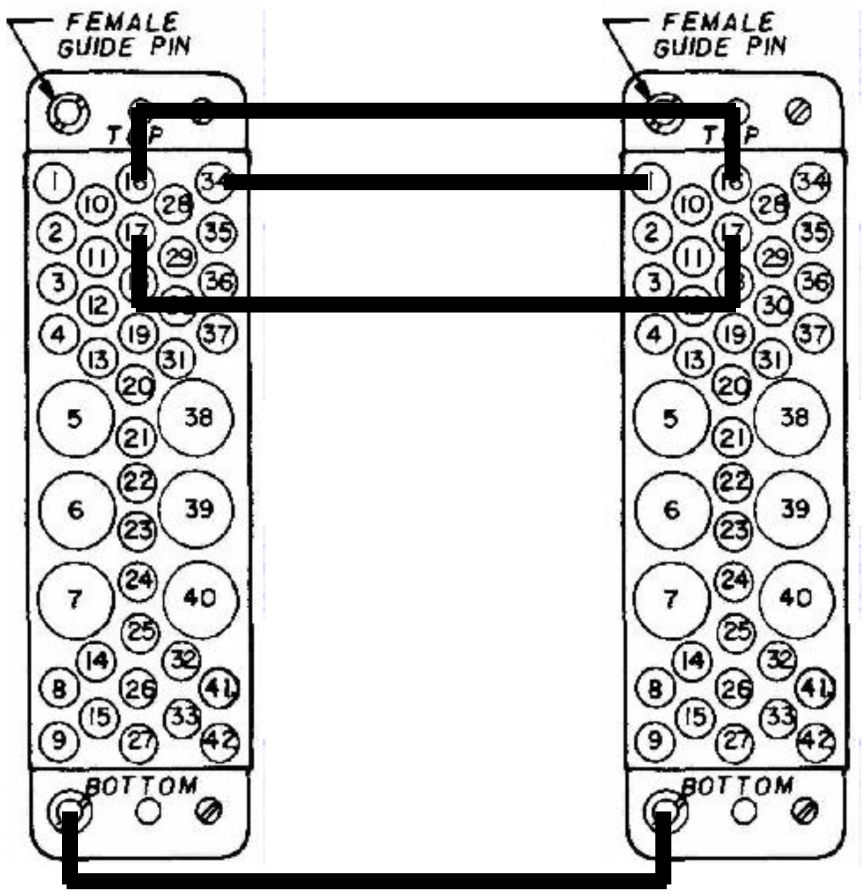
Back of FEE

NIM crate



Well Logging NIMS Bin (NIM Crate) Pinout			
Pin	**Description**	**Pin**	**Description**
1	Bell/Worth Temp. Interconnect	**22**	
2	Bell/Worth Bond Gate	**23**	
3		**24**	
4	Bell/Worth Scope	**25**	
5		**26**	
6		**27**	
7		**28**	+24 Volts (Not In All Bell Bins)
8	Voltage Control - 300 Volt P.S.	**29**	- 24 Volts (Not In All Bell Bins)
9	+300 Volts Downhole P.S.*	**30**	
10	+6 Volts / Non-Bell Bond Gate	**31**	
11	- 6 Volts (If Implemented)	**32**	
12		**33**	120 Vac Line Power "Hot"
13		**34**	Ground, Clean (Digital)**
14	- 300 Volts Downhole P.S.*	**35**	
15		**36**	Bell/Worth Scope Sync
16	+12 Volts (Always Present)	**37**	Bell/Worth Recorder
17	- 12 Volts (Always Present)	**38**	
18	Electrode #1	**39**	
19	Bell/Worth Scope Z Mod	**40**	RA Logging Line (Coax)
20	Electrode #2	**41**	120 Vac Line power "Neutral"
21	Electrode #3	**42**	Ground, Dirty (Signal)**

* ±250 or ±200 Volts in Comprobe bins.
**Pins 34 and 42 are usually connected together in logging bins.



Cables to relay and LV power supply

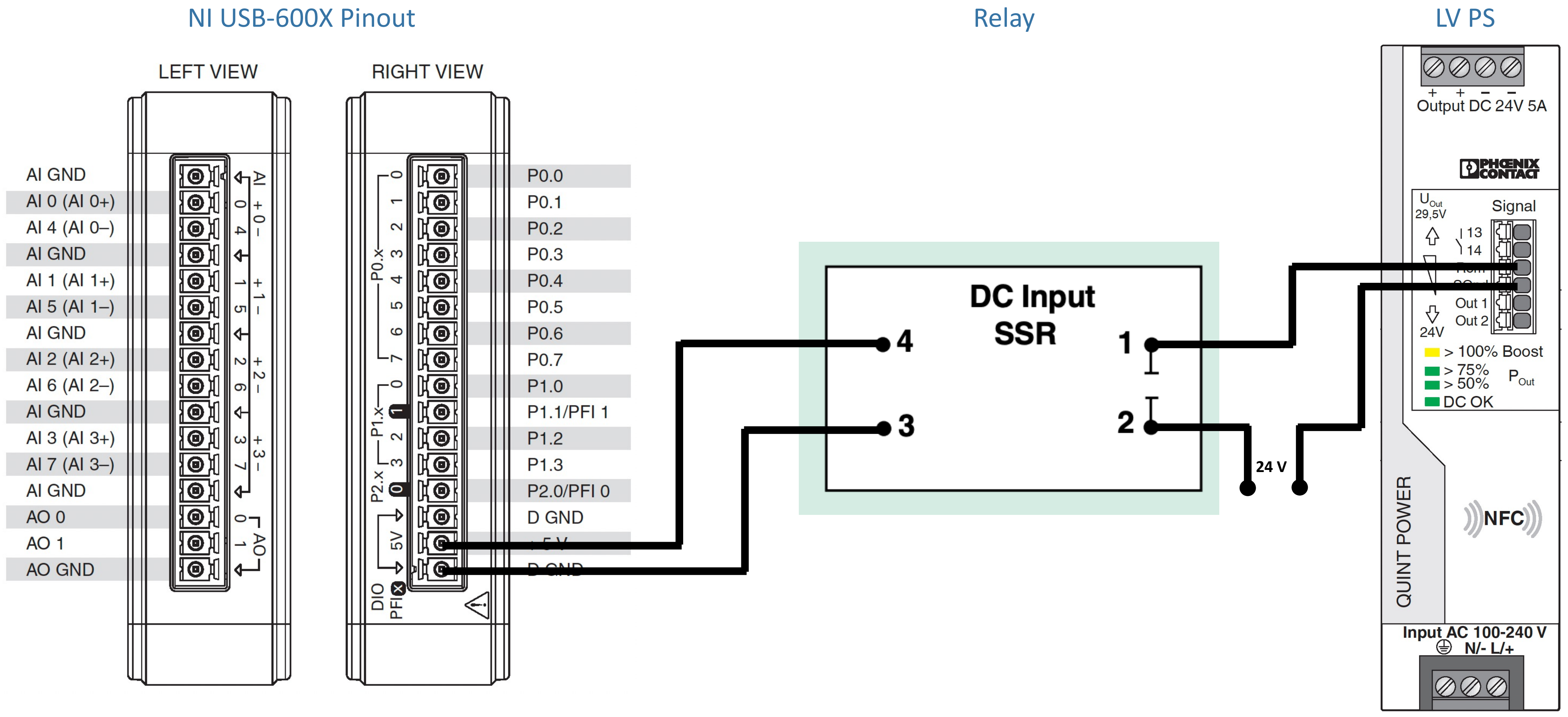
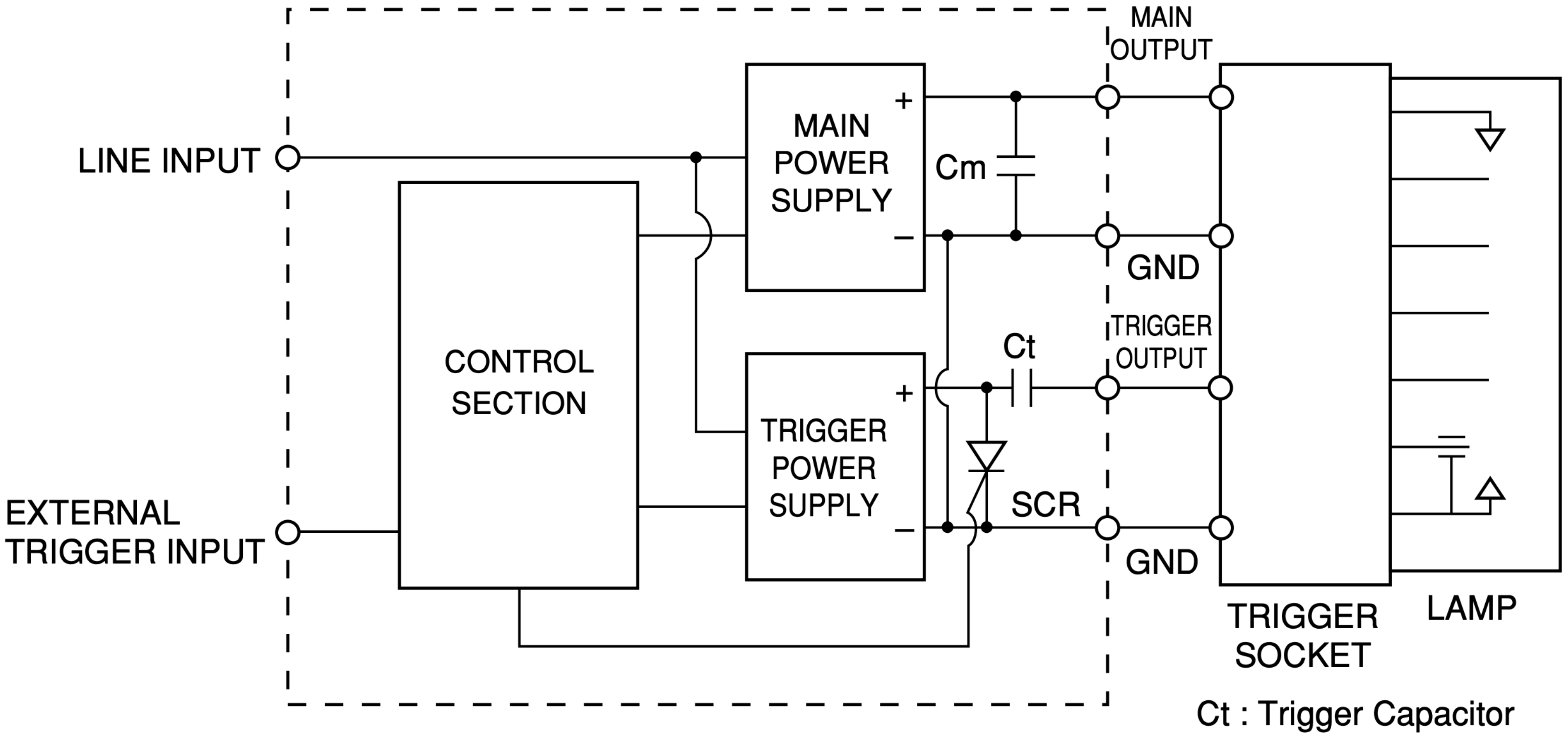


Diagram: Flash lamp system

- Flash lamp (L7684), Cooling jacket (E6611), Trigger socket (E6647), Discharge capacitor (E7289-02), Power supply (C6096-02)



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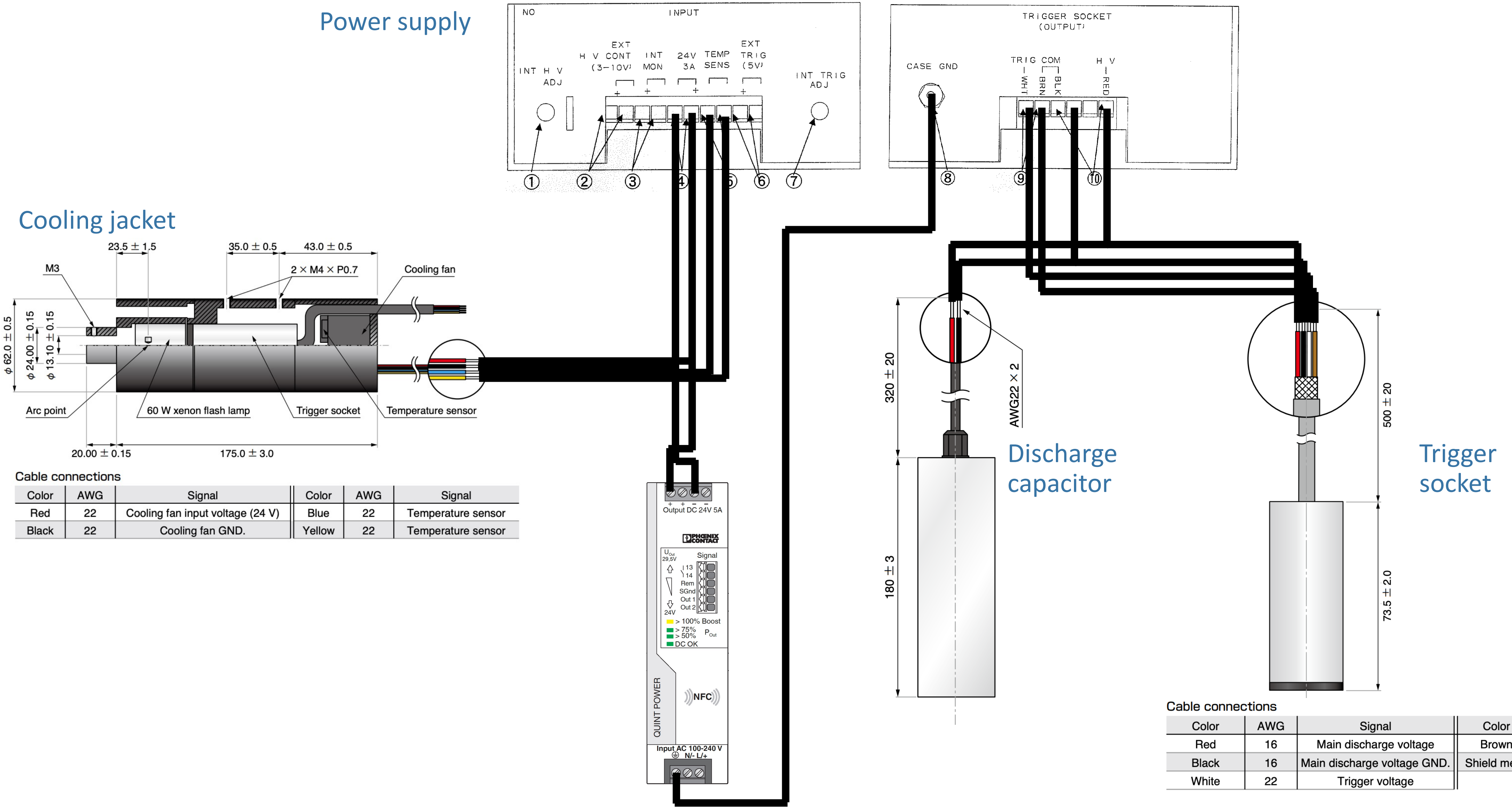


Cable connections

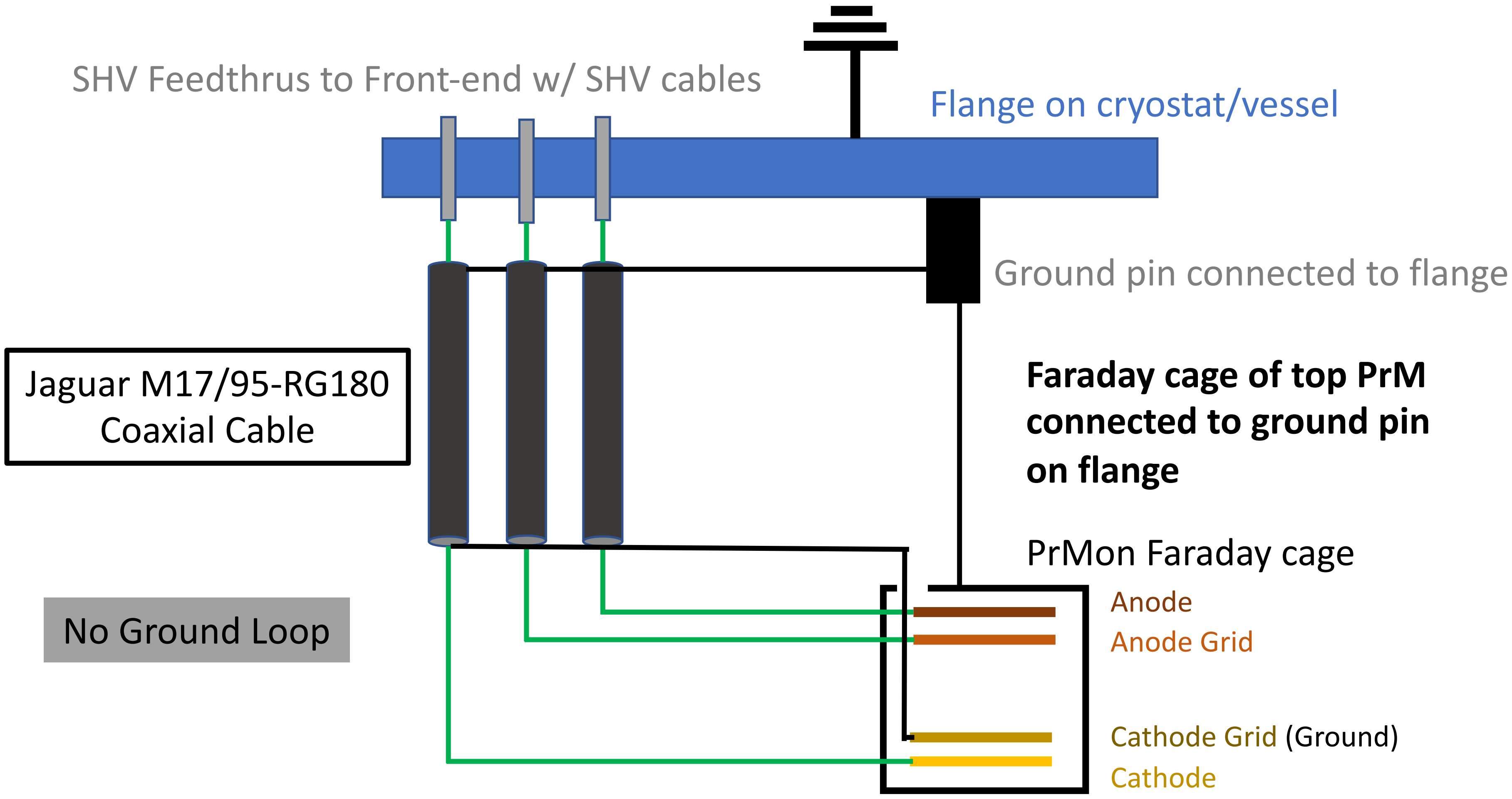
Color	AWG	Signal	Color	AWG	Signal
Red	22	Cooling fan input voltage (24 V)	Blue	22	Temperature sensor
Black	22	Cooling fan GND.	Yellow	22	Temperature sensor

Cable connections

Color	AWG	Signal	Color	AWG	Signal
Red	16	Main discharge voltage	Brown	22	Trigger GND.
Black	16	Main discharge voltage GND.	Shield mesh	—	Case GND.
White	22	Trigger voltage			

Grounding & Shielding Plan

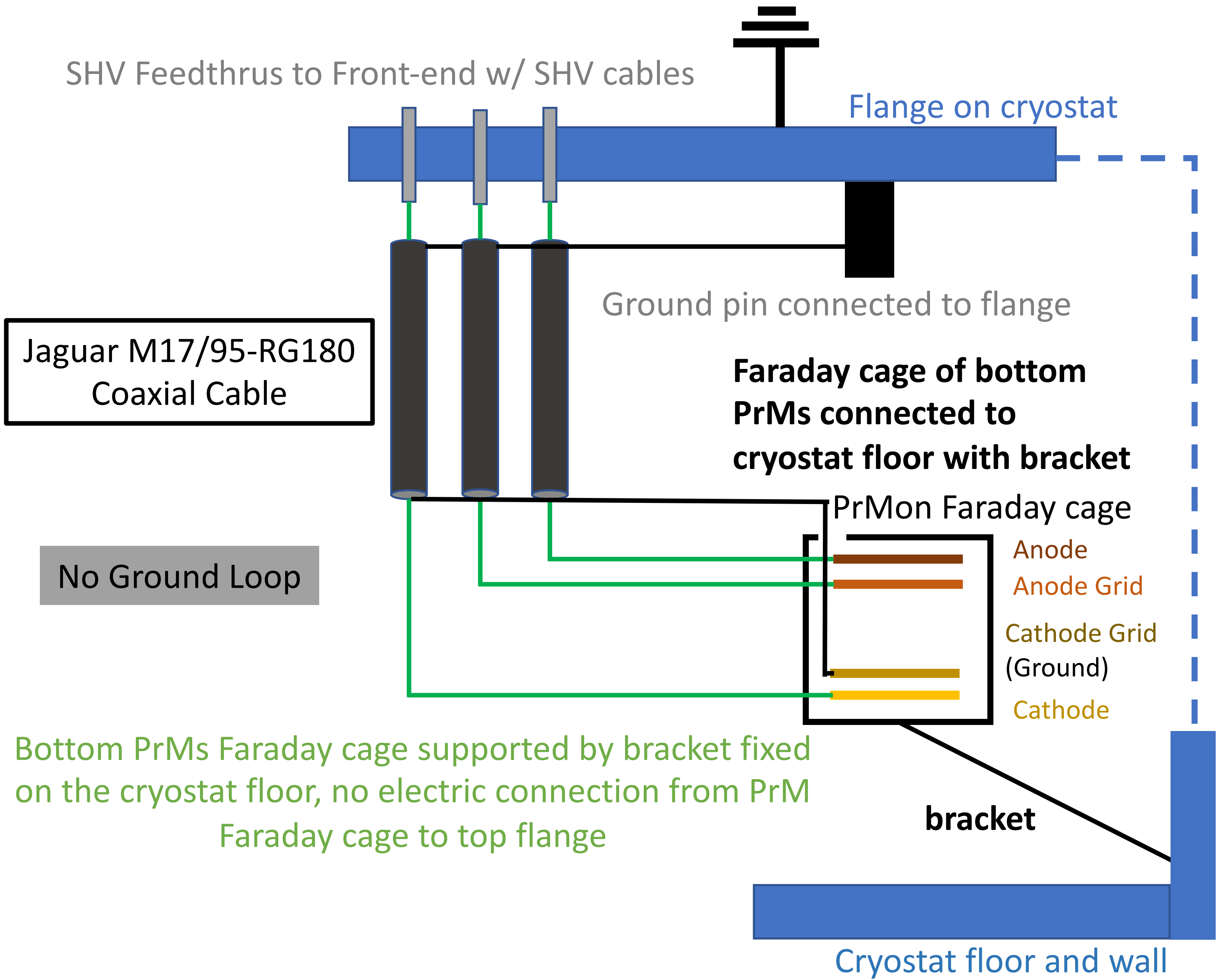
Grounding Scheme: top cryostat PrM and inline PrM



Top PrM Faraday cage hung from the top flange, no electric connection on floor

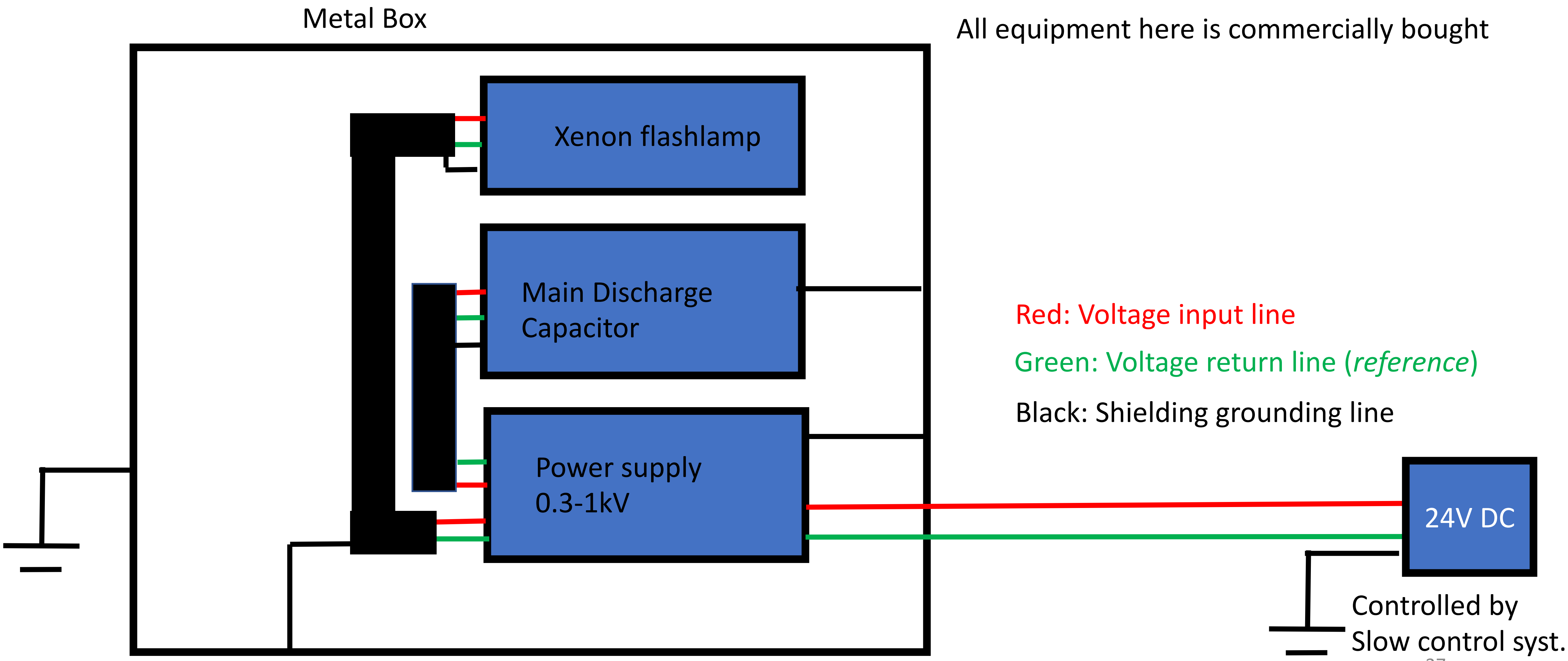
- Bias HV and anode/cathode signals fed-in and read-out through SHV feedthrus (3 for each PrMon)
- Coaxial cable inside cryostat/vessel, conductor connects feedthru pins to cathode, anode and anode grid
- Shield of cables connected to flange on feedthru side
- Other side of shield not connected anywhere
- Cathode grid connected to cryostat ground through cable shield

Grounding Scheme: bottom Cryostat PrM



- Bias HV and anode/cathode signals fed-in and read-out through SHV feedthrus (3 for each PrMon)
- Coaxial cable inside cryostat, conductor connects feedthru pins to cathode, anode and anode grid
- Shield of cables connected to flange on feedthru side
- Other side of shield not connected anywhere
- Cathode grid connected to cryostat ground through cable shield

Grounding Scheme: Flash Lamp



Installation and Qa/Qc (requirements see document)

- In the baseline design, each DUNE FD cryostat will deploy 4 purity monitors (2 standard and 2 long purity monitors). 2 purity monitors (1 long and 1 standard) will be installed on the east side in the same port at different heights (top, bottom, and the other 2 will be installed on the west side in the same way. On each side, the top purity monitor will be mounted to a 4-m stainless steel tube under the purity monitor top flange, and the bottom purity monitor will be fixed on the cryostat floor with a bracket.

Before shipping to SURF:

(1) Visual inspection of all electrical components for mechanical damage

(2) Visual inspection of all mechanical components for mechanical damage

(3) Test the mechanical strength of PrM field ring resistor soldering on lugs: there should not be any loose solder joints

(4) Test PrM HV feedthroughs in vacuum and argon gas: 4kV operation voltage should achieve

(5) Test PrM Electronic Box with function generator: pulse output signal observed

(6) Measure PrM field ring resistors at warm and cold (87 K): individual and total resistance should be consistent with nominal resistance values

(7) Test individual PrMs in vacuum and gas (a) in a dewar for cryostat PrMs (b) in the inline vessel for the inline PrM

Installation and Qa/Qc (requirements see document)

Test PrMs at SURF

(1) Measure PrM field ring resistors at warm and cold (87 K): individual and total resistance should be consistent with nominal resistance values

(2) Test individual PrMs in vacuum and gas in a dewar

(3) Mount cryostat purity monitors on the assembly. The top purity monitor will be mounted to the 4-m-long supporting tube under the PrM flange to be inserted in the cryostat. The bottom purity monitor will be attached under the top purity monitor with a short, temporary mounting tube. Cables and fibers will be connected to the top and bottom purity monitors to make electrical and optical connections.

(4) Test PrM electrical connections on the assembly

(5) Test PrM optical connection on the assembly

(6) Test PrMs on the assembly in vacuum (a) in a long tube for cryostat PrMs (b) in the inline vessel for the inline PrM

(7) After assembly tests (4), (5) and (6), fibers and cables will be disconnected from the bottom purity monitor

(8) During top PrM insersion, use a multimeter to test the electrical connection to feedthrough and top flange from the PrM cathode, anode, anode grid, and faraday cage.

(9) After the bottom purity monitor is installed, since the bottom purity monitor was disconnected and reconnected to the PrM flange, repeat electrical and optical connection tests (4) and (5).

Installation and Qa/Qc (requirements see document)

After the PrM top flange is closed:

(1) Test overall resistance and capacitance

- Use an electrometer (high resistance meter, ~1000V, 0.01fA, >10000M Ohm) to measure the over resistance between the cathode and anode/cathode and anode grid/anode and anode grid from outside connection points of PrM HV/signal feedthrough.
- Measure the capacitance of the various purity monitor connections from the outside of the vacuum vessel. This measurement is done directly at the PrM HV/signal feed through to reduce the number of variables and is a relative type of measurement. The cathode normally will show the greatest capacitance to ground (surface of the top flange), the Anode Grid next, and the Anode is expected to be the least. Typically the three readings should be within 20% of each other. If one get a large difference in one or more of the readings then something is disconnected or there is a broken wire internally in the purity monitor connections.