CI final design review
18/01/2023

Temperature Monitoring System

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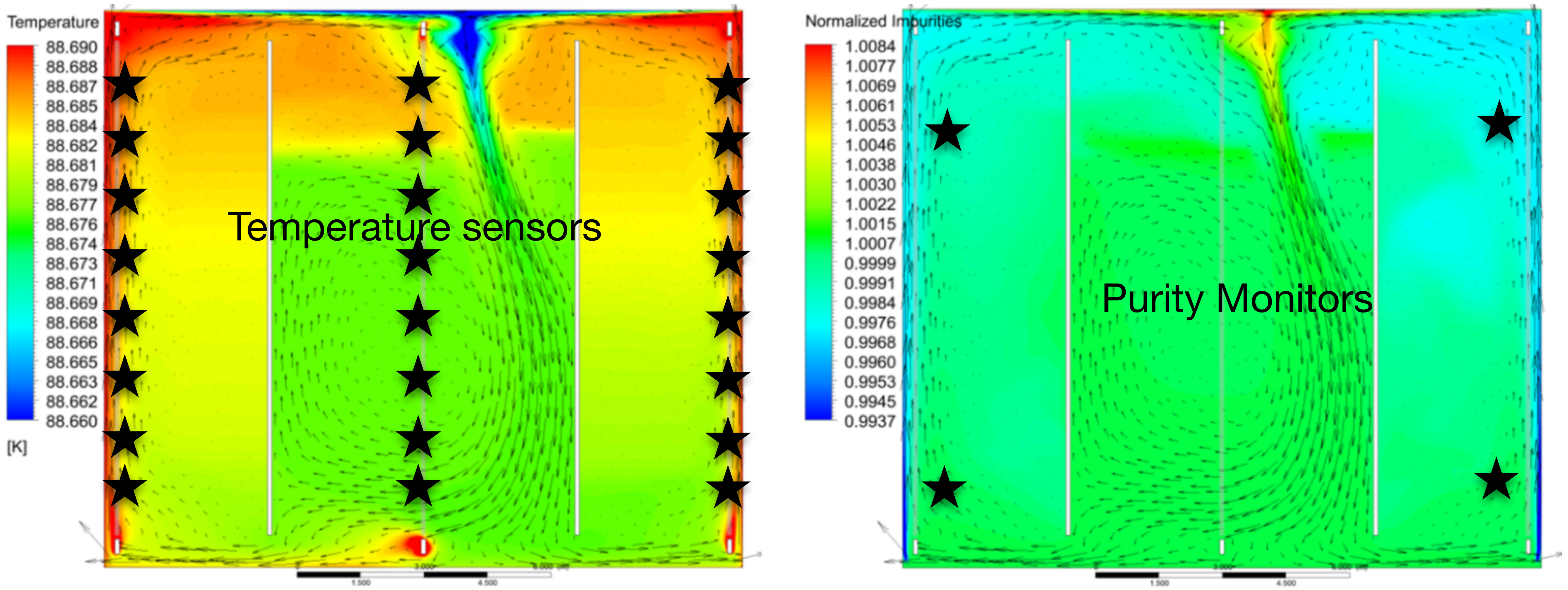
Motivation

- Purpose is twofold:
  - **Monitoring**: health of cryostat and LAr recirculation system, APA frame gradient during cool-down and filling.
  - **Calibration**: Predict electron lifetime everywhere in the cryostat using CFD simulations with input from temperature, purity, level and pressure

E. Voirin DUNE-doc-1046-v2



There is a clear correlation between temperature and purity

System design

EDMS documents

Design Documents:
https://edms.cern.ch/project/CERN-0000237151

1)Design Report: https://edms.cern.ch/document/2812057/1

2)Mechanical Models: https://edms.cern.ch/document/2811665/1

3)Mechanical Drawings: https://edms.cern.ch/document/2811661/1

4)Board Schematics and Layouts: https://edms.cern.ch/document/2813822/1

5)Board Bill of Materials (BOMs): https://edms.cern.ch/document/2812877/1

6)Grounding & Shielding Plan: https://edms.cern.ch/document/2811678/1

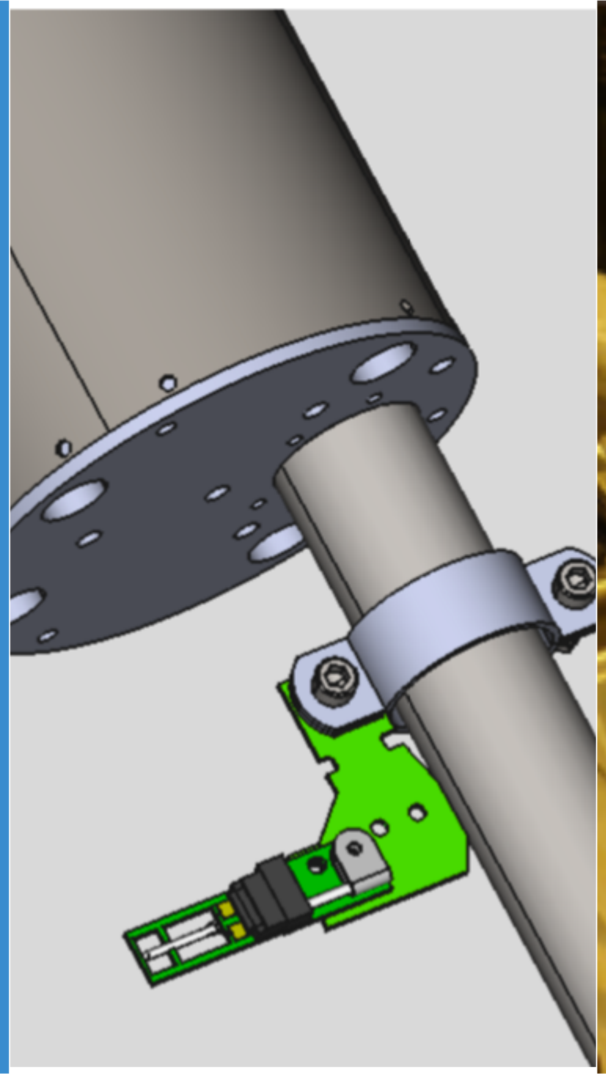
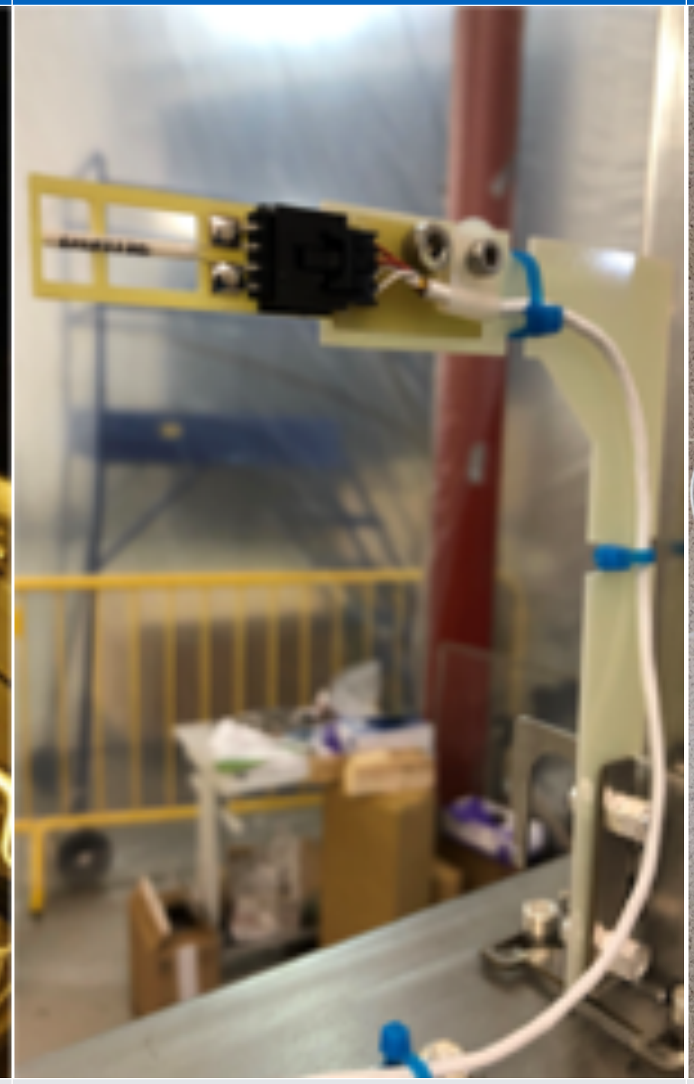
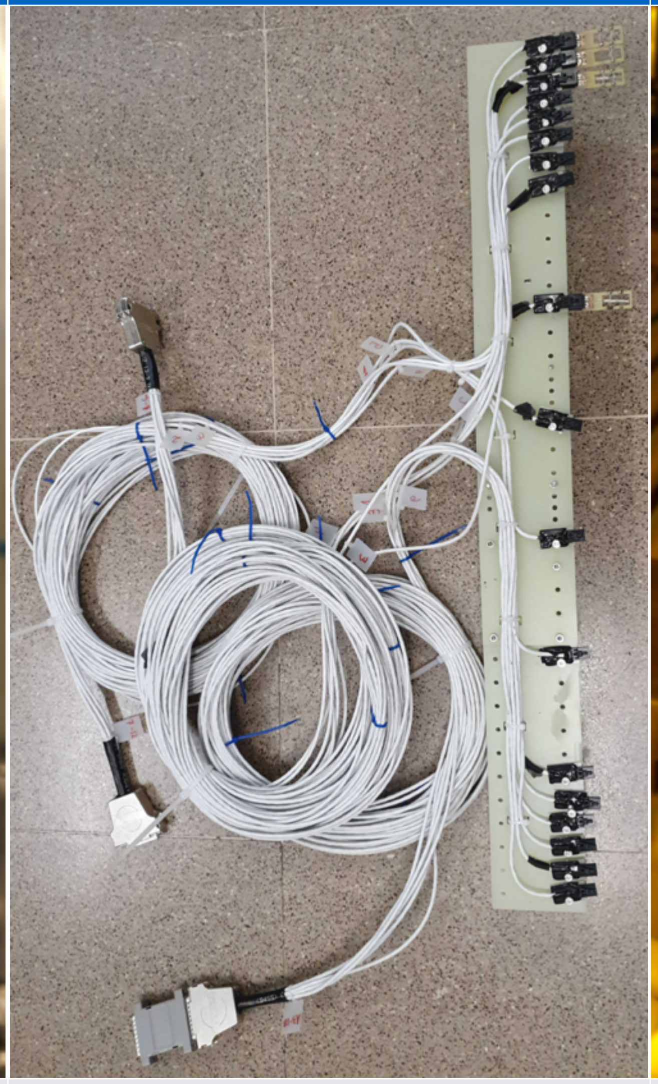
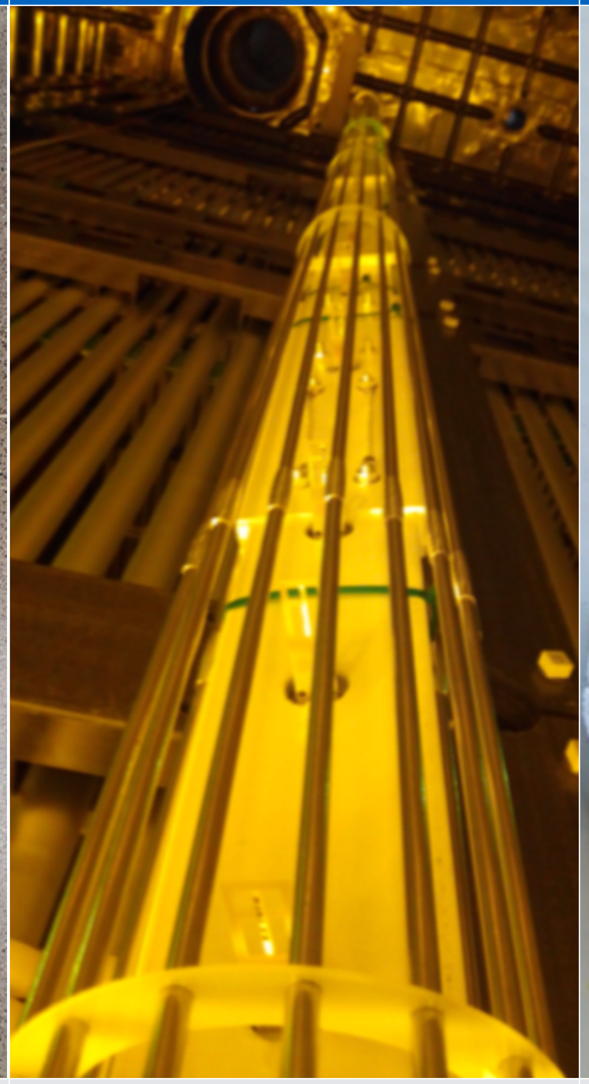
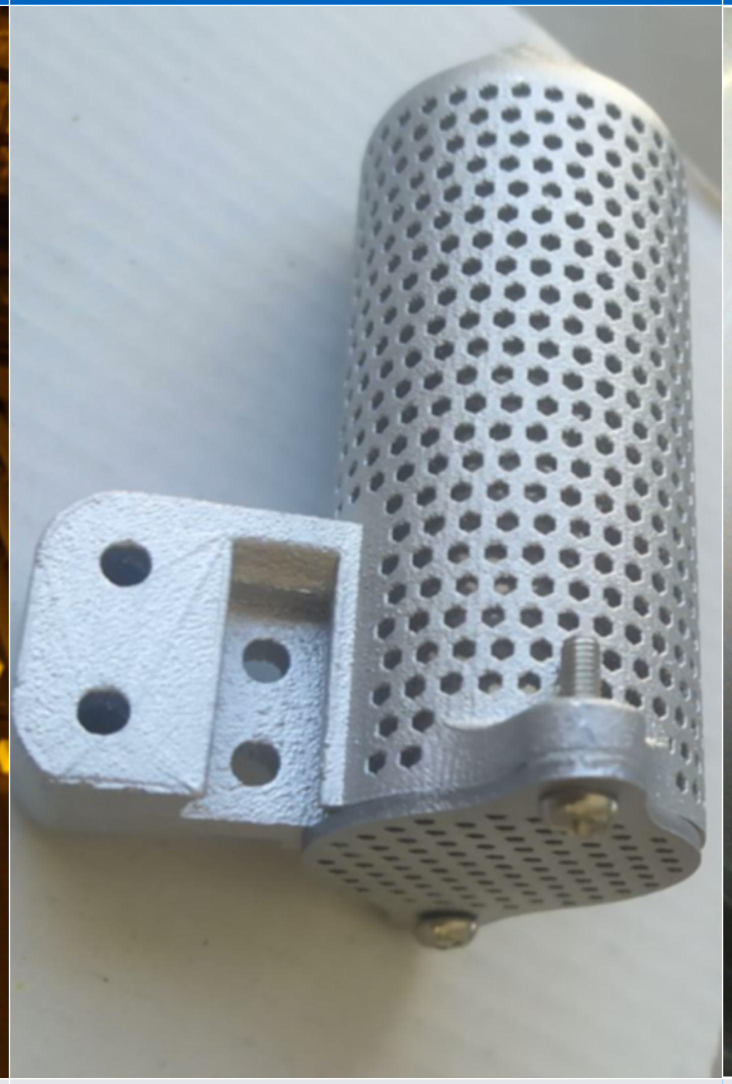
7)Specification of Electrical Connections: https://edms.cern.ch/document/2812051/1

8)Readout System Specification: https://edms.cern.ch/document/2813399/1

System description

- As described in the updated TDR section (EDMS 2812057) the TMS for DUNE FD1 has several subsystems.
- The main system are precision **RTDs on APAs** (450 sensors), which will monitor the temperature with mK precision near the active volume
- This is complemented by several other sets of precision RTDs located at singular locations (**LAr inlets, LAr pumps, Purity Monitors,** 32 sensors)
- Standard RTDs will monitor the vertical gradient on the **membrane wall** (26 sensors) and the **APA frames** (150 sensors) during cool-down and filling
- Finally, a mixture of precision and standard RTDs will monitor the vertical gradient on the gas phase and its proximities (swallow depth in LAr) with the so-called **gas arrays** (10 arrays with 18 RTDs each)

System description

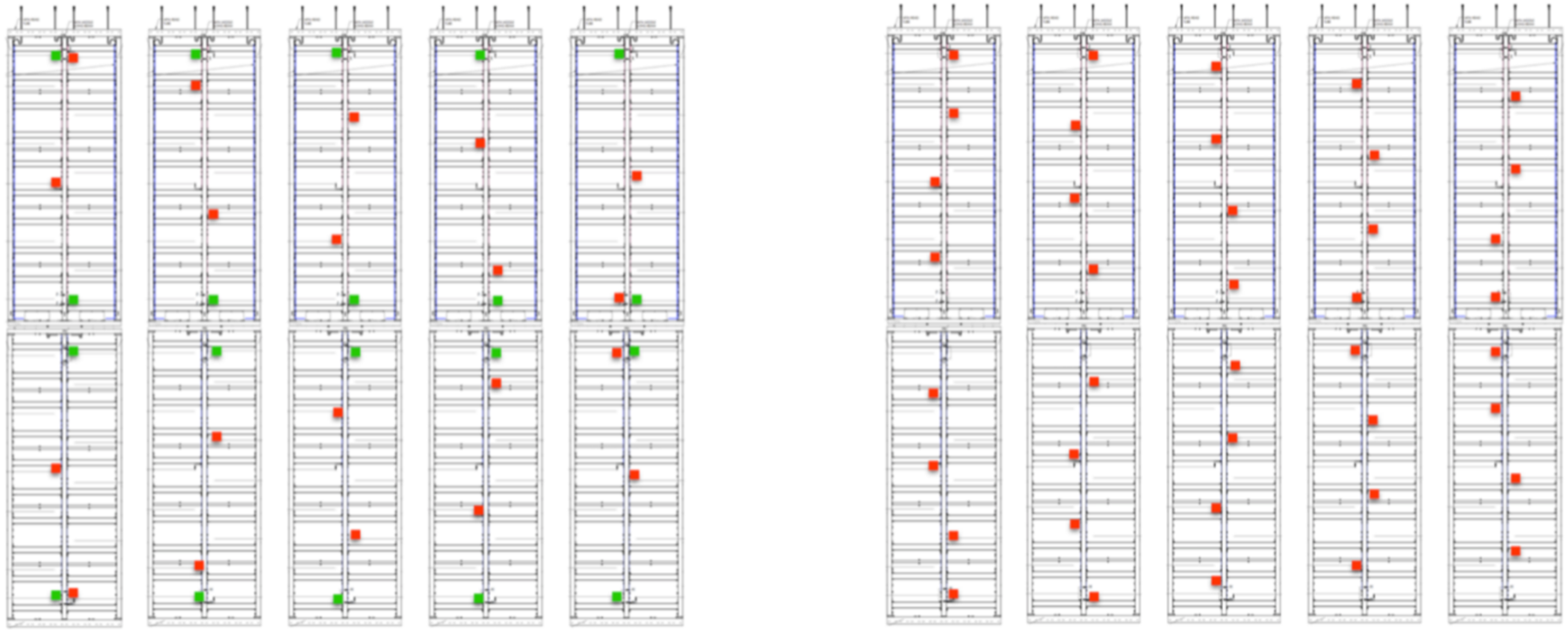
	Purity Monitors	LAr Inlets + Pipes	APAs	ullage	T-Gradients	pumps	wall
							
PD-HD	6	4+8	16	36	48+24*	2	5
PD-VD	Under discussion, mainly monitoring, minimal calibration with CFD						
FD1	12	16+0	600	180	0	8	26
FD2	12	16+0	Fibers instead	180	0	8	26

APA configurations

- Each APA has 4 sensors: 600 in total
- 20 possible configurations:
  - 2 (A or B) x 2 (upper or lower) x 5 (possible locations)
  - Half APAs will be of type A and half of type B (450 LAr and 150 frame)

Type A: 2 frame + 2 LAr

Type B: 4 LAr

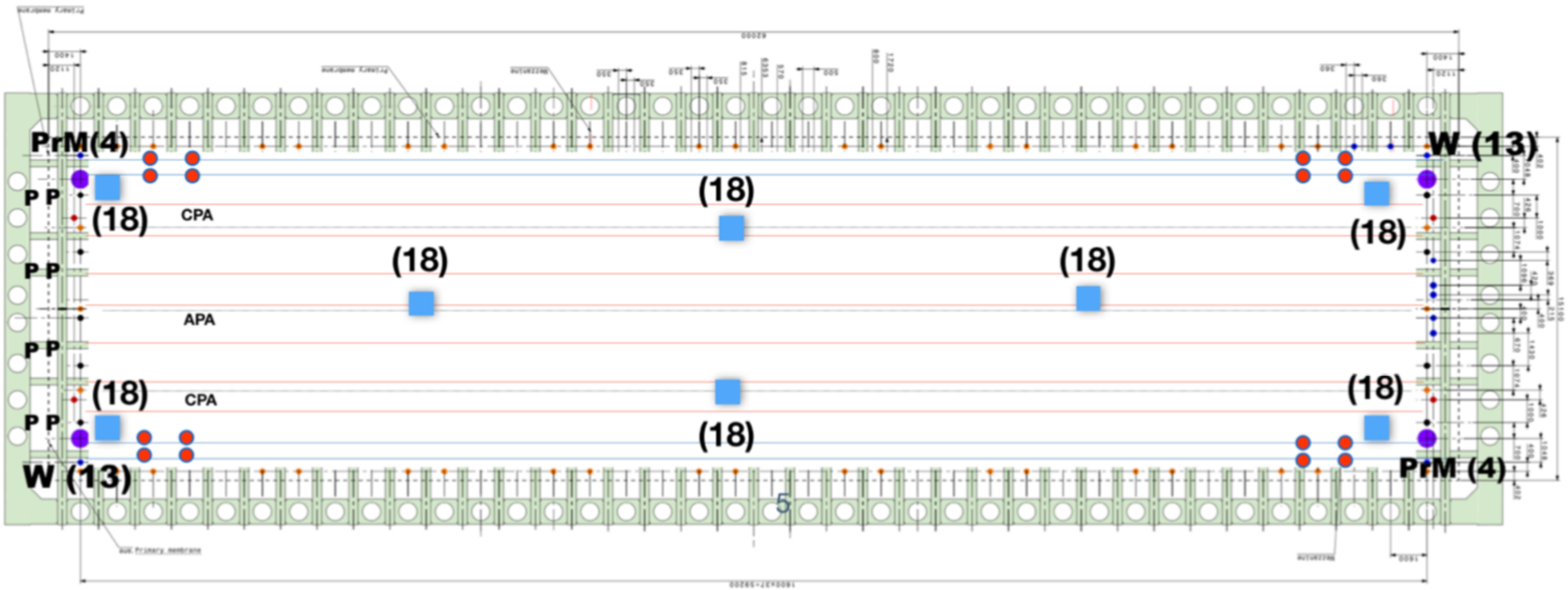


■ frame sensor
■ LAr sensor

Non-APA sensors

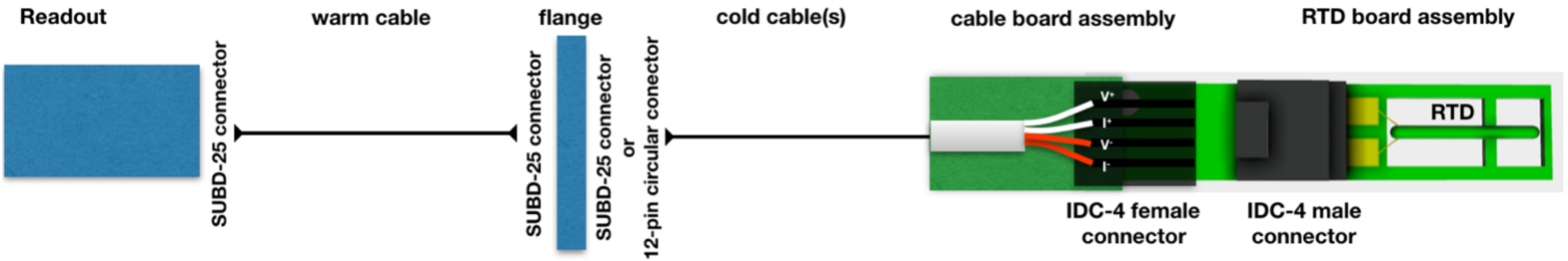
- This is the distribution on non-APA sensors

Inlet sensor
Gas array (18 sensors in each array)
P pump sensor
W Wall sensors (13 sensors in each array)
PrM PrM sensors (4 units in each array)



System components I

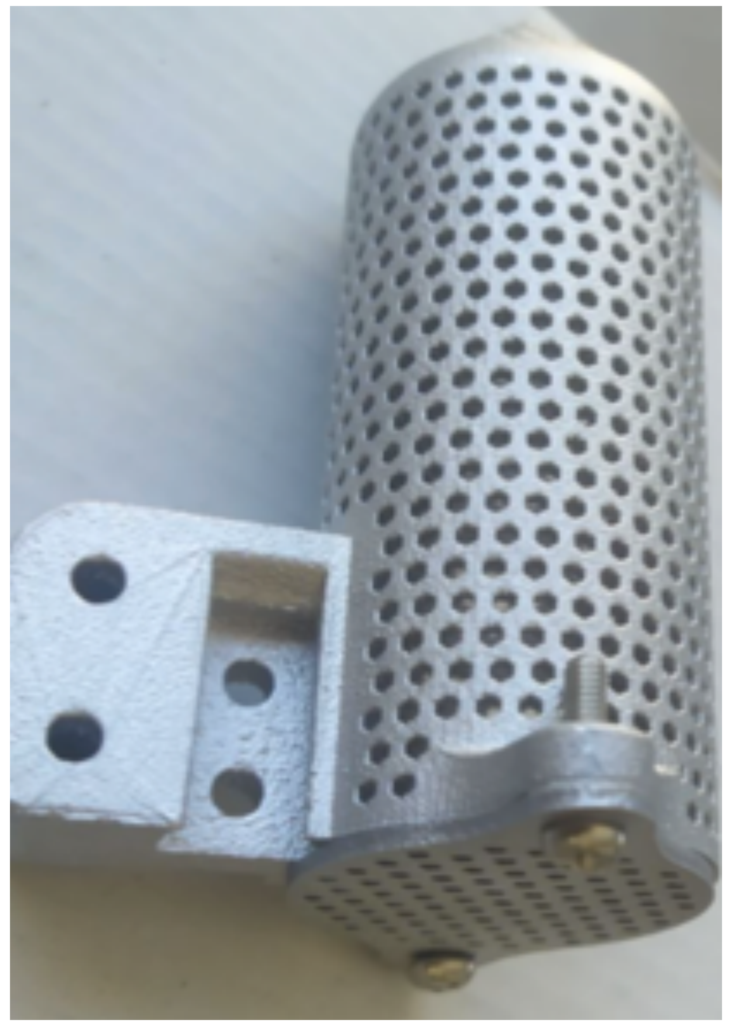
- Common to all subsystems:
  - **RTDs**: precision (Lakeshore PT103) and standard (RS PRO)
  - **Connectors on sensor side**: IDC-4 (Molex)
  - **Cold Cables**: Tempsens 4-twisted wire, with EMC shielding and teflon jacket
  - **Warm Cables (24 wires) and connectors (SUBD-25**): standard at CERN
  - **Readout**: CERN custom made multiplexing card + NI modules (ADC, FPGA, Controller)



System components II

- Anchoring mechanism:
  - Different for each subsystem
- Connectors on cold flange side:
  - **APA sensors**: Hirose circular 12-pin connector (same as PDS)
  - **non-APA sensors**: SUBD-25
- Intermediate connectors:
  - **APA sensors**: Hirose circular 12-pin connector (same as PDS)
  - **non-APA sensors**: none
- Sensor capsule:
  - only for pump sensors

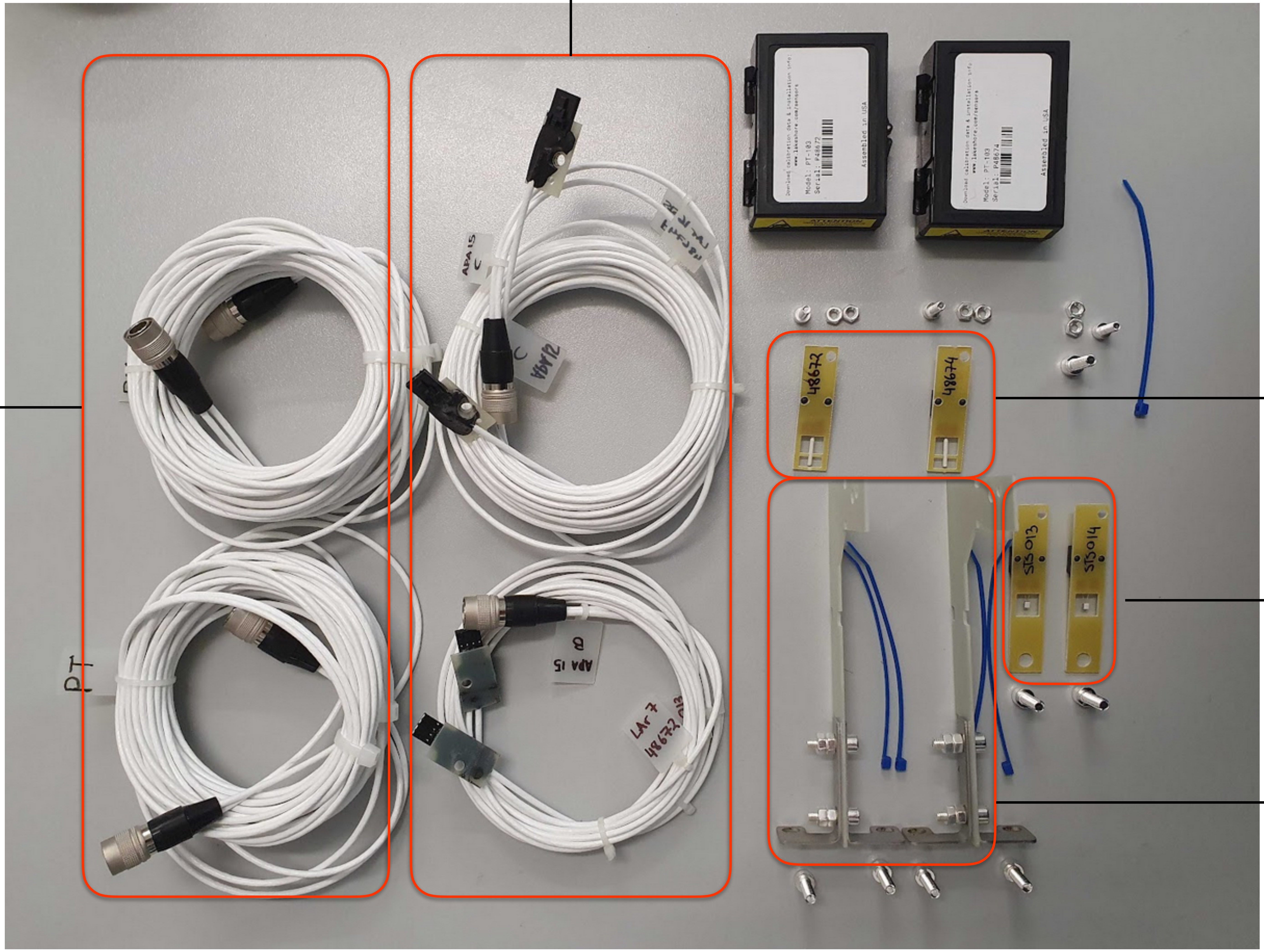
pump sensor capsule



APA sensors hardware

RTD cables
One circular connector for 2 RTDs

passthrough cables
(Installed in upper APA
to readout lower APA in the
same doublet)



Precision RTDs (LAr)

Standard RTDs (frame)

Support for LAr sensors

Grounding

- Follow recommendations from this engineering note in DocDB#1953 and https://edms.cern.ch/document/2811678/1

Engineering Note

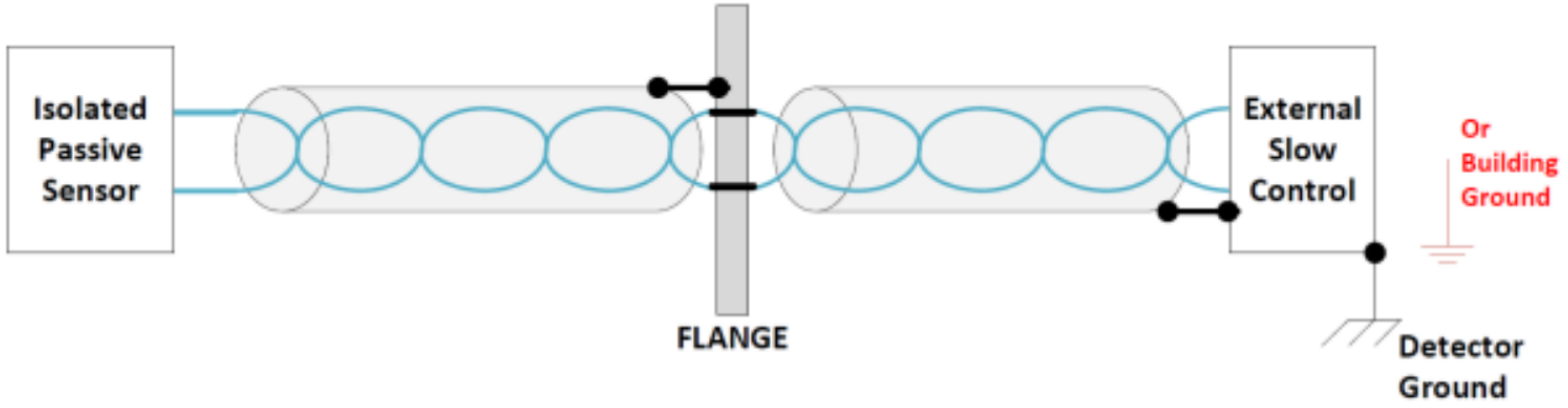
Date: 11.21.16
Rev Date:

Project: ProtoDUNE
Doc. No: DUNE DocDB#1953, SBN DocDB#1431
Team: L. Bagby, T. Shaw

Subject: ProtoDUNE/SBND Detector Sensor Guidance

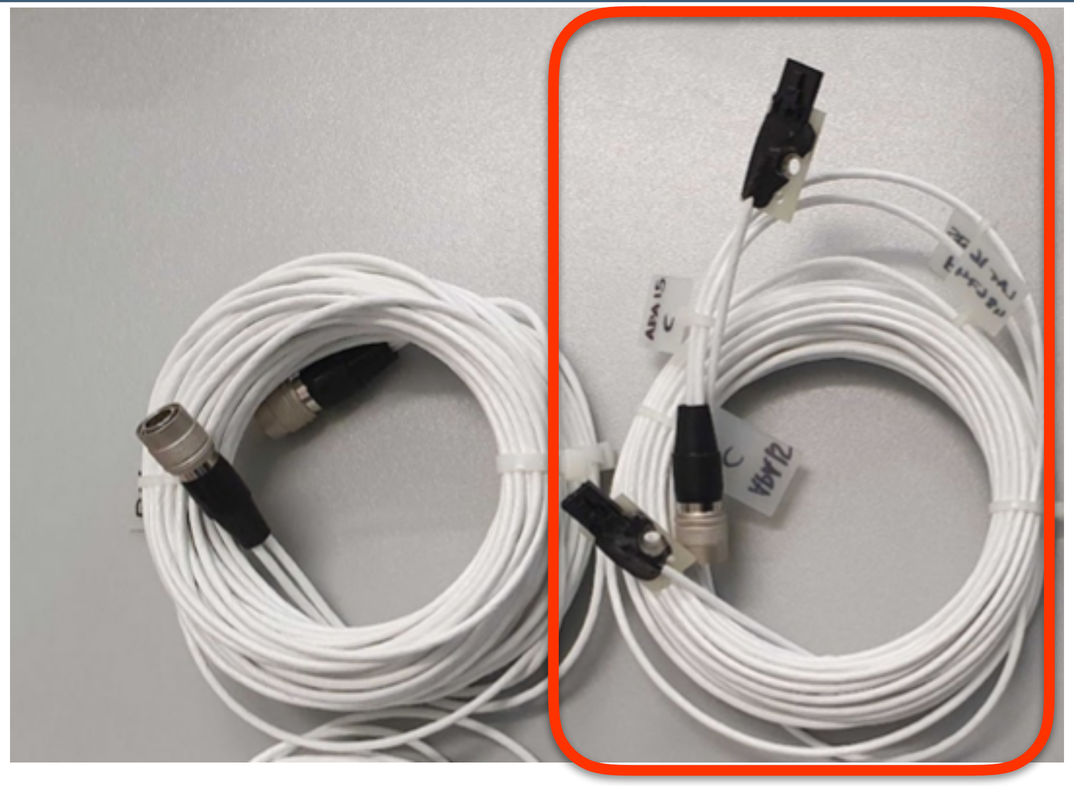
Grounding Points

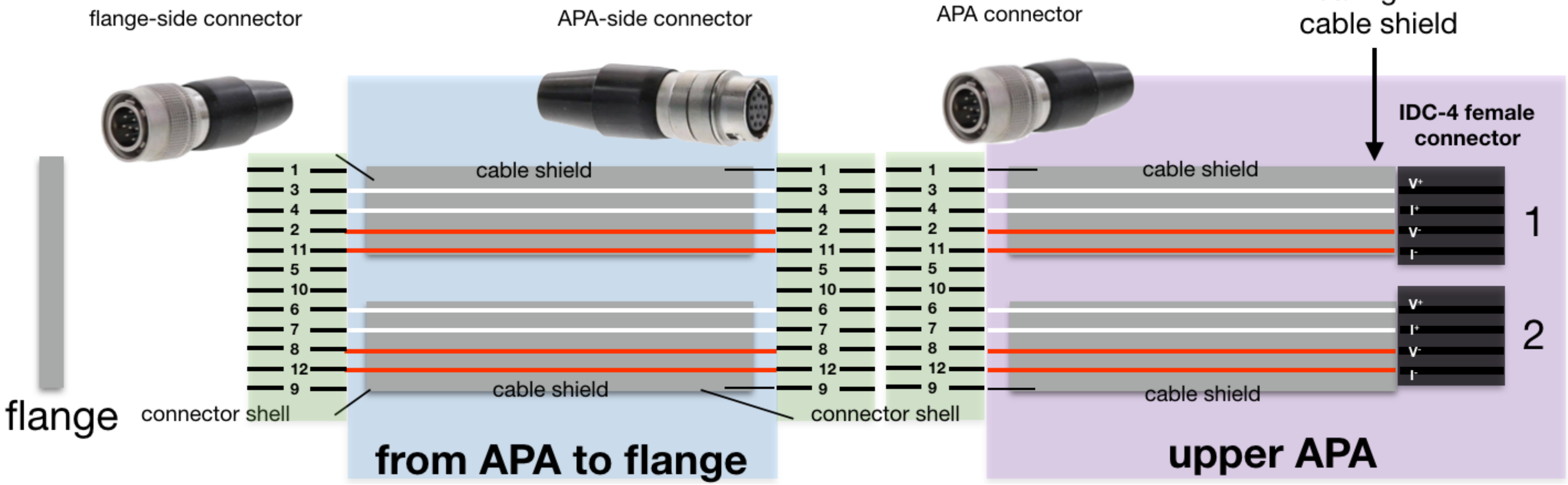
1. Cabling
   a. Twisted pair cables should be used to bring signals into and out of the cryostate. The shield of the external cables should be terminated at the signal conditioning electronics crate. It is recommended that the internal cable's shield should be terminated on the inside of the cryost.
2. Passive elements
   a. RTD elements should be affixed within the cryostat such that neither terminal touch the detector or membrane wall. Two, three, or four wire devices may be used. All leads enter the cryostat on individual pins.



Cables for APA sensors: upper APA

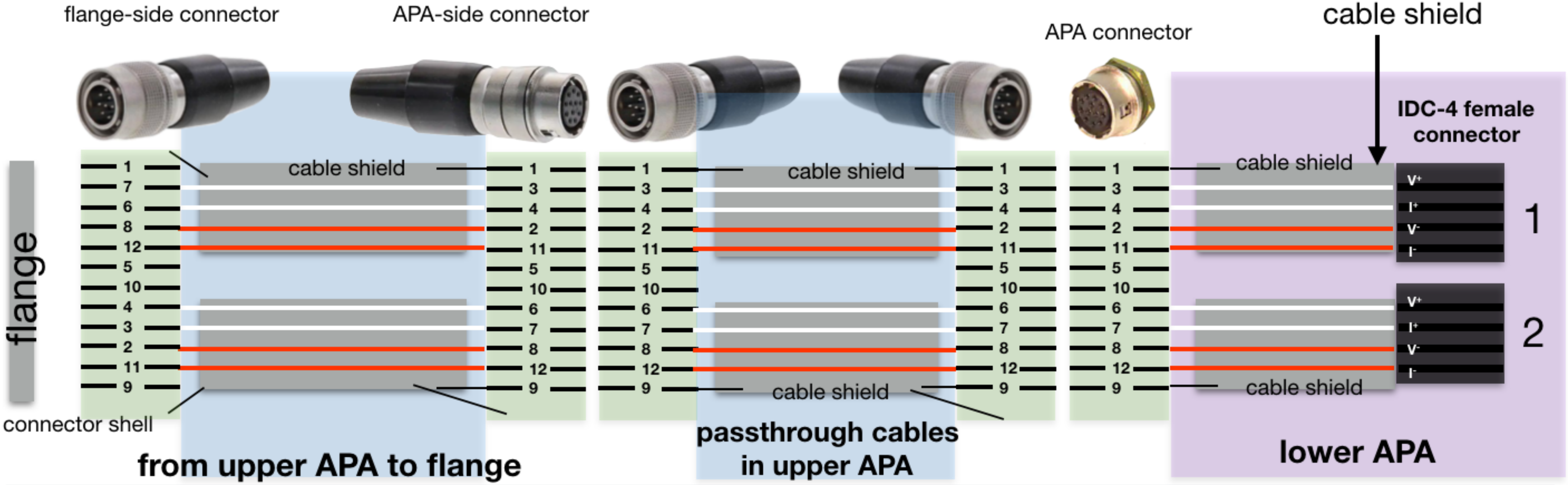
- Cable shields grounded independently down to the flange using pins 1 and 9 in circular connectors





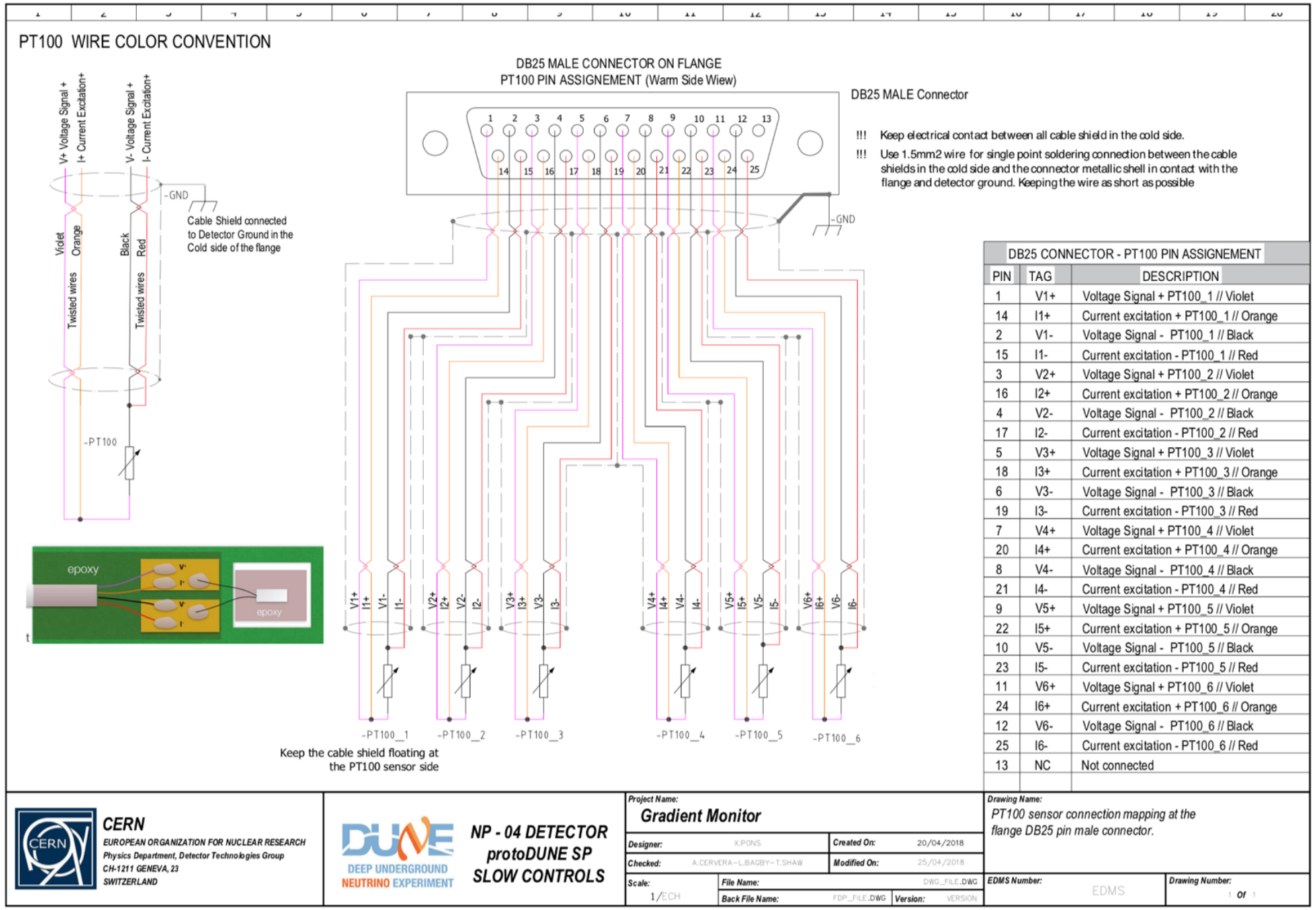
Cables for APA sensors: lower APA

passthrough cable sent with upper set



Cables for no-APA sensors

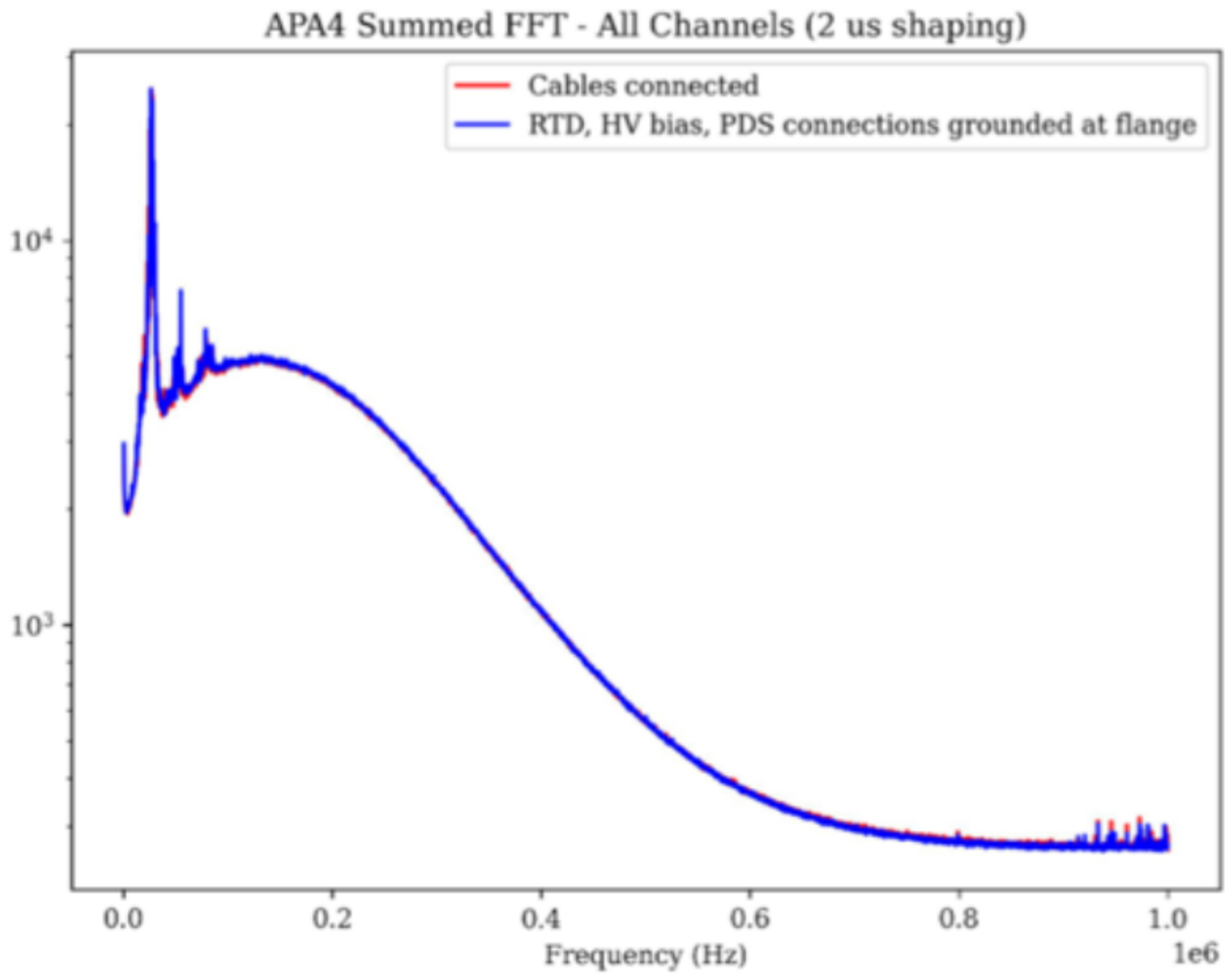
- This document shows the wire layout and grounding scheme for non-APA sensors
- 6 RTDs are connected to a SUBD-25 female connector
- Each sensor uses 4 wires
- Grounding:
  - Cable shield connected to SUBD-25 connector shell
  - Cable shield floating at sensor side

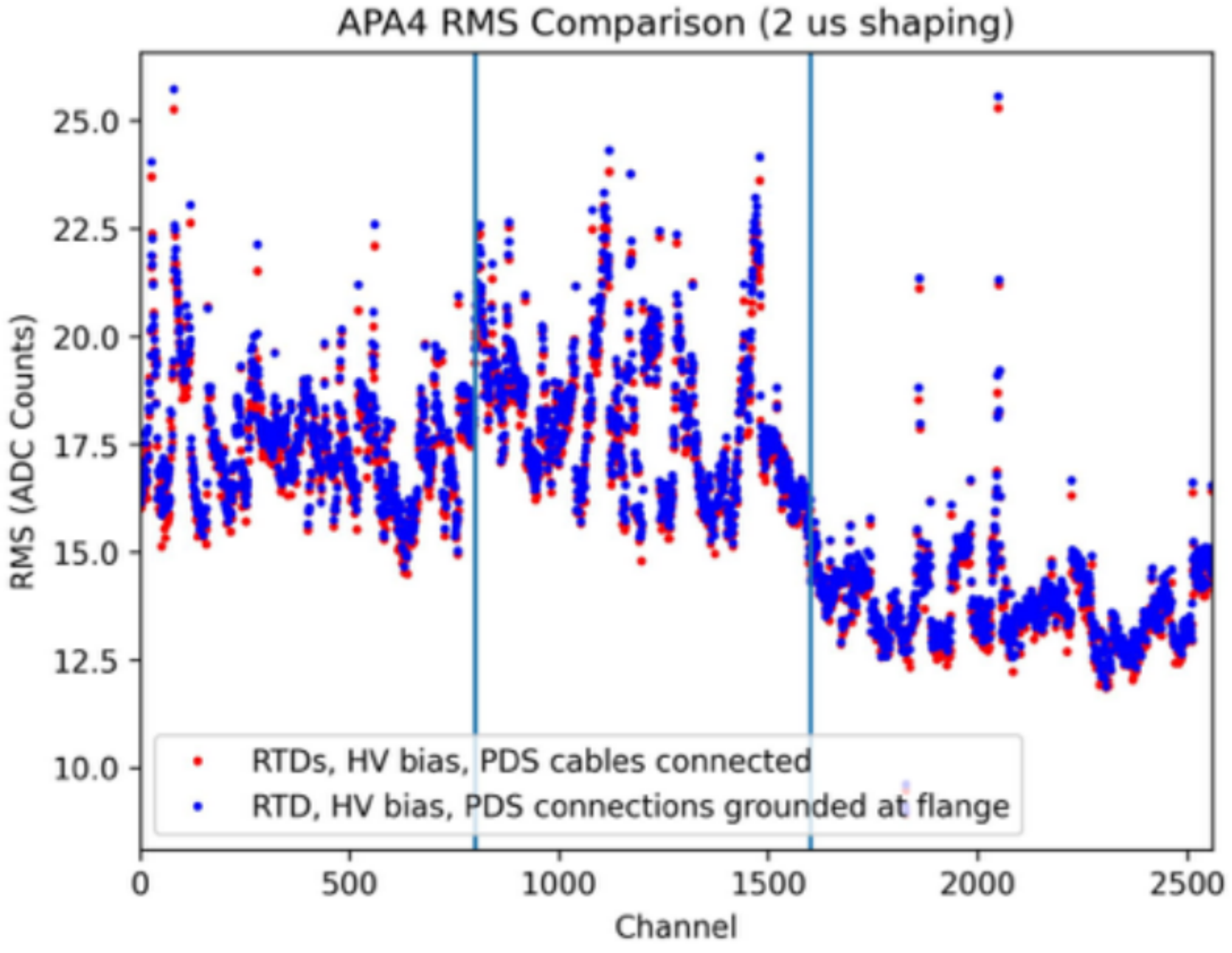


Block diagram for non-APA sensors

Noise induced by APA sensors on CE

- https://edms.cern.ch/ui/file/2811678/1/DUNE_TMS_noise_in_APAS.pdf
- Demonstrated in the cold box that temperature sensors on APAs do not induce noise on Cold Electronics





QA/QC

EDMS documents

QA/QC Documents:
https://edms.cern.ch/project/CERN-0000237156

1) QA/QC plan: https://edms.cern.ch/document/2811710/1

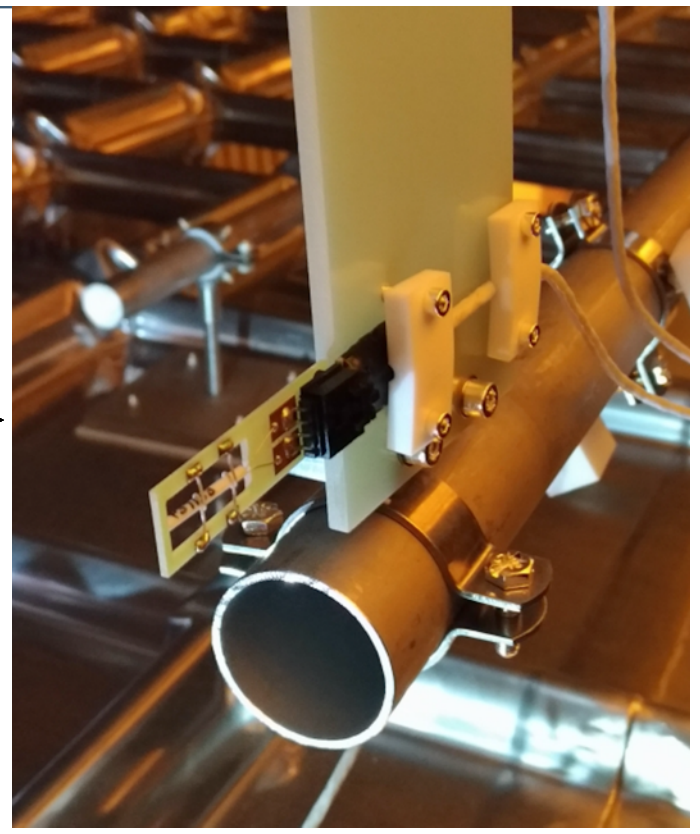
2) Prototyping plan: https://edms.cern.ch/document/2811709/1

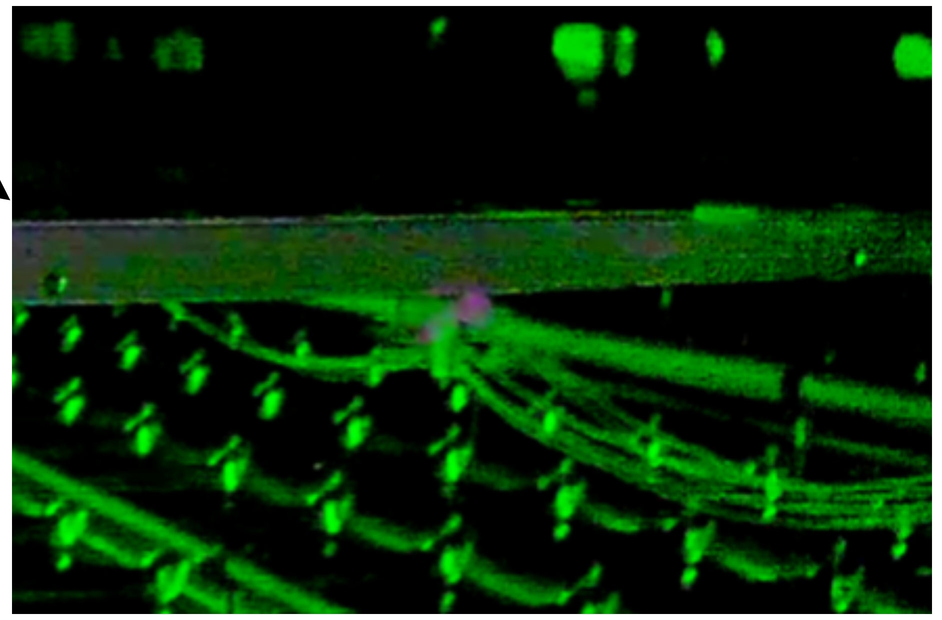
3) ProtoDUNE lessons-learned: https://edms.cern.ch/document/2812052/1

Lessons learned from ProtoDUNE-SP

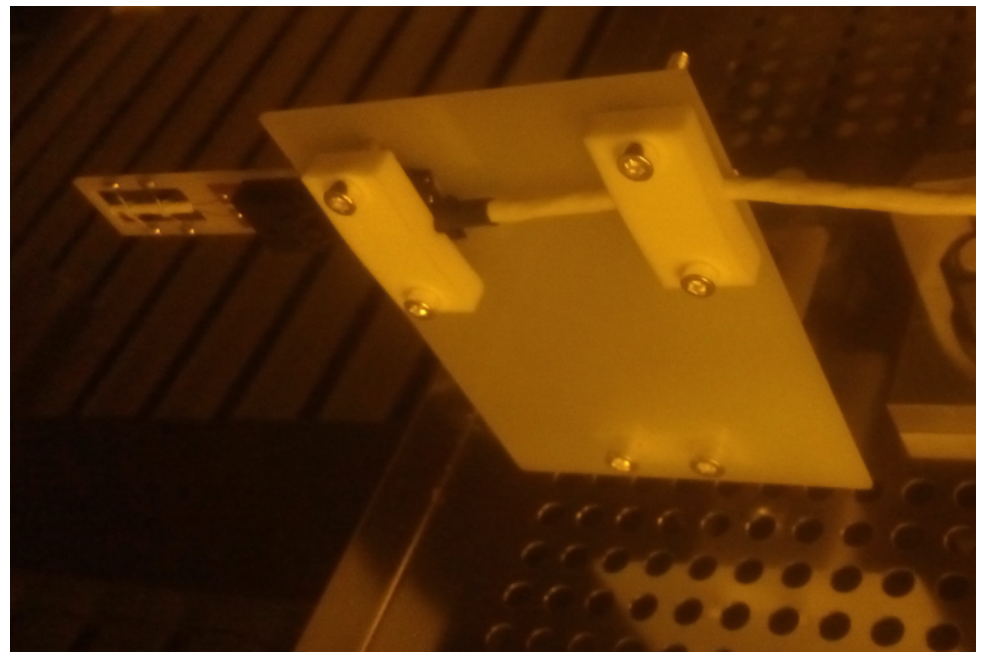
- https://edms.cern.ch/document/2812052/1
- Sensors on inlets should be directly exposed to the incoming LAr
- RTD cables do not show significant contraction in LAr
  - slack can be reduced
- Outer teflon jacket of RTD cables does not deteriorate
  - cables can be safely routed in bundles
- RTDs near the surface show a rather chaotic behaviour
  - Not worth of dedicated horizontal arrays near the surface
- Need of additional systems to farther constraint CFD
  - LAr inlets, LAr pumps, PrMs, APAs

inlet RTD in PD-SP



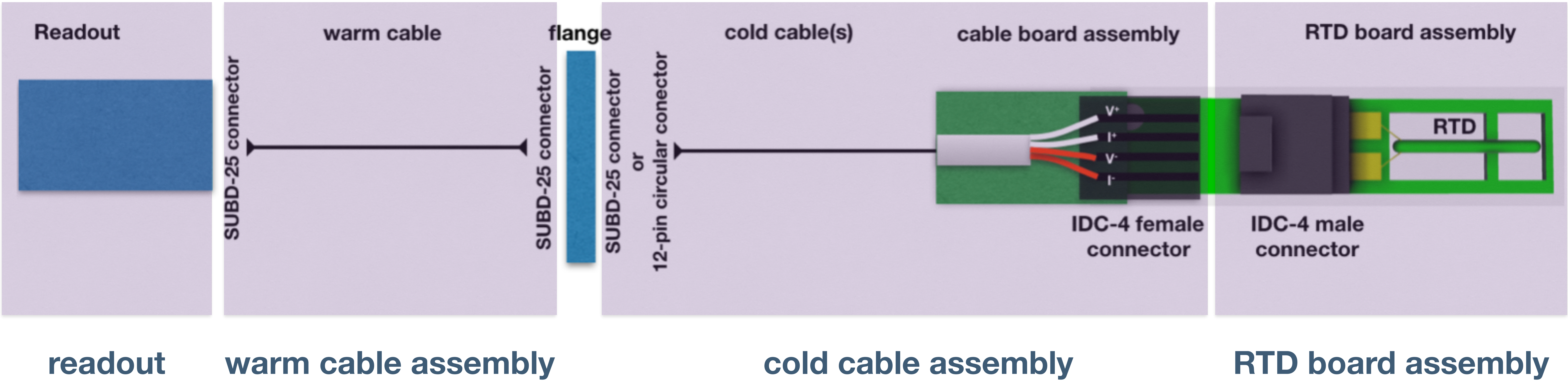


top RTD in PD-SP



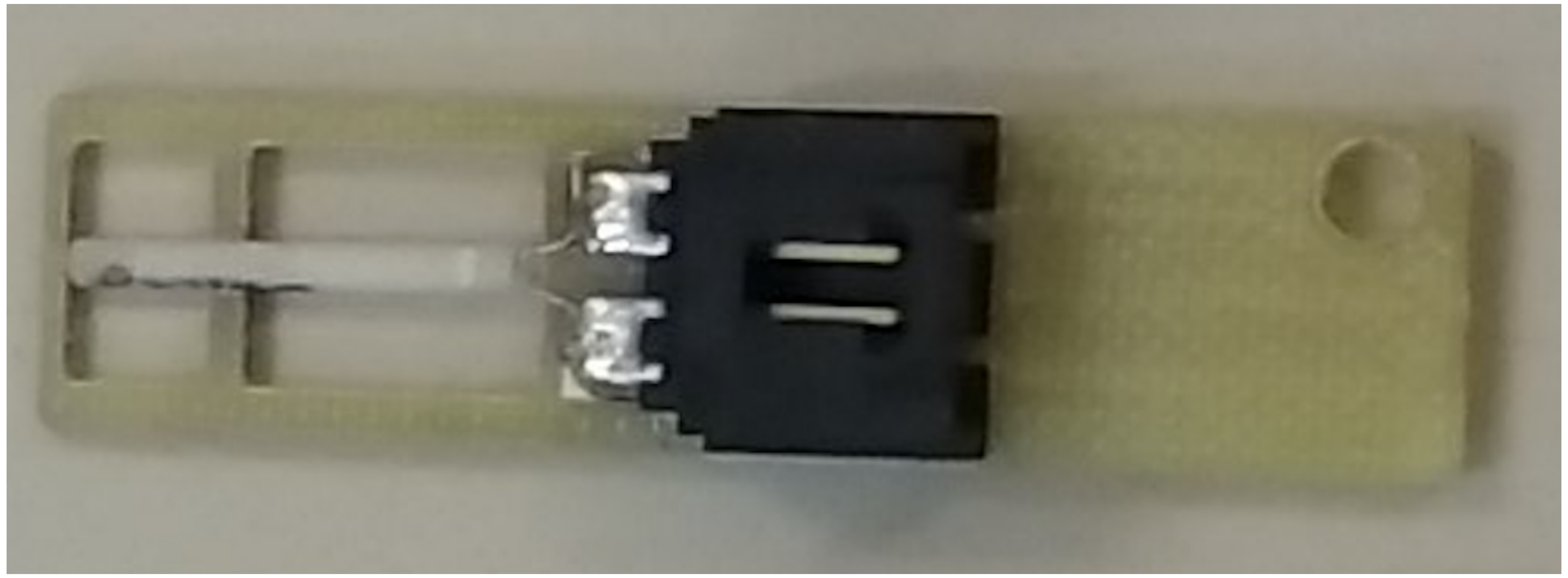
QA/QC plans

- https://edms.cern.ch/document/2811710/1
- There will be tests on each element of the chain



QA/QC: RTD board assembly

- Laboratory calibration in LN2 to:
  - Find calibration constant for each RTD
  - Identify RTDs being defective or out of specifications
  - Identify failures in the IDC-4 connector or soldering of the connector/sensor to the board



QA/QC: Cold Cable assembly

- Includes the cable board assembly, the cable it self and the connector on the cold flange side
- In all cases, the full chain with an RTD at the end is tested in LN2 to ensure temperature readings are not affected by defective cable soldering, crimping or mapping.

two cables

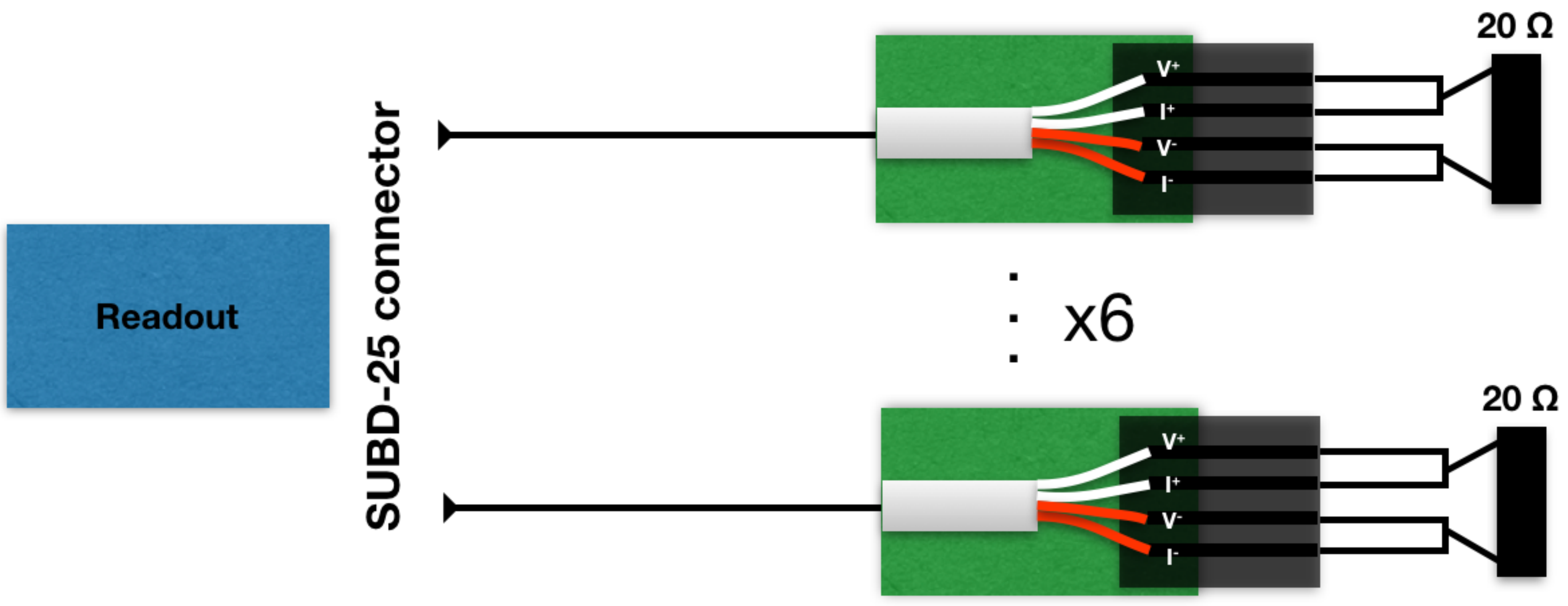
IDC-4 female connector

hirose 12-pin connector

IDC-4 female connector

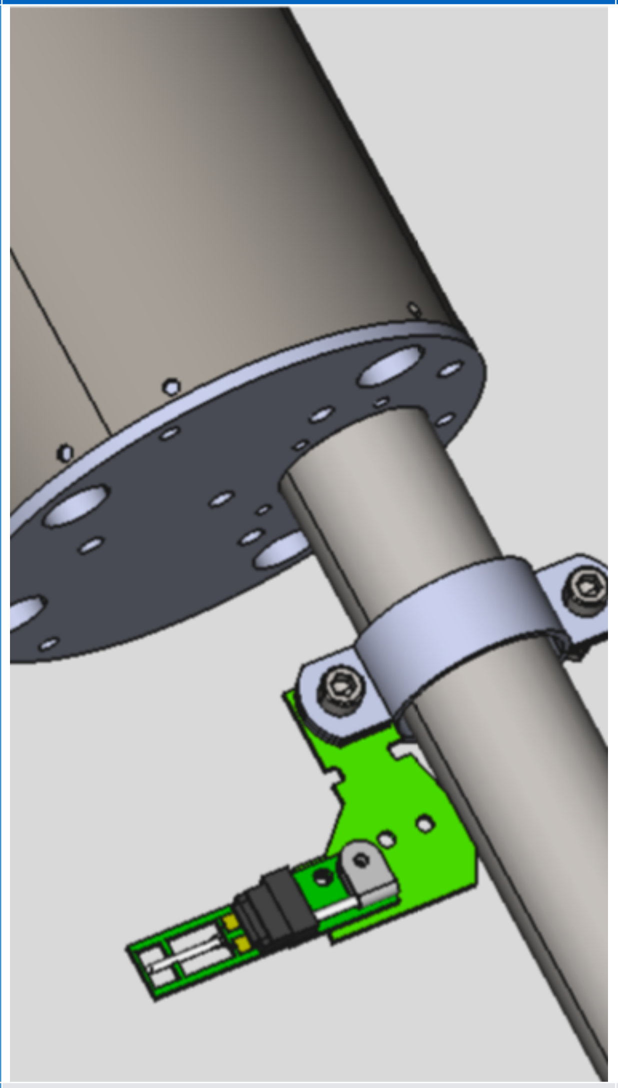
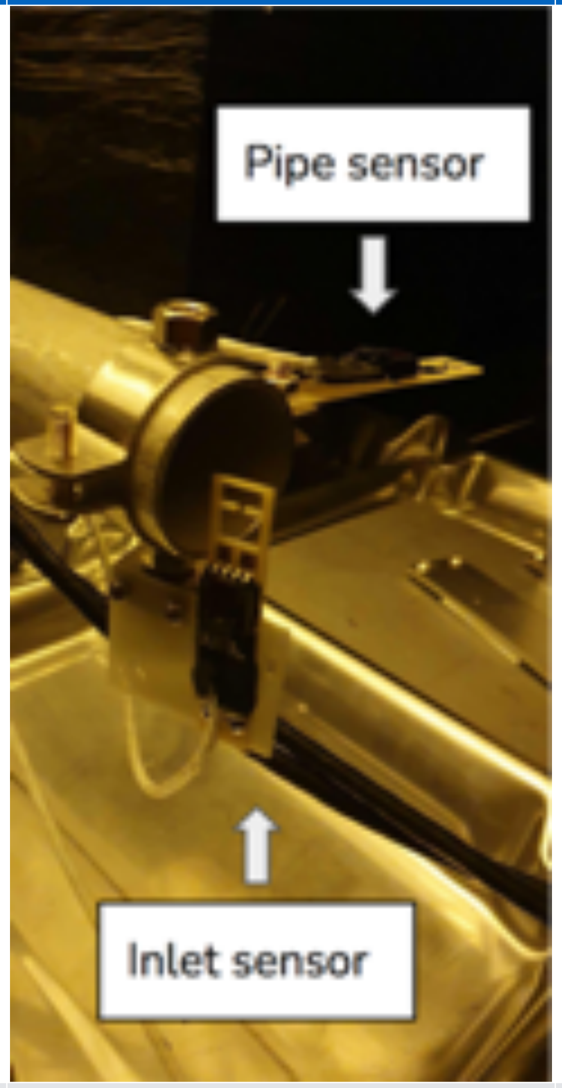
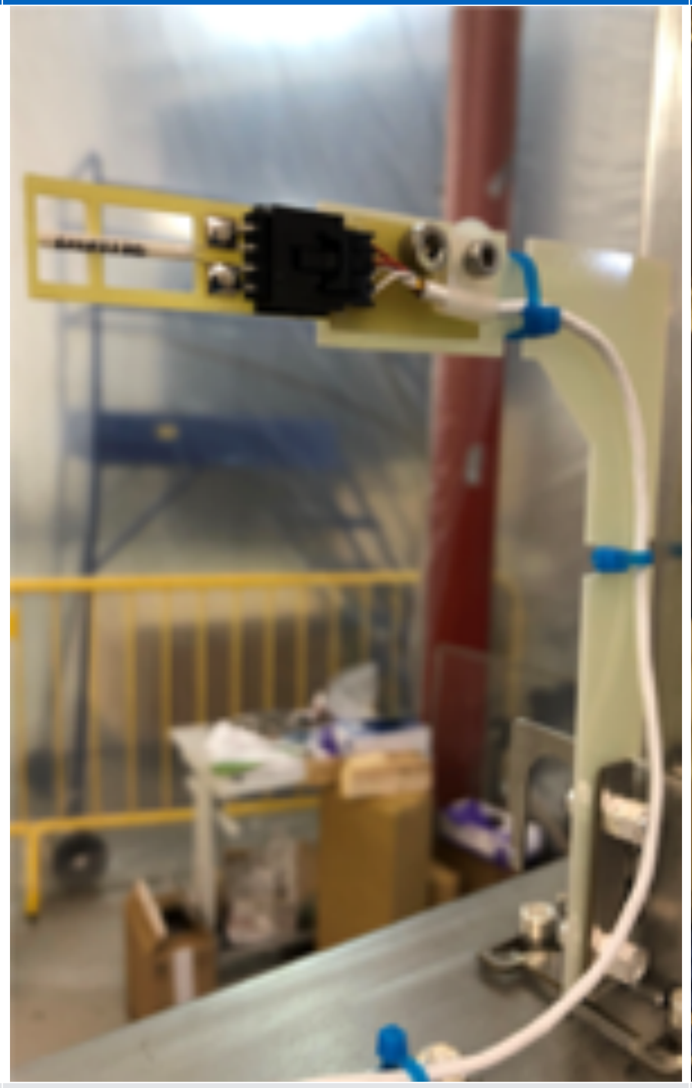
QA/QC: Readout

- Each channel of the readout system will be tested with fix 20 ohms precision resistors to verify the RMS of equivalent temperature readings (76 K) does not exceed 0.5 mK. This is done with a dedicated assembly of 6 cables with a single SUBD-25 connector in one side and 6 cable boards assemblies on the other side, to tests 6 channels simultaneously.

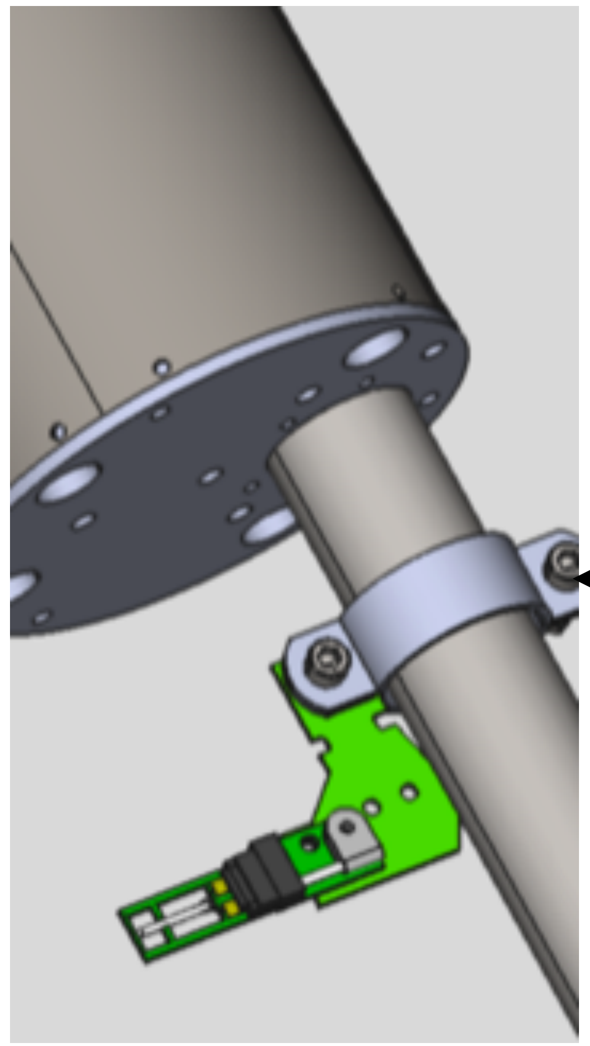


Prototyping I

- https://edms.cern.ch/document/2811709/1
- All systems have been prototyped for ProtoDUNE-HD

	Purity Monitors	LAr Inlets + Pipes	APAs	gas arrays	pumps	wall
						
#sensors	6	4+8	16	36	2	5
Installed	NO	Yes	Yes	Yes	NO	Yes

Prototyping II



- Anchoring mechanism in FD1 will differ for some subsystems. To be prototyped well in advance at IFIC
- **gas arrays**: In PH-HD thy are suspended from the GP support beams. In FDs, DSS is probably a better choice
- **inlet sensors**: LAr inlets in PD-HD are at the pipe's edge, while in FD1/FD2 consist in small openings along the pipe. Split clamps can still be used but the sensor support should be such that the sensor is directly exposed to the incoming LAr
- **PrM sensors:** In PD-HD they 40 mm split clamps are used. The support structure for te PrM needs to be finalized before designing te one for te RTDs

Interface documents

EDMS documents

Interface Documents:
https://edms.cern.ch/project/CERN-0000237155

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

- Other documents are from CISC times and need to be updated

Installation

EDMS documents

Installation Documents:
https://edms.cern.ch/project/CERN-0000237154

1)DUNE Installation plan: https://edms.cern.ch/document/2811714/1

2)APA Temperature Sensor Mounting Plan: https://edms.cern.ch/document/2811713/1

Installation

- An overview of the installation plan is available at EDMS 2811714
  - No details available at the moment for most systems (see below some examples)
- Installation of sensors on APAs is covered in more detailed in a separated document (EDMS 2811713)
- APA production started in March and the procedure has been exercised

DUNE FD1 Temperature Monitoring System installation plan

The different subsystems composing the Temperature Monitoring System (TMS) will be installed at different stages of the DUNE-FD1 installation.

APA sensors

Installation of RTDs on APAs occurs during APA manufacturing process at APA factories. The document at https://edms.cern.ch/document/2811713/1 describes the installation procedure for Temperature sensors on the APAs.

Purity monitor sensors

In DUNE FD1 there will be two sets of two PrMs in opposite cryostat corners. Precision RTDs will be installed below and above each PrM before PrMs are inserted into the cryostat. Cable routing and flange will be the same as for PrMs.

Gas arrays

Ten gas arrays with 18 sensors each will be preassembled at IFIC and installed above the top ground planes. The anchoring system for those devices is still under discussion. Ideally the system will use the DSS, such that its installation can be decoupled from the one of the detector.

Tracking

EDMS documents

Previous Review Documentation:
https://edms.cern.ch/project/CERN-0000237158

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

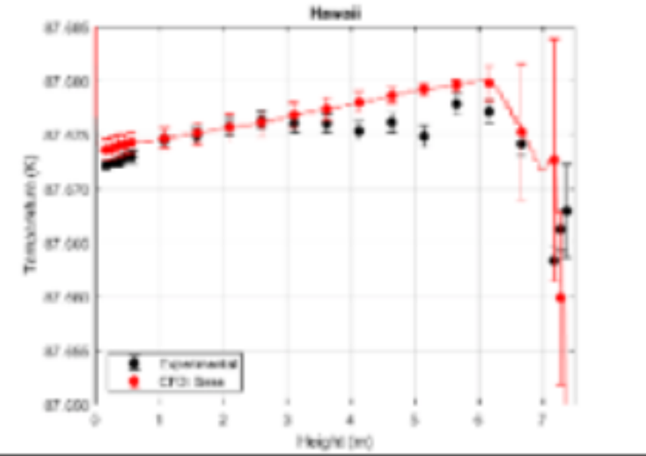
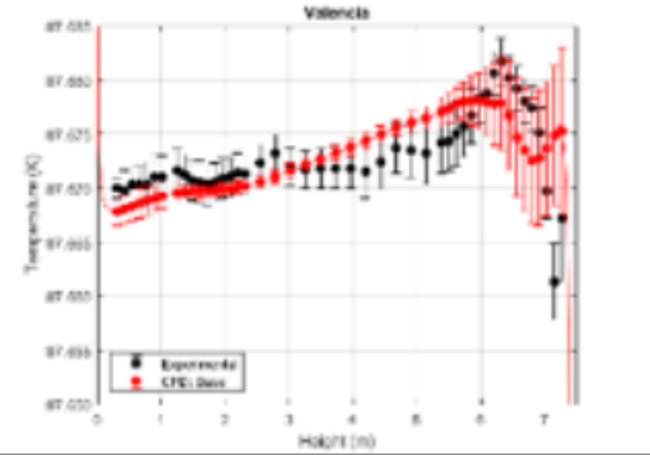
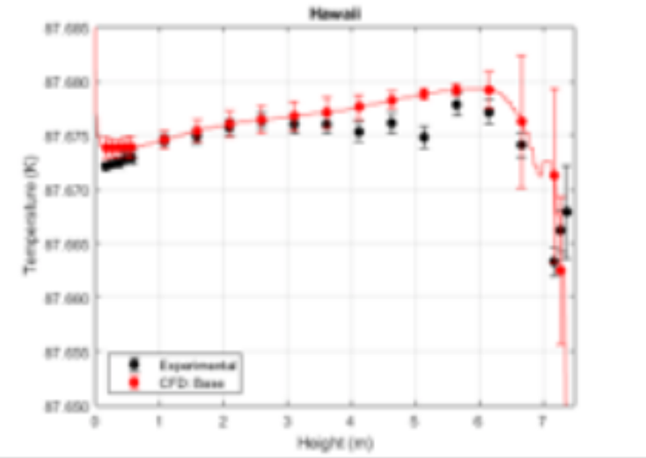
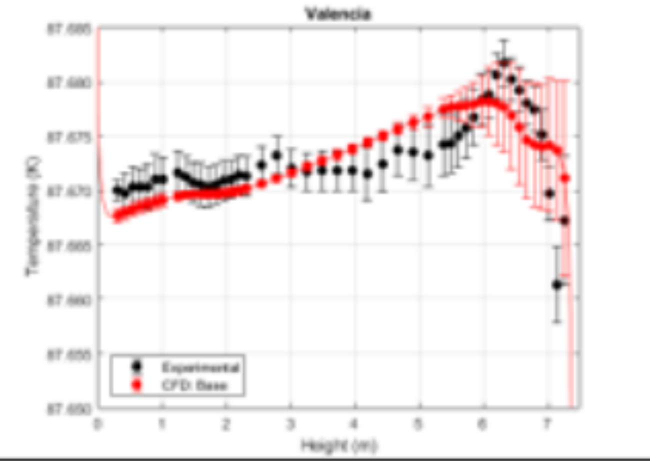
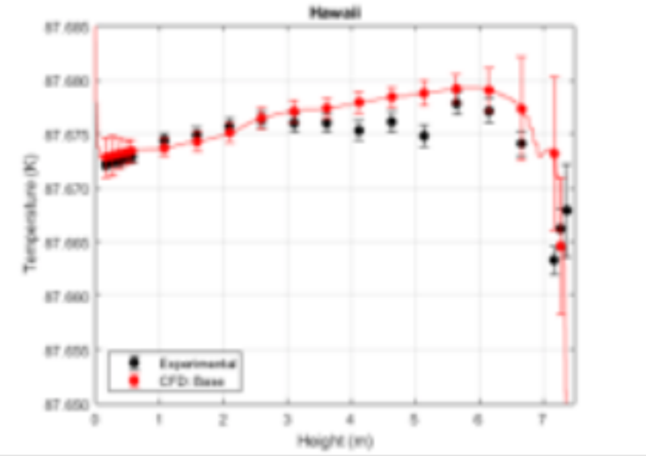
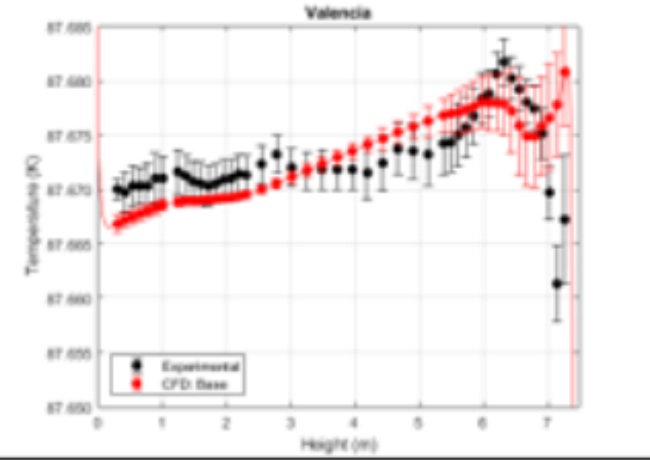
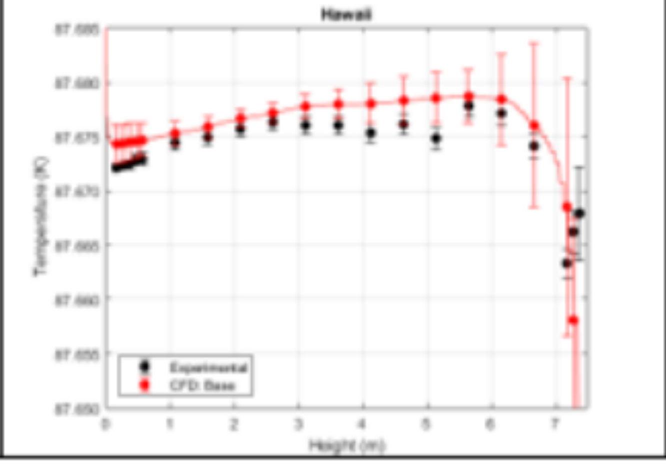
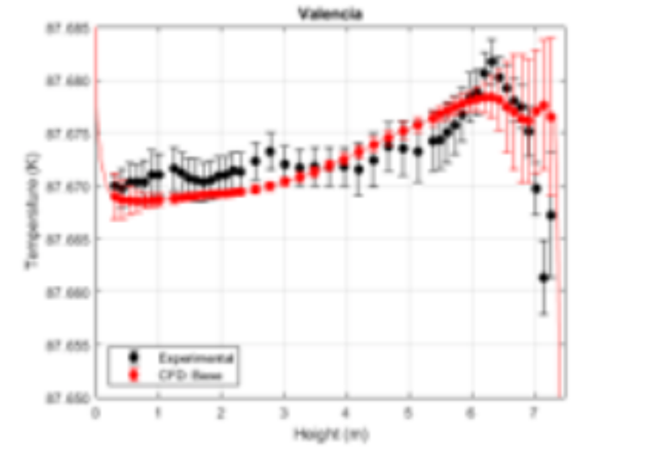
2)PDR Recommendation Tracking: https://edms.cern.ch/document/2801352/1

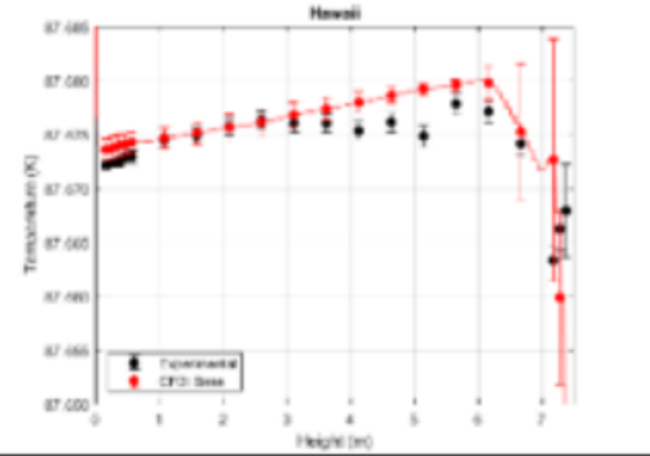
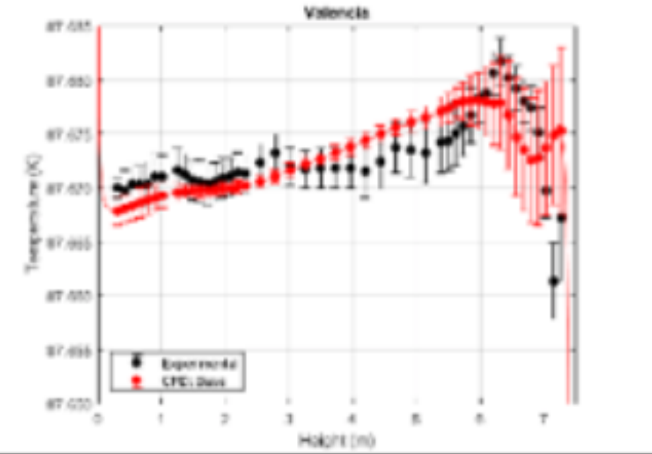
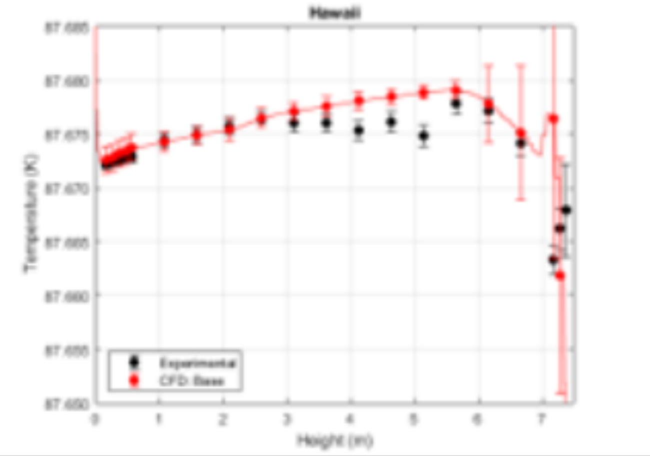
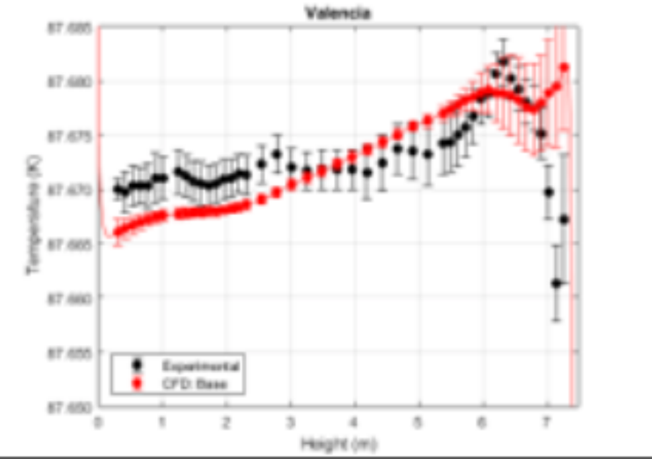
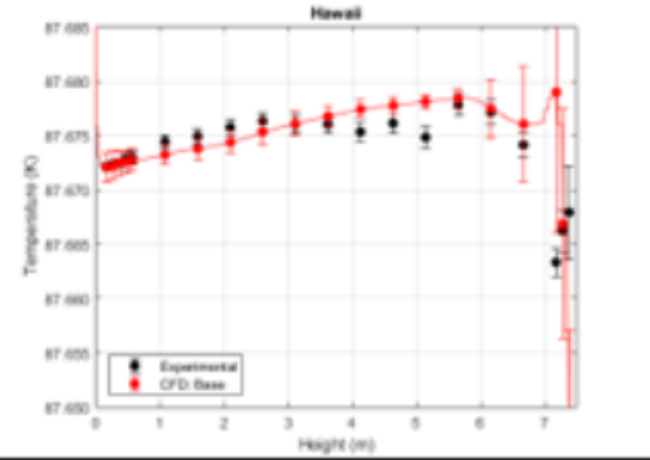
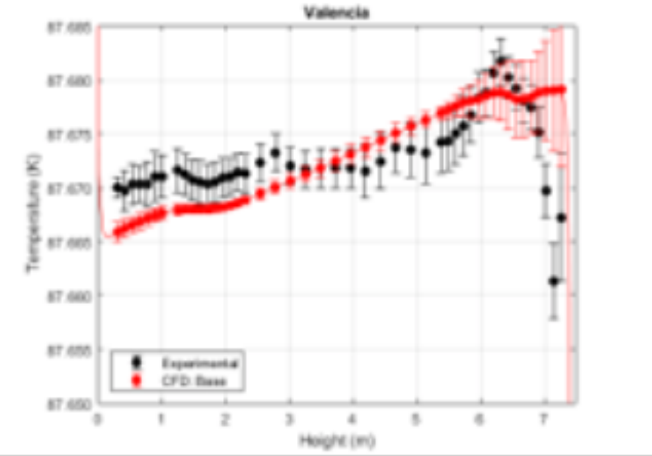
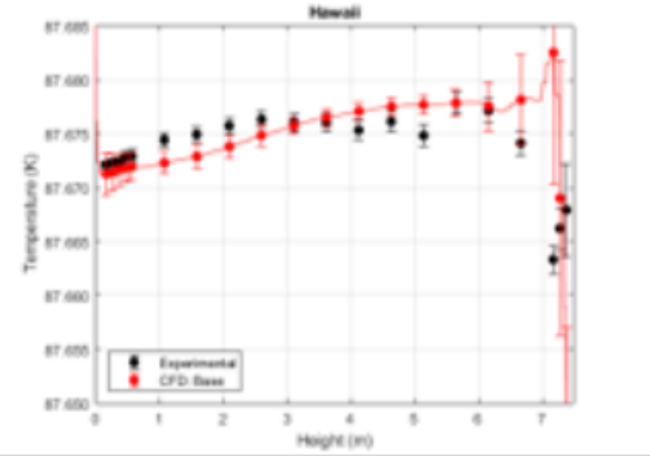
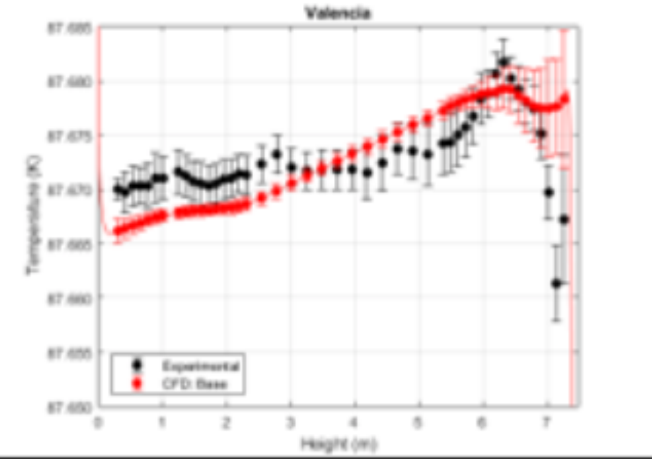
Recommendation 1

- **Recommendation**: Continue to work on understanding the impact of heat generated by the TPC electronics on the temperature measurements, including additional heat sources (active electronics for the photon detectors and heat dissipation in the cables for the FEMBs). Multiple scenarios should be investigated (recirculation on/off and TPC electronics completely on, partially on, completely off) to understand whether it is really feasible to constrain via high precision RTDs the CFD simulations at the few mK level.
- **Answer**: ProtoDUNE-SP CFD simulations have been performed with different heat values from the cold electronics. Variations on the temperature gradients are small. In protoDUNE-HD the measurement of temperature maps with electronics on/off and recirculation on/off are planned

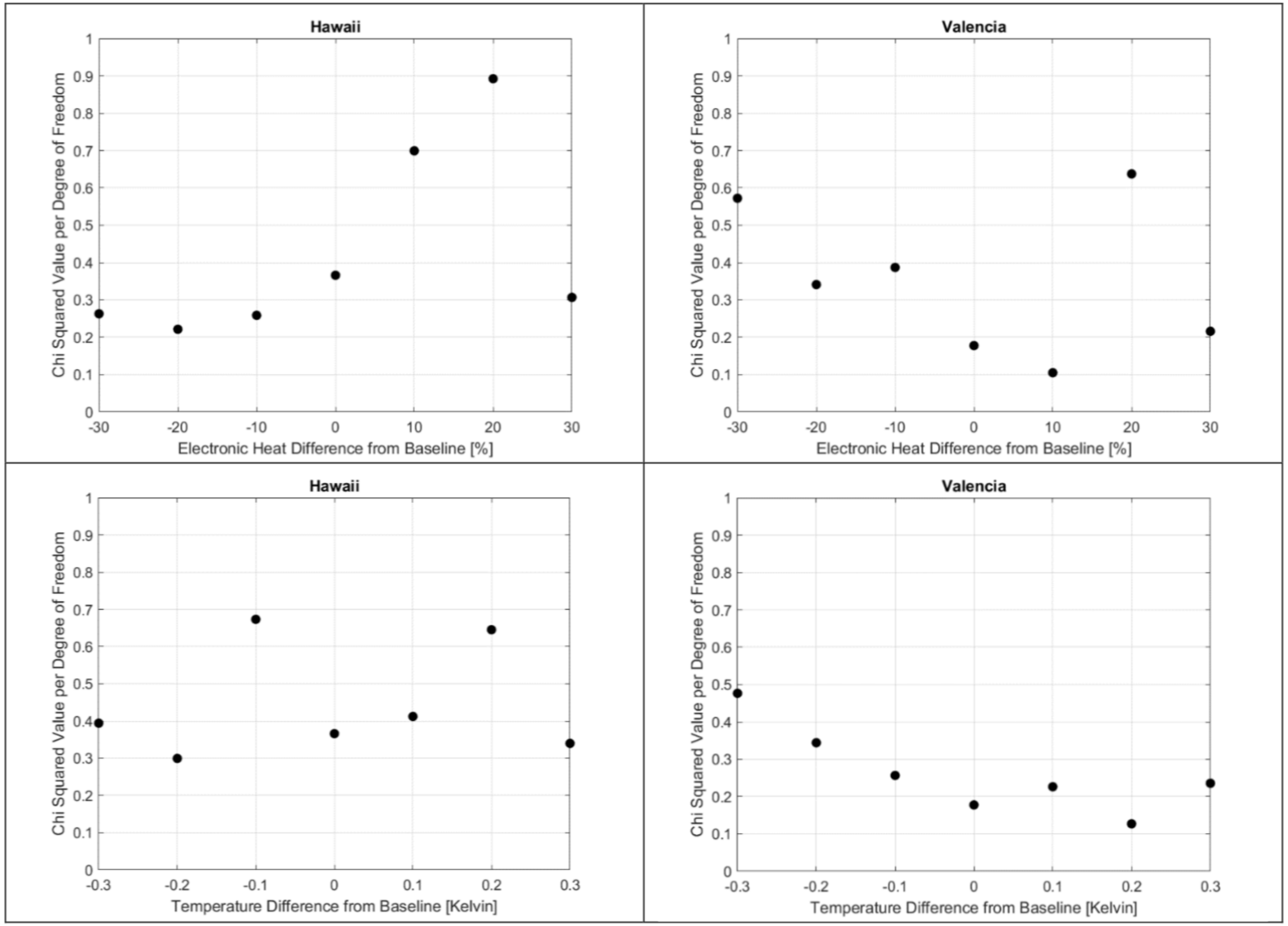
Electronic heat variations

- CFD simulation produced by SDSU group and comparison with real data

	Hawaii	Valencia
Baseline		
Electronic Heat Minus 10% Watts		
Electronic Heat Minus 20% Watts		
Electronic Heat Minus 30% Watts		

	Hawaii	Valencia
Baseline		
Electronic Heat Plus 10% Watts		
Electronic Heat Plus 20% Watts		
Electronic Heat Plus 30% Watts		

χ^2 comparisons



$$X_H^2 = \sum \left(\frac{(T_{Experiment,Hawaii} - T_{CFD,Hawaii})^2}{(\sigma_{CFD,Hawaii})^2 * N_{Hawaii}} \right)$$

$$X_V^2 = \sum \left(\frac{(T_{Experiment,Valencia} - T_{CFD,Valencia})^2}{(\sigma_{CFD,Valencia})^2 * N_{Valencia}} \right)$$

Recommendation 2

- **Recommendation**: Tests with the TPC readout electronics should be performed well ahead of the second run of ProtoDUNE to ensure that the RTDs do not induce electronics noise
- **Answer:** RTDs on the APAs have been extensively tested in the cold boxes with no impact on the cold electronics noise

Cost/Schedule documents

EDMS documents

Cost/Schedule Documents:
https://edms.cern.ch/project/CERN-0000237157

1)Cost Tables: https://edms.cern.ch/document/2812053/1
2)Schedule documents: https://edms.cern.ch/document/2814588/1

No Recent overall schedule documents available at this time, only for APA production

M&S costs

- Summary table for FD1 and FD2
- More details available in EDMS

	Unit price	Unit price (prec. sensors)	Unit price (st. sensors)	Unit price (rest)	# units	total cost	funding source	unit definition
Summary table								
CI:Temp sensors FD1								
Sensors on APAs - B - UPPER	$829	$678	$0	$341	38	$31,498	IFIC	APA with 4 LAr sensors
Sensors on APAs - B - LOWER	$817	$678	$0	$329	38	$31,041	IFIC	APA with 4 LAr sensors
Sensors on APAs - A - UPPER	$463	$339	$12	$302	37	$17,141	IFIC	APA with 2 LAr sensors and 2 frame sensors
Sensors on APAs - A - LOWER	$451	$339	$12	$290	37	$16,696	IFIC	APA with 2 LAr sensors and 2 frame sensors
Sensors on APAs: passthrough cable	$90	$0	$0	$90	75	$6,759	IFIC	4 cables integrated in upper APA to readout lower APA
Sensors on APAs: cable to PDS flange	$182	$0	$0	$182	75	$13,645	IFIC	8 cables per doublet, from upper APA to PDS flange
Sensor on LAr inlet	$203	$169	$0	$81	16	$3,245	IFIC	single sensor
Sensor on LAr pump	$540	$169	$0	$419	8	$4,323	IFIC	single sensor
Sensors on PrMs	$194	$169	$0	$72	8	$1,554	IFIC	single sensor
Sensors on wall	$28	$0	$6	$69	8	$222	IFIC	single sensor
Gas array for ullage	$1,106	$678	$86	$1,199	10	$11,061	IFIC	array with 4 precision sensors and 14 standard sensors
Readout channel	$48	$0	$0	$48	820	$39,034	DUNE Project	single sensor
Total Temp Sensors FD1 (no spares)						**$176,220**		
		$10,200						
CI:Temp sensors FD2						[3]		
Sensor on LAr inlet	$203	$169	$0	$28	16	$3,245	IFIC	single sensor
Sensor on LAr pump	$540	$169	$0	$366	8	$4,323	IFIC	single sensor
Sensors on PrMs	$194	$169	$0	$20	8	$1,554	IFIC	single sensor
Sensors on wall	$28	$0	$6	$22	8	$222	IFIC	single sensor
Gas array for ullage	$1,106	$678	$86	$218	10	$11,061	IFIC	array with 4 precision sensors and 14 standard sensors
Readout channel	$48	$0	$0	$0	212	$10,092	DUNE Project	single sensor
Total Temp Sensors FD2 (no spares)						**$30,497**		

Labor cost

- Only for FD1 and PD-HD

Subsystem	Temperature sensors								
Detector	DUNE far detector #1								
					Person-power				
Category	# of FTE	How long? (years)	Total hours	Institute	Country	Funding Source 1	Funding Source 2	Funding Source 3	What Tasks?
Scientist	0,2	2	707,2	IFIC	Spain	non-US: IFIC			Design, assembly, installation, commissioning, simulation and analysis
Postdocs	0,2	2	707,2	IFIC	Spain	non-US: IFIC			Assembly, installation, commissioning, simulation and analysis
Graduate Students	0,4	3	2121,6	IFIC	Spain	non-US: IFIC			Assembly, installation, commissioning, simulation and analysis
Undergraduates			0	IFIC	Spain	non-US: IFIC			Assembly, installation, commissioning, simulation and analysis
Engineers	0,1	1	176,8	IFIC	Spain	non-US: IFIC			Design, assembly and installation
Technicians	0,2	1	353,6	IFIC	Spain	non-US: IFIC			Construction, assembly and installation
Sub-total			**4066,4**	IFIC	Spain				
Scientist			0	SDSU	USA				
Postdocs			0	SDSU	USA				
Graduate Students	0,5	2	1768	SDSU	USA	US: DUNE Project			Simulations and analysis
Undergraduates			0	SDSU	USA				
Engineers	0,1	2	353,6	SDSU	USA	US: DUNE Project			Simulations and analysis
Technicians			0	SDSU	USA				
Sub-total			**2121,6**	SDSU	USA				
Total			**6188**						
Note: 1 FTE =	1768	hours/year at Fermilab							

Subsystem	Temperature sensors								
Detector	ProtoDUNE-HD								
					Person-power				
Category	# of FTE	How long? (years)	Total hours	Institute	Country	Funding Source 1	Funding Source 2	Funding Source 3	What Tasks?
Scientist	0,1	1	176,8	IFIC	Spain	non-US: IFIC			Design, assembly, installation, commissioning, simulation and analysis
Postdocs			0	IFIC	Spain	non-US: IFIC			Assembly, installation, commissioning, simulation and analysis
Graduate Students	0,05	1	88,4	IFIC	Spain	non-US: IFIC			Assembly, installation, commissioning, simulation and analysis
Undergraduates			0	IFIC	Spain	non-US: IFIC			Assembly, installation, commissioning, simulation and analysis
Engineers	0,03	1	53,04	IFIC	Spain	non-US: IFIC			Design
Technicians	0,1	1	176,8	IFIC	Spain	non-US: IFIC			Construction
Sub-total			**495,04**	IFIC	Spain				
Scientist			0	SDSU	USA				
Postdocs			0	SDSU	USA				
Graduate Students	0,5	1	884	SDSU	USA	US: DUNE Project			Simulations and analysis
Undergraduates			0	SDSU	USA				
Engineers	0,1	1	176,8	SDSU	USA	US: DUNE Project			Simulations and analysis
Technicians			0	SDSU	USA				
Sub-total			**1060,8**	SDSU	USA				
Total			**1555,84**						
Note: 1 FTE =	1768	hours/year at Fermilab							

APA TMS production status and schedule

APA ID	UPPER/ LOWER	TYPE	CALCI config	APA Configuration	Sensor 1			Sensor 2			Sensor 3			Sensor 4			Cable bundle B		Cable bundle C		PT cable bundle	Production date	Shipping date	Delivery date	Needed date	APA Factory
					cable length	sensor type	sensor ID	cable length	sensor type	sensor ID	cable length	sensor type	sensor ID	cable length	sensor type	sensor ID	Pin 1	Pin 9	Pin 1	Pin 9						
1	UPPER	A	UA-2	U-F-3-12-F	1017	F1	STS 001	1705	LAr3	48178	4762	LAr12	48179	6429	F2	STS 002	F1	LAr3	LAr12	F2	2	2022/02/11	2022/02/12	2022/02/14	2022/01/31	Daresbury
2	LOWER	A	LA-2	L-F-7-16-F	5968	F1	STS 004	4485	LAr7	48181	1629	LAr16	48180	977	F2	STS 003	LAr7	F1	F2	LAr16		2022/03/09	2022/03/11	2022/03/17	2022/01/31	Daresbury
3	UPPER	B	UB-2	U-1-6-11-16	1101	LAr1	48182	2803	LAr6	48183	4269	LAr11	48184	6044	LAr16	48185	LAr6	LAr11	LAr1	LAr16	2	2022/03/10	2022/03/11	2022/03/17	2022/03/07	Daresbury
4	LOWER	B	LB-2	L-3-8-13-18	5701	LAr3	48189	4061	LAr8	48188	2705	LAr13	48187	977	LAr18	48186	LAr18	LAr3	LAr13	LAr8		2022/03/10	2022/03/11	2022/03/17	2022/03/07	Daresbury
5	UPPER	B	UB-1	U-1-5-10-15	1101	LAr1	48190	2383	LAr5	48191	4084	LAr10	48192	5551	LAr15	48193	LAr10	LAr15	LAr1	LAr5	2	2022/05/03	2022/05/03	2022/06/03	2022/04/19	Daresbury
6	LOWER	B	LB-1	L-4-9-14-18	5277	LAr4	48197	3921	LAr9	48196	2193	LAr14	48195	977	LAr18	48194	LAr18	LAr14	LAr9	LAr4		2022/05/03	2022/05/03	2022/06/03	2022/04/19	Daresbury
7	UPPER	A	UA-1	U-F-1-10-F	1017	F1	STS 005	1101	LAr1	48198	4084	LAr10	48199	6429	F2	STS 006	F1	LAr10	LAr1	F2	2	2022/05/03	2022/05/03	2022/06/03	2022/04/19	Daresbury
8	LOWER	A	LA-1	L-F-9-18-F	5968	F1	STS 008	3921	LAr9	48201	977	LAr18	48200	977	F2	STS 007	LAr18	F1	F2	LAr9		2022/05/03	2022/05/03	2022/06/03	2022/04/19	Daresbury
9	UPPER	B	UB-3	U-2-7-12-17	1520	LAr2	48060	2987	LAr7	48061	4762	LAr12	48062	6229	LAr17	48063	LAr2	LAr7	LAr12	LAr17	2	2022/06/10	2022/06/13	2022/06/03	2022/05/30	Daresbury
10	LOWER	B	LB-3	L-2-7-12-17	5841	LAr2	48477	4485	LAr7	48476	2845	LAr12	48204	1489	LAr17	48202	LAr7	LAr2	LAr17	LAr12		2022/06/10	2022/06/13	2022/06/03	2022/05/30	Daresbury
11	UPPER	A	UA-3	U-F-5-14-F	1017	F1	STS 009	2383	LAr5	48480	5366	LAr14	48481	6429	F2	STS 010	F1	LAr14	LAr5	F2	2	2022/06/10	2022/06/13	2022/06/03	2022/05/30	Daresbury
12	LOWER	A	LA-3	L-F-5-14-F	5968	F1	STS 012	5137	LAr5	48483	2193	LAr14	48482	977	F2	STS 011	LAr14	F1	F2	LAr5		2022/06/10	2022/06/13	2022/06/03	2022/05/30	Daresbury
13	UPPER	B	UB-4	U-3-8-13-18	1705	LAr3	48486	3480	LAr8	48487	4946	LAr13	48488	6648	LAr18	48489	LAr3	LAr18	LAr8	LAr13	2	2022/10/11	02/12/2022	05/12/2022	2022/07/11	Daresbury
14	LOWER	B	LB-4	L-1-6-11-16	6353	LAr1	48495	4625	LAr6	48494	3296	LAr11	48493	1629	LAr16	48492	LAr11	LAr6	LAr16	LAr1		2022/10/11	02/12/2022	05/12/2022	2022/07/11	Daresbury
15	UPPER	A	UA-4	U-F-7-16-F	1017	F1	STS 013	2987	LAr7	48672	6044	LAr16	48674	6429	F2	STS 014	F1	LAr7	LAr16	F2	2	2022/10/11	02/12/2022	05/12/2022	2022/07/11	Daresbury
16	LOWER	A	LA-4	L-F-3-12-F	5968	F1	STS 016	5701	LAr3	48798	2845	LAr12	48675	977	F2	STS 015	LAr3	F1	F2	LAr12		2022/10/11	02/12/2022	05/12/2022	2022/07/11	Daresbury
17	UPPER	B	UB-5	U-4-9-14-18	2198	LAr4	48799	3665	LAr9	48726	5366	LAr14	48727	6648	LAr18	48728	LAr14	LAr18	LAr4	LAr9	2	2022/10/11	02/12/2022	05/12/2022	2022/08/22	Daresbury
18	LOWER	B	LB-5	L-1-5-10-15	6353	LAr1	48734	5137	LAr5	48732	3409	LAr10	48730	2053	LAr15	48729	LAr15	LAr10	LAr5	LAr1		2022/10/11	02/12/2022	05/12/2022	2022/08/22	Daresbury
19	UPPER	A	UA-5	U-F-9-18-F	1017	F1	STS 017	3665	LAr9	48735	6648	LAr18	48748	6429	F2	STS 018	F1	LAr18	LAr9	F2	2	2022/10/11	02/12/2022	05/12/2022	2022/08/22	Daresbury
20	LOWER	A	LA-5	L-F-1-10-F	5968	F1	STS 020	6353	LAr1	48750	3409	LAr10	48749	977	F2	STS 019	LAr10	F1	F2	LAr1		2022/10/11	02/12/2022	05/12/2022	2022/08/22	Daresbury
21	UPPER	B	UB-1	U-1-5-10-15	1101	LAr1	48752	2383	LAr5	48755	4084	LAr10	48837	5551	LAr15	48838	LAr10	LAr15	LAr1	LAr5	2	2022/10/11	02/12/2022	05/12/2022	2022/09/03	Daresbury
22	LOWER	B	LB-1	L-4-9-14-18	5277	LAr4	48844	3921	LAr9	48843	2193	LAr14	48842	977	LAr18	48840	LAr18	LAr14	LAr9	LAr4		2022/10/11	02/12/2022	05/12/2022	2022/09/03	Daresbury
23	UPPER	A	UA-1	U-F-1-10-F	1017	F1	STS 021	1101	LAr1	48846	4084	LAr10	48847	6429	F2	STS 022	F1	LAr10	LAr1	F2	2	2022/10/11	02/12/2022	05/12/2022	2022/09/03	Daresbury
24	LOWER	A	LA-1	L-F-9-18-F	5968	F1	STS 024	3921	LAr9	48850	977	LAr18	48849	977	F2	STS 023	LAr18	F1	F2	LAr9					2022/09/03	Daresbury
25	UPPER	A	UA-2	U-F-3-12-F	1017	F1		1705	LAr3		4762	LAr12		6429	F2		F1	LAr3	LAr12	F2	2				2022/11/14	Daresbury
26	LOWER	A	LA-2	L-F-7-16-F	5968	F1		4485	LAr7		1629	LAr16		977	F2		LAr7	F1	F2	LAr16					2022/11/14	Dearesbury
27	UPPER	B	UB-2	U-1-6-11-16	1101	LAr1		2803	LAr6		4269	LAr11		6044	LAr16		LAr6	LAr11	LAr1	LAr16	2				2022/11/14	Dearesbury
28	LOWER	B	LB-2	L-3-8-13-18	5701	LAr3		4061	LAr8		2705	LAr13		977	LAr18		LAr18	LAr3	LAr13	LAr8					2022/11/14	Dearesbury
29	UPPER	B	UB-3	U-2-7-12-17	1520	LAr2		2987	LAr7		4762	LAr12		6229	LAr17		LAr2	LAr7	LAr12	LAr17	2				2023/01/09	Dearesbury
30	LOWER	B	LB-3	L-2-7-12-17	5841	LAr2		4485	LAr7		2845	LAr12		1489	LAr17		LAr7	LAr2	LAr17	LAr12					2023/01/09	Dearesbury
31	UPPER	A	UA-3	U-F-5-14-F	1017	F1		2383	LAr5		5366	LAr14		6429	F2		F1	LAr14	LAr5	F2	2				2023/01/09	Dearesbury
32	LOWER	A	LA-3	L-F-5-14-F	5968	F1		5137	LAr5		2193	LAr14		977	F2		LAr14	F1	F2	LAr5					2023/01/09	Dearesbury
33	UPPER	B	UB-4	U-3-8-13-18	1705	LAr3		3480	LAr8		4946	LAr13		6648	LAr18		LAr3	LAr18	LAr8	LAr13	2				2023/02/20	Dearesbury
34	LOWER	B	LB-4	L-1-6-11-16	6353	LAr1		4625	LAr6		3296	LAr11		1629	LAr16		LAr11	LAr6	LAr16	LAr1					2023/02/20	Dearesbury
35	UPPER	A	UA-4	U-F-7-16-F	1017	F1		2987	LAr7		6044	LAr16		6429	F2		F1	LAr7	LAr16	F2	2				2023/02/20	Dearesbury
36	LOWER	A	LA-4	L-F-3-12-F	5968	F1		5701	LAr3		2845	LAr12		977	F2		LAr3	F1	F2	LAr12					2023/02/20	Dearesbury
37	UPPER	B	UB-5	U-4-9-14-18	2198	LAr4		3665	LAr9		5366	LAr14		6648	LAr18		LAr14	LAr18	LAr4	LAr9	2				2023/04/03	Dearesbury
38	LOWER	B	LB-5	L-1-5-10-15	6353	LAr1		5137	LAr5		3409	LAr10		2053	LAr15		LAr15	LAr10	LAr5	LAr1					2023/04/03	Dearesbury
39	UPPER	A	UA-5	U-F-9-18-F	1017	F1		3665	LAr9		6648	LAr18		6429	F2		F1	LAr18	LAr9	F2	2				2023/04/03	Dearesbury
40	LOWER	A	LA-5	L-F-1-10-F	5968	F1		6353	LAr1		3409	LAr10		977	F2		LAr10	F1	F2	LAr1					2023/04/03	Dearesbury

Overview

Overview

- TMS production (except APA sensors) is still far in time
- This review has been extremely useful to formalize TMS activities and have the appropriate written documentation. Since there is only one group working on the TMS, this is not always easy.
- We know some documents are missing and some others need more details
- We will be happy to receive recommendations and implement them ASAP