Istituto Nazionale di Fisica Nucleare
SEZIONE DI FERRARA

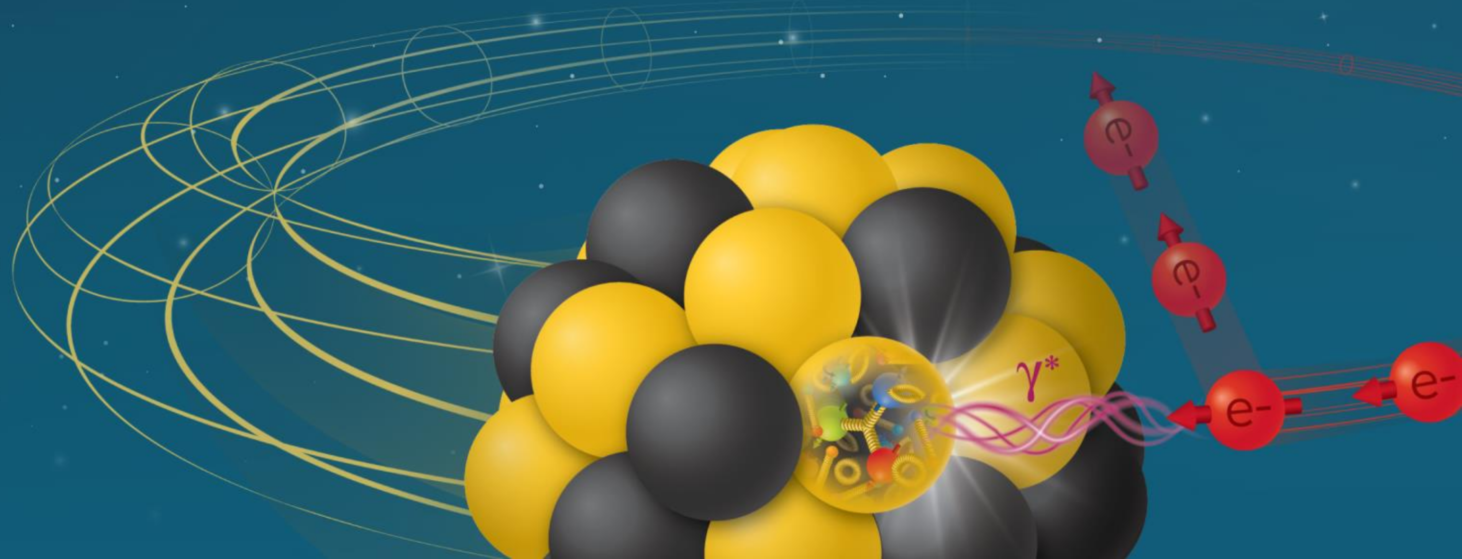
ePIC experiment
dRICH

dRICH Meeting

Detector Box & Test Beam - Status Report

Alessandro Saputi – 08 July 2026

Electron-Ion Collider



Outline

- Detector Box Design
- dRICH Real Scale Prototype

Photo Detector Unit (PDU)

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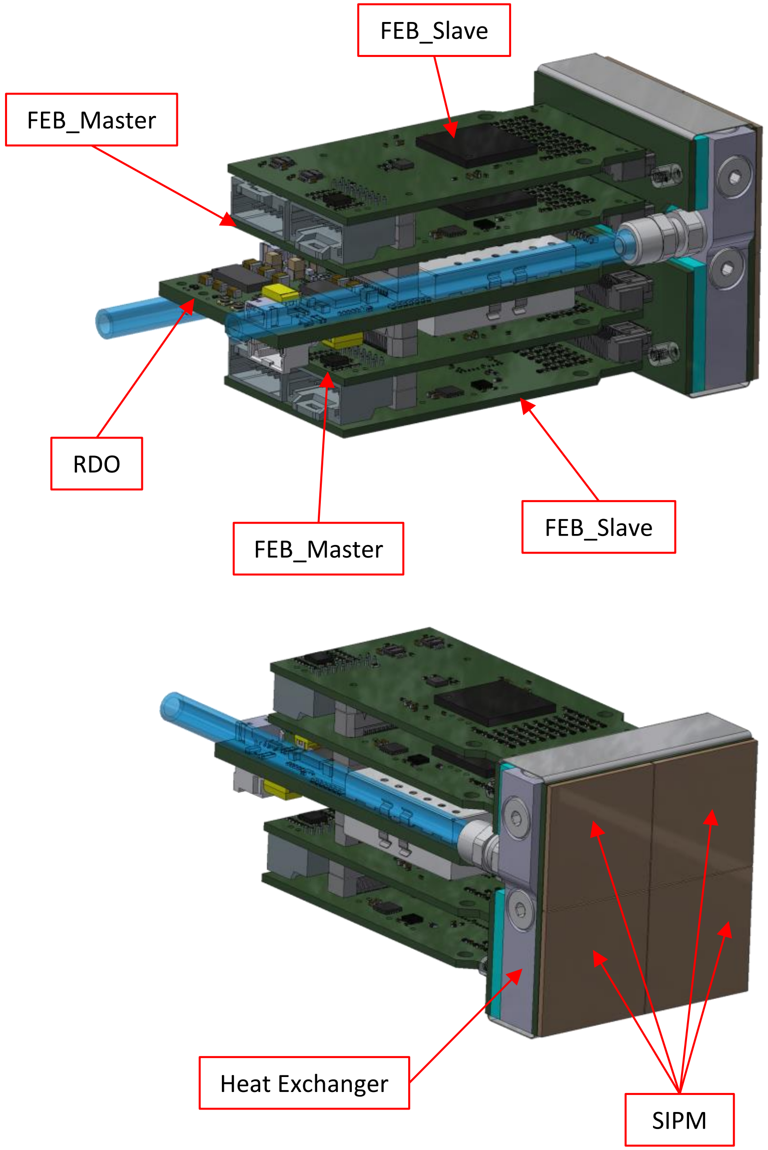
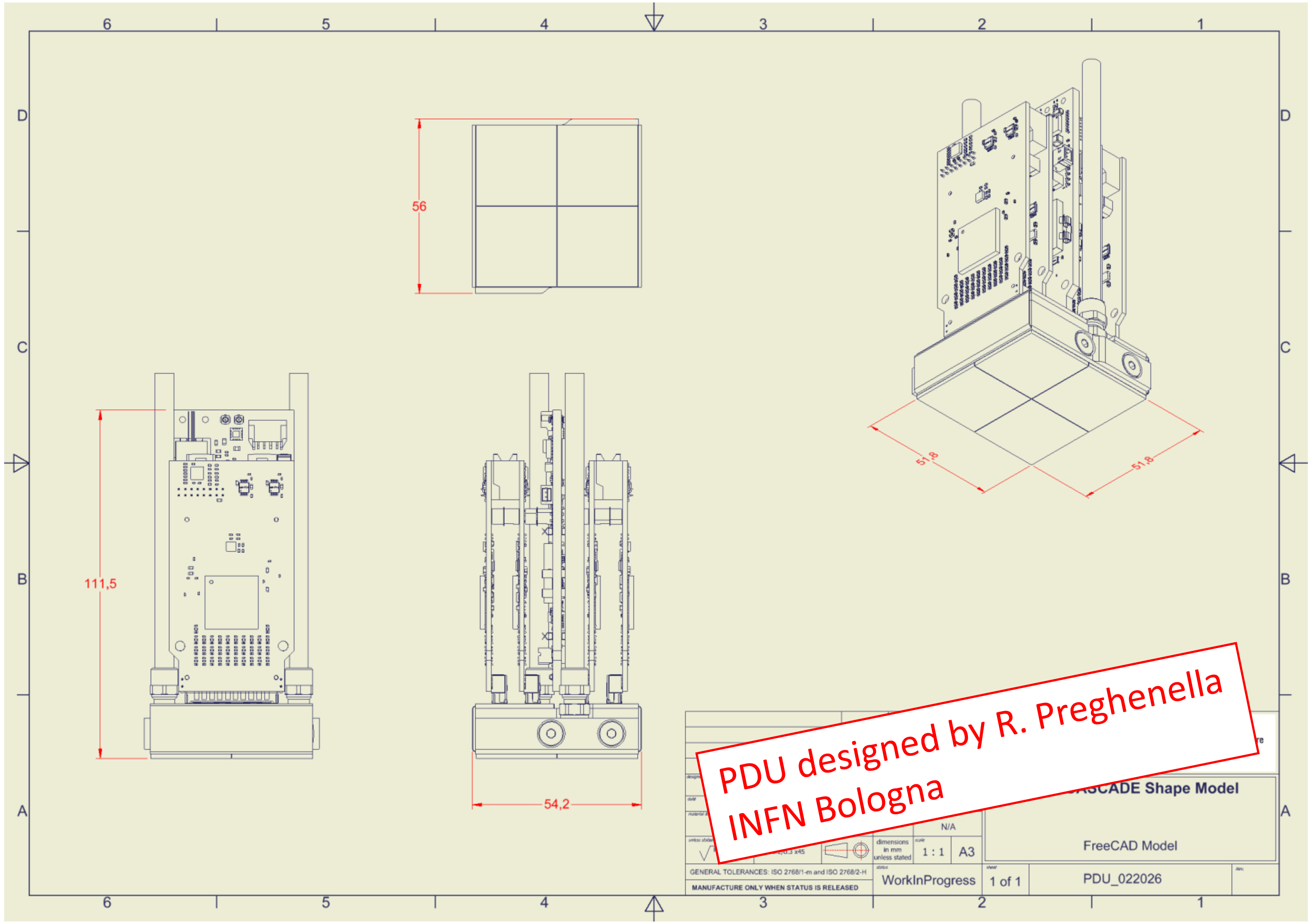
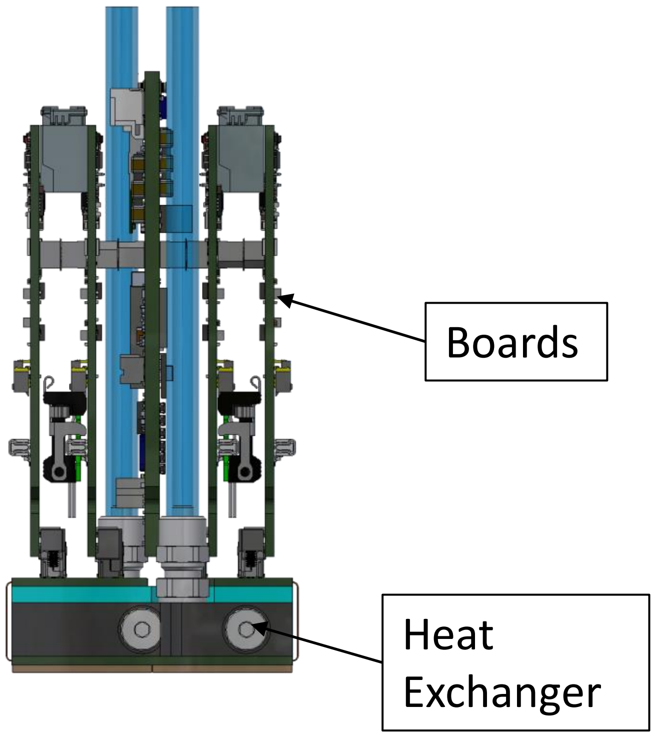
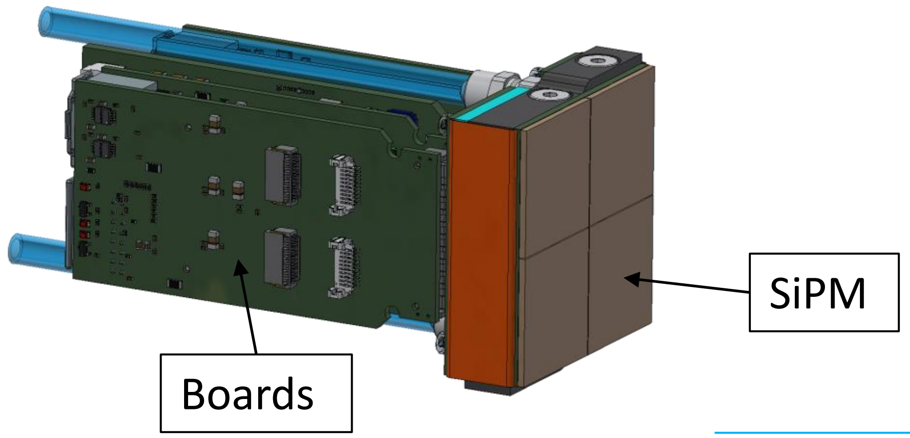




PDU: cooling and thermal power





Detector Box PDU = 208
dRICH Detector Boxes = 6
dRICH PDU = 208x6 = 1248

SiPM cooling mode

PPDU = 5 W (cooling power to be supplied to all 1,248 PDUs)
TSiPM = -40°C +/- 1°C (SiPM temperature)

The thermal power generated by the 1,248 PDUs is negligible.

SiPM heating mode (annealing)

TSiPM = 100°C (SiPM temperature)

Heating mode (annealing): Maximum temperature 100 °C

Electronic Boards cooling

P_{boards} = **15 W** (thermal power generated by each PDU unit)
T_{boards} = **65°C +/- 5 °C** (maximum admissible boards temperature)

P_{BDT} = **208 × 13 W = 2704 W** (thermal power generated by each detector box)
P_{dRICH} = **6 x 2288 W = 16224 W** (thermal power generated by dRICH)

PDU: FEE

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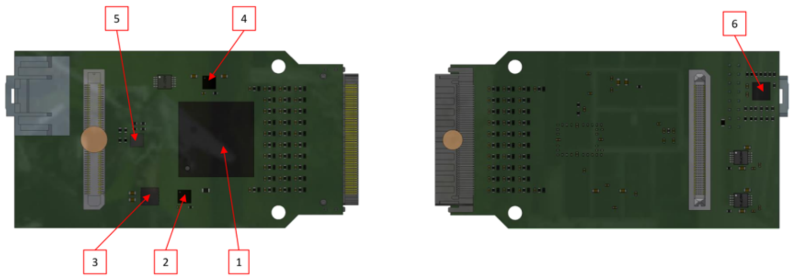
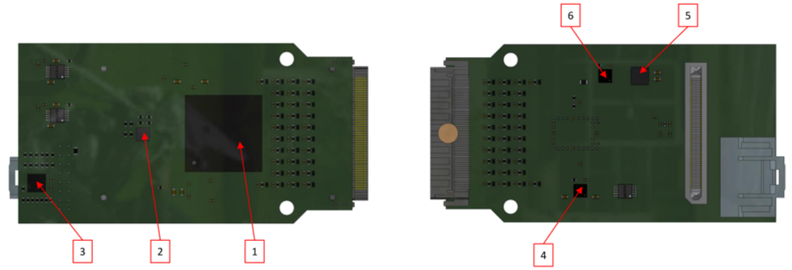
FEB master

Number	Reference	Part number	Description	Power (mW)	Tjunction max (ºC	Tambient max (ºC)
1	U1	ALCOR64-BGA256	ALCOR asic chip	980		
2	U9	ADP1761ACPZ-R7	Linear voltage regulato	55	125	85
3	U5	ADP1752ACPZ-2.5-R	Linear voltage regulato	25	150	85
4	U8	ADP1761ACPZ-R7	Linear voltage regulato	80	125	85
5 (*)	U2 (*)	LMK1D2102-VQFN16	Clock buffer	150	135	85
6	U3	PCF8575RGER	I/O expander	0.1	125	85
				1290.1		
	(*)	this component is likely to be moved to the RDO in a next iteration of the eletronics				



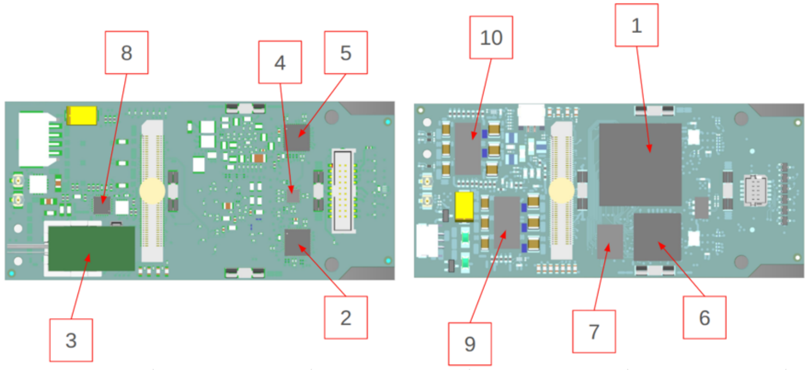
FEB slave

Number	Reference	Part number	Description	Power (mW)	Tjunction max (ºC	Tambient max (ºC)
1	U1	ALCOR64-BGA256	ALCOR asic chip	980		
2 (*)	U2 (*)	LMK1D2102-VQFN16	Clock buffer	150	135	85
3	U3	PCF8575RGER	I/O expander	0.1	125	85
4	U8	ADP1761ACPZ-R7	Linear voltage regulato	80	125	85
5	U5	ADP1752ACPZ-2.5-R	Linear voltage regulato	25	150	85
6	U9	ADP1761ACPZ-R7	Linear voltage regulato	55	125	85
				1290.1		
	(*)	this component is likely to be moved to the RDO in a next iteration of the eletronics				



RDO

Number	Reference	Part number	Description	Power (mW)	Tjunction max (ºC	Tambient max (ºC)
1	U9	xcau15psbvb484-2-e	Xilinx Artix Ultrascale+	2726	100	85
2	U7	SI5319C-C-GM	Clock multiplier	457	125	85
3		VTRX+		156		
4	U11	SI53306-B-GM	Clock buffer	75	125	85
5	U13	SI5326B-C-GM	Clock multiplier	457	125	85
6	U12	MPF50T-FCSG325E	Microchip PolarFire	438	100	85
7	IC1	MT25QU01GBBB8E1	Flash Memory 1Gb	149	125	85
8 (*)	U1 (*)	ATTINY417-MNR	ATMEL MCU	6	125	85
9	IC7	LTM4709HY#PBF	LDO Low	1085	125	85
10	IC2	LTM4709HY#PBF	LDO High	1392	125	85
				6941		
	(*)	this component will be updated with a different one in a next iteration of the electronics				



FEB master = 2x1290 mW
FEB slave = 2x1290 mW
RDO = 1x6941 mW

Total thermal power = 12101 mW

We assume **15 W/PDU**

Cooling and heating plant: main requirements

Carrier fluid

- working range from -50 °C to 100 °C
- dielectric fluid (preferable)

Cooling/Heating system type

- Closed-loop system with freeze protection, ideal for both cooling and heating operations, and designed to prevent leakage

Annealing

- The annealing of the dRICH PDUs will take place once the dRICH has been installed inside the ePIC apparatus
- This process will need to be repeated many times throughout the detector's lifetime.
- During the assembly of the dRICH, it will also be necessary to cool down and warm up the PDU, so the carrier fluid should be available in the assembly hall too.

Carrier Fluid Options

Silicon Oil	−80 °C to 200-400 °C	High viscosity at low temperatures
PDMS	−70 °C to +120 °C	Low-viscosity silicone oil
Sintetic Fluids (Therminol / Dowtherm)	−75 °C to 300 °C	Medium viscosity at low temperatures
PFPE (Galden)	−80 °C to 250 °C	Like C6F14. Expensive.
Glicole / acqua	−40 °C to 130 °C	risk of freezing

For the temperature range −70 °C to +120 °C, the most practical choice is:

- low-viscosity silicone oil (PDMS) (https://www.swantek.com)
- synthetic fluid such as Therminol LT / Dowtherm (https://www.swantek.com)

PDU Detector

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PDU designed by R. Preghenella

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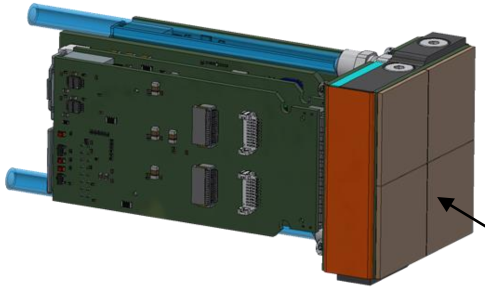


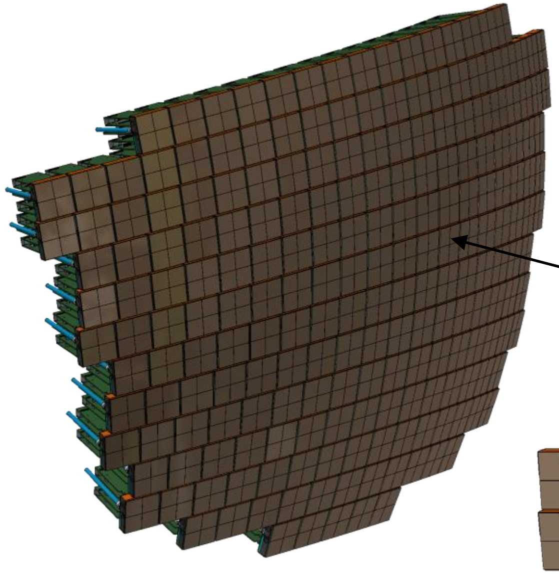
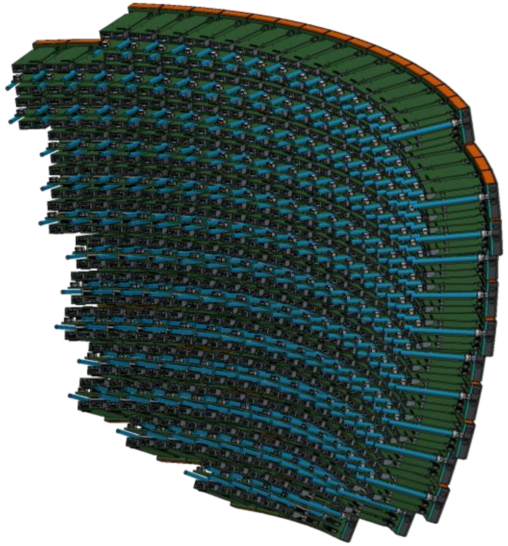
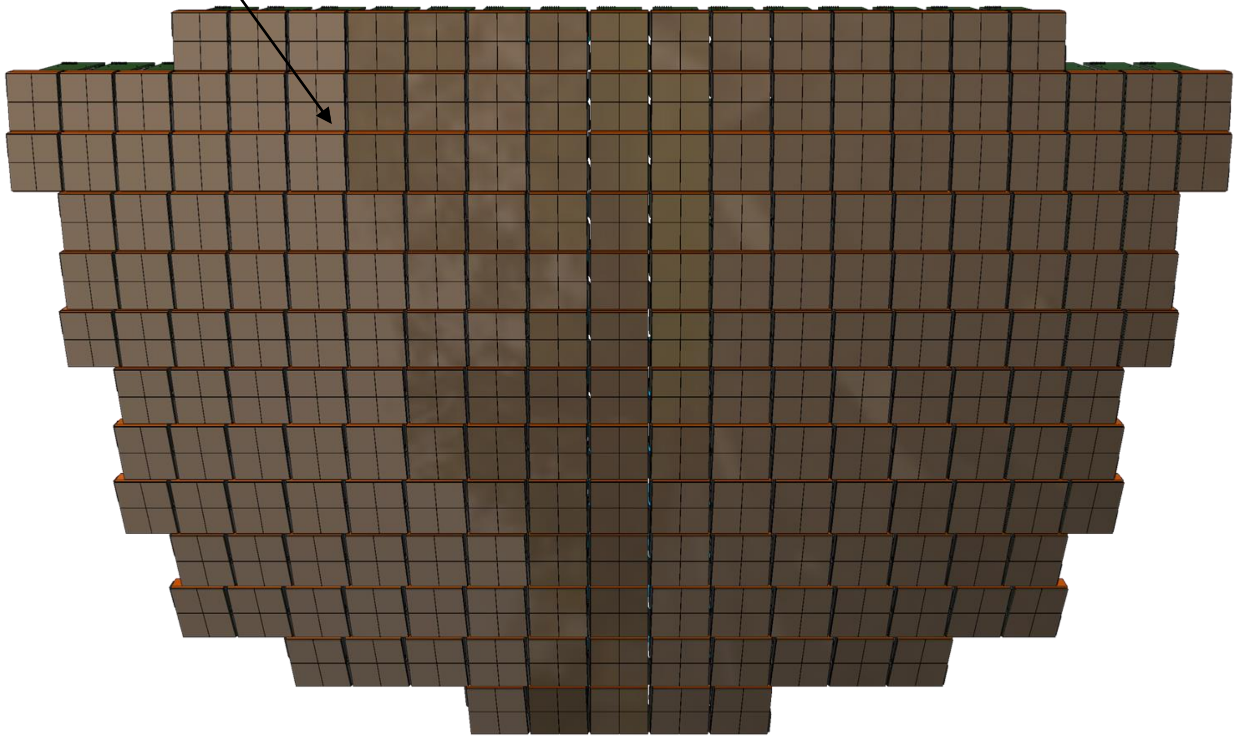


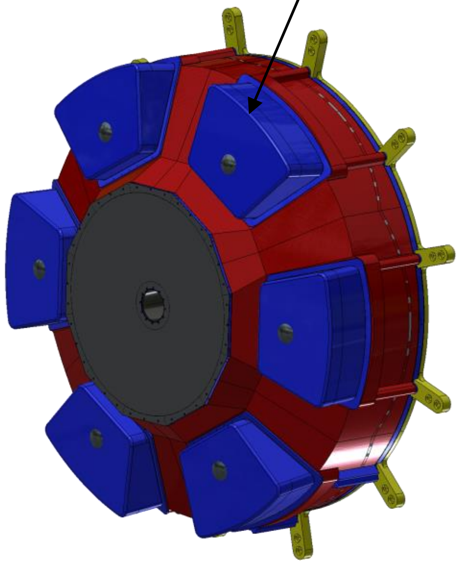
Photo Detector Unit (PDU)

Detector





Detector Box



The detector is composed of 208 PDUs arranged on a sphere with a radius of 1100 mm

PDU Detector

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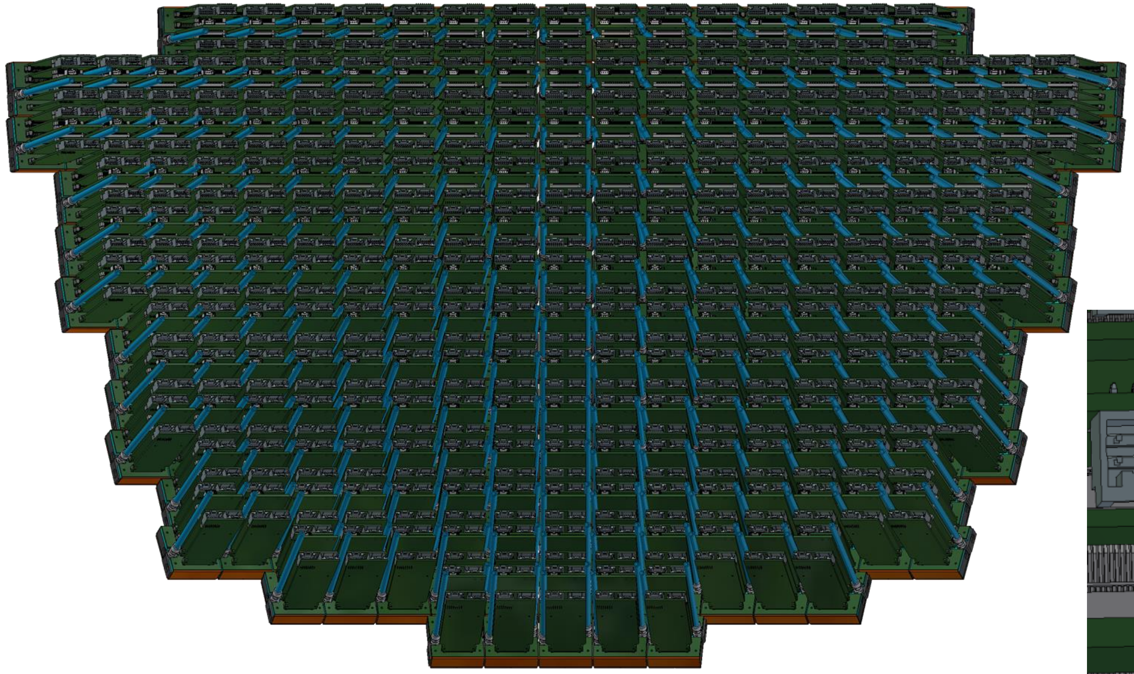

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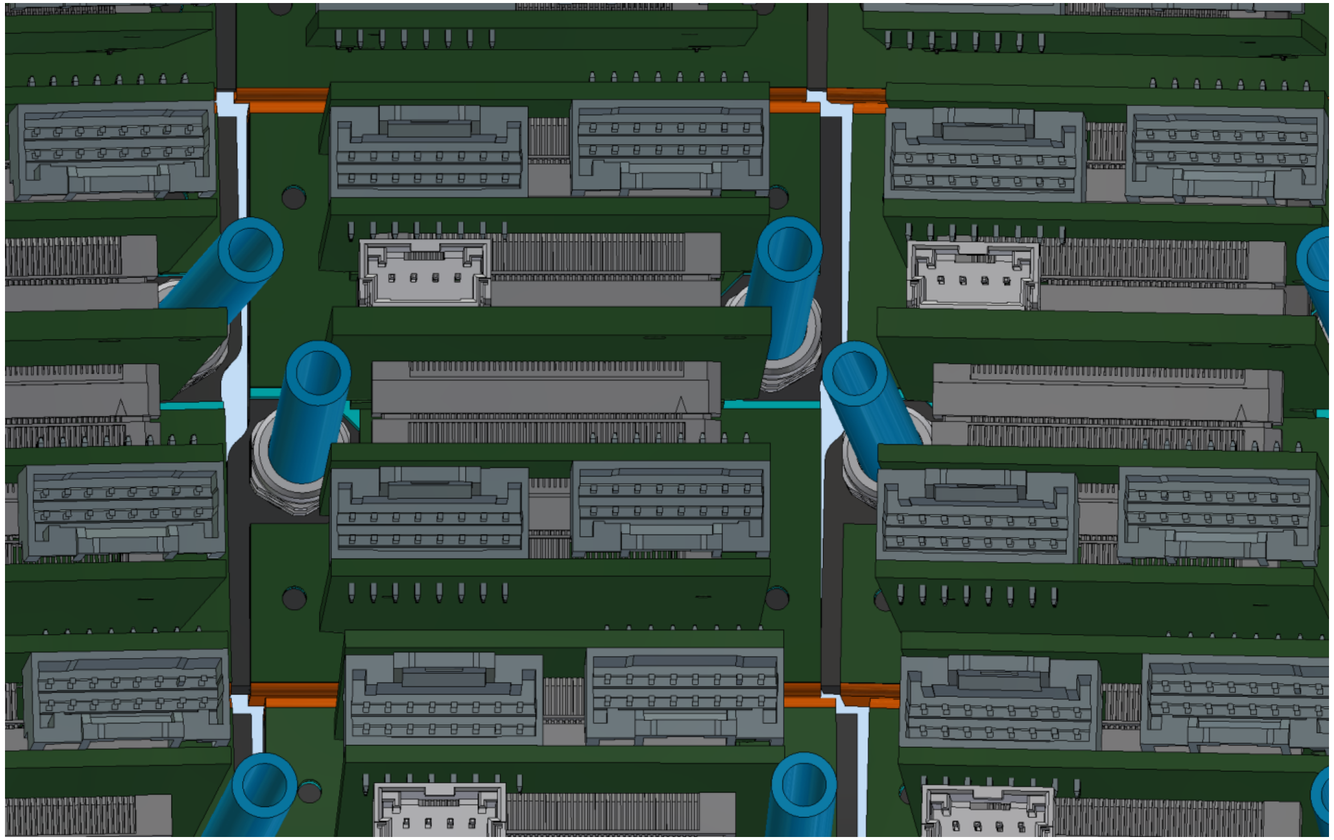
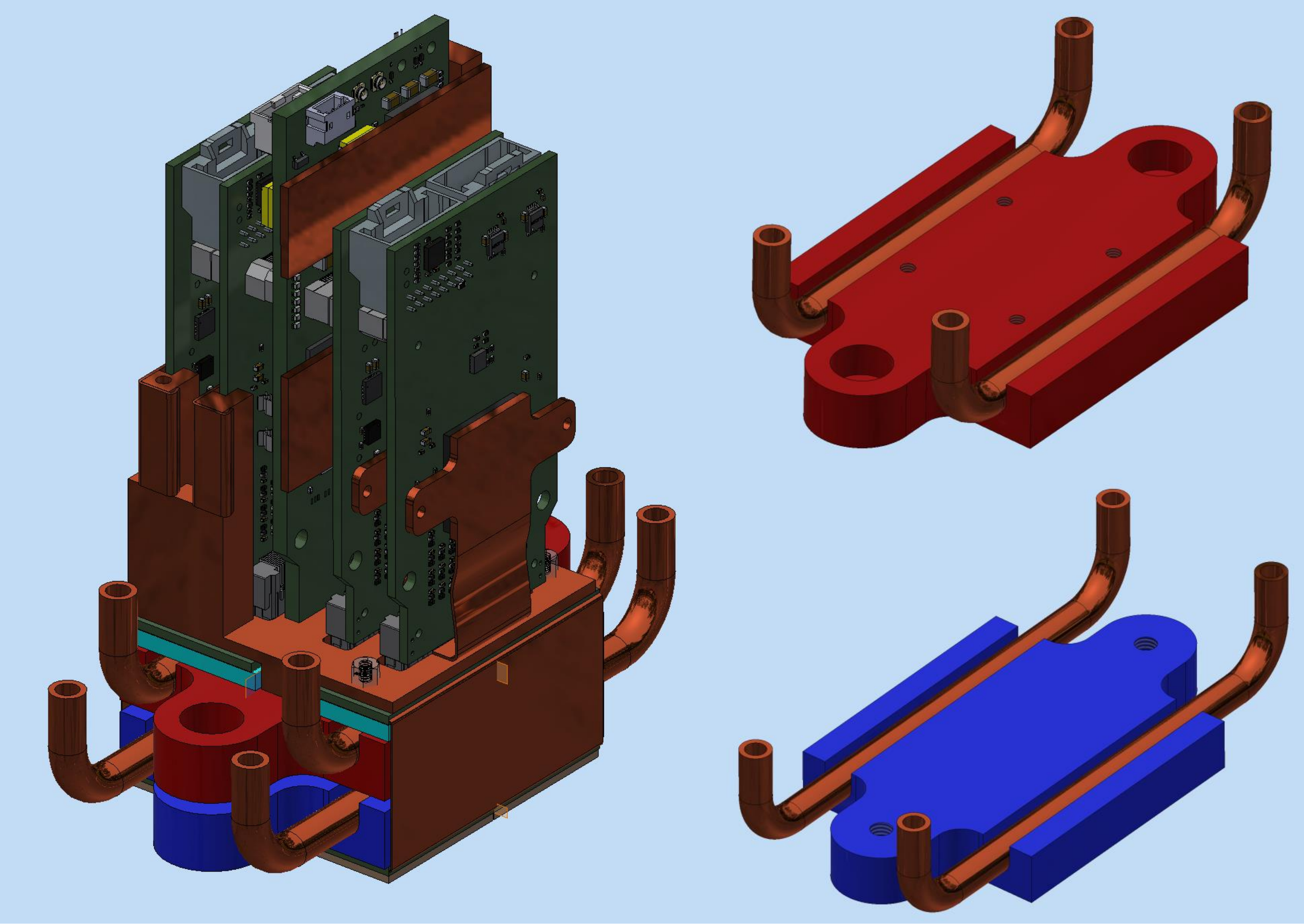
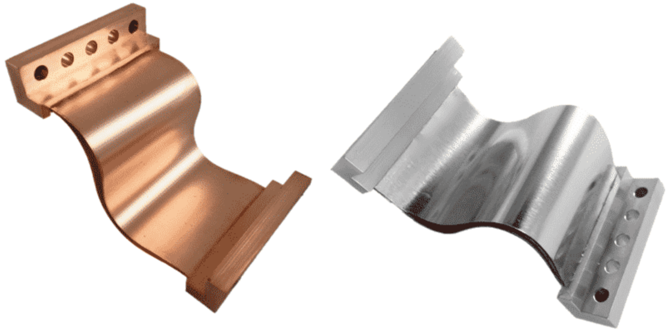


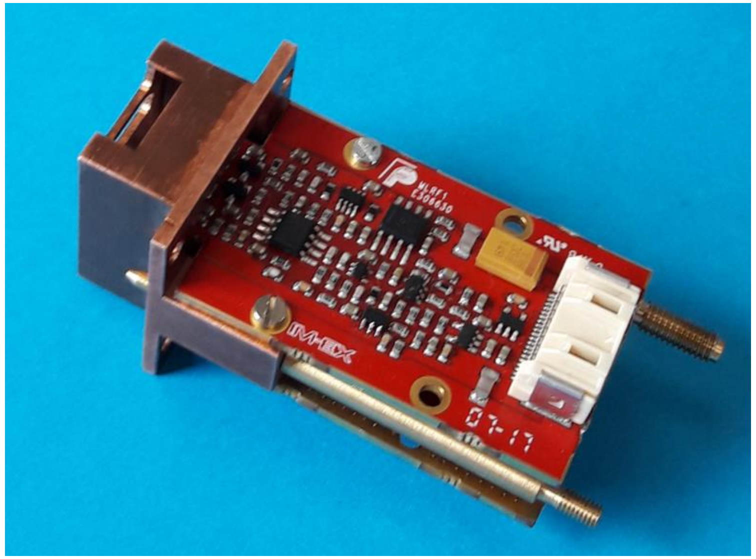
- the mechanical joint between PDUs is difficult to realize;
- maintaining the spherical geometry is challenging;
- the hydraulic series connection increases the pressure drop;
- there is a higher risk of fluid leakage;
- the number of pipes is very large;
- maintenance operations are complicated.

Double Heat Exchanger: proposal





Thermal Straps made of graphite & graphene or copper



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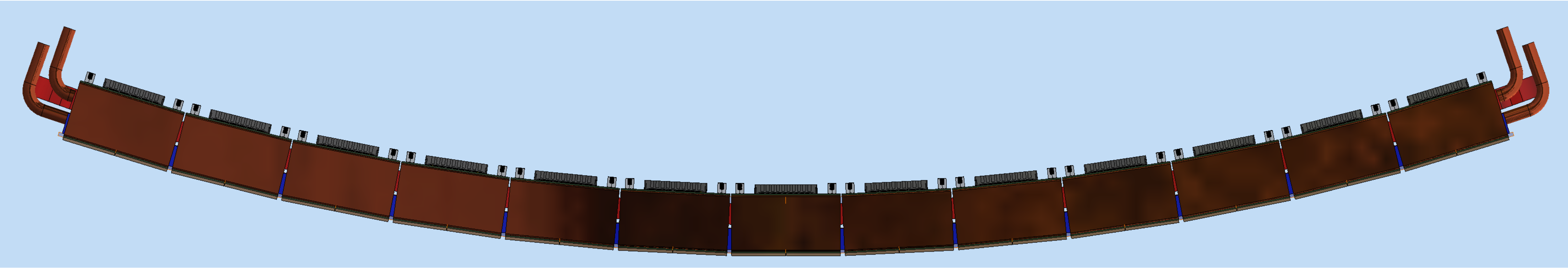
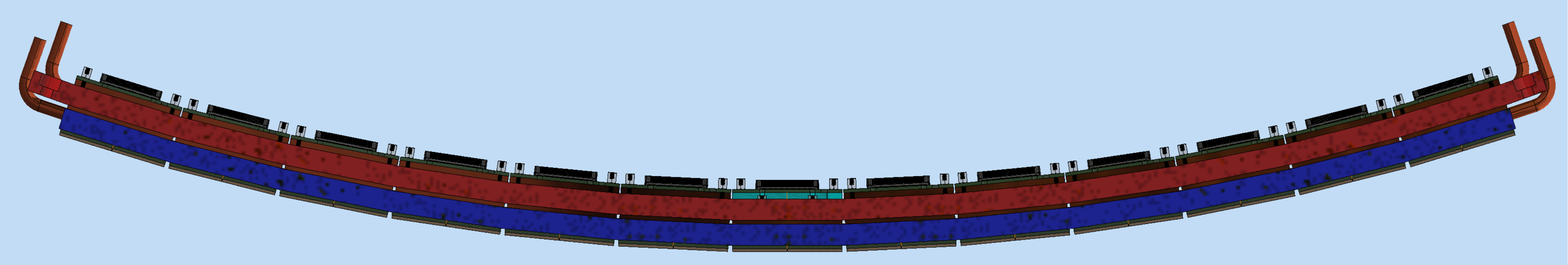
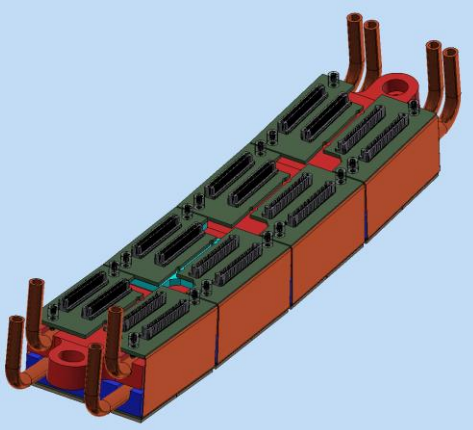
Double Heat Exchanger: proposal







Example: column with 13 PDUs

Double Heat Exchanger: proposal

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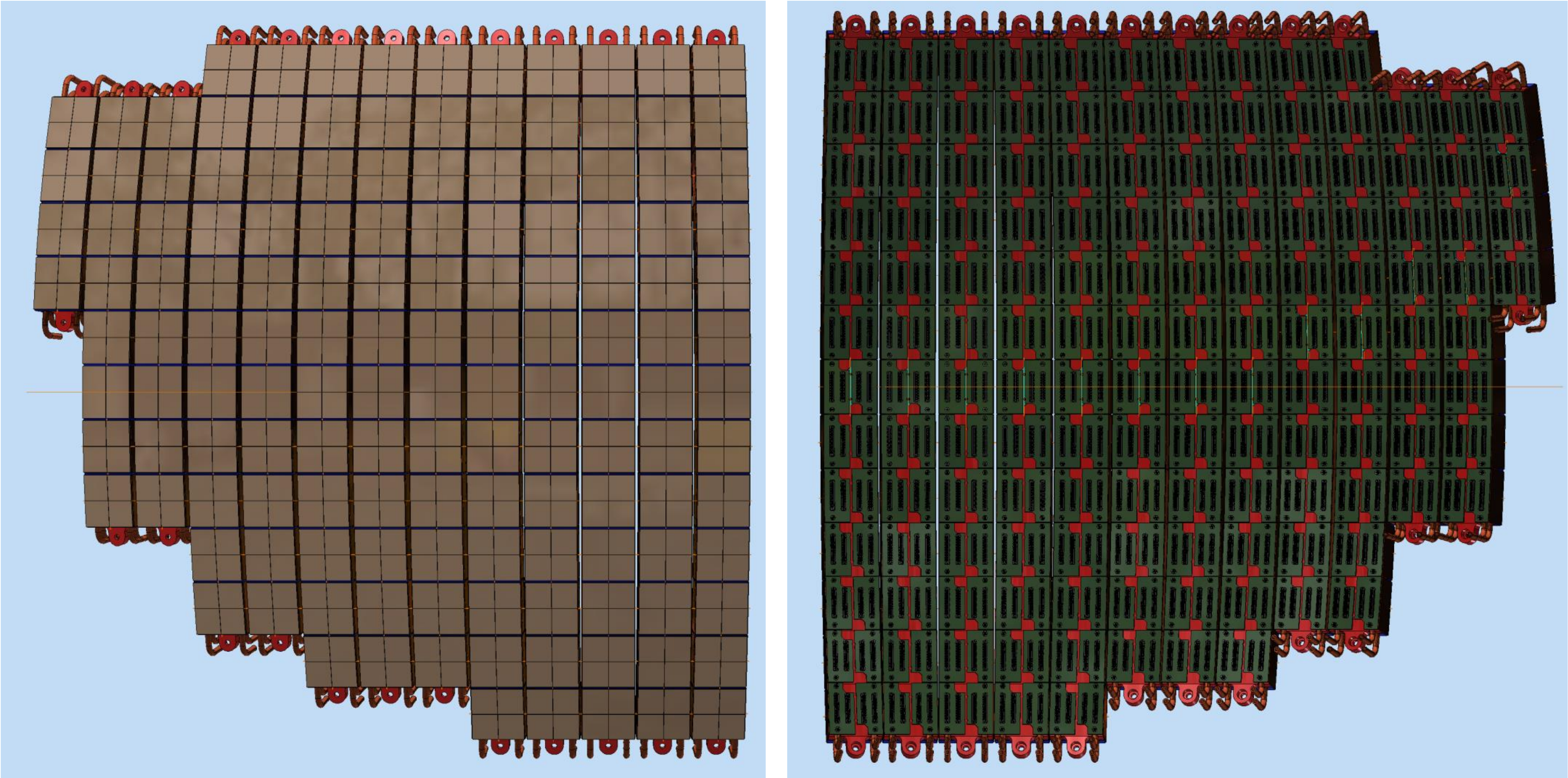
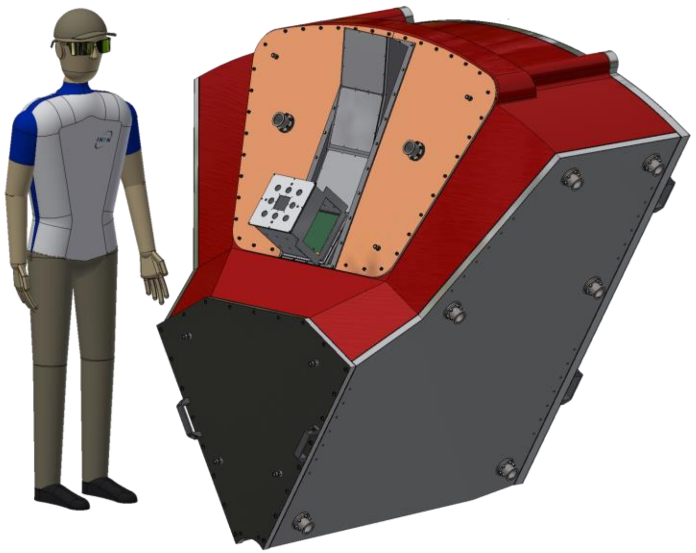
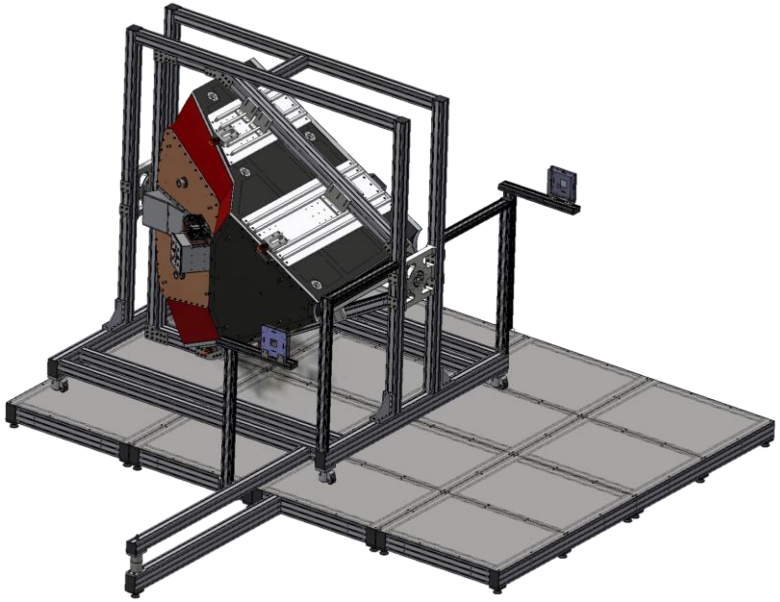
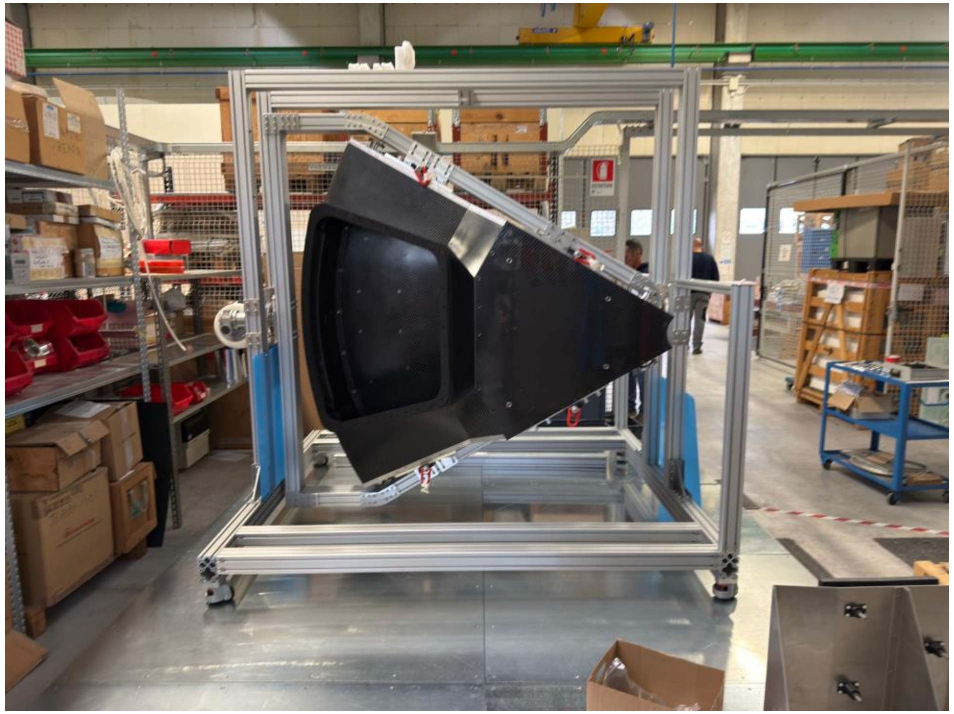


dRICH Prototype







Building a **full-scale (1:1)** prototype representing one-sixth of the complete dRICH detector.

Purposes:

- **Validate the preliminary design**
- **Test beam:** study and optimize the performance of dRICH components

dRICH Prototype

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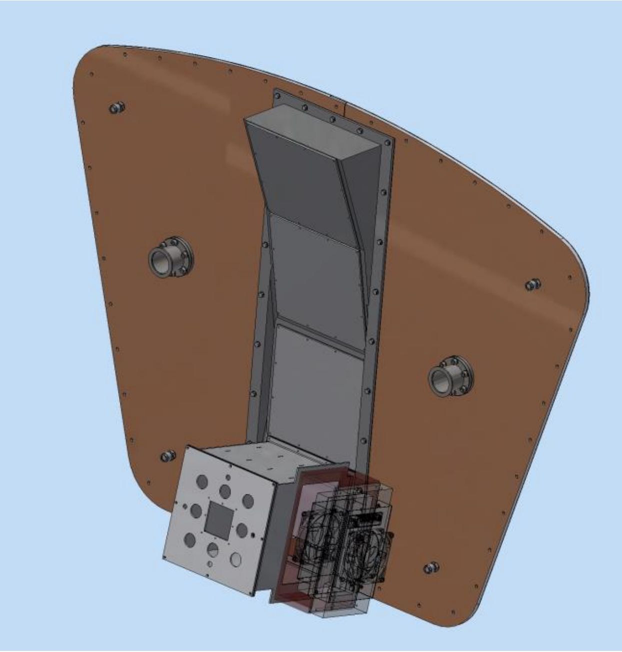
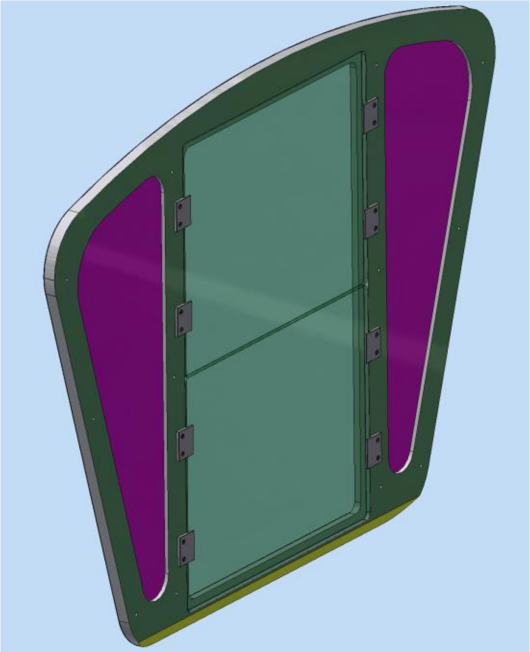
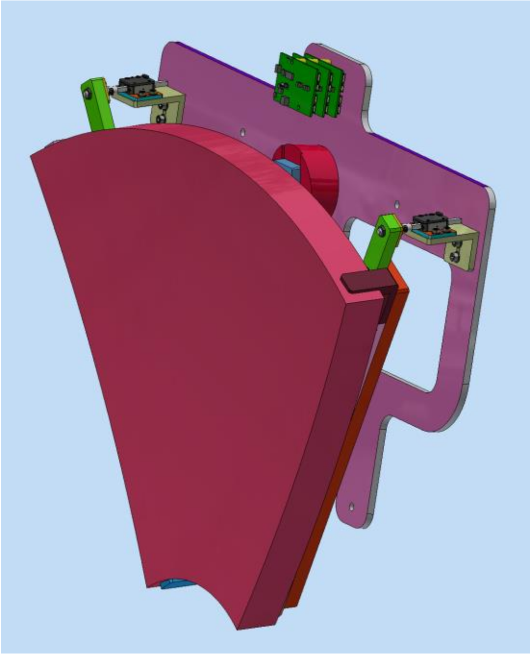
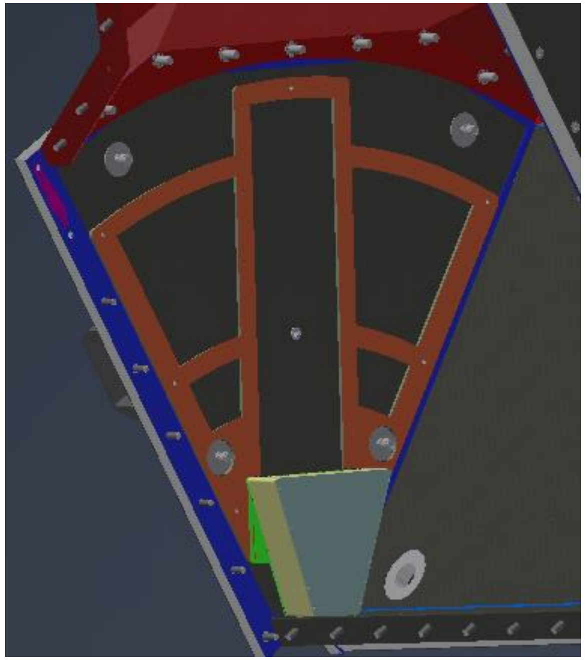
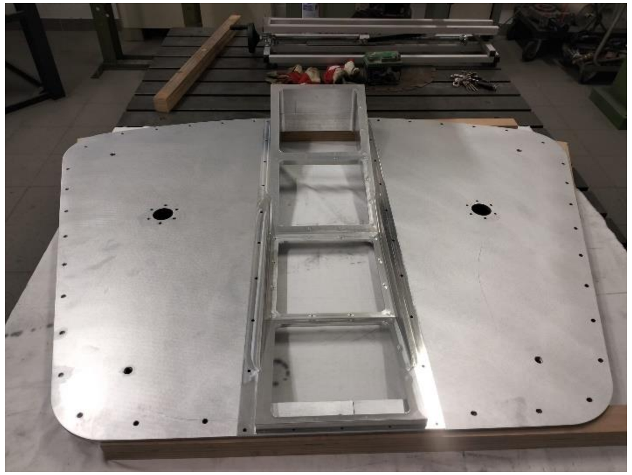

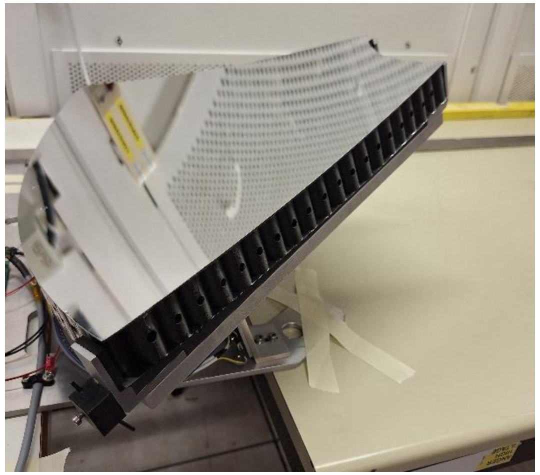
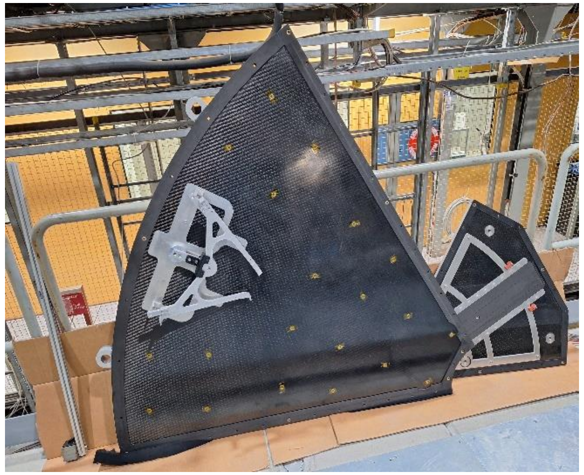

dRICH Prototype: test beam setup installed at SPS

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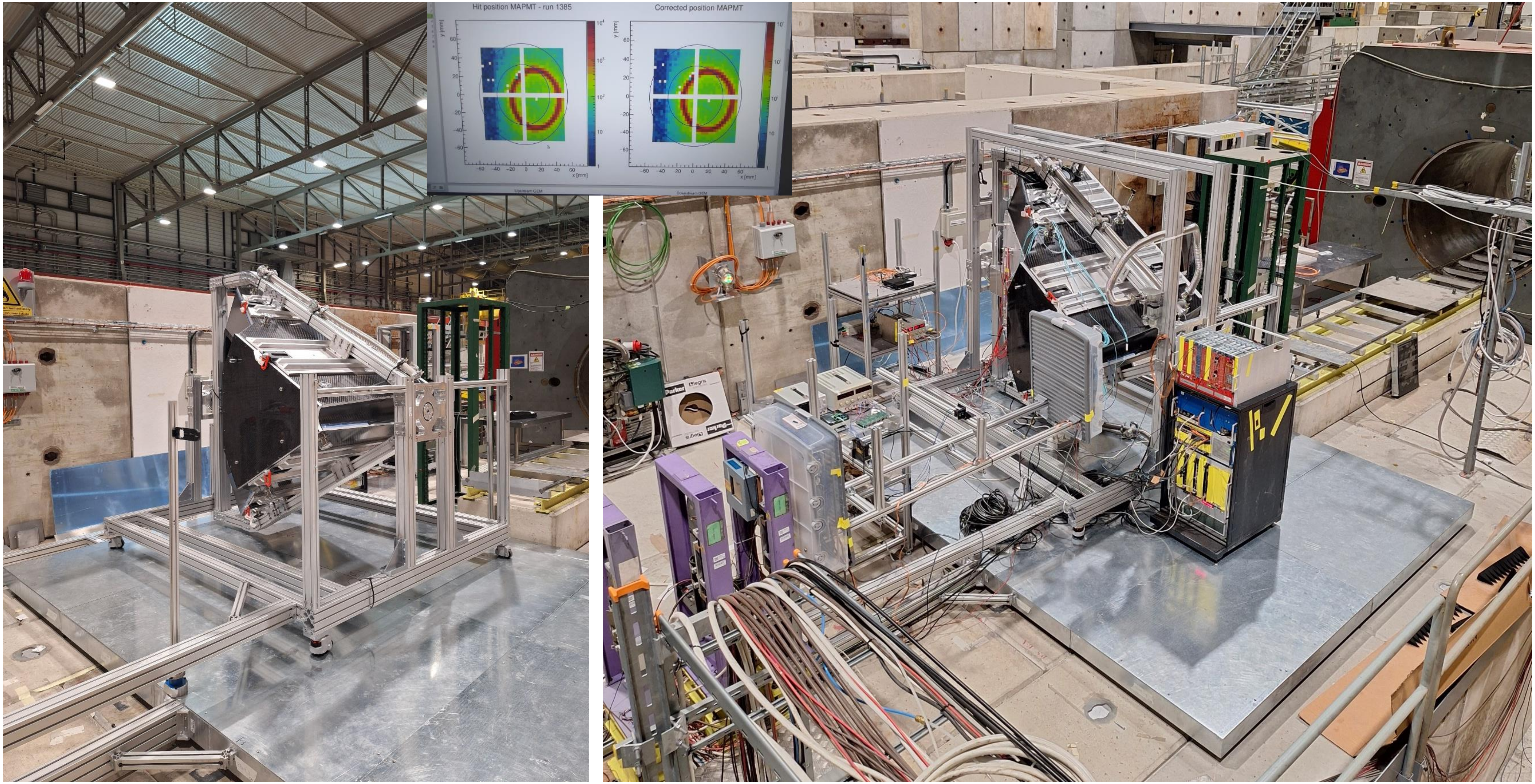

dRICH Prototype: test beam setup installed at PS

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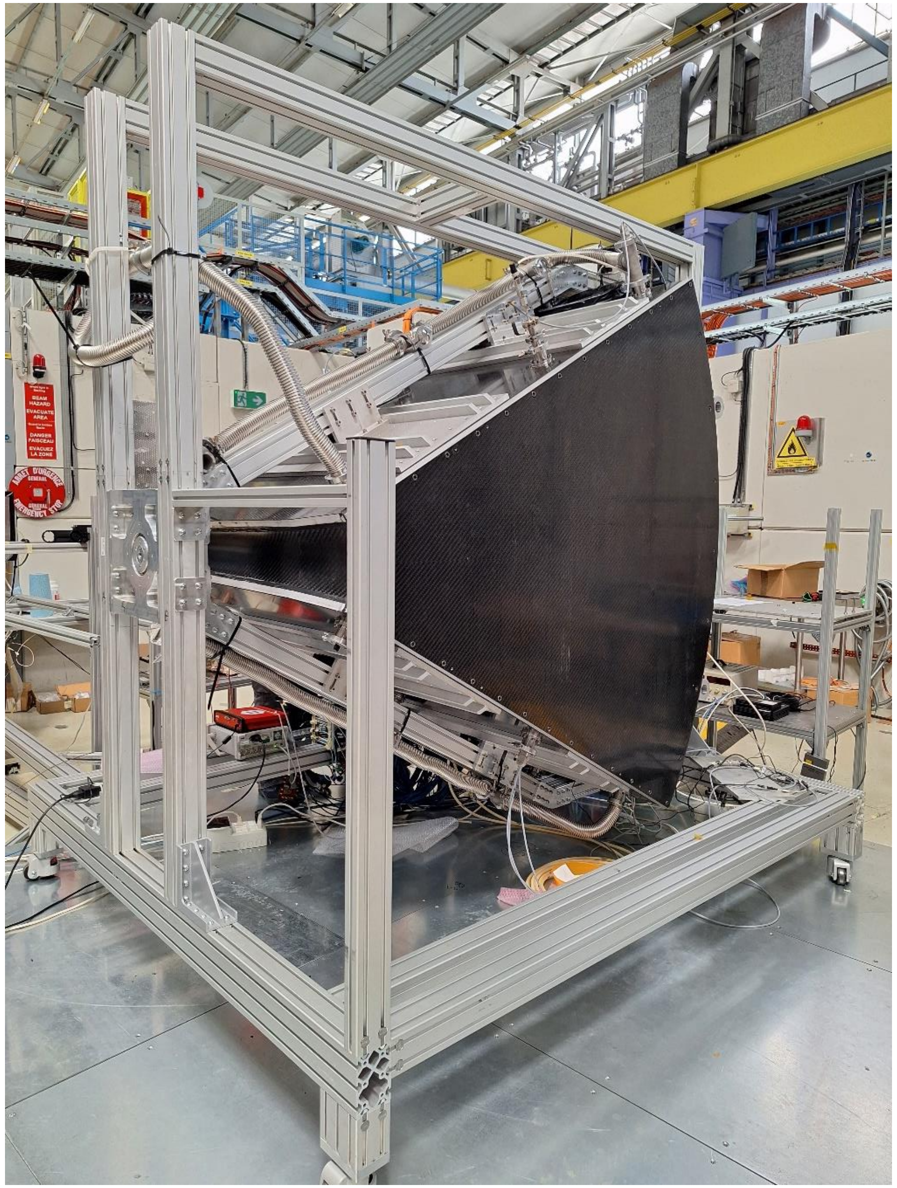

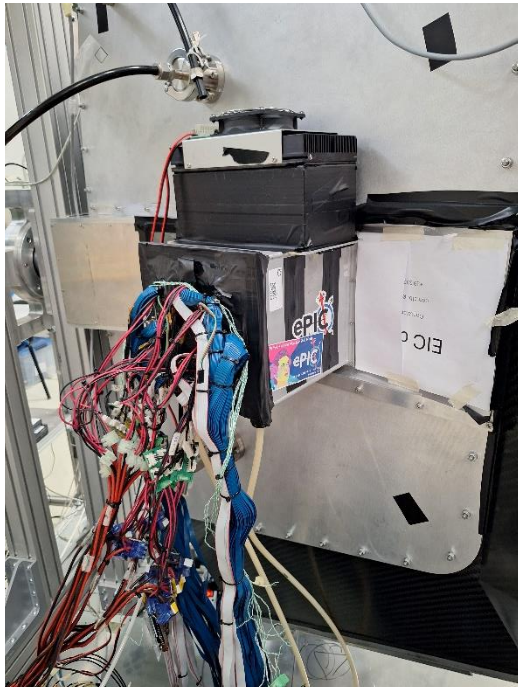

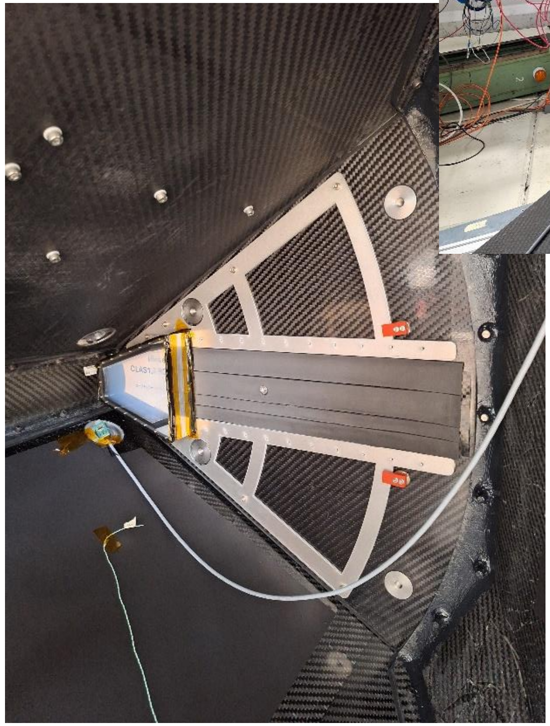

What went well?

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- The setup was assembled fairly quickly on the test platform (SPS and PS).
- The gas enclosure is sufficiently rigid.
- No structural failure.
- The flat gas enclosure seals provide a good seal.
- Excellent light seal.
- Relatively easy access to the internal components (mirror, aerogel and quartz window).
- Easy to transport, less problematic than expected.

Problems observed and analysis of their causes

- Sealing problems with C2F6: the flat gaskets used with shims work well with nitrogen and CO_2, but with C2F6 they start to leak after a short while. C2F6 is a dense gas and behaves almost like a liquid.
- Sealing problems at the joints of the gas enclosure: the same problems as those encountered with the flat gaskets on the windows.
- Difficulties in adjusting the mirror (PS): the mirror drive mechanism is over-constrained, so the motors are overloaded.
- Another problem is that C2F6 appears to act as a lubricant and, as the piezo elements remain under load due to friction when not powered, they tend to move under load.
- Reflection from the carbon fibre: the inner surfaces are glossy and reflect light off the mirror.
- Aerogel container: transparent base and poor gas-tightness.

Lesson Learned and Corrective Actions

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- Sealing issues with C2F6: the flat gaskets are critical; the problem was resolved by removing the spacers. Flanges will need to be fitted to accommodate O-ring seals.
- Sealing problems at the gas enclosure joints: the flat gaskets could be removed and all the gas enclosure components glued together, which would also improve the alignment of the side panels.
- Difficulties in adjusting the mirror (PS): the mirror drive mechanism needs to be completely redesigned.
- Carbon fibre reflection: the interior of the gas enclosure must be painted with matt black paint or lined with a matt black film.
- Aerogel container: introduction of O-ring seals and an opaque base.

Future Priorities

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- Construction and installation of flanges with o-ring seal on the inlet, outlet and quartz windows.
- Improvement of the mirror handling system.
- Improvements of the mirror alignment system.
- Improvements to the aerogel case.
- Mitigation of the light reflections.

Conclusion

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- The prototype proved suitable for the two beam tests. The results were very good.
- Some issues were identified regarding gas tightness and mirror movement.
- The modifications identified will be implemented in the next revision.

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