World’s first conduction-cooled NbTi Magnet System for Magnetic Density Separation

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Urban Mining Corp
Columbus Superconductors
NWO Applied and Engineering Sciences
TU Delft
Radboud University

Magnetic Density Separation?

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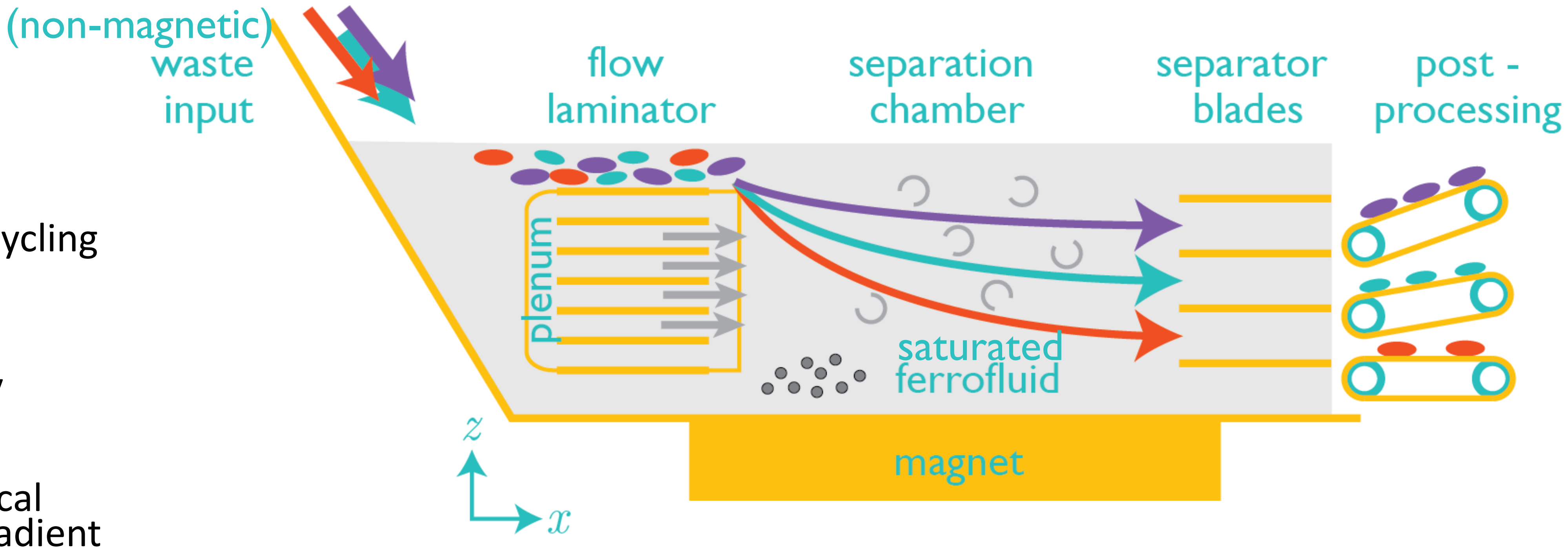
- **MDS:** A novel recycling technology
- Circular Economy
- Ferrofluid + Vertical magnetic field gradient
- Particles are separated by **mass density**



E. Bakker, P.C. Rem and N. Fraunholcz. "Upgrading mixed polyolefin waste with magnetic density separation". In: Waste Management 29.5 (2009), pp. 1712–1717.

Why use *superconductors* in MDS?

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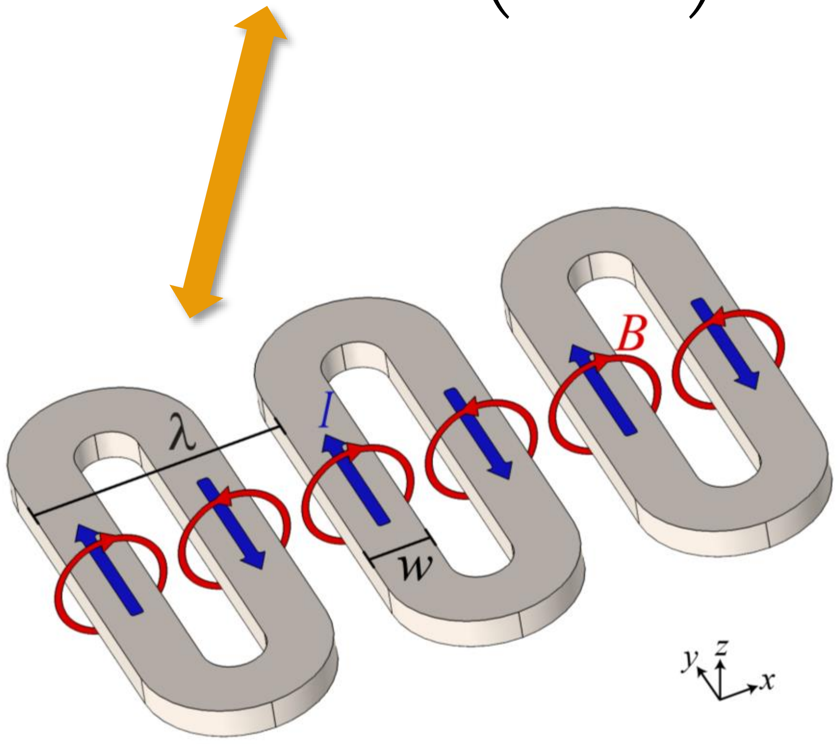
EMS

$$|H|(z) \approx H_0 \exp\left(-\frac{2\pi}{\lambda} z\right)$$



Higher magnetic **field strength** (H_0) & **Larger periodicity** (λ):

- Enhanced separation **resolution** (e.g. for similar plastics)
- **Deeper** usable fluid bed (higher throughput)
- More **dilute** ferrofluid (lower OPEX)
- Wider density **range** (e.g. e-waste)

Project goal: demonstrator magnet

- **3 NbTi/Cu racetrack coils**
- 5 T peak magnetic field
- λ = 600 mm
- Targeted application: electronic waste

J. J. Kosse et al. “Optimum Coil-System Layout for Magnet-Driven Superconducting Magnetic Density Separation”, IEEE Transactions on Magnetics (2021)
J. J. Kosse et al. “Fundamental Electromagnetic Configuration for Generating One-Directional Magnetic Field Gradients”, IEEE Transactions on Magnetics (2021)
J. J. Kosse et al. “Mechanical design of a superconducting demonstrator for magnetic density separation”, SuST (2021)

Project steps

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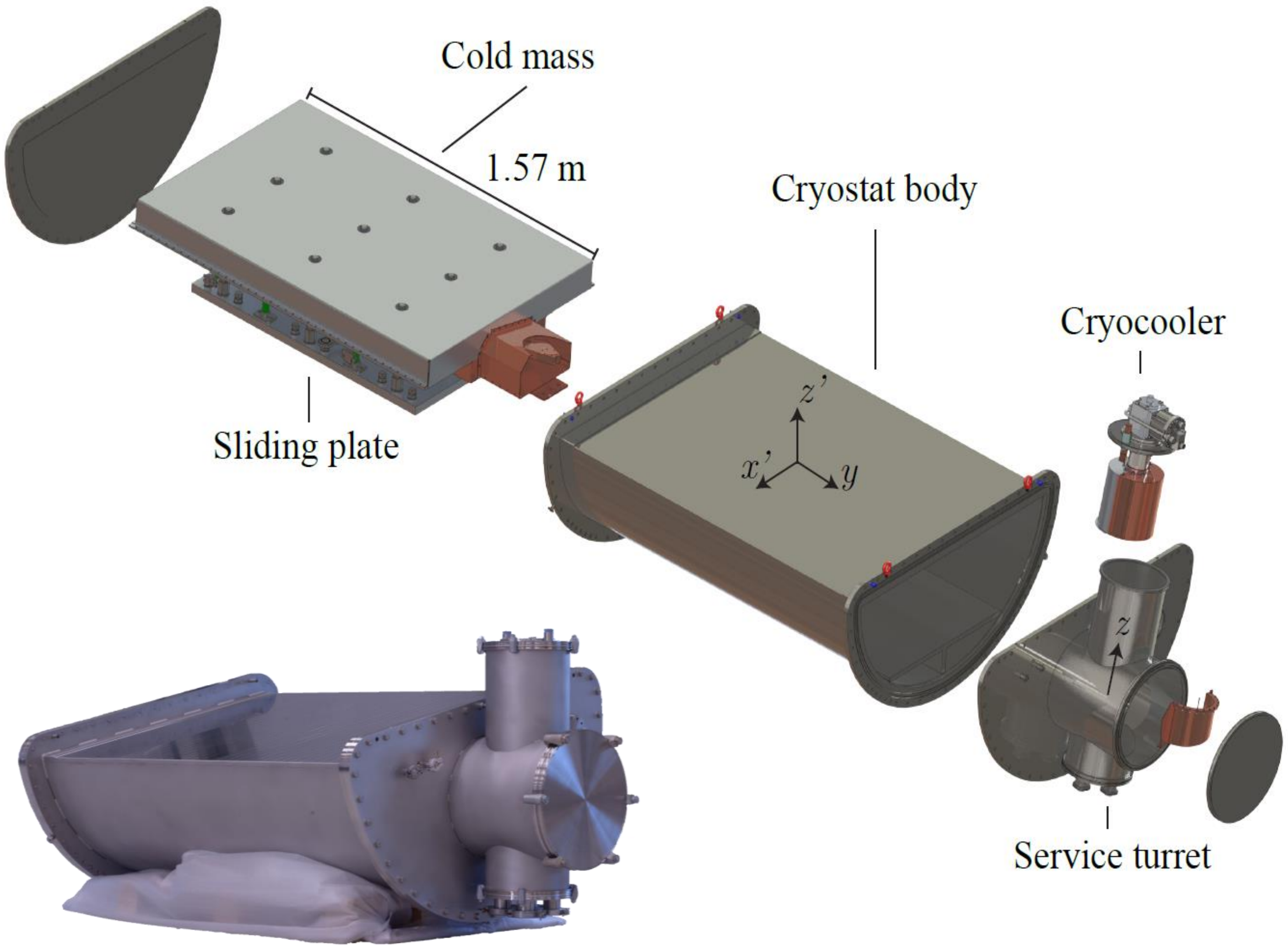
Where we are:

- ✓ Coils in-house manufacturing completed
- ✓ All parts are present
- ✓ Test assembly completed
- ✓ Thermal design validated
- ✓ BSCCO current leads made and tested
- ✓ Cryocooler assembly completed & validated
- ✓ Quench detection & protection completed
- ✓ Coils enclosed in casing



Thermal layout of cold mass
- Single cryocooler conduction-cooled system

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Aluminum radiation shield
+3 multilayer insulation blankets

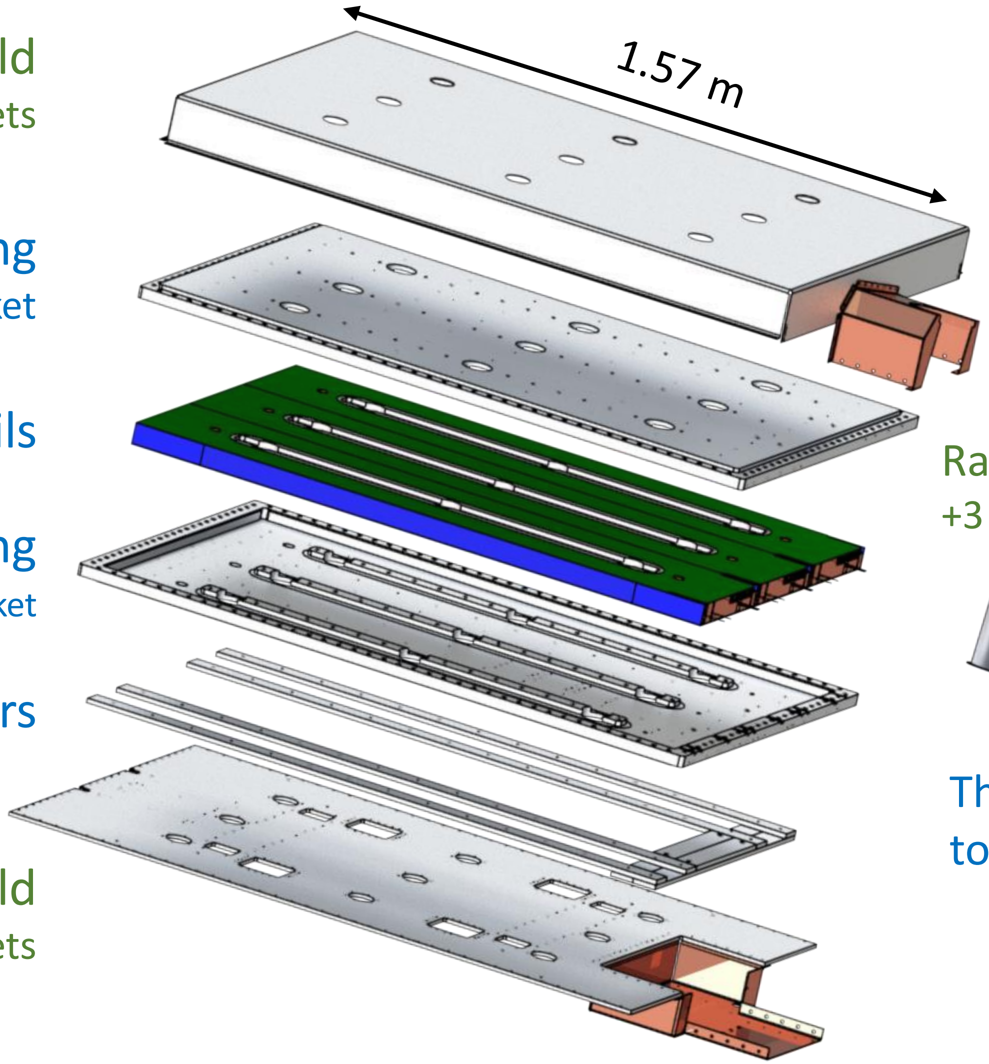
Al alloy coil casing
+1 multilayer insulation blanket

3 NbTi racetrack coils

Al alloy coil casing
+1 multilayer insulation blanket

5N pure Al heat drain bars

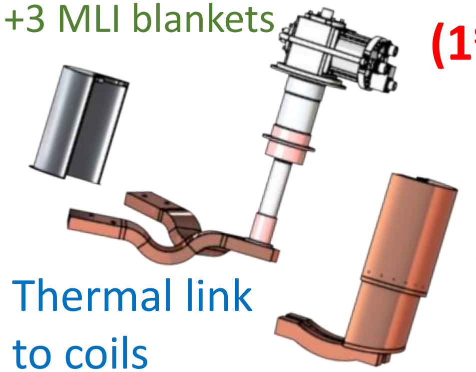
Al radiation shield
+3 multilayer insulation blankets



Heat budget [W]	1st stage	2nd stage
Radiation	9.8	0.14
Support structure	3.1	0.26
Current leads	27	0.18
Total	40	0.58

Radiation shield
+3 MLI blankets

1.5 W GM cooler @4.2K
(1st stage 60 W @77K)



Radiation shield
+3 MLI blankets

Thermal link
to coils

Thermal link
to radiation shield

1st Cool down
- without coils and 5N Al heat drain bars

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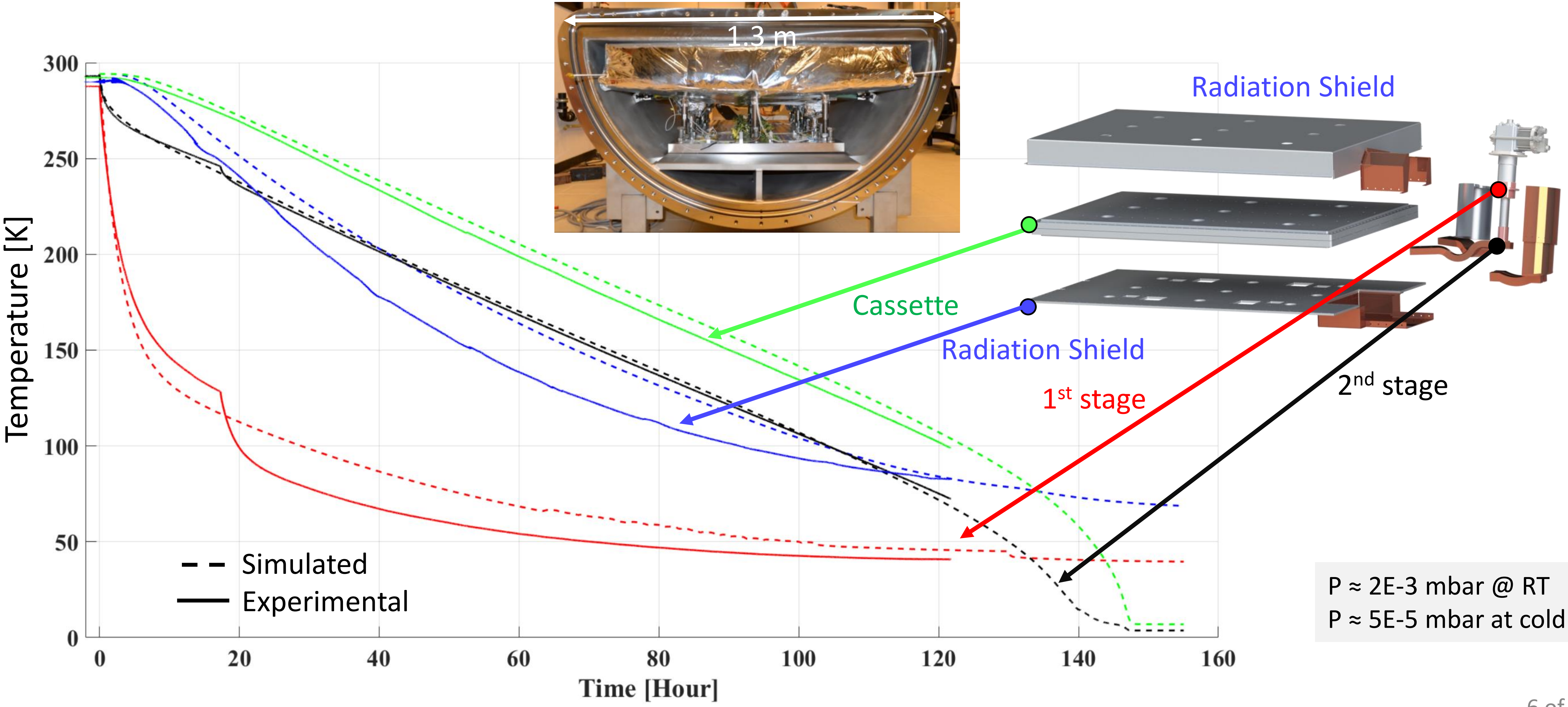
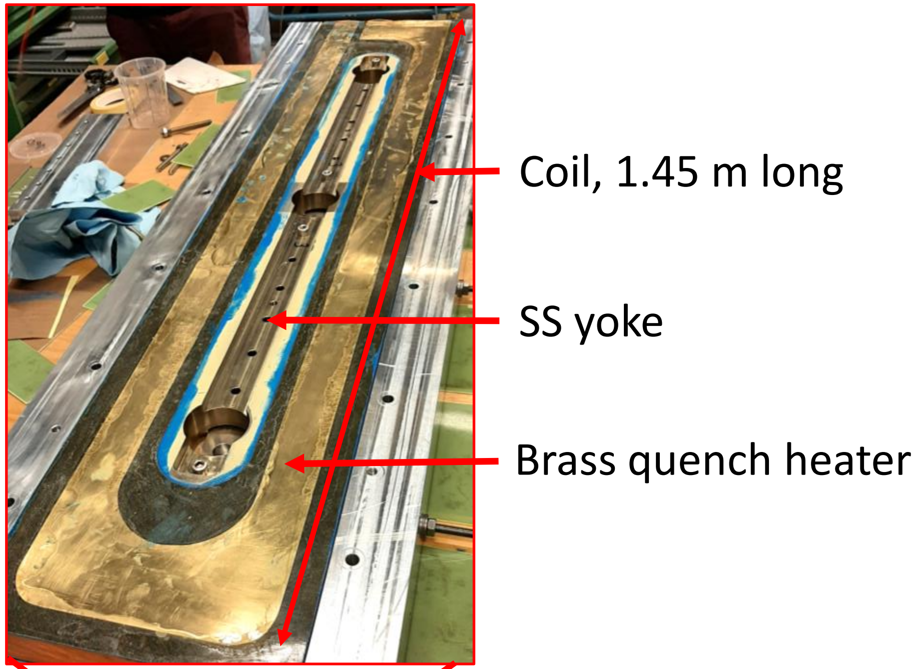
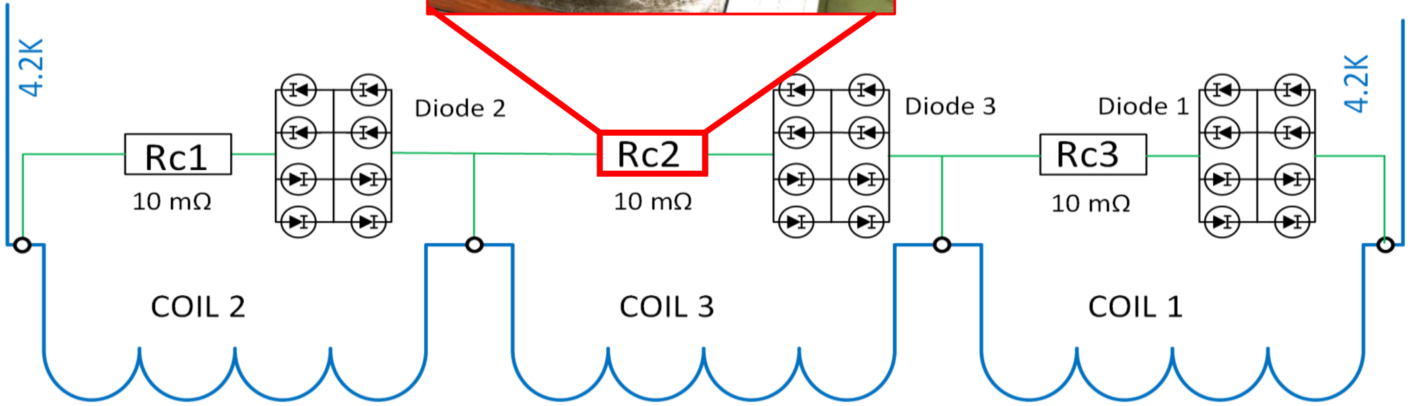


P ≈ 2E-3 mbar @ RT
P ≈ 5E-5 mbar at cold

Quench protection
- Passive system

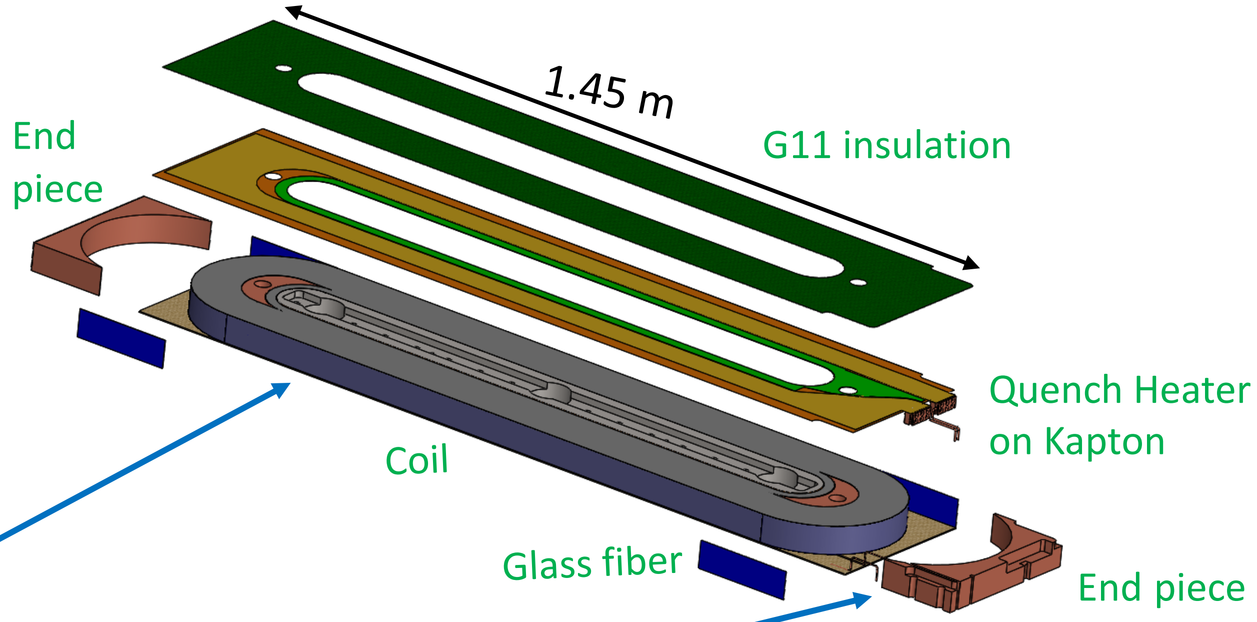
- **Cold diodes**
  - Voltage over coil limited to 4 V
  - Number of diodes doubled for redundancy
- **Brass foil quench heater resistor**
  - Initiates a quench in the case of emergency
  - Propagates quench to other coils (<2.5 ms)
  - Glued on coils for maximum efficiency
- **Stored energy dumped in coils**
  - Worst case in one coil
  - Max. temperature < 135 K

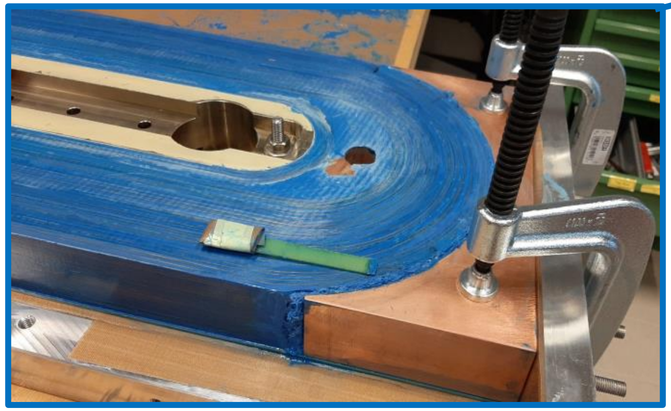




Cold section of quench protection

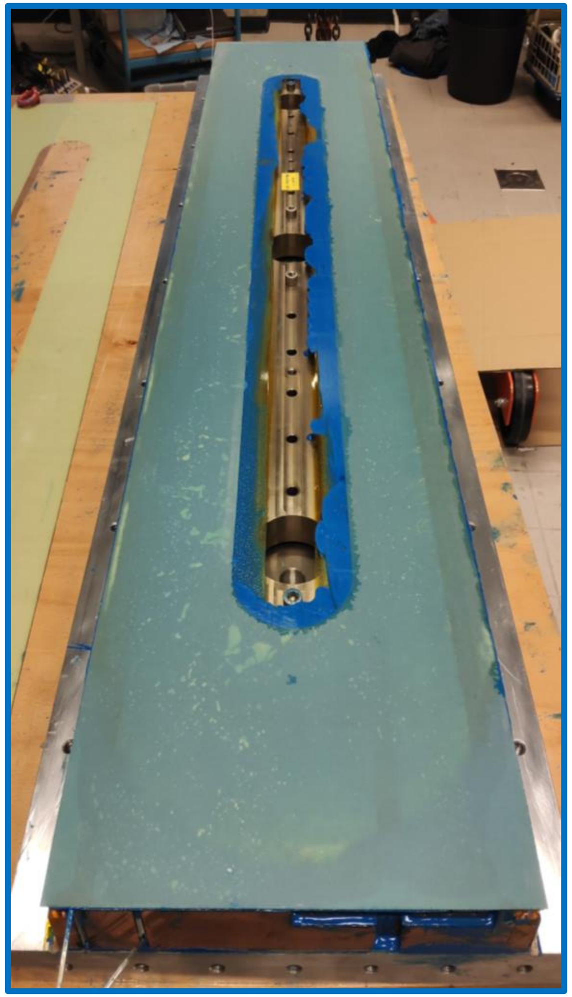
Coil winding and assembly





End piece glued to coil

- ✓ Wet winding
- ✓ G11/glass ground insulation
- ✓ Brass quench heater
- ✓ End piece for shaping



Aluminum alloy casing enclosing the coils

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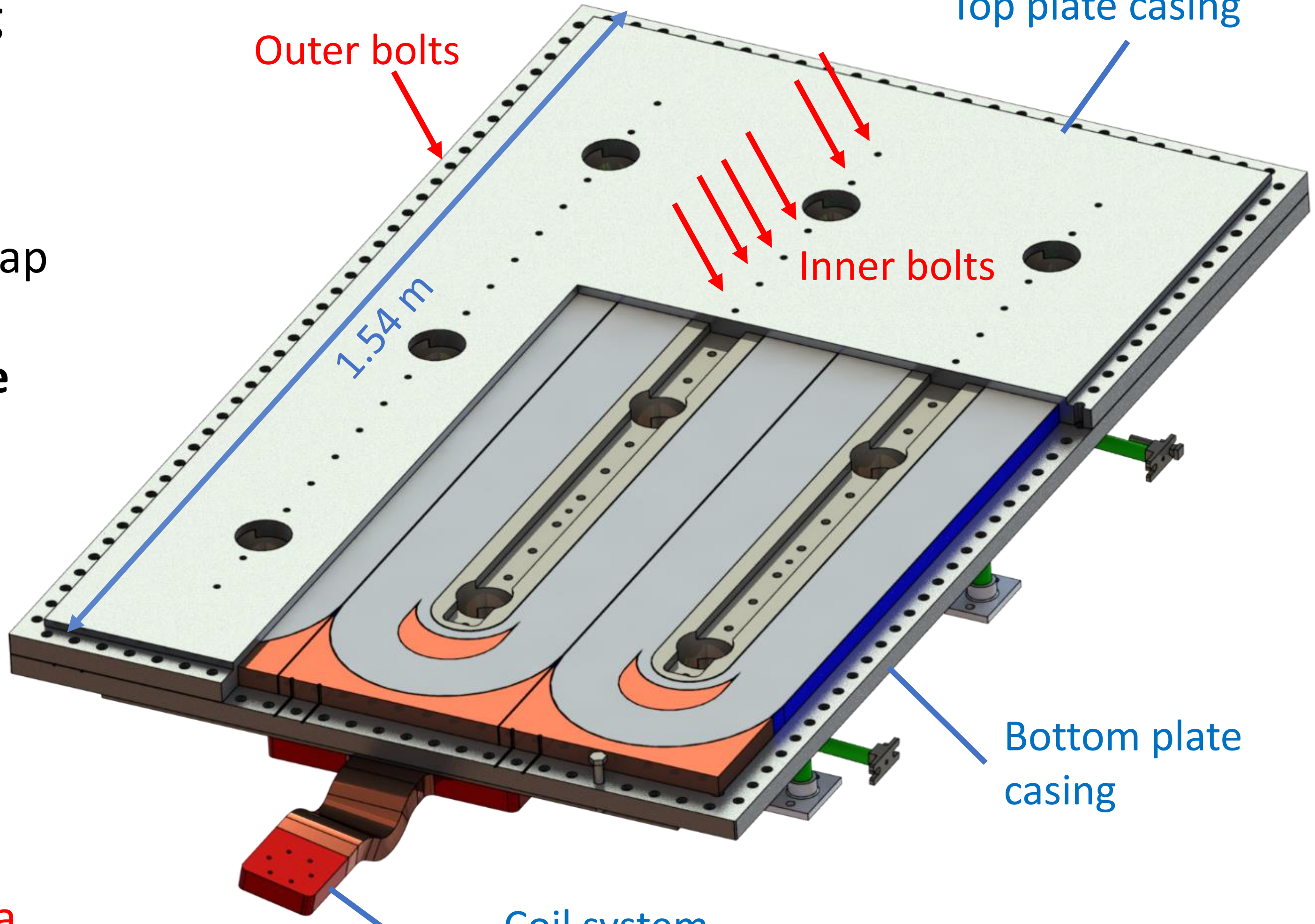
- **Two-part thin high-strength aluminum casing**
  - Keeps coils in place
  - Shrink fits around coils upon cool-down
  - Coils under compression always
  - Ti shims around coils ensures < 0.1 mm gap
- **Conduction coil cooling through bottom plate casing**
  - Good thermal contact required
- **Top plate casing cool down through the coils**
  - Good thermal contact required
- **Aluminum casing plates not perfectly flat**
  - Large number of bolts required
  - Contact area and gap with coils requires a minimum



Contact area test before casing closing

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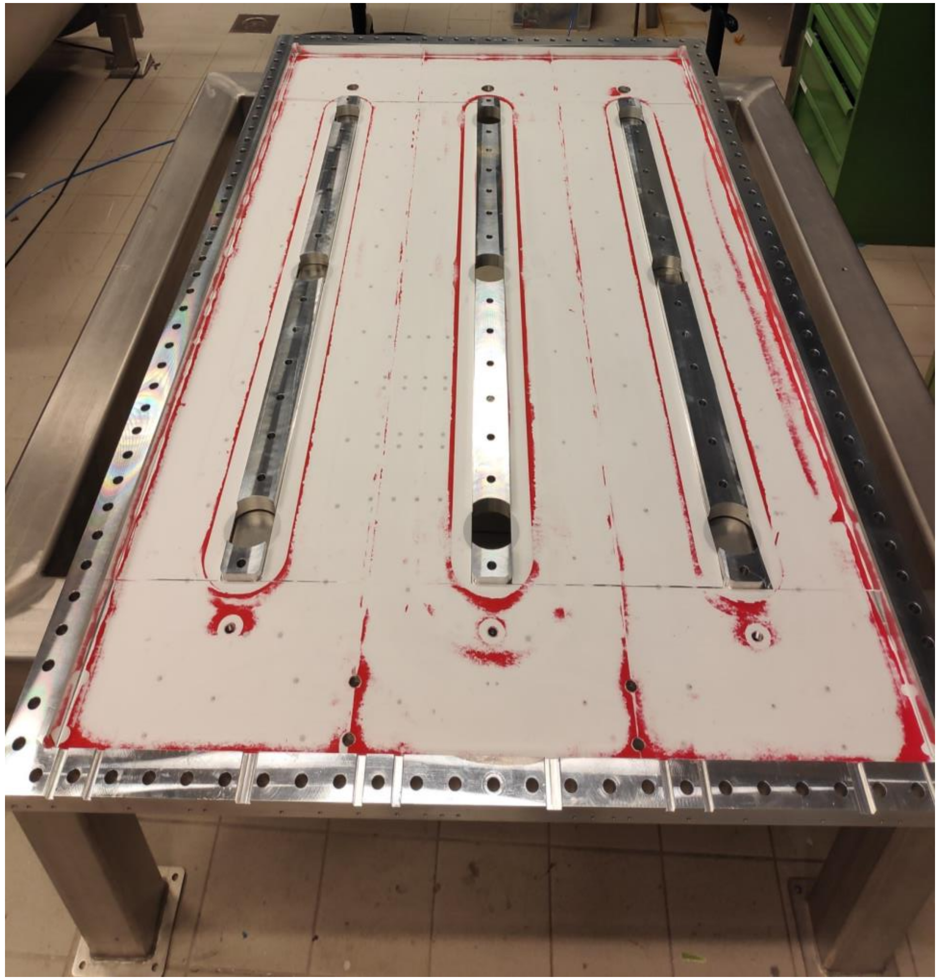
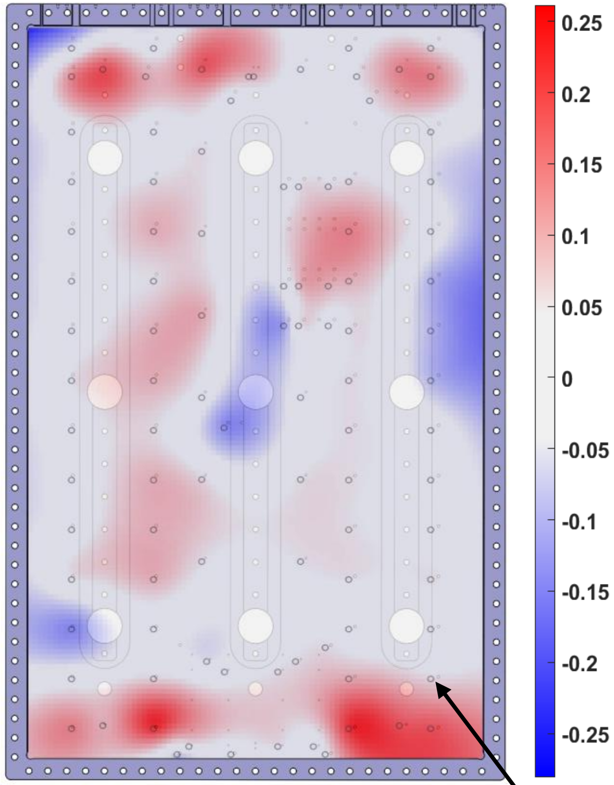


Fuji paper *–* *Good contact around bolts*

Mostly < 0.2 mm gap

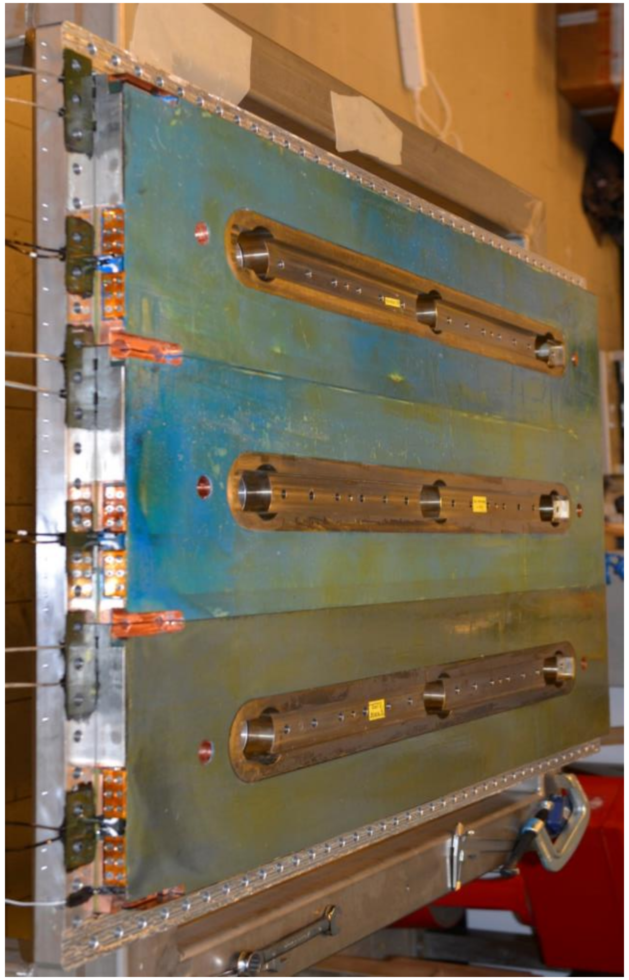
Apiezon-N used to fill voids & gaps

Gap [mm]



Bottom plate casing

Array of holes to check for gaps



Bottom plate casing

Conclusion

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Where we are:

- ✓ All parts are in house, test assembly done
- ✓ Thermal design validated
- ✓ Cryocooler assembly finished and validated
- ✓ Quench detection and protection finished
- ✓ BSCCO current leads finished and tested
- ✓ Coils assembled & inserted in casing

What in next few months ?

- Complete joints and instrumentation
  (20 thermometers, 2 heaters, 8 strain gages, 20 V-taps)
- Integration of cold mass into cryostat
- Cool down & System commission in Jan-March 2022……
- Delivery to the MDS separation plant in Q2-2022