Karlsruher Institut für Technologie

Progress in the cryogenics work package / March 2023

InnovEEA Project Meeting, 08.03.2023

Jonas Arnsberg, Steffen Grohmann

Motivation

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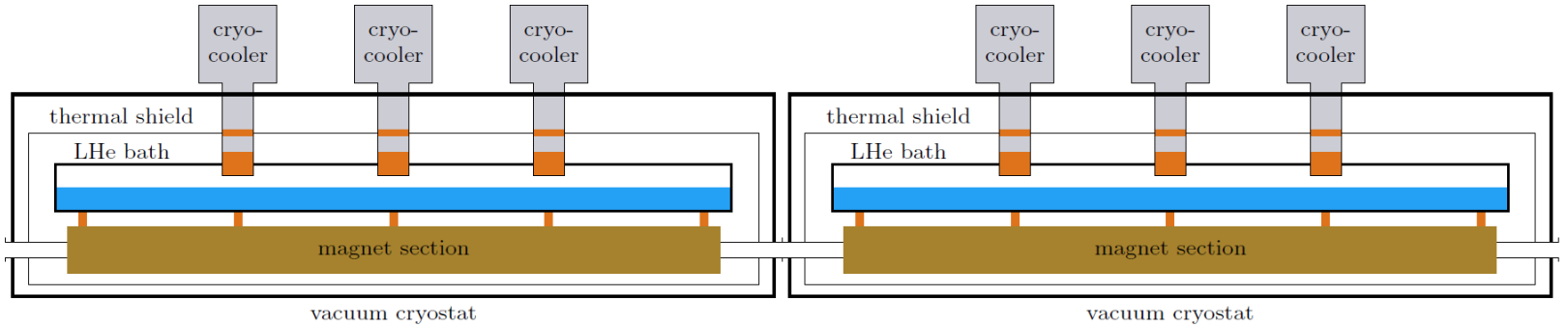
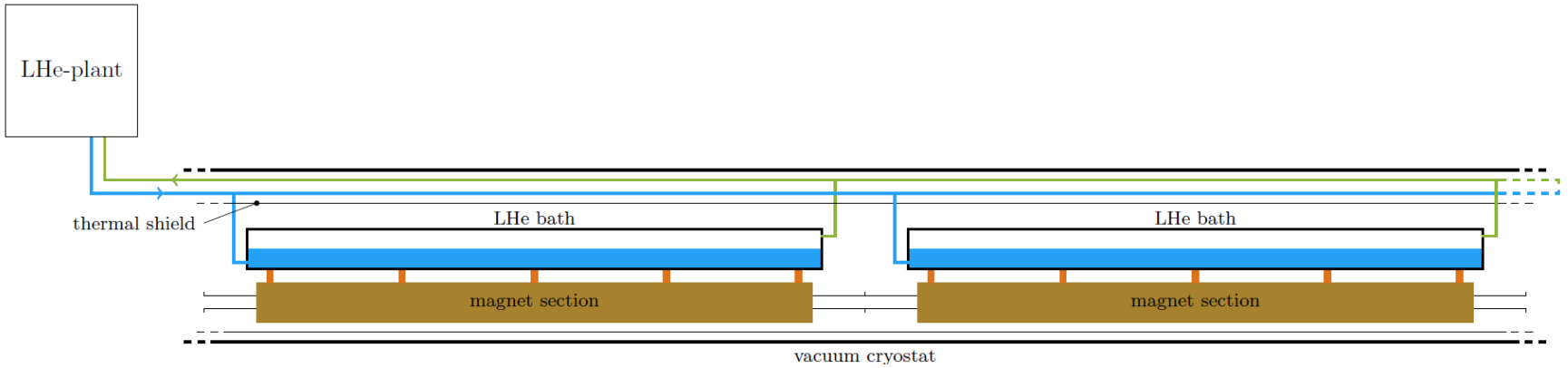
- Comparison of cryostat designs for compact accelerator systems (CompactLight design study)
  - Cryocooler-cooled design:



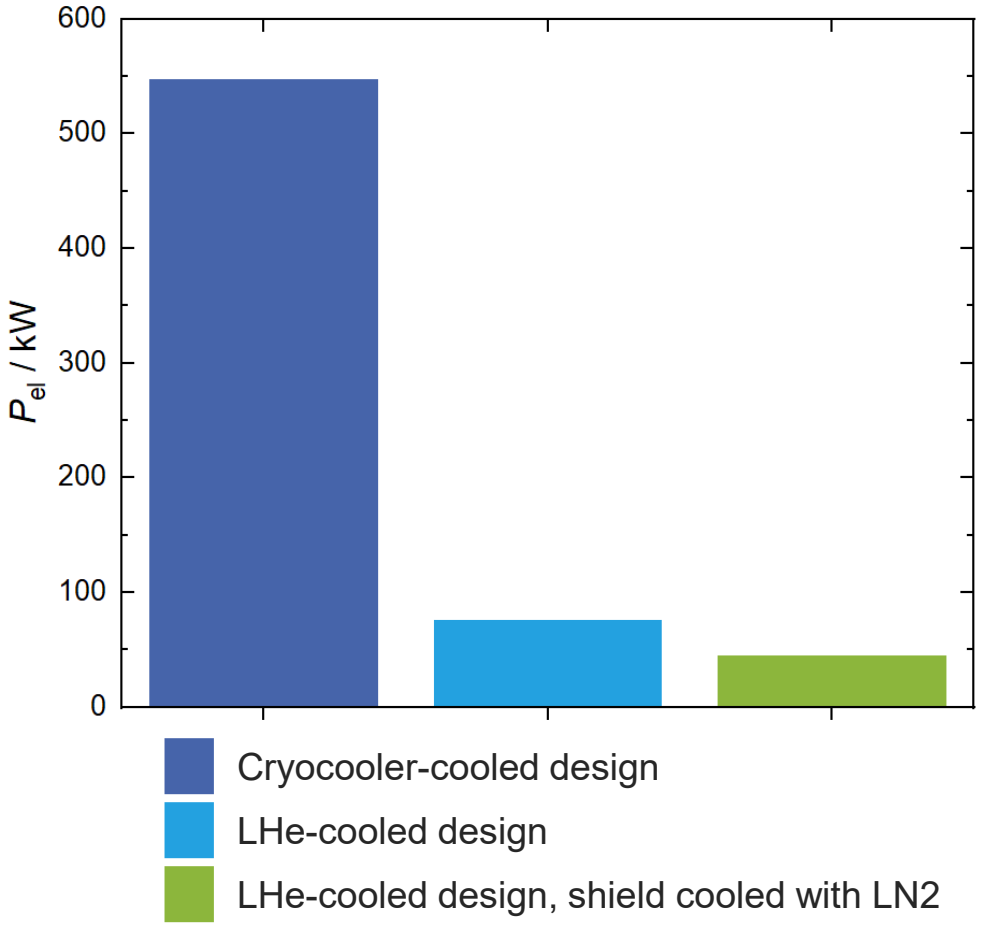
  - LHe-cooled design:



Motivation

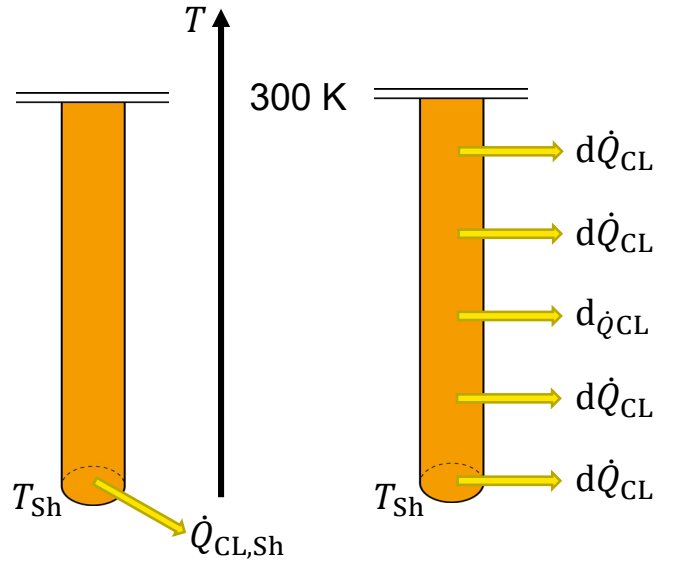
- Heat load estimation for both cryostat designs
  - Cryocooler-cooled design
  - LHe-cooled design
- Comparison of required **power input** for cooling
- Cryocooler-cooling especially interesting for compact and/or stand-alone cryostats

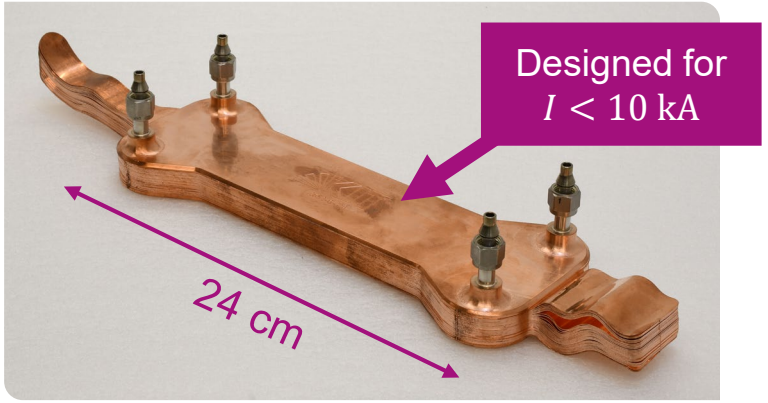
Need for optimization!



Motivation

- Heat load estimation shows **75 %** of cryogenic heat load arises from current leads
- Comparison of current lead cooling designs
  - (Classical) conduction cooled current leads with heat absorption at the cold end
  - (Novel) mixed-refrigerant cooled current leads with continous heat absorption
- Current leads cooled by mixed-refrigerant cycles promise **reduction of power demand by ⅔** [1]





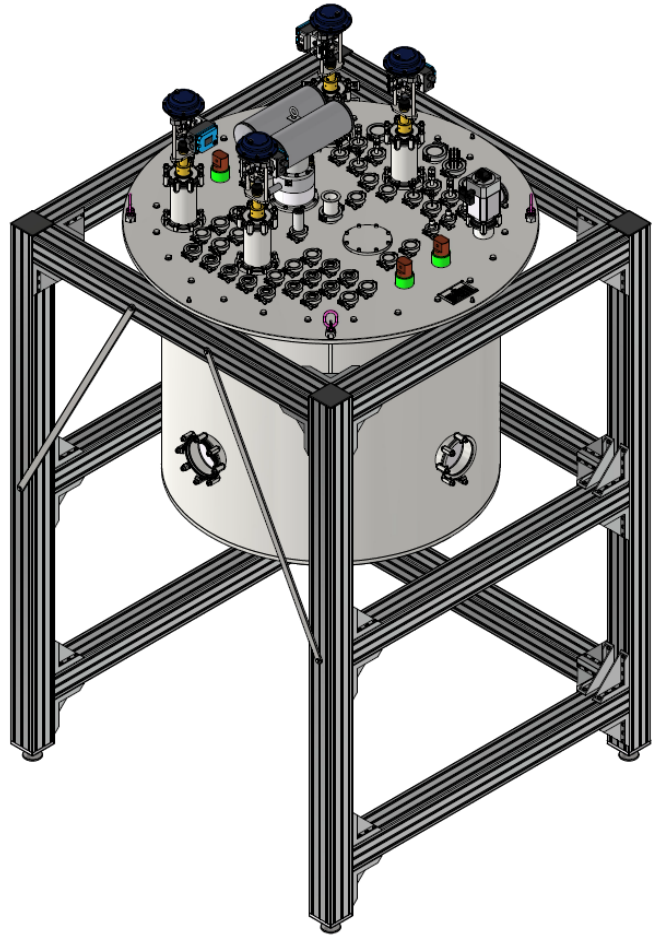
High potential for optimization!

[1] Shabagin, 2022.

Compact Accelerator Systems Test Stand (COMPASS)

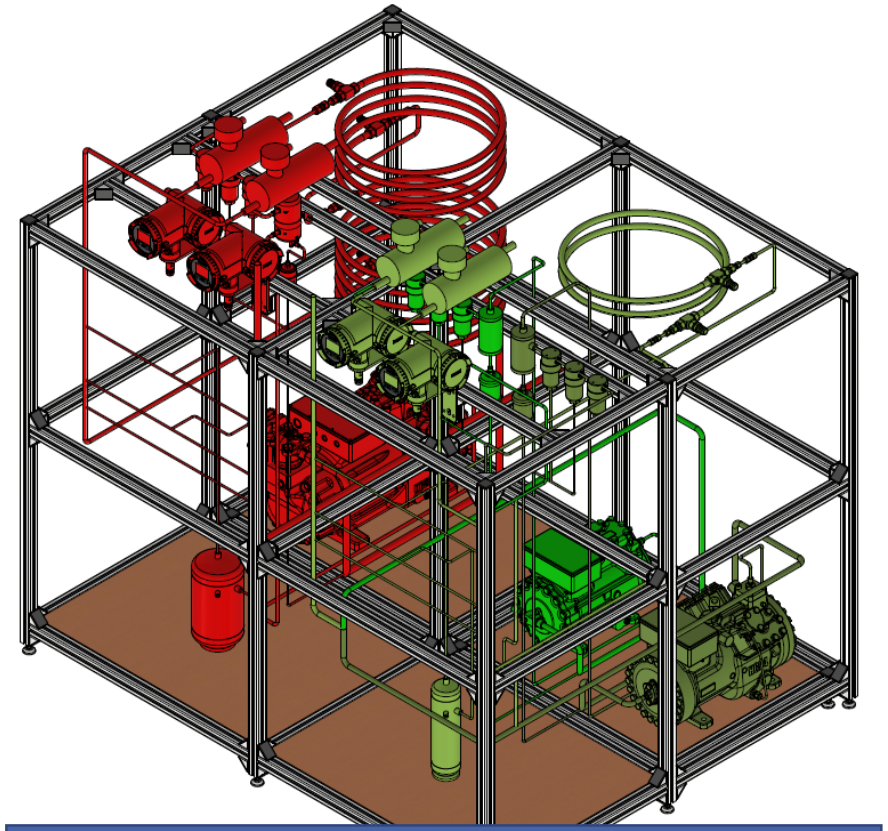
COMPASS – General Overview

- Dedicated experimental facility to study components of compact accelerators
  - Microstructured mixed-refrigerant cooled current leads (MSCL)
  - Superconducting magnets and coils
  - Conduction-cooled SC-cavities



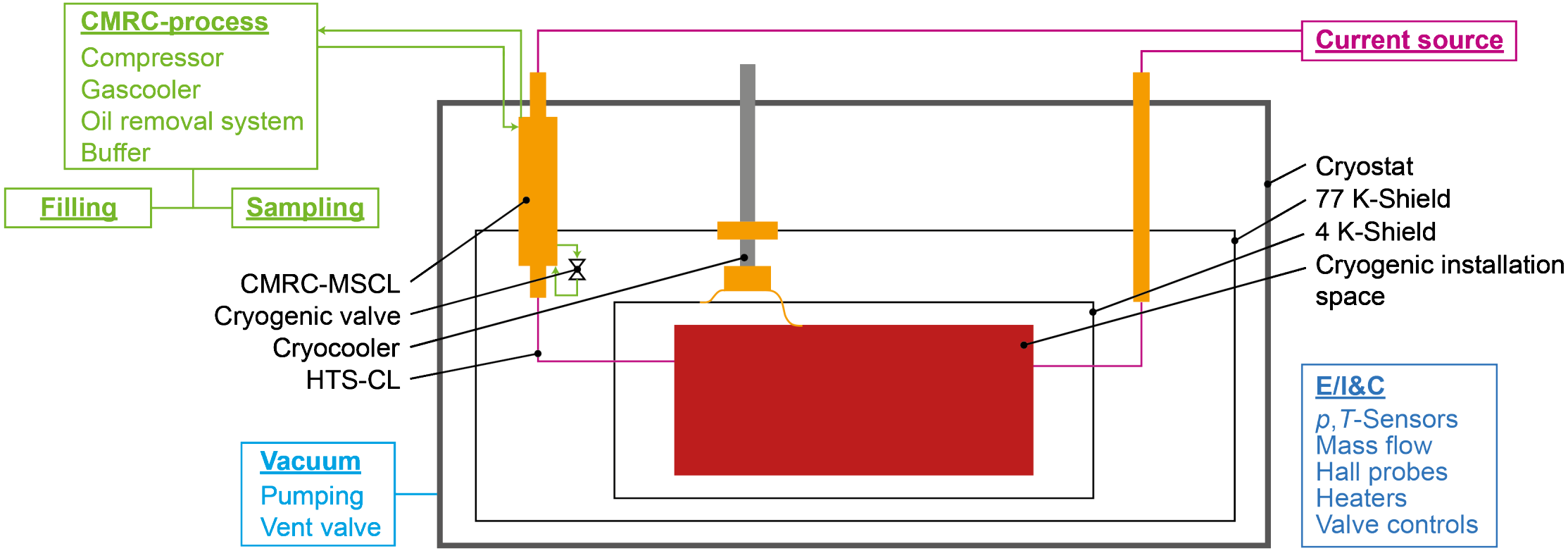
COMPASS – General Overview

- Dedicated experimental facility to study components of compact accelerators
  - Microstructured mixed-refrigerant cooled current leads (MSCL)
  - Superconducting magnets and coils
  - Conduction-cooled SC-cavities
- Cooling power in the temperature range between 4 K and 300 K
  - Cryomech PT425 cryocooler
  - Two mixed-refrigerant cycles
- Fabrication of test stand by Bilfinger Noell GmbH

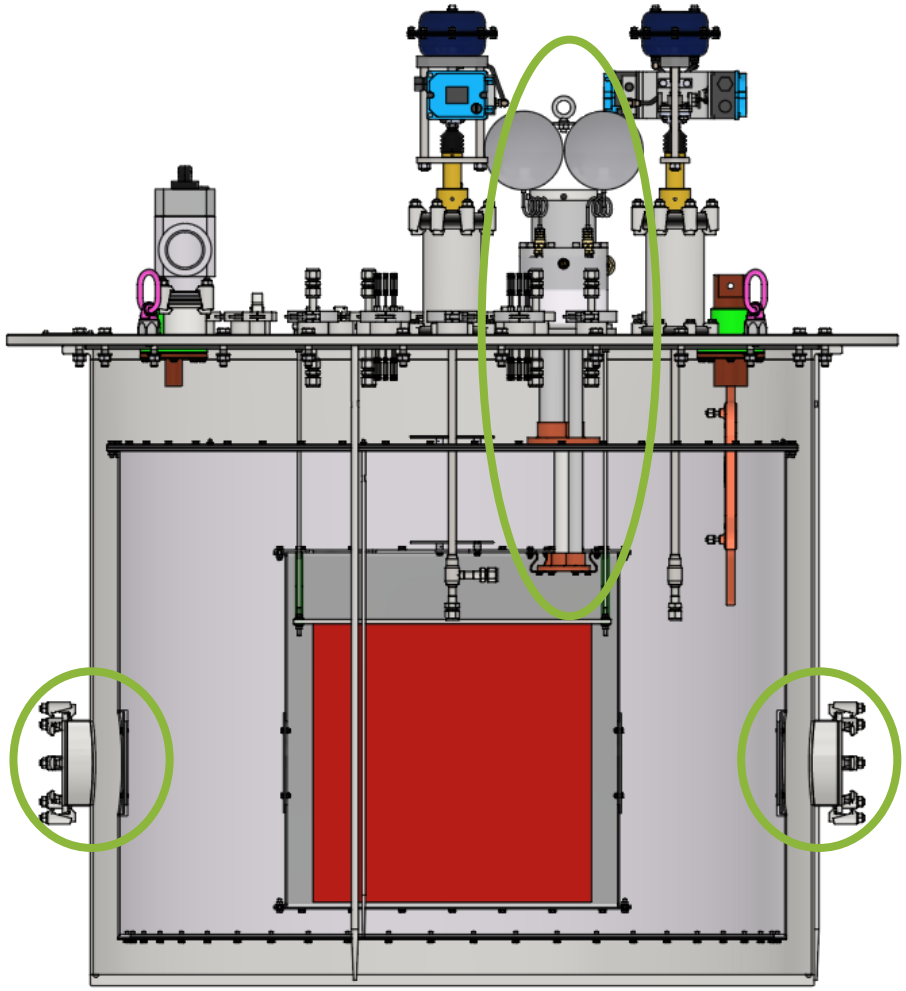


Project finalization in **03/2024**

COMPASS – Schematic Overview



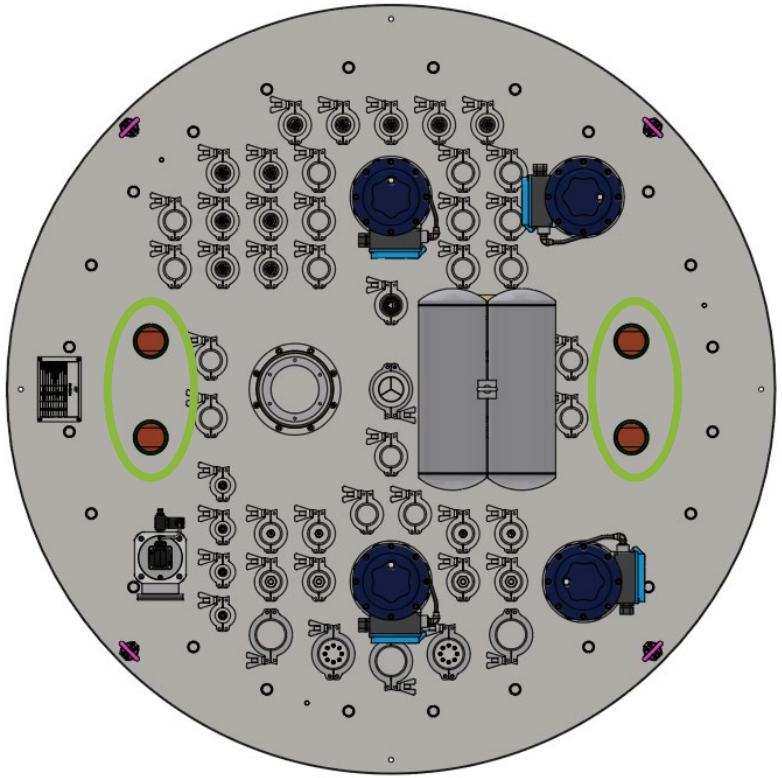
COMPASS – Cryostat Design



- Cryostat vessel of 1300 mm diameter
- Two thermal shields cooled by Cryomech PT425 cryocooler (2.7 W @ 4.2 K[3])
- Field measurements in **LTS-magnets** or **conduction cooled cavities** possible
  - Installation space for cold mass 50x50x50 cm³
  - Current supply via two seperate circuits
  - CMRC-cooled and classical conduction cooled current leads possible
  - Optical access from four sides

[3] www.cryomech.com.

COMPASS – Cryostat Design



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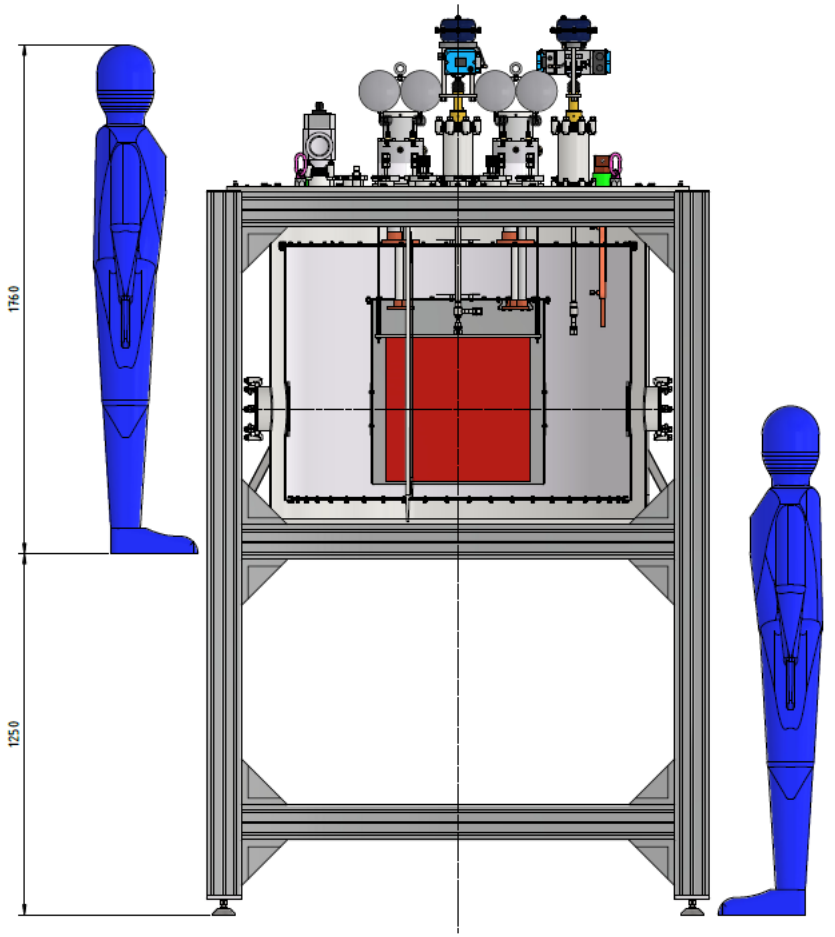
[3] www.cryomech.com.

COMPASS – Cryostat Design

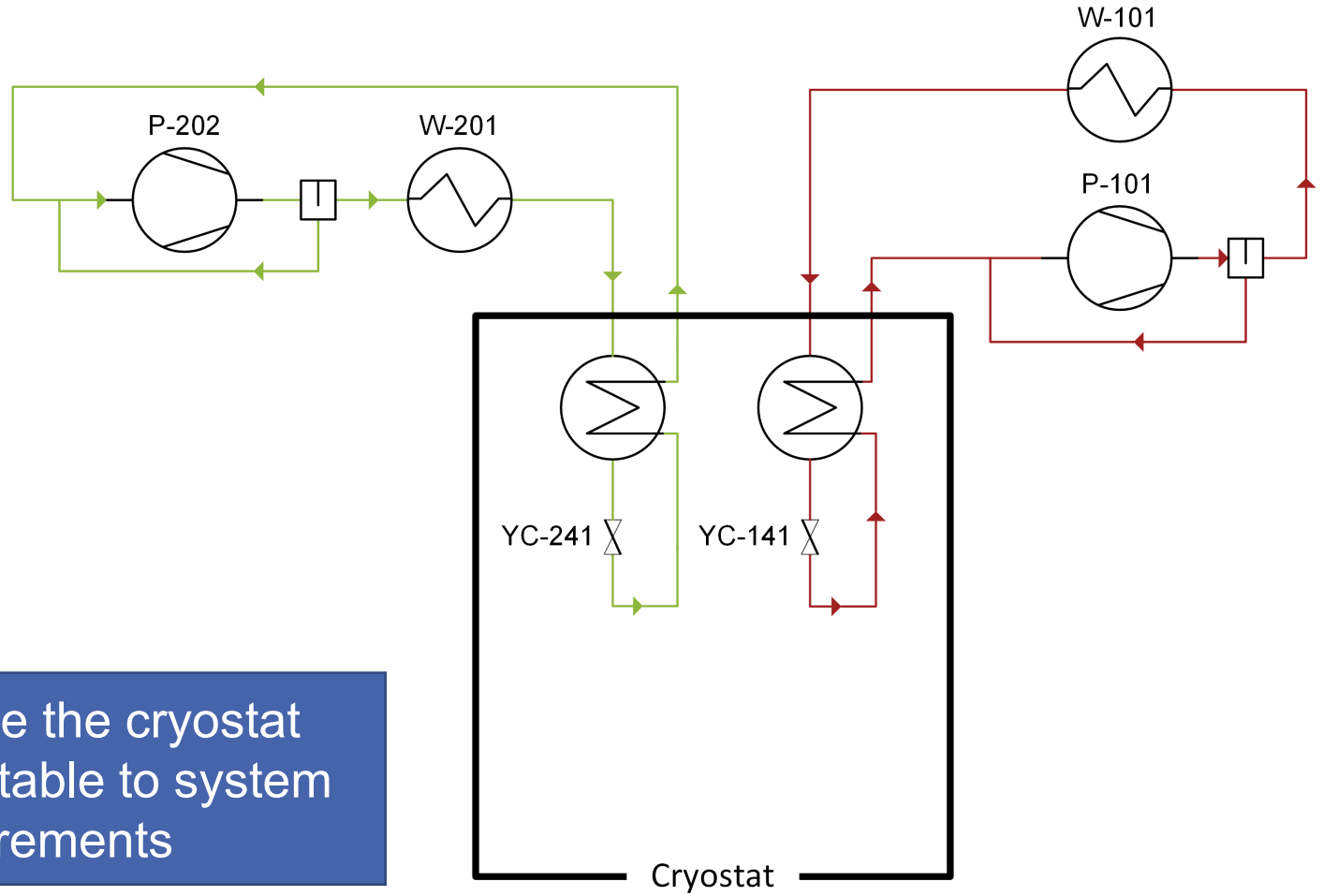
- Cryostat in hanging setup
  - Lid attached on frame
  - Cryostat vessel to be attached and detached from below
    - ➢ No movement of the lid needed
    - ➢ Permanently installed wiring and piping
- COMPASS frame dimensioned for total load of 2500 kg
- Working platforms for access to cryostat lid



Cryogenic mixed-refrigerant cycles (CMRC)

CMRC – Basic process layout

LC-CMRC
- Ne-N_2-Ar-Mixtures
- T< 60 K
- HP < 90 bar

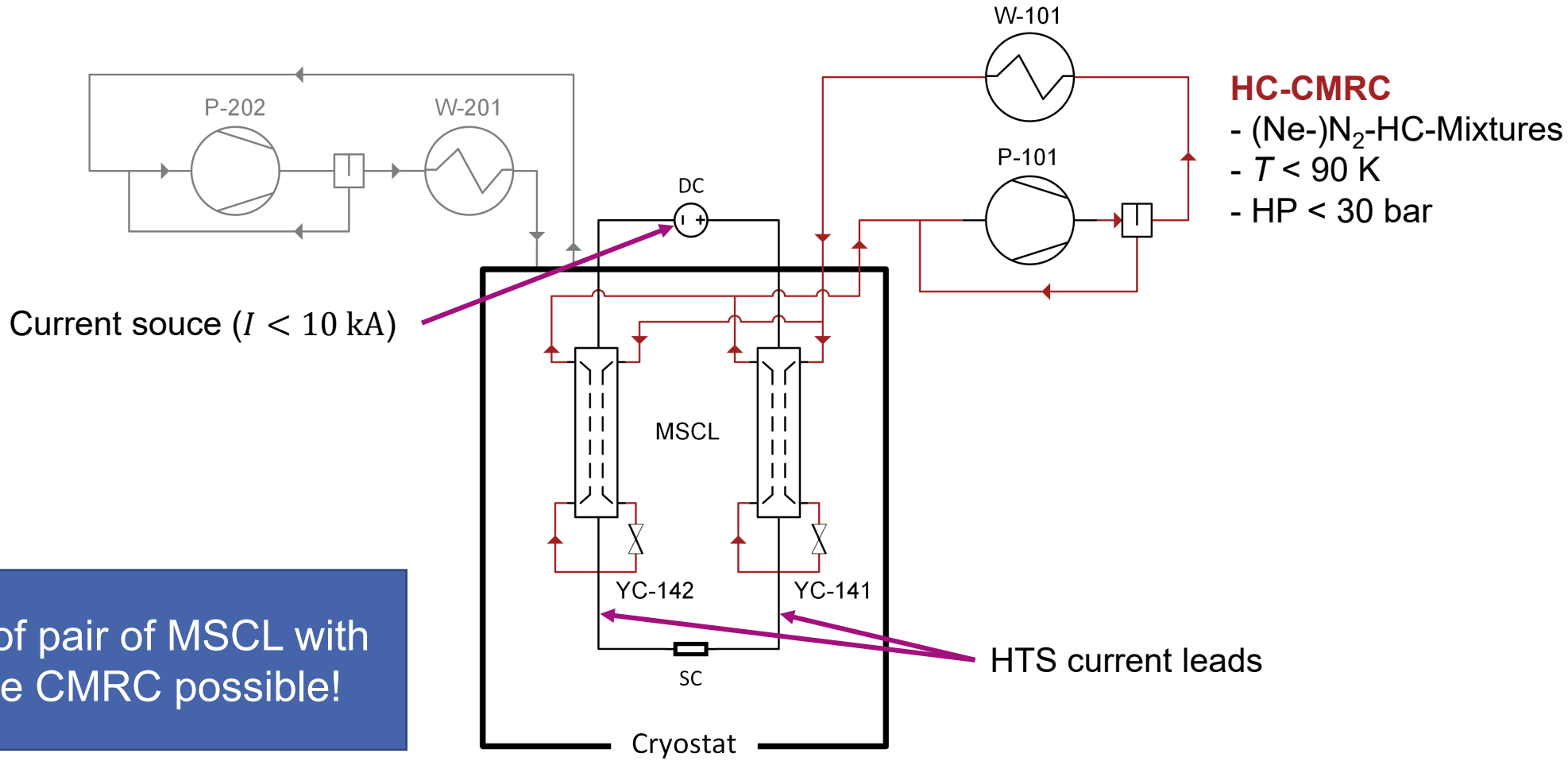


HC-CMRC
- (Ne-)N_2-HC-Mixtures
- *T* < 90 K
- HP < 30 bar

Setup inside the cryostat vessel adjustable to system requirements

CMRC – Cooling of current leads

LC-CMRC not in operation



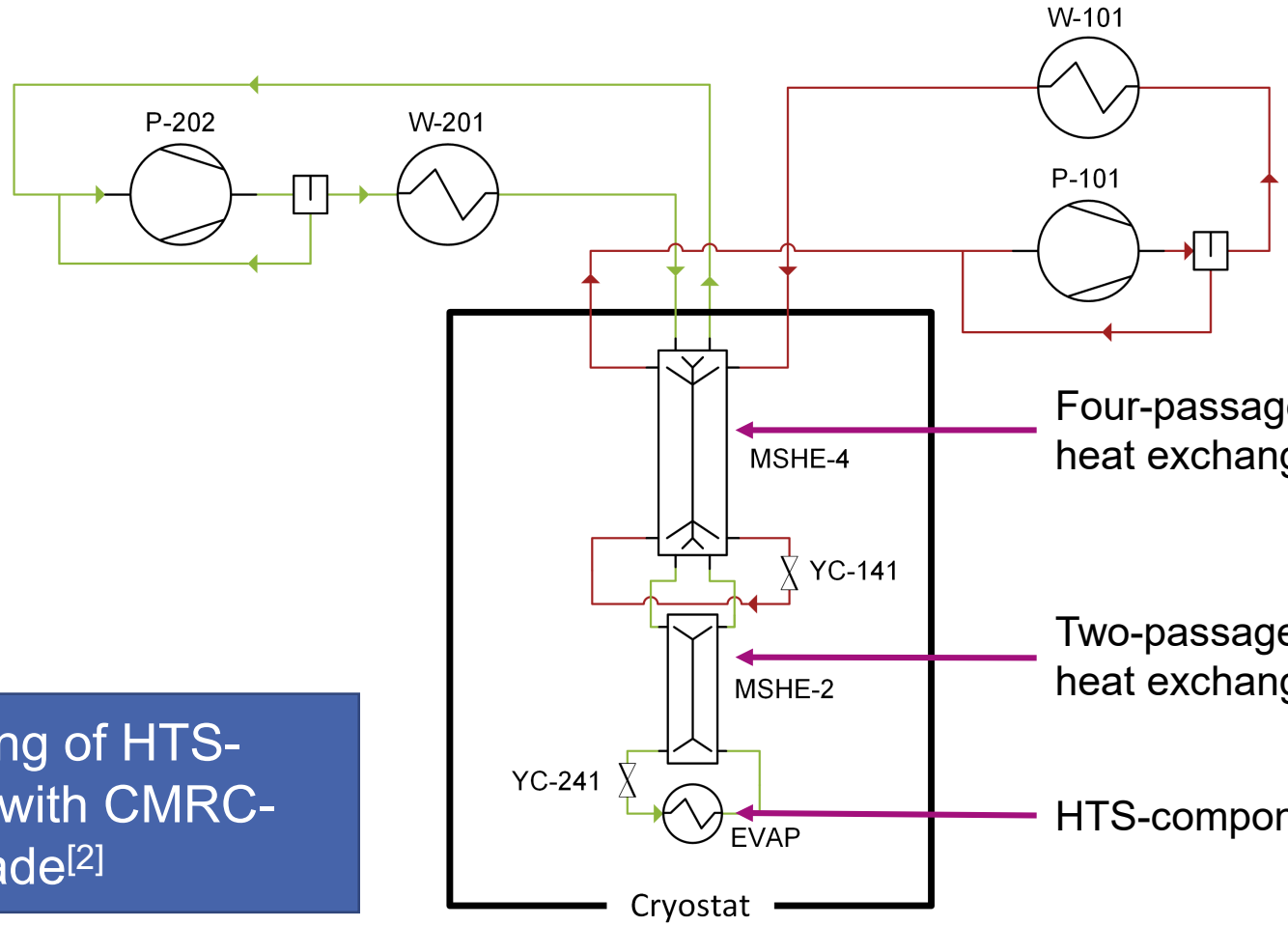
HC-CMRC
- (Ne-)N_2-HC-Mixtures
- T < 90 K
- HP < 30 bar

Cooling of pair of MSCL with only one CMRC possible!

CMRC – Direct cooling of HTS

LC-CMRC
- Ne-N_2-Ar-Mixtures
- T< 60 K
- HP < 90 bar

HC-CMRC
- (Ne-)N_2-HC-Mixtures
- *T* < 90 K
- HP < 30 bar



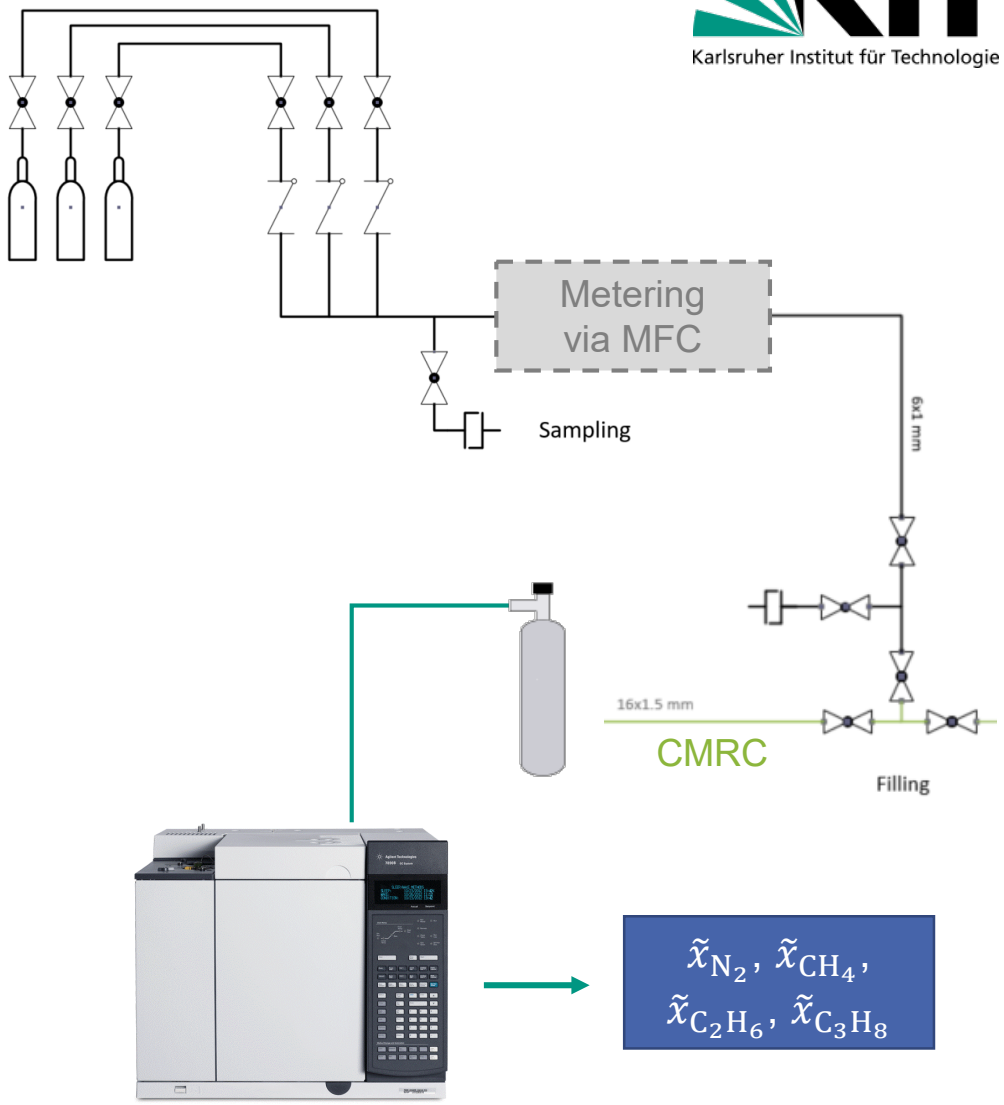
Direct cooling of HTS-components with CMRC-cascade[2]

[2] Kochenburger, 2019.

CMRC – Filling & Sampling

- Filling directly from gas cylinder cabinet via leakage-proof pipe connections
- Bronkhorst mass flow controller for precise dosing of single components
- Manual valves for sampling in sample cylinders
- Offline composition analysis via in-house gas chromatogrophy

Exactly determined mixture compositions

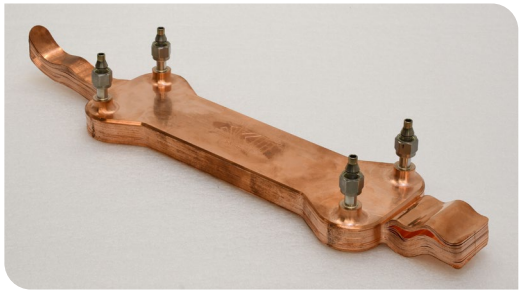


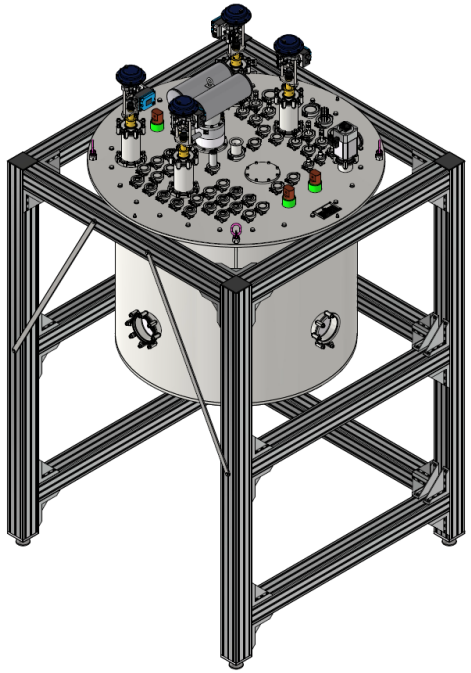
[4] www.agilent.com

Summary & Outlook

Summary

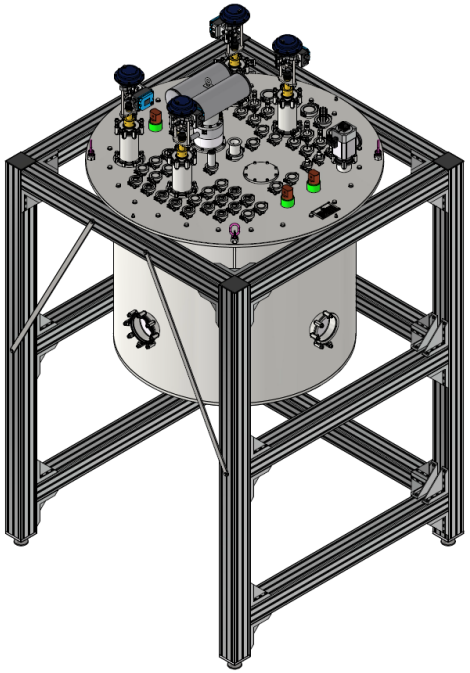
- Current leads cooled by mixed-refrigerant cycles promise **reduction of power demand by ⅔**
- **Mechanical prototype** of microstructured CMRC-cooled current lead **available**
- COMPASS test stand as unique platform for testing compact accelerator components cooled by cryogenic mixed-refrigerant cycles
  - Cryogenic installation space for conduction cooled accelerator components
  - Cryocooler providing cooling power of 2.7 W @ 4.2 K
  - Two mixed-refrigerant cycles providing between 100 W and 500 W at T < 80 K

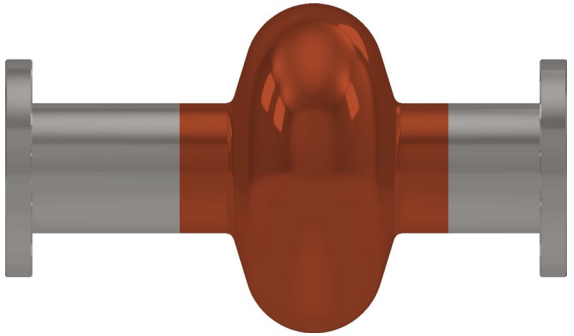


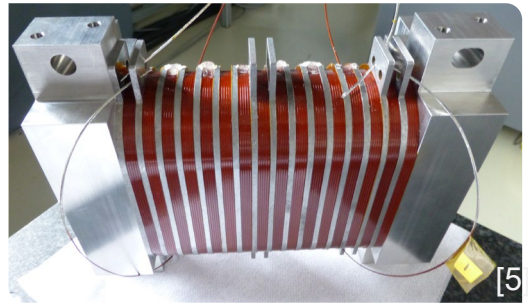


Outlook

- **Realization** of COMPASS in cooperation with Bilfinger Noell GmbH **in 03/2024**
- Development of thermally **optimized MSCLs** with numerical tools in 2023
- **Experimental investigation** of MSCLs **in COMPASS**
- Experimental investigation of thermal behaviour of **sc magnets and cavities** in COMPASS







[5] David Saez de Jauregui, 2022.

Thank you for your attention! Questions?

Literature

[1] E. Shabagin, „Development of a CMRC cooled 10 kA current lead for HTS applications, PhD thesis, Karlsruhe Institute of Technology, Karlsruhe, 2022.

[2] T. Kochenburger, „Kryogene Gemischkältekreisläufe für hochtemperatursupraleitende Anwendungen“, PhD thesis, Karlsruhe Institute of Technology, Karlsruhe, 2019.

[3] https://www.cryomech.com/products/pt425/, called 07.03.2023.

[4] https://www.agilent.com/en/product/gas-chromatography/gc-analyzers/energy-chemical-gc-analyzers/liquefied-petroleum-gas-analyzers, called 03.11.2020.

[5] David Saez de Jauregui, personal communication, 2022.