FROM RESEARCH TO INDUSTRY

DISCUSSION ON SARAF-LINAC CRYOMODULES

HB 2018

N. Pichoff (presentation)

D. Chirpaz-Cerbat, R. Cubizolles, J. Dumas, R. Duperrier, G. Ferrand, B. Gastineau, F. Leseigneur, C. Madec, T. Plaisant, J. Plouin,

CEA/IRFU, Gif-sur-Yvette, France

www.cea.fr

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TOP LEVEL REQUIREMENTS

Input beam (from phase 1 RFQ):

- Proton or Deuteron;
- 176 MHz;
- 40 µA-5 mA;
- cw to pulse (0.1-1 ms @ 0.1-400 Hz);
- 0.2 π.mm.mrad rms norm. emittance;
- 1.3 MeV/u;

Output beam (to HEBT):

- 40 MeV for deuterons or 35 MeV for protons;
- Emittance growth < 25%.

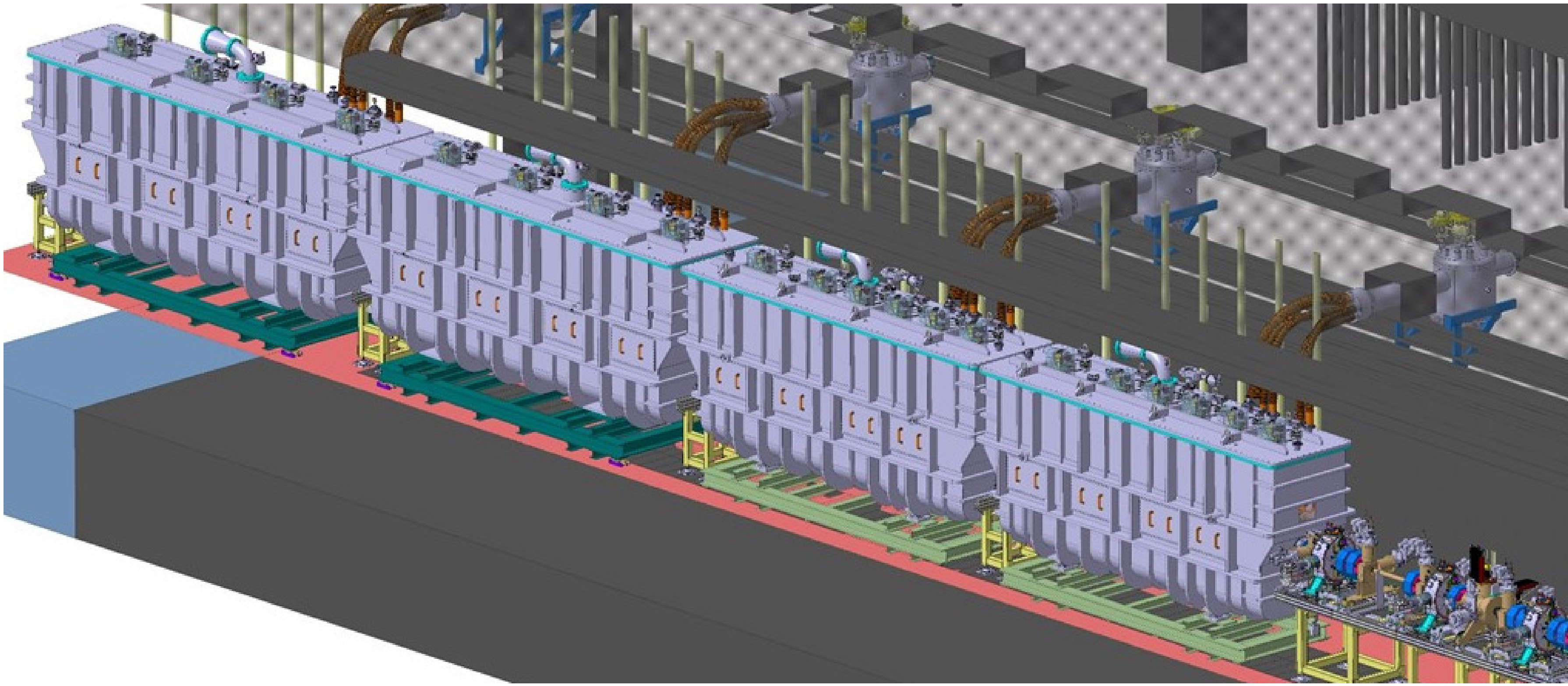
Operation:

Beam losses lower than: 150 nA/m below 5 MeV,
40 nA/m below 10 MeV,
5 nA/m below 20 MeV
1 nA/m above;

6000 h/y 90% availability.

THE SCL

→ The energy is given by a SuperConducting Linac made of four ~5 m cryomodules.



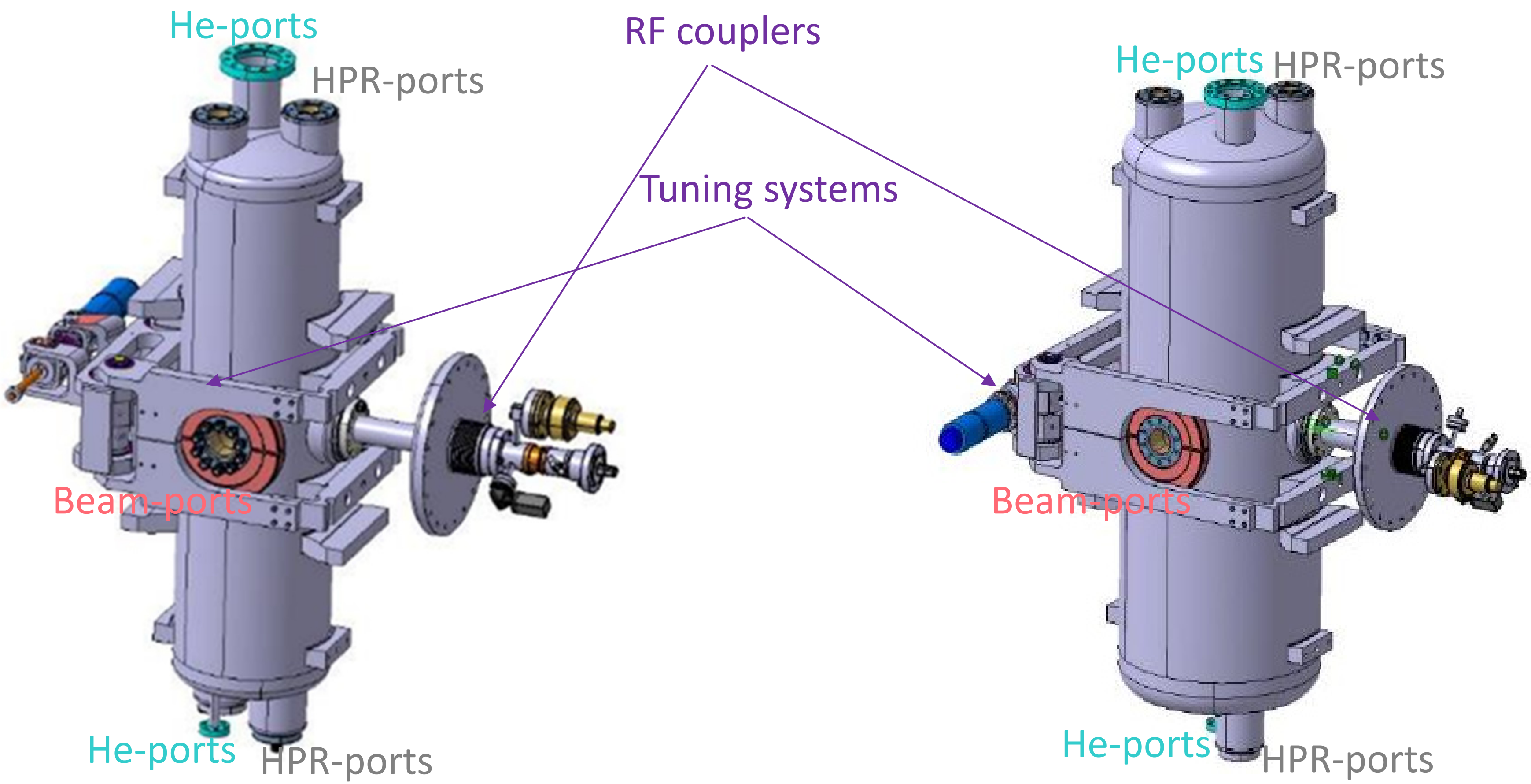
→ The cryomodules just passed the CDR (March 2018).

THE HWR RESONATORS

The **energy gain** primary function (to the beam) is provided by 27 HWR resonators

2 families (β=9.2% (LB) and β=18.2% (HB)) HWR resonators have been chosen

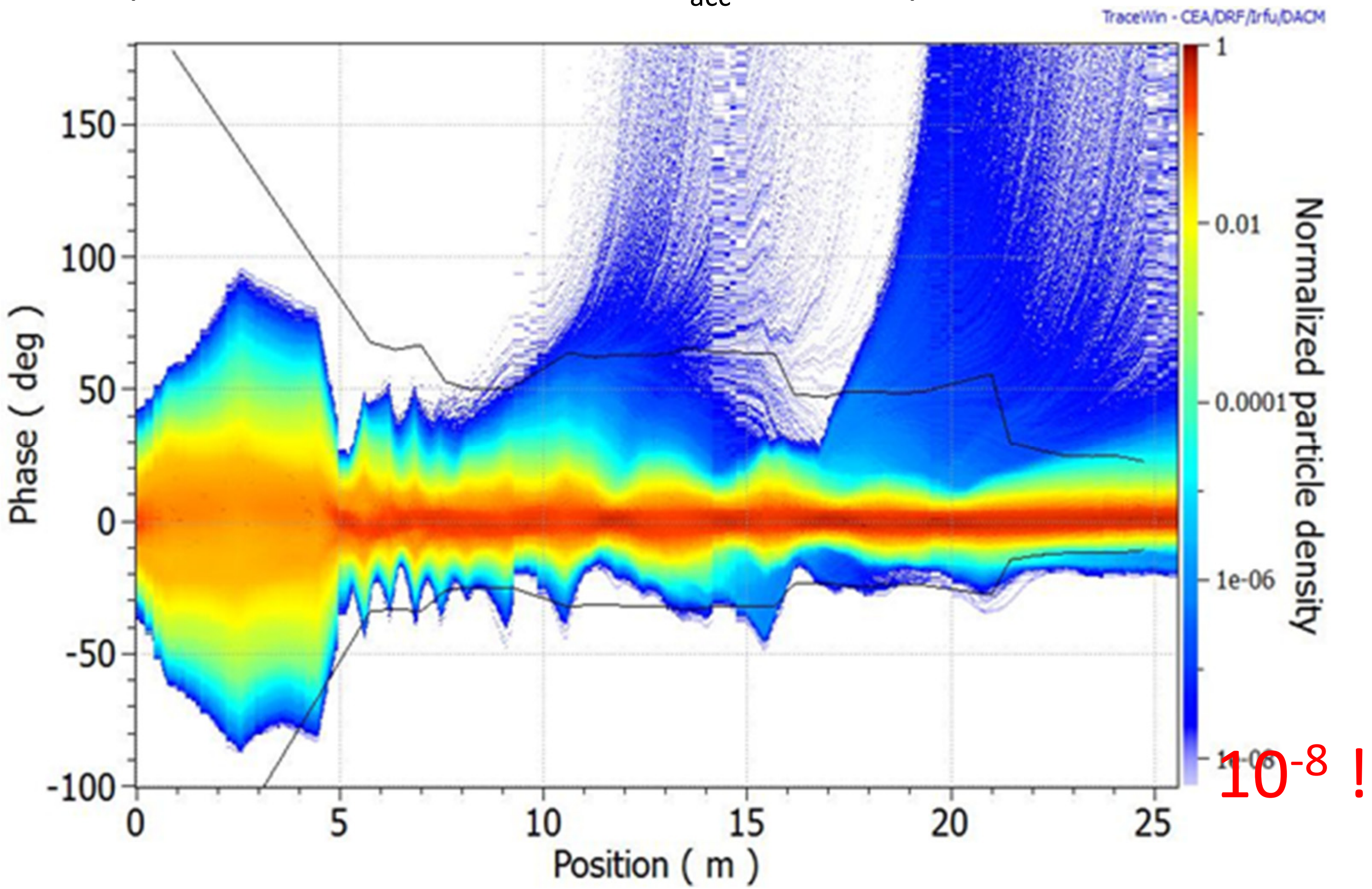
6 LB in CM1; 6+1 LB in CM2; 7 HB in CM3 and 7 HB in CM4



CAVITY TUNING

HWR are tuned (phase and amplitude) to limit longitudinal beam losses

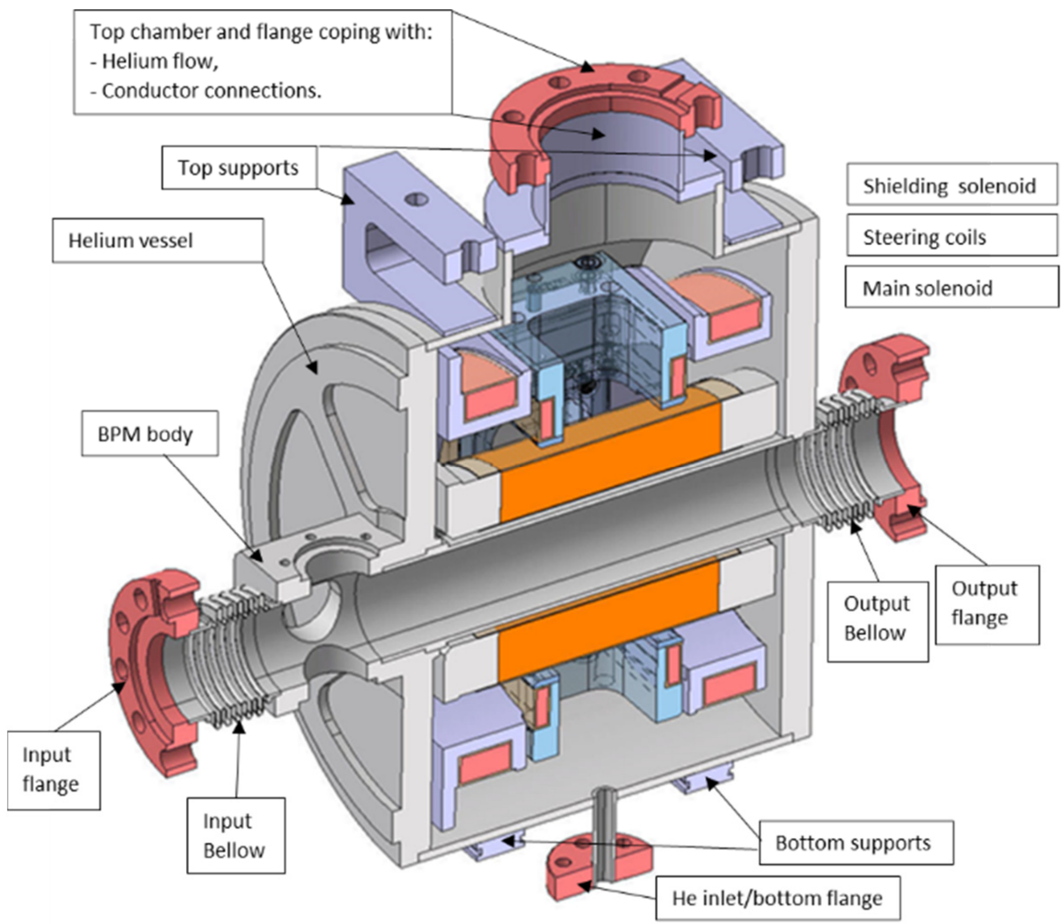
LB $E_{acc} \leq 6.5$ MV/m HB $E_{acc} \leq 7.5$ MV/m



Longitudinal beam « probability » profile (cavities tuned with BPM & ±1%/±1° tuning errors)

THE SOLENOID PACKAGES

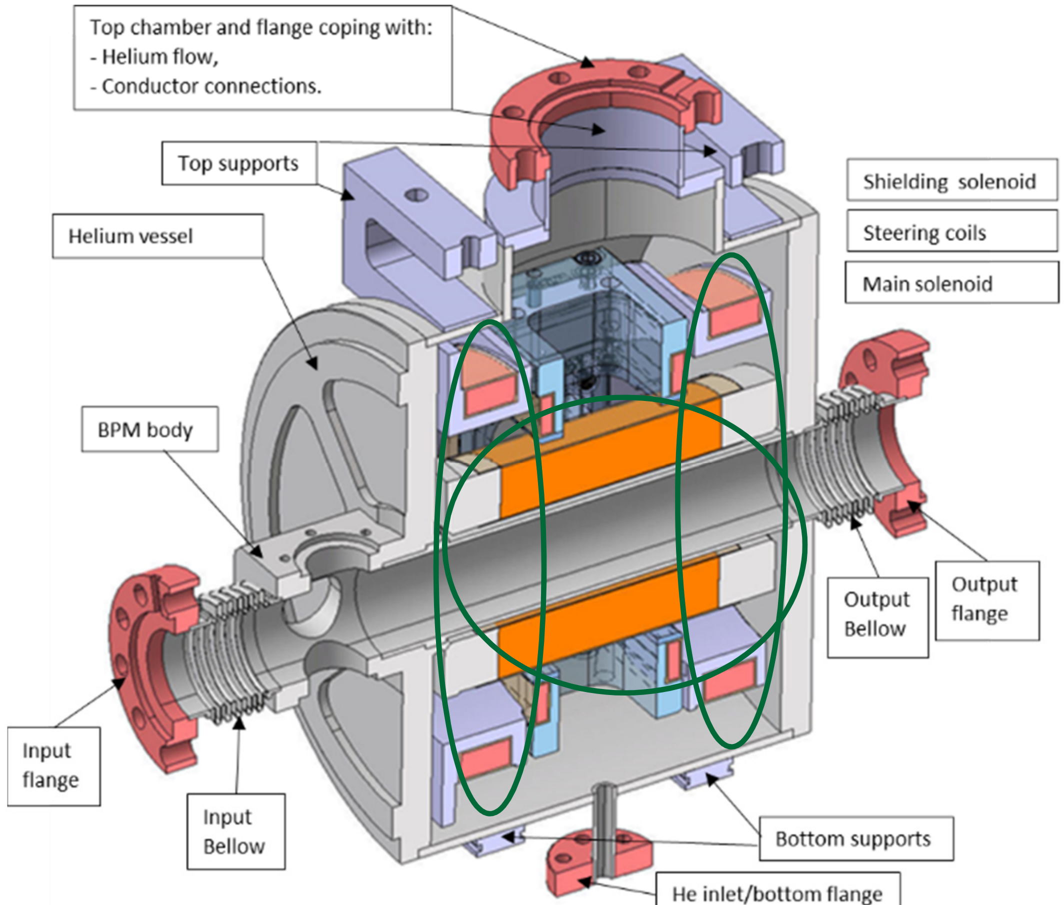
The **beam transverse size and position** is controlled (primary function) by 20 SP



THE SOLENOID PACKAGES

The **beam transverse size and position** is controlled (primary function) by 20 SP

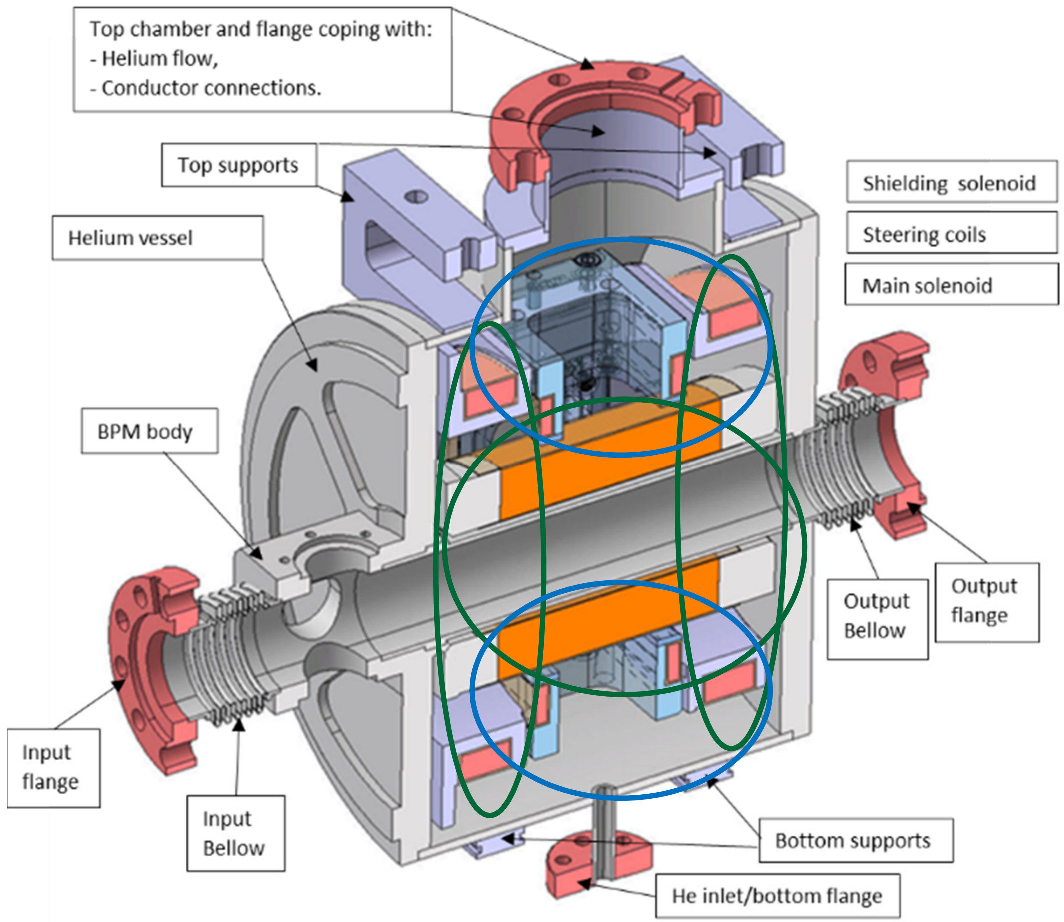
Focalisation + field limitation on cavities → 3 axial solenoids



THE SOLENOID PACKAGES

The **beam transverse size and position** is controlled (<u>primary function</u>) by 20 SP

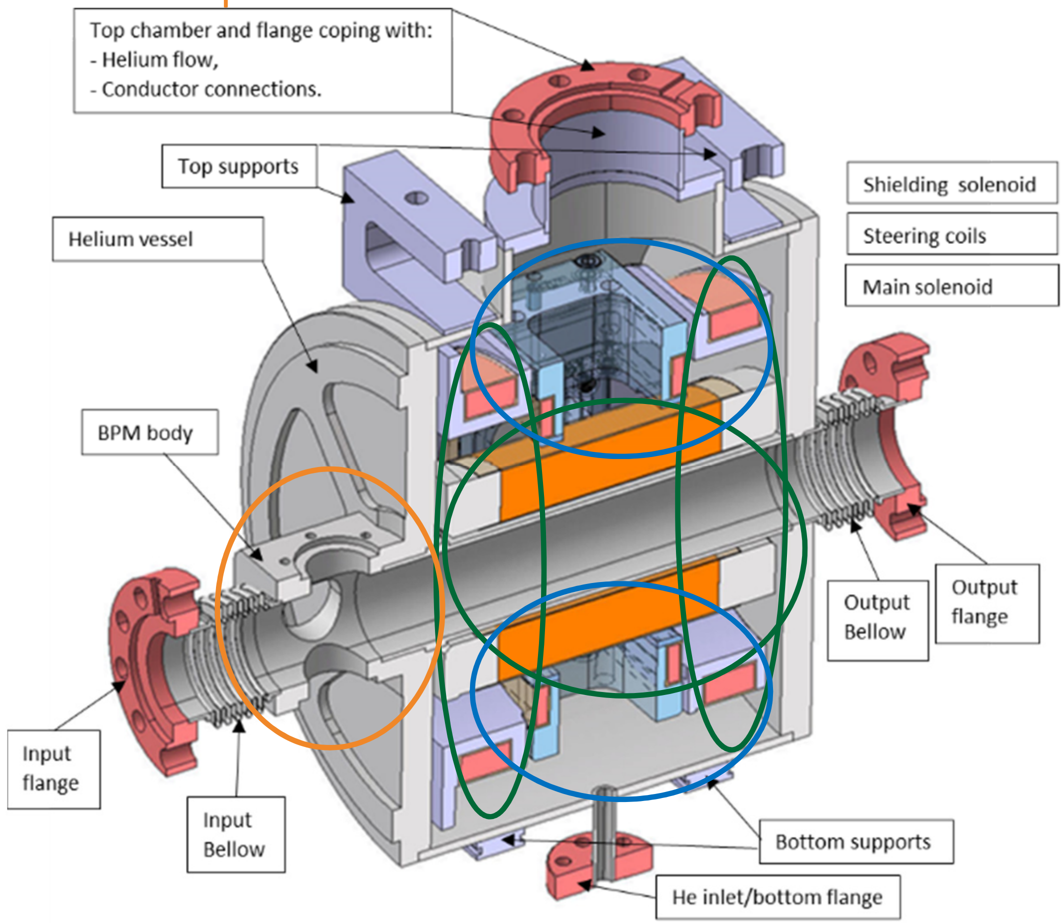
- Focalisation + field limitation on cavities → 3 axial solenoids
- Steering → 2 pairs of transversal coils



THE SOLENOID PACKAGES

The **beam transverse size and position** is controlled (<u>primary function</u>) by 20 SP

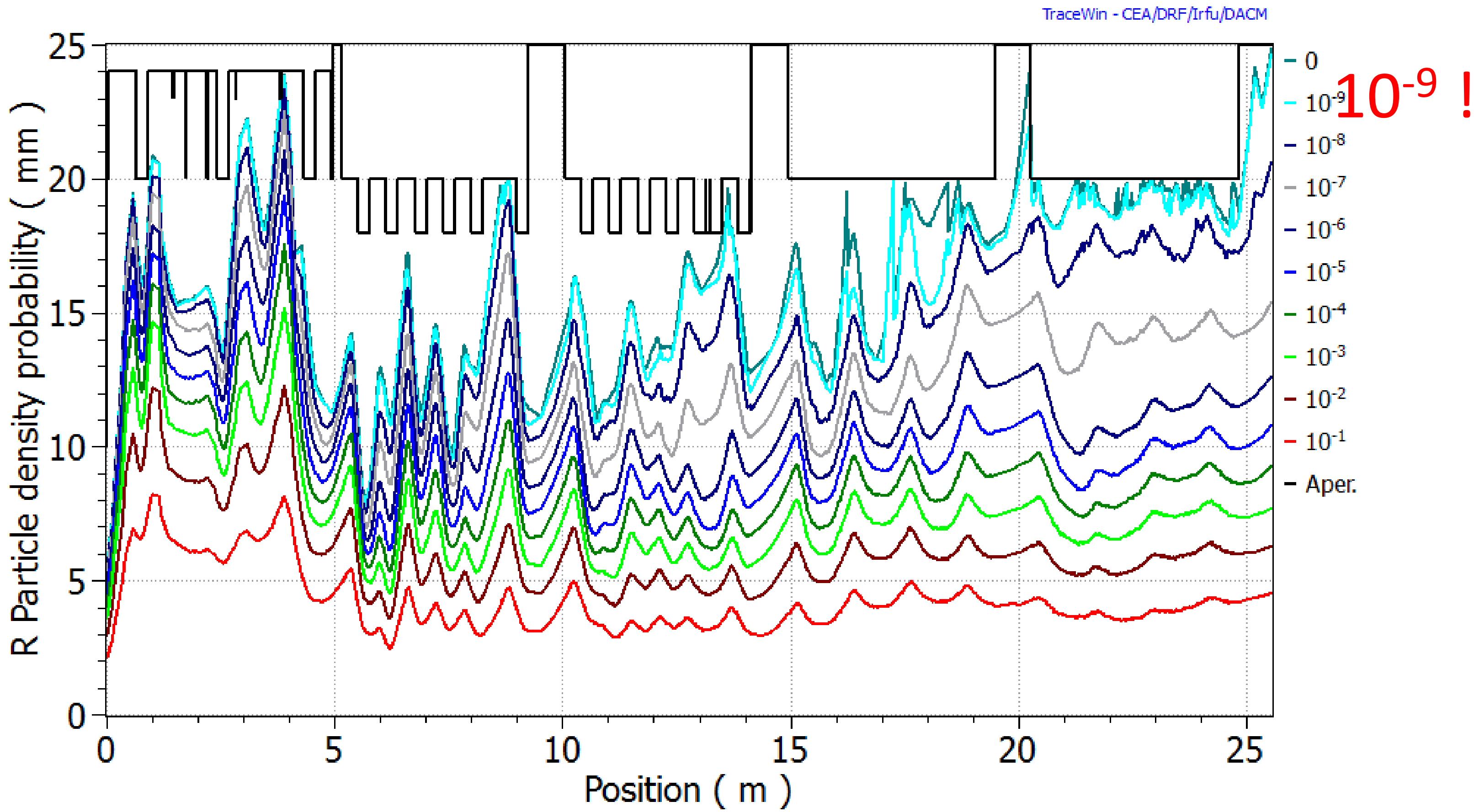
- Focalisation + field limitation on cavities → 3 axial solenoids
- Steering → 2 pairs of transversal coils
- Position measurement → 1 upstream BPM



SP TUNING

SP are tuned (focusing/steering) to keep the beam matched (between CM) and on axis (BPM)

Foc: $B^2L \geq 2.9\ T^2.m$ Steer: $BL \geq 7$ T.mm



Transverse beam « probability » contour plots (steerer with BPM & ±2 mm position errors)

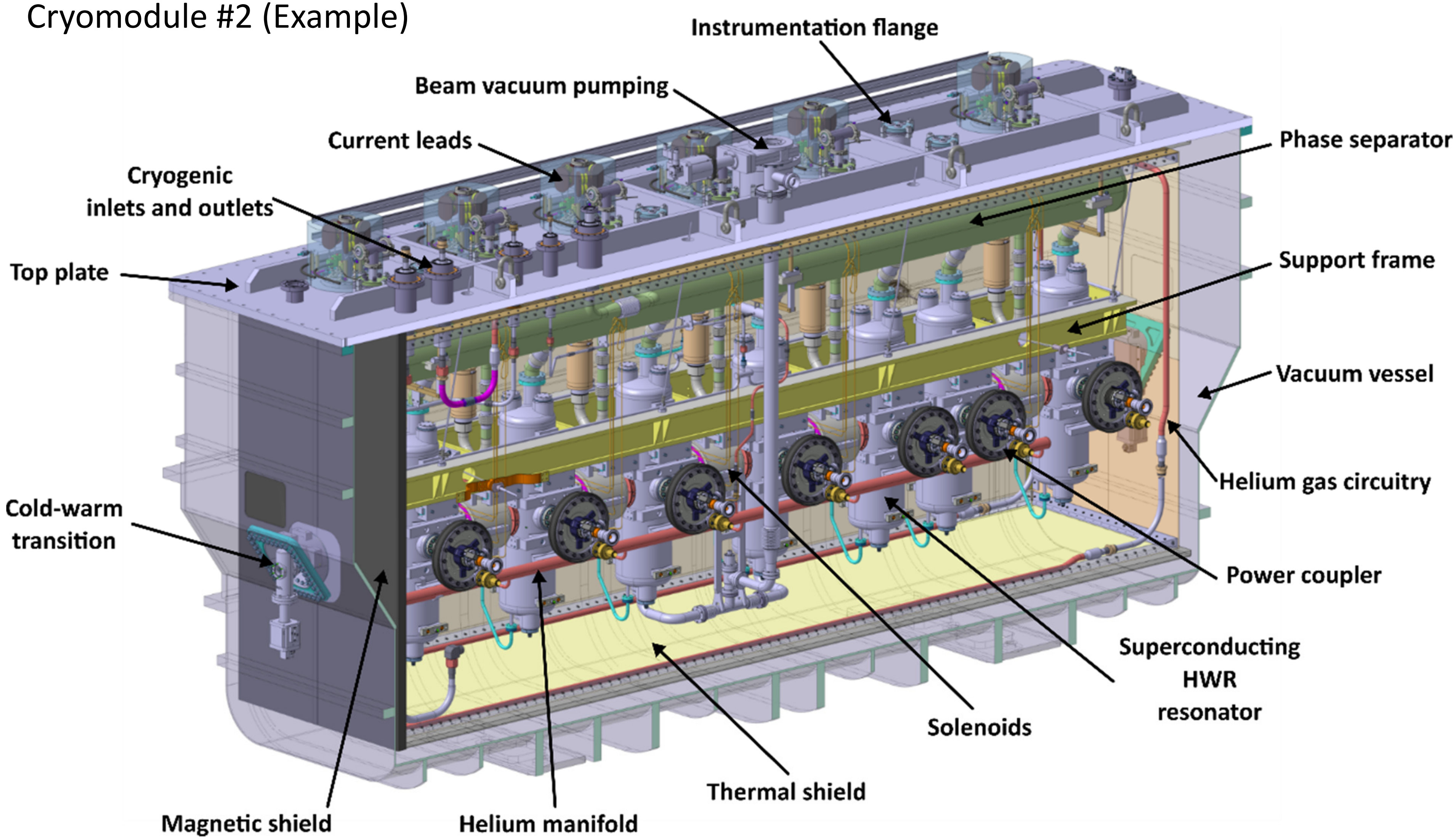
THE CRYOMODULE REQUIREMENTS

The cryomomdule serves secondary functions (to the HWR and the Solenoid Package)

- Keep @ 4 K → He distribution / isolation from 300 K
- Keep on axis → Deformation estimation, alignement
- Keep under vacuum → Beam pipe pumping
- Keep from magnetic field → Magnetic shield + Non magnetic material
- Keep feeded by power → House RF coupler and Current leads
- Keep accessible for maintenance → Trap doors, redundances

THE CRYOMODULE SOLUTION

Cryomodule #2 (Example)

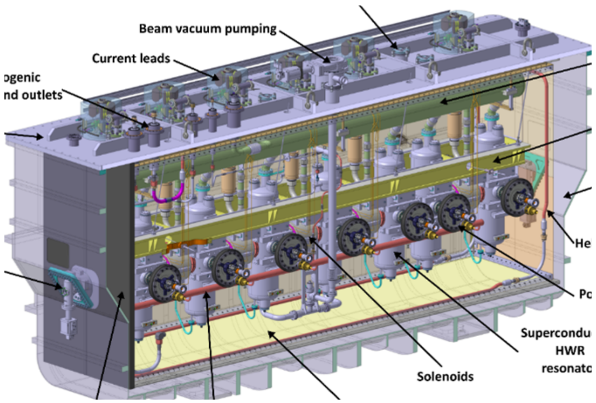


KEEP @ 4 K

Req: << 9 K

→ 4.45 K chosen, the LHe/GHe transition @ 1.25 bar (± 0.005)

→ He Distribution by

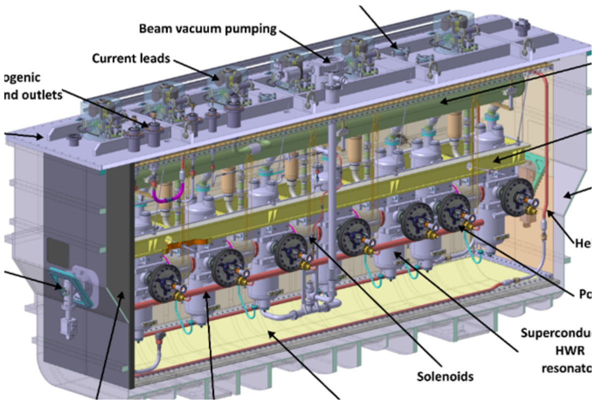


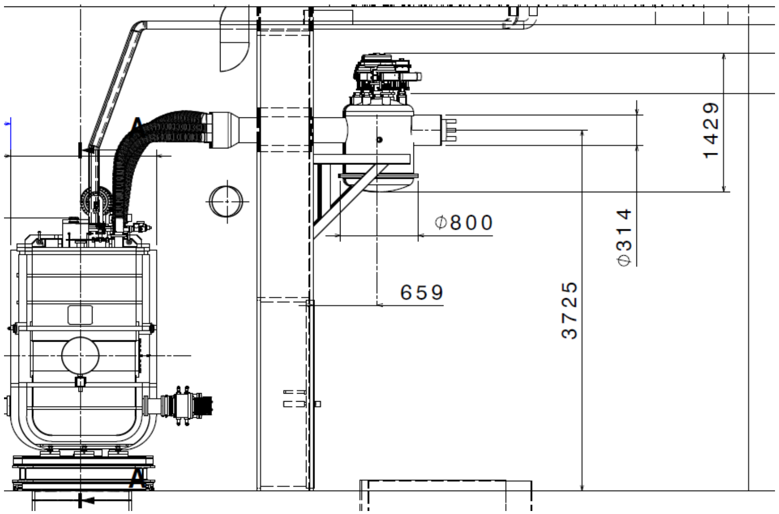
KEEP @ 4 K

<u>Req</u>: << 9 K

→ 4.45 K chosen, the LHe/GHe transition @ 1.25 bar (± 0.005)

→ He Distribution by **valves boxes**



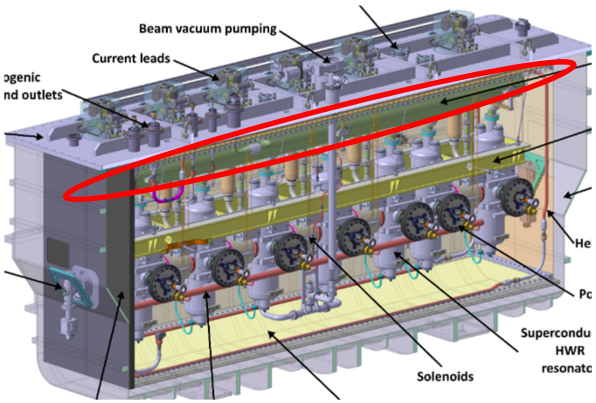


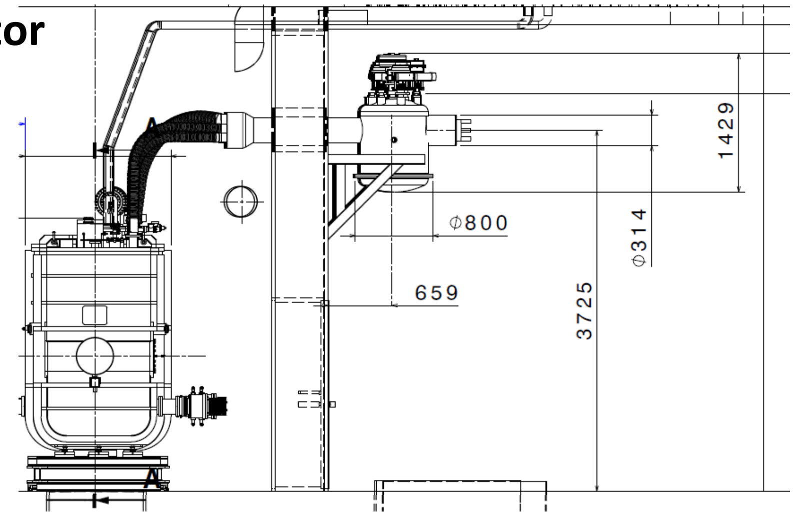
KEEP @ 4 K

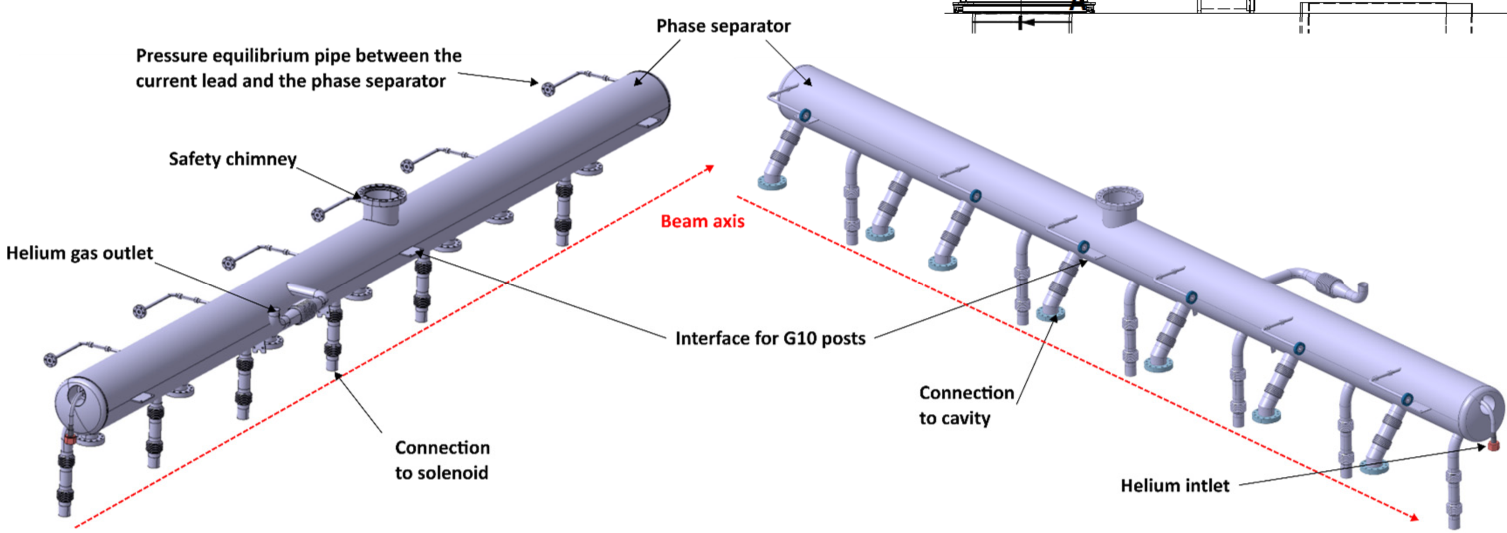
<u>Req</u>: << 9 K

→ 4.45 K chosen, the LHe/GHe transition @ 1.25 bar (± 0.005)

→ He Distribution by **valves boxes** and **phase separator**

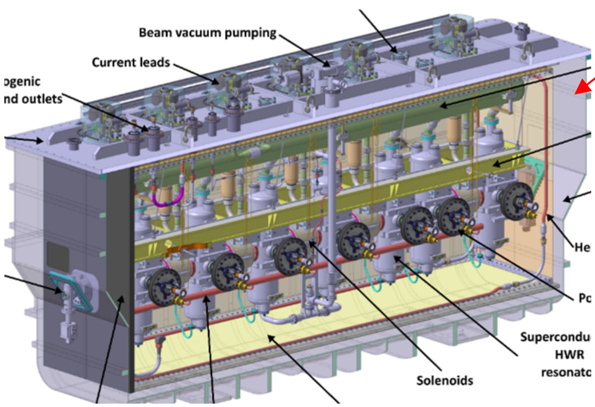




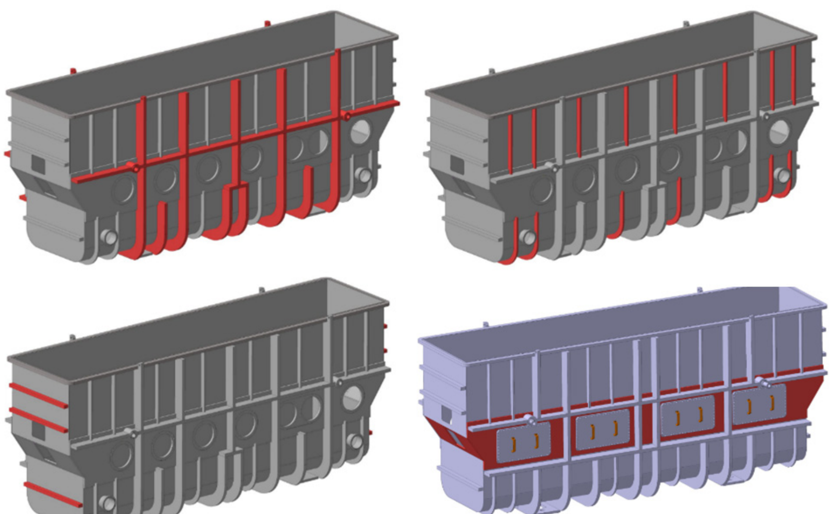


KEEP @ 4 K

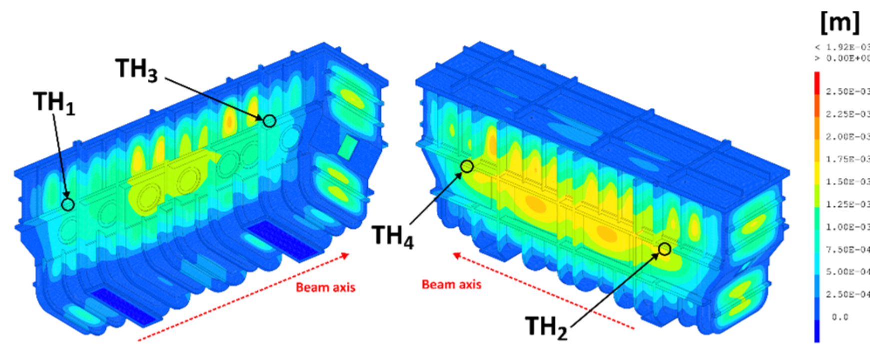
Req: as low power losses as possible



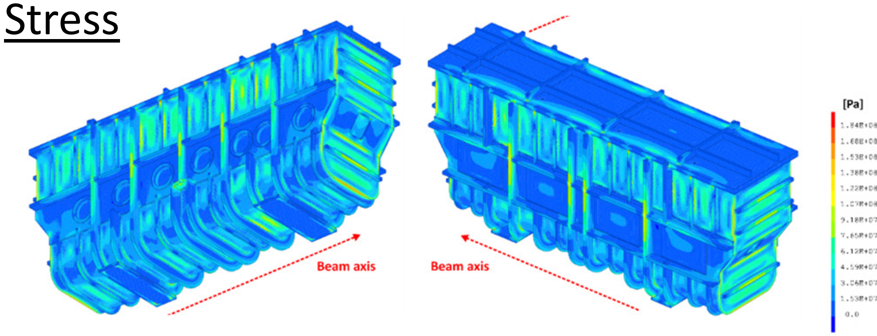
→ Isolation vacuum : pumped airtight tank ~5 m



Deformations

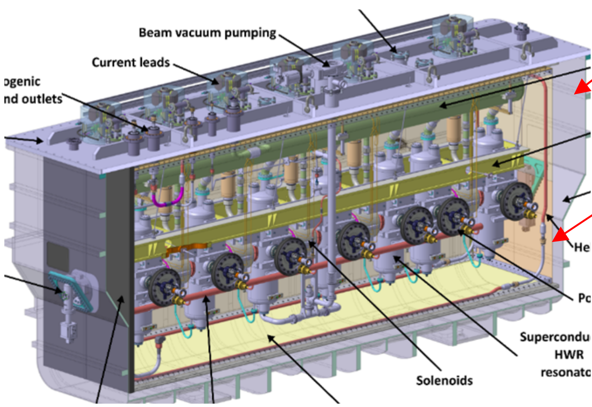


Stress



KEEP @ 4 K

Req: as low power losses as possible

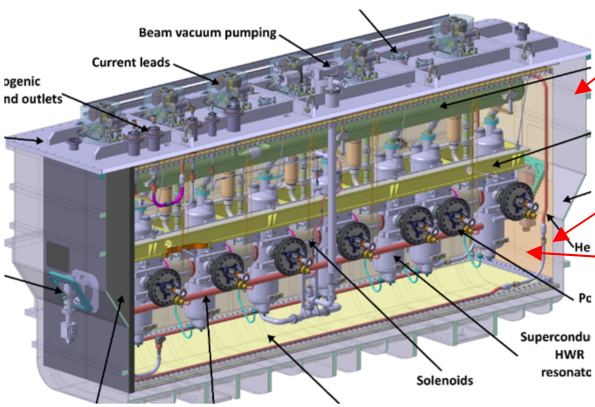


→ Isolation vacuum : pumped airtight tank

→ MLI

KEEP @ 4 K

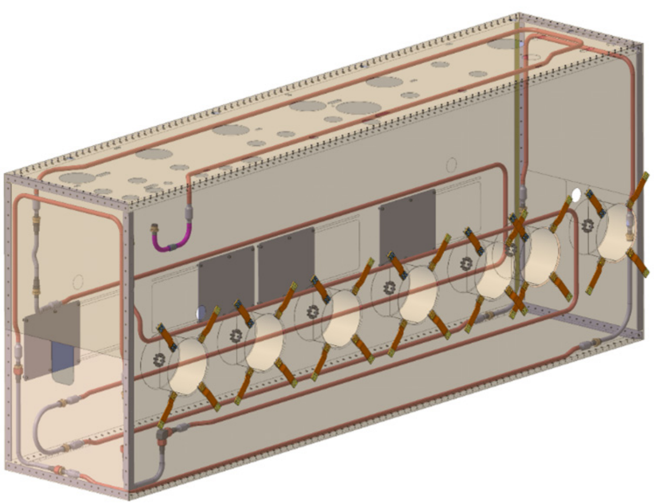
<u>Req</u>: as low power losses as possible



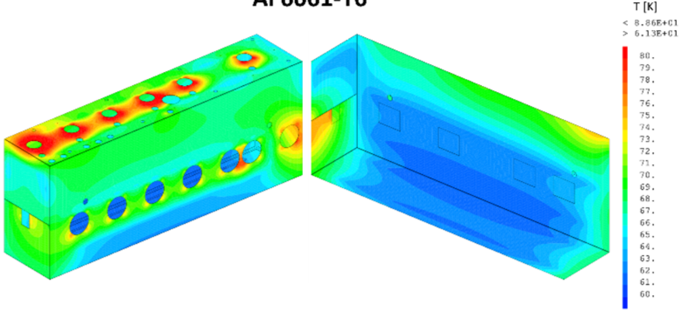
→ Isolation vacuum : pumped airtight tank

→ MLI

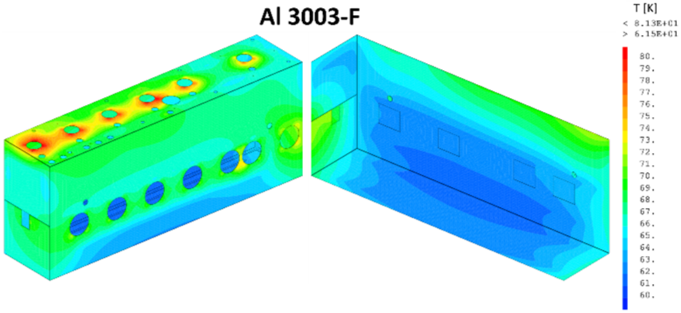
→ thermal shield (~60K),



Al 6061-T6

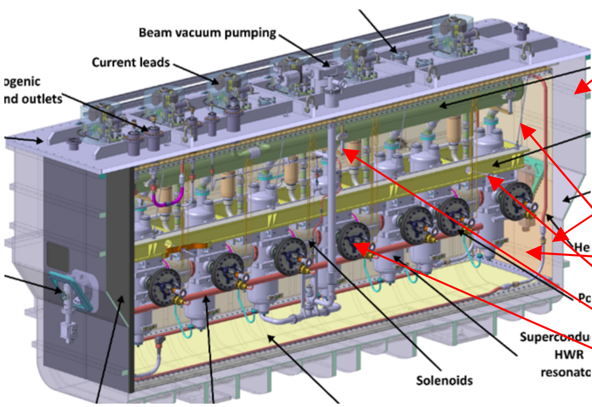


Al 3003-F



KEEP @ 4 K

Req: as low power losses as possible

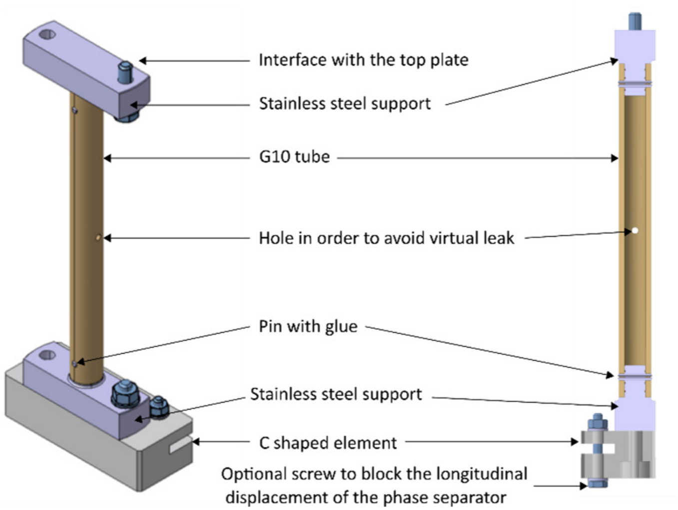


→ Isolation vacuum : pumped airtight tank

→ MLI

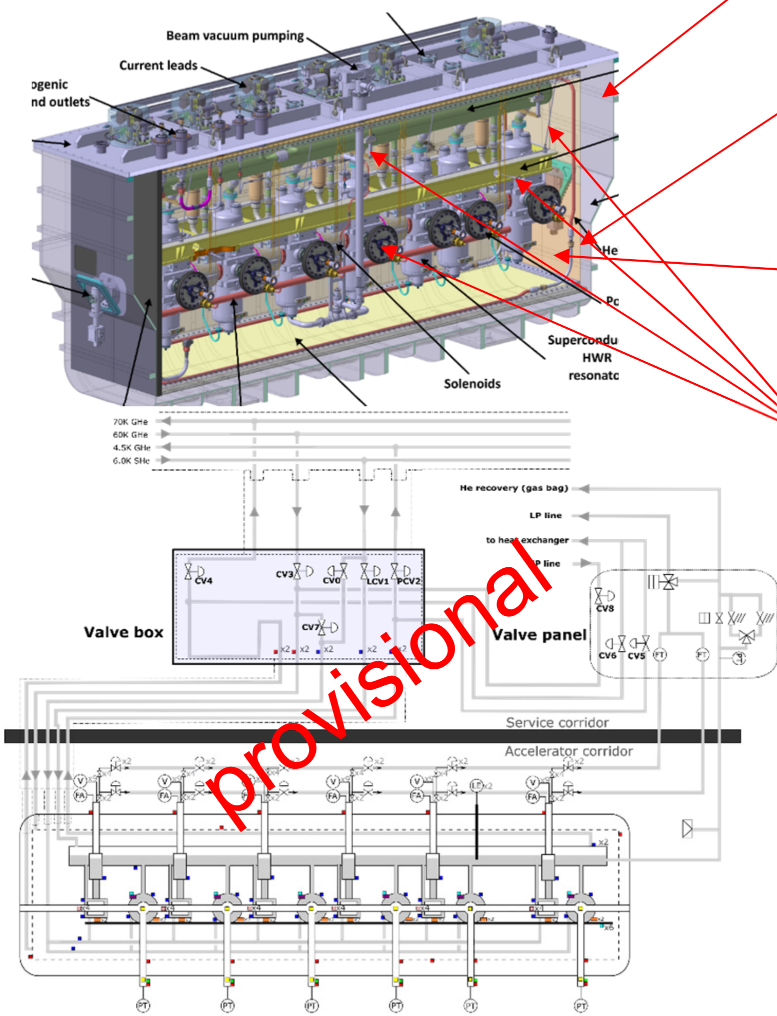
→ thermal shield (~60K),

→ 4K-60K-300K connexions with low thermal conductivity (couplers, Current leads, tie rods…).



KEEP @ 4 K

Req: as low power losses as possible



→ Isolation vacuum : pumped airtight tank

→ MLI

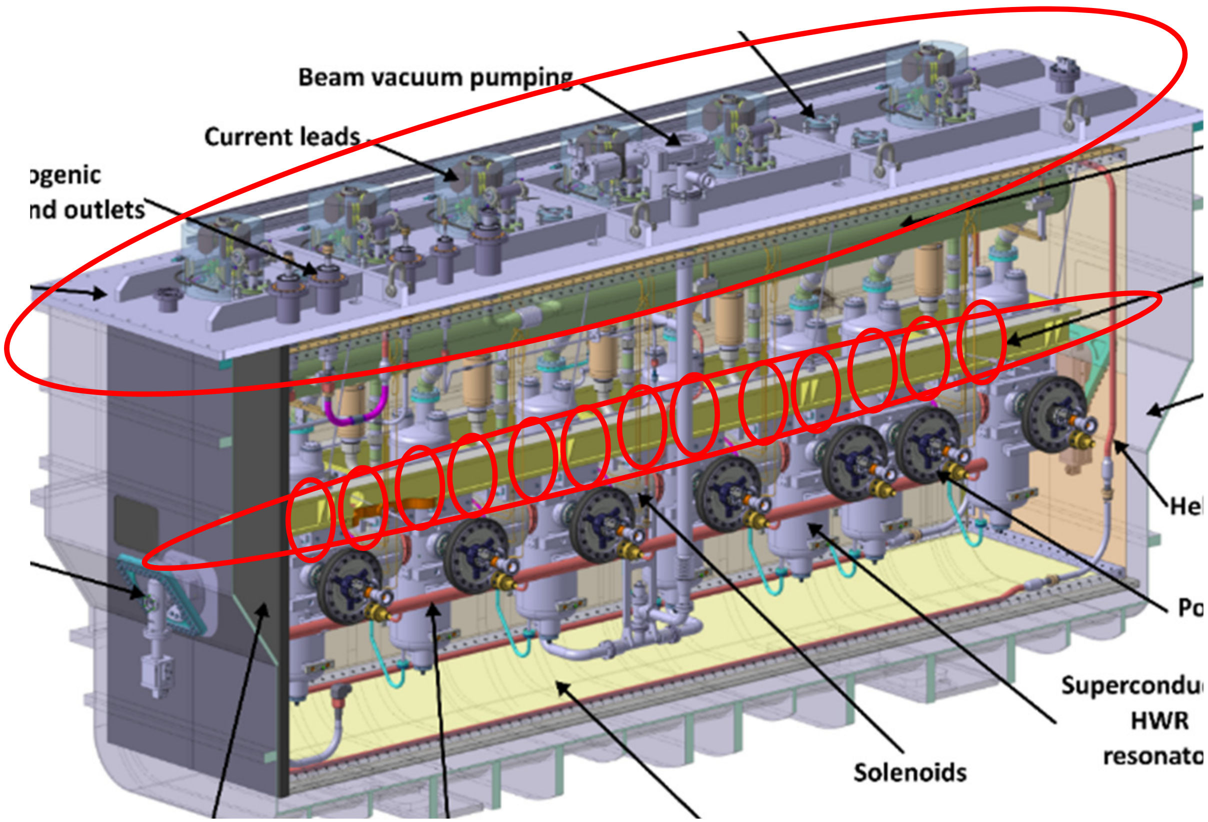
→ thermal shield (~60K),

→ 4K-60K-300K connexions with low thermal conductivity (couplers, Current leads, tie rods…).

→ Temperature sensors

Req: major components ± 1 mm from beam axis

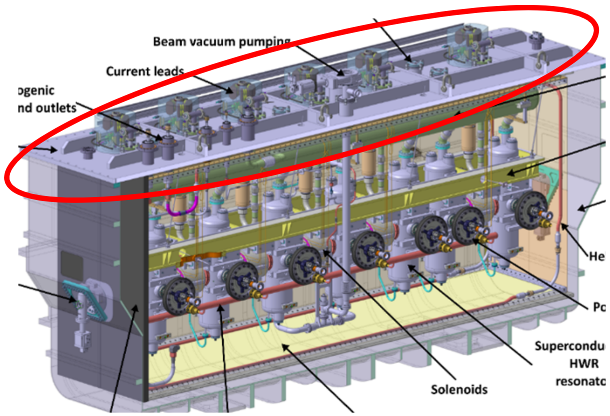
→ The components are hanged with C-shapes to the support frame hanged to the top plate



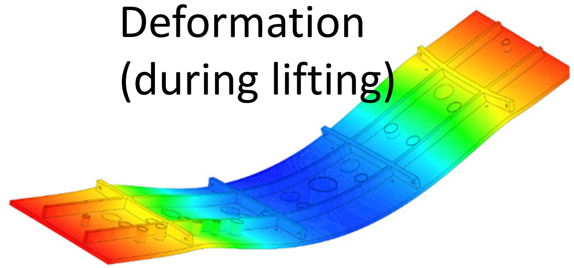
KEEP ON AXIS

Req: major components ± 1 mm from beam axis

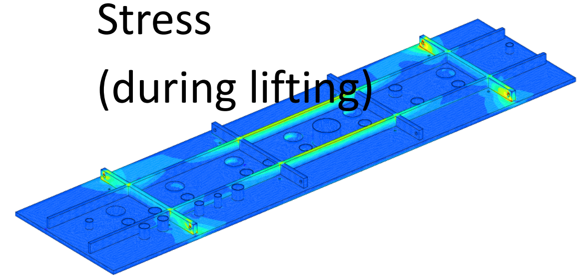
→ The components are hanged with C-shapes to the support frame hanged to the **top plate**



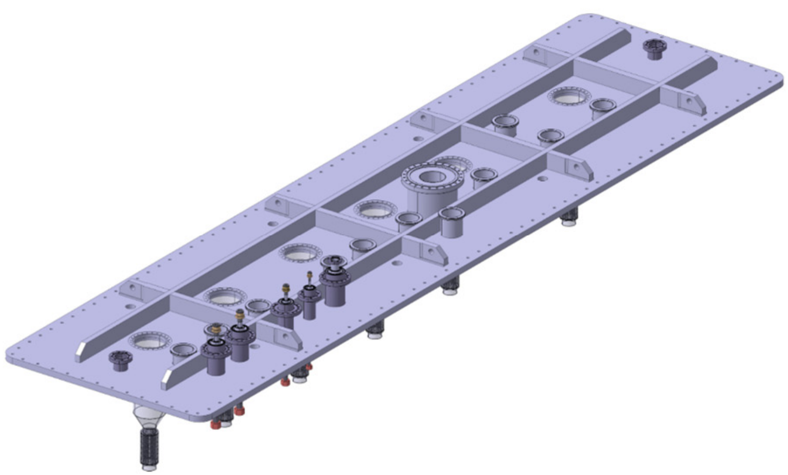
Deformation
(during lifting)

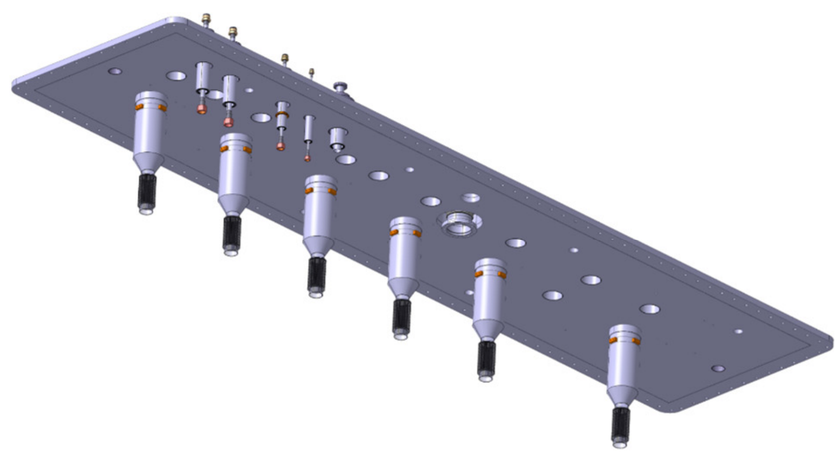


Stress
(during lifting)



Max : 0.8 mm
Min : -1.8 mm

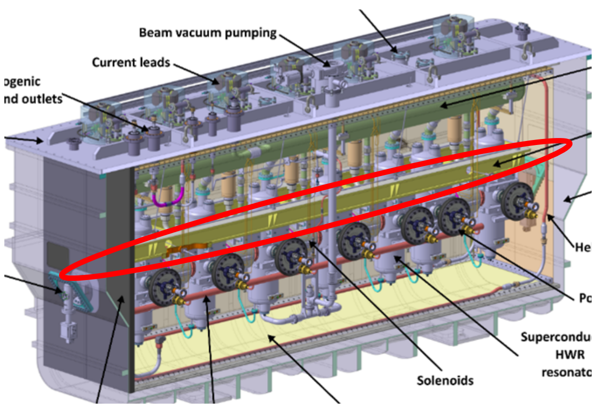




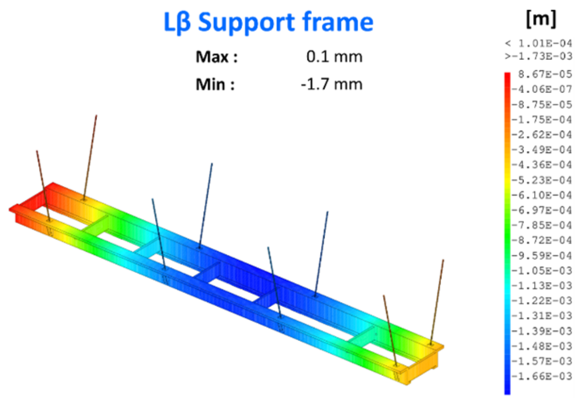
KEEP ON AXIS

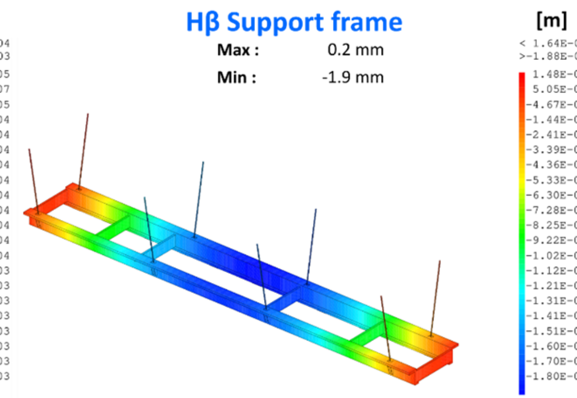
Req: major components ± 1 mm from beam axis

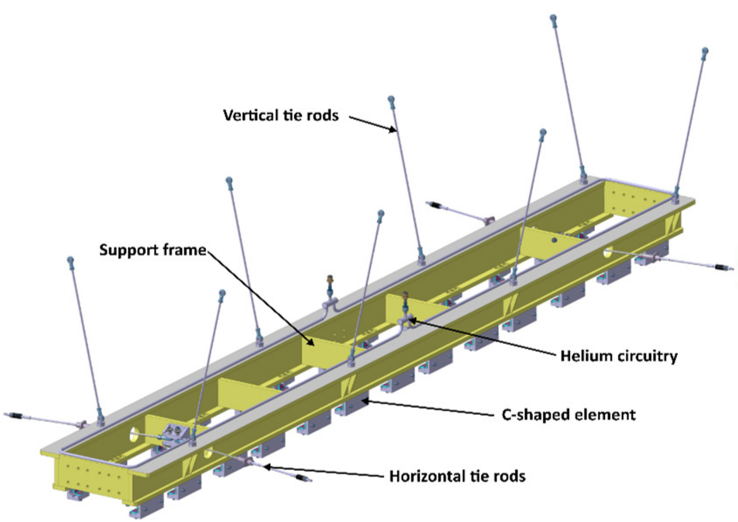
→ The components are hanged with C-shapes to the **support frame** hanged to the top plate



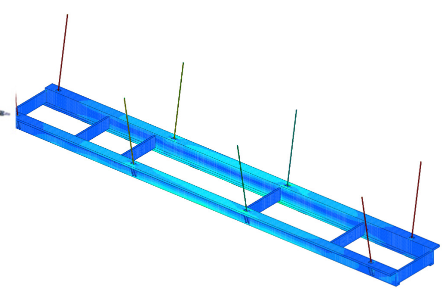
Deformation (during lifting)

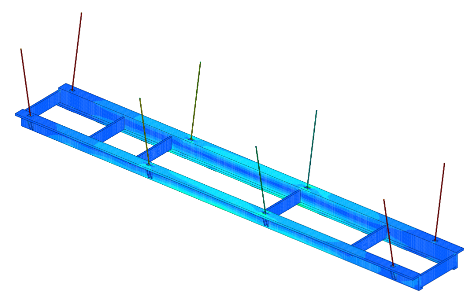






Stress (during lifting)

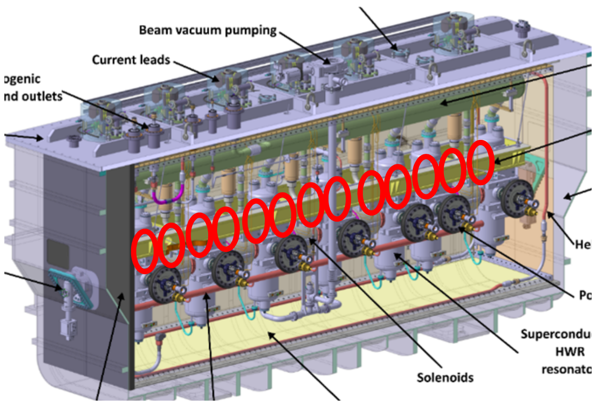


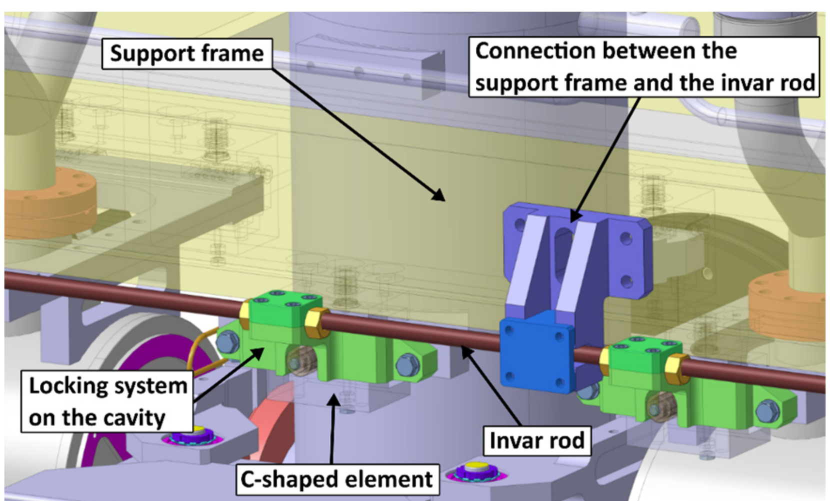


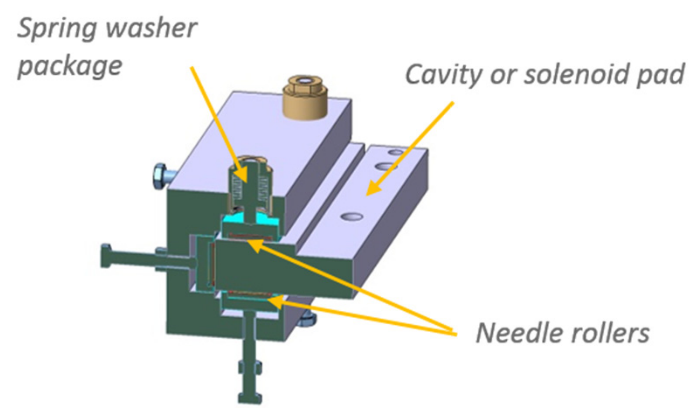
KEEP ON AXIS

Req: major components ± 1 mm from beam axis

→ The components are hanged with **C-shapes** to the support frame hanged to the top plate



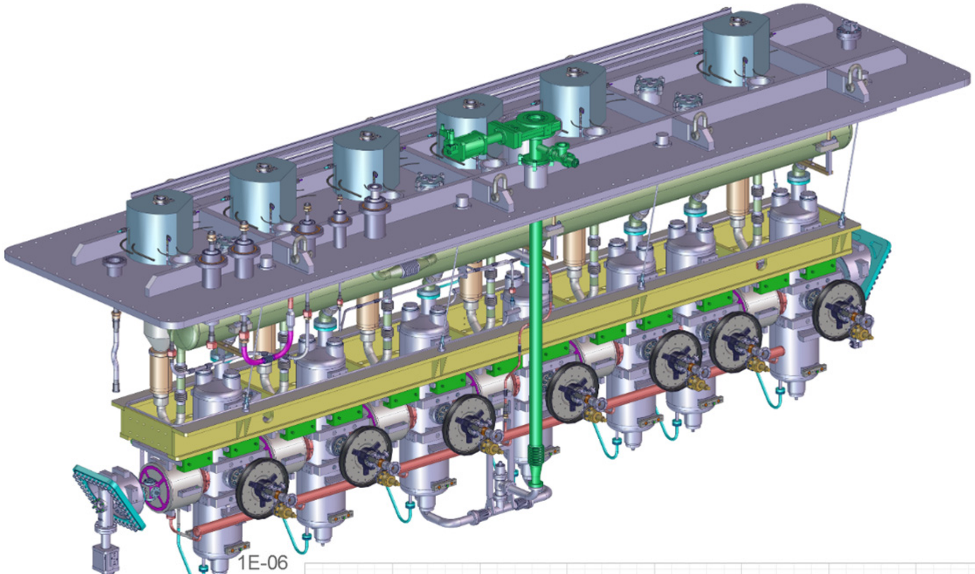


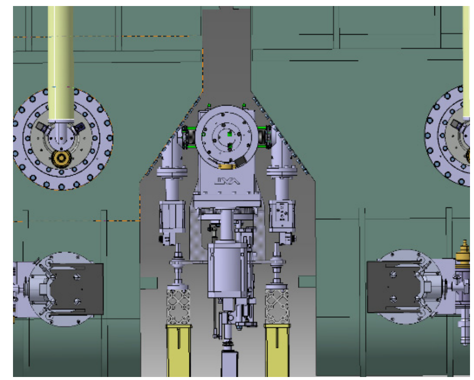


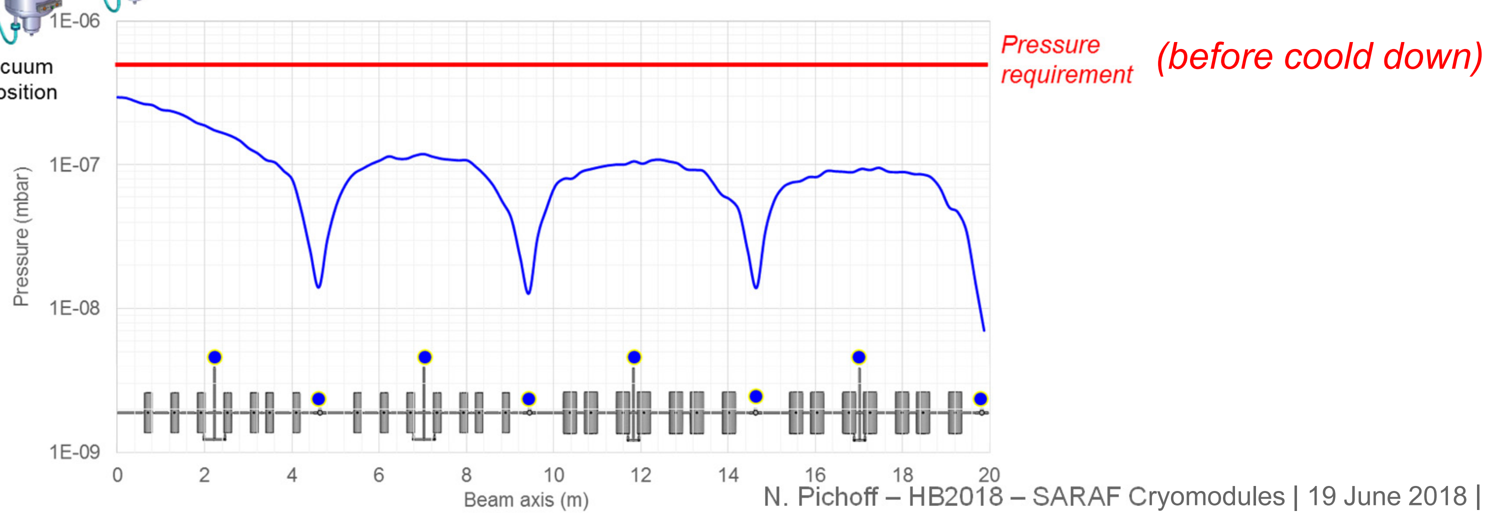
KEEP BEAM UNDER VACUUM

Req: pressure < 5 10^{-7} before cool down

→ The cryomodule allows pumping of central cavities and warm sections (between CM)



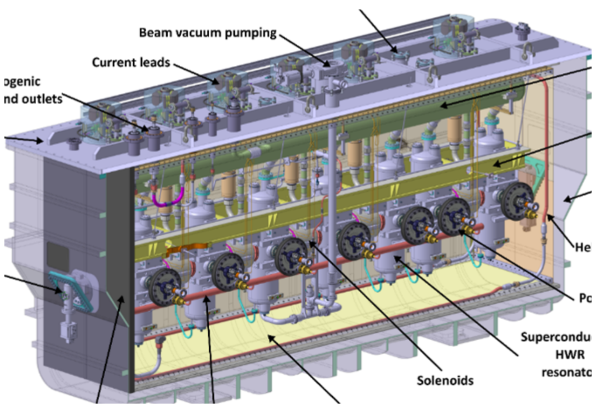




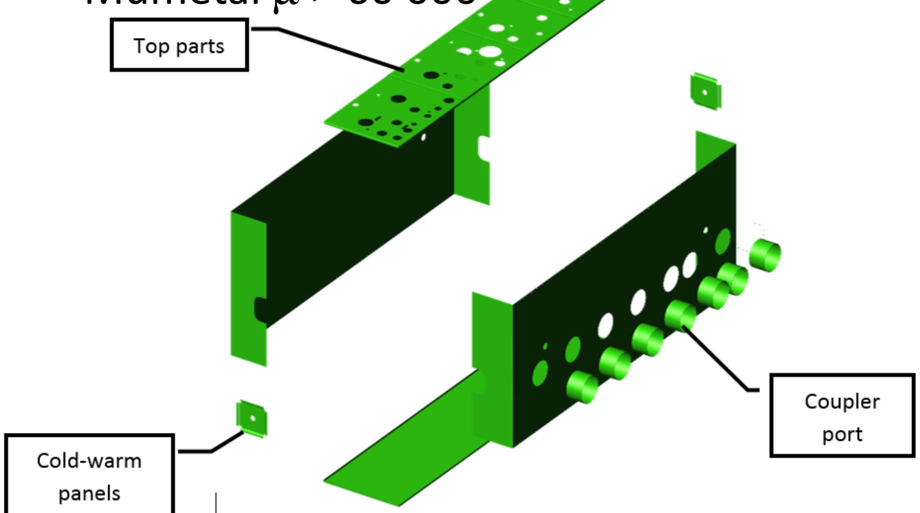
KEEP FROM MAGNETIC FIELD

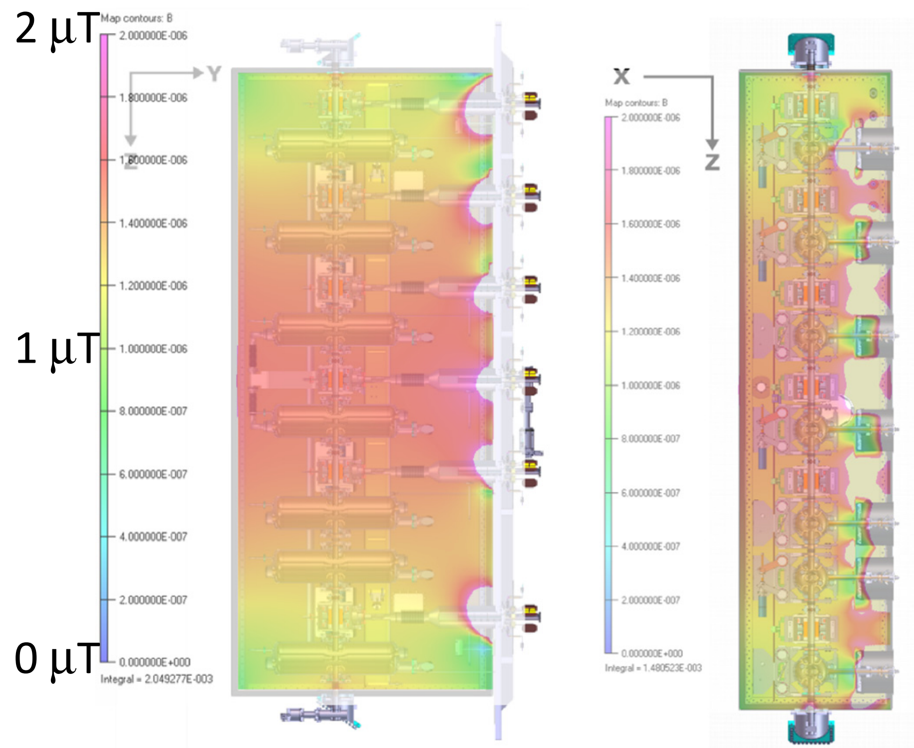
Req: B < 2μT during HWR cool-down

→ The cryomodule should preserve the HWR from external (earth) magnetic field



Mumetal μ > 60 000



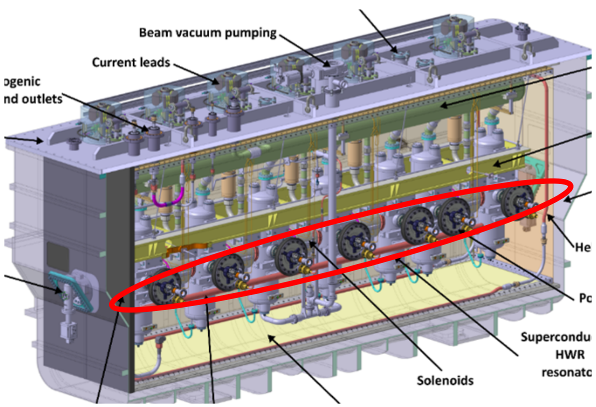


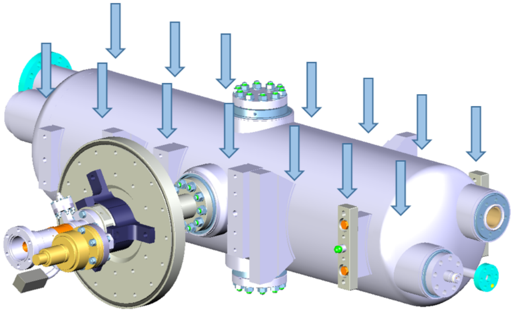
Considering 50 μT external field

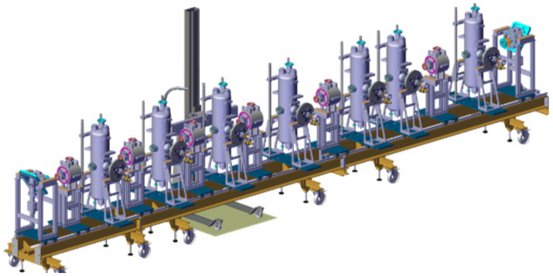
KEEP FEEDED BY POWER

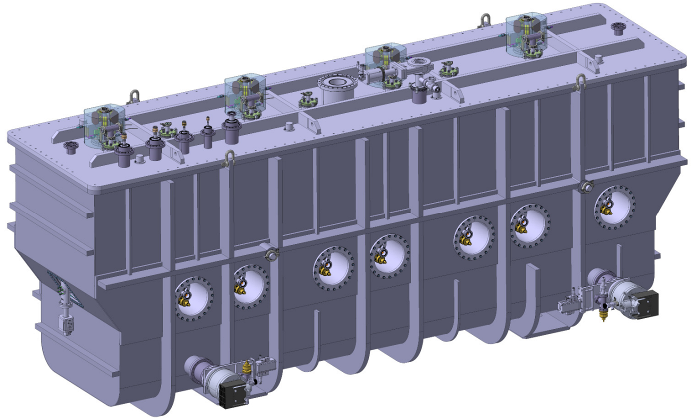
Req: Allow HWR (< 20 kW) and Magnets (< 100 A) power feeding

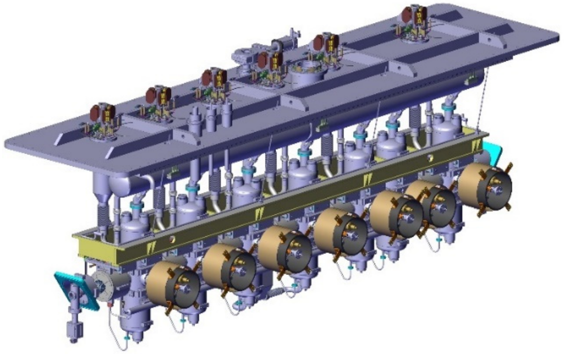
→ The cryomodule should cope with **RF power couplers** and Current Leads.







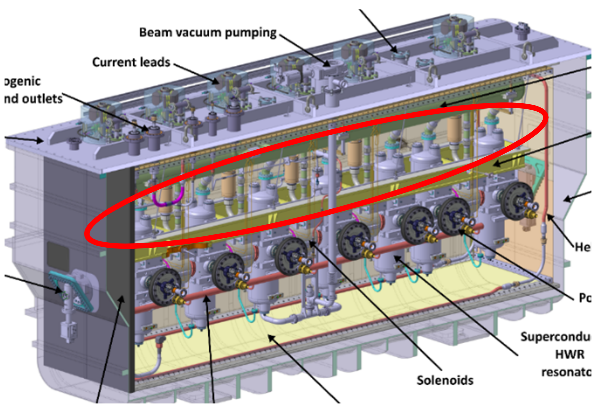


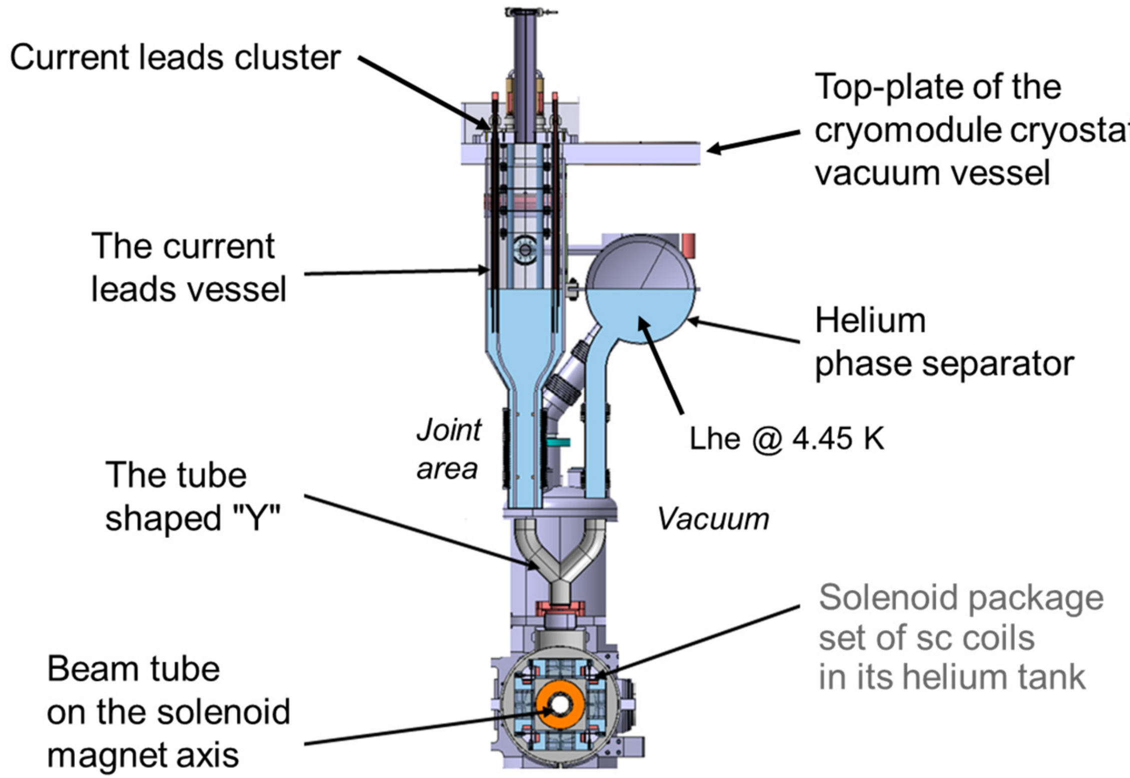


KEEP FEEDED BY POWER

<u>Req</u>: Allow HWR (< 20 kW) and Magnets (< 100 A) power feeding

→ The cryomodule should cope with RF power couplers and **Current Leads**.

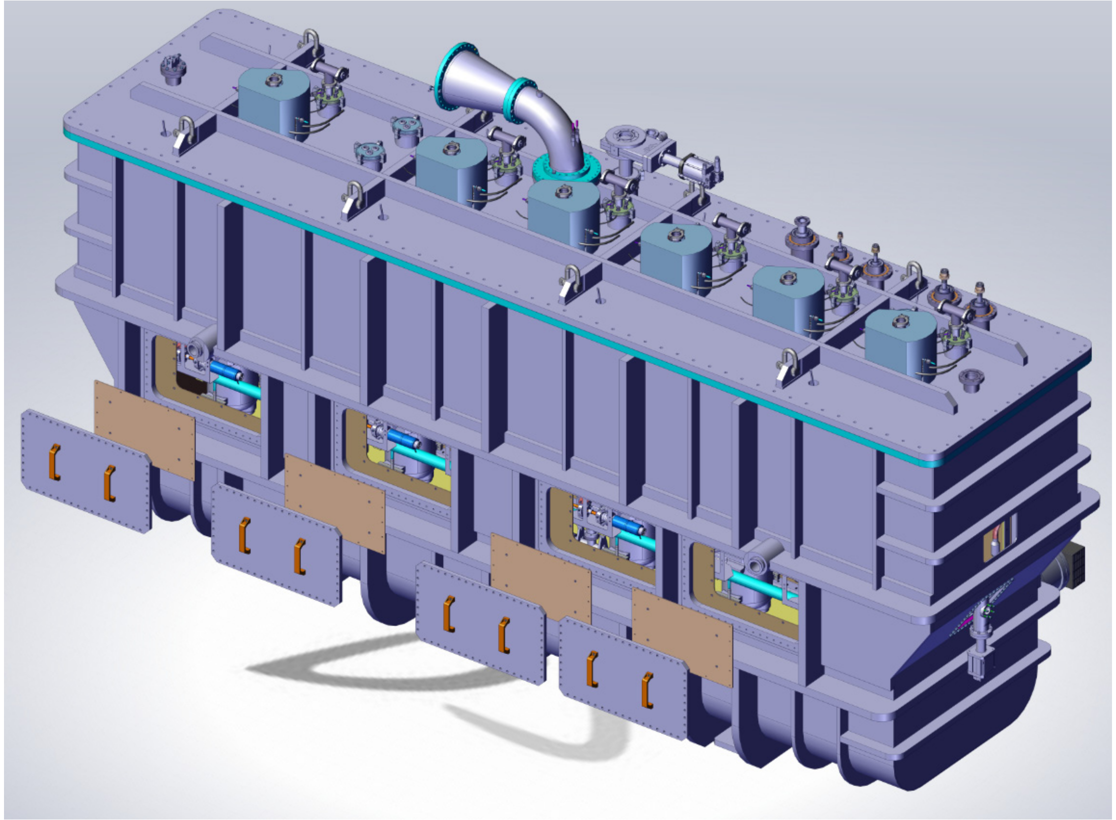


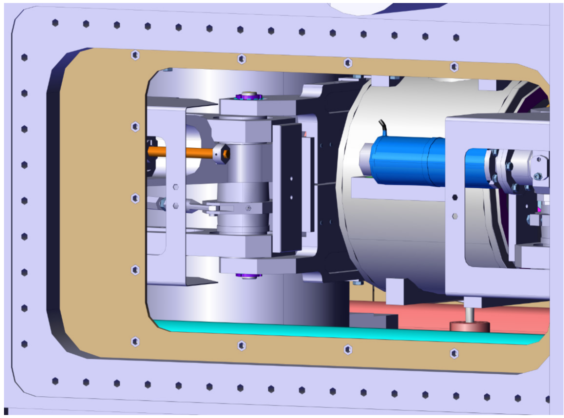


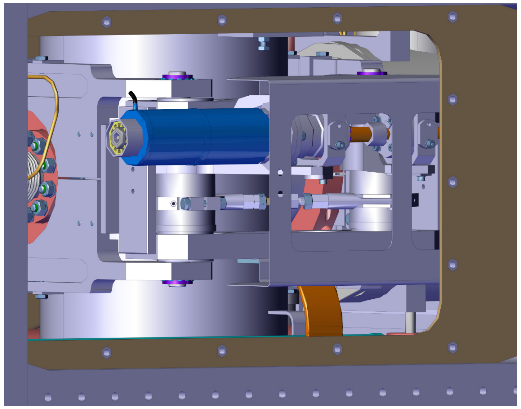
KEEP ACCESSIBLE FOR MAINTENANCE

Req: Maintenance operations should be facilitated

→ Some fragile components (motors, redundant sensors) are accessible through trap doors.







CONCLUSION

A special care special care has been performed for defining **functional requirements** for the cryomodules. This facilitates the **selection and justification of the solutions** and to prepare **inspection and testing** occurring during the integration and commissioning phases.