THE VSR DEMO MODULE DESIGN –

a spaceframe-based Module for Cavities with warm waveguide HOM-Absorbers

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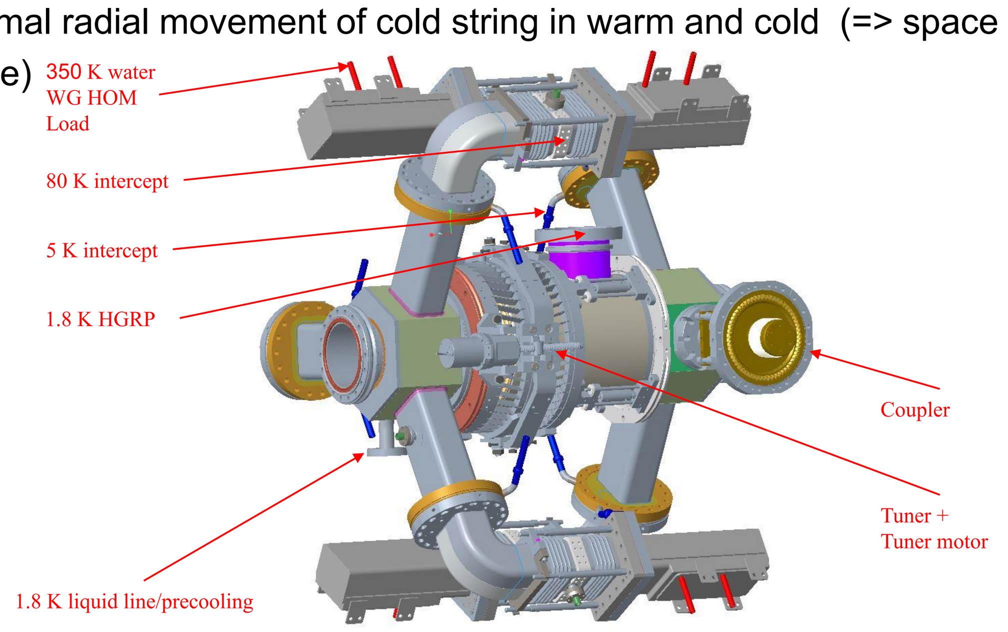
Abstract

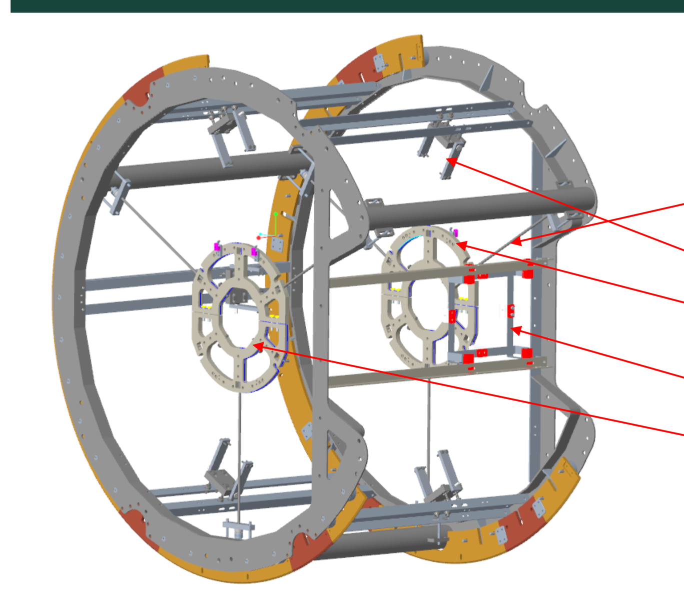
The variable pulse length Storage Ring (VSR) demo module is a prototype for the superconducting upgrade of HZB's BESSY II. The module houses two 1.5 GHz superconducting cavities operated at 1.8K in continuous wave (CW) mode. Each cavity has five water cooled waveguide HOM absorbers with high thermal load (450 W), which requires water cooling. This setup introduces several design challenges, concerning space restriction, the interconnection of warm and cold parts and alignment. An innovative space frame was designed to provide support and steady alignment. The transition from cold to warm over the partially superconducting waveguides made a complex design for shielding and cooling system necessary. With the design close to completion, we are now entering the purchase phase.

Design requirements and challenges

- Space restriction → Axial and radial
- Waveguides and HOMs
  - high HOM loads: (20 x 450 W) => water cooling required
  - long, partially superconducting waveguides required
  - warm parts (HOMs) and cold parts on one axial plane (=> shield)
- Alignment:
  - fix points (couplers) during cool down
  - long rectangular waveguides with rectangular bellows
  - bellows need shielding (lateral compensation very limited)
  - minimal radial movement of cold string in warm and cold (=> space frame)



Spaceframe



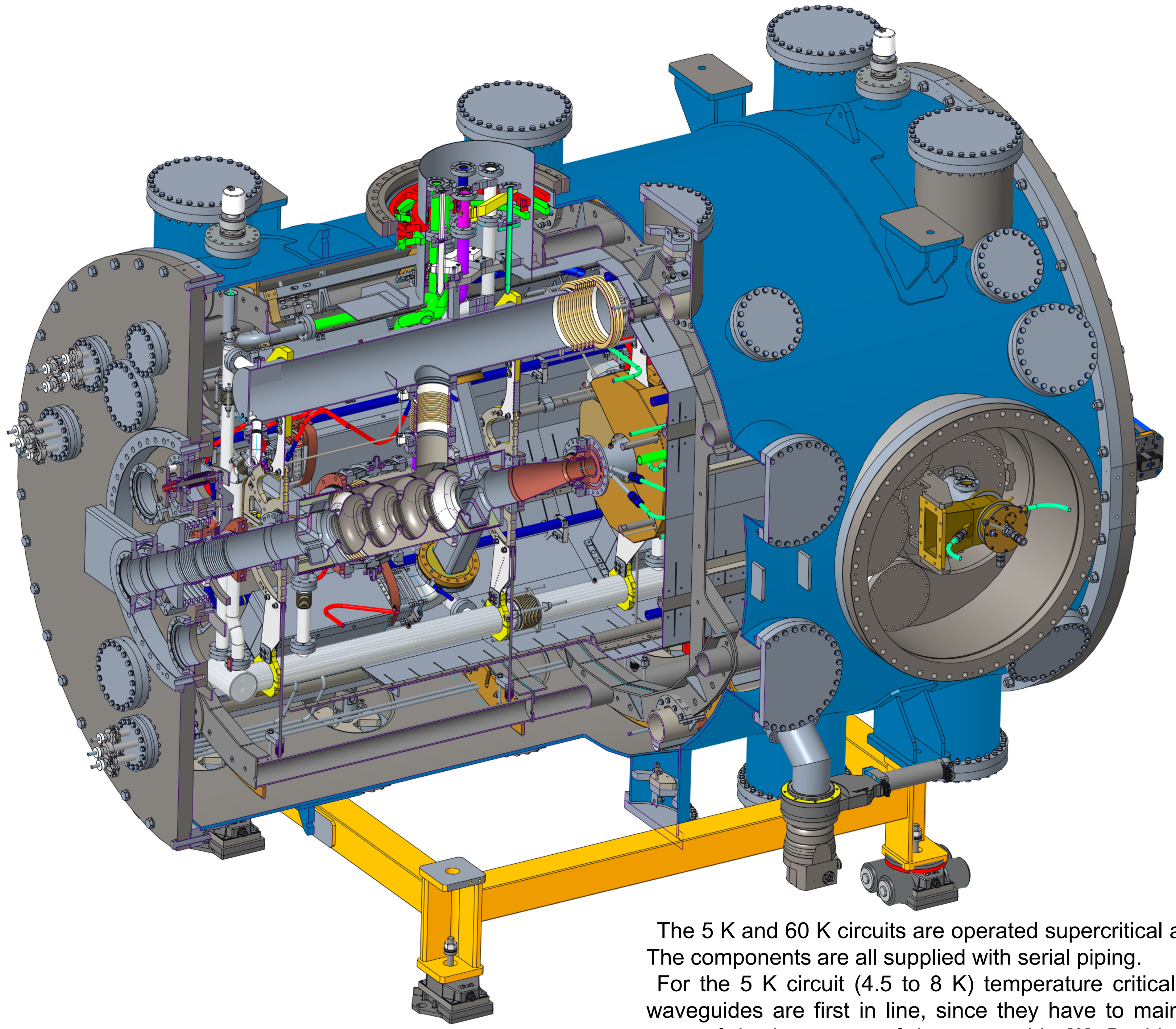
- modular
- minimal displacement during cool-down
- titanium rods
- support for
  - HOM-loads
  - Cavity
  - magnetic shield
  - Coupler
- assembly frame for cavity
- thermal decoupled cold support

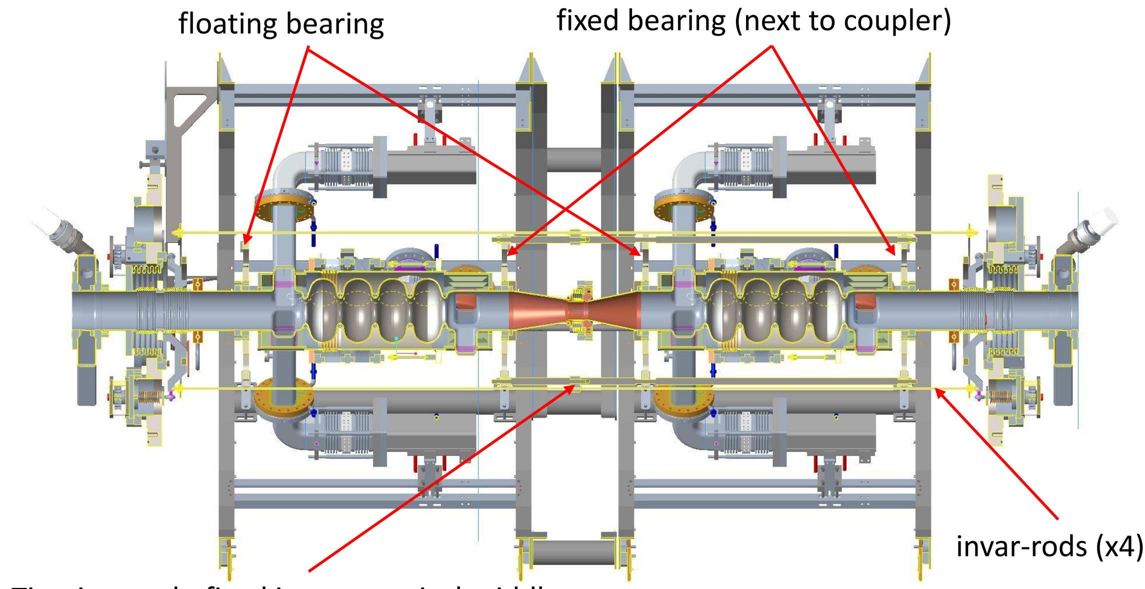
The Titanium rods are arranged in 120° angles to compensate the thermal shrinkage of each other as well as provide thermal decoupling of the cold and warm structures. Springs on the warm side bearing keep the forces and stresses low. The springs are also serve for preloading the rods, to minimalize moment in warm and compensate for (unsymmetrical) gravity.

The support structure is divided in warm and cold. Down to the 80 K level components are supported from the warm side. Everything below 80 K is supported by the cold supports, which are decoupled by the Titanium rods. The spaceframe is designed in a modular fashion. Each cavity its own wheel section. This section is in principle inter-changeable, so that perspectival a 1.75 GHz cavity could be integrated as well.

The section provides support for HOM loads, magnetics shield and coupler in the final module, and also during assembly. This is from importance since the five wave-guide (WG) HOM absorbers and the coupler need support from the beginning of the assembly.

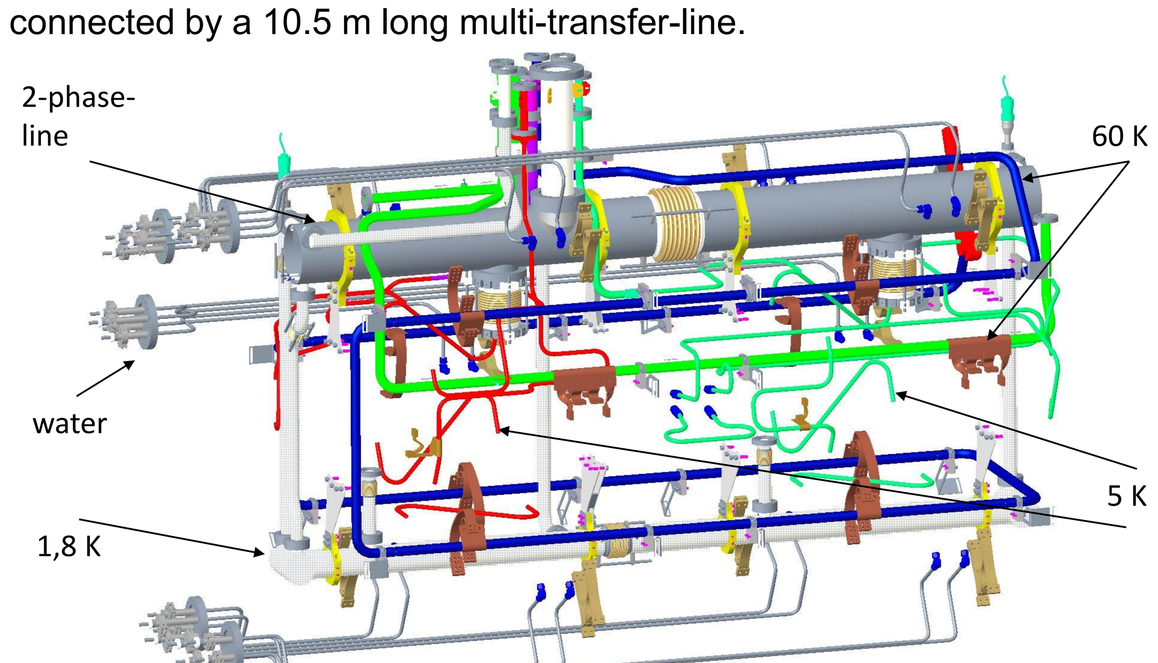
The attached rails (orange) allow a controlled turning (on a toolng with rollers) and mounting of the waveguides and the cold coupler part horizontally. Two turns of 60° are sufficient.





Cooling system

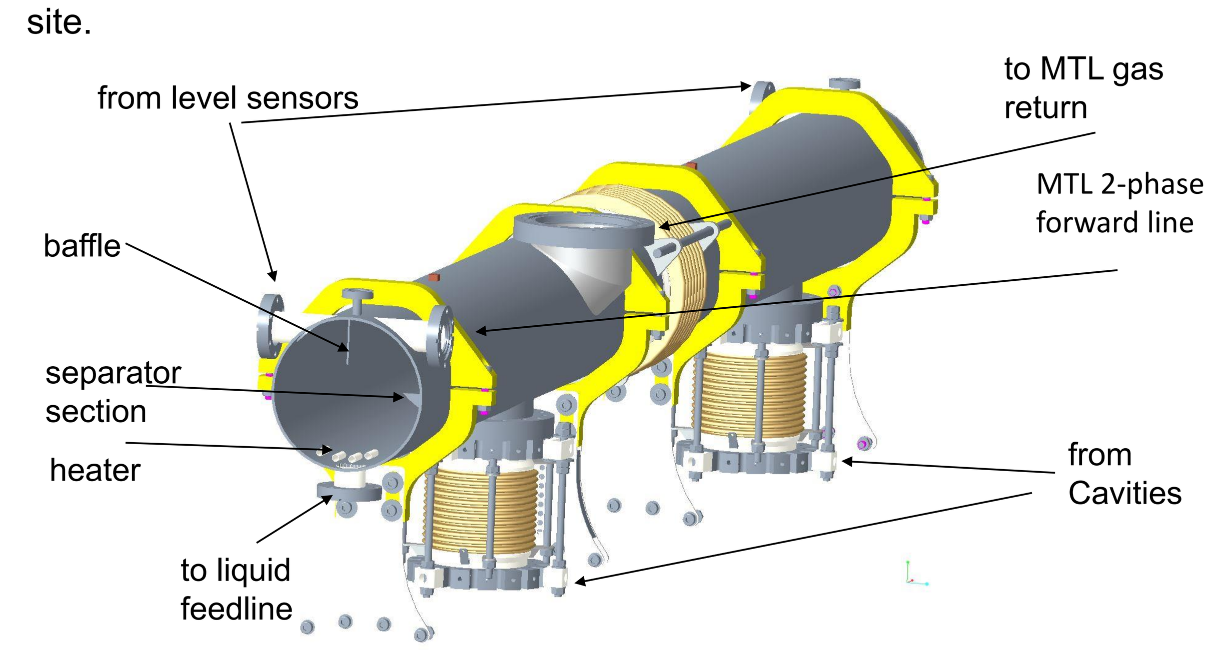
For the BESSY II test site a cryo-plant was planned and bought. The feedbox, which contains all valves (including safety valves) and provides the different helium temperature levels. It is placed outside the storage ring and connected by a 10.5 m long multi-transfer-line.



The 5 K and 60 K circuits are operated supercritical at 3 bara and 12 bara. The components are all supplied with serial piping.

For the 5 K circuit (4.5 to 8 K) temperature critical components like the waveguides are first in line, since they have to maintain superconducting state of the lower part of the waveguide [3]. Besides the intercept of the coupler, all intercepts are directly flown through, to avoid temperature gradient over a copper braids. Copper braids are used for intercepts in the 60 K circuit since the temperature level is less critical and the assembly is easier.

In the 5 K and 60 K circuits all connections are orbital welded except of the connection to the MTL which has to be detachable in order to install and remove the module quickly. This is especially important for the BESSY II site.

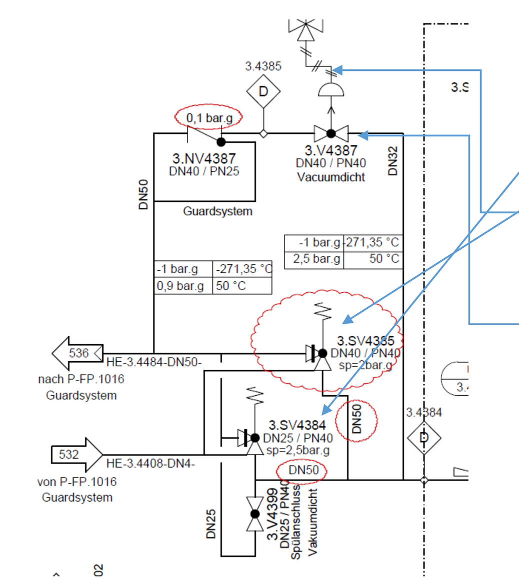


Since the feedbox has a Joule-Thomson-valve in the forward flow of the 1.8 K circuit 22%, flash gas (for BESSY II) is expected. This makes a phase separator in the module necessary. Due to the space restrains the only possible way is to include this in the two-phase line. The left section of 2-phase-line serves as separator. Since the two cavities are in parallel piping the 1.8 K circuit has a liquid feedline. This is primarily for cool down operation. It can be feed directly with (tempered) helium from the precooling line. If the regular inlet over the phase separator is used, the liquid phase flows to the lower feedline and cools down the cavities evenly.

Parts like the 2-phase-line or the cavities are bigger and will be fabricated separately. Therefore, from an assembly point of view detachable connection are necessary, where CF connection are used. Since the CF flanges are not licensed for these high pressure levels they get an approval for specific use from our notified body.

Safety concept

To dimension the safety vales for a higher opening pressure is for the 1.8 K system not a possibility. In the opposite the pressure levels for opening the safety valve already to high. The opening pressure is defined by the counter pressure of the guard system. For the cold operations this would be acceptable, but at room temperature RRR Niob especially after heat treatment 800°C, like it is planned for the cavities, the Yield Strength is too low. In order to avoid deformation of the cavity in a warm state there are two lower pressure levels implemented.



pressure levels

- 3.5 bar(a): safety valves (full flow – phase change)
- 3 bar(a) safety valve (partial flow)
- 2 bar(a) hard wired cutting of power supply of software controlled process-valve (fail open)
- 1.5 bar(a) software controlled process valve (maximal operation pressure - machine protection warm)
- guardsystem:
  - pressure controller at 1.4 bar(a)
  - rupture disk at 1.7 bar(a)

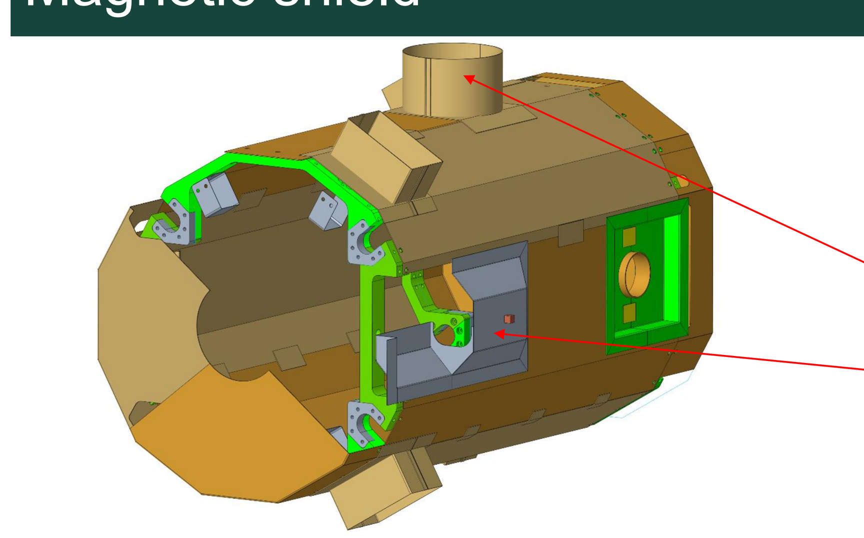
Due to space restrains on the possible sites it was not possible to integrate safety valves inside the module. Therefore, they had to be integrated in the feedbox.

To discharge the high ass-flows (calculated according to DIN EN ISO 21013-3:2016-12) with an acceptable pressure drop, following measures were taken.

For the 5 K and 60 K circuit the safety valve for the 5 K and 60 K circuit have a nominal opening pressure of 15 barg. This helps to keep the volume flow smaller and in the case of the 5 K System there is no air condensation. Furthermore, the MTL return pipes are dimensioned accordingly.

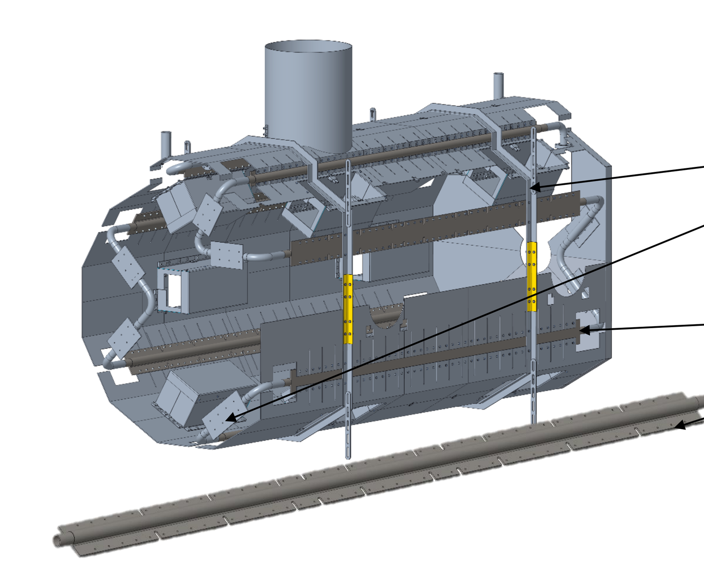
For the 1.8 K circuit a phase change and air condensation (in the case of a breached insolation vacuum) is not avoidable, but the return pipe is dimensioned for under pressure operation.

Magnetic shield



- 1 mm Mu-metal
- heavily segmented
- G10 support structure
- collars for opening
- pocket for tuner motor

Thermal shield



- extra covers for HOM absorber
- support frame + inside piping for easy assembly
- bolted plates
- pipe connection: orbital welding
- Aluminum extruded profile
- 3 mm aluminum shield
- each segment with helium cooling
- 30 Layers Multi-Layer-Insulation