Microphonics and Resonance Control from the Cryo-Mechanical Perspective

Based on the TTF-XFEL experience

Kay Jensch

Brooklyn, 25th October 2018

HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

DESY.

Summary

Subheading, optional

01 Introduction

- Microphonics VS vibrations
- Vibrations in TTF (TESLA Technology Facility, e.g. FLASH,…..)

02 Main sources of microphonics

- Mechanical design
- Cryogenic
- Vacuum
- RF

03 Conclusions

Introduction

Microphonics or vibrations?

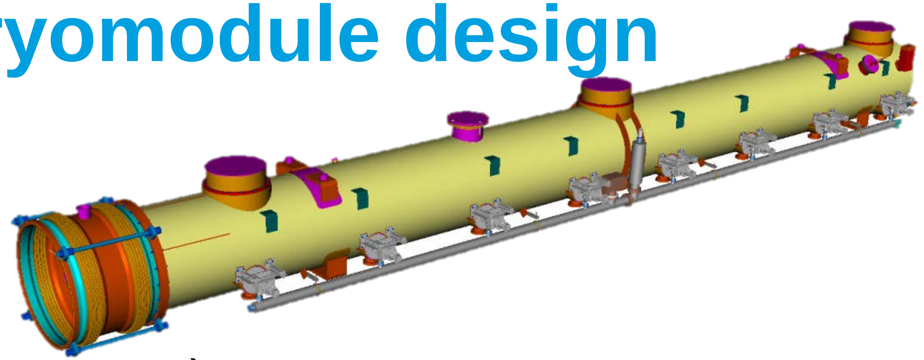
Subheading, optional

Is there any difference?

- In the cryo and mechanical world we call them mainly vibrations
- Wider range of amplitude
- Looking mainly at low frequencies -> up to 100 Hz
- Consider also very low frequency (<1 Hz)

Vibrations in the TTF cryomodule design

Where did we cross them?



TTF based accelerators @ DESY

- FLASH (7 cryomodules, different design stages)
- XFEL (97 cryomodules, final “evolution” of the TTF design)

Impact of vibrations

- Not a primary issue for the RF control
  - Pulsed machine, main detuning effect from Lorenz Force
- At the early stage of the design (first FLASH modules)
  - Stability concerns at the quadrupole -> possible alignment issue
  - Possible effect of cryo-operation conditions
- For the XFEL 1.3 km machine
  - Concerns on the stability of the new hanging supports

→ see Serena later today

Main sources of vibrations

Main sources of vibrations

In an accelerator environment

Environment

- Ground vibrations
- Surroundings -> highways, traffic, construction sites,….

Mechanical design

- Resonances of subcomponents
- Support system
- Connections to the environment

Cryogenics

- Valves
- Cryoplants

Vacuum

- Pumps
- Clean rooms

RF sources

- Cooling system

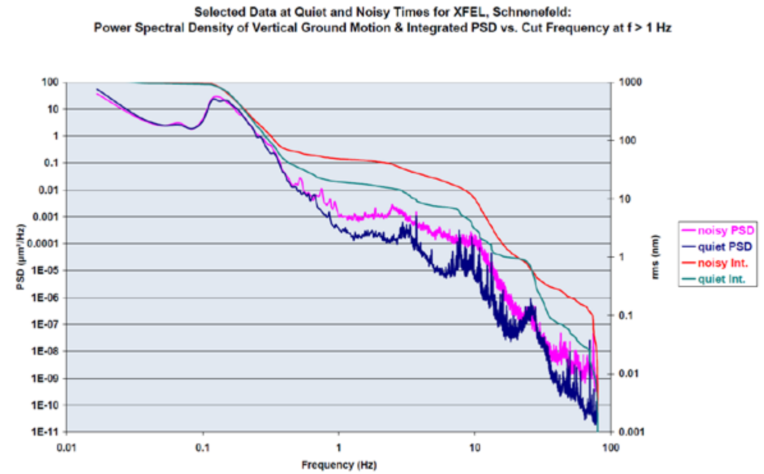
Environment

The environment

From the vibration point of view

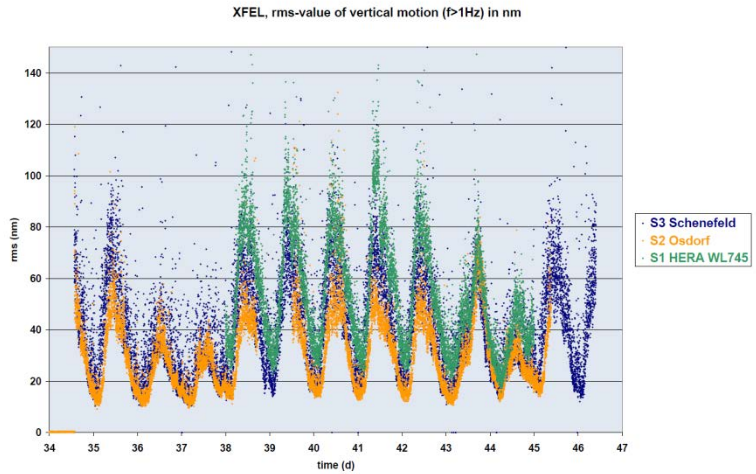
Ground vibration

- Can’t be change, once the site is chosen
- Not constant, mainly daily fluctuations



Surroundings and occasional events

- Highways, railroads, big cities, constructions
- Earthquakes

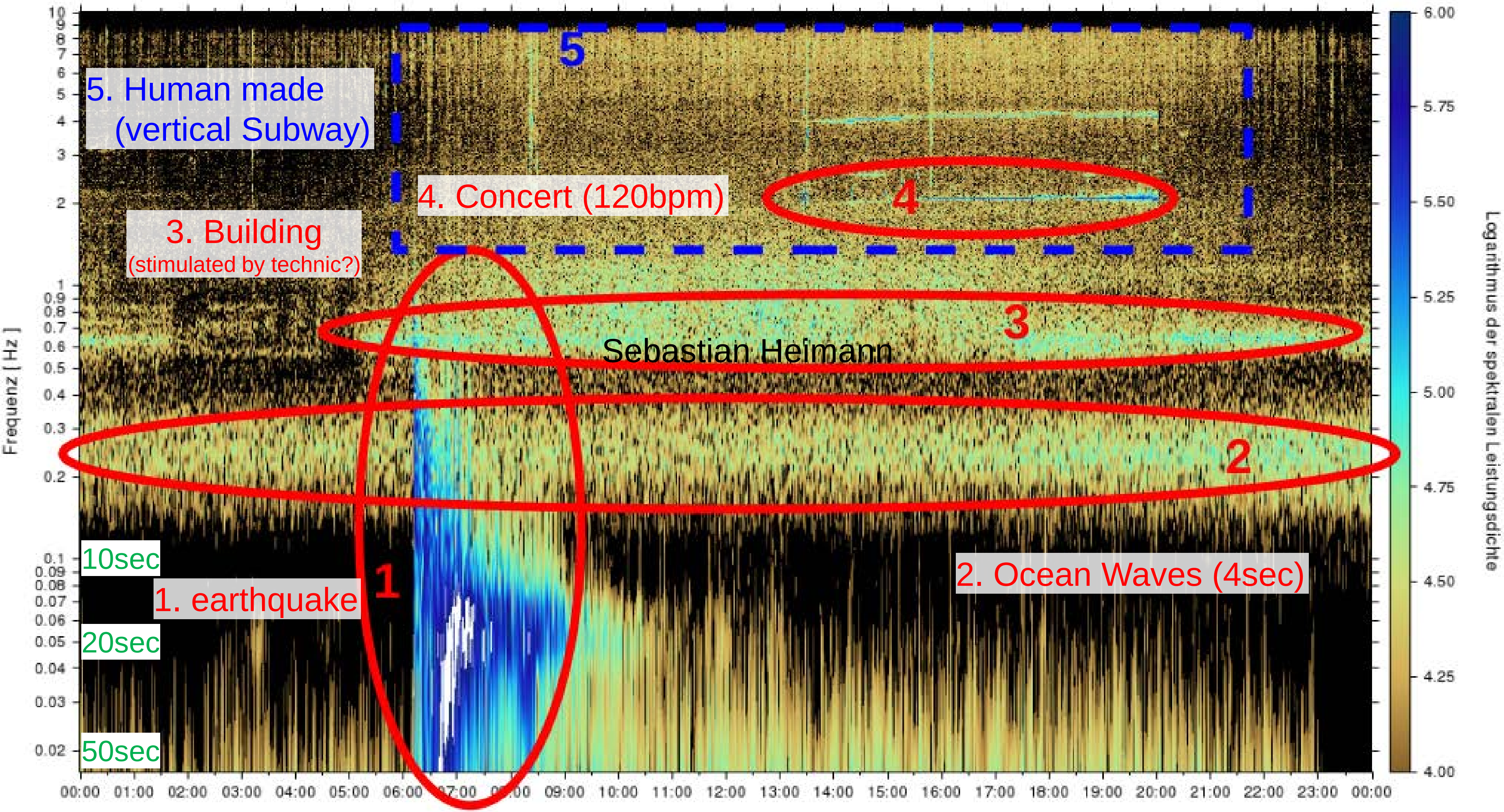


Mitigation possible?

- **E.g. LCLS and ILC (Japan) build on one tectonic plate**

Examples

Spektrogramm der Bodenunruhe unter dem Geomatikum vom 09.05.2010 (Sonntag)



Von Sebastian Heimann, Institut für Geophysik; Universität Hamburg

Mechanical design

A foreword: why do we need cryomodules?

- Mechanically support the cavity string, allowing thermal shrinkage of parts from 300 K to 2 K without introducing stresses during cool down and warm up
- Guarantee the cavity string alignment with a precision less than 0.5 mm
- Supply the cavity string with 2 K liquid helium
- Thermally isolate the cavity string at 2K from the 300 K environment
- Bring high power RF to the cavity string (coupler)

1. Mechanical design

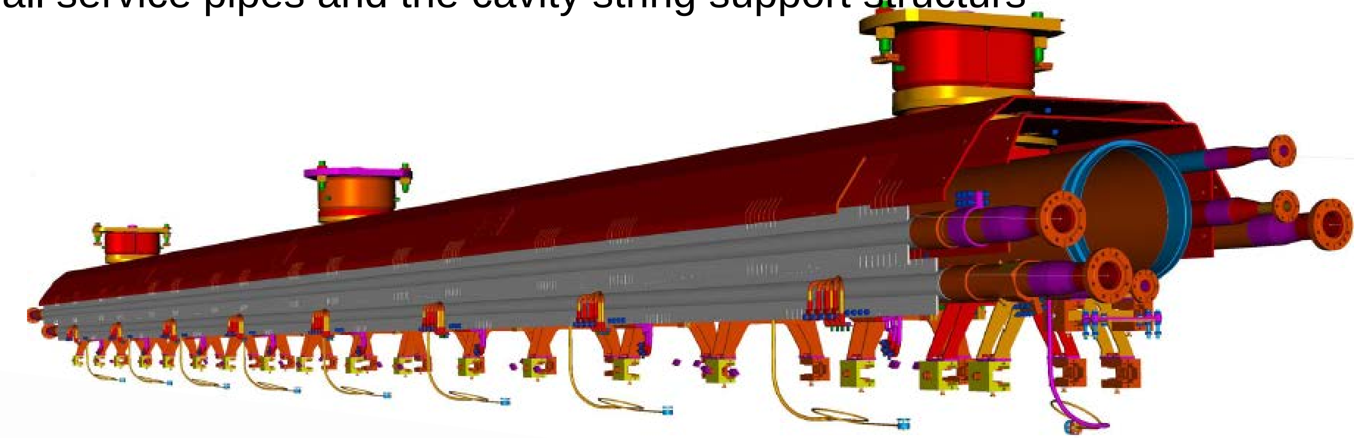
From the vibration point of view

Sources of vibrations

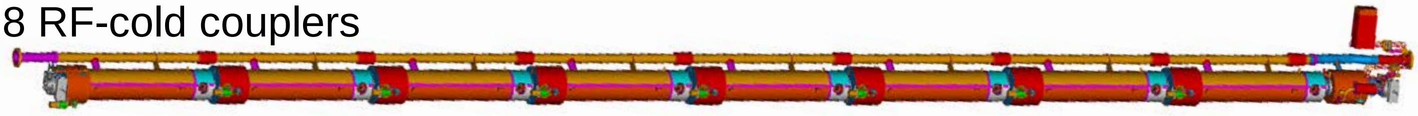
- Resonances of subcomponents
  - Reduction -> e.g. optimize design with modal analysis
  - Limitation -> cavity design optimized for performances, no much play
- Position of the support “feet” and brackets
  - Reduction -> e.g. move the components
  - Limitation -> design to minimize movement of inner components (quadrupole/BPM)
- Cavity supports
  - Reduction -> e.g. make them as stiff as possible
  - Limitation -> alignment requirements special for warm/cold
- Module to module connection
  - Reduction -> e.g. reduce coupling of vibration between consecutive components
  - Limitation -> more complicated cryo destribution (e.g. valves, boxes, …..)

1. Support of the cavity string

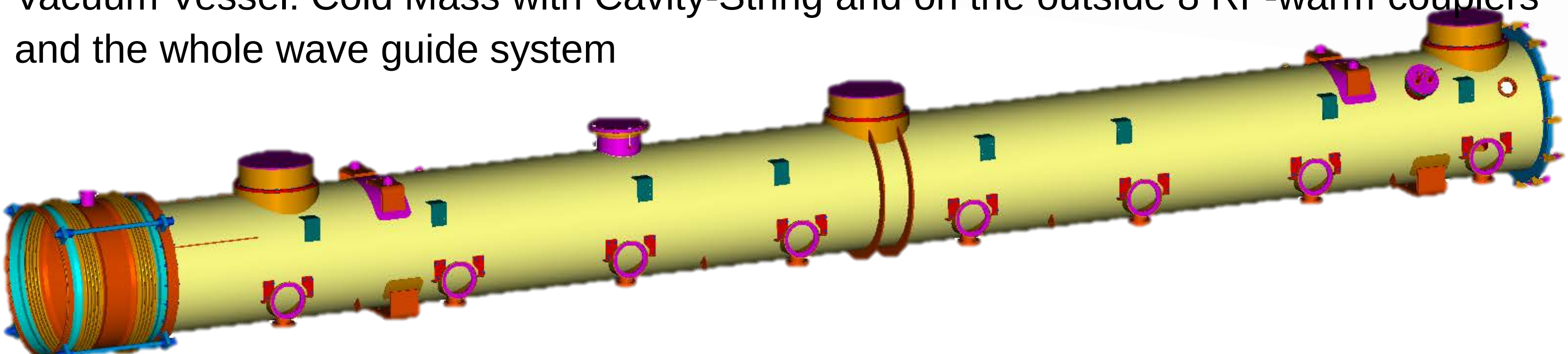
- Cold Mass: includes all service pipes and the cavity string support structurs



- Cavity-String: 8 SCRF cavities (with helium tank, 2 phase line, tuner with piezos,…, 1 quadrupole and 8 RF-cold couplers

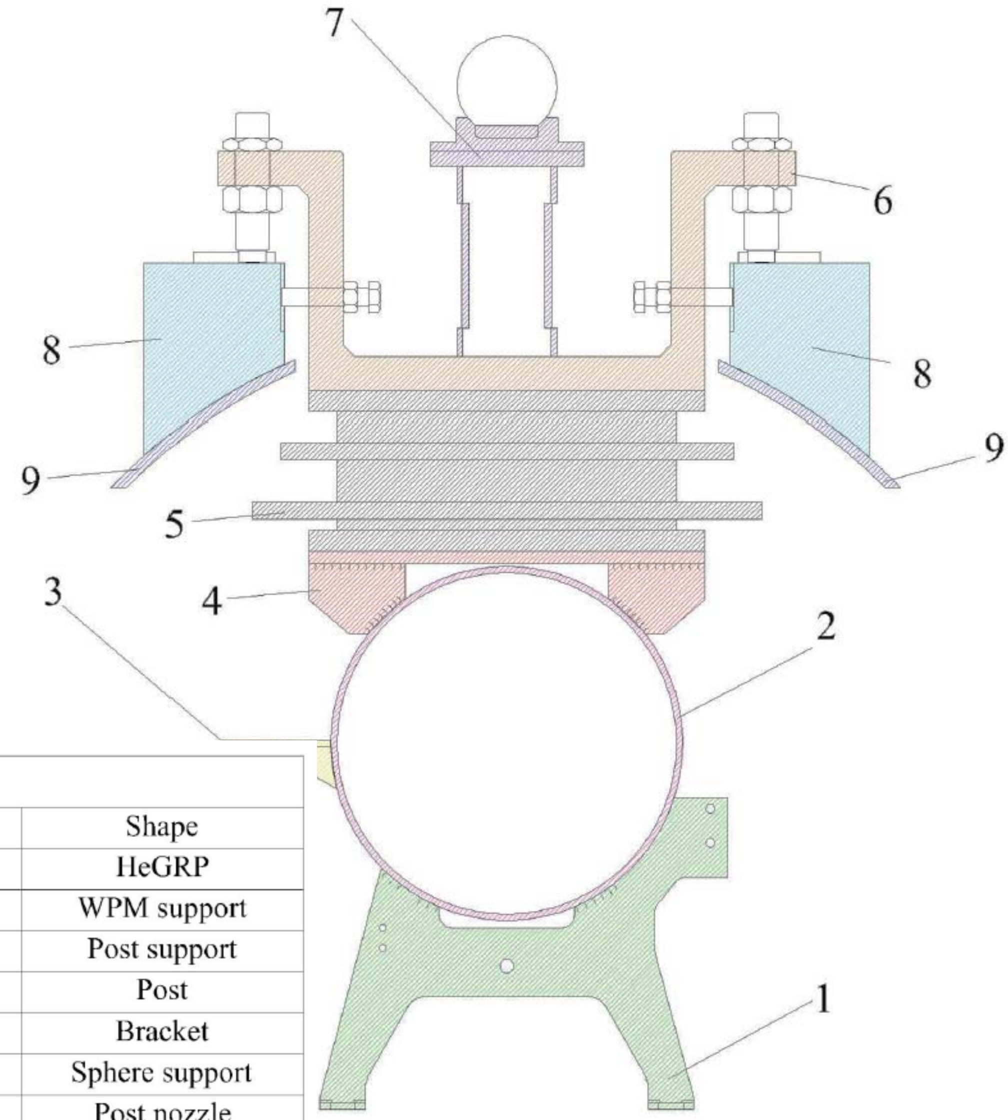


- Vacuum Vessel: Cold Mass with Cavity-String and on the outside 8 RF-warm couplers and the whole wave guide system



2. Support of the cavity string

- The vacuum vessel is either hanging from the ceiling of the XFEL tunnel or supported on the floor in the AMTF a. CMTB
- The cold mass is supported via the bracket + post assembly to the vacuum vessel. The center bracket is fixed to the vacuum vessel, while the 2 lateral ones are free to slide longitudinally, to allow the thermal shrinkage of the cold mass without introducing stresses.



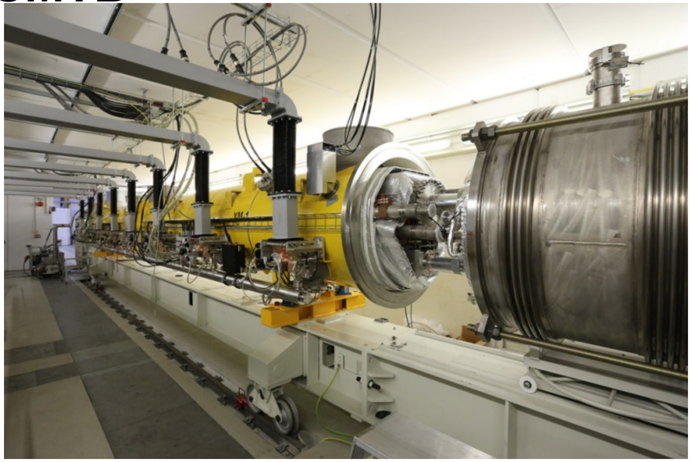
1	Shape
2	HeGRP
3	WPM support
4	Post support
5	Post
6	Bracket
7	Sphere support
8	Post nozzle
9	Vacuum vessel

Examples: supports

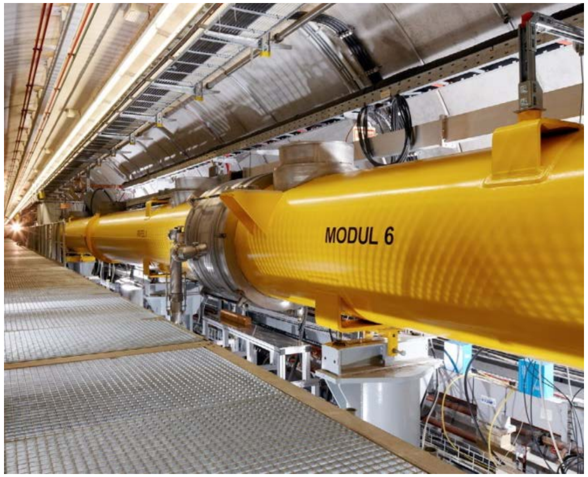
Support position

AMTF a. CMTB

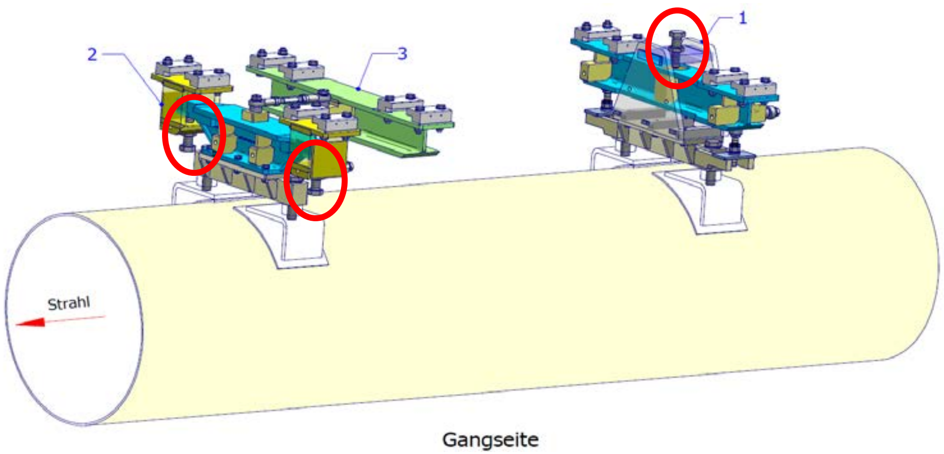
- Ground

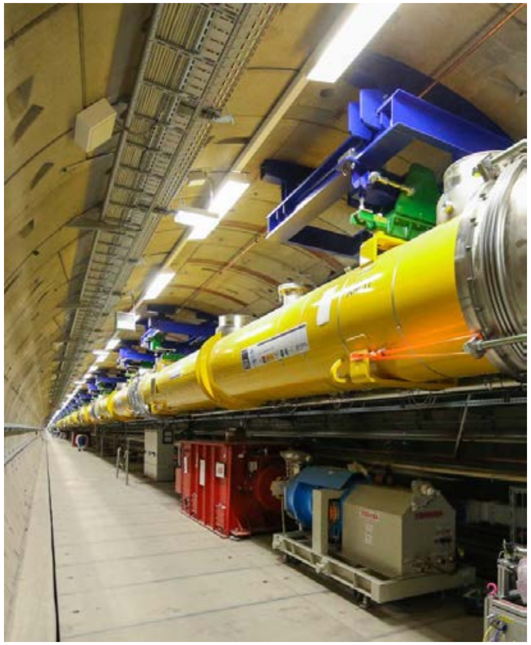


FLASH – Ground



XFEL - Ceiling



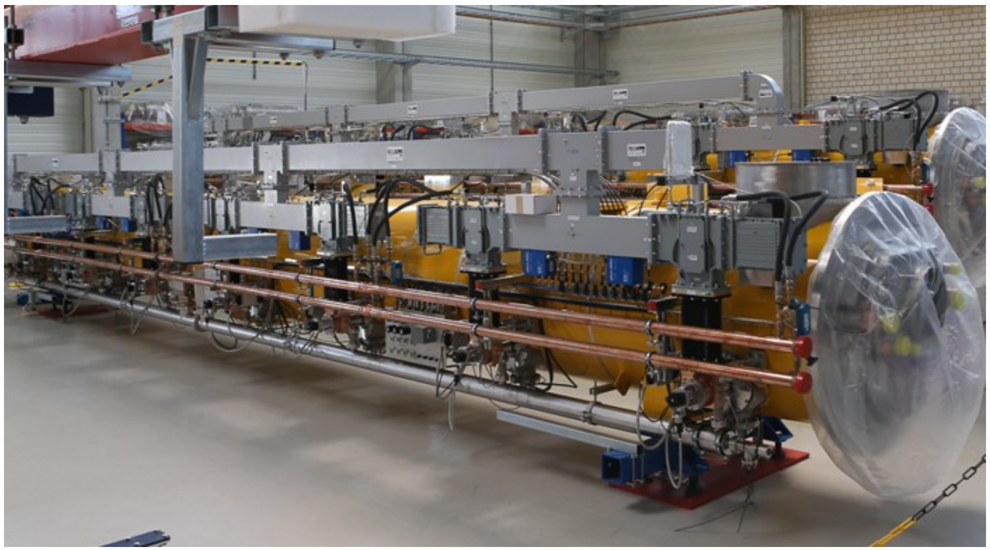


Examples: subcomponents

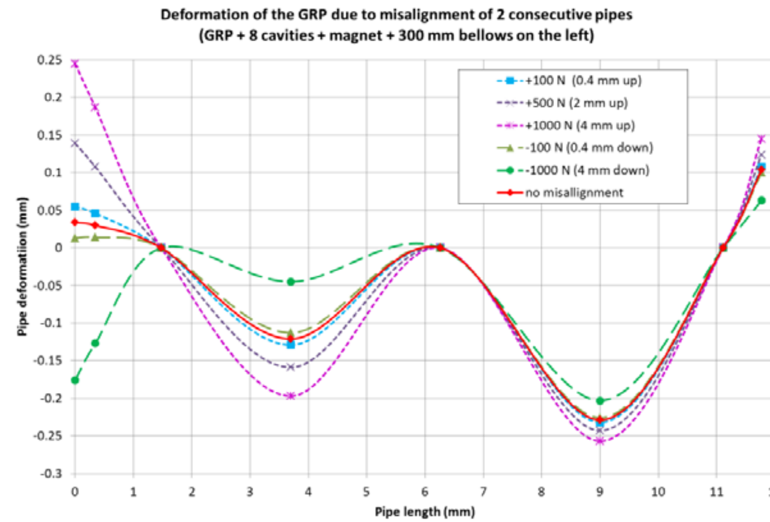
inside and outside

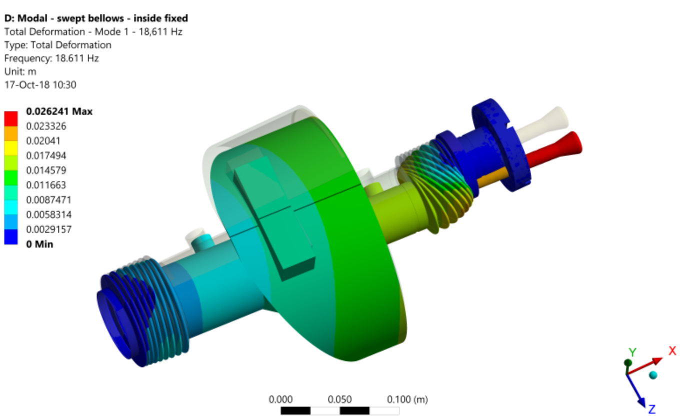
Dressed XFEL Cryomodule:

Wave Guide System with Water Cooling, Cabling, Patch Panel



Coupling of modules



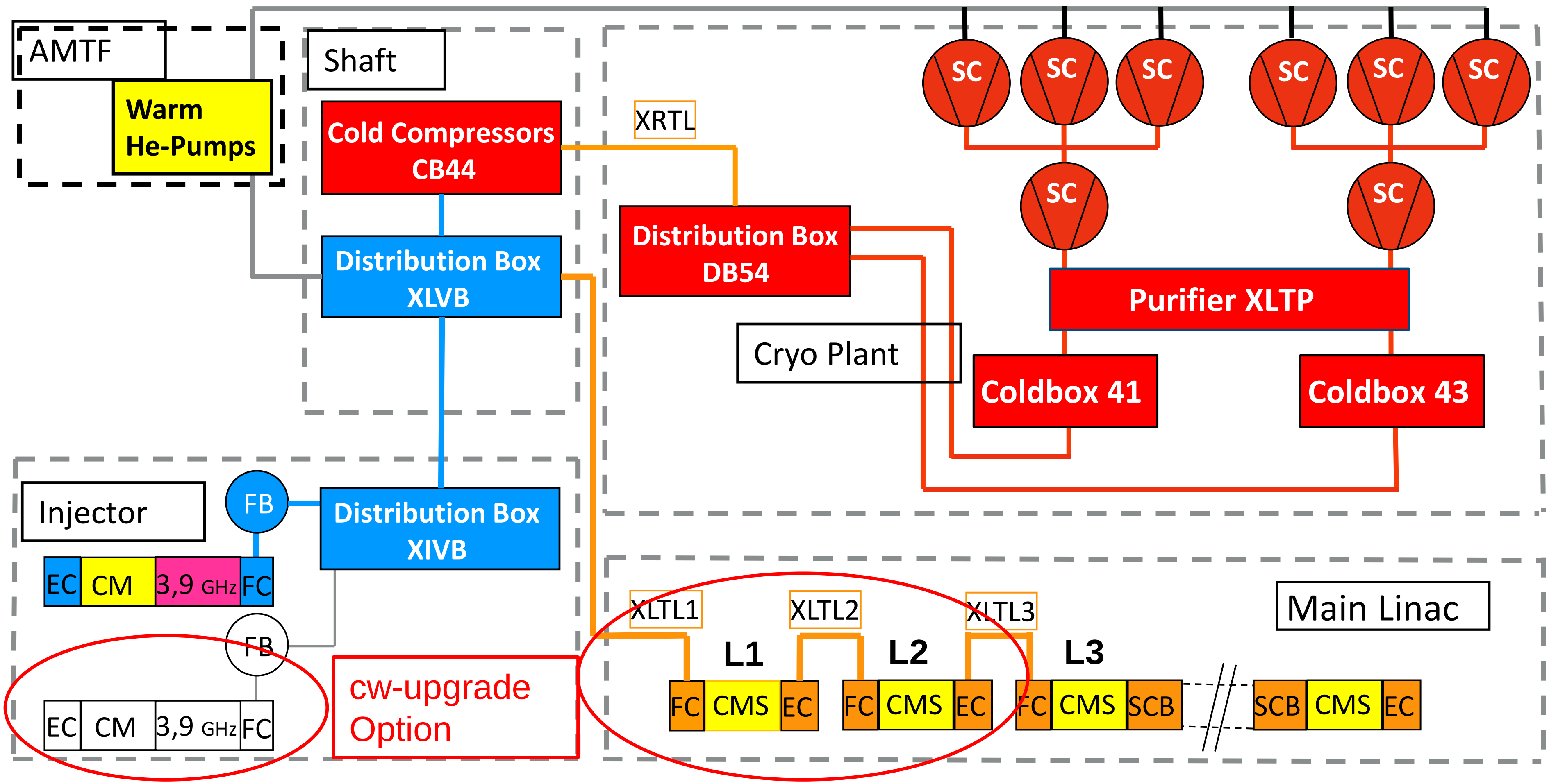


coupler modal analysis

Cryogenics

The XFEL cryogenic system

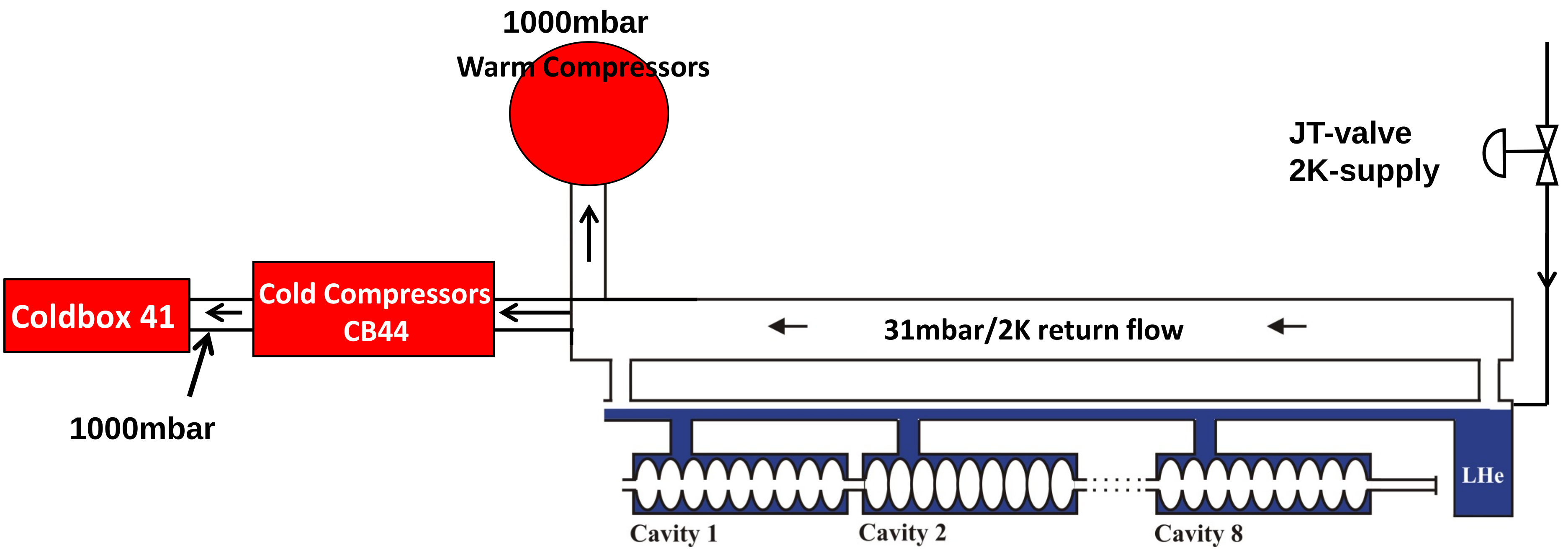
A very quick overview



2K princip of XFEL

Cold and warm compressors

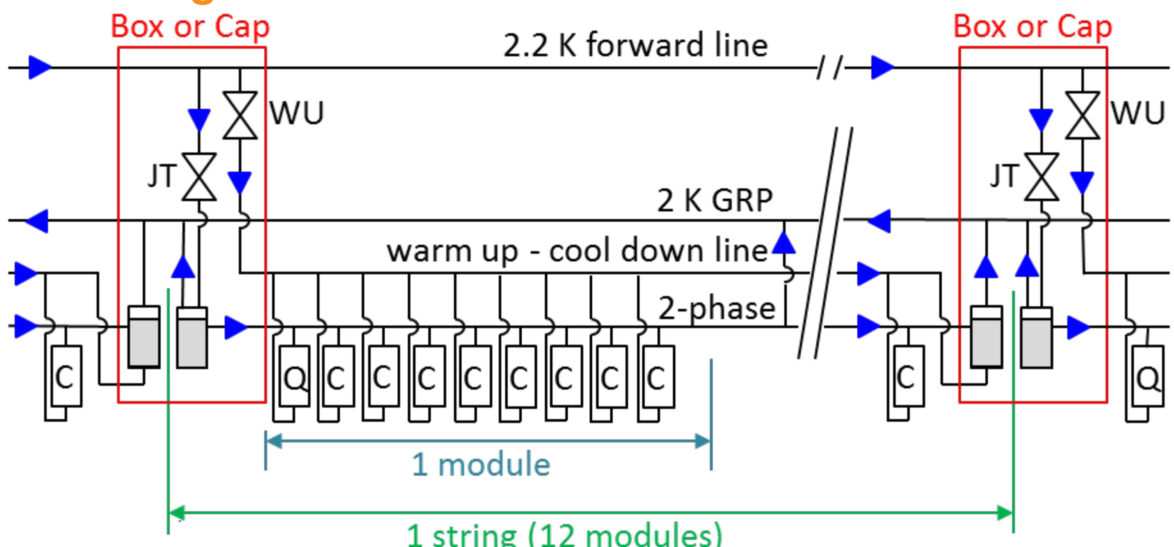
- Coldbox and Cold Compressors are for standard 2K operation
- Warm compressors are a backup -> only for the static losses
  - Remark: The Test Benches and FLASH are operated only with warm compressors
- Cold/Warm compressors is there an difference in case of vibration?

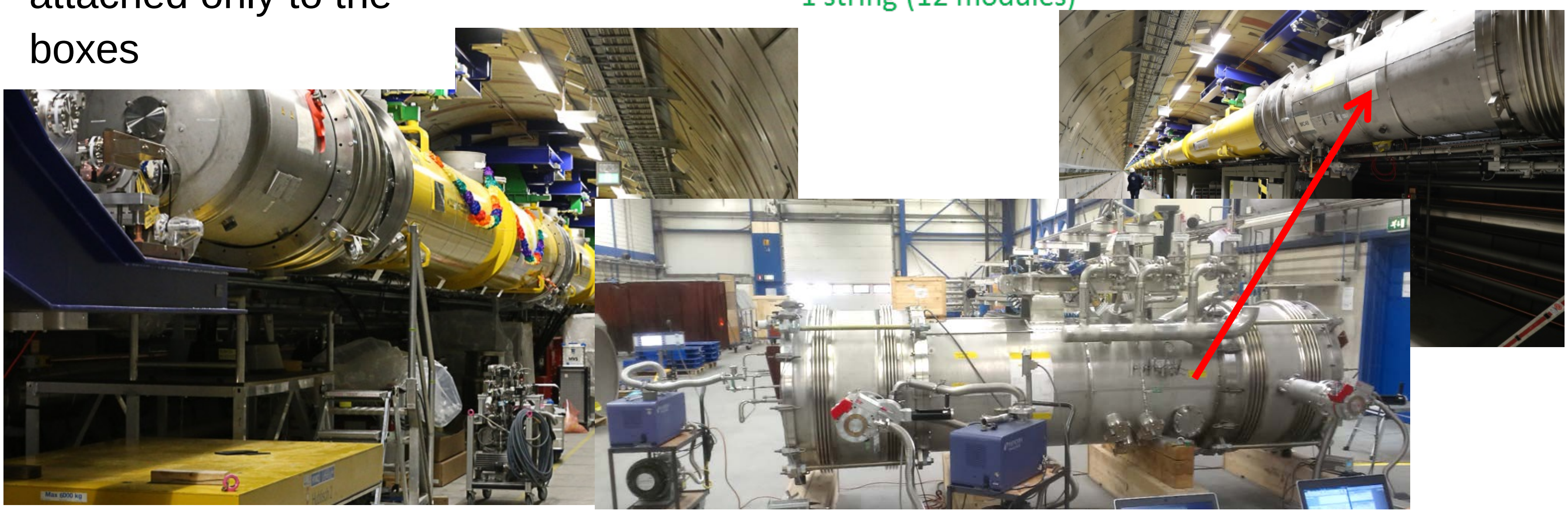


2K-He for one cold string

Flow scheme for one cold string

- JT-valves only in the boxes
- Boxes directly attached to the modules
- Vacuum pumps attached only to the boxes





Main cryogenic components

From the vibration point of view

High Pressure Compressors 300K/18bar

Cold Box Turbines

Cold Compressors 2K/31mbar

Warm Pressure Compressors 300K/31mbar

Valves

Flow meters

Bellows in the He circuits warm and cold

LHe-Heaters

Vacuum

Main vacuum components

From the vibration point of view

Pumps

- Rotating components -> vibration source
- Fundamental for beam and isolation vacuum -> Cannot be removed!
- Mitigation:
  - Isolating the supports from ground (like for the washing machine)
  - Decouple: use flexible hoses, avoid direct connection to the module (boxes, transfer lines)

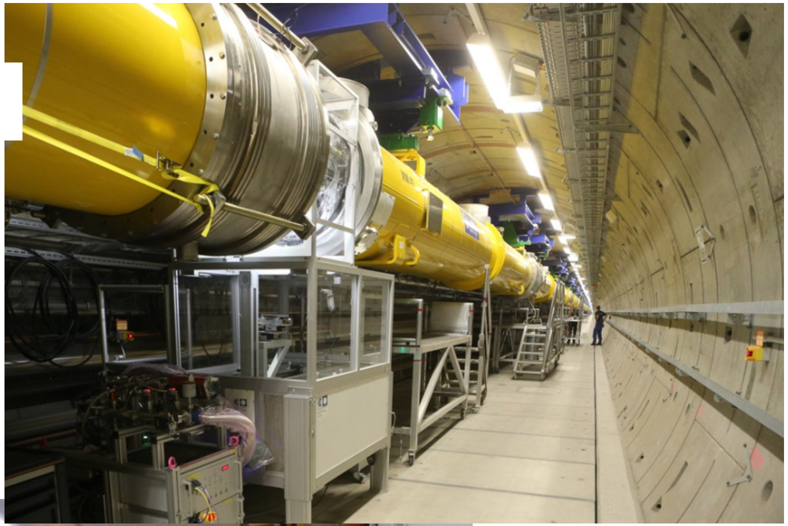
Clean rooms

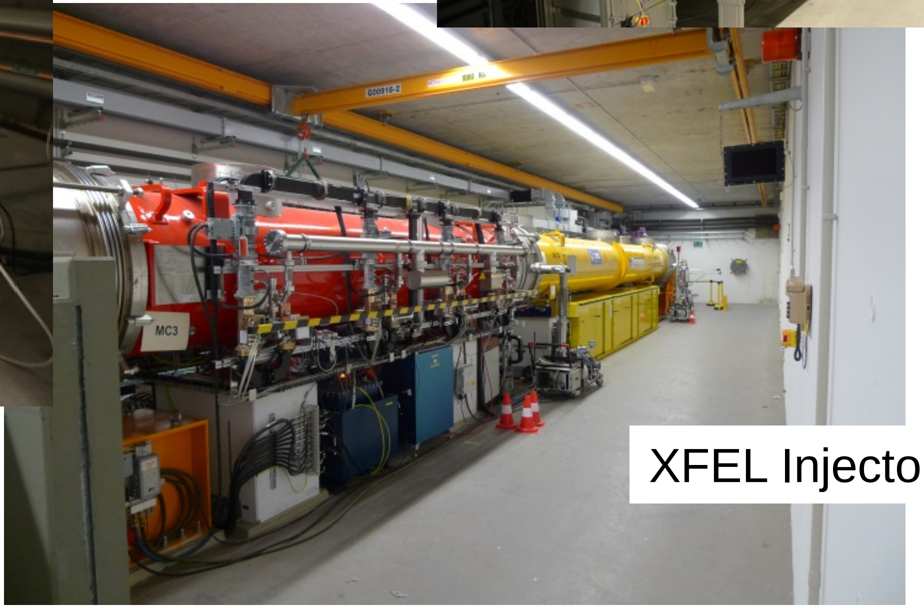
- Needed during assembly work
- Mitigation:
  - Can be turned off during vibration studies
  - Can be a problem during preliminary studies

Examples

The XFEL vacuum pumps and the Injector clean room

XFEL Main Linac





XFEL Injector

RF cooling

Main RF cooling components

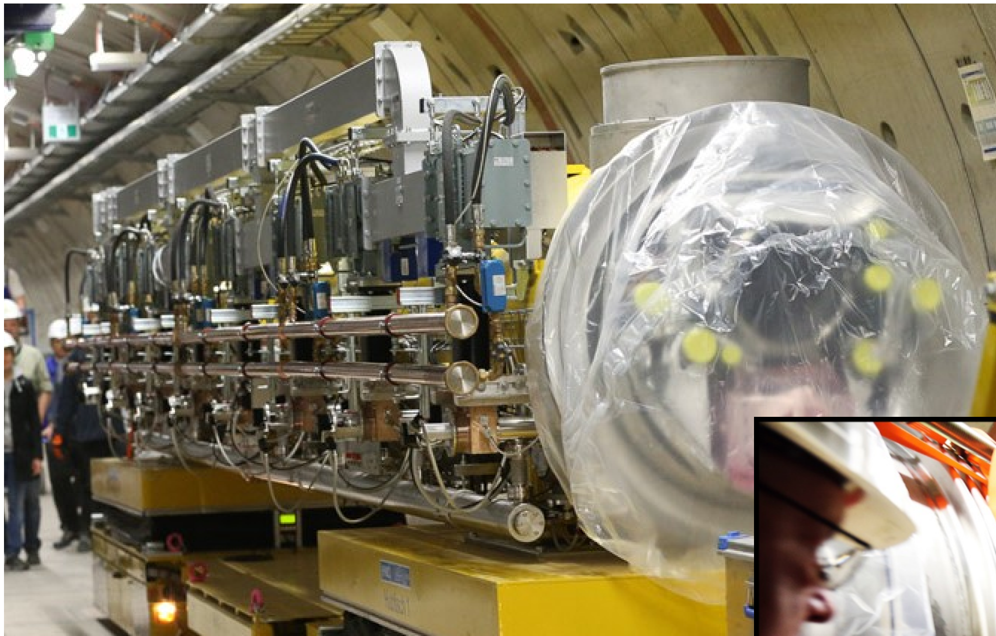
From the vibration point of view

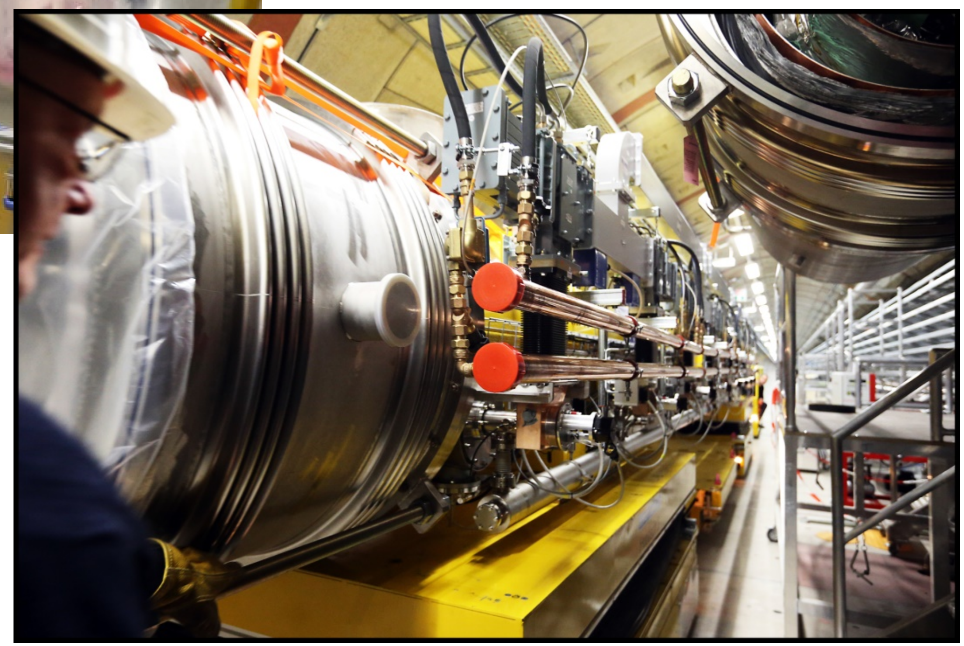
Water circuit

- Cooled phase shifter support fixed at the cryomodules
- Cooling water pumps
- Mitigation:
  - No support on the Cryomodules
  - Isolating the supports from ground (like for the washing machine)

Examples

RF cooling system on the Cryomodules





Conclusions

Conclusions

From the cryo - mechanical point of view

Not an easy task?

- Many sources, some can be reduced modified, but difficult to isolate
- Many “interference” with other design requests

Not the typical experties in the cryo environment?

- Usually affected by much slower events (see the 2KF pipe vibration in S. Barbanotti, later today)
- Inter-group topic, need the close interaction of Cryo, Mechanical, RF, Control People

Thank you

Contact

DESY. Deutsches Elektronen-Synchrotron

www.desy.de

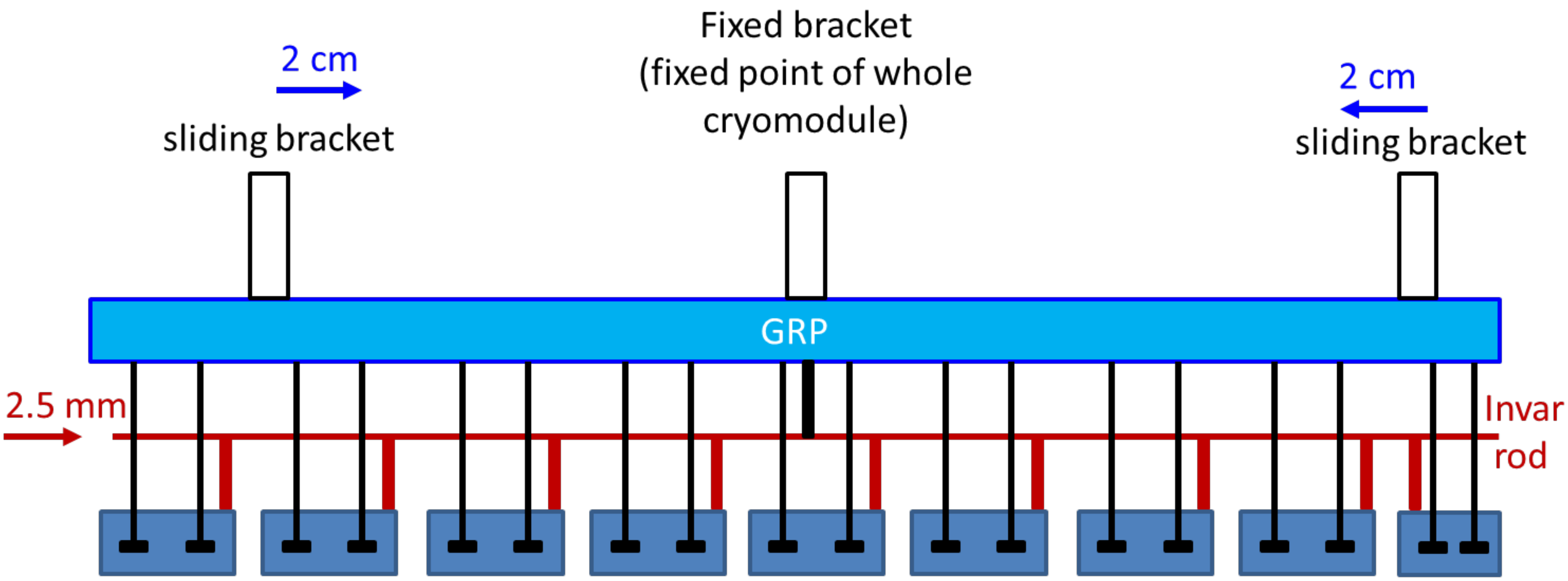
Kay Jensch
MKS1
Kay.Jensch@desy.de

Backup Slides

2. Guarantee string alignment (1/2)

- Only one fixed point: the middle post (no stresses due to shirinkage)
- Coupler longitudinal flexibility (in the mm range)
- Cavity string fixed to an invar bar
(integral shrinking coefficient 300 K – 2 K = 0.04 mm/m)
- Pins between GRP and post and post and brackets, to reproduce exact position after multiple assemblies
- Cavity string support system with rollers: very low friction

2. Guarantee string alignment (2/2)



Invar rod, 300 K -> 2 K shrinkage 0.4 mm/m: 6 m -> about 2.5 mm
GRP, stainless steel, 300 K -> 2 K shrinkage 3.1 mm/m: 6 m -> about 2 cm

4. Thermally isolate the cavity string

- Design of the support post:
  - thin pipe of G10 material to reduce conduction;
  - shirink-fit assembly tecnique to guarantee strength

- Thermal intercepts at 4K and 80K to readuce direct conduction 2 K -> 300 K

- Multi Layer Insulation (MLI)

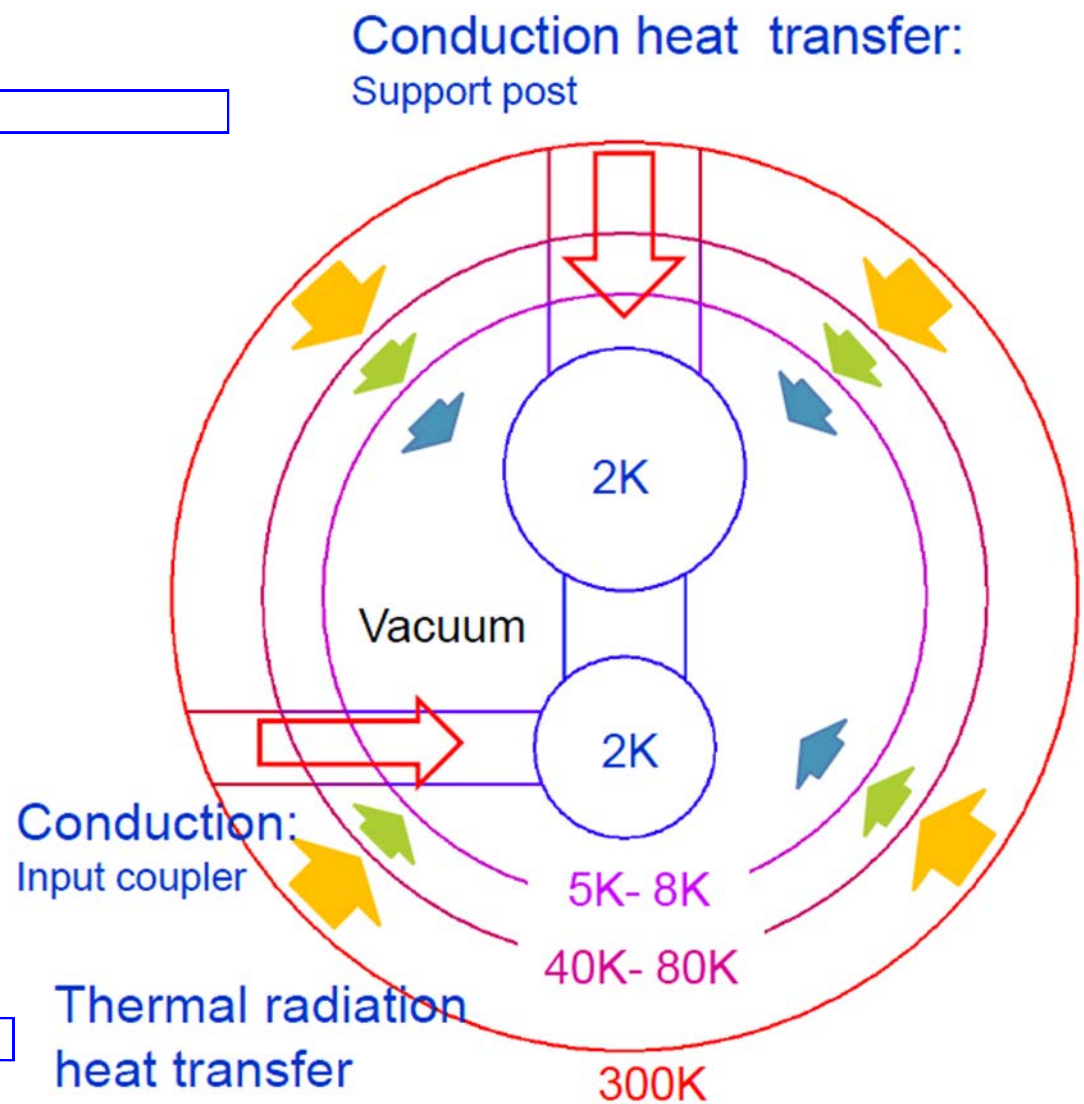
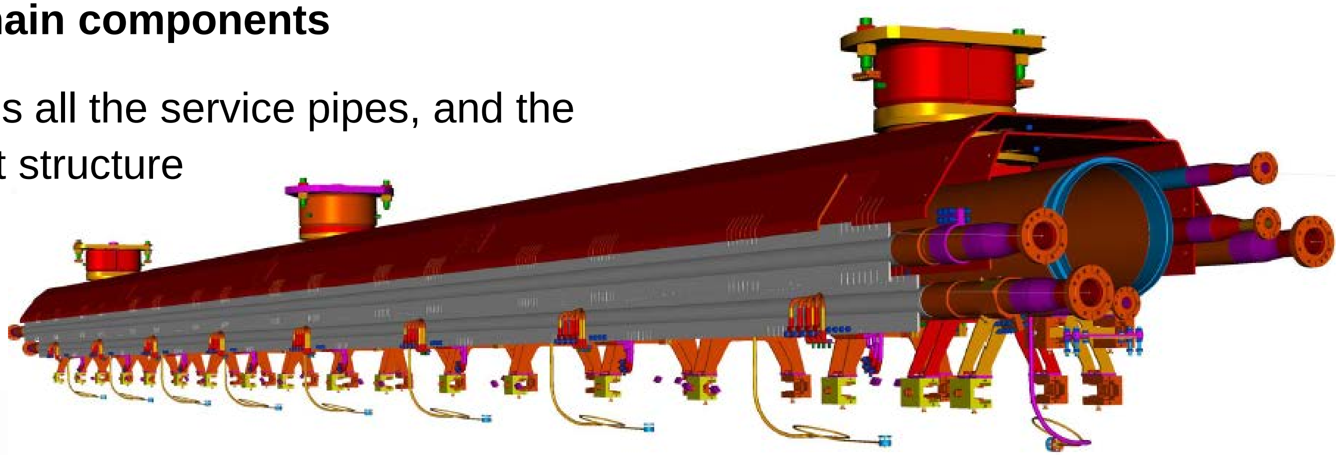


Image cortesy of N. Ohuchi

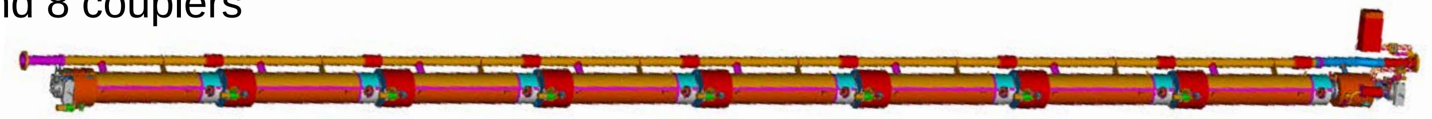
Inside a cryomodule

A cryomodule has 3 main components

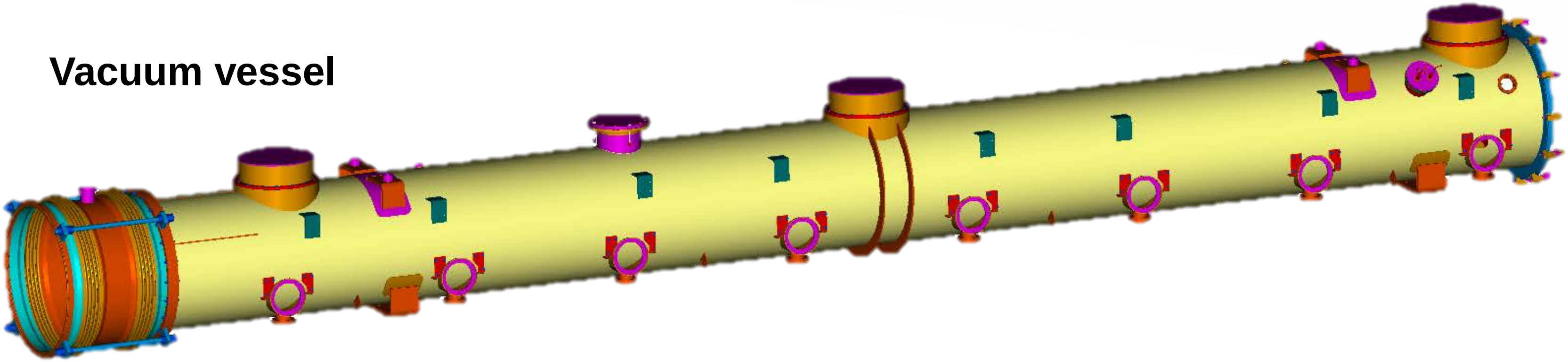
- **Cold mass**: includes all the service pipes, and the cavity string support structure



- **Cavity string**: 8 SCRF cavities (with helium tank, 2 phase line, tuner, …), 1 quadrupole and 8 couplers

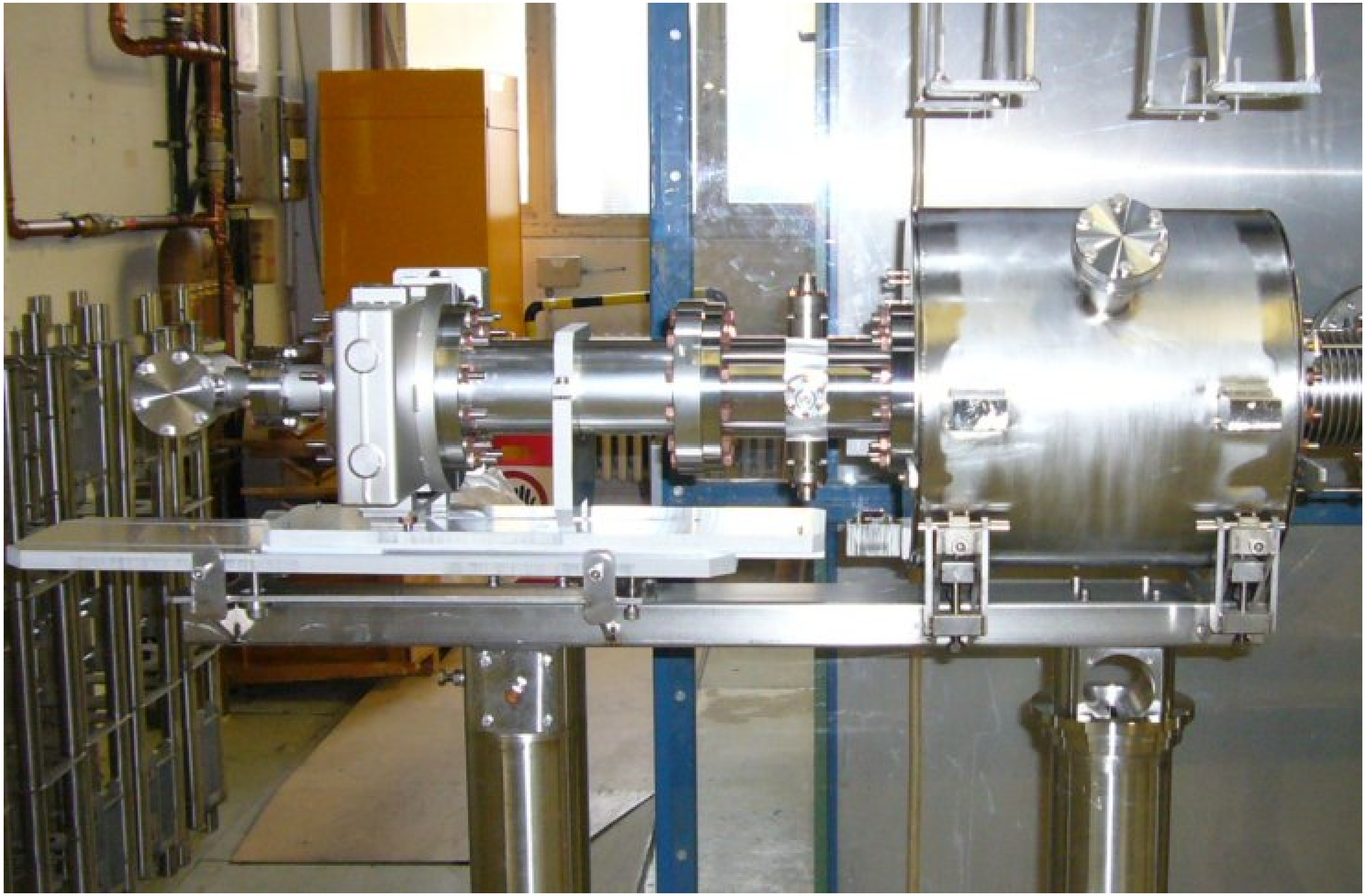


- **Vacuum vessel**



Let‘s see a bit more inside…

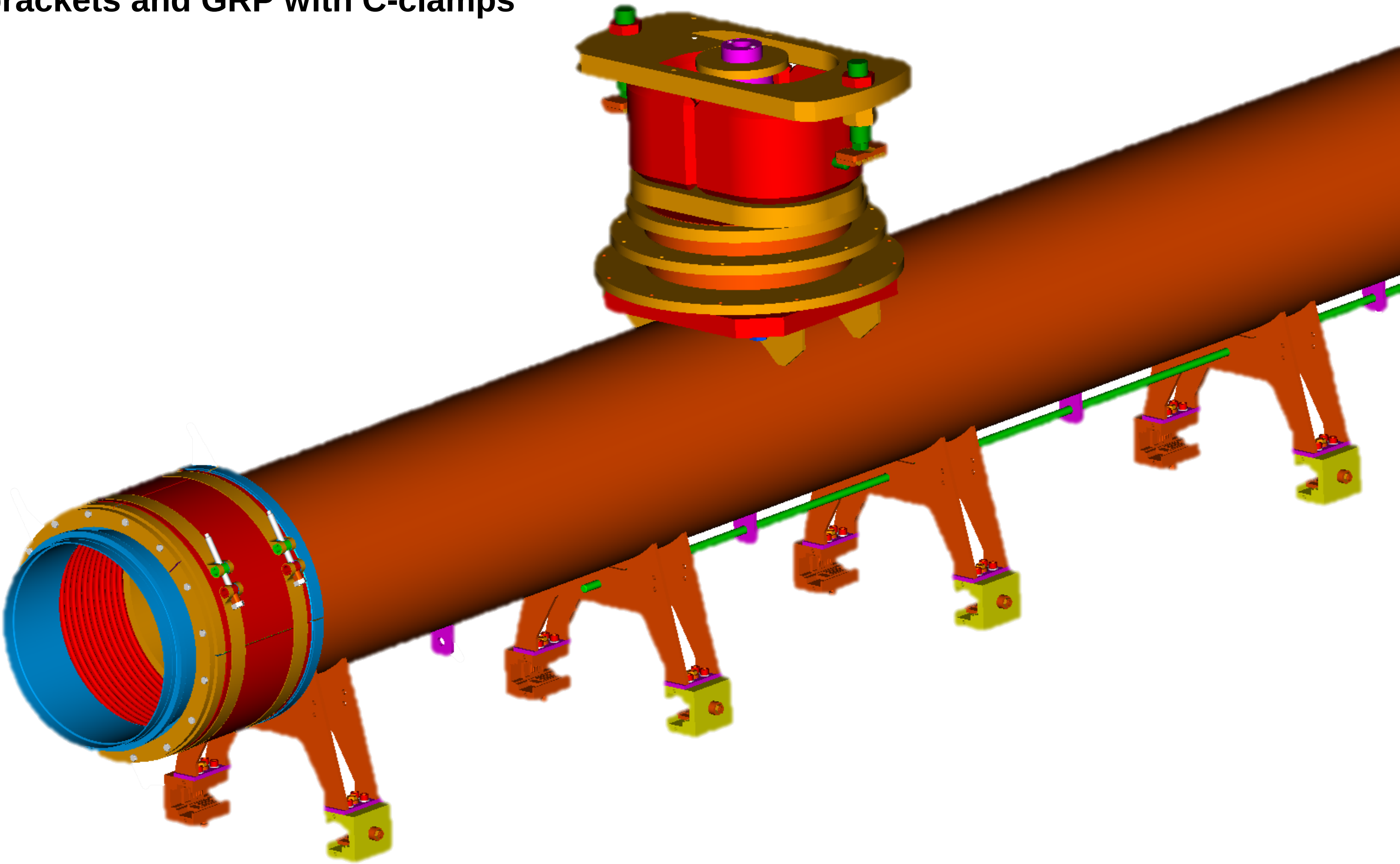
BPM + magnet + gave valve unit



Let's see a bit more inside…

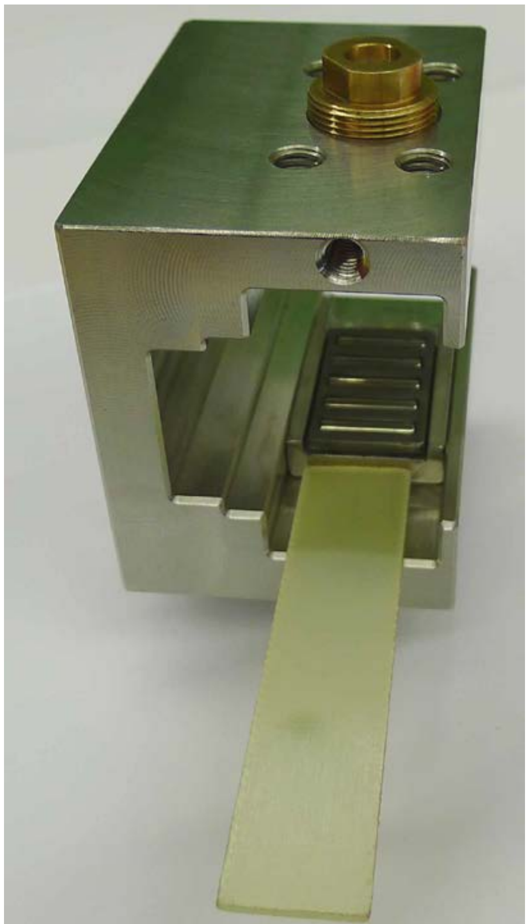
The cavity hanging system:

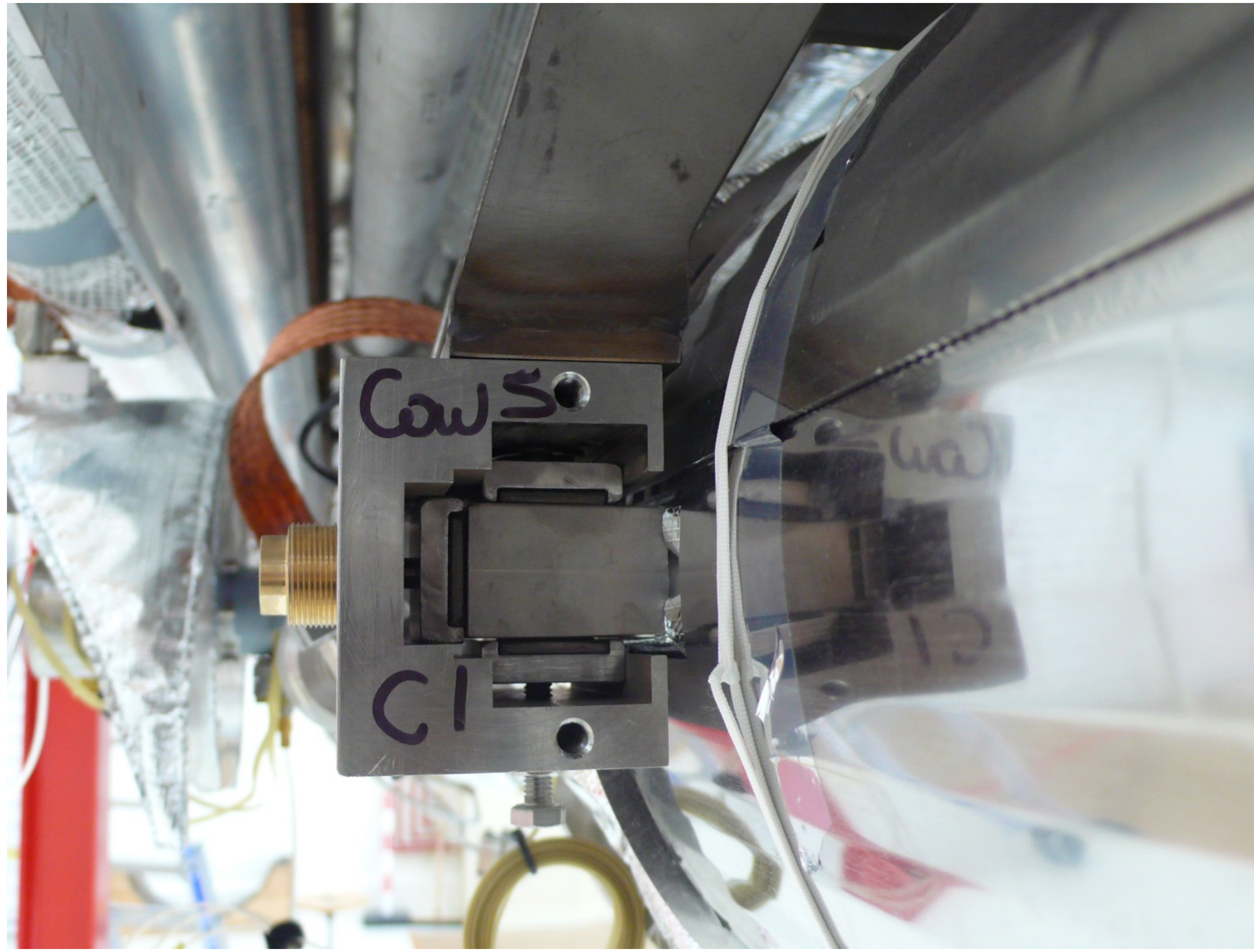
Post, brackets and GRP with C-clamps



Let‘s see a bit more inside…

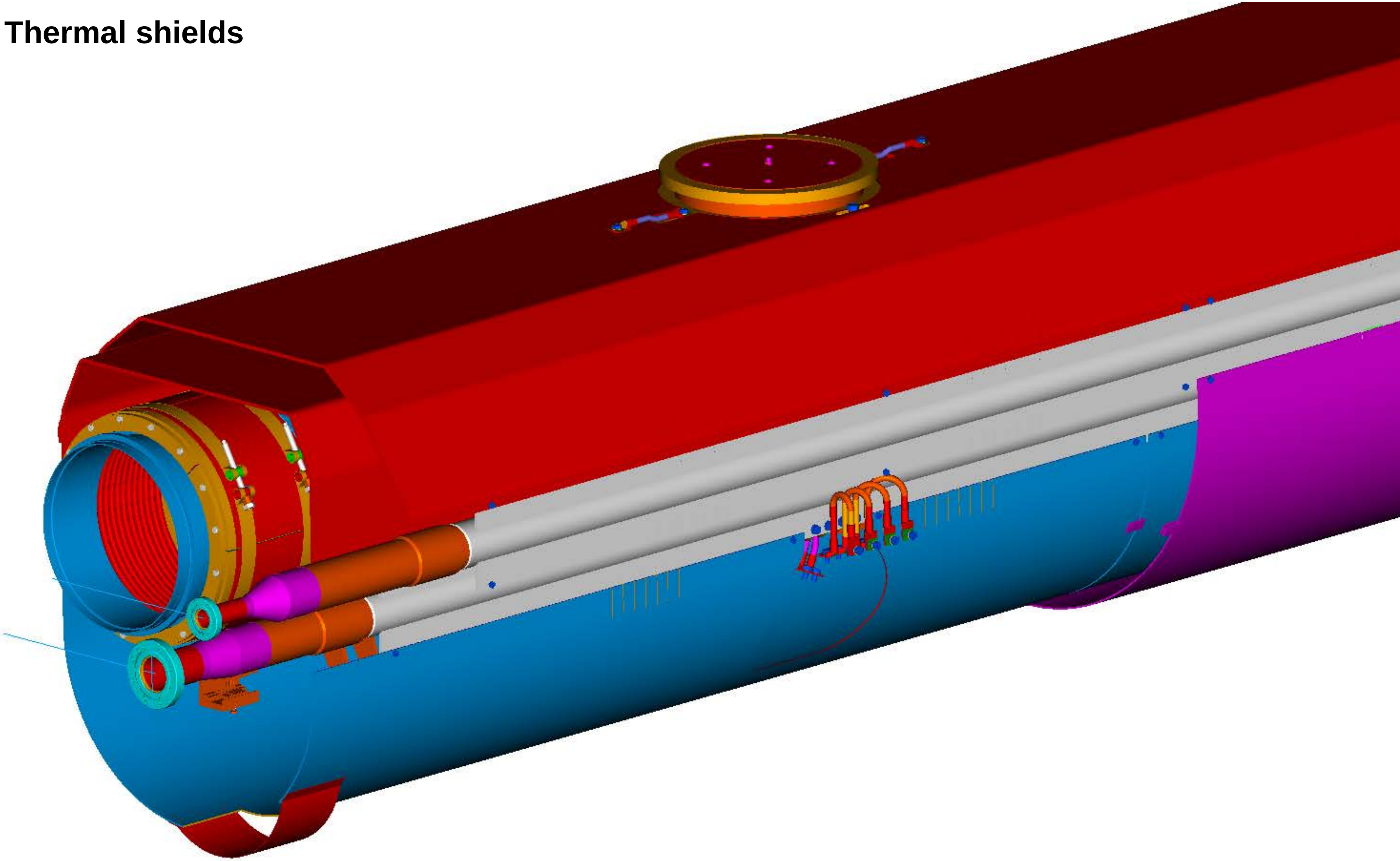
The cavity supports





Let's see a bit more inside…

Thermal shields



Let's see a bit more inside…

Cross section of the piping