# Mock-ups of the SPL cavity supporting system

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# Summary

1. Overview of cavity supporting system
2. Double tube mock-up
3. Supporting system mock-up

# 1. Overview of cavity supporting system

## Requirements of the cavity supporting system

- Provide support of components: cavities, helium vessels, tuners, etc.
- Guarantee cavity (beam axis) alignment during entire life cycle
- Minimize thermal load

### Cavities positioning tolerance with respect to beam axis:

**BUDGET OF TOLERANCE**

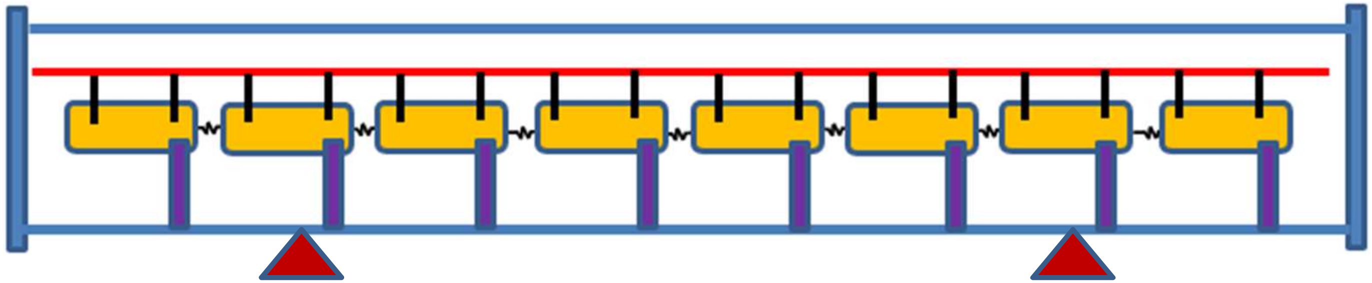
| Step | Sub-step | Tolerances (3σ) | Total envelopes |
|---|---|---|---|
| Cryo-module assembly | Cavity and He vessel assembly | *± 0.1 mm (TBD)* | Positioning of the cavity w.r.t. beam axis **± 0.5 mm** |
| | Supporting system assembly | *± 0.2 mm (TBD)* | |
| | Vacuum vessel construction | *± 0.2 mm (TBD)* | |
| Transport and handling (± 0.5 g any direction) | N.A. | *± 0.1 mm (TBD)* | Stability of the cavity w.r.t. beam axis **± 0.3 mm** |
| Testing/operation | Vacuum pumping | *± 0.2 mm (TBD)* | |
| | Cool-down | | |
| | RF tests | | |
| | Warm-up | | |
| | Thermal cycles | | |

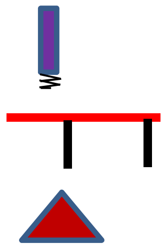
Construction precision (Cryo-module assembly)

Long-term stability (Transport and handling; Testing/operation)

# 1. Overview of cavity supporting system

*Power coupler as support* concept





RF coupler + longitudinal positioner + vertical support

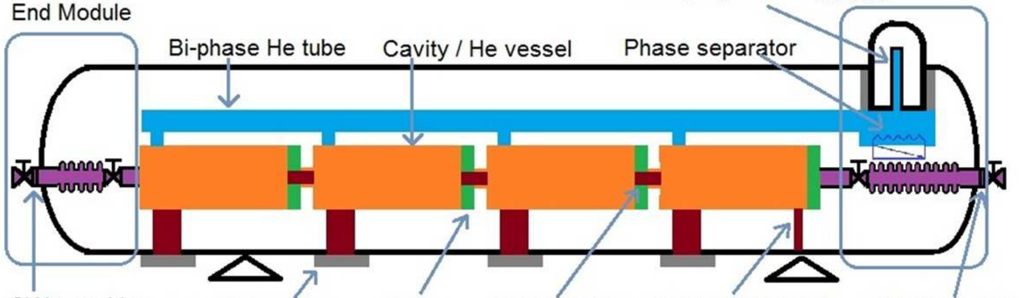
Intercavity support structure

External supports (jacks)

- The power coupler double tube acts as vertical support and longitudinal positioner
- The design is simplified
  - Better thermal performance - less heat conduction paths from room temperature

# 1. Overview of cavity supporting system

<u>*Power coupler as support* concept</u>

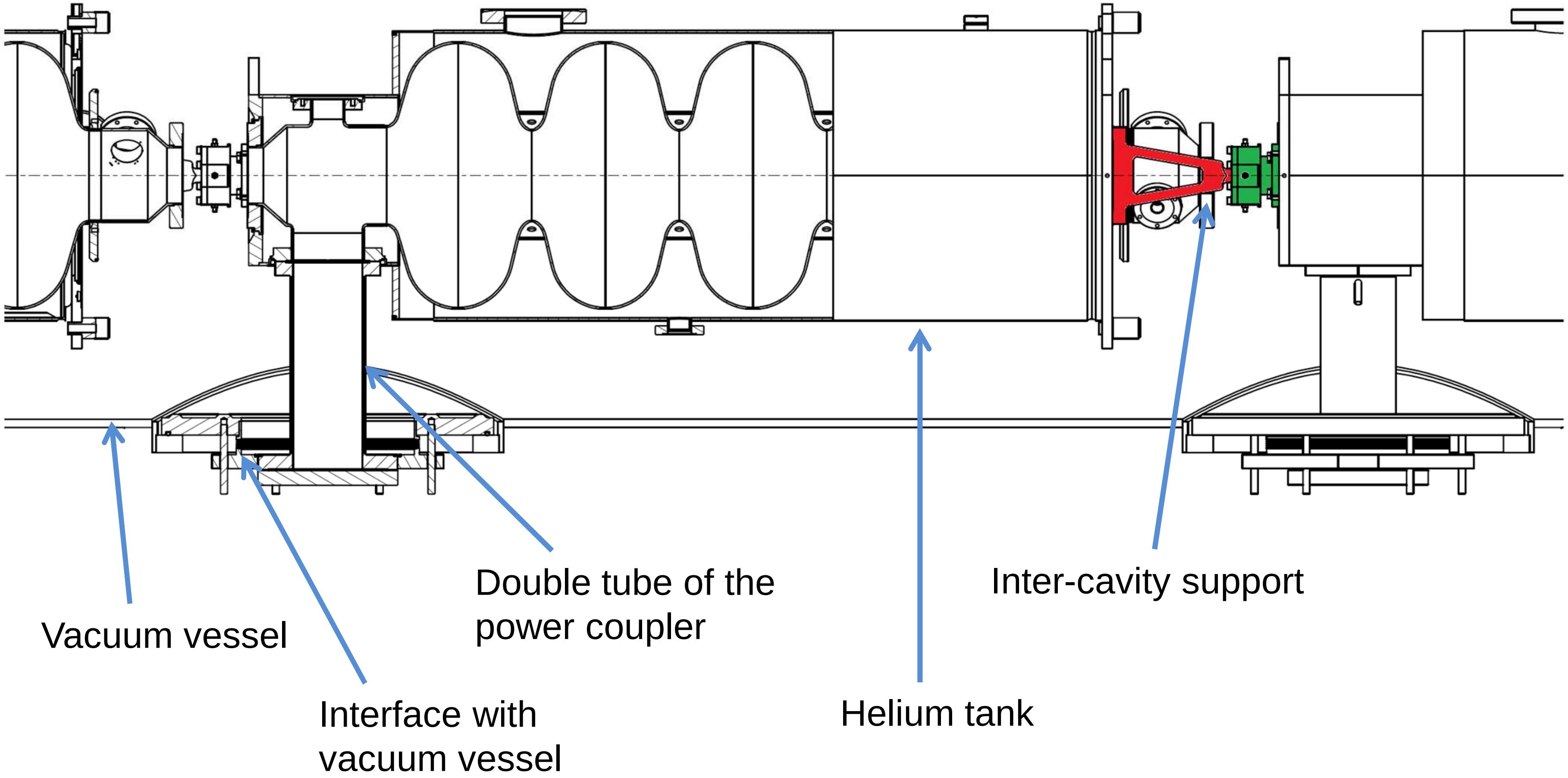



**Approximate weights and dimensions:**

| Weights (kg) | |
|---|---|
| Dressed cavity | 200 |
| Short vacuum vessel | 7000 |
| Long vacuum vessel | 10000 |
| **Lengths (mm)** | |
| Double tube | 300 |
| Cavities pitch (distance between consecutive double walled tubes) | 1500 |
| Short vacuum vessel | 7000 - 8000 |
| Long vacuum vessel | 12000 – 13000 |
| **Diameters (mm)** | |
| Helium vessel | 400 |
| Vacuum vessel | 800-900 |

# 1. Overview of cavity supporting system

*Power coupler as support* concept

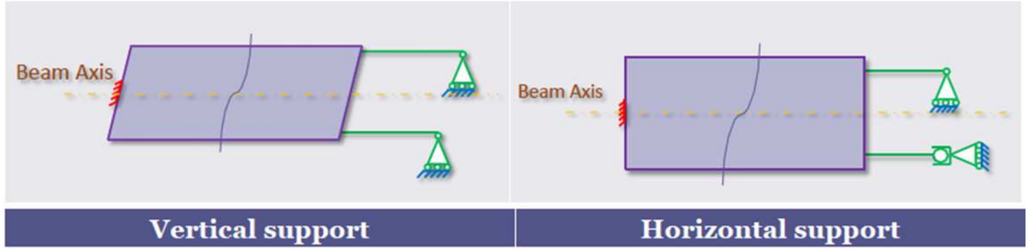


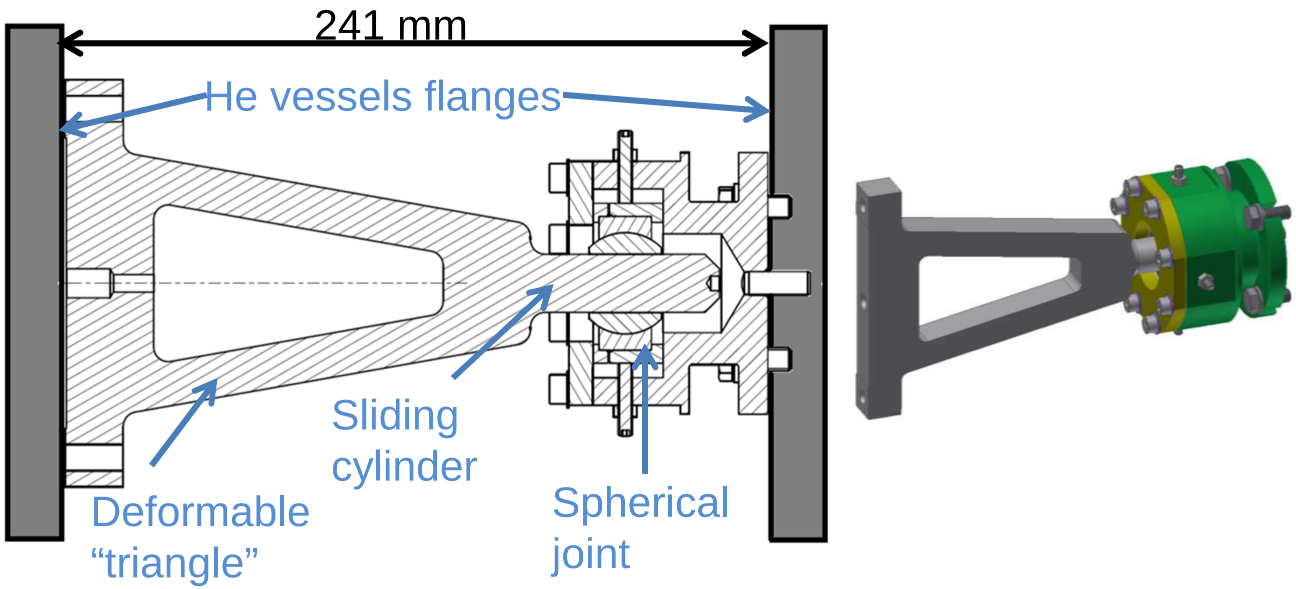
# 1. Overview of cavity supporting system

Designed by A.Vande Craen and J.B.Deschamps in collaboration with EN/MME

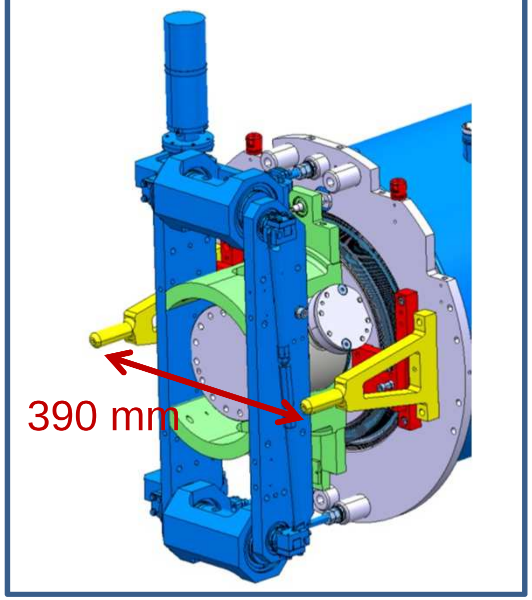
## Inter-cavity support

- Sustain any load case (static, transport, thermal transient…)
- Allow alignment
- Keep alignment in steady state (warm and cold)
- Minimize stresses in helium tank
- Designed to work at 2K
- Allow contraction of helium tank




Courtesy of F.Pillon (EN/MME)

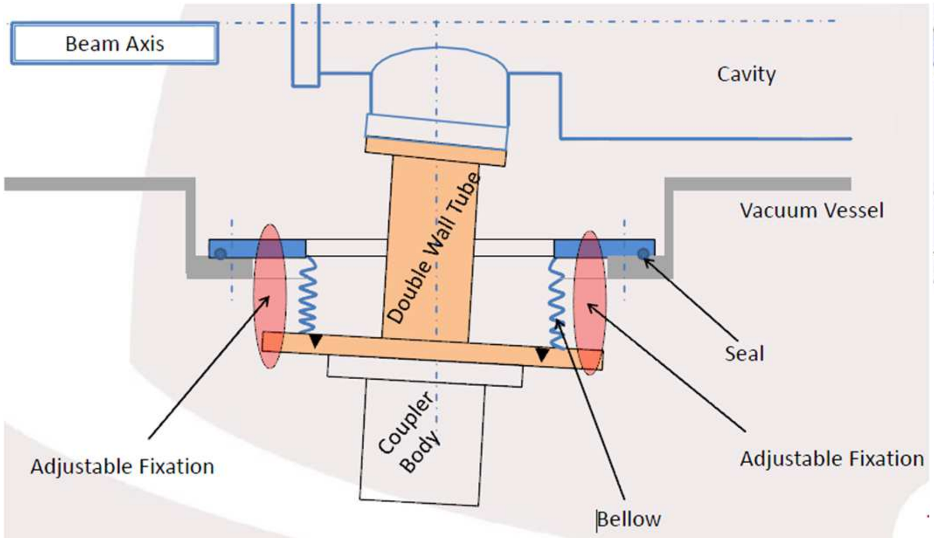


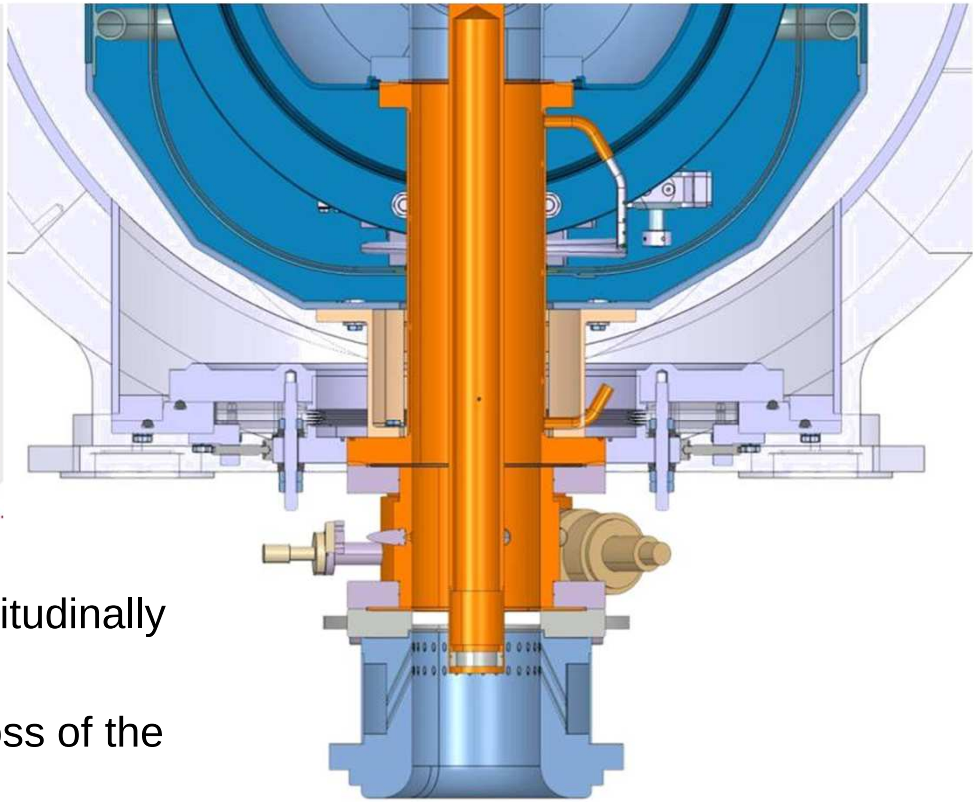

Design of spherical joint is being finished - to be tested soon

# 1. Overview of cavity supporting system

Vacuum vessel / double tube interface

Designed by CNRS/IPNO



- Compensates the assembly tolerances (longitudinally and angularly)
- Enables the support of the cavities without loss of the alignment (fixed point)

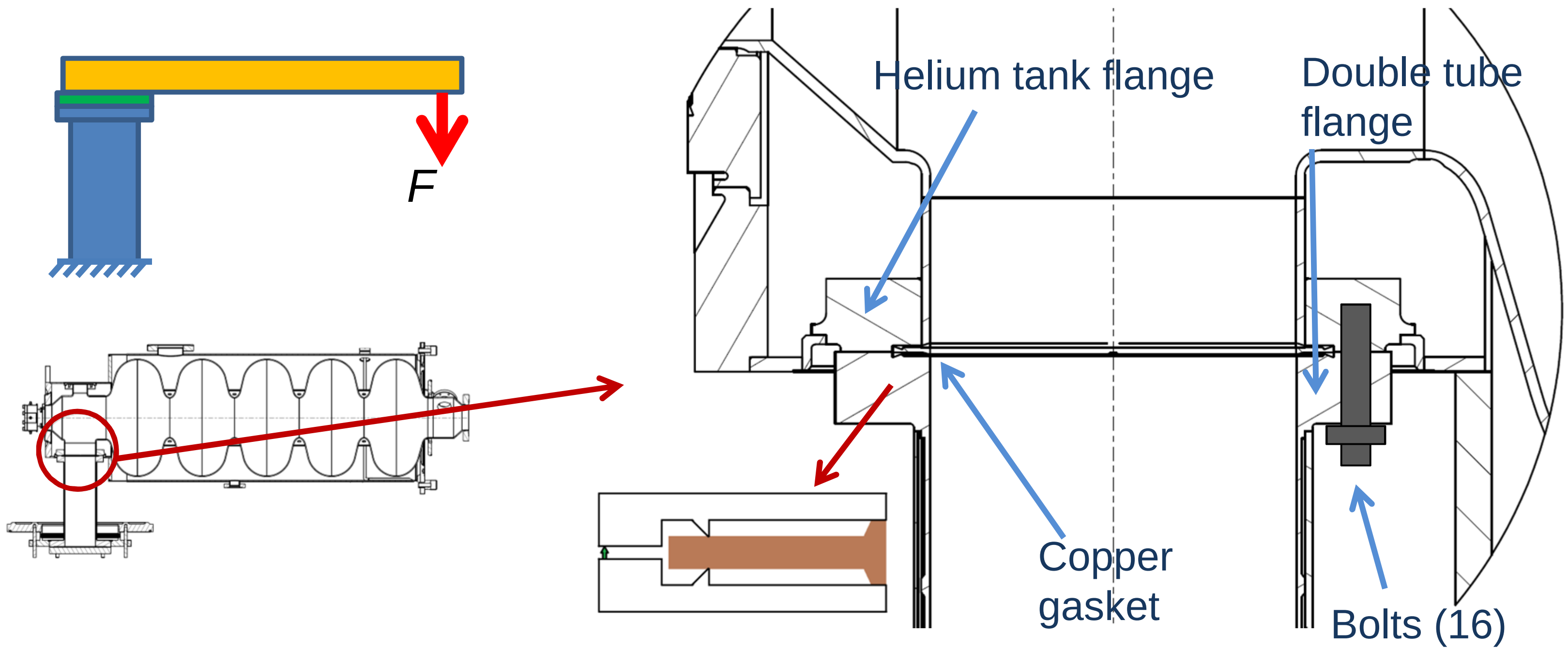
Courtesy of P.Duthil / S.Rousselot (CNRS/IPNO)

# 2. Double tube mock-up

## Introduction

Design and tests by A.Vande Craen

- The UHV-CF flanges connection between the double tube of the power coupler and the helium vessel / cavity assembly is critical – a leak would contaminate beam vacuum
- In this mock-up, a bending moment is applied to this connection and the leak tightness is measured - these tests are carried out at room temperature
- One of the goals of this mock-up is the validation of the value of torque which is to be applied to the bolted connection



# 2. Double tube mock-up

Test setup and procedure

• A controlled torque is applied to each bolt to close the flanges

• A simple tube with the same stiffness and length of the double tube is used

• Copper gaskets from different manufacturers (*Garlock* and *Meca Design*) are used - these gaskets were annealed at CERN

• A plastic cover is wrapped around the flanges and the space is filled with helium for the leak tightness measurements

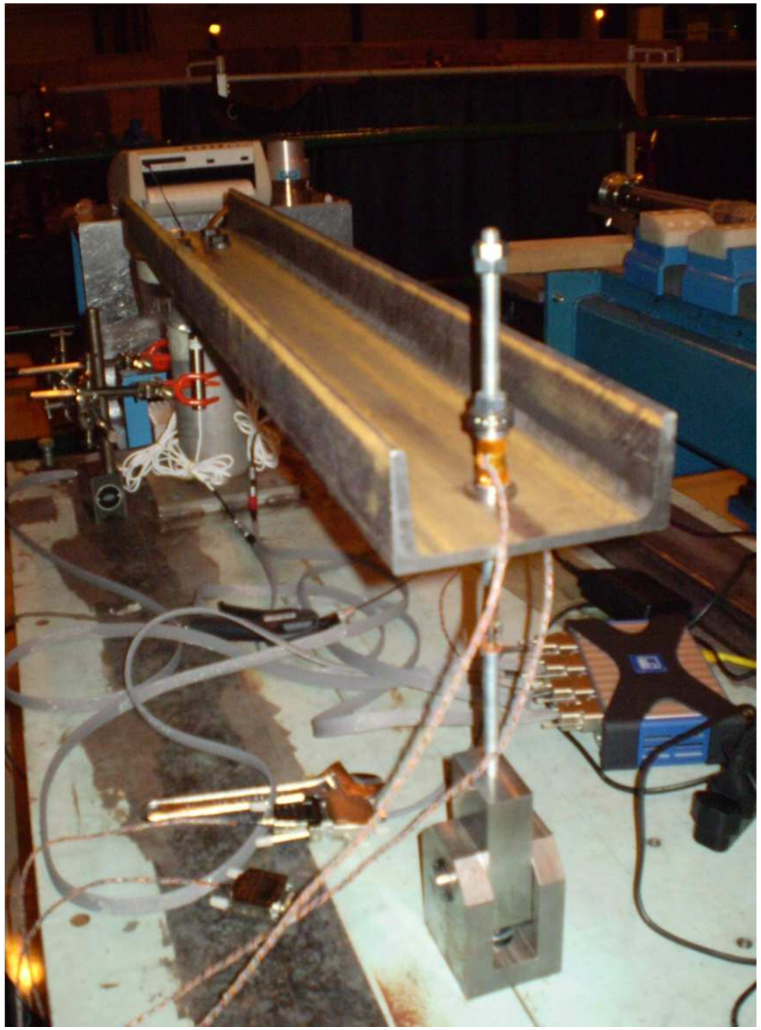
• Two displacement sensors (LVDTs) are installed on each flange to measure possible opening

• The force is applied by a traction rod and measured by a load cell

• The load is applied until a leak is detected and then released. This process is carried out at least three times for a torque of 15 Nm and three times for a torque of 20 Nm (optimum value according to tests and value recommended by manufacturers)

# 2. Double tube mock-up

Test setup and procedure



The tests were carried out with the help of the Mechanical Measurements Laboratory (EN/MME)

# 2. Double tube mock-up

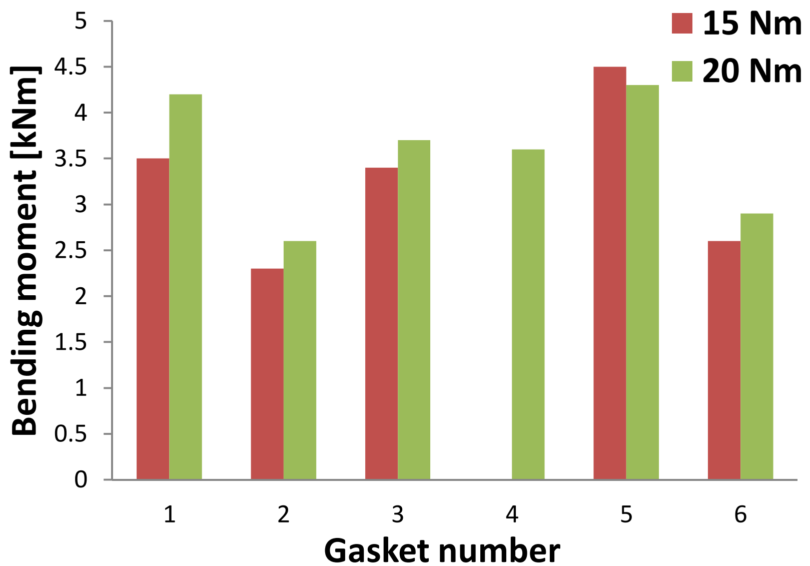
## Results and conclusions

- All leaks were detected for bending moments which are well beyond expected load cases
- The influence of the torque applied to the bolts is rather small

**Calculated bending moments for different cavity support scenarios:**

| Inter-cavity support | M (kNm) |
|---|---|
| On both sides | 0.09 |
| No inter-cavity support | 2.12 |
| On power coupler side only | 1.82 |
| On tuner side only | 0.15 |
| *Loads are weight of components and transport acceleration (0.5 g in all directions)* | |

**Test results - bending moment for leak:**




These support scenarios are not realistic, since the absence of inter-cavity support on the tuner side of the dressed cavity assembly represents failure - the mechanical integrity of the double tube and the helium vessel would be compromised

# 2. Double tube mock-up

Results and conclusions

- The results change significantly from gasket to gasket
- A permanent leak was detected for gasket no. 5 after the first loading
- At no point during the tests was a separation of the flanges detected by the displacement sensors – stress relaxation of the gasket seems to be the cause of the leaks

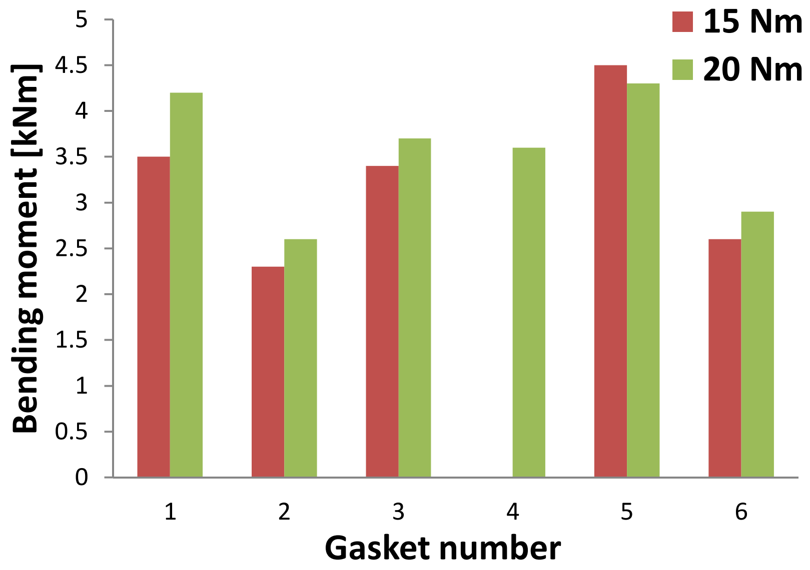
**Possible explanations:**

- The mounting of the copper gaskets, a delicate operation, was not carried out by an experience person - reproducibility becomes hard to achieve
- Gaskets from different manufacturers were used

**Future work:**

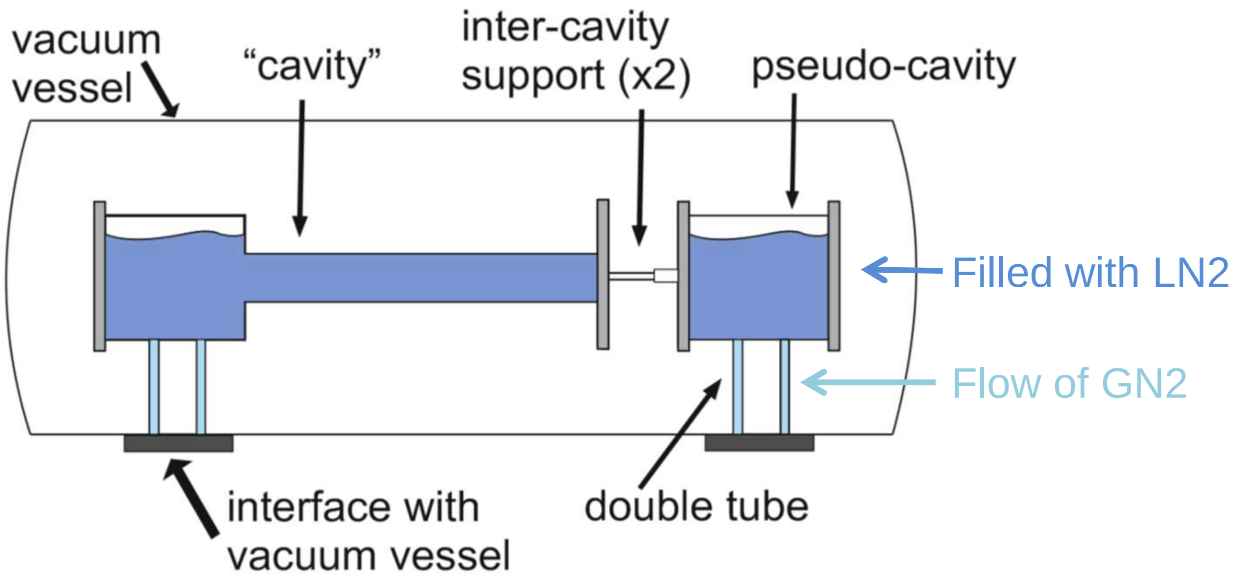
- The surface of the gaskets will be analysed
- Further tests will be carried out, involving the CERN vacuum group in the definition of an appropriate mounting procedure

**Test results - bending moment for leak:**



# 3. Supporting system mock-up

Introduction




- Validate the supporting and alignment concept
- Test critical components of unknown behaviour, the interface with vacuum vessel and the inter-cavity support, during assembly and cool-down
- Validate thermal calculations – namely the thermal model of actively cooled double tube
- First tests foreseen for the summer of 2012

# 3. Supporting system mock-up

<u>Design – in progress</u>

• Double tube, inter-cavity support and interface with vacuum vessel are the “real” components of this mock-up.

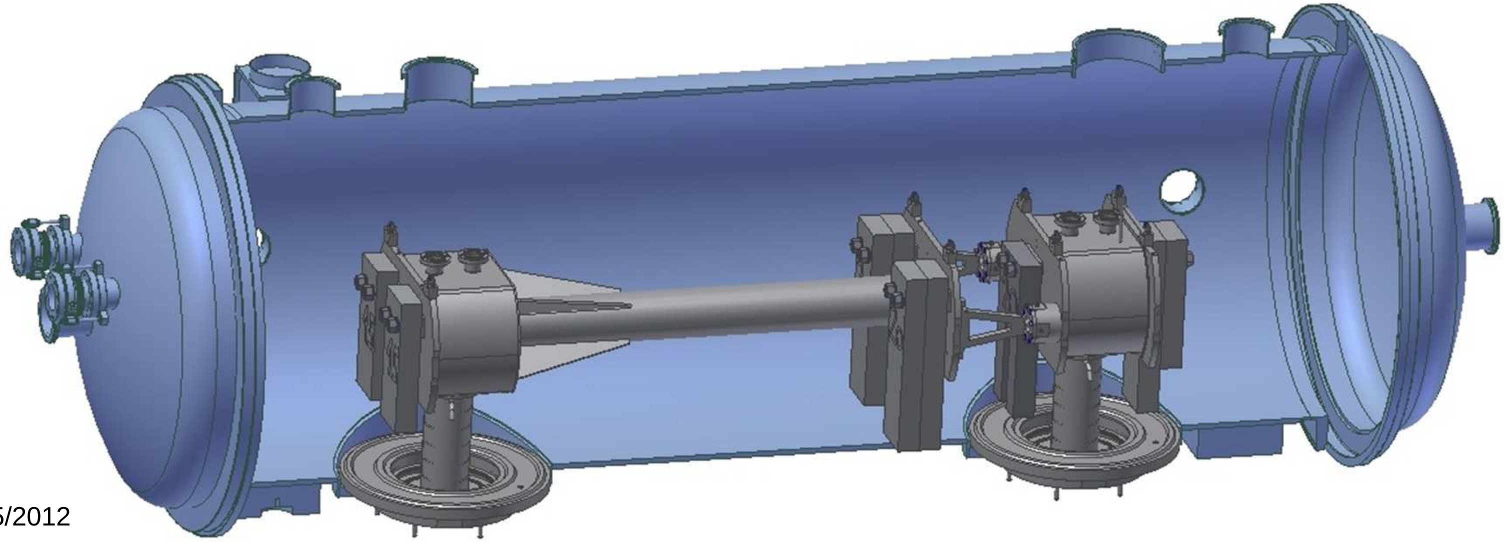
• A simplified cold mass is designed so that its mechanical stiffness is similar to the real cavity/helium vessel assembly

• Weights are added to the cold mass to guarantee that the loads applied to the supporting components are identical to the “real” loads

• A welded/brazed pipe to be filled with LN2 is used to thermalize flanges of fake “cavities”

• MLI will be wrapped around cold mass

• Targets and windows on the vacuum vessel are used for alignment measurement (laser tracker and BCAM); wire positioning monitors may be added in a $2^{nd}$ stage

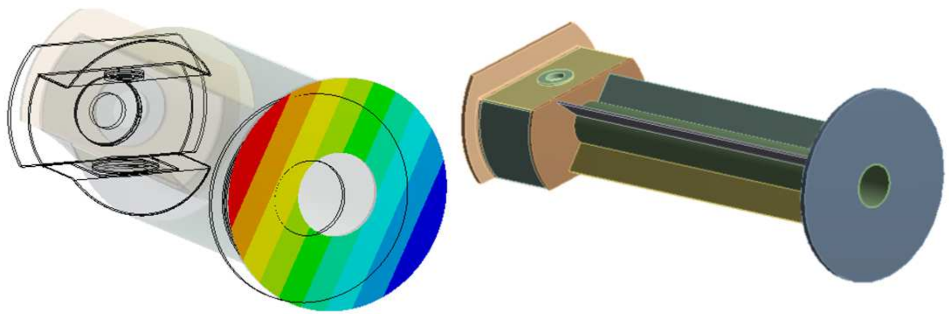


# 3. Supporting system mock-up

<u>Design – in progress</u>

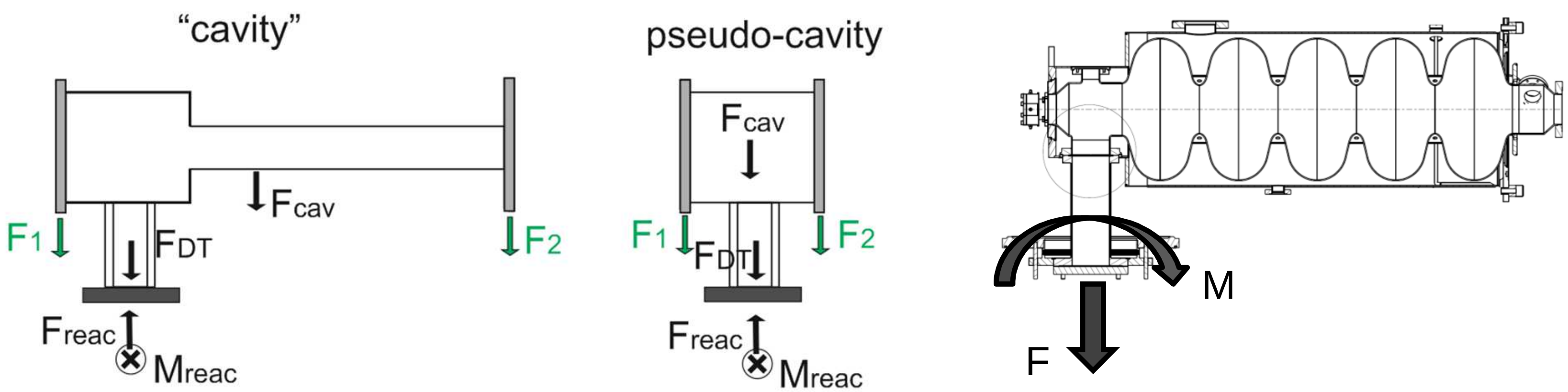
**Calculation of the stiffness of the mock-up "cavity"**

The mock-up cavity torsion and bending stiffness should be as close as possible to the ones of the real dressed cavity



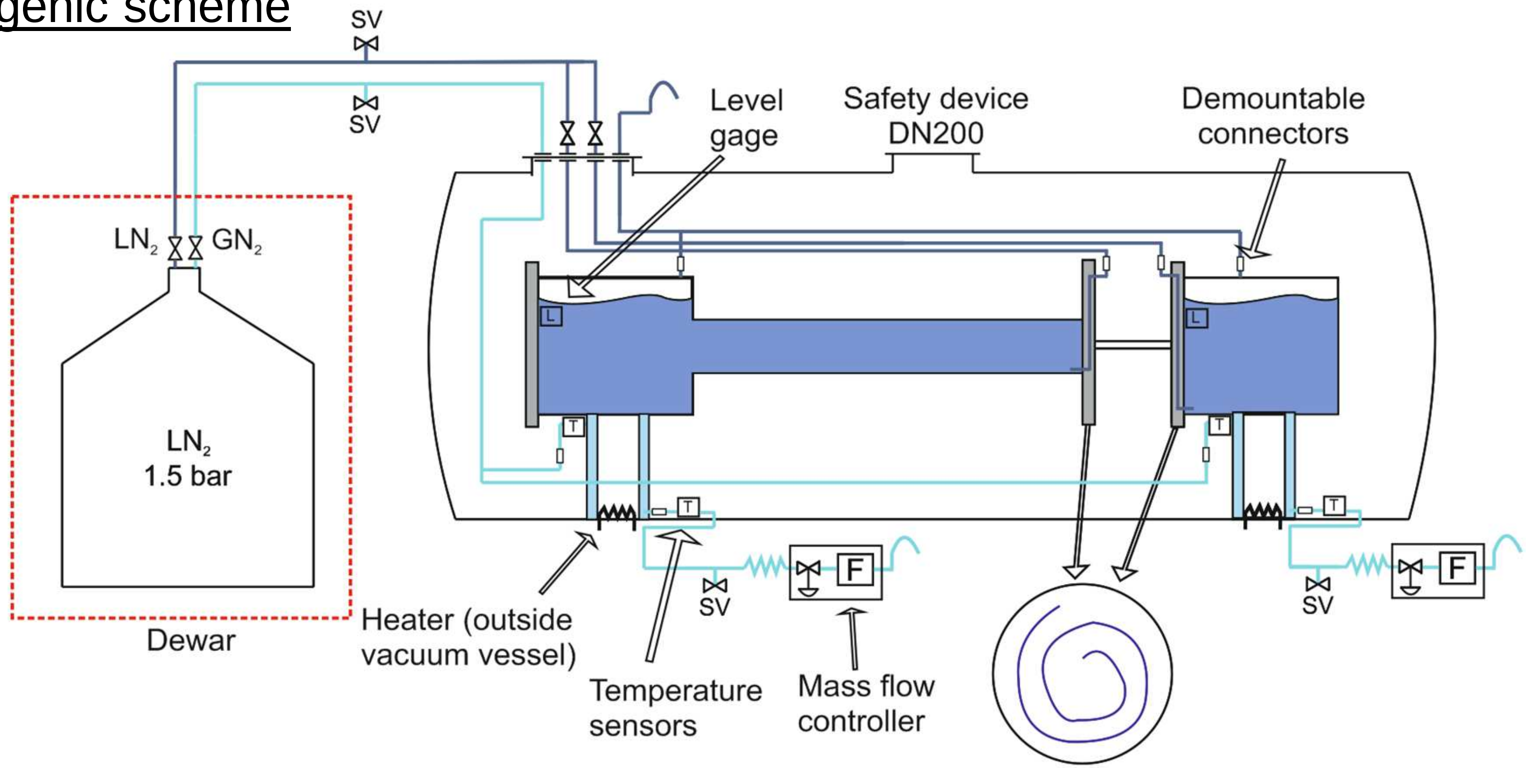
**Calculation of the weights to be added to the mock-up cold mass**

For the mock-up cavity, force and moment at the interface with the vacuum vessel should match those of the real dressed cavity assembly (including tuner)



# 3. Supporting system mock-up

Cryogenic scheme




• The "cavities" are filled with liquid nitrogen and the flanges to which the inter-cavity supports are attached are thermalized

• The double tubes are cooled by a flow of gaseous nitrogen between 77 and 300 K – heaters guarantee 300 K at the vacuum vessel / double tube interface.

• The cold mass alignment will be measured for different combinations of cold / warm "cavities" and double tubes

# 3. Supporting system mock-up

Cryogenic scheme

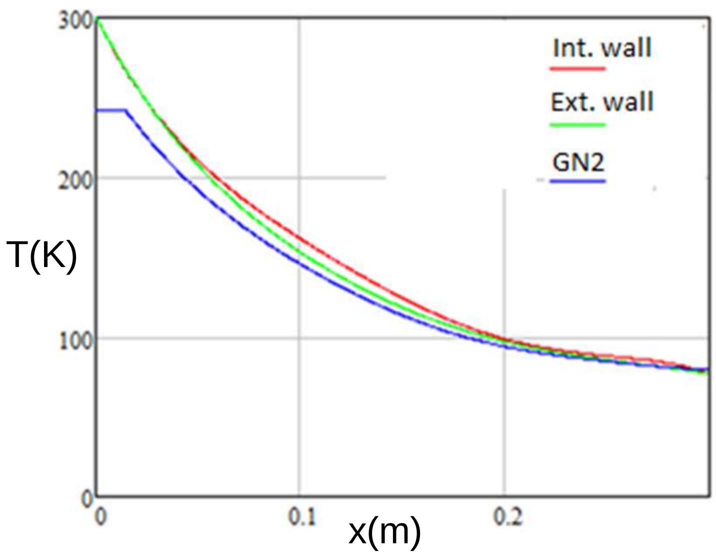
Calculations by R.Bonomi – see presentation *SPL Thermal studies* (04/05)

- This mock-up will allow the validation of the thermal model of the actively cooled double tube - critical aspect of the SPL Short Cryo-module design
- The temperature profile of the double tube walls and the required heating power at the vacuum vessel interface were calculated for different $GN_2$ mass flows

**Results for different mass flows:**

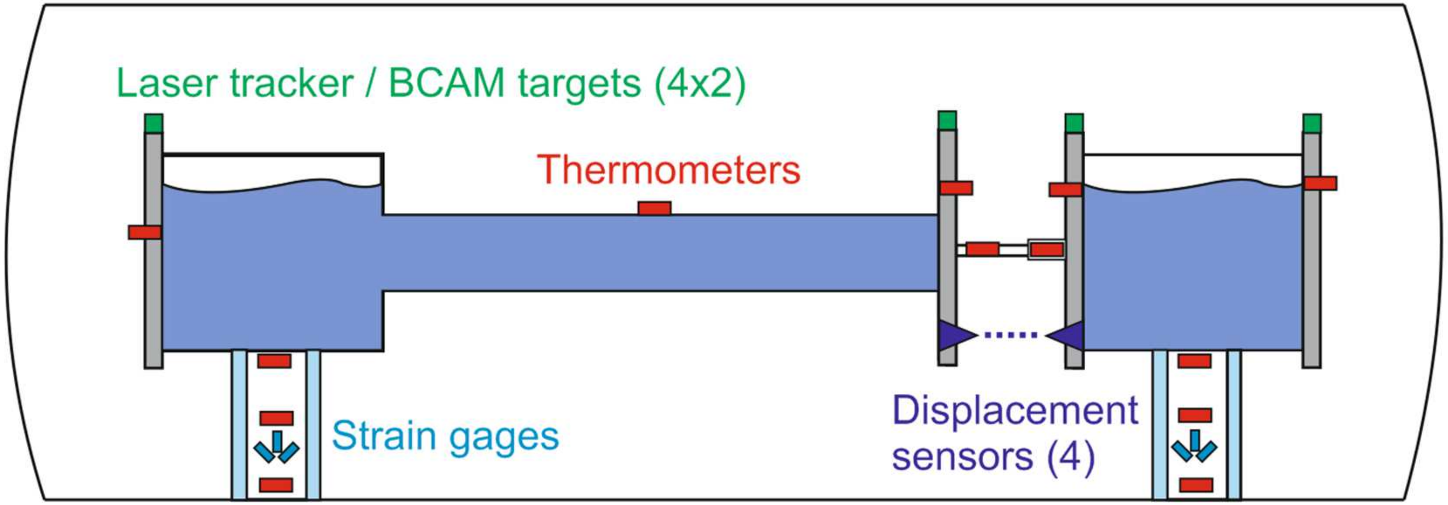
| Mass flow (req vap power) | 100 mg/s (20 W) | | 200 mg/s (40 W) | | 300 mg/s (60 W) | |
|---|---|---|---|---|---|---|
| $P_{rf}$ | ON | OFF | ON | OFF | ON | OFF |
| $Q_{bath}$ [W] | **9.145 ±5 mW** | **3.962 ±0.5 mW** | **4.735 ±5 mW** | **1.834 ±1 mW** | **3.476 ±4 mW** | **1.392 ±1 mW** |
| $Q_{heater}$ [W] | **9.681** | **22.698** | **24.508** | **35.830** | **36.872** | **46.172** |
| ΔL [mm] | 0.408 | 0.552 | 0.543 | 0.640 | 0.617 | 0.685 |
| ΔL tot [mm] | **0.144** | | **0.097** | | **0.068** | |

**Temperature profile for 300 mg/s:**



# 3. Supporting system mock-up

Instrumentation scheme



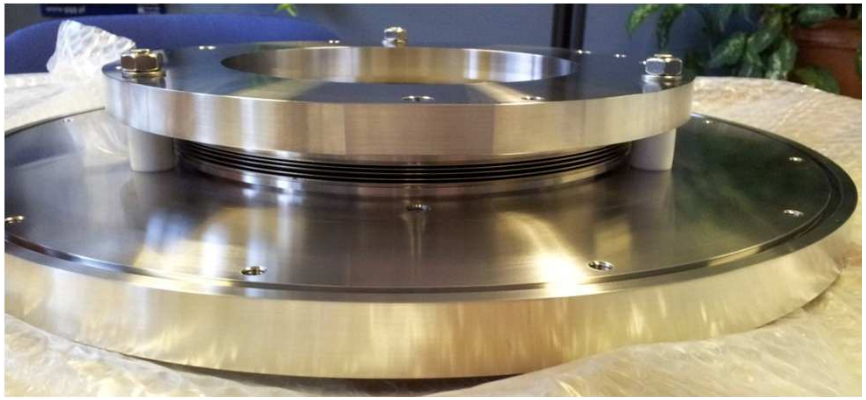

• **Alignment** – two lines of four targets (one per flange) should provide a comprehensive view of the cold mass movements

• The alignment measurements will be complemented by strain measurements on the double tubes external walls and displacement sensors between the two cavities

• **Thermometers** – Various Pt100 sensors will be placed on the cold mass, under vacuum. The temperature measurements on the double tubes walls and inter-cavity supports are fundamental for understanding the functioning of the mock-up components

# 3. Supporting system mock-up

<u>Some components</u>

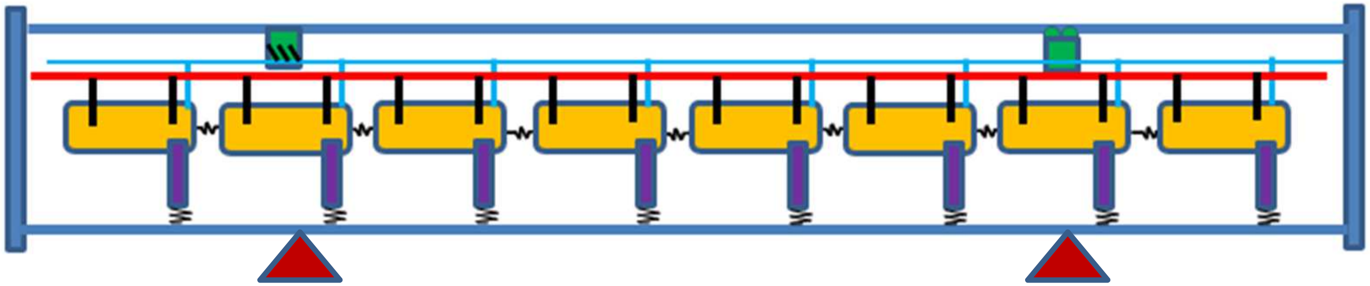



# Thank you for your attention

# Spare slides

# Supporting concepts

## "Standard" supporting scheme



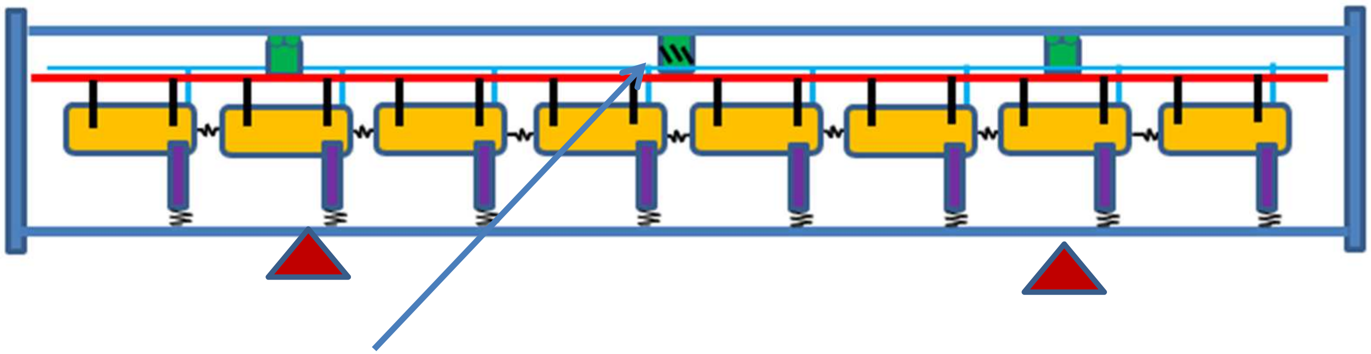
Two-support preferable (isostatic - well defined forces on supports)

If cavity straightness not enough...

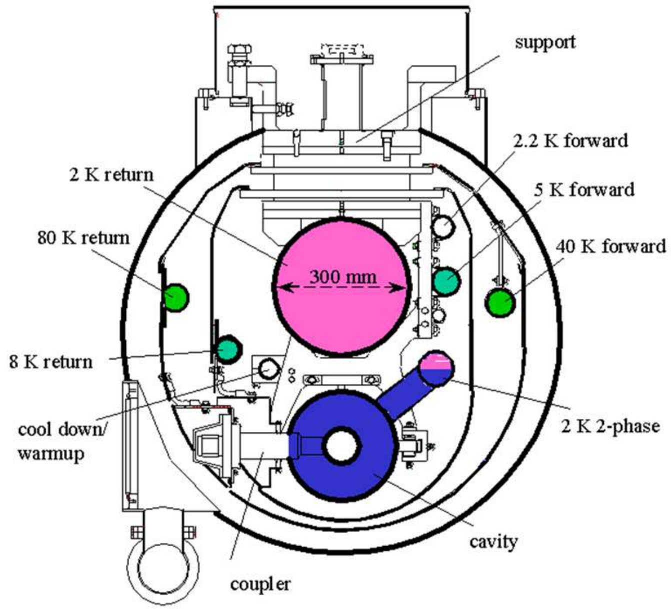
| | |
|---|---|
| RF coupler (with bellows) | Fixed support |
| Invar longitudinal positioner | Sliding support |
| Inertia beam | External supports (jacks) |

# Supporting concepts

"Standard" supporting scheme with third support

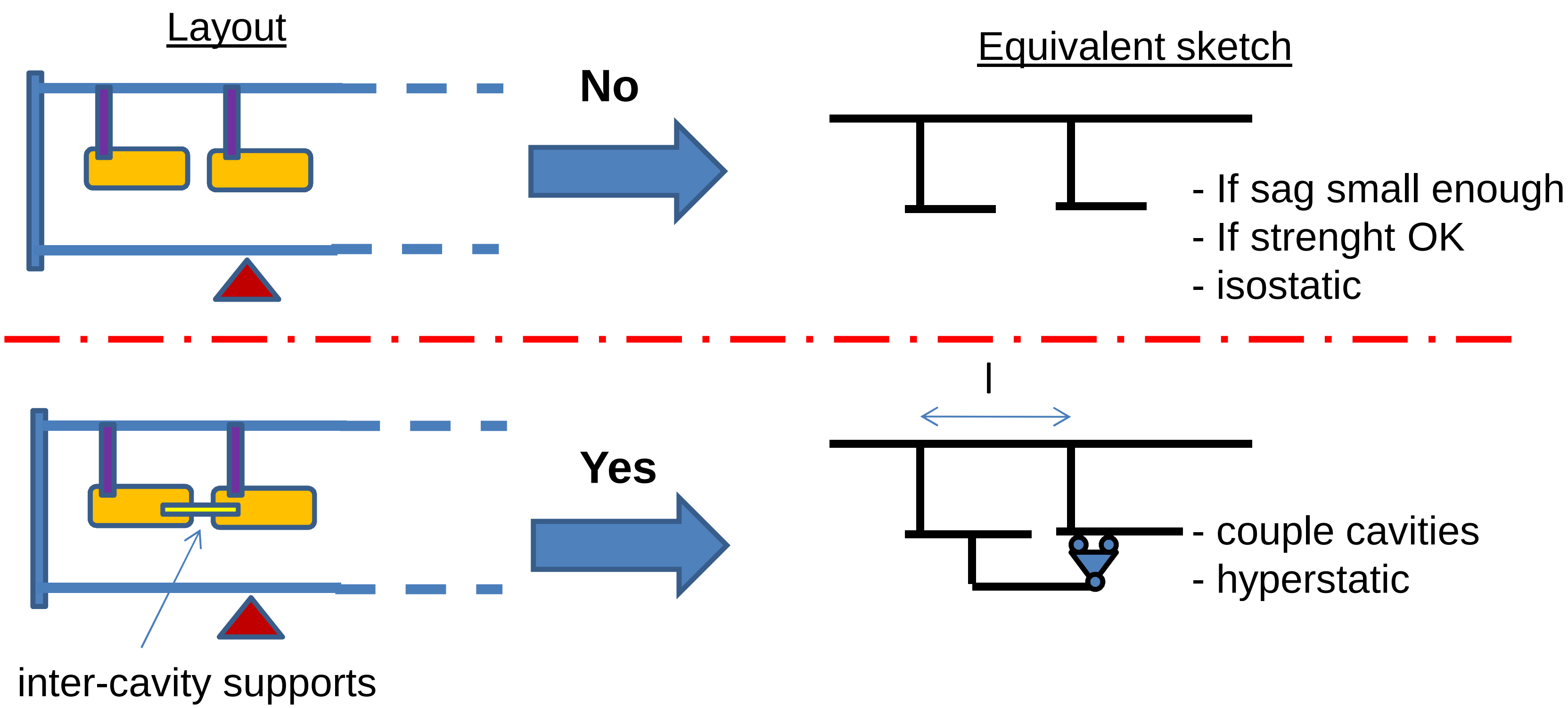


...add 3rd support → becomes hyperstatic (forces depend on mech. coupling vessel/inertia beam)




Cross section of XFEL cryomodule, from *TESLA Technical Design Report*

# Additional cavity support




Need for support : cavities alignment, structural integrity

Why an inter-cavity support: double tube can take full compressive load, heat load, assembly simplicity, thermal transients