Cavity Supporting Scheme

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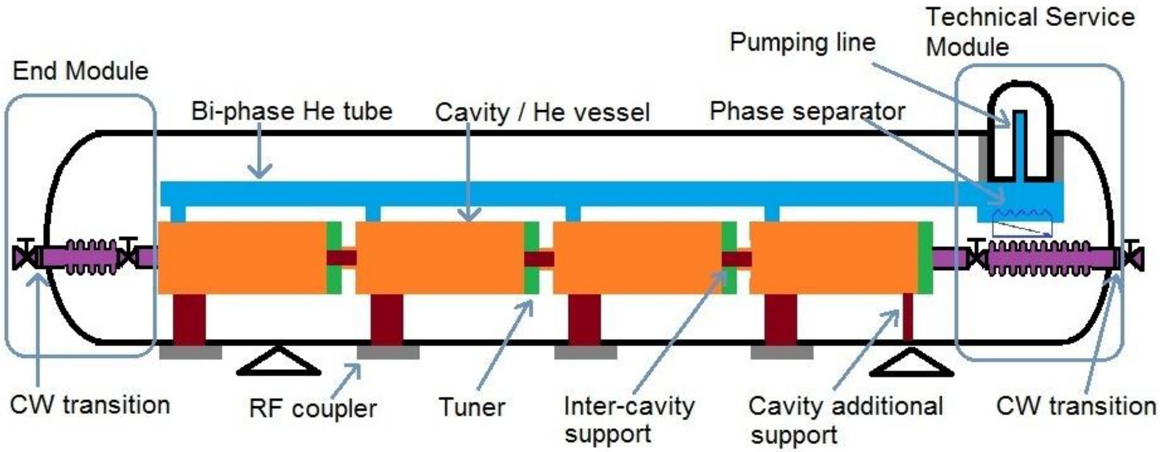
SPL Conceptual Review, 04/11/2010

Contents

1. Introduction

Requirements of cavity supporting system

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



All calculations described in this presentation were carried out or are valid for an 8 cavities cryomodule

1. Introduction

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	800-1200

*According to estimations by *CMI Enteprise*

1. Introduction

Cavities positioning tolerance with respect to beam axis

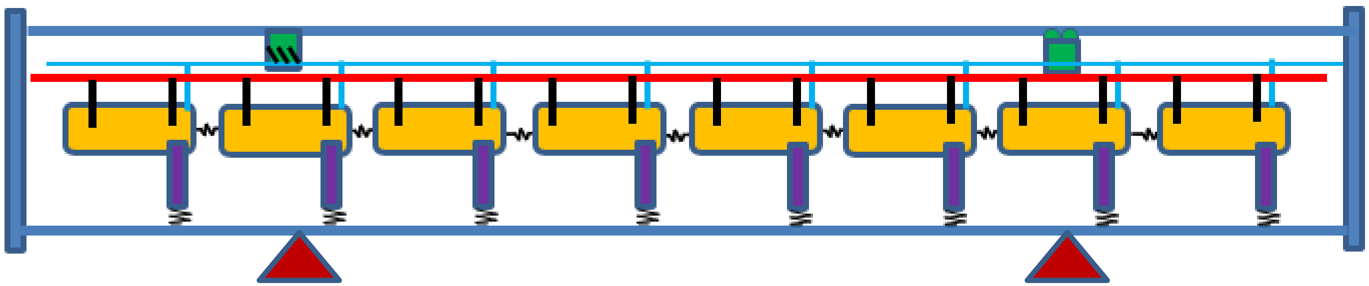
BUDGET OF TOLERANCE			
Step	**Sub-step**	**Tolerances (3σ)**	**Total envelopes**
Cryo-module assembly	Cavity and He vessel assembly	*± 0.1 mm (TBD)*	Positioning of the cavity w.r.t. beam axis **± 0.5 mm**
	Supporting system assembly	*± 0.2 mm (TBD)*	
	Vacuum vessel construction	*± 0.2 mm (TBD)*	
Transport 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

Long-term stability

1. Introduction

Possible supporting schemes: “standard” supporting scheme



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

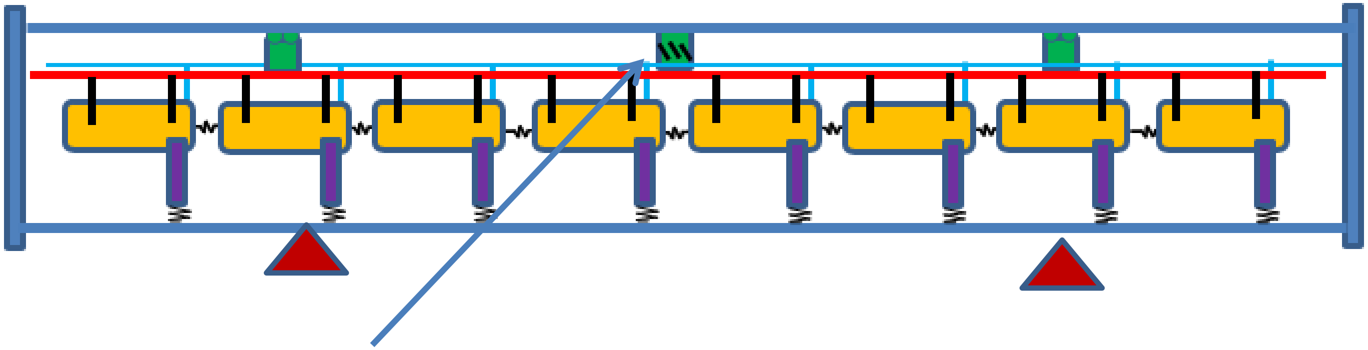
If cavity straightness not enough...

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

Courtesy of Vittorio Parma

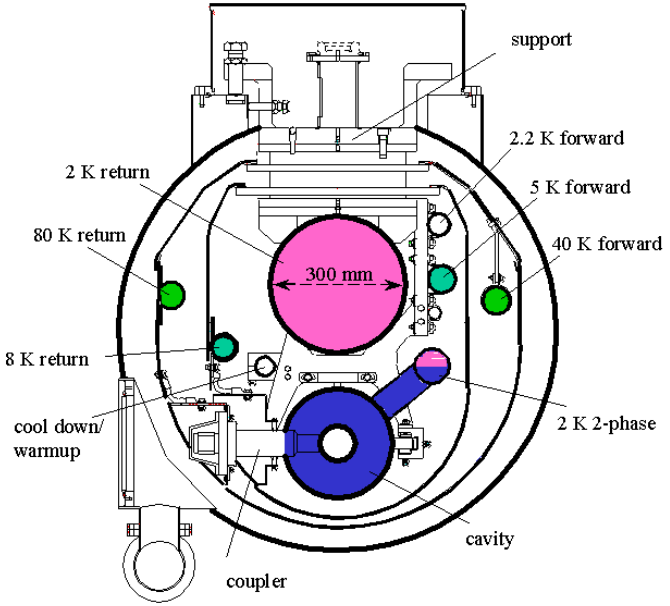
1. Introduction

Possible supporting schemes: “standard” supporting scheme with third support



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

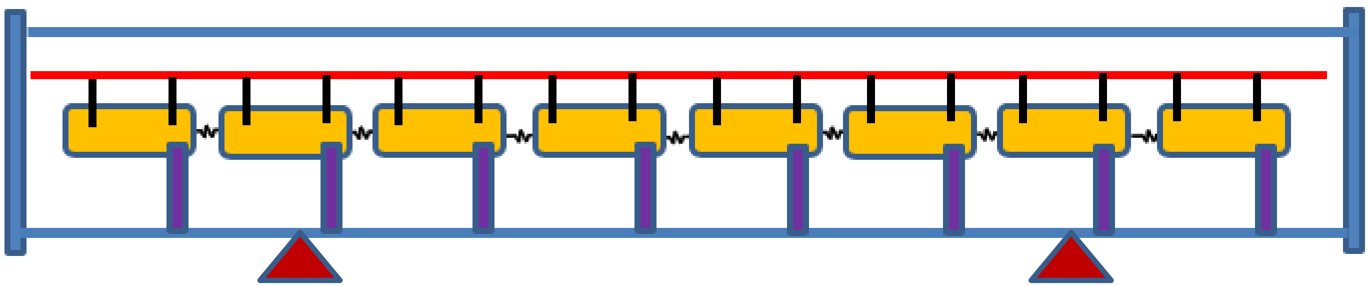
Courtesy of Vittorio Parma



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

1. Introduction

Possible supporting schemes: power coupler as support



The coupler is also a supporting/aligning element

 RF coupler + longitudinal positioner + vertical support

 Intercavity support structure

 External supports (jacks)

Courtesy of Vittorio Parma

Why?

This solution simplifies the design of the cryostat and enhances thermal performance to 2 K by limiting the number of heat conduction paths from RT

1. Introduction

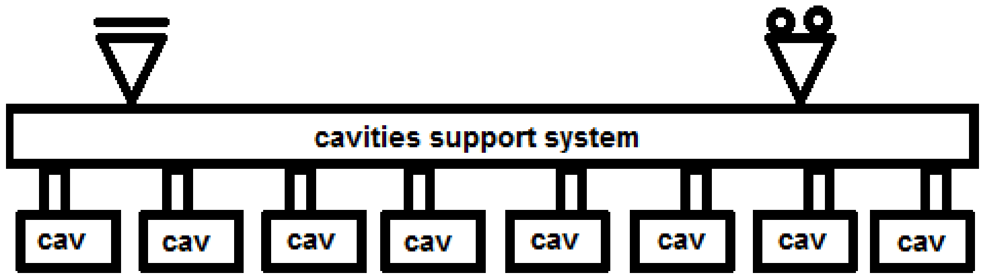
Possible supporting schemes: required stiffness

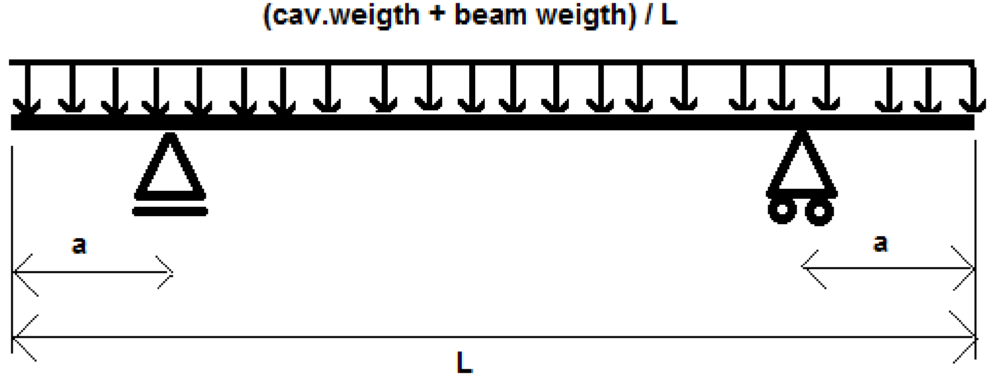
Calculations performed with the aim of estimating the stiffness which the support system ("Standard "supporting solution) of the SPL cavities would have to provide for the string of cavities to be kept inside a certain alignment tolerance.

- Beam simply and symmetrically supported on two points, loaded by the weight of the cavities and by its own weight

- Loads are distributed uniformly along the beam

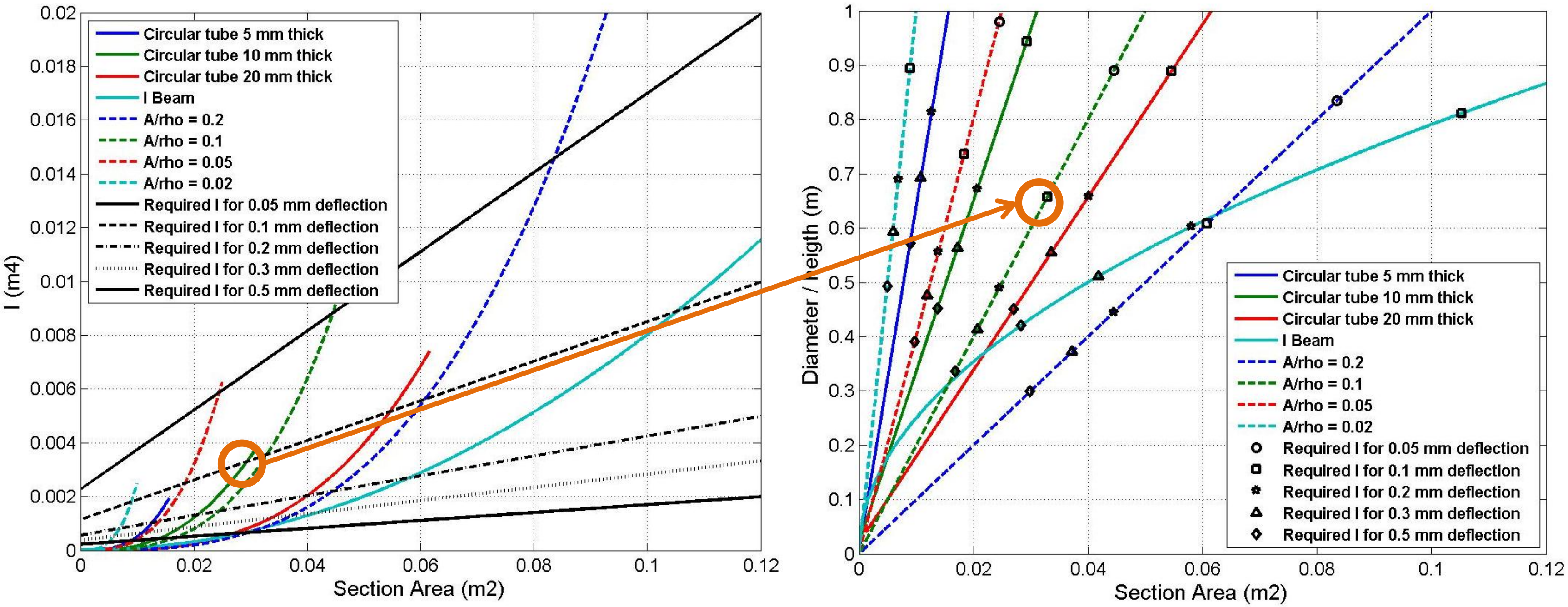
-The cavities and the supports are considered to be rigid -maximum beam deflection is a measure of the maximum cavity misalignment





1. Introduction

Possible supporting schemes: required stiffness



L=13 m, m_{cav}=200 Kg, n_{cav}=8 , g=9.8 m/s^2

Stainless steel 304 L: ρ=8000 kg/m^3; E=1.93e^{11} Pa

For a circular tube with a thickness of 10 mm and a maximum 0.1mm deflection...

1. Introduction

Possible supporting schemes: required stiffness, third support

- Three vertical displacements (simple supports)
- Loads remain the same
- One support in the middle of the beam, the other two at a distance of 0.16 *L* from each end of the beam

	S **[*m^2*]**	***I*** **[*m^4*]**	**Deflection; 2 supports (analytical) [*mm*]**	**Deflection; 3 supports (FE beam analysis) [*mm*]**
Circular tube *tck. 6 mm diam. 300 mm*	0.0055	5.99E-05	2.3	0.358
Circular tube *tck.* 12 *mm diam. 1000 mm*	0.0372	4.55E-03	0.075	0.018

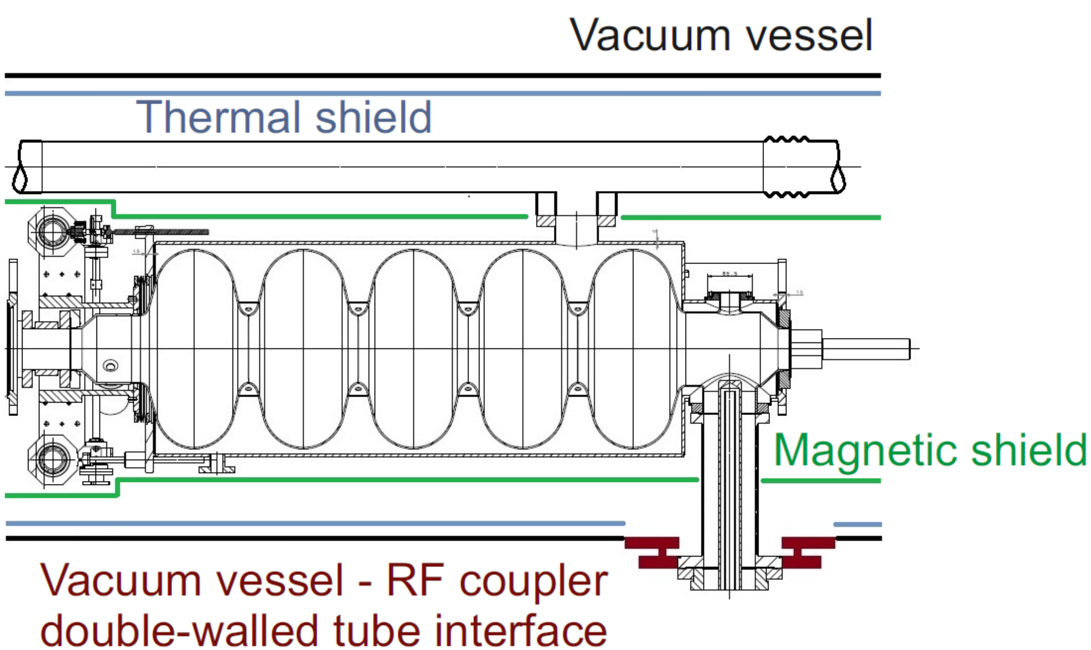
1. Introduction

Possible supporting schemes: table of comparison

	Standard, 2 supports	Standard, 3 supports	PC as support
Design simplicity	-	-	+
Thermal load	+/-	-	+
Need for extra supports	+	+	-
Proven concept	+	+	-
Vacuum vessel structural demands	+	+/-	-
Vacuum vessel dimensional stability	+	+/-	-
Vacuum vessel size	-	+/-	+
Longitudinal positioning of cavities	-	-	+

2. Power coupler as support

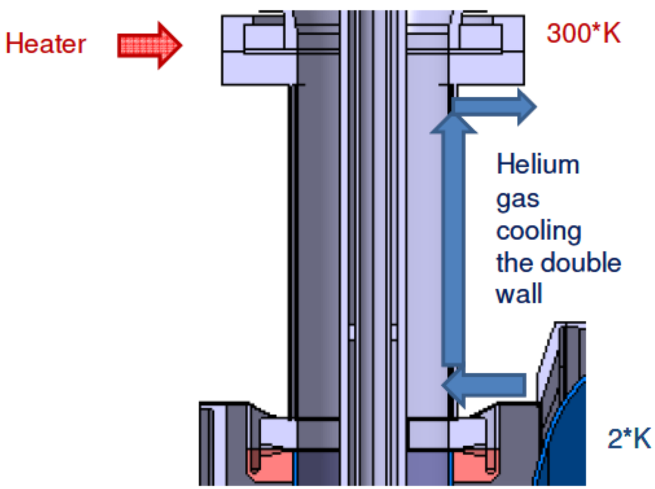
- Power coupler double tube as cavity support to vacuum vessel and longitudinal positioner
- Vacuum vessel acts as “inertia beam”
- Adjustable connection between vacuum vessel and power coupler double tube
- Additional support may be needed to guarantee cavities alignment



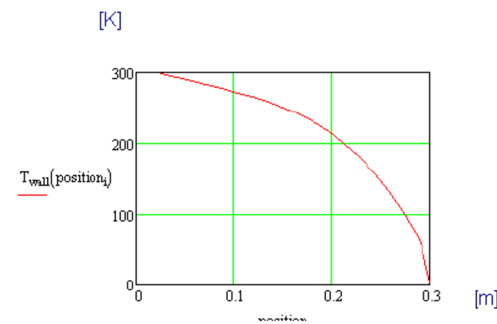
2. Power coupler as support

Active cooling of PC double walled tube

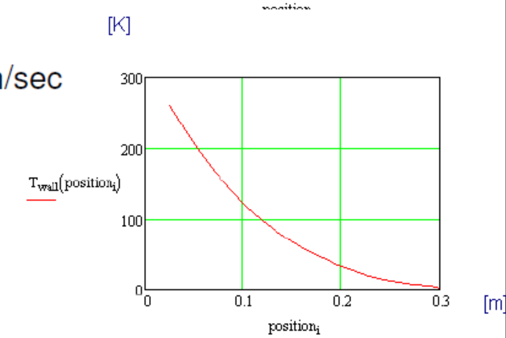
- Cooling gas at 4.5 K input
- Lower part at 2 K and upper part at 300 K
- Heater at upper part to insure 30 ºC of flange temperature
- 1000 kW pulsed (100 kW average), 704.4 MHz, 50 Ω
- H=300 mm; D=100 mm; eint=1.5 mm; eext=2 mm
- Copper on stainless steel; Copper RRR = 30 (Sergio Calatroni)



- Why cooling the wall?
  - No cooling temperature profile => Gives 21W to 2K



  - Cooling with 42 mgram/sec temperature profile => Gives 0.1W to 2K



Courtesy of Ofelia Capatina

The active cooling of the double walled tube was not conceived to cope with its support function. However, due to the cavity alignment requirements, the thermal profile of the double tube and its reproducibility become a fundamental issue.

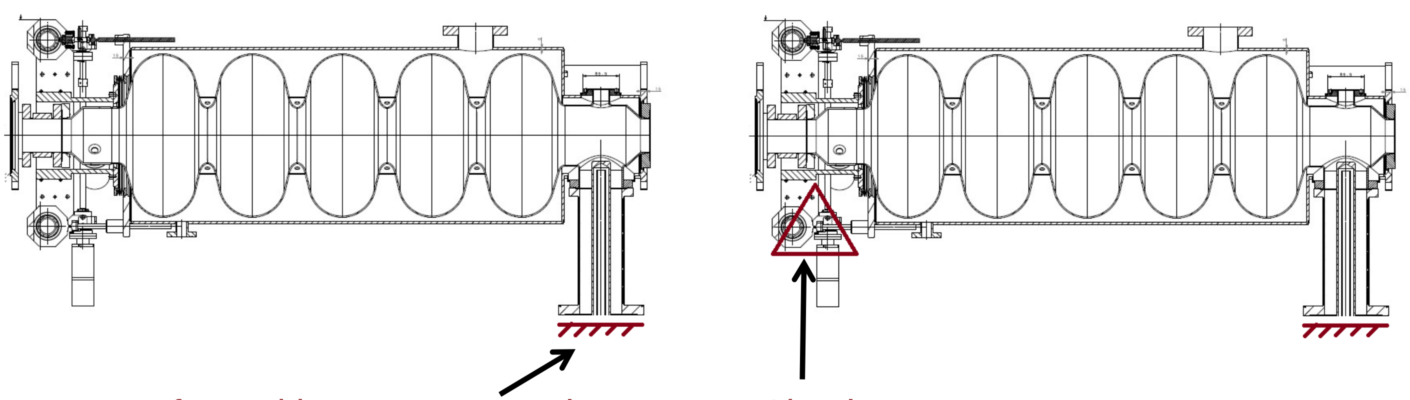
Further work on this subject is being carried out by Rossana Bonomi (TE/MSC).

2. Power coupler as support

FE calculations of helium vessel

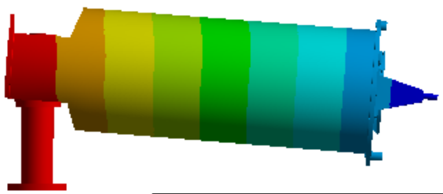
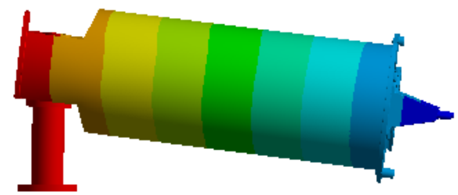
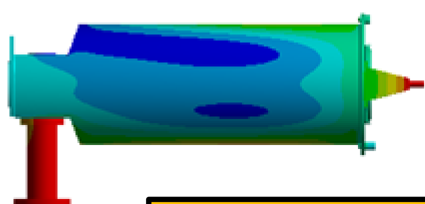
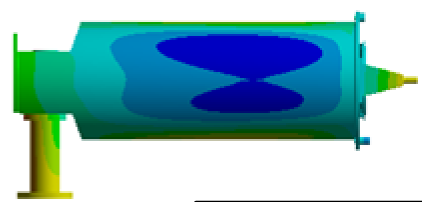
The helium vessel provides rigidity to the dressed cavity assembly.

- Supporting options: Cantilever and simply supported
- Loads: Weight and weight plus transport loads (0.5g in all directions) – including weight of tuner, cavity and power coupler double tube



2. Power coupler as support

FE calculations of helium vessel: vertical displacement

	Weight loads	Weight plus transport loads
Cantilever	 Max: 5.5 mm	 Max: 8.8 mm
Supported	 Max: 0.01 mm	 Max: 0.02 mm

deformed shape amplified 20x

Models by EN/MME

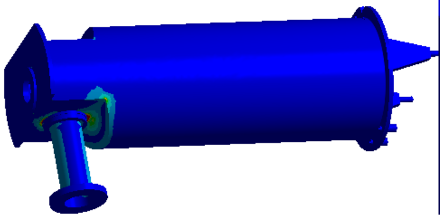
Additional support required for cavity alignment

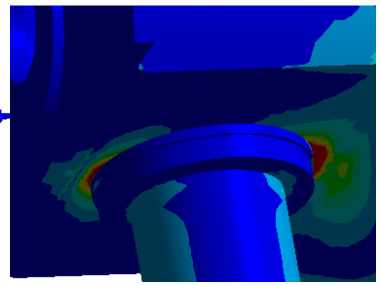
2. Power coupler as support

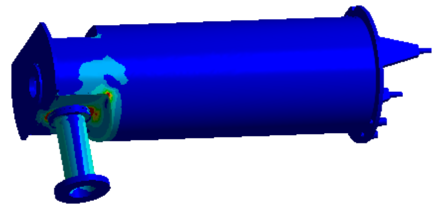
FE calculations of helium vessel: von Mises stress

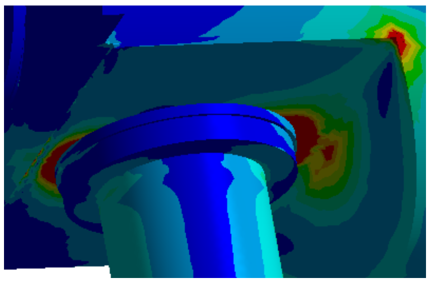
Weight loads | Weight plus transport loads

Cantilever

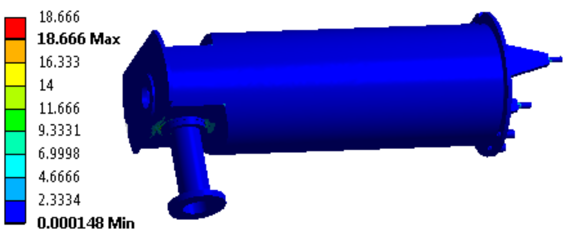


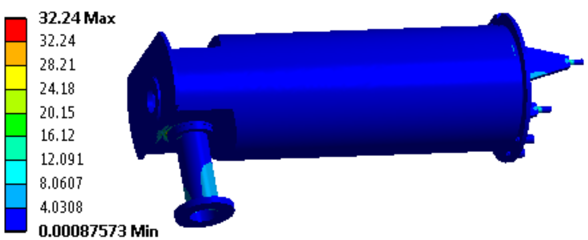






Supported





Stresses in MPa, red for values above 190 MPa

Models by EN/MME

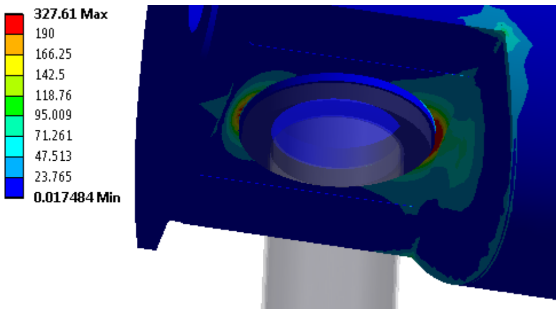
Additional support should be required for structural integrity of helium vessel, for transport loads at least

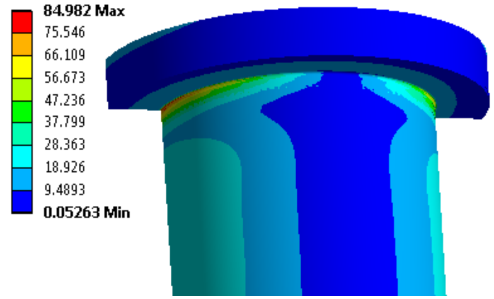
2. Power coupler as support

FE calculations of helium vessel: detailed model

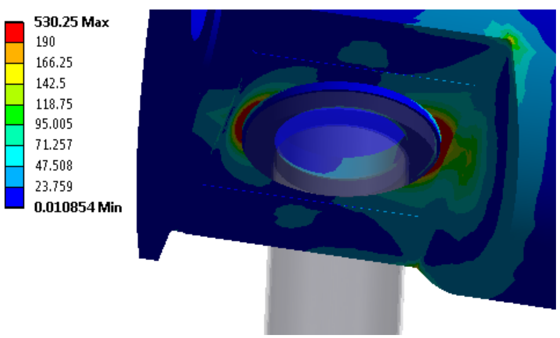
Von Mises stress [MPa] for helium vessel in cantilever under weight loads:

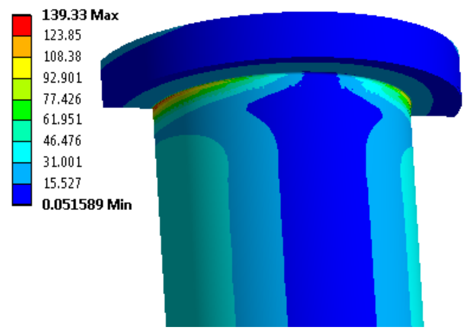
1st step: weight of helium vessel, cavity, double tube





2nd step: weight of helium vessel, cavity, double tube and tuner



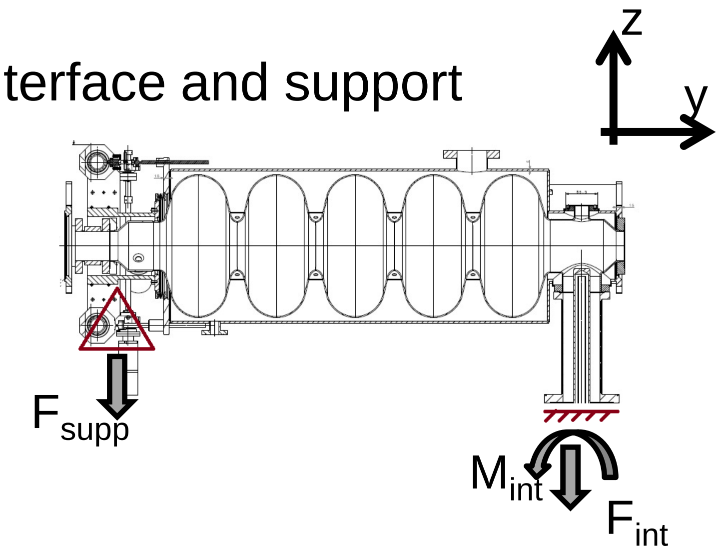


Models by EN/MME

Additional support should be required for structural integrity of helium vessel at all times, and not only during transport

2. Power coupler as support

FE calculations of helium vessel: loads on interface and support



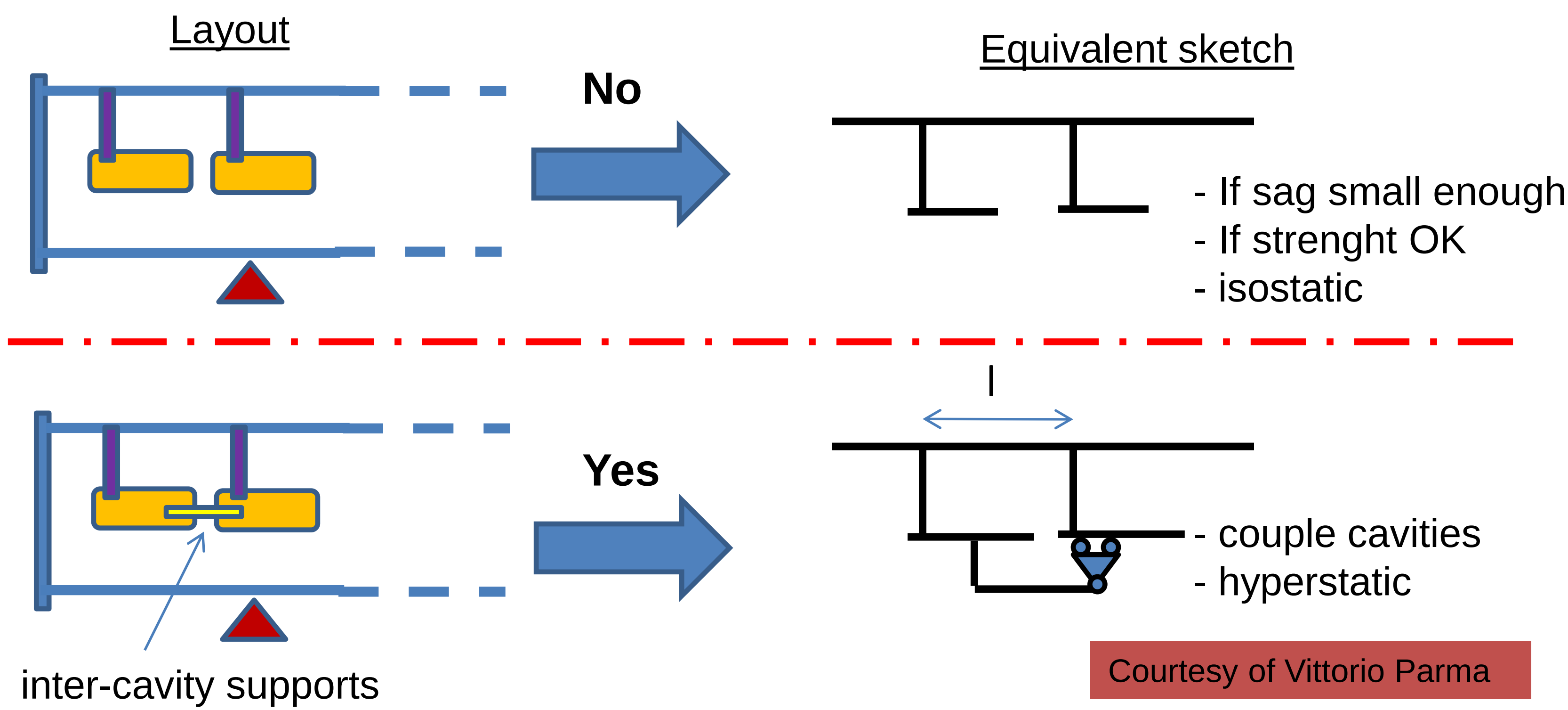
Interface	Weight		Weight + Transport	
	Cantilever	Supported	Cantilever	Supported
Fx (N)	-	-	-970	-391
Fy (N)	-	-	-968	-968
Fz (N)	-1938	-798	-2907	-1092
Mx (Nm)	1178	-20	1854	-50
My (Nm)	-	-	-107	5
Mz (Nm)	-	-	-674	-4

Support	Weight	Weight + Transport
Fx (N)	0	-579
Fz (N)	-1140	-1815

See Arnaud Vande-Craen's presentation – SPL test mock-up

Balance of forces largely dependent on nature of additional support

2. Power coupler as support

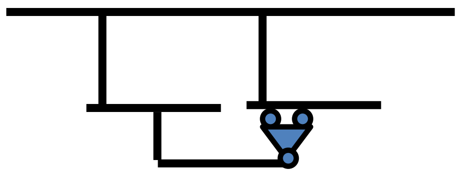


Need for support : cavities alignment, structural integrity

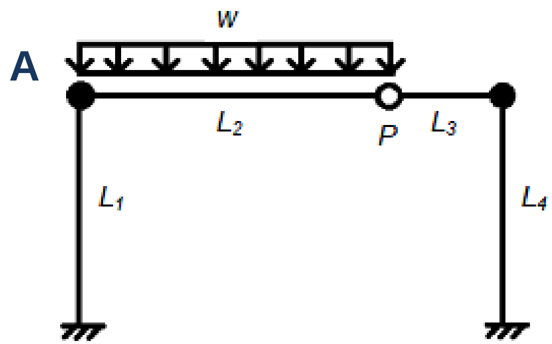
Why an inter-cavity support: double tube can take full compressive load, heat load, assembly simplicity, thermal transients

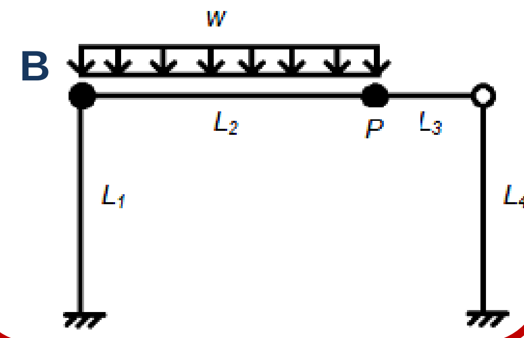
3. Inter-cavity support

Best position for spherical / sliding joint



2 degrees of freedom constrained





Bar	L (m)	E (Pa)	D_e (m)	D_i (m)
1 Double tube*	0.425	2e11	0.108	0.1
2 He vessel	1.4	2e11	0.418	0.408
3 Inter – cavity support	0.3	2e11	0.04	0
4 Double tube*	0.425	2e11	0.108	0.1

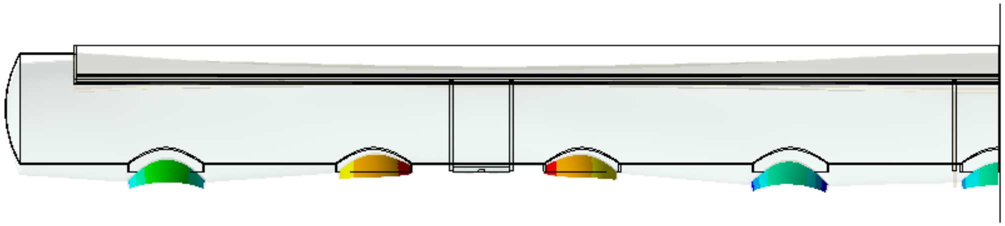
* Equivalent simple tube.

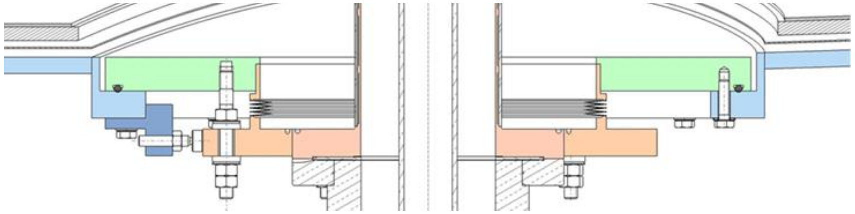
Position of articulation	Second Double Tube	Displacement Method	FEM
A	Flexible	0.26	0.28
B	Flexible	0.21	0.21
A	Rigid	0.23	0.25
B	Rigid	0.17	0.19

4. Vacuum vessel and vacuum vessel interface

The importance of the structural stability of vacuum vessel is not limited to the integrity of the vessel itself (buckling, plastic yield). It will also affect the alignment of the string of cavities.

Displacement of vacuum vessel interfaces with double tube must be minimized, especially between cryostating and vacuum pumping – no further adjustment of the interfaces will be permitted.





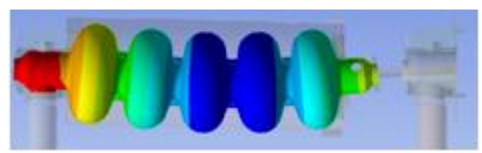
CNRS presentation will deal with the vacuum vessel in detail

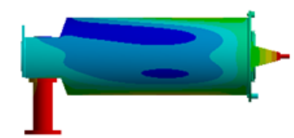
5. Conclusion

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)*	

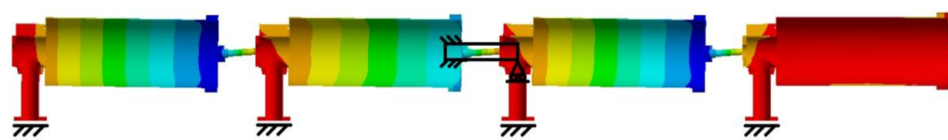
Loads: Self weight and weight of components

Cavity (measured by ends only)
Helium vessel

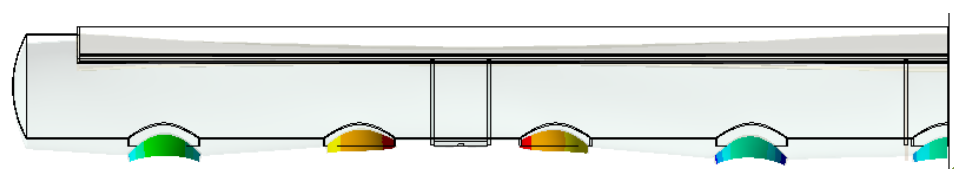




Helium vessel, inter-cavity support, string of cavities



Vacuum vessel, interfaces.



Models above are obsolete or conceptual

5. Conclusion

BUDGET OF TOLERANCE			
Step	**Sub-step**	**Tolerances (3σ)**	**Total envelopes**
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		

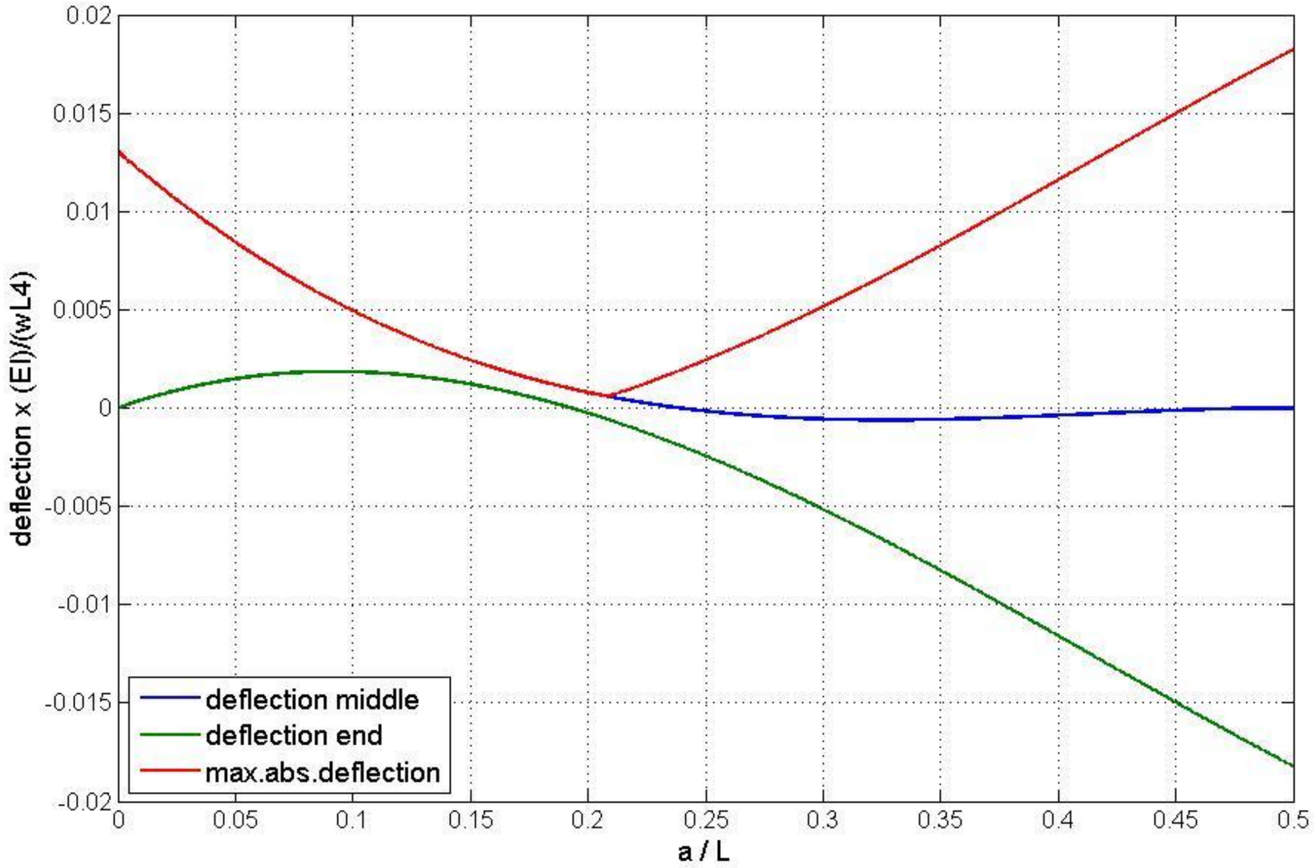
Transport and handling: transport loads

Testing and operation: cavity tuning, thermal transients, vacuum...

Thank you for your attention

Spare Slides

Supporting system: Position of 2 supports



The position of the supports which minimizes the maximum deflection is *a / L*=0.208