ESRF | The European Synchrotron

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MECHANICAL ENGINEERING DESIGN OF SYNCHROTRON
RADIATION EQUIPMENT AND INSTRUMENTATION

BARCELONA

The Girders System for the new ESRF storage ring
11/09/2016

European Synchrotron radiation Facility, CS 40220, 38043 Grenoble Cedex 9, France

Cianciosi Filippo
(Lin Zhang, Thierry Brochard, Philippe Marion, Loys Goirand, Yves Dabin, Marc Lesourd)

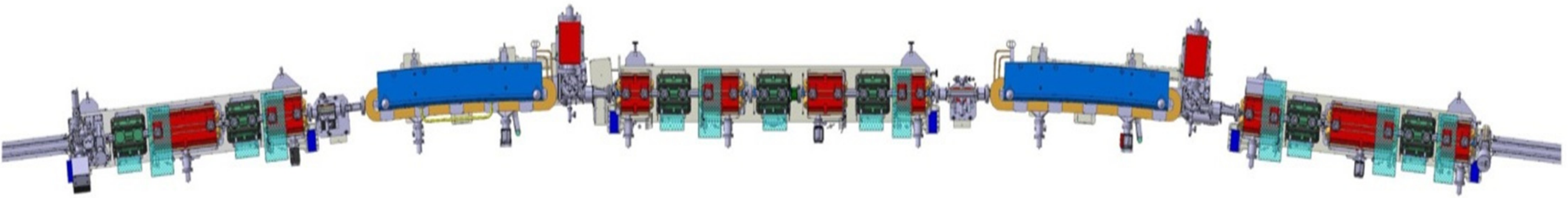
- ESRF storage ring = 32 cells   each cell = 26.4m long

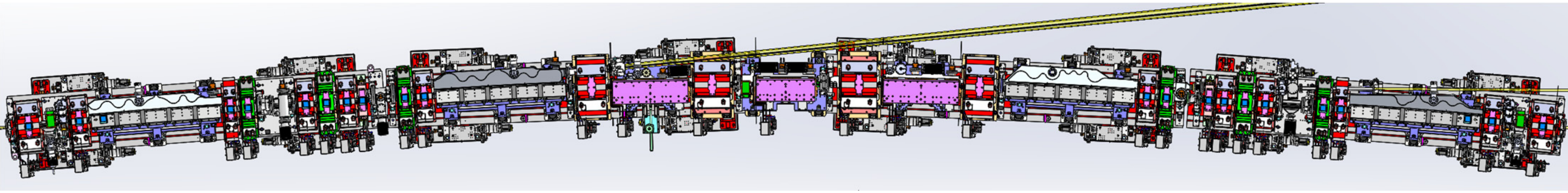
Present ESRF lattice

Double Bend Achromat = (2 dipoles + 15 quad. sext.) per cell

ESRF II lattice

Hybrid 7 Bend Achromat = (4 dipoles + 3 dipoles-quad + 24 quad., sext., oct.) per cell





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(P. Marion will introduce tomorrow all the issues of the new machine)

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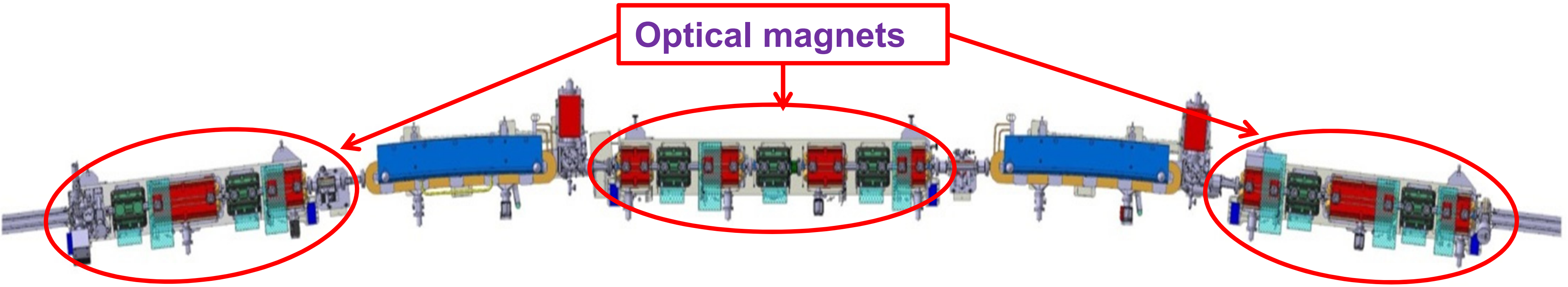

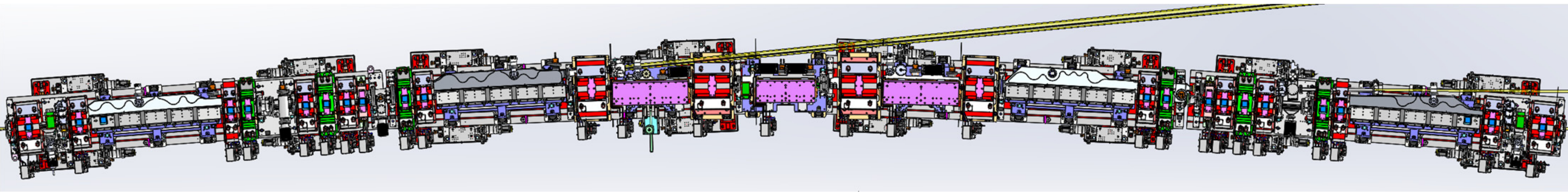

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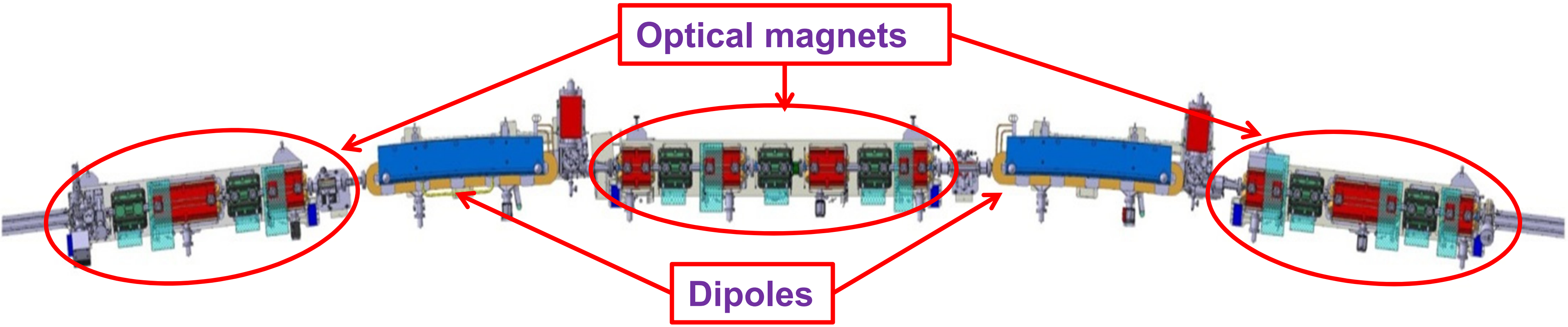

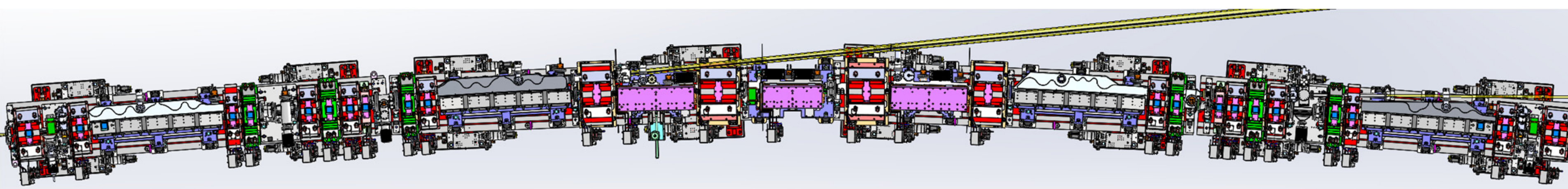

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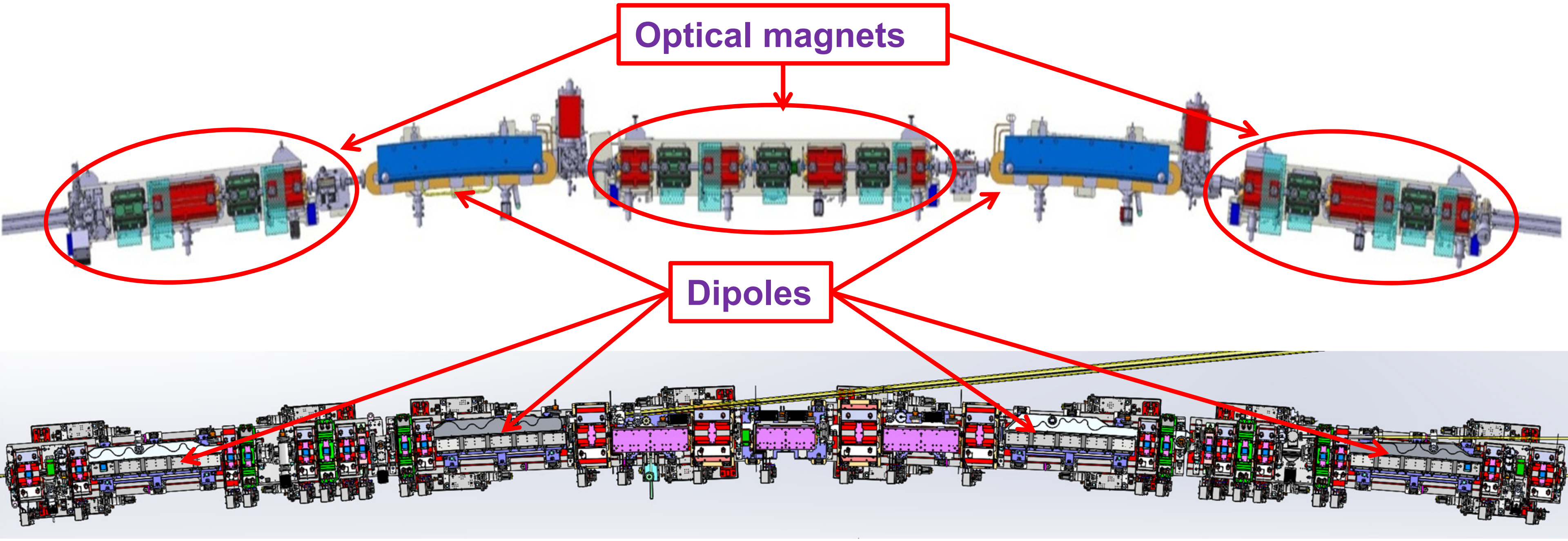

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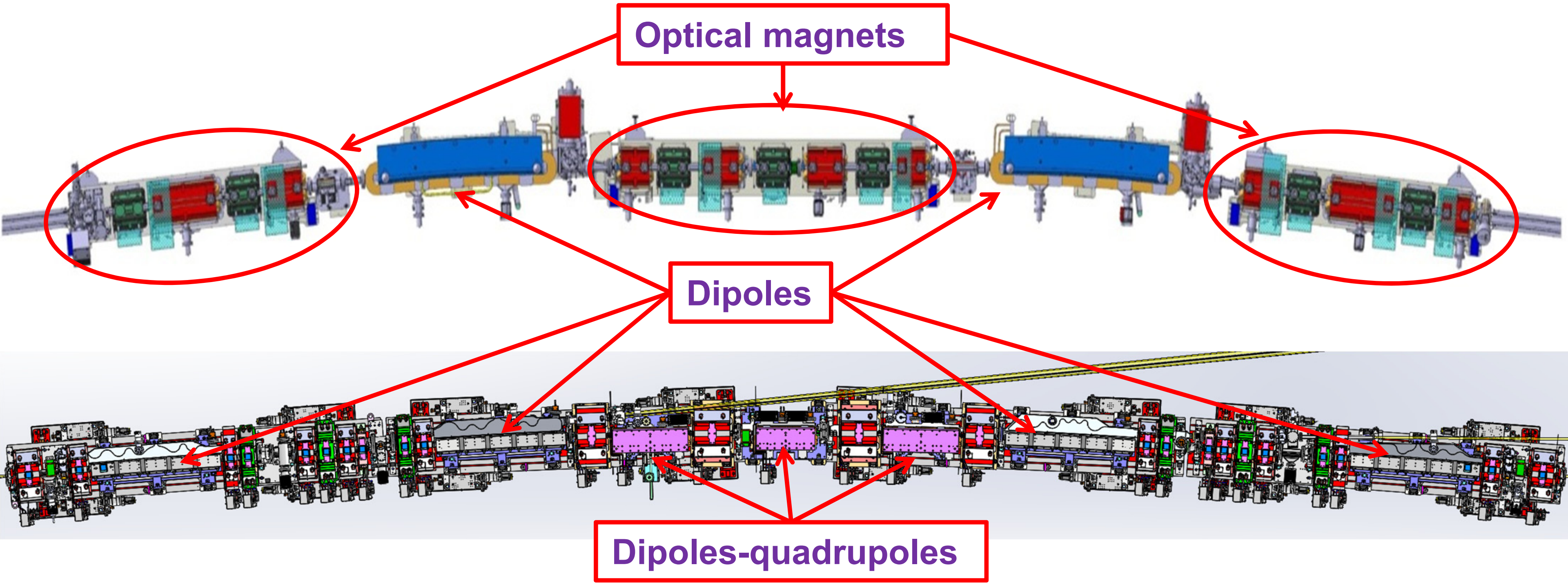

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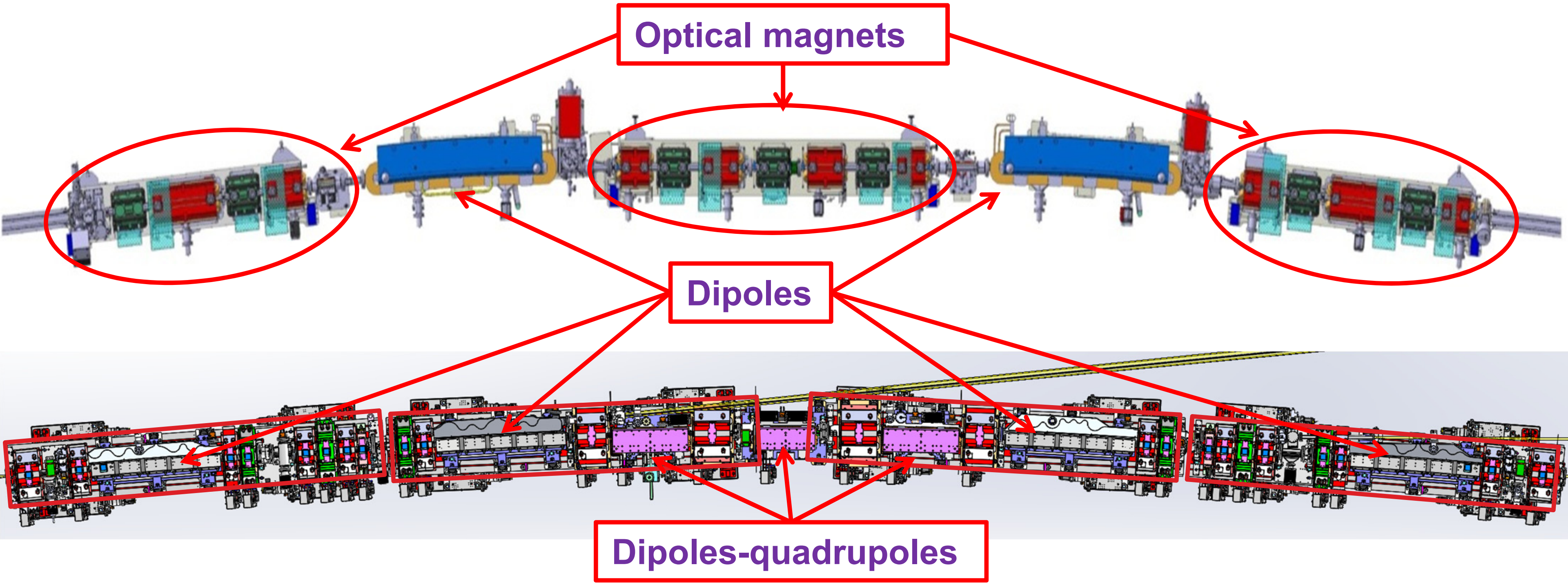

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SPECIFICATIONS

INPUT DATA

- Girder length = 5.1m, magnets weight = 6-7T
- Static positioning required

	HORIZONTAL (Y)	VERTICAL (Z)
Girder to girder	50 µm	50 µm

- ESRF site and slabs large displacements
  - Static = 150 µm / 6 months
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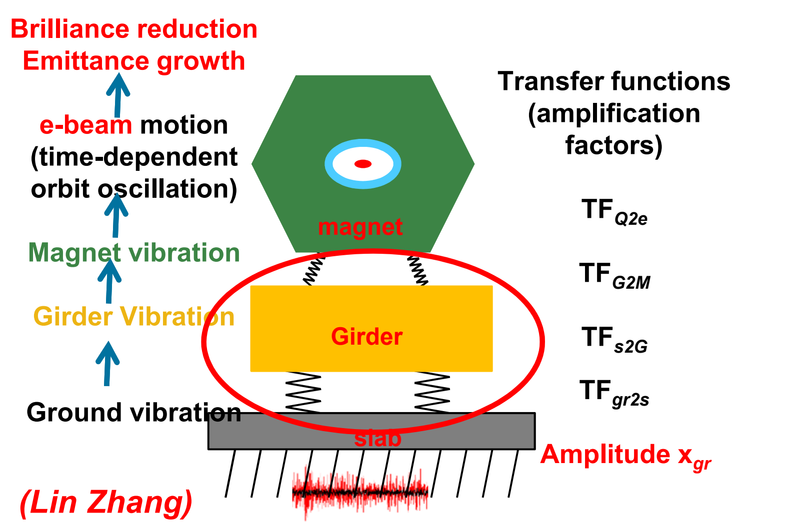

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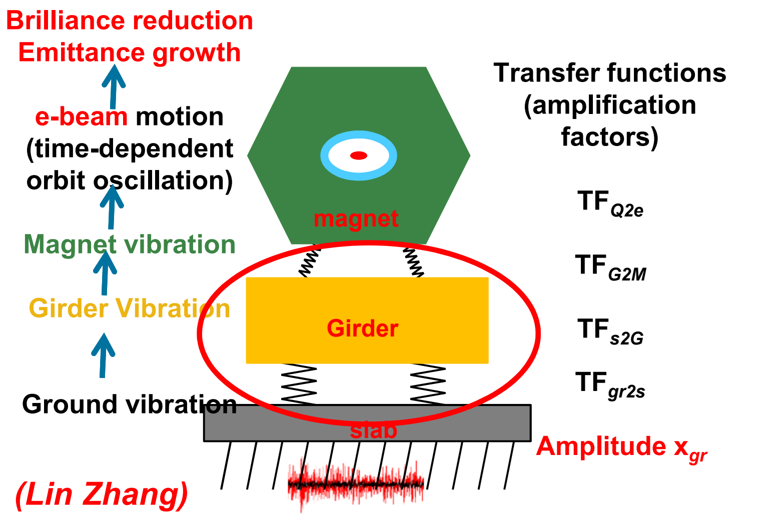

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- Motorized Z adjustment resolution 5µm
- Manual Y adjustment resolution 5µm
- 1st natural frequency = 50Hz (design criteria)
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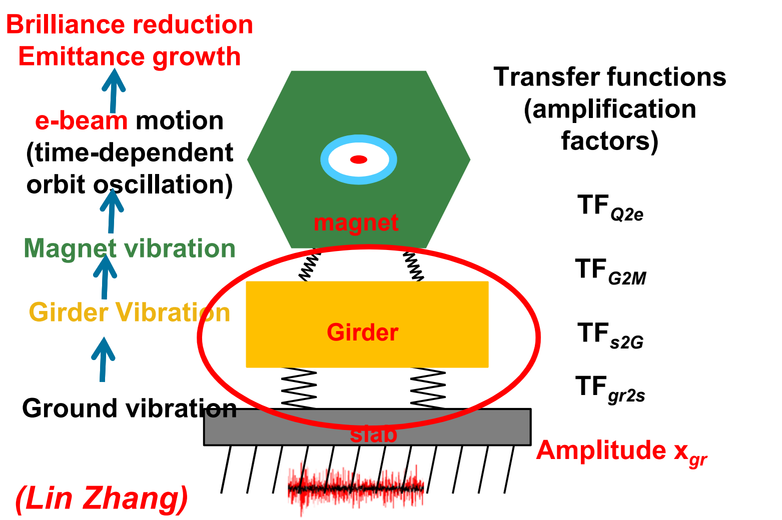

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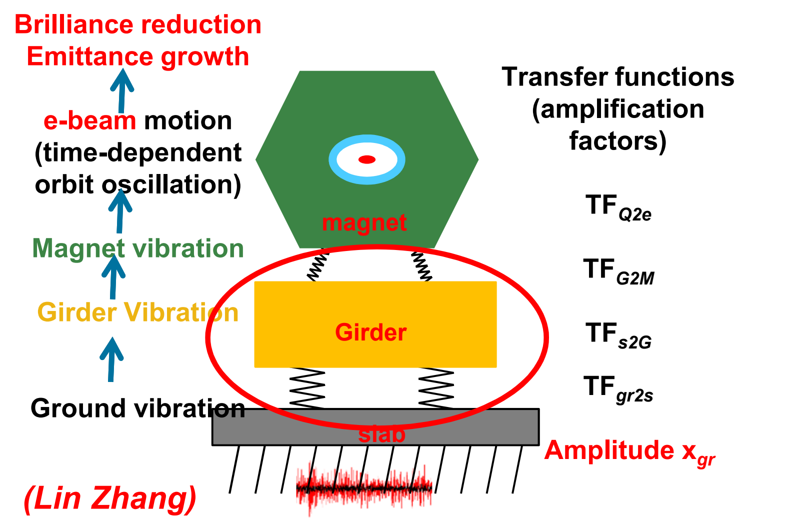

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Difficult to match (applies to the first two challenges)

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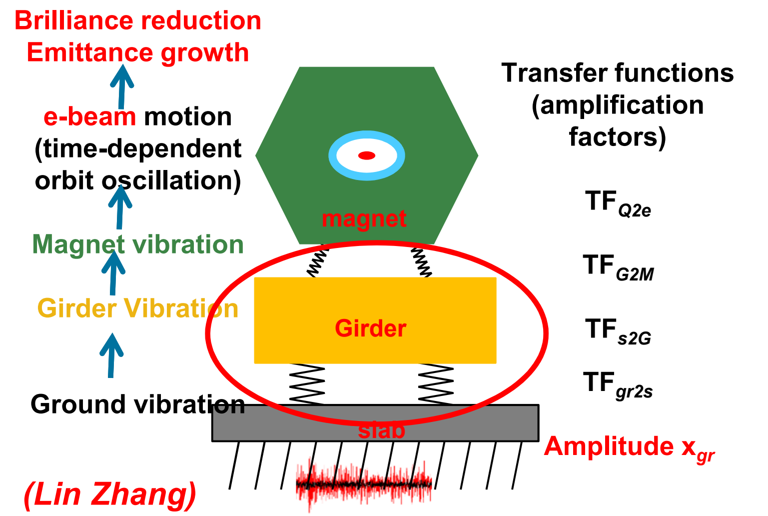

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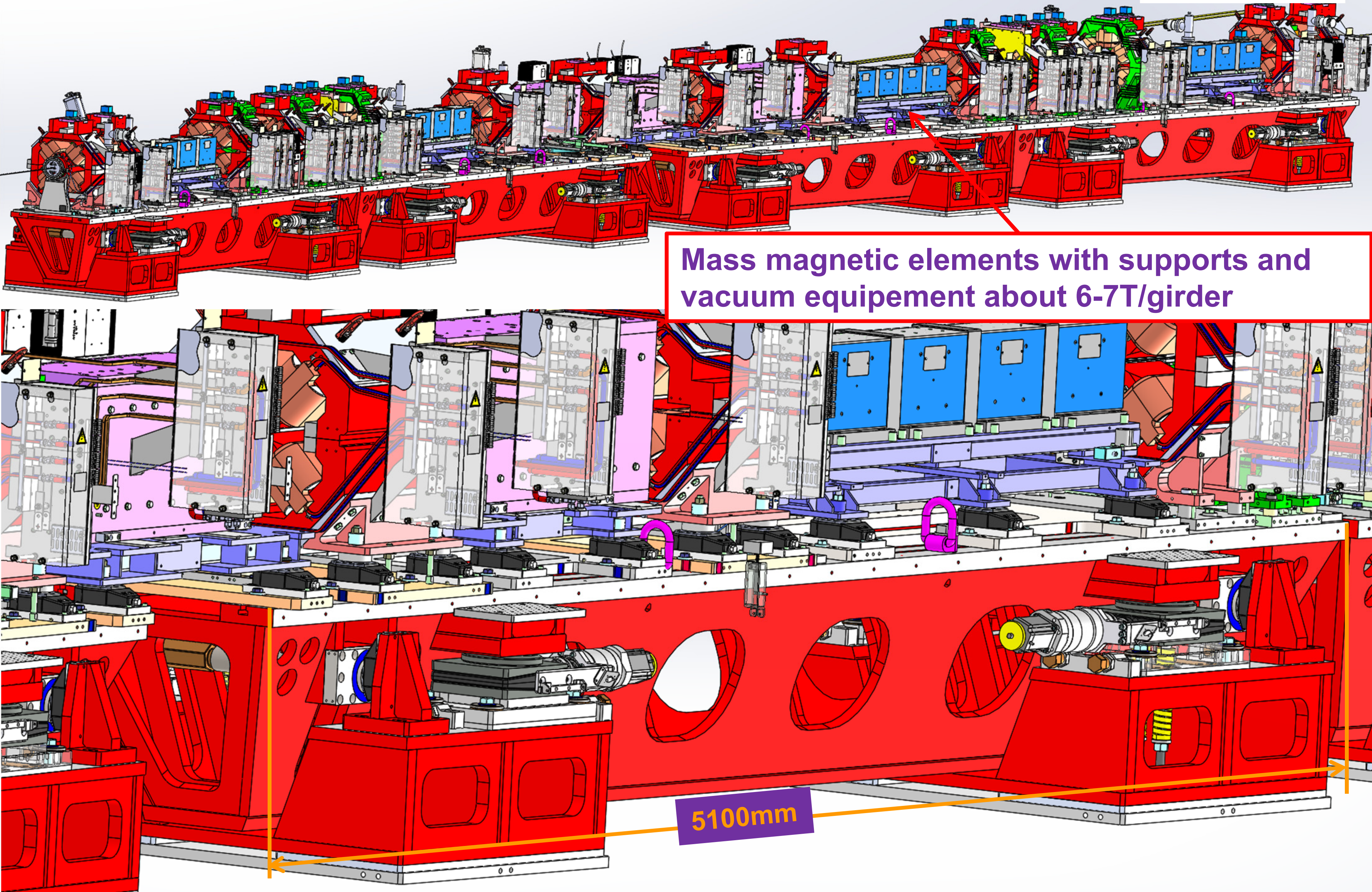
→ **Difficult to match**

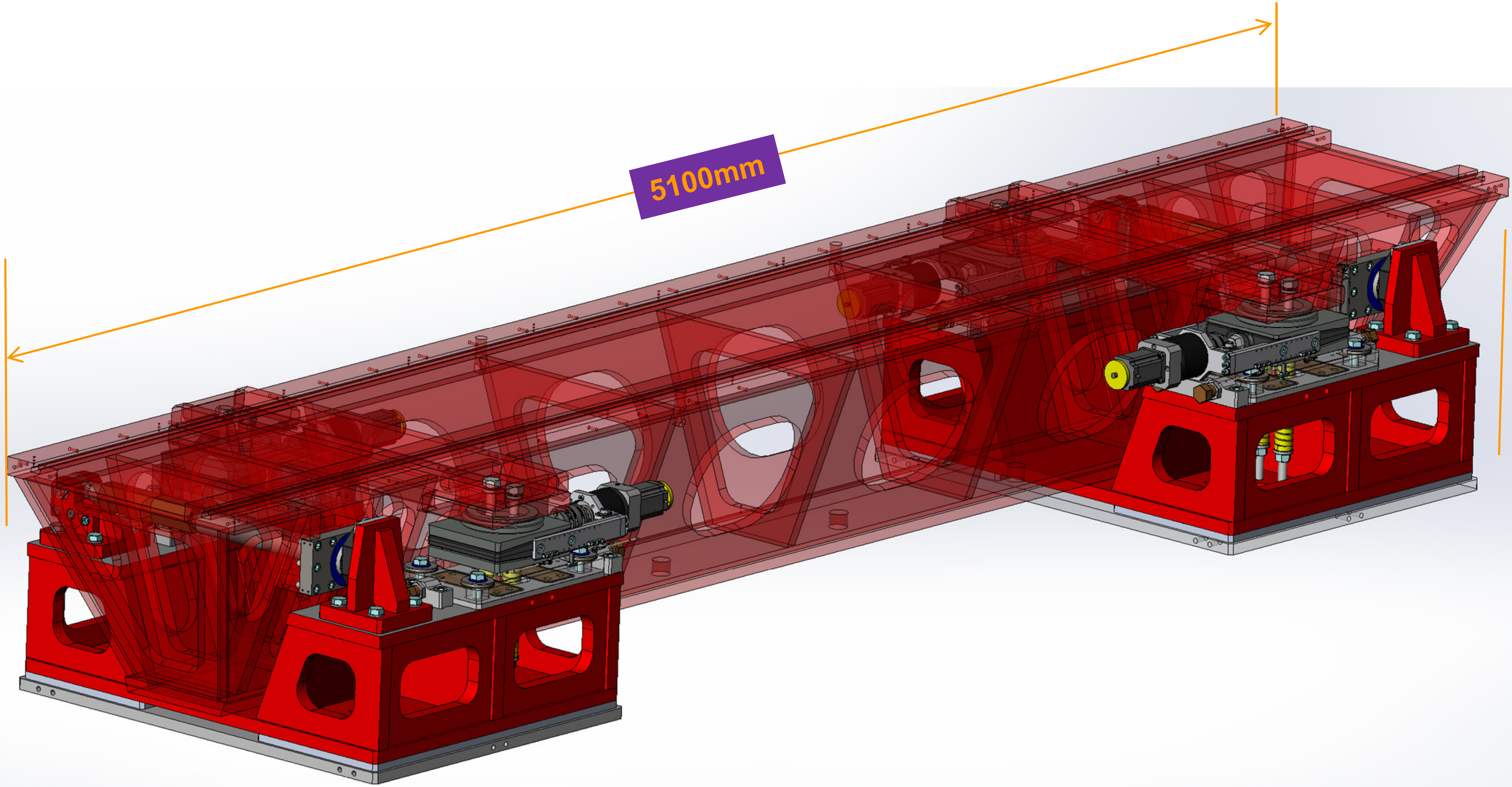
- **Lack of space**
- **Budget limits**

→ **Usual engineer's problems** ***(C'est la vie!)***

GENERAL DESIGN



THE ORTHOGONAL HEPTAPODE



Girder material: carbon steel - Typical tickness: 30mm (15-50mm)
Piece junction: full penetration and continuos weldings
Flatness of the upper face: +/-0.04mm (without payload)

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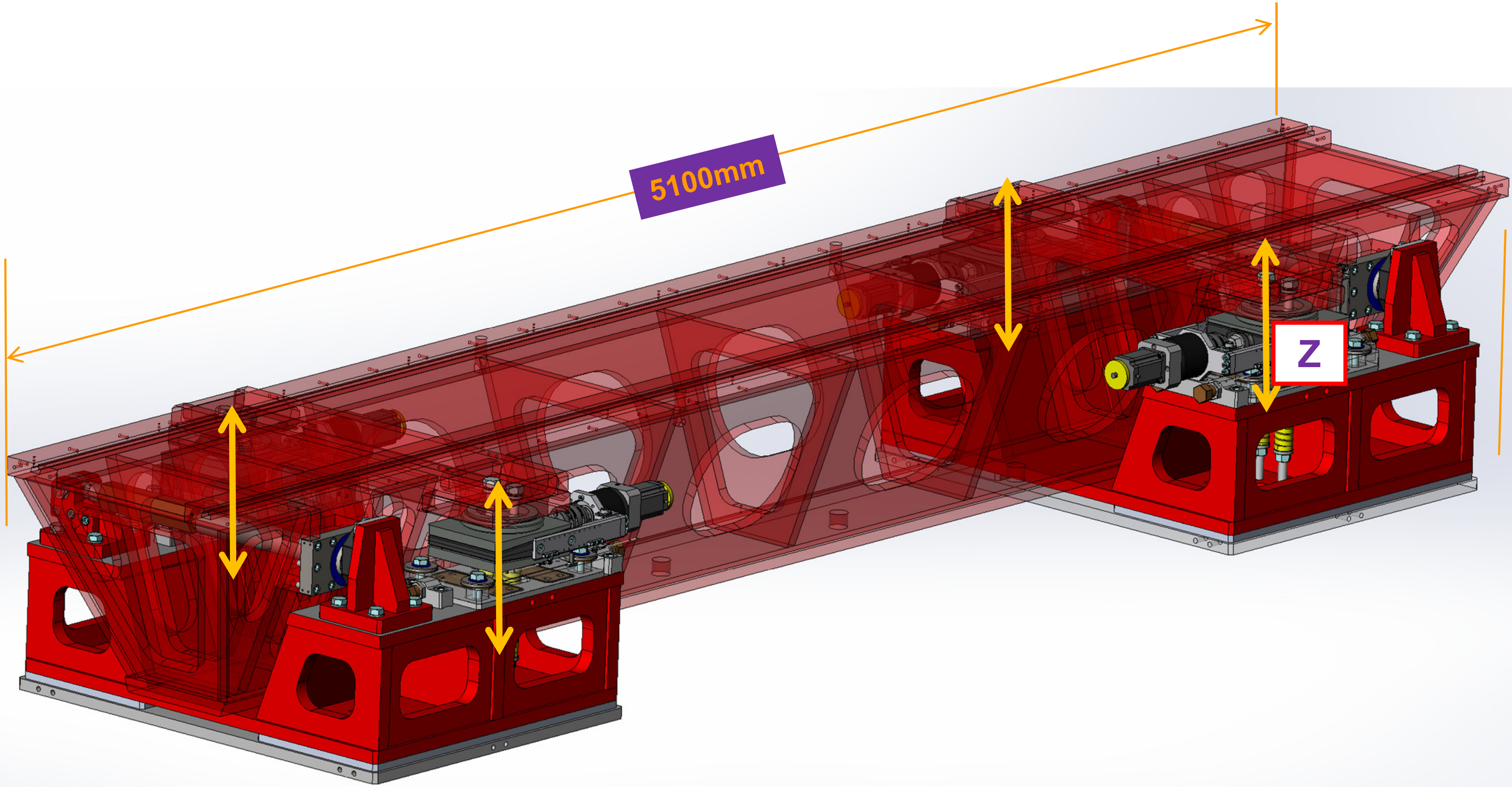

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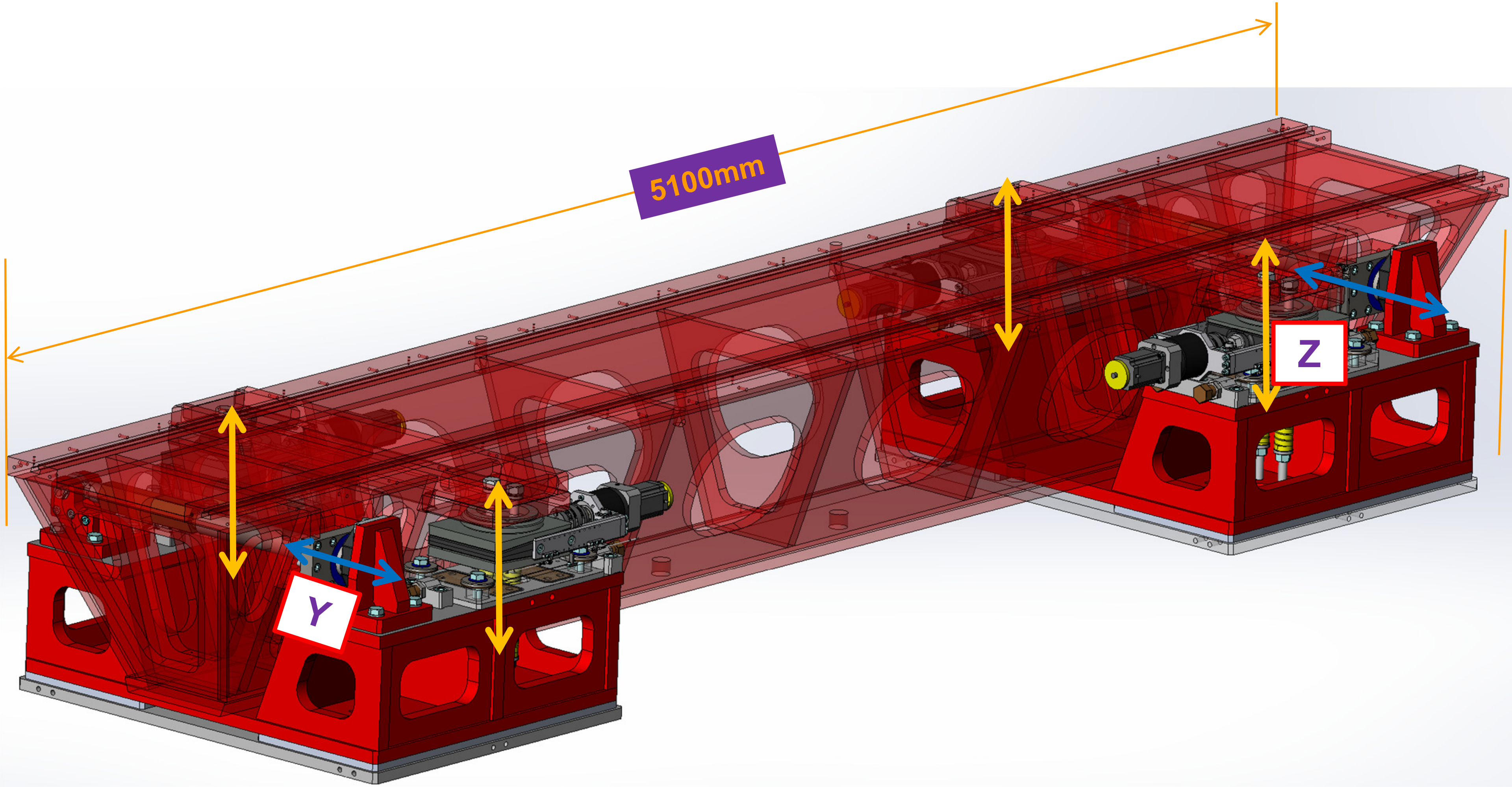

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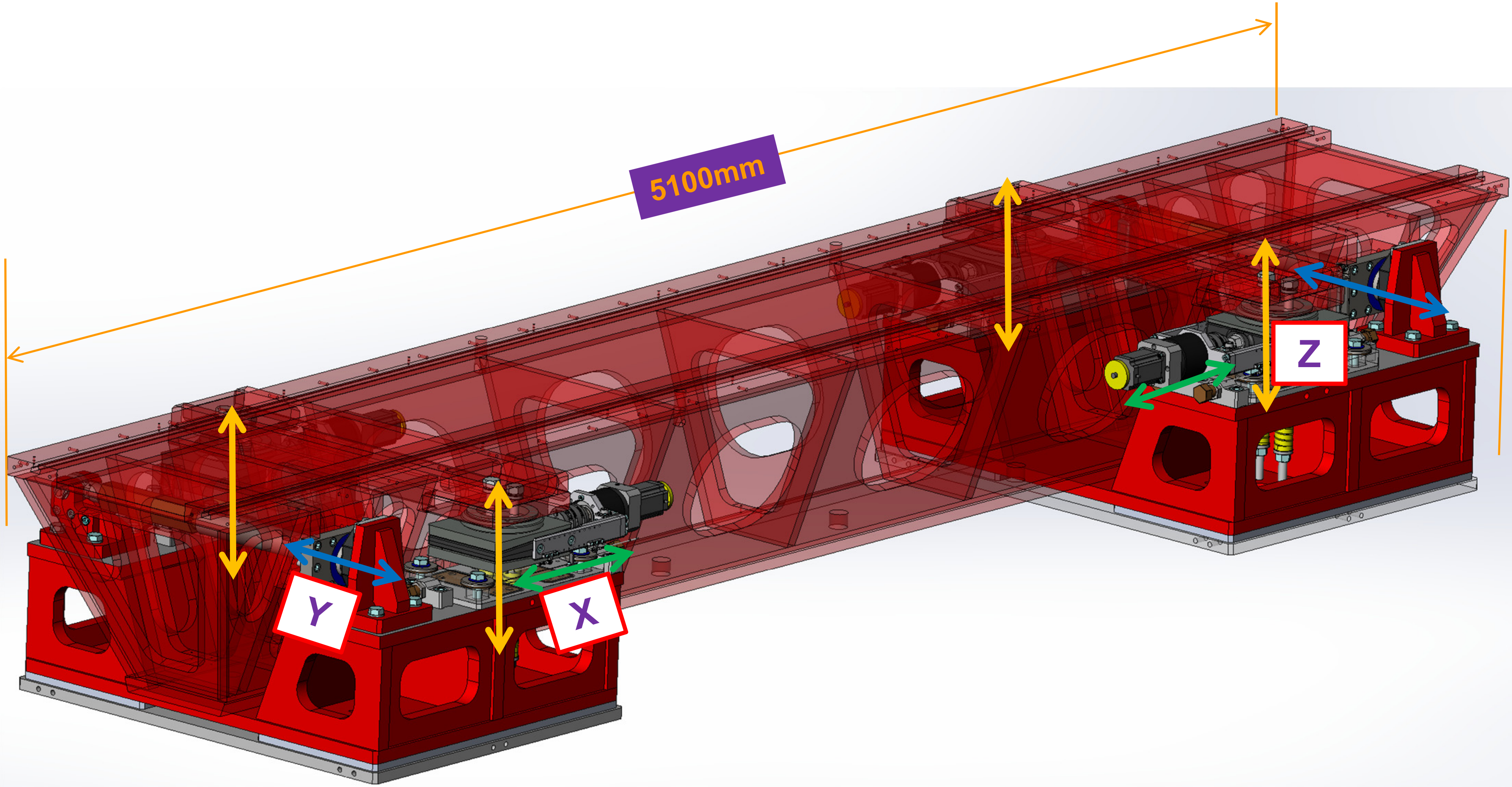

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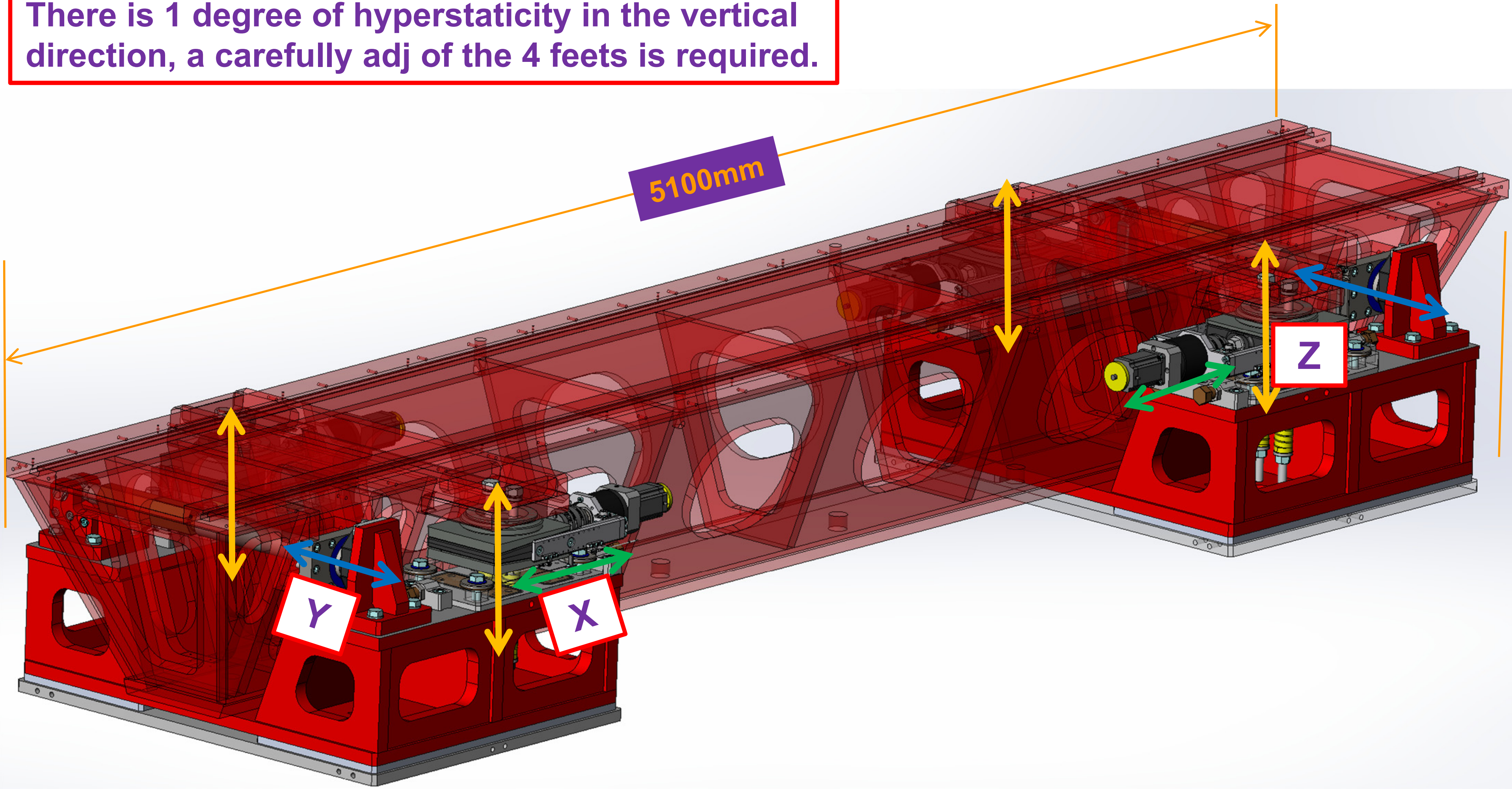
There is 1 degree of hyperstaticity in the vertical direction, a carefully adj of the 4 feets is required.



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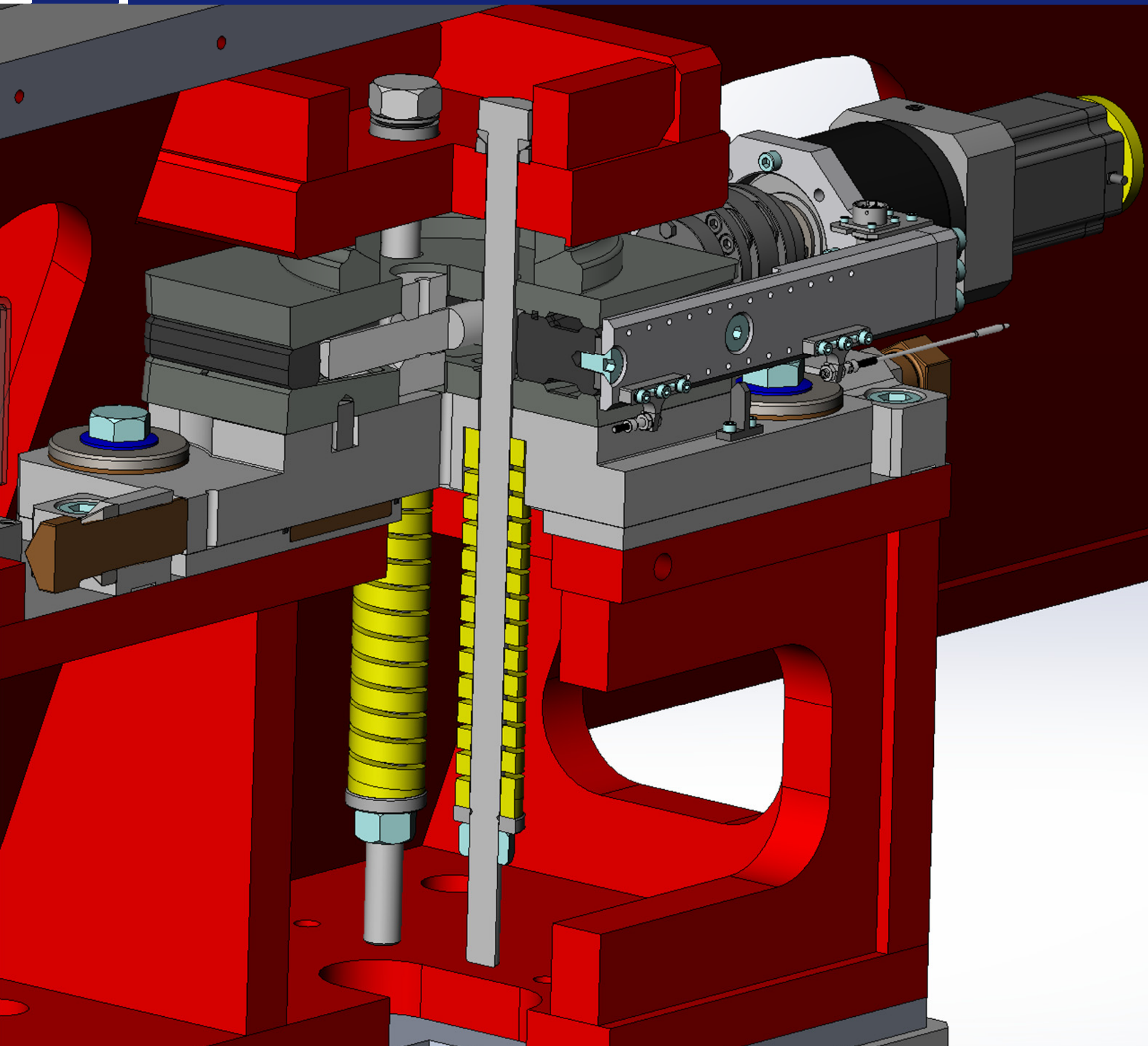
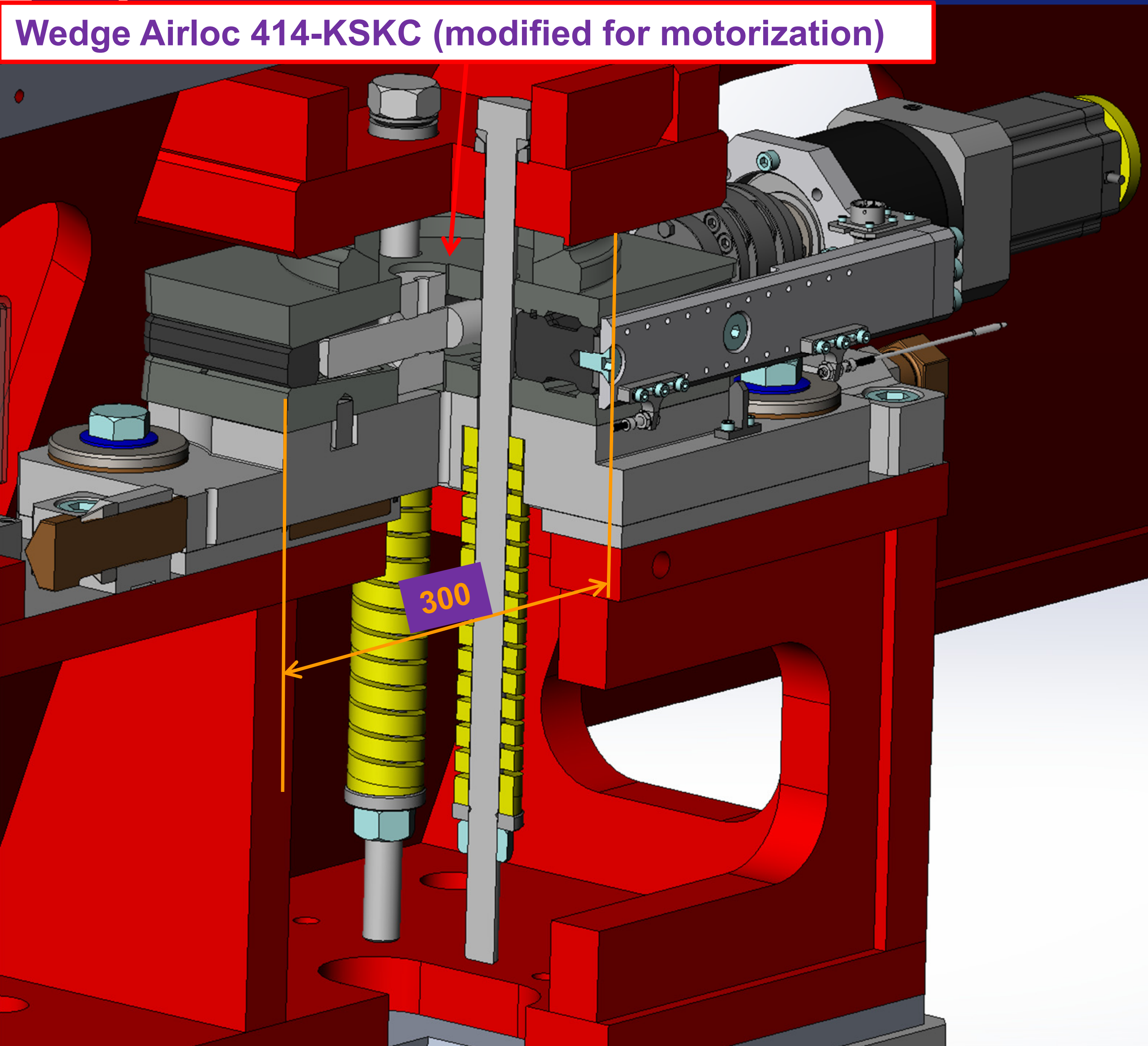


VERTICAL SUPPORTS

Wedge Airloc 414-KSKC (modified for motorization)



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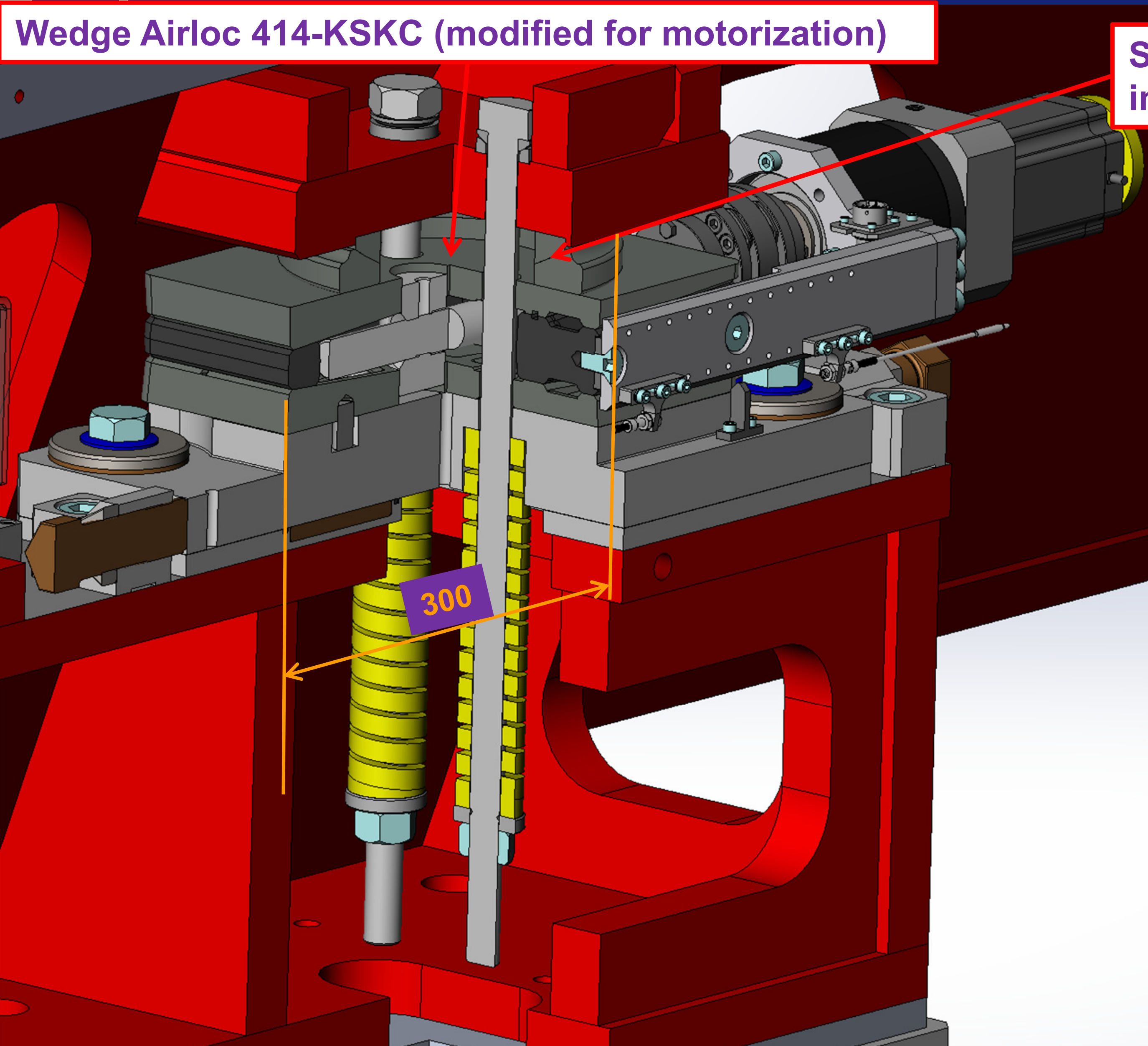

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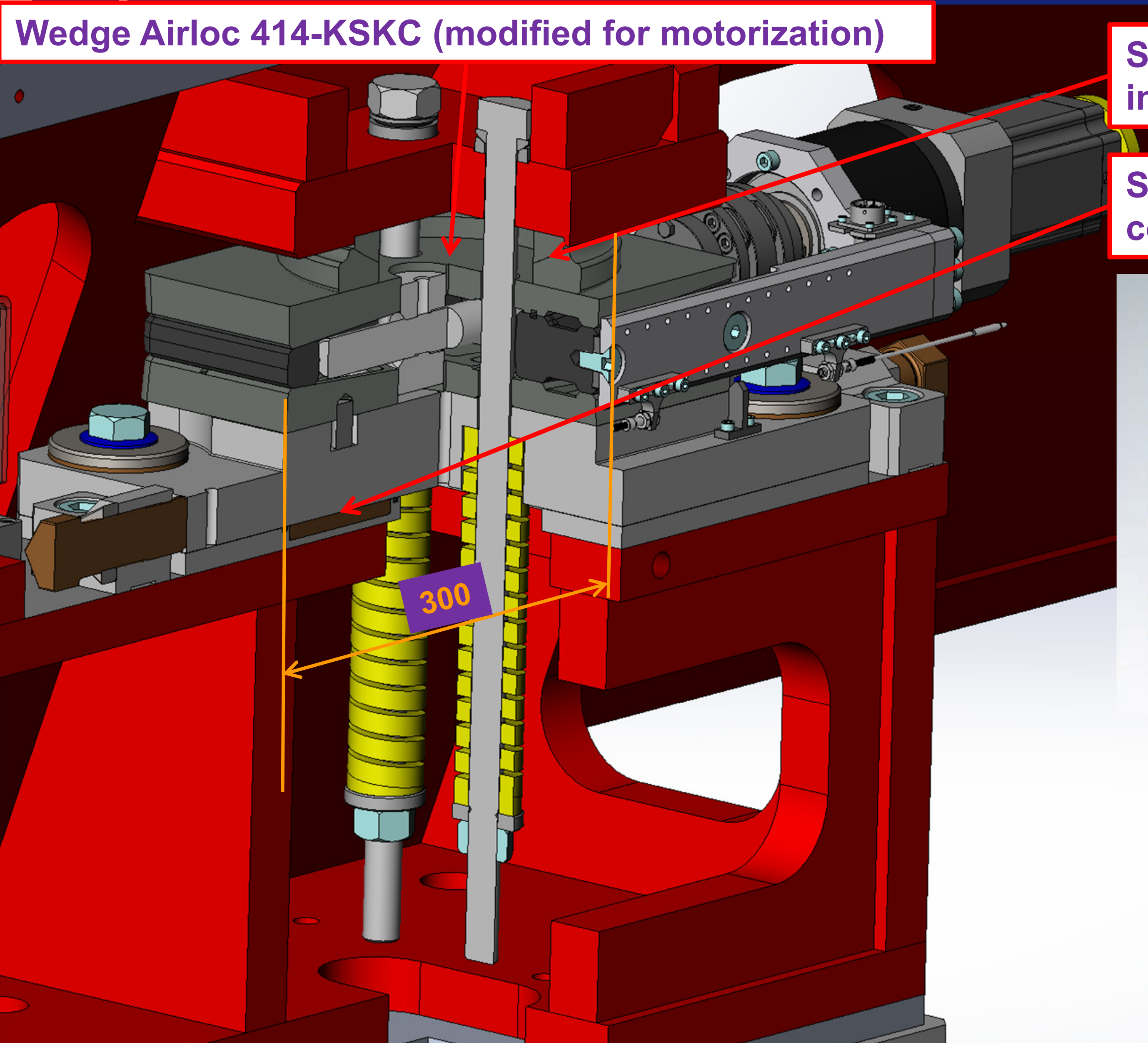
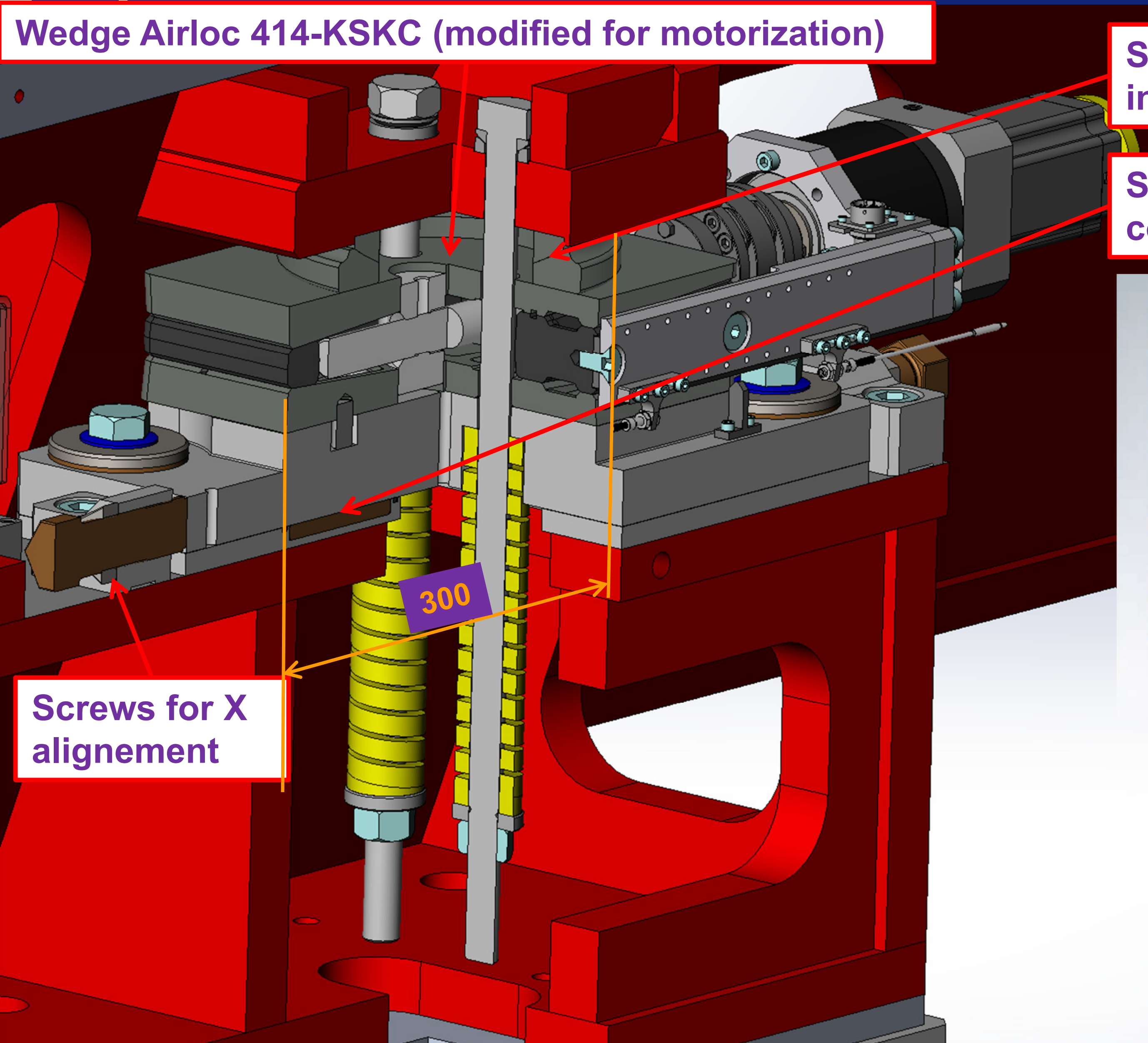
Spherical seat integrated in the wedge

Sliding contact (Fibro commercial plate)

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300
Screws for X alignement

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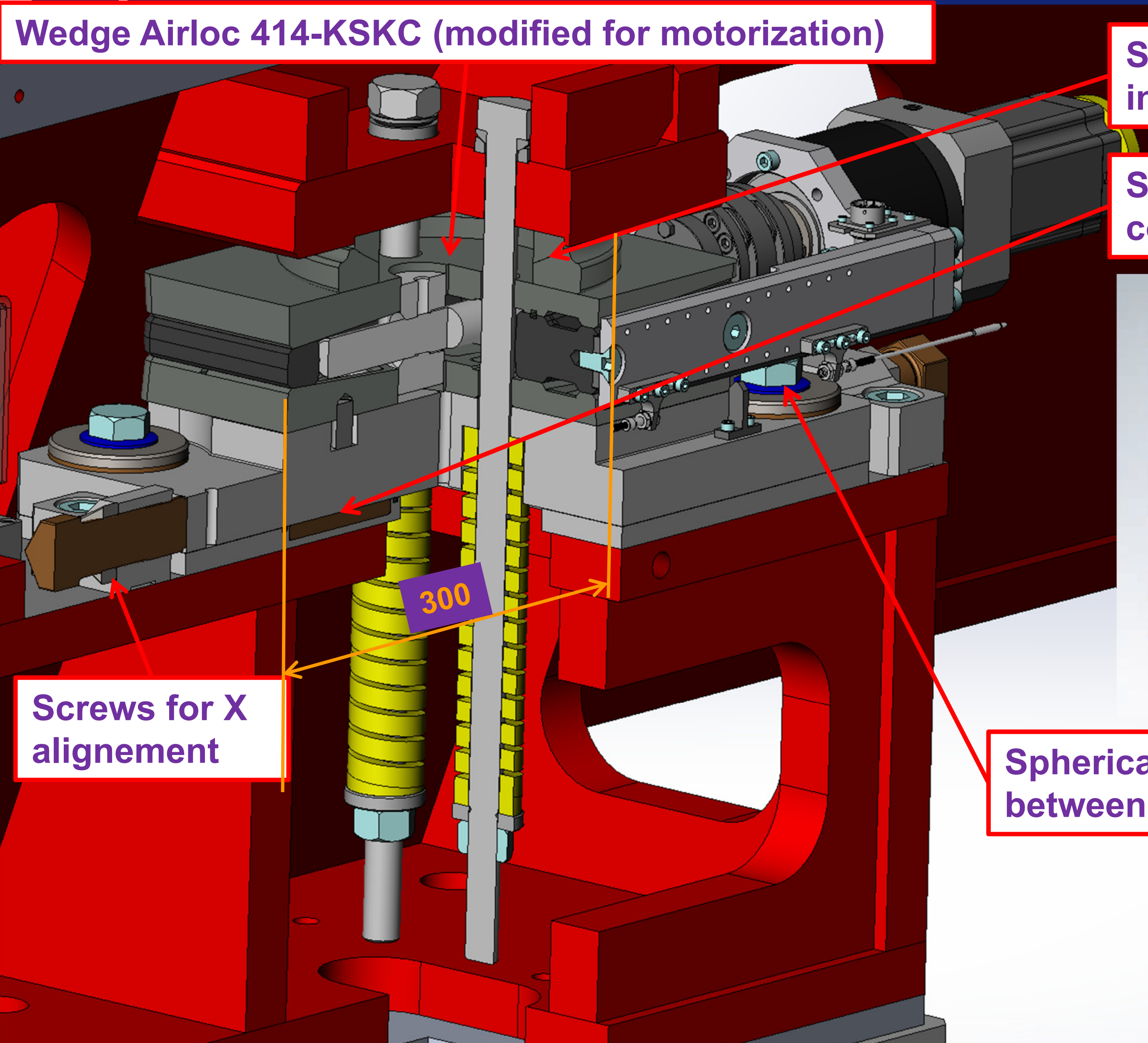

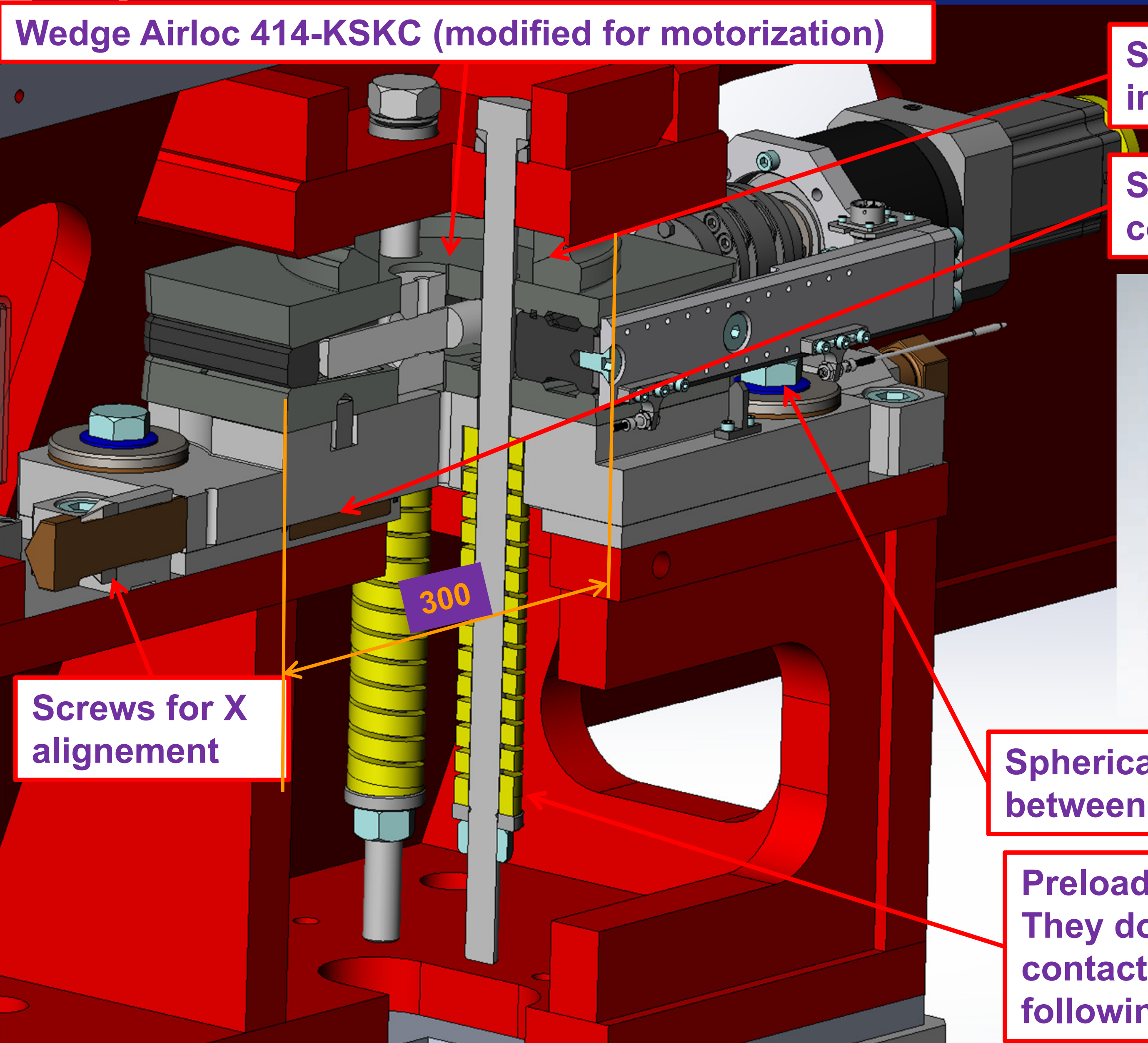

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Spherical seat integrated in the wedge

Sliding contact (Fibro commercial plate)

Spherical washers to put preload between the sliding surfaces

Preload springs (2x0.7T)
They don't press the sliding contact, no adjustement needed following the vertical movement.

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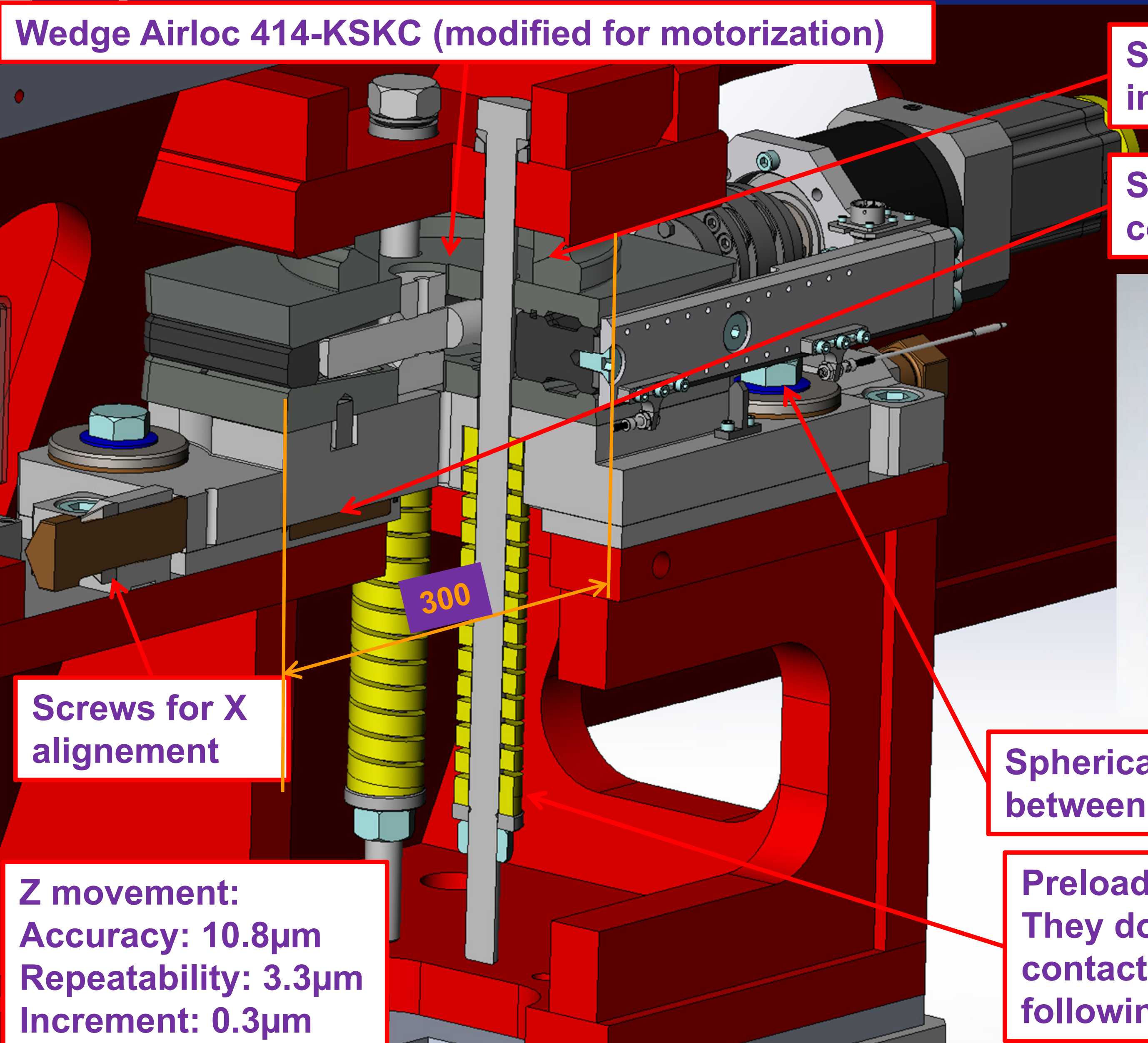

Screws for X alignement

Spherical washers to put preload between the sliding surfaces

Z movement:
Accuracy: 10.8µm
Repeatability: 3.3µm
Increment: 0.3µm

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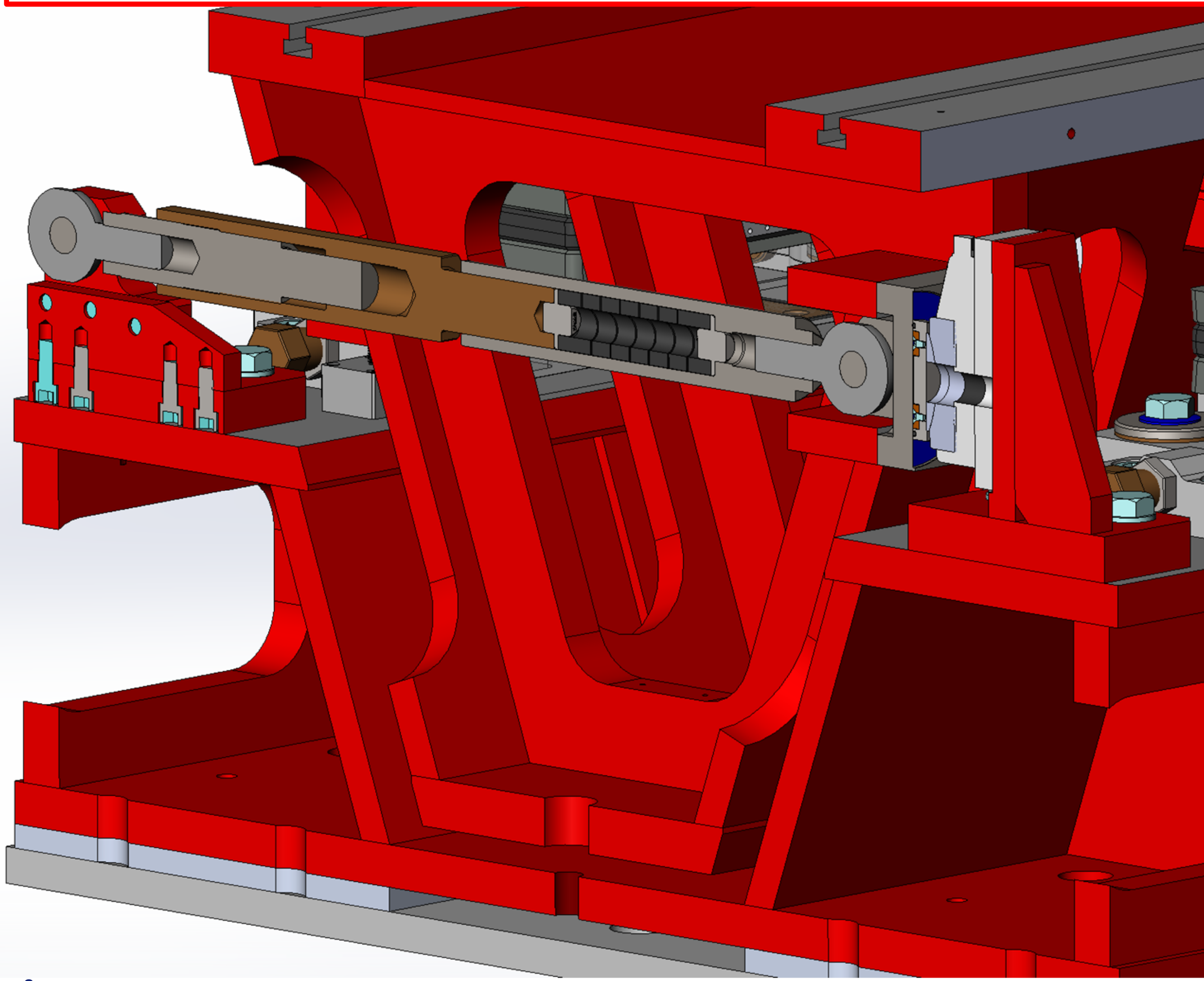
HORIZONTAL JACKS

3 functions:
-horizontal adjustment (+/- 3.5mm continuous, +/-15mm global)
-guiding the vertical movement (ensuring no lateral dipl. during the vertical adjustement)
-improoving the stiffness of the girder



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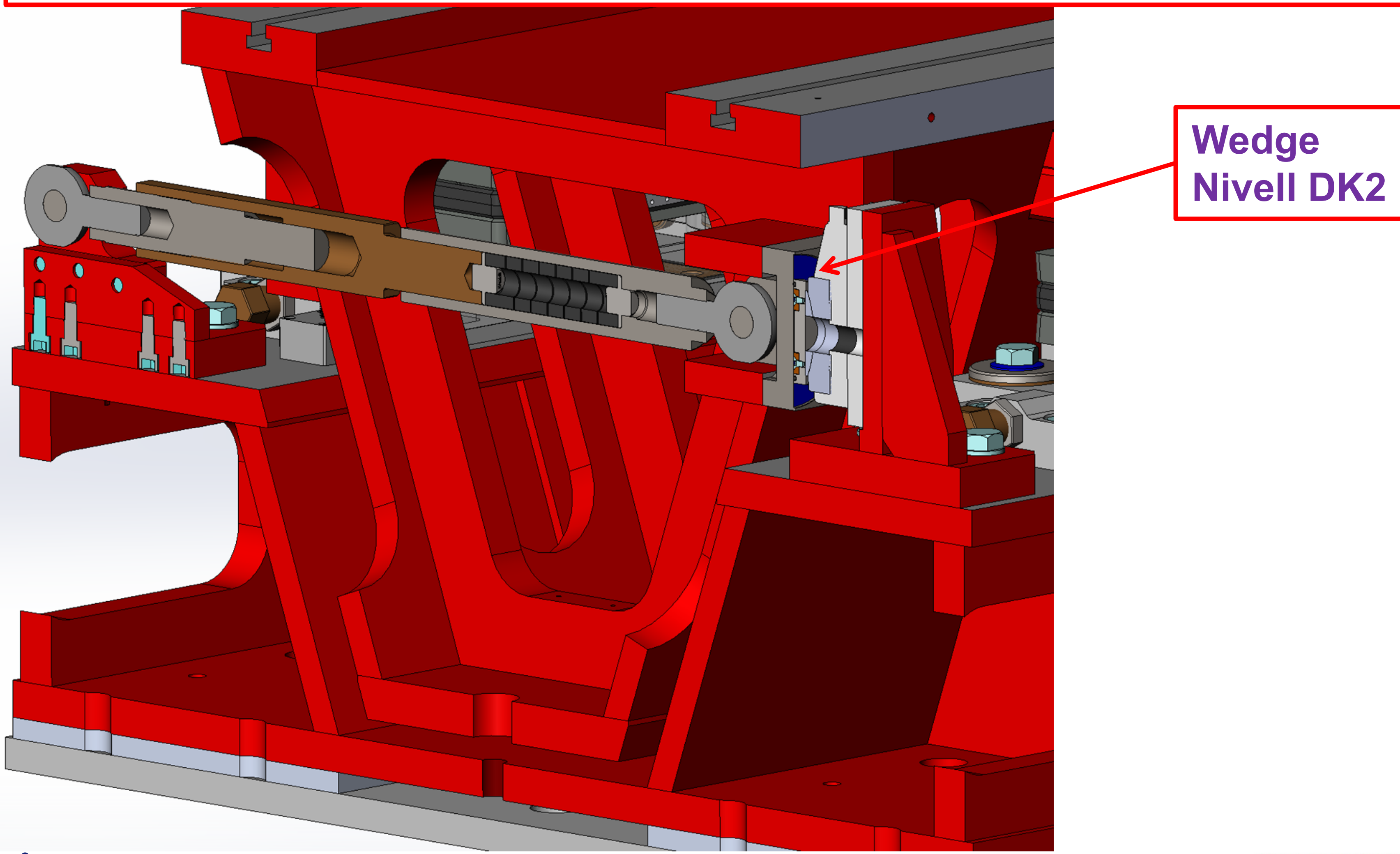

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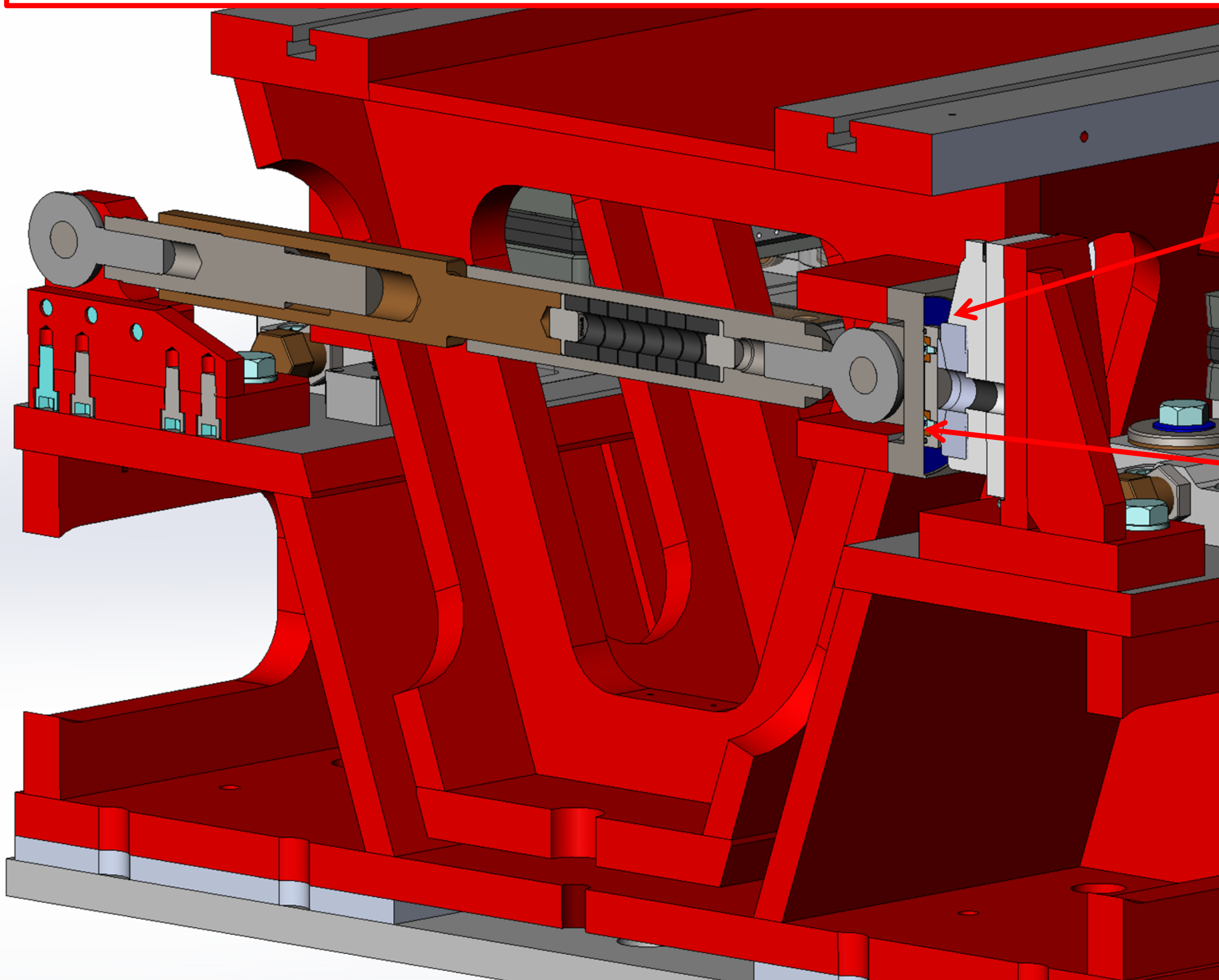

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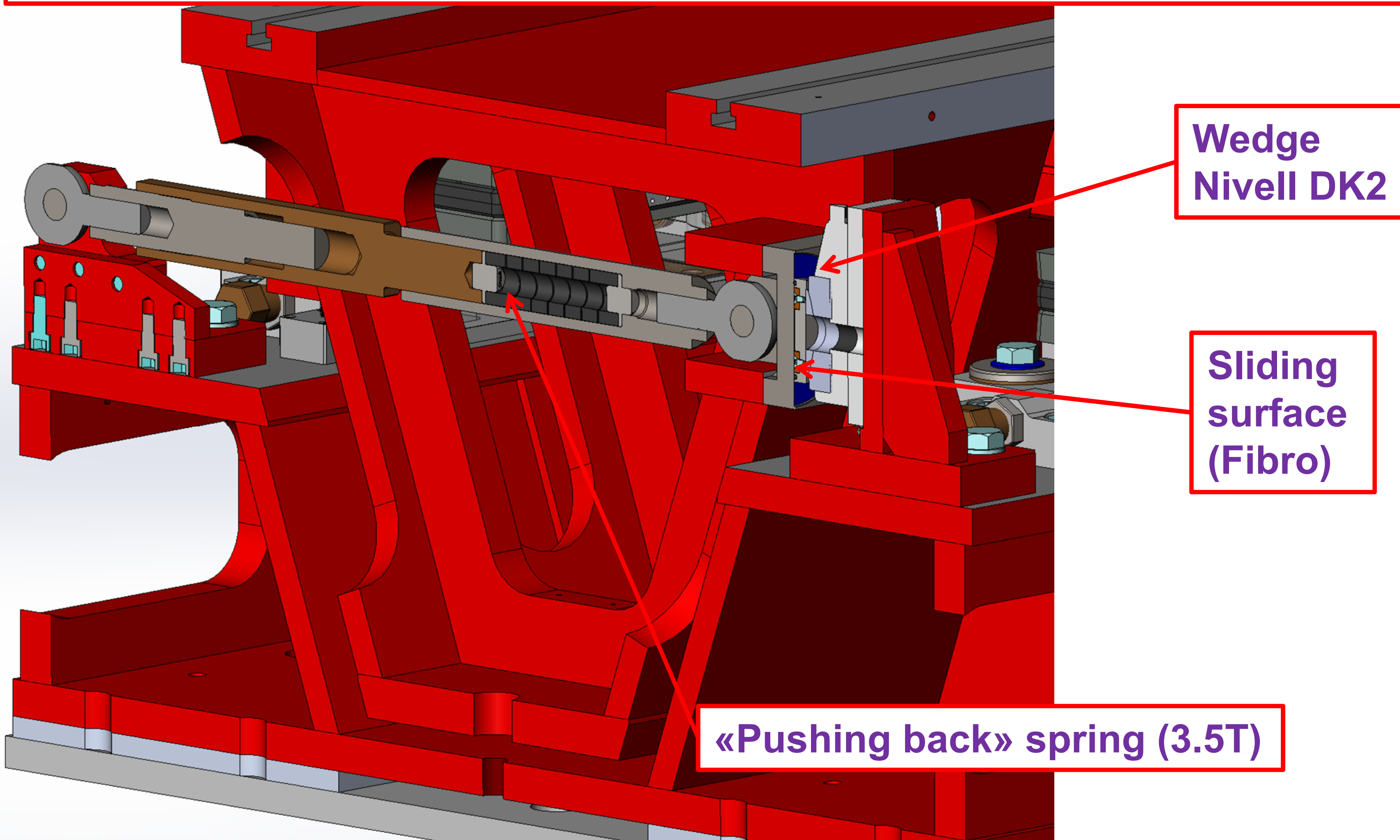

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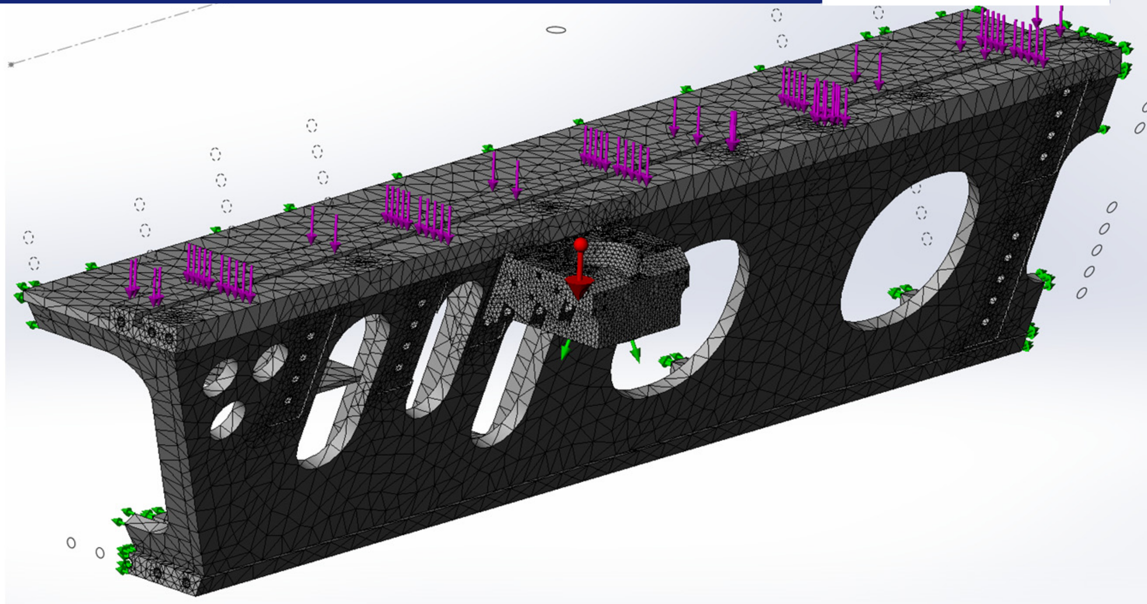

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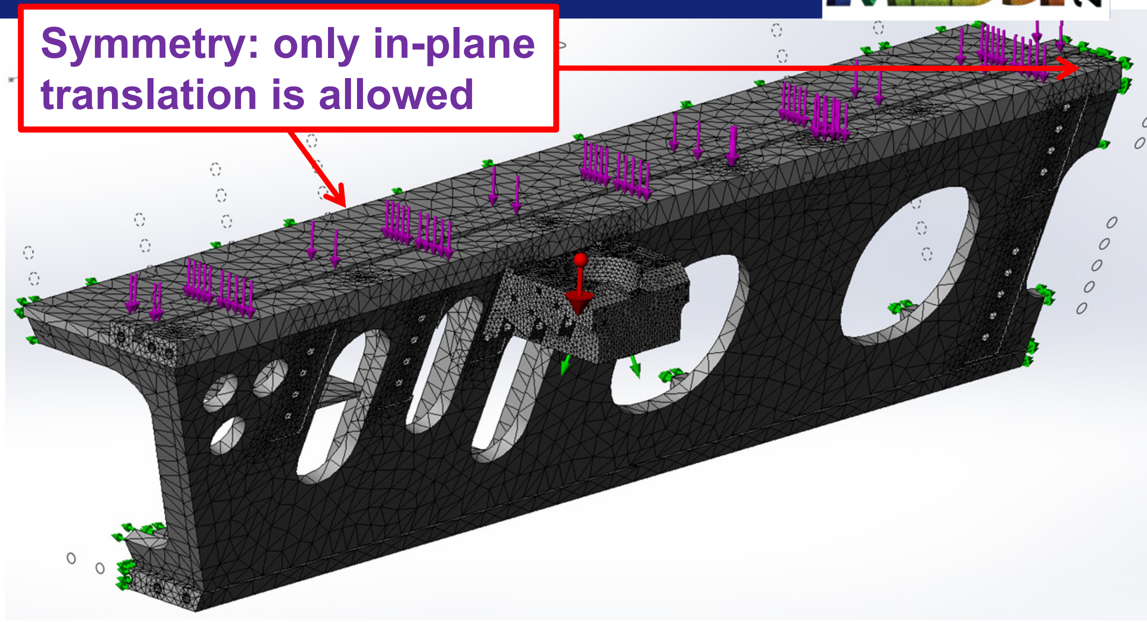

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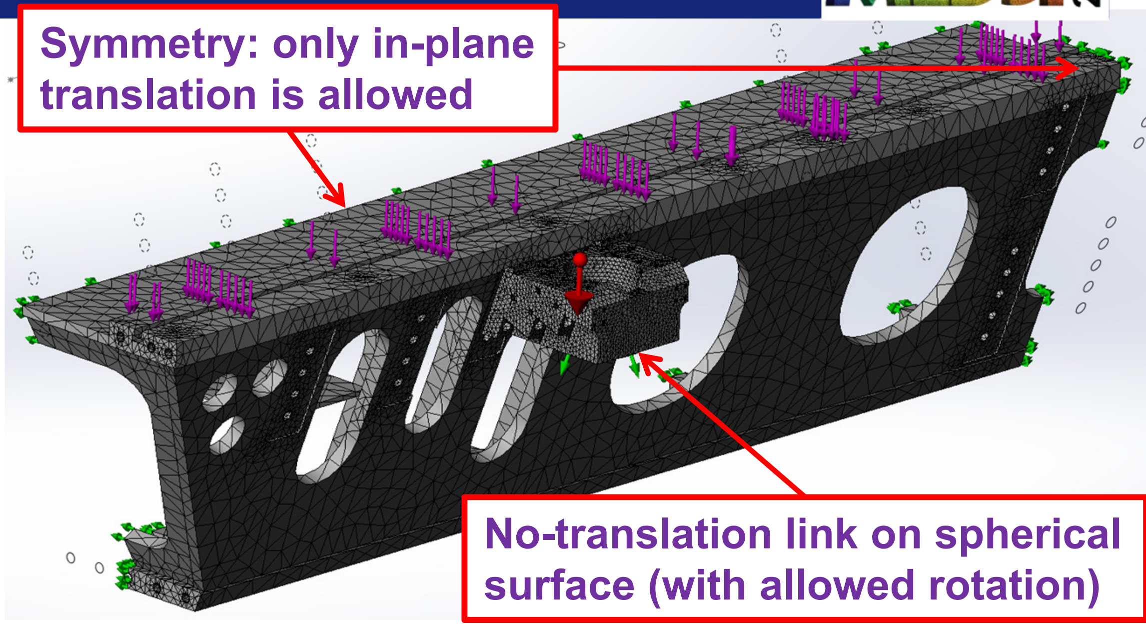

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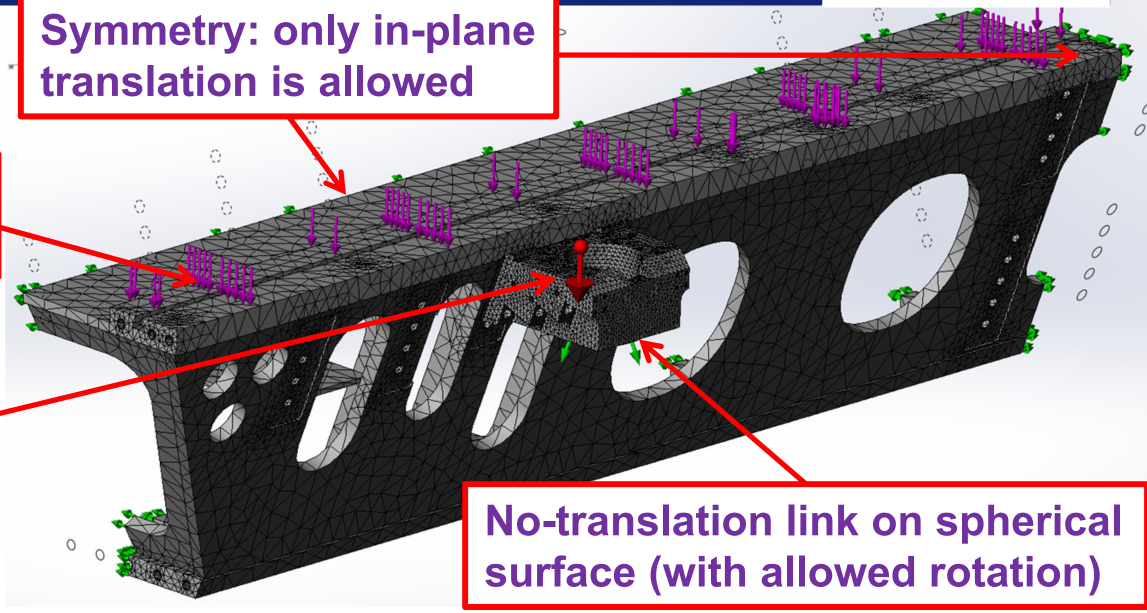

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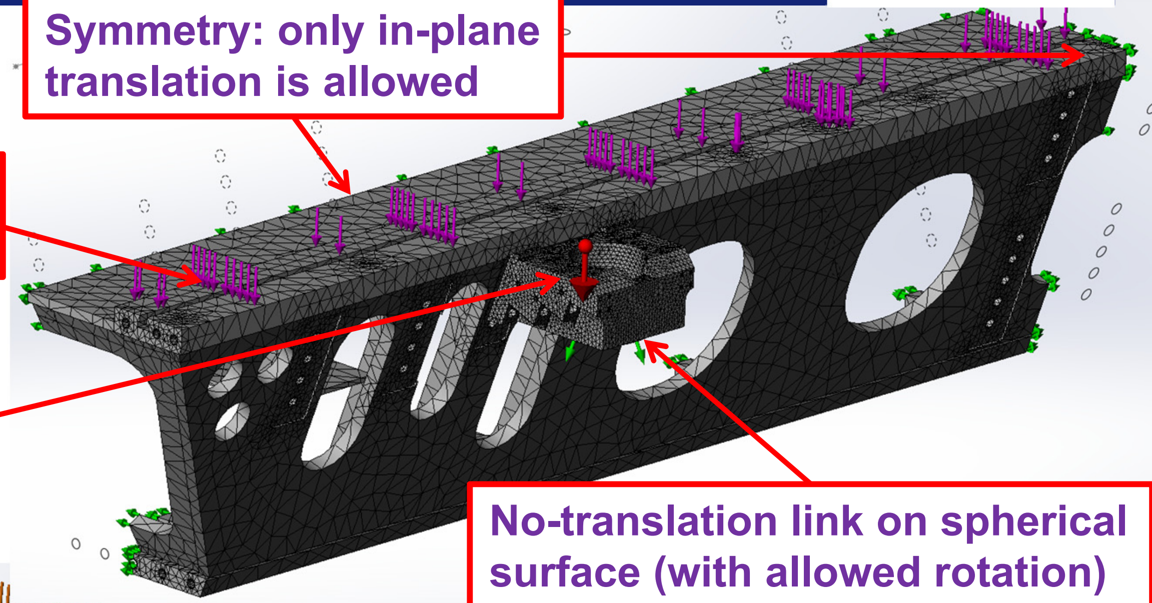
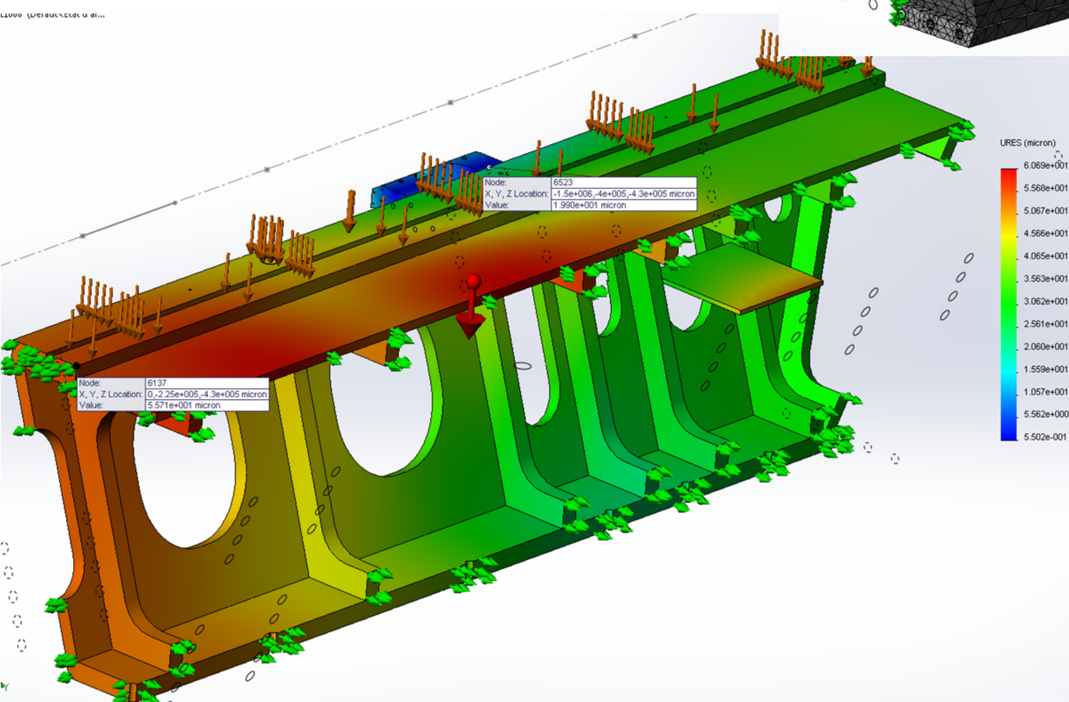


Symmetry: only in-plane translation is allowed

Payload (about 6T on the whole girder, 15000N in this ¼ analysis)

Gravity force

No-translation link on spherical surface (with allowed rotation)



Max vertical deformation of the machined surface carrying the magnets 36µm (difference between highest and lowest points).

EFFORTS IN STRUCTURE DUE TO SUPPORT OVERDEFINITION

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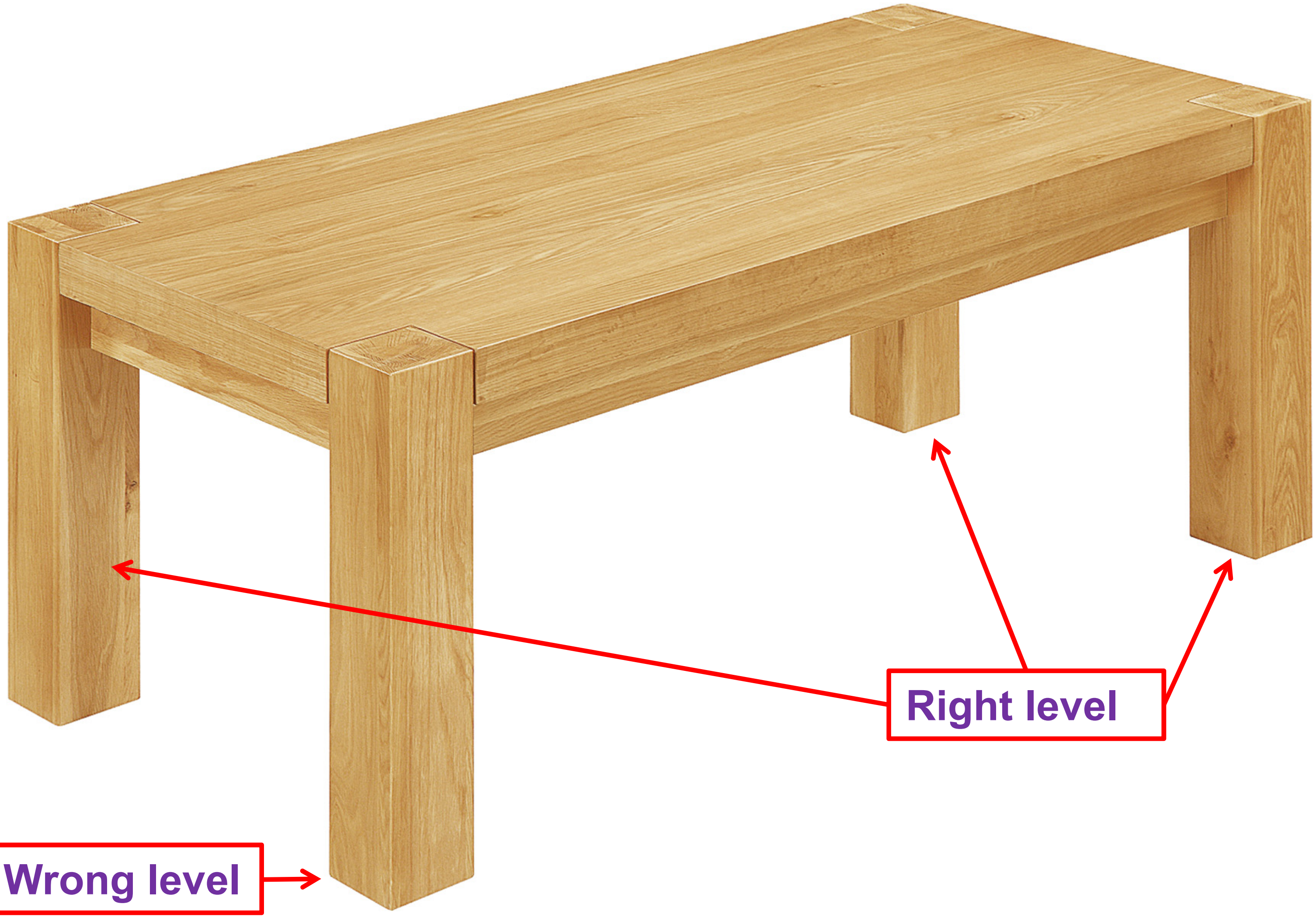

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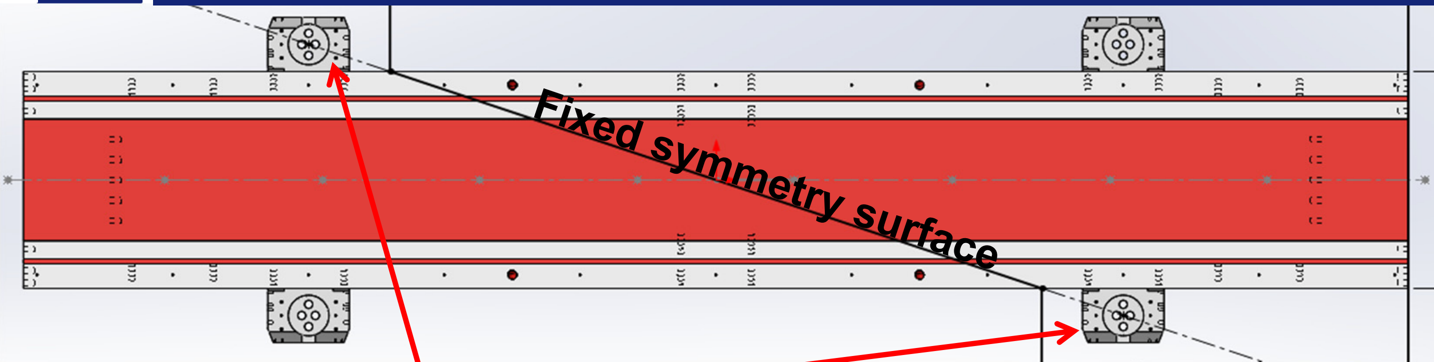
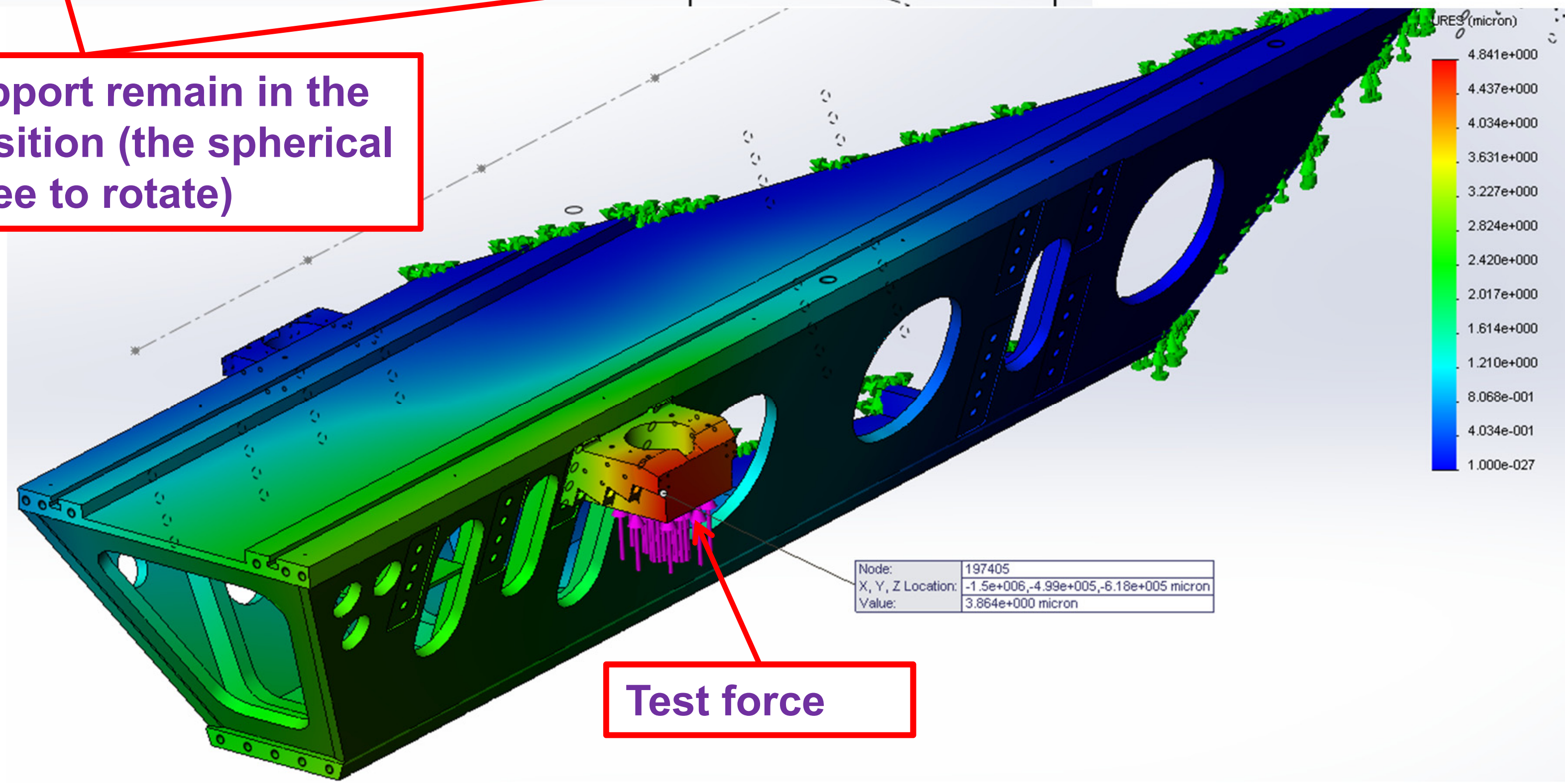
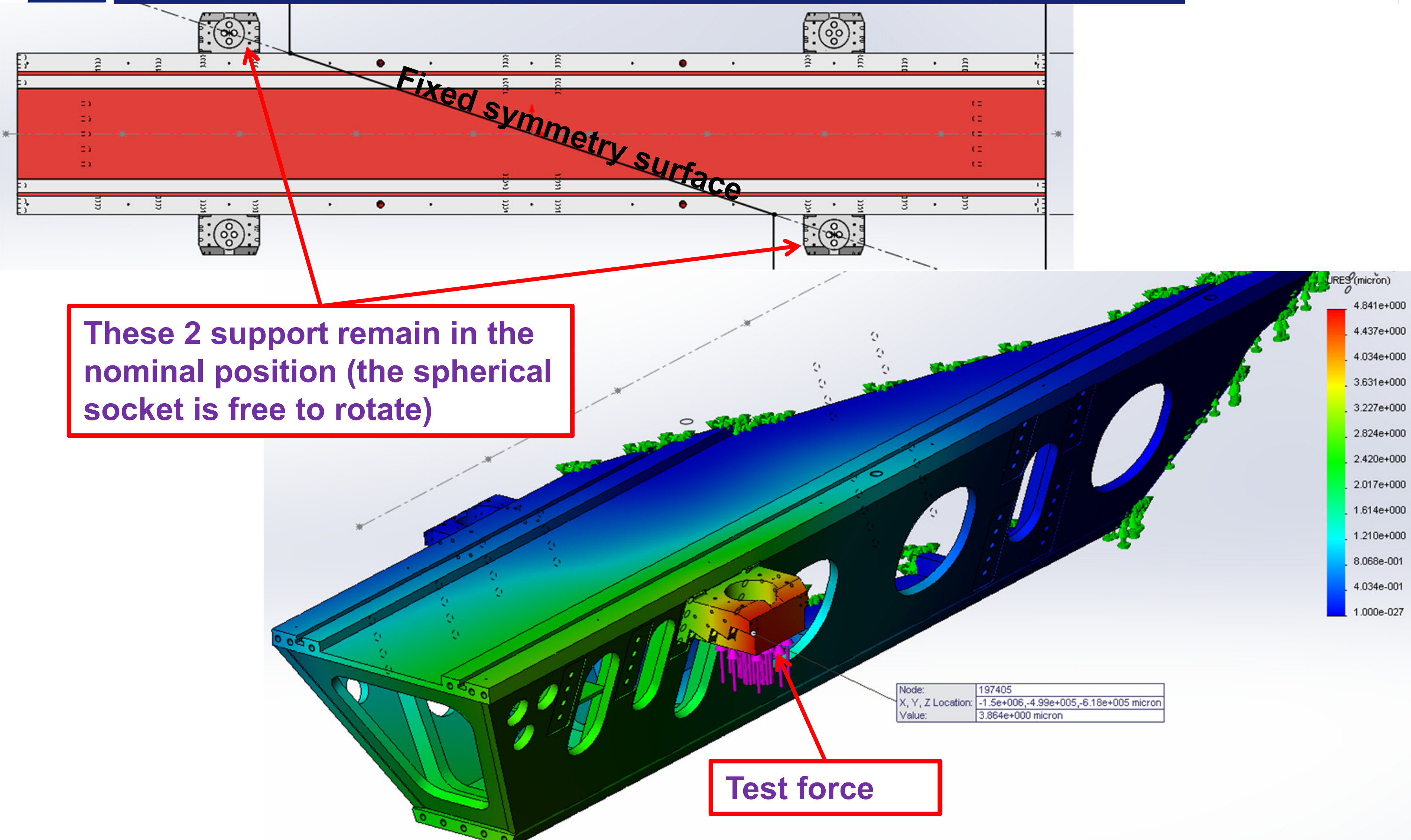


These 2 support remain in the nominal position (the spherical socket is free to rotate)

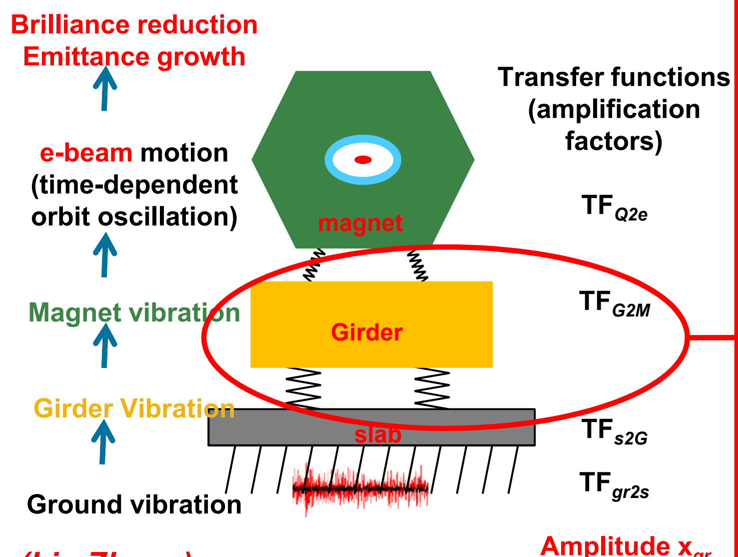


Test force



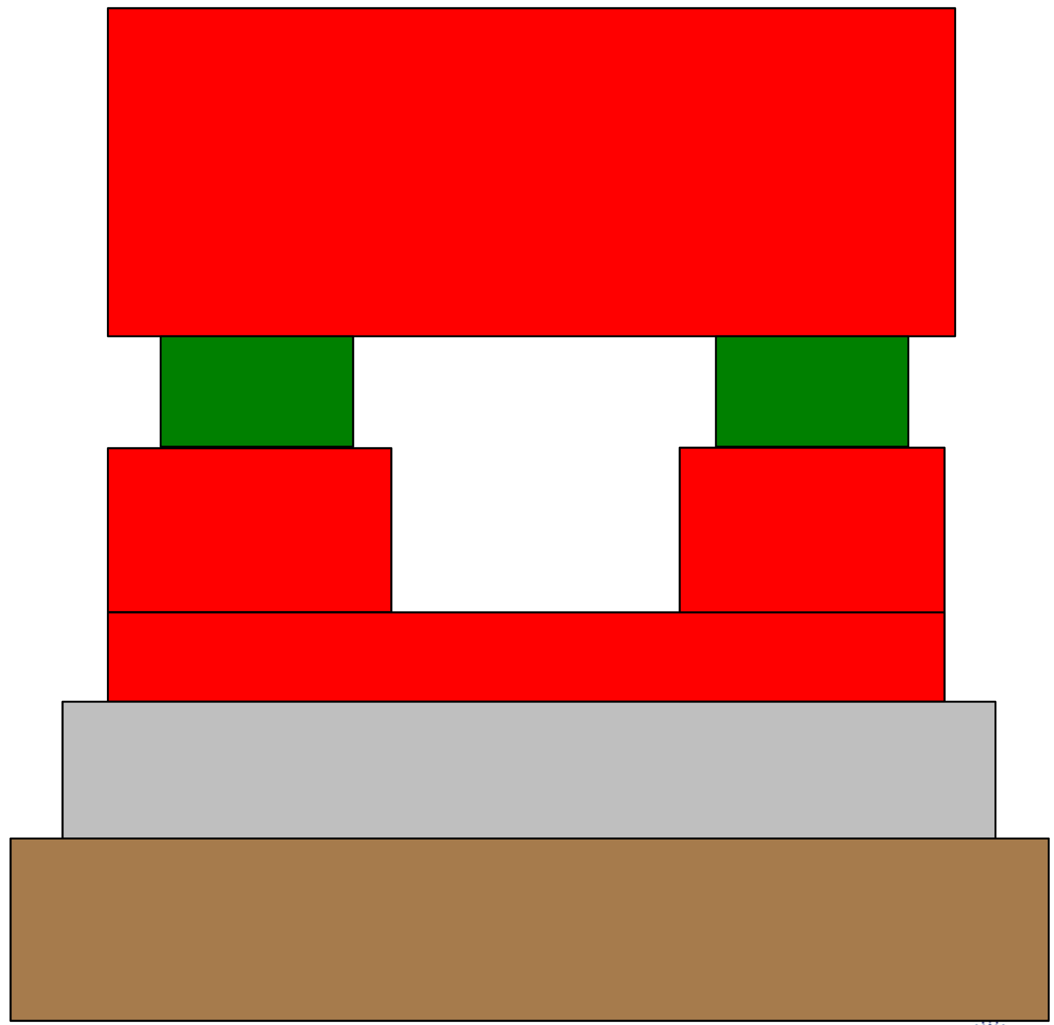
Effort=1000N → Displacement=3.864µm → 259N/µm (→ 2640Kg/0.1mm)
If we consider only one Z support out of position → 129N/µm (→ 1314Kg/0.1mm)

Vibration amplification ground to beam



(Lin Zhang)

Component defining the stiffness of the system:



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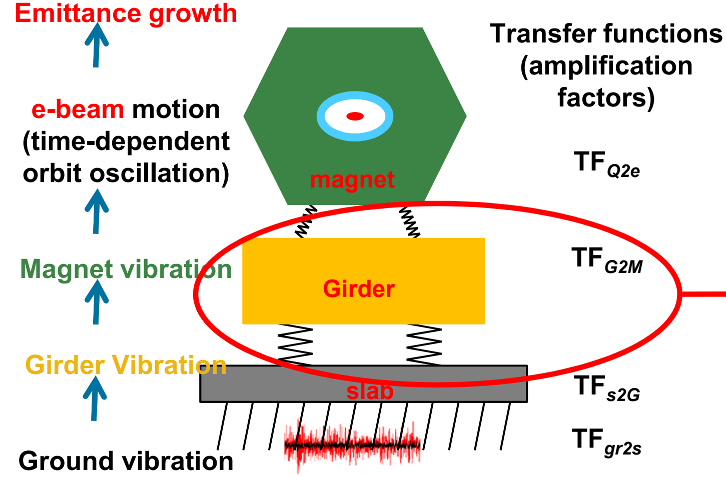

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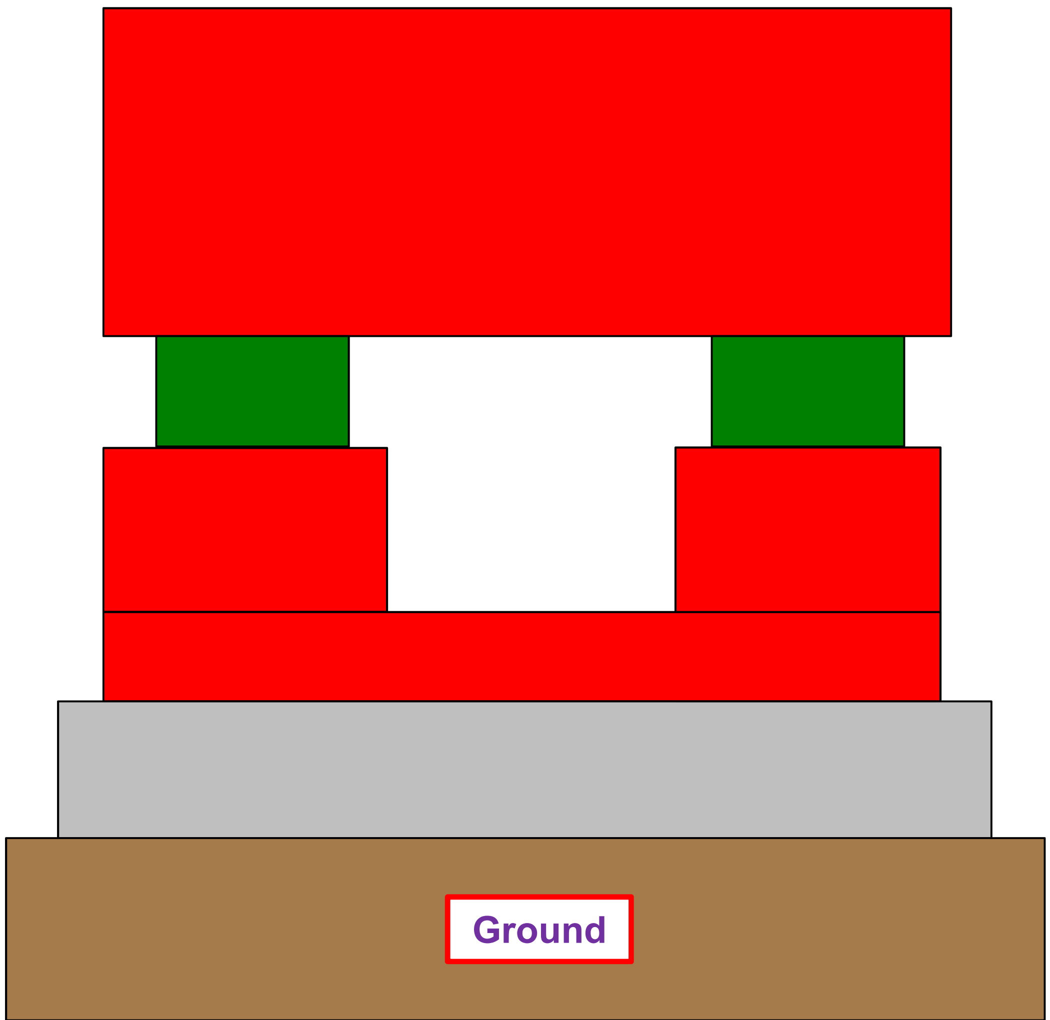

MODAL ANALYSIS OVERVIEW

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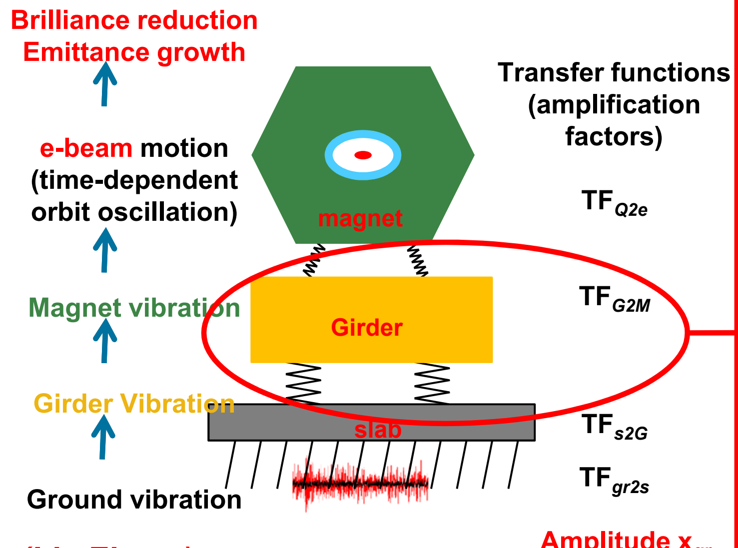

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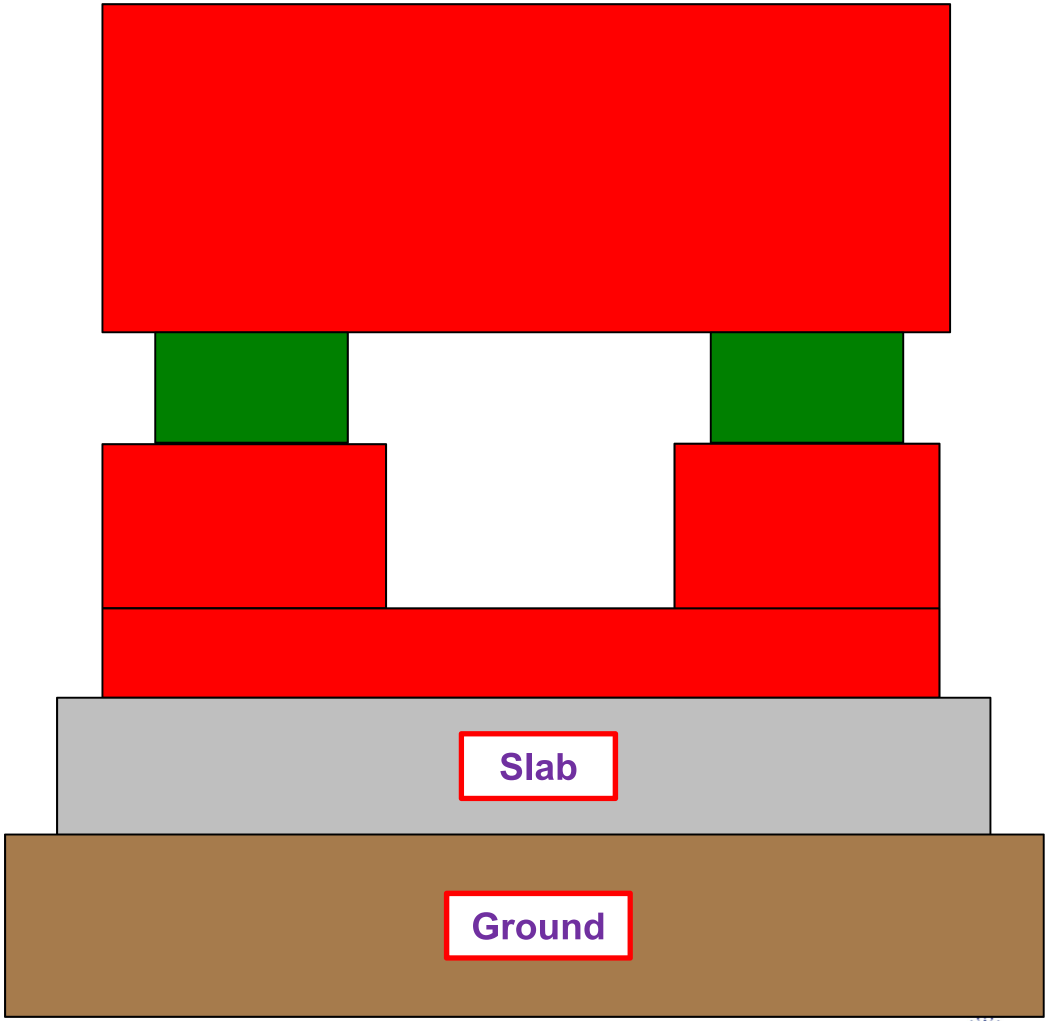
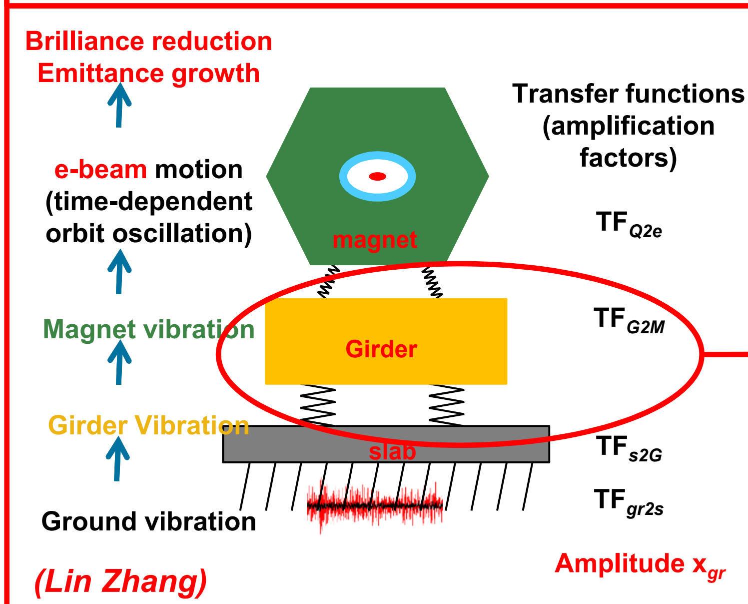


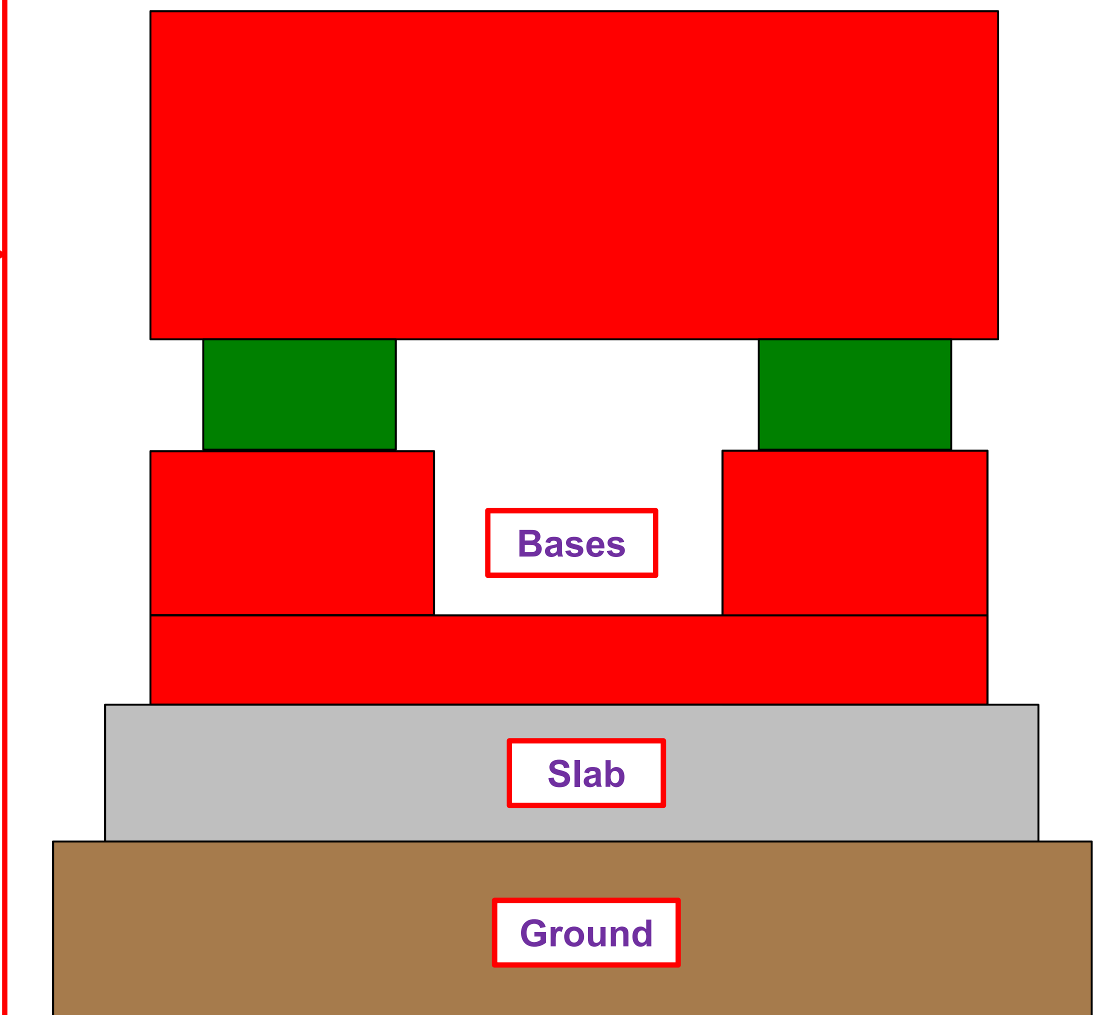
MODAL ANALYSIS OVERVIEW

Vibration amplification ground to beam

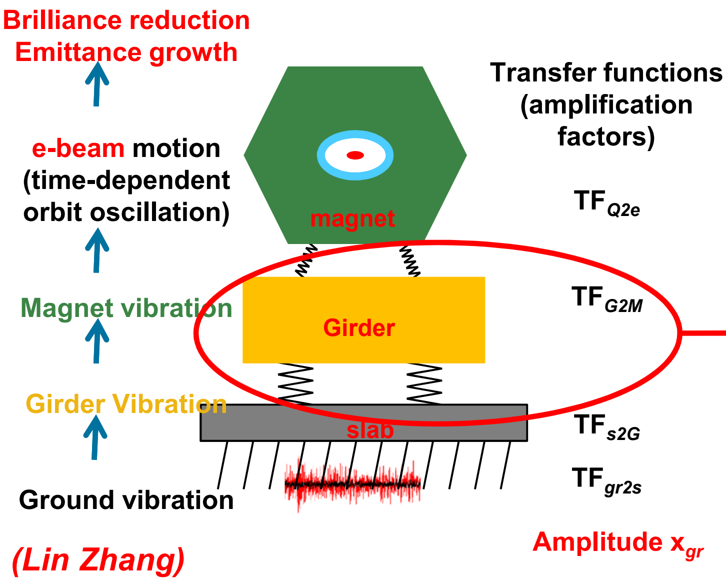


(Lin Zhang)

Component defining the stiffness of the system:



Vibration amplification ground to beam



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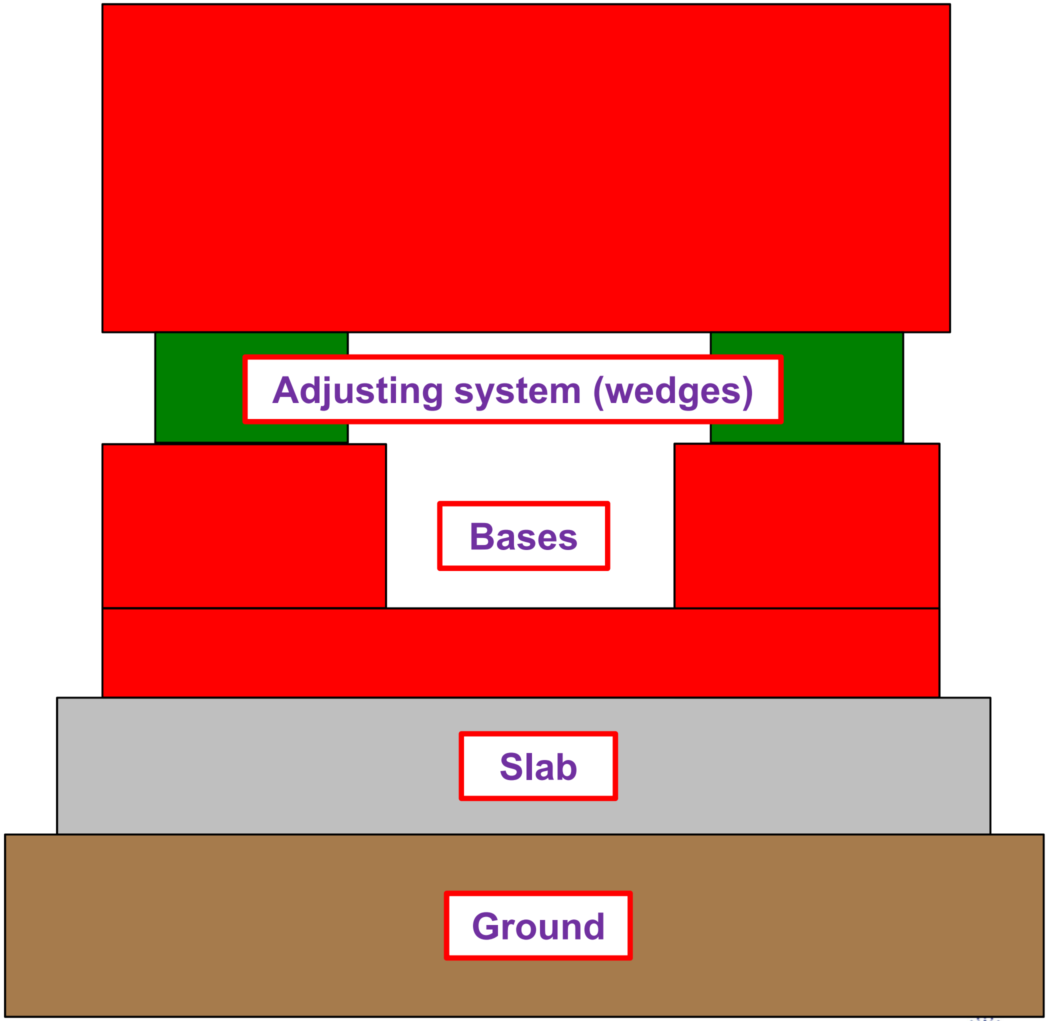
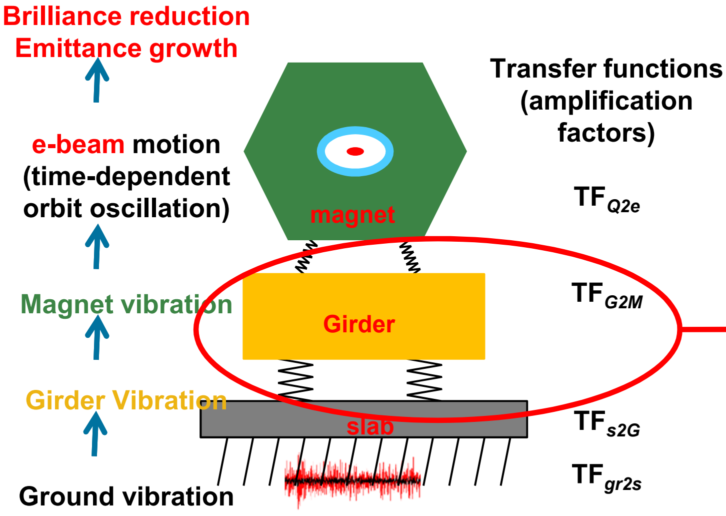


Vibration amplification ground to beam



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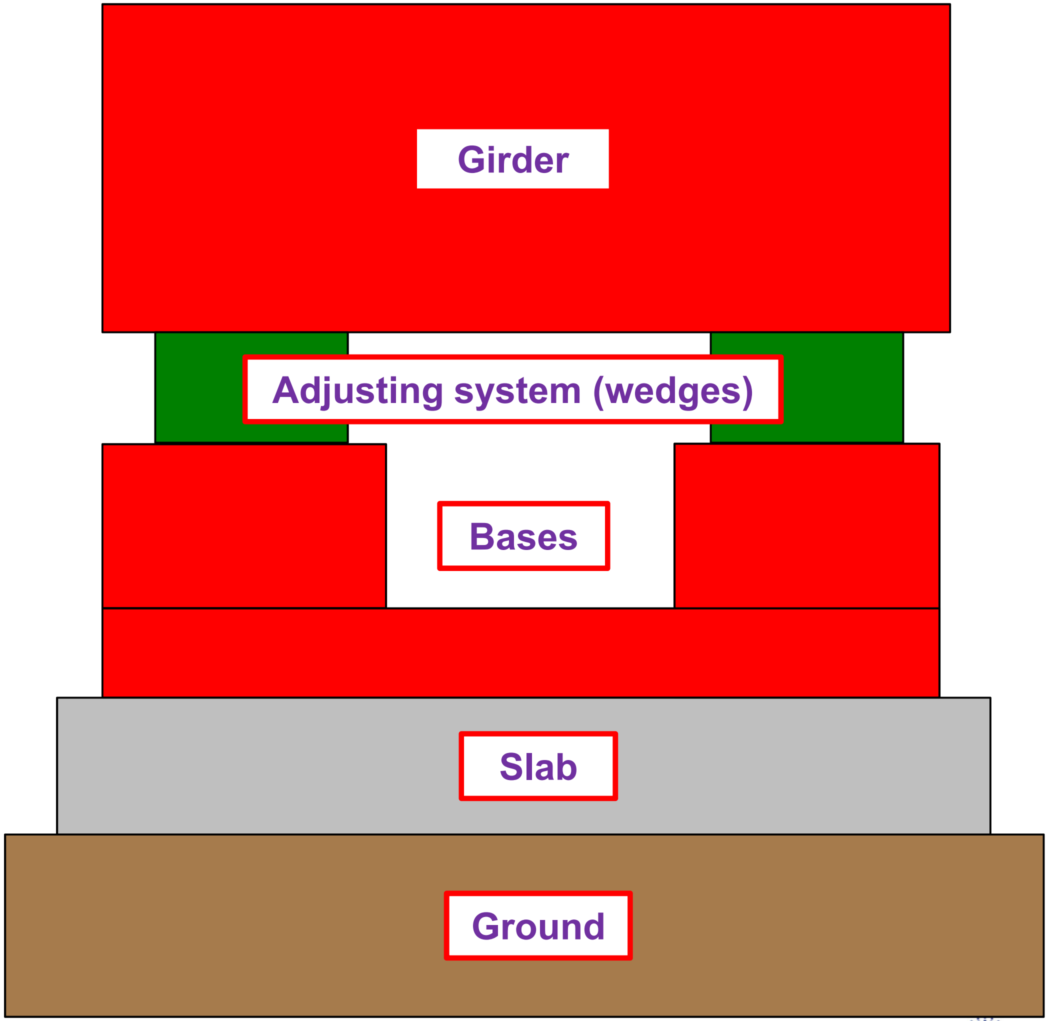
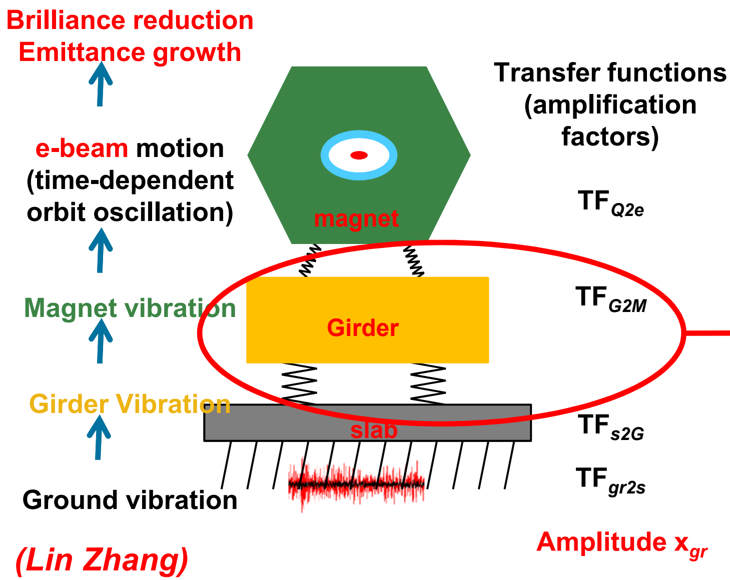
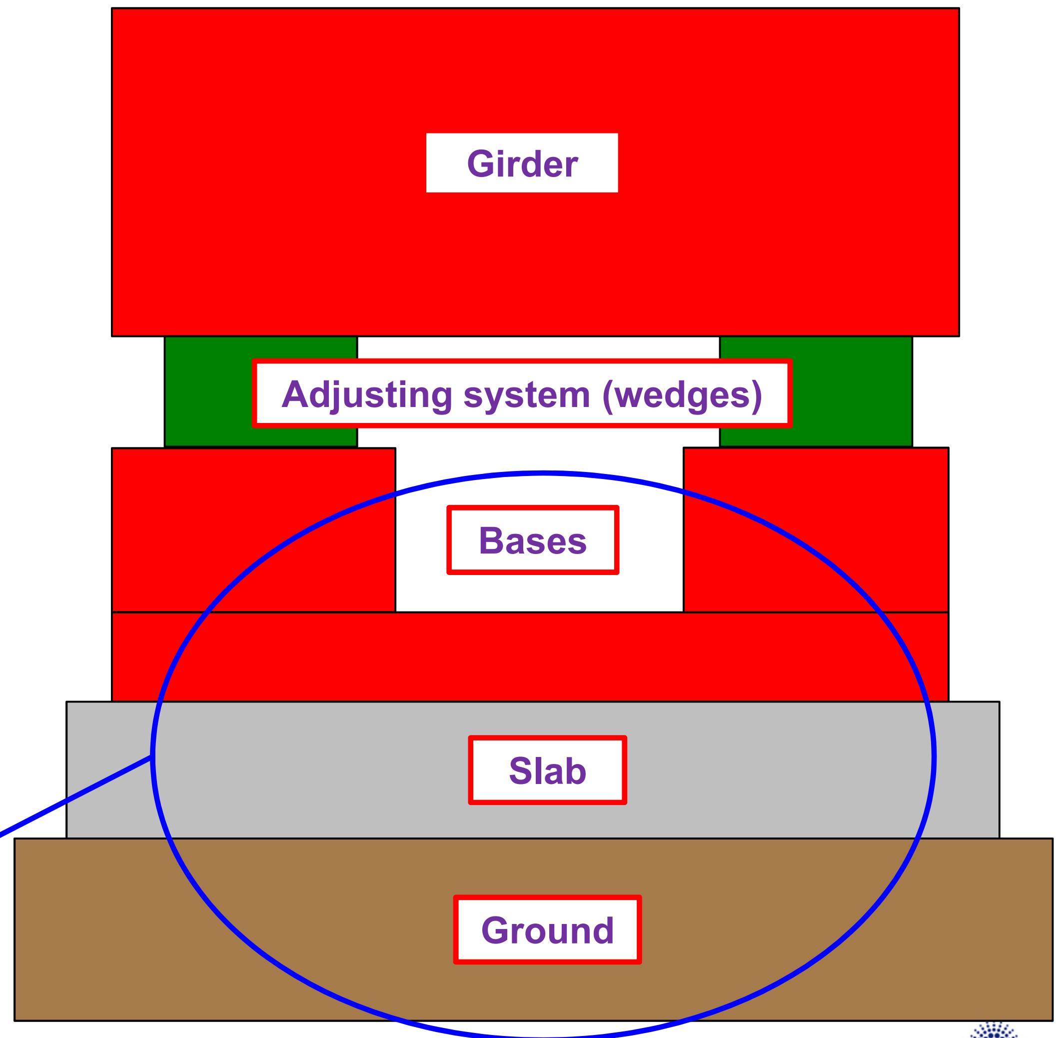


MODAL ANALYSIS OVERVIEW

Vibration amplification ground to beam



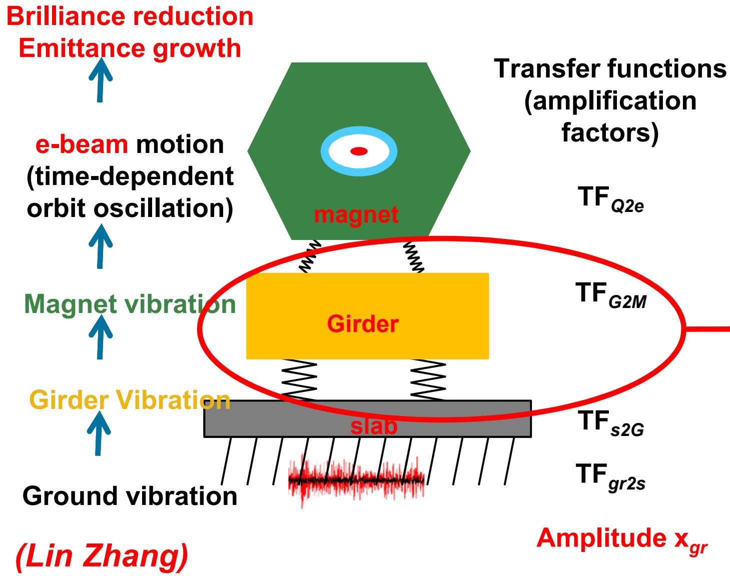
Component defining the stiffness of the system:



Static FEM analysis

MODAL ANALYSIS OVERVIEW

Vibration amplification ground to beam



(Lin Zhang)

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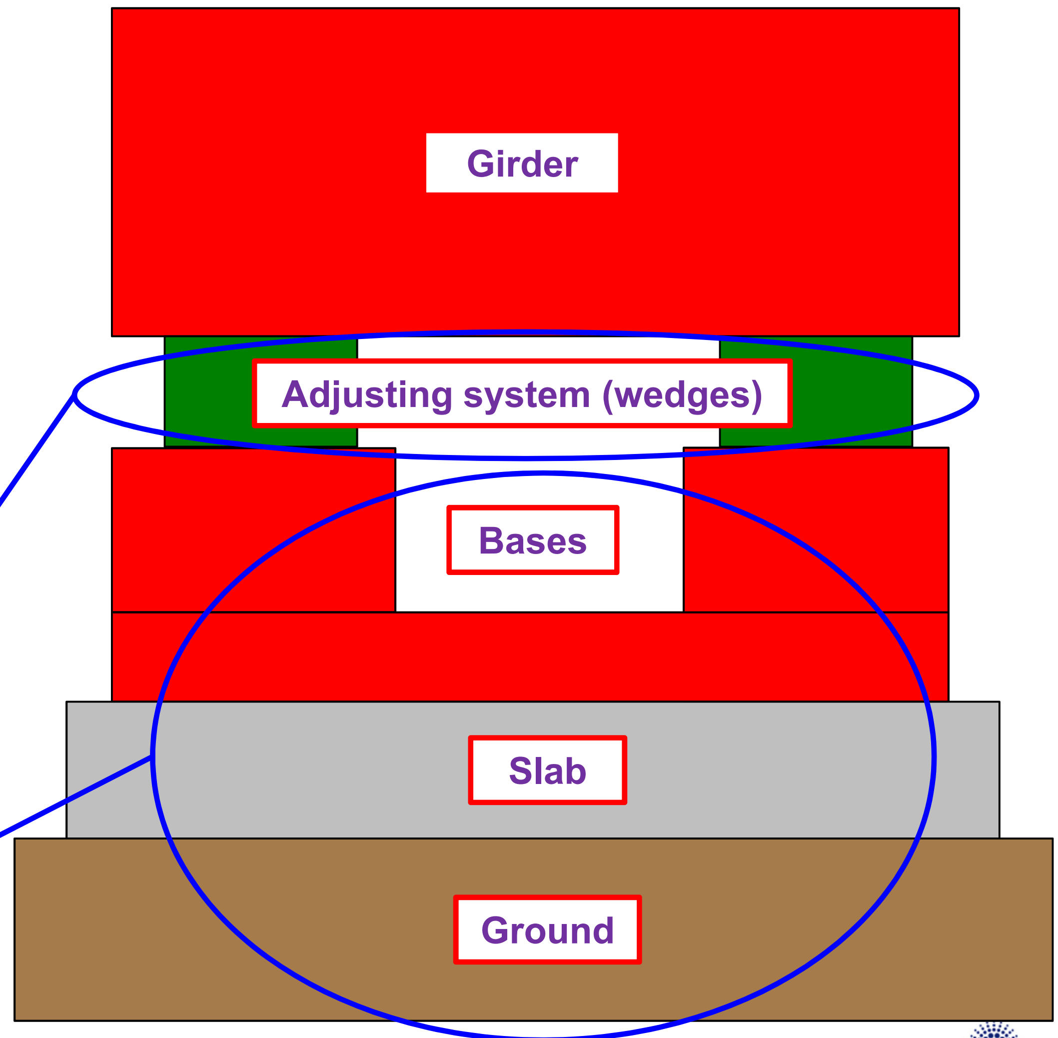
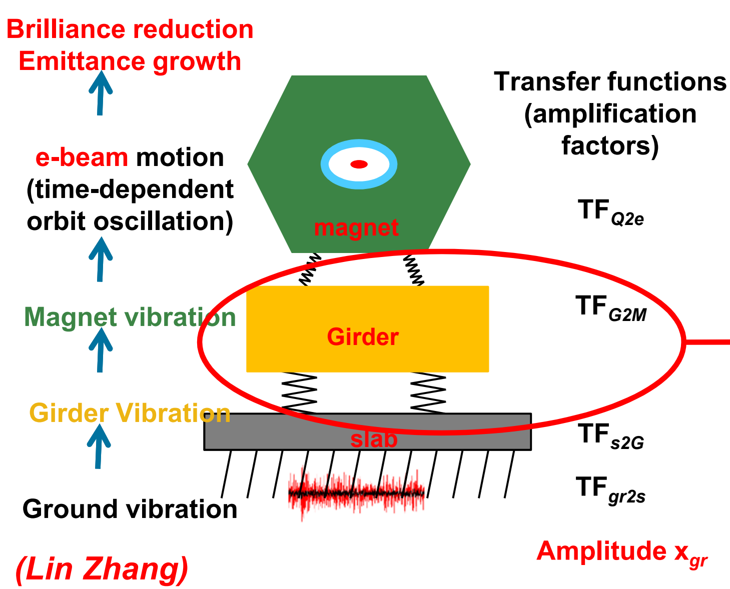


Laboratory test

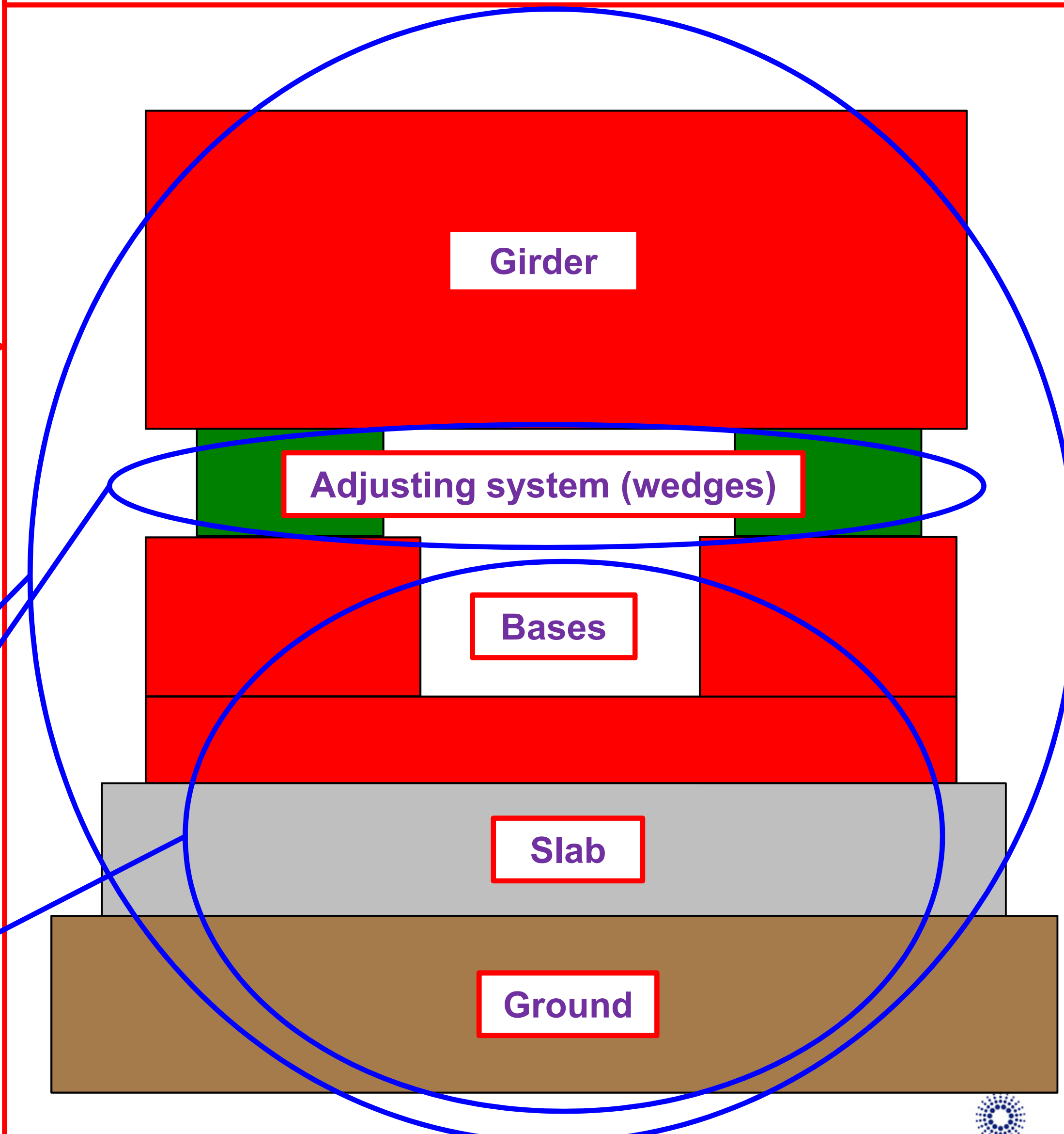
Static FEM analysis

MODAL ANALYSIS OVERVIEW

Vibration amplification ground to beam



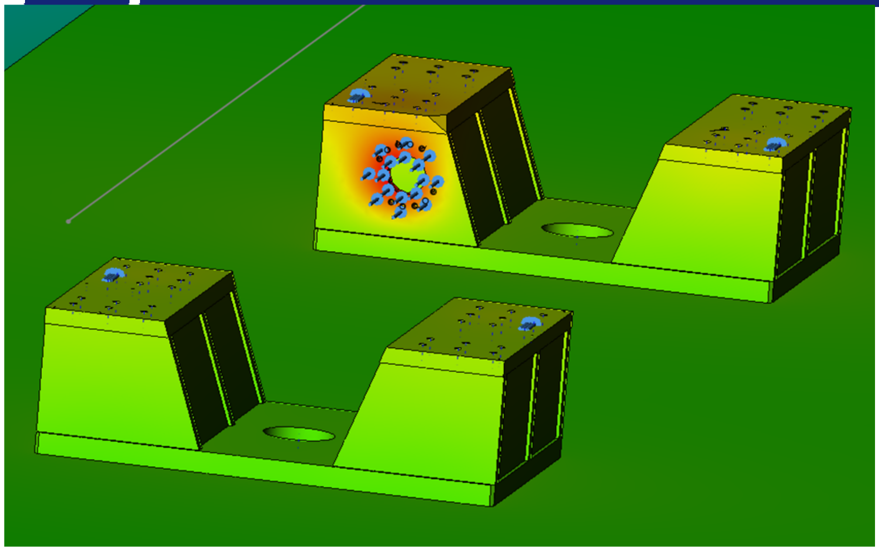
Component defining the stiffness of the system:

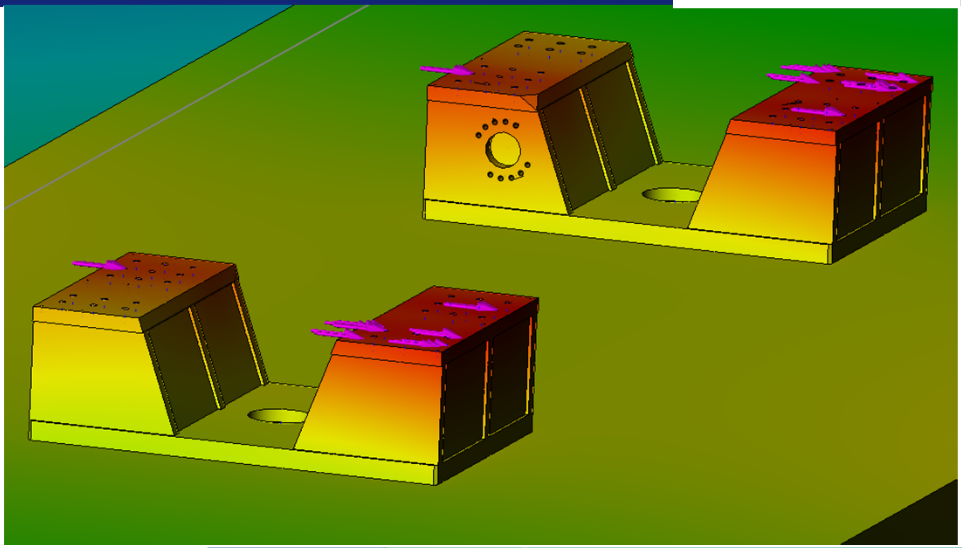


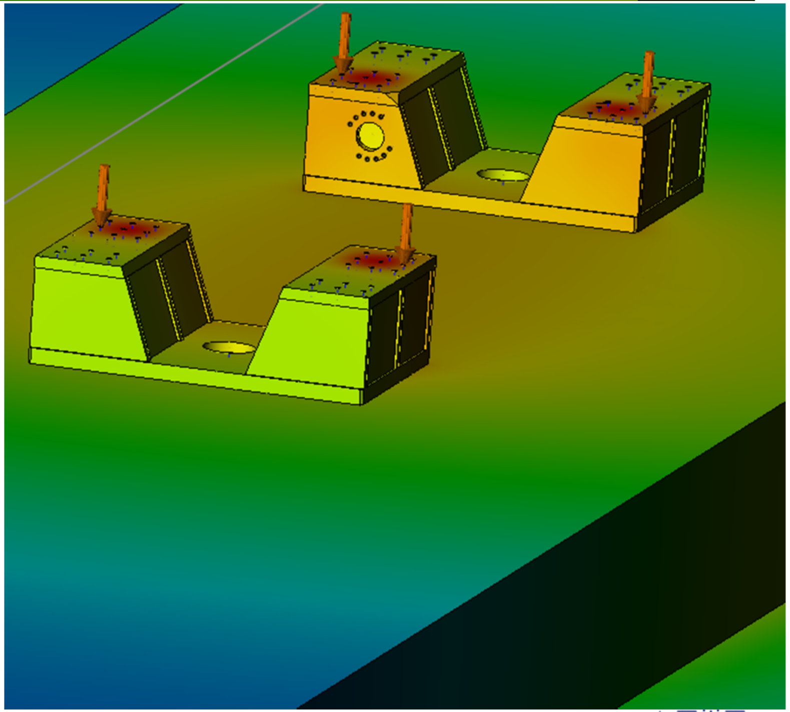
Modal FEM analysis

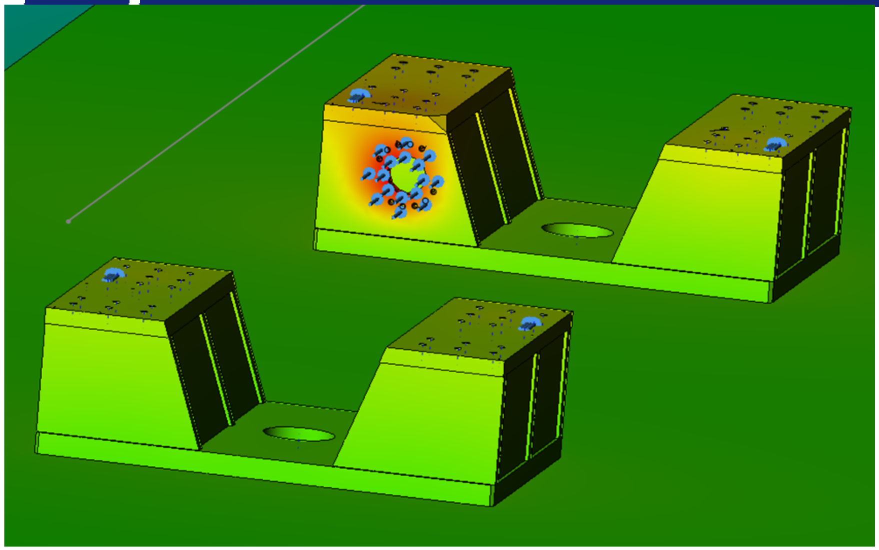
Laboratory test

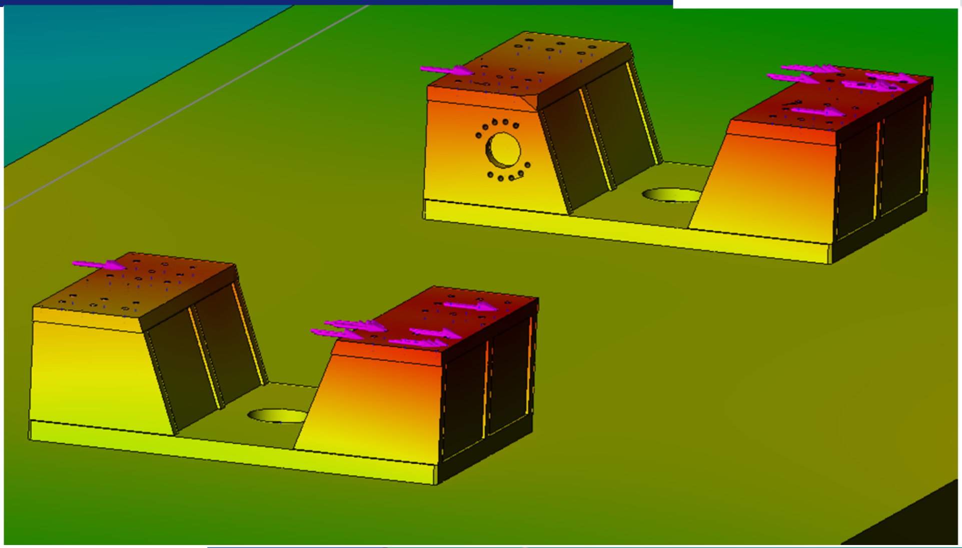
Static FEM analysis

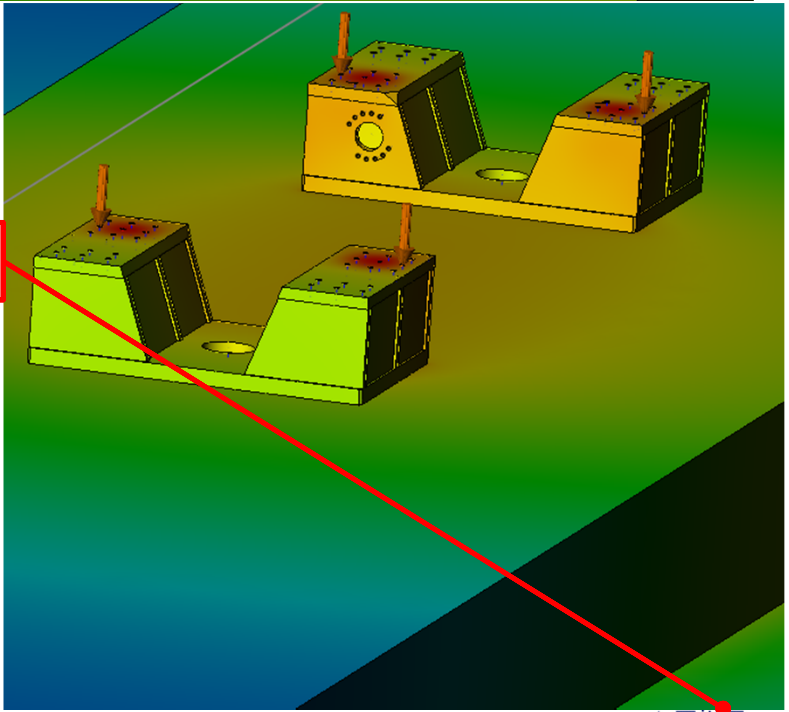






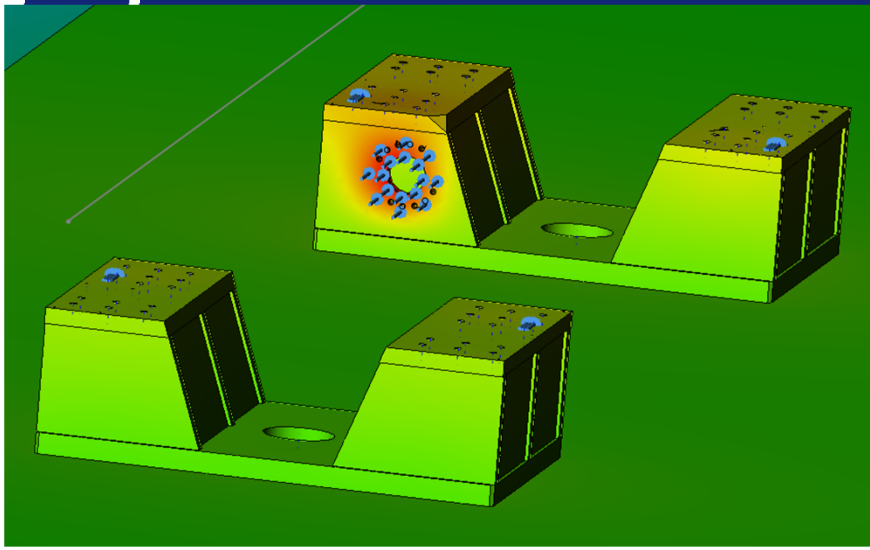


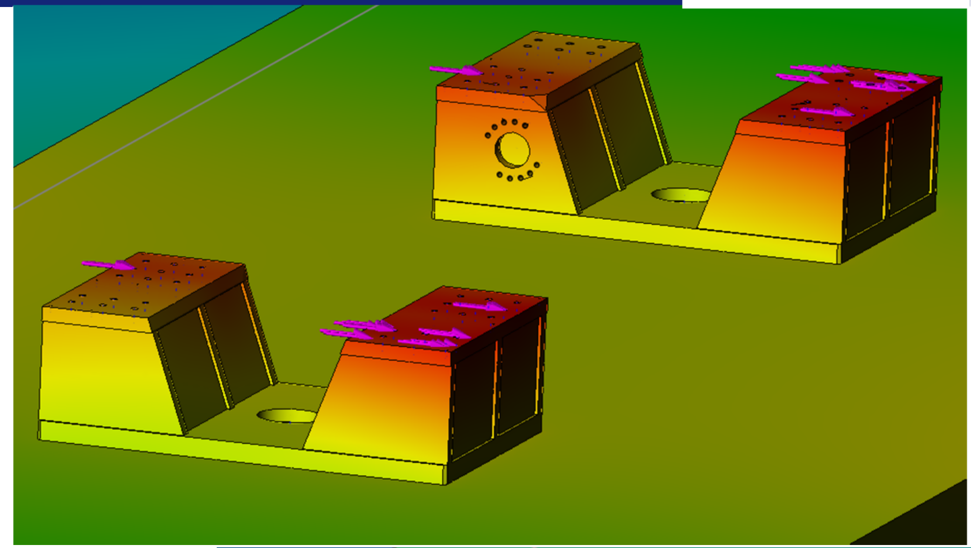


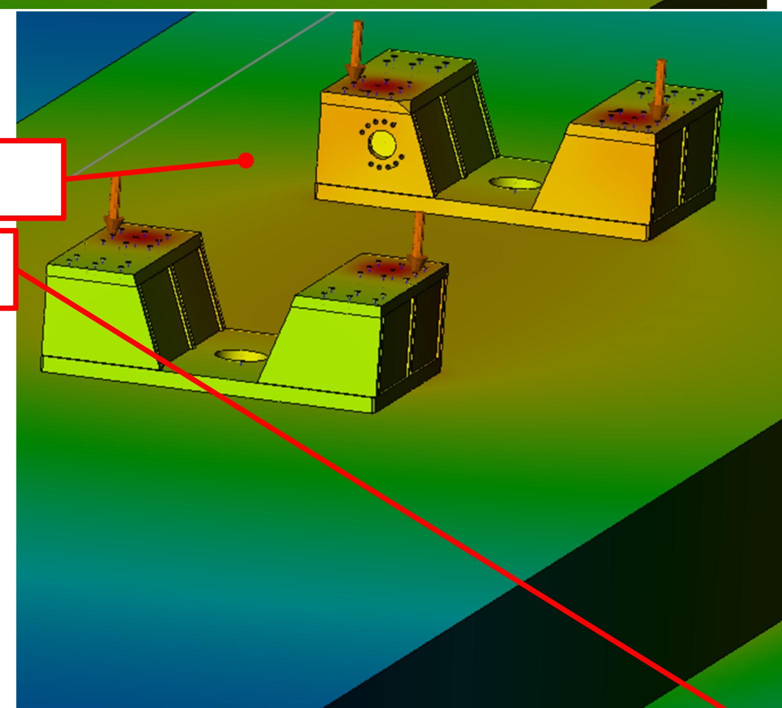


Ground: 200x200x100m E=520MPa G=179MPa

STIFFNESS OF BASES + SLAB + GROUND



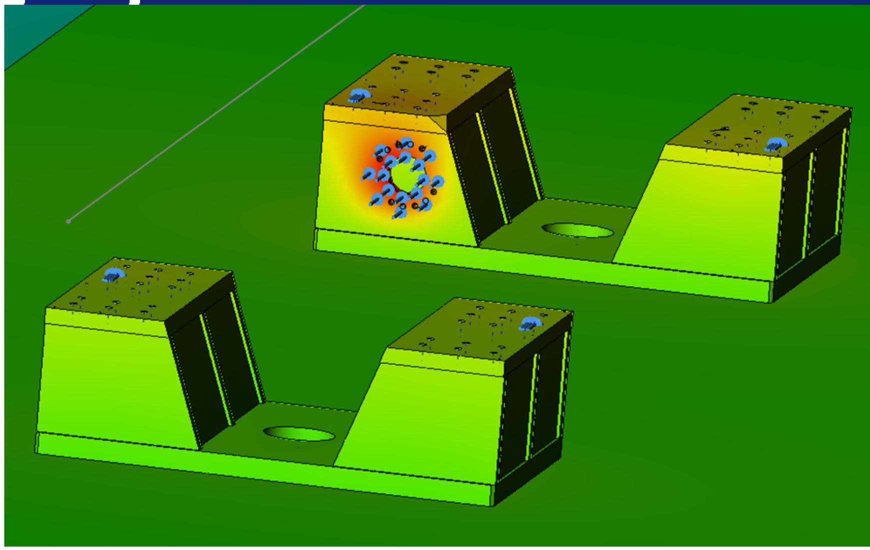


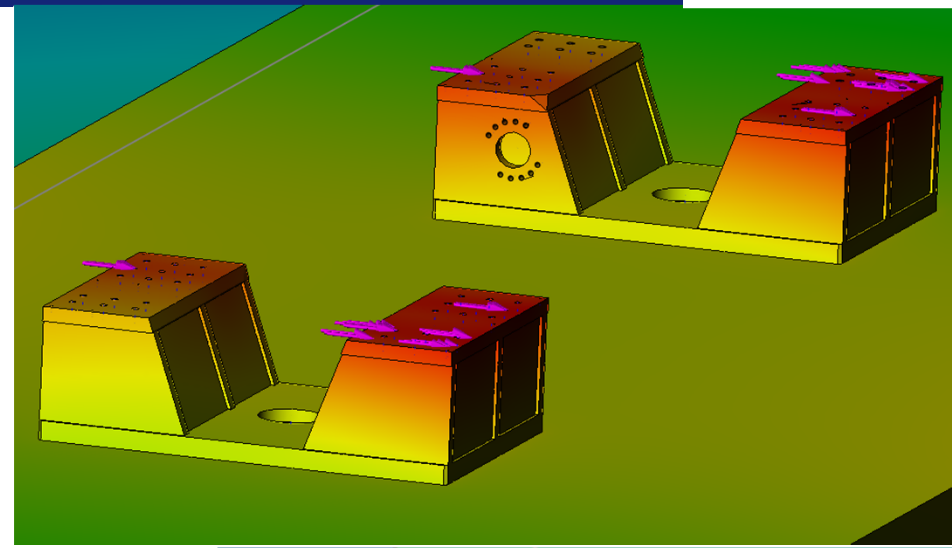


Concrete floor: 20x4x0.8m E=30*GPa* G=12.5*GPa*

Ground: 200x200x100m E=520*MPa* G=179*MPa*

STIFFNESS OF BASES + SLAB + GROUND

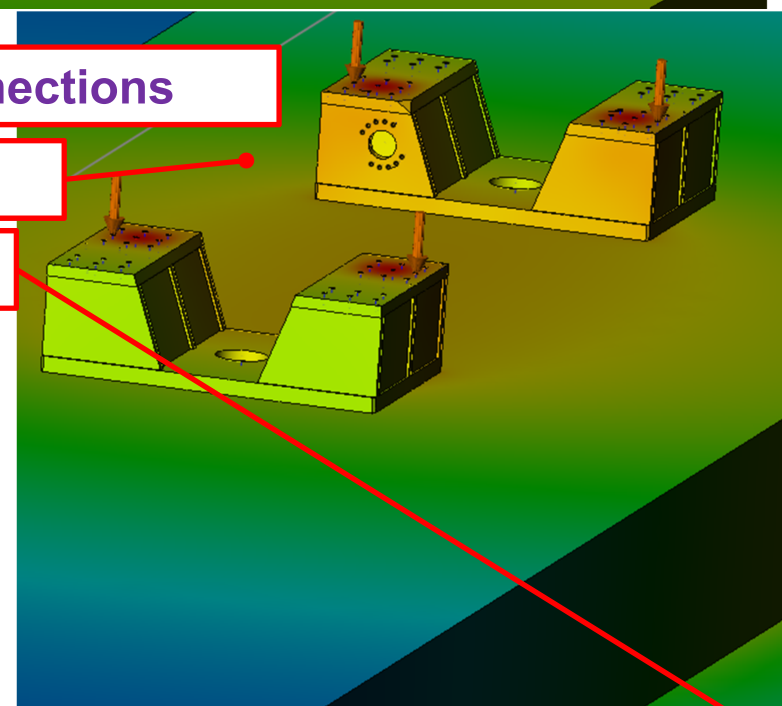




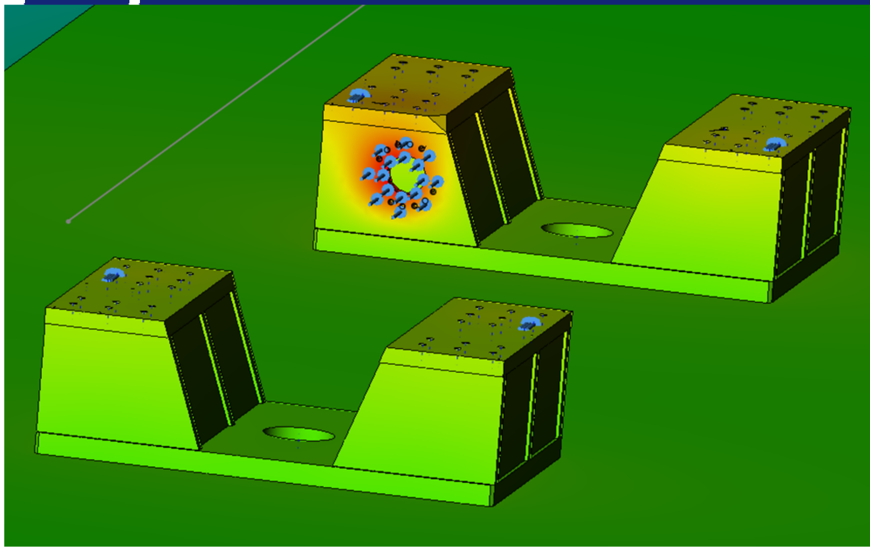
A test force is put on each of the support's connections

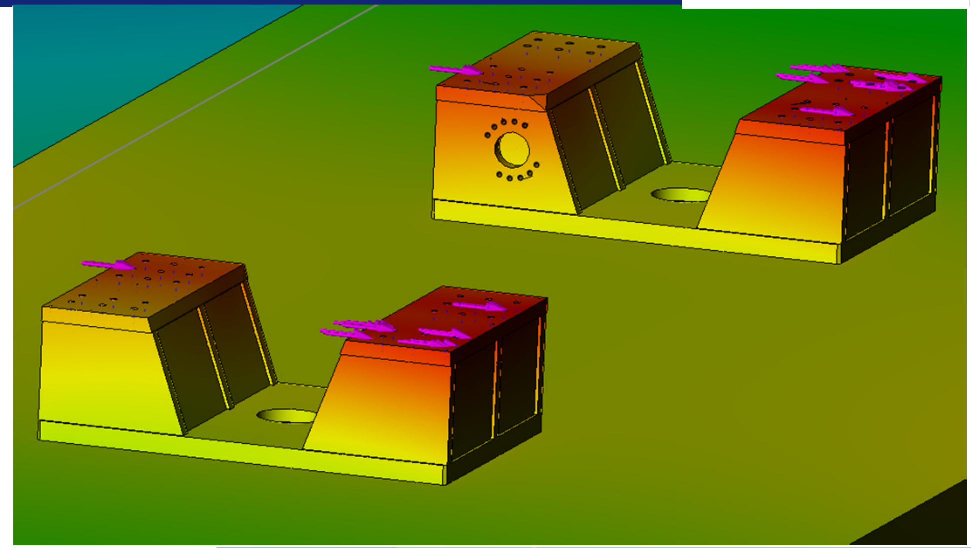
Concrete floor: 20x4x0.8m E=30*G*Pa G=12.5*G*Pa

Ground: 200x200x100m E=520*M*Pa G=179*M*Pa



STIFFNESS OF BASES + SLAB + GROUND





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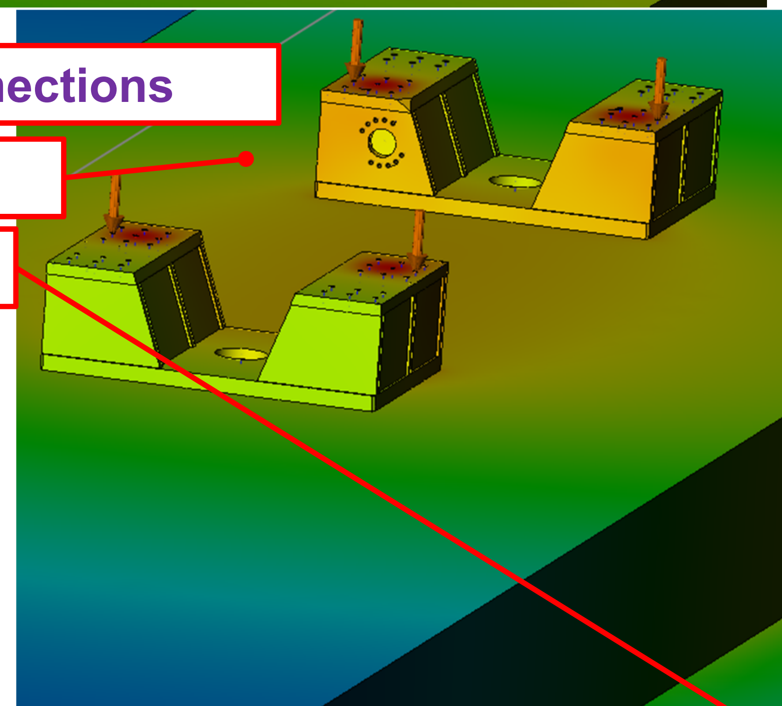
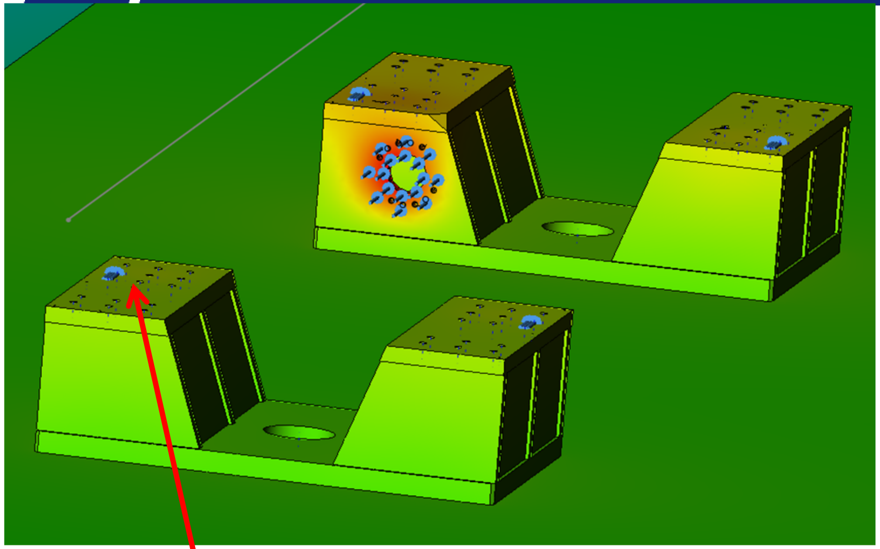
Concrete floor: 20x4x0.8m E=30*G*Pa G=12.5*G*Pa

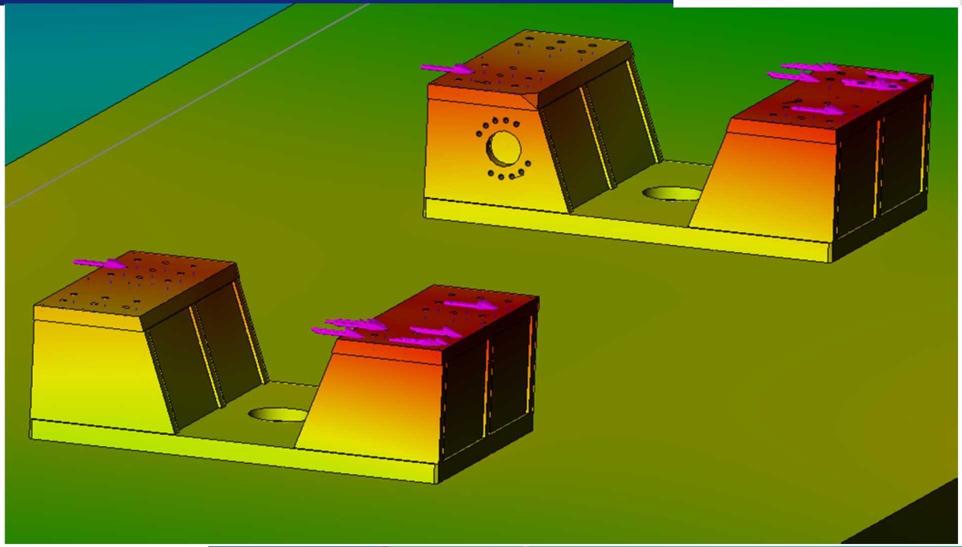
Ground: 200x200x100m E=520*M*Pa G=179*M*Pa

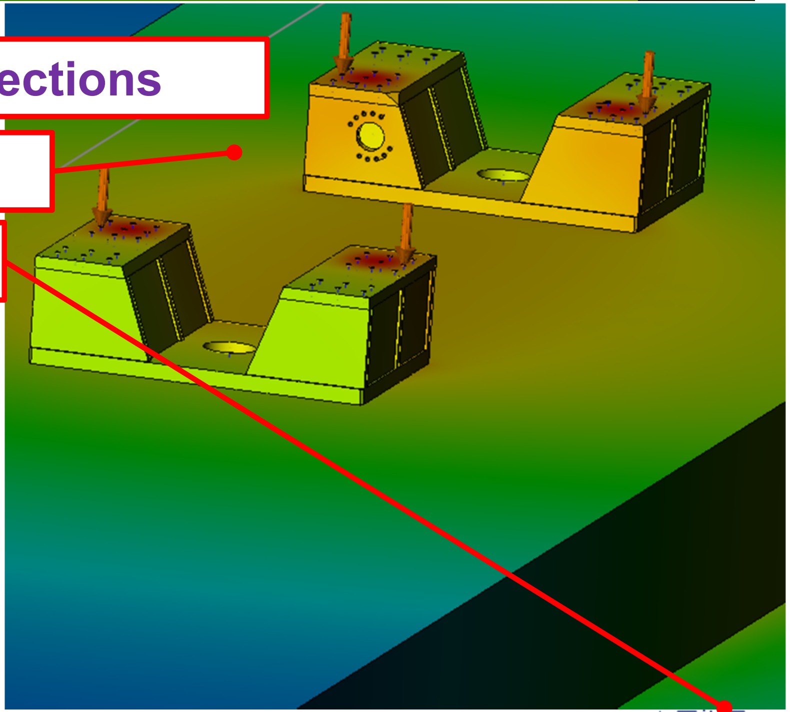


Dir.	Position	Equivalent stiffness (each)
X	Vertical support	667N/µm
X	X jack	588N/µm
Y	Vertical support	435N/µm
Y	Y jack	417N/µm
Z	Vertical support	769N/µm

STIFFNESS OF BASES + SLAB + GROUND







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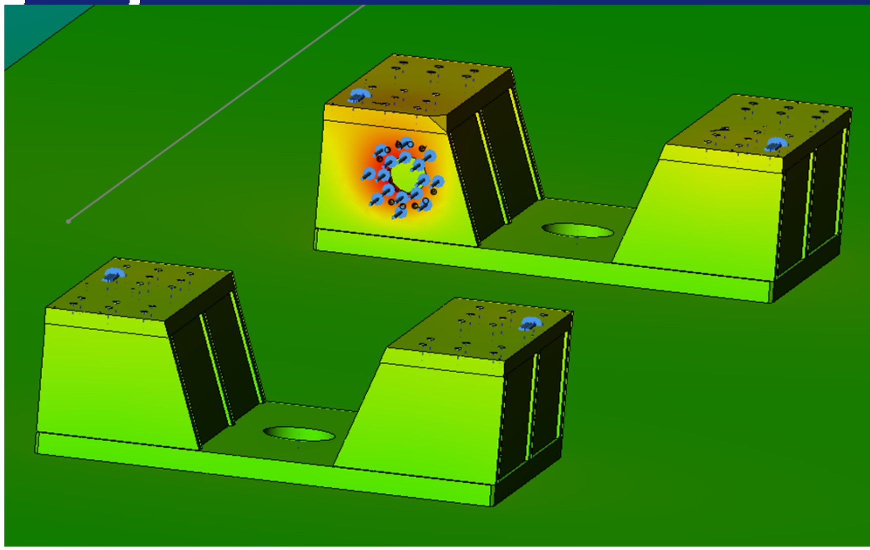
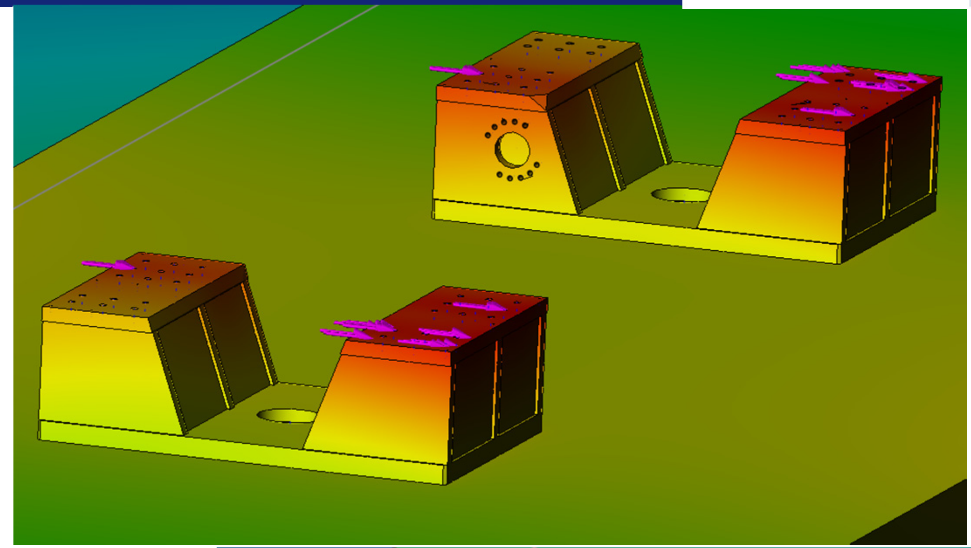
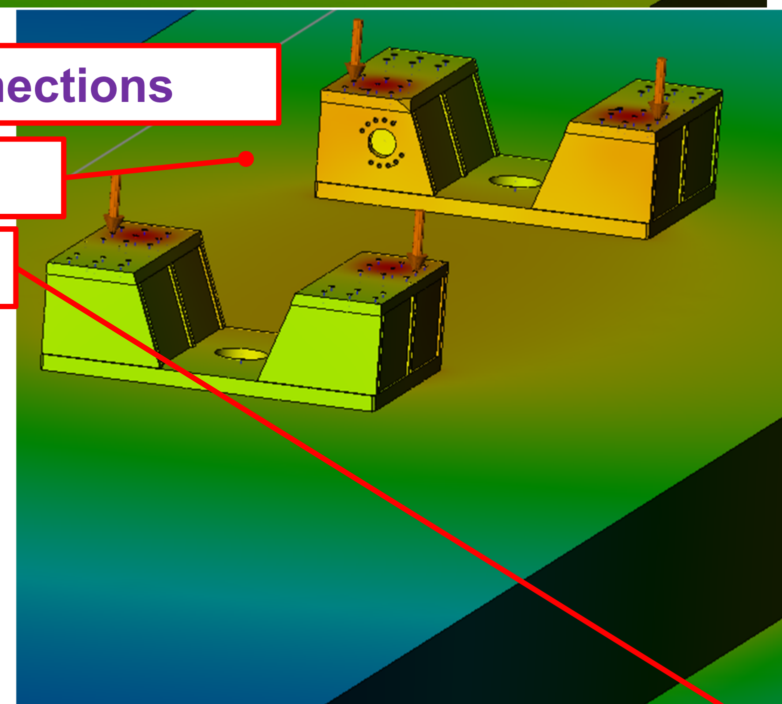
STIFFNESS OF BASES + SLAB + GROUND







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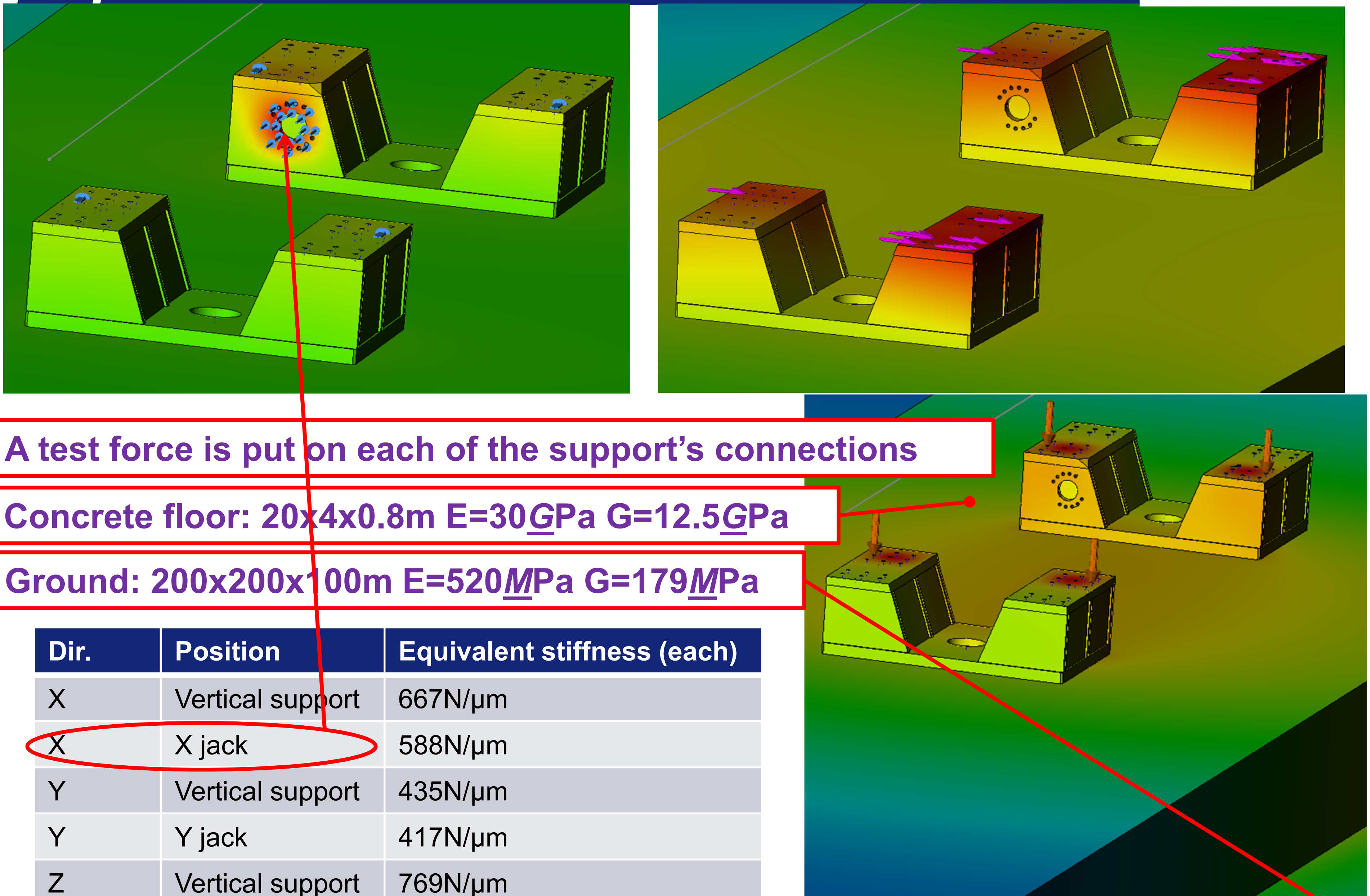
STIFFNESS OF BASES + SLAB + GROUND



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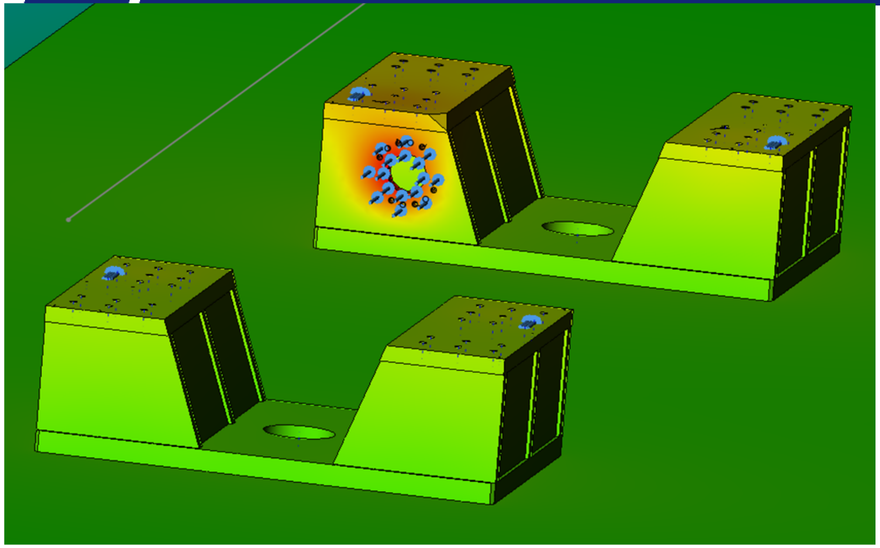
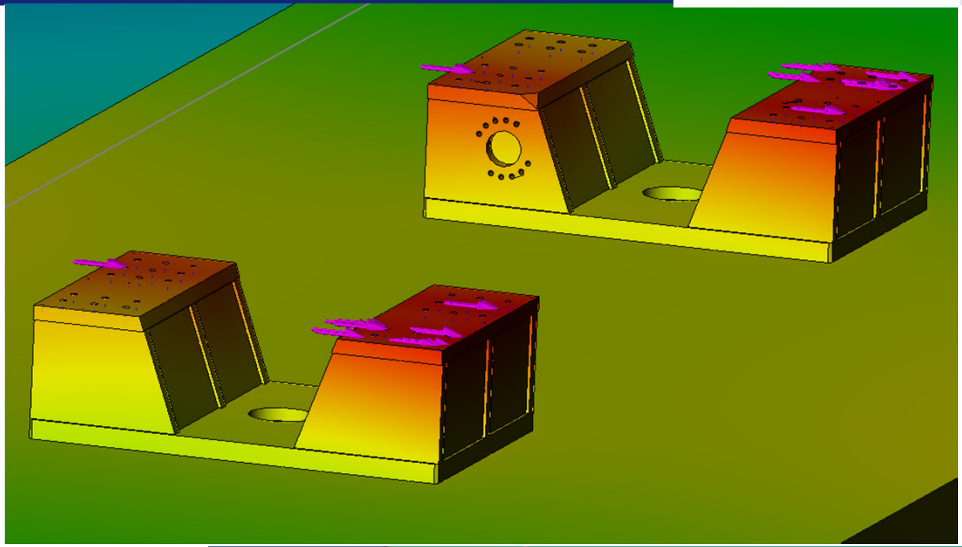
STIFFNESS OF BASES + SLAB + GROUND





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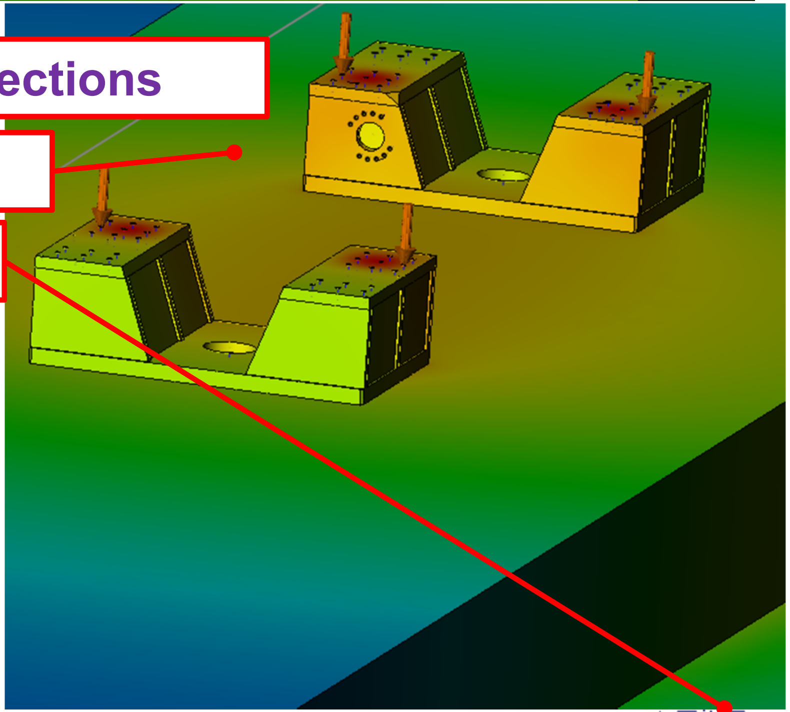

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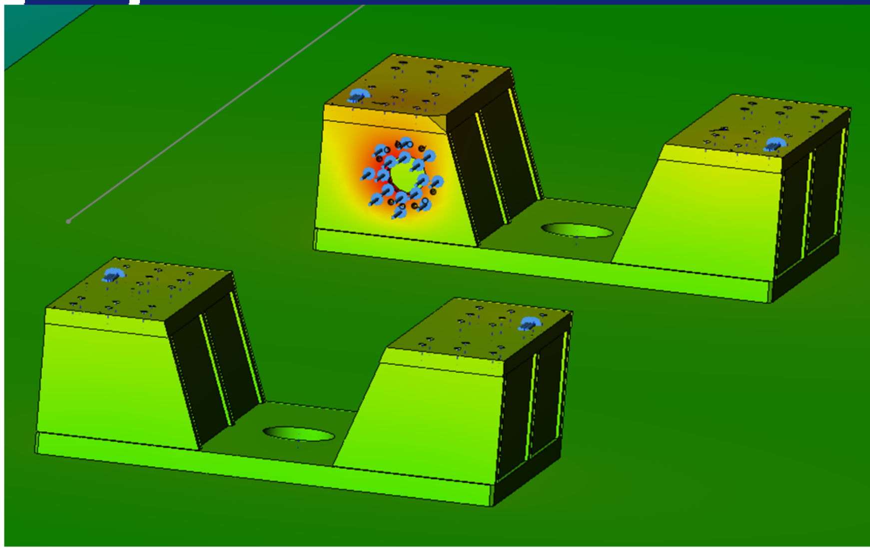
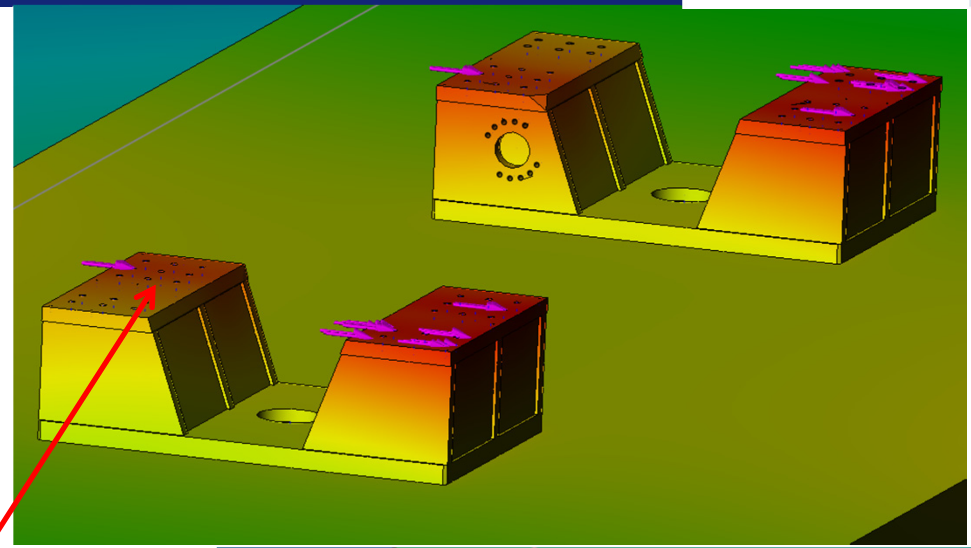
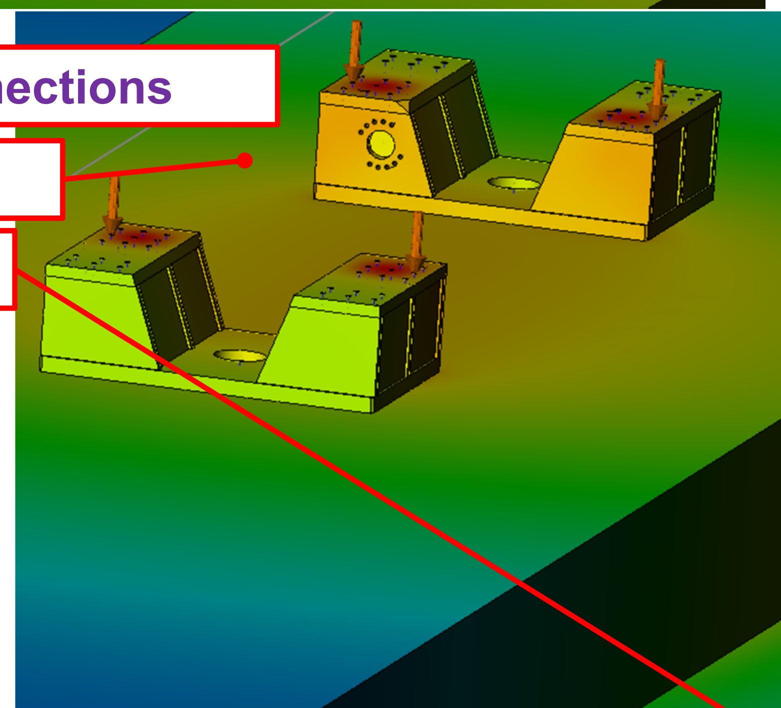
STIFFNESS OF BASES + SLAB + GROUND







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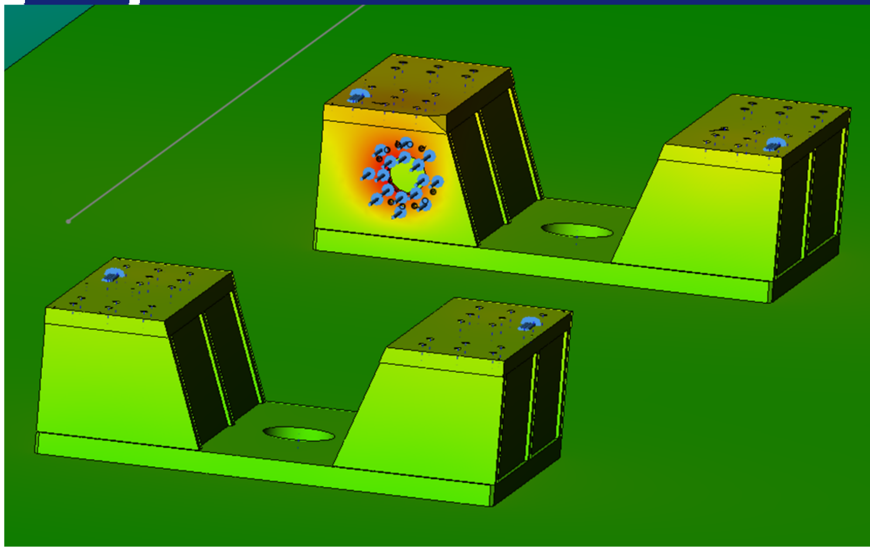

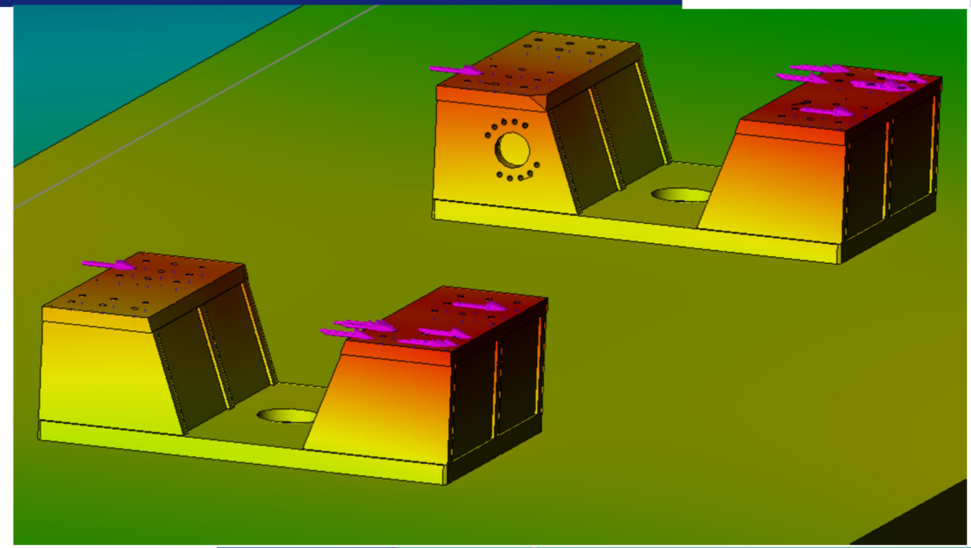

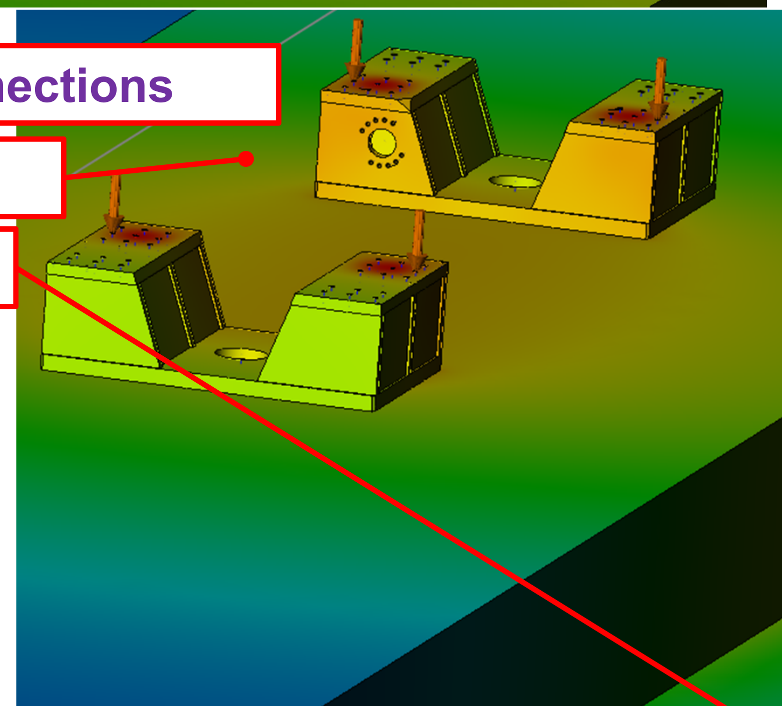

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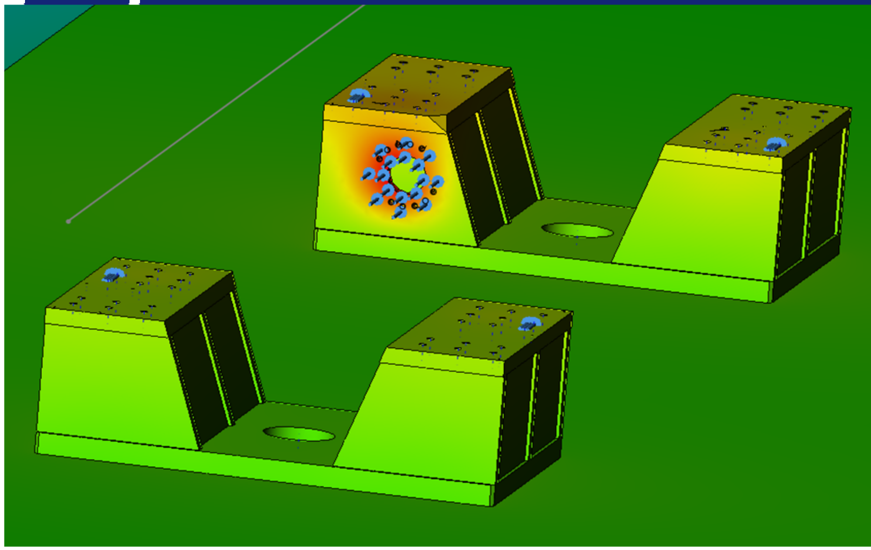
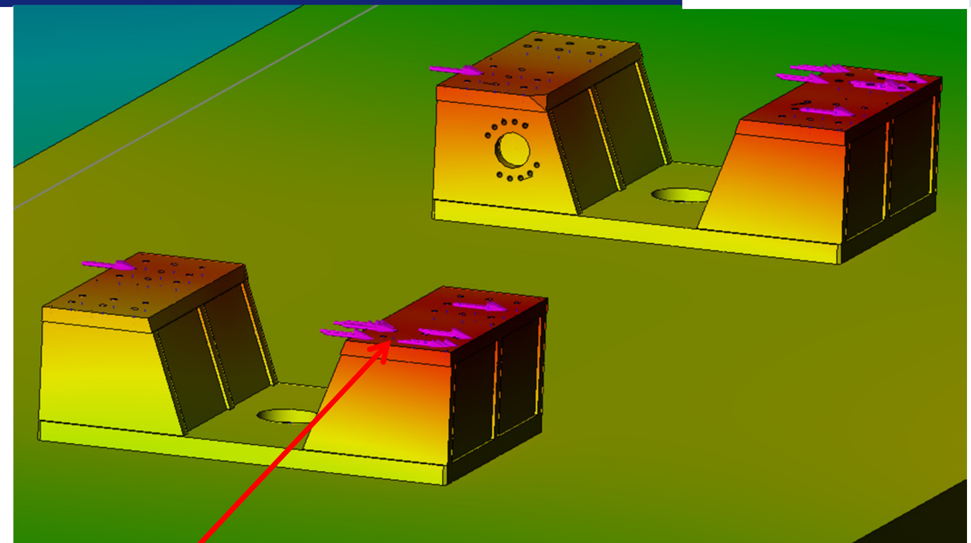
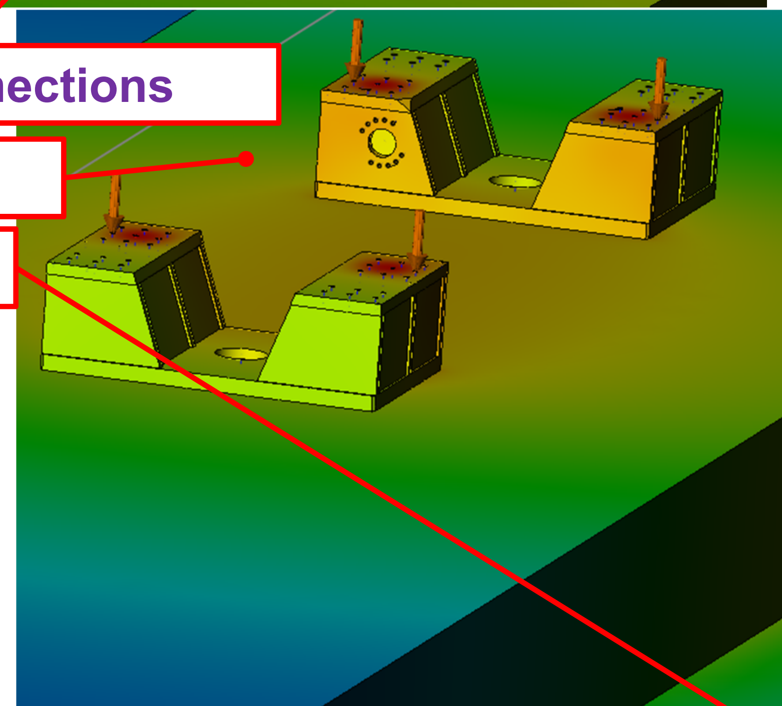
STIFFNESS OF BASES + SLAB + GROUND







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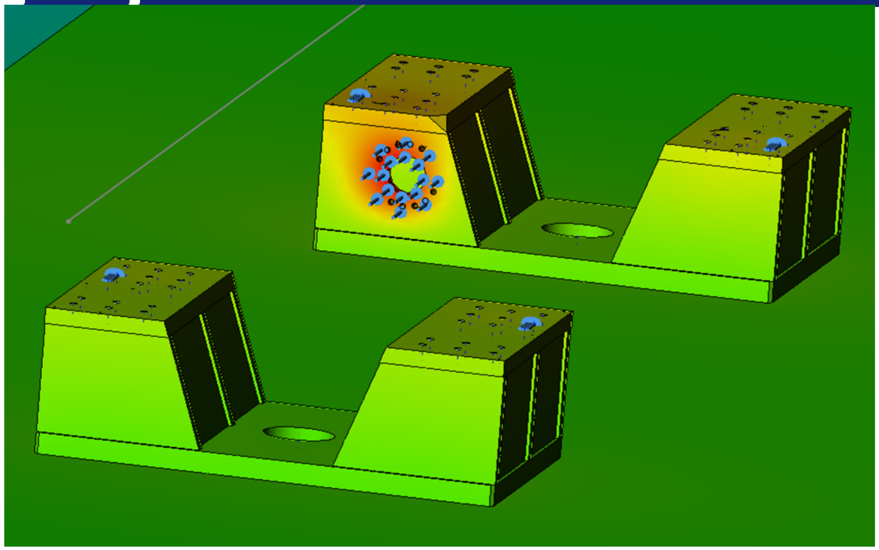

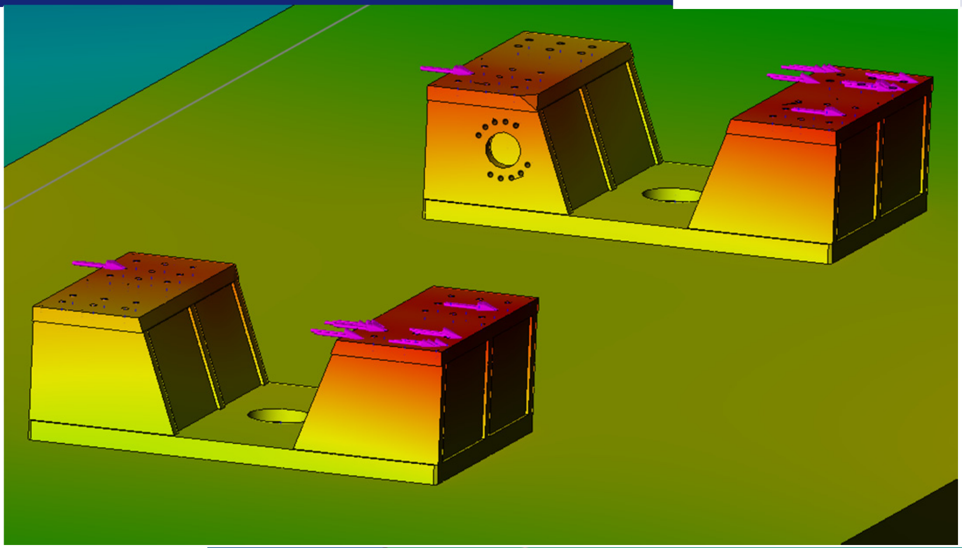

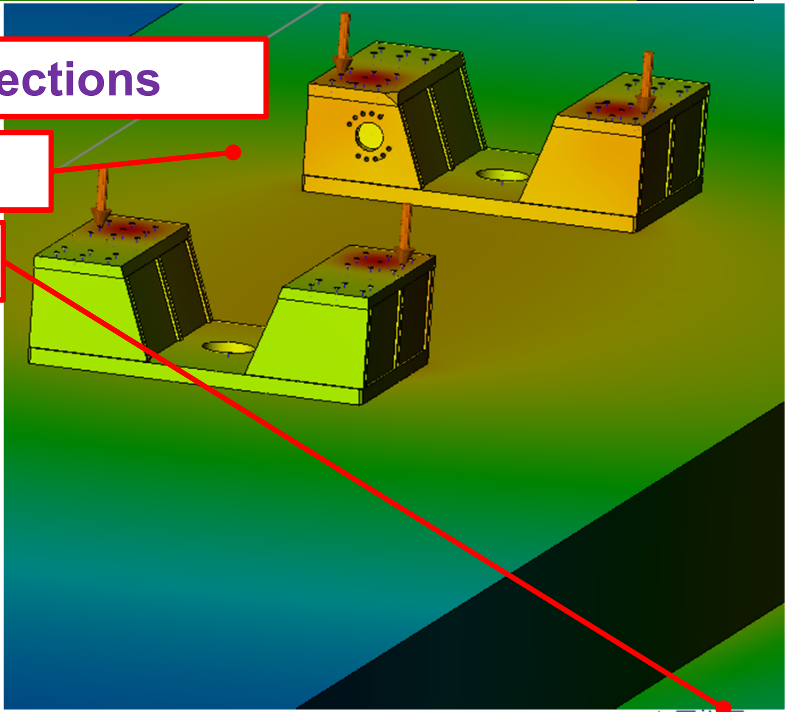

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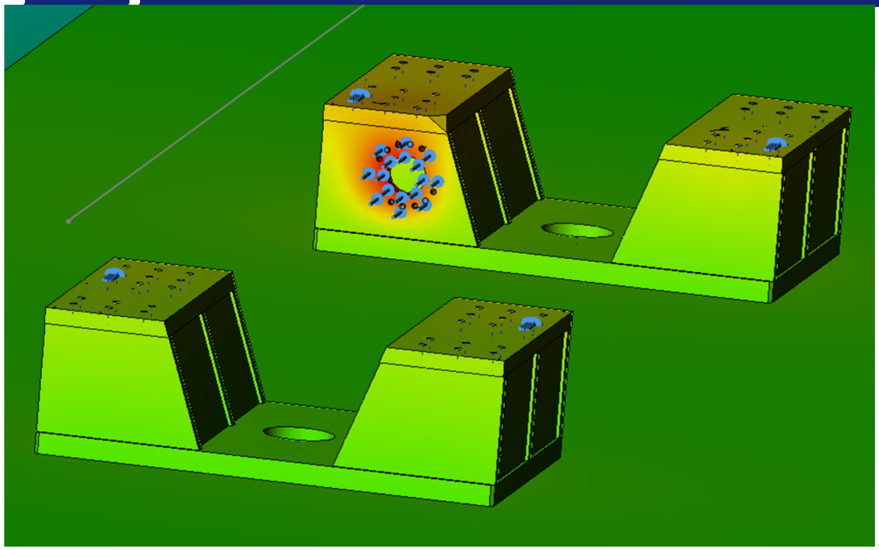
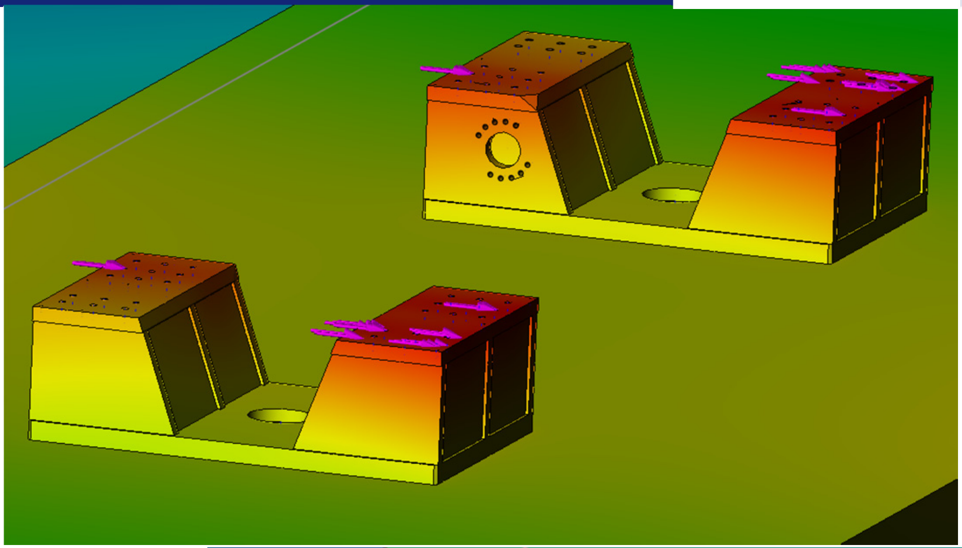
STIFFNESS OF BASES + SLAB + GROUND





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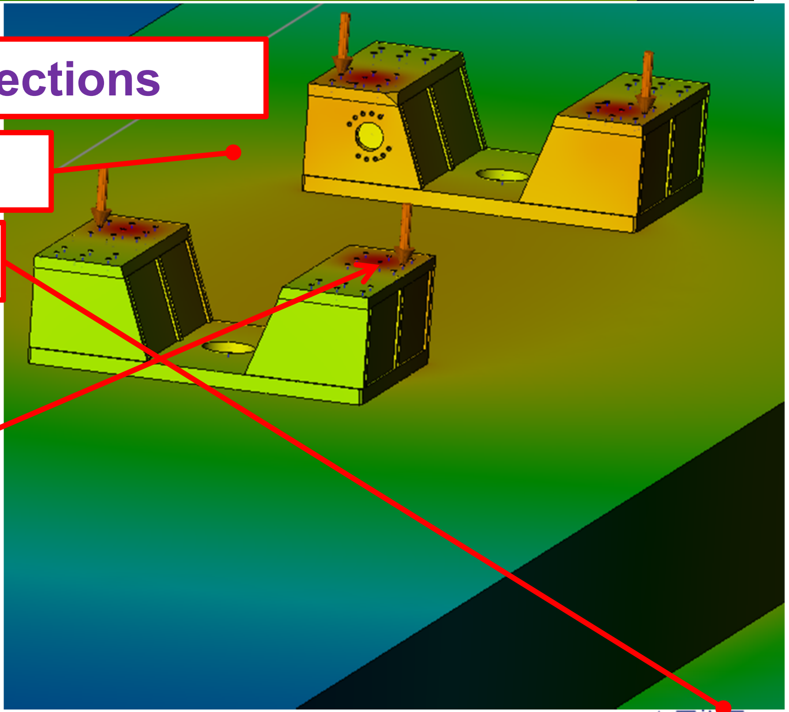

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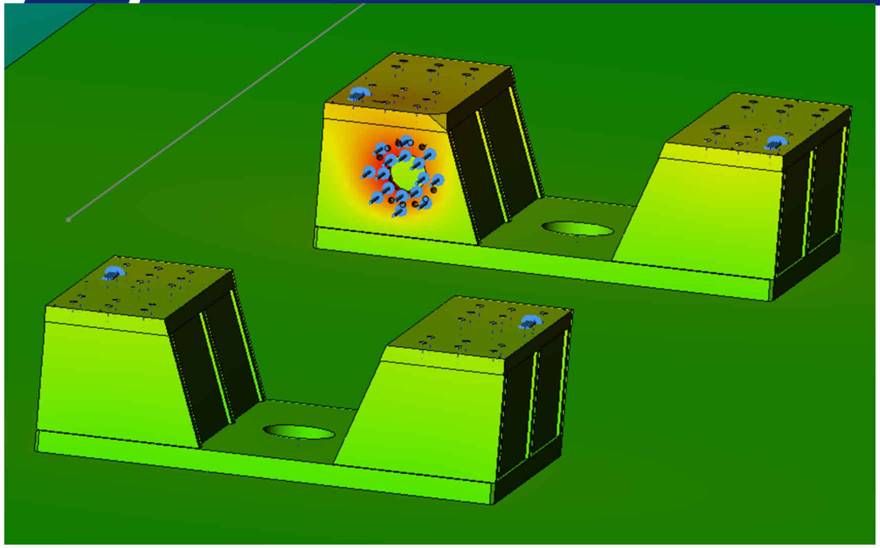
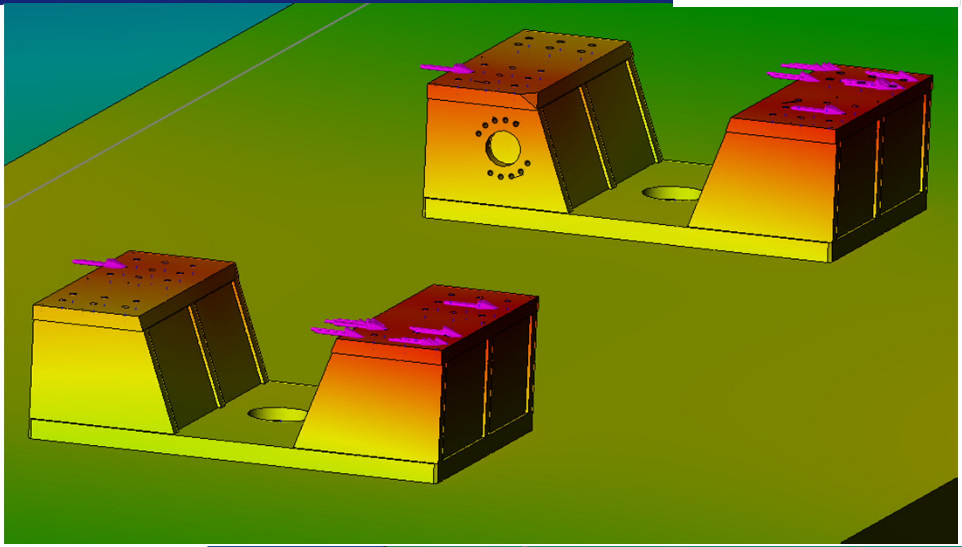
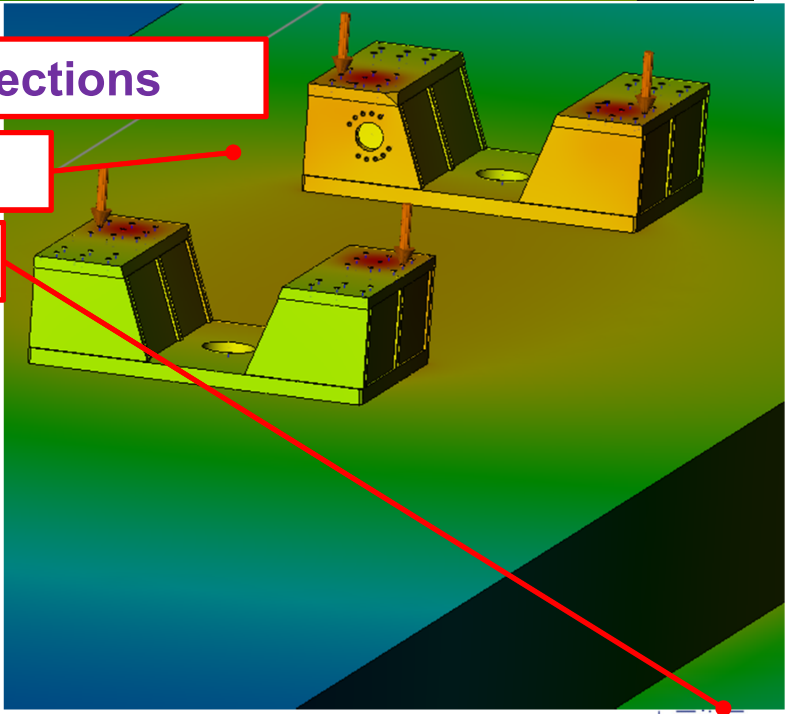
STIFFNESS OF BASES + SLAB + GROUND







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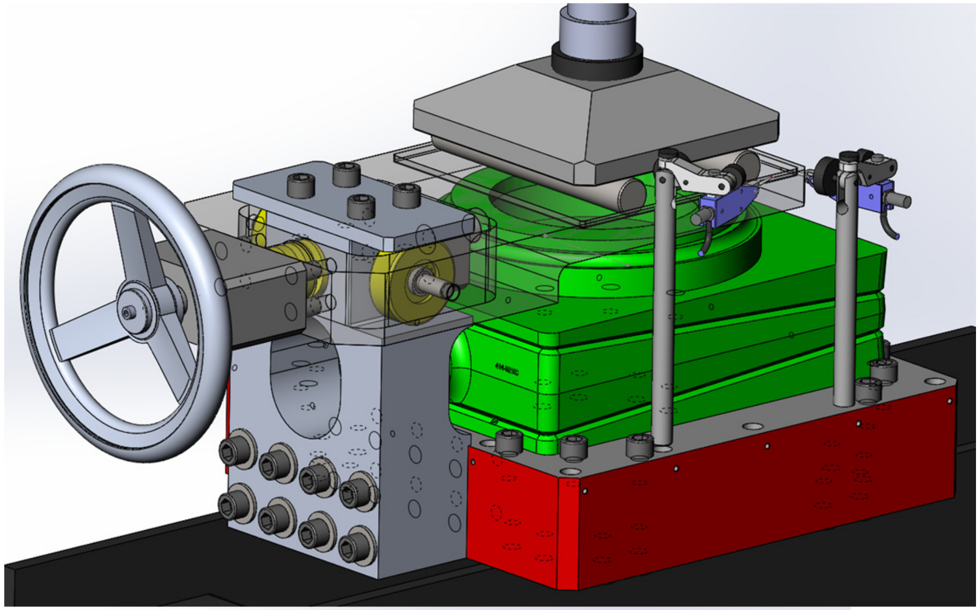
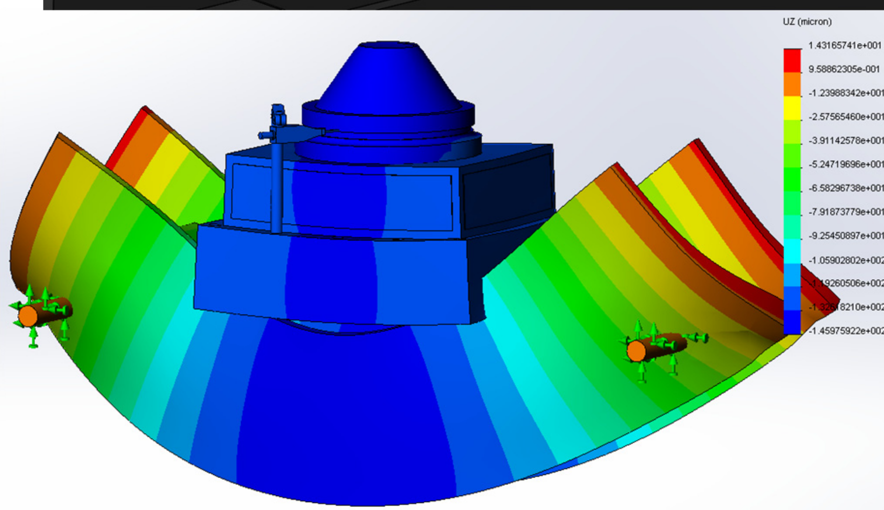
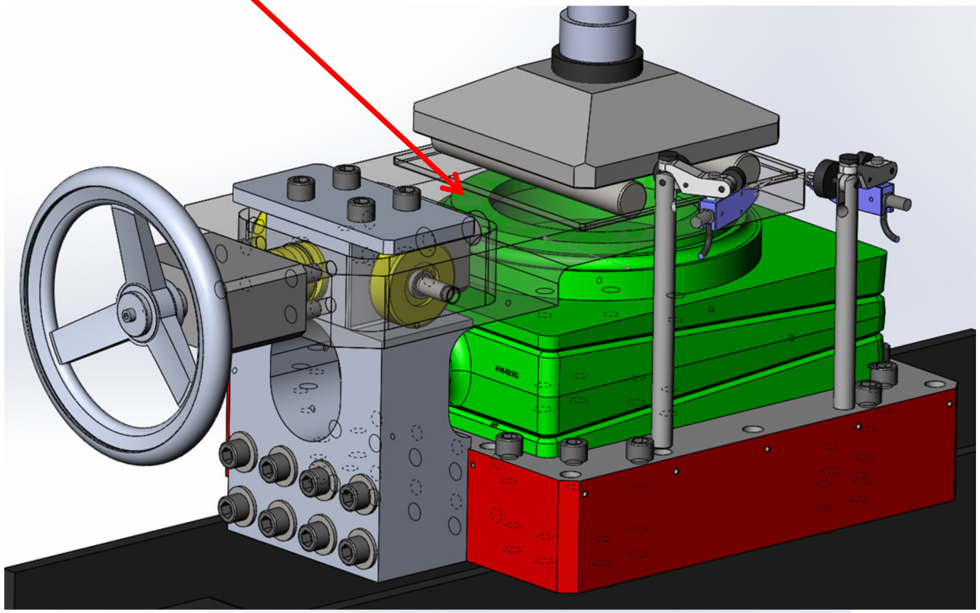
TEST OF NIVELL AND AIRLOC WEDGES

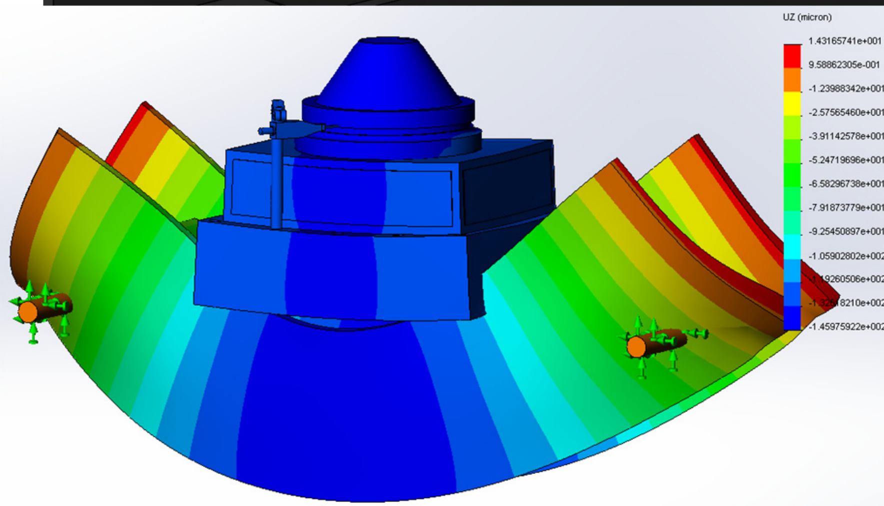




TEST OF NIVELL AND AIRLOC WEDGES

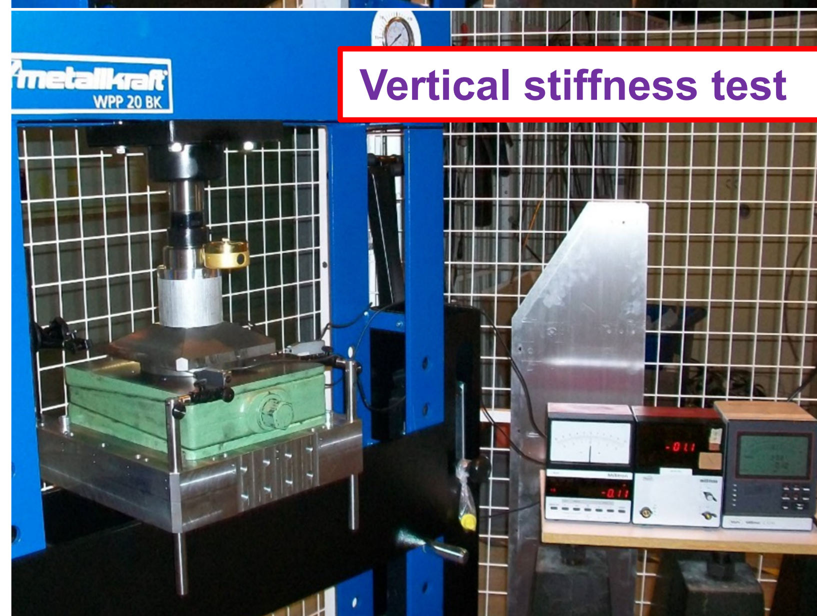
Airlocs with spherical joint



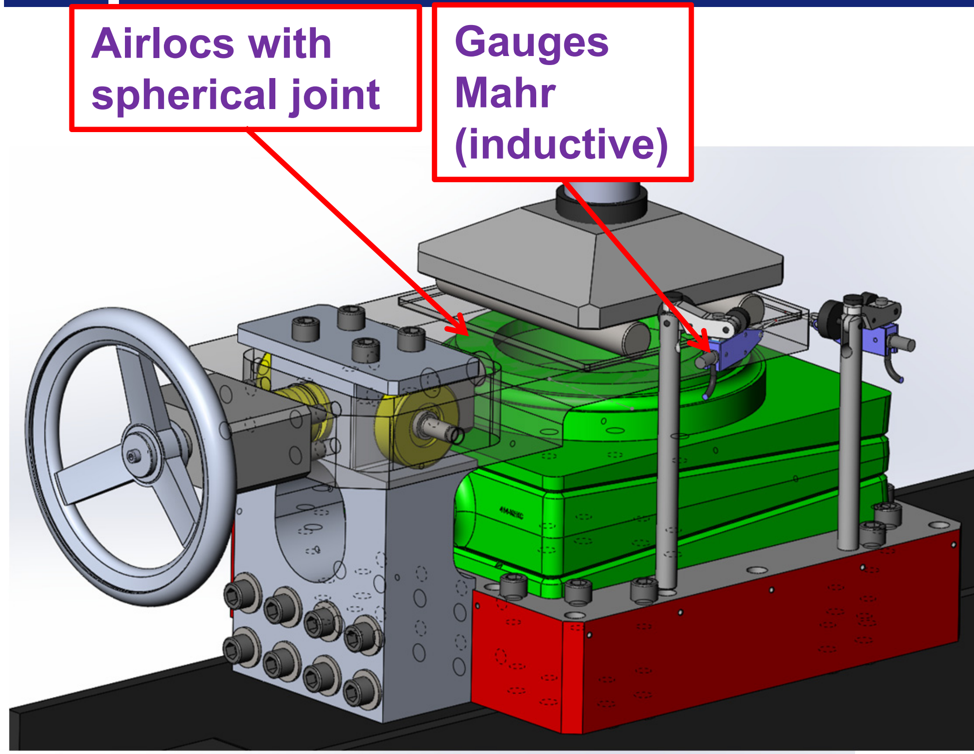


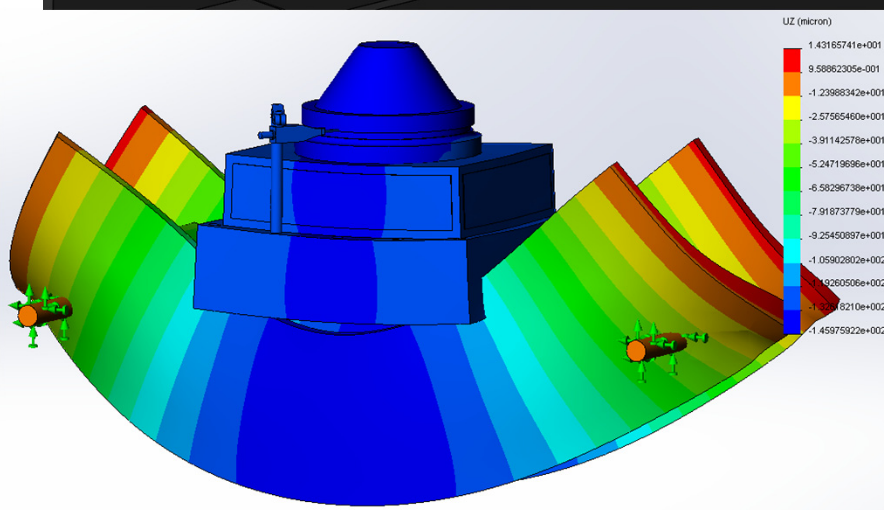
Horizontal stiffness test

Vertical stiffness test



TEST OF NIVELL AND AIRLOC WEDGES



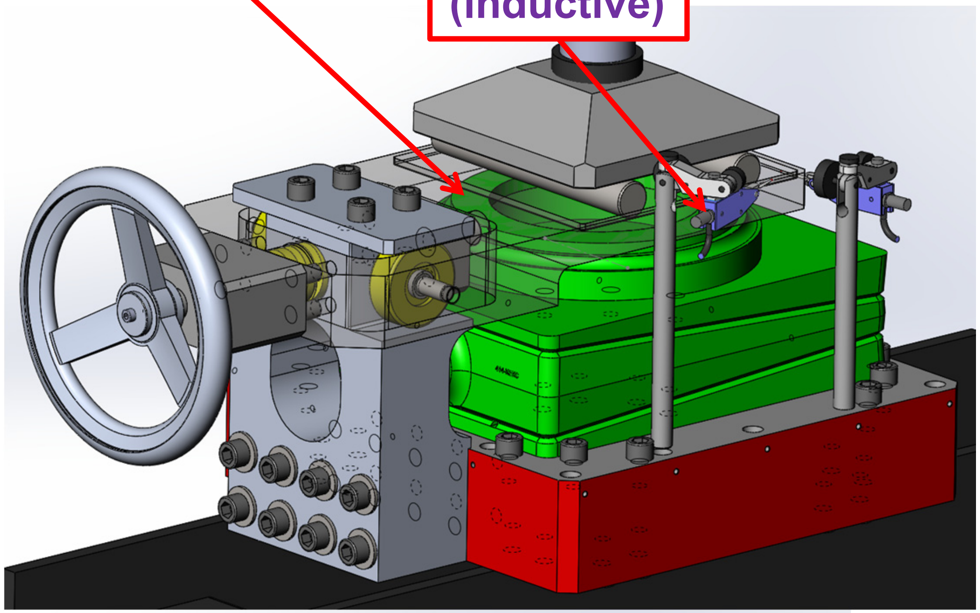


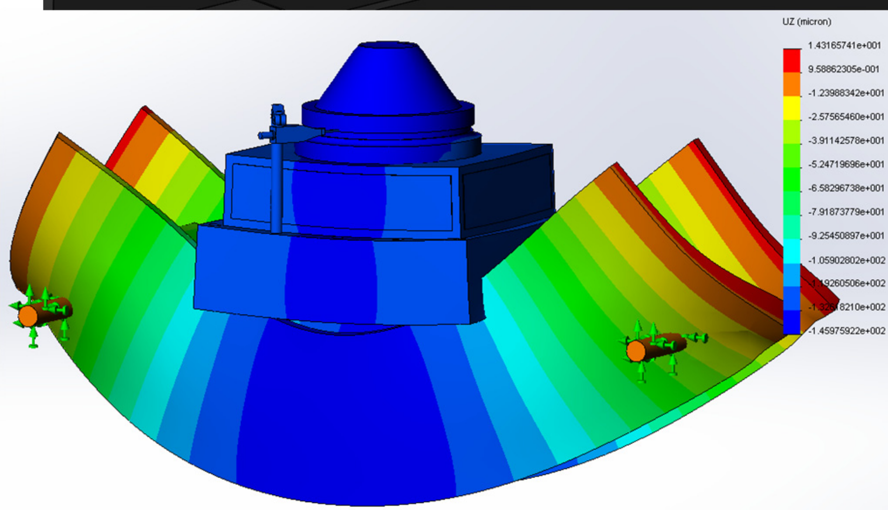
TEST OF NIVELL AND AIRLOC WEDGES

Airlocs with spherical joint

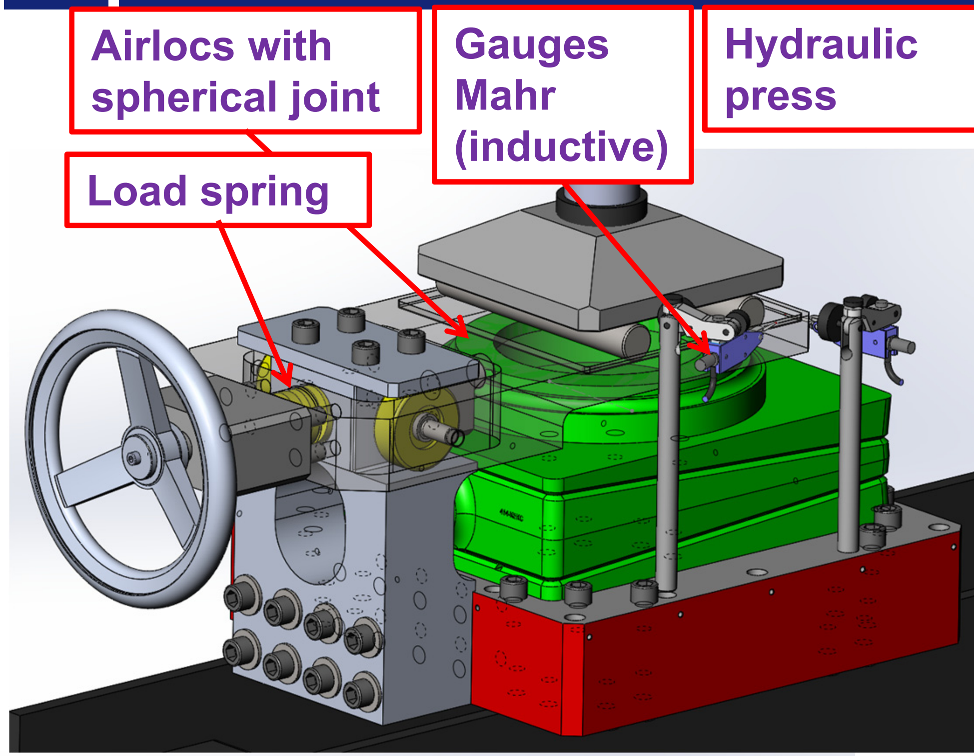
Gauges Mahr (inductive)

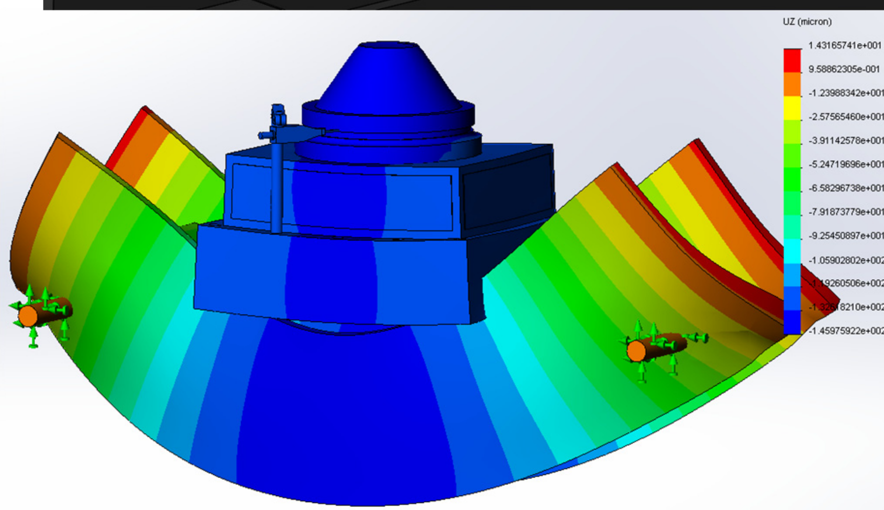
Hydraulic press





TEST OF NIVELL AND AIRLOC WEDGES





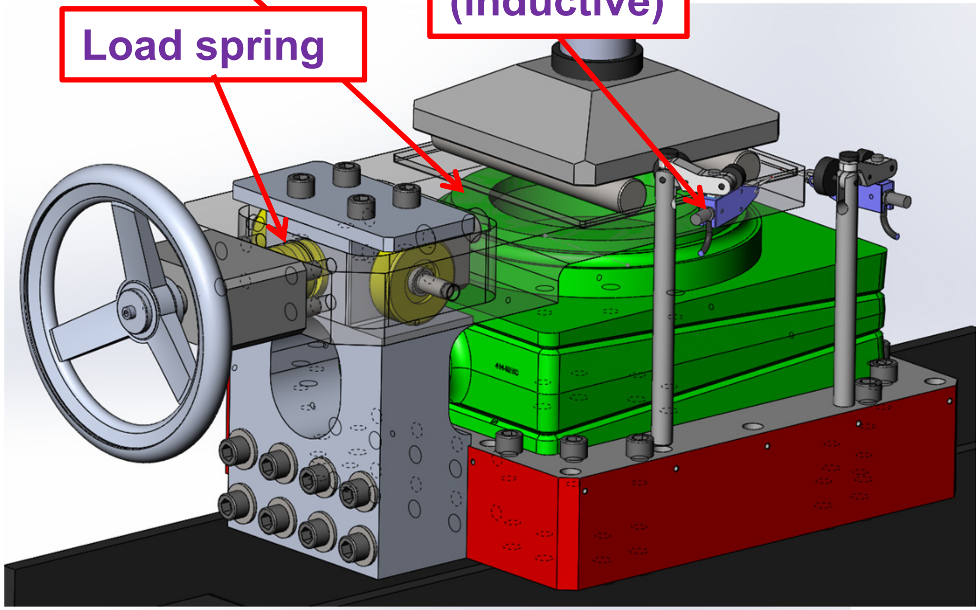
TEST OF NIVELL AND AIRLOC WEDGES

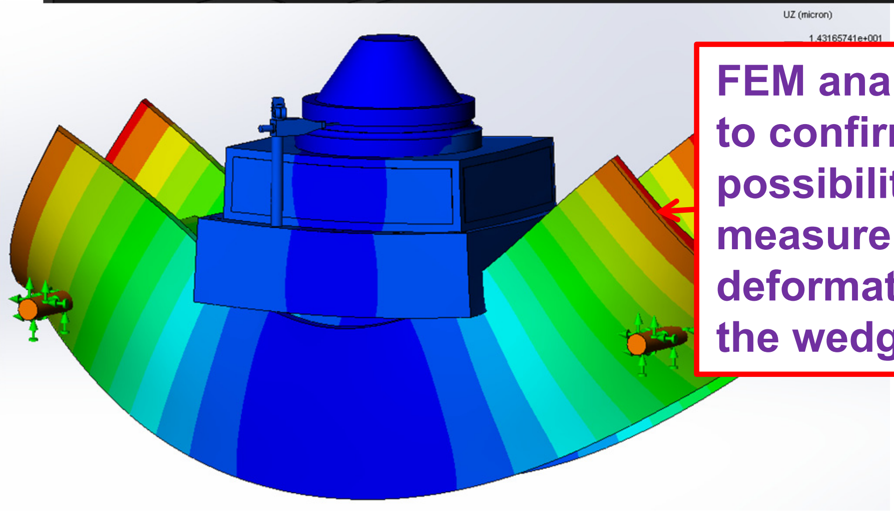
Airlocs with spherical joint

Gauges Mahr (inductive)

Hydraulic press

Load spring



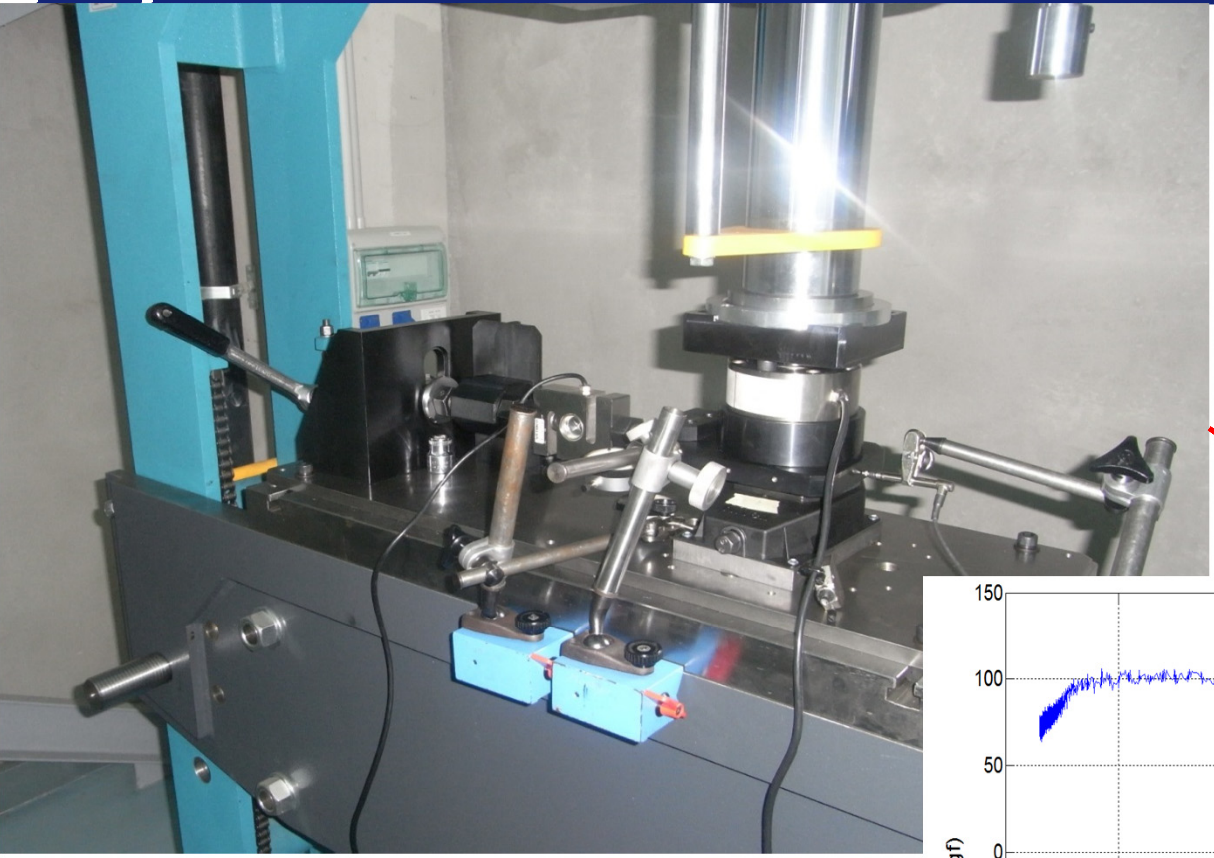


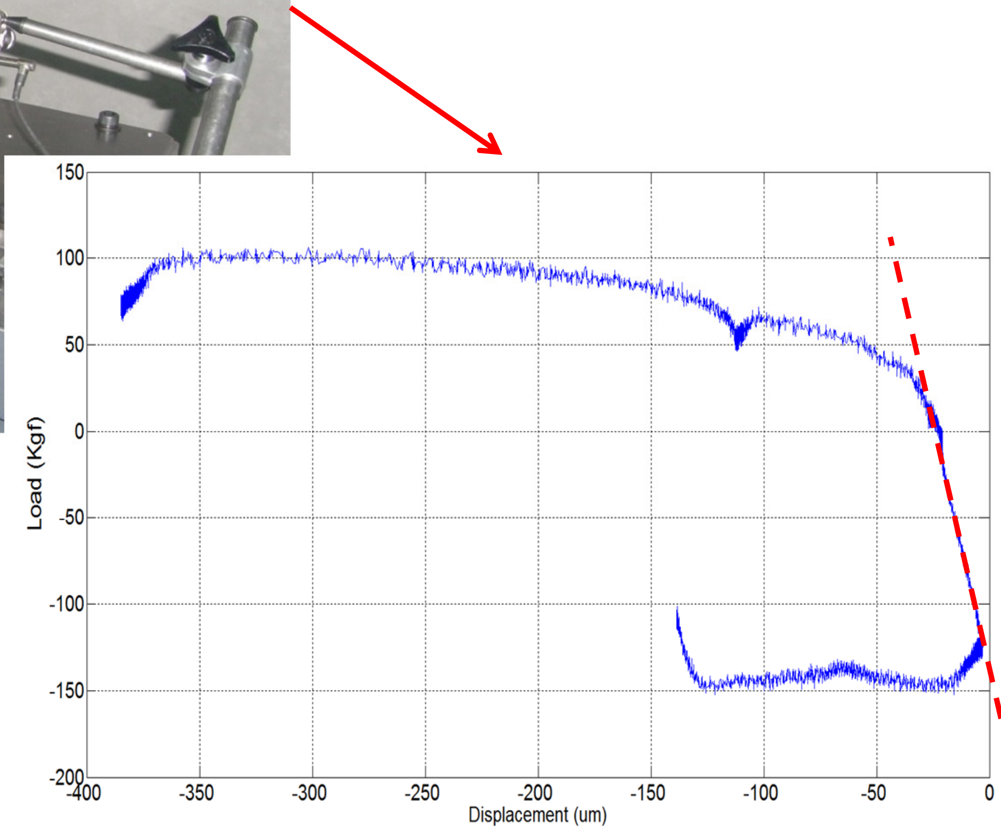
FEM analysis to confirm the possibility to measure small deformation in the wedge

Horizontal stiffness test

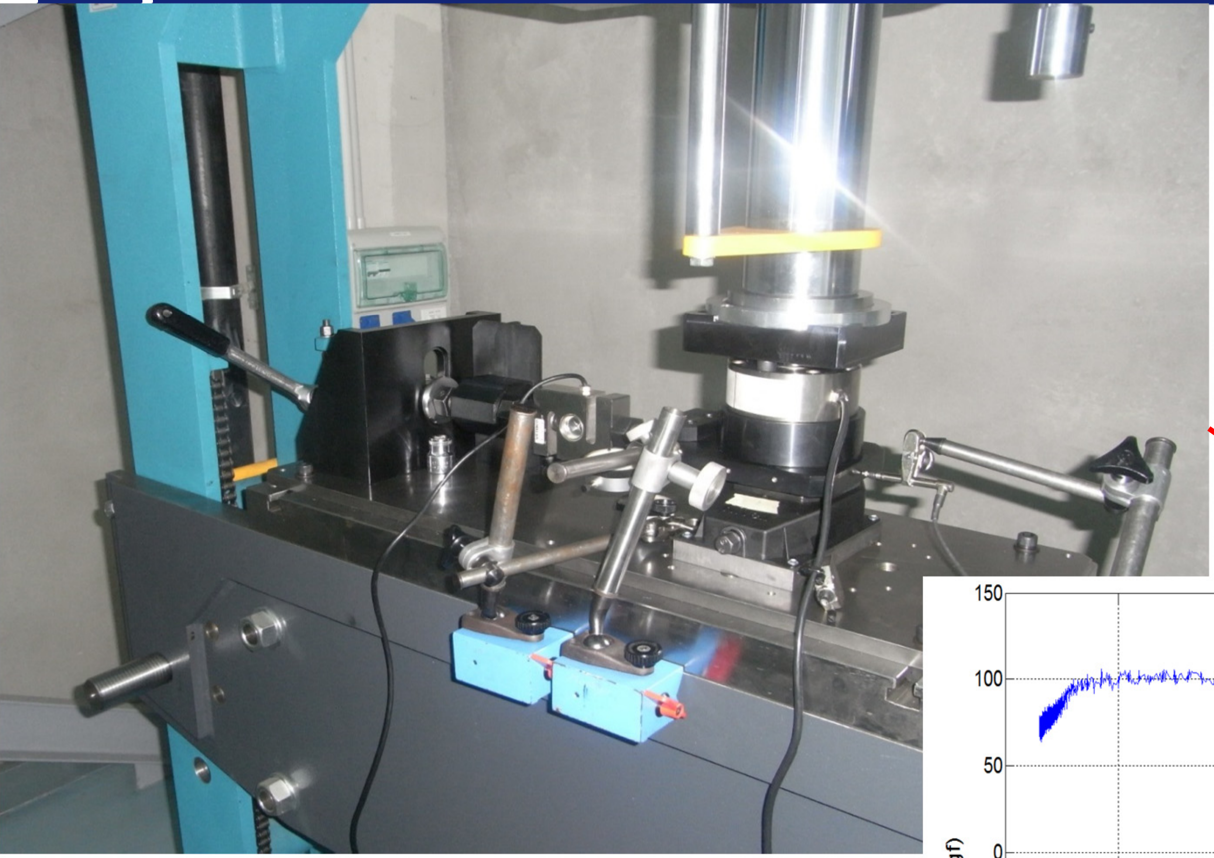
Vertical stiffness test

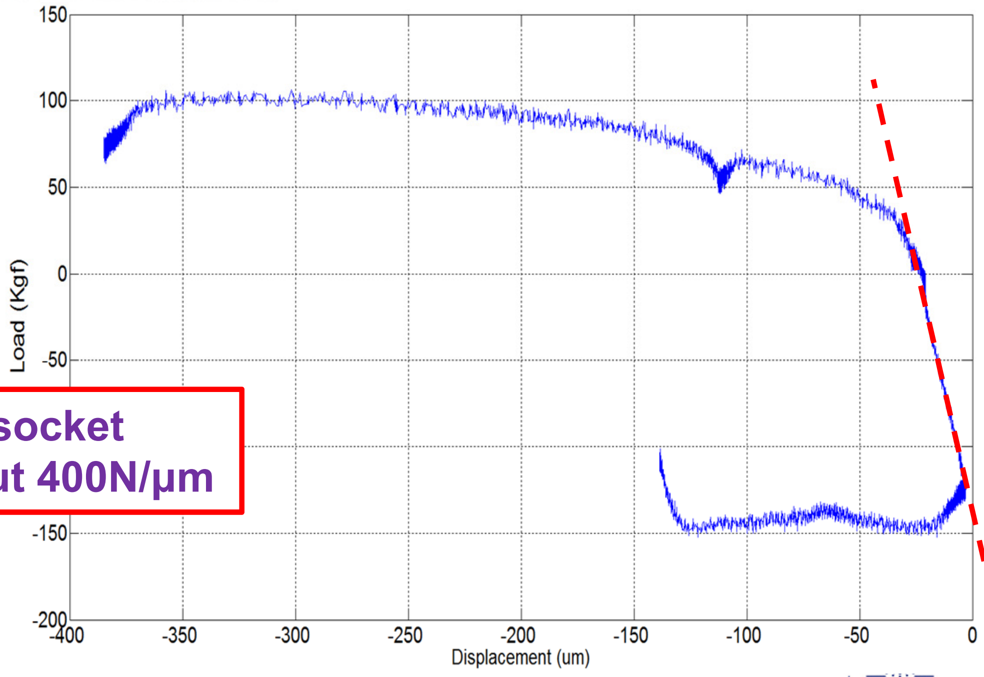
TEST OF NIVELL WEDGES BY TEKNIKER



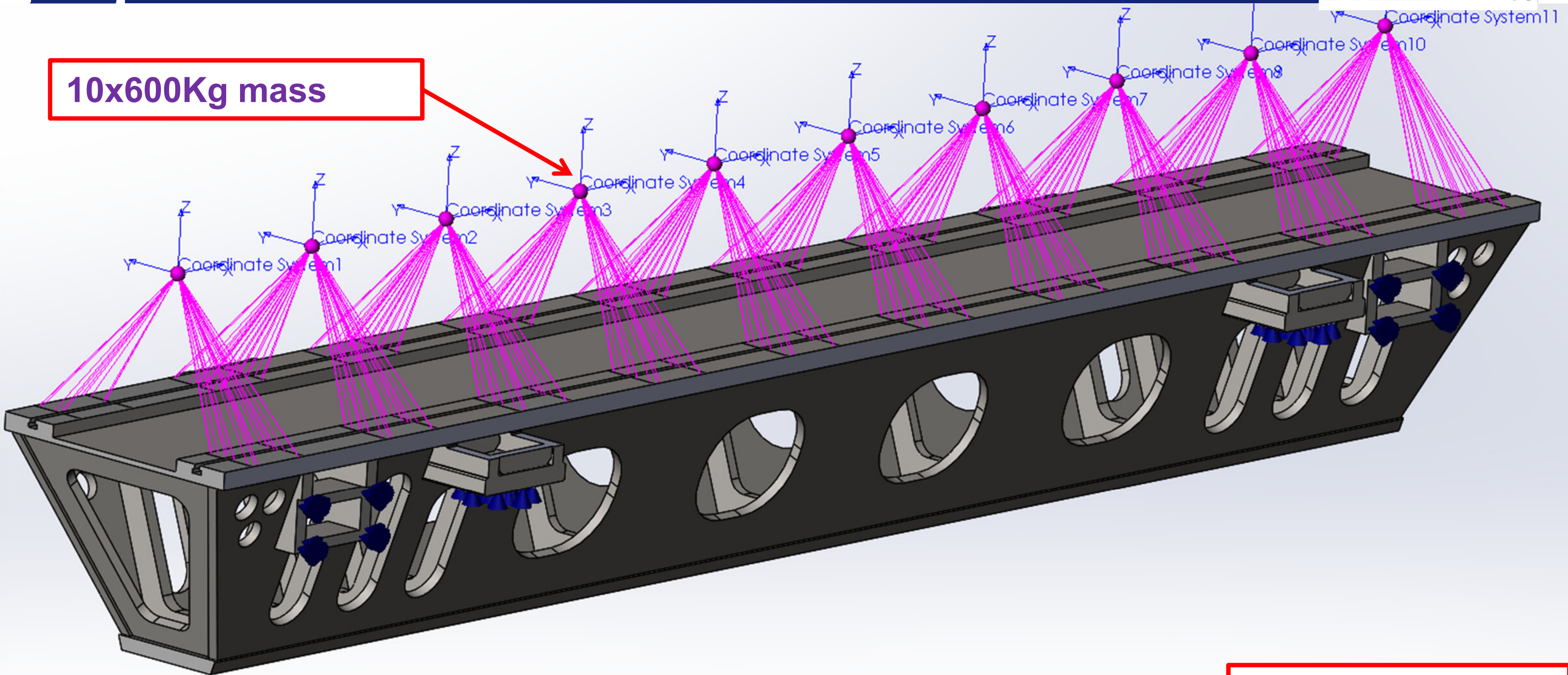


TEST OF NIVELL WEDGES BY TEKNIKER





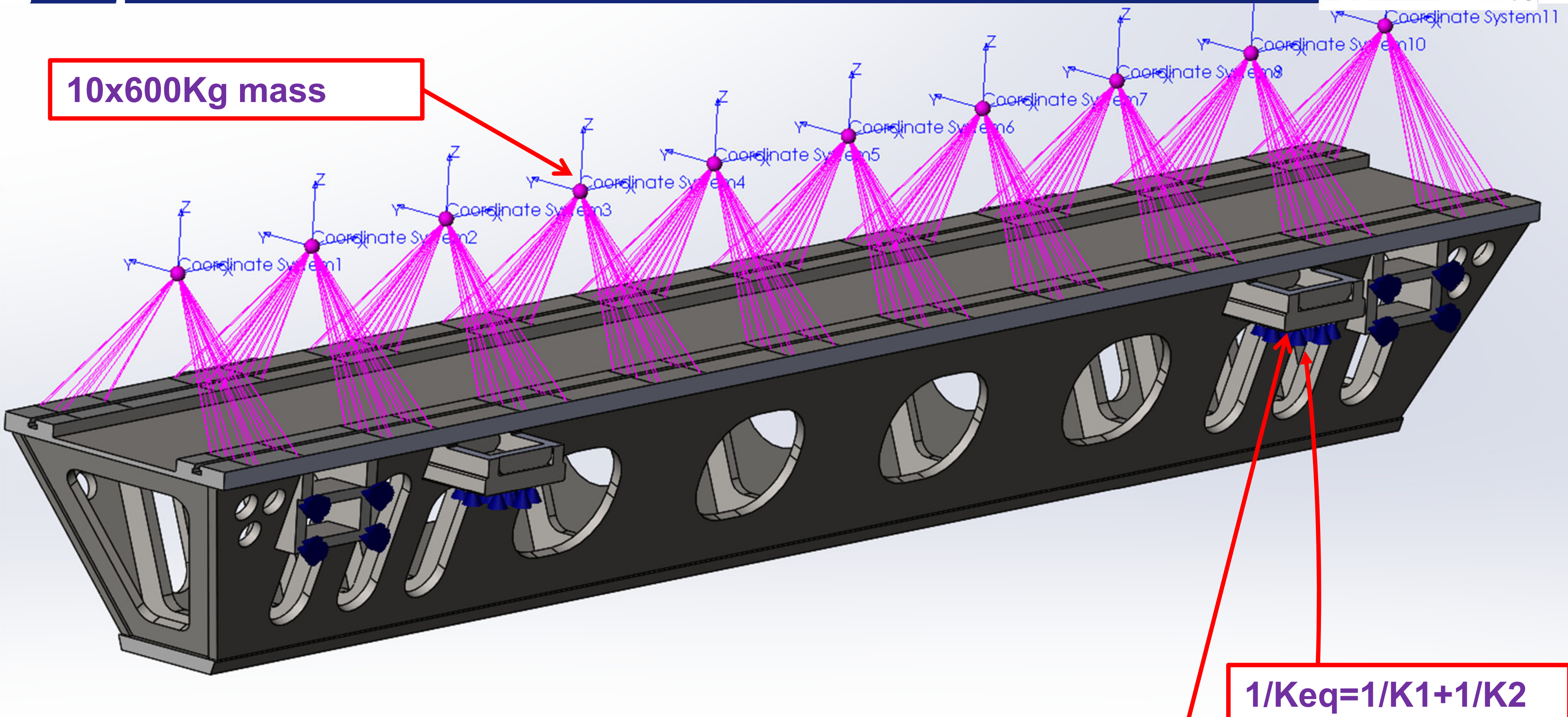
For the Nivell DK4 with modified spherical socket charged with 5T the lateral stiffness is about 400N/µm



$$1/K_{eq}=1/K1+1/K2$$

Dir.	Position	Ground+slab+base stiffness	Adj system (in the relative direction):	Global stiffness of equivalent elastic foundation
X	Vertical support	667N/μm	1200N/μm	429N/μm
Y	Vertical support	435N/μm	1100N/μm	311N/μm
Y	Y jack	417N/μm	500N/μm	227N/μm
Z	Vertical support	769N/μm	1600N/μm	519N/μm

FINAL ANALYSIS



Dir.	Position	Ground+slab+base stiffness	Adj system (in the relative direction):	Global stiffness of equivalent elastic foundation
X	Vertical support	667N/µm	1200N/µm	429N/µm
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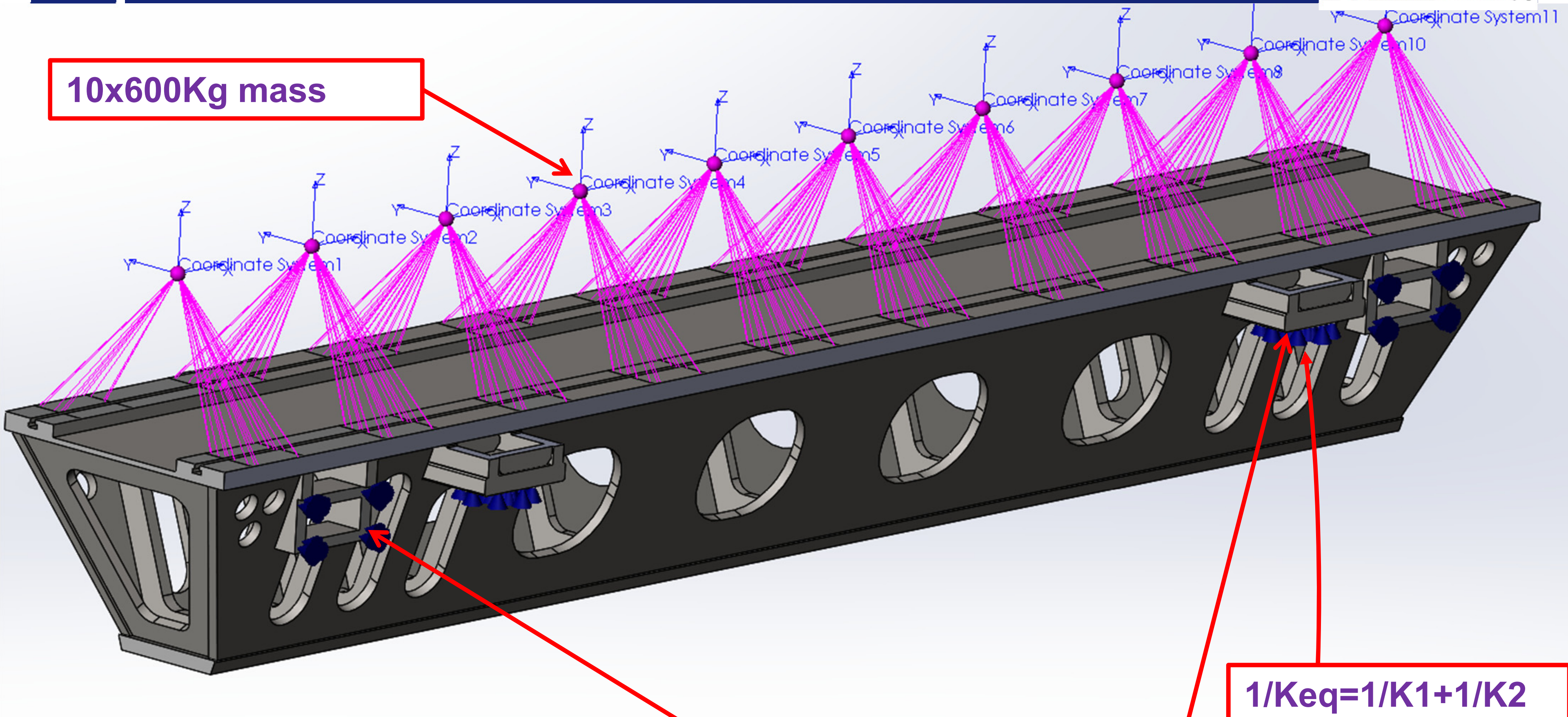
FINAL ANALYSIS



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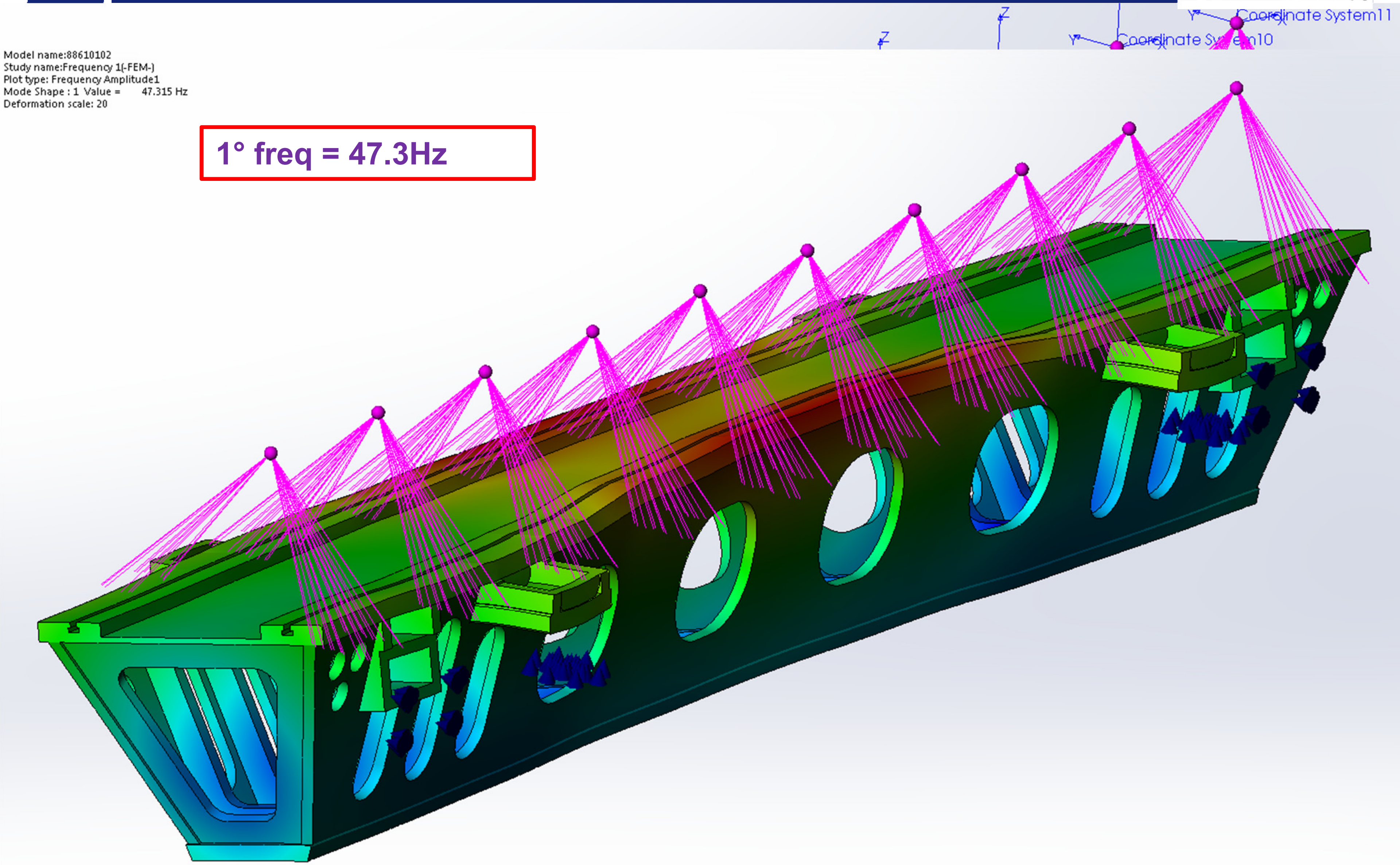
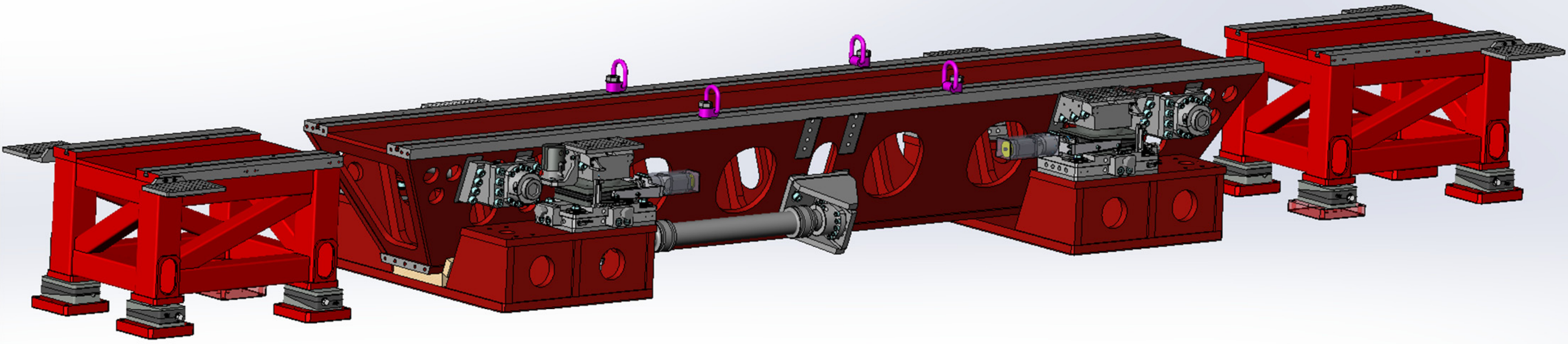
FINAL ANALYSIS

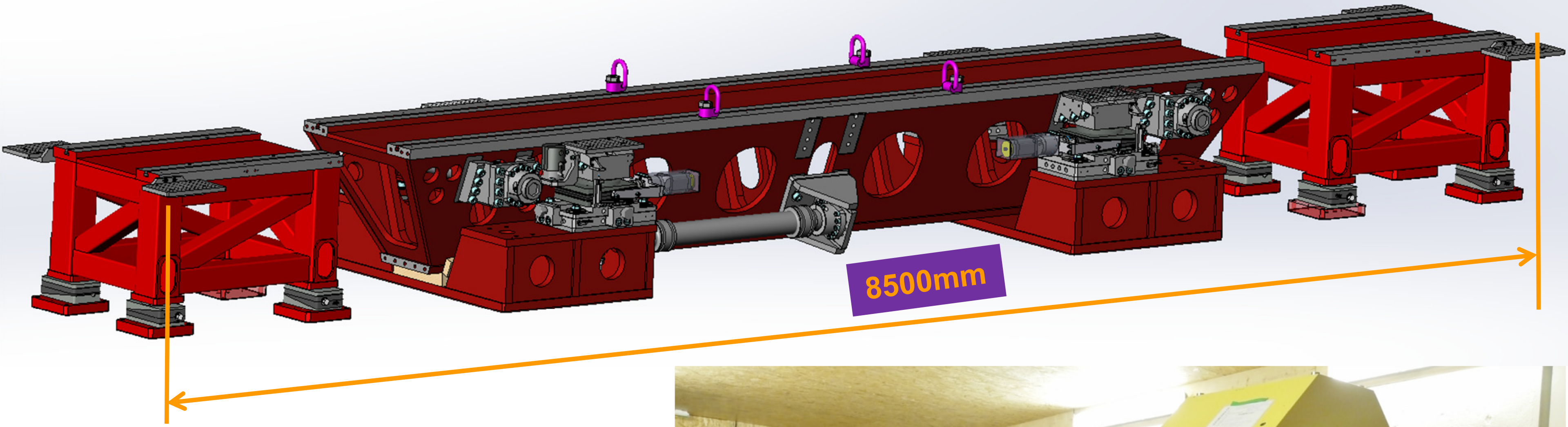


Z	Vertical support	769N/µm	1600N/µm	519N/µm

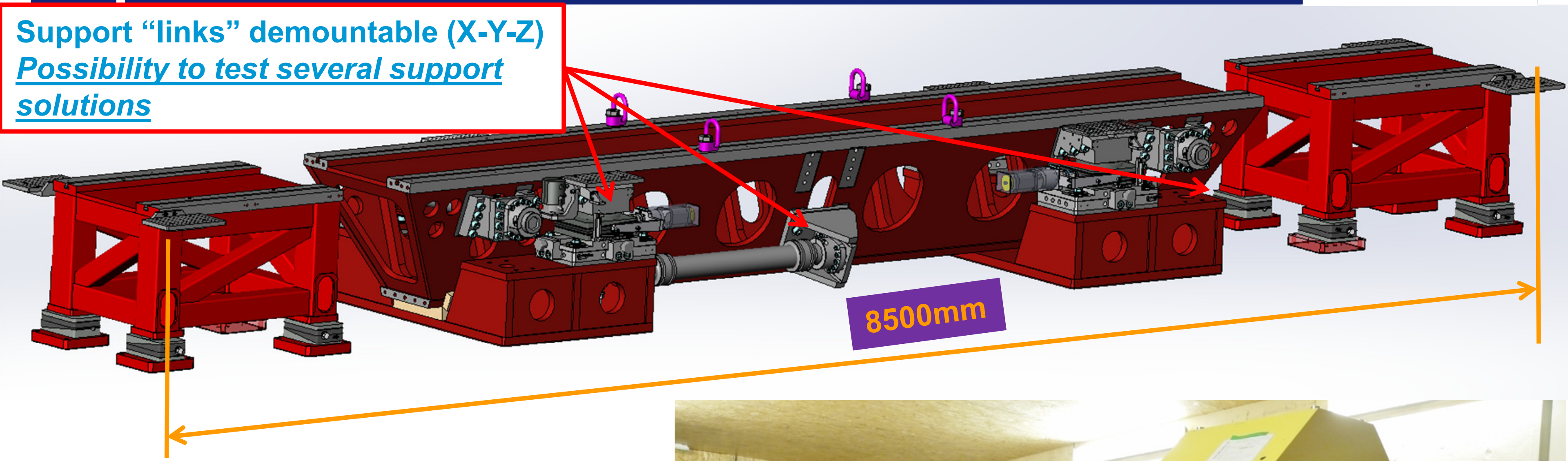
PROTOTYPE



PROTOTYPE



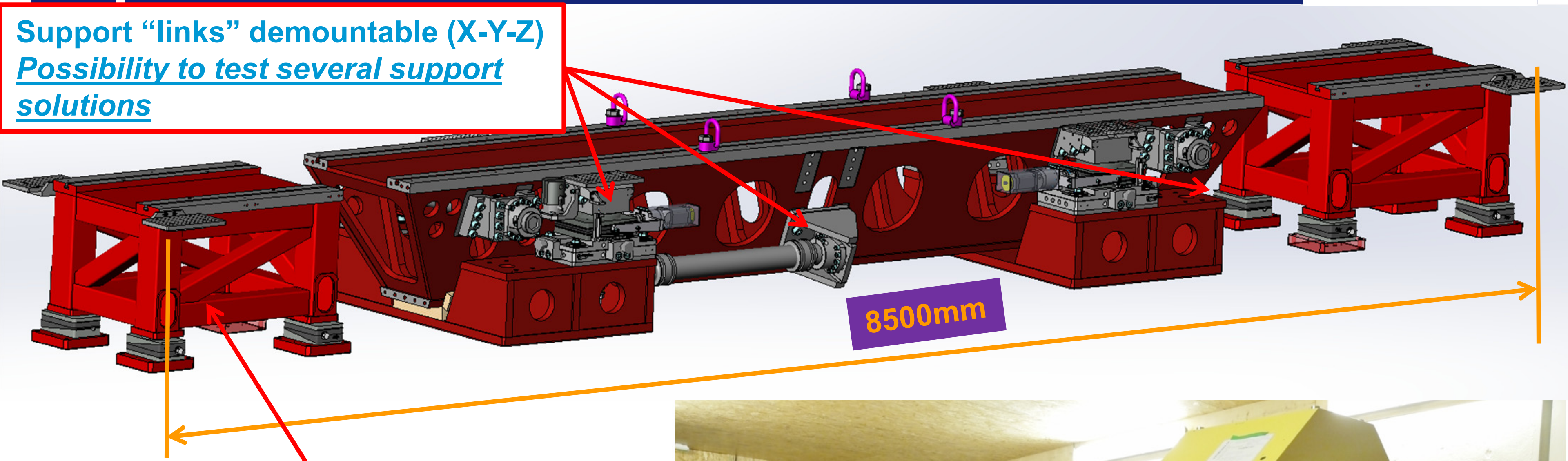
PROTOTYPE



Support "links" demountable (X-Y-Z)
Possibility to test several support solutions
8500mm

PROTOTYPE

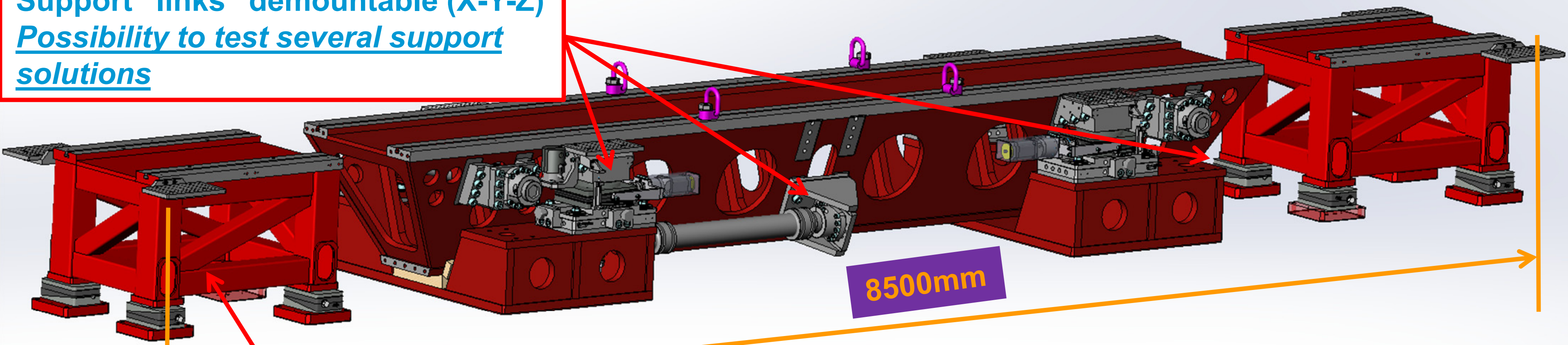
Support “links” demountable (X-Y-Z)
Possibility to test several support solutions



“Fake” girders to test the alignment system of different girders and support of the central magnet (DQ2)

PROTOTYPE

Support "links" demountable (X-Y-Z)
Possibility to test several support solutions

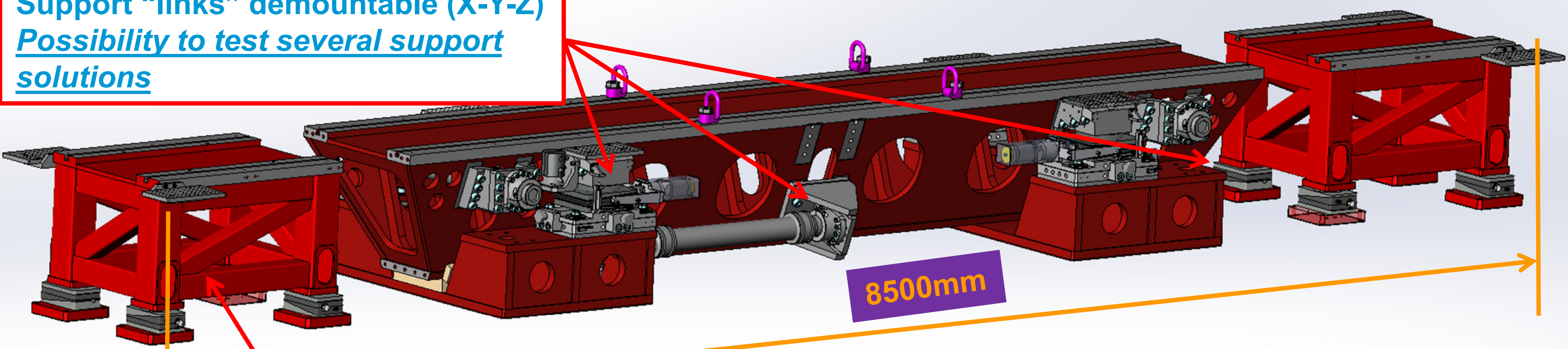


"Fake" girders to test the alignment system of different girders and support of the central magnet (DQ2)

Dummy magnets

PROTOTYPE

Support "links" demountable (X-Y-Z)
Possibility to test several support solutions

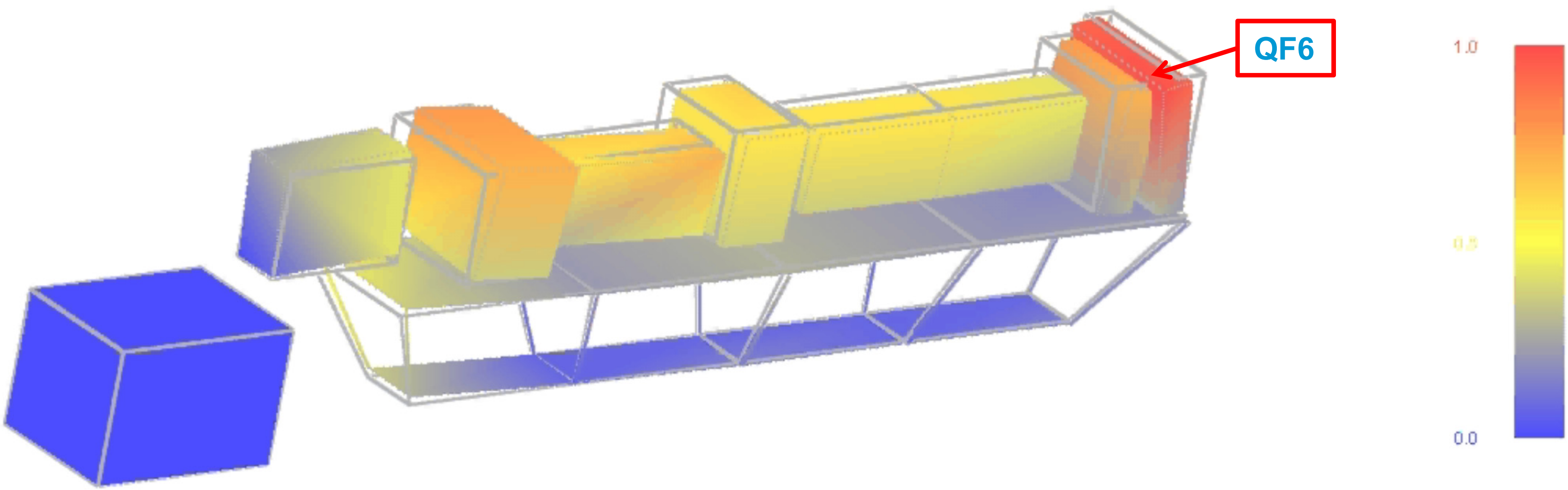


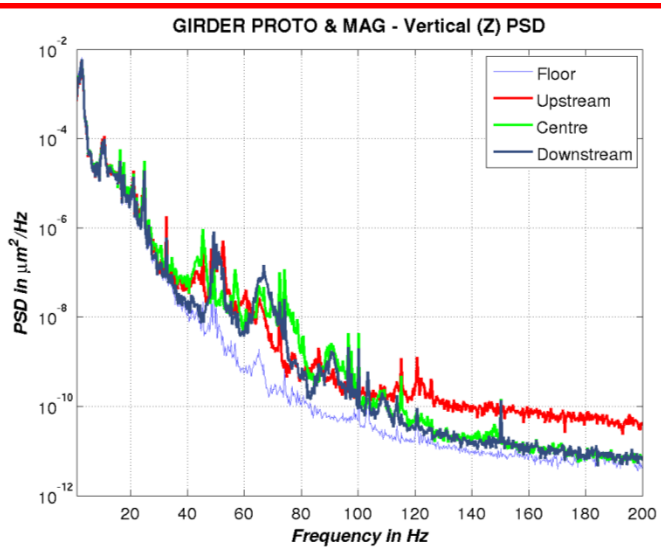
"Fake" girders to test the alignment system of different girders and support of the central magnet (DQ2)

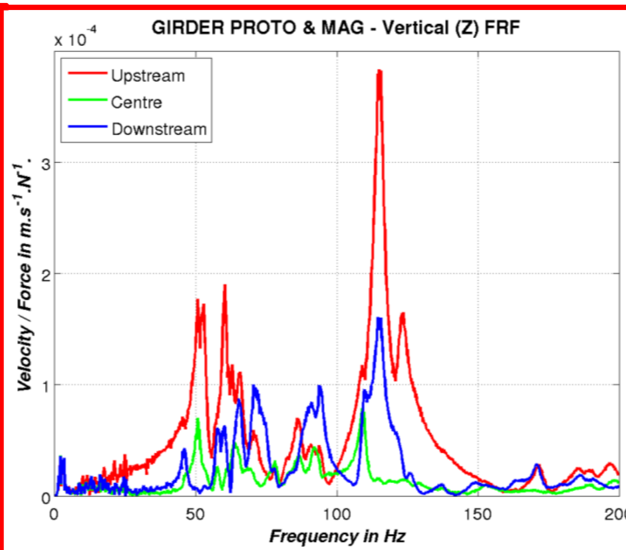
Dummy magnets

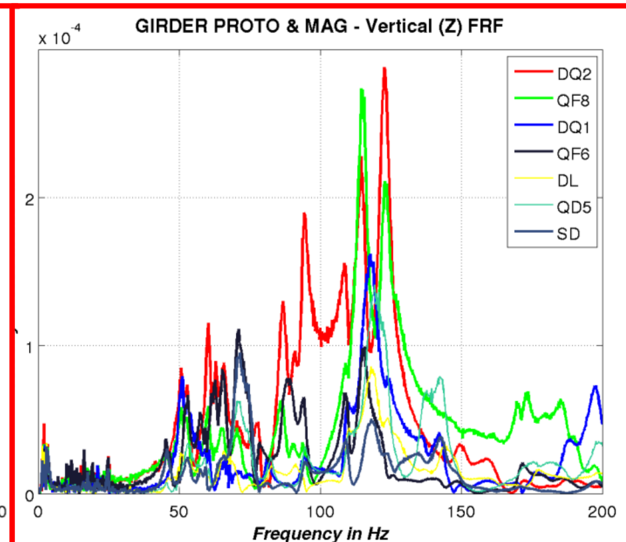
The girder prototype was completed adding walls and roof simulating a segment of the tunnel, in order to make installation test of plants and alignment system

PROTOTYPE TEST (MARC LESOURD)

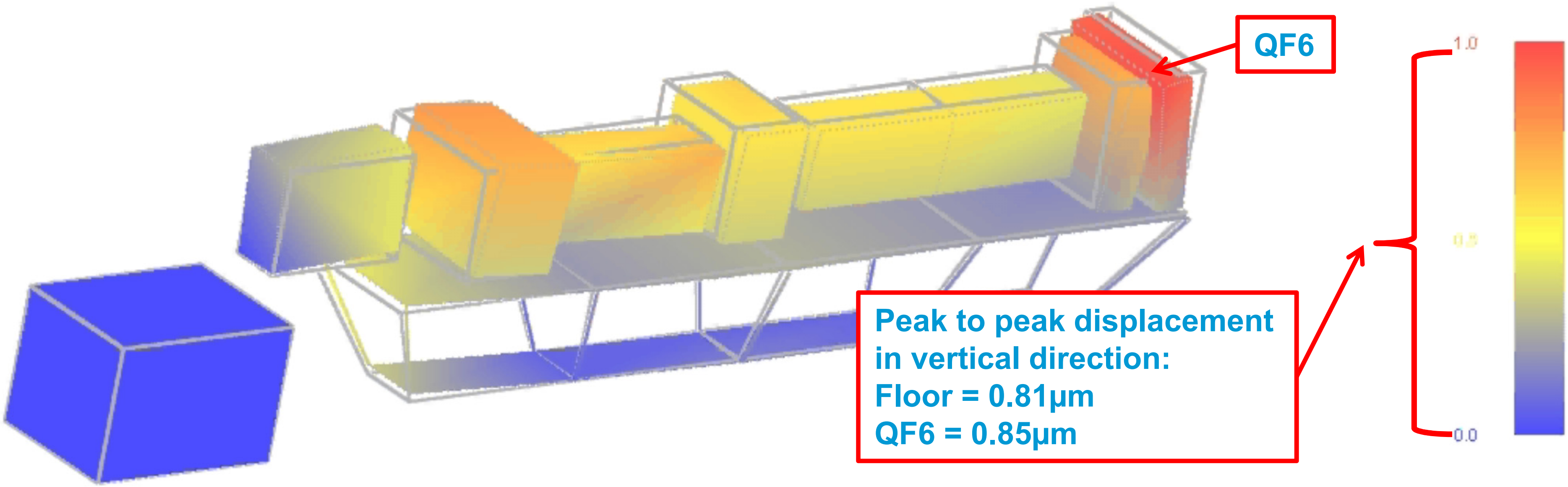




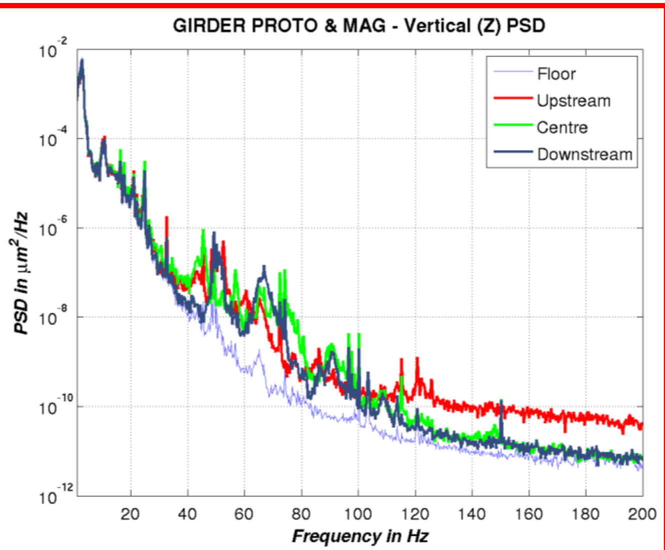


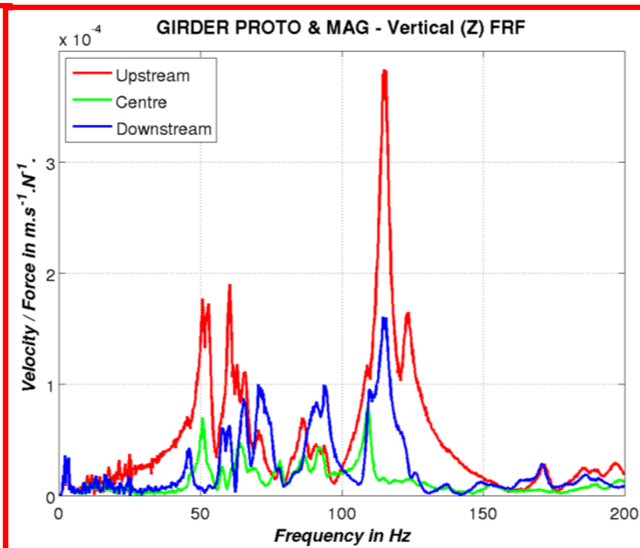


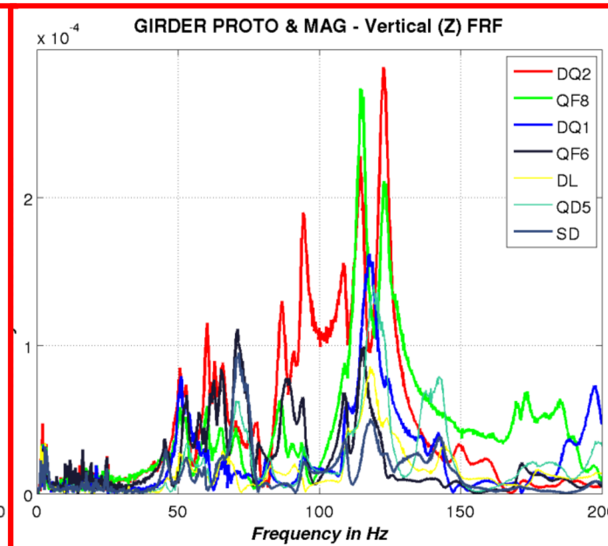
PROTOTYPE TEST (MARC LESOURD)



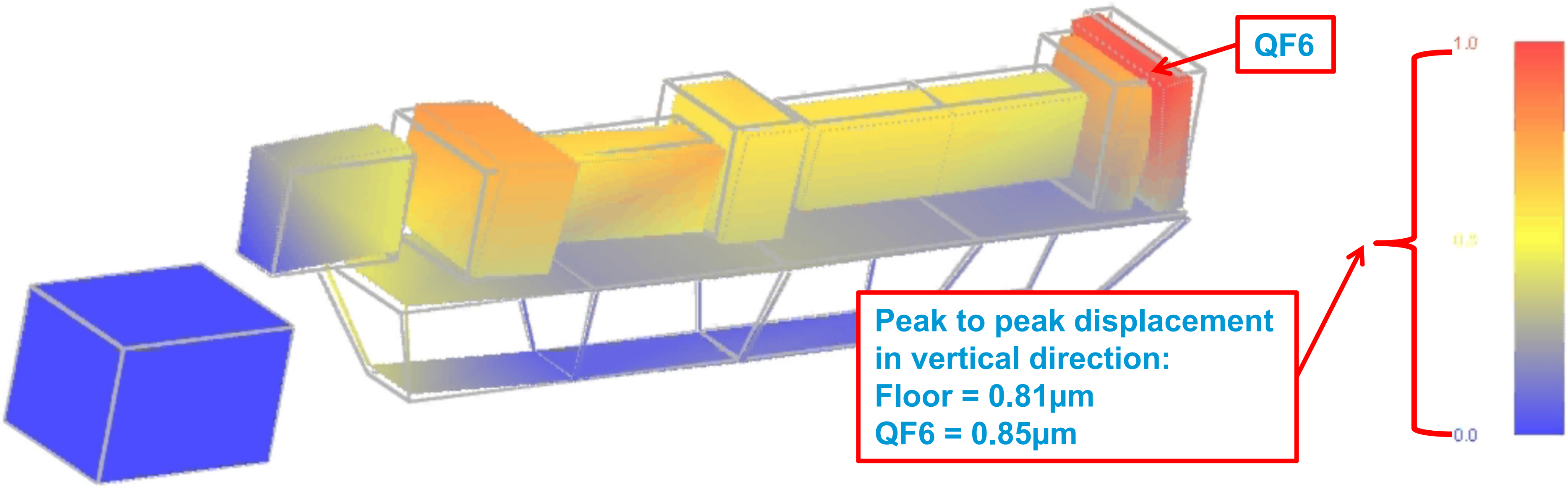
Peak to peak displacement in vertical direction:
Floor = 0.81µm
QF6 = 0.85µm

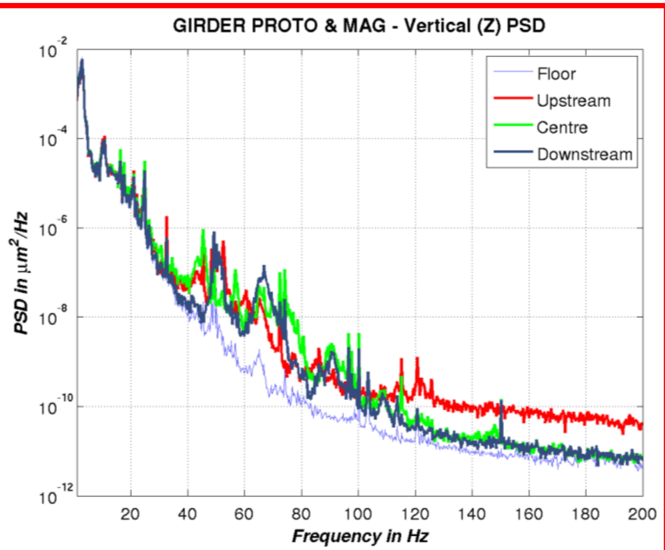


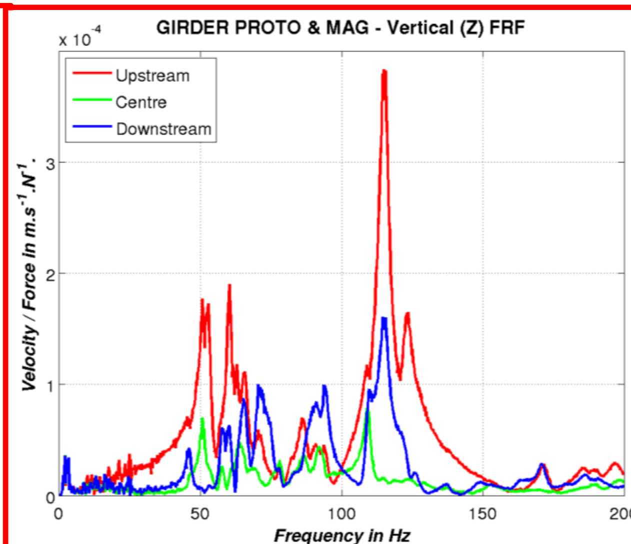


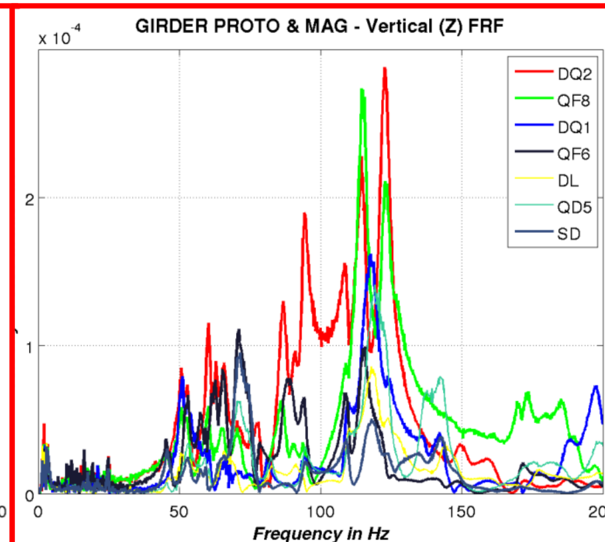


PROTOTYPE TEST (MARC LESOURD)



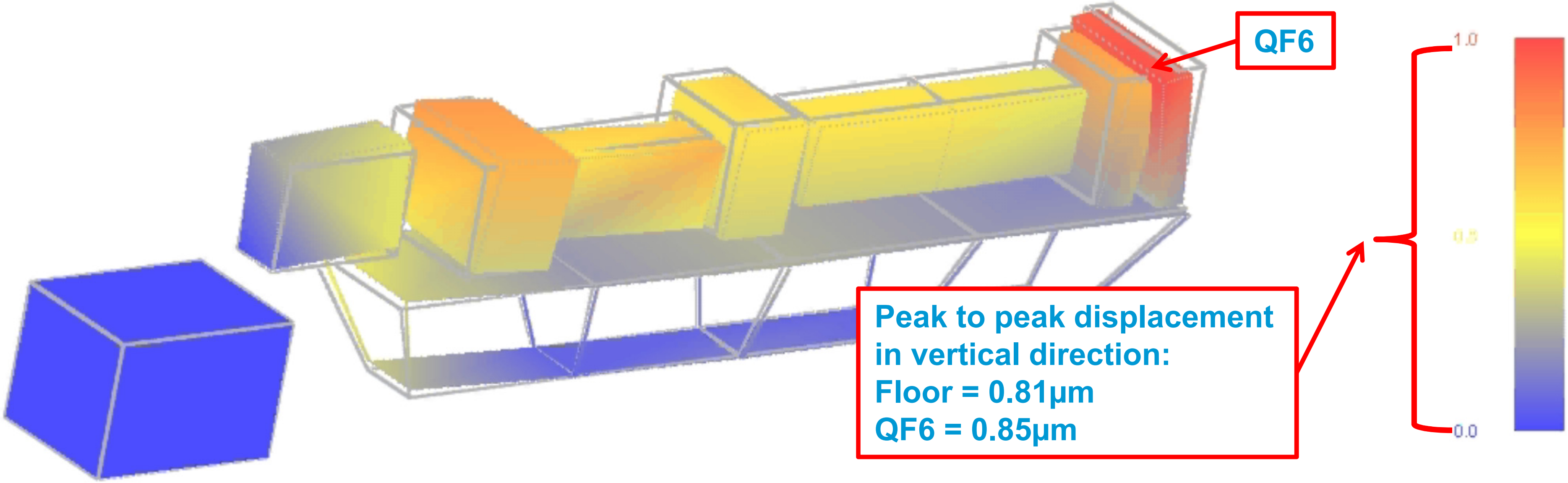


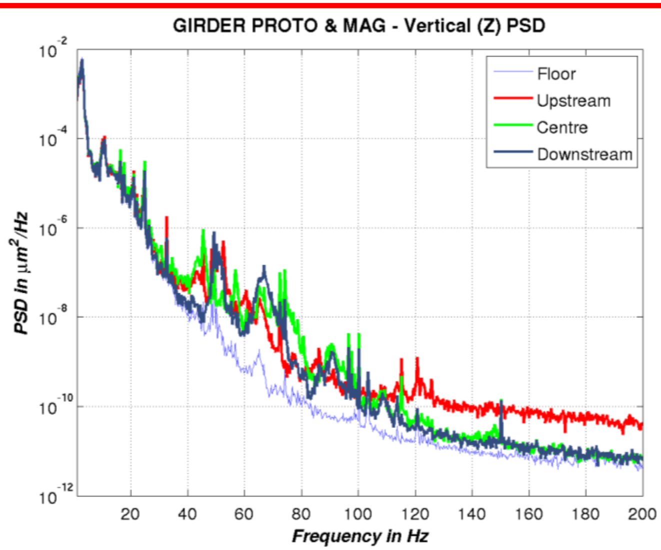




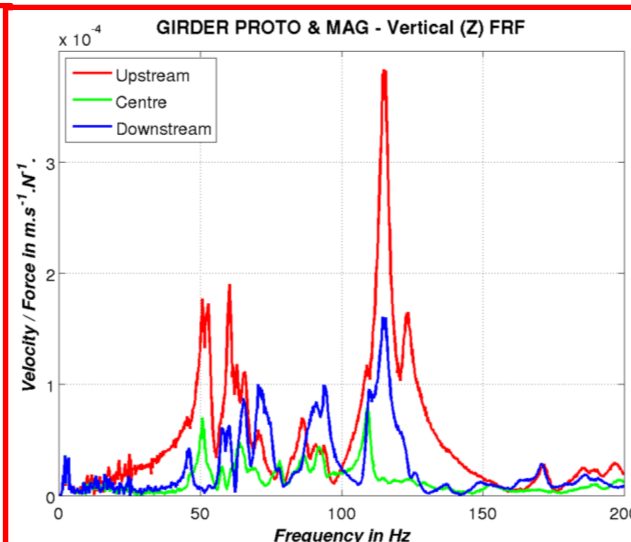
Ground noise amplification

PROTOTYPE TEST (MARC LESOURD)

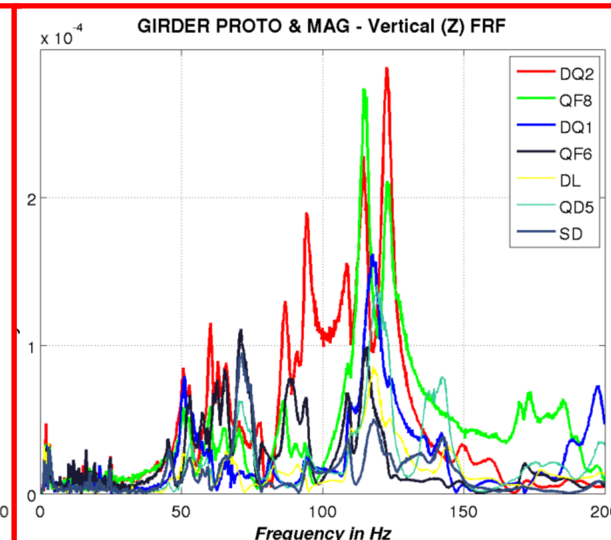




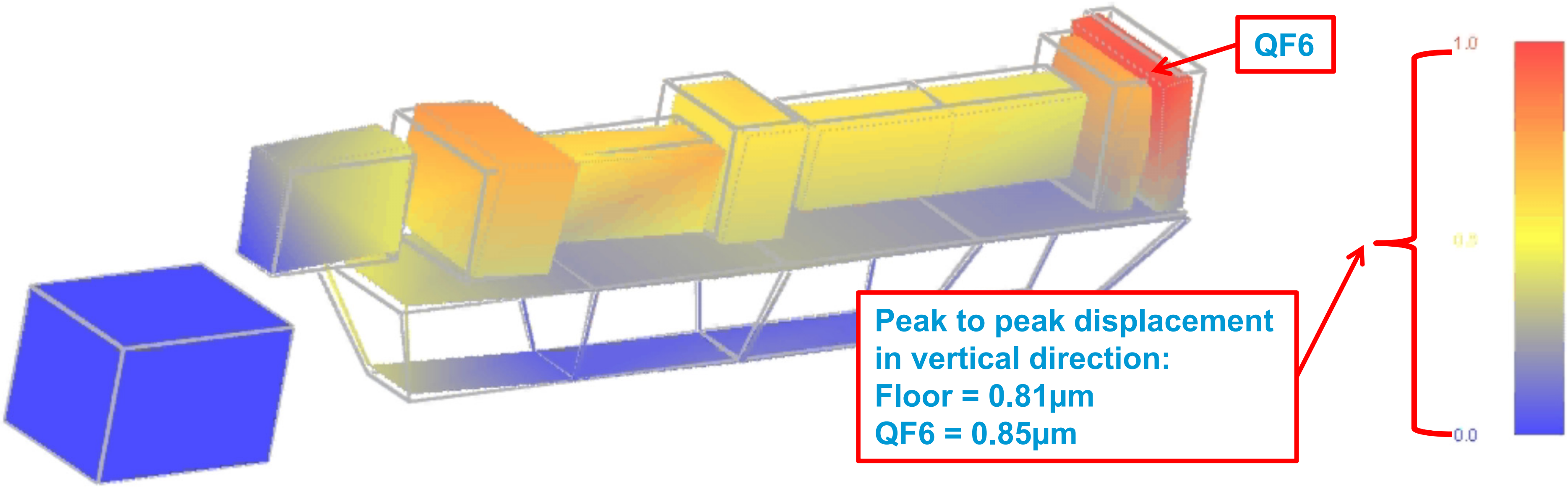
Ground noise amplification

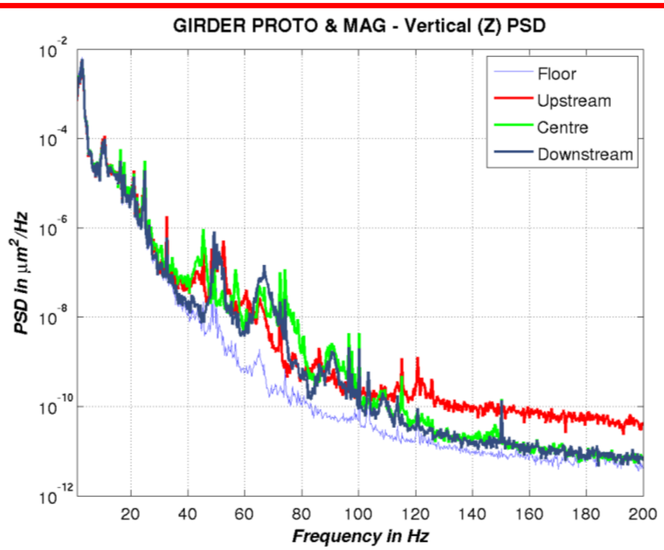


Excitation with hammer on girder

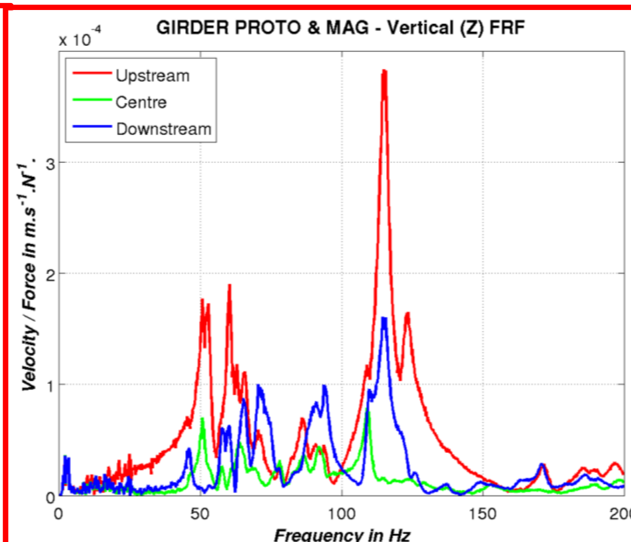


PROTOTYPE TEST (MARC LESOURD)

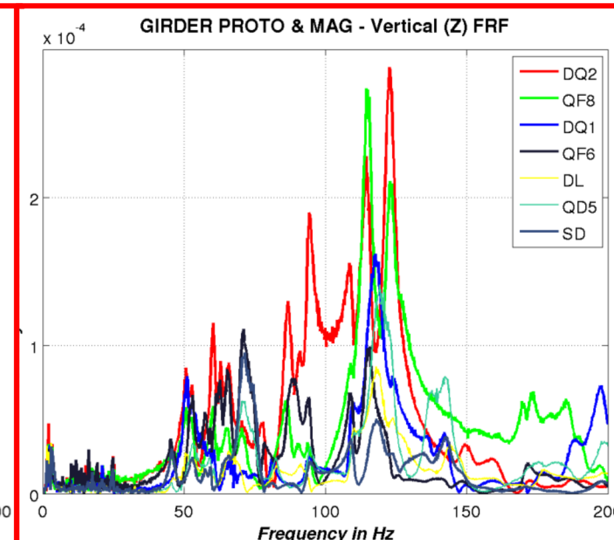




Ground noise amplification

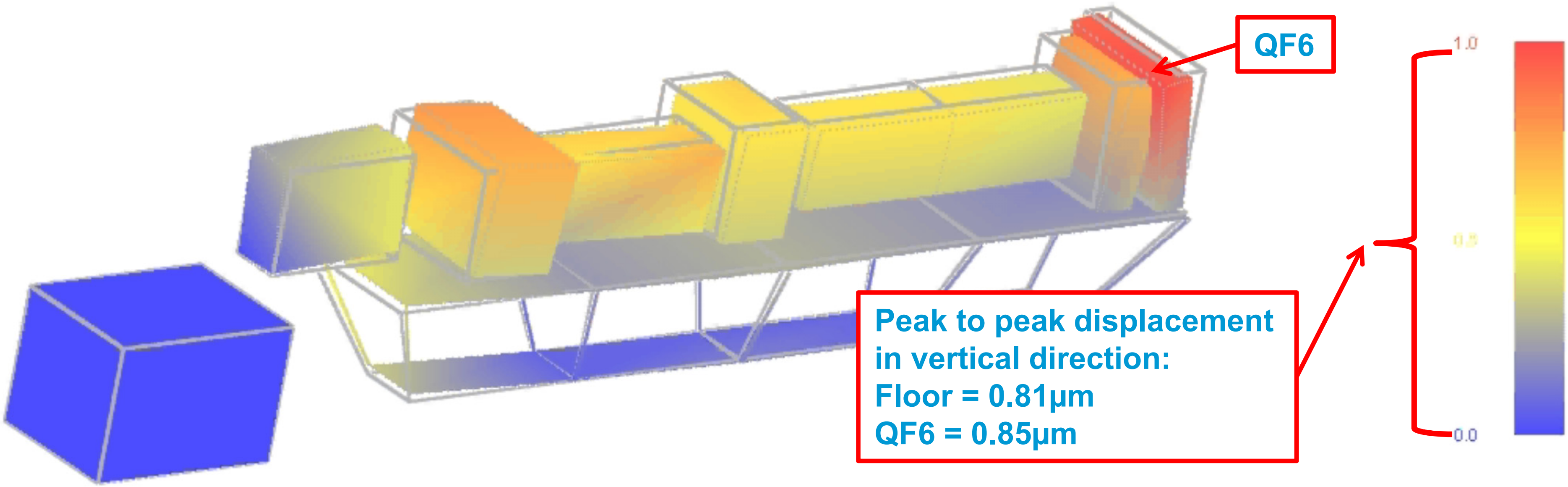


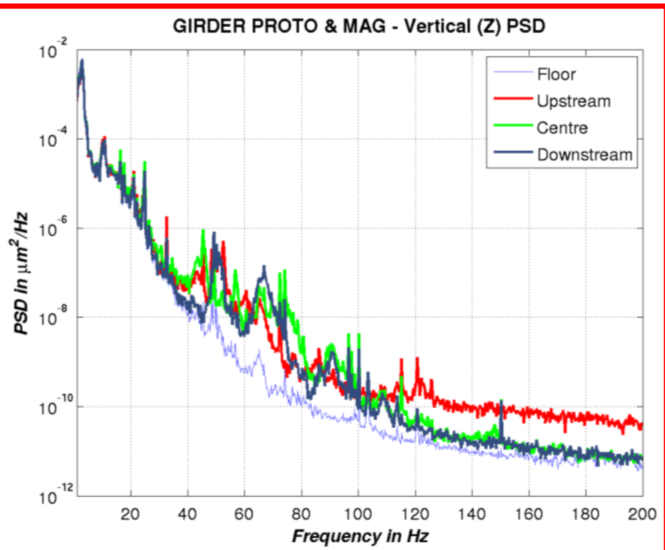
Excitation with hammer on girder

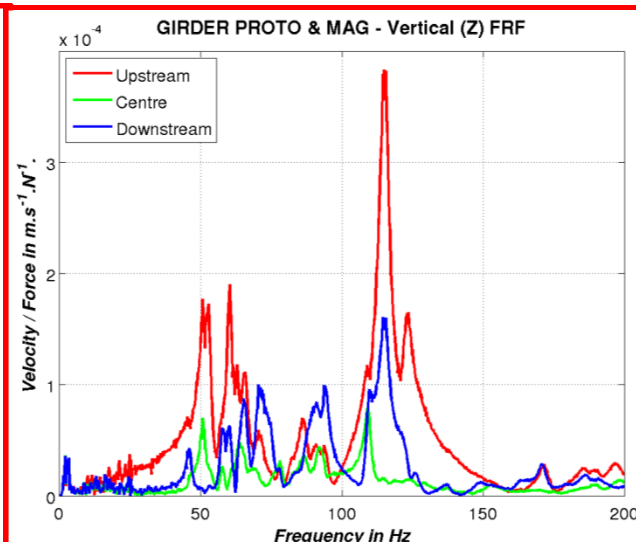


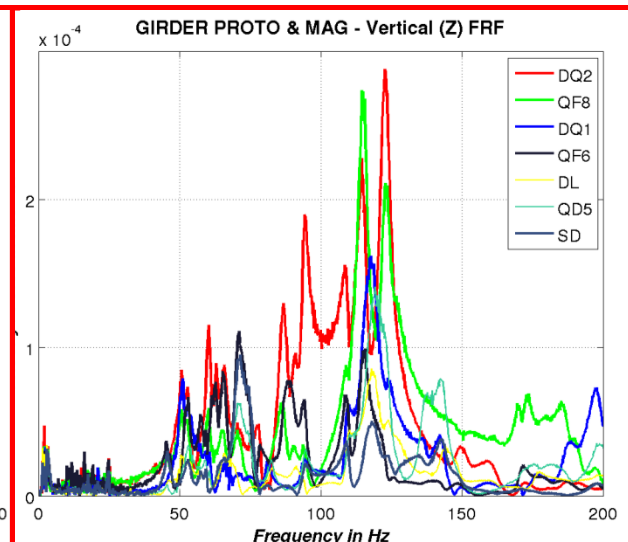
Excitation with hammer on magnets

PROTOTYPE TEST (MARC LESOURD)









Ground noise amplification

Excitation with hammer on girder

Excitation with hammer on magnets

First vibration mode involving the girder: 51Hz

Thanks for your attention!

Filippo Cianciosi – cianciosi@esrf.fr