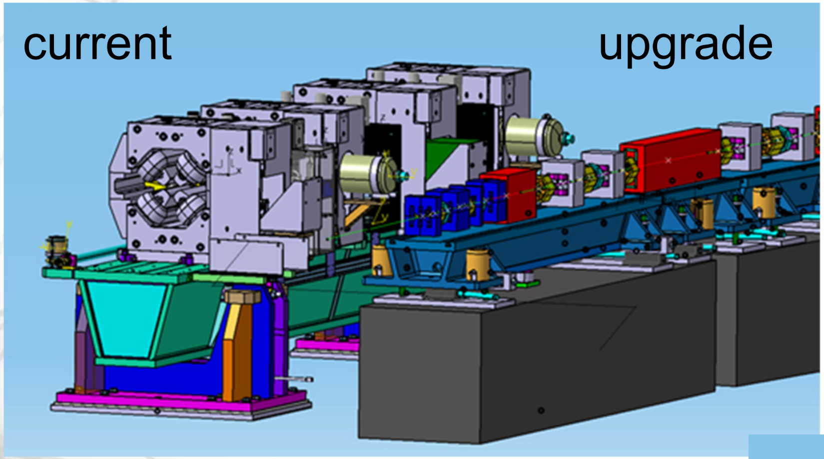
Design of girders on the new upgrade lattice at SOLEIL

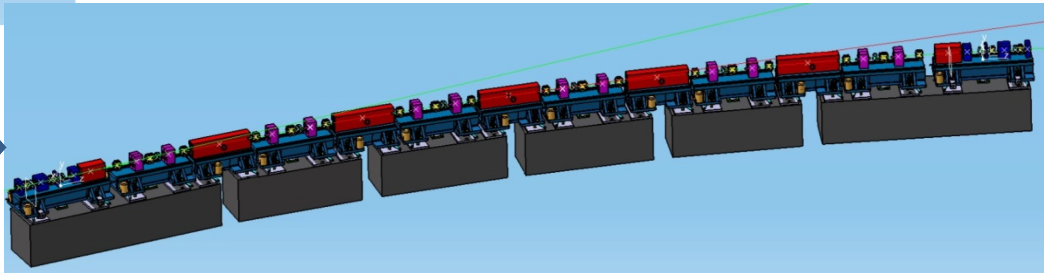
What's new for the upgrade?



Current girder set features 4 girder types:

- weight : 1.85 Ton to 3 Tons
- mass payload : 4.1 Tons to 8 Tons
- length : 2.40 m to 4.80 m

REFERENCE LATTICE FOR UPGRADE CDR :



Smaller size of new generation magnets :

- size and weight reduction of the magnet-girder assemblies.
- number of magnets and girders increased by a factor of 3.
- alignment and installation operations must be optimized.

Greater compactness of the new lattice :

- Limited access in the area between girders and tunnel wall.

Main guidelines for magnet / girder design

- Smaller magnets => distance between beam axis and top face: 240 mm vs 400 mm.
- Girder/ground position higher => the previous pedestal system is no longer suitable.
- Great number of magnets and girders => alignment operation must be optimized.
- needs cost effective manufacturing.
- Lighter payload and shorter girders => better mass/stiffness ratio.
- Greater stability requirements => use of high preload on levelling system.

Specifications not yet defined or subject to change:

- Dynamic sensitivity of beam towards magnet position: lowest frequency > 70 Hz
- Sensitivity of beam towards magnet alignment: girder to girder 30 µm vertical and 50µm horizontal
  100 µm RMS in both planes for all girders
- Thermal stability based upon BPM specification:
  - 50 nm a couple of minutes
  - 500 nm on one day
  - ~ 1 µm on a week
- Actual size of all magnets not yet defined.
- Ex situ bake-out has been decided => use of C-shape dipoles and transverse motion mandatory to insert or remove the vacuum chamber.

Common features of the new magnet / girder

- Girders lay on steel or granite blocs glued to the ground with ±1mm accuracy.
- 4 or 6 setting points using wedge jacks and pushing screws.
- Magnet positioning using top and side datum surfaces.
- Permanent pre-load springs on setting points.
- Motorized setting not necessary considering the stability of the slab.
- Construction based on cast steel parts welded to plates.
- Integration of Hydrostatic Levelling System (HLS): used during alignment operations only.

3 LAYOUTS HAVE BEEN STUDIED:

- 212 girders
- 116 girders
- 172 girders with standalone long dipoles

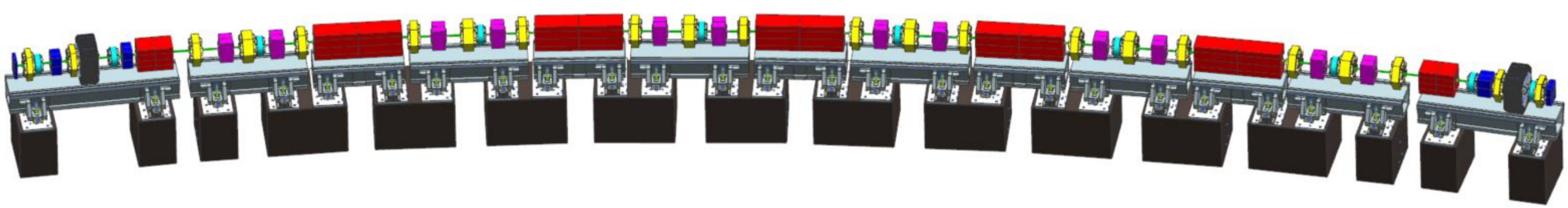
SOLEIL SYNCHROTRON UPGRADE

Typical lattice setup with 212 girders

Girder type	Length	Width x height	Mass	Payload*	Number
long	1.80 m	400 x 250 mm	712 Kg	500 Kg	8
medium	1.50 m		650 Kg	400 Kg	32
short	1.24 m		570 Kg	300 Kg	96
dipole	0.96 m		485 Kg	490 Kg	76

Plinth type	Width x height	Length	Mass	Number
double	700 x 575 mm	0.85 m	923 Kg	168
simple		0.40 m	435 Kg	64

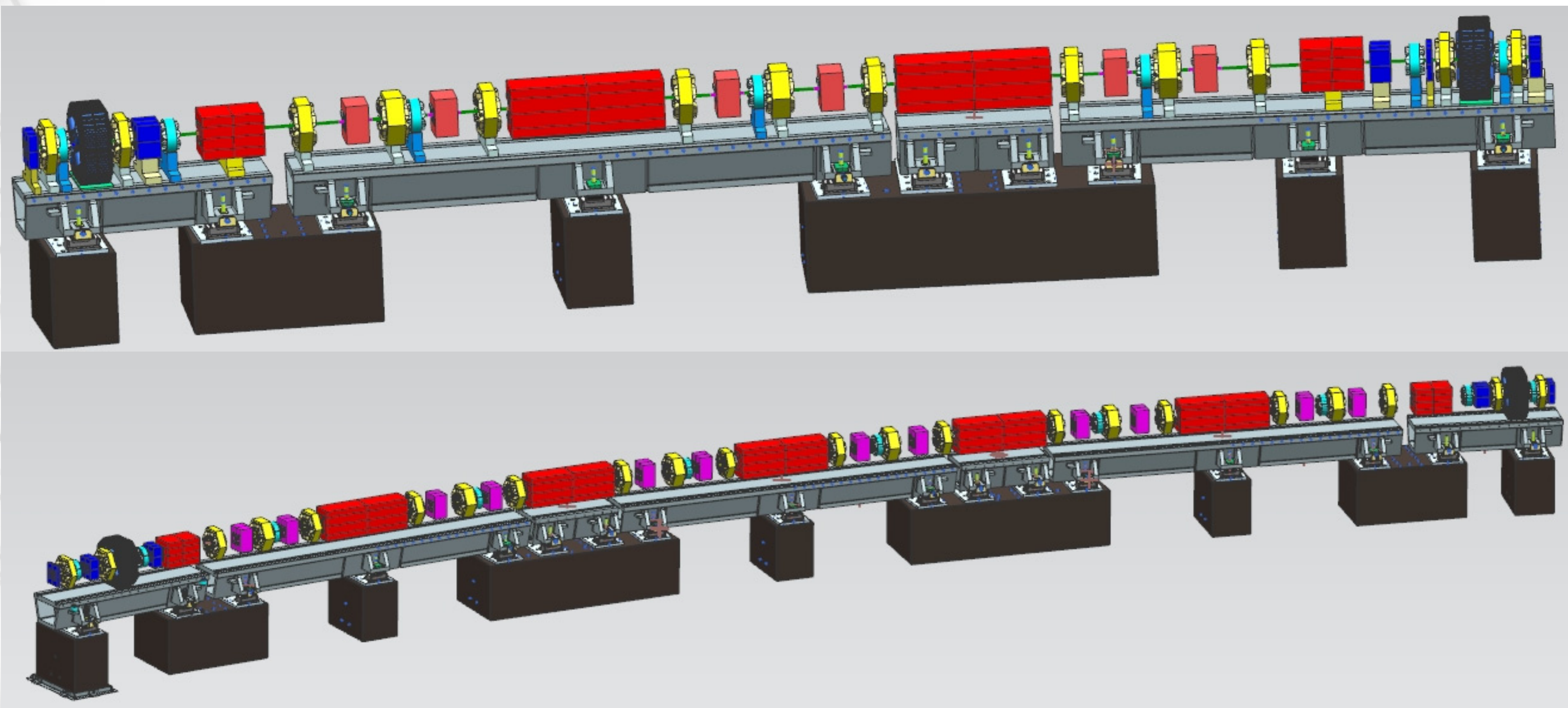
* Estimated values based on preliminary design of magnets



TYPICAL 7 BENDING ACHROMAT LAYOUT

Typical lattice setup with 116 girders

Girder type	Length	Width x height	Mass	Payload	Number	Plinth type	Width x height	Length	Mass	Number
long	3.60 m		1516 Kg	900 Kg	44	**triple**		2.10 m	2785 Kg	32
medium	2.95 m		1284 Kg	600 Kg	8	**double**	700 x 575 mm	1.15 m	1525 Kg	32
matching 1	1.80 m	450 x 290 mm	712 Kg	500 Kg	12	**simple**		0.40 m	530 Kg	92
Matching 2	1.50 m		650 Kg	400 Kg	20					
dipole	0.96 m		485 Kg	490 Kg	32					

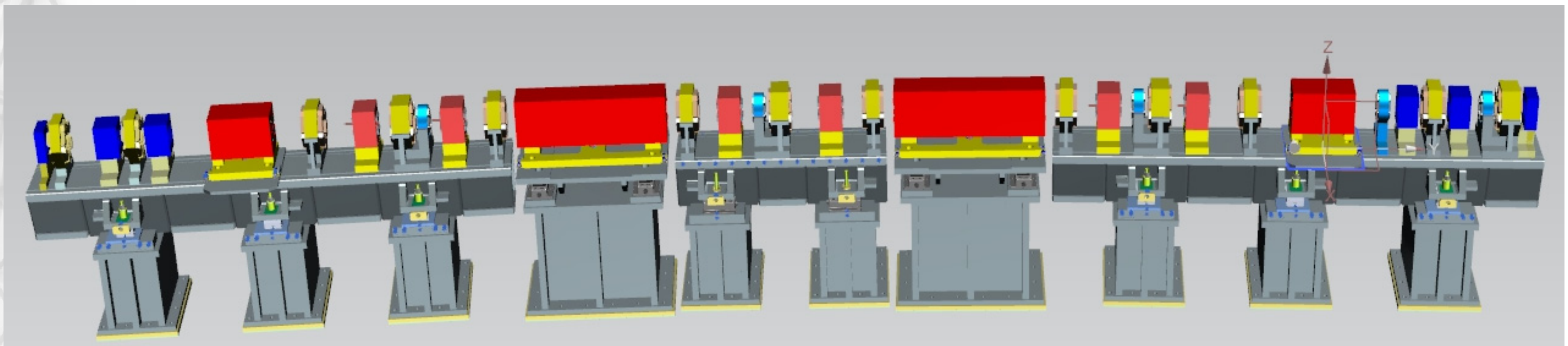


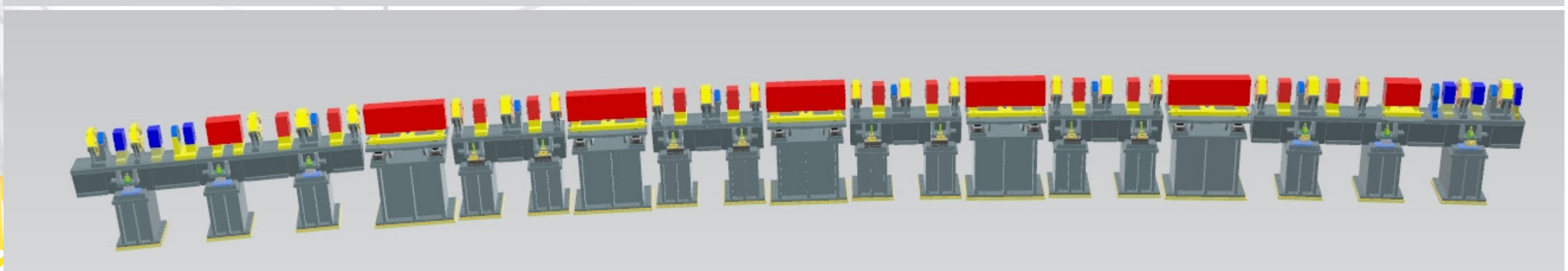
Typical lattice setup with 172 girders

Girder type	Length	Width x height	Mass	Payload	Number
Matching 1	3.20 m	450 x 290 mm	1516 Kg	900 Kg	20
Matching 2	2.95 m		1284 Kg	900 Kg	20
single	1.30 m		712 Kg	500 Kg	56
dipole	0.96 m		485 Kg	490 Kg	76

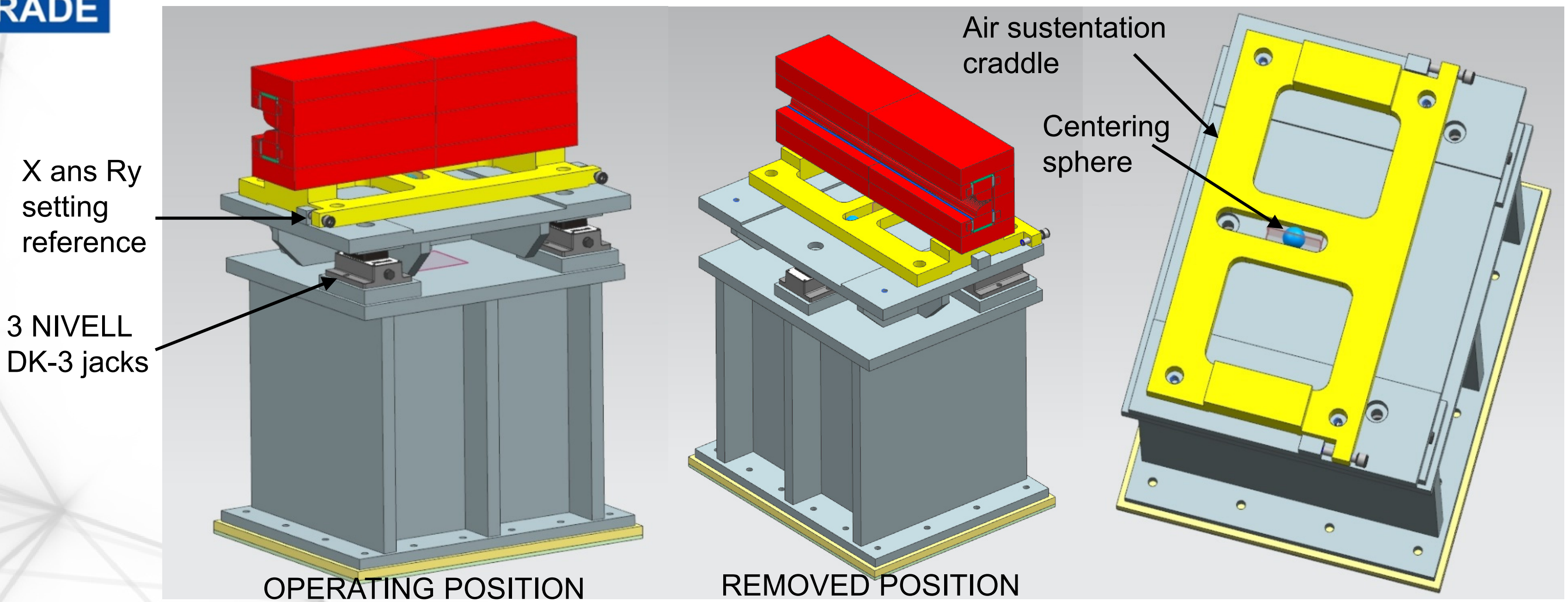
Plinth type	Width x height	Length	Mass	Number
dipole	700 x 575 mm	0.95 m	1525 Kg	76
simple		0.40 m	530 Kg	232

Cast iron or welded steel stands

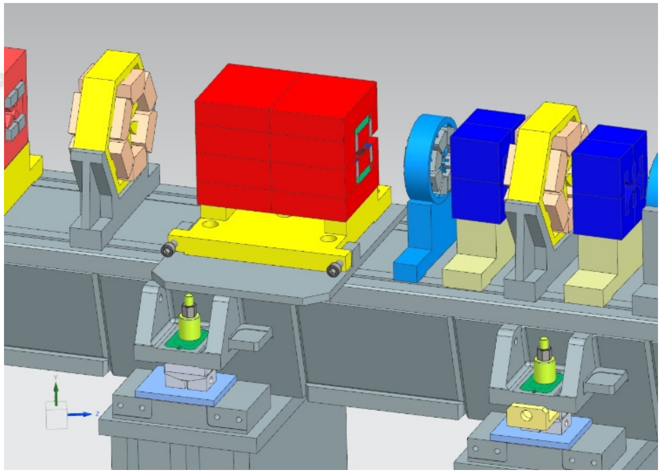




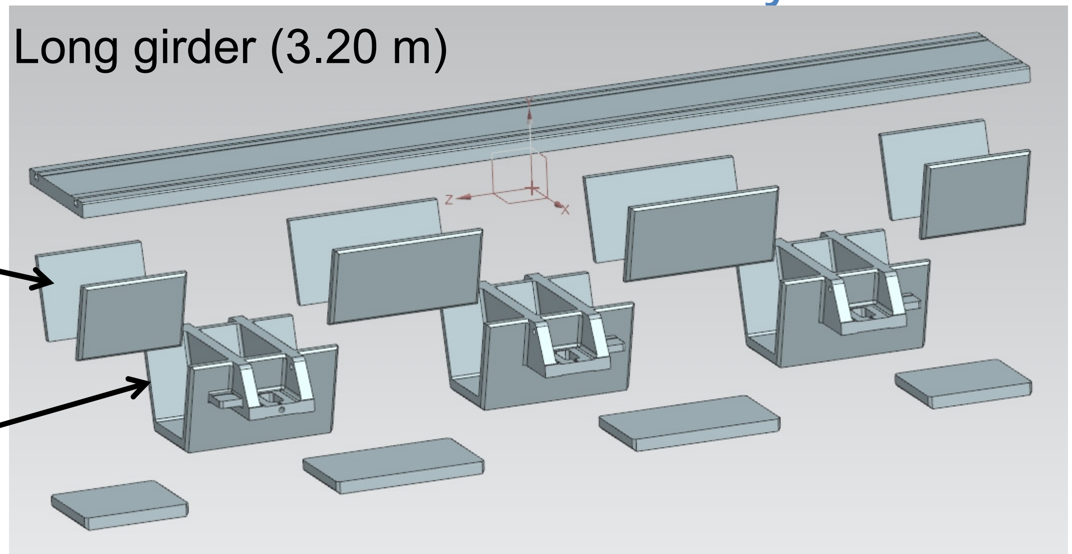
Dipole supports



Short dipole on long girder



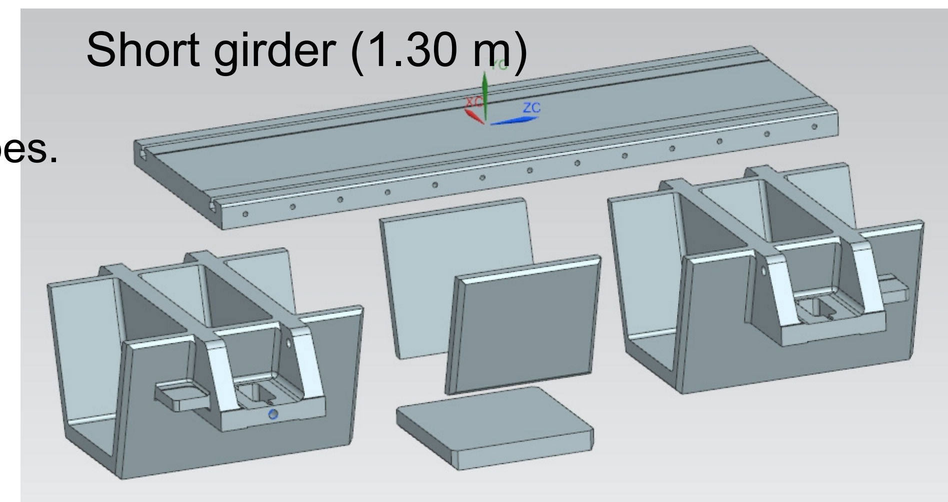
Girder assembly



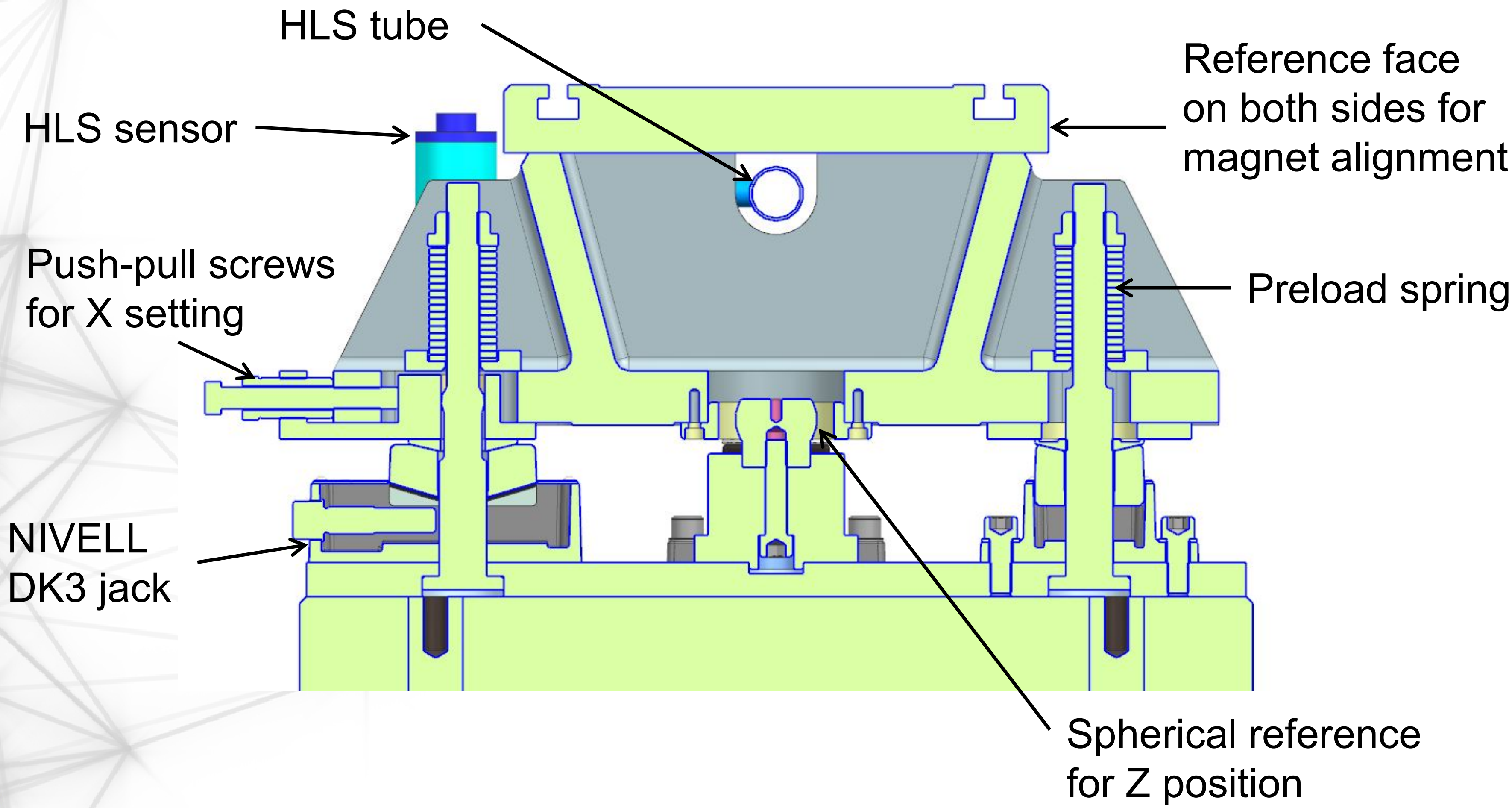
Welded plates

3 Cast steel parts

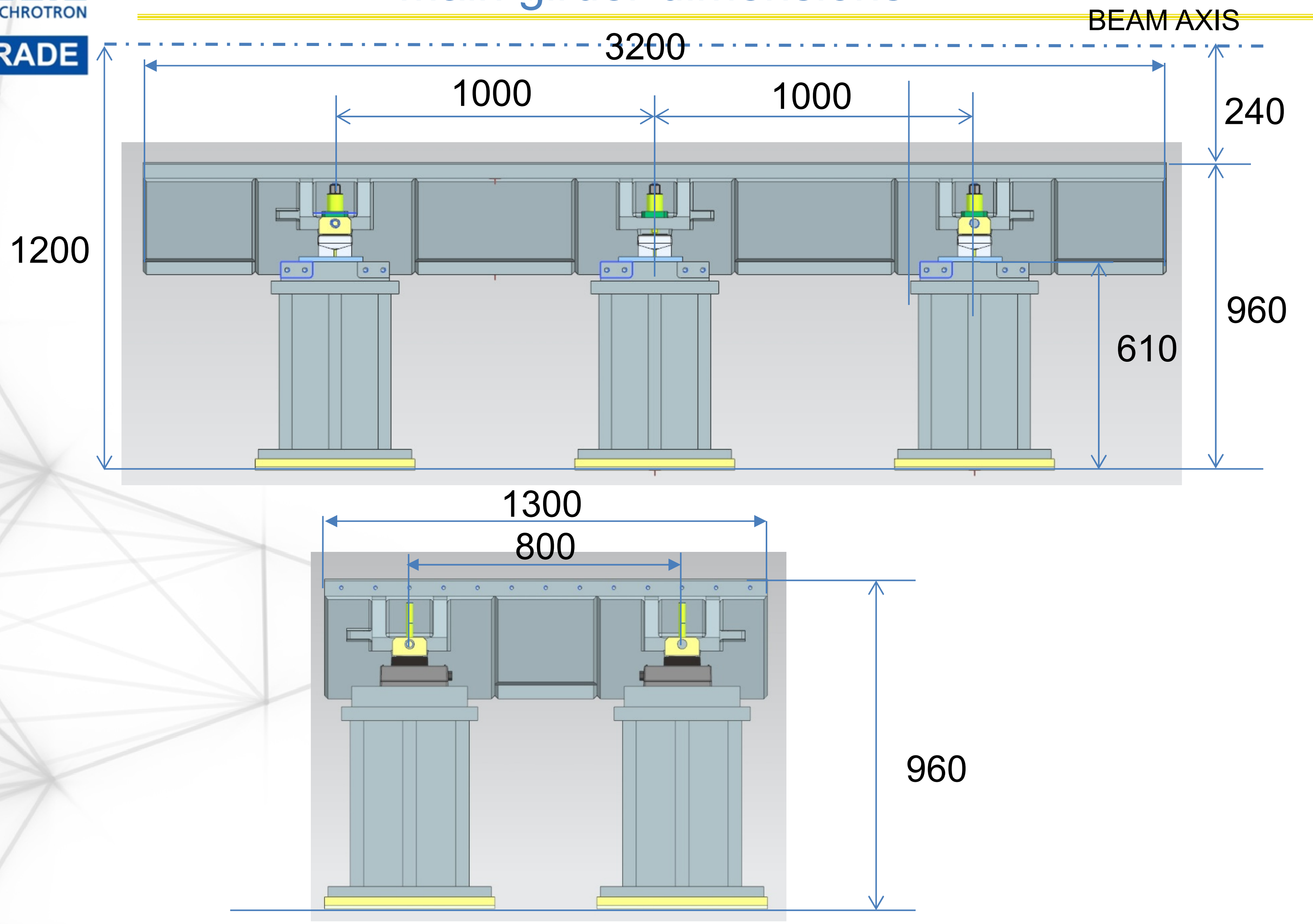
- Assembly of cast steel and welded plates.
- Allows internal stiffeners and complex shapes.
- Cast steel parts are all identical: 232 part series for 172 girder version.
- Less residual stress due to welding.



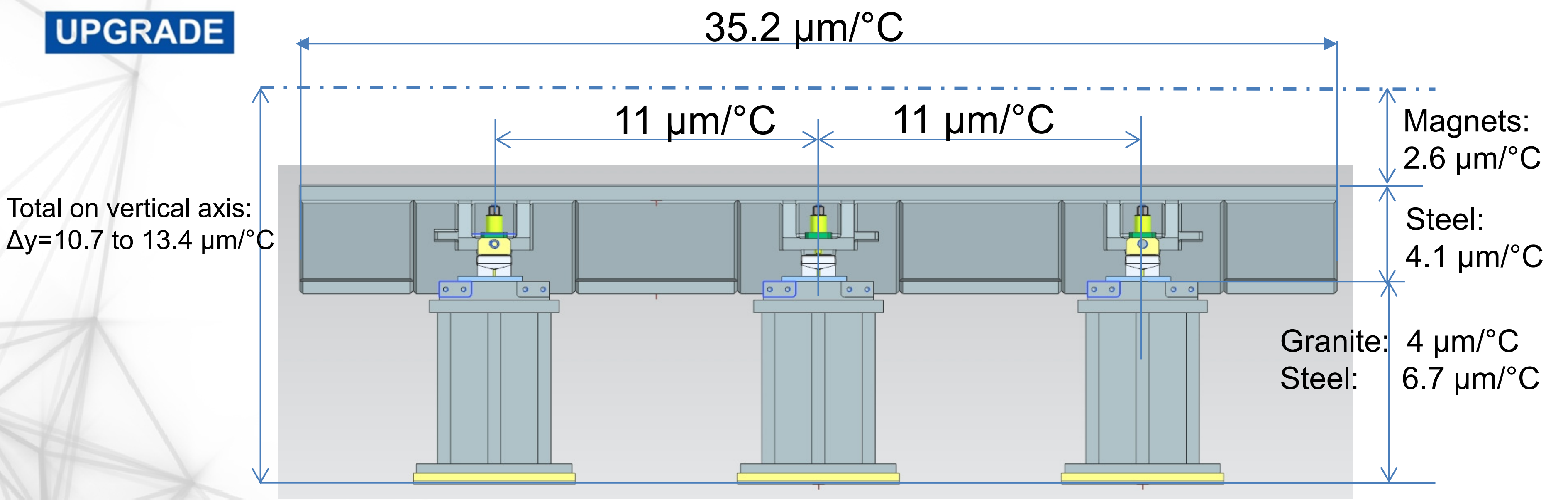
Girder fixation and setting



Main girder dimensions

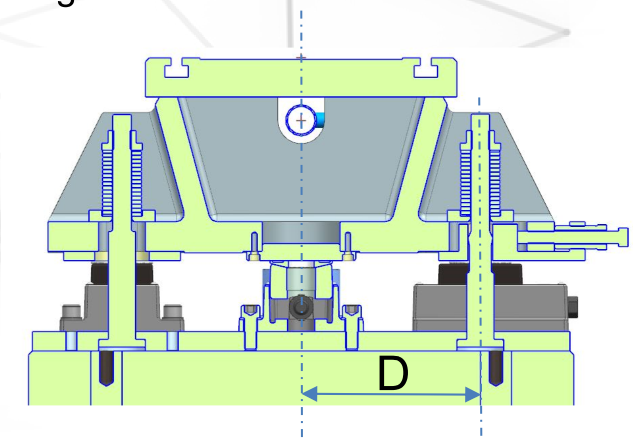


Thermal drift evaluation



Coefficient of thermal expansion (CTE):

- granite: 6.5×10^{-6}
- steel and magnets: 11×10^{-6}



Temperature regulation is ±0.1° in the tunnel

In the transverse direction, thermal expansion is supposed to be symetrical if all the materials are the same.

If the stand is made of granite, an horizontal drift is induced by the difference between granite and steel CTE applied to the D=230 mm distance.

In this case: Δx= 1.5 µm/°C

STEEL OR GRANITE ?

	STEEL	GRANITE
CTE	$11x10^{-6}$	$6.4x10^{-6}$
Density	7.8 $Kg.m^{-3}$	2.7 $Kg.m^{-3}$
Thermal capacity	435 $J.Kg^{-1}.K^{-1}$	837 $J.Kg^{-1}.K^{-1}$
Volumic thermal capacity	3393 $J.m^{-3}.K^{-1}$	2260 $J.m^{-3}.K^{-1}$
Young modulus	210 GPa	60 GPa

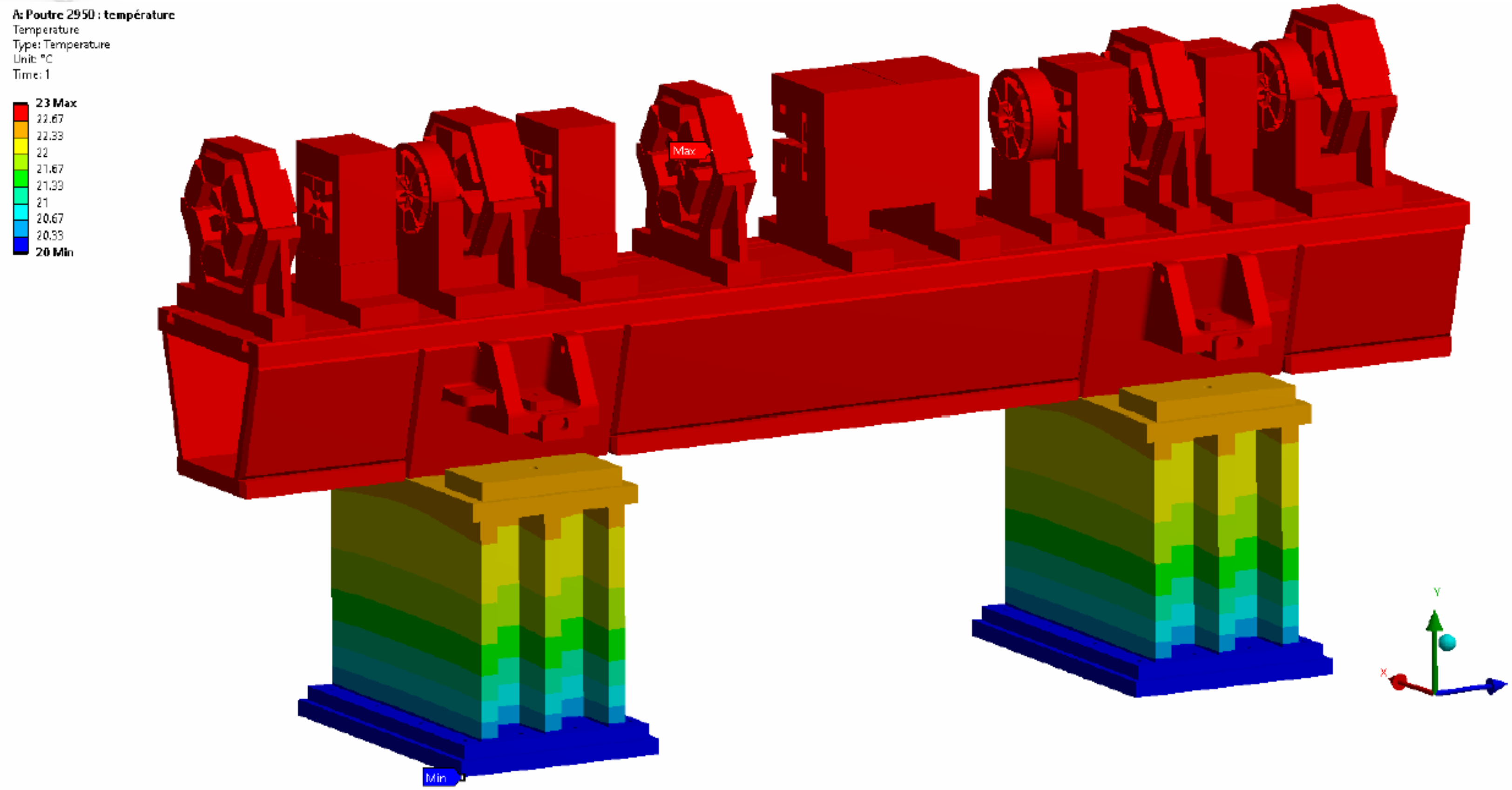
Although volumic heat capacity of granite is lower, stands are massive blocks and yield a better thermal inertia than welded steel plate stands.

In the same way, considering stiffness, low Young modulus of granite is compensated by greater inertia of granite stands.

Steel allows more complex shapes than natural granite.

Cost depends on design and manufacturing process for both materials.

Thermal simulation



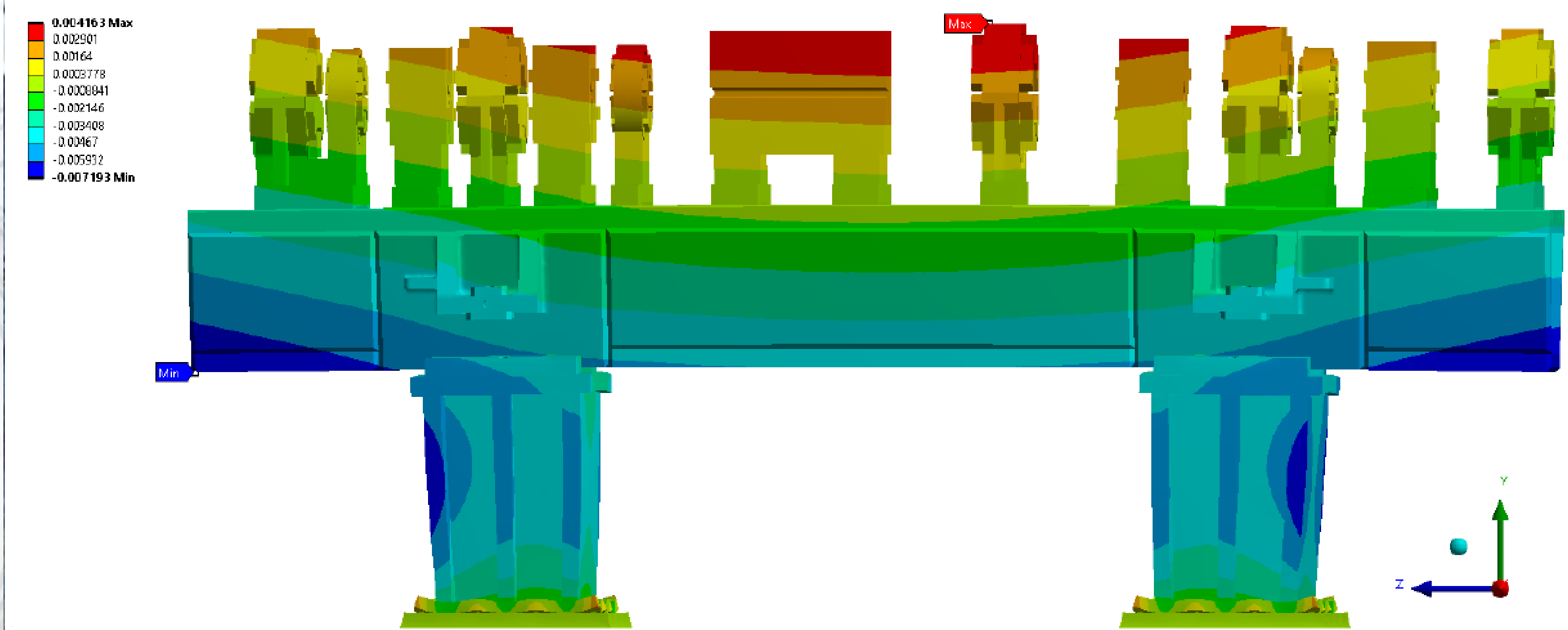
Ground plates temperature is fixed at 20°C, which is the temperature of the slab.
Jacks are modelized by a thermal link.
The whole system exchanges heat by convection in 23°C air (10 $W.m^{-2}.°C^{-1}$).

![SOLEIL Synchrotron Upgrade logo]

Heat-induced deformation

Thermal stability based upon BPM specification:

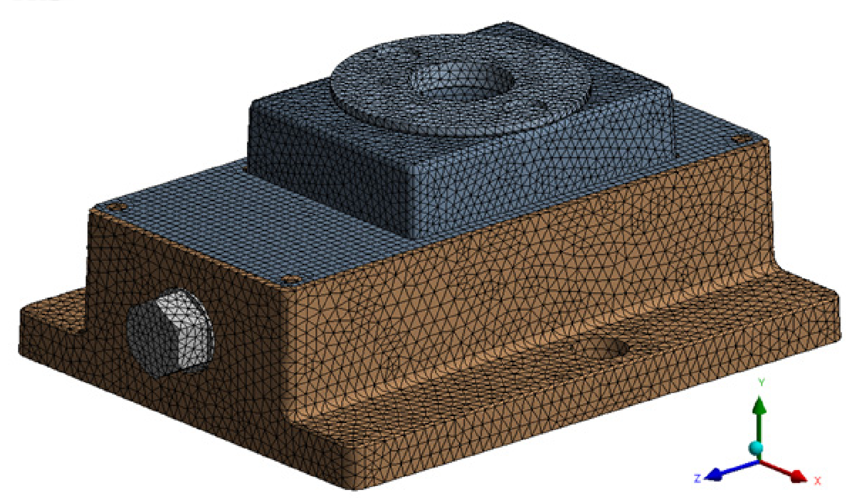
- 50 nm a couple of minutes
- 500 nm on one day
- ~ 1 µm on a week



Ground at 20°C Air temperature 23°C

Temperature gradient effect: maximum deflection along Y axis= -7.2 / + 4.2 µm

NIVELL DK-3 model used for stiffness evaluation



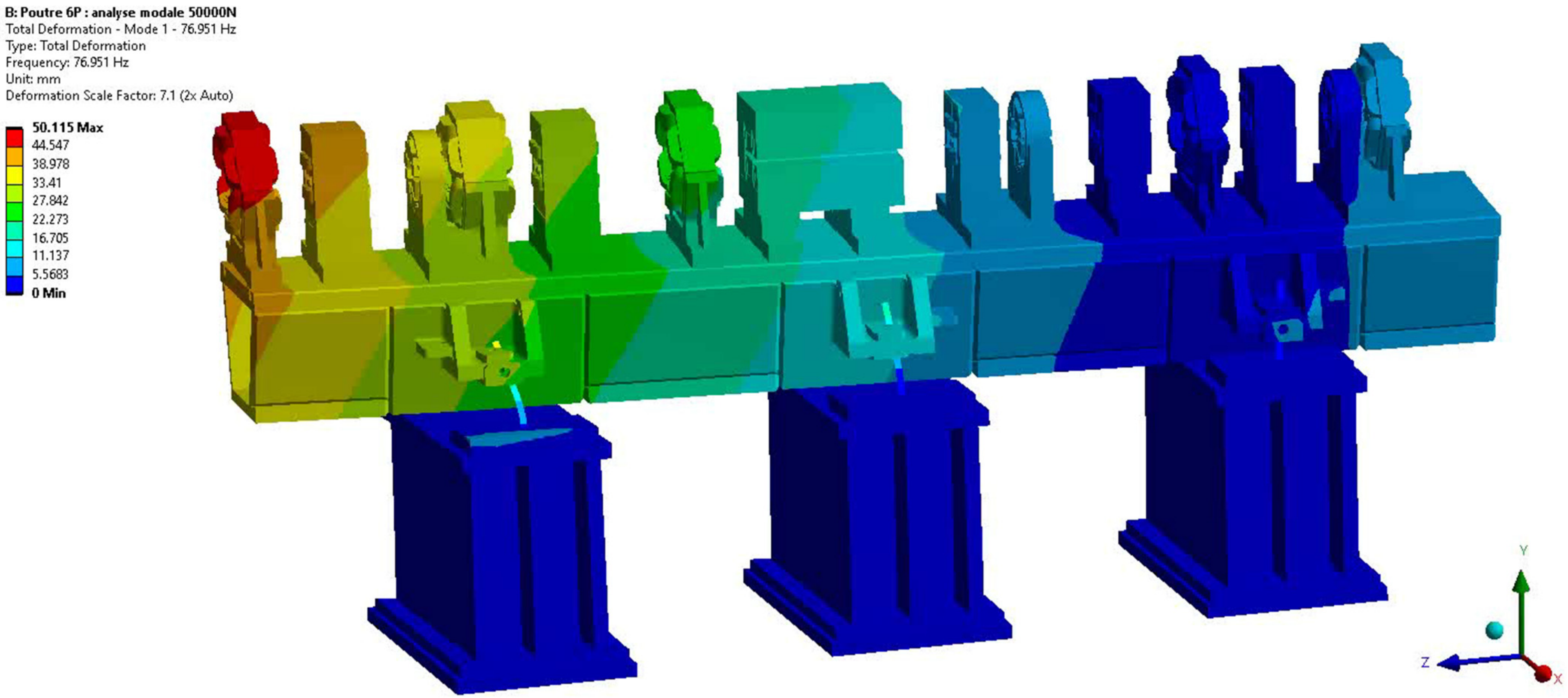
Max load= 25 KN
Stroke ±3.5 mm
Stiffness: 6.10^9 N.m^{-1}

Stiffness along X		
Effort (N)	deflexion (m)	Stiffness (N/m)
1 000	7,16E-06	1,40E+08
5 000	3,58E-05	1,40E+08
10 000	7,16E-05	1,40E+08
25 000	1,79E-04	1,40E+08
50 000	3,56E-04	1,40E+08
100 000	7,10E-04	**1,41E+08**

Stiffness along Y		
Effort (N)	deflexion (m)	stiffness (N/m)
1 000	1,35E-07	7,39E+09
5 000	7,27E-07	6,88E+09
10 000	1,46E-06	6,87E+09
25 000	3,64E-06	6,87E+09
50 000	7,28E-06	6,87E+09
100 000	1,45E-05	**6,87E+09**

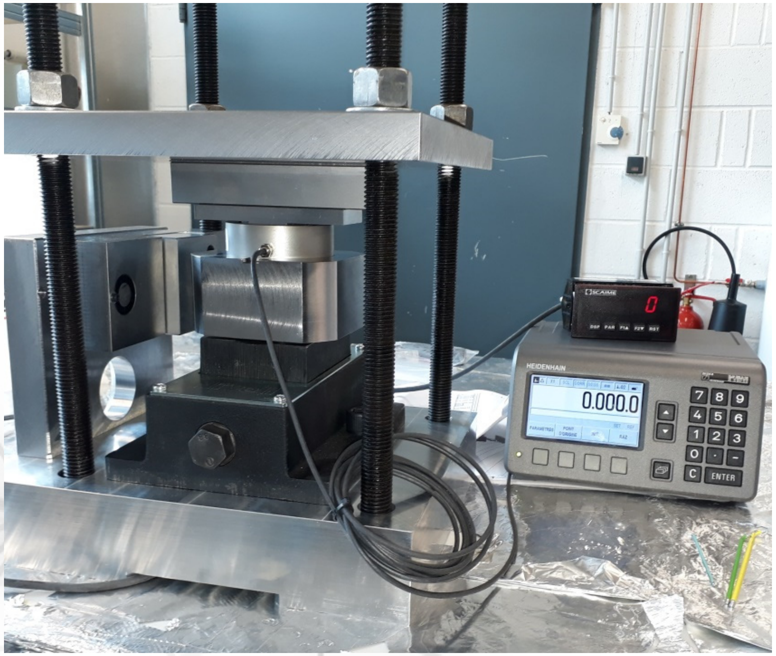
Stiffness along Z		
Effort (N)	deflexion (m)	stiffness (N/m)
1 000	4,09E-06	2,45E+08
5 000	2,04E-05	2,45E+08
10 000	4,09E-05	2,45E+08
25 000	1,02E-04	2,45E+08
50 000	2,04E-04	2,45E+08
100 000	4,08E-04	**2,45E+08**

Dynamic simulation on a 6 point 2,95 m girder

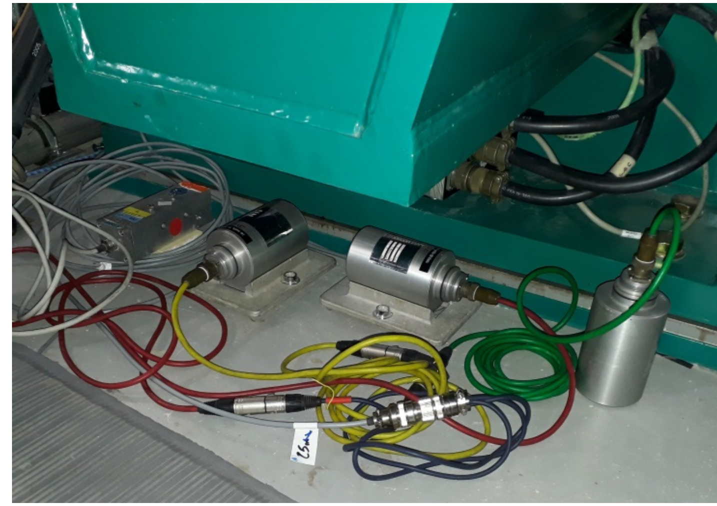


First mode: Yaw motion at 77 Hz

Experimental tests



Jack stiffness measurement bench (load 10 to 50 KN)



Set of velocimeter triedres implemented at the 4 quadrants on SR floor

Experimental results will be used as input data for dynamic simulation on girders:

- jack stiffness matrix
- ground vibration spectrum

A girder prototype with dummy magnets will be launched as soon as the configuration on lattice is fixed (212, 172 or 116 girders).

Conclusion

- Several setups have been evaluated, choice will be made considering stability, alignment and dark time reduction.

- Magnets are still in design phase, but the preliminary models of girders can be easily changed to meet the final requirements.

- Need for experimental measurements to get realistic data for FEA simulation, in particular a correct stiffness evaluation of jacks.

- Construction of a pedestal prototype to perform thermal and dynamic tests.

- Prototype of a complete girder planned for first term of 2022, but depending on magnet definition.

THANK YOU FOR YOUR ATTENTION

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