Elettra Sincrotrone Trieste

ELETTRA GIRDERS DESIGN

IVAN CUDIN AND DIEGO RAINONE

ON BEHALF OF THE MECHANICAL ENGINEERING TEAM

GENERAL REQUIREMENTS

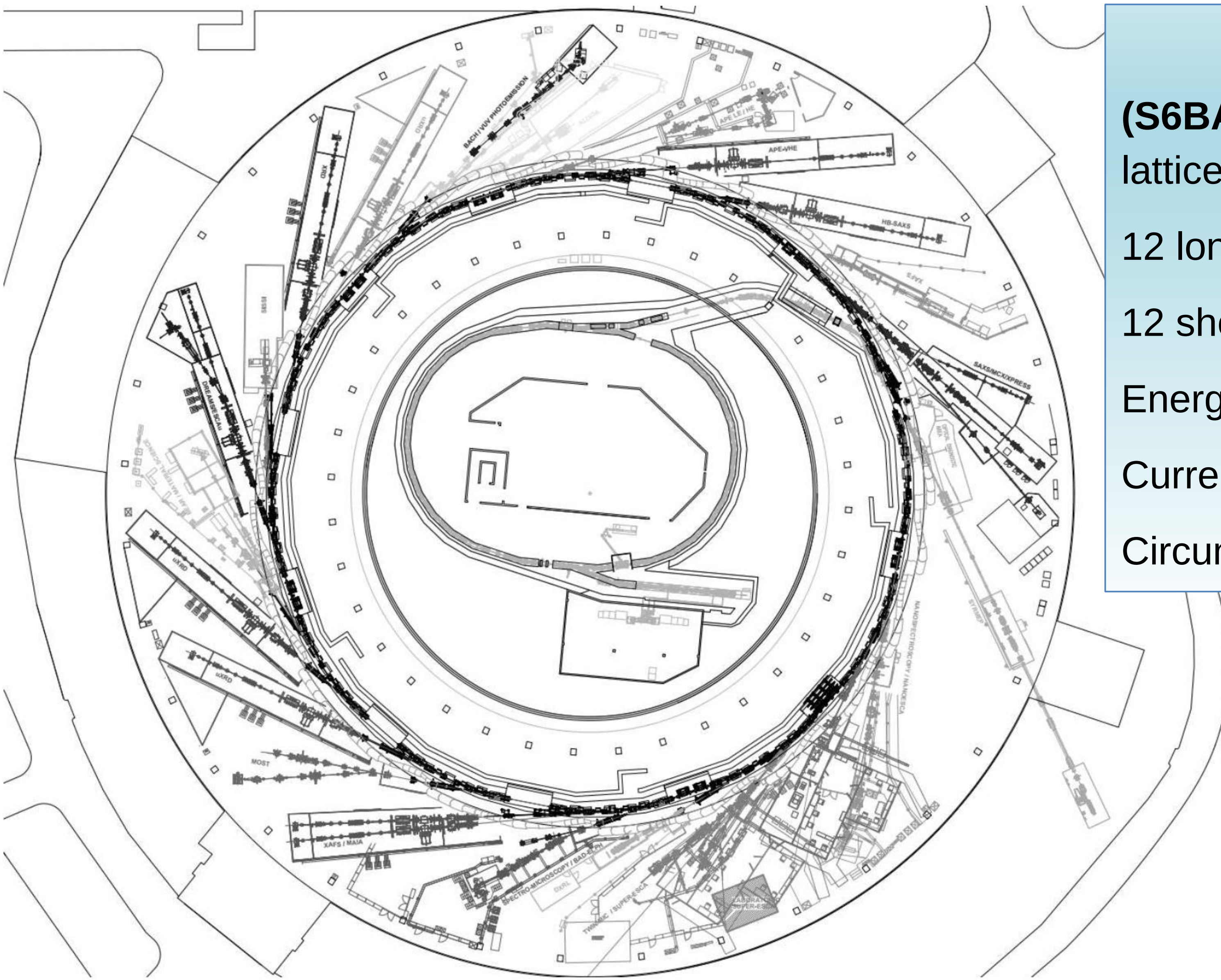
GOALS:

- ✓ increase of the brilliance and coherence fraction
- ✓ reduction of the emittance

CONSTRAINTS:

- ➢ reusing the same tunnel and infrastructure
- ➢ maintaining the existing ID straight sections in their current position
- ➢ maintaining the existing dipole magnet beamlines
- ➢ keeping the present injection scheme
- ➢ minimizing operation costs and electric power consumption
- ➢ limiting downtime for installation

GENERAL REQUIREMENTS



Elettra 2.0

(S6BA-E) 6 bend achromat lattice

12 long straight sections

12 short straight sections

Energy 2.4 GeV

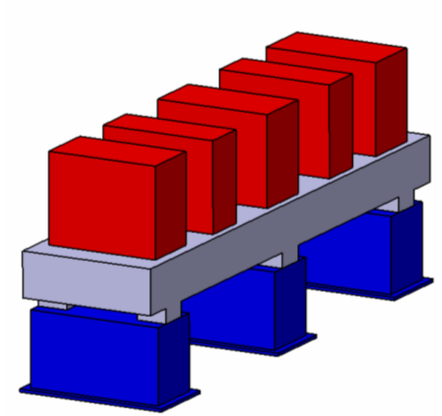
Current 400 mA

Circumference 259.2 m

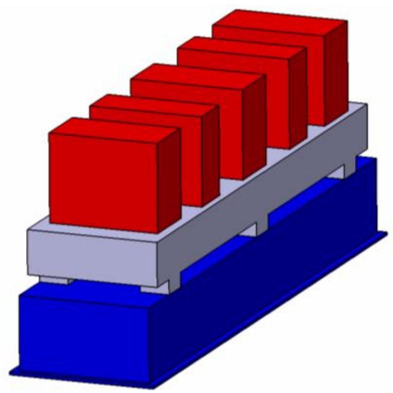
GIRDER BASIC CONCEPTS

The grouping of elements on girders and the mechanical design of the girders is guided by requirements like:

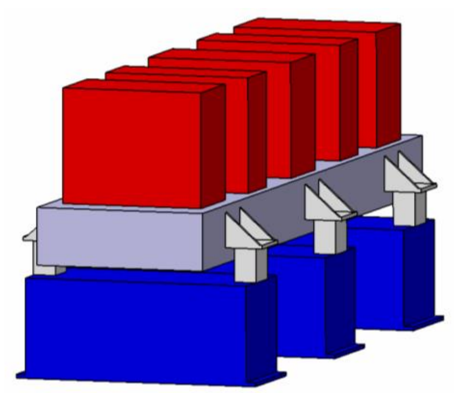
- easy installation and maintenance
- complete preassembly in order to minimize the time required to mount the girder ring in the storage ring
- low deformation
- stiffness
- high eigenfrequencies.



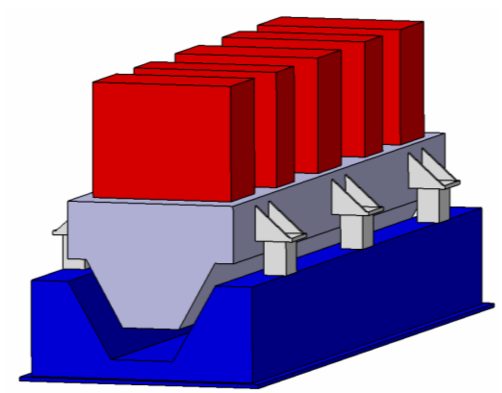
PEDESTAL BOTTOM SUPPORT



PLINT BOTTOM SUPPORT



PEDESTAL SIDE SUPPORT



PLINTH SIDE SUPPORT

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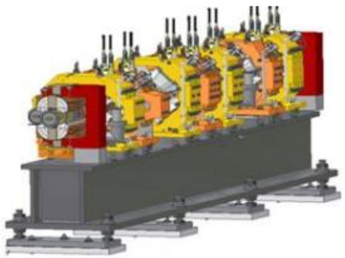
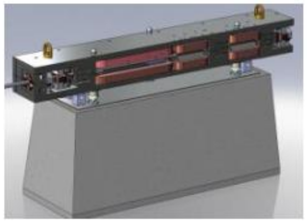
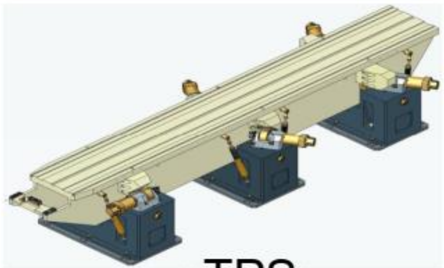
GIRDER DESIGNS


NSLS-II

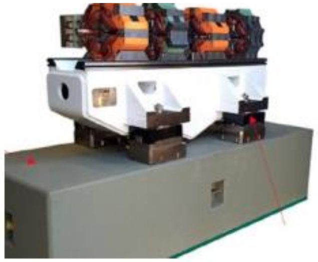

MAX IV

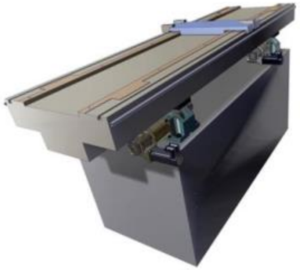

ESRF


APSU


TPS


HEPS


SIRIUS


SLS-II

Extremely different girder designs show large difference in the constraints and requirements

- Ring dimension and lattice
- Ground and support points
- Need to realign achromats

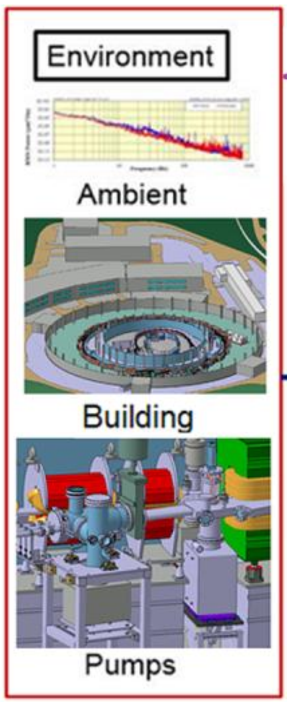
Alignment mechanism: cam movers, wedge jacks, threaded rods

DESIGN PROCESS

PERFORMANCE
REQUIREMENT
stability
alignment
installation-transport

GIRDER
DESIGN

Performance
evaluation



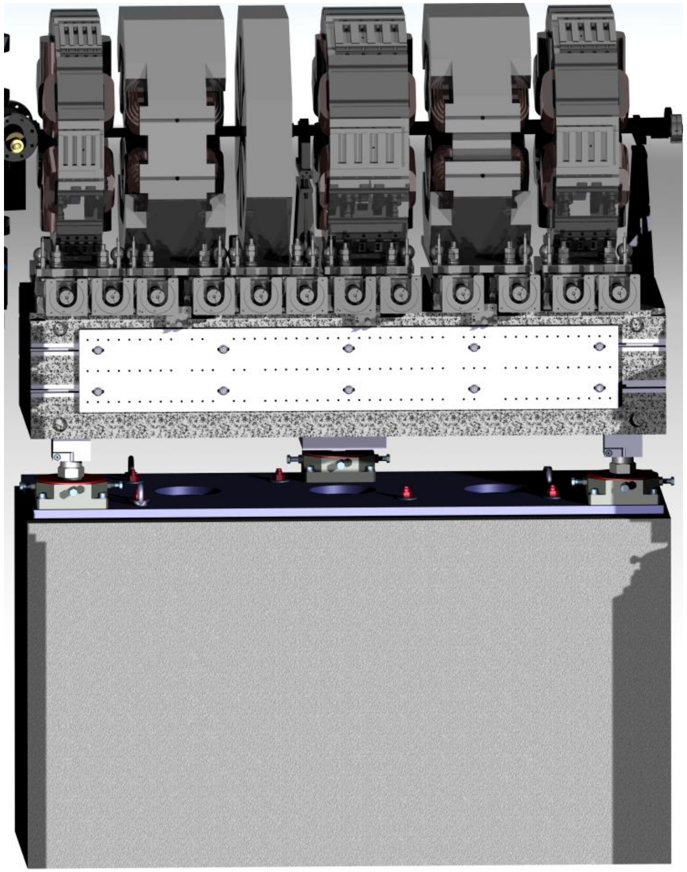
EXTERNAL
CONSTRAINTS

GIRDER REQUIREMENTS

- ✓ Beam height of 1300 mm
- ✓ Stiffness
- ✓ Weight lower than 5000 kg for the crane limit
- ✓ Length limit 3 m
- ✓ Precise alignment of the magnets
- ✓ Tightening girder supports without loosing position accuracy
- ✓ Easy installation in the SR tunnel
- ✓ High mechanical stability: minimized thermal and mechanical vibrations and excitations (water, electricity…)
- ✓ Friction at supports may lead to non-repeatable gravity deflections
- ✓ Meet budget and schedule

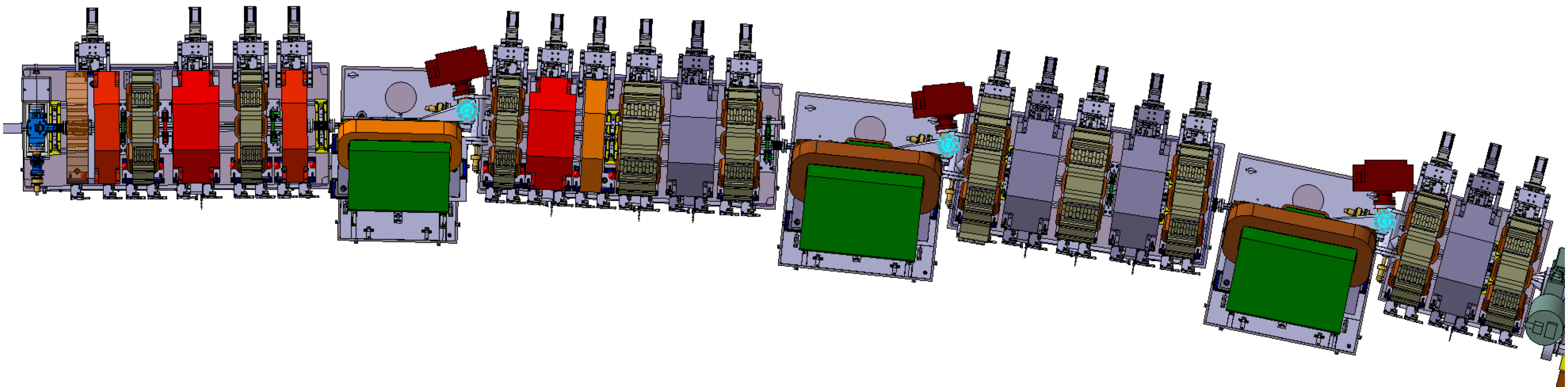
DESIGN CONCEPT

Weight max: 3000 Kg
Overall Length: 1.57 m
Overall Width: 600 mm
Overall Height: 1300 mm
Beam height: 1.3 m



- Girder design developed to satisfy stability and alignment requirements
- Low deformability with real load case
- Girder rigidly connected to grouting using wedges and equipped with manual adjustments
- Cost effective girder design, using conventional fabrication (flatness 0.02 mm)
- Increase system stability
- Complete preassembly in order to minimize the time required to mount the girder in the storage ring
- Easy transportation

ACHROMAT



Parameter	Q13	Q24	Q24RB	Sx12	Sx16	Sx20	B64	B80	
Overall Length	130	240		170	210	230	640	800	*mm*
Pole length	90	222		110	150	190	TBD	TBD	*mm*
Overall height	580	580	580	580	580	580	580	680	*mm*
Total weight	~ 130	~ 300		~ 180	~ 230	~ 250	~ 1050	~ 1790	*kg*
Bore diameter	26	30			30		-	-	*mm*
Pole minimum gap	10	12			10		-	-	*mm*

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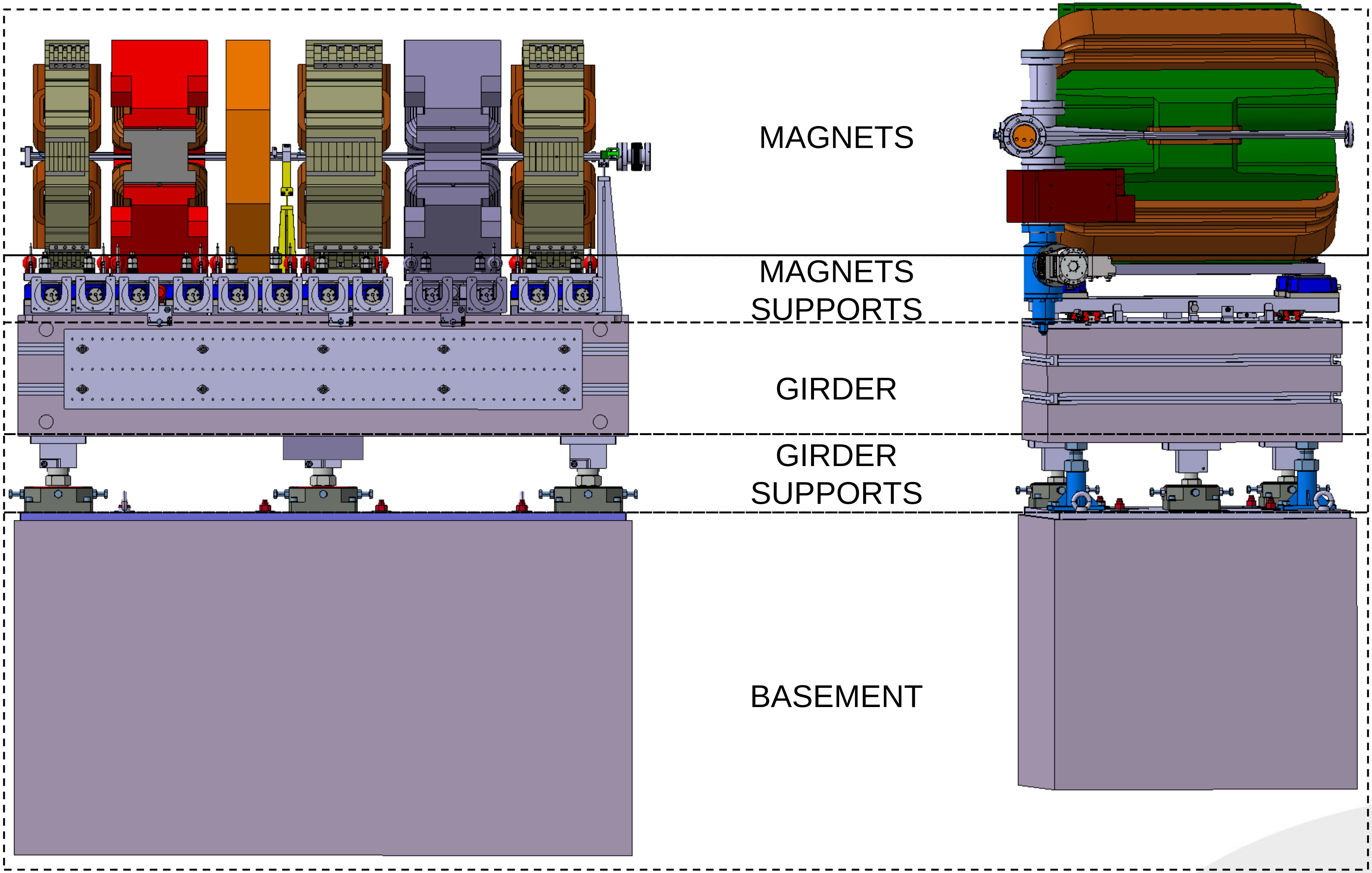
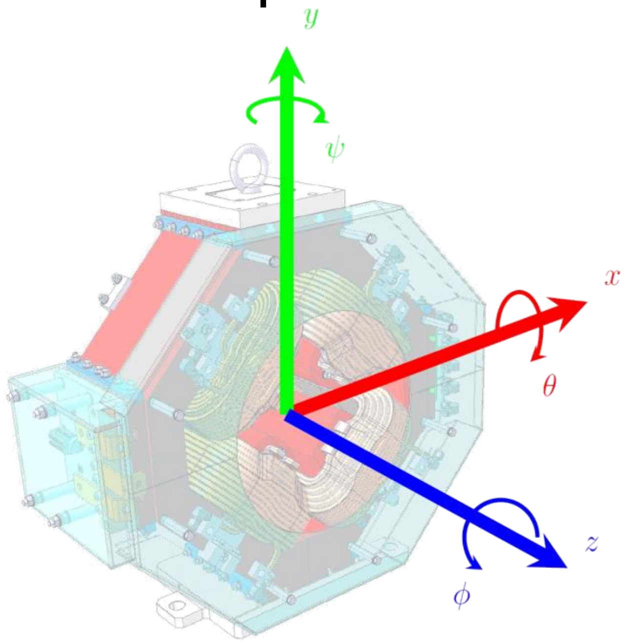
MAGNETS



ALIGNMENT TARGET

Element Type	Parameter	Value	Unit
Dipoles	Δx	50	μm
	Δy	50	μm
	Δz	300	μm
	Roll angle	100	μrad
	ΔBl/Bl	0.01	%
Quadrupoles on the girder	Δx	20	μm
	Δy	20	μm
	Δz	300	μm
	Roll angle	50	μrad
	ΔBl/Bl	0.03	%
Sextupole /multipoles on the girder	Δx	20	μm
	Δy	20	μm
	Δz	300	μm
	Roll angle	50	μrad
	ΔBl/Bl	0.03	%
Correctors	Δz	20	μm
	Roll angle	100	μrad
BPMs	Δx	20	μm
	Δy	20	μm
	Δz	300	μm
	Roll angle	100	μrad
Girders	Δx	50	μm
	Δy	50	μm
	Δz	300	μm
	Roll angle	100	μrad

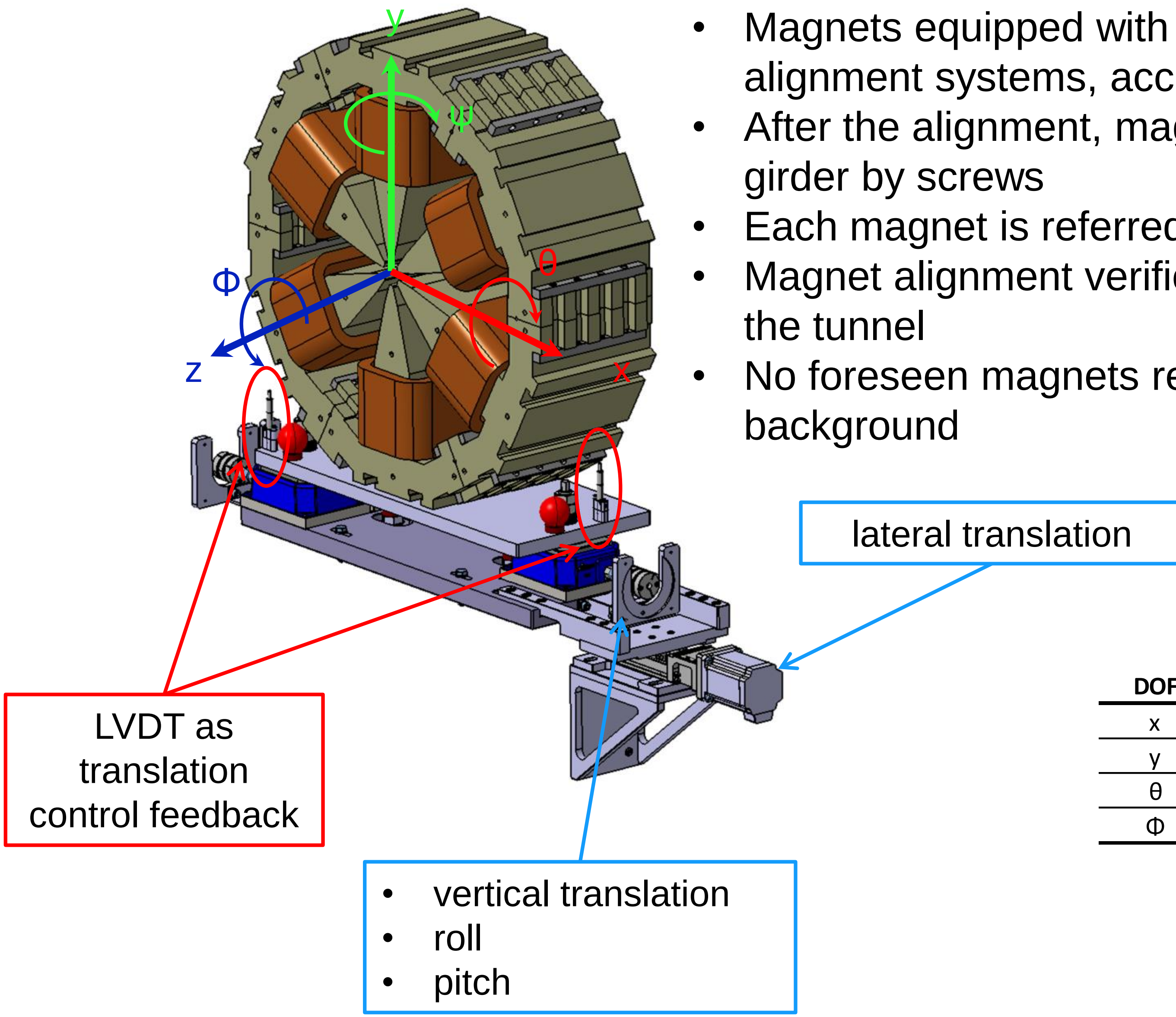
The magnets must be fixed to the girder by means of a stiff system, avoiding vibration amplifications, but providing adjustment for the alignment of each magnet within the required tolerances



Picture by courtesy of. D.Castronovo

ALIGNMENT TARGET

- Magnets equipped with motorized and manual alignment systems, according to the accuracy targets
- After the alignment, magnet supports are fixed to the girder by screws
- Each magnet is referred to the girder by laser tracker
- Magnet alignment verification after the transport in the tunnel
- No foreseen magnets realignment, very stable background



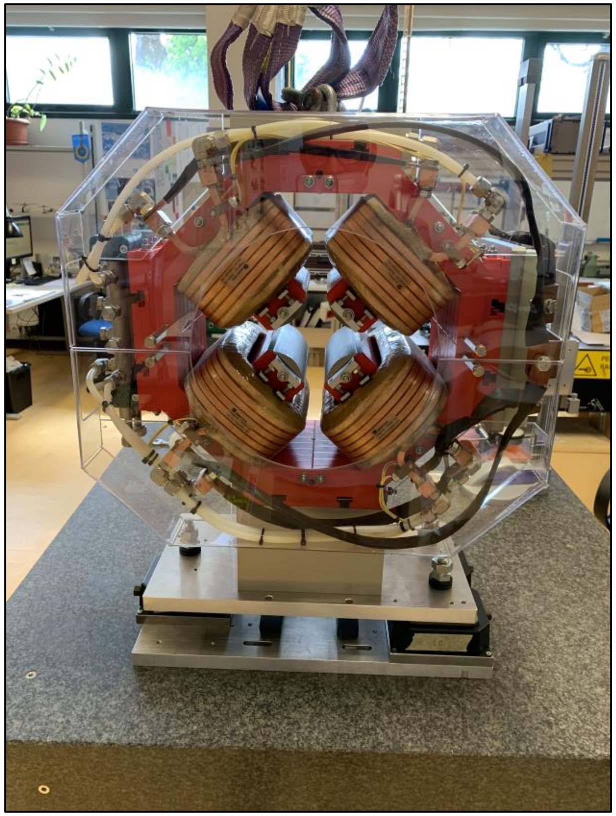
DOF	RESOLUTION	
x	5,00	µm/step
y	1,85	µm/step
θ	0,017	µrad/step
Φ	0,005	µrad/step

MAGNET SUPPORTS TESTS

A mock up of the magnet alignment system was created in order to characterize the levelling wedges and identify any design improvement and installation issue.

Levelling wedges characterization

Levelling wedges installation



Mock up of the magnet support system

GIRDER SUPPORTS POSITION

Deformations generated by girder and magnets weight

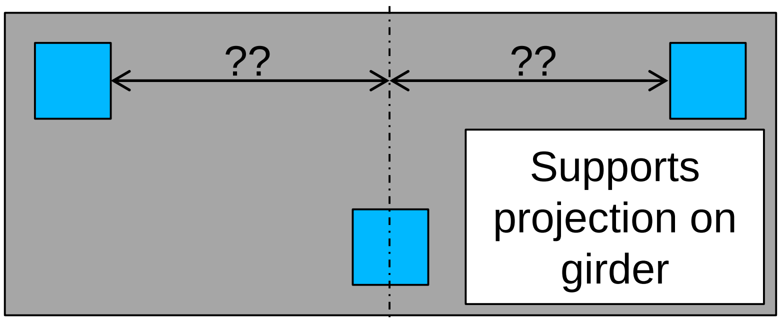
Supports position designed to:

- reduce girder deformation → optimization analysis
- easy and accurate alignment → larger inter axle spacing
  → two supports on inner ring side (easy access)

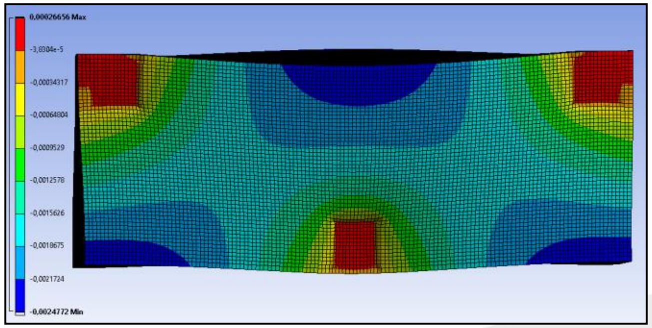
VARIABLE SUPPORT POSITION

TARGET: LOWER VERTICAL DEFORMATION

INNER RING SIDE



OPTIMAL SUPPORT POSITION

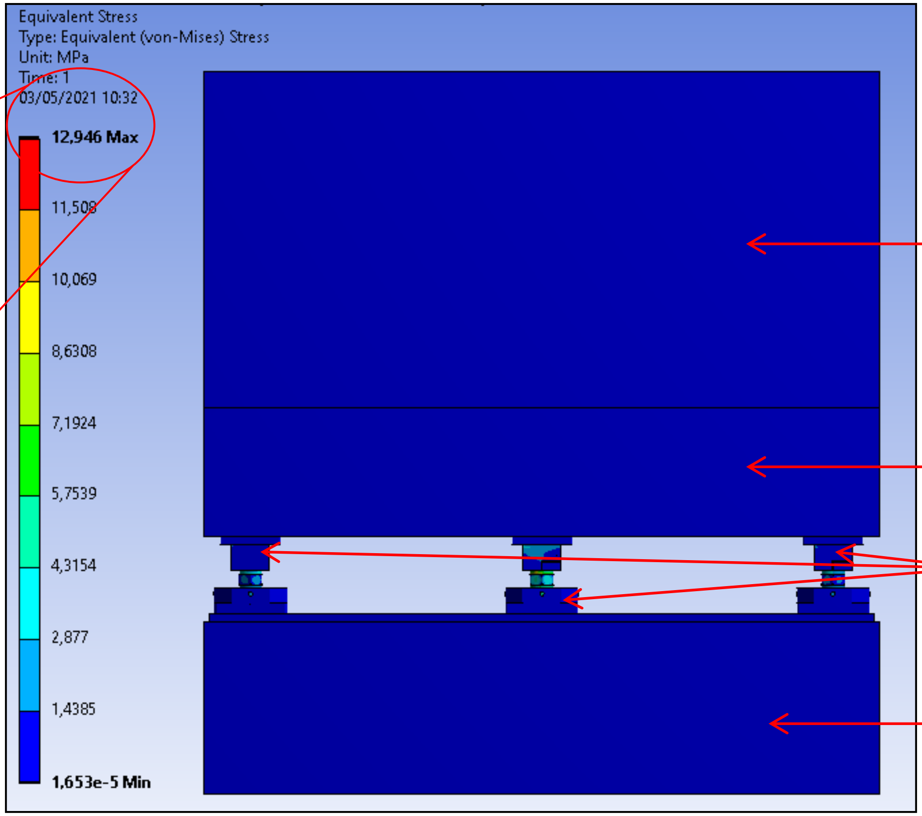


VERTICAL DEFORMATION **2,7 µm**

GIRDER STATIC ANALYSIS

Deformations generated by girder and magnets weight

Model integrated with basement, girder supports and magnet equivalent mock-up in order to define equivalent stress:

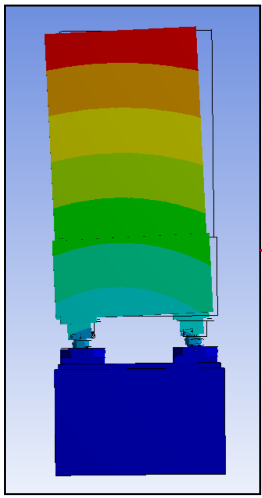


Max equivalent stress 13 MPa on steel supports

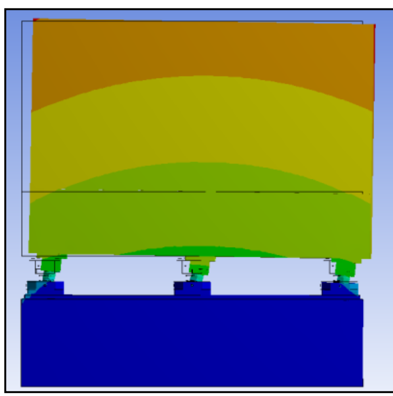
Safe disegn

GIRDER DINAMIC ANALYSIS

Girder supports are designed to lead satisfactory vibration stability (higher eigen frequencies → lower displacement vibration):

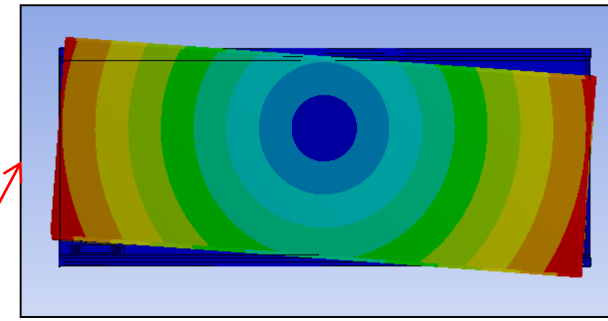


ROLL

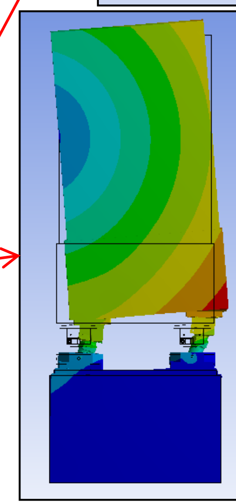


PITCH

MODE	FREQUENCY
1	46,4 Hz
2	71,7 Hz
3	96,6 Hz
4	181,25



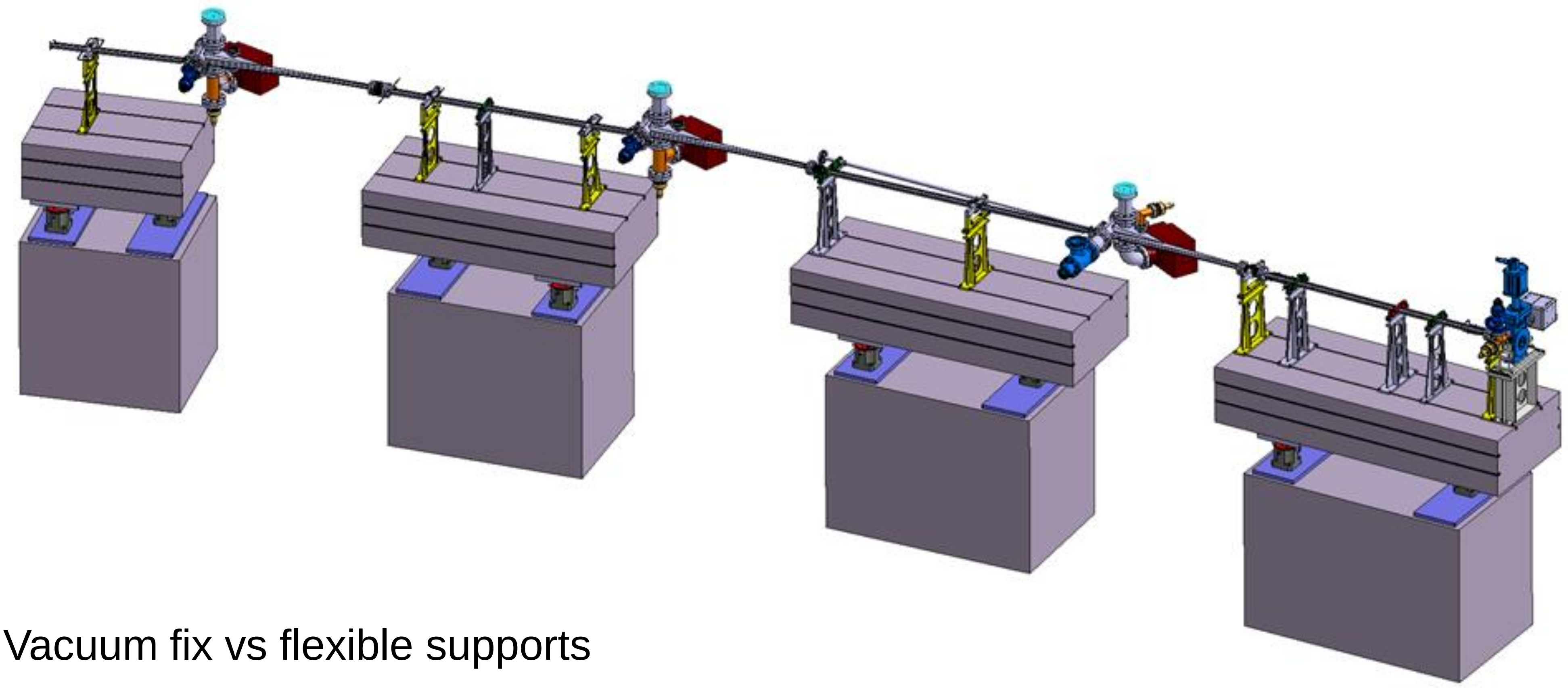
YAW



I FLEXION

Numerical model is stiffer than real one: we suppose that those frequencies on the real mock-up will be lower → ***experimental vibration measurements on mock-up***.

VACUUM CHAMBER SUPPORTS



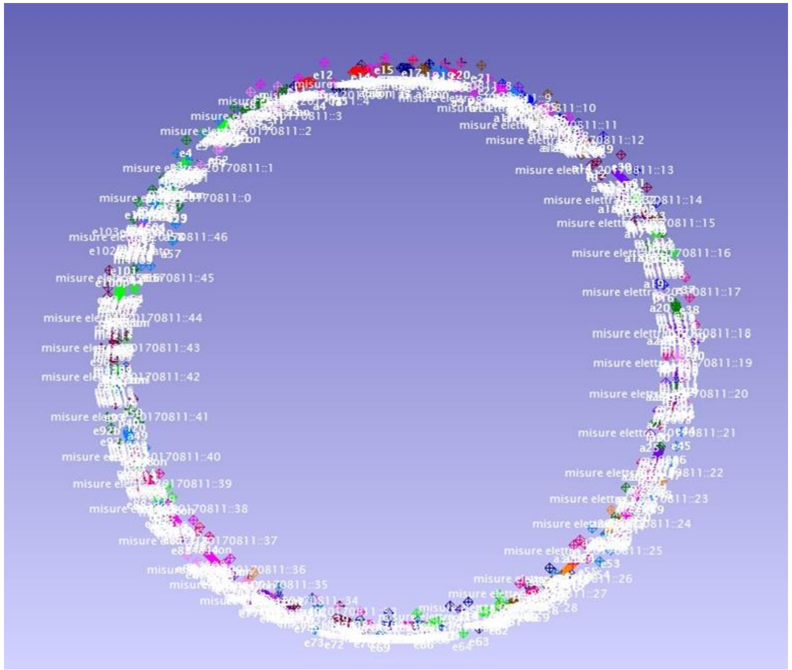
Vacuum fix vs flexible supports

GIRDER ALIGNMENT

Tight tolerances and space and time limitations.

GLOBAL SURVEY NETWORK:
to be positioned 450 control points / survey targets

Absolute uncertainties in the network < 30 μm



Picture by courtesy of alignment team

SURVEY EQUIPMENT

Leica Laser Tracker AT401

Accuracy: 20 µm

Absolute Angular Performance:
accuracy (MPe): +/- 15 µm + 6 µm/m
repeatability (MPe): +/- 7.5 µm + 3 µm/m

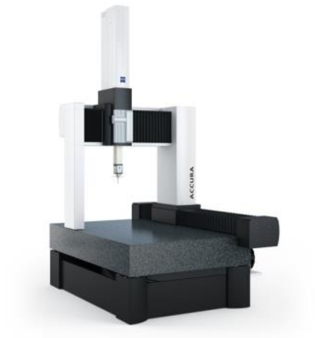
Absolute Distance Performance:
accuracy (MPe): +/- 10 µm
repeatability (MPe): +/- 5 µm

Faro Cam2 Quantum

Accuracy: 16 µm

CMM

Accuracy: 2.5 µm



Available equipment: LS15 Digital Levels
Leica TDRA 6000 Laser Station
Leica N3 Precision Level

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AMBIENT BACKGROUND

Thermal stability – expected conditions

Tunnel air Temperature stability

± 0.5 °C/day

≤ 1.5°C in 100m

Water cooling systems

± 0.5 °C

Maximum magnet motion in 24 H

100 nm

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MAGNETS ALIGNMENT

IN METROLOGY LAB – THERMALIZED ROOM

- Multipoles calibration and fiducialization by rotating coils on a measurement bench, referencing magnetic axes to survey targets
- Magnets installation on the girder
- Wait for temperature to stabilize and pre-alignment
- Set up stretched wire alignment system
- Magnetic measurement with wire in order to refine their intra-alignment with a reliability of about ± 15 µm. (In order to minimize any possible systematic and random errors, the support structures of the measuring equipment with the wire will be installed directly on the girder)
- Referencing magnetic axes to the girder fiducial references
- Manually lock the magnets in place, using displacement sensors while monitoring the magnet positions
- Magnets opening and installation of vacuum chamber
- Alignment check and fiducialization of the girder by laser tracker with respect to the layout nominal path

INSTALLATION IN TUNNEL

IN TUNNEL

- Girder transport to storage ring
- Girder alignment using laser trackers
- Lock girder in the final position
- Girder, vacuum chamber and magnets final positions check

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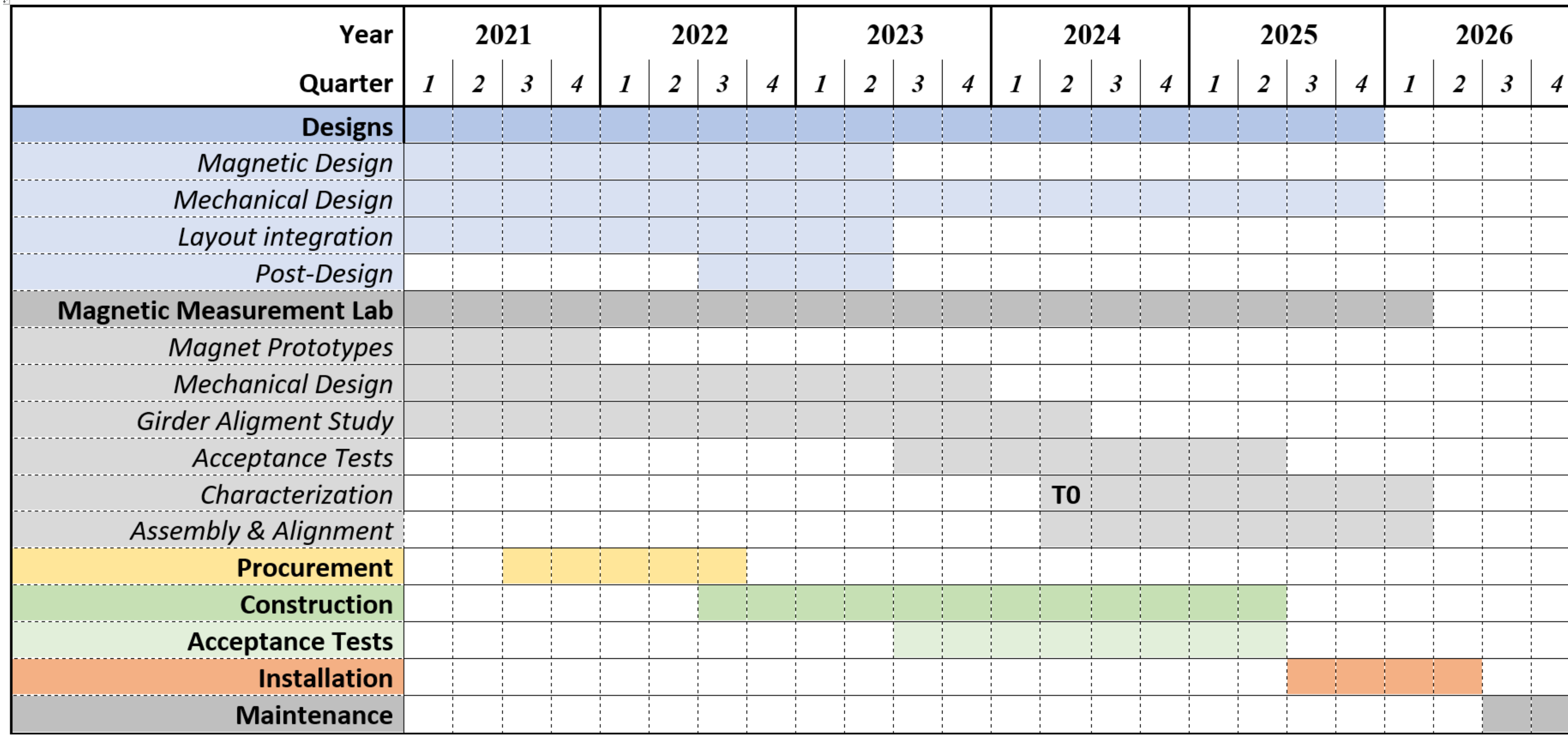
SCHEDULING



By courtesy of. D.Castronovo

RESOURCES

DARK TIME START | GIRDER INSTALLATION | COMMISSIONING START

YEAR	2024				2025				2026			
QUARTER	1	2	3	4	1	2	3	4	1	2	3	4
Characterization		2	2	2	2	2	2					
Assembly and alignment		5	5	5	5	5	5					
Installation							6	6	6	6		

The ring is made up of 12 achromats with 8 multipole girders of maximum 6 magnets each plus 72 bending girder.

Taking into consideration the measurement and calibration times of the magnets, the expertise and the available staff, the total preparation of a girder, including the installation of the vacuum chamber inside the magnets, will take on average a week (7 CDs).

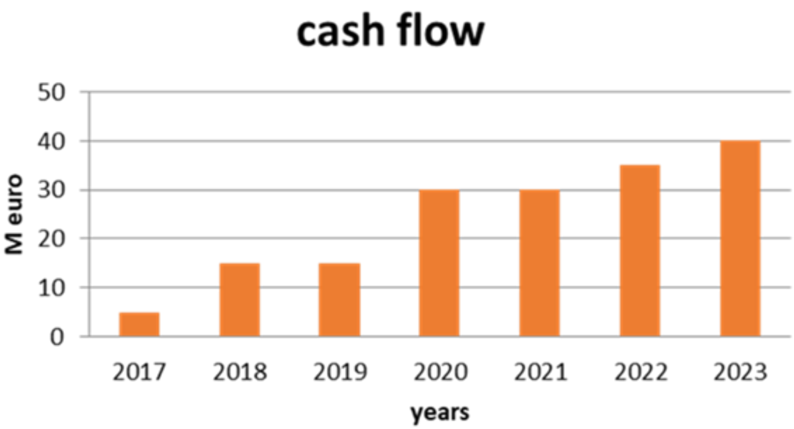
The preparation of all the girders will cover about 96 calendar weeks, or two calendar years.
The last girder will be delivered no earlier than T0 + 728 CDs.

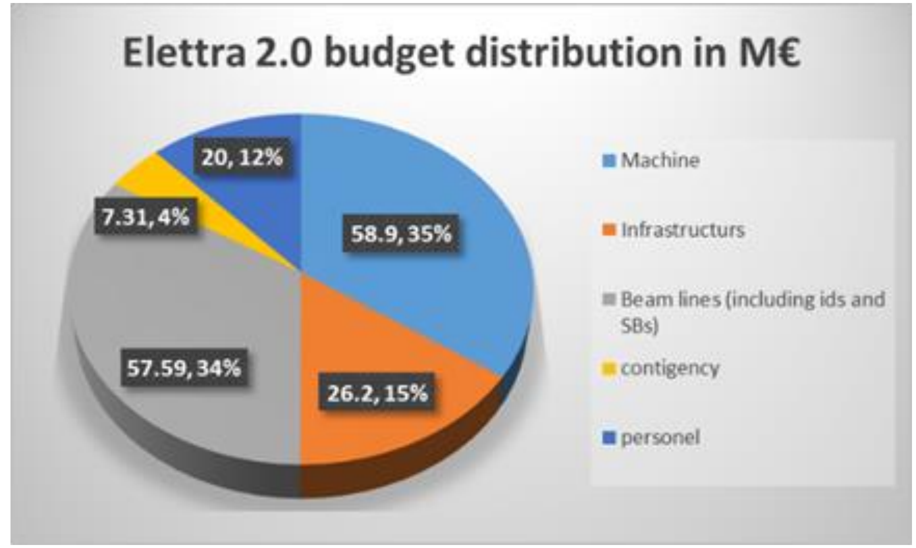
GIRDER BUDGET

COMPONENTS	BUDGET [€]	BUDGET [€] + VAT
Girders	484000	614880
Standard feet	120000	146400
Girder feet	334000	431880
No-tipping feet	90000	122000
Grouting plates	49000	59780
Girder plates	390000	488000
Cables and wires fixing plates	42000	51240
Screws and ISO components	35000	48800
Anchor bolts	19000	23180
Alignment systems	48000	61000
Bending guides and tools	27000	32940
Vacuum chamber supports	288000	351360
TOTAL	1926000	2349720

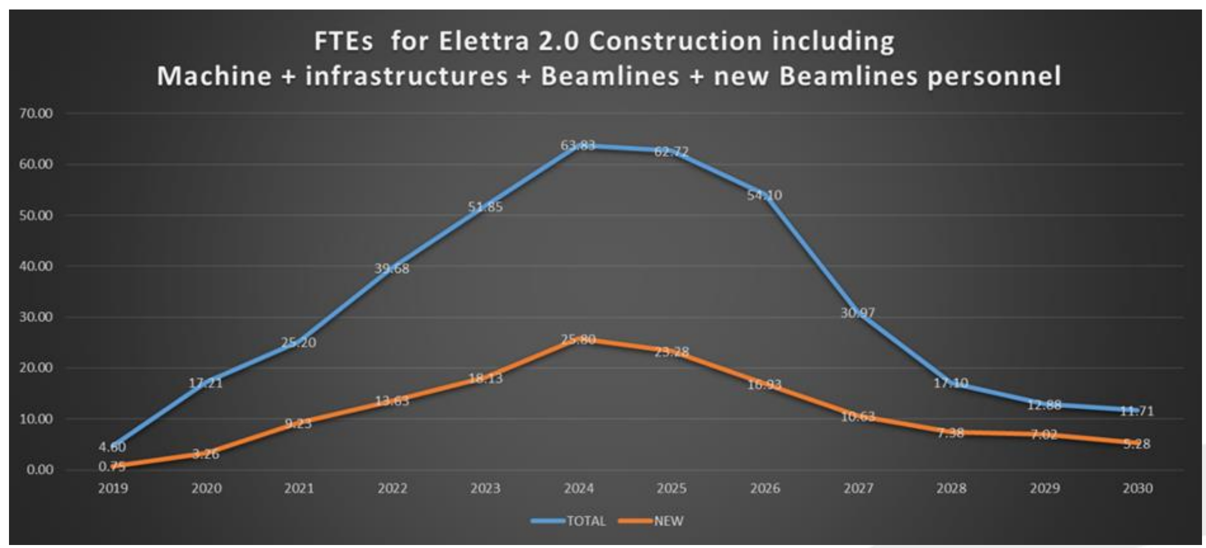
PROJECT BUDGET AND MANPOWER

Total cost 170 M€





On the average about 40 FTEs/year are considered to be needed for the project from 2020 to 2030 including on the average about 14 FTEs/year new personnel.



INSTALLATION PROCEDURE

CONCEPTUAL DESIGN → PRELIMINARY DESIGN → PROTOTYPE DESIGN → FABRICATION DESIGN

PROOF OF CONCEPT

ONGOING TASKS

- Girder and stages design and optimization
- Vacuum chamber design
- Design of vacuum chambers stands
- Systems integration

NEXT TASKS

- ✓ Finalization of prototypes to be fabricated
- ✓ Tests on prototypes
- ✓ Final design

CONTACTS

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THANK YOU FOR YOUR ATTENTION

SPECIAL THANKS ALL THE MECHANICAL ENGINEERING AND THE ALIGNMENT TEAM

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