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THE GIRDER SYSTEM PROTOTYPE FOR ALBA II STORAGE RING*

J. Boyer†, L. Ribó Mor, N. Gonzalez, B. de Abreu Francisco, P. Salmeron Roma, C. Colldelram
ALBA Synchrotron, Barcelona, Spain.

Abstract

ALBA Synchrotron is upgrading its accelerator to a diffraction-limited storage ring, achieving a twenty-fold emittance reduction. The upgrade, planned before the decade's end, will maximize use of existing infrastructure, such as the tunnel, while replacing components like magnets, vacuum chambers, and girders. This paper outlines the design status of the new girder system needed to support the expanded magnet array of the Alba II lattice, which more than doubles in number. Key design requirements include 50 µm positioning accuracy between adjacent magnets, allowing repositioning due to long-term slab deformation, vibrational stability of mounted components, and modular construction for reduced installation time. Each of the 16 arcs is divided into preassembled modules to ease assembly, transport, and final installation. A dedicated project was launched to build ALBA II prototypes. Two girders are currently under construction and expected to be tested by year-end.

FROM ALBA TO ALBA II

ALBA storage ring is composed by 264 magnets, which are distributed in 16 cells in an array of 2 girders (GI) of 6 meters for each cell, in a circumference of 268.8 m. ALBA II proposed layout is composed by 720 magnets (MA), in the same arc length of 12.8 m and circumference as current ALBA storage ring [1], meaning that the compactness ratio of the element on top of the girder has increased by a factor of 2. In Fig. 1 is represented an overall distribution of one sector for the current and new storage ring, where the reduction of free space can be appreciated.

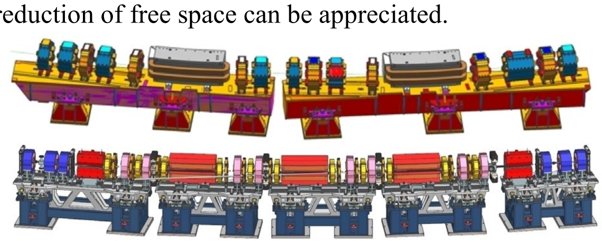

Figure 1: Magnetic distribution of ALBA (top) and ALBA II cell layout (bottom).

The ALBA II upgrade aims to transform ALBA into a fourth-generation, diffraction-limited storage ring, reducing emittance by at least a factor of twenty. This demands tighter tolerances for positioning girders and components, along with high stability requirements [1], as shown in Table 1.

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† jboyer@cells.es

Table 1: Sizes Comparison

Dimension	ALBA	ALBA II
Compactness grade	49%	80%
Vacuum chamber size	28x56 mm	18 mm
Dynamic aperture	50 mm	6 mm

ALBA II GIRDER PROTOTYPES

Two girder prototypes and a granite plinth were designed for manufacturing and will be available at ALBA for testing by Q4 2025, as part of the ALBA01 prototype project under the Next GenEU framework [2]. The prototypes were mechanically developed with all components for the new SR, in sync with the lattice design [3], keeping both aligned.

Originally developed for the 6BA lattice, the prototypes differ in several aspects from current 5BA requirements [3]. Based on slab movement study results [4], automatic height adjustment was considered unnecessary. The design was swiftly adapted and remains fully functional for testing all elements required to evaluate the optimal construction concept. Updated requirements are shown in Table 2.

Table 2: Requirements for the Girders

Specification	Value	Comments
Length	2 to 3 m	Limited by weight
Top surface height	1000 mm	Beam height 1.4 m
Width	1200 mm	Limited by tunnel
MA positioning Tol.	50 µm	GI to GI magnets
Eigenmodes	>50 Hz	By design
XY range	+/-3 mm	Manual
XY resolution	20 µm	Manual
Z range	+/-5 mm	Manual
Z resolution	5 µm	Manual
Assembly weight	<12 Tn	Module GI+MA

In Fig. 2 is shown all prototypes considered to build: two different geometries in welded steel for the top frame, two units of the same design of welded steel for the plinth and an extra one plinth of granite, along with several and redundant mechanics for positioning.

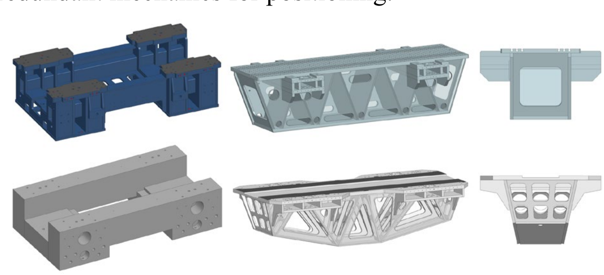

Figure 2: Girder prototypes components.

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Figure 3 shows girder prototypes and a mock-up magnet array made of raw steel, manufactured as well to assess the effect of mass and geometry in stability tests. Various XYZ magnet alignment mechanisms will also be evaluated.

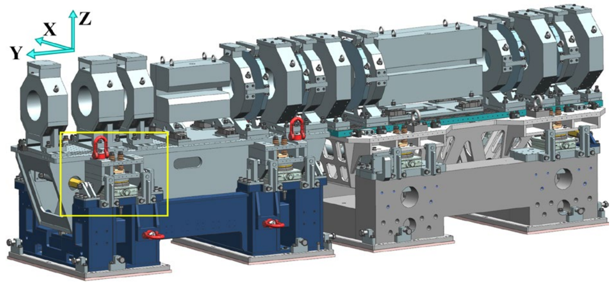

Figure 3: Girder prototypes, mock-up magnets setup.

The prototypes will include redundant mechanisms for XYZ alignment of the magnet array to evaluate the best procedure during testing. XY positioning can be adjusted using pusher screws from the floor plate, the four top frame supports (Fig. 4), or, on the trapezoidal frame, via a top plate with the full magnet array pre-assembled. Additionally, the top frame can be aligned in X using a preloaded screw and a commercial wedge system, similar to that on EBS-ESRF girders [5]. Z positioning will use four commercial wedge mounts with spherical contact.

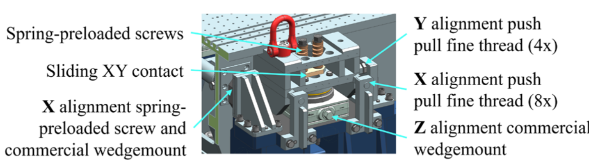

Figure 4: Girder prototype manual adjustments.

The next project step is the testing phase, planned for Q4 2025. Now in the final construction stages (Fig. 5), combining prototypes will enable evaluation of different positioning systems and the stability of a full girder module, including ground and externally induced vibrations. Assembly and transport procedures, along with the most effective and ergonomic alignment strategies, will also be assessed, together with a cost-benefit analysis and the optimal manufacturing approach between the two top frame geometries for the series.

Figure 5: Current status of the prototypes production at Nortemecánica [6] facilities.

Both trapezoidal and orthogonal top frames can be assembled either in the steel or the granite plinth.

GIRDER DESIGN OPTIMIZATION FOR 5BA LATTICE

The shift from a 6BA to a 5BA lattice, removal of Z-motorization, and use of interchangeable setups with redundant adjustments resulted in oversized prototypes, complicating arc integration and tunnel installation [7]. This prompted the need to optimize the girder design, focusing on reducing width, footprint, and weight. Optimization results are shown in Fig. 6.

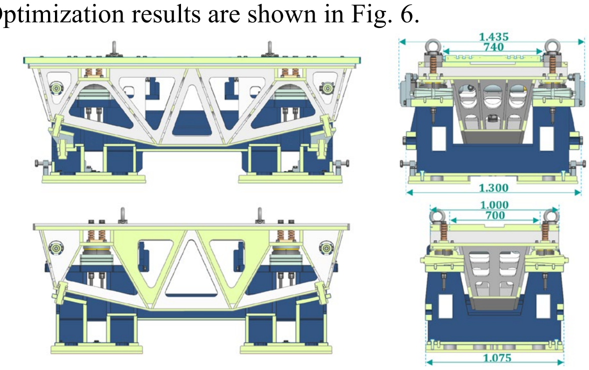

Figure 6: Prototype (top) and current design (bottom).

Simplification included selecting positioning mechanisms suited to current constraints. The top plate—once used to standardize 5-cell girder lengths despite varying magnet arrays—is no longer needed, nor are the XY pusher screws on floor plates or lateral fine-thread X pushers

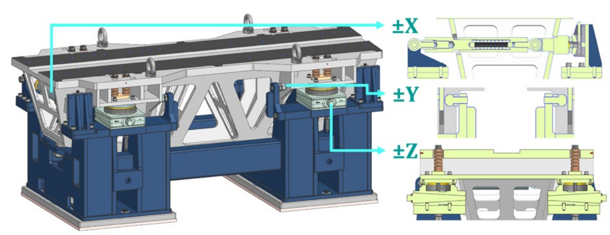

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Figure 7: Girder X, Y, Z manual adjustments

Thus, as shown in Fig. 7, X positioning uses the spring-preload screw, Y uses fine metric thread screws M30 with 1.5 mm pitch, and Z uses commercial wedge mounts. Table 3 lists adjustment characteristics.

Table 3: X, Y Z, Adjustments for Last Design

Edge	Range	Resolution		
	mm	µm/Rev.	µm/rad	µm/º
X	±3.5	375	60	1.1
Y	±6	1,500	239	4.2
Z	±8	230	37	0.7

GIRDERS INTEGRATION IN THE ARC

It has been explored different alternatives for the arc split. In Fig. 8 is shown the current scenario of 1-3-1, identical for all 16 arcs, solution primarily driven by: being the best case in terms of beam dynamic stability due to keep both QF over the same girder [3] and always having the BPMs vertically supported in the girder surface.

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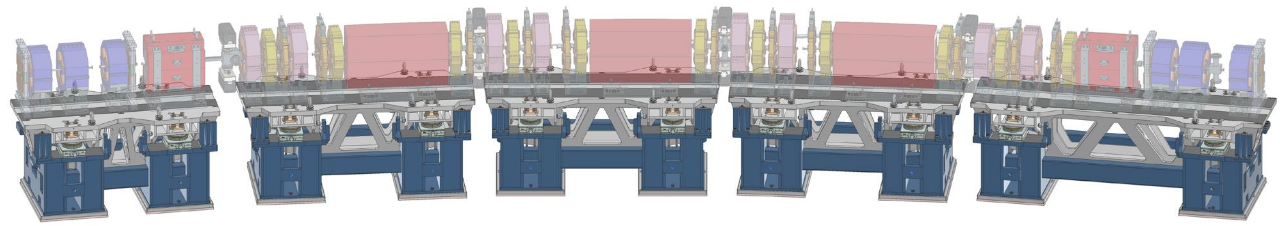

Figure 8: Arc split in 5 girders; 1 short, 3 medium, 1 large.

All while staying within the 12 TN modular design limit-ALBA's crane capacity-to reduce installation time and complexity, as girders must fit the existing tunnel and primary cooling system [1,3]. Splitting the arc at vacuum pump areas maximizes space between girders, easing installation of the ex-situ baked vacuum chamber [8].

The three intermediate girders are identical, including magnet footprints, each holding one dipole. The first and last are adapted to their magnet arrays, allowing extra space needed for QDS permanent magnet installation [1,3]. Quantities and modular weights listed in Table 4.

Table 4: Single Unit of Girder and Magnet Array Specs.

Type	Quantity	Length [mm]	Weight [kg]
Short	16	2,100	5,000
Medium	48	2,400	6,600
Large	16	3,100	7,000

Installation and Transportations

The installation strategy involves preassembling girders with magnets in the ancillary assembly area, then transporting them to the tunnel, opening the magnet top-halves, installing the vacuum chamber, closing the magnets, and connecting services [9].

To define optimal procedures and tooling, initial designs and simulations are underway to characterize girder module transport from the ancillary area to the tunnel [3]. It is crucial to move the assembly (GI+MA) as a single unit using a rigid tool (see Fig. 9) to prevent stress on the girder and minimize elastic deformation.

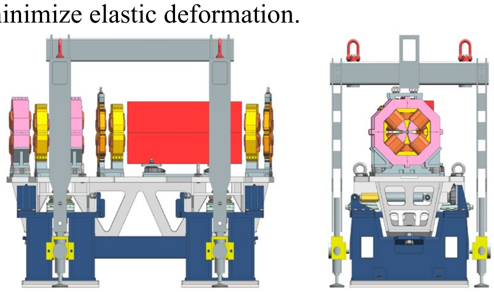

Figure 9: Tolling for transportations.

These tooling will add weight to the module, which is another limitation for justifying the arc split in 5 girders.

FEA FOR LAST 5BA DESIGN

In order to verify that the design size optimization does not compromise the stability of the design, the new model has been simulated by FEA with the new loading hypothesis of the 5BA lattice. Two cases are analysed for the intermediate girders, the first (top view in Fig. 9) without considering any load, just the girder itself, and the second considering the effect of the magnet's masses and their centres of gravity.

Boundary conditions has been considered for all the contacts as bonded, due to the effect of the preloading screws for the 4 wedge mounts.

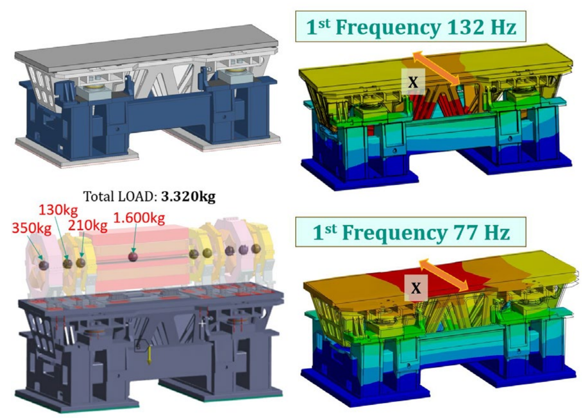

Figure 10: FEA for the optimized design for 5BA lattice. Isolated girder (top), with magnets masses (bottom).

Figure 10 shows a drop in the first eigenmode compared to the 6BA prototypes with Z motorization and wider girders, from 150 Hz [10] to 132 Hz for the isolated girder. With magnet masses included, the first eigenmode stays at 77 Hz, still above the 50 Hz requirement.

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CONCLUSIONS

Testing multiple prototype setups will identify the best balance of stability, ergonomic alignment, ease of assembly, modular transport, and tunnel installation.

Height motorization removed, simplifying the design.

Prototypes have manual positioning: four options for X, three for Y, and one for Z.

Size optimization doesn't affect stability or the loading assumptions for the 5BA lattice.

Arc split is now optimal for installation and beam dynamic stability.

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