ISBN: 978-3-95450-247-9 ISSN: 2673-5490 doi: 10.18429/JACoW-IPAC2024-MOPG01

EFFECTS OF THE ALBA SLAB MOVEMENT ON ALBA-II

O. R. Blanco García*, G. Benedetti, M. Carlà, J. Ladrera Fernández, M. Llonch, Z. Martí
ALBA-CELLS, Carrer de la Llum, 2, 26, 08290 Cerdanyola del Vallès, Spain

Abstract

ALBA, the Spanish third generation synchrotron light source, is studying the future construction in the same location of a fourth generation light source called ALBA-II. Since the construction of ALBA in 2008, its critical slab has moved significantly, changing with it the accelerator elements positions. In this study, the effect on the closed orbit is simulated from data of the survey campaigns on the ALBA electron beam storage ring and compared to measurements using the closed orbit and orbit correctors. The results of this study on ALBA are used to infer the effect of the slab movement on the future machine through simulations, predicting yearly and seasonal changes. Plausible correction methods are discussed.

INTRODUCTION

ALBA [1] has been in continuous operation from 2012 to the date. The facility is supported on a slab common to the storage ring and beam lines made of 1 m thick reinforced concrete resting on a base 2 m thick composed of a gravel filling that was properly compacted and protected by two 15 cm poor concrete layers, see [2,3]. Over the years the slab movement has changed; right after the ALBA installation larger movement was measured due to the settlement of the new building, while in the most recent years the movement has been smaller [3,4].

In particular, in the last two years campaigns of surveys every 6 months the variation of the slab position appears to be non-cumulative, of high amplitude and low spatial-frequency.

In the following we describe the slab position measurements, the effect it had on ALBA in 2022 and 2023, and the simulations for the new storage ring, ALBA-II.

ALBA SLAB MEASUREMENTS

The alignment group at ALBA periodically surveys the position of the facility elements every 6 months during the winter and summer shutdown. Data inside the storage ring tunnel is taken at 64 locations known as Tunnel Floor (TF) points. In addition, for each one of the 32 girders, a bending magnet and a quadrupole are also measured, and referred as MAGNETS along this article.

TF and MAGNETS are all obtained from the survey network grid which consists in TF and tunnel wall points (TW). TF points are directly measured. On the other hand, MAGNETS points correspond to measurements averaged over 5 different points on bending magnets and 4 points on quadrupoles, and acquired through interface/reflector nest with a known height offset positioned on top of the magnet at the moment of the measurement.

The acquired data is then processed to subtract from measurements the mean vertical inclination through a definition of an average machine plane. The position of every point is provided by the alignment group as three Cartesian coordinates referred to the center of the machine.

Apart from the measurements, the nominal position of each point with respect to the same reference system is provided. A verification of the survey nominal points show differences below 1 μm for different dates, confirming the usage of the same reference system.

The first hypothesis on the study assumes that movement of the slab should be measurable in both the TF and MAGNETS points. Data from four measurement campaigns has confirmed such hypothesis by subtracting two different dates and checking that they provide the same movement profile. An estimated error, or difference, of 50 μm rms has been obtained from the summer 2022 to winter 2023 variation measured on TFs and MAGS.

EFFECT ON THE ORBIT

The ALBA ring model [5] in the MATLAB Accelerator Toolbox [6, 7] and magnet position definition tools available in the Simulated Commissioning toolkit [8, 9] have been used to simulate the effect of the slab position on the electron beam orbit.

Data from alignment has been transformed from a Cartesian system with origin at the nominal center of the machine to a local reference system on the electron nominal trajectory.

Taking into account the distance among the measured points, the individual magnet offsets have been estimated from interpolation using the measured data on TF points and the geometrical constraints of the girder and dipole distribution along the ring.

In order to validate the model, we compare the 6-months orbit changes evaluated in three different ways: the bare orbit measured at the beam position monitors (i.e. the orbit due to magnet misalignments without correctors); the simulated orbit produced by the correctors setting variations; the simulated orbit produced by the girder displacements inferred from the TF survey.

Figure 1 shows very good agreement on the closed orbit changes between summer 2022 and 2023. This implies that the slab movement is driving the closed orbit variations of the two last years. The change in mean radius has been removed from the offsets in order to keep the nominal RF frequency and effectively eliminating the dispersion from the BPM readings.

* oblanco@cells.es

ISBN: 978-3-95450-247-9 ISSN: 2673-5490 doi: 10.18429/JACoW-IPAC2024-MOPG01

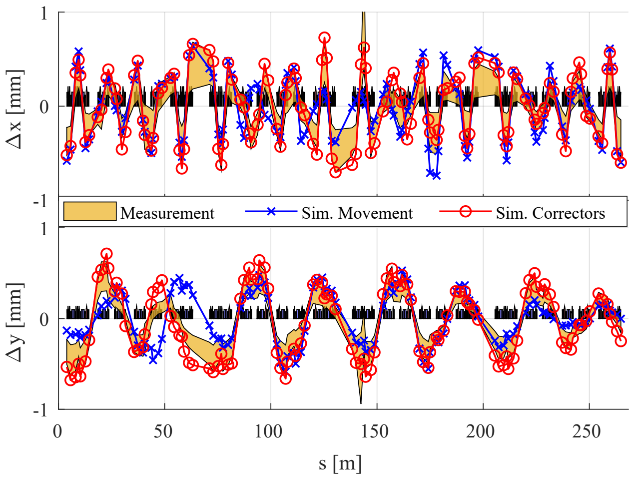

Figure 1: Change between summer 2022 and summer 2023 on the closed orbit without correction. The blue line shows the simulated orbit produced by girder displacement, the red line shows the simulated orbit produced by orbit correctors variations, and the yellow strip correspond to the mean $\pm 1\sigma$ of the measured closed orbit without correction taken before and after every summer shutdown. The ALBA ring synoptic is superimposed.

A second comparison using the total displacement with respect to the nominal magnet position instead of differences between two dates has been tried out but was inconclusive due to missing information on one girder. In an attempt to fill the missing information, singular value decomposition in a girder-to-orbit response matrix was used to infer what would be the girder displacement that better explains the closed orbit on the ALBA storage ring.

Once the reliability of the model has been checked, we introduce the effect of the girder movement over time in the simulations.

SLAB MOVEMENT MODEL

The large correlation on the girder to girder displacement prevents the use of rms values to characterize their movement, therefore, we have opted for a sin-wave decomposition with varying frequency, amplitude and phase.

The 6-months and 1-year differences from the 2022 and 2023 summer and winter data shown in Fig. 2 show a movement of high amplitude, low spatial-frequency and non-cumulative trend, meaning that the movement of a year does not necessarily increase the amplitude.

They were analyzed through Fast Fourier transform and reconstructed from fewer high amplitude terms in order to verify the result. Table 1 shows the peak values obtained for both time periods. Those results are used for ALBA-II simulations.

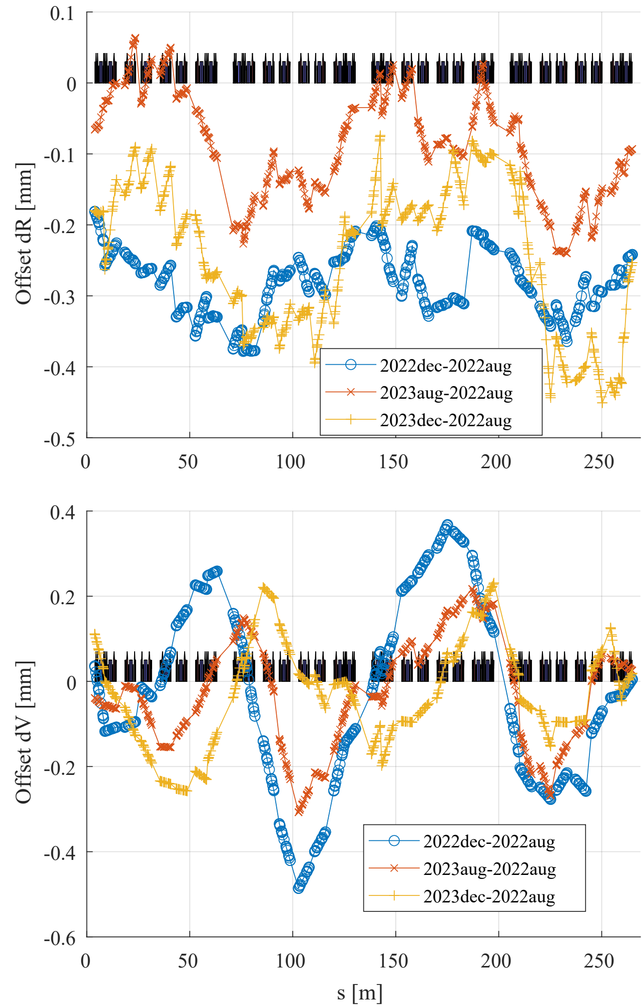

Figure 2: Alignment data transformed to the Radial (R) and Vertical (L) reference system centered on the nominal beam trajectory for three different dates (2022/dec, 2023/aug and 2023/dec) with respect to 2022/aug. ALBA ring synoptic superimposed.

ALBA-II

The new ALBA-II lattice [10] has been studied using the slab movement model. The highest amplitude values in Table 1 with random phases have been added up to the model with varying locations for orbit and optics correctors [11]. Figures 3 and 4 show the effect on the beam lifetime and dynamic aperture (DA) after optics correction. The recovered horizontal DA exceeds -5 mm which is required for off-axis injection while the loss in the recovered lifetime seems tolerable.

Orbit corrector budget is increased by 30 μrad as shown in Fig. 4 from simulations including only the slab movement model. This amounts to less than 10% of the 500 μrad max. foreseen for ALBA-II, and therefore does not impose a big limitation.

ISBN: 978-3-95450-247-9 ISSN: 2673-5490 doi: 10.18429/JACoW-IPAC2024-MOPG01

Table 1: Peak values of the sin-wave decomposition performed over the alignment data taken between 2022 and 2023. The symbol – means that the value is below the estimated error of 50 µm. T is the ALBA storage ring circumference of 268.8 m. The mean radius variation over 6-months period equal to 280 µm corresponds to 520 Hz of the main RF cavity system. The mean radius variation (*) over a 1-year period was estimated to be 90 µm, but, it was inconsistent between TF and MAGNETS data. Values have been rounded to 10 µm.

Period	6-months			one-year		
	dL	dR	dV	dL	dR	dV
	µm	µm	µm	µm	µm	µm
Mean	-	280	-	-	-*	-
T	-	-	-	-	-	-
$T/2$	-	70	260	70	110	320
$T/3$	-	-	110	-	-	160

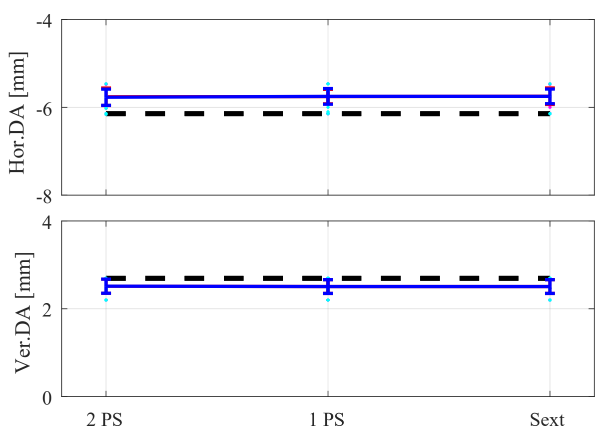

Figure 3: (TOP) Negative side of the horizontal and (BOTTOM) positive side of the vertical dynamic aperture (DA) of the ideal ALBA-II lattice in dashed lines, and the recovered DA for different optics and orbit correctors configurations.

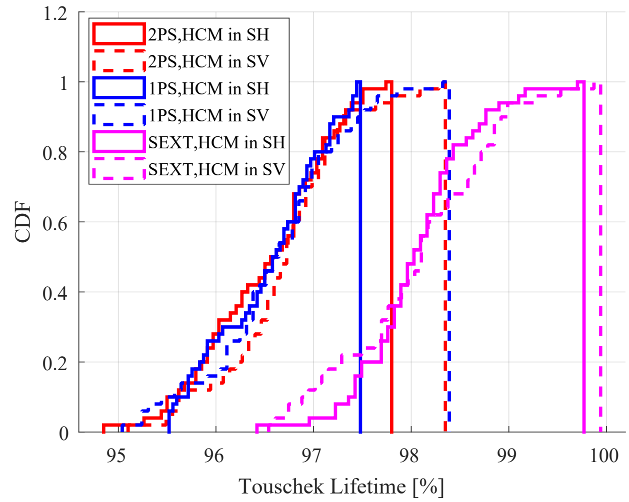

Figure 4: Touschek lifetime of the corrected lattice with respect to the ideal lattice.

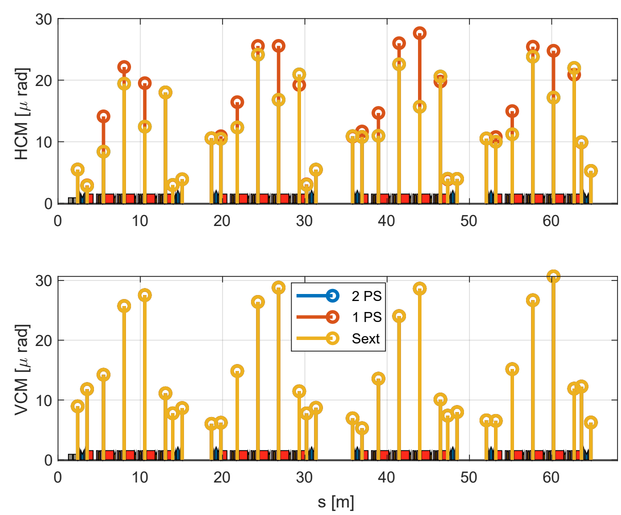

Figure 5: Horizontal (HCM) and vertical (VCM) orbit correctors along 1/4 of the ALBA-II ring from the slab movement correction.

CONCLUSIONS

The ALBA synchrotron critical slab has moved over the more than 10 years of machine operation, however, the movement due to the ground settlement after the initial installation of equipment differs from the smaller differences seen in the most recent years through alignment survey campaigns.

Data from 2022 and 2023 from alignment surveys has been used to cross-check with orbit simulations and orbit corrections of the ALBA electron beam storage ring, and a good agreement has been found with the effect of girder displacement interpolated from measurements on the tunnel floor.

An error of 50 µm rms on the radial and vertical directions has been estimated from differences between magnet and tunnel floor data. The latter has been decomposed in sin-waves of varying amplitude, phase and spatial frequency and results show a low-frequency high-amplitude movement. In addition, the movement appears to be non-cumulative, i.e., the movement of one year does not increase the amplitude of the displacement.

The effect of the slab movement on the ALBA-II lattice has been simulated. An additional orbit corrector budget that amounts to 30 µrad peak is necessary to correct the modeled slab movement. This value corresponds to less than 10% of the total budget foreseen for orbit correction and does not pose a risk. The effect on the dynamic aperture and Touschek beam lifetime is well corrected.

Further work would be dedicated to the study of high spatial-frequency and low amplitude variation of the girders along the ring.

ISBN: 978-3-95450-247-9 ISSN: 2673-5490 doi: 10.18429/JACoW-IPAC2024-MOPG01

REFERENCES

[1] F. Perez, "First Year Operation of the ALBA Synchrotron Light Source", in *Proc. IPAC'13*, Shanghai, China, May 2013, paper MOPEA055, pp. 202–204.

[2] F. Rey *et al.*, "Status Report on Survey and Alignment for the ALBA Synchrotron", presented at *the 10th International Workshop on Accelerator Alignment, IWAA 2008*, February 11-15, 2008, KEK, Tsukuba, Japan.

[3] M. Llonch Burgos *et al.*, "Slab Evolution and Status at ALBA Synchrotron", presented at *the 13th International Workshop on Accelerator Alignment, IWAA 2014*, October 13-17, 2014, IHEP, Beijing, China.

[4] M. Llonch Burgos *et al.*, "ALBA Global Stability analysis", in *Proc. IWAA 2022*, CERN, Switzerland. `https://indi.to/b4zKY`

[5] G. Benedetti *et al.*, "LOCO in the ALBA Storage Ring", in *Proc. IPAC'11*, San Sebastian, Spain, Sep. 2011, paper WEPC024, pp. 2055–2057.

[6] MATLAB. `https://matlab.mathworks.com`

[7] Accelerator Toolbox (AT) github. `https://atcollab.github.io/at`

[8] Toolkit for Simulated Commissioning (SC). `https://sc.lbl.gov`

[9] T. Hellert *et al.*, "Toolkit for simulated commissioning of storage-ring light sources and application to the advanced light source upgrade accumulator", *Phys. Rev. Accel. Beams*, vol. 24, p. 100702, 2019. `doi:10.1103/PhysRevAccelBeams.22.100702`

[10] M. Carlà, *et al.*, "Status of the ALBA-II lattice studies", presented at the IPAC'24, Nashville, TN, USA, May 2024, paper THPC01, this conference.

[11] Z. Martí *et al.*, "ALBA-II first tolerance studies", in *Proc. IPAC'23*, Venice, Italy, May 2023, pp. 3104-3107. `doi:10.18429/JACoW-IPAC2023-WEPL003`