EFFECT OF PHASE ONE INSERTION DEVICES IN THE ALBA STORAGE RING

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Abstract

The synchrotron light source ALBA incorporates 6 insertion devices (2 Apple-II type elliptical undulators, 2 planar in vacuum undulators, one wiggler and one superconducting wiggler) at the start of operation. The effect of the different Ids in the performance, using several models (kick maps, hard edge model and dynamic multipoles) is evaluated for different configurations of the IDs, including an evaluation of the agreement of the different models running in Accelerator Toolbox.

INTRODUCTION

The ALBA synchrotron [1] comisioning will begin sometime in next year with 6 insertion devices (IDs) installed. The location off the insertion devices and their parameters have been already defined [2]. Most of the IDs have already been delivered and measured. Table 1 shows the parameters of such IDs. For the elliptically polarizing IDs three values of K are supplied, one for each polarization mode: horizontal, circular and vertical.

Table 1: Specification of the phase 1 IDs for ALBA. Betas are β_x= 2 m and β_y=1.3 m.

ID	L (m)	gap(mm)	B_0 (T)	K	λ (mm)
SCW31	2.00	12.0	2.2	6.1	31
$IVU21$	2.00	5.5	0.8	1.6	21
W80	1.00	11.0	1.6	13.3	80
EPU62	1.76	11.0	0.9	5.1/3.6/4.8	62
EPU71	1.66	11.0	0.9	6.2/4.7/5.3	71

Previous works [3] showed a big impact on the off momentum dynamical aperture due to the inclusion off insertion devices. After modifying the working point and the sextupole setting [4] the effect seems to be quite small.

MODELS

Up to three different models for the ID simulations are compared. the models are:

- KMM: kick map method [5].
- HEM: Hard edge model [6].
- DMM: Dynamic multipoles method [11].

The models have been chosen according to their speed, accuracy and the easiness of an implementation of the method with measured magnetic fields. More exact methods like [7], [8] or [9] have been discarted due to its complexity and calculation time.

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In all cases, the Accelerator Toolbox [10] running on MatLab has been used to calculate the effect of such devices in the linear and nonlinear parameters of the ALBA lattice.

MAGNETIC FIELD

The magnetic field used in the simulations can be either calculated with RADIA [12] or measured with a hall probe. In the case of the calculated fields, the 3D field is directly available, while for measured fields, usually only the medium plane of the undulator is measured. An extrapolated 3D mesh can be obtained, using Maxwell equations, from that measured field map.

KMM and DMM make use of the full 3D field, however, the HEM only takes into account on plane fields.

LINEAR EFFECTS

Table 2 shows the vertical tune shift induced by each ID using the above mentioned models. The horizontal tune shift is in general less relevant (reaching a maximum of -24×10^{-4} when all vertically polarizing devices are active). The letters H, C and V stand for horizontal, circular and vertical polarization respectively. The letters a, b and c stand 12 mm gap, 12 mm gap with taper and 18 mm gap with taper. For the tapered devices, due to the complexity of such RADIA simulation, no theoretical magnetic field were calculated. In table 2 the last row combines the following IDs: $SCW31$, $2 \times IVU21$, $W80_{12}$, $EPU62_V$ and $EPU71_V$.

Table 2: Vertical tune shift $\Delta Q_y \times 10^4$. Subindex a, b and c stand for 12 mm gap, 12 mm gap with taper and 18 mm gap with taper.

	Theoretical field			Measured field		
ID	KMM	HEM	DMM	KMM	HEM	DMM
$SCW31$	55	53	50	53	46	45
IVU_1	8	8	7	8	7	8
$W80_a$	12	18	13	19	13	14
$W80_b$	0	0	0	16	12	14
$W80_c$	0	0	0	10	7	7
$EPU62_H$	6	8	6	4	7	9
$EPU62_C$	9	8	9	15	3	5
$EPU62_V$	11	8	11	10	6	10
$EPU71_H$	7	9	6	8	9	8
$EPU71_C$	11	9	11	13	10	12
$EPU71_V$	14	10	14	13	7	13
All IDs	107	104	100	110	84	98

The HEM gives systematically lower effects for vertically polarizing devices, this is consistent with the fact that, in the calculations, this model is extracted from the on-axis field. For such devices the electron beam can move away the mid plane of the ID. In general, the HEM does not take into account properly the vertical variation of the field. The KMM and the DMM are usually in good agreement which allows us using any of those approaches. However KMM is much faster and hence that is our preferred method to simulate both theoretical or measured IDs.

NON LINEAR EFFECTS

Dynamical aperture

The effect on the 4D, 500 turns, dynamic apertures (including all physical apertures: 4 mm vertically due to the IVUs and 16 mm horizontally due to the septum), has been calculated for the same set of cases studied in the previous section. On and off momentum dynamic apertures (figures 1, 2 and 3) reduction ratios have been calculated.

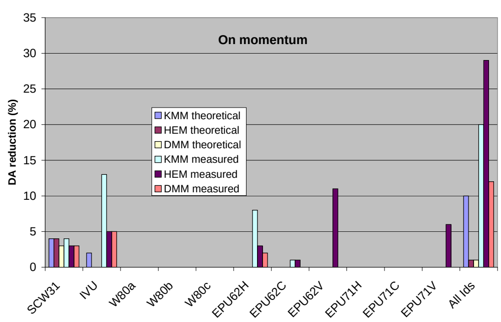

Figure 1: On momentum Dynamic aperture reduction ratio (%) for every IDs setting.

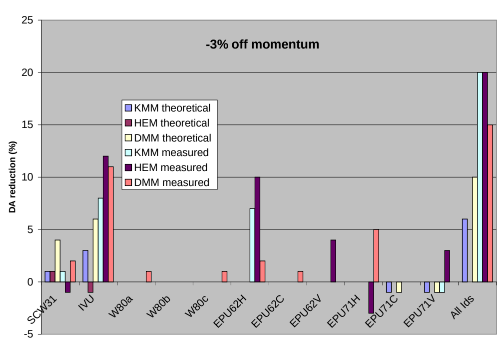

Figure 2: -3% off momentum Dynamic aperture reduction ratio (%) for every IDs setting.

Despite the simulated fields of the IDs Seemed not to have a noticeable influence on the off momentum dynamical aperture, the effect using the measured field seems quite strong in some cases. In general, it can be assessed that this extra effect found with measured field is not due to the field treatment, as the three models are quite consistent. However the effect may come from the field measure itself. In any case, the on momentum aperture is only weakly affected, even when including all the field maps in

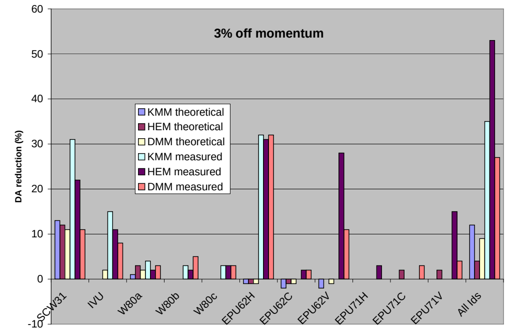

Figure 3: 3% off momentum Dynamic aperture reduction ratio (%) for every IDs setting.

the model. A good visual proof for that are the tune shifts and frequency maps in figures 4, 5 and 6.

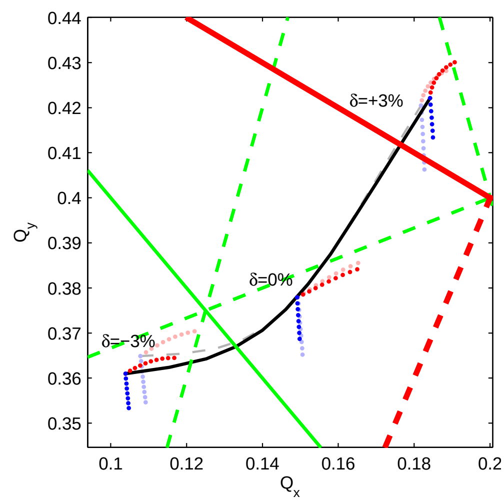

Figure 4: tune shifts with amplitude (red points for up to 16 mm horizontally and blue points for up to 4.5 mm vertically) and with energy (black lines from -3% to 3%) for the unperturbed (light colors) and the lattice with all IDs (KMM with simulated field). Red and green lines represent 3rd and 4th order resonance respectively. Beta beating and working point change have been corrected.

Energy acceptance and Touschek lifetime

The local 6D, 500 turns, energy acceptance (EACC) around the machine is calculated for every ID configuration. The mean energy acceptance values for the bare lattice are -4.5% and 4.2% (without considering the RF limit which will be set to around 3%). The effect is negligible except when all the IDs are considered at the same time, and only for the DMM. For such case the EACC reduces around a 15%.

The Touschek lifetimes for all the studied cases have been roughly calculated using H.Bruck's formula [13]. The reference value, assuming no RF limitation, is 60 hours. The beam sizes are estimated by means of calculat-

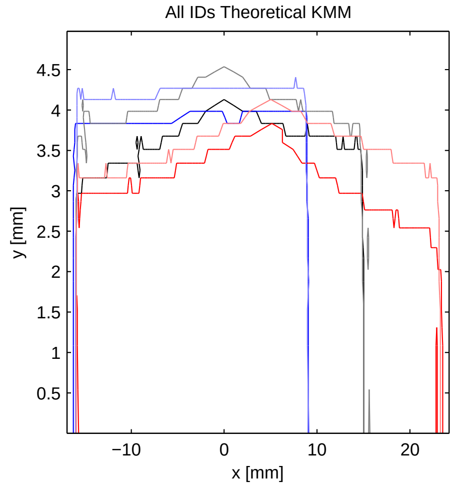

Figure 5: 500 turns, 4D, on and off momentum dynamic aperture for the bare lattice with all the IDs using the KMM and the theoretical field. Beta beating and working point change have not been corrected. Notice that the left side is limited by the semptum.

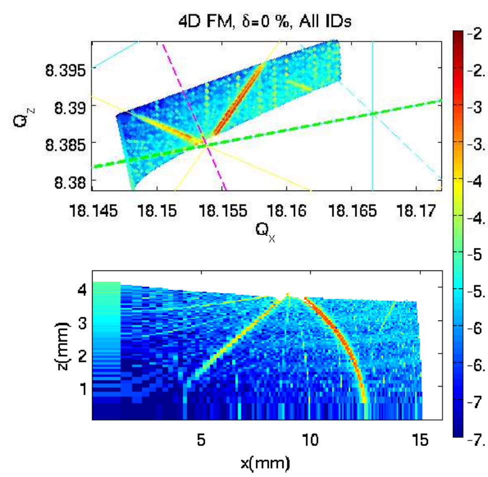

Figure 6: 2000 turns, 4D, on momentum frequency map for the bare lattice with all the IDs using the KMM and the theoretical field. Beta beating and working point change have not been corrected.

ing the synchrotron integrals. The authors have not implemented rigorous calculations, like [14], for the ID models presented here in AT. Again, the effect in the lifetime is only relevant when all IDs are considered together, and only when the IDs are simulated via the DMM. Reductions around 25 % are expected for such cases. In any case, the life time would be dominated by the RF energy acceptance.

CONCLUSIONS

The effect of the phase one insertion devices in the ALBA lattice has been studied. No significant reduction of its performance can be predicted. The models give similar results. Due to its calculation speed, the kick map method is our preferred model.

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