EFFECT OF THE MEASURED MAGNETIC MULTIPOLES IN THE ALBA LATTICE

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Abstract

The Spanish synchrotron light source ALBA is in the process of installation, with the large majority of components already manufactured and delivered. Among them, the magnets of the storage ring. As part of the acceptance process of the magnets, a campaign to measure the quality of them (magnetic length, effective bending and focusing, high order multipolar components) has been performed inhouse and in the manufacturer. The results of this measures have been applied to the model of the storage ring, analyzing the effects in the performance (lifetime, dynamic aperture, orbit, etc). The results of the study confirm the quality of the magnets design and manufacturing as well as the performance of the lattice.

INTRODUCTION

ALBA [1] is a medium energy light source under construction close to Barcelona, Spain. The lattice of the storage ring is based in a DBA-like structure with distributed dispersion and combined function magnets, providing a small emittance with small natural chromaticities (the lattice is similar to a TME one)[2], with a large space avalaible for insertion devices. Due to the small chromaticity, its compensation is not too complicated and the sextupoles families (9 in the ALBA case) do not required many special phase advances between them. The solution chosen for the default working point provide an ample dynamic aperture for injection and an energy acceptance larger than the provided by the RF system. Table 1 show the main parameters of the storage ring and Figure 1 show the optical function for one quarter of the machine.

The inclusion of the high order multipoles of the quadrupole and sextupole magnets will have an effect of on the dynamic aperture and the energy acceptance. In order to provide for a reliable machine, with enough lifetime and injection efficiency, those should still be large enough after the effects introduced by the high order multipoles. In the case of ALBA, it is required that the horizontal dynamic aperture should be at least 16 mm at the middle of the long straight section (injection point) and the energy acceptance of the lattice over 3%.

In this paper the effect of the high order magnetic multipoles of the quadrupoles and sextupoles and the effect of the sextupole component of the dipole is reviewed.

Table 1: Parameters of the storage ring

Circumference	268.8 m
Energy	3 GeV
Emittance	4.5 nm×rad
Tunes	(18.18, 8.37)
Natural Chromaticity	(-40, -27)
Relative Energy Spread	1.05×10^{-3}
Momentum Compaction Factor	8.8×10^{-4}
Damping Partition Numbers	(1.3, 1, 1.7)
Energy Loss per Turn	1.007 keV

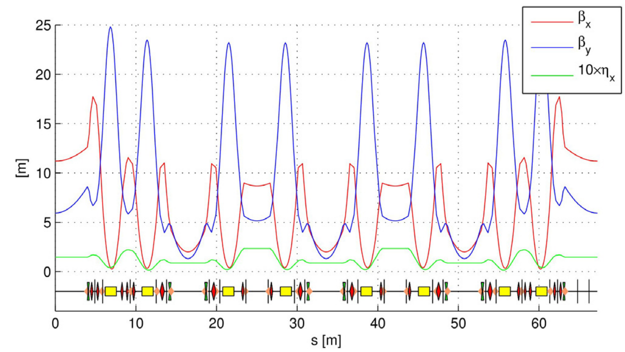

Figure 1: Optical functions for one quarter of the machine.

MULTIPOLE COMPONENT OF THE MAGNETS

The sextupole and quadrupole magnets of the ALBA storage ring have been manufactured and measured at the Brudker Institute of Nuclear Physics. 120 quadrupoles and 114 sextupoles were measured. Figure 2 shows the measured normal harmonics with respect of the main field. The solid bar shows the systematic component and the error bar the variation between the different magnets. From there, is possible to see that only the multipoles allowed by symmetry of the field have a significant systematic part. The values will vary slightly in function of the length of the magnets (the quadrupoles are grouped in three families in function of the length (200 mm, 260 mm and 500 mm), and two families (120 mm and 220 mm) for the sextupoles) Those values (and the ones of the skew components) are related to the usual units of the multipoles (a_n, b_n) using in the simulation codes by:

$$a_n = \frac{A_{n+1}}{\rho_0^n}, \qquad b_n = \frac{B_{n+1}}{\rho_0^n} \tag{1}$$

where ρ is the radius at which the coefficients are measured (25 mm in the ALBA case).

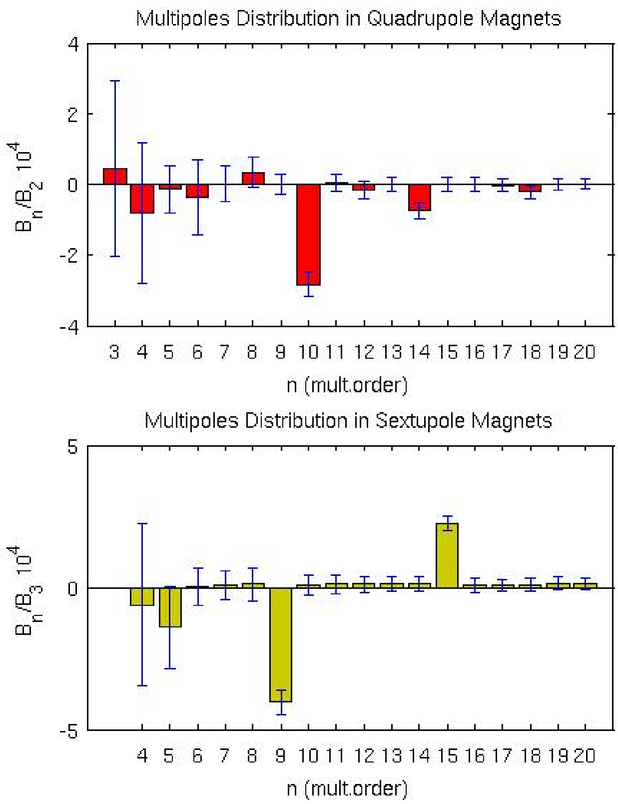

Figure 2: Normal high order multipole component for the quadrupoles (upper plot) and the sextupoles (lower plot). The solid bar correspons to the average value all the measured magnets of a given type and the error bar to the standart deviation.

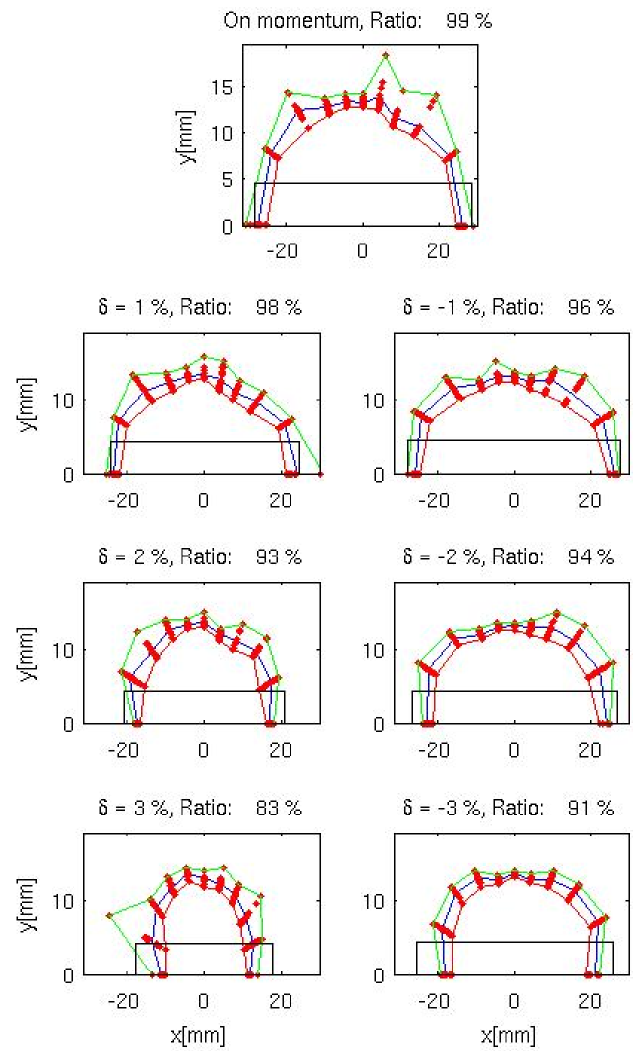

Figure 3: Dynamic aperture for 20 different sample machines at the injection point (s=0 in figure 1). The top figure is for the on energy particle, and each row for increasing values of the energy deviation. The green value is for the case with larger DA, the red for the one with smaller DA and the blue is for the average value. The black line is the projection of the physical aperture (excluding the septum). The percentage is the reduction of the DA respect the ideal case.

Effect of the multipoles

The Accelerator Toolbox has been used to simulate the impact of the multipoles in both the dynamic aperture and the energy acceptance, and the results crosschecked with MAD. The first step is to evaluate the impact in the dynamic aperture. Figure 3 shows the calculated dynamic aperture for 20 different cases. For each case, a random distribution of multipole components, using as average value the systematic component of the multipole, and as sigma the random component, has been applied to the magnets and the dynamic aperture evaluated. Figure 4 shows the local energy acceptance for the same 20 cases.

The DA remains large enough even for an energy deviation of a 3%. Further simulations [3] proves that the even an increase by a factor 10 in the values of the multipoles will not affect the predicted performance of the machine. Equally, the energy acceptace is (except in a few points) larger the 3% provided by the RF cavities, not affecting the Touschek contribution to the lifetime. Also, When including the effect of the misalignment of the magnets, the values obtained for the dynamic aperture at the different energies do not degrade in excess, and the values are recover once the orbit is corrected.

Finally, figure 5 shows the frequency map for a sample case. The third order resonance excited at amplitudes of 12 mm could be the limiting factor in the aperture, so a possible small variation of the working point in order to avoid it is under study.

EFFECT OF THE SEXTUPOLAR COMPONENT IN THE BENDING MAGNET

The other large contribution to the non-linearities of the machine would be the multipoles of the bending magnet. ALBA uses a combined function bending magnet, with a

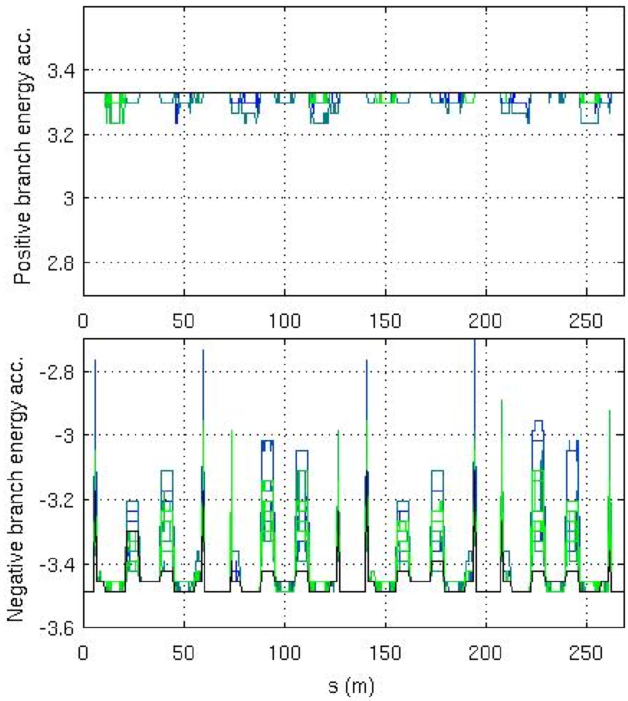

Figure 4: Local energy acceptance along the lattice. In order to provide the desired Touschek lifetime, it is required a 3% acceptance.

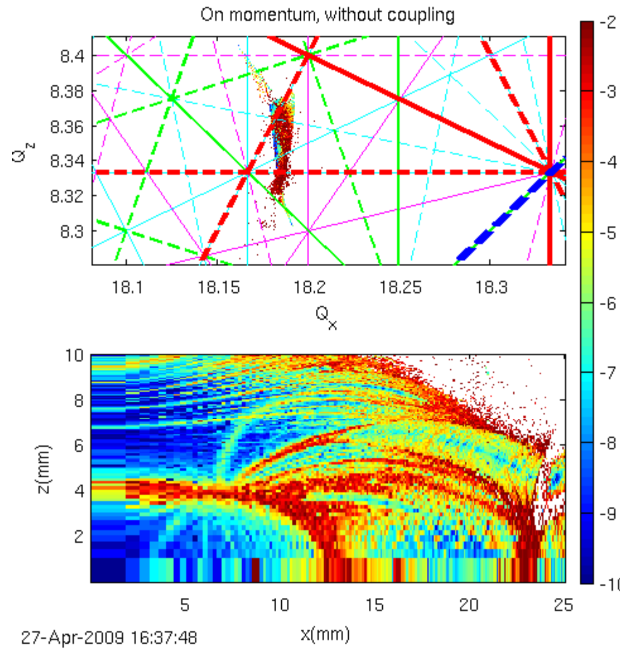

Figure 5: On energy frequency map for a sample case. The resonance visible at 12 mm is a third order $2Q_x - Q_y = 28$

large field (1.42 T) and gradient (5.6 T/m), in order to provide most of the vertical focusing required by the machine. The 32 bending magnets have been manufactured by Danphysick and measured in-house. A very detailed analysis of the field quality has been carried in the last year, in order to evaluate the effect in the orbit and optical functions, and to evaluate the correct chamfer required to obtain the desired edge focusing.

Figure 6 shows the distribution of the sextupolar component along the reference trajectory of the electrons for the average magnets. As it can be seen, a small contribution is present in the body of the dipole as well as two larger ones in the edges. The total contribution of this component is to change the vertical chromaticity by one unit, but it can be easily compensated by the sextupoles without any degradation of the dynamical aperture and energy acceptance.

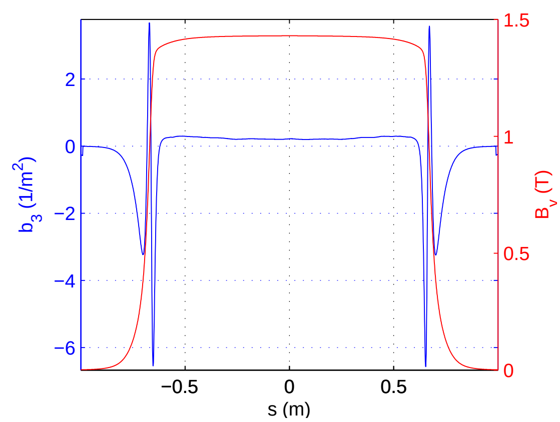

Figure 6: Sextupolar component (in blue) and dipolar component (in red) of the field in the bending magnet along the ideal trajectory of the electrons, for the reference bending magnet.

CONCLUSIONS

The excellent quality of the manufacturing of the magnets of ALBA, as well as the robustness of the lattice have reduced the impact of the multipole components in the dynamic aperture and energy acceptance down to values that will no affect the performance of the machine. The degradation due to the multipole components is smaller than the error introduced by randon variation between quadrupoles and sextupoles.

REFERENCES

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[3] Z. Martí, "Including multipole components from the magnetic measurements", ALBA internal report AAD-SRBD-A-0011