ACDIV-2013-17
June, 2013

LOCO accuracy simulations with ALBA lattice

Zeus Martí, ALBA-CELLS, Barcelona, Spain

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Accelerator Division
Alba Synchrotron Light Source
c/de la Llum, 2-26
08290 Cerdanyola del Valles, Spain

Accelerator Division

ALBA Project Document No:	EDMS Document No.	Created: **13.05.13**	Page: **1 of 33**
ACDIV-2013-17		Modified: **06.06.13**	Rev. No.: **0.0**

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Abstract

We performed a simulation of the LOCO fitting accuracy at ALBA. 300 randomly perturbed lattices with misalignments and with random errors in the BPM and correctors coupling coefficients where generated and fitted with LOCO. Beta beating accuracy measurement is established to be around 1%.

Prepared by:	Checked by:	Approved by:
Z.Martí	**U.Iriso, G.Benedetti**	
Authorship:		
Z.Martí		

Distribution list

Accelerators Division

Record of Changes

Rev. No.	Date	Pages	Description of changes
0.0	13.05.13	All	first release

References

[1] ICFA newsletter, num 44, pag 67, 2007.

[2] G.Benedetti et alt, *BEAM OPTICS MEASUREMENTS DURING ALBA COMMISSIONING*, Proceedings of IPAC2012, New Orleans, Louisiana, USA, pag. 1656.

Contents

1 Introduction

LOCO [1] is routinely used at ALBA, mainly to measure its beat beating. It has been used since the commissioning started and during the operation [2]. During this time, it has proved to be a very useful tool for the electron beam optics diagnose and correction. Also, it has been very useful to diagnostic major problems with the optical elements like a single quadrupole power cable exchange. However, its real accuracy at ALBA has not been determined precisely yet.

The document has been divided in 5 sections, introduction plus 3 sections and the conclusions.

After this introduction, section 2 is dedicated to present the parameters of the simulated perturbed lattices. In this section the error distribution used to emulate the real lattice behavior are presented.

Section 3 is dedicated to present the fitting parameters and constants used in the LOCO analysis. LOCO in this internal report is used in diagnostic mode. This means that the number of fitting parameters used is greater than the number of knobs in the real machine. However, different configurations of the number of fitting parameters are compared. Also, the constants of the LOCO analysis such the dispersion weights and the λ constant are varied to optimize the LOCO analysis.

Finally, before the conclusions, section 4 presents the statistical results for a set of 300 LOCO fits. For each simulated lattice case, the following steps are executed:

1. A lattice with random magnet misalignments, rotations and strength errors is generated.
2. Random coupling and gain errors in BPMs and correctors are added to the simulation. This errors are the same at every reading for a given BPM. The distributions width is calculated according to LOCO's results with the real machine.
3. Random errors for each BPM and reading are added. The distributions width is based on real machine measures during 2012 and 2013. For both planes the σ of the distribution is taken as 0.25 μm.
4. Dispersion and response matrix are simulated from the lattice. This simulations include the effects induced by the previous steps 1, 2 and 3.
5. The BPM noise level used by LOCO to weight the relative weights of the response matrix is averaged from real machine measures during 2012 and 2013.
6. Each simulated data set is fitted to the model with LOCO.
7. The initial simulated lattice (without the reading errors) and the fitted lattice are compared.

2 Simulated lattices

The lattices were generated including random displacements (in x and y planes), roll rotations (a ϕ angle around the longitudinal direction), and magnetic dipole (b) and quadrupole (k) errors in the quadrupoles, sextupoles and bending magnets. Gaussian distributed errors cut at 3σ are used. At ALBA, each bending magnet together with its neighboring quadrupoles and sextupoles is mounted in a separated girder. As seen in table 1, the alignment tolerances for the girders are bigger than the ones for the magnets. both the magnet and the girder tolerances are combined in the simulations.

girder σ_x	150 μm
girder σ_y	150 μm
girder σ_ϕ	50 μrad
magnet σ_x	25 μm
magnet σ_y	25 μm
magnet σ_ϕ	50 μrad
σ_b	0.1 %
σ_k	0.1 %

Table 1: Sigma values for the Gaussian error distribution to generate the perturbed lattices.

Once the errors have been included, the orbit is corrected below 10 μm at the 88 BPMs chosen for this purpose. This mimethises what is done in the real machine. To further approach the models to the real case, coupling and gain errors are included in the BPM readings and corrector kicks. The coupling and gain errors in the BPMs and the correctors have been set at with Gausian random errors witha a 3σ cut with offsets and rms values taken from real measurements LOCO fits.

	mean	standard deviation
horizontal BPM gain	2 %	1.5 %
vertical BPM gain	-5 %	1.5 %
BPM crunch	0 rad	0.1 rad
BPM roll	0 rad	0.1 rad
horizontal corrector gain	-10 %	10 %
vertical corrector gain	-10 %	10 %
horizontal corrector roll	0 rad	0.1 rad
vertical corrector roll	0 rad	0.1 rad

Table 2: offset and peak to peak values for the uniform error distribution to generate the perturbed lattices.

For the 300 generated latices, the standard deviation beta beating and dispersion beating are presented in figures 1 and 2 respectively. These measurements do not include the reading errors.

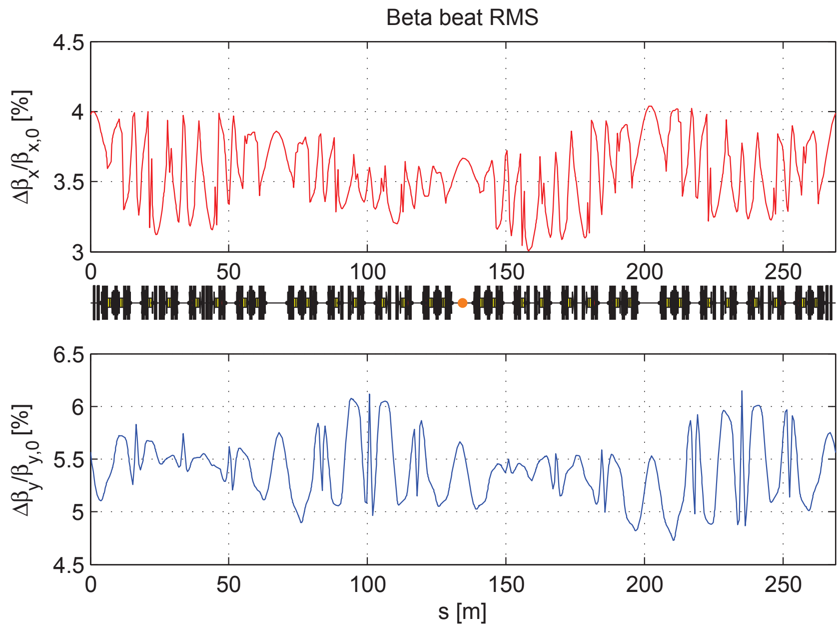

Figure 1: standard deviation beta beating for the 300 randomly generated lattices along the machine position. Vertical plane has bigger values as it is dominated by the focusing at the bending magnets. This behavior is also observed in the real data measurements.

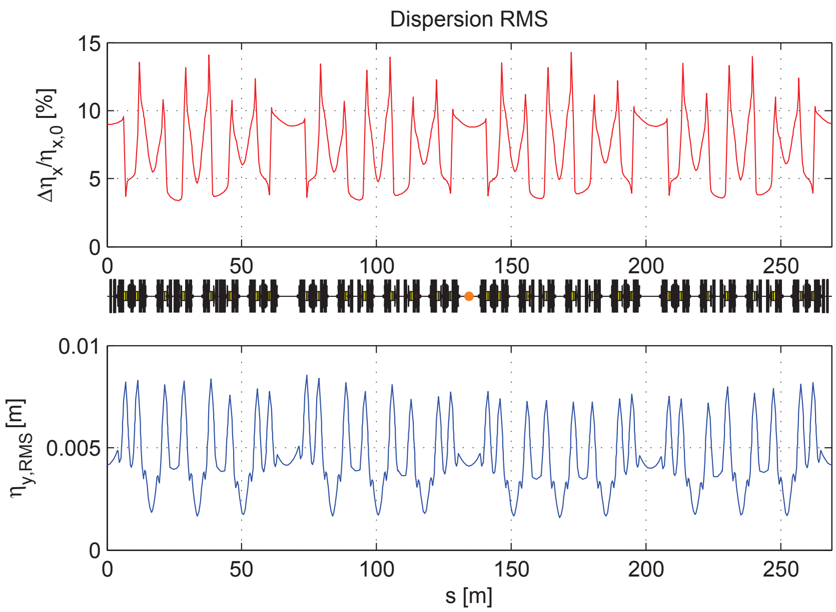

Figure 2: standard deviation dispersion beating for the 300 randomly generated lattices along the machine position. since the reference value in the vertical plane is zero, the absolute dispersion generated is plotted instead of the relative errors.

3 LOCO fitting parameters and constants

For the present set of analysis, the LOCO algorithm has been applied with the following options:

Algorithm	Scaled Levenberg-Marquardt
λ	0.1, 0.05 or 0.01
LOCO iterations	5
uncoupled optics fitting	at quadrupoles (112)) and/or dipoles(32) and/or sextupoles (120)
coupled optics fitting	at sextupoles (120) and/or quadrupoles(112) and/or dipoles (32)
Dispersion weight	from 1 to 30
SVD method	rank

Table 3: LOCO fitting parameters. The meaning of these parameters has been explained in [1].

On the other hand, in each LOCO fit in this report, the following fitting parameters are always used:

horizontal BPM gain	104 or 120
vertical BPM gain	104 or 120
horizontal BPM roll	104 or 120
vertical BPM roll	104 or 120
horizontal corrector gain	88
vertical corrector gain	88
horizontal corrector roll	88
vertical corrector roll	88
total	768 or 832

Table 4: Fitting parameters used in the LOCO fits apart from the optics fitting parameters. The number of parameters introduced into the fits by each parameter type is specified.

At ALBA, Only 104 of the 120 BPMs installed have the corresponding electronics. Our default number of BPMs is 104, however, in this section the simulations are done also with 120 for comparison.

Next subsections discuss on the selection of the rest of the firring parameters, namely the optics fitting parameters, and the other constants involved in the fitting procedure.

For each fitting parameter and optic function ξ at the i-th simulated lattice and the j-th position in the ring, we make the following definitions:

$$\begin{aligned}
\Delta\xi_{i,j} &= \xi_{LOCO,i,j} - \xi_{Model,i,j} \\
\hat{\Delta\xi_i} &= \langle \Delta\xi_{i,j} \rangle_j = \sum_j \frac{\Delta\xi_{i,j}}{M} \\
\sigma_{\xi,i} &= \sqrt{\langle (\Delta\xi_{i,j} - \hat{\Delta\xi_i})^2 \rangle} \\
\hat{\Delta\xi} &= \langle \hat{\Delta\xi_i} \rangle_i \\
\hat{\sigma_\xi} &= \langle \sigma_{\xi,i} \rangle_i \\
\sigma_{\hat{\xi}} &= \sqrt{\langle (\hat{\Delta\xi_i} - \hat{\Delta\xi})^2 \rangle}
\end{aligned} \tag{1}$$

In this section for each fitting parameter we will show the mean and standard deviation values in the format $\hat{\Delta\xi}(\sigma_{\hat{\xi}})(\hat{\sigma_\xi})$.

3.1 Optics fitting parameters

In this study, LOCO has been used in diagnostic like mode. This means that the number of fitting parameters used is greater than the number of knobs in the real machine. Despite the data obtained with this mode can not be used for a proper optics correction, the fitting of the optical functions and parameters should be more accurate. However, increasing the number of fitting parameters may cause fitting parameters cross talk, excessive degrees of freedom and computational time. For this reason, different configurations of fitting parameters are compared. For each configuration, we have calculated the fitting errors for a set of randomly generated latices.

Appendix A contains a set of tables with the mean and standard deviation errors of 125 random different lattices studied with different setts of fitting parameters. 9 combinations have been studied for each lattice. The uncoupled optics is fitted at quadrupoles (112 parameters), at quadrupoles and dipoles (144 parameters) or at quadrupoles, dipoles and sextupoles (264 parameters). The coupled optics is fitted at sextupoles (120 parameters), at sextupoles and quadrupoles (232 parameters) or at sextupoles, quadrupoles and dipoles (264 parameters). Appendix B contains the same set of tables using 120 BPMs instead of 104. Table 5 summarizes the total number of fitting parameters used in this section.

	120S	120S+112Q	120S+112Q+32D
112Q	1000	1112	1144
112Q+32D	1032	1144	1176
112Q+32D+120S	1152	1264	1296

Table 5: . Total number of fitting parameters for different numbers of optics fitting cases. In this case, we use 104 BPMs.

In this study, both average and standard deviation values among the elements in the ring are shown. The results are averaged for the 125 cases and the standard deviation of the average is also shown. After examining the results of the simulations, we do the following observations:

1. Including skew components in the fit in quadrupoles or dipoles does not improve the fitting performance at all.
2. The results show a cross talk between vertical correctors gain and vertical BPM gain around 2.5%. This will be addressed in next section.
3. The inclusion of quadrupole fitting parameters at dipoles decreases the standard deviation among the studied cases of the BPMs horizontal gain mean error among the elements.
4. The inclusion of quadrupole fitting parameters at dipoles decreases the beta beating standard deviation along the ring a factor 2 in both planes.
5. The inclusion of quadrupole fiting parameters at dipoles decreases the quadrupole fitting at quadrupoles.
6. Quadrupole errors in the Quadrupoles do not fit the actual errors even if quadrupole components in the fitting are allowend in sextupoles and dipoles as well.
7. Using 120 BPMs instead of 104 does not reduces proportionally the quadrupole errors fit. This indicates that the measurement errors are limiting the precision of the fit more than the lack of diagnostics.

8. The inclusion of quadrupole fitting parameters at dipoles reduces χ^2 by a factor 2

In the rest of the report, the fitting of the quadrupolar components will be done at the 112 quadrupoles and at the 32 dipoles. In the rest of the report, the fitting of the skew quadrupolar components will be done at the 120 sextupoles.

3.2 Fitting constants

In this section, the dispersion weight and the λ value for the LOCO fits will be selected. Two lattices with errors as described in the previous sections, are used for this purpose. The first lattice is based on the nominal lattice. The second lattice has an additional strong skew quadrupole magnet. The inclusion of the skew quadrupole magnet in the reference lattice is motivated by the cross talk between vertical BPM gains and vertical corrector gains.

Similarly to the previous subsection, we have calculated the fitting errors for a set of randomly generated latices. This time, due to the large amount of studied cases and for calculation time issues, we base our analysis on 60 randomly generated lattices only. Again, mean and standard deviation values are shown for different values of the horizontal and vertical dispersion weights and the λ values. Appendix C shows that data for a nominal lattice while appendix D shows the corresponding data for the lattice with an additional strong skew quadrupole magnet. We do the following observations:

1. As see in table 38 and 42, the overall cross talk between vertical BPMs and correctors gain depends slightly on the λ. It also depends on the dispersion weights, but only for $\lambda = 0.1$. The average value decreases with λ while the standard deviation increases.
2. As see in table 41, the horizontal BPM gains get worse as λ increases.
3. Tables 43, 44 and 45 show how the beta and horizontal dispersion beat standard deviation along the ring increases a factor 2 whenever λ changes from 0.01 to 0.05. Also an increase of this quantity can be observed when increasing the horizontal dispersion weight.
4. The behaviour shown by the vertical dispersion error in table 46 is more subtle. The λ

4 LOCO fitting errors

Fitting simulated lattices allows us to check the error of the fit. This will be useful when interpreting the results of the LOCO fits with real data. Figures 3 and 4 show how the fitted lattice functions differ from the simulated ones. This confirms, for the ALBA case, the commonly accepted level of 1% accuracy of the beta beating fitted by loco.

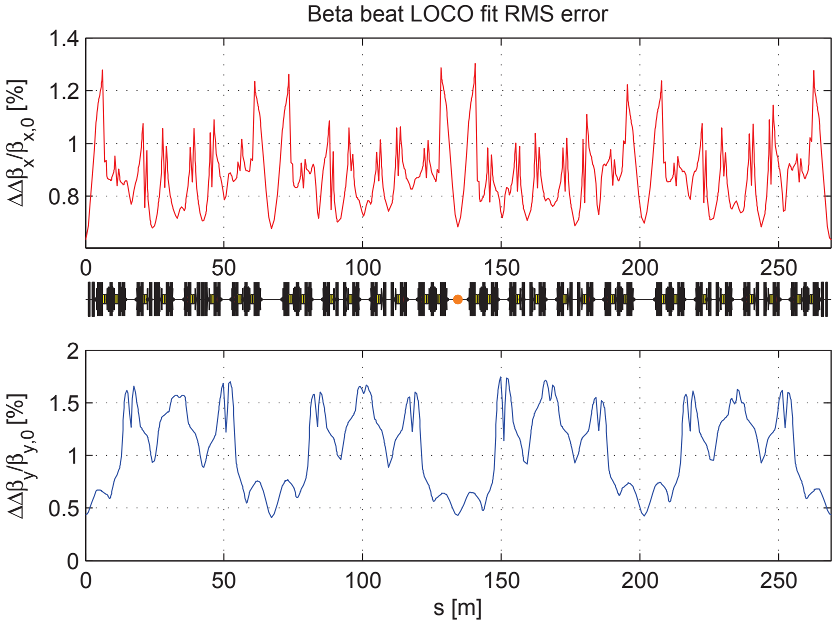

Figure 3: standard deviation beta beating LOCO fitting error for the 300 randomly generated lattices along the machine position.

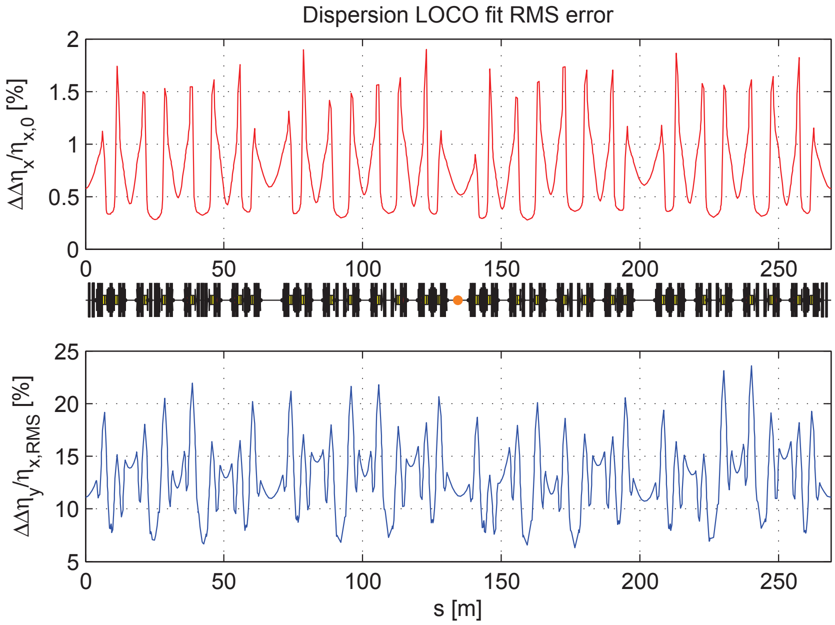

Figure 4: standard deviation dispersion beating LOCO fitting error for the 300 randomly generated lattices along the machine position. Since the reference value in the vertical plane is zero, the reference value is taken as the standard deviation vertical dispersion along the machine for each case.

Figures 5, 6 and 7 show how the fitted BPM couplings and gains and the correctors coupling differ from the simulated values.

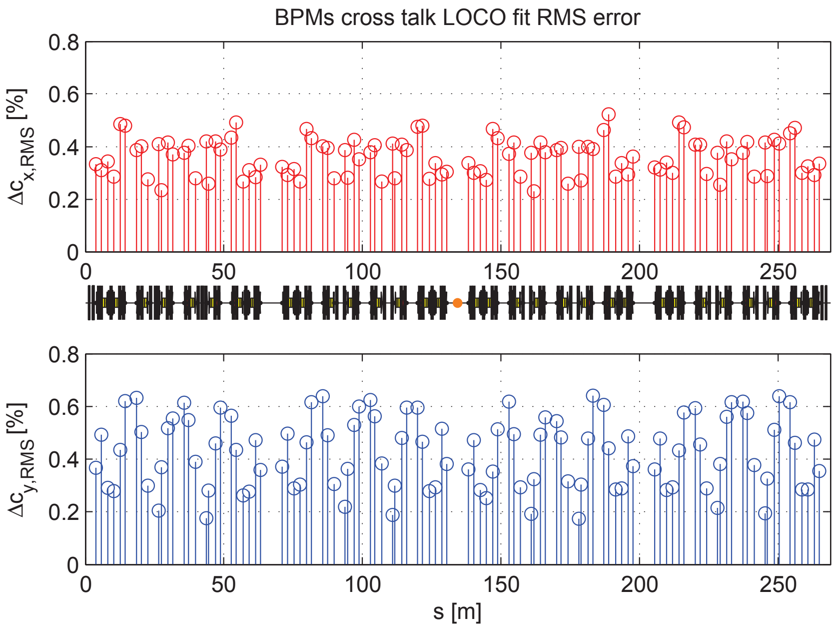

Figure 5: standard deviation BPM coupling LOCO fitting error for the 300 randomly generated lattices along the machine position.

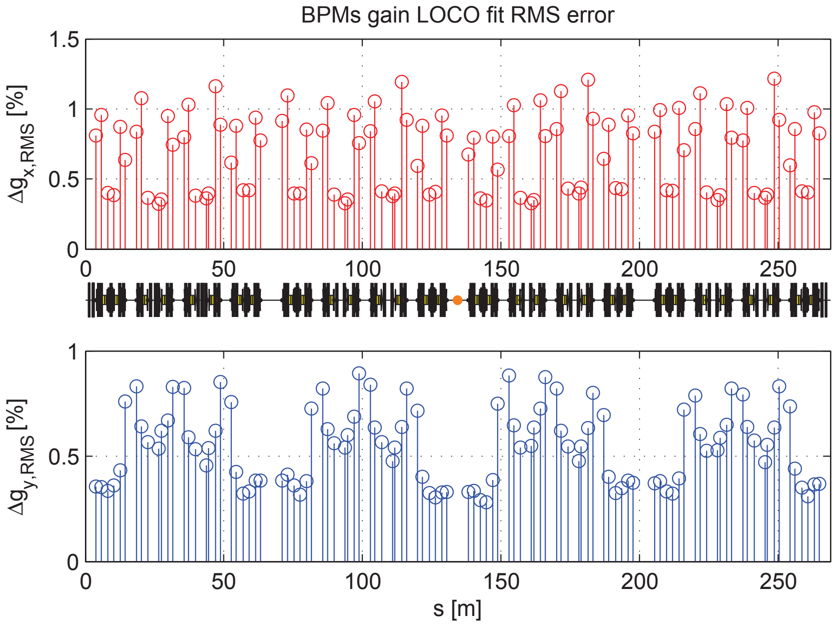

Figure 6: standard deviation BPM gain LOCO fitting error for the 300 randomly generated lattices along the machine position.

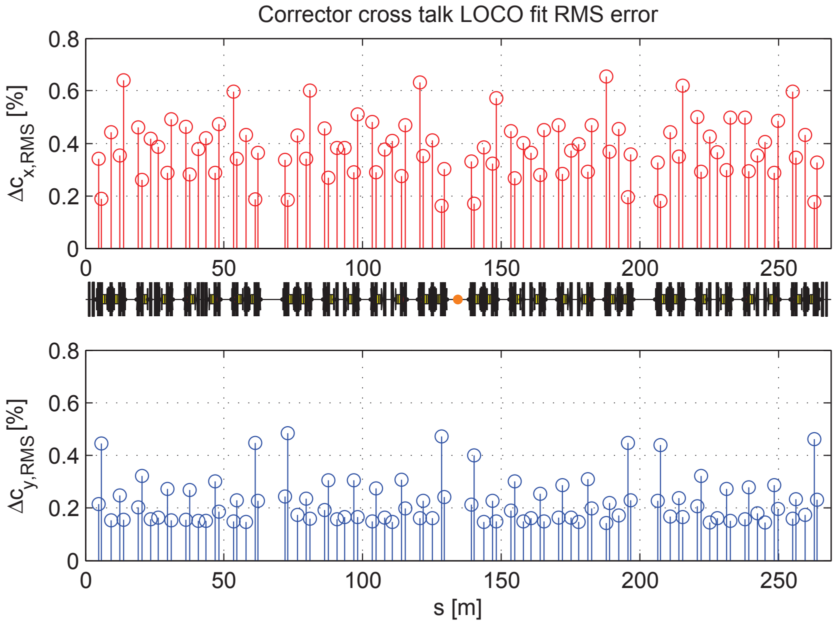

Figure 7: standard deviation correctors coupling LOCO fitting error for the 300 randomly generated lattices along the machine position.

The average of the standard deviation values above presented are summarized in table 6.

	Hor.Plane [%]	Vert. Plane[%]
$\Delta\beta/\beta$	0.89	1.06
$\Delta\eta/\eta$	0.69	12.32
BPM coupling	0.36	0.36
BPM gain	0.69	0.69
CORR coupling	0.38	0.23

Table 6: Mean standard deviation LOCO fitting errors.

5 Conclusions

LOCO fitting method has been validated against simulations. As commonly stated, the beta beating standard deviation fitting error is about 1%.

A Tables for the fitting parameters study with a nominal lattice

	120S	120S+112Q	120S+112Q+32D
112Q	0.0 (0.0)(0.4)	0.0 (0.0)(0.4)	0.0 (0.0)(0.4)
112Q+32D	0.0 (0.0)(0.4)	0.0 (0.0)(0.4)	0.0 (0.0)(0.4)
112Q+32D+120S	0.0 (0.0)(0.4)	0.0 (0.0)(0.4)	0.0 (0.0)(0.4)

Table 7: Horizontal corrector coupling error in % mean and standard deviation (first bracket) for 125 random different lattices. Both the mean and standard deviation (second bracket) among the ring elements are presented. We have studied different uncoupled optics fitting parameters (rows) and different coupled optics fitting parameters (columns). We have used λ=0.1.

	120S	120S+112Q	120S+112Q+32D
112Q	0.0 (0.1)(0.4)	-0.0 (0.1)(0.4)	0.0 (0.1)(0.4)
112Q+32D	-0.0 (0.1)(0.4)	-0.0 (0.0)(0.4)	-0.0 (0.0)(0.3)
112Q+32D+120S	-0.0 (0.1)(0.4)	-0.0 (0.0)(0.4)	-0.0 (0.0)(0.3)

Table 8: Vertical corrector coupling error in % mean and standard deviation (first bracket) for 125 random different lattices. Both the mean and standard deviation (second bracket) among the ring elements are presented. We have studied different uncoupled optics fitting parameters (rows) and different coupled optics fitting parameters (columns). We have used λ=0.1.

	120S	120S+112Q	120S+112Q+32D
112Q	-0.1 (0.3)(1.0)	-0.1 (0.3)(1.0)	-0.1 (0.3)(1.0)
112Q+32D	-0.1 (0.2)(0.8)	-0.1 (0.2)(0.8)	-0.1 (0.2)(0.8)
112Q+32D+120S	-0.1 (0.2)(0.6)	-0.1 (0.2)(0.6)	-0.1 (0.2)(0.6)

Table 9: Horizontal corrector gain error in % mean and standard deviation (first bracket) for 125 random different lattices. Both the mean and standard deviation (second bracket) among the ring elements are presented. We have studied different uncoupled optics fitting parameters (rows) and different coupled optics fitting parameters (columns). We have used λ=0.1.

	120S	120S+112Q	120S+112Q+32D
112Q	-2.5 (0.2)(1.0)	-2.5 (0.2)(1.0)	-2.5 (0.2)(1.0)
112Q+32D	-2.5 (0.2)(0.5)	-2.5 (0.2)(0.5)	-2.5 (0.2)(0.5)
112Q+32D+120S	-2.5 (0.2)(0.5)	-2.5 (0.2)(0.5)	-2.5 (0.2)(0.5)

Table 10: Vertical corrector gain error in % mean and standard deviation (first bracket) for 125 random different lattices. Both the mean and standard deviation (second bracket) among the ring elements are presented. We have studied different uncoupled optics fitting parameters (rows) and different coupled optics fitting parameters (columns). We have used λ=0.1.

	120S	120S+112Q	120S+112Q+32D
112Q	0.0 (0.1)(0.5)	0.0 (0.1)(0.5)	0.0 (0.1)(0.5)
112Q+32D	0.0 (0.1)(0.5)	0.0 (0.1)(0.5)	0.0 (0.1)(0.5)
112Q+32D+120S	0.0 (0.1)(0.5)	0.0 (0.1)(0.5)	0.0 (0.1)(0.5)

Table 11: Horizontal BPM coupling error in % mean and standard deviation (first bracket) for 125 random different lattices. Both the mean and standard deviation (second bracket) among the ring elements are presented. We have studied different uncoupled optics fitting parameters (rows) and different coupled optics fitting parameters (columns). We have used λ=0.1.

	120S	120S+112Q	120S+112Q+32D
112Q	-0.0 (0.0)(0.3)	-0.0 (0.0)(0.3)	-0.0 (0.0)(0.3)
112Q+32D	-0.0 (0.0)(0.3)	-0.0 (0.0)(0.3)	-0.0 (0.0)(0.3)
112Q+32D+120S	-0.0 (0.0)(0.3)	-0.0 (0.0)(0.3)	-0.0 (0.0)(0.3)

Table 12: Vertical BPM coupling error in % mean and standard deviation (first bracket) for 125 random different lattices. Both the mean and standard deviation (second bracket) among the ring elements are presented. We have studied different uncoupled optics fitting parameters (rows) and different coupled optics fitting parameters (columns). We have used λ=0.1.

	120S	120S+112Q	120S+112Q+32D
112Q	0.5 (2.3)(0.8)	0.5 (2.3)(0.8)	0.5 (2.3)(0.8)
112Q+32D	0.8 (0.4)(0.6)	0.8 (0.4)(0.6)	0.8 (0.4)(0.6)
112Q+32D+120S	0.8 (0.3)(0.5)	0.8 (0.3)(0.5)	0.8 (0.3)(0.5)

Table 13: Horizontal BPM gain error in % mean and standard deviation (first bracket) for 125 random different lattices. Both the mean and standard deviation (second bracket) among the ring elements are presented. We have studied different uncoupled optics fitting parameters (rows) and different coupled optics fitting parameters (columns). We have used λ=0.1.

	120S	120S+112Q	120S+112Q+32D
112Q	2.4 (0.2)(0.9)	2.4 (0.2)(0.9)	2.4 (0.2)(0.9)
112Q+32D	2.5 (0.2)(0.5)	2.5 (0.2)(0.5)	2.5 (0.2)(0.5)
112Q+32D+120S	2.5 (0.2)(0.4)	2.5 (0.2)(0.4)	2.5 (0.2)(0.4)

Table 14: Vertical BPM gain error in % mean and standard deviation (first bracket) for 125 random different lattices. Both the mean and standard deviation (second bracket) among the ring elements are presented. We have studied different uncoupled optics fitting parameters (rows) and different coupled optics fitting parameters (columns). We have used λ=0.1.

	120S	120S+112Q	120S+112Q+32D
112Q	-0.0 (0.2)(1.7)	-0.0 (0.2)(1.7)	-0.0 (0.2)(1.7)
112Q+32D	-0.1 (0.1)(1.1)	-0.1 (0.1)(1.1)	-0.1 (0.1)(1.1)
112Q+32D+120S	-0.1 (0.1)(1.0)	-0.1 (0.1)(1.0)	-0.1 (0.1)(1.0)

Table 15: Horizontal beta beat error in % mean and standard deviation (first bracket) for 125 random different lattices. Both the mean and standard deviation (second bracket) among the ring elements are presented. We have studied different uncoupled optics fitting parameters (rows) and different coupled optics fitting parameters (columns). We have used λ=0.1.

	120S	120S+112Q	120S+112Q+32D
112Q	-0.0 (0.2)(2.0)	-0.0 (0.2)(2.0)	-0.0 (0.2)(2.0)
112Q+32D	-0.1 (0.1)(1.0)	-0.1 (0.1)(1.0)	-0.1 (0.1)(1.0)
112Q+32D+120S	-0.1 (0.1)(0.9)	-0.1 (0.1)(0.9)	-0.1 (0.1)(0.9)

Table 16: Vertical beta beat error in % mean and standard deviation (first bracket) for 125 random different lattices. Both the mean and standard deviation (second bracket) among the ring elements are presented. We have studied different uncoupled optics fitting parameters (rows) and different coupled optics fitting parameters (columns). We have used λ=0.1.

	120S	120S+112Q	120S+112Q+32D
112Q	0.1 (0.2)(1.1)	0.1 (0.2)(1.1)	0.1 (0.2)(1.1)
112Q+32D	0.1 (0.2)(0.8)	0.1 (0.2)(0.8)	0.1 (0.2)(0.8)
112Q+32D+120S	0.1 (0.2)(0.6)	0.1 (0.2)(0.6)	0.1 (0.2)(0.6)

Table 17: Horizontal dispersion beat error in % mean and standard deviation (first bracket) for 125 random different lattices. Both the mean and standard deviation (second bracket) among the ring elements are presented. We have studied different uncoupled optics fitting parameters (rows) and different coupled optics fitting parameters (columns). We have used λ=0.1.

	120S	120S+112Q	120S+112Q+32D
112Q	0.0 (3.1)(13.9)	0.1 (2.6)(12.6)	0.1 (2.8)(12.6)
112Q+32D	0.4 (2.5)(13.3)	0.4 (2.2)(12.4)	0.4 (2.3)(12.3)
112Q+32D+120S	0.4 (2.5)(13.3)	0.4 (2.2)(12.4)	0.4 (2.3)(12.3)

Table 18: Vertical dispersion error in % mean and standard deviation (first bracket) for 125 random different lattices. Both the mean and standard deviation (second bracket) among the ring elements are presented. We have studied different uncoupled optics fitting parameters (rows) and different coupled optics fitting parameters (columns). We have used λ=0.1.

	120S	120S+112Q	120S+112Q+32D
112Q	-16.2 (81.1)(540.0)	-16.2 (80.7)(538.8)	-16.2 (80.7)(538.8)
112Q+32D	11.9 (23.7)(208.0)	11.9 (23.7)(208.0)	11.9 (23.7)(208.0)
112Q+32D+120S	10.7 (15.5)(181.0)	10.7 (15.5)(181.0)	10.7 (15.5)(181.0)

Table 19: Quadrupole error in % relative to σ_k mean and standard deviation (first bracket) for 125 random different lattices. Both the mean and standard deviation (second bracket) among the ring elements are presented. We have studied different uncoupled optics fitting parameters (rows) and different coupled optics fitting parameters (columns). We have used λ=0.1.

	120S	120S+112Q	120S+112Q+32D
112Q	3.4 (0.8)	3.4 (0.8)	3.4 (0.8)
112Q+32D	1.8 (0.1)	1.8 (0.1)	1.8 (0.1)
112Q+32D+120S	1.6 (0.1)	1.6 (0.1)	1.6 (0.1)

Table 20: Chi squared error in mean and standard deviation (first bracket) for 125 random different lattices. We have studied different uncoupled optics fitting parameters (rows) and different coupled optics fitting parameters (columns). We have used λ=0.1.

B Tables for the fitting parameters study with a nominal lattice and using 120 BPM

	120S	120S+112Q	120S+112Q+32D
112Q	0.0 (0.1)(0.4)	-0.0 (0.0)(0.4)	-0.0 (0.0)(0.4)
112Q+32D	-0.0 (0.0)(0.4)	-0.0 (0.0)(0.4)	-0.0 (0.0)(0.4)
112Q+32D+120S	-0.0 (0.0)(0.4)	-0.0 (0.0)(0.4)	-0.0 (0.0)(0.4)

Table 21: Horizontal corrector coupling error in % mean and RMS (first braket) for 125 random different lattices. Both the mean and RMS (second braket) among the ring elements are presented. We have studied diferent uncoupled optics fitting parameters (rows) and different coupled optics fitting parameters (columns). We have used λ=0.1. 120 BPMs are used in the fit.

	120S	120S+112Q	120S+112Q+32D
112Q	0.0 (0.1)(0.4)	0.0 (0.1)(0.3)	0.0 (0.1)(0.3)
112Q+32D	0.0 (0.0)(0.4)	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)
112Q+32D+120S	0.0 (0.0)(0.4)	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)

Table 22: Vertical corrector coupling error in % mean and RMS (first braket) for 125 random different lattices. Both the mean and RMS (second braket) among the ring elements are presented. We have studied diferent uncoupled optics fitting parameters (rows) and different coupled optics fitting parameters (columns). We have used λ=0.1. 120 BPMs are used in the fit.

	120S	120S+112Q	120S+112Q+32D
112Q	-0.0 (0.2)(1.0)	-0.0 (0.2)(0.9)	-0.0 (0.2)(0.9)
112Q+32D	-0.0 (0.2)(0.8)	-0.0 (0.2)(0.8)	-0.0 (0.2)(0.8)
112Q+32D+120S	-0.0 (0.2)(0.6)	-0.0 (0.2)(0.6)	-0.0 (0.2)(0.6)

Table 23: Horizontal corrector gain error in % mean and RMS (first braket) for 125 random different lattices. Both the mean and RMS (second braket) among the ring elements are presented. We have studied diferent uncoupled optics fitting parameters (rows) and different coupled optics fitting parameters (columns). We have used λ=0.1. 120 BPMs are used in the fit.

	120S	120S+112Q	120S+112Q+32D
112Q	-2.4 (0.3)(1.1)	-2.4 (0.5)(1.1)	-2.4 (0.5)(1.1)
112Q+32D	-2.4 (0.5)(0.5)	-2.4 (0.5)(0.5)	-2.4 (0.5)(0.5)
112Q+32D+120S	-2.4 (0.5)(0.5)	-2.4 (0.5)(0.5)	-2.4 (0.5)(0.5)

Table 24: Vertical corrector gain error in % mean and RMS (first braket) for 125 random different lattices. Both the mean and RMS (second braket) among the ring elements are presented. We have studied diferent uncoupled optics fitting parameters (rows) and different coupled optics fitting parameters (columns). We have used λ=0.1. 120 BPMs are used in the fit.

	120S	120S+112Q	120S+112Q+32D
112Q	0.0 (0.1)(0.5)	0.0 (0.1)(0.5)	0.0 (0.1)(0.5)
112Q+32D	-0.0 (0.1)(0.5)	-0.0 (0.1)(0.5)	-0.0 (0.1)(0.5)
112Q+32D+120S	-0.0 (0.1)(0.5)	-0.0 (0.1)(0.5)	-0.0 (0.1)(0.5)

Table 25: Horizontal BPM coupling error in % mean and RMS (first braket) for 125 random different lattices. Both the mean and RMS (second braket) among the ring elements are presented. We have studied diferent uncoupled optics fitting parameters (rows) and different coupled optics fitting parameters (columns). We have used λ=0.1. 120 BPMs are used in the fit.

	120S	120S+112Q	120S+112Q+32D
112Q	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)
112Q+32D	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)
112Q+32D+120S	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)

Table 26: Vertical BPM coupling error in % mean and RMS (first braket) for 125 random different lattices. Both the mean and RMS (second braket) among the ring elements are presented. We have studied diferent uncoupled optics fitting parameters (rows) and different coupled optics fitting parameters (columns). We have used λ=0.1. 120 BPMs are used in the fit.

	120S	120S+112Q	120S+112Q+32D
112Q	0.8 (1.8)(0.7)	0.8 (1.8)(0.7)	0.8 (1.8)(0.7)
112Q+32D	0.8 (0.4)(0.5)	0.8 (0.4)(0.5)	0.8 (0.4)(0.5)
112Q+32D+120S	0.7 (0.3)(0.5)	0.7 (0.3)(0.5)	0.7 (0.3)(0.5)

Table 27: Horizontal BPM gain error in % mean and RMS (first braket) for 125 random different lattices. Both the mean and RMS (second braket) among the ring elements are presented. We have studied diferent uncoupled optics fitting parameters (rows) and different coupled optics fitting parameters (columns). We have used λ=0.1. 120 BPMs are used in the fit.

	120S	120S+112Q	120S+112Q+32D
112Q	2.5 (0.4)(1.1)	2.4 (0.5)(1.1)	2.4 (0.5)(1.1)
112Q+32D	2.4 (0.5)(0.5)	2.4 (0.5)(0.5)	2.4 (0.5)(0.5)
112Q+32D+120S	2.4 (0.5)(0.5)	2.4 (0.5)(0.5)	2.4 (0.5)(0.5)

Table 28: Vertical BPM gain error in % mean and RMS (first braket) for 125 random different lattices. Both the mean and RMS (second braket) among the ring elements are presented. We have studied diferent uncoupled optics fitting parameters (rows) and different coupled optics fitting parameters (columns). We have used λ=0.1. 120 BPMs are used in the fit.

	120S	120S+112Q	120S+112Q+32D
112Q	-0.0 (0.1)(1.4)	-0.0 (0.1)(1.4)	-0.0 (0.1)(1.4)
112Q+32D	-0.0 (0.1)(1.0)	-0.0 (0.1)(1.0)	-0.0 (0.1)(1.0)
112Q+32D+120S	-0.0 (0.1)(0.9)	-0.0 (0.1)(0.9)	-0.0 (0.1)(0.9)

Table 29: Horizontal beta beat error in % mean and RMS (first braket) for 125 random different lattices. Both the mean and RMS (second braket) among the ring elements are presented. We have studied diferent uncoupled optics fitting parameters (rows) and different coupled optics fitting parameters (columns). We have used λ=0.1. 120 BPMs are used in the fit.

	120S	120S+112Q	120S+112Q+32D
112Q	-0.2 (0.3)(2.5)	-0.2 (0.3)(2.4)	-0.2 (0.3)(2.4)
112Q+32D	-0.1 (0.1)(1.1)	-0.1 (0.1)(1.1)	-0.1 (0.1)(1.1)
112Q+32D+120S	-0.1 (0.1)(1.1)	-0.1 (0.1)(1.1)	-0.1 (0.1)(1.1)

Table 30: Vertical beta beat error in % mean and RMS (first braket) for 125 random different lattices. Both the mean and RMS (second braket) among the ring elements are presented. We have studied diferent uncoupled optics fitting parameters (rows) and different coupled optics fitting parameters (columns). We have used λ=0.1. 120 BPMs are used in the fit.

	120S	120S+112Q	120S+112Q+32D
112Q	0.1 (0.2)(1.0)	0.1 (0.2)(1.0)	0.1 (0.2)(1.0)
112Q+32D	0.1 (0.2)(0.8)	0.1 (0.2)(0.8)	0.1 (0.2)(0.8)
112Q+32D+120S	0.1 (0.2)(0.6)	0.1 (0.2)(0.5)	0.1 (0.2)(0.5)

Table 31: Horizontal dispersion beat error in % mean and RMS (first braket) for 125 random different lattices. Both the mean and RMS (second braket) among the ring elements are presented. We have studied diferent uncoupled optics fitting parameters (rows) and different coupled optics fitting parameters (columns). We have used λ=0.1. 120 BPMs are used in the fit.

	120S	120S+112Q	120S+112Q+32D
112Q	-0.7 (3.8)(14.9)	-0.5 (2.9)(12.6)	-0.6 (3.3)(12.6)
112Q+32D	-0.2 (1.9)(13.4)	-0.1 (1.6)(12.1)	-0.2 (1.6)(12.0)
112Q+32D+120S	-0.2 (1.9)(13.3)	-0.1 (1.5)(11.9)	-0.2 (1.6)(11.7)

Table 32: Vertical dispersion error in % mean and RMS (first braket) for 125 random different lattices. Both the mean and RMS (second braket) among the ring elements are presented. We have studied diferent uncoupled optics fitting parameters (rows) and different coupled optics fitting parameters (columns). We have used λ=0.1. 120 BPMs are used in the fit.

	120S	120S+112Q	120S+112Q+32D
112Q	-3.5 (65.5)(464.4)	-3.2 (65.0)(451.8)	-3.2 (64.9)(451.7)
112Q+32D	8.1 (23.9)(206.5)	8.1 (23.9)(206.5)	8.1 (23.9)(206.5)
112Q+32D+120S	7.1 (14.8)(176.2)	6.9 (14.7)(174.9)	6.9 (14.7)(174.9)

Table 33: Quadrupole error in % relative to σ_k mean and RMS (first braket) for 125 random different lattices. Both the mean and RMS (second braket) among the ring elements are presented. We have studied diferent uncoupled optics fitting parameters (rows) and different coupled optics fitting parameters (columns). We have used λ=0.1. 120 BPMs are used in the fit.

	120S	120S+112Q	120S+112Q+32D
112Q	3.9 (1.2)	3.8 (1.4)	3.8 (1.4)
112Q+32D	1.7 (0.3)	1.7 (0.3)	1.7 (0.3)
112Q+32D+120S	1.4 (0.3)	1.4 (0.3)	1.4 (0.3)

Table 34: Chi squared error in mean and RMS (first braket) for 125 random different lattices. We have studied diferent uncoupled optics fitting parameters (rows) and different coupled optics fitting parameters (columns). We have used λ=0.1. 120 BPMs are used in the fit.

C Tables for dispersion weight study with a nominal lattice

λ =0.01	5.0	12.5	15.0	20.0	25.0	30.0
5.0	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)
12.5	0.0 (0.0)(0.2)	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)
20.0	0.0 (0.0)(0.2)	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)
30.0	0.0 (0.0)(0.2)	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)
λ =0.05						
5.0	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)	0.0 (0.0)(0.4)	0.0 (0.0)(0.4)	0.0 (0.0)(0.4)
12.5	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)	0.0 (0.0)(0.4)	0.0 (0.0)(0.4)	0.0 (0.0)(0.4)
20.0	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)	0.0 (0.0)(0.4)	0.0 (0.0)(0.4)	0.0 (0.0)(0.4)
30.0	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)	0.0 (0.0)(0.4)	0.0 (0.0)(0.4)	0.0 (0.0)(0.4)
λ =0.10						
5.0	0.0 (0.0)(0.3)	0.0 (0.0)(0.4)	0.0 (0.0)(0.4)	0.0 (0.0)(0.4)	0.0 (0.0)(0.4)	0.0 (0.0)(0.4)
12.5	0.0 (0.0)(0.3)	0.0 (0.0)(0.4)	0.0 (0.0)(0.4)	0.0 (0.0)(0.4)	0.0 (0.0)(0.4)	0.0 (0.0)(0.4)
20.0	0.0 (0.0)(0.3)	0.0 (0.0)(0.4)	0.0 (0.0)(0.4)	0.0 (0.0)(0.4)	0.0 (0.0)(0.4)	0.0 (0.0)(0.4)
30.0	0.0 (0.0)(0.3)	0.0 (0.0)(0.4)	0.0 (0.0)(0.4)	0.0 (0.0)(0.4)	0.0 (0.0)(0.4)	0.0 (0.0)(0.4)

Table 35: Horizontal corrector coupling error in %. We present mean and RMS (first bracket) values for 60 random different lattices. Also, both the mean and RMS (second bracket) among the ring elements are presented. We have studied different horizontal dispersion weights (rows) and different vertical dispersion weights (columns), all for three different three λ values.

λ =0.01	5.0	12.5	15.0	20.0	25.0	30.0
5.0	-0.0 (0.0)(0.2)	-0.0 (0.0)(0.3)	-0.0 (0.0)(0.3)	-0.0 (0.0)(0.3)	-0.0 (0.0)(0.3)	-0.0 (0.0)(0.3)
12.5	-0.0 (0.0)(0.2)	-0.0 (0.0)(0.3)	-0.0 (0.0)(0.3)	-0.0 (0.0)(0.3)	-0.0 (0.0)(0.3)	-0.0 (0.0)(0.3)
20.0	-0.0 (0.0)(0.2)	-0.0 (0.0)(0.3)	-0.0 (0.0)(0.3)	-0.0 (0.0)(0.3)	-0.0 (0.0)(0.3)	-0.0 (0.0)(0.3)
30.0	-0.0 (0.0)(0.2)	-0.0 (0.0)(0.3)	-0.0 (0.0)(0.3)	-0.0 (0.0)(0.3)	-0.0 (0.0)(0.3)	-0.0 (0.0)(0.3)
λ =0.05						
5.0	-0.0 (0.0)(0.2)	-0.0 (0.0)(0.3)	-0.0 (0.0)(0.3)	-0.0 (0.0)(0.4)	-0.0 (0.1)(0.4)	-0.0 (0.1)(0.5)
12.5	-0.0 (0.0)(0.2)	-0.0 (0.0)(0.3)	-0.0 (0.0)(0.3)	-0.0 (0.0)(0.4)	-0.0 (0.1)(0.4)	-0.0 (0.1)(0.5)
20.0	-0.0 (0.0)(0.2)	-0.0 (0.0)(0.3)	-0.0 (0.0)(0.3)	-0.0 (0.0)(0.4)	-0.0 (0.1)(0.4)	-0.0 (0.1)(0.5)
30.0	-0.0 (0.0)(0.3)	-0.0 (0.0)(0.3)	-0.0 (0.0)(0.3)	-0.0 (0.0)(0.4)	-0.0 (0.1)(0.4)	-0.0 (0.1)(0.5)
λ =0.10						
5.0	-0.0 (0.0)(0.3)	-0.0 (0.0)(0.4)	-0.0 (0.0)(0.4)	-0.0 (0.1)(0.4)	0.0 (0.1)(0.5)	0.0 (0.1)(0.5)
12.5	-0.0 (0.0)(0.3)	-0.0 (0.0)(0.4)	-0.0 (0.0)(0.4)	-0.0 (0.1)(0.4)	0.0 (0.1)(0.5)	0.0 (0.1)(0.5)
20.0	-0.0 (0.0)(0.3)	-0.0 (0.0)(0.4)	-0.0 (0.0)(0.4)	-0.0 (0.1)(0.4)	0.0 (0.1)(0.5)	0.0 (0.1)(0.5)
30.0	-0.0 (0.0)(0.3)	-0.0 (0.0)(0.4)	-0.0 (0.0)(0.4)	-0.0 (0.1)(0.4)	0.0 (0.1)(0.5)	0.0 (0.1)(0.5)

Table 36: Vertical corrector coupling error in %. We present mean and RMS (first bracket) values for 60 random different lattices. Also, both the mean and RMS (second bracket) among the ring elements are presented. We have studied different horizontal dispersion weights (rows) and different vertical dispersion weights (columns), all for three different three λ values.

λ =0.01	5.0	12.5	15.0	20.0	25.0	30.0
5.0	0.0 (0.2)(0.3)	0.0 (0.2)(0.3)	0.0 (0.2)(0.3)	0.0 (0.2)(0.3)	0.0 (0.2)(0.3)	0.0 (0.2)(0.3)
12.5	0.0 (0.2)(0.3)	0.0 (0.2)(0.3)	0.0 (0.2)(0.3)	0.0 (0.2)(0.3)	0.0 (0.2)(0.3)	0.0 (0.2)(0.3)
20.0	0.0 (0.1)(0.4)	0.0 (0.1)(0.4)	0.0 (0.1)(0.4)	0.0 (0.1)(0.4)	0.0 (0.1)(0.4)	0.0 (0.1)(0.4)
30.0	0.0 (0.2)(0.6)	0.0 (0.2)(0.6)	0.0 (0.2)(0.6)	0.0 (0.2)(0.6)	0.0 (0.2)(0.6)	0.0 (0.2)(0.6)
λ =0.05						
5.0	-0.0 (0.2)(0.4)	-0.0 (0.2)(0.4)	-0.0 (0.2)(0.4)	-0.0 (0.2)(0.4)	-0.0 (0.2)(0.4)	-0.0 (0.2)(0.4)
12.5	-0.0 (0.2)(0.6)	-0.0 (0.2)(0.6)	-0.0 (0.2)(0.6)	-0.0 (0.2)(0.6)	-0.0 (0.2)(0.6)	-0.0 (0.2)(0.6)
20.0	-0.0 (0.2)(0.8)	-0.0 (0.2)(0.8)	-0.0 (0.2)(0.8)	-0.0 (0.2)(0.8)	-0.0 (0.2)(0.8)	-0.0 (0.2)(0.8)
30.0	0.0 (0.2)(1.0)	0.0 (0.2)(1.0)	0.0 (0.2)(1.0)	0.0 (0.2)(1.0)	0.0 (0.2)(1.0)	0.0 (0.2)(1.0)
λ =0.10						
5.0	-0.1 (0.1)(0.4)	-0.1 (0.1)(0.4)	-0.1 (0.1)(0.4)	-0.1 (0.1)(0.4)	-0.1 (0.1)(0.4)	-0.1 (0.1)(0.4)
12.5	-0.0 (0.2)(0.7)	-0.0 (0.2)(0.7)	-0.0 (0.2)(0.7)	-0.0 (0.2)(0.7)	-0.0 (0.2)(0.7)	-0.0 (0.2)(0.7)
20.0	-0.0 (0.2)(1.0)	-0.0 (0.2)(1.0)	-0.0 (0.2)(1.0)	-0.0 (0.2)(1.0)	-0.0 (0.2)(1.0)	-0.0 (0.2)(1.0)
30.0	0.0 (0.2)(1.1)	0.0 (0.2)(1.1)	0.0 (0.2)(1.1)	0.0 (0.2)(1.1)	0.0 (0.2)(1.1)	0.0 (0.2)(1.1)

Table 37: Horizontal corrector gain error in %. We present mean and RMS (first bracket) values for 60 random different lattices. Also, both the mean and RMS (second bracket) among the ring elements are presented. We have studied different horizontal dispersion weights (rows) and different vertical dispersion weights (columns), all for three different three λ values.

λ =0.01	5.0	12.5	15.0	20.0	25.0	30.0
5.0	-2.4 (0.2)(0.2)	-2.4 (0.2)(0.2)	-2.4 (0.2)(0.2)	-2.3 (0.4)(0.2)	-2.3 (0.4)(0.2)	-2.3 (0.5)(0.2)
12.5	-2.3 (0.5)(0.2)	-2.3 (0.5)(0.2)	-2.3 (0.5)(0.2)	-2.3 (0.5)(0.2)	-2.3 (0.5)(0.2)	-2.3 (0.5)(0.2)
20.0	-2.3 (0.5)(0.2)	-2.3 (0.5)(0.2)	-2.3 (0.5)(0.2)	-2.3 (0.5)(0.2)	-2.3 (0.5)(0.2)	-2.3 (0.5)(0.2)
30.0	-2.3 (0.5)(0.2)	-2.3 (0.5)(0.2)	-2.3 (0.5)(0.2)	-2.3 (0.5)(0.2)	-2.3 (0.5)(0.2)	-2.3 (0.5)(0.2)
λ =0.05						
5.0	-2.4 (0.5)(0.4)	-2.4 (0.5)(0.4)	-2.4 (0.5)(0.4)	-2.4 (0.5)(0.4)	-2.4 (0.5)(0.4)	-2.4 (0.5)(0.4)
12.5	-2.4 (0.5)(0.4)	-2.4 (0.5)(0.4)	-2.4 (0.5)(0.4)	-2.4 (0.5)(0.4)	-2.4 (0.5)(0.4)	-2.4 (0.5)(0.4)
20.0	-2.4 (0.5)(0.4)	-2.4 (0.5)(0.4)	-2.4 (0.5)(0.4)	-2.4 (0.5)(0.4)	-2.4 (0.5)(0.4)	-2.4 (0.5)(0.4)
30.0	-2.4 (0.5)(0.4)	-2.4 (0.5)(0.4)	-2.4 (0.5)(0.4)	-2.4 (0.5)(0.4)	-2.4 (0.5)(0.4)	-2.4 (0.5)(0.4)
λ =0.10						
5.0	-2.4 (0.5)(0.5)	-2.4 (0.5)(0.5)	-2.4 (0.5)(0.5)	-2.4 (0.5)(0.5)	-2.4 (0.5)(0.5)	-2.4 (0.5)(0.5)
12.5	-2.4 (0.5)(0.5)	-2.4 (0.5)(0.5)	-2.4 (0.5)(0.5)	-2.4 (0.5)(0.5)	-2.4 (0.5)(0.5)	-2.4 (0.5)(0.5)
20.0	-2.4 (0.5)(0.5)	-2.4 (0.5)(0.5)	-2.4 (0.5)(0.5)	-2.4 (0.5)(0.5)	-2.4 (0.5)(0.5)	-2.4 (0.5)(0.5)
30.0	-2.4 (0.5)(0.5)	-2.4 (0.5)(0.5)	-2.4 (0.5)(0.5)	-2.4 (0.5)(0.5)	-2.4 (0.5)(0.5)	-2.4 (0.5)(0.5)

Table 38: Vertical corrector gain error in %. We present mean and RMS (first bracket) values for 60 random different lattices. Also, both the mean and RMS (second bracket) among the ring elements are presented. We have studied different horizontal dispersion weights (rows) and different vertical dispersion weights (columns), all for three different three λ values.

λ =0.01	5.0	12.5	15.0	20.0	25.0	30.0
5.0	0.0 (0.0)(0.4)	0.0 (0.0)(0.4)	0.0 (0.0)(0.4)	0.0 (0.1)(0.5)	0.0 (0.1)(0.5)	0.0 (0.1)(0.5)
12.5	0.0 (0.0)(0.4)	0.0 (0.0)(0.4)	0.0 (0.0)(0.4)	0.0 (0.1)(0.4)	0.0 (0.1)(0.5)	0.0 (0.1)(0.5)
20.0	0.0 (0.0)(0.4)	0.0 (0.0)(0.4)	0.0 (0.0)(0.4)	0.0 (0.1)(0.4)	0.0 (0.1)(0.5)	0.0 (0.1)(0.5)
30.0	0.0 (0.0)(0.4)	0.0 (0.0)(0.4)	0.0 (0.0)(0.4)	0.0 (0.1)(0.5)	0.0 (0.1)(0.5)	0.0 (0.1)(0.5)
λ =0.05						
5.0	0.0 (0.1)(0.4)	0.0 (0.1)(0.5)	0.0 (0.1)(0.5)	0.0 (0.1)(0.5)	0.0 (0.1)(0.5)	0.0 (0.1)(0.5)
12.5	0.0 (0.1)(0.4)	0.0 (0.1)(0.5)	0.0 (0.1)(0.5)	0.0 (0.1)(0.5)	0.0 (0.1)(0.5)	0.0 (0.1)(0.5)
20.0	0.0 (0.1)(0.4)	0.0 (0.1)(0.5)	0.0 (0.1)(0.5)	0.0 (0.1)(0.5)	0.0 (0.1)(0.5)	0.0 (0.1)(0.5)
30.0	0.0 (0.1)(0.4)	0.0 (0.1)(0.5)	0.0 (0.1)(0.5)	0.0 (0.1)(0.5)	0.0 (0.1)(0.5)	0.0 (0.1)(0.5)
λ =0.10						
5.0	0.0 (0.1)(0.5)	0.0 (0.1)(0.5)	0.0 (0.1)(0.5)	0.0 (0.1)(0.5)	0.0 (0.1)(0.6)	0.0 (0.1)(0.6)
12.5	0.0 (0.1)(0.5)	0.0 (0.1)(0.5)	0.0 (0.1)(0.5)	0.0 (0.1)(0.5)	0.0 (0.1)(0.6)	0.0 (0.1)(0.6)
20.0	0.0 (0.1)(0.5)	0.0 (0.1)(0.5)	0.0 (0.1)(0.5)	0.0 (0.1)(0.5)	0.0 (0.1)(0.6)	0.0 (0.1)(0.6)
30.0	0.0 (0.1)(0.5)	0.0 (0.1)(0.5)	0.0 (0.1)(0.5)	0.0 (0.1)(0.5)	0.0 (0.1)(0.6)	0.0 (0.1)(0.6)

Table 39: Horizontal BPM coupling error in %. We present mean and RMS (first bracket) values for 60 random different lattices. Also, both the mean and RMS (second bracket) among the ring elements are presented. We have studied different horizontal dispersion weights (rows) and different vertical dispersion weights (columns), all for three different three λ values.

λ =0.01	5.0	12.5	15.0	20.0	25.0	30.0
5.0	-0.0 (0.0)(0.2)	-0.0 (0.0)(0.2)	-0.0 (0.0)(0.2)	-0.0 (0.0)(0.2)	-0.0 (0.0)(0.2)	-0.0 (0.0)(0.2)
12.5	-0.0 (0.0)(0.2)	-0.0 (0.0)(0.2)	-0.0 (0.0)(0.2)	-0.0 (0.0)(0.2)	-0.0 (0.0)(0.2)	-0.0 (0.0)(0.2)
20.0	-0.0 (0.0)(0.2)	-0.0 (0.0)(0.2)	-0.0 (0.0)(0.2)	-0.0 (0.0)(0.2)	-0.0 (0.0)(0.2)	-0.0 (0.0)(0.2)
30.0	-0.0 (0.0)(0.2)	-0.0 (0.0)(0.2)	-0.0 (0.0)(0.2)	-0.0 (0.0)(0.2)	-0.0 (0.0)(0.2)	-0.0 (0.0)(0.2)
λ =0.05						
5.0	-0.0 (0.0)(0.2)	-0.0 (0.0)(0.2)	-0.0 (0.0)(0.3)	-0.0 (0.0)(0.3)	-0.0 (0.0)(0.3)	-0.0 (0.0)(0.3)
12.5	-0.0 (0.0)(0.2)	-0.0 (0.0)(0.2)	-0.0 (0.0)(0.3)	-0.0 (0.0)(0.3)	-0.0 (0.0)(0.3)	-0.0 (0.0)(0.3)
20.0	-0.0 (0.0)(0.2)	-0.0 (0.0)(0.2)	-0.0 (0.0)(0.3)	-0.0 (0.0)(0.3)	-0.0 (0.0)(0.3)	-0.0 (0.0)(0.3)
30.0	-0.0 (0.0)(0.2)	-0.0 (0.0)(0.2)	-0.0 (0.0)(0.3)	-0.0 (0.0)(0.3)	-0.0 (0.0)(0.3)	-0.0 (0.0)(0.3)
λ =0.10						
5.0	-0.0 (0.0)(0.2)	-0.0 (0.0)(0.3)	-0.0 (0.0)(0.3)	-0.0 (0.0)(0.3)	-0.0 (0.0)(0.3)	-0.0 (0.0)(0.3)
12.5	-0.0 (0.0)(0.2)	-0.0 (0.0)(0.3)	-0.0 (0.0)(0.3)	-0.0 (0.0)(0.3)	-0.0 (0.0)(0.3)	-0.0 (0.0)(0.3)
20.0	-0.0 (0.0)(0.2)	-0.0 (0.0)(0.3)	-0.0 (0.0)(0.3)	-0.0 (0.0)(0.3)	-0.0 (0.0)(0.3)	-0.0 (0.0)(0.3)
30.0	-0.0 (0.0)(0.3)	-0.0 (0.0)(0.3)	-0.0 (0.0)(0.3)	-0.0 (0.0)(0.3)	-0.0 (0.0)(0.3)	-0.0 (0.0)(0.3)

Table 40: Vertical BPM coupling error in %. We present mean and RMS (first bracket) values for 60 random different lattices. Also, both the mean and RMS (second bracket) among the ring elements are presented. We have studied different horizontal dispersion weights (rows) and different vertical dispersion weights (columns), all for three different three λ values.

λ =0.01	5.0	12.5	15.0	20.0	25.0	30.0
5.0	0.0 (0.1)(0.2)	0.0 (0.1)(0.2)	0.0 (0.1)(0.2)	0.0 (0.1)(0.2)	0.0 (0.1)(0.2)	0.0 (0.1)(0.2)
12.5	0.0 (0.1)(0.3)	0.0 (0.1)(0.3)	0.0 (0.1)(0.3)	0.0 (0.1)(0.3)	0.0 (0.1)(0.3)	0.0 (0.1)(0.3)
20.0	0.0 (0.1)(0.4)	0.0 (0.1)(0.4)	0.0 (0.1)(0.4)	0.0 (0.1)(0.4)	0.0 (0.1)(0.4)	0.0 (0.1)(0.4)
30.0	0.0 (0.2)(0.5)	0.0 (0.2)(0.5)	0.0 (0.2)(0.5)	0.0 (0.2)(0.5)	0.0 (0.2)(0.5)	0.0 (0.2)(0.5)
λ =0.05						
5.0	0.2 (0.1)(0.4)	0.2 (0.1)(0.4)	0.2 (0.1)(0.4)	0.2 (0.1)(0.4)	0.2 (0.1)(0.4)	0.2 (0.1)(0.4)
12.5	0.2 (0.2)(0.5)	0.2 (0.2)(0.5)	0.2 (0.2)(0.5)	0.2 (0.2)(0.5)	0.2 (0.2)(0.5)	0.2 (0.2)(0.5)
20.0	0.3 (0.3)(0.6)	0.3 (0.3)(0.6)	0.3 (0.3)(0.6)	0.3 (0.3)(0.6)	0.3 (0.3)(0.6)	0.3 (0.3)(0.6)
30.0	0.4 (0.5)(0.7)	0.4 (0.5)(0.7)	0.4 (0.5)(0.7)	0.4 (0.5)(0.7)	0.4 (0.5)(0.7)	0.4 (0.5)(0.7)
λ =0.10						
5.0	0.7 (0.2)(0.5)	0.7 (0.2)(0.5)	0.7 (0.2)(0.5)	0.7 (0.2)(0.5)	0.7 (0.2)(0.5)	0.7 (0.2)(0.5)
12.5	0.7 (0.3)(0.6)	0.7 (0.3)(0.6)	0.7 (0.3)(0.6)	0.7 (0.3)(0.6)	0.7 (0.3)(0.6)	0.7 (0.3)(0.6)
20.0	0.9 (0.6)(0.7)	0.9 (0.6)(0.7)	0.8 (0.6)(0.7)	0.8 (0.6)(0.7)	0.8 (0.6)(0.7)	0.8 (0.6)(0.7)
30.0	1.0 (1.0)(0.8)	1.0 (1.0)(0.8)	1.0 (1.0)(0.8)	1.0 (1.0)(0.8)	1.0 (1.0)(0.8)	1.0 (1.0)(0.8)

Table 41: Horizontal BPM gain error in %. We present mean and RMS (first bracket) values for 60 random different lattices. Also, both the mean and RMS (second bracket) among the ring elements are presented. We have studied different horizontal dispersion weights (rows) and different vertical dispersion weights (columns), all for three different three λ values.

λ =0.01	5.0	12.5	15.0	20.0	25.0	30.0
5.0	2.4 (0.2)(0.2)	2.3 (0.2)(0.2)	2.3 (0.2)(0.2)	2.3 (0.4)(0.2)	2.3 (0.4)(0.2)	2.2 (0.5)(0.2)
12.5	2.3 (0.5)(0.2)	2.3 (0.5)(0.2)	2.3 (0.5)(0.2)	2.3 (0.5)(0.2)	2.2 (0.5)(0.2)	2.2 (0.5)(0.2)
20.0	2.3 (0.5)(0.2)	2.3 (0.5)(0.2)	2.3 (0.5)(0.2)	2.3 (0.5)(0.2)	2.2 (0.5)(0.2)	2.2 (0.5)(0.2)
30.0	2.3 (0.5)(0.2)	2.3 (0.5)(0.2)	2.3 (0.5)(0.2)	2.3 (0.5)(0.2)	2.2 (0.5)(0.2)	2.2 (0.5)(0.2)
λ =0.05						
5.0	2.4 (0.5)(0.4)	2.4 (0.5)(0.4)	2.4 (0.5)(0.4)	2.4 (0.5)(0.4)	2.4 (0.5)(0.4)	2.4 (0.5)(0.4)
12.5	2.4 (0.5)(0.4)	2.4 (0.5)(0.4)	2.4 (0.5)(0.4)	2.4 (0.5)(0.4)	2.4 (0.5)(0.4)	2.4 (0.5)(0.4)
20.0	2.4 (0.5)(0.4)	2.4 (0.5)(0.4)	2.4 (0.5)(0.4)	2.4 (0.5)(0.4)	2.4 (0.5)(0.4)	2.4 (0.5)(0.4)
30.0	2.4 (0.5)(0.4)	2.4 (0.5)(0.4)	2.4 (0.5)(0.4)	2.4 (0.5)(0.4)	2.4 (0.5)(0.4)	2.4 (0.5)(0.4)
λ =0.10						
5.0	2.4 (0.5)(0.4)	2.4 (0.5)(0.4)	2.4 (0.5)(0.4)	2.4 (0.5)(0.4)	2.4 (0.5)(0.4)	2.4 (0.5)(0.5)
12.5	2.4 (0.5)(0.5)	2.4 (0.5)(0.5)	2.4 (0.5)(0.5)	2.4 (0.5)(0.5)	2.4 (0.5)(0.5)	2.4 (0.5)(0.5)
20.0	2.4 (0.5)(0.5)	2.4 (0.5)(0.5)	2.4 (0.5)(0.5)	2.4 (0.5)(0.5)	2.4 (0.5)(0.5)	2.4 (0.5)(0.5)
30.0	2.4 (0.5)(0.5)	2.4 (0.5)(0.5)	2.4 (0.5)(0.5)	2.4 (0.5)(0.5)	2.4 (0.5)(0.5)	2.4 (0.5)(0.5)

Table 42: Vertical BPM gain error in %. We present mean and RMS (first bracket) values for 60 random different lattices. Also, both the mean and RMS (second bracket) among the ring elements are presented. We have studied different horizontal dispersion weights (rows) and different vertical dispersion weights (columns), all for three different three λ values.

λ =0.01	5.0	12.5	15.0	20.0	25.0	30.0
5.0	-0.0 (0.1)(0.4)	-0.0 (0.1)(0.4)	-0.0 (0.1)(0.4)	-0.0 (0.1)(0.4)	-0.0 (0.1)(0.4)	-0.0 (0.1)(0.4)
12.5	-0.0 (0.1)(0.5)	-0.0 (0.1)(0.5)	-0.0 (0.1)(0.5)	-0.0 (0.1)(0.5)	-0.0 (0.1)(0.5)	-0.0 (0.1)(0.5)
20.0	-0.0 (0.1)(0.7)	-0.0 (0.1)(0.7)	-0.0 (0.1)(0.7)	-0.0 (0.1)(0.7)	-0.0 (0.1)(0.7)	-0.0 (0.1)(0.7)
30.0	-0.0 (0.1)(0.9)	-0.0 (0.1)(0.9)	-0.0 (0.1)(0.9)	-0.0 (0.1)(0.9)	-0.0 (0.1)(0.9)	-0.0 (0.1)(0.9)
λ =0.05						
5.0	-0.0 (0.1)(0.7)	-0.0 (0.1)(0.7)	-0.0 (0.1)(0.7)	-0.0 (0.1)(0.7)	-0.0 (0.1)(0.7)	-0.0 (0.1)(0.7)
12.5	-0.0 (0.1)(0.9)	-0.0 (0.1)(0.9)	-0.0 (0.1)(0.9)	-0.0 (0.1)(0.9)	-0.0 (0.1)(0.9)	-0.0 (0.1)(0.9)
20.0	-0.0 (0.1)(1.1)	-0.0 (0.1)(1.1)	-0.0 (0.1)(1.1)	-0.0 (0.1)(1.1)	-0.0 (0.1)(1.1)	-0.0 (0.1)(1.1)
30.0	-0.1 (0.1)(1.4)	-0.1 (0.1)(1.4)	-0.1 (0.1)(1.4)	-0.1 (0.1)(1.4)	-0.1 (0.1)(1.4)	-0.1 (0.1)(1.4)
λ =0.10						
5.0	-0.1 (0.1)(0.9)	-0.1 (0.1)(0.9)	-0.1 (0.1)(0.9)	-0.1 (0.1)(0.9)	-0.1 (0.1)(0.9)	-0.1 (0.1)(0.9)
12.5	-0.1 (0.1)(1.1)	-0.1 (0.1)(1.1)	-0.1 (0.1)(1.1)	-0.1 (0.1)(1.1)	-0.1 (0.1)(1.1)	-0.1 (0.1)(1.1)
20.0	-0.1 (0.1)(1.4)	-0.1 (0.1)(1.4)	-0.1 (0.1)(1.4)	-0.1 (0.1)(1.4)	-0.1 (0.1)(1.4)	-0.1 (0.1)(1.4)
30.0	-0.1 (0.1)(1.8)	-0.1 (0.1)(1.8)	-0.1 (0.1)(1.8)	-0.1 (0.1)(1.8)	-0.1 (0.1)(1.8)	-0.1 (0.1)(1.8)

Table 43: Horizontal beta beat error in %. We present mean and RMS (first bracket) values for 60 random different lattices. Also, both the mean and RMS (second bracket) among the ring elements are presented. We have studied different horizontal dispersion weights (rows) and different vertical dispersion weights (columns), all for three different three λ values.

λ =0.01	5.0	12.5	15.0	20.0	25.0	30.0
5.0	0.0 (0.1)(0.5)	0.0 (0.1)(0.5)	0.0 (0.1)(0.5)	0.0 (0.1)(0.4)	0.0 (0.1)(0.4)	0.0 (0.1)(0.4)
12.5	-0.0 (0.1)(0.4)	-0.0 (0.1)(0.4)	-0.0 (0.1)(0.4)	-0.0 (0.1)(0.4)	-0.0 (0.1)(0.4)	-0.0 (0.1)(0.4)
20.0	-0.0 (0.1)(0.4)	-0.0 (0.1)(0.4)	-0.0 (0.1)(0.4)	-0.0 (0.1)(0.4)	-0.0 (0.1)(0.4)	-0.0 (0.1)(0.4)
30.0	-0.0 (0.1)(0.4)	-0.0 (0.1)(0.4)	-0.0 (0.1)(0.4)	-0.0 (0.1)(0.4)	-0.0 (0.1)(0.4)	-0.0 (0.1)(0.4)
λ =0.05						
5.0	-0.0 (0.1)(0.8)	-0.0 (0.1)(0.8)	-0.0 (0.1)(0.8)	-0.0 (0.1)(0.8)	-0.0 (0.1)(0.8)	-0.0 (0.1)(0.8)
12.5	-0.0 (0.1)(0.8)	-0.0 (0.1)(0.8)	-0.0 (0.1)(0.8)	-0.0 (0.1)(0.8)	-0.0 (0.1)(0.8)	-0.0 (0.1)(0.8)
20.0	-0.0 (0.1)(0.8)	-0.0 (0.1)(0.8)	-0.0 (0.1)(0.8)	-0.0 (0.1)(0.8)	-0.0 (0.1)(0.8)	-0.0 (0.1)(0.8)
30.0	-0.0 (0.1)(0.8)	-0.0 (0.1)(0.8)	-0.0 (0.1)(0.8)	-0.0 (0.1)(0.8)	-0.0 (0.1)(0.8)	-0.0 (0.1)(0.8)
λ =0.10						
5.0	-0.1 (0.1)(1.0)	-0.1 (0.1)(1.0)	-0.1 (0.1)(1.0)	-0.1 (0.1)(1.0)	-0.1 (0.1)(1.0)	-0.1 (0.1)(1.0)
12.5	-0.0 (0.1)(1.0)	-0.0 (0.1)(1.0)	-0.0 (0.1)(1.0)	-0.0 (0.1)(1.0)	-0.0 (0.1)(1.0)	-0.0 (0.1)(1.0)
20.0	-0.0 (0.1)(1.0)	-0.0 (0.1)(1.0)	-0.0 (0.1)(1.0)	-0.0 (0.1)(1.0)	-0.0 (0.1)(1.0)	-0.0 (0.1)(1.0)
30.0	-0.0 (0.1)(1.0)	-0.0 (0.1)(1.0)	-0.0 (0.1)(1.0)	-0.0 (0.1)(1.0)	-0.0 (0.1)(1.0)	-0.0 (0.1)(1.0)

Table 44: Vertical beta beat error in %. We present mean and RMS (first bracket) values for 60 random different lattices. Also, both the mean and RMS (second bracket) among the ring elements are presented. We have studied different horizontal dispersion weights (rows) and different vertical dispersion weights (columns), all for three different three λ values.

λ =0.01	5.0	12.5	15.0	20.0	25.0	30.0
5.0	0.0 (0.1)(0.2)	0.0 (0.1)(0.2)	0.0 (0.1)(0.2)	0.0 (0.1)(0.2)	0.0 (0.1)(0.2)	0.0 (0.1)(0.2)
12.5	0.0 (0.1)(0.3)	0.0 (0.1)(0.3)	0.0 (0.1)(0.3)	0.0 (0.1)(0.3)	0.0 (0.1)(0.3)	0.0 (0.1)(0.3)
20.0	0.1 (0.1)(0.4)	0.1 (0.1)(0.4)	0.1 (0.1)(0.4)	0.1 (0.1)(0.4)	0.1 (0.1)(0.4)	0.1 (0.1)(0.4)
30.0	0.1 (0.1)(0.5)	0.1 (0.1)(0.5)	0.1 (0.1)(0.5)	0.1 (0.1)(0.5)	0.1 (0.1)(0.5)	0.1 (0.1)(0.5)
λ =0.05						
5.0	0.1 (0.1)(0.4)	0.1 (0.1)(0.4)	0.1 (0.1)(0.4)	0.1 (0.1)(0.4)	0.1 (0.1)(0.4)	0.1 (0.1)(0.4)
12.5	0.1 (0.1)(0.5)	0.1 (0.1)(0.5)	0.1 (0.1)(0.5)	0.1 (0.1)(0.5)	0.1 (0.1)(0.5)	0.1 (0.1)(0.5)
20.0	0.1 (0.1)(0.8)	0.1 (0.1)(0.8)	0.1 (0.1)(0.8)	0.1 (0.1)(0.8)	0.1 (0.1)(0.8)	0.1 (0.1)(0.8)
30.0	0.0 (0.2)(1.0)	0.0 (0.2)(1.0)	0.0 (0.2)(1.0)	0.0 (0.2)(1.0)	0.0 (0.2)(1.0)	0.0 (0.2)(1.0)
λ =0.10						
5.0	0.1 (0.1)(0.5)	0.1 (0.1)(0.5)	0.1 (0.1)(0.5)	0.1 (0.1)(0.5)	0.1 (0.1)(0.5)	0.1 (0.1)(0.5)
12.5	0.1 (0.1)(0.7)	0.1 (0.1)(0.7)	0.1 (0.1)(0.7)	0.1 (0.1)(0.7)	0.1 (0.1)(0.7)	0.1 (0.1)(0.7)
20.0	0.0 (0.2)(1.0)	0.0 (0.2)(1.0)	0.0 (0.2)(1.0)	0.0 (0.2)(1.0)	0.0 (0.2)(1.0)	0.0 (0.2)(1.0)
30.0	0.0 (0.2)(1.1)	0.0 (0.2)(1.1)	0.0 (0.2)(1.1)	0.0 (0.2)(1.1)	0.0 (0.2)(1.1)	0.0 (0.2)(1.1)

Table 45: Horizontal dispersion beat error in %. We present mean and RMS (first bracket) values for 60 random different lattices. Also, both the mean and RMS (second bracket) among the ring elements are presented. We have studied different horizontal dispersion weights (rows) and different vertical dispersion weights (columns), all for three different three λ values.

λ =0.01	5.0	12.5	15.0	20.0	25.0	30.0
5.0	0.2 (2.2)(10.2)	0.3 (2.3)(10.5)	0.3 (2.2)(10.6)	0.2 (2.1)(10.6)	0.2 (1.9)(11.1)	0.2 (1.8)(11.5)
12.5	0.1 (2.1)(9.8)	0.2 (2.3)(10.1)	0.2 (2.2)(10.2)	0.2 (2.1)(10.5)	0.2 (1.9)(10.9)	0.2 (1.8)(11.5)
20.0	0.1 (2.1)(9.8)	0.2 (2.3)(10.1)	0.2 (2.2)(10.2)	0.2 (2.0)(10.5)	0.2 (1.9)(10.9)	0.2 (1.8)(11.5)
30.0	0.1 (2.1)(9.8)	0.2 (2.3)(10.1)	0.2 (2.2)(10.2)	0.2 (2.0)(10.5)	0.2 (1.9)(10.9)	0.2 (1.8)(11.5)
λ =0.05						
5.0	0.2 (2.2)(10.7)	0.2 (1.8)(11.5)	0.2 (1.8)(12.2)	0.2 (1.9)(13.8)	0.1 (2.1)(15.8)	0.1 (2.3)(17.8)
12.5	0.2 (2.2)(10.7)	0.2 (1.8)(11.5)	0.2 (1.8)(12.2)	0.2 (1.9)(13.8)	0.1 (2.1)(15.8)	0.1 (2.3)(17.8)
20.0	0.2 (2.2)(10.8)	0.2 (1.8)(11.6)	0.2 (1.8)(12.2)	0.2 (1.9)(13.8)	0.1 (2.1)(15.8)	0.1 (2.3)(17.8)
30.0	0.3 (2.2)(10.8)	0.2 (1.8)(11.6)	0.2 (1.8)(12.2)	0.2 (1.9)(13.9)	0.1 (2.1)(15.8)	0.1 (2.3)(17.8)
λ =0.10						
5.0	0.2 (1.9)(11.1)	0.2 (1.8)(13.2)	0.2 (2.0)(14.5)	0.1 (2.3)(17.2)	0.1 (2.6)(19.7)	0.1 (2.8)(21.7)
12.5	0.2 (1.9)(11.1)	0.2 (1.8)(13.2)	0.2 (2.0)(14.5)	0.1 (2.3)(17.2)	0.1 (2.6)(19.7)	0.1 (2.9)(21.7)
20.0	0.2 (1.9)(11.1)	0.2 (1.8)(13.2)	0.2 (2.0)(14.5)	0.1 (2.3)(17.2)	0.1 (2.6)(19.7)	0.1 (2.9)(21.7)
30.0	0.2 (1.9)(11.2)	0.1 (1.9)(13.2)	0.1 (2.0)(14.5)	0.1 (2.3)(17.2)	0.1 (2.6)(19.7)	0.1 (2.9)(21.7)

Table 46: Vertical dispersion error in %. We present mean and RMS (first bracket) values for 60 random different lattices. Also, both the mean and RMS (second bracket) among the ring elements are presented. We have studied different horizontal dispersion weights (rows) and different vertical dispersion weights (columns), all for three different three λ values.

λ =0.01	5.0	12.5	15.0	20.0	25.0	30.0
5.0	0.4 (26.1)(241.1)	0.4 (26.0)(241.1)	0.4 (26.0)(241.1)	1.4 (24.9)(235.8)	1.4 (24.9)(235.7)	1.7 (24.7)(231.7)
12.5	4.8 (20.2)(211.9)	4.8 (20.2)(211.9)	4.8 (20.2)(211.9)	4.8 (20.2)(211.8)	4.8 (20.2)(211.8)	4.8 (20.2)(211.8)
20.0	6.3 (19.6)(208.4)	6.3 (19.6)(208.4)	6.3 (19.6)(208.3)	6.3 (19.6)(208.3)	6.3 (19.6)(208.3)	6.3 (19.6)(208.3)
30.0	7.1 (20.9)(205.0)	7.1 (20.8)(205.0)	7.1 (20.8)(205.0)	7.1 (20.8)(204.9)	7.2 (20.8)(204.9)	7.2 (20.8)(204.9)
λ =0.05						
5.0	10.5 (18.3)(221.8)	10.5 (18.3)(221.8)	10.5 (18.3)(221.8)	10.5 (18.3)(221.8)	10.4 (18.3)(221.8)	10.4 (18.3)(221.8)
12.5	9.9 (19.3)(201.1)	9.9 (19.3)(201.1)	9.9 (19.3)(201.1)	9.9 (19.3)(201.1)	9.9 (19.3)(201.1)	9.8 (19.3)(201.1)
20.0	10.0 (20.7)(195.2)	10.0 (20.7)(195.2)	10.0 (20.7)(195.2)	10.0 (20.7)(195.2)	9.9 (20.7)(195.2)	9.9 (20.7)(195.1)
30.0	10.8 (20.7)(190.5)	10.9 (20.7)(190.5)	10.9 (20.7)(190.5)	10.8 (20.7)(190.5)	10.8 (20.7)(190.4)	10.8 (20.7)(190.4)
λ =0.10						
5.0	16.6 (17.3)(223.6)	16.6 (17.3)(223.6)	16.6 (17.3)(223.6)	16.5 (17.3)(223.6)	16.5 (17.3)(223.6)	16.5 (17.3)(223.6)
12.5	14.2 (19.5)(198.1)	14.2 (19.5)(198.1)	14.2 (19.5)(198.1)	14.2 (19.4)(198.1)	14.1 (19.4)(198.1)	14.1 (19.4)(198.1)
20.0	14.7 (20.1)(190.8)	14.7 (20.1)(190.8)	14.7 (20.1)(190.8)	14.7 (20.1)(190.7)	14.7 (20.1)(190.7)	14.6 (20.1)(190.7)
30.0	15.6 (18.9)(186.8)	15.6 (18.9)(186.8)	15.6 (18.9)(186.8)	15.6 (18.9)(186.8)	15.5 (18.9)(186.8)	15.5 (18.9)(186.8)

Table 47: Quadrupole error in % relative to σ_k. We present mean and RMS (first bracket) values for 60 random different lattices. Also, both the mean and RMS (second bracket) among the ring elements are presented. We have studied different horizontal dispersion weights (rows) and different vertical dispersion weights (columns), all for three different three λ values.

λ =0.01	5.0	12.5	15.0	20.0	25.0	30.0
5.0	1.3 (0.0)	1.3 (0.0)	1.3 (0.0)	1.3 (0.2)	1.3 (0.2)	1.3 (0.3)
12.5	1.2 (0.2)	1.3 (0.2)	1.3 (0.2)	1.3 (0.3)	1.3 (0.3)	1.3 (0.3)
20.0	1.3 (0.2)	1.3 (0.3)	1.3 (0.3)	1.3 (0.3)	1.4 (0.3)	1.4 (0.3)
30.0	1.4 (0.3)	1.4 (0.3)	1.4 (0.3)	1.4 (0.3)	1.5 (0.3)	1.5 (0.3)
λ =0.05						
5.0	1.3 (0.3)	1.4 (0.3)	1.4 (0.3)	1.4 (0.3)	1.5 (0.3)	1.5 (0.3)
12.5	1.4 (0.3)	1.5 (0.3)	1.5 (0.3)	1.5 (0.3)	1.6 (0.3)	1.6 (0.3)
20.0	1.6 (0.3)	1.7 (0.3)	1.7 (0.3)	1.7 (0.4)	1.8 (0.4)	1.8 (0.4)
30.0	1.9 (0.4)	2.0 (0.4)	2.0 (0.4)	2.1 (0.4)	2.1 (0.4)	2.1 (0.5)
λ =0.10						
5.0	1.4 (0.3)	1.5 (0.3)	1.5 (0.3)	1.6 (0.3)	1.6 (0.3)	1.7 (0.3)
12.5	1.6 (0.3)	1.7 (0.3)	1.7 (0.3)	1.8 (0.4)	1.8 (0.4)	1.9 (0.4)
20.0	2.0 (0.4)	2.0 (0.4)	2.1 (0.4)	2.1 (0.4)	2.2 (0.5)	2.2 (0.5)
30.0	2.4 (0.6)	2.5 (0.6)	2.5 (0.6)	2.5 (0.6)	2.6 (0.6)	2.7 (0.6)

Table 48: Chi squared error in no units. We present mean and RMS (first bracket) values for 60 random different lattices. We have studied different horizontal dispersion weights (rows) and different vertical dispersion weights (columns), all for three different three λ values.

D Tables for dispersion weight study with a nominal lattice, with artificial vertical dispersion using a single skew magnet

$\lambda = 0.01$	5.0	12.5	15.0	20.0	25.0	30.0
5.0	-0.0 (0.0)(0.3)	-0.0 (0.0)(0.4)	-0.0 (0.0)(0.4)	-0.0 (0.0)(0.4)	-0.0 (0.0)(0.4)	-0.0 (0.0)(0.4)
12.5	-0.0 (0.0)(0.4)	-0.0 (0.0)(0.4)	-0.0 (0.0)(0.4)	-0.0 (0.0)(0.4)	-0.0 (0.0)(0.4)	-0.0 (0.0)(0.4)
20.0	-0.0 (0.0)(0.4)	-0.0 (0.0)(0.4)	-0.0 (0.0)(0.4)	-0.0 (0.0)(0.4)	-0.0 (0.0)(0.4)	-0.0 (0.0)(0.4)
30.0	-0.0 (0.0)(0.4)	-0.0 (0.0)(0.4)	-0.0 (0.0)(0.4)	-0.0 (0.0)(0.4)	-0.0 (0.0)(0.5)	-0.0 (0.0)(0.5)
$\lambda = 0.05$						
5.0	-0.0 (0.0)(0.4)	-0.0 (0.0)(0.4)	-0.0 (0.0)(0.4)	-0.0 (0.0)(0.5)	-0.0 (0.0)(0.5)	-0.0 (0.0)(0.5)
12.5	-0.0 (0.0)(0.4)	-0.0 (0.0)(0.5)	-0.0 (0.0)(0.5)	-0.0 (0.0)(0.5)	-0.0 (0.0)(0.5)	-0.0 (0.0)(0.5)
20.0	-0.0 (0.0)(0.5)	-0.0 (0.0)(0.5)	-0.0 (0.0)(0.5)	-0.0 (0.0)(0.5)	-0.0 (0.0)(0.5)	-0.0 (0.0)(0.5)
30.0	-0.0 (0.0)(0.5)	-0.0 (0.0)(0.5)	-0.0 (0.0)(0.5)	-0.0 (0.0)(0.5)	-0.0 (0.0)(0.5)	-0.0 (0.0)(0.6)
$\lambda = 0.10$						
5.0	-0.0 (0.0)(0.4)	-0.0 (0.0)(0.5)	-0.0 (0.0)(0.5)	-0.0 (0.0)(0.5)	-0.0 (0.0)(0.5)	-0.0 (0.0)(0.5)
12.5	-0.0 (0.0)(0.5)	-0.0 (0.0)(0.5)	-0.0 (0.0)(0.5)	-0.0 (0.0)(0.5)	-0.0 (0.0)(0.5)	-0.0 (0.0)(0.6)
20.0	-0.0 (0.0)(0.5)	-0.0 (0.0)(0.5)	-0.0 (0.0)(0.5)	-0.0 (0.0)(0.5)	-0.0 (0.0)(0.6)	-0.0 (0.0)(0.6)
30.0	-0.0 (0.1)(0.6)	-0.0 (0.1)(0.6)	-0.0 (0.1)(0.6)	-0.0 (0.1)(0.6)	-0.0 (0.1)(0.6)	-0.0 (0.1)(0.6)

Table 49: Horizontal corrector coupling error in %. We present mean and RMS (first bracket) values for 60 random different lattices. Also, both the mean and RMS (second bracket) among the ring elements are presented. We have studied different horizontal dispersion weights (rows) and different vertical dispersion weights (columns), all for three different three λ values. We have used the nominal lattice with artificial vertical dispersion.

λ =0.01	5.0	12.5	15.0	20.0	25.0	30.0
5.0	0.0 (0.0)(0.2)	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)	0.0 (0.0)(0.4)
12.5	0.0 (0.0)(0.2)	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)	0.0 (0.0)(0.4)
20.0	0.0 (0.0)(0.2)	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)	0.0 (0.0)(0.4)
30.0	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)	0.0 (0.0)(0.4)
λ =0.05						
5.0	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)	0.0 (0.0)(0.4)	0.0 (0.1)(0.4)	0.0 (0.1)(0.4)	0.0 (0.1)(0.5)
12.5	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)	0.0 (0.1)(0.4)	0.0 (0.1)(0.4)	0.0 (0.1)(0.4)	0.0 (0.1)(0.5)
20.0	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)	0.0 (0.1)(0.4)	0.0 (0.1)(0.4)	0.0 (0.1)(0.4)	0.0 (0.1)(0.5)
30.0	0.0 (0.0)(0.3)	0.0 (0.0)(0.4)	0.0 (0.1)(0.4)	0.0 (0.1)(0.4)	0.0 (0.1)(0.4)	0.0 (0.1)(0.5)
λ =0.10						
5.0	0.0 (0.0)(0.3)	0.0 (0.1)(0.4)	0.0 (0.1)(0.4)	0.0 (0.1)(0.5)	0.0 (0.1)(0.5)	0.0 (0.1)(0.5)
12.5	0.0 (0.0)(0.3)	0.0 (0.1)(0.4)	0.0 (0.1)(0.4)	0.0 (0.1)(0.5)	0.0 (0.1)(0.5)	0.0 (0.1)(0.5)
20.0	0.0 (0.0)(0.3)	0.0 (0.1)(0.4)	0.0 (0.1)(0.4)	0.0 (0.1)(0.5)	0.0 (0.1)(0.5)	0.0 (0.1)(0.5)
30.0	0.0 (0.0)(0.3)	0.0 (0.1)(0.4)	0.0 (0.1)(0.4)	0.0 (0.1)(0.5)	0.0 (0.1)(0.5)	0.0 (0.1)(0.5)

Table 50: Vertical corrector coupling error in %. We present mean and RMS (first bracket) values for 60 random different lattices. Also, both the mean and RMS (second bracket) among the ring elements are presented. We have studied different horizontal dispersion weights (rows) and different vertical dispersion weights (columns), all for three different three λ values. We have used the nominal lattice with artificial vertical dispersion.

λ =0.01	5.0	12.5	15.0	20.0	25.0	30.0
5.0	-0.0 (0.2)(0.3)	0.0 (0.2)(0.3)	0.0 (0.2)(0.3)	0.0 (0.2)(0.3)	0.0 (0.2)(0.3)	0.0 (0.2)(0.3)
12.5	-0.0 (0.2)(0.4)	0.0 (0.2)(0.4)	0.0 (0.2)(0.4)	0.0 (0.2)(0.4)	0.0 (0.2)(0.4)	0.0 (0.2)(0.4)
20.0	-0.0 (0.2)(0.5)	0.0 (0.2)(0.5)	0.0 (0.2)(0.5)	0.0 (0.2)(0.5)	0.0 (0.2)(0.5)	0.0 (0.2)(0.5)
30.0	0.0 (0.2)(0.6)	0.0 (0.2)(0.6)	0.0 (0.2)(0.6)	0.0 (0.2)(0.6)	0.0 (0.2)(0.7)	0.0 (0.2)(0.7)
λ =0.05						
5.0	-0.1 (0.2)(0.4)	-0.1 (0.2)(0.4)	-0.0 (0.2)(0.4)	-0.0 (0.2)(0.4)	0.0 (0.2)(0.5)	0.0 (0.2)(0.5)
12.5	-0.0 (0.2)(0.6)	-0.0 (0.2)(0.6)	-0.0 (0.2)(0.6)	-0.0 (0.2)(0.6)	-0.0 (0.2)(0.7)	0.0 (0.2)(0.7)
20.0	-0.0 (0.3)(0.9)	-0.0 (0.3)(0.9)	-0.0 (0.3)(0.9)	0.0 (0.3)(0.9)	0.0 (0.3)(0.9)	0.0 (0.3)(0.9)
30.0	0.0 (0.3)(1.1)	0.0 (0.3)(1.1)	0.0 (0.3)(1.1)	0.0 (0.3)(1.1)	0.0 (0.3)(1.1)	0.0 (0.3)(1.1)
λ =0.10						
5.0	-0.1 (0.2)(0.5)	-0.1 (0.2)(0.5)	-0.1 (0.2)(0.5)	-0.1 (0.2)(0.5)	-0.0 (0.2)(0.6)	-0.0 (0.2)(0.6)
12.5	-0.0 (0.2)(0.8)	-0.0 (0.2)(0.8)	-0.0 (0.2)(0.8)	-0.0 (0.2)(0.8)	-0.0 (0.3)(0.9)	0.0 (0.3)(0.9)
20.0	-0.0 (0.3)(1.0)	-0.0 (0.3)(1.1)	0.0 (0.3)(1.1)	0.0 (0.3)(1.1)	0.0 (0.3)(1.1)	0.0 (0.3)(1.1)
30.0	0.0 (0.3)(1.2)	0.0 (0.3)(1.2)	0.0 (0.3)(1.2)	0.0 (0.3)(1.2)	0.0 (0.3)(1.2)	0.0 (0.3)(1.2)

Table 51: Horizontal corrector gain error in %. We present mean and RMS (first bracket) values for 60 random different lattices. Also, both the mean and RMS (second bracket) among the ring elements are presented. We have studied different horizontal dispersion weights (rows) and different vertical dispersion weights (columns), all for three different three λ values. We have used the nominal lattice with artificial vertical dispersion.

λ =0.01	5.0	12.5	15.0	20.0	25.0	30.0
5.0	-0.4 (0.2)(0.2)	-0.3 (0.2)(0.3)	-0.2 (0.2)(0.3)	-0.1 (0.2)(0.3)	0.1 (0.2)(0.3)	0.4 (0.3)(0.4)
12.5	-0.4 (0.2)(0.2)	-0.3 (0.2)(0.2)	-0.2 (0.2)(0.3)	-0.1 (0.2)(0.3)	0.1 (0.3)(0.3)	0.4 (0.3)(0.4)
20.0	-0.4 (0.2)(0.2)	-0.3 (0.2)(0.2)	-0.2 (0.2)(0.3)	-0.1 (0.3)(0.3)	0.1 (0.3)(0.3)	0.4 (0.3)(0.3)
30.0	-0.4 (0.3)(0.2)	-0.3 (0.3)(0.3)	-0.2 (0.3)(0.3)	-0.1 (0.3)(0.3)	0.1 (0.3)(0.3)	0.4 (0.3)(0.4)
λ =0.05						
5.0	-1.7 (0.2)(0.4)	-1.1 (0.2)(0.5)	-0.9 (0.2)(0.5)	-0.4 (0.2)(0.5)	0.2 (0.3)(0.5)	0.7 (0.3)(0.6)
12.5	-1.7 (0.2)(0.4)	-1.1 (0.2)(0.4)	-0.9 (0.2)(0.5)	-0.4 (0.3)(0.5)	0.2 (0.3)(0.5)	0.7 (0.3)(0.6)
20.0	-1.6 (0.3)(0.4)	-1.1 (0.3)(0.5)	-0.9 (0.3)(0.5)	-0.4 (0.3)(0.5)	0.2 (0.3)(0.5)	0.7 (0.3)(0.6)
30.0	-1.6 (0.3)(0.4)	-1.1 (0.3)(0.5)	-0.9 (0.4)(0.5)	-0.4 (0.4)(0.5)	0.2 (0.4)(0.5)	0.7 (0.4)(0.6)
λ =0.10						
5.0	-2.0 (0.2)(0.5)	-1.4 (0.2)(0.5)	-1.1 (0.2)(0.6)	-0.4 (0.2)(0.6)	0.2 (0.3)(0.6)	0.8 (0.3)(0.6)
12.5	-2.0 (0.2)(0.5)	-1.3 (0.2)(0.5)	-1.1 (0.2)(0.6)	-0.4 (0.3)(0.6)	0.2 (0.3)(0.6)	0.8 (0.3)(0.6)
20.0	-2.0 (0.2)(0.5)	-1.3 (0.3)(0.5)	-1.0 (0.3)(0.6)	-0.4 (0.3)(0.6)	0.2 (0.3)(0.6)	0.8 (0.3)(0.6)
30.0	-2.0 (0.3)(0.5)	-1.3 (0.3)(0.5)	-1.0 (0.3)(0.6)	-0.4 (0.3)(0.6)	0.2 (0.3)(0.6)	0.8 (0.3)(0.6)

Table 52: Vertical corrector gain error in %. We present mean and RMS (first bracket) values for 60 random different lattices. Also, both the mean and RMS (second bracket) among the ring elements are presented. We have studied different horizontal dispersion weights (rows) and different vertical dispersion weights (columns), all for three different three λ values. We have used the nominal lattice with artificial vertical dispersion.

λ =0.01	5.0	12.5	15.0	20.0	25.0	30.0
5.0	-0.0 (0.0)(0.4)	-0.0 (0.0)(0.4)	-0.0 (0.1)(0.4)	-0.0 (0.1)(0.5)	-0.0 (0.1)(0.5)	-0.0 (0.1)(0.5)
12.5	-0.0 (0.0)(0.4)	-0.0 (0.1)(0.4)	-0.0 (0.1)(0.4)	-0.0 (0.1)(0.5)	-0.0 (0.1)(0.5)	-0.0 (0.1)(0.5)
20.0	-0.0 (0.0)(0.4)	-0.0 (0.1)(0.4)	-0.0 (0.1)(0.4)	-0.0 (0.1)(0.5)	-0.0 (0.1)(0.5)	-0.0 (0.1)(0.5)
30.0	-0.0 (0.0)(0.4)	-0.0 (0.1)(0.4)	-0.0 (0.1)(0.5)	-0.0 (0.1)(0.5)	-0.0 (0.1)(0.5)	-0.0 (0.1)(0.5)
λ =0.05						
5.0	-0.0 (0.1)(0.5)	-0.0 (0.1)(0.5)	-0.0 (0.1)(0.5)	-0.0 (0.1)(0.5)	-0.0 (0.1)(0.5)	-0.0 (0.1)(0.6)
12.5	-0.0 (0.1)(0.5)	-0.0 (0.1)(0.5)	-0.0 (0.1)(0.5)	-0.0 (0.1)(0.5)	-0.0 (0.1)(0.6)	-0.0 (0.1)(0.6)
20.0	-0.0 (0.1)(0.5)	-0.0 (0.1)(0.5)	-0.0 (0.1)(0.5)	-0.0 (0.1)(0.6)	-0.0 (0.1)(0.6)	-0.0 (0.1)(0.6)
30.0	-0.0 (0.1)(0.6)	-0.0 (0.1)(0.6)	-0.0 (0.1)(0.6)	-0.0 (0.1)(0.6)	-0.0 (0.1)(0.6)	-0.0 (0.1)(0.6)
λ =0.10						
5.0	-0.0 (0.1)(0.5)	-0.0 (0.1)(0.6)	-0.0 (0.1)(0.6)	-0.0 (0.1)(0.6)	-0.0 (0.1)(0.6)	-0.0 (0.1)(0.6)
12.5	-0.0 (0.1)(0.6)	-0.0 (0.1)(0.6)	-0.0 (0.1)(0.6)	-0.0 (0.1)(0.6)	-0.0 (0.1)(0.6)	-0.0 (0.1)(0.6)
20.0	-0.0 (0.1)(0.6)	-0.0 (0.1)(0.6)	-0.0 (0.1)(0.6)	-0.0 (0.1)(0.6)	-0.0 (0.1)(0.6)	-0.0 (0.1)(0.7)
30.0	-0.0 (0.1)(0.6)	-0.0 (0.1)(0.6)	-0.0 (0.1)(0.6)	-0.0 (0.1)(0.6)	-0.0 (0.1)(0.7)	-0.0 (0.1)(0.7)

Table 53: Horizontal BPM coupling error in %. We present mean and RMS (first bracket) values for 60 random different lattices. Also, both the mean and RMS (second bracket) among the ring elements are presented. We have studied different horizontal dispersion weights (rows) and different vertical dispersion weights (columns), all for three different three λ values. We have used the nominal lattice with artificial vertical dispersion.

λ =0.01	5.0	12.5	15.0	20.0	25.0	30.0
5.0	0.0 (0.0)(0.2)	0.0 (0.0)(0.2)	0.0 (0.0)(0.2)	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)
12.5	0.0 (0.0)(0.2)	0.0 (0.0)(0.2)	0.0 (0.0)(0.2)	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)
20.0	0.0 (0.0)(0.2)	0.0 (0.0)(0.2)	0.0 (0.0)(0.2)	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)
30.0	0.0 (0.0)(0.2)	0.0 (0.0)(0.2)	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)
λ =0.05						
5.0	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)
12.5	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)
20.0	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)
30.0	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)
λ =0.10						
5.0	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)	0.0 (0.0)(0.4)
12.5	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)	0.0 (0.0)(0.4)
20.0	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)	0.0 (0.0)(0.4)
30.0	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)	0.0 (0.0)(0.3)	0.0 (0.0)(0.4)

Table 54: Vertical BPM coupling error in %. We present mean and RMS (first bracket) values for 60 random different lattices. Also, both the mean and RMS (second bracket) among the ring elements are presented. We have studied different horizontal dispersion weights (rows) and different vertical dispersion weights (columns), all for three different three λ values. We have used the nominal lattice with artificial vertical dispersion.

λ =0.01	5.0	12.5	15.0	20.0	25.0	30.0
5.0	0.1 (0.1)(0.2)	0.1 (0.1)(0.2)	0.1 (0.1)(0.2)	0.0 (0.1)(0.3)	-0.1 (0.1)(0.3)	-0.1 (0.1)(0.3)
12.5	0.1 (0.1)(0.3)	0.1 (0.1)(0.3)	0.1 (0.1)(0.3)	0.0 (0.1)(0.3)	-0.1 (0.1)(0.3)	-0.1 (0.1)(0.4)
20.0	0.1 (0.2)(0.4)	0.1 (0.2)(0.4)	0.1 (0.2)(0.4)	0.0 (0.2)(0.4)	-0.1 (0.2)(0.4)	-0.1 (0.2)(0.4)
30.0	0.1 (0.2)(0.5)	0.1 (0.2)(0.5)	0.1 (0.2)(0.5)	0.0 (0.2)(0.5)	-0.1 (0.2)(0.5)	-0.1 (0.2)(0.5)
λ =0.05						
5.0	0.6 (0.2)(0.4)	0.5 (0.2)(0.4)	0.4 (0.2)(0.4)	0.2 (0.2)(0.5)	0.0 (0.2)(0.5)	-0.1 (0.2)(0.5)
12.5	0.6 (0.3)(0.5)	0.5 (0.2)(0.5)	0.4 (0.2)(0.5)	0.2 (0.2)(0.5)	0.1 (0.3)(0.5)	-0.1 (0.3)(0.5)
20.0	0.6 (0.4)(0.6)	0.5 (0.4)(0.6)	0.4 (0.4)(0.6)	0.3 (0.4)(0.6)	0.2 (0.4)(0.6)	0.0 (0.4)(0.6)
30.0	0.8 (0.7)(0.7)	0.6 (0.6)(0.7)	0.6 (0.6)(0.7)	0.5 (0.6)(0.7)	0.3 (0.6)(0.7)	0.2 (0.6)(0.7)
λ =0.10						
5.0	1.1 (0.3)(0.5)	0.9 (0.3)(0.5)	0.8 (0.3)(0.5)	0.7 (0.3)(0.5)	0.5 (0.3)(0.6)	0.3 (0.3)(0.6)
12.5	1.1 (0.4)(0.6)	1.0 (0.4)(0.6)	0.9 (0.4)(0.6)	0.7 (0.4)(0.6)	0.6 (0.4)(0.6)	0.5 (0.5)(0.6)
20.0	1.3 (0.7)(0.7)	1.1 (0.7)(0.7)	1.1 (0.7)(0.7)	0.9 (0.7)(0.7)	0.8 (0.7)(0.7)	0.7 (0.7)(0.7)
30.0	1.4 (1.2)(0.8)	1.3 (1.2)(0.8)	1.3 (1.2)(0.8)	1.1 (1.2)(0.8)	1.0 (1.2)(0.8)	0.9 (1.2)(0.8)

Table 55: Horizontal BPM gain error in %. We present mean and RMS (first bracket) values for 60 random different lattices. Also, both the mean and RMS (second bracket) among the ring elements are presented. We have studied different horizontal dispersion weights (rows) and different vertical dispersion weights (columns), all for three different three λ values. We have used the nominal lattice with artificial vertical dispersion.

λ =0.01	5.0	12.5	15.0	20.0	25.0	30.0
5.0	0.4 (0.2)(0.2)	0.3 (0.2)(0.2)	0.2 (0.2)(0.2)	0.1 (0.2)(0.2)	-0.1 (0.2)(0.3)	-0.4 (0.2)(0.3)
12.5	0.4 (0.2)(0.2)	0.3 (0.2)(0.2)	0.2 (0.2)(0.2)	0.1 (0.2)(0.2)	-0.1 (0.2)(0.3)	-0.4 (0.2)(0.3)
20.0	0.4 (0.2)(0.2)	0.3 (0.2)(0.2)	0.2 (0.2)(0.2)	0.1 (0.2)(0.2)	-0.1 (0.2)(0.3)	-0.4 (0.3)(0.3)
30.0	0.4 (0.2)(0.2)	0.3 (0.2)(0.2)	0.2 (0.3)(0.2)	0.1 (0.3)(0.2)	-0.1 (0.3)(0.3)	-0.3 (0.3)(0.3)
λ =0.05						
5.0	1.7 (0.1)(0.4)	1.1 (0.2)(0.4)	0.9 (0.2)(0.4)	0.4 (0.2)(0.4)	-0.1 (0.2)(0.5)	-0.6 (0.3)(0.5)
12.5	1.6 (0.2)(0.4)	1.1 (0.2)(0.4)	0.9 (0.2)(0.4)	0.4 (0.2)(0.4)	-0.1 (0.2)(0.5)	-0.6 (0.3)(0.5)
20.0	1.6 (0.2)(0.4)	1.1 (0.2)(0.4)	0.9 (0.2)(0.4)	0.4 (0.3)(0.4)	-0.1 (0.3)(0.5)	-0.6 (0.3)(0.5)
30.0	1.6 (0.3)(0.4)	1.1 (0.3)(0.4)	0.9 (0.3)(0.4)	0.4 (0.3)(0.4)	-0.1 (0.3)(0.5)	-0.6 (0.3)(0.5)
λ =0.10						
5.0	2.0 (0.2)(0.5)	1.4 (0.2)(0.5)	1.1 (0.2)(0.5)	0.5 (0.2)(0.5)	-0.1 (0.2)(0.5)	-0.7 (0.2)(0.5)
12.5	2.0 (0.2)(0.5)	1.3 (0.2)(0.5)	1.1 (0.2)(0.5)	0.5 (0.2)(0.5)	-0.1 (0.2)(0.5)	-0.7 (0.3)(0.5)
20.0	2.0 (0.2)(0.5)	1.3 (0.2)(0.5)	1.0 (0.2)(0.5)	0.4 (0.2)(0.5)	-0.1 (0.3)(0.5)	-0.7 (0.3)(0.5)
30.0	2.0 (0.3)(0.5)	1.3 (0.3)(0.5)	1.0 (0.3)(0.5)	0.4 (0.3)(0.5)	-0.1 (0.3)(0.5)	-0.7 (0.3)(0.6)

Table 56: Vertical BPM gain error in %. We present mean and RMS (first bracket) values for 60 random different lattices. Also, both the mean and RMS (second bracket) among the ring elements are presented. We have studied different horizontal dispersion weights (rows) and different vertical dispersion weights (columns), all for three different three λ values. We have used the nominal lattice with artificial vertical dispersion.

λ =0.01	5.0	12.5	15.0	20.0	25.0	30.0
5.0	-0.0 (0.1)(0.4)	-0.0 (0.1)(0.5)	-0.0 (0.1)(0.5)	-0.0 (0.1)(0.5)	-0.0 (0.1)(0.6)	-0.0 (0.1)(0.6)
12.5	-0.0 (0.1)(0.6)	-0.0 (0.1)(0.6)	-0.0 (0.1)(0.6)	-0.0 (0.1)(0.6)	-0.0 (0.1)(0.7)	-0.0 (0.1)(0.7)
20.0	-0.0 (0.1)(0.7)	-0.0 (0.1)(0.8)	-0.0 (0.1)(0.8)	-0.0 (0.1)(0.8)	-0.0 (0.1)(0.8)	-0.0 (0.1)(0.8)
30.0	-0.0 (0.1)(0.9)	-0.0 (0.1)(0.9)	-0.0 (0.1)(0.9)	-0.0 (0.1)(0.9)	-0.0 (0.1)(1.0)	-0.0 (0.1)(1.0)
λ =0.05						
5.0	-0.1 (0.1)(0.8)	-0.1 (0.1)(0.8)	-0.1 (0.1)(0.9)	-0.0 (0.1)(0.9)	-0.0 (0.1)(1.0)	-0.0 (0.1)(1.0)
12.5	-0.1 (0.1)(1.0)	-0.1 (0.1)(1.0)	-0.1 (0.1)(1.0)	-0.0 (0.1)(1.0)	-0.0 (0.1)(1.1)	-0.0 (0.1)(1.1)
20.0	-0.1 (0.1)(1.2)	-0.1 (0.1)(1.2)	-0.1 (0.1)(1.2)	-0.1 (0.1)(1.2)	-0.0 (0.1)(1.2)	-0.0 (0.1)(1.2)
30.0	-0.1 (0.2)(1.5)	-0.1 (0.2)(1.5)	-0.1 (0.2)(1.5)	-0.1 (0.2)(1.5)	-0.1 (0.2)(1.5)	-0.1 (0.2)(1.5)
λ =0.10						
5.0	-0.1 (0.1)(1.0)	-0.1 (0.1)(1.0)	-0.1 (0.1)(1.0)	-0.1 (0.1)(1.1)	-0.0 (0.1)(1.1)	-0.0 (0.2)(1.2)
12.5	-0.1 (0.1)(1.1)	-0.1 (0.1)(1.2)	-0.1 (0.1)(1.2)	-0.1 (0.1)(1.2)	-0.1 (0.2)(1.2)	-0.0 (0.2)(1.3)
20.0	-0.1 (0.2)(1.4)	-0.1 (0.2)(1.4)	-0.1 (0.2)(1.4)	-0.1 (0.2)(1.5)	-0.1 (0.2)(1.5)	-0.1 (0.2)(1.5)
30.0	-0.1 (0.2)(1.8)	-0.1 (0.2)(1.8)	-0.1 (0.2)(1.8)	-0.1 (0.2)(1.8)	-0.1 (0.2)(1.8)	-0.1 (0.2)(1.8)

Table 57: Horizontal beta beat error in %. We present mean and RMS (first bracket) values for 60 random different lattices. Also, both the mean and RMS (second bracket) among the ring elements are presented. We have studied different horizontal dispersion weights (rows) and different vertical dispersion weights (columns), all for three different three λ values. We have used the nominal lattice with artificial vertical dispersion.

λ =0.01	5.0	12.5	15.0	20.0	25.0	30.0
5.0	-0.0 (0.1)(0.5)	-0.0 (0.1)(0.5)	-0.0 (0.1)(0.6)	-0.0 (0.1)(0.6)	-0.0 (0.1)(0.7)	-0.0 (0.1)(0.7)
12.5	-0.0 (0.1)(0.5)	-0.0 (0.1)(0.5)	-0.0 (0.1)(0.5)	-0.0 (0.1)(0.6)	-0.0 (0.1)(0.6)	-0.0 (0.1)(0.7)
20.0	-0.0 (0.1)(0.5)	-0.0 (0.1)(0.5)	-0.0 (0.1)(0.5)	-0.0 (0.1)(0.6)	-0.0 (0.1)(0.6)	-0.0 (0.1)(0.7)
30.0	-0.0 (0.1)(0.5)	-0.0 (0.1)(0.5)	-0.0 (0.1)(0.5)	-0.0 (0.1)(0.6)	-0.0 (0.1)(0.6)	-0.0 (0.1)(0.7)
λ =0.05						
5.0	-0.1 (0.1)(0.8)	-0.1 (0.1)(0.9)	-0.1 (0.1)(0.9)	-0.1 (0.1)(1.0)	-0.1 (0.1)(1.0)	-0.1 (0.1)(1.1)
12.5	-0.1 (0.1)(0.8)	-0.1 (0.1)(0.9)	-0.1 (0.1)(0.9)	-0.1 (0.1)(1.0)	-0.1 (0.1)(1.0)	-0.1 (0.1)(1.1)
20.0	-0.1 (0.1)(0.8)	-0.1 (0.1)(0.9)	-0.1 (0.1)(0.9)	-0.1 (0.1)(1.0)	-0.1 (0.1)(1.0)	-0.1 (0.1)(1.1)
30.0	-0.1 (0.1)(0.8)	-0.1 (0.1)(0.9)	-0.1 (0.1)(0.9)	-0.1 (0.1)(1.0)	-0.1 (0.1)(1.0)	-0.1 (0.1)(1.1)
λ =0.10						
5.0	-0.1 (0.1)(1.0)	-0.1 (0.1)(1.1)	-0.1 (0.1)(1.1)	-0.1 (0.1)(1.1)	-0.1 (0.1)(1.2)	-0.1 (0.1)(1.3)
12.5	-0.1 (0.1)(1.0)	-0.1 (0.1)(1.1)	-0.1 (0.1)(1.1)	-0.1 (0.1)(1.1)	-0.1 (0.1)(1.2)	-0.1 (0.1)(1.2)
20.0	-0.1 (0.1)(1.0)	-0.1 (0.1)(1.1)	-0.1 (0.1)(1.1)	-0.1 (0.1)(1.1)	-0.1 (0.1)(1.2)	-0.1 (0.1)(1.3)
30.0	-0.1 (0.1)(1.0)	-0.1 (0.1)(1.1)	-0.1 (0.1)(1.1)	-0.1 (0.1)(1.1)	-0.1 (0.1)(1.2)	-0.1 (0.1)(1.3)

Table 58: Vertical beta beat error in %. We present mean and RMS (first bracket) values for 60 random different lattices. Also, both the mean and RMS (second bracket) among the ring elements are presented. We have studied different horizontal dispersion weights (rows) and different vertical dispersion weights (columns), all for three different three λ values. We have used the nominal lattice with artificial vertical dispersion.

λ =0.01	5.0	12.5	15.0	20.0	25.0	30.0
5.0	0.1 (0.2)(0.3)	0.1 (0.2)(0.3)	0.1 (0.2)(0.3)	0.1 (0.2)(0.3)	0.1 (0.2)(0.3)	0.1 (0.2)(0.3)
12.5	0.1 (0.2)(0.3)	0.1 (0.2)(0.3)	0.1 (0.2)(0.3)	0.1 (0.2)(0.3)	0.1 (0.2)(0.4)	0.1 (0.2)(0.4)
20.0	0.1 (0.2)(0.4)	0.1 (0.2)(0.4)	0.1 (0.2)(0.4)	0.1 (0.2)(0.4)	0.1 (0.2)(0.4)	0.1 (0.2)(0.5)
30.0	0.1 (0.2)(0.6)	0.1 (0.2)(0.6)	0.1 (0.2)(0.6)	0.1 (0.2)(0.6)	0.1 (0.2)(0.6)	0.1 (0.2)(0.6)
λ =0.05						
5.0	0.1 (0.2)(0.4)	0.1 (0.2)(0.4)	0.1 (0.2)(0.5)	0.1 (0.2)(0.5)	0.1 (0.2)(0.5)	0.1 (0.2)(0.6)
12.5	0.1 (0.2)(0.6)	0.1 (0.2)(0.6)	0.1 (0.2)(0.6)	0.1 (0.2)(0.6)	0.1 (0.2)(0.7)	0.1 (0.2)(0.7)
20.0	0.1 (0.2)(0.8)	0.1 (0.2)(0.9)	0.1 (0.2)(0.9)	0.1 (0.2)(0.9)	0.1 (0.2)(0.9)	0.1 (0.2)(0.9)
30.0	0.1 (0.2)(1.0)	0.1 (0.2)(1.0)	0.1 (0.2)(1.0)	0.1 (0.2)(1.1)	0.1 (0.2)(1.1)	0.1 (0.2)(1.1)
λ =0.10						
5.0	0.1 (0.2)(0.5)	0.1 (0.2)(0.6)	0.1 (0.2)(0.6)	0.1 (0.2)(0.6)	0.1 (0.2)(0.7)	0.1 (0.2)(0.8)
12.5	0.1 (0.2)(0.8)	0.1 (0.2)(0.8)	0.1 (0.2)(0.8)	0.1 (0.2)(0.9)	0.1 (0.2)(0.9)	0.1 (0.2)(0.9)
20.0	0.1 (0.2)(1.0)	0.1 (0.2)(1.0)	0.1 (0.2)(1.0)	0.1 (0.2)(1.1)	0.1 (0.2)(1.1)	0.1 (0.2)(1.1)
30.0	0.0 (0.2)(1.1)	0.0 (0.2)(1.2)	0.0 (0.2)(1.2)	0.0 (0.2)(1.2)	0.0 (0.2)(1.2)	0.1 (0.2)(1.2)

Table 59: Horizontal dispersion beat error in %. We present mean and RMS (first bracket) values for 60 random different lattices. Also, both the mean and RMS (second bracket) among the ring elements are presented. We have studied different horizontal dispersion weights (rows) and different vertical dispersion weights (columns), all for three different three λ values. We have used the nominal lattice with artificial vertical dispersion.

λ =0.01	5.0	12.5	15.0	20.0	25.0	30.0
5.0	0.1 (0.2)(1.1)	0.0 (0.2)(1.1)	0.0 (0.2)(1.1)	-0.0 (0.2)(1.1)	-0.1 (0.2)(1.1)	-0.1 (0.2)(1.3)
12.5	0.1 (0.2)(1.1)	0.0 (0.2)(1.1)	0.0 (0.2)(1.1)	-0.0 (0.2)(1.1)	-0.1 (0.2)(1.1)	-0.1 (0.2)(1.3)
20.0	0.1 (0.2)(1.1)	0.0 (0.2)(1.1)	0.0 (0.2)(1.1)	-0.0 (0.2)(1.1)	-0.1 (0.2)(1.1)	-0.1 (0.2)(1.3)
30.0	0.0 (0.2)(1.2)	0.0 (0.2)(1.1)	0.0 (0.2)(1.1)	-0.0 (0.2)(1.1)	-0.1 (0.2)(1.2)	-0.1 (0.2)(1.3)
λ =0.05						
5.0	0.3 (0.2)(2.1)	0.2 (0.2)(1.7)	0.1 (0.2)(1.6)	0.0 (0.3)(1.5)	-0.1 (0.3)(1.7)	-0.2 (0.3)(2.0)
12.5	0.3 (0.2)(2.1)	0.2 (0.2)(1.7)	0.1 (0.2)(1.6)	0.0 (0.3)(1.5)	-0.1 (0.3)(1.7)	-0.2 (0.3)(2.0)
20.0	0.3 (0.2)(2.1)	0.2 (0.2)(1.7)	0.1 (0.3)(1.6)	0.0 (0.3)(1.5)	-0.1 (0.3)(1.7)	-0.2 (0.3)(2.0)
30.0	0.3 (0.2)(2.1)	0.2 (0.3)(1.8)	0.1 (0.3)(1.7)	0.0 (0.3)(1.6)	-0.1 (0.3)(1.7)	-0.2 (0.3)(2.0)
λ =0.10						
5.0	0.3 (0.2)(2.5)	0.2 (0.3)(2.0)	0.1 (0.3)(1.9)	0.0 (0.3)(1.8)	-0.1 (0.3)(2.0)	-0.2 (0.3)(2.3)
12.5	0.3 (0.2)(2.5)	0.2 (0.3)(2.0)	0.1 (0.3)(1.9)	0.0 (0.3)(1.8)	-0.1 (0.3)(2.0)	-0.2 (0.3)(2.3)
20.0	0.3 (0.2)(2.5)	0.2 (0.3)(2.0)	0.1 (0.3)(1.9)	0.0 (0.3)(1.8)	-0.1 (0.3)(2.0)	-0.2 (0.3)(2.3)
30.0	0.3 (0.3)(2.5)	0.2 (0.3)(2.0)	0.1 (0.3)(1.9)	0.0 (0.3)(1.9)	-0.1 (0.3)(2.0)	-0.2 (0.3)(2.3)

Table 60: Vertical dispersion error in %. We present mean and RMS (first bracket) values for 60 random different lattices. Also, both the mean and RMS (second bracket) among the ring elements are presented. We have studied different horizontal dispersion weights (rows) and different vertical dispersion weights (columns), all for three different three λ values. We have used the nominal lattice with artificial vertical dispersion.

λ =0.01	5.0	12.5	15.0	20.0	25.0	30.0
5.0	5.5 (26.3)(241.5)	4.5 (25.4)(242.5)	4.1 (25.1)(243.3)	3.1 (24.3)(245.4)	2.2 (23.5)(248.0)	1.3 (22.7)(250.8)
12.5	4.7 (21.6)(221.2)	4.2 (21.4)(220.7)	3.9 (21.3)(220.9)	3.4 (21.1)(221.8)	2.8 (20.9)(223.7)	2.2 (20.8)(226.2)
20.0	3.8 (22.9)(217.4)	3.5 (22.9)(216.2)	3.4 (22.8)(215.8)	3.1 (22.7)(215.4)	2.7 (22.6)(215.7)	2.2 (22.5)(216.5)
30.0	3.3 (25.7)(214.9)	3.1 (25.6)(213.9)	3.0 (25.6)(213.5)	2.7 (25.5)(212.8)	2.4 (25.4)(212.3)	2.0 (25.3)(212.2)
λ =0.05						
5.0	11.8 (20.6)(234.2)	10.6 (20.4)(237.1)	10.1 (20.4)(238.7)	9.1 (20.4)(242.5)	8.3 (20.5)(246.9)	7.5 (20.7)(251.2)
12.5	8.4 (24.0)(213.3)	7.7 (23.8)(214.6)	7.3 (23.7)(215.4)	6.6 (23.6)(217.7)	5.8 (23.5)(220.6)	5.1 (23.4)(223.9)
20.0	7.7 (26.4)(207.4)	6.9 (26.2)(207.5)	6.6 (26.2)(207.6)	5.8 (26.0)(208.2)	5.0 (25.8)(209.2)	4.2 (25.6)(210.6)
30.0	8.3 (26.6)(202.6)	7.5 (26.5)(202.4)	7.2 (26.5)(202.4)	6.3 (26.4)(202.3)	5.5 (26.2)(202.5)	4.7 (26.0)(202.8)
λ =0.10						
5.0	16.5 (20.9)(237.3)	15.3 (21.0)(240.3)	14.9 (21.0)(241.9)	13.9 (21.1)(245.5)	13.0 (21.3)(249.3)	12.2 (21.5)(252.8)
12.5	12.4 (24.8)(211.4)	11.6 (24.6)(212.9)	11.2 (24.5)(213.7)	10.5 (24.3)(216.0)	9.7 (24.1)(218.7)	9.0 (23.9)(221.6)
20.0	12.5 (25.9)(203.5)	11.6 (25.7)(203.7)	11.2 (25.6)(203.9)	10.4 (25.3)(204.6)	9.6 (25.1)(205.6)	8.8 (24.8)(207.0)
30.0	13.5 (24.3)(198.5)	12.7 (24.3)(198.5)	12.3 (24.2)(198.5)	11.4 (24.0)(198.6)	10.6 (23.8)(198.8)	9.9 (23.6)(199.2)

Table 61: Quadrupole error in % relative to σ_k. We present mean and RMS (first bracket) values for 60 random different lattices. Also, both the mean and RMS (second bracket) among the ring elements are presented. We have studied different horizontal dispersion weights (rows) and different vertical dispersion weights (columns), all for three different three λ values. We have used the nominal lattice with artificial vertical dispersion.

λ =0.01	5.0	12.5	15.0	20.0	25.0	30.0
5.0	1.3 (0.0)	1.4 (0.0)	1.4 (0.0)	1.4 (0.0)	1.4 (0.0)	1.5 (0.0)
12.5	1.3 (0.0)	1.4 (0.0)	1.4 (0.0)	1.4 (0.0)	1.5 (0.0)	1.5 (0.1)
20.0	1.4 (0.0)	1.4 (0.0)	1.5 (0.0)	1.5 (0.1)	1.5 (0.1)	1.5 (0.1)
30.0	1.5 (0.1)	1.5 (0.1)	1.6 (0.1)	1.6 (0.1)	1.6 (0.1)	1.6 (0.1)
λ =0.05						
5.0	1.5 (0.0)	1.5 (0.1)	1.6 (0.1)	1.6 (0.1)	1.7 (0.1)	1.7 (0.1)
12.5	1.6 (0.1)	1.7 (0.1)	1.7 (0.1)	1.7 (0.1)	1.8 (0.1)	1.9 (0.1)
20.0	1.8 (0.1)	1.9 (0.2)	1.9 (0.2)	2.0 (0.2)	2.0 (0.2)	2.1 (0.2)
30.0	2.2 (0.3)	2.2 (0.3)	2.3 (0.3)	2.3 (0.3)	2.4 (0.3)	2.4 (0.3)
λ =0.10						
5.0	1.6 (0.1)	1.7 (0.1)	1.7 (0.1)	1.8 (0.1)	1.9 (0.1)	2.0 (0.2)
12.5	1.8 (0.1)	1.9 (0.1)	2.0 (0.2)	2.0 (0.2)	2.2 (0.2)	2.3 (0.2)
20.0	2.2 (0.2)	2.3 (0.3)	2.3 (0.3)	2.4 (0.3)	2.5 (0.3)	2.6 (0.3)
30.0	2.7 (0.4)	2.8 (0.4)	2.8 (0.4)	2.9 (0.4)	3.0 (0.5)	3.1 (0.5)

Table 62: Chi squared error in no units. We present mean and RMS (first bracket) values for 60 random different lattices. We have studied different horizontal dispersion weights (rows) and different vertical dispersion weights (columns), all for three different three λ values. We have used the nominal lattice with artificial vertical dispersion.