BNL-99237-2013-TECH

C-A/AP/84;BNL-99237-2013-IR

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October 2002

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U.S. Department of Energy

USDOE Office of Science (SC)

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C-A/AP/#84
September 2002

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Abstract

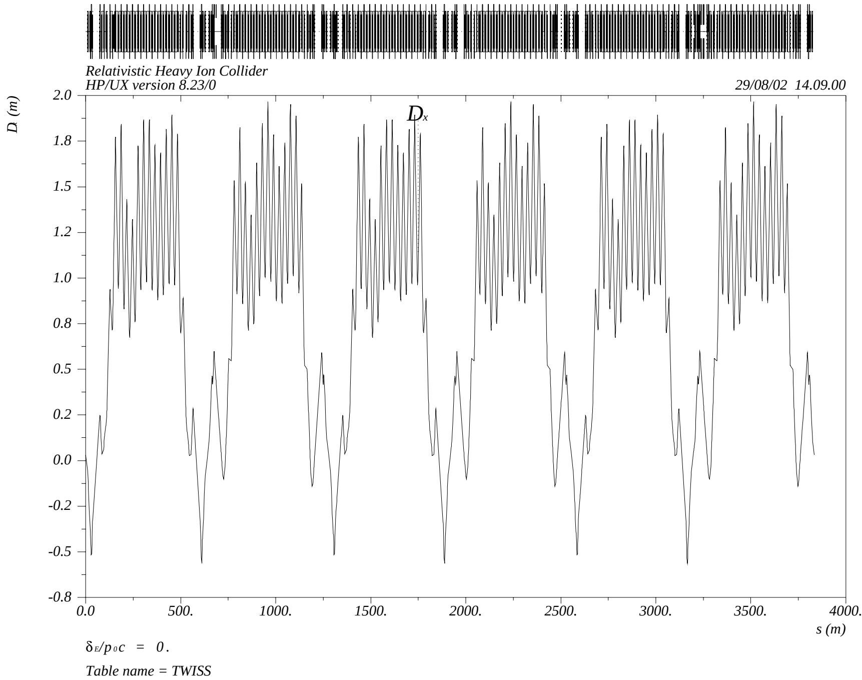
This report summarizes the dynamic aperture studies for a chromaticity jump of ± 2 units at transition, provided by two sextupoles per outer arc, one horizontal and one vertical (in total six per ring). Two sextupole configurations have been compared with the regular scheme without jump sextupoles. Based on these studies we recommend adopting scenario B, which will be implemented in RHIC during the next run.

1 Introduction

Different schemes have been considered to provide a dedicated chromaticity jump from $\xi = -2$ to $\xi = +2$ at transition. The first scheme jumps all sextupoles in RHIC. Since this scheme requires substantial modifications or even replacement of the existing power supplies, it is considered impractical. The second scheme exploits the fact that the γ_t jump quadrupoles modify the dispersion function, as shown in Figure 1 for a γ_t jump of $\Delta\gamma_t = 1.0$. This scheme uses a small number of strong sextupoles in the the region where the dispersion change is largest, resulting in a chromaticity jump at the exact time of the transition jump. However, this method also requires expensive new power supplies and quench protection modifications.

The two schemes (called configuration A and B) we propose and discuss in this paper are hybrids of the above two schemes. Even with the regular sextupole scheme, the modified dispersion function due to the transition jump provides a chromaticity jump of $\Delta\xi_x = +2.1$ and $\Delta\xi_y = +2.4$. The dedicated sextupole jump therefore has to provide the remaining 1.9 units in the horizontal plane and 1.6 units in the vertical plane to accomplish a total desired chromaticity jump of +4 units in both planes.

The basic idea for configuration A is to jump a few sextupoles (at locations where the dispersion function after the transition jump is largest) from zero to a certain strength, which causes the total chromaticity to jump from $\xi = -2$ to $\xi = +2$. This can be accomplished by the sextupoles SXF16 and SXD17 within the γ_t quadrupole family in all outer arcs, see Figure 1. The required sextupole strengths for this scheme are found to be similar ($-0.342\,\mathrm{m}^{-3}$ instead of $-0.353\,\mathrm{m}^{-3}$ vertically and $0.204\,\mathrm{m}^{-3}$ instead of $0.186\,\mathrm{m}^{-3}$ horizontally) to those of the corresponding regular arc sextupoles, which is preferable in terms of dynamic aperture considerations.



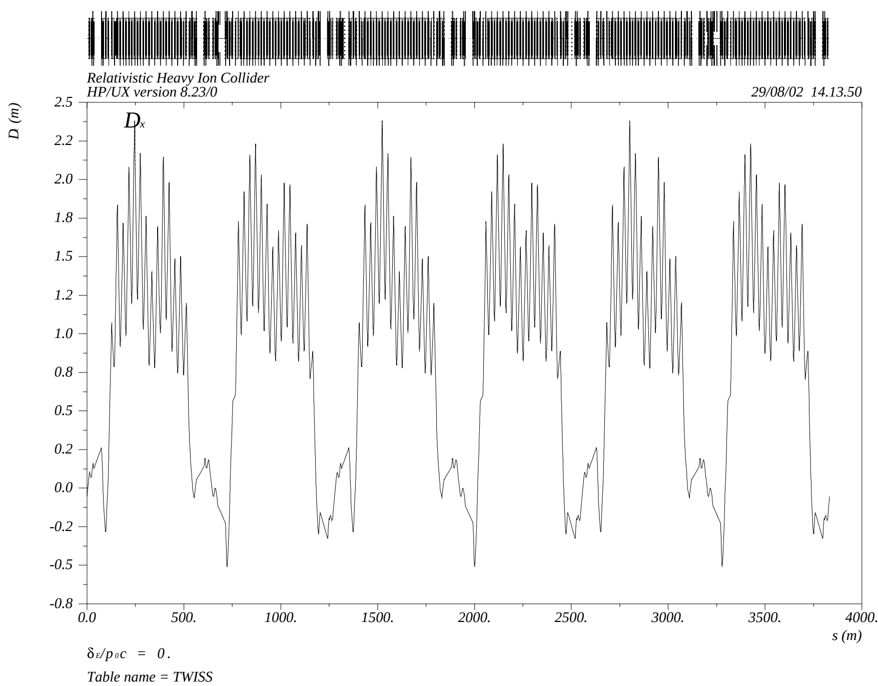


Figure 1: *Dispersion function D_x before (top) and after (bottom) crossing transition for $\Delta\gamma_t = 1.0$.*

configuration	A	B
hor. sextupole	SXF16	SXF10
vert. sextupole	SXD17	SXD9/SXD11
$m_{\text{jump}}(\text{SXD})/\text{m}^{-3}$	-0.342	-0.179
$m_{\text{jump}}(\text{SXF})/\text{m}^{-3}$	0.204	0.069
$m_{\text{regular}}(\text{SXD})/\text{m}^{-3}$	-0.353	-0.359
$m_{\text{regular}}(\text{SXF})/\text{m}^{-3}$	0.186	0.191

Table 1: *Jump sextupole parameters for configuration A and B.*

Configuration B uses two sextupoles at the beginning of each outer arc, namely SXF10 and SXD11 in BLUE, and SXF10 and SXD9 in YELLOW. As in configuration A, these sextupoles are kept at zero before transition. At γ_t, they are jumped to their final value. Compared to configuration A, this requires significantly weaker jump sextupoles. The vertical jump sextupole strength is $-0.179\,\text{m}^{-3}$ instead of $-0.359\,\text{m}^{-3}$ for the regular sextupoles, while in the horizontal plane a jump sextupole strength of $0.069\,\text{m}^{-3}$ is required, compared to $0.191\,\text{m}^{-3}$ for the regular arc sextupoles. This uneven sextupole distribution might lead to dynamic aperture problems, but it would be advantageous if a larger chromaticity jump is required, which would require stronger jump sextupoles. Table 1 summarizes the basic parameters of these two schemes.

To check the feasibility of these schemes, we studied the dynamic aperture for four situations, namely injection, before transition, after transition, and store, and compared them to the corresponding results obtained for the regular 2001 lattice.

2 Results

The dynamic aperture was calculated for three different values of $\Delta p/p$: -0.002, 0.0, and 0.002. At injection and during transition crossing, $\Delta p/p = 0.002$ corresponds to roughly one σ_p, while at store it correponds to about two σ_p. Simulations were performed using MAD [1], tracking 1024 turns for each particle. The tunes were set to $Q_x = 28.21$, $Q_y = 29.23$. The b_2 component of the main dipoles was included according to magnetic field measurements, with $b_2 = -10.0$ at injection, $b_2 = -2.85$ at transition, and $b_2 = -4.5$ at store [2].

At injection, the proposed jump sextupoles are off, as well as the γ_t quadrupoles. The remaining regular arc sextupoles set the chromaticities to $\xi_{x,y} = -2$. The β-function in all IPs is $\beta^* = 10\,\text{m}$. Figure 2 shows the dynamic aperture in the $(x-y)$ plane, together with the corresponding plot for the run 2001 configuration. With the jump sextupole configuration A, the dynamic aperture at injection gets even larger, while configuration B does not significantly differ from the 2001 scheme.

Before the transition jump, the jump sextupoles are still off, while the regular arc sextupoles set the chromaticities to $\xi_{x,y} = -2$. Additionally, the γ_t quadrupoles are turned on, increasing the γ_t value by about $\Delta\gamma_t \approx 0.5$. This results in a distorted horizontal dispersion function, as depicted in Figure 1. The resulting dynamic aperture is shown in Figure 3. Though the dynamic aperture with configuration B is significantly smaller than in the two other cases, it is still at least 12σ.

After the transition jump, the γ_t quadrupoles have flipped their polarity. The jump sextupoles are turned on now and set the total chromaticity to $\xi_{x,y} = +2$, as described in the introduction. The resulting dynamic aperture is depicted in Figure 4 and is practically the same for all three schemes.

At store, both the jump sextupoles and the γ_t quadrupoles are off. This means that the required positive chromaticity of $\xi_{x,y} = +2$ is provided by the remaining regular arc sextupoles. This situation has been studied for $\beta^* = 2\,\mathrm{m}$ at all interaction points. The resulting dynamic aperture is shown in Figure 5. The dynamic aperture of configurations A and B appears significantly smaller than with the regular scheme. However, the jump power supplies will be capable of providing the same sextupole strength as the regular sextupoles in the horizontal plane, and about 50% in the vertical plane. This more balanced sextupole distribution provides provides practically the same dynamic aperture as the regular 2001 configuration, as Figure 6 shows.

3 Conclusion

Dynamic aperture studies have been performed for two proposed new jump sextupole schemes. A comparison with the regular sextupole configuration shows a somewhat smaller dynamic aperture, but the effect is by far not disastrous. The differences between the two configurations (A and B) are marginal, while configuration B is preferred if a chromaticity jump with $\Delta\xi_{x,y} > 4$ is required to overcome the fast transverse instability currently suppressed by octupoles [3]. We therefore recommend adopting scenario B, which will be implemented in RHIC during the next run.

References

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[2] S. Tepikian, private communication

[3] C. Montag, J. Kewisch, D. Trbojevic, F. Schmidt, Overcoming a Fast Transverse Instability by Means of Octupole-induced Tune-spread in the Relativistic Heavy Ion Collider, Phys. Rev. ST - Accel. Beams 5, 084401 (2002)

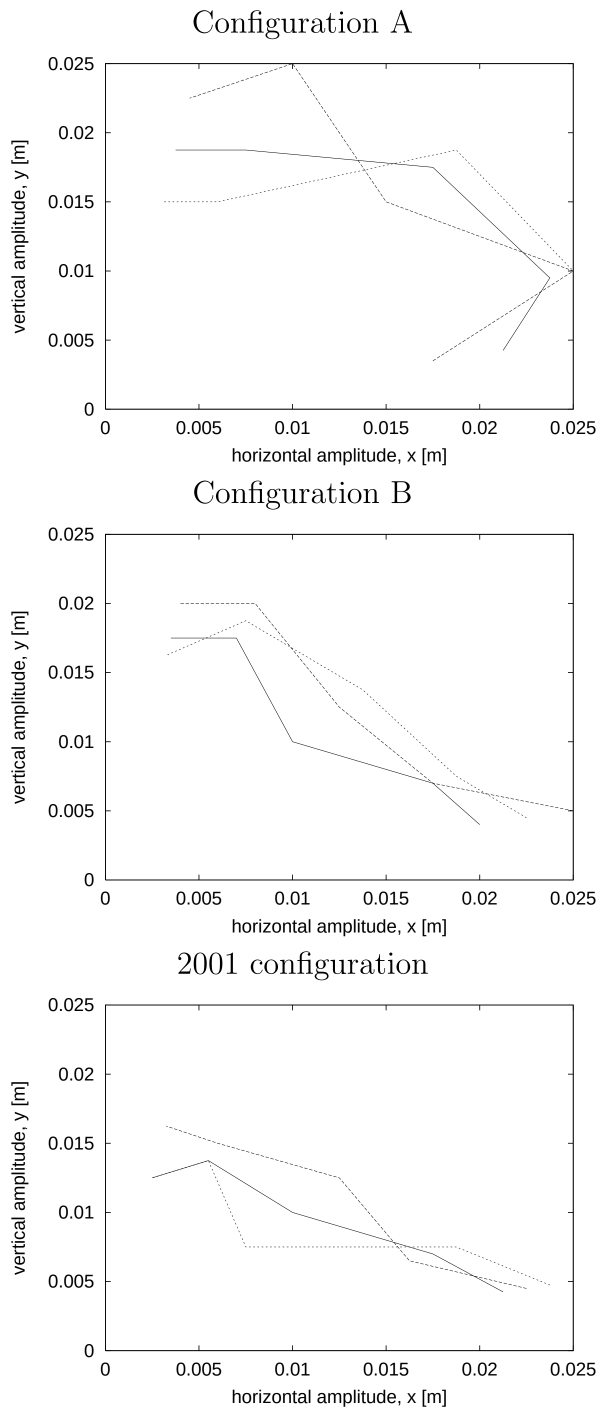

Figure 2: *Dynamic aperture at injection in the* $(x-y)$ *plane, for* $\Delta p/p = 0.0$ *(solid),* 0.002 *(dashed) and* -0.002 *(dotted). The* β*-function in all IPs is set to* $\beta^* = 10\,\mathrm{m}$. *One* σ *corresponds to* $1.25\,\mathrm{mm}$ *in both planes for an emittance of* $\epsilon = 10\pi\,\mathrm{mm\,mrad}$. *The top graph shows the situation with jump sextupole configuration A, the middle one for configuration B, while the lower plot exhibits the dynamic aperture for the regular run 2001 scheme.*

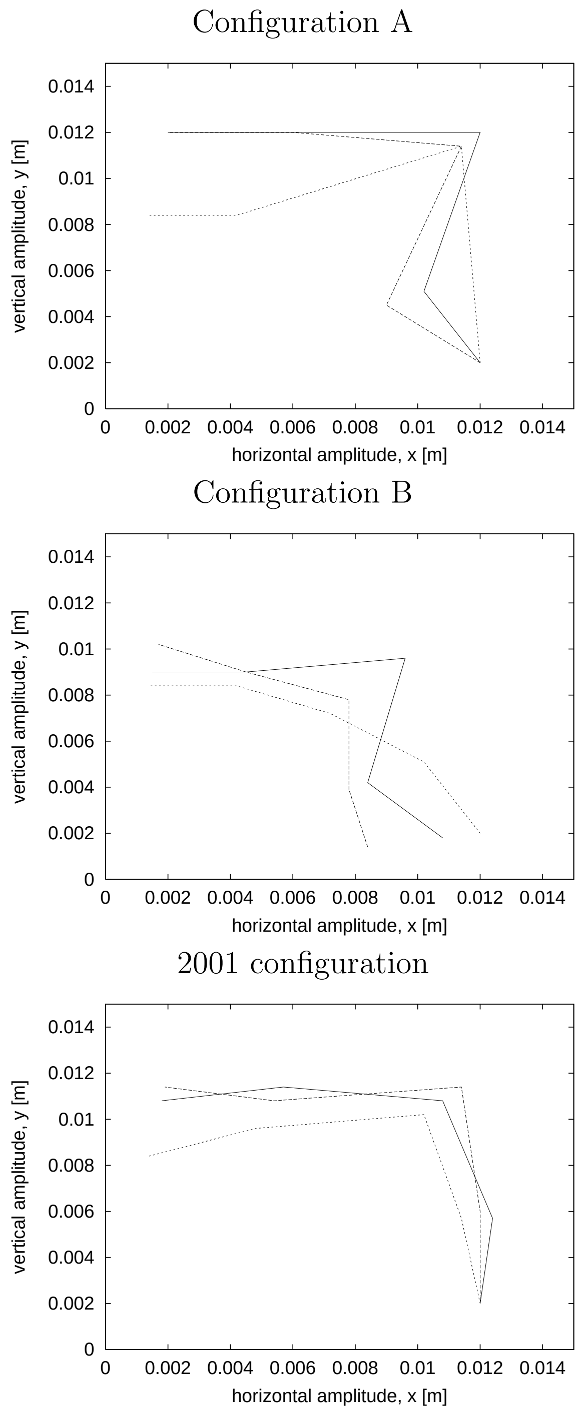

Figure 3: *Dynamic aperture just before the transition jump, for* $\Delta p/p = 0.0$ *(solid),* 0.002 *(dashed) and* -0.002 *(dotted). The* β*-function in all IPs is* $\beta^* = 5\,\mathrm{m}$*. One* σ *corresponds to* $0.6\,\mathrm{mm}$ *in both planes for an emittance of* $\epsilon = 10\pi\,\mathrm{mm\,mrad}$*. The top graph shows the situation with the jump sextupole configuration A, the middle one the corresponding plot for configuration B, while the lower plot exhibits the dynamic aperture for the regular run 2001 scheme.*

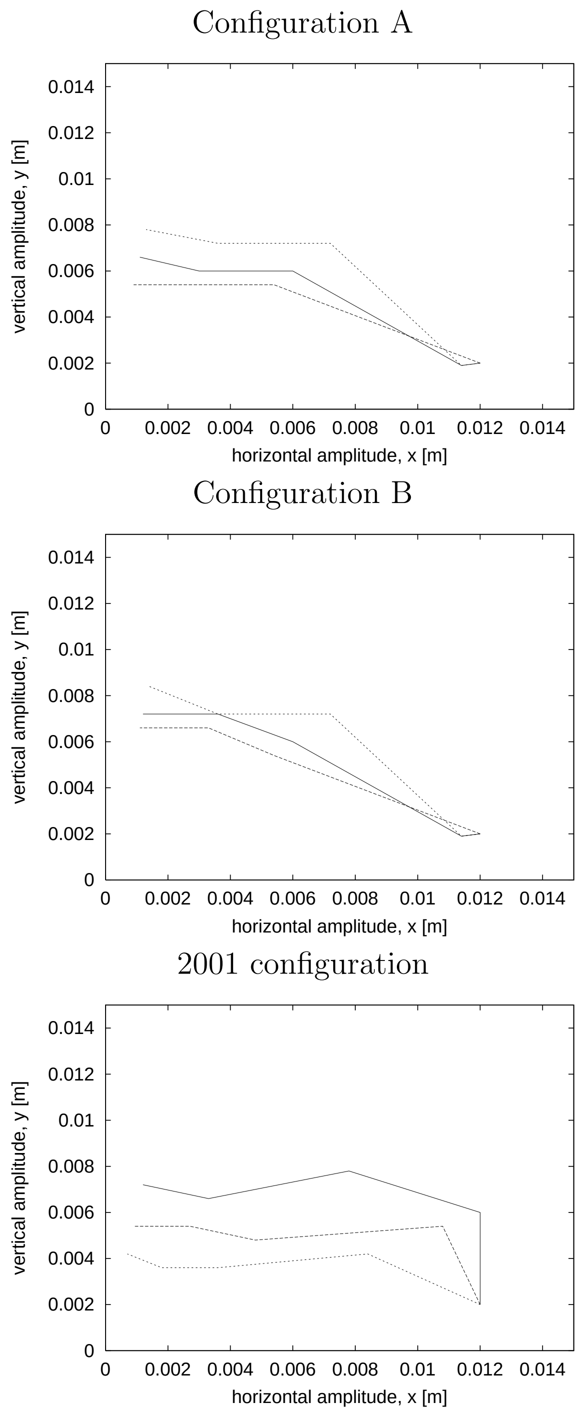

Figure 4: *Dynamic aperture just after the transition jump, for* $\Delta p/p = 0.0$ *(solid),* 0.002 *(dashed) and* -0.002 *(dotted), for* $\beta^* = 5\,\mathrm{m}$ *in all IPs. One* σ *corresponds to* $0.6\,\mathrm{mm}$ *in both planes for an emittance of* $\epsilon = 10\pi\,\mathrm{mm\,mrad}$. *The top graph shows the situation with the jump sextupole configuration A, the middle one corresponds to configuration B, while the lower plot exhibits the dynamic aperture for the regular run 2001 scheme.*

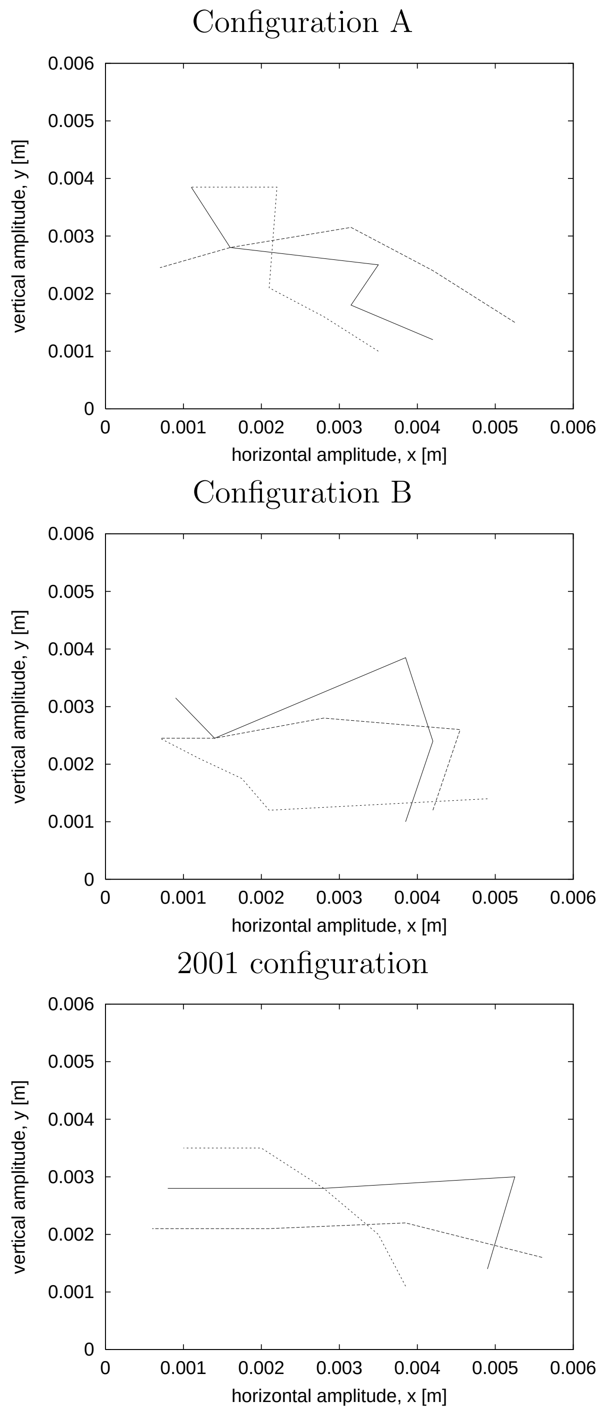

Figure 5: *Dynamic aperture at store, for* $\Delta p/p = 0.0$ *(solid),* 0.002 *(dashed) and* -0.002 *(dotted), for* $\beta^* = 2\,\mathrm{m}$ *in all IPs. The jump sextupoles are OFF in schemes A and B. One* σ *corresponds to* $0.35\,\mathrm{mm}$ *in both planes for an emittance of* $\epsilon = 40\pi\,\mathrm{mm\,mrad}$ *(end of store). The top graph shows the situation with jump sextupole configuration A, the middle one depicts configuration B, while the lower plot exhibits the dynamic aperture for the regular run 2001 scheme. Note that at the end of the store, the emittance is assumed to be blown up to* $\gamma\epsilon = 40\pi\,\mathrm{mm\,mrad}$, *resulting in an rms beam size of* $0.35\,\mathrm{mm}$ *at the IP.*

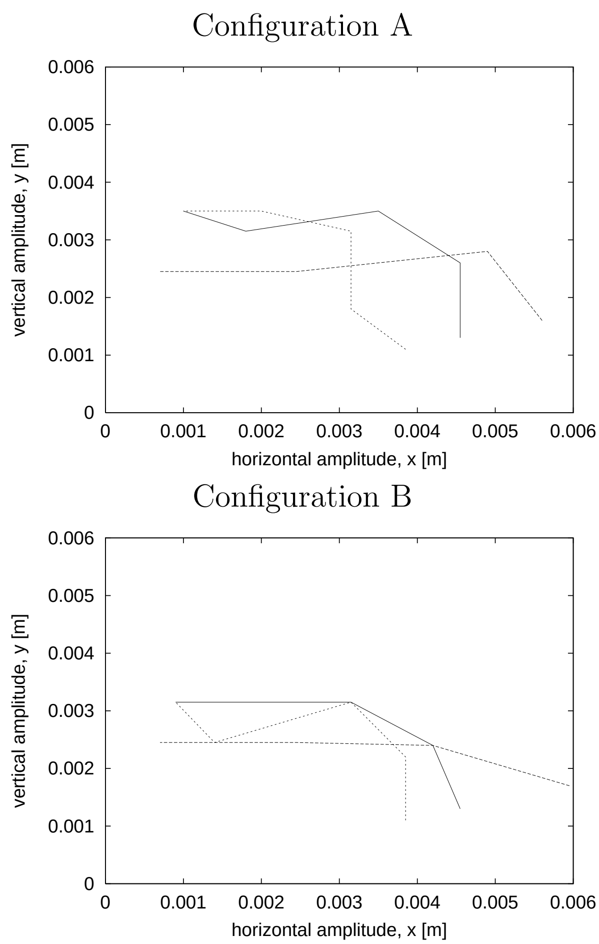

Figure 6: *Dynamic aperture at store, for* $\Delta p/p = 0.0$ *(solid),* 0.002 *(dashed) and* -0.002 *(dotted), for* $\beta^* = 2\,\mathrm{m}$ *in all IPs. The jump sextupoles are ON, providing* 87% *of the regular sextupole strength in the horizontal direction, and* 44% *in the vertical plane. One* σ *corresponds to* $0.35\,\mathrm{mm}$ *in both planes for an emittance of* $\epsilon = 40\pi\,\mathrm{mm\,mrad}$ *(end of store). The top graph shows the situation with jump sextupole configuration A, while the middle one depicts configuration B. Note that at the end of the store, the emittance is assumed to be blown up to* $\gamma\epsilon = 40\pi\,\mathrm{mm\,mrad}$, *resulting in an rms beam size of* $0.35\,\mathrm{mm}$ *at the IP.*