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Optimizing the Septum Sheet Position from the Chamber Centre

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Optimizing the Septum Sheet Position from the Chamber Centre

Introduction

In the optimized 4-kicker injection scheme for SESAME storage ring [1], the injection septum sheet has been placed at x = -25 mm from the vacuum chamber centre. This position of the septum sheet resulted in a net half width of 36.5 mm for the inner side of the vacuum chamber in the injection section and just downstream the septum [1]. The considered injection orbit bump was -20 mm high. On the other hand, the peaks of the orbit bump before and after the septum were -22.2 mm high which caused part of the injected beam to get lost at the chamber wall at the beginning of the first turn [1]. To overcome this problem, more horizontal space was offered for the injected beam downstream the septum (keeping the -20 mm amplitude for the orbit bump) [1]. Consequently, we ended up with -40 mm as a net inner half width for the vacuum chamber downstream the septum. This increase in chamber width has to be added as a slot which is vertically limited to a maximum half-height z = 7 mm (out of 14 mm which is the basic half-height of the vacuum chamber) due to the sextupole poles limitations. To come back to the normal vacuum chamber half aperture of 35 mm, a horizontal taper can start at the beginning of the defocusing quadrupole downstream the septum [1]. This adds a complication to the design of the injection section vacuum chamber and makes the pre-dipole section there a special one [2].

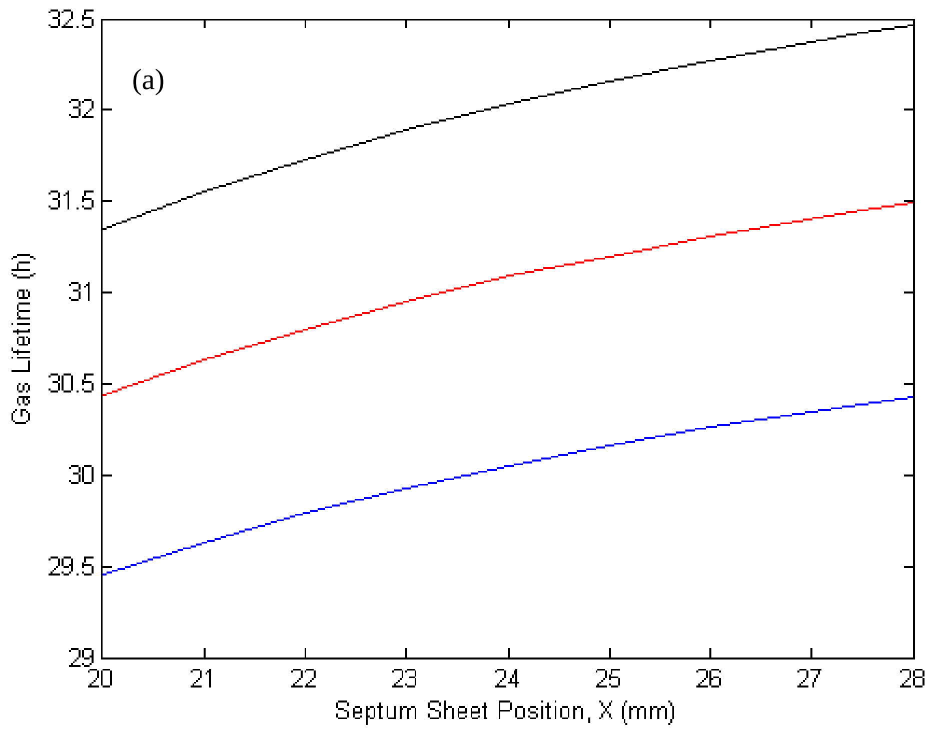
In order to solve this problem, the amplitude of the orbit bump should be reduced. To keep a small injected emittance [1], consequently high injection efficiency, the septum sheet should be placed at smaller amplitude x from the vacuum chamber centre. Although the smaller septum height is better for lower injection kicker strengths, the beam lifetime could be reduced due to this action. Therefore, position of the septum sheet is a compromise between these two demands.

This note will investigate the possibility of bringing the septum closer to the vacuum chamber center from beam lifetime and injection performance point of views.

1 Effect of the septum sheet position on the beam lifetime

Since the septum sheet determines the physical acceptance of SESAME storage ring, a closer septum to the vacuum chamber center means smaller machine physical acceptance offered for the gas-scattered electrons and lower linear transverse energy acceptance at the septum position. The Touschek and Bremsstrahlung lifetimes are determined by the RF energy acceptance (which is ~1.5% in the bare lattice case) up to ~ 1.9% (which could change by changing the machine transverse energy acceptance).

The beam lifetime has been calculated as a function of the septum position for different energy acceptances 1.5%, 1.75% and 2%, at a pressure of 1nTorr, using an average bunch current I_b = 2.75 mA, with a bunch length of 11.5 mm and a coupling of 1%. The higher values of energy acceptance 1.75% and 2% are considered also in order to take into account any potential increment in the RF energy acceptance, in the future, if the over voltage factor is kept constant when the Insertion Devices are installed. Figure 1 shows the effect of septum position on the gas-scattering lifetime, the Touschek lifetime and the total beam lifetime at different energy acceptances.



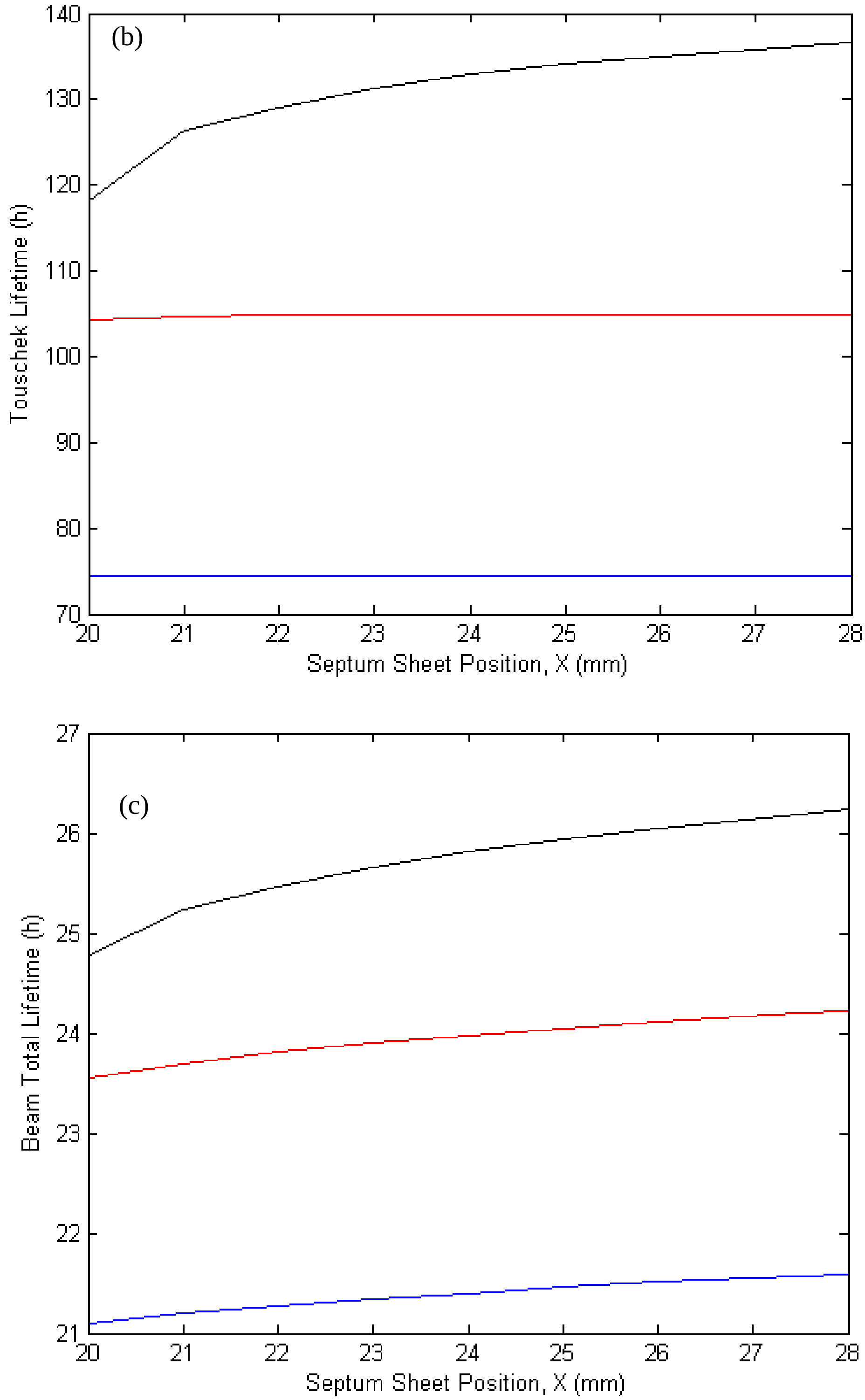


Figure 1: Effect of septum sheet position on gas-scattering lifetime (a), Touschek lifetime (b) and total beam lifetime (c) at energy acceptances: 1.5% (blue line), 1.75% (red line) and 2% (black line).

Figure 1 shows that moving the septum sheet from the present position at x = -25 mm to the positions x = -23 mm or -22 mm will not significantly affect the beam lifetime, mainly at the energy acceptances 1.5% and 1.75%.

2 Consequences of reducing the septum sheet height on the beam injection

Using the conventional kickers with 2.5 – 3 μs pulse, it is not possible, in SESAME case, to have 100% injection efficiency by just reducing the amplitude of the orbit injection bump keeping the old position of the septum sheet. The large injection angle needed to inject the beam will cause part of the injected beam to get lost at the septum sheet at the end of the first turn. Hence the septum sheet amplitude must be reduced too. Several cases of different septum sheet positions and orbit bump amplitudes will be investigated.

2.1 Orbit bump of -18 mm amplitude and septum sheet at -23 mm

By moving the septum sheet to the position x = -23 mm, the injection orbit bump height then can be reduced from -20 mm to -18 mm without any increase in the injected emittance. The -18 mm orbit bump is shown in Fig. 2.

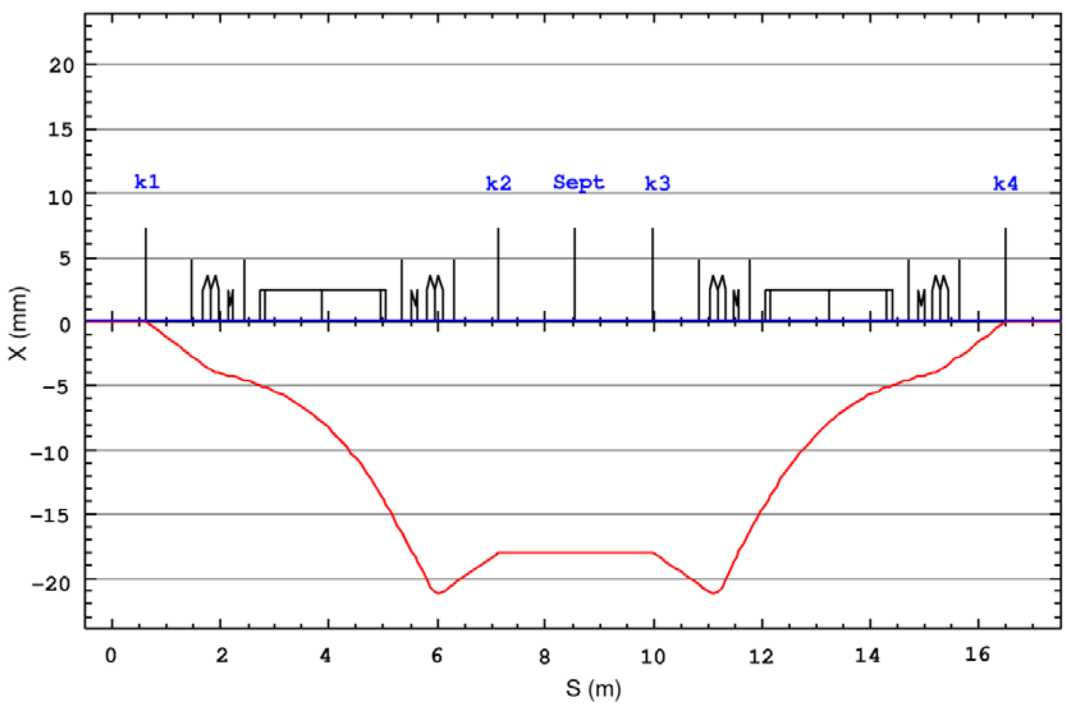


Figure 2: The 18 mm-orbit bump. The distances between the centers of the kickers K1, K2, K3, K4 and the centers of the nearest sextupoles are always 86 cm.

The kickers, as shown in Fig. 2, are symmetrically distributed. Due to the vacuum design needs, the centers of these kickers are placed at 86 cm from the centers of the adjacent sextupoles [2]. The septum is placed in an optically symmetric point, at the middle of the injection section.

The aim of this study is to cancel the extra horizontal chamber width mentioned above so that the horizontal half width of the vacuum chamber comes back to -35 mm before the sextupole downstream the kicker K3. This condition is taken into account in optimizing the injection process.

With the new injection conditions: an orbit bump amplitude = -18 mm, position for the septum sheet at x = -23 mm and the new shape for the vacuum chamber, more restrictions on the injection parameters have been imposed. For example, it is not possible to inject with fully matched horizontal beta function β_x. Moreover the injected beam must enter the vacuum chamber with positive angle (i.e. towards the center of the vacuum chamber). The injection process has been investigated using a 3 μs kicker pulse with half-sinusoidal shape, 3 rms values for the injected beam size, a 3 mm thickness for the septum sheet and a fully matched dispersion function [1]. Figure 3 shows 100 injected particles rotating for 10 turns in the storage ring with 100% efficiency.

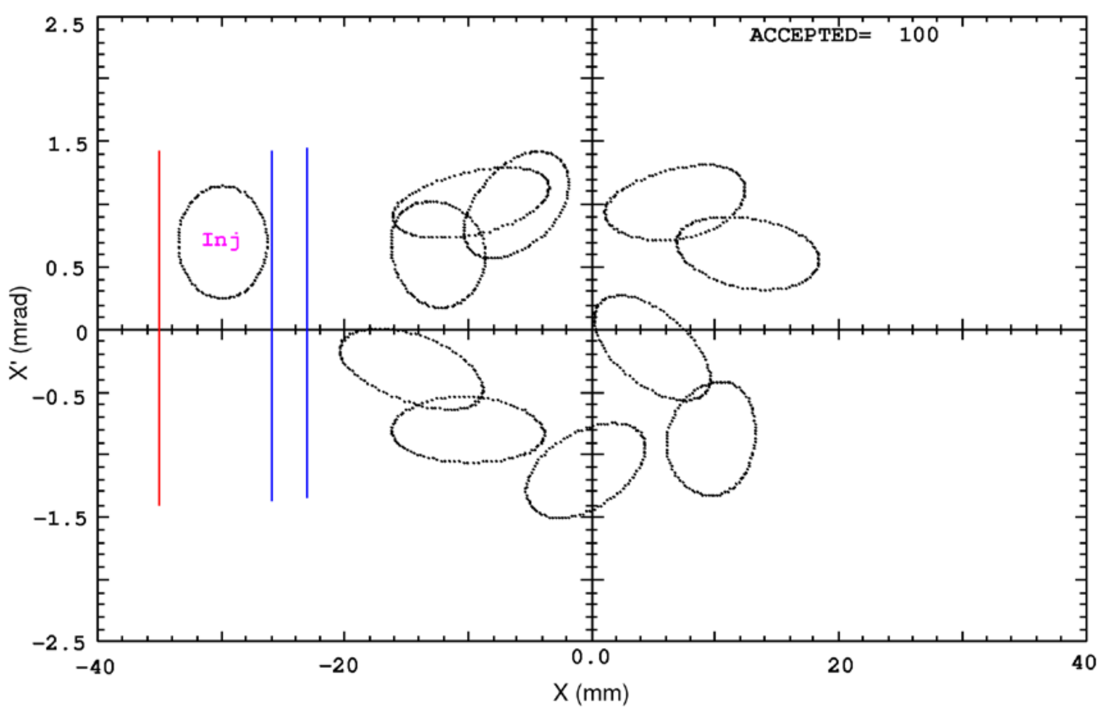


Figure 3: The horizontal phase-space of the injected beam with orbit bump amplitude of -18 mm. The injected beam executes 10 turns in the storage ring. The red and blue lines represent the chamber horizontal half-width and the septum sheet borders respectively. The injected beam marked by “Inj” is shown coming out of the septum pipe with angle 0.70 mrad.

It should be mention that the considered inner diameter of the septum pipe is 9 mm which has the possibility to be increased [3]. The beam in Fig. 3 is injected from an amplitude of -30 mm from the center of the vacuum chamber, with an angle 0.70 mrad and an injection beta function β_{xi} = 8 m [1].

Figure 4 shows the transverse (i.e. in the (x, s) plane) layout of the injected beam of Fig. 3. It can be seen that the injected beam enters the vacuum chamber via the septum pipe without hitting the wall of the vacuum chamber at the peak of the orbit bump (at s = 2.5 m), and rotates for 10 turns in the storage ring without hitting the septum sheet. The radiation damping effect is not taken into account in this study.

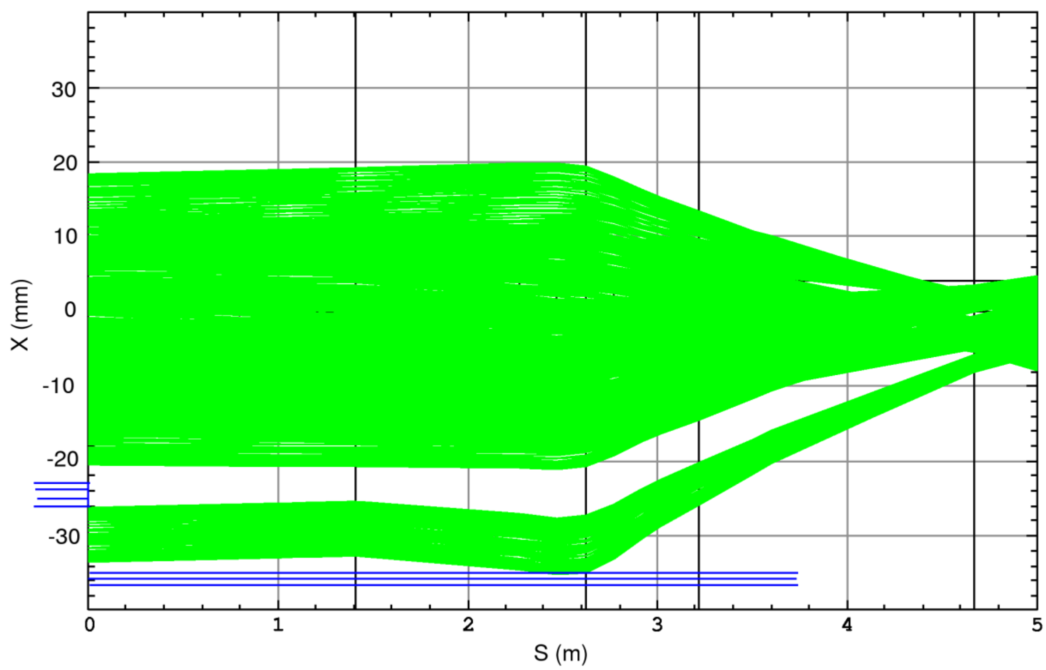


Figure 4: A transverse sketch for the injected beam showing the horizontal size of the injected beam which comes out of the septum pipe of 9 mm diameter (the septum pipe is determined by the septum sheet which is represented by the upper set of blue lines and the vacuum chamber wall which is represented by the lower set of blue lines). The injected beam oscillates in the storage ring between x = -21 mm and -18 mm. The septum position is x = -23 mm and the horizontal half-width of the vacuum chamber is -35 mm.

The strengths of the injection kickers which correspond to this injection scheme are listed in Table 1. The effect of sextupolar kicks are always taken into account.

Kicker	K1	K2	K3	K4
Strength (mrad)	-3.2219	-2.8861	-2.8861	-3.2219

Table 1: The kicker strengths corresponding to -18 mm injection orbit bump.

2.2 Orbit bump of -16 mm amplitude and septum sheet at -23 mm

The injection angle could be minimized by reducing the amplitude of the closed orbit bump. So, an orbit bump of -16 mm amplitude will be checked. The septum sheet position is kept at x = -23 mm. The consequent injection performance is shown in Figs. 5 and 6 where the beam is injected with angle 0.57 mrad.

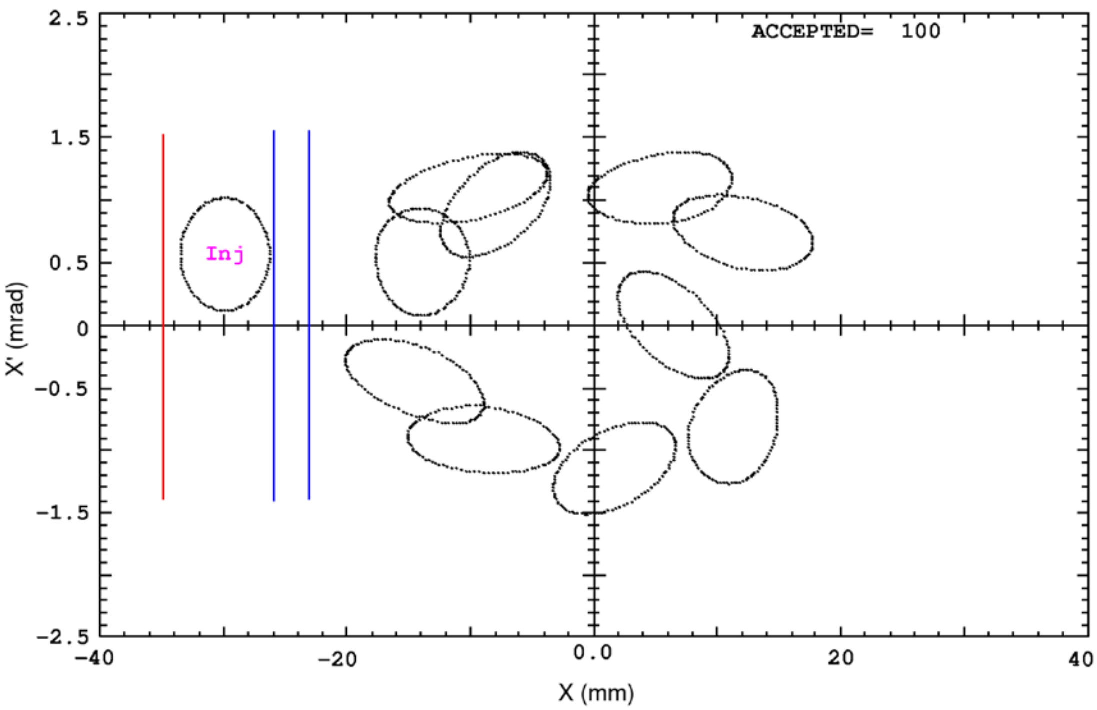


Figure 5: The horizontal phase-space of the injected beam with orbit bump amplitude of -16 mm. The septum sheet position is x = -23 mm. The beam is injected from amplitude of -30 mm from the center of the vacuum chamber and angle of 0.57 mrad.

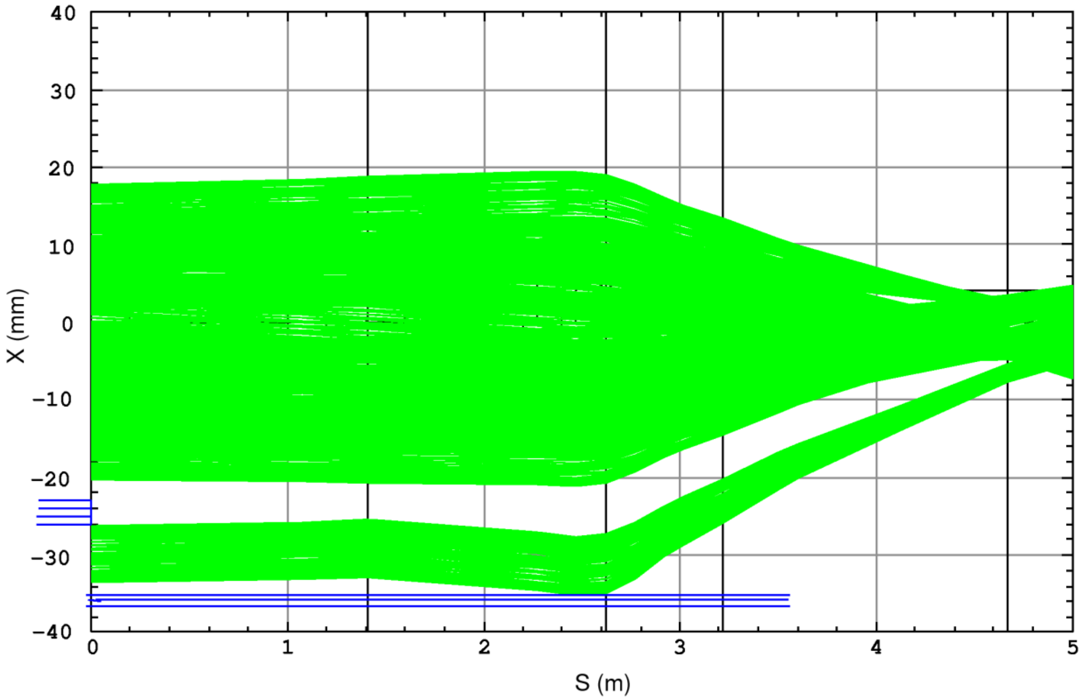


Figure 6: A transverse sketch for the injected beam in a vacuum chamber of half-width of 35 mm. The beam is injected with angle 0.57 mrad.

A comparison between Figs. 3, 4, 5 and 6 shows that the injection with lower orbit bump amplitude and lower injection angle resulted in a little bit smaller injection emittance. Moreover, the needed strengths of injection kickers are reduced as can be seen from Table 2.

Kicker	K1	K2	K3	K4
Strength (mrad)	-2.8639	-2.5770	-2.5770	-2.8639

Table 2: The kicker strengths corresponding to -16 mm injection orbit bump.

2.3 Orbit bump of -16 mm amplitude and septum sheet at -22 mm

For more options, the injection performance has been checked also with the septum position at x = -22 mm keeping the orbit bump amplitude of -16 mm. In this case the injection amplitude can be reduced to -29 mm from the center of the vacuum chamber. With vacuum chamber half-width of -35 mm the injection angle can be decreased to 0.45 mrad as shown in Figs. 6 and 7.

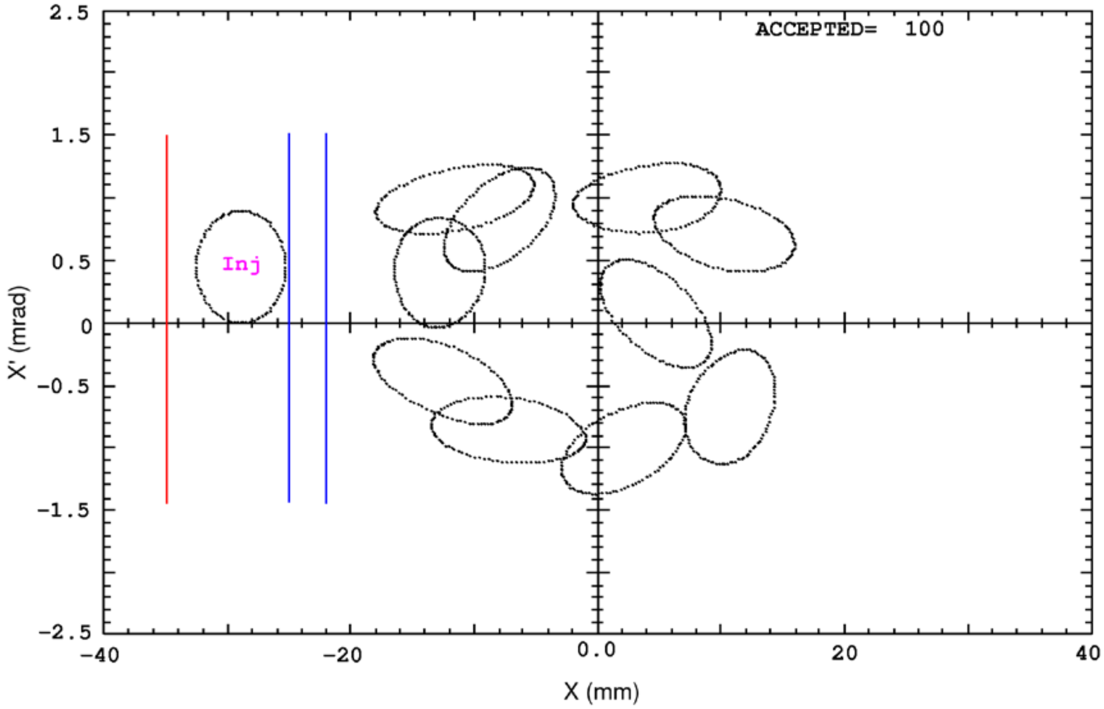


Figure 6: The horizontal phase-space of the injected beam with orbit bump amplitude of -16 mm and the septum sheet is placed at *x* = -22mm. The injection angle is 0.45 mrad.

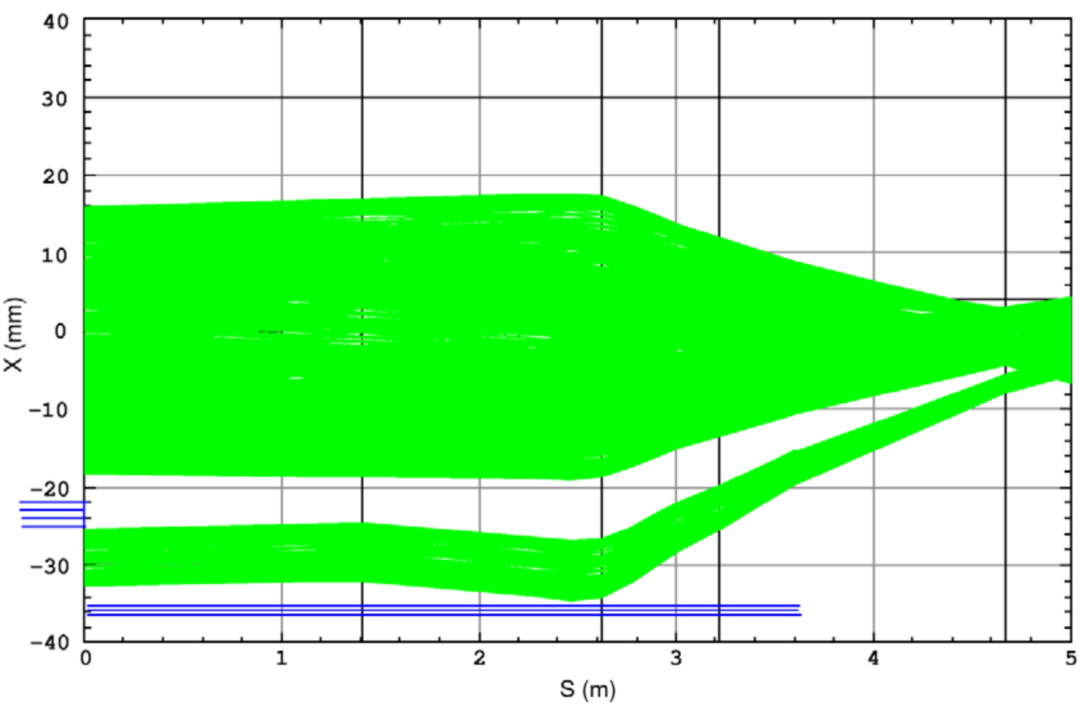


Figure 7: A transverse sketch for the injected beam in a vacuum chamber of half-width of 35 mm and septum sheet placed at x = -22 mm. The beam is injected with angle 0.45 mrad.

2.4 Orbit bump of -14 mm amplitude and septum sheet at -23 mm

By reducing the bump amplitude to -14 mm we will have lower kicker strengths and smaller injection angle. The injection emittance will be similar to the case of -16 mm bump in case if the septum sheet is placed at x = -23 mm. The injection performance is shown by Fig. 8. In this injection scheme the beam is injected from amplitude of -30 mm from the vacuum chamber center and with injection angle of 0.43 mrad.

The needed kicker strengths for this scheme are listed in Table 3.

Kicker	K1	K2	K3	K4
Strength (mrad)	-2.4959	-2.2549	-2.2549	-2.4959

Table 3: The kicker strengths corresponding to -14 mm injection orbit bump.

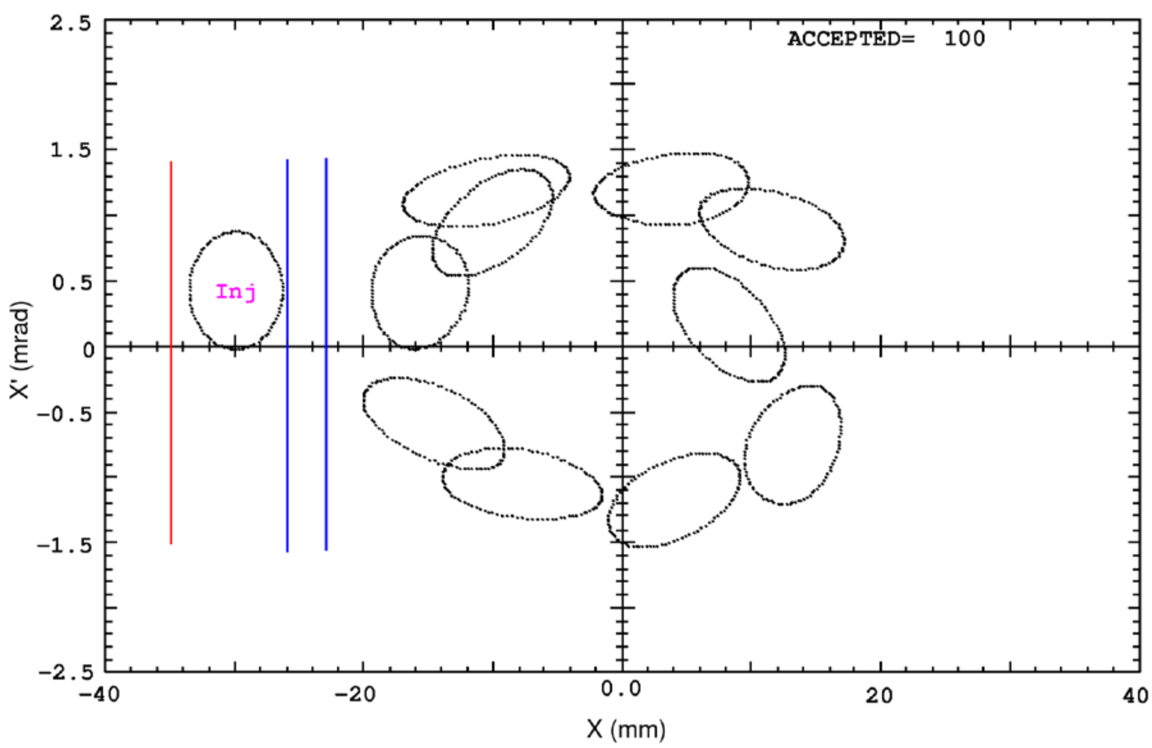


Figure 8: The horizontal phase-space of the injected beam with orbit bump amplitude of -14 mm and septum sheet is placed at x = -23 mm. The injection angle is 0.43 mrad.

3 Conclusion

It was possible to reduce the septum sheet position from -25 mm to -23 mm and -22 mm without significant reduction in the beam lifetime. This is expected in SESAME case where the vertical physical acceptance is the determinant one due to the high β_z in the bending magnet and the vertical half-aperture of 14 mm there.

By the above different injection schemes it was possible to overcome problem of the orbit bump peak and to cancel the proposed extra half width of the vacuum chamber in the injection section which passed through the sextupole and quadrupole magnets.

Among the different injection schemes shown above, the one with -16 mm orbit bump amplitude and x = -22 mm as septum sheet position had the smallest injection emittance. Nevertheless, the injection scheme with -14 mm orbit bump and -23 mm as septum sheet position had more than one advantage. It had the smallest corresponding kicker strengths with more reasonable septum position from beam lifetime point of view. Moreover, it had the smallest injection angle. So, this scheme has been chosen for the injection in SESAME storage ring.

References

[1] M. Attal, " *800 MeV Injection*", Technical Note I-2, June 4, 2006.

[2] F. Makahleh and M. Attal, "*Internal Discussion*".

[3] S. Varnaserri and M. Attal, "*Internal Discussion*".