PAUL SCHERRER INSTITUT

Projekt / *Project*	**SLS 2.0**
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Autor(en) / Author(s) Masamitsu Aiba	Datum / *Datee* 18.02.2020

Summary

A layout of injection straight section is discussed: two injection schemes, namely the conventional injection scheme and an injection with short pulse kicker, are applicable to SLS2. With a thin final septum, they can be quasi-on-axis injection, fulfilling the demand from the insertion device, i.e., the physical aperture can be ±2 mm in both plane. The layout proposed enables both injection schemes, providing a backup solution for one or the other.

The required aperture can be even smaller when these two injection schemes are combined: the oscillations of the beams can be limited to ±1 mm or less at in-vacuum undulator locations. It is noted, however, that the beam lifetime is deteriorated by a horizontal aperture below ~3 mm (full).

The injection can be implemented in either the horizontal or the vertical plane. The dynamic aperture at the septum is about 6 mm in the horizontal plane (for β_x=17 m) and 13 mm in the vertical plane (for β_y=22.5 m) for the perfect machine. The former would be enough even for the real machine with imperfections, but the latter is fully comfortable/convincing.

History

From Version 1 to 2

The lattice B025 was used in the previous version. This updated version is for the lattice B038. The major changes between B025 and B038 are 1) the normal bend BN is converted to a flat dipole (no longitudinal gradient bend) and 2) the photon extraction issue is solved by inserting the sextupole SDM between BEH and BEV magnets. These changes do not directly influence the injection layout but vary the optics parameters at the end of the matching section.

The injection straight is slightly modified to have more space between elements. This result is going to be integrated, generating B039 lattice.

From Version 2 to 3

The kick angle of short pulse kicker, about 320 μrad, is added to Figure 6 caption.

Introduction

The injection into SLS2 and the layout of injection straight section are discussed, including relevant findings that we come up after CDR was published. It is important to fix the layout as soon as possible to build SLS2 as scheduled.

Changes and findings after CDR

The following points are important changes and findings since CDR:

1) "Pseudo symmetry lattice" is introduced by A. Streun in order to fit the SLS2 storage ring into the existing tunnel structure. It is realized by imposing a constraint that the phase advances in the horizontal and vertical planes over the straight section are identical while the length of the straight section and the beta functions are arbitrary. The super-periodicity of the lattice is as high as 12 for the on-momentum particle whereas the ring is geometrically three-fold symmetry. For off-momentum particles, the super-periodicity is three as well. Nonetheless, it turned out that the deterioration of off-momentum dynamic aperture is acceptable. With respect to the injection, it enables enlarging the beta function at the location of septum while keeping it low at the locations of insertion devices. It is noted that the dynamic aperture is proportional to the square root of the beta function value.
2) It was realized that the dynamic aperture in the vertical plane can be larger than that of the horizontal plane by 50% or more (for the same beta function value). Our understanding is that only even order resonances (2Qy, 4Qy, 6Qy, …) are excited in the vertical plane due to the upper-lower symmetry while both odd and even order resonances in the horizontal plane. In case, where the injection is implemented in the vertical plane, we may have more tolerance for the machine imperfections.
3) In the CDR, an injection scheme using "Anti-septum" was proposed, which offers a septum blade thickness of 1 mm equivalently. Such a thin septum enables a top-up injection into a small dynamic aperture. However, it may require a dedicated simulation study and a prototyping. Instead, it is considered to split the septum into two, i.e., strong thick septum and weak thin septum (Ch. Gough, 2nd TWIIS Workshop at PSI). We recently learned that such a device was built and installed into ALS (1.5-mm thick, see Fig. 1). It also turned out that the blade of Lambertson type septum can be also as thin as 1 mm when the field is rather low (~0.3 T, see Fig. 2).
4) It seems that a demand for on-axis injection is increasing from the insertion device point of view such that the apertures of the insertion devices can be eventually smaller to increase the photon beam performance. It is noted that a special device (Apple-X undulator) imposes a physical aperture in both planes and thus it is not compatible with off-axis injection.

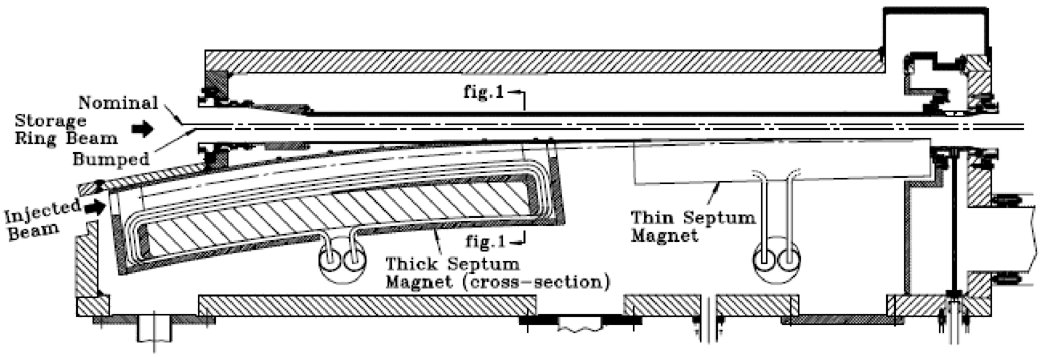

Figure 1. ALS septum. Taken from D. Shuman et al., PAC'05.

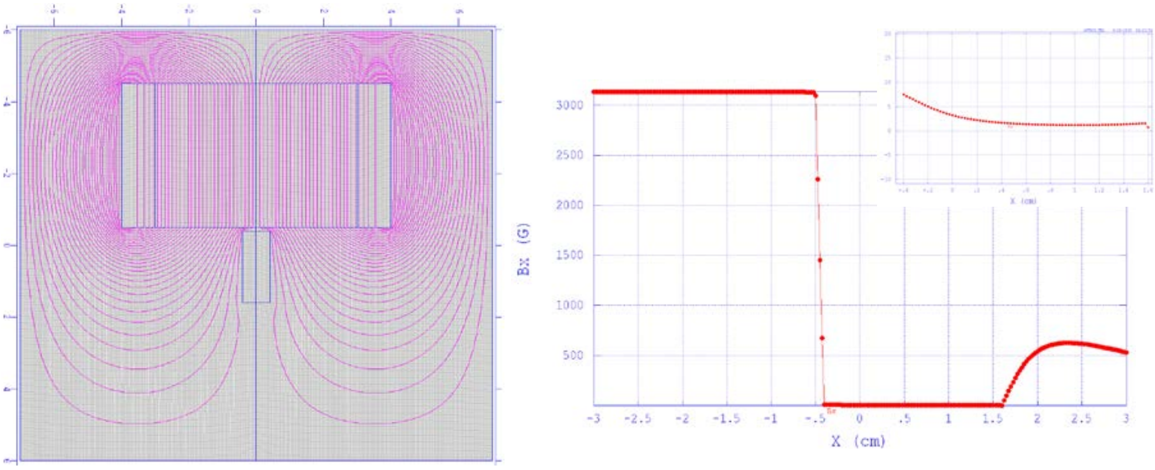

Figure 2. Lambertson type septum with 1 mm blade. 2D FEM field computation.

Injection schemes and injection straight layout

With a thin septum together with the pseudo symmetry lattice, it is possible to inject a beam even within a small aperture comparable to the in-vacuum undulator mini-gap, ±2 mm. The aperture can be magnified by a factor of two or more at the location of the injection septum in a pseudo symmetry lattice. Within the magnified aperture (±4 mm or more), the stored beam, the injection beam and the 1-mm thick septum blade can fit, and thus the conventional injection scheme is applicable.

A thin septum also enables an aperture sharing: a single dipole kicker (short pulse kicker) deflects both stored and injection beams, and they stay within the aperture. A rather weak deflection is enough to "pull out" the injection beam from the septum channel over a thin septum blade. The stored beam is not kicked out from the aperture. The septum should be close to the closed orbit (only 4 mm for a magnification factor of two) in this case. The beam impedance of the septum may not be critical issue given that it is much shorter with respects to the total length of insertion devices. In order to realize a full transparent on-axis injection, we need very fast kicker with a pulse length shorter than the bunch spacing in the longitudinal injection or a twice bunch spacing for the swap-out injection. However, in the above aperture sharing, the kicker pulse length can be arbitrary and a few times longer when we accept an injection disturbance to a few bunches. In the future, the kicker can be upgraded to minimize or ultimately eliminate the disturbance.

A discussion with M. Dehler and L. Stingelin confirmed that transverse coupled bunch instability may not be an issue when we disturb a few bunches although their peak oscillation amplitude will be a few mm. The argument is that "an equivalent oscillation" is at least a factor of 100 smaller compared to a case where all the stored bunches are disturbed. At the SLS, all the bunches are disturbed during the injection and oscillating a few tens of μm or more that is equivalent to a few mm oscillation for a few bunches.

The injection can be in either the horizontal or the vertical plane. In any case, once we manage such a quasi-on-axis injection, the physical aperture can be small in both planes, fulfilling the above-mentioned demand (4) from insertion devices. It is also of interest to distribute the physical aperture bottlenecks between the horizontal and vertical planes so as to maximize the transverse instability threshold beam current. It is noted that the transverse resistive wall impedance is proportional to b^{-3}, where b is the gap size.

Acceptable minimum aperture in the horizontal plane at the standard straight section was evaluated by A. Streun from the viewpoint of Tauschek scattering: an aperture of >3 mm (full) does not deteriorate the lifetime significantly. It is, however, noted that the off-momentum beta beat may impose a more strict condition, a minimum aperture of >4.6 mm (Discussion on 13.11.2019).

Layout for vertical injection

A layout to realize the two injection schemes described above (the conventional injection and the injection with short pulse kicker) is outlined in Fig. 3, and the positions of the components are listed in Table. 1. In case where the "ambitious" scheme with short pulse kicker does not work, we may switch back to the conventional injection scheme. It is of interest that, when the two injection schemes are combined, the injection beam can be brought even closer to the closed orbit and that the undulator full gap can be even smaller than 4 mm. Therefore, the kicker bump will be not only a backup solution but also an important element when an undulator gap smaller than 4 mm is desired.

Between QP7YO and QP8YO (also QP7YI and QP8YI), a corrector and a BPM can be installed. A profile monitor may be installed between the thin septum and QP8YI to ease the injection tuning. For the injection in the vertical plane, one or two weak vertical bending magnets are necessary in the transfer line. Short pulse kicker is not included in Fig. 3 but it is installed in the next straight section. It is assumed that the injection components of the SLS are all reused here.

An asymmetry layout/optics (Fig. 4) is employed to enable an adjustment of the phase advance between the septum and kicker as close to the optimum (90+360 deg) as possible: more phase advance after the thin septum. This requires QP6YI and QP5YI but the phase advance adjustment is important for successful injection.

QP7YO magnet should be large aperture one to let the injection beam go through (see Fig. 5). It is preferred to make QP8YO/QP8YI/QP7YI large aperture ones as well, otherwise the injection beam trajectory is rather close to the aperture at these magnets. Therefore, these magnets are longer than the normal SLS2 quadrupole magnet, assuming that SLS QA quadrupoles are reused (20 cm long, gradient of 20 T/m, bore radius of 33 mm).

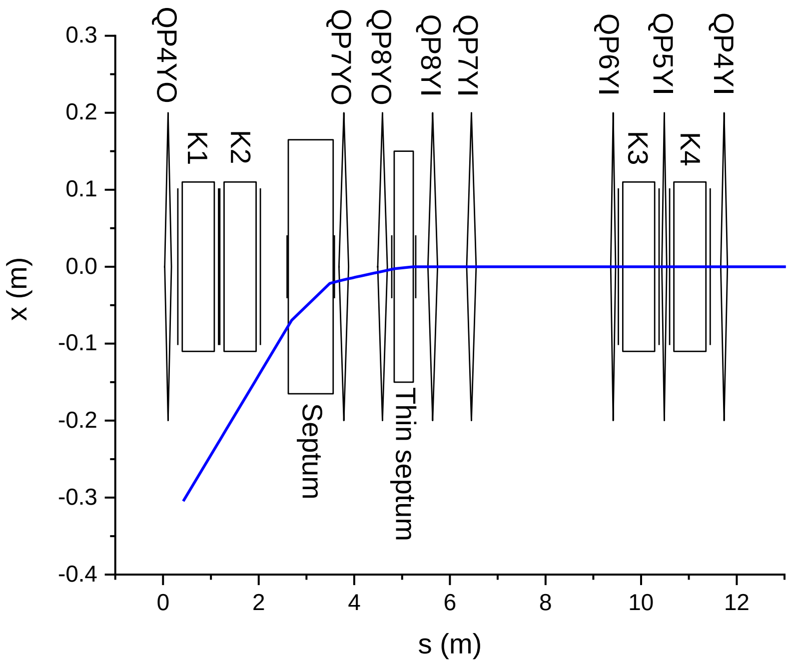

Figure 3. Possible layout of injection straight. Horizontal injection orbit is also indicated (Blue).

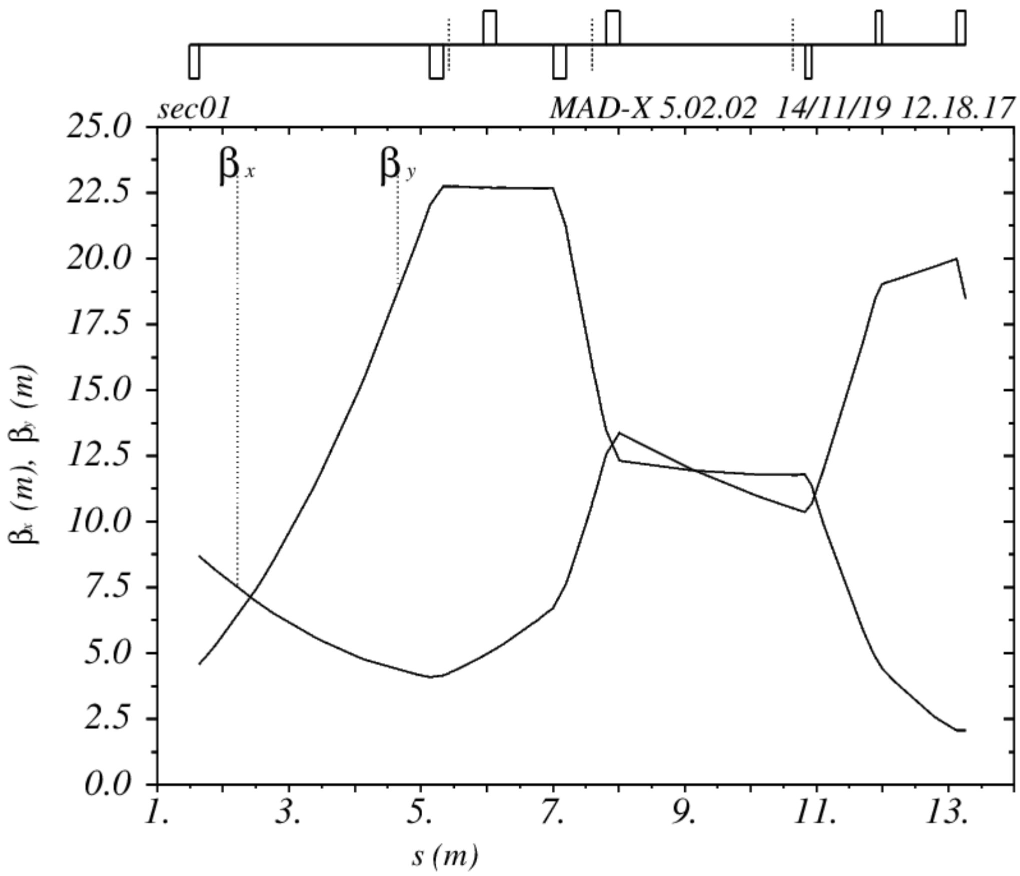

Figure 4. Beta function along the injection straight.

Table 1. Possible layout of injection straight. Unit=mm.

For Kickers and septa, the length is flange-to-flange. For quads, the length is for magnet plus coil space .

	Entrance	Exit	Length
QP4YO	0	210	210
K1	310	1160	850
K2	1185	2035	850
Septum	2594	3585	991
QP7YO	3610	3950	340
BPM+CH/CV			
QP8YO	4420	4760	340
Thin septum	4785	5285	500
Screen			
QP8YI	5470	5810	340
BPM+CH/CV			
QP7YI	6280	6620	340
BPM+CH/CV			
QP6YI	9330	9500	170
K3	9525	10375	850
QP5YI	10400	10570	170
K4	10595	11445	850
QP4YI	11630	11840	210

The injection beam trajectory is also plotted (blue) in Fig. 3 for the case of vertical injection, where the thin septum is Lambertson type, 0.4-m long. (magnetic length) The field of the thin septum is set to be 0.27 T, resulting in a deflection angle of 13.5 mrad and a distance between the trajectory and the K2 kicker flange is about 2.5 cm. The thin septum field can be higher if necessary. The thick septum deflection angle is assumed to be 5 deg as it is for the SLS septum. An injection in the vertical plane with a thin eddy-current type septum is also an option but we need to build also a new Lambertson main septum.

Finally, the vertical orbit bump for the conventional injection scheme and the injection beam trajectory are shown in Figs. 5 and 6. When the two injection schemes are combined, the beam oscillation amplitudes (Fig. 6) can be half.

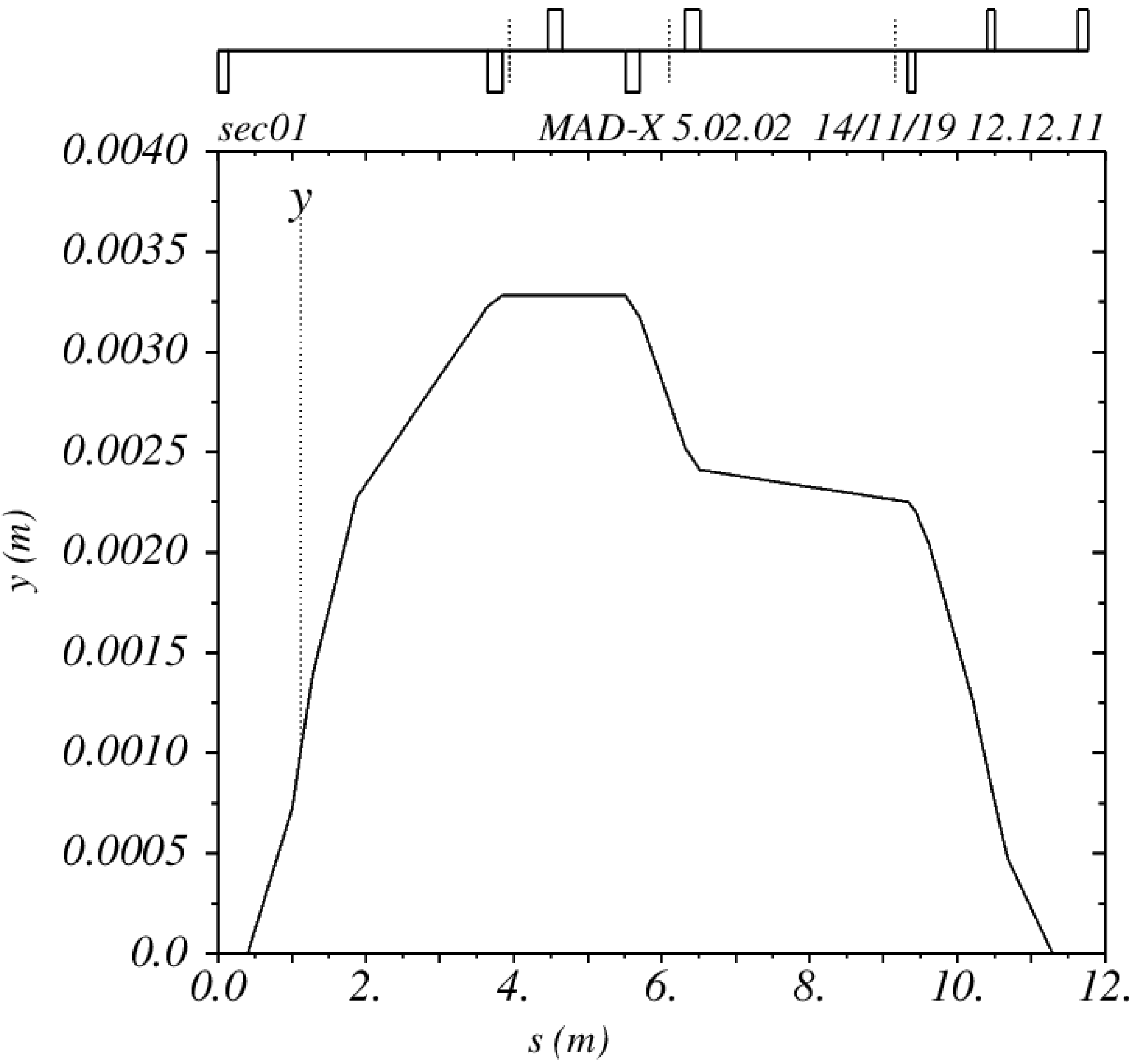

Figure 5. Vertical orbit bump for the conventional injection scheme. The thin septum is at the peak of bump. Kicker strengths are 2.4 / -1.9 / -0.9 / 1.6 mrad for K1/K2/K3/K4 while the maximum kick angle is 4.5 mrad.

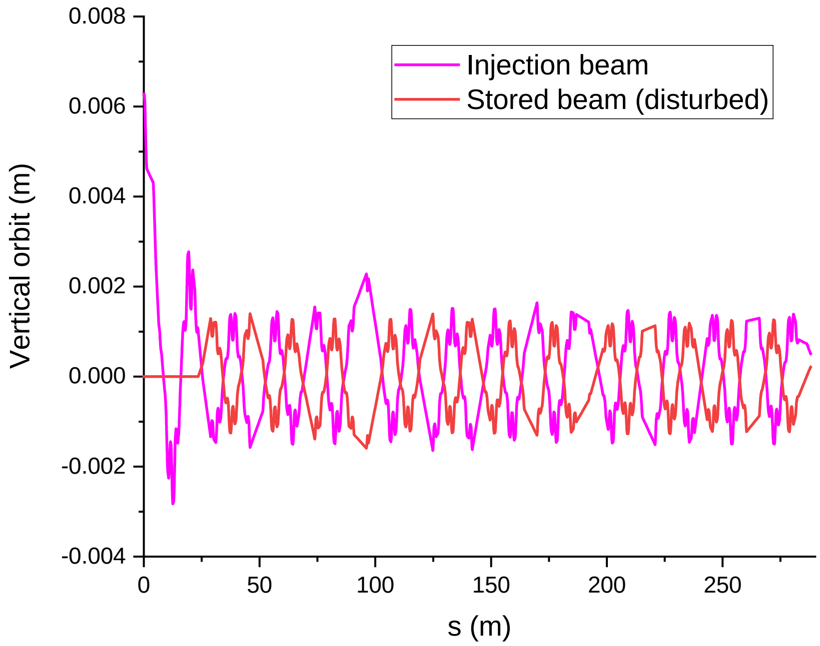

Figure 6. Injection beam trajectory for the injection with short pulse kicker. The vertical beta function at the thin septum is 22.7 m and at the kicker about 3.8 m. The stored beam oscillation induced by the short pulse kicker is limited to about ±1.5 mm at the locations of mini-gap IDs. The kick angle of short pulse kicker for the aperture sharing is about 320 μrad.

Layout for horizontal injection

The layout for a horizontal injection is also investigated. It turned out that the horizontal injection optics is less flexible, and it is difficult to find a solution fulfilling the required conditions. The optics shown in Fig. 7 has been found with the same quadrupole layout to the one for the vertical injection. The beta function at the septum is not as high as the vertical injection optics, resulting in a less margin.

Once we have a solution for the optics, it is straightforward to find the orbit bump and the injection beam trajectory, similar to Figs. 5 and 6 but in the other plane.

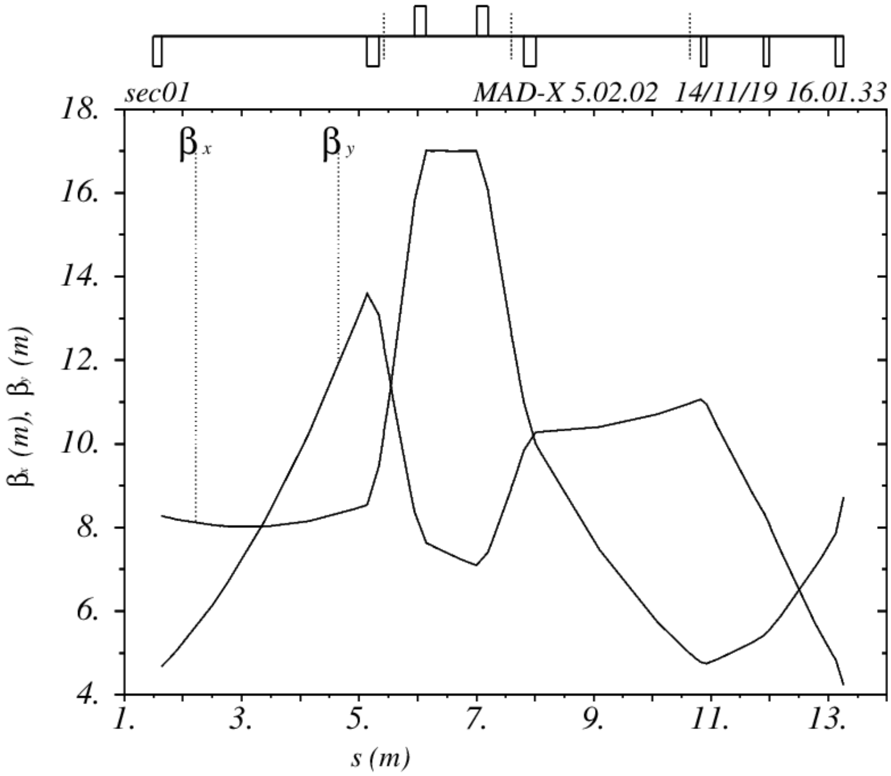

Figure 7. Beta function along the injection straight. Horizontal injection.