BEAM-BEAM EFFECTS SIMULATION FOR VEPP-2M WITH FLAT AND ROUND BEAMS

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Abstract

Increasing of the luminosity is one of the main reasons of VEPP-2M optics modernization and transition from flat to round beams, which can be realized by a few optical schemes, including so-called Möbius lattice. The beam-beam simulations have been performed for the different schemes of VEPP-2M optics, such as Möbius, conventional round (equal betatron tunes), and flat beams. The main source of nonlinearities on the ring, sextupoles, have been accounted as well as nonlinear beam-beam kick. The simulations show an essential advantage of the round beams over the flat ones, but the Möbius scheme turns out to be more difficult for realization and in general worse than the conventional round beams.

1 INTRODUCTION

This work has been initiated with the plans of VEPP-2M optics modernization. In particular, a transition from the flat to round beams is expected to be useful and provide an essential increasing of the luminosity. In the proposed scheme [1] the changes in the VEPP-2M optics are reduced to the installation of the superconducting solenoids instead of the quadrupole lenses near the Interaction Points (see Fig. 1). On the other hand, such a scheme can be easily transformed to so-called Möbius lattice [2]. So, the study of beam dynamics with the purpose to compare these different optical schemes in the particular VEPP-2M case becomes very important and useful in order to make the best decision.

Beam-beam simulations, carried out for VEPP-2M collider, help us to clarify the situation, although there are some restrictions of the obtained results' validity, since the tracking model was not perfect.

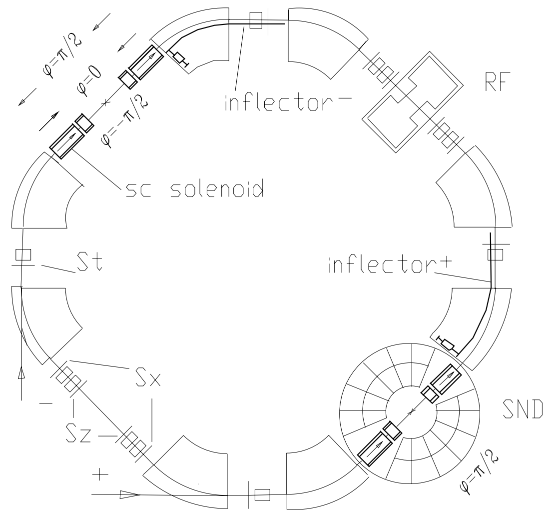

Figure 1: Layout of the VEPP-2M collider. Arrows inside solenoids indicate the direction of the longitudinal magnetic field.

2 TRACKING TECHNIQUE

The subjects of our study are the core region of the equilibrium distribution and r.m.s. beam sizes. A separate investigation of the lifetime problem also is necessary, since the dynamic aperture in the considering variants is about 13-15 sigmas only, but this work will be performed in future and it is not discussed in this paper. We used two tracking codes: TURN (author E. Simonov) and LIFETRAC (author D. Shatilov). Detailed comparison has been performed and a perfect agreement between them has been detected.

2.1 Data gathering

In our simulations both codes track a single test particle for a long time (over 500 damping times, i.e. more than 10^8 turns). Equilibrium phase volume and r.m.s. beam sizes are obtained by the averaging of the particle coordinates on each turn at the first IP. If the particle's coordinate exceeds the aperture, it is lost and then restarted again, so that the total tracking time remains unchanged. However, when the lifetime becomes comparable or less than the damping time, these restarts affect the obtained beam sizes, since the initial distribution for restarts (unperturbed Gaussian) differs from the true equilibrium one. On the other hand, there is no sense to care about correct beam sizes while the lifetime drops to a few milliseconds.

2.2 Tracking through IP

The simulations are performed by a "weak - strong" model, with the strong bunch assumed Gaussian in all three directions, and longitudinally divided into 5 slices. A few working points have been also tested with the twice number of slices, and actually the same results have been obtained. The beam-beam kicks are calculated by means of 6-dimensionally symplectic formulas [3].

2.3 Transport map between IPs

The lattice of the collider is defined by the sequence of elements, such as bending magnets, lenses, solenoids, sextupoles, etc. We consider all the elements as linear, except the sextupoles. The linear elements are defined by their transport 4×4 matrixes, which may contain coupling. These matrixes are assumed do not depend on the particle's coordinates, that means in particular that the natural chromaticity is ignored, otherwise the tracking would be much more complicated and CPU consuming. The sextupoles are tracked by separate formulas as thin nonlinear lenses.

2.4 Dispersion function

The dispersion function is assumed equal to zero elsewhere on the ring. Although it seems strange and incorrect, this is the only way to include sextupoles in our consideration. The matter is that since the linear elements of the ring are simulated without natural chromaticity, sextupoles should also give no chromaticity, otherwise it will not be compensated and the beam will be damaged dramatically. On the other hand, since we know a priory that the natural chromaticity is compensated by sextupoles, we need not to care about it, but we still are interested in nonlinear dynamics which is affected by sextupoles significantly. So we try to account these nonlinear effects, although we realize that this approach cannot be considered as a completely correct.

2.5 Next step

In the nearest future we plan to develop tracking codes which will be able to track the particle through a real nonlinear lattice with account of the chromaticity, edge fields, etc. However, we believe that the present results also describe the situation, at least qualitatively.

3 MACHINE PARAMETERS AND SIMULATION RESULTS

The layout of VEPP-2M collider is shown on Fig. 1, the main working parameters are presented in the Table 1.

Parameter	R, M1, M2	M3	F
ε_x [cm $\cdot$ rad]	$1.7 \cdot 10^{-5}$	$1.4 \cdot 10^{-5}$	$1.1 \cdot 10^{-5}$
ε_y [cm $\cdot$ rad]	$1.7 \cdot 10^{-5}$	$1.4 \cdot 10^{-5}$	$1.3 \cdot 10^{-7}$
τ_x [turns]	$2.7 \cdot 10^5$	$2.6 \cdot 10^5$	$3.4 \cdot 10^5$
τ_y [turns]	$2.7 \cdot 10^5$	$2.6 \cdot 10^5$	$2.1 \cdot 10^5$
τ_z [turns]	$8.4 \cdot 10^4$	$8.7 \cdot 10^4$	$8.7 \cdot 10^4$
β_x^* [cm]	5.0	5.0	43.9
β_z^* [cm]	5.0	5.0	6.4
σ_z [cm]	3.3	2.9	2.8
σ_ε	$3.5 \cdot 10^{-4}$	$3.6 \cdot 10^{-4}$	$3.6 \cdot 10^{-4}$
ν_x	3.092	2.680	3.057
ν_y	3.092	3.680	3.097
ν_z	0.006	0.006	0.006

Table 1: The VEPP-2M parameters relevant for simulations. In fact, betatron tunes for M1 and M2 cases are shifted by ± 0.25 and ± 0.5 from the values shown in the table.

As is seen, there are two Interaction Points (IP) with the *different* transport maps between them. The round beams can be obtained from the existent scheme with the flat beams by replacing the nearest to the IPs Q-lenses by SC solenoids, as described in [1]. Each pair of solenoids rotates the plane of betatron oscillations on the angle $\phi = \pi/2$. In the base operating mode (R) these rotations compensate each other, so that we have a conventional round beams. Besides, the Möbius lattice can be also obtained easily by the change of polarity of one solenoid: in this case (M1) one pair of solenoids makes the rotation on $\pi/2$, but the second pair does not compensate it. Another possibility we have with the change of polarity of the whole solenoids pair: in these cases (M2, M3) both pairs make the rotations in the same direction on the same angle $\pi/2$. Here the differences between M2 and M3 are the only initial betatron tunes.

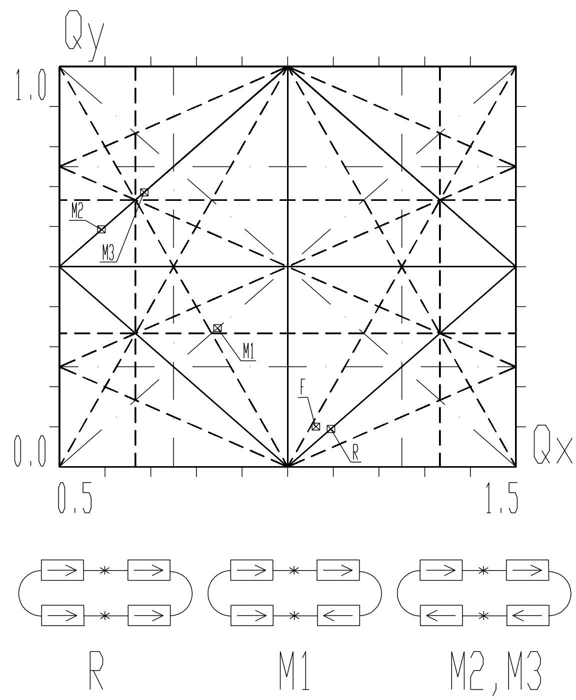

Figure 2: The grid of working resonances up to 4th order. Sextupole resonances are shown as bold dashed, betatron resonances of 4th order as long-dashed. For the Möbius cases Q_x and Q_y should be read as Q_+ and Q_- for "+" and "-" modes. At the very bottom the schemes of solenoids polarities are shown for the described cases.

An important peculiarity of the Möbius lattice is the betatron tunes splitting:

$$\mu_\pm = (\mu_x + \mu_y)/2 \pm \theta, \qquad (1)$$

where $\theta = \pi/2$ in the M1 case and $\theta = \pi$ in the M2, M3 cases. This jump from the main coupling resonance turns out to be the source of troubles. The main working resonances (without synchro-betatron ones) are shown on Fig. 2. It is clear from this plot that the base working point (conventional round beams, R) has the most room free of resonances. The M1 and especially M2 working points have not enough room for increasing ξ parameter. However, M2 case can be shifted (it is M3) in up-right direction to step over the crowd of sextupole resonances, but in any case the base working point just on the main coupling resonance is preferable. A further shift to step over 4th order resonances requires an additional increasing of the focussing lenses strength and, therefore, sextupoles strength to compensate natural chromaticity, that causes the problems with dynamical aperture.

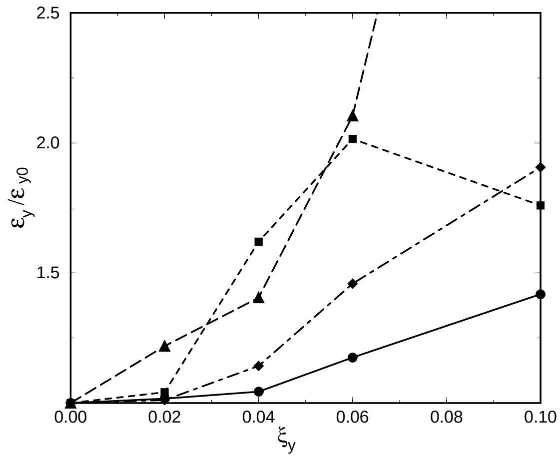

Figure 3: Equilibrium emittances for the different schemes: R (circles), M1 (squares), M3 (diamonds), and F (triangles).

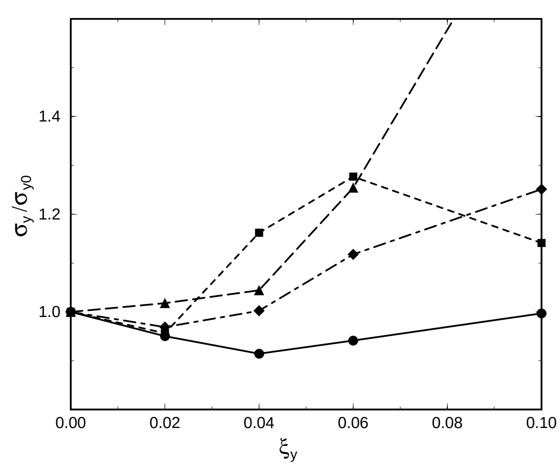

Figure 4: Equilibrium beam sizes for the different schemes: R (circles), M1 (squares), M3 (diamonds), and F (triangles). The decrease of the beam size for a small ξ occurs due to the dynamic beta effect.

The simulation results for all the described schemes except M2, which is the worst one, are presented on Figures 3 and 4. The only conventional round beams have a acceptable lifetime when $\xi = 0.1$. The corresponding points for the flat beams and Möbius cases are shown for the sake of completeness, but they are not very correct (see 2.1). The parameter ξ_x for the flat beams can be evaluated by the equation $\xi_x = 0.23 \cdot \xi_y$.

4 CONCLUSION

Our study demonstrated that the conventional round beams take an essential advantage over both the Möbius lattice and the flat beams for the VEPP-2M collider.

5 ACKNOWLEDGMENTS

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6 REFERENCES

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