THE VEPP-4M DYNAMIC APERTURE DETERMINATION WITH BEAM-BEAM EFFECTS

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Abstract

To determine experimentally the particle stable area in the electron-positron collider VEPP-4M we measure the beam lifetime with high accuracy as a function of moving aperture. The measurement is performed by a photodiode installed in the collider diagnostic beam line. The experimental setup and the measurement results are described. Comparison with the tracking simulation is presented.

INTRODUCTION

Measurement of the dynamic aperture (DA) is one of the interesting experimental problems on the accelerator complex VEPP-4M [1]. Usually dynamic aperture is estimated from the results of simulation; we made an attempt to measure the dynamic aperture by two different methods and to compare methods between themselves. Also, the dependence of the dynamic aperture on chromaticity was received and was compared with the results of the simulation. Besides, the influence of beam-beam effects on the DA was checked.

EXPERIMENTS

Method of Artificial Limitation of the Aperture

For experimental measurement of the dynamic aperture we determined the beam lifetime as a function of artificially limited geometrical aperture (GA) [2]. If the artificially limited geometrical aperture is larger than the dynamic aperture the lifetime remains constant. As soon as geometrical limitation appears in the field of the dynamic aperture - we see the reduction of the beam lifetime. Let us consider this inflection point as the dynamic aperture.

The limitation of the vertical and the radial apertures was carried out using scrapers 1,2 (Fig.1) operated by a computer. The beam lifetime was measured from the intensity of synchrotron radiation (SR) extracted from the bending magnet (Fig.1). The SR intensity, proportional to a number of particles in a bunch, was measured using the HAMAMATSU S2387-33R photodiode. The signal from the photodiode was digitized by a 16-digit ADC. The relative accuracy of the beam current measurements was $3 \cdot 10^{-4}$.

The measurements of the aperture were performed with the beam current of I_b < 1mA to limit the influence of collective effects. The dependence of lifetime on the beam current was also taken into account.

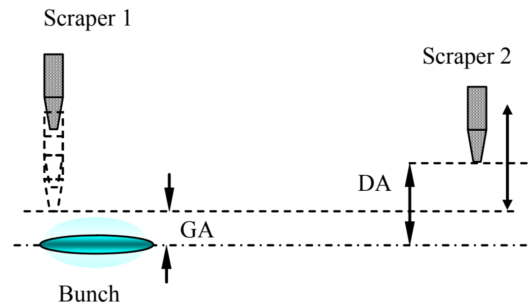

Figure 1: GA – geometrical aperture depended on the transverse coordinate of Scraper 1. DA – dynamical aperture, measured with dependence of the beam lifetime on transverse coordinate of Scraper 2. Case of GA<DA is shown.

To test the validity of the method we artificially limited the radial aperture by scraper 1 (Fig.1) and tried to see this restriction with scraper 2. The dependence of the beam lifetime on the position of scraper 2 with the restriction of geometrical aperture (GA) by scraper 1 is presented in Fig.2.

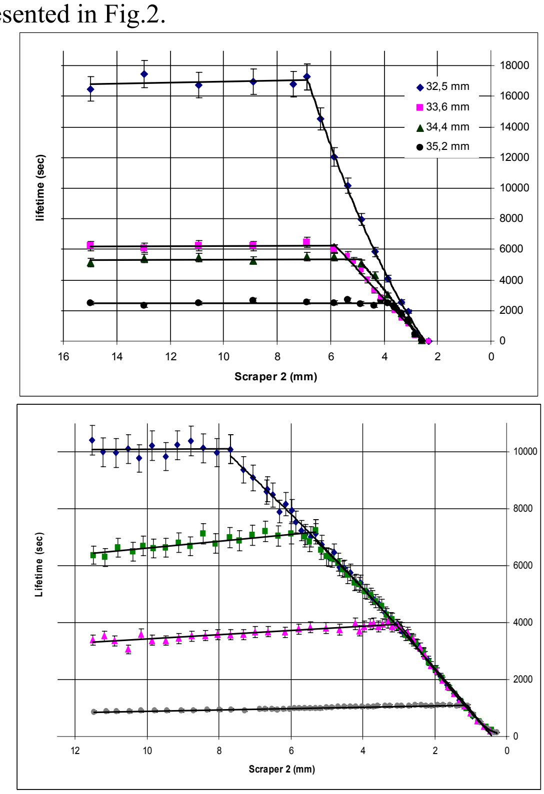

Figure 2: The beam lifetime dependence on horizontal (top) and vertical (bottom) positions of scraper 2 at different insertion depth of scraper 1.

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The dependence of the radial aperture, determined with the scraper 2 on various positions of scraper 1 is presented in Fig.3.

A linear character of the dependence of the aperture on the insertion depth of scraper 1 gives us the basis to consider the method as valid.

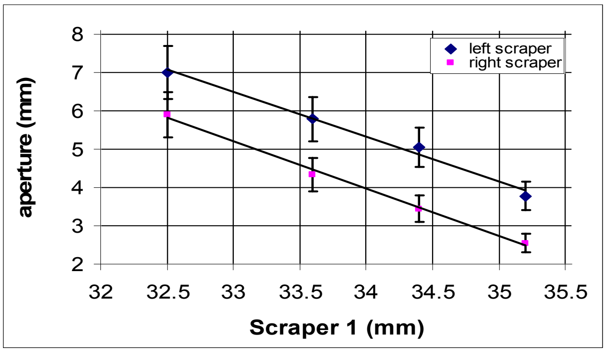

Figure 3: Dependence of the aperture measured by scraper 2 on the insertion depth of scraper 1.

The Dependence of the Dynamic Aperture on the Chromaticity

To decrease the dynamic aperture we increased the chromaticity $C_{x,y}$ using sextupole final focus lenses which mainly influence the vertical dynamical aperture.

The measurement of the dynamic aperture was carried out applying the method described above.

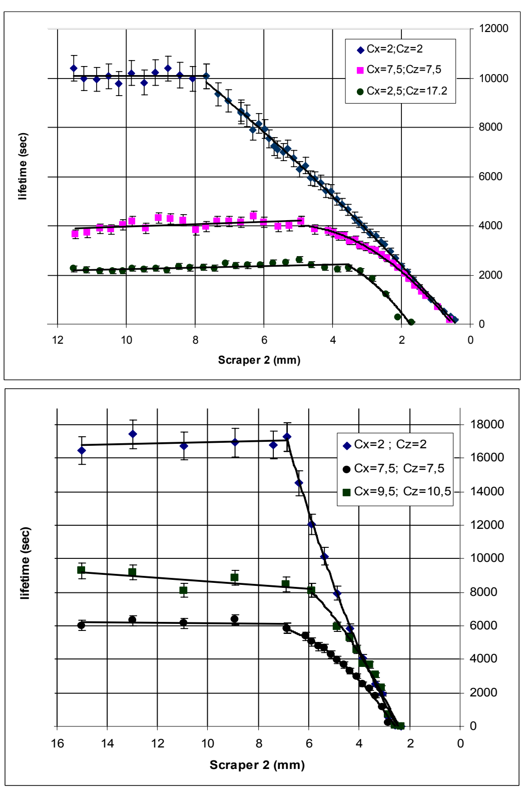

Figure 4: The vertical (top) and horizontal (bottom) aperture with different chromaticity values Cx, Cz.

The results of the measurement with different chromaticity values are shown in Fig.4; Fig.5. presents the results of the simulation and experimental points.

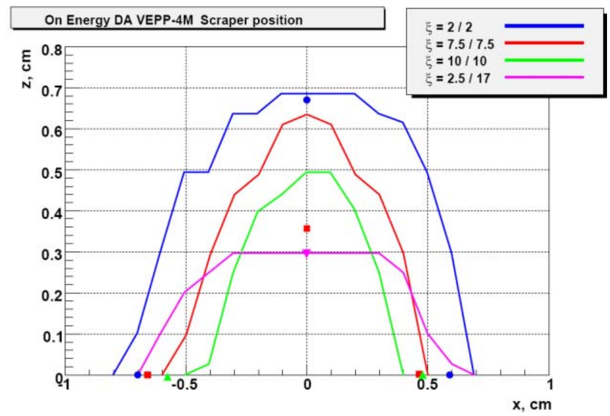

Figure 5.The results of simulation with experimental points.

DA Measurement by the Fast Kick

A detailed description of the measurement technique can be found in [3]. The dynamic aperture was measured by the coherent beam motion excitation by fast electromagnet kickers. The beam displacement and intensity were measured by the single-turn BMP system.

For low kick amplitudes the BPM does not indicate the intensity reduction because all particles move inside the stable area. But with the kick strength increasing a beam loss appears and for large kick the bulk of the beam is cut off by the DA boundary in a rather short time (~ tens of revolutions) as it is shown in Fig.6.

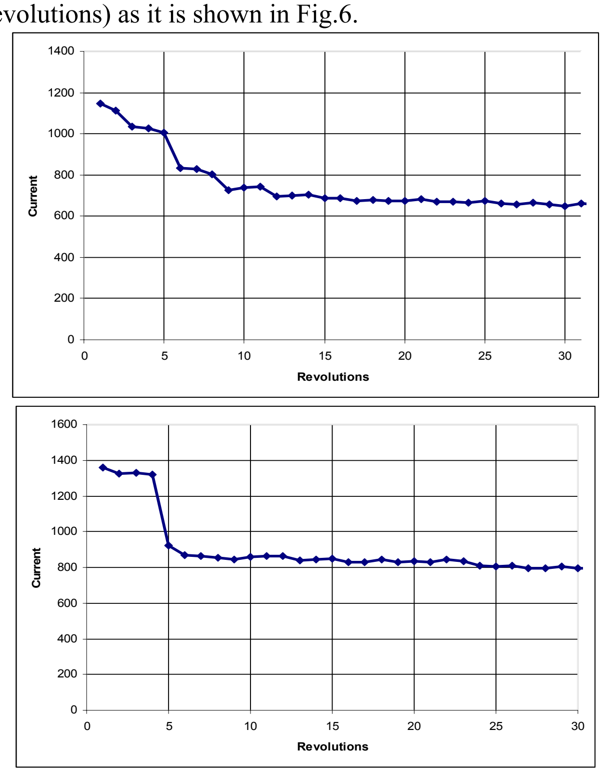

Figure 6: Beam loss at the dynamic (top) and mechanic (bottom) apertures.

To distinguish the beam lost at the dynamic or the mechanic aperture we arranged an artificial limitation of the geometrical aperture by insertion of the scraper blade inside the vacuum chamber. The difference is clearly seen from the Fig.6. Outside the dynamic aperture the particle trajectories are exponentially unstable and it takes ~ tens of turns to lose the particles while in the case of geometrical limitation for our betatron tunes (~0.5) two revolutions are quite enough.

Considering the beam loss process turn-by-turn it is possible to determine the border of the DA with good accuracy. For VEPP-4M the vertical aperture has been measured by this method and it is equal to A_z= 6.9 mm.

DA Measurement with Beam-beam Effects

Beam-beam interaction accompanies with their vertical dimension growth and “tails” formation. It is well known, that beam-beam effects cause the reduction of beam lifetime. It is interesting to determine the connection of this reduction with the reduction of the DA or with the “tails” losses. We studied only the case of “strong” positron beam and beam currents were of about ¾ from the threshold determined by beam-beam effects. Vertical size σ_y of electron beam changed slightly from 0.15 mm (single beam operation mode) to 0.17 mm (luminosity operation mode) of the collider. Fig. 7 demonstrates the reduction of the beam lifetime in the process of the restriction of GA of the collider by the scraper for both of the modes. Apparently, that inflection of both graphs coincides within the measurement accuracy. At the same time, the dependence of beam lifetime on scraper coordinate at beam-beam interaction mode differs sufficiently from single beam case. It indicates the filling of the DA with non-gaussian tails caused by beam-beam effects.

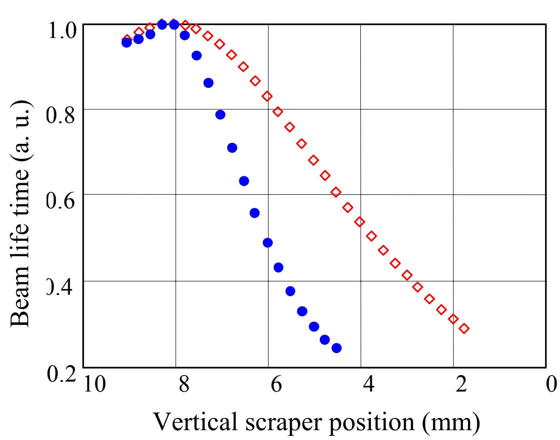

Figure.7. Beam lifetime depending on the vertical scraper coordinate. Circles – colliding beams, diamonds – single beam.

CONCLUSION

The horizontal aperture of VEPP-4M was measured by a precise determination of the beam lifetime. In the case of limitation of the beam lifetime by the scraper blade the aperture was A_x = 6.45 mm.

As for the vertical aperture, the scraper limitation method (A_z = 6.7 mm) was compared with the fast kick method (A_z=6.9 mm); and both results are rather close to each other. It was determined, that the vertical dynamic aperture doesn’t change in the case of colliding beams, and at the same time the appearance of non-gaussian tails is evident.

REFERENCES

[1] V. Smaluk, Status of the VEPP-4M collider. XX RUPAC, Novosibirsk, 2006.

[2] B. Simon, P. Kuske. The dynamic aperture of BESSY. 2nd Advanced ICFA Beam Dynamics Workshop, 1988.

[3] V. Kiselev, E. Levichev, V. Sajaev, V. Smaluk. Dynamic aperture study at the VEPP-4M storage ring. Proc. of the 1997 Particle Accelerator Conference, Vancouver, 1997.