3.22.6 Acknowledgement

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3.23 First Commissioning Results of VEPP-2000

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3.23.1 Introduction

The new e^+e^- collider VEPP-2000 [1] based on round beams approach was constructed at BINP and now is in commissioning stage. It will operate in the energy range from pion-production threshold up to 2 GeV. First luminosity $10^{31}\mathrm{cm}^{-2}\mathrm{s}^{-1}$ at phi-meson energy was successfully achieved in a single bunch mode. At the moment two detectors are in final preparation for data taking. Below a brief activity report and first results of a commissioning are presented.

3.23.2 Layout, Lattice and Design Parameters

VEPP-2000 complex consists of high-intensity 3 MeV electron linac ILU, 250 MeV pulsed synchrotron B-3M, 900 MeV booster storage ring BEP and 1 GeV collider storage ring VEPP-2000.

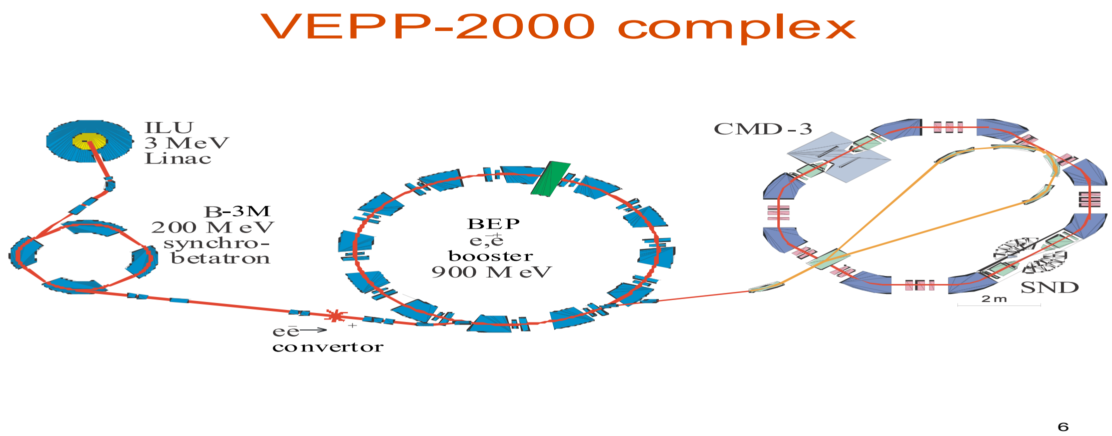

Figure 1: Layout of VEPP-2000 complex.

Table 1: Main Parameters of VEPP-2000 at 1 GeV.

Circumference	24.38 m
RF frequency	172 MHz
RF voltage	100 kV
RF harmonic number	14
Momentum compaction	.036
Synchrotron tune	.0035
Energy spread	$6.4\cdot10^{-4}$
Beam emittances (in round mode)	$1.29\cdot10^{-7}$ m·rad
Dimensionless damping decrements (x,y,s)	$2.19\cdot10^{-5}$, $2.19\cdot10^{-5}$, $4.83\cdot10^{-5}$
Betatron tunes (x,y)	4.1, 2.1
Betatron beta-functions at IP	10 cm
Number of bunches per beam	1
Number of particles per bunch	$1\cdot10^{11}$
Beam-beam space charge parameter (x,y)	0.075, 0.075
Luminosity per IP (at 1 GeV)	$1\cdot10^{32}$ $cm^{-2}s^{-1}$

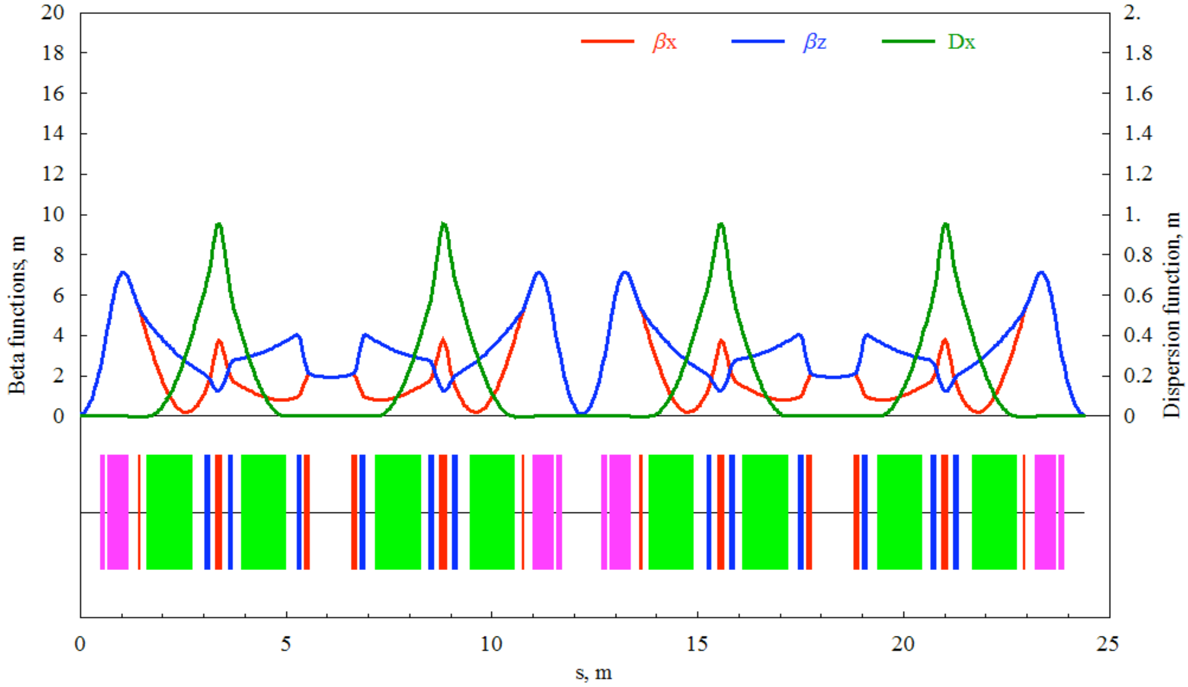

Figure 2: Lattice functions of VEPP-2000 storage ring.

3.23.3 Single Beam Studies

Commissioning of a collider started in the fall of 2007. First injection of electrons and positrons was performed at the beam energy 508 MeV. A temporary optics with switched off solenoids was prepared for that. This simplified optics has provided the functionality test of all the beam diagnostics. Besides, an extensive beam scrubbing was performed in optics with switched off solenoids. The vacuum chambers walls were subjected to irradiation by the synchrotron light with the total electron current exposure of about 20 Ampere*hours in both circulation directions.

Sixteen CCD cameras and the four pickups have shown 1 micron sensitivity to the orbit distortions at few milliamperes of the stored current. Besides, these fast pickups provided the tune measurements, sampling the signal of coherent oscillations induced by the kicker pulse.

By measuring the orbit responses to small changes of field gradients in quads (ΔG wobbling method) the closed orbit was determined in all 20 quads and then the orbit was corrected with accuracy to about 0.1 mm.

Subsequently, by measuring the orbit responses to dipole correctors and then applying SVD analisys the actual optics reconstructrion was achieved.

Then the beam based alignment of solenoids was performed. The orbit responses to changes of currents in solenoids were measured and then the solenoids transverse displacements and inclinations were deduced using the optics theoretical model. After realignement the solenoids were powered with required currents and electrons were captured in almost nominal optics with the temporary working point $\nu_x = 4.4,\ \nu_y = 2.4$, which was shifted as far as possible from the integer resonances. Finally, after making a set of orbit corrections, it was possible to shift the working point down to optimal for getting of high luminosity values: $\nu_x = 4.125,\ \nu_y = 2.125$.

Significant efforts were undertaken for the cancellation of the dynamical orbit distortions caused by the stray fields generated by a pulsed septum magnet. These distortions were successfully damped and stacking of positrons and electrons was achieved. The beam transfer efficiency from the booster storage ring BEP to VEPP-2000 has reached 80-90%.

To avoid the developing of head-tail instability the natural chromaticity was slightly overcompensated by two families of sextupole lenses. No coherent instabilities were observed up to 150 mA of the stored beam current.

Damping time of horizontal oscillations and its dependence versus the revolution frequency were found in perfect agreement with the theoretical model: $\tau_x = 21\,\text{ms},\ d(\tau_x^{-1})/df_0 = 0.0098\ \text{ms}^{-1}\text{kHz}^{-1}$.

It was interesting to investigate of how close to integer tunes we can brought the working point. For this we made a 2D tune scan, measuring tunes and checking that the single beam life time exceeds 100 s. Results are presented in the Fig. 3. Clearly, the widths of integer resonances are in the order of: $\Delta\nu_x = 0.05,\ \Delta\nu_y = 0.025$.

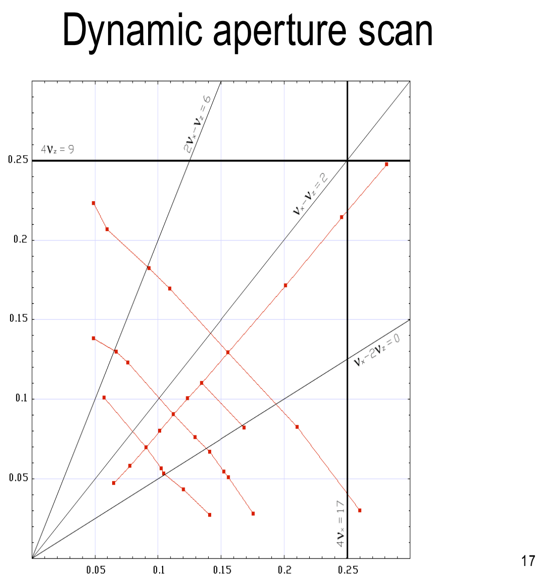

Figure 3: Experimental points show the accessible region of tunes in vicinity of integer resonances (no collisions, single beam).

3.23.4 Beam-Beam Experiments

It was decided to perform the first beam-beam study in a mode having the zero field integrals in both - SND and CMD detectors straight sections, i.e. having opposite polarities of longitudinal fields in two solenoids of each straight section, see the Fig. 4. In such decoupled optics the roundness of beams was organized by placing the tune working point exactly on the main coupling resonance $\nu_x - \nu_y = 2$. The minimal residual coupling was reached $|\nu_1 - \nu_2| = 0.004$.

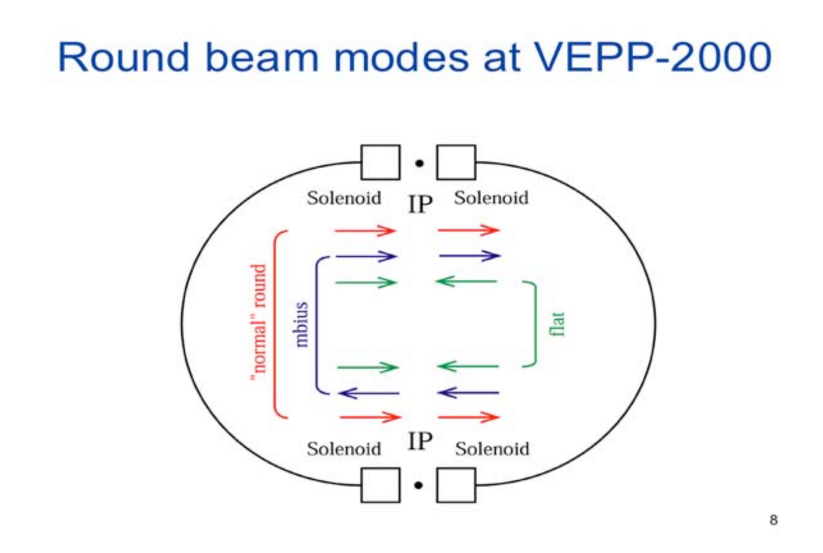

Figure 4: Three possible optics schemes with different polarities of longitudinal field in solenoids. Green arrows show the polarities used in first commissioning run.

The tune scan across the main coupling resonance $\nu_x - \nu_y = 2$ reveals a drastic decrease of the beam-beam current threshold in case of large detuning from the diagonal line. We have found that allowable by beam-beam effects detuning should not exceed of $|\nu_1 - \nu_2| = 0.01$, or less.

The results of a tune scan along the diagonal line $\nu_x - \nu_y = 2$ are presented in the Fig. 5. Many resonances are seen there and the node: $\{\nu\} = 1/6$ is the strongest one. Seems, the reduction of dynamic aperture, when the working point approaches too much the integer tunes node, limits the observed beam-beam current threshold.

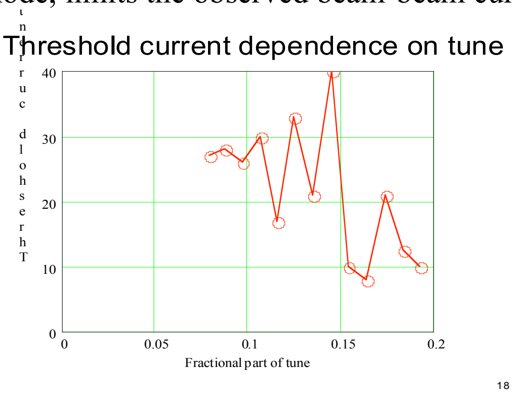

Figure 5: Beam-beam limit on a strong beam current versus the fractional part of tunes: $\{\nu\} = \{\nu_x\} = \{\nu_y\}$.

Also the beta-function at IP was varied by a special knob. Results are presented in the Fig. 6. The optimum around $\beta^* = 5$ cm is not very sharp.

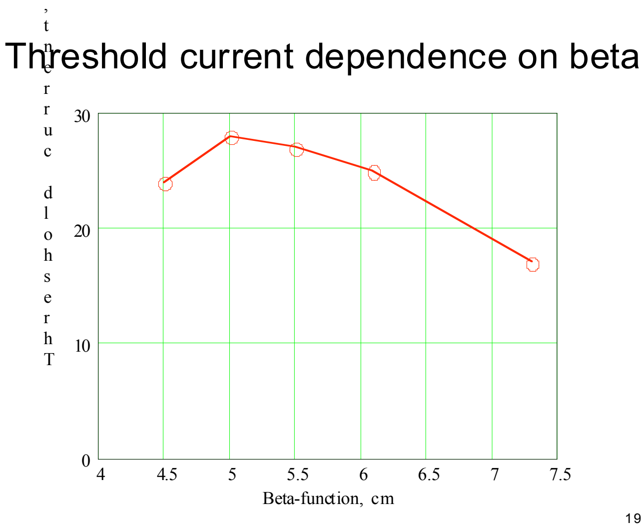

Figure 6: Beam-beam limit on a strong beam current versus the beta-function value at IP.

We also have measured the dependence of sizes of a weak positron beam on the strong electron beam current, see the Fig. 7.

Beam sizes were measured by four CCD cameras located at different places. The large semi-axis corresponds to the vertical direction and the small one to the horizontal direction. This plot was obtained at the nominal working point and with $\beta^* = 4.5\ \mathrm{cm}$. At $I^- = 41\ \mathrm{mA}$ the positron beam-beam parameter reaches $\xi = 0.08$! This value of ξ exceeds the design number of $\xi = 0.075$, which was assumed to be achieved only at highest beam energy 1 GeV. In somewhat better conditions the strong beam current threshold has reached $I^- = 53\ \mathrm{mA}$. This corresponds to $\xi = 0.1$ per one crossing!

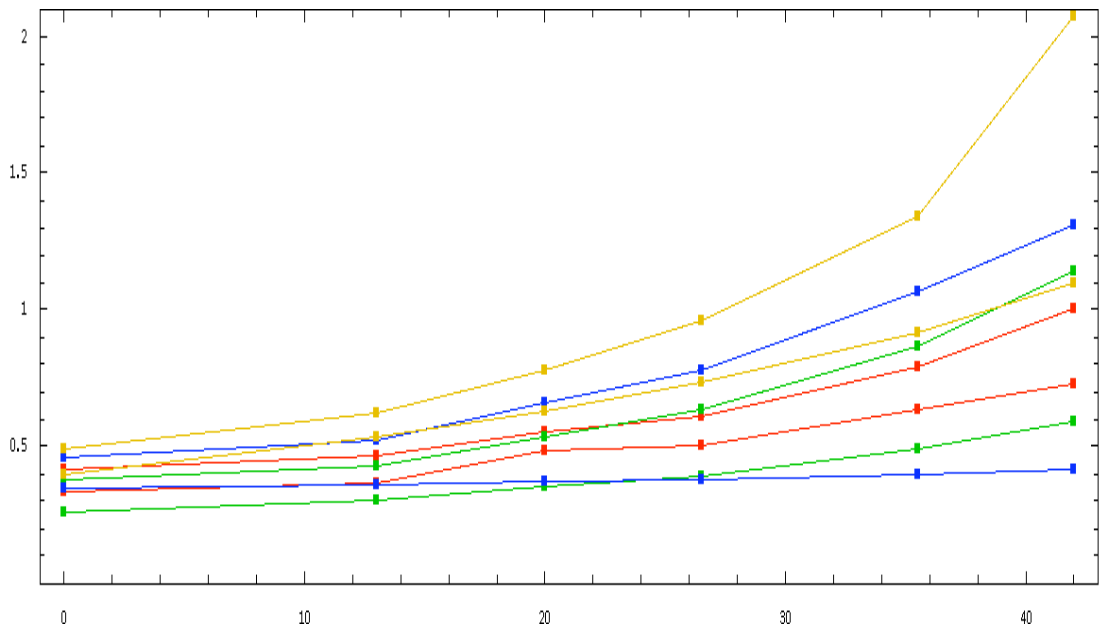

Figure 7: Dependence of sizes of a weak positron beam on the strong electron beam current.

In the Fig. 8 one can see how the positron beam looks like at 3 different CCD cameras. Practically everywhere the vertical beam size is larger than a horizontal one, because of larger vertical beta-function value there. Therefore some ellipses are stretched mainly in the vertical direction.

In January 2008 a short run with the full intensity colliding beams was made. The best luminosity $L = 1 \cdot 10^{31}\ \mathrm{cm^{-2}s^{-1}}$ was achieved with equal stored currents $I^+ = I^- = 42\ \mathrm{mA}$, ($\xi = 0.08$). The luminosity was monitored by the SND detector, which has identified the events of e^+e^- scattering at large angles.

Unfortunately, a burning of one superconducting current lead happens just the next day after this success and the collider operation was stopped for repairing of this current lead. Later on, it was decided to upgrade the suspension system of all four solenoids with the aim to reduce the liquid helium consumption. This goal was achieved: the helium consumption was improved roughly by a factor of 2. Commissioning was restored in January 2009 and new results are expected soon.

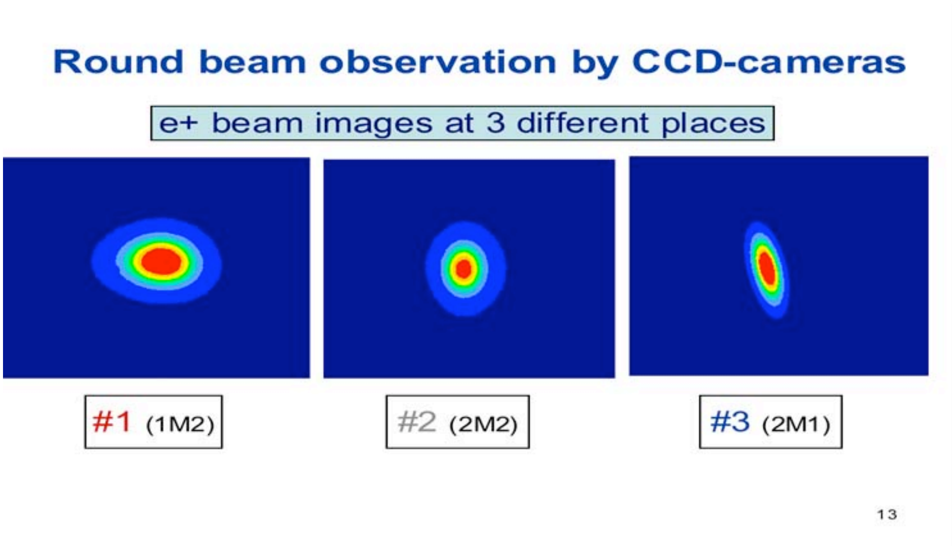

Figure 8: Beam profile measured in 3 different azimuths. The transverse motions are fully coupled due to choice of tune point sitting exactly at the linear coupling resonance $\nu_x - \nu_y = 2$.

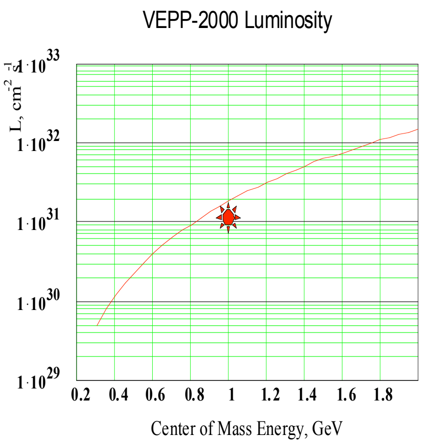

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Figure 9: The luminosity theoretical curve and one experimental point measured at $\phi-\text{meson}$ energy.

3.23.5 Conclusion

Round beams mode approach was successfully tested at VEPP-2000 collider. The maximum luminosity was observed $L = 1\cdot 10^{31}\ \text{cm}^{-2}\text{s}^{-1}$ at $\phi-\text{meson}$ energy. The space charge beam-beam parameter has reached $\xi = 0.08$ per each of two crossings. Potentially $\xi = 0.1$ could be expected and, correspondingly, the luminosity could reach $2\cdot 10^{31}\ \text{cm}^{-2}\text{s}^{-1}$ at this energy. At 2 GeV of centre of mass energy we expect to reach $1.6\cdot 10^{32}\ \text{cm}^{-2}\text{s}^{-1}$.

3.23.6 References

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