VEPP-4M COLLIDER: CURRENT ACTIVITY AND FUTURE PLANS

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Results of the activity at VEPP-4M collider of the Budker Institute of Nuclear Physics over the period of 2000-2001 and the near future plans are presented.
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1 INTRODUCTION

VEPP-4M is a single-ring e+e- collider intended for high-energy physics experiments, photo-nuclear study at the ROKK-1M facility and synchrotron radiation research [1, 2]. Maximum designed energy of VEPP-4M is around 6 GeV. An electron (or positron) beam consists of two bunches which are spaced at one-half of the ring circumference (183 m). The beams collide at zero crossing angle in the interaction point (IP) where the KEDR detector is located.

Basically, VEPP-4M is intended to study physics of ϒ-meson and two-photon processes. However, because of the interest growing to the range of J/ψ and ψ′ physics, it was proposed to concentrate efforts in the low energy range E = 1.5 –1.8 GeV [3]. This energy range is unusual for our storage ring and additional investigation has to be done to obtain optimal performance.

Two possible ways to reach reasonable luminosity in J/ψ region under consideration: (i) redistribution of damping partition numbers with the help of the gradient wigglers (GWs) installed in the technical straight at places of non zero dispersion and (ii) introducing of a strong radiation damping by two 3-pole dipole wigglers (DWs) located on the opposite sides of the VEPP-4M experimental straight section.

In the near future we plan to perform an experiment on measurement of the τ lepton mass in the vicinity of its production threshold (1.777 GeV) with a relative accuracy better than 10^{-4} using the method of the resonance depolarization for beam energy calibration [4]. Earlier, such a method was successfully used in measurements of the J/ψ and ψ′mass at VEPP-4 [5].

2 LUMINOSITY

For VEPP-4 the peak luminosity at 5 GeV was about $5{\times}10^{30}$ cm^{-2}s^{-1}. Now for VEPP-4M at the same energy we hope to reach $2{\times}10^{31}$ cm^{-2}s^{-1} with the existing optics. At low energy the luminosity reduces significantly ($\propto E^4$) and different problems arise due to the low damping rates ($1/\tau \sim 10$ s^{-1}).

VEPP-4M has relatively large horizontal dispersion at the IP, so the horizontal beam size here is mainly defined by the energy spread. The ratio between synchrotron and betatron horizontal beam size (monochromatization factor) is equal to $\lambda = 1.8$ in the nominal operation mode. However, at a low energy we can vary this parameter by the GWs, which can redistribute damping decrements between horizontal and longitudinal planes. By changing the GWs strength and VEPP-4M lattice, we can vary λ within the rather wide range (from ~ 1 to 4). Analytical studies [6] shows that the beam-beam effects are most dangerous for $\lambda \approx 1$. In this case all three degrees of freedom are coupled and synchro-betatron resonances become strong. On the contrary, when $\lambda >> 1$, the particle horizontal co-ordinate at the IP practically does not depend on the betatron motion and the beam behaviour becomes almost two-dimensional. The width of horizontal and coupled synchro-betatron resonances falls down with increasing λ (for the mere vertical and synchrotron resonances it is not the case).

Additionally redistribution of the damping decrements by the GWs provides:

- suppression of high-order non-linear resonances with increasing the horizontal betatron damping,
- reduction of the horizontal betatron emittance (a dynamic aperture become larger in units of rms beam size).
- reduction of the horizontal beam-beam parameter ξ_x, since the total horizontal beam size at the IP increases.

The latter allows increasing a bunch intensity keeping ξ_x constant. Experimental results show that for $\lambda \approx 3$ the maximum bunch current obtained is around 2 mA that corresponds to $\xi_x \approx 0.02$. For the nominal operation mode ($\lambda \approx 1.8$) such current can not be reached because in this case $\xi_x = 0.032$ is well above the beam-beam limit.

To study the method of the resonance depolarization and to check the KEDR detector acquisition system, a J/ψ test run was performed in summer 2001. Fig. 1 shows luminosity obtained during this run while Fig. 2 shows the beam-beam parameter as a function of the bunch current. The maximum peak luminosity that was achieved $L = 4.7{\times}10^{29}$ cm^{-2}s^{-1} corresponds to $\xi_y = 0.037$ (1×1 bunch mode with 2.2 mA per bunch).

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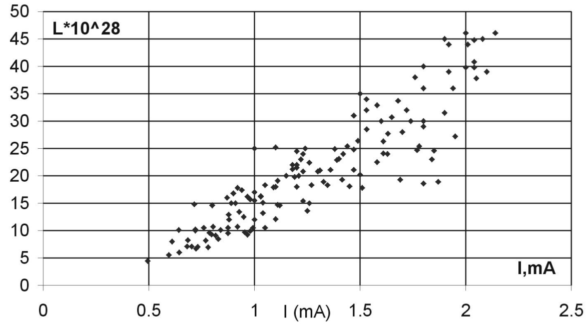

Fig. 1. Single bunch luminosity versus of beam current (DWs off).

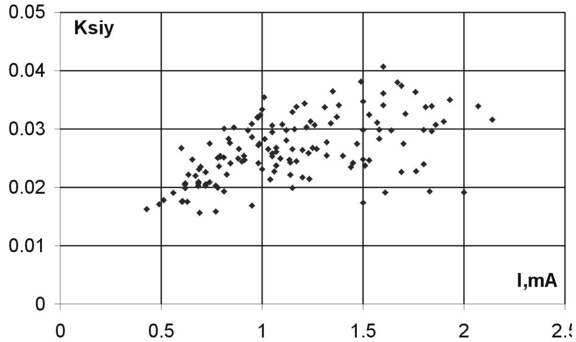

Fig. 2. Test run vertical beam-beam parameter calculated from luminosity data.

Another way to improve the luminosity performance is using of the dipole wigglers (DWs) with the peak field H = 1.8 T, which allows one to increase the horizontal emittance by a factor of 4 at 1.5 GeV. Numerical simulations of the beam-beam interaction with the LIFETRACK code [7] shows that with the help of the DWs we can reach the single bunch luminosity $L \approx 10^{30}\,cm^{-2}s^{-1}$ for 1.5 GeV (with beam-beam parameters ξ_x = 0.015 and ξ_y =0.03). The experimental data with the switching-on DWs correspond to $L \approx 0.7\times 10^{30}\,cm^{-2}s^{-1}$ (I_b = 3.2mA, ξ_y = 0.046) and the beam lifetime τ = 1.3 hour. Experiments show that the maximum emittance increasing with DWs (4 times) is not optimal for the luminosity increasing. The reason as it is considered now is the dynamic aperture limitation.

3 DYNAMIC APERTURE

Study of the non-linear beam dynamics was already performed at VEPP-4M several years ago [8]. Since that time, the new final focus quadrupoles with improved gradient quality replaced two old ones. Besides, the working betatron tune point was moved from (8.62; 7.57) to (8.55; 7.60). These two factors yielded to significant increase of the horizontal border of stable motion (twice). However, when two dipole wigglers are used to enlarge the beam phase volume, the horizontal aperture shrinks.

At an energy of 1.5 GeV, two 1.8 T dipole wigglers provide strong distortion to the beam motion (especially vertical). At their maximum field the linear tune shift is $\Delta Q_y \approx 0.13$ and $\Delta Q_x \approx 0.02$ [9].

Linear wiggler effects, including the tune matching and the beta-function recovering (inside a 15% accuracy), are completed by three pairs of quadrupoles in the experimental straight section. However, non-linear components of the wiggler field (mainly, strong chromatic sextupoles) together with the fringe field yield a significant reduction of the dynamic aperture (by approximately 30%) as it is illustrated in Fig. 3 [10]. The vertical border of the aperture is limited by mechanical factors well below the dynamic aperture limitation and is not changed due to the wiggler switching-on.

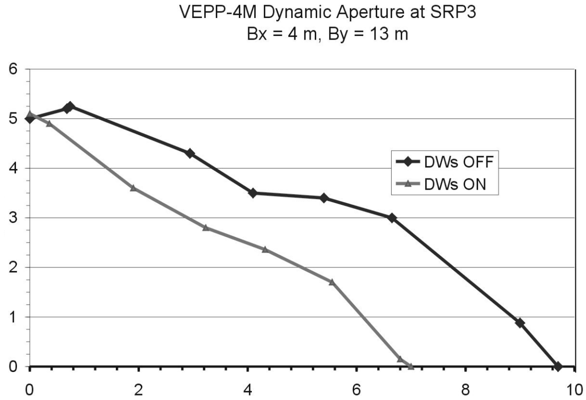

Fig. 3. VEPP-4M dynamic aperture.

As the next step, study of non-linear components of the wiggler field is planning to be performed. The final goal is suppression of the DWs non-linearity by the use of octupoles and sextupoles magnets.

4 POLARIZATION AT VEPP-4

A measurement of the $\tau^+\tau^-$ production cross section will be done by the detector KEDR in the energy region just above the threshold (1.78 GeV). To calibrate the beam energy, the polarized electron beams are injected in the storage ring VEPP-4M from a booster storage ring VEPP-3 (see Fig. 4). Radiation polarization of particles in VEPP-3 occurs with the characteristic time $\tau_p \approx 40$ minutes near to the τ threshold (for VEPP-4M $\tau_p \approx$ 85 hours).

Quantum fluctuation of radiation together with imperfection of the magnetic field destroys the beam polarization with the characteristic spin relaxation time τ_r. We assume the horizontal magnetic field produced by the vertically misaligned quadrupole magnets as a main factor of depolarization. Estimation shows that for the τ threshold energy region of 1.777 GeV and vertical COD of ~ 100 μm (rms), the spin decay time for VEPP-4M is equal to τ_r = 30 min [4]. A depolarization rate depends strongly on the spin resonance tune: $\tau_p/\tau_r \propto (\nu_s-k)^{-4}$ (at E = 1.777 GeV we have ν_s = 4.032). This fact can limit the energy calibration time.

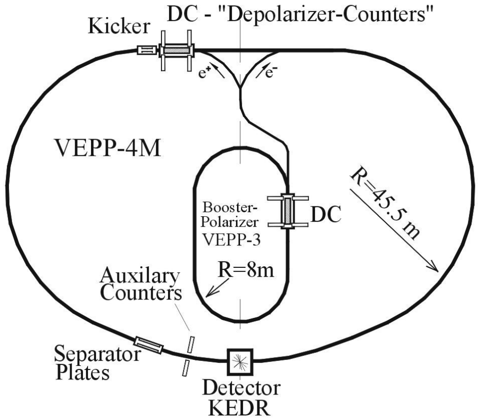

Fig. 4. A set up for the polarization experiments at VEPP-4M.

Experimental set up for the depolarisation study at VEPP-4M includes 4 movable scintillation counters inserted into the vacuum tube and two stripline electrodes and electronics (a frequency synthesiser, wide band amplifier, etc.) to produce resonant spin depolarization. The counters detect the Touschek scattering electrons whose scattering rate depends on the particle spin. Two bunches with depolarised/polarized particles are used to measure the ratio $1\text{-}N_2/N_1$ depending on the stripline electrodes signal frequency where N_2 and N_1 are count rates for the fist and second bunch.

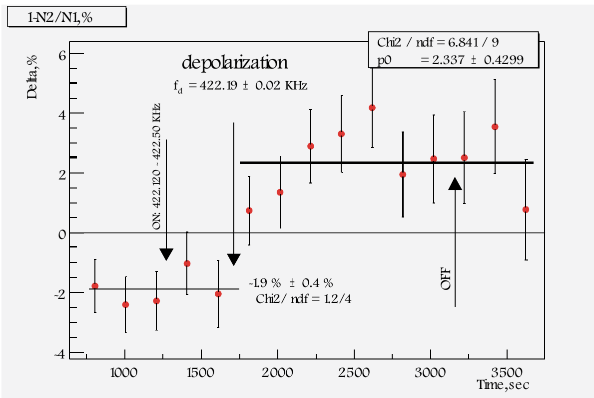

Fig. 5. Test run on the spin energy calibration.

During a *J/ψ* test run (summer 2001), a method of the resonance depolarization was used to calibrate beam energy. Fig.5 shows typical “jump” in $1\text{-}N_2/N_1$ due to the beam depolarization. The error of the beam energy definition obtained during the test run is ≈ 30 keV ($\Delta E/E \approx 2\times10^{-5}$).

5 FUTURE PLANS

- Commissioning of the new polarimeter system at the VEPP-4M.
- Measurement of the beam energy by the method of resonance depolarization with reasonable accuracy ($\Delta E/E \approx 1\times10^{-5}$) in to the energy range between J/ψ and τ.
- The KEDR run at J/ψ peak and in the vicinity of the threshold of τ - lepton production.

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