STUDY OF BEAM ENERGY SPREAD AT THE VEPP-4M

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Abstract

The knowledge of beam energy spread is necessary for the experimental program of the VEPP-4M collider. In this report we discuss the application of optical diagnostics for measurement of this value. The diagnostics is based on multi-anode photomultiplier and provides information about betatron and synchrotron frequencies of electron beam [1]. The beam energy spread is derived from the spectra of betatron oscillation. The results, obtained with this method, are compared with data, provided by Compton Back Scattering technique.

INTRODUCTION

The experimental program of the VEPP-4M collider and the KEDR detector consists of precise J/ψ -, ψ/-, ψ//-mesons and c-τ lepton mass determination, for which the method of resonance depolarization is applied [2]. Essential requirement of experimental program is a stability of the collider parameters, including the energy spread of electron and positron beam.

The knowledge of the energy spread is especially important during the experiments on the threshold of c-τ lepton production. This parameter of the VEPP-4M is under routine monitoring of Compton Back Scattering (CBS) diagnostics [3]. Another calibration of energy spread can be obtained from FWHM of J/ψ, ψ/ meson peaks. Both these methods provide an accuracy of 1-2 percent.

We have attempted to determine the energy spread of electron beam, using the chromatic dependence of vertical betatron oscillations ν_y in accordance with the approach, that was proposed in [4]. These measurements, besides utility for VEPP-4M experimental program, have methodical significance because they enable us to compare the data obtained from several diagnostics.

METHOD

Chromaticity of a storage ring causes appearing of synchrotron sideband peaks in a spectrum of beam oscillation. The amplitude of the central betatron frequency and the synchrotron satellites is [4]:

$$R_m(y) = \frac{1}{y^2}\int_0^\infty J_m^2(x) e^{-\frac{x^2}{2y^2}} x dx\,, \qquad (1)$$

where $y = \left(\frac{\omega_\beta \alpha}{\omega_s} + \frac{\omega_0 C_y}{\omega_s}\right)\delta_E$, m is the number of harmonic, δ_E is the energy spread. Fig. 1 represents peaks height normalized to the peak of $m = 0$ for $\alpha = 0.017$, $\omega_s = 0.061$, $\omega_\beta = 7.571$, $\delta_E = 4\cdot 10^{-4}$.

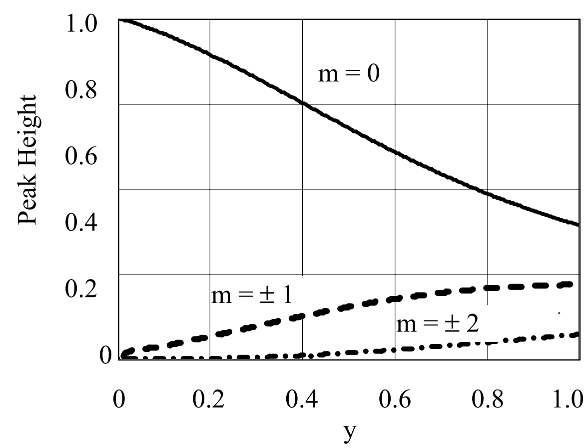

Figure 1: Relative intensities of the betatron peak and synchrotron satellites.

Determination of energy spread is based on the ratio measurement of synchrotron satellites to the main peak height.

DIAGNOSTICS LAYOUT

The experiments were done with the diagnostics based on the Multi-Anode Photomultiplier Tube (MAPMT, Fig. 2). The lens sets up a beam image on the photocathode of the MAPMT.

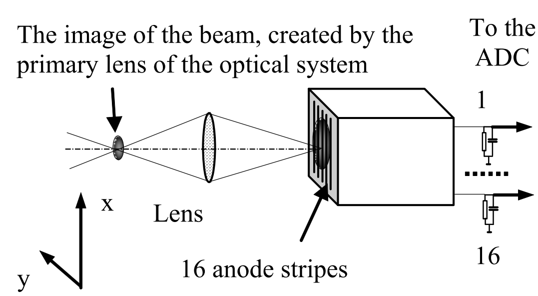

Figure 2: Optical layout of the diagnostics.

The Fast Profile Meter (FPM) is a part of the VEPP-4M optical diagnostic system [1]. FPM is used to study turn-to-turn dynamics of the transverse beam profile during 2^{17} turns. In addition, it provides a permanent measurement of synchrotron and betatron frequencies. It is applied also for determination of synchro-betatron resonances, phase oscillation monitoring and studying of collective effects.

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The sensitivity of the FPM enables us to measure the betatron motion of the beam with the current less then 1 μA. Typical experimental value was 10 - 20 mkA. It is low enough to avoid any collective effects.

EXPERIMENT

Beam oscillation was excited by a short kick with amplitude of $A_y \geq \sigma_y$

Figure 3 presents typical beam size and position behavior for vertical chromaticity $C_y = 20$.

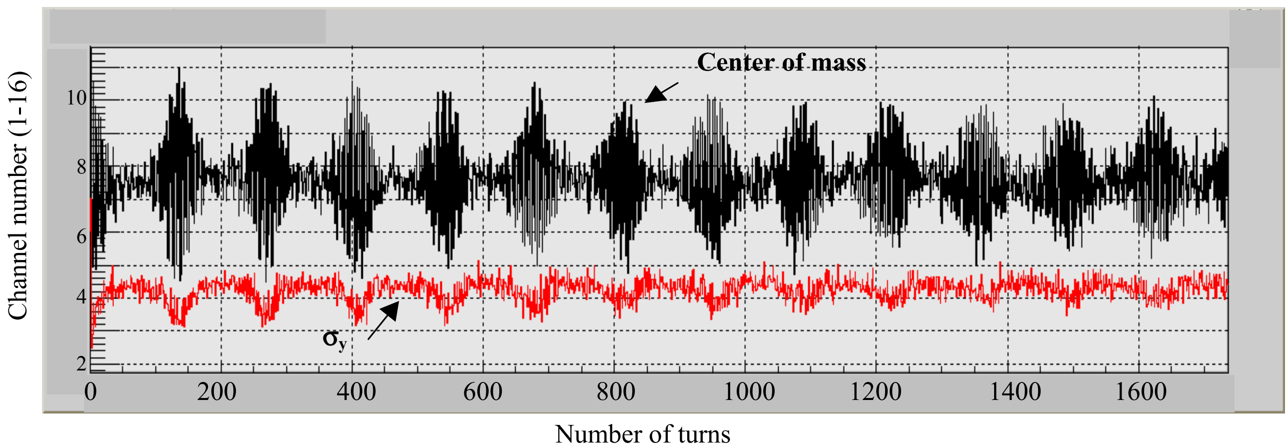

Figure 3: Beam dipole y-oscillations (upper plot) and σ_Y behavior (down plot) after a short kick. Duration of the single turn is 1220 ns. Channel constant is 0.12 mm. $Ie^- = 20$ μA. $C_y = 20$. E = 1843 MeV.

Spectrum of betatron motion was derived with FFT. Frequency and amplitude of the peaks were defined more exactly with the method proposed in [5]. Blackman-Harris window was also applied. All the measurements were made during 1024 beam turns following the kick. An example of measured spectrum is presented at Fig.4 Three sideband satellites are clearly seen. This spectrum is derived from the beam motion presented at Fig. 3.

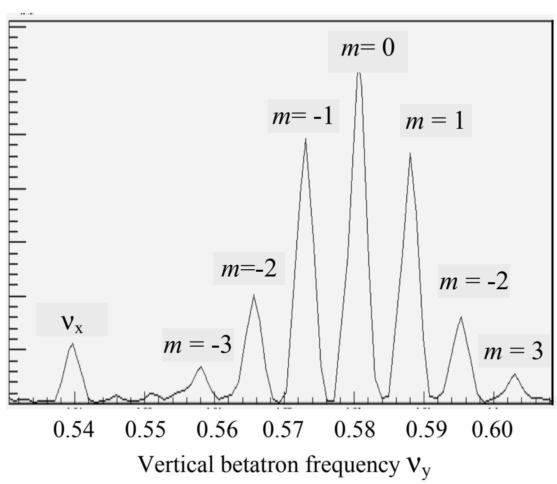

Figure 4: A spectrum of vertical betatron oscillations.

The same measurements were made for various vertical chromaticities $C_y = 5 \div 25$. Chromaticity was changed with sextupole magnets and measured from the dependence of betatron tune on the energy shift.

The measured dependence of height of $m = 1$ synchrotron satellite to the main peak is shown in Fig.5.

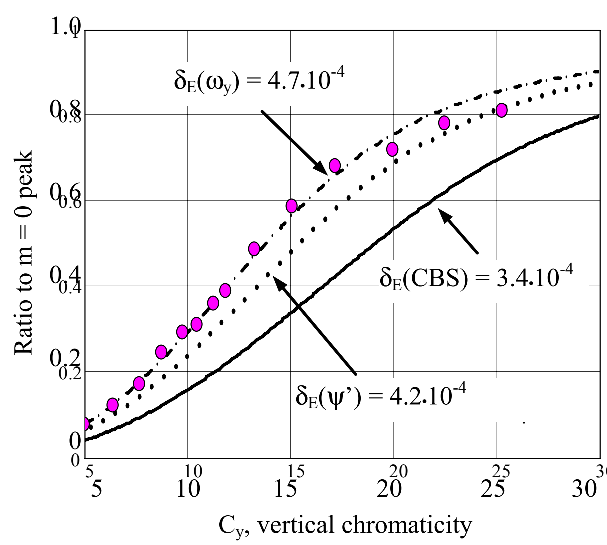

Figure 5: Ratio of R_1/R_0 for different energy spread δ_E. Experimental points for E = 1843 MeV are shown.

The best fit of experimental points corresponds to the energy spread $\delta_E = 4.7 \cdot 10^{-4}$. The solid curve corresponds to the energy spread determined by CBS and the dotted curve corresponds to the KEDR data for ψ' width. Compton Back Scattering technique gives a result of $\delta_E(CBS) = 3.4 \cdot 10^{-4}$. The energy spread, determined by the KEDR team from FWHM of ψ' meson is equal to $\delta_E(\psi') = 4.2 \cdot 10^{-4}$. Data of the experiments, described above, are preliminary ones. Total set of the experimental data is much extensive. We changed energy of the collider down to 1556 MeV and varied the energy spread of the beam with the wiggler strength. These results, as well as measurements of the energy spread with sideband peaks of $m = \pm 2, \pm 3$, will be published later. We are going also to determine the energy spread from the obtained data with the approach, proposed in [6].

SUMMARY

The energy spread of the VEPP-4M collider was measured with the chromatic dependence of the vertical betatron oscillations. The obtained value corresponds to the results of other diagnostics.

REFERENCES

[1] O. I. Meshkov et al. Application of the beam profile monitor for the VEPP-4M tuning . 7th European Workshop on Diagnostics & Instrumentation for Particle Accelerators (DIPAC'05), June 6 – 8, 2005, Lyon, France, POM008.
[2] V. E. Blinov et al. Absolute calibration of particle energy at VEPP-4M. Nuclear Instruments and Method in Physics Research A 494 (2002) 81-85.
[3] Nickolai Muchnoi. Fast and Precise Beam Energy Monitor Based on the Compton Backscattering at the VEPP-4M Collider, this conference
[4] T. Nakamura et al. Chromaticity for energy spread measurement and for cure of transverse multi-bunch instability in the SPRING-8 storage ring. Proceed. Of the 2001 Particle Accelerator Conference, Chicago, p. 1972-1974.
[5] V. V. Smaluk. PhD thesis (in Russian)
[6] N.A. Vinokurov et ai. Preprint BINP SB RAS 76-87, Novosibirsk, 1976 (in Russian).