CALIBRATION OF THE VEPP-4M COLLIDER BEAM ENERGY BY INFRARED LASER

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Abstract

For J/ψ, ψ', and τ masses measurement with the KEDR detector, the VEPP-4M collider is planned to operate at 1200–2000 MeV beam energies. Electron beam energy calibration with backscattered laser photons, performed at BESSY I storage ring [1], has shown the accuracy compatible with that obtained by resonant spin depolarization technique. We propose the non-head-on configuration of electron-laser beams interaction: electron beam intersects the CO_2 laser cavity axis at close to $\pi/2$ angle. The resulting spectrum of backscattered Compton photons has two edges, their sum is used to determine the electron beam energy and depends weakly from the intersection angle. The estimated accuracy for beam energy calibration is about 10^{-4}.

1 INTRODUCTION

The basic idea of the electron beam energy calibration by inverse Compton scattering of laser photons is to measure the high energy edge of the photon energy spectrum. In case of head-on collision of laser and electron beams it reaches maximum possible value, which depends on laser photon energy ω_0 and electron enegry ε only. CO_2 laser radiation of ω_0 = 0.12 MeV at BESSY I [1] was scattered on 350–850 MeV electron beam, and backscattered photons were registered by HPGe detector of 500 cm^3 volume. The ^{60}Co radioactive source was used for absolute calibration of the detector energy response. The obtained precision of electron beam energy measurement was about $1 \cdot 10^{-4}$. It seems to be a good idea to give preference to this approach, rather then to the resonant depolarization technique, when there is no possibility or it is hard to obtain the polarized electron beam.

2 METHOD

Let's consider a possibility of application of this method for measurement of the electron beam energy of the VEPP-4M collider with alternative set-up of electron-photon interaction area. The electron beam intersects the axis of laser cavity with α angle and interacts with photons, propagating in both directions (Figure 1). In this case we have two edges ω_1 and ω_2 in the Compton spectrum of scattered photons, corresponding to the α and $(\pi - \alpha)$ interaction angles:

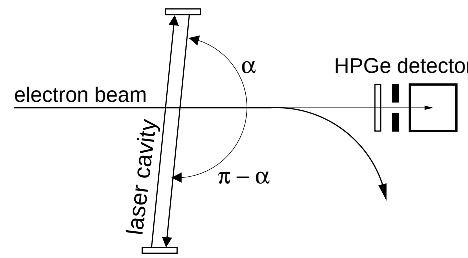

Figure 1: Laser-electron interaction scheme.

$$\omega_1 = \frac{\varepsilon^2 \cos^2 \frac{\alpha}{2}}{\frac{m_e^2}{4\omega_0} + \varepsilon \cos^2 \frac{\alpha}{2}}; \qquad \omega_2 = \frac{\varepsilon^2 \sin^2 \frac{\alpha}{2}}{\frac{m_e^2}{4\omega_0} + \varepsilon \sin^2 \frac{\alpha}{2}}. \quad (1)$$

Here m_e is the electron rest mass, ε and ω_0 are the initial electron and photon energies correspondingly. The photons are scattered into a narrow cone in the forward direction of the electron beam (Klein-Nishina differential cross section), where the HPGe detector with collimator and calibration gamma source is installed the same manner as in [1]. From (1) one can see that the strict compliance between the values of ω_1, ω_2, ω_0 and ε is implemented for any α:

$$\frac{4\,\omega_0\,\varepsilon}{m_e^2} = \frac{\omega_1}{\varepsilon - \omega_1} + \frac{\omega_2}{\varepsilon - \omega_2}. \quad (2)$$

While $\omega_1, \omega_2 \ll \varepsilon$ we can deduce from (2) the approximate expression for the electron beam energy ε determination through the measured values of ω_1 and ω_2:

$$\varepsilon \simeq \sqrt{\frac{m_e^2}{4\omega_0}(\omega_1 + \omega_2)} + \frac{\omega_1^2 + \omega_2^2}{2(\omega_1 + \omega_2)}. \quad (3)$$

Precision of approximation (3) for ω_0=0.12 eV and the electron beam energy ε around 1800 MeV is not worse than $1.5 \cdot 10^{-6}$ for any α. The necessity to deal with both edges, ω_1 and ω_2, rises from the fact that their separate values are linearly proportional to the angle $\alpha \simeq \pi/2$ and energy measurement accuracy will be determined by the accuracy of the interaction angle measurement. As the electron rest mass is well known $(\Delta m_e/m_e = 4 \cdot 10^{-8})$ [2], in our case we have

$$\frac{\Delta\varepsilon}{\varepsilon} \simeq \frac{1}{2}\left(\frac{\Delta\omega_0}{\omega_0} \oplus \frac{\Delta\omega_1}{\omega_1} \oplus \frac{\Delta\omega_2}{\omega_2}\right). \quad (4)$$

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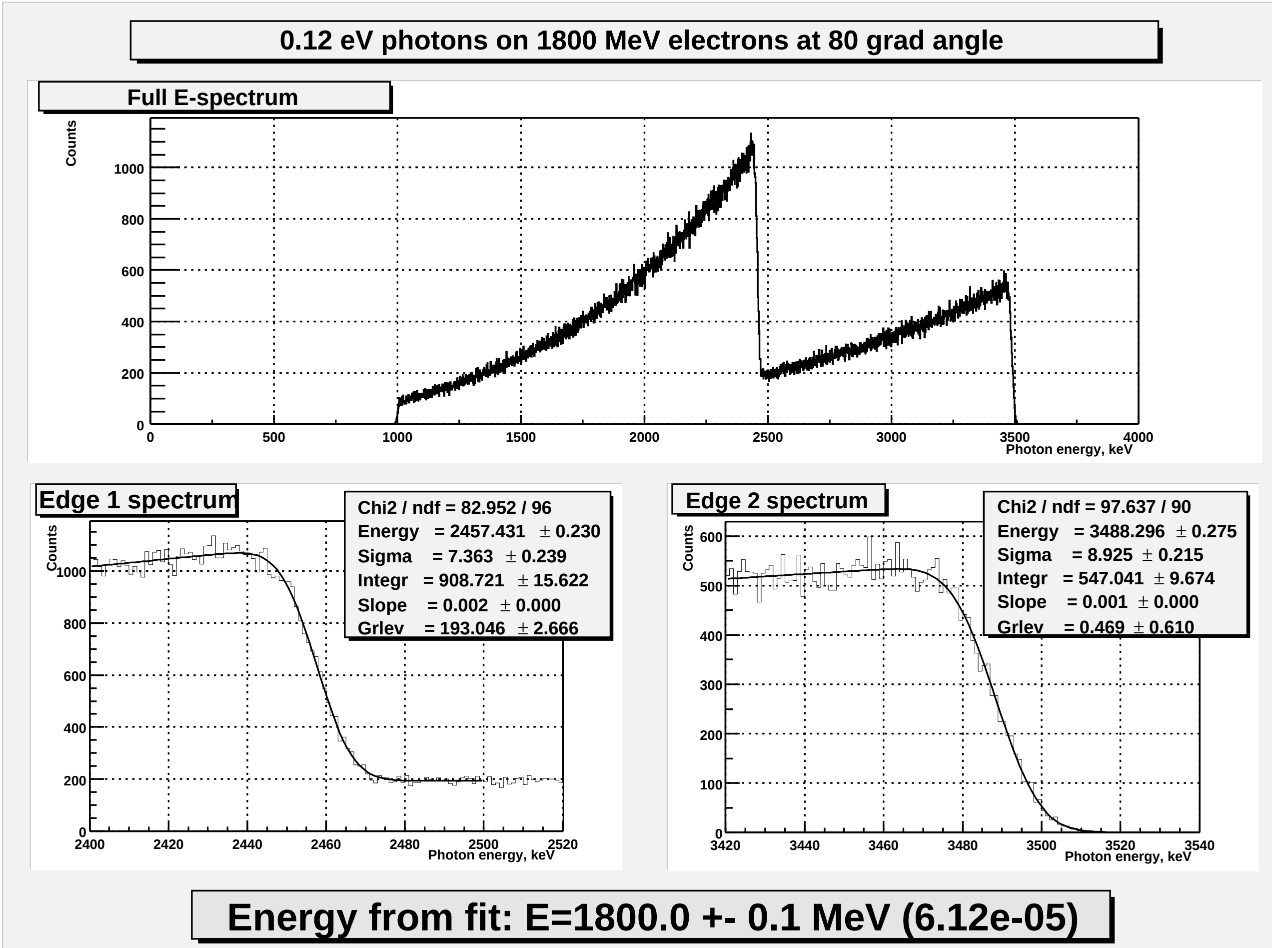

Figure 2: Simulation results for the scattered photon spectrum and the energy, obtained from fitting the spectrum edges. Main simulation parameters are ε=1800 MeV, ω_0=0.12 eV, α=80°.

3 SPECTRUM SIMULATION

According to preliminary estimations, the statistical error at the level of $5 \cdot 10^{-5}$ can be achieved with the following parameters:

- electron beam current 10 mA,
- CO_2 laser power (inside the cavity) 100 W,
- laser waist size at the interaction area 1 mm,
- HPGe detector energy resolution 5 keV,
- HPGe registration efficiency 10%,
- spectrum acquisition time 10^3 s.

The simulation results for the photon spectrum and the electron beam energy ε, obtained from data fitting, are presented on Figure. 2.

4 CONCLUSION

The proposed set-up for the absolute electron beam energy calibration by CO_2 laser photons has the following advantages relatively to the head-on interaction scheme:

- The average energy of the scattered photons spectrum edges is twice lower then in the head-on interaction case. This simplifies the calibration of the HPGe detector and increase its efficiency.
- The transverse configuration of the interaction area simplifies the alteration of the existing accelerator vacuum chamber.
- If the entire laser cavity angular alignment is foreseen in hardware realization of experimental equipment, it provides the additional control over systematical errors, cause the offered scheme is insensitive to the interaction angle.

The obvious complication of the offered scheme is to achieve the high enough intensity of the scattered photons beam, cause the electron-photon luminosity is much smaller then in the head-on interaction.

5 REFERENCES

[1] R.Klein et al., NIM A **384** (1997) 293-298, J. Synchrotron Rad. (1998) **5**, 392-394

[2] Particle Data Group, 2000