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LETTER TO THE EDITOR

QED CORRECTIONS FOR POLARIZED MØLLER SCATTERING

N. M. SHUMEIKO and J. G. SUAREZ

National Scientific and Education Center of Particle and High Energy Physics attached to Byelorussian State University, Bogdanovich Str. 153, Minsk 220040, Belarus

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Principal contributions to QED radiative effects for Møller scattering of polarized particles are investigated. Explicit formulae for the cross section of radiative effects are given in covariant form. A FORTRAN code based on exact expressions for radiative corrections to cross section was used for calculations. Detailed numerical analysis for cross sections as well as for polarization asymmetries is given.

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In CEBAF and other laboratories, Møller scattering is chosen as the method for measuring the electron beam polarization (P_b). Since the measurement aims to be very precise, a detailed analysis of the photonic radiative corrections (RC) has to be carried out. At present time, the systematic error of the measurement of P_b is about $2-3\%$. The consideration of RC allows to give a more exact meaning of P_b. In order to extract the beam polarization, it is neccesary to calculate theoretically, taking into account the experimental conditions, the cross section $\sigma^{\rm th}$ and polarization asymmetry $A^{\rm th}$. If the experimental data for polarization asymmetry ($A^{\rm meas}$) and target polarization (P_t) are known (the sytematic error of the measurement of target polarization is about 4%), the ratio

$$A^{\rm meas} = P_b P_t A^{\rm th}, \tag{1}$$

permits to find the polarization of the electron beam. The purpose of this paper is to calculate the electromagnetic corrections to experimentally observed cross section and polarization asymmetry for kinematics of a fixed target.

Using the parametrization given in Ref. 1 for polarization vectors of the beam and target, and considering the case when the target is longitudinally polarized, the Born cross section to Møller scattering can be presented in the following form

(in ultrarelativistic approximation)

$$\frac{\mathrm{d}\sigma_o}{\mathrm{dy}} = \frac{4\pi\alpha^2}{S}\Bigg[\left(\frac{S^2+X_0^2}{2Q^4}+\frac{S^2+Q^4}{2X_0^2}+\frac{S^2}{Q^2X_0}\right) + P_bP_t\left(\frac{Q^2-2S}{2Q^2}+\frac{Q^4-S^2}{2X_0^2}-\frac{S^2}{Q^2X_0}\right)\Bigg]. \qquad (2)$$

Here $S = 2p_1k_1$, $Q^2 = -(k_1 - k_2)^2$, $X_0 = 2p_1k_2$, and $y = (p_1k_1 - p_1k_2)/(p_1k_1)$, where k_1, p_1 (k_2, p_2) are four momenta of initial(final) electrons. $P_b(P_t)$ are the polarization degrees of the beam(target).

The cross section for Møller scattering ($e^-e^- \to e^-e^-$) in order $\mathrm{O}(\alpha^3)$ is given

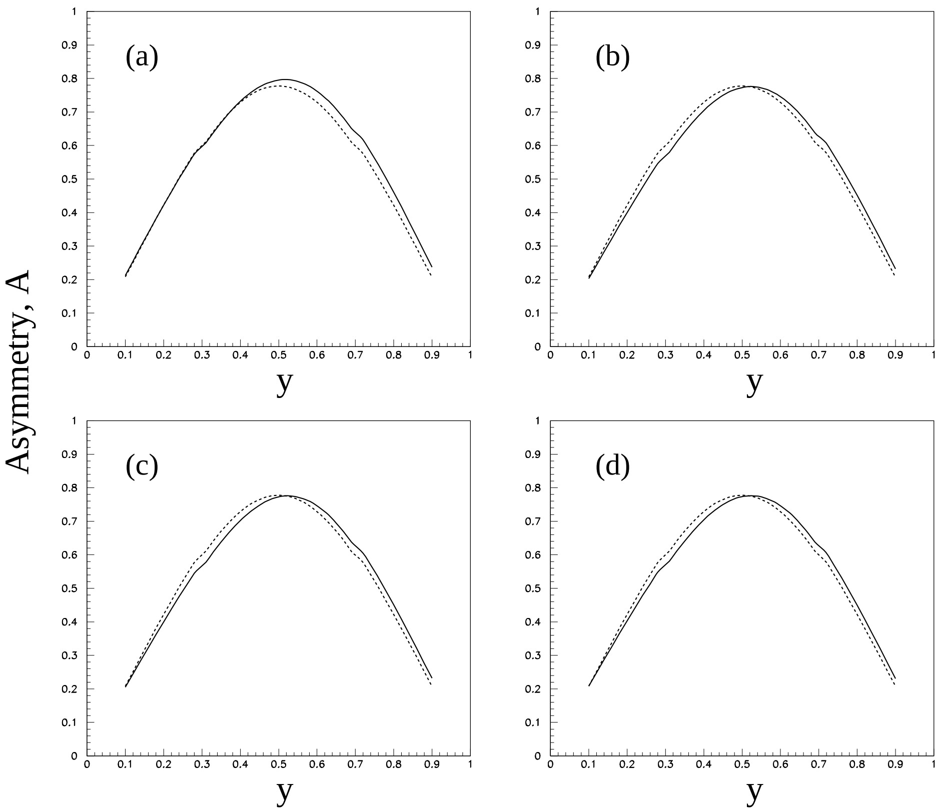

Fig. 1. y-dependence of the Born asymmetry (dashed line) and corrected asymmetry (solid line) in the polarized Møller scattering for CEBAF kinematics when: a) $E = 1$ GeV, *b)* 5 GeV, *c)* 10 GeV *and d)* 15 GeV. *Longitudinally polarized target.*

(in QED) by

$$\frac{d\sigma}{dy} = \sum_k (\sum_i \frac{d\sigma_k^{u,i}}{dy} + P_b P_t \sum_i \frac{d\sigma_k^{p,i}}{dy}) + \sum_h (\sum_j \frac{d\sigma_h^{u,j}}{dy} + P_b P_t \sum_j \frac{d\sigma_h^{p,j}}{dy}), \quad (3)$$

where the sum over k corresponds to the contributions of linear and exchange diagrams and their interference. The sum over i corresponds to the contributions of vacuum polarization, vertex diagrams and bremsstrahlung. Index j denotes the sum over anomalous magnetic moment and two-photon exchange. For the last corrections, the contribution of the interference of linear and exchange diagrams is divided into two parts. For this reason we separate these corrections from the other ones and use the index h instead of k. The index $u(p)$ is used to separate the contribution of unpolarized(polarized) parts.

For the calculations, it is neccesary to consider the contribution of n "soft-photons". This contribution modifies the cross section given above by Eq. (3) in the following way

$$\sum_k \left(\sum_i \frac{d\sigma_k^{u(p),i}}{dy} + \frac{d\sigma_{o,k}^{u(p)}}{dy} \right) \rightarrow \exp \frac{\alpha}{\pi} \delta_{inf} \sum_k \left(\frac{d\sigma_{o,k}^{u(p)}}{dy} + \sum_i \frac{d\sigma_k^{u(p),i}}{dy} - \frac{\alpha}{\pi} \delta_{inf} \frac{d\sigma_{o,k}^{u(p)}}{dy} \right), \quad (4)$$

Here δ_{inf} is the correction due to the inclusion of the multi-soft-photon emission. The expression for this correction was given in Ref. 7. For more details see Refs. 5, 6 and 8.

We pay special attention to the analysis of the longitudinal polarization asymmetry

$$A_l = \frac{\sigma^{\uparrow\downarrow} - \sigma^{\uparrow\uparrow}}{\sigma^{\uparrow\downarrow} + \sigma^{\uparrow\uparrow}}, \quad (5)$$

and the radiative correction to it

$$\delta^{\rm QED} = \frac{A^{\rm QED}}{A_0} - 1\,. \quad (6)$$

In Eq. (6) $A^{\rm QED}$ is the asymmetry with corrections and A_0 is the Born asymmetry.

The results presented in this paper were obtained with the help of the FORTRAN code MØLLERAD and are shown in Fig. 1 (polarization asymmetry) and Fig. 2 (RC to the polarization asymmetry). The kinks in the figures are not physical. They are due to the uncertainties in the integration procedure.

The radiative corrections to polarized Møller scattering have been calculated. The contribution of "soft" and "hard" photons has been considered exactly. For CEBAF kinematics ($E = 0.8 - 15$ GeV), in the kinematical region of interest for experimentalists ($y = 0.4 - 0.6$), the RC to the polarization asymmetry reach 2%. This result points out that the contribution of RC must be considered for defining P_b.

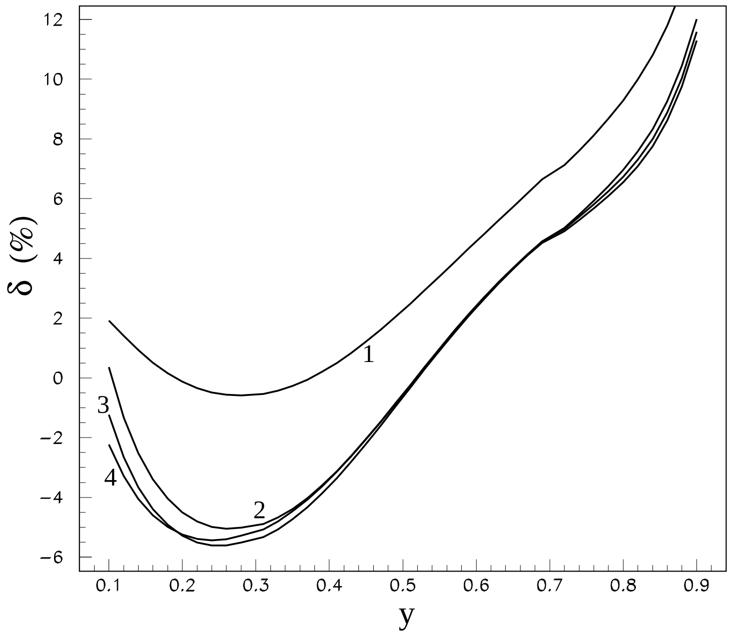

Fig. 2. The QED radiative corrections to the polarization asymmetry when: 1) $E = 1$ GeV, *2) 5* GeV, *3) 10* GeV *and 4) 15* GeV.

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KVANTNO-ELEKTRODINAMIČKE POSPRAVKE ZA POLARIZIRANO MØLLEROVO RASPRŠENJE

Istražuju se glavni doprinosi kvantno-elektrodinamičkih popravaka za Møllerovo raspršenje polariziranih čestica. Izlažu se podrobni ishodi računa za udarne presjeke i polarizacijske asimetrije.