QED CORRECTIONS TO POLARIZED DEEP-INELASTIC AND SEMI-INCLUSIVE DEEP-INELASTIC SCATTERING

G.I. Gakh, N.P. Merenkov, O.N. Shekhovtsova

National Science Center "Kharkov Institute of Physics and Technology", Kharkov, Ukraine

Leading-log model-independent QED corrections in DIS of unpolarized electron off tensor-polarized deuteron are considered. Same approach was used for investigation of semi-inclusive DIS of electron by nucleus with detection of hadron and scattered electron. Calculations are based on covariant parametrization of polarization and use of Drell-Yan like representation to describe radiation by initial and scattered electron. Applications to polarization transfer from polarized electron to detected hadron and to scattering by polarized target are considered. DIS of unpolarized electron on tensor-polarized deuteron with tagged collinear photon radiated from initial-state electron are investigated.

PACS: 12.20.-m, 13.40.-f, 13.60.-Hb, 13.88.+e

1. INTRODUCTION

The purpose of this paper is developing a unified approach to computation of the radiative corrections (RC) for inelastic scattering of polarized electron beam in the inclusive and semi-inclusive (SI) setups. We investigated the deep-inelastic scattering (DIS) of unpolarized electron beam off the tensor-polarized deuteron target (a process with tagged collinear photon, radiated from the initial-state electron, has also been investigated). The ELFE project provides a good opportunity for the measurement of some hadron tensor structure functions [1], which could give clues to physics of non-nucleonic components in spin-one nuclei and study the tensor structure on the quark-gluon level. The use of the tensor-polarized deuteron target at HERMES allows investigating the nuclear binding effects and nuclear gluon components [2]. As stated above, we considered also inelastic scattering of polarized electrons in the coincidence setup, namely, when one produced hadron is detected in coincidence with the scattered electron. A broad range of measurements falls into the category of coincidence electron scattering experiments. It includes deep-inelastic SI leptoproduction of hadrons, (e, e' h), as well as quasielastic nucleon or deuteron knock-out processes, (e, e' N) or (e, e' d). The former class of experiments gives access to the flavour structure of quark-parton distributions and fragmentation functions. It is in focus of experimental programs at CERN, DESY, SLAC and JLab. Some experiments have already been completed and some are being in preparation. Quasielastic nucleon knock-out processes allow to study single-nucleon properties in nuclear medium and probe the nuclear wave function.

We calculated the QED RC to the above mentioned processes by means of the electron structure function method [3] which allows to treat the observed cross section including both the lowest order and higher order effects by the same way. As a result we can obtain clear and physically transparent formulae for RC. In this report we restrict our consideration to leading accuracy. It allows us to avoid an attraction of any model for the hadron structure functions and, as a result, to obtain some general formulae for quite wide class of the physical processes.

2. THE TENSOR-POLARIZED TARGET

In present section we give the covariant description of the cross section of DIS of unpolarized electron beam off the tensor-polarized deuteron target

$$e^-(k_1) + d_T(p_1) \to e^-(k_2) + X(p_x). \qquad (1)$$

We use approach which is based on the covariant parametrization of the deuteron quadrupole polarization tensor in terms of the 4-momenta of the particles in process (1) [4] and use of the Drell-Yan like representation [5] in electrodynamics, which allows to sum the leading-log model-independent RC in all orders.

To begin with, we define the DIS cross section of the process (1), with accounting RC, in terms of the leptonic $L_{\mu\nu}$ and hadronic $H_{\mu\nu}$ tensors contraction

$$\frac{d\sigma}{dQ^2dy} = \frac{\pi\alpha^2}{Vq^4} L_{\mu\nu} H_{\mu\nu}, \quad y = \frac{p_1(k_1 - k_2)}{k_1 p_1}, \qquad (2)$$

where q is the 4-momentum of the intermediate heavy photon that probes the deuteron structure. Note that only in the Born approximation (without accounting RC) $q=k_1-k_2$.

The model-independent RC exhibits themselves by means of the corrections to the leptonic tensor. In the framework of the leading accuracy this tensor can be written as a convolution of two electron structure functions D and the Born form of the leptonic tensor $L^B_{\mu\nu}$ that depends on the scaled electron momenta

$$L_{\mu\nu}(k_1,k_2)=\int\int\frac{dx_1dx_2}{x_1x_2^2}D(x_1,L)D(x_2,L)$$

$$L^B_{\mu\nu}(\tilde{k}_1,\tilde{k}_2),\ L=\ln\frac{Q^2}{m^2},\ \tilde{k}_1=x_1k_1,\ \tilde{k}_2=\frac{k_2}{x_2},$$

$$\tilde{k}_1-\tilde{k}_2=q,\ Q^2=-(k_1-k_2)^2, \qquad (3)$$

where m is the electron mass.

The limits of integration on the right side of Eq. (3) can be derived from the condition that the DIS process (1) takes place. It is possible if the final undetected hadron system consists, at least, of a deuteron and a pion. In this case we have

$$x_1x_2+y-1-x_1xy\geq x_2\delta,\ x=Q^2/2p_1(k_1-k_2),$$

$$\delta=((M+m_\pi)^2-M^2)/V,\quad V=2k_1p_1, \qquad (4)$$

where M (m_π) is the deuteron (pion) mass. This inequality defines the integration limits as follows

$$1\geq x_1\geq(1-y+\delta)/(1-xy), \qquad (5)$$

$$1\geq x_2\geq(1-y+xyx_1)/(x_1-\delta).$$

The Born leptonic tensor is (for the case of the longitudinally-polarized electron beam)

$$L^B_{\mu\nu}(k_1,k_2)=-2k_1k_2g_{\mu\nu}+2(k_{1\mu}k_{2\nu}+k_{1\nu}k_{2\mu})+$$

$$+\ 2i\lambda\,\varepsilon_{\mu\nu\rho\sigma}k_{1\rho}k_{2\sigma}, \qquad (6)$$

where quantity λ is the degree of longitudinal polarization of the electron beam.

The hadron tensor has polarization-independent and polarization-dependent parts. We consider only the case of the tensor polarization

$$H^{(T)}_{\mu\nu}=aB_1\tilde{g}_{\mu\nu}+(aB_2/p_1q)\tilde{p}_{1\mu}\tilde{p}_{1\nu}+(M^2/$$

$$(p_1q)^2)B_3q_\alpha(\tilde{p}_{1\mu}Q_{\tilde{\nu}\alpha}+\tilde{p}_{1\nu}Q_{\tilde{\mu}\alpha})+(M^2/p_1q)$$

$$B_4\tilde{Q}_{\mu\nu},\ \tilde{g}_{\mu\nu}=g_{\mu\nu}-q_\mu q_\nu/q^2,\ \tilde{p}_{1\mu}=p_{1\mu}-$$

where $Q_{\mu\nu}$ is the deuteron quadrupole polarization tensor. In general all the hadron structure functions B_j (j=1,2,3,4) depend on two independent variables: q^2 and $x'=q^2/(2p_1q)$ (within the chosen accuracy $x'=\tilde{x}=xyx_1/(y-1+x_1x_2)$). We used the notation of Ref. [4].

Because the polarization-independent part of the hadronic tensor depends on the scaled electron momenta only (by means of $q=\tilde{k}_1-\tilde{k}_2$), we can write the respective contribution to the cross section in the form of the Drell-Yan representation in the electrodynamics that takes into account the leading part of the radiative corrections

$$\frac{d\sigma^{(u)}(k_1,k_2)}{dQ^2dy}=\int\int\frac{dx_1dx_2}{x_2^2}D(x_1,L)$$

$$D(x_2,L)\frac{d\sigma_B^{(u)}(\tilde{k}_1,\tilde{k}_2)}{d\tilde{Q}^2d\tilde{y}}, \qquad (7)$$

where $\tilde{Q}^2=x_1Q^2/x_2$, $\tilde{y}=(y-1+x_1x_2)/x_1x_2$ and u means unpolarized Born cross section.

As concerns the polarization-dependent contribution to the cross section $d\sigma^{(T)}$ the situation is somewhat different. In general we cannot use for it the representation (7) with simple substitution

$$d\sigma^{(u)}/dQ^2dy\rightarrow d\sigma^{(T)}/dQ^2dy \qquad (8)$$

in both sides of Eq. (7). The reason is that the axes, respect to which the components of the deuteron quadrupole polarization tensor are defined, can change their directions at the scale transformation of the electron momenta: $k_{1,2}\rightarrow\tilde{k}_{1,2}$. But substitution (8) can be useful and applicable if all axes remain stabilized under this transformation.

Therefore, first we have to find the set of stabilized axes and write them in covariant form in terms of 4-momenta of the particles participating in the reaction. If we choose the longitudinal direction **l** along the electron beam and the transverse one **t** in the plane ($\boldsymbol{k}_1$, $\boldsymbol{k}_2$) and perpendicular to **l**, then

$$S^{(l)}_\mu=(2\tau k_{1\mu}-p_{1\mu})/M,$$

$$S^{(t)}_\mu=[k_{2\mu}-(b-xy\tau)k_{1\mu}-xyp_{1\mu}]/d,$$

$$S^{(n)}_\mu=2(Vd)^{-1}\varepsilon_{\mu\nu\rho\sigma}p_{1\nu}k_{1\rho}k_{2\sigma},\ d=\sqrt{Vxyb},$$

$$b=1-y-xy\tau,\ \tau=M^2/V. \qquad (9)$$

One can verify that the set $S^{(l,t,n)}_\mu$ remains stabilized under the scale transformation and

$$S^{(\alpha)}_\mu S^{(\beta)}_\mu=-\delta_{\alpha\beta},\ S^{(\alpha)}_\mu p_{1\mu}=0,\ \alpha,\beta=l,t,n.$$

If to add one more 4-vector $S^{(0)}_\mu=p_{1\mu}/M$ to the set (9), we receive the complete set of orthogonal 4-vectors with the following properties

$$S^{(m)}_\mu S^{(m)}_\nu=g_{\mu\nu},\ S^{(m)}_\mu S^{(n)}_\mu=g_{mn},\ m,n=0,l,t,n.$$

This allows expressing the deuteron quadrupole polarization tensor in general case as follows

$$Q_{\mu\nu}=S^{(m)}_\mu S^{(n)}_\nu R_{mn}\equiv S^{(\alpha)}_\mu S^{(\beta)}_\nu R_{\alpha\beta},$$

$$R_{\alpha\beta}=R_{\beta\alpha},\ R_{\alpha\alpha}=0 \qquad (10)$$

because the components R_{00}, $R_{0\alpha}$, $R_{\alpha 0}$ identically equal to zero due to the condition $Q_{\mu\nu}p_{1\nu}=0$.

So, if the components of the deuteron polarization tensor are defined in the coordinate system with the axes along the directions **l**, **t** and **n**, the polarization-dependent contribution to the cross section of the process (1) with accounting leading RC can be written in the same way as polarization-independent one

$$\frac{d\sigma^{(Ts)}(k_1,k_2)}{dQ^2dy} = \int\int \frac{dx_1dx_2}{x_2^2} D(x_1,L)D(x_2,L)$$

$$\frac{d\sigma_B^{(Ts)}(\tilde{k}_1,\tilde{k}_2)}{d\tilde{Q}^2d\tilde{y}}. \qquad (11)$$

Symbol Ts indicates that components of the quadrupole polarization are defined with respect to stabilized set (9). The simple calculation gives

$$\frac{d\sigma_B^{(Ts)}(k_1,k_2)}{dQ^2dy} = \frac{2\pi\alpha^2}{yQ^4}[S_{ll}R_{ll} + S_{tt}(R_{tt} - R_{nn}) +$$

$$+ S_{lt}R_{lt}],\ S_{ll} = [2xb\tau - y(1+2x\tau)^2]G + 2b(1+$$

$$+ 3x\tau)B_3 + (b - xy\tau)B_4,\ S_{lt} = 2\sqrt{xb\tau y^{-1}}[2y$$

$$(1+2x\tau)G + (2 - y - 4b)B_3 + yB_4], \qquad (12)$$

$$S_{tt} = -2xb\tau(G + B_3),\ G = xyB_1 - (b/y)B_2 .$$

3. SEMI-INCLUSIVE DIS WITH POLARIZED FINAL PARTICLE

Here we clarify the question how to calculate QED RC to the cross section and polarization observables in the following process (within the considered approach)

$$e^-(k_1) + A(p_1) \to e^-(k_2) + p(p_2) + X. \qquad (13)$$

We use the following definition of the cross section of the process (13) with definite spin orientation of the proton in terms of the leptonic and hadronic tensors

$$d\sigma = N_k \frac{L_{\mu\nu}H_{\mu\nu}}{2q^4}\frac{d^3k_2}{\varepsilon_2}\frac{d^3p_2}{E_2}, \qquad (14)$$

where $N_k = \alpha^2[(2S_A+1)V(2\pi)^3]^{-1}$, S_A is the target spin, $\varepsilon_2(E_2)$ is the energy of the scattered electron (detected proton) and q is the 4-momentum of the virtual photon that probes the hadron block. Hadronic tensor is defined by the standard way.

The hadronic tensor in general case can be written as

$$H_{\mu\nu} = H_{\mu\nu}^{(u)} + H_{\mu\nu}^{(p)}, \qquad (15)$$

$$H_{\mu\nu}^{(u)} = h_1\tilde{g}_{\mu\nu} + h_2\tilde{p}_{1\mu}\tilde{p}_{1\nu} + h_3\tilde{p}_{2\mu}\tilde{p}_{2\nu} +$$

$$+ h_4(\tilde{p}_1\tilde{p}_2)_{\mu\nu} + ih_5[\tilde{p}_1\tilde{p}_2]_{\mu\nu},\ H_{\mu\nu}^{(p)} = (Sp_1)[h_6$$

$$(\tilde{p}_1N)_{\mu\nu} + ih_7[\tilde{p}_1N]_{\mu\nu} + h_8(\tilde{p}_2N)_{\mu\nu} + ih_9$$

$$[\tilde{p}_2N]_{\mu\nu}] + (Sq)[h_{10}(\tilde{p}_1N)_{\mu\nu} + ih_{11}[\tilde{p}_1N]_{\mu\nu} +$$

$$+ h_{12}(\tilde{p}_2N)_{\mu\nu} + ih_{13}[\tilde{p}_2N]_{\mu\nu}] + (SN)[h_{14}\tilde{g}_{\mu\nu} +$$

$$+ h_{15}\tilde{p}_{1\mu}\tilde{p}_{1\nu} + h_{16}\tilde{p}_{2\mu}\tilde{p}_{2\nu} + h_{17}(\tilde{p}_1\tilde{p}_2)_{\mu\nu} +$$

$$+ ih_{18}[\tilde{p}_1\tilde{p}_2]_{\mu\nu}],\ N_\mu = \varepsilon_{\mu\nu\rho\sigma}p_{1\nu}p_{2\rho}q_\sigma,$$

$$(ab)_{\mu\nu} = a_\mu b_\nu + a_\nu b_\mu,\ [ab]_{\mu\nu} = a_\mu b_\nu - a_\nu b_\mu,$$

where S_μ is the 4-vector of the proton spin that satisfies conditions: $S^2 = -1, (Sp_2) = 0$, and h_i (i=1-18) are the hadron SI structure functions which depend in general on four invariants. These invariants can be taken as $q^2, (qp_1), (qp_2), (p_1p_2)$.

To completely describe this process we will use the following set of invariant variables

$$y = 2p_1(k_1 - k_2)/V,\ x = -q^2/2p_1q,\ q = k_1 - k_2,$$

$$z = 2p_1p_2/V,\ z_1 = 2k_1p_2/V,\ z_2 = 2k_2p_2/V.$$

The set of stabilized 4-vectors can be chosen as

$$S_\mu^{(l)} = (zp_{2\mu} - 2\tau_2p_{1\mu})/md_1,\ \tau_1 = M^2/V,$$

$$\tau_2 = m^2/V,\ S_\mu^{(t)} = [d_1^2k_{1\mu} + (2z_1\tau_1 - z)p_{2\mu} +$$

$$+ (2\tau_2 - zz_1)p_{1\mu}]/d_1d_2\sqrt{V},\ S_\mu^{(n)} = 2\varepsilon_{\mu\nu\rho\sigma}k_{1\nu}$$

$$p_{1\rho}p_{2\sigma}/d_2\sqrt{V^3},\ d_1^2 = z^2 - 4\tau_1\tau_2, \qquad (16)$$

$$d_2^2 = zz_1 - \tau_2 - z_1^2\tau_1,\ (S^jS^i) = -\delta_{ji},$$

where M (m) is the mass of the target nucleus (detected proton).

Now we can write down the spin-independent (we bear in mind that it means independent on the proton spin only) and spin-dependent parts of the cross section of the process (13) as

$$\varepsilon_2E_2\frac{d\sigma_{(u),l,t,n}}{d^3k_2d^3p_2} = \int\int\frac{dx_1dx_2}{x_2^2}D(x_1,L)D(x_2,L)$$

$$\tilde{\varepsilon}_2E_2\frac{d\tilde{\sigma}^B_{(u),l,t,n}}{d^3\tilde{k}_2d^3p_2}, \qquad (17)$$

where $d\tilde{\sigma}^B$, with any low index, denotes the corresponding Born cross section given at shifted values of $k_{1,2} \to \tilde{k}_{1,2}$. The corresponding shifted dimensionless variables, introduced earlier, read

$$\tilde{x} = \frac{xyx_1}{(y - 1 + x_1x_2)},\ \tilde{y} = \frac{(y - 1 + x_1x_2)}{x_1x_2},$$

$$\tilde{V} = x_1V,\ \tilde{z} = z/x_1,\ \tilde{z}_1 = z_1,\ \tilde{z}_2 = z_2/x_1x_2 .$$

The spin-independent part of the cross section for longitudinally-polarized electron beam is expressed in terms of the hadron structure functions as

$$\varepsilon_2E_2\frac{d\sigma^B_{(u)}}{d^3k_2d^3p_2} = \frac{N_kV^2}{2q^4}H_1, \qquad (18)$$

$$H_1 = -2xyV^{-1}h_1 + (1 - y - xy\tau_1)h_2 + (z_1z_2 -$$

$$- xy\tau_2)h_3 + (z_2 + z_1(1-y) - xyz)h_4 - \lambda\eta h_5,$$

$$\eta^2 = -(xyd_1)^2 + 2xy[z(z_2 + z_1(1-y)) -$$

$$- 2z_1z_2\tau_1 - 2(1-y)\tau_2] - (z_2 - z_1(1-y))^2 .$$

If the proton spin is directed along $S_\mu^{(l)}$ then the spin-dependent part of the Born cross section reads

$$\varepsilon_2 E_2 \frac{d\sigma_l^B}{d^3k_2 d^3p_2} = -\frac{N_k V^4 \eta d_1}{8mq^4}[H_2 + d_1^{-2}[z(z_1 - z_2) - 2y\tau_2]H_3],$$

$$H_2 = (2-y)h_6 + (z_1+z_2)h_8 + (\lambda/\eta)(\eta_1 h_7 + \eta_2 h_9),\ H_3 = H_2(h_i \to h_{i+4}),\ \eta_1 = y[z_2 - z_1(1-y) - xz(2-y) + 2x(z_1+z_2)\tau_1],\ \eta_2 = (z_1 - z_2)(z_2 - z_1(1-y)) + xyz(z_1+z_2) - 2xy(2-y)\tau_2.$$

In the case of transverse orientation of the proton spin (along $S_\mu^{(t)}$) we have

$$\varepsilon_2 E_2 \frac{d\sigma_t^B}{d^3k_2 d^3p_2} = \frac{N_k V^3 \sqrt{V}\eta}{8q^4 d_1}[\psi H_3 - \frac{d_1^2}{d_2}H_4],$$

$$\psi = [xyd_1^2 + (z - 2z_1\tau_1)(z_1 - z_2) + (zz_1 - 2\tau_2)y]/d_2,\ H_4 = H_1(h_i \to h_{i+13}).$$

At last, for the normal orientation of the proton spin (along $S_\mu^{(n)}$) the spin-dependent part of the cross section of the process (13) reads

$$\varepsilon_2 E_2 \frac{d\sigma_n^B}{d^3k_2 d^3p_2} = -\frac{N_k V^3 \sqrt{V}}{8q^4}[\psi H_4 + \frac{\eta^2}{d_2}H_3].$$

4. SEMI-INCLUSIVE DIS ON POLARIZED TARGET

In this section we consider the polarization phenomena in SI DIS off polarized nucleus

$$e^-(k_1) + A(p_1) \to e^-(k_2) + H(p_2) + X, \quad (19)$$

where H is arbitrary hadron and nucleus A has definite vector polarization P. In this case the leptonic tensor is as before, and the hadronic tensor has the same structure as defined by Eq. (15), where one needs to use polarization of the nucleus P instead of the proton spin S and write (Pp_2) instead of (Sp_1). Besides, we will use the notation $g_1 - g_{18}$ for the corresponding hadron structure functions.

As a stabilized set we can use the 4-vectors given in Eq. (9), where it is necessary to do the substitution $\tau \to \tau_1$. The simple calculation gives

$$\varepsilon_2 E_2 \frac{d\sigma_{(u)}^B}{d^3k_2 d^3p_2} = \frac{N_k V^2}{q^4}G_1. \quad (20)$$

Note that numerical coefficient in front of G_1 is twice as much as compared with that on the right side of Eq. (18) in front of H_1. The reason is that in this case we do not fix the spin state of the final hadron H.

The polarization-dependent part of the cross section for the longitudinal polarization is

$$\varepsilon_2 E_2 \frac{d\sigma_l^B}{d^3k_2 d^3p_2} = -\frac{N_k V^4 \eta}{4Mq^4}[(2\tau_1 z_1 - z)G_2 - y(1+2x\tau_1)G_3 + 2\tau_1 G_4],$$

where the functions G_i (i=1-4) can be derived from H_i by replacement the hadron structure functions g_j instead of h_j.

The corresponding part of the cross section in the case of the transverse polarization can be written as

$$\varepsilon_2 E_2 \frac{d\sigma_t^B}{d^3k_2 d^3p_2} = -\frac{N_k V^3 \sqrt{Vxyb_1}\eta}{4q^4}[(xyb_1)^{-1}(z_2 - xyz - z_1(b_1 - xy\tau_1))G_2 + 2G_3 + (xb_1)^{-1}(1 + 2x\tau_1)G_4],\ b_1 = 1 - y - xy\tau_1.$$

For the normal polarization the spin-dependent part of the cross section is

$$\varepsilon_2 E_2 \frac{d\sigma_n^B}{d^3k_2 d^3p_2} = \frac{N_k V^3 \sqrt{V}}{4q^4\sqrt{xyb_1}}[\eta^2 G_2 - y(z_2(1 + 2x\tau_1) - z_1(1 - y - 2x\tau_1) - xz(2-y))G_4].$$

5. DIS FROM TENSOR POLARIZED TARGET WITH TAGGED PHOTON

The initial-state collinear radiation is very important in certain regions of DIS at HERA kinematics domain. It leads to reduction of the projectile electron energy and therefore to a shift of the effective Bjorken variables in the hard scattering process as compared to those determined from the actual measurement of the scattered electron alone. That is why the radiative events in the DIS process

$$e^-(k_1) + d(p_1) \to e^-(k_2) + \gamma(k) + X(p_x) \quad (21)$$

have to be carefully taken into account.

In this section we investigate events for the process (21) with unpolarized electron and tensor-polarized deuteron. We suggest that the hard photon is emitted very close to the direction of the incoming electron beam $(\theta_\gamma \le \theta_0, \theta_0 << 1)$, where θ_γ is the angle between 3-momenta of the initial electron and hard photon. Besides, the photon detector (PD) measures the energy of all photons inside the narrow cone with the opening angle $2\theta_0$ around the electron beam (the scattered-electron 3-momentum is also measured).

A set of the kinematics variables, that is especially adapted to the case of the collinear-photon radiation, is given by the shifted Bjorken variables

$$\hat{Q}^2 = -(k_1 - k_2 - k)^2,\ \hat{x} = \hat{Q}^2/2p_1(k_1 - k_2 - k),$$

$$\hat{y} = 2p_1(k_1 - k_2 - k)/2p_1(k_1 - k),$$

$$\hat{V} = 2p_1(k_1 - k),$$

and the energy fraction of the electron after the initial-state radiation of a collinear photon $z = 2p_1(k_1 - k)/V = (\varepsilon_1 - \varpi)/\varepsilon_1$, where ε_1 is the initial electron energy and ϖ is the energy deposited in PD.

The relation between the shifted and standard Bjorken variables reads

$$\tilde{Q}^2 = zQ^2\,,\ \tilde{x} = \frac{xyz}{z+y-1}\,,\ \tilde{y} = \frac{z+y-1}{z}\,,\ V = zV.$$

The simple calculation gives

$$\frac{d\sigma}{dxdydz} = \frac{\alpha}{2\pi}P(z,L_0)\Sigma(\tilde{x},\tilde{y},\tilde{Q}^2)\,, \qquad (22)$$

$$\Sigma(\tilde{x},\tilde{y},\tilde{Q}^2) = 2\pi\alpha^2 VQ^{-4}[S_{ll}R_{ll} + \tilde{S}_{tt}(R_{tt} -$$
$$- R_{nn}) + \tilde{S}_{lt}R_{lt}]\,,\ L_0 = \ln(\varepsilon_1^2\theta_0^2/m^2)\,,$$
$$P(z,L_0) = [(1+z^2)L_0 - 2z]/(1-z)\,,$$

where the quantities $\tilde{S}_{ll},\tilde{S}_{tt},\tilde{S}_{lt}$ can be obtained from the quantities S_{ll},S_{tt},S_{lt}, given by the Eq. (12), using the following substitution $x,y,b,\tau \to \tilde{x},\tilde{y},\tilde{b},\tilde{\tau}$. Note that components of the quadrupole polarization tensor are defined with respect to the set of 4-vectors described by Eq. (9). We restrict ourselves to the model-independent RC related to the radiation of the real and virtual photons by leptons. Our approach to the calculation of RC is based on the account of all essential Feynman diagrams that describe the observed cross section in framework of the used approximation. To get rid of cumbersome expressions we retain in RC the terms that accompanied at least by one power of large logarithms: L_0, $L_Q = \ln(Q^2/m^2)$, $L_\theta = \ln(\theta_0^2/4)$. Besides, in chosen approximation we neglect the terms of the order of $\theta_0^2, m^2/\varepsilon_1^2\theta_0^2, m^2/Q^2$ in the cross section.

The total RC to the Born cross section (21) is given by the sum of the virtual and soft photon corrections and the hard-photon emission contribution. The last one is different for the exclusive and calorimeter event selection. In the considered approximation it is convenient to write this RC in the form

$$\frac{d\sigma^{RC}}{dxdydz} = \frac{\alpha^2}{4\pi^2}(\Sigma_i + \Sigma_f)\,.$$

The first term is independent on the experimental selection rules for the scattered electron and reads

$$\Sigma_i = L_0\{\frac{1}{2}L_0P_\theta^{(2)}(z) + \frac{1+z^2}{1-z}[3\ln z - \frac{1}{2}\ln^2 z +$$
$$+ \ln Y\ln(Y/z^2) + 2\ln z\ln(1-z) - 2\ln(1-z) -$$
$$- \frac{\pi^2}{3} + 2Li_2(1-z) + 2Li_2(\frac{1+c}{2})] + \frac{\ln^2 z}{1-z} +$$
$$+ \frac{4z}{1-z}\ln(\frac{z}{1-z}) + \frac{1-16z-z^2}{2(1-z)}\}\Sigma(\tilde{x},\tilde{y},\tilde{Q}^2) +$$
$$+ P(z,L_0)[\tilde{y}\ln[\frac{2(1-c)}{\theta_0^2}]\int_0^{u_0}\frac{du}{1-u}P^{(1)}(1-u)$$
$$y_t^{-1}\Sigma(x_t,y_t,Q_t^2) + \frac{1+z^2}{1-z}L_0\tilde{y}Z\,,\ u_0 = \frac{x_{1\max}}{z}\,,$$

where the quantities $P^{(1)}(x), P_\theta^{(2)}(z), c, x_{1\max}, x_t,$ y_t, Q_t^2, Y and the definition of the function $Li_2(x)$ can be found in Ref. [6]. The expression for the Z term is rather cumbersome and it will be published elsewhere.

The second term, denoted by Σ_f, explicitly depends on the rule for the event selection. It includes the main effect of the scattered-electron radiation. In the case of exclusive event selection, when only the scattered bare electron is measured, and any photon, collinear with respect to its momentum direction, is ignored, this contribution is

$$\Sigma^{excl} = \tilde{y}P(z,L_0)\int_0^{y_{1\max}}dy_1[(L_Q + \ln Y - 1)$$
$$P^{(1)}(\frac{1}{1+y_1}) + \frac{y_1}{1+y_1}]y_s^{-1}\Sigma(x_s,y_s,Q_s^2)\,,$$

where the quantities $x_s, y_s, Q_s^2, y_{1\max}$ can be found in Ref. [6]. Note that the mass singularity that is connected with the scattered-electron radiation, exhibits itself through L_Q term.

The situation is quite different for the calorimeter event selection, when the detector cannot distinguish between the events with a bare electron and events where the scattered electron is accompanied by a hard photon emitted within a narrow cone with the opening angle $2\theta_0'$ around the scattered-electron momentum direction. For such experimental setup we derive

$$\Sigma^{cal} = P(z,L_0)[\tilde{y}\ln[\frac{2(1-c)}{\theta_0'^2}]\int_0^{y_{1\max}}dy_1P^{(1)}(\frac{1}{1+y_1})$$
$$y_s^{-1}\Sigma(x_s,y_s,Q_s^2) + \frac{1}{2}\Sigma(\tilde{x},\tilde{y},\tilde{Q}^2)]\,.$$

REFERENCES

1. P. Hoodbhoy, R.L. Jaffe, and A. Manohar. Novel effects in deep inelastic scattering from spin-one hadrons // *Nucl. Phys.* 1989, v. B312, p. 571-588.
2. C. Amsler, T. Bressani, F.E. Close et al. Perspectives in hadron and quark dynamics // *Nucl. Phys.* 1997, v. A622, p. 315c-354c.
3. L.N. Lipatov. Parton model and perturbation theory // *J. Nucl. Phys.* 1974, v. 20, p. 181-198 (in Russian); G. Altarelli, G. Parisi. Asymptotic freedom in parton language // *Nucl. Phys.* 1977, v. B126, p. 298-312.
4. G.I. Gakh, N.P. Merenkov. QED corrections in deep-inelastic scattering from tensor polarized deuteron target // *JETP Letter.* 2001, v. 73, p. 579-583.
5. S.D. Drell and T.M. Yan. Massive lepton-pair production in hadron-hadron collisions at high energies // *Phys. Rev. Lett.* 1970, v. 25, p. 316-320.
6. G.I. Gakh, M.I. Konchatnij, N.P. Merenkov. Tagged-photon events in polarized DIS processes // *Sov. Phys. JETP.* 2001, v. 92, p. 930-939.