Possible Method for Measuring the Proton Sachs Form Factors in Processes with and without Proton Spin Flip

M.V. Galynskii

Joint Institute for Power and Nuclear Research-Sosny BAS, Minsk, Belarus

XXIV Annual Seminar
NONLINEAR PHENOMENA IN COMPLEX SYSTEMS
MAY 16 – 19, 2017, Minsk, Belarus

The matrix elements of the process $ep \to ep$

$$e(p_1) + p(q_1, s_1) \to e(p_2) + p(q_2, s_2)\,, \tag{1}$$

$$M_{ep\to ep} = (J_e)^\mu \, (J_p)_\mu \, \frac{1}{q^2}\,, \tag{2}$$

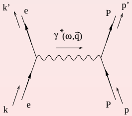
$$(J_e)^\mu = \overline{u}(p_2)\gamma^\mu u(p_1)\,, (J_p)_\mu = \overline{u}(q_2)\Gamma_\mu(q^2)u(q_1)\,, \tag{3}$$

$$\Gamma_\mu(q^2) = F_1\gamma_\mu + \frac{F_2}{4M}(\hat{q}\gamma_\mu - \gamma_\mu\hat{q}\,)\,,\; q = q_2 - q_1, \tag{4}$$

$\overline{u}(p_i)u(p_i) = 2m_e$, $\overline{u}(q_i)u(q_i) = 2M$; $p_i^2 = m_e^2$, $q_i^2 = M^2(i = 1, 2)$;
F_1 and F_2 are the Dirac and Pauli proton form factors (FFs).

The Sachs electric G_E and magnetic G_M FFS have advantage that the scattering cross section has only terms proportional to G_E^2 and G_M^2 [1].

$$G_E = F_1 - \tau\, F_2\,,\; G_M = F_1 + F_2\,, \tag{5}$$
$$\tau = Q^2/4M^2,\; Q^2 = -q^2.$$



[1]. A.I. Akhiezer and V.B. Berestetsky, Quantum Electrodynamics, Nauka, Moscow, 1969.

1. Rosenbluth Method or Rosenbluth Technique

In elastic electron proton scattering $e(p_1) + p(q_1) \to e(p_2) + p(q_2)$ there are primarily two methods used to extract the proton form factors. The first method is the Rosenbluth separation method, which uses measurements of the unpolarized cross section and in the laboratory reference frame when $q_1 = (M, \mathbf{0})$ and $m_e = 0$ in one-photon exchange (Born) approximation read as [1]:

$$\frac{d\sigma}{d\Omega} = \frac{\alpha^2 E_2 \cos^2(\theta_e/2)}{4E_1^3 \sin^4(\theta_e/2)} \frac{1}{1+\tau} \left(G_E^2 + \frac{\tau}{\varepsilon} G_M^2 \right) . \tag{6}$$

$$G_E = F_1 - \tau F_2 \, , \; G_M = F_1 + F_2 \, .$$

Here $\tau = Q^2/4M^2$, $Q^2 = -q^2 = 4E_1 E_2 \sin^2(\theta_e/2)$, $q = q_2 - q_1$, $\alpha = 1/137$ - fine structure constant, $\varepsilon^{-1} = 1 + 2(1+\tau)\tan^2(\theta_e/2)$,

ε is the degree of the linear polarization of the virtual photon [2-4]!

[1]. M. Rosenbluth, Phys. Rev. **79**, 615 (1950)
[2]. N. Dombey, Rev. Mod. Phys. **41**, 236 (1969).
[3]. A. Akhiezer, M. Rekalo, Fiz.Elem.Chast.Atom.Yadra **4**, 662 (1973).
[4]. M. Galynskii and M. Levchuk, Yad. Fiz. **60**, 2028 (1997).

The Rosenbluth formula in the arbitrary reference frame

[A.I. Akhiezer and V.B. Berestetsky, Quantum Electrodynamics, Nauka, Moscow, 1969, in Russian, eq.(34.3.3), page 475.]

The Rosenbluth formula in the arbitrary reference frame read as:

$$d\sigma = \frac{\alpha^2 do}{4w^2} \frac{1}{1+\tau} \left(G_E^2 \, Y_I + \tau \, G_M^2 \, Y_{II} \right) \frac{1}{q^4} \, , \tag{7}$$

$$Y_I = (p_+ q_+)^2 + q_+^2 q^2, \qquad Y_{II} = (p_+ q_+)^2 - q_+^2 (q^2 + 4m_e^2) \, ,$$

$$p_+ = p_1 + p_2 \, , \; q_+ = q_1 + q_2 \, .$$

The G_E and G_M FFS have the advantage that the scattering cross section has only terms proportional to G_E^2 and G_M^2 [2].

[2]. A.J.R. Puckett, arXiv:1508.01456 [nucl-ex],
Recoil Polarization Measurements of the Proton Electromagnetic Form Factor Ratio to High Momentum Transfer. MIT Ph.D. thesis, final version accepted by MIT on Oct. 13, 2009. 313 pages.

It is the question arises: whether there is any physical meaning in the decomposition of G_E^2 and G_M^2 in Rosenbluth's cross section ????

2. Polarization transfer method of Akhiezer and Rekalo

A.I. Akhiezer and M.P. Rekalo proposed a method for measuring the ratio of the Sachs form factors in the reaction $\vec{e}p \to e\vec{p}$ [1,2]. Their method relies on the phenomenon of polarization transfer from the longitudinally polarized initial electron to the final proton and requires measurement of the spin-dependent cross section. This method is called by the polarization transfer or polarized target (PT) method. In papers [1,2] was shown that the ratio of the degrees of longitudinal (P_l) and transverse (P_t) polarizations of the scattered proton has the form

$$\frac{P_l}{P_t} = -\frac{G_M}{G_E}\frac{E_1+E_2}{2M}\tan\frac{\theta_e}{2}\,. \tag{8}$$

[1] A. Akhiezer, M. Rekalo, DAN SSSR **13**, 572 (1968),
[2] A. Akhiezer, M. Rekalo, Fiz.Elem.Chast.Atom.Yadra **4**, 662 (1973).

Erroneous terminology (red color)

I. A. Qattan, J. Arrington, A. Alsaad, arXiv: 1502.02872 [nucl-ex]

Citation 1: In electron scattering there are primarily two methods used to extract the proton form factors.

The first method is the Rosenbluth or Longitudinal-Transverse (LT) separation method [1] for the case of the unpolarized cross section;

the second is the polarization transfer or polarized target (PT) method [2, 3], which requires measurement of the spin-dependent cross section.

Citation 2: ε is the virtual photon longitudinal polarization parameter...

[1]. M. Rosenbluth, Phys. Rev. **79**, 615 (1950).
[2]. N. Dombey, Rev. Mod. Phys. **41**, 236 (1969).
[3]. A. Akhiezer, M. Rekalo, Fiz. Elem. Chast.Atom.Yadra **4**, 662 (1973).

Erroneous terminology (red color)

A. V. Gramolin, V. S. Fadin, A. L. Feldman *et al.*
J.Phys. G: Nucl. Part. Phys. 41 (2014) 115001

$$\frac{\mathrm{d}\sigma_{\mathsf{Born}}}{\mathrm{d}\Omega_\ell} = \frac{1}{\varepsilon(1+\tau)}\left[\varepsilon\, G_E^2(q^2) + \tau\, G_M^2(q^2)\right] \frac{\mathrm{d}\sigma_{\mathsf{Mott}}}{\mathrm{d}\Omega_\ell}, \qquad (9)$$

Citation:

1. where $\varepsilon = \left[1 + 2(1+\tau)\tan^2(\theta/2)\right]^{-1}$ is a convenient dimensionless variable, lying in the range $0 < \varepsilon < 1$;

2. ε describing the separation between the longitudinal (charge) and transverse (magnetic) parts of the cross section;

The absolutely correct terminology (red color)

I found only one work [4], where the written words about the physical meaning of the variable ε are absolutely correct....

Citation from [4], top of page 5:
"Let us introduce another set of kinematical variables: Q^2, and the degree of the linear polarization of the virtual photon, ε.

[4] G.I. Gakh, E. Tomasi-Gustafsson,
Model independent analysis of polarization effects in elastic electron-deuteron scattering in presence of two-photon exchange.
Nuclear Physics A 799 (2008), pp. 127–150.

The discrepancy between the RT and JLab experiments

With the aid of Rosenbluth's technique, it was found that the experimental dependences of G_E and G_M on Q^2 are well described up to $5-6$ GeV^2 by the dipole-approximation expression

$$G_E = G_M/\mu_p = G_D(Q^2) \equiv \frac{1}{(1+Q^2/0.71)^2} \sim \frac{1}{Q^4},\ \ \mu_p \frac{G_E}{G_M} \approx 1\,, \quad (10)$$

where μ_p is the proton magnetic moment ($\mu_p = 2.79$).

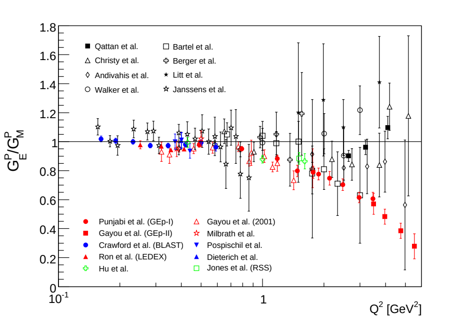
Precision experiments based on employing of the method of Akhiezer and Rekalo were performed at JLab. They showed that, in the range of $0.5 < Q^2 < 5.5$ GeV^2, there was a linear decrease in the ratio $R = \mu_p G_E/G_M$ with increasing Q^2:

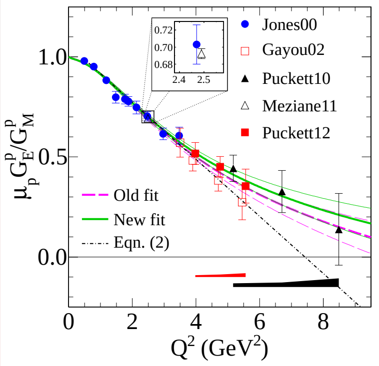
$$R \equiv \mu_p G_E/G_M = 1 - 0.13\,(Q^2 - 0.04) \approx 1 - \frac{1}{8}\,Q^2\,, \qquad (11)$$

which indicates that G_E falls faster than G_M. In the non-relativistic limit, this fact could be interpreted as indicating that the spatial distributions of charge and magnetization currents in the proton are definitely different.

Polarization transfer experiments JLab data for G_E^p/G_M^p

A. Puckett *et al.*, PRC, **85** (2012) 045203 →





World data (left figure) of the ratio $\mu_p G_{E_p}/G_{M_p}$ using the Rosenbluth method (black symbols) and from polarization experiments by Akhiezer and Rekalo method (colored symbols).

$$R \equiv \mu_p G_E/G_M \approx 1 - \frac{1}{8} Q^2 \,.$$

Present status of the question

In order to resolve this contradiction, it was assumed that the discrepancy in question may be caused by disregarding, in the respective analysis, the contribution of two-photon exchange (TPE):

[P. Guichon and M. Vanderhaeghen, Phys. Rev. Lett. **91**, 142303 (2003)].
[C. Perdrisat *et al.*, Prog. Part. Nucl. Phys. **59**, 694 (2007)]
[J. R. Arrington *et al.*, Prog. Part. Nucl. Phys. **66**, 782 (2011)].

At the present time, three experiments aimed at studying the contribution of TPE are known:

1) experiment at the VEPP-3 storage ring in Novosibirsk
I. A. Rachek, J. Arrington, V. F. Dmitriev *et al.*
Phys. Rev. Lett. 114, 062005 (2015)

2) the EG5 CLAS experiment at JLab
D. Adikaram, D. Rimal, L.B. Weinstein *et al.*
Phys. Rev. Lett. 114, 062003 (2015)

3) the OLYMPUS experiment at the DORIS accelerator at DESY
B.S. Henderson, L.D. Ice, C. O'Connor, R. Russell, J.C. Bernauer *et al.*
Phys. Rev. Lett. 118, 092501 (2017)

Present status of the question

[M. V. Galynskii and E.A. Kuraev, Phys.Rev.D **89**, 054005 (2014)]

We use of the hard-scattering mechanism (HSM) of perturbative QCD (pQCD) under the assumption that the onset of pQCD starts around the lower boundary of the region $1.0 \leq Q^2 \leq 8.5$ GeV^2 of the experimental measurements.

Abandoning the massless quarks, we were able to explain in the one-photon exchange approximation the unexpected results of measurements of the proton Sachs FFs ratio and analytically derive the experimentally established formula of the linear decrease law for this ratio at $\tau < 1$.

For this purpose, we developed an approach which essentially is a generalization of the constituent-counting rules of the pQCD for the case of massive quarks. Our interpretation can be considered as a possible way to solve the G_E/G_M problem.

Diagonal spin basis (DSB)

In the diagonal spin basis (DSB) spin 4-vectors s_1 and s_2 of protons with 4-momenta q_1 and q_2 ($s_1 q_1 = s_2 q_2 = 0, s_1^2 = s_2^2 = -1$) have the form [1]:

$$s_1 = -\frac{(v_1 v_2) v_1 - v_2}{\sqrt{(v_1 v_2)^2 - 1}} \ , \ \ s_2 = \frac{(v_1 v_2) v_2 - v_1}{\sqrt{(v_1 v_2)^2 - 1}} \ , v_i = q_i / M \, . \tag{12}$$

The spin vectors (12) obviously do not change under transformations of the Lorentz little group (little Wigner group) common to particles with 4-momenta q_1 and q_2: $L_{q_1,q_2} q_1 = q_1$, $L_{q_1,q_2} q_2 = q_2$. This group is isomorphic to one-parameter subgroup of the rotation group SO_3 with axis whose direction is determined by the 3-vector [2]:

$$\boldsymbol{a} = \boldsymbol{q}_2 / q_{20} - \boldsymbol{q}_1 / q_{10} \, . \tag{13}$$

The direction of $\boldsymbol{a}$ (13) have property that the projections of the spins of both particles on it simultaneously have definite values. Therefore, the DSB naturally makes it possible to describe the spin states of systems of any two particles by means of the spin projections on the common direction given by the 3-vector (13).

[1] S. Sikach, Vesti AN BSSR, ser. fiz.-m.n, 2, 84 (1984)
[2] F.I. Fedorov, TMF **2**, 3, 343 (1970)

Diagonal spin basis (DSB)

Since vector $\boldsymbol{a}$ (13) is the difference of two vectors and the geometrical image of the difference of two vectors is the diagonal of a parallelogram, hence the name "diagonal spin basis" given by academician F.I. Fedorov.

Let us consider the realization DSB in the rest frame of the initial proton, where $q_1 = (M, \mathbf{0})$. Here $\boldsymbol{a}$ (13) equal $\boldsymbol{a} = \boldsymbol{n}_2 = \boldsymbol{q}_2/|\boldsymbol{q}_2|$, i.e. common direction for spin projection is the direction of the motion of the final proton, thus this final proton polarization state is a helicity and spin 4-vectors s_1 and s_2 (12) have the form:

$$s_1 = (0, \boldsymbol{n}_2),\; s_2 = (|\boldsymbol{v}_2|, v_{20}\, \boldsymbol{n_2}), \boldsymbol{c}_1 = \boldsymbol{c}_2 = \boldsymbol{n}_2 = \boldsymbol{q_2}/|\boldsymbol{q}_2|\,, \tag{14}$$

i.e. axis $\boldsymbol{c}_1$ and $\boldsymbol{c}_2$ is coincide with the direction of the final proton.

Breit system, where $\boldsymbol{q}_2 = -\boldsymbol{q}_1$, is a special case of DSB. In the Breit system where $q_1 = (q_0, -\boldsymbol{q}), q_2 = (q_0, \boldsymbol{q})$, the spin states of the initial and final protons are helicity, so they spin 4-vectors s_1 and s_2 in DSB have the form:

$$s_1 = (-|\boldsymbol{v}|, v_0 \boldsymbol{n}_2),\; s_2 = (|\boldsymbol{v}|, v_0 \boldsymbol{n}_2)\,, \boldsymbol{n}_2 = \boldsymbol{q_2}/|\boldsymbol{q}_2|\,. \tag{15}$$

Spin operators in the DSB

In the DSB spin operators for initial and final proton have the same form [1]:

$$\sigma = \sigma_1 = \sigma_2 = \gamma^5 \hat{s_1}\hat{v_1} = \gamma^5 \hat{s_2}\hat{v_2} = \gamma^5 \hat{b}_0\hat{b}_3 = i\hat{b}_1\hat{b}_2 \ , \tag{16a}$$

$$\sigma^{\pm\delta} = \sigma_1^{\pm\delta} = \sigma_2^{\pm\delta} = -i/2\gamma^5\hat{b}_{\pm\delta}, \ b_{\pm\delta} = b_1 \pm i\delta b_2 \ , \ \delta = \pm 1 \ , \tag{16b}$$

$$\sigma u^\delta(q_i) = \delta u^\delta(q_i) \ , \ \sigma^{\pm\delta}u^{\mp\delta}(q_i) = u^{\pm\delta}(q_i). \tag{16c}$$

The set of unit 4-vectors b_0, b_1, b_2, b_3 is an orthonormal basis of 4-vectors b_A, $b_A b_B = g_{AB}$ $(A, B = 0, 1, 2, 3)$:

$$\begin{aligned} & b_0 = q_+/\sqrt{q_+^2} \ , \ b_3 = q_-/\sqrt{-q_-^2} \ , \\ & (b_2)_\mu = \varepsilon_{\mu\nu\kappa\sigma} b_0^\nu b_3^\kappa p_1^\sigma/\rho \, , (b_1)_\mu = \varepsilon_{\mu\nu\kappa\sigma} b_0^\nu b_3^\kappa b_2^\sigma \ , \end{aligned} \tag{17}$$

where $q_- = q_2 - q_1$, $q_+ = q_2 + q_1$, $\varepsilon_{\mu\nu\kappa\sigma}$ is the Levi-Civita tensor $(\varepsilon_{0123} = -1)$, ρ is determined from the normalization conditions $b_1^2 = b_2^2 = b_3^2 = -b_0^2 = -1$.

[1]. M. Galynskii, S. Sikach, Phys.Part.Nucl. **29**, 469 (1998),

The matrix elements of the proton current in the DSB

$$e(p_1) + p(q_1, s_1) \to e(p_2) + p(q_2, s_2)\,. \tag{18}$$

$$M_{ep\to ep} = \overline{u}(p_2)\gamma^{\mu} u(p_1) \cdot \overline{u}(q_2)\Gamma_{\mu}(q^2)u(q_1)\,\frac{1}{q^2}\,, \tag{19}$$

$$\Gamma_{\mu}(q^2) = f_1\,\gamma_{\mu} + \frac{f_2}{4M}(\,\hat{q}\gamma_{\mu} - \gamma_{\mu}\hat{q}\,)\,, \tag{20}$$

Matrix elements (amplitudes) for proton current defined as:

$$(J_p^{\pm\delta,\delta})_{\mu} = \overline{u}^{\pm\delta}(q_2)\Gamma_{\mu}(q^2)u^{\delta}(q_1)\,, \tag{21}$$

$$\Gamma_{\mu}(q^2) = F_1\,\gamma_{\mu} + \frac{F_2}{4M}(\,\hat{q}\gamma_{\mu} - \gamma_{\mu}\hat{q}\,)\,. \tag{22}$$

They were calculated in DSB by S.Sikach (1984):

$$(J_p^{\delta,\delta})_{\mu} = 2MG_E(b_0)_{\mu}\,, \tag{23}$$

$$(J_p^{-\delta,\delta})_{\mu} = -2\delta M\sqrt{\tau}\,G_M(b_{\delta})_{\mu}\,. \tag{24}$$

S. Sikach, Vesti AN BSSR, ser. fiz.-m.n, 2, 84 (1984)

The Rosenbluth formula in the arbitrary reference frame

$$\frac{d\sigma}{dQ^2} = \frac{\pi\alpha^2}{4I^2}\,|M_{ep\to ep}|^2\,,\quad I^2 = (p_1 q_1)^2 - m^2 M^2\,. \tag{25}$$

$$|M_{ep\to ep}|^2 = \frac{(1+\delta_1\delta_2)}{2}\,W^{\delta,\delta}_{ep\to ep} + \frac{(1-\delta_1\delta_2)}{2}\,W^{-\delta,\delta}_{ep\to ep}\,. \tag{26}$$

$$W^{\delta,\delta}_{ep\to ep} \quad = \quad \frac{4M^2}{q_-^4}\,G_E^2\frac{1}{2}\,Tr(\hat{p}_2+m)\hat{b}_0(\hat{p}_1+m)\hat{b}_0\,, \tag{27}$$

$$W^{-\delta,\delta}_{ep\to ep} \quad = \quad \frac{4M^2}{q_-^4}\,\tau\,G_M^2\,\frac{1}{2}Tr(\hat{p}_2+m)\hat{b}_\delta(\hat{p}_1+m)\hat{b}^*_\delta)\,. \tag{28}$$

$$W^{\delta,\delta}_{ep\to ep} = G_E^2\;Y_1\;\frac{4\,M^2}{q_+^2 q_-^4},\;\; Y_1 = (p_+q_+)^2 + q_+^2 q_-^2\,, \tag{29}$$

$$W^{-\delta,\delta}_{ep\to ep} = \tau G_M^2\;Y_2\frac{4M^2}{q_+^2 q_-^4}\,,\; Y_2 = (p_+q_+)^2 - q_+^2(q_-^2 + 4m^2)\,, \tag{30}$$

$$\frac{d\sigma_{\delta_1,\delta_2}}{dQ^2} = \frac{\pi\alpha^2}{4I^2\,(1+\tau)}\left(\frac{1+\delta_1\delta_2}{2}\;G_E^2\;Y_1 + \frac{1-\delta_1\delta_2}{2}\;\tau\;G_M^2\;Y_2\right)\;\frac{1}{q_-^4}\,. \tag{31}$$

Differential cross section for the $e\vec{p} \to e\vec{p}$ process in the arbitrary reference frame

$$\frac{d\sigma_{\delta_1,\delta_2}}{dQ^2} = \frac{\pi\alpha^2}{4I^2\,(1+\tau)} \left(\frac{1+\delta_1\delta_2}{2}\, G_E^2\, Y_1 + \frac{1-\delta_1\delta_2}{2}\, \tau\, G_M^2\, Y_2 \right) \frac{1}{q_-^4}\,. \quad (32)$$

Thus, the differential cross section for the $e\vec{p} \to e\vec{p}$ process naturally splits into the sum of two terms containing only the squares of the Sachs FFs and corresponding to the contribution of transition without ($\sim G_E^2$) and with ($\sim G_M^2$) proton spin-flip.

$$\frac{d\sigma_0}{dQ^2} = \frac{\pi\alpha^2}{4I^2\,(1+\tau)} \left(\, G_E^2\, Y_1 + \tau\, G_M^2\, Y_2 \, \right) \frac{1}{q_-^4}\,, \quad (33)$$

$$\boldsymbol{a} = \boldsymbol{q}_2/q_{20} - \boldsymbol{q}_1/q_{10}, \quad \boldsymbol{c} = \boldsymbol{c}_1 = \boldsymbol{c}_2 = \boldsymbol{a}/|\boldsymbol{a}|, \boldsymbol{c}^2 = 1\,. \quad (34)$$

Differential cross section for the $e\vec{p} \to e\vec{p}$ process in the laboratory system

$$\boldsymbol{a} = \boldsymbol{q}_2/q_{20} - \boldsymbol{q}_1/q_{10}, \quad \boldsymbol{c} = \boldsymbol{c}_1 = \boldsymbol{c}_2 = \boldsymbol{a}/|\boldsymbol{a}|, \boldsymbol{c}^2 = 1\,. \tag{35}$$

In the laboratory system (LS), where $q_1 = (M, \mathbf{0})$, $q_2 = (q_{20}, \boldsymbol{q}_2)$, the axes $\boldsymbol{c}_1$ and $\boldsymbol{c}_2$ coincide with the direction of motion of the final proton

$$\boldsymbol{c}_1 = \boldsymbol{c}_2 = \boldsymbol{n}_2 = \boldsymbol{q_2}/|\boldsymbol{q}_2|\,, \tag{36}$$

$$s = (s_0, \boldsymbol{s})\,,\; s_0 = \boldsymbol{v}\,\boldsymbol{c}\,,\; \boldsymbol{s} = \boldsymbol{c} + ((\boldsymbol{c}\,\boldsymbol{v})\,\boldsymbol{v})/(1+v_0)\;, \tag{37}$$

$$s_1 = (0, \boldsymbol{n}_2)\,,\; s_2 = (|\boldsymbol{v}_2|, v_{20}\,\boldsymbol{n_2})\,, \tag{38}$$

$$\tau_{q_1} = (\hat{q_1} + M)(1 - \delta_1\gamma_5\hat{s}_1)/2\,,\; s_1 q_1 = 0\,, \delta_1 = \pm 1\,,$$

$$\tau_{q_2} = (\hat{q_2} + M)(1 - \delta_2\gamma_5\hat{s}_2)/2\,,\; s_2 q_2 = 0\,, \delta_2 = \lambda_2 = \pm 1\,.$$

$$\frac{d\sigma_{\delta_1,\delta_2}}{d\Omega_e} = \frac{\alpha^2 E_2\cos^2(\theta_e/2)}{4E_1^3\sin^4(\theta_e/2)}\frac{1}{1+\tau}\left(\frac{1+\delta_1\delta_2}{2}G_E^2 + \frac{1-\delta_1\delta_2}{2}\frac{\tau}{\varepsilon}G_M^2\right). \tag{39}$$

$$\frac{d\sigma}{d\Omega} = \frac{\alpha^2 E_2\cos^2(\theta_e/2)}{4E_1^3\sin^4(\theta_e/2)}\frac{1}{1+\tau}\left(G_E^2 + \frac{\tau}{\varepsilon}G_M^2\right)\,. \tag{40}$$

Conclusion

We showed that the term in Rosenbluth's cross section proportional to G_E^2 corresponds to the contribution without spin-flip whereas the term proportional to G_M^2 corresponds to spin-flip transition.

We offer an new independent approach to measure of the squares of Sachs form factors. In our approach this Sachs form factors are determined by the differential cross sections with non-spin-flip and spin-flip of initial proton, which must be rest and totally polarized in the direction of motion of the recoil proton.

We supposed that both initial and the recoil protons are polarized collinearly (anti-collinearly) to the 3-momentum of the recoil proton and, besides the polarization states are pure ones.

THANK FOR YOUR ATTENTION