Государственный научный центр Российской Федерации
Институт физики высоких энергий (ГНЦ ИФВЭ)

Упругие формфакторы нуклона в одно- и двух- фотонном приближении

Дипломная работа бакалавра

2007

The Nobel Prize in Physics 1961

"for his pioneering studies of electron scattering in atomic nuclei and for his thereby achieved discoveries concerning the stucture of the nucleons"

Robert Hofstadter

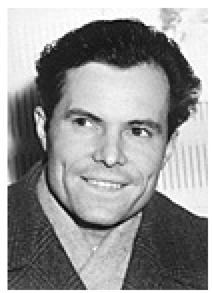
1/2 of the prize

USA

Stanford University
Stanford, CA, USA

b. 1915
d. 1990

"for his researches concerning the resonance absorption of gamma radiation and his discovery in this connection of the effect which bears his name"



Rudolf Ludwig Mössbauer

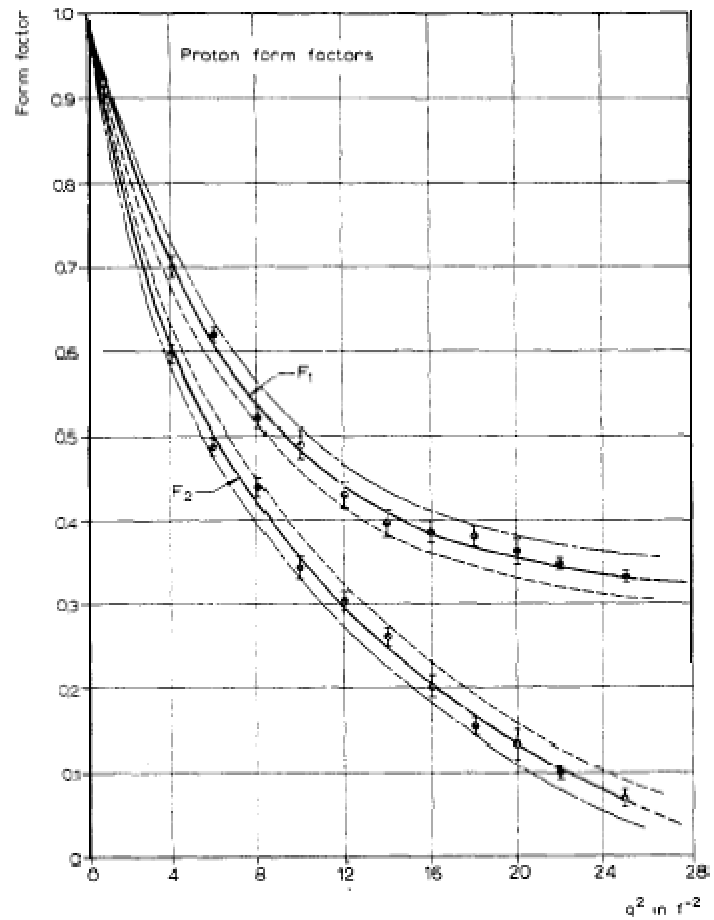
1/2 of the prize

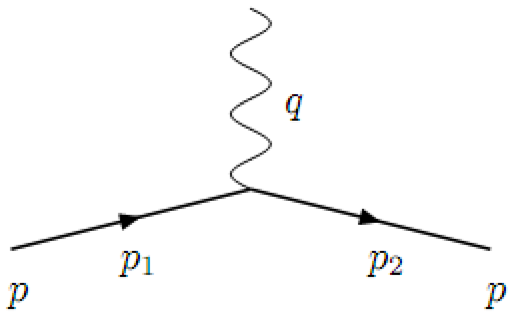
Federal Republic of Germany

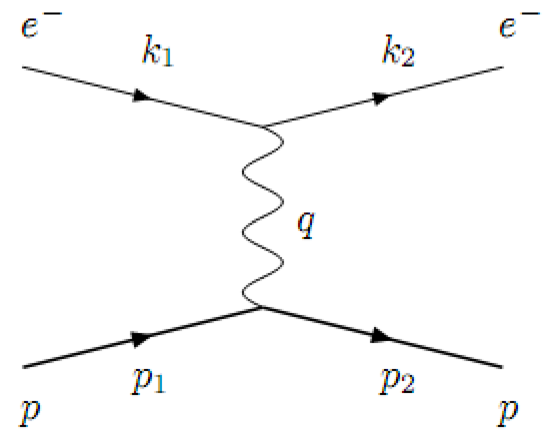
Technical University
Munich, Federal Republic of Germany; California Institute of Technology
Pasadena, CA, USA

b. 1929

ELECTRON-SCATTERING METHOD







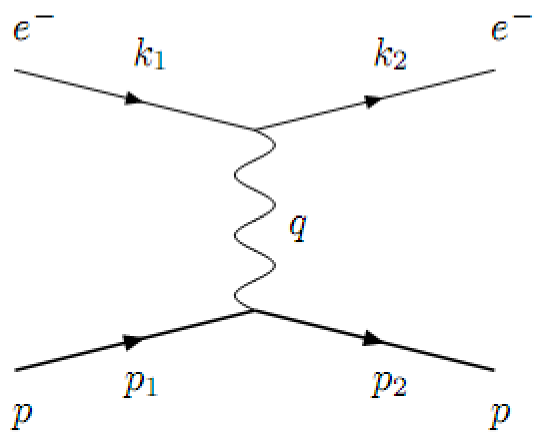
Наиболее общее Лоренц инвариантное выражение для вершины взаимодействия фотона с нуклоном записывается как

$$\Gamma^\mu = \gamma^\mu F_1(q^2) + \frac{1}{4M} F_2(q^2)[\hat{q}\gamma^\mu] \equiv \gamma^\mu F_1(q^2) + \frac{i\sigma^{\mu\nu} q_\nu}{2M} F_2(q^2),$$

$$F_1 = \frac{\tau G_M - G_E}{1+\tau},\ \ F_2 = \frac{G_M + G_E}{1+\tau},$$

$$\tau = \frac{Q^2}{4M^2},\ \ Q^2 = -q^2 = -t > 0.$$

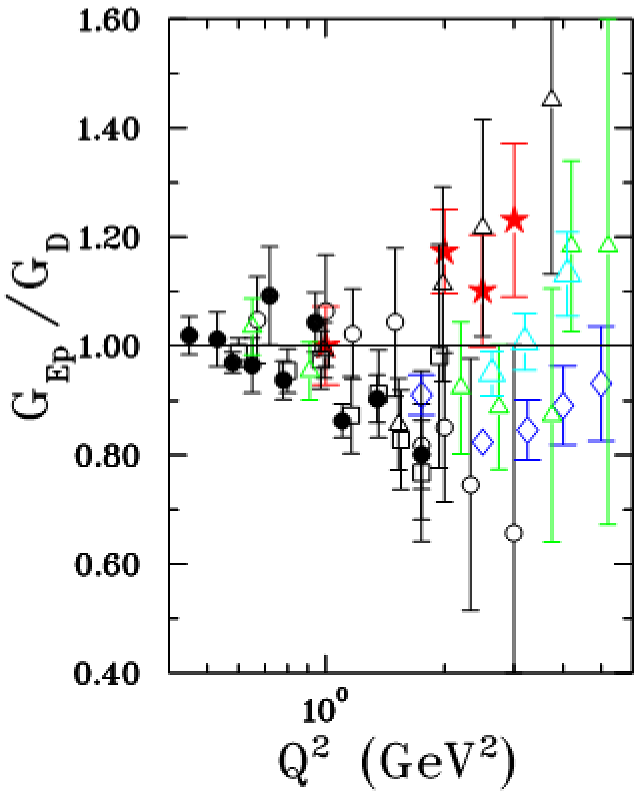
$$\mathcal{M}_1 \ = \ \frac{4\pi\alpha}{q^2} \bar{u}(k_2)\gamma_\mu u(k_1) \cdot \bar{u}(p_2)\Gamma^\mu u(p_1)$$

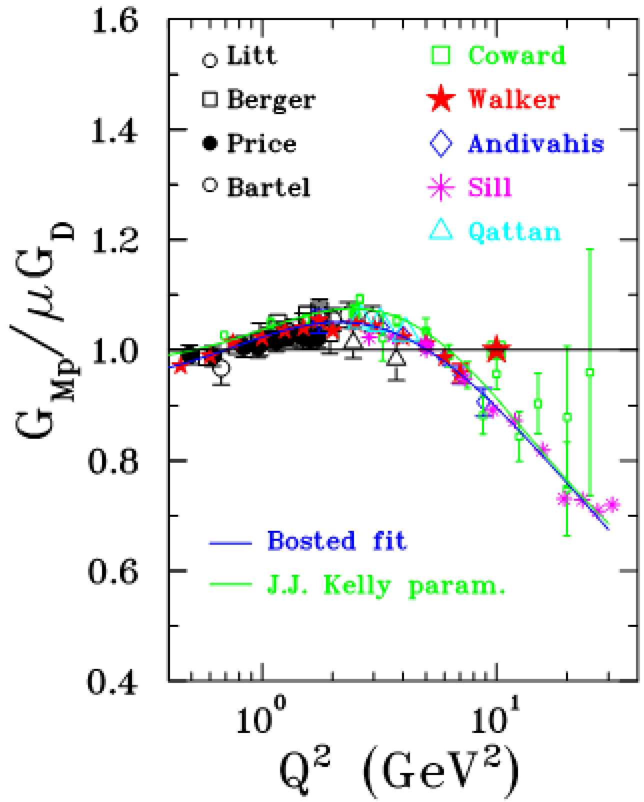


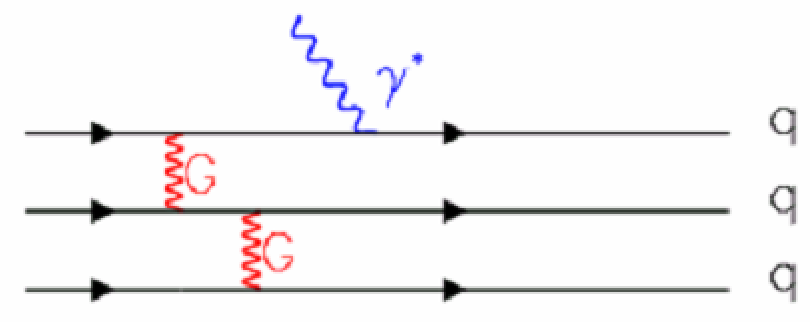
$$\frac{d\sigma}{d\cos\theta} = \frac{\alpha^2\cos^2\frac{\theta}{2}}{4E^2\sin^4\frac{\theta}{2}\;\epsilon(\tau+1)(1+\frac{2E}{M}\sin^2\frac{\theta}{2})}\left[G_E^2\epsilon + G_M^2\tau\right],$$

$$\tau = \frac{Q^2}{4M^2},\;\; \epsilon = \left(1 + 2(1+\tau)\tan^2\frac{\theta}{2}\right)^{-1}.$$

Dipole approximation: $G_D=(1+Q^2/0.71\ GeV^2)^{-2}$







– $F_n(Q^2) = C_n [1/(1+Q^2/m_n)^{n-1}]$,

$m_n = n\beta^2$

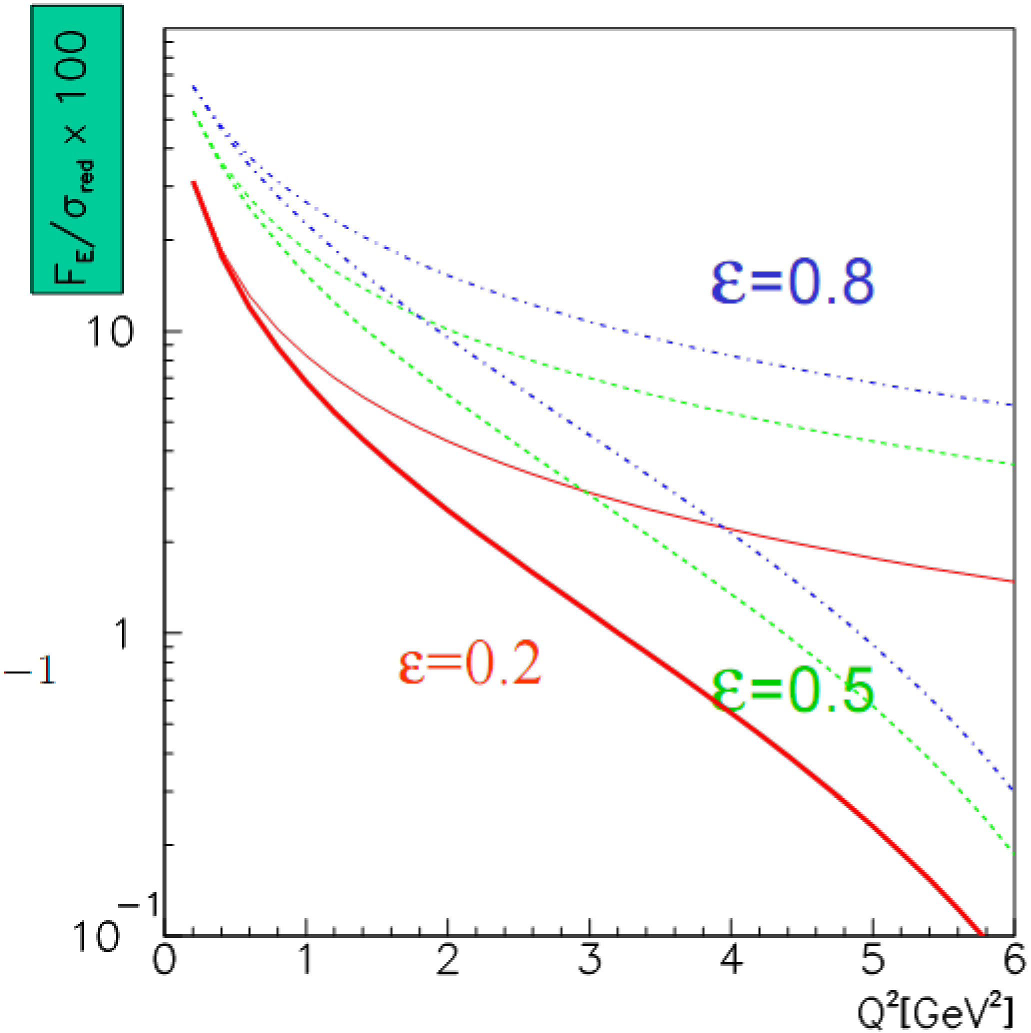
– Setting $\beta^2 = (0.471 \pm .010)$ GeV^2

- pion: $F_\pi(Q^2) = C_\pi [1/(1+Q^2/0.471\ \text{GeV}^2)^1]$,
- nucleon: $F_N(Q^2) = C_N [1/(1+Q^2/0.71\ \text{GeV}^2)^2]$,
- deuteron: $F_d(Q^2) = C_d [1/(1+Q^2/1.41\ \text{GeV}^2)^5]$

$$\sigma_R = \tau G_M^2(Q^2) + \varepsilon G_E^2(Q^2)$$

$$\tau = \frac{Q^2}{4M^2},$$

$$\epsilon = \left(1 + 2(1+\tau)\tan^2\frac{\theta}{2}\right)^{-1}$$



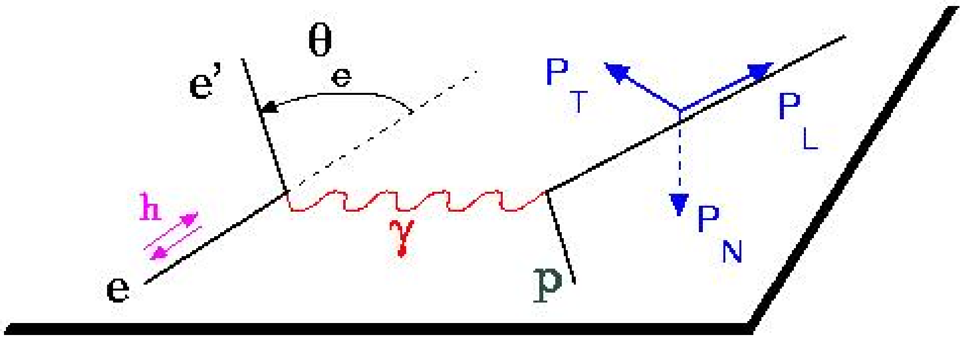
SOVIET PHYSICS – DOKLADY VOL. 13, NO. 6 DECEMBER, 1968

PHYSICS

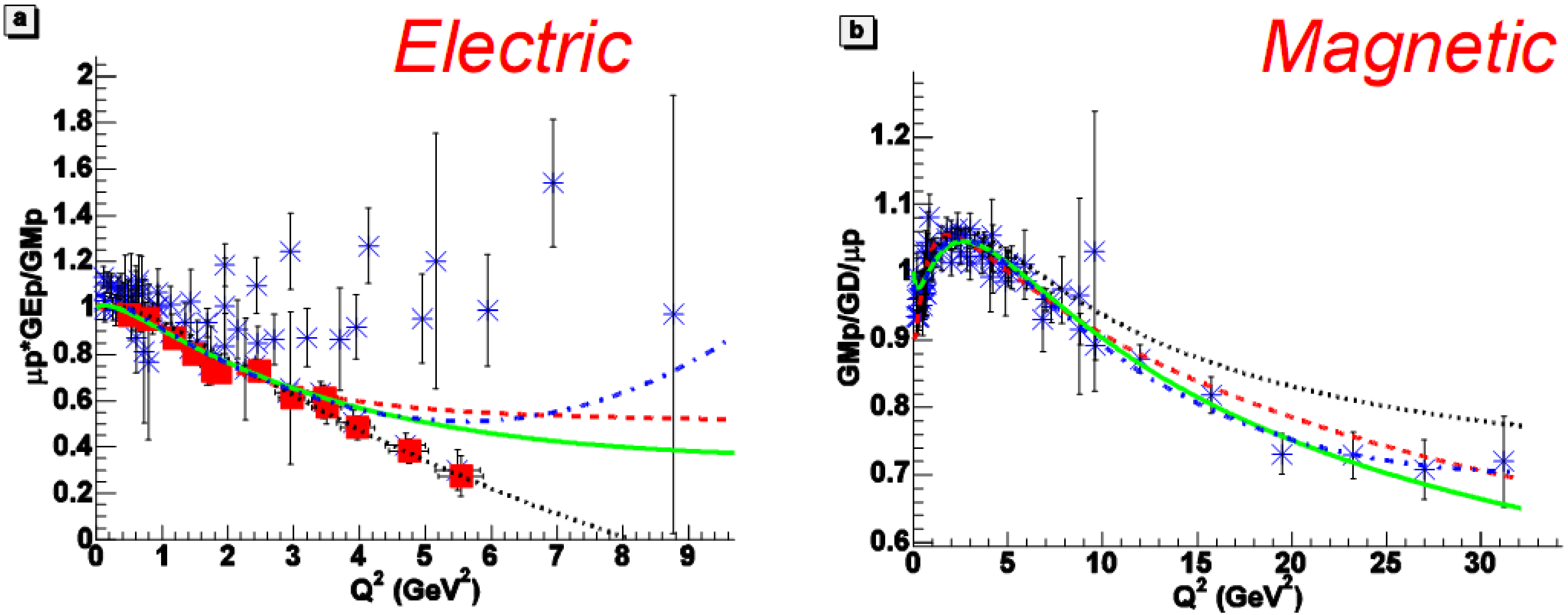
POLARIZATION PHENOMENA IN ELECTRON SCATTERING BY PROTONS IN THE HIGH-ENERGY REGION

Academician A. I. Akhiezer* and M. P. Rekalo

Physicotechnical Institute, Academy of Sciences of the Ukrainian SSR
Translated from Doklady Akademii Nauk SSSR, Vol. 180, No. 5, pp. 1081-1083, June, 1968
Original article submitted February 26, 1967



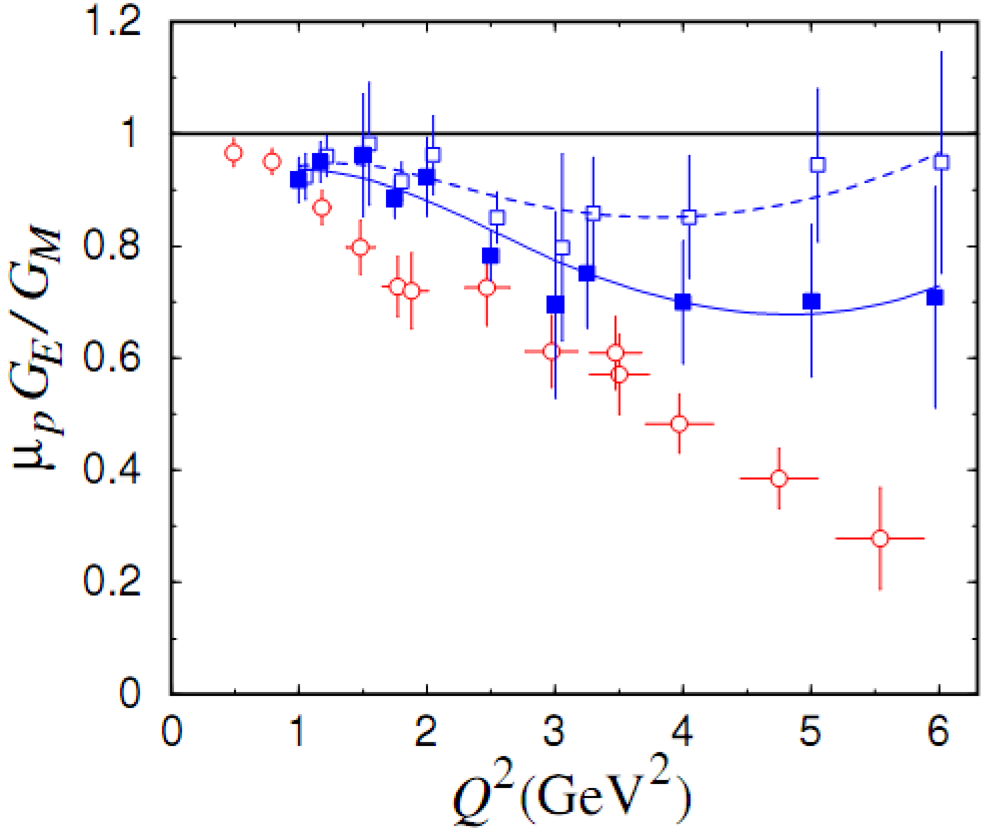
$$\Longrightarrow \frac{G_E^p}{G_M^p} = -\frac{P_t}{P_l}\frac{E_e + E_{e'}}{2M}\tan\left(\frac{\theta_e}{2}\right)$$

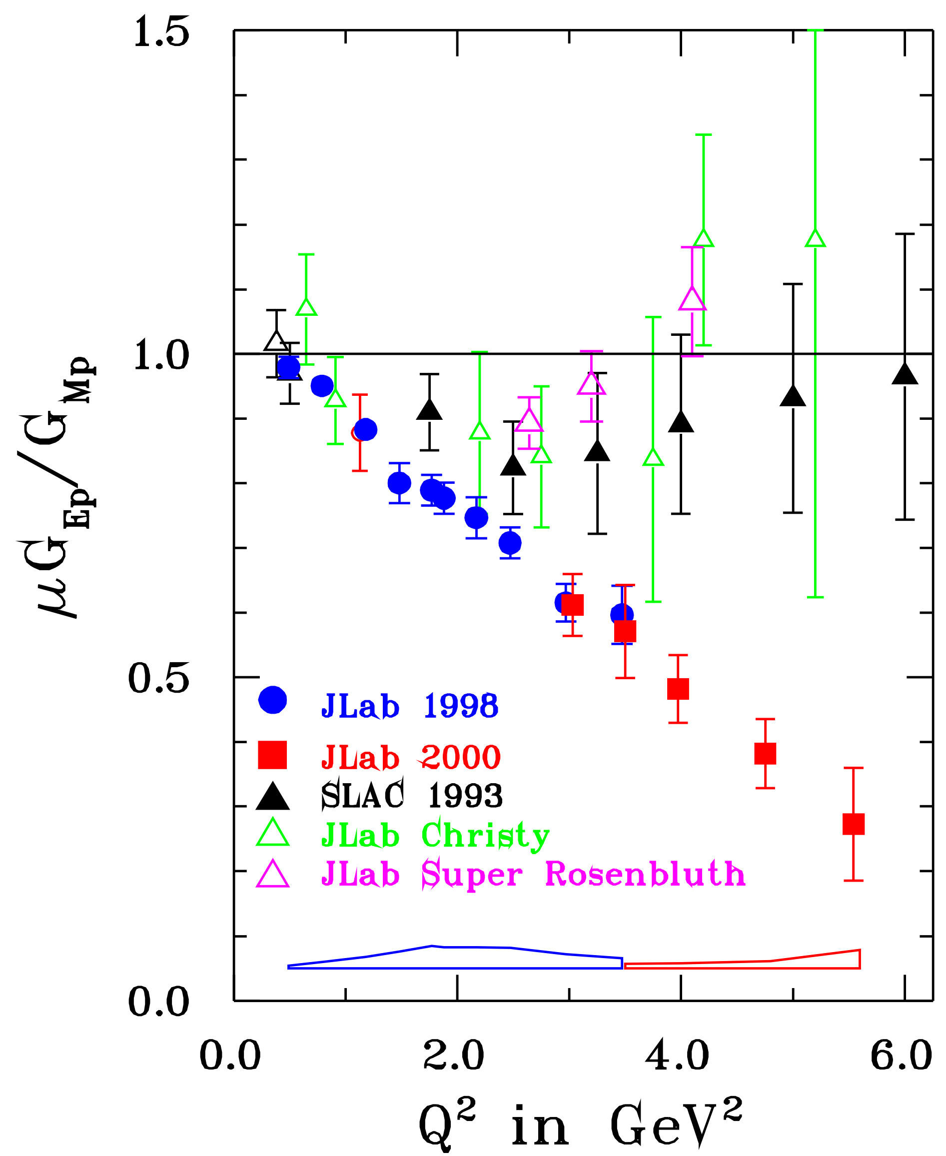


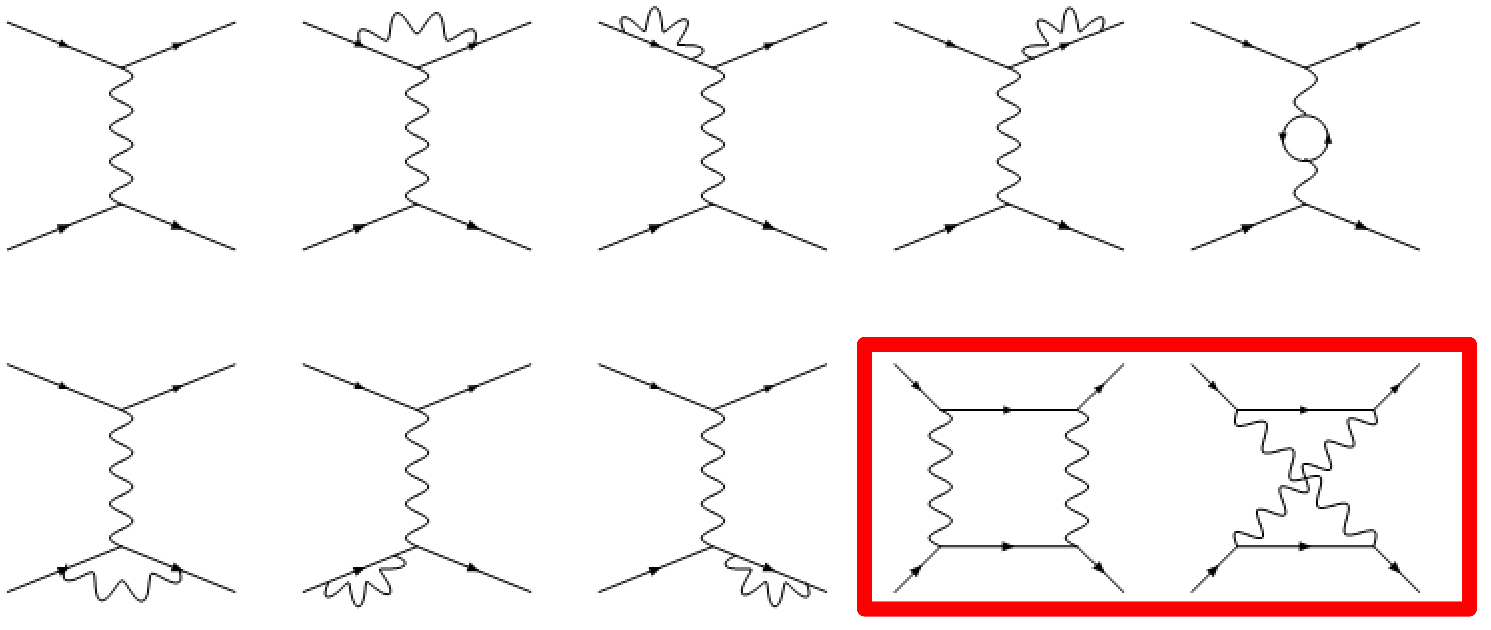
a
Electric
μp*GEp/GMp
Q² (GeV²)
b
Magnetic
GMp/GD/μp
Q² (GeV²)

$\mu G_{Ep} \neq G_{Mp}$

$$\frac{\mu G_E}{G_M} = 1 - 0.13(Q^2[\text{ГэВ}^2] - 0.04)$$







Все возможные диаграммы первого и второго порядков

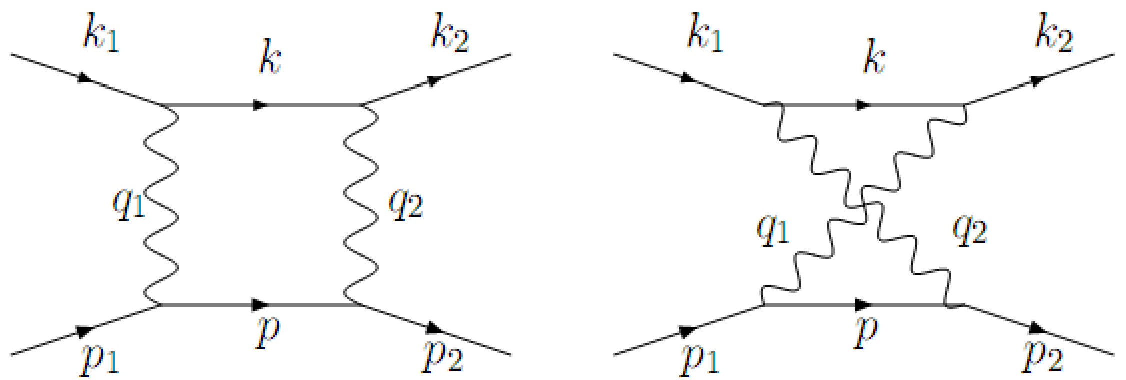
$$A = \frac{\sigma(e^-) - \sigma(e^+)}{\sigma(e^-) + \sigma(e^+)} = \frac{1 - R_\sigma}{1 + R_\sigma},$$

$$R_\sigma = \frac{\sigma(e^+)}{\sigma(e^-)}$$

$$A = \frac{|\mathcal{M}^-|^2 - |\mathcal{M}^+|^2}{|\mathcal{M}^-|^2 + |\mathcal{M}^+|^2}$$

$$\mathcal{M} = \mathcal{M}_1 + \mathcal{M}_2 \qquad \begin{aligned} \mathcal{M}_1^+ &= -\mathcal{M}_1^- \\ \mathcal{M}_2^+ &= \mathcal{M}_2^- \end{aligned}$$

$$A = \frac{2Re(\mathcal{M}_1^- \mathcal{M}_2^{-*})}{|\mathcal{M}_1^-|^2}$$



$$iM_{\substack{\text{box}\\ \text{x-box}}} = \left(\frac{\alpha}{\pi}\right)^2 \int \frac{N(p)d^4p}{(q_1^2-\lambda^2)(q_2^2-\lambda^2)(k^2-m^2)(p^2-M^2)},$$

$$N_{\text{box}}(p) = \bar{u}(k_2)\gamma_\mu(\hat{k}+m)\gamma_\nu u(k_1)\cdot \bar{U}(p_2)\Gamma_\mu(q_2)(\hat{p}+M)\Gamma_\nu(q_1)U(p_1)$$

$$I_n = \int \frac{A(t_1,t_2)\bar{F}(t_1)\bar{F}(t_2)}{D_n} d^4p,$$

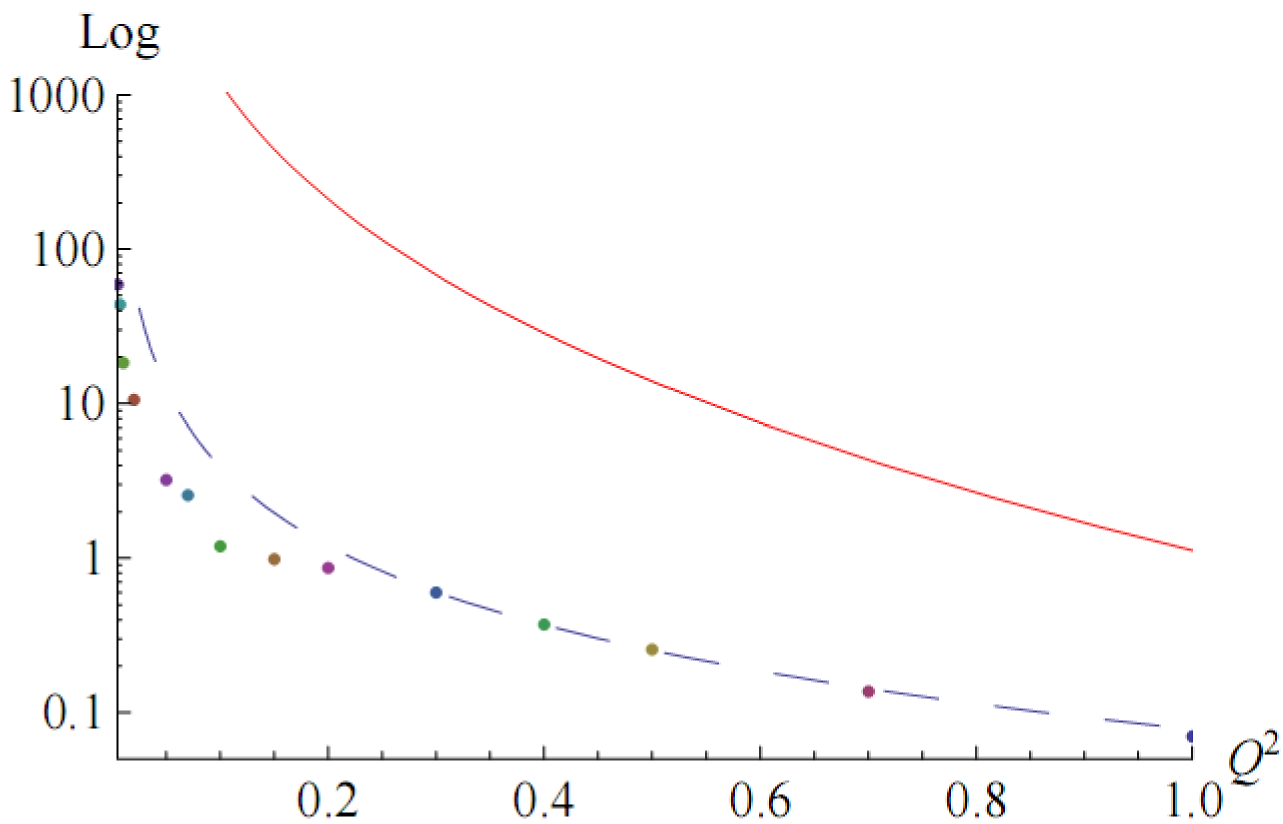
$$\bar{F}(t) = F(t)/(t-\lambda^2),$$

$$\begin{aligned} D_1 &= 1 \\ D_2 &= k^2-m^2 \\ D_3 &= p^2-M^2 \\ D_4 &= (k^2-m^2)(p^2-M^2). \end{aligned}$$

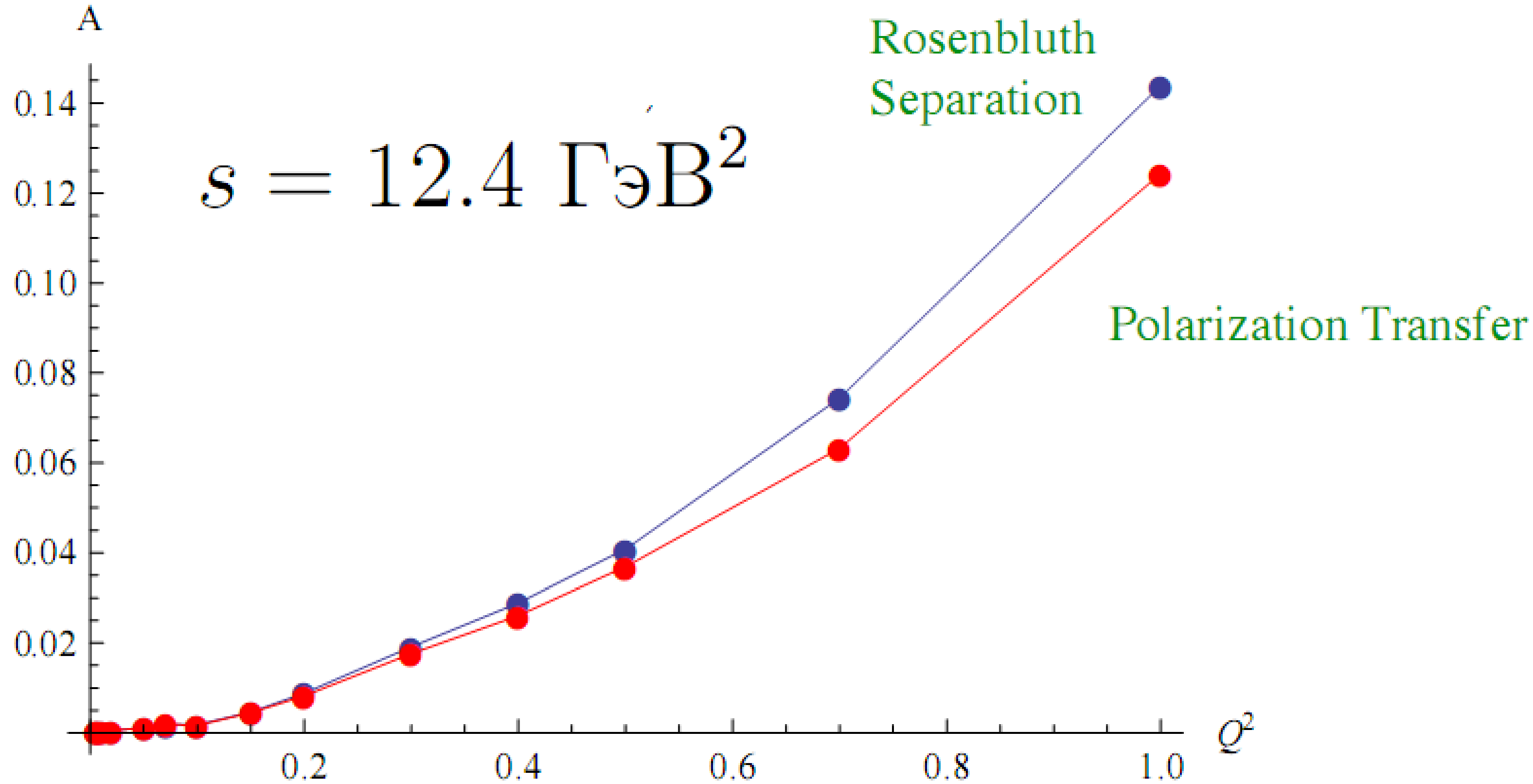
$$\tilde{\mathcal{I}} = \int \sum_{1,2,3,4,4x} \mathcal{K}_n(t_1,t_2)A_n(t_1,t_2)\bar{F}(t_1)\bar{F}(t_2)dt_1dt_2$$

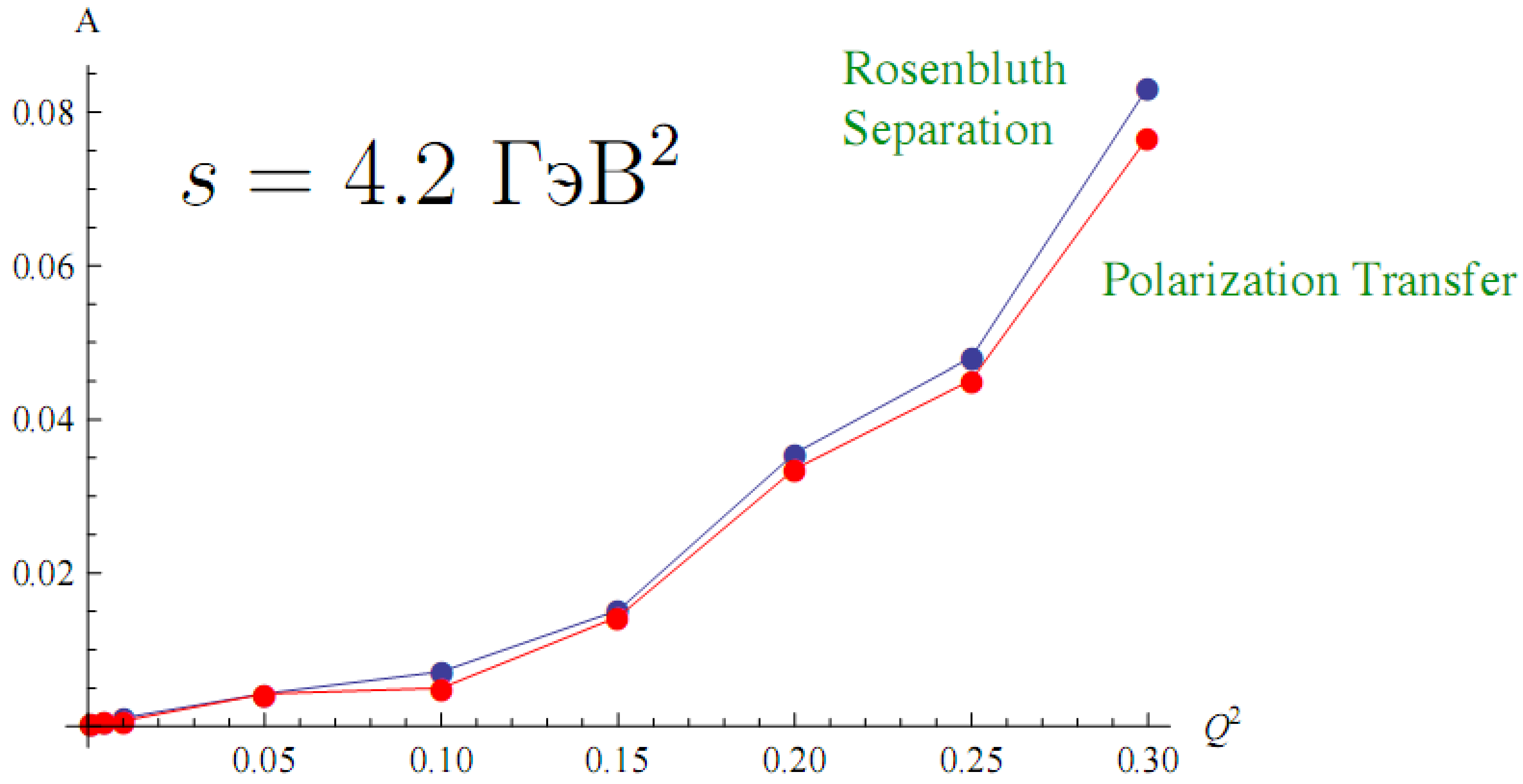
$$\tilde{\mathcal{I}} = a\ln\lambda + b + o(\lambda)$$

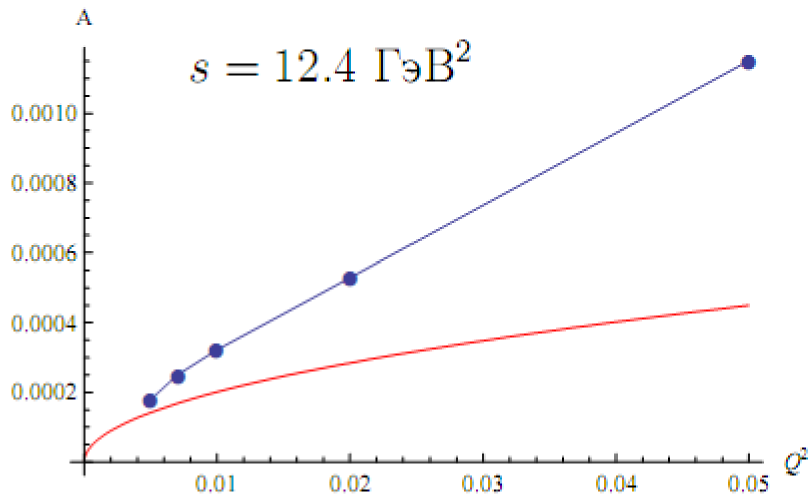
$$\mathcal{I} = b$$



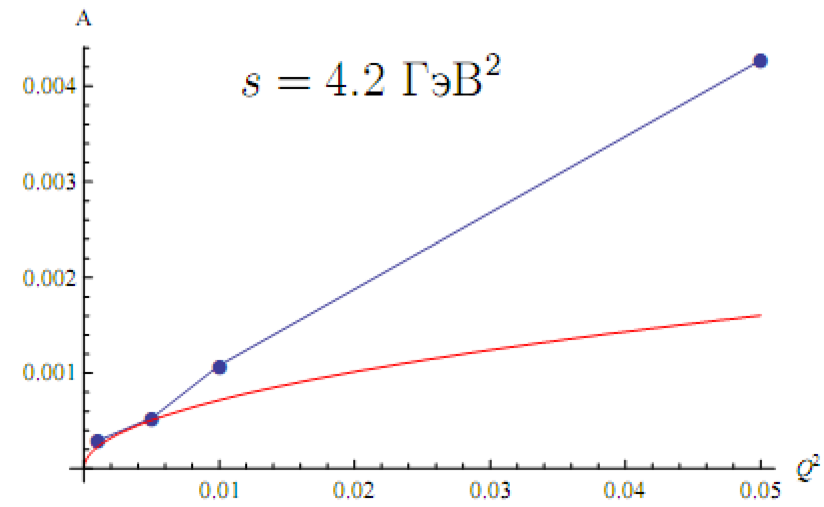
Точки соответствуют интерференционному члену, пунктирная линия - их фиту функцией $1/x^{1.5}$, сплошная линия - квадрату однофотонного


A
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.2
0.4
0.6
0.8
1.0
Q^2
$s = 12.4$ ГэВ^2
Rosenbluth
Separation
Polarization Transfer


A
0.08
0.06
0.04
0.02
$s = 4.2$ ГэВ^2
Rosenbluth
Separation
Polarization Transfer
0.05
0.10
0.15
0.20
0.25
0.30
Q^2



A
$s = 12.4$ ГэВ^2
0.0010
0.0008
0.0006
0.0004
0.0002
0.01
0.02
0.03
0.04
0.05
Q^2



A
$s = 4.2$ ГэВ^2
0.004
0.003
0.002
0.001
0.01
0.02
0.03
0.04
0.05
Q^2