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GPDs and nucleon form factors

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Contents

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Hep-ph/0708.0162

"One doesn't know explicit form of the nucleon matrix element of the EM current"

$$J_\mu^{EM} = \frac{2}{3}\bar{u}\gamma_\mu u - \frac{1}{3}\bar{d}\gamma_\mu d - \frac{1}{3}\bar{s}\gamma_\mu s.$$

$$J_\mu(P',s';P,s) = \bar{u}(P',s')\Lambda_\mu(q,P)u(P,s) =$$

$$\bar{u}(P',s')(\gamma_\mu F_1(q^2) + \frac{1}{2M} i\sigma_{\mu\nu} q_\nu F_2(q^2))u(P,s).$$

Sachs electric and magnetic form factors

With defines space-like $(t = -q^2 = Q^2 > 0);$

$$G_{Ep}(t) = F_{1p}(t) + \frac{t}{4m_p^2} F_{2p}(t);$$

$$G_{Mp}(t) = F_{1p}(t) + F_{2p}(t);$$

Suitable for the analysis of the experiments

Iso-scalar and iso-vector Dirac and Pauli form factors

Suitable for models

Standard definitions

$$G_{Ep}(0)=1;\ G_{En}(0)=0;\qquad G_M(0)=(G_E(0)+k)=\mu;$$

$$\mu_p=(1+1.79)\frac{e}{2M};\qquad k_p=1.79;$$

$$F_1^D(t)=\frac{4M_p^2-t\,\mu_p}{4M_p^2-t}G_D(t);\qquad F_2^P(t)=\frac{1}{1-t/4M_p^2}G_D(t);$$

$$G_D(t)=\frac{\Lambda^2}{(\Lambda-t)^2};\qquad \Lambda=0.71GeV^2;$$

GPDs

Fallowing to A. Radyushkin

Phys.ReV. D58, (1998) 114008

$$lmit \;\; Q_\gamma^2 = 0, \;\; and \;\; \xi = 0$$

$\mathcal{F}_{\xi=0}$ (x;t) = $\mathcal{F}$ (x;t)

$$F_1^q(t) = \int_{-1}^{1} dx \; H^q\left(x, \xi, t\right); \qquad F_2^q(t) = \int_{-1}^{1} dx \; E^q\left(x, \xi, t\right);$$

$\mathcal{H}^q$(x;t) = H ^{q}(x,0,t) + H ^{q}(-x,0,t) $\mathcal{E}^q$(x;t) = E ^{q}(x,0,t) + E ^{q}(-x,0,t)

$$F_1^q(t) = \int_{0}^{1} dx \; \mathcal{H}^q\left(x, \xi, t\right); \qquad F_2^q(t) = \int_{0}^{1} dx \; \boldsymbol{\mathcal{E}}^q\left(x, \xi, t\right);$$

Choosing a frame where r is pure transverse

$$r = r_\perp$$

$$F^{tb}(t) = \int_0^1 dz \int_0^1 \Psi^*(x, k_\perp + \bar{x} r \perp)\, \Psi(x, k_\perp) \frac{d^2 k_\perp}{16\pi^3};$$

Assuming the Gaussian ansatz

$$\Psi(x, k_\perp) \sim \exp\left(-\frac{k_\perp^2}{2x(1-x)\lambda^2}\right)$$

$$F^{(2)}(q_\perp^2) = \int_0^1 dx\; q^{(2)}(x)\, e^{(1-x) q^2 / 4 x \lambda^2},$$

K. Goeke, M. Polyakov, M. Vanderhaeghen (2001)

Regge-like picture with the factorization

$$\mathcal{H}^q(x,t) \sim \frac{1}{x^{\alpha' t}} q(x)$$

P. Stoler (2001, 2003)

$$\Psi^{soft}(x,k_\perp) + \Psi^{hard}(x,k_\perp)$$

M. Guidal, M. Polyakov, A. Radyushkin, M. Vanderhaeghen (2005)

Regge like picture without the factorization

$$\mathcal{H}^q\left(x,t\right) \sim \frac{1}{x^{\alpha'(1-x)t}} q(x) = e^{\alpha'(1-x)\ln(x)t} q(x)$$

M. Burkardt (2004)

$$\mathcal{H}^q\left(x,t\right) \sim e^{\alpha'(1-x)^n t} q(x) \qquad n \geq 2;$$

M. Diehl, Th. Feldmann, R. Jakob, P.Kroll (2005, 2006)

$$\mathcal{H}^q\left(x,t\right) \sim e^{f(x)\,t} q(x);$$

with

$$f(x) = \alpha'(1-x)^2 \ln(1/x) + B_q(1-x)^2 + A_q x(1-x);$$

or

$$f(x) = \alpha'(1-x)^3 \ln(1/x) + B_q(1-x)^3 + A_q x(1-x)^2;$$

$t^2\ F_1$ has maximum at Q^2=12 GeV^2
and then it is slowly decreasing

S. Ahmad, H. Honkanen, S. Liuti, S. Taneja (2006-2007)

$$H^{I,II}\left(x,t\right) = G_{M_x^{I,II}}^{\lambda^{I,II}}(x,t)\ x^{-\alpha^{I,II} - \beta_1^{I,II}(1-x)^{p_1^{I,II}} t};$$

$$E^{I,II}\left(x,t\right) = k\ G_{M_x^{I,II}}^{\lambda^{I,II}}(x,t)\ x^{-\tilde{\alpha}^{I,II} - \beta_2^{I,II}(1-x)^{p_2^{I,II}} t};$$

$$\beta_1^u = 1.9567\,GeV^{-2};\ \ \beta_1^d = 1.5896\,GeV^{-2};$$

$$\beta_2^u = 0.17670\,GeV^{-2};\ \ \beta_2^d = 3.2866\,GeV^{-2};$$

Our ansatz

1. Simplest;

2. Not fare from Gaussian represantation

3. Satisfy the $(1\text{-}x)^n$ (n>= 2)

4. Valid for large t

$$\mathcal{H}^q(x,t) \sim q(x)\exp[a_+ \frac{(1-x)^2}{x^{0.4}} t];$$

q(x) is based on the MRST2002 and A. Radyushkin (2005)

$$u(x) = 0.262\, x^{-0.69}(1-x)^{3.50}\,(1+3.83\, x^{0.5}+37.65\, x);$$

$$d(x) = 0.061\, x^{-0.65}(1-x)^{4.03}\,(1+49.05\, x^{0.5}+8.65\, x);$$

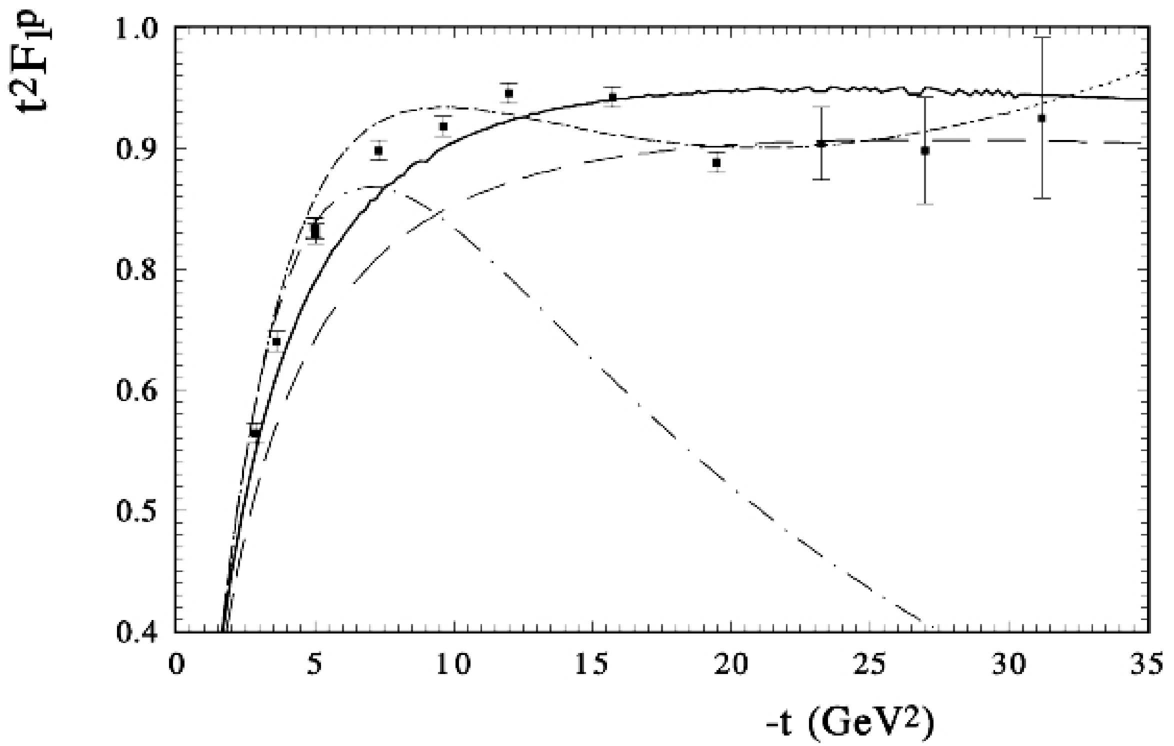
$$\mathcal{E}^q\left(x,t\right) \sim \varepsilon^q(x)\exp[a_- \frac{(1-x)^2}{x^{0.4}}t];$$

$$\varepsilon^u(x) = \frac{k_u}{N_u}(1-x)^{k_1}u(x); \qquad \varepsilon^d(x) = \frac{k_d}{N_d}(1-x)^{k_2}d(x);$$

$$k_1 = 1.52; \quad k_2 = 2.033; \quad N_u = 1.53; \quad N_d = 0.946;$$

$$a_+ = 1.1; \qquad a_-^{(1)} = 1.18; \qquad a_-^{(2)} = 1.4;$$

F_{1p} *t^2



Rosenbluth technique

$$\frac{d\sigma(e^- p \to e^- p)}{d\Omega} = \frac{\alpha^2}{4E^2} \frac{\cos^2(\theta/2)}{\sin^4(\theta/2)} \frac{1}{1+(2E/m_p)\sin^2(\theta/2)}$$

$$*[A(t)+B(t)\tan^2(\theta/2)];$$

$$A(t) = \frac{G_{Ep}^2 - (t/4m_p^2)G_{Mp}^2(t)}{1-(t/4m_p^2)}; \qquad B(t) = -2\frac{t}{4m_p^2}G_{Mp}^2(t);$$

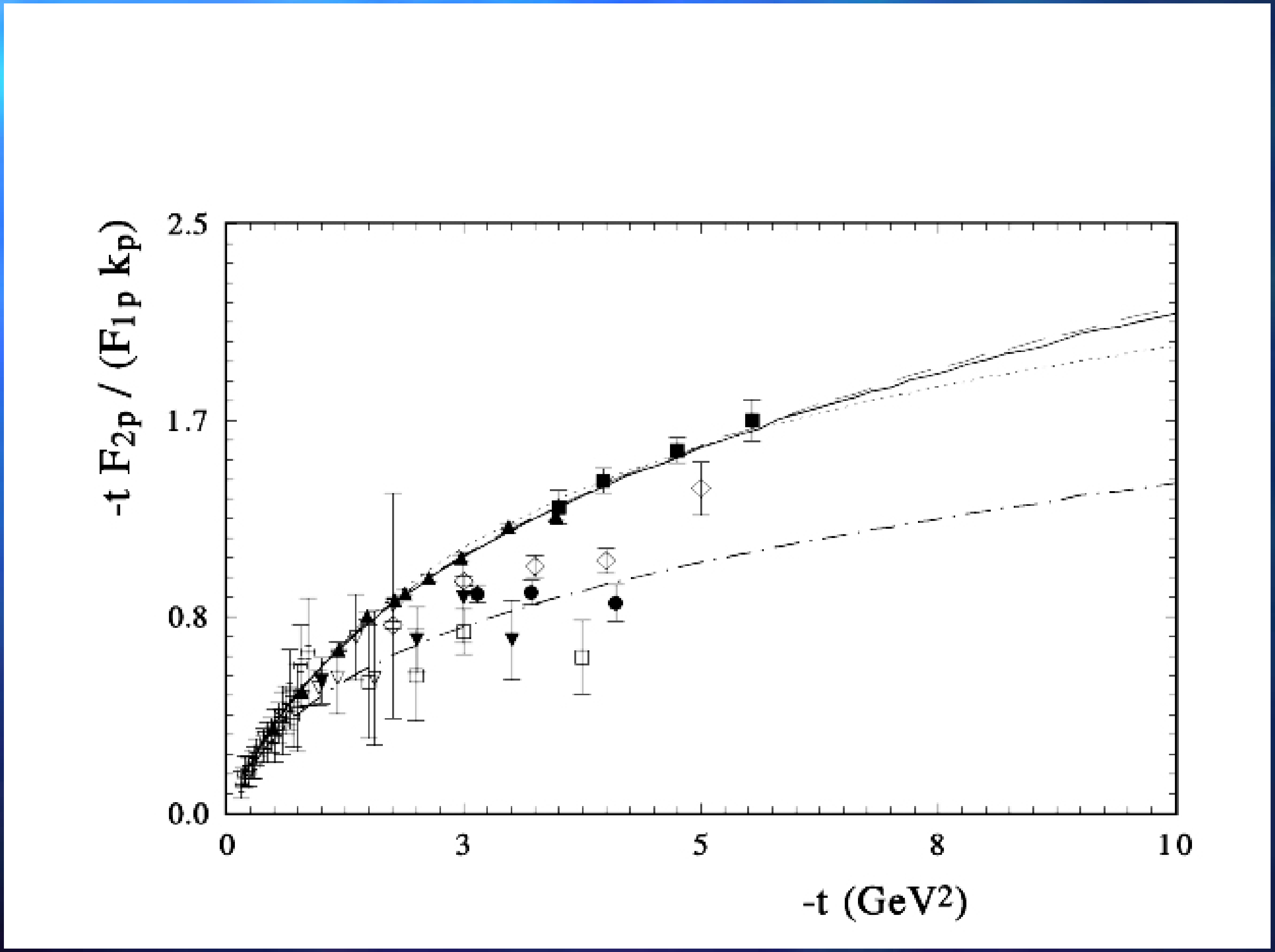
Polarization technique (Jefferson Lab)

$$P_t(t) = \frac{h}{I_0}(-2)\sqrt{\tau(1+\tau)}\, G_{Mp} G_{Ep} \tan(\theta/2);$$

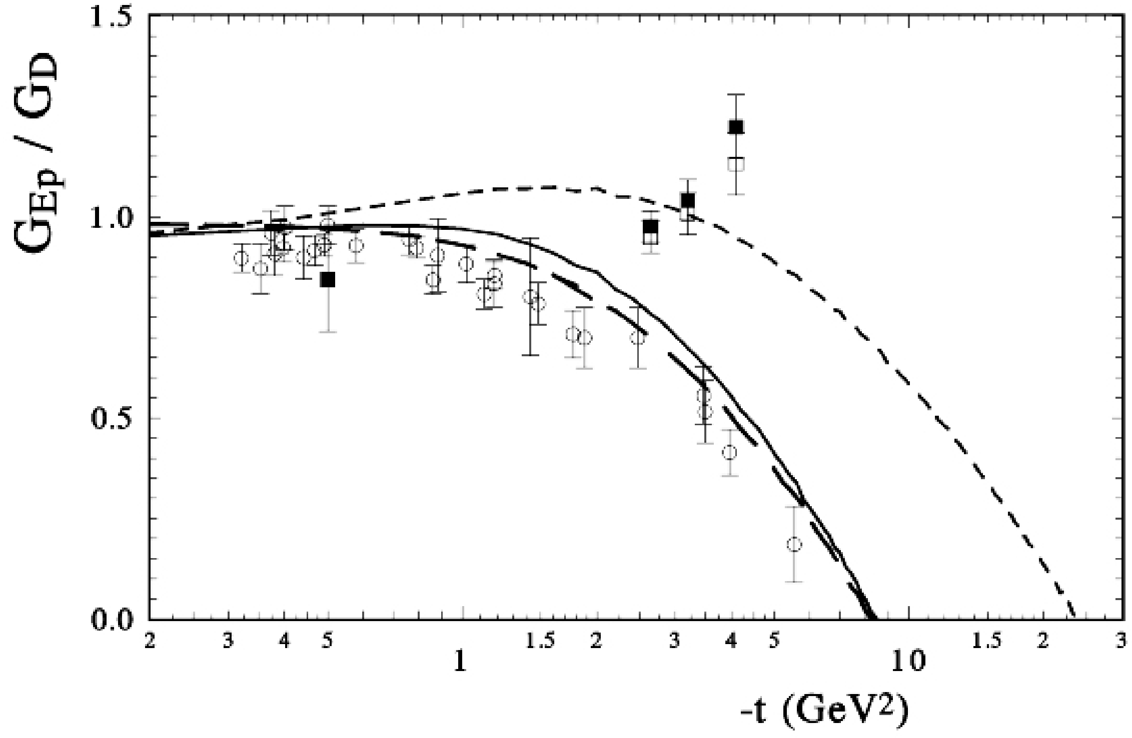
$$P_l(t) = \frac{h(E+E')}{I_0 m_p}\sqrt{\tau(1+\tau)}\, G_{Mp}^2 \tan^2(\theta/2);$$

$$\frac{G_{Ep}}{G_{Mp}} = \frac{P_t}{P_l}\frac{(E+E')}{2m_p}\tan(\theta/2);$$

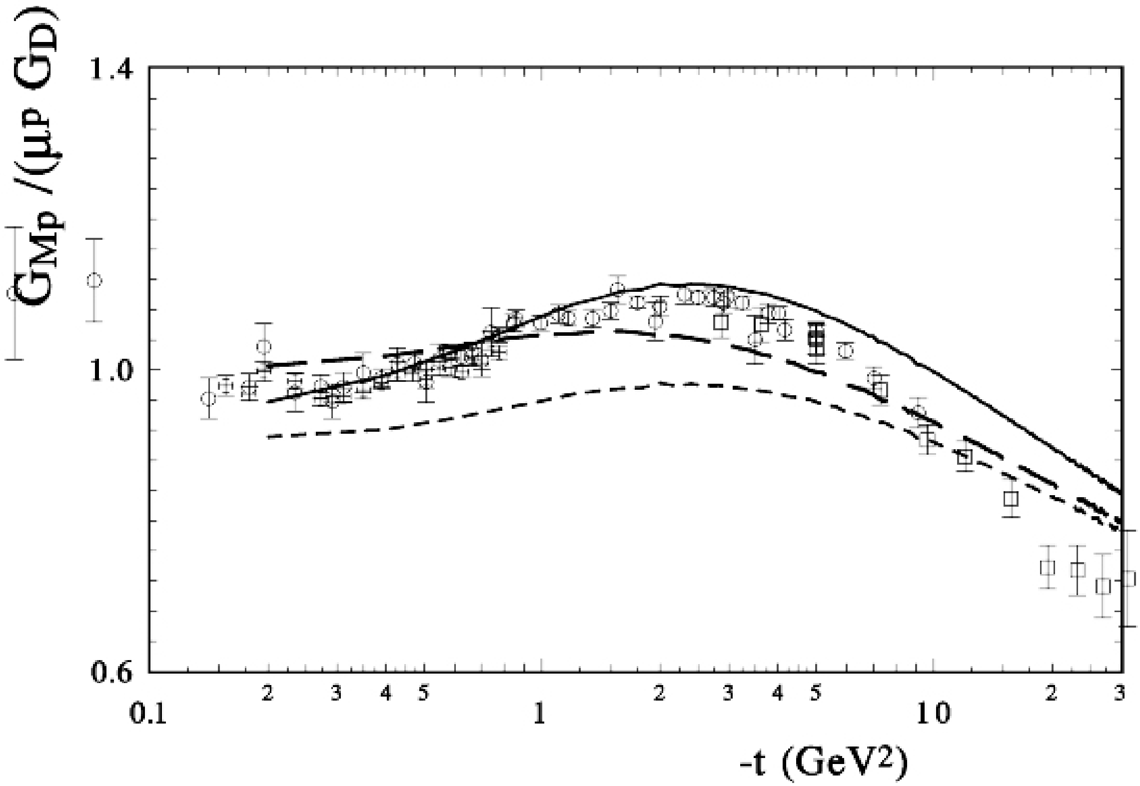
Ratio F_{2p}/F_{1p}



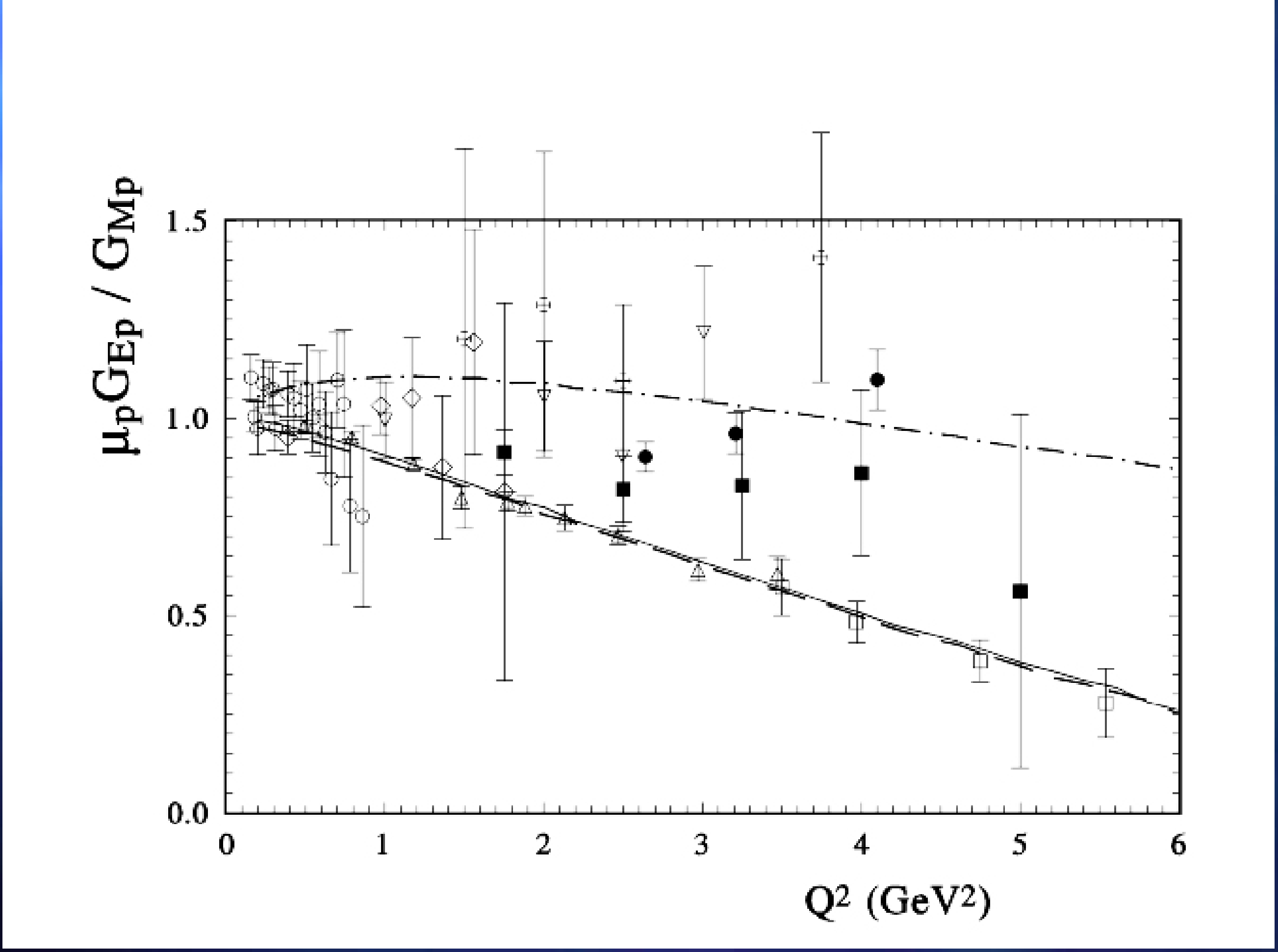
G_{ep}/Gd



$G_{Mp}/(\mu_p\ Gd)$



G_{ep}/G_{Mp}



Neutron form factors

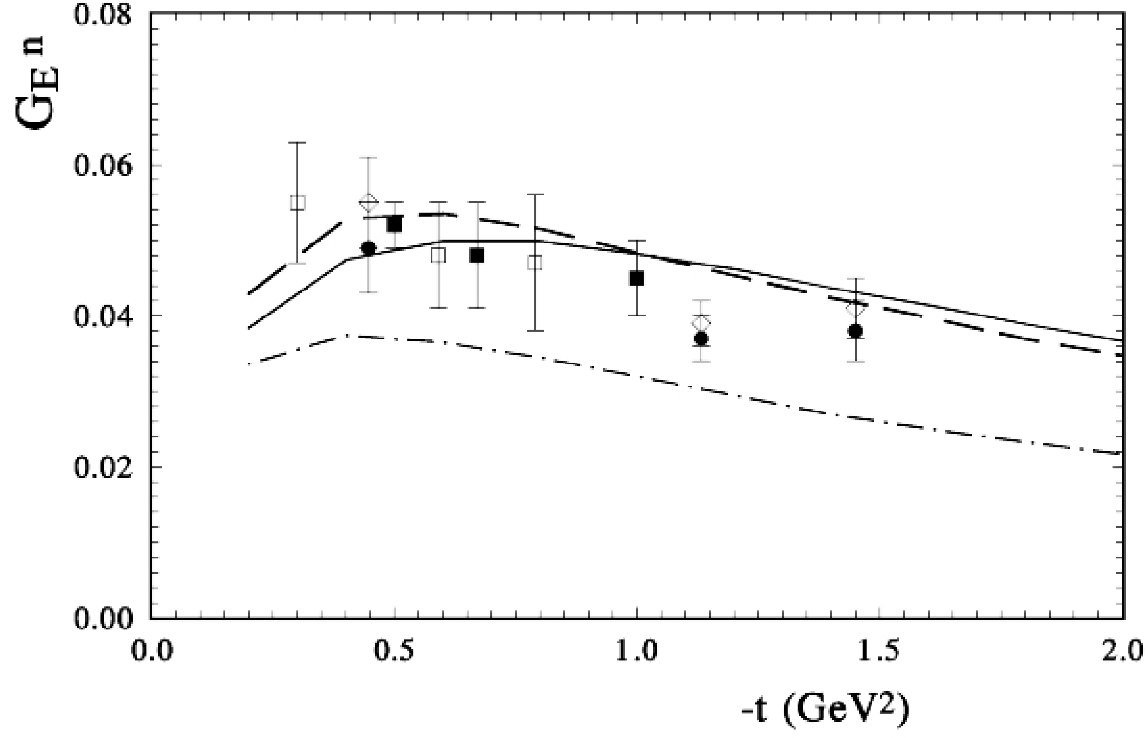
$$\mathcal{H}^q(x,t) = q_+(x)^n \; exp[a_+ \frac{(1-x)^2}{x^{0.4}} t],$$

$$q_+(x)^n = \frac{2}{3} d(x) - \frac{1}{3} u(x);$$

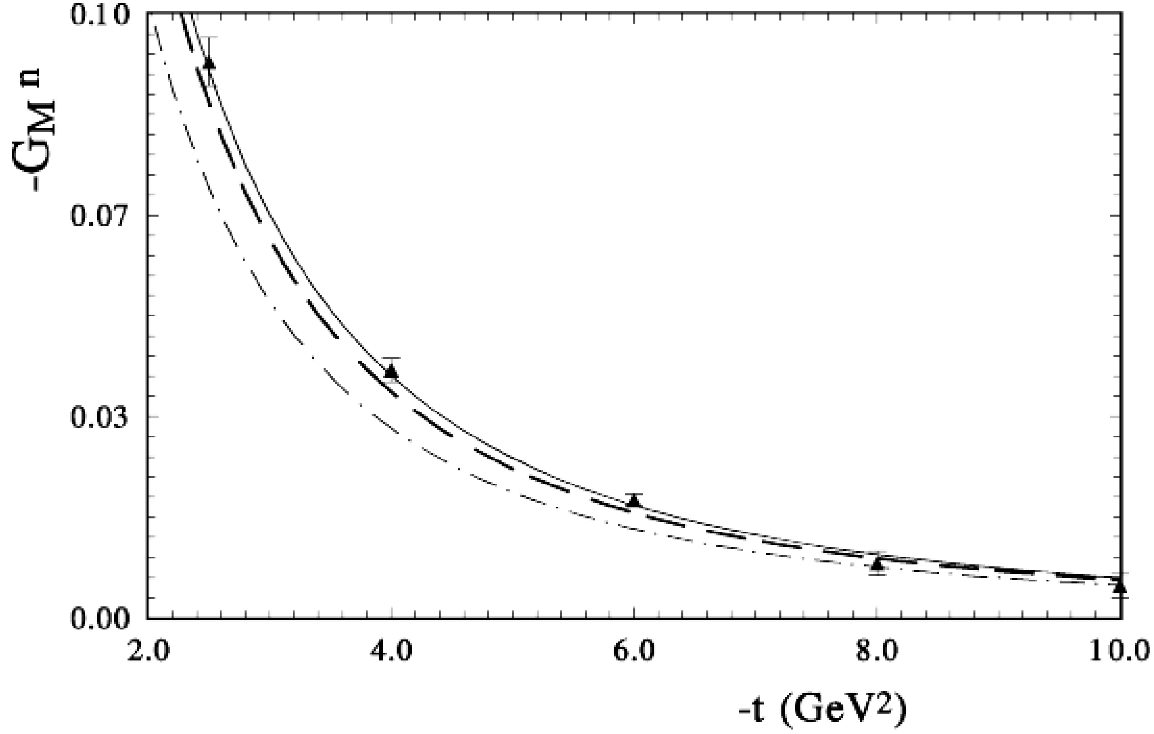
$$\mathcal{E}^n(x,t) = q_-(x)^n \; exp[a_- \frac{(1-x)^2}{x^{0.4}} t],$$

$$q_-(x)^n = -\frac{k_u}{3N_u}(1-x)^{k_1} u(x) - \frac{2k_d}{3N_d}(1-x)^{k_2} d(x);$$

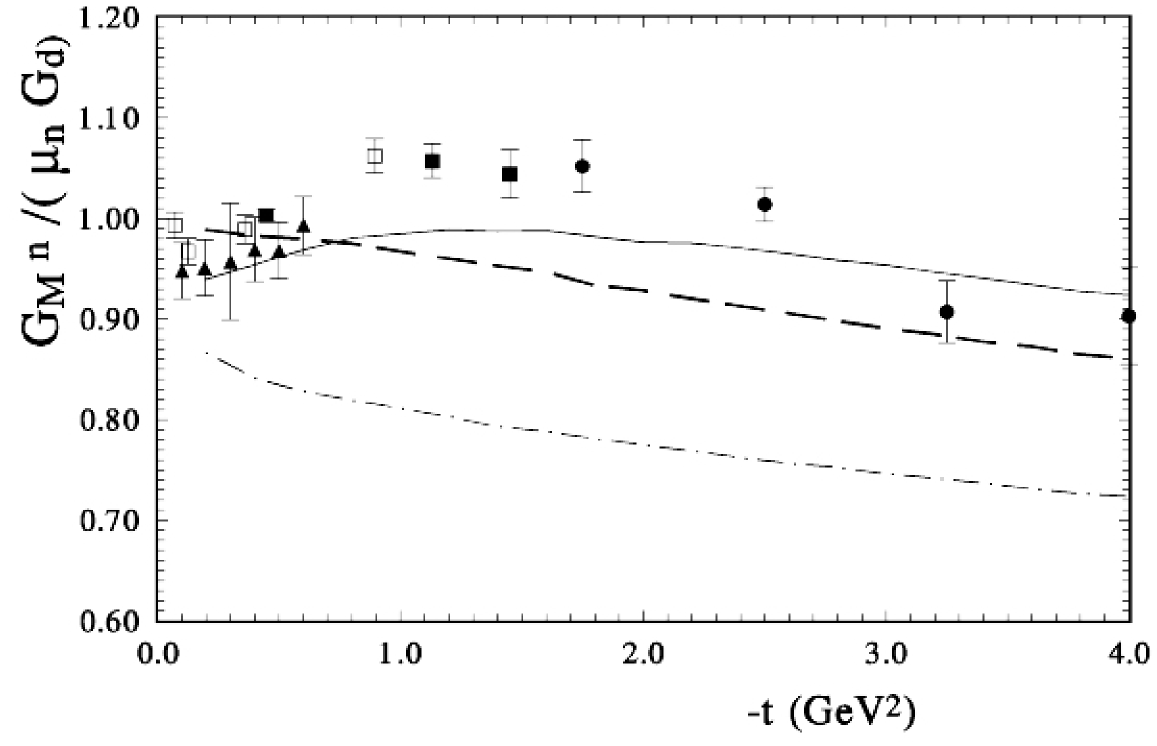
G_{En}

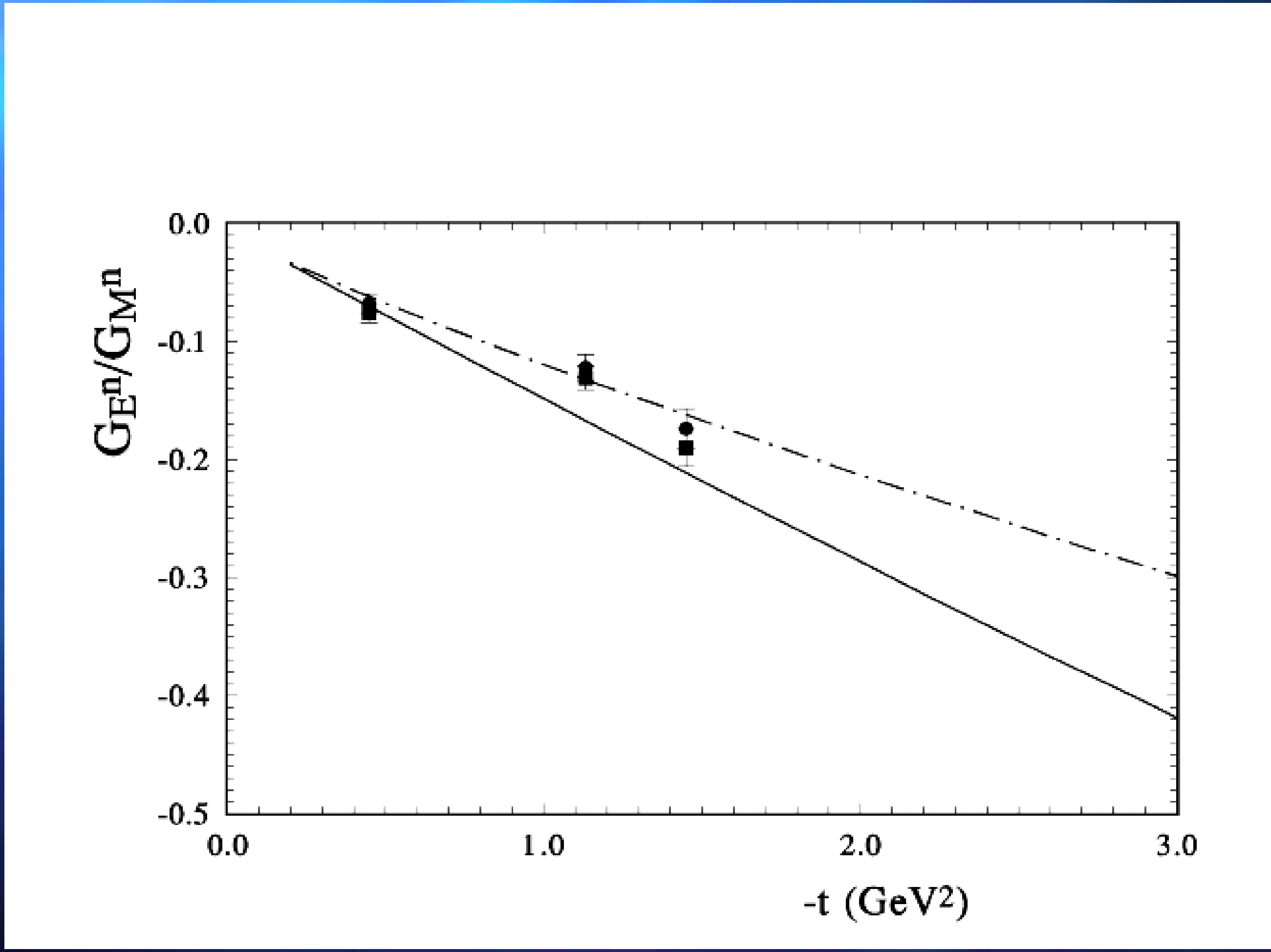


G_{Mn}



$G_{Mn}/(\mu_n\ Gd)$





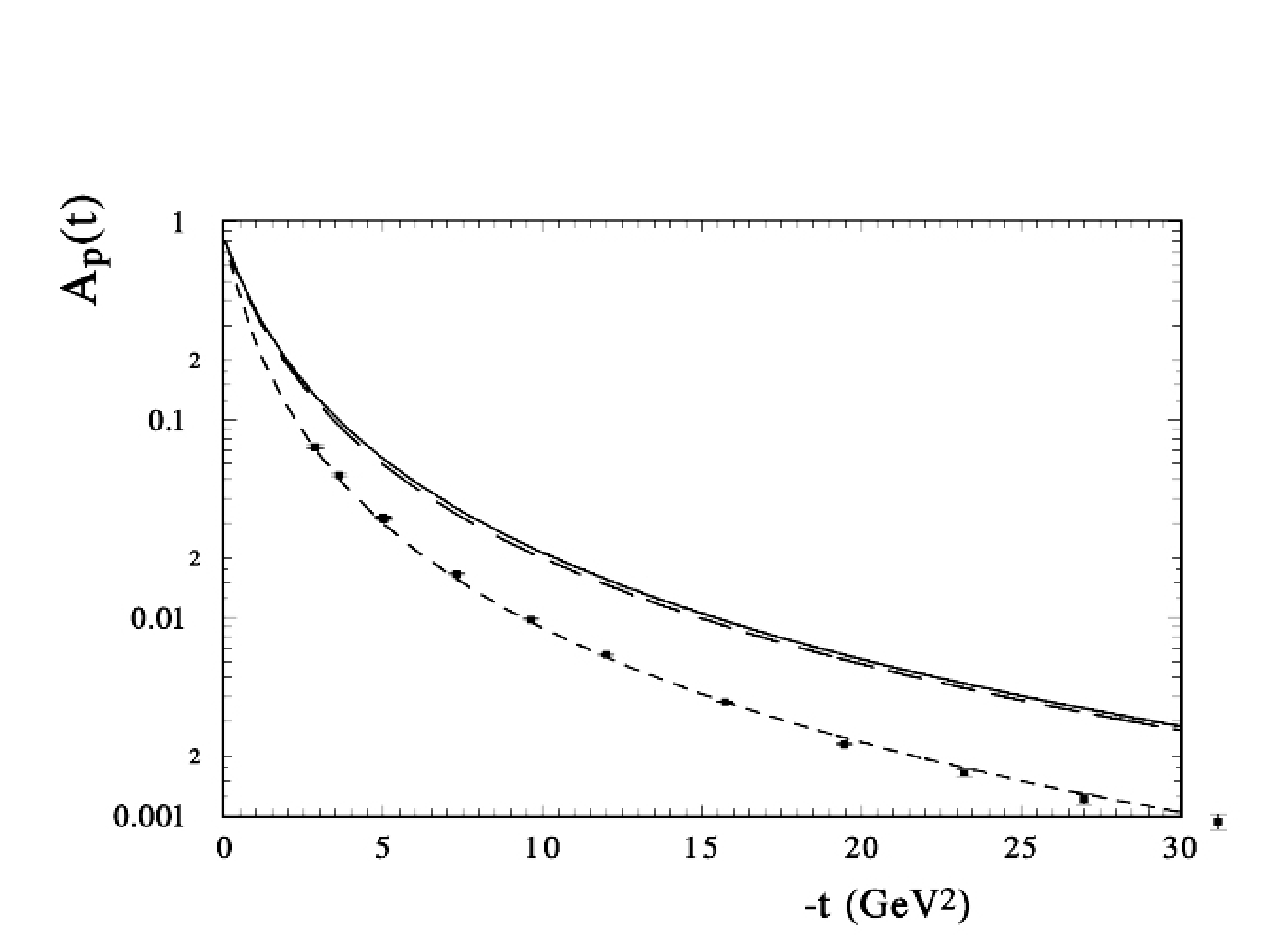
G_E^n/G_M^n
0.0
-0.1
-0.2
-0.3
-0.4
-0.5
0.0
1.0
2.0
3.0
-t (GeV^2)

Gravitation form factor

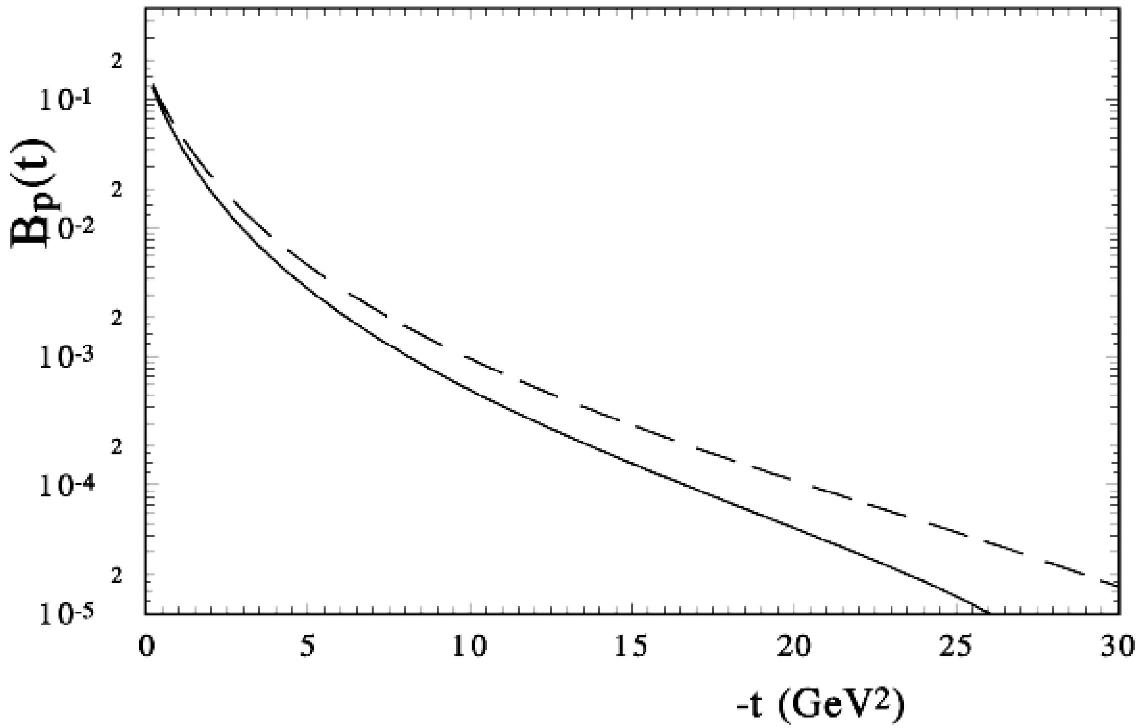
$$\int_{-1}^{1} dx\ x[H^q(x,\xi,t)+E^q(x,\xi,t)] = A_q(\Delta^2)+B_q(\Delta^2);$$

$$A^q(t)=\int_0^1 dx\ x\ \mathcal{H}^q(x,t); \qquad B^q(t)=\int_0^1 dx\ x\ \boldsymbol{\mathcal{E}}^q(x,t);$$

$A_p(t)$ Gravitation form factor A_p and proton Dirac FF



$B_p(t)$ Gravitation form factor B_p and proton Pauli FF*t^2



Summary

1. Proposed the new simple t- dependence of the GPDs

2. The well description of the proton and neutron electromagnetic form factors are obtained.

3. It is shown that in the framework of the same model assumptions the “Rosenbluch” and “Polarization” data of FF can be obtained using the difference slopes of the F_2.

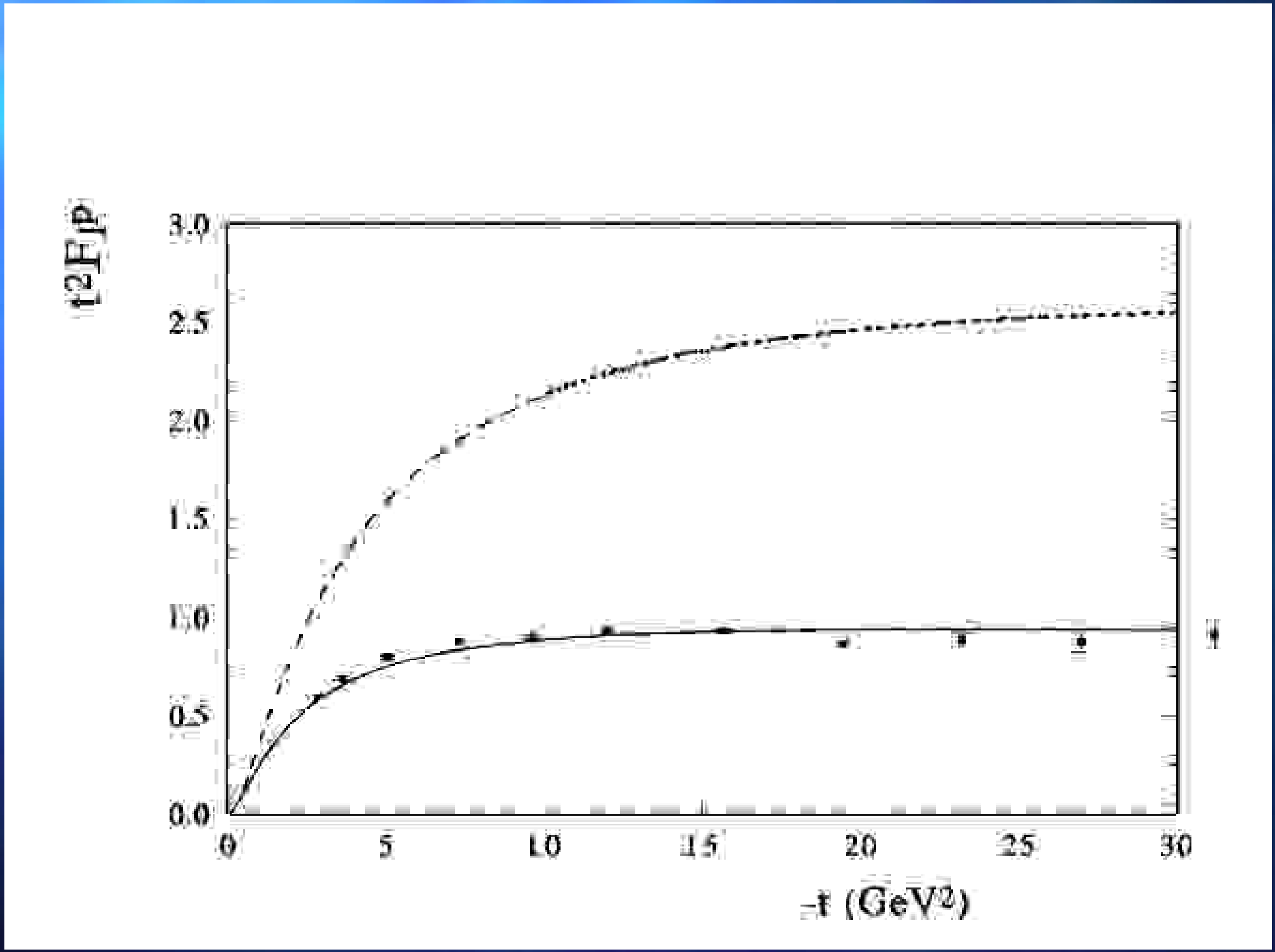
4. The compare the calculations and full row of the data shows the preference the “Polarization” case.

5. The corresponding gravitation form factors of the proton are calculated.

END

Thank you

(Gravitation form factor A_q and proton Dirac FF)*t^2



(Gravitation form factor B_q and proton Pauli FF)*t^2