Nucleon structure at large momentum transfer

Bogdan Wojtsekhowski, Jefferson Lab

Many manifestations of nonperturbative QCD

Outline

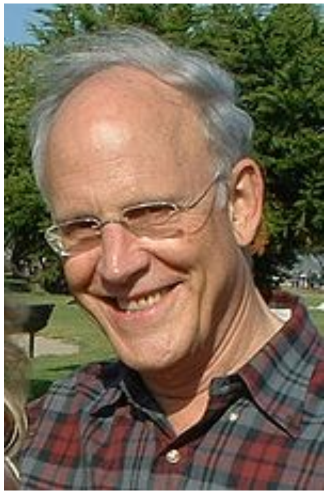
- The role of the nucleon

- Many aspects of the structure
- Nucleon structure and Form Factors

- Experimental data at high-Q^2
- Plans for EMFFs at JLab

- Related high-Q^2 experiment
- Future possibilities

The goal is understanding of QCD



from the D. Gross Nobel Lecture:

"It is sometimes claimed that the origin of mass is the Higgs mechanism that is responsible for the breaking of the electroweak symmetry that unbroken would forbid quark masses.
This is incorrect. Most, 99%, of the proton mass is due to the kinetic and potential energy of the massless gluons and the essentially massless quarks, confined within the proton."

The goal is understanding of QCD

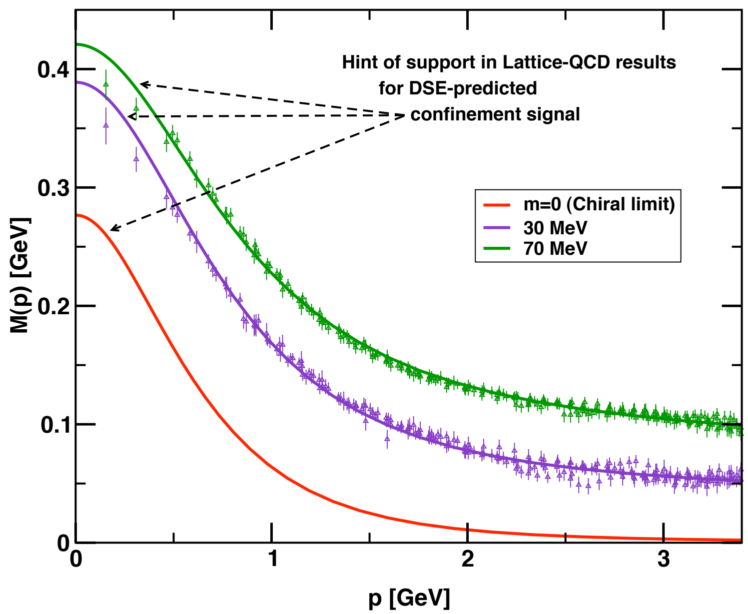
C.Roberts: the dressed-quark mass function $M(p^2)$

Frontiers of Nuclear Science: Theoretical Advances

Mass from nothing.

In QCD a quark's effective mass depends on its momentum. The function describing this can be calculated and is depicted here. Numerical simulations of lattice QCD (data, at two different bare masses) have confirmed model predictions (solid curves) that the vast bulk of the constituent mass of a light quark comes from a cloud of gluons that are dragged along by the quark as it propagates. In this way, a quark that appears to be absolutely massless at high energies ($m = 0$, red curve) acquires a large constituent mass at low energies.

$$S(p) = \frac{Z(p^2)}{i\gamma \cdot p + M(p^2)}$$



U.S. DEPARTMENT OF ENERGY
Office of Science
Office of Nuclear Physics
Exploring Nuclear Matter - Quarks to Stars
UChicago Argonne LLC
Argonne NATIONAL LABORATORY

First | Contents | Back | Conclusion

Craig Roberts – *Exposing the Dressed Quark's mass*
4th Workshop on Exclusive Reactions at High Momentum Transfer, 18-21 May 2010 . . . 27 – p. 13/28

The goal is understanding of QCD

C.Roberts: the dressed-quark mass function $M(p^2)$

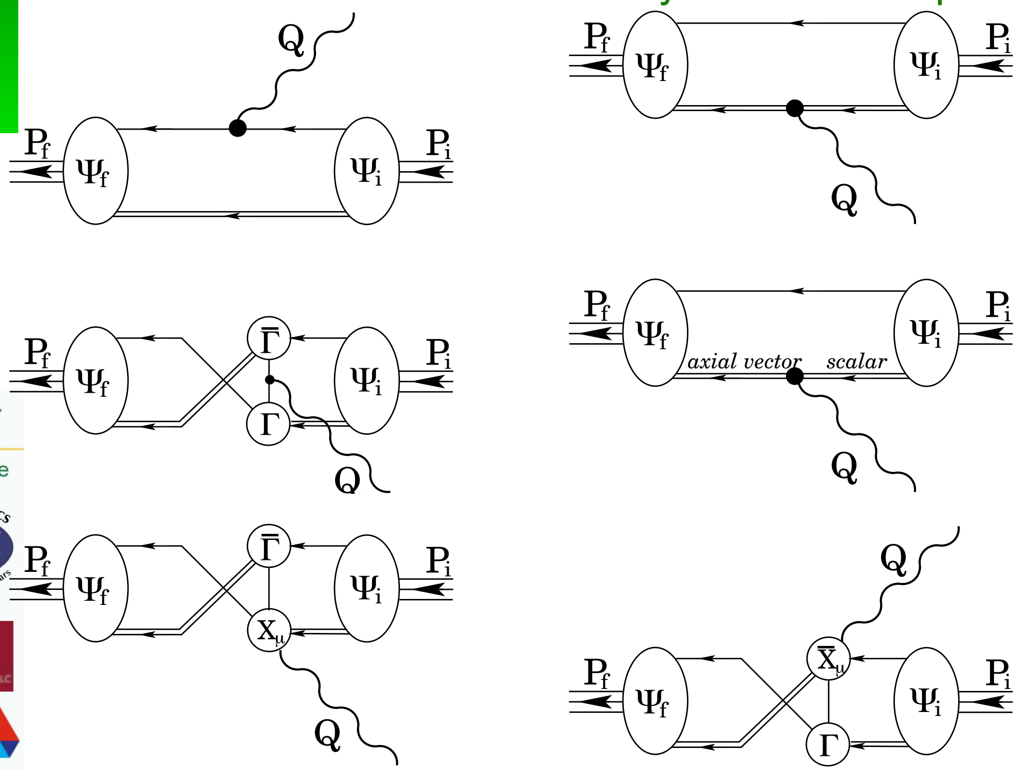
M. Oettel, M. Pichowsky
and L. von Smekal, nu-th/9909082

Nucleon-Photon Vertex

6 terms . . .

constructed systematically . . . current conserved automatically

for on-shell nucleons described by Faddeev Amplitude



U.S. DEPARTMENT OF ENERGY
Office of Science
Office of Nuclear Physics
UChicago Argonne LLC
Argonne NATIONAL LABORATORY

First Contents Back Conclusion

Craig Roberts – *Exposing the Dressed Quark's mass*
4th Workshop on Exclusive Reactions at High Momentum Transfer, 18-21 May 2010 . . . **27** – p. 22/28

Composite structure of the nucleon

O.Stern,1937

The magnetic moment of the proton was measured by the method of the magnetic deflection of molecular beams employing H_2 and HD. The result is $\mu P = 2.46\mu_0 \pm 3$ *percent.*

PHYSICAL REVIEW VOLUME 72, NUMBER 12 DECEMBER 15, 1947

On the Interaction Between Neutrons and Electrons*

E. FERMI AND L. MARSHALL
Argonne National Laboratory and Institute for Nuclear Studies, University of Chicago, Chicago, Illinois

(Received September 2, 1947)

The possible existence of a potential interaction between neutron and electron has been investigated by examining the asymmetry of thermal neutron scattering from xenon. It has been found that the scattering in the center-of-gravity system shows exceedingly little asymmetry. By assuming an interaction of a range equal to the classical electron radius, the depth of the potential well has been found to be 300±5000 ev. This result is compared with estimates based on the mesotron theory according to which the depth should be 12000 ev. It is concluded that the interaction is not larger than that expected from the mesotron theory; that, however, no definite contradiction of the mesotron theory can be drawn at present, partly because of the possibility that the experimental error may have been underestimated, and partly because of the indefiniteness of the theories which makes the theoretical estimate uncertain.

INTRODUCTION

THE purpose of this paper is to investigate an interaction between neutrons and electrons due to the possible existence of a short range potential between the two particles. If such a short range force should exist, one would expect some evidence of it in the scattering of neutrons by atoms. The scattering of neutrons by an atom is mostly due to an interaction of the of nuclear forces. According to these theories, proton and neutron are basically two states of the same particle, the nucleon. A neutron can transform into a proton according to the reaction:

$$N = P + \bar{\mu}. \qquad (1)$$

(N = neutron, P = proton, $\bar{\mu}$ = negative mesotron)

Actually, a neutron will spend a fraction of its time as neutron proper (left-hand side of Eq. (1))

E.Fermi,1947

Structure of the Nucleon

"We must constantly remember, therefore, that different experiments probe different components of nucleon structure. The term "structure" in fact is misleading in that it may connote some kind of detailed spatial distribution of matter "inside" the nucleon. The combination of principles of relativity and quantum mechanics implies that no meaning can be attached to such a spatial distribution." G.F. Chew

Structure since 1937	Nucleon Structure. Proceedings of the international conference held in June 1963. Robert Hofstadter and Leonard I. Schiff
Many books	
Recent review	The Structure of the Nucleon, Anthony W. Thomas, Wolfram Weise
Many faces	Confinement, Quark, Gluon, Spin, Color, OAM, Bjorken x_{Bj}, …
Connections	The GPD phenomenology connects the elastic FFs to DIS and other
My report	I will discuss the structure visible at a specific point, x_{Bj} = 1, and, as the title suggested, only at large momentum transfer, $Q^2 >> M^2$

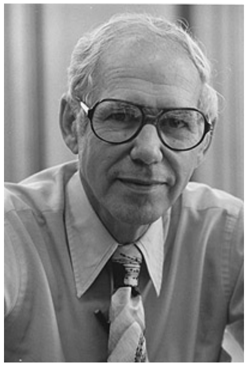
Introduction of the Form Factors

Nucleon current, one-photon approximation, α_{em} = 1/137,

Rosenbluth,1950

$$\mathcal{J}^{\mu}_{hadron} = ie\bar{N}(p_f)\,[\gamma^{\nu} F_1(Q^2) + \frac{i\sigma^{\mu\nu}q_{\nu}}{2\,M} F_2(Q^2)]\,N(p_i)$$

$$\frac{d\sigma}{d\Omega}(E,\theta) = \frac{\alpha^2 E'\cos^2(\frac{\theta}{2})}{4E^3\sin^4(\frac{\theta}{2})}[(F_1^2 + \kappa^2\tau F_2^2) + 2\tau(F_1 + \kappa F_2)^2\tan^2(\frac{\theta}{2})]$$



Sachs,1962

$$\frac{d\sigma}{d\Omega}(E,\theta) = \sigma_M[\frac{G_E^2 + \tau G_M^2}{1+\tau} + 2\tau G_M^2\tan^2(\frac{\theta}{2})]$$

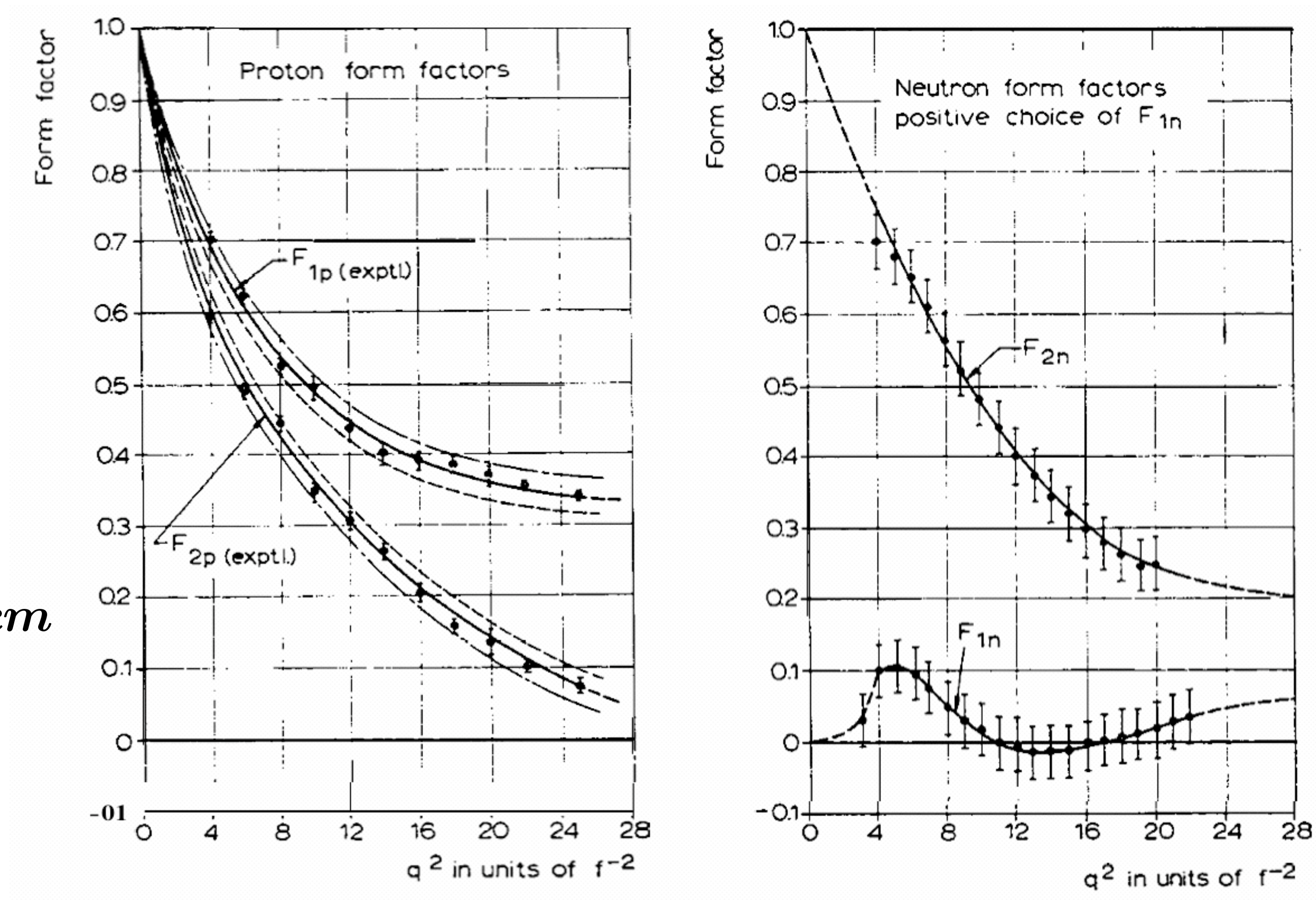
The first Form Factor measurement

R.Hofstadter, 1956

$$r_e = r_m = 0.8 \times 10^{-13}\, cm$$

$$\rho = \rho_o \times e^{-\sqrt{12}\, r/r_{e,m}}$$

$$F(q) = \frac{1}{[1+(q\,r)^2/12]^2}$$



Dirac, Pauli and Sachs Form Factors

Nucleon current, one-photon approximation, α_{em} = 1/137, Rosenbluth,1950

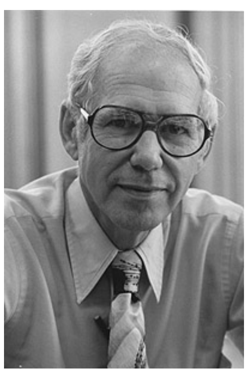
$$\mathcal{J}^{\mu}_{hadron} = ie\bar{N}(p_f)\left[\gamma^{\nu} F_1(Q^2) + \frac{i\sigma^{\mu\nu} q_{\nu}}{2M} F_2(Q^2)\right] N(p_i)$$

Cross section and asymmetry for electron-nucleon scattering

$$d\sigma = d\sigma_{NS}\left\{\underline{\varepsilon(G_E)^2 + \tau(G_M)^2}\right\} \cdot \left[1 + h_e A(G_E, G_M)\right]$$

$$A = A_{\perp} + A_{\parallel} = \frac{a \cdot G_E G_M \sin\theta^{\star} \cos\phi^{\star}}{G_E^2 + c \cdot G_M^2} + \frac{b \cdot G_M^2 \cos\theta^{\star}}{G_E^2 + c \cdot G_M^2}$$

Sachs,1962



Does a nucleon have a core ?

$$G_E = F_1(Q^2) - \frac{Q^2}{4M^2} F_2(Q^2) \qquad G_M = F_1(Q^2) + F_2(Q^2)$$

$$J_{fi} = 2E \cdot F(-\vec{q}^{\,2}), \quad \vec{J} = 0 \qquad \rho(r) = \frac{1}{(2\pi)^3} \int F(-\vec{q}^{\,2}) e^{i\vec{q}\vec{r}} d^3\vec{q}$$

Dirac, Pauli and Sachs Form Factors

Nucleon current, one-photon approximation, α_{em} = 1/137, Rosenbluth, 1950

$$\mathcal{J}^{\mu}_{hadron} = ie\bar{N}(p_f)\left[\gamma^{\nu} F_1(Q^2) + \frac{i\sigma^{\mu\nu}q_{\nu}}{2M} F_2(Q^2)\right] N(p_i)$$

Cross section and asymmetry for electron-nucleon scattering

$$d\sigma = d\sigma_{NS}\left\{\underline{\varepsilon(G_E)^2 + \tau(G_M)^2}\right\}\cdot\left[1 + h_e A(G_E, G_M)\right]$$

$$A = A_{\perp} + A_{\parallel} = \frac{a\cdot G_E G_M \sin\theta^{\star}\cos\phi^{\star}}{G_E^2 + c\cdot G_M^2} + \frac{b\cdot G_M^2 \cos\theta^{\star}}{G_E^2 + c\cdot G_M^2}$$

M.Burkardt

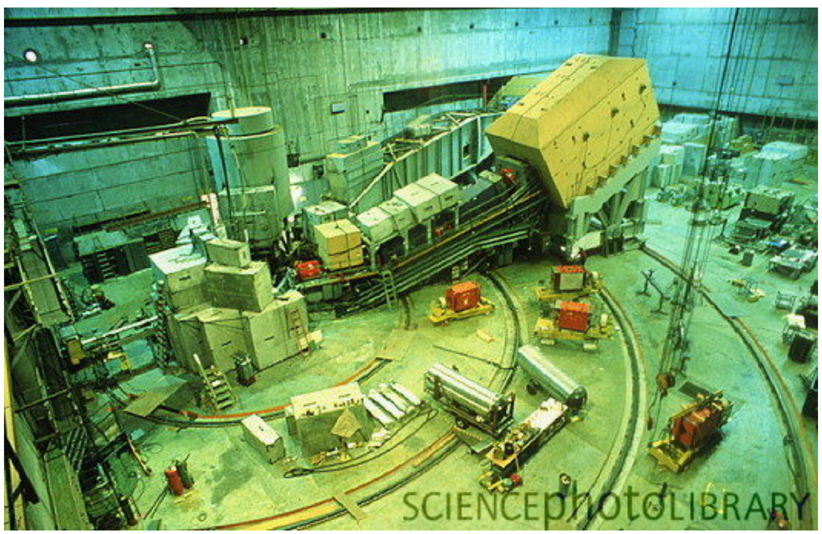
G.Miller

Impact parameter representation of the GPDs

$$q(x, \mathrm{b}) = \int \frac{d^2 q}{(2\pi)^2} e^{i\,\mathrm{q}\cdot\mathrm{b}} H_q(x, t = -\mathrm{q}^2)$$

$$\rho_{\mathrm{T}}(\mathbf{b})$$

SLAC accelerator



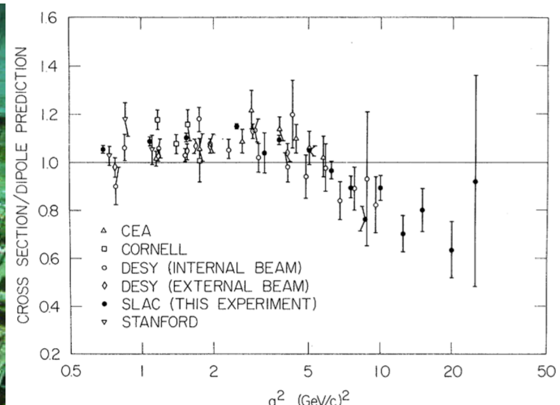


FIG. 1. Compilation of electron-proton elastic-scattering cross sections for q^2 greater than 0.7 $(\mathrm{GeV}/c)^2$. The cross sections are normalized to the Rosenbluth formula and the dipole relation. Systematic errors in the SLAC data are not shown, but would be up to 6%.

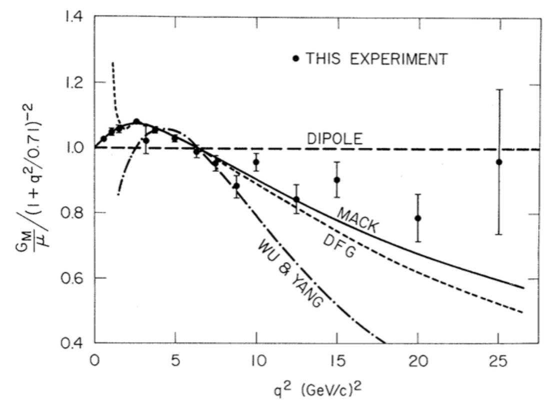


FIG. 2. Comparison of several theoretical expressions for G_M/μ and the SLAC data from Table I. Details of the fits are given in the text.

SLAC results in 1968

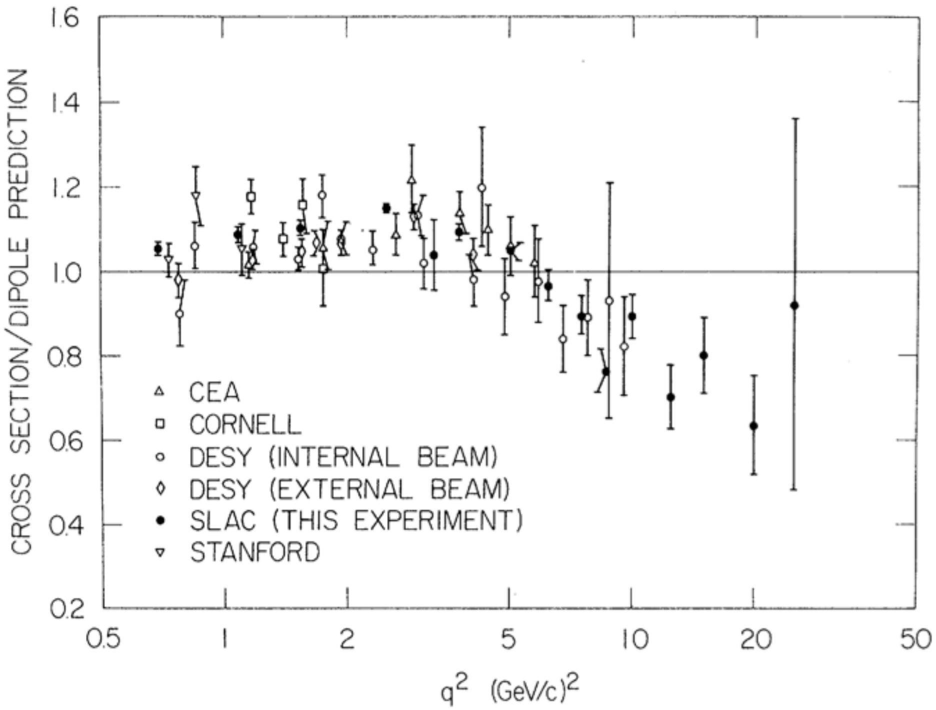


FIG. 1. Compilation of electron-proton elastic-scattering cross sections for q^2 greater than 0.7 (GeV/c)^2. The cross sections are normalized to the Rosenbluth formula and the dipole relation. Systematic errors in the SLAC data are not shown, but would be up to 6%.

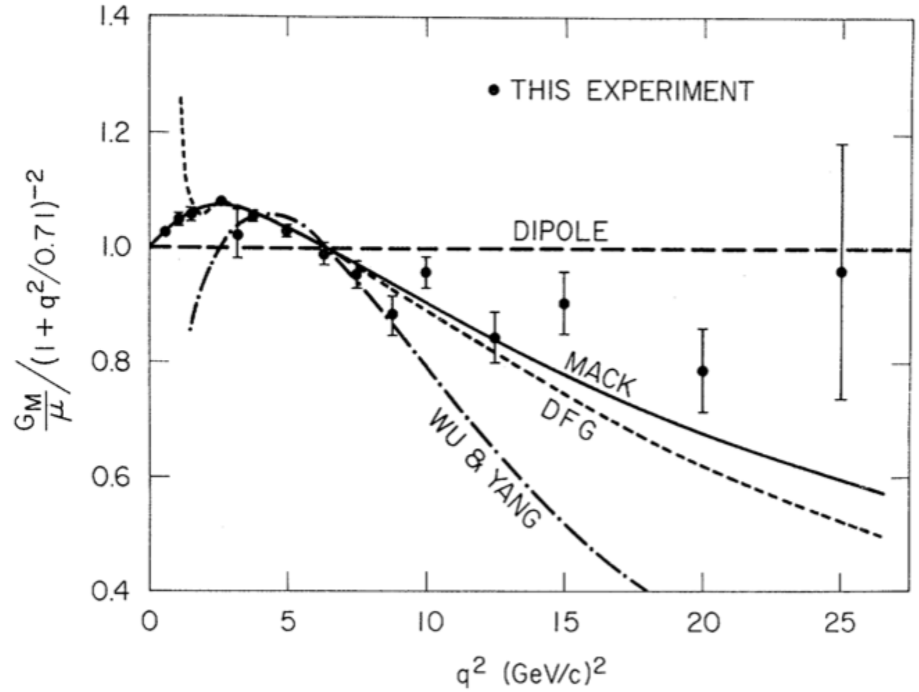


FIG. 2. Comparison of several theoretical expressions for G_M/μ and the SLAC data from Table I. Details of the fits are given in the text.

PRL 20, 292 (1968), GMp scales to $G_D = 1/(1+Q^2/0.71)^2$

SLAC results for the proton Form Factors

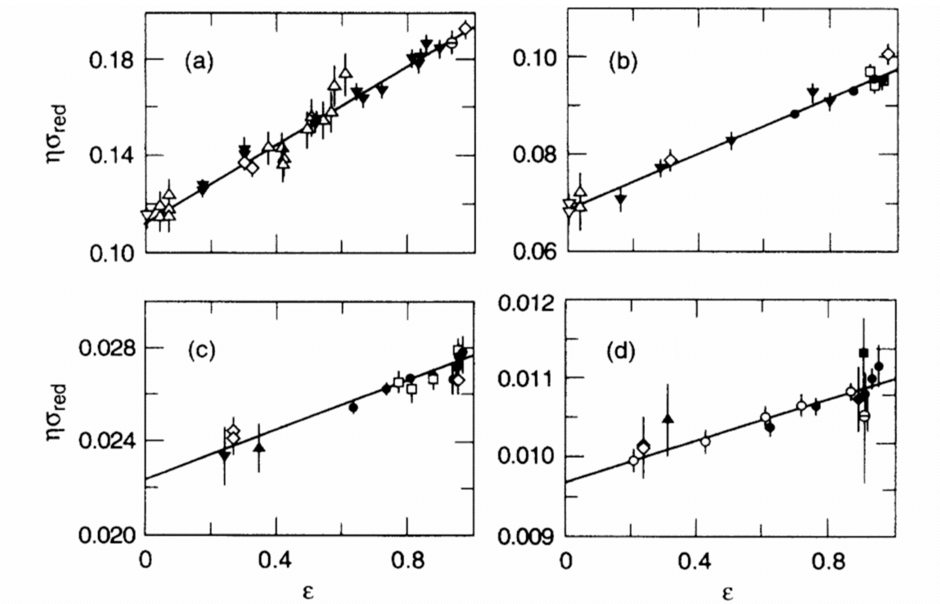
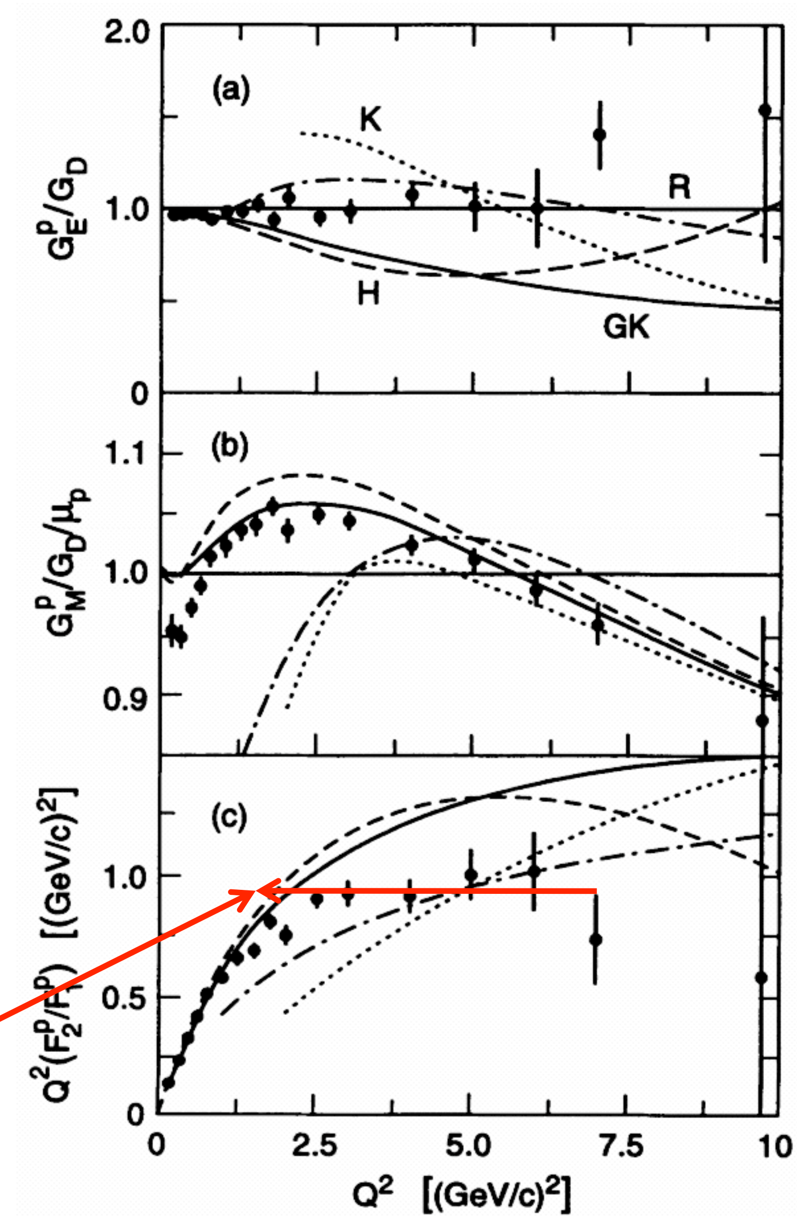


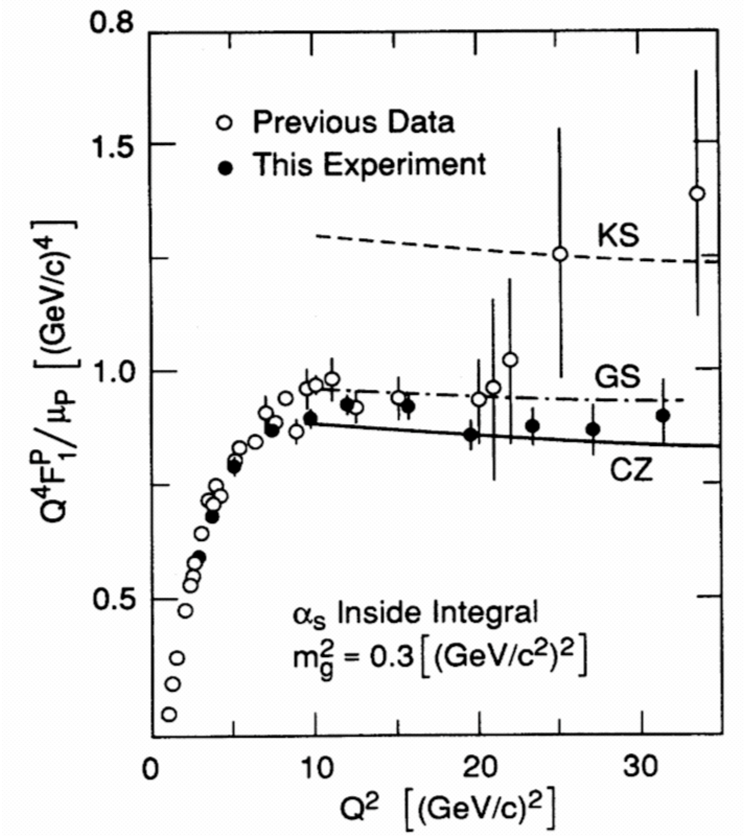
FIG. 9. Four typical Rosenbluth fits for the form factor extraction from the global data set at (a) $Q^2 = 0.6$, (b) $Q^2 = 1.0$, (c) $Q^2 = 2.0$, and (d) $Q^2 = 3.0$ $(\mathrm{GeV}/c)^2$.

Walker et al (1993)



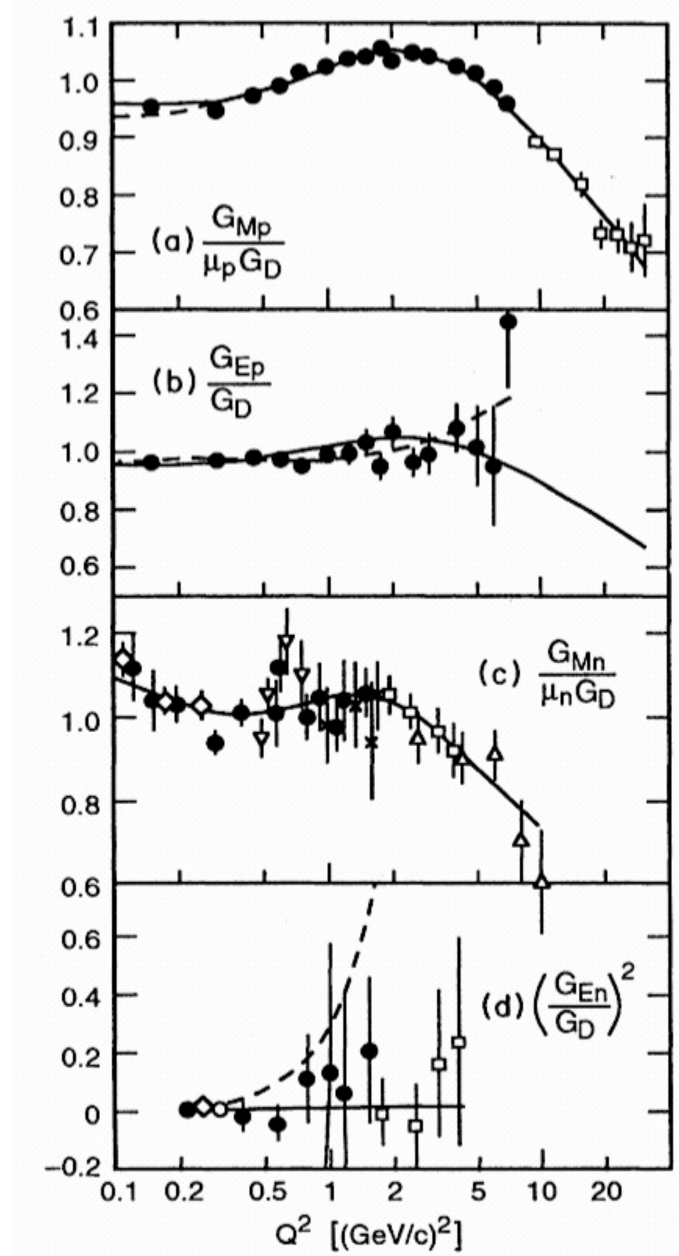
The onset of the pQCD scaling?

SLAC results for the Form Factors



Sill et al (1993)

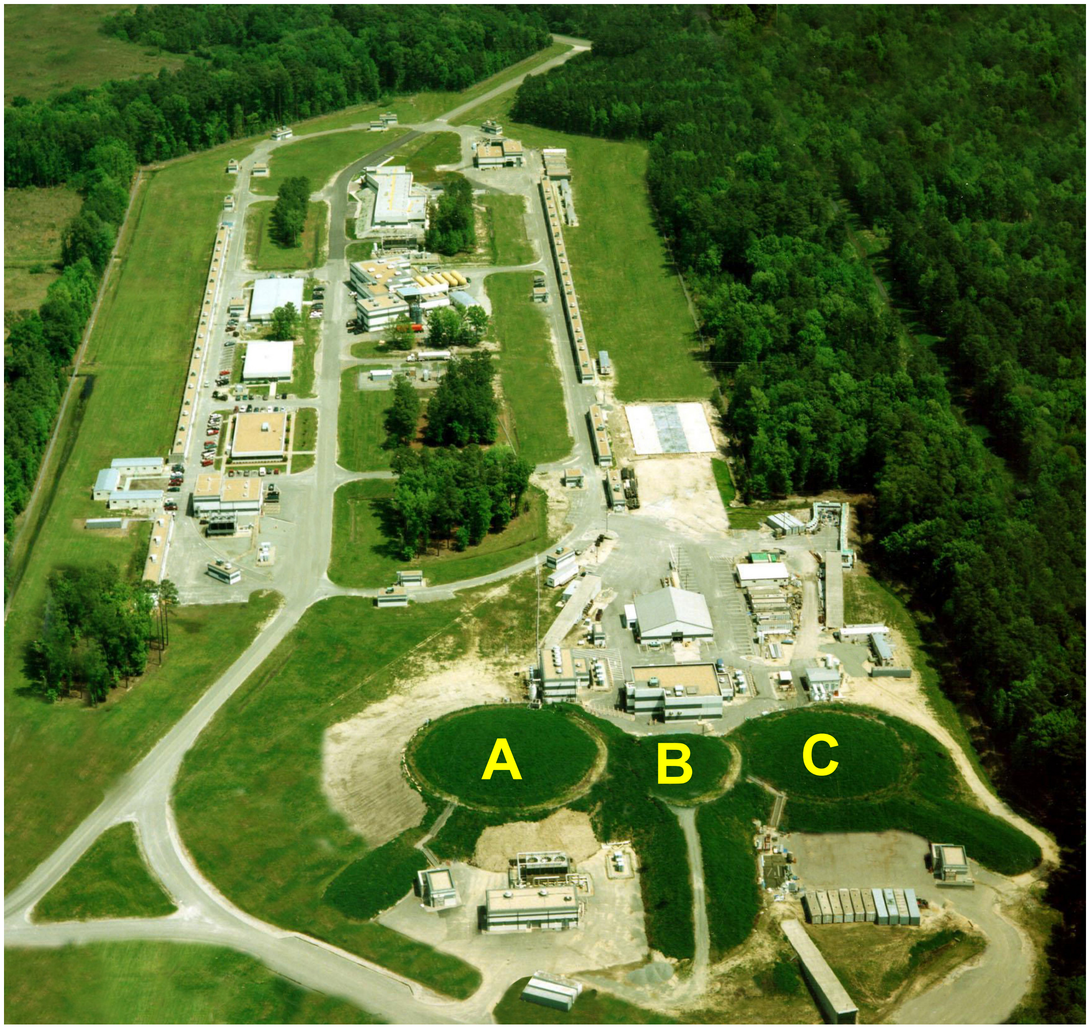
Bosted (1995)



What does it mean?

These are the (e,e') single arm measurements

TJNAF accelerator



Re-circulating linac

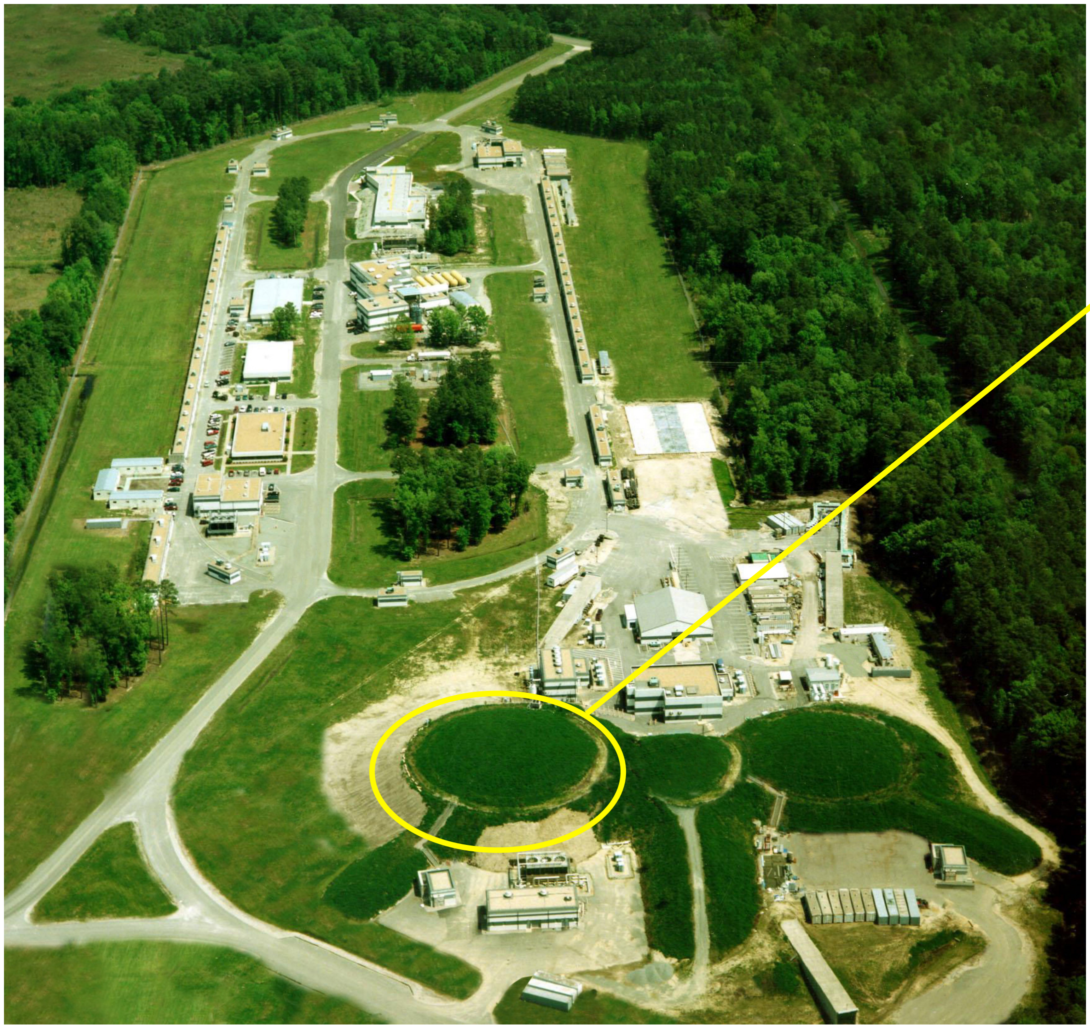
6.0 GeV max beam energy

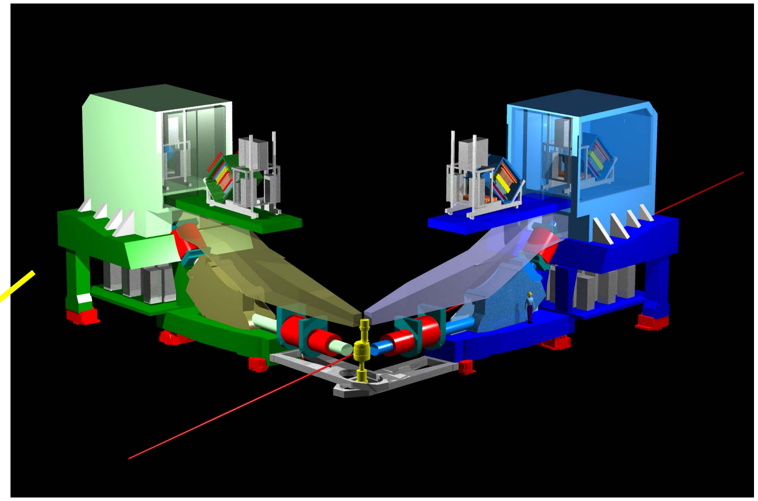
100% duty cycle

2 ns microstructure

Beam polarization up to 85%
180 μA max current

Hall A at Jefferson Lab



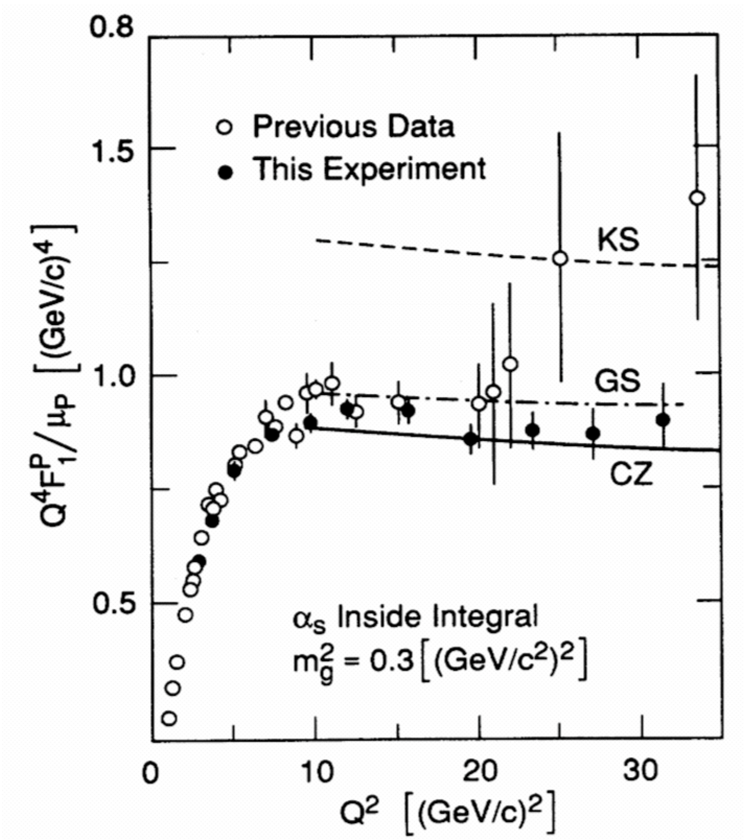


$\sigma_E/E < 2\cdot10^{-4}$ (absolute)

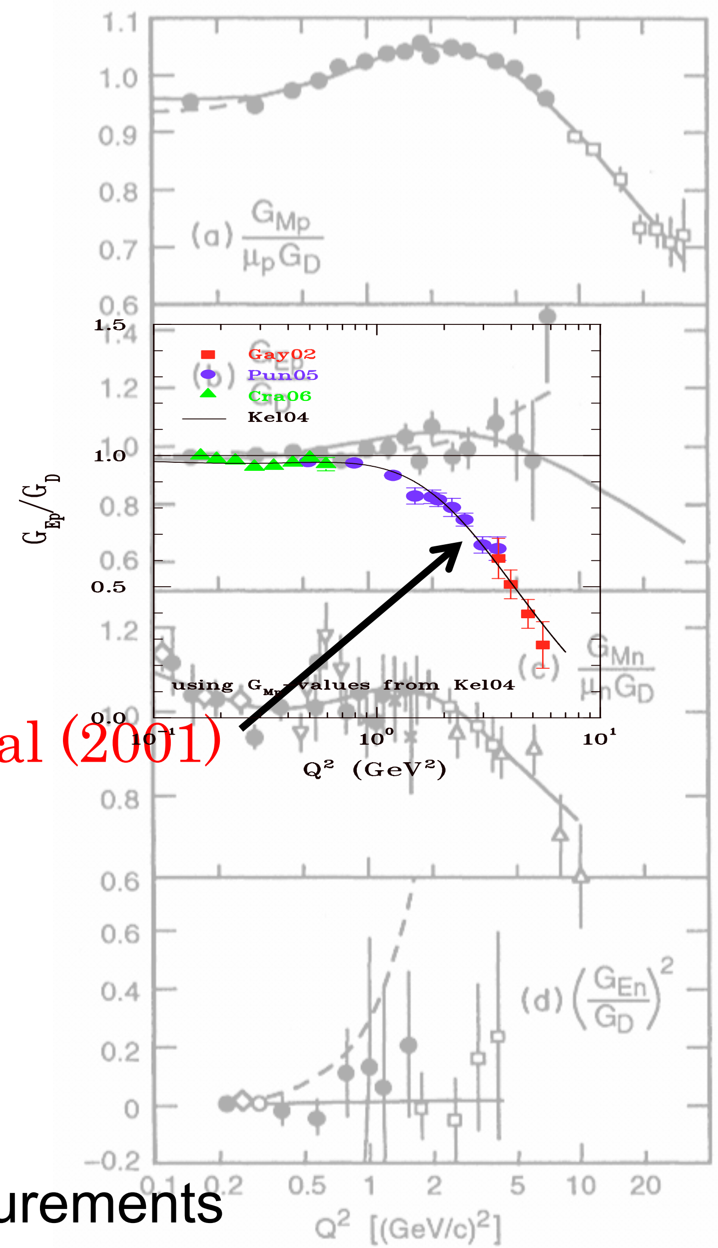
Two <u>H</u>igh <u>R</u>esolution <u>S</u>pectrometers originally designed for A(e,e´p) expts.

The polarimeter for the proton

Results for the Form Factors



Sill et al (1993)



Perdrisat et al (2001)

What could it possibly mean?

These are the (e,e'p) double polarization measurements

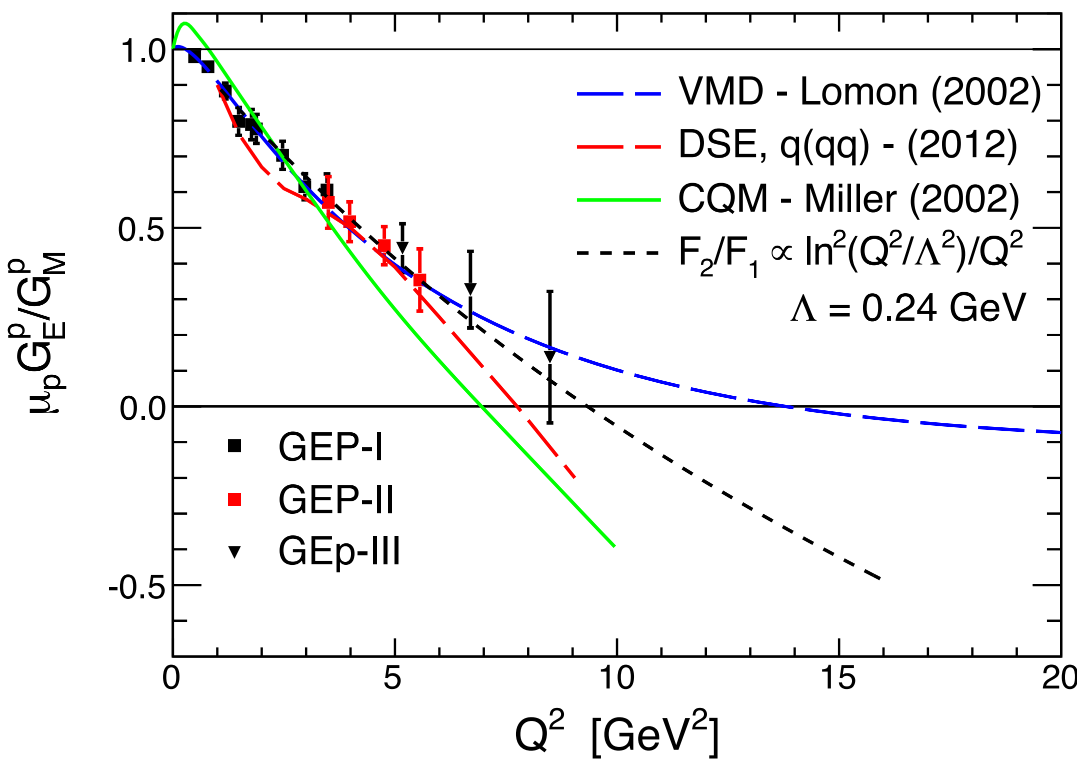
The goal is understanding of the nucleon

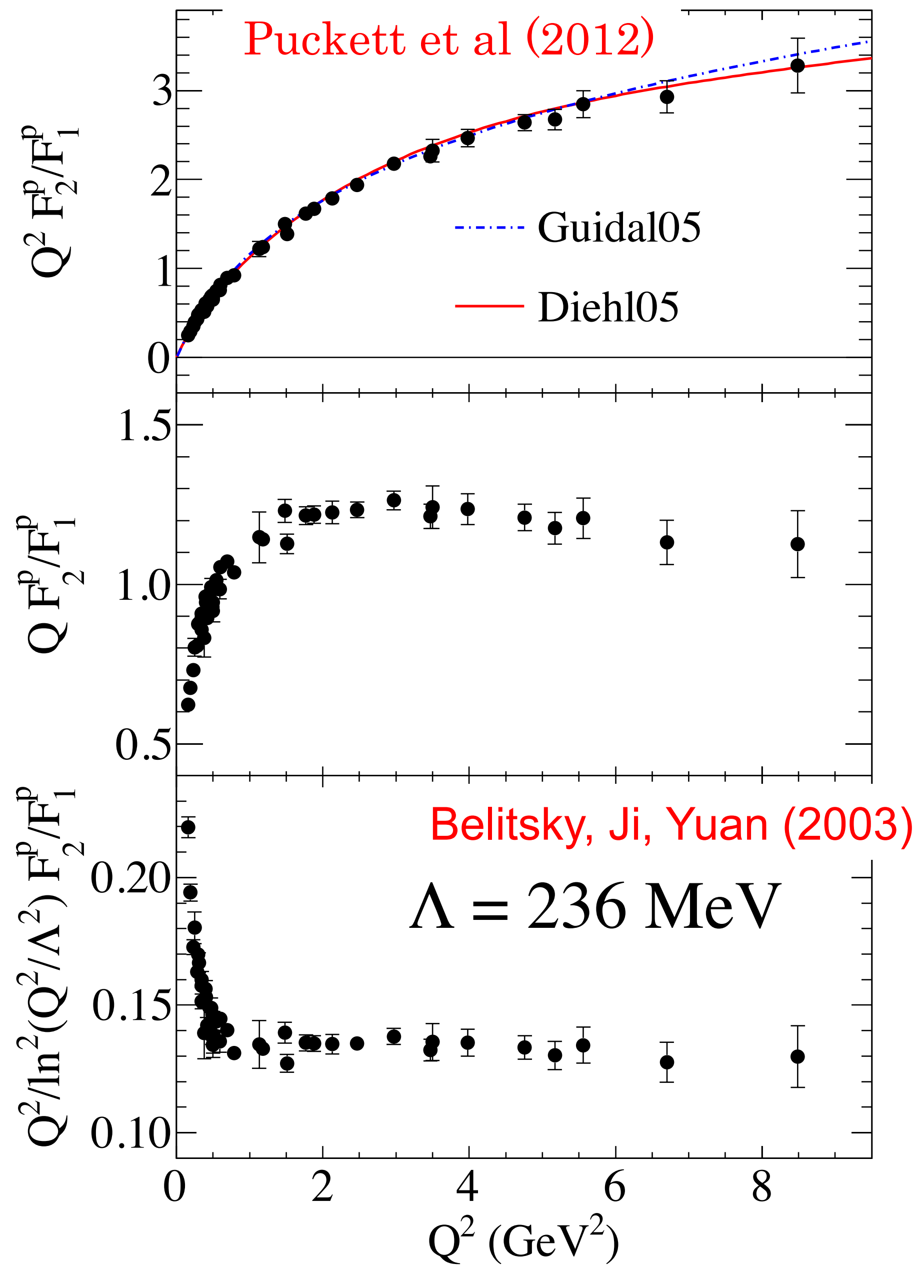
From the Sachs FFs to the Dirac&Pauli

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

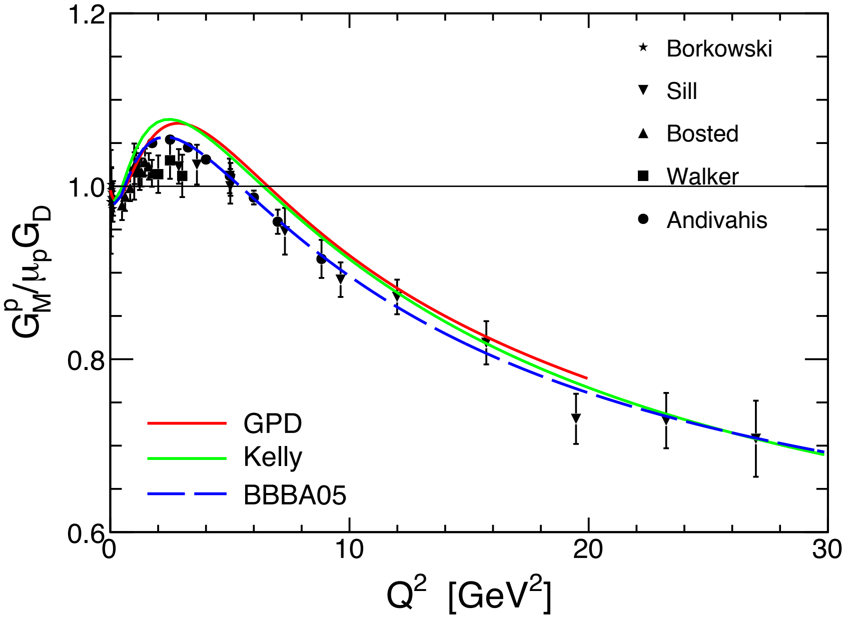
$$F_2 = -\frac{G_E - G_M}{1 + \tau}$$

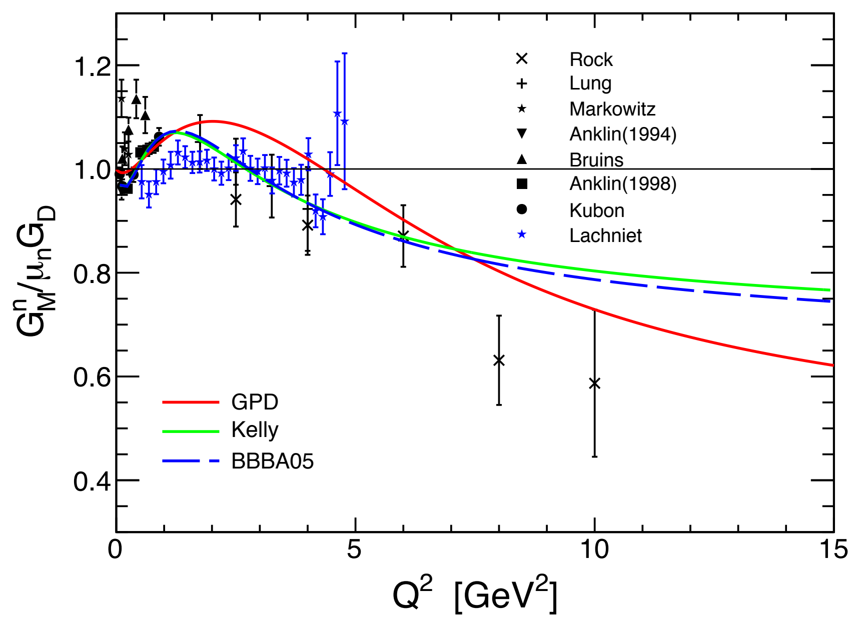
$$F_2/F_1 = \frac{1 - G_E/G_M}{\tau + G_E/G_M}$$

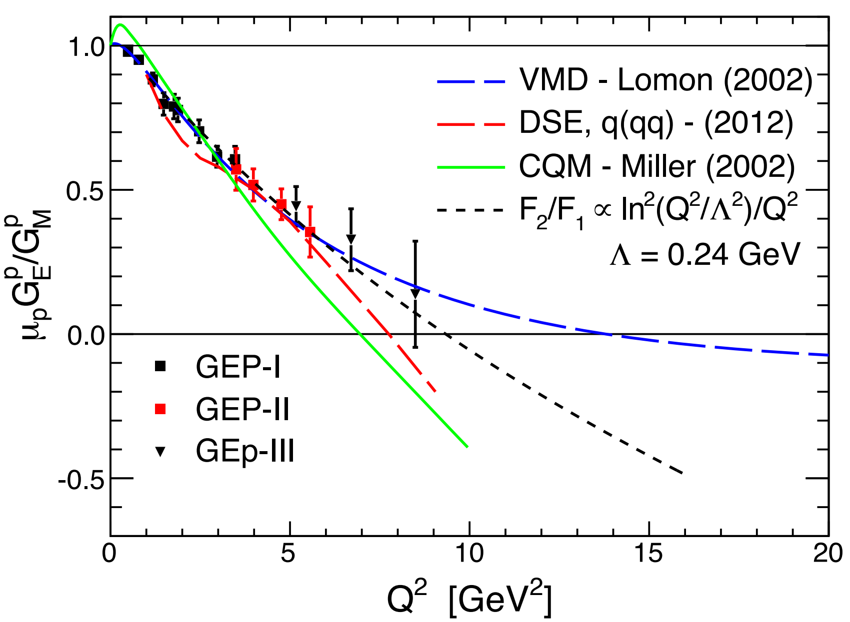


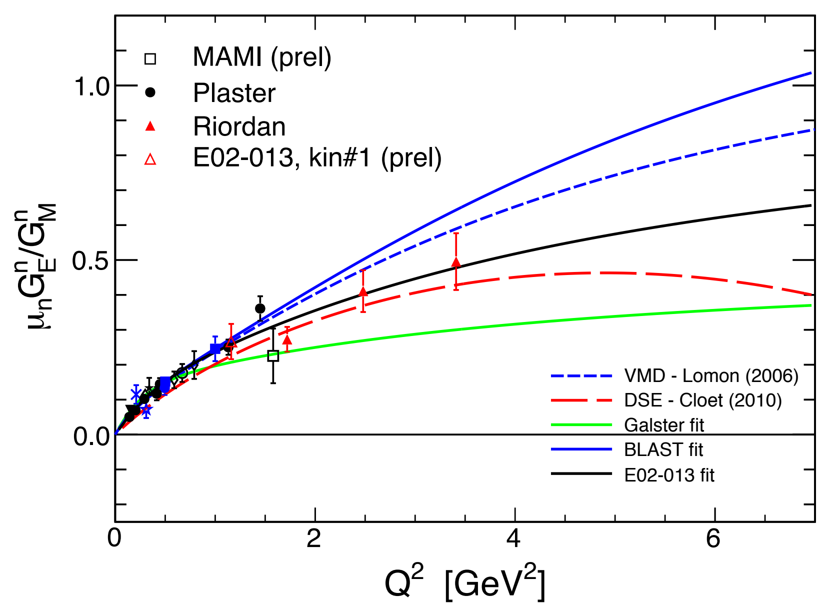


High Q^2 data for EMFFs of the nucleon



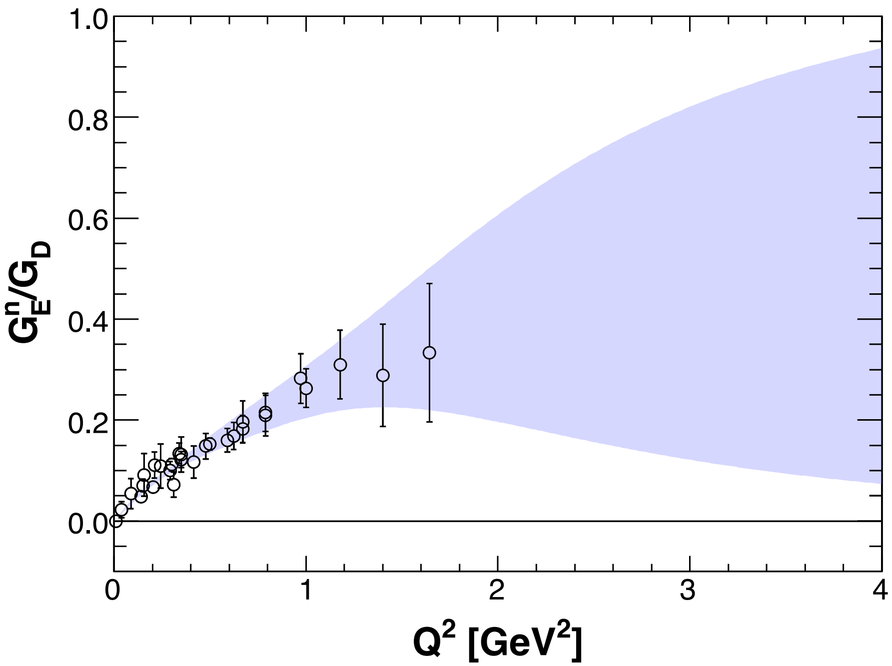




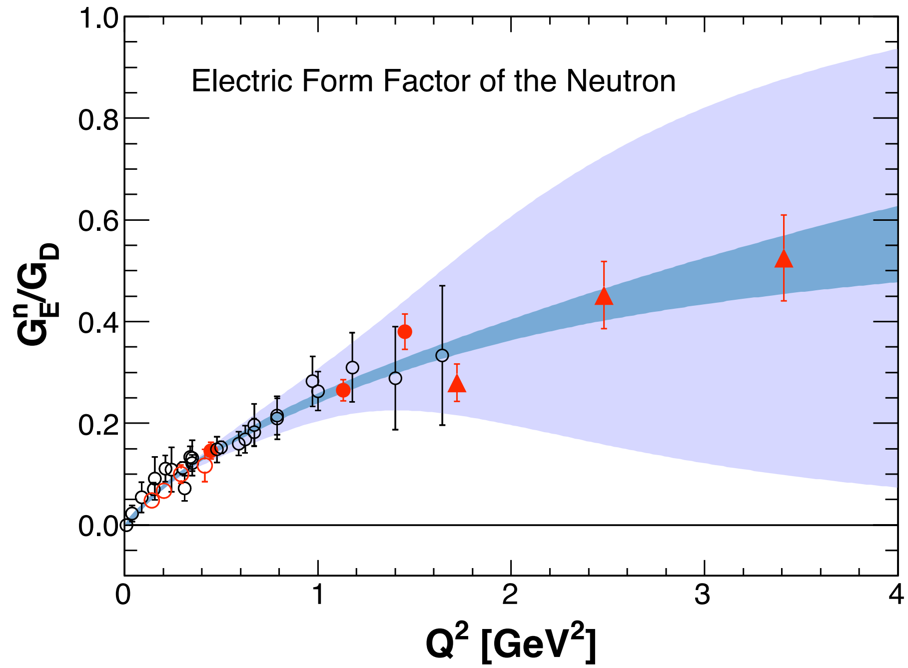


The JLab G_E^n experiments

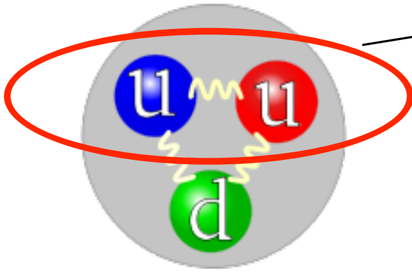
without JLab GEn experiments



significantly better accuracy for high Q^2



The goal is understanding of the nucleon

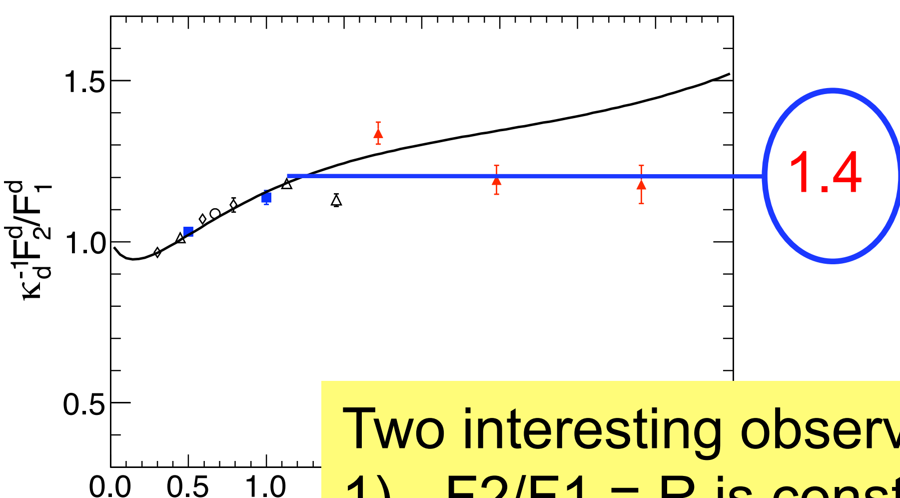


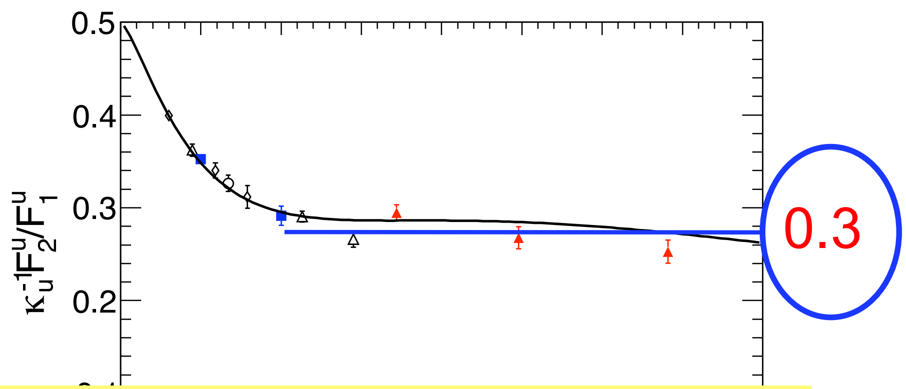
$$F_p = \frac{+2}{3} F_{dual} + \frac{-1}{3} F_{lone}$$

$$F_n = \frac{-1}{3} F_{dual} + \frac{+2}{3} F_{lone}$$

$$F_{1,dual} = F_1^{u,p} = 2\, F_{1p} + F_{1n} \qquad F_{1,lone} = F_1^{d,p} = 2\, F_{1n} + F_{1p}$$

Results of E02-013 Hall A GEn

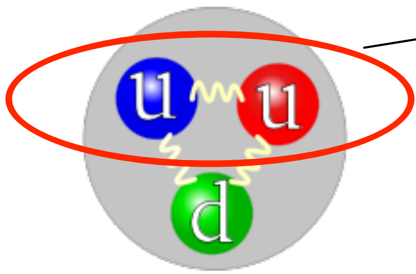




Two interesting observations:

1) F2/F1 = R is constant in the Q^2-range 1 - 3.5 GeV^2
2) The value of R for d-quark >> than R for u-quark

The goal is understanding of the nucleon

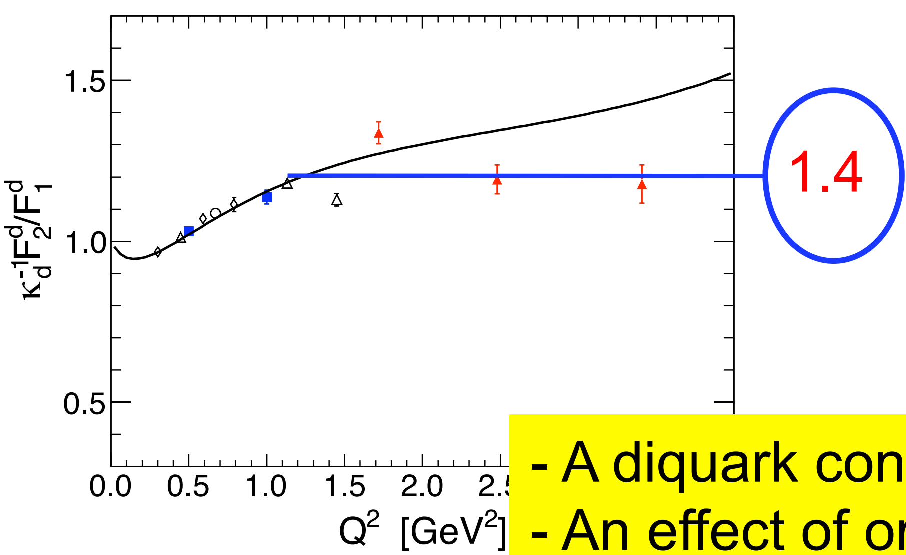


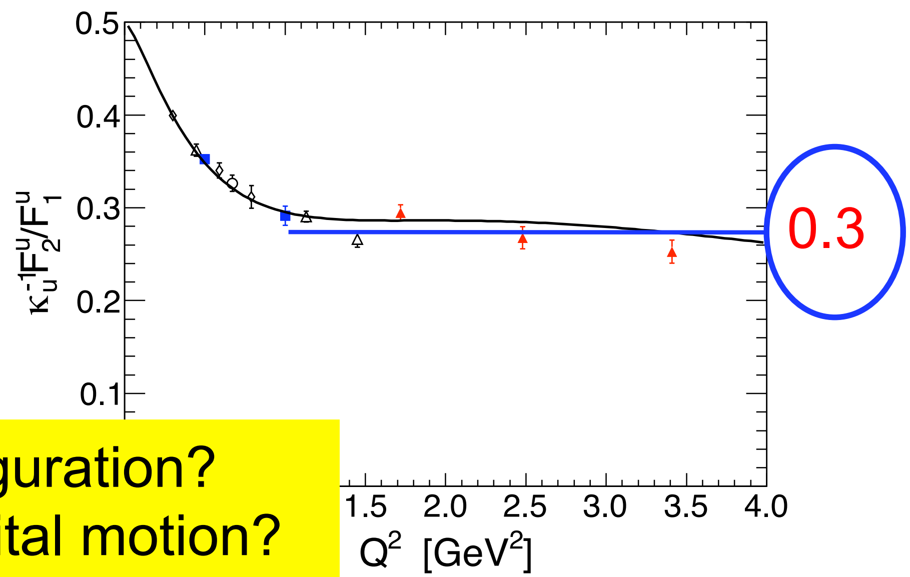
$$F_p = \frac{+2}{3} F_{dual} + \frac{-1}{3} F_{lone}$$

$$F_n = \frac{-1}{3} F_{dual} + \frac{+2}{3} F_{lone}$$

$$F_{1,dual} = F_1^{u,p} = 2\,F_{1p} + F_{1n} \qquad F_{1,lone} = F_1^{d,p} = 2\,F_{1n} + F_{1p}$$

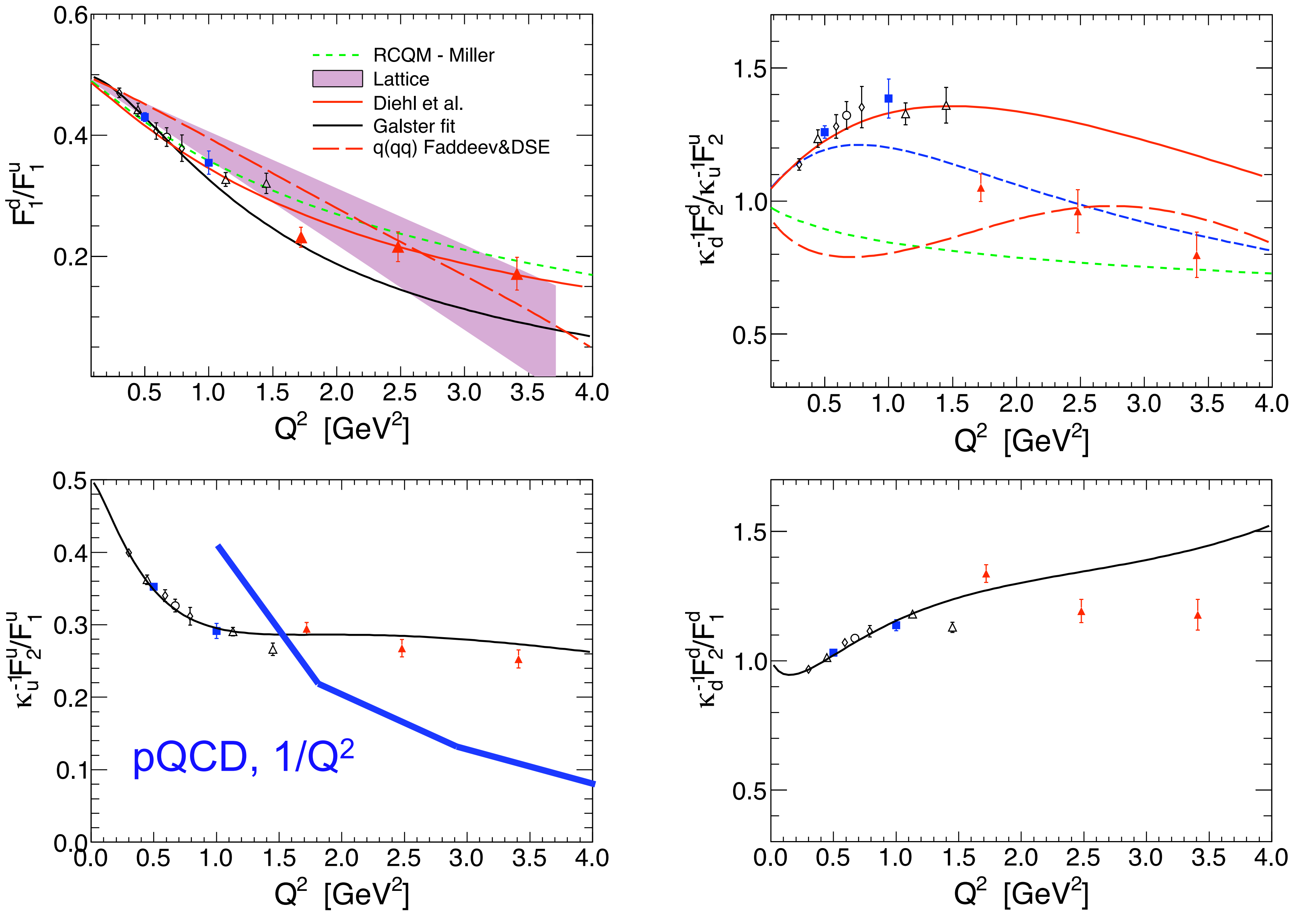
Results of E02-013 Hall A GEn



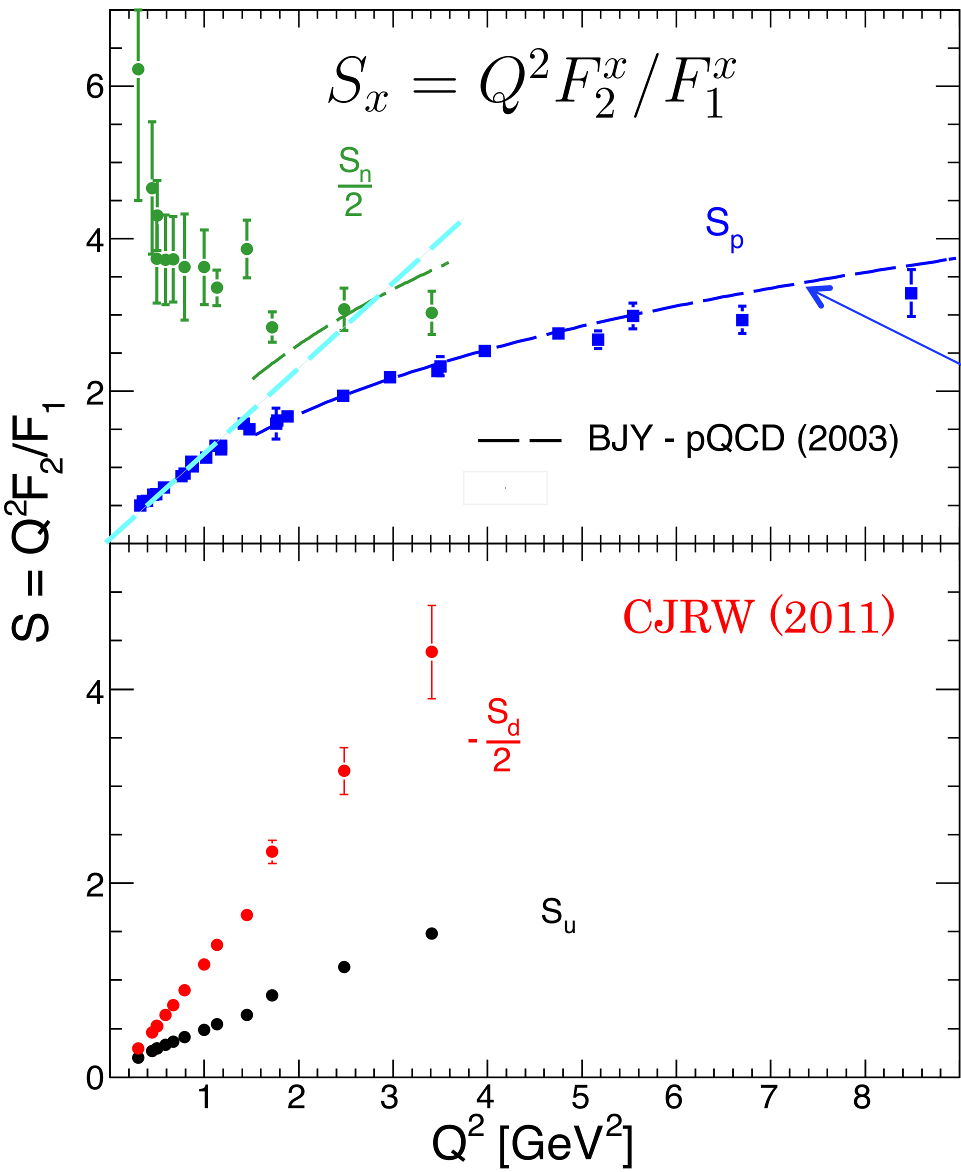


- A diquark configuration?
- An effect of orbital motion?

F_2/F_1 and other ratios



The goal is understanding of the nucleon



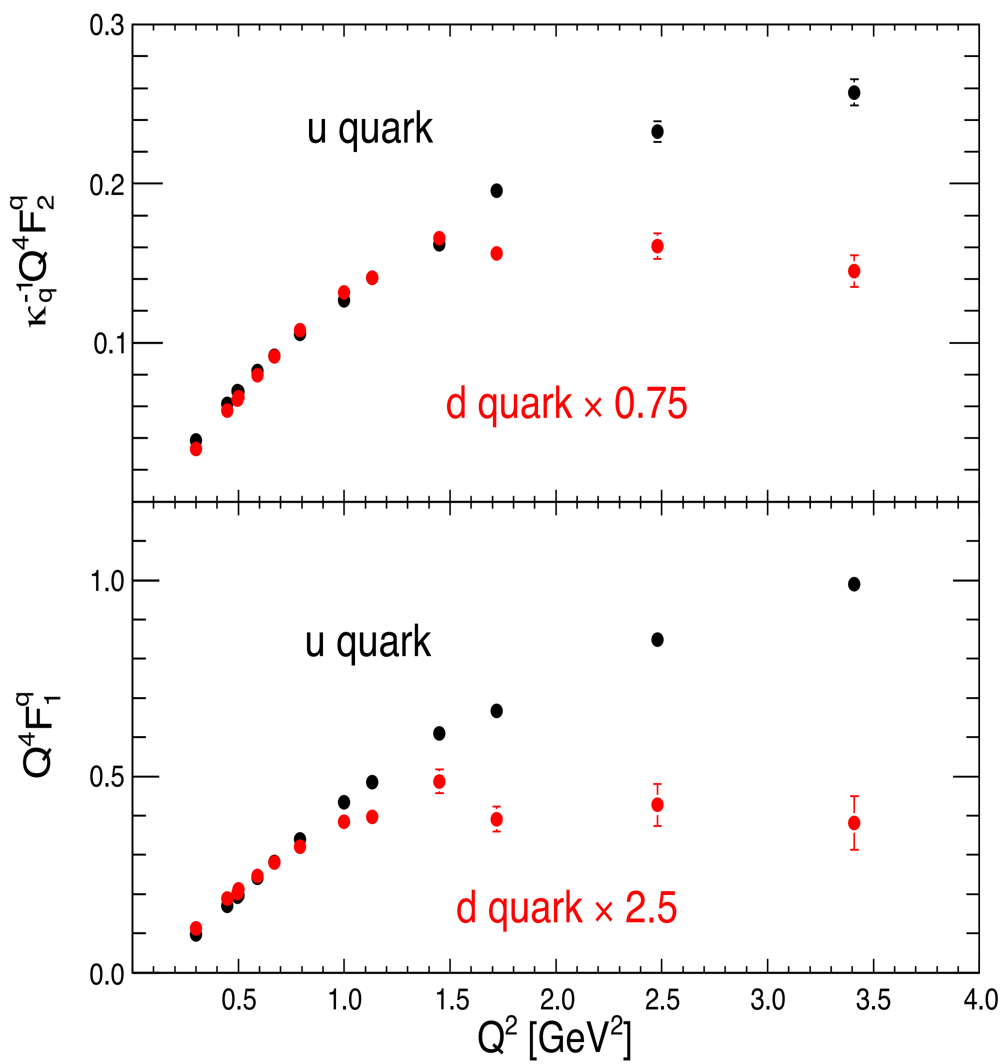
pQCD prediction for large Q^2:
$$S \rightarrow Q^2 F_2/F_1$$

pQCD updated prediction:
$$S \rightarrow \left[Q^2/\ln^2(Q^2/\Lambda^2)\right] F_2/F_1$$

Flavor separated contribution:
The log scaling for the proton
Form Factor ratio at few GeV^2
is "accidental".

The lines for each individual flavor are straight!

The goal is understanding of the nucleon



The d-quark contributions to both F1 and F2 are strongly suppressed at high Q^2

At Q^2 above 1.5 GeV^2 both F1 and F2 d-quark contributions are close to $1/Q^4$

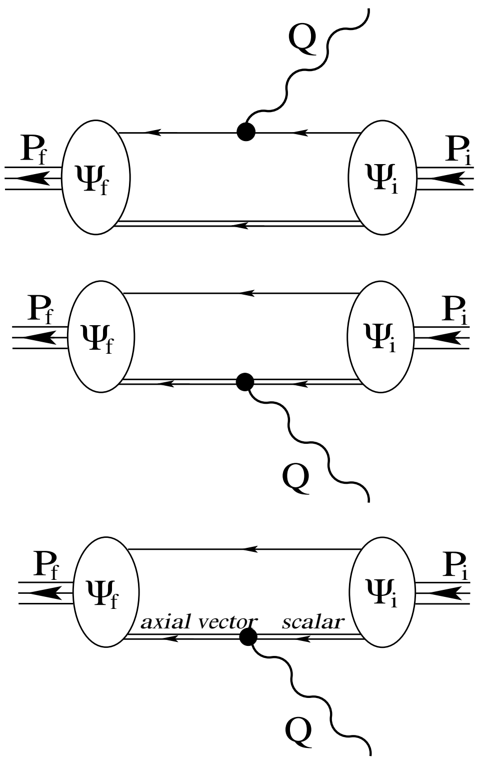
It should be due to the difference between a singly represented d-quark and doubly rep. u-quark

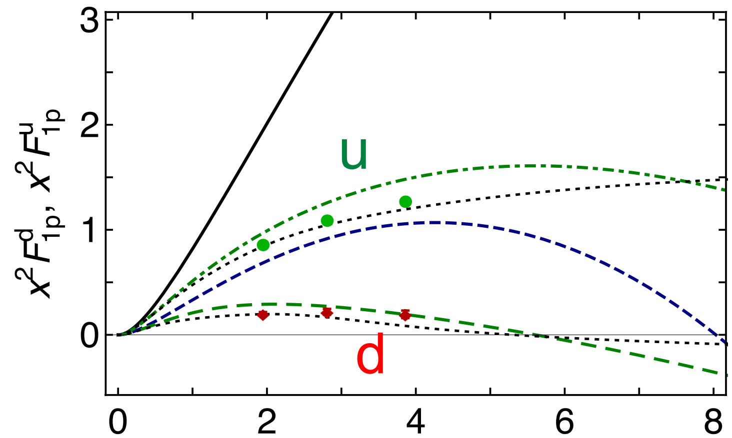
To what is it pointing?

The goal is understanding of the nucleon

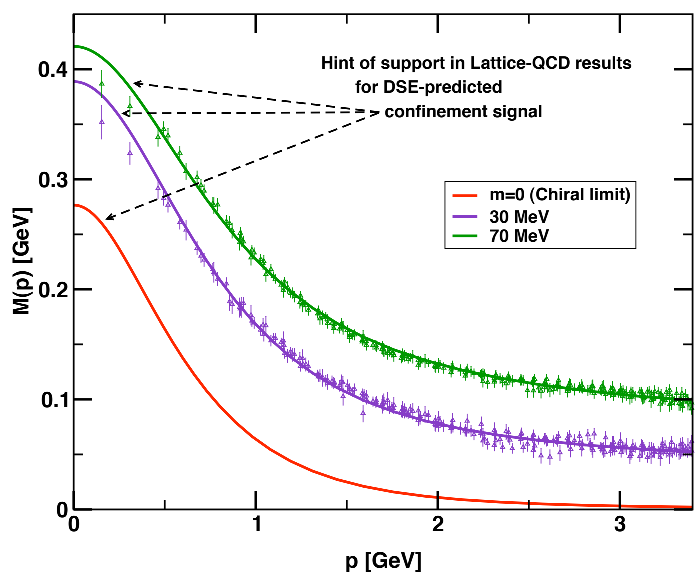
Nucleon and Roper electromagnetic elastic and transition form factors

Wilson, Cloet, Chang, Roberts, PRC 85, 025205 (2012)





Interplay between the [qq] and {qq} diquarks creates a zero crossings



Could the diquarks produce a flavor dependence of M(p)?

The goal is understanding of the nucleon

Nucleon electromagnetic form factors from the covariant Faddeev equation

G. Eichmann, Phys. Rev. D 84, 014014 (2011)

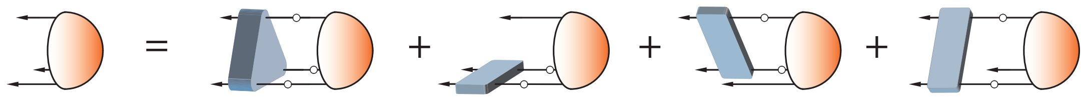
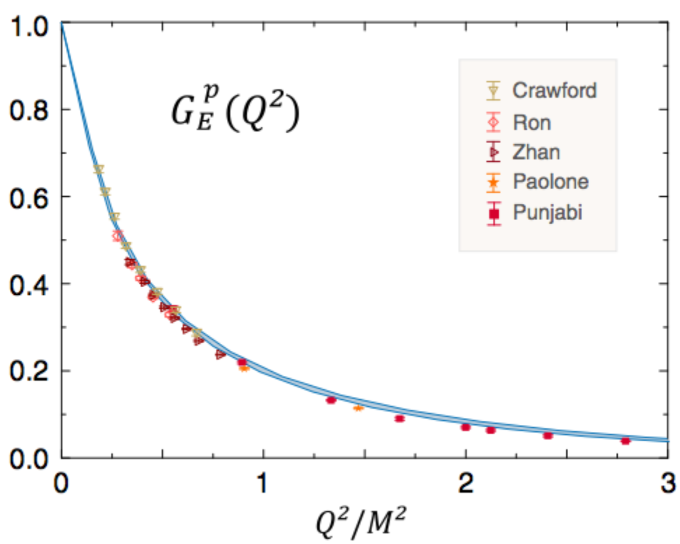
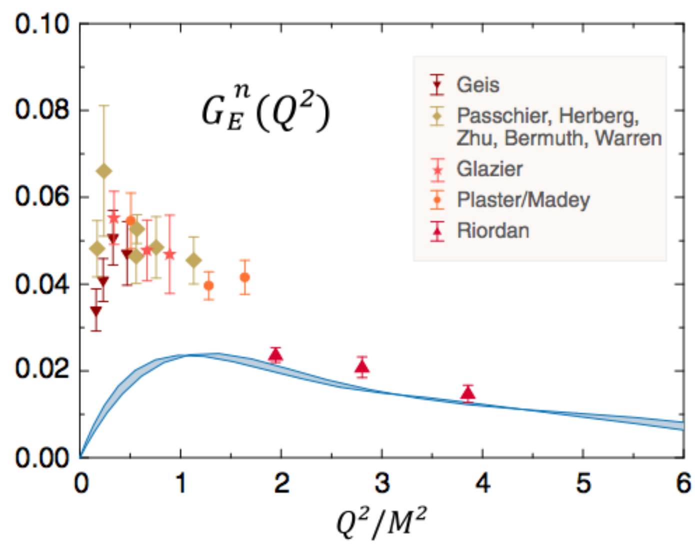


TABLE II. Results for the nucleon mass and static electromagnetic properties, compared to experiment. The parentheses indicate the dependence on the infrared parameter η of Eq. (9). M_N is given in GeV, the magnetic moments are expressed in nuclear magnetons, and the charge radii are given in fm.

	M_N	μ^p	μ^n	κ^v	κ^s	r_E^p	$(r_E^n)^2$	r_M^p	r_M^n
Faddeev	0.94	2.21(1)	−1.33(1)	2.54(2)	−0.12(1)	0.75(3)	−0.01	0.72(2)	0.72(2)
Experiment	0.94	2.79	−1.91	3.70	−0.12	0.89	−0.12	0.86	0.87

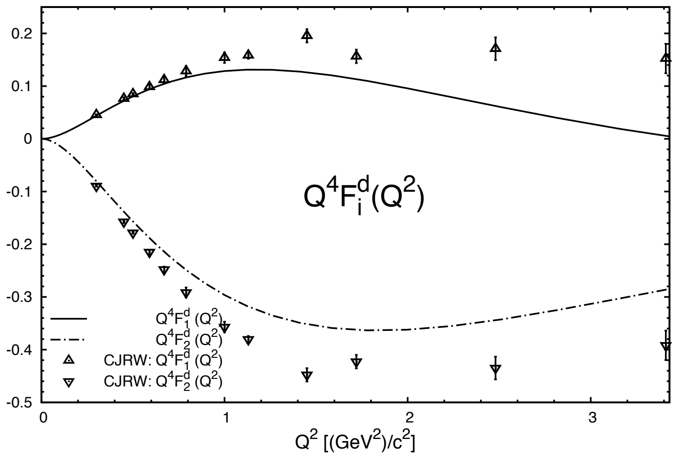




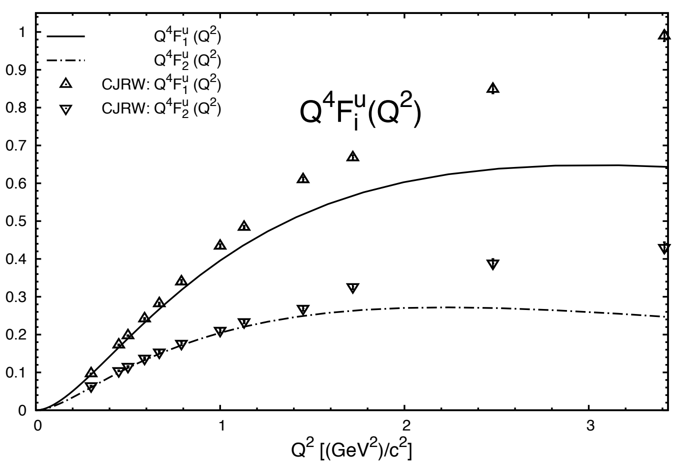
The goal is understanding of the nucleon

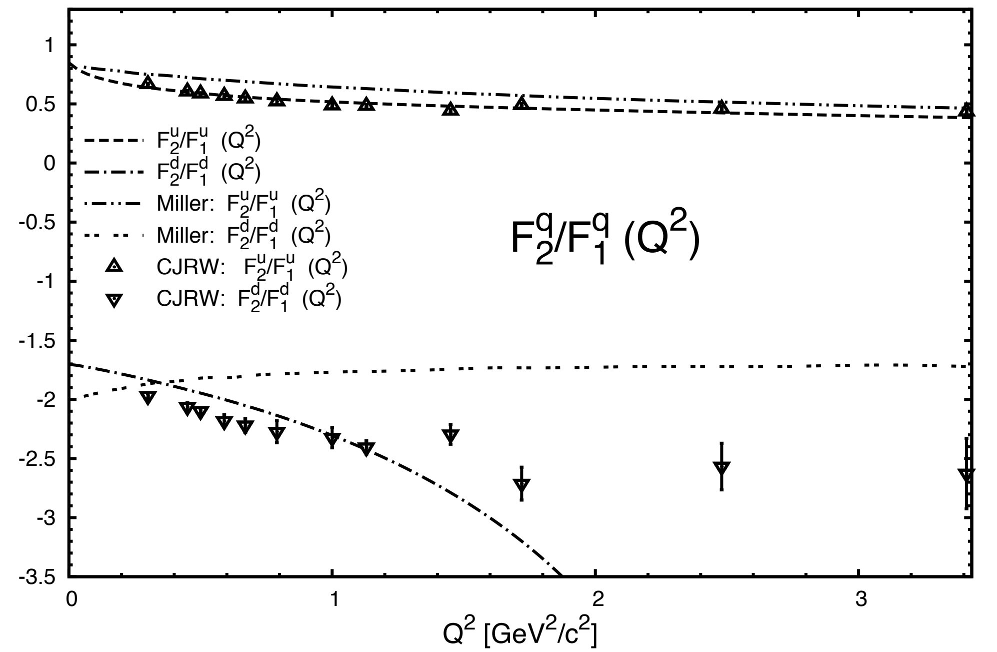
Flavor analysis of nucleon electromagnetic form factors

M. Rohrmoser, K. -S. Choi, W. Plessas, arXiv:1110.3665 [hep-ph]



The relativistic constituent-quark model (RCQM) whose quark-quark hyperfine interaction is based on Goldstone-boson exchange (GBE)





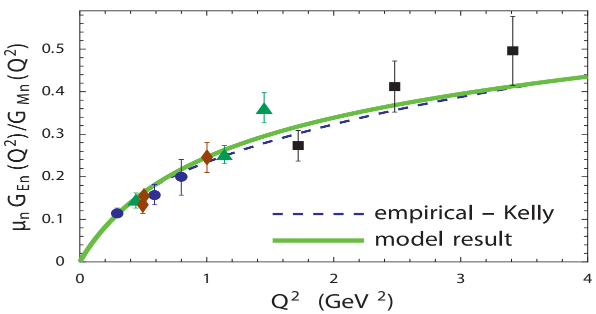
The goal is understanding of the nucleon

Nucleon form factors and spin content in a quark-diquark model with a pion cloud

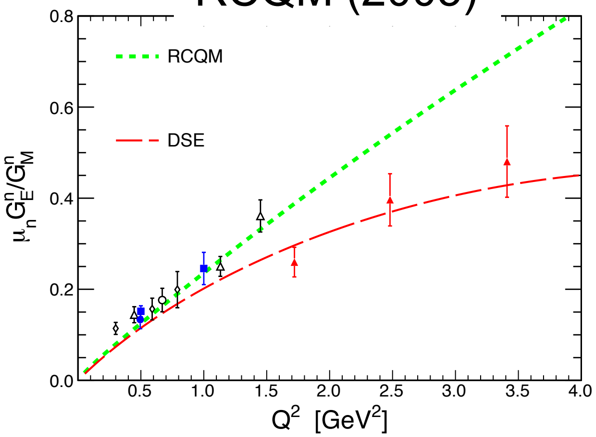
Ian C. Cloet and Gerald A. Miller, arXiv:1204.4422 [nucl-th]

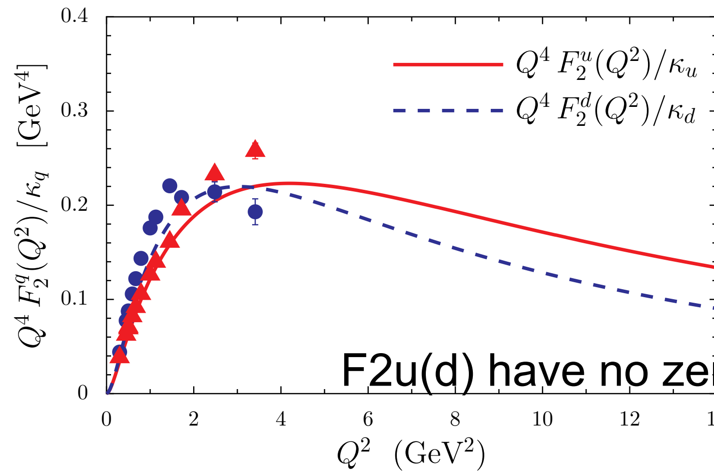
"new model of the nucleon in which quark-diquark configurations immersed in a pion cloud …"

RCQM with diquarks

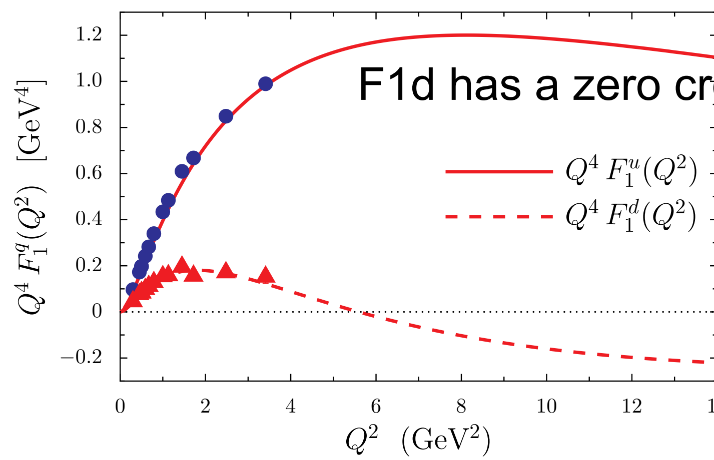


RCQM (2005)



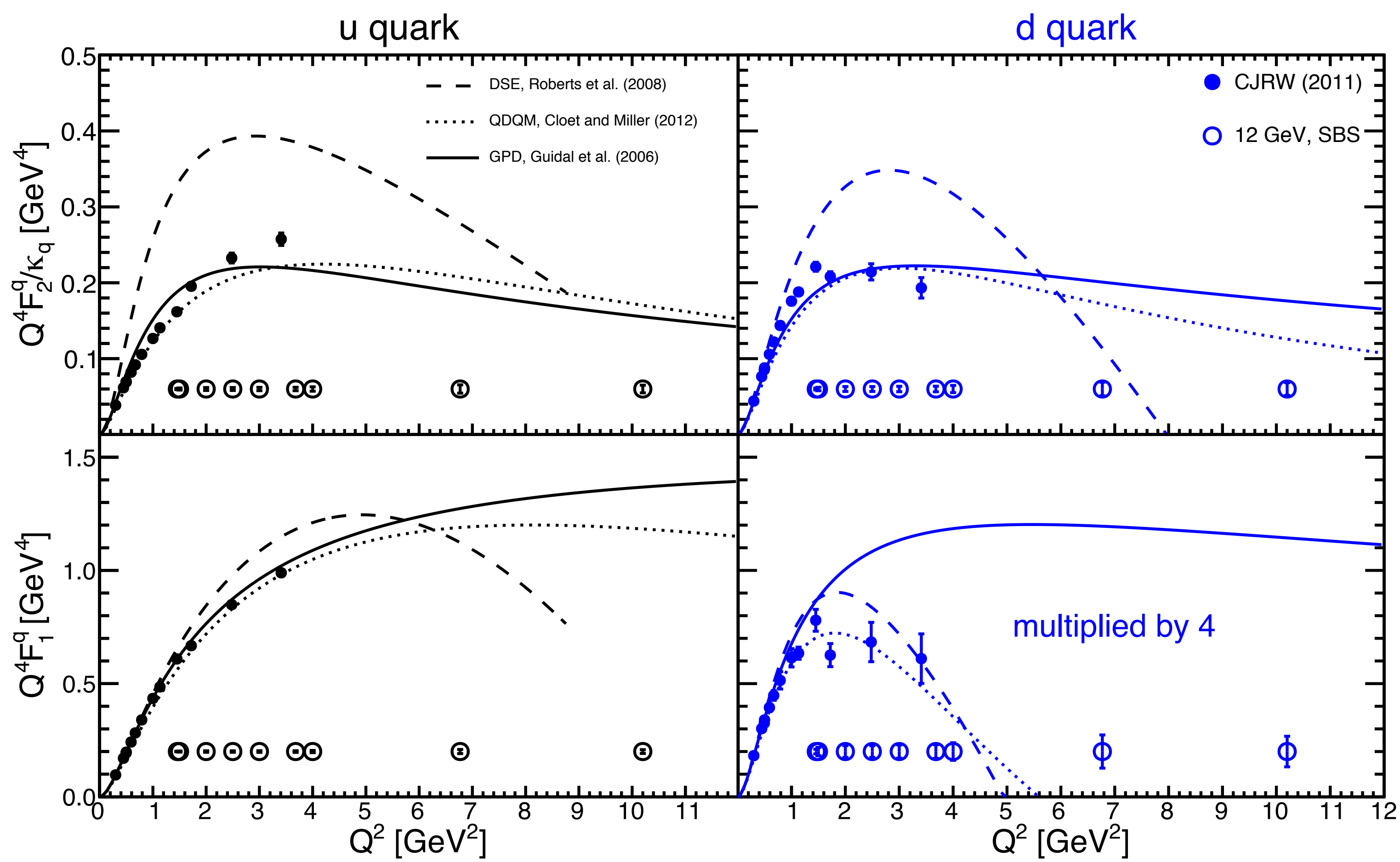


F2u(d) have no zero crossings



F1d has a zero crossing

The goal is understanding of the nucleon



In the result from Dyson-Schwinger Equations approach easy to see importance of both a scalar and an axial vector diquark.

The zero crossing for GEp and GEn at 5-8 GeV^2 is a prediction which could be tested.

One- and Two-Arm experiments (O&TA)

The most productive experiments in the field belong to this category O&TA.
Among them are DIS, SIDIS, FFs (GEP), RCS, DVCS, ...

The main advantage of the (e,e') & (e,e'h/γ) is the simplicity of such processes for physics interpretation

$$\boldsymbol{FOM = \mathcal{L} \times \Omega_1 (\times \Omega_2)}$$

Figure-of-Merit for O&TA experiments

One-arm experiments: high $\mathcal{L}$ and large Ω ($\Delta Q^2/Q^2 \sim 0.1$) :
The Super Bigbite Spectrometer is the best choice due to large solid angle Ω = 70 msr and detector rate capability (not L/T separation)

Two-arm experiments deal with elastic or quasi-elastic
$p_m \sim 0.2$ GeV/c for the nuclei; ~ 0.5-1 GeV/c for the nucleon
The high $Q^2/t/\nu$ experiment N(e,e'h) means $p_h \sim$ 2-8 GeV/c;
70 msr of SBS acceptance: the detector captures efficiently events up to
$p_m \sim p_h/5$ => one setting could be a whole experiment

$$FOM = \mathcal{L} \times \Omega_{electron} = 10^{38} \cdot 0.07 = 7 \times 10^{36}$$

$$electron/s \times nucleon/cm^2 \times sr$$

One- and Two-Arm experiments (O&TA)

$$FOM = \mathcal{L} \times \Omega_{electron} = 10^{38} \cdot 0.07 = 7 \times 10^{36}$$

$$electron/s \times nucleon/cm^2 \times sr$$

Now we can formulate a detector configuration
for productive one- and two-arm experiments

- Magnetic analysis with “vertical bend”
- Moderate solid angle
- Independent arms
- Small angle capability
- Space for segmented PID

One- and Two-Arm experiments (O&TA)

$$FOM = \mathcal{L} \times \Omega_{electron} = 10^{38} \cdot 0.07 = 7 \times 10^{36}$$

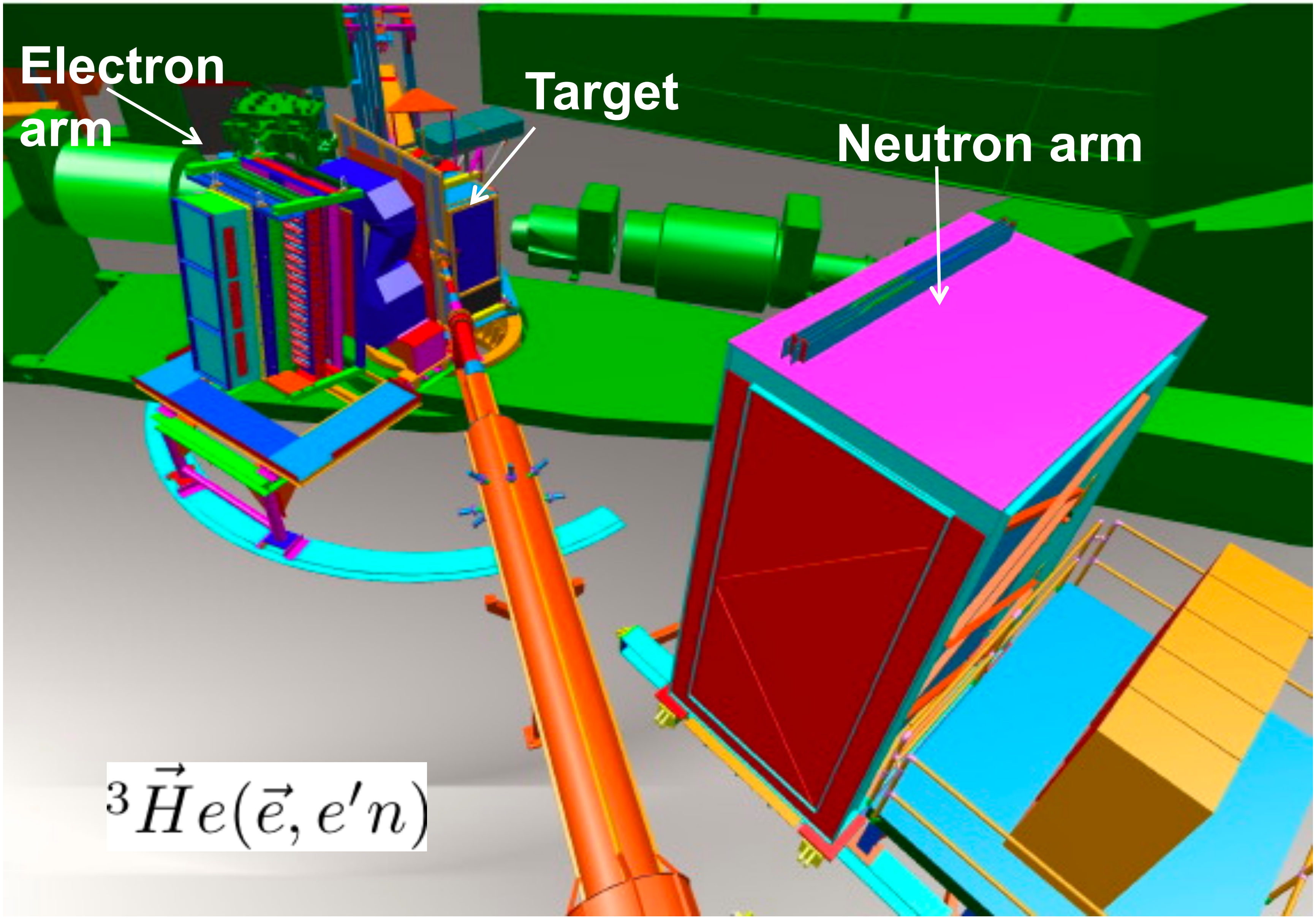
$$electron/s \times nucleon/cm^2 \times sr$$

Now we can formulate a detector configuration
for productive one- and two-arm experiments

- Magnetic analysis with "vertical bend" => protected detector
- Moderate solid angle => high luminosity
- Independent arms => full range of angles
- Small angle capability => high x, t
- Space for segmented PID => RICH counter

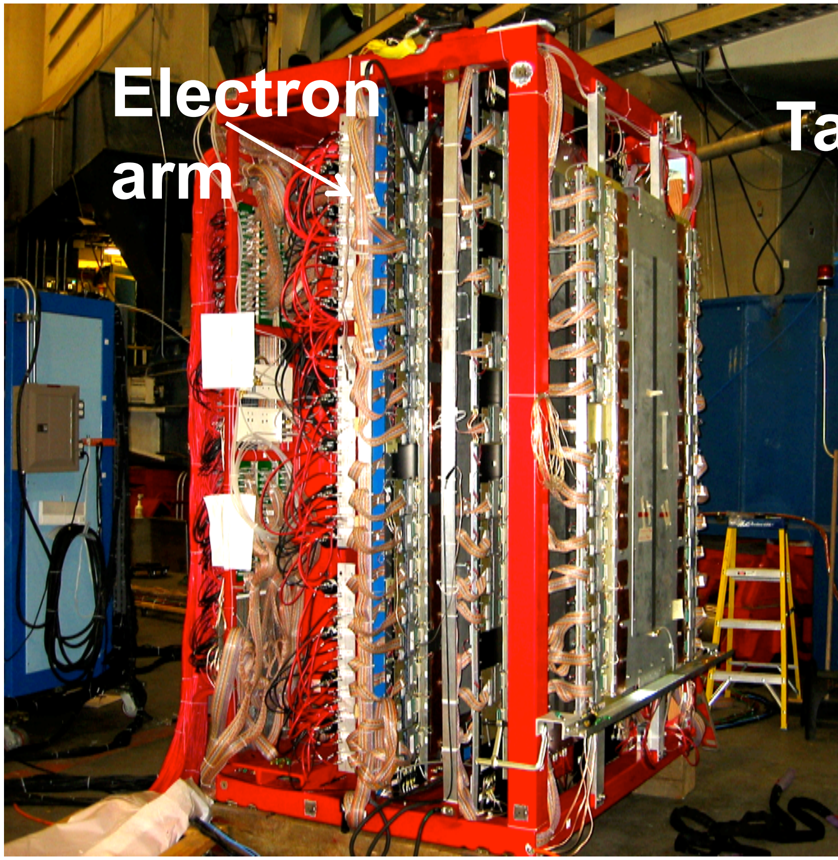
Hall A G_E^n experiment

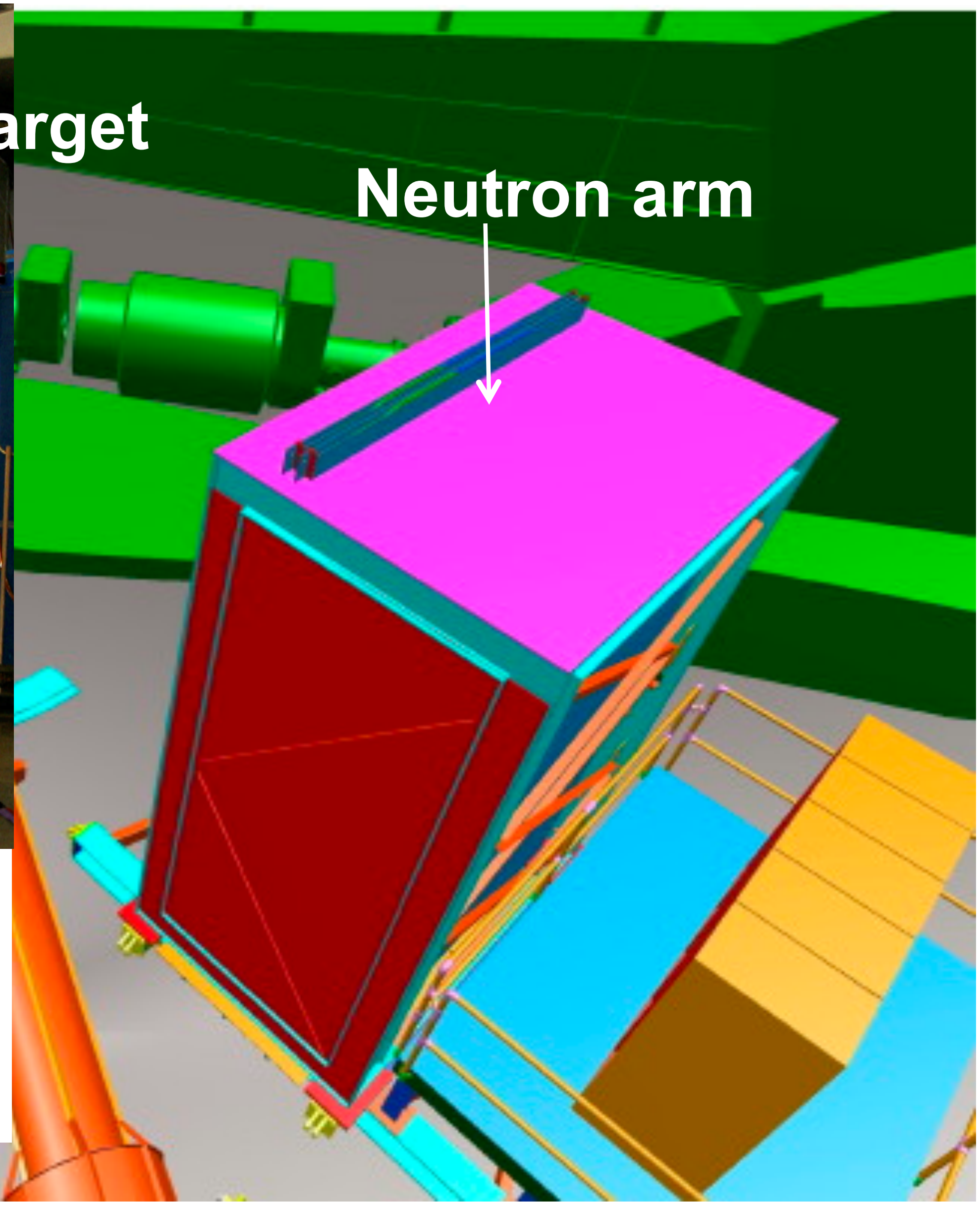
Beam



$$^3\vec{H}e(\vec{e}, e'n)$$

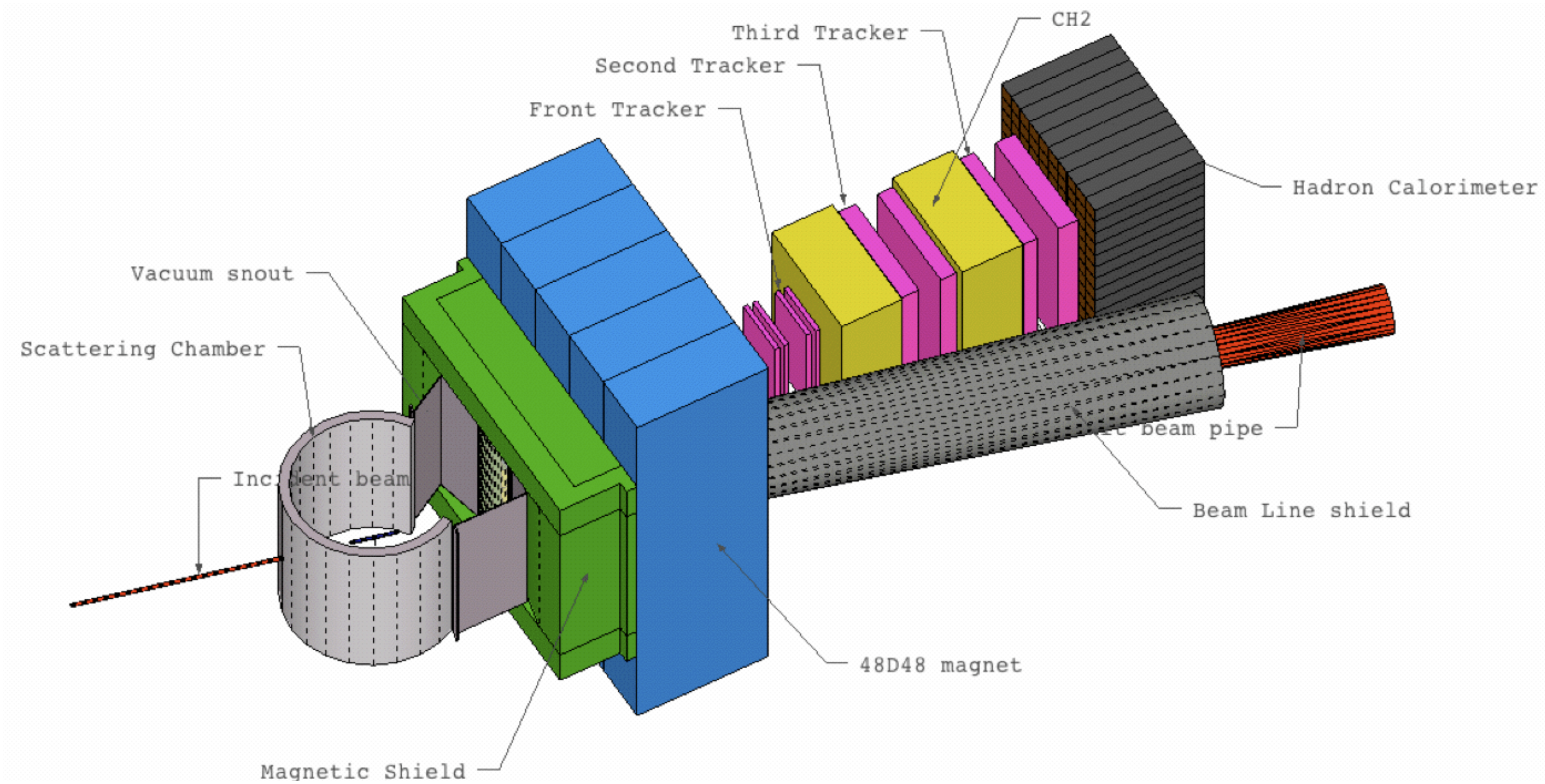
Hall A G_E^n experiment



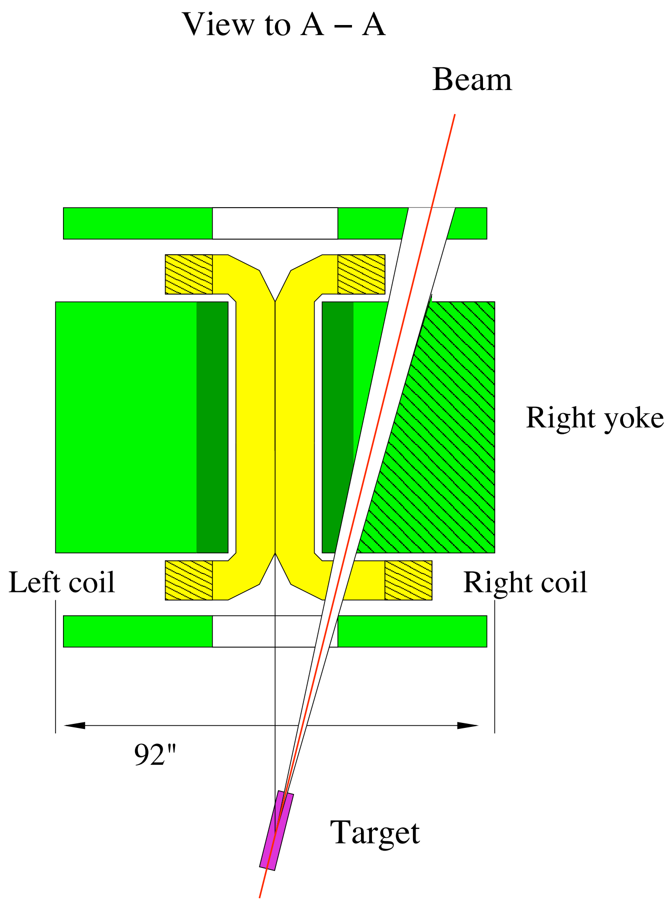


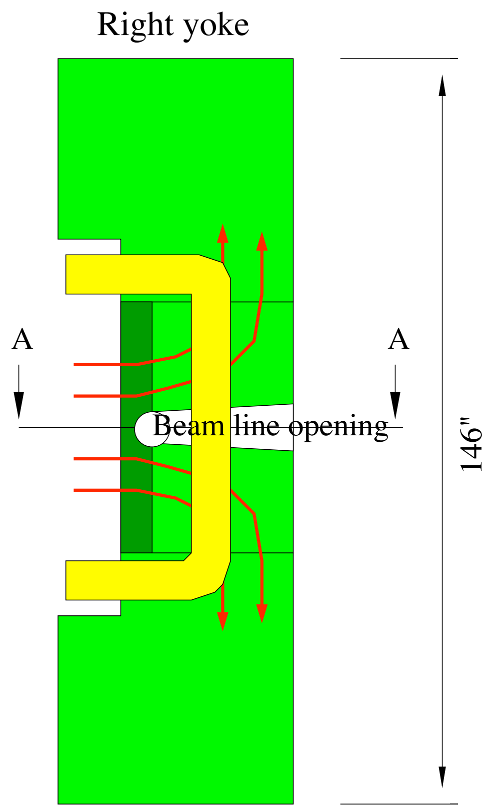
- Solid angle of 76 msr (12 times higher than HRS)
- 40 cm long target
- Momentum resolution of 1%

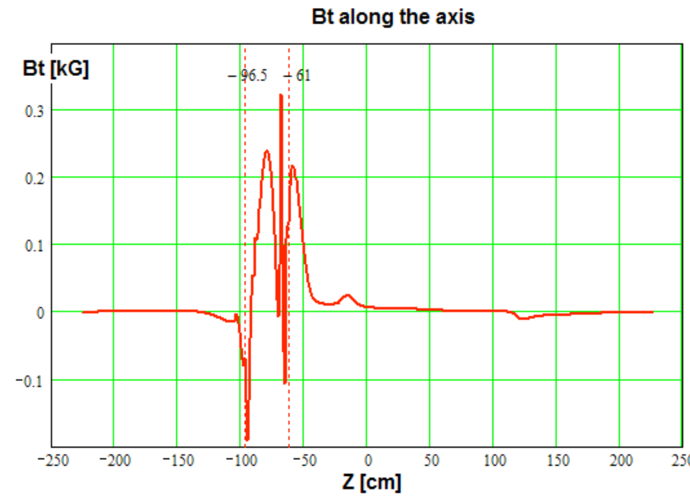
Super Bigbite Spectrometer in GEp



Super Bigbite Spectrometer in GEp







48D48 – 46x155 cm^2 aperture and 2.5 Tesla*m

GEM chambers with 70 μm resolution

- momentum resolution is 0.5% for 5 GeV/c
- solid angle is 70 msr at angle 15^o
- angular resolution is 0.3 mr

Parameters of SBS

$\theta_{central}$, degree	Ω, msr	D, meter	Hor. range, degree	Vert. range, degree
3.5	5	9.5	$\pm$ 1.3	$\pm$3.3
5.0	12	5.8	$\pm$ 1.9	$\pm$4.9
7.5	30	3.2	$\pm$ 3	$\pm$8
15	72	1.6	$\pm$ 4.8	$\pm$12.2
30	76	1.5	$\pm$ 4.9	$\pm$12.5

Solid angle =>

Resolution:

Momentum => $\frac{\sigma_p}{P} = 0.0029 + 0.0003 \times p[\mathrm{GeV}]$

Angular => $\sigma_\theta = 0.14 + 1.3/p\ [\mathrm{GeV}]$, mrad

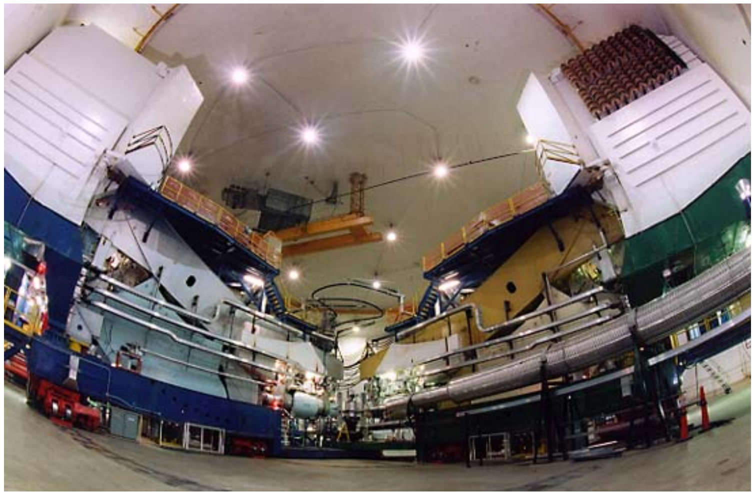
Momentum acceptance

=> unlimited above 1-2 GeV/c

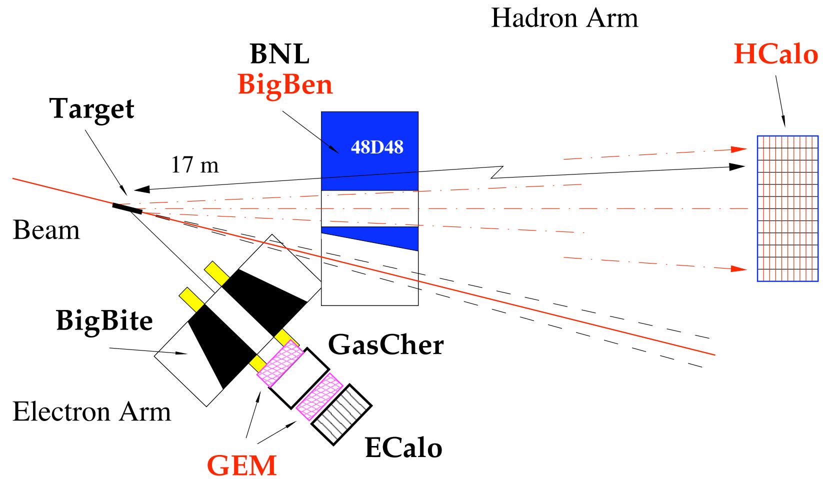
Target length (y) 50 cm

Optimization of the experimental setup

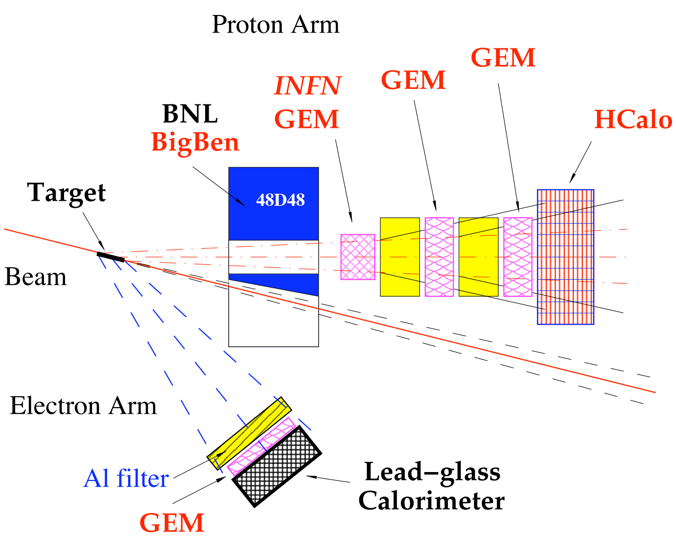
Proton magnetic form factor: E12-07-108



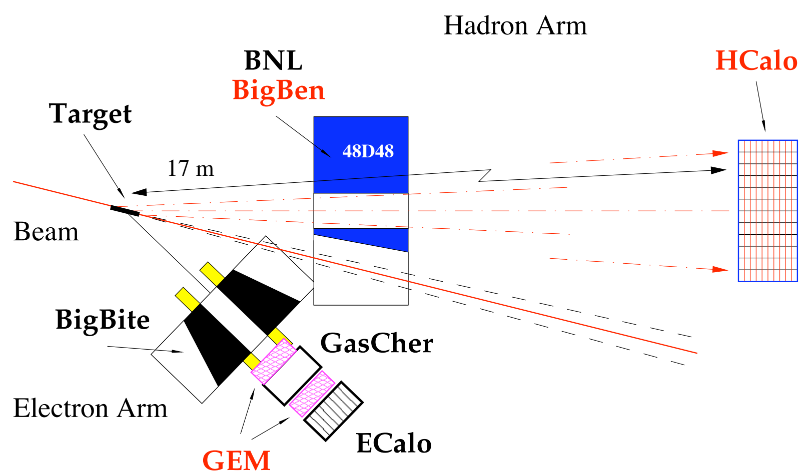
Neutron/proton form factors ratio: E12-09-019



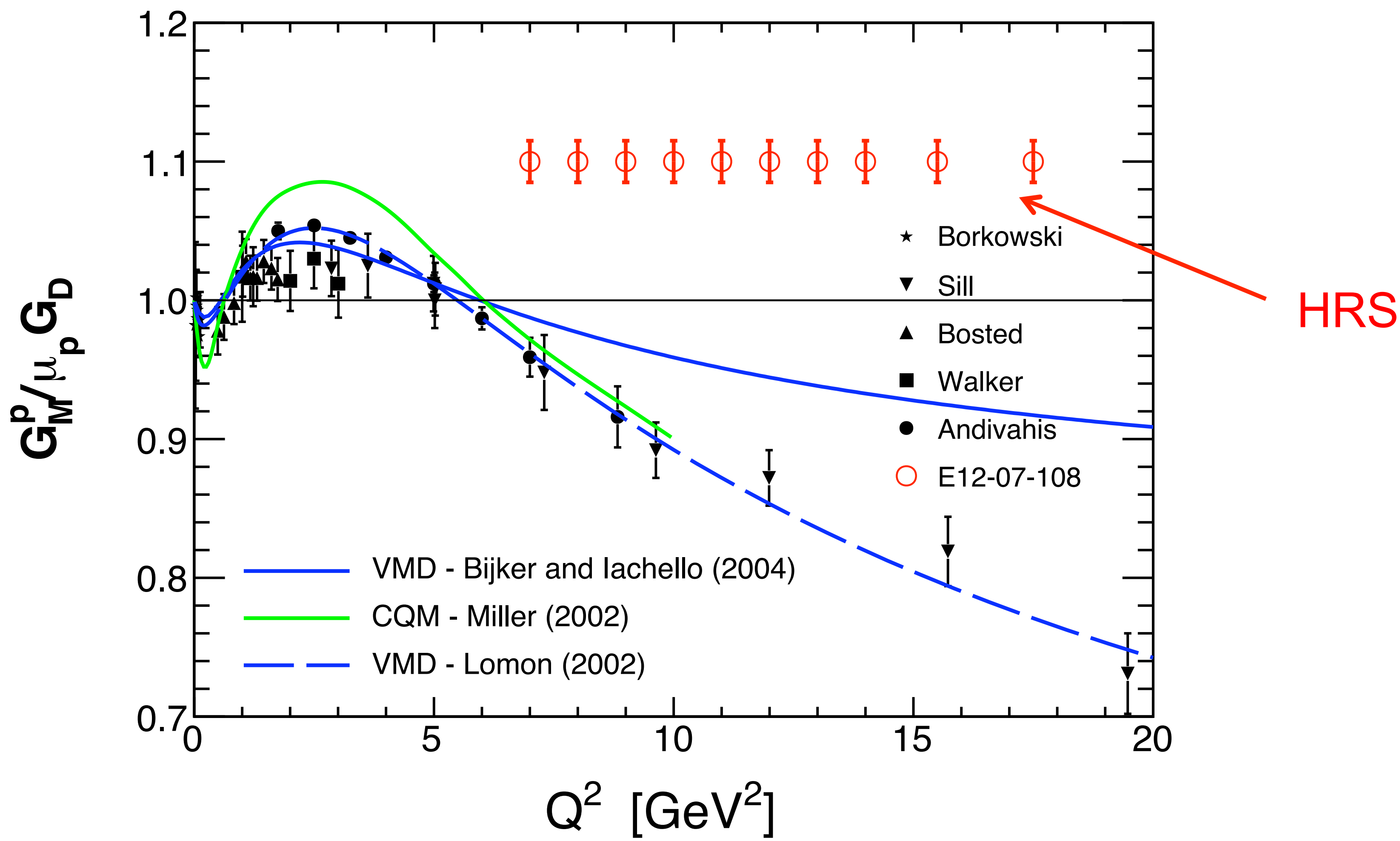
Proton form factors ratio, GEp(5): E12–07–109



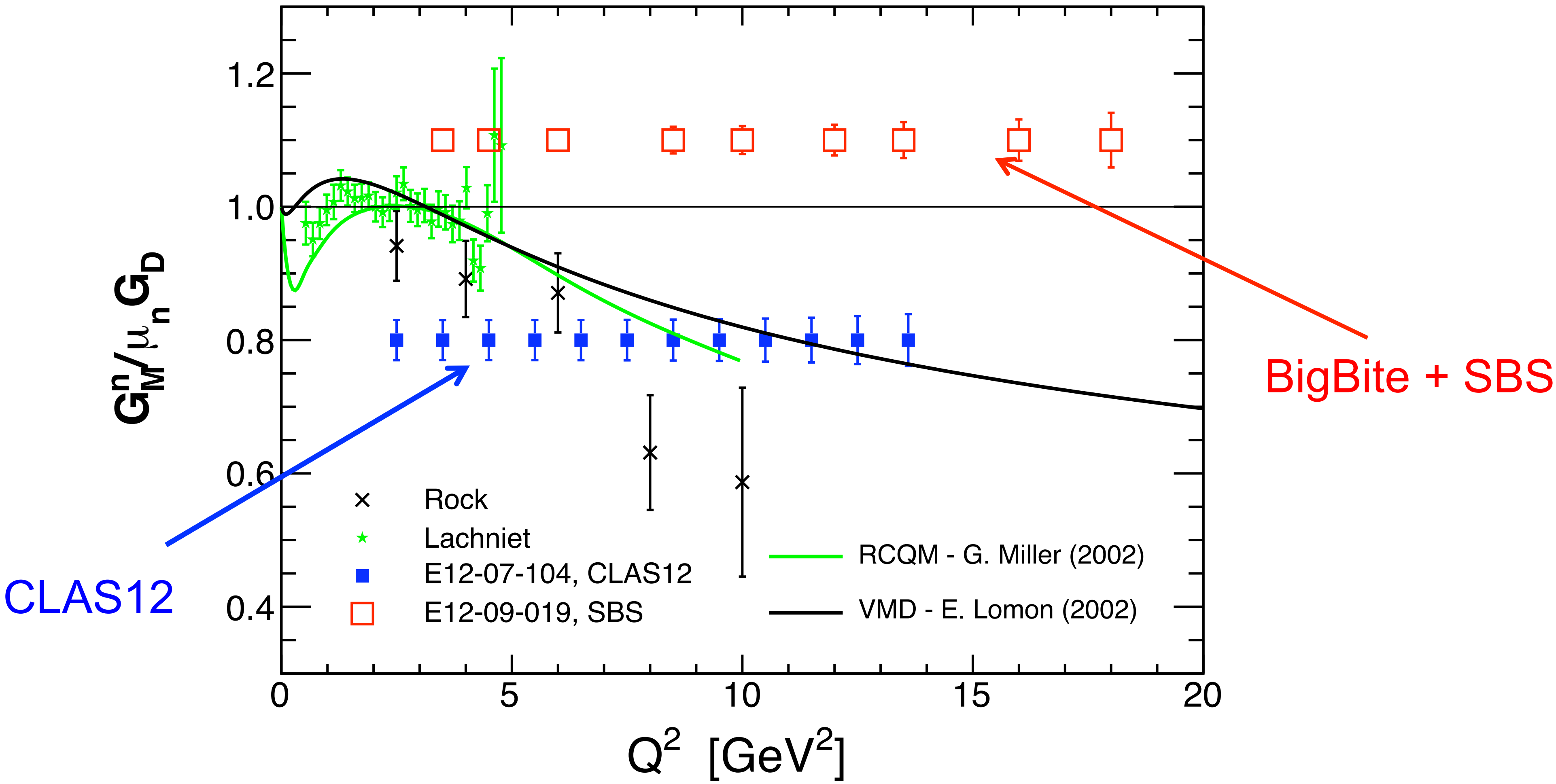
Neutron form factors ratio, GEn(2):E12-09-016



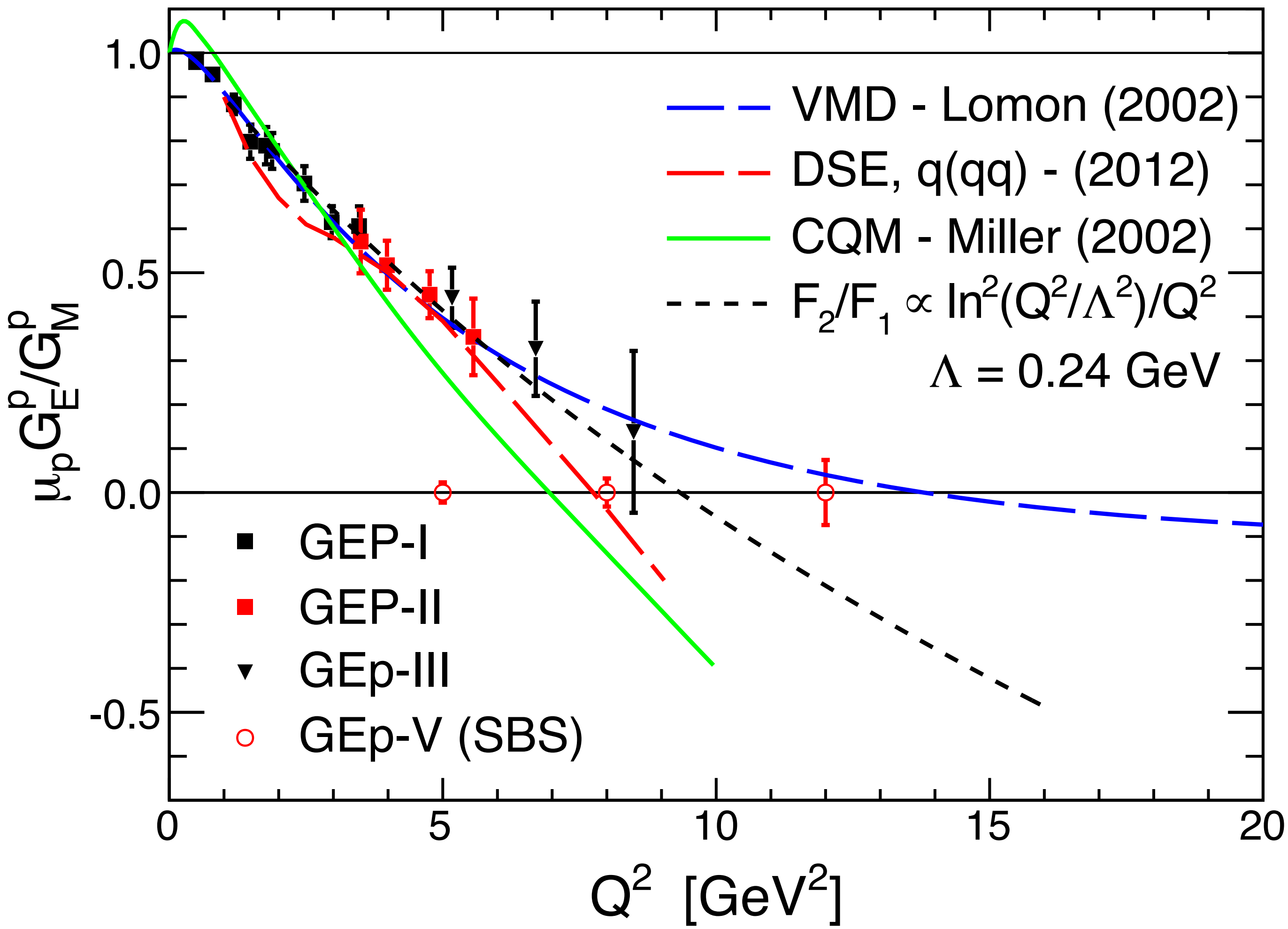
12-GeV GMp experiments



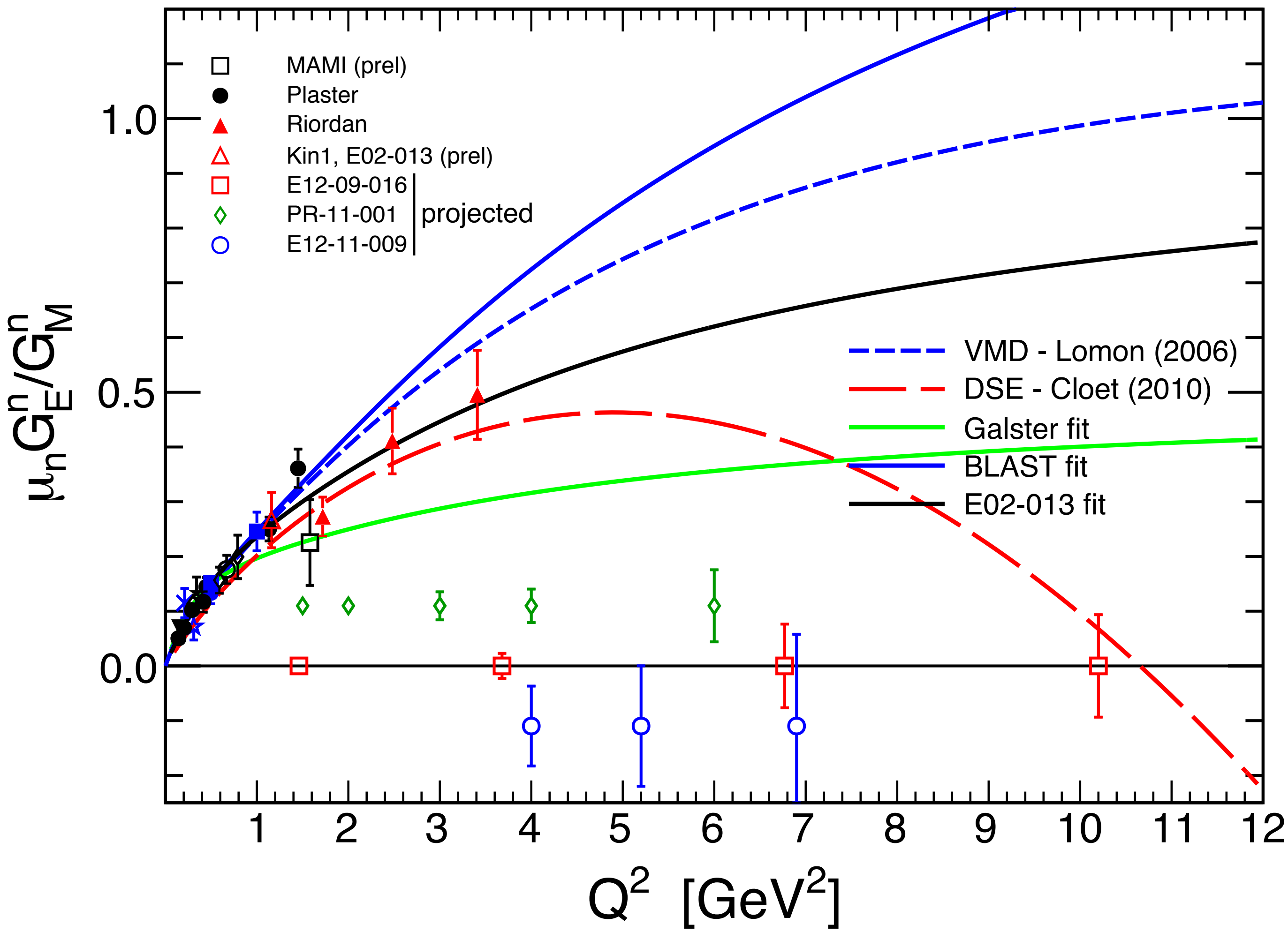
12-GeV GMn experiments



12-GeV GEp experiment



12-GeV GEn experiment



F_1^d/F_1^u from GMn/GMp at max Q^2

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

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

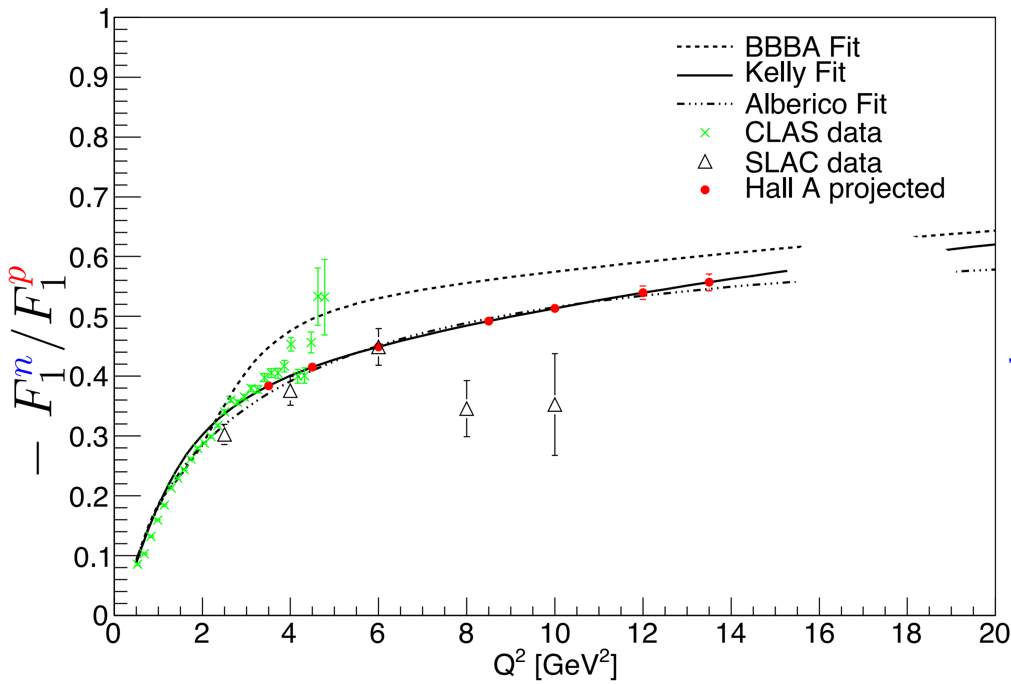
At Q^2 = 8 GeV^2 (τ = 2)

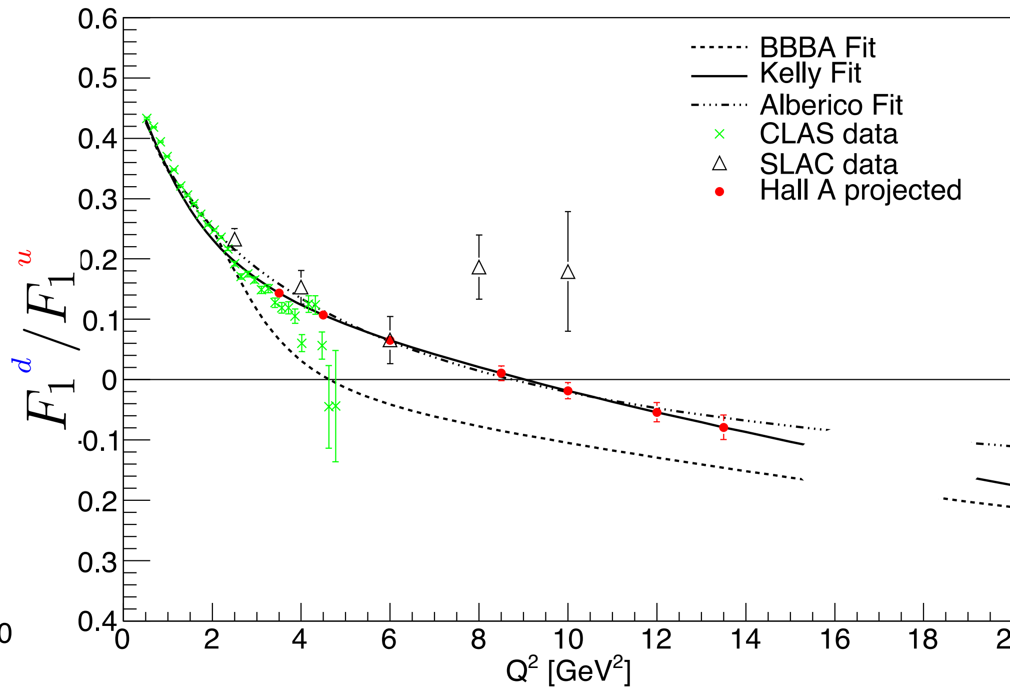
GEp/GMp ~ 0.1 and

GEn/GMn ~ 0.1?

$$F_1^u = 2\,F_{1p} + F_{1n}$$

$$F_1^d = 2\,F_{1n} + F_{1p}$$





$F_1^d < 0$ presents an interesting feature!

F_1^d/F_1^u from GMn/GMp at max Q^2

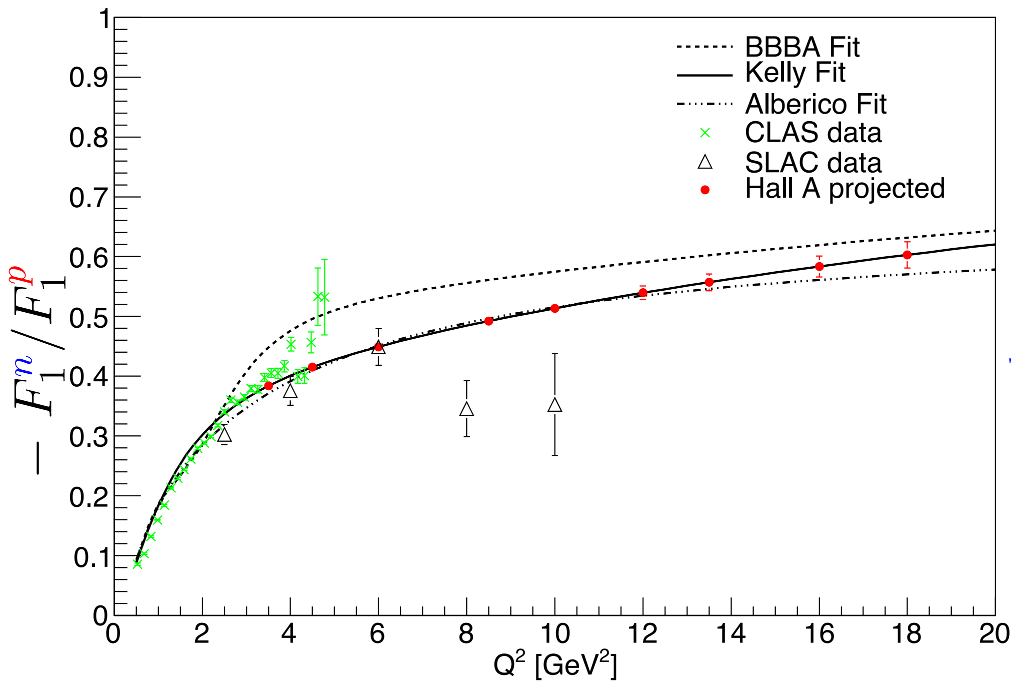
$$F_1 = \frac{G_E + \tau G_M}{1+\tau} \qquad F_2 = -\frac{G_E - G_M}{1+\tau}$$

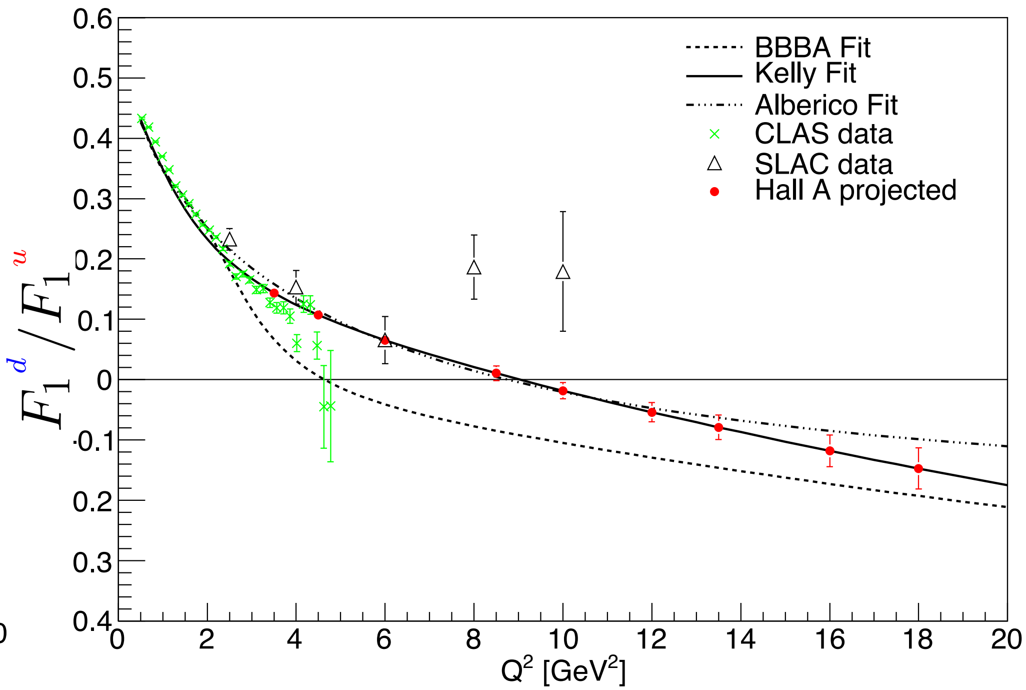
At Q^2 = 8 GeV^2 (τ = 2)

GEp/GMp ~ 0.1 and

GEn/GMn ~ 0.1

$$F_1^u = 2\,F_{1p} + F_{1n} \qquad F_1^d = 2\,F_{1n} + F_{1p}$$





$F_1^d < 0$ presents an interesting feature!

F_1^d/F_1^u from GMn/GMp at max Q^2

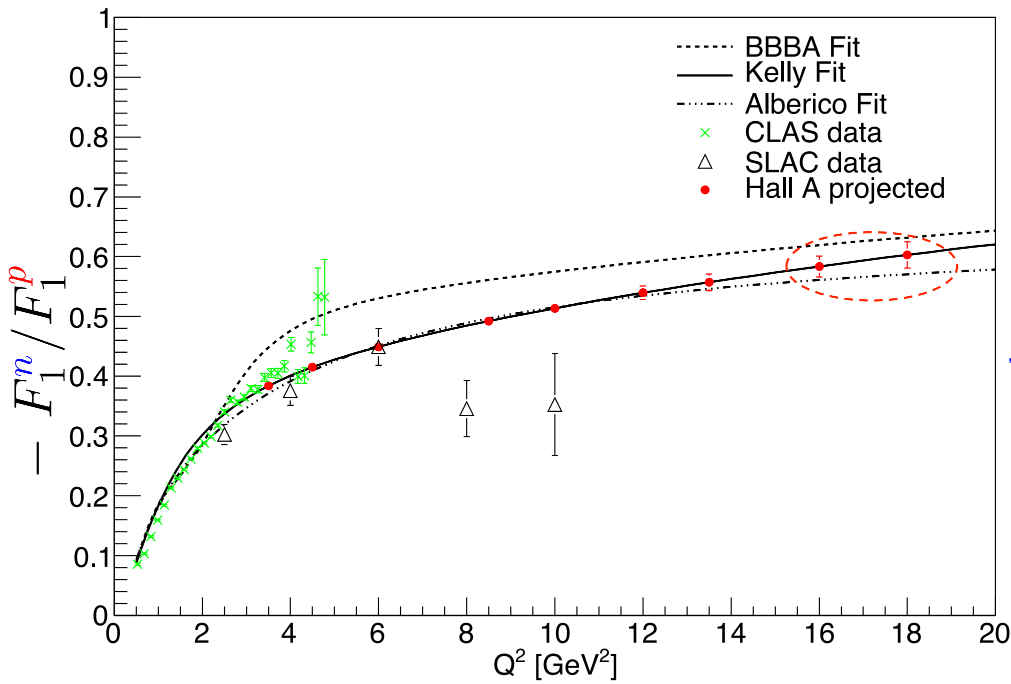
GPD model (Guidal et al) and crossing zero

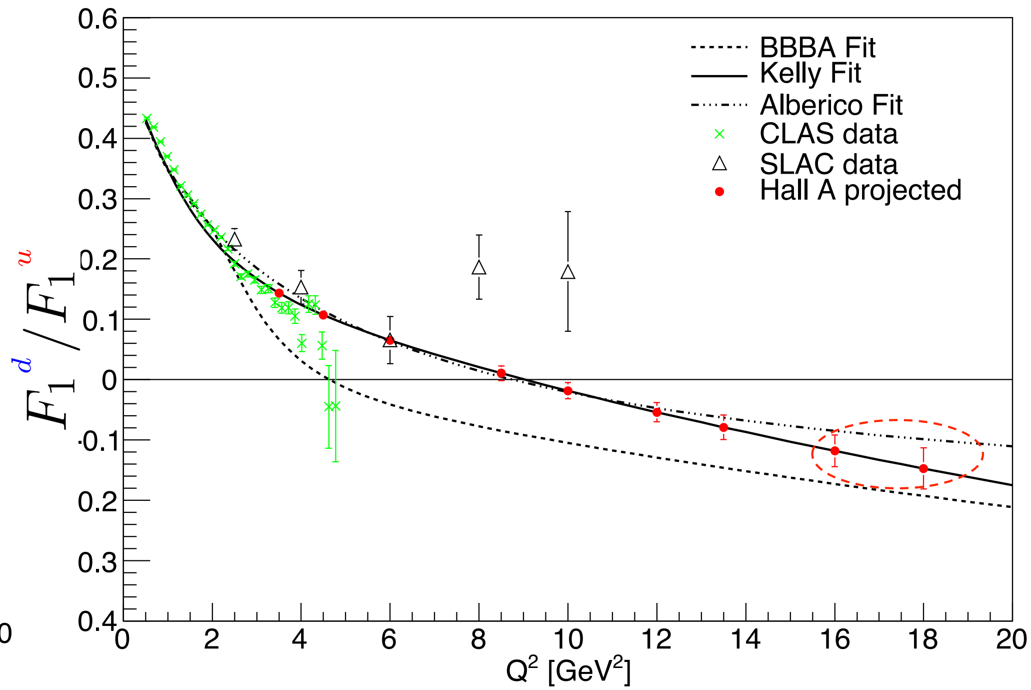
$$u_v = 0.262\,x^{-0.69}(1-x)^{3.50}\left(1+3.83\,x^{0.5}+37.65\,x\right)$$

$$d_v = 0.061\,x^{-0.65}(1-x)^{4.03}\left(1+49.05\,x^{0.5}+8.65\,x\right)$$

$$F_1^u(t) = \int_0^1 dx u_v(x) e^{-t\alpha' \ln x},$$

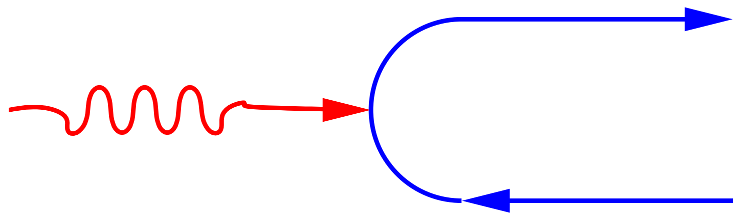
$$F_1^d(t) = \int_0^1 dx d_v(x) e^{-t\alpha' \ln x}.$$





$F_1^d < 0$ presents an interesting feature!

A1 physics



for the case $Q^2 \gg M^2$ helicity conservation leads to

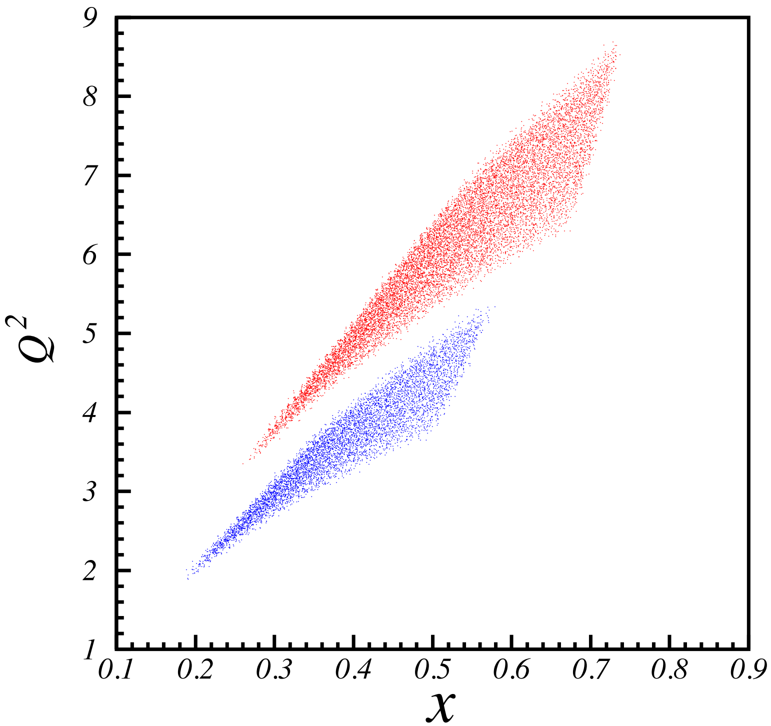
$$\mathcal{A}_1 = \frac{\sigma_{1/2} - \sigma_{3/2}}{\sigma_{1/2} + \sigma_{3/2}} \cong \frac{\Sigma e_i^2 (q_i^\uparrow + \bar{q}_i^\uparrow - q_i^\downarrow - \bar{q}_i^\downarrow)}{\Sigma e_i^2 (q_i^\uparrow + \bar{q}_i^\uparrow + q_i^\downarrow + \bar{q}_i^\downarrow)}$$

A_1 is a measure of quark polarization at given x_{Bj}
A_1 Q^2-dependence is predicted in QCD and could be tested
The same dependence could be interpreted as a mass effect

E12-06-112 (A1n)

Highly rated experiment
It will do the best physics with the first 6.6+ GeV polarized beam

Test of the Q^2-dependence



Result from E155 is not sufficiently accurate:

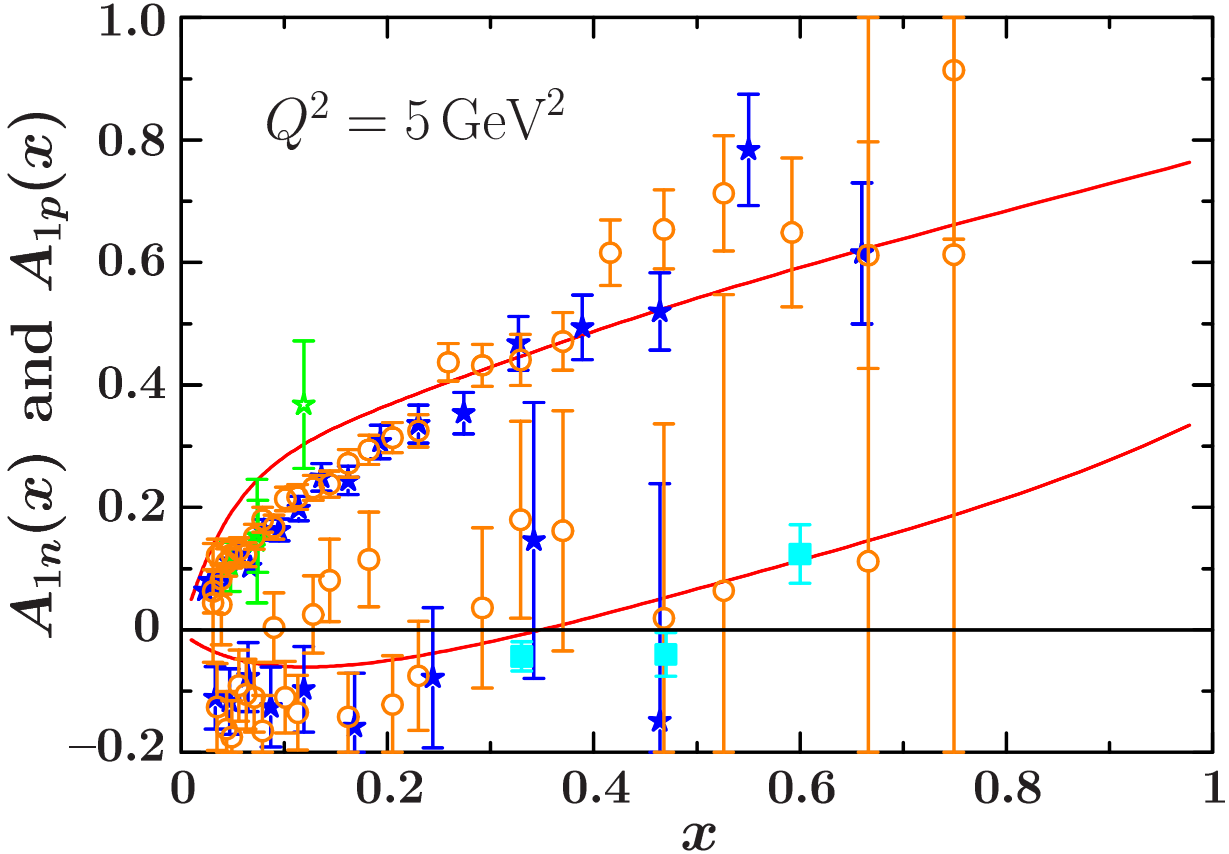
$$\frac{g_1^n}{F_1^n} = x^{-0.335}(-0.013 - 0.330x + 0.761x^2) \times (1 + \frac{c^n}{Q^2})$$

$$c^n = 0.13 \pm 0.45$$

E12-06-112 (A1n)

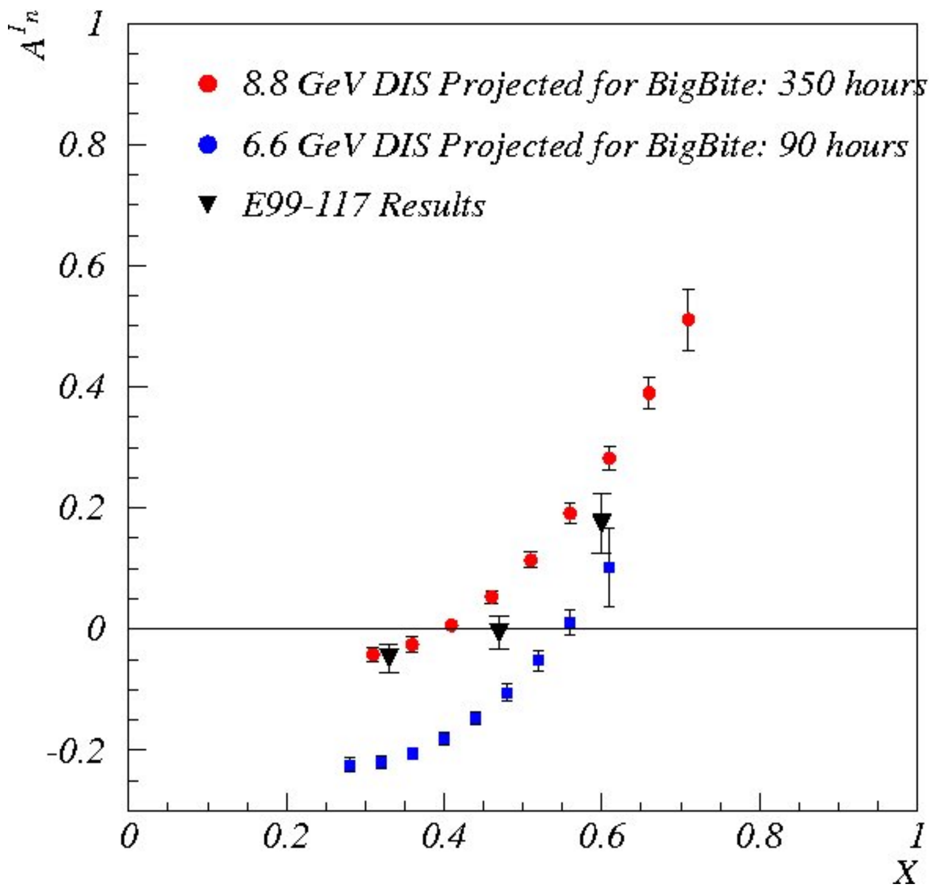
Nucleon quark distributions in a covariant quark-diquark model

Cloet, Bentz, A.W.Thomas (2005)



E12-06-112 (A1n)

What is new in this A1n experiment?



- up to 11 GeV beam energy
- 50+ msr solid angle, F= 8
- Momentum range, F= 3
- 65% target pol., F=1.6
- 85% beam pol., F=1.1
- 2.+ longer target, F= 2
- 30 μA beam, F=2.5

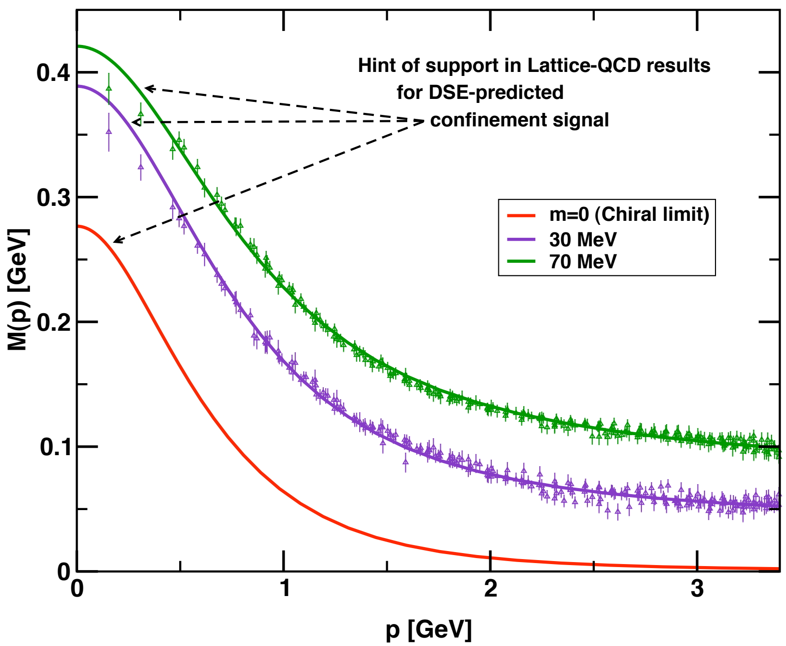
The total gain of experiment productivity is about 300+

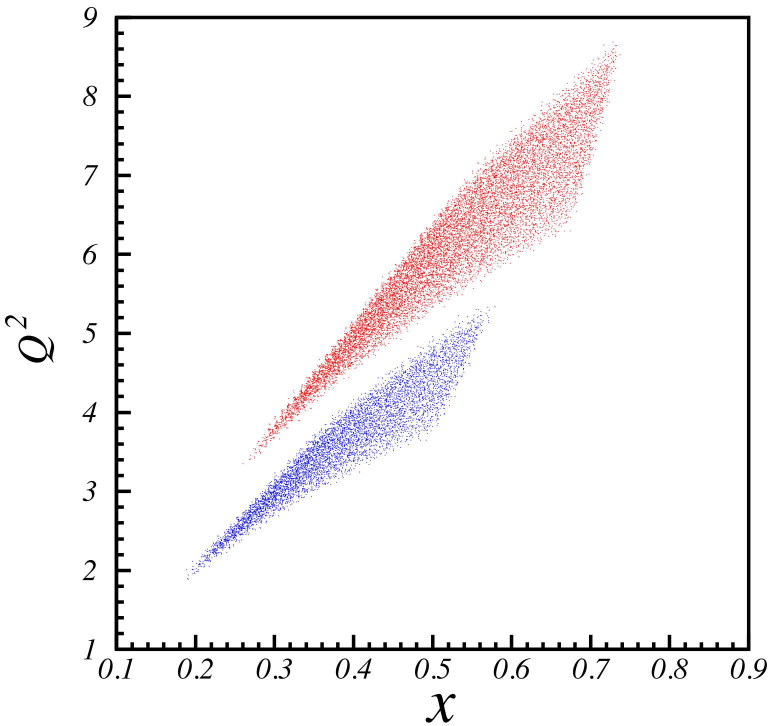
E12-06-112 (A1n)

Highly rated experiment
It will do the best physics with the first 6.6+ GeV polarized beam

Test of the Q^2-dependence

How is it related to M(p)?





There could be a change in A_1^n on the order of 0.10 between Q^2 = 3 and 6 GeV^2

Future measurements of F1p & F1n

$$\frac{d\sigma}{(dt/t)} \approx \frac{4\pi\alpha^2}{t} \times F_1^2(t)$$

$$\Delta\sigma = 0.2 \cdot 4\pi r_e^2 \times \frac{m_e^2}{t} \times \left(\frac{0.71^2}{t^2}\right)^2 \quad \text{x } 2.79^2$$

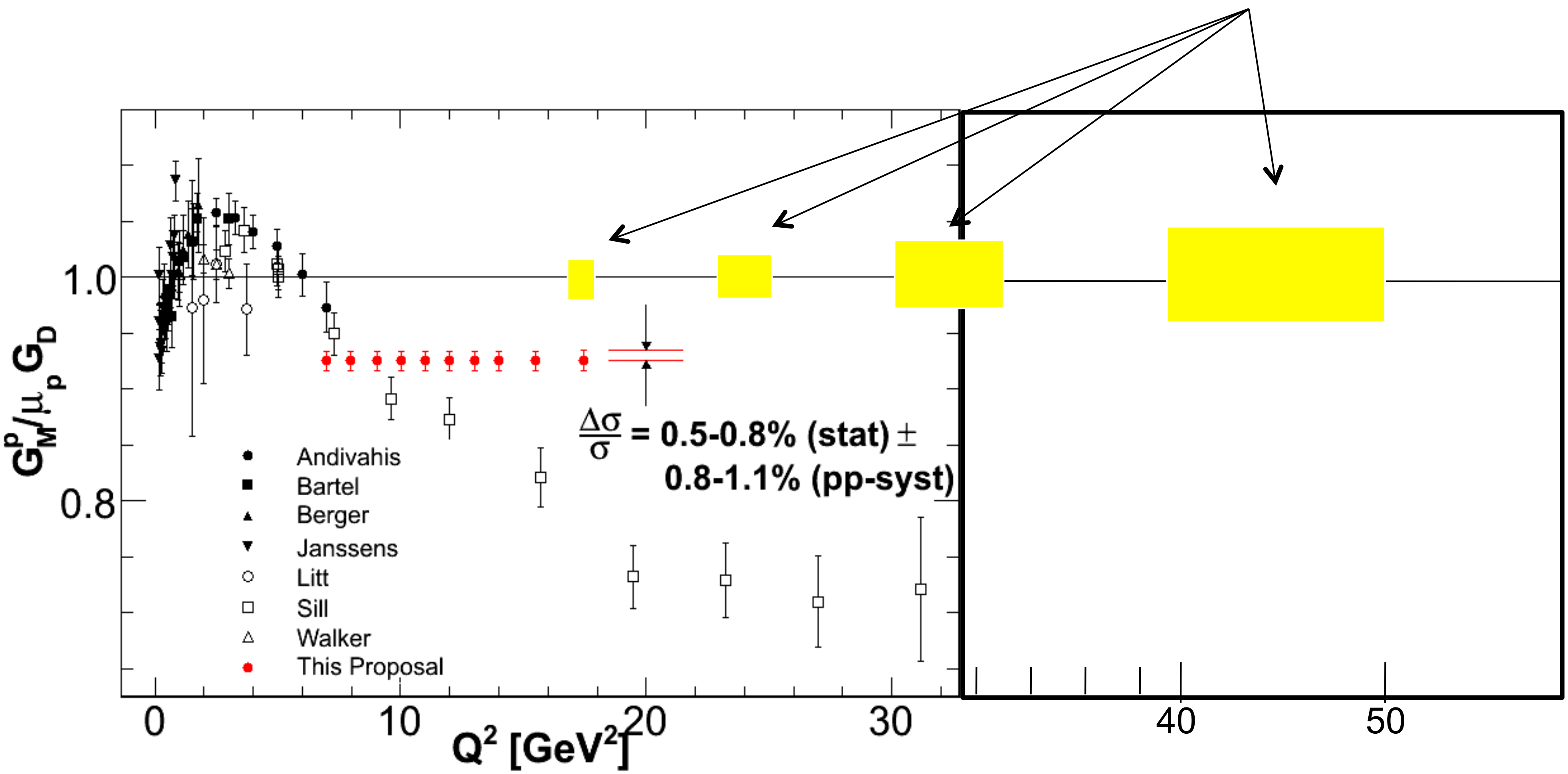
$$s \approx 4E_eE_p \text{ and } t = s\,\frac{1-\cos\theta_{cm}}{2}$$

for s = 4 x 3 x 30 = 360 GeV^2 and t = 50 GeV^2

$$\Delta\sigma = 4 \times 10^{-41}\ \text{cm}^2 \quad \text{x } 2.79^2$$

90 events per year at L = 10^{34} cm^{-2}/s

GMp Form Factor with EIC



$$F_1(t) \approx G_M \sim \mu_p G_{Dipole} = \mu_p[1 + Q^2/0.71]^{-2}$$

Summary

- Diquarks are likely emerging in EMFFs

- JLab Nucleon FF program will provide precision data for ..... up to:
  - ✓ G^p_E @ 12 (14) GeV^2
  - ✓ G^p_M @ 14 (17.5) GeV^2
  - ✓ G^n_E @ 10 GeV^2
  - ✓ G^n_M @ 14 (18) GeV^2