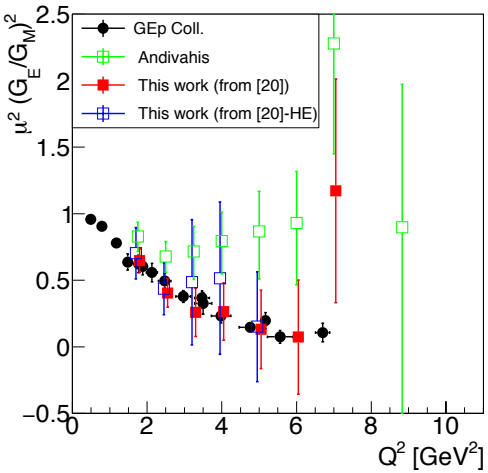
GSI, June 6, 2016

Nucleon Space-like Form Factors: is there any discrepancy?

Egle Tomasi-Gustafsson
IRFU, SPhN-Saclay
and
Simone Pacetti
INFN &University, Perugia



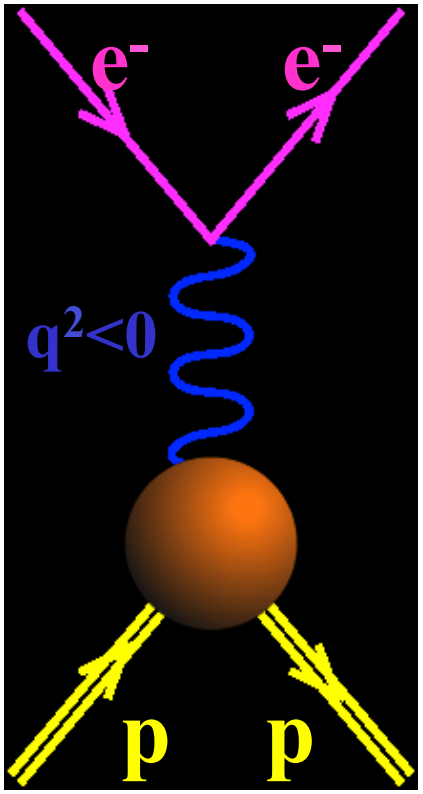
S. Pacetti, R. Baldini-Ferroli, E.T-G.,Phys. Rep. 51 (2014)1

Question

Discrepancy between polarized and unpolarized measurements of elastic EMFFs:

- *Is it real?*
- *Radiative corrections?*
- *Two photon echange?!*

Electromagnetic Interaction



The electron vertex is known, γ_μ

The interaction is carried by a virtual photon of mass q^2

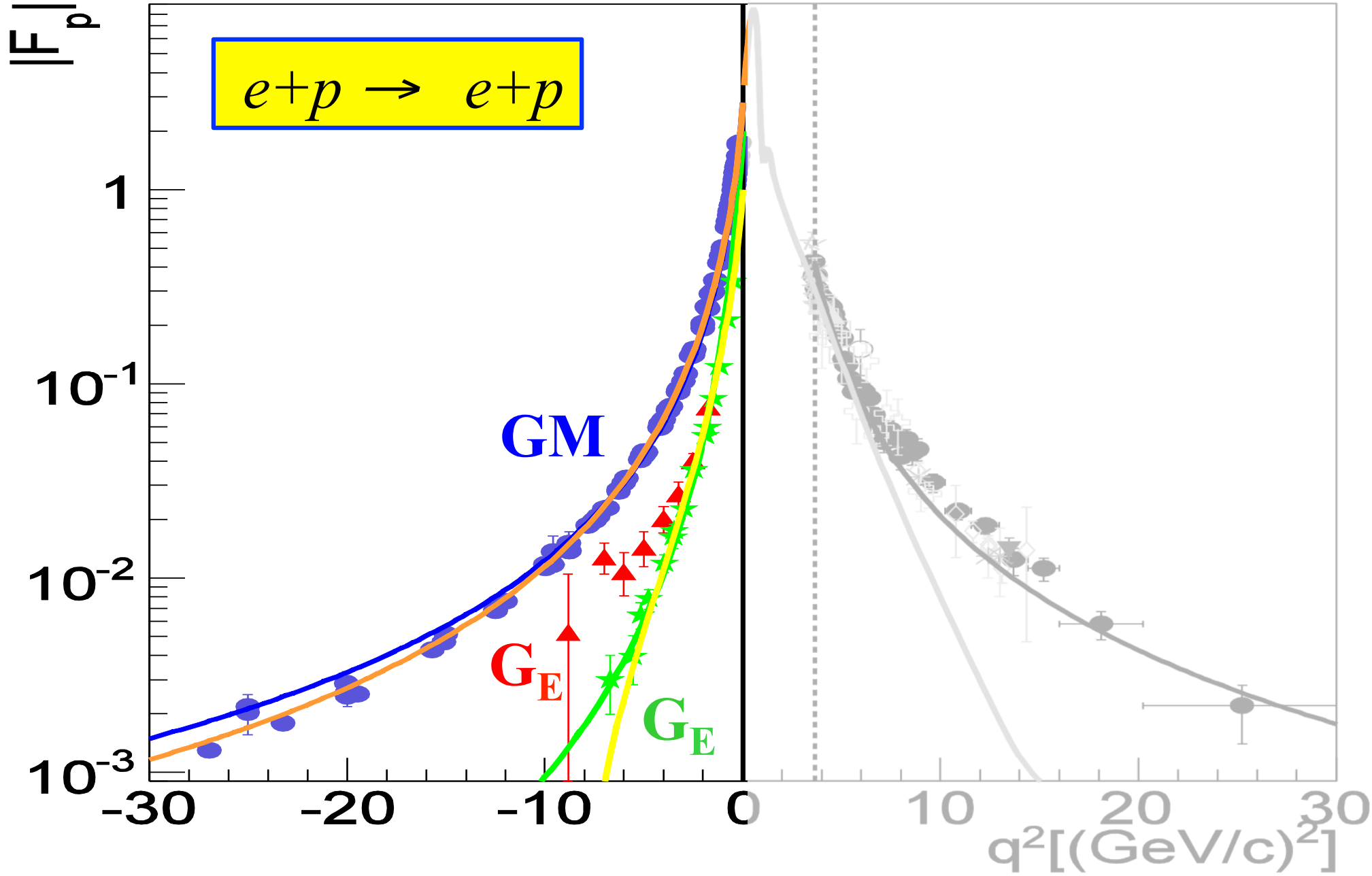
The proton vertex is parametrized in terms of FFs: Pauli and Dirac F_1, F_2

$$\Gamma_\mu = \gamma_\mu F_1(q^2) + \frac{i\sigma_{\mu\nu}q^\nu}{2M} F_2(q^2)$$

or in terms of Sachs FFs:
$GE = F_1 - \tau F_2$, $GM = F_1 + F_2$, $\tau = -q^2/4M^2$

What about high order radiative corrections?

The Space-Like region

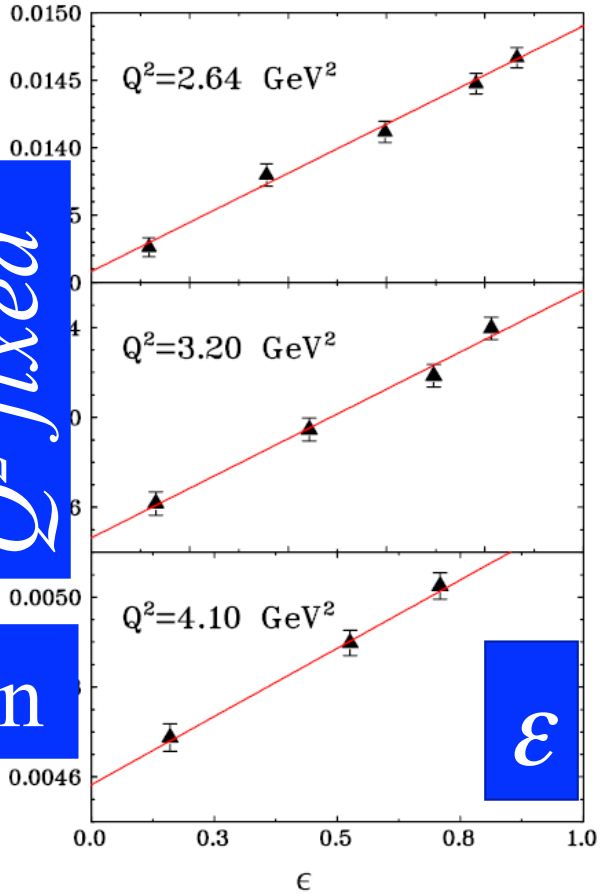


The Rosenbluth separation

$$\frac{d\sigma}{d\Omega} = \left(\frac{d\sigma}{d\Omega}\right)_{Mott} \frac{1}{(1+\tau)}\left(G_E^2(Q^2) + \frac{\tau}{\varepsilon} G_M^2(Q^2)\right)$$

$$\varepsilon = \left(1 + 2(1+\tau)\tan^2\left(\frac{\theta_e}{2}\right)\right)^{-1}, \tau = \frac{Q^2}{4M^2}$$

$$\sigma_R = \varepsilon G_E^2 + \tau G_M^2$$



Q^2 fixed

ε

Linearity of the reduced cross section

→ $\tan^2\theta_e$ dependence

→ Holds for 1γ exchange only

PRL 94, 142301 (2005)

The polarization method (theory:1967)

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

PHYSICS

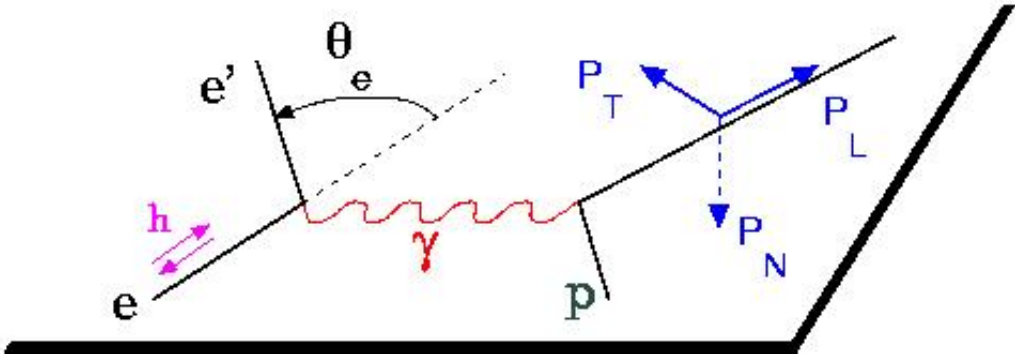
POLARIZATION PHENOMENA IN ELECTRON SCATTERING BY PROTONS IN THE HIGH-ENERGY REGION

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,

$$s_2 \frac{d\sigma}{d\Omega_R} = 4p_2 \frac{(s \cdot q)}{1+\tau} \Gamma(\theta, \varepsilon_1) \left[\tau G_M (G_M + G_E) - \frac{1}{4\varepsilon_1} G_M (G_E - \tau G_M) \right],$$



The polarization induces a term in the cross section proportional to $G_E G_M$

Polarized beam and target or

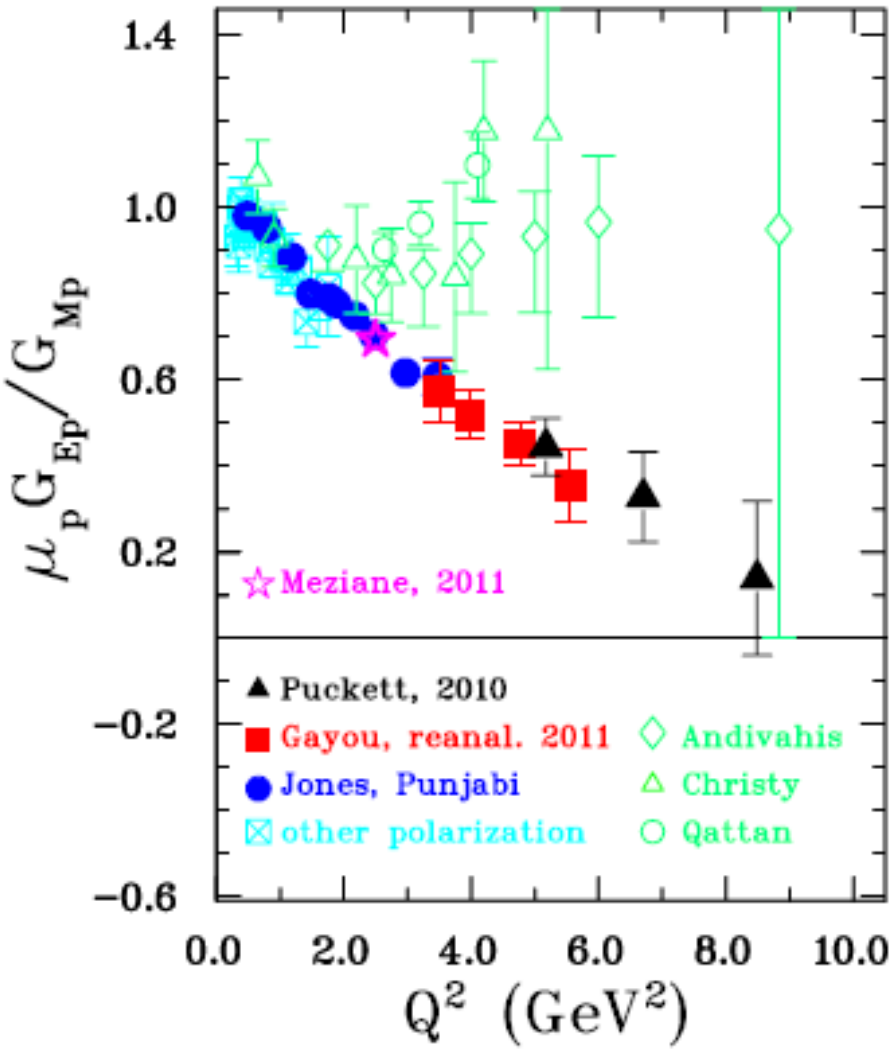
polarized beam and recoil proton polarization

Polarization Experiments

A.I. Akhiezer and M.P. Rekalo, 1967

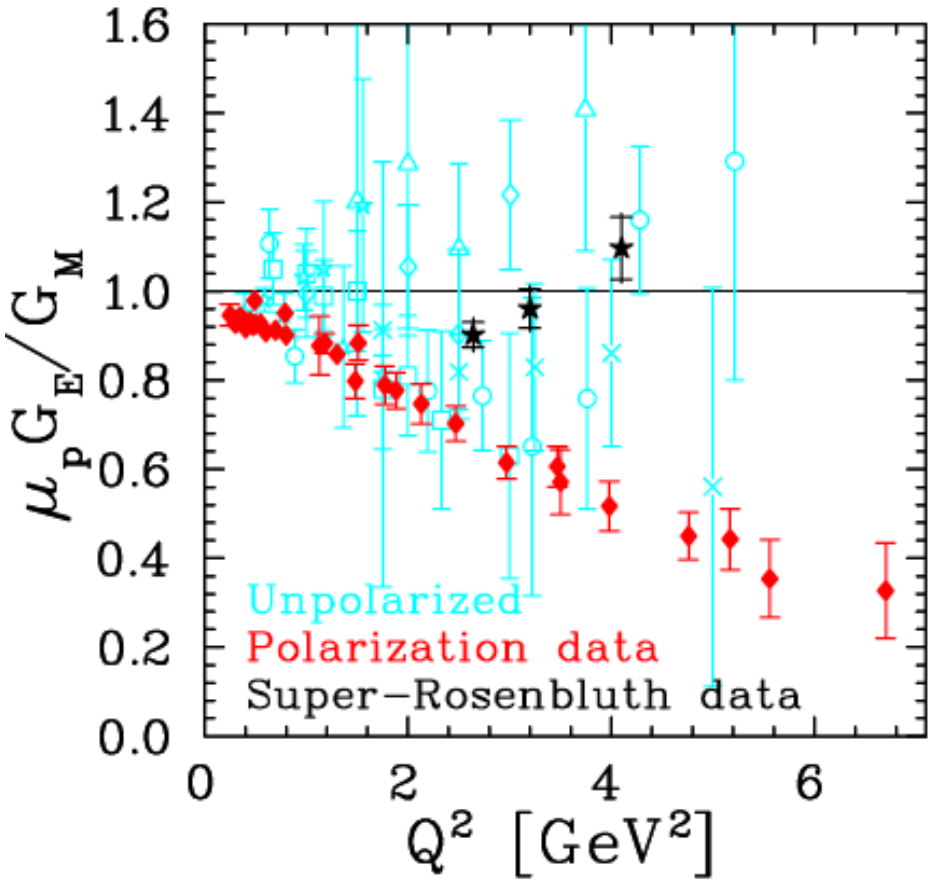
Jlab-GEp collaboration

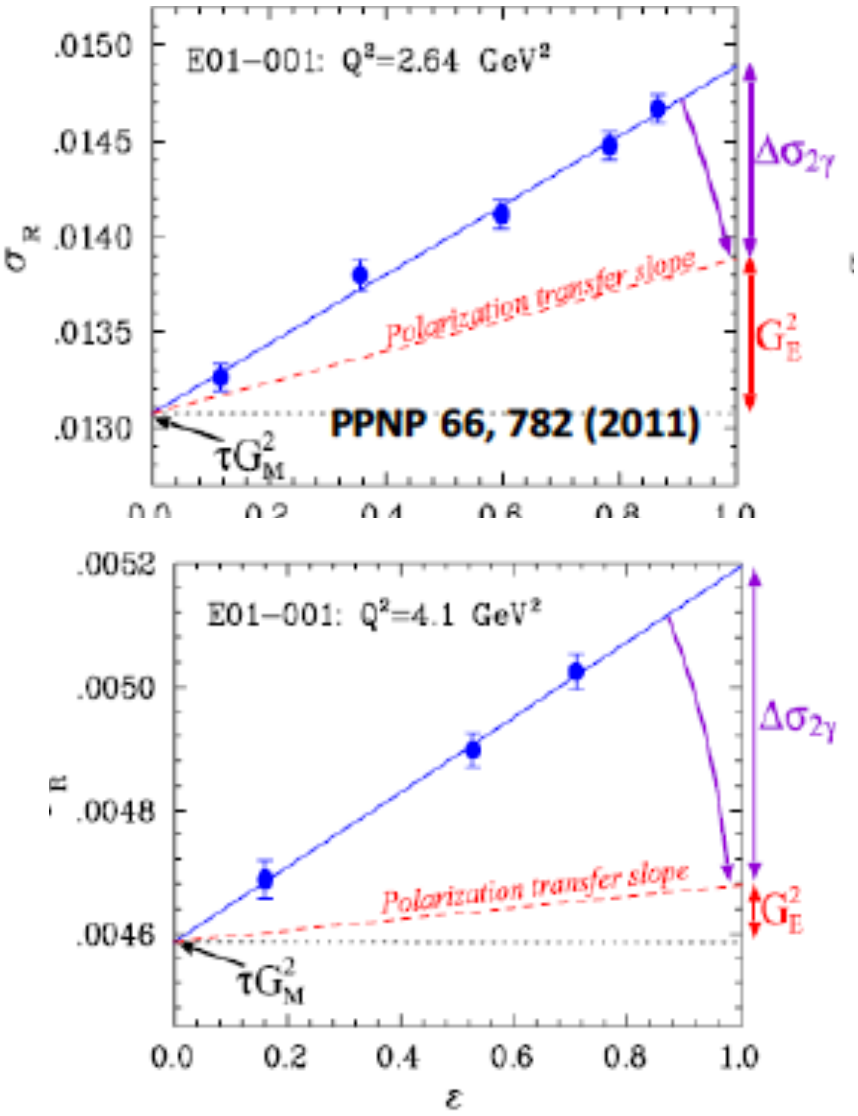
1) "standard" dipole function for the nucleon magnetic FFs GMp and GMn
2) linear deviation from the dipole function for the electric proton FF Gep
3) QCD scaling not reached
3) Zero crossing of Gep?
4) ***contradiction between polarized and unpolarized measurements***



A.J.R. Puckett et al, PRL (2010), PRC (2012)

The discrepancy: R=GE/GM





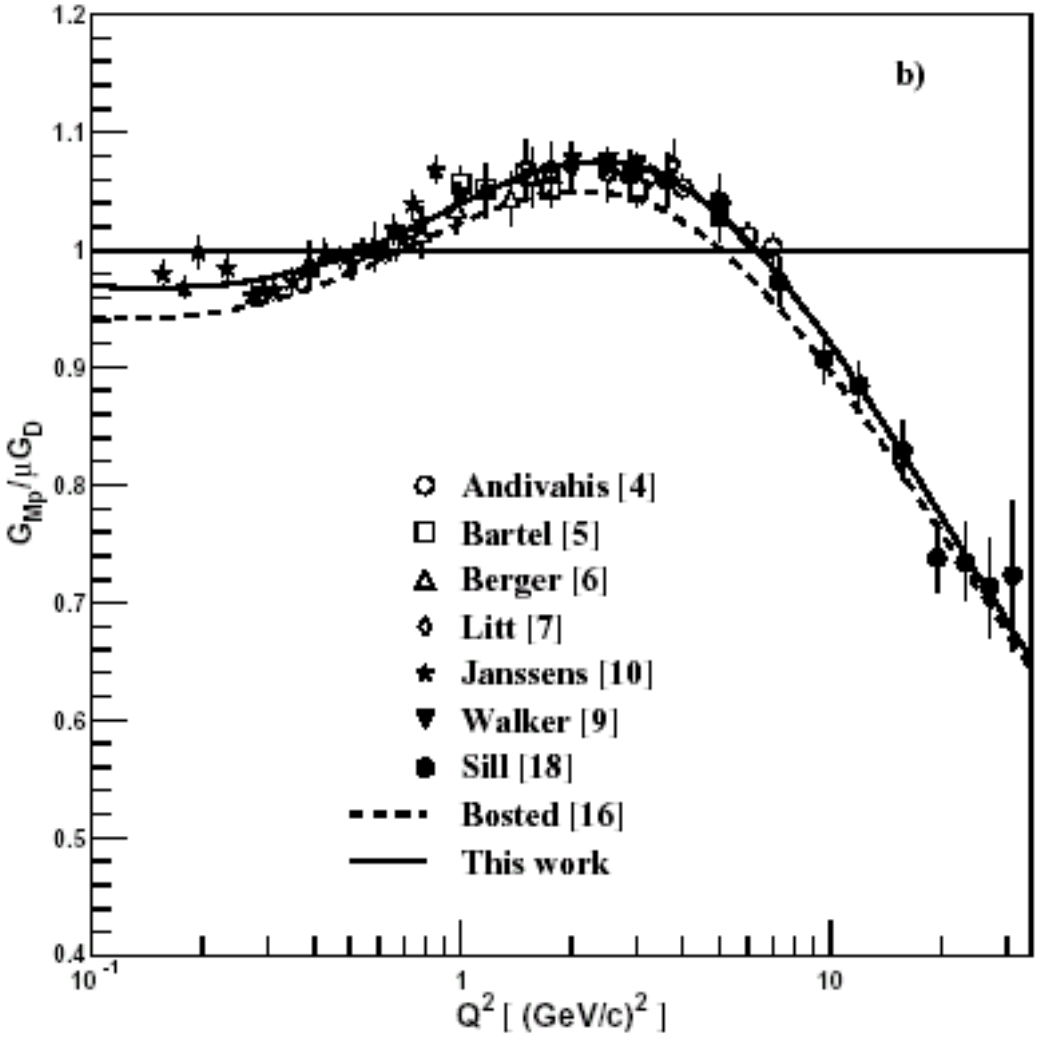
The discrepancy is

- **on the ratio : slope?**
- **NOT on the observables (cross section, polarizations)**

The proton magnetic form factor

The new results induce
1.5-3% global effect

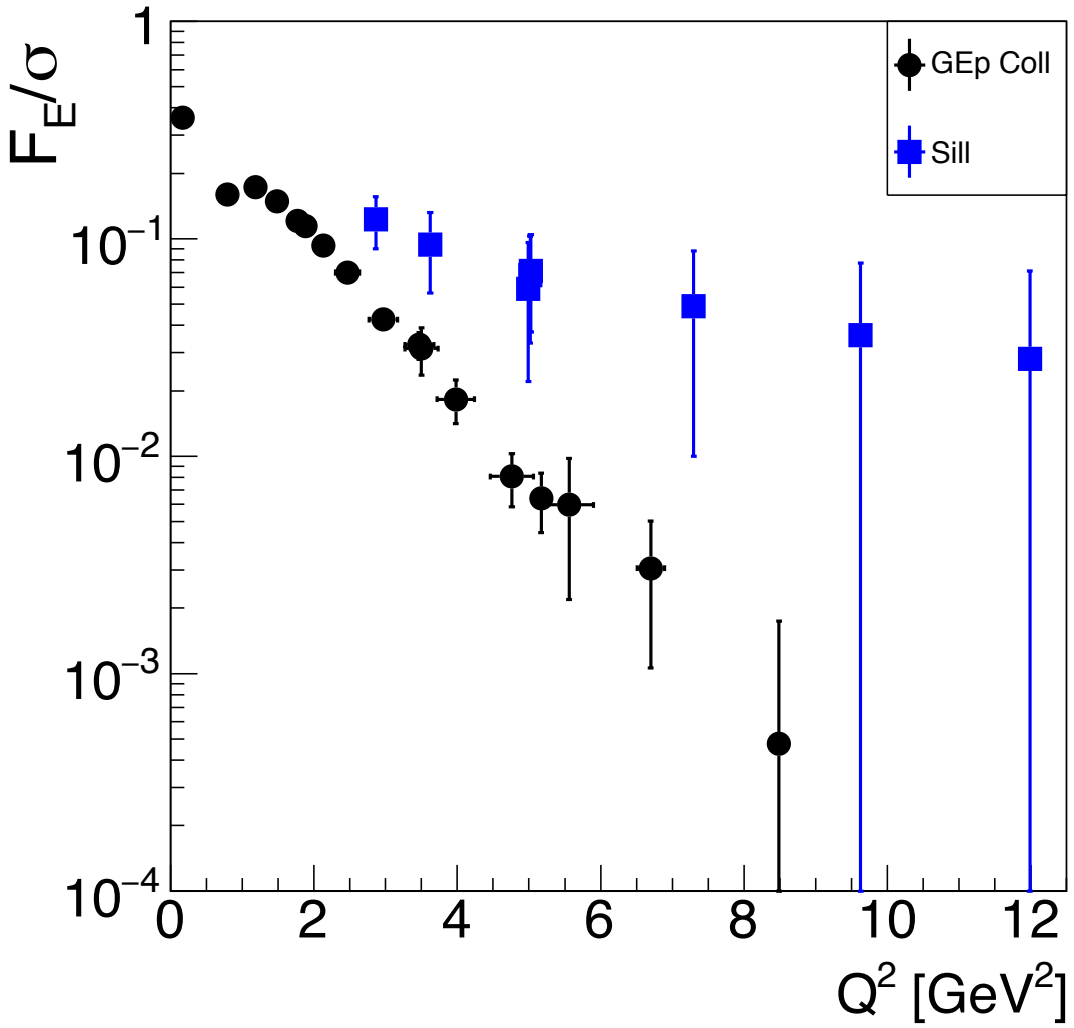
The difference is not at the level of the measured observables, but on the slope (derivative)!



E. Brash et al. Phys. Rev. C65:051001, 2002

Electric contribution to ep cross section

$$F_E = \frac{\epsilon G_E^2}{1 + \tau/(\epsilon R^2)}.$$



$$\sigma_R = \varepsilon G_E^2 + \tau G_M^2$$

$G_E \approx G_D$

$G_E < G_D$

Reaction mechanism: 1γ-2γ interference ?

Radiative corrections?

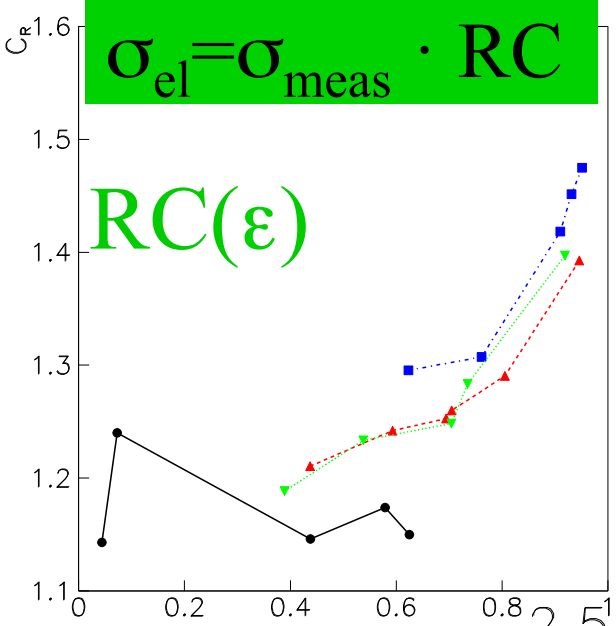
Other issues in data

- Correlations

- Normalizations
  - + of different sets of data
  - + in a series

Experimental correlation

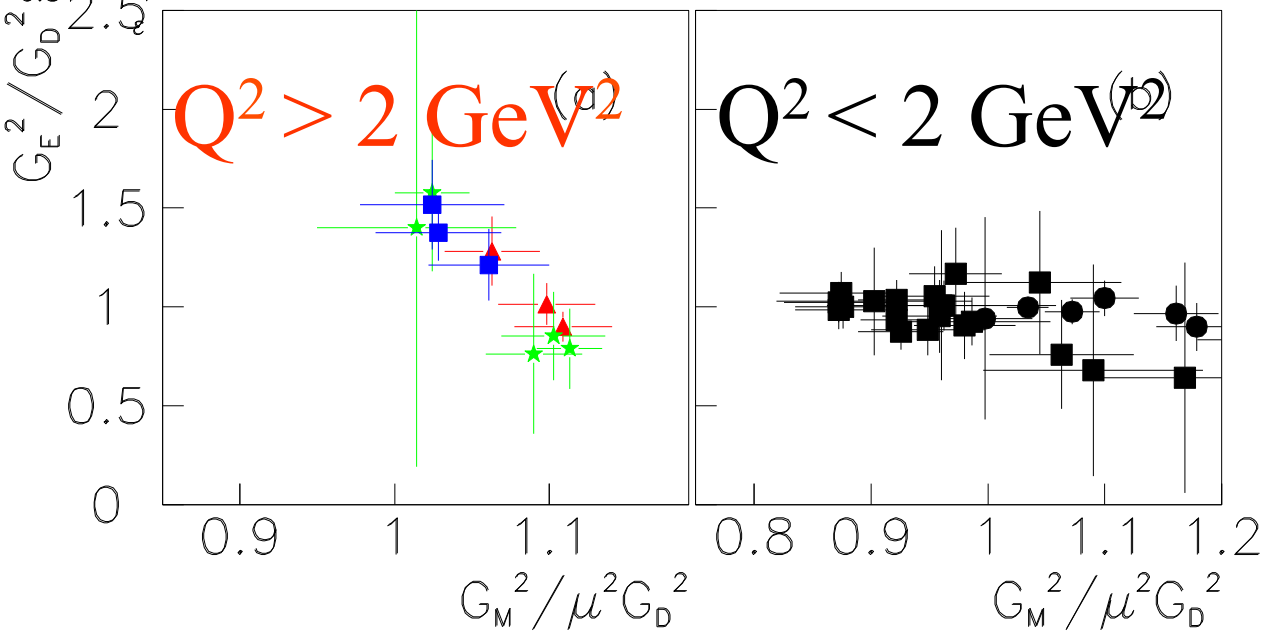
$\sigma_{el}=\sigma_{meas} \cdot RC$



E.T-G, Phys. Part. Nucl. Lett. ***4,*** *281 (2007)*

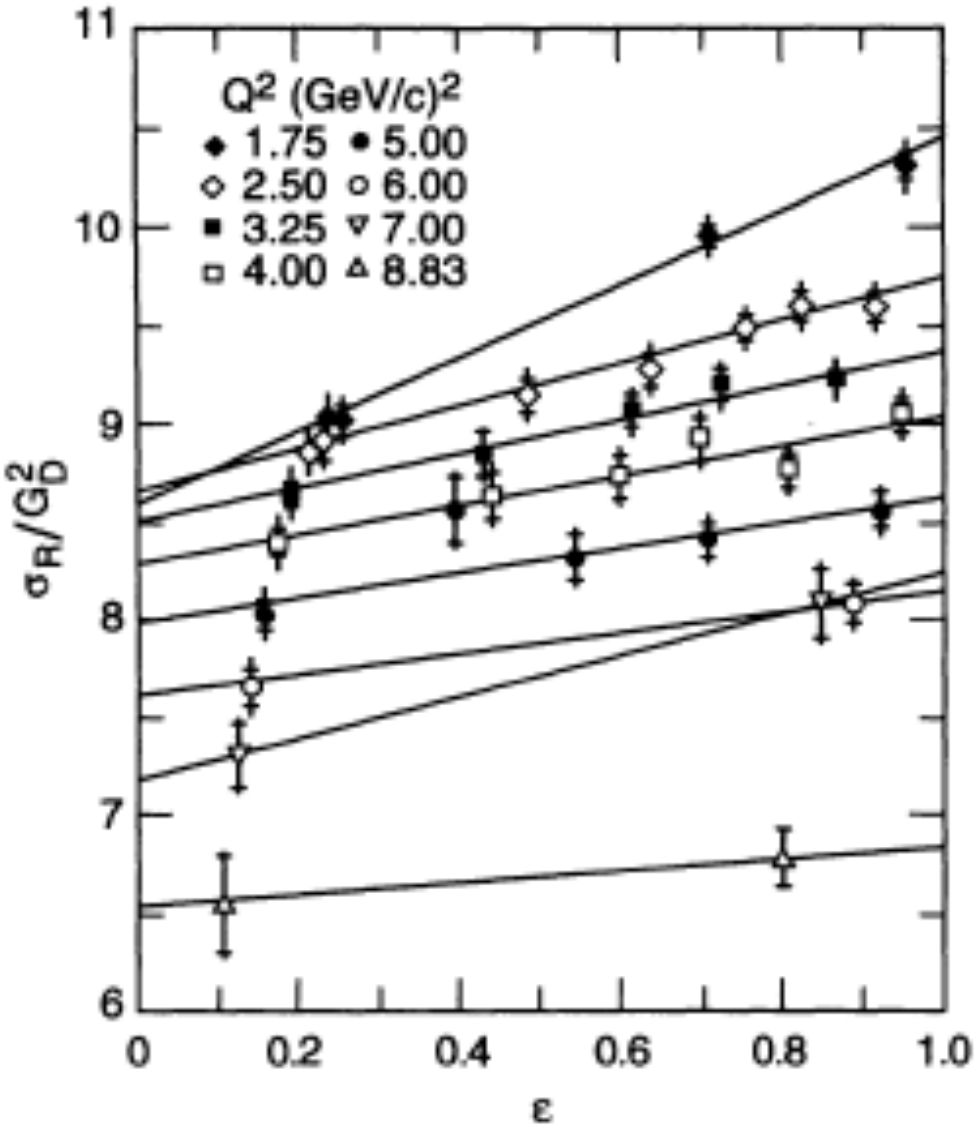
$$\sigma_{red} = \tau G_{Mp}^2 + \epsilon G_{Ep}^2$$

only published values!!



Normalization

Andivahis et al., PRD50, 5491 (1994)



Two spectrometers (8 and 1.6 GeV)

2 points at low ε

Fixed renormalization for the lowest ε point c=0.956 (acceptance correction)

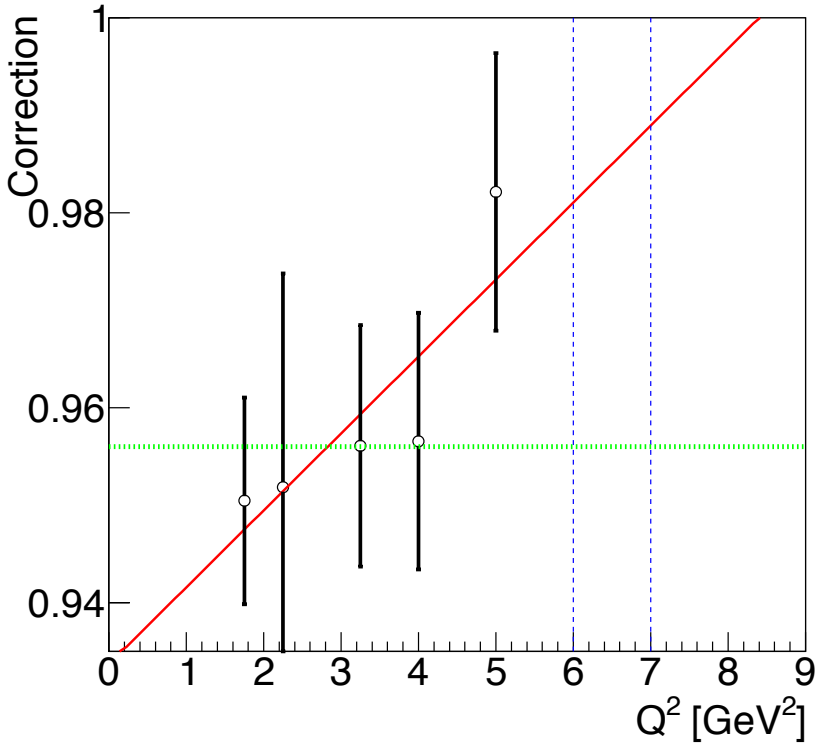
Increases the slope!

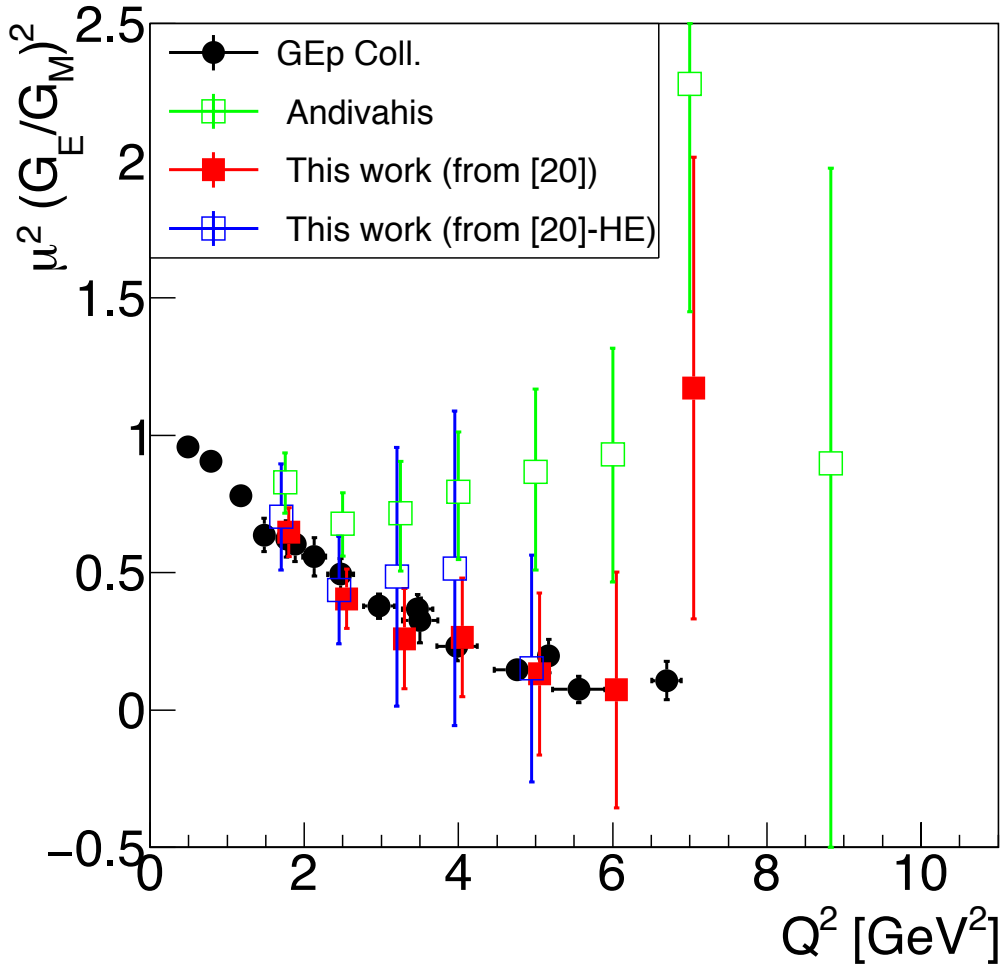
$G_E \approx G_D$

Direct extraction of the Ratio

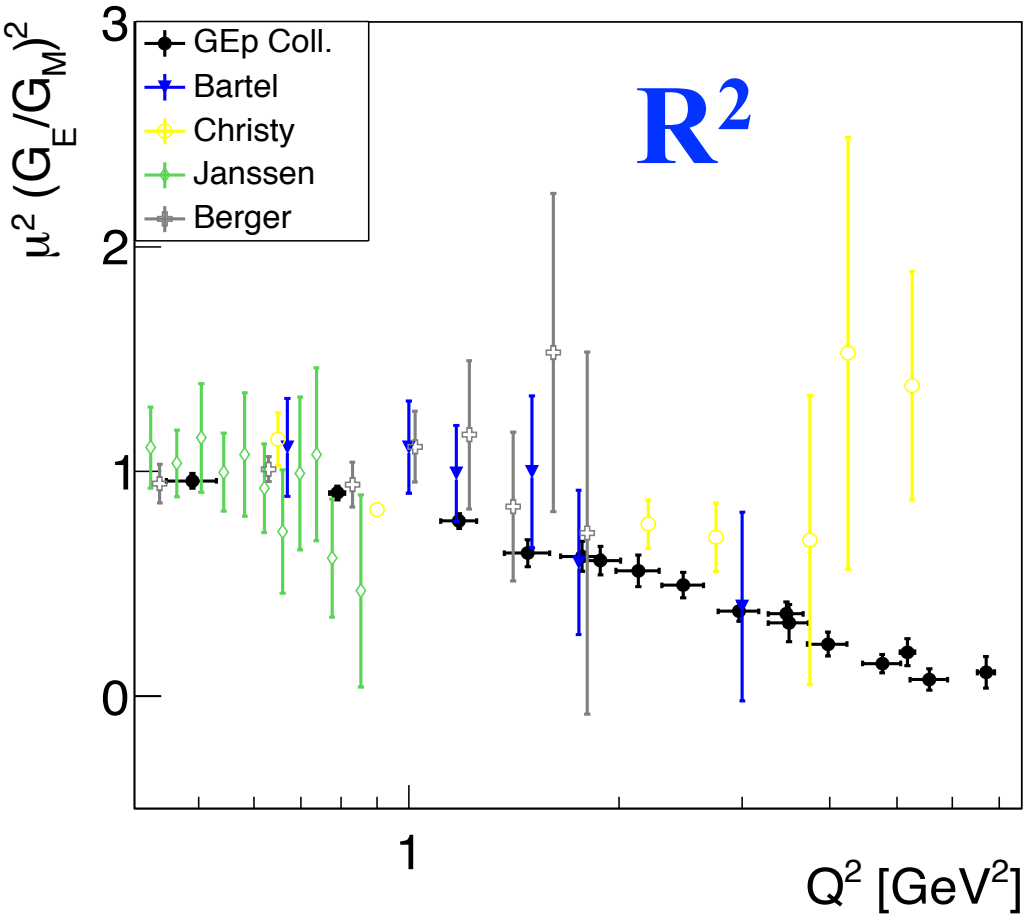
Andivahis et al., PRD50, 5491 (1994)

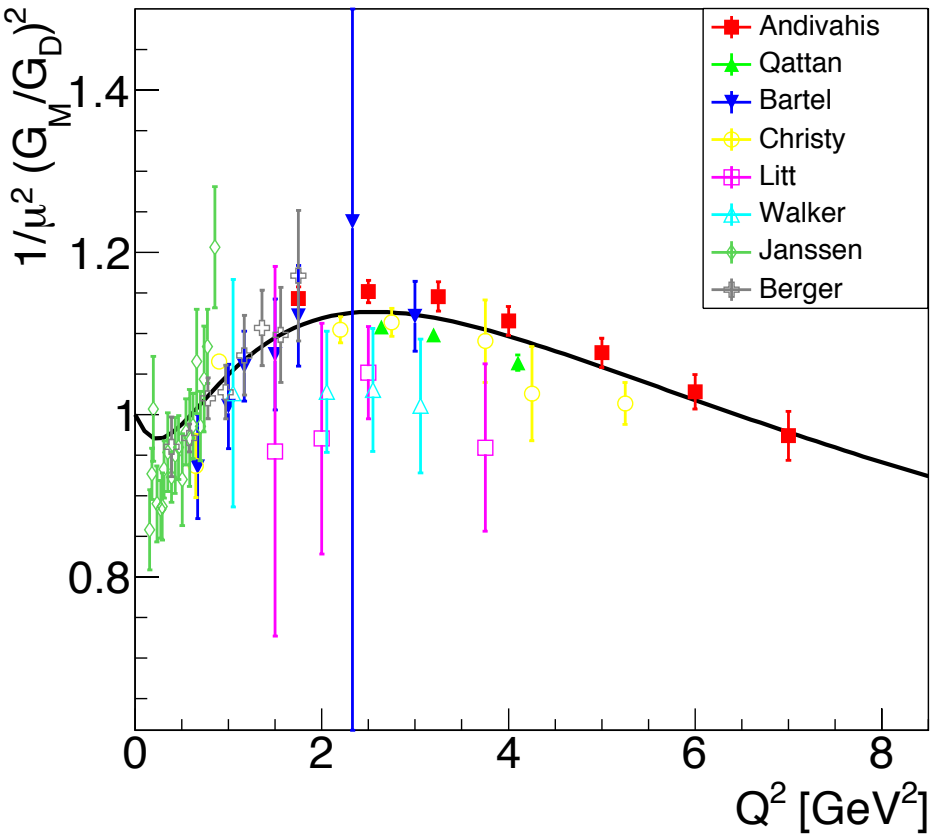
$$\sigma_{\rm red} = G_M^2(R^2\epsilon + \tau),$$



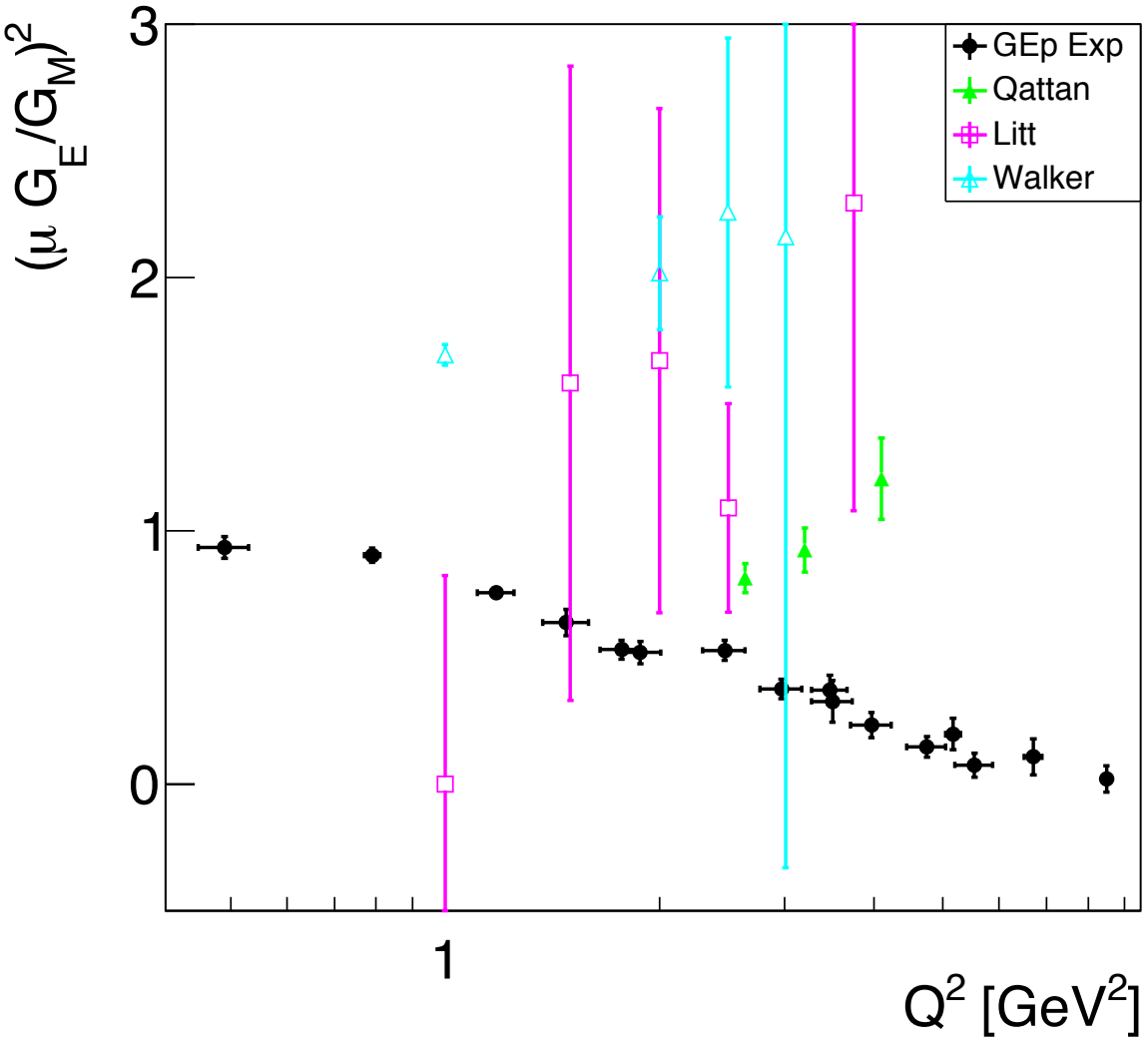


Different Data Sets





Other data sets



3 sets show increasing R^2 with Q^2

Large radiative corrections

Large correlations

Conclusion - Discussion

•Large activity in Space and Time-like regions to increase precision or extend q^2 range

Jefferson Lab

VEPP-3 Novosibirsk

- *Neutron/proton EM structure: FFs contain essential information (in one photon exchange)*
- *Effect of deviation of GE and GM from dipole*

- *If problems were not in observables… but in derivatives?*