# Measurement of the Proton Elastic Form Factor Ratio at Low $Q^2$

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On Behalf of E08-007 Collaboration

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Hall A Collaboration Meeting

# Outline

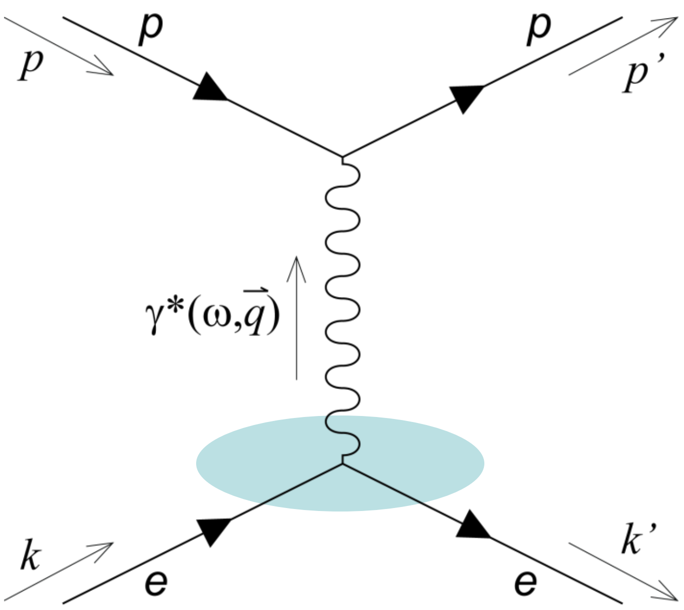
- Background
- Experiment
- Preliminary Analysis

# Proton Form Factors

Electron elastic scattering from proton:

$$\frac{d\sigma}{d\Omega} = \frac{d\sigma_{Mott}}{d\Omega}\frac{1}{1+\tau}[G_E^2 + \frac{\tau}{\varepsilon}G_M^2]$$

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




Leading order pQED
(single photon exchange)

## Sachs Form Factors:

*Electric:* $G_E(Q^2)$

*Magnetic:* $G_M(Q^2)$

$Q^2$=0

$$G_{Ep}(0) = 1, G_{Mp}(0) = \mu_p$$

$$G_{En}(0) = 0, G_{Mn}(0) = \mu_n$$

Dipole

$$G_D(Q^2) = (1+\frac{Q^2}{0.71\,GeV^2})^{-2}$$

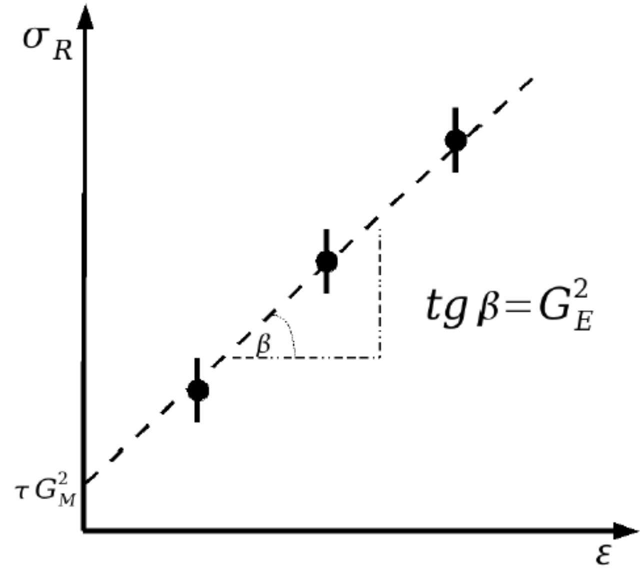
$$\mu_P\frac{G_E}{G_M} = 1$$

MIT

Jefferson Lab

# Rosenbluth Separation (Unpolarized)

$$\sigma_R \equiv \frac{d\sigma}{d\Omega}\frac{\varepsilon(1+\tau)}{\sigma_{Mott}} = \tau G_M^2(Q^2) + \varepsilon G_E^2(Q^2)$$




Method: Vary $\varepsilon$ at fixed $Q^2$, fit linearly

Slope → $G_E$

Intercept → $G_M$

## Difficulties:

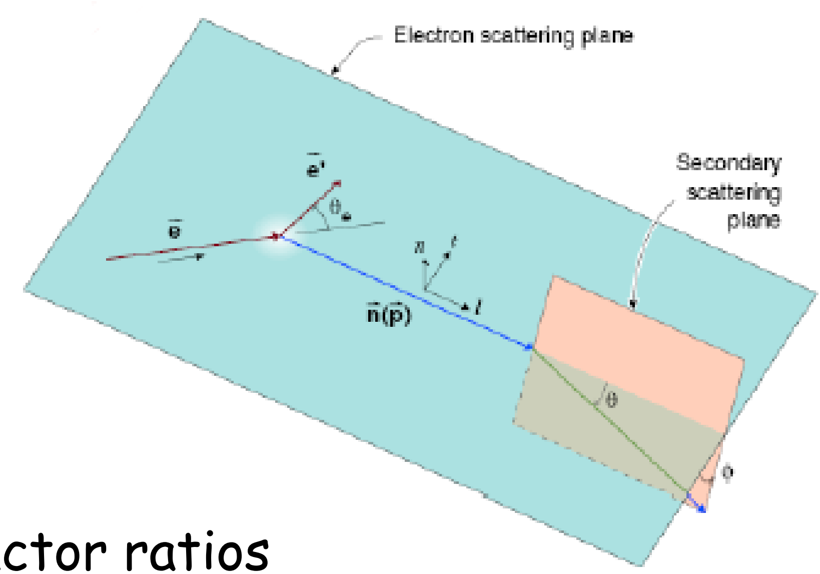
- $\sigma$ not sensitive to $G_E$ at large $Q^2$ and to $G_M$ at small $Q^2$
- Limited by accruaby of cross section measurement at different settings.

# Recoil Polarization

$$l_0 P_t = -2\sqrt{\tau(1+\tau)}\, G_E G_M \tan\frac{\theta_e}{2}$$

$$l_0 P_l = \frac{E_e + E_{e'}}{M}\sqrt{\tau(1+\tau)}\, G_M^2 \tan^2\frac{\theta_e}{2}$$

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

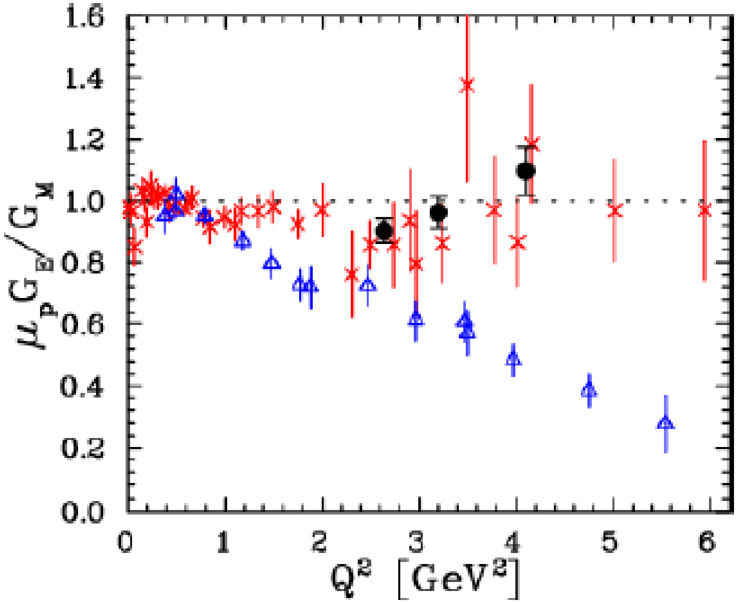



Direct measurement of form factor ratios by measuring the ratio of the transferred polarization $P_t$ and $P_l$ .

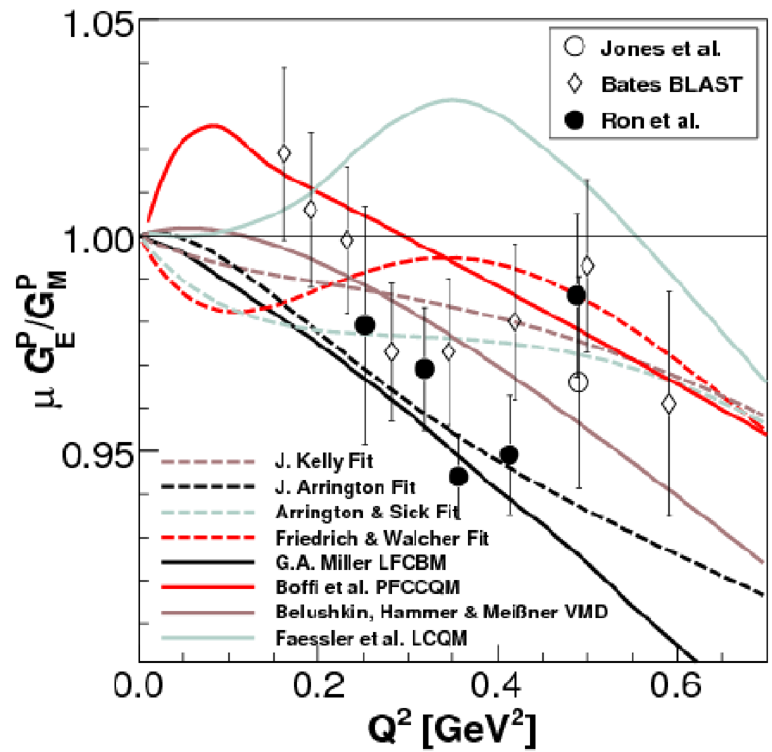
Advantages:

- only one measurement is needed for each $Q^2$.
- much better precision than a cross section measurement.

# World Data




I. Qattan *et al.*, Phys. Rev. Lett. 94, 142301 (2005).




G. Ron *et al.*, Phys. Rev. Lett. 99, 202002 (2007).

At high $Q^2$, Rosenbluth and Polarization methods do NOT agree.

2γ exchange?

We focus on low $Q^2$

# E08-007

- Approved by PAC33
- Part I: a high precision survay of Proton FF ratio by recoil polarization method

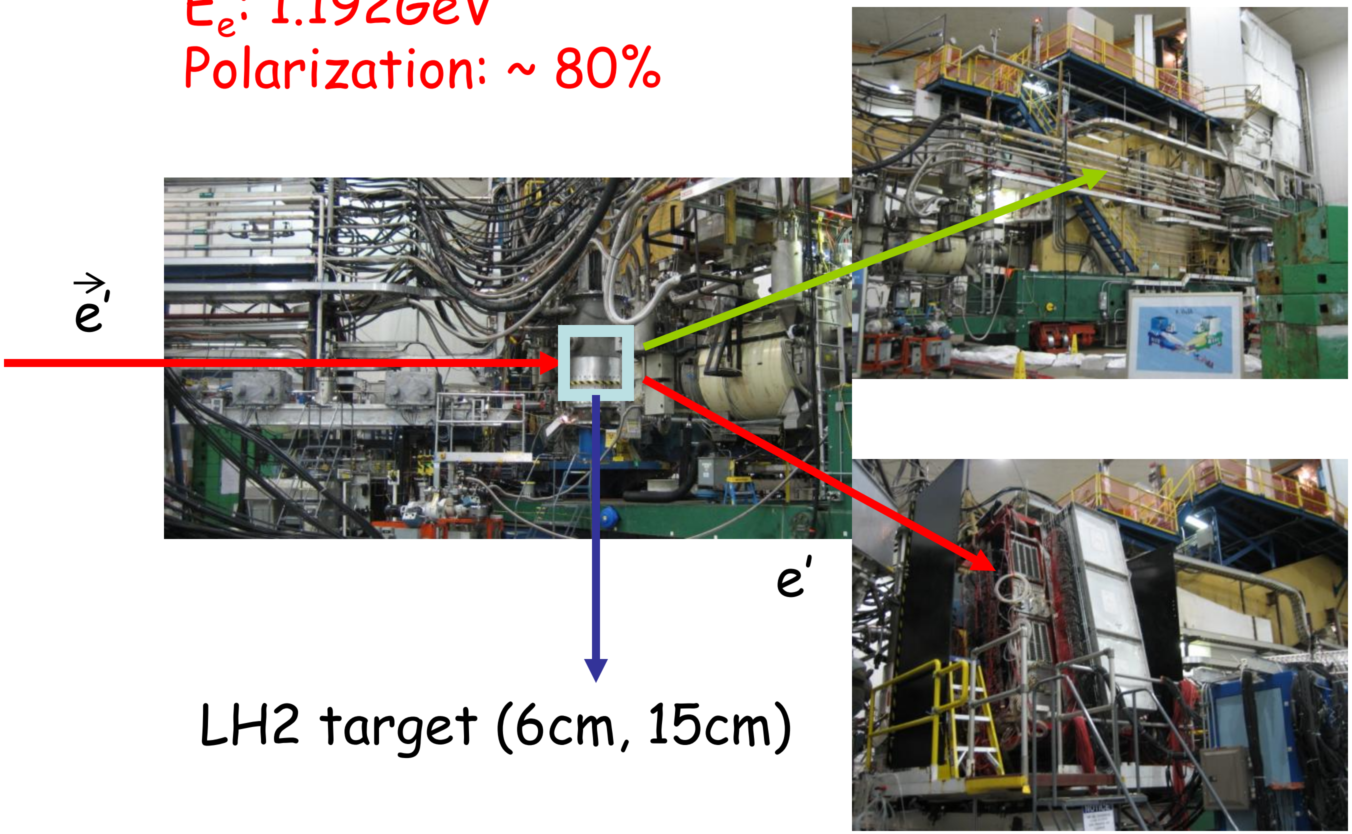
| $Q^2$ [GeV$^2$] | ($\Delta$ Ratio/Ratio)$_{stat.}$ [%] | ($\Delta$ Ratio/Ratio)$_{total}$ [%] |
|---|---|---|
| ~~0.25~~ | ~~1.00~~ | ~~1.41~~ |
| 0.3 | 0.73 | 1.03 |
| 0.35 | 0.46 | 0.65 |
| 0.4 | 0.32 | 0.45 |
| 0.45 | 0.28 | 0.39 |
| 0.5 | 0.37 | 0.52 |
| 0.55 | 0.34 | 0.48 |
| 0.6 | 0.32 | 0.45 |
| 0.7 | 0.31 | 0.43 |

- Scheduled from May 15$^{th}$ ~ June 9$^{th}$ 2008
- Succesfully completed!

# Experiment Setup

$E_e$: 1.192GeV
Polarization: ~ 80%

$P_p$ : 0.5 ~ 0.9 GeV/c




$E'_e$: ~ 1 GeV

LHRS

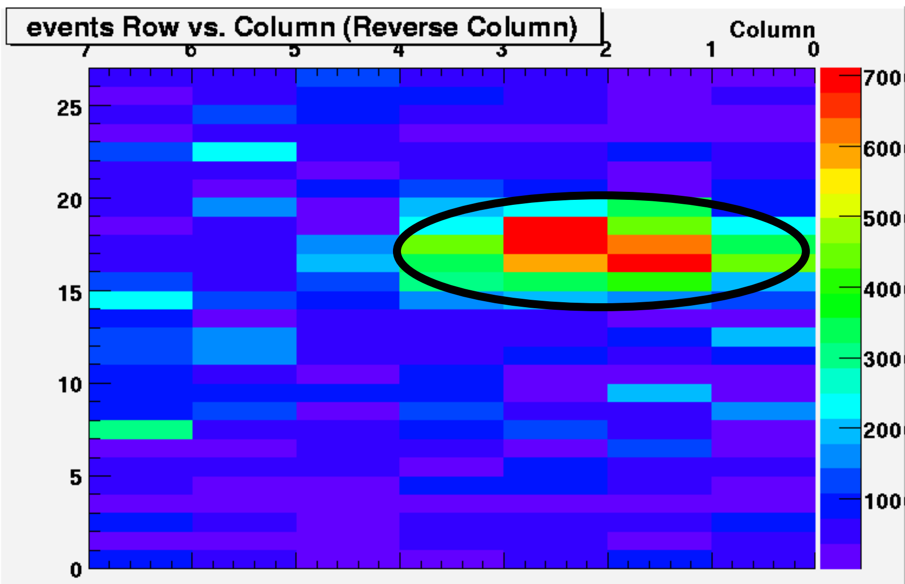
VDC + FPP
S1 + S2
Pion rejector 1
Pion rejector 2

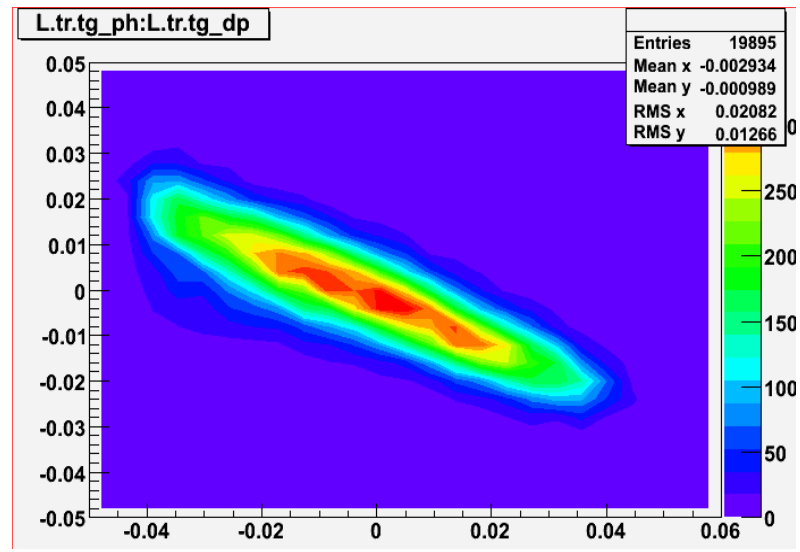
BigBite

Scintillator: 13
Preshower: 27x2
Shower: 27x7

# BigBite

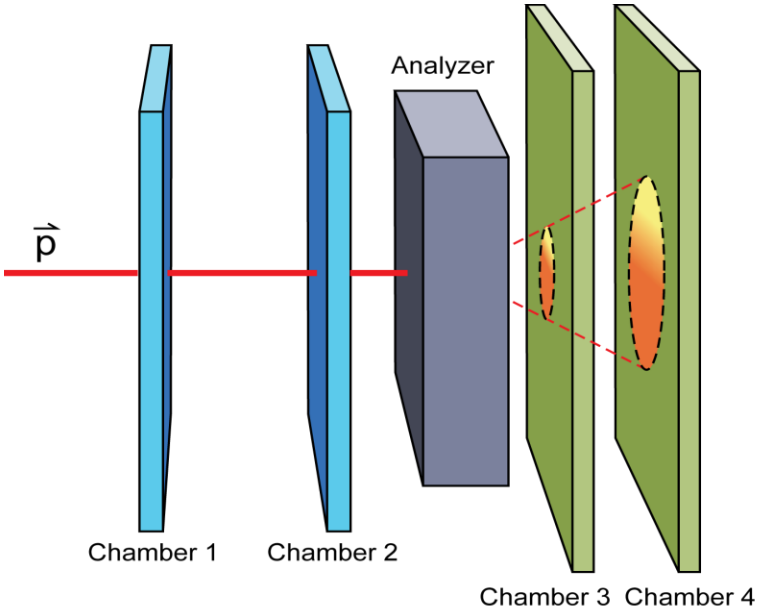
- Used for electron tagging (coincidence trigger).
- Turned on preshower and shower every time we changed kinematics.
- Selected shower blocks were on for production to reduce background

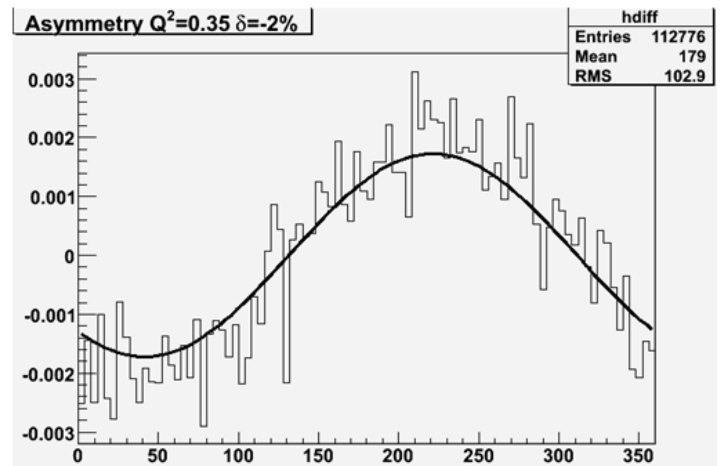


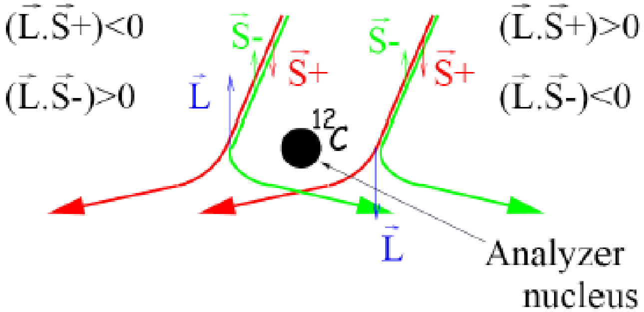



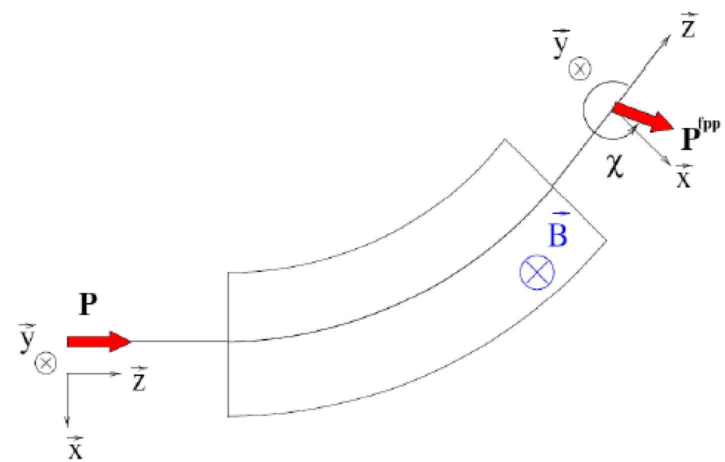
# Focal Plane Polarimeter

$$f^{diff}(\theta,\varphi) = f^{+}(\theta,\varphi) - f^{-}(\theta,\varphi) \propto (P_x^{fpp}\cos\varphi - P_y^{fpp}\sin\varphi)$$



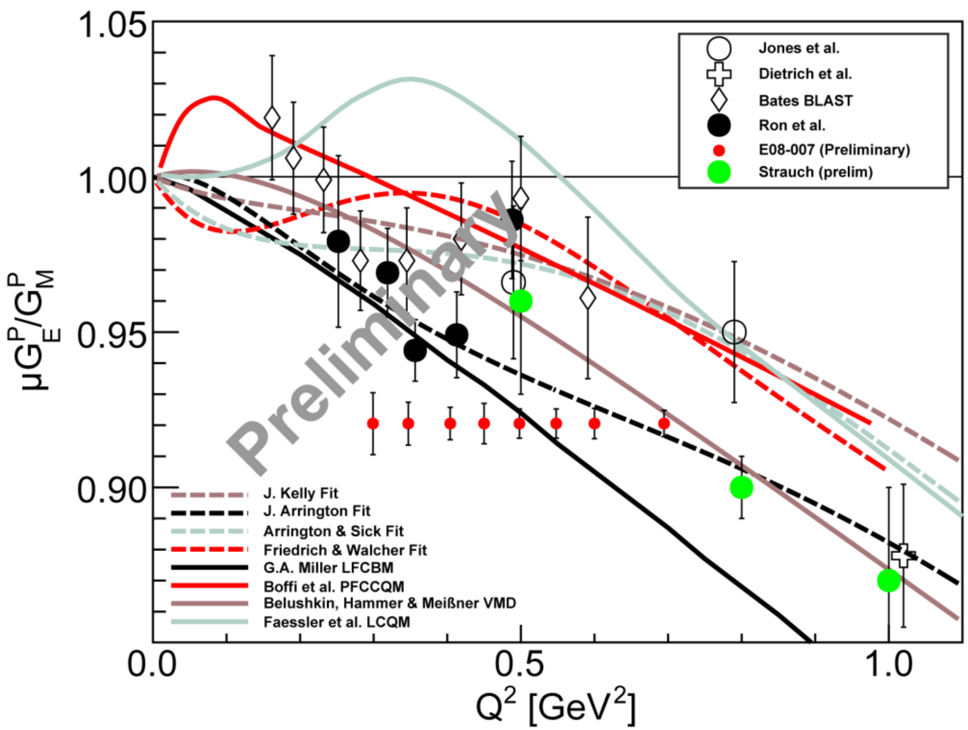



# Preliminary Analysis

| $Q^2[GeV^2]$ | 0.30 | 0.35 | 0.40 | 0.45 | 0.50 | 0.55 | 0.60 | 0.70 |
|---|---|---|---|---|---|---|---|---|
| $\Delta_{R(stat.)}[\%]$ | 0.95 | 0.70 | 0.55 | 0.70 | 0.46 | 0.52 | 0.53 | 0.44 |




E08-007 statistical error and world data & fits

- Statistical error can be smaller after adding the weight of different analyzing power for different $\theta_{scatter}$
- Systematic analysis :
  3 different delta settings for every Kine.
  Different spin precession method: COSY, Pentchev, Dipole
- Background substraction:
  Aluminum end-cap
  accidental

# Impact

- Many competing effective field theories:

  VMD, Lattice, RCQM, Di-Quark, CBM/LFCBM, pQCD …

- Combine ratio and cross section data (Mainz).
- Proton charge density
- Zemach radius/hyperfine splitting
- Improved isovector/isoscalar form factors
- Possible impacts on other experiments: DVCS, HAPPEX & G0, …

# Thank you!