Precision measurement of the proton magnetic form factor at high Q^2

(The GMp experiment, E12-07-108)

Thir Gautam
Hampton University

on behalf of the GMp collaboration

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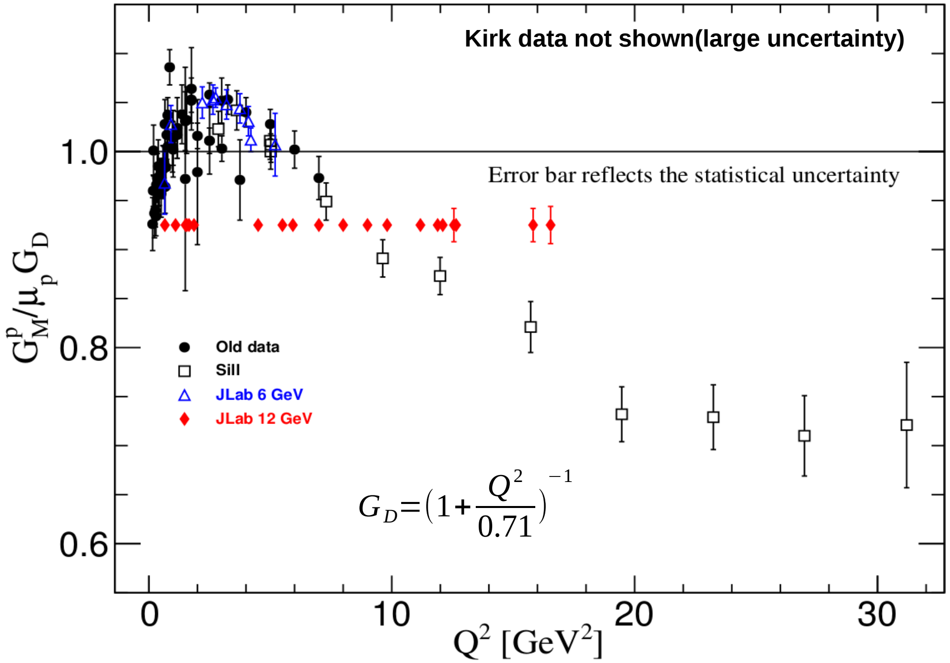
Overview of GMp experiment

- Precision measurement of the elastic *ep* cross-section over a wide range of Q^2 and extraction of proton magnetic form factor

  - To improve the precision of cross section at high Q^2 by a factor of 3
  - Supposed to have impact on entire form factor program
  - To provide insight into scaling behavior of the form factors at high Q^2

Statistical: Better than 2%

Systematic:
Point to point: 0.8-1.1%
Normalization: 1.0-1.3%
Total Error Budget: 1.2-2.6%



GMp analysis status

System Calibration:

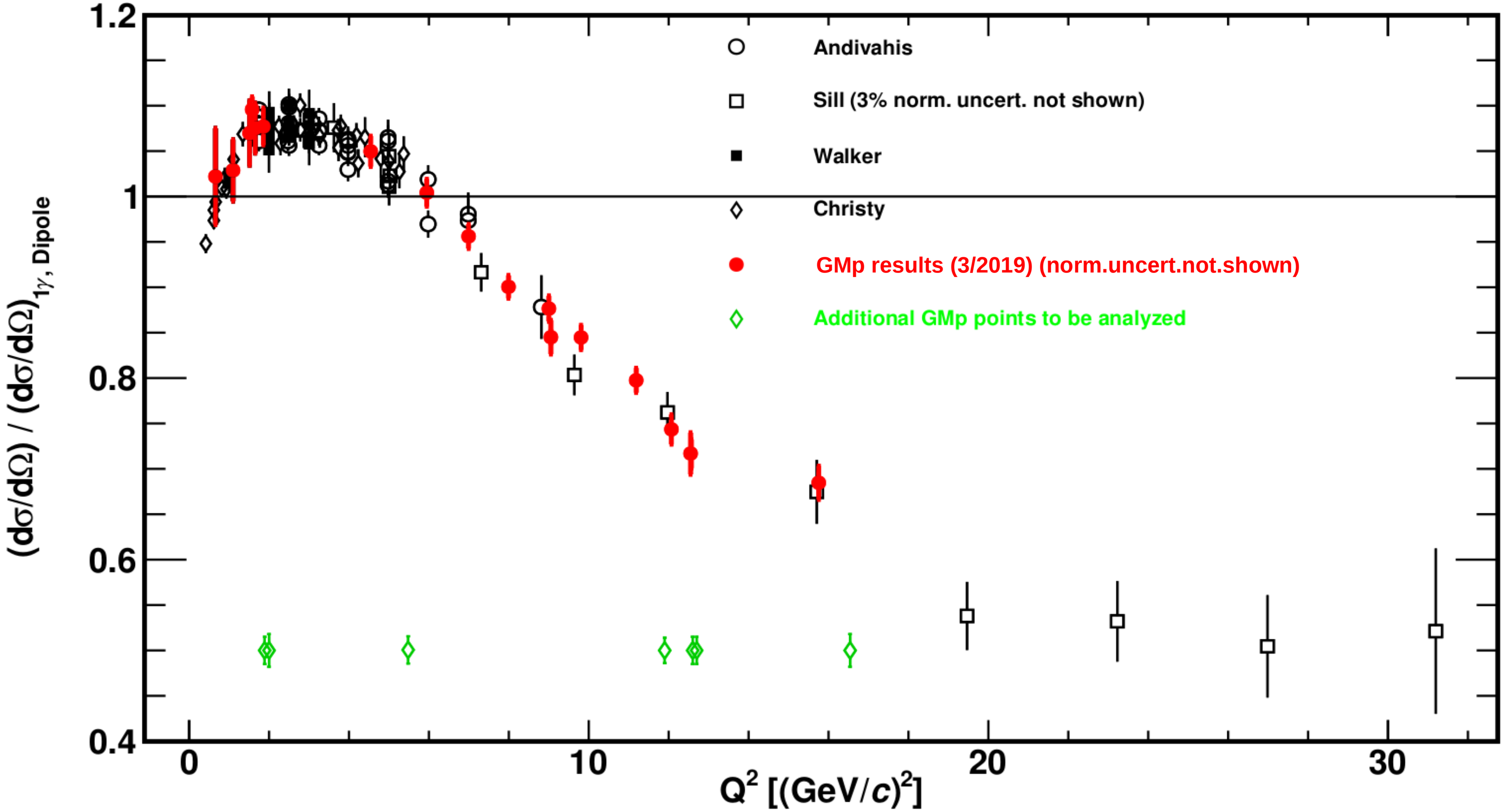
→ Beamline component Calibration (done)
→ PID detector calibration (done)
→ Tracking detector(VDC, Straw chamber) calibration (done)
→ Timing (s0, s2m) calibration (done)
→ Optics calibration (done for LHRS Fall 16 kinematics)

Data Analysis:

→ Tracking, trigger, PID efficiencies, DAQ live-time (done)
→ Target boiling analysis (done)
→ HRS acceptance studies and detailed aperture checks in the simulation model(done)
→ Extraction of cross section with both data to MC ratio and acceptance correction method (done)

GMp - E012-07-108 results

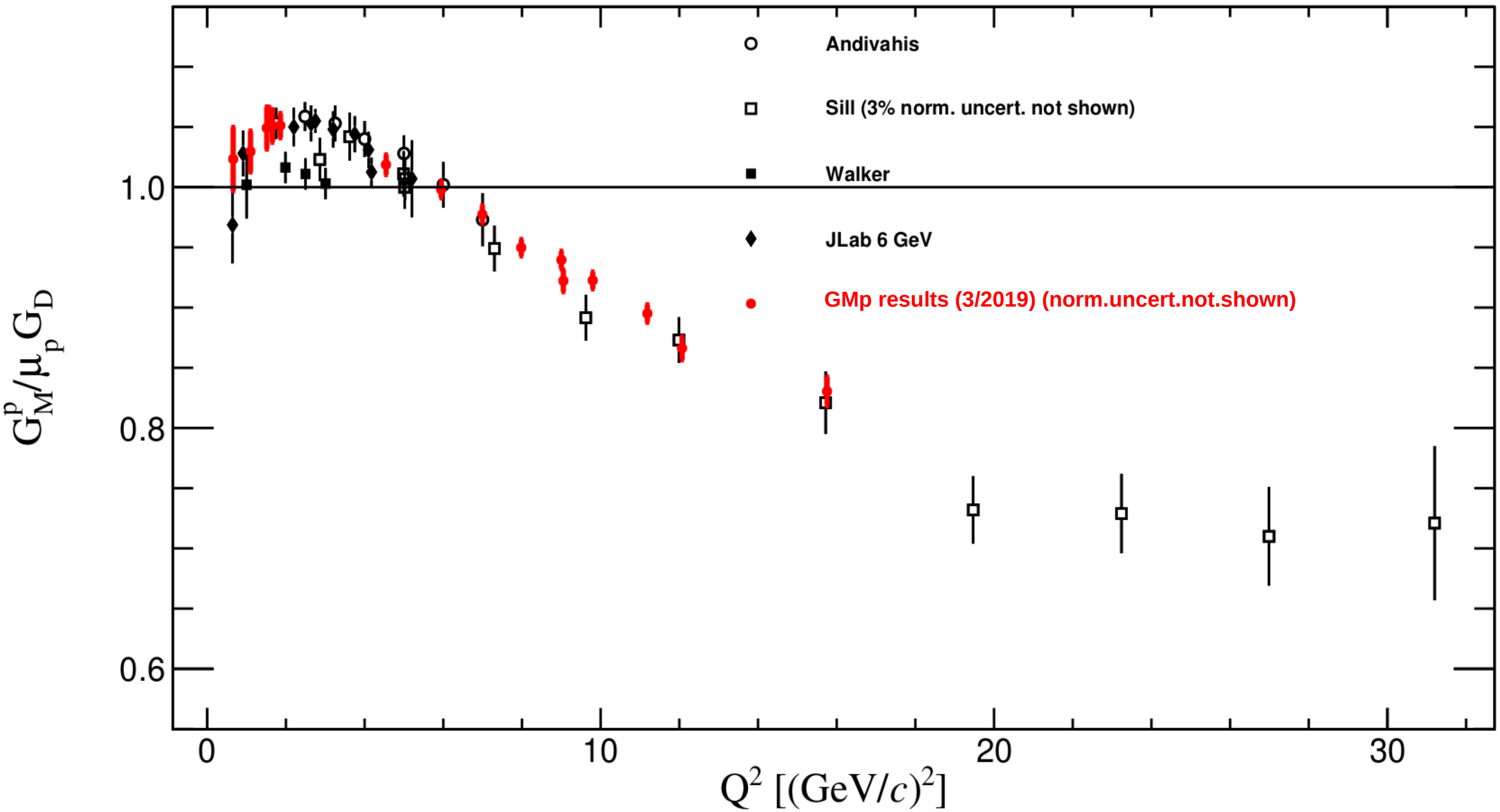
- Cross-section results presented below with ~1.2 – 1.3 %(pt-pt), 1.4 – 1.6%(norm)
- Significant uncertainty improvement in precision for Q^2>6 GeV^2



1γ refers to single photon approximation and Dipole corresponds to both form factor

Model dependent extraction of G_M

- Utilized the G_E to G_M ratio using parametrization from a fit to the existing cross section data in one photon exchange approximation
- Reduced uncertainty by more than factor of 2 at high Q^2



Sample GMp Global Rosenbluth separations

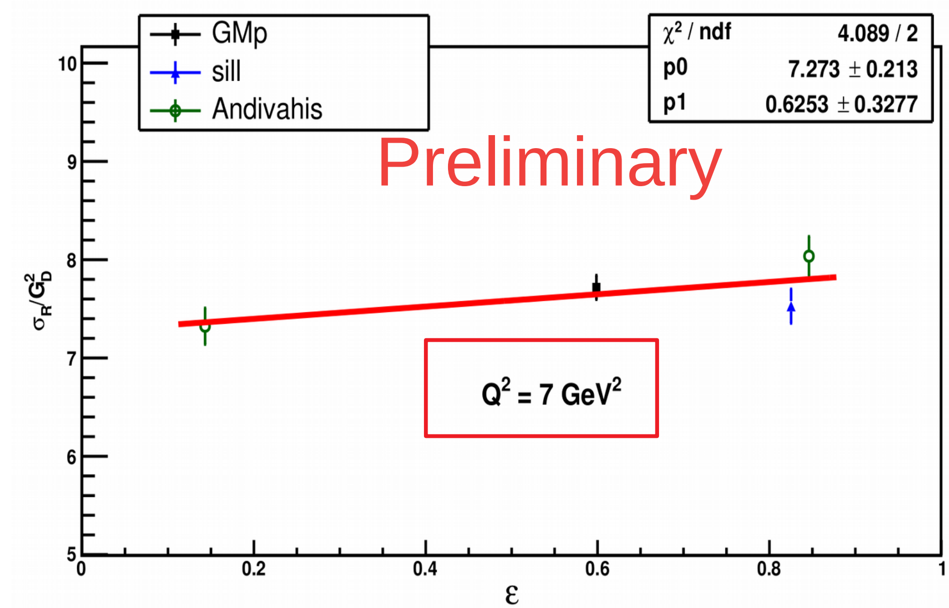
→ Selected groups of data where Q^2 is same or close

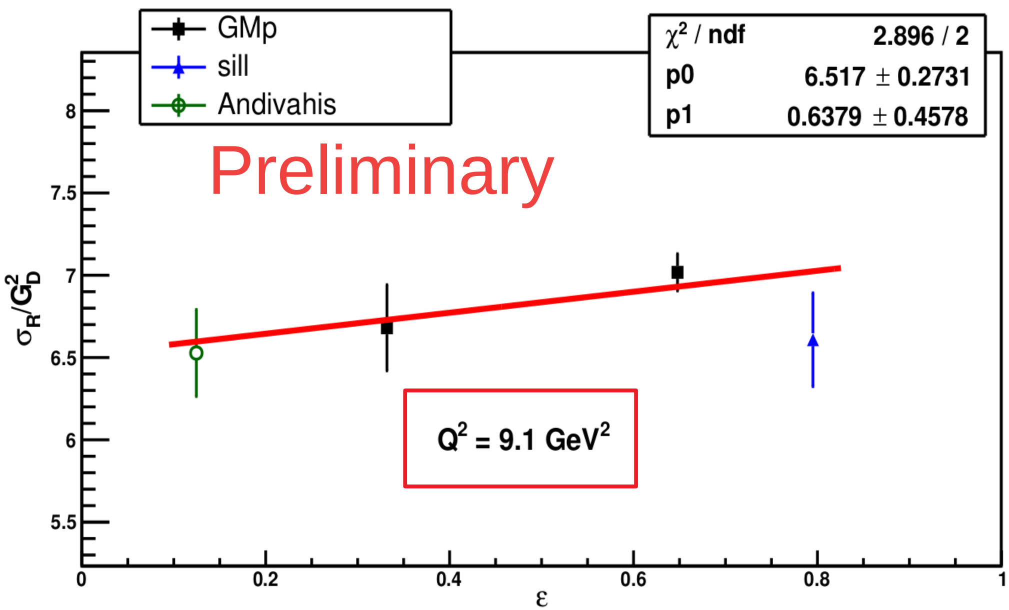
→ Applied correction factor to move all data to common Q^2 using a model as

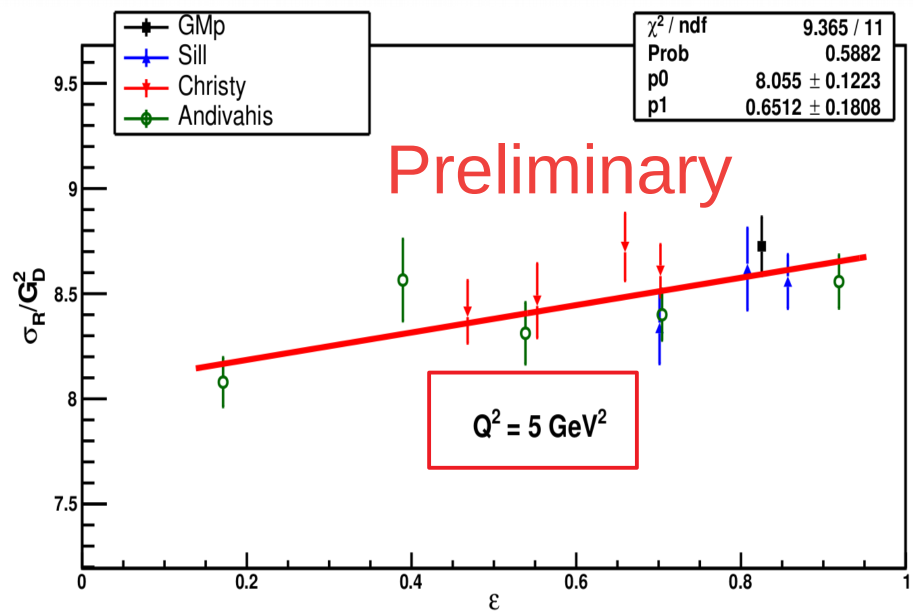
Where,

$$\sigma_R(Q_c^2,\varepsilon) = \sigma_R(Q^2) \times \frac{\sigma_R^{Mod}(Q_c^2,\varepsilon)}{\sigma_R^{Mod}(Q^2,\varepsilon)}$$

σ^{Mod} → Model cross section

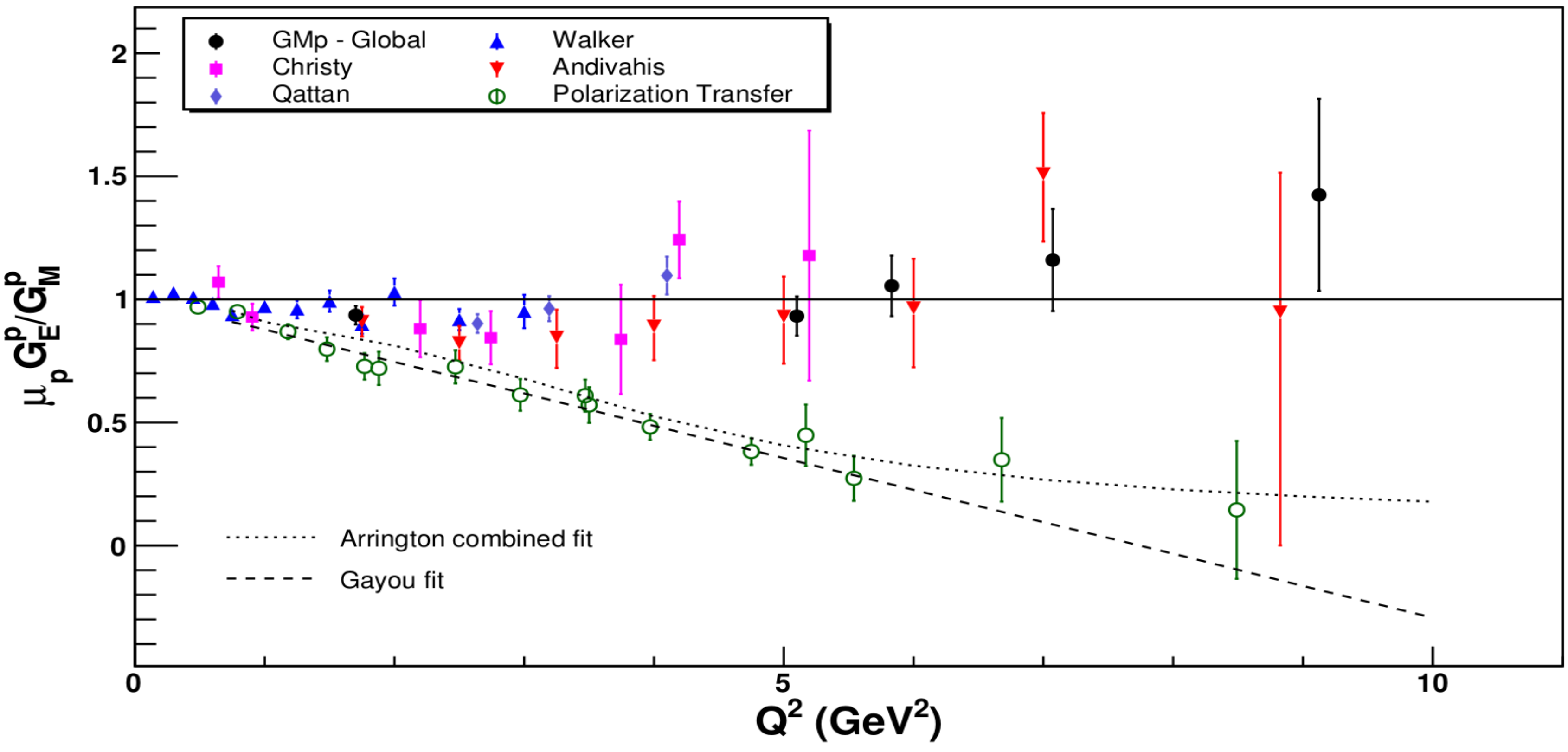






Relative normalization not yet applied

Electromagnetic form factor ratio (G_E/G_M)



→Hall A GMp data significantly reduce uncertainties on G_E/G_M at largest Q^2

→Increased tension between the Rosenbluth separation and polarization transfer at high Q^2

2-γ form factors

P. A. M. Guichon and M. Vanderhaeghen, PRL 91, 142303 (2003).

$$\sigma_r = \underbrace{G_M^2 + 2G_M \Re(\delta\tilde{G}_M)}_{\text{Rosenbluth intercept}} + \frac{\epsilon}{\tau}\left[\underbrace{G_E^2 + \frac{4\tau^2}{M^2}\Re(\tilde{F}_3)(G_M + \frac{1}{\tau}G_E) + 2G_E\Re(\tilde{G}_E)}_{\text{Rosenbluth Slope}}\right]$$

Rosenbluth intercept

Rosenbluth Slope

$$\sigma_r = G_M^2 + \frac{\epsilon}{\tau}G_E^2 + 2G_M\Re(\delta\tilde{G}_M) + \epsilon\left[\frac{2}{\tau}G_E\Re(\delta\tilde{G}_E) + \frac{4\tau}{M^2}\Re(\tilde{F}_3)(G_M + \frac{1}{\tau}G_E)\right]$$

$r = \mu G_E / G_M$

Assuming $2G_E\Re(\tilde{G}_E)$ is negligible

$$\sigma_r \approx G_M^2 + 2G_M\Re(\delta\tilde{G}_M) + \frac{\epsilon}{\tau}\left[\frac{r^2}{\mu^2}G_M^2 + \frac{4\tau^2}{M^2}\Re(\tilde{F}_3)G_M(1 + \frac{r}{\tau\mu})\right]$$

→ r constrained by fit to P-T data

→ global fit to cross section data provides access to

$G_M^2(Q^2)$ $\overline{\Re(\delta\tilde{G}_M)}(Q^2)$ And $\overline{\Re(\tilde{F}_3)}(Q^2)$ ← ε average

Summary

- Data analysis is completed for fall 2016 LHRS kinematics.
- Current status systematic uncertainties:

  1.2 – 1.3% pt-pt

  1.4 – 1.6% normalization

- G_M extracted from two methods: model dependent and Rosenbluth separation are in agreement with existing data with uncertainty reduced by a factor of 2 or more.
- Indication of increased tension between the Rosenbluth separation and polarization transfer at high Q^2