Precision Measurement of the Proton Elastic Cross Section at High Q^2

Jefferson Lab

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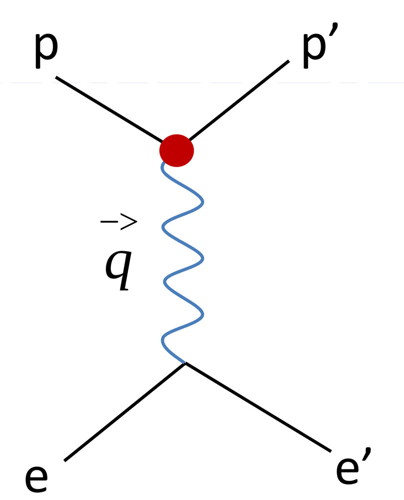
Proton's Form Factors

In the Born approximation, the cross section for elastic *e-p* scattering can be written as:

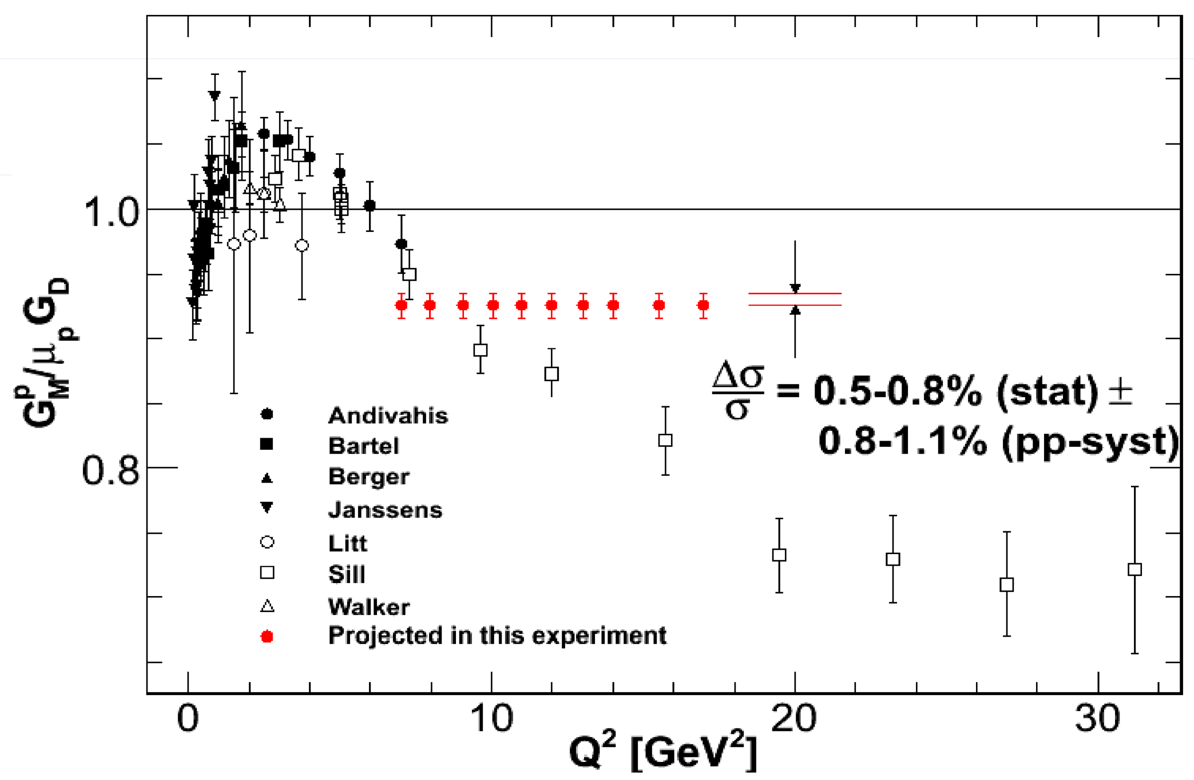


$$\frac{d\sigma}{d\Omega} = \sigma_{Mott} \frac{\varepsilon (G_E^p)^2 + \tau (G_M^p)^2}{\varepsilon (1+\tau)},$$

Where $\sigma_{Mott} = (\frac{\alpha}{2E} \frac{\cos(\theta/2)}{\sin^2(\theta/2)})^2 \frac{E'}{E},$

With $\tau = Q^2/4M_p$ and $\varepsilon = \left[1 + 2(1+\tau)\tan^2\left(\frac{\theta_e}{2}\right)\right]^{-1}$

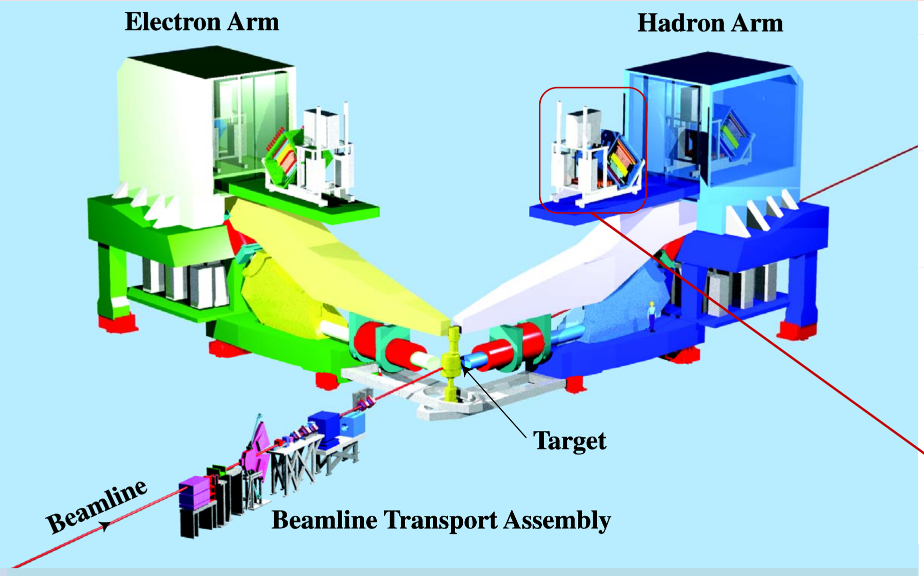
Existing Data of G_M^p



Motivations of GMp Experiment

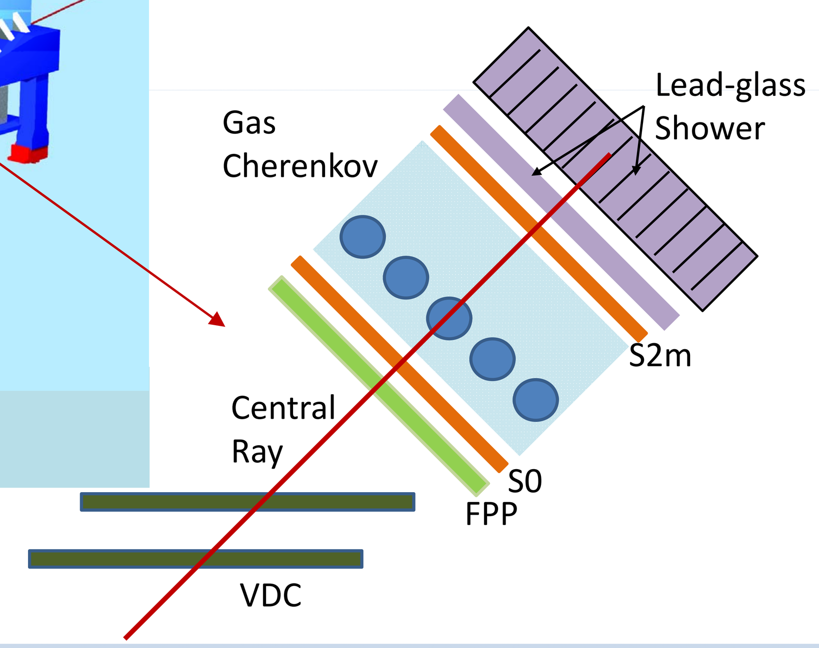
- Accurately measure *e-p elastic cross section* in kinematics similar to other JLab form factors measurements ($Q^2 = 7 - 11\ GeV^2$).
- Aim to improve the accuracy of the e-p elastic cross section to better than **2%**.
- Important for all form factor measurements, and many of other experiments where elastic scattering is used for cross section normalization

Experiment Layout



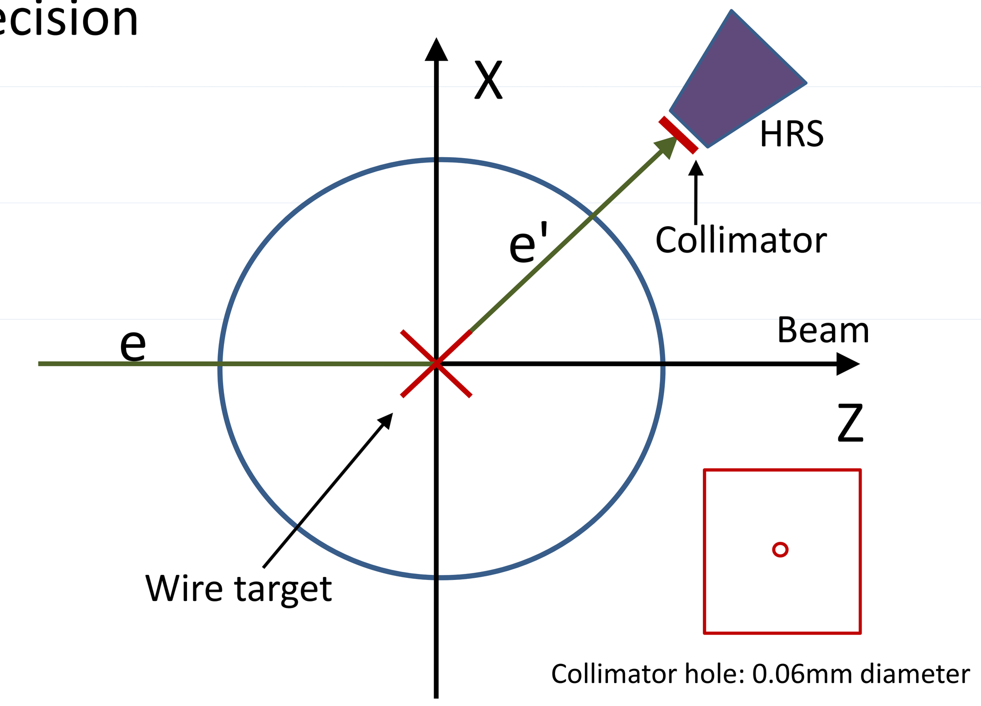
3D schematic of Hall A HRSs

Schematic of detector hut



Accuracy Controls

- Tracking efficiency
  -- A straw chamber is installed in each arm: reduce uncertainties associated with tracking reconstruction efficiency.
- DAQ dead time
  -- EDTM pulser for dead time measurement
- Target density: using newly designed 15cm long LH_2 cell
  -- new design => reduce the effects of density fluctuations
  -- we will characterize the beam-related density changes
- Scattering angle: two independent methods to cross check
  -- floor marks: ± 0.4 mrad precision
  -- PAM (Precision Angle Measurement): less than 0.5 mrad precision



Precision angle measurement principle

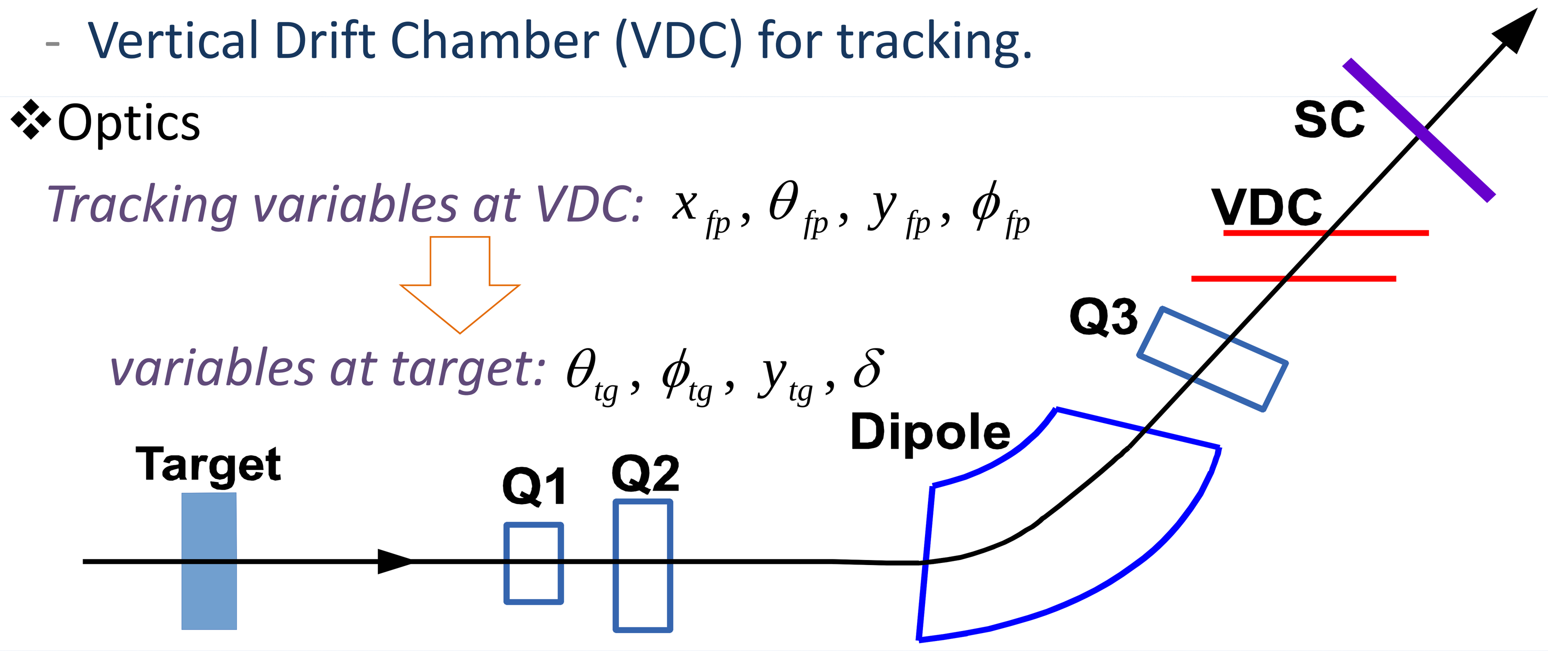
- Determination of solid angle
  -- improved optics

Magnetic Spectrometer Optics

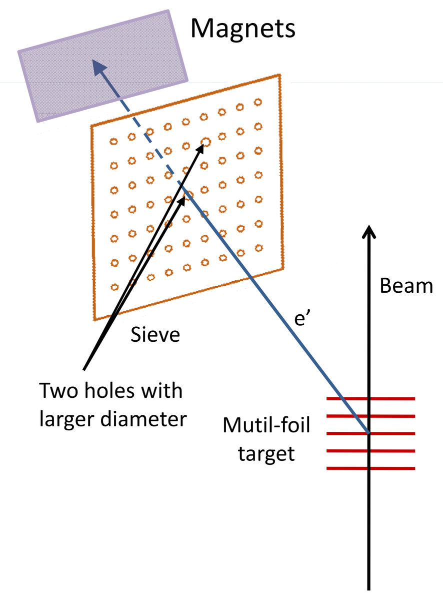
- Setup
  - QQDQ, vertical bending 45 degrees.
  - Vertical Drift Chamber (VDC) for tracking.
- Optics

Tracking variables at VDC: $x_{fp}, \theta_{fp}, y_{fp}, \phi_{fp}$

variables at target: $\theta_{tg}, \phi_{tg}, y_{tg}, \delta$



Magnetic Spectrometer Optics



$$\alpha_{tg} = \sum_{i=0}^{m} C^x_{i,j,k,l}\, x^m_{fp} \sum_{j,k,l} \theta^j_{fp} y^k_{fp} \phi^l_{fp}$$

where α_{tg} can be any target variables $\theta_{tg}, \phi_{tg}, y_{tg}, \delta$

- 3 groups of calibrations

- Angles: θ_{tg}, ϕ_{tg} *Sieve slit data*

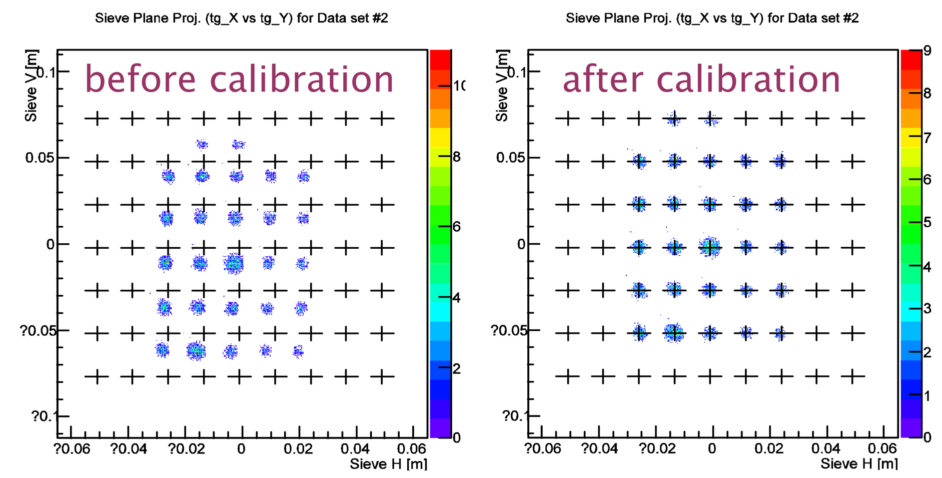
$$\chi^2(\theta_{tg}) = \sum_{i=1}^{N\text{-hole}} \sum_{j=1}^{N\text{-event}} (x_{i,j}^{recon.} - x_i^{survey})^2$$

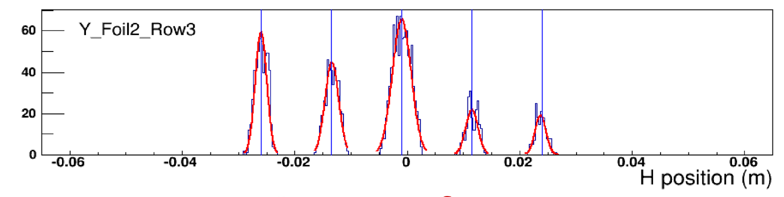
Varying $C^x_{i,j,k,l}$ to minimize $\chi^2(\theta_{tg})$

- Vertex: y_{tg} *Multi-foil targets data*

- Momentum: $\delta = p/p_{central} - 1$ *Elastic data*

Optics Precision Study





-- Gaussian fitting
-- surveyed position

Optics precision requirement:

$\frac{\delta\sigma}{\sigma} \le 2\%$

$\frac{\delta\Delta\Omega}{\Delta\Omega} \le 0.5\%$

$\frac{\delta\Delta\theta_{tg}}{\Delta\theta_{tg}} \le 0.35\%, \frac{\delta\Delta\phi_{tg}}{\Delta\phi_{tg}} \le 0.35\%$

3/25 holes fail to meet the precision requirement in both horizontal and vertical direction.