The CLAS Two Photon Exchange Experiment: Experimental Methods

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Outline

- Proton form factor measurements
- Two photon exchange correction
- Producing a mixed electron positron beam
- Background control
- The TPE experiment
- Summary

Proton form factor measurements

In non-relativistic limits, $G_E(Q^2)$ and $G_M(Q^2)$ give the spatial distribution of charge and magnetism carried by proton.

Rosenbluth separation method - $p(e, e')$

- Elastic electron-proton scattering (one photon exchange)

$$\frac{d\sigma}{d\Omega} = \sigma_{mott} \frac{E'_e}{E_e} \left\{ \frac{G_E^2 + \tau G_M^2}{1+\tau} + 2\tau G_M^2 \tan^2(\theta_e/2) \right\}$$

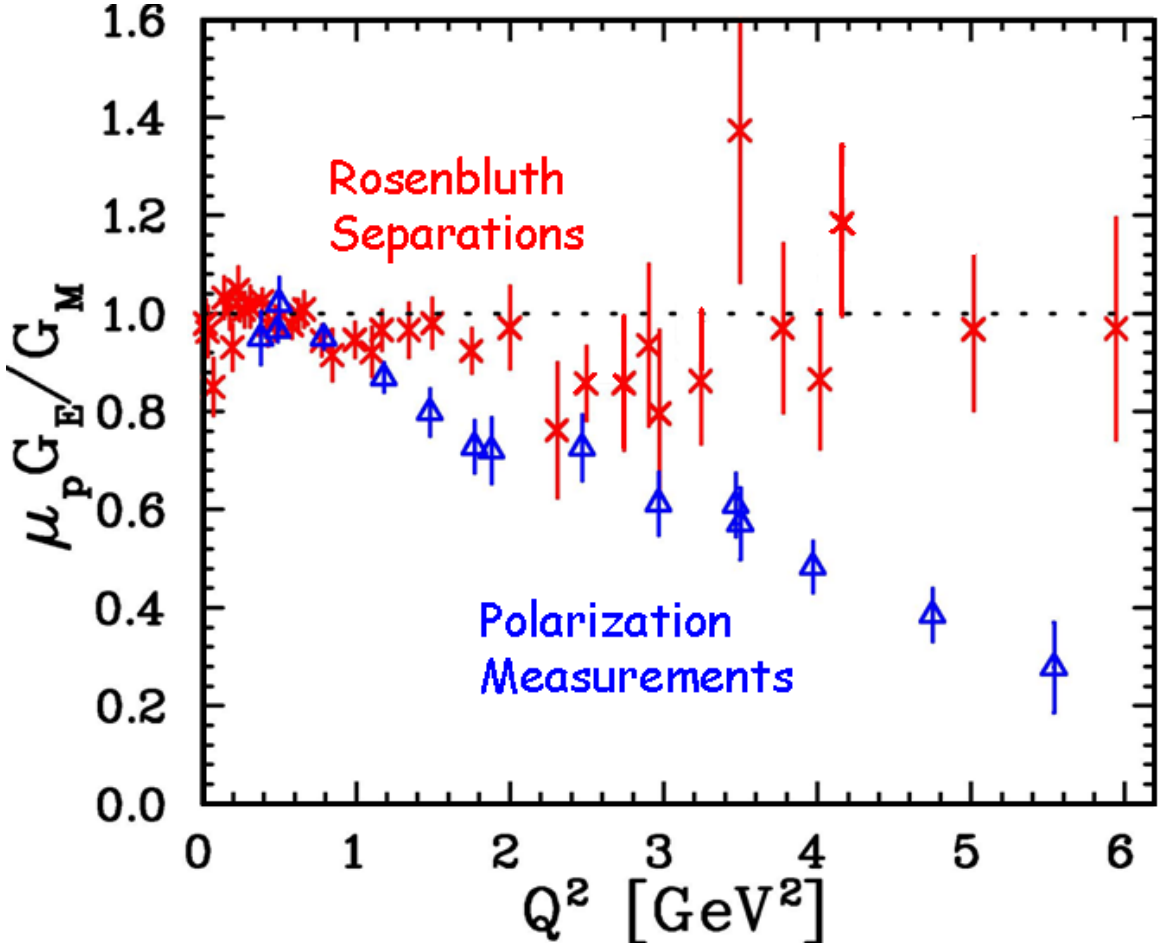
  where $\tau = \frac{Q^2}{4{M_p}^2}$

- Separate G_E and G_M by varying incident electron energy (E_e) and scattering angle (θ_e) at fixed Q^2

Polarization transfer method - $p(\vec{e}, e'\vec{p})$

- A longitudinally polarized electron transfers its polarization to recoil proton.
- Transverse (P_t) and longitudinal (P_l) polarization of the recoiled proton are measured.

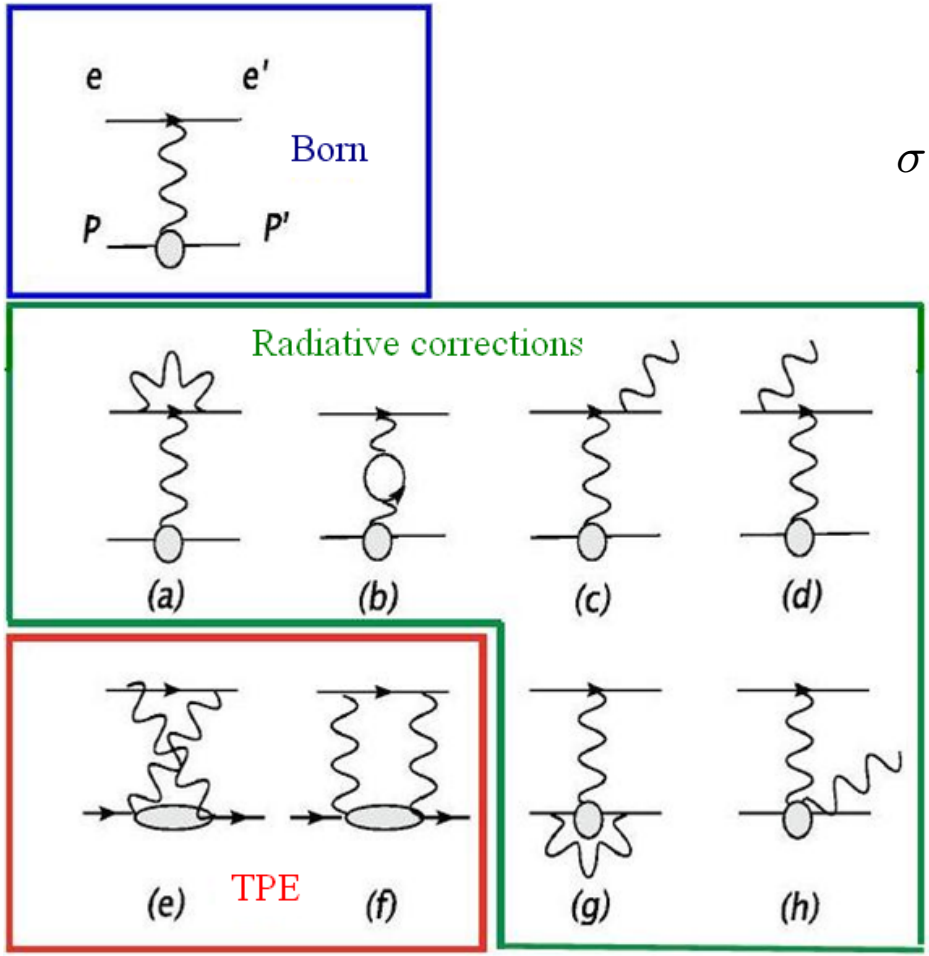
$$\frac{G_E}{G_M} = -\frac{P_t}{P_l} \frac{E_e + E'_e}{2M_p} \tan(\theta_e/2)$$



- Big discrepancy !
- Possible explanation: two photon exchange (TPE) correction to the Rosenbluth separation measurements.
- TPE contribution expected to be $\sim 5 - 8\%$.

Two photon exchange correction

Measure the positron-proton to electron-proton cross section ratio to determine the TPE correction.



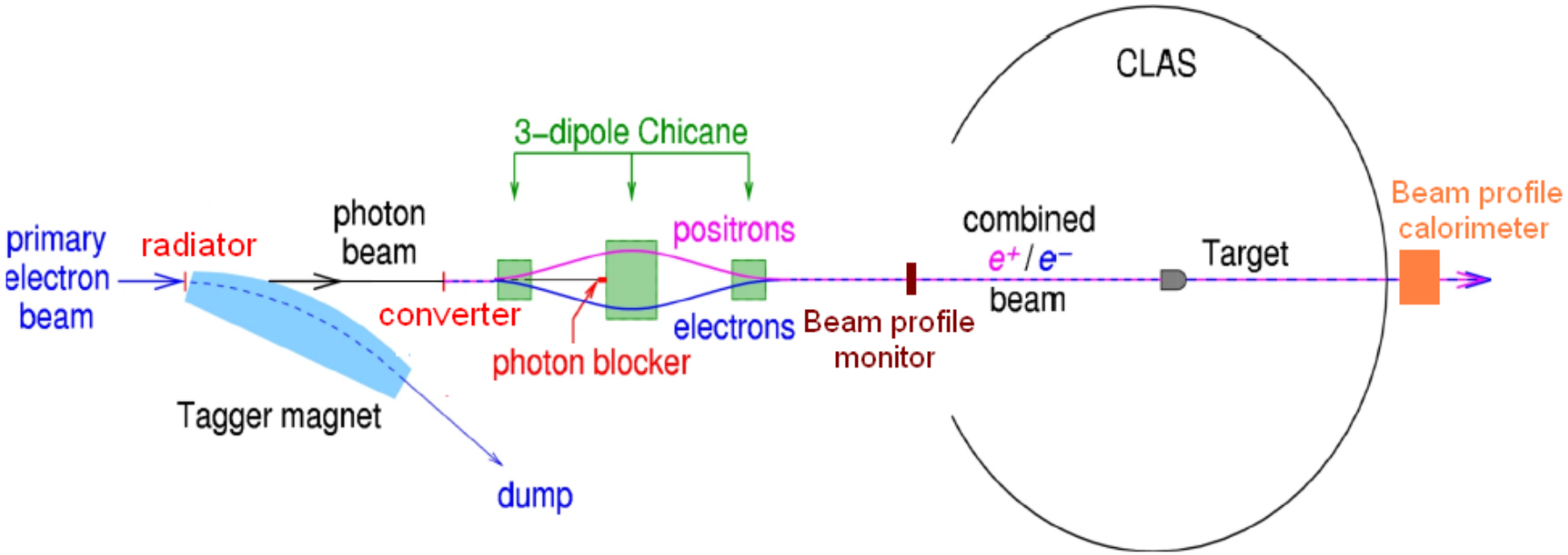
$$\sigma(e^{\pm}p) \propto |A_{ep\to ep}|^2 = |A_{Born} + ... + A_{2\gamma}|^2$$

$$\sigma(e^{\pm}p) \propto |A_{Born}|^2 \pm 2A_{Born}\mathrm{Re}(A_{2\gamma})$$

$$R = \frac{\sigma(e^+p)}{\sigma(e^-p)} = 1 - \frac{4\mathrm{Re}(A_{2\gamma})}{A_{Born}}$$

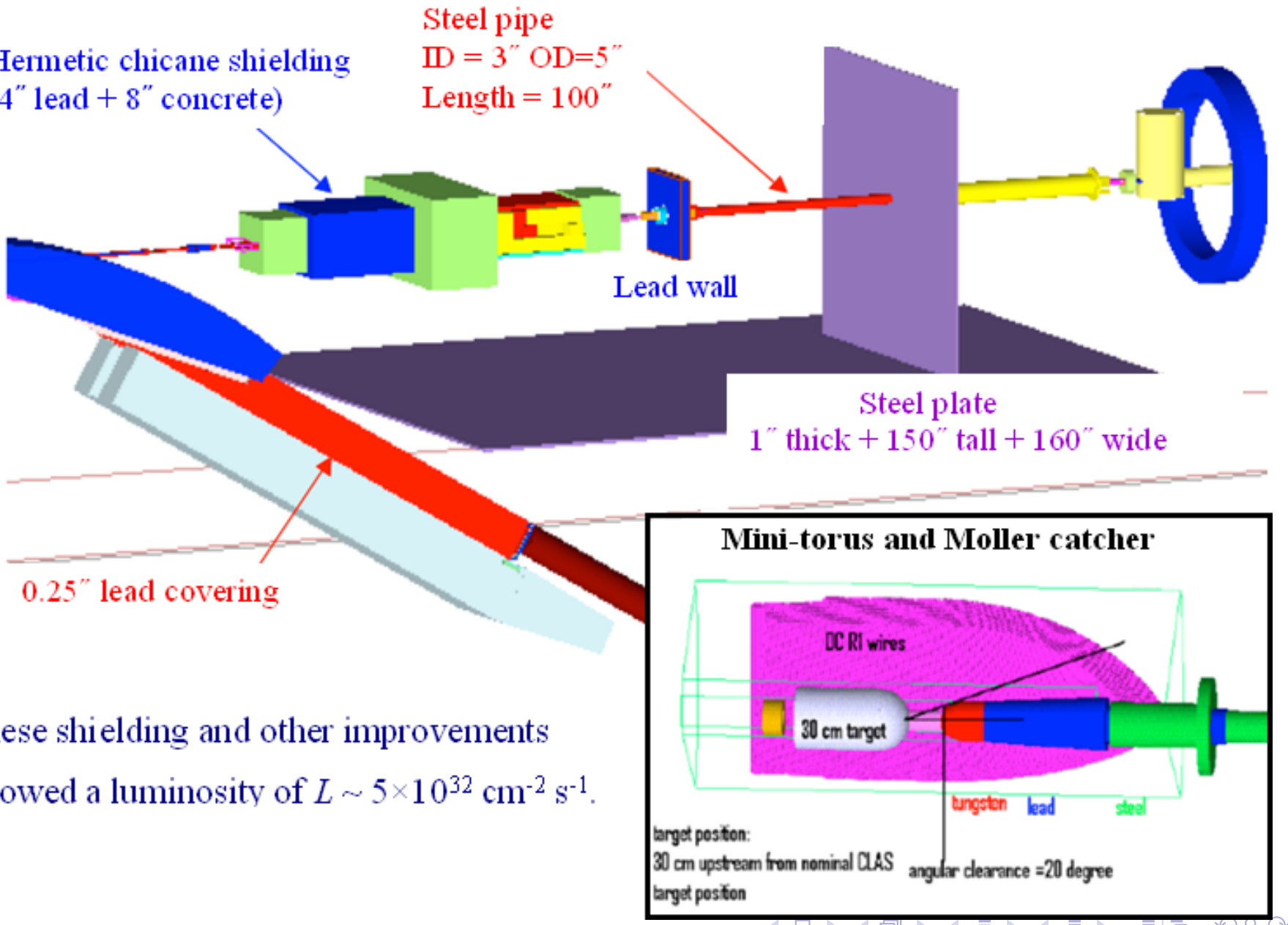
- Need positrons
- Need to make mixed simultaneous electron and positron beam

Producing a mixed electron positron beam



- Primary electron beam: 5.5 GeV and 100-120 nA
- Radiator: 0.9% of primary electrons radiate high energy photons
- Tagger magnet: sweep the primary electrons to the tagger dump
- Converter: 9% of photons convert to electron/positron pairs
- Chicane: separate the lepton beams, stop photons and recombine the e+ and e- beams
- Target: 30 cm liquid hydrogen
- Detector: CEBAF Large Acceptance Spectrometer (CLAS)
- Lots of shielding (not shown)

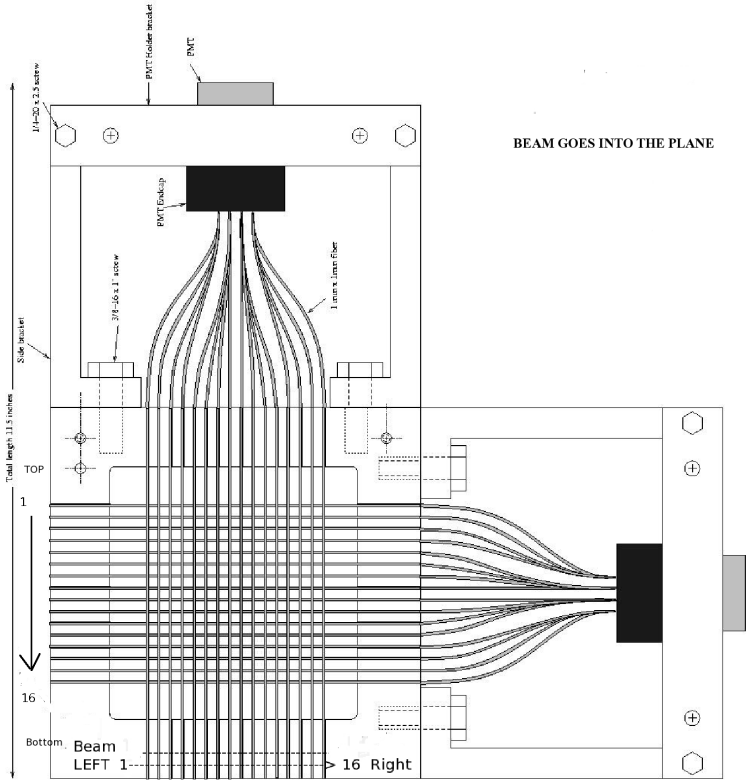
Background control

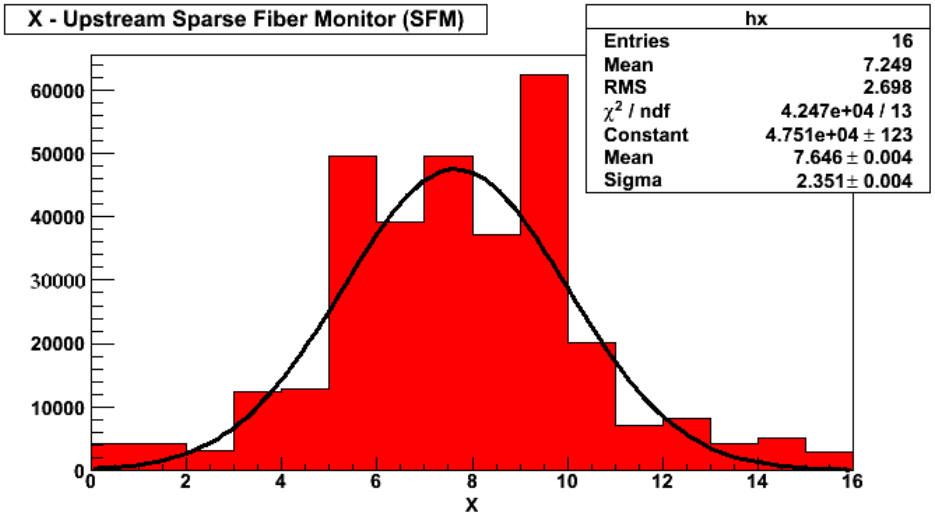


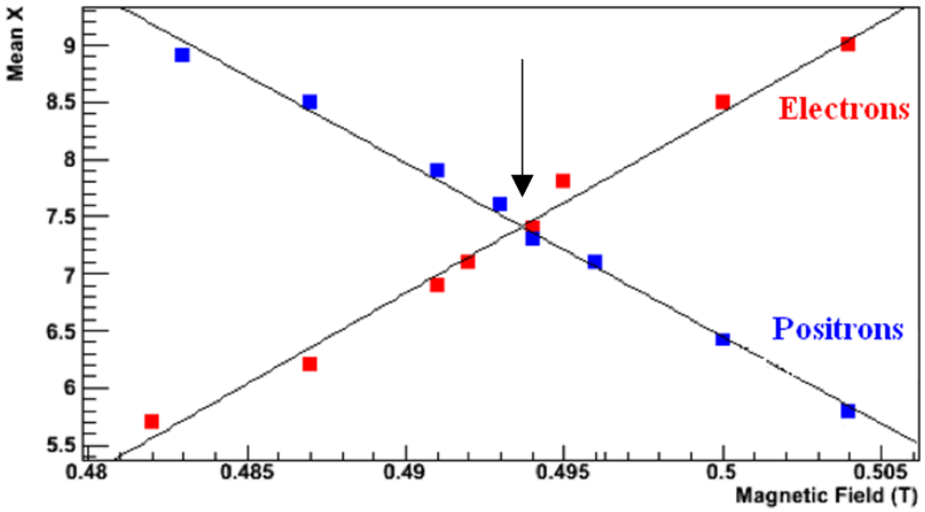
These shielding and other improvements allowed a luminosity of $L \sim 5\times10^{32}$ cm^{-2} s^{-1}.

Beam profile monitor & chicane tuning

Sparse fiber monitor







- Kept the second dipole field fixed
- Varied first & third chicane magnet field
- Measured individual lepton beam positions

The TPE experiment

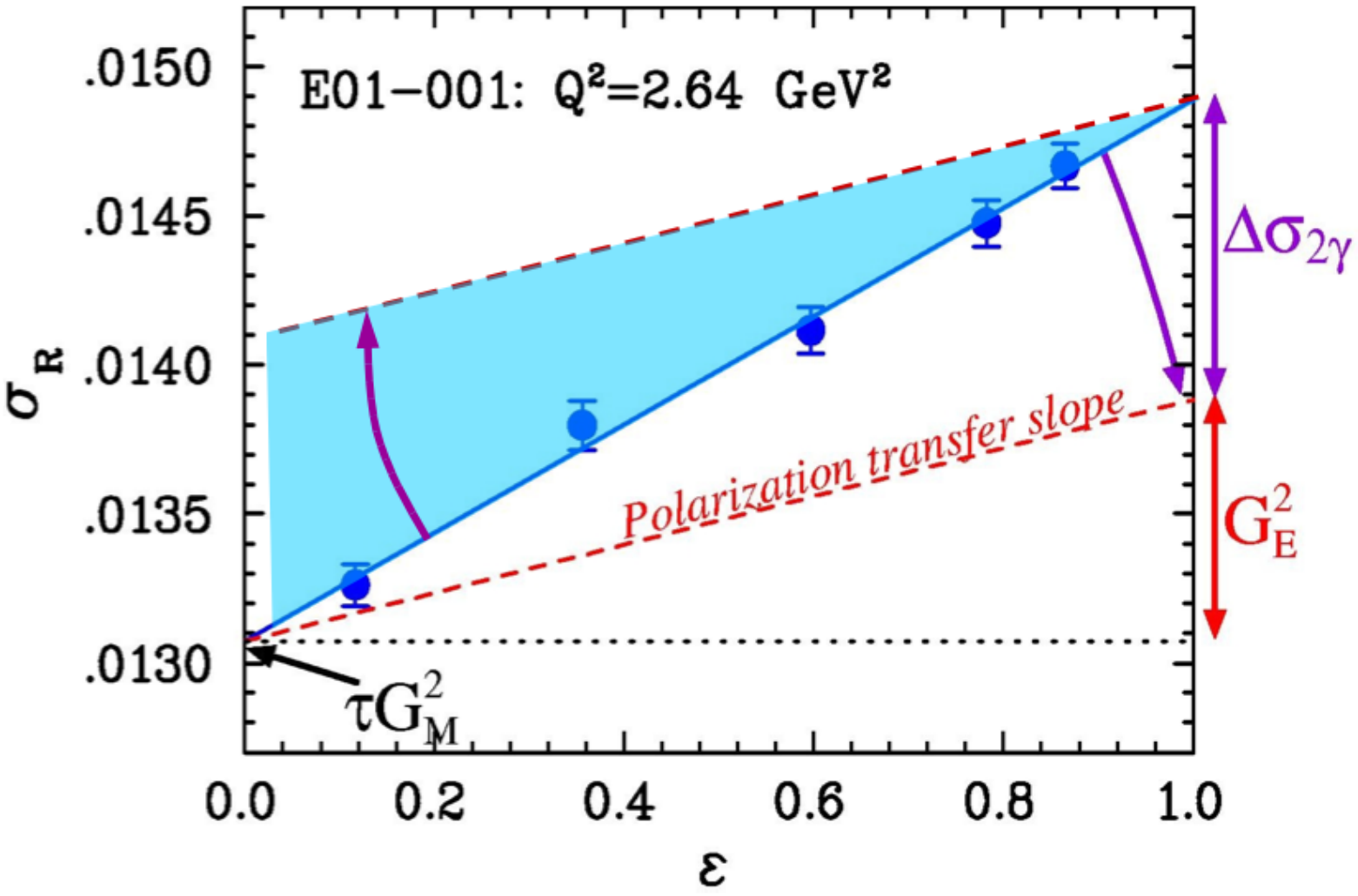
- Run period
  Nov 30, 2010 - Feb 25, 2011
- Beam monitors
  Sparse fiber monitor
  - continuously monitored beam spread and position
  TPE calorimeter
  - periodically measured position vs energy of the $e+$ and $e-$ beams separately
- Systematic error control
  reversed all possible magnetic fields periodically
  dedicated calibration runs

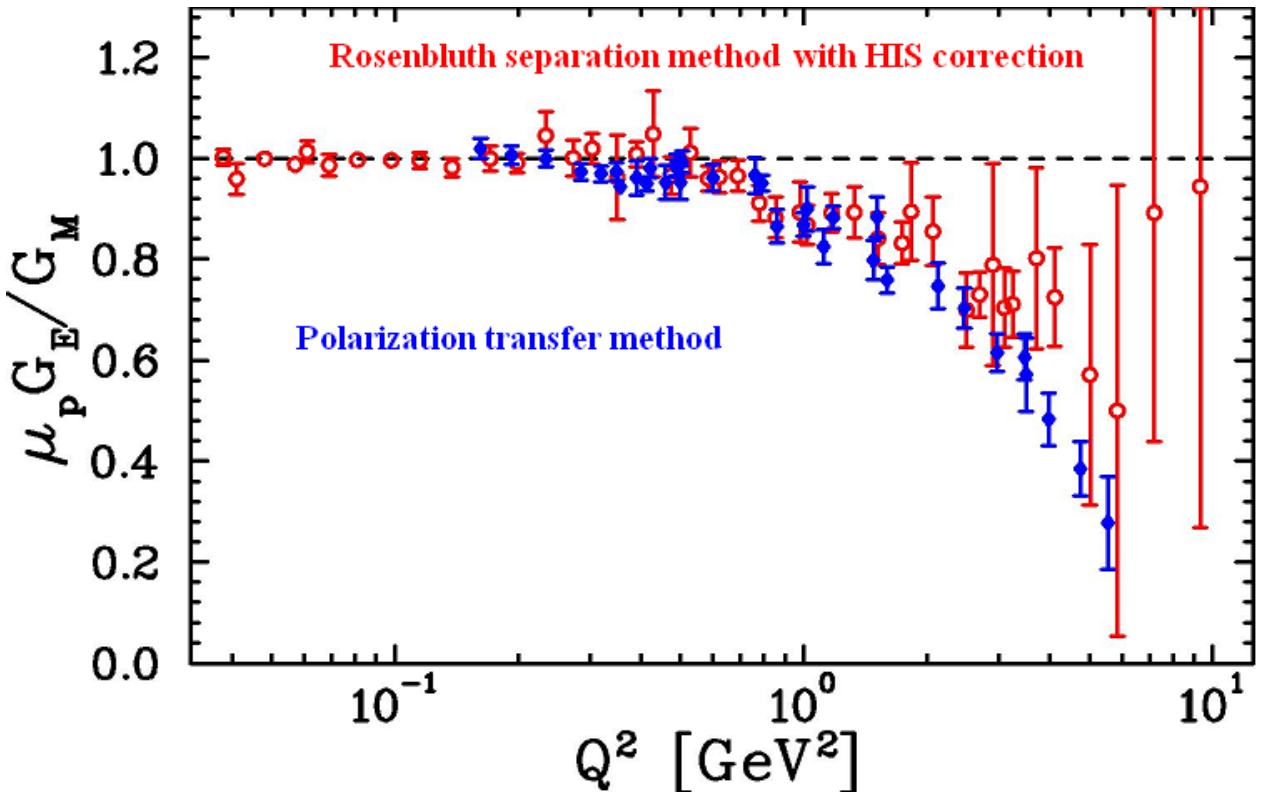
Summary

- There is a significant difference between the proton form factor measurements obtained from Rosenbluth & polarization transfer methods.
- The likeliest explanation is two photon exchange.
- This experiment will measure the TPE correction to elastic electron-proton scattering by measuring the e^+p to e^-p elastic scattering ratio.
- Data has been collected.
- Calibration and analysis work have begun.
- The preliminary results will be ready by 2012.
- See the next talk by D.Rimal.

Backup slides

Two-Photon Contribution to the Rosenbluth





Hadronic Intermediate State (HIS) Model by Blunden, Melnitchouk, & Tjon (PRC 72, 034612 (2005))