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

- Separate $G_E$ and $G_M$ by varying incident electron energy ($E_e$) and scattering angle ($\theta_e$) 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.

\[ \sigma(e^\pm p) \propto |A_{ep\rightarrow ep}|^2 = |A_{Born} + \ldots + A_{2\gamma}|^2 \]

\[ \sigma(e^\pm p) \propto |A_{Born}|^2 \pm 2A_{Born}\text{Re}(A_{2\gamma}) \]

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

- 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

Hermetic chicane shielding
(4” lead + 8” concrete)

Steel pipe
ID = 3” OD=5”
Length = 100”

Lead wall

Steel plate
1” thick + 150” tall + 160” wide

0.25” lead covering

These shielding and other improvements allowed a luminosity of $L \sim 5 \times 10^{32} \text{ cm}^{-2} \text{ s}^{-1}$.
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

![Image of sparse fiber monitor and data analysis graphs]

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CLAS TPE Experiment: Experimental Methods

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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
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

E01-001: $Q^2 = 2.64 \text{ GeV}^2$

$\sigma_R$ vs $\varepsilon$

$\Delta \sigma_{2\gamma}$

Polarization transfer slope

$G_E^2$

$\tau G_M^2$
Hadronic Intermediate State (HIS) Model by Blunden, Melnitchouk, & Tjon (PRC 72, 034612 (2005))

HIS corrections using the Rosenbluth separation method and the polarization transfer method.