Electron vs Positron Elastic Scattering
(testrun data analysis)

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$G_E$ Problem:

- Discrepancy!
- Rosenbluth separation much more sensitive to Two Photon Exchange (TPE)
- We need to measure TPE
How to measure TPE effect:

\[
R^{e^+e^-} \equiv \frac{d\sigma^{(e^+)}}{d\sigma^{(e^-)}} \approx \frac{|M_{1\gamma}^{(e^+)}|^2 + 2\Re \{M_{1\gamma}^{(e^+)}M_{2\gamma}^{(e^+)}\}}{|M_{1\gamma}^{(e^-)}|^2 + 2\Re \{M_{1\gamma}^{(e^-)}M_{2\gamma}^{(e^-)}\}}
\]

\[
M_{1\gamma} \sim \theta^{\pm} = \pm 1
\]

\[
M_{2\gamma} \sim (e^{\pm})^2 = +1
\]

\[
R^{e^+e^-} \equiv \frac{d\sigma^{(e^+)}}{d\sigma^{(e^-)}} = 1 - 2\delta_{2\gamma}
\]

Compare the ratio of positron-proton to electron-proton elastic scattering cross sections to measure the real part of TPE amplitude.
Existing World Positron Data

- Limited kinematic range
- Large uncertainties

Need:
- more data covering wide $\varepsilon$ range and at moderate to high $Q^2$
- High precision measurement as TPE is only a few percent of the cross section

Solid line is a fit assuming a linear $\varepsilon$ dependence and no $Q^2$ dependence to the ratio (slope $-(5.7 \pm 1.8) \%$)

Making Positrons in Hall B at JLAB

1. Electron beam hits radiator foil, producing photon beam
2. Photon beam strikes converter foil. e-/e+ pairs are produced.
3. Magnetic chicane:
   a) separates lepton beams
   b) blocks photon beam
   c) recombines lepton beams
Test Run, October 2006

Purpose:
- Make identical mixed simultaneous electron positron beam
- Determine maximum beam luminosity and limiting factors
- Measure $e^+e^-$ cross sections ratio (if possible)

Experiment Conditions:
- 80 nA of 3.2 GeV beam
- Radiator 0.5% $X_0$
- Converter 5% $X_0$
- 20 pA $e^+e^-$ beam current
- 18 cm long, 6 cm diameter LH2 target
- Normal & reversed torus fields
  - to control systematic uncertainties
Selecting Good Events:

**vertex cut:**
- keep only events coming from the target

**TOF cut:**
- difference between measured and calculated TOF of proton
- ± 10 ns
Selecting Elastic Events:

**Beam energy**
- calculate from total momentum along beam direction
- calculate from particle angles (assuming elastic scattering)

\[ \Delta E = E(P_{1z}, P_{2z}) - E(\theta_1, \theta_2) \]
\[ \Delta E = 0 \text{ for elastic scattering} \]

\[ E_1 = m_p \left( \cot \frac{\theta_e}{2} \cot \theta_p - 1 \right) \]
\[ E_2 = p_e \cos \theta_e + p_p \cos \theta_p \]
Selecting Elastic Events:

co-planarity cut:
- difference between lepton and proton phi angle

Proton momentum difference:
- difference between measured and calculated momentum of proton
Invariant mass ($W$) cut:

- mass of particle that satisfy energy conservation
- reconstructed from the detected lepton, the known target, and the beam energy

$$W^2 = (P_0^\mu + E_0^\mu - E_f^\mu)^2$$
Acceptance cuts:
Fiducial cut:
applied twice for each particle
1) in bending
2) out bending

Eliminate bad TOF scintillator paddles:
Lepton hitting good TOF paddles are kept and the rest discarded

Acceptance matching:
- Accept only electrons that would have been accepted as positrons (and vise versa)
Kinematic Acceptance and Binning:

Bin 1
0.4 <=Q2<=1.0
0.3<= \( \varepsilon \) <=0.55

Bin 2
0.4 <=Q2<=1.0
0.75<= \( \varepsilon \) <=0.92

Lower Q2 and higher \( \varepsilon \) analyzed @FIU
### positron-proton to electron-proton ratio:

<table>
<thead>
<tr>
<th>Combination of Cuts</th>
<th>Ratio Bin 1 (Q2=0.6, (\varepsilon=0.42))</th>
<th>Ratio Bin2 (Q2=0.54, (\varepsilon=0.83))</th>
</tr>
</thead>
<tbody>
<tr>
<td>elastic</td>
<td>1.03 +- 0.05</td>
<td>1.00 +- 0.02</td>
</tr>
<tr>
<td>elastic + fiducial</td>
<td>1.03 +- 0.05</td>
<td>1.00 +- 0.02</td>
</tr>
<tr>
<td>elastic + acc. matching</td>
<td>1.02 +- 0.05</td>
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Double ratio: \[
\frac{(e^+/e^-)_{pos}}{(e^-/e^+)_{neg}} \text{ (acceptance affects cancel out)}
\]

Ratio = Sqrt (Double ratio)
TPE $e^+/e^-$ ratio:

$\langle Q^2 \rangle = 0.095$ GeV$^2$

$\langle Q^2 \rangle = 0.16$ GeV$^2$

$\langle Q^2 \rangle = 0.27$ GeV$^2$

$\langle Q^2 \rangle = 0.54$ GeV$^2$

0.99 $\pm$ 0.02

Other points analyzed by M. Moteabad @ FIU
Future:

• Run full experiment
• Higher luminosity
  (100 nA, 2% rad, 5% conv., 30 cm tgt.)
• Higher beam energy (5.5 GeV)
• Larger $Q^2$, $\epsilon$ coverage

The horizontal dashed lines indicate the expected ±1% systematic uncertainties.
TPE Summary:

- testrun produced simultaneous mixed identical e+e- beam
- identified elastic scattering events
- measured preliminary e+p/e-p cross sections ratio
- need to determine systematic uncertainty and finalize result
- we are ready to run the full experiment