Radiative Corrections for Polarized Electron Beam Experiments

presented by

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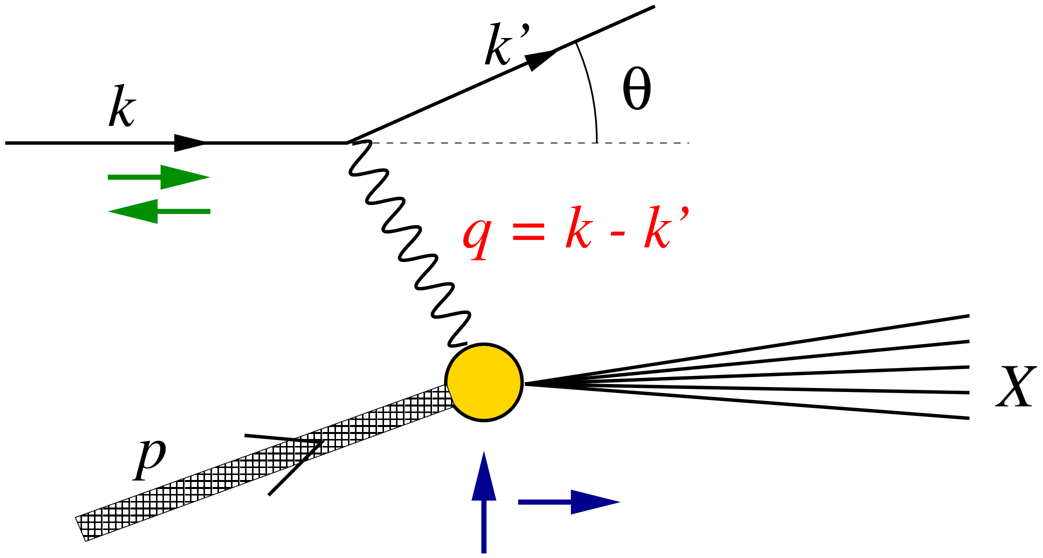
Hall A Analysis Workshop

December 11, 2002

General Overview

- Relevant experiments
  - GDH on ^{3}He
  - A_1^n at high x_{Bj}
  - Precision measurement of g_2^n
  - Neutron spin duality
  - GDH on ^{3}He at small Q^2
  - More future experiments
- Interaction of polarized electrons inside matter
- Polarization dependent radiative corrections (POLRAD)

Radiative Corrections (Basics)



- Emission of real photons

  before, during and after

  scattering off the target

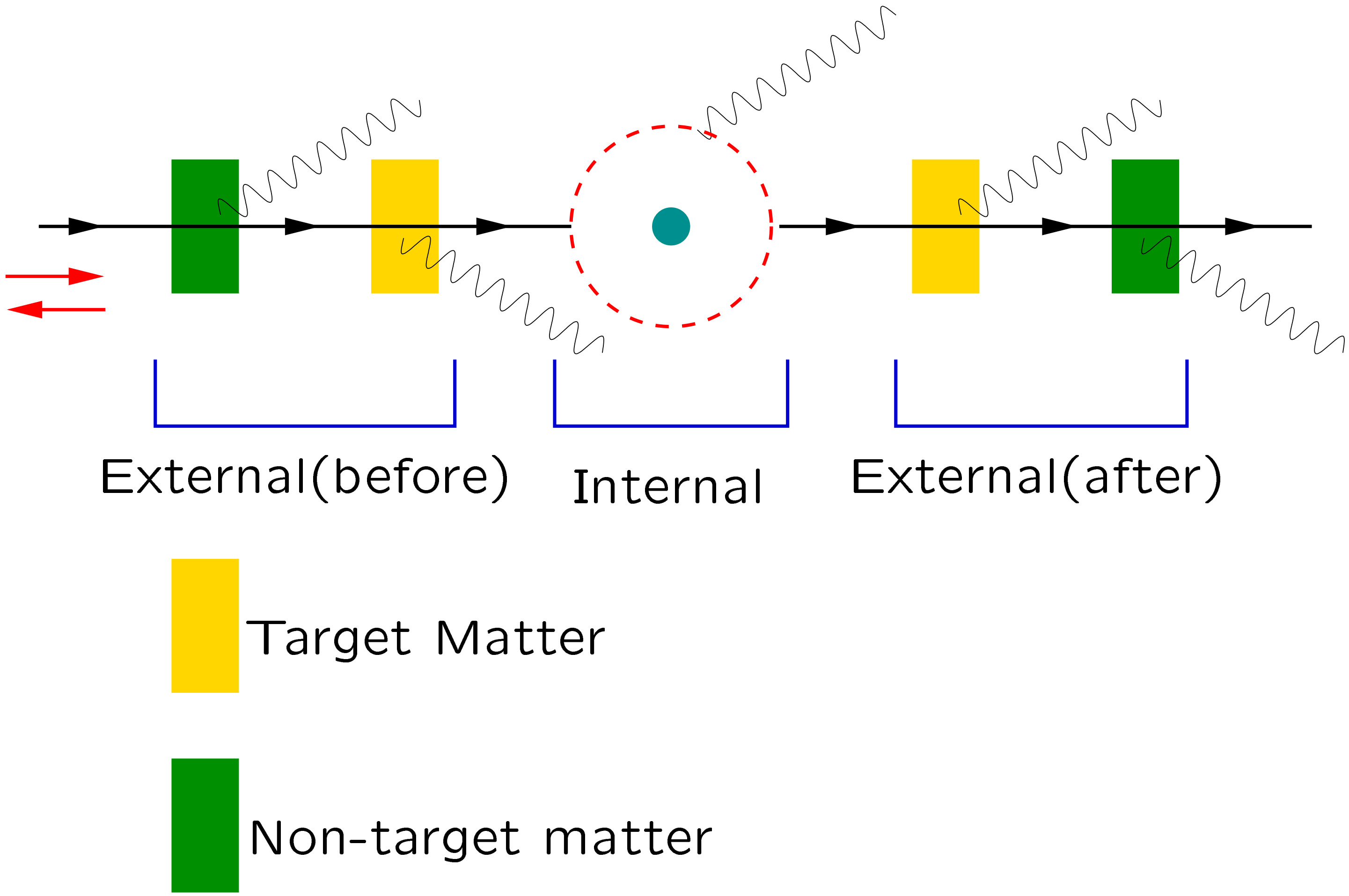
- Division of radiative effects in two parts: external and internal

- For unpolarized electron beam, method by Mo and Tsai.

  L. W. Mo and Y. S. Tsai, Reviews of Modern Physics, **41** 205 (1969)
  Yung-Su Tsai, SLAC-PUB-848 (1971)

- For polarized electron beam, things are getting a little tricky.

Radiation Effects



Interaction of $\vec{e}$ with Matter

➜ Scattering by Coulomb field

For 100% polarized electrons, the final polarization becomes

$$P \simeq 1 - \frac{2m_e^2}{E^2} \tan^2 \frac{\theta}{2} \quad \text{relativistic limit}$$

which becomes one for small angle scattering

➜ Scattering with atomic electrons

$$P = \frac{1 + \frac{1}{2}\cos\theta(1 + \cos^2\theta)}{1 + \sin^8\theta/2 + \cos^8\theta/2}$$

which becomes one for small angle scattering

➜ Bremsstrahlung of soft photons

Due to soft-photon theorem (or low energy theorem), polarization change is the same for Coulomb scattering.

External Effects

- As long as the direction of the electron beam remains the same, polarization of the electron does not change during interaction with matter.

- Good old method by Mo and Tsai can be used for external radiative corrections.

$$\sigma_{exp}^{\uparrow\Uparrow(\downarrow\Uparrow)}(E_s, E_p) = \int_0^T \frac{dt}{T} \int_{E_s^{min}(E_p)}^{E_s} dE_s' \int_{E_p^{max}(E_s')}^{E_p} dE_p' \times$$

$$I(E_s, E_s', t)\, \sigma_r^{\uparrow\Uparrow(\downarrow\Uparrow)}(E_s', E_p')\, I(E_p', E_p, T - t)$$

where $I(E, E', t)$ becomes spin independent.

- $\sigma_r^{\uparrow\Uparrow(\downarrow\Uparrow)}(E_s', E_p')$ contains all internal effects but no external effects.

Internal Radiative Effects

- Underlying reaction

$$\vec{e}(k_1) + \vec{N}(p) \to e'(k_2) + X + \gamma(k)$$

- Involves integration over photon phase space with proper consideration of the electron and target polarization
- Quite complicated math and integration are dealt by POLRAD program
- A few shortcomings of the original POLRAD
  - A few approximations only valid for DIS
  - No proper treatment below pion threshold (including QE region)
  - No easy way to use experimental cross sections
  - Slow speed
- Most of these issues resolved by house modified POLRAD

Practical Examples

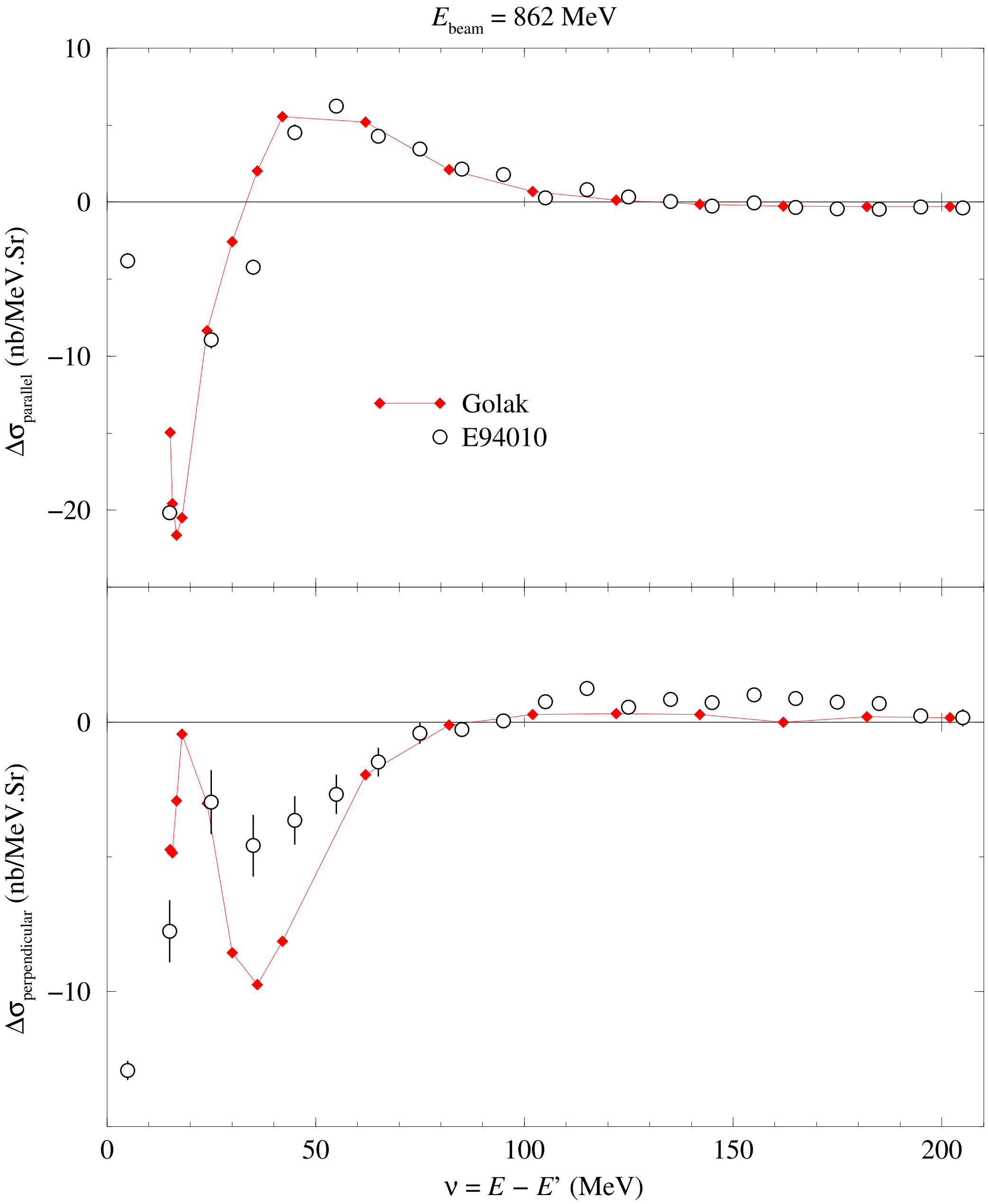
GDH on ^{3}He

- Use $\Delta\sigma_{\|}$ and $\Delta\sigma_{\perp}$ (or g_1 and g_2) instead of asymmetries
  - Immune to symmetric dilution effect
  - No need to know unpolarized cross sections precisely
- First, unfold for external effects to get σ_r which contains only internal radiation effects (use Mo & Tsai method)
- Second, unfold for internal radiative effects to get Born cross sections using modified POLRAD

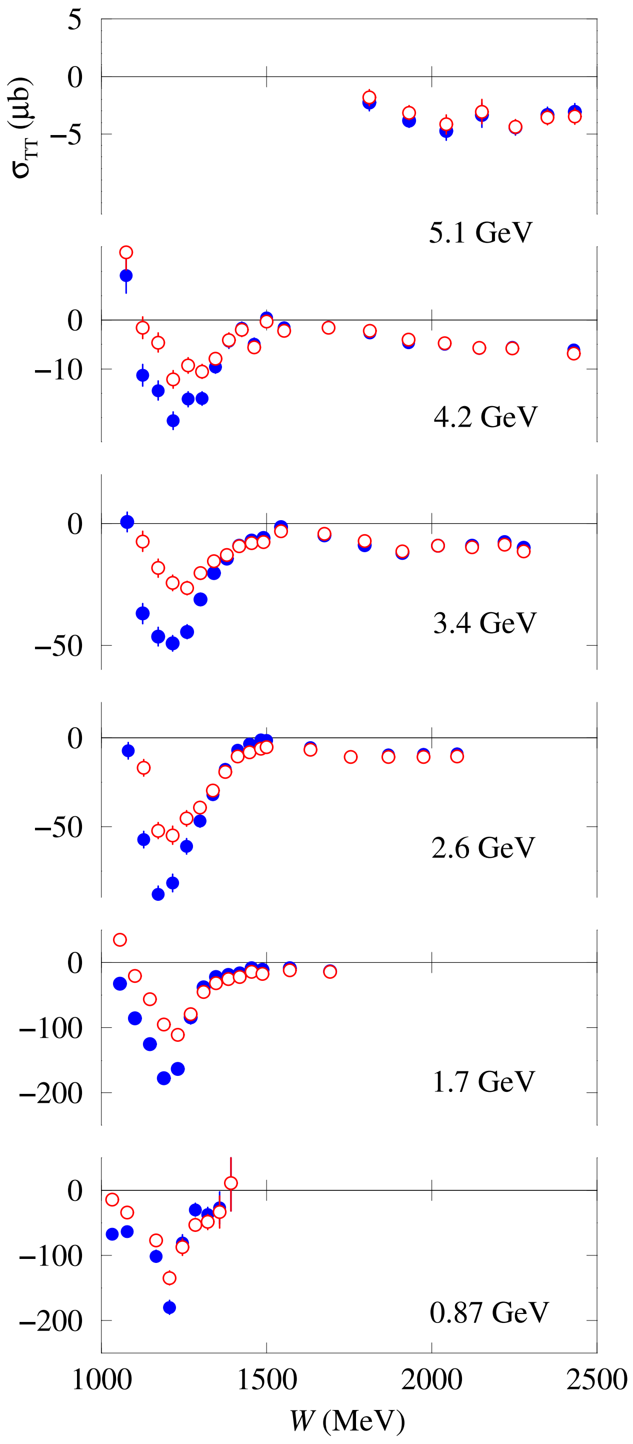
A_1^n at high x_{Bj}

- Assume $A_1^n(x)$ does not depend on Q^2
- Using $A_1^n \simeq g_1/F_1$ and known $F_1(x,Q^2)$, get $g_1(x,Q^2)$
- Use the original POLRAD to unfold measured A_1^n

Corrections on $\Delta\sigma_{\parallel}$ and $\Delta\sigma_{\perp}$



Corrections on $\sigma_{\mathrm{TT}'}$



Conclusions

- Use of unpolarized formalism for external radiative effects
- POLRAD for internal radiative effects
- Need $g_1(x, Q^2)$ and $g_2(x, Q^2)$ over wide kinematic range for unfolding
  - Cross sections ($\Delta\sigma_{\parallel}$ and $\Delta\sigma_{\perp}$)
  - Asymmetry (A_1^n) and F_1 with a few assumption
- Radiative corrections for $g_2^n(x, Q^2)$ in progress
- Future experiments
  - Neutron Spin Duality: very similar to GDH
  - small angle GDH: challenging due to very large radiative effects