Real and Not-So-Real Compton Scattering

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Compton Scattering at High $p_\perp$

- A probe of high momentum quarks
  - Produced either non-perturbatively or perturbatively
  - Small size configurations required
- Sub-asymptotic amplitude modeled by Feynman mechanism. “Handbag” amplitude
  - Klein-Nishina amplitude on a single high-momentum quark
    - A. Radyushkin
    - P. Kroll, M. Diehl, et al
    - G. Miller, et al.
    - Brodsky et al.
  - Extended Regge, J-M Laget.
\[ \gamma p \rightarrow \gamma p \]

E99-114 Statistical errors only

Light Front Cloudy Bag Model
(only 3-quark content included
at large x for RCS)

Handbag amplitude &
Wavefunction ansatz

\[ \Phi(k_1, k_2, k_3) = \frac{(spin)N}{\left[ M_{123}^2 + \beta^2 \right]^\gamma} \]

Parameters \( \beta, \gamma, m_q \)
fitted to \( H(e,e')p \)

Real Compton Scattering


Real Compton Scattering at 12 GeV

- G.A. Miller model curves
RCS Scaling

- Precocious $s^{-6}$ scaling of Compton scattering from constituent quarks.
- G.A. Miller
RCS Polarization Observables

- $K_{LL}$:
  \[ \bar{\gamma} + p \rightarrow \gamma + \bar{p} \]

- $A_{LL}$:
  \[ \bar{\gamma} + \bar{p} \rightarrow \gamma + p \]

- On-shell massless quarks
  $A_{LL} = K_{LL}$
Experimental Approaches

- Spectrometers (Halls A & C) vs Full Acceptance (Halls B & D)
- So far, correlated final state means spectrometer × calorimeter yields largest product of luminosity × acceptance.
- Recoil Polarimeter (44 cm CH + 50 cm C)
  Efficiency x (Analyzing Power)$^2 = 4.5 \times 10^{-3}$ at $p_p = 3$ GeV/c
- Polarized Targets
  - $\text{NH}_3$ electron luminosity $\approx 10^{35}$/cm$^2$/s
    - $P_p \approx 70\%$
  - HD ice, photon beams
    - $P_p \approx 70\%$
RCS Kinematics

- 8.8 GeV Photon incident
RCS Kinematics

- 11 GeV Photon incident
Hall D Count Rate Estimates

- Dedicated run, photon flux $d\Phi_\gamma \approx (2\cdot10^8/s)\, dk_\gamma/k_\gamma$
- Target 2 g/cm$^2$.
- One month
- Energy bins span factor of 2 in $d\sigma$
Virtual Compton Scattering

• Naïve idea: Measure the size of the constituent quark in the handbag amplitude

• Dynamical complications
  – Longitudinal and Transverse amplitudes
  – Longitudinal momentum transfer
  – Challenge for theory

• Two kinematic domains
  – $\Lambda^2 \approx Q^2 << -\Delta^2$                  CLAS12
  – $Q^2 \in [1,2\text{GeV}^2] << -\Delta^2$           Hall A,C
Virtual Compton Scattering with a small angle tagger in CLAS12
Virtual Photon Flux (CLAS12)

\[
\frac{d\sigma(e,e'\gamma)}{dE'd\Omega dt} = \Gamma \frac{d\sigma(\gamma,\gamma)}{dt} + BH + I
\]

\[
\int dE' d\Omega \Gamma = \int dE' d\Omega \frac{\alpha E'}{2\pi^2} \frac{W^2 - M^2}{E} \frac{1}{2MQ^2} \frac{1}{1 - \epsilon}
\]

- Photon Flux at \(10^{35}\) on 5 cm LH$_2$.
- \(\geq 1.5 \cdot 10^7 / \text{s per bin}\)
Low $Q^2$ VCS yield in CLAS12
(neglecting BH and interference)

- One month on 5 cm LH$_2$ target.
VCS in Hall A

• 50μA × 11 GeV incident on 1 g/cm² H₂
  – L = 2•10³⁸/cm²/s
• 2 GeV Scattered electron in HRS at 12.5°
  – Q²=1 GeV²
  – ΔΦγ = (Iγ/e) ΓΔΩΔk’ = 2.8•10⁸ quanta/sec
  – Photon Luminosity is 40× CLAS12 VCS case
• Detect Proton in SBS, Photon in Calo
  – Azimuthal acceptance φ ≈ ±θγ/sinθ
  – at θγCM=90°, θγLab ≈ 25°, θpLab ≈ 30°
  – with =100mr, Δφ=400mr ≈ 2π/16
  – A single Q², Δ² bin will count 2.5× faster at Q²=1.0 GeV² in Hall A than at at Q²=0.2 GeV² in CLAS
• Old 4 GeV proposal PR94-106 HRS²
Conclusions

• A diverse program of VCS and RCS Cross section measurements is feasible, spanning all four Halls.
  – More detailed theory of VCS is needed, including BH amplitude
    • (only full calculation is Kroll, Shürmann, Guichon with diquark model).

• Polarization observables need detailed study.
  – B. Wojtsekhowski et al.
VCS - DiQuark

Fig. 6. The difference of the full photon electroproduction cross section and the VC contribution to it over the full cross section versus \( \cos \theta \) for several combinations of values of the beam energy \( k_{\mu} \), \( Q^2 \) and the azimuthal angle \( \phi \). (a) \( s = 5 \text{ GeV}^2 \), (b) \( 10 \text{ GeV}^2 \).

Fig. 8. The electron asymmetry at CEBAF. Top: \( A_L \) versus \( \phi \) for several values of \( \cos \theta \). Bottom: \( A_L \) versus \( \cos \theta \) for several values of \( \phi \).