Probing the two–component structure of the virtual photon in exclusive $\pi^0$ photo/electroproduction at JLab

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Aim: “Disentangle” components of virtual photon:

- hadronic size  VDM, Regge
- size $1/Q$  GPDs

→ Energy dependence
→ $t$–slopes, dip structure
→ Azimuthal dependence

... No “explicit” $L/T$ separation!

How do they change with $Q^2$?
Space–time picture of photo/electroproduction at $W \gg 1$ GeV

$Q^2 = 0$

$Q^2 \gg M_V^2$

$Q^2 \to \text{Infinity}$

$\frac{l_{coh}}{} = \frac{2v}{M_V^2}$

Vector dominance
Regge phenomenology

size $1/\nu$

size $1/Q$

GPDs
"Hard scattering"
**W dependence — How does it change with $Q^2$**

- Change of $W$ dependence with $Q^2$ indicates presence of $L$ components

- Vector dominance at $Q^2 > 0$:
  - No change in $W$–dependence of $\sigma_T$
  - $\to$ Change due to $\sigma_L + \text{interf.}$

- Regge exchange at $Q^2 > 0$
  - Poles only: No change
  - Poles + absorption: Change

$W$–dependence in $Q^2$ bins

$Q^2 \sim \omega, \rho \rightarrow S$ 

(cf. “color transparency” )
$t$–dependence in forward peak — How does it change with $Q^2$?

- $\Delta_\perp$–dependence of cross section (fixed $x$) reflects transverse size of interaction region

- $Q^2 \to \infty$: Pointlike probe
  $\Rightarrow \Delta_\perp$ slope becomes $Q^2$–independent

- Important: $t_{\text{min}}$ depends on $x, Q^2$
  $t$–slope $\neq \Delta_\perp^2$–slope

- $x \to 1$: Shrinkage of target size
Dip in $t$–dependence — How does it evolve with $Q^2$?

- Regge phenomenology for $Q^2 = 0$:
  Two competing explanations for dip
  - Zeroes of residues (NWSZ) No $Q^2$–dep.
  - Pole + absorption $Q^2$–dep.

- DESY data: Large–$t$ shoulder disappears at $\langle Q^2 \rangle \sim 0.28 \text{ GeV}^2$
  ... very strange! [Collins, Wilkie 81]
  ... Can we confirm these measurements?

$1.8 < W < 2.7 \text{ GeV}$, $0.1 < Q^2 < 0.7 \text{ GeV}$
[DESY: Berger et al. 77]
Azimuthal dependence — How does it change with $Q^2$?

$$\sigma = \sigma_T + \epsilon \cos 2\phi \sigma_{TT} + \epsilon \sigma_L + \sqrt{2\epsilon(\epsilon + 1)} \cos \phi \sigma_{LT}$$

Unpolarized beam/target

alt.: $\sigma_T = \frac{1}{2} (\sigma_\parallel + \sigma_\perp)$, $\sigma_{TT} = \frac{1}{2} (\sigma_\parallel - \sigma_\perp)$

- $Q^2 = 0$: $\sigma_\perp \gg \sigma_\parallel$, $\sigma_{TT} \approx -\sigma_T$ (natural parity exchange $\omega, \rho^0$)
  Azimuthal dependence $\sigma \sim 1 - \epsilon \cos 2\phi$

- $Q^2 \to \infty$: $\sigma_L$ dominates, no azimuthal dependence!

- Beam polarization: $h \sqrt{2\epsilon(\epsilon + 1)} \sin \phi \sigma_{LT}$

- Target polarization (longitudinal): $P_l \sqrt{2\epsilon(\epsilon + 1)} \sin 2\phi \sigma_{TT'}$
  Regge phenomenology: Interference of $\omega$ and $\rho$ exchange

... How does it evolve with $Q^2$?
Summary

- Many interesting tests of two–component structure of virtual photon in $\pi^0$ production without explicit L/T separation

- Need to develop truly interpolating model for meson electroproduction

- What happens between $Q^2 = 0$ and 1 GeV$^2$ is key to understanding approach to the hard regime and relating meson electroproduction data to GPDs!