Inclusive electroproduction in the resonance region

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The rich nucleon excitation structure

\[ F_1 \propto \sigma_T(W, Q^2) \]
\[ F_2 \propto \sigma_T(W, Q^2) + \sigma_L(W, Q^2) \]
\[ F_L \propto \sigma_L(W, Q^2) \]

- Structure functions/cross sections give access to PDFs
- Resonance region displays highly non-trivial behaviour with \( W \) and \( Q^2 \)
- Precise CLAS data; CLAS12 to reach \( 0.05 \text{ GeV}^2 < Q^2 < 12 \text{ GeV}^2 \), \( W \) up to 4 GeV
- Tests on quark-hadron duality and access to PDFs at large \( x \) in global analyses
From exclusive to inclusive electron scattering

\[ \sigma_{T,L}(W, Q^2) = \sigma_{T,L}^{R}(W, Q^2) + \sigma_{T,L}^{NR}(W, Q^2) \]

Breit-Wigner resonance model: coherent sum!

Mokeev et al., PRC 86 (2012) 035203

\[ \sigma_{T,L}^{R}(W, Q^2) \propto \frac{\Gamma_{T,L}^{-1}(M_r, Q^2)}{Q^2} \]

World and CLAS data on longitudinal and transverse electrocouplings allow us to determine each of the resonant contributions separately:

\[ \Gamma_{\gamma}^{-}(M_r, Q^2) \sim |A_{1/2}(Q^2)|^2 + |A_{3/2}(Q^2)|^2 \]

\[ \Gamma_{\gamma}^{L}(M_r, Q^2) \sim |S_{1/2}(Q^2)|^2 \]

https://userweb.jlab.org/~mokeev/resonance_electrocouplings/  
https://userweb.jlab.org/~isupov/couplings/
Resonant contributions at different $Q^2$

(a) $Q^2 = 1.025$ GeV$^2$
- $N(1440)$ $\frac{1}{2}^+$
- $N(1520)$ $\frac{3}{2}^+$
- $N(1535)$ $\frac{1}{2}^-$
- $N(1650)$ $\frac{1}{2}^-$

(b) $Q^2 = 2.025$ GeV$^2$
- $N(1675)$ $\frac{5}{2}^-$
- $N(1680)$ $\frac{5}{2}^+$
- $N(1710)$ $\frac{1}{2}^+$
- $N(1720)$ $\frac{3}{2}^+$

(c) $Q^2 = 3.025$ GeV$^2$
- $\Delta(1232)$ $\frac{3}{2}^+$
- $\Delta(1620)$ $\frac{1}{2}^-$
- $\Delta(1700)$ $\frac{3}{2}^-$
- $N'(1720)$ $\frac{3}{2}^+$

(d) $Q^2 = 4.025$ GeV$^2$
- Total incoherent
- Total
- Data

Tails of resonances give substantial contributions to neighbouring regions!

Second resonance region decreases less with $Q^2$: intricate differences in $Q^2$ evolution of electrocouplings.

2nd and 3rd resonance regions remain strong at all $Q^2$: studies of respective electrocouplings at larger $Q^2$ with CLAS12 is very promising.

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Q² evolution of ratio resonance/total

- Resonance contributions decrease with Q², but so do the total contributions
- Δ(1232): even at 4 GeV², ~50% significance; 2nd region: nearly flat ratio
- Points to non-vanishing resonances!
Integration over energies: better comparison in regions with resonant structures: global duality onset at $Q^2 > 3.0$ GeV$^2$ motivates CLAS12 studies! Resonance contributions stay relatively large in the whole range.
Summary and outlook

• Computed coherent sum of resonant contributions to structure functions.

• CLAS electrocouplings allow mapping of highly non-trivial behaviour for first time.

• **Resonances** compared to full data do not seem to vanish at larger $Q^2$: promising prospects for CLAS12!

• Towards an insight into PDFs at large $x$ and duality behavior in truncated moments.

• Extension to polarized structure functions.