

Nucleon resonance structure from the studies of space- and timelike electroexcitation amplitudes

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The structure of nucleon resonances (N), as revealed via N electroexcitation amplitudes, provide unique information on the many facets of the strongly coupled QCD (sQCD) regime. These amplitudes give insight into sQCD dynamics underlying the generation of a variety of nucleon resonances having different structural features. Exploration of excited nucleon structure in the spacelike region ($Q^2 > 0$) through exclusive meson electroproduction at CLAS at JLab advances our knowledge of the *Nelectroexcitation amplitudes*. *Analyses of these quantities within continuum Schwinger methods shed light on the emergence of hadron mass and N structure from the QCD Lagrangian*. Although the transition amplitudes from CLAS will be the focus of this talk, we shall also touch upon the complementary timelike region ($Q^2 < 0$), such as HADES at GSI. Spanning across the spacelike (CLAS) and timelike (HADES) in Q^2 will further extend insight into the structure of the excited states of the nucleon in the range of distances where the transition from the interplay between meson-baryon and quark degrees freedom to the dominance of three-quark contributions is expected. Progress towards extracting resonance excitation amplitudes by means of virtual photons in both the space- and timelike regions requires a robust multi-channel analysis. The same nucleon resonance must be found in different reaction channels with the same electroexcitation amplitudes and Q^2 -independent hadronic decay widths. Many nucleon resonances have recently been established in the analyses of the CLAS KY photoproduction data as well as in photo- and electroproduction $\gamma\gamma p$ data. For a global multi-channel analyses of the CLAS and CLAS12 data in the N region –and especially for invariant masses of excited baryons with $W > 1.6$ GeV –precise information on $\gamma N \rightarrow \gamma N$ and $\gamma N \rightarrow KY$ reactions are needed to account for final-state interactions. The data from the upcoming E45 experiment at J-PARC (130x the world's data for the $\pi N \rightarrow \pi\pi N$ reaction), moreover, will advance our knowledge on amplitudes for N s that decay through the two-pion mode.

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