Contribution ID: **6** Type: **not specified**

Finite-Energy Sum Rules in Eta Photoproduction off the Nucleon

Friday, 17 March 2017 11:30 (30 minutes)

Pseudoscalar-meson photoproduction on the nucleon is of current interest for hadron reaction studies. At low energies it provides information about the nucleon spectrum, while at high energies it reveals details of the residual hadron interactions due to cross-channel particle (Reggeon) exchanges. These two regimes are analytically connected, a feature that can be used to relate properties of resonances in the direct channel to Reggeons in the cross channels. In practice this can be accomplished through dispersion relations and finite-energy sum rules (FESR) [1].

At high energies ($E_{\text{lab}} > 4$ GeV), only the unpolarized differential cross section has been measured, providing little constraints on theoretical models. Forthcoming data from the GlueX experiment at Jefferson Lab are expected to improve the situation.

Even though photons couple to both isospin $I = 0, 1$ states, there are some notable differences between high energy photoproduction of the η ($I = 0$) and the π^0 ($I = 1$). In contrast to the η, the π^0 differential cross section has a dip in the momentum transfer range, $-t \sim 0.5 - 0.6$ GeV^2. The dip in π^0 photoproduction is expected to be associated with zeros in the residues of the dominant ρ/ω Regge exchanges [2,3]. It is an open question, what mechanisms are responsible for filling in the dip in eta photoproduction. It is often assumed that large unnatural contributions come into play. Finite-energy sum rules can provide clues here by relating the t-dependence of Regge amplitudes to that of the low-energy amplitude, usually described in terms of a finite number of partial waves. Early attempts could not resolve this issue due to the low quality of the data and the large uncertainties in the parametrization of the partial waves. Nowadays, however, there are several models that have been developed for the resonance region of η photoproduction allowing for a more precise FESR analysis.

The largest uncertainty in η photoproduction stems from the unnatural parity Regge exchanges. These contributions can be isolated through photon beam asymmetry measurement. Such measurement will soon be published by the GlueX collaboration. The experiment uses linearly polarized photons with energy $E_\gamma^{\text{lab}} \sim 9$ GeV and it has simultaneously measured η and π^0 production. Those data will reduce the systematic uncertainties and provide a better constraint on Regge amplitudes.

We have analyzed $\gamma N \to \eta N$ within a FESR framework [4]. Using these sum rules, one is able to obtain the t-dependence of the high-energy Regge residues using low-energy models. We found that a residue nonsense-wrong signature zero (NWSZ) seems to be lacking in the t-channel helicity flip amplitude of the ρ residue. Including this in our model results in a mechanism where the dip in η photoproduction is filled up with natural contributions, rather than genuinely assumed unnatural b exchange [5]. The upcoming GlueX results will be able to either confirm or refute this explanation: photon beam asymmetry close to $\Sigma = +1$ within the range $-t \approx 0.5 - 0.6$ GeV^2 indicate that the absence of a dip in eta photoproduction should indeed be attributed to natural exchanges.

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Session Classification: Session

Track Classification: Topic 2: Tools and Methods for Partial Wave Analyses