Quasifree eta photoproduction from nuclei and medium modifications of resonances

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The η electro- and photo-production processes continue to enjoy significant investigations from a variety of approaches. This interest stems from the fact that η processes form a gate to understand several fundamental puzzling issues in nuclear and particle physics today. While the η photoproduction process is only one of many meson photoproduction processes from nuclei, the distinctive reactive content of this process near threshold provides it with a distinguished role among other meson photoproduction processes. Part of the reason is that the interaction is dominated cleanly by only one resonance near threshold. This is the $S_{11}(1535)$ resonance with its peculiar status as the lowest lying negative parity resonance in the baryon spectrum. Favorably, the theoretical interest has been correlated with experimental advances, particularly with the construction and running of modern electron-scattering facilities, such as the Thomas Jefferson National Accelerator Facility (JLab) and Mainz.

In this work [1], we assume the impulse approximation and provide a fully relativistic study in both the reactive content and the nuclear structure. Furthermore, we use a robust dynamical content for the elementary process and study this process in a variety of kinematic regimes. In this manner, the work constitutes the third application of our established quasifree formalism after studying the kaon and the electron quasifree reactions [1]. Nevertheless, our goal here is to shed light on the elementary process $\gamma N \rightarrow \eta N$ by furnishing a different physical setting from the on-shell point for studying the elementary amplitude. We also examine the possibility of using this process to extract medium modification effects to the propagation of the S_{11} and D_{13} resonances. We provide special attention in our work to the polarization observables, the recoil polarization of the ejected nucleon and the photon asymmetry, as they are very sensitive to the fine details in the reactive content and are effective discriminators of subtle physical effects compared to the unpolarized cross section. Moreover, the quasifree polarization observables, while very sensitive to the fundamental processes, are insensitive to distortion effects. Finally, by comparing against the polarization observables of the free process, medium effects can be discerned.

We use a plane wave formalism which greatly simplifies the calculation of the transition matrix element. Gardner and Piekarewicz showed that by introducing a bound-state propagator one can still write $|\mathcal{M}|^2$ in terms of traces over Dirac matrices. This not only allows one to use Feynman's trace techniques even for quasifree scattering, but additionally results in analytical expressions for the spin observables [1]. The boundstate wavefunction of the bound nucleon was calculated within a relativistic mean-field approximation to the Walecka model. For the elementary process we used the effective Lagrangian approach of Benmerrouche, Zhang, and Mukhopadhyay [1].

We investigated the sensitivity of the various observables to the elementary amplitude, medium modifications to the masses of the S_{11} and D_{13} resonances as well as nuclear target effects. Our results indicate that the nucleon polarization is practically target independent, whereas the asymmetry exhibits some small sensitivity. The polarization observables are very sensitive to the elementary amplitude. We find that, in contrast to coherent η photoproduction, the S_{11} resonance completely dominates the unpolarized cross section. However, the two spin observables are dominated by the D_{13} resonance, while the S_{11} contribution is very small. As a consequence the polarization and asymmetry are very sensitive to variations in the mass of the D_{13} resonance. Indeed, a reduction in the mass of this resonance leads to significant variations in the polarization and asymmetry. This finding agrees with the nonrelativistic analysis. The polarization and asymmetry are ideal to study the two ambiguities at the ηNN vertex. The sensitivity of these observables to the magnitude of the coupling constant depends to a large extent on the type of coupling. The polarization (asymmetry) is insensitive to the magnitude of the coupling constant for pseudoscalar (pseudovector) coupling. However, the polarization (asymmetry) does indeed exhibit a sensitivity to the magnitude of the coupling constant for pseudovector (pseudoscalar) coupling.

The η photoproduction process shares many features with kaon photoproduction when viewed within a relativistic framework. There are several differences when compared to the findings of the nonrelativistic calculations for eta photoproduction. A stark similarity, however, is that both formalism identify the polarization observables as the prime candidates to investigate medium modifications of the background processes such as the D_{13} resonance. Meanwhile, as a consequence of the large dominance in the differential cross section of the S_{11} resonance, the quasifree differential cross section provides an excellent tool to study medium modifications to the S_{11} resonance in order to distinguish between various models that attempt to understand the S_{11} resonance and its prized position as the lowest lying negative parity state in the baryon spectrum. The basic message of this work is clear: to probe medium modifications to the S_{11} resonance, measure the differential cross section, to study the background processes and their medium modifications with a minimal contamination of the dominant S_{11} contribution, measure the polarization observables.

References

[1] B.I.S. van der Ventel, L.J. Abu-Raddad, and G.C. Hillhouse, Phys. Rev. C, in press (2003), and references therein.