A relativistic Glauber approach to polarization transfer in ^{4}He$(\vec{e}, e'\vec{p})$

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Abstract

Polarization-transfer components for ^{4}He$(\vec{e}, e'\vec{p})^3$H are computed within the relativistic multiple-scattering Glauber approximation (RMSGA). The RMSGA framework adopts relativistic single-particle wave functions and electron-nucleon couplings. The predictions with free and various parametrizations for the medium-modified electromagnetic form factors are compared to the world data.

In conventional nuclear physics nuclei are described in terms of point-like protons and neutrons, interacting through the exchange of mesons. It has been a long-standing and unresolved issue whether the electromagnetic properties of bound nucleons differ from those of free nucleons. Exclusive $A(\vec{e}, e'\vec{p})$ measurements have been put forward as a tool to investigate the possible modifications attributed to the presence of a medium. In polarized electron free-proton scattering,the ratio of the electric $(G_E(Q^2 = -q^\mu q_\mu))$ to the magnetic $(G_M(Q^2))$ Sachs form factors, can be extracted from [1]

$$\frac{P'_x}{P'_z} = -\frac{G_E(Q^2)}{G_M(Q^2)} \frac{2M_p}{E_e + E_{e'}} \tan^{-1}\left(\frac{\theta_e}{2}\right) . \tag{1}$$

Here, q^μ is the four-momentum transfer, P'_x and P'_z is the transferred polarization in the direction perpendicular to and parallel with the three-momentum transfer, and θ_e the electron scattering angle. For bound nucleons, deviations from the measured ratio of P'_x/P'_z from the above value (thereby adopting free-nucleon form factors) can indicate the existence of medium modifications. Finding signatures of medium modifications, however, requires an excellent control over all those ingredients of the $A(\vec{e}, e'\vec{p})$ reaction process that are directly related to the presence of a nuclear medium, such as final-state interactions (FSI), meson-exchange currents (MEC) and isobar currents (IC). Of all observables accessible in $A(\vec{e}, e'\vec{p})$, the transferred polarization components have been recognized as the ones with the weakest sensitivity to FSI, MEC and IC distortions. Recently, ^{4}He$(\vec{e}, e'\vec{p})$ data have been reported [2, 3], covering the range $0.4 \leq Q^2 \leq 2.6$ (GeV/c)^2. This kinematic regime may outreach the range of applicability of optical-potential approaches for describing FSI mechanisms. Indeed, given the highly inelastic and diffractive nature of proton-nucleon scattering at proton lab momenta exceeding 1 GeV/c, the use of optical potentials seems rather unnatural and Glauber multiple-scattering theory provides a more natural and economical description of FSI mechanisms [4]. Recently, we developed an unfactorized and relativistic version and dubbed it the relativistic multiple-scattering Glauber approximation (RMSGA) [5]. In Ref. [6], numerical calculations for the polarization-transfer components in ^{4}He$(\vec{e}, e'\vec{p})$ are performed with both free and medium-modified electromagnetic form factors. For the latter we used the

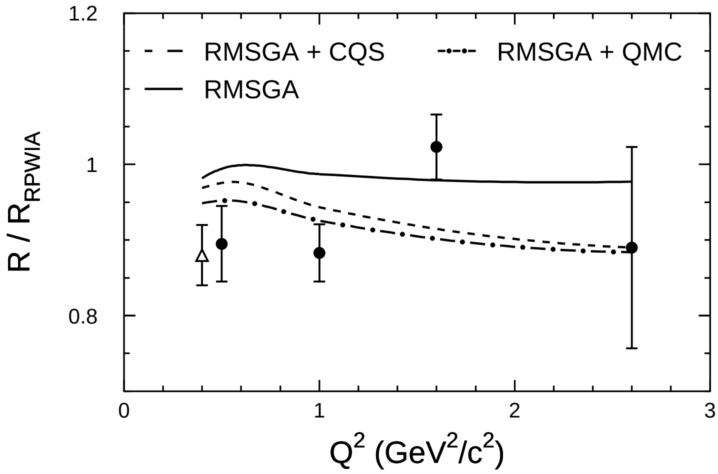

Figure 1: The superratio R/R_{RPWIA} as a function of Q^2 in ^{4}He. The solid curve shows RMSGA predictions using free-proton electromagnetic form factors. The dotted (dot-dashed) curve represents RMSGA calculations with in-medium electromagnetic form factors from the CQS (QMC) model. Data are from Refs. [2](open triangle) and [3](solid circles).

predictions of the quark-meson coupling model (QMC) [7]. In this contribution we use alternative predictions of the chiral quark-soliton model (CQS) [8]. The CQS nucleon model puts more emphasis on the role of the sea than the QMC framework. As a result, the value of the magnetic moment remains practically unchanged.

In Figure 1, the ^{4}He polarization-transfer results are expressed in terms of a double ratio R

$$R = \frac{(P'_x/P'_z)_{^4He}}{(P'_x/P'_z)_{^1H}} \ , \tag{2}$$

with the relativistic plane-wave impulse approximation (RPWIA) result as baseline. Substituting the free forms factors with the CQS ones reduces R. At $Q^2 \leq 1$ (GeV/c)^2 the reductions are smaller than those observed for the computed values of the QMC model. At higher Q^2, both models predict very similar effects. A better overall description of the data is obtained with the medium-modified form factors.

References

[1] R.G. Arnold, C.E. Carlson, and F. Gross, Phys. Rev. 23 (1981) 363

[2] S. Dieterich et al., Phys. Lett. B 500 (2001) 47

[3] S. Strauch et al., Phys. Rev. Lett. 91 (2003) 052301

[4] R. Glauber, and G.Matthiae, Nucl. Phys. B 21 (1970) 135

[5] J. Ryckebusch, D. Debruyne, P. Lava, S. Janssen, B. Van Overmeire, and T. Van Cauteren, Nucl. Phys. A 728 (2003) 226

[6] P. Lava, J. Ryckebusch, B. Van Overmeire, and S. Strauch, preprint nucl-th/0407105

[7] D.H. Lu, A.W. Thomas, K. Tsushima, A.G. Williams, and K. Saito, Phys. Lett. B 417 (1998) 217

[8] J.R. Smith and G.A. Miller, preprint nucl-th/0407093