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Skewed recoil polarization in $(e, e'p)$ reactions from polarized nuclei

J.E. Amaro [a,*], M.B. Barbaro [b], J.A. Caballero [c]

[a] *Departamento de Física Moderna, Universidad de Granada, Granada 18071, Spain*
[b] *Dipartimento di Fisica Teorica, Università di Torino and INFN, Sezione di Torino, Via P. Giuria 1, 10125 Turin, Italy*
[c] *Departamento de Física Atómica, Molecular y Nuclear Universidad de Sevilla, Apdo. 1065, E-41080 Seville, Spain*

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Abstract

The general formalism describing $\vec{A}(\vec{e}, e'\vec{p})B$ reactions, involving polarization of the electron beam, target, and ejected proton, is presented within the framework of the relativistic plane wave impulse approximation for medium and heavy nuclei. It is shown that the simultaneous measurement of the target and ejected proton polarization can provide new information which is not contained in the separate analysis of the $\vec{A}(\vec{e}, e'p)B$ and $A(\vec{e}, e'\vec{p})B$ reactions. The polarization transfer mechanism in which the electron interacts with the initial nucleon carrying the target polarization, making the proton exit with a fractional polarization in a different direction, is referred to here as "skewed polarization." The new observables characterizing the process are identified, and written in terms of polarized response functions and asymmetries which are of tensor nature. The corresponding half-off-shell single-nucleon responses are analyzed using different prescriptions for the electromagnetic vertex and for different kinematics. Numerical predictions are presented for selected perpendicular and parallel kinematics in the case of ^{39}K as polarized target.

* Corresponding author. Fax: +958 249487.
E-mail address: amaro@ugr.es (J.E. Amaro).

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1. Introduction

It is well known that polarization degrees of freedom in electron scattering reactions lead to new observables which provide additional information on the nuclear structure as well as on the reaction mechanism [1–4]. In general, the control of leptonic and hadronic polarizations allows new combinations of electromagnetic multipole matrix elements that show different sensitivities to the diverse ingredients entering in the description of the reaction mechanism.

In inclusive $(\vec{e}, e')$ processes, the polarization of the incident lepton yields information not only on the nucleonic structure (in particular the strange and axial nucleon's form factors, see, e.g. [5,6]), but also on some specific nuclear correlations which are not probed by unpolarized electrons [7–10].

In recent years a great effort, both from experimental and theoretical points of view, has been devoted to the analysis of exclusive $(e, e'p)$ with leptonic and/or hadronic polarization measurements for medium nuclei. This has been for instance the case of $(e, e'\vec{p})$ processes and the measurement of induced polarization [11,12] as it crucially depends on final state interactions (FSI) (the induced polarization is zero in the plane wave limit) [13–19]. Double-polarized $(\vec{e}, e'\vec{p})$ experiments have been also carried out to measure polarization transfer asymmetries for medium [20,21] and light nuclei [22,23], as they may provide information on the possible modifications of the nucleon form factors in the nuclear interior [15,24]. Finally, the case of electron scattering on polarized targets, i.e., $\vec{A}(e, e'p)$ and $\vec{A}(\vec{e}, e'p)$ processes, has been analyzed as well from the theoretical point of view for medium nuclei in a number of papers [25–30] and, in particular, important connections between FSI and the nuclear polarization direction have been found [31,32].

However, studies of spin observables in $\vec{A}(\vec{e}, e'\vec{p})$ when the beam, target, and final nucleon are simultaneously polarized exist only scarcely. Apart from the general approach of [2], research on these reactions has only been performed for light nuclei. In particular, it is worth mentioning the systematic research on general sets of spin observables for deuterium performed in the last decade by Arenhövel et al. [33–38]. In the present paper we try to fill this gap and begin an exploration of the new spin observables that arise in these exclusive reactions from medium nuclei. Although no experiments of this kind are presently under planning, theoretical studies of such reactions are needed to gauge the magnitude and properties of the new observables, and to determine if new relevant physical information can be extracted from them. Accordingly, in this work we focus on a new polarization mechanism of the recoil proton, which is absent in the reactions previously studied. In fact, for unpolarized nuclei, there are two such mechanisms: (i) For unpolarized electrons *induced polarization* is produced on the recoil protons by effect of the FSI with the