Fewbody theoretical studies of Quasi Free Scattering reactions

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Introduction

Proton-induced quasifree scattering nucleon knockout reactions have been recently measured and are planed in future experiments of the R3B collaboration aiming extracting spectroscopy of valence and deeply bound nuclei, and pinning down structure correlation effects. To model and analyze these experiments it is of utmost importance to have a reliable reaction framework in order to extract meaning structure information. Few-body reaction frameworks recently developed are a useful tool to interpret this experiments.

Electron scattering reactions (e,e'p) have been a long-standing tool to obtain information from single-nucleon structure information of nuclei. Systematic studies have shown that for a wide range of magic and near magic nuclei, the single particle occupancies are significantly bellow the values expected from the values predicted by independent-particle shell model calculations (IPSM).

Occupancies have also been extracted using nuclear probes. In particular, single-nucleon (p,2p) and (p,pn) knockout reactions from light target at intermediate have also been used in the past to obtain information on single-particle occupancies.

Proton-induced quasifree scattering nucleon knockout reactions have been performed recently at GSI in inverse kinematics within the R3B program, at around 400 MeV per nucleon. At high incident projectile energies, it is expected the reaction mechanism to be simpler and that one be able to obtain structure information about inner and outer shells. In particular, one aims to obtain information about deviations from single particle occupancies, and correlation effects.

There are several timely issues associated with single nucleon (p,2p) and (p,pn) QFS knockout reactions: (i) A key issue is to disentangle structure correlations from effective dynamical effects. In particular, one needs to get insight to what extent the reduced factors found by comparing the theoretical cross sections with the results extracted from the experimental data can, be traced exclusively to structure correlations or to effective dynamical effects associated with the reaction framework used to interpreted the data. Thus a tight control on the reaction formalism is needed; (ii) Another important aspect is to identify clearly the role of distortion effects to the nucleon-nucleon free scattering; (iii) The recent experiments performed at GSI, have allowed a unique opportunity to perform systematic studies of knockout reactions along the isotope chain at nearly the same incident energy. The study of the behaviour of calculated observables using a well constrained reaction framework, with respect to angular momentum, mass and binding will allow to identify and analyse common features, and identify new physics as experimental deviations to this systematic. (iv)A reliable assessment of possible dynamical core excitation effects and nucleon knockout contributions from inner shells is also mandatory for the interpretation of recent and future experiments at GSI.

Reaction studies

The study of proton-induced quasifree scattering nucleon knockout reactions can be addressed by the three-body Faddeev/AGS [1, 2] reaction formalism, which treats all relevant three-body observables in equal footing [3]. According to this reaction framework, one needs to evaluate the operators $U^{\beta\alpha}$, whose on-shell matrix elements are the transition amplitudes. These operators are obtained by solving the three-body Faddeev/AGS integral equations

$$U^{\beta\alpha} = \bar{\delta}_{\beta\alpha} G_0^{-1} + \sum_{\gamma} \bar{\delta}_{\beta\gamma} t_\gamma G_0 U^{\gamma\alpha} \, , \qquad (1)$$

with $\alpha, \beta, \gamma = (1, 2, 3)$, ($\beta = 0$ in the final breakup state). In here, $\bar{\delta}_{\beta\alpha} = 1 - \delta_{\beta\alpha}$ and the pair transition operator is

$$t_\gamma = v_\gamma + v_\gamma G_0 t_\gamma \, , \qquad (2)$$

where G_0 is the free resolvent $G_0 = (E + i0 - H_0)^{-1}$, and E is the total energy of the three-particle system in the center of mass (c.m.) frame. For breakup, the solution of the Faddeev/AGS equations can be found by iteration

$$U^{\beta\alpha} = \sum_{\gamma} \bar{\delta}_{\beta\gamma} t_\gamma \bar{\delta}_{\gamma\alpha} + \sum_{\gamma} \bar{\delta}_{\beta\gamma} t_\gamma \sum_{\xi} G_0 \bar{\delta}_{\gamma\xi} t_\xi \bar{\delta}_{\xi\alpha} + \cdots \, .$$

The successive terms of this series can be considered as terms of first order or single scattering, represented diagrammatically in Fig. 1, second order or double scattering, represented diagrammatically in Fig. 2 and so on in the transition operators t_γ.

In order to model and interpret recent proton-induced quasifree scattering nucleon knockout reactions by the R3B collaboration we have evaluated total cross sections and core momentum distributions for several isotopes in inverse kinematics at around 400 MeV making use of the AGS/Faddeev reaction framework:

We have analyzed QFS (p,2p), for the case of valence proton knockout from ^{12}C. In particular, we have studied the role of higher order distortions, valence-nucleon rescattering contributions and the effect of some approximations

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performed by the standard Distorted Wave Impulse Approximation reaction framework. We found that the multiple scattering expansion of the DWIA might differ from the corresponding Faddeev/AGS result.

We have analyzed the Faddeev/AGS equations in terms of its multiple scattering expansion, and found that at high incident energies that the terms up to second order provide the dominant contribution of the series.

We have analyzed QFS (p,pn), for the case of valence neutron knockout from the halo nuclei ^{11}Be, ^{15}C and along the Oxygen isotope chain ^{17,22,23}O. A detailed analyse of the role of higer terms distortion and its dependence of the binding energy and angular dependence of the valence particle was made.

Most few-body theoretical reaction studies rely on the a model of an inert core and a valence nucleon. However, the internal degrees of freedom might pay an important role as shown in [4], [5]. In order to predict the total cross sections obtained at recent experiments performed at GSI, the effects of dynamical core excitation were estimated. Also the contribution from the knockout of nucleons from the core were evaluated and found to be important.

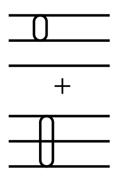

Figure 1: Single scattering diagrams for breakup in the Faddeev scattering framework.

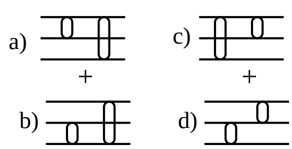

Figure 2: Double scattering diagrams for breakup in the Faddeev scattering framework.

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