Eur. Phys. J. A (2021) 57:212
https://doi.org/10.1140/epja/s10050-021-00497-6

THE EUROPEAN PHYSICAL JOURNAL A

Regular Article - Theoretical Physics

Nucleon-induced inelastic scattering with statistical strength functions and the ECIS direct reaction code

E. V. Chimanski[1,a], **B. V. Carlson**[2]

[1] Lawrence Livermore National Laboratory, Livermore, CA 94550, USA
[2] Depto. de Física, Instituto Tecnológico de Aeronáutica, São José dos Campos, SP 12228-900, Brazil

Received: 4 April 2021 / Accepted: 22 May 2021 / Published online: 29 June 2021

Communicated by Nicolas Alamanos

Abstract Modern theoretical descriptions of inelastic scattering make use of multi-step direct reaction approaches together with transition potentials obtained from sophisticated nuclear structure models. Here we demonstrate how the complexity of such calculations can be reduced to permit simpler ones, also using the ECIS code, but providing an almost equally precise alternative to a much more detailed calculation. We have studied the transition form factors within the random phase approximation (RPA), where these are obtained as linear combinations of particle–hole states. At moderate to high excitation energies, where interference effects tend to disappear, we have proposed an independent particle–hole formalism in which particle–hole states are spread in energy with an appropriate strength function obtained from the RPA. The effects of more complex modes, such as 2p–2h ones, are simulated with widths calculated in a semi-classical context. Here, we verify the validity of our approximations for pre-equilibrium proton-induced reactions on ^{90}Zr target. Our calculations provide a good description of the reaction data and point toward a simplification of the description of nucleon-induced reactions based on averages of microscopic details of the projectile–target interaction.

1 Introduction

Nuclear cross sections are key ingredients for a variety of applications from nucleosynthesis, radioisotope production for medical treatments and nuclear power plant strategies [1–3]. Theoretical reactions models are required to supplement experimental data values and sometimes to even provide them in cases where, for example, the target is a short-lived or rare isotope or when no experimental facility can perform measurements in the desired energy range.

Although inelastic multi-step direct reaction scattering models have been developed for many years, a complete description that can be directly implemented numerically is difficult to achieve. For nucleon induced reactions, simpler models introduce limited information about the nuclear structure of the target while more sophisticated approaches, when available, quickly reach a high level of complexity.

A successful approach relies on the combination of detailed nuclear structure information that can be introduced into a detailed reaction description, such as the DWBA or coupled channel theory [4]. The RPA has been successfully employed in calculations of nucleon-induced reactions ([5,6], and for surrogate studies [7,8]). The price of such an approach is the need for fast modern computers to perform the calculations. Although the desktop and multi-processor servers available at present can handle such elaborate coupled structure and reaction calculations of one-step reactions, or with a few simplifications, two-step ones, they are no match for the combinatorial complexity of higher multi-step processes. With the aim of reducing the complications expected in such calculations, we show in this work how RPA form factors can be simplified at excitation energies typical of pre-equilibrium reactions by substituting statistical averages for a detailed microscopic description of the transition densities. Cross sections can be obtained for independent particle–hole configurations and then spread in energy according to the statistical distributions obtained from an analysis of the microscopic description.

This work is organized as follows: We present a short introduction to the theoretical formalism. Next, the transition densities and the averaging scheme are presented. The numerical cross sections obtained and the concluding remarks are given in the results and conclusion sections, respectively.

[a] e-mail: chimanski1@llnl.gov (corresponding author)