Transitions between rotational nuclear few-body states in the continuum

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Bremsstrahlung emission in collision between two charged nuclei is a physically well defined process. Such continuum-to-continuum transitions would be strongly influenced by the presence of resonances in the two-body combined system at energies corresponding to the initial and final two-body cluster states [1]. Calculation of the cross sections requires knowledge of the continuum wave functions. We use two different techniques to describe these continuum states, that is genuine continuum states on the real energy axis and bound states obtained by discretization in a large box [2].

We choose the simplest nucleus for illustration, that is two α-particles in both initial and final states. We first compute the directly observable bremsstrahlung cross section as function of initial energy and given photon energy. We then address the question of resonance structures and signals within these observables. The general belief has been that the three lowest states in ^{8}Be, (0^+, 2^+ and 4^+), constitute a rotational band. However, the two excited states have rather large widths of decays into two α-particles. The γ-transitions between these states is therefore not measured directly, and the signal of a possible rotational structure has not been extracted experimentally.

We show that the very definition of a γ-transition between continuum states in itself already is ambiguous. This prohibits a rigorous test of a possible rotational character of these resonance states. However, by suitable definitions of multipole transitions we are able to investigate whether the three resonances have structures connected into a rotational band [3]. This inherently is ambiguous and at most a useful approximation. A further annoying complication is the apparent divergent properties of the decisive matrix elements. The numerical treatment is thereby delicate. We solve this problem by regularizing analogous to the Zel'dovic procedure.

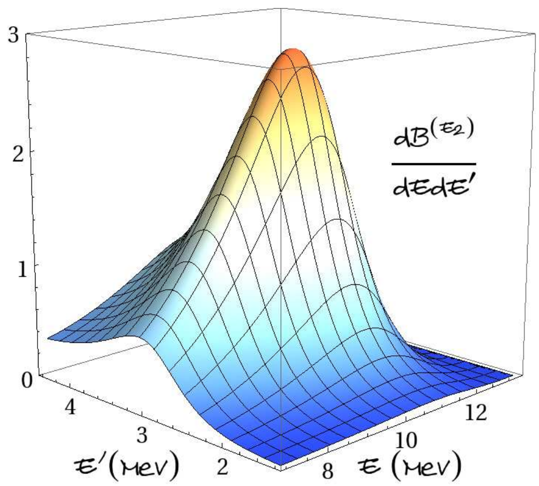

Figure 1: Differential $E2$-transition strength as a function of the initial and final energies, E and E', for the $4^+ \to 2^+$ transition in ^{8}Be.

We shall show results of cross sections, $E2$-transition strengths, energies, and radii, and compare to expectation from properties of rotational bands. We show a distribution in the present figure. We find that both static and transition probabilities are far from rotational values but still rather large and exhibiting strong rotational character. This observation is traced to the properties of the two high-lying resonances which resemble free continuum solutions already at rather small distances of about 5 fm. We test with different interactions, that is the shallow Ali-Bodmer and the Buck potential with spurious deep-lying states. No interaction differences are found even though the Buck-potential necessarily has additional nodes of the wave functions. Comparison to the scarce available data is very good, whereas we disagree with some previous theoretical values.

The present investigation is by nature of few-body character. However, it is a necessary prerequisite for discussions of much more complicated structures of resonances, and of subsequent extraction and corresponding comparison to measurements of such states. The possible applications are abundant in nuclear physics where numerous states are treated, both theoretically and in analyses, as if they were bound states although the strong interaction decay widths often are large. A pertinent topic is to separate contributions to transitions into resonance-to-resonance and continuum background parts. We suggest a tempting way of dividing the theoretical and perhaps the analysis of experimental results as well. The different parts add coherently and the interference is sometimes rather strong and has to be included.

[1] K. Langanke, Phys. Lett. B **174** (1986) 27.

[2] E. Garrido, A.S. Jensen, D.V. Fedorov, Phys. Rev. C **86** (2012) 064608.

[3] E. Garrido, A.S. Jensen, D.V. Fedorov, to be published in Phys. Rev. C.

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