Continuum spectroscopy of Borromean two-neutron halo nuclei

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The task of continuum spectroscopy is to determine which modes of nuclear excitations are dominant at given excitation energy or in some region of excitation energies. For two-body breakup the excitation energy unambiguously defines the linear momentum between fragments. Also, only one orbital angular momentum characterizes their relative motion. A breakup into three fragments is richer and more complicated in comparison with breakup into two fragments. New degrees of freedom appear and more quantum numbers are necessary to characterize unambiguously the motion of the fragments. The nuclear excitation energy fixes only a total phase volume accessible for fragments. Kinetic energies for fragments have continuous distributions within this volume. In addition, two (Jacobian) relative orbital angular momenta characterize their motion. The specific structure of the continuum defines the accessible excitation modes. Finally, continuum excitations and structure of the ground state are tightly intertwined by reaction mechanisms.

The experimental study of three-body correlations of halo fragments in breakup reactions demands kinematically complete measurements when three particles, halo neutrons and core, are detected in coincidence. Then it is possible to reconstruct the spectrum of the halo nucleus and select events that correspond to low-energy excitations. For fixed excitation energy, the three fragments can still move relative to each other in a variety of ways. Thus in parallel to the excitation spectrum we can study many different angular and energy correlations between fragments. They are sensitive to different aspects of reaction dynamics. Thus continuum spectroscopy implies a consistent analysis of a variety of exclusive and inclusive cross sections accessible in kinematically complete experiments.

Recently, experimental data on different angular and energy correlations of the three fragments from breakup of ^{6}He on lead target at collision energy 240 MeV/nucleon, obtained at GSI, have been published [1]. They reveal a very interesting picture. The *low-energy spectrum* of ^{6}He shows a smooth behaviour, while with increasing excitation energy, the shape of some *correlations* changes dramatically along the spectrum.

Here we present theoretical analysis of various angular and energy correlations of the three fragments in ^{6}He breakup on ^{208}Pb at collision energy 240 MeV/nucleon measured recently at GSI [1]. The analysis has been based on a microscopic four-body distorted wave approach to breakup reactions [2] and uses the three-body model for the nuclear structure of the two-neutron Borromean halo nucleus ^{6}He. The method of hyperspherical harmonics was used for calculations of the ground state wave function and low-lying continuum states including monopole, dipole and quadrupole excitations.

Theoretical calculations reproduce quite well the low-lying excitation spectrum and fragment angular and energy correlations near breakup threshold. The fundamental fermionic nature of the halo neutrons is clearly exibited by the correlations. While dipole dominates at most excitation energies other multipolarities can significantly distort the dipole correlation pictures and for a consistent analysis of experimental data all excitations have to be taken into account. With increasing excitation energy some angular and energy correlations are described within the theoretical model while some are not. Possible reasons for this are discussed.

[1]L.V. Chulkov et al., Nucl. Phys. **A759**, 23 (2005);

[2] S.N. Ershov, B.V. Danilin, J.S. Vaagen, Phys. Rev. C **64**, 064609 (2001).