Study of four-neutron correlations in cluster decay of ^{12}Be highly-exited states on RADEX channel

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In ^{12}Be highly-exited states it is possible the formation of ^{8}Be-cluster and a 4*n*-correlated cluster with a radius of ≤3 fm in a nuclear field ≥3 MeV or as a resonance with an energy of 2 MeV in the continuous spectrum (fig. 1).

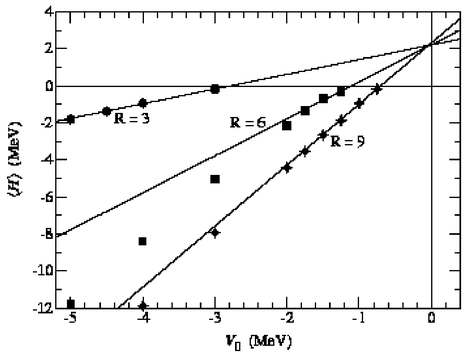

Fig.1. Energies of 4*n*-claster in external wells versus the well-depth parameter V_0 [1]. Monte Carlo (GFMC) calculations by using three-nucleon potential that good descript of 1*p* shell nuclei predicts the existence of a 4*n*-correlated cluster in a nuclear field V_0.

Calculations using the antisymmetric model of molecular dynamics revealed the α-cluster structure of the isotopes Be, B, and C [2] (Fig. 2).

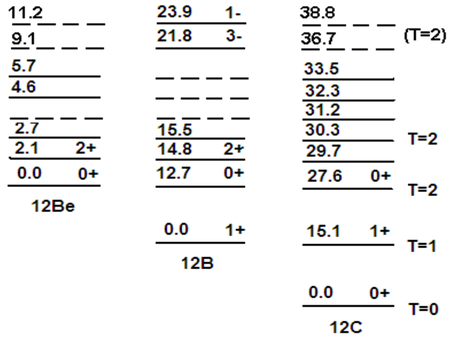

Fig.2. Exited states of ^{12}Be, ^{12}B and ^{12}C. Resonant doubly analog α-cluster states with isospin T = 2 were found in the spectra of ^{12}Be, ^{12}B and ^{12}C nuclei. There is the excitation possibility of α-cluster resonance state in ^{12}Be with the formation of ^{8}Be and a 4*n*-correlated cluster.

We consider the possibilities of searching for excited cluster states in the ^{13}C(*n*, 2*p*)^{12}Be* charge exchange reaction on the cascade neutron of the RADEX pulsed source (Fig. 3).

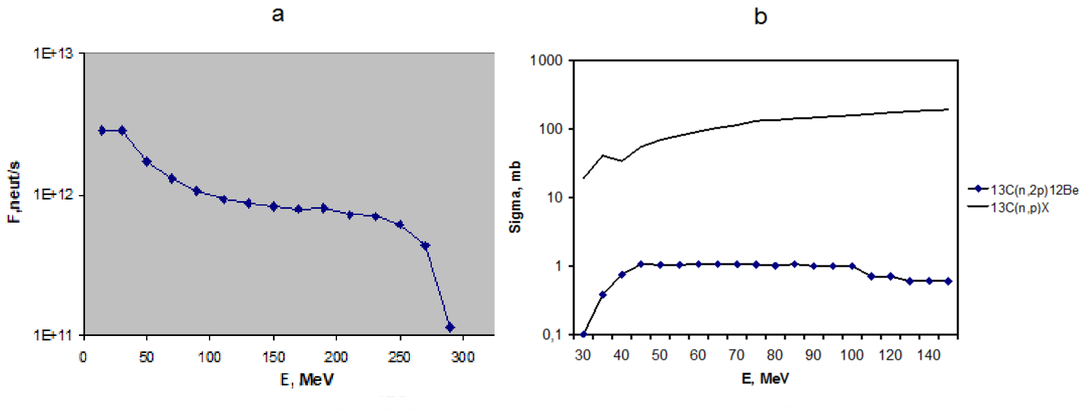

Fig.3. a – Spectrum of RADEX cascades neutrons in the forward direction; b – Cross section of the charge exchange reactions.

The cluster decay fragments should have specific energy and angular correlations reflecting strong spatial correlations of "valence" nucleons orbiting in the decay nucleus [3]. Excitation of the highly-exited α-cluster states in ^{12}Be is possible when a proton pair is quasi-elastically knocked out of ^{13}C at an angle of ~ 15° by a cascade neutron with an energy of ≥ 40 MeV or in an *n*-*p* charge exchange reaction followed by rescattering by a proton at an energy ≤100 MeV. In the work a two-stage kinematic simulation of the process of formation and escape of 4*n*-correlated cluster in ^{13}C(*n*, 2*p*2α)4*n* reaction was carried out. At the first stage, the ^{13}C(*n*, 2*p*)^{12}Be* reaction was considered with excitation of double analog state of ^{12}C. At the second stage, subsequent α-cluster decay of ^{12}Be* on 4*n*-correlated cluster and ^{18}Be or α-particles was considered. Estimated parameter of the pulsed source of cascade neutrons at an energy of 40-100 MeV is 10^{13} *n*/s (Fig. 4).

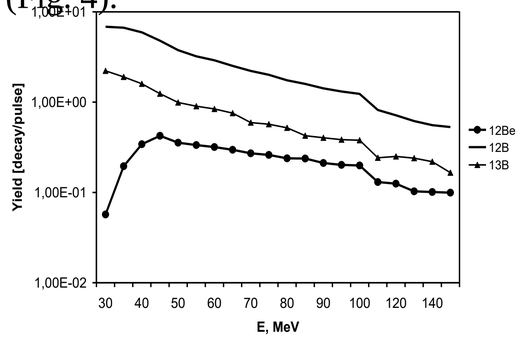

Fig.4. Yields of the main charge exchange reactions. Calculations show that of two-proton registration from the formation of an excited state of ^{12}Be* is possible in a narrow cone. The decay of the α-cluster excited state of ^{8}Be+4*n* should be recorded at the widest solid angle.

Kinematic simulation of simultaneous four-neutron emission at α-cluster decay of ^{12}Be highly-exited states has been considered in ^{13}C(*n*, 2*p*2α)4*n* reaction. Registration of a *p*-pair in coincidence with two α-particles and neutrons should suppress the background. The background is a reaction with the formation and decay of the ground state of beryllium ^{13}C(*n*, 2*p*)^{12}Be→^{11}Be+*n*. The half-life of ^{12}Be is 11.4 ms. The ^{11}Be isotope subsequently undergoes β-decay with the formation of an electron and γ-rays. Registration of the particles from ^{11}Be и ^{12}Be decays makes it possible to isolate this reaction and use it to calibrate the detection system. Background reactions are also ^{13}C(*n*, *p*)^{13}B(18.8 ms) → ^{13}C+ $\beta^-+\gamma$ and ^{13}C(*n*, *np*)^{12}B(20.3 ms) → ^{12}C+ $\beta^-+\gamma$.

The study of characteristics of cluster decay channels is extremely important for studying the cluster properties of various nuclear states.

References:
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3. P. Sharov at al, Int. Conf. "Nucleus-2020", Book of Abstracts, Dubna, 38 (2020).