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Near-threshold states in dissociation of relativistic nuclei

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Joint Institute for Nuclear Research, Dubna, Russia The use of nuclear emulsions (NEs) in beams of relativistic nuclei expands the study of nuclear clustering and, above all, resonance states near α-particle separation thresholds [nsr-2026]. The current focus is on searching for extremely low-energy α-particle states, described as Bose-Einstein condensates. Following the 2α-state of 8Be(0+) and the 3α-state of Hoyle 12C(0+2), the excitation of 16O(0+6) at 15.1 MeV or 296 keV above the 12C(0+2)α threshold has been proposed as a 4α-condensate. In general, decays of unstable states can be identified in distributions of invariant masses Q, defined as sums of the scalar products of the fragment 4-momenta. For convenience, the masses of the fragments or the parent nucleus are subtracted from Q. In the relativistic case, the 4-momenta are determined with sufficient accuracy in the approximation of conservation of momentum per nucleon of the parent nucleus from their emission angles. In the dissociation of 12C and 16O nuclei, the assumption that He fragments correspond to α particles is justified. Due to their minimal energy, their decays can manifest themselves as ensembles of relativistic He fragments with the smallest scattering angles. The contribution of the 8Be(0+)α channel at Q2α ≤ 200 keV to the dissociation of 12C ⟶ 3α at 3.65 GeV per nucleon was determined to be 43%, including 26% through 12C(0+2) at Q3α ≤ 700 keV. The contribution of 12C(0+2) to the coherent dissociation of 16O ⟶ 4α at 3.65 GeV per nucleon was 22%, significantly increasing compared to the case of 12C (11%). However, 16O(0+6) at Q4α ≤ 1 MeV did not manifest itself in the 12C(0+2)α and 28Be(0+) channels. Such suppression can be explained by the extremely small energy difference between 16O(0+6) and 12C(0+2)α, leading to a decay width of only 10-9 MeV . At the same time, the structure of 16O(0+6 as 12C(0+2)α, makes possible the internal conversion of 12C(0+2) to the ground state 12C(0+1) with a width of 0.2 MeV. By allowing 16O(0+6) to be considered as an excitation near the 4α threshold, this scenario motivated the search for binary decays 16O(0+6) ⟶ 12C(0+1)α presented here. The distribution over invariant mass of 12Cα pairs produced in the dissociation of 16O indicates decays of the excited state 16O(0+6). An estimate of the probabilities of the 12C(0+1)α and 12C(0+2)α channels indicates a dominance of the former with a factor of about 20. It supports the hypothesis of decay of the 16O(0+6) state via internal conversion of its substructure 12C(0+2) to 12C(0+1). This makes it possible to synthesize the isotope 12C through the decay 16O(0+6) ⟶ 12C(0+2)α ⟶ 12C(0+1)α without a radiative transition as an addition to the known 3α-process. The study of binary dissociation of 16O nuclei stimulated a reanalysis of data on the α-particle dissociation of 22Ne nuclei for observations of near-threshold resonances, as follows. The invariant mass distribution of 18Oα pairs produced in the dissociation of 22Ne at 3.22 GeV per nucleon exhibits a peak that can be interpreted as 22Ne excitation with a mean value of approximately 11.6 MeV. Corresponding to sub barrier fusion of 18O + α, this observation provides further evidence for the feasibility of nucleosynthesis reactions in the fragmentation cone of relativistic nuclei.

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