

UNSTABLE NUCLEI ${}^8\text{Be}$ AND ${}^9\text{B}$ AND THE HOYLE STATE IN RELATIVISTIC NUCLEAR FRAGMENTATION

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The BECQUEREL experiment is aimed at solving topical problems in nuclear clustering physics. The used method of nuclear track emulsion (NTE) makes it possible, due to its unique sensitivity and spatial resolution, to study in a unified approach multiple final states arising in dissociation of relativistic nuclei. Currently, a research focus is on the theoretical concept of α -particle Bose-Einstein condensate (αBEC) - the ultra cold state of several S-wave α -particles near coupling thresholds. The unstable ${}^8\text{Be}$ nucleus is described as $2\alpha\text{BEC}$, and the ${}^{12}\text{C}(0+2)$ excitation or Hoyle state (HS) as $3\alpha\text{BEC}$. Decays ${}^8\text{Be} \rightarrow 2\alpha$ and ${}^{12}\text{C}(0+2) \rightarrow {}^8\text{Be}\alpha$ can serve as signatures for more complex αBEC decays. Thus, the $0+6$ state of the ${}^{16}\text{O}$ nucleus at 660 keV above the 4α threshold, considered as $4\alpha\text{BEC}$, can sequentially decay ${}^{16}\text{O}(0+6) \rightarrow \alpha{}^{12}\text{C}(0+2)$ or ${}^{16}\text{O}(0+6) \rightarrow {}^{28}\text{Be}(0+)$.

The consideration of αBEC as an invariant phenomenon indicates possibility of its search in the relativistic fragmentation. A practical alternative is provided by NTE layers longitudinally exposed to relativistic nuclei. The invariant mass of ensembles of He and H fragments can be determined from emission angles in the approximation of conservation of momentum per nucleon of a parent nucleus. Owing to extremely small energies and widths, the ${}^8\text{Be}$ and HS decays, as well as ${}^9\text{B} \rightarrow {}^8\text{Be}p$, are identified in fragmentation of light nuclei by an upper constraint on the invariant mass.

Having been tested, this approach has been used to identify ${}^8\text{Be}$ and HS and search for more complex states of αBEC in fragmentation of medium and heavy nuclei. Recently, based on the statistics of dozens of ${}^8\text{Be}$ decays, an enhancement in probability of detecting ${}^8\text{Be}$ in an event with an increase in number of relativistic α -particles was found. A preliminary conclusion is drawn that contributions of ${}^9\text{B}$ and HS decays also increase. The exotically large sizes and lifetimes of ${}^8\text{Be}$ and HS allowing suggesting possibility of synthesizing αBEC by successively connecting the emerging α -particles. The main task of the forthcoming stage of the project is to clarify the relation between the appearance of ${}^8\text{Be}$ and HS and α -ensemble multiplicities and search on this basis for decays of the ${}^{16}\text{O}(0+6)$ state. Currently, the BECQUEREL experiment aims to measure multiple channels of ${}^{84}\text{Kr}$ fragmentation below 1 GeV per nucleon. Searches for αBEC lead to the study of nuclear matter with temperature and density ranging from red giants to supernovae. In this respect NTE layers exposed to heavy nuclei at several GeV per nucleon of the NICA accelerator complex will make it possible to study relativistic ensembles of H and He isotopes of unprecedented multiplicity under optimal conditions.

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