**Proposal for extending the project "BECQUEREL2023"**

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**ANNOTAION**

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. Progress in this direction relies on computerized microscopy.

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 8Be nucleus is described as 2αBEC, and the 12C(0+2) excitation or Hoyle state (HS) as 3αBEC. Decays 8Be → 2α and 12C(0+2) → 8Beα can serve as signatures for more complex αBEC decays. Thus, the 0+6 state of the 16O nucleus at 660 keV above the 4α threshold, considered as 4αBEC, can sequentially decay 16O(0+6) → α12C(0+2) or 16O(0+6) → 28Be(0+). Its search is being carried out in several experiments on fragmentation of light nuclei at low energies. Confirmation of the existence of this and more complex forms of αBEC could provide a basis for expanding scenarios for the synthesis of medium and heavy nuclei in nuclear astrophysics.

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 8Be and HS decays, as well as 9B → 8Be*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 8Be 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 8Be decays, an enhancement in probability of detecting 8Be in an event with an increase in number of relativistic α-particles was found. A preliminary conclusion is drawn that contributions of 9B and HS decays also increase. The exotically large sizes and lifetimes of 8Be 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 8Be and HS and α-ensemble multiplicities and search on this basis for decays of the 16O(0+6) state. In this regard, the BECQUEREL experiment aims to measure multiple channels of 84Kr fragmentation below 1 GeV per nucleon. There are a sufficient number of NTE layers, transverse scanning of which on the motorized microscope Olympus BX63 makes it possible to achieve required statistics. At the same time, the existing MBI-9, KSM, and MPE-11 microscopes need to be upgraded to continue precision measurements according to proven procedures.

In continuation of the study of the fragmentation of light nuclei, searches for decays of isobar-analogue states (IAS) including excitations 8Be\* and 9B\* has begun. Manifesting at high excitation energy, but also having very small widths, IASs serve as “beacons” for structural rearrangement in the direction of similarity with their less stable isobars. In the context of nαBEC and IAS, the analysis of NTE exposed to 9Be, 10C, 14N, 22Ne, 24Mg, and 28Si nuclei will continue.

Searches for αBEC and IAS 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. The special advantages of the NTE method will manifest themselves for nuclei at the proton stability boundary, which will require formation of secondary beams (for example, 31Ar).