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Classical excluded volume of loosely bound light (anti)nuclei and their chemical freeze-out in high energy nuclear collisions

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From the analysis of light (anti)nuclei multiplicities [1, 2] that were measured recently by the ALICE collaboration in Pb+Pb collisions at the center-of-mass collision energy $\sqrt{s}$ =2.76 TeV [3] there arose a highly non-trivial question about the excluded volume of composite particles. Surprisingly, the hadron resonance gas model (HRGM) is able to perfectly describe the light (anti)nuclei multiplicities [1, 2] under various assumptions. For instance, one can consider the (anti)nuclei with a vanishing hard-core radius (as the point-like particles) or with the hard-core radius of proton, but the fit quality is the same for these assumptions. However, it is clear that such assumptions are unphysical. Hence we derived a new formula for the hard-core radius of a nuclei consisting of A baryons or antibaryons which does not lead to the hard-core radius expression R(A) = R(1) $\sqrt[3]{A}$ used in [2] recently for A>1. To implement a new relation into the HRMG we employ the induced surface tension concept [1, 4] and perform a thorough analysis of hadronic and (anti)nuclei multiplicities measured by the ALICE collaboration. The HRGM with the induced surface tension allows us to verify different assumptions on the values of hard-core radii and different scenarios of chemical freeze-out of (anti)nuclei. It is shown that the most successful description of hadrons can be achieved at the chemical freeze-out temperature of about Th=150 MeV, while the one for all (anti)nuclei is TA=168-172 MeV. Similar analysis is made for the 6-quark states suggested in [5] and their yields for the central high energy nuclear collisions are predicted.

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Primary author: Prof. BUGAEV, Kyrill (BITP, Kiev, Ukraine)

Co-authors: Dr SAGUN, Violetta; Dr GRINYUK, Boris (BITP, Kiev, Ukraine); Dr KABANA, Sonia; Dr FARRAR, Glennys; Dr IVANYTSKYI, Aleksei; Prof. BRAVINA, Larissa (University of Oslo, Norway); Dr TARANENKO, Arkadii; Dr ZABRODIN, Eugene (University of Oslo)

Presenter: Prof. BUGAEV, Kyrill (BITP, Kiev, Ukraine)

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