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Peeling away surface neutrons from ^{209}Bi in asymmetric collisions

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The ratio of neutron to proton densities increases toward the periphery of heavy nuclei. While this leads to a subtle difference (~0.5 fm) in the mean square radii of neutrons and protons, the thickness of such a neutron skin (NS) is very sensitive to the nuclear symmetry energy term in the equation of state (EOS) of nuclear matter important for both nuclear physics and astrophysics [1]. There have been several measurements of the NS thickness in ^{208}Pb, see e.g. [2, 3], but their results diverge. In this respect, the estimation of the NS thickness in a neighboring nucleus such as ^{209}Bi by new methods may help to solve the puzzle.

In this work, by means of Abrasion-Ablation Monte Carlo for Colliders (AAMCC) model [4] with MST-clustering [5] we simulate the emission of free spectator neutrons and protons in ultracentral collisions of ^{209}Bi with target nuclei equal to (Bi) or smaller (Au, W) than ^{209}Bi. It is expected that an excited donut-shaped spectator mater can be produced in such asymmetric ultracentral collisions. Then, an immediate break-up to free spectator neutrons and protons is predicted, and the detection of these neutrons and protons can provide a unique possibility to analyze the n/p ratio at the nuclear periphery.

The multiplicity distributions of spectator neutrons and protons were calculated with and without neutron skin in ^{209}Bi. It was found that the neutron multiplicity distributions are different in Bi-Bi, Bi-Au and Bi-W collisions and they are sensitive to the presence of neutron skin in the projectile nucleus. The average neutron yield was calculated as a function of the volume of spectator matter in the considered ultracentral collisions.

The studies of ultracentral ^{208}Pb–^{208}Pb collisions at the LHC were proposed previously [6] to identify the presence of NS in ^{208}Pb. The ultracentral ^{96}Zr–^{96}Zr and ^{96}Ru–^{96}Ru collisions were also investigated at RHIC [7]. In all these cases the collisions of equal mass nuclei were investigated. In this work the method of Ref. [6] was extended to collisions of ^{209}Bi with lighter projectiles. The yields of spectator nucleons in ultracentral collisions and the n/p-ratio of released spectator nucleons were studied as a probe of NS thickness.

As known, the BM@N experiment is equipped with forward detectors capable of detecting spectator nucleons and fragments from ^{209}Bi projectiles [8]. In view of further upgrades of the BM@N setup one can rely on the possibility to disentangle free spectator neutrons from protons to conduct the measurements proposed in the present work.

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Section

Heavy ion collisions at Intermediate and high energies

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