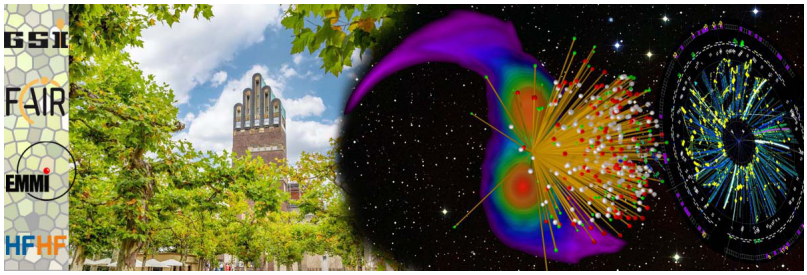

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Probing neutron skin with free spectator nucleons in ultracentral relativistic heavy-ion collisions

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The neutron-skin thickness is one of the most robust probes of the slope parameter of the nuclear symmetry energy, which is responsible for the main uncertainty of the nuclear matter equation of state. Relativistic heavy-ion collisions may serve as a complementary measurement of the neutron-skin thickness, in addition to various methods in nuclear structure studies. In these collisions, we propose that the free spectator nucleons, which can be measured by zero-degree calorimeters, are clean probes of the neutron-skin thickness of the colliding nuclei. Based on the initial density distributions of typical nuclei calculated from the Skyrme-Hartree-Fock-Bogolyubov model, the information of spectator matter can be obtained from the Glauber model, and the free spectator nucleons are produced from a multi-fragmentation process from the spectator matter. In ultracentral collisions, these free spectator nucleons are most robust probes of the neutron skin, free from the uncertainty of the deexcitation process. In deformed nuclei, the neutron-skin thickness may have a polar angular distribution, which is sensitive to the nuclear spin-orbit interaction as well as the neutron and proton numbers of the nucleus. We have further explored the possibility of probing the polar angular distribution of the neutron skin in colliding nuclei, by measuring the numbers of free spectator neutrons and protons in different collision configurations.

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