Peeling Off Neutron Skins from Neutron-Rich Nuclei: Symmetry Energy and Neutron Stars

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Abstract

An experimentally constrained equation of state of neutron-rich matter is fundamental for the physics of nuclei and the astrophysics of neutron stars, mergers, core-collapse supernova explosions, and the synthesis of heavy elements. To this end, we investigate the potential of constraining the density dependence of the symmetry energy close to saturation density through measurements of nucleon-removal cross sections in high-energy nuclear collisions of about 1 GeV/nucleon. We show that the sensitivity of the total neutron-removal and interaction cross sections are high enough so that the required accuracy can be reached experimentally with the recent developments of new detection techniques. We quantify two crucial points to minimize the model dependence of the approach and to reach the required accuracy: the contribution to the cross section from inelastic scattering has to be measured separately in order to allow a direct comparison of experimental cross sections to theoretical cross sections based on density functional theory and eikonal theory. The accuracy of the reaction model should be investigated and quantified by the energy and target dependence of various nucleon-removal cross sections. Our calculations explore the dependence of nucleon-removal cross sections on the neutron skin of medium-heavy neutron-rich nuclei, and we demonstrate that the slope parameter L of the symmetry energy could be constrained down to 10 MeV by such a measurement, with a 2% accuracy of the measured and calculated cross sections.