Asymmetric Nuclear Matter

Atomic nuclei common in Nature tend to have a similar number of protons and neutrons and detailed neutron-proton content is, for those nuclei, tied rather tightly to the mass number. Recent availability of exotic beams such as at NSCL, and planned for FRIB, makes it possible to study, more thoroughly than before, nuclei with a very different neutron-proton content than typical in Nature. With this, interest has risen in understanding of the evolution of nuclear properties with neutron-proton imbalance. Understanding of that evolution is, in particular, critical for extrapolating from nuclei, explored in laboratory, to neutron stars. The changes with neutron-proton imbalance are constrained by the symmetry of nuclear interactions under interchange of protons and neutrons, termed charge symmetry, and by a broader symmetry, termed charge invariance, of invariance under rotations in the neutron-proton space. Those symmetries put the so-called symmetry energy at the center of the evolution of nuclear properties with neutron-proton imbalance.

The symmetry energy is behind nuclei having similar number of neutrons and protons and the pressure sustaining neutron stars is largely tied to the density dependence of symmetry energy. The symmetry energy governs how neutrons distribute themselves relative to protons in a nucleus and how they oscillate against each other in collective nuclear oscillations. That energy also determines the current of neutron-proton imbalance flowing when nuclei with different neutron-proton asymmetries collide. The talk will review the physics of neutron-proton imbalance in nuclear systems, with focus on the symmetry energy.