Neutron-proton effective mass splitting

Abstract
The neutron-proton effective mass splitting at normal and super-saturation density will be explored through the study of differential flow observables in mid-peripheral collisions of exotic nuclei.
High incident energies will be needed to overcome the flow balance energy and to reach high baryon density values. Symmetric collisions with global isospin ratios ranging from N/Z~1 to N/Z~1.7 will be needed to discriminate between the different theoretical predictions.

Keywords
Effective mass, Lane potential, transverse flow, elliptic flow, pre-equilibrium particles

Physics case

The density functional theory (DFT) through self-consistent mean field calculations (and their extensions) is probably the only possible framework in order to understand the structure of medium-heavy nuclei; in particular the isovector part of the energy functional of asymmetric nuclear matter is still very poorly known. One of the key quantities characterizing this functional is the difference in the effective mass of protons and neutrons, which widely differs in the different theoretical approaches already at normal density. Experimental constraints on this quantity are essential for nuclear structure as well as for the structure of neutron stars crusts, therefore we expect important synergies on this issue with the Single Particle and Collective Properties, Ground State Properties, and Astrophysics subtasks.
The difference between the effective masses can be recasted in the form of a microscopic optical Lane potential which in turn determines the transport properties of intermediate energy fragmentation reactions. Intermediate energies are important to have high momentum pre-equilibrium particles and to test regions of high baryon (isoscalar) and isospin (isovector) density during the collision dynamics.

Observables

The main observables sensitive to the isovector momentum dependence of the mean field are: high p_t distributions of pre-equilibrium particles, differential (proton minus neutrons, tritons minus ^{3}He) transverse and elliptic flow.

Proposed experiment

The different effective masses $m_n(\rho)$, $m_p(\rho)$ can be implemented in transport equations and confronted to transport observables. The momentum dependence rules the kinetic observables established in the entrance channel, namely the transverse momentum distributions of pre-equilibrium particles, and collective flows. To extract the isovector part one needs to measure differential quantities (proton minus neutron, or ^{3}He minus t). To minimize the theoretical as well as experimental uncertainties it is essential to compare systems of similar size and largely different N/Z from ~1 to ~1.7. To measure flow observables we need an extremely complete 4π detection for a precise determination of the reaction plane and impact parameter selection.

Requirements:

Beam properties

Different isotopes of medium and medium-heavy beams from neutron poor to neutron rich (e.g. ^{56}Ni -> ^{74}Ni, ^{106}Sn ->^{132}Sn) in an energy range 50-100 A.MeV.

Detection

- 4π and low threshold complete A and Z identification for IMF (FAZIA)
- 4π neutron detector

Theoretical support

Transport calculations (BUU,SMF,QMD,AMD,FMD). We will need extensive simulations with different effective interactions. A strong effort is also needed at the theoretical level, in a first time to assess and improve the compatibility between the different codes, and on a longer timescale to improve the description of clusterization in dilute quantum media.