Isospin fractionation and isoscaling

Abstract
Isoscaling is a well established experimental technique to quantify the global fragment isotopic content. This latter is directly linked to the symmetry energy coefficient at the time of fragment formation. Studying isoscaling parameters in well identified emission sources as a function of excitation energy, isospin content and fragment charge will allow to strongly constrain the symmetry energy of excited and diluted correlated matter.

Keywords
Isotopic distributions, isoscaling, symmetry energy, fractionation

Physics case

Fractionation is a generic feature of phase separation in multi-component systems; in nuclear physics it implies a different isotopic composition of coexisting phases for isospin asymmetric systems.
Since an increased fractionation is expected if fragmentation occurs out of equilibrium, a quantitative study of fractionation will allow elucidating the yet unclear mechanism of fragment production in excited and correlated quantum media. Moreover if fractionation is associated to finite temperature, the first moments of the isotopic distributions give a direct measure of the temperature dependence of the symmetry energy in correlated matter at sub-saturation density with important consequences for the dynamical evolution of massive stars and the supernova explosion mechanisms. In particular, the electron capture rate on nuclei and/or free protons in pre-supernova explosions is especially sensitive to the symmetry energy at finite temperatures.

Observables

Fractionation can be directly measured from isotopic ratios of light particles and fragments from well selected space-time emission regions. Different effects can be disentangled with isoscaling observables concerning ratios of isotopic distributions measured in different reactions.

Proposed experiment

Different space-time fragments emission regions will be separated with collective observables and imaging techniques. The resulting isotopic distributions will be studied through isoscaling comparing sources of similar size and different N/Z in order to pin down isovector components. The same technique will be applied to distribution widths. The comparison of data with different asymmetries and similar centrality will allow quantifying fractionation, while the study with fragment size will give a measure of the temperature dependence of the surface symmetry term.

Requirements:

Beam properties

Different isotopes of medium and heavy beams from neutron poor to neutron rich (e.g. ^{56}Ni -> ^{74}Ni, ^{106}Sn ->^{132}Sn, ^{200}Rn->^{228}Rn) in an energy range 30-100 A.MeV.

Detection

- 4π and low threshold complete A and Z identification for IMF (FAZIA)
- 4π neutron detector
- High angular resolution $\Delta\theta<0.5$ LCP and neutron arrays for correlation measurements

Theoretical support

We will need extensive simulations of both dynamical (QMD,AMD,FMD, SMF) and statistical (SMM,MMM) approaches with different effective interactions and prescriptions for the finite temperature symmetry energy. A theoretical improvement on evaporation codes for side feeding corrections will also be needed.