PhD position in experimental nuclear physics

Study of the density dependence of the symmetry energy and cluster production

Collisions of heavy ions at intermediate energies are a unique tool to lead nuclear matter to extreme conditions of density, pressure, temperature, and neutron-proton asymmetry. The initially compressed nuclear system expands towards low densities where several intermediate mass fragments are produced. Nucleons and light clusters such as deuterons, tritons and alpha particles are also emitted during this fragmentation process as well as products of evaporation by excited primary fragments. Selecting reactions from peripheral to central collisions (e. g. by means of the geometric impact parameter), it is possible to study the phenomena that depend on isospin transport (N/Z) and thus extract information on the density dependence of symmetry energy. This term of the nuclear equation of state plays an important role both in studying the structure of exotic nuclei and astrophysical phenomena.
Studies have been carried out in recent years to determine the density dependence of symmetry energy. In semi-peripheral collisions, the amount of isospin diffusion between collision partners of different neutron-proton asymmetries is controlled by the symmetry energy at low densities. The degree of diffusion of isospin is assessed in terms of isospin transport ratio (N/Z) by comparing systems with different neutron-proton asymmetries. For example, measurements of ^{40,48}Ca + ^{40,48}Ca systems at E/A=35 MeV allowed the degree of diffusion to be assessed. By using the latter, constraints on symmetry energy were obtained for densities lower than the saturation density. However, the determination of the degree of diffusion assumes that the production of clusters does not affect the effect induced by the density dependence of the symmetry energy.
This thesis project consists in exploring the symmetry energy by considering the measurements of the properties of the clusters produced during the evolution of the system. At low density, uniform nuclear material becomes unstable with respect to clustering. Indeed, at densities lower than the saturation density, the inter-nucleon separation becomes comparable to the NN interaction, so that it becomes energetically favourable for the system to fragment into neutron-rich clusters. Clustering significantly increases symmetry energy at very low densities, which could be useful for modelling the explosion of Core Collapse Supernovae Type II. The project will focus on the detailed measurement of these clusters (energy spectra, angular distributions, multiplicities and their correlations) and compare them with the predictions of transport models.
The student will be involved in the following activities:
- participation in the campaign of measurement, using stable beams, with the INDRA-FAZIA experimental device;
- analysis of experiments with INDRA and or other arrays (for ex. MUST2) already carried out to
acquire a better understanding of the analysis tools, especially regarding correlation observables;
- reduction of data collected from new experiments performed with the coupling INDRA-FAZIA, including their analysis and interpretation.

Expected skills:
Nuclear physics, experimental profile, C++, ability to work in team

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