Collective excitations and particle production: from static nuclei to reactions at $\overline{\text{P}}$ANDA*

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Collective excitations (CE) play a crucial role in modern nuclear and hadron physics and astrophysics. They are of great relevance for a deeper understanding of the still less known density behaviour of the isovector sector of the Equation of State (EoS) for highly asymmetric matter. Indeed, various modes of CE in finite nuclei are closely correlated to the structure of the neutron star crust, whereas high-energy CE of hadron matter produced in reactions induced by heavy-ions and hadron beams provide more information for highly compressed matter and its composition. The latter is relevant for the inner structure of a neutron star at supra-normal densities far beyond saturation. Our present studies are motivated by the new FAIR project and, in particular, they are directly connected with the forthcoming $\overline{\text{P}}$ANDAexperiments [1].

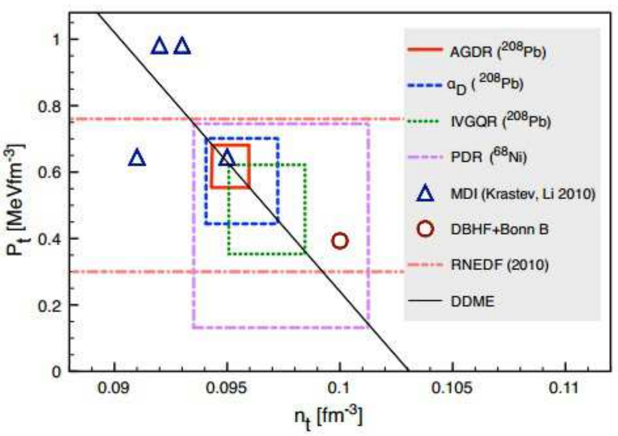

Figure 1: The liquid-to-solid transition pressure P_t for neutron-rich matter versus the transition density n_t. The various rectangles (AGDR, IVGQR, α_D, PDR) correspond to experimental constraints. The MDI, DBHF+Bonn B and the self-consistent RNEDF calculations are shown for comparison [2].

The theoretical study of CE in static finite nuclei is performed within relativistic density functional methods allowing to determine the nature of liquid-to-solid phase for neutron-rich matter. This is shown in Fig. 1, where the transition pressure versus the transition density is shown for various theoretical models: the present approach (DDME, solid line) in comparison with experimental constraints (triangle regions) and other microscopic models. This type of analyses leads to stringent constraints on the low-density thermodynamic state, relevant for the corresponding low-density region in the crust of neutron stars.

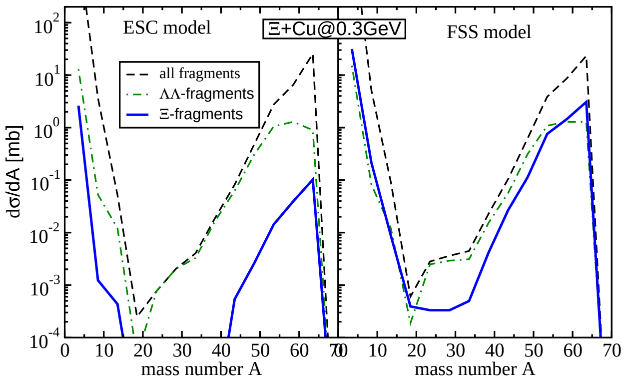

Figure 2: Production cross sections for single fragments (dashed), $\Lambda\Lambda$- (dott-dashed) and Ξ-hypernuclei (solid) versus the mass number for Ξ-induced reactions and two interaction models as indicated [3].

Furthermore, we investigate the dynamics of heavy-ion collisions and antiproton-induced reactions within the relativistic transport theory in the realization of the Giessen-BUU transport model [4]. Collective dynamics excites cold nuclear matter to phases of high compression, with the particular production of long-lived baryons (and mesons). Of importance are here particles with strangeness degree of freedom S, such as the $(\Lambda, \Sigma)(S=-1)$, $\Xi(S=-2)$ and $\Omega(S=-3)$ hyperons. Indeed, the production of multi-strangeness bound systems at conditions beyond ground state is possible. This is shown in Fig. 2 in terms of the production cross sections of single fragments, $\Lambda\Lambda$- and also Ξ-clusters versus the mass number. Here we have used reactions induced by secondary Ξ-beams as they will be available at $\overline{\text{P}}$ANDA. Of particular interest is the very strong dependence of these observables (left and right panels) on the interaction model. Hence, data of this type will serve to constrain YN and YY in-medium interactions under the dynamical conditions of high-energy heavy-ion reactions. We emphasize the relevance of our theoretical results for the future activities at FAIR.

References

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