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Bayesian inference of maximum density in central collisions and contribution to compression energy between 40 to 100 MeV/nucleon

This study introduces an innovative method for characterizing the nuclear equation of state (EOS) through the analysis of central heavy-ion collisions within the Fermi energy range. We examine experimental data from Nickel-Nickel and Xenon-Tin collisions at energies of 32–100 MeV/nucleon, collected using the INDRA 4π array at GANIL. By leveraging Artificial Intelligence (AI) and Machine Learning (ML) techniques, we enhance the precision of our analysis. Our approach features a neural-network-based reconstruction of the impact parameter, trained on HIPSE and ELIE simulations, which achieves sub-femtometer accuracy. This high precision facilitates the accurate selection of central collision events for detailed investigation.

We further employ a Bayesian inference framework to estimate in-medium nucleon-nucleon cross-sections and maximal density, drawing on probabilities derived from a comprehensive set of global observables. Our findings align with prior phenomenological studies, particularly for reactions below 100 MeV/nucleon, while the Bayesian method provides both mean values and their associated uncertainties, yielding a more robust depiction of nuclear medium effects. We also provide estimates of compression energy and freeze-out time, using experimental insights from our inference analysis. These advancements offer refined constraints on the nuclear EOS across a spectrum of densities and isospin asymmetries, enhancing our understanding of nuclear matter properties in both laboratory and astrophysical scenarios.

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