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Polarised Deuteron Breakup as a Probe of the Nuclear Symmetry Energy

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The Nuclear Equation of State (EoS) provides a fundamental link between nuclear physics and astrophysics, yet its predictive power is limited by our incomplete understanding of the nuclear symmetry energy, $E_{\mathrm{sym}}(\rho)$. This critical component, which quantifies the energy cost of proton–neutron asymmetry, is well constrained at the saturation density found in stable nuclei, but remains a major uncertainty at the sub-saturation and supra-saturation densities relevant to neutron stars. This uncertainty leads to significant discrepancies in astrophysical models, particularly those predicting the mass–radius relationship of neutron stars.

This research outlines a novel laboratory experiment designed to directly constrain the symmetry energy, reducing our reliance on rare astrophysical observations. The core of the approach is to use the Improved Quantum Molecular Dynamics (ImQMD) framework to model the peripheral collision of a polarised deuteron with a heavy, neutron-rich target. The isovector force - a component of the strong nuclear interaction that distinguishes between protons and neutrons - acts attractively on the deuteron's proton and repulsively on its neutron. These opposing forces cause the two nucleons to scatter at different angles.

The resulting difference in scattering angle serves as a highly sensitive probe of the symmetry energy's "stiffness", a property parameterised by the variable γ in the model. By measuring the differential cross-sections of the outgoing protons and neutrons in an experiment conducted at RIKEN's Radioactive Isotope Beam Factory (RIBF) using the SAMURAI spectrometer, the data can be compared to a library of ImQMD simulations. This comparison enables the determination of the γ value that best fits the experimental results, providing a new and precise constraint on the nuclear symmetry energy —and ultimately refining our understanding of nuclear matter, from the laboratory to the cosmos.

Research field of your presentation

Experimental Low-energy nuclear physics

Authors: Mr TIAN, Baiting (Department of Physics, Tsinghua University); Dr ISOBE, Tadaaki (RIKEN Nishina Center); Prof. XIAO, Zhigang (Department of Physics, Tsinghua University); LUO, Zichen (Department of Physics, Tsinghua University)

Presenter: LUO, Zichen (Department of Physics, Tsinghua University)

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