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Constraining The Symmetry Energy (Far) Above Saturation Density Using Elliptic Flow

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Using a quantum molecular dynamics type transport model coupled to a phase-space coalescence algorithm to determine final spectra of intermediate energy heavy-ion collisions it has been shown that the elliptic flow ratios of neutrons-to-protons and neutrons-to-hydrogen probe, on average, different density regimes of the compressed nuclear matter created in such reactions [1]. This fact is used to study the density dependence of the symmetry energy around twice saturation density by extracting constraints for the slope L and curvature Ksym parameters at saturation using the mentioned observables [2]. To that end, the Gogny type parametrization of the nuclear matter equation of state [3] is extended by the introduction of an extra term that allows independent adjustments of the values of the L and Ksym parameters and without affecting the value of the isovector nucleon mass splitting. The momentum dependent part is modified to agree with the empirical energy dependence of the nucleon optical potential. Constraints of the value of the symmetry energy at particular sub-saturation density values, extracted from nuclear structure experimental data, are accounted for [4]. Values for the slope and curvature parameters are determined from a comparison with experimental data for elliptic flow ratios in 197Au+197Au collisions at an impact energy of 400 MeV/nucleon due to the FOPI-LAND [5,6] and ASYEOS [1] Collaborations: L=50±20 MeV and Ksym=150±300 MeV. The magnitude of the residual model dependence due to elastic cross-sections parametrizations, value of the isovector mass splitting and scenario chosen for the conservation of the total energy of the system [7,8] is investigated. The results are compatible with a stiffer density dependence of the symmetry
energy than the one advanced by studies that limit themselves to the extraction of constraints only for the slope parameter L and may offer a simple resolution of the hyperon puzzle. The sizable uncertainties that plague the extrapolation of our result in the 3-4rho0 density region will need to be substantially reduced before a final conclusion on this problem can be drawn. Experimental measurements of elliptic flow observables that are in the planning phase at GSI (Darmstadt) will provide such an opportunity in the near future.

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