Measurement of Nuclear Responses for the Study of Nuclear Matter Equation of State

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Nuclear spin-isospin responses of are of fundamental importance for the study of nuclear equation of state (EOS). The symmetry energy term of the EOS is relevant to the size, structure and dynamic properties of neutron stars and various astrophysical simulations, e.g. neutron star cooling, X-ray burst, supernova, neutron star merger and nucleosynthesis. Even at and below the saturation density the symmetry energy parameter is poorly known. The first order density dependence of the symmetry energy, called slope parameter, is of particular interest since it is directly related to the baryonic pressure in the neutron star. The symmetry energy can be studied by precisely measuring the proton and neutron density distributions or the difference between the proton and neutron radii in neutron rich nuclei like $^{208}$Pb. The experimental data have, however, large uncertainty. As an alternative method, we have precisely determined the electric dipole response of $^{208}$Pb and $^{120}$Sn by measuring electromagnetic excitation via proton inelastic scattering at very forward angles [1,2]. The experiment has been carried out at the Research Center for Nuclear Physics, Osaka University employing a 295 MeV polarized proton beam, accelerated by cascade cyclotrons, and the high-resolution spectrometer Grand Raiden. The nuclear dipole polarizabilities of $^{208}$Pb and $^{120}$Sn have been determined as $20.1(6)$ and $8.93(36)$ fm$^3$, respectively, by applying the inversely-energy weighted sum-rule of the measured $E1$ reduced transition probabilities. The constraints on the symmetry energy parameters have been extracted with a help of mean field calculations of the nuclear energy density functional approach [3,4]. The results are quite consistent between the measured two nuclei as well as with the recent measurement on the unstable $^{68}$Ni nucleus at GSI [5].

The spin-M1 responses of self-conjugate even-even nuclei in the sd-shell have been studied with the similar proton scattering measurement at very forward angles [6]. The difference of quenching between the isoscalar and isovector excitations and the attempt to extract the magnetic property of the nuclear EOS, spin magnetic polarizability (susceptibility), will also be discussed.