Neutron Skin Thickness of ^{208}Pb and Constraints on Symmetry Energy

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The symmetry energy term of the nuclear equation of state (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, 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 a neutron rich matter [1].

The nuclear EOS 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, *e.g.* $^{208}\mathrm{Pb}$. The proton density distribution of $^{208}\mathrm{Pb}$ was well determined by electron scattering experiments. The neutron radius has been studied by proton elastic scattering [2], anti-protonic atom X-ray [3], and parity-violating asymmetry in electron scattering [4]. The experimental data have, however, large uncertainty due to model-dependence of the strong interaction (the former two), and statistical uncertainty (the last).

As an alternative method, we have precisely determined the electric dipole ($E1$) response of $^{208}\mathrm{Pb}$ by using electromagnetic excitation via proton inelastic scattering at very forward angles. 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 high-resolution spectrometer *Grand Raiden*. The details can be found in publications [5]. The nuclear dipole polarizability of $^{208}\mathrm{Pb}$ has been determined as α_D=20.1(6) fm$^3/e^2$ by inversely-energy weighted sum-rule of the measured $E1$ reduced transition probability combining with existing data. The dipole polarizability is closely correlated with the neutron skin thickness: difference between the proton and neutron radii [6]. With help of mean-field calculations, the neutron skin thickness of $^{208}\mathrm{Pb}$ has been determined as 0.168(22) fm including the model-uncertainty [7]. This result constrains the slope parameter as $L = 46 \pm 15$ MeV. The allowed region of L is small. Reasonably consistent values are reported from other experimental methods [1], theoretical predictions [8], and astrophysical observation [9].

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