Charge exchange spin dipole sum rule and the neutron skin thickness

K. Yako for ICHOR-SHARAQ collaboration

Department of Physics, University of Tokyo, Tokyo 113-0033, Japan

Proton and neutron distributions in nuclei are among the most fundamental issues in nuclear physics. The neutron skin thickness, defined as the difference between the root mean square (rms) radii of the proton and neutron distributions, is known to be correlated with the nuclear symmetry energy and to be related to the equation of state of the neutron matter [1, 2]. Several attempts have been made to determine neutron distributions [3, 4, 5, 6]. Nevertheless the results are model-dependent and they should be checked against one another.

We present a method for determining neutron rms radius by using the model-independent sum rule strength of charge exchange spin dipole (SD) excitations. The operators for SD transitions are defined by $\hat{S}_{\pm} = \sum_{im\mu} t^i_{\pm}\sigma^i_m r_i Y^{\mu}_1(\hat{r}_i)$ with the isospin operators $t_3 = t_z$, $t_{\pm} = t_x \pm it_y$. The model-independent sum rule is

$$S_{-} - S_{+} = \frac{9}{4\pi}\left(N\langle r^2\rangle_{\rm n} - Z\langle r^2\rangle_{\rm p}\right), \tag{1}$$

where $S_{\pm}$ are the total SD strengths. The mean square radii of the neutron and proton distributions are denoted as $\langle r^2\rangle_{\rm n}$ and $\langle r^2\rangle_{\rm p}$, respectively. The $S_{-}-S_{+}$ value was extracted from the $({\rm p,n})$ and the $({\rm n,p})$ spectra on ^{90}Zr.

The dipole components of the cross section spectra were identified by multipole decomposition analysis of the $^{90}{\rm Zr(p,n)}$ [7] and $^{90}{\rm Zr(n,p)}$ [8] data at 300 MeV. Then the SD strengths were obtained by using a proportionality relation between $B({\rm SD})$ and the cross section. Using the rms radius of the proton matter estimated from the charge radius, we obtained the neutron skin thickness of 0.07 ± 0.04 fm from Eq. (1). This value is consistent with the analysis of the proton elastic scattering [3].

We also present the status of the first physics experiment using the spectrometer SHARAQ at RIBF [10]. This beamtime is dedicated to a study of the isovector spin monopole resonance, for which the sum rule is more sensitive to the neutron skin thickness than the SD sum rule.

[1] J.M. Lattimer and M. Prakash, Science 304 (2004) 536.

[2] P. Danielewicz, Nucl. Phys. A727 (2003) 233.

[3] L. Ray et al., Phys. Rev. C 18 (1978) 1756.

[4] A. Krasznahorkay et al., Phys. Rev. Lett. 66 (1991) 1287.

[5] A. Trzcińska et al., Phys. Rev. Lett. 87 (2001) 082501.

[6] C.J. Horowitz et al., Phys. Rev. C 63 (2001) 025501.

[7] T. Wakasa et al., Phys. Rev. C 55 (1997) 2909.

[8] K. Yako et al., Phys. Lett. B615 (2005) 193.

[9] K. Yako, H. Sagawa, and H. Sakai, Phys. Rev. C 74 (2006) 051303(R).

[10] K. Miki, beamtime proposal, NP0811-SHARAQ72.