NUCLEAR MEDIUM EFFECT IN NUCLEON KNOCKOUT REACTIONS
– A trial for studying nucleon and meson mass in nuclear field –

T. Noro[a], H. Akimune[a], H. Akiyoshi[b], I. Daito[a], H. Fujimura[a], K. Hatanaka[a], F. Ihara[a], T. Ishikawa[c], M. Itoh[c], M. Kawabata[a], T. Kawabata[c], Y. Maeda[a], N. Matsuoka[a], S. Morinobu[b], M. Nakamura[c], E. Obayashi[a], A. Okihana[d], K. Sagara[b], H. Sakaguchi[c], H. Takeda[c], T. Taki[c], A. Tamii[c], K. Tamura[a], H. Yamazaki[e], H. Yoshida[a], M. Yoshimura[a], M. Yosoi[c]

[a] *Research Center for Nuclear Physics, Osaka University, Osaka 567, Japan*
[b] *Department of Physics, Kyushu University, Fukuoka 812, Japan*
[c] *Department of Physics, Kyoto University, Kyoto 606, Japan*
[d] *Kyoto University of Education, Kyoto 600, Japan*
[e] *Laboratory of Nuclear Science, Tohoku University, Sendai 982, Japan*

Various kinds of spin observables have been measured for proton knockout reactions from $s_{1/2}$ orbits of several target nuclei aiming at studying nuclear medium effects in nucleon and meson properties through the nucleon-nucleon (NN) interactions. The experimental data suggests existence of some nuclear medium effect in the interactions in nuclear field, which is potentially caused by reduction of nucleon and meson masses.

In recent theoretical works based on the QCD framework, it is suggested that the partial restoration of chiral symmetry causes systematic reduction of nucleon and meson masses even in nuclear medium of normal density.[1] From a different point of view, a reduction of the nucleon mass, and a modification of nucleon spinor, is also proposed in the relativistic treatment of nuclei, which predicts a strong scaler field as a part of nuclear potential.[2] Such modification of nucleon and meson properties causes modification of the nucleon–nucleon (NN) interaction in nuclear field. We are studying this phenomenon through a direct comparison of p–p scattering in free space and $(p, 2p)$ reactions which correspond to p–p scattering in nuclear field.

The kinematical condition, zero-recoil condition for $s_{1/2}$-nucleon knockout, has been selected to minimize ambiguities caused by nuclear structure and reaction mechanism. Another advantage of this condition is that an *averaged density* of the reaction points can be defined and estimated by using distorted wave impulse approximations (DWIA). This averaged density varies from small values to almost a half of the saturation density, depending on target nuclei and bound orbits of knocked-out protons.[3] Thus we can study the density

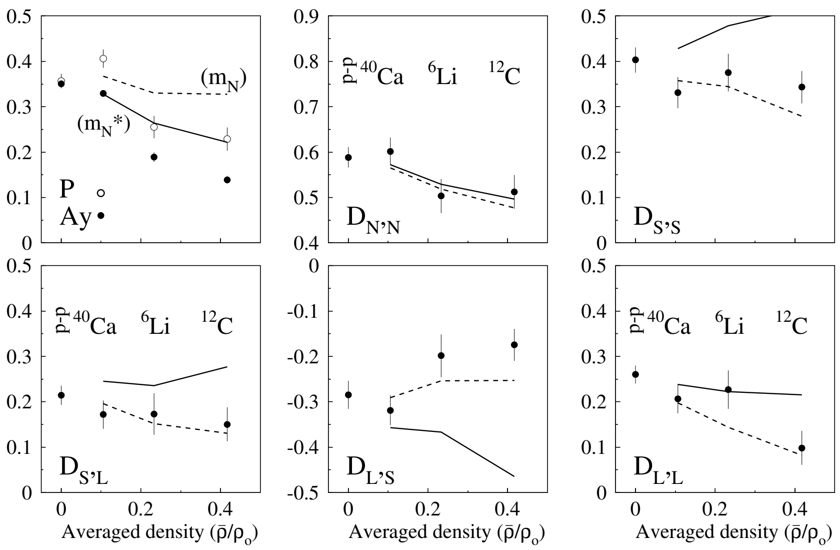

Figure 1: Various spin observables for p–p scattering and $(p, 2p)$ reactions of $1s_{1/2}$-nucleon knockout are plotted as functions of the averaged density. The dashed (solid) lines are a DWIA result with free (reduced) nucleon mass.

dependence of the NN interaction from a systematic study of this reaction.

The analyzing power (A_y), polarization (P) and all of spin transfer coefficients (D_{ij}'s), to forward outgoing protons, have been measured for three target nuclei at 392 MeV. A two-arm spectrometer system has been used to detect two outgoing protons and the detection angle of forward outgoing protons is 25.5°. The $2s_{1/2}$ orbit of ^{40}Ca and the $1s_{1/2}$ orbits of ^{6}Li and ^{12}C nuclei are selected in separation energy spectra.

The experimental results for $(p, 2p)$ reactions as well as p–p scattering are plotted in Fig. 1 as functions of the averaged density $\bar{\rho}$. The data show smooth functions of $\bar{\rho}$ with a few exceptions.

The experimental results and comparison to a DWIA calculation, which is also plotted in the figure with dashed lines, are summarized as;

- A_y is distinctly reduced from free p–p value as a monotonic function of the averaged density and this reduction cannot reproduced by usual DWIA calculations. This fact strongly suggests the existence of some medium effect.

- Almost all of D_{ij}'s are reduced from the free values but they are reasonably reproduced by the DWIA calculation and PWIA calculations, which are not plotted here. This shows that these reductions are results of a kinematical effect, which is caused by a finite Q–values of the reactions.

- P and A_y equality, which is required for p–p scattering because of time reversal invariance, does not hold for these (p,2p) reactions. This indicates importance off-shell effects in the NN–interaction.

From cross section data and from separation-energy spectra of these reaction, it is concluded that the concentration of multi-step processes is only a few percent and does not cause the distinct reduction of A_y and inequality of P and A_y.[4,5]

The reduction of A_y in proton quasifree scattering has been predicted as an effect of nucleon mass reduction in nuclear field and has been claimed to be an example which shows superiority of the Dirac approach [2]. Results of a DWIA calculation with this effect is also shown in the the figure and they predicts, qualitatively, the density dependent reduction of the A_y data to some extent. However, it also predicts significant enhancement in magnitude for D_{ij}, especially for $D_{S'S}$ and $D_{L'S}$, which does not observed in the experimental data. This suggests existence of an additional modification, such as modification of Lorentz invariant NN amplitudes assumed to be unchanged in the calculation, if we accept the relativistic approach which predict the A_y reduction reasonably.

This study is now being extended to measurements of the spin transfer coefficients to backward outgoing protons K_{ij}'s. These measurements, in addition to present data, form a spin complete measurement of in-medium NN scattering and the NN amplitudes in nuclear medium will be completely determined, with an assumption that the DW approximation works properly. This means, if we employ a meson exchange model of the NN interaction, we can study medium effect for each meson separately. Through such analysis, valuable information on meson properties in nuclear field will be extracted.

References

1. G. E. Brown and M. Rho, Phys. Rev. Lett. **66**, 2720 (1991).
2. C. J. Horowitz and M. J. Iqbal, Phys. Rev. **C33**,2059 (1986).
3. K. Hatanaka *et al.*, Phys. Lev. Lett. **78**, 1014 (1997).
4. T. Noro *et al.*, Nucl. Phys. **A629** (1998) 324c.
5. A.A. Cowley *et al.*, Phys. Rev. **C57** (1998) 3185.