TOTAL SPIN TRANSFER AND PARITY DECOMPOSITION IN THE CONTINUUM FOR THE ^{90}Zr(p,n) REACTION AT 295 MeV

T. Wakasa, [1] H. Sakai, H. Okamura, H. Otsu, [1] T. Nonaka, T. Ohnishi, K. Yako, K. Sekiguchi, S. Fujita, [2] T. Uesaka, [1] Y. Satou, S. Ishida,[a] N. Sakamoto,[a] M.B. Greenfield,[b] and K. Hatanaka[c]

Department of Physics, University of Tokyo, Bunkyo, Tokyo 113-0033, Japan
[a]*Institute for Chemical and Physical Research (RIKEN), Wako, Saitama 351-0198, Japan*
[b]*International Christian University (ICU), Mitaka, Tokyo 181-8585, Japan*
[c]*Research Center for Nuclear Physics (RCNP), Ibaraki, Osaka 567-0047, Japan*

The central interest in the so-called *quenching* of the total Gamow-Teller (GT) strength is the amount of GT strength in the continuum region beyond the GTGR. Clearly, an understanding of the spin-parity composition in the continuum is of special relevance for the GT quenching problem. One important means of studying the strength distribution of spin-flip excitations is the measurement and interpretation of polarization transfer (PT) observables.

In the present study we report measurements of a complete set of PT observables for the ^{90}Zr(p,n) reaction at $T_p = 295$ MeV and $\theta_{\rm lab} = 0^\circ$. The top and middle panels of Fig. 1 show the double differential cross section and the total spin transfer $\Sigma(0^\circ)$ defined as $\Sigma(0^\circ) = [3 - \sum D_{ii}(0^\circ)]/4$ as a function of excitation energy. It should be noted that $\Sigma(0^\circ)$ value takes a distinctive value either 0 ($\Delta S = 0$) or 1 ($\Delta S = 1$) without depending on the effective nucleon-nucleon interaction and distortion effects [1]. The isobaric analog state (IAS) transition, which has a theoretical $\Sigma(0^\circ)$ value of 0, is responsible for the dip in the measured $\Sigma(0^\circ)$ value at $E_x \simeq 5$ MeV. It should be noted that the $\Sigma(0^\circ)$ values in the continuum are almost independent of excitation energy and take values larger than 0.86 up to 50 MeV excitation indicating the predominance of spin-flip strength. The averaged $\Sigma(0^\circ)$ value in the GTGR region (6 MeV $\leq E_x <$ 16 MeV) is found to be 0.99 ± 0.01.

The continuum cross section beyond the GTGR is the result of excitations proceeding through various ΔL transfers. Both natural-parity and unnatural-parity transitions are possible for $\Delta L \geq 1$, and natural-parity transitions contribute to $\Delta S = 1$ as well as to $\Delta S = 0$ strength. Two unique PT observables, $D_{NN}(0^\circ)$ and $D_{LL}(0^\circ)$, are not independent but are related by $D_{NN}(0^\circ) = \pm[1 + D_{LL}(0^\circ)]/2$ where plus and minus signs apply for natural-parity and unnatural-parity transitions, respectively [2]. Thus the fractions of natural-parity and unnatural-parity transitions (f_0 and f_1) in the continuum region can be obtained by using this relation.

The bottom panel of Fig. 1 represents the obtained f_1 values. A prominent reduction of f_1 from unity at $E_x \simeq 5$ MeV is due to the contribution from the natural-parity IAS transition. The averaged f_1 value in the GTGR region becomes 0.93 ± 0.03, which is consistent with the preceeding result for $\Sigma(0^\circ)$ indicating the predominance of spin-flip strength.

In our previous MD analysis of Ref. [3] (denoted as MDA-I), we have grouped all ΔJ^π transitions to the lowest ΔL values, and have decomposed continuum cross sections into the

[1]Present address: The Institute of Physical and Chemical Research, Wako, Saitama 351-0198, Japan.
[2]Present address: Power Reactor and Nuclear Fuel Development Corporation, O-arai, Ibaraki 311-1393, Japan.

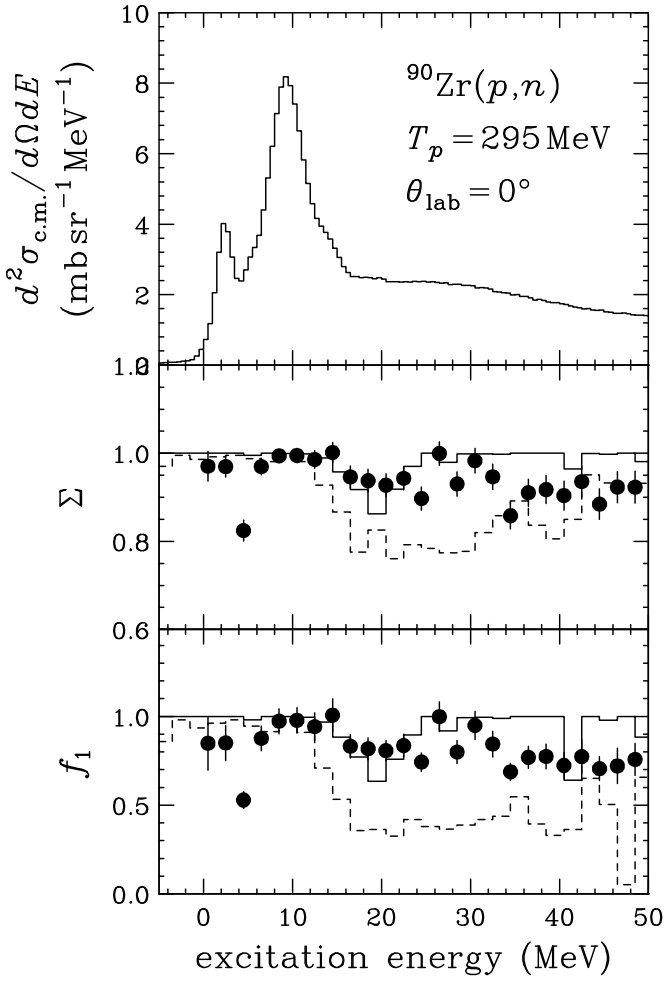

Figure 1: The double differential cross section (top panel), the total spin transfer Σ (middle panel), and the ratio of unnatural-parity transitions f_1 (bottom panel) for the ^{90}Zr(p,n) reaction at $T_p = 295$ MeV and $\theta_{\rm lab} = 0°$. The experimental values are shown by the filled circles. The error bars represent statistical uncertainties only. The solid and dashed histograms correspond to the calculations by using the results of MDA-I and MDA-II, respectively. See text for details.

following ΔL transfers: $\Delta L = 0$ ($\Delta J^\pi = 1^+$); $\Delta L = 1$ ($\Delta J^\pi = 0^-$, 1^-, and 2^-); $\Delta L = 2$ ($\Delta J^\pi = 3^+$); and $\Delta L = 3$ ($\Delta J^\pi = 4^-$). The ΔJ^π states for $\Delta L \geq 2$ are restricted into *unnatural-parity* states due to the meaningful numbers of parameters in the analysis. It is interesting to see whether or not the results of MDA-I can reproduce the present observables. Here we would like to focus our discussions on the $\Sigma(0°)$ and f_1 values since they are independent of the various ambiguities. The $\Sigma(0°)$ and f_1 values deduced from the results of MDA-I are shown in Fig. 1 by the solid histograms. The uncertainties of the calculated values originating from the uncertainties of the results of MDA-I are in the range from 1–7%. The calculations are successful in reproducing all of the experimental values up to 30 MeV excitation. In the region beyond 30 MeV excitation, however, the difference between the experimental and calculated values becomes large for both values. This deviation might be explained by the contribution from natural-parity transitions for $\Delta L \geq 2$ which has not been included in MDA-I. Thus we have performed the MD analysis (denoted as MDA-II) with the restriction of the ΔJ^π states into *natural-parity* transitions for $\Delta L \geq 2$, namely $\Delta J^\pi = 2^+$ and 3^-, and have deduced the $\Sigma(0°)$ and f_1 values. The results are shown by the dashed histograms in Fig. 1. Note that both values beyond the GTGR region ($E_x \geq 16$ MeV) become significantly small compared with the experimental values. At high excitation region around 40 MeV excitation, however, the $\Sigma(0°)$ values deduced from the results of MDA-II agree fairly well with the experimental values. This fact suggests the importance of natural-parity transitions in this region.

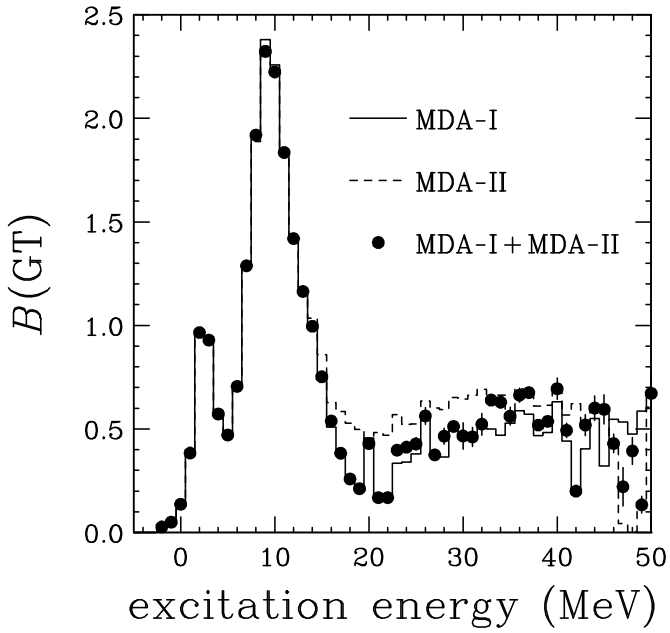

Figure 2: Gamow-Teller strength distribution obtained from the 0° $\Delta L = 0$ cross section which is deduced from the MD analysis. The solid histogram represents the GT strength deduced from the results of MDA-I, and the dashed histogram represent the GT strength deduced from the results of MDA-II. The filled circles show the calculation by using a combination of the results of MDA-I and MDA-II reproducing the $\Sigma(0°)$ values. See text for details.

Almost all of the experimental $\Sigma(0°)$ and f_1 values are located between the values deduced from the results of MDA-I and MDA-II. Thus one can make a combination of the results of MDA-I and MDA-II to reproduce either $\Sigma(0°)$ or f_1 values, or both of them. It is interesting to see the effect of this combination to the GT strength $B(\mathrm{GT})$ deduced from the $\Delta L = 0$ contribution in the MD analysis. The $B(\mathrm{GT})$ values deduced from the results of MDA-I and MDA-II are shown in Fig. 2 by the solid and dashed histograms, respectively. We have calculated the $B(\mathrm{GT})$ values by using a combination of these results to reproduce the $\Sigma(0°)$ values, and the results are shown by the filled circles in Fig. 2. Note that there is almost no difference in $B(\mathrm{GT})$ when the combination is done to reproduce the f_1 values. In other word we can reproduce $\Sigma(0°)$ and f_1 simultaneously. The total GT strength thus obtained becomes $S_{\beta^-} = 34.4 \pm 0.6$ after summing over the region up to 50 MeV excitation. Note that the present S_{β^-} value contains the contribution from the isovector spin-monopole strength which has been estimated to be 6.2 [3]. The S_{β^-} value deduced from the results of MDA-I in the previous study without using the $\Sigma(0°)$ and f_1 information is $S_{\beta^-} = 34.2 \pm 1.6$ which is almost identical to the present value.

References

[1] T. Suzuki, Prog. Theor. Phys. **86**, 1129 (1991).

[2] T. N. Taddeucci, in *Proceedings of the International Conference on Spin and Isospin in Nuclear Interactions, Telluride, Colorado, 1991*, edited by Scott W. Wissink, Charles D. Goodman, and George E. Walker (Plenum Press, New York, 1991), p. 393.

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