Determination of the Gamow-Teller quenching factor via the ^{90}Zr(n,p) reaction at 293 MeV

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Gamow-Teller (GT) resonances have been extensively studied since its discovery in 1975. The GT transition involves the operator $\sigma\tau$ and is characterized as spin-flip ($\Delta S = 1$), isospin-flip ($\Delta T = 1$) and no transfer of orbital angular momentum ($\Delta L = 0$). There exists a model-independent sum rule, $S_{\beta^-} - S_{\beta^+} = 3(N - Z)$, where S_{β^-} and S_{β^+} are the GT strength of β^- and β^+ types, respectively [1]. Surprisingly, however, only a half of the GT sum rule value was identified from the (p,n) measurement on targets throughout the periodic table [2]. This problem, so-called the quenching of the GT strengths, has been one of the most interesting phenomena in nuclear physics because it is related to non-nucleonic (Δ-isobar) degrees of freedom in nuclei; the quenching factor sets a strong constraint on the Landau-Migdal parameters, g'_{NN} and $g'_{\mathrm{N}\Delta}$, in the π+ρ+g' model [3].

Recently, Wakasa *et al.* have measured the angular distribution of the double differential cross sections for the ^{90}Zr(p,n) reaction at 295 MeV. By performing multipole decomposition (MD) analysis, the GT strengths of $S_{\beta^-} = 28.0 \pm 1.6$ has been obtained in the continuum up to 50 MeV excitation in ^{90}Nb [4]. Determination of the Δ-isobar contribution to the GT sum rule, however, requires precise (n,p) cross section data at the same energy. For this purpose we have measured the double differential cross sections for the ^{90}Zr$(n,p)^{90}$Y reaction at 293 MeV.

The measurement was performed at the (n,p) facility which had been newly constructed in the WS experimental hall at RCNP. Figure 1 shows a schematic layout of the (n,p) facility. A nearly mono-energetic neutron beam was produced by the ^{7}Li(p,n) reaction at 295 MeV. The primary proton beam, after going through the ^{7}Li target, was bent away by 23° by the clearing magnet [5] to a beam dump in the floor. The typical intensity of the beam was 450 nA and the thickness of the ^{7}Li target was 320 mg/cm^2. About 2×10^6/sec neutrons bombarded the target area of $30^W \times 20^H$ mm^2 downstream by 95 cm from the ^{7}Li target. Three ^{90}Zr targets with thicknesses of 200–400 mg/cm^2 and a polyethylene (CH_2) target with a thickness of 46 mg/cm^2 were mounted in a multiwire drift chamber (tar-

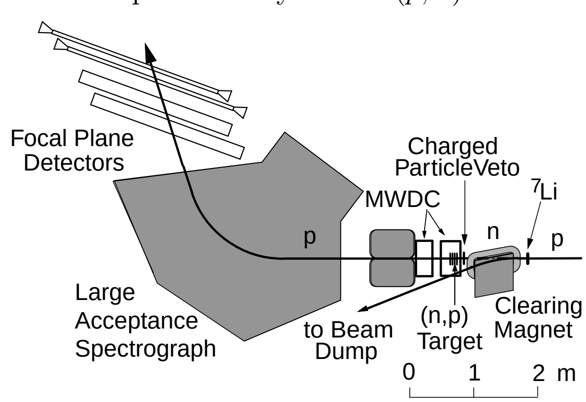

Figure 1: A schematic drawing of the (n,p) facility.

get MWDC). Wire planes placed between the targets detected outgoing protons and enabled one to determine the target in which a reaction occurred. Charged particles coming from the beam line were rejected by the veto scintillator with a thickness of 1 mm. The $^1\mathrm{H}(n,p)$ events from the $\mathrm{CH_2}$ target were used for normalization of the neutron beam flux. The position of outgoing protons were detected by six wire planes installed just behind the targets in the target MWDC. Another MWDC, front end MWDC, was installed at the entrance of the Large Acceptance Spectrometer (LAS). The scattering angle of the (n,p) reaction was determined by the information from the two MWDCs. The outgoing protons were momentum analyzed by LAS and were detected by the focal plane detectors. Blank target data were also taken for background subtraction.

We have obtained the differential cross sections up to 70 MeV excitation energy over an angular range of 0°–12° with a statistical accuracy of 1.7%/2 MeV·1° at 1°–2°. The overall energy resolution expected from the target thicknesses and the energy spread of the beam is 1.5 MeV. The angular resolution is 10 mr which is dominated by the the effect of multi scattering in the $^{90}\mathrm{Zr}$ targets.

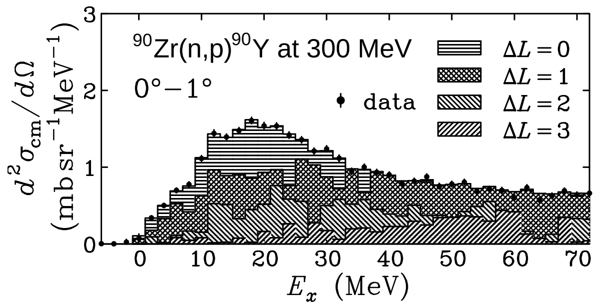

Figure 2: The result of MD analysis on the double differential cross sections for the $^{90}\mathrm{Zr}(n,p)^{90}\mathrm{Y}$ reaction at 293 MeV.

The MD analysis has been performed on the excitation energy spectra to extract the GT strengths. Figure 3 shows the result of the MD analysis in 2-MeV bins. The $\Delta L = 0$ component has a broad (~ 10 MeV in FWHM) bump at $E_x \simeq 20$ MeV mainly due to the isovector spin monopole (IVSM) resonance [6], which is excited through the $r^2\sigma\tau$ operator. The contribution of the IVSM is estimated by the distorted wave impulse approximation calculations in which all the IVSM strengths are assumed to lie below 31 MeV excitation. We have obtained the GT strengths from $\sigma_{\Delta L=0}(q,\omega) = \hat{\sigma}_{\mathrm{GT}} F(q,\omega) B(\mathrm{GT})$, where $\hat{\sigma}_{\mathrm{GT}}$ is the GT unit cross section and $F(q,\omega)$ is the kinematical correction factor [7]. After subtracting the IVSM contribution of 2.4 ± 0.8 GT units, we have obtained a total GT strength of $S_{\beta+} = 3.0 \pm 0.3 \pm 0.8 \pm 0.5$ up to 31.4 MeV excitation where the errors are uncertainties of the MD analysis, the IVSM contribution, and the GT unit cross section.

By using the $S_{\beta-}$ value by Wakasa *et al.* the quenching factor Q, which is defined by $Q \equiv \dfrac{S_{\beta-} - S_{\beta+}}{3(N-Z)}$, has been deduced to be $Q = 0.83 \pm 0.06$ in regard to Ikeda's sum rule value of $3(N-Z) = 30$. Therefore the quenching of the GT strength due to the $\Delta\mathrm{N}^{-1}$ admixture into the $1p1h$ GT state is significantly smaller than the quenching of $\sim 50\%$, observed in the previous studies [2] where the GT strengths in the continuum are not taken into account. Then the Landau-Migdal parameters, $g'_{\mathrm{N\Delta}}$ and g'_{NN}, have been determined from the quenching factor. The deduction by Suzuki and Sakai [3] in Chew-Low model leads to $g'_{\mathrm{NN}} \approx 0.6$ and $0.16 < g'_{\mathrm{N\Delta}} < 0.35$ for $g'_{\Delta\Delta} = 0.6$. Therefore the universality ansatz of the Landau-Migdal parameters, *i.e.* $g'_{\mathrm{NN}} = g'_{\mathrm{N\Delta}} = g'_{\Delta\Delta} (= 0.6 \sim 0.8)$, does not hold.

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