# Precise determination of Gamow-Teller unit cross sections for the (p,n) reactions at 200 and 300 MeV

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Charge exchange reactions are powerful tools in the study of GT excitations because they can see the GT transition strength, $B(\mathrm{GT})$, in the excitation energy region inaccessible to the beta decay. In 1987, Taddeucci *et al.* [1] established a proportionality relation between $B(\mathrm{GT})$ and a differential cross section of the $(p,n)$ reaction at 0 degrees, $\frac{d\sigma}{d\Omega} = \hat{\sigma}_{\mathrm{GT}} F(q,\omega) B(\mathrm{GT})$. Here, $\frac{d\sigma}{d\Omega}$ is the differential cross sections at 0 degrees, $F(q,\omega)$ is a kinematic correction factor and $\hat{\sigma}_{\mathrm{GT}}$ is the proportionality constant, so-called GT unit cross section. Although the GT cross sections in the $(p,n)$ spectra at $0^\circ$ are most prominent at incident energies around 200 to 300 MeV due to the energy dependence of the effective interaction, few $\hat{\sigma}_{\mathrm{GT}}$ values have been derived at energies higher than 160 MeV. Therefore, we determined the $\hat{\sigma}_{\mathrm{GT}}$ values as following.

The $(p,n)$ measurements at 200 and 300 MeV were performed at the neutron time-of-flight (NTOF) facility [2] at RCNP. The scattered neutrons were detected by a newly developed neutron detection system, NPOL3, with a high time resolution of about 200 psec [3]. Enriched $^{58}$Ni, $^{70}$Zn, $^{118}$Sn and $^{120}$Sn targets were used. The thicknesses of the targets were 99 mg/cm$^2$, 9.3 mg/cm$^2$, 100 mg/cm$^2$ and 160 mg/cm$^2$ respectively. In order to determine the neutron detection efficiency of NPOL3, an enriched $^7$Li target with a thickness of 2.617 mm was used.

Figure 1 shows the obtained double differential cross section spectrum for the $^{58}\mathrm{Ni}(p,n)^{58}\mathrm{Cu}(0^\circ)$ reaction at 300 MeV. The differential cross section to the ground $1^+$ state was derived by peak fitting using the peak positions of excited states reported by a $(^3\mathrm{He},t)$ measurement [4] as shown in Fig. 2. From the obtained differential cross section and $B(\mathrm{GT})$ measured by beta decay experiments, the $\hat{\sigma}_{\mathrm{GT}}$ value was obtained. The $\hat{\sigma}_{\mathrm{GT}}$ values of $^{70}$Zn, $^{118}$Sn and $^{120}$Sn were similarly obtained. The obtained values are shown as a function of the nuclear mass number, $A$, in Fig. 3 and 4. The error bar of each data point is the quadratic sum of the statistical and systematic error. The systematic errors are due to the errors of the $B(\mathrm{GT})$ values, the target thicknesses and the neutron detection efficiency. The $A$-dependences of $\hat{\sigma}_{\mathrm{GT}}$ were derived in a mass region of $50 < A < 130$ at 200 and 300 MeV. Here, we assumed that $\hat{\sigma}_{\mathrm{GT}}$ is proportional to $\exp(-x \times A^{1/3})$ neglecting the effects of the detailed structures of individual nuclei.

The $A$-dependences have consequences for the results of some other experiments. Yako *et al.* have derived a GT quenching factor [5] of $Q = 0.88 \pm 0.03$ with a systematic uncertainty

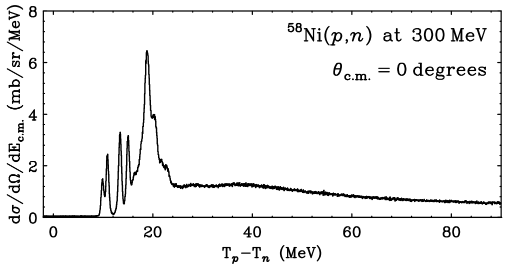


Figure 1: Double differential cross sections for the $^{58}$Ni$(p,n)$ reactions at 300 MeV.

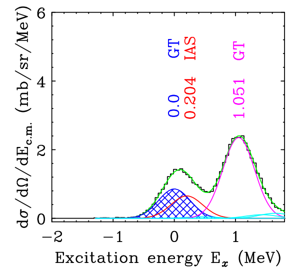


Figure 2: Peak fitting of the $^{58}$Ni$(p,n)$ spectrum at 300 MeV.

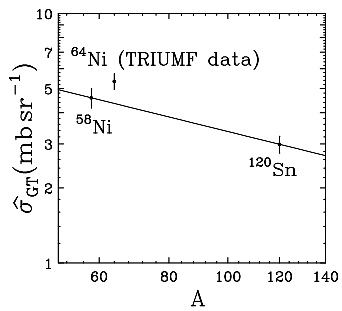


Figure 3: The $\hat{\sigma}_{\rm GT}$ values as a function of the mass number, $A$, at 200 MeV.

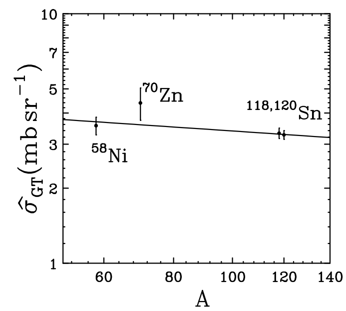


Figure 4: The $\hat{\sigma}_{\rm GT}$ values as a function of the mass number, $A$, at 300 MeV.

of 16% due to $\hat{\sigma}_{\rm GT}$. If the $\hat{\sigma}_{\rm GT}$ value of $3.45 \pm 0.12$ mb/sr deduced from the $A$-dependence is used, the quenching factor remains the same, but with much smaller uncertainty of 4%.

Using the $A$-dependence at 200 MeV, the $\hat{\sigma}_{GT}$ value of *fp*-shell nuclei at 200 MeV was deduced as $4.36 \pm 0.34$ mb/sr. This value is smaller by about 20% than that used in Ref. [6]. This reduction increases the $B$(GT) values of electron capture processes in *fp*-shell nuclei and it may give a key effect to the super nova explosion phenomena [7].

A significant difference was also observed between the $B$(GT) values obtained by the $(p,n)$ and $(^3\text{He},t)$ reactions. The $B$(GT) ratios for the GT transition of $^{58}$Cu$(gnd)$ to $^{58}$Cu(1.051 MeV) are $2.62 \pm 0.23$ and $2.74 \pm 0.25$ by the $(p,n)$ reaction at 200 and 300 MeV, respectively. Both ratios are consistent with each other within errors. On the other hand, the ratio reported by the $(^3\text{He},t)$ measurement at 150 MeV per nucleon [4] is $1.71 \pm 0.08$ which is significantly smaller than those of the $(p,n)$ measurements. This discrepancy between these reactions may cast a serious question on the proportionality relation between $B$(GT) and $\frac{d\sigma}{d\Omega(0^\circ)}$.

# References


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