

THE (p,n) MEASUREMENTS FOR SPECTRA CONTAINING GT
STRENGTH KNOWN FROM β DECAY

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The complementarity between beta decay and nucleon charge exchange has provided an exceedingly useful tool for the exploration of nuclear structure and for the quantitative determination of certain parts of the nucleon-nucleus interaction. In a simple sense both processes induce the same nuclear transitions. The relationship between beta decay transition rates and nuclear structure overlap matrix elements is well understood and can be calculated precisely. On the other hand the nucleon charge-exchange interaction is not well understood and transition rates cannot be calculated precisely even when the structure overlap matrix elements are known. Nevertheless, with the combined use of both processes considerable progress can be made in furthering our understanding of nuclear structure and interactions. Furthermore, the (p,n) reaction when appropriately calibrated against beta decay can be used to measure Gamow-Teller transition rates inaccessible to beta decay including transitions needed to calibrate neutrino detectors.

Isobaric analog state (IAS) transitions provide important calibration points. It is believed that the conserved vector current (CVC) hypothesis applies here, and that for all nuclei with excess neutrons the ground state isospin is the lowest possible consistent with the neutron excess. All the Fermi strength is contained in the IAS transition, and the overlap matrix element is simply equal to the neutron excess. These points have been verified through beta-decay studies to better precision than we can achieve with reaction measurements and corrections are of the order of a percent or less.

The IAS transition can be seen in all (p,n) spectra and is potentially the best calibration point available. For a 0^+ target it can be used to calibrate the spectrum for Gamow-Teller transitions to the precision with which the ratio of GT/F strength is known. For a target with spin greater than zero there is an additional complication in that the GT content of the IAS transition might not be known.

Much of what is already known about the specific GT and F cross sections, $\hat{\sigma}_{GT} = \sigma_{GT}/B(GT)$, and $\hat{\sigma}_F = \sigma_F/B(F)$ has been reported in the literature.¹ The purpose of IUCF Experiment 320 is to extend to higher mass and to greater precision the (p,n) measurements for spectra containing GT strength known from beta decay. In particular, the value of the parameter $R^2 = \hat{\sigma}_{GT}/\hat{\sigma}_F$ extracted from the new data will be compared to a value that describes a body of data for light nuclei, namely $R = E_p/E_0$, where $E_0 = 55$ MeV.¹

The experiments were carried out using the IUCF beam swinger and a flight path of 120 m. Measurements were made at 120 and 160 MeV. Twelve neutron detectors, each with a volume of 0.015 m^3 , were oriented parallel to the flight path. This orientation yields better energy resolution than transverse orientation because the position resolution of 2-3 cm is much less than the 10 cm thickness of the detectors. The overall energy resolutions at 120 and 160 MeV respectively were 250 and 300 keV. These include contributions from the beam energy spread, the beam bunch time width, and the target thickness added to the detector resolution. The stripper loop was used to achieve a pulse separation of three microseconds. This eliminates wrap-around background.

The calibration targets which provide transitions with known GT strength are ^{51}V , ^{87}Rb , ^{113}In , ^{118}Sn , and ^{141}Pr . The (p,n) cross sections are measured at 0, 3.0 and 6.0 degrees at energies of 120 and 160 MeV. The measurements of the angular distributions (near zero degrees) of the (p,n) cross sections are important in the evaluation of the ratio of the specific cross sections, $\hat{\sigma}_{GT}/\hat{\sigma}_F$, especially in odd-mass cases. The $\sigma(\theta)$ can be used to estimate the contribution of $L > 0$ components at zero degrees in the GT transitions in an odd-mass nucleus, where the spin of the initial and final states both are non-zero. From measured $\sigma(\theta)$, one also knows the cross sections vs momentum transfer q . This is important in the evaluation of the specific cross section, $\hat{\sigma}_F$, for IAS transition, where a correction for the momentum transfer is needed. For the targets studied here the momentum transfers, q , are quite different for the IAS and GT transition, since the IAS is a highly excited state, while the GT state is located near the ground state or is the ground state. The correction to the cross sections for the momentum transfer differences is as high as 20% for some of these nuclei. The measured dependence of the cross section on momentum transfer, q , provides important information.

In addition we measured spectra from $^{69,71}\text{Ga}$, $^{97,98}\text{Mo}$ and ^{127}I because these nuclei are either being used or being considered as neutrino detectors. The last part of E320 was finished in April, 1990, where the (p,n) measurements were conducted at non-zero degrees as well as at zero degrees. The analysis of the data is still in process. The preliminary results of the empirical R obtained from the analysis of the data taken during 1988-1989 are listed in Table I. In Table I, $B_{p,n}(GT)$ is the B(GT) value for the transition in the (p,n) reaction deduced from β decay information. The ratio $k(F)/k(GT)$ is the correction factor for the phase space. The energy E_0 listed in last column in Table I is the ratio of the incident proton energy to the empirical R. Values of E_0 seems to be independent of the incident proton energy, and the average E_0 value for the odd-mass nuclei is lower than the value $E_0 = 55 \text{ MeV}$. However, these are preliminary results since they are based only on the zero degree spectrum and the cross sections have not been corrected for the momentum transfer.

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Table I.
Empirical Values of R

Nuclei	$B_{p,n}(\text{GT})$	B(F)	$E_p(\text{MeV})$	σ_{GT}/σ_F	k(F)/k(GT)	R	E_0^*
^{51}V	$0.0158 \pm 0.0002^a)$	5	120	0.0243 ± 0.0011	0.916	2.65 ± 0.06	45.3 ± 1.1
			160	0.0434 ± 0.0033	0.937	3.55 ± 0.14	45.1 ± 1.8
^{87}Rb	$0.0643 \pm 0.0155^b)$	13	120	0.0388 ± 0.0024	0.872	2.62 ± 0.32	45.8 ± 5.6
^{113}In	$0.0695 \pm 0.0168^c)$	15	120	0.0424 ± 0.0023	0.852	2.79 ± 0.34	43.0 ± 5.2
			160	0.0816 ± 0.0082	0.887	3.87 ± 0.50	41.3 ± 5.3
^{118}Sn	$0.349 \pm 0.010^d)$	18	120	0.130 ± 0.006	0.879	2.43 ± 0.07	49.4 ± 1.4
			160	0.214 ± 0.018	0.910	3.11 ± 0.14	51.4 ± 2.0
^{141}Pr	$0.0145 \pm 0.0003^e)$	23	160	0.0096 ± 0.0023	0.878	3.60 ± 0.43	44.4 ± 5.3

a) Ref. 2, b) Ref. 3, c) Ref. 4, d) Ref. 5 and e) Ref. 6 The B(GT) values were calculated using Eq. 1.2 in Ref. 1 and the coupling constants are those recommended by Wilkinson.⁷

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