GAMOW TELLER STRENGTH DISTRIBUTIONS VIA (p,n) AND IMPLICATIONS FOR SOLAR NEUTRINO DETECTION

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We continue to investigate (p,n) reactions on targets which have been proposed as possible solar neutrino detectors. The discrepancy between the ^{37}Cl experiment and prediction has led to many suggested remedies, including modifications of the standard solar model, neutrino oscillations in vacuum due to mixing among mass eigenstates, and oscillations enhanced by energy dependent resonant absorption processes in the sun. Resolution of this problem will likely require a careful program of solar neutrino spectroscopy which in turn will require knowledge of the neutrino capture cross section presented by each neutrino detector as a function of neutrino energy. Direct determination of this capture cross section requires quantitative information on the Gamow Teller transition strengths which connect the ground state of the detecting nucleus with all excited states up to the particle emission energy in the final nucleus. Such information can be obtained via small angle measurements of the (p,n) reaction at intermediate energies.[1]

We have published initial results of (p,n) studies on targets of ^{37}Cl, ^{98}Mo, ^{115}In, and most recently ^{71}Ga.[2-4] We have recently finished analysis of the ^{205}Tl(p,n)^{205}Pb reaction. This target has been suggested as a potential low-solar-neutrino-energy detector based primarily on the estimated capture strength associated with the first-forbidden transition to the 2.3 keV state in ^{205}Pb. However, neutrino capture into ^{205}Pb would also occur via excited GT strength. The B(GT) strength function derived from our 120 MeV (p,n) data is presented in Fig. 1. Note that in such a heavy nucleus, very little GT strength can be identified below about 5 MeV of excitation. In addition, by comparing measured 5° cross sections with an analogous first-forbidden transition of known log ft

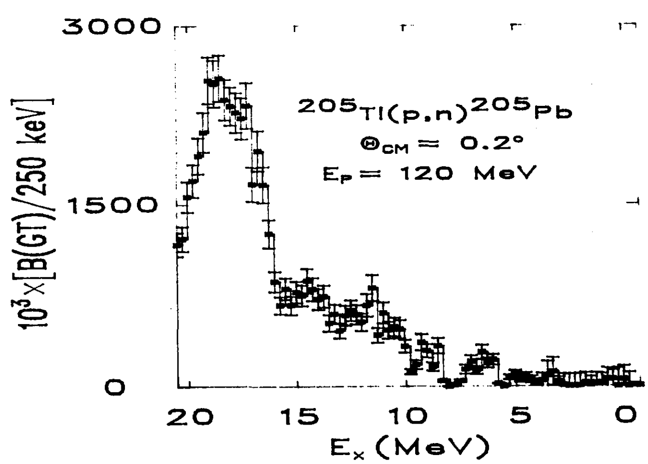

Figure 1. The GT strength distribution in ^{205}Pb derived from 0° and 5° ^{205}Tl(p,n)^{205}Pb data at E_p = 120 MeV.

in the $^{199}Hg(p,n)^{199}Tl(gs)$ reaction, we have estimated the log ft for the 2.3 keV level.

In all these previous studies, precise determination of the small concentrations of low-lying GT strength was impaired by uncertainties associated with the more intense contributions from low-energy neutrons due to previous beam bursts ("wrap-around neutrons") and from random background events. This for instance made it impossible to identify in the 0° cross section data the weakly populated, first excited state of ^{71}Ge at 175 keV of excitation for comparison with the lower energy (p,n) results of Orihara et al.[5] Related difficulties have also limited the uncertainties associated with the higher-excitation portions of the B(GT) spectrum to about ±al5% in these studies. The recent availability of the low-energy stripper loop[6] for all IUCF proton beam energies has provided a means to significantly improve this situation.

In the past year we remeasured to 0° (p,n) reactions at 120 MeV on ^{71}Ga and ^{81}Br using the stripper loop to provide beam bursts separated by about 2 μsec. This improved the ^{71}Ga data such that the first excited state can now be identified in the 0° double differential cross section spectrum, as can be seen in Fig. 2. An upper limit of 0.005 on the B(GT) value for the 175 keV state has been deduced from this recent data. The (1-σ) uncertainties associated with the B(GT) values for higher-lying excitation regions has also been reduced to about ±7%.

The ^{81}Br data have provided a number of interesting results. The predicted response of this detector is dominated by capture of ^{7}Be neutrinos into the excited state at 190 keV. The B(GT) = 0.038 ± 0.011 for this transition derived from

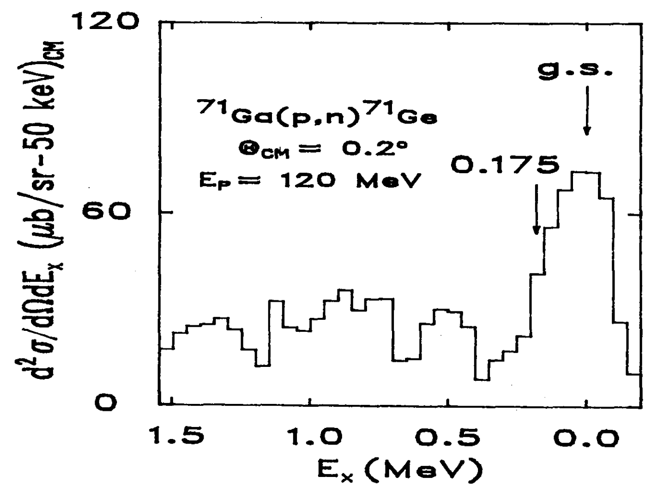

Figure 2. Center-of-mass double differential cross section for region of low excitation in the $^{71}Ga(p,n)^{71}Ge$ reaction at 0°.

our (p,n) data is significantly lower than the value obtained by Bennett et al.[7], but is consistent with more recent direct measurements of the electron capture rate from this metastable state.[8,9] In addition, however, we find that the GT strength to all final states below the particle emission threshold in ^{81}Kr contribute significantly to the capture rate of ^{8}B solar neutrinos. Assuming the fluxes of the standard solar model,[10] we find that the total response of the ^{81}Br detector would be predominantly due to neutrinos from the ^{8}B source reaction.[11]

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THE (p,n) REACTION ON CARBON ISOTOPES AT $\vec{E}_p$ = 160 MeV

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Differential cross-section and analyzing powers for the $(\vec{p},n)$ reaction on carbon isotopes have been measured for angles up to $\Theta_L = 50°$ using 160 MeV protons. An excitation energy spectra for (p,n) reactions on carbon isotopes at $\Theta_L = 0°$ is presented in Fig. 1. The angular distributions for the stronger transitions have been compared with the results of DWIA calculations which utilize transition densities from existing shell model calculations (Cohen and Kurath) and the free nucleon-nucleon interaction strength as parameterized by Franey and Love at E_p = 175 MeV. The shapes of the calculated differential cross-section distributions are in reasonable quantitative agreement with the data for $q < 1.2$ fm^{-1} and the qualitative differences in the distributions are well described even at higher q. The forward-angle cross sections for transitions with known B(GT) scale with the beta decay transition strengths, permitting the experimental determination of B(GT) for levels whose beta decay is energetically forbidden. The scale factor required for ^{13}C is different from that for $^{12,14}C$. This effect has been noted in studies of other even and odd isotopes.

The total observed B(GT) for ^{12}C is in agreement with the predictions of CKWF. For ^{13}C and ^{14}C we obtain the missing strength fractions Q_{GT} = 0.46 and 0.60 respectively, when comparing with CKWF. These results are consistent with global values of Q_{GT} presented elsewhere. The experimental and calculated