A recent high-energy inelastic proton scattering study on the even Ni isotopes reported the observation of peaks that are believed to be the $T_0$ and $T_0+1$ components of the $M1$ resonance. Here $T_0$ is the isospin of the target ground state. Motivated by this, we undertook a study of the $(p,n)$ reaction on the even Ni isotopes to excite the analogues of these states, as well as the dominant $T_0-1$ component. The $T_0$ and $T_0+1$ components are expected to be populated more weakly in general, partly as a result of isospin coupling geometry.

The measurements were performed using a 134-MeV proton beam. The $0^\circ (p,n)$ spectra for the four targets are shown in Fig. 1. The energy resolution is about 400 keV. The $^{58}$Cu spectrum is similar to those measured by Rapaport et al. at 120 and 160 MeV. The ground-state isobaric analogue state (IAS) occurs at excitations of 0.2, 2.5, 4.6, and 6.8 MeV, respectively, in $^{58,60,62,64}$Cu. By adding to the IAS energies the $T_0$ and $T_0+1$ excitation energies observed in $(p,p')$, the positions of these isospin components in the $(p,n)$ spectra can be predicted. The comparison between the predicted and observed positions is shown in Table I. Based on this comparison, we tentatively make the isospin assignments indicated in Table I to some of the $(p,n)$ peaks. The $T_0+1$ level is not observed in $^{64}$Cu, probably because it is too weak.

The remaining broad structures in the spectra, at excitations above 5.5 MeV, are given the isospin

![Figure 1. Spectra of neutrons from the $(p,n)$ reaction on $^{58,60,62,64}$Ni.](image-url)
Table I. Expected and observed energies of $T_0$ and ($T_0+1$) states in Cu isotopes.

<table>
<thead>
<tr>
<th>Nucleus</th>
<th>Energy in Parent Nucleus (MeV)</th>
<th>IAS Energy (MeV)</th>
<th>Expected Energy (MeV)</th>
<th>Observed Energy (MeV)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$T_0$</td>
<td>$T_0+1$</td>
<td>$T_0$</td>
<td>$T_0+1$</td>
</tr>
<tr>
<td>$^{58}_{\text{Cu}}$</td>
<td>8.5</td>
<td>10.7</td>
<td>8.7</td>
<td>10.9</td>
</tr>
<tr>
<td>$^{60}_{\text{Cu}}$</td>
<td>8.9</td>
<td>11.9</td>
<td>11.4</td>
<td>14.4</td>
</tr>
<tr>
<td>$^{62}_{\text{Cu}}$</td>
<td>8.8</td>
<td>14.0</td>
<td>13.4</td>
<td>18.6</td>
</tr>
<tr>
<td>$^{64}_{\text{Cu}}$</td>
<td>8.9</td>
<td>15.6</td>
<td>15.7</td>
<td>22.4</td>
</tr>
</tbody>
</table>

*From the (p,p') data of reference 1.

Assignment $T_0$-1. We emphasize that such division of the observed peaks into different isospin components is open to question, and that it is possible that there is an overlapping of Gamow-Teller (GT) strength for the different isospin components. However, inspection of the spectra indicates that the $T_0+1$ strengths in $^{60,62}_{\text{Cu}}$ and the $T_0$ strengths in $^{62,64}_{\text{Cu}}$ can be determined with reasonable precision. Moreover, shell-model calculations done by us for the $T_0$ and $T_0+1$ strength distributions in the four nuclei show that these components are non-overlapping in energy (Fig. 2). The model space used is similar to that of Ref. 2, and the modified surface delta interaction is used for the residual two-body force.

Yields were extracted using the "experimentalist's" backgrounds shown by the solid lines in Fig. 1. Angular distributions for the high-lying ($E_x>5.5$ MeV) $T_0$-1, $T_0$ and $T_0+1$ components of the GT strength in $^{58,60}_{\text{Cu}}$ are shown in Fig. 3. The solid lines are the results of microscopic DWIA calculations using the nucleon-nucleon effective interaction of Love and Franey\textsuperscript{3} and simple $f_{5/2}$ wave functions. The fits to the data are good.

Figure 2. Shell-model results for the $T_0$ and $T_0+1$ Gamow-Teller strength distributions in $^{58}_{\text{Cu}}$ and $^{60}_{\text{Cu}}$.

B(GT) values were obtained in a model-independent way by the method of Taddeucci et al.\textsuperscript{4} by considering the ratio of the $0^+$ GT and IAS cross sections. They are compared with our shell-model predictions in Fig. 4. As shown there, a uniform reduction of the theoretical values to 0.35 of the prediction is
Figure 3. Angular distributions for the high-lying GT isospin components in $^{58,60}\text{Ni}$. 

required to bring agreement between experiment and theory for the $T_0^{-1}$ and $T_0$ components for all for nuclei. For the weak $T_0^{+1}$ component, there are large fluctuations between experiment and (reduced) theory, at least partly due to the uncertainties in the extraction of the experimental values.

The determination of the amount of the GT strength in the background shown in Fig. 1 is presently in progress. When all the $L=0$ strength in the background is included, the overall "reduction factor" rises from 0.35 to 0.54. This latter value is consistent with values found for the quenching of the GT strength in other medium-weight and heavy nuclei.$^5$