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MICROSCOPIC CALCULATIONS OF THE BACKGROUND BELOW GIANT RESONANCES

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Résumé - En appliquant un modèle microscopique à 1 particule-1 trou "doorway" pour des états nucléaires excités, nous montrons que les spectres d'énergie continue des réactions d'énergie intermédiaire (p,n) en direction avant sont essentiellement un résultat des processus à un pas. Le modèle est appliqué aux réactions \(^{48}\text{Ca}(p,n)\) à une énergie incidente de 160 MeV et \(^{90}\text{Zr}(p,n)\) à 200 MeV. Dans le cas du \(^{90}\text{Zr}\) nous trouvons qu'une partie importante de la force Gamow-Teller est localisée dans la région de haute énergie d'excitation, \(15<E<50\) MeV. Il y a des indications que la force de transition du dipôle géant énergétique "spin-flip" (\(\Delta L=1, \Delta S=1, \Delta T=1\)) est réduite d'environ 50%.

Abstract - Using a microscopic 1 particle-1 hole doorway model for nuclear excited states we show that the continuous forward angle energy spectra of medium energy (p,n)-reactions are mainly a result of direct one-step processes. The model is applied to the reactions \(^{48}\text{Ca}(p,n)\) at 160 MeV and to \(^{90}\text{Zr}(p,n)\) at 200 MeV incident energy. In case of \(^{90}\text{Zr}(p,n)\) we find that a large fraction of Gamow-Teller strength is located in the high excitation energy region \(15<E<50\) MeV. There are indications that the transition strength of the spin-flip giant dipole (\(\Delta L=1, \Delta S=1, \Delta T=1\)) resonance is quenched by roughly 50%.

I - INTRODUCTION

One of the most serious problems in the analysis of giant resonance states which appear energetically in the continuum region of the nuclear excitation spectrum is the decomposition of the spectra into resonance and the underlying physical background. This is particularly true for the excitation of giant resonances by inelastic hadron scattering /1/ where the resonances are located on top of a large continuum (background) whose shape and magnitude is not known and whose nature depends on the probe used. Uncertainties in the decomposition of the spectra into resonance and background seriously limit the accuracy with which the amount of sum rule strength exhausted by the giant resonance states can be determined.

The nature of the background is especially complicated in reactions induced by projectiles (protons, deuterons, α-particles) with relatively low incident energy (energy/nucleon < 100 MeV). In this case multistep processes produce the dominant contribution (75 %) to the background cross section as has been reported by various authors /2-5/. For composite particle scattering additional difficulties arise because of the possibility of the projectile breakup combined with other reaction mechanisms /6/. The situation should be much simpler, however, for proton scattering at high incident energy (\(E > 100\) MeV) where the energy dependent projectile-target nucleon coupling potential becomes weak /7/ and the reaction mechanism therefore dominantly direct. That this supposition is, indeed, correct was recently shown by
Chiang and Hufner /8/, by Bertsch and Scholten /9/, and also by one of the present authors /10/. In the latter publication /10/ a microscopic background model was developed which allowed to calculate the continuous spectrum of high energy \((p,n)\)-spectra with an accuracy of 30%. The model is only applicable for forward angle spectra and for excitation energies which are smaller than half the incident projectile energy. To describe higher Q-value reactions \(|Q| > \frac{E_{\text{inc}}}{2}\) and large angle scattering one has to come back to the models and methods discussed in Machner's contribution /11/ to this conference.

In the resent paper we extend our studies of the background below giant resonances to the \(^{90}\text{Zr}(p,n)\) reaction at \(E_{\text{inc}} = 200\) MeV /12/. The motivation for this investigation was to determine as accurate as possible the sum rule strength exhausted by the famous giant Gamow-Teller (GT) resonance which was recently discovered in high energy \((p,n)\)-experiments /13-16/ at the Indiana University Cyclotron Facility. The GT-resonance is the spin-isospin \((\Delta S=1, \Delta T=1, \Delta L=0)\) collective mode, which was already predicted by Ikeda, Fujii and Fujita as early as 1963 /17/. The exciting thing about the GT-resonances is that only roughly 65±5% of the theoretically /17/ expected total GT-strength is found in these experiments /18,19/ (with the background subtraction as suggested in ref. 10). Several authors /20,21/ have suggested that this so-called quenching of the total GT-strength is due to the admixture of \(^{\Delta}1\Delta\text{N}\) isobar-nucleon hole \((\Delta^{	ext{N-1}})\) excitations into the proton particle-neutron hole \((\text{PN}^{-})\) GT-state. For a quantitative understanding of this \(\Delta\) isobar effect, however, it is of utmost importance to calculate the background in a most reliable way.

Recently Bertsch and Hamamoto /22/ have pointed out that a large fraction of GT-strength (more than 50% of the missing strength) could be shifted into the energy region above the GT-resonance (10 to 45 MeV excitation energy region) due to the mixing of the \(lp\) \(lp\) GT-state with energetically high-lying two particle-two hole \((2p-2h)\) configurations and that this shifted strength would produce a substantial part of the continuum background seen in the 200 MeV zero degree \(^{90}\text{Zr}(p,n)\)-spectra at high negative Q-values. In this paper we test this conjecture of Bertsch and Hamamoto /22/ in very detail by performing a detailed analysis of the \(^{90}\text{Zr}(p,n)\)-spectra using our microscopic background model. In addition, we also try to determine the background below the spin isospin giant dipole resonance \((\Delta S=1, \Delta T=1, \Delta L=1)\) in order to make a statement about the spin dependence of the quenching /21,23/. The spin dipole resonance appears energetically roughly 10 MeV above the GTR and has a width of about 10 MeV /12,16,18/. It has been interpreted as the envelope of 3 collective states with spin parity \(0^-\), \(1^-\) and \(2^-\) /12,23/. Before we discuss the results, however, we shortly describe the background model used in the calculations.

II - THE BACKGROUND MODEL

Our background model /10/ is chosen such that it describes the discrete and the continuous parts of the spectrum as consistently as possible, and that it also includes specific properties of the target nucleus like its shell structure, neutron excess, collectivity, etc., in detail. The model assumptions are as follows:

1. For \((p,p')\) and \((p,n)\) reactions at high incident energies \((E > 100\) MeV) the cross section at forward angles is dominated by direct processes as long as the excitation energy is less than half the beam energy. This assumption is supported by both experiment and theory. The \(0^2\)-cross sections of the 200 MeV \((p,n)\)-data of Gaarde et al. /12/, for instance, show a characteristic falling off with increasing excitation energy. Large contributions of multistep processes, however, should instead lead to a rise in cross section with increasing excitation energy due to the greater number
of intermediate states possible for higher energy losses. Calculations of multistep reaction cross sections by Chiang and Hüfner /8/ show that the forward angle cross sections in high energy \((p,p')\) reactions are largely due to 1 step processes. Last but not least, also our own model calculations should prove or disprove this assumption.

(2) The effective projectile-target nucleon interaction can be approximated by the free N-N t-matrix, i.e. by the G3Y-interaction of Love and Franey /7/.

(3) The only nuclear states contributing to the \((p,n)\)-background at \(E > 100\) MeV are spin flip \((\Delta S=1, \Delta T=1)\) states. This argument is based on the fact that the \(\sigma\pi\pi\)-part of the G3Y-interaction which excites spin flip states is nearly energy independent while the \(\pi\pi\)-part which excites the non-spin-flip states gets strongly reduced at \(E > 100\) MeV /7/.

(4) The final nuclear states are assumed to be of simple proton particle-neutron hole doorway nature including bound, quasibound and continuum states (see Fig. 1). The single particle wave functions of the bound and continuum states are generated from a Woods-Saxon potential which is chosen to reproduce the known experimental single particle energies. The proton particle and neutron hole are coupled to states of spin parity \(J^\pi\). This is advantageous since to \(0^+\) cross sections only states with low multipolarity can contribute. Furthermore, by this procedure we obtain the contributions to the background due to different final nucleus spins \(J^\pi\) separately. This gives us the possibility to treat the nuclear structure of states with differ-

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**Fig. 1** - Schematic representation of the microscopic model used for the background calculations. In the figure \(e_F\) denotes the Fermi energy, \(E_s\) the nucleon separation energy, and \(E_p\) the incident projectile energy. For the effective projectile target nucleon interaction \(V_{\text{eff}}\) the G3Y-interaction of Love and Franey /7/ is used.
ent $J^\pi$ in nuclear models of varying sophistication. For example, we may include /22/ nuclear collectivity and $\Delta(1232)$-isobar effects into the nuclear structure calculations for the Gamow-Teller ($1^+$)-states while we use a simple particle-hole model for the rest of the states. The latter form then the "background" for the GT-states. In addition, we can disentangle the spectrum into the various multipolarities and discuss the strength distribution for each $J^\pi$.

(5) The whole background is assumed to be a simple superposition of cross sections of inelastic excitations to bound, quasibound and continuum states.

(6) The cross sections are calculated in the DWIA-approximation using the fast speed DWIA-code FROST-MARS /24/ which includes knock-out exchange amplitudes exactly.

The particle-hole doorway model discussed includes the nuclear continuum exactly but treats nuclear collectivity explicitly only for certain selected states like the GTR or the isobaric analogue $0^+$-state (IAS). We argue that for our purpose such a limited inclusion of nuclear collectivity is sufficient. Our argument is based on the work of Speth et al. /25/ who have shown that for $\Delta S=1, \Delta T=1$ transitions collectivity plays only a role for low multipolarities, i.e. for $0^-, 1^-, 1^-$ ($\Delta S=1$) and, maybe, $2^-$ states. This is simply an effect of the finite range residual particle-hole (ph)-interaction in the $\Delta S=1, \Delta T=1$ channel /25/ which is strongly repulsive for low spin states and weak for high spin states ($J^\pi > 2^-$). Therefore states with large $J^\pi$ are nearly unaffected by the residual ph-interaction (see also ref. 23 for a detailed discussion).

III - RESULTS AND DISCUSSION

In the microscopic 1 particle-1 hole doorway model we have calculated the background at various scattering angles for the reactions $^{48}$Ca($p,n$) at 160 MeV incident energy /10/ and for $^{90}$Zr($p,n$) at 200 MeV. First we shall discuss the background below the GT-resonance in the $0^+$-spectra and afterwards the background below the giant dipole spin-flip ($\Delta S=1, \Delta T=1, \Delta L=1$) resonance the cross section of which peaks at 4.5°.

III.1 - Calculations of the Background Below the GT-Resonance

In Fig. 2 we show the $0^+$-spectrum for the reaction $^{48}$Ca($p,n$). The experimental data (thick full line) have been taken from Anderson et al. The calculations for the continuous spectrum (dot-dashed curve) reproduce the data at high negative Q-values remarkably well in both shape and magnitude. The calculated spectrum is the incoherent sum of all cross sections with multipolarities $\Delta L=0$ through $\Delta L=3$ ($J^\pi = 0^-, 1^-, 1^-, 2^+, 2^-, 3^+, 3^-$). The calculated continuum falls off sharply at $Q \sim -20$ MeV. This falling off is a combined effect of the Coulomb and the centrifugal barrier which make the continuum wave function of the excited proton $|E_p, \ell, j_p\rangle$ small in the nuclear surface region, especially for smaller energies ($E_p < 10$ MeV) and angular momenta $\ell \neq 0$. As a consequence the nuclear transition densities are small for these energies and therefore also the cross sections. The background just below the GT-resonance has then to be produced from all the transitions which promote a neutron from the $2s-1d$-shell and $1f_{7/2}$ shell via charge exchange into the proton $2p-1f$-shell (see Fig. 1). The cross sections produced by these states are shown in Fig. 2 as discrete lines. (Note that the cross sections to the GTR and IAS have not been plotted.) Most of this background cross section is due to $\Delta L=1$ ($0^-, 1^-, 2^-$) and $\Delta L=2$ ($3^+$) excitations. The sum of all cross sections in the $Q$-interval from 2 to 15 MeV amounts to 5.4 mb from which 2.5 mb are due to $0^-$, 1.4 mb due to $2^-$, and 1.0 mb due...
Fig. 2 - Zero degree spectra for the reactions $^{48}\text{Ca}(p,n)$ and $^{40}\text{Ca}(p,n)$. The data (thick full line) are taken from refs. 26 and 12 (see text). The discrete lines are calculated cross sections due to bound and quasibound states. The arrow labelled with $\Delta L=1$ indicates the location where the $\Delta L=1$ resonance ($0^-,1^-,2^-$) would occur if nuclear collectivity were included for these states. The theoretical cross sections due to the GTR and IAS are not plotted. The optical parameters for the cross section calculations have been taken from ref. 39.

to $3^+$ excitations. Note that most of the $\Delta L=1$ ($0^-,1^-,2^-$) strength is shifted into the energy region around $Q = -22$ MeV (as indicated in the figure) when the residual ph-interaction is switched on. We emphasize that there exists a sum rule for $\Delta L=1$ charge exchange modes /14/. This sum rule tells us that when we consider a residual ph-interaction the strength is only redistributed, i.e. the strength is moved from the low to the high excitation energy region. Therefore the 5 mb calculated in our unperturbed ph-doorway model represent an upper limit for the background below the GTR in $^{48}\text{Ca}$. In the experimental analysis, however, a background of roughly 17 mb is subtracted (see Fig. 2a). Our calculations show that at least 12 mb of this background are actually GT-strength. By adding this cross section of 12 mb to that of the $1^+, T=3, 11$ MeV state the GT-cross section at $0^0$ is changed from 48 to 60 mb which makes an effect of 25 %.

The results presented above have been confirmed in the meantime by Rapaport /19/ and by Anderson et al. /29/. Both groups /19,29/ are using quite different methods than ours to determine the background. Anderson et al. /29/, for instance, first subtract a quasifree scattering cross section from the $0^0$-(p,n)-spectrum. Then they perform a multipole decomposition of the remaining background and find that most of this cross section has an $\Delta L=0$ angular distribution like the GTR. They also conclude that 13 mb of the experimentally subtracted background below the GTR in $^{48}\text{Ca}(p,n)$ is actually GT-strength.
Fig. 3 - Zero degree spectrum for the reaction $^{90}$Zr(p,n). The data (thick full line) are taken from ref. 12. The discrete lines are calculated cross sections due to bound and quasibound states. The theoretical cross sections due to the GTR and IAS are not plotted. The optical parameters for the cross section calculations have been taken from ref. 39.

In Fig. 3 we show the $0^+$-spectrum of the reaction $^{90}$Zr(p,n). The experimental data (full curve) have been taken from ref. 12. The dashed curve represents the calculated continuous background. Again we sum all cross sections with multipolarities $\Delta L=0$ through $\Delta L=3$ ($J^m = 0^-, 1^-, 1^+, 2^-, 2^+, 3^-, 3^+, 4^-$) and include therefore at least all $3N\omega$-lph-excitations in the calculations. There exists one difference between the calculations for $^{48}$Ca(p,n) and $^{90}$Zr(p,n), namely the latter includes also a spin-orbit potential for the continuum wave function of the excited proton while the spin-orbit potential was neglected in $^{48}$Ca(p,n) /10/. It is actually the spin-orbit potential which is responsible for the resonance type structures in the calculated continuous background around Q-values $Q = -25$ and $Q = -31$ MeV. Both bumps are essentially due to $(\Delta L=2) J^m = 1^+, 2^+, 3^+$ excitations and form the building "blocks" for the $\Delta L=2$ resonance. The spin-orbit potential $V_{SO}$ splits the strength which is essentially degenerate when $V_{SO} = 0$. It should be mentioned that the bumps would be appreciably smeared out if we would also include a spreading width in the calculations.

There is another important difference between the results for the continuous spectra in $^{48}$Ca(p,n) and $^{90}$Zr(p,n). While the background calculations reproduce the experimental data at high negative Q-values for $^{48}$Ca(p,n) they fail to do so for $^{90}$Zr(p,n) and underestimate here the data by a factor of about 2. The "missing" cross section in the calculated spectrum around $Q = -28$ MeV is not really missing since most of the cross section due to $0^-$, $1^-$, and $2^-$ states which appear in our model at lower
excitation energies (the discrete lines in Fig. 3) would be shifted to this energy region if we would include nuclear collectivity in our calculations. To demonstrate this we show in Fig. 4 the strength distribution for the $0^-, 1^-$ and $2^-$ states in $^{90}\text{Zr}$ obtained in an RPA calculation by Bertsch, Cha and Toki /30/. In these RPA calculations all the $0^-$ and most of the $1^-$ strength is moved to the energy region around $Q = -28$ MeV while the $2^-$ strength is distributed over a somewhat wider energy range. The sum of $0^-$, $1^-$, and $2^-$ cross sections in Fig. 3 amounts roughly to $\sim 14$ mb, from which $6.6$ mb are due to $0^-$, $1.4$ mb due to $1^-$, and $\sim 6$ mb due to $2^-$ transitions (see Table 1). Using the results of Bertsch et al. /30/ displayed in Fig. 4 we find a maximum of about $7.8$ mb $\Delta L=1$ cross section directly below the GT-resonance. This means that also in $^{90}\text{Zr}(p,n)$ we have practically no background below the GT-resonance, i.e., all the cross section in the $Q$-value range $-12 \leq Q \leq -20$ is GT-strength. A real problem, however, is that the calculated continuous spectrum underestimates the experimental data in the $Q$-value range $-32 \leq Q \leq -50$. One could argue that this "missing" cross section might be produced by $\Delta L=4$ excitations not included in our calculations. We have checked this point by calculating cross sections for transitions with the largest B(M4)-values. These transitions have either spin parity $\pi^\pi = 4^+$ or $5^+$. We found that these states make a negligible contribution to the cross section at forward angles as one would expect from the $\Delta L=4$ shape of their angular distributions. Furthermore, if the missing cross section would be due to $\Delta L=4$ transitions the discrepancy between experimental and calculated cross section should increase with angle since cross sections of $\Delta L=4$ shape give the biggest contribution at larger scattering angles. This behaviour, however, is not seen in the spectra. There is actually just the opposite tendency in that the difference between measured and calculated cross section becomes smaller with increasing scattering angle, as can be seen from Figs. 5 and 6. We therefore conclude that this "missing" cross section at large $Q$-values and forward angles can only be produced by another mechanism. An explanation consistent with the suggestions of Bertsch and Hamamoto /22/ (see also refs. 31,32,33) is that this cross section not described by the background cal-

![Fig. 4 - Strength distribution of the $\Delta L=1$ ($0^-, 1^-, 2^-$) charge exchange resonance in $^{90}\text{Zr}$ as determined by an RPA-calculation of Bertsch, Cha and Toki /30/.

- $Zr$ $\Delta L=1$ STRENGTH
- Strength
- $-Q(p,n)$ [MeV]
- $5$ $10$ $15$ $20$ $25$ $30$
- $0^-$ $2^-$ $1^-$
Table 1 - Sum of cross sections of all $l\hbar\omega, \Delta l=1$ transitions with spin-parities $J^m = 0^-, 1^-, 2^-$ obtained for different scattering angles $\theta$. Column 4 shows the sum of $0^-, 1^-$ and $2^-$ cross sections while column 5 shows the cross section obtained by subtracting the calculated continuous cross section from the experimental one in the $Q$-value range $-20 < Q < -50$ MeV.

<table>
<thead>
<tr>
<th>$\theta$ (deg)</th>
<th>$\sum \sigma_i (0^-)$ [mb]</th>
<th>$\sum \sigma_i (1^-)$ [mb]</th>
<th>$\sum \sigma_i (2^-)$ [mb]</th>
<th>$\sum \sigma_i (0^-, 1^-, 2^-)$ [mb/sr]</th>
<th>$\sigma_{\text{exp}} - \sigma_{\text{calc}}$ [mb/sr]</th>
</tr>
</thead>
<tbody>
<tr>
<td>$0^\circ$</td>
<td>8.8</td>
<td>1.4</td>
<td>6</td>
<td>16.2</td>
<td>40</td>
</tr>
<tr>
<td>4.5$^\circ$</td>
<td>12</td>
<td>23</td>
<td>28</td>
<td>63</td>
<td>52</td>
</tr>
<tr>
<td>9.5$^\circ$</td>
<td>10</td>
<td>17</td>
<td>21</td>
<td>48</td>
<td>38</td>
</tr>
<tr>
<td>12.8$^\circ$</td>
<td>2.7</td>
<td>6.3</td>
<td>12</td>
<td>21</td>
<td>20</td>
</tr>
</tbody>
</table>

Fig. 5 - Same as Fig. 3 but for $\theta_{\text{c.m.}} = 4.5^\circ$.

Calculations is actually GT-strength which was shifted to this high excitation energy region due to the mixing of the "low-lying" $1p-1h$ GT-state with high-lying $2p-2h$ configurations. Corresponding to our calculations the amount of GT-strength located in the energy range $-20 < Q < -50$ could be as large as 25 mb. This conclusion is also in agreement with estimates of Scholten, Bertsch and Toki /34/ who used a more phenomenological model for the calculation of the background in the $0^0$-spectrum.
One might ask why the 2p-2h polarization effect seems to be more important for $^{90}$Zr than for $^{48}$Ca. This is probably due to a simple shell structure effect. For example, the giant M1-resonance observed in inelastic electron /35/ and inelastic proton /36/ scattering experiments is very sharp in $^{48}$Ca but rather broad in $^{90}$Zr /36/ indicating a different degree of coupling of the M1-states with 2p-2h states in both nuclei. The damping mechanism of the GT-state due to 2p-2h states is much more efficient in heavy than in light nuclei due to the larger density of 2p-2h states in heavy nuclei.

III.2 - Calculation of the Background Below the Giant Dipole ($\Delta L=1$) Resonance

In Figs. 5 and 6 we show $^{90}$Zr(p,n) spectra for angles of 4.5° and 9.5°, respectively. The data (full line) have been taken from ref. 12 and the dotted lines represent the calculated continuous spectrum. The peaks at Q-values of Q = -24 and Q = -32 MeV are again due to the ($\Delta L=2$) $J^m = 1^+,2^+,3^+$ resonance. As is seen from the figures the ($\Delta L=1$) $J^m = 0^-,1^-,2^-$ resonance gives a large contribution to the cross section (discrete lines in the figures). The summed cross section of all $\Delta L = 0^-, 1^-, 2^-$ excitations amounts to 63 mb at the scattering angle of 4.5° and to 48 mb at 9.5° (see Table 1). Most of the $\Delta L=1$ strength will be shifted into the energy region around Q = -26 MeV when the residual ph-interaction is switched on (see Fig. 4). As one can see from Figs. 5 and 6 we have now, however, a big problem since we have much more ($\Delta L=1$) cross section to distribute than the experimental data permit. This is especially striking for the 9.5° spectrum. If we subtract in the Q-value range...
from 20 to 50 MeV the calculated continuous cross section from the experimental one we obtain roughly $\sim 31$ mb. The calculated $\Delta L=1$ cross section, on the other hand, amounts to 48 mb which is by a factor of $\sim 1.5$ larger than the estimated cross section above. This happens although we have implicitly assumed already that the $\Delta L=1$ strength is distributed over the whole Q-value range from -20 to -50 MeV. The latter amounts to the assumption that high-lying $2p-2h$ configurations /22/ couple to the $\Delta L=1$ resonance in a similar way as to the GT-resonance and spread out the $\Delta L=1$ strength over a wide energy range. In spite of this assumption we still need a quenching of about 50 % in order to reconcile the theoretical and experimental cross sections. Part of this quenching is certainly due to ground state correlations not included in our calculations. Ground state correlations will reduce both the $\Delta L=1$ cross section and also the calculated continuous cross section being therefore an effective agent to diminish the surplus cross section mentioned above. If we assume a reduction of $\sim 25$ % for both the background and the $\Delta L=1$ cross sections then the experimental and calculated cross sections would just agree. It may, however, also well be that this is an overestimate and that an additional quenching due to admixtures of $\Delta(1232)$ isobar-nucleon hole configurations into the $\Delta L=1$ resonance is needed to describe the data as has been repeatedly pointed out in the analysis of $2^+$ states measured in inelastic electron scattering experiments /37/.

**SUMMARY**

We have presented microscopic background calculations for $(p,n)$-reactions at intermediate energies which reproduce the $^{48}\text{Ca}(p,n)$ continuum at 0°, but which underestimate the zero degree $^{90}\text{Zr}(p,n)$ continuum at high Q-values by a factor of about 2. We show that this missing cross section in case of $^{90}\text{Zr}(p,n)$ is most probably due to Gamow-Teller strength which has been shifted to the high excitation energy region by mixing of the "low-lying" $1p-1h$ Gamow-Teller state with high-lying $2p-2h$ configurations. The amount of GT-strength shifted to the energy region $-22<Q>-50$ MeV in $^{90}\text{Zr}(p,n)$ could be as much as $\sim 25$ mb. Then $\sim 80\%$ of GT-strength is seen in the $(p,n)$ experiments. We also show that there is essentially no background just below the GT-resonance. This statement holds for both reactions, $^{48}\text{Ca}(p,n)$ and $^{90}\text{Zr}(p,n)$. We have also calculated the background below the giant dipole ($\Delta L=1$, $\Delta S=1$) resonance. We find that also the $\Delta L=1$ strength suffers from the coupling to $2p-2h$ states and has to be spread out over a wide energy range up to 50 MeV excitation energy. Even then the theoretical $\Delta L=1$ cross section at angles of 4.5° and 9.5° is much larger than the cross section which is obtained by subtracting the calculated microscopic background from the experimental cross section. We have to introduce a quenching of the $\Delta L=1$ strength by about 50 % which may be partly due to ground state correlations not considered in our calculations and partly due to the admixture of $\Delta$ isobar-nucleon hole states into the $\Delta L=1$ giant dipole state.

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