TEMPERATURE DEPENDENCE OF THE GDR WIDTH IN ^{120}Sn

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One area of major experimental and theoretical efforts in the study of the giant dipole resonance (GDR) is the angular momentum and temperature dependence of the GDR width. Recently different experimental techniques have been applied to study the angular momentum dependence and the temperature dependence independently [1–5]. Gamma-ray multiplicity measurements in fusion-evaporation reactions allow the gating on different angular momentum ranges at approximately the same temperature [1,2]. Inelastic α-scattering at forward angles involves only small angular momenta while populating different excitation energies [3–5].

The α-scattering experiments have several advantages but also some additional uncertainties compared to the fusion-evaporation reactions. The advantages include the possibility to measure the whole excitation function within one experiment by gating on the different energy losses of the projectile, and to measure the properties of the hot GDR in stable nuclei where the results can directly be compared to the ground state values. In addition, the GDR can in principle be measured at lower temperatures because it is not limited by the Coulomb barrier in the entrance channel. One of the major disadvantages is the uncertainty in the determination of the excitation energy. It has been shown that the full energy loss of the projectile is not converted into equilibrated excitation energy in the target nucleus [6,7]. Other processes like knock-out or pickup/decay reactions can contribute to the inelastic spectrum and have to be taken into account in the analysis.

The most extensive studies of the hot GDR have been performed in Sn nuclei. There are apparent differences between the GDR widths inferred from fusion-evaporation and the (α,$\alpha'\gamma$) experiments [8]. The widths from the latter reaction lie somewhat above the fusion-evaporation results. To understand these differences and to further explore the excitation energy deposition in inelastic scattering experiments we studied the reaction ^{120}Sn(^{17}O,^{17}O$'$) at 80 MeV/nucleon. Oxygen was chosen as the projectile because the yield of nucleon knock-out reactions is expected to be much smaller in heavy-ion scattering than in α-scattering reactions [9]. In addition, the neutron binding energy is small so that projectile excitations are limited to low excitation energies.

The experiment was performed at the NSCL in November of 1998. A 7.45 mg/cm^2 thick ^{120}Sn target was bombarded by 80 MeV/nucleon ^{17}O particles. The inelastically scattered ^{17}O and other reaction products were measured in the S800 spectrometer. This allowed for accurate particle identification and energy loss measurements. The S800 was set at a scattering angle of 7°. The angular acceptance of the S800 is 5°, which allows for scattering angles between 2° and 12°; the grazing angle for this reaction is about 2.2°. The energy acceptance of the S800 is approximately 10%, which corresponds to 136 MeV. This acceptance is sufficient to measure the whole excitation function with one setting.

The high-energy γ rays were detected with the ORNL - Texas A&M - MSU BaF_2 array, consisting of 136 BaF_2 scintillators, in coincidence with fragments in the S800. The scintillators were arranged in two close-packed arrays of 68 detectors each. The arrays were placed at a distance of ≈ 50 cm from the target at angles of $\pm$90° with respect to the beam axis. The γ rays were effectively separated from other particles by using fast vs. slow signals and energy signals from the individual BaF_2 detectors vs. time of

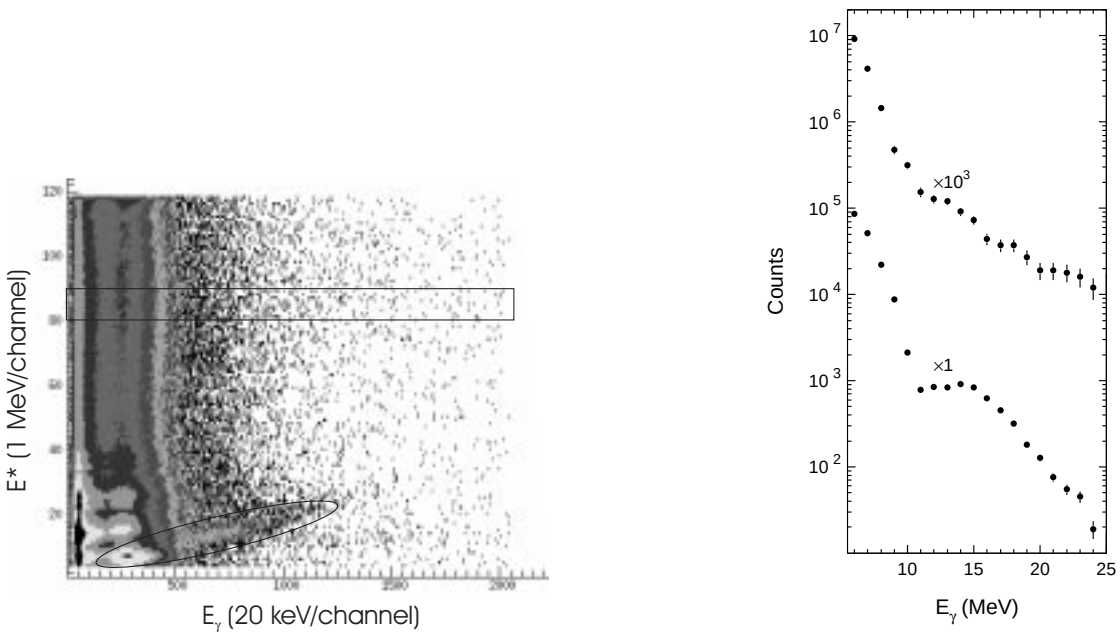

Figure 1: Left: Plot of excitation energy vs. γ-ray energy. Right: The top γ-spectrum corresponds to excitation energies of 80–90 MeV, as gated by the upper band in the left plot. The bottom γ-spectrum corresponds to decays back to the ground state, as gated by the lower band in the left plot.

flight measurements.

In the preliminary analysis the excitation energy of the target was directly determined from the energy loss of the scattered ^{17}O particles assuming full equilibration. Contributions from incomplete energy transfer can be extracted from the spectra of twelve CsI telescopes which were placed in the scattering chamber to detect light particle emissions from the target. The CsI detectors were mounted above the target covering angles of 30° to 150°.

The left side of Figure 1 shows the two-dimensional plot of the apparent excitation energy (initial beam energy minus measured energy of the scattered particle) vs. γ-ray energy. The diagonal band at low energies (E$_\gamma$ $\leq$25 MeV) represents the kinematical limit and shows that the applied identification and reconstruction is correct. The events below the kinematic limit are due to random coincidences which have not been subtracted from the left plot in Figure 1. Gating on the diagonal allows the analysis of the GDR built on the ground state including the γ-decay branch back to the ground state. The corresponding γ-ray spectrum is shown at the bottom of the right side of Figure 1.

In order to extract the GDR parameters of the excited Sn nuclei it is necessary to gate the two-dimensional excitation energy vs. γ-ray energy spectrum for a given excitation energy range and project the γ-ray spectrum. Such a gate is shown in the left plot of Figure 1 for an excitation energy range of 80–90 MeV. The corresponding γ-ray spectrum is shown as the top spectrum on the right side of Figure 1. The GDR parameters can then be extracted by fitting the spectra with a modified version of the statistical model code CASCADE [10] and folding the calculated spectrum with the response function of the detector array.

For these calculations it is necessary to include the correct initial angular momentum and excitation energy population in the code. As mentioned earlier the conversion from energy loss to excitation energy

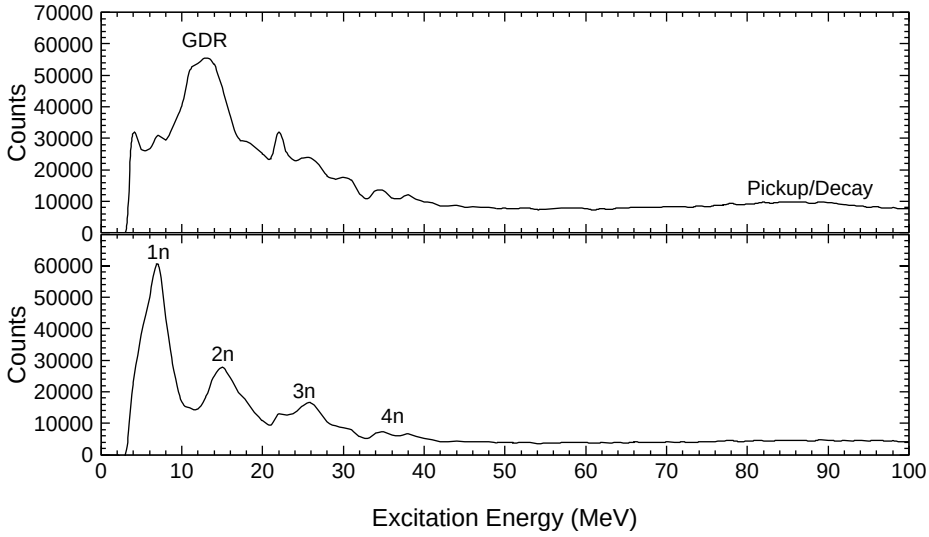

Figure 2: Top: ^{17}O Singles spectrum. Bottom: ^{17}O in coincidence with γ rays with E$_\gamma$ $\geq$4 MeV.

is not straightforward and the spectra of the CsI detectors have to be analyzed first.

However, it is possible to get some indication of the deposited excitation energy by plotting the energy loss spectrum gated by γ rays with E$_\gamma$ $\geq$4 MeV. Figure 2 shows the ^{17}O singles data (top) as well as the coincidence data (bottom). In the singles spectrum, the ground-state GDR is apparent around 15 MeV. There is also an enhancement potentially due to pickup/decay contributions around 80 MeV. The spectrum gated by γ rays shows distinct peaks which can be interpreted as successive openings of neutron evaporation channels [11]. These structures would be washed out if there is not a correlation between energy loss and excitation energy. These peaks can be identified up to 40 MeV corresponding to the 4n channel.

Although no detailed CASCADE calculations to fit the data have been performed, it is possible to compare the extracted excitation energy gated γ-ray spectra with the results from the (α,$\alpha'\gamma$) experiment. Figure 3 shows the present data (solid circles) and the (α,$\alpha'\gamma$) data (open circles) for excitation energy ranges of 30–40 MeV, 50–60 MeV, and 70–80 MeV. The spectra were normalized with respect to each other at 7 MeV. While the data at the two lower excitation energies are similar for the two reactions, the 70–80 MeV spectra seem to have reduced strength in the energy range of the GDR for the^{17}O data. This could be an indication of other mechanisms (for example pickup/decay) contributing to the γ-ray spectrum. The fact that the low-energy spectra are similar for the two reactions suggests that the extracted GDR parameters will also be similar. Thus the ^{17}O reaction would confirm the GDR width increase extracted from the α-scattering experiments. However, this has to be confirmed in the final analysis because the experimental conditions were not exactly the same, for example the response function for the detector arrays was different.

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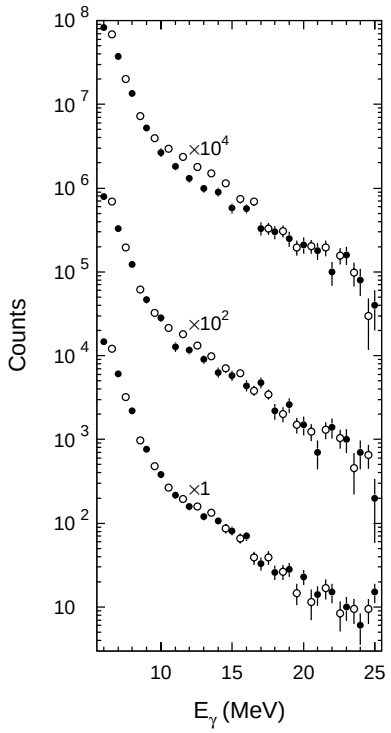

Figure 3: Comparison of the γ spectra following ^{17}O scattering (filled circles) and α-scattering (open circles). The spectra correspond to excitation energies of 70–80, 50–60, and 30–40 MeV respectively from top to bottom.

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