The effects of deformation in compressional-mode giant resonances

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The giant monopole resonance (GMR) and the isoscalar giant dipole resonance (ISGDR), which are called the compressional-mode giant resonances, are of considerable interest since their excitation energies directly relate to the incompressibility of nuclear matter, an important component of the nuclear equation of state which plays a crucial role in describing nucleon motion in nuclei, and in cosmological events such as type II supernova explosions.

It was reported two decades ago that the giant resonance "bump" in the deformed nucleus ^{154}Sm had a larger "lower" component when compared with that in the spherical nucleus ^{144}Sm [1, 2]. This was interpreted as resulting from K-splitting of the giant quadrupole resonance (GQR) and a coupling between the GMR and the K=0 component of GQR. For the ISGDR, there were no data dealing with the effect of deformation. In the ISGDR and the high energy octupole resonance (HEOR), strengths was also expected to be coupled.

The experiments were performed at the Ring Cyclotron Facility of RCNP using the Grand Raiden spectrometer in the WS beam line. Double-differential cross sections of the inelastic α scattering at E_α=386 MeV were measured for the ^{144,148,150,152,154}Sm targets at angles from 0° to 13° for ^{144}Sm, to 9° for the other samarium targets. The instrumental background have been subtracted using the property of the ion-optics of Grand Raiden.

In order to identify strengths corresponding to different giant resonances, we have carried out a multipole-decomposition analysis for the angular distribution with each 1-MeV bin including the physical continuum. In this method, the experimentally obtained cross sections, $\sigma^{exp}(\theta, E_x)$, are expressed as the sum of the contributions from various multipole components:

$$\sigma^{exp}(\theta, E_x) \;=\; \sum_L a_L(E_x)\, \sigma_L^{calc}(\theta, E_x), \tag{1}$$

where E_x and θ, are the excitation energy and the scattering angle, respectively, and $\sigma_L^{calc}(\theta, E_x)$ is the distorted-wave Born approximation (DWBA) cross section exhausting 100 % of the energy-weighted sum-rule (EWSR) value for the transferred angular momentum L. The fractions of the EWSR, $a_L(E_x)$, for various multipole components were determined by minimizing χ^2. In DWBA calculations, a single-folded potential model was employed, with a nucleon-α interaction of the density-dependent Gaussian form, as described in Ref. [3, 4]. The interaction parameters were determined by fitting the differential cross sections of elastic α-scattering measured for ^{144}Sm at the same energy. The macroscopic collective transition densities were used.

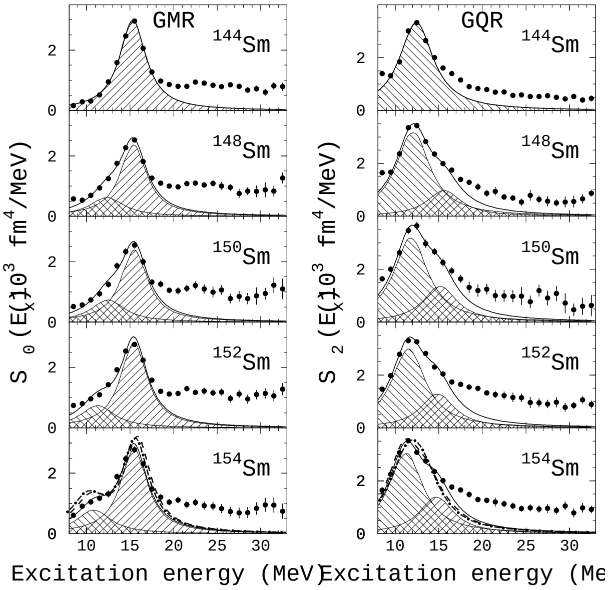

Figure 1: Strength distributions of the GMR and GQR for $^{144-154}$Sm.

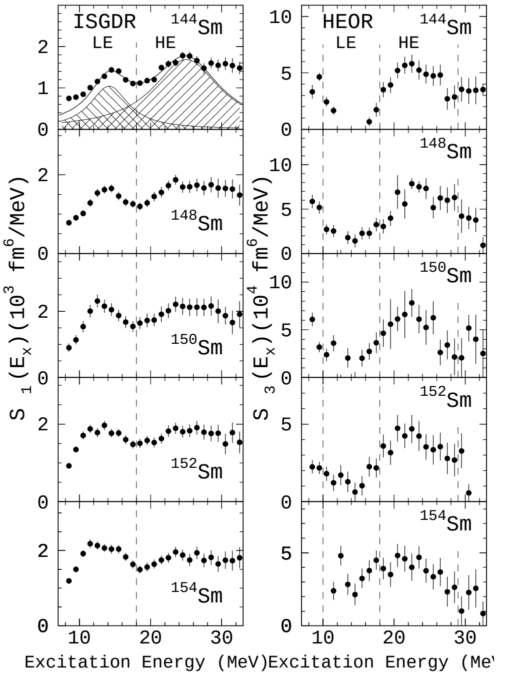

Figure 2: Strength distributions of the ISGDR and HEOR for $^{144-154}$Sm.

The extracted GMR and GQR strength distributions for the Sm isotopes are shown in Fig. 1. Both the GMR and GQR strengths have a clear peak each, however also extend to higher excitation energies. The total EWSR fractions integrated over the measured excitation energy regions are over 150%. A possible reason for the excess in the EWSR fractions is that the macroscopic transition transition dentities of the GMR and GQR are not valid in the high-excitation energy region. Therefore further analysises were carried out for 'peak' regions by fitting the strength distribution with two Breit-Wigner functions. The peak energies for the high excitation energy component of the GMR were in good agreement with the predictions of the adiabatic cranking model of Abgrall *et al.* [5] and the fluid-dynamical model of Nishizaki and Andō [6]. However, the low-excitation energy components, which correspond to the coupling between the GMR and GQR, are ~0.6 MeV higher than the predictions.

Figure 2 show the obtained strength distributions of the ISGDR and HEOR. For the ISGDR, the effects of the deformation were different for the low- and high-excitation energy compoents: The width and strength of the low-excitation energy component increase with increasing nuclear deformation, whereas the high-excitation energy component hardly changes. The HEOR strength broadened and shifted towards lower excitation energy as the nuclear deformation increased.

References

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