MEASUREMENT OF THE E1 STRENGTH FUNCTION OF ^{11}Be

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An interesting question in the study of radioactive nuclei is how collective excitations, such as the giant dipole resonance (GDR), evolve as one moves away from β-stability. Various models have been used to explore this question. It has been suggested, for example, that the E1 strength of very neutron-rich nuclei could spread over a very wide energy region,and appear at energies lower than expected from the systematics of stable nuclei.[1,2]

The nucleus ^{11}Be is a single-neutron halo nucleus and has been widely studied, particularly its low-lying states and particle decay modes. The E1 strength at E* = 0.6-4.0 MeV has been investigated through kinematic reconstruction following Coulomb dissociation.[3] However, this strength accounts for only about 5% of the total TRK sum rule. Most of the E1 strength is expected to be located at higher excitation energies (E* $>$ 8 MeV). We have extended the studies of the E1 strength distribution to the higher excitation energies, by measuring the photabsorption cross section of ^{11}Be using Coulomb excitation followed by photon-decay to the ground state.

We performed two experiments, the first one has been described elsewhere[4] and is fully analyzed. In the second experiment we used an improved particle detector.[5] That experiment has not been completely analyzed.

In the analysis of the first experiment[6] only events with one photon and no neutron in the BaF_2 array, and one particle detected were accepted to enhance the ground state γ-ray decays from the ^{11}Be nucleus. We subtracted random coincidences from the data and extracted our photon yields by using particle spectra gated by γ-rays with different energies. This was especially important at excitation energies between the thresholds of (γ,n) (504 keV) and (γ,2n) (8.73MeV), where the photon spectra are dominated by the γ-rays emitted by ^{10}Be daughter nuclei. At excitation energies well above the (γ,2n) threshold (8.73MeV), the γ-ray branching ratio of ^{11}Be and ^{10}Be are comparable. The photon cross-sections were unfolded from the measured yields, using the simulated response of the BaF_2 detector array. We then used the method described by Bertulani and Nathan[7] to relate ground-state γ-ray decays from the GDR following the Coulomb excitation to the elastic photon scattering and extracted the photo-absorption cross section from our virtual photon scattering data.[6] The energy resolution of these data prevent us from studying detailed structures in the GDR region, but the results show that the E1 strength distribution is spread from 8 MeV to 26 MeV, and shows few prominent features except a broad peak near the energy of the 10.59 MeV state in ^{11}Be and a rise near 14.5 MeV. This is qualitatively consistent with the Hartree-Fock calculations for neutron rich nuclei.[1,2] Unfortunately, we know of no theoretical calculations for the GDR region of ^{11}Be.

We have compared observed strength distribution of the GDR with oscillator sum rules, which can be related to the bulk and surface parameters of the nuclear medium (nucleus radius, symmetry energy, incompressibility etc.).[8] The results for various moments of the GDR strength are shown in Table 1 along with the moments for the $1 \leq 4 \leq$ MeV.[3]

Our results shows that the total strength between 8 and 25 MeV exhausts 120% of the TRK sum rule. The observed low energy strength exhausts about 80% of the "cluster sum rule"[11] expected for a neutron weakly coupled to a ^{10}Be core.

Table 1: Comparison between the sum rules and the experimental values.

Moment	Calculated Sum Rule Limit	Experimental value	E=1-4MeV
σ_0 (MeV-mb)	152	181^{+23}_{-35}	6.7
σ_{-1} (mb)	15.49	$11.4^{+1.4}_{-2.2}$	4.7
σ_{-2} (MeV^{-1}-mb)	0.484	$0.784^{+0.095}_{-0.162}$	3.8

The experimental value of the σ_{-1} is consistent with the corresponding sum rule[8] using the experimental[9] RMS charge radius $\sqrt{< r^2 >}$ = 2.52 fm. The σ_{-2} moment should be particularly interesting in this case, since the corresponding sum rule is proportional to the nuclear dipole polarizability, which is extremely sensitive to nuclear surface properties. We are considering the implications of our result, which exceeds reasonable estimates of the sum rule strength.

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