ELECTROMAGNETIC EXCITATION OF NEUTRON-RICH OXYGEN NUCLEI $^{17-22}$O*

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The dipole response of neutron-rich oxygen nuclei $^{17-22}$O has been studied using the electromagnetic excitation process in heavy ion collisions at beam energies around 600 MeV/nucleon. The subsequent neutron decay after inelastic scattering of the secondary beam projectiles on a Pb target was measured in a kinematically complete experiment. Differential electromagnetic excitation cross sections were deduced up to 30 MeV excitation energy. For all isotopes low-lying E1 strength was obtained exhausting between 5% and 12% of the energy-weighted dipole sum rule.

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1. Introduction

The question how the giant resonance strength evolves when going from stable nuclei to exotic, weakly bound nuclei is nowadays frequently discussed [1–6]. For the neutron-rich nuclei, calculations of different type predict dramatic effects, in particular a strong fragmentation and redistribution of the strength towards lower excitation energies, well below the giant resonance region. But also new collective modes are discussed, *e.g.*, a coherent motion of the valence neutrons against a core. This is often called soft dipole mode or pygmy resonances. In the picture of a collective dipole vibration of the valence neutrons against a core, the occurring low-lying strength can be compared to the cluster sum rule [12] which is related to the Thomas–Reiche–Kuhn(TRK) sum rule and depends on the number of valence neutrons.

$$S_{\mathrm{cluster}} = \frac{Z_{\mathrm{c}}}{A_{\mathrm{c}}} \cdot \frac{N_{\mathrm{v}}}{N} \cdot S_{\mathrm{TRK}}\,.$$

Here S_{TRK} stands for the TRK dipole sum rule limit, and the indices c and v refer to the core and valence neutrons, respectively.

In a first attempt to study giant resonances in exotic nuclei, we investigated the dipole strength in neutron-rich oxygen isotopes ^{17}O to ^{22}O. As experimental tool, we use the electromagnetic excitation of fast projectiles by large Z targets. Besides the high cross sections, one advantage of this method is the direct relationship between the differential electromagnetic dissociation cross section and the E1 strength, which can be obtained without free parameters by applying semi classical calculations.

2. Experimental setup

The secondary neutron-rich ion beams were produced in a fragmentation reaction of an ^{40}Ar primary beam, delivered by the heavy–ion synchrotron SIS at GSI, Darmstadt, impinging on a beryllium target. The fragments were separated using the Fragment Recoil Separator (FRS) [9] and identified event-by-event by measuring the energy loss and the time-of-flight. The trajectory of the incoming ions was measured by a multi-wire proportional chamber and a position sensitive Si-PIN-diode. Behind the target, the fragments were deflected by a large-gap dipole magnet. By measuring energy-loss and time-of-flight again as well as by position measurements in front of and behind the magnet the nuclear charge, velocity, mass and scattering angle of the fragments can be determined. The neutrons, which come from the excited projectile or excited projectile-like fragment are strongly forward focused due to the relativistic velocities and are detected with high efficiency in the LAND neutron detector [10], placed at zero degree about 11 m downstream from the target and covering an angular range of ± 90 mrad.

To detect γ-rays, the target was surrounded by the 4π Crystal Ball spectrometer, consisting of 160 NaI detectors.

By measuring the four-momenta of fragment and neutron(s) as well as the emitted γ-energy the excitation energy of the projectile can be reconstructed via the invariant mass.

3. Results

The differential cross section for the electromagnetic excitation to the continuum with following neutron decay were measured for the whole isotopic chain ^{17}O to ^{22}O. In case of the stable ^{18}O photoabsorption data are available, which we compare to our results of the electromagnetic dissociation.

The electromagnetic excitation cross section which has been calculated from the photoabsorption data of Refs. [7, 8] has been convoluted with our experimental detector response and shows a good agreement with our data.

In Fig. 1, the integrated low-lying strength for the whole isotopic chain is shown. In the upper frame the integrated strength below 15 MeV in units of the TRK sum rule is seen, while in the lower one, the same is shown in units

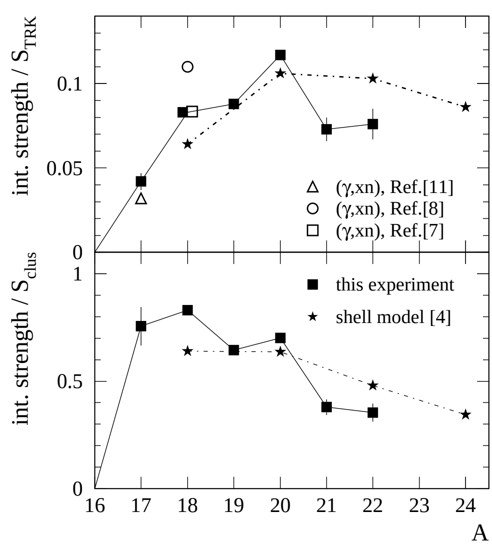

Fig. 1. Evolution of integrated (up to 15 MeV excitation energy) strength in units of the TRK sum rule (upper panel) and the cluster sum rule limit (lower panel) for the whole oxygen chain. The data (black boxes) are compared to shell model calculations by Sagawa and Suzuki [4] (asterisks). For the stable isotopes ^{17}O and ^{18}O, data from photoabsorption measurements [7,8,11] are shown for comparison.

of the cluster sum rule assuming a ^{16}O core. For the stable isotopes ^{17}O and ^{18}O, also data from photoabsorption measurements [7, 8, 11] are shown for comparison.

The agreement with our data is very good. The larger value that we obtain for ^{17}O is consistent with the higher experimental threshold in [11].

The amount of low-lying strength in units of the TRK sum rule increases up to A=20 and then decreases again. This is qualitatively reproduced by the shell model calculation [4] (shown as asterisks connected by dashed-dotted lines).

In case of a fully collective motion of the valence neutrons against a core, this quantity should increase continuously with increasing mass number.

The cluster sum rule is approached only for the stable isotopes ^{17}O and ^{18}O. For the heavier isotopes, this limit is not reached, indicating that only a fraction of the valence neutrons participate in the dipole motion.

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