Electromagnetic Excitation of Neutron–Rich Oxygen Nuclei $^{17-22}$O

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Giant resonances are basic nuclear excitation modes which carry a lot of information on the nuclear structure as well as on the effective nucleon–nucleon forces in the medium. The investigation of isovector giant resonances in exotic nuclei, more generally a study of the continuum multipole strength distributions, helps in testing the quality of such effective forces in the asymmetric medium.

Apart from increasing fragmentation of the resonances with isospin, RPA-calculations predict low-lying strength (near particle threshold). On one side this could be understood as the coupling of weakly bound valence nucleons to the continuum, on the other side it is possible to interpret it as a coherent oscillation of the valence neutrons against the core [1].

In a first attempt of a study of giant resonances in exotic nuclei, we investigated the dipole strength distribution in neutron-rich oxygen isotopes, employing electromagnetic excitation in peripheral heavy-ion collisions at large relative velocity. Secondary beams of $^{17-22}$O were produced at the FRS by fragmentation of a ^{40}Ar primary beam and transmitted to the Cave B experimental area. The excitation energy after inelastic scattering on the Pb target is obtained by reconstructing the invariant mass utilising the LAND-setup. To disentangle electromagnetic excitation from nuclear interaction processes we measured the fragment masses with a good resolution ($\sigma_A \approx 0.1$) and compared it to the number of neutrons emitted in forward direction. In case of electromagnetic excitation the difference in mass number between projectile and fragments equals the number of neutrons. Nucleons, which were knocked out in nuclear reactions were scattered to large angles and are missed in forward direction [2]. The remaining nuclear background was determined from a measurement with a C target.

The resulting energy weighted E1 strength (integrated up to 15 MeV excitation energy) is shown in Fig. 1 in units of the Thomas–Reiche–Kuhn (TRK) sumrule for the neutron–rich oxygen nuclei studied in this experiment. We observe a considerable amount of strength at low excitation energies (below the giant dipole resonance region) corresponding to about ten percent of the total sumrule strength. The low lying E1 strength increases up to ^{20}O and decreases again for higher neutron numbers. ^{18}O is the only isotope where the cluster sumrule limit (solid curve) is almost exhausted[6,7].

To test the validity of the experimental method we have compared our result obtained with the stable ^{18}O beam to measurements of the photoabsorption cross section [3,4]. As can be seen in Fig. 1, our data reproduce the (γ,n) cross section (full circle) very well.

Fig. 1 shows also a shell model calculation by Sagawa and Suzuki [5] using the Warburton–Brown interaction, which reproduces the overall trend in the experimental observation. A more detailed comparison of the differential electromagnetic excitation cross section (Fig. 2) shows also good agreement. Especially the low energy part of the spectrum, and in particular the sharp resonance at the threshold, is reproduced very well by the theory. The deviations at higher excitation energies might partly be explained by the opening of the proton channel. For a final comparison a detailed simulation of the experimental response including the gamma detection will be performed.

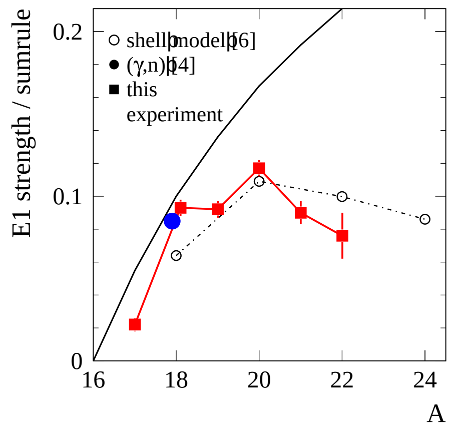

Figure 1: Integrated E1 strength (up to 15 MeV excitation energy) in units of the TRK-sumrule for neutron rich oxygen isotopes. The experimental data are compared to a shell model calculation [5] (open circles). For ^{18}O the value obtained from photoabsorption measurements [4] is shown as the full circle. The cluster sumrule limit assuming an ^{16}O core is displayed by the solid curve.

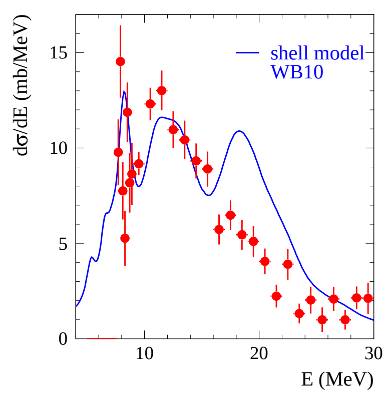

Figure 2: Electromagnetic excitation cross section for 590 MeV/u ^{20}O on Pb as deduced from the invariant mass analysis of the ^{19}O+n and ^{18}O+2n channels. The results are compared to a shell model calculation [5] (solid curve) which was folded with the experimental resolution.

References

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