

Measurement of the Isovector Giant Quadrupole Resonance in ^{40}Ca

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The location of the IVQR in nuclei has been studied, and the excitation energy of its location is found to be proportional to $A^{-1/3}$. However data for light nuclei is rather sparse. A measurement of the neutron capture reaction $^{40}\text{Ca}(n,\gamma_0)$ by Berquist *et al.* at Lund¹ located the IVGQR for ^{41}Ca , and a recent measurement at Illinois² has located it for ^{40}Ca , but much of the strength lies above the energy range of the Illinois accelerator. The present measurement extends the data to higher energies using the tagged photon facility of the MAX-LAB at Lund University.

Interference effects between E1 and E2 absorptions produce a forward-backward asymmetry in the emitted neutrons, and this asymmetry is an indication of the presence of the Iso-Vector Giant Quadrupole Resonance (IVGQR). The aim of the present experiment was to measure the $^{40}\text{Ca}(\gamma,n)$ reaction cross-section to the ground-state of ^{39}Ca , at forward and backward angles. The measurement, using tagged photons was performed at MAX lab in 1993.

The $^{40}\text{Ca}(\gamma,n)$ reaction was measured using tagged photons in the energy range 25-50 MeV. Neutrons were detected using two 9-element, liquid scintillator, neutron detectors placed at angles of 55° and 125° at flight paths of 3.2 m. The target was a cylinder of 215 gram of natural calcium metal, of diameter 42 mm and length 100 mm, which was kept under an argon atmosphere. The absolute cross section was determined relative to that for $\text{D}(\gamma,n)\text{p}$, which was measured using a heavy water target.

On-line PSD allowed the major part of the electron response in the neutron detectors to be eliminated. Further off-line analysis allowed extremely clean neutron time-of-flight spectra to be obtained. The resulting missing-energy spectra clearly resolve the neutron population to the ground state of ^{39}Ca from population of the group of states near 2.5 MeV: such separation was not seen in an earlier measurement from Melbourne by Eden *et al.*³

The forward/backward asymmetry in the $^{40}\text{Ca}(\gamma,n_0)$ cross section, resulting from E1/E2 interference has been used to locate and parameterise the IVQR. The asymmetry was fitted according to predictions of both the semi-classical model⁴ and the Direct/Semi/direct model. Figure 1 shows the experimental asymmetry and the fit using the semi-classical model.

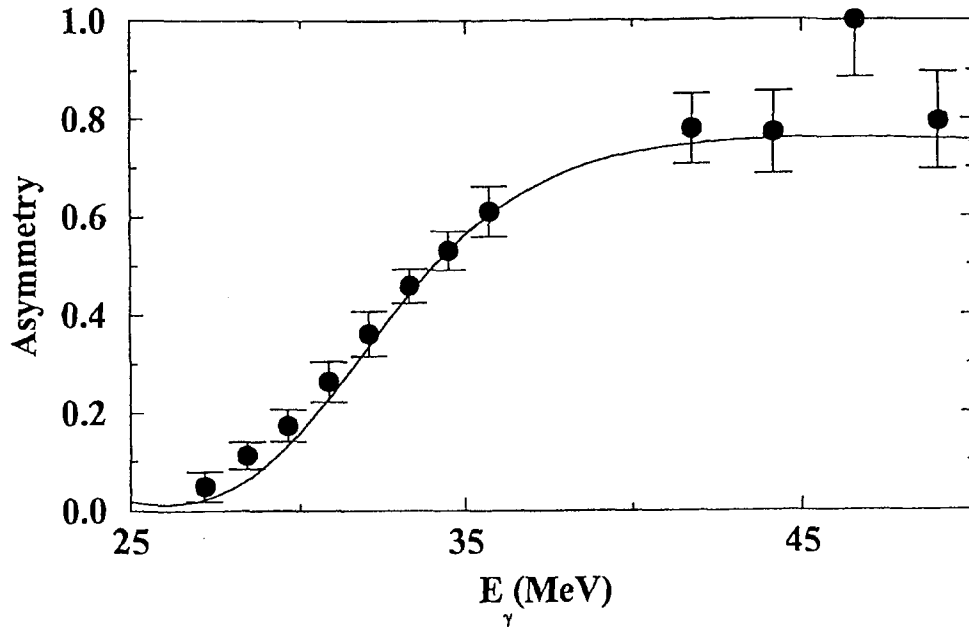


Figure 1. The $^{40}\text{Ca}(\gamma, n_0)$ asymmetry fitted by the semi/classical model.

The parameters obtained indicate that the IVQR in ^{40}Ca occurs at 31 ± 1.5 MeV, and has a width of 16 ± 1.5 MeV. It exhausts $(95 \pm 10)\%$ of the EWSR. Although the width of the resonance is consistent with theoretical predictions, the resonance energy is lower than that predicted on the basis of $E_{\text{IVQR}} = 130A^{-1/3}$. However it is consistent with the trend for collective resonances in light nuclei.

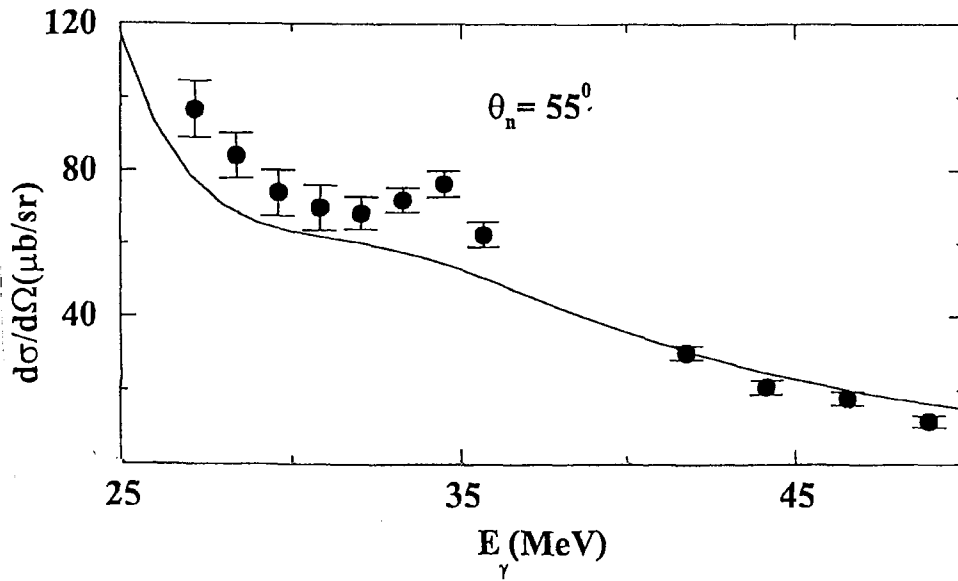


Figure 2. The $^{40}\text{Ca}(\gamma, n_0)$ cross section at $\theta_n = 55^\circ$

An interesting feature of the data is shown in Figure 2, where there is clear evidence of structure at 35 MeV. Evidence of this structure can be found in the total absorption measurement of Ahrens⁵, but there has so been no discussion of its origin. This structure is not the IVQR, as its characteristics are entirely wrong. Evidence of similar structure has been seen in the $^{12}\text{C}(\gamma, n_0)$ and $^{12}\text{C}(\gamma, p_0)$ cross sections⁶, and has been suggested as indicating a change in the reaction mechanism. A further experiment is planned at the MAX Lab. To investigate this structure.

References

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