Using $^6$Li in Measuring Giant Monopole Resonances

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Theory

Giant resonances are collective modes of excitation of a nucleus. In a macroscopic liquid drop model the protons and neutrons are treated as separate liquids. The resonances are then shape or density oscillations of the nucleus. These resonances are classified by spin ($S$) and isospin ($T$). Spin can be either $S=0$ referring to electric oscillations and $S=1$ referring to magnetic oscillations. Isospin refers to whether the protons and neutrons are moving in phase or out of phase isoscalar ($T=0$) and isovector ($T=1$).

Experiment Setup

To measure the ISGMR particles are scattered in inelastic collisions with the target and the products of the reaction are measured with the MDM Spectrometer at small angles.

The Decay Detector

In the survey of giant resonances the study has moved from stable isotopes to unstable isotopes. In these reactions the heavier particle cannot be used as a target because it would decay before the experiment could be done. The inverse reaction can be looked at where the incoming particle is radioactive and the target source we setup an experiment with two test scintillators placed horizontally in the rack pictured to the left. The scintillators were hooked up as close to experiment type conditions with the scintillators connected via fiber optics to a PMT. The MDM spectrometer can detect the larger particles, but to detect the lighter particles the decay detector needs to be built.

By finding the energies of the Isoscalar Giant Monopole Resonance (IGSMR) also called the breathing mode, we can determine $K_A$ for different nuclei.

$$E_0 = \frac{M_A K_A}{m^2 M_0}$$

For lighter nuclei the macroscopic approach does not work as well because the $K_{vol}$ term is hard to interpret. But a microscopic approach using the Hartree-Fock Random Phase Approximation has been used to determine $K_{nm}$ also. We then use the compressibility of nuclear matter ($K_{nm}$) to determine the nuclear equation of state.

$$K_{nm} = \frac{\partial^2 E/A}{\partial^2 p/A} = \frac{\partial^2 E/A}{\partial^2 t/A}$$

Also $K_{nm}$ is used in the fields of astrophysics in relation to star collapse, black holes, supernova, and neutron stars.

The incident particles come off the target with different energies related to which transition they went through. These different particles are separated with the dipole magnet and then measured in the Focal Plane Detector according to energies and mass.

By finding $E_0$ for many nuclei ranging from heavy to light, we can use the semi-empirical mass formula as a macroscopic way to determine $K_{nm}$.

$$K_A = K_{nm} A^{1/3} + K_{sat} \left( \frac{N-Z}{A} \right)^{1/3} + K_{nuc} \frac{Z^2}{A^{1/3}}$$

The five larger scintillators which measure the total energy of the light fragments are behind the grid of 1mm scintillators and are connected via light guides to five larger PMT’s through the lid of the target chamber (pictured on the right).

By using a program called SRIM, which calculates range and energy lost for ions in material, a graph for the light output of the scintillators was drawn. The light output of the scintillators was counted with the MDM spectrometer.

When a photon from the scintillator hits the photocathode it produces electrons by the photoelectric effect. Then a series of dynodes, each at a higher potential difference than the one before it, will trigger a cascade of electrons which show up as a current pulse which can be measured.