Plastic Scintillator Response to Light Ions

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Nuclear Compressibility and Giant Resonance

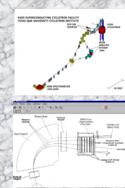
- The compressibility of nuclear matter (N=Z and no Coulomb interaction) is important because we can use it to better understand properties of the nucleus (radii, masses, giant resonances, etc), supernova, neutron stars, and heavy ion collisions.
- The study of the energy range of Isoscalar Giant Monopole Resonance (ISGMR) is an important source of information for the value of the nuclear compressibility.
- Giant Resonance is the collective excitation of all the nucleons in the nucleus resulting in their collective motion.

Different Types of Giant Resonance

- The specific type of giant resonance my group is interested in is Isoscalar Monopole Resonance.
- This type of resonance occurs when protons and neutrons move in phase such that the nucleus still remains in the shape of a sphere and the density and volume changes.

GR Study by Inelastic Scattering

- Determination of energies of ISGMR has been made for many nuclei using alpha inelastic scattering.
- My group has recently experimented with elastic and inelastic scattering of 40 MeV/nucleon ^{6}Li ions on ^{116}Sn to determine their usefulness in giant resonance investigations.
- By using ^{6}Li as a target with ^{28}Si beam as opposed to a projectile, this scattering might allow investigations of unstable nuclei.



MDM Spectrometer Detector

- We are using a multifunctional focal plane detector for detecting the horizontal angle and position, as well as the vertical angle of high energy particles such as ^{27}Al and ^{24}Mg which make it past the spectrometer. There are four wires for detecting horizontal angle and vertical drift planes to determine vertical angle.

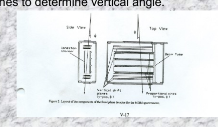


Figure 2: Layout of the components of the focal plane detector for the MDM spectrometer.

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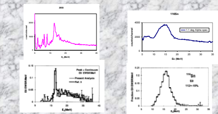
Identification of Giant Resonance



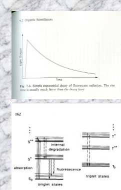
- The strength functions show the possible energy levels that can be achieved when a certain excitation energy is input.
- This peak in the ^{116}Sn is more of a broad bump due to the fact that the energy states are much more dense and it is harder to distinguish between them due to the resolution. With the ^{28}Si the spectrum is more of a series of overlapping narrow peaks because each energy level is more distinguishable.

Experimental Objectives

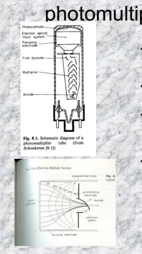
- What we want to do is study ISGMR in unstable nuclei but we can not use an unstable target because the decay make a different target and what we are studying will change. The target must remain the same for the duration of the experiment.
- This is the reason why we will try using ^{6}Li as a target for unstable projectiles.
- Also we can not use helium as a target because it would be difficult to use since it is a gas.
- In order to determine if ^{6}Li will be a suitable target we will use a stable beam of ^{28}Si and see if we can get the expected results.
- In this case the reactions which result from ISGMR are when ^{28}Si breaks up into ^{27}Al + P or ^{24}Mg + Alpha.
- For the detection of these particles we will use an array of scintillation detectors.

Scintillation Material

- For detecting decay of protons and alpha particles from the projectiles reaction with the target.
- The material is BC 408 ($H_{11}C_{10}$).
- It has a fast decay constant (2-3 ns).
- Very high light output which makes it easier to identify particles using this detector.
- Incoming ion excites scintillation molecule to higher energy level.Then scintillator molecule de-excites and emits a photon.

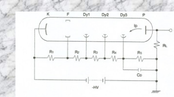


photomultiplier tube



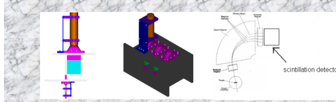
- Once a photon reaches the photocathode it is turned into electron due to the photo electric effect.
- After photoelectrons are created they are directed to the first dynode by high voltage.
- When a photoelectron reaches the first dynode it is then turned multiplied into several more electrons which are then directed to the next dynode.
- This process continues until the electrons reach the anode they are collected to create a current which is then amplified and analyzed for particle identification.

Voltage Divider Network



- The voltage divider uses resistors to divide the high voltage across the dynodes, the anode, and the photocathode in such a way as to guide the photoelectrons on a path to each dynode and to the anode in order to make use of as many photoelectrons as possible.

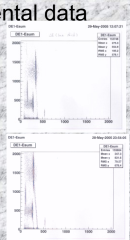
Testing Decay Detector



- The scintillation detector is going to be used for Identifying protons, deuteron, tritons, and alpha particles in various locations dependent upon the particle trajectories.
- The identification of these particles is dependent on the light produced by the total energy (E) deposited in the scintillator material as well as the energy deposited in the distance of 1mm, 2 mm, and 3 mm (dE) after the ion enters the material.
- Light output for E and dE will be used to make a 2-D plot which will then be used to identify the particles.

Experimental data

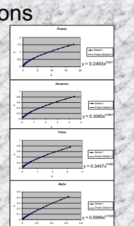
- Data taken from test run of scintillation detectors to be used for analyzing the accuracy of the scintillation detector using 1mm and 2 mm dE.
- These are the spectra that we used to compare our calculated light values with.



Calculations

- In order to verify our experimental data we had to calculate what the light output should be in a (E, dE) graph for the required energies of the particles we hoped to identify.
- To do this we used a program called Stopping Range of Ions in Matter (SRIM) to give us the stopping power (dE/dx), and the projected range (x) which corresponded to a set of energies for each particle. Using this equation[1]: $\frac{dL}{dx} = Log(1 + a\frac{dE}{dx})$ $a = .025g/cm^2/MeV$ we got a set of numbers for dL/dx which corresponds to projected range which we used to fit a curve to in order to obtain a function of dL/dx which could be easily integrated to give a function of L with respect to x.

$$\int_0^x \frac{dL}{dx}dx = L(x)$$



[1] T.J. Gooding and H.G. Pugh, Nuclear Instruments And Methods 7, 189-192

Calculations (continued)

- Having found a suitable function of L(x) we needed to determine what energy each particle would have in order to determine the light output we need to identify them. We knew the necessary energy of protons in which we are interested, so we used these equations

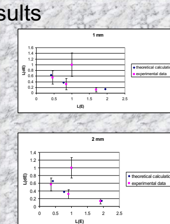
$$B = \frac{\sqrt{2Em}}{q} \qquad E = \frac{(B\ q)^2}{2m}$$

to determine the energy of the remaining particles.

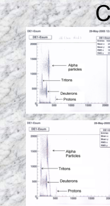
- Having obtained the energies of the particles I fit another curve to find x(E) in order to find the projected range which corresponded to a specific energy.
- Having found this, in order to find light output which corresponded to dE I subtracted L(x) – L(x – dx) where dx is 1mm or 2mm.

Results

- Having obtained the light output for the theoretical calculations as well as from the test run we normalized them by the light output of the alpha particle for E and dE in order to compare the two data sets.



Conclusions



- Because the calculated light output was comparable to the experimentally obtained light output from the test run we identified each particle from the test run successfully.
- For this reason we have determined that the scintillation detector used is acceptable for detecting these particles and can be used for later experiments involving ^{28}Si reacting to produce these particles as a result of the excitation of GR.
- 1mm scintillator is good enough to get measurable light output for high energy protons (~100 MeV).

Clean Room


- In order to use the MDM spectrometer detector we have to repair it. But first we had to rebuild the clean room in which we intend to repair the detector in the high bay because it was getting in the way of another groups work. This is actually what I spent most of the project working on as it was quite an undertaking.

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WHERE DISCOVERIES BEGIN