Building a Decay Detector For The Study of Isoscalar Giant Monopole Resonances In Radioactive Nuclei

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Giant Resonances

• Small amplitude, high-frequency collective excitations of the nucleus

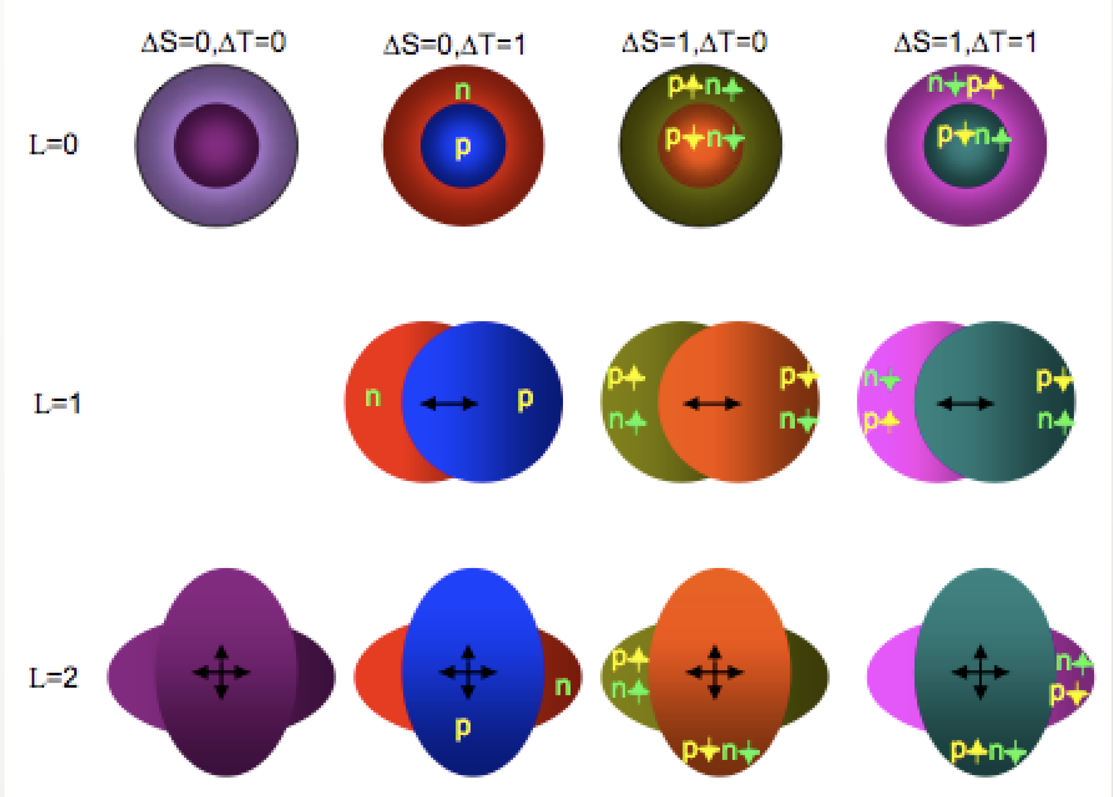


Figure 1: depiction of giant resonance modes (ref. Xinfeng Chen, "Giant Resonance Study By ^{6}Li Scattering"

Classical description: Liquid Drop Model

- Protons and neutrons are treated as independent fluids

Quantum Mechanical Description: Nuclear Shell Model

- Analogous to the electron shell model
- Levels in the system correspond to energy levels that protons and neutrons jump between during various processes
- Resonance can be thought of as protons and neutrons jumping up to a higher energy level, leaving a hole in the lower shell

• Energy Weighted Sum Rule (EWSR) is used to measure the strength of the giant resonance

$$S(Q) \equiv \sum_n (E_n - E_0)\left|\langle n|Q|0\rangle\right|^2 = \frac{1}{2}\langle 0|[Q,[H,Q]]|0\rangle$$

• From studying the Isoscalar Giant Monopole Resonance (ISGMR), E_{GMR} can be determined

• E_{GMR} can be used to find K_{nm}, a main component in the nuclear matter equation of state (EOS)

• Applications to astrophysics:

- Supernova collapse
- Neutron Stars

Unstable Nuclei

• Studying ISGMR in unstable nuclei may allow us to determine the dependence of the nuclear incompressibility on (N-Z)/A

• Cannot successfully make a target out of unstable nuclei

• Study the inverse reaction instead, unstable beam on light target

• Normal Kinematics:

$$^{26}Si(^6Li,^6Li)^{26}Si^*$$

• Inverse Kinematics:

$$^6Li(^{26}Si,^{26}Si^*)^6Li$$

Experimental Setup

• Decay particles will hit decay detector placed inside target chamber

• Remaining particles will go on to the MDM spectrometer

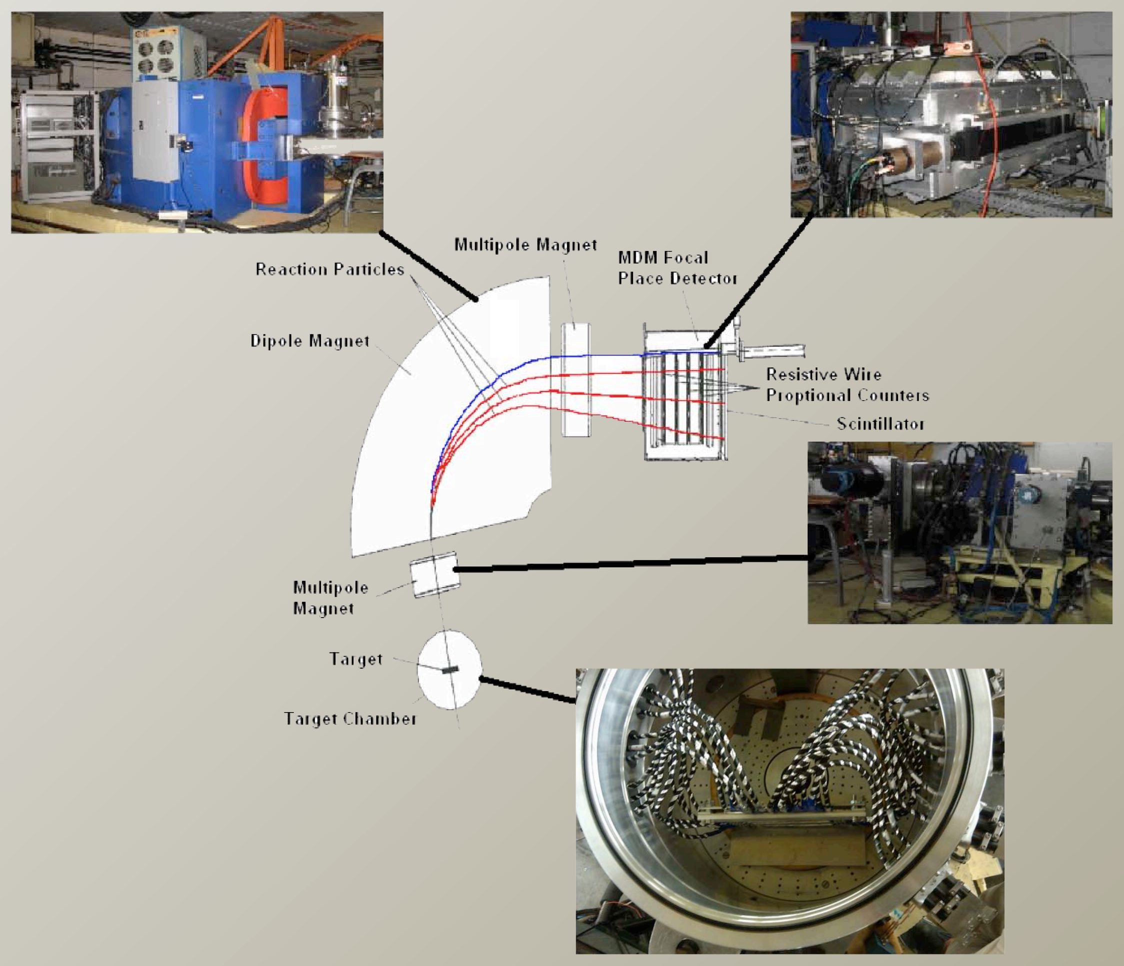


Figure 2: depiction of the experimental setup (ref. Xinfeng Chen, "Giant Resonance Study By ^{6}Li Scattering"

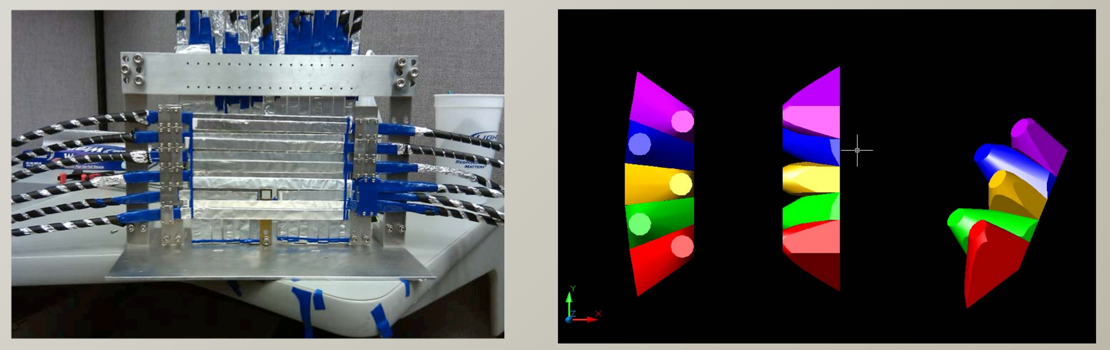
• MDM Spectrometer separates particles of different momentum and charge

• Ionization chamber measures the position

• Scintillator measures the total energy

Decay Detector

• Composed of a layer of horizontal 1 mm thick scintillator strips followed by a layer of vertical 1 mm thick scintillator strips in front of 5 block scintillators.



Figures 3 & 4: Strip scintillator assembly with optical fibers and block scintillator drawings.

• Each scintillator is connected to optical fibers that carry the signal to a photomultiplier tube (PMT)

• In the PMT, the photon's energy is converted to an electric signal and is amplified

• Scintillator strips give the angle of the particle as well as the energy loss through the strip

• The strip scintillator is also used for particle ID within the 7 < E/A < 11 (MeV/amu) range

• The block scintillators measure the remaining energy of the particle within 11 < E/A < 70 (MeV/amu) and IDs particles

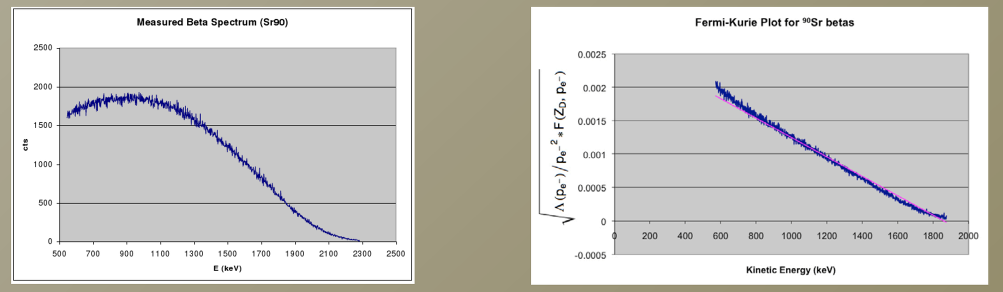
• Detector was tested with a beam of 30 MeV protons and 100 MeV alpha particles on a target of ^{12}C

Checking the Detector

• It was necessary to check the connection between each optical fiber and strip scintillator.

• Individual scintillator/PMT combinations were tested using a ^{90}Sr β-source.

• By using a Fermi-Kurie plot it is possible to calibrate raw data to known β spectra, eliminating differences in gain between PMTs.



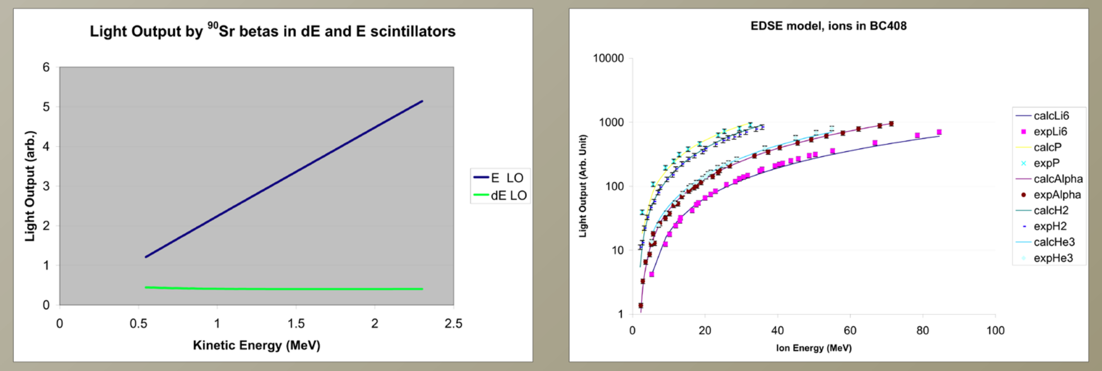
Figures 5 & 6: Beta spectrum and Fermi-Kurie plots

Predicting Light Output

Energy Deposition By Secondary Electrons (EDSE) Model:

- Specific detector response, dL/dx is related to the number of energy carriers.
- Possible to extract parameters from data set by fitting model to collected data.

$$\frac{dL}{dx} = C\frac{dN_e}{dx}\left(1 - F\frac{dN_e/dx}{A + dN_e/dx}\right)$$



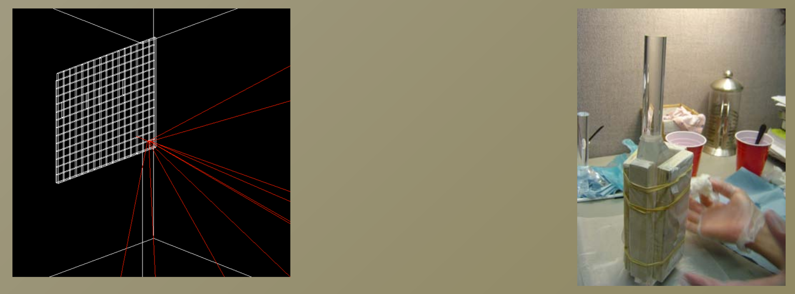
Figures 7 & 8: Light output versus kinetic energy of beta particles in different decay scintillators and EDSE model comparison to data for various ions.

Future Directions

• Use Monte Carlo simulation to predict detector response to collision events.

• Further analyze data collected during beam time.

• Make additional refinements to alignment of strip and block scintillators.



Figures 9 & 10: Simulation of collision event in GEANT4 and realignment of block scintillator

References

1.Chen, Xinfeng. Giant Resonance Study by ^{6}Li Scattering. Diss. Texas A&M University. 2008.

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3.J. F. Ziegler and J. P. Biersack and M. D. Ziegler (2008). SRIM - The Stopping and Range of Ions in Matter. SRIM Co.. ISBN 0-9654207-1-X.

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