Light Collection Efficiency in Thin Strip Plastic Scintillator for the Study of ISGMR in Unstable Nuclei
Giant Resonances

- Collective excitations of the nuclei
- Discovered in the 1940s while bombarding nuclei with gamma rays
- Monopole resonance is a spherical oscillation
- Isoscalar – neutrons and protons move in phase with one another
- Isovector – neutrons and protons move out of phase with one another
Isoscalar Giant Monopole Resonance (ISGMR)

- ISGMR: the breathing mode
- From studying the Isoscalar Giant Monopole Resonance (ISGMR), $E_{GMR}$ can be determined
- $E_{GMR}$ can be used to find $K_A$.
- $K_A$ can be used to find $K_{NM}$
- $K_{nm}$ is a quantity which describes a ground state property of nuclear matter
- Uses include:
  - Determining the nuclear equation of state
  - Neutron Stars
  - Supernova collapse
  - Heavy ion collisions

\[ E_{GMR} = \sqrt{\frac{\hbar^2 AK_A}{m <r^2>}} \]
Unstable Nuclei

ISGMR in unstable nuclei:

- Determine the dependence of the nuclear incompressibility on \((N-Z)/A\)
- Cannot successfully make a target out of unstable nuclei
- Study the inverse reaction

Normal Kinematics:

\[ ^{26}\text{Si}(^{6}\text{Li},^{6}\text{Li})^{26}\text{Si}^* \]

Inverse Kinematics:

\[ ^{6}\text{Li}(^{26}\text{Si},^{26}\text{Si}^*)^{6}\text{Li} \]
Experimental Setup

Decay detector:
- Detects decay by proton and alpha emission
- Particle type
- Angle
- Energy

Gas detector:
- Detects heavy ions
- Energy
- Angle
Measuring Protons and Alphas from Decay of ISGMR

- **Detector:**
  - Layer of horizontal 1 mm thick scintillator strips
  - Layer of vertical 1 mm thick scintillator strips
  - 5 block scintillators

- **Scintillator strips:**
  - Angle
  - Energy loss

- **Block scintillators:**
  - Total energy

- **Angular resolution ~4°**
Scintillators

- Scintillator:
  - absorbs energy
  - emits light

- Particle:
  - Excites electrons
  - Photons are emitted as electrons return to low energy states.

- Photons are translated into an electrical signal by a photomultiplier which is coupled to the scintillator.

Calculation of light output in $\Delta E_1$ and $\Delta E_2$ for protons and alpha ions
Photomultiplier

- Photomultiplier:
  - Absorbs light
  - Releases Electrons via photoelectric effect at the photocathode
  - The cathode, dynodes, and anodes create a potential “ladder”
  - Electrons travel from the photocathode to the first dynode and excite more electrons in the dynode
  - Excited electrons leave the dynode and travel to the next dynode in sequence and repeats the process
  - At the anode all the electrons are collected and then amplify to create a readable current

- Increasing light collection efficiency:
  - Wrap the scintillators in reflective material
Scintillator Wrapping

- Wrapping:
  - Light tight
  - Reflective

- Reflective material:
  - Ensures the maximum number of photons enter the photomultiplier.

- Optimize the improved signal vs. the energy lost by the particle.
Types of Wrapping

- Aluminum foil
- Aluminized Mylar
- 3M Tyvek
- reflective paint
Scintillator Testing Setup

- BC408 Scintillator
- Fiber Optic Bundle
- PMT
- Spec-amp
- Pre-amp
- PMCA
- Computer
- 241Am
- HV
\(^{241}\)Am Spectrum

Typical \(^{241}\)Am Spectrum Obtained with an ORTEC Partially-Depleted Detector.
$^{241}$Am Spectrum

Am241 Decay Spectrum

- Electrons, gammas, & x-rays
- Alpha Peak ~5.46 MeV
- Detector Resolution ~ 2 MeV

MeV vs. dN/dE graph with energy range from 0 to 10 MeV and dN/dE values from 0 to 0.01.
Spectrum Shift with Distance

1 Layer Aluminized Mylar Wrapping

Light intensity loss with distance from optical connection

Counts

Ch
For 0 layer $A_0 = 675 \pm 7$
$B_0 = 37.6 \pm 0.8$

For 1 layer $A_1 = 661 \pm 13$
$B_1 = 30.0 \pm 1.5$
Testing

- Light proof box
- Scintillator to PMT coupling
- Calibrating electronics
Continuing Work

- Test various wrapping to determine the most effective type to use in the detector
- Assemble, test and use detector to study ISGMR in various unstable nuclei
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