GAMMA DETECTION EFFICIENCY OF STATE-OF-THE-ART Ge DETECTORS

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Motivation

Nuclear Structure of ^{23}Al

- Like mass, ground state spin and parity are fundamental characteristics of a nucleus.
  - What are the ground state spin and parity for the exotic nucleus **^{23}Al**, $5/2^+$ or $1/2^+$?

Mirror Symmetry

- Mirror symmetry occurs between two nuclei with the same atomic number, but mutually interchangeable number of protons and neutrons.
- ^{23}Ne has a ground state spin and parity of 5/2+. Is mirror symmetry between these two nuclei broken?

Halo Nucleus

- Previous experiment has shown that ^{23}Al has a very large reaction cross section (PRC 65, 024610 (2002)).
- In a halo nucleus, a proton orbits around a central core of nucleons, similar to the electron and the nucleus in the atomic model, with an extended wave function.
- Is ^{23}Al, this loosely bound nucleus with Sp = 145 keV, a halo nucleus?

Experiment at GANIL laboratory, France

Breakup Mechanism

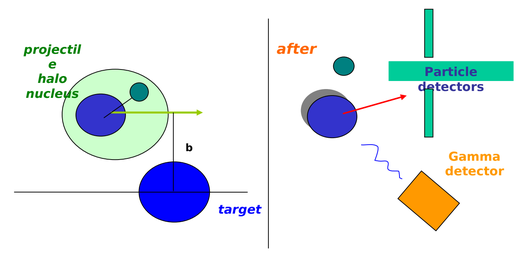

Figure 1. An illustration showing the breakup of ^{23}Al. After colliding with the target, the nucleus breaks up into a core ^{22}Mg nucleus and a proton. The ^{22}Mg nucleus then decays down from the excited states to its ground state, and the gammas are detected.

Experimental Setup

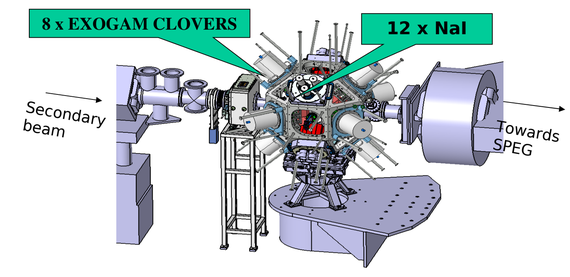

Figure 2. An illustration of the experimental setup at GANIL. The beam enters from the left where it interacts with the target surrounded by 8 Ge and 12 NaI detectors.

EXOGAM Germanium Detectors

- Each of the 8 clovers used in the setup is segmented into 4 crystals (A, B, C, D) and segmented again into parts (1, 2, 3, 4).
- Segmentation provides for careful consideration of Doppler corrections such as energy shifting and energy broadening.

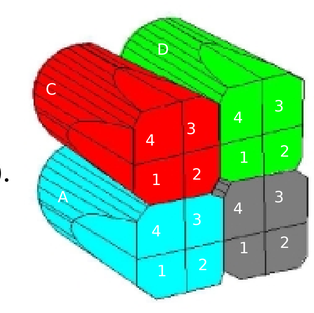

Figure 3. An illustration of an EXOGAM clover.

My Project

Detector Efficiency Determination

- In order to accurately determine the energies of the emitted gamma rays of ^{22}Mg, an analytical expression for the efficiency must be derived
- Four sources were used to calibrate the detectors: ^{60}Co (1.1-1.2 MeV, 13988 Bq), ^{137}Cs (0.6 MeV, 34825 Bq), ^{152}Eu (121 keV-1.5 MeV, 23209 Bq), and **^{56}Co** (0.8 – 3.6 MeV, **unknown activity**).
- ^{56}Co is of particular importance because it is the only source that supplies high energy gammas (>3 MeV). However, since its activity at the time of the experiment was unknown, **an estimate needed to be determined**.

Efficiency

$$\varepsilon_{ph}(E_\gamma) = \frac{N(E_\gamma)}{A_o * \Delta t' * b_\gamma} \qquad \delta\varepsilon = \varepsilon * \sqrt{\left(\frac{\delta N_{decays}}{N_{deacys}}\right)^2 + \left(\frac{\delta b_\gamma}{b_\gamma}\right)^2}$$

- $N(E\gamma)$ is the area underneath each photopeak, A_0 is the activity at the time of the experiment, $\Delta t'$ is the run time of the experiment (with dead-time corrections) and b_γ is the branching ratio of the beta-decay into certain excited states or ground state of the corresponding stable daughter nucleus.

RADWARE software was used.

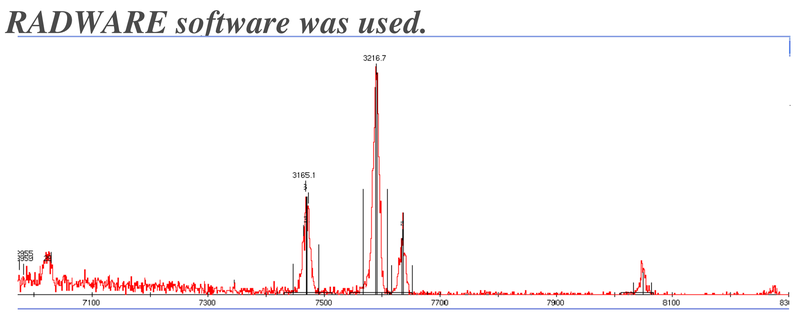

Figure 4. An image from RADWARE demonstrating three gamma rays. The peaks are fit, energies are labeled and the area under the curve is calculated.

- Since the efficiency calculations are dependent on the energy, a graph will be prepared and fit with a curve to find the analytical expression.

Results

Efficiency calibration using ^{60}Co, ^{152}Eu, ^{137}Cs

$$Activity = \frac{N(E_\gamma)}{\varepsilon * \Delta t' * b_\gamma}$$

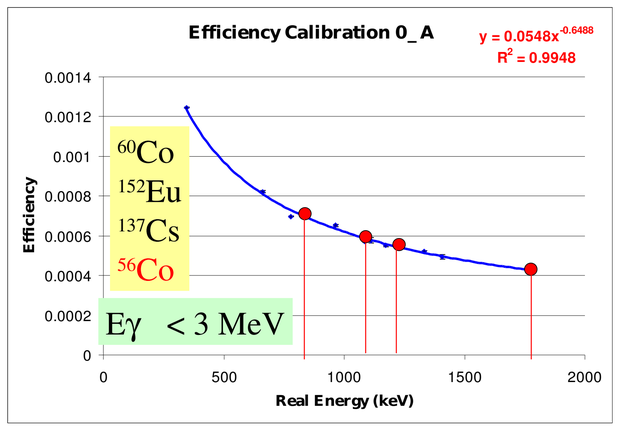

Figure 5. An efficiency calibration for one of the EXOGAM clovers. *Without ^{56}Co we cannot extrapolate the analytical expression for the efficiency beyond 2 MeV.*

A_1 = 20292.6 ± 82.3

A_2 = 20300.4 ± 279.3

A_3 = 20501.2 ± 128.8

…

A_4 = 20319.4 ± 285.5

<Ā> = 20123.9 ± 128.7

^{56}Co Activity determination

- we determined analytical (see above) expressions of the efficiency for each of the 32 crystals up to γ -ray energies below 2 MeV using ^{60}Co, ^{152}Eu and ^{137}Cs.
- we applied those analytical expressions to the low γ -ray energies of ^{56}Co such as: 846.76 keV, 1238.27 keV, and 1771.32keV
- as a result, using conversely the relation between efficiency and activity, the activity corresponding to each of the low energies of 56Co was determined.
- Next, an average value for the activity was obtained as follows:

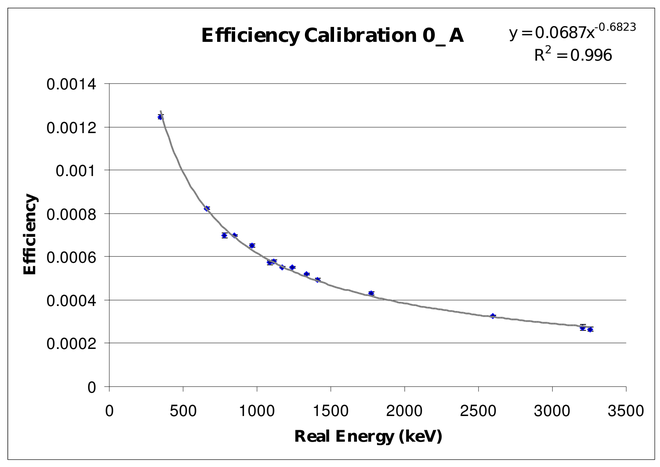

Figure 6. The total efficiency calibrationfor the whole energy range of interest (up to 3 MeV) of an EXOGAM clover. The same work was done for each of the 32 crystals of the EXOGAM setup.

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