Ba Double Gamma Decay Measurement with GAMMASPHERE

Edana Merchán, C. J. (Kim) Lister, K. Moran
University of Massachusetts Lowell

An E5 decay from the $J^\pi = 11/2^-$ isomer in $^{137}$Ba

K. Moran$^1$, E.A. McCutchan$^2$, C.J. Lister$^1$, S. Zhu$^3$, M.P. Carpenter$^3$
P. Chowdhury$^1$, J.P. Greene$^3$, T. Lauritsen$^3$, E. Merchant$^1$, and R. Shearman$^1$*

$^1$Department of Physics, University of Massachusetts, Lowell, MA 01854
$^2$National Nuclear Data Center, Brookhaven National Laboratory, Upton, NY 11973
$^3$Physics Division, Argonne National Laboratory, Lemont, IL 60439
(Dated: July 29, 2014)

Submitted to Phys Rev C
2-photon decay

- One of a family of second order electromagnetic processes.
- They are sensitive to the initial and final state wave functions.

On the probability of a collaboration of two light quanta in an elementary process

M. Goppert. Natureweiss 17 932 (1929)
Classic Nuclear Experiment

J. Kramp et al. Nucl. Phys. A474 (1987) 412

- Studied $0^+ \rightarrow 0^+$ transition on $^{16}$O, $^{40}$Ca, and $^{90}$Zr.
- Using crystallball a 162 NaI(Tl) $4\pi$ array.
A total of 68 Compton suppressed HpGe were used.

The forward section was removed to avoid scattering from FMA.

A calibrated 19.27 $\mu$Ci $^{137}$Cs source was used.

Doubles trigger.

Collected data for $\sim$10 days.

A total of $6.42 \times 10^{11}$ decays.
Source experiment @ GAMMASPHERE

- A total of 68 Compton suppressed HpGe were used.
- The forward section was removed to avoid scattering from FMA.
- A calibrated 19.27 µCi $^{137}\text{Cs}$ source was used.
- Doubles trigger.
- Collected data for $\sim 10$ days.
- A total of $6.42 \times 10^{11}$ decays.
A total of 68 Compton suppressed HpGe were used.

The forward section was removed to avoid scattering from FMA.

A calibrated 19.27 $\mu$Ci $^{137}$Cs source was used.

Doubles trigger.

Collected data for $\sim$10 days.

A total of $6.42 \times 10^{11}$ decays.
Source experiment @ GAMMASPHERE

- A total of 68 Compton suppressed HpGe were used.
- The forward section was removed to avoid scattering from FMA.
- A calibrated 19.27 $\mu$Ci $^{137}$Cs source was used.
- Doubles trigger.
  - Collected data for $\sim$10 days.
  - A total of $6.42 \times 10^{11}$ decays.
A total of 68 Compton suppressed HpGe were used.

The forward section was removed to avoid scattering from FMA.

A calibrated 19.27 $\mu$Ci $^{137}$Cs source was used.

Doubles trigger.

Collected data for $\sim$10 days.

A total of $6.42 \times 10^{11}$ decays.
Source experiment @ GAMMASPHERE

- A total of 68 Compton suppressed HpGe were used.
- The forward section was removed to avoid scattering from FMA.
- A calibrated 19.27 $\mu$Ci $^{137}$Cs source was used.
- Doubles trigger.
- Collected data for $\sim$10 days.
- A total of $6.42 \times 10^{11}$ decays.
$^{137}$Cs Decay

- 662 keV dominant transition ($>10^6$ stronger than other decays).
- 284 keV $\gamma$ previously detected (much stronger than 378 keV $\gamma$, fed by $\beta$-decay)
$^{137}$Cs Decay

- 662 keV dominant transition (> $10^6$ stronger than other decays).
- 284 keV $\gamma$ previously detected
  (much stronger than 378 keV $\gamma$, fed by $\beta$-decay)
Background Subtraction

- $\gamma - \gamma$ coincidence windows of 400 ns.
- Trigger level around $2 \times 10^6$ counts/ns
- 15 ns window at zero time difference to extract about 10% of the prompt coincidence events.
Sum Energy vs Energy Difference Matrix

- Sum Energy (keV)
- Energy Difference (keV)
- Counts

Compton Ridge
Compton Background
Angular selection, follow Klein-Nishina distribution.
Compton Background

Angular selection, follow Klein-Nishina distribution.
Compton Background
Angular selection, follow Klein-Nishina distribution.
deltaE vs Opening Angle (det. 1-35 removed)
Gamma Cascade (Duotrigesapole Transition)

- Cascade is isotropic (no angular correlation).
- Values correspond to $\pm (378 \text{ keV}-284 \text{ keV})$, or $\pm 94 \text{ keV}$
Branching Ratio

\[ Br_{\gamma}^{E5} = \frac{I_{\gamma}^{E5}}{\sum I(\gamma + CE)} = 1.12 \pm 0.9 \times 10^{-7} \]

- Gammasphere efficiency.
- Detector selection.
- Total time (dead time).
- Factor of 2 accounting for symmetrized matrix.
- Correction due to EC.
Intensities

| $E_\gamma$ (keV) | Intensity $\gamma$ |
|-----------------|-------------------|
| 662             | 94.7(14)          |
| 284             | 5.8(8) × $10^{-4}$|
| 378             | 1.06(9) × $10^{-5}$|

New estimate value:
$\log ft = 16.49(12)$
Distribution of $B(E5)$ values

$B(E5) = 0.71(6) \text{ W.u.}$ → Typical value for "single particle" decays of this type.
\[ ^{137}\text{Cs Decay} \]

- Determine the 1-photon vs. 2-photon branching ratio.
- Investigate high multipolarity competition, Q-Q vs. Oct-Dip.
- A test of both QED and nuclear wave functions.
Geant4 Simulation*

- Approximate geometry.
- No background.
- No doubles trigger.
- Time consuming ($6.42 \times 10^{11}$ decays).

*Simulation geometry provided by the GFNUN - Colombia
Geant4 Simulation*

- Approximate geometry.
- No background.
- No doubles trigger.
- Time consuming (6.42 \times 10^{11} decays).

*Simulation geometry provided by the GFNUN - Colombia
Compton Distribution

- Distribution of the Compton from the 662 keV with the opening angle.
Compton Distribution

Distribution of the Compton from the 662 keV with the opening angle.
GRETA Simulation
Expected the order of $10^{-6}$ branching ratio for the double gamma events.
Results and Perspectives

- The branch of the $^{137}$Ba cascade of two photons has been measured.
- The calculated branching ratio is of $1.12 \pm 0.9 \times 10^{-7}$
- The intensity of the 378 keV transition has been measured to be $1.06(9) \times 10^{-5}$
- The cascade is about two orders of magnitude less than the expected double gamma decay.
- A distribution for the double gamma decay has been observed, its angular distribution must be carefully studied.
- Compton correction is ongoing by using the GS simulation.

Thanks.
Results and Perspectives

- The branch of the $^{137}\text{Ba}$ cascade of two photons has been measured.
- The calculated branching ratio is of $1.12 \pm 0.9 \times 10^{-7}$
- The intensity of the 378 keV transition has been measured to be $1.06(9) \times 10^{-5}$
- The cascade is about two orders of magnitude less than the expected double gamma decay.
- A distribution for the double gamma decay has been observed, its angular distribution must be carefully studied.
- Compton correction is ongoing by using the GS simulation.

Thanks.
Results and Perspectives

- The branch of the $^{137}$Ba cascade of two photons has been measured.
- The calculated branching ratio is of $1.12 \pm 0.9 \times 10^{-7}$
- The intensity of the 378 keV transition has been measured to be $1.06(9) \times 10^{-5}$
- The cascade is about two orders of magnitude less than the expected double gamma decay.
- A distribution for the double gamma decay has been observed, its angular distribution must be carefully studied.
- Compton correction is ongoing by using the GS simulation.

Thanks.
Results and Perspectives

- The branch of the $^{137}$Ba cascade of two photons has been measured.
- The calculated branching ratio is of $1.12 \pm 0.9 \times 10^{-7}$
- The intensity of the 378 keV transition has been measured to be $1.06(9) \times 10^{-5}$
- The cascade is about two orders of magnitude less than the expected double gamma decay.

- A distribution for the double gamma decay has been observed, its angular distribution must be carefully studied.
- Compton correction is ongoing by using the GS simulation.

Thanks.

E. Merchan (UMass Lowell)
Results and Perspectives

- The branch of the $^{137}$Ba cascade of two photons has been measured.
- The calculated branching ratio is $1.12 \pm 0.9 \times 10^{-7}$
- The intensity of the 378 keV transition has been measured to be $1.06(9) \times 10^{-5}$
- The cascade is about two orders of magnitude less than the expected double gamma decay.
- A distribution for the double gamma decay has been observed, its angular distribution must be carefully studied.
- Compton correction is ongoing by using the GS simulation.

---

Thanks.

E. Merchan (UMass Lowell)
Results and Perspectives

- The branch of the $^{137}$Ba cascade of two photons has been measured.
- The calculated branching ratio is of $1.12 \pm 0.9 \times 10^{-7}$
- The intensity of the 378 keV transition has been measured to be $1.06(9) \times 10^{-5}$
- The cascade is about two orders of magnitude less than the expected double gamma decay.
- A distribution for the double gamma decay has been observed, its angular distribution must be carefully studied.
- Compton correction is ongoing by using the GS simulation.

Thanks.