^{137}Ba Double Gamma Decay Measurement with GAMMASPHERE

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University of Massahusetts Lowell

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

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2-photon decay

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

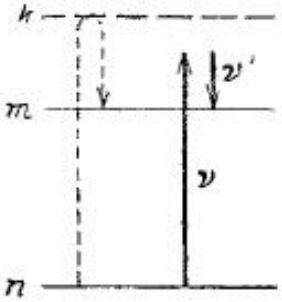


Fig. 1.
Stokesscher Fall
des Raman-Effekts.

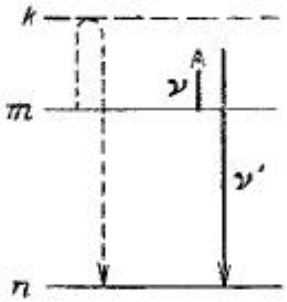


Fig. 2.
Antistokesscher Fall
des Raman-Effekts.

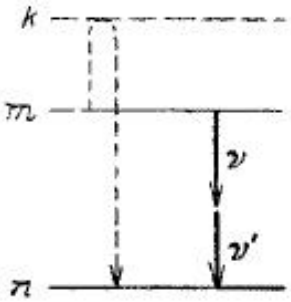


Fig. 3.
Doppelemission.

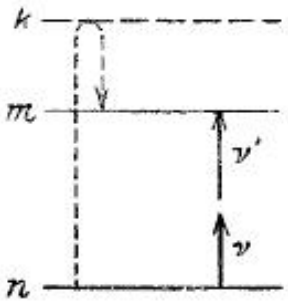


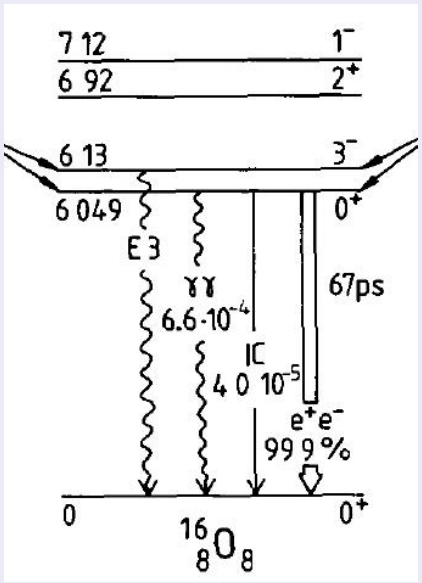
Fig. 4.
Doppelabsorption.

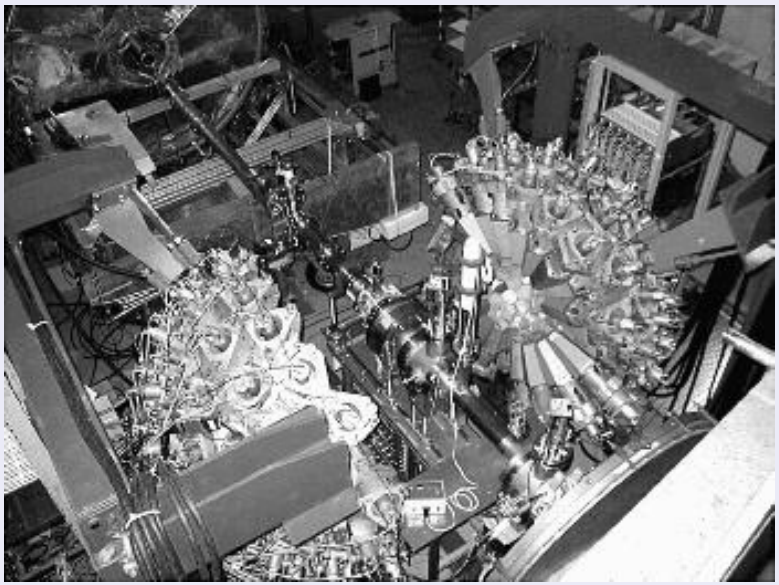
On the probability of a collaboration of two light quanta in an elementary process

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) 4π array.

Source experiment @ GAMMASPHERE

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

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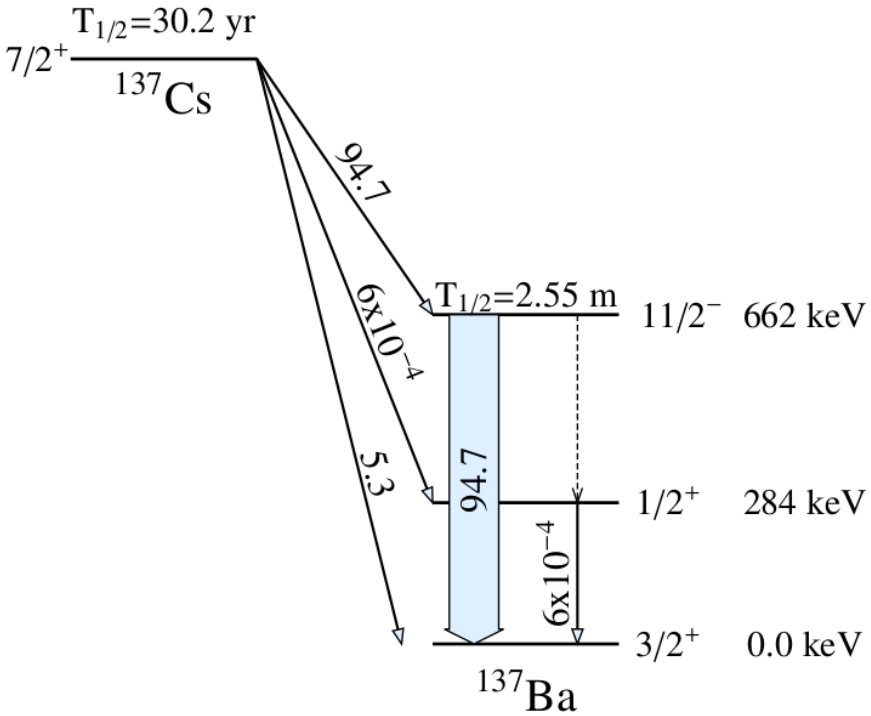
^{137}Cs Decay



- 662 keV dominant transition ($> 10^6$ stronger than other decays).
- 284 keV γ previously detected
  (much stronger than 378 keV γ, fed by β-decay)

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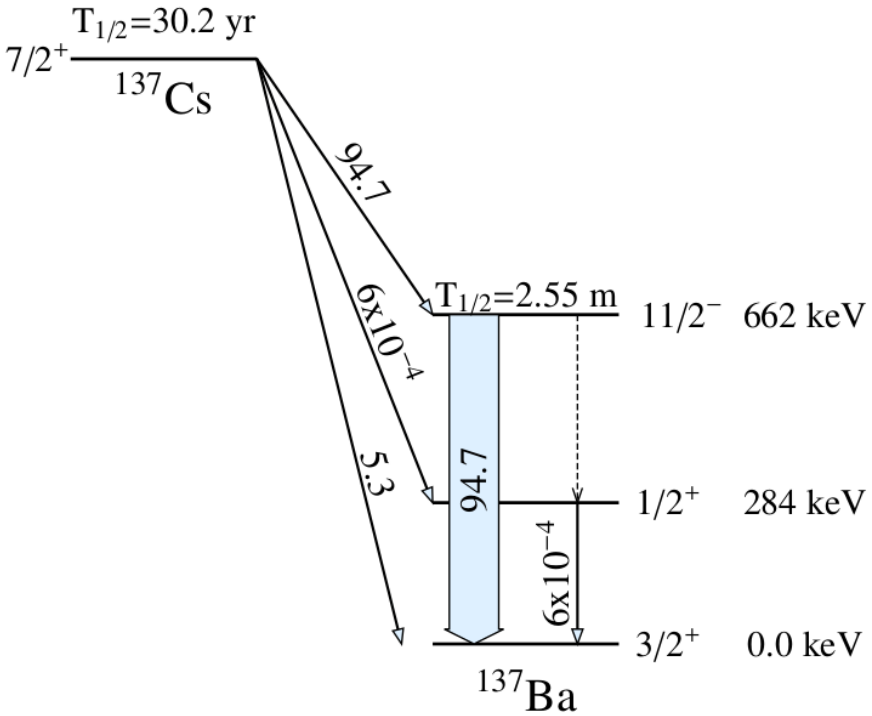

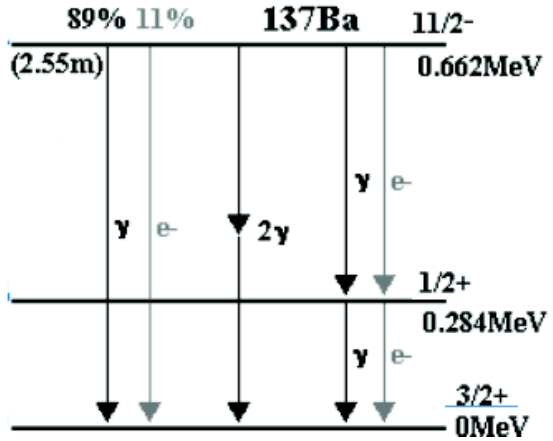

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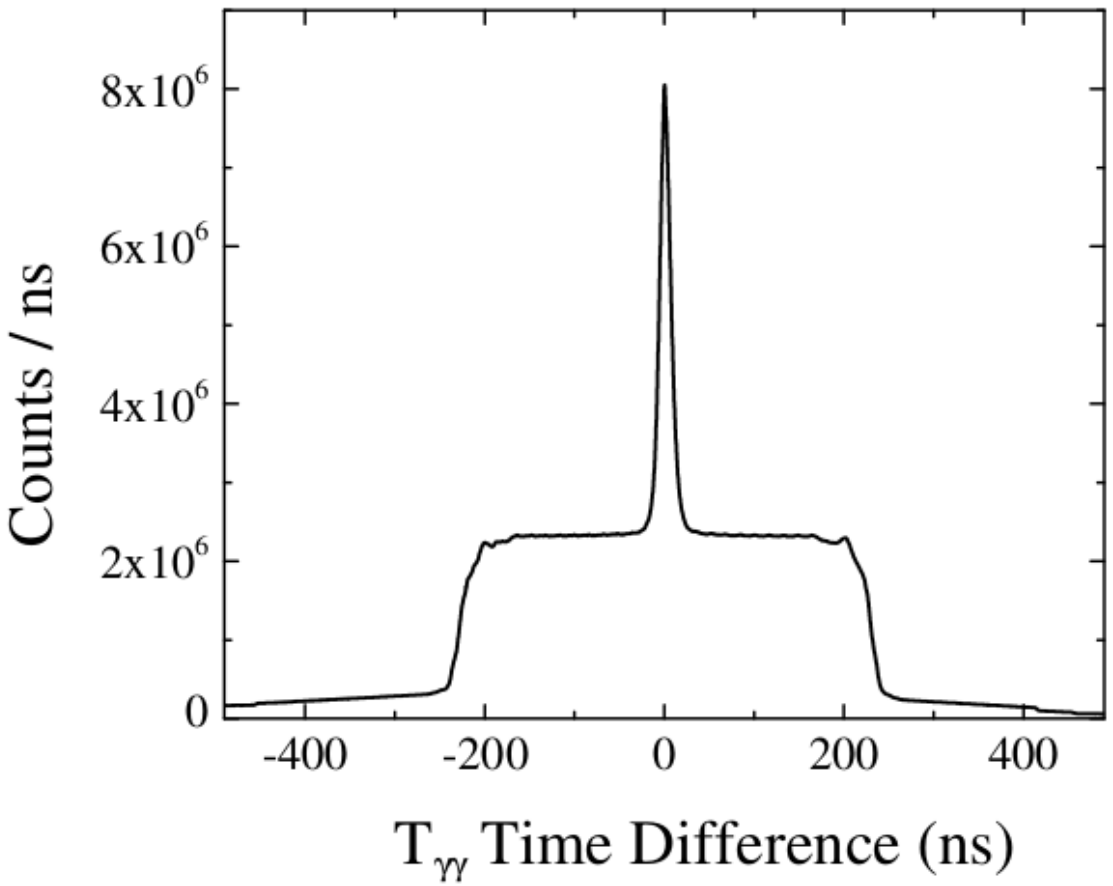
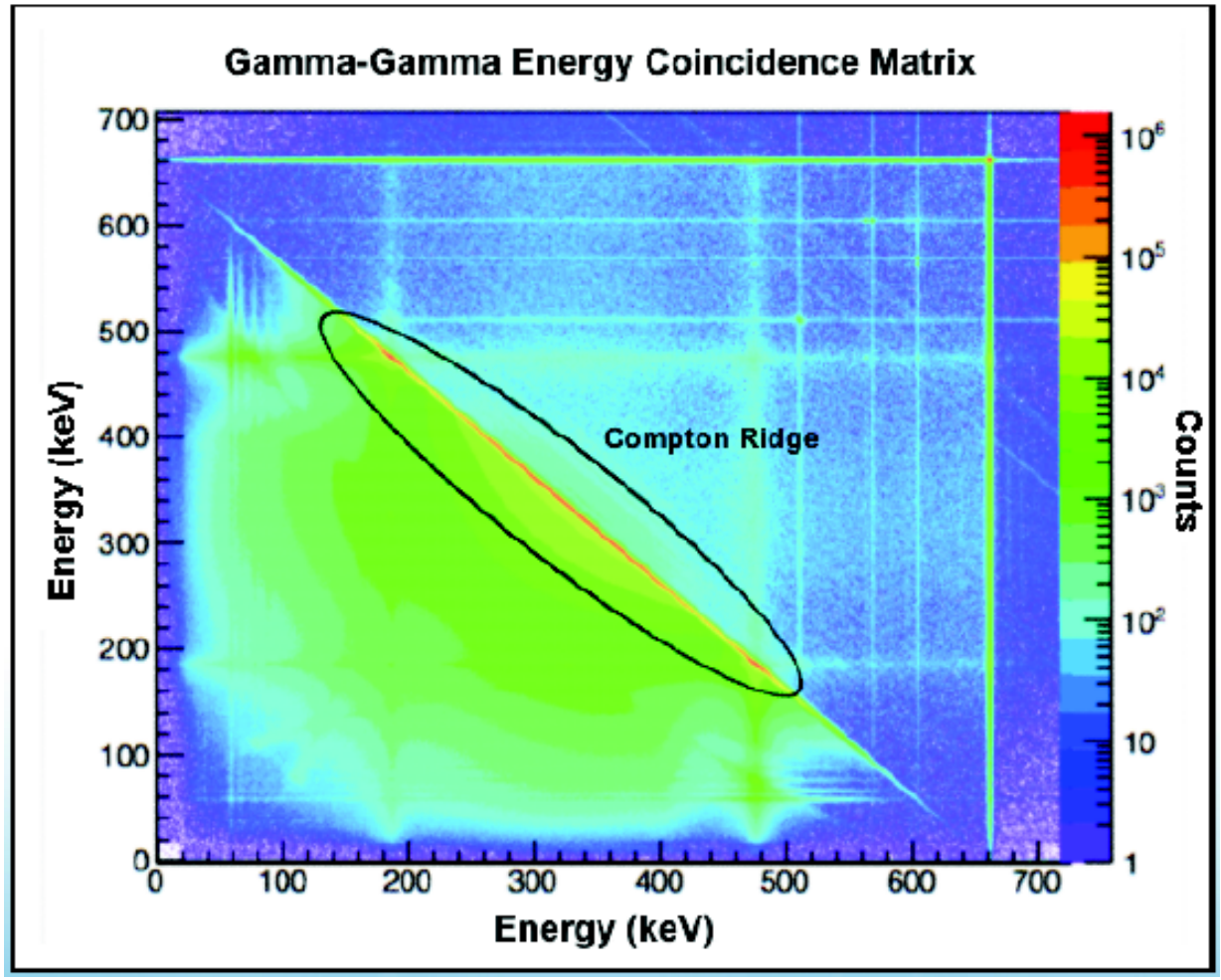
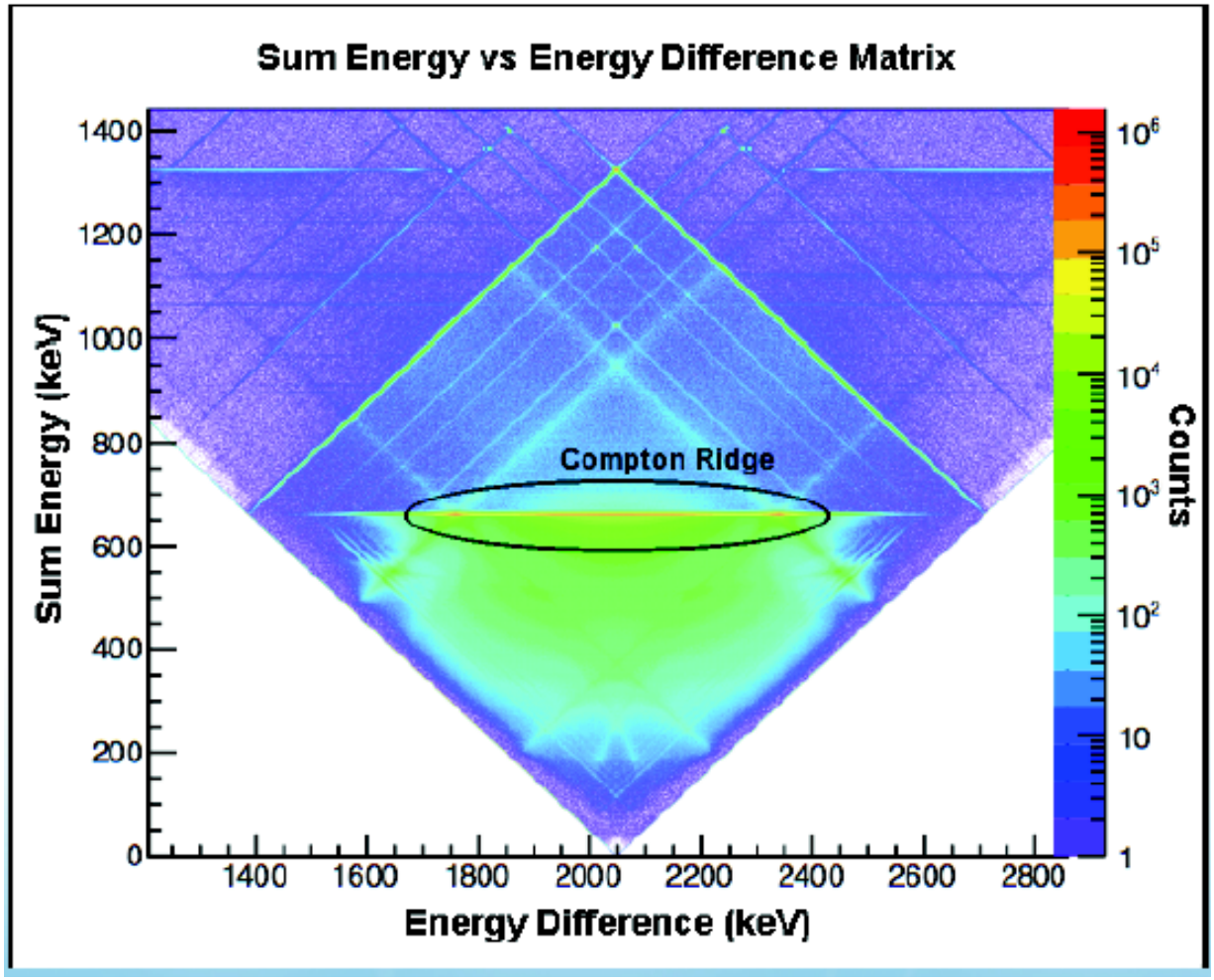
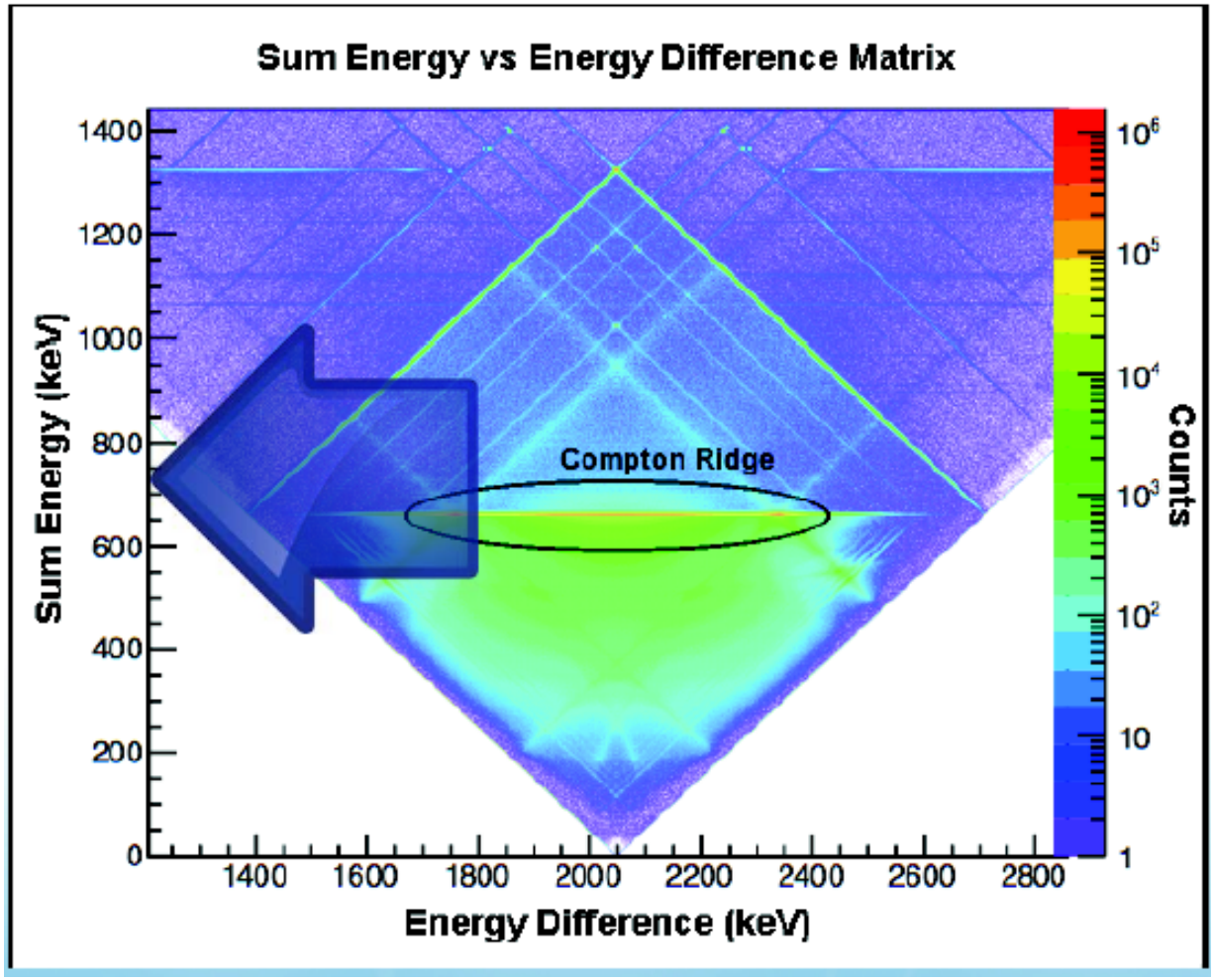
Background Substraction

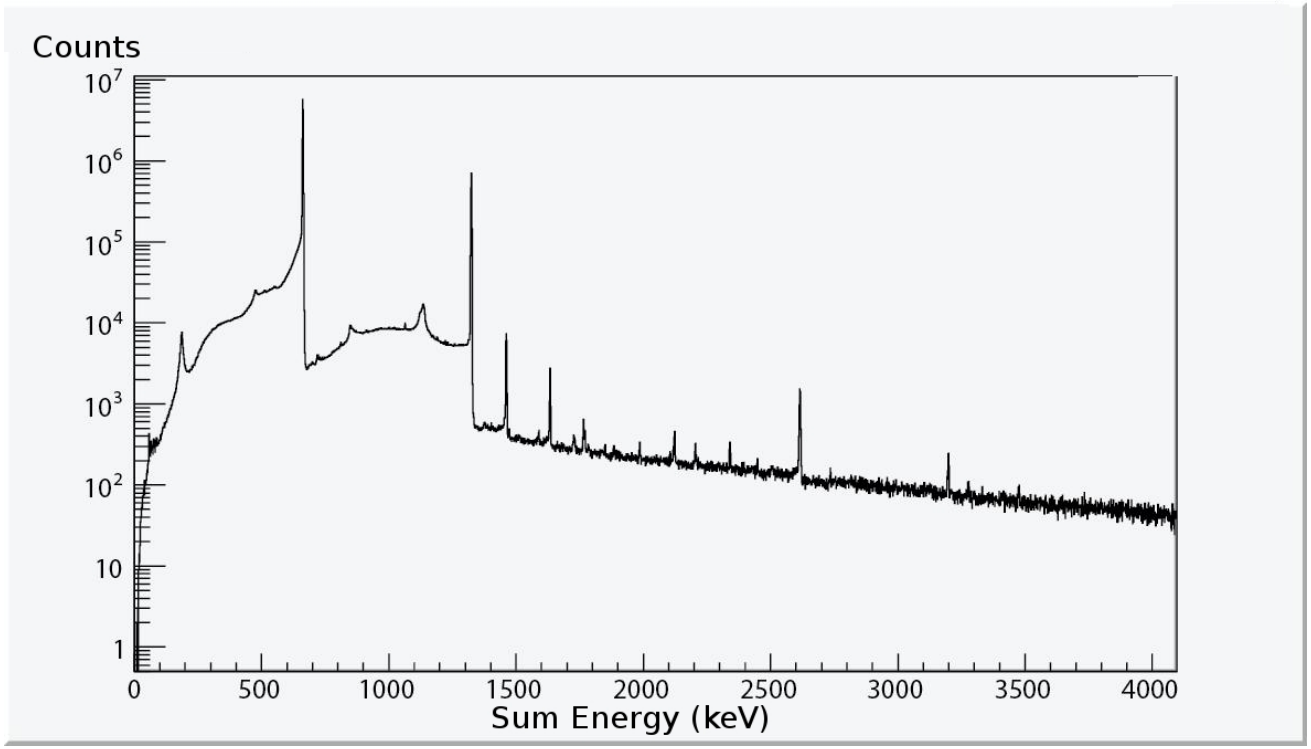


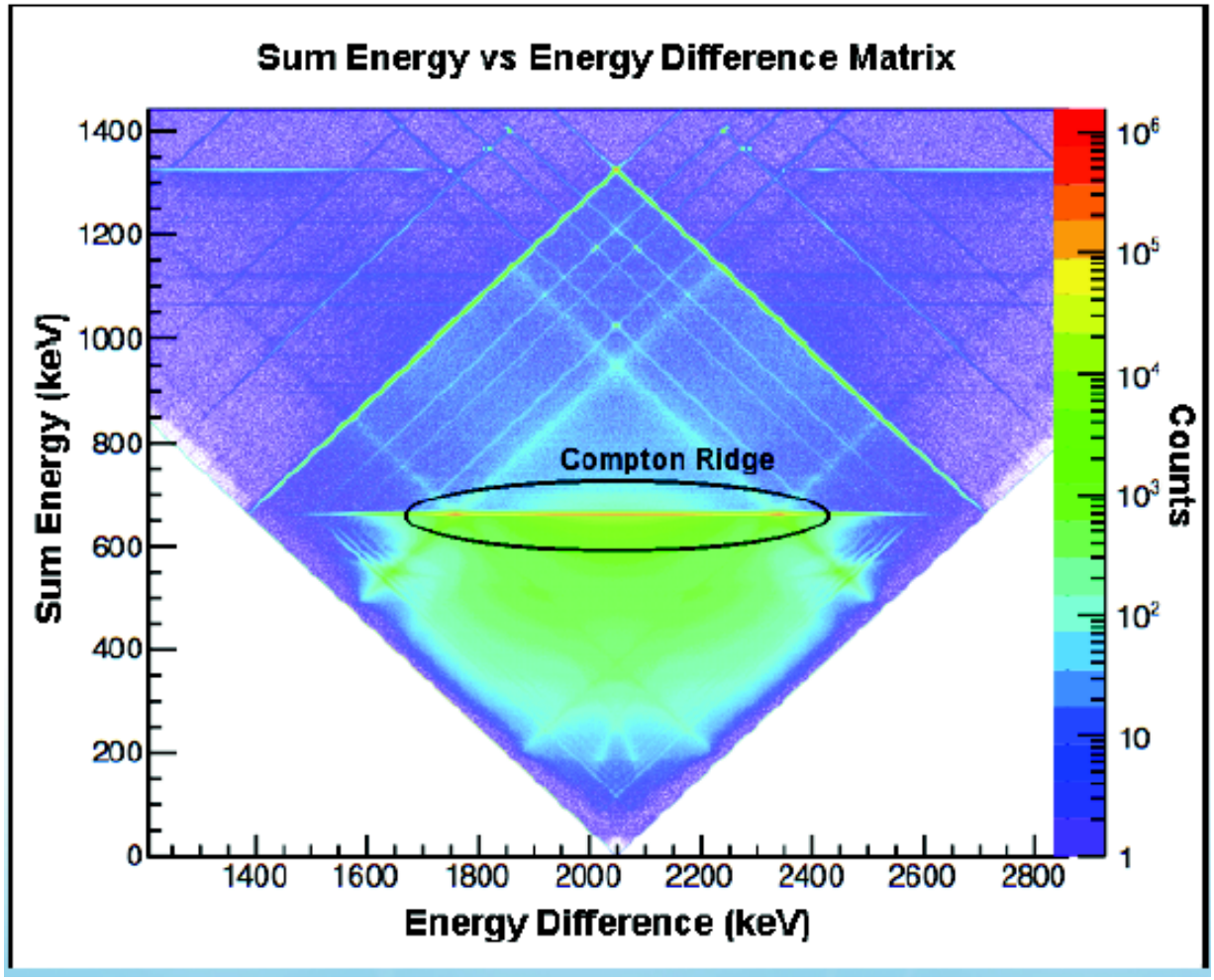
- $\gamma - \gamma$ coincidence windows of 400 ns.
- Trigger level around 2×10^6 counts/ns
- 15 ns window at zero time difference to extract about 10% of the prompt coincidence events.

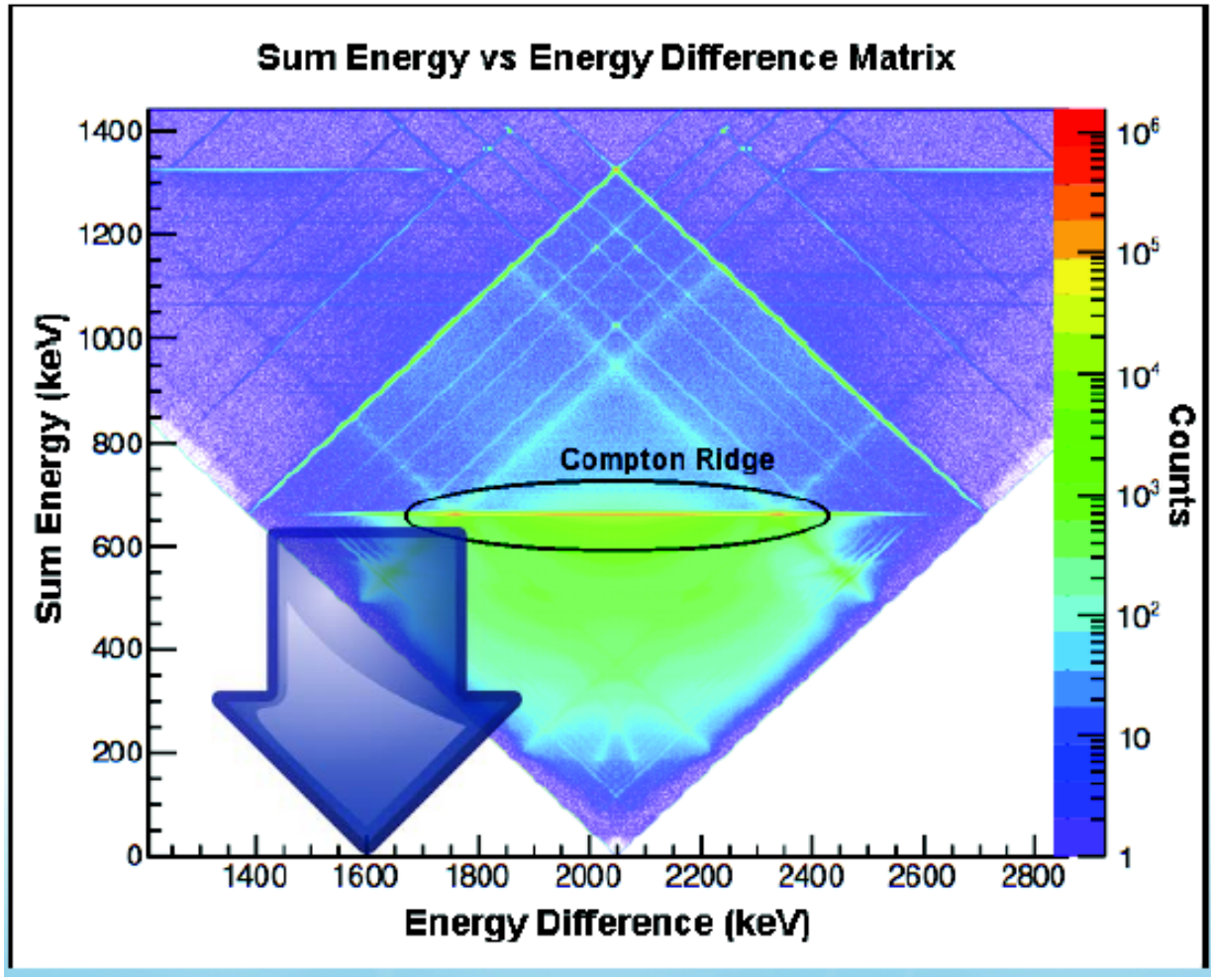

Gamma-Gamma Energy Coincidence Matrix
Compton Ridge
Energy (keV)
Energy (keV)
Counts
0
100
200
300
400
500
600
700
1
10
10^2
10^3
10^4
10^5
10^6

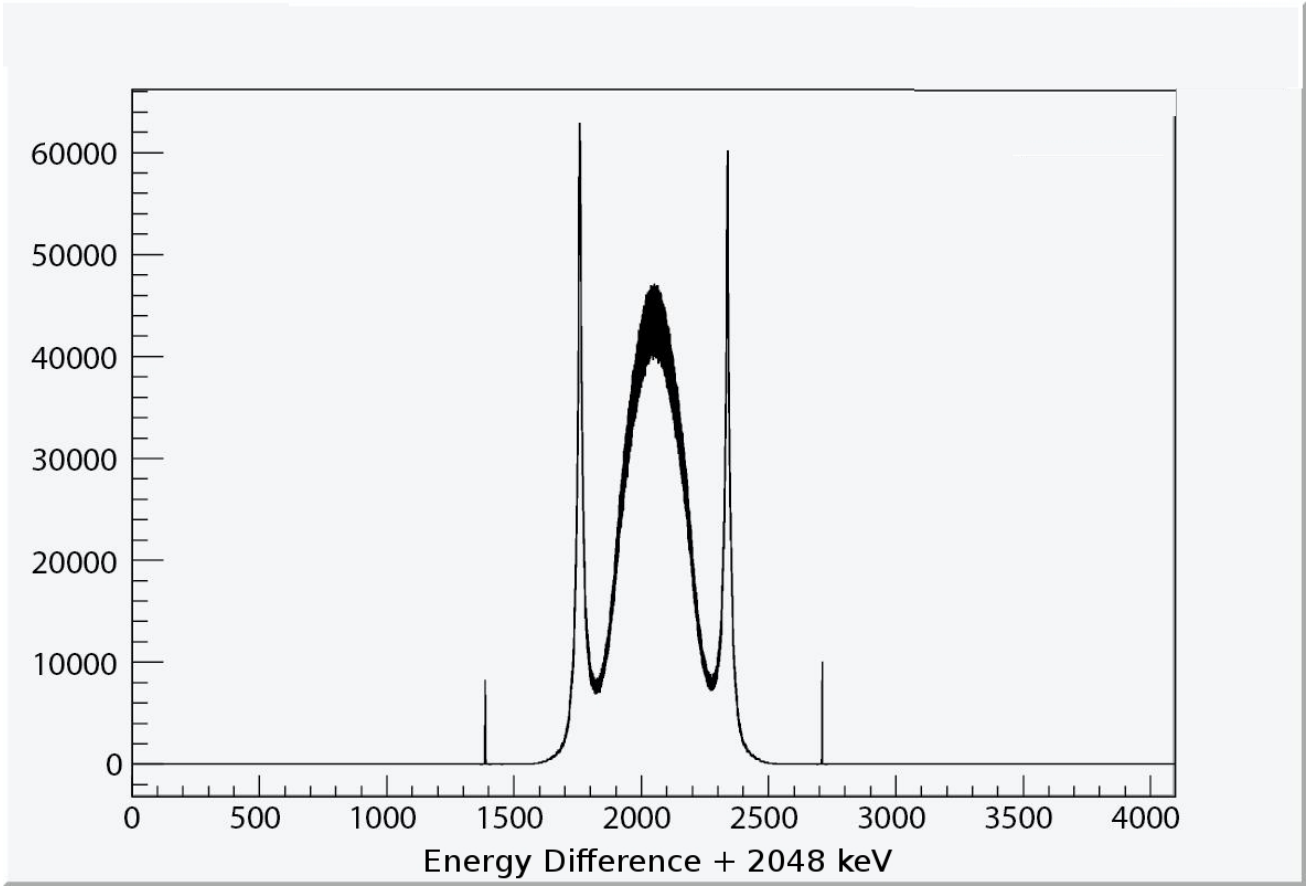

Sum Energy vs Energy Difference Matrix
Compton Ridge
Sum Energy (keV)
Energy Difference (keV)
Counts
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
1
10
10^2
10^3
10^4
10^5
10^6


Sum Energy vs Energy Difference Matrix
Compton Ridge
Sum Energy (keV)
Energy Difference (keV)
Counts
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
1
10
10^2
10^3
10^4
10^5
10^6


Counts
10^7
10^6
10^5
10^4
10^3
10^2
10
1
0
500
1000
1500
2000
2500
3000
3500
4000
Sum Energy (keV)

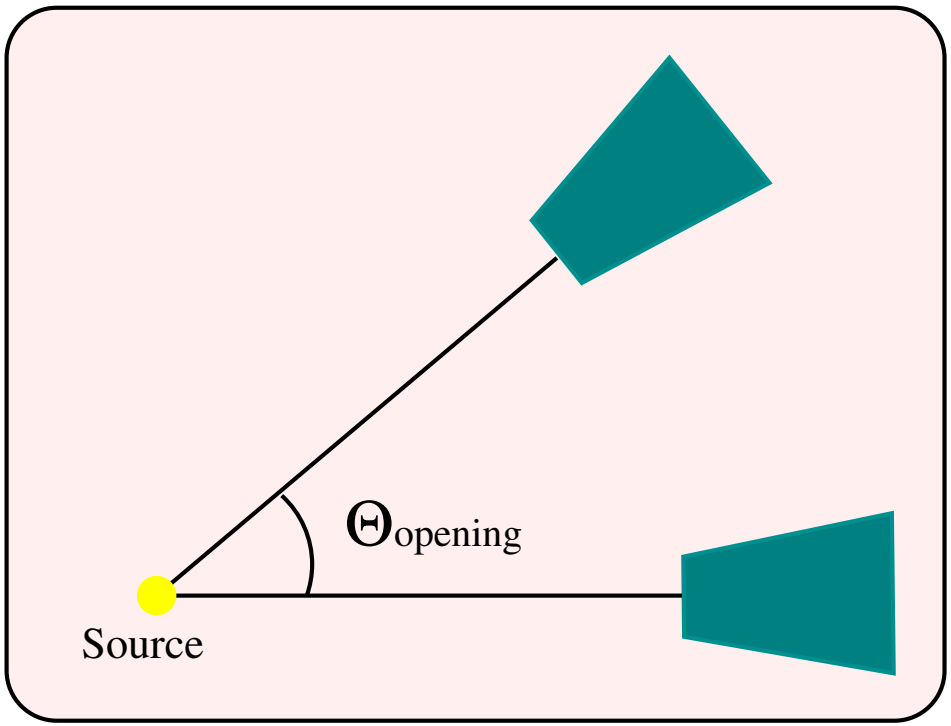

Sum Energy vs Energy Difference Matrix
Compton Ridge
Sum Energy (keV)
Energy Difference (keV)
Counts
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
1
10
10^2
10^3
10^4
10^5
10^6


Sum Energy vs Energy Difference Matrix
Compton Ridge
Sum Energy (keV)
Energy Difference (keV)
Counts
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
1
10
10^2
10^3
10^4
10^5
10^6


60000
50000
40000
30000
20000
10000
0
0
500
1000
1500
2000
2500
3000
3500
4000
Energy Difference + 2048 keV

Compton Background

Angular selection, follow Klein-Nishina distribution.



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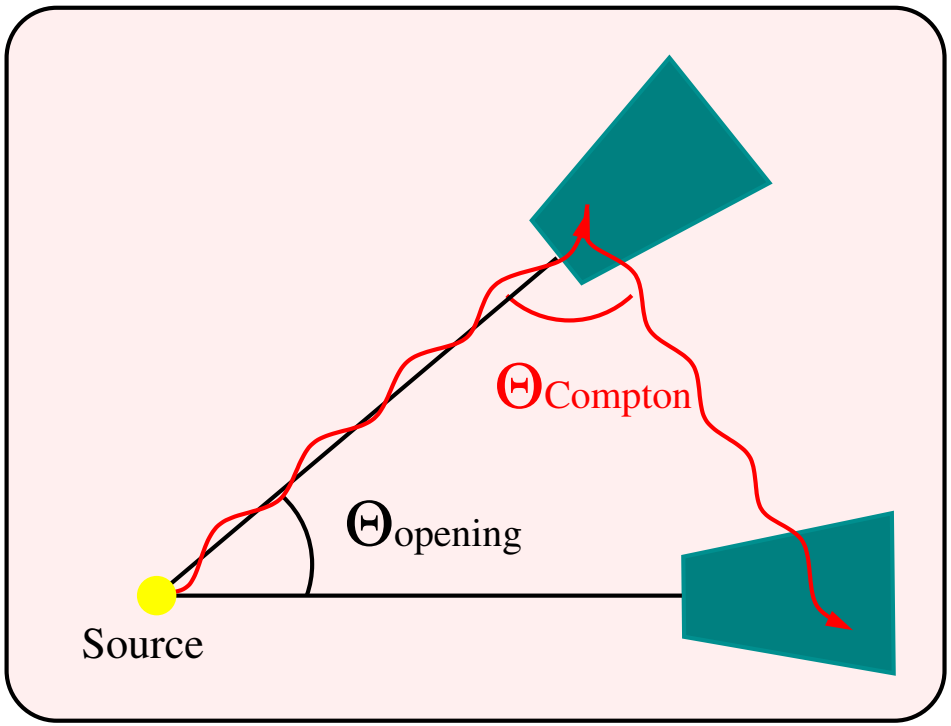

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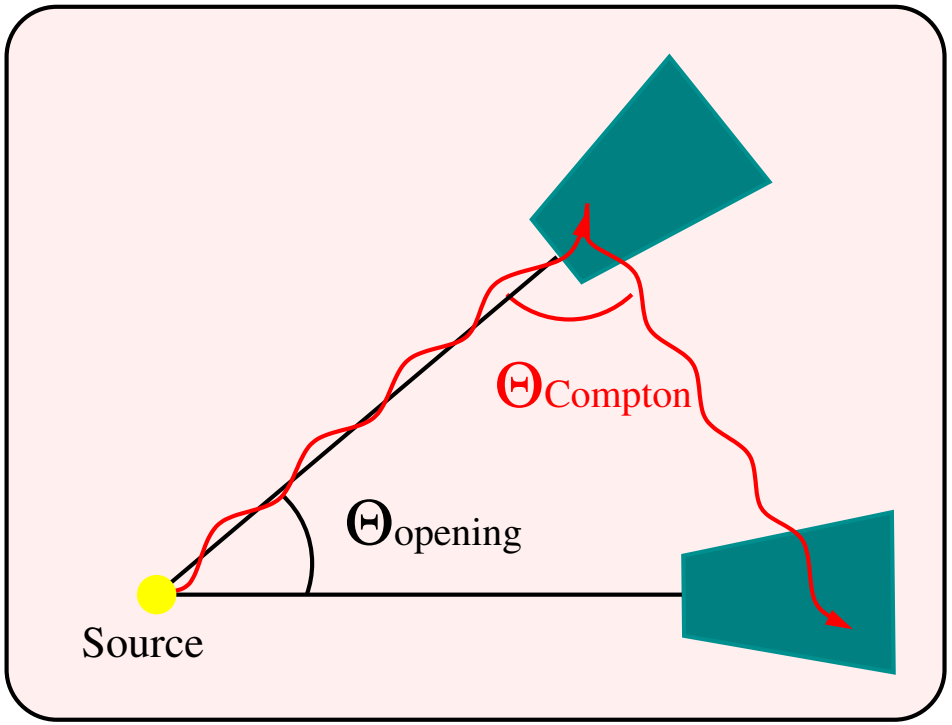
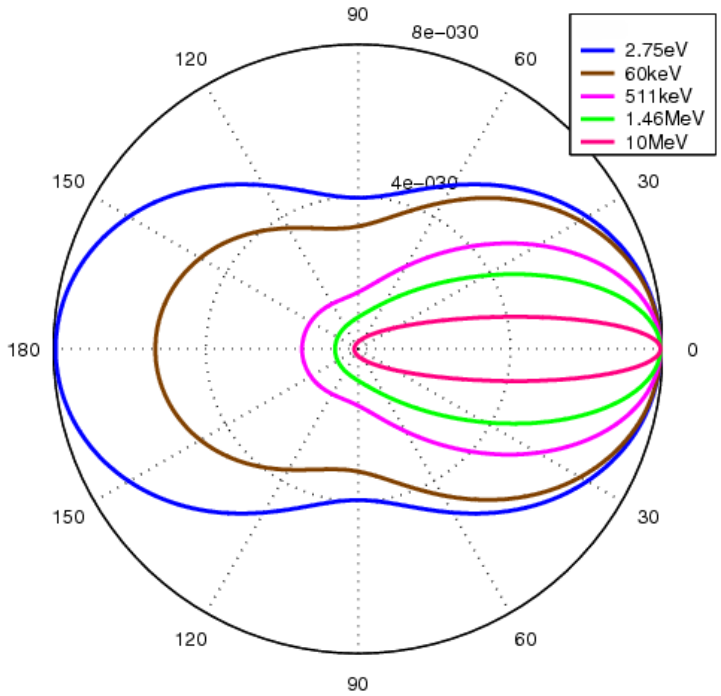
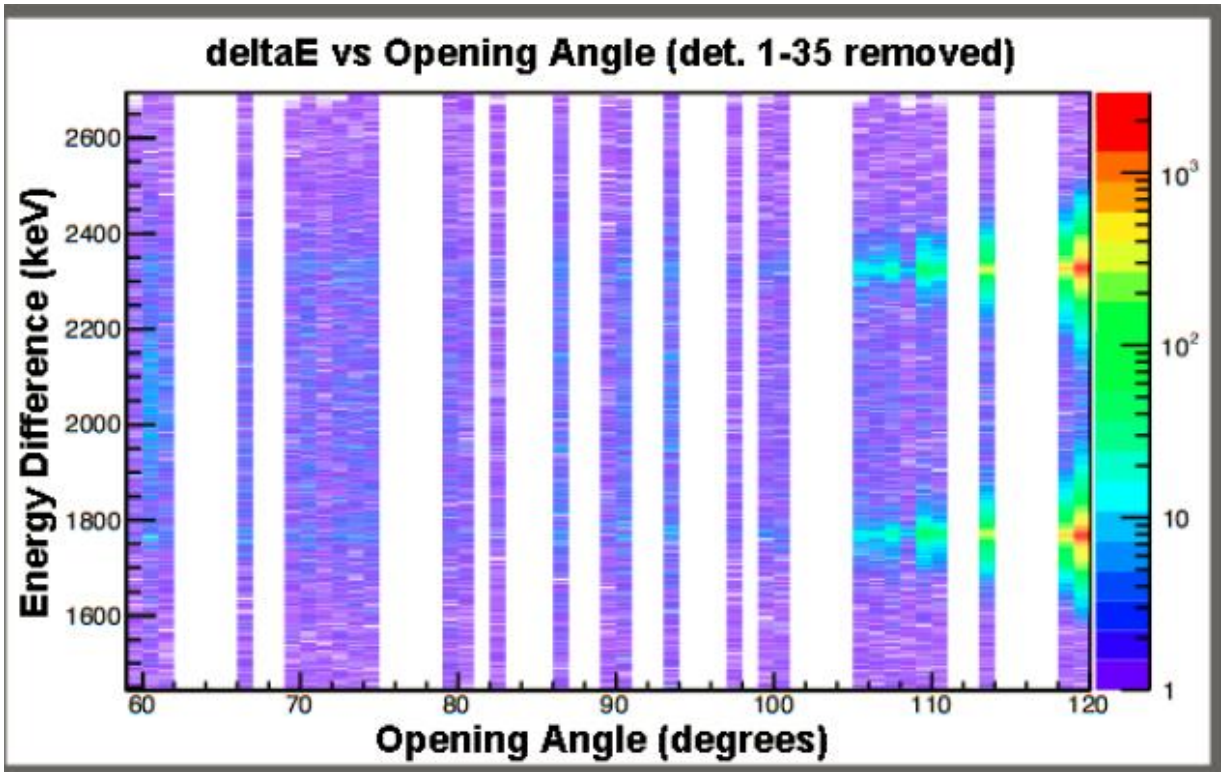
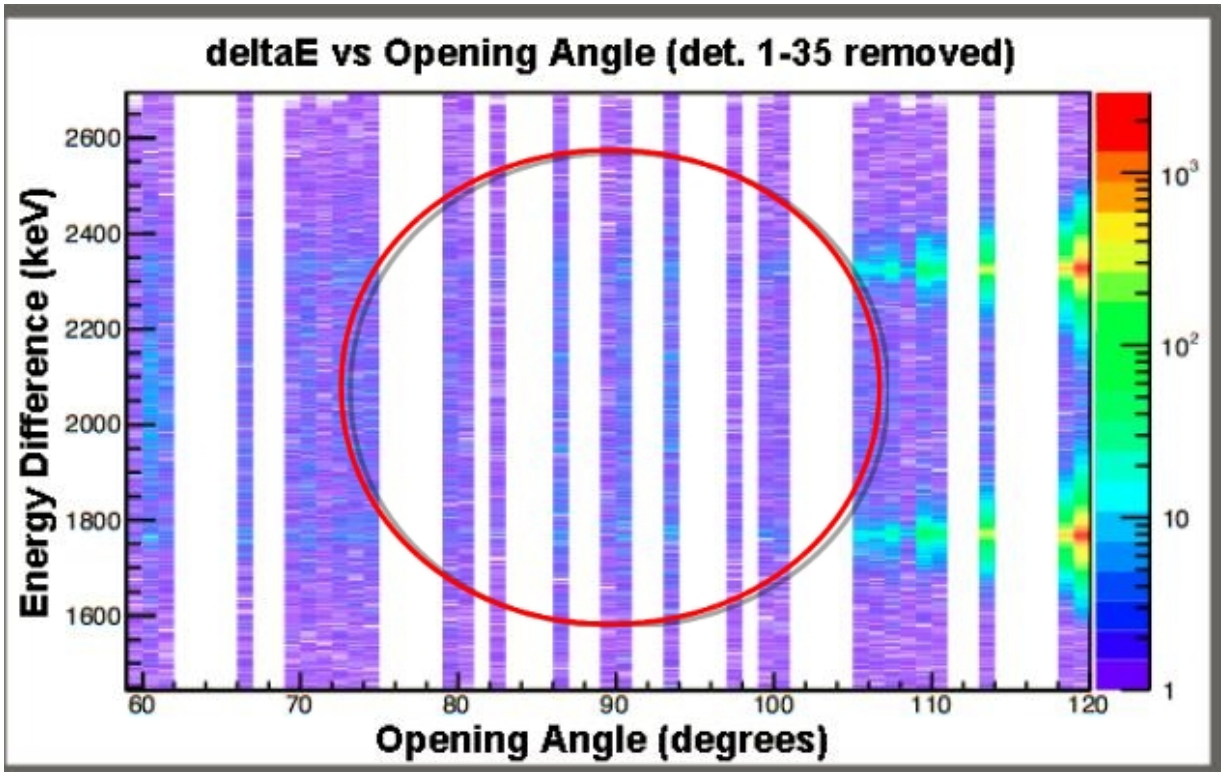
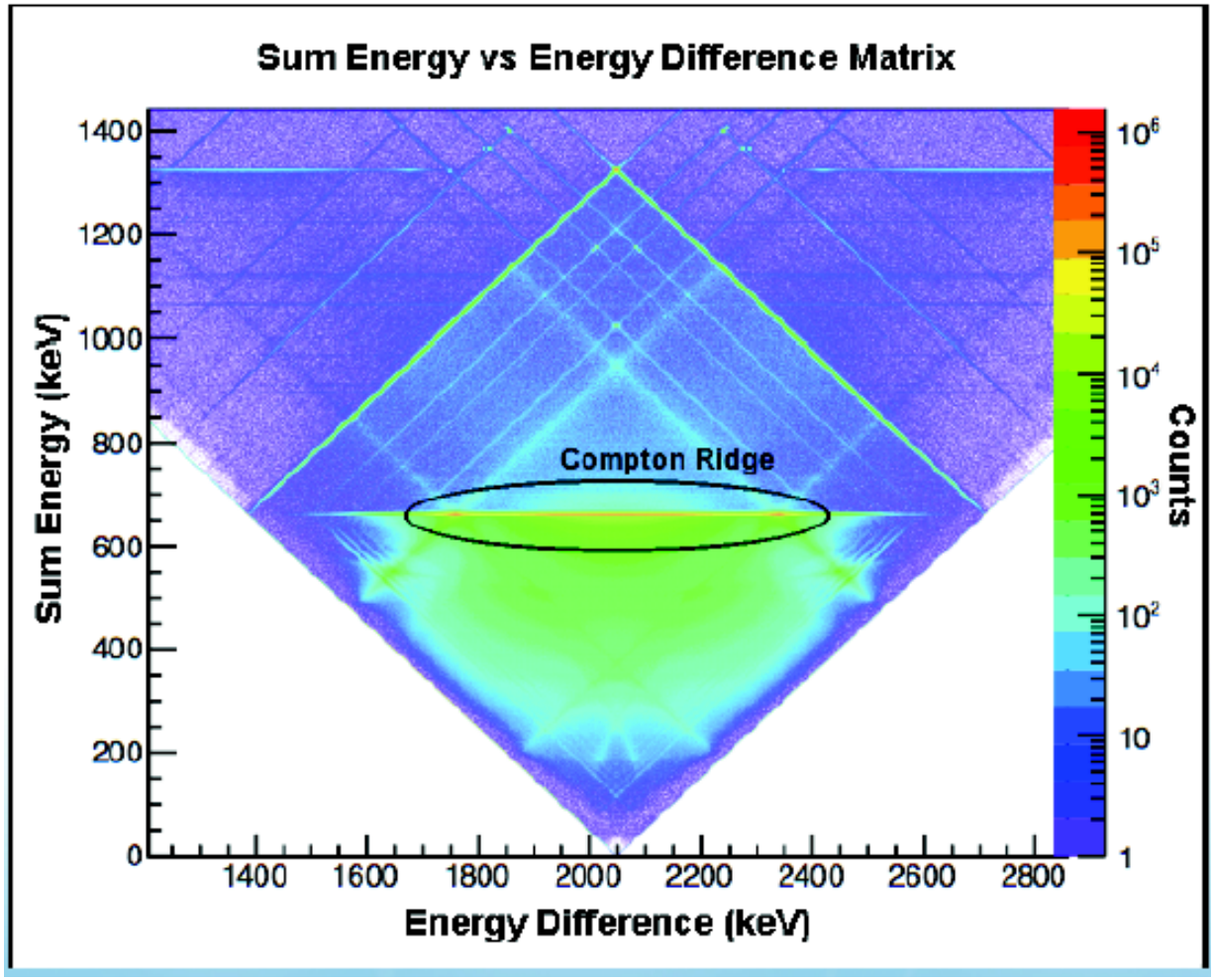
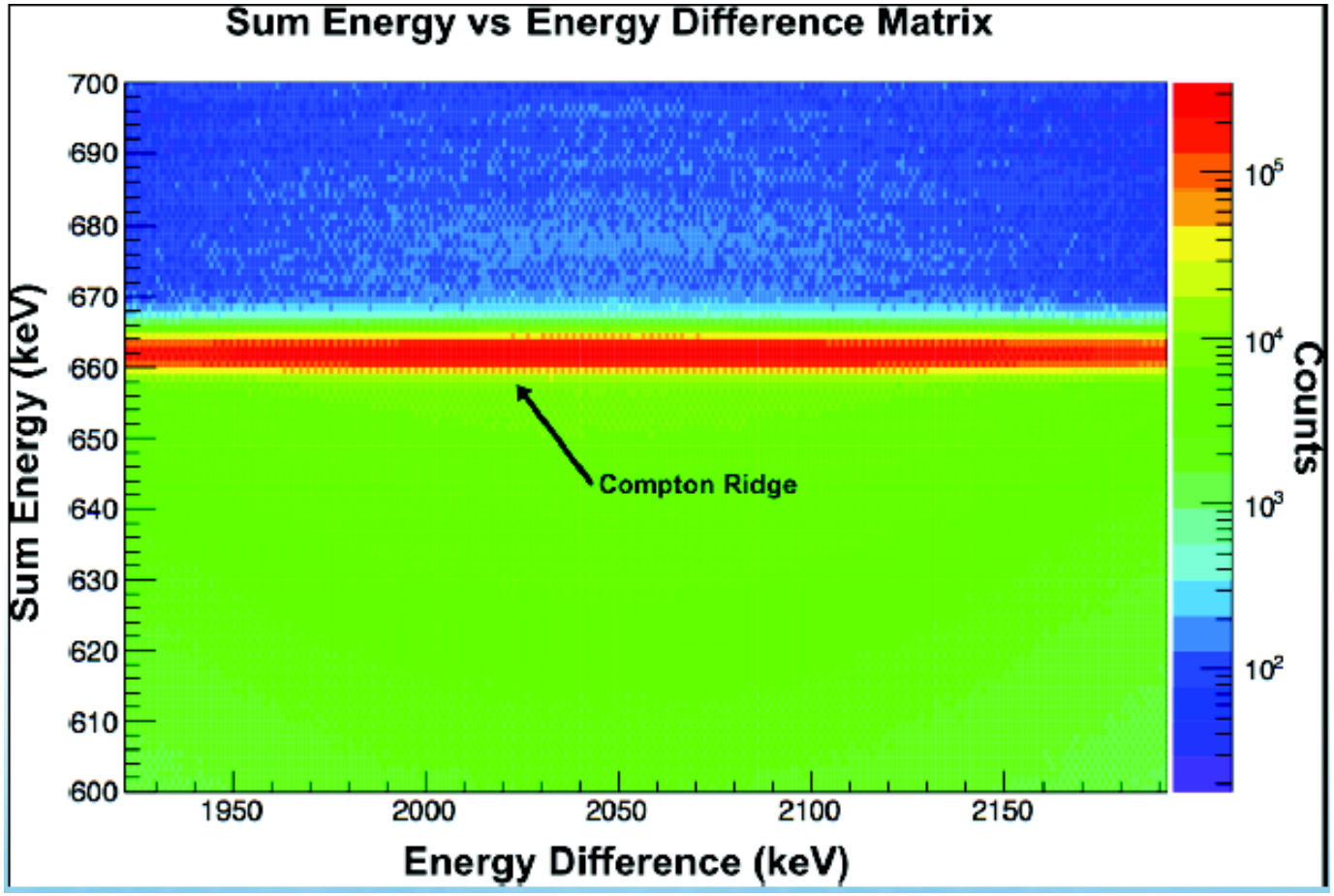


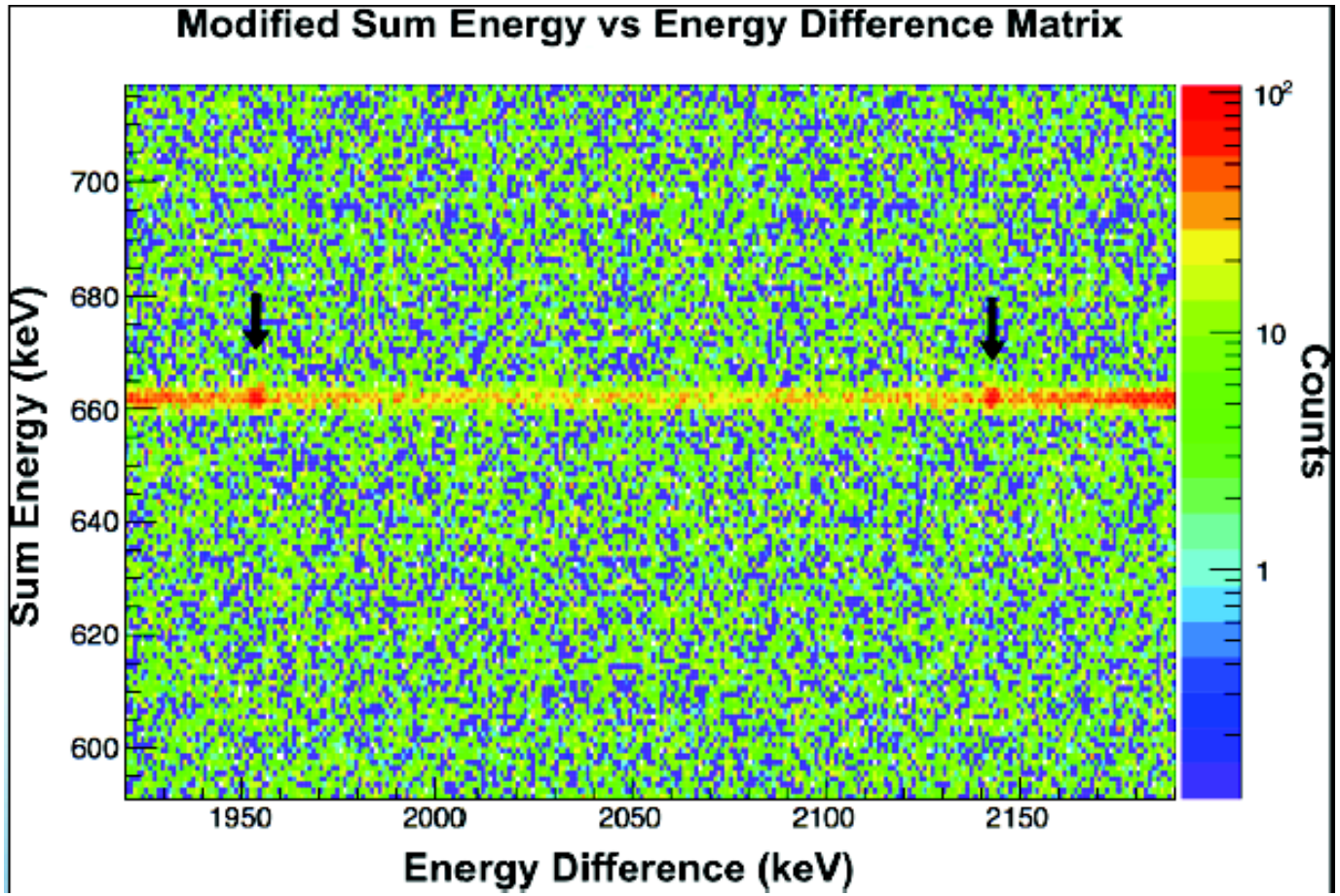



deltaE vs Opening Angle (det. 1-35 removed)
Energy Difference (keV)
2600
2400
2200
2000
1800
1600
60
70
80
90
100
110
120
Opening Angle (degrees)
10^3
10^2
10
1

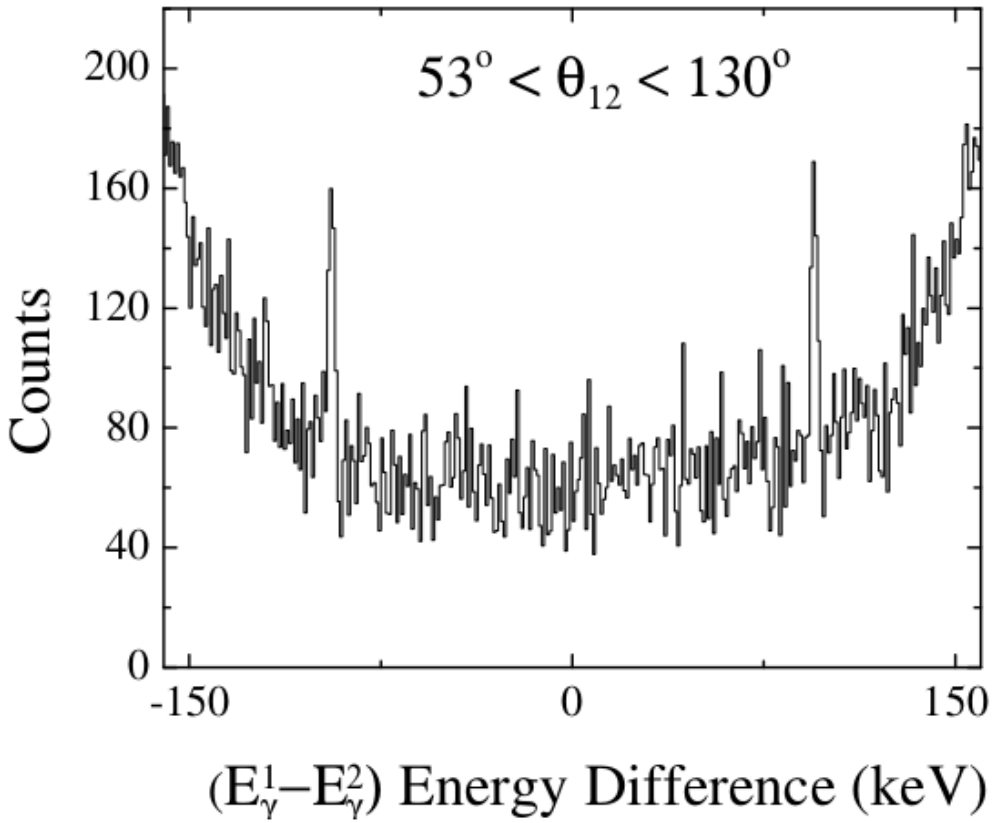

deltaE vs Opening Angle (det. 1-35 removed)
Energy Difference (keV)
2600
2400
2200
2000
1800
1600
60
70
80
90
100
110
120
Opening Angle (degrees)
10^3
10^2
10
1

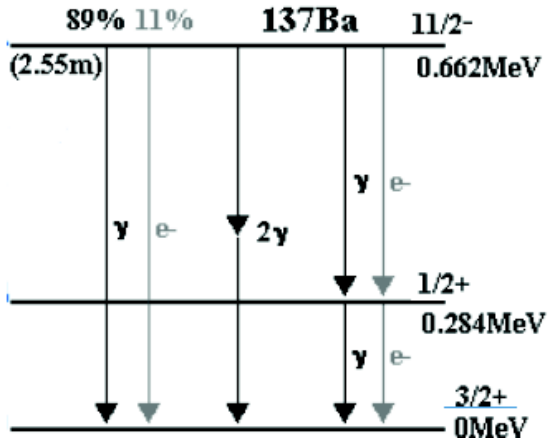

Sum Energy vs Energy Difference Matrix
Compton Ridge
Sum Energy (keV)
Energy Difference (keV)
Counts
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
1
10
10^2
10^3
10^4
10^5
10^6


Sum Energy vs Energy Difference Matrix
Sum Energy (keV)
700
690
680
670
660
650
640
630
620
610
600
1950
2000
2050
2100
2150
Energy Difference (keV)
Compton Ridge
Counts
10^5
10^4
10^3
10^2


Modified Sum Energy vs Energy Difference Matrix
Sum Energy (keV)
700
680
660
640
620
600
1950
2000
2050
2100
2150
Energy Difference (keV)
10^2
10
1
Counts

Gamma Cascade (Duotrigesapole Transition)





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

Branching Ratio

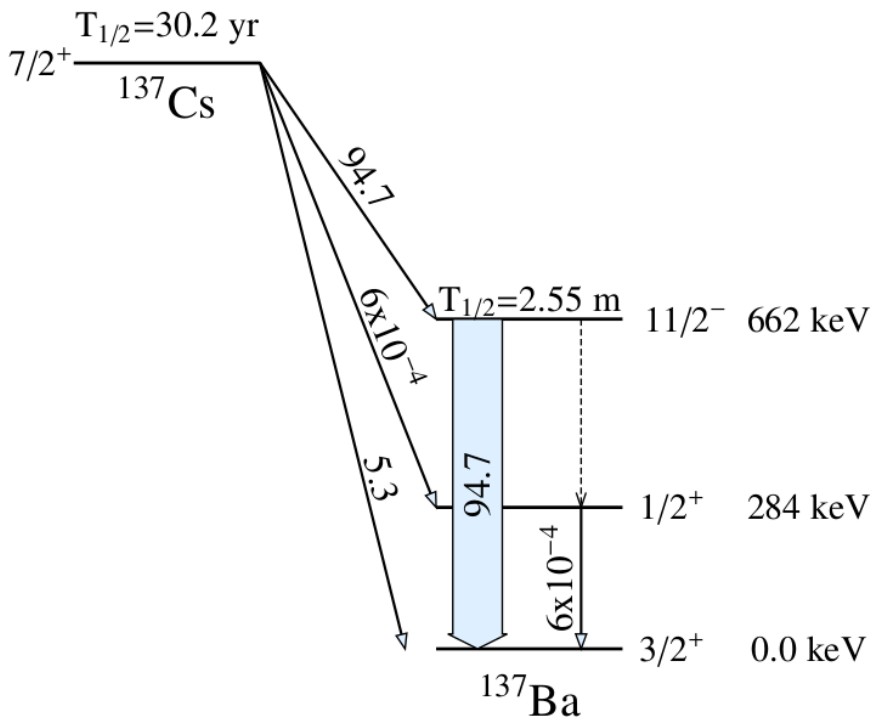
$$Br_{\gamma}^{E5} = \frac{I_{\gamma}^{E5}}{\sum I(\gamma + CE)} = 1.12 \pm 0.9 \times 10^{-7}$$

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

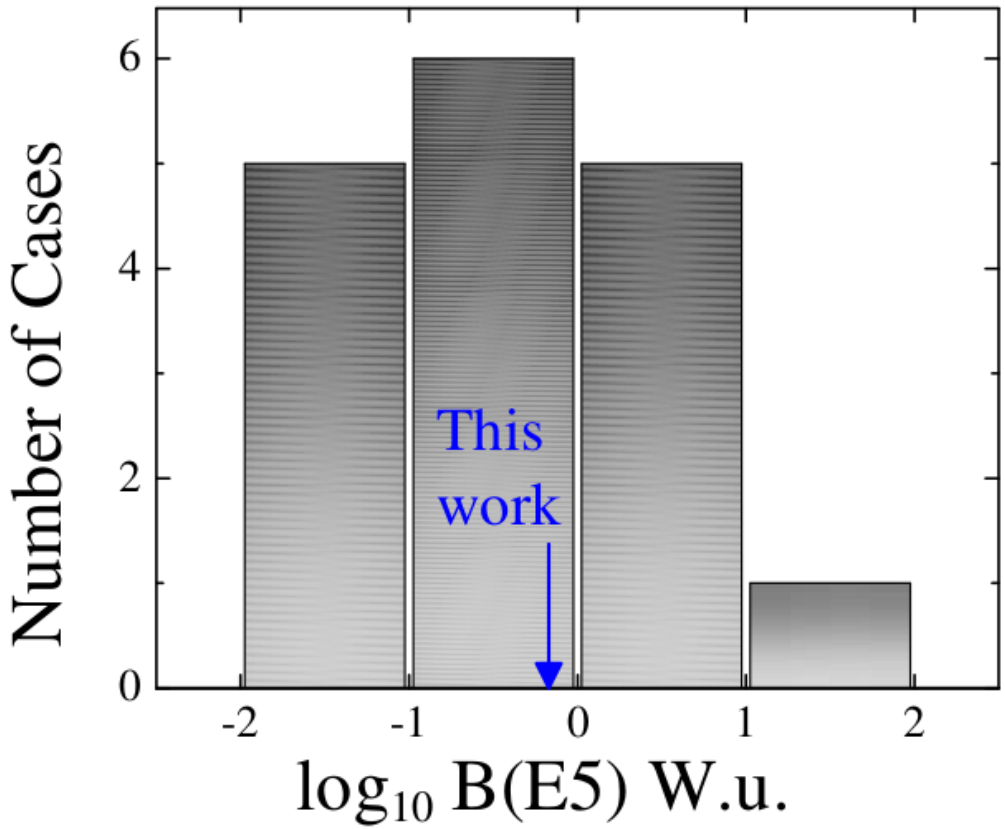
Intensities

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

New estimate value:
$\log ft = 16.49(12)$



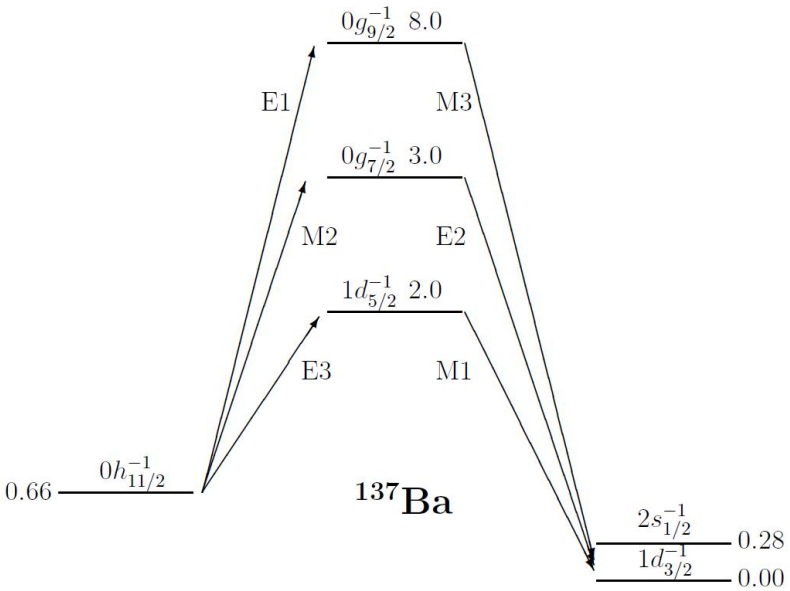
Distribution of B(E5) values

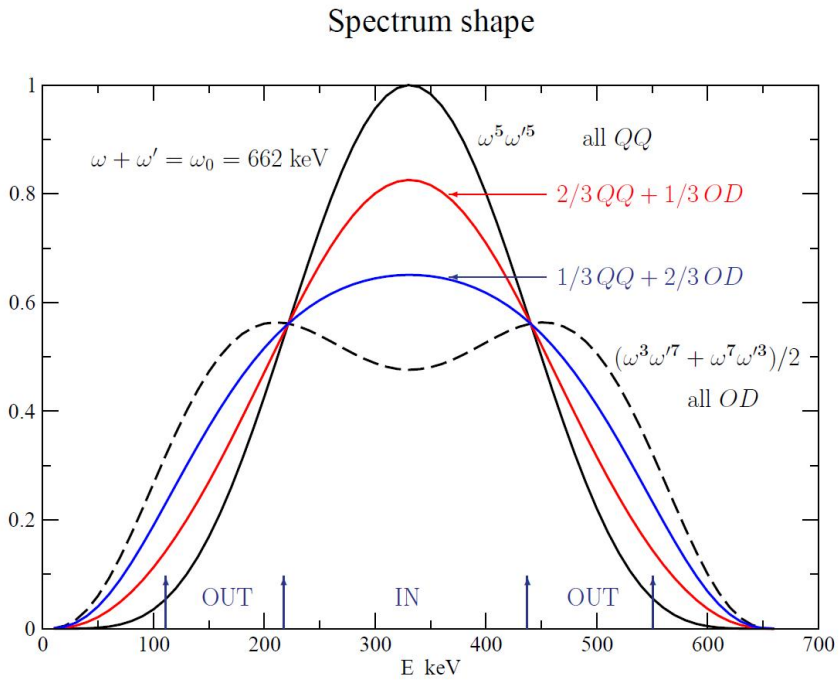


- B(E5) = 0.71(6) W.u. $\rightarrow$ Typical value for ”single particle” decays of this type.

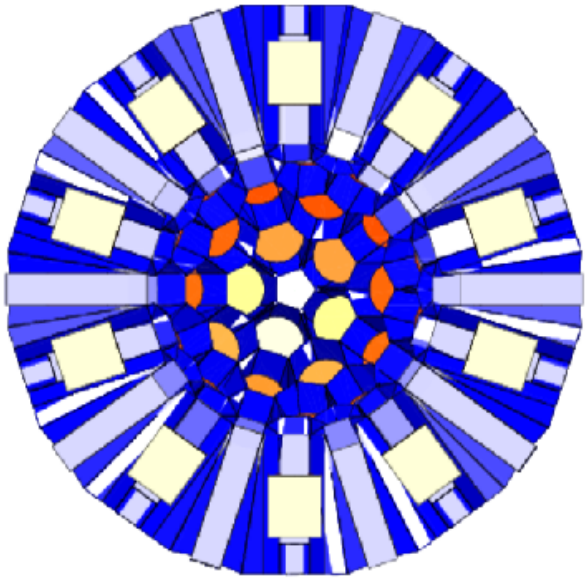
^{137}Cs Decay

- 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.





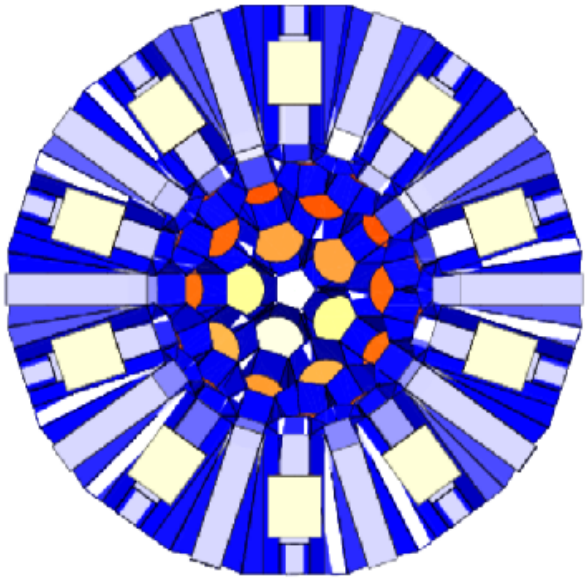
Geant4 Simulation*



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

*Simulation geometry provided by the GFNUN - Colombia

Geant4 Simulation*



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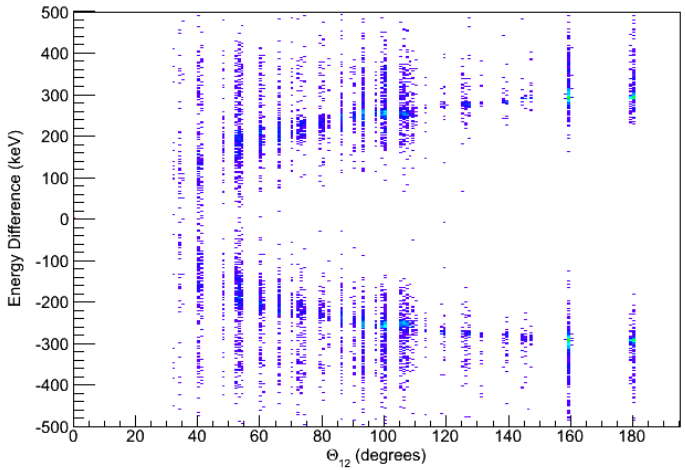
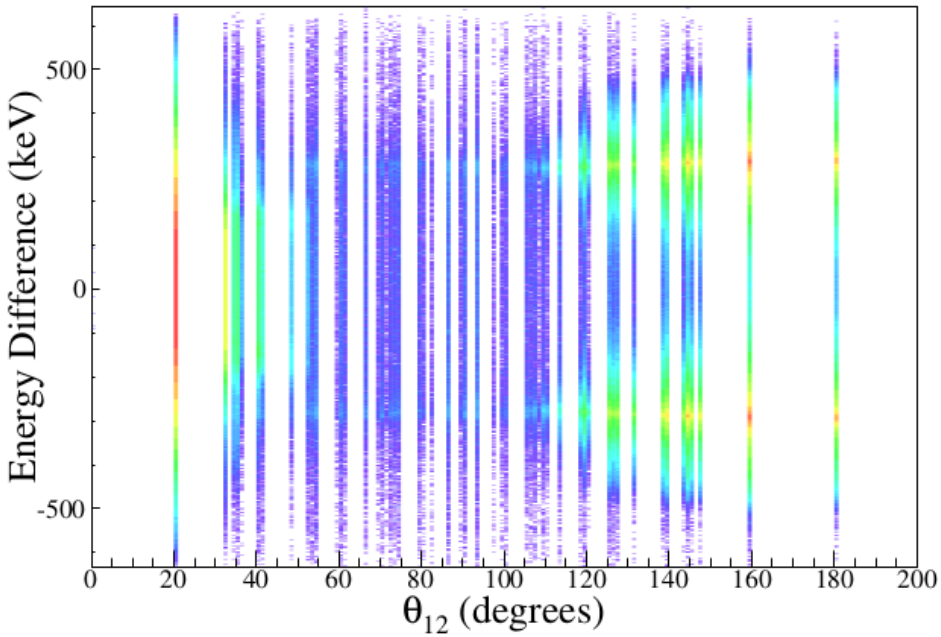
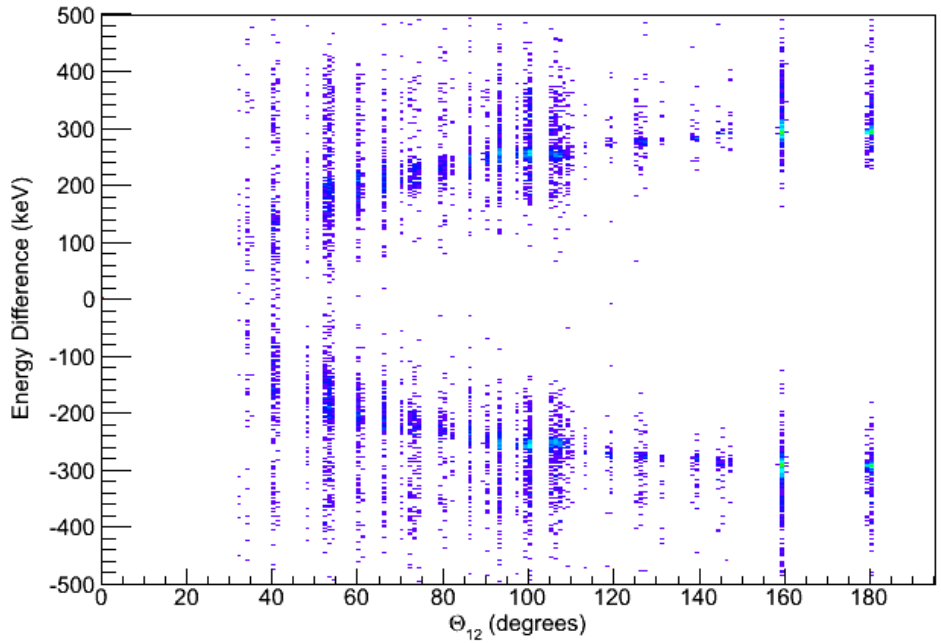


*Simulation geometry provided by the GFNUN - Colombia

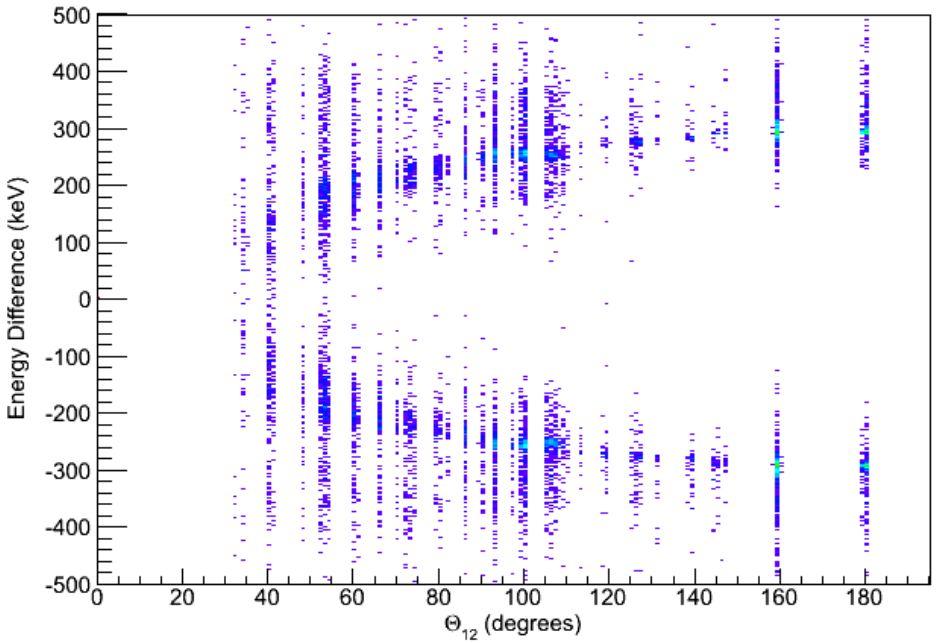
Compton Distribution

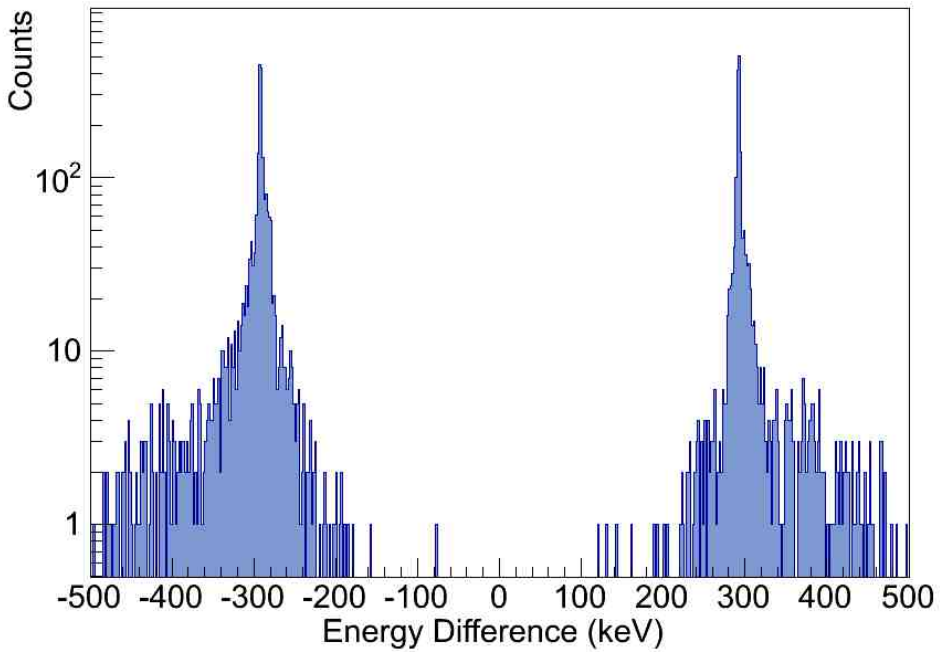




- Distribution of the Compton from the 662 keV with the opening angle.

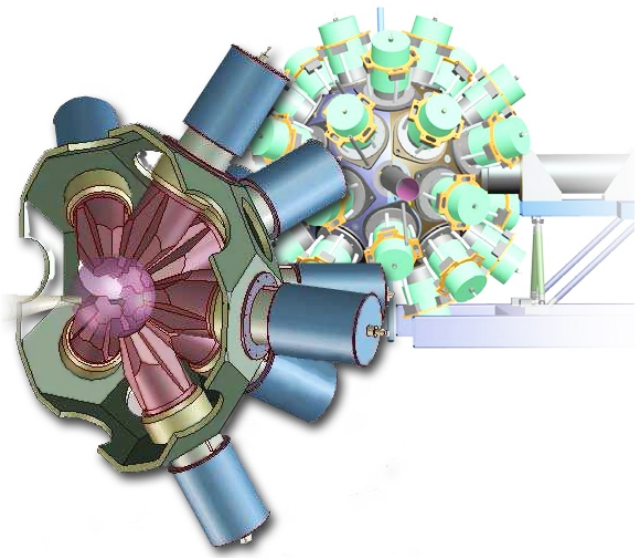
Compton Distribution

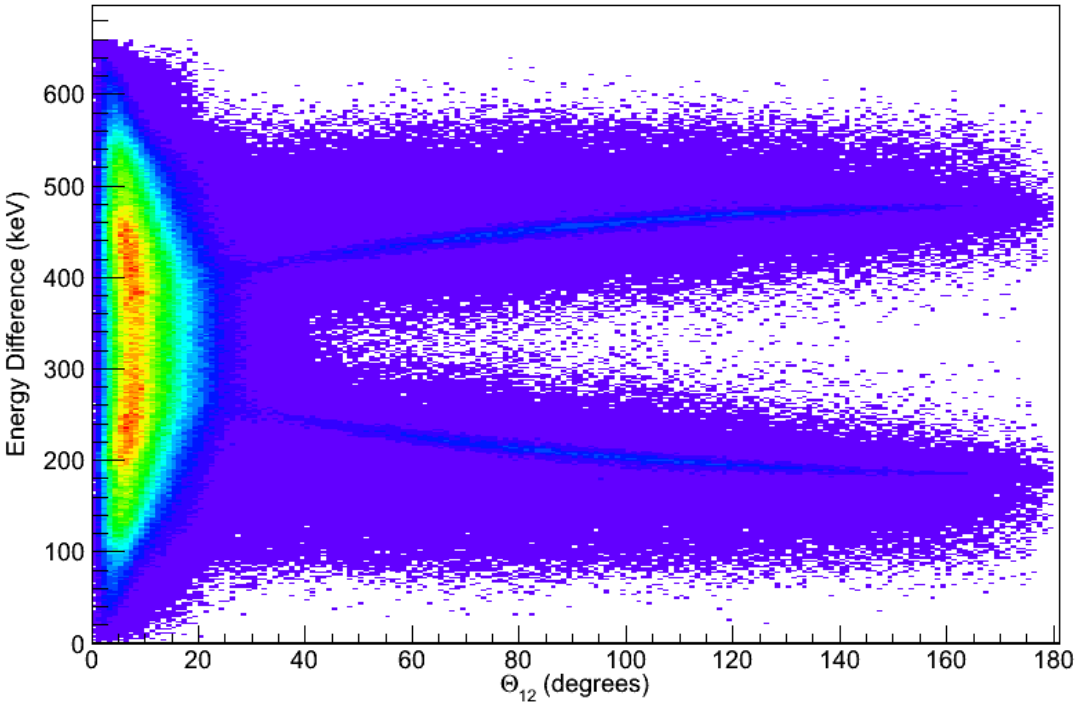




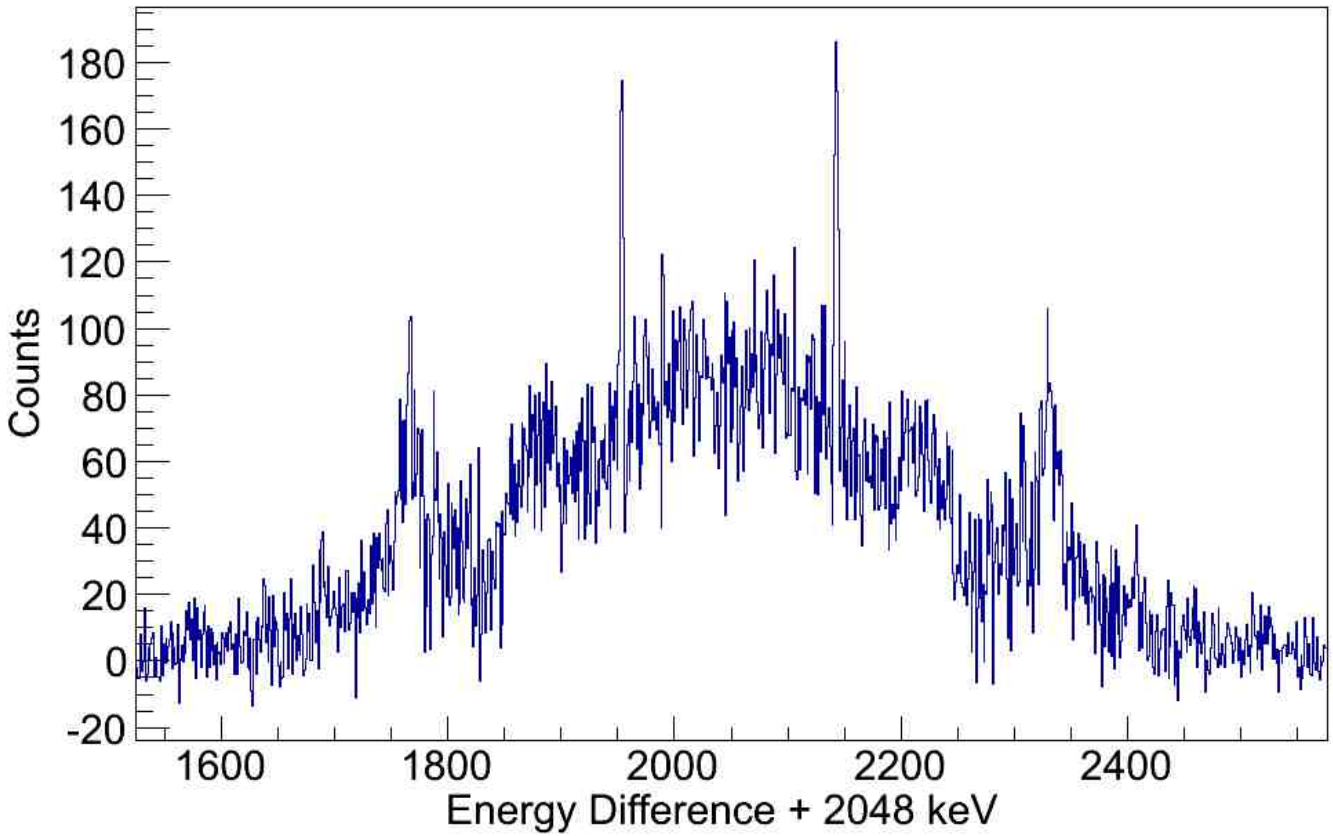
- Distribution of the Compton from the 662 keV with the opening angle.

GRETA Simulation





Double Gamma Distribution



- 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.

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