Level scheme and level half lives of ^{30}Al

Trabajo de Investigación de Posgrado
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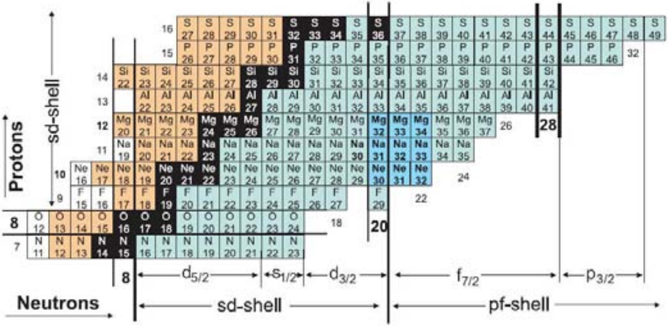
Introduction

- Data analysis of experiment IS414
- Study of the region known as Island of Inversion around ^{32}Na
- β-decay chains of ^{30,31,32,33}Na
- Use of the fast timing technique ATD$\beta\gamma\gamma(t)$
- This analisys focuses on ^{30}Al level scheme and excited levels half lives

Island of Inversion

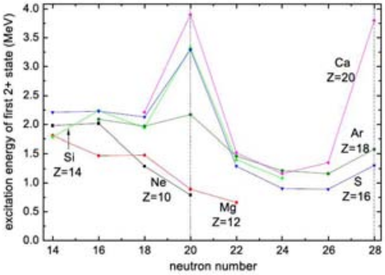


Island of Inversion

Possible inversion of the $f_{7/2}$ and $d_{3/2}$ orbits in the $Z = 10 - 12$ and $N = 20 - 22$ region

^{32}Mg $N = 20$ $Z = 12$

- Far more bound than predicted
- First 2^+ at very low energy (885 keV)
- Indicates deformation properties
- Presence of intruder estates



Experiment on ^{32}Mg and decay chain

- Measurement of the half life of the first 2^+ state (885 keV)
- Precission of about 1.5 ps

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- Characterization of level schemes
- Search for intruder states
- Candidate for 0^+ in ^{30}Mg
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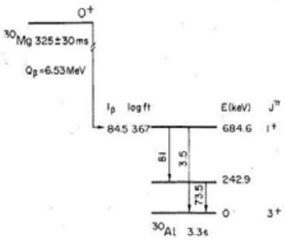
^{30}Al

- The nucleus ^{30}Al can provide information on the evolution from the Valley of Stability towards the Island of Inversion.

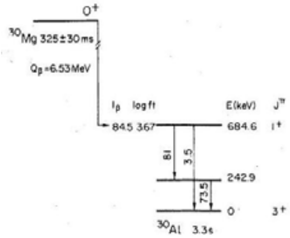
Previous level schemes

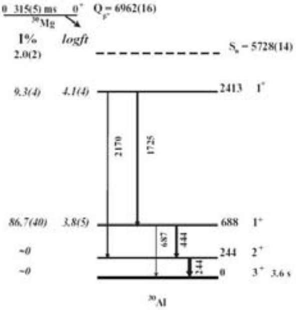


Détraz *et al.* 1979

"Beta decay of 27-32Na and their descendants", by C. Détraz *et al.* Phys. Rev. C 19, 164176 (1979)

Previous level schemes





Détraz *et al.* 1979

"Beta decay of 27-32Na and their descendants", by C. Détraz *et al.* Phys. Rev. C 19, 164176 (1979)

Hinners *et al.* 2008

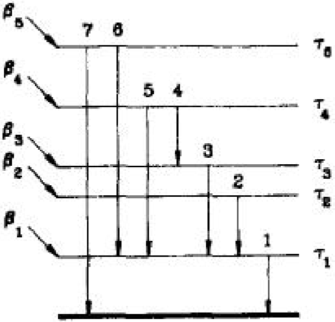
"Complementary studies of T $=$ 2 ^{30}Al and the systematics of intruder states" by T. A. Hinners *et al.* Phys. Rev. C 77, (2008)

Advance Time Delayed $\beta\gamma\gamma(t)$

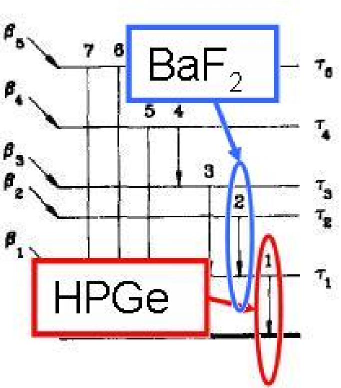
Outline

- The technique is based in triple coincidence $\beta\gamma\gamma(t)$
- The level scheme is determined by coincidences between two HPGe
- The timing is done with a TAC between the β and BaF_2 detector
- The half-life of the excited levels is measured by the slope of the time response ($T_{1/2} > 60ps$) or the displacement of the centroid from the prompt calibration curve ($T_{1/2} < 60ps$)
- The method relies on precise calibration of the time response of the fast detectors
- Half-lives down to the picoseconds can be measured

Sequential transition



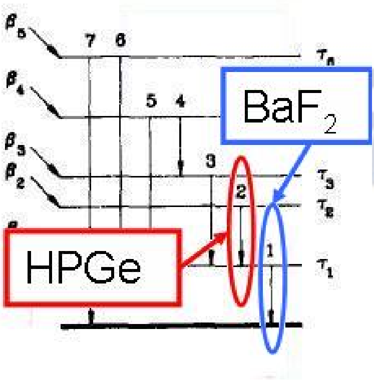
Sequential transition



γ_1 in Ge and γ_2 in the fast timing

$t_1 = \tau_0 + \tau_2$

Sequential transition



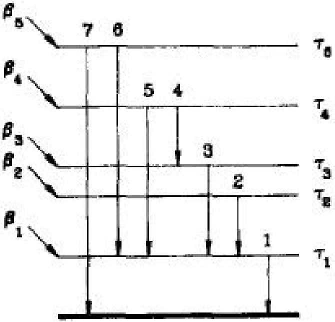
γ_1 in Ge and γ_2 in the fast timing

$t_1 = \tau_0 + \tau_2$

γ_2 in Ge and γ_1 in the fast timing

$t_2 = \tau_0 + \tau_1 + \tau_2$

Sequential transition



γ_1 in Ge and γ_2 in the fast timing

$t_1 = \tau_0 + \tau_2$

γ_2 in Ge and γ_1 in the fast timing

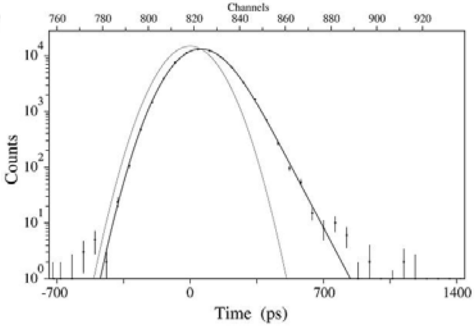
$t_2 = \tau_0 + \tau_1 + \tau_2$

Substracting we obtain

$\tau_1 = t_2 - t_1$

Convolution technique

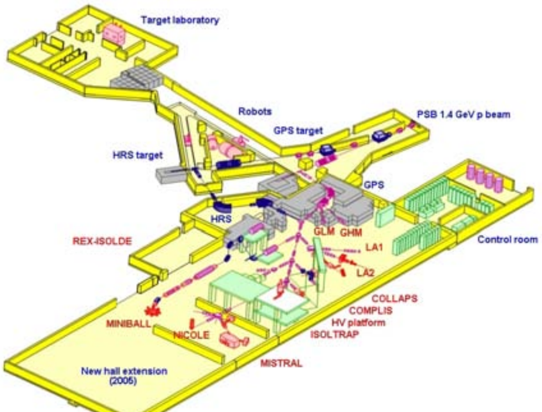
- Convolution technique may be used if $T_{1/2} > 60ps$
- Fit of the timing distribution to a prompt transition plus a exponential decay
- Prompt part may be approximated to a gaussian distribution
- $F(t_j) = \gamma \int_A^{+\infty} e^{-\delta(t_j - t)} e^{-\lambda(t-A)} dt$



Experiment run

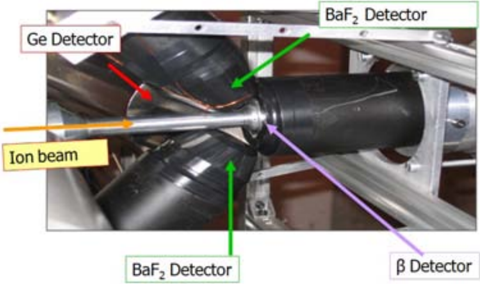
Experiment at ISOLDE

- Three runs performed:
  1. 2003 ^{30,31,32}Na
  2. 2004 ^{30,32}Na (data presented)
  3. 2005 ^{30,32,33}Na (e^- conversion station)
- 1.4 GeV protons on 45 g/cm^2 UC_x target at 2100 $^\circ$C
- Na isotopes are ionized with a surface source
- High purity Na beams are separated by mass by the GPS, and the desired mass implanted in an aluminum foil in the experimental chamber



Detectors

- 1 X NE111A: β-detector 3 mm width
- 2 X BaF_2: timing (1.5" base, 1" top, 1" height)
- 2 X HPGe: energy resolution and selection of decay branches



Data were acquired with 2 systems simultaneously

- DMP - Analog
- XIA (PIXIE 4) - Digital

Analog system

- ADC-0: Starter logical signal
- ADC-1: β-detector energy
- ADC-2: Fast TAC-1
- ADC-3: BaF_2-1 energy
- ADC-4: Fast TAC-2
- ADC-5: BaF_2-2 energy
- ADC-6: HPGe-1 energy
- ADC-7: HPGe-2 energy

Digital system

- Card 1-0: PSBooster proton impacts
- Card 1-1: HPGe-1 energy
- Card 1-2: HPGe-2 energy
- Card 2-0: Fast TAC-1
- Card 2-1: BaF_2-1 energy
- Card 3-0: Fast TAC-2
- Card 3-1: BaF_2-2 energy
- Card 4-0: β-detector energy

β^--decay chain

Z	28P 270.3 MS ε: 100.00% εp: 1.3E-3%	29P 4.142 S ε: 100.00%	30P 2.498 M ε: 100.00%	31P STABLE 100%	32P 14.262 D β-: 100.00%	33P 25.34 D β-: 100.00%	34P 12.43 S β-: 100.00%	35P 47.3 S β-: 100.00%	36P 5.6 S β-: 100.00%
14	27Si 4.16 S ε: 100.00%	28Si STABLE 92.230%	29Si STABLE 4.683%	30Si STABLE 3.087%	31Si 157.3 M β-: 100.00%	32Si 153 Y β-: 100.00%	33Si 6.11 S β-: 100.00%	34Si 2.77 S β-: 100.00%	35Si 0.78 S β-: 100.00%
13	26Al 7.17E+5 Y ε: 100.00%	27Al STABLE 100%	28Al 2.2414 M β-: 100.00%	29Al 6.56 M β-: 100.00%	30Al 3.60 S β-: 100.00%	31Al 644 MS β-: 100.00%	32Al 33.0 MS β-: 100.00% β-n: 0.70%	33Al 41.7 MS β-: 100.00% β-n: 8.50%	34Al 42 MS β-: 100.00% β-n: 27.00%
12	25Mg STABLE 10.00%	26Mg STABLE 11.01%	27Mg 9.458 M β-: 100.00%	28Mg 20.915 H β-: 100.00%	29Mg 1.30 S β-: 100.00%	30Mg 335 MS β-: 100.00%	31Mg 232 MS β-: 100.00% β-n: 1.70%	32Mg 86 MS β-: 100.00% β-n: 5.50%	33Mg 90.5 MS β-: 100.00% β-n: 17.00%
11	24Na 14.997 H β-: 100.00%	25Na 59.1 S β-: 100.00%	26Na 1.077 S β-: 100.00%	27Na 301 MS β-: 100.00% β-n: 0.13%	28Na 30.5 MS β-: 100.00% β-n: 0.58%	29Na 44.9 MS β-: 100.00% β-n: 21.50%	30Na 48 MS β-: 100.00% β-n: 30.00%	31Na 17.0 MS β-: 100.00% β-n: 37.00%	32Na 13.2 MS β-: 100.00% β-n: 24.00%
	13	14	15	16	17	18	19	20	N

β^--decay chain

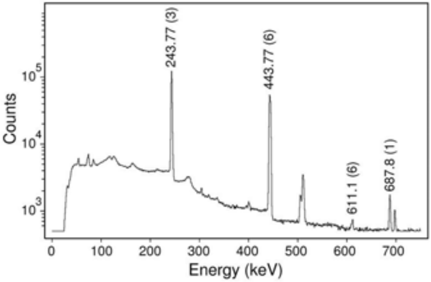
β^{-}-decay chain

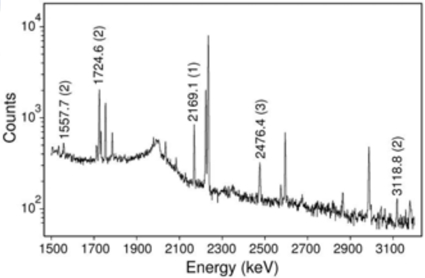
β^--decay chain

Peak identification

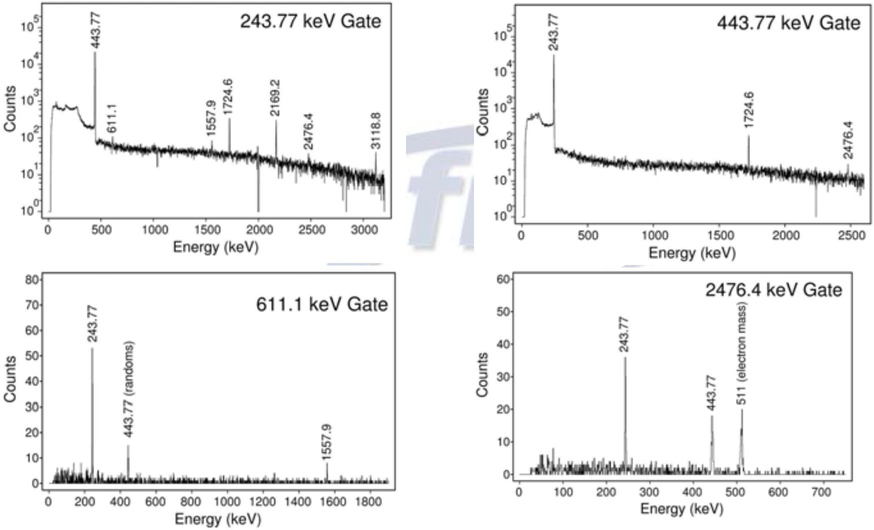
Peak identification

Digital system was used to set a 300-1200 ms time gate after the proton impact on the target to enhance the ^{30}Al activity

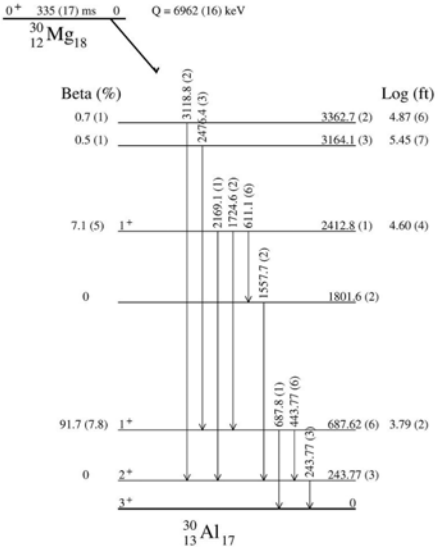




Coincidences HPGe-HPGe



Level scheme



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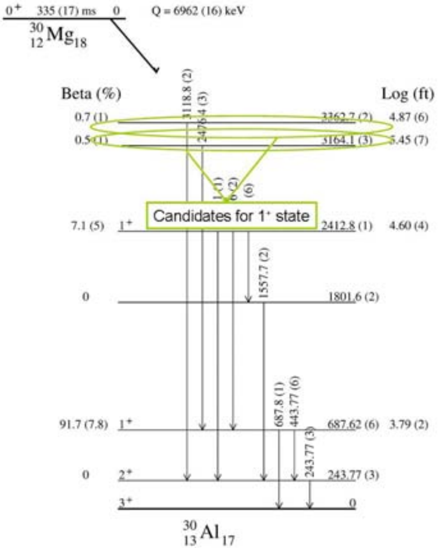
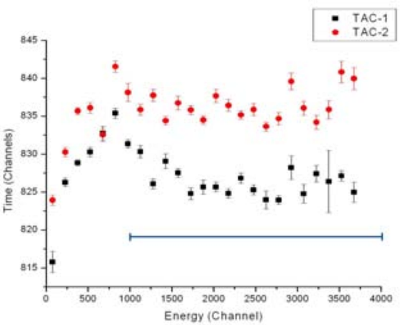


Timing ADT

- There are three corrections in the technique:
  1. β-walk curve
  2. Compton-walk curve
  3. Compton from different energies give different responses (2nd order)
- We need to calibrate the time response of each detector as a function of energy - Prompt calibration curve
- These calibrations and corrections are common to every nucleus in the experiment
- Each BaF_2 produces an indepedent set of data

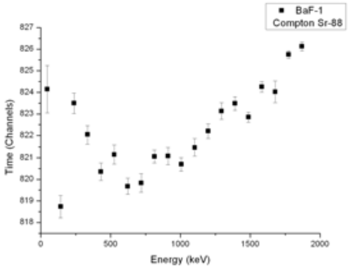
β-walk curve

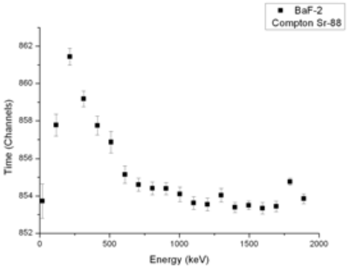


Energy gate on the β-detector

A common gate for both BaF_2 was set in the 1000-4595 channel region to ensure a time constant response from the detector.

Compton-walk curve

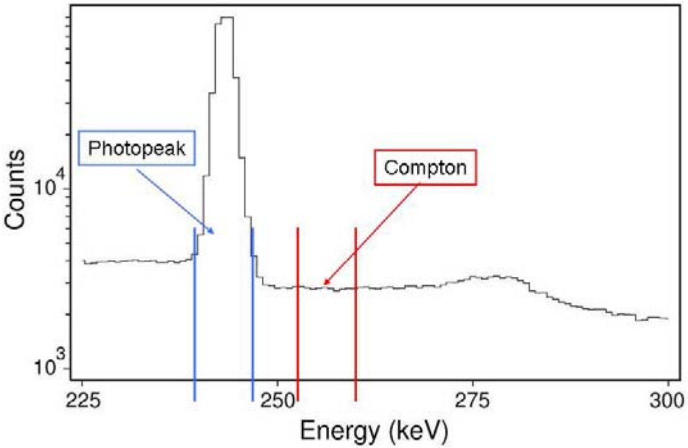




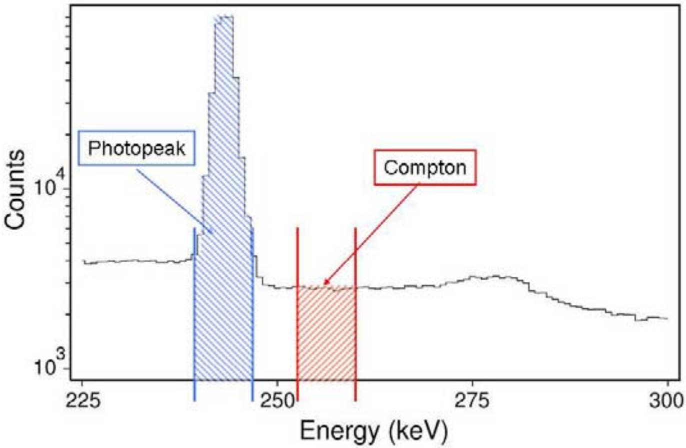
Time calibration

Comtpon walk curve from 1836 keV transition in ^{88}Sr

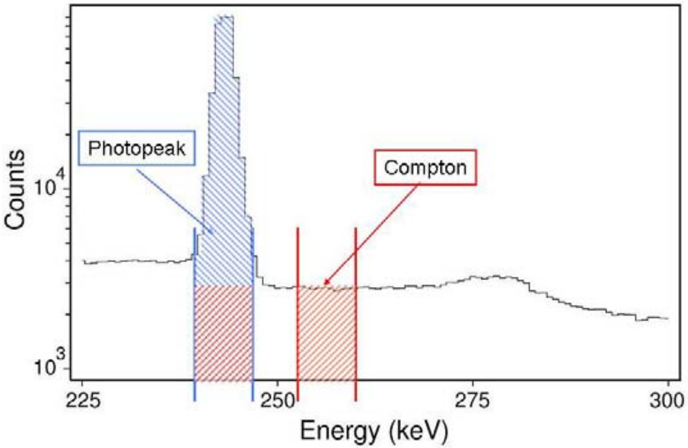
Compton correction



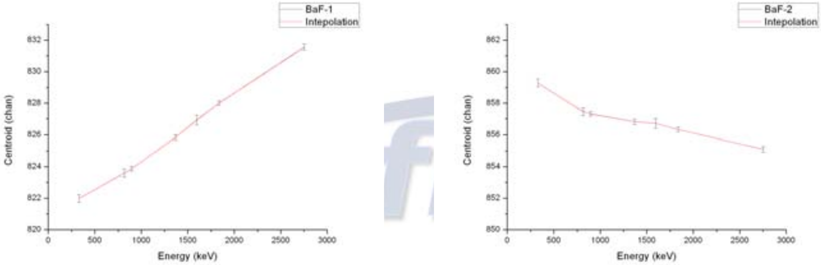
Compton correction



Compton correction



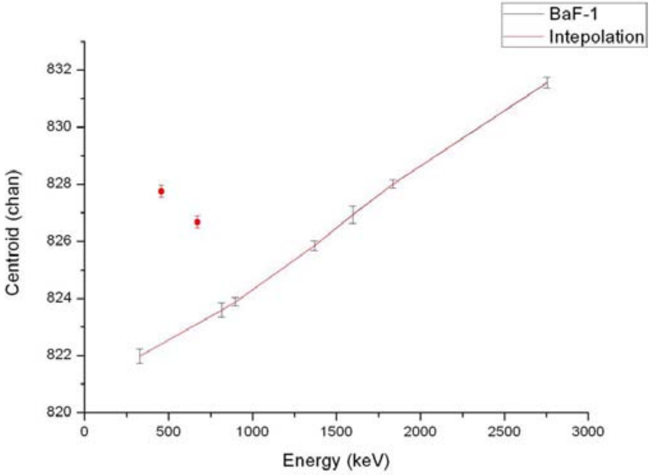
Prompt-time calibration



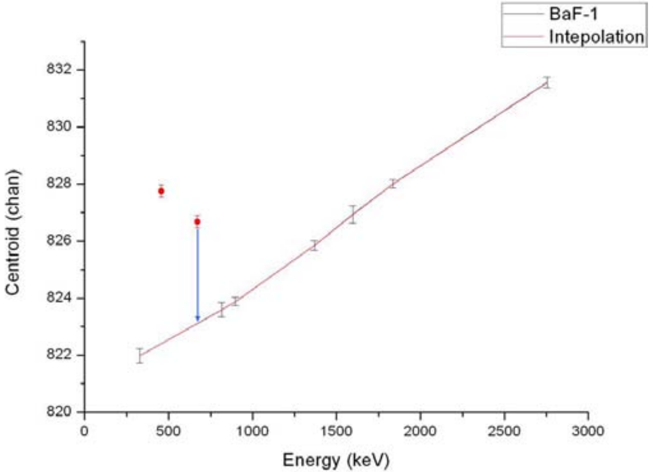
Time calibration

Relative time response curve for both crystals made with calibration sources ^{24}Na, ^{88}Rb and ^{140}Ba. The time calibration is 12 ps/chan.

Half life analysis



Half life analysis



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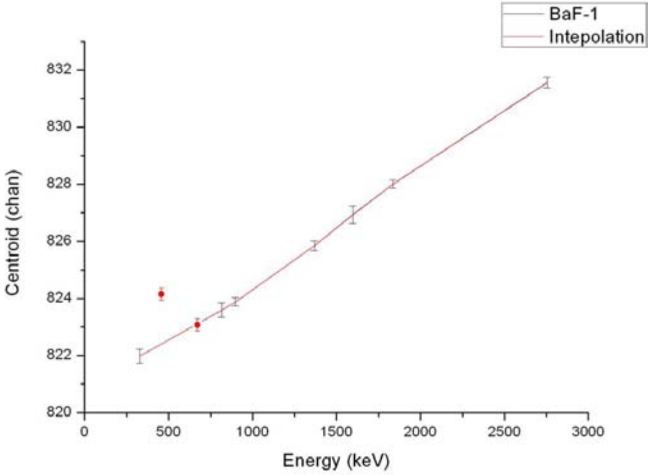

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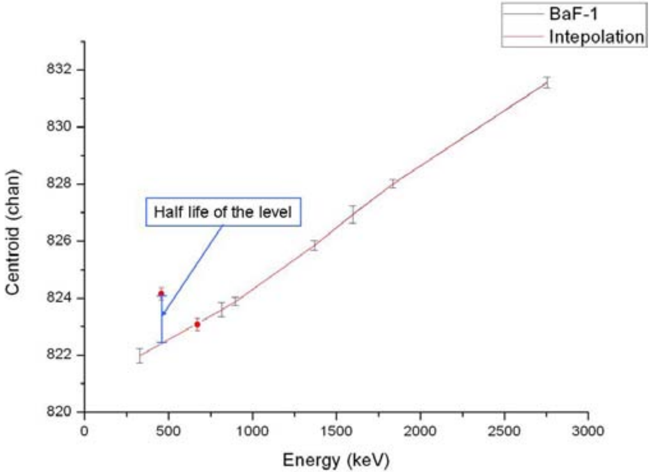

Level (keV)	τ(BaF_2-1)	τ (BaF_2-2)	$T_{1/2}(ps)$
243.77 (3)	11.9 (4.3)	13.9 (5.8)	18.5 (5.0)
687.62 (6)	20.7 (9.2)	19.1 (8.2)	28.6 (8.8)

γ (keV)	Multi	B(GT) W.u.
243.77 (3)	M1	0.17 (5)
443.77 (6)	M1	0.017 (6)
687.8 (1)	E2	2.9 (9)

Conclusions

- Level scheme with new levels and transitions
- Two candidates for a third 1+ state in this nucleus
- Half lifes of the first two excited estates

Thanks for your attention!