Alpha-particle emission probabilities in the decay of ^{240}Pu

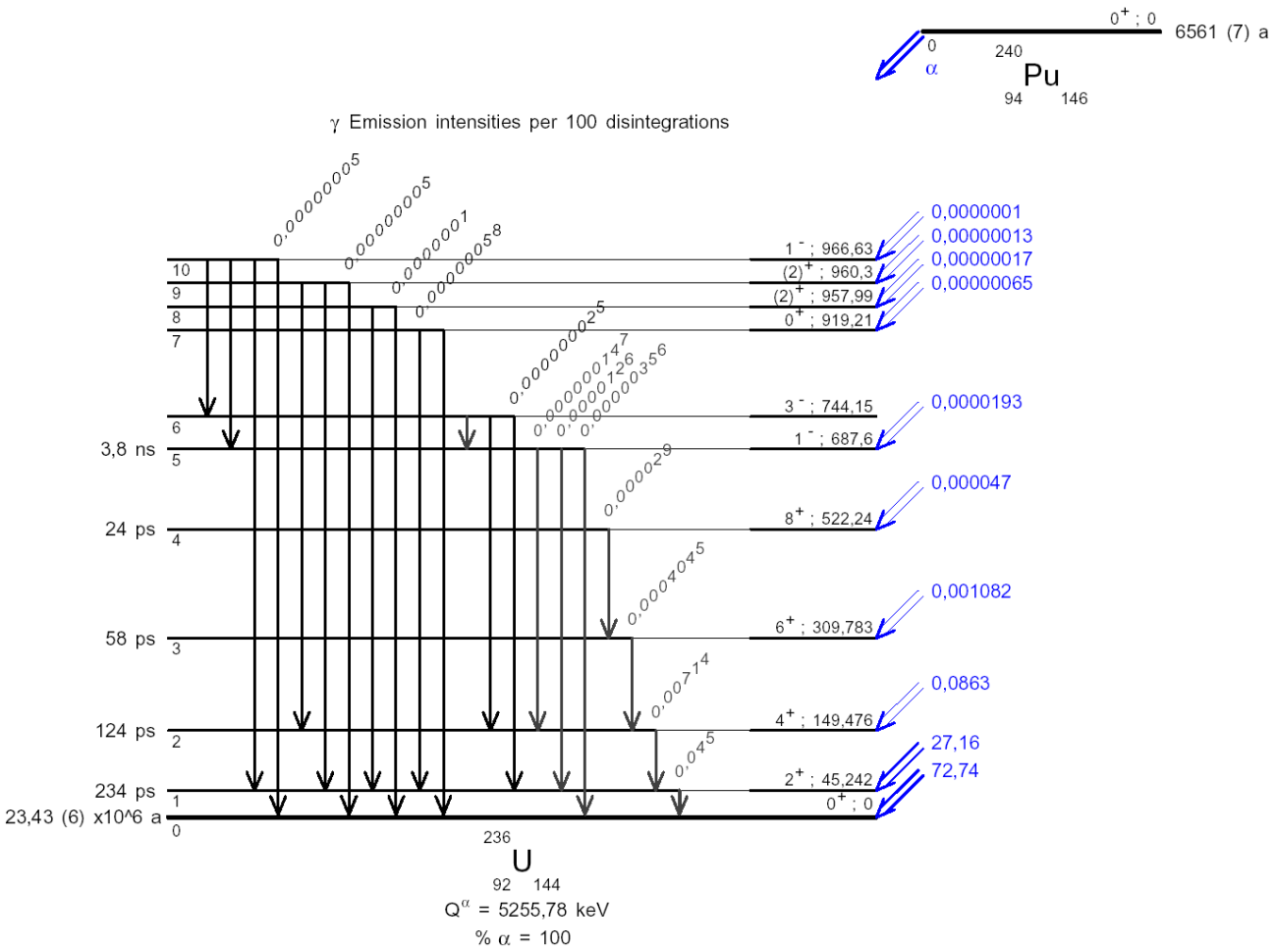
G. Sibbens, S. Pommé, T. Altzitzoglou, E. García-Toraño, H. Janßen, R. Dersch, O. Ott, A. Martín Sánchez, M.P. Rubio Montero, M. Loidl, N. Coron, P. de Marcillac, T.M. Semkow

IRMM - Institute for Reference Materials and Measurements
Geel - Belgium

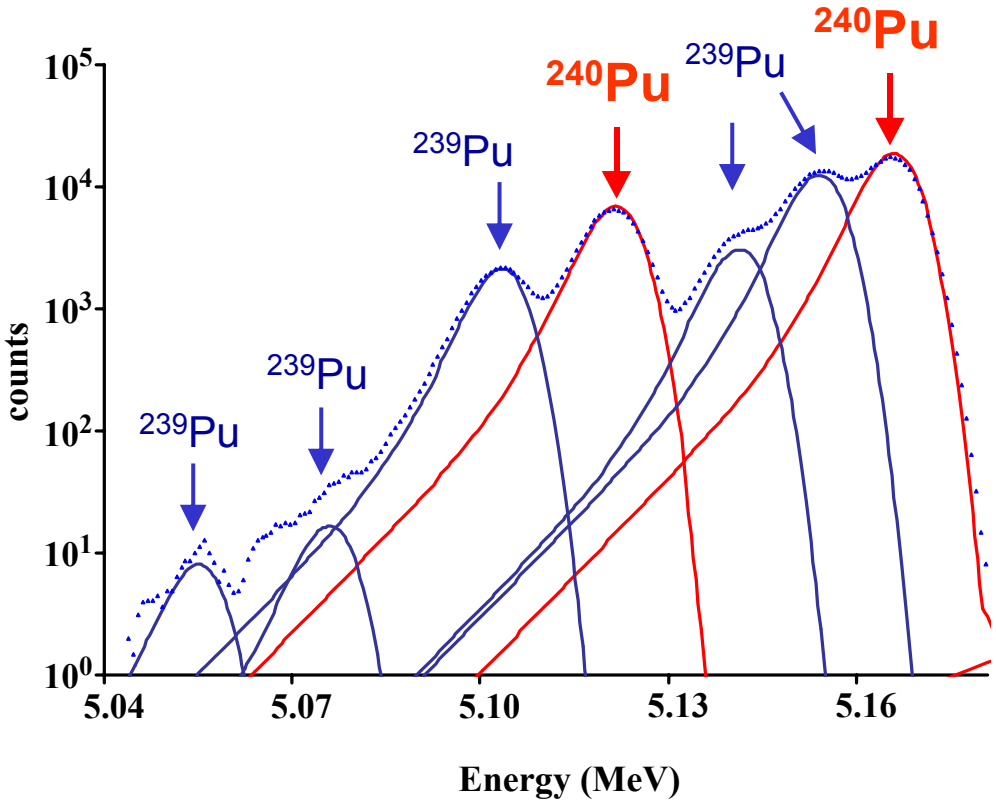
http://irmm.jrc.ec.europa.eu/
http://www.jrc.ec.europa.eu/

LNE-LNHB/CEA - Table de Radionucléides

$^{240}_{94}Pu_{146}$



Alpha-particle emission probabilities and energies in the decay of ^{240}Pu incorrect?



Bortels, G., Verbruggen, A., Sibbens, G., Altzitzoglou, T.,1996. EUROMET Project No 325: Analysis of Plutonium Alpha-Particle Spectra. IRMM Internal Report GE/R/RN/01/96.

Sibbens G., Pommé S. Study of alpha-particle emission probabilities and energies in the decay of ^{240}Pu. Appl. Radiat. Isot. 60 (2004) 155-158.

Alpha-particle emission probabilities in the decay of ^{240}Pu

IRMM (co-ordinator), CIEMAT, PTB, Univ. of Extremadura,
LNE/CEA-LIST, CNRS, NYSDOH

Project : experimental investigation by *alpha-particle spectrometry*

and a re-measurement of the alpha decay data of ^{240}Pu

Deliverables : a new set of *alpha-particle emission probabilities*,

also for the less intense peaks

- Preparation of thin ^{240}Pu sources
- Alpha-particle spectrometry
- Spectral analysis
- New set of measured alpha-particle emission probabilities for ^{240}Pu

^{240}Pu material

Solution: 1.4 g 20 MBq/g Pu-240 in 1M HNO3

isotopes	Pu-240	Pu-238	Pu-239	Pu-241	Pu-242
mass %	99.83	0.002	0.102	0.0560	0.0100
α-activity %	99.82	0.151	0.028	0.0006	0.0002

Sibbens, G., Altzitzoglou, T., Benedik, L., Pommé, S., Van Ammel, R., 2008. α-particle and γ-ray spectrometry of a plutonium solution for impurity determination, Appl. Radiat. Isot. 66, 813-818.

source preparation – spectrometry – spectral analysis – new set of P_α

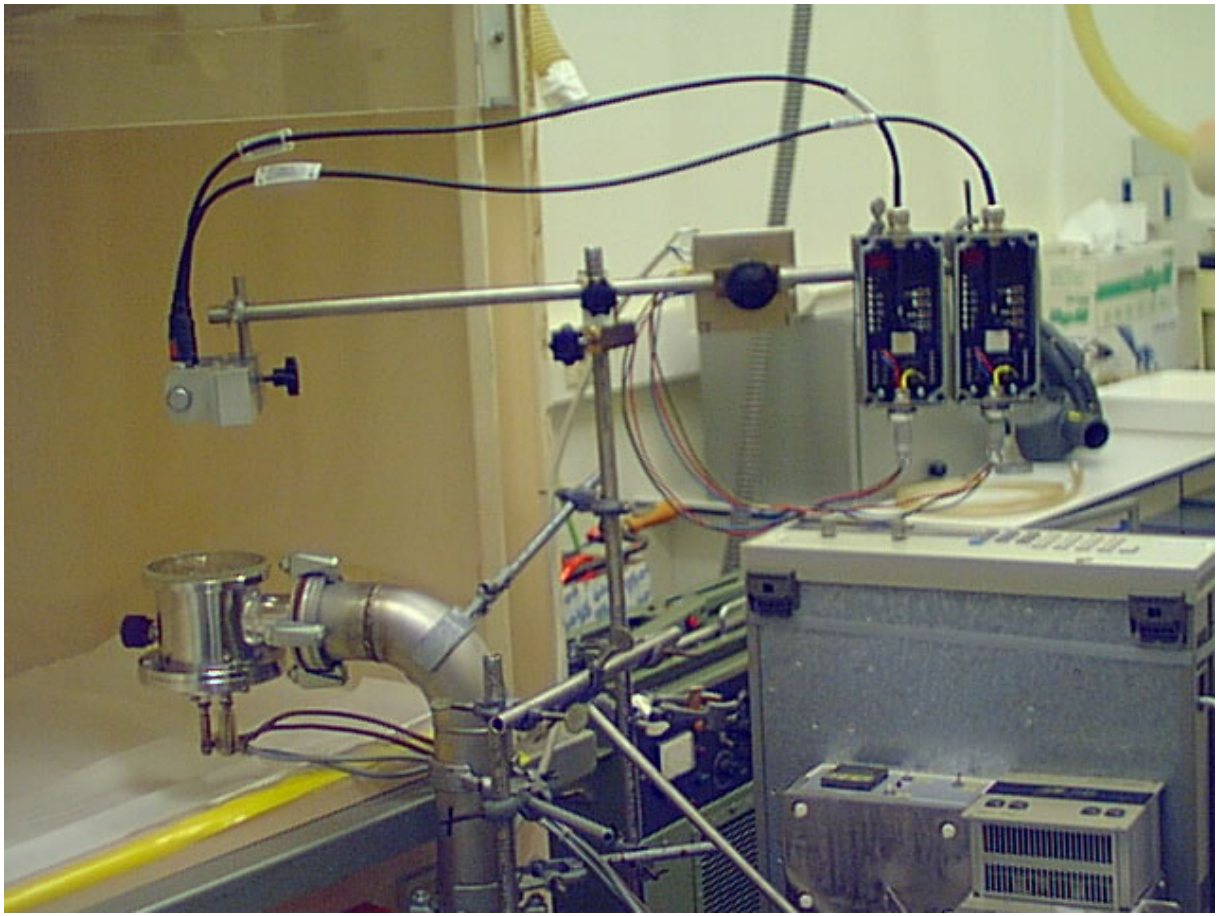
Pu-240 sources prepared by vacuum evaporation

Substrate: material: quartz
diameter: 20 mm
thickness: 1 mm

Sources: activity: 7.5 – 30 kBq
active diameter: 9 and 12 mm
thickness: 3 µg/cm^2

source preparation – spectrometry – spectral analysis – new set of P_α

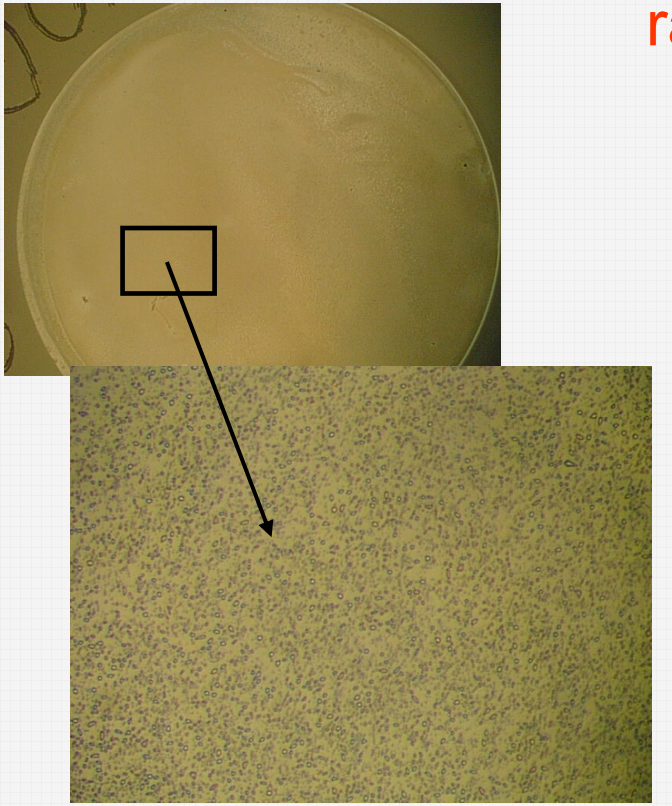
Vacuum evaporation system at IRMM



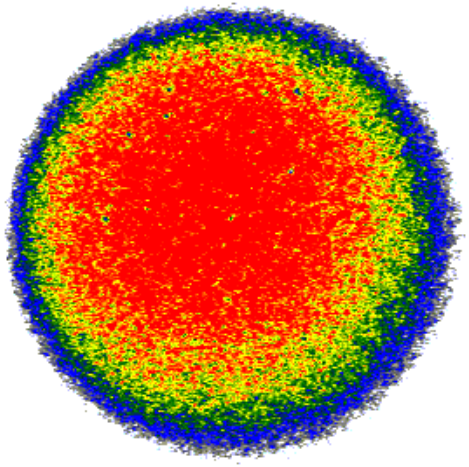
source preparation – spectrometry – spectral analysis – new set of P_{α}

Quality check ^{240}Pu sources

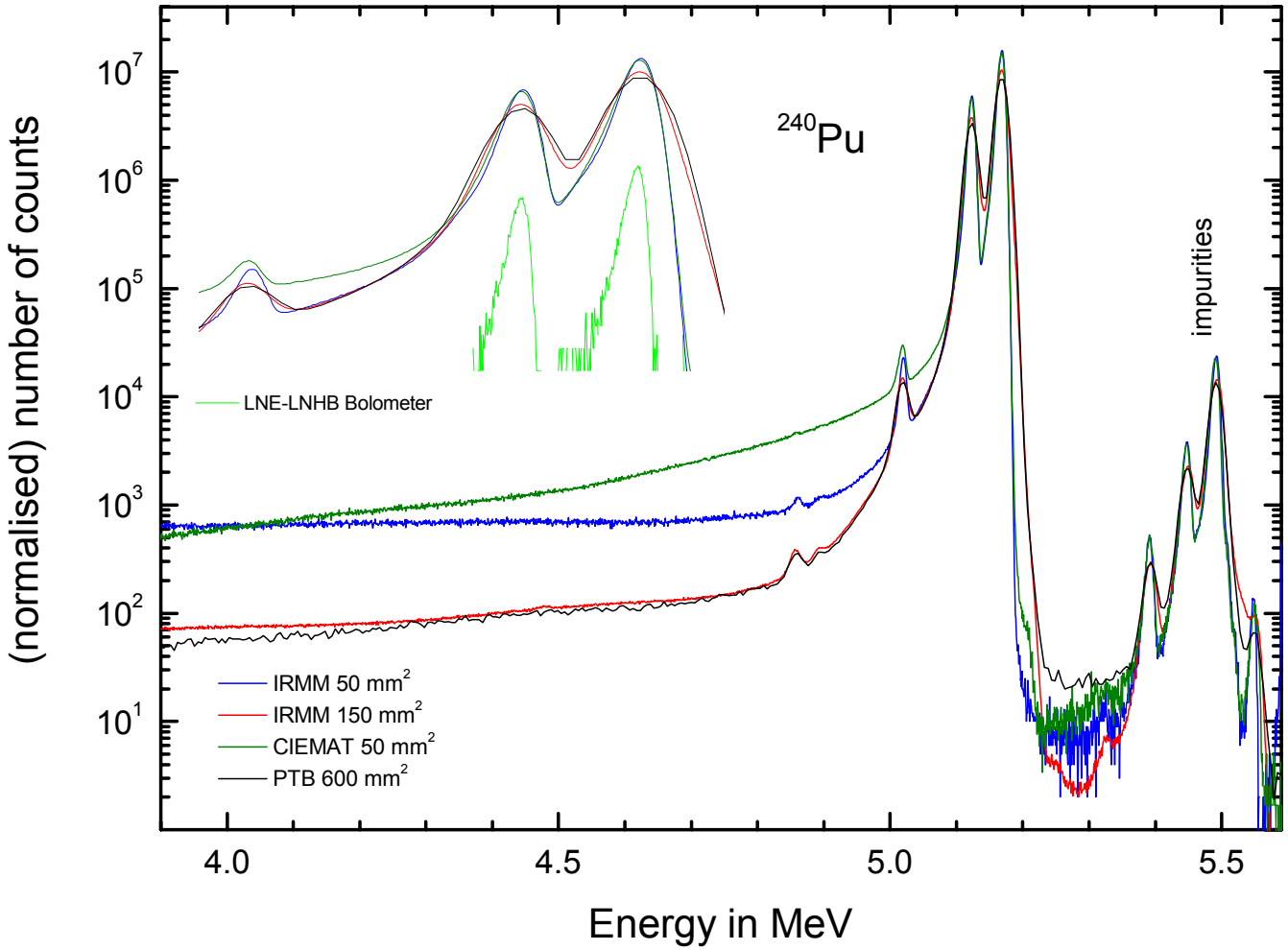
microscope:
material distribution



autoradiograph:
radioactivity distribution



source preparation – spectrometry – spectral analysis – new set of P_α



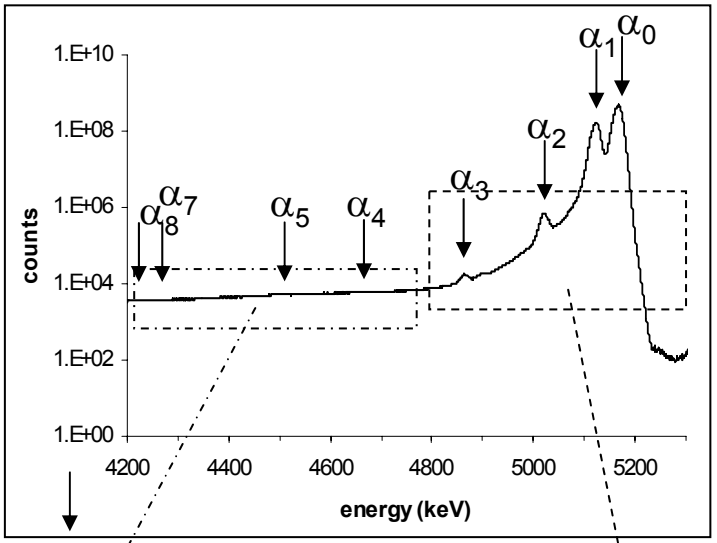
source preparation – spectrometry – spectral analysis – new set of P_α

Characteristics of ^{240}Pu spectra

nr	name	detector area in mm^2	$\Omega/4\pi$	#events	FWHM in keV	tailing
1	IRMM HR01	50	0.08 %	3.6×10^{8}	10.5	3×10^{-5}
2	CIEMAT sum21	25	0.5 %	3.3×10^{8}	11.2	6×10^{-5}
3	CIEMAT sum0106	50	0.5 %	4.3×10^{8}	11.2	1×10^{-4}
4	CIEMAT sum1006	50	0.5 %	1.0×10^{9}	13.1	2×10^{-4}
5	CIEMAT sum0326	100	1.3 %	1.7×10^{9}	14.1	1×10^{-4}
6	PTB spectrum	600	0.47 %	3.4×10^{8}	21	1×10^{-5}
7	IRMM HE01	150	2.2 %	1.7×10^{10}	16.6	1×10^{-5}

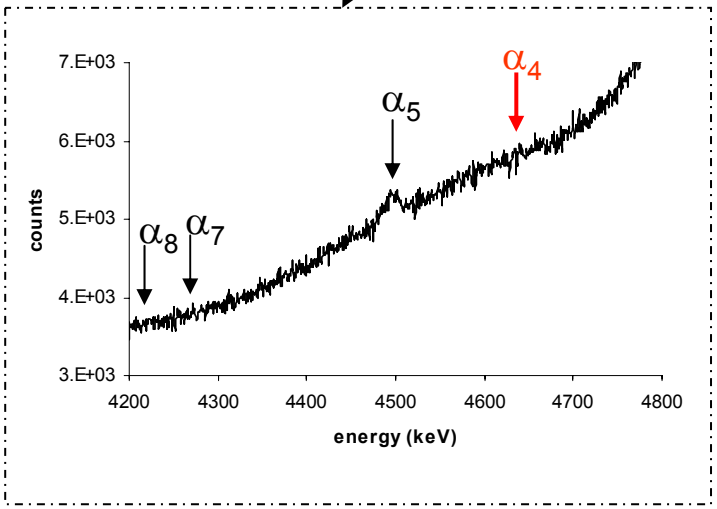
source preparation – spectrometry – spectral analysis – new set of P_α

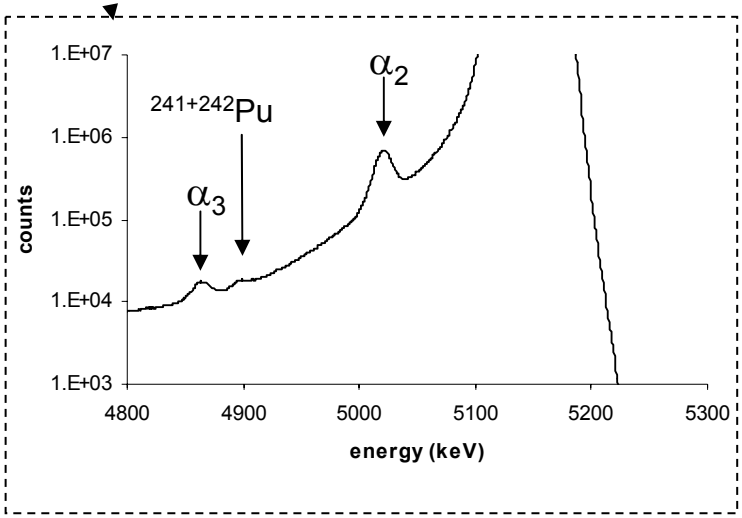
Pu240 IRMM HE01
150 mm² PIPS
300 days



	Energy keV	Probability × 100
$\alpha_{0,10}$	4217,62 (18)	$< 1{,}0\ 10^{-7}$
$\alpha_{0,9}$	4223,8 (4)	$< 1{,}3\ 10^{-7}$
$\alpha_{0,8}$	4226,12 (23)	$< 1{,}7\ 10^{-7}$
$\alpha_{0,7}$	4264,25 (23)	$\approx 6{,}5\ 10^{-7}$
$\alpha_{0,5}$	4492,00 (16)	$1{,}93\ (4)\ 10^{-5}$
$\alpha_{0,4}$	4654,60 (16)	$4{,}7\ (5)\ 10^{-5}$
$\alpha_{0,3}$	4863,51 (15)	$1{,}082\ (18)\ 10^{-3}$
$\alpha_{0,2}$	5021,15 (15)	0,0863 (18)
$\alpha_{0,1}$	5123,64 (15)	27,16 (11)
$\alpha_{0,0}$	5168,13 (15)	72,74 (11)

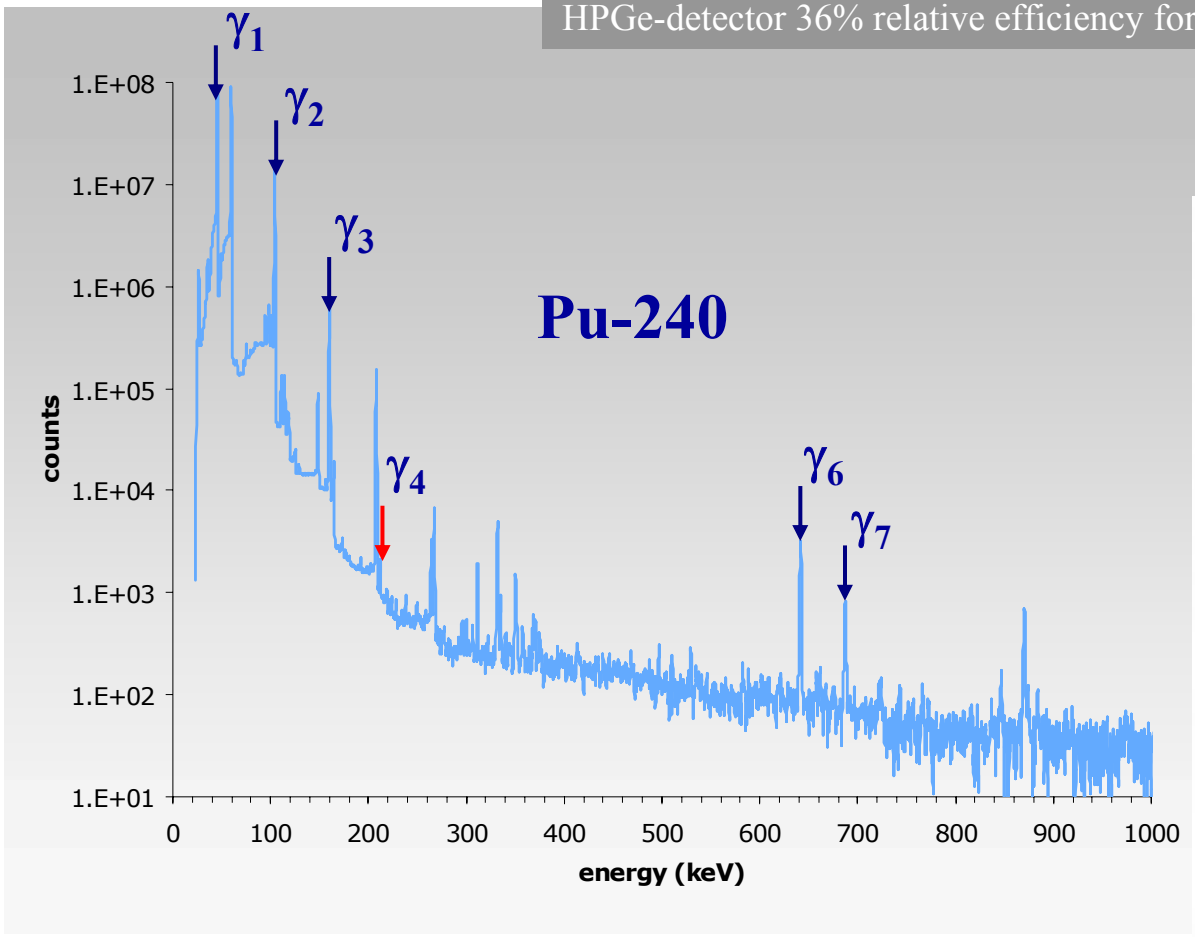
Chechev, 2004





source preparation – spectrometry – spectral analysis – new set of P_α

HPGe-detector 36% relative efficiency for ^{60}Co



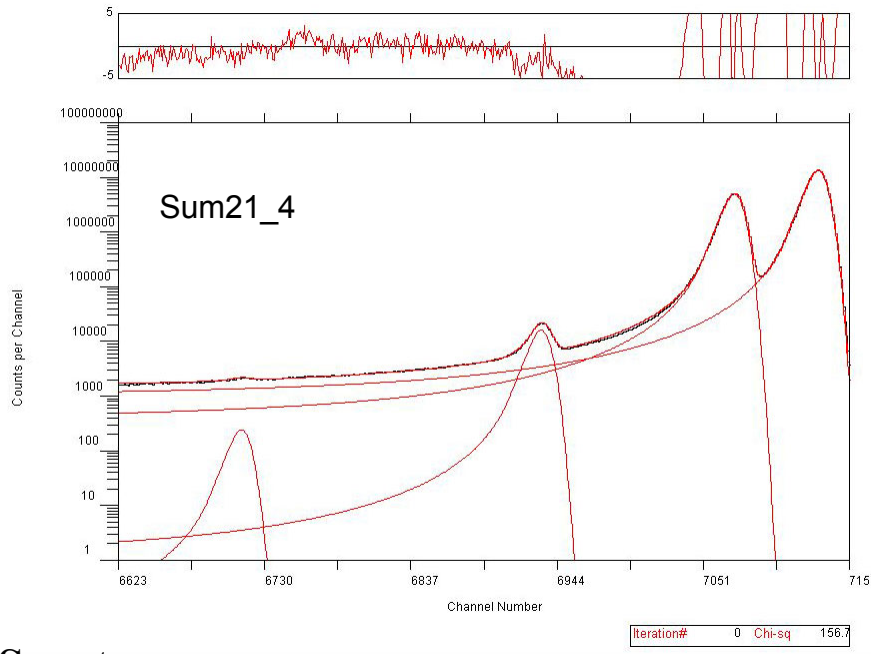
	Energie keV	Intensité absolue %
X_L	11,6 – 21,6	10 ± 1
X_K	94,66 – 115,39	(8,9 ± 0,2) x 10^{-5}
γ_1	45,244 ± 0,002	0,0447 ± 0,0007
γ_2	104,234 ± 0,006	0,00714 ± 0,00006
γ_3	160,308 ± 0,003	(4,02 ± 0,04) x 10^{-4}
γ_4	212,48 ± 0,05	(2,7 ± 0,3) x 10^{-5}
γ_5	538,15 ± 0,12	(1,4 ± 0,1) x 10^{-7}
γ_6	642,35 ± 0,04	(1,23 ± 0,05) x 10^{-5}
γ_7	687,69 ± 0,07	(3,4 ± 0,3) x 10^{-6}
γ_8	699,0 ± 0,5	< 2,4 x 10^{-8}
γ_9	873,92 ± 0,15	(5,6 ± 0,6) x 10^{-7}
γ_{11}	958,3 ± 0,3	< 1 x 10^{-7}
γ_{12}	960,0 ± 0,5	< 5 x 10^{-8}
γ_{13}	967,0 ± 0,2	< 5 10^{-8}

source preparation – spectrometry – spectral analysis – new set of P_α

Spectral deconvolution algorithms

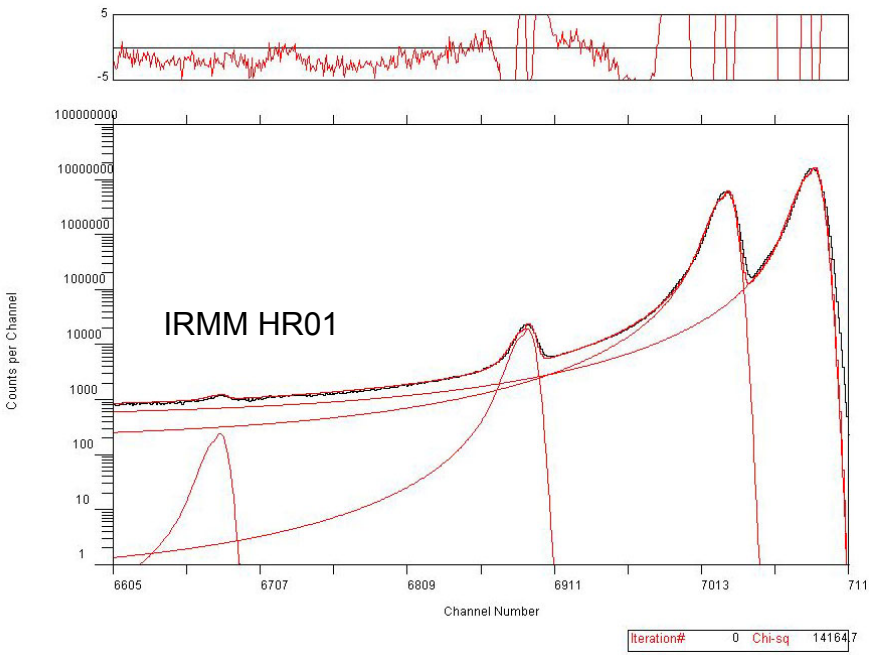
lab	code	peak shape
IRMM	ALPHA	Gaussian with 3 exponentials at low-energy side
CIEMAT	ALPACA	two-branch line shape
PTB	Fit9	2 exp. low-energy, 1 exp. high-energy tailing and step function
UNEX	FITBOR	Gaussian with 3 exponentials at low-energy side
NYSDOH	GAPQ	generalised exponent for alpha peak and generalised power function for the left tail

source preparation – spectrometry – spectral analysis – new set of P_α



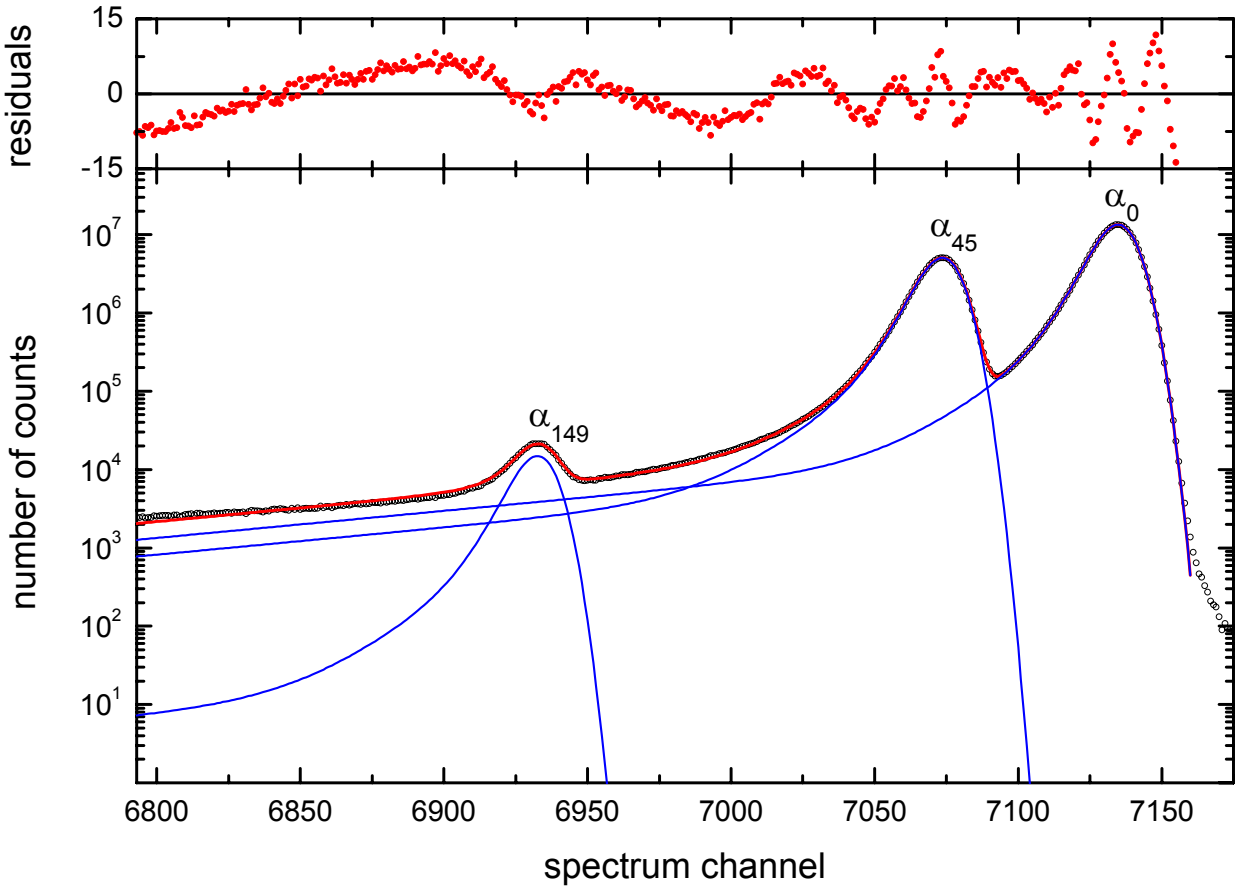
Spectrum:
CIEMAT sum21
Analysis code:
CIEMAT ALPACA

Spectrum:
IRMM HR01
Analysis code:
CIEMAT ALPACA



source preparation – spectrometry – spectral analysis – new set of P_α

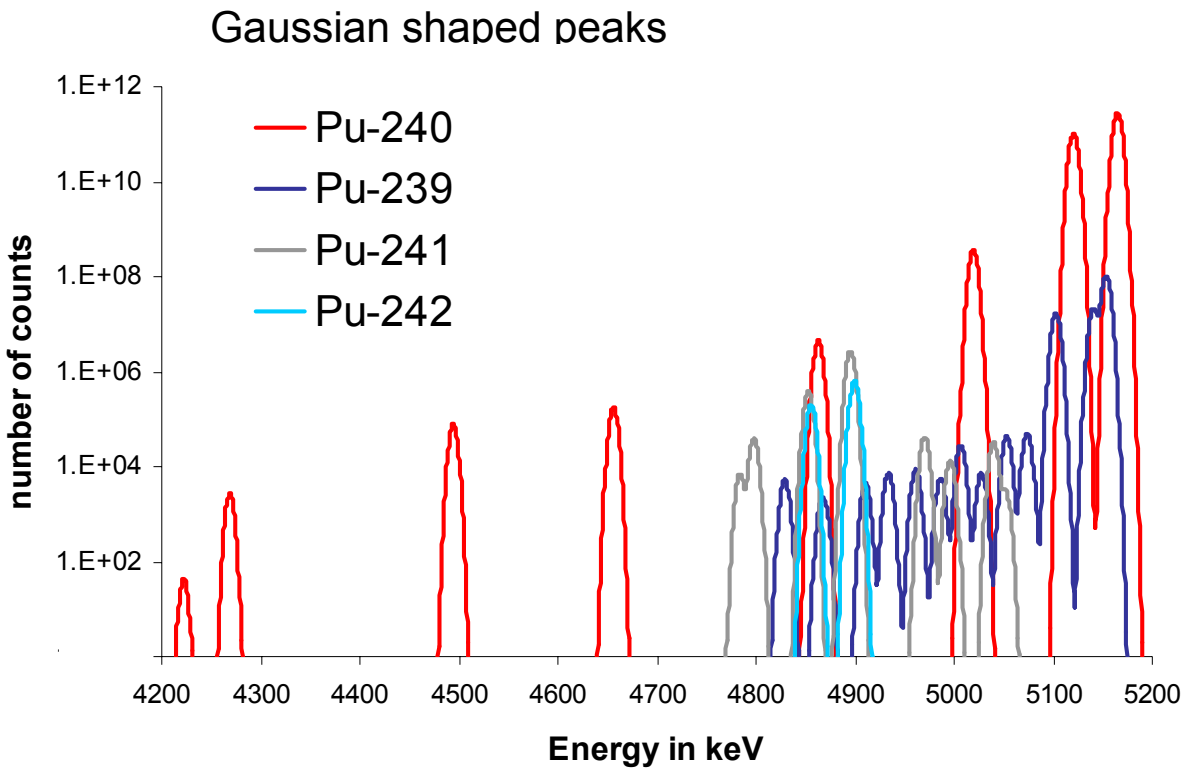
Fitted peaks



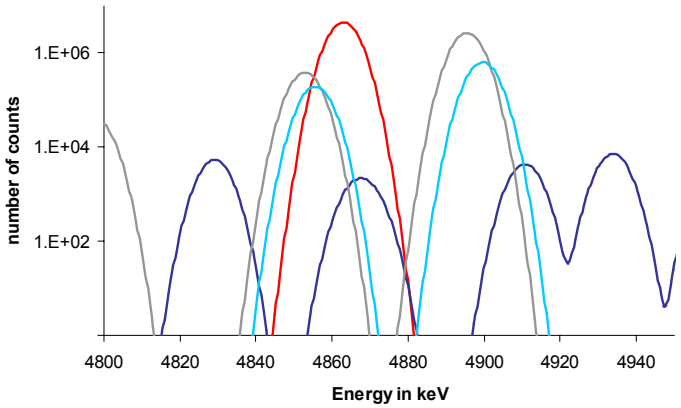
Spectrum:
CIEMAT sum21
Analysis code:
IRMM ALPHA

source preparation – spectrometry – spectral analysis – new set of P_α

Impurities in the ^{240}Pu material

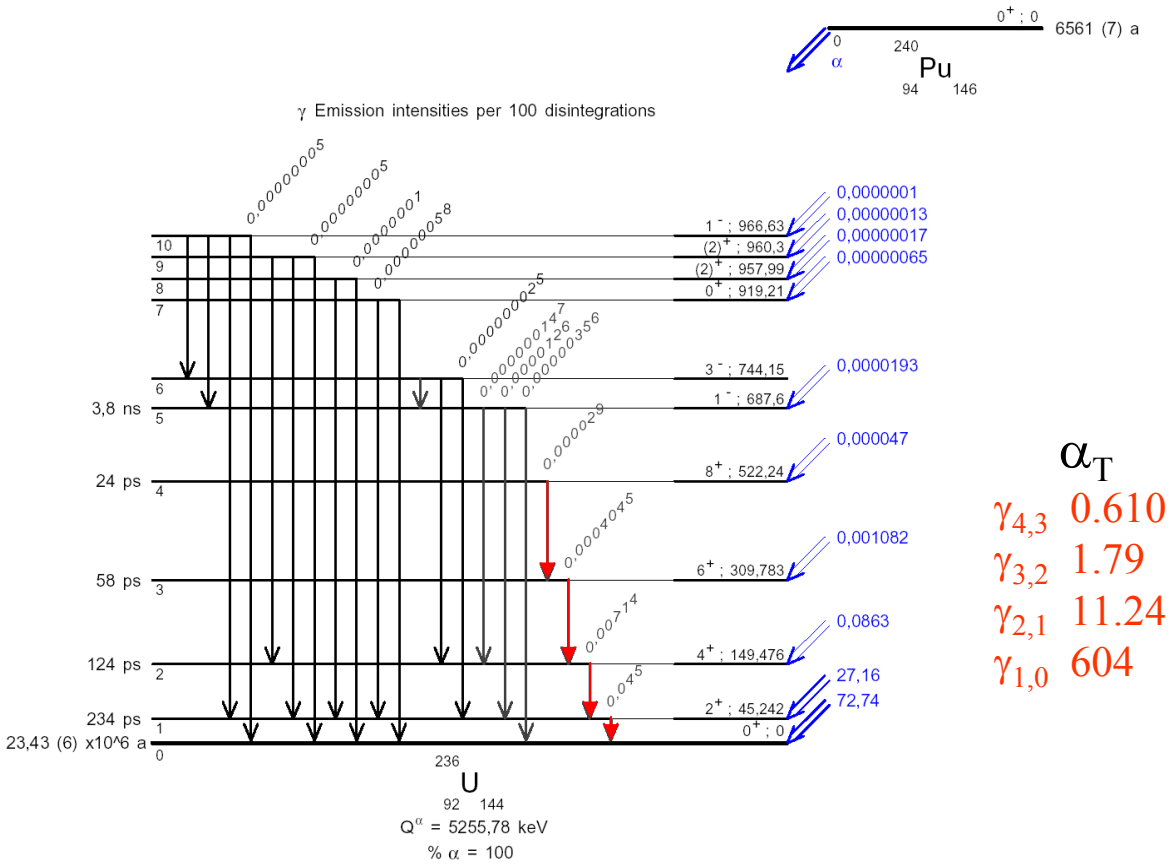


isotopes	mass %	α-activity %
Pu-240	99.83	99.82
Pu-238	0.002	0.151
Pu-239	0.102	**0.028**
Pu-241	0.0560	**0.0006**
Pu-242	0.0100	**0.0002**



source preparation – spectrometry – spectral analysis – new set of P_α

LNE-LNHB/CEA - Table de Radionucléides $^{240}_{94}Pu_{146}$



α_T

$\gamma_{4,3}$ 0.610

$\gamma_{3,2}$ 1.79

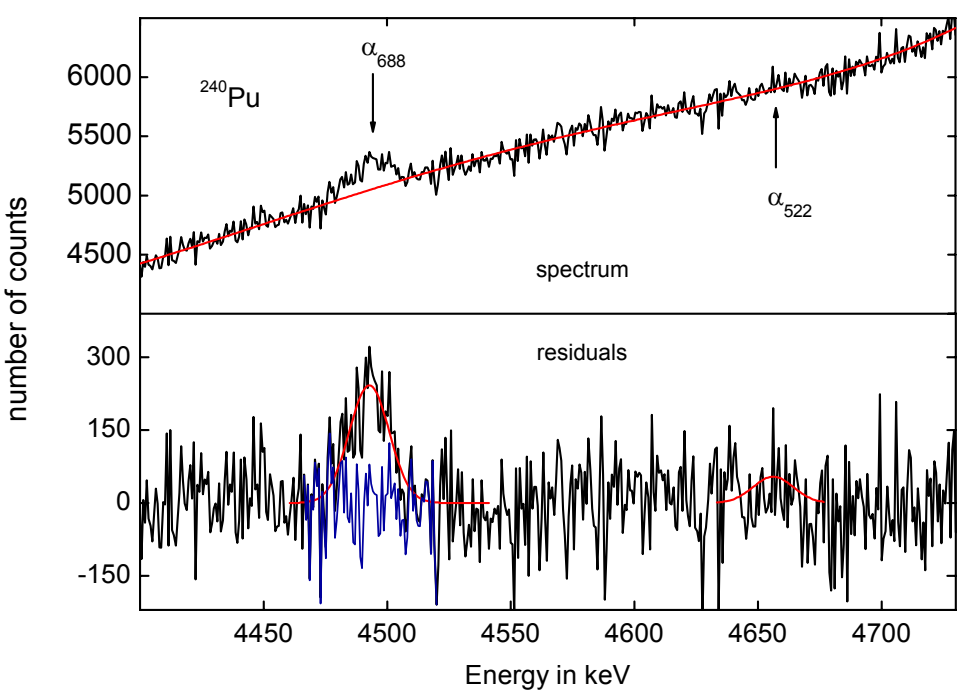
$\gamma_{2,1}$ 11.24

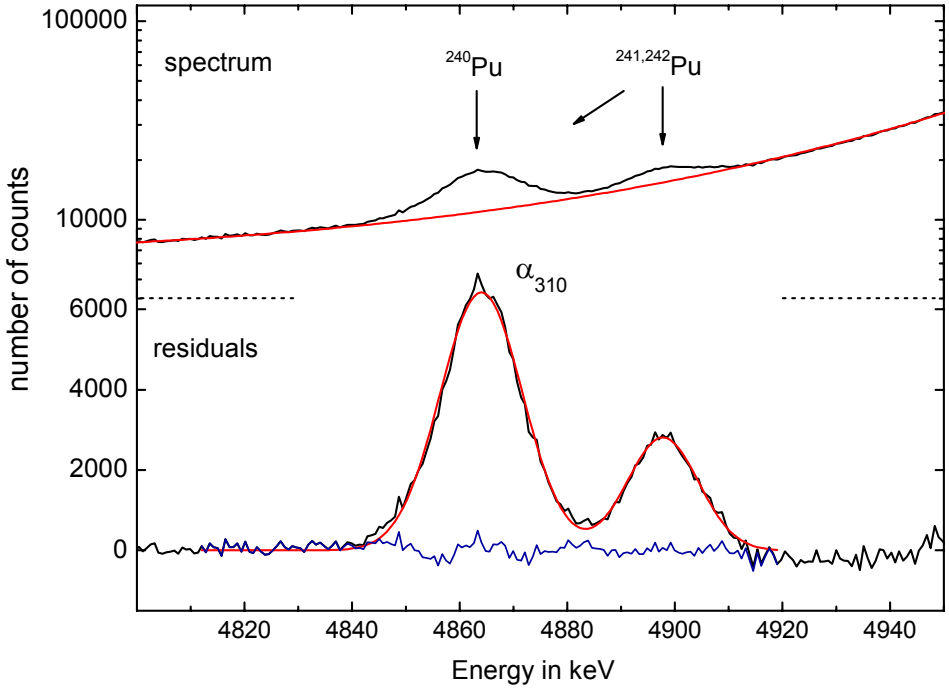
$\gamma_{1,0}$ 604

KRI / V. P. Chechev Scheme page : 1/1 09/09/2003 - 09/09/2003

source preparation – spectrometry – spectral analysis – new set of P_α

Independent fit of tailing





Spectrum: IRMM HE01

source preparation – spectrometry – spectral analysis – new set of P_α

New set of P_α for ^{240}Pu

branch	Chechev (2004) E_α in keV	Chechev (2004) P_α in %	this work P_α in %
α_{688}	4492.00	0.0000193 (4)	0.000040 (10) 0.000032 (5) *
α_{522}	4654.60	0.000047 (5)	$< 10^{-5}$ $1.72(7)\,10^{-6}$ *
α_{310}	4863.51	0.001082 (18)	0.00097[a] (9)
α_{149}	50.21.15	0.0863 (18)	0.085 (4)
α_{45}	5123.64	27.16 (11)	27.21 (7)
α_0	5168.13	72.74 (11)	72.70 (7)

* result obtained by γ-ray spectrometry

[a] measured fraction was corrected for interfering ^{241}Pu and ^{242}Pu peaks and for estimated summing-out effects

source preparation – spectrometry – spectral analysis – new set of P_α