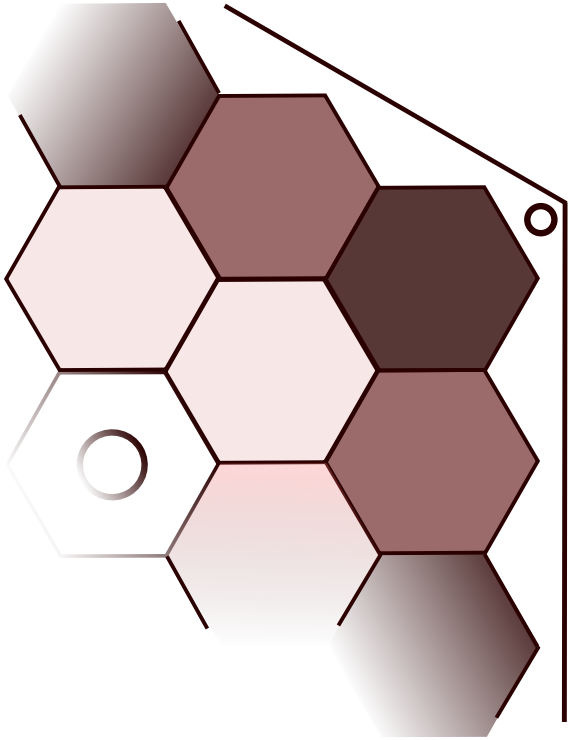
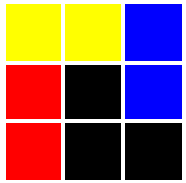
First total absorption spectrometry measurement of the β-decay of ^{139}Xe



Aleksandra Fijałkowska
Faculty of Physics, University of Warsaw

M. Karny, K.P. Rykaczewski, M. Wolińska-Cichocka, B.C. Rasco,
R. Grzywacz, C.J. Gross, J.W. Johnson, D. Miller, E.F. Zganjar,
R. Goans, K.C. Goetz, J.H. Hamilton, C. Jost, M. Madurga,
K. Miernik, S.W. Padgett, S.V. Paulauskas, A.V. Ramayya, D. Stracener



06.06.2014 ARIS, Tokyo

Decay heat

Beta and gamma energy released by the decay of fission products

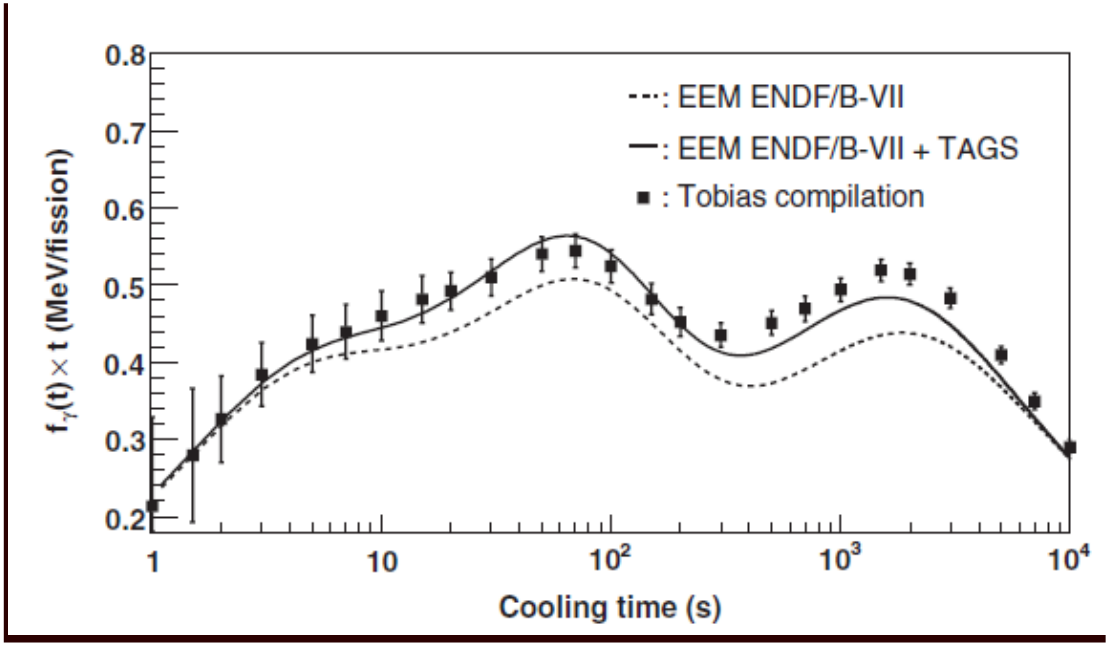
$$f(t) = \Sigma_i (E_{\gamma,i} + E_{\beta,i}) \lambda_i N_i(t)$$

E_i - mean decay energy of nucleus i (β and γ)

λ_i - decay constant

$N_i(t)$ - number of nuclei i at time t

Gamma component of ^{239}Pu decay heat



A. Algora et al., PRL 105, 202501 (2010)

A. Tobias, CEGB Report No. RD/B/6210/R89, 1989

Decay heat

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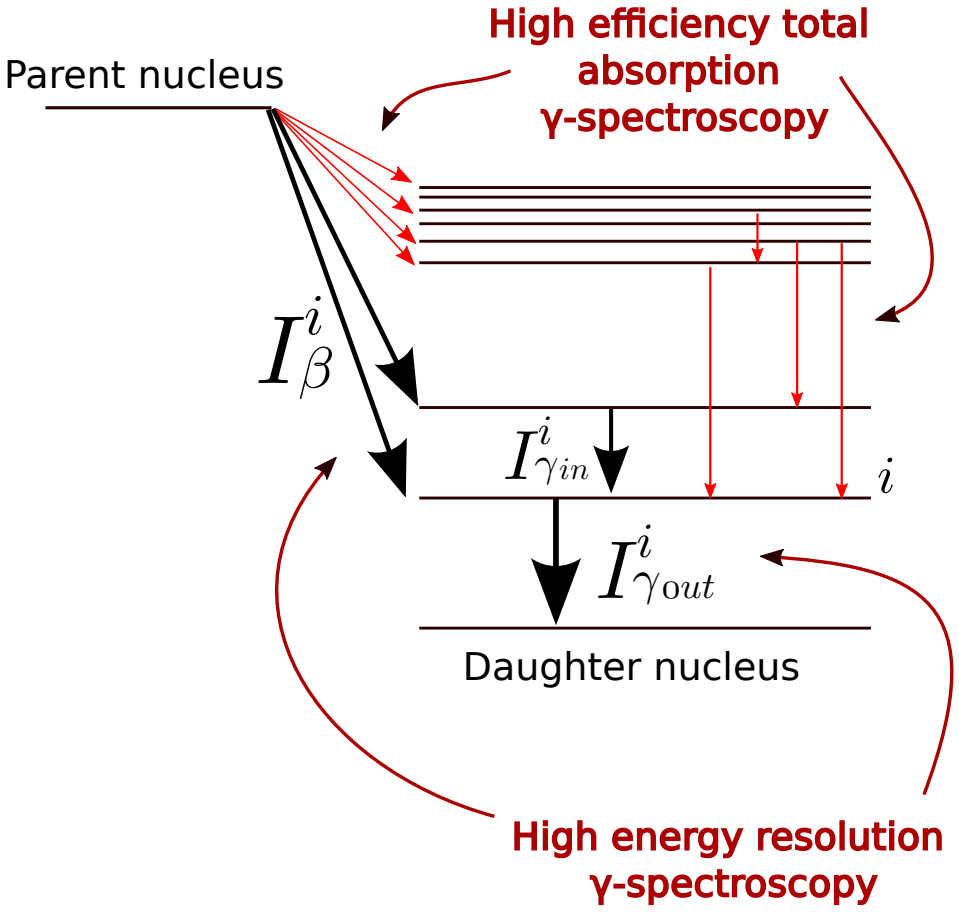
Radionuclides recommended for TAGS measurements
Assessment offission product, decay data for decay heat calculations,
T. Yoshida, A.L. Nichols, OECD NEA, 2007
+ Neutron-induced Cummulative Fission Yields (235U)

86 Br 1.6 %
87 Br
88 Br
89 Kr 4.5 %
90 Kr
98 Nb
99 Nb
100 Nb
101 Nb
103 Mo
105 Mo
102 Tc
103 Tc
104 Tc
105 Tc
106 Tc
132 Sb
136 I
137 I
137 Xe
139 Xe 5.0 %
140 Xe

} B. C. Rasco, β-γ and β-n-γ Emission in Mass A=137 Decay Chain Studied with the Modular Total Absorption Spectrometer (MTAS)

High efficiency spectrometry



Compete β-feeding pattern

Gamma and beta average energy per decay

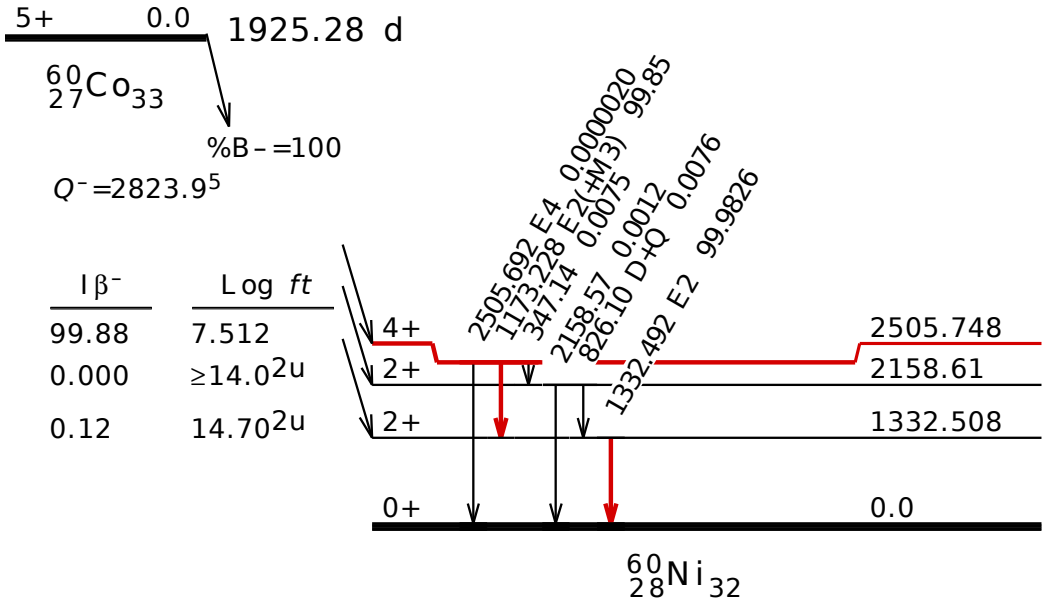
$$E_\gamma \approx \sum E^i \cdot I^i_\beta$$

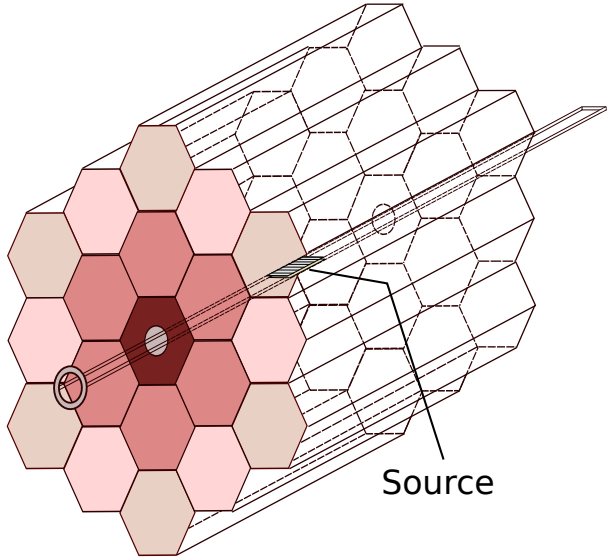
Beta strength function

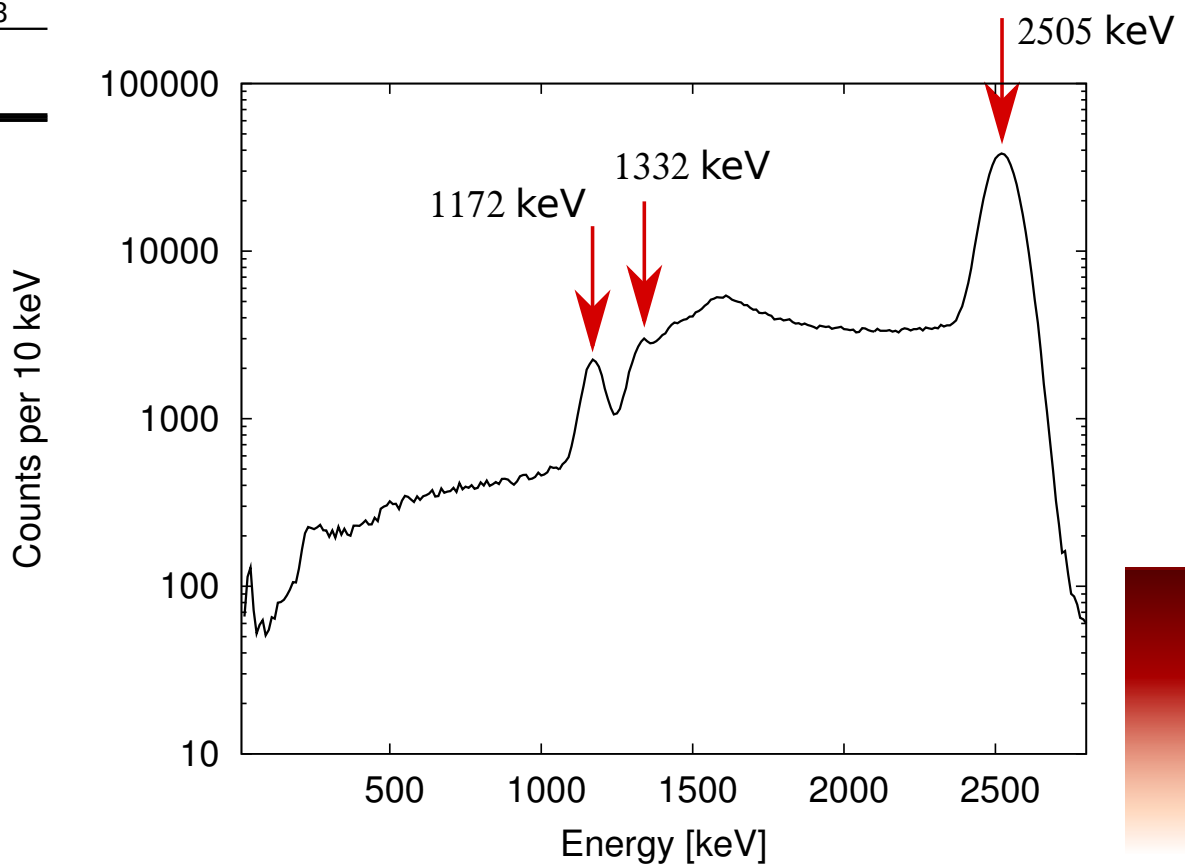
Pandemonium Efect

J. C. Hardy et al., Physics Letter B 71 (1977) 307-310

Total Absorption Spectrometry, ^{60}Co spectrum

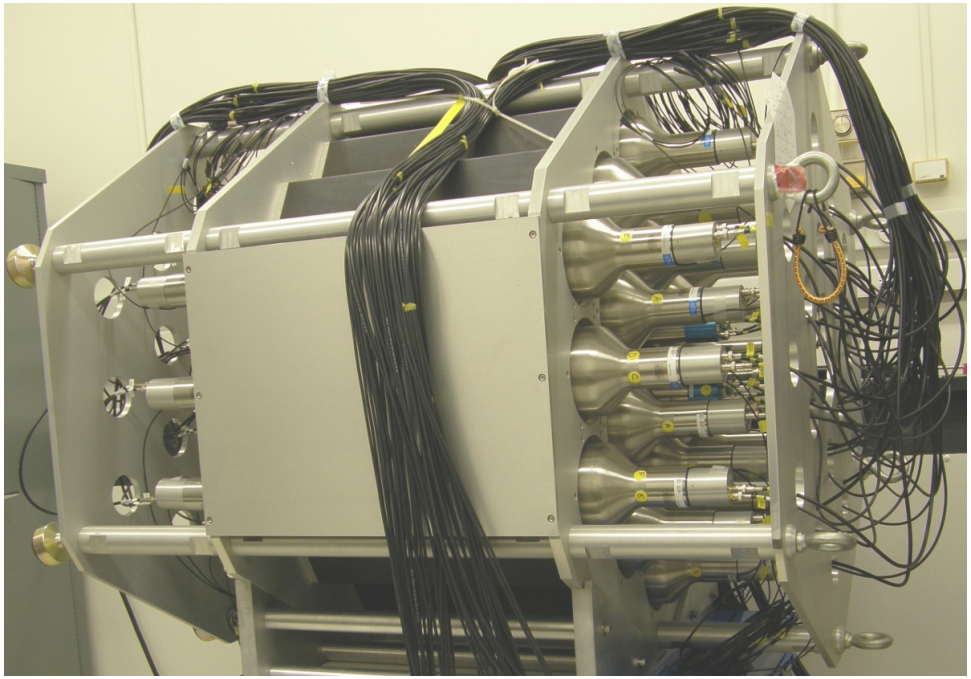


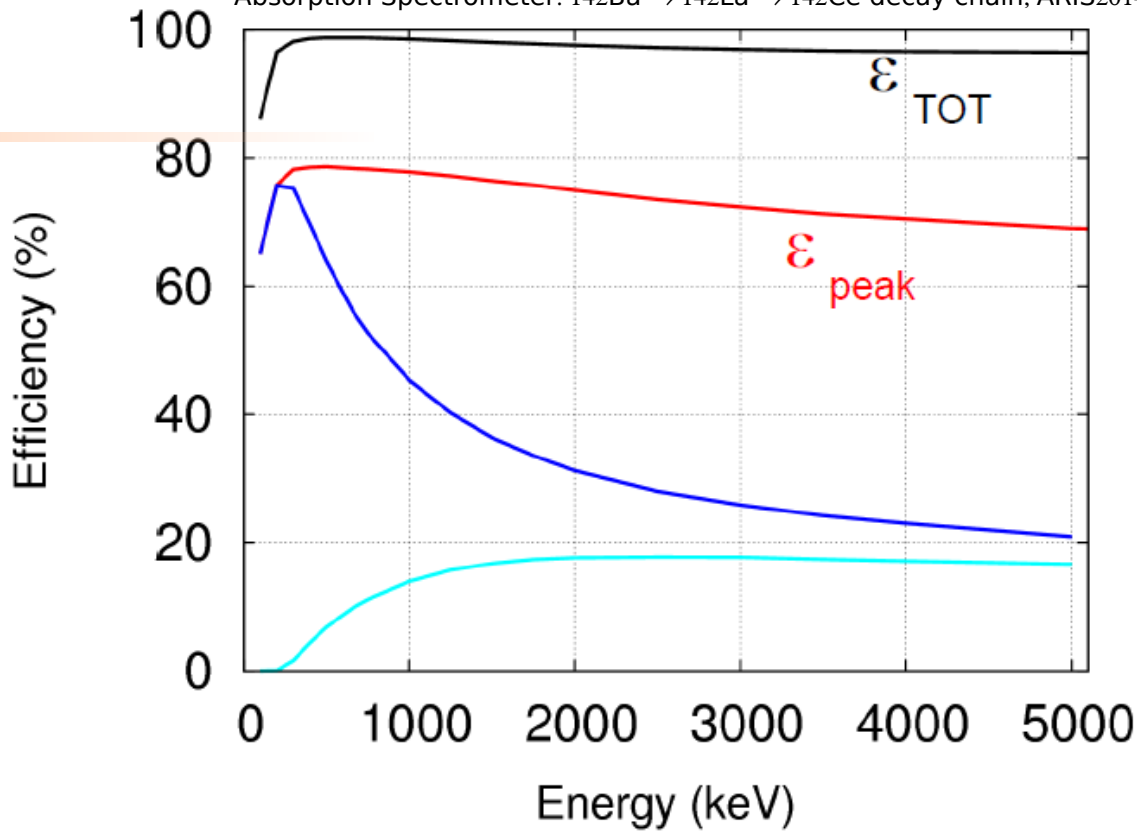




Modular Total Absorption Spectrometer (MTAS)

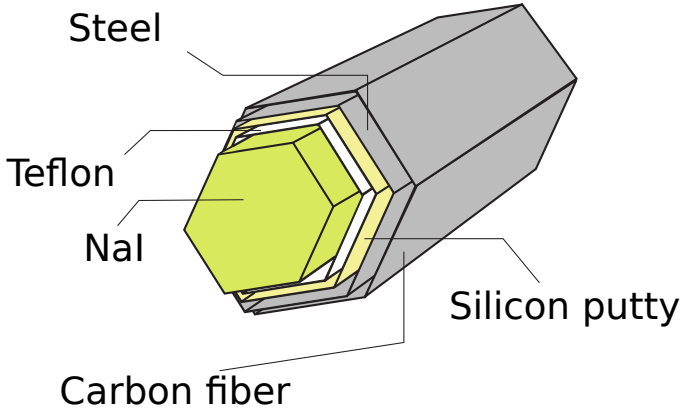
M. Wolińska-Cichocka, Testing the on-line response of Modular Total Absorption Spectrometer: $^{142}Ba \rightarrow {}^{142}La \rightarrow {}^{142}Ce$ decay chain, ARIS2014



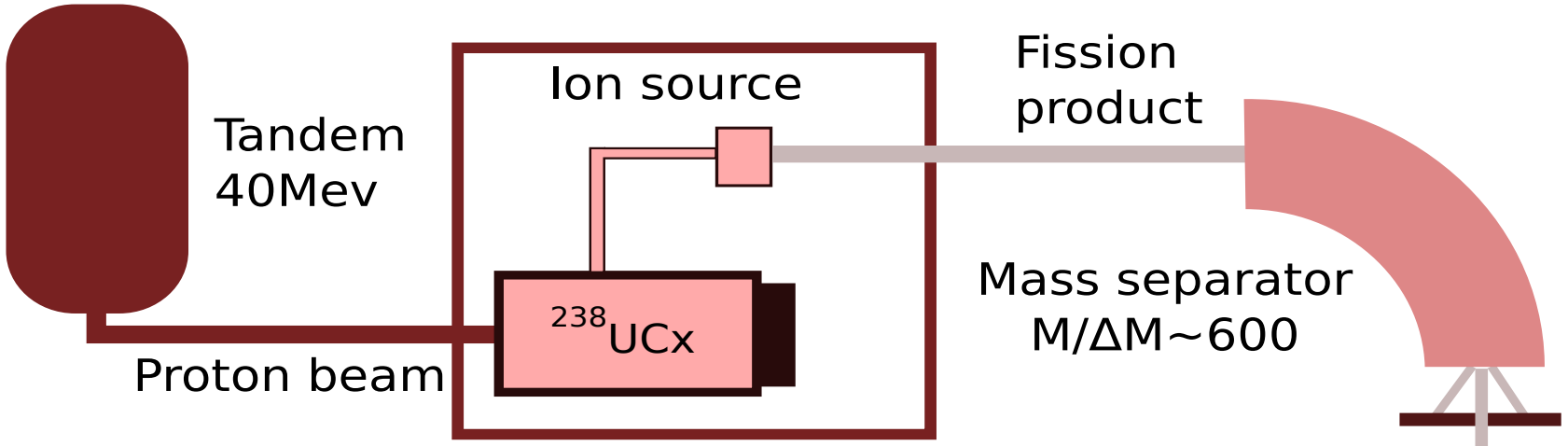


Simulated full energy gamma ray efficiency for Central detector, Inner ring, and all MTAS for complete MTAS array.

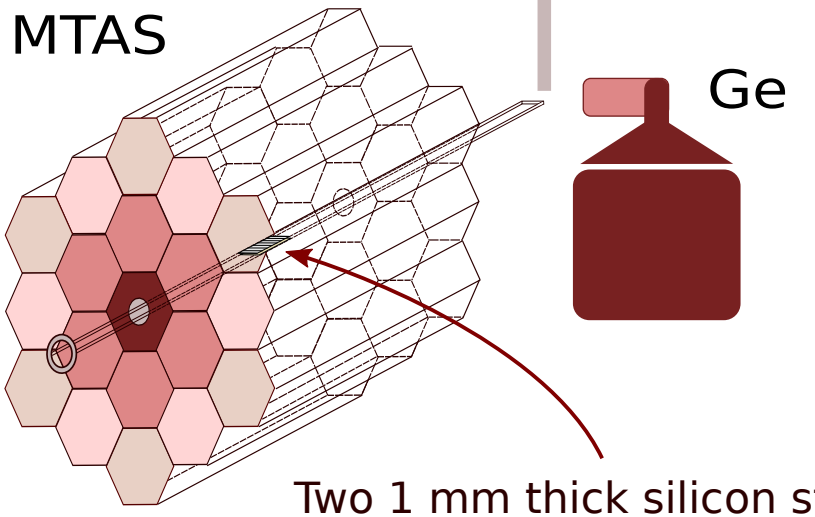
19 hexagonal NaI crystals.
Diameter: 8” length: 21” each.



Experiment



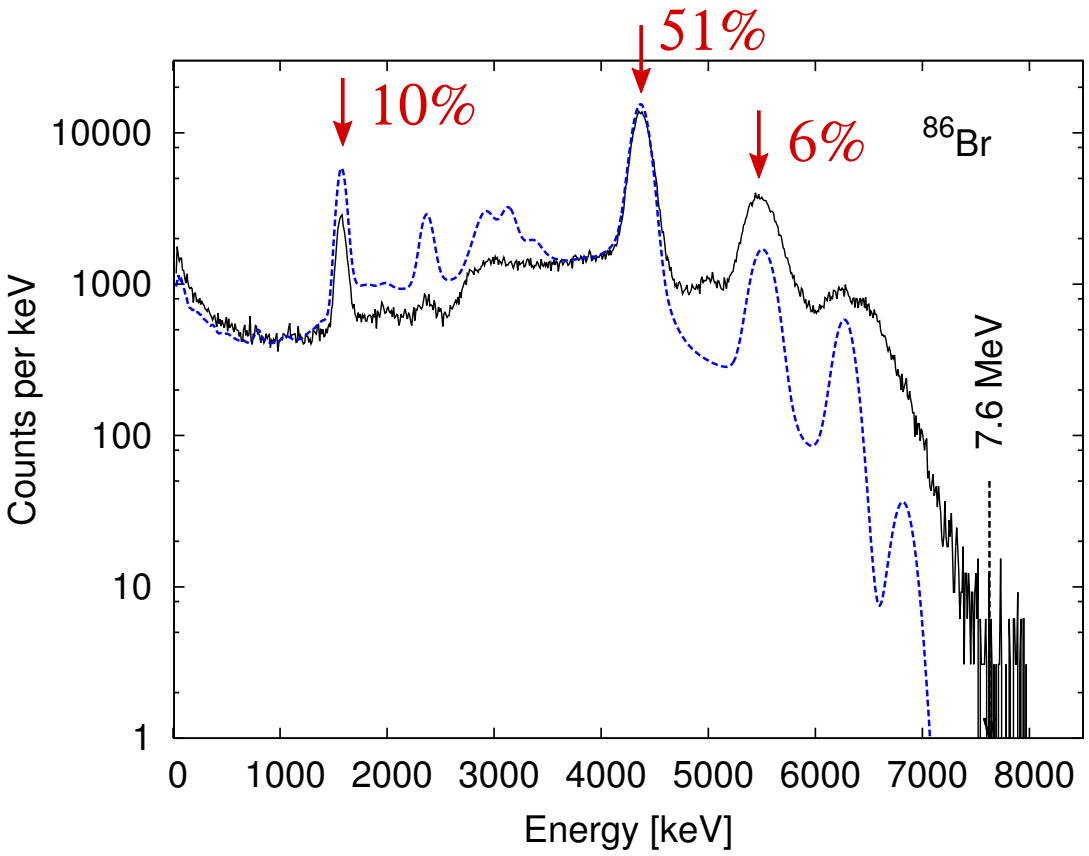
January 2012
Holifield Radioactive Ion Beam Facility



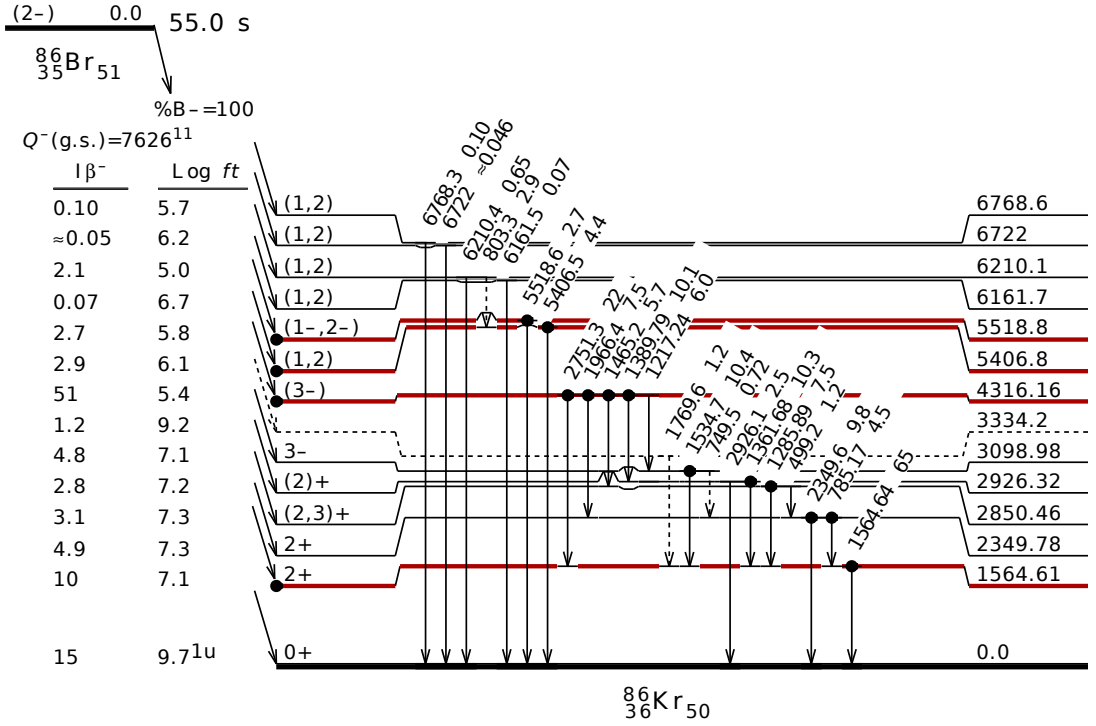
Measurement cycle:
1. Sample impantation
2. Waiting
3. Activity transportation
4. Measurement
5. Second transportation

Two 1 mm thick silicon strip detectors placed around the tape transporting collected activity.

^{86}Br



14 levels
22 gamma transitions

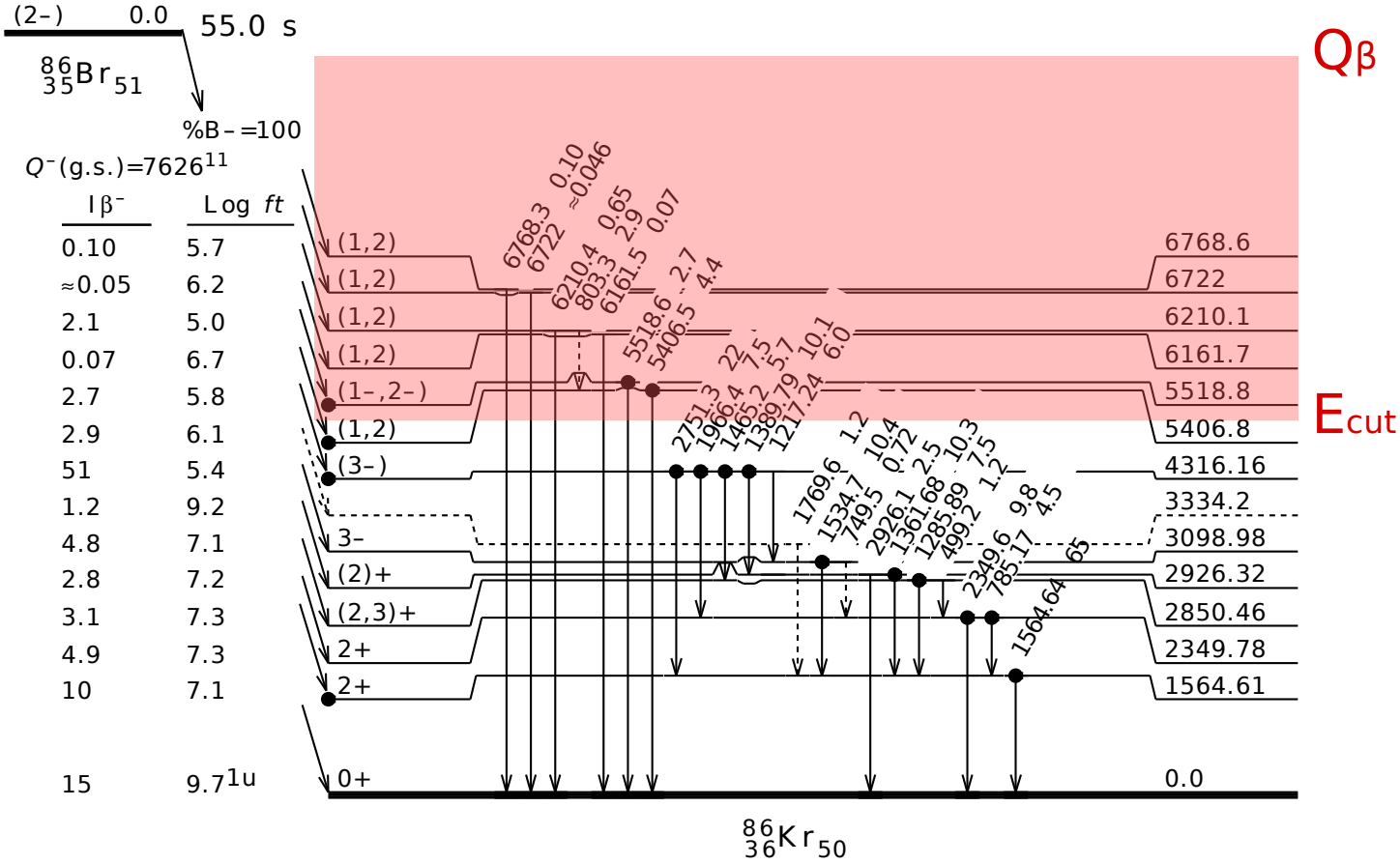


Peaks in MTAS spectrum correspond to the levels being fed, NOT to the individual gamma transitions.

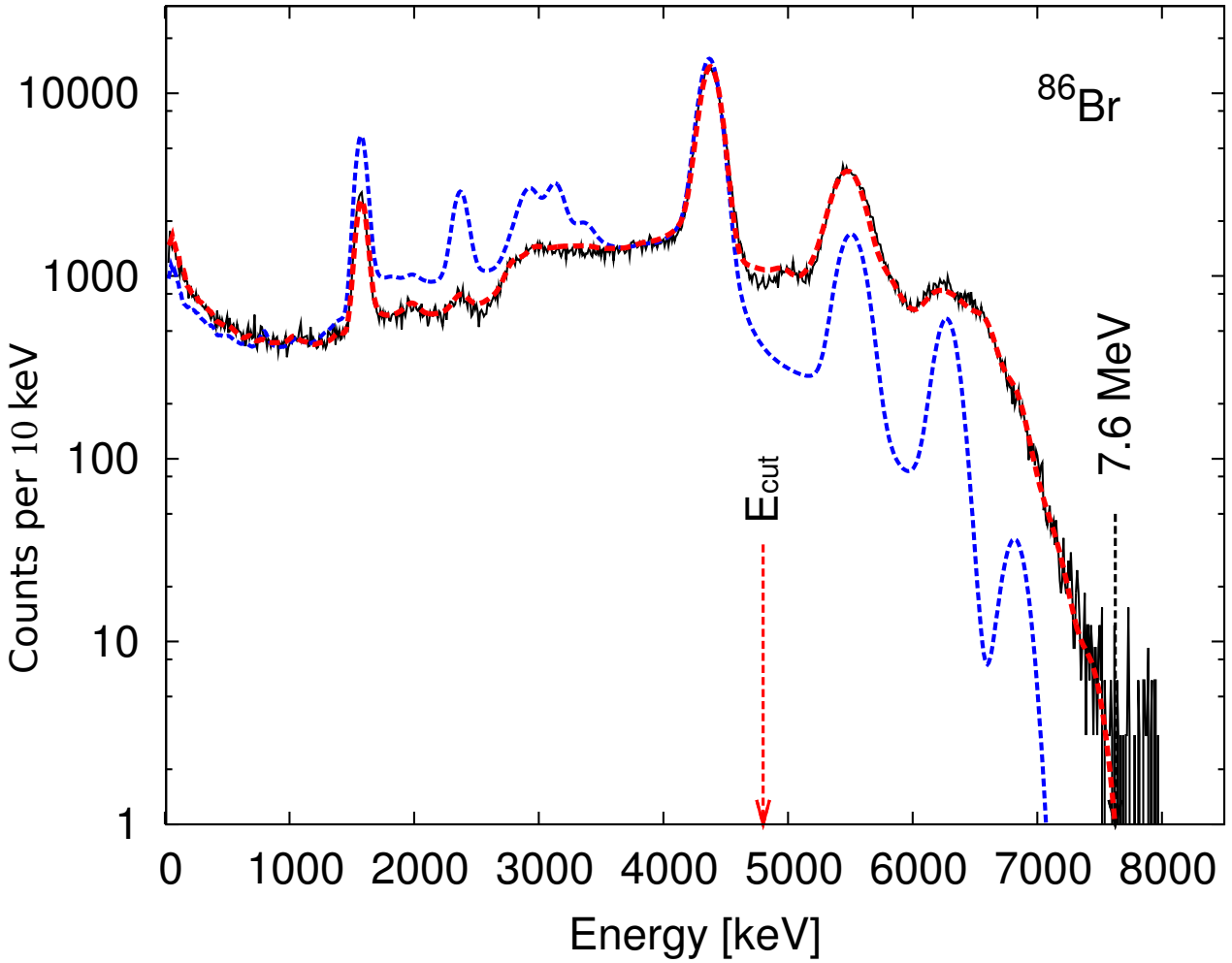
Decay scheme modification

Assumptions:

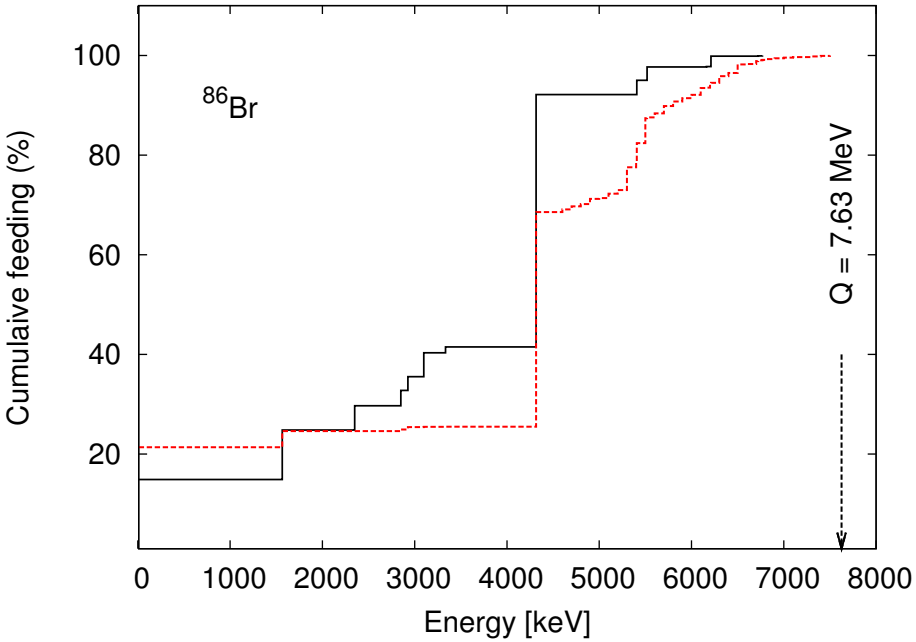
1. Decay scheme is completed up to Ecut energy
2. Above E_{cut} pseudo-levels every 100 keV, up to Q_β
3. Only allowed Gamow-Teller transitions
   (level density formula - A. Gilbert, A. G. W. Cameron, Can. Jurn. of Phys. 43 (1965))
4. Pseudo-levels deexcite to "known" levels.
5. Only E1, M1 and E2 transitions



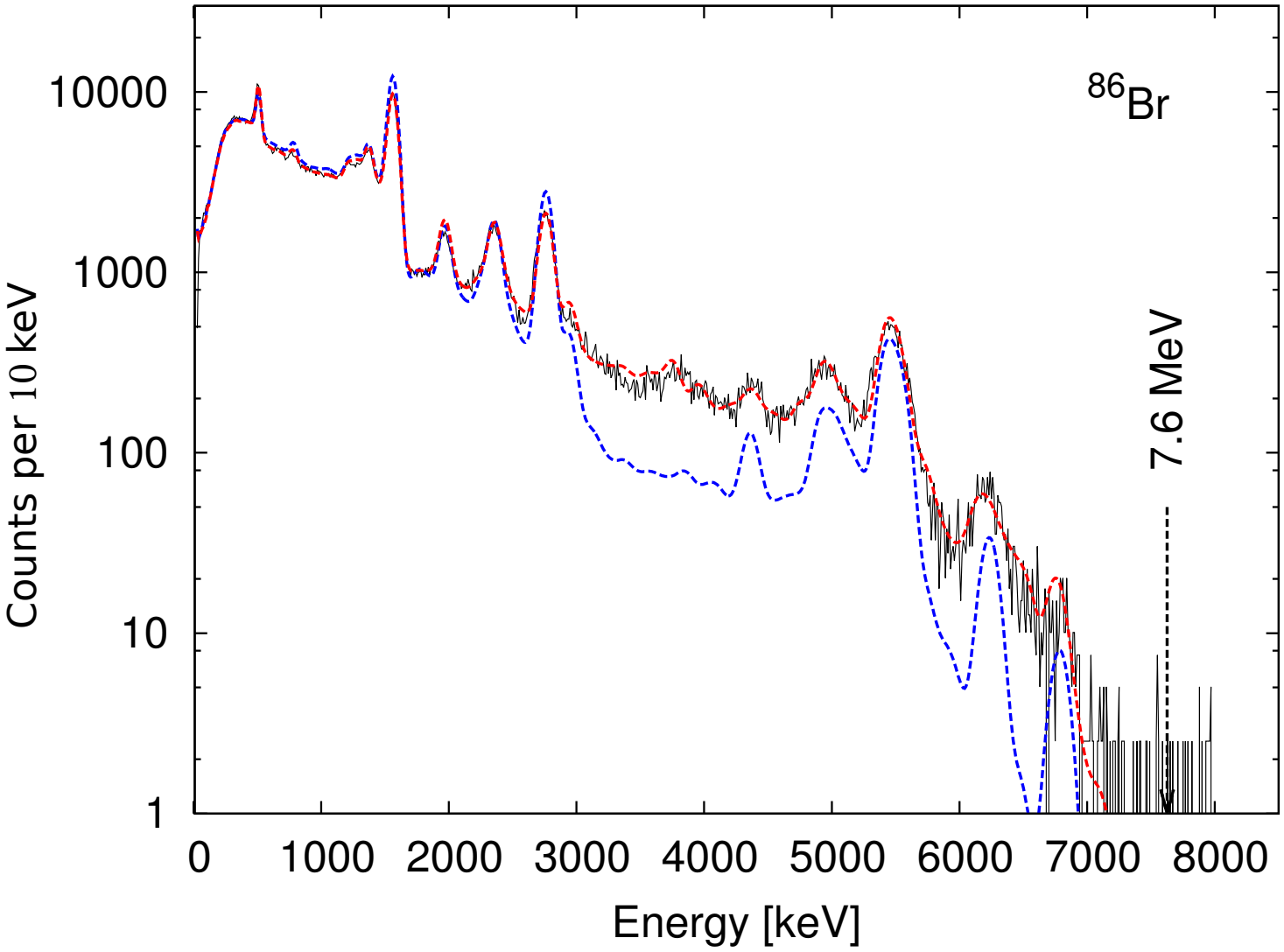
^{86}Br

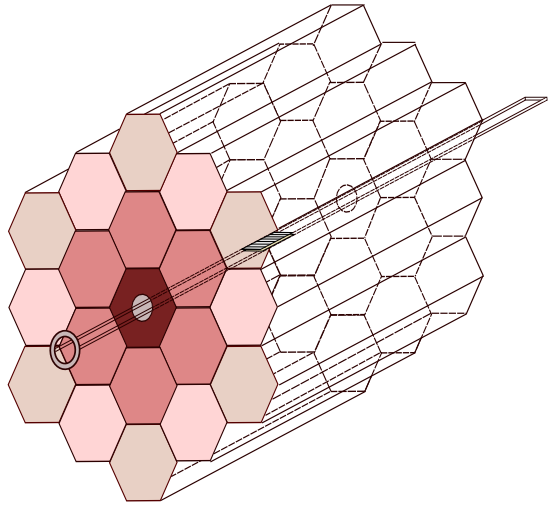


average gamma energy increased from 3259 keV to 3712 keV (14%)

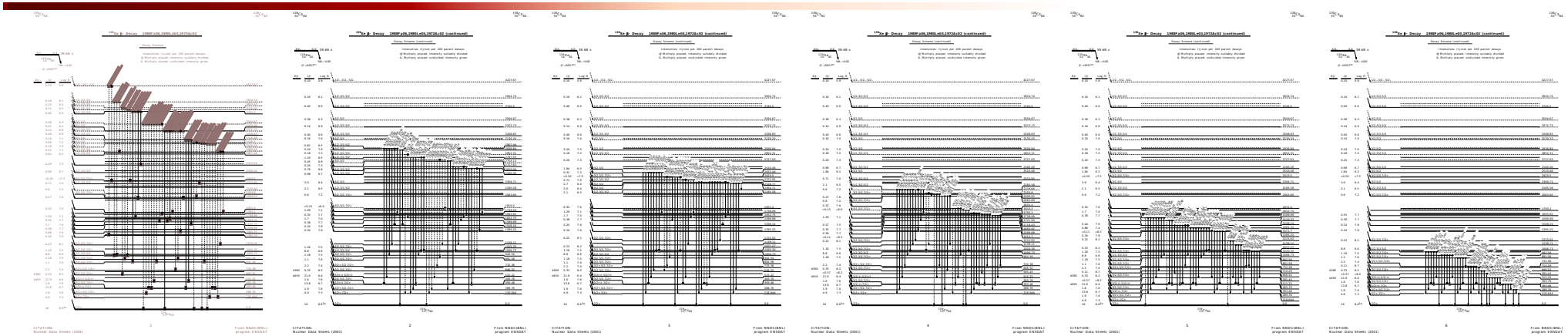


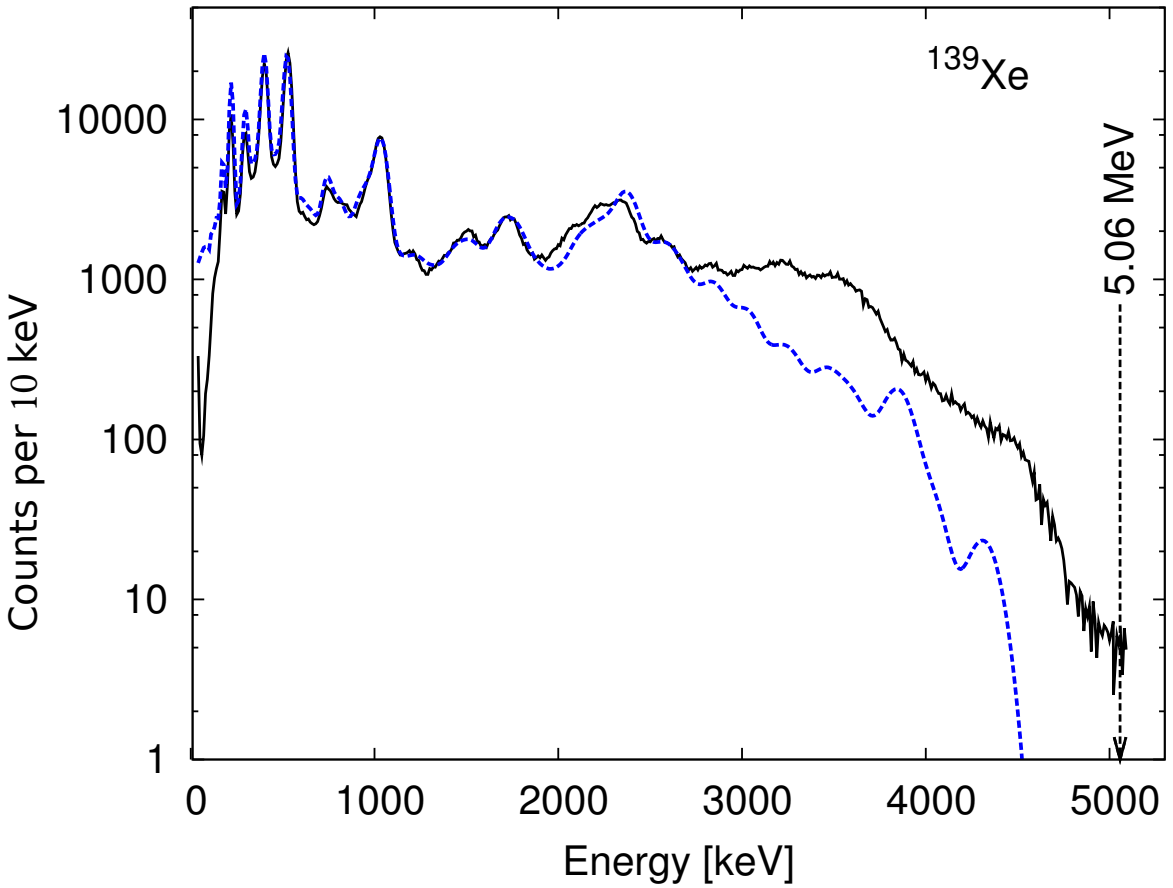
^{86}Br, gamma spectrum





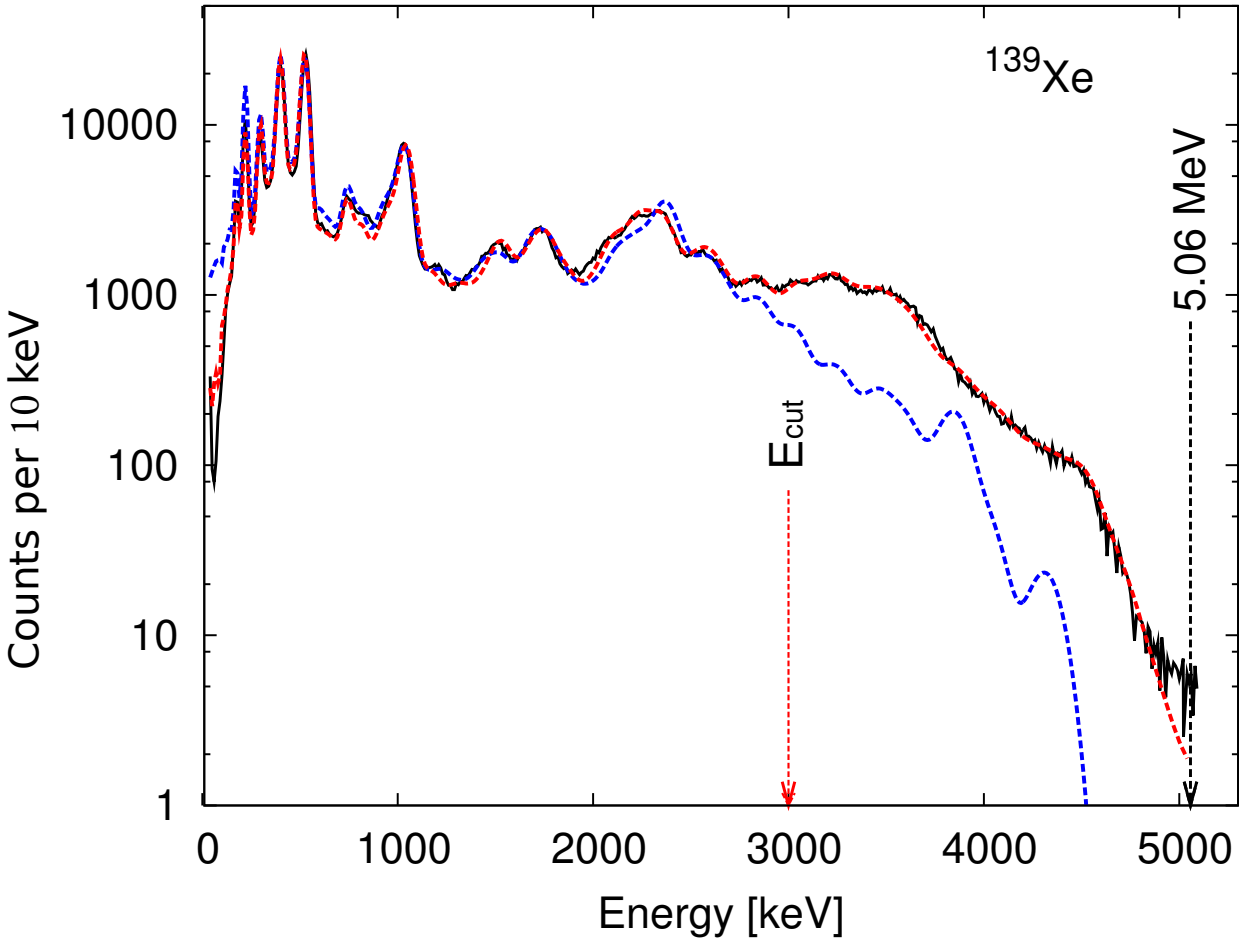
^{139}Xe



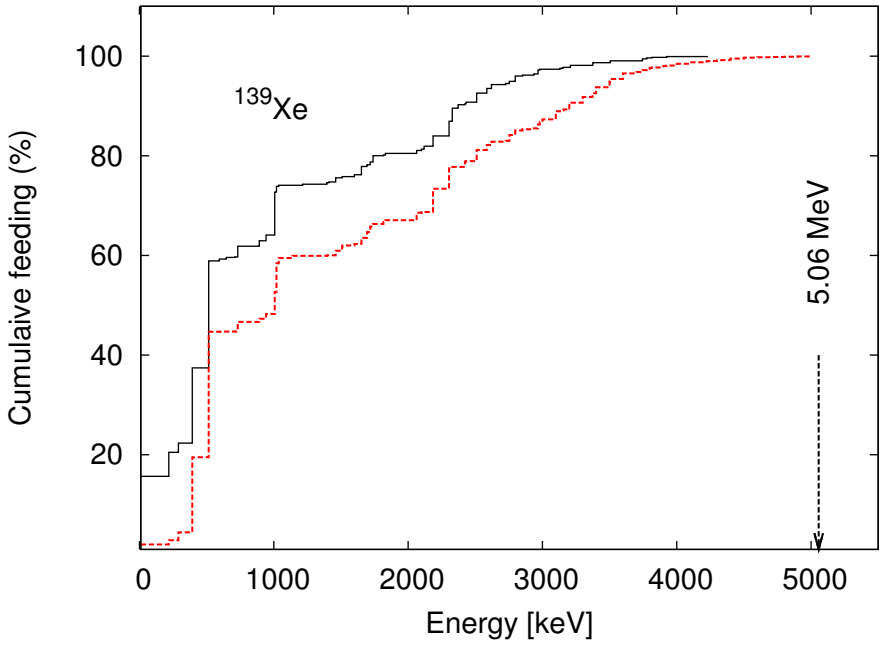


63 levels
263 gamma transitions

^{139}Xe

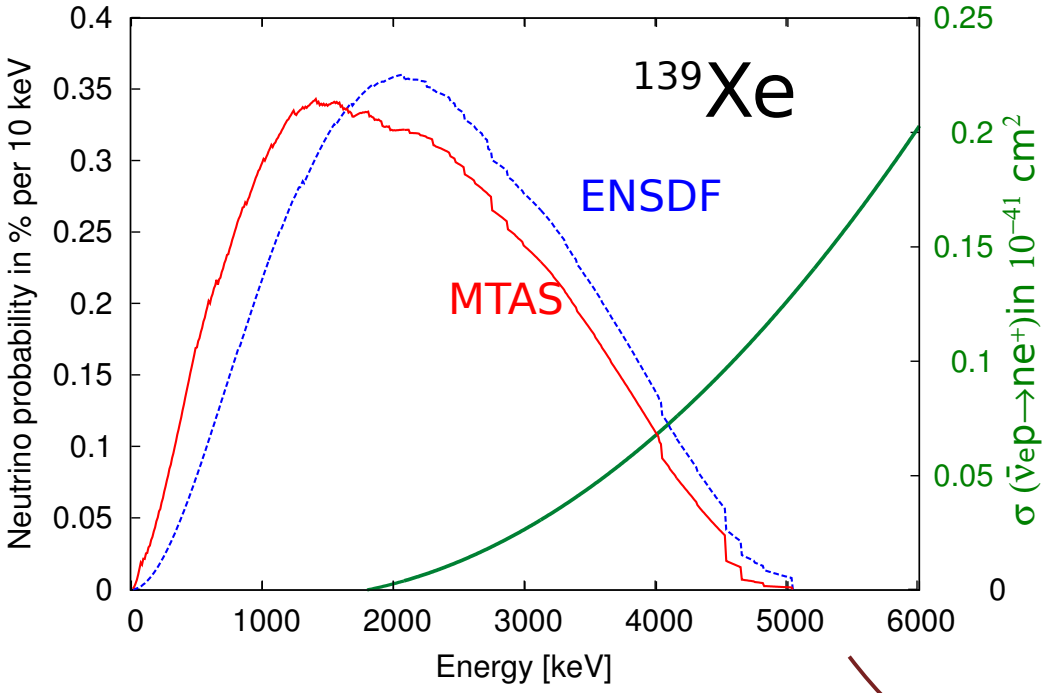


63 levels
263 gamma transitions
average gamma energy increased from 935 keV to 1370 keV (43%)



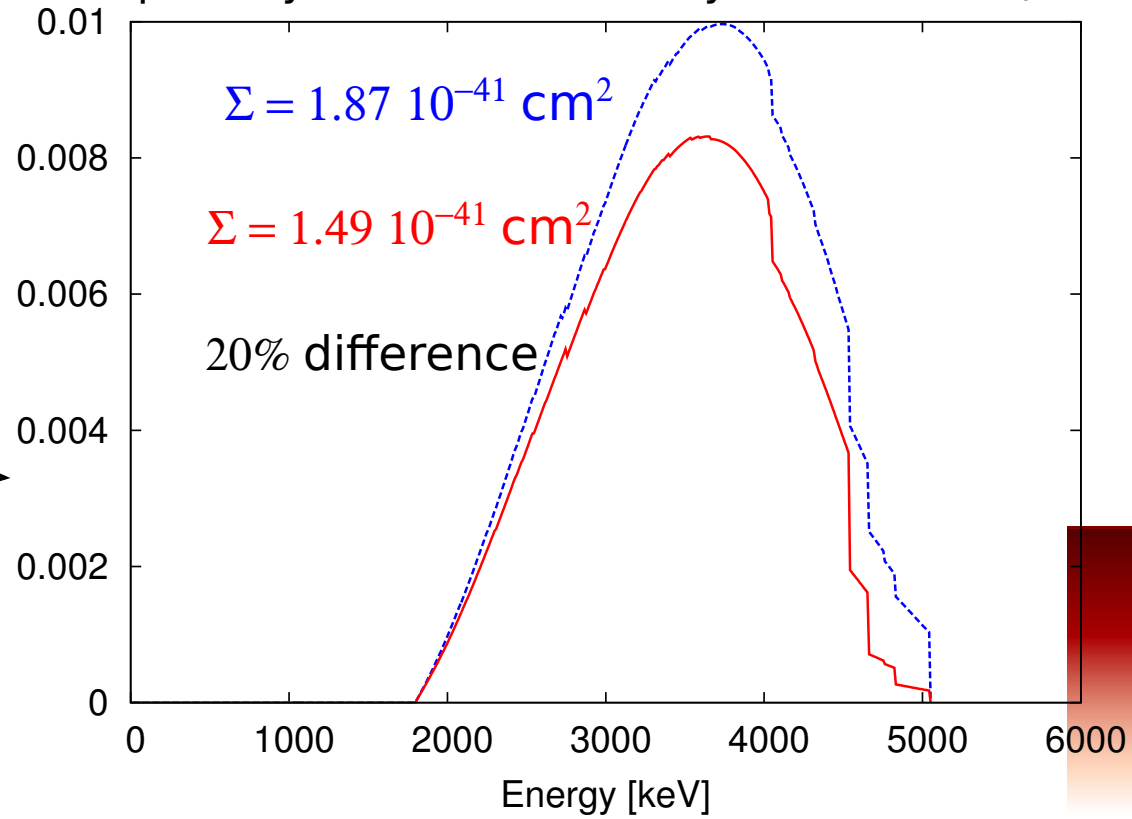
Anti-neutrino spectrum

Deduced anti-neutrino spectrum

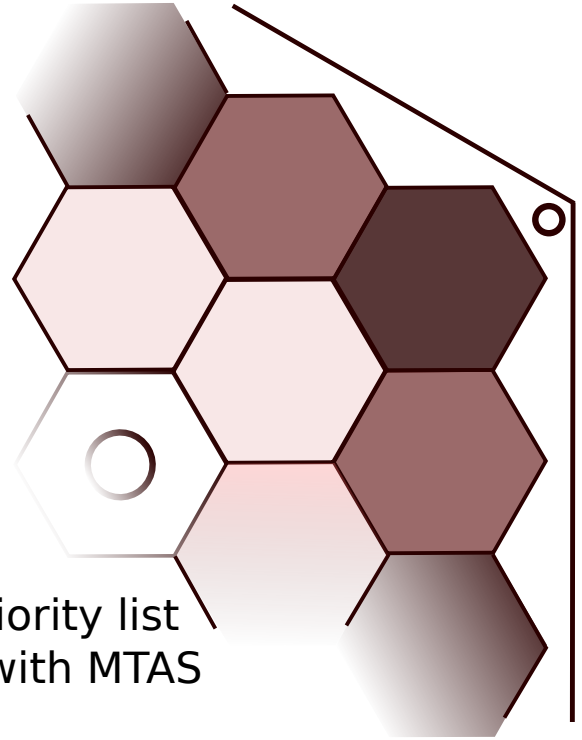


A. Strumia, F. Vissani, PLB 564 (2003)

Number of ^{139}Xe anti-neutrino interactions with protons
(Antineutrino energy distribution
multiplied by inverse beta decay cross section)



Summary



Twenty-two decays of fission product, including seven of the first priority list established by the OECD NEA assessment in 2007 were measured with MTAS

Experimental spectrum shows excess of high-energy gamma-transitions not present in the ENSDF data base

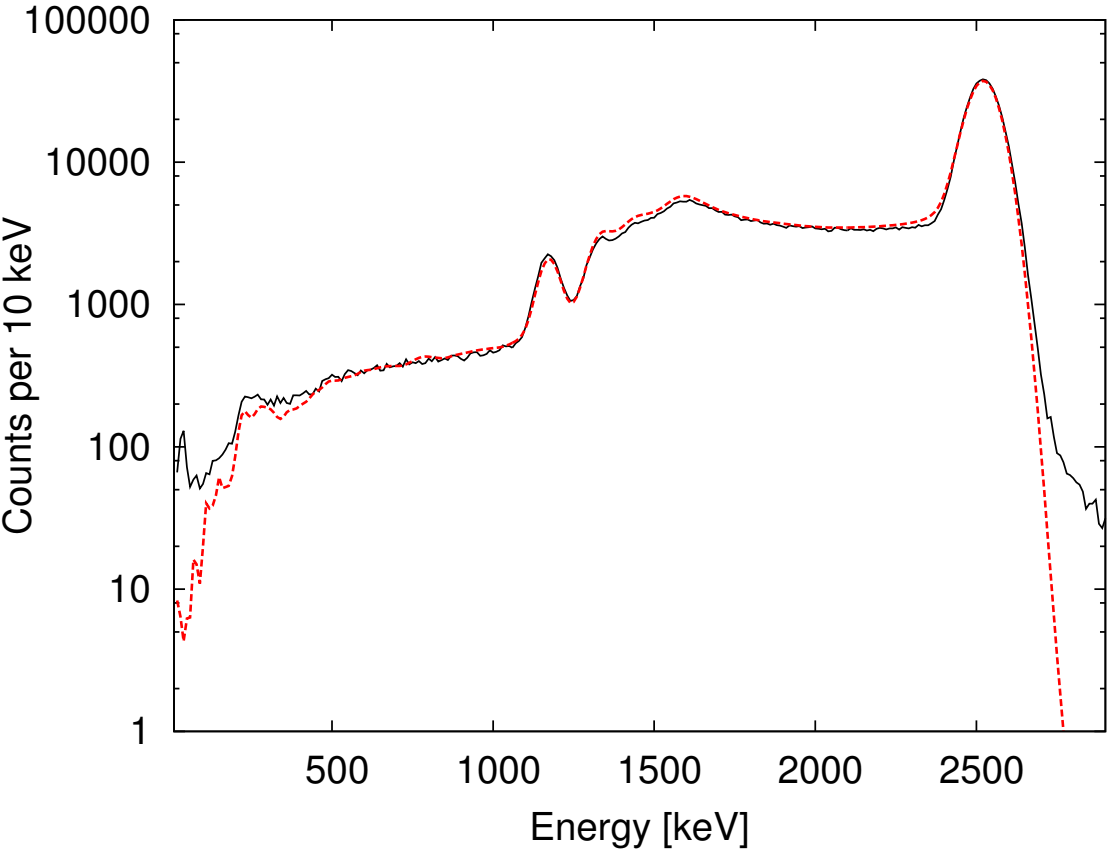
MTAS measurements led to different beta decay patterns, resulting in a decrease of average energy of emitted beta and anti-neutrino particles and in an increase in average gamma energy (increase of "decay heat")

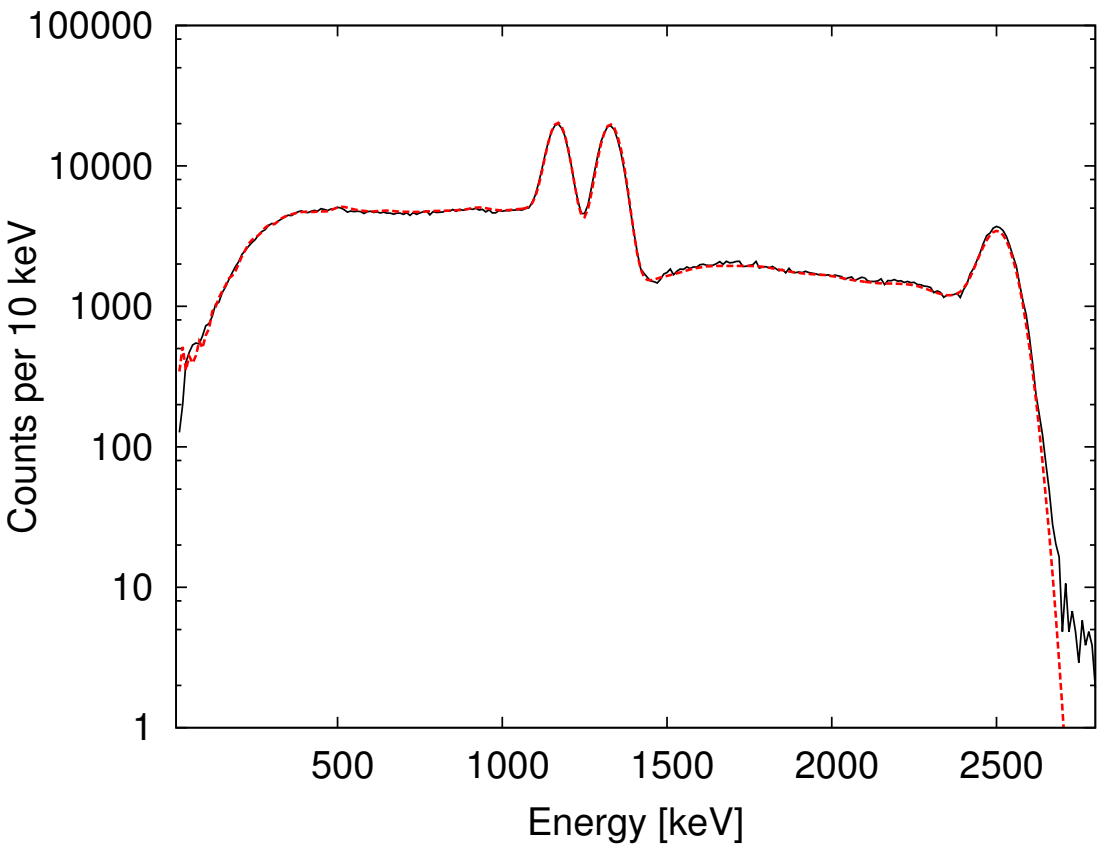
Analysis changed the knowledge about average gamma energy per decay:

^{86}Br	3259 keV	3712 keV	14%
^{139}Xe	935 keV	1370 keV	43%
^{89}Kr	1801 keV	2647 keV	47%

M. Karny First results from the Modular Total Absorption Spectrometer (MTAS) at the HRIBF (ORNL, Oak Ridge), ARIS 2014

^{60}Co


100000
10000
1000
100
10
1
Counts per 10 keV
500
1000
1500
2000
2500
Energy [keV]


100000
10000
1000
100
10
1
Counts per 10 keV
500
1000
1500
2000
2500
Energy [keV]

B. C. Rasco

β-γ and β-n-γ Emission in Mass A=137 Decay Chain Studied with the Modular Total Absorption Spectrometer (MTAS)