Technical Visit on

Coincidence summing and geometry correction in gamma spectrometry
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Coincidence summing correction

Simplified procedures

Alessia Ceccatelli
Terrestrial Environment Laboratory-Chemistry Unit

IAEA
International Atomic Energy Agency

Semi-empirical Method – 1/2

If **1/C$_i$ is the correction factor**. the equations for calculating C$_i$ have been written in matrix form by Semkow et al.(1990). With some modifications (De Felice et al.. 2000), we have:

Summing in Summing out

$$C_i = \left[1 + \frac{\sum_{k,m} P_{t_{km}} P_k P_m \varepsilon_k \varepsilon_m}{I_{\gamma_i} \varepsilon_i}\right]\left[1 - \frac{\sum_j P_{t_{ij}} P_i P_j \varepsilon_{t_j}}{I_{\gamma_i}}\right]$$

Pt$_{km}$. Pt$_{ij}$ = probabilities per decay that the coincidence transitions k and m, or i and j, occur

P$_k$. P$_m$. P$_i$. P$_j$ = probabilities that in each transition the respective photons γ_k, γ_m, γ_i, γ_j will be emitted

ε_k. ε_m.. ε_i = FEP efficiencies for the photons γ_k, γ_m, γ_i

εt_j = total efficiency for a generic photon γ_j

Semi-empirical Method – 2/2

Summing in Summing out

$$C_i = \left[1 + \frac{\sum_{k,m} P_{t_{km}} P_k P_m \varepsilon_k \varepsilon_m}{I_{\gamma_i} \varepsilon_i} \right] \left[1 - \frac{\sum_j P_{t_{ij}} P_i P_j \varepsilon_{t_j}}{I_{\gamma_i}} \right]$$

Pt_{km}
Pt_{ij} → obtained **combining the various transition probabilities** for each nuclear level involved in the coincidence process

$\varepsilon_k . \varepsilon_m . \varepsilon_i . \varepsilon t_j$ → obtained by **fitting experimental data** (spectra analysis)

Simplified procedure - 1/2

Summing in Summing out

$$C_i = \left[1 + \frac{\sum_{k,m} P_{t_{km}} P_k P_m \varepsilon_k \varepsilon_m}{I_{\gamma_i} \varepsilon_i} \right] \left[1 - \frac{\sum_j P_{t_{ij}} P_i P_j \varepsilon_{t_j}}{I_{\gamma_i}} \right]$$

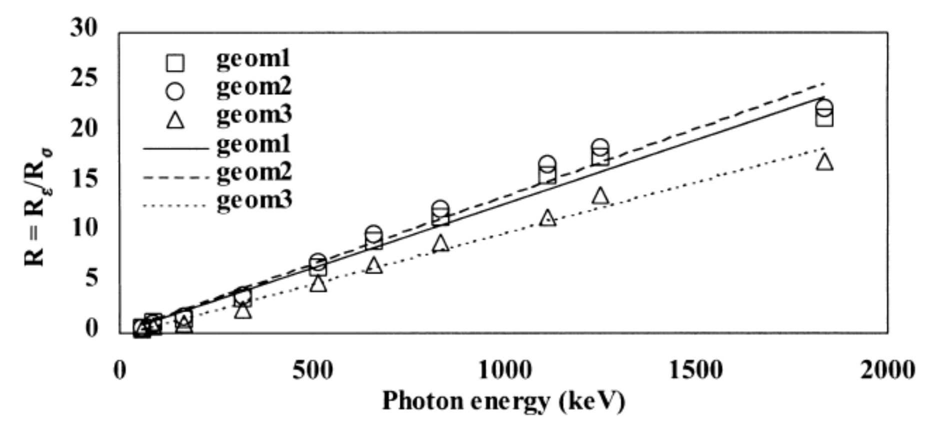
Pt_{km} Pt_{ij} → obtained **combining the various transition probabilities** for each nuclear level involved in the coincidence process

$\varepsilon_k \cdot \varepsilon_m \cdot \varepsilon_i$ → obtained by **fitting the experimental data** (spectra analysis)

εt_j → obtained, for each energy value, using **just one experimental point** (single source of a monoenergetic radionuclide)

Simplified procedure - 2/2

$$\varepsilon_{t_j} = \frac{\varepsilon_j}{K R_\sigma E_\gamma}$$



De Felice et al. Applied Radiation and Isotopes 52 (2000)

$$K = R / E_\gamma$$

A simple proportionality was observed between R and Eγ

$$R = R_\varepsilon / R_\sigma$$

Rε = peak-to-total efficiency ratio

Rσ = photoelectric-to-total cross section (in germanium) ratio

In each measurement geometry **the slope K can be calculated only for one radionuclide (i.e. ^{137}Cs at 662 keV)**

General criteria applied

Coincidences considered:

- γ - γ
- γ - Xk_{α} (internal conversion)
- γ - Xk_{α} (electron capture decay – Sm branch)

Coincidences neglected:

- triple coincidences
- X - X
- X – γ
- γ – annihilation photon at 511 keV

Selection criteria applied

Some photon selection criteria were applied at ^{152}Eu

⇨ simplified decay scheme

If γ_i are the photons to which correction must be applied and γ_j are the photons which contribute to that correction:

- **Summing-out effect**: for each γ_i photon with an emission probability $I\gamma_i$. only coincidences with γ_j having an emission probability $I\gamma_j \geq 10\ \%\ I\gamma_i$ were considered.
- **Summing-in effect**: only couples γ_k. γ_m where at least one of the two photons has $I\gamma \geq 10\ \%\ I\gamma_i$ were considered.

Symbols used in the calculation sheet

Semkow formula: $C_i = (1 + \Sigma_{k,m} C_{k,m} \varepsilon_k \varepsilon_m / \varepsilon_i) \; (1 - \Sigma_j C_{i,j} \varepsilon_{tj})$

$$\boxed{C_i = (1 + F_i) \; (1 - G_i)}$$

Where:

$F_i = \Sigma(i^* \; F_{i^*})$ (i^* is the specific summing-in contribution to the photon i)

$F_{i^*} = \Sigma_{k,m} C_{k,m} \varepsilon_k \varepsilon_m / \varepsilon_{i^*}$

$C_{k,m} = P_{tk,m} \; P_k P_m / I_{\gamma i^*}$

$G_i = \Sigma_j C_{i,j} \varepsilon_{tj}$

$C_{i,j} = P_{ti,j} \; P_i P_j / I_{\gamma i^*}$

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Results at different source-to-detector distances-1/2

	Cs-134		
E (keV)	1/Ci_10 cm	1/Ci_5 cm	1/Ci_2 cm
242.8	1.0244	1.0656	1.1943
326.5	1.0241	1.1398	1.4770
475.3	1.0223	1.0607	1.1761
563.2	1.0244	1.0659	1.1948
569.3	1.0244	1.0654	1.1938
604.7	1.0148	1.0388	1.1104
795.8	1.0145	1.0390	1.1086
801.9	1.0222	1.0605	1.1754
1038.6	1.0057	1.0130	1.0395
1167.9	0.9910	0.9708	0.9389
1365.2	0.9826	0.9515	0.8921

Results at different source-to-detector distances-2/2

	Eu-152		
E (keV)	1/Ci_10 cm	1/Ci_5 cm	1/Ci_2 cm
121.8	1.0230	1.0722	1.2141
244.7	1.0285	1.0910	1.2779
344.3	1.0089	1.0231	1.0638
411.1	1.0196	1.0549	1.1532
444.0	1.0273	1.0865	1.2589
564.0	1.0546	1.1844	1.6433
688.7	1.0207	1.0659	1.2000
778.9	1.0117	1.0324	1.0868
867.4	1.0331	1.1066	1.3346
964.1	1.0221	1.0698	1.2099
1085.8	1.0020	1.0061	1.0152
1089.7	1.0101	1.0277	1.0745
1112.1	1.0136	1.0428	1.1255
1212.9	1.0256	1.0813	1.2412
1299.1	1.0117	1.0326	1.0873
1408.0	1.0166	1.0519	1.1523

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References

[1] M. Korun and R. Martini *Coincidence summing in gamma and X-ray spectrometry* Nucl. Instrum. and Methods in Phys. Res. A 325 (1993) 478-484

[2] T.M. Semkow. G. Mehmood. P. Parekh. M. Virgil *Coincidence summing in gamma-ray spectroscopy* Nucl. Instrum. and Methods in Phys. Res. A 290 (1990) 437-444

[3] R.G. Helmer. R.J. Gehrke *Calculation of coincidence summing corrections for a specific small soil sample geometry* Proceedings of the symposium on advances in alpha-. beta- and Gamma-Spectrometry. St Petersburg. Russia. Sept. 1996

[4] Pierino De Felice. Paola Angelini. Aldo Fazio and Roberto Biagini *Fast procedures for coincidence-summing correction in γ-ray spectrometry* Applied Radiation and Isotopes 52 (2000) 745-752

[5] Pierino De Felice. Paola Angelini. Aldo Fazio and Marco Capogni *A national campaign for coincidence-summing correction in γ-ray spectrometry* Applied Radiation and Isotopes 56 (2002) 117-123

Thank you

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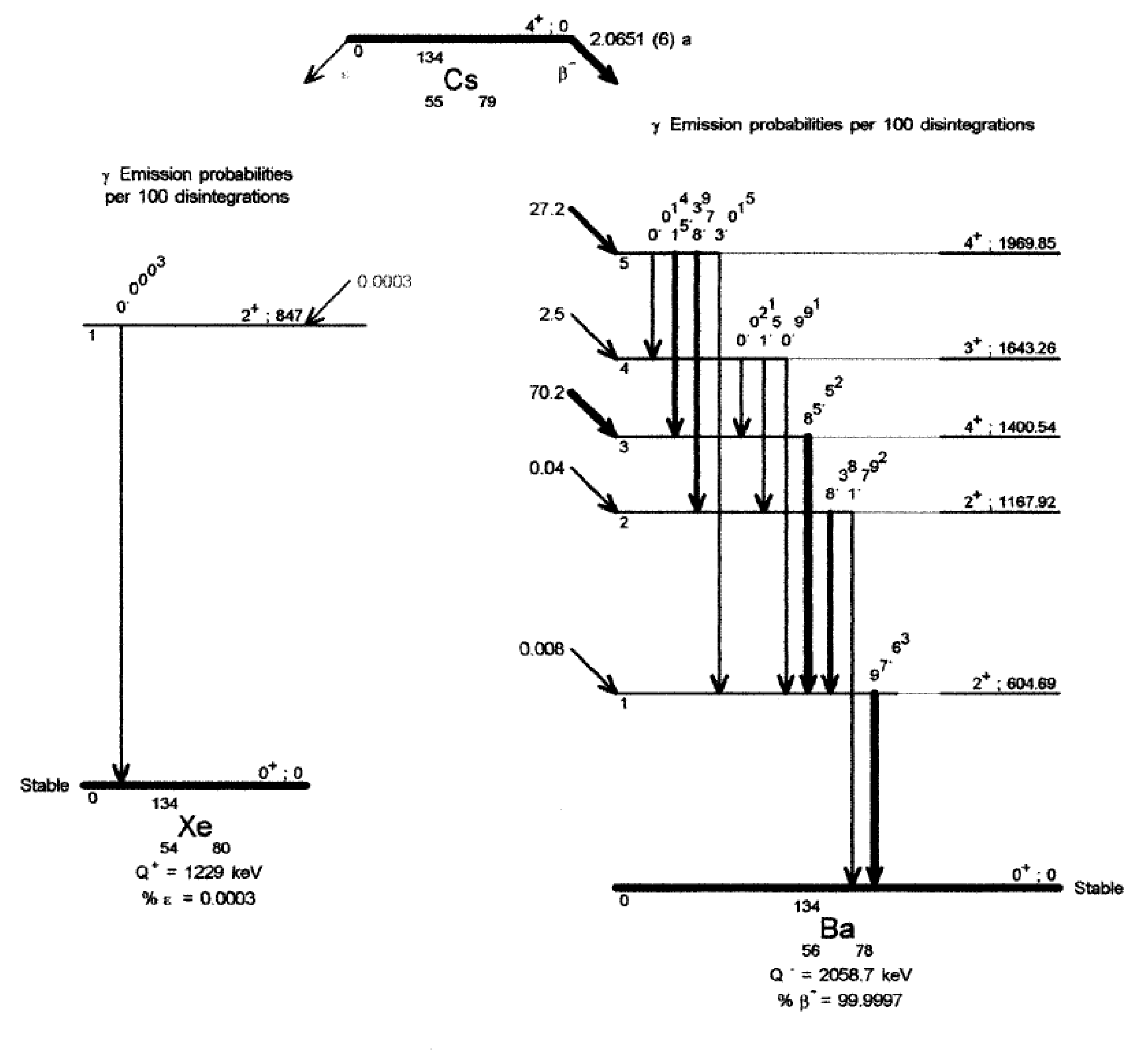
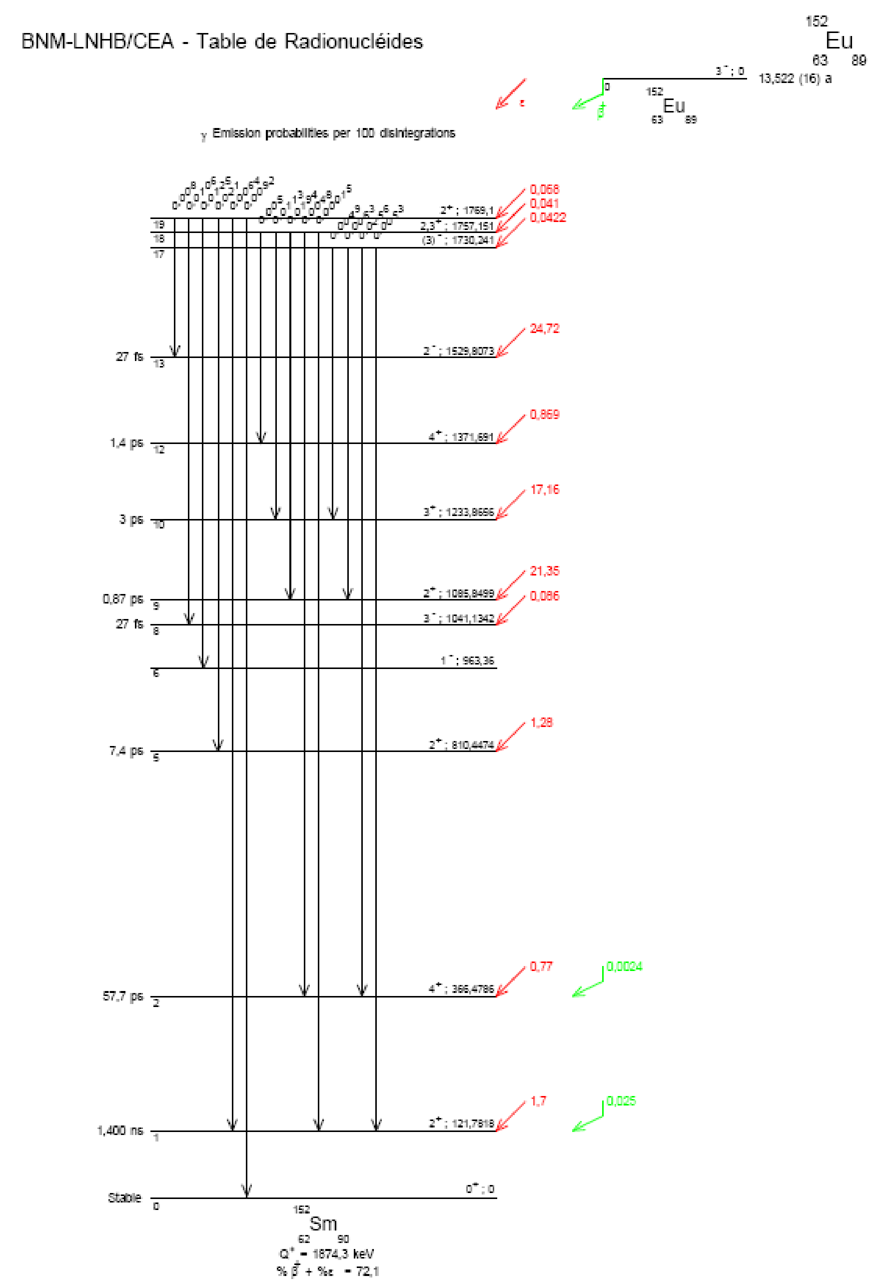
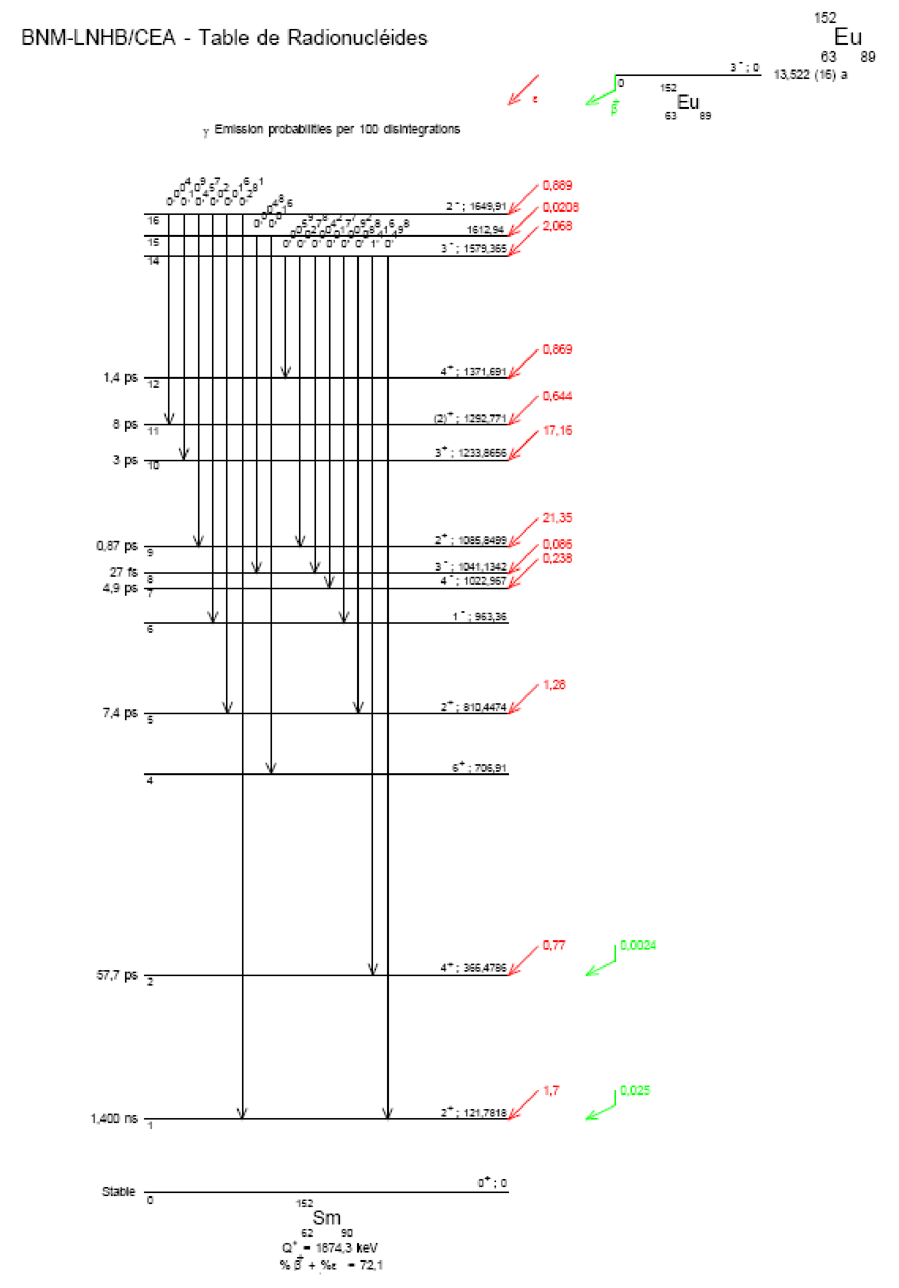
Cs 134 decay scheme

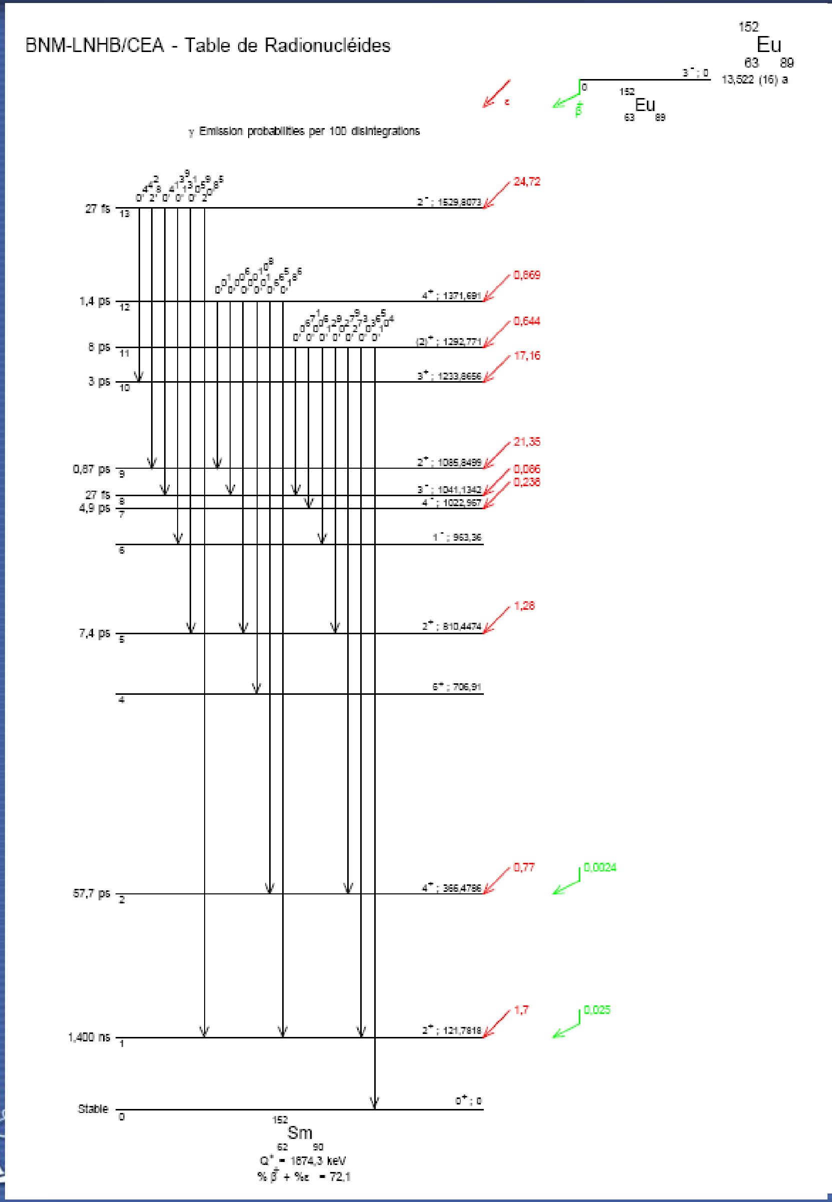


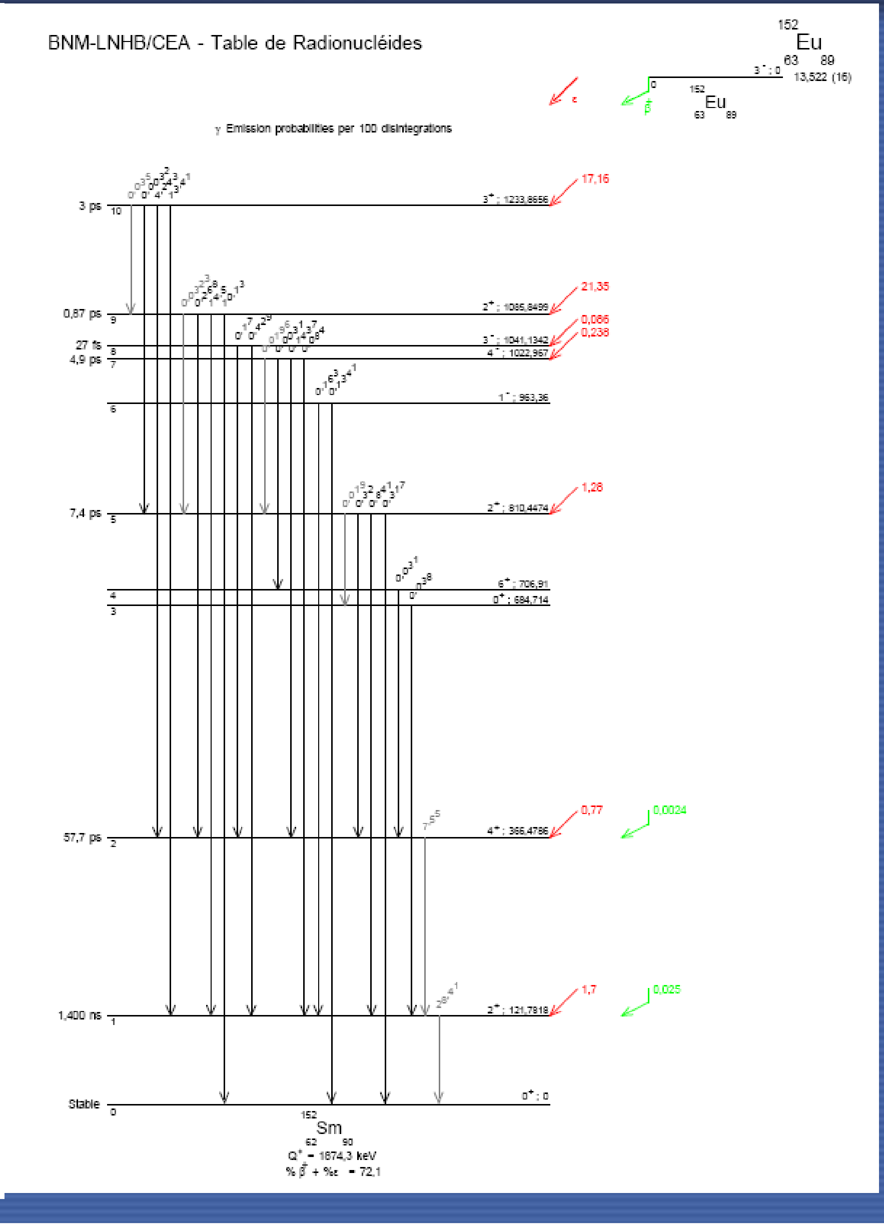
Eu 152 (Sm) decay scheme – 1/2





Eu 152 (Sm) decay scheme – 2/2





Eu 152 (Gd) decay scheme