Argonne NATIONAL LABORATORY

Member of the US Nuclear Data Program

Inclusion of Absolute γ−ray Emission Probabilities in ENSDF Decay Data

Proposal from
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- Part I: Why do we need it
- Part II: How it should be implemented

ENSDF decay data - core datasets

ENSDF

Applications

Basic NP Research

ENDF, JEFF, JENDL …

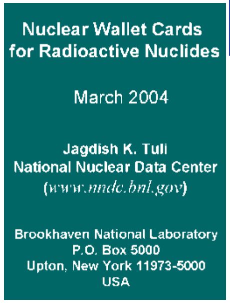
ORTEC & CANBERRA

MIRD

RIPL

PGAA

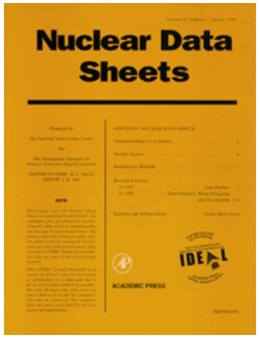
RNAL

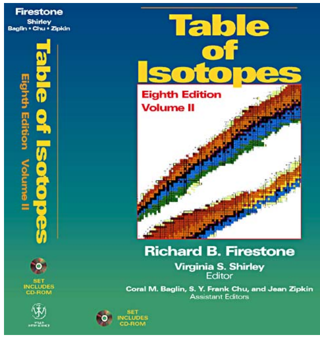


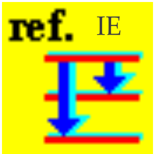
Simulations

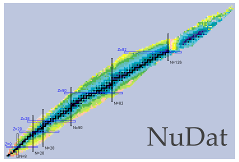
Monte-Carlo Codes
MCNP, GEANT, EGS4

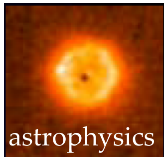
ORIGEN, CINDER90











NUBASE

RADWARE

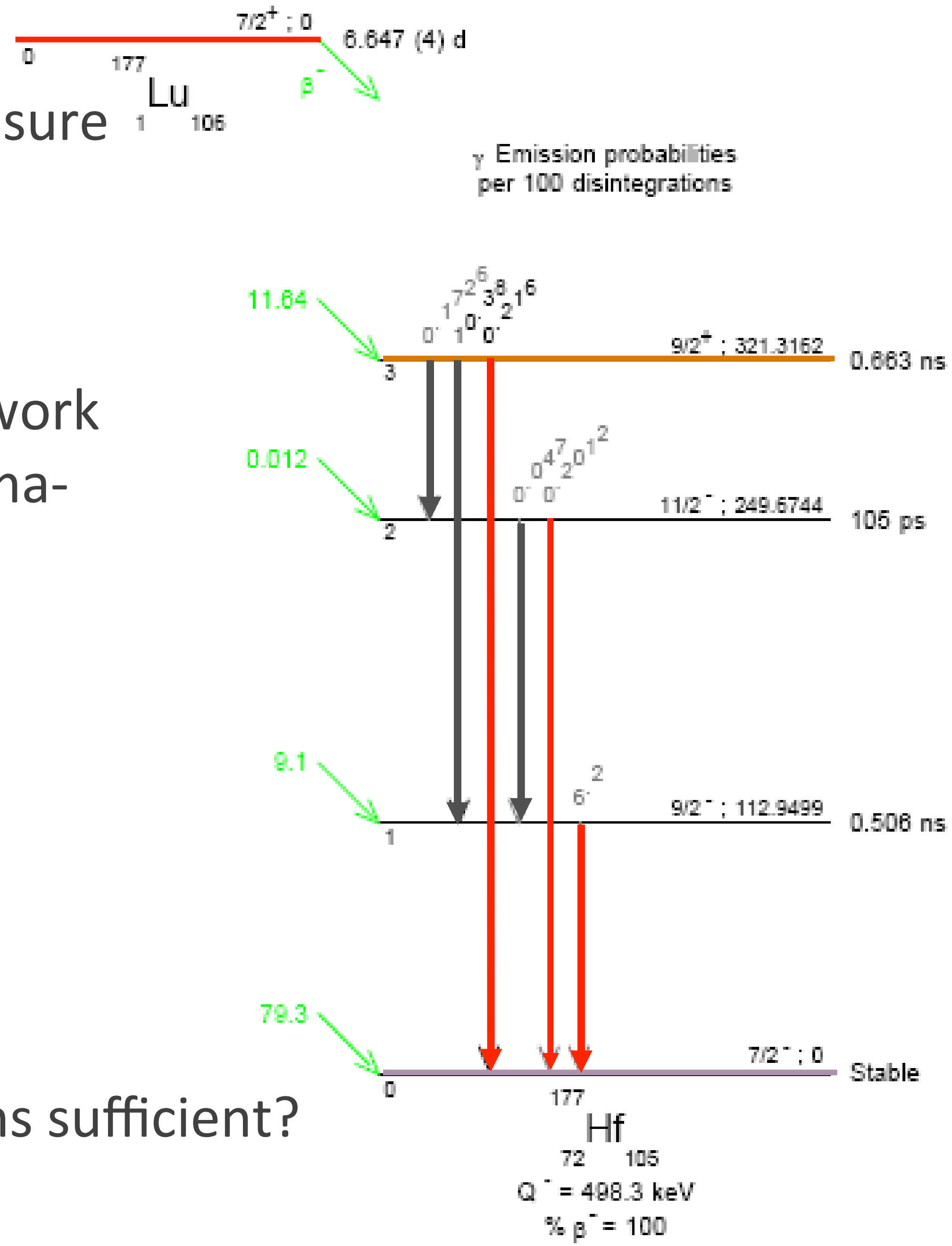
- for any applications one needs absolute emission (γ, β, α, CE, etc.) probabilities, e.g. **% per decay of the parent**
  - ✓ %α decay involves discrete radiations – no problem
  - ✓ %γ and %β are mostly determined from the decay scheme, while CE, X-ray, Auger are deduced from %Iγ and ICC

- ✓ what actually the authors measure and report are relative γ-ray emission probabilities

- ✓ crucial part of the evaluation work is to convert the relative gamma-ray emission probabilities to absolute ones

$$NR = \frac{(100 - I_{\beta 0})}{\sum I_{\gamma i} \times (1 + \alpha_{Ti})}$$

$$\%I_{\gamma i} = NR \times I_{\gamma i}$$



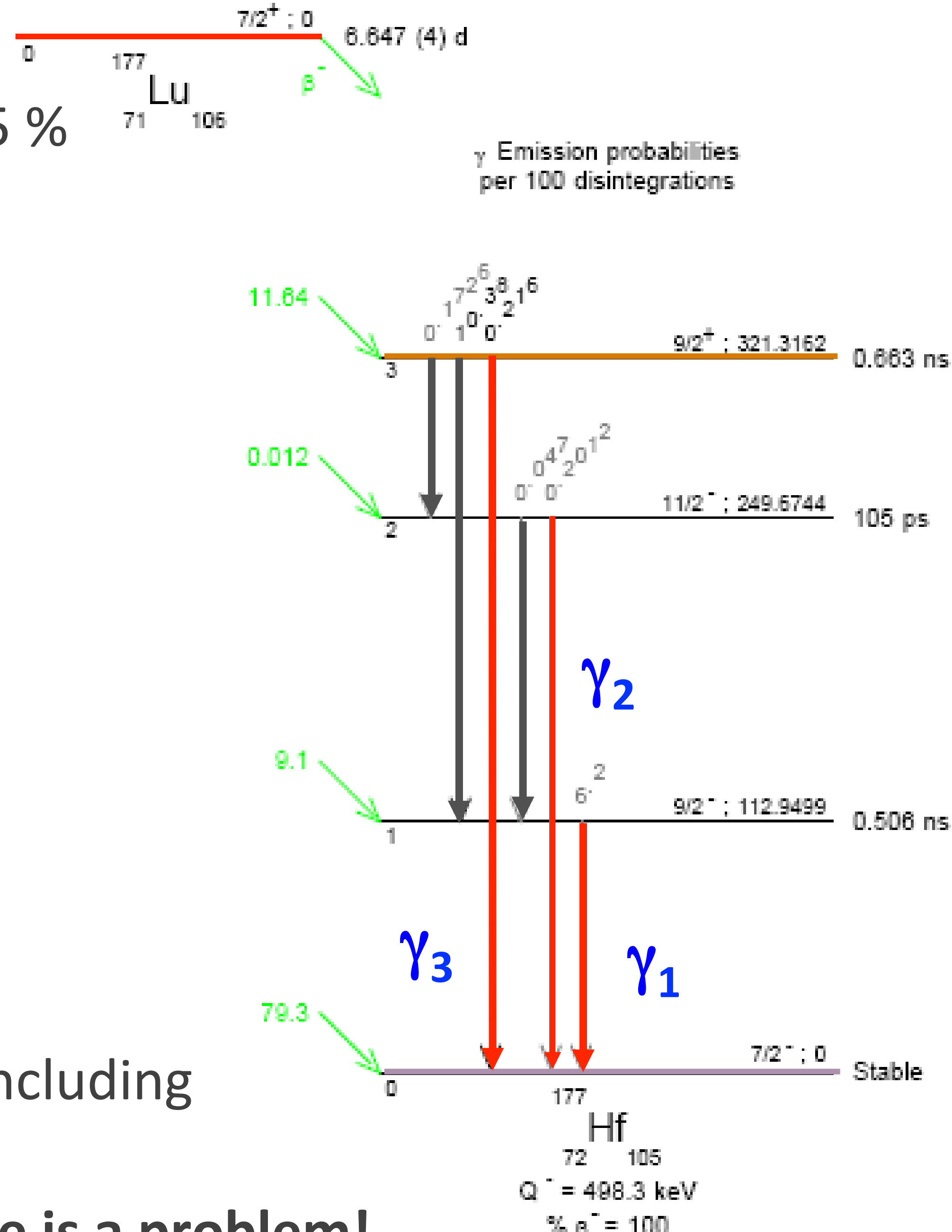
providing NR and relative Iγ seems sufficient?

If $I\gamma_1$=100 +/- 10

$I\gamma_2$= 60 +/- 6

$I\gamma_3$= 50 +/- 5

$I_{\beta 0}$=79.4 +/- 0.5 %



$$NR = \frac{(100 - I_{\beta 0})}{\sum I_{\gamma i} \times (1 + \alpha_{Ti})}$$

NR = 0.098 +/- 0.006

$\%I\gamma_i$ = NR x $I\gamma_i$

$\Delta^2(\%I\gamma_i) = \Delta^2(NR) + \Delta^2(I\gamma_i)$

$\%I\gamma_1$= 9.8 +/- 1.2 – unc. 12.2 %

$\%I\gamma_2$= 5.9 +/- 0.7

$\%I\gamma_3$= 4.9 +/- 0.6

....

this is what every user is doing, including NuDat & LiveChart

BUT – there is a problem!

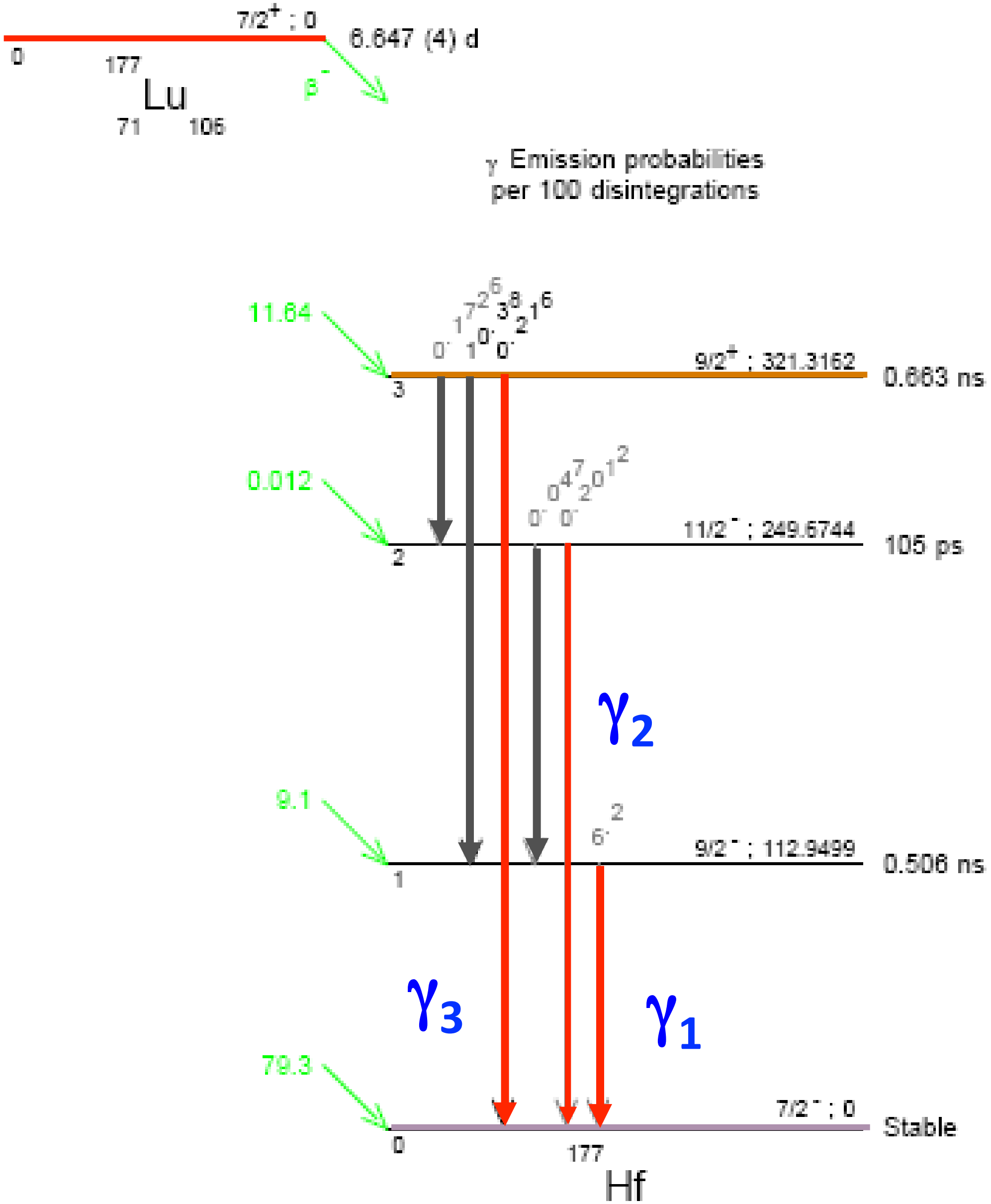
$$\%I_{\gamma j} = \frac{(100 - I_{\beta 0})}{\sum I_{\gamma i} \times (1 + \alpha_{Ti})} \times I_{\gamma j}$$

- ✓ E. Browne, NIM A249 (1986)
- ✓ uncertainties package (python) www.pythonhosted.org/uncertainties/

%Iγ_1= 9.8 +/- 0.7 – unc. **7.1 %**
%Iγ_2= 5.9 +/- 0.5
%Iγ_3= 4.9 +/- 0.5

compared to: $\%I_{\gamma j} = NR \times I_{\gamma j}$

%Iγ_1= 9.8 +/- 1.2 – unc. **12.2 %**
%Iγ_2= 5.9 +/- 0.7
%Iγ_3= 4.9 +/- 0.6



may end up with a huge difference in cases where precision matters!

Consequences

- ✓ using NR and relative $I\gamma_{i,}$ the end-users may end up with incorrect uncertainties for the absolute γ-ray emission probabilities for gamma rays that were used in the normalization procedure

- ✓ in many cases the uncertainties for absolute γ-ray emission probabilities that you can find in NuDat and/or LiveChart are incorrect (same is true for DDEP)

Solution

%Iγ must be provided by the evaluators in the ensdf decay data sets, by correctly taking into account uncertainty propagations – we have the tool to do that – the (modified) **GABS** analysis program

we propose that from October 1, 2015 the inclusion of absolute gamma-ray emission probabilities (%Iγ) in ensdf decay data sets to become mandatory

Implementation

Present status

209PB N 1.0 Un 1.0 Un a.a Un a.a Un a.a Un

NR NT BR NB NP

209PB G 1567.08 2 99.52 5 E2 0.00294 99.42 5

%Iγ %TI

- If NR=1 and NT=1 then %Iγ and %TI are given in the decay data set
- current version of GABS (TXK) works with Iγ, deduces NR and calculates %Iγ in a comment record
  - ✓ not transparent to the end user – hidden somewhere in the details

Implementation

after running GABS

Eγ[#]	E(level)	Iγ[@]	Mult.[&]	α	Comments
117.21 *5*	2149.42	76 *3*	E1	0.295	%Iγ=76 *3*, using the calculated normalization. α(K)=0.235 *4*; α(L)=0.0455 *7*; α(M)=0.01073 *15*. α(N)=0.00268 *4*; α(O)=0.000507 *8*; α(P)=4.03×10^{-5} *6*. Eγ: weighted average of 117.211 *21* (1977Vy02), 117.25 *5* (1981Di14), 117.21 *1* (1989Ko26), 117.24 *5* (1998Ar03) and 117.18 *10* (2000Gr35). Iγ: weighted average of 73 *4* (1998Ar03) and 78 *4* (2000Gr35) Others: 90.3 *22* (1977Vy02), 85 *3* (1981Di14) and 85 *4* (1989Ko26),. Mult.: α(K)exp=0.25 *2* (2000Gr35).
284.04‡ *23*	2315.90	0.14‡ *7*	[E1]	0.0335	%Iγ=0.14 *7*, using the calculated normalization. α(K)=0.0275 *4*; α(L)=0.00467 *7*; α(M)=0.001091 *16*. α(N)=0.000275 *4*; α(O)=5.33×10^{-5} *8*; α(P)=4.91×10^{-6} *7*.
311.5‡ *3*	2460.9	0.028‡ *14*	[E2]	0.1034	%Iγ=0.028 *14*, using the calculated normalization. α(K)=0.0596 *9*; α(L)=0.0329 *5*; α(M)=0.00842 *13*. α(N)=0.00213 *3*; α(O)=0.000392 *6*; α(P)=2.44×10^{-5} *4*.
375.5‡ *2*	2524.92	0.070‡ *15*			%Iγ=0.070 *15*, using the calculated normalization. α(K)=0.190 *3*; α(L)=0.0322 *5*; α(M)=0.00754 *11*; α(N+..)=0.00234 *4*. α(N)=0.00192 *3*; α(O)=0.000382 *6*; α(P)=4.09×10^{-5} *6*.
465.14 *1*	2032.21	95.7 *10*	E2	0.0350	%Iγ=95.4 *10*, using the calculated normalization.

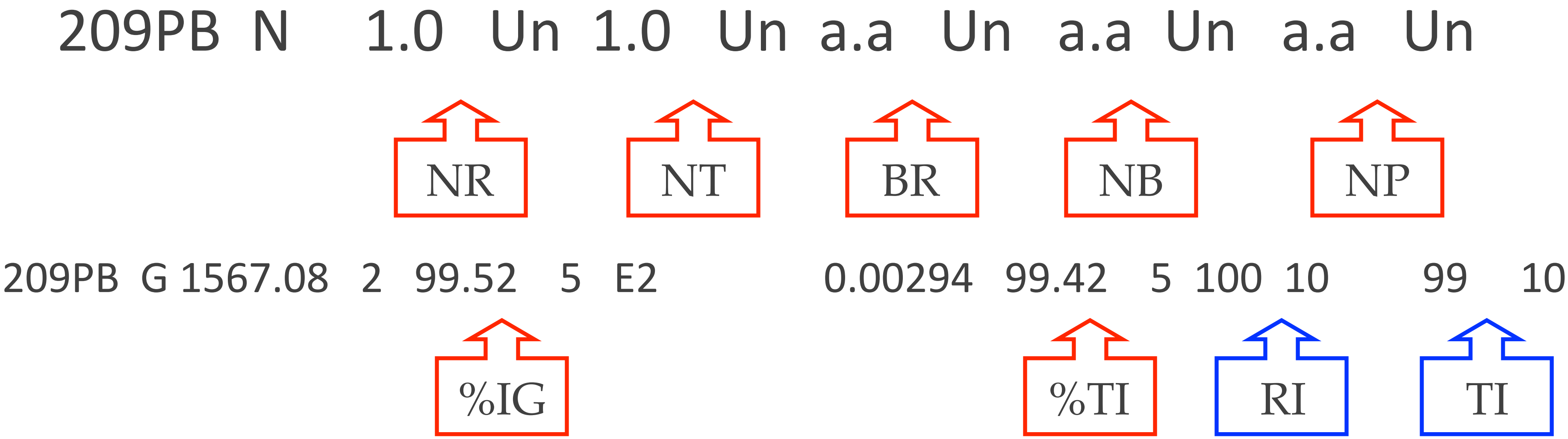
Implementation – cont.

PRO: would require not many changes to be made

- ✓ new GABS program and documentation is available – T. Kibedi (ANU) - needs to be benchmarked and rigorously tested
- ✓ need to have changes to the current policies and those need to be enforced

CONS: the NDS output is not transparent – %IG will be on a continuation record and there may be difficulties in extracting those data for future processing

beyond the 80 column …



- ✓ always give %IG and %TI in columns 22-29 and 65-74 which requires NR=1 and NT=1
- ✓ store RI at columns 82-89 (Unc. 90-91) and TI at columns 92-99 (Unc. 100-101) – extend the 80 column ensdf format to a 132 column one
- ✓ will need to modify a number of programs – do we have capabilities to do that?