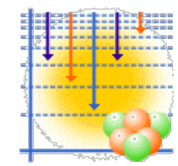
Inclusion of Absolute γ–ray Emission Probabilities in ENSDF Decay Data



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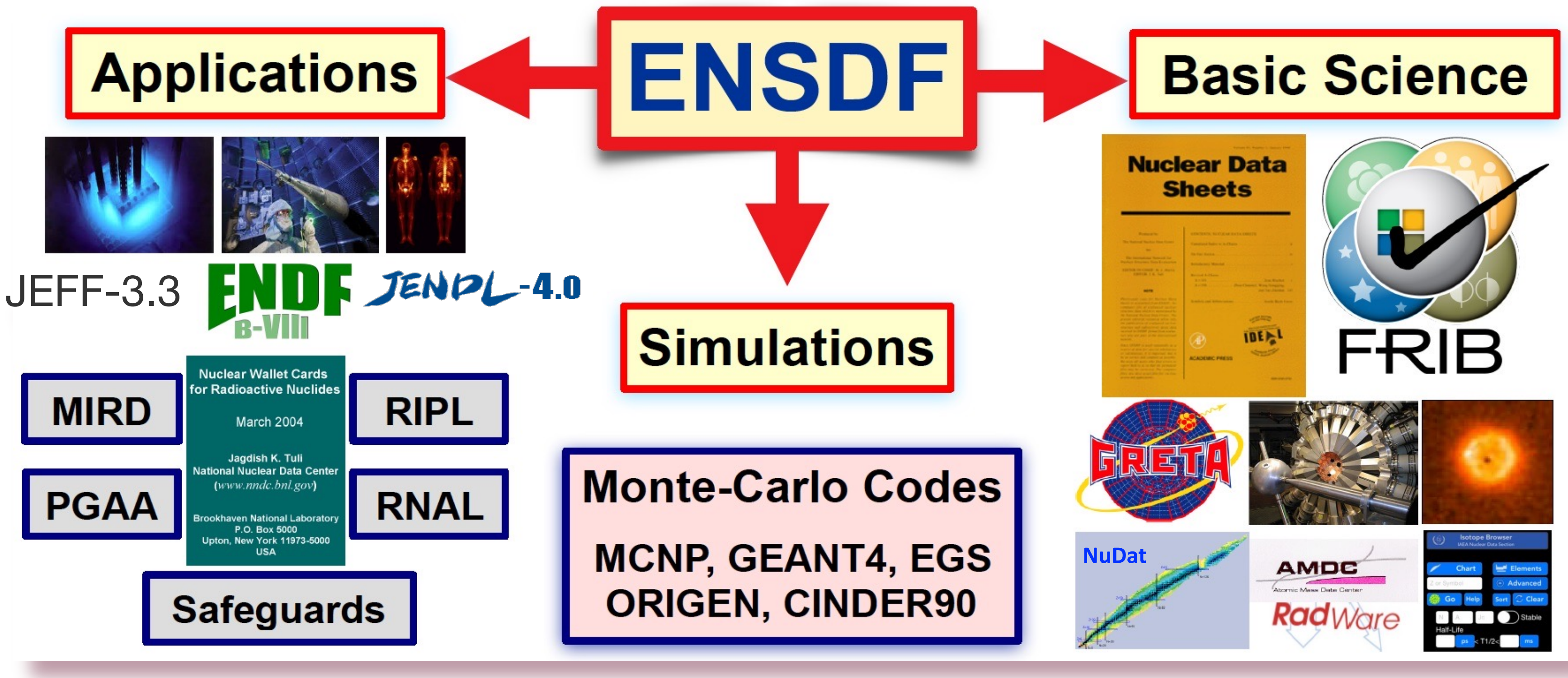
- a proposal [F.G. Kondev (ANL), T. Kibedi (ANU) & E. Browne (LBNL)] was made at the 21th Meeting of the NSDD Network, Vienna, Austria 2015, but was not adopted - it was recommended that the necessary computational infrastructure is developed and tested prior the adoption

- a lot of progress was made since 2015 with the modernization and improvement of existing ENSDF codes [IAEA ENSDF-codes development project and effort from T. Kibedi (ANU) and J. Chen (MSU)] - we (Tibor, Jun and I) would like to bring the proposal to the next NSDD meeting for discussion and its adoption as a policy

ENSDF decay data



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

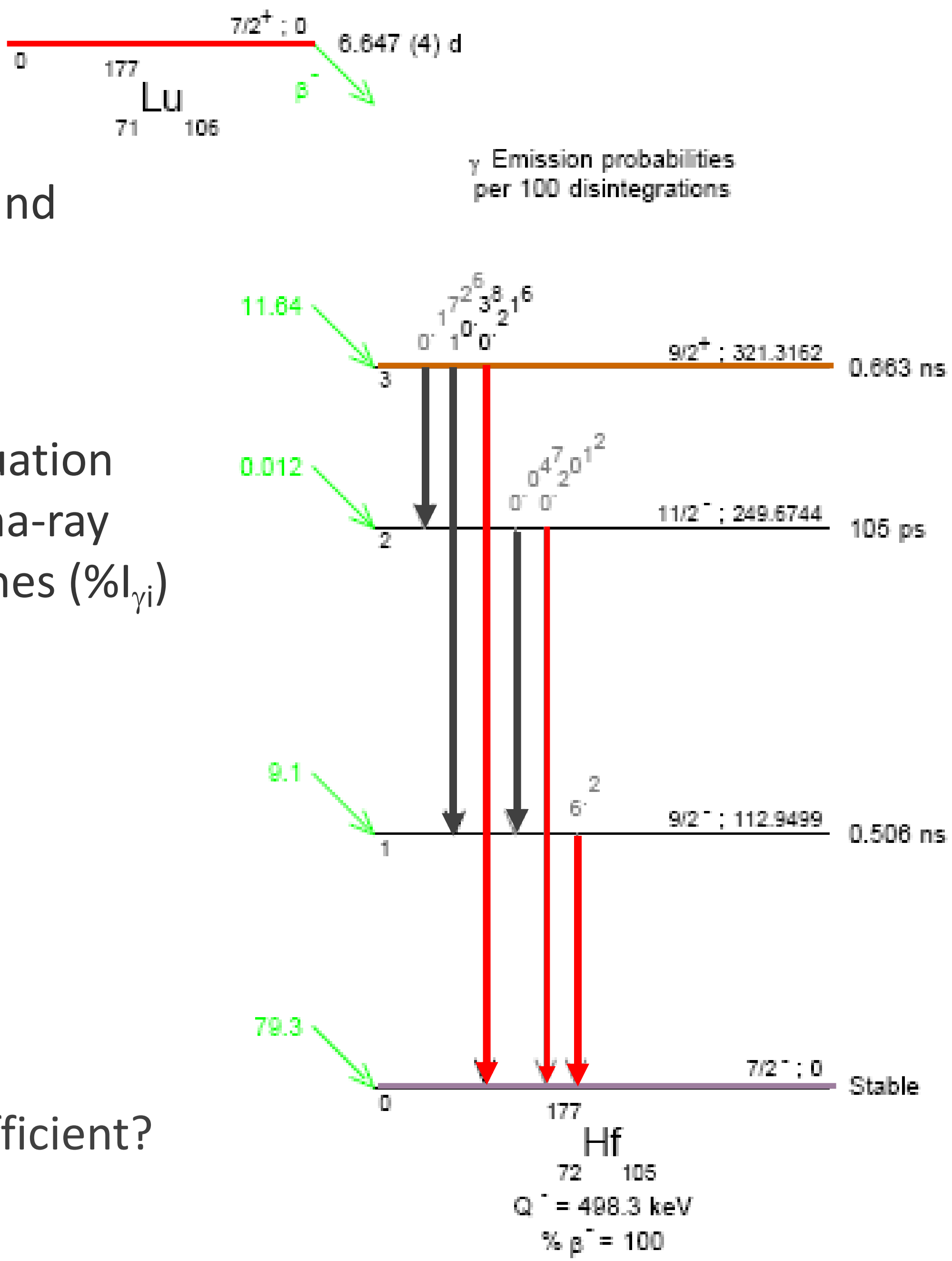
- ✓ what actually the authors measure and publish are relative γ-ray emission probabilities ($I_{\gamma i}$)
- ✓ crucial part of the nuclear data evaluation work is to convert the relative gamma-ray emission probabilities to absolute ones ($\%I_{\gamma i}$)

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

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

in ENSDF

providing NR and relative Iγ seems sufficient?



$I\gamma_1 = 100 \pm 10$

$I\gamma_2 = 60 \pm 6$ $\quad$ $I_{\beta 0} = 79.4 \pm 0.5\ \%$

$I\gamma_3 = 50 \pm 5$

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

$\Delta^2(NR) = \Delta^2(I_{\beta 0}) + SUM[\Delta^2(I\gamma_i)]$

$NR = 0.098 \pm 0.006$

$\%I\gamma_i = NR \times I\gamma_i$

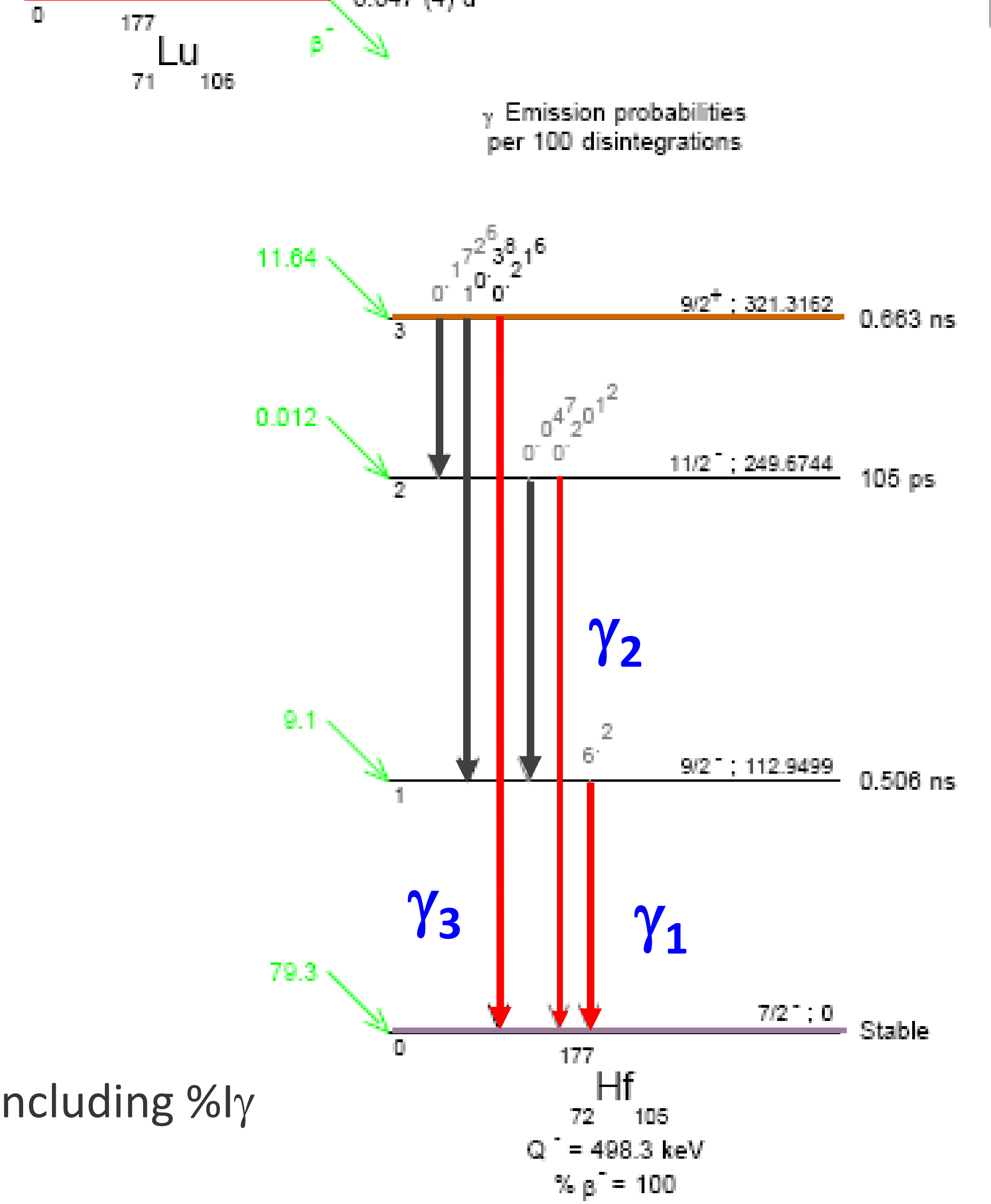
$\Delta^2(\%I\gamma_i) = \Delta^2(NR) + \Delta^2(I\gamma_i)$

$\%I\gamma_1 = 9.8 \pm 1.1$ – unc. 11.2 %

$\%I\gamma_2 = 5.9 \pm 0.7$

$\%I\gamma_3 = 4.9 \pm 0.6$

....



this is what every ENSDF user is doing, including %Iγ quoted in LiveChart & NUDAT

... 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/

$\%I\gamma_1$= 9.8 +/- 0.7 – relative unc. **7.1 %**

$\%I\gamma_2$= 5.9 +/- 0.5

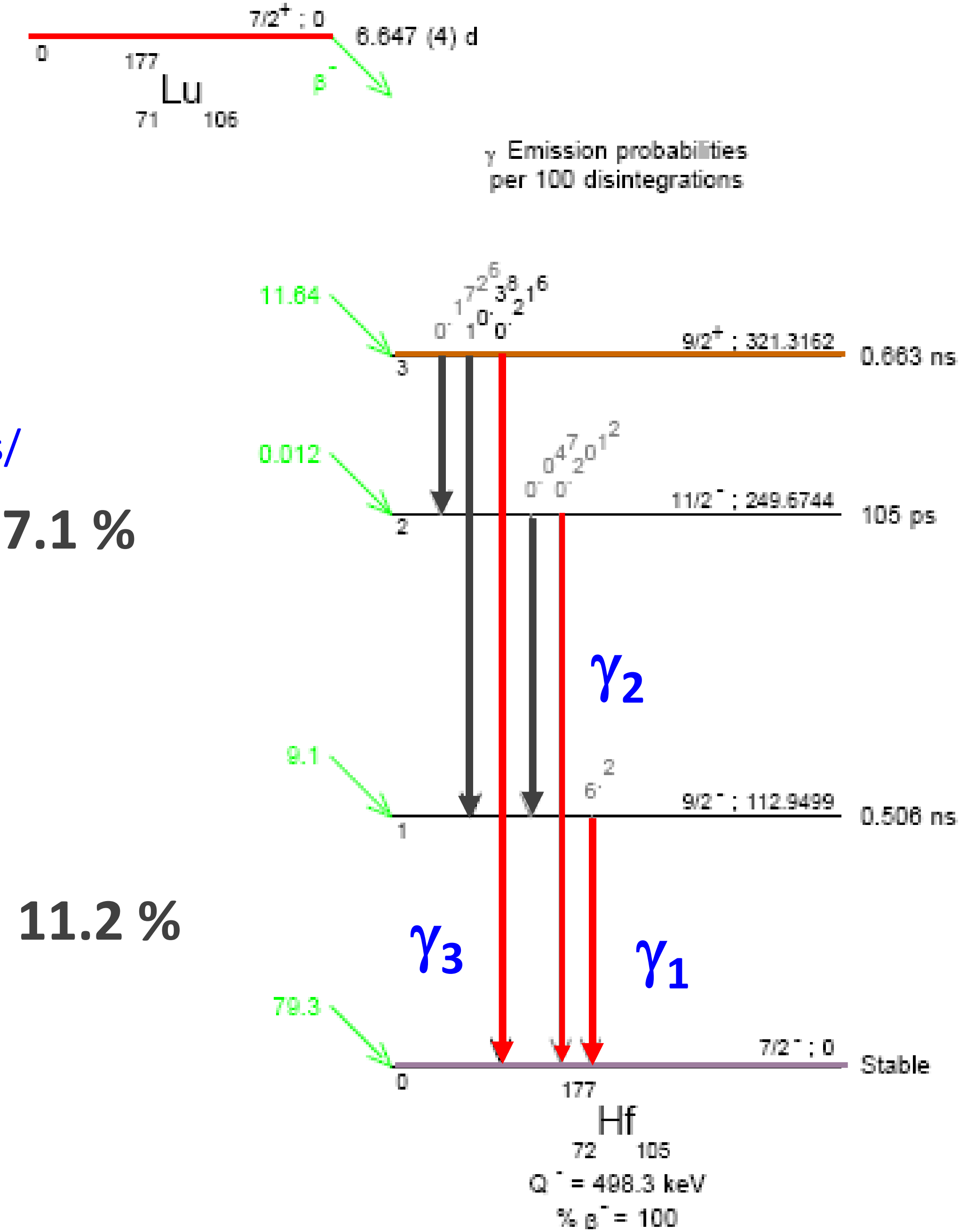
$\%I\gamma_3$= 4.9 +/- 0.5

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

$\%I\gamma_1$= 9.8 +/- 1.1 – relative unc. **11.2 %**

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

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



might end up with a huge differences 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 are used in the normalization procedure

- ✓ in many such cases the uncertainties for absolute γ-ray emission probabilities that you can find in derivative database such as NuDat , LiveChart, ENDF, JEFF … are incorrect - same is true for DDEP

Solution & Implementation

- **%Iγ** must be provided by the evaluators in the ENSDF decay data sets, by correctly taking into account the uncertainty propagation & correlations

- we have the tools to do that promptly and with little additional effort
  - ✓ the (modified) **GABS** analysis program – T. Kibedi (ANU)
  - ✓ the **GLSC** code – J. Chen (MSU)

- change the ENSDF policy that %Iγ are provided mandatory in each decay data set