

# Nuclear Heating theory and data - White paper -

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**IAEA**

International Atomic Energy Agency

# Objectives

- Technical meeting on nuclear heating theory and data; prompt, delayed and decay radiation heat, secondary particle's energy productions and energy balance
- The white paper describes the existent with regards to the field actual cover, capability, need and challenge ahead

# Objectives

- Heating is an important parameter in nuclear systems, particularly in unchartered R&D, while secondary radiation sources need to be better characterised, quantified and qualified when they are required for an application
- R&D is needed to support the necessary enhancements, processes and data forms, foreseen for the multiple energy, non-energy, earth and life sciences applications and provision for high-fidelity Multiphysics simulation efforts

# Practical applications

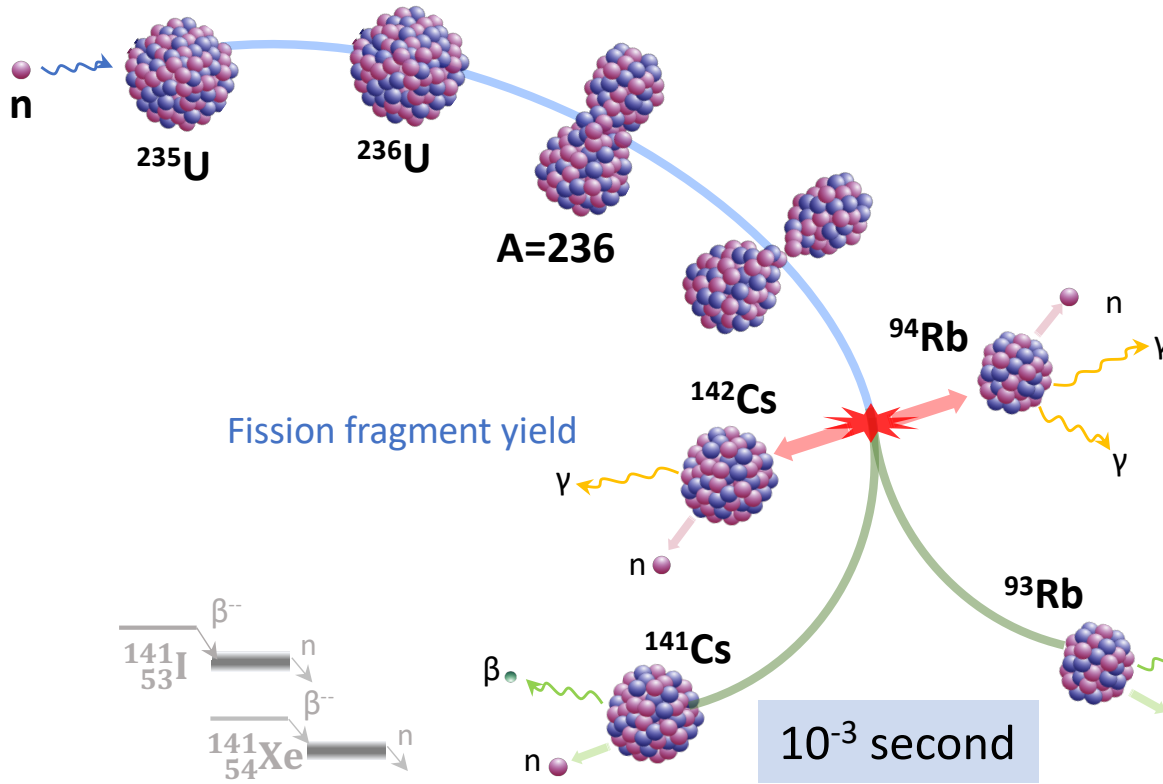
- Nuclear Energy, Power
  - NPP, pile Fuel Cycle frontend and backend
  - NPP, pile internals
- Accelerator physics, shielding
- Irradiation source terms
- Earth and materials sciences
- Life sciences
- Space applications

# The particles, beyond neutron only

- Prompt: neutron, gamma
  - but also, secondary CP's alpha, proton,.. and for some applications the “heavy” residual
  - Angular-energy secondary distribution
- Delayed: neutron (b-4n), gamma
- Decay: beta+, beta-, alpha, IT, neutron (still), SF, X-rays, ... 27 RTYP in ENDF-6

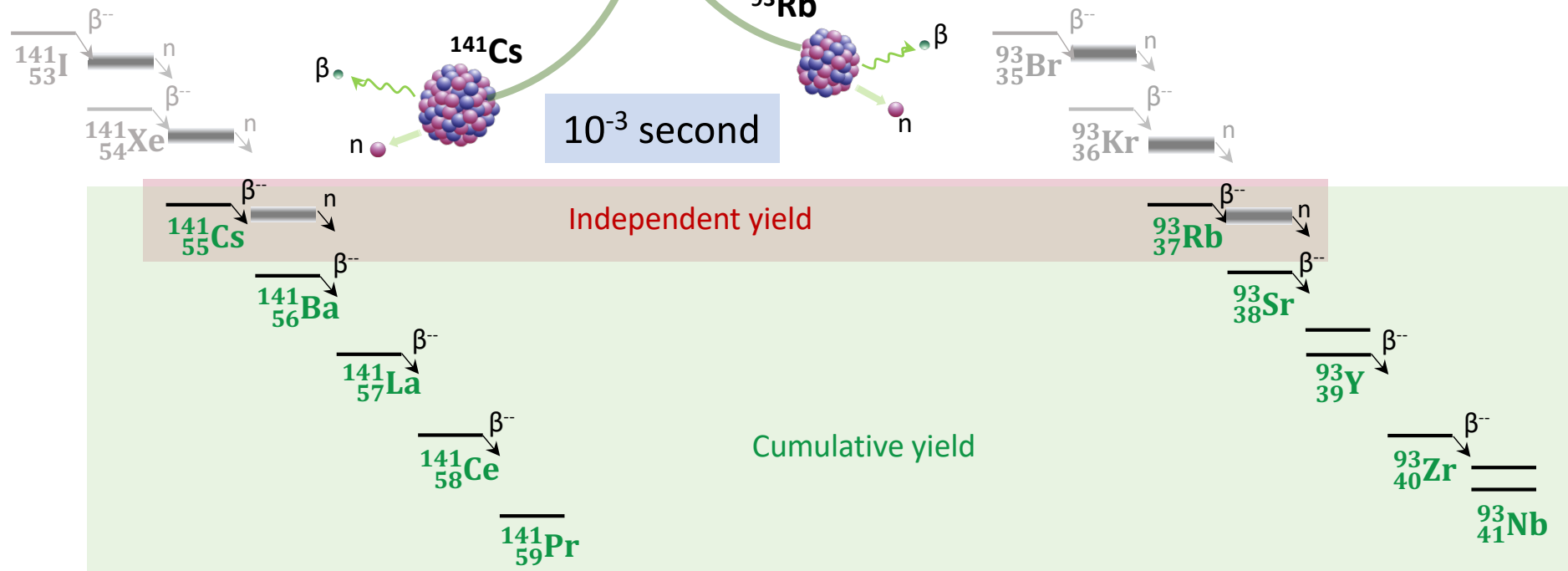
not that rare events !  
for the lesser God !

# A fission event



## Nuclear Fission Processes

1. Capture neutron by  $^{235}\text{U}$
2. Compound nucleus:  $^{236}\text{U}$
3. Deformation and elongation
4. Scission
5. Prompt  $n$ ,  $\gamma$  release to ground- or metastable-state
6. Beta decay until stable nuclide



A=141  $\beta^-$  decay chain

A=93  $\beta^-$  decay chain

# Particles and heating

- A lot depend on the applications need and timescale
  - $^{235\text{m}}\text{U}$  generated by  $\alpha$ -decay of  $^{239}\text{Pu}$
  - CP's induced fission in space embarqued electronic
  - Ternary fission
  - Am-Be, Pu-Be,  $^{238}\text{PuO}_2$ ,  $^{\text{nat}}\text{UO}_2$  sources
  - Irradiated material properties (supraconductor)
  - Active, passive cooling

# Observables

- How accurate are the simulations ? knowing that over prediction result in design conservatisms:
  - Fission observables before 1s ?
  - Fission observables after 10 years cooling ?
  - Fusion observables before 1minute ?
  - For operation and accidental scenario
  - Gamma, beta measurements ?
  - Experimentally measured observables? What exactly are they? event(s) contribution



# Observables

- Experiment versus simulation
  - measured observable versus evaluation
  - evaluation versus simulation
- Availability, accuracy and interpretation of the nuclear data forms
- Simulation requires
  - Verified protocol
  - Validated data if, and when they exists !

# Discrete, excited and isomeric states

- On unifying the definition of discrete, excited and isomeric states across the nuclear data model and form frames
- A subtle distinction between discrete level and excited state could be made with regards to the tempo of the phenomenon studied, whereby discrete is considered instantaneous (HL = 0.0 and gamma emission) while excited is having a half-life greater than a given value and more complex deexcitation, decaying properties if needed
  - ZA
  - ELFS its excitation energy in eV
  - HL its half life in seconds,  $T_{1/2} > 1 \text{ ms}$

# Challenges

- Filling the gaps, the crevasses left wide open by decades of indulgence
- Hopes in JENDL-5, TENDL-2021, ENDF/B-VIII.1, JEFF-4.0...
- Still a lot to check, verify, cross-correlate

# Challenges

- experimental integral radiation information

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## Compilation of Nuclear Data Experiments for Radiation Characterisation (CoNDERC)

The purpose of the CoNDERC project is to transfer into technology the experimental integral radiation information that can be used as part of the Validation and Verification processes of nuclear model and code systems, and to provide various schema to perform the V&V. Under the auspices of the IAEA Nuclear Data Section, individuals and institutions are assembling several of databases and code infrastructures based on their own V&V activities mainly associated with inventory, activation-transmutation, source term and radiation shielding R&D.

### Decay Heat

- Fusion Events
- Fission Events

### Spectra

- Spectra

### Shielding


- Aspis CIAE FNS
- NIST Oktavian Pulsed
- Replica Tiara

### Beyond Keff

- MCNP
- TRIPOLI

### Experiments

- Thermal Resonance
- Baghdad Atlas ↗



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# Conclusions

- The R&D field covers a combination of databases and methods, processes, codes, tools and know-how
- Every applications has its preferred target, material and/or emitted particles, niches
- Proper knowledge dissemination is required
- Unification is on its way