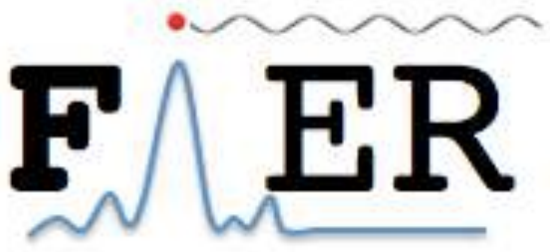
Eric F. Matthews
Brian J. Quiter
Bethany L. Goldblum

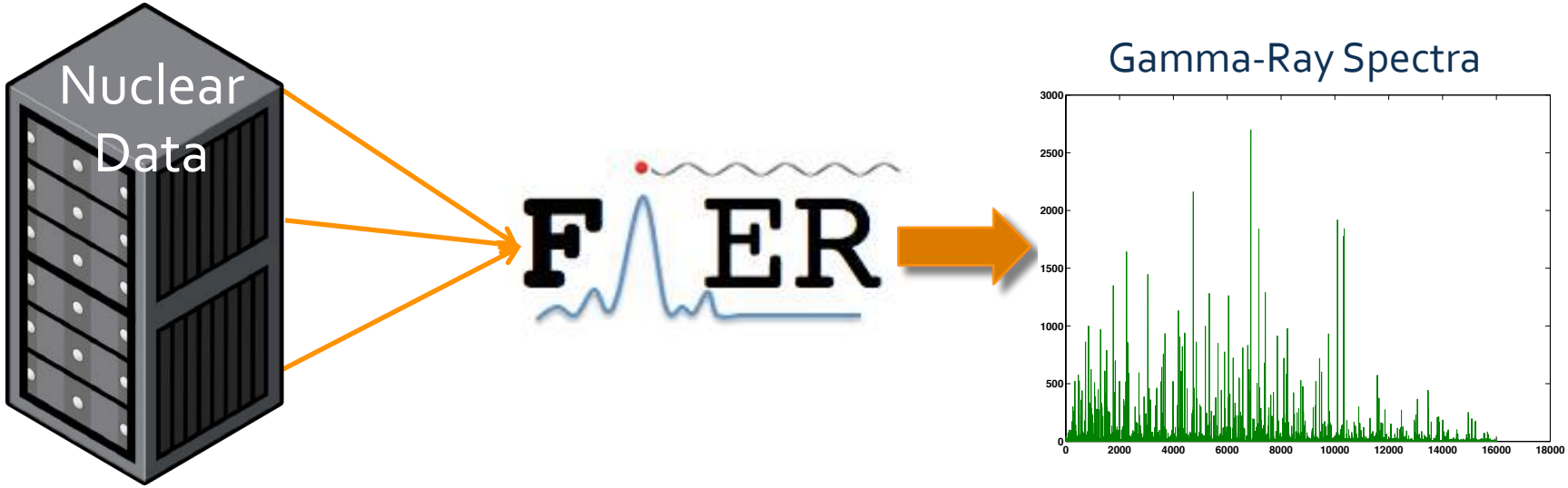


Fission Induced Electromagnetic Response

This material is based upon work supported by the Department of Energy National Nuclear Security Administration under Award Number DE-NA0000979.

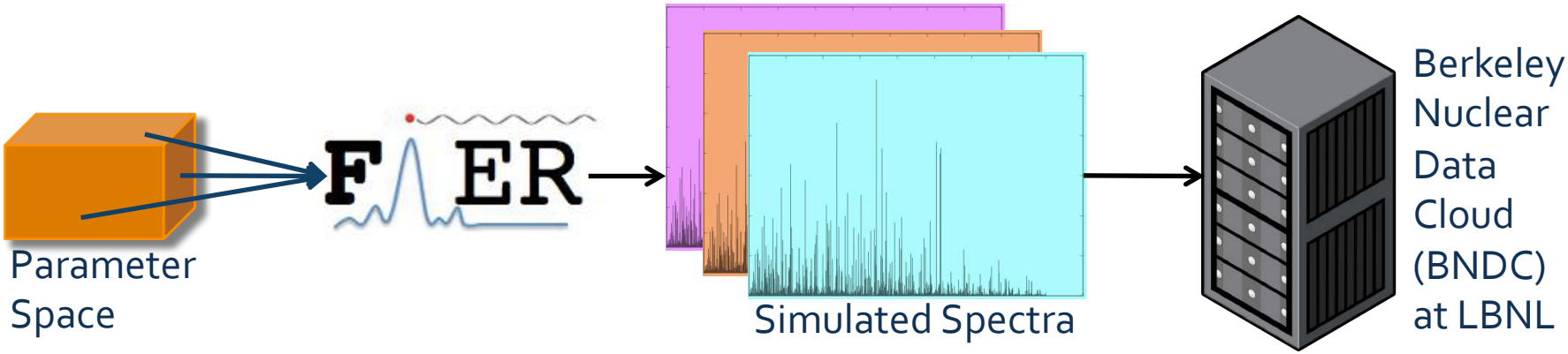

What is FIER?

- FIER (Fission Induced Electromagnetic Response) models time-dependent delayed gamma-ray spectra from fission.
- FIER's development was motivated by the need for an analytical model to predict experimental outcomes for the quantitative assay of fissile material samples.



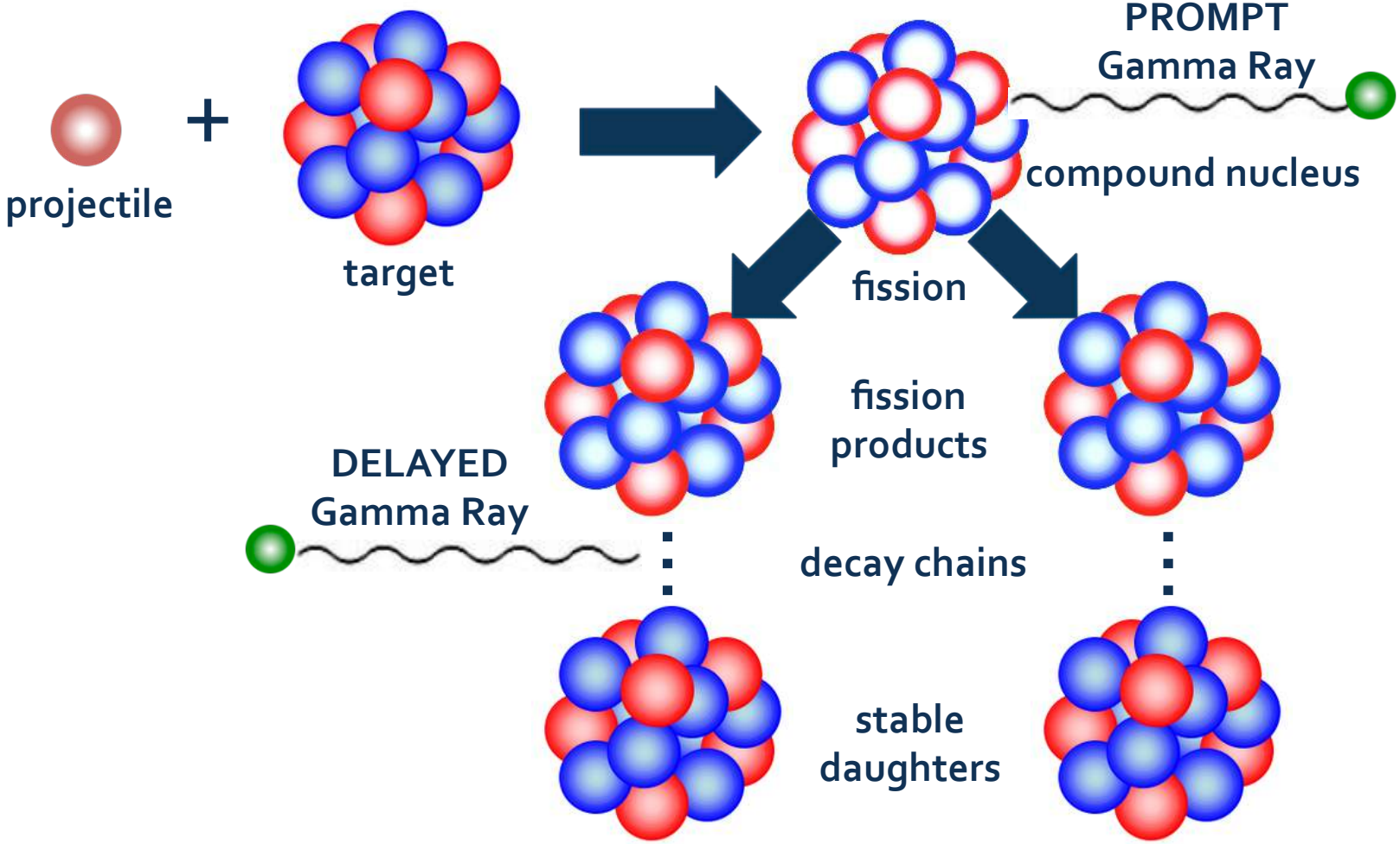
Nuclear Forensics Applications

- FIER will be used to generate delayed gamma-ray spectra using systematically perturbed input parameters.
- These simulated spectra placed in a database for later comparison to experimentally measured spectra.



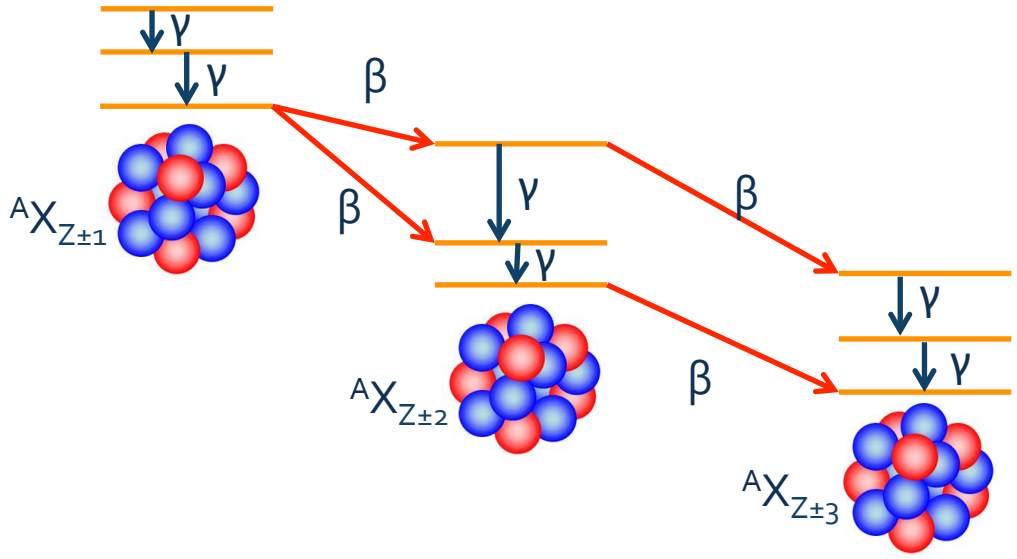
- This will allow easy access to spectra for nuclear forensics comparison, that would otherwise be very time consuming to reproduce.

Delayed Gamma Emission Explained



Delayed Gamma Emission Explained

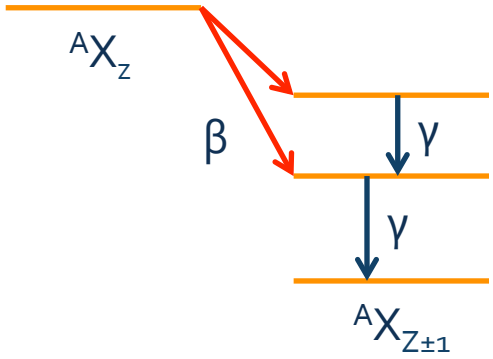
- Many fission products are unstable and often have multi-step decay chains.
- Most steps in these decay chains, particularly in the case of beta decay, will produce gamma rays.



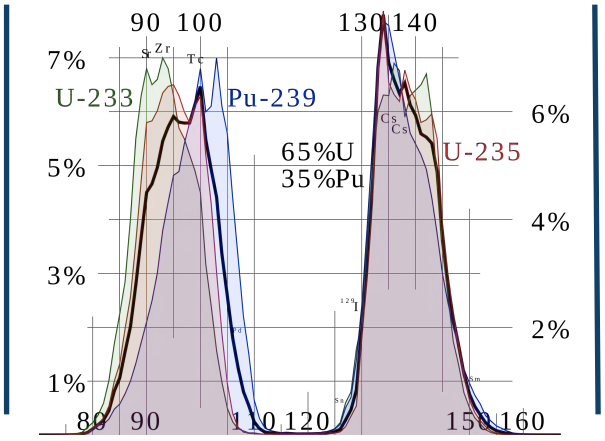
FIER Inputs

- Nuclear Structure Data (e.g., ENSDF)
  - Half lives
  - Branching Ratios
  - Level and Gamma Energies
- Fission Product Distribution (e.g., England and Rider)
- Irradiation Scheme – User Specified

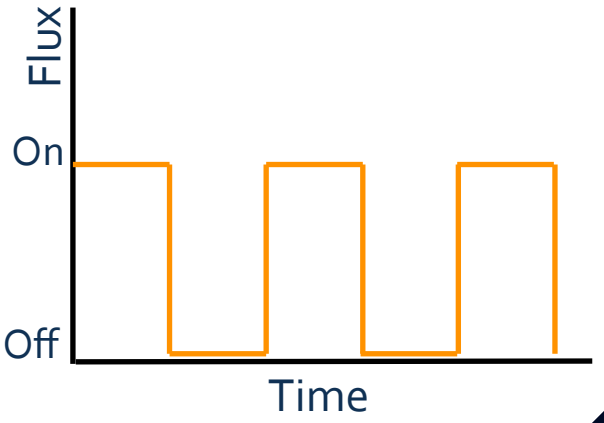
Structure and Decay Data



Fission Product Distribution



Irradiation Scheme



FIER Workflow

1. Using nuclear structure data, construct a list of decay chains for each fission product.

2. For each possible decay chain, use the Bateman equation with continuous production to calculate population of each daughter in that chain.

$$N_i(t) = \sum_{l=1}^{i-1} \left[P_l(\lambda_l \lambda_{l+1} \dots \lambda_i) \sum_{j=1}^{i} \frac{1 - e^{-\lambda_j t}}{\lambda_j \prod_{\substack{k=1 \\ k \neq j}}^{i} (\lambda_k - \lambda_j)} \right] + P_i \frac{1 - e^{-\lambda_i t}}{\lambda_i}$$

N_i – population of daughter i in decay chain
P_l – production rate of the l^{th} isotope before i
λ_x – decay constant of isotope x
l,j,k – precursor isotopes to the i isotope

FIER Workflow

3. Using nuclear structure data (i.e., lifetimes and branching ratios), FIER yields a delayed gamma-ray spectrum per number of fission events.

$$A_i = \lambda_i N_i$$

$$r^{\gamma} = A_i I_i^{\gamma}$$

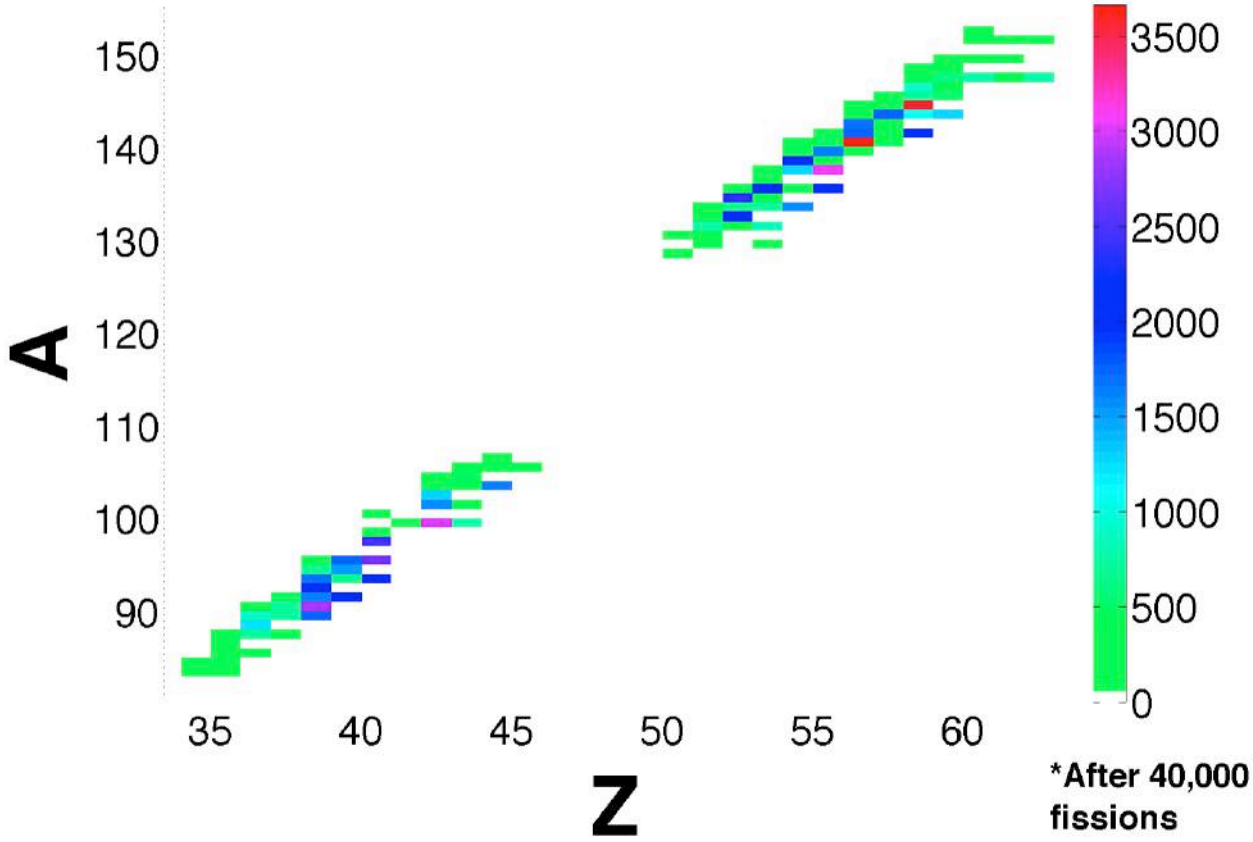
A_i – activity of ith isotope in decay chain
λ_i – decay constant of ith isotope in decay chain
N_i – population of ith isotope in decay chain
I_i^{γ} – branching ratio of gamma-ray
r^{γ} – gamma-ray emission rate

4. This gamma-ray spectrum is calculated at various times (usually a linearly spaced time interval).

FIER Output – Population Data

NSSC 7
NUCLEAR SCIENCE and SECURITY CONSORTIUM

- FIER outputs isotope populations as a function of time.

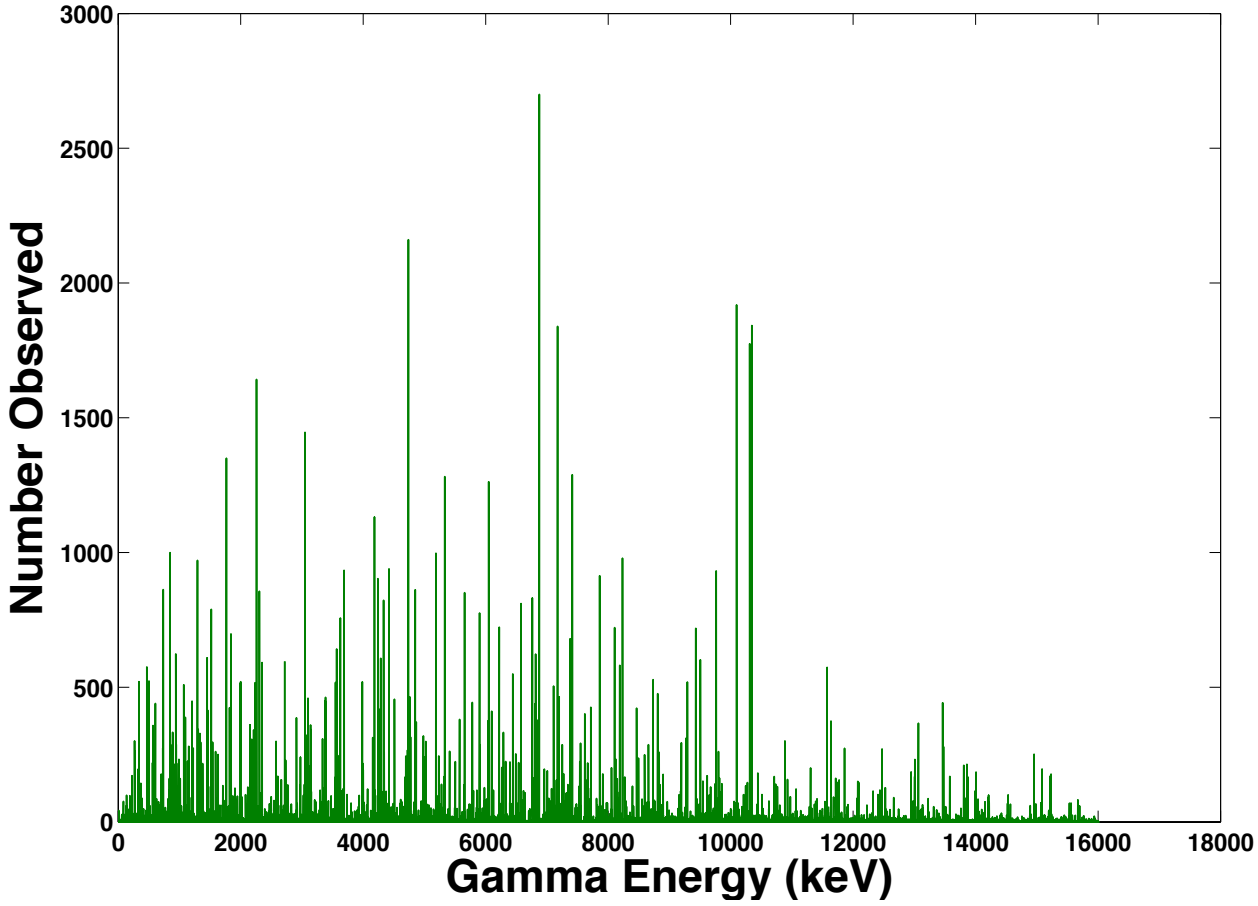


- Pure ^{235}U
- Thermal irradiation for 360 seconds
- Populations after 24 hours

FIER Output – Delayed Gamma-Ray Spectrum

NSSC 7
NUCLEAR SCIENCE and SECURITY CONSORTIUM

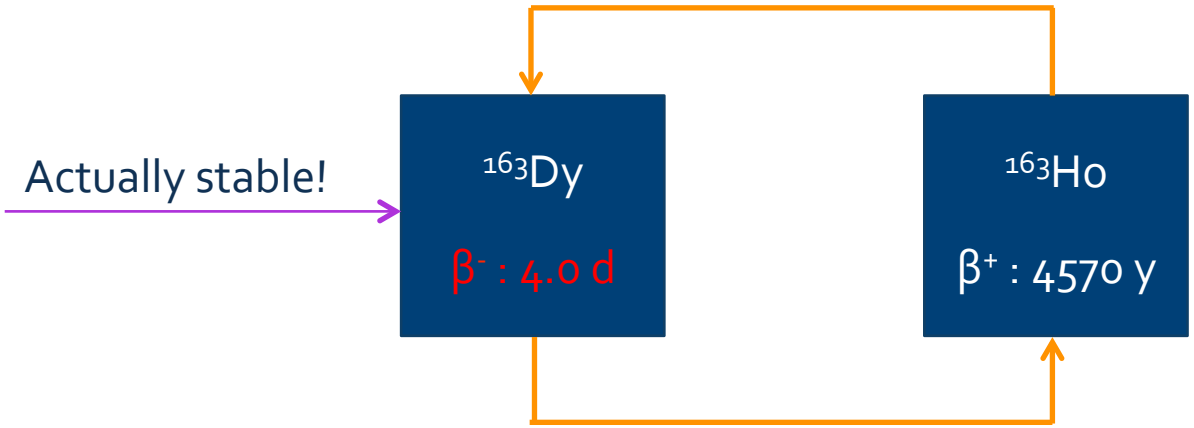
+ FIER outputs delayed gamma-ray emissions as a function of time.



- Pure ^{235}U
- Thermal irradiation for 360 seconds
- 24 hour counting period

Nuclear Data Challenges

- The recent development of the FIER code has been dominated by processing and handling nuclear data.
- Proper operation of FIER requires correct nuclear data.
- For example: a misplaced decay set can cause FIER to enter an infinite loop.



Nuclear Data Needs

- FIER needs data that is easy to access and that can be accessed without error.
- FIER also needs the data it is accessing to be correct.
- Because FIER, is heavily dependent on fission yield data, new measurements of fission yields is desirable for accurate simulations.

Collaborators

Krystal Alfonso[1], Josh Brown[1], Dan Chivers[2], Bethany Goldblum[1], Eric Matthews[1], Isaac Meyer[1], Brian Quiter[2], Nidhi Patel[2]

1 University of California: Berkeley – Department of Nuclear Engineering

2 Lawrence Berkeley National Laboratory – Applied Nuclear Physics Group

Special Thanks

Walid Younes of Lawrence Livermore National Laboratory
For his ongoing collaboration on the FIER code

Acknowledgements and Disclaimer

This material is based upon work supported by the Department of Energy National Nuclear Security Administration under Award Number: DE-NA0000979.


NSSC
7
NUCLEAR SCIENCE and SECURITY CONSORTIUM


THE UNIVERSITY OF CALIFORNIA BERKELEY
LET THERE BE LIGHT
1868


BERKELEY LAB
Lawrence Berkeley National Laboratory

Thank You!