OAK RIDGE National Laboratory

Fission Product Yields: SCALE/ORNL Perspective

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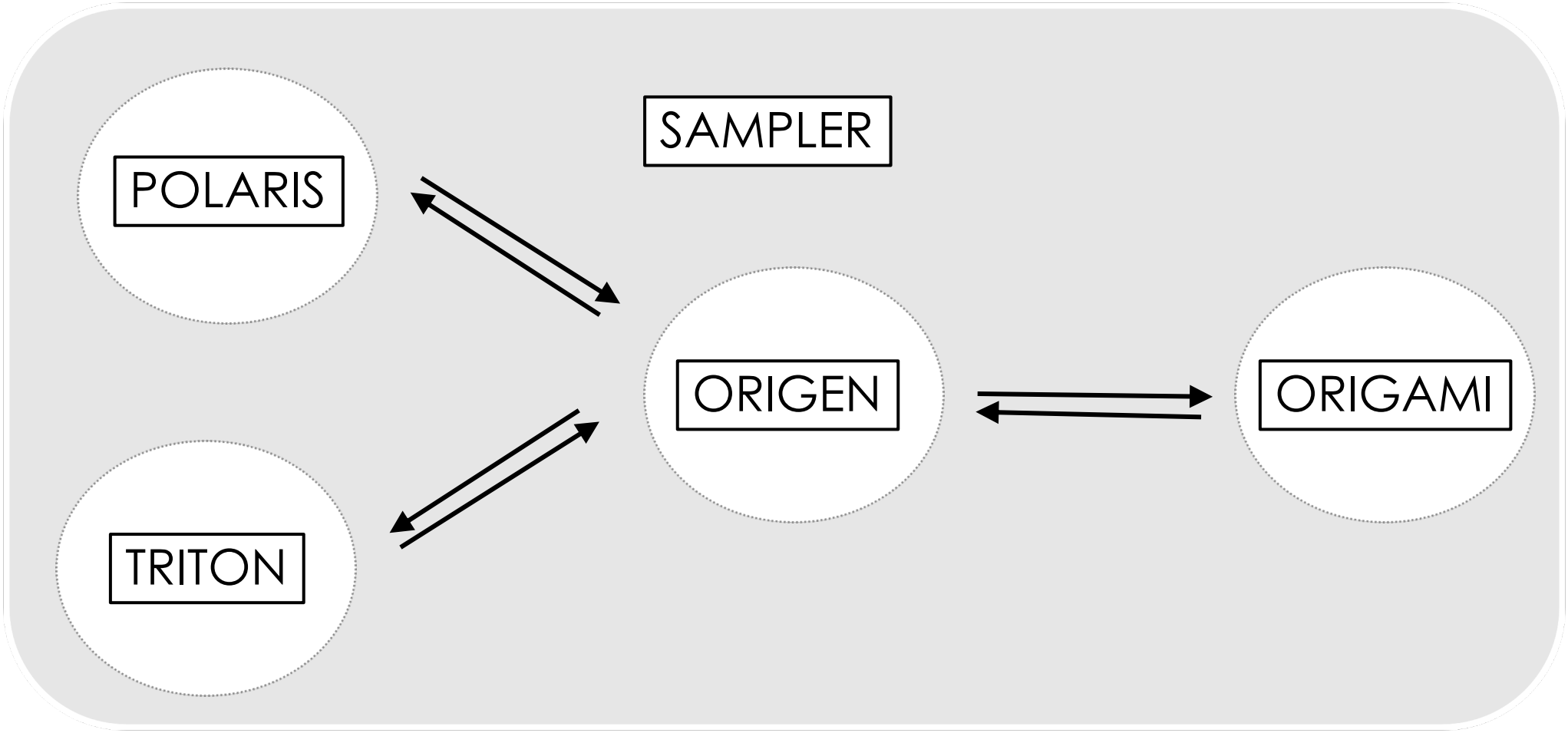
SCALE products using FPY



Critical Asset for Validation

ORIGEN

- **O**ak **R**idge **I**sotope **Gen**eration code in SCALE
- Irradiation and decay simulation code for general purpose isotopic inventory tracking, ***not*** *tracking an application-specific subset of isotopes*
  - 2,237 isotopes
    - 176 actinides
    - **1151 fission products**
    - 910 structural activation nuclides
  - 54,000 transitions between isotopes
    - All pathways in modern nuclear data for neutron transmutation, fission, & decay
    - All nuclides with half-lives > 1 ms

Key Capabilities

- Calculation of isotopic inventories and source terms
  - Nuclide concentrations (atoms and mass)
  - Activities
  - Decay heat
  - Radiation emission rates and spectra (neutron and gamma)
  - Radiotoxicity
- Application environments
  - operating reactors
  - spent fuel storage/handling
  - Structural material activation (in-core, ex-core)
  - Fuel cycle analysis (Material feed and removal processing)
- Methods and data enable comprehensive isotopic characterization of fuel **over a large time scale (milliseconds to billions of years)**

Note that FPY is very important immediately after shutdown!

Accuracy of **ORIGEN** is determined by the accuracy of the **nuclear data**

- **Decay data**
  - Half lives
  - Branching fractions,
  - Decay energy release (reaction Q-value)
- Cross sections (Multigroup)
  - ENDF/B-VII.0, -VII.1
  - JEFF-3.1/A special purpose activation file
- Gamma ray production data
  - X-ray and gamma ray emissions per decay
- **Fission product yields**
  - Energy-dependent data
- Neutron production data
  - Alpha decay energies
  - Stopping powers
  - (a,n) yield cross sections
  - Spontaneous fission spectral parameters
  - Delayed neutron spectra

Fission product yield data used by SCALE

- Energy dependent FPY from ENDF/B-VII.0
  - 30 actinides: ^{227,228,232}Th, ^{231}Pa, $^{232\text{-}238}$U, $^{238\text{-}242}$Pu, ^{241,242m,243}Am, ^{237,238}Np, $^{242\text{-}246,248}$Cm, ^{249,252}Cf, and ^{254}Es
  - Data are from England and Rider compilations
  - Energy-dependent yields tabulated at
    - **Thermal fission:** 0.0253 eV
    - **Fast fission:** 500 keV
    - **High energy fission:** 14 MeV
  - Actual yields are interpolated using the mean energy of neutrons causing fission (EALF)
- *As of SCALE-7.0-beta* we have incorporated spontaneous FPY from ENDF/B-VIII.0

Combining ORIGEN with Transport Applications

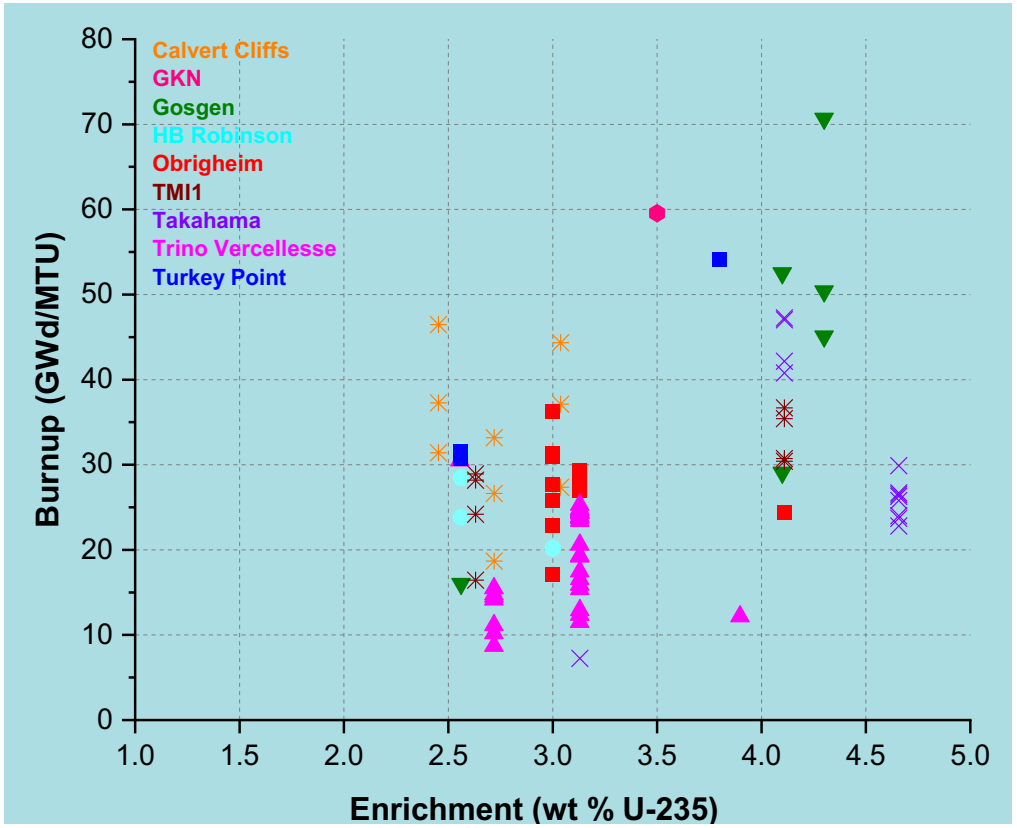
POLARIS

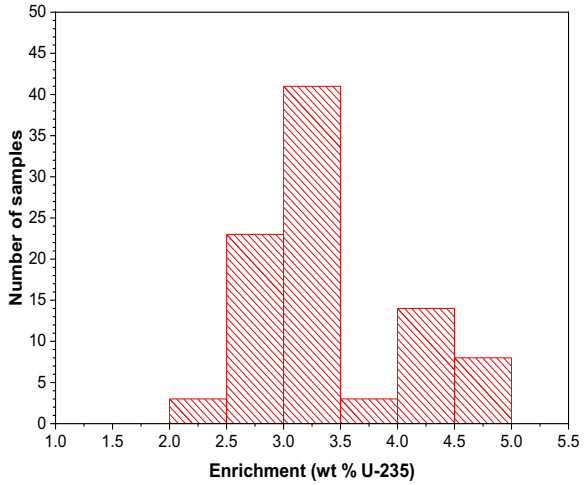
TRITON

- Employ ORIGEN as a depletion solver in their coupled transport-depletion sequences
- Use detailed models (assemblies, reactors, etc.) to predict inventory of those models over time

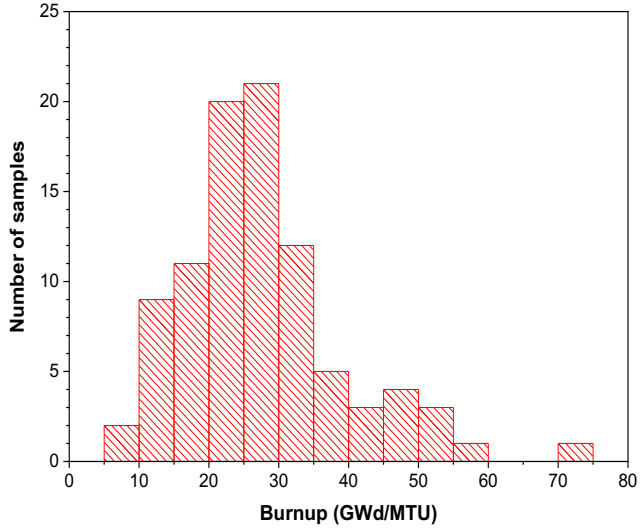
Validation: Comparisons to radiochemical assay experiments

Nuclide inventory from experimental data for PWR fuel (92 samples)



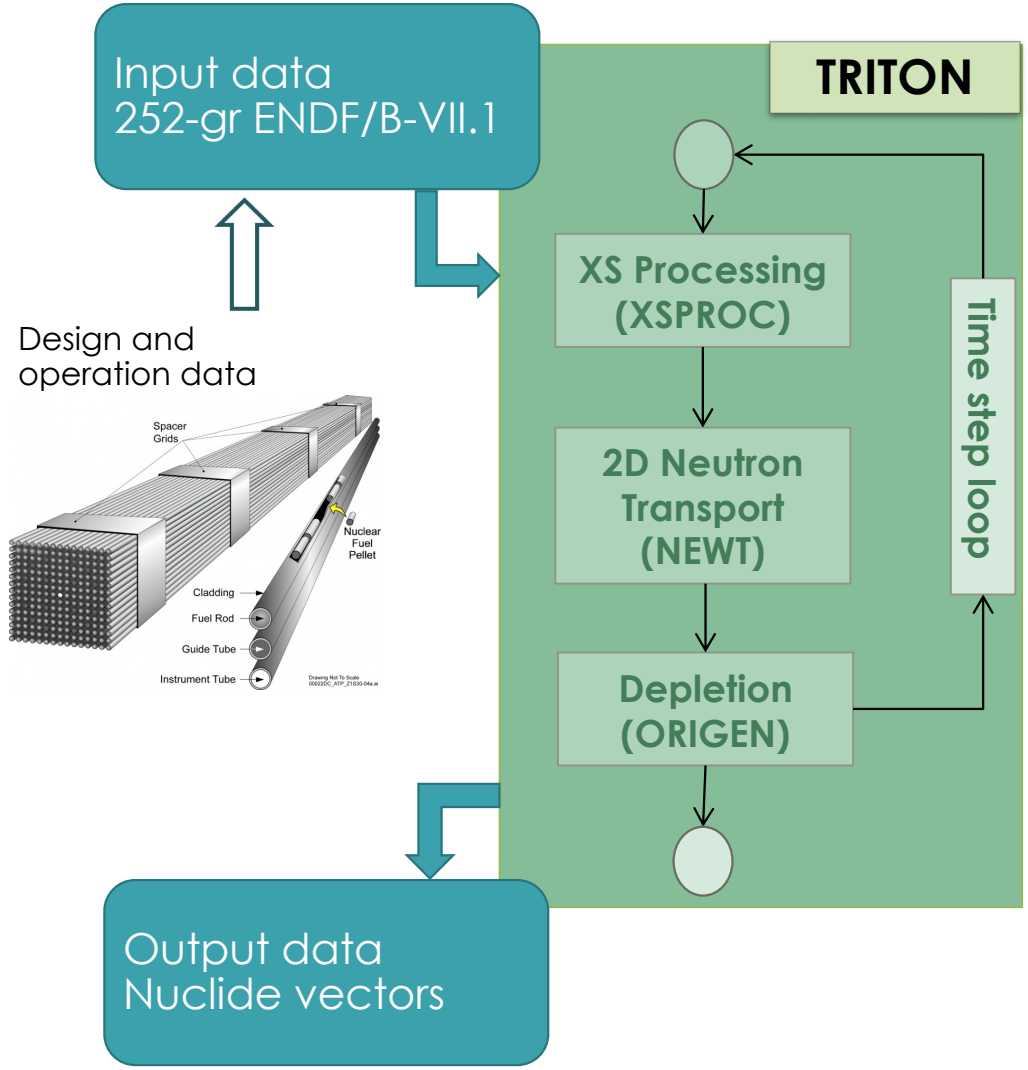


Burnup & enrichment space covered

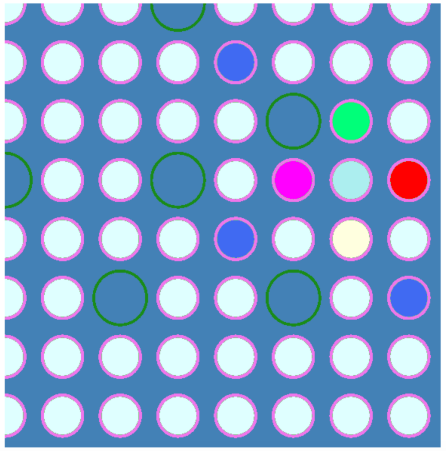


G. Ilas, J. Burns, B. Hiscox, U. Mertyurek, *SCALE 6.2.4 Validation: Reactor Physics*, ORNL/TM/2020-1500/V3 (2022) https://www.osti.gov/biblio/1902818

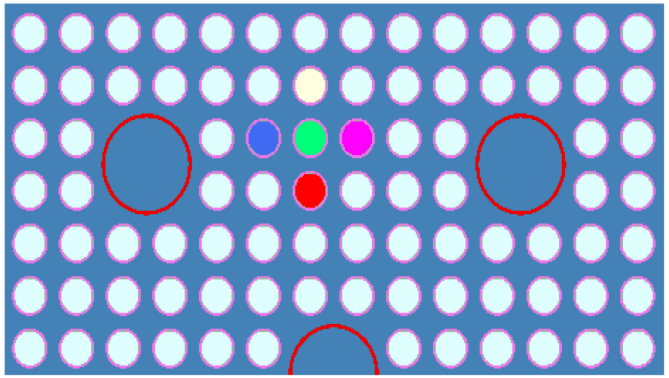
Validation: SCALE simulations for nuclide inventory



Sample irradiation and decay history modeling

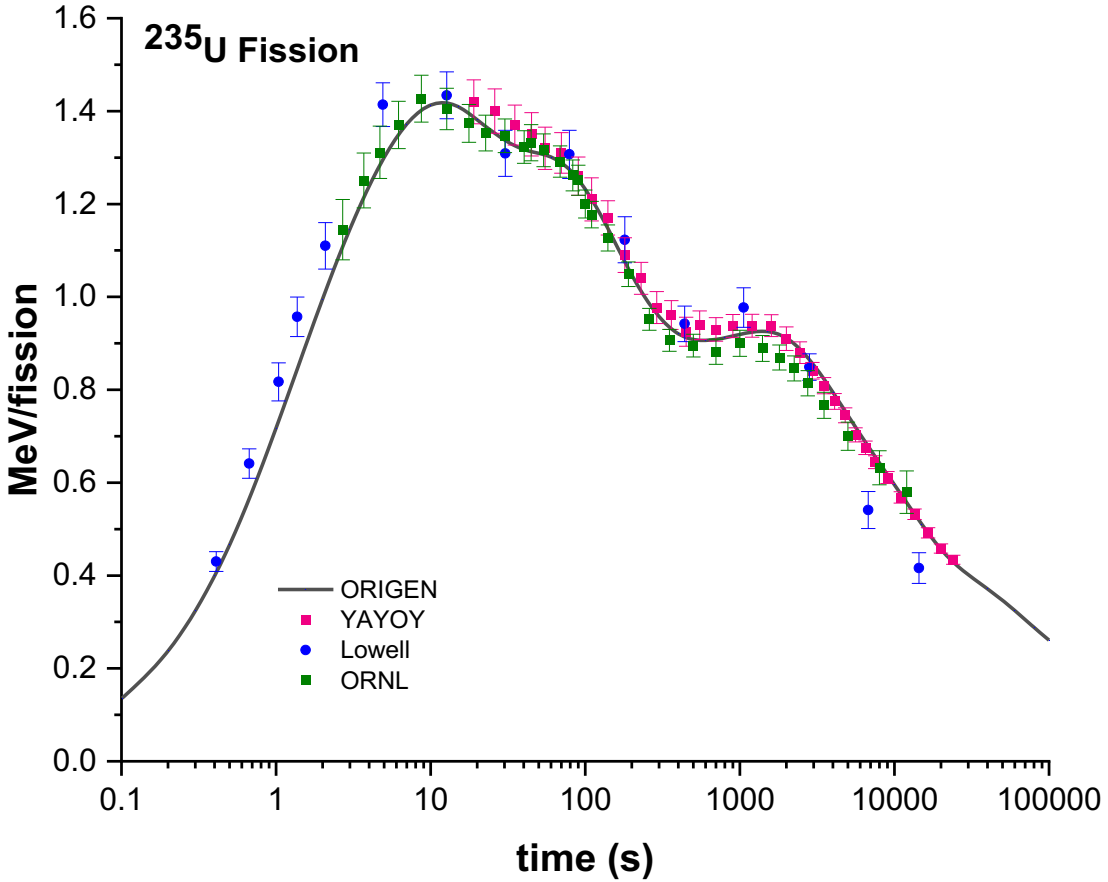


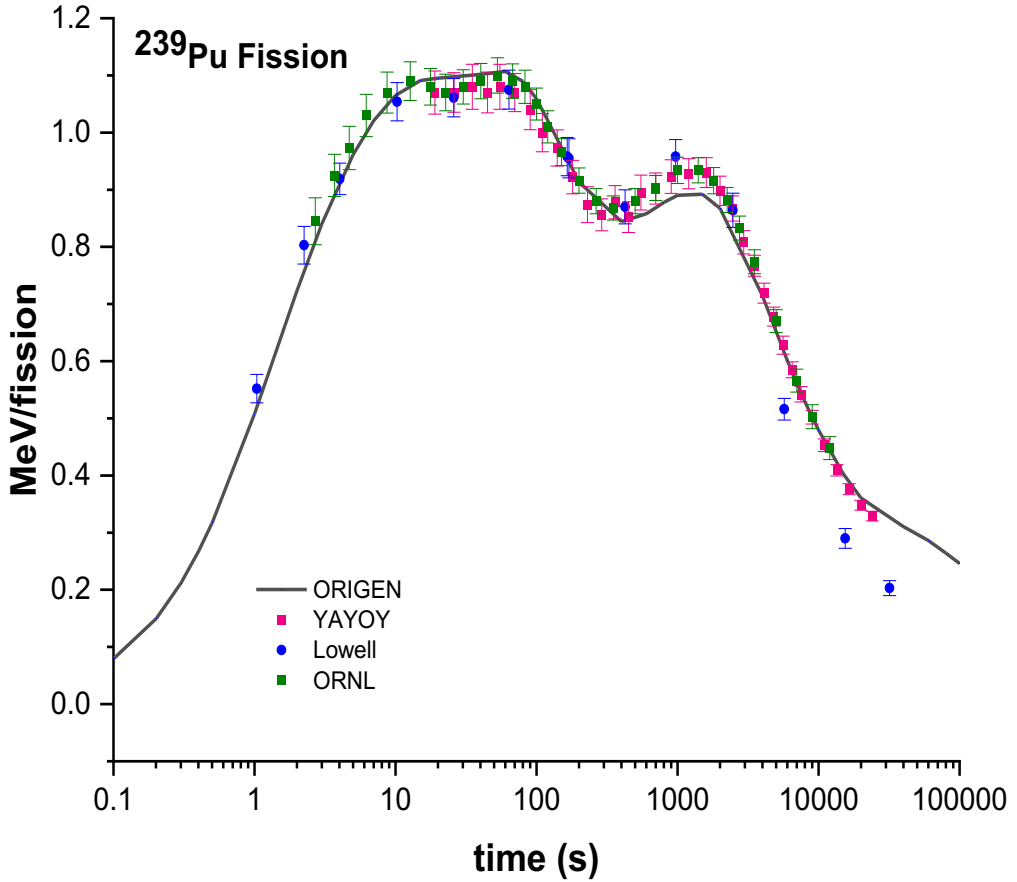
¼ assembly model for Gosgen GU3 sample



½ assembly model for Calvert Cliffs MKP109-CC sample

Validation: Fissile material irradiation experiment-to-calculation comparisons





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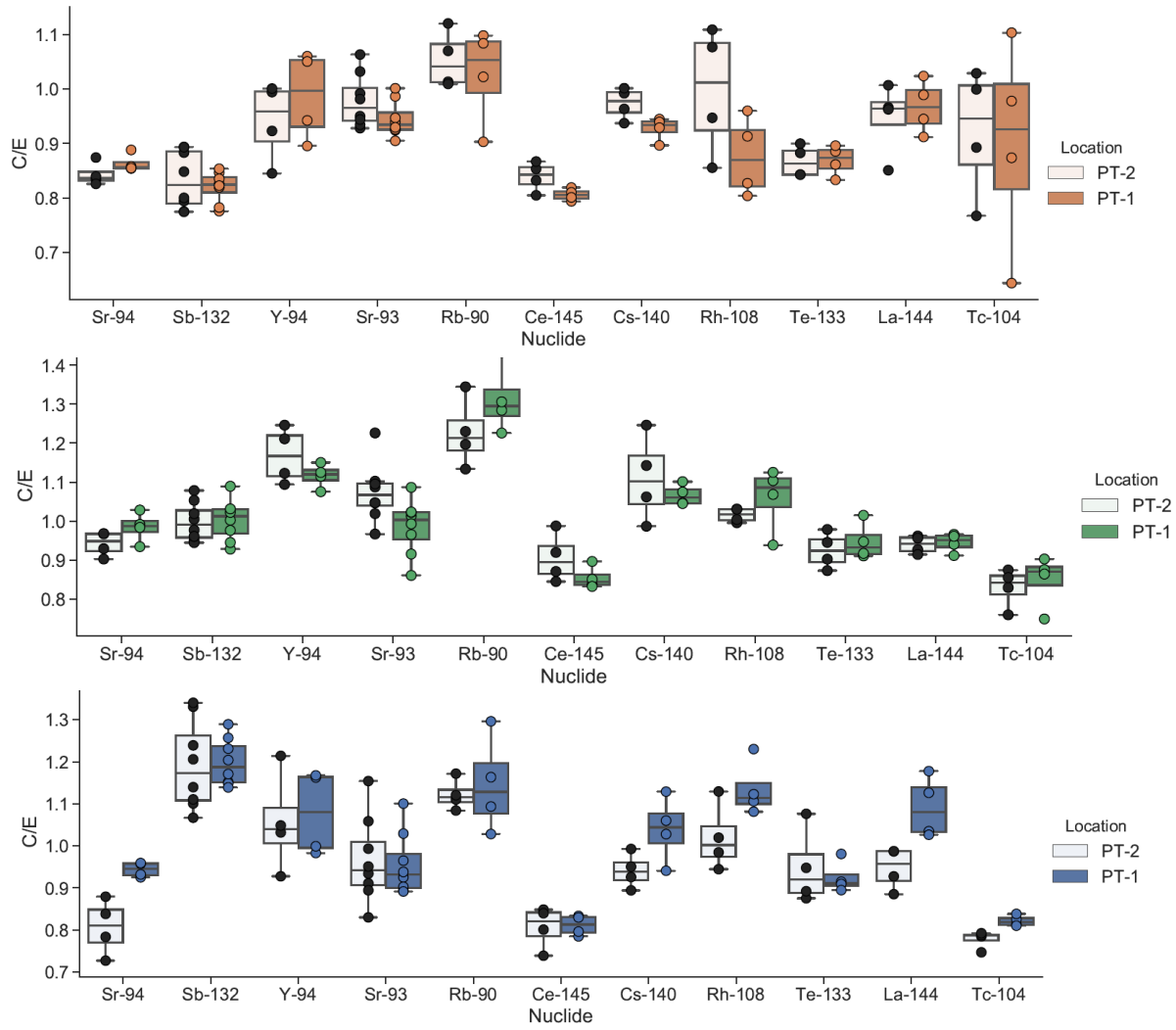
Proposal for New Validation Efforts

a) Overall decay heat from burst fission

b) Fission product measurements

Notes on comparison:
- New measurements for Tc-104 beta feeding / gamma emissions
- Rb-90 branching fractions issue identified

ORIGEN vs. HFIR meas. via HPGe



S. Skutnik, J. Knowles, and D. Glasgow, "Quantification of Trace-Level Fissile Samples via Short-Lived Delayed Gamma Spectroscopy," *IEEE Transactions on Nuclear Science*, 66(9), September 2019. **DOI:** 10.1109/TNS.2019.2934677

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Key takeaways

- ORIGEN is a **consumer** of FPY data
- TRITON & POLARIS are assets which can be used to **validate** new FPY data
  - e.g., from **existing** radiochemical benchmarks and **new** irradiation experiments
- New capabilities with covariance data should be developed
- V&V methods and analysis also needed for the covariance data

Acknowledgements

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The entire Nuclear Energy and Fuel Cycle Division at ORNL