ADVANCED REACTOR SAFEGUARDS & SECURITY

Recommendations to Improve Burnup Measurement System (BUMS)

Spring Program Review Meeting
April 28-30, 2026

PRESENTED BY Callie Goetz

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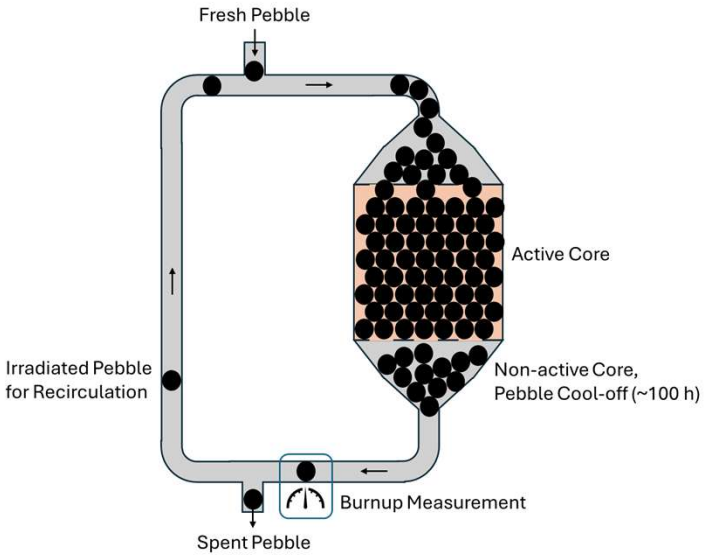
Burn up measurements in Pebble Bed Reactors

- Burnup measurement of a discharged pebble in a pebble bed reactor is integral to safe, efficient, and economic reactor operation and can also be used for nuclear material accounting
- Requires cost-effective online monitoring system to judge pebble burnup
- ~150 hours cooled
- Project goal: assess nondestructive assay techniques for burnup monitoring system (BUMS) with data from HFIR irradiation campaign

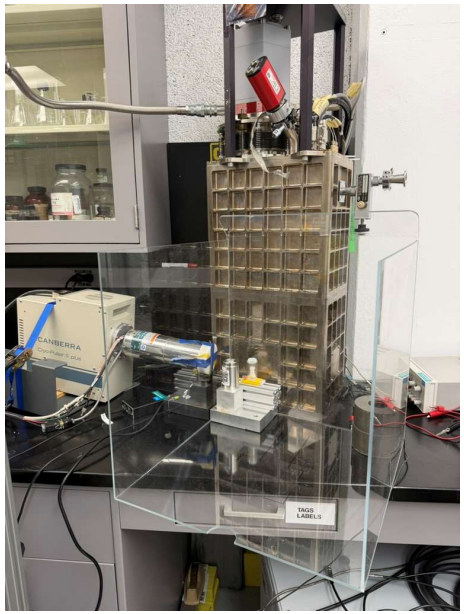


Long Mott Project Collaboration with X-Energy

- As part of the ARDP award, ORNL is collaborating with X-Energy on deployment of a “4-pack” of Xe-100 high-temperature gas cooled pebble bed reactors (PBRs) for the joint project with Dow at the UCC Seadrift Operations in Calhoun County, Texas.
- This will be through the wholly-owned subsidiary, Long Mott LLC, called the Long Mott Generating Station (LMGS).
- Construction application submitted March 31, 2025. Processing time is expected to take 30 months.
- Dow’s Seadrift site covers 4,700 acres and manufactures more than 4 billion pounds of materials per year used across a wide variety of applications including food packaging and preservation, footwear, wire and cable insulation, solar cell membranes, and packaging for medical and pharmaceutical products.
- The plant will produce both power and process heat for Dow's Seadrift chemical facility, which is currently powered by natural gas.
- Under the ARSS project, ORNL is leveraging non-proprietary design information on the XE-100 to develop MC&A approaches for PBRs, focusing on the design aspects and performance of the burnup monitoring system (BUMS), which is integral to the operation of the facility and can also be used, along with reactor modelling and statistical PIEs, to support mass accountancy.

HFIR Experimental Campaign

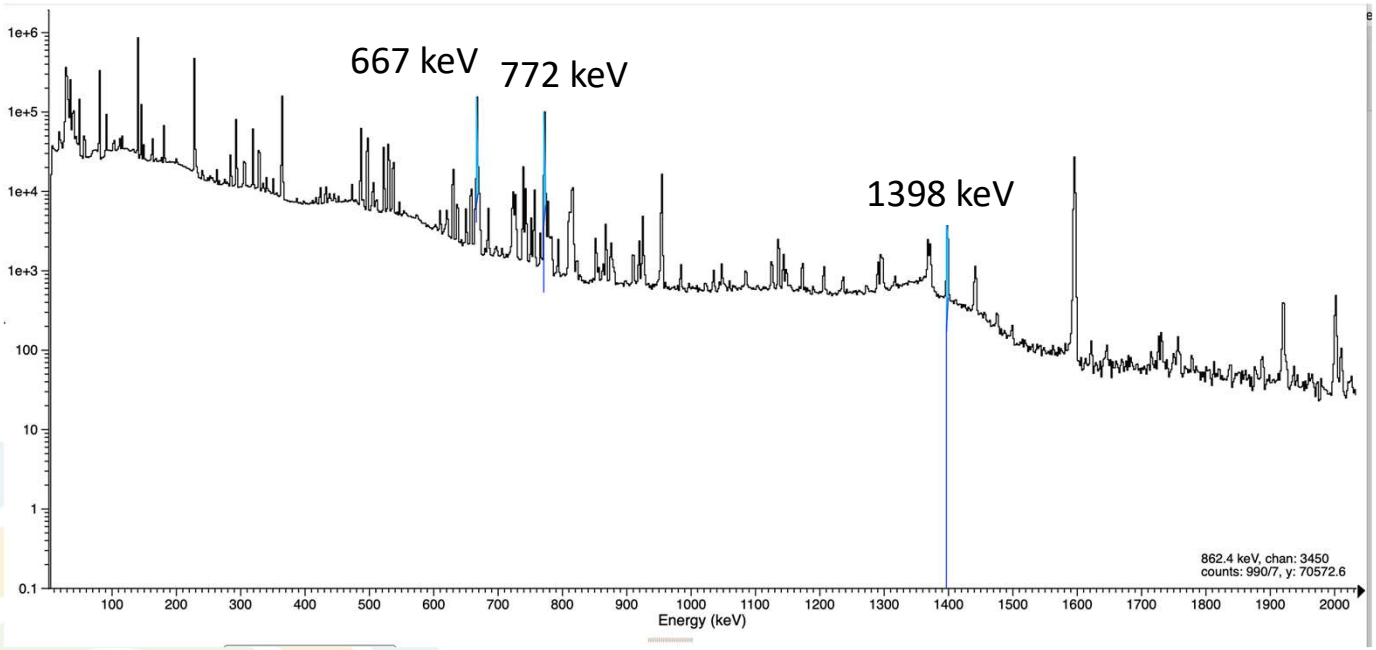
- Irradiations performed immediately post reactor shutdown (gamma heating concerns in plastic rabbits)
- “Short-cooled” setup
  - SOFIA Microcalorimeter
  - ~30 seconds – 90 minutes post irradiation
- “Long-cooled” setup
  - 2 HPGe’s in gamma-gamma coincidence mode
  - 90 minutes – 200 hours post irradiation
- Irradiation Targets:
  - Pu239 – 97%, 70%
  - AGR2 TRISO Particles with 7.42%, 8.22%, and 12.05% FIMA burnup

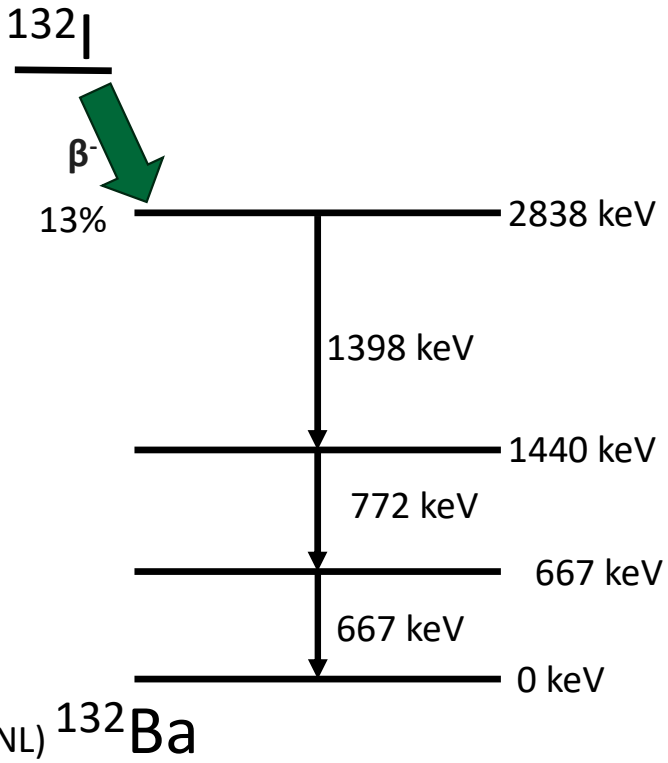


BUMS Test Setup

- Serving as “long-cooled” setup
- Measures samples post SOFIA
- Up to 200 hours post irradiation
- 2 HPGe’s in coincidence mode
  - List mode data collection on separate channels of same digitizer
  - **Not** 180-degree angle (511 keV)

BUMS – Example Nucleus: ^{132}I

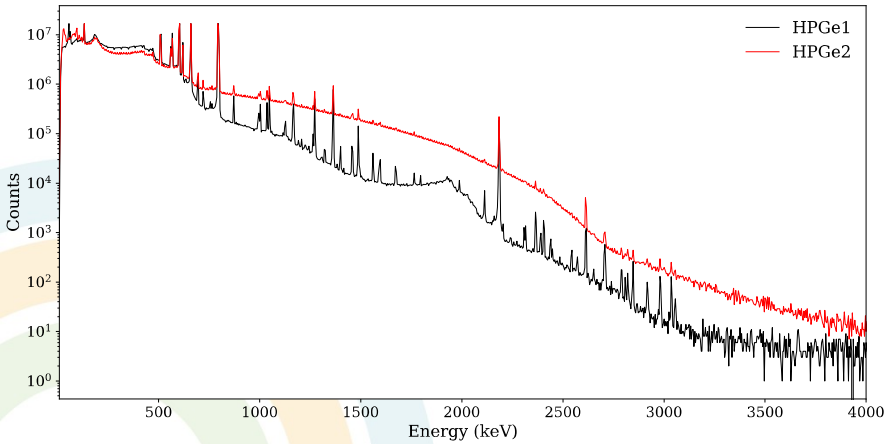


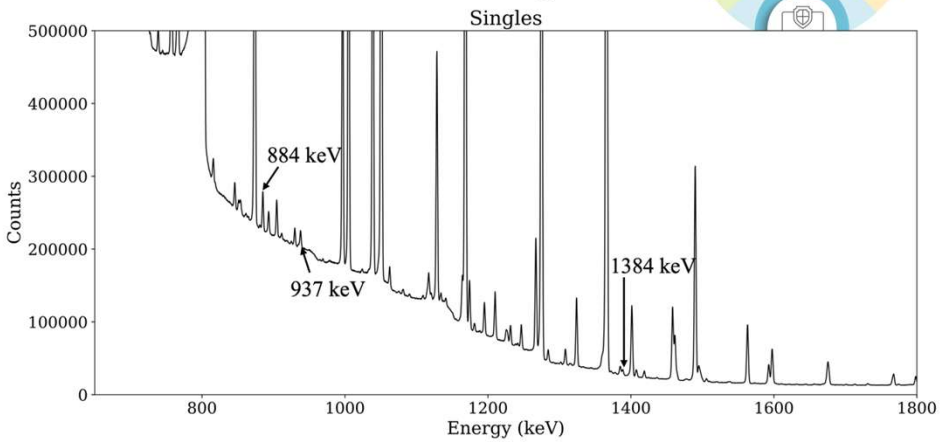


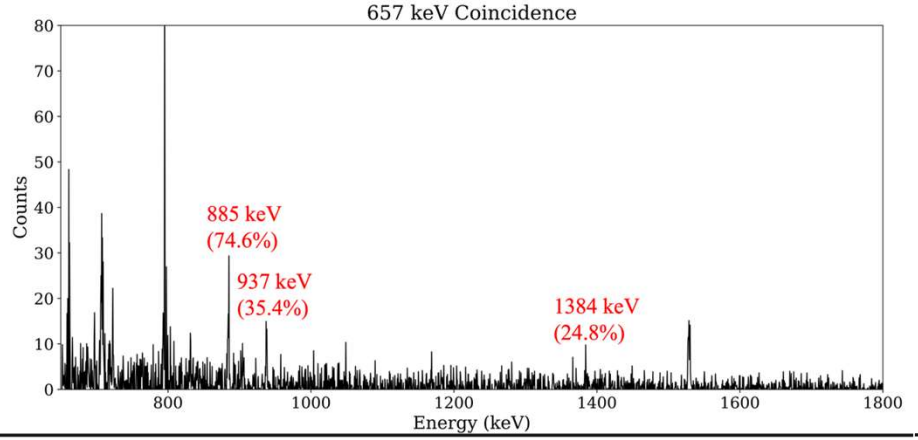
^{239}Pu sample, irradiated in HFIR pneumatic tube, cooled 122 hours
Data taken for Nuclear Forensics Energy and Survivability (PI: Steve Skutnik, ORNL)

BUMS – Example of Coincidence Method

- 2 HPGe detectors
- AGR5/6/7 TRISO particle
- ^{110m}Ag decay – reduce minimum detectable activity
- **<u>450X improvement over singles</u>**

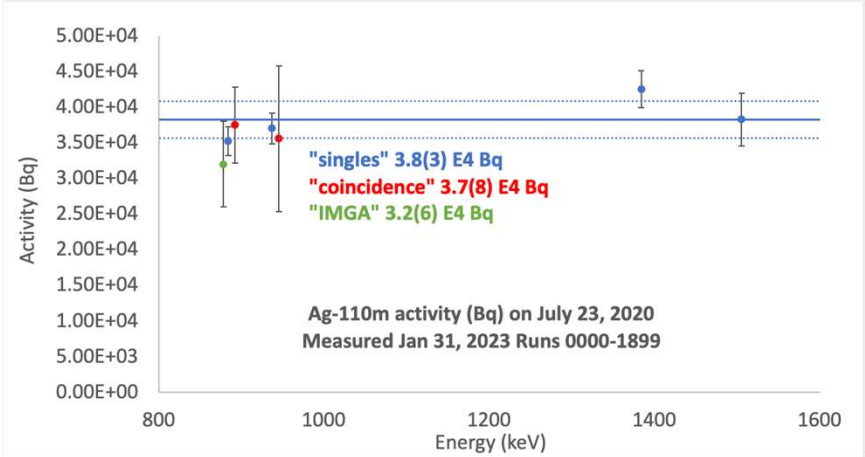






Outlook and Conclusion

- Coincidence counting could increase number of accessible nuclei for burnup calculations in PBRs
- Calculate burnup using multiple nuclei, and multiple gamma rays from those nuclei to reduce error
- Technique could increase confidence in burnup calculations
- Multiple detectors could also operate in singles mode if one detector goes down mid-measurement
- FY26:
  - 1 irradiation with SOFIA and coincidence-capable BUMS completed
  - Data analysis ongoing
  - 2nd irradiation planned at end of next HFIR cycle
- FY27 Outlook: quartz encapsulation of TRISO particles for mid-cycle irradiations



Thank you!

I’m happy to answer any questions that you have.

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