



NEUP – Pebble Database for PBR MC&A

Advanced Reactor Safeguards Spring Working Group Meeting, April 18-20, 2023

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VCU

College of Engineering

Mechanical and Nuclear Engineering

Project Team

Core VCU team

- Braden Goddard (PI)
 - Zeyun Wu (co-PI)
 - Zachary Crouch (Ph.D. student)
 - Ben Impson (undergrad)
 - TBD (postdoc)
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- Project duration: Oct. 2022 – Sept. 2024
 - Funding amount: \$400k

External advisory team

- Claudio Gariazzo (ANL)
- Yonggang Cui (BNL)
- Philip Gibbs (ORNL)
- Donny Hartanto (ORNL)

The Challenge

- Knowing the nuclear and radiological material content in used pebbles is important for:
 - Safeguards
 - Facility operations
 - Waste management
 - Etc.
- Used pebbles are measured relatively quickly after discharge and there path through the reactor can vary between pebbles
 - Traditional LWR gamma and neutron NDA correlations may not be applicable

Project Goal

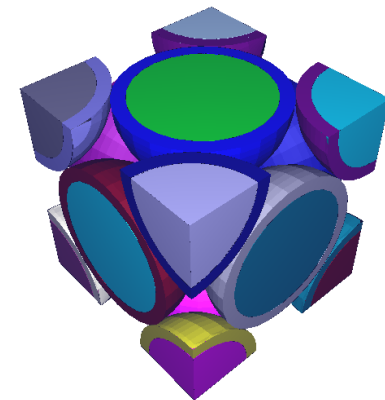
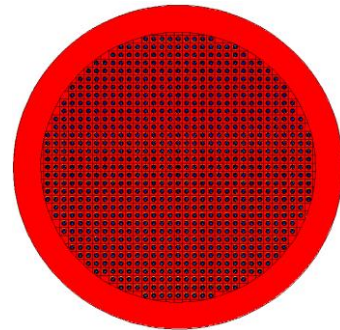
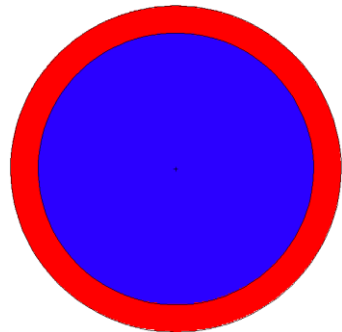
- Create a data library of used pebble NDA signatures
 - Gamma spectra (HPGe)
 - Neutron counts (fission chapter)
- Validate data library using an independent code
 - INDEPTH (ORIGEN)
- Document methodology used to create the data library
 - Focus is Xe-100

Project Approach

- Use MCNP 6.2 for initial pebble models and NDA signature models
 - Use Serpent 2 for full core burnup simulations
- Pebble history parameters to monitor
 - Pebble path and speed in core
 - Neutron fluence energy and magnitude
 - Cooling time before measurement and reinsertion into core
- Coordinate with other pebble bed reactor researchers to insure the content and format of the data library meets their needs
 - ANL, BNL, ORNL collaborators
 - ARS Spring Program Review
 - Domestic and international conferences

Current Work

- Initial work as focused on:
 - Recruiting and training students
 - Creating pebble variations to understand modeling sensitivities
 - Reflective boundary mirror vs white
 - Homogeneous vs heterogeneous
 - Simple cubic vs face centered cubic
 - Latticed TRISO particles vs semi-random
 - Effect of clipped TRISO particles
 - Reflective boundary at pebble surface vs cube with helium



Current Work – Pebble Parameters

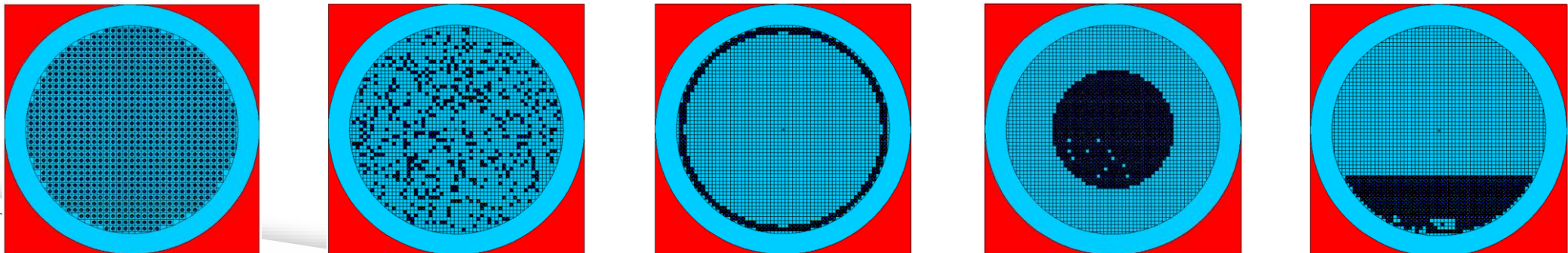
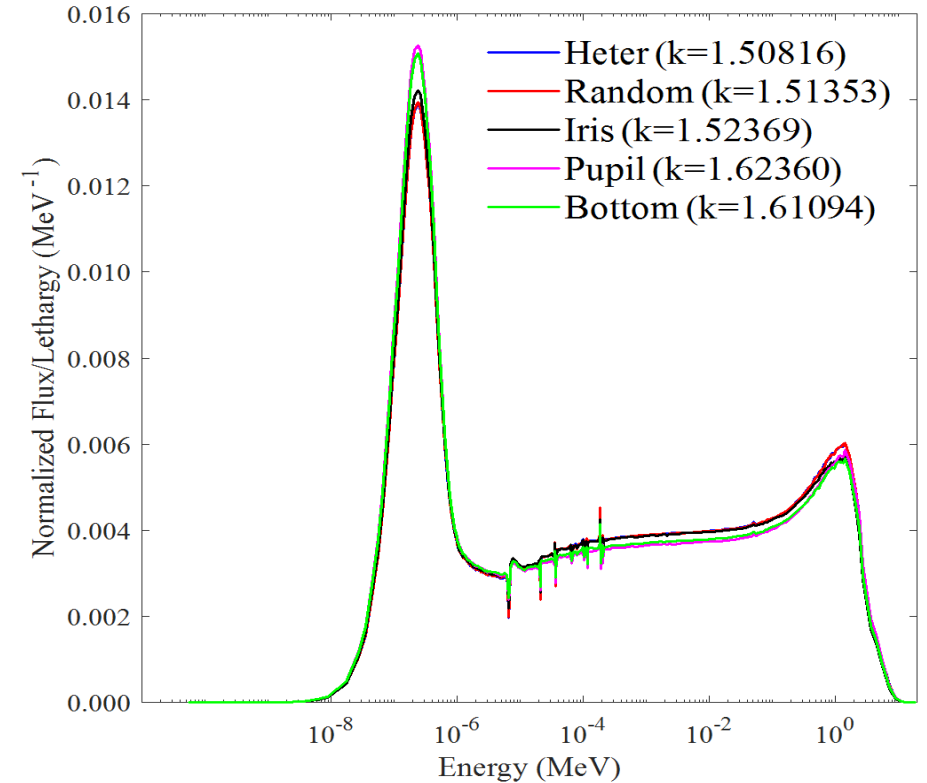
Pebble Model	k-infinity (White)	k-infinity (Mirror)
Homogeneous	1.39962 ± 0.00063	1.41510 ± 0.00055
Clipped Heterogeneous	1.50473 ± 0.00077	1.51247 ± 0.00063
Unclipped Heterogeneous	1.50631 ± 0.00068	1.51638 ± 0.00054
Unclipped Heterogeneous w/ He	1.50816 ± 0.00062	1.50822 ± 0.00063
FCC Homogeneous w/ He	1.40165 ± 0.00078	1.39875 ± 0.00063
FCC Heterogeneous w/ He	1.49654 ± 0.00077	1.49598 ± 0.00071
FCC Heterogeneous Semi-Random	1.51061 ± 0.00069	1.50827 ± 0.00056

- Boundary condition matters when modeling spheres
- Modeling heterogeneous pebbles is important
- Having clipped TRISO particles does not matter
- TRISO particles must be randomly dispersed

Current Work – TRISO Particle Patterns

Pebble Model (simple cubic)	k-infinity (Mirror)
Heterogeneous	1.50816 ± 0.00083
Semi-Random	1.51353 ± 0.00101
Iris	1.52369 ± 0.00080
Pupil	1.62360 ± 0.00083
Bottom	1.61094 ± 0.00075

- TRISO particle patterns impact k_{∞} and the neutron energy spectrum



Current Work – Pebble Sensitivity Study



- Attend INMM meeting in Vienna in May to see results 🤖

Future Work (Next 6 Months)

- Publish k_{∞} related work in Nuclear Engineering and Technology
- Create pebble NDA MCNP models
- Start full core modeling
- Start INDEPTH modeling
- Take my daughter to the water park for her birthday

Acknowledgements

- Savannah Fitzwater and Ben Cipiti
- Claudio Gariazzo, Yonggang Cui, Philip Gibbs, Donny Hartanto
- Everyone in this room for the constructive feedback on this work



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