

HTGRs and FHR Research Capabilities and Needs

Panelists:

David Reger, INL

Jacob Hirschhorn, INL

Josh Hanophy, INL

Laurent Capolungo, LANL

Robby Kile, INL

Moderator: Ling Zou, ANL



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Introduction to Panelists



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Multi-physics TA Highlights

David Reger, INL

Ling Zou, ANL

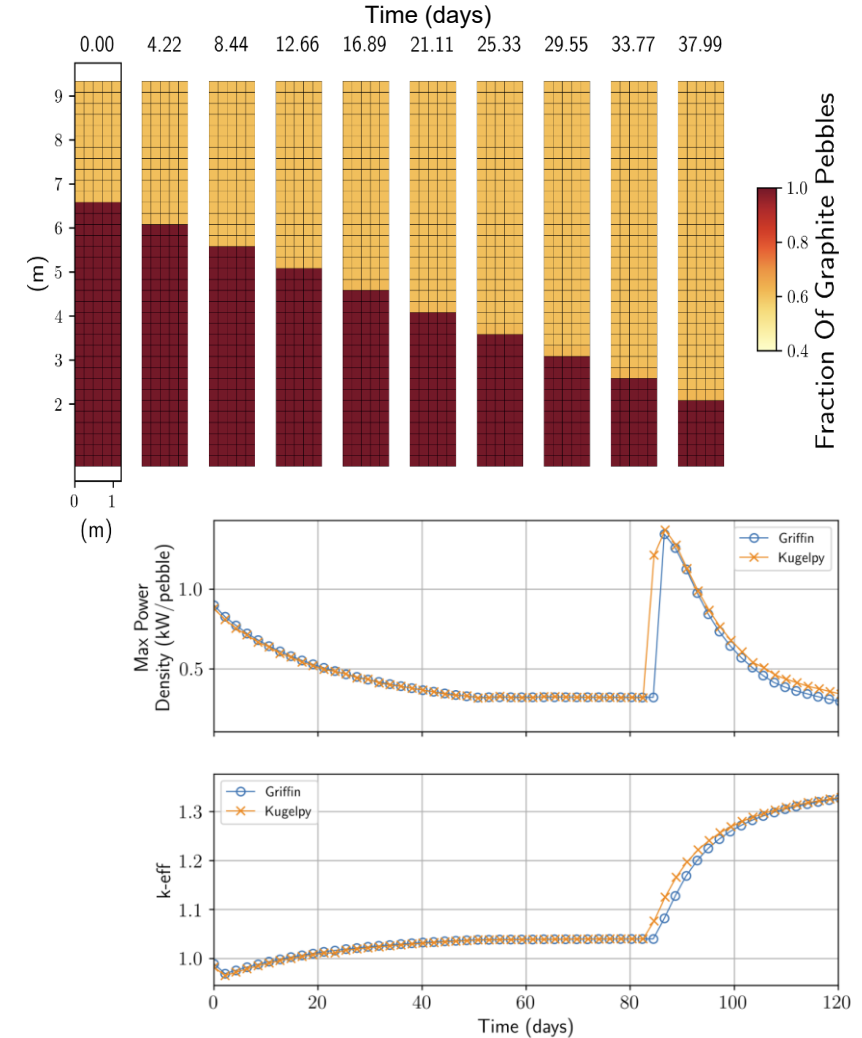


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Multi-physics Area – PBR Running-in Simulation

- Developing capabilities for modeling the running-in process in pebble bed reactors with Griffin.
- Improvements were made to the definition of pebble movement streamlines in FY25.
- Comparing Griffin with high-fidelity running-in simulation using Kuglepy as a reference Lagrangian solution. Good agreement is achieved between codes.
- Current work this FY is applying Griffin's online cross section generation capabilities to the running-in models.

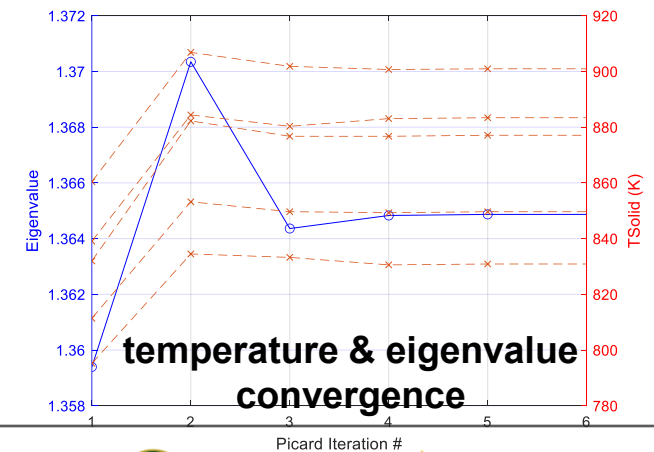
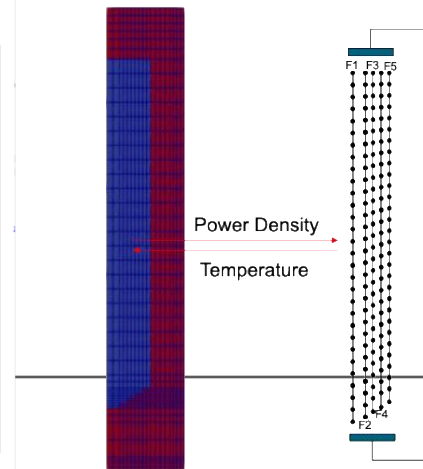
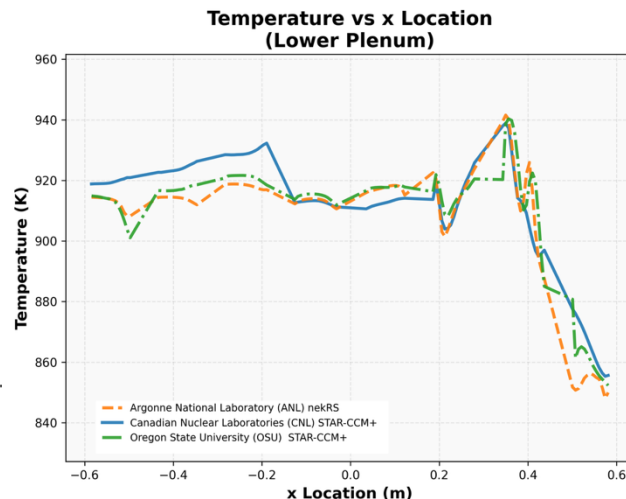
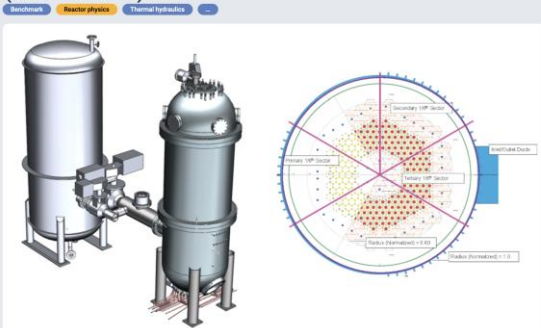


Multi-physics Area – Codes Benchmark and Demonstration

- OECD/NEA HTTF international benchmark being successfully wrapped up led by the ART-GCR INL team.
- All participating organizations have submitted their results for the three benchmark problems, including PCC, DCC, and lower plenum mixing.
- A final OECD/NEA report is being developed to wrap up the benchmark, in which Argonne NEAMS HTGR team is leading the PCC problem part as one of the benchmark coordinators.
- An ongoing HTTR multi-physics benchmark case is being studied in close collaboration with the ART-GCR team.
- Multi-physics Griffin/SAM coupling testing on online cross section generation module of Griffin
- Online cross section generation capability is an important new feature of Griffin that could eliminate users' burden to generate their own data.
- A Griffin/SAM coupled simulation was set up to test this capability for a generic pebble bed reactor (GPBR) design, showing good convergence and consistent results.
- Depletion capability will be used to inform thermal hydraulics analysis to gain additional local temperature resolutions using sub-gird models.

Thermal hydraulic code validation benchmark for high temperature gas-cooled reactors using HTTF data (HTGR T/H)

Ongoing



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NEAMS fuels modeling for HTGRs: FY25 accomplishments and outlook for FY26

Presenter: Jacob Hirschhorn

Contributors (alphabetically): Larry Aagesen, Chaitanya Bhave,
Somayajulu Dhulipala, Kyle Gamble, Carlotta Ghezzi, Jacob Hirschhorn,
Wen Jiang, Katheren Nantes, Stephen Novascone, Hongsup Oh,
Pierre-Clément Simon, Ryan Sweet, and Mathew Swisher

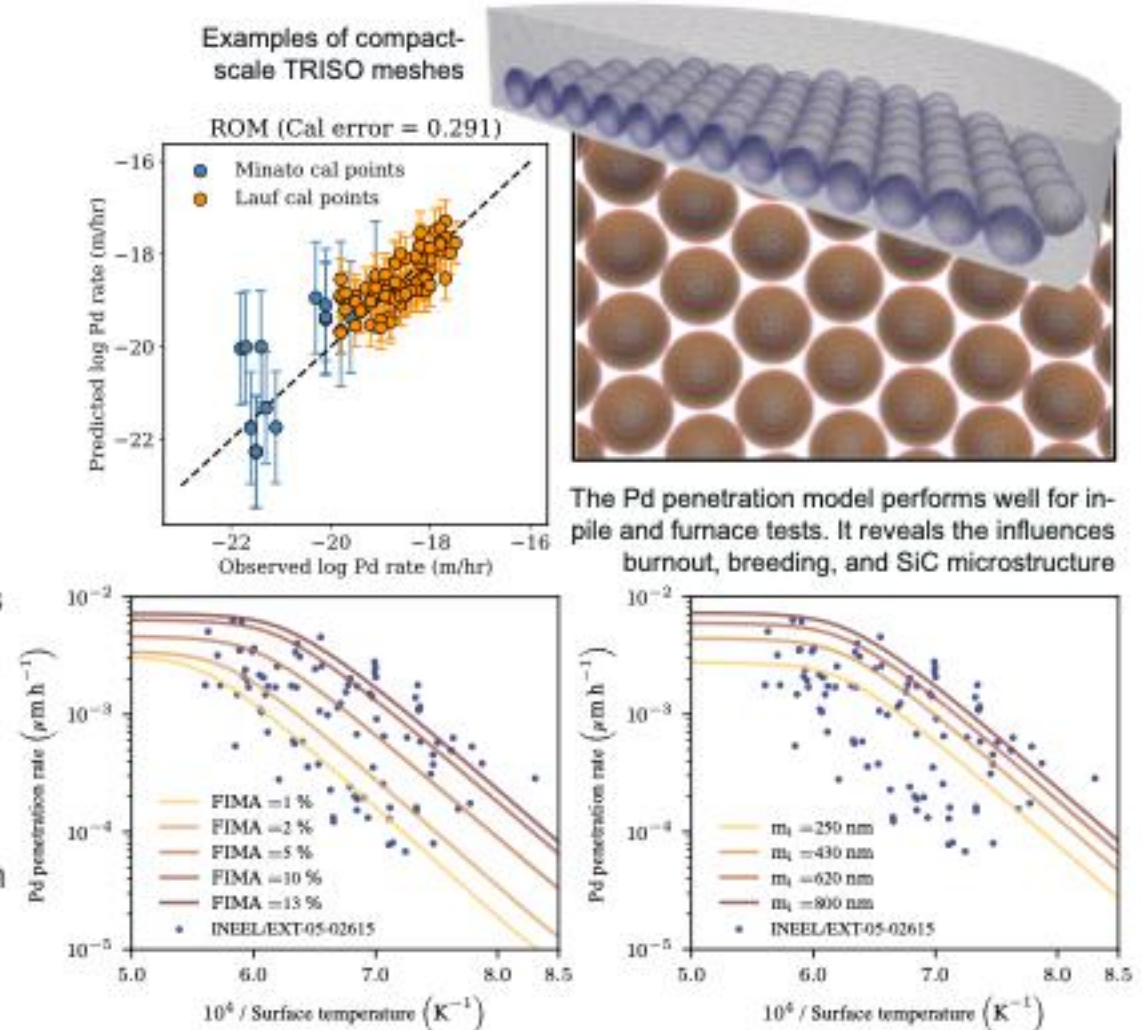


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Summary of accomplishments in FY25

- Continued development of a mechanistic Pd penetration model for the SiC layer of TRISO particles and validated it against historical data (INL/RPT-25-87511, [CMS](#) paper, accepted *JNM* paper)
- Began developing methods for meshing and modeling realistic, spatially-resolved, compact-scale fuel performance
- Developed a BISON validation case for the NSRR transient experiment (INL/RPT-25-88014, *NED* submission)
- Continued development of user-friendly mortar debonding models for TRISO layers using AGR micro-tensile data
- Updated existing BISON validation cases and investigated contributions to observed model inadequacy (INL/RPT-25-88091)
- Published work from prior years ([JNM](#) and [NPJ](#) papers)
- Significant synergies with other DOE programs: AGR, AFC, and ART
 - Refined multiphysics tools for designing TREAT transients with fresh and irradiated particles (INL/RPT-25-87354, [NED](#))
 - Began assessing TRISO time-at-temperature effects (*NED* subm.)



Modeling priorities and plans for FY26 and beyond

- Guiding principles
 - Model observed behaviors for high-priority materials (develop necessary models)
 - Bolster the BISON validation database (assess prediction accuracy)
 - Support qualification, licensing, and deployment by performing broad, systematic uncertainty quantification (make predictions as useful as possible)
 - Tackle high-priority exploratory work (bear the brunt of high-risk work)
- Ongoing tasks
 - Continue involvement with other DOE programs: AGR, AFC, and ART
 - Continue to deliver BISON Training to industry and academia
- Specific FY26 tasks
 - Validate the mechanistic Pd penetration model using modern data, model accelerated corrosion due to IPyC cracking, and link the model to the particle failure probability prediction framework
 - Complete development of user-friendly mortar debonding models for TRISO layers using AGR micro-tensile data
 - Perform a preliminary assessment of potential UN kernel performance using capabilities developed by the fast reactors technical area
 - Continue developing methods for meshing and modeling realistic, spatially-resolved, compact-scale fuel performance
 - Begin developing mechanistic, material-specific models for UCO kernels

Improve
understanding
and predictive
capabilities

Facilitate
qualification,
licensing, and
deployment

Support
operating margin
reduction



Thermal Hydraulics TA Highlights

INL: David Reger, Peter German

ANL: Rui Hu, Ling Zou



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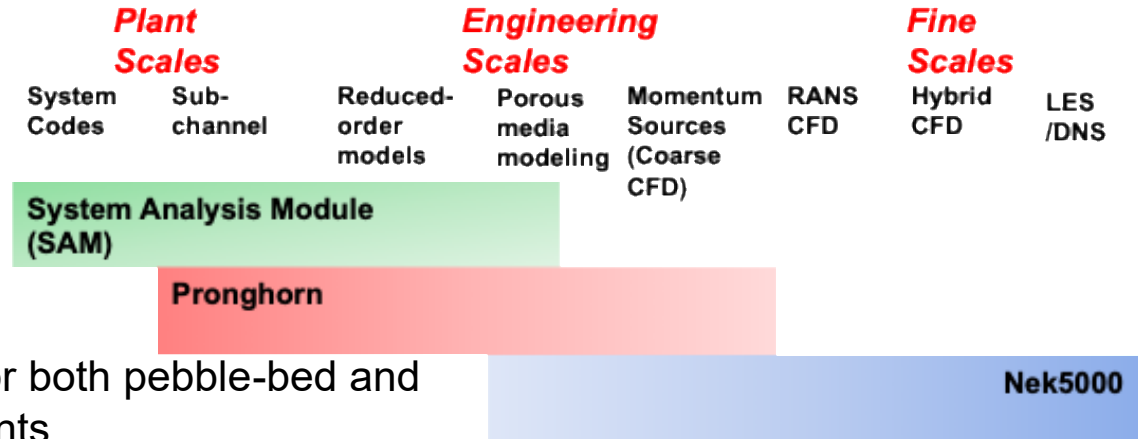
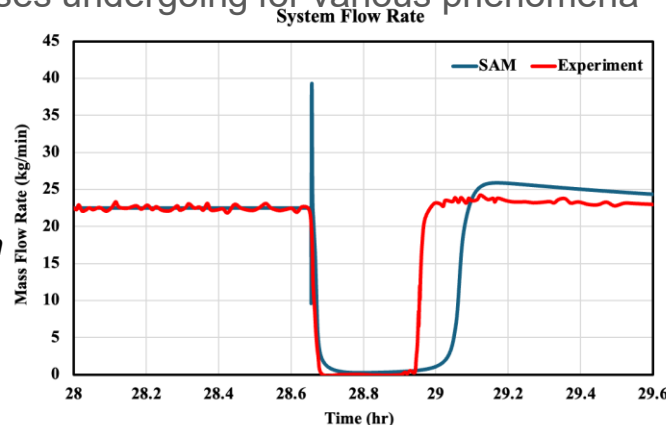
System-scale Modeling Capability

- NEAMS develops different tools to answer the needs for modeling and simulations of thermal and fluid flow phenomena involving a wide range of length and time scales.

- SAM** (System scale)

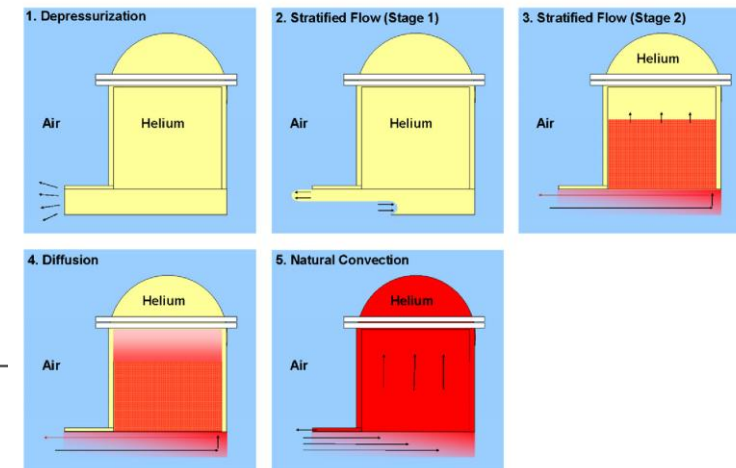
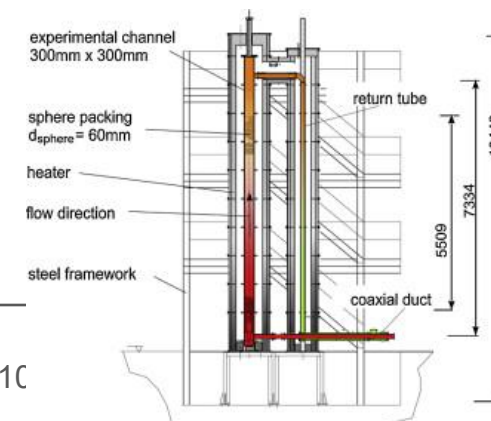
- Develop system-level thermal fluids modeling methodologies for both pebble-bed and prismatic gas-cooled reactors for both steady-state and transients
- Recently focusing on code enhancement for air ingress event simulation
 - Develop/improve capabilities for multi-component gas mixture flow model
 - Develop/improve graphite oxidation model
 - Implement critical flow model for break flow
 - Multiple validation cases undergoing for various phenomena

NSTF Ar-Ingress test validation
(supported by Multiphysics Application TA in FY26)



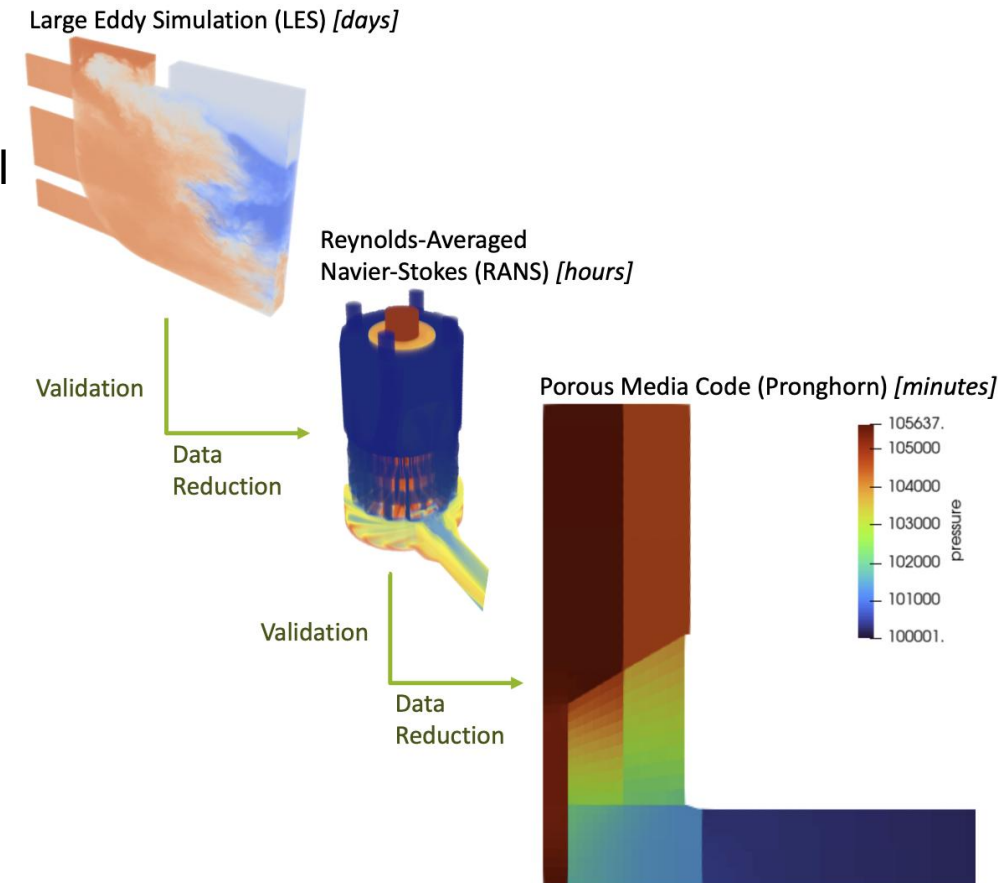
Air-ingress in HTGR (Oh and Kim, 2011)

NACOK test facility



Engineering- and Low Length-scale Modeling Capability

- **Pronghorn** (Engineering-scale)
 - Pronghorn was applied to simulation of lower plenum mixing in a pebble-bed HTGR.
 - Results were compared between a pronghorn porous media model and a RANS model to assess the accuracy of porous media correlations.
 - Development continued on an overlapping domain coupling between Pronghorn and SAM to couple multi-D core models with 1D system models.
 - New solvers were implemented in Pronghorn to provide significant computational speed improvements. Porous media capabilities for these solvers are in development.
- **NekRS/Nek5000** (Lower length scale)
 - Support benchmark simulation of HTTF lower plenum mixing validation
 - Implemented models for radiation heat transfer



Reactor Physics TA Highlights

Josh Hanophy, INL



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NEAMS Reactor Physics – FY25

Technical Area Overview

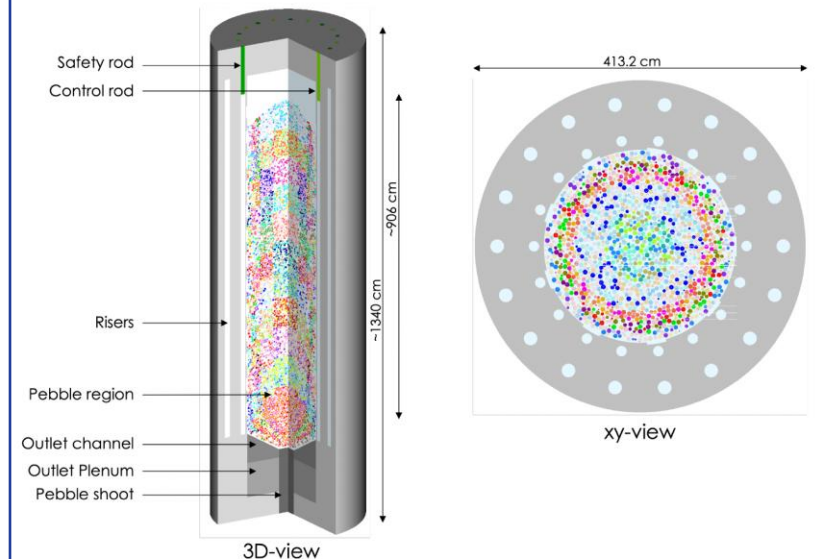
- ❖ **Goal:** Develop and deploy codes for modeling **neutral particle transport** and **nuclide depletion/decay**
- **Griffin:** non-LWR MOOSE-based reactor physics code focusing on transients and multiphysics modeling
- **Shift:** LWR and non-LWR Monte Carlo (MC) reactor physics code (ORIGEN depletion)

FY25 Griffin Updates

- Deployed improvements to online-xs for thermal reactors:
 1. Accuracy improvements to self-shielding method
 2. On-the-fly condensation with leakage correction
- Deployed macroscopic cross section generation with poison tracking for PBRs (currently for offline cross section method only)

FY25 Shift Updates

- Deployed *kugelpy* with Shift and demonstrated a GPBR model



Shift GPBR-200 model



NEAMS Reactor Physics – Look Ahead

FY26 and Beyond

1. Continued improvements to Griffin online-xs for thermal reactors:
 - a) Transient capability and optimizations
 - b) Adding depletion capability for prismatic core reactors (capability for PBRs already implemented)
2. Griffin perturbation capability reported in FY25 for fast reactors and micro-reactor problem will be demonstrated for HTGR in the future
3. Continued improvements and investigations into Shift for generating reference solutions for Griffin benchmarking

Milestones for More Information

1. T. Pandya, et al., “Demonstration of Monte Carlo Reference Equilibrium Core Solutions for Pebble Bed Reactors Using Shift in kugelpy,” Jul. 2025. url: <https://www.osti.gov/biblio/3013655>
2. H. Park, C. Lee, “Improvement and Verification of Online Cross Section Generation Capability of Griffin for TRISO-fueled Reactors,” Sep. 2025, ANL/NSE-25/82. url: <https://www.osti.gov/biblio/2998013>
3. S. Jeon, et al., “Implementation of Perturbation Theory and Sensitivity Capabilities in Griffin,” Sep. 2025, ANL/NSE-25/73. url: <https://www.osti.gov/biblio/2997904>



Structural Materials & Chemistry TA Highlights

V. Vivekanandan, J. Joy, A. Talapatra, A. Ruybalid, L. Capolungo

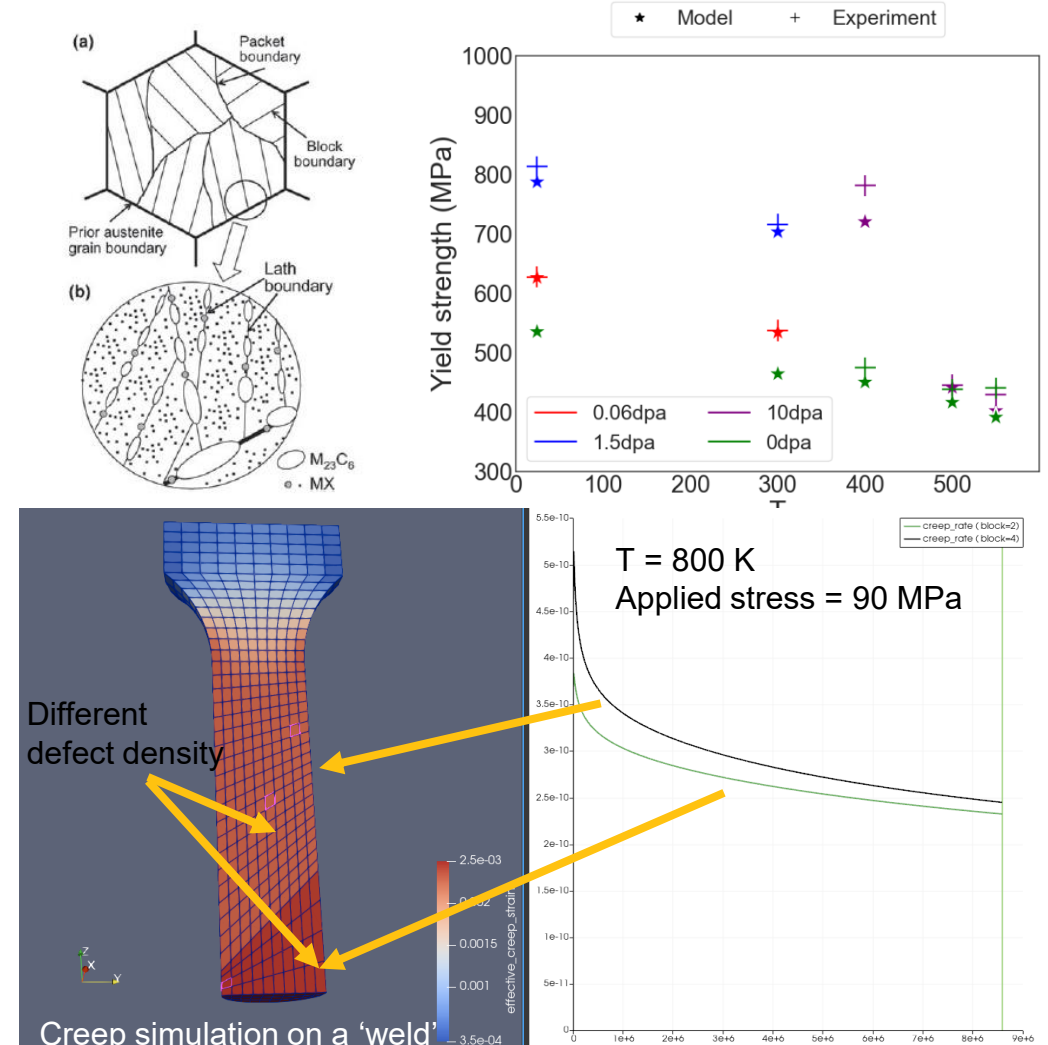


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Key accomplishments: structural materials

- ❑ We can predict the performance envelope of Grade 91 during tensile and creep loads.
- ❑ We can relate the mechanical performance of RA/FMs to their microstructure (including the loss of high temperature strength).
- ❑ Predict the post irradiation response of Ferritic/Martensitic steels.
- ❑ Predict the in-pile response of Ferritic Martensitic steels*.
- ❑ Microstructure informed surrogate models have been developed and integrated in MOOSE. A new GUI was developed.
- ❑ Rapidly calibrate our models on new materials systems



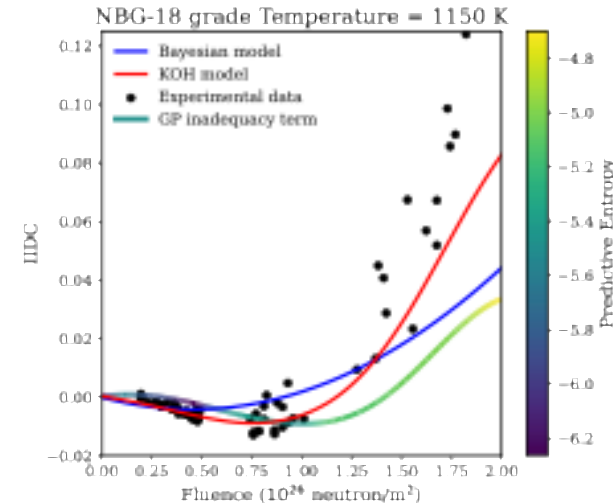
Key accomplishments: Graphite Performance Under Irradiation

❑ Background

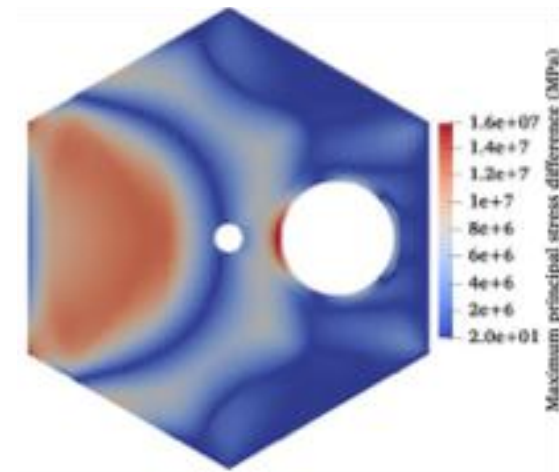
- ❑ Graphite is used extensively as a moderator and reflector in HTGRs and other reactors
- ❑ Under irradiation it experiences shrinkage, swelling, creep, changes to modulus and thermal expansion coefficient
- ❑ This causes multiple operation and safety concerns

❑ NEAMS Efforts

- ❑ FY25 effort expanded the set of graphite models in Grizzly, using a framework that quantifies uncertainty, including a model-form correction term:
 - ❑ Grades: IG-110, NBG-18, PCEA, NBG-17, 2114
 - ❑ Properties: Irradiation-induced dimensional change, creep, elastic modulus, thermal expansion
- ❑ Ongoing work to include more grades, improve model implementations



Irradiation-induced expansion model, showing improved fit to data when model inadequacy correction is included.



Difference in stresses in a prototypical NBG-18 graphite reflector block due to including model inadequacy correction

Future directions

Vision

To maximize impact, microstructure informed models for the mechanical response of engineering metals and metallic structures need to:

- ☐ Facilitate decision making (acceptance of a material, design of experiments) by enabling risk assessment.
- ☐ Enable material selection, (design) and rapid screening of material solution
- ☐ Be trustworthy to extrapolate in extreme environments (irradiation, corrosion, etc.)

Proposed milestones

- ☐ Develop surrogate constitutive models capturing the effects of irradiation.
- ☐ Develop predictors for failure (ductile failure and loss of ductility) as a function of irradiation conditions and microstructure.
- ☐ Develop both spatially resolved and homogenized cluster dynamics models for microstructure evolution
- ☐ Deploy this framework to new materials systems
- ☐ Long Term: introduce strong coupling with environmental effects





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