February 10, 2026

Tommy Holschuh
Radiochemistry and Nuclear Measurements Department

Uncertainties in Power Coupling Factors and Uranium Fissile Split in the Transient Reactor Test (TREAT) Facility

Idaho National Laboratory

Layout

- TREAT Reactor
- Issues #1-#2 and Solutions
- TREAT BUSTER Conversion
- Issue #3 and Solution
- Summary

Layout

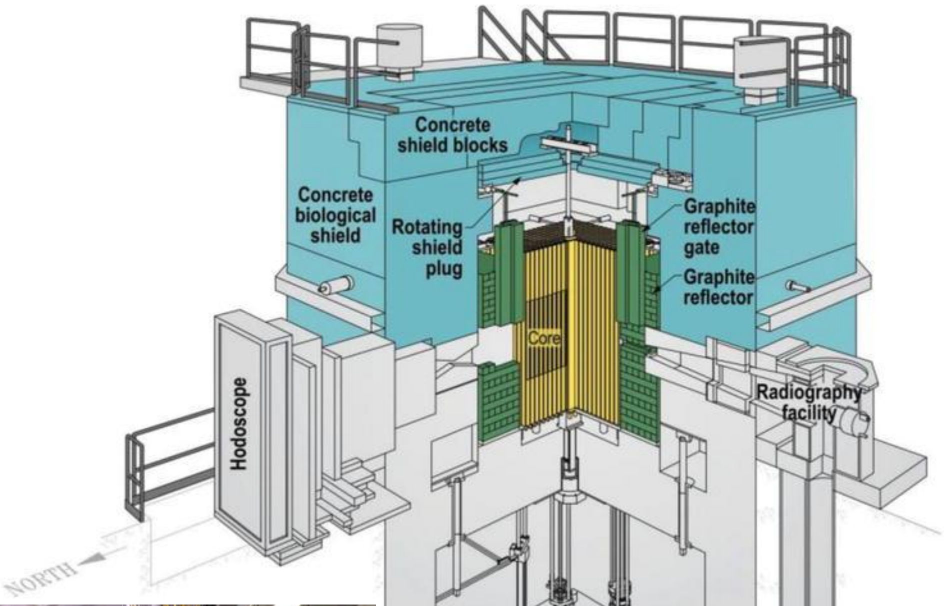
- TREAT Reactor
- Issues #1-#2 and Solutions
- TREAT BUSTER Conversion
- Issue #3 and Solution
- Summary

Transient Reactor Test (TREAT)

- Unique characteristics
  - Built in 1959
  - Graphite moderated core, limited to 600 °C
  - HEU fuel dispersed in graphite
  - 1 atom U per 10,000 atoms C
  - One test position

- Transient rods forcibly moved in both directions
  - Clipped pulses
  - Shaped transients

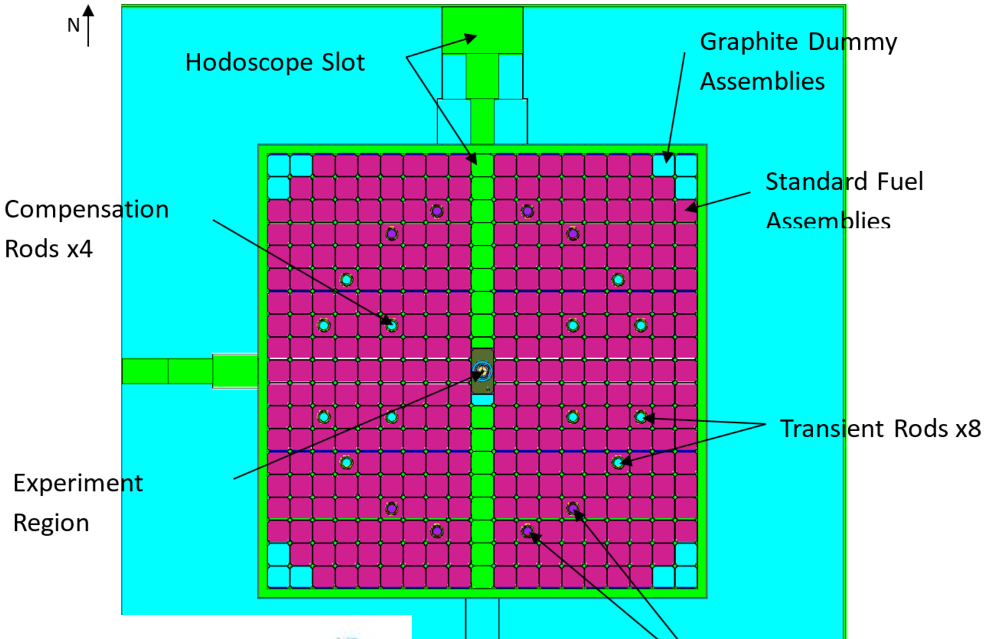
- Purpose is “crash test” nuclear fuel

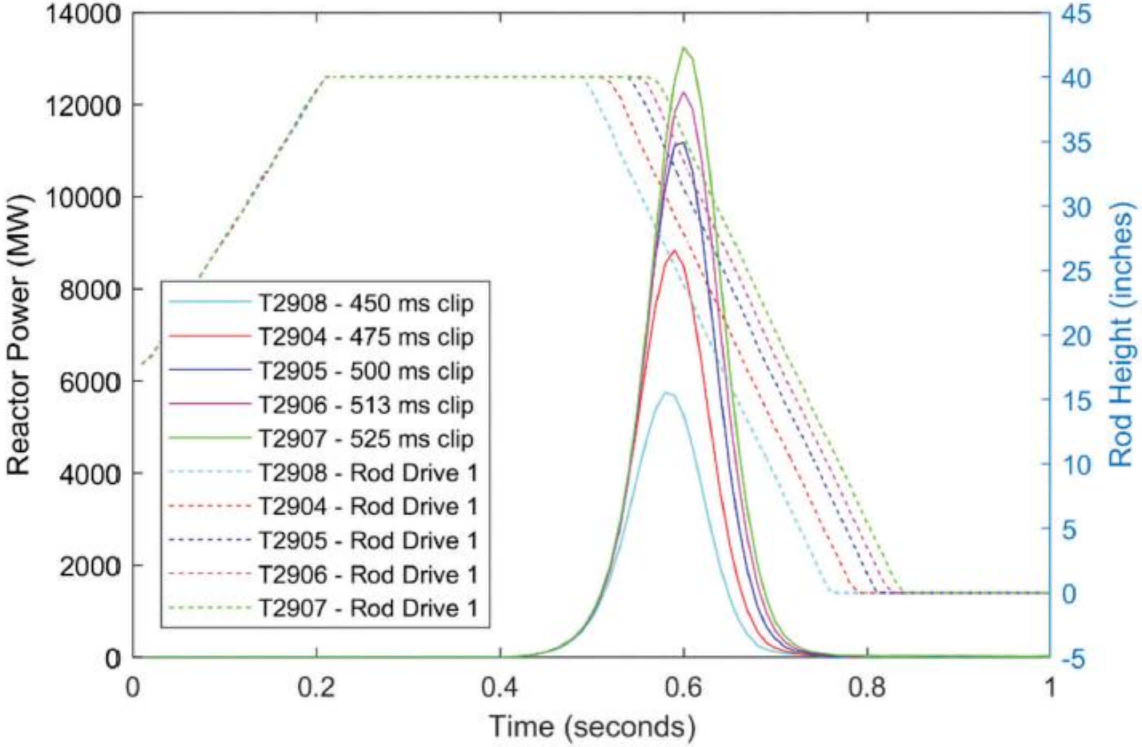


Transient Reactor Test (TREAT)

- Adiabatic and leaky
- Half-slot or full-slot core designs
- Reactivity insertions up to 4.2 %Δk/k (~$5.80)
  - Larger insertions in wintertime in Idaho
- Prompt neutron lifetime
  - 880 ms
- Neutron migration length
  - ~ 2 meters
- ~3400 transients

- 80 kW steady-state
- 20 GW peak transient
- Minimum 89 ms transient



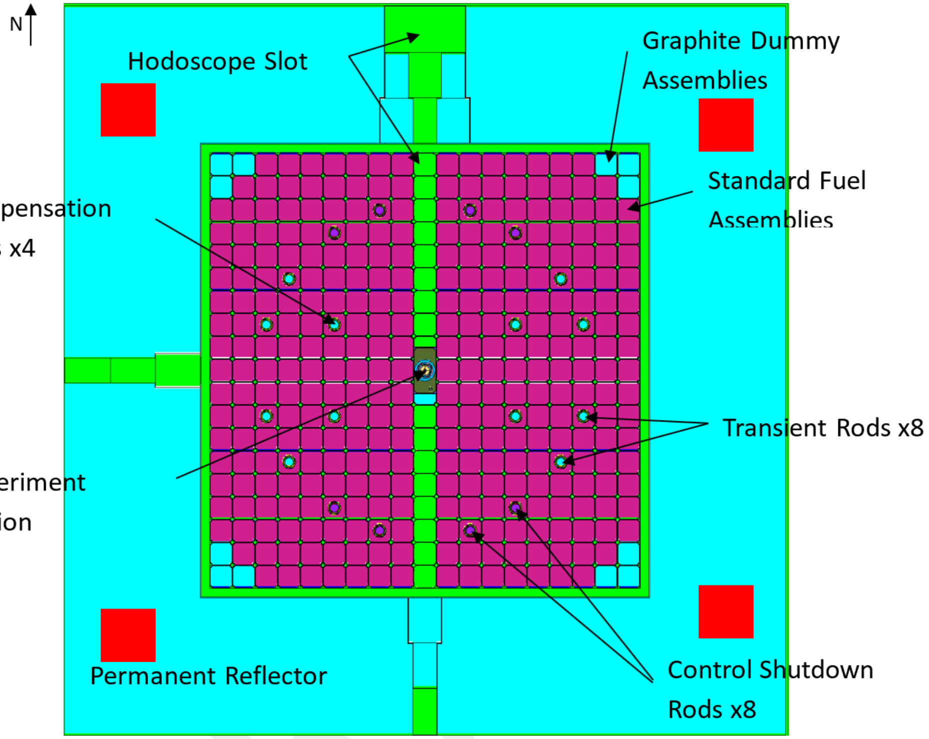


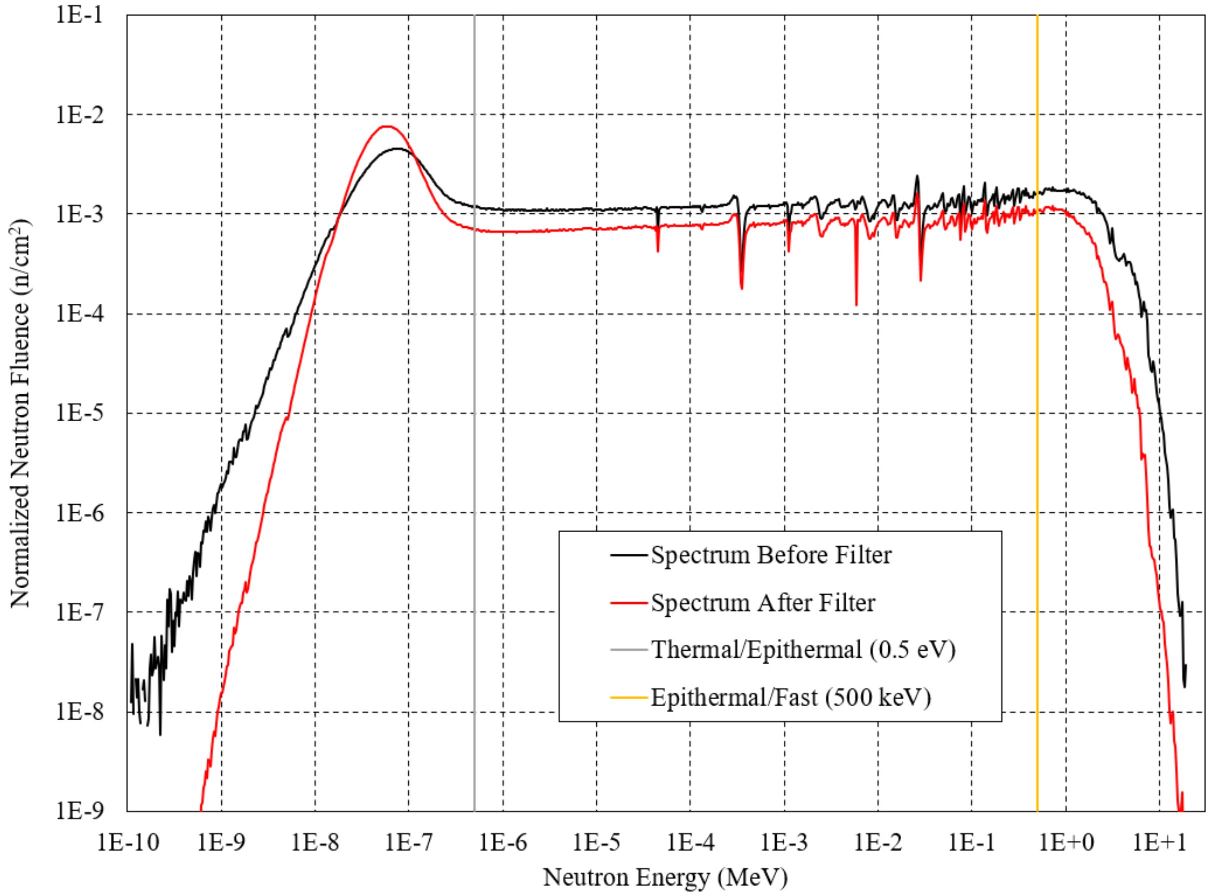
Layout

- TREAT Reactor
- Issues #1-#2 and Solutions
- TREAT BUSTER Conversion
- Issue #3 and Solution
- Summary

Issue #1: Instrument Position

- Neutron detectors located in bio shield
- The power, and total energy released, is unknown in TREAT.
- Instead, power is referred by MW_{TREAT}





Fraction Reduction in Each Energy Regime	Before Filter	After Filter	Percentage Change
Thermal (E <= 0.5 eV)	0.319	0.399	25.0
Epithermal (0.5 eV < E < 500 keV)	0.579	0.376	-35.1
Fast (E >= 500 keV)	0.102	0.050	-50.8
Total	1.000	0.825	-17.5

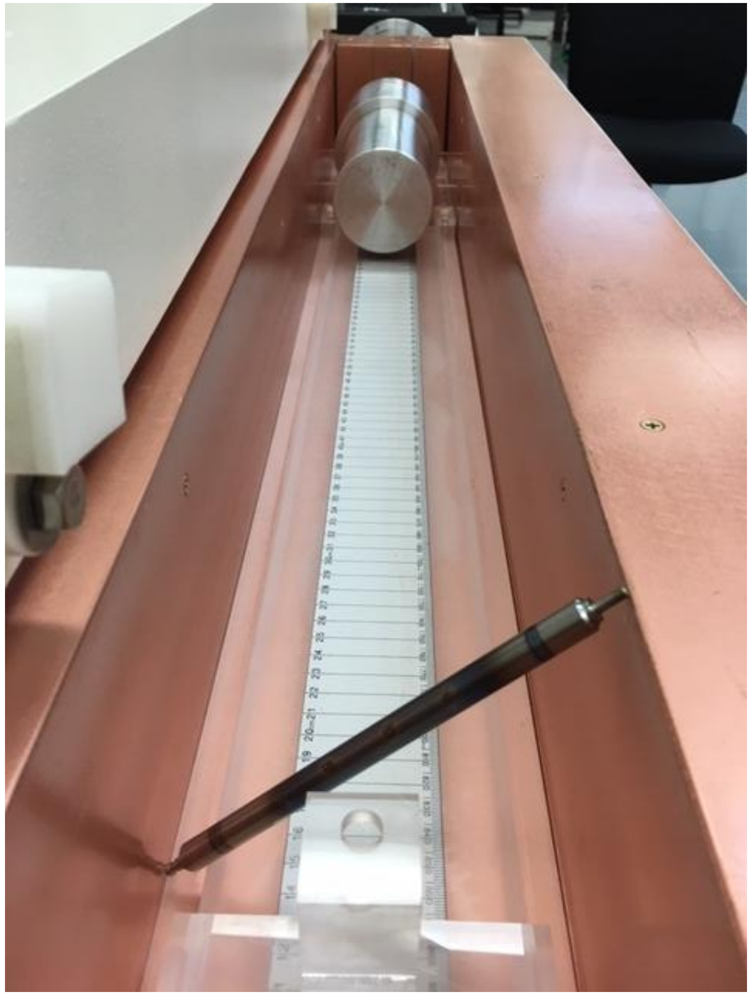
Issue #2: Q-value

- ~200 MeV per fission is typical number found in literature
- For TREAT computational modeling, 182 MeV/fission matches
- Core is not airtight, so a "heat balance" is difficult
- Transient versus steady-state
- Repeated experiments have confirmed ability of engineering, modeling, and diagnostics to predict future reactor behavior.

Component	Energy (MeV)
Fission Fragments	168
Fission Product Decay (i) Beta-rays (ii) Gamma-rays	 8 7
Neutrinos	12
Prompt Gamma-rays	7
Prompt Neutrons	5
Total	207

Solution #1-2: There are ways around it

- Relative power is all that's needed
- Power Coupling Factor:
  - Joules of energy deposited in target fuel
  - $J/gUO_2/MJ_{TREAT}$
  - A "calibration run" with exact fuel/coolant configuration
  - Gamma spectrometry used to determine fissions
- Power coupling factor is extremely sensitive
  - Water in experiment capsule 2x multiplier
- Transient versus static power coupling factor as well
- Neutron activation performed (~8-10 reactions) to ascertain fluence spectrum

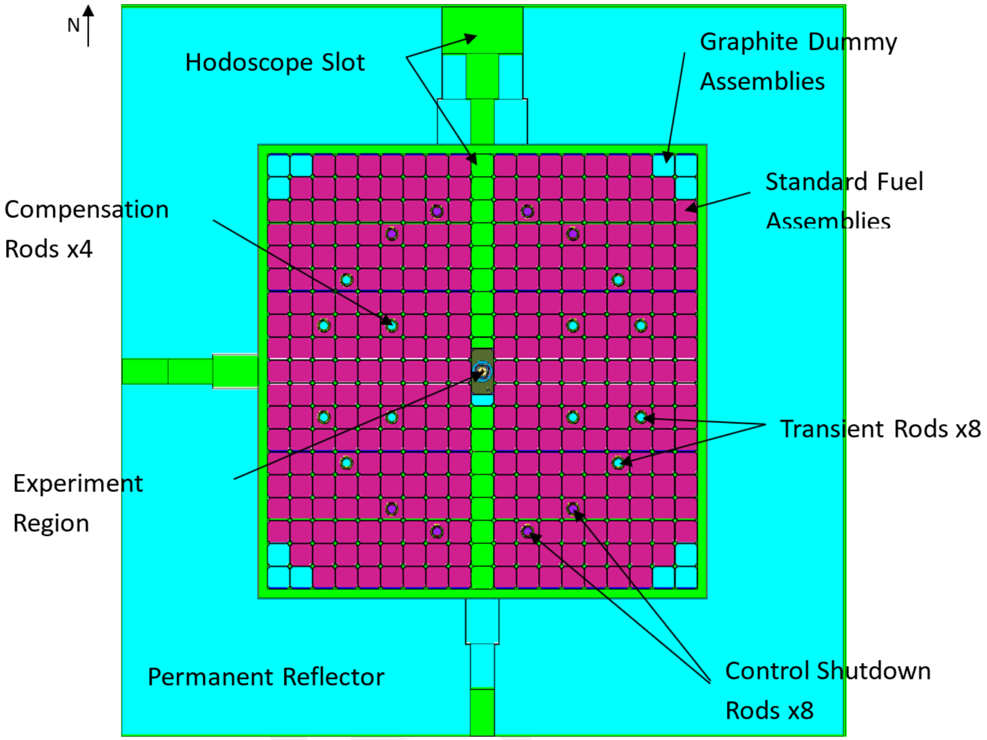


Layout

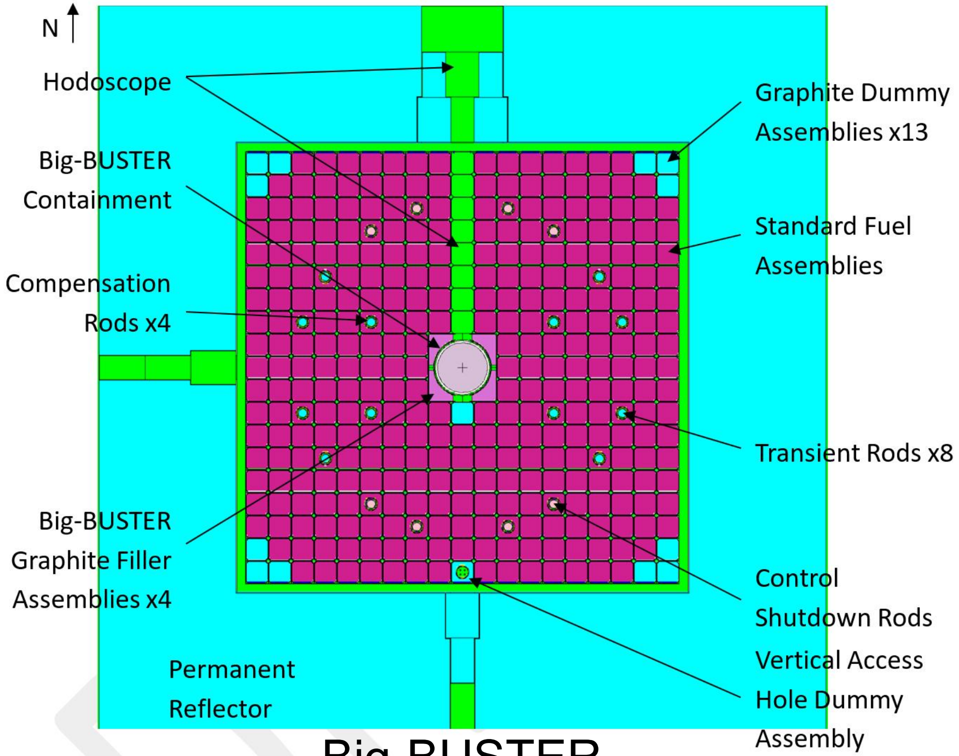
- TREAT Reactor
- Issues #1-#2 and Solutions
- TREAT BUSTER Conversion
- Issue #3 and Solution
- Summary

TREAT Reactor Conversion

- BUSTER to Big-BUSTER configuration
  - Broad Use Specimen Transient Experiment Rig
  - September 2023 Converted



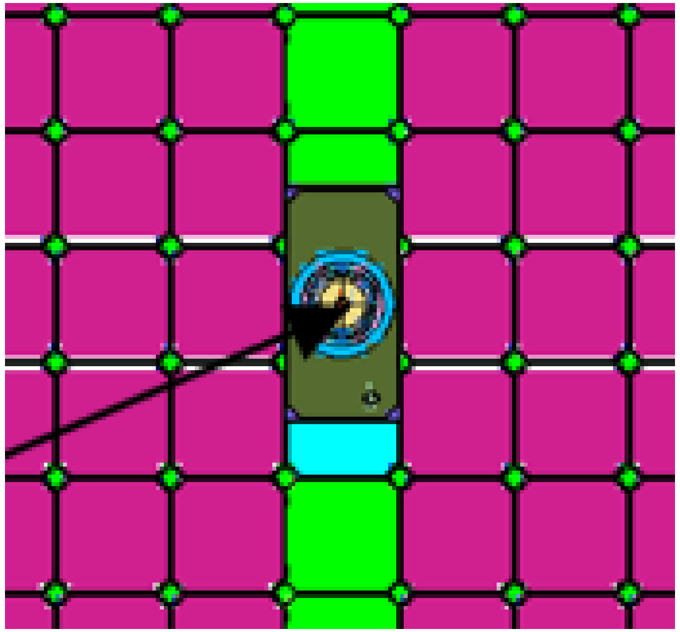
BUSTER



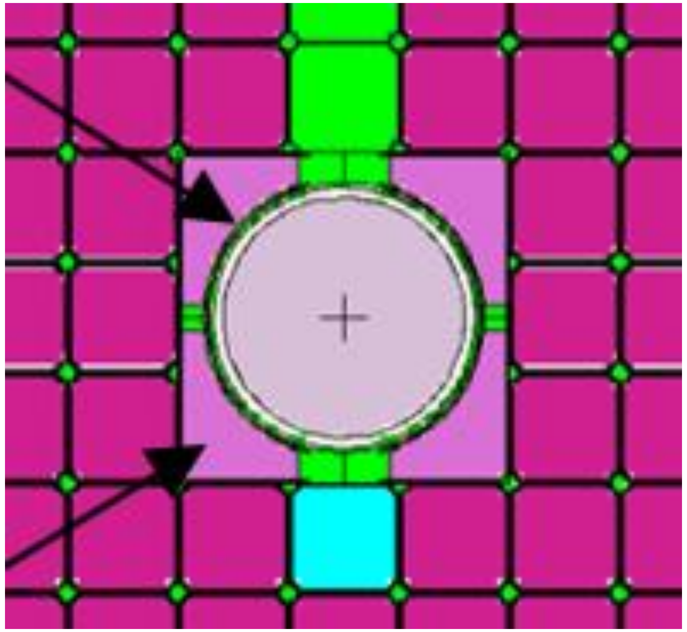
Big-BUSTER

TREAT Reactor Conversion

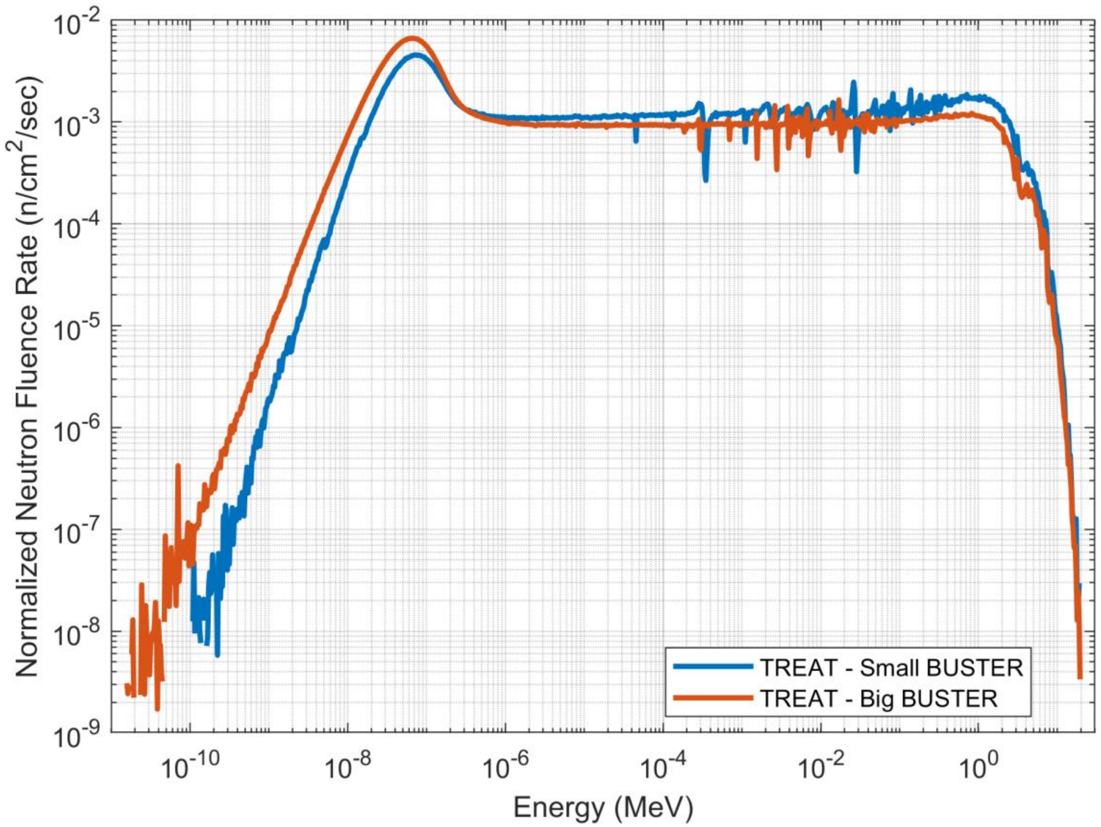
Fluence Region	TREAT (Small)-BUSTER	TREAT Big-BUSTER
Thermal	0.32	0.47
Epithermal	0.58	0.46
Fast	0.10	0.07



BUSTER



Big-BUSTER



(Small)-BUSTER = 1.75 x 10^{16} n/cm^2 per 2000 MJ

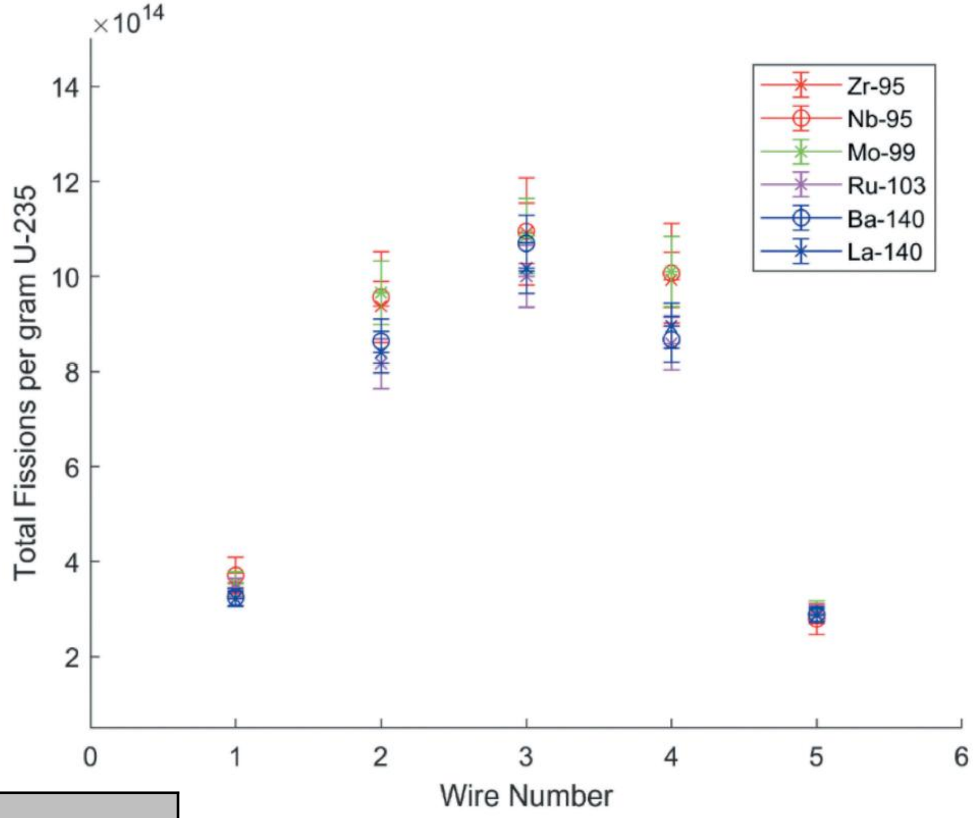
Big-BUSTER = 8.08 x 10^{16} n/cm^2 per 2000 MJ

Layout

- TREAT Reactor
- Issues #1-#2 and Solutions
- TREAT BUSTER Conversion
- Issue #3 and Solution
- Summary

Issue #3: Fission Split

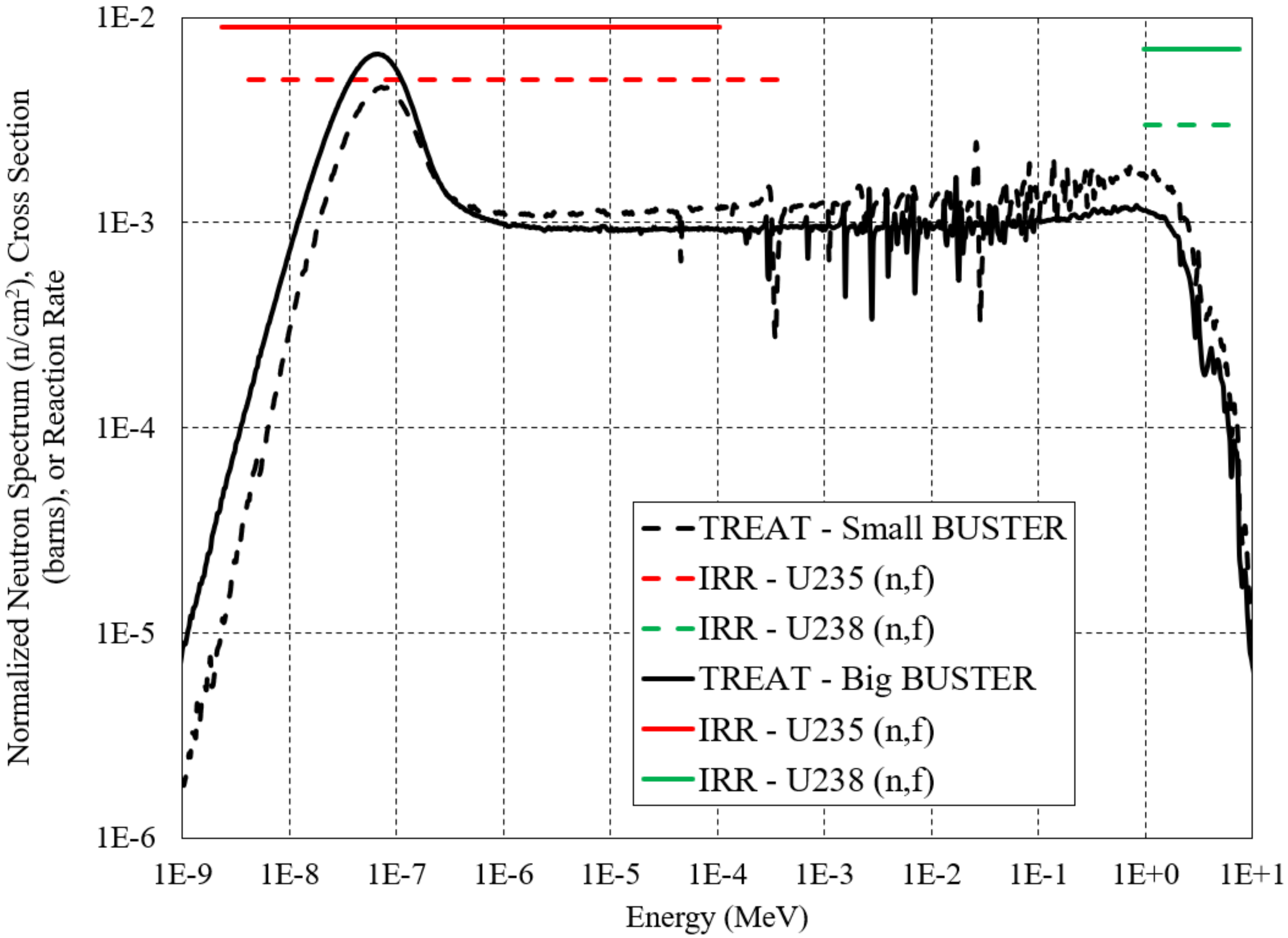
- Difference in fission yields for ^{235}U and ^{238}U
- Specifically, ^{103}Ru
- Approximately double in CFY for ^{238}U compared to ^{235}U thermal or fast fission



Uranium Type	U235/U238 Fissions	
	TREAT (Small)-BUSTER	TREAT Big BUSTER
Depleted Uranium	11.5	29.3
Natural Uranium	41.5	106
Low-Enriched Uranium	238	608
HALEU	1,407	3,593
High Enriched Uranium	82,265	209,991

Solution(?) #3:

- CTFW #4 (BUSTER):
  - ^{103}Ru/^{99}Mo: 1.13 +/- 0.03
  - 1.09 derived from previous slide
- FFC (Big-BUSTER)
  - ^{103}Ru/^{99}Mo: 1.01 +/- 0.03
  - 1.00 derived from previous slide)
  - If ratio is equal to 1, ^{238}U fissions cannot be differentiated
- Improvement to ^{103}Ru nuclear data
  - Uncertainty is already 1.34% in gamma
  - Fission yield uncertainty is 1.4%



Layout

- TREAT Reactor
- Issues #1-#2 and Solutions
- TREAT BUSTER Conversion
- Issue #3 and Solution
- Summary

Summary

- TREAT's focus is nuclear fuel
- Improvements in fission yields and gamma-ray branching ratios would be useful
  - Particular fission products that reveal differences between irradiation conditions is most useful

- Positioning of instrumentation impacts the implementation of nuclear data for useful measurements

- The list of new SMR demonstrations at INL in the next few years will present similar challenges

References

- J.D. Bess and M. D. Dehart, “Baseline Assessment of TREAT for Modeling and Analysis Needs,” INL/EXT-15- 35372, Idaho National Laboratory (2015).
- M.N. Cinbiz, et al., “A Pulse-Controlled Modified-Burst Test Instrument for Accident-Tolerant Fuel Cladding,” Ann. Nucl. Energy, 109, 396 (2017); https://doi.org/10.1016/j.anucene.2017.05.058.
- G. A. Freund, H. P. Iskendarian, and D. Okrent, “TREAT, A Pulsed Graphite-Moderated Reactor for Kinetics Experiments,” Proc. 2nd United Nations Int. Conf. Peaceful Uses of Atomic Energy, Geneva, Switzerland, 1958, Vol. 10, p. 461 (1958).
- T. Goorley, “MCNP6.1.1-Beta Release Notes,” LA-UR-14-24680, Los Alamos National Laboratory (2014).
- Thomas Holschuh, Nicolas Woolstenhulme, Benjamin Baker, John Bess, Cliff Davis & James Parry (2019): Transient Reactor Test Facility Advanced Transient Shapes, Nuclear Technology
- Thomas Holschuh, Scott Watson & David Chichester (2019) Metrology for Transient Reactor Characterization Using Uranium Wires, Nuclear Technology, 205:10, 1336-1345
- D.D. Imholte and F. Aydogan, “Comparison of Nuclear Pulse Reactor Facilities with Reactivity-Initiated-Accident Testing Capability,” Ann. Nucl. Energy, 91, 310 (2016); https://doi.org/10.1016/j.pnucene.2016.05.012.
- D.R. Macfarlane, G.A. Freund, and J.F. Boland, “Hazards Summary Report on the Transient Reactor Test Facility (TREAT),” ANL-5923, Argonne National Laboratory (1958).
- D. Reilly, et al., “Passive Nondestructive Assay of Nuclear Materials,” LA-UR-90-732, Los Alamos National Laboratory (1991).
- N.E. Woolstenhulme, D.M. Wachs, and A.B. Beasley, “Transient Experiment Design for Accident Tolerant Fuels,” Trans. Am. Nucl. Soc., 111, 604 (2014).
- L. Yegorova, et al., “Data Base on the Behavior of High Burnup Fuel Rods with Zr-1%Nb Cladding and UO2 Fuel (VVER Type) Under Reactivity Accident Conditions,” NUREG/IA-0156, Vol. 2, U.S. Nuclear Regulatory Commission (July 1999).
- International Atomic Energy Agency Nuclear Data Services website; https://www-nds.iaea.org (current as of Nov. 20, 2018).
- “Q-value (MeV/fission) Determination for the Advanced Test Reactor,” Sterbentz, J., October 2013, INL/EXT-13-29256
- “Nuclear Fuel Behavior Under Reactivity-Initiated Accident (RIA) Conditions,” NEA/CSNI/R, Organisation for Economic Co-operation and Development/Nuclear Energy Agency
- “TREAT Baseline Description Document,” ANL/RAS-72-73, Argonne National Laboratory (1972).