OAK RIDGE National Laboratory

Update to Implementing a Subcritical Assembly for Training at ORNL

Presented by Alexander Lang

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NCSP TPR in Santa Fe, NM

December 5, 2024

U.S. DEPARTMENT OF ENERGY

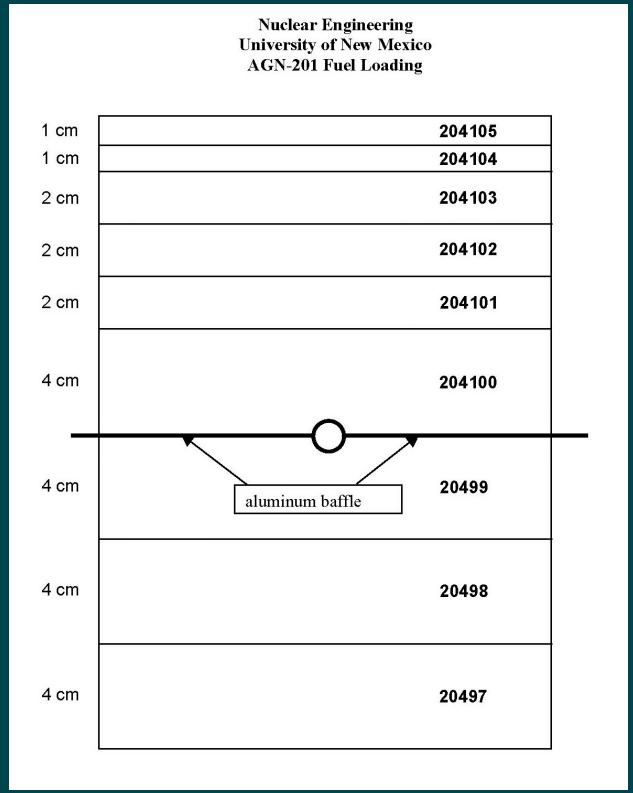
ORNL IS MANAGED BY UT-BATTELLE LLC
FOR THE US DEPARTMENT OF ENERGY

Outline

- Background
- Previous Design
- New Design and Changes
- Current Progress
- Summary

Subcritical assembly derived from the AGN-201M Reactor

- Designed in the 1950s
- UO_2 powder matrixed in polyethylene
- Enriched near 20 wt% ^{235}U
- Capable of going critical with 665 g ^{235}U
- Y-12 has 4 retired reactors in storage
- A DOE/NRC Collaboration for Criticality Safety Support (DNCSH) proposal has been submitted to benchmark the Idaho State University (ISU) Aerojet-General Nucleonics (AGN)-201m Reactor



Slice view of AGN-201 Reactor Configuration

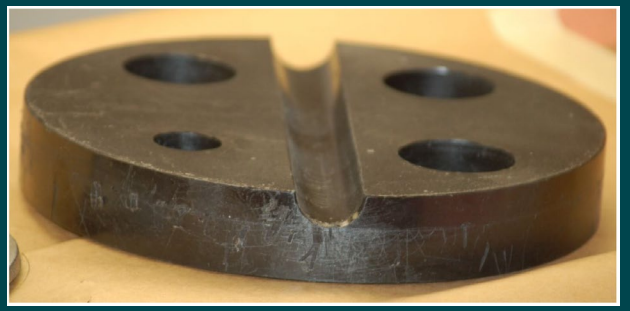


Plate 204100

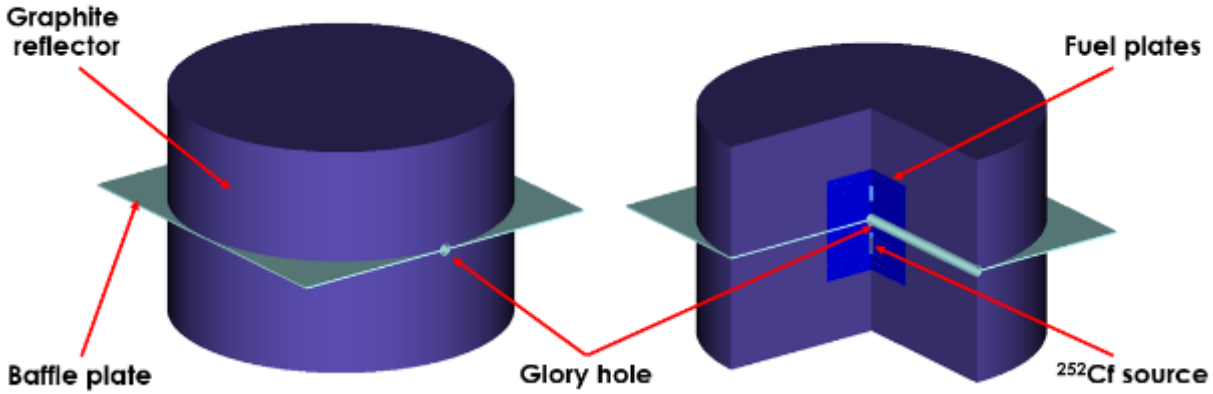
1- or 2-cm plate

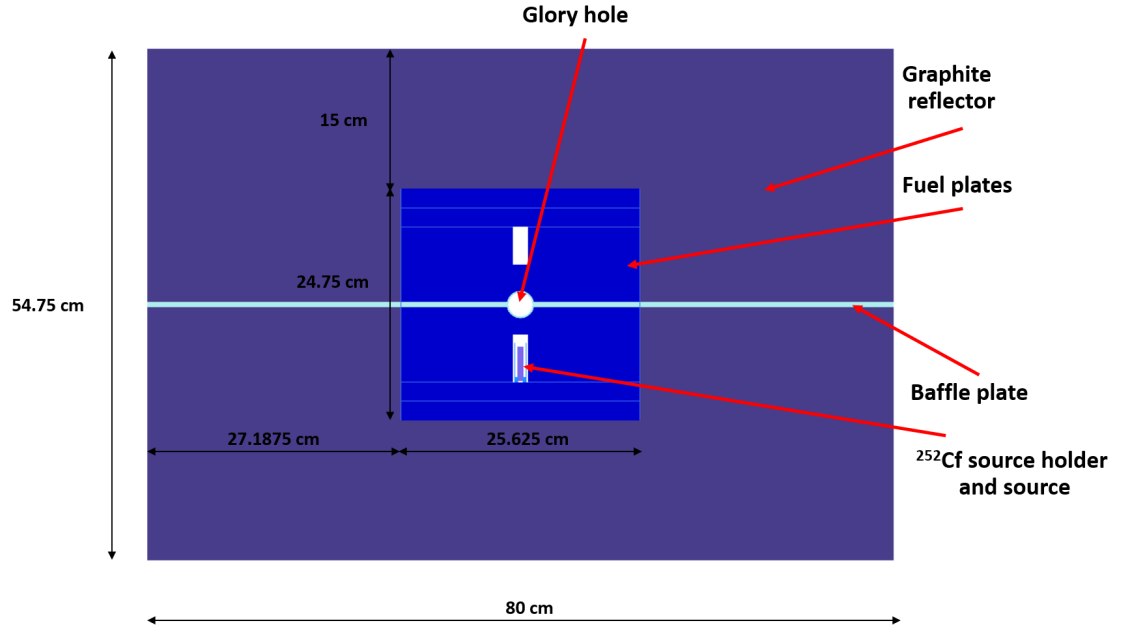
Previous Design of the Subcritical Assembly

Feasibility Report: ORNL/TM-2020-1598

Design Report: ORNL/TM-2022/2748

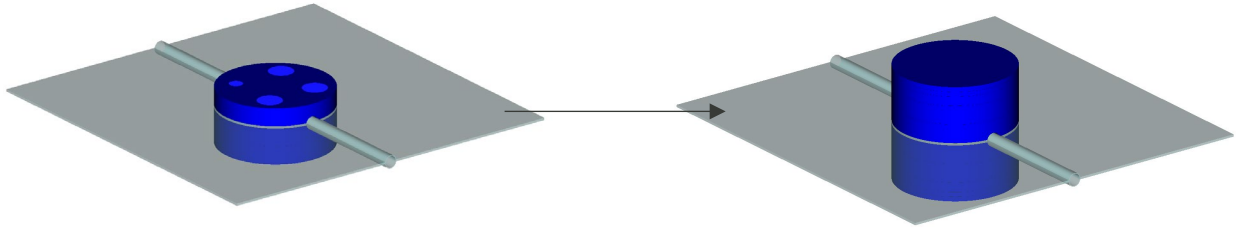
- Essentially reorganized form of the AGN-201M reactor
- Considers aluminum cladding of fuel
- Graphite Reflector



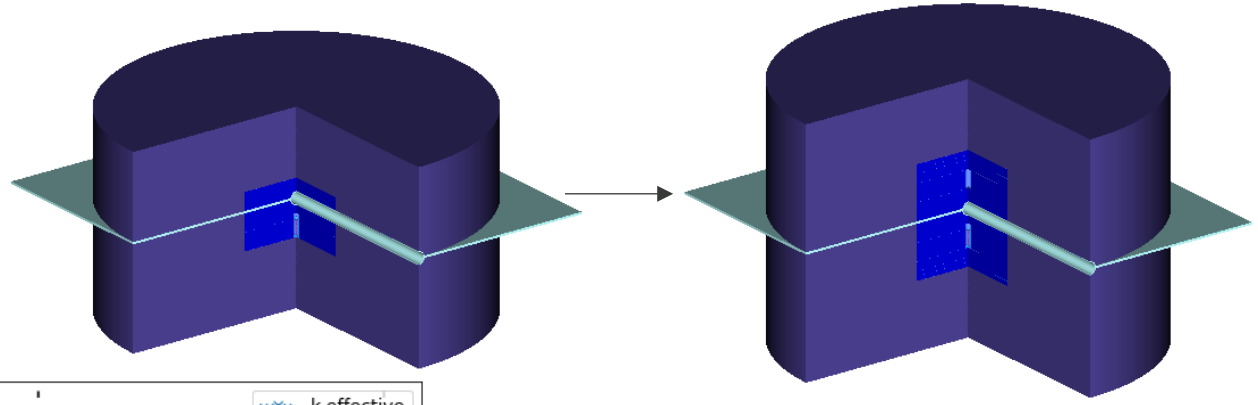


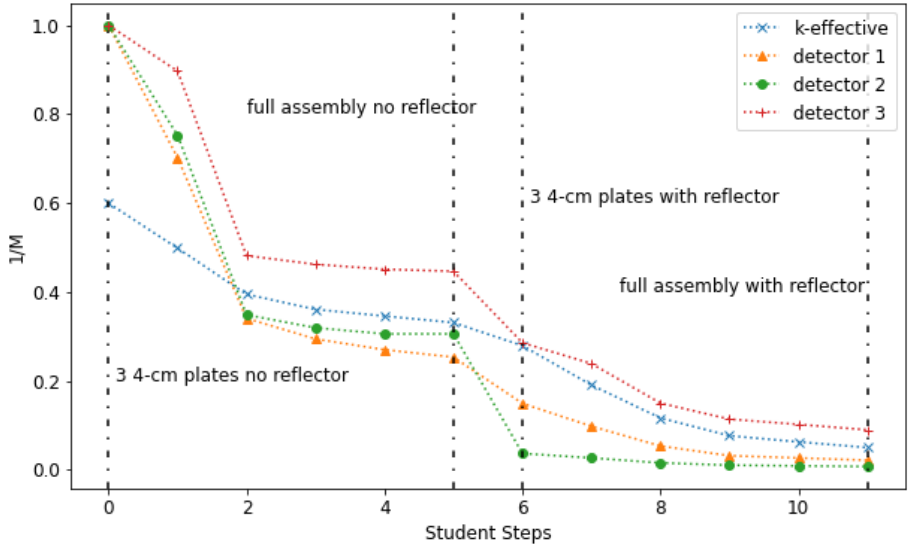
Experiments using the Subcritical Assembly

Mass



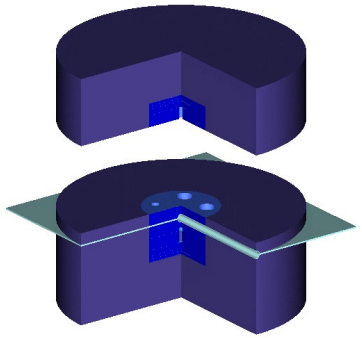
Reflection

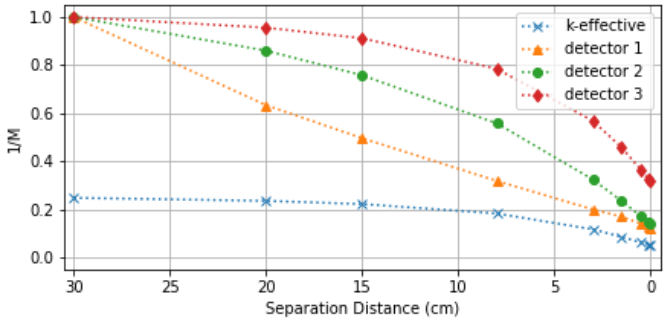




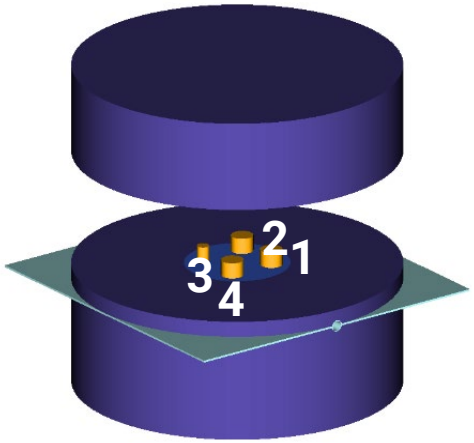
Experiments using the Subcritical Assembly

Interaction





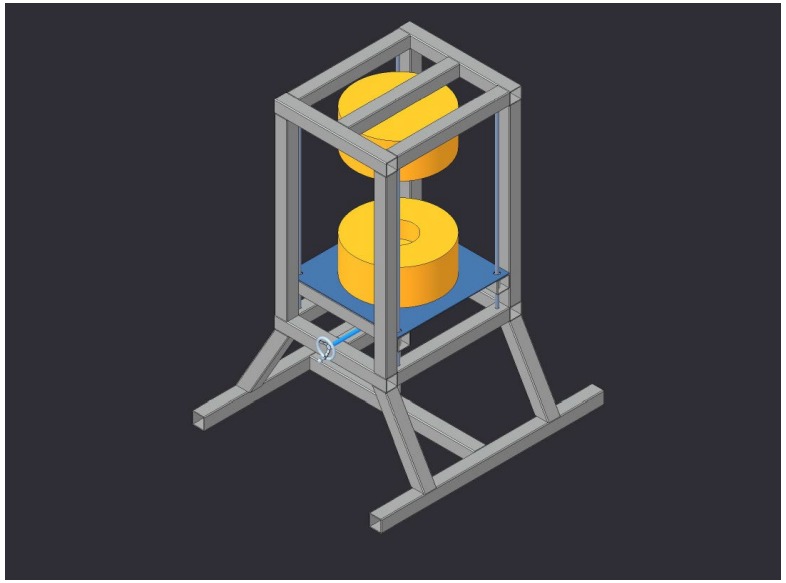
Moderation and Absorption



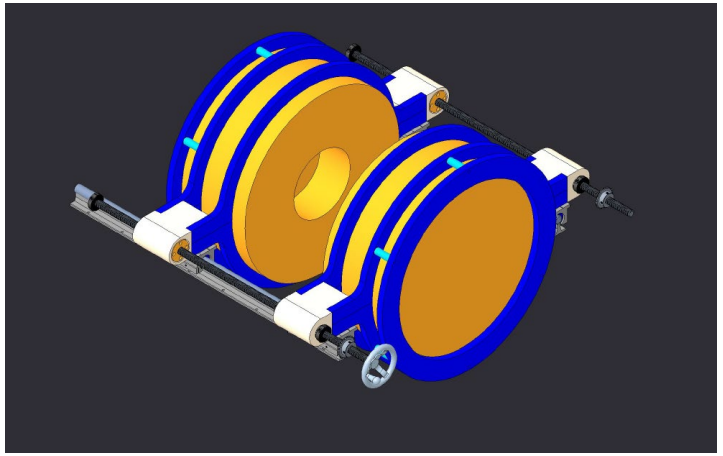
Source Multiplication (M)					
Item	**No Rods**	**Rod 1**	**Rod 1-2**	**Rod 1-3**	**Rods 1-4**
H_2O	20.1	21.4	23.2	23.7	27.2
SS304		15.4	12.4	11	9.2

Design lost sight of simplicity and hands-on capabilities

- The required 1,000 lb graphite reflector makes the system heavy
- Designs to manage weight were becoming complex, adding several industrial safety components
- Challenges with placement of the detector and source should be addressed to remove measurement complexity
- Retrieving material from Y-12 was becoming complex and expensive
    - Opened drums cannot be returned
    - Opening of drums is costly



Base: 62 in. × 72 in.
Height: 90 in.

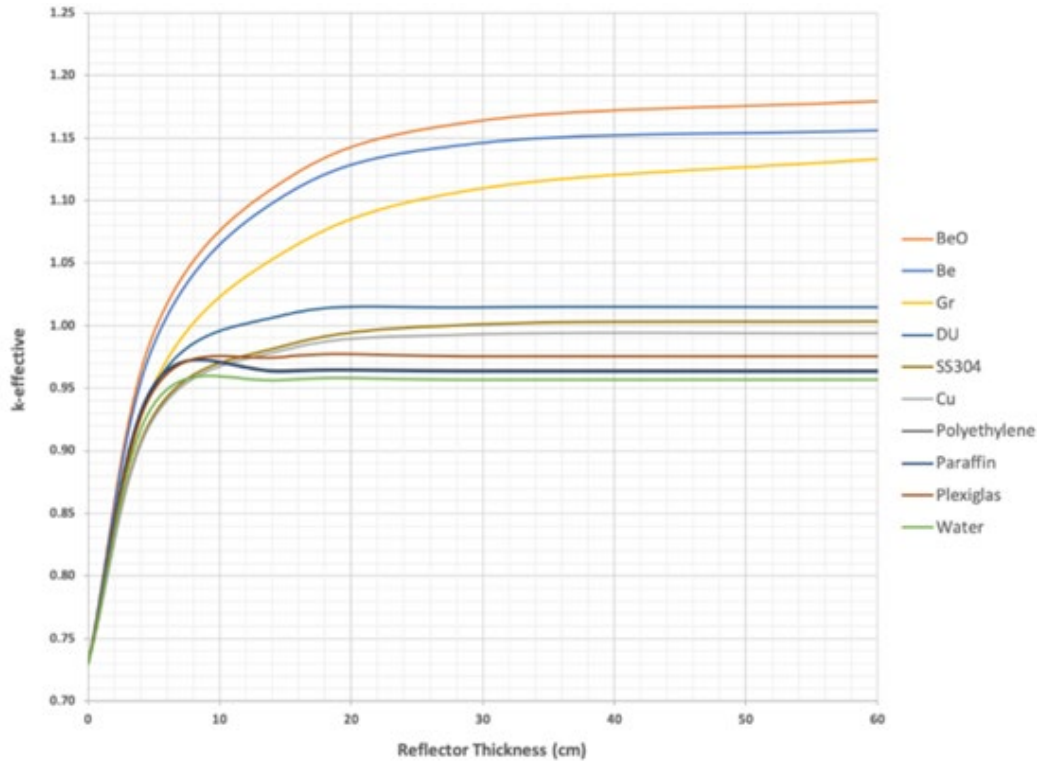


Base: 49 in. × 60.4 in.
Height: standard table height

Considerations for redesign

- Design availability
  - Availability of 4 full AGN-201m fuel plates from Y-12
  - Consideration of other reflectors

Fuel plate	^{235}U Mass (g)	# per AGN-201M
4 cm	96.8169	2
2 cm	57.3544	3
1 cm	28.6772	2



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  - Criticality must not be credible
  - Limit must be ≤700 g ^{235}U total
  - High neutron multiplication is needed with a target of k_{eff} = 0.95
  - Weight should be limited such that activity can through be simple hand stacking

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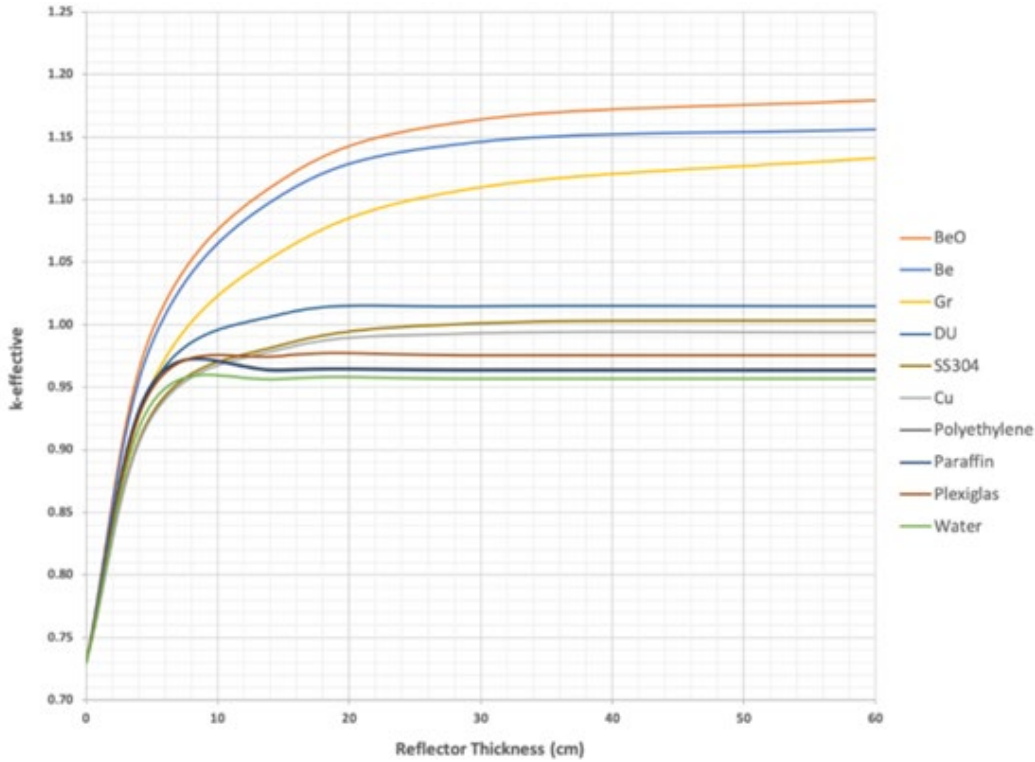

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  - High neutron multiplication is needed with a target of k_{eff} = 0.95
  - Weight should be limited such that activity can through be simple hand stacking
- Other considerations
  - Size and arrangements of detectors
  - Symmetry and minimal adjustments during experiments
  - Restriction to simple 4 cm plates
  - Focus on general results: no need to “over model”

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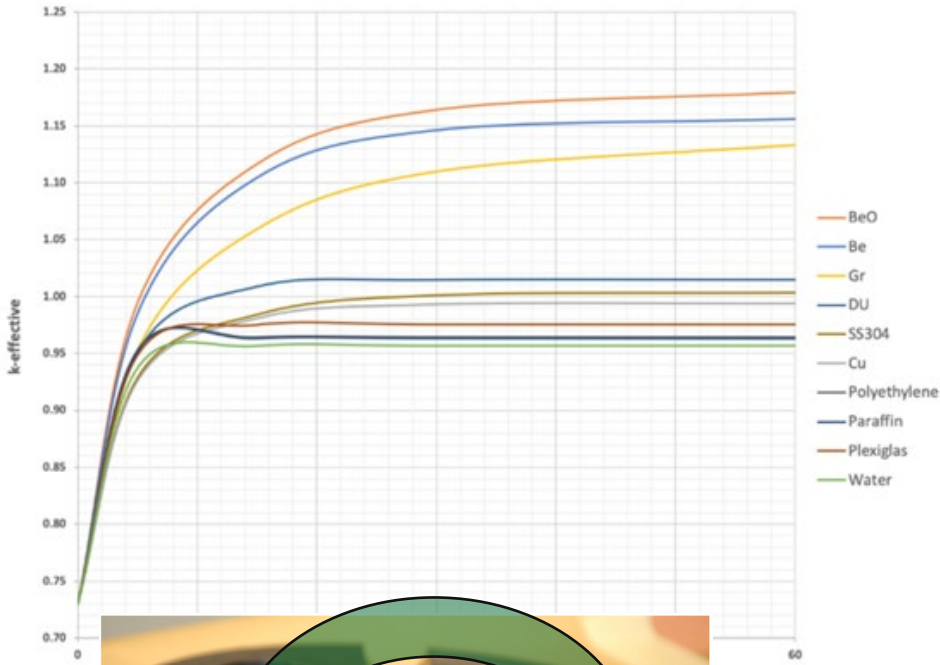
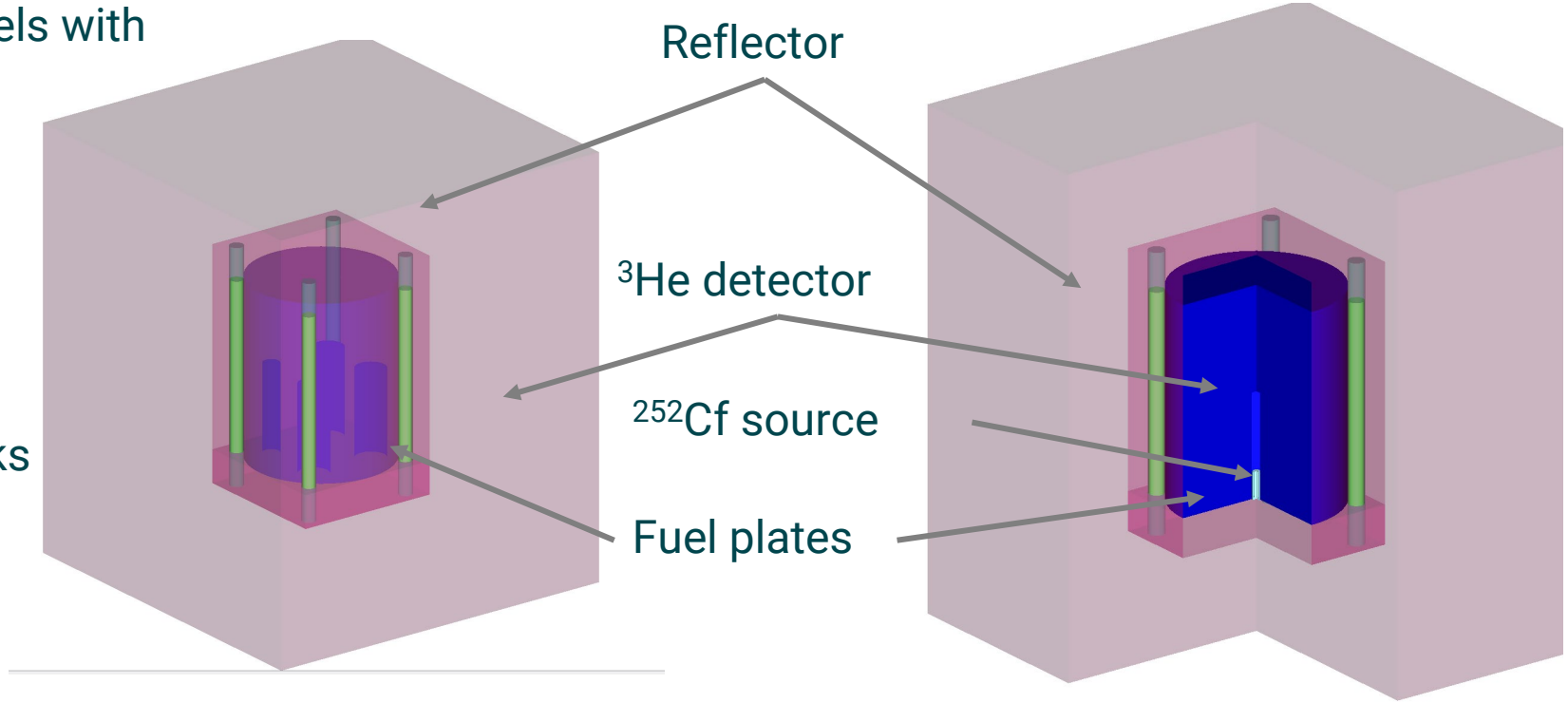
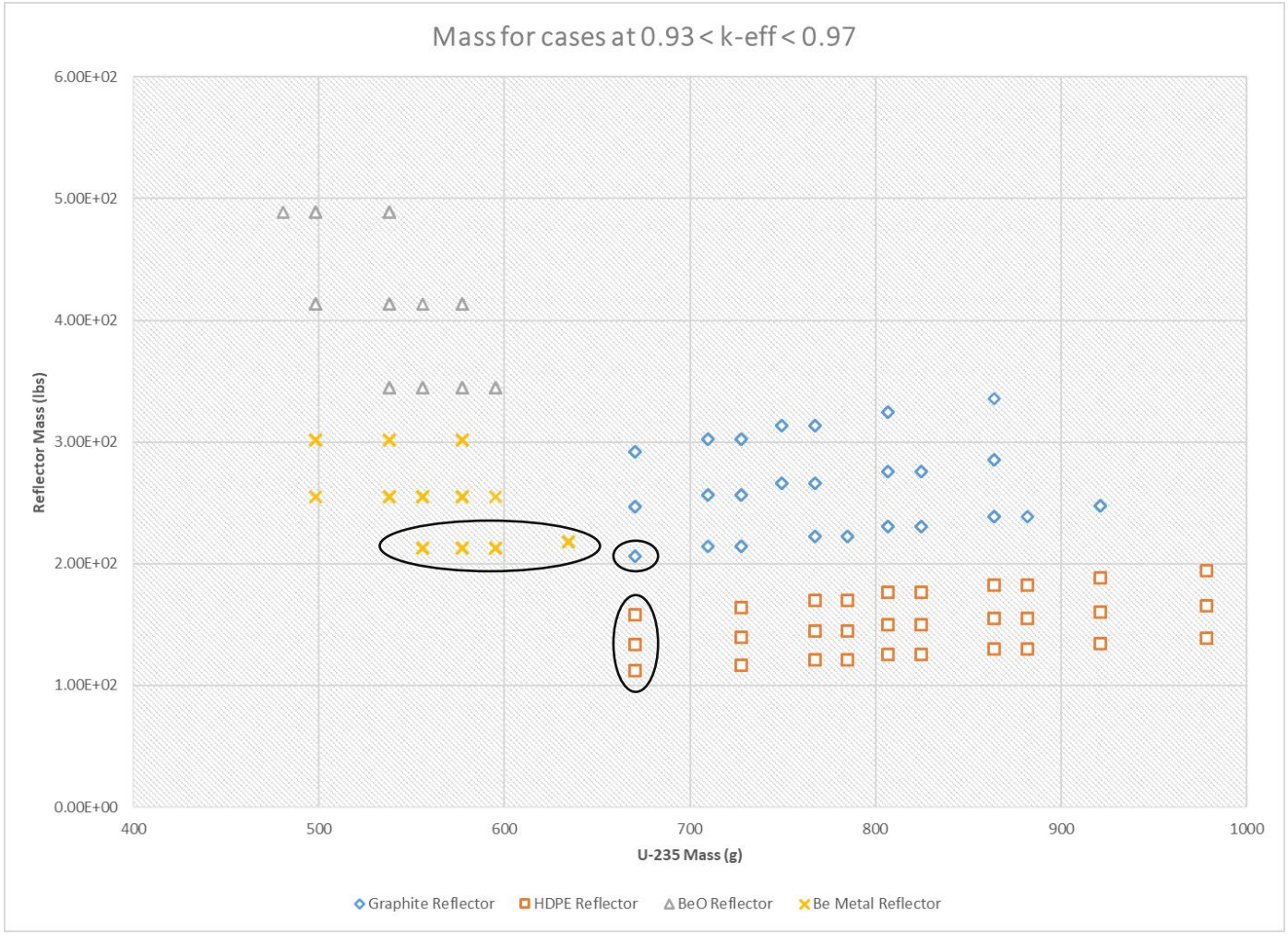


SCALE SAMPLER: one input – all results

- SAMPLER used to create CSAS5 models with the following perturbations:
  - 4 reflector materials
    - Graphite, HDPE, Be, BeO
  - Reflector thickness
  - Number of 4 cm disks
  - Thickness of stack of solid disks
  - Different ^{3}He detectors
  - Number of ^{3}He detectors

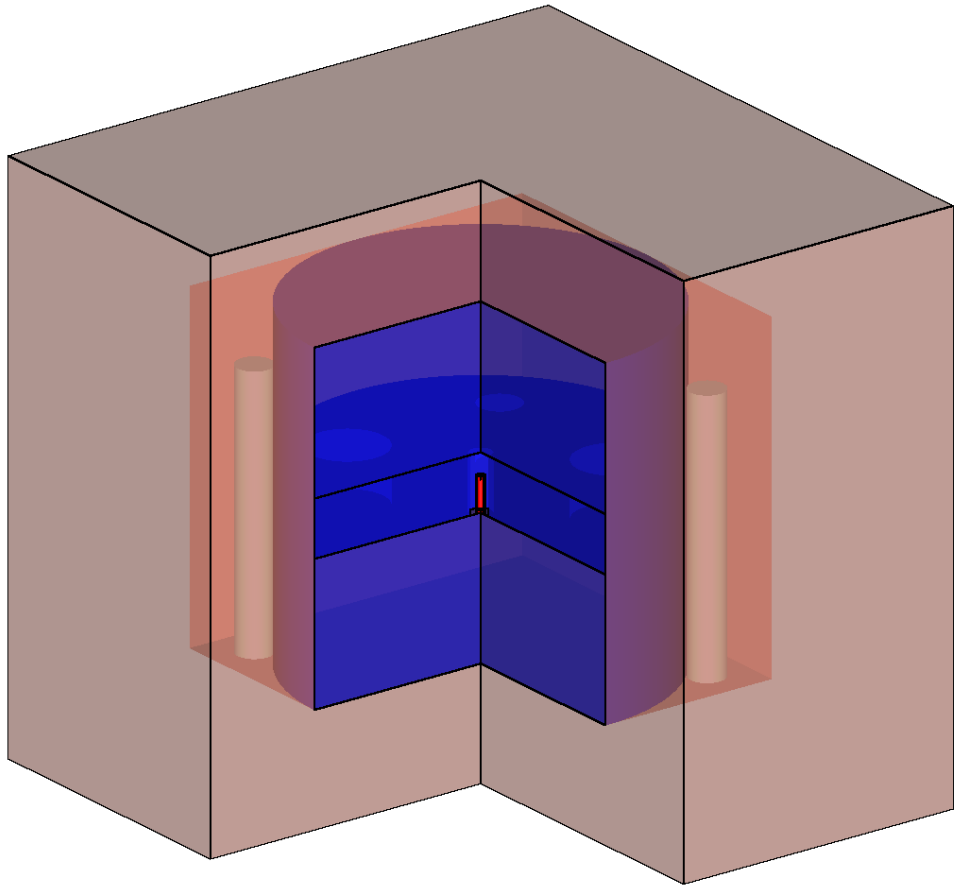


Determining Reflector Options

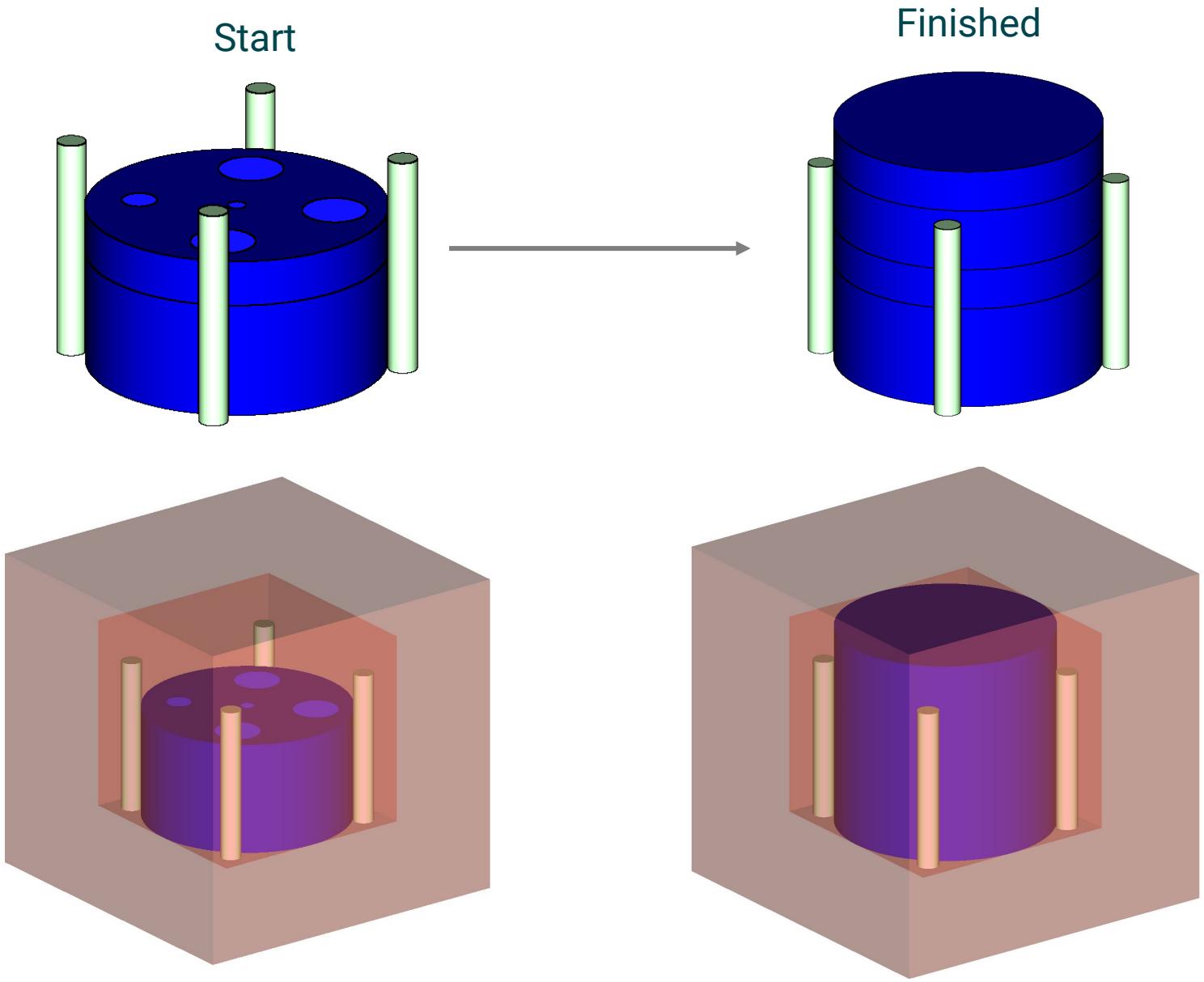


Current Design of the Subcritical Assembly

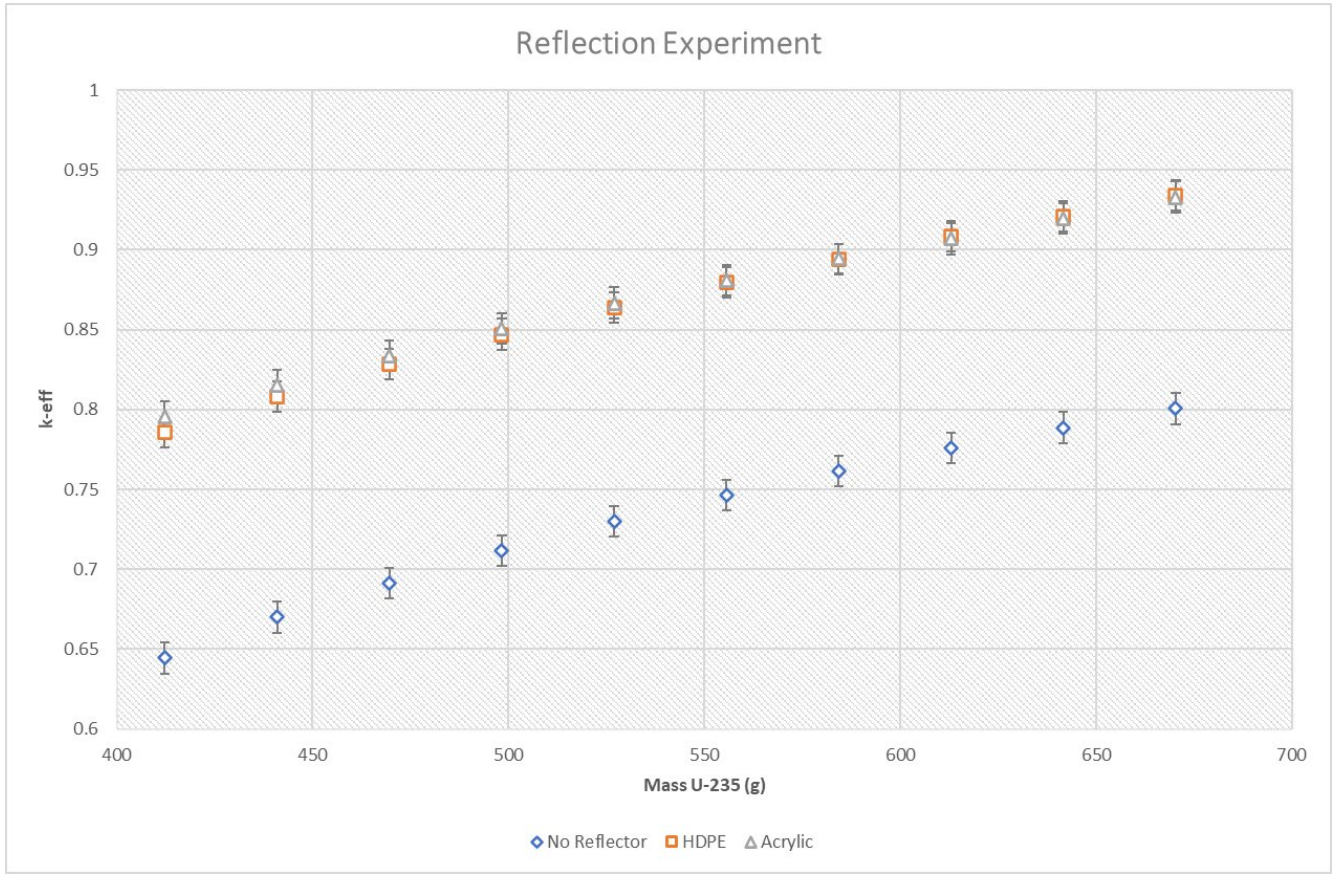
# of 4-cm plates	1
# of 2-cm plates	8
# of 1-cm plates	4
Total U-235 mass (g)	670
Total Height (cm)	24

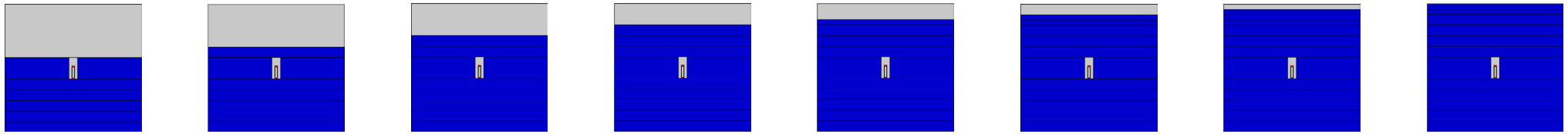


Experiments: Mass and Reflection



Mass and Reflection Steps





5 2-cm plates
1 4-cm plate

+1 2-cm plate

+1 2-cm plate

+1 2-cm plate

+1 1-cm plate

+1 1-cm plate

+1 1-cm plate

+1 1-cm plate

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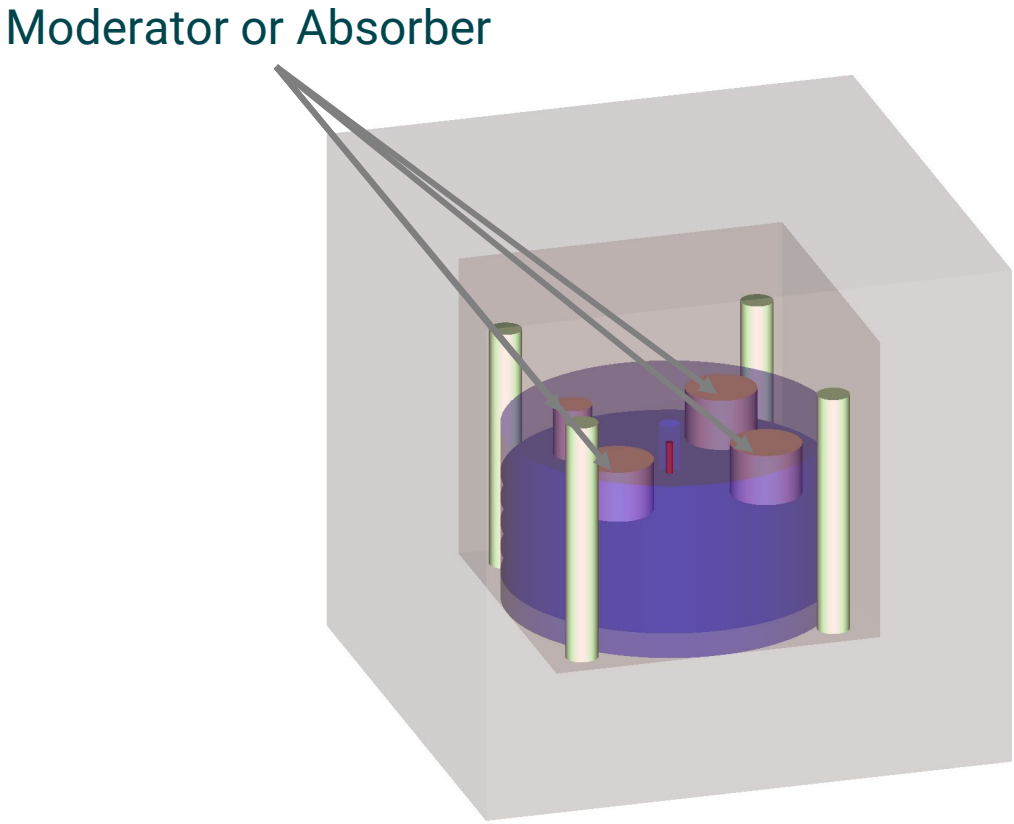
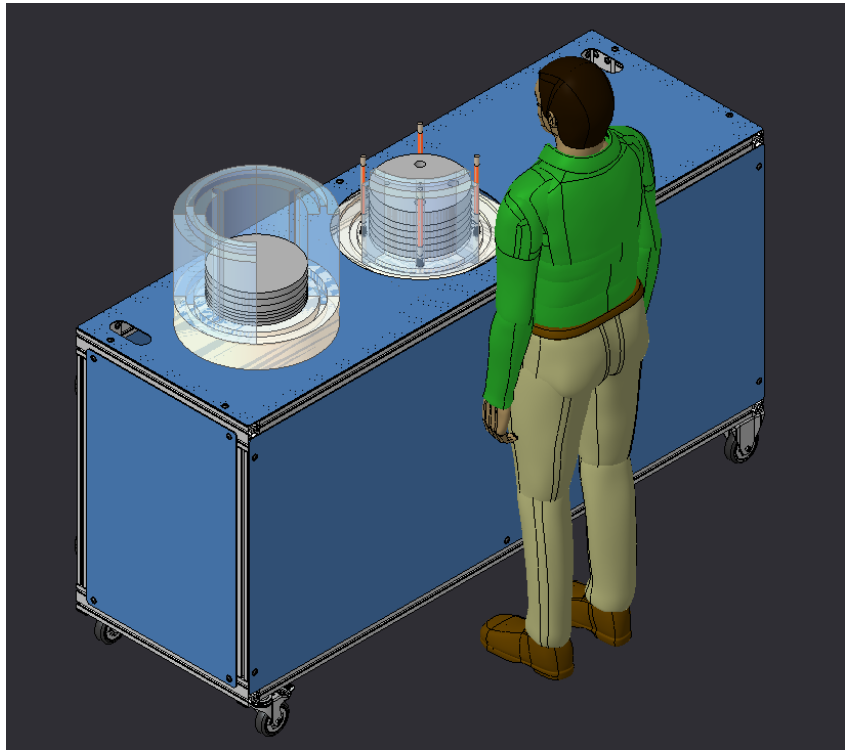
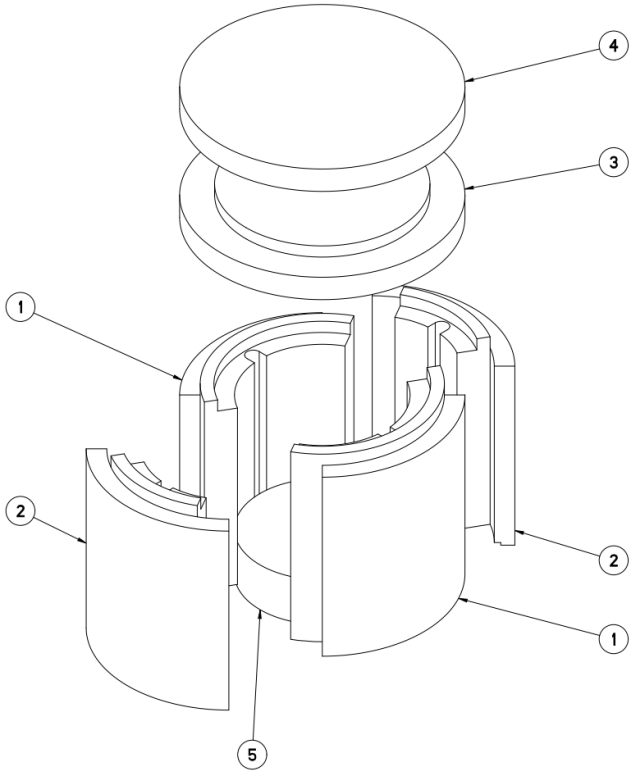
Experiments: Moderation and Absorption

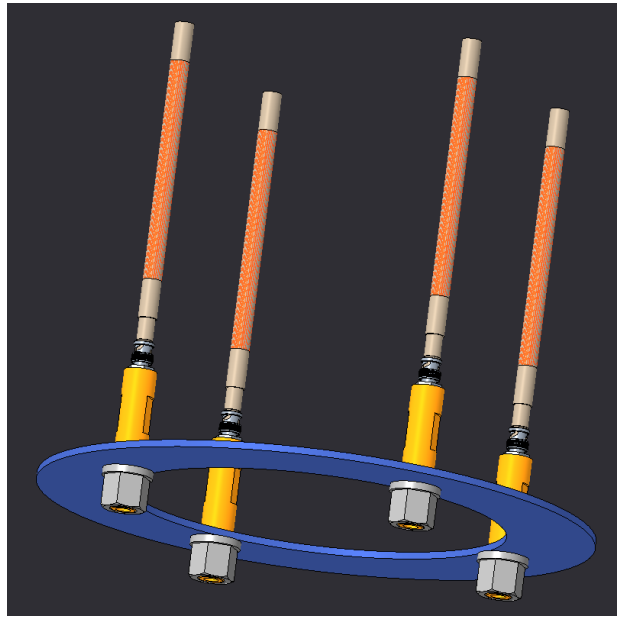
- Insert materials into 4-cm plate
- Evaluate whether item behaves as a moderator or absorber
- Moderator Examples
  - H_2O, Be
- Absorber Examples
  - B_4C, SS304

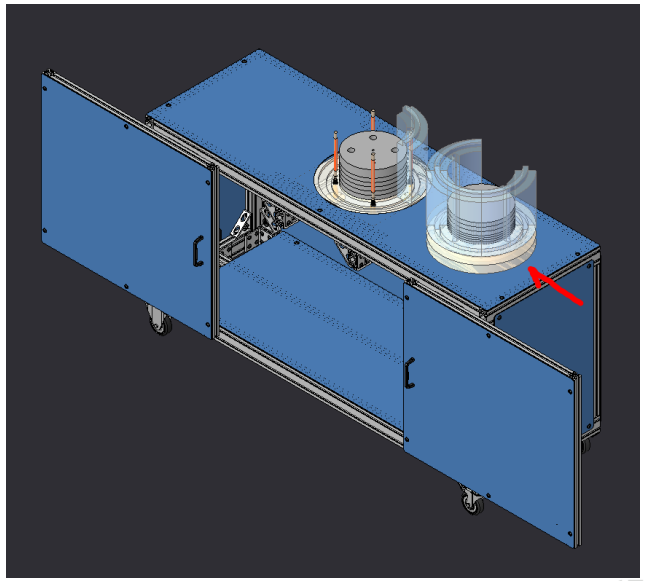


Mechanical Design of Hands-On Experiment



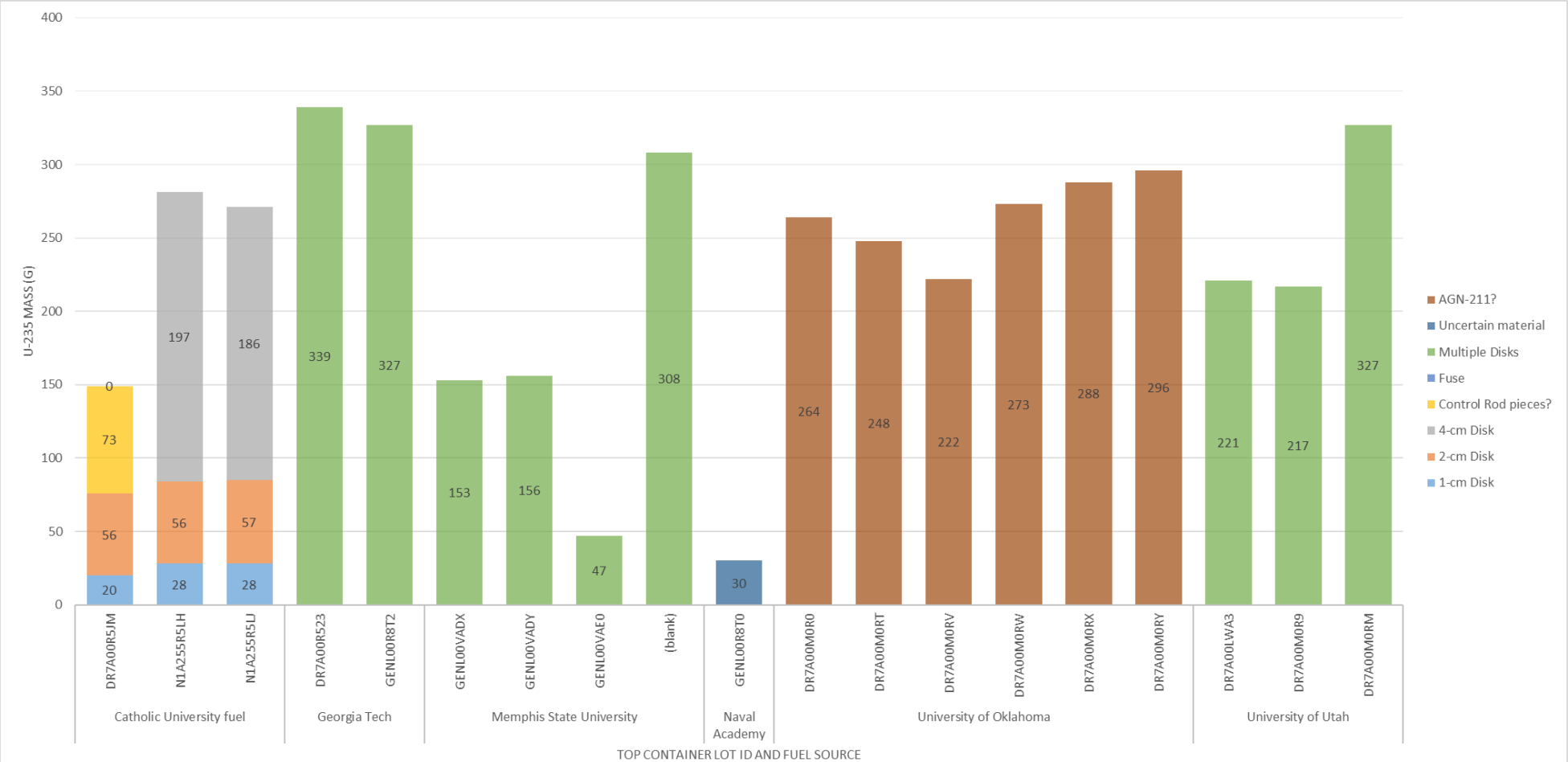






Lab Location

Best Guess Inside Drums at Y-12



Fuel Source	Catholic University	University of Utah	Georgia Tech	Memphis State	University of Oklahoma	Naval Academy
Total U-235 Mass (g)	701	765	666	664	1591	30

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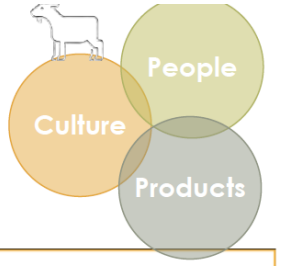
Oak Ridge Subcritical Assembly: Training the workforce

- Considering procuring table and reflectors
- Considering obtaining lab support for room preparation and detection equipment
- Awaiting a quote from Y-12 for selecting and receiving fuel (expected December 2024 or January 2025)

Nuclear Energy and Fuel Cycle Division

Our pathway to realizing our clean energy future



	FY 2024 Goals	FY 2025– FY2028 Goals
Drive the Next Evolution of Nuclear Energy Modeling and Simulation	• Update software development, collaboration and distribution strategies to maximize internal and external impact of our tools, while maintaining appropriate quality assurance and information protection.	• Transition ORNL Modeling and Simulation (M&S) nuclear analysis workflows for operational support to modern computational tools, using ORNL tools where available • Develop innovative computational approaches to outstanding problems in nuclear technology • Advocate for on-site capacity computing for ORNL NEFCD programs, sponsors, and external customers
Realize the Return on Advanced Technology Fuel investments	• Complete testing that addresses NRC concerns regarding high burnup commercial nuclear fuel through loss of coolant accident tests, transient fission gas release tests and microstructural analysis	• Leverage ORNL infrastructure and expertise to expand service envelope for existing coated particle fuel architectures and develop advanced coated particle fuel forms for diverse applications • Develop integral strategy supporting fuel performance data, accelerated material testing and qualification, and fuel cycle development at ORNL
Innovate While Enabling Advanced Reactor Fuel Deployment	• Execute safety testing of AGR 5/6/7 compacts • Develop Inter-Irradiation Examination (IEE) capability concept • Develop strategy for instrumented MiniFuel irradiation	• Conclude AGR 5/6/7 PIE to demonstrate performance of TRISO fabricated at industrial scale • Establish fast neutron spectrum irradiation vehicle for fast reactors, fusion, and spallation neutron materials • Pre-conceptual design of Inter-Irradiation Examination (IEE) capability for improved datasets and enhanced understanding of how fuels and materials evolve during reactor service • Field an instrumented MiniFuel irradiation capability • Define and implement coated particle fuel technology transfer strategy
Accelerate Siting, Licensing, Construction, and Efficient Operations of Advanced Reactors	• Develop ORNL molten salt strategy • Integrated ORNL I&C capabilities strategy • Advanced structures analysis strategy • Revitalize ORNL risk analysis capability	• Integrate ORNL capabilities to enable true optimization of Safety, Safeguards, and Security by Design • Strengthen ORNL leadership in I&C, Risk Assessment, Operations Optimization, and Siting Analysis • Extend impacts of ORNL capabilities to the full lifecycle of nuclear facilities – design, construction, operations, maintenance, and monitoring • Expand system engineering experience beyond the primary containment • Advance high temperature reactor development and end-use integration
Leverage ORNL Capabilities to Bring an Integrated Fuel Cycle into Focus	• Develop integral R&D strategy to support fuel cycles for particle fuel forms • Complete laboratory space assessment • Expand pre-conceptual development of Nuclear Packaging Comprehensive Research and Testing Facility (NuPaC Facility)	• Expand knowledge of used fuel aging through Sister Rod Campaign • Establish lightly irradiated fuel chemistry capability • Convert Nuclear Packaging Comprehensive Research and Testing Facility (NuPaC Facility) development to funded program • Evaluate opportunities for long term used fuel monitoring
Build the Nuclear Energy Workforce of Today and Tomorrow	• Review ORNL capabilities and identify opportunities for additional training courses • Complete design of subcritical test and training facility experimental components	• Leverage advanced visualization strategies to make ORNL capabilities more accessible • Extend access, training, and awareness of SCALE and other strategic NEFCD codes • Establish subcritical experiment center for nuclear data and nuclear criticality safety testing and training • Establish nuclear package testing center for transportation and storage testing and training

Summary

- The efforts in design this year have accomplished
    - The flexibility of using fuel plates from multiple AGN reactors
    - Significant reduction in weight of reflectors with multiple options
    - Ability to perform hands-on experiments as a table-top activity
    - Design consideration includes use for potential research use
- Oak Ridge National Laboratory is working to prepare a space for training
- Working with Y-12 to obtain a quote for fuel receipt

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