Los Alamos NATIONAL LABORATORY

IER-517 MOBY DICK
HEU CED-2 Overview

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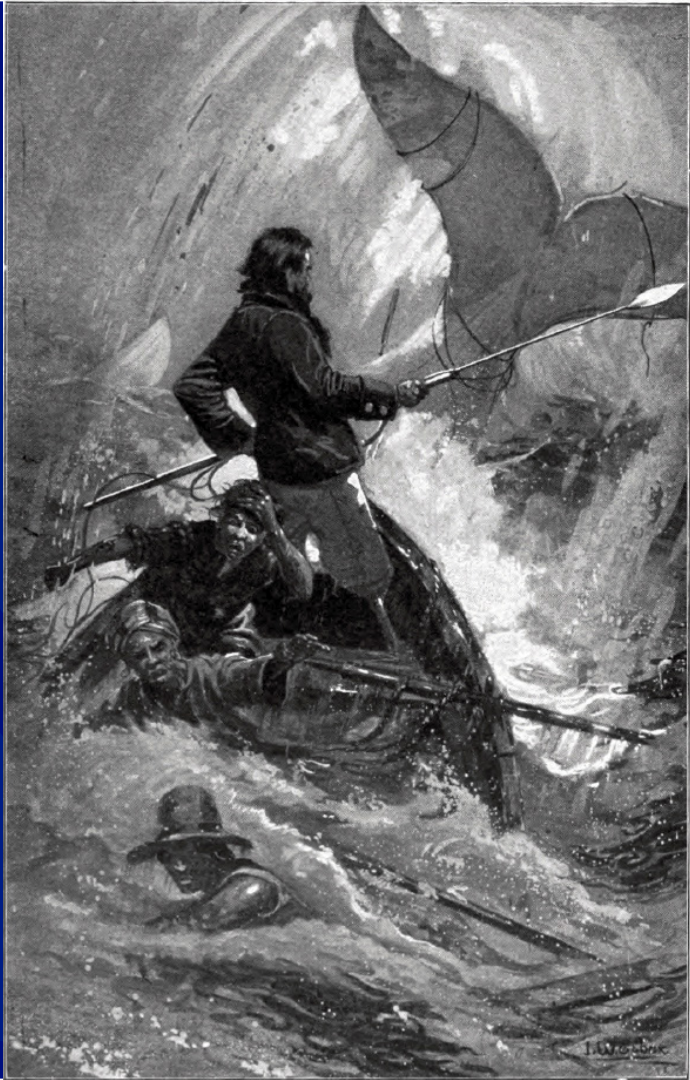
2/21/24

LA-UR-24-21129



MOBY DICK

Molybdenum **O**ptimized **B**enchmark S**y**stem **D**emonstrating **I**ntegral **C**orrelations

- LANL, Y-12, and IRSN collaboration

- New differential measurements of isotopic Molybdenum cross sections in unresolved resonance region (URR) from RPI need validation and measurements from IRSN and JAEA at J-PARC need validation

- Lack of Molybdenum sensitive benchmarks in ICSBEP Handbook

- Recent thermal molybdenum integral experiments at SNL (IER-305)

Molybdenum in Nuclear

- **In Fuels:** U-Mo metallic fuels are used in new space reactor designs and new research reactor fuels. MITR, MURR, and NBSR reactors plan on converting from different HEU fuels to a U-10Mo HALEU fuel within the next decade.

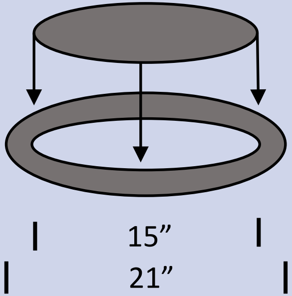
- **In Spent Nuclear Fuel:** ^{95}Mo is one of the 15 main absorbing fission products in irradiated LWR fuel. This makes it important for criticality safety studies in transportation and reprocessing.

- **In Structural Materials:** Molybdenum is found commonly in alloys that make up the structural materials of nuclear reactors such as type 316 SS. Molybdenum helps to improve high temperature performance and corrosion resistance.

Experiment Goals

- A total of four critical configurations of HEU that are maximally sensitive to the ^{95}Mo radiative capture cross section in the follow energy regions:
  - Fast (200 keV – 10 MeV)
  - Unresolved Resonance Region (2 keV – 200 keV)
  - Epithermal (0.625 eV – 2 keV)
  - Thermal (<0.625 eV)

General Design

21” Jemima Plate	
Name	Full Plate + Ring
Diameter	21” (53.34 cm)
Thickness	0.118” (3 mm)
HEU Mass/Plate	12.68 kg
	

- Configurations will be built on Comet and fueled by the 21” Jemima plates similar to recent NCERC experiments (i.e. CERBERUS, CURIE, …)
- CED-1 demonstrated a larger Beryllium reflector is most desirable to achieve high sensitivities to ^{95}Mo (especially in URR and epithermal regions)

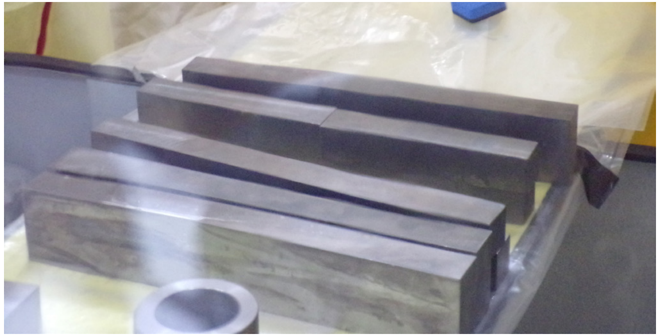
	Be Reflector	Graphite Reflector
Pros	+Performed best in CED-1	+Cheap +Short lead time
Cons	-Expensive -Long lead time	- 30% reduced nuclear data sensitivity to URR ^{95}Mo

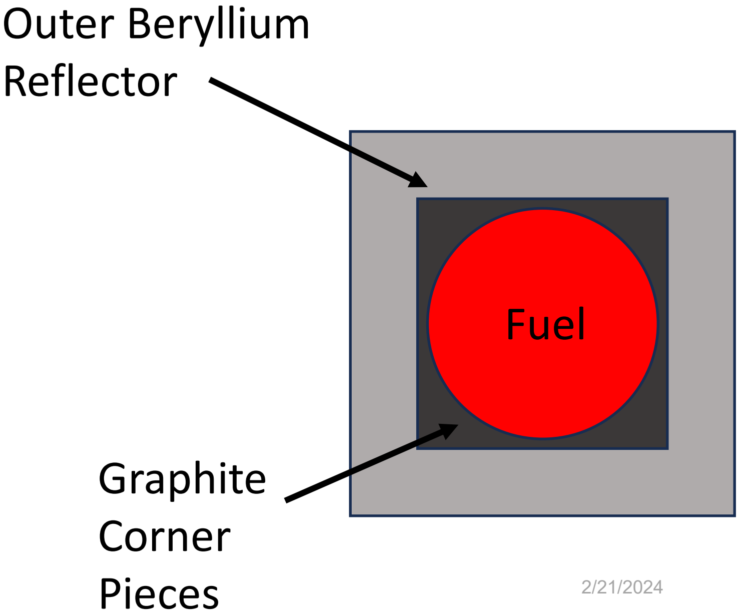
Beryllium Reflector

- A 15 cm rectangular beryllium reflector can be constructed with existing NCERC inventory. Inner graphite corner pieces will be used to mate circular fuel stack with rectangular reflector.

- This design can be used in the future as an additional reflector option to the large copper bricks commonly used on Comet

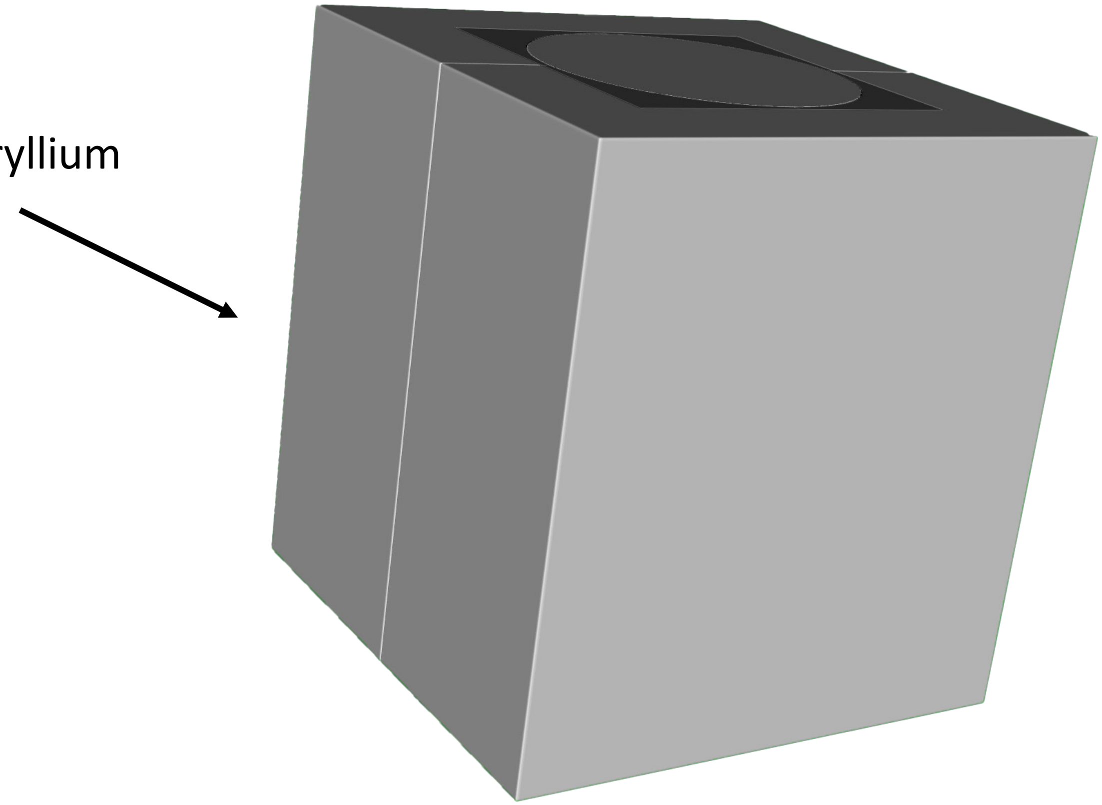
- This method has been used for the Hypatia experiment and will be used for the upcoming Deimos experiment



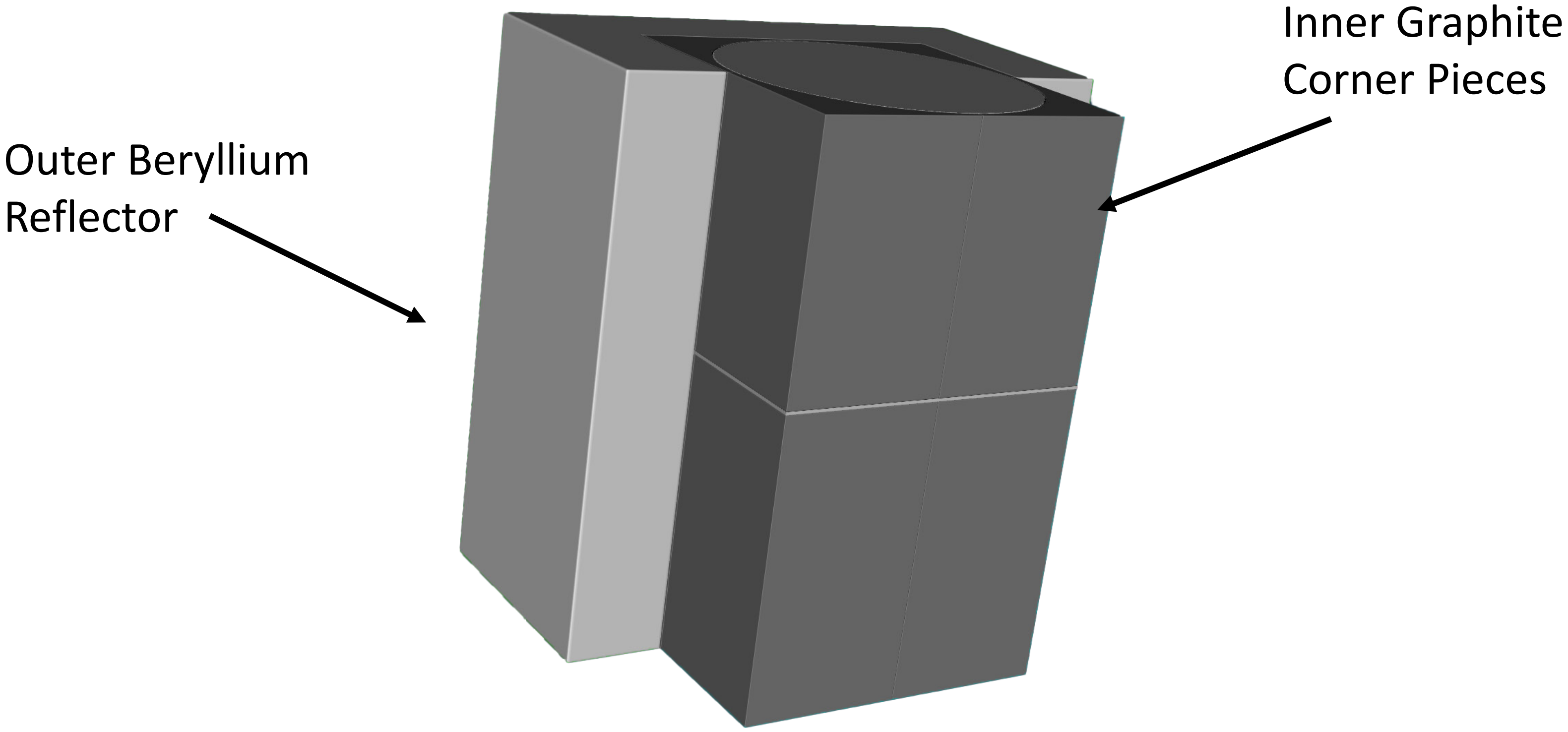


Basic Design

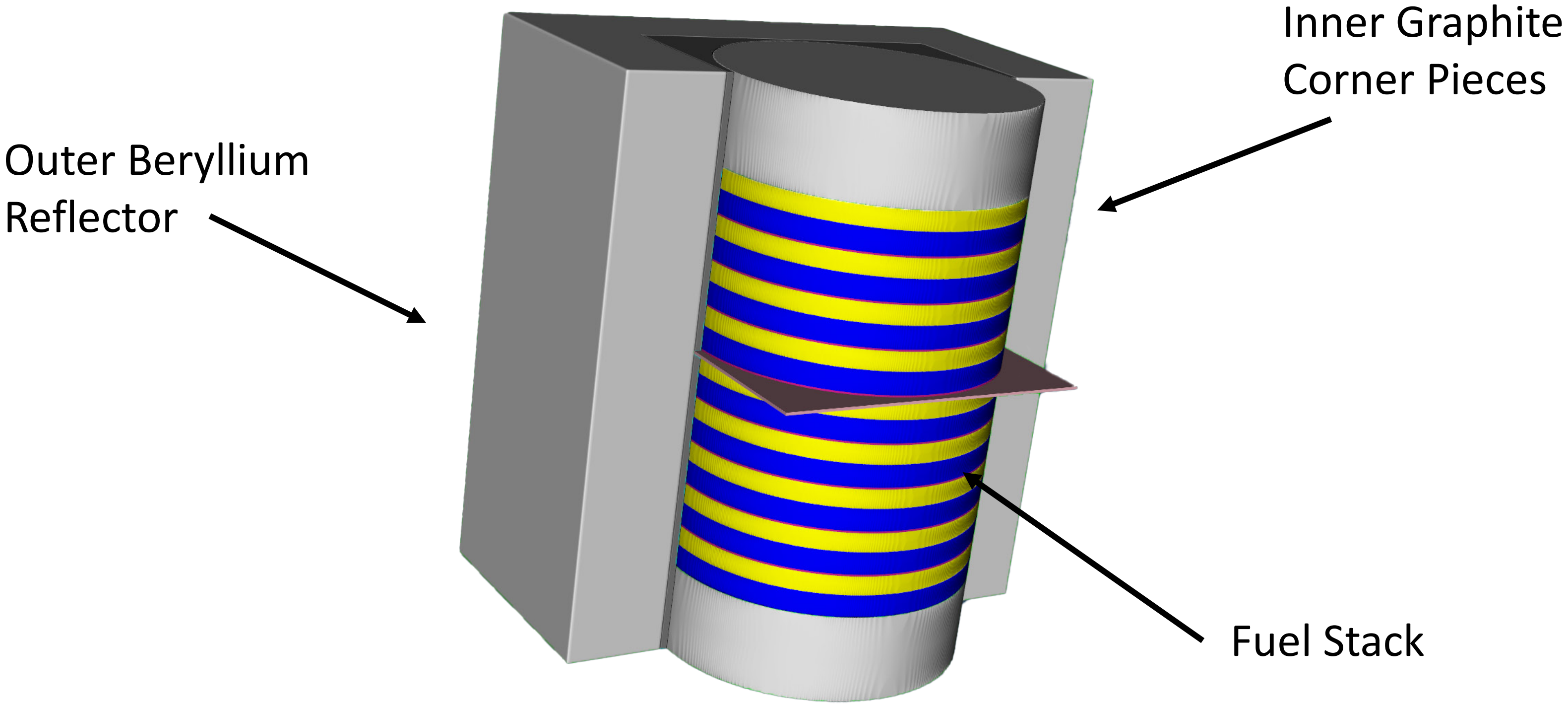
Outer Beryllium
Reflector



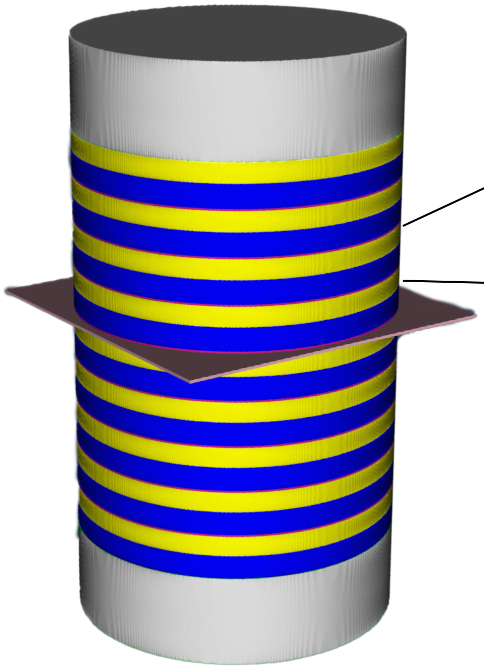
Basic Design

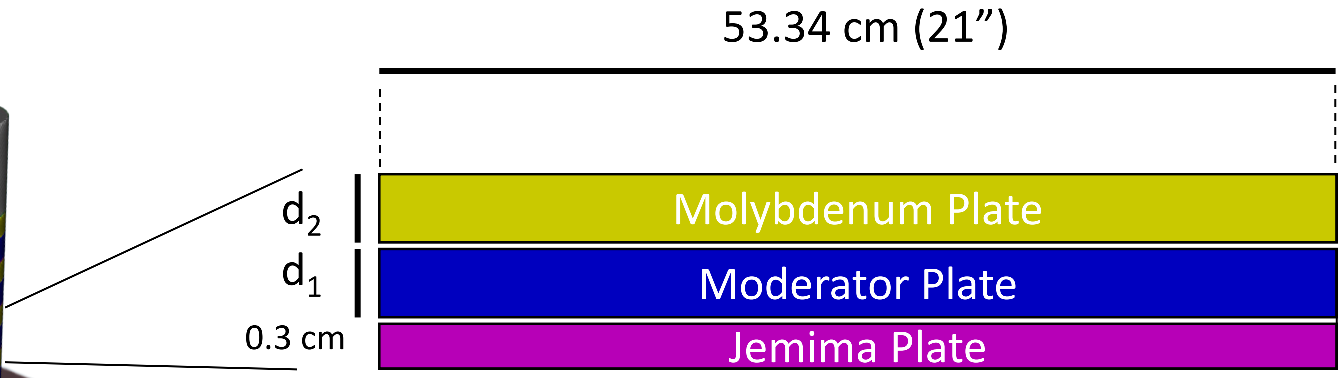


Basic Design



Basic Design



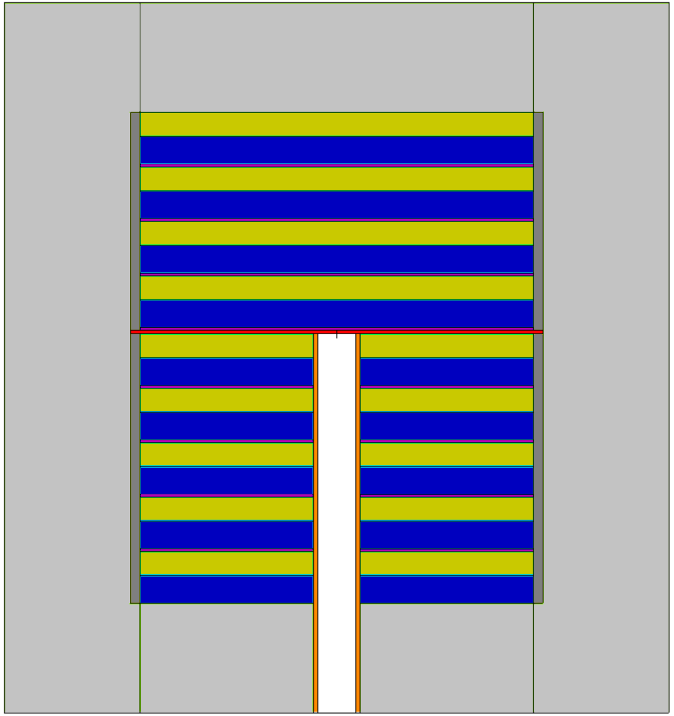


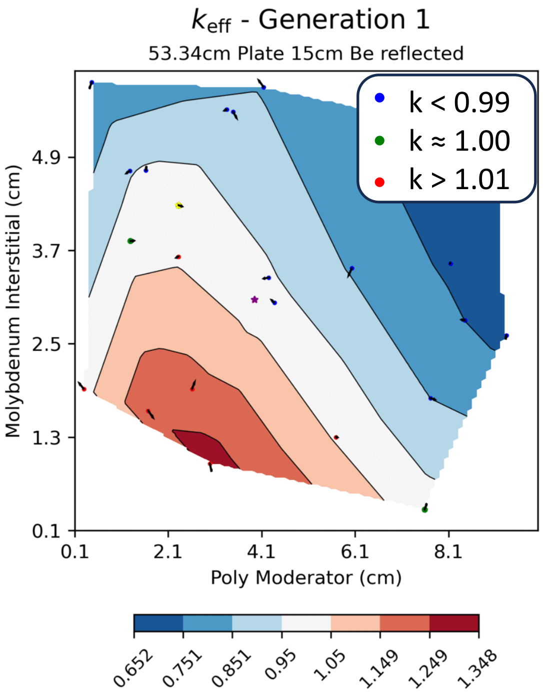
- Thickness of moderator and molybdenum plates selected using Particle Swarm Optimization (PSO) for each energy case
- Total number of units chosen to keep H:W ratio as close to one as possible

Thermal – Maximizing ^{95}Mo (n,γ) Sens. <0.625 eV

Poly Mod. Be Ref.

Specifications	
Units	8
Beryllium Reflector	15 cm
Polyethylene Plate Thickness	3.88 cm
Molybdenum Plate Thickness	3.27 cm
Stack Height	97.2 cm
H:W	1.06
k_{eff}	0.99823 ± 33
$S_{Mo\text{-}95\ (n,g),\ Thermal}$	-0.9007

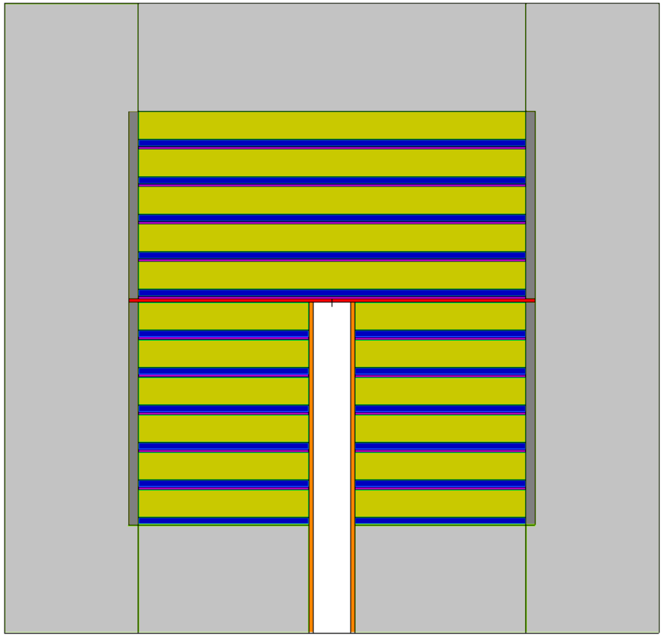


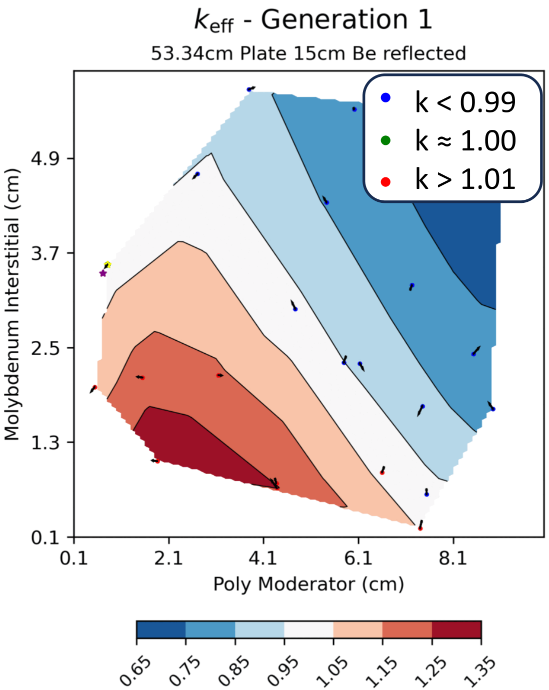


Epithermal – Maximizing ^{95}Mo (n,γ) Sens. 0.625 eV -2 keV

Poly Mod. Be Ref.

Specifications	
Units	10
Beryllium Reflector	15 cm
Polyethylene Plate Thickness	1.0 cm
Molybdenum Plate Thickness	3.91 cm
Stack Height	87.5 cm
H:W	0.97
k_{eff}	0.99913 ± 30
$S_{Mo\text{-}95\ (n,g),\ Epithermal}$	-0.045

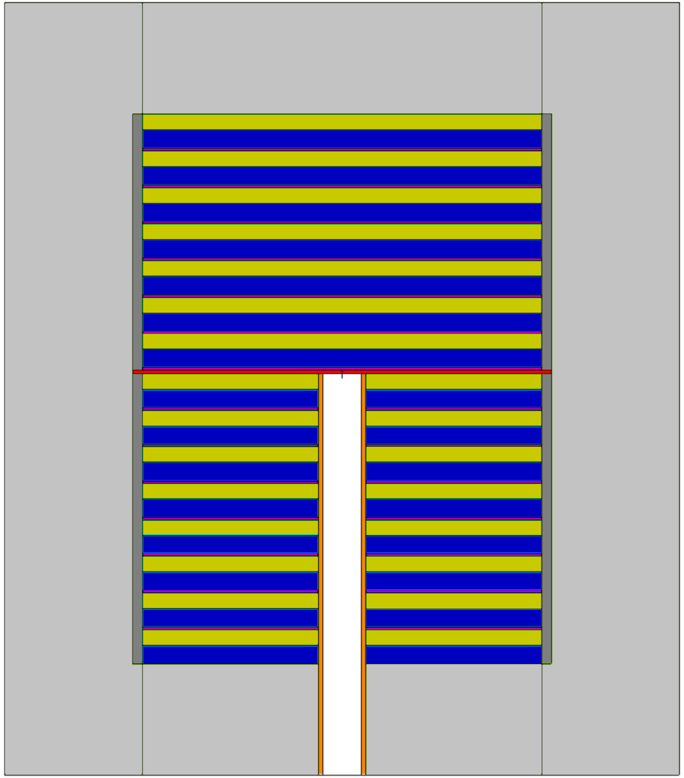


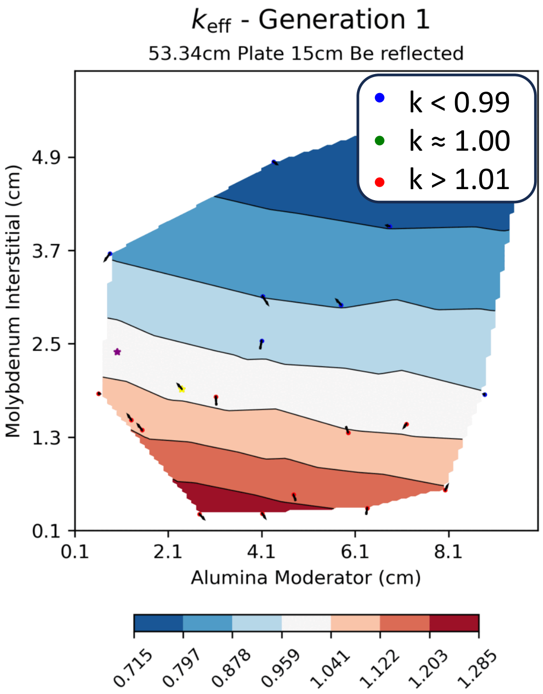


URR – Maximizing ^{95}Mo (n,γ) Sens. 2 keV – 200 keV

Alumina Mod. Be Ref.

Specifications	
Units	14
Beryllium Reflector	15 cm
Alumina Plate Thickness	2.5 cm
Molybdenum Plate Thickness	2.13 cm
Stack Height	104.1 cm
H:W	1.16
k_{eff}	0.99721 ± 30
$S_{Mo\text{-}95\ (n,g),\ URR}$	-0.05104

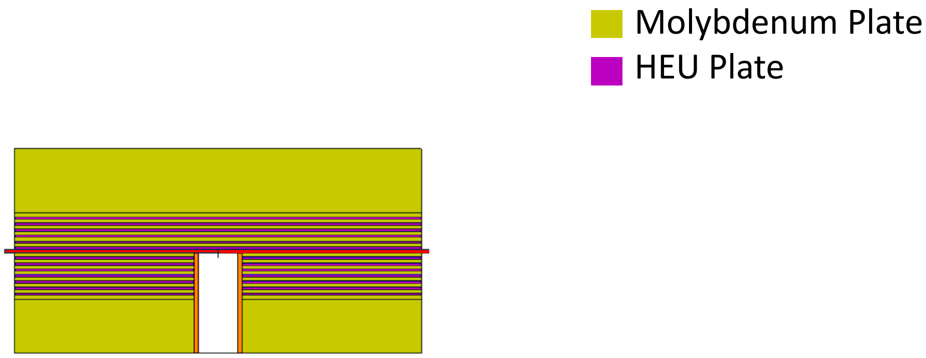




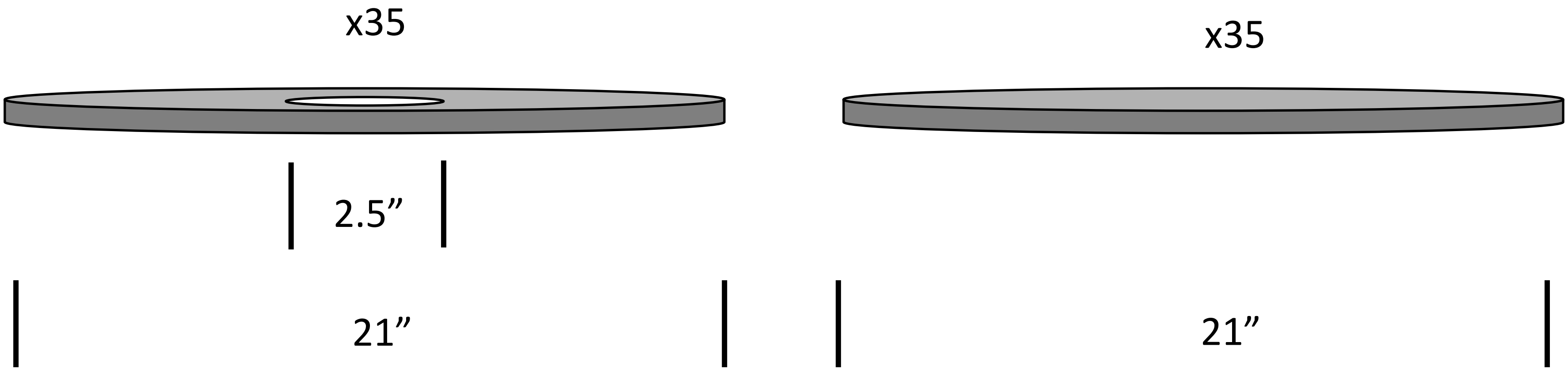
Fast – Maximizing ^{95}Mo (n,γ) Sens. >200 keV

Unmoderated, Axially Molybdenum Reflected

Specifications	
Units	14
Molybdenum Plate Thickness	0.5 cm
Molybdenum Axial Reflector Thickness	7.5 cm
Stack Height	27 cm
H:W	0.5
k_{eff}	1.00193 ± 26
$S_{Mo\text{-}95\ (n,g),\ Fast}$	-0.00732



Molybdenum Plates (0.5 cm Thick)

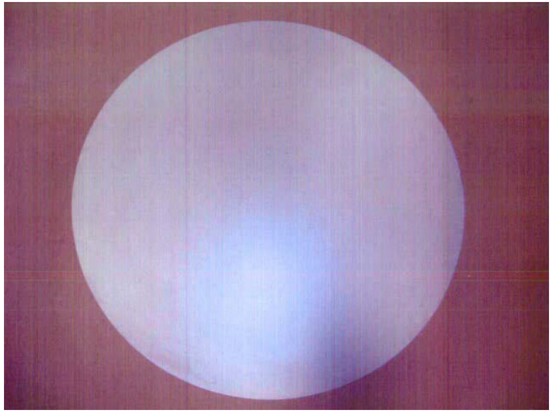


JIMO Molybdenum Plates (0.0762 cm Thick)

Procured in early 2000's for critical experiments in support of Project Prometheus

Will be used in combination with 0.5 cm plates to get exact plate thicknesses

For example, if the needed Mo plate thickness is 2.15 cm we would stack:
4x 0.5 cm plates and 2 JIMO plates



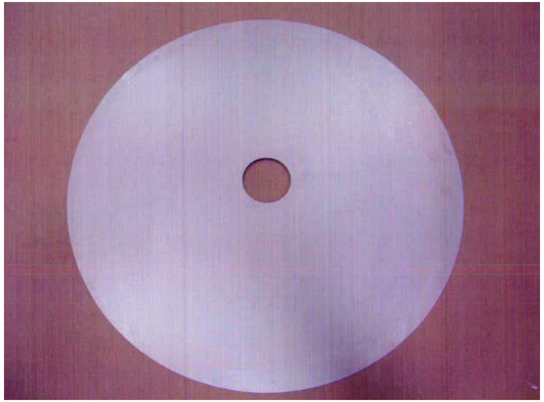
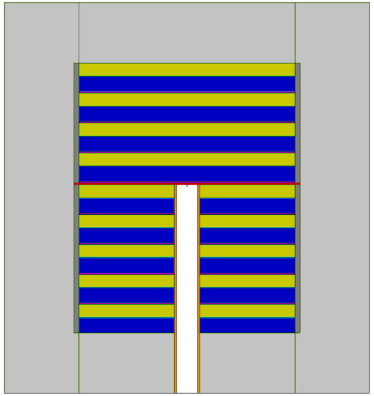


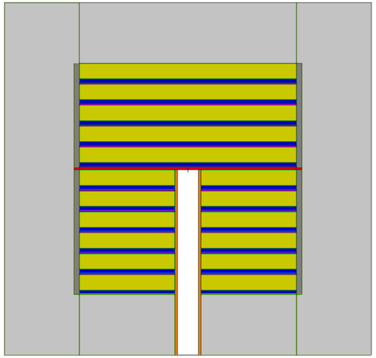
Table 15. Specifications for Mo Plates

Type	Quantity	Outer Diameter (in)	Inner Diameter (in)	Thickness (in)
Solid	32	21.000 ± 0.010	-	0.0300 ± 0.0030
Annular	32	21.000 ± 0.010	2.510 ± 0.010	0.0300 ± 0.0030
Solid	4	21.000 ± 0.010	-	0.0600 ± 0.0060
Annular	4	21.000 ± 0.010	2.510 ± 0.010	0.0600 ± 0.0060

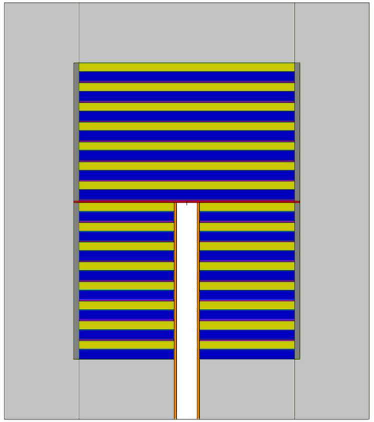
8 Units
THERMAL (<0.625 eV)



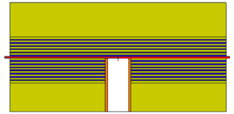
10 Units
EPITHERMAL (0.625 eV – 2 keV)

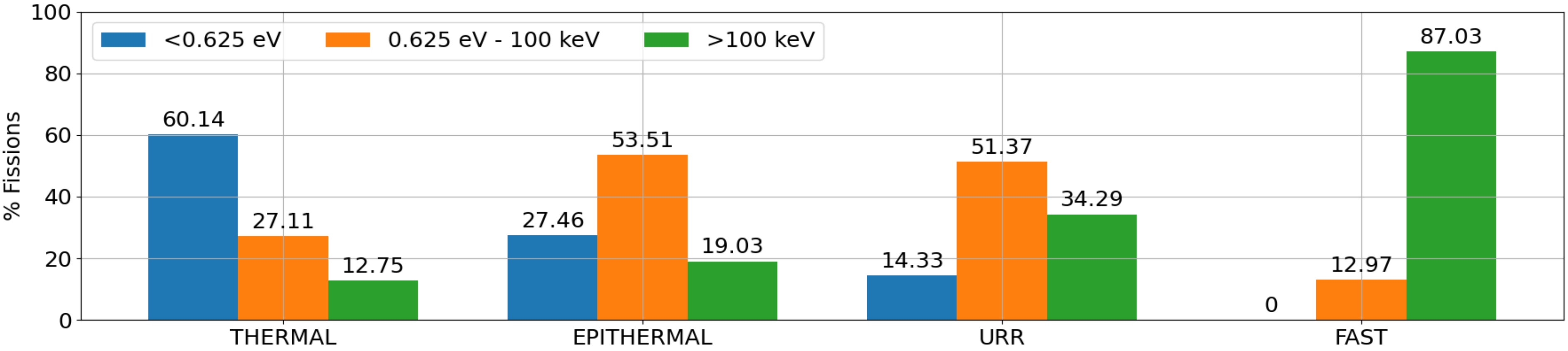


14 Units
URR (2 keV – 200 keV)

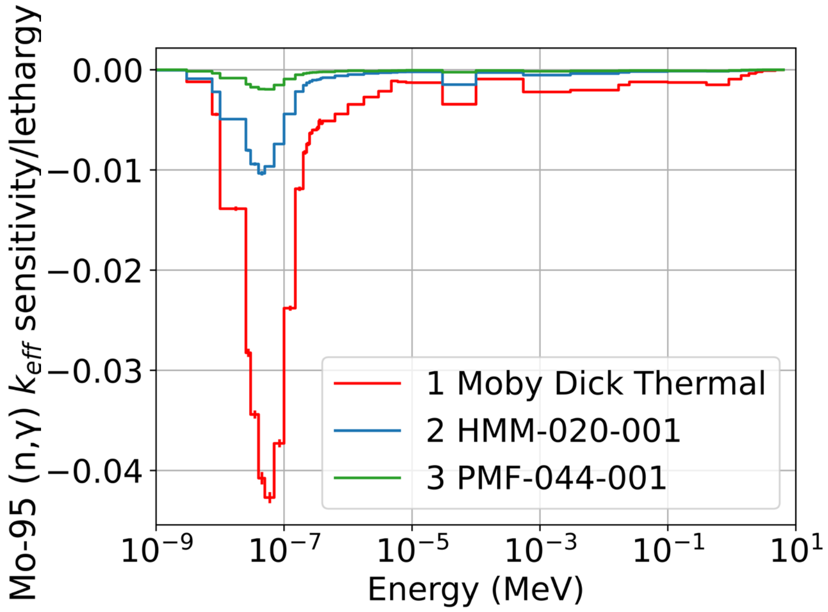


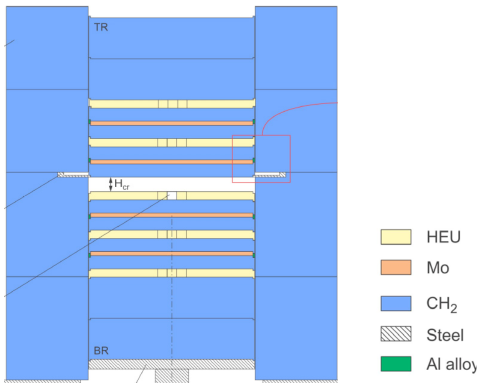
14 Units
FAST (>200 keV)



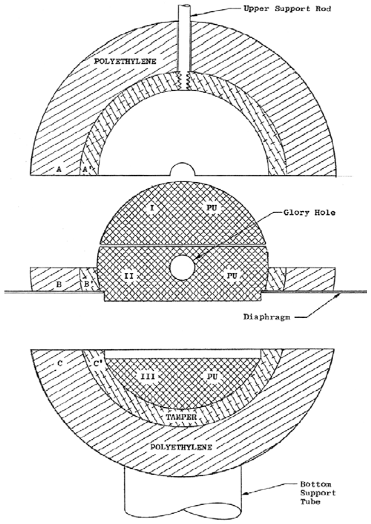


THERMAL - Comparison to Existing Benchmarks



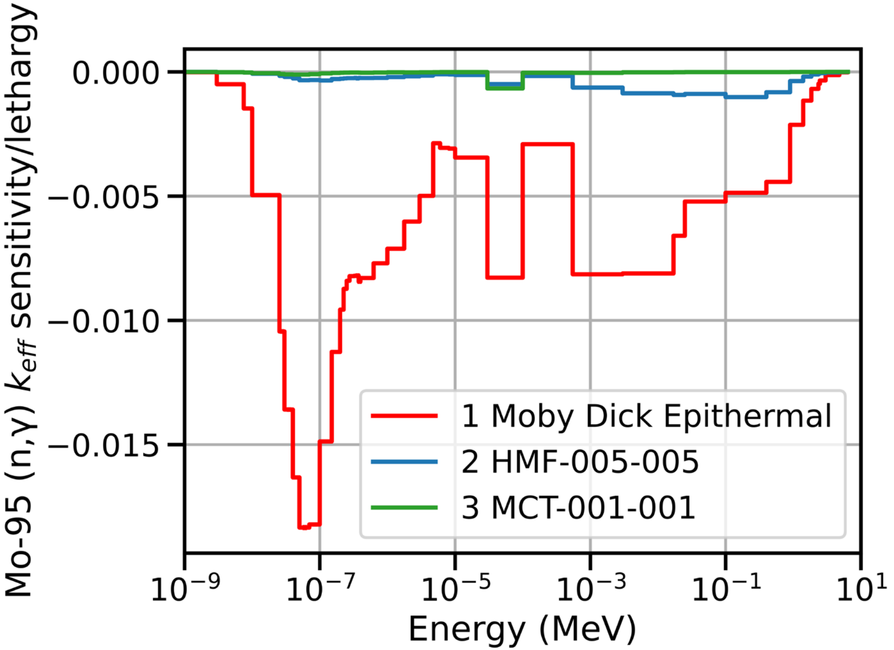


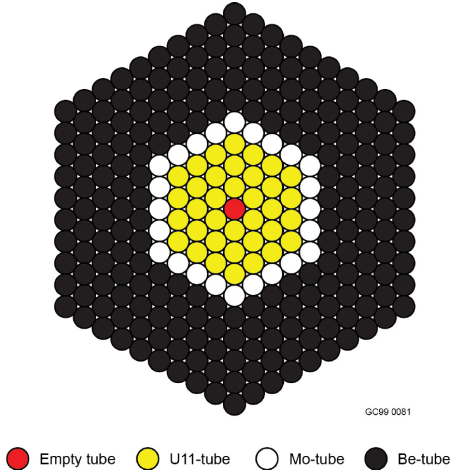
HMM-020-001
VNIITF, Russia 2012



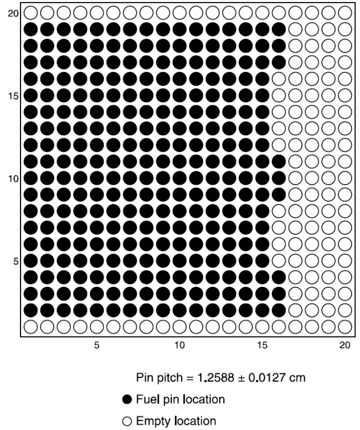
PMF-044-001
LACEF, USA 1973

EPITHERMAL - Comparison to Existing Benchmarks



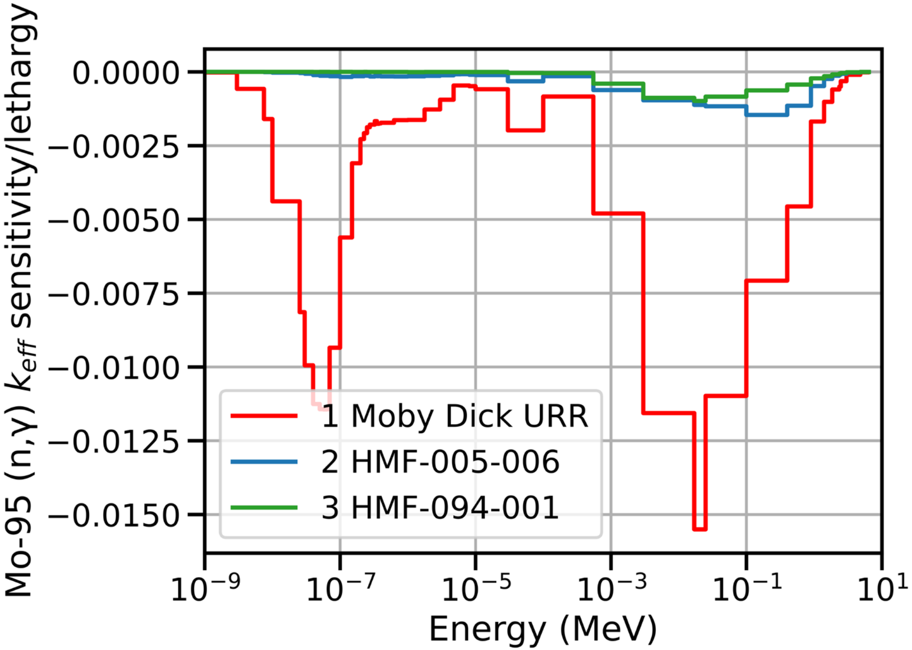


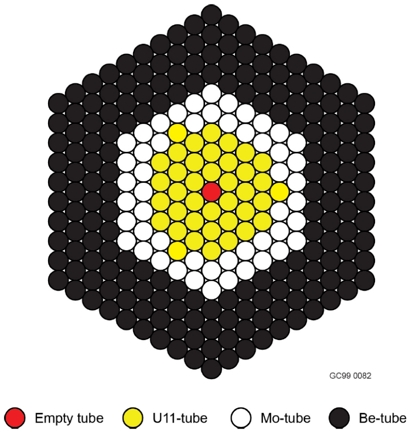
HMF-005-005
IPPE, Russia 1987

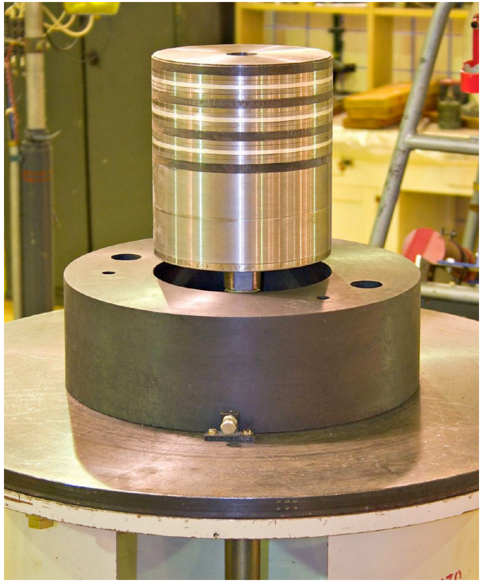


MCT-001-001
PNNL, USA 1978

URR - Comparison to Existing Benchmarks







HMF-005-006
IPPE, Russia 1987

HMF-094-001
VNIITF, Russia 2012

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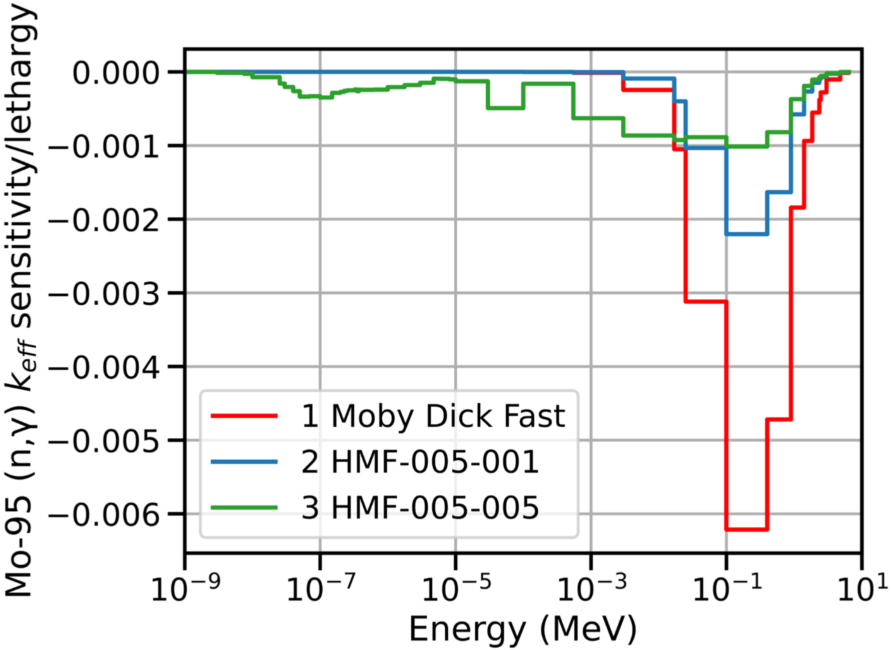
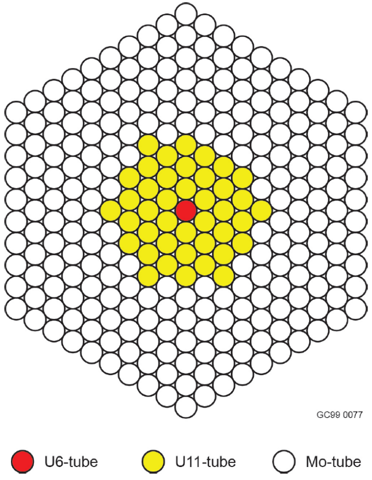
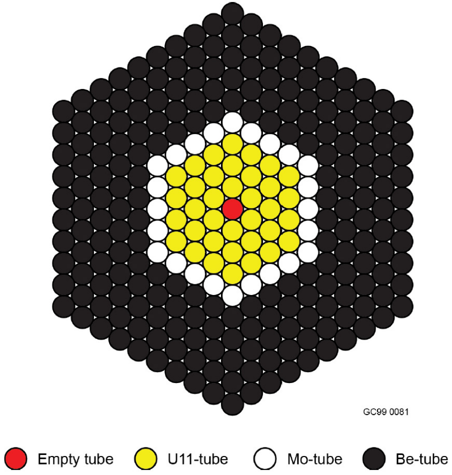


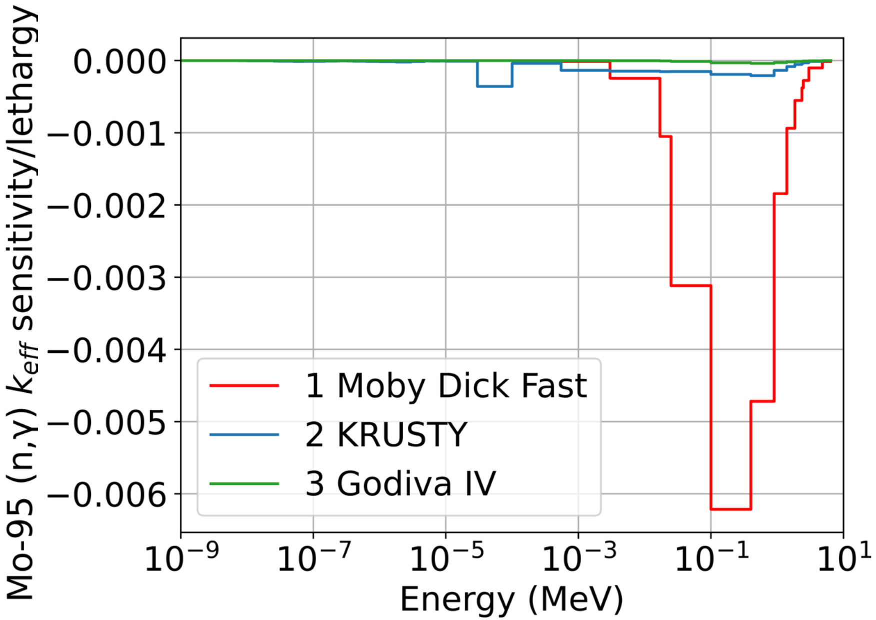


HMF-005-001
IPPE, Russia 1987

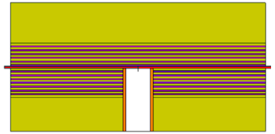


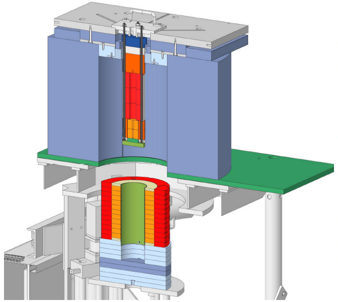
HMF-005-005
IPPE, Russia 1987

FAST - Comparison to NCERC Benchmarks



	Moby Dick Fast	KRUSTY	Godiva-IV
Weight % Mo	73.4 %	7.6 %	1.5 %
Mo Mass	491 kg	2.3 kg	~1 kg





HMF-101

HMF-086

Concluding Remarks

- A series of four HEU Molybdenum configurations were designed using the PSO algorithm developed as part of the CED-1 of this project.
- These configurations were shown to be significantly more sensitive to ^{95}Mo (n,γ) than existing benchmarks.
- Existing NCERC materials were leveraged to reduce costs and procurement times (JIMO Plates and Beryllium reflector).
- Beryllium reflector can be used for future experiments, including the future Plutonium configurations of this experiment

Acknowledgements

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NCSP
NUCLEAR CRITICALITY SAFETY PROGRAM

NCERC
NATIONAL CRITICALITY EXPERIMENTS RESEARCH CENTER

Questions?