Analysis of VNIITF Mo Benchmarks

M. L. Zerkle
Bettis Atomic Power Laboratory

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VNIITF Mo Benchmarks

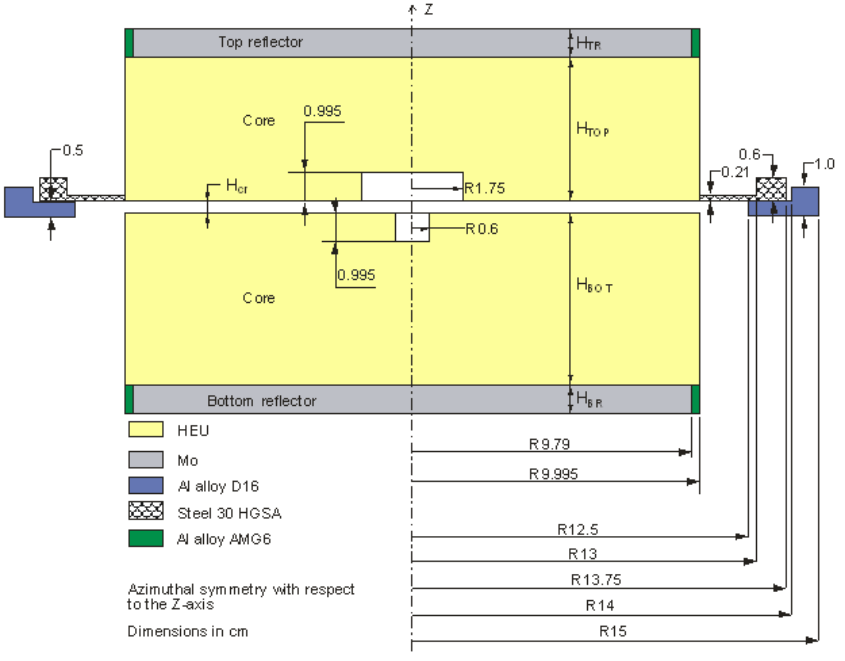
- New ICSBEP Mo Benchmarks
  - HMF092 – fast, Mo reflected
  - HMF093 – fast, Mo reflected/diluted
  - HMF094 – fast, Mo diluted, Be/BeO mod, DU/Be/BeO Reflected
  - HMM020 – mixed, Mo diluted, CH_2 mod/reflected
- Analyzed with MC21
  - ENDF/B-VII.0 cross section
  - ENDF/B-VII.1 cross section
  - 10^8 active neutron histories (~0.0001 Δk 95% CI)

ENDF/B-VII.1 Changes

- ^{9}Be – new evaluation by G. Hale
- ^{92}Mo – new evaluation by Mughabghab + JENDL-3.3
- ^{95}Mo – new evaluation by Kim, Herman, Mughabghab

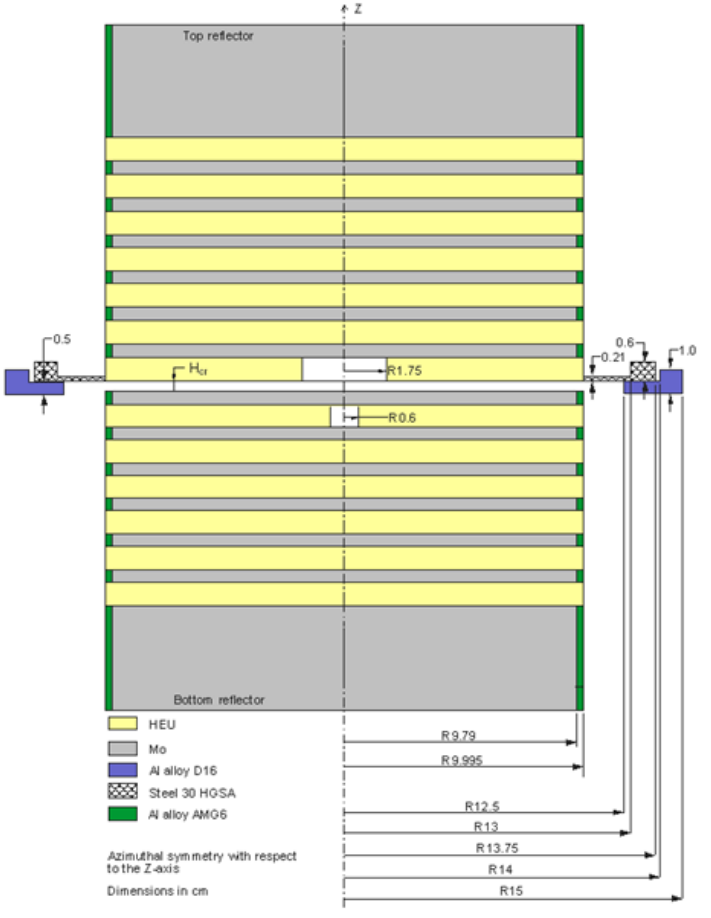
HMF092

- Mo reflected HEU cylinder
- Mo axial reflector thicknesses
  - 1.0 cm
  - 3.1 cm
  - 8.4 cm
  - 10.5 cm
- Tests following cross sections
  - Mo fast elastic scattering
  - Mo fast scattering angular distribution data



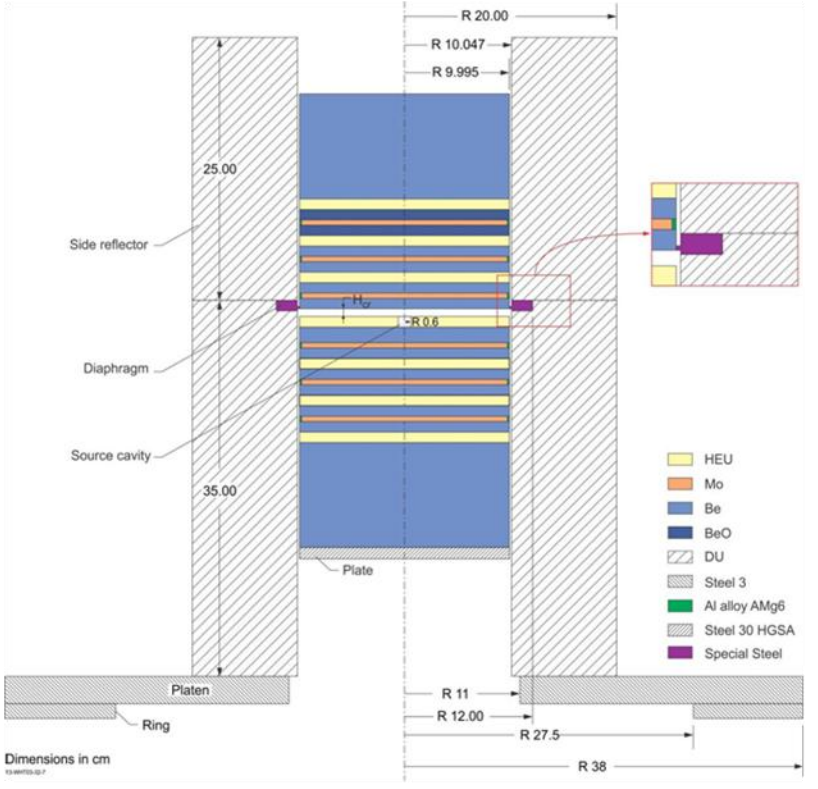
HMF093

- Mo diluted/reflected HEU Cylinder
  - 0.5 cm thick Mo diluent plates
  - 7.3 cm thick Mo axial reflector
- Tests following cross sections
  - Mo fast capture
  - Mo fast elastic scattering
  - Mo fast scattering angular distribution data



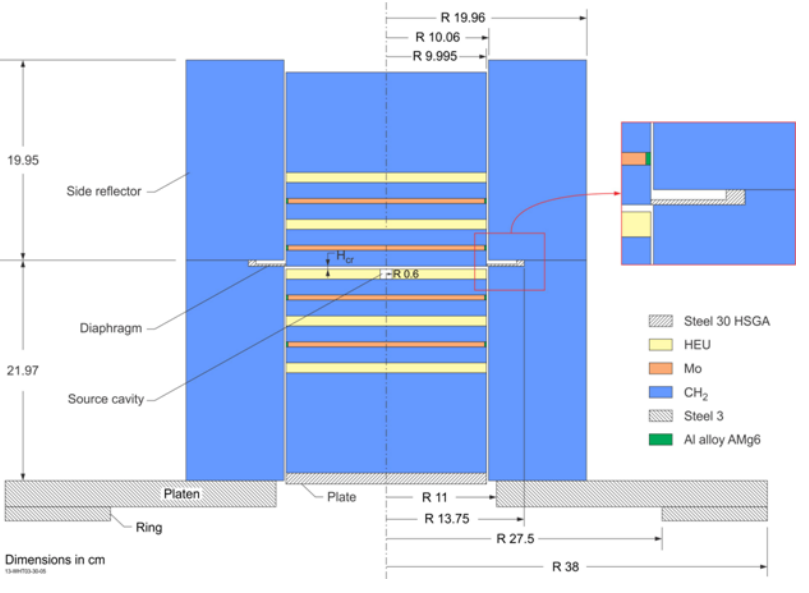
HMF094

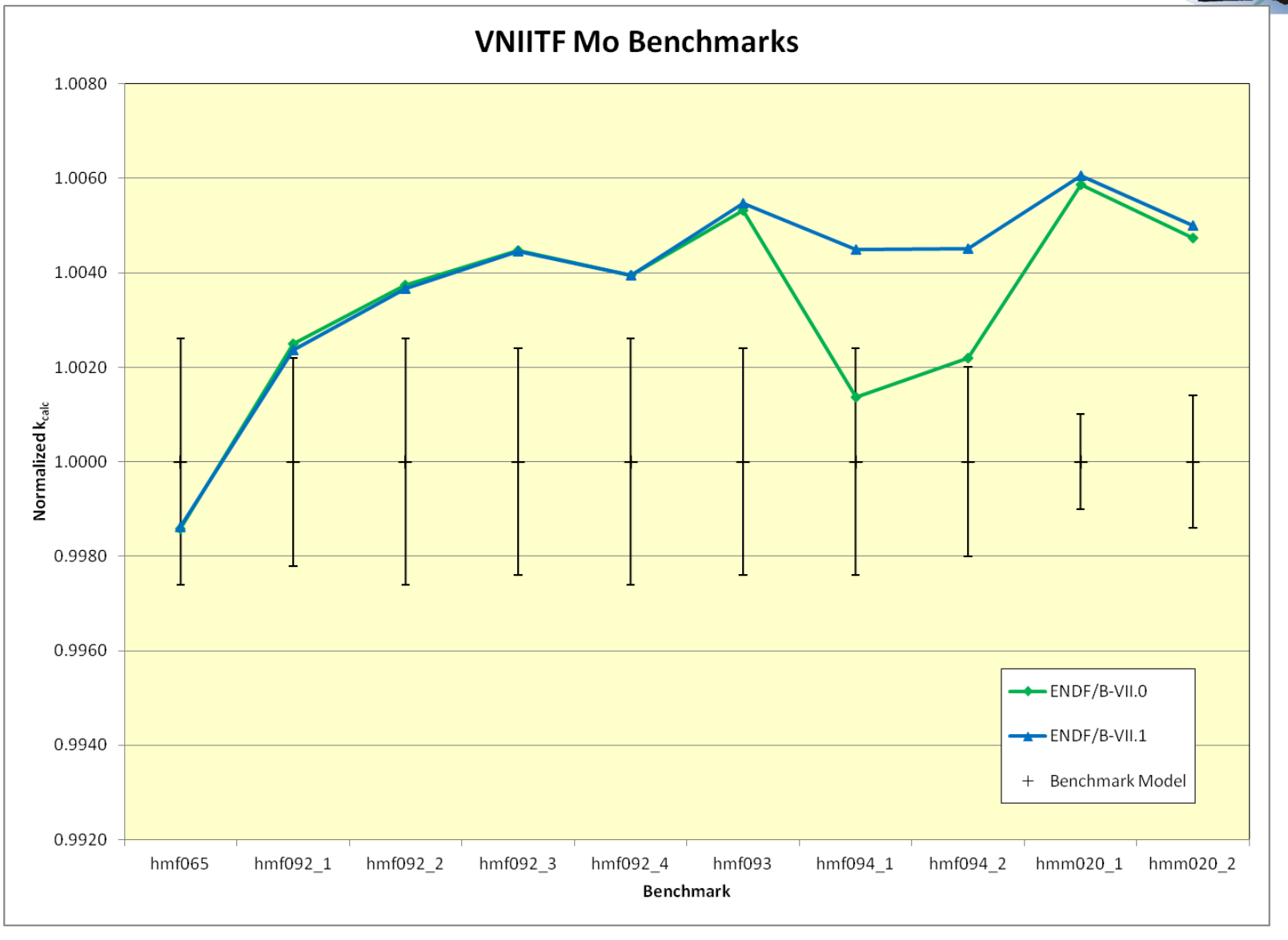
- Mo diluted, Be/BeO moderated, Be/DU reflected HEU Cylinder (Case 1)
  - 0.5 cm thick Mo diluent
  - 1.0 cm thick Be/BeO moderator
  - 10 cm thick Be axial reflector
  - 10 cm thick DU radial reflector
- Mo diluted, Be/BeO moderated, Be/DU reflected HEU Cylinder (Case 2)
  - 0.5 cm thick Mo diluent
  - 1.5 cm thick Be/BeO moderator
  - 15 cm thick Be/BeO axial reflector
  - 10 cm thick DU radial reflector
- Tests following cross sections
  - Mo capture in fast and URR
  - Be capture and scattering

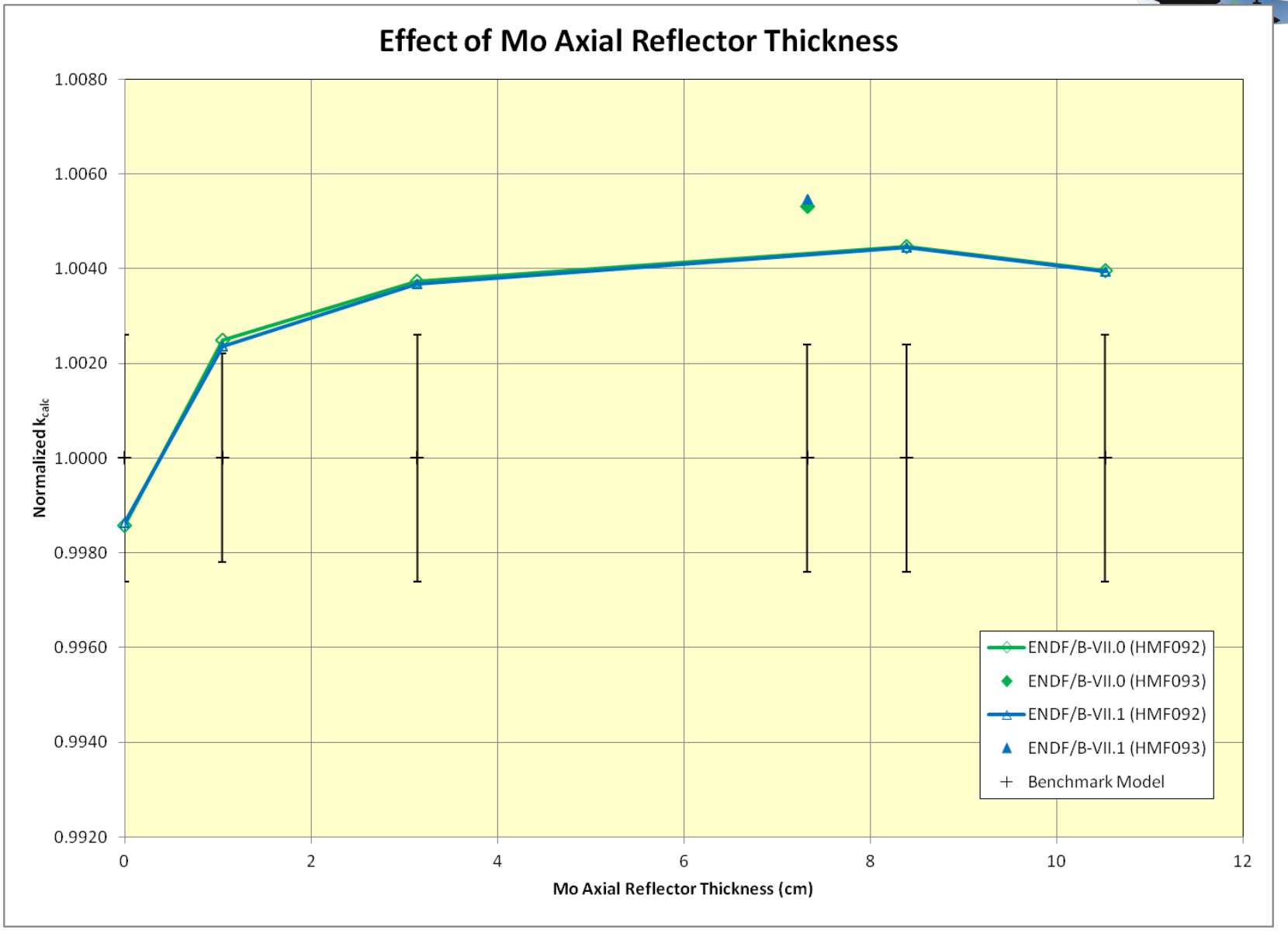


HMM020

- Mo diluted, CH_2 moderated/reflected HEU Cylinder (Case 1)
  - 0.5 cm thick Mo diluent
  - 1.6 cm thick CH_2 moderator
  - 10 cm thick CH_2 axial reflector
  - 10 cm thick CH_2 radial reflector
- Mo diluted, CH_2 moderated/reflected HEU Cylinder (Case 2)
  - 0.5 cm thick Mo diluent
  - 2 cm thick CH_2 moderator
  - 10 cm thick CH_2 axial reflector
  - 10 cm thick CH_2 radial reflector
- Tests following cross sections
  - Mo Capture (thermal, RRR, URR, fast)




VNIITF Mo Benchmarks
1.0080
1.0060
1.0040
1.0020
1.0000
0.9980
0.9960
0.9940
0.9920
Normalized k_{calc}
hmf065
hmf092_1
hmf092_2
hmf092_3
hmf092_4
hmf093
hmf094_1
hmf094_2
hmm020_1
hmm020_2
Benchmark
ENDF/B-VII.0
ENDF/B-VII.1
Benchmark Model


Effect of Mo Axial Reflector Thickness
Normalized k_{calc}
1.0080
1.0060
1.0040
1.0020
1.0000
0.9980
0.9960
0.9940
0.9920
0
2
4
6
8
10
12
Mo Axial Reflector Thickness (cm)
ENDF/B-VII.0 (HMF092)
ENDF/B-VII.0 (HMF093)
ENDF/B-VII.1 (HMF092)
ENDF/B-VII.1 (HMF093)
Benchmark Model

Detailed MC21 Results

Model	Benchmark σ (Δk)	ENDF/B-VII.0		ENDF/B-VII.1		Fission Fraction		
		k_{calc}	$(1-k_{calc})/\sigma$	k_{calc}	$(1-k_{calc})/\sigma$	Fast	Inter	Thermal
hmf092_1	0.0011	1.00250(12)	2.27	1.00236(12)	2.15	94.63%	5.37%	0.00%
hmf092_2	0.0013	1.00374(12)	2.87	1.00367(12)	2.82	94.30%	5.70%	0.00%
hmf092_3	0.0012	1.00447(12)	3.73	1.00445(12)	3.70	93.84%	6.16%	0.00%
hmf092_4	0.0013	1.00395(12)	3.04	1.00395(12)	3.04	93.79%	6.21%	0.00%
hmf093	0.0012	1.00532(13)	4.42	1.00547(12)	4.55	92.90%	7.10%	0.00%
hmf094_1	0.0012	1.00136(15)	1.13	1.00448(14)	3.73	66.31%	33.13%	0.56%
hmf094_2	0.0010	1.00220(14)	2.19	1.00451(14)	4.51	61.00%	38.89%	0.10%
hmm020_1	0.0005	1.00586(16)	11.71	1.00606(16)	12.10	26.40%	34.71%	38.90%
hmm020_2	0.0007	1.00475(16)	6.77	1.00501(16)	7.15	25.22%	32.61%	42.17%

Conclusions

- ENDF/B-VII.0 and ENDF/B-VII.1 results consistent except for Be moderated/reflected cases (HMF094)
  - Implies improvement in ENDF/B-VII.1 Be evaluation
- Positive k_{calc} bias with Mo reflector thickness
  - Bias grows from +0.4% to +0.6% Δk for HMF092
  - Mo ESAD insufficiently forward peaked and/or
  - Mo fast capture too low
- Bias increases to +0.7% Δk when Mo dilution added (HMF093)
  - Mo fast capture too low
- k_{calc} biased high in moderated cases
  - +0.6% Δk bias for Be/BeO moderated cases (HMF094)
  - +0.64% to 0.74% Δk bias for CH_2 moderated cases (HMM020)
  - capture too low (RR, fast)
  - Spectral dependence on bias in RR (bias reduced for softer spectrum CH_2 moderated cases)