Calculated Critical Masses of ^{242m}Am for Unreflected Spherical Homogeneous Water Moderated Systems

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Road Map

- What is ^{242m}Am?
- Method of Calculation using MCNP
- Critical Mass versus Nuclide Density
- Comparison with an Sn Method
- Conclusions

What is ^{242m}Am?

- ^{242m}Am is one of the actinides studied in ANS 8.15 "Nuclear Criticality Control of Selected Actinide Nuclides"
- Very large thermal fission cross section
- Minimum critical mass much smaller than ^{233}U, ^{235}U, or ^{239}Pu
- Present in spent fuel in small quantities

Modeling Assumptions

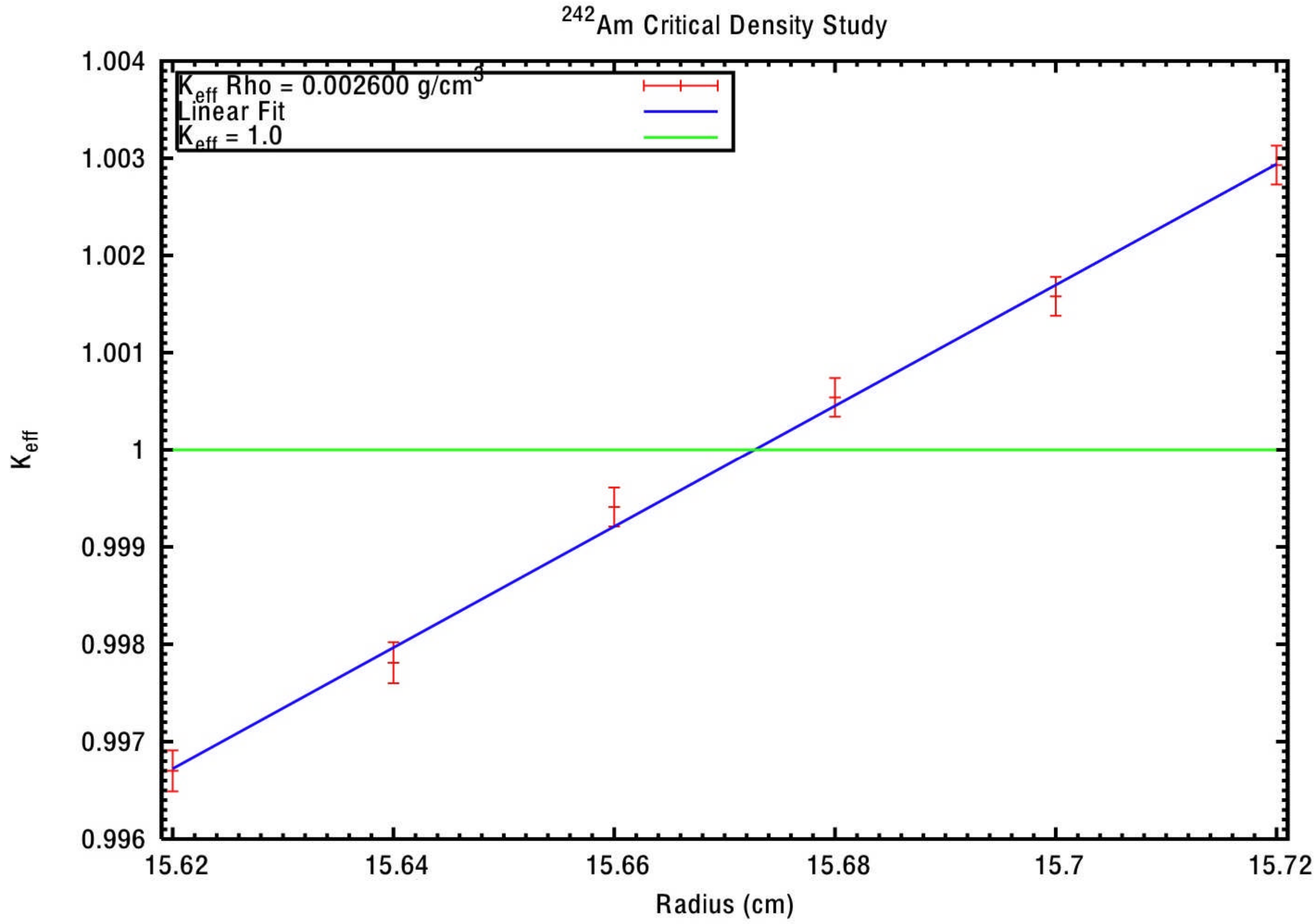
- Homogeneous Metal-Water Mixture
- Spherical Geometry
- Unreflected (bare)
- From Limiting Critical Density to Pure Metal

MCNP Calculation Method

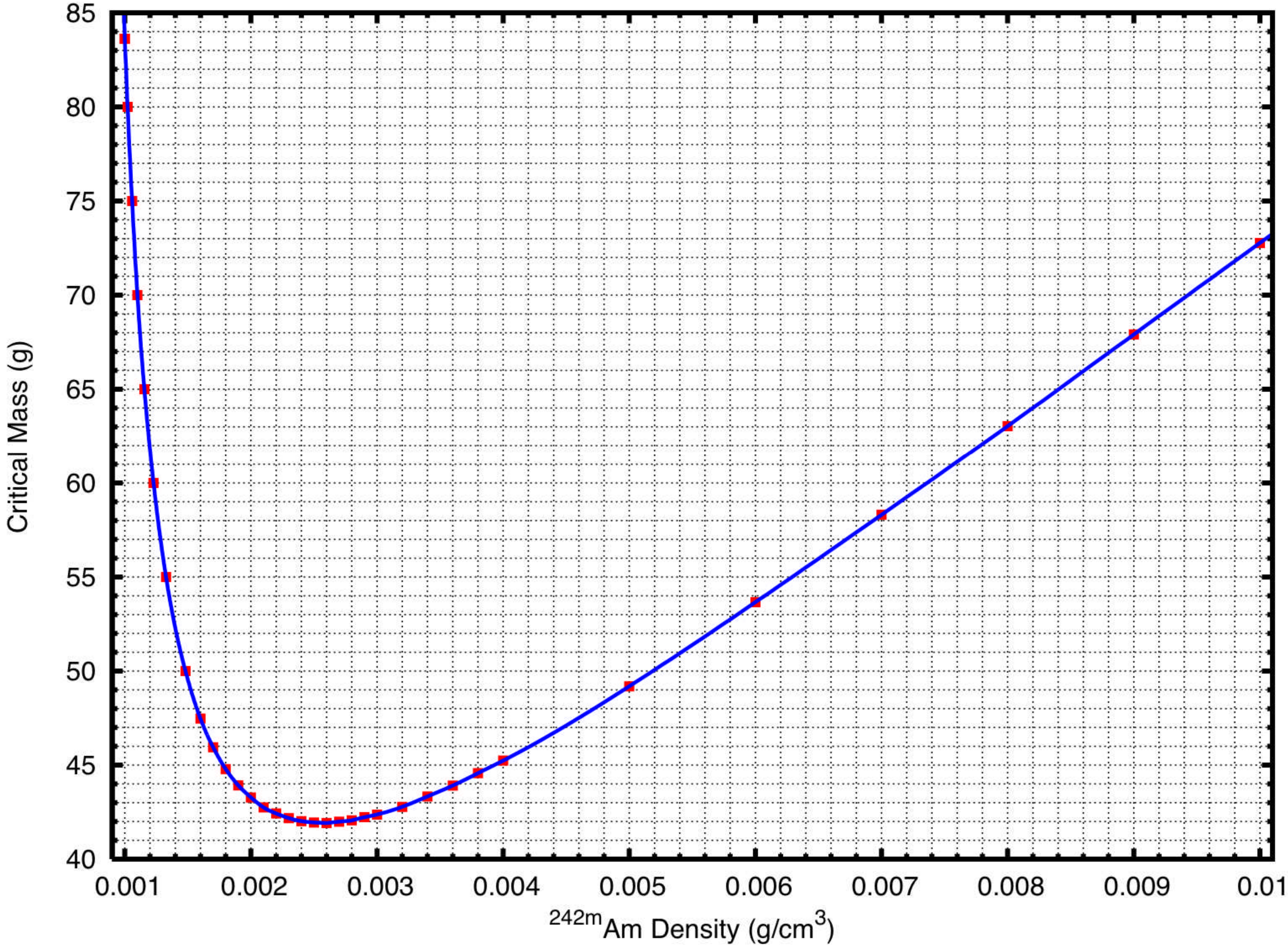
- MCNP 5, Version 1.40
- Continuous Energy Cross Sections
- ENDF/B-VI.8
- Skip first 100 cycles
- 1000 active cycles with 40,000 neutrons per cycle
- Each data point based on 40 million histories

MCNP Calculation Method

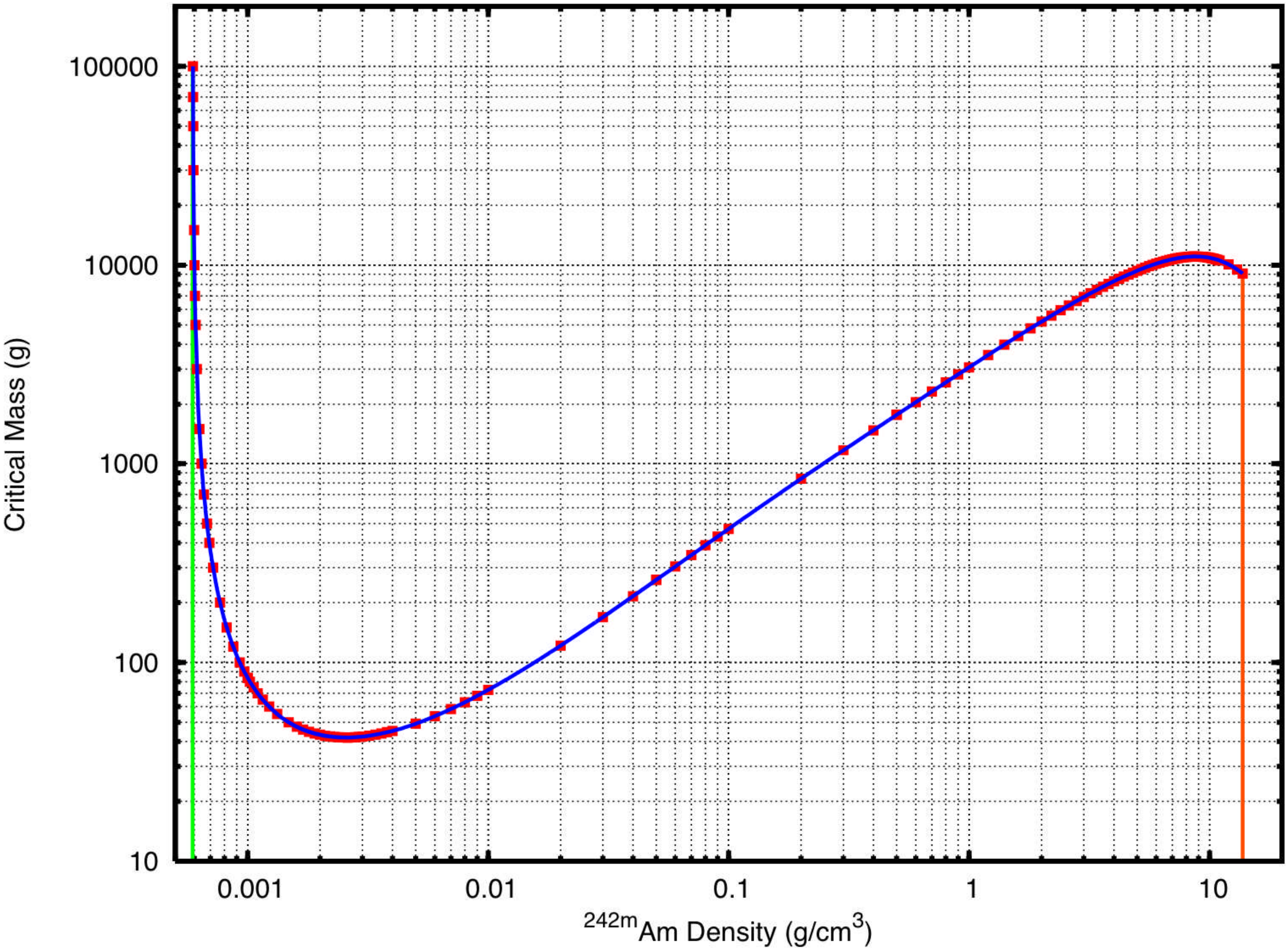
- Each critical radius determined from six runs (k_{eff} less than 1.00 for 3 runs and k_{eff} greater than 1.00 for 3 runs)
- Linear least squares fit to determine radius at which $k_{eff} = 1.00$
- A total of 125 critical radii were determined



^{242}Am Critical Density Study
K_{eff} Rho = 0.002600 g/cm^3
Linear Fit
K_{eff} = 1.0
K_{eff}
1.004
1.003
1.002
1.001
1
0.999
0.998
0.997
0.996
15.62
15.64
15.66
15.68
15.7
15.72
Radius (cm)



85
80
75
70
65
60
55
50
45
40
Critical Mass (g)
0.001
0.002
0.003
0.004
0.005
0.006
0.007
0.008
0.009
0.01
242mAm Density (g/cm3)



100000
10000
1000
100
10
0.001
0.01
0.1
1
10
Critical Mass (g)
^{242m}Am Density (g/cm^3)

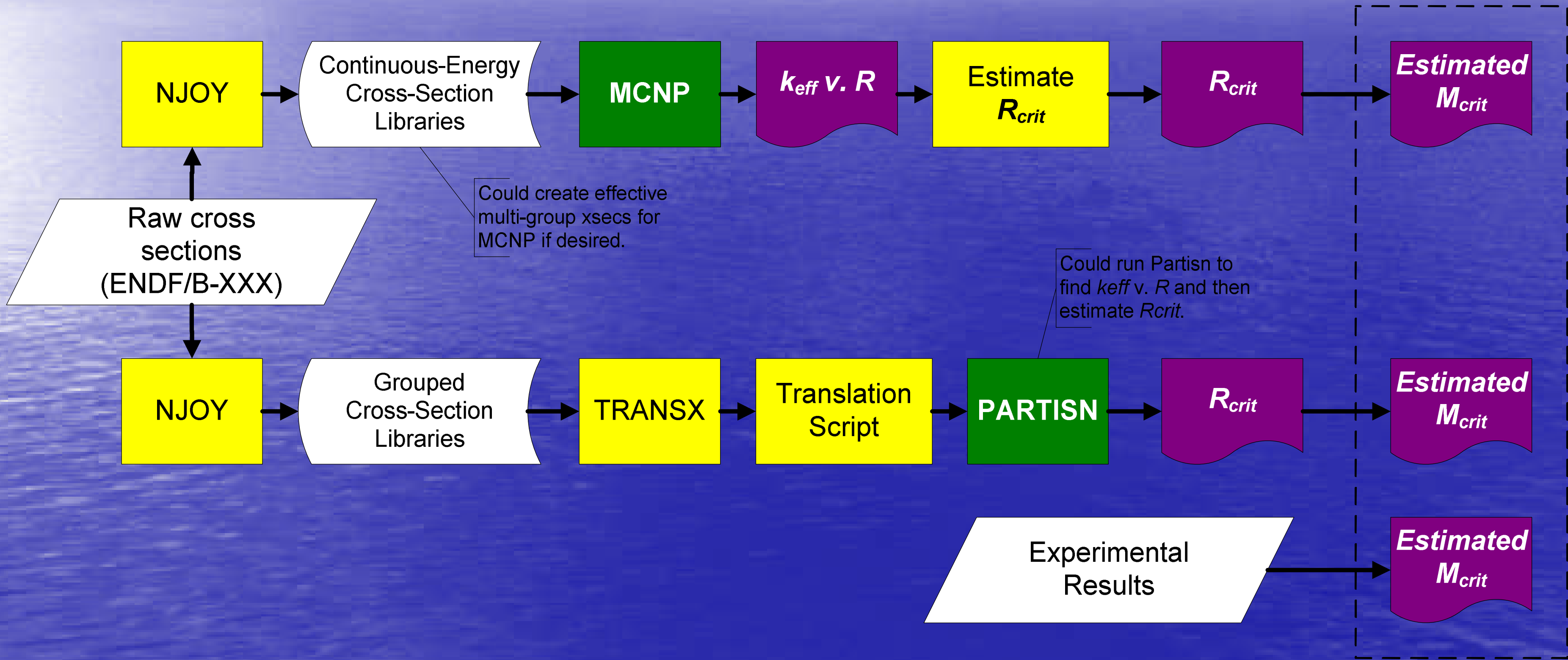
MCNP Results for ^{242m}Am

- Limiting critical density is 0.00059 g/cc (^{235}U LCD is ~ 0.012 g/cc)
- Bare minimum critical mass is 41.9 grams (^{235}U bare min. critical mass is ~ 1300 grams)
- Bare critical mass for the pure metal is 9.08 kilograms (^{235}U bare metal critical mass is ~ 45 kilograms)
- Discharged fuel contains ~ 50 grams/yr/reactor or 5 kg/yr in U.S.

Comparison to PARTISN

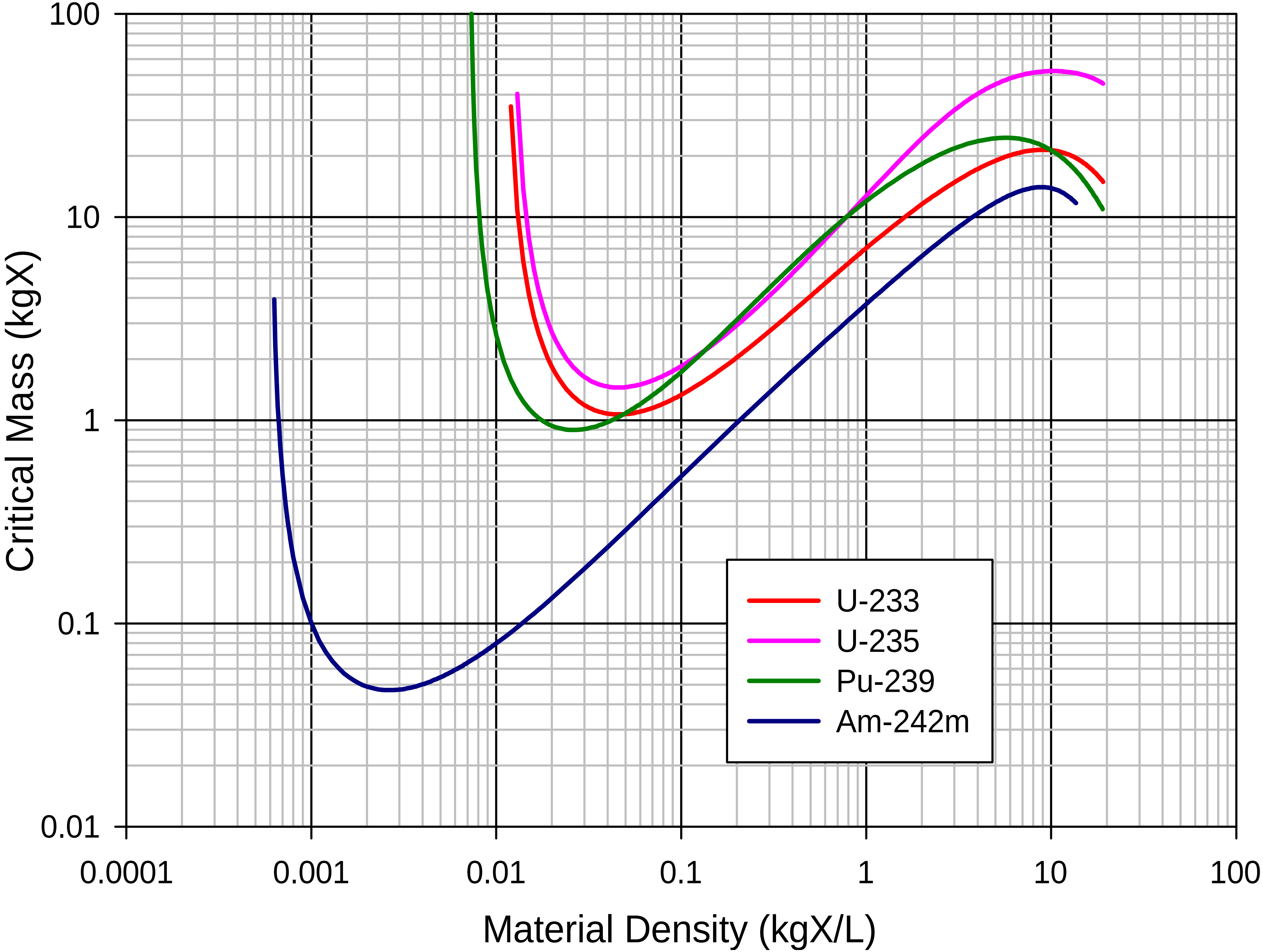
- There are multiple paths to the goal – all with pros and cons
- However, all paths provide an estimate of a critical mass

MCNP vs. PARTISN



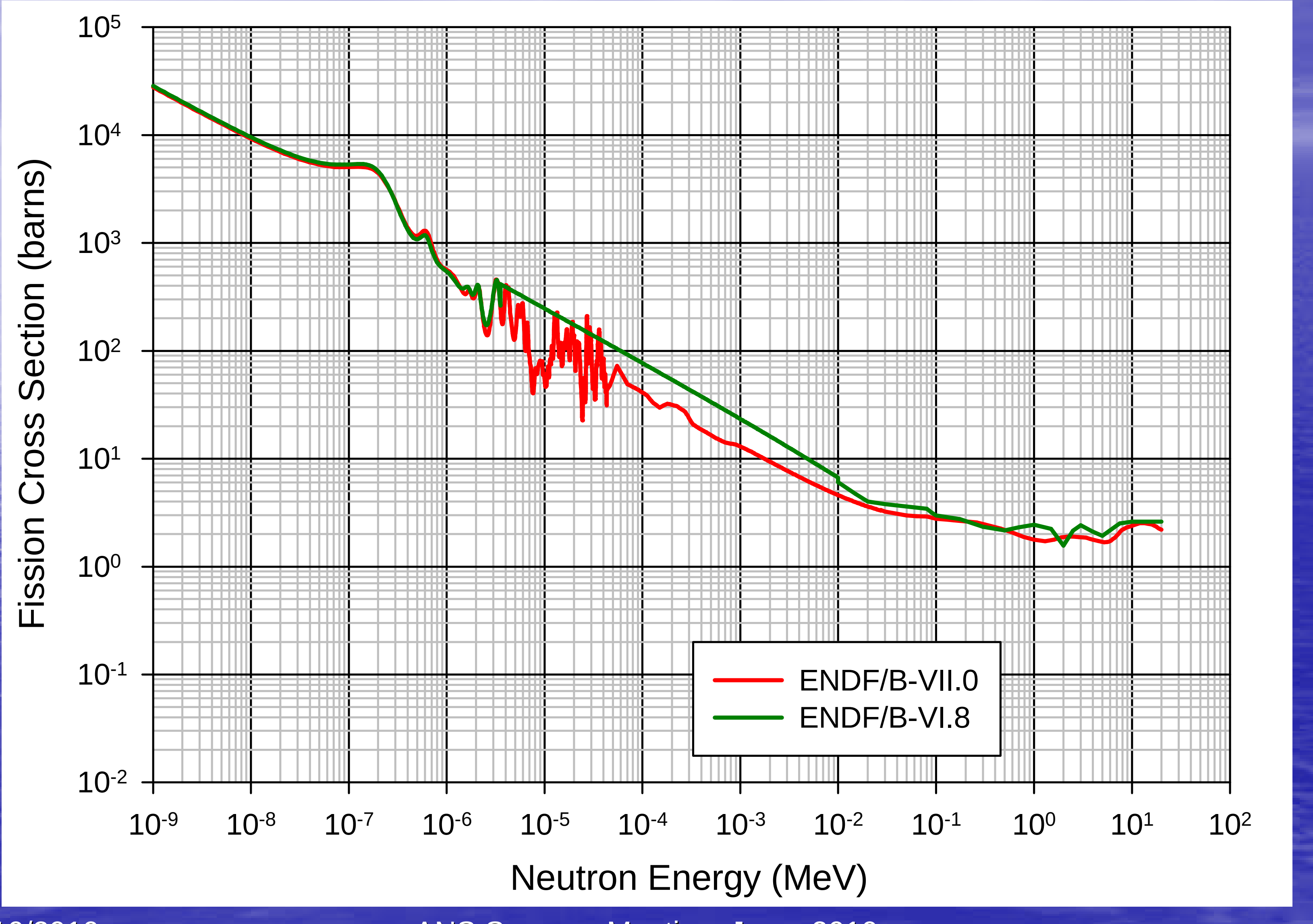
The Difficulty with ^{242m}Am

- The "big 3" (^{235}U, ^{239}Pu, ^{233}U) are well supported with experimental data
- The selected actinides covered by ANS-8.15 such as ^{242m}Am have little to no experimental data, other than that used to generate cross section data



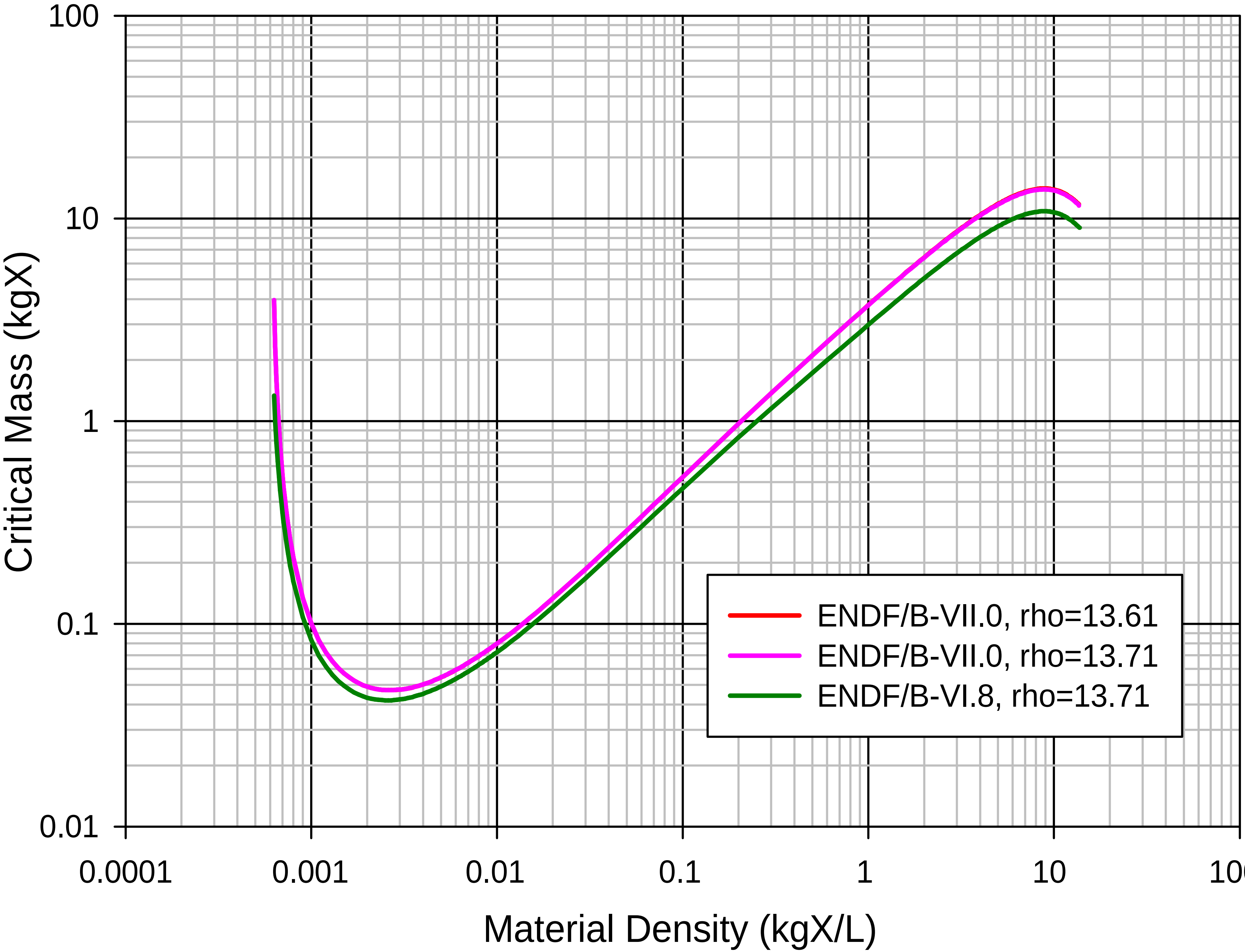
100
10
1
0.1
0.01
Critical Mass (kgX)
0.0001
0.001
0.01
0.1
1
10
100
Material Density (kgX/L)
U-233
U-235
Pu-239
Am-242m

The ^{242m}Am fission cross section



Am-242m Metal-Water Mixtures as Calculated with Partisn

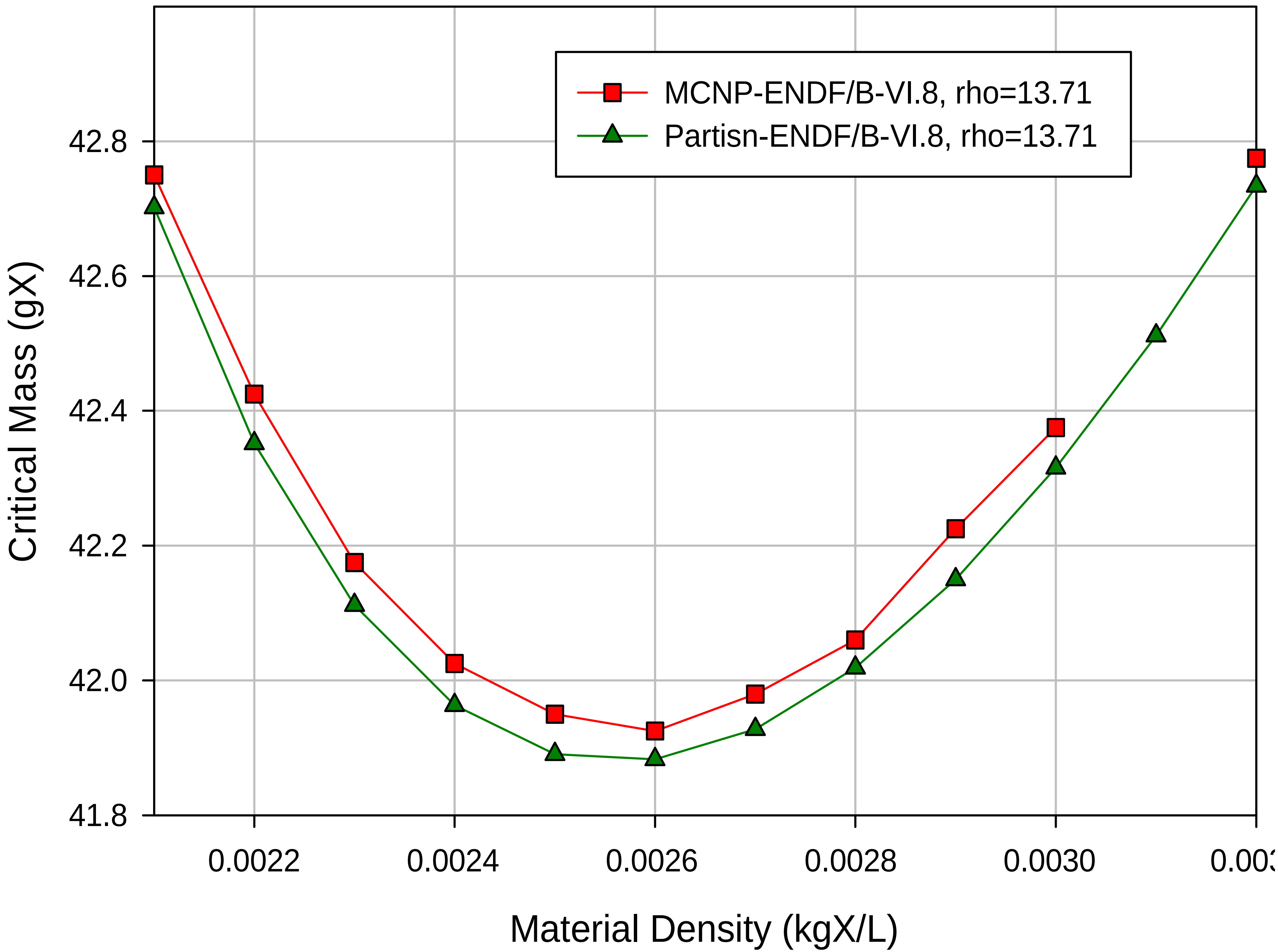
- There is a discernable difference between results using ENDF/B-VI.8 and ENDF/B-VII.0
- Partisn Model
  - Bare spherical geometry
  - S16
  - 69-group structure
  - 100 fine mesh intervals
  - Critical radius search



Critical Mass (kgX)
100
10
1
0.1
0.01
0.0001
0.001
0.01
0.1
1
10
100
Material Density (kgX/L)
ENDF/B-VII.0, rho=13.61
ENDF/B-VII.0, rho=13.71
ENDF/B-VI.8, rho=13.71

MCNP5/Partisn Comparison at Estimated Minimum Critical Mass

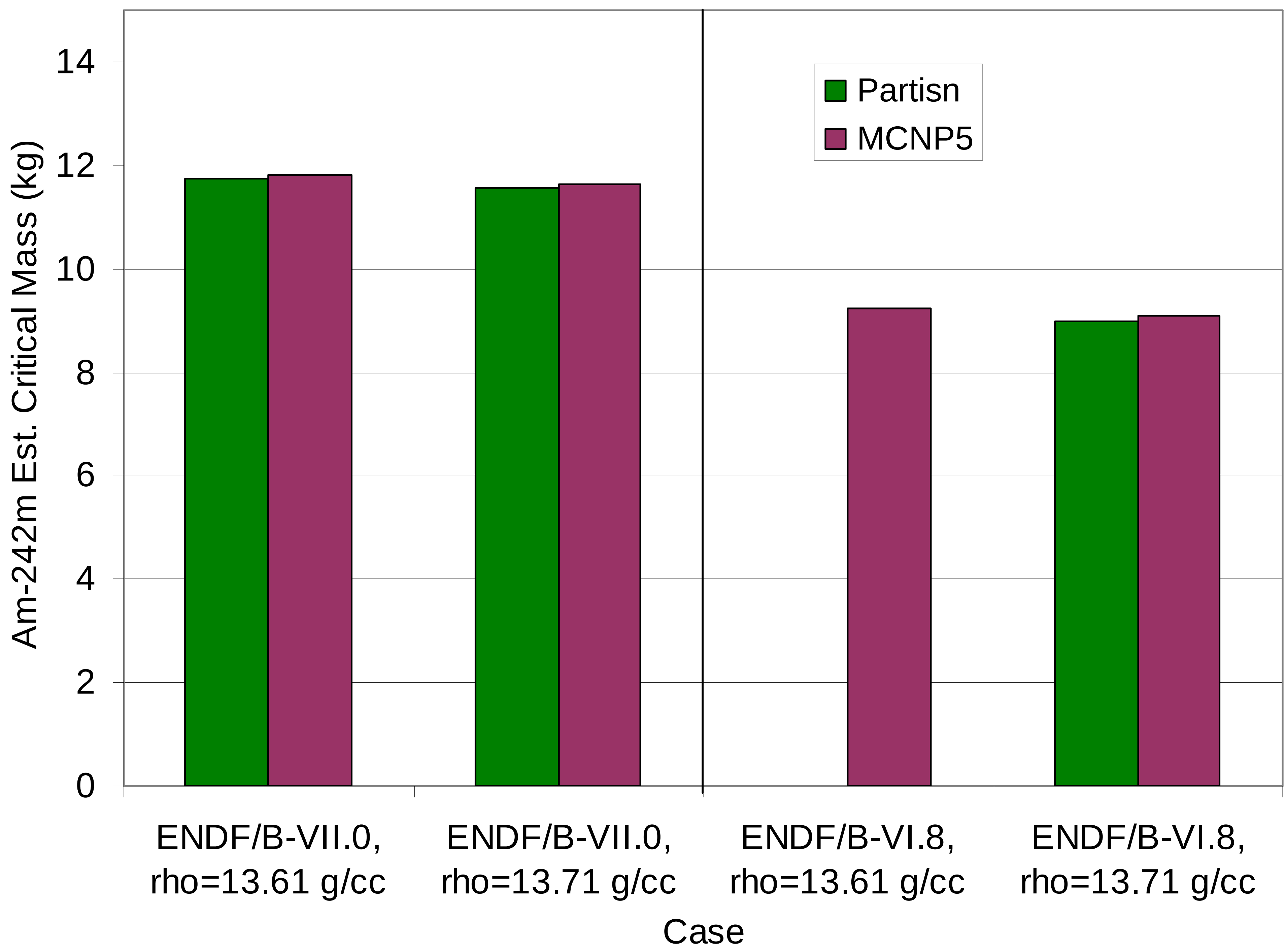
- Partisn uniformly yields smaller estimated critical masses than MCNP5
- Average relative error between Partisn and MCNP5
  – ENDF/B-VI.8 ~ 0.13%
  – ENDF/B-VII.0 ~ 0.74%



MCNP-ENDF/B-VI.8, rho=13.71
Partisn-ENDF/B-VI.8, rho=13.71
Critical Mass (gX)
42.8
42.6
42.4
42.2
42.0
41.8
0.0022
0.0024
0.0026
0.0028
0.0030
Material Density (kgX/L)

MCNP5-Partisn Comparison for Estimated Metal Critical Mass

- Partisn produces slightly smaller estimated critical masses relative to MCNP5
- ENDF/B-VI.8 produces significantly smaller metal critical masses relative to ENDF/B-VII.0 calculations


Partisn
MCNP5
Am-242m Est. Critical Mass (kg)
0
2
4
6
8
10
12
14
ENDF/B-VII.0, rho=13.61 g/cc
ENDF/B-VII.0, rho=13.71 g/cc
ENDF/B-VI.8, rho=13.61 g/cc
ENDF/B-VI.8, rho=13.71 g/cc
Case

Current Revision to Standard ANS-8.15

- Each selected nuclide covered by ANS-8.15 is evaluated and judged independent of other nuclides
- Judgment is required to set the appropriate subcritical limits for these selected nuclides:
  - Subcritical limits are established based on judgment relative to calculated results
  - Subcritical limits are generally NOT established based on experimental data *because* the experimental data do not exist
- The unreflected subcritical limit for ^{242m}Am in metal-water mixtures can be conservatively set to 21 grams (50% of the minimum calculated value)

Conclusions

- MCNP can be used to precisely calculate the critical mass of a highly fissionable nuclide for the complete range of metal-water mixtures
- MCNP and an Sn model (PARTISN) give similar results when using the same evaluated cross section data
- PARTISN consistently gives slightly smaller critical masses than MCNP (group x-sections vs. continuous energy, different method, etc.)

Audience Participation

- Thank you for your attention
- Comments?
- Questions?