OAK RIDGE National Laboratory

Effect of Varying Reflection on the Estimated Minimum Critical Mass of Moderated ^{235}U

Ellen M. Saylor

ANS Winter Meeting & Expo
Washington, D.C.
November 21, 2019

ORNL is managed by UT-Battelle, LLC for the US Department of Energy

U.S. DEPARTMENT OF ENERGY

Overview

- Motivation – why do this now?
- Results
- Future work plans

Motivation

- Result of work supporting operations group
- Looking for reflector comparison for moderated ^{235}U
- Similar to work for metal systems found in:
  - TID-7028, *Critical Dimensions of Systems Containing ^{235}U, ^{239}Pu, and ^{233}U* (June 1964)
  - LA-10860-MS, *Critical Dimensions of Systems Containing ^{235}U, ^{239}Pu, and ^{233}U* (1986 Revision)

Similar work
TID-7028

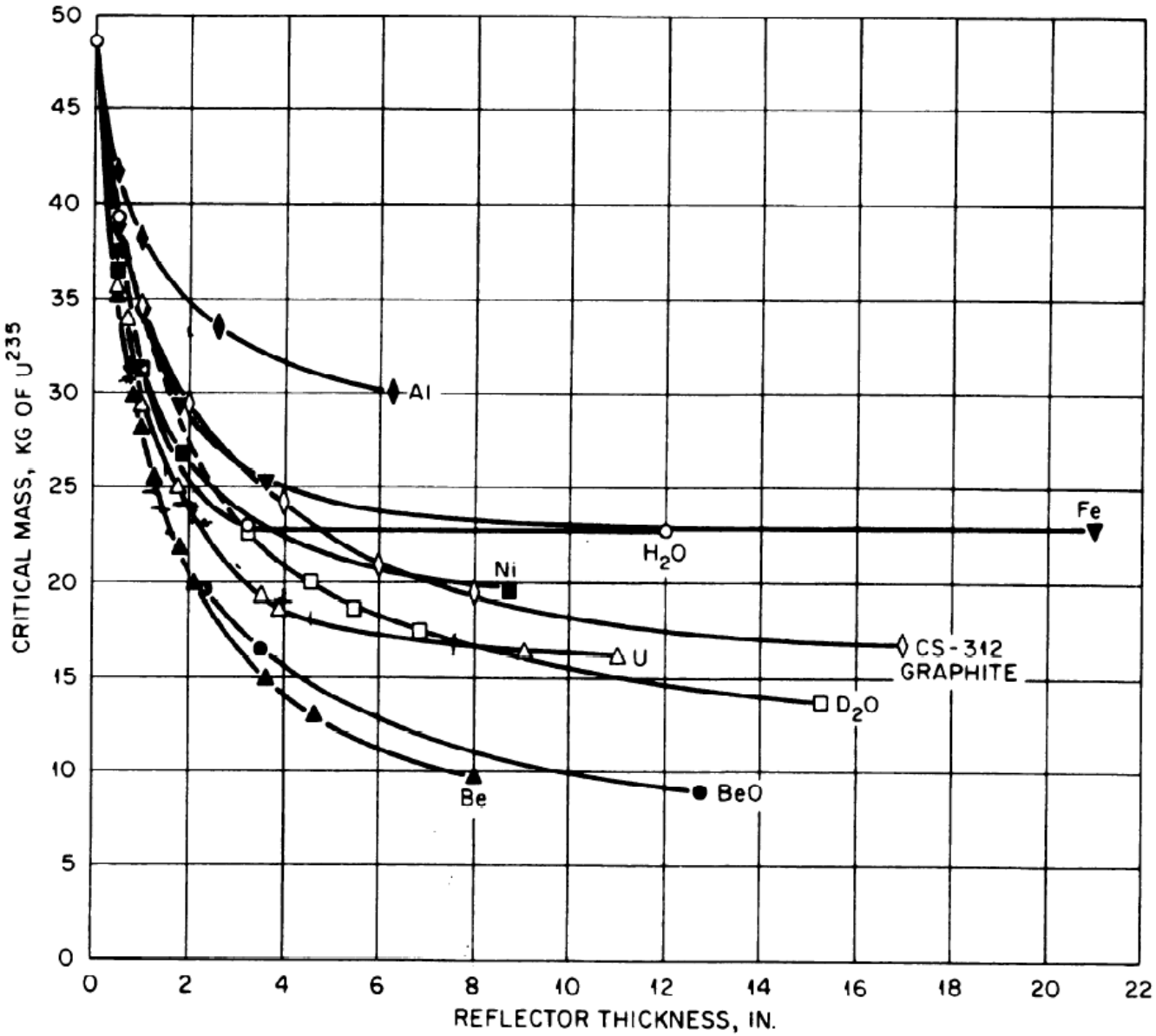


Fig. 44 – Critical masses of U(93.5) metal spheres in various reflectors. $\rho(U) = 18.8\ g/cm^3$.

Similar work LA-10860-MS

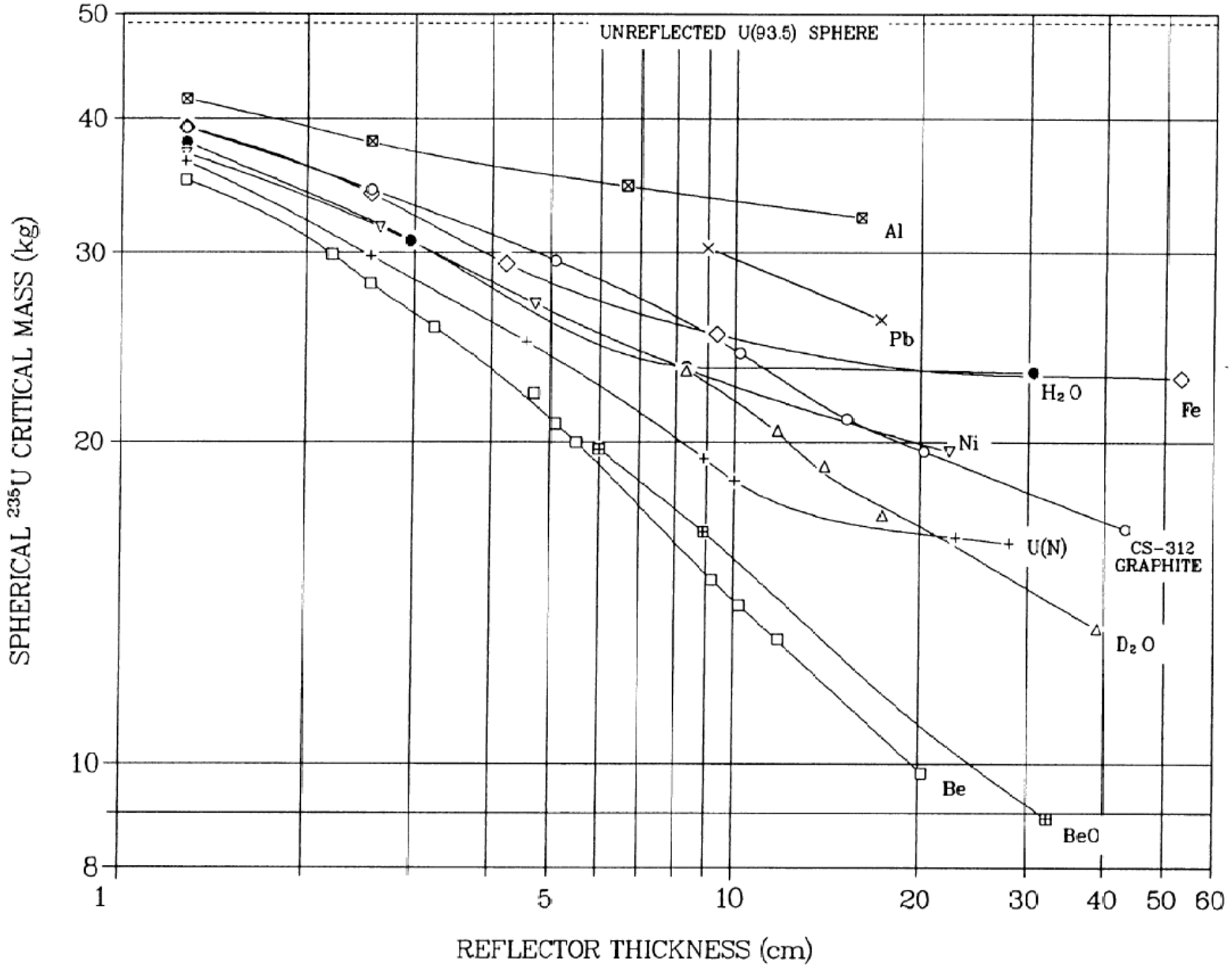


Fig. 42. Critical masses of U(93.5) metal spheres in various reflectors. Uranium density = 18.8 g/cm³.

Reflection

- When added as a reflector, any material will decrease the critical mass – returns neutrons
- Not all reflectors are equal
  - Number and energy spectrum of reflected neutrons depends on
    - Reflector material
    - Reflector material thickness
- Optimum H/ ^{235}U ratio also varies depending on material and material thickness – but not by the same degree as the minimum critical mass

Calculational Model

- Moderated ^{235}U modeled as a homogeneous mixture
  - ^{235}U (density of 18.81 g/cm^3)
  - Water (density of 0.9982 g/cm^3)
  - Sphere with each reflector added as a close-fitting spherical reflector
  - Calculations performed with
    - SCALE 6.0
    - ENDF/B-V cross section library
    - Monte Carlo uncertainty of 0.0001

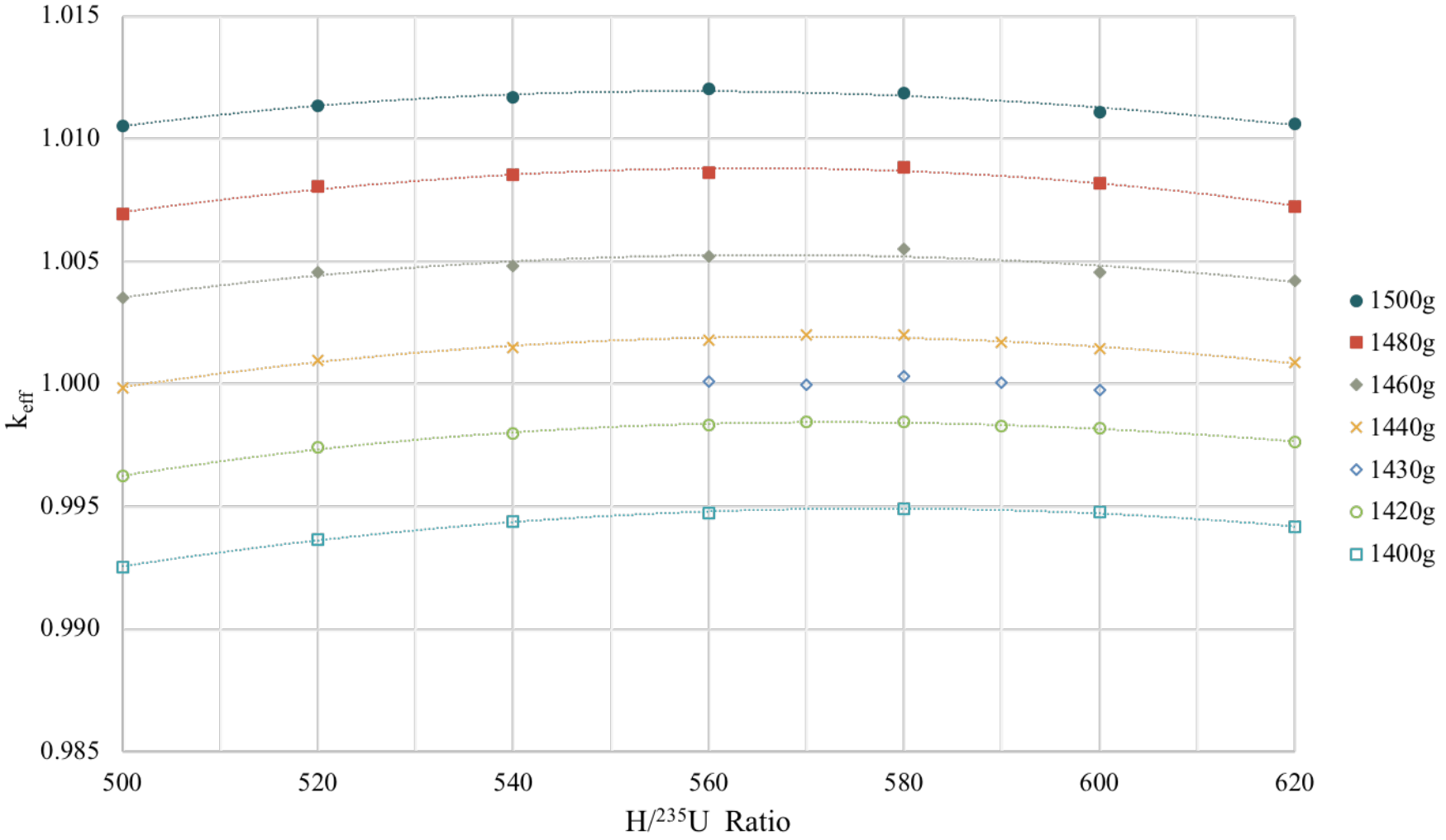
Reflection

- Reflectors considered:
  - Aluminum
  - Beryllium
  - Beryllium oxide
  - Heavy water
  - Graphite
  - Water
  - Iron
  - Lead
  - Natural uranium
  - Nickel
  - Polyethylene
  - Pyrex
  - Concrete (standard SCALE reg-concrete)
- Reflector thicknesses considered (inches):
  - 0.5
  - 1.0
  - 2.0
  - 5.0
  - 10.0
  - 12.0
  - 20.0
  - 30.0

Calculations

- First – bare sphere
  - Based on TID-7028 (Figure 8)
    - Homogeneous water moderated U(93.2) sphere with a 0.0625-in. stainless steel reflector
    - About 1400 grams of ^{235}U with an H/^{235}U ratio of slightly more than 500
  - As calculated here
    - 1420 grams of ^{235}U with an H/^{235}U ratio 570

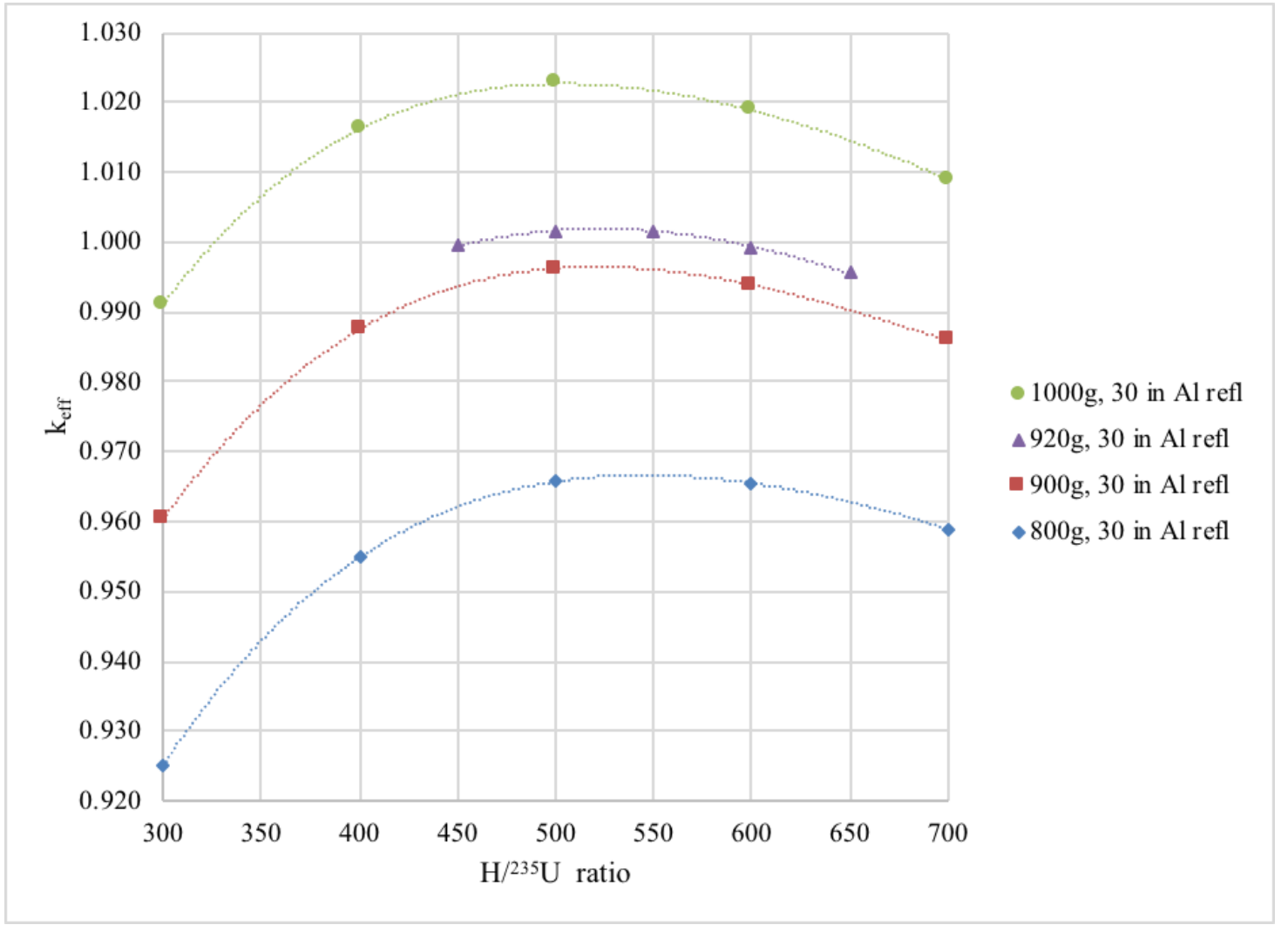
Bare Moderated Sphere



Example of process with Aluminum

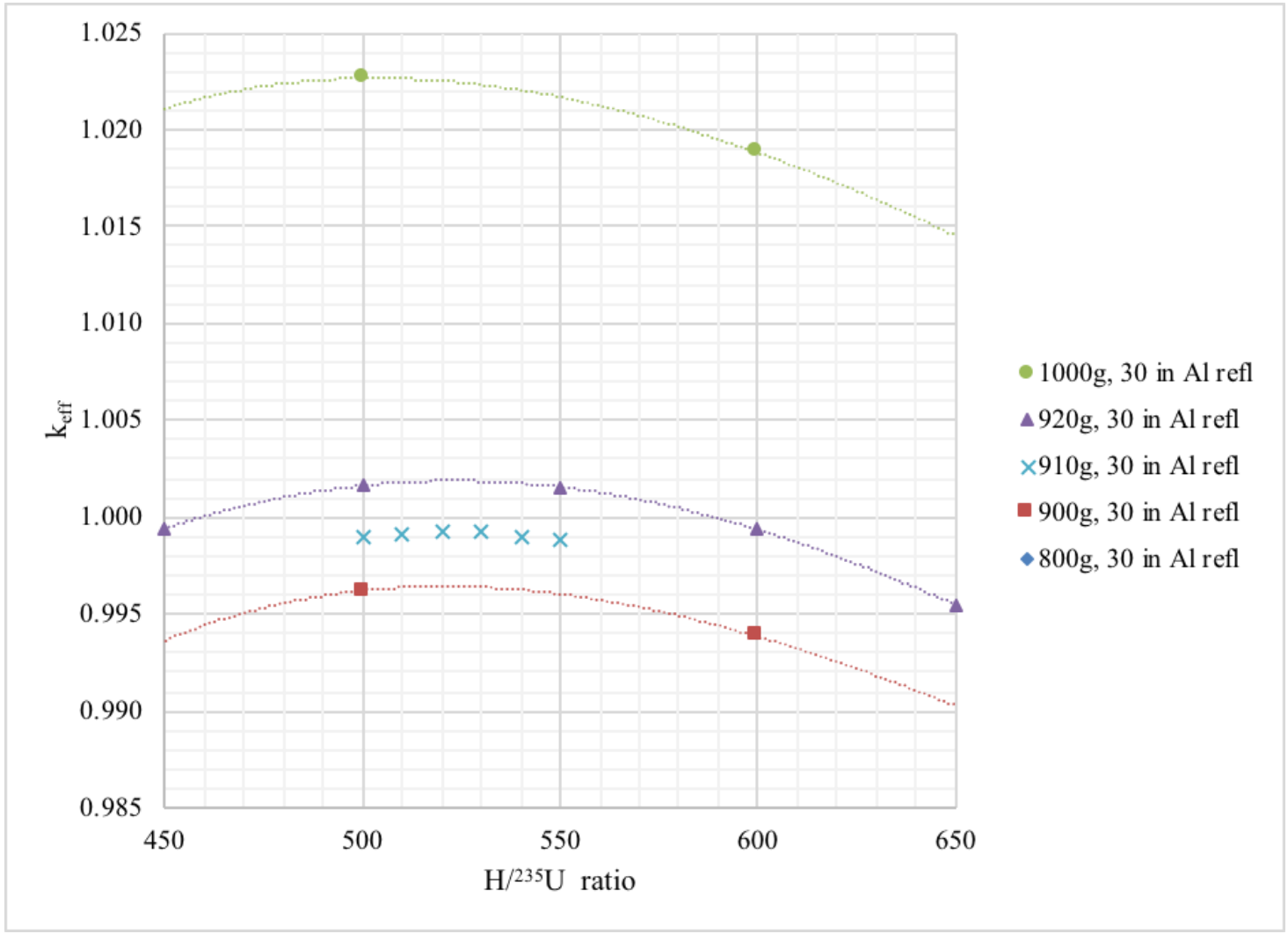
- Scoping ranges performed in steps
  - At hundred gram intervals
    - H/U range of 300 – 700, at intervals of a hundred
  - Added intervals at 20s (or 10s, depending on the previous results)
    - H/U intervals of 50 within a reduced range (depends on slope from previous results)
  - Added intervals at 10s (if necessary
    - H/U intervals of 10 within a reduced range
- Examples in next few slides

Aluminum Reflection of 30 inches



Aluminum reflection of 30 inches (continued)

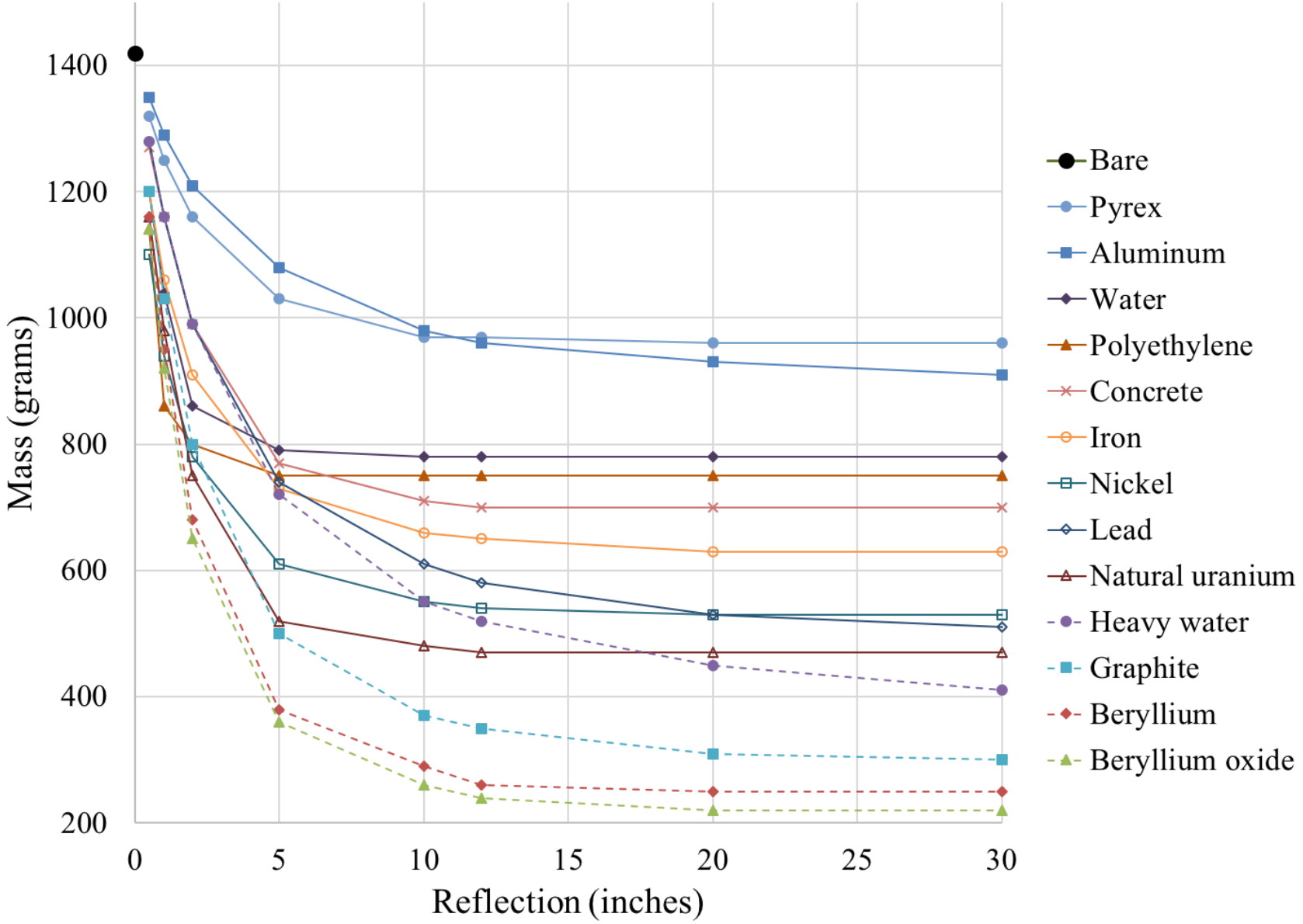
- Estimated minimum critical mass for this work with 30 inches of aluminum reflection:
  - 910 grams ^{235}U
  - H/ ^{235}U of 520



Results – Observations

- Again – reflector materials are not all equal in how they affect the system
  - At 2 inches of reflection
    - Water is better reflector than iron, heavy water, or concrete – has a smaller minimum critical mass
  - At 30 inches of reflection
    - Water has a larger minimum critical mass than iron, heavy water, or concrete
  - Steepest change is between 0.5 and 5 inches of reflection
  - Most start to level out (act as infinite) at around 12 inches of reflection
  - Smallest change – Pyrex
  - Largest change – beryllium oxide

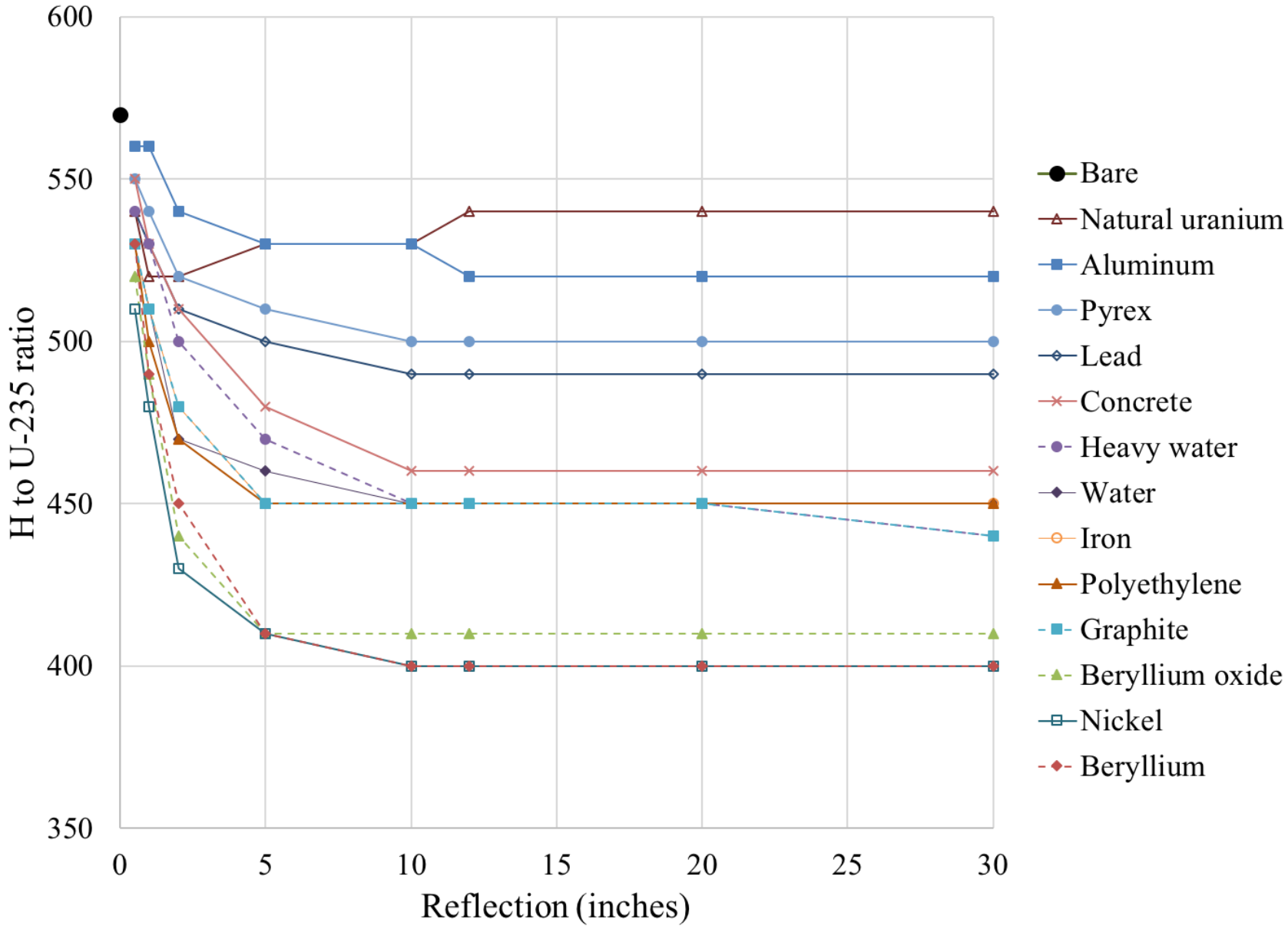
Consolidated Results



Results – Observations (continued)

- For most reflectors – optimum H/^{235}U ratio decreases with increasing reflector thickness
  - Steepest change is between 0.5 and 5 inches of reflection
  - Most start to level out (act as infinite) at around 12 inches of reflection
  - Smallest variation is with natural uranium (540 to 520 to 540)
  - Noticeably small decrease with aluminum (from 560 to 520)
  - Largest decrease – beryllium and nickel

Consolidated Results – H/^{235}U Ratio



OAK RIDGE National Laboratory

Questions?