Data Testing for ENDF/B-VIIβ2

A. C. (Skip) Kahler & R. E. MacFarlane
Los Alamos National Laboratory

Presented at the
CSEWG Validation Meeting
at Brookhaven National Laboratory

June 27, 2006

Introduction

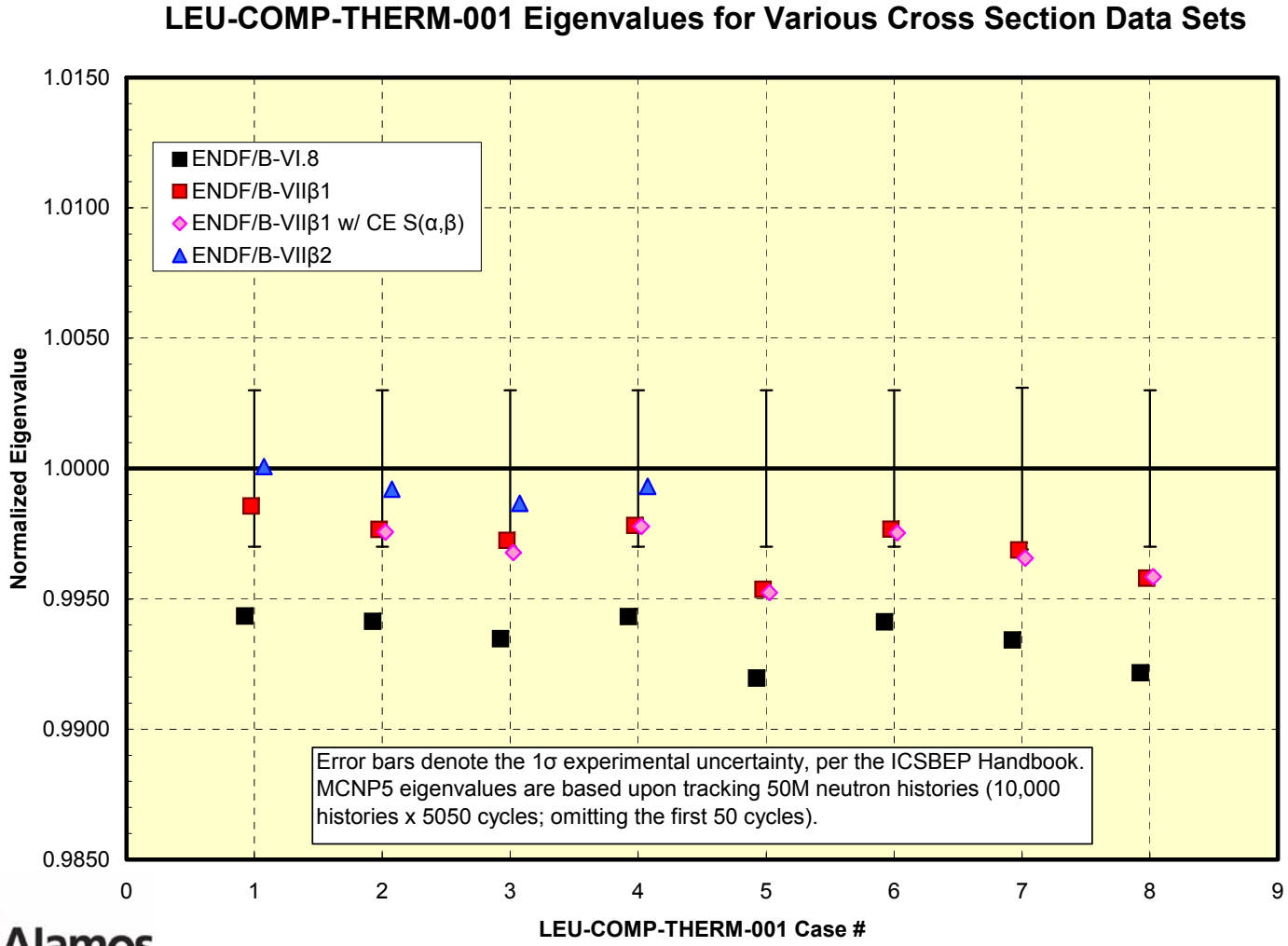
- Data testing at LANL has concentrated on executing MCNP5 calculations for a variety of critical benchmarks defined in the International Criticality Safety Benchmark Evaluation Project (ICSBEP) Handbook.
  - xxx-MET-FAST (HEU, PU, MIX; bare, water and/or polyethylene reflected, metallic reflectors);
  - xxx-SOL-THERM (HEU, LEU or Pu; bare and water reflected);
  - LEU-COMP-THERM (water moderated, with and without metallic reflectors).

- Eigenvalues are determined based upon tracking 25 million to 50 million neutron histories.
  - The uncertainty in the MCNP5 eigenvalue is typically less than 25 pcm.

LEU-COMP-THERM Benchmarks

- Have calculated critical configurations from a suite of seven LEU-COMP-THERM evaluations representing experimental data from five countries:
  - LEU-COMP-THERM-001 (2.35 w/o ^{235}U, United States – PNL)
  - LEU-COMP-THERM-002 (4.31 w/o ^{235}U, United States – PNL)
  - LEU-COMP-THERM-006 (2.6 w/o ^{235}U, Japan)
  - LEU-COMP-THERM-007 (4.74 w/o ^{235}U, France, Valduc)
  - LEU-COMP-THERM-022 (9.8 w/o ^{235}U, Russia - Kurchatov)
  - LEU-COMP-THERM-024 (9.8 w/o ^{235}U, Russia - Kurchatov)
  - LEU-COMP-THERM-039 (4.74 w/o ^{235}U, France, Valduc)

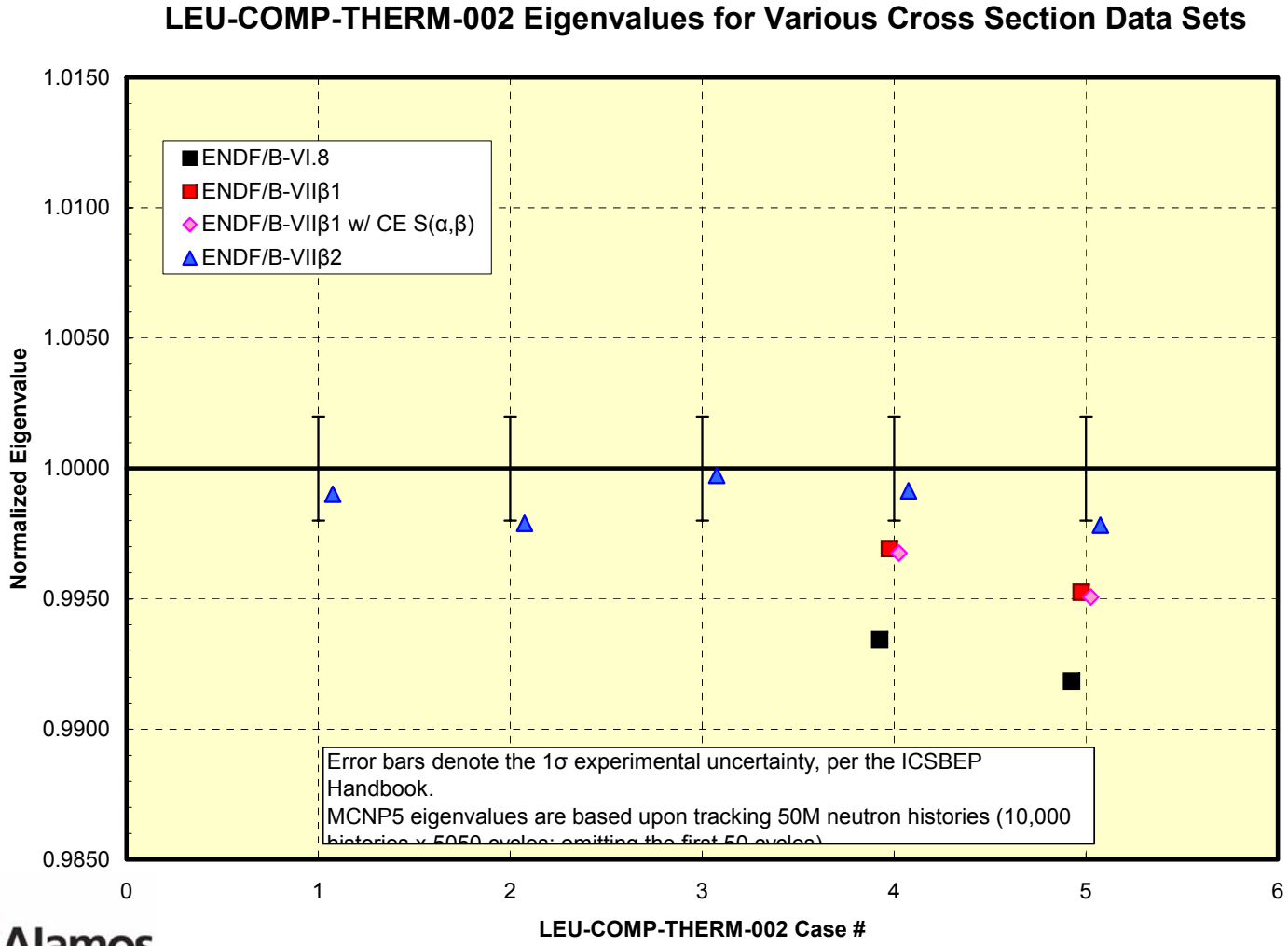
LEU-COMP-THERM Benchmarks



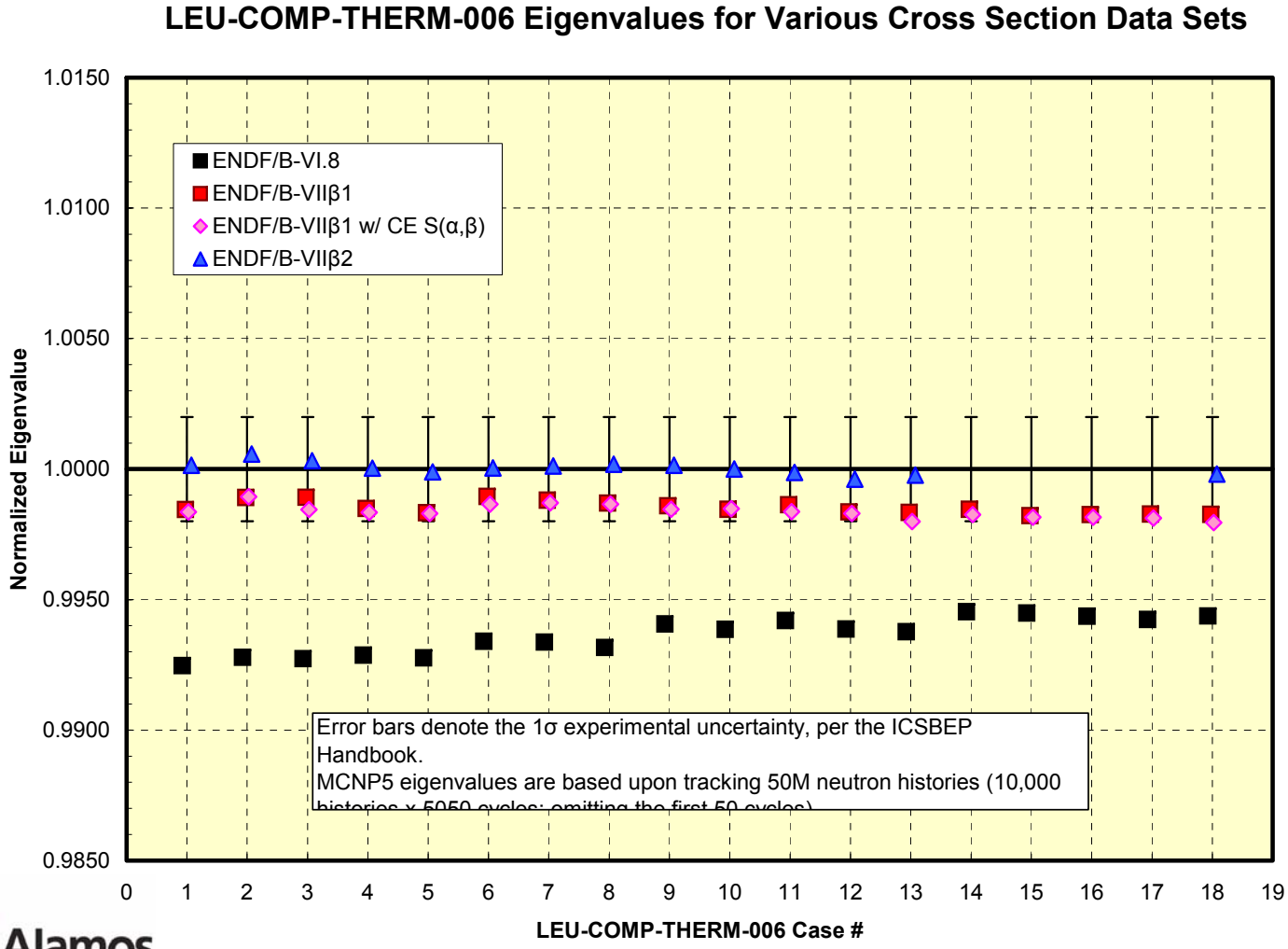
Los Alamos NATIONAL LABORATORY EST.1943

NNSA

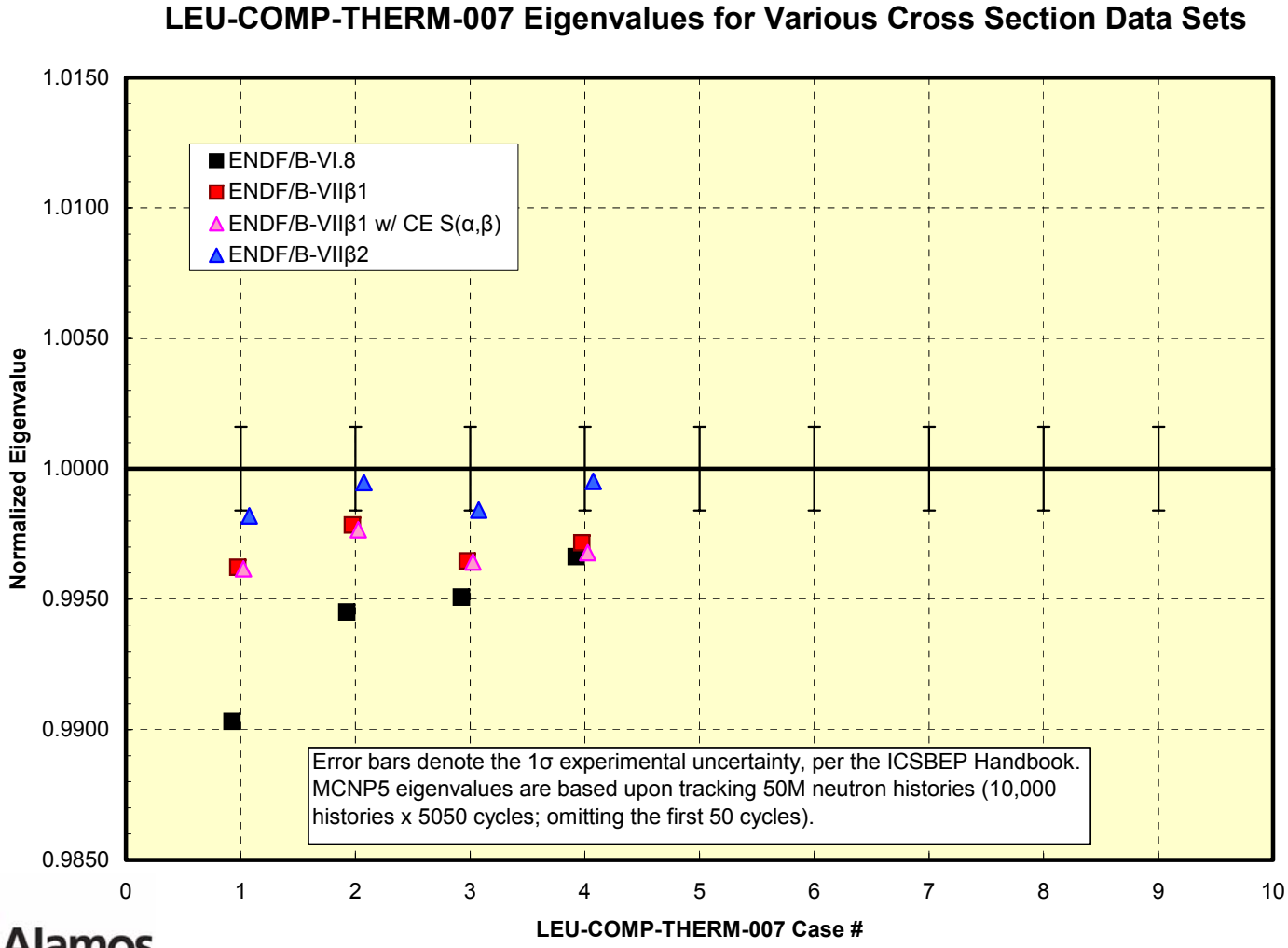
LEU-COMP-THERM Benchmarks



LEU-COMP-THERM Benchmarks



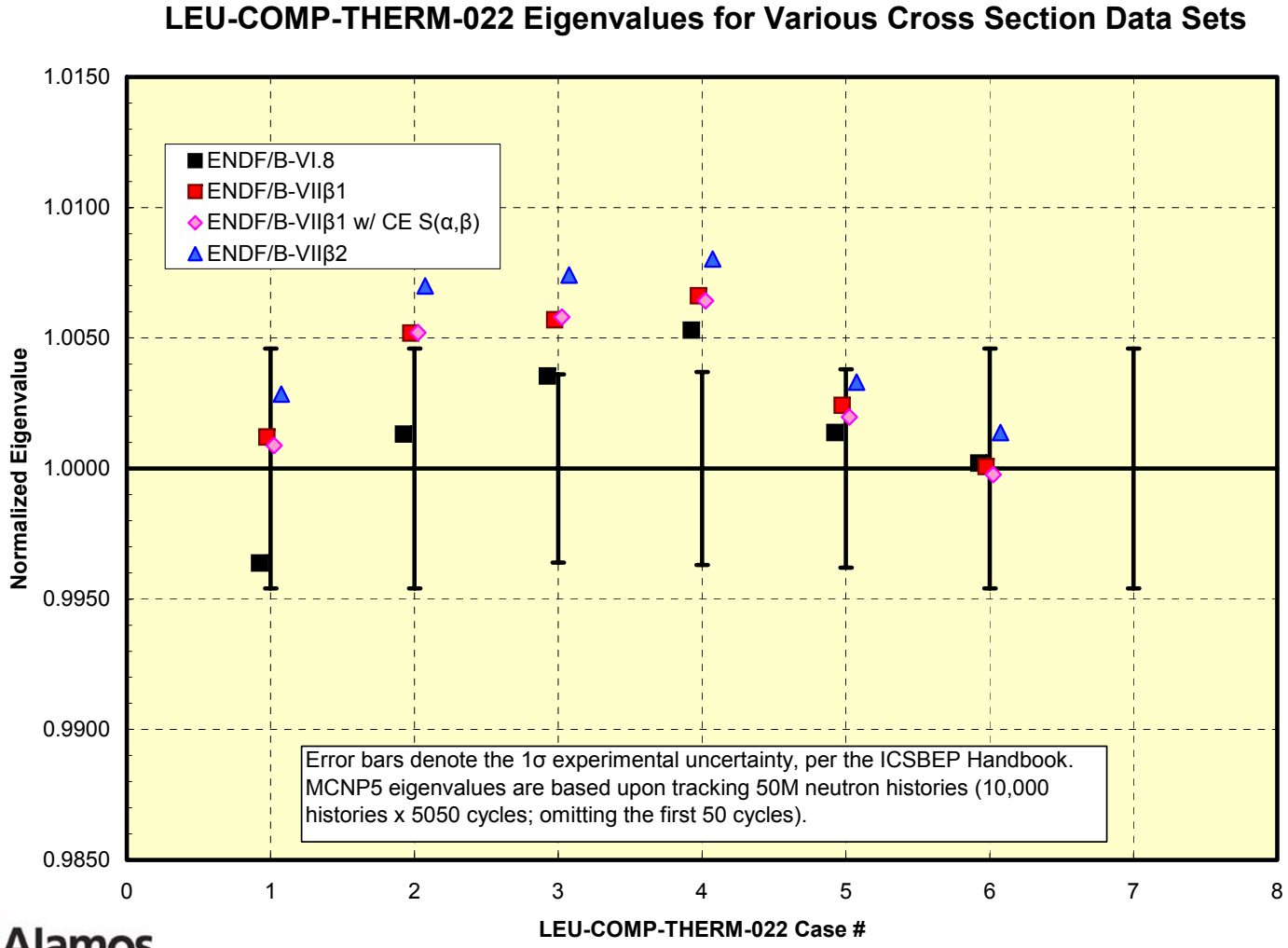
LEU-COMP-THERM Benchmarks



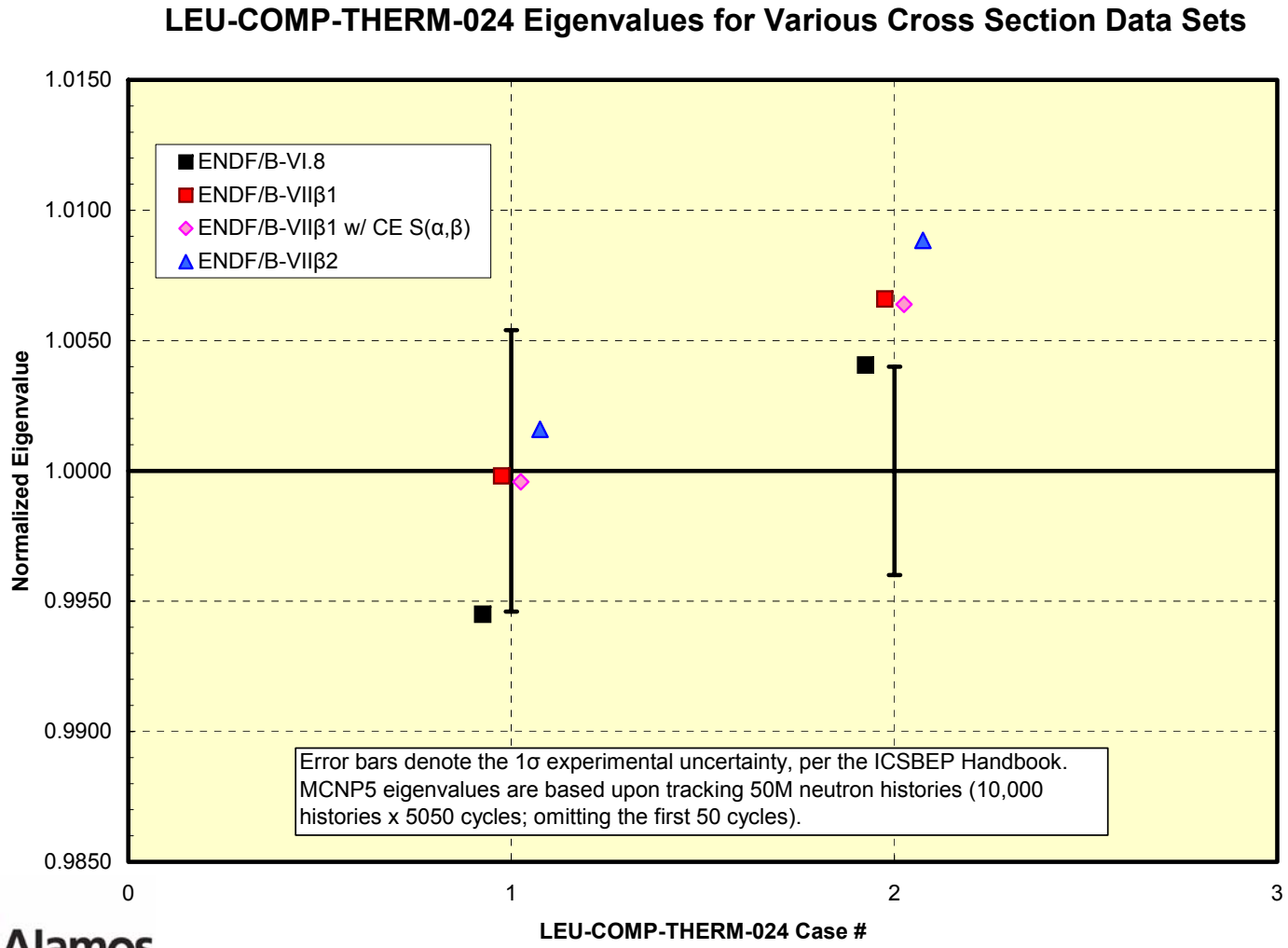
Los Alamos NATIONAL LABORATORY EST.1943

NNSA

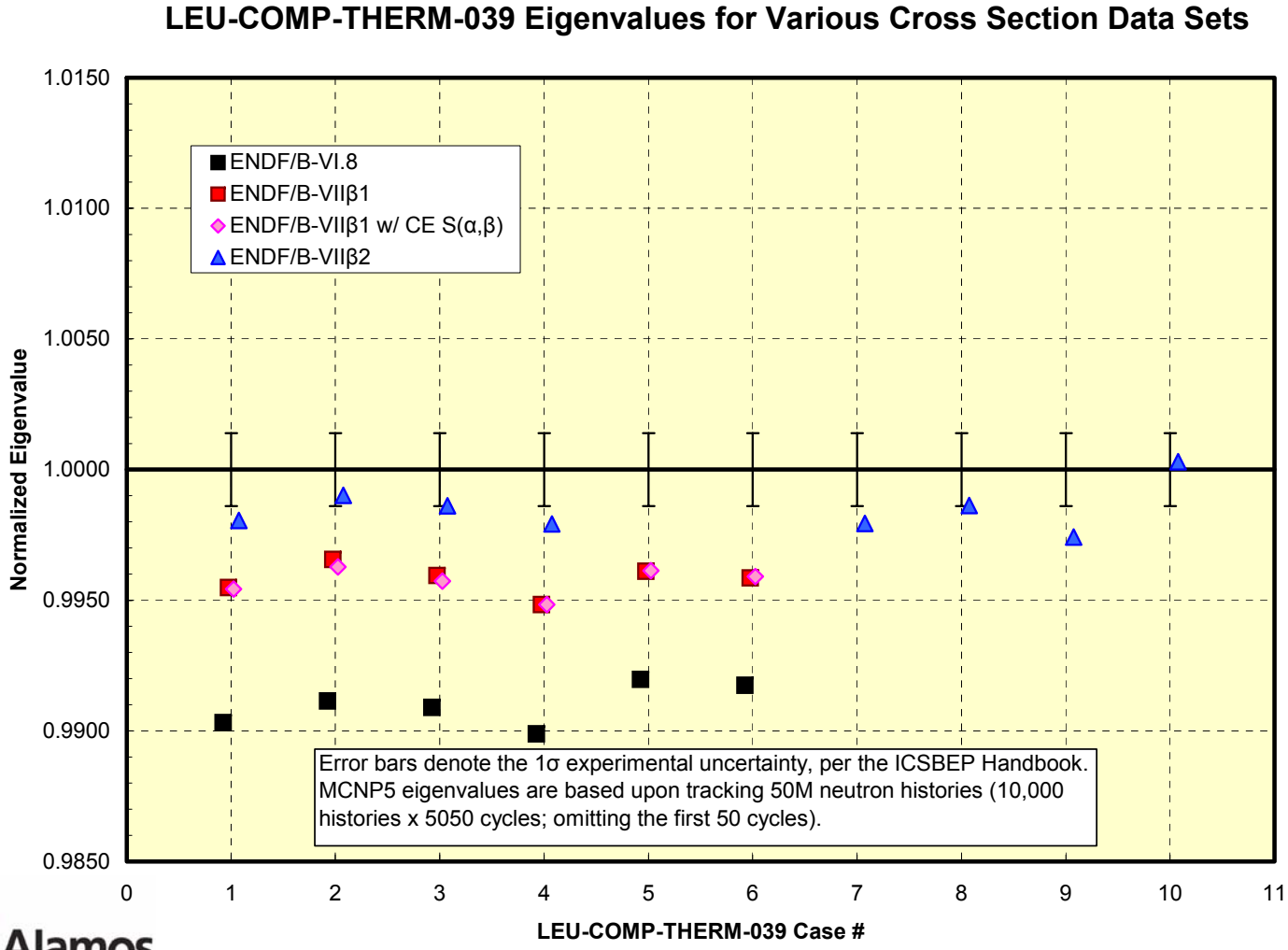
LEU-COMP-THERM Benchmarks



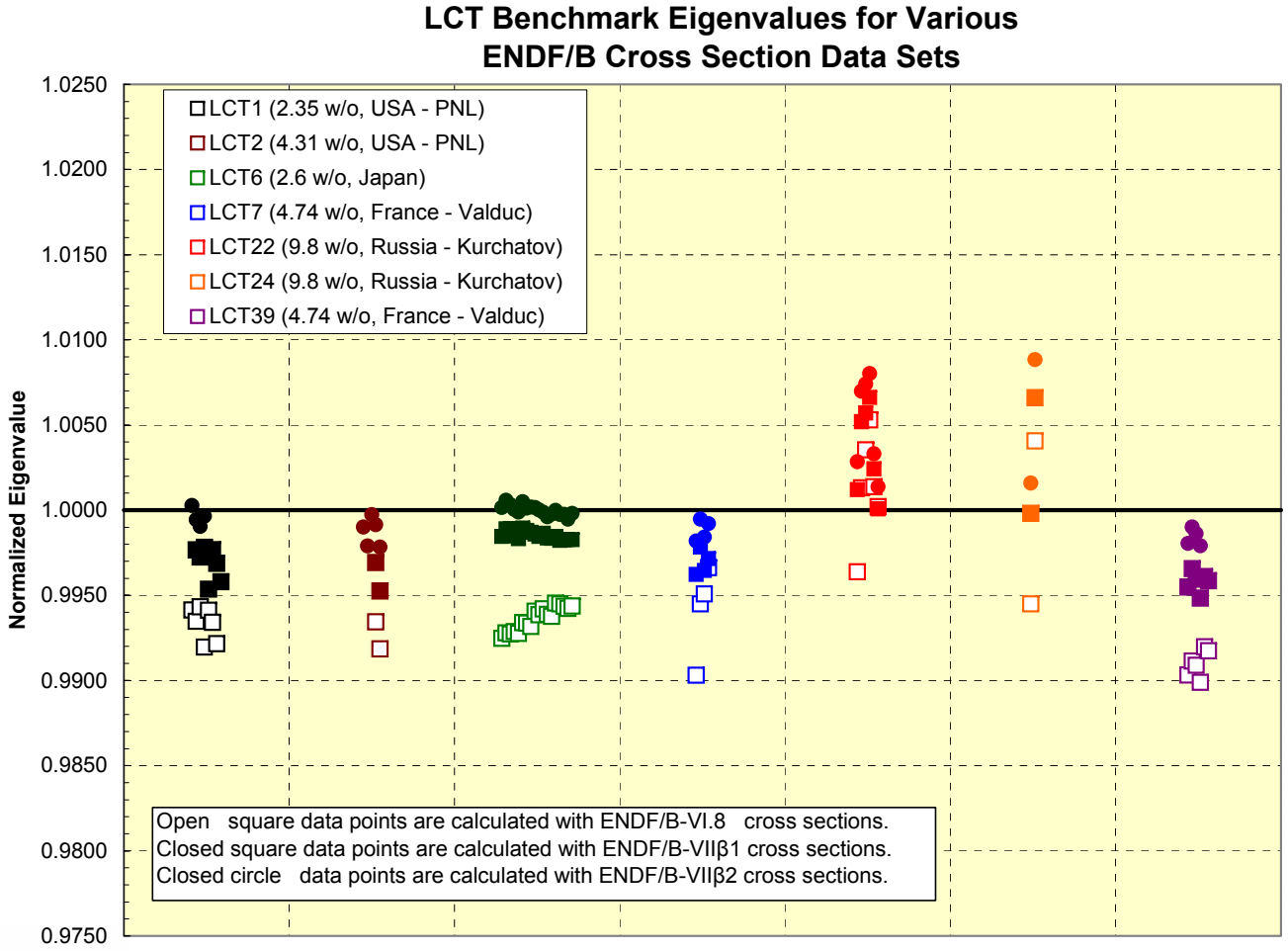
LEU-COMP-THERM Benchmarks



LEU-COMP-THERM Benchmarks



LEU-COMP-THERM Benchmarks



Los Alamos NATIONAL LABORATORY EST.1943

NNSA

LEU-COMP-THERM Benchmarks

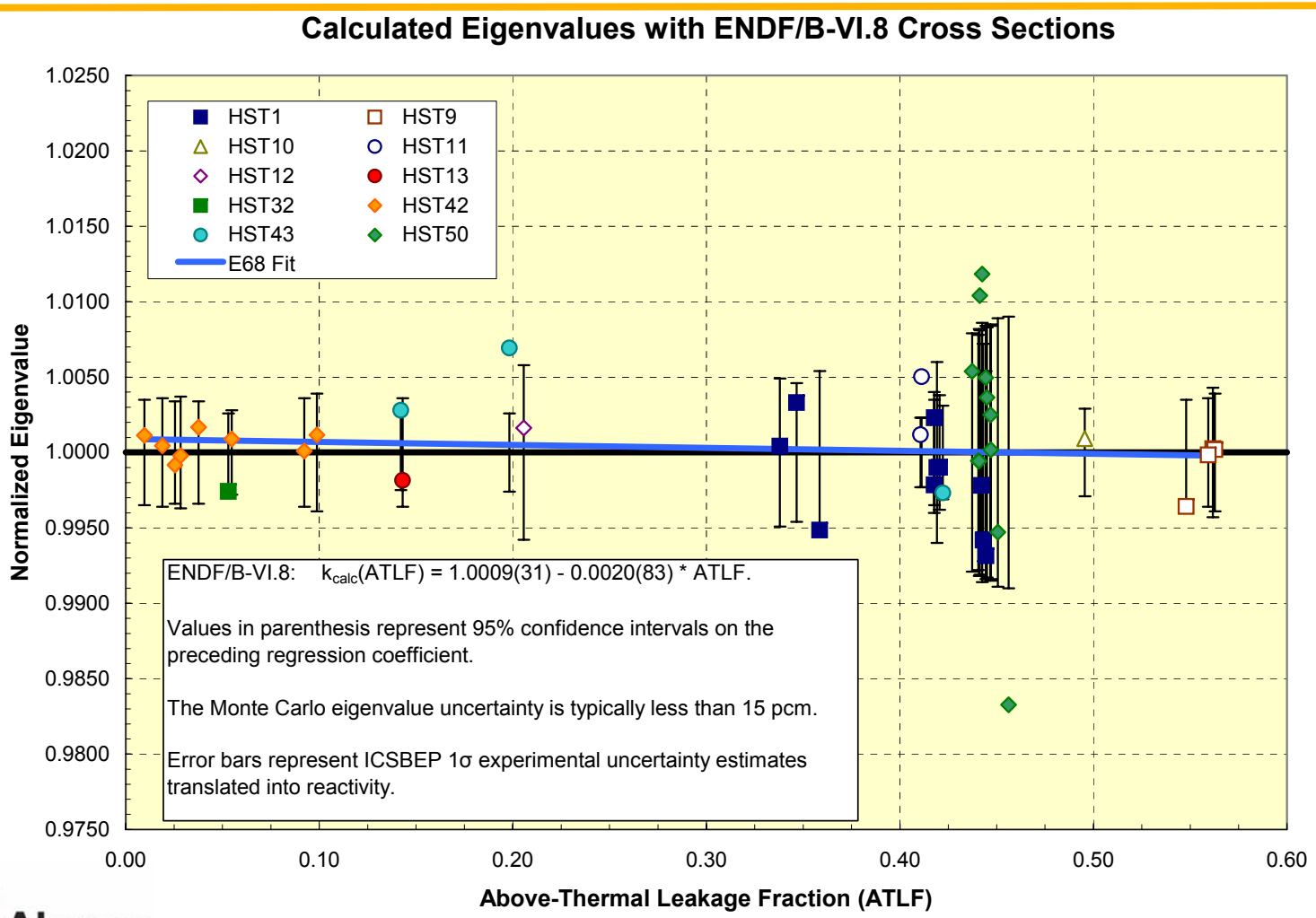
- LEU-COMP-THERM eigenvalues are generally low (by 500 to 1000 pcm) with ENDF/B-VI.8 cross sections.
  - Average eigenvalue for 45 critical configurations from seven LEU-COMP-THERM evaluations is 0.9945(5).

- LEU-COMP-THERM eigenvalues have increased to near unity with ENDF/B-VIIβ2 cross sections.
  - Average eigenvalue for 43 critical configurations from seven LEU-COMP-THERM evaluations is 1.0005(4).

HEU-SOL-THERM Benchmarks

- Homogenous solution benchmarks have been correlated against Above-Thermal Leakage Fraction (ATLF).
- The benchmark suite consists of 42 critical configurations defined in ten HEU-SOL-THERM evaluations.
  - All Rocky Flats and ORNL benchmarks used on past data testing efforts are now incorporated in the ICSBEP Handbook.
- HEU-SOL-THERM benchmark eigenvalue results are supplemented with calculations of Japanese LEU-SOL-THERM benchmarks.

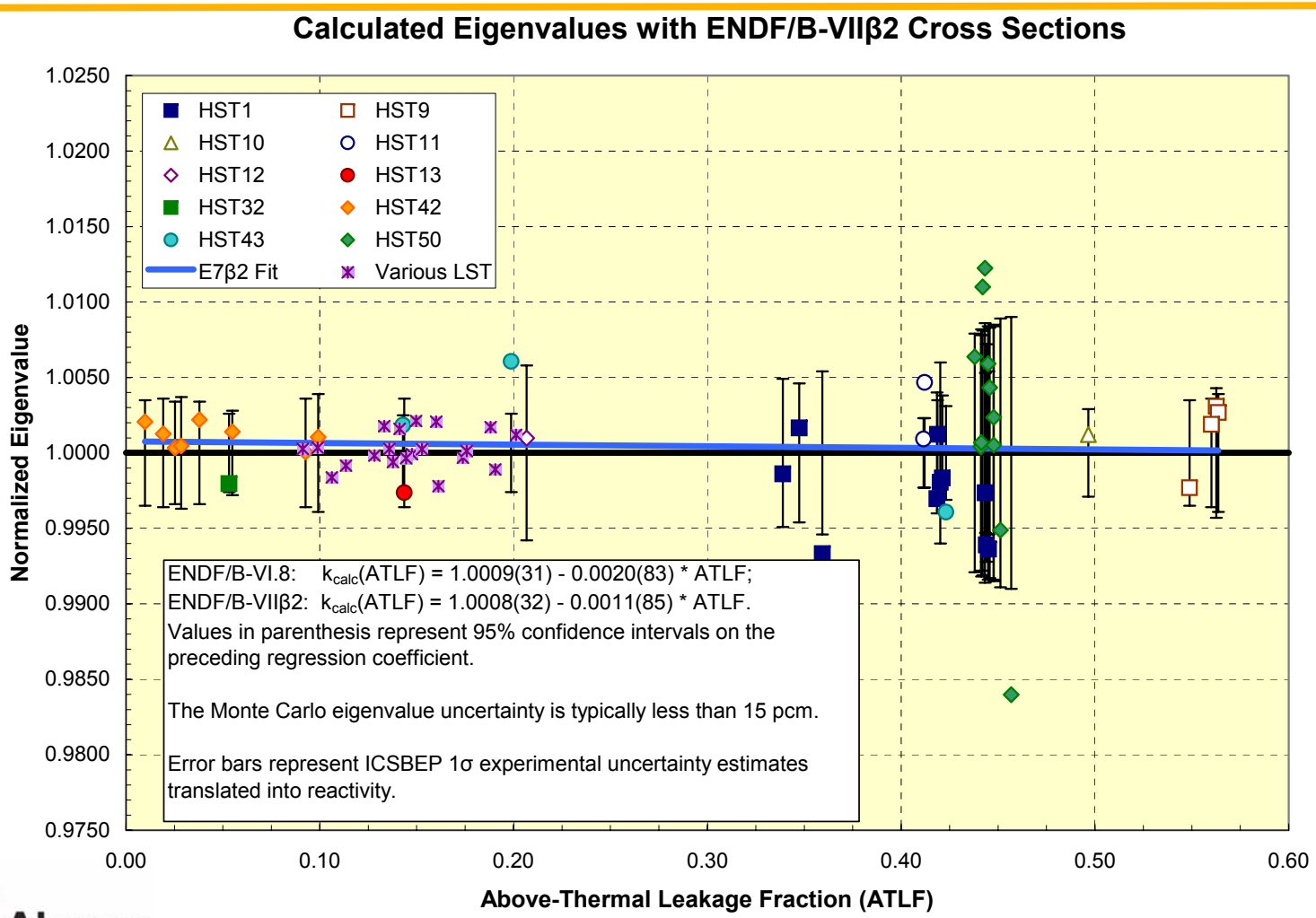
HEU-SOL-THERM Benchmarks



Los Alamos NATIONAL LABORATORY EST.1943

NNSA

HEU-SOL-THERM Benchmarks



Los Alamos NATIONAL LABORATORY EST.1943

NNSA

HEU-SOL-THERM Benchmarks

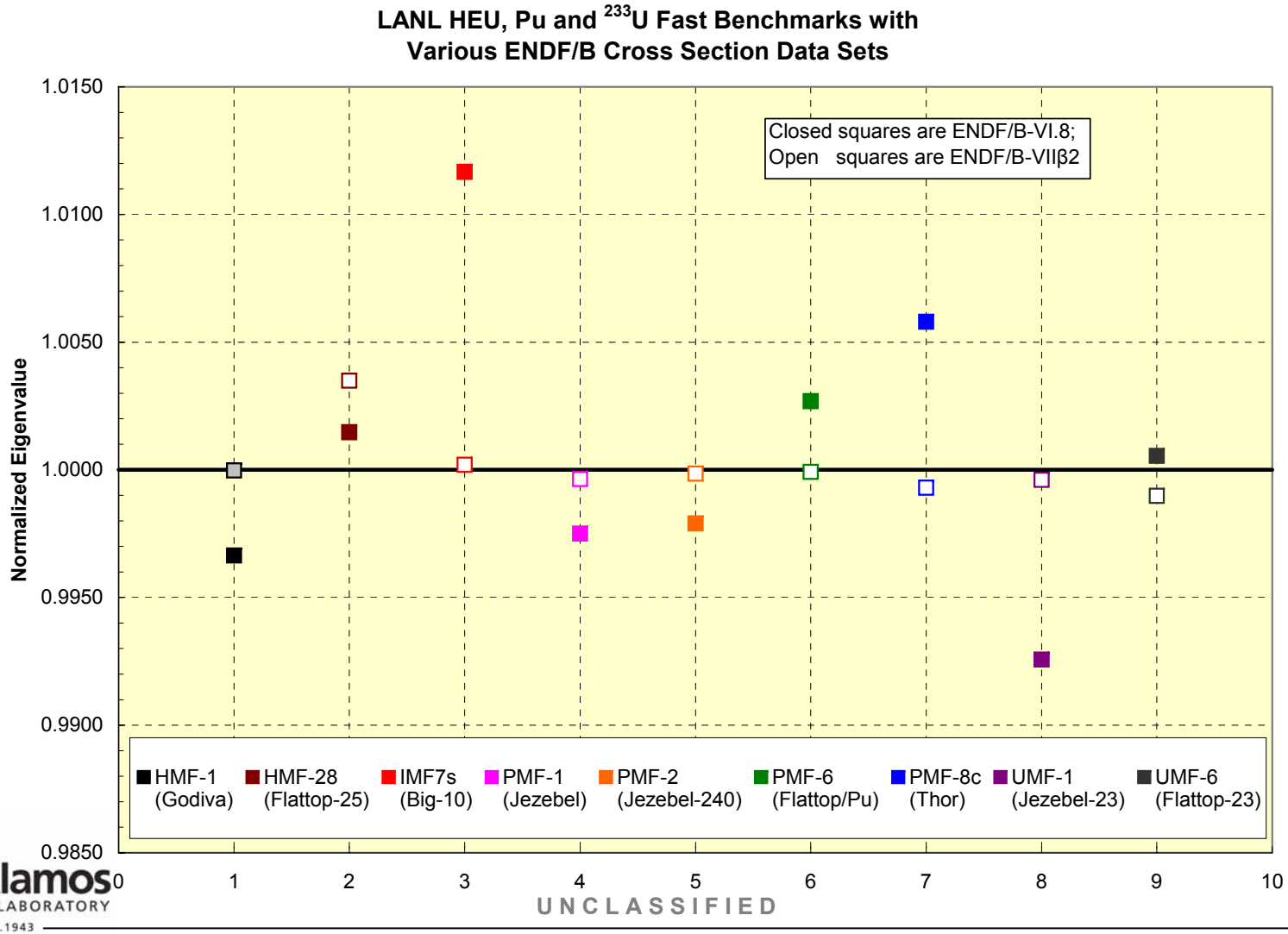
- ENDF/B-VI.8 HST & LST eigenvalues are very good; average is near unity with no apparent trend.
  - The average eigenvalue for 42 HST critical configurations from ten HST evaluations is 1.0002(7); and from 62 HST & LST critical configurations is 1.0001(5).

- ENDF/B-VIIβ2 HST & LST eigenvalues are very good; average is near unity with no apparent trend.
  - The Above-Thermal Leakage Fraction (ATLF) correlation is insensitive to weighting of the individual HST eigenvalues.
  - The average eigenvalue for 42 HST critical configurations from ten HST evaluations is 1.0004(7); and from 62 HST & LST critical configurations is 1.0003(5).

"LANL"-MET-FAST Benchmarks

- "Traditional" LANL Fast Benchmarks are significantly improved with ENDF/B-VIIβ2 cross sections
  - HEU-MET-FAST-001 (Godiva)
  - HEU-MET-FAST-028 (Flattop-28)
  - IEU-MET-FAST-007 (Big-10)
  - PU-MET-FAST-001 (Jezebel)
  - PU-MET-FAST-002 (Jezebel-240)
  - PU-MET-FAST-006 (Flattop-Pu)
  - PU-MET-FAST-008c (Thor)
  - U233-MET-FAST-001 (Jezebel-23)
  - U233-MET-FAST-006 (Flattop-23)

"LANL"-MET-FAST Benchmarks



Los Alamos NATIONAL LABORATORY EST.1943

NNSA

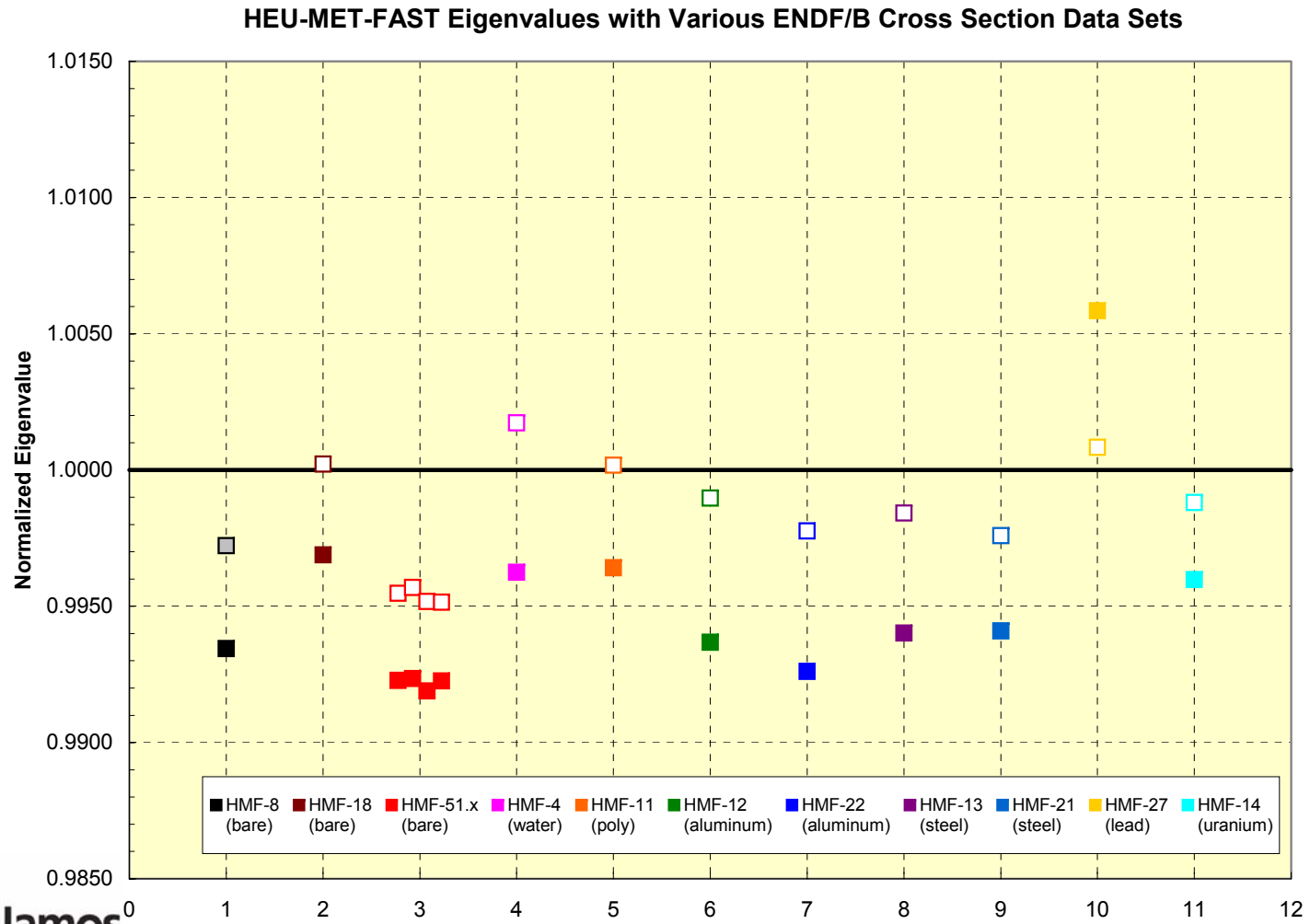
Other HEU & PU-MET-FAST Benchmarks

- Other xxx-MET-FAST Benchmarks
  - HEU-MET-FAST bare systems
    - HEU-MET-FAST-008
    - HEU-MET-FAST-018
    - HEU-MET-FAST-051
  - HEU-MET-FAST reflected systems
    - HEU-MET-FAST-004 (water)
    - HEU-MET-FAST-007, -011 (polyethylene)
    - HEU-MET-FAST-012, -022 (aluminum)
    - HEU-MET-FAST-013, -021 (steel)
    - HEU-MET-FAST-027, -057 (lead)
    - HEU-MET-FAST-014 (uranium)
    - HEU-MET-FAST-041, -066, -077 (beryllium)

Other HEU & PU-MET-FAST Benchmarks

- Other xxx-MET-FAST Benchmarks (con't)
  - PU-MET-FAST bare systems
    - PU-MET-FAST-022
  - PU-MET-FAST Reflected Systems
    - PU-MET-FAST-011 (water)
    - PU-MET-FAST-020 (uranium)
    - PM-MET-FAST-019 (beryllium)
    - PU-MET-FAST-023 (graphite)
    - PU-MET-FAST-024 (polyethylene)
    - PU-MET-FAST-035 (lead)
    - PU-MET-FAST-009 (aluminum)
    - PU-MET-FAST-025, -026 (steel)

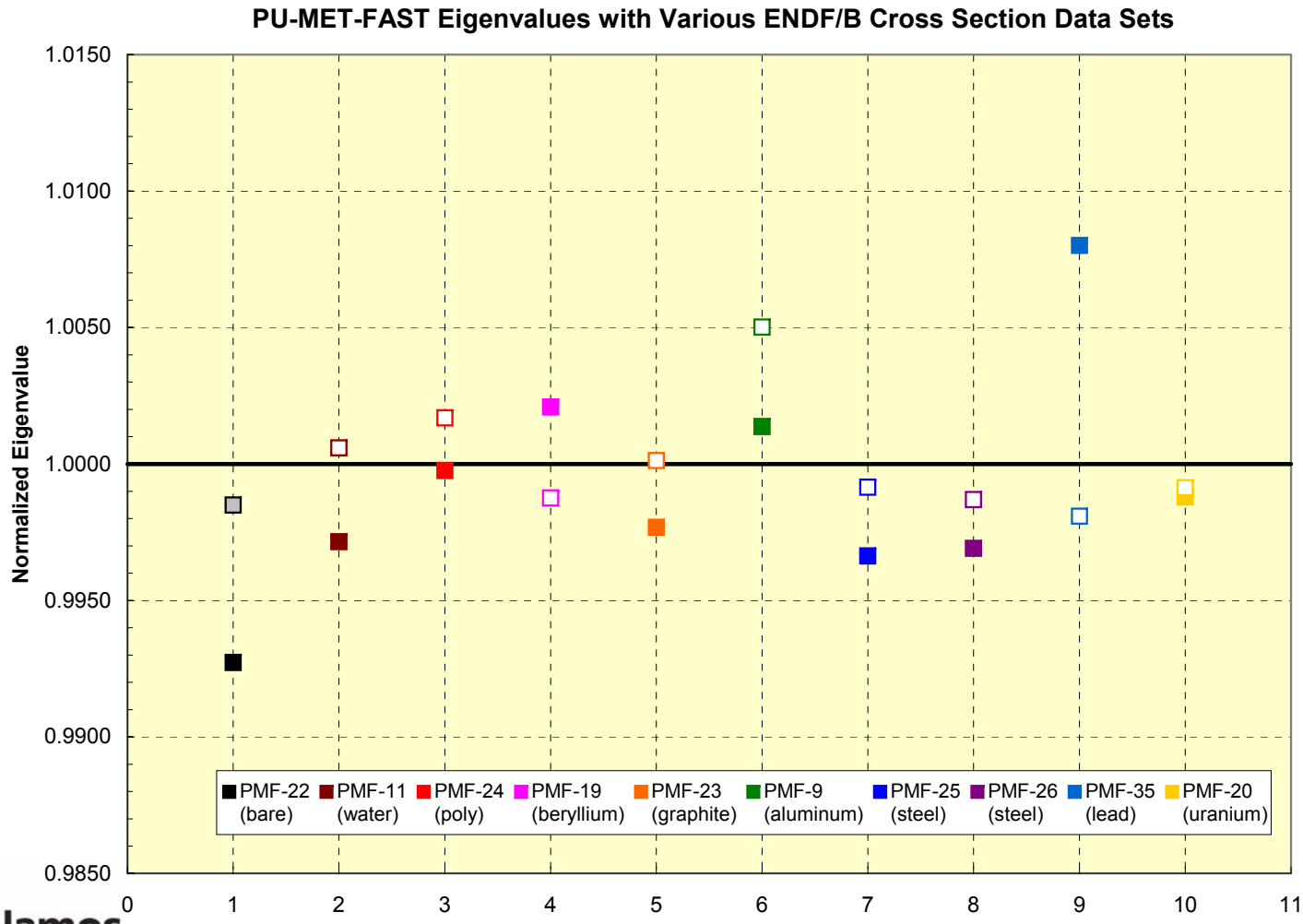
Other HEU & PU-MET-FAST Benchmarks



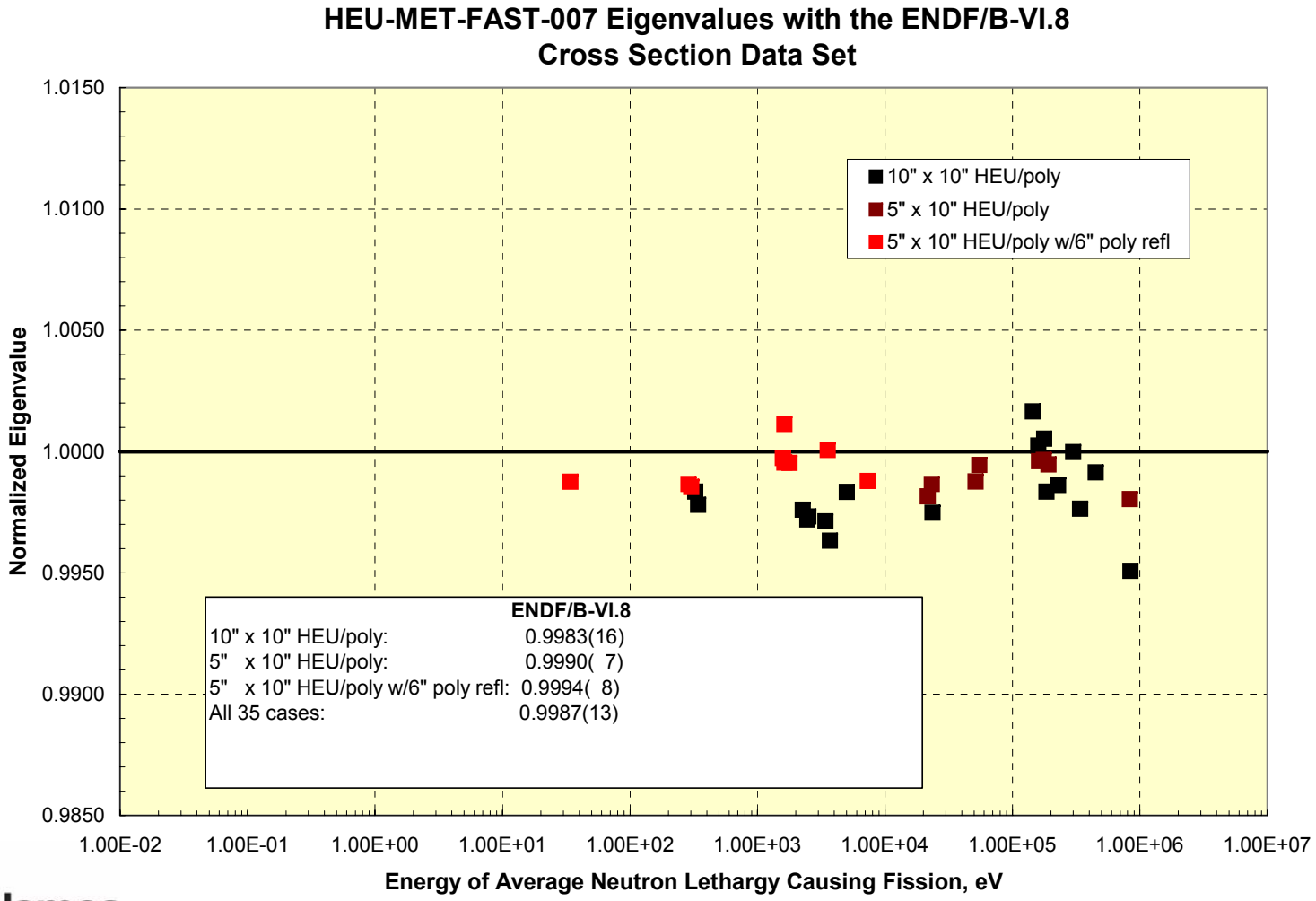
Los Alamos NATIONAL LABORATORY EST.1943

NNSA

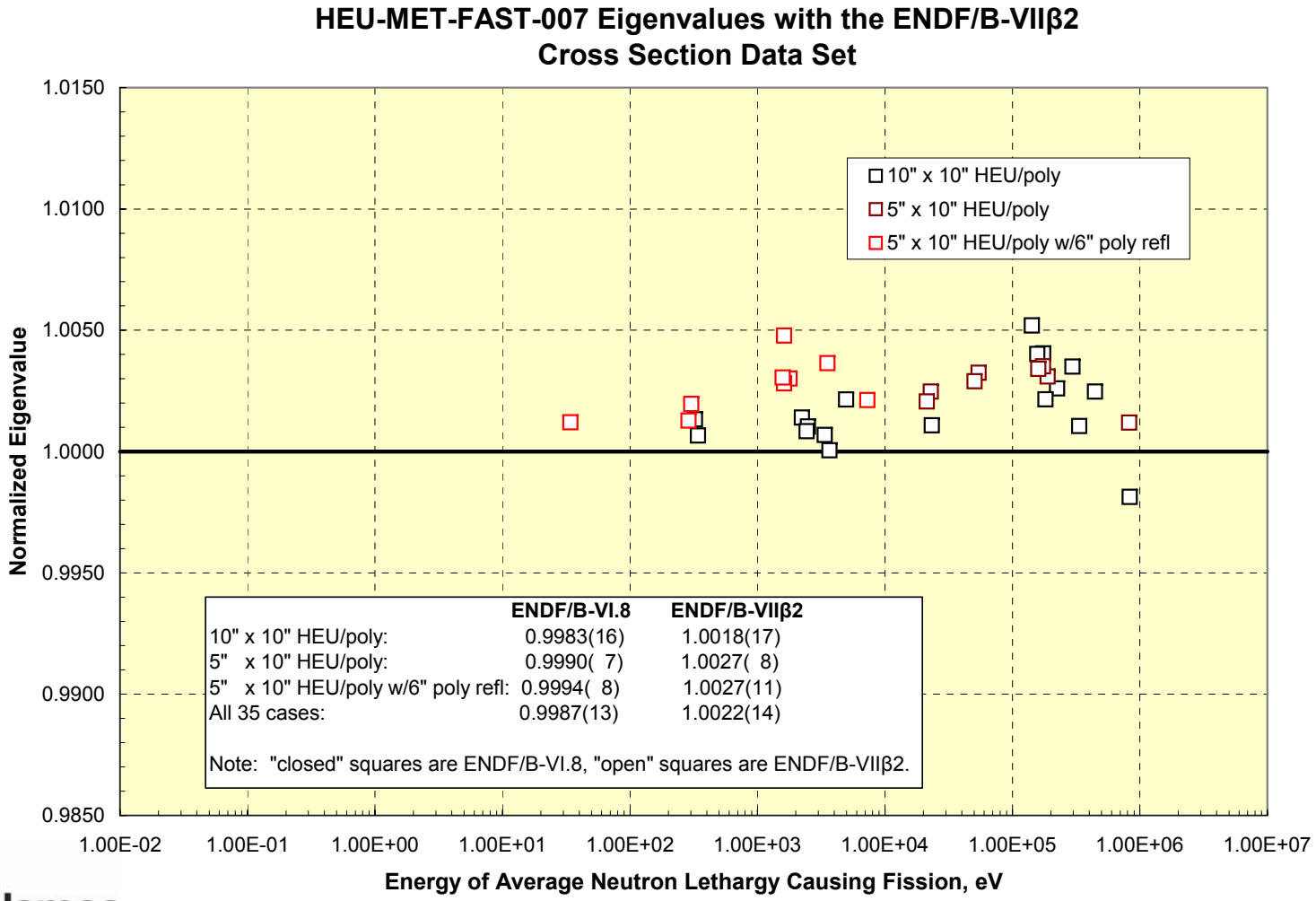
Other HEU & PU-MET-FAST Benchmarks



HEU-MET-FAST-007 Benchmark



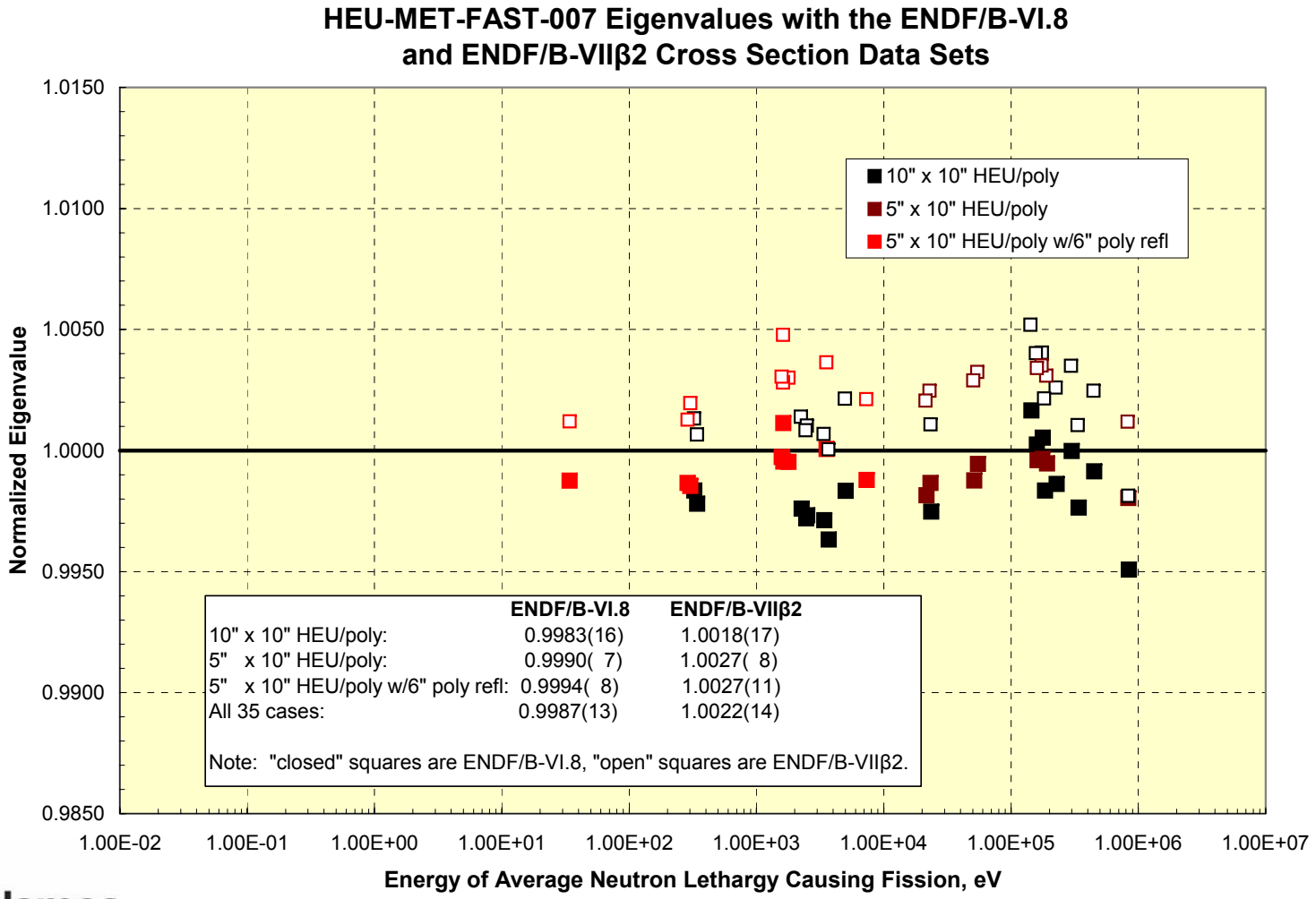
HEU-MET-FAST-007 Benchmark



Los Alamos NATIONAL LABORATORY EST.1943

NNSA

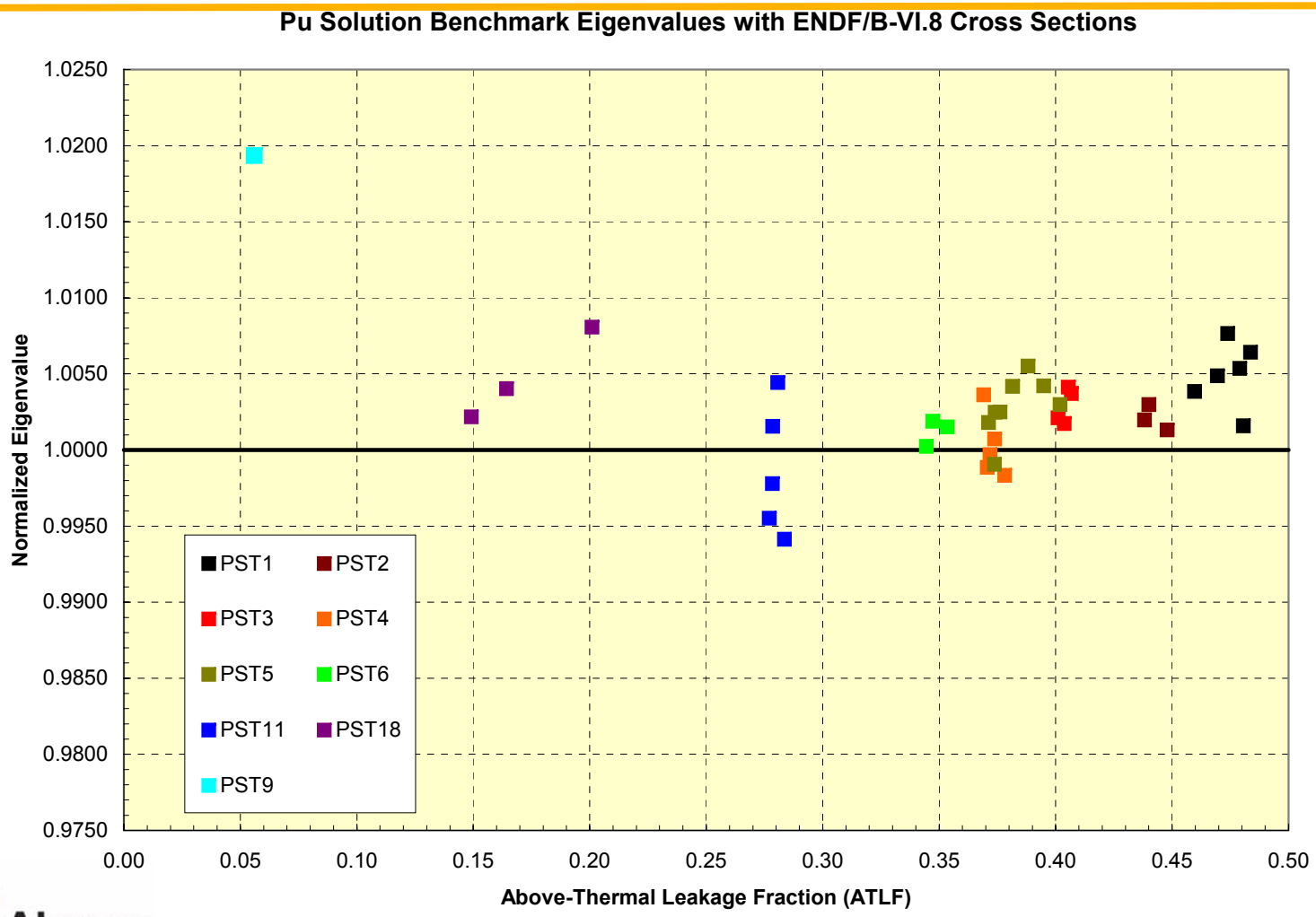
HEU-MET-FAST-007 Benchmark



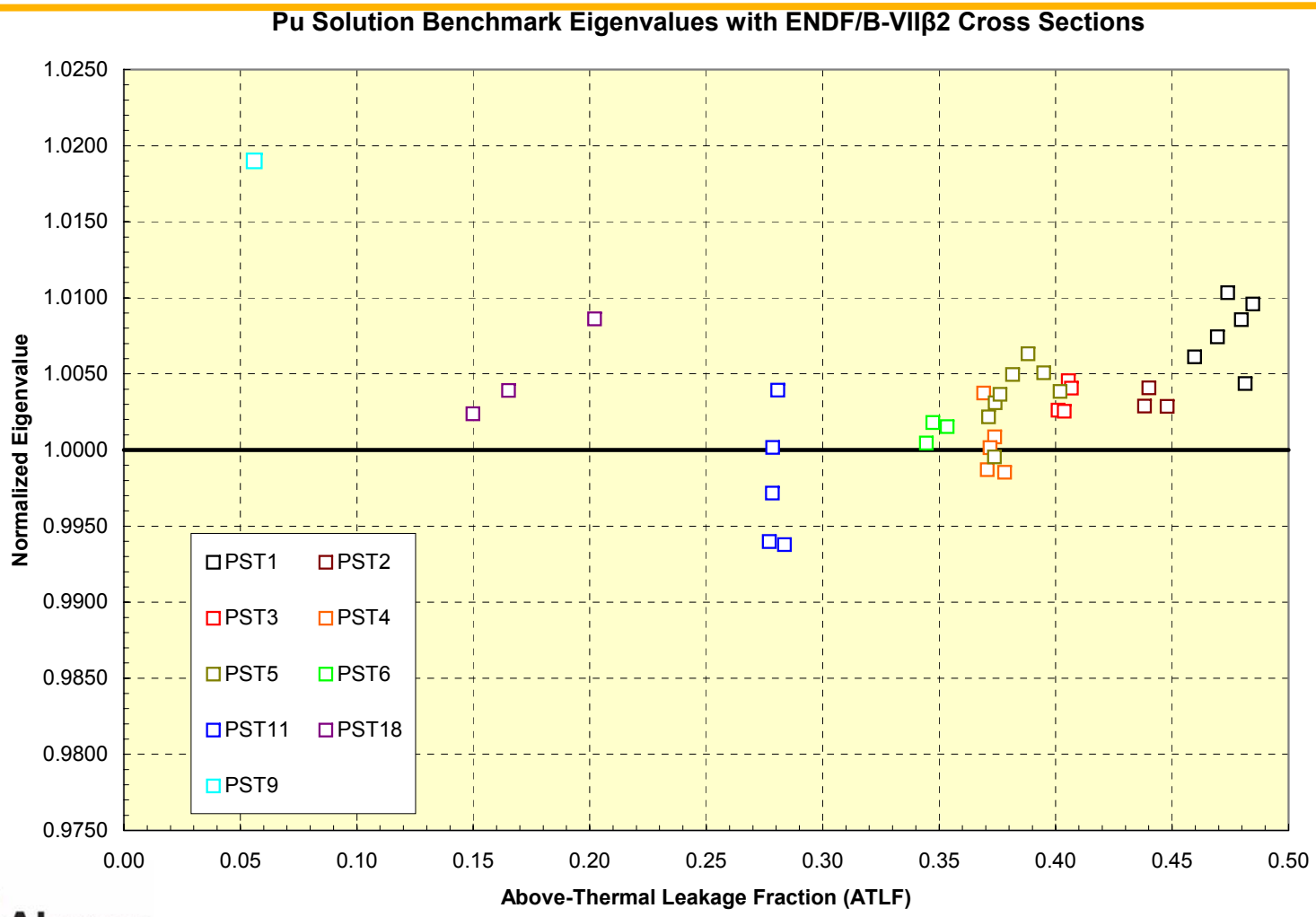
PU-SOL-THERM Benchmarks

- Have calculated critical configurations from a suite of nine PU-SOL-THERM evaluations:
  - PU-SOL-THERM-001 (11.5” diameter water reflected sphere)
  - PU-SOL-THERM-002 (12” diameter water reflected sphere)
  - PU-SOL-THERM-003 (13” diameter water reflected sphere)
  - PU-SOL-THERM-004 (14” diameter water reflected sphere)
  - PU-SOL-THERM-005 (more 14” diameter …)
  - PU-SOL-THERM-006 (15” diameter water reflected sphere)
  - PU-SOL-THERM-009 (48” diameter sphere, bare)
  - PU-SOL-THERM-011 (16”, 18” diameter spheres, bare)
  - PU-SOL-THERM-018 (24” diameter water reflected cylinder)
    - To be published in the 2006 edition of the ICSBEP Handbook)

PU-SOL-THERM Benchmarks



PU-SOL-THERM Benchmarks



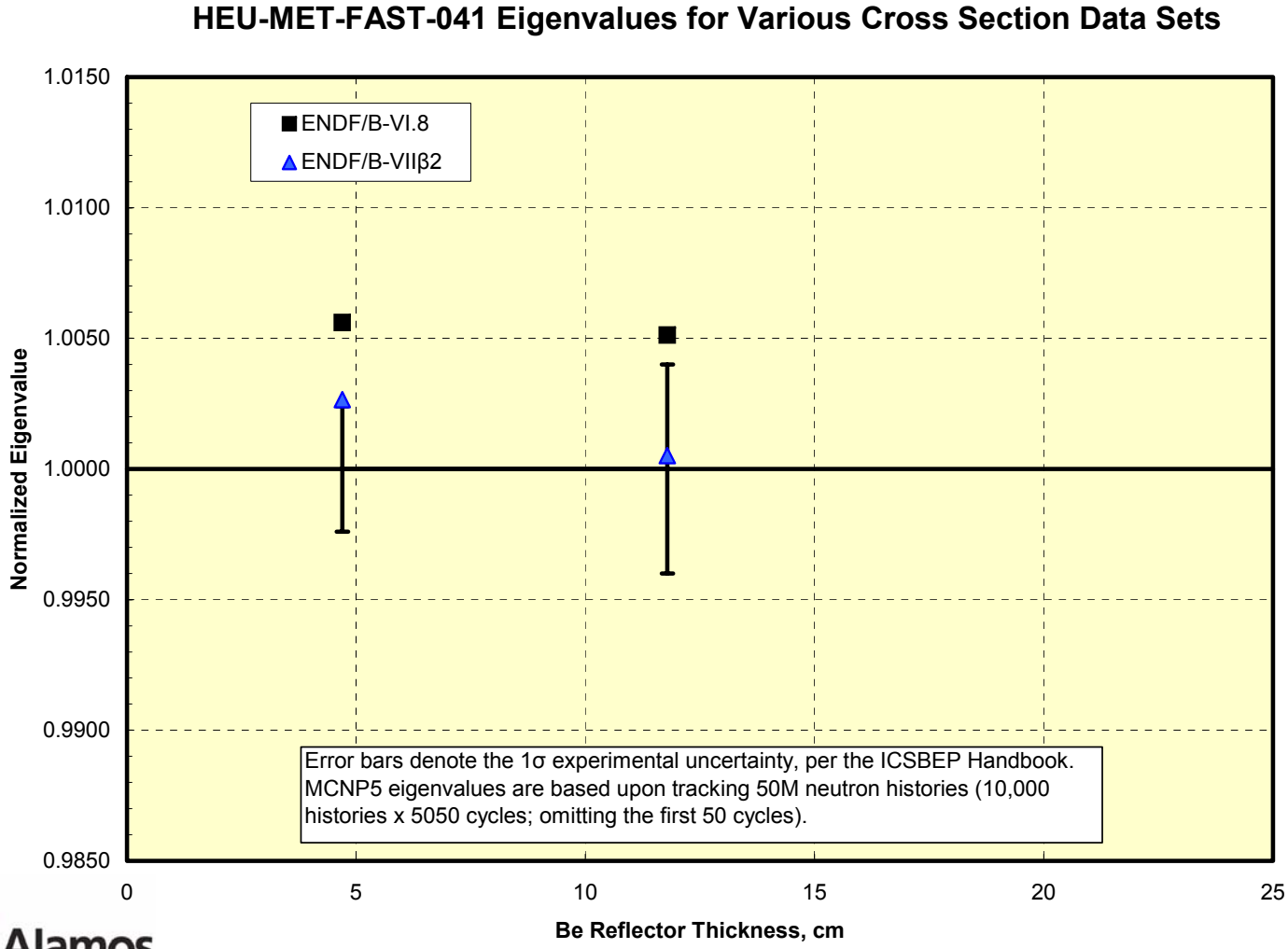
Los Alamos NATIONAL LABORATORY EST.1943

NNSA

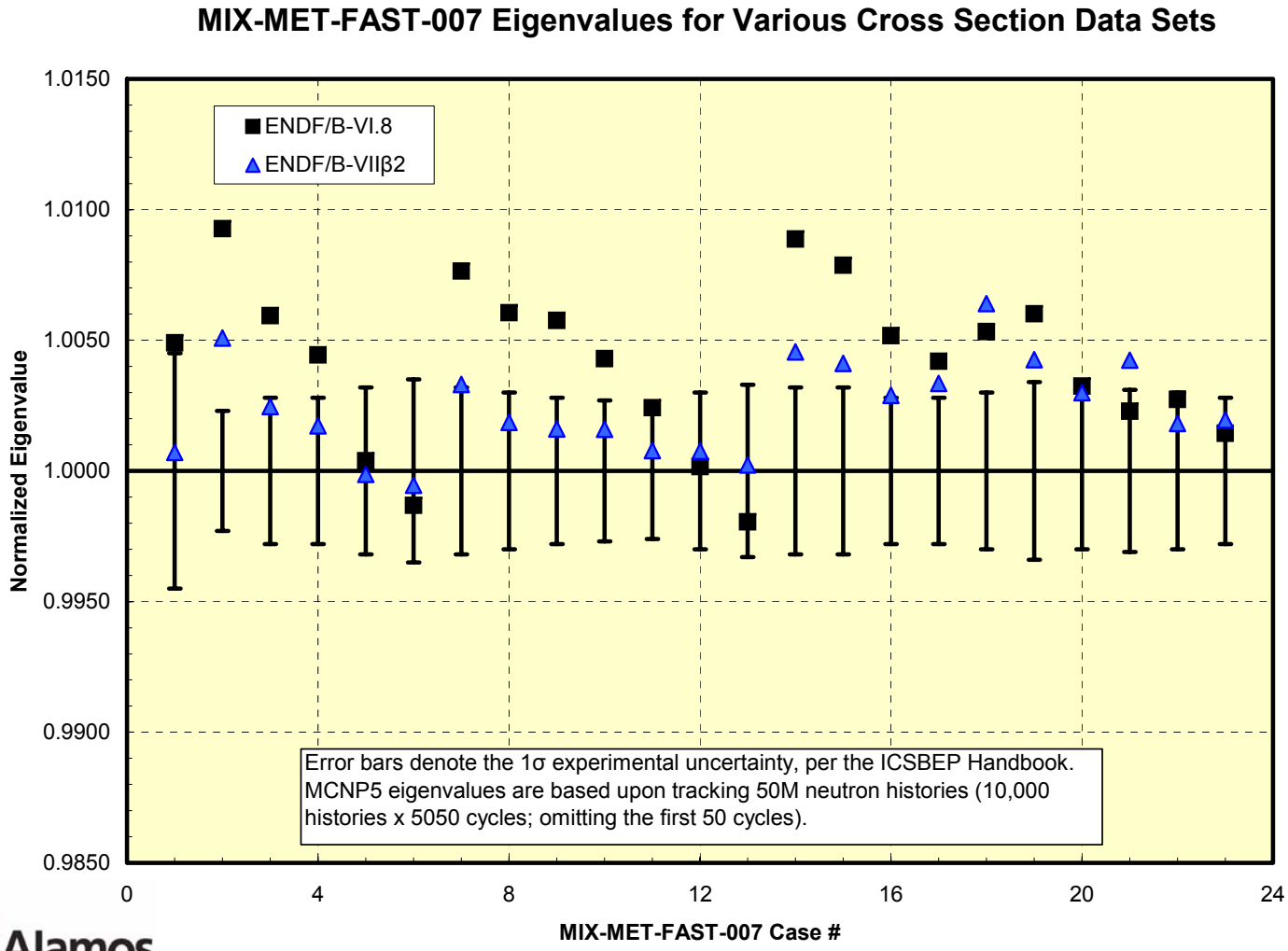
xxx-MET-FAST Benchmarks

- Fast, beryllium reflected benchmarks
  - HEU-MET-FAST-041
  - HEU-MET-FAST-066
  - HEU-MET-FAST-077
    - To be published in the 2006 edition of the ICSBEP Handbook
  - MMF-MET-FAST-007

Beryllium Reflected Benchmarks



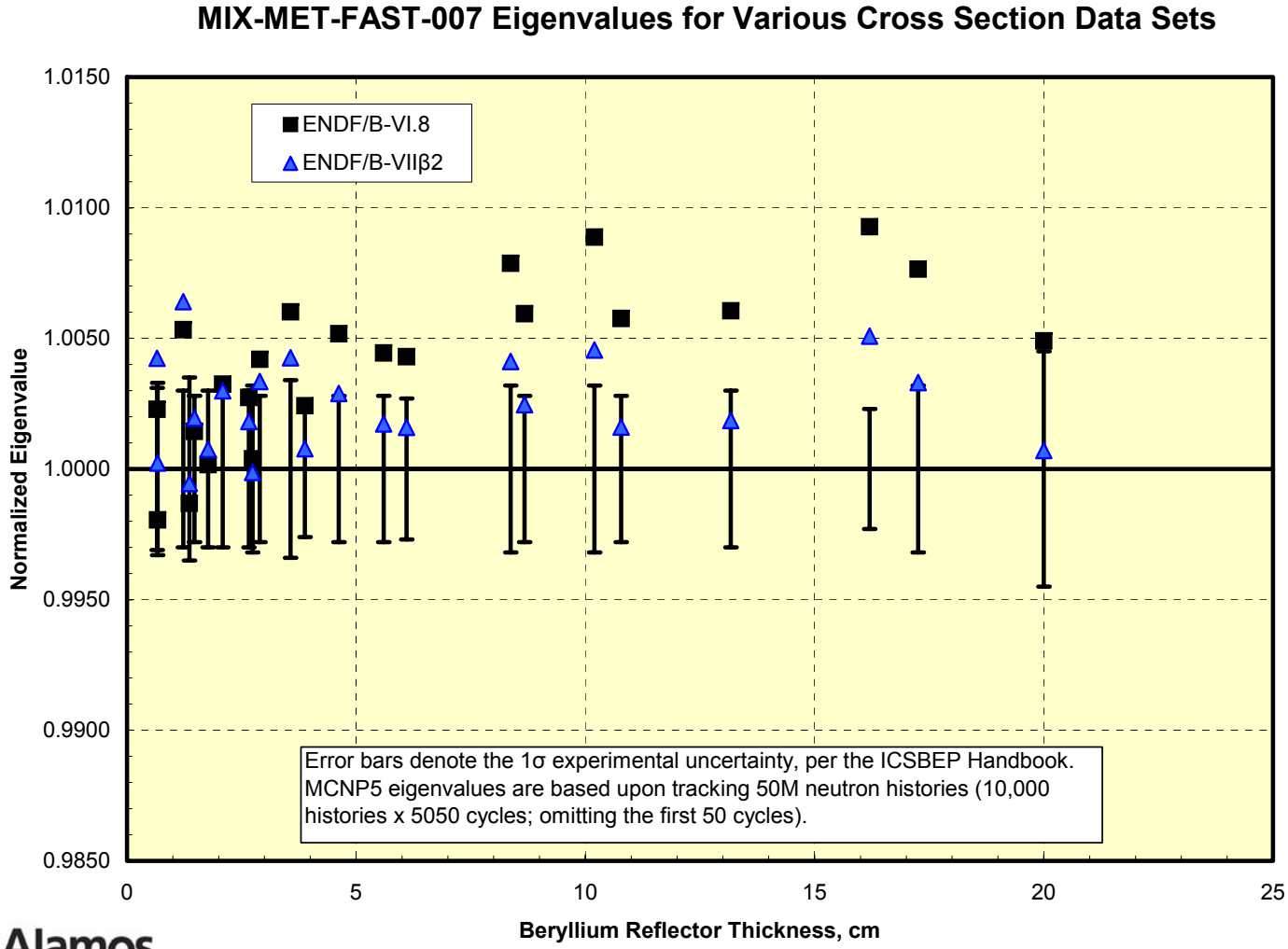
Beryllium Reflected Benchmarks



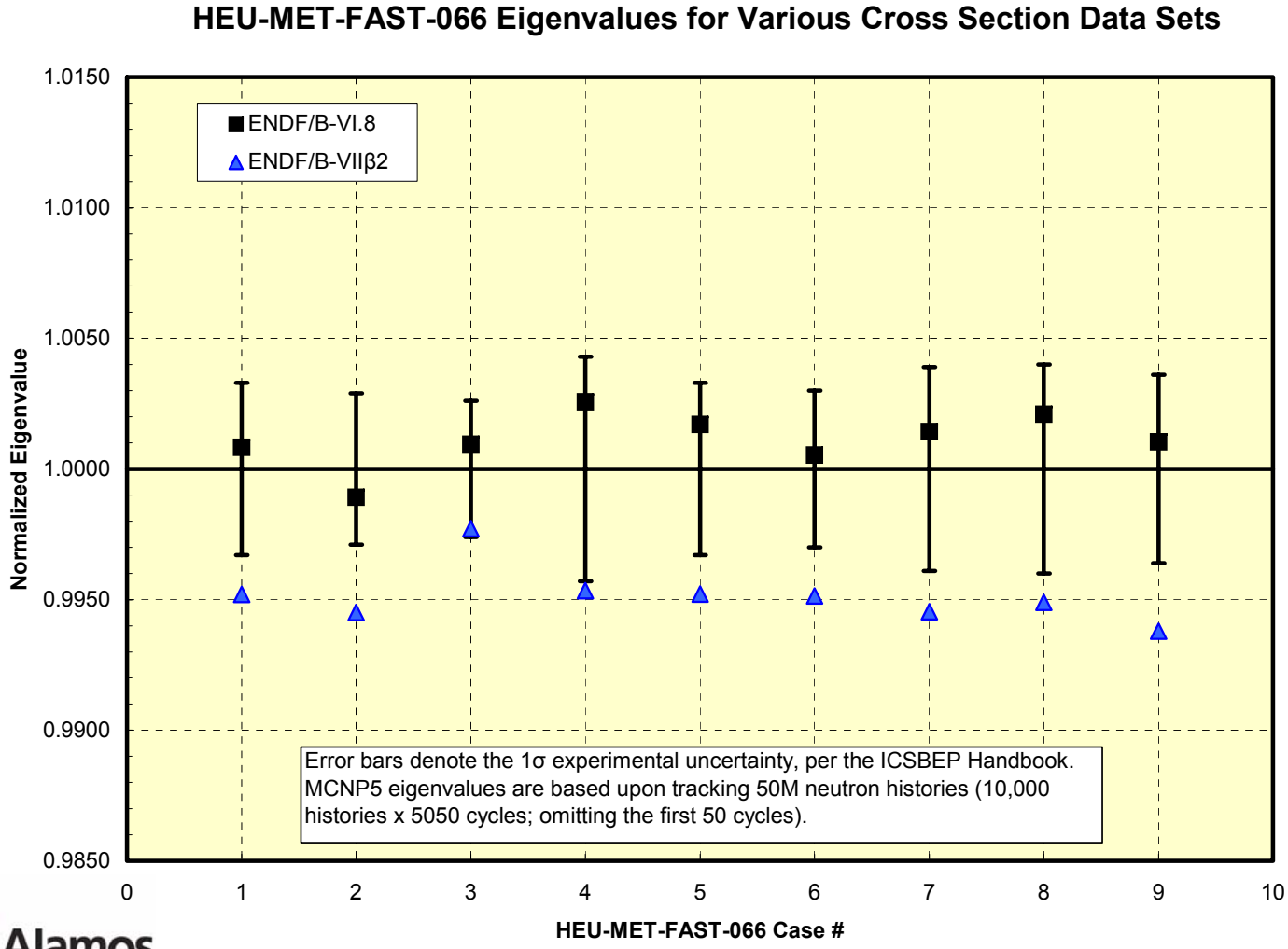
Los Alamos NATIONAL LABORATORY EST.1943

NNSA

Beryllium Reflected Benchmarks



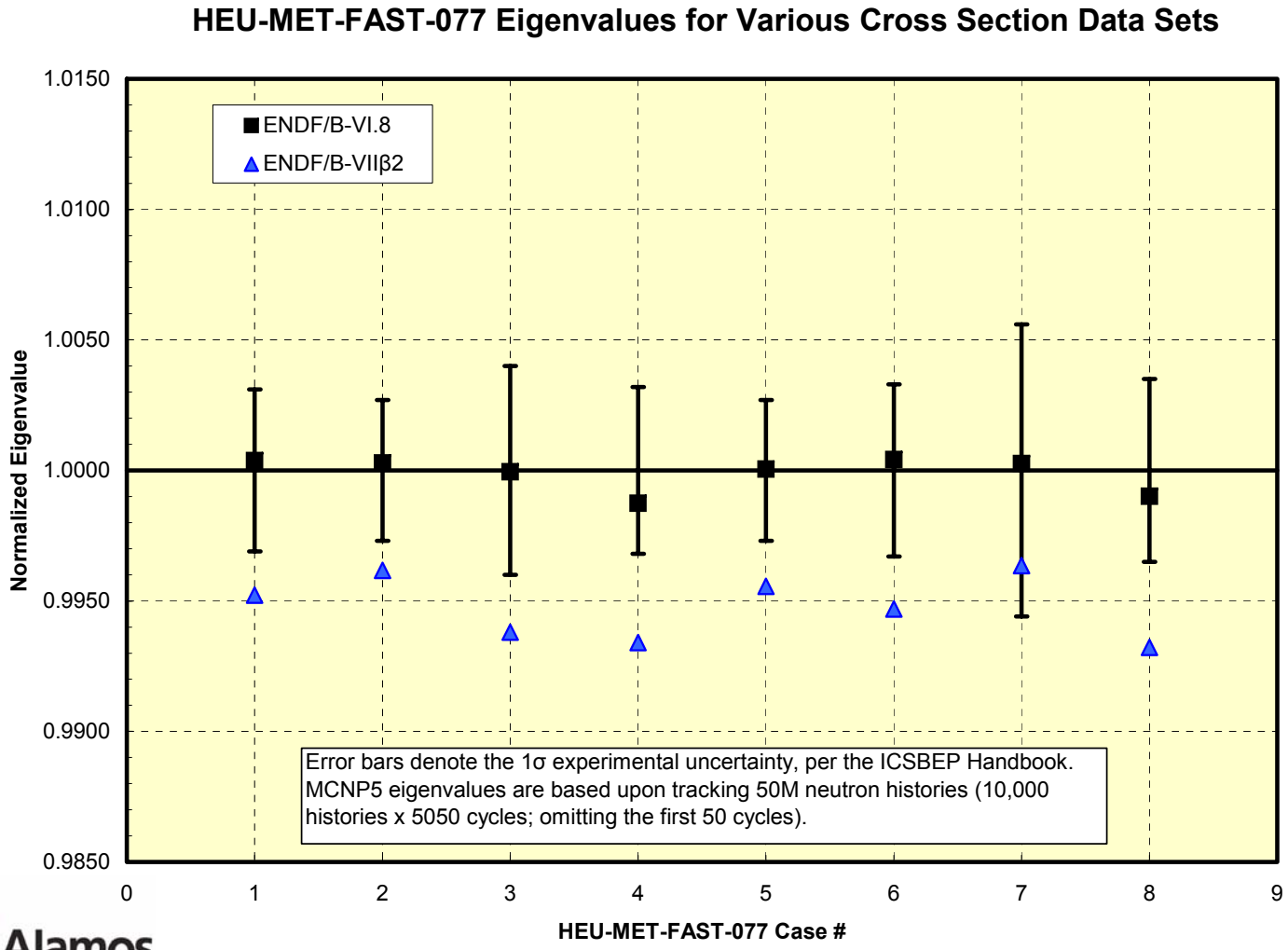
Beryllium Reflected Benchmarks



Los Alamos NATIONAL LABORATORY EST.1943

NNSA

Beryllium Reflected Benchmarks



Los Alamos NATIONAL LABORATORY EST.1943

NNSA

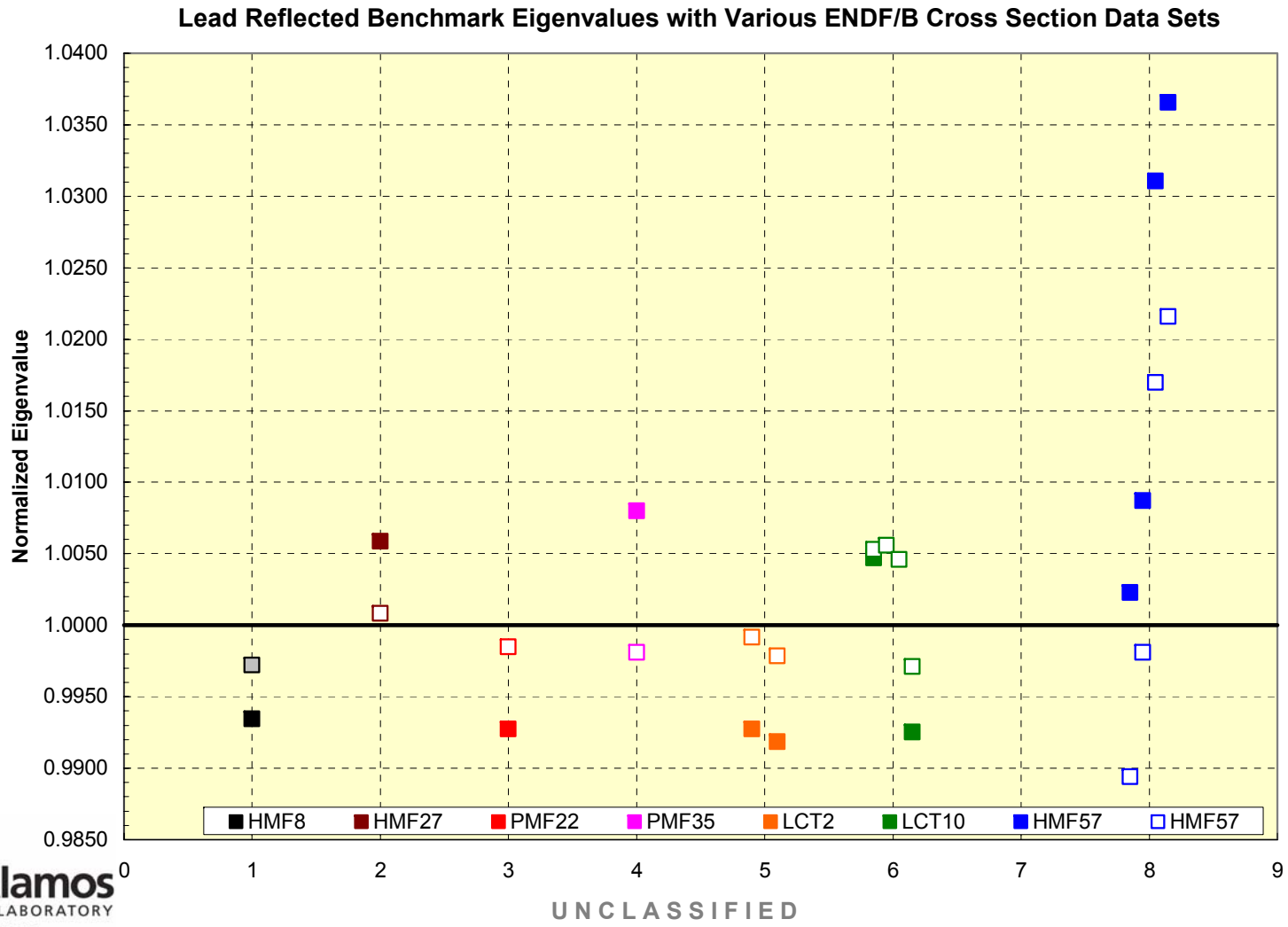
Beryllium Reflected Benchmarks

- Impact of revised beryllium cross sections is questionable, as the
  - revised beryllium cross sections have lead to needed reductions in the calculated eigenvalues for HEU-MET-FAST-041 and MIX-MET-FAST-007 benchmarks.
  - but the revised beryllium cross sections have lead to un-needed reductions in calculated eigenvalues for HEU-MET-FAST-066 and HEU-MET-FAST-077 benchmarks.
  - More work is needed in this area.

Lead Reflected Benchmarks

- Benchmarks come from HEU, PMF and LCT categories
  - HEU-MET-FAST-008 versus HEU-MET-FAST-027
  - PU-MET-FAST-022 versus PU-MET-FAST-035
  - LEU-COMP-THERM-002 versus LEU-COMP-THERM-010
  - HEU-MET-FAST-057 – in a class by itself ☹

Lead Reflected Benchmarks



Los Alamos NATIONAL LABORATORY EST.1943

NNSA

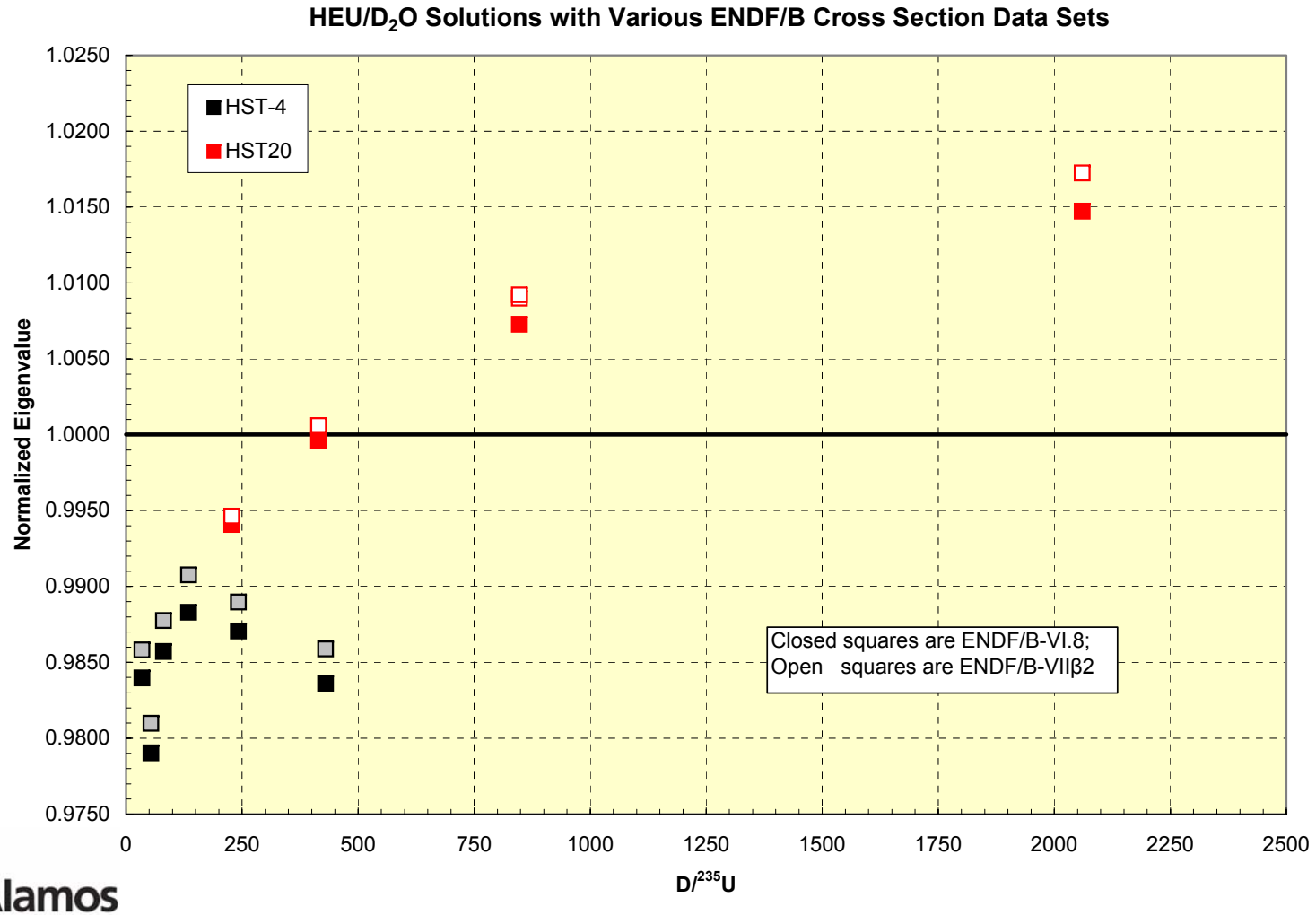
Lead Reflected Benchmarks

- Calculated eigenvalues are a mixed bag, with some improvements seen in some HMF and PMF benchmarks but significant deviations from unity are still seen in HMF57 and LCT10.
  - More work is needed in this area.

HEU/D_2O Benchmarks

- HEU-SOL-THERM-004
  - Heavy water reflected benchmarks
- HEU-SOL-THERM-020
  - Heavy water unreflected benchmarks
- Significant biases are observed in calculated eigenvalues for both ENDF/B-VI.8 and ENDF/B-VIIβ2 cross section data sets.
  - Unreflected benchmark eigenvalues exhibit an increasing trend with increasing D/^{235}U.

HEU/D_2O Benchmarks

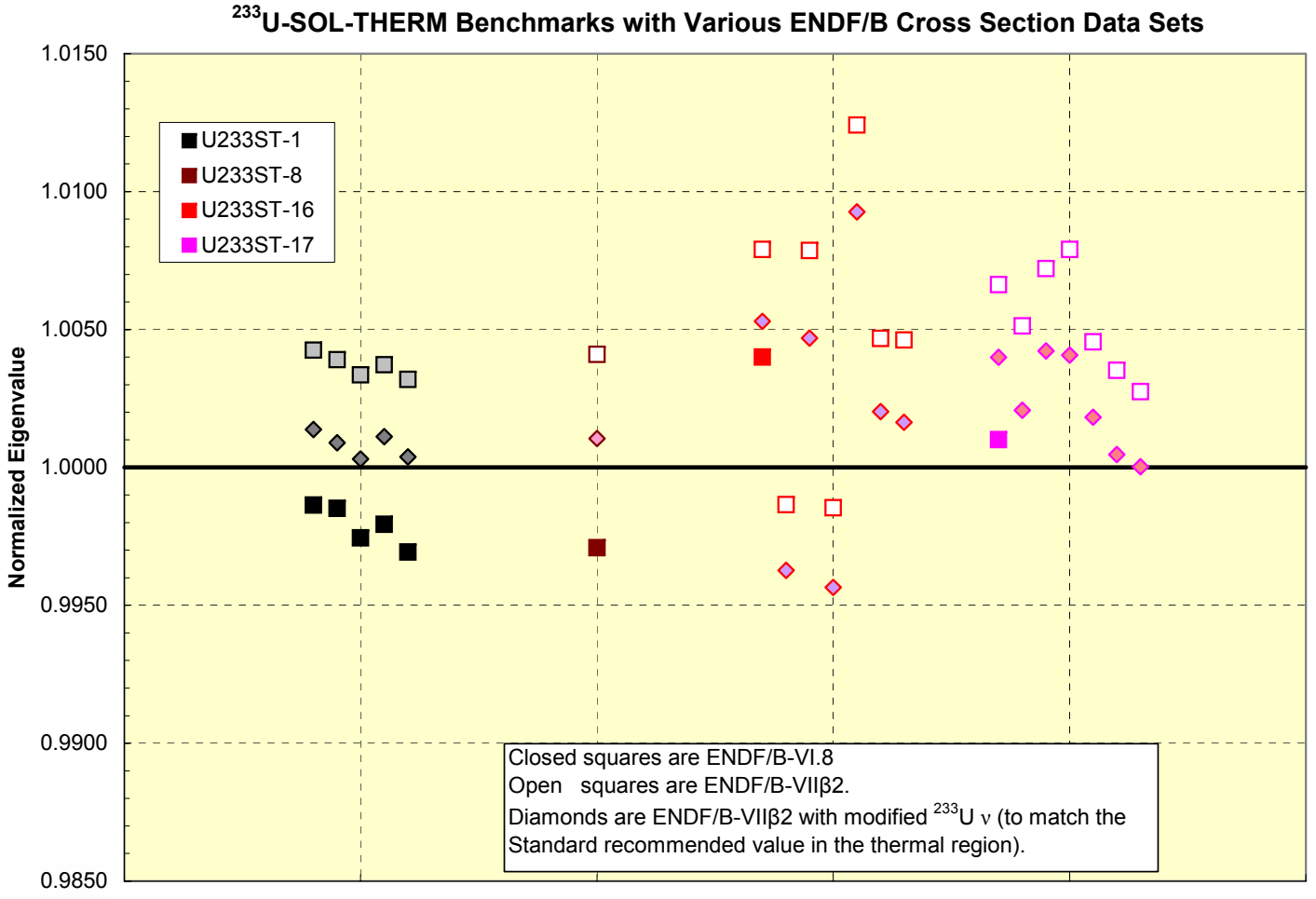


^{233}U-SOL-THERM Benchmarks

- ^{233}U homogeneous solution benchmark suite includes spherical and cylindrical solution containers.
  - U233-SOL-THERM-001 (unreflected sphere)
  - U233-SOL-THERM-008 (unreflected sphere)
  - U233-SOL-THERM-016 (unreflected cylinder)
  - U233-SOL-THERM-017 (water reflected cylinder)

- ^{233}U nu-bar in the data set submitted for ENDF/B-VIIβ2 testing does NOT match the Standards recommendation.
  - Thermal nu needs to be decreased by ~0.3% to match the Standard.

^{233}U-SOL-THERM Benchmarks



Los Alamos NATIONAL LABORATORY EST.1943

NNSA

Comparison Between MCNP5 (LANL) and Tripoli 4.4.1 (Sublet)

- Excellent agreement is observed between MCNP5 and Tripoli eigenvalues for a variety of benchmarks.
  - Previous differences in LEU-COMP-THERM-006 have been attributed to slightly different fuel compositions.
  - Previous differences in selected HEU-SOL-THERM-001 eigenvalues are attributed to different normalizations.

Comparison of MCNP5 (Kahler/ MacFarlane) and Tripoli (Sublet)