# $^{16}O$ and H in $H_2O$ Data Set Testing with ICSBEP Benchmarks

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# Introduction

- Bettis has performed continuous energy Monte Carlo (RCP01) eigenvalue calculations for a variety of ICSBEP uranium fueled benchmarks with ENDF/B-VI.8 cross sections, with the "ENDF/B-VII.β1" cross sections, with "ENDF/B-VII.β2" cross sections released by BNL, and with LANL's $^{16}O$ data set.
- RCP01 eigenvalues are calculated based on 50 million neutron histories in ten independent 5 million history jobs.
  - For RCP01, the 95% eigenvalue confidence interval is determined from the variance in the ten independent eigenvalue estimates and is typically less than 0.0005 Δk (i.e., roughly the size of the plot symbol in subsequent graphs).
- Calculated eigenvalues and subsequent correlations are based upon RCP01 results unless explicitly labeled otherwise.
- A majority of these calculations use models derived from the ICSBEP Handbook:
  - xxx-SOL-THERM
    - 9 HEU evaluations, 31 critical configurations plus two ORNL experiments (L5, L6) that appear in the 2005 edition of the Handbook.
      - 4 evaluations (8 critical configurations) include a $H_2O$ reflector.
    - 9 LEU evaluations, 39 critical configurations
      - 4 evaluations (19 critical configurations) include a $H_2O$ reflector.

# HST Benchmarks

| Benchmark Name | ENDF/B-VI.8 | ENDF/B-VI.8 + ENDF/B-VII.b1 $^{16}$O | | ENDF/B-VI.8 + LANL $^{16}$O | | ENDF/B-VI.8 + Mattes | | ENDF/B-VI.8 + ENDF/B-VII.β2 HH2O | |
|---|---|---|---|---|---|---|---|---|---|
| HST1.1 | 0.99869(39) | 0.99848(25) | * | 0.99909(19) | * | 0.99760(32) | ↓ | 0.99787(23) | ↓ |
| HST1.2 | 0.99540(37) | 0.99548(28) | * | 0.99587(31) | * | 0.99502(14) | * | 0.99496(33) | * |
| HST1.3 | 1.00193(29) | 1.00179(31) | * | 1.00243(24) | * | 1.00077(30) | ↓ | 1.00089(27) | ↓ |
| HST1.4 | 0.99756(27) | 0.99752(29) | * | 0.99789(26) | * | 0.99702(28) | ↓ | 0.99723(45) | * |
| HST1.5 | 0.99966(32) | 0.99963(35) | * | 1.00014(26) | * | 0.99867(23) | ↓ | 0.99801(16) | ⇊ |
| HST1.6 | 1.00290(23) | 1.00285(25) | * | 1.00351(21) | ↑ | 1.00168(35) | ↓ | 1.00138(27) | ⇊ |
| HST1.7 | 0.99822(24) | 0.99834(26) | * | 0.99866(38) | * | 0.99707(23) | ↓ | 0.99720(40) | ↓ |
| HST1.8 | 0.99851(31) | 0.99837(30) | * | 0.99845(25) | * | 0.99723(25) | ↓ | 0.99725(27) | ↓ |
| HST1.9 | 0.99339(37) | 0.99343(34) | * | 0.99400(14) | ↑ | 0.99285(33) | ↓ | 0.99323(35) | * |
| HST1.10 | 0.99325(17) | 0.99326(32) | * | 0.99392(38) | ↑ | 0.99189(21) | ↓ | 0.99155(24) | ⇊ |
| HST-9.1 | 0.99927(29) | 0.99933(17) | * | 0.99994(26) | ↑ | 0.99975(32) | * | 1.00169(24) | ⇈ |
| HST-9.2 | 0.99989(29) | 1.00016(21) | * | 1.00029(16) | * | 1.00019(25) | * | 1.00196(30) | ⇈ |
| HST-9.3 | 0.99977(25) | 0.99993(43) | * | 1.00042(23) | ↑ | 0.99967(24) | * | 1.00186(29) | ⇈ |
| HST-9.4 | 0.99459(21) | 0.99465(27) | * | 0.99499(32) | * | 0.99463(34) | * | 0.99635(50) | ⇈ |
| HST10.1 | 1.00027(34) | 1.00050(36) | * | 1.00089(32) | ↑ | 0.99968(29) | ↓ | 1.00115(23) | ↑ |
| HST11.1 | 1.00428(26) | 1.00459(23) | * | 1.00511(32) | ↑ | 1.00374(27) | ↓ | 1.00421(20) | * |
| HST11.2 | 1.00062(23) | 1.00078(30) | * | 1.00131(26) | ↑ | 0.99988(27) | ↓ | 1.00037(27) | * |
| HST12.1 | 1.00098(23) | 1.00086(15) | * | 1.00164(14) | ↑ | 1.00032(17) | ↓ | 1.00009(22) | ↓ |
| HST13.1 | 0.99738(14) | 0.99724(24) | * | 0.99809(21) | ↑ | 0.99668(17) | ↓ | 0.99625(17) | ↓ |
| HST32.1 | 0.99677(13) | 0.99677(08) | * | 0.99776(12) | ↑ | 0.99637(15) | * | 0.99640(12) | * |

**NOTE: (Relative to ENDF/B-VI.8 values)**

⇊: $\Delta k < -0.0015$ ↓: $-0.0015 < \Delta k < -0.0005$ *: $-0.0005 < \Delta k < 0.0005$

⇈: $\Delta k > 0.0015$ ↑: $0.0005 < \Delta k < 0.0015$

# HST Benchmarks (Cont'd)

| Benchmark Name | ENDF/B-VI.8 | ENDF/B-VI.8 + ENDF/B-VII.b1 $^{16}O$ | | ENDF/B-VI.8 + LANL $^{16}O$ | | ENDF/B-VI.8 + Mattes | | ENDF/B-VI.8 + ENDF/B-VII.β2 HH2O | |
|---|---|---|---|---|---|---|---|---|---|
| HST42.1 | 1.00033(18) | 1.00055(16) | * | 1.00129(08) | * | 1.00001(18) | * | 0.99971(17) | ↓ |
| HST42.2 | 0.99935(16) | 0.99930(13) | * | 1.00015(14) | * | 0.99886(12) | * | 0.99877(14) | ↓ |
| HST42.3 | 1.00033(13) | 1.00031(13) | * | 1.00126(13) | * | 0.99998(13) | * | 0.99996(09) | * |
| HST42.4 | 1.00102(10) | 1.00096(09) | * | 1.00195(10) | * | 1.00070(11) | * | 1.00068(11) | * |
| HST42.5 | 0.99872(08) | 0.99872(12) | * | 0.99973(08) | ↑ | 0.99845(09) | * | 0.99863(11) | * |
| HST42.6 | 0.99910(08) | 0.99909(07) | * | 1.00006(15) | ↑ | 0.99883(11) | * | 0.99891(13) | * |
| HST42.7 | 0.99988(10) | 0.99986(08) | * | 1.00089(07) | ↑ | 0.99969(07) | * | 0.99984(10) | * |
| HST42.8 | 1.00042(11) | 1.00039(09) | * | 1.00150(07) | ↑ | 1.00022(08) | * | 1.00047(10) | * |
| HST43.1 | 0.99650(22) | 0.99658(23) | * | 0.99681(15) | * | 0.99568(25) | ↓ | 0.99589(31) | ↓ |
| HST43.2 | 1.00633(21) | 1.00639(25) | * | 1.00704(21) | ↑ | 1.00561(19) | ↓ | 1.00513(22) | ↓ |
| HST43.3 | 1.00207(16) | 1.00204(19) | * | 1.00281(16) | ↑ | 1.00136(09) | ↓ | 1.00103(08) | ↓ |
| L5 | 1.00093(27) | 1.00077(23) | * | 1.00134(36) | * | 1.00071(21) | * | 1.00088(26) | * |
| L6 | 1.00107(26) | 1.00088(21) | * | 1.00144(18) | * | 1.00059(36) | * | 1.00078(26) | * |

**NOTE: (Relative to ENDF/B-VI.8 values)**

↓↓: $\Delta k < -0.0015$ ↓: $-0.0015 < \Delta k < -0.0005$ *: $-0.0005 < \Delta k < 0.0005$

↑↑: $\Delta k > 0.0015$ ↑: $0.0005 < \Delta k < 0.0015$

# LST Benchmarks

| Benchmark Name | ENDF/B-VI.8 | ENDF/B-VI.8 + ENDF/B-VII.b1 $^{16}O$ | | ENDF/B-VI.8 + LANL $^{16}O$ | | ENDF/B-VI.8 + Mattes | | ENDF/B-VI.8 + ENDF/B-VII.β2 HH2O | |
|---|---|---|---|---|---|---|---|---|---|
| LST1 | 1.01024(17) | 1.01028(23) | * | 1.01110(12) | ↑ | 1.00954(21) | ↓ | 1.01055(25) | * |
| LST2.1 | 0.99384(18) | 0.99384(19) | * | 0.99474(14) | ↑ | 0.99351(12) | * | 0.99387(13) | * |
| LST2.2 | 0.99180(22) | 0.99188(21) | * | 0.99254(26) | ↑ | 0.99111(16) | ↓ | 0.99162(19) | * |
| LST3.3 | 0.99937(18) | 0.99937(24) | * | 1.00016(19) | ↑ | 0.99876(21) | ↓ | 0.99937(18) | * |
| LST3.6 | 0.99715(16) | 0.99725(28) | * | 0.99803(24) | ↑ | 0.99663(14) | ↓ | 0.99711(17) | * |
| LST3.9 | 0.99638(10) | 0.99637(10) | * | 0.99735(10) | ↑ | 0.99597(10) | * | 0.99633(11) | * |
| LST4.1 | 0.99957(11) | 0.99959(22) | * | 1.00007(17) | ↑ | 0.99894(29) | ↓ | 0.99954(19) | * |
| LST4.2 | 1.00033(18) | 1.00022(20) | * | 1.00105(22) | ↑ | 0.99960(20) | ↓ | 1.00025(16) | * |
| LST4.3 | 0.99812(16) | 0.99809(21) | * | 0.99908(22) | ↑ | 0.99758(21) | ↓ | 0.99821(13) | * |
| LST4.4 | 1.00050(22) | 1.00041(14) | * | 1.00128(18) | ↑ | 0.99993(21) | ↓ | 1.00052(18) | * |
| LST4.5 | 1.00044(18) | 1.00036(13) | * | 1.00136(12) | ↑ | 0.99996(16) | * | 1.00038(18) | * |
| LST4.6 | 0.99992(22) | 1.00010(13) | * | 1.00091(20) | ↑ | 0.99954(13) | * | 0.99998(16) | * |
| LST4.7 | 1.00001(17) | 0.99996(11) | * | 1.00090(15) | ↑ | 0.99951(13) | ↓ | 0.99989(16) | * |
| LST7.1 | 0.99765(17) | 0.99775(14) | * | 0.99857(13) | ↑ | 0.99696(13) | ↓ | 0.99775(27) | * |
| LST7.2 | 0.99880(21) | 0.99876(23) | * | 0.99972(19) | ↑ | 0.99789(13) | ↓ | 0.99877(18) | * |
| LST7.3 | 0.99635(18) | 0.99637(24) | * | 0.99715(19) | ↑ | 0.99571(23) | ↓ | 0.99628(28) | * |
| LST7.4 | 0.99803(14) | 0.99799(17) | * | 0.99898(16) | ↑ | 0.99747(19) | ↓ | 0.99818(15) | * |
| LST7.5 | 0.99791(28) | 0.99774(16) | * | 0.99888(19) | ↑ | 0.99725(18) | ↓ | 0.99775(17) | * |

**NOTE: (Relative to ENDF/B-VI.8 values)**

↓↓: $\Delta k < -0.0015$ ↓: $-0.0015 < \Delta k < -0.0005$ *: $-0.0005 < \Delta k < 0.0005$

↑↑: $\Delta k > 0.0015$ ↑: $0.0005 < \Delta k < 0.0015$

# LST Benchmarks (Cont'd)

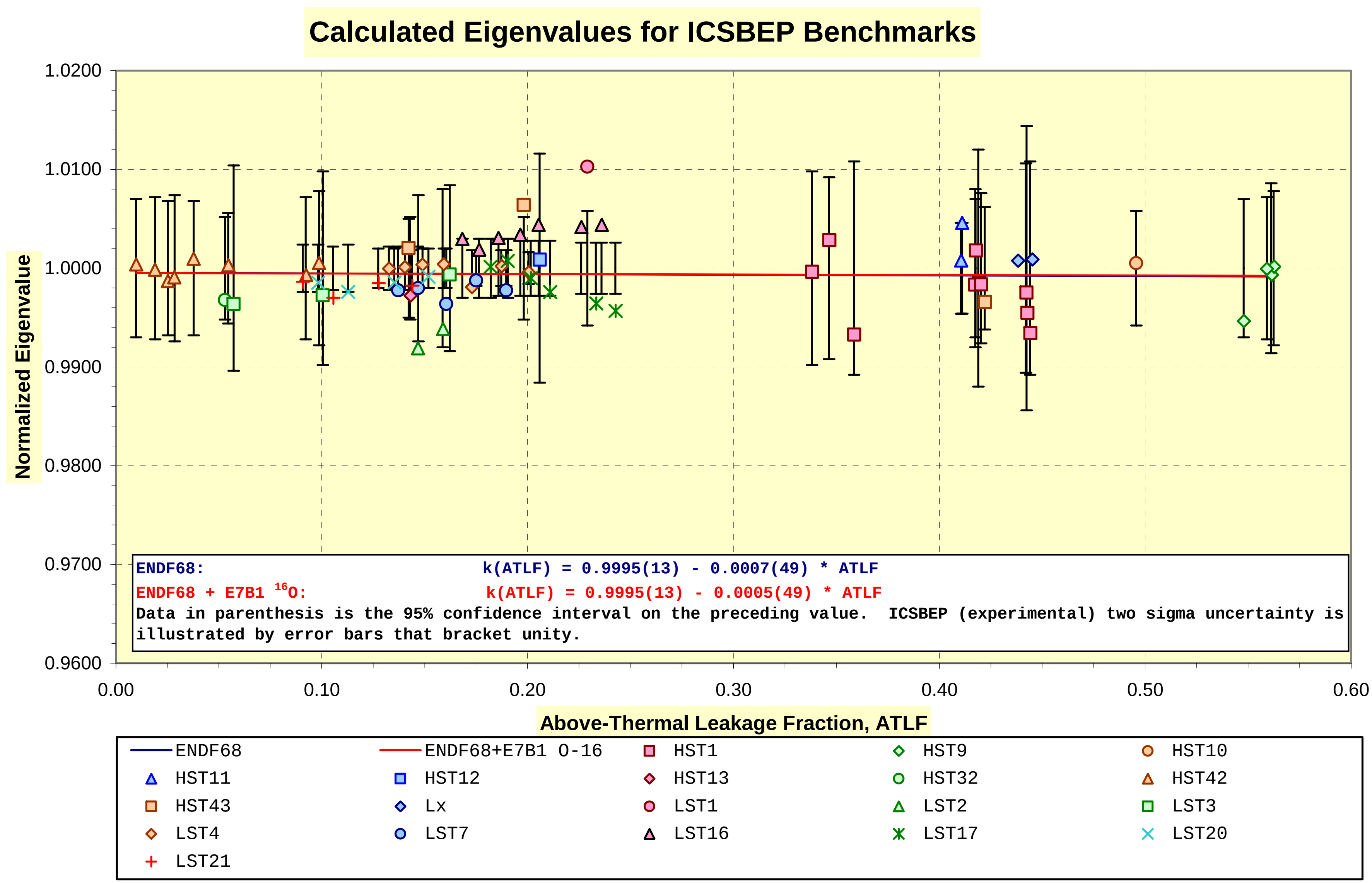
| Benchmark Name | ENDF/B-VI.8 | ENDF/B-VI.8 + ENDF/B-VII.b1 $^{16}O$ | ENDF/B-VI.8 + LANL $^{16}O$ | ENDF/B-VI.8 + Mattes | ENDF/B-VI.8 + ENDF/B-VII.β2 HH2O |
|---|---|---|---|---|---|
| LST16.1 | 1.00443(23) | 1.00438(24) * | 1.00503(33) ↑ | 1.00370(28) ↓ | 1.00427(18) * |
| LST16.2 | 1.00417(16) | 1.00417(26) * | 1.00492(21) ↑ | 1.00337(29) ↓ | 1.00425(23) * |
| LST16.3 | 1.00426(17) | 1.00438(20) * | 1.00504(24) ↑ | 1.00351(28) ↓ | 1.00410(24) * |
| LST16.4 | 1.00340(15) | 1.00340(25) * | 1.00418(14) ↑ | 1.00256(14) ↓ | 1.00340(27) * |
| LST16.5 | 1.00300(21) | 1.00306(15) * | 1.00391(15) ↑ | 1.00232(18) ↓ | 1.00316(18) * |
| LST16.6 | 1.00203(29) | 1.00188(08) * | 1.00289(26) ↑ | 1.00106(24) ↓ | 1.00188(15) * |
| LST16.7 | 1.00297(17) | 1.00296(11) * | 1.00372(27) ↑ | 1.00223(14) ↓ | 1.00295(15) * |
| LST17.1 | 0.99558(23) | 0.99567(18) * | 0.99644(33) ↑ | 0.99467(19) ↓ | 0.99580(19) * |
| LST17.2 | 0.99647(13) | 0.99643(13) * | 0.99718(22) ↑ | 0.99552(27) ↓ | 0.99649(16) * |
| LST17.3 | 0.99751(23) | 0.99757(28) * | 0.99848(25) ↑ | 0.99659(20) ↓ | 0.99768(20) * |
| LST17.4 | 0.99919(12) | 0.99898(32) * | 1.00000(17) ↑ | 0.99832(24) ↓ | 0.99915(27) * |
| LST17.5 | 1.00040(13) | 1.00073(14) * | 1.00134(16) ↑ | 0.99973(12) ↓ | 1.00045(16) * |
| LST17.6 | 0.99994(19) | 1.00012(16) * | 1.00089(25) ↑ | 0.99929(28) ↓ | 1.00007(20) * |
| LST20.1 | 0.99912(21) | 0.99913(13) * | 0.99995(17) ↑ | 0.99839(19) ↓ | 0.99913(17) * |
| LST20.2 | 0.99853(19) | 0.99855(21) * | 0.99930(15) ↑ | 0.99802(21) ↓ | 0.99855(24) * |
| LST20.3 | 0.99762(13) | 0.99761(18) * | 0.99853(19) ↑ | 0.99722(14) * | 0.99767(12) * |
| LST20.4 | 0.99868(27) | 0.99852(22) * | 0.99945(16) ↑ | 0.99806(18) ↓ | 0.99853(17) * |
| LST21.1 | 0.99831(12) | 0.99823(30) * | 0.99916(15) ↑ | 0.99774(16) ↓ | 0.99830(21) * |
| LST21.2 | 0.99851(15) | 0.99848(12) * | 0.99943(16) ↑ | 0.99791(18) ↓ | 0.99849(16) * |
| LST21.3 | 0.99711(15) | 0.99699(18) * | 0.99798(17) ↑ | 0.99657(21) ↓ | 0.99714(15) * |
| LST21.4 | 0.99867(12) | 0.99864(18) * | 0.99974(17) ↑ | 0.99824(14) * | 0.99867(23) * |

**NOTE: (Relative to ENDF/B-VI.8 values)**

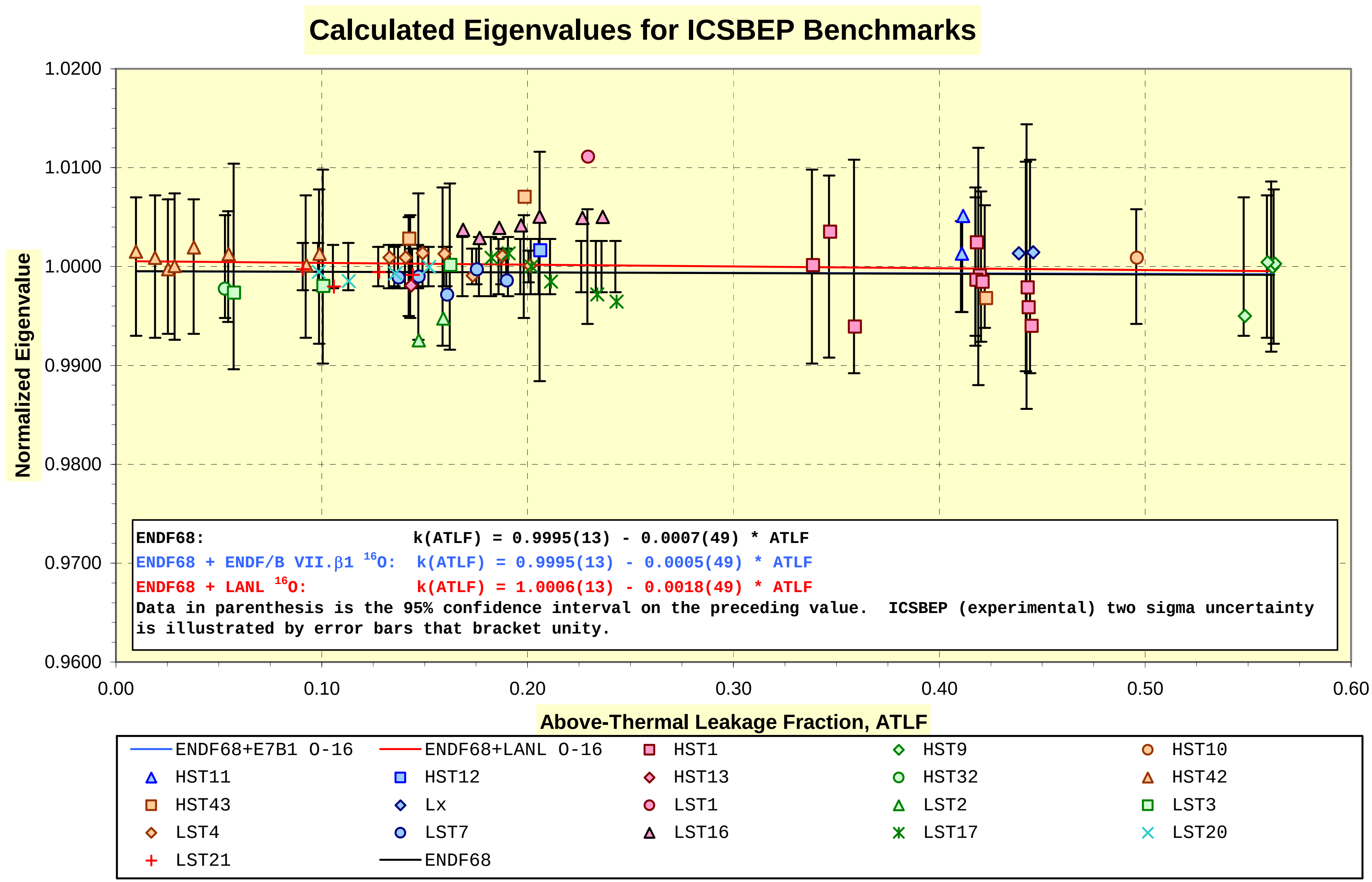
⇊: $\Delta k < -0.0015$ ↓: $-0.0015 < \Delta k < -0.0005$ *: $-0.0005 < \Delta k < 0.0005$

⇈: $\Delta k > 0.0015$ ↑: $0.0005 < \Delta k < 0.0015$

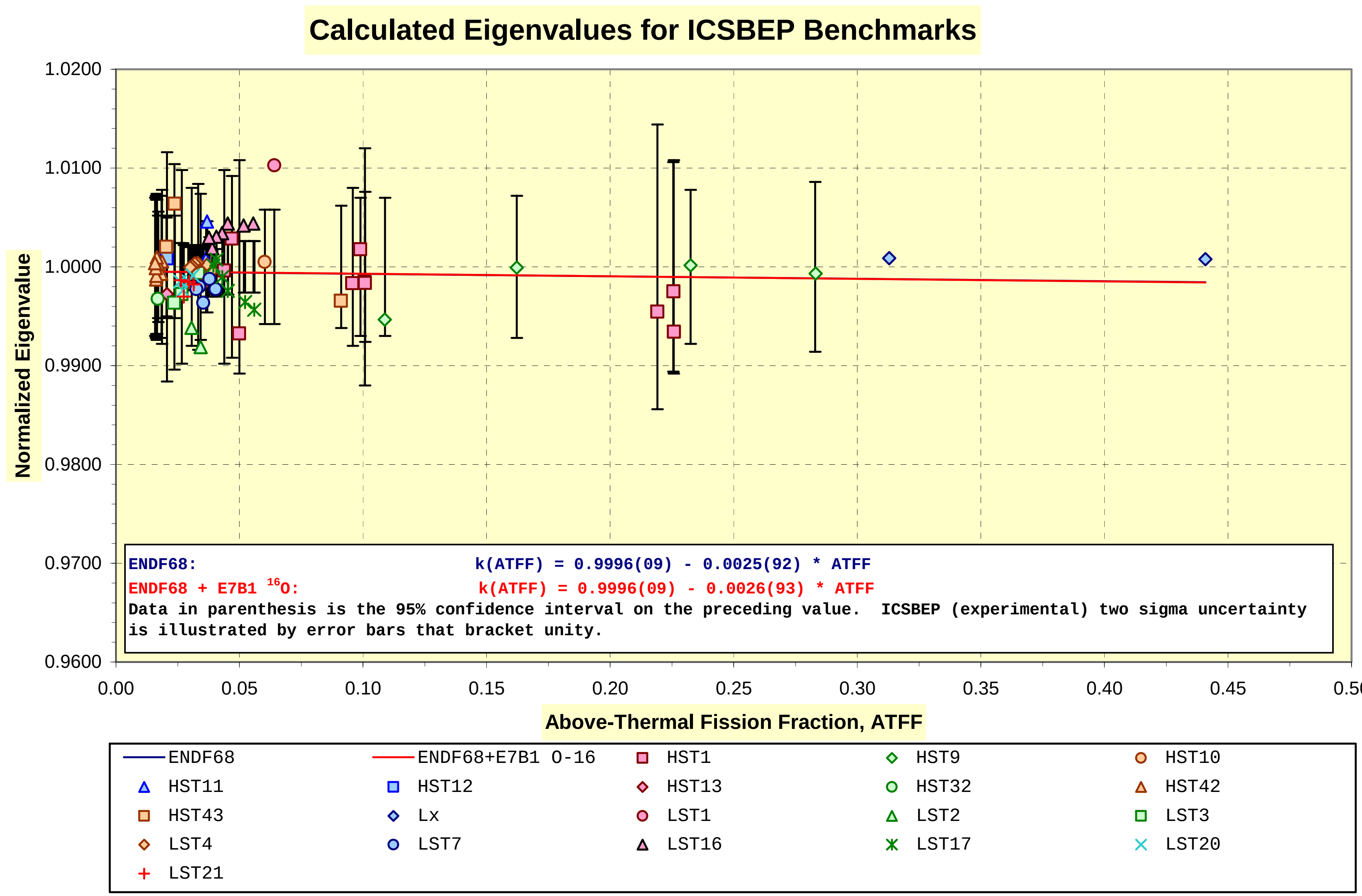
# Comparison between ENDF/B VI.8 $^{16}O$ vs. ENDF/B VII.β1 $^{16}O$



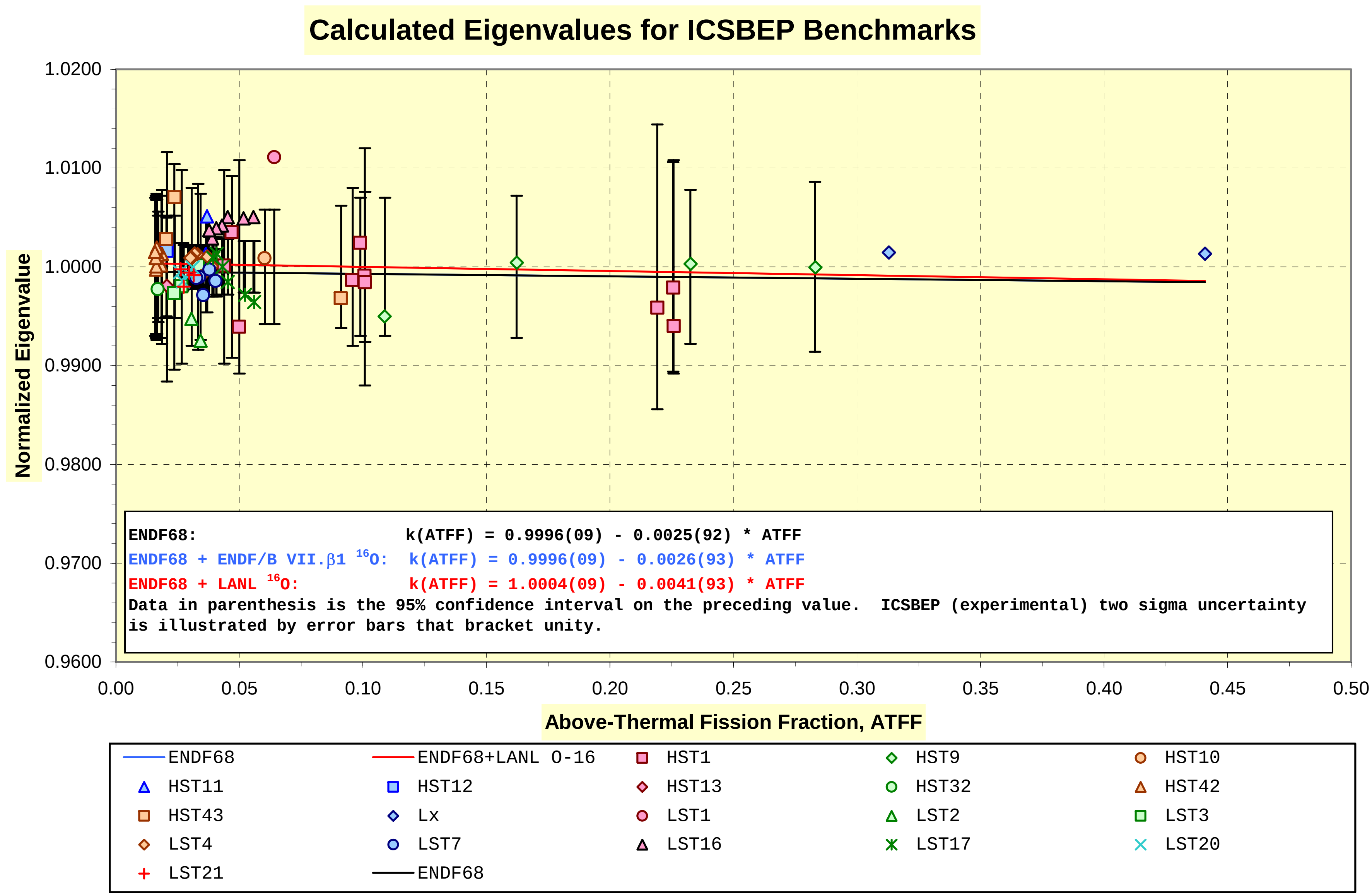
# Comparison between ENDF/B VI.8 $^{16}$O vs. LANL $^{16}$O



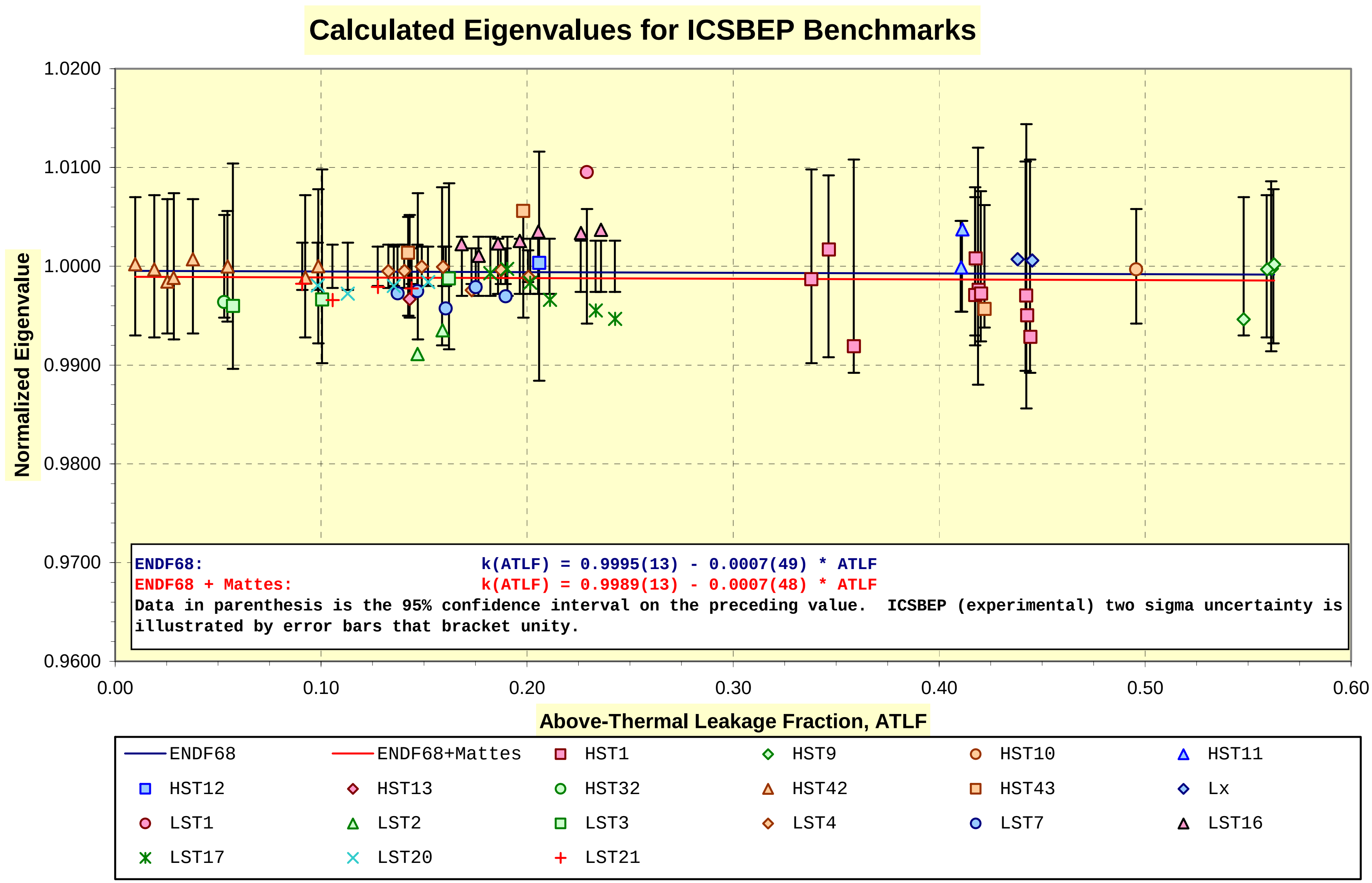
# Comparison between ENDF/B VI.8 $^{16}O$ vs. ENDF/B VII.β1 $^{16}O$



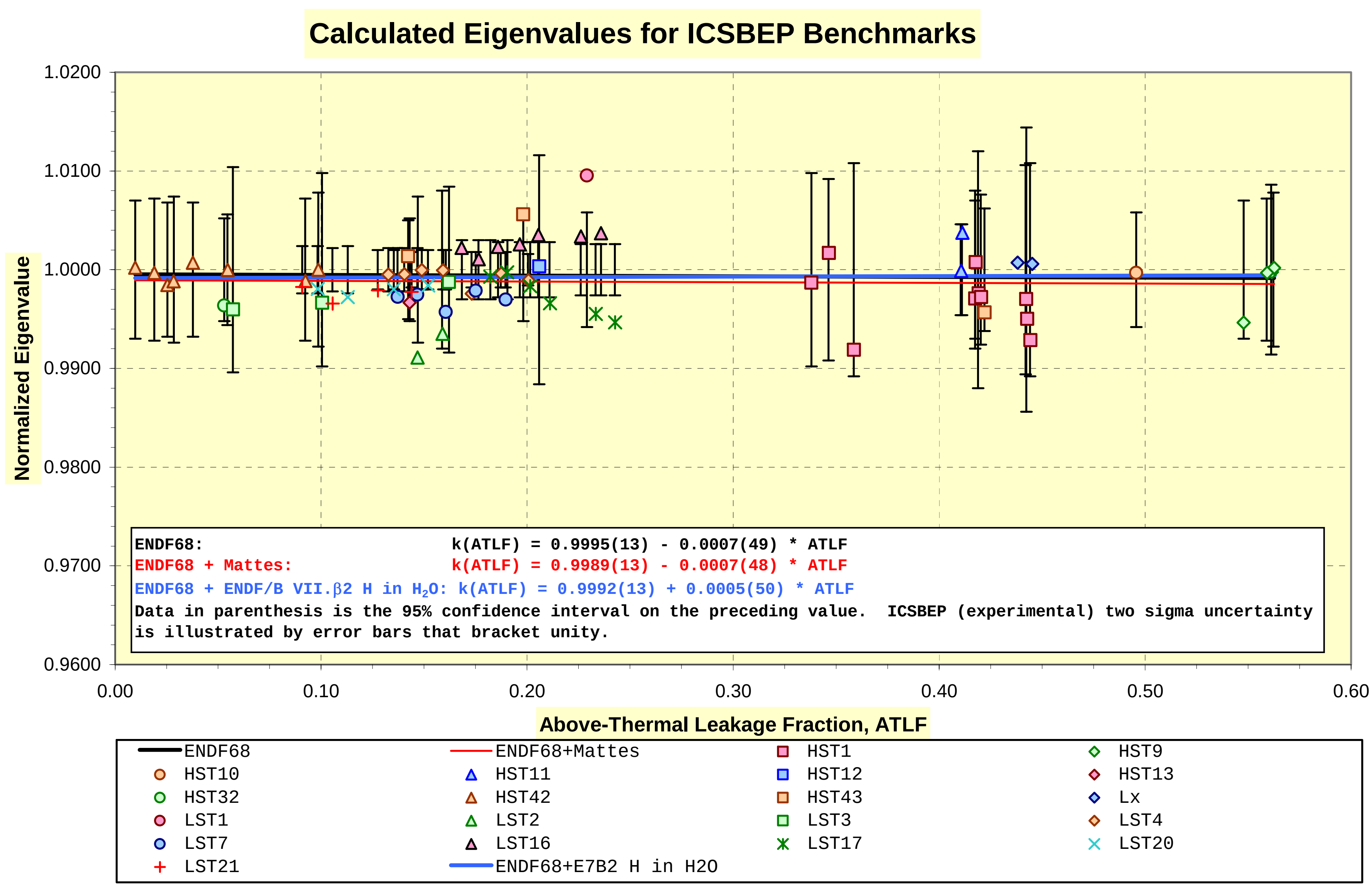
# Comparison between ENDF/B VI.8 $^{16}$O vs. LANL $^{16}$O



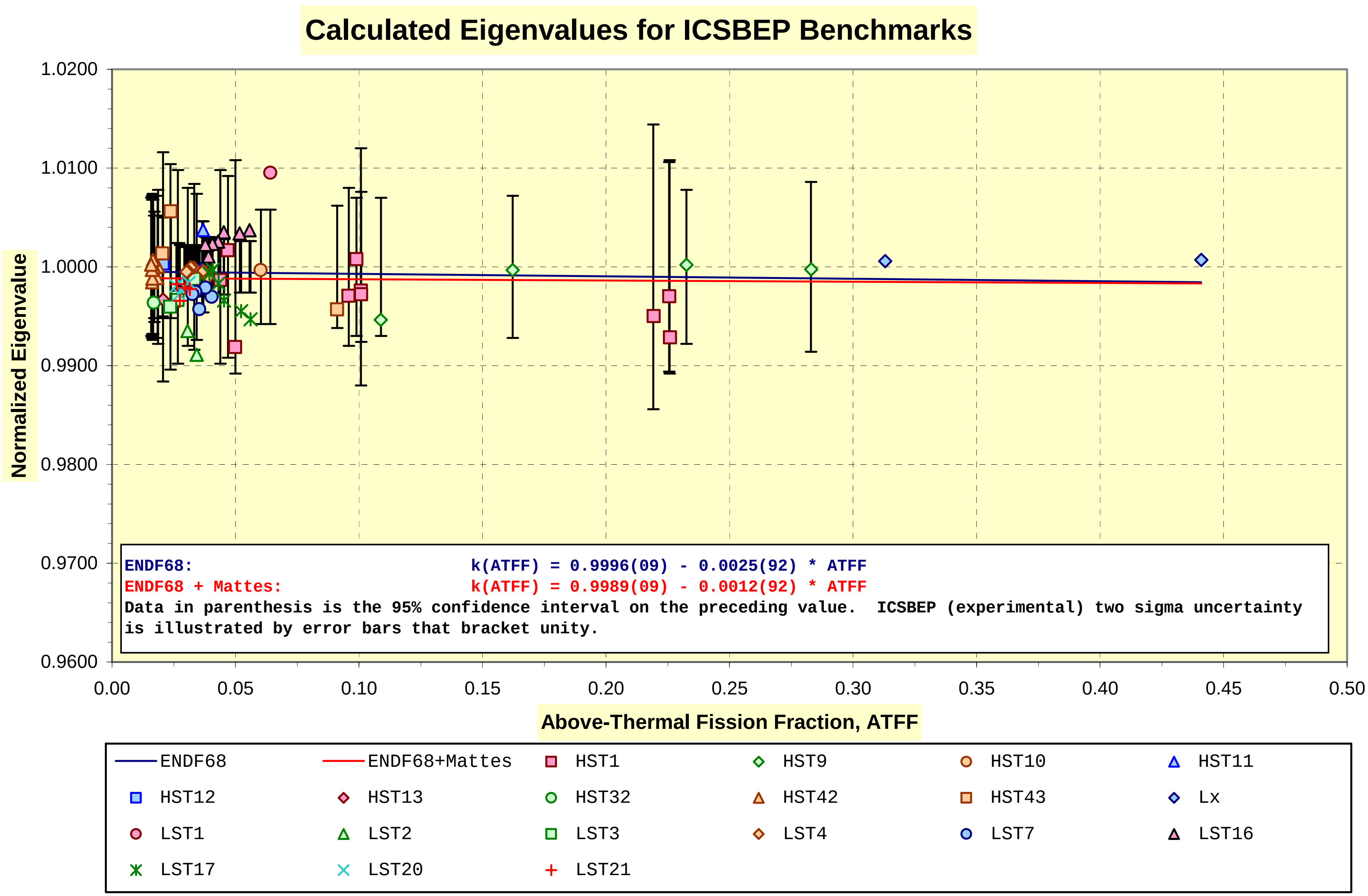
# Comparison between ENDF/B VI.8 H in $H_2O$ vs. Mattes H in $H_2O$



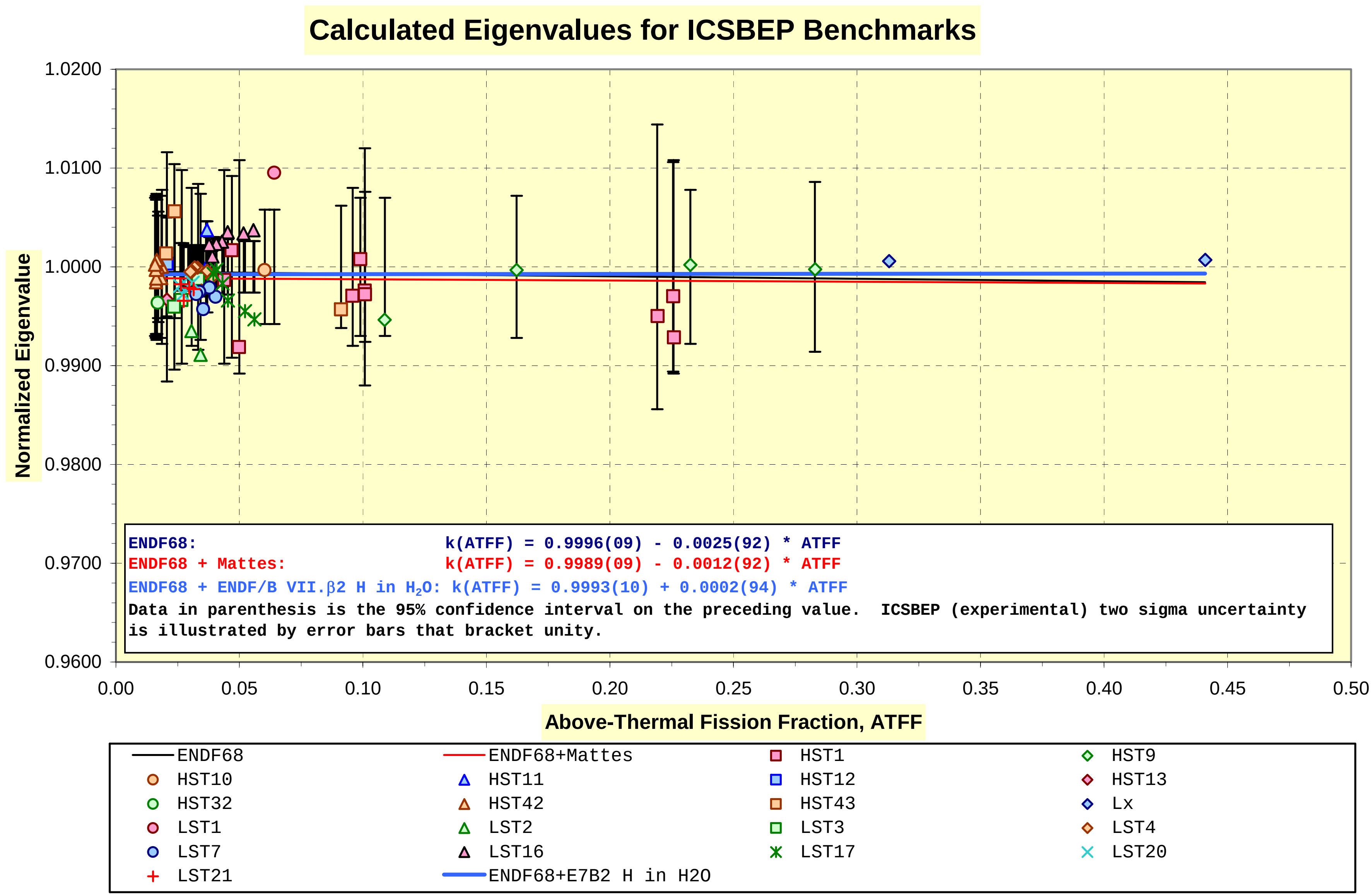
# Comparison between ENDF/B VI.8 H in $H_2O$ vs. ENDF/B VII.β2 H in $H_2O$



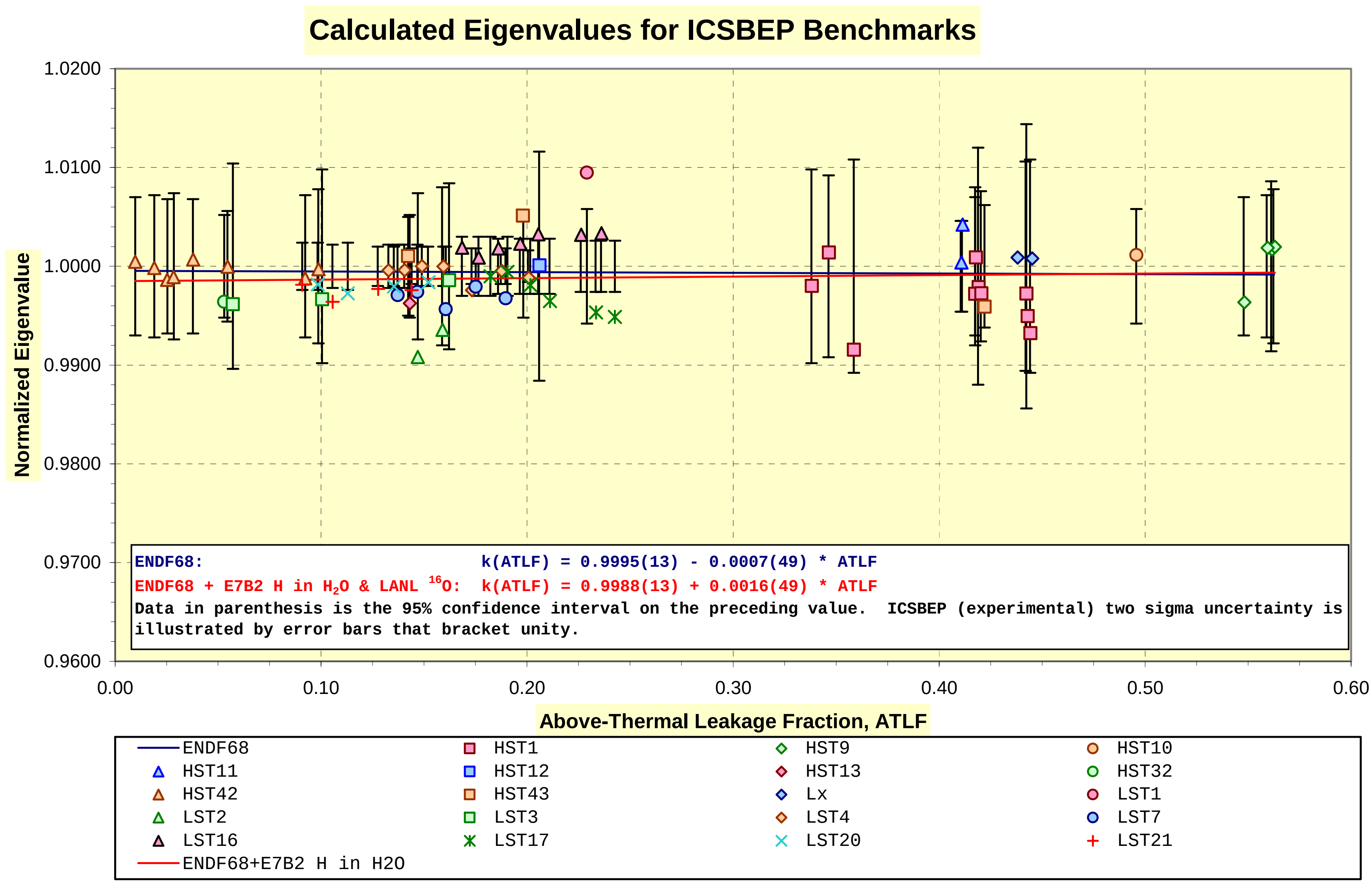
# Comparison between ENDF/B VI.8 H in $H_2O$ vs. Mattes H in $H_2O$



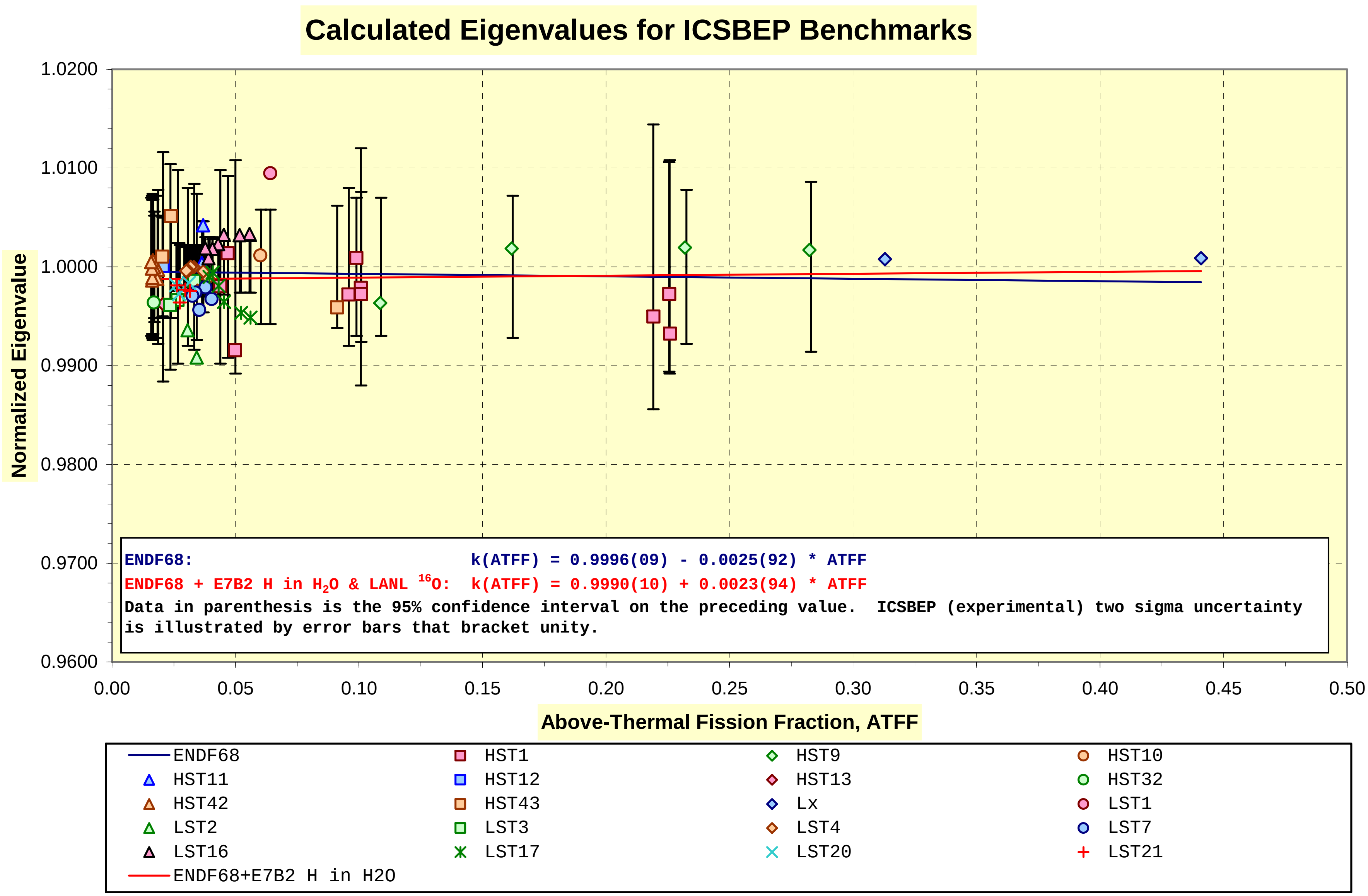
# Comparison between ENDF/B VI.8 H in $H_2O$ vs. ENDF/B VII.β2 H in $H_2O$



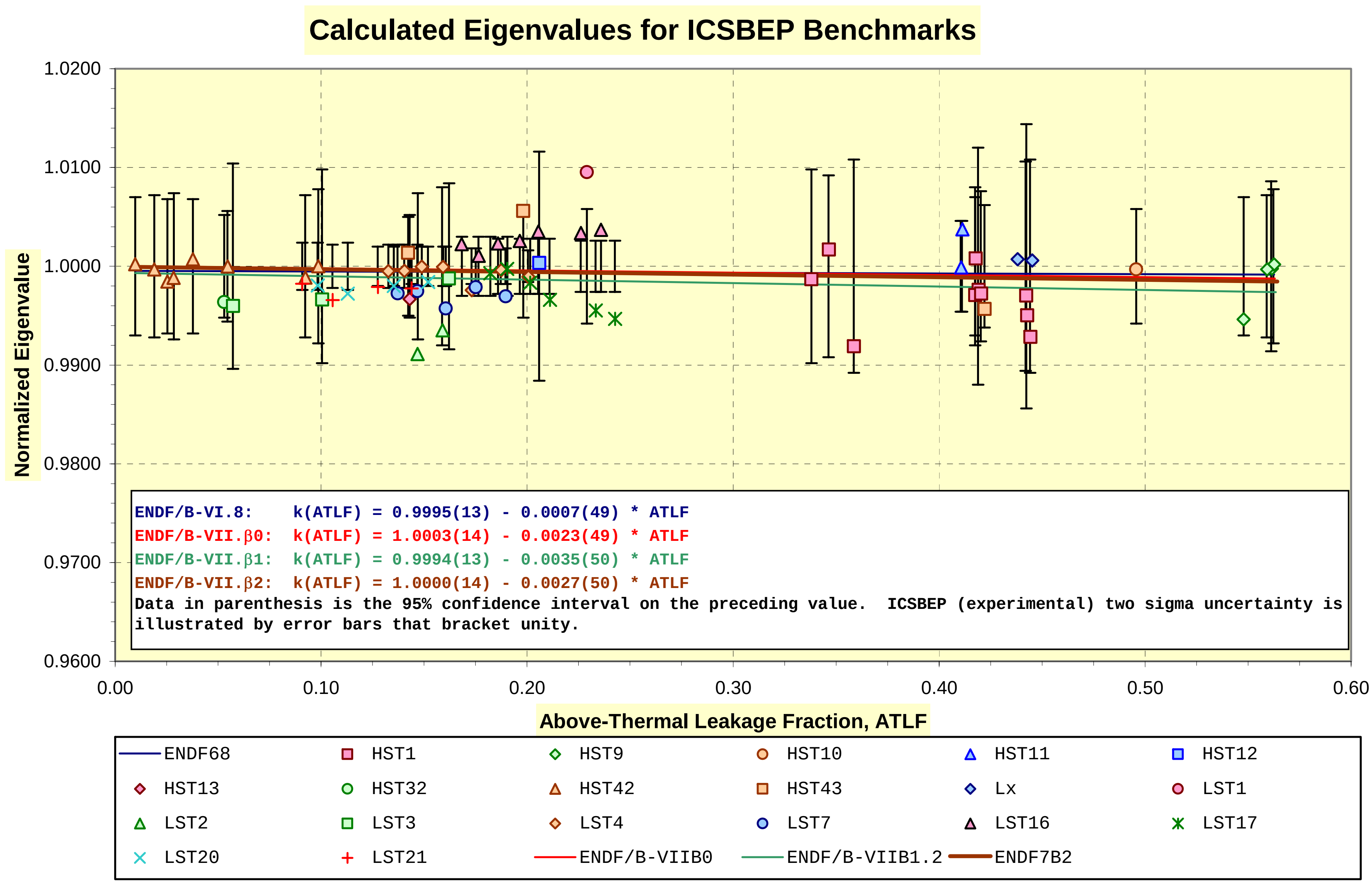
# Comparison between ENDF/B VI.8 H in $H_2O$ vs. combination of ENDF/B VII.β2 H in $H_2O$ and LANL $^{16}O$



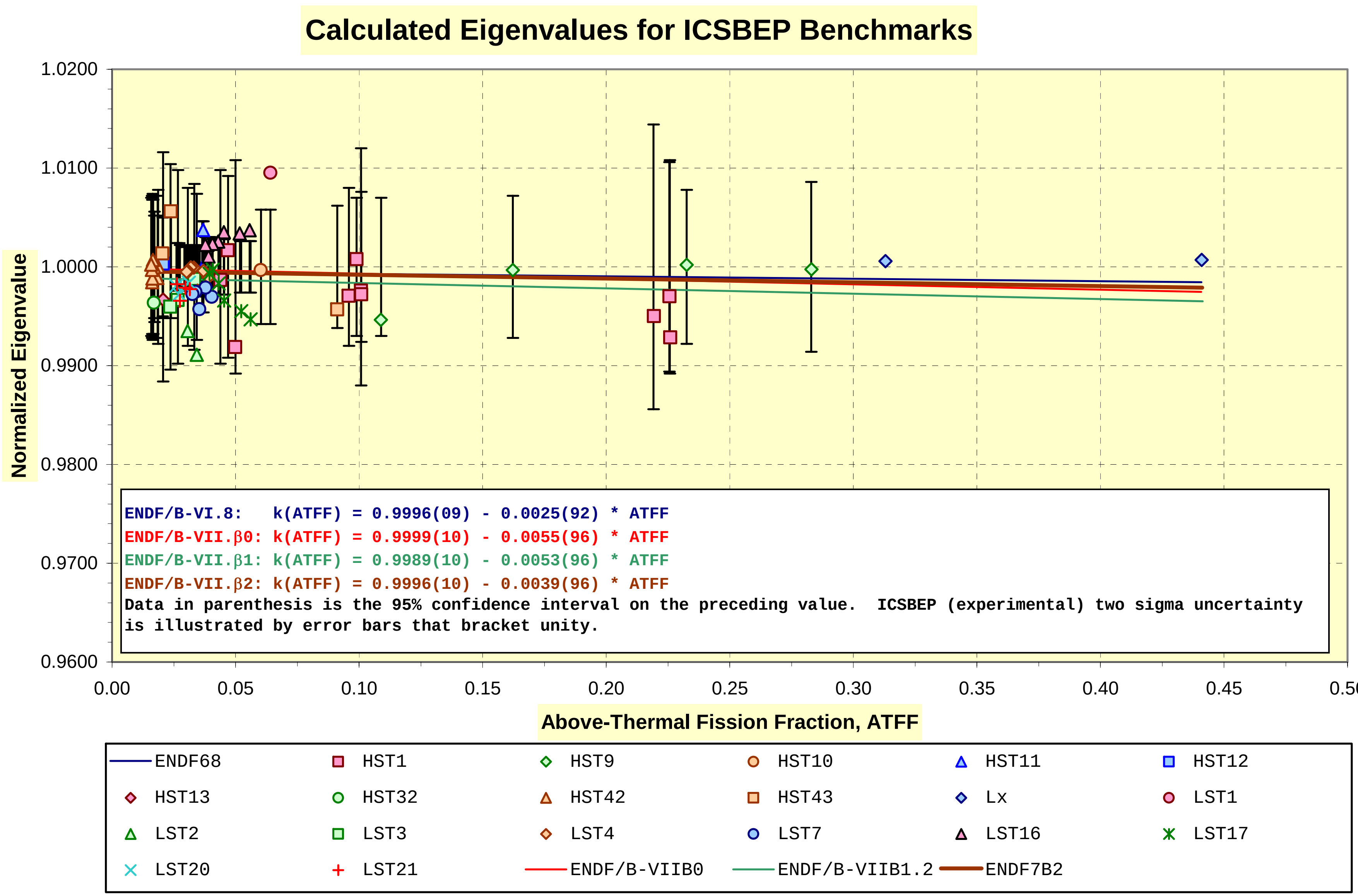
# Comparison between ENDF/B VI.8 H in $H_2O$ vs. combination of ENDF/B VII.β2 H in $H_2O$ and LANL $^{16}O$



# Comparison between ENDF/B VI.8, ENDF/B-VII.β0, ENDF/B-VII.β1, and ENDF/B-VII.β2



# Comparison between ENDF/B VI.8, ENDF/B-VII.β0, ENDF/B-VII.β1, and ENDF/B-VII.β2



# Summary

- ATLF
  - k(ATLF) = 0.9995(13) – 0.0007(49)*ATLF    ENDF/B VI.8
  - k(ATLF) = 0.9995(13) – 0.0005(49)*ATLF    ENDF/B VI.8 + ENDF/B VIIβ1 $^{16}$O
  - k(ATLF) = 1.0006(13) – 0.0018(49)*ATLF    ENDF/B VI.8 + LANL $^{16}$O
  - k(ATLF) = 0.9989(13) – 0.0007(48)*ATLF    ENDF/B VI.8 + Mattes S(α,β)
  - k(ATLF) = 0.9992(13) + 0.0005(50)*ATLF    ENDF/B VI.8 + ENDF/B VIIβ2 S(α,β)
  - k(ATLF) = 0.9988(13) + 0.0016(50)*ATLF    ENDF/B VI.8 + ENDF/B VIIβ2 S(α,β) & LANL $^{16}$O
- ATFF
  - k(ATFF) = 0.9996(09) – 0.0025(92)*ATFF    ENDF/B VI.8
  - k(ATFF) = 0.9996(09) – 0.0026(93)*ATFF    ENDF/B VI.8 + ENDF/B VIIβ1 $^{16}$O
  - k(ATFF) = 1.0004(09) – 0.0041(93)*ATFF    ENDF/B VI.8 + LANL $^{16}$O
  - k(ATFF) = 0.9989(09) – 0.0012(92)*ATFF    ENDF/B VI.8 + Mattes S(α,β)
  - k(ATFF) = 0.9993(10) + 0.0002(94)*ATFF    ENDF/B VI.8 + ENDF/B VIIβ2 S(α,β)
  - k(ATFF) = 0.9990(10) + 0.0023(94)*ATFF    ENDF/B VI.8 + ENDF/B VIIβ2 S(α,β) & LANL $^{16}$O
- LANL $^{16}$O
  - slight increase in eigenvalues on average.
  - slight increase to ATLF and ATFF regression trends.
- Mattes H-$H_2O$ Thermal Scattering Kernel:
  - slight reduction to eigenvalues on average.
  - slight improvement to ATFF regression trend.
- ENDF/B-VII.β2 H-$H_2O$ Thermal Scattering Kernel
  - recovers Mattes eigenvalue reduction.
  - improved ATFF and ATLF (slightly) regression trends.

# Recommendation

- ATLF
  - k(ATLF) = 0.9995(13) – 0.0007(49)*ATLF ENDF/B VI.8
  - k(ATLF) = 1.0003(14) – 0.0023(49)*ATLF ENDF/B VIIβ0
  - k(ATLF) = 0.9994(14) – 0.0035(50)*ATLF ENDF/B VIIβ1
  - k(ATLF) = 1.0000(14) - 0.0027(50)*ATLF ENDF/B VIIβ2
- ATFF
  - k(ATFF) = 0.9996(09) – 0.0025(92)*ATFF ENDF/B VI.8
  - k(ATFF) = 0.9999(10) – 0.0055(96)*ATFF ENDF/B VIIβ0
  - k(ATFF) = 0.9989(10) – 0.0053(96)*ATFF ENDF/B VIIβ1
  - k(ATFF) = 0.9996(10) – 0.0039(92)*ATFF ENDF/B VIIβ2
- Bettis recommends use of both LANL $^{16}O$ and β2 H-$H_2O$ scattering kernel in ENDF/B-VII.

# Preliminary ENDF/B-VII.β2 Decay File Checking

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Presented at the June 28, 2006
Cross Section Evaluation Working Group (CSEWG)
Data Testing Subcommittee Meeting
held at
Brookhaven National Laboratory

# Introduction

- Bettis has performed a series of consistency check on ENDF/B-VII.β2 decay file (MF=8, MT=457) data.
- Screened all 3380 nuclides
- Concerned with potential impact on decay heat analyses.

# Observations

- Branching fractions do not sum to unity for 837 nuclides
  - Round-off for 695 nuclides (not technically significant)
  - Discrepancies beyond round-off for 142 nuclides (some errors)
- Identical average LP and EM decay energies for 1676 nuclides
  - Mostly appear to be neutron rich/poor nuclides from JEF
  - Need additional review to determine impact on decay heat analyses
- Identical average LP, EM, and HP decay energies for 12 nuclides
  - Mostly appear to be neutron rich/poor nuclides from JEF
  - Need additional review to determine impact on decay heat analyses
- Round-off issues with half-life for 805 nuclides
  - Not technically significant an annoyance

# Branching Fraction Discrepancies

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 2-He-  5    Sum of BFs = 0.5
 5-B - 15    Sum of BFs = 1.54
11-Na- 27    Sum of BFs = 1.0013
18-Ar- 31    Sum of BFs = 1.31, duplicate b+
19-K - 52    Sum of BFs = 1.36, duplicate b+
20-Ca- 38    Sum of BFs = 1.009438
20-Ca- 48    Sum of BFs = 1.09
25-Mn- 52M   Sum of BFs = 1.0161, duplicate b+
26-Fe- 46    Sum of BFs = 10.0
30-Zn- 69M   Sum of BFs = 3.3E-4, missing IT
31-Ga- 80    Sum of BFs = 1.0086
32-Ge- 60    Sum of BFs = 0.5
35-Br- 78    Sum of BFs = 1.0001
35-Br- 88    Sum of BFs = 0.9982
36-Kr- 73    Sum of BFs = 1.0025
36-Kr- 81M   Sum of BFs = 1.000025
36-Kr- 93    Sum of BFs = 1.0195
37-Rb- 84    Sum of BFs = 1.002
39-Y - 85M   Sum of BFs = 1.00002
39-Y - 90M   Sum of BFs = 1.000018
41-Nb- 89M   Sum of BFs = 0.995
41-Nb- 92    Sum of BFs = 1.0005
43-Tc- 99M   Sum of BFs = 1.000037
43-Tc-102M   Sum of BFs = 0.98, missing IT
46-Pd- 93M   Sum of BFs = 0.5
47-Ag- 98    Sum of BFs = 1.000011
47-Ag-110M   Sum of BFs = 0.9992
48-Cd-107    Sum of BFs = 1.001284
48-Cd-115    Sum of BFs = 1.001662
49-In-127    Sum of BFs = 1.0003
49-In-129    Sum of BFs = 1.0015
49-In-129M   Sum of BFs = 1.026
50-Sn-126    Sum of BFs = 1.049088
50-Sn-129M   Sum of BFs = 1.00002
51-Sb-104    Sum of BFs = 1.01
51-Sb-128M   Sum of BFs = 0.964, missing IT
52-Te-110    Sum of BFs = 1.00003
52-Te-136    Sum of BFs = 1.013
53-I -108    Sum of BFs = 1.01
53-I -112    Sum of BFs = 1.000012
54-Xe-113    Sum of BFs = 1.0001
54-Xe-135M   Sum of BFs = 0.994
55-Cs-114    Sum of BFs = 1.0002
56-Ba-142    Sum of BFs = 0.9991
56-Ba-144    Sum of BFs = 0.964
56-Ba-147    Sum of BFs = 0.9998
60-Nd-141M   Sum of BFs = 1.0495
61-Pm-139M   Sum of BFs = 0.9994
63-Eu-140M   Sum of BFs = 1.01
65-Tb-149M   Sum of BFs = 0.99978, missing alpha
65-Tb-150    Sum of BFs = 1.0005
65-Tb-151    Sum of BFs = 1.000095
65-Tb-154    Sum of BFs = 1.001
65-Tb-154M   Sum of BFs = 0.783, missing IT
65-Tb-154M2  Sum of BFs = 0.982, missing IT
65-Tb-158M   Sum of BFs = 1.0061
66-Dy-149M   Sum of BFs = 1.00144
66-Dy-153    Sum of BFs = 1.0000939
67-Ho-154M   Sum of BFs = 1.00001
68-Er-152    Sum of BFs = 1.01
69-Tm-162M   Sum of BFs = 0.18
70-Yb-158    Sum of BFs = 1.000021
71-Lu-155M2  Sum of BFs = 10.0
71-Lu-156M   Sum of BFs = 1.9, (2 alpha?)
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# Branching Fraction Discrepancies

| | |
|---|---|
| 71-Lu-159 | Sum of BFs = 1.001 |
| **71-Lu-167M** | **Sum of BFs = 0.5** |
| 71-Lu-176M | Sum of BFs = 1.00095 |
| 72-Hf-156 | Sum of BFs = 0.97 |
| 72-Hf-157 | Sum of BFs = 0.94 |
| **72-Hf-178M2** | **Sum of BFs = 1.000449** |
| 73-Ta-161 | Sum of BFs = 0.95 |
| 74-W -165 | Sum of BFs = 1.002 |
| 74-W -168 | Sum of BFs = 1.000032 |
| 75-Re-168 | Sum of BFs = 1.00005 |
| 76-Os-166 | Sum of BFs = 0.9 |
| 76-Os-172 | Sum of BFs = 0.901 |
| 76-Os-181M | Sum of BFs = 1.03 |
| 77-Ir-167M | Sum of BFs = 1.004 |
| 77-Ir-168 | Sum of BFs = 0.82 |
| 77-Ir-190M2 | Sum of BFs = 1.0007586 |
| 77-Ir-196M | Sum of BFs = 1.003 |
| 78-Pt-180 | Sum of BFs = 1.003 |
| 78-Pt-181 | Sum of BFs = 1.0008 |
| 78-Pt-183 | Sum of BFs = 1.000013 |
| 79-Au-171M | Sum of BFs = 1.02 |
| 79-Au-172 | Sum of BFs = 1.02 |
| 79-Au-183 | Sum of BFs = 1.0019 |
| 79-Au-184M | Sum of BFs = 1.0002 |
| 79-Au-187 | Sum of BFs = 1.00003 |
| 80-Hg-174 | Sum of BFs = 0.997 |
| 80-Hg-175 | Sum of BFs = 0.99 |
| 80-Hg-185M | Sum of BFs = 1.0003 |
| 80-Hg-186 | Sum of BFs = 1.00018 |
| **81-Tl-180** | **Sum of BFs = 0.07** |
| **81-Tl-181** | **Sum of BFs = 0.1** |
| 81-Tl-186 | Sum of BFs = 1.00006 |

| | |
|---|---|
| 82-Pb-191M | Sum of BFs = 1.00018 |
| 83-Bi-197M | Sum of BFs = 1.003 |
| 83-Bi-199M | Sum of BFs = 1.0001 |
| 83-Bi-201M | Sum of BFs = 1.001 |
| **83-Bi-212M** | **Sum of BFs = 1.3** |
| 84-Po-195M | Sum of BFs = 1.0001 |
| 84-Po-197M | Sum of BFs = 1.0001 |
| 84-Po-201M | Sum of BFs = 0.999 |
| **85-At-193M2** | **Sum of BFs = 0.24** |
| 85-At-196 | Sum of BFs = 0.94 |
| 85-At-200M2 | Sum of BFs = 0.99 |
| 85-At-202M2 | Sum of BFs = 1.0005 |
| 85-At-217 | Sum of BFs = 0.99988 |
| 86-Rn-196 | Sum of BFs = 0.998 |
| 86-Rn-221 | Sum of BFs = 0.98 |
| 87-Fr-206M | Sum of BFs = 0.96 |
| 89-Ac-208 | Sum of BFs = 0.99 |
| **89-Ac-208M** | **Sum of BFs = 0.11** |
| 89-Ac-215 | Sum of BFs = 0.9991 |
| 90-Th-212 | Sum of BFs = 1.003 |
| **90-Th-225** | **Sum of BFs = 0.9** |
| 92-U -228 | Sum of BFs = 0.975 |
| 92-U -231 | Sum of BFs = 1.00004 |
| 92-U -238 | Sum of BFs = 1.0000546 |
| 93-Np-233 | Sum of BFs = 1.00001 |
| 93-Np-235 | Sum of BFs = 1.000026 |
| 93-Np-236 | Sum of BFs = 0.9996 |
| 93-Np-240 | Sum of BFs = 0.9988 |
| 94-Pu-237 | Sum of BFs = 1.000042 |
| 94-Pu-244 | Sum of BFs = 1.00004 |
| 96-Cm-240 | Sum of BFs = 0.997 |
| 96-Cm-243 | Sum of BFs = 0.9995 |

# Branching Fraction Discrepancies

| | |
|---|---|
| 96-Cm-248 | Sum of BFs = 0.9987 |
| 98-Cf-247 | Sum of BFs = 1.0001 |
| 98-Cf-248 | Sum of BFs = 0.999971 |
| 99-Es-248 | Sum of BFs = 0.9995 |
| 99-Es-255 | Sum of BFs = 1.000041 |
| 100-Fm-250 | Sum of BFs = 1.000069 |
| **100-Fm-250M** | **Sum of BFs = 0.2** |
| 100-Fm-254 | Sum of BFs = 0.99941 |
| 100-Fm-257 | Sum of BFs = 0.9979 |
| 101-Md-248 | Sum of BFs = 1.0005 |
| 102-No-256 | Sum of BFs = 0.995 |
| 103-Lr-258 | Sum of BFs = 0.95 |
| **103-Lr-262** | **Sum of BFs = 1.9** |
| **108-Hs-267** | **Sum of BFs = 0.8** |