TSL Validation using HTR-PROTEUS

John D. Bess (JFA), Volkan Seker (UMich), Olin W. Calvin (INL), Zachary D. Bevans (INL), Spencer C. Ercanbrack (INL), Javier Ortensi (X-energy, formerly INL)

Objective

- Calculation of eigenvalues for HTR-PROTEUS cores using MCNP and various ENDF/B nuclear data libraries
  - -VII.0, -VII.1, -VIII.0, and -VIII.1

- Y-axis is $(C-E)/\sigma$, where C = calculated eigenvalue, E = benchmark experiment eigenvalue, and σ = 1σ uncertainty in benchmark value
  - Ideally, a good calculation falls within 1, 2, or 3σ
  - Using revised HTR-PROTEUS critical configurations

- Look at the results; what stands out?

Target HTR-PROTEUS Values
## (to be submitted to next ICSBEP TRG)

Table 3.55. Experimental and Benchmark Eigenvalues, Biases, and Uncertainties.

Case	Core	Experimental			Bias			Benchmark		
		k_{eff}	±	σ	Δk	±	σ	k_{eff}	±	σ
1	1	1.00000	±	0.00266	0.00495	±	0.00017	1.0049	±	0.0027
2	1A	1.00000	±	0.00267	0.00356	±	0.00019	1.0036	±	0.0027
3	2	1.00000	±	0.00280	0.00317	±	0.00016	1.0032	±	0.0028
4	3	1.00000	±	0.00298	0.00012	±	0.00051	1.0001	±	0.0030
5	4.2	1.00000	±	0.00319	0.00393	±	0.00074	1.0039	±	0.0033
6	4.3	1.00000	±	0.00319	0.00388	±	0.00074	1.0039	±	0.0033
7	5	1.00000	±	0.00282	0.00240	±	0.00013	1.0024	±	0.0028
8	6	1.00000	±	0.00402	0.00155	±	0.00017	1.0015	±	0.0040
9	7	1.00000	±	0.00329	0.00178	±	0.00017	1.0018	±	0.0033
10	8	1.00000	±	0.00288	0.00302	±	0.00013	1.0030	±	0.0029
11	9	1.00000	±	0.00320	0.00303	±	0.00016	1.0030	±	0.0032
12	10	1.00000	±	0.00349	0.00210	±	0.00013	1.0021	±	0.0035

Graphite TSL has a significant impact upon eigenvalue calculation.

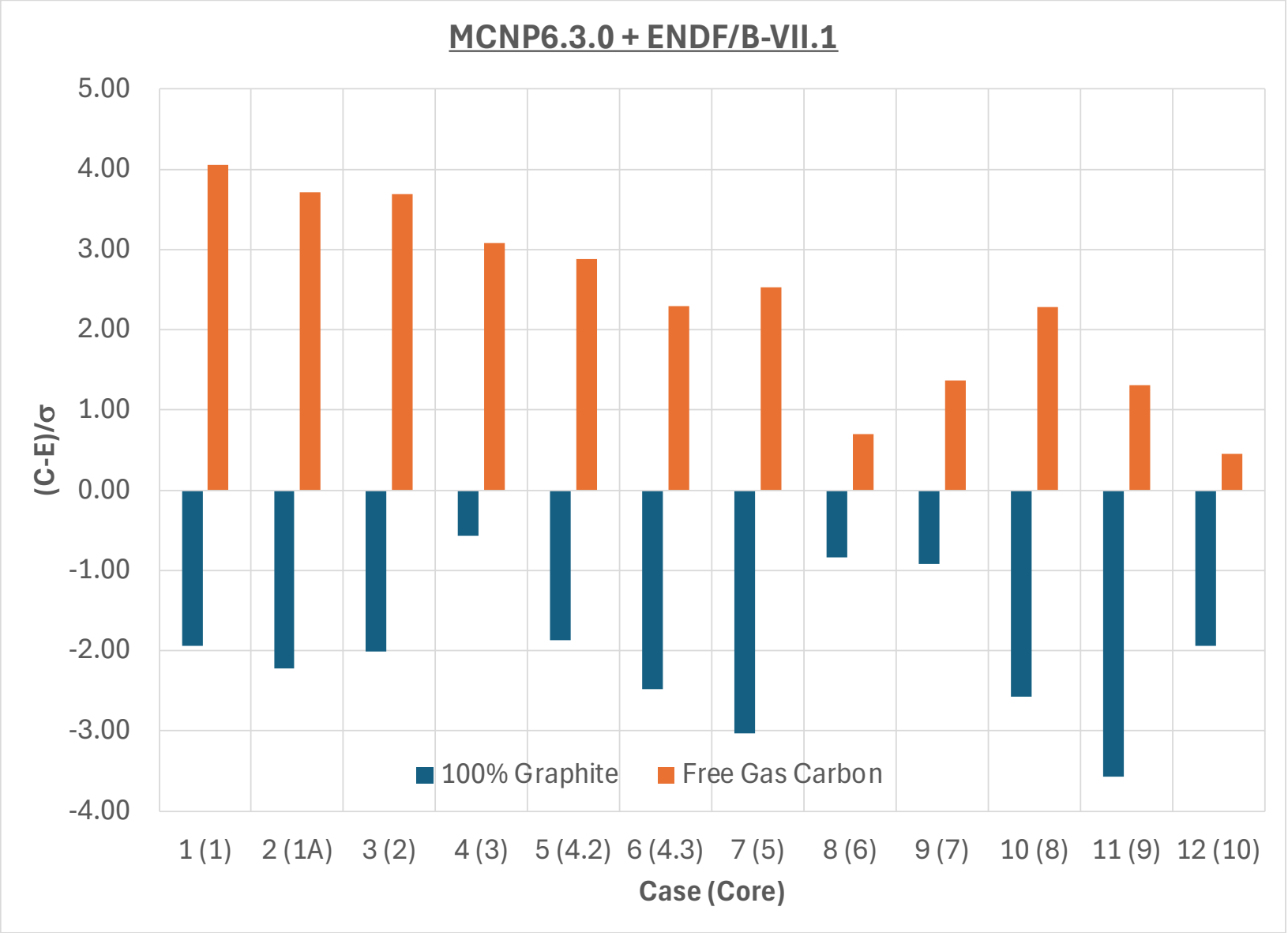As-expected, it is less pronounced in "water ingress" cores: 3, 6, 7, and 10.

Most 100% graphite TSL results within 3σ

MCNP6.3.0 + ENDF/B-VII.0
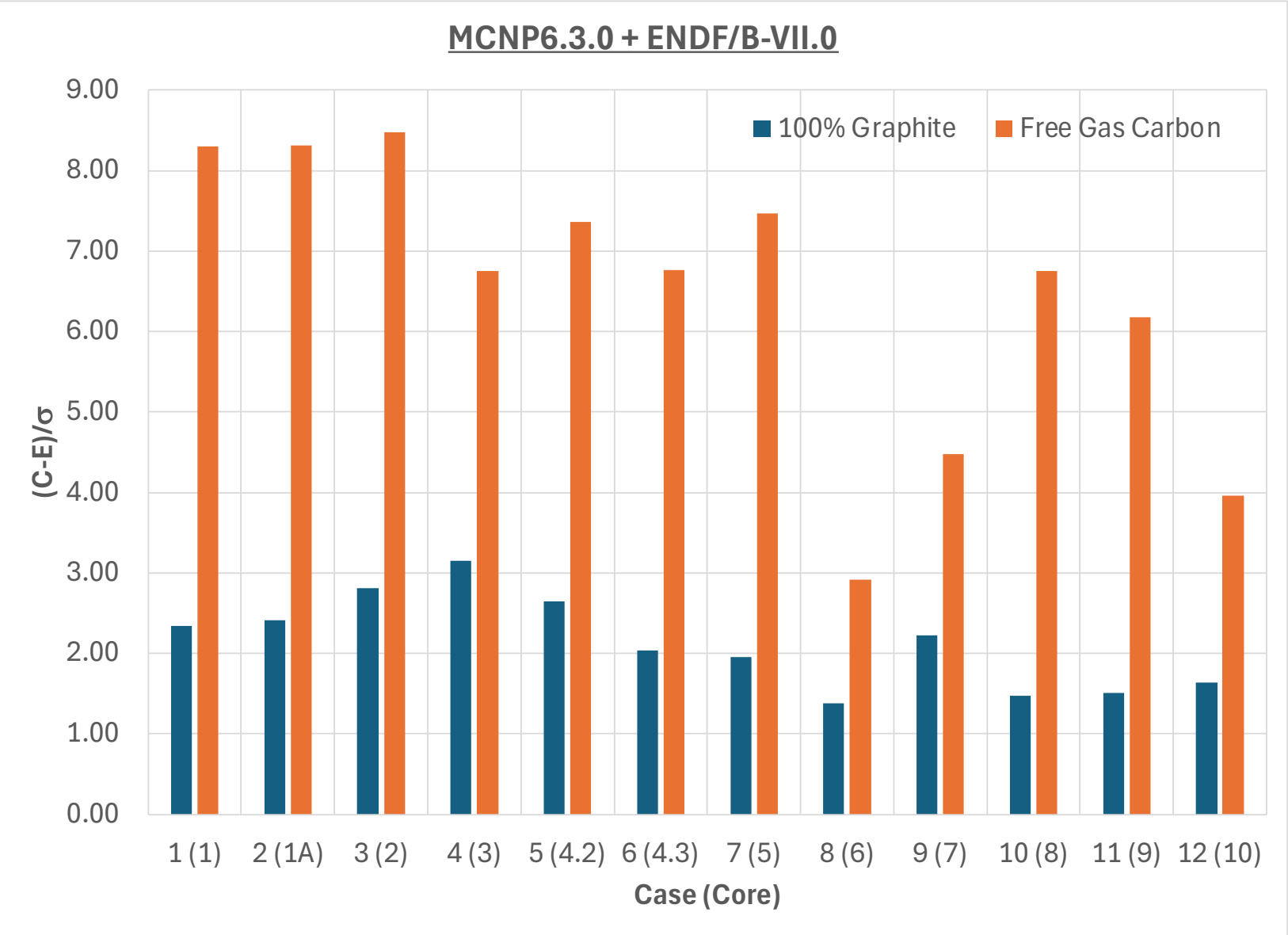
TSL impact about the same.

The drop in eigenvalue is due to the increase in carbon absorption cross section

Most 100% graphite TSL results within 3σ

MCNP6.3.0 + ENDF/B-VII.1

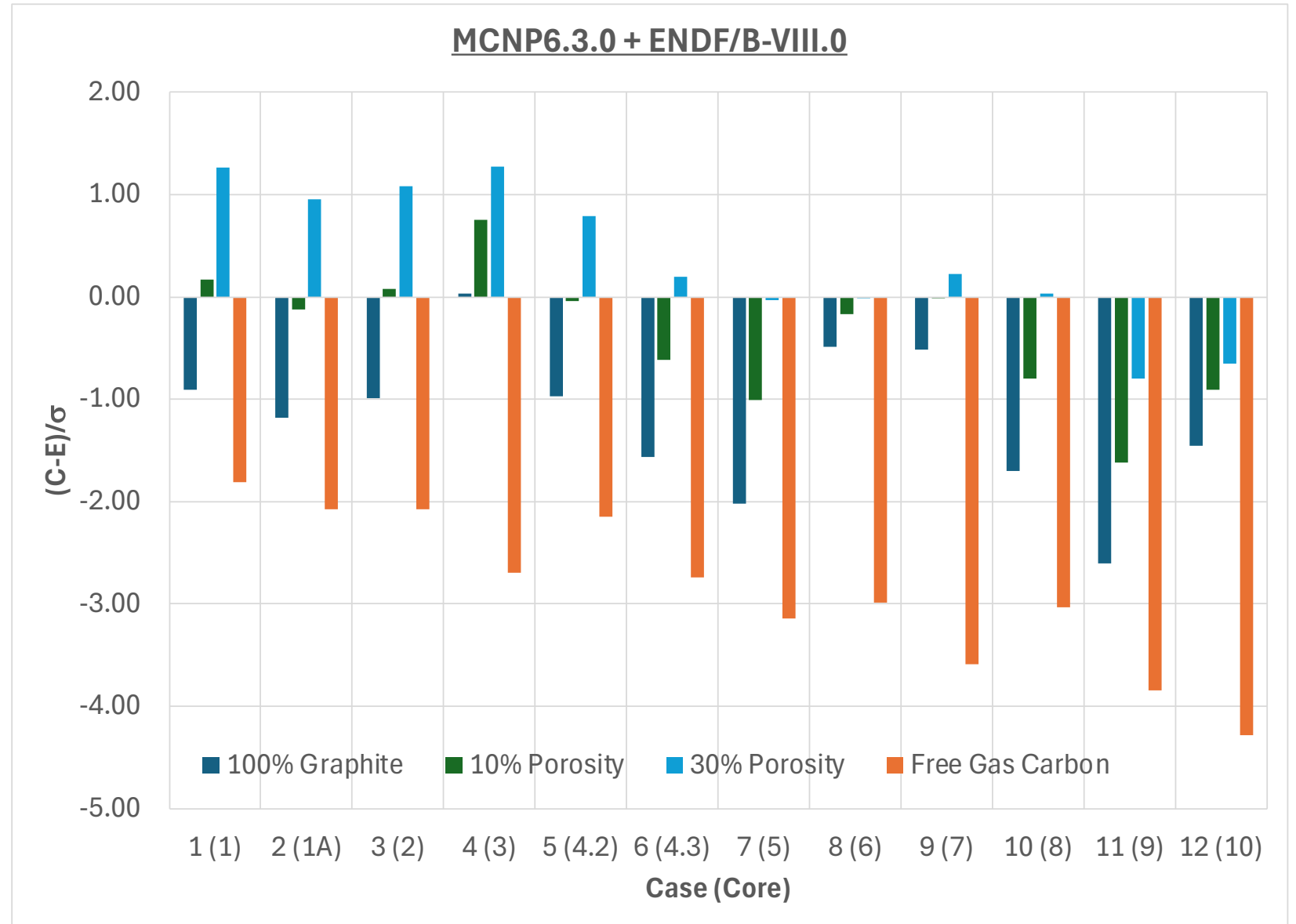(C-E)/σ

■ 100% Graphite   ■ Free Gas Carbon

Case (Core)

Something isn't right with the free gas treatment of carbon

The porosity of HTR-PROTEUS graphite is ~25%

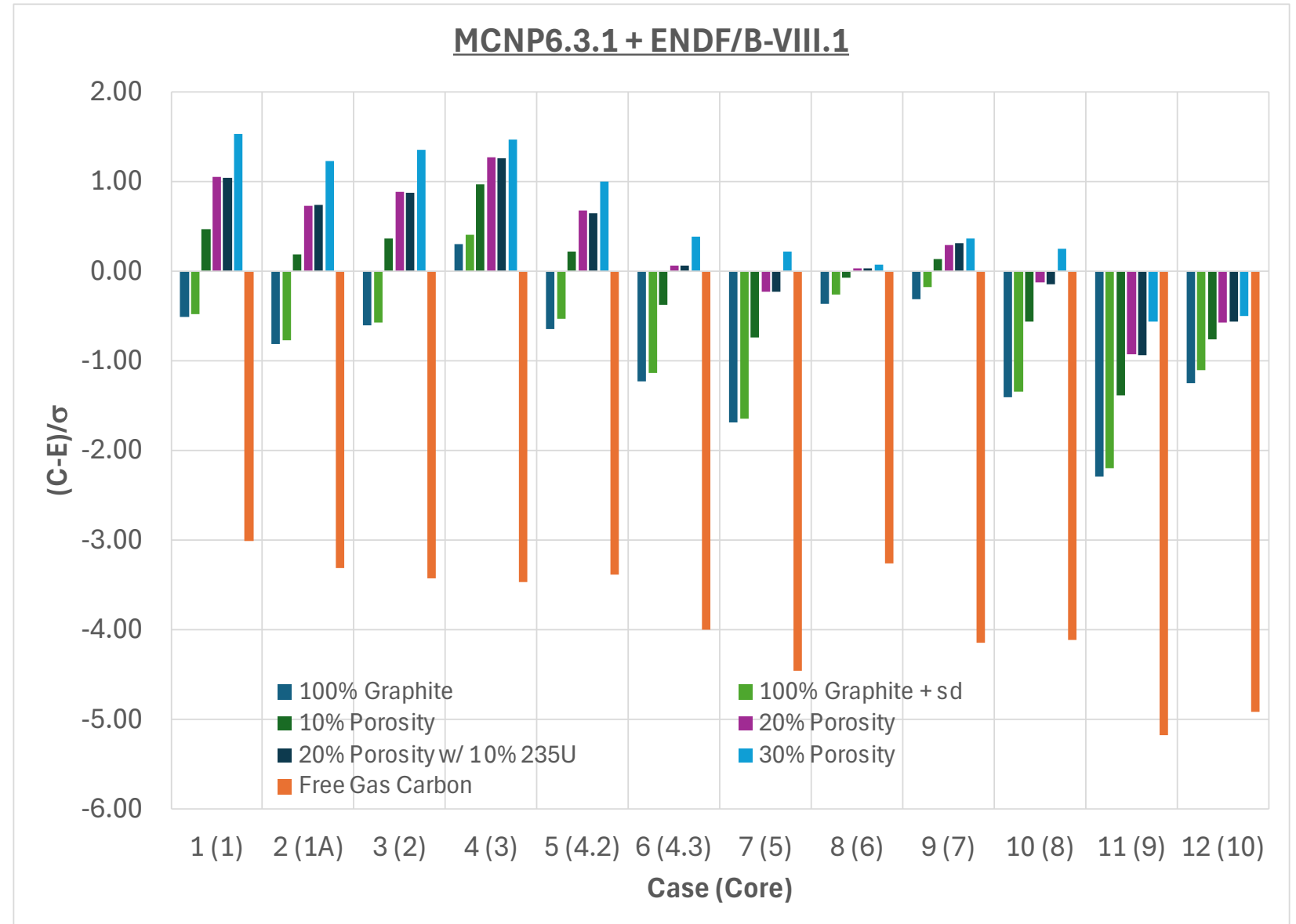Less spread in "water ingress" cores

Most TSL results within 2σ

MCNP6.3.0 + ENDF/B-VIII.0

Something isn't right with the free gas treatment of carbon

The porosity of HTR-PROTEUS graphite is ~25%, ^{235}U is 16.7%

10% vs. 20% ^{235}U TSL had no real impact

Impact of s_d minor

Most TSL results within 2σ

MCNP6.3.1 + ENDF/B-VIII.1

Legend:
- 100% Graphite
- 10% Porosity
- 20% Porosity w/ 10% 235U
- Free Gas Carbon
- 100% Graphite + sd
- 20% Porosity
- 30% Porosity

Y-axis: (C-E)/σ
X-axis: Case (Core)

Cases: 1 (1), 2 (1A), 3 (2), 4 (3), 5 (4.2), 6 (4.3), 7 (5), 8 (6), 9 (7), 10 (8), 11 (9), 12 (10)

Improvement of 100% graphite TSL with ENDF/B library evolution

Most 100% graphite TSL results within 3σ

Comparison of 100% Graphite TSLs

Legend: ENDF/B-VII.0, ENDF/B-VII.1, ENDF/B-VIII.0, ENDF/B-VIII.1, ENDF/B-VIII.1 + sd

y-axis: (C-E)/σ, from -4.00 to 4.00

x-axis: Case (Core) — 1 (1), 2 (1A), 3 (2), 4 (3), 5 (4.2), 6 (4.3), 7 (5), 8 (6), 9 (7), 10 (8), 11 (9), 12 (10)