Using LLNL Pulsed Spheres for Nuclear Data Validation

Denise Neudecker (LANL), Oscar Cabellos (UPM)

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Thanks for discussions with: R. Capote, M. White, A. Trkov, A. Clark, W. Haeck, M. Herman, S. Frankle

LA-UR-20-23490

Aim of this work: Understand which nuclear-data observables can be validated with pulsed spheres

This is studied by:

- Simulating and comparing to 75 LLNL pulsed-sphere neutron-leakage spectra for 20 different materials using ENDF/B-VII.1 and ENDF/B-VIII.0 and MCNP input decks by S. Frankle
- Oscar calculated sensitivity profiles for 17 spheres with FRENDY, SANDY and MCSEN (neutron-leakage spectra with respect to several nuclear-data observables)

75 pulsed spheres enable studying light elements, structural materials and actinides separately

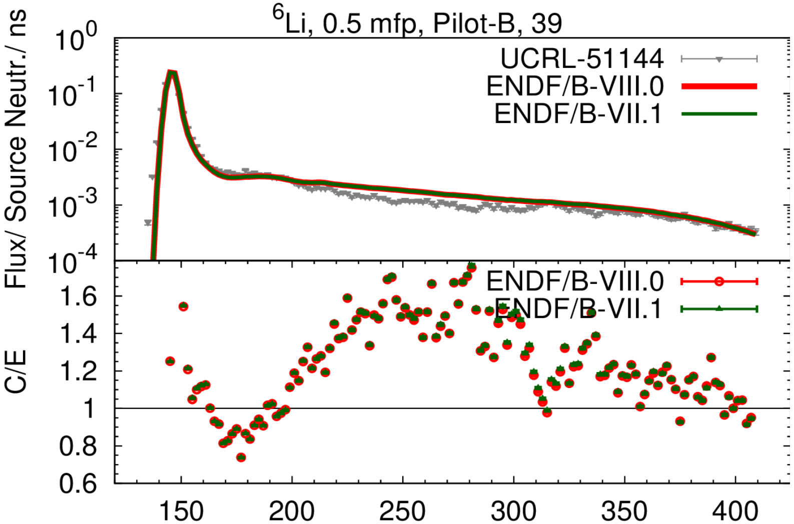
Core	Validates	# of Exp.	Core	Validates	# of Exp
Light water	^{1}H, ^{16}O	6	Teflon	^{19}F, ^{12}C	3
Heavy Water	^{2}H, ^{16}O	2	Magnesium	$^{24,25}Mg$	3
^{6}Li	^{6}Li	5	^{27}Al	^{27}Al	2
^{7}Li	^{7}Li	5	Titanium	^{48}Ti	2
^{9}Be	^{9}Be	6	Iron	^{56}Fe	6
Polyethylene	^{1}H, ^{12}C	3	Lead	$^{206-208}Pb$	2
Carbon	^{12}C	4	Tungsten	$^{182-184,186}W$	2 (0 ok)
^{14}N	^{14}N	3 (2 ok)	^{235}U	^{235}U	7
^{16}O	^{16}O	2 (1 ok)	^{238}U	^{238}U	5
Concrete	^{1}H, ^{16}O, ^{28}Si (very little)	4	^{239}Pu	^{239}Pu	3

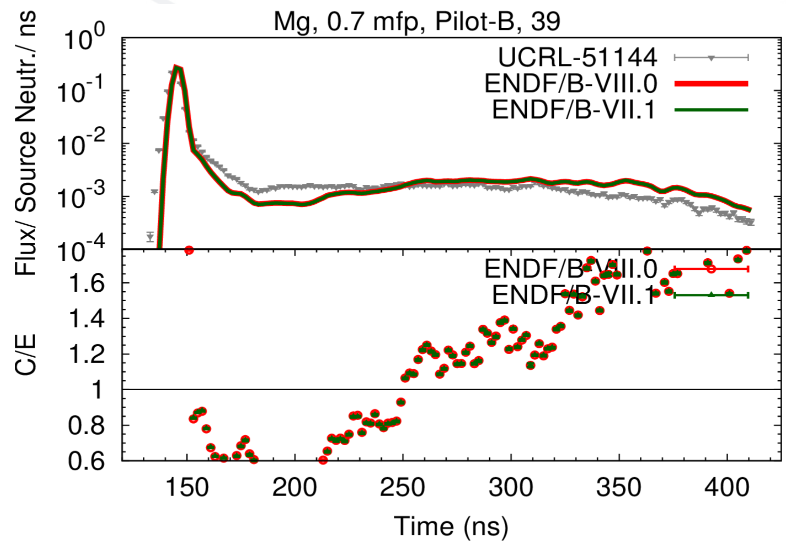
S. Frankle provided MCNP input decks for these benchmarks, LA-UR-05-5879 (2005).

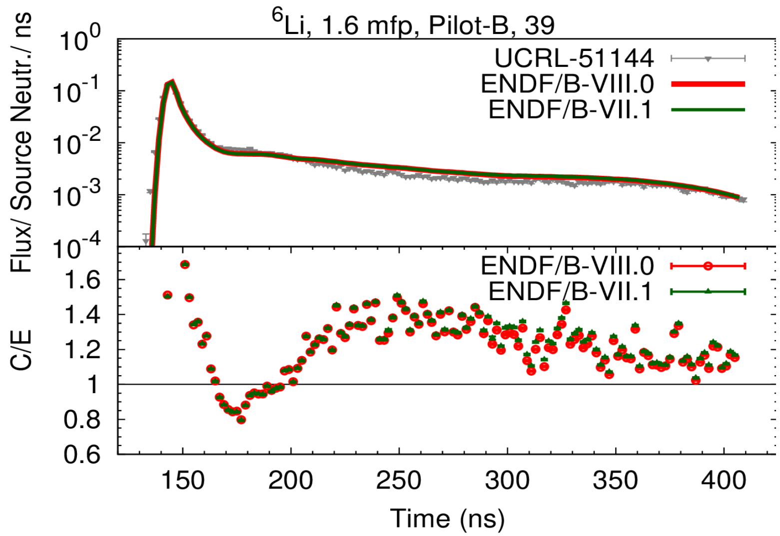
75 pulsed spheres enable studying light elements, structural materials and actinides separately

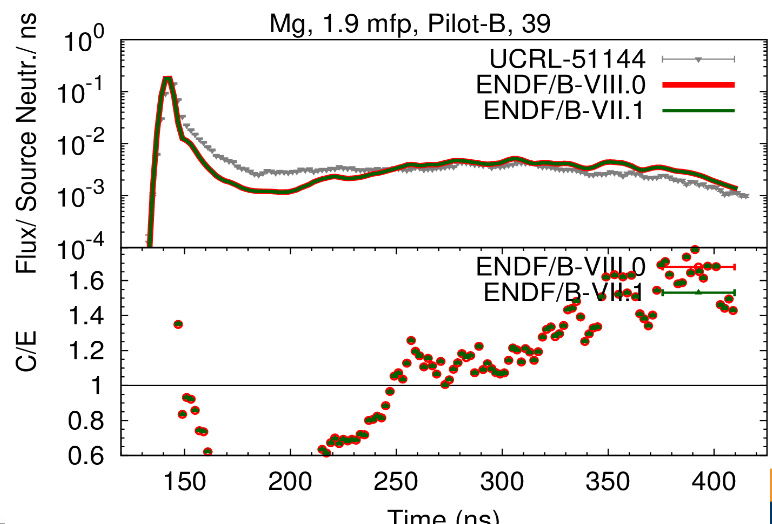
Core	Validates	C/E ok?	Core	Validates	C/E ok?
Light water	^{1}H, ^{16}O	Ok-good	Teflon	^{19}F, ^{12}C	fair
Heavy Water	^{2}H, ^{16}O	Ok-good	Magnesium	^{24,25}Mg	Bad (exp?)
^{6}Li	^{6}Li	bad	^{27}Al	^{27}Al	fair
^{7}Li	^{7}Li	good	Titanium	^{48}Ti	Fair-to-bad
^{9}Be	^{9}Be	good	Iron	^{56}Fe	fair
Polyethylene	^{1}H, ^{12}C	good	Lead	$^{206-208}$Pb	fair
Carbon	^{12}C	bad	Tungsten	$^{182-184,186}$W	Bad (exp.)
^{14}N	^{14}N	good	^{235}U	^{235}U	good
^{16}O	^{16}O	bad	^{238}U	^{238}U	good
Concrete	^{1}H, ^{16}O, ^{28}Si (very little)	fair	^{239}Pu	^{239}Pu	good

^{6}Li: minimal change from VII.1 to VIII.0
Magnesium: no change from VII.1 to VIII.0, exp ok?

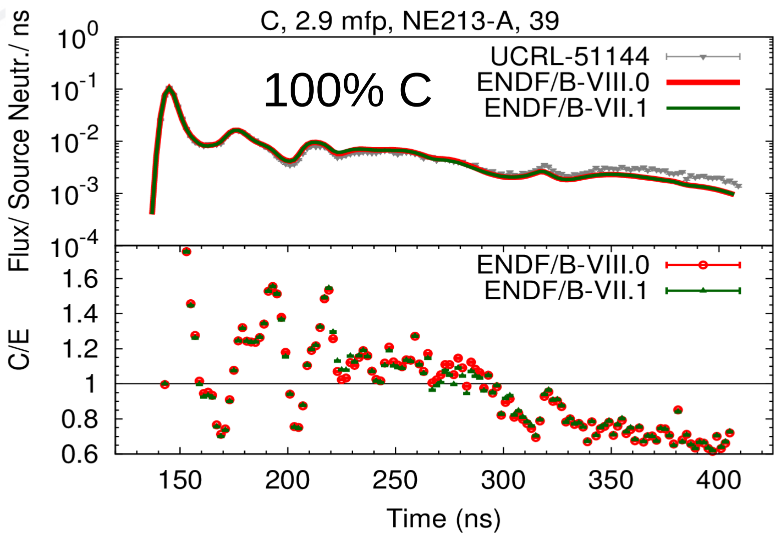


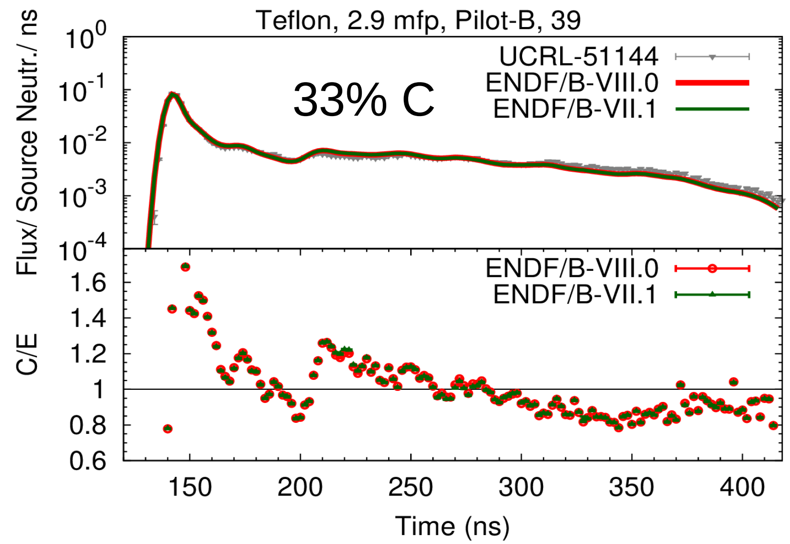


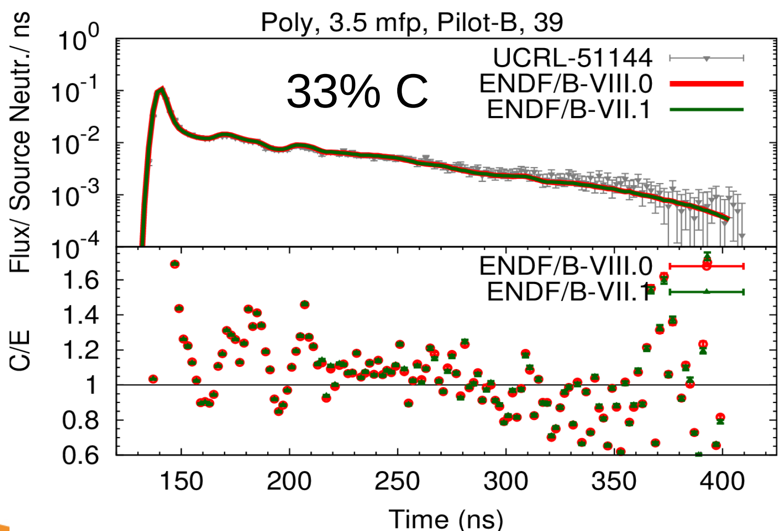


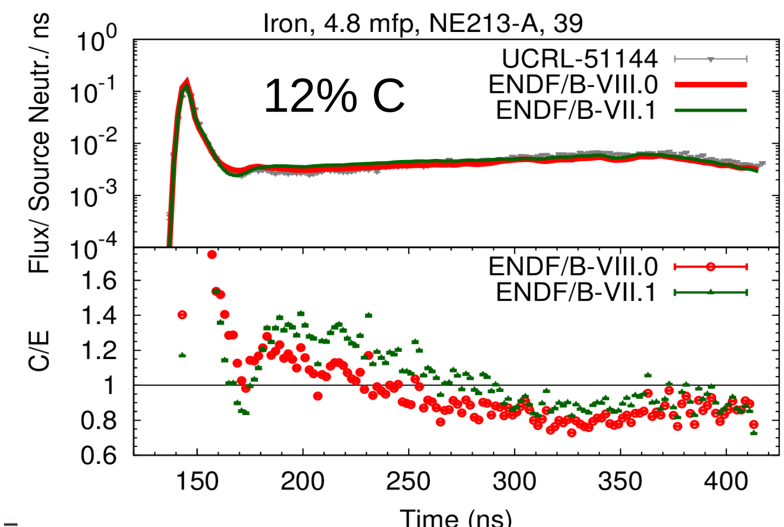


Carbon: small changes from VII.1 to VIII.0, structures can be observed in many spheres with C

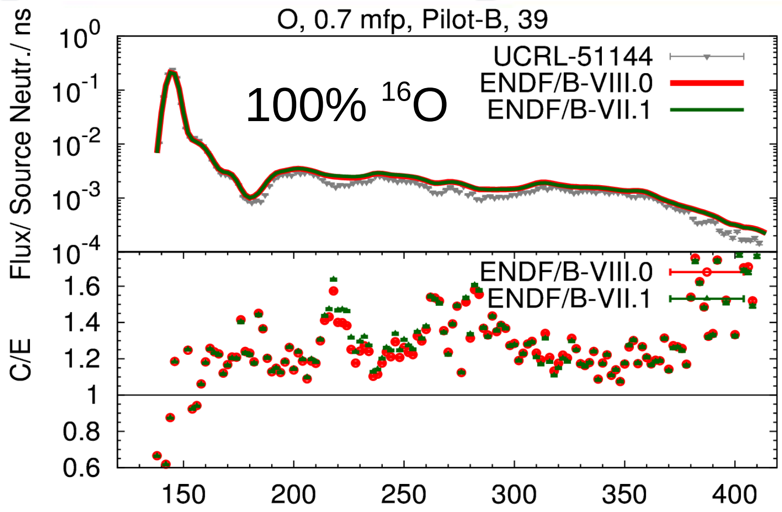


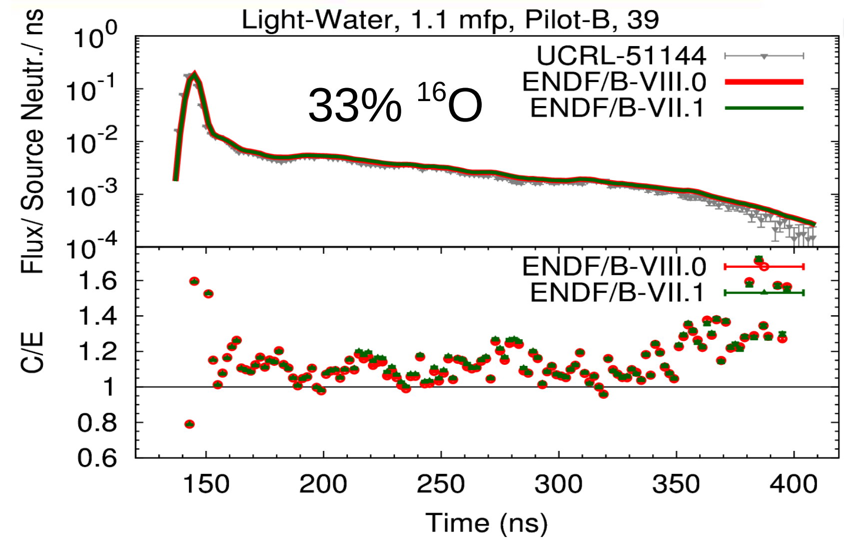


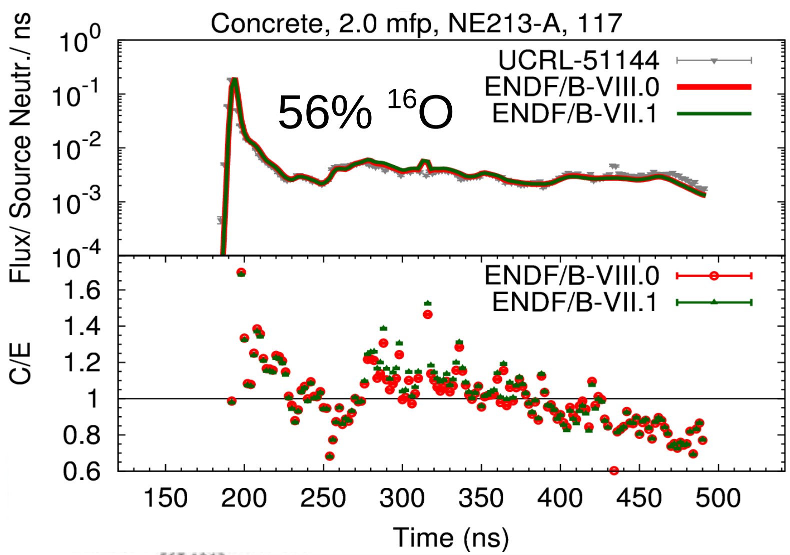


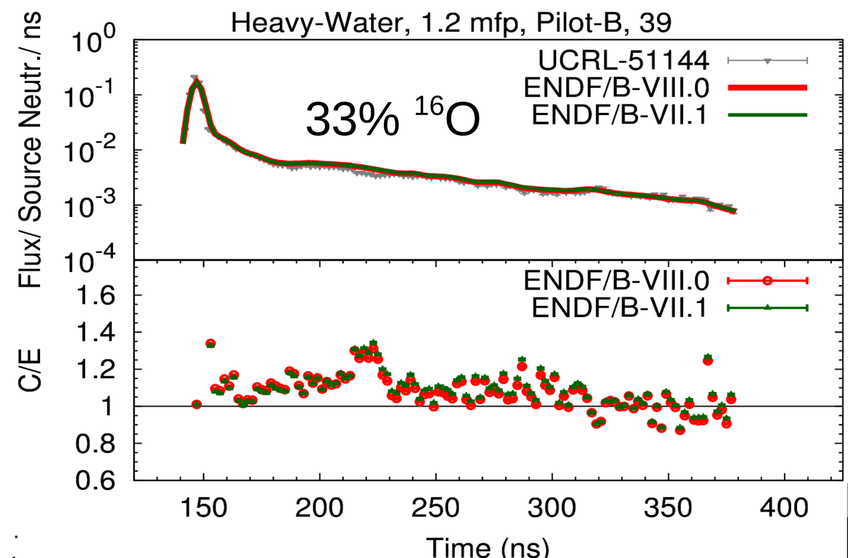


^{16}O: small improvements from VII.1 to VIII.0, structures can be observed spheres with ^{16}O







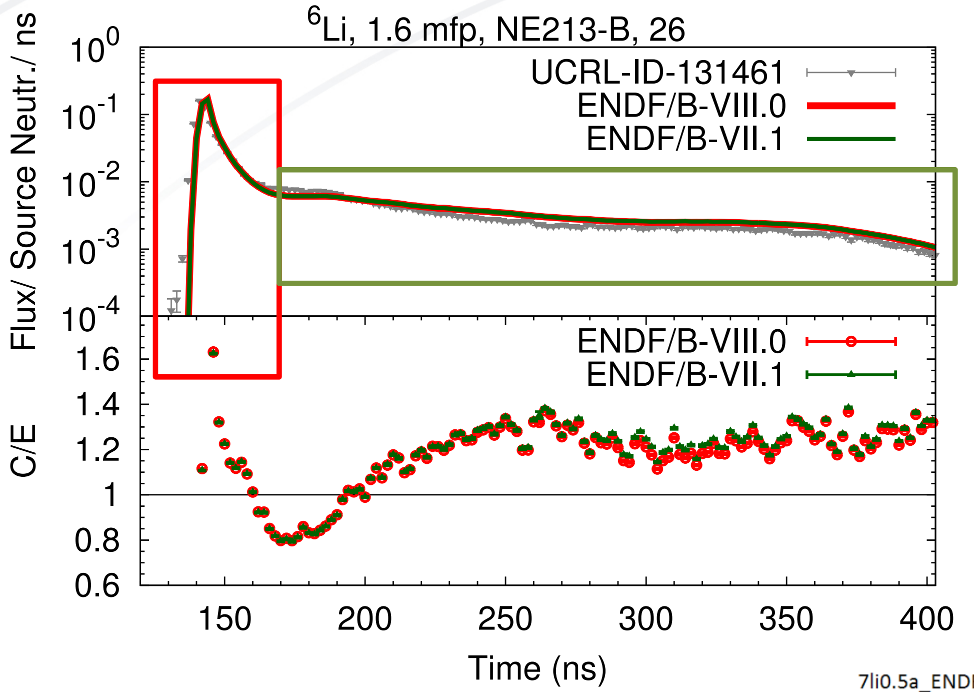


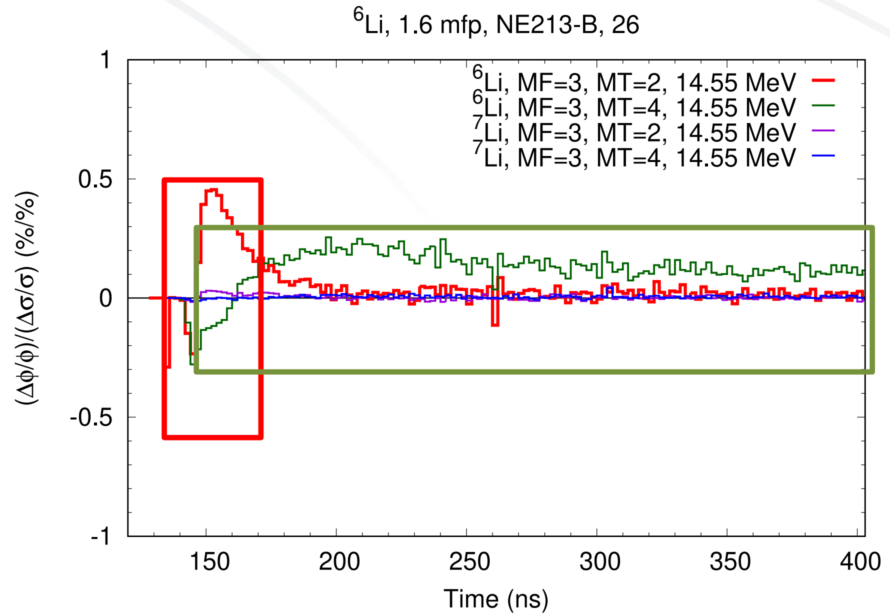
Pulsed spheres are sensitive to MF=1 (MT=452), 3 (2,4,16,18,51,91), 4 (2,51), 5 (18), 6 (4,91), etc.

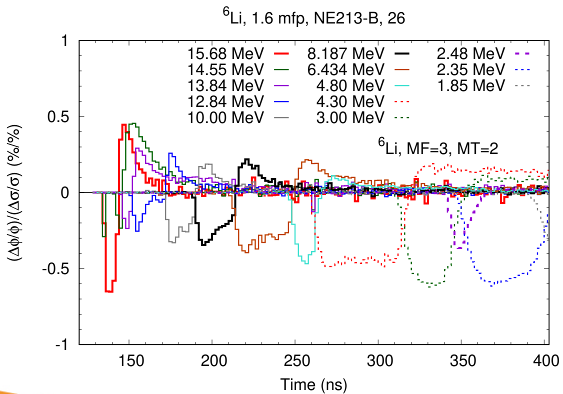
Core	Validates	Sensit. to MT	Core	Validates	Sensit. to MT
Light wtr.	^{1}H, ^{16}O	2, 4 (^{16}O)	Teflon	^{19}F, ^{12}C	2, 4, 51 (^{12}C)
Heavy wtr.	^{2}H, ^{16}O	2, 4(^{16}O),16(^{2}H)	Magnesium	^{24,25}Mg	2 & 4(^{24}Mg), 91
^{6}Li	^{6}Li	2, 4, 51	^{27}Al	^{27}Al	2, 4, 91
^{7}Li	^{7}Li	2, 4, 51	Titanium	^{48}Ti	2, 4, 91
Poly.	^{1}H, ^{12}C	2, 4 & 51 (^{12}C)	Iron	^{56}Fe	2, 4, 16, 51, 91
Carbon	^{12}C	2, 4, 51, 91	Lead	$^{206-208}$Pb	2, 4, 16, 91
^{16}O	^{16}O	2, 4, 91	^{235}U	^{235}U	2, 4, 18, 91, 452
Concrete	^{1}H, ^{16}O, ^{28}Si	2, 4 (^{16}O, ^{28}Si)	^{238}U	^{238}U	2, 4, 18, 91, 452
			^{239}Pu	^{239}Pu	2, 4, 18, 91, 452

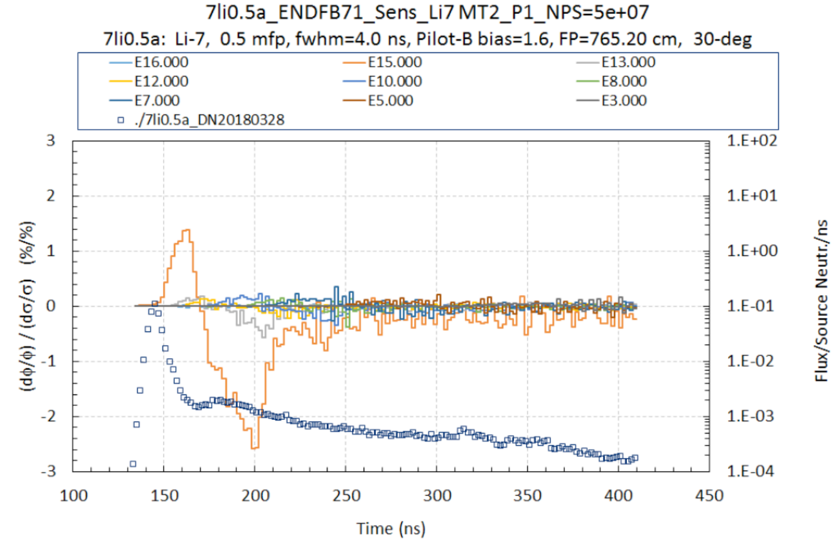
2 ... elastic, 4 … combined inelastic, 16 … (n,2n), 18 … (n,f), 51… first inelastic level, 91 … continuum inelastic, 452 … total nu-bar

Light elements are sensitive to MF=3, MT=2,4,51 and MF=4, MT=2,41, in some cases MF=6, MT=91

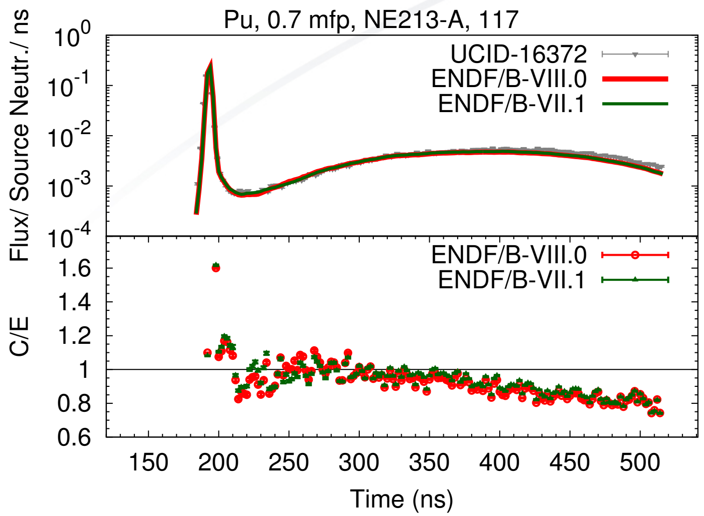


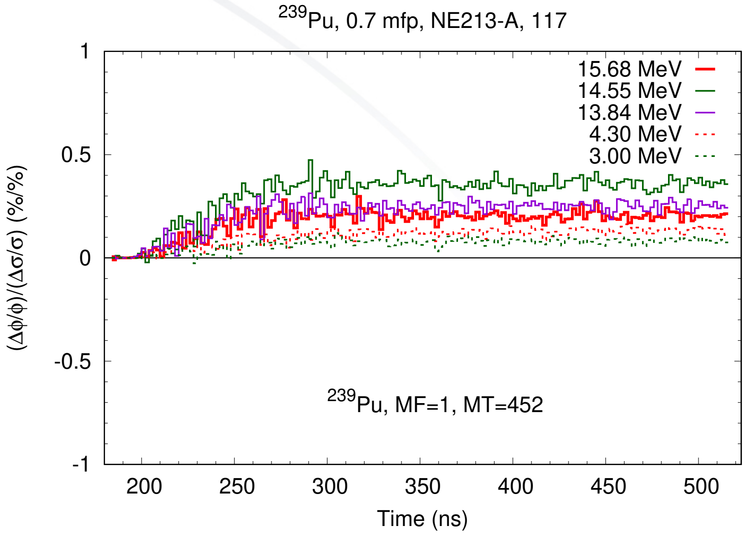


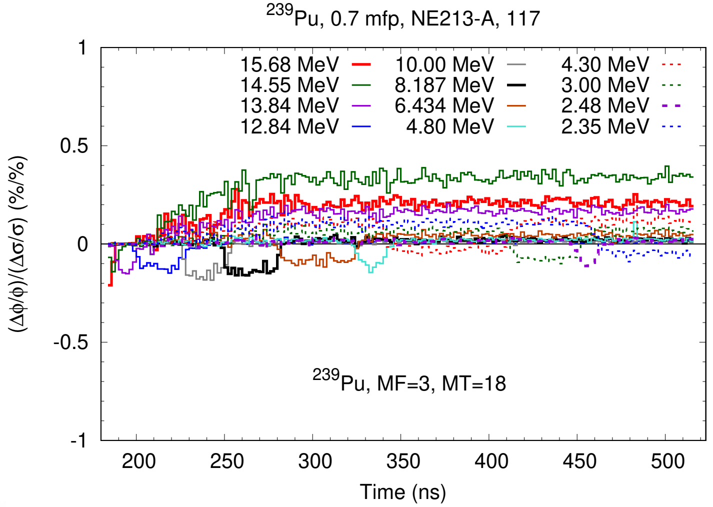


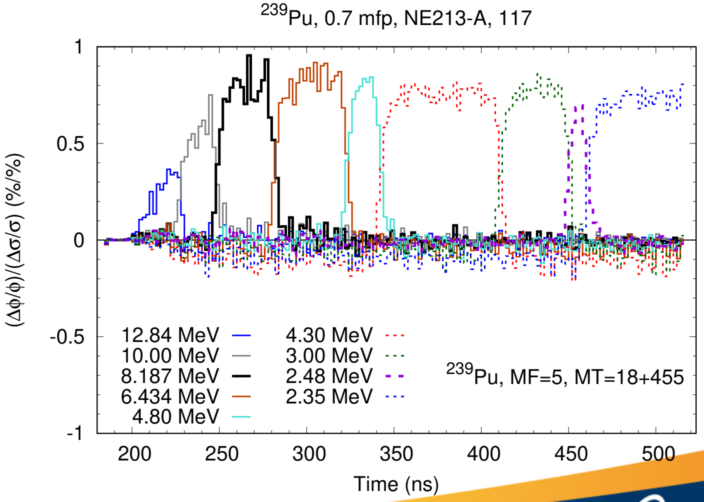


Actinides are very sensitive to MF=3 &5, MT=18 and MF=1, MT=452









LLNL pulsed spheres allow us to validate nuclear data beyond criticality benchmarks

- LLNL pulsed spheres allow us to validate nuclear data of light elements and structural materials independently from fuels and at higher incident neutron energies
- They are mostly sensitive to elastic and inelastic scattering & fission source term observables for actinides, mostly at 13-15 MeV, but multiple scatters do happen in thicker spheres.

- VIII.0 performs well: ^{1,2}H, ^{7}Li, ^{9}Be, ^{14}N, ^{235,238}U, ^{239}Pu
- Inconclusive: ^{14}F, ^{28}Si, ^{56}Fe
- **Could be better: ^{6}Li, ^{12}C, ^{16}O, ^{24,25}Mg, ^{27}Al, ^{48}Ti, $^{206-208}$Pb**

Thank you for your attention!