Fast Criticality Benchmark Testing of ENDF/B-VIII.1 beta2

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AWE

Validation Session
CSEWG
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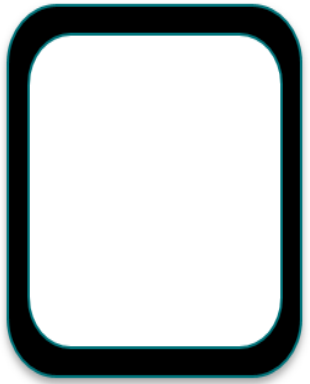
First Do No Harm



Data and Processing

- 3 Datasets
  - beta2 tag, commit b8fdd619
  - beta1.1 tag, commit 4852090a
  - beta1.0 tag, commit 9611a574
  - ENDF/B-VIII.0 taken from NNDC website.
- Processing with NJOY
  - B/VIII.0 and beta1 processed with NJOY2016.67, commit 1cb7237.
    - Reprocessed ENDF/B-VIII.0 from scratch to eliminate differences in processing.
  - Beta2 processed with NJOY2016.72, commit 8964054
  - Groupwise, GROUPR, 460 groups.
  - Pointwise, ACER

Benchmark tests

- 143 ICSBEP cases.
  - Pu, HEU, Mixed and U233 cores.
  - 20 different reflectors.
  - 1D Deterministic Sn transport and MCNP Monte Carlo Transport calculations.
- LLNL Pulsed Spheres.
  - AWE first real use for data testing.

Benchmark	Reflector	Benchmark	Reflector	Benchmark	Reflector
HMF01	Bare	HMF32 (a-d)	Natural Uranium	PMF11	Water
HMF02	Natural Uranium	HMF41 (a-b)	Beryllium	PMF18	Beryllium
HMF03 (a-g)	Natural Uranium	HMF41 (c-f)	Graphite	PMF19	Beryllium
HMF03 (h-k)	Tungsten	HMF44 (a-e)	Aluminium	PMF20	Depleted Uranium
HMF03 (l)	Nickel	HMF57 (a-b)	Lead	PMF21 (a)	Beryllium
HMF04	Water	HMF63 (a-b)	Lithium Duteride	PMF21(b)	Beryllium Oxide
HMF08	Bare	HMF66 (a-i)	Beryllium	PMF22	Bare
HMF09 (a)	Beryllium	HMF79 (a-e)	Titanium	PMF23	Graphite
HMF09 (b)	Beryllium Oxide	HMF84 (a)	Aluminium	PMF24	Polythene
HMF11	Polythene	HMF84 (m)	Titanium	PMF25	Steel
HMF12	Aluminium	HMF85 (a)	Copper	PMF26	Steel
HMF13	Steel	HMF85 (e)	Thorium	PMF27	Polythene
HMF14	Depleted Uranium	IMF03	None	PMF28	Steel
HMF15	Bare	MMF1	Bare	PMF29	Bare
HMF18	Bare	MMF2	Natural Uranium	PMF30	Carbon
HMF19	Graphite	MMF03	Bare	PMF31	Polythene
HMF20	Polythene	MMF7 (a-w)	Beryllium	PMF32	Steel
HMF21	Steel	PMF01	Bare	PMF41	Depleted Uranium
HMF22	Duralumin	PMF02	Bare	U3MF1	Bare
HMF25 (a-e)	Vanadium	PMF05	Tungsten	U3MF2 (a-b)	Highly Enriched Uranium
HMF27	Lead	PMF06	Natural Uranium	U3MF3 (a-b)	Natural Uranium
HMF28	Natural Uranium	PMF08 (a-b)	Thorium	U3MF4 (a-b)	Tungsten
HMF29	Depleted Uranium	PMF09	Aluminium	U3MF5 (a-b)	Beryllium
HMF31	Polythene	PMF10	Natural Uranium	U3MF6	Natural Uranium

Goodness of Fit parameters

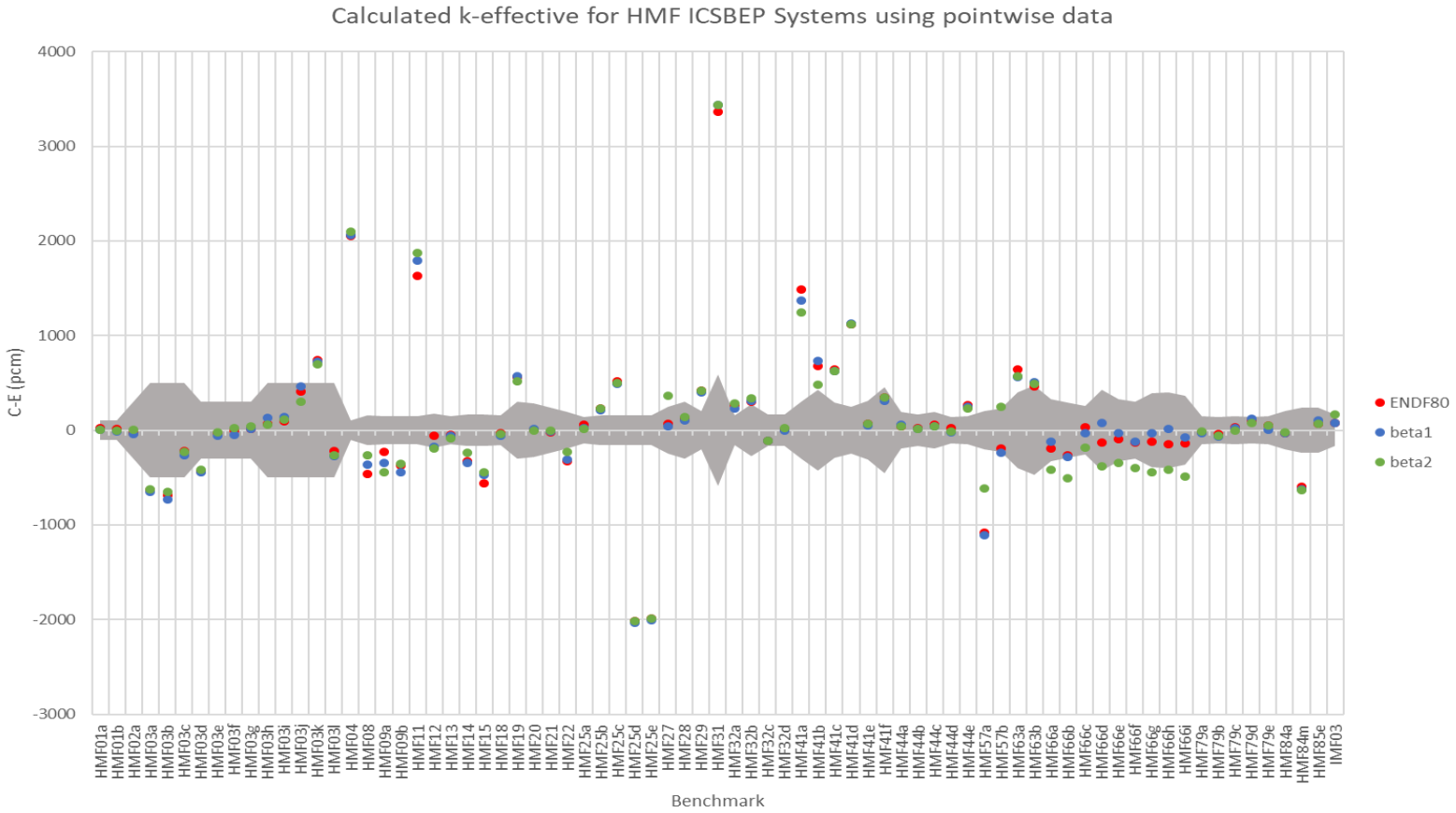
- Chi Squared like parameter

$$\chi^2 = \sum \frac{\left(\left(k_{calc} - k_{exp}\right)/\delta k_{exp}\right)^2}{n}$$

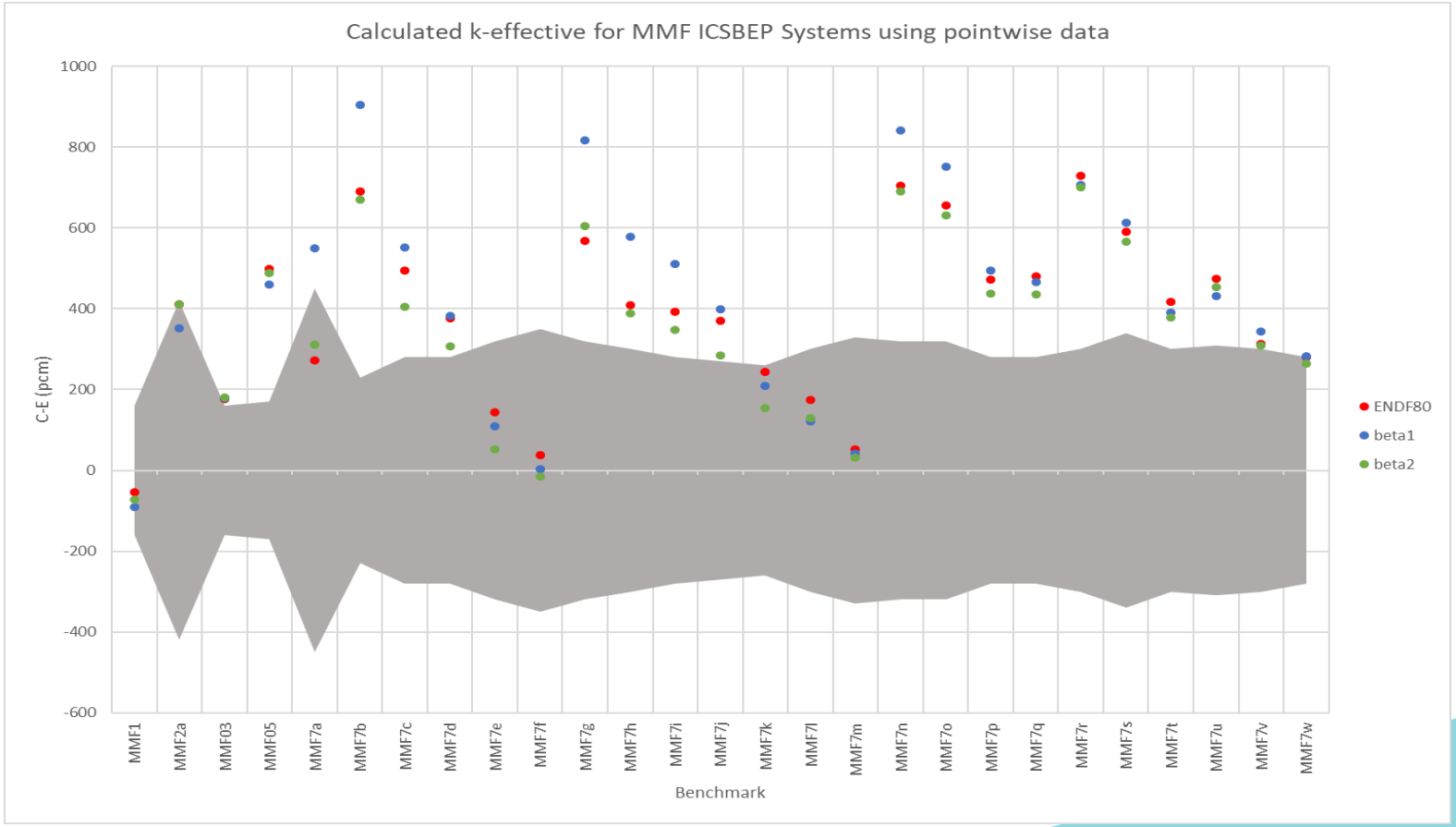
- Average difference between calculation and benchmark values.

$$\langle|\Delta|\rangle = \sum \frac{\left|k_{calc} - k_{exp}\right|}{n}$$

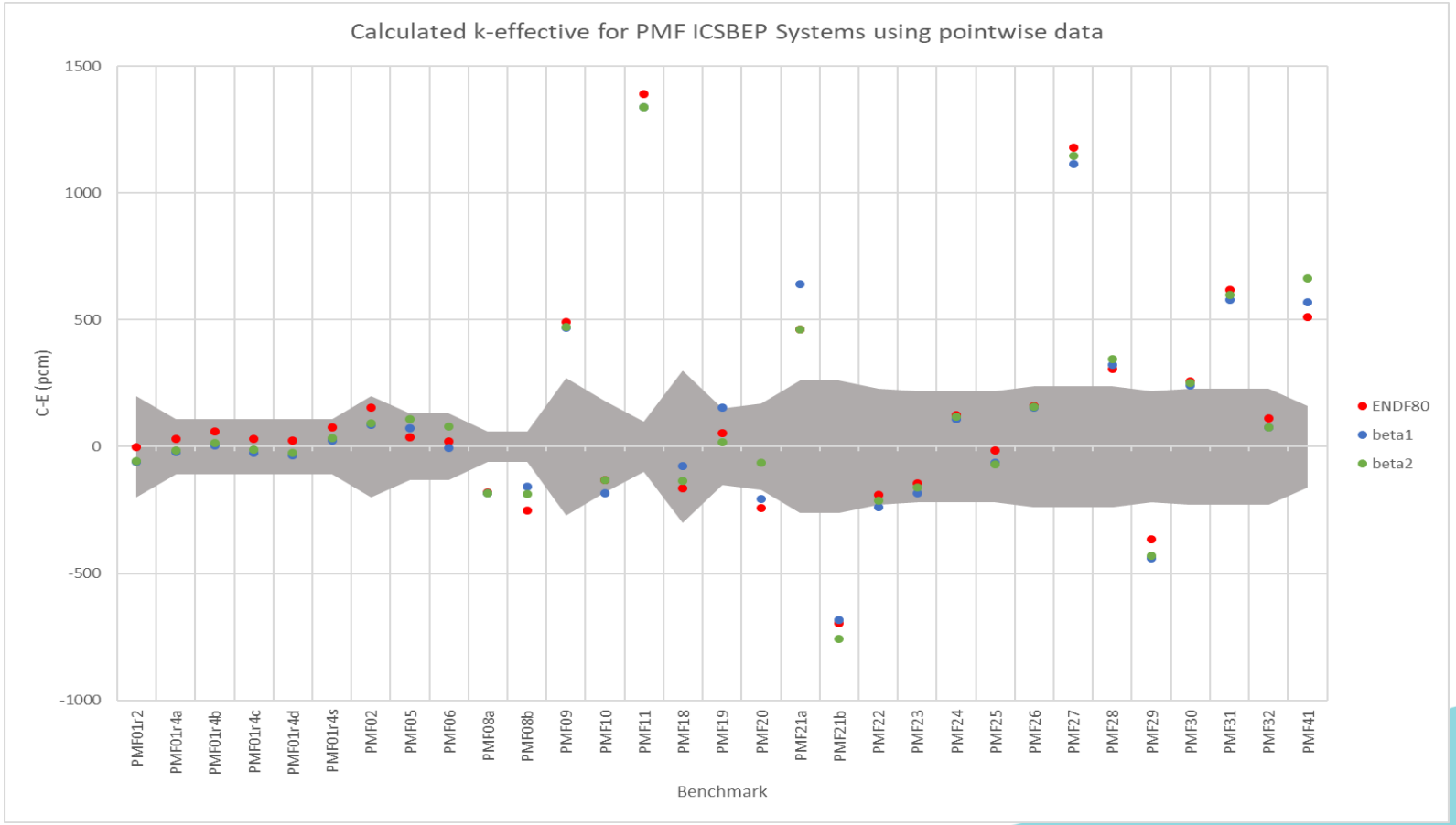
HEU MET FAST


Calculated k-effective for HMF ICSBEP Systems using pointwise data
C-E (pcm)
4000
3000
2000
1000
0
-1000
-2000
-3000
ENDF80
beta1
beta2
Benchmark
HMF01a
HMF01b
HMF02a
HMF03a
HMF03b
HMF03c
HMF03d
HMF03e
HMF03f
HMF03g
HMF03h
HMF03i
HMF03j
HMF03k
HMF03l
HMF04
HMF08
HMF09a
HMF09b
HMF11
HMF12
HMF13
HMF14
HMF15
HMF18
HMF19
HMF20
HMF21
HMF22
HMF25a
HMF25b
HMF25c
HMF25d
HMF25e
HMF27
HMF28
HMF29
HMF31
HMF32a
HMF32b
HMF32c
HMF32d
HMF41a
HMF41b
HMF41c
HMF41d
HMF41e
HMF41f
HMF44a
HMF44b
HMF44c
HMF44d
HMF44e
HMF57a
HMF57b
HMF63a
HMF63b
HMF66a
HMF66b
HMF66c
HMF66d
HMF66e
HMF66f
HMF66g
HMF66h
HMF66i
HMF79a
HMF79b
HMF79c
HMF79d
HMF79e
HMF84a
HMF84m
HMF85e
IMF03

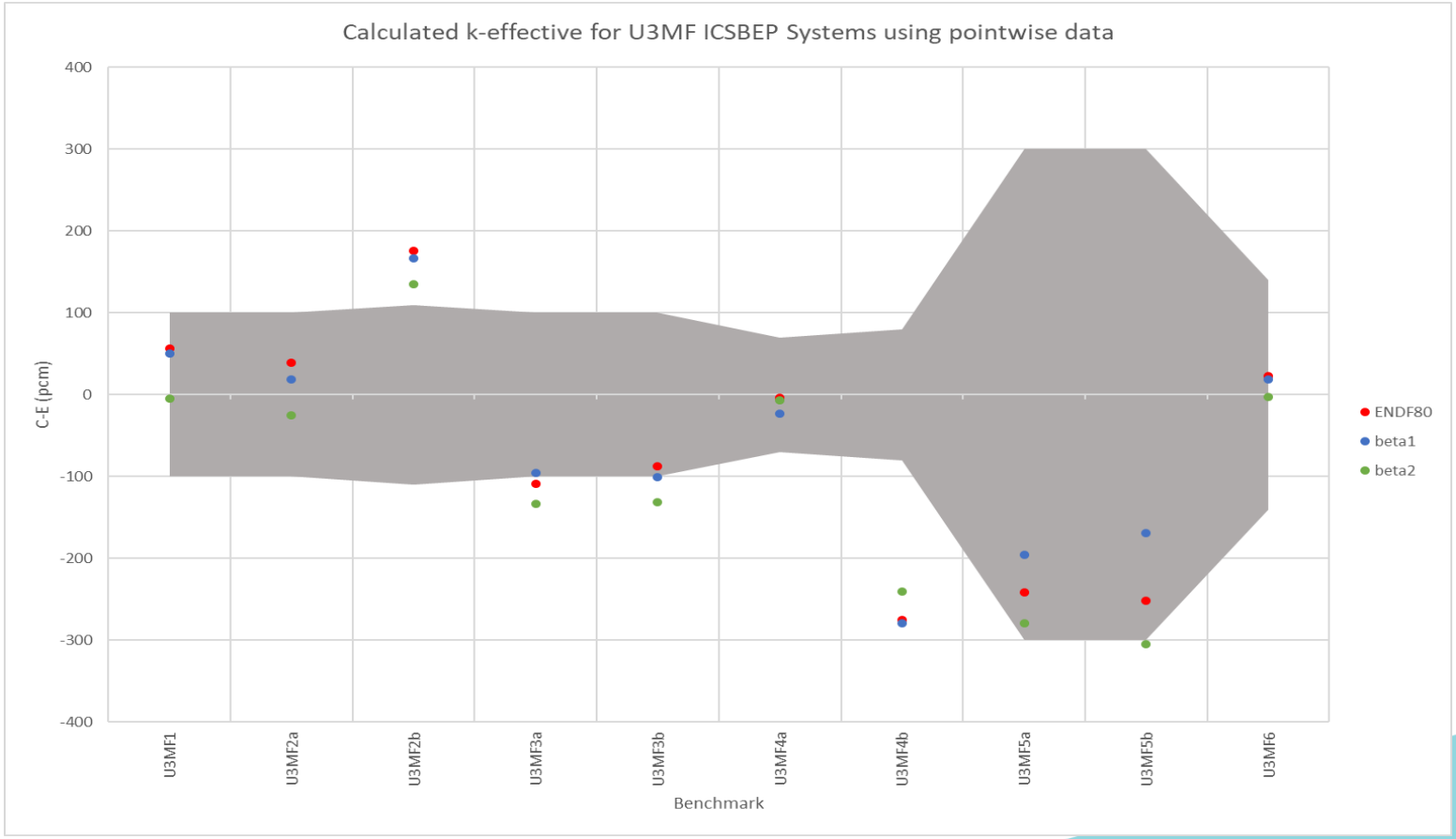
Mixed MET FAST



PU MET FAST


Calculated k-effective for PMF ICSBEP Systems using pointwise data
C-E (pcm)
1500
1000
500
0
-500
-1000
PMF01r2
PMF01r4a
PMF01r4b
PMF01r4c
PMF01r4d
PMF01r4s
PMF02
PMF05
PMF06
PMF08a
PMF08b
PMF09
PMF10
PMF11
PMF18
PMF19
PMF20
PMF21a
PMF21b
PMF22
PMF23
PMF24
PMF25
PMF26
PMF27
PMF28
PMF29
PMF30
PMF31
PMF32
PMF41
Benchmark
ENDF80
beta1
beta2

U233 MET FAST



Average Difference

	Pointwise			Groupwise		
	ENDF80	beta1	beta2	ENDF80	beta1	beta2
ALL	348	355	353	408	434	425
HMF	393	394	415	410	422	456
MMF	388	429	360	319	388	292
PMF	274	275	272	765	787	799
U3MF	126	112	126	160	144	149
ALL						
None	137	126	117	127	111	113
Beryllium	360	384	393	317	382	347
Steel	111	114	122	2089	2133	2145
Tungsten	105	125	119	74	95	103
Lead	447	461	410	305	300	388
Highly Enriched Uranium	90	92	78	113	109	81
Natural Uranium	191	198	199	274	275	279
Aluminium	166	169	169	606	647	665
Titanium	140	145	138			
HEU						
None	217	180	151	22	16	17
Beryllium	304	269	478	337	402	487
Steel	36	34	43	2851	2834	2845
Tungsten Carbide	327	362	293	276	250	255
Lead	447	461	410	305	300	388
Natural Uranium	219	231	223	237	237	242
Aluminium	71	85	80			
Lithium Deuteride	549	535	531			
Titanium	140	145	138			
MIX						
None	176	179	180	120	88	78
Beryllium	406	457	373	318	394	288
Aluminium	498	461	489			
Highly Enriched Uranium	55	91	73			
Natural Uranium	411	352	411	544	559	601
PU						
None	103	104	99	238	219	215
Beryllium	227	291	205			
Steel	149	154	162	1899	1958	1970
Tungsten	37	73	110	1	64	104
Depleted Uranium	376	389	364	467	558	615
Natural Uranium	76	95	106	453	465	479
PMF1	37	28	26			
U233						
None	56	50	5	70	65	29
Beryllium	246	182	292	208	144	254
Tungsten	140	151	123	110	111	103
Highly Enriched Uranium	107	93	80	113	109	81
Natural Uranium	73	72	89	223	216	196

“Chi-Squared”

	Pointwise			Groupwise		
	ENDF80	beta1	beta2	ENDF80	beta1	beta2
ALL	9.92	10.08	9.98	8.31	8.63	8.43
HMF	14.23	14.63	14.68	6.50	6.53	6.50
MMF	2.43	3.04	2.18	1.51	2.08	1.31
PMF	9.30	6.82	6.91	30.24	31.29	31.65
U3MF	1.82	1.76	1.60	2.43	2.33	2.03
ALL						
None	1.53	1.18	1.00	1.04	0.74	0.76
Beryllium	2.27	2.77	2.34	1.75	2.25	1.80
Steel	0.41	0.43	0.50	101.64	105.52	106.51
Tungsten	3.97	4.20	3.24	1.78	1.99	1.75
Lead	10.00	10.57	4.25	4.35	4.51	3.07
Highly Enriched Uranium	0.94	0.89	0.59	1.50	1.43	0.75
Natural Uranium	0.73	0.74	0.85	2.98	2.78	2.75
Aluminium	1.70	1.58	1.67	5.03	5.75	6.07
Titanium	1.17	1.31	1.24			
HEU						
None	3.86	2.56	1.92	0.06	0.03	0.04
Beryllium	2.61	2.53	3.35	2.40	2.79	2.79
Steel	0.05	0.07	0.15	141.16	139.46	140.49
Tungsten Carbide	0.73	0.77	0.60	0.36	0.30	0.31
Lead	10.00	10.57	4.25	4.35	4.51	3.07
Natural Uranium	0.79	0.80	0.83	1.24	1.21	1.32
Aluminium	0.48	0.55	0.53			
Lithium Deuteride	1.75	1.57	1.56			
Titanium	1.17	1.31	1.24			
MIX						
None	1.21	1.25	1.27	0.56	0.30	0.24
Beryllium	2.38	3.15	2.09	1.55	2.17	1.32
Aluminium	8.58	7.35	8.27			
Highly Enriched Uranium	0.12	0.32	0.21			
Natural Uranium	0.96	0.70	0.96	1.68	1.77	2.04
PU						
None	0.55	0.62	0.57	2.26	1.64	1.55
Beryllium	1.19	2.39	1.13			
Steel	0.58	0.60	0.68	91.77	97.04	98.01
Tungsten	0.08	0.32	0.72	0.00	0.24	0.63
Depleted Uranium	6.08	7.10	8.68	8.53	12.17	14.78
Natural Uranium	0.28	0.52	0.45	12.17	10.77	10.40
PMF1	0.16	0.05	0.04			
U233						
None	0.31	0.25	0.00	1.53	0.79	0.76
Beryllium	0.68	0.37	0.95	2.36	2.37	1.80
Tungsten	5.91	6.14	4.50	3.97	1.99	1.75
Highly Enriched Uranium	1.36	1.17	0.78	0.94	1.05	0.75
Natural Uranium	0.66	0.65	1.16	0.73	2.78	2.75

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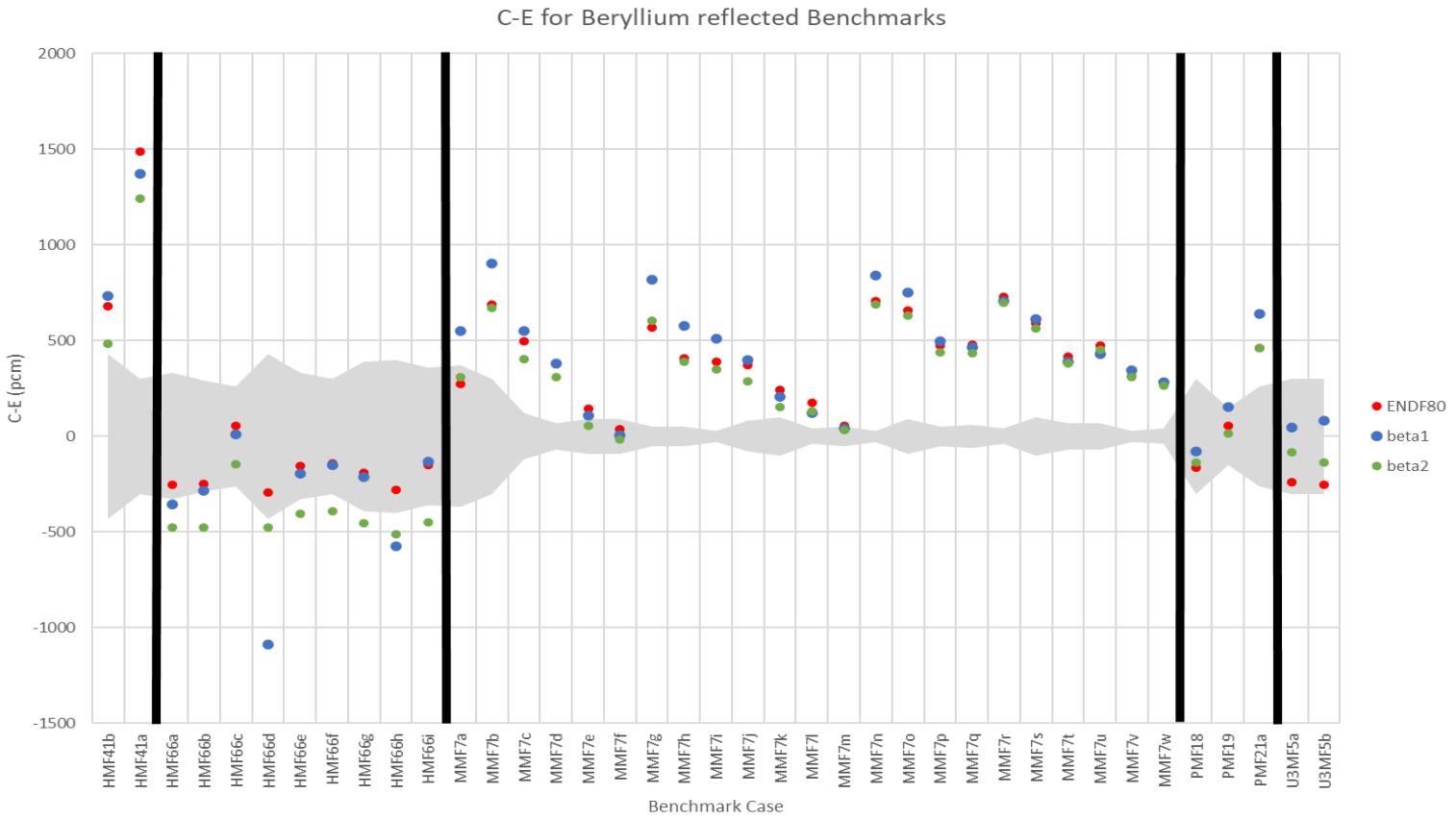
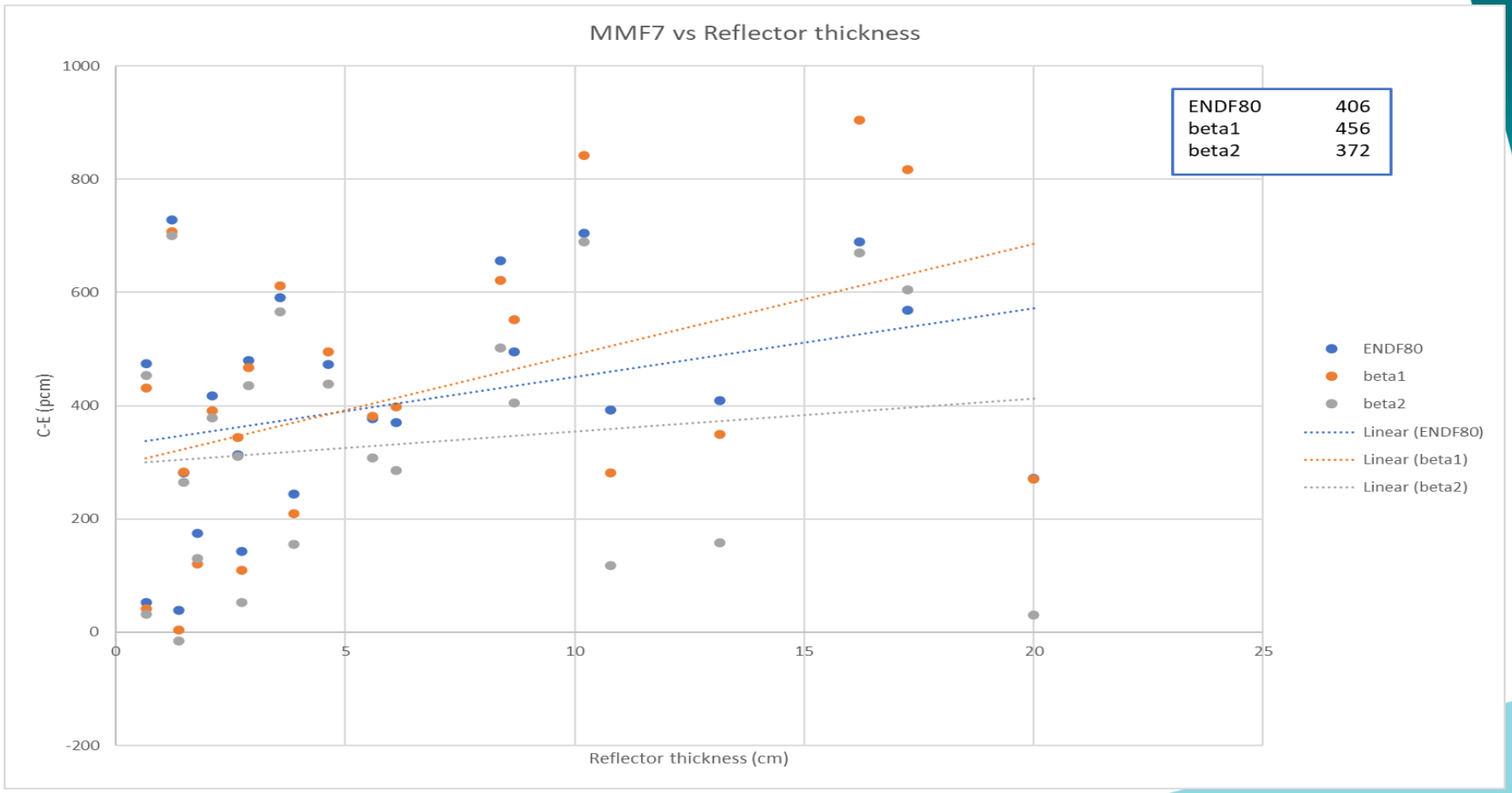
Highly Enriched Uranium	1.36	1.17	0.78	0.94	1.05	0.75
Natural Uranium	0.66	0.65	1.16	0.73	2.78	2.75

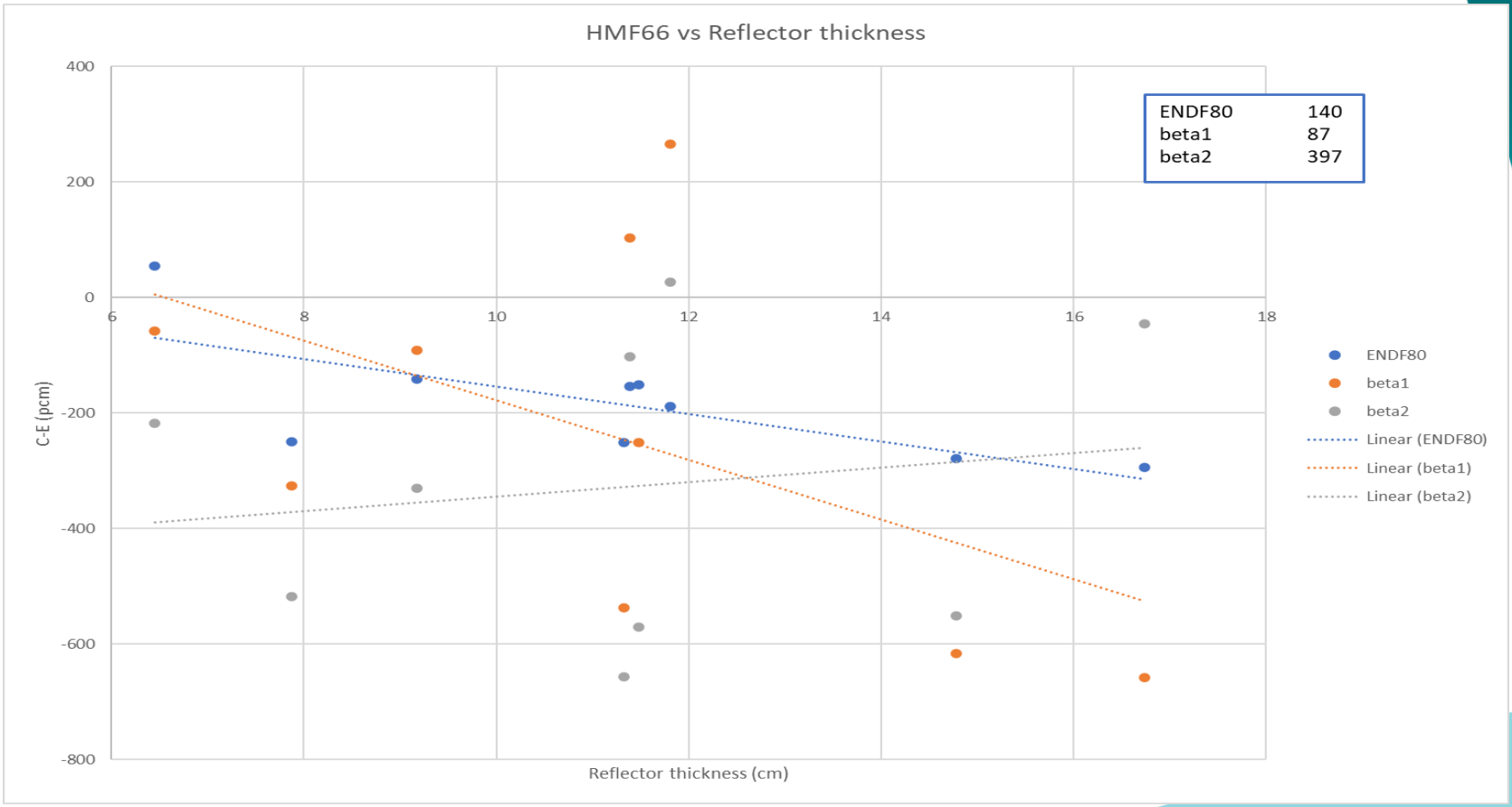
Beryllium


C-E for Beryllium reflected Benchmarks
C-E (pcm)
2000
1500
1000
500
0
-500
-1000
-1500
HMF41b
HMF41a
HMF66a
HMF66b
HMF66c
HMF66d
HMF66e
HMF66f
HMF66g
HMF66h
HMF66i
MMF7a
MMF7b
MMF7c
MMF7d
MMF7e
MMF7f
MMF7g
MMF7h
MMF7i
MMF7j
MMF7k
MMF7l
MMF7m
MMF7n
MMF7o
MMF7p
MMF7q
MMF7r
MMF7s
MMF7t
MMF7u
MMF7v
MMF7w
PMF18
PMF19
PMF21a
U3MF5a
U3MF5b
Benchmark Case
ENDF80
beta1
beta2

MMF7


MMF7 vs Reflector thickness
1000
800
600
400
200
0
-200
C-E (pcm)
0
5
10
15
20
25
Reflector thickness (cm)
ENDF80 406
beta1 456
beta2 372
ENDF80
beta1
beta2
Linear (ENDF80)
Linear (beta1)
Linear (beta2)

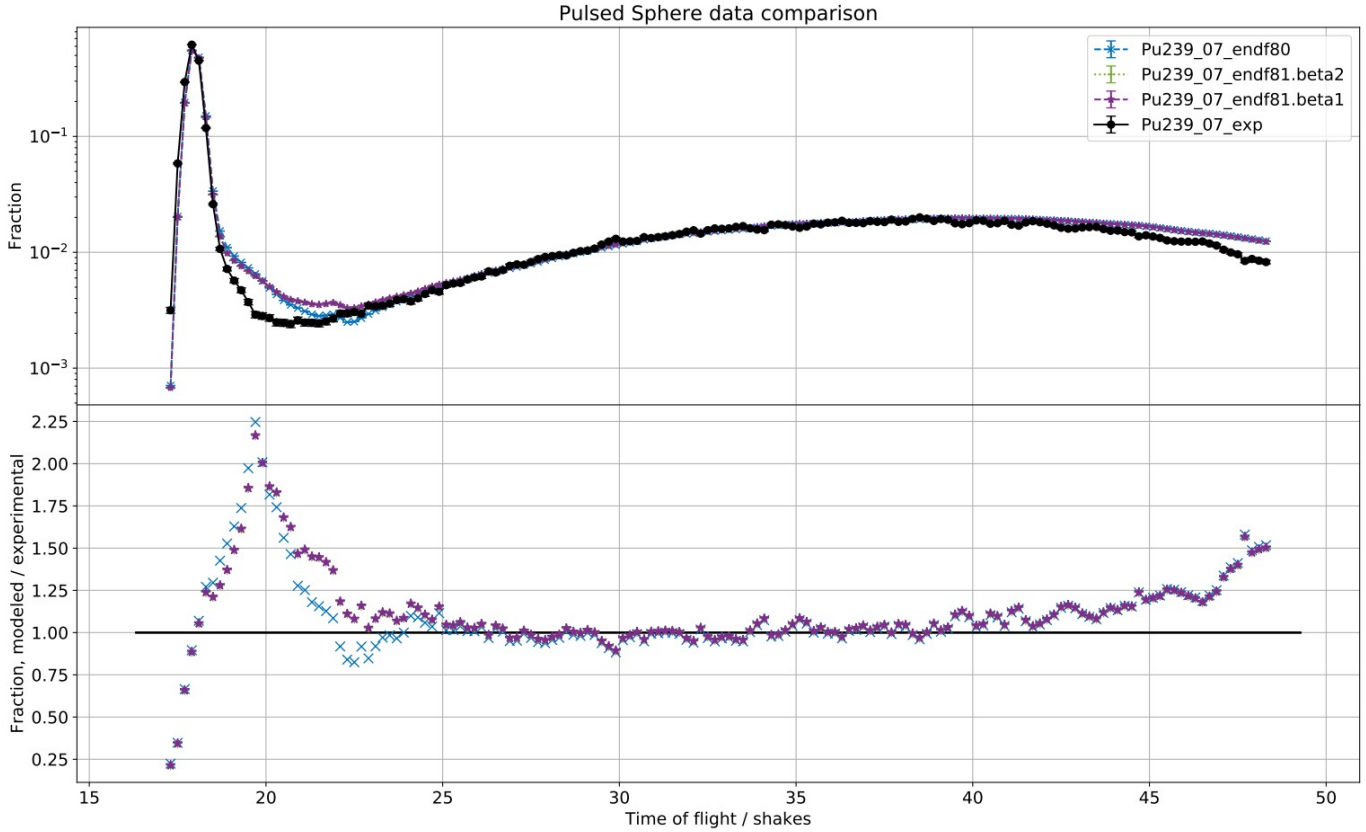
HMF66


HMF66 vs Reflector thickness
ENDF80 140
beta1 87
beta2 397
C-E (pcm)
Reflector thickness (cm)
ENDF80
beta1
beta2
Linear (ENDF80)
Linear (beta1)
Linear (beta2)

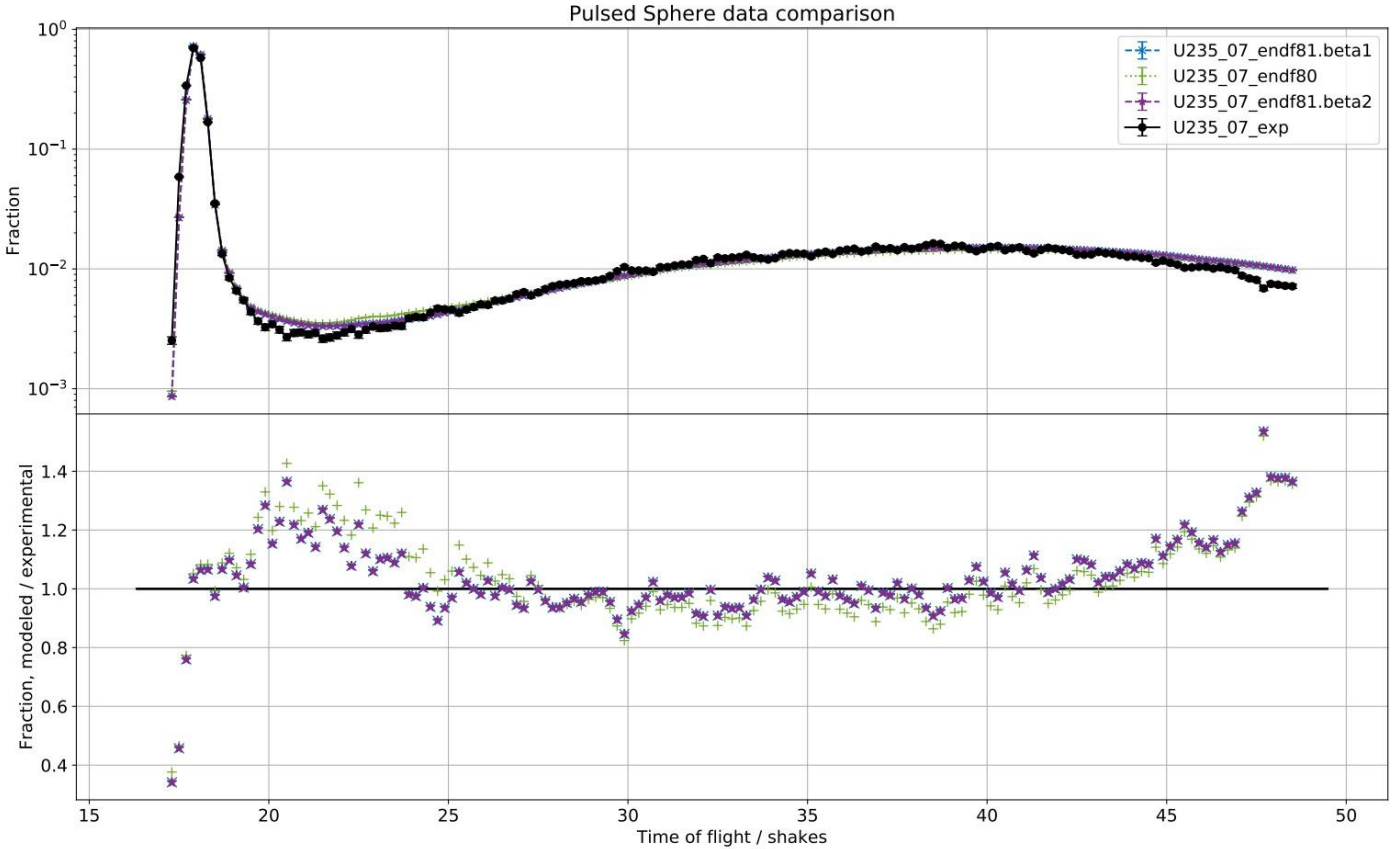
Criticality Observations

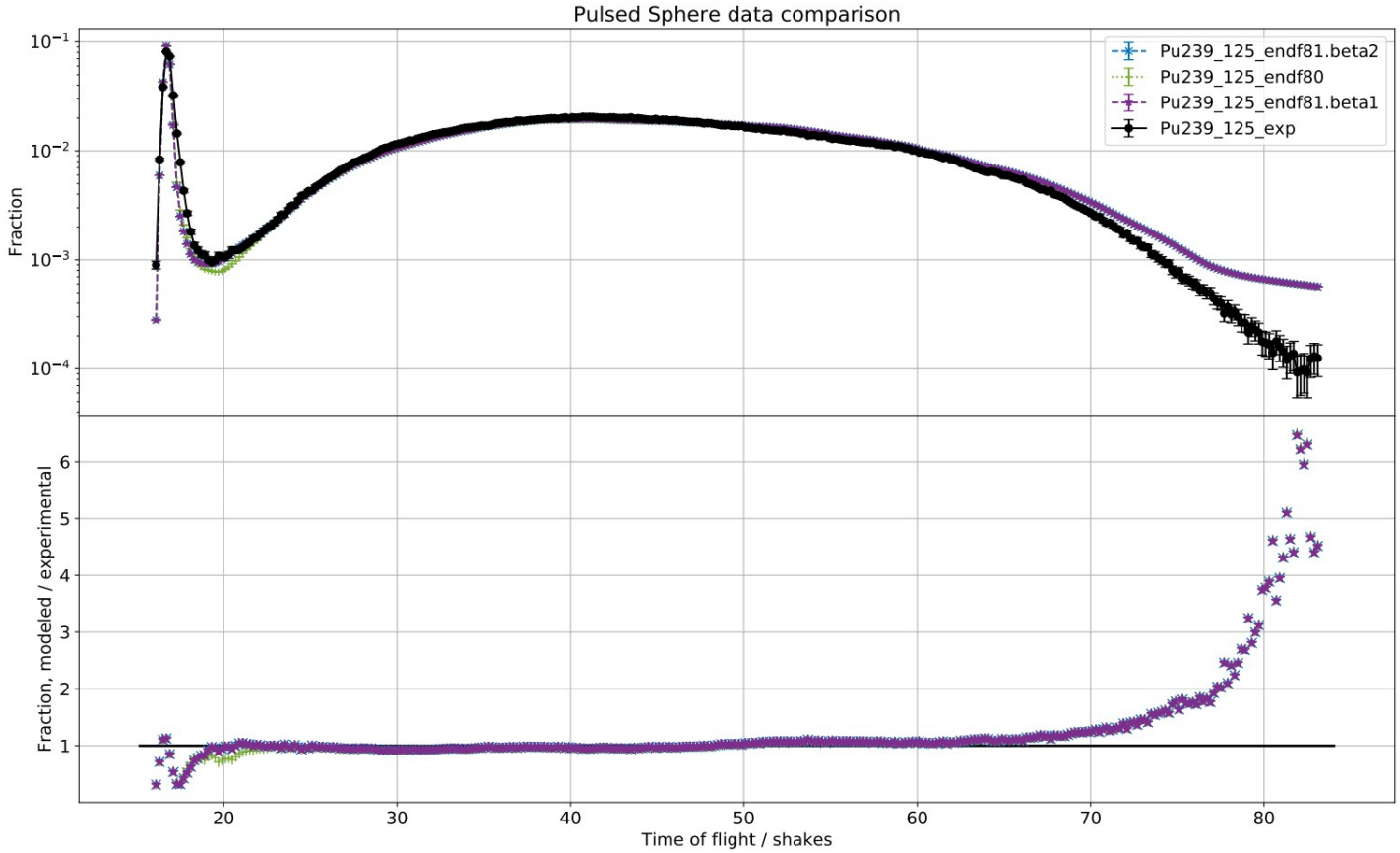
- Generally, very small changes from ENDF80 to beta2
  - On average ~ 20 pcm,
- Small decrease in Criticality PMF1 Variants vs 8.0.
  - ~10 pcm statistical uncertainty of MCNP calcs ~10 pcm
- Beryllium Benchmarks still misbehaving.
  - Change seen in MMF7 (Be) for beta1 removed for beta2.
  - However, improvement in HMF66 (Be) with beta1 removed in beta2.
    - Trend with reflector thickness also very different with beta2.
- Groupwise results consistent with pointwise
- No major issues with Fast Critical systems in Groupwise or Pointwise calculations.

Plutonium 239

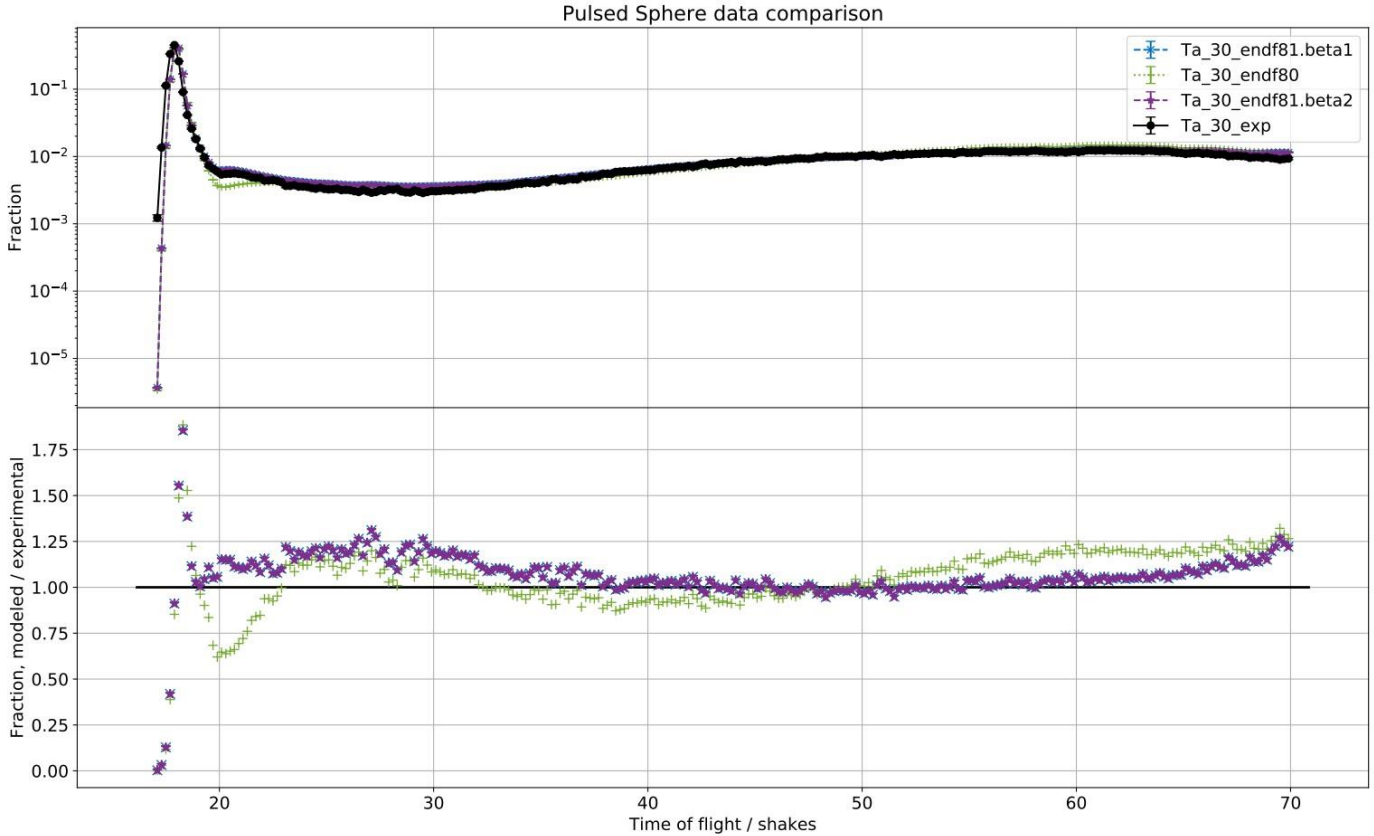


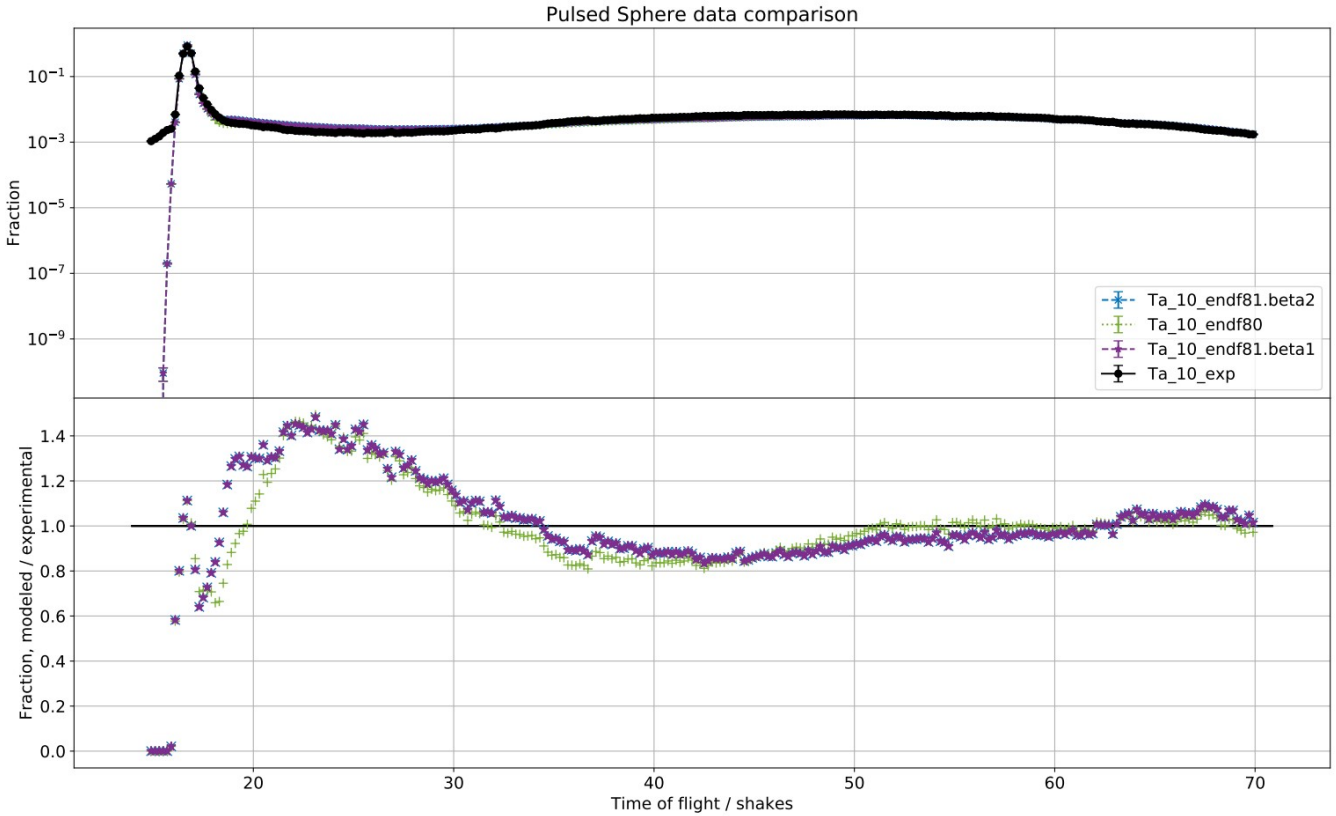
Uranium 235


Pulsed Sphere data comparison
U235_07_endf81.beta1
U235_07_endf80
U235_07_endf81.beta2
U235_07_exp
Fraction
Fraction, modeled / experimental
Time of flight / shakes

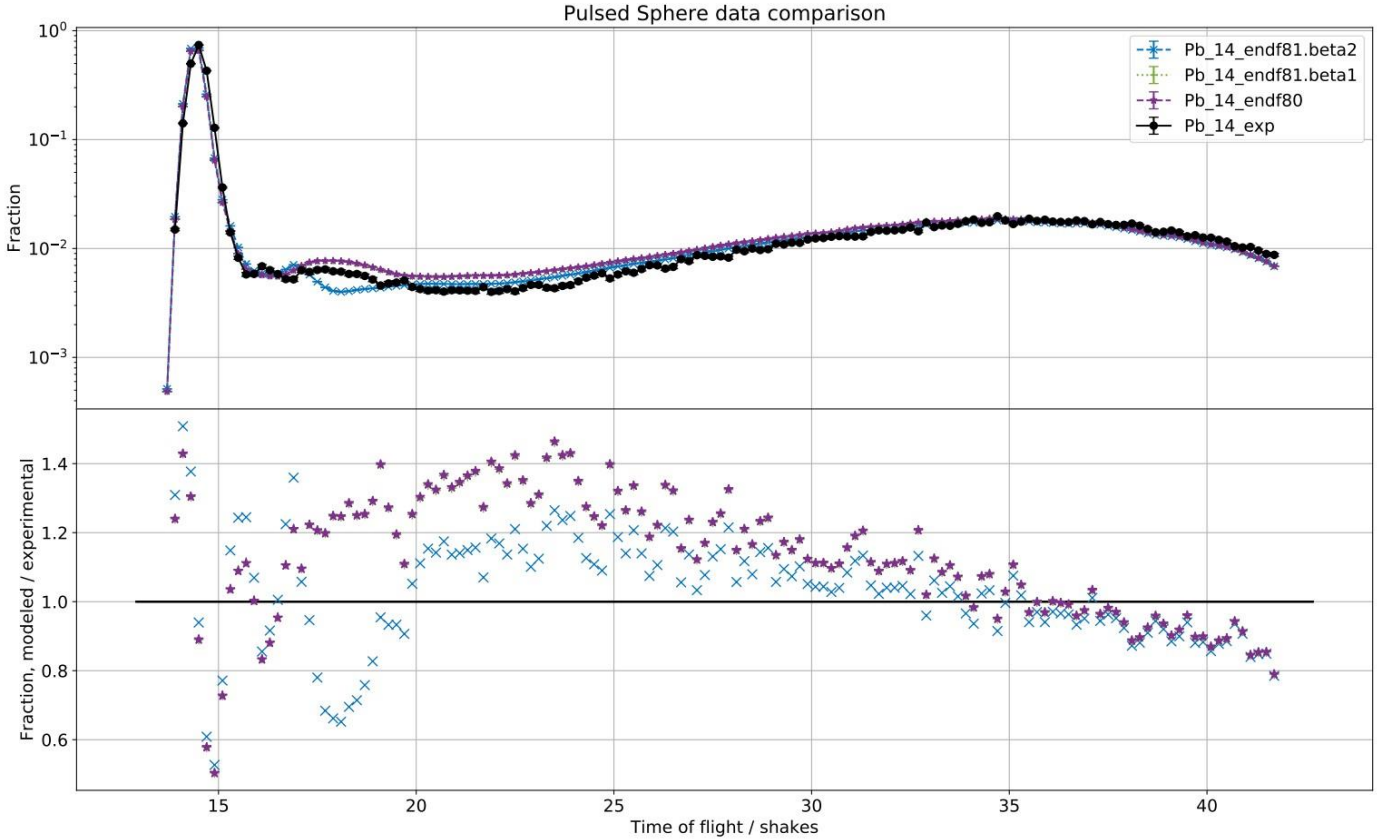

Pulsed Sphere data comparison
Pu239_125_endf81.beta2
Pu239_125_endf80
Pu239_125_endf81.beta1
Pu239_125_exp
Fraction
Fraction, modeled / experimental
Time of flight / shakes

Tantalum

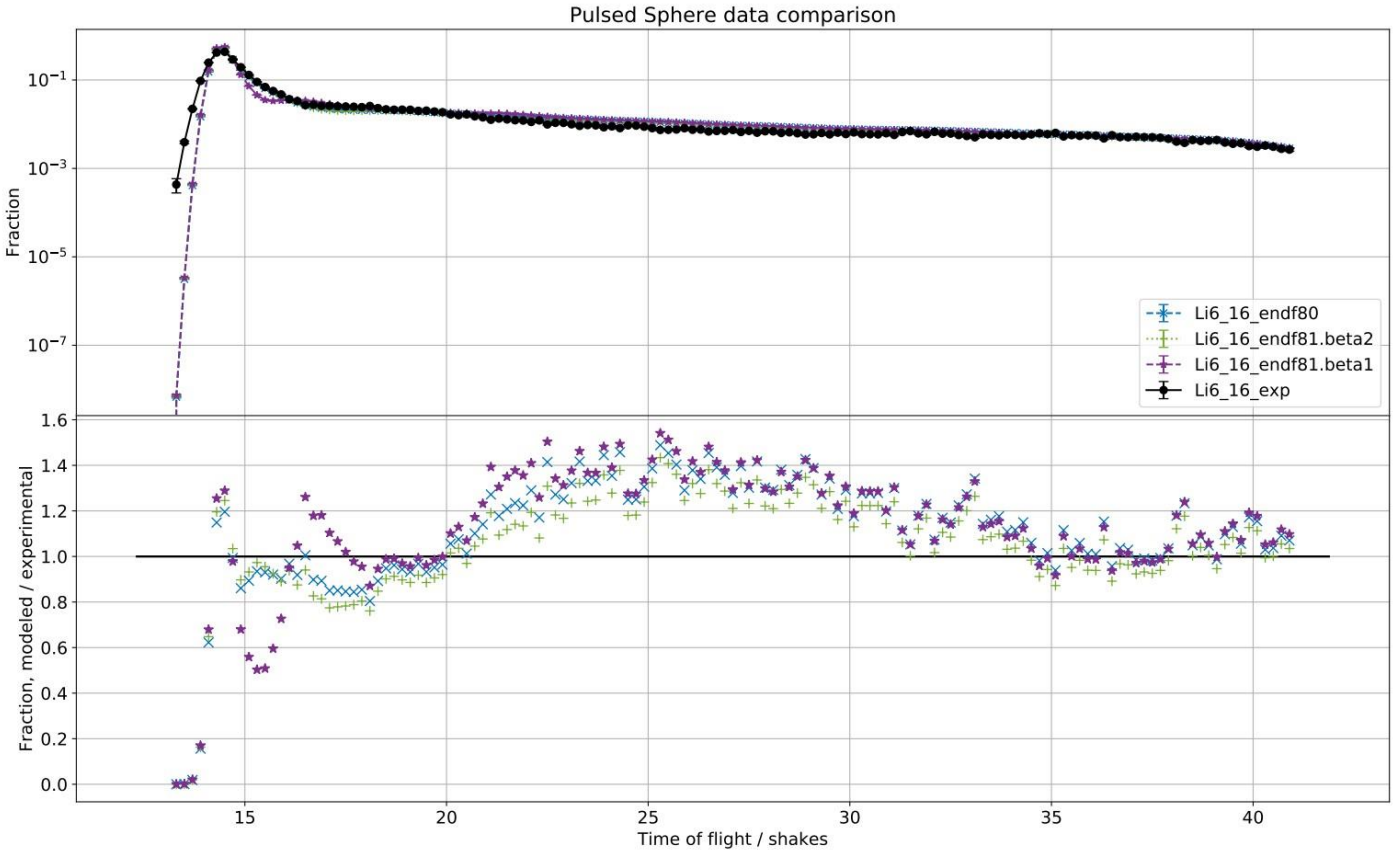

Pulsed Sphere data comparison
Ta_30_endf81.beta1
Ta_30_endf80
Ta_30_endf81.beta2
Ta_30_exp
Fraction
Fraction, modeled / experimental
Time of flight / shakes

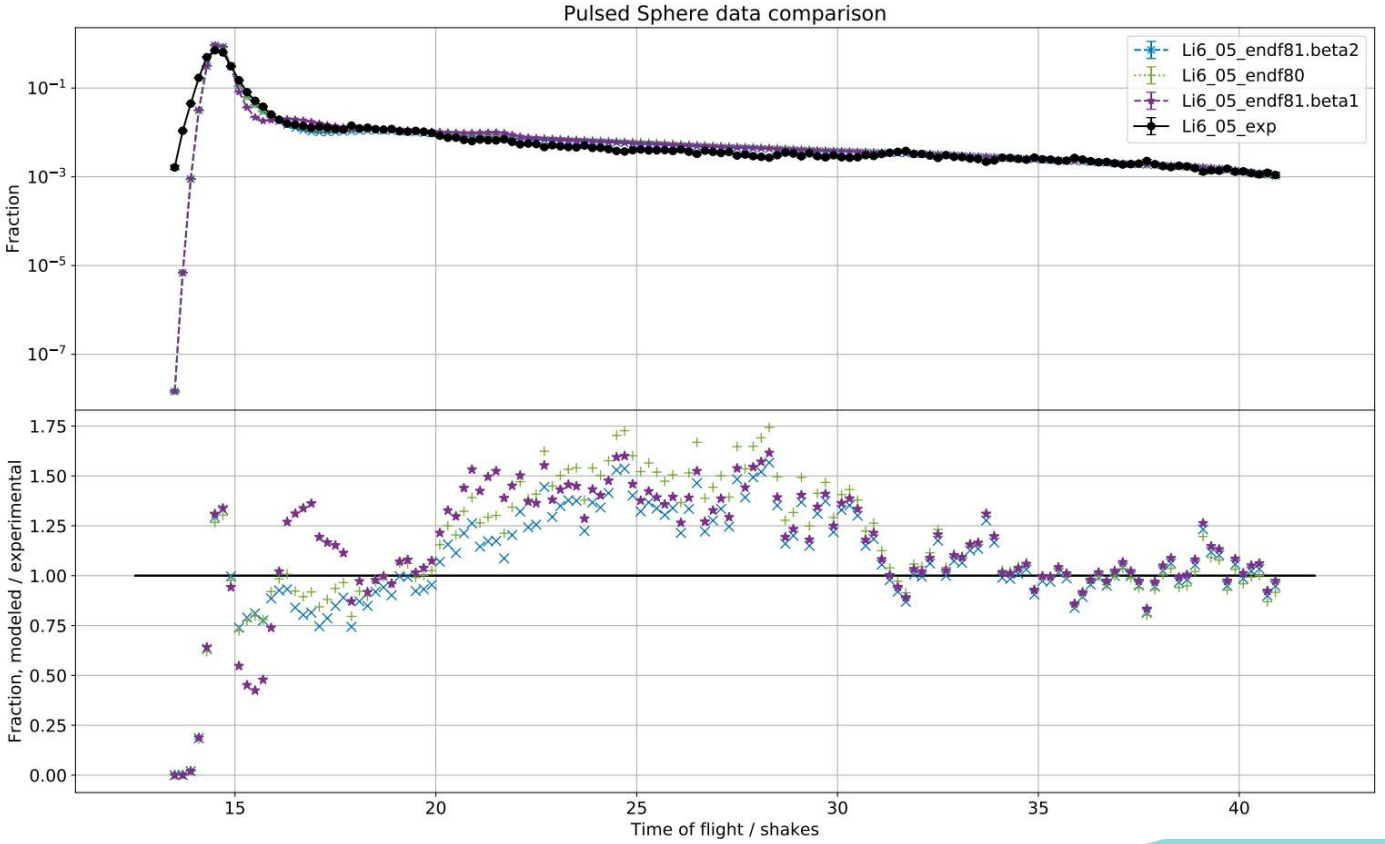

Pulsed Sphere data comparison
Fraction
Fraction, modeled / experimental
Time of flight / shakes
Ta_10_endf81.beta2
Ta_10_endf80
Ta_10_endf81.beta1
Ta_10_exp

Lead

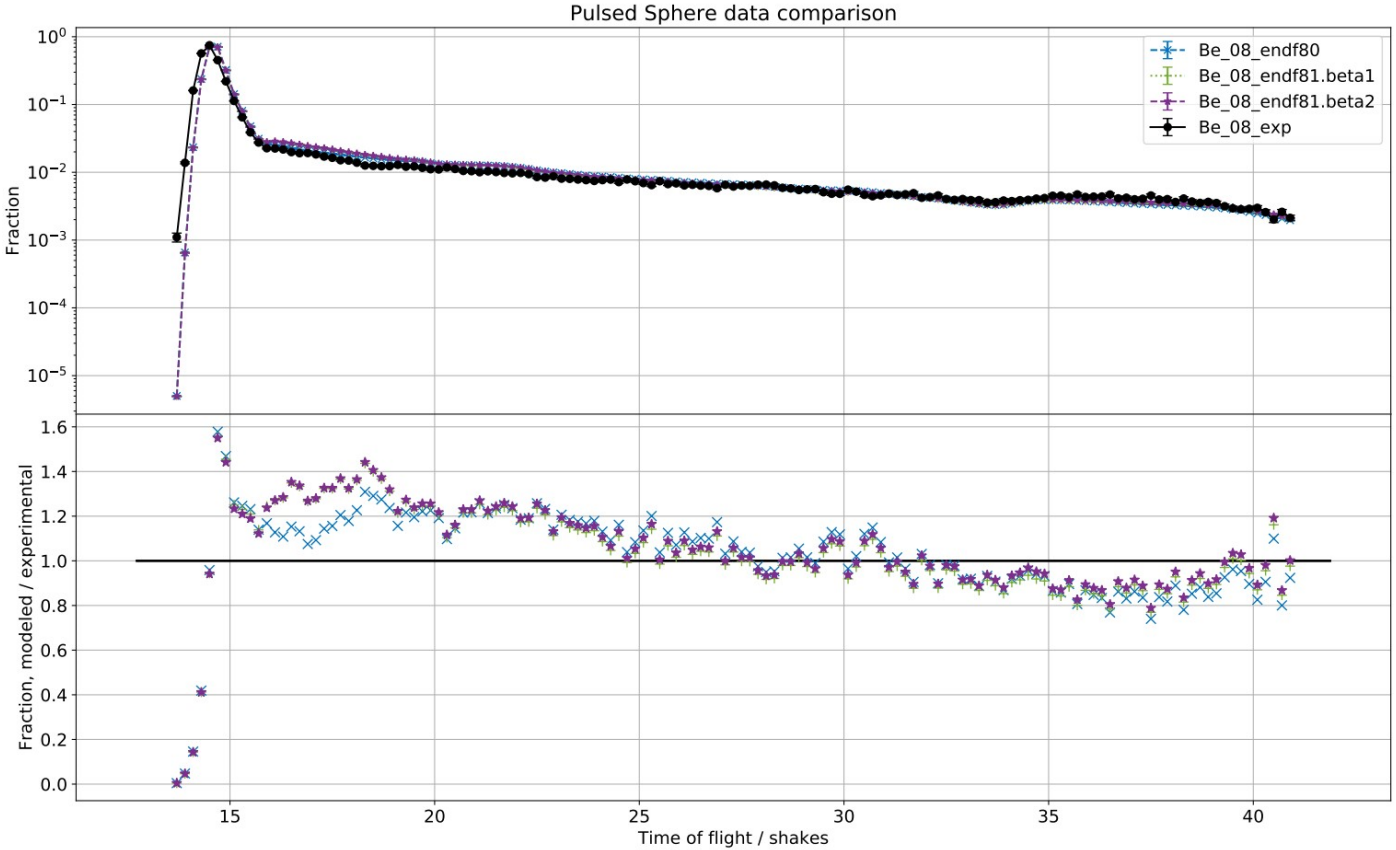

Pulsed Sphere data comparison
Pb_14_endf81.beta2
Pb_14_endf81.beta1
Pb_14_endf80
Pb_14_exp
Fraction
Fraction, modeled / experimental
Time of flight / shakes

Lithium 6


Pulsed Sphere data comparison
Fraction
Fraction, modeled / experimental
Time of flight / shakes
Li6_16_endf80
Li6_16_endf81.beta2
Li6_16_endf81.beta1
Li6_16_exp


Pulsed Sphere data comparison
Li6_05_endf81.beta2
Li6_05_endf80
Li6_05_endf81.beta1
Li6_05_exp
Fraction
Fraction, modeled / experimental
Time of flight / shakes

Beryllium


Pulsed Sphere data comparison
Be_08_endf80
Be_08_endf81.beta1
Be_08_endf81.beta2
Be_08_exp
Fraction
Fraction, modeled / experimental
Time of flight / shakes

Pulsed Sphere Observation

- Pu239, U235 and Ta beta1 and beta2 the same but different from 8.0
- Lead, new changes for beta2
- High energy changes in Li6 sphere introduced in beta1 removed in beta2, still some small differences between beta1 and beta2
  - Beta2 slightly lower, difference decreases with energy
- Changes in seen in MMF7 and HMF66 beta1 vs beta2 are not obvious in the Be sphere.
  - Some subtle difference seen at low energies?
- Very initial analysis but nothing stands out as show stopping.

First Do No Harm

Thank you for your attention

Questions

		Exp	err	ENDF80	beta1	beta2			Exp	err	ENDF80	beta1	beta2			Exp	err	ENDF80	beta1	beta2
HMF01a	None	1	0.001	1.00022	1.00003	1.00008	HMF21	Steel	1	0.0024	0.99975	0.99989	0.99995	HMF57b	Lead	1	0.0023	0.99806	0.99765	1.00251
HMF01b	None	1	0.001	1.00014	0.9999	0.99998	HMF22	Duralumir	1	0.0019	0.99676	0.99691	0.99775	HMF63a	LiD	0.9993	0.004	1.00569	1.00493	1.00498
HMF02a	Nat U	1	0.003	0.99973	0.99963	1.00004	HMF25a	Vanadium	0.9987	0.0014	0.9993	0.99893	0.99886	HMF63b	LiD	0.9988	0.0047	1.00339	1.00386	1.00374
HMF03a	Nat U	1	0.005	0.99369	0.99351	0.99379	HMF25b	Vanadium	0.999	0.0016	1.00134	1.00116	1.00134	HMF66a	Beryllium	1.003	0.0033	1.00104	1.00181	0.99887
HMF03b	Nat U	1	0.005	0.99315	0.99264	0.99346	HMF25c	Vanadium	0.9991	0.0016	1.00427	1.00403	1.00407	HMF66b	Beryllium	1.0023	0.0029	0.99966	0.99948	0.99726
HMF03c	Nat U	1	0.005	0.99777	0.99735	0.99772	HMF25d	Vanadium	0.9995	0.0016	0.9793	0.97916	0.97933	HMF66c	Beryllium	1.0023	0.0026	1.0026	1.00201	1.0005
HMF03d	Nat U	1	0.003	0.99563	0.99556	0.99587	HMF25e	Vanadium	0.9991	0.0016	0.97921	0.97906	0.9792	HMF66d	Beryllium	1.0043	0.0043	1.00297	1.00507	1.00053
HMF03e	Nat U	1	0.003	0.99973	0.99946	0.99982	HMF27	Lead	1	0.0025	1.00066	1.00042	1.00365	HMF66e	Beryllium	1.003	0.0033	1.00206	1.00272	0.99951
HMF03f	Nat U	1	0.003	0.99994	0.99954	1.00019	HMF28	Nat U	1	0.003	1.00121	1.00103	1.00141	HMF66f	Beryllium	1.0028	0.003	1.00146	1.00156	0.99881
HMF03g	Nat U	1	0.003	1.00014	1.00011	1.00042	HMF29	DU	1	0.002	1.00418	1.00402	1.00421	HMF66g	Beryllium	1.0048	0.0039	1.0036	1.00448	1.0004
HMF03h	WC	1	0.005	1.00065	1.00128	1.00061	HMF31	Polythene	1	0.0059	1.03366	1.03437	1.03438	HMF66h	Beryllium	1.0039	0.004	1.00241	1.00407	0.99972
HMF03i	WC	1	0.005	1.00097	1.00138	1.00115	HMF32a	Nat U	1	0.0016	1.00261	1.0023	1.00283	HMF66i	Beryllium	1.0027	0.0036	1.0013	1.00196	0.99781
HMF03j	WC	1	0.005	1.00409	1.00461	1.00298	HMF32b	Nat U	1	0.0027	1.00301	1.00309	1.00338	HMF79a	Titanium	0.9996	0.0015	0.99942	0.99933	0.9995
HMF03k	WC	1	0.005	1.00739	1.00721	1.007	HMF32c	Nat U	1	0.0017	0.9989	0.99886	0.99888	HMF79b	Titanium	0.9996	0.0014	0.99921	0.99893	0.999
HMF03l	Nickel	1	0.005	0.99777	0.99728	0.99735	HMF32d	Nat U	1	0.0017	1.00008	0.99999	1.00022	HMF79c	Titanium	0.9996	0.0015	0.99988	0.99984	0.99953
HMF04	Light wate	0.9985	0.001	1.01901	1.01908	1.01945	HMF41a	Beryllium	1.0013	0.003	1.01616	1.01501	1.01371	HMF79d	Titanium	0.9996	0.0014	1.00061	1.00079	1.00033
HMF08	None	0.9989	0.0016	0.99429	0.99531	0.99629	HMF41b	Beryllium	1.0022	0.0043	1.00898	1.00953	1.00704	HMF79e	Titanium	0.9996	0.0015	1.00012	0.99963	1.00008
HMF09a	Beryllium	0.9992	0.0015	0.99692	0.99579	0.99474	HMF41c	Graphite	1.0006	0.0029	1.00702	1.00681	1.00684	HMF84a	Aluminiur	0.9994	0.002	0.99911	0.99906	0.99917
HMF09b	BeO	0.9992	0.0015	0.99549	0.99477	0.99567	HMF41d	Graphite	1.0006	0.0025	1.01181	1.01184	1.0118	HMF84m	Titanium	0.9994	0.0024	0.9934	0.99312	0.99311
HMF11	Polythene	0.9989	0.0015	1.01524	1.01684	1.01765	HMF41e	Graphite	1.0006	0.0031	1.00124	1.00111	1.00127	HMF85e	Thorium	0.9995	0.0024	1.00021	1.00057	1.00017
HMF12	Aluminiur	0.9992	0.0018	0.99861	0.99748	0.99726	HMF41f	Graphite	1.0006	0.0045	1.00406	1.00372	1.00403	IMF03	None	1	0.0017	1.00073	1.00078	1.00164
HMF13	Steel	0.999	0.0015	0.99853	0.99843	0.99819	HMF44a	Aluminiur	0.9995	0.0019	0.99995	1.00012	0.99995							
HMF14	DU	0.9989	0.0017	0.99562	0.99542	0.99656	HMF44b	Aluminiur	0.9995	0.0017	0.99975	0.99966	0.99962							
HMF15	None	0.9996	0.0017	0.99399	0.9949	0.99514	HMF44c	Aluminiur	0.9995	0.0019	1.0001	0.99989	0.99989							
HMF18	None	1	0.0016	0.99972	0.99943	0.99962	HMF44d	Aluminiur	0.9995	0.0014	0.99969	0.99928	0.99938							
HMF19	Graphite	1	0.003	1.00559	1.00572	1.00518	HMF44e	Aluminiur	0.9995	0.0015	1.00212	1.00197	1.00183							
HMF20	Polythene	1	0.0028	1.00009	1.00013	0.99995	HMF57a	Lead	1	0.002	0.98919	0.98893	0.99386							

		Exp	err	ENDF80	beta1	beta2			Exp	err	ENDF80	beta1	beta2			Exp	err	ENDF80	beta1	beta2
MMF1	HEU	1	0.0016	0.99945	0.99909	0.99927	PMF01r2	None	1	0.002	0.99998	0.99939	0.99944	U3MF1	None	1	0.001	1.00056	1.0005	0.99995
MMF2a	Nat U	1	0.0042	1.00411	1.00352	1.00411	PMF01r4a	None	0.99999	0.0011	1.00031	0.99977	0.99985	U3MF2a	HEU	1	0.001	1.00039	1.00019	0.99975
MMF03	None	0.9993	0.0016	1.00106	1.00109	1.0011	PMF01r4b	None	1.00016	0.0011	1.00077	1.00021	1.00032	U3MF2b	HEU	1	0.0011	1.00176	1.00167	1.00135
MMF05	Aluminiur	0.999	0.0017	1.00398	1.00361	1.00389	PMF01r4c	None	1.0002	0.0011	1.0005	0.99997	1.00008	U3MF3a	Nat U	1	0.001	0.99891	0.99904	0.99867
MMF7a	Beryllium	1	0.0045	1.00272	1.0055	1.00311	PMF01r4d	None	1.00128	0.0011	1.00151	1.00095	1.00104	U3MF3b	Nat U	1	0.001	0.99913	0.99899	0.99869
MMF7b	Beryllium	1	0.0023	1.0069	1.00904	1.0067	PMF01r4s	None	1	0.0011	1.00076	1.00024	1.00033	U3MF4a	Tungsten	1	0.0007	0.99996	0.99977	0.99993
MMF7c	Beryllium	1	0.0028	1.00495	1.00552	1.00405	PMF02	None	1	0.002	1.00153	1.00087	1.00093	U3MF4b	Tungsten	1	0.0008	0.99725	0.99721	0.9976
MMF7d	Beryllium	1	0.0028	1.00377	1.00382	1.00308	PMF05	Tungsten	1	0.0013	1.00037	1.00073	1.0011	U3MF5a	Beryllium	1	0.003	0.99759	0.99804	0.99721
MMF7e	Beryllium	1	0.0032	1.00143	1.00109	1.00053	PMF06	Nat U	1	0.0013	1.0002	0.99994	1.00078	U3MF5b	Beryllium	1	0.003	0.99748	0.99831	0.99695
MMF7f	Beryllium	1	0.0035	1.00038	1.00004	0.99985	PMF08a	Thorium	1	0.0006	0.99819	0.99818	0.99818	U3MF6	Nat U	1	0.0014	1.00023	1.00019	0.99997
MMF7g	Beryllium	1	0.0032	1.00569	1.00817	1.00605	PMF08b	Thorium	1	0.0006	0.99747	0.99841	0.99812							
MMF7h	Beryllium	1	0.003	1.00409	1.00579	1.00388	PMF09	Aluminiur	1	0.0027	1.00493	1.00469	1.00473							
MMF7i	Beryllium	1	0.0028	1.00392	1.00511	1.00348	PMF10	Nat U	1	0.0018	0.99868	0.99816	0.99867							
MMF7j	Beryllium	1	0.0027	1.0037	1.00398	1.00285	PMF11	Light Wate	1	0.001	1.01392	1.01337	1.01338							
MMF7k	Beryllium	1	0.0026	1.00244	1.00209	1.00155	PMF18	Beryllium	1	0.003	0.99835	0.99922	0.99864							
MMF7l	Beryllium	1	0.003	1.00175	1.00121	1.0013	PMF19	Beryllium	0.9992	0.0015	0.99973	1.00074	0.99937							
MMF7m	Beryllium	1	0.0033	1.00053	1.00042	1.00032	PMF20	DU	0.9993	0.0017	0.99689	0.99724	0.99866							
MMF7n	Beryllium	1	0.0032	1.00705	1.00842	1.0069	PMF21a	Beryllium	1	0.0026	1.00462	1.0064	1.00462							
MMF7o	Beryllium	1	0.0032	1.00656	1.00752	1.00632	PMF21b	BeO	1	0.0026	0.99303	0.99317	0.99242							
MMF7p	Beryllium	1	0.0028	1.00473	1.00495	1.00438	PMF22	None	1	0.0023	0.99811	0.99762	0.99788							
MMF7q	Beryllium	1	0.0028	1.0048	1.00467	1.00435	PMF23	Graphite	1	0.0022	0.99857	0.99816	0.9984							
MMF7r	Beryllium	1	0.003	1.00729	1.00707	1.007	PMF24	Polythene	1	0.0022	1.00126	1.0011	1.00118							
MMF7s	Beryllium	1	0.0034	1.00591	1.00612	1.00566	PMF25	Steel	1	0.0022	0.99986	0.99937	0.9993							
MMF7t	Beryllium	1	0.003	1.00417	1.00391	1.00379	PMF26	Steel	1	0.0024	1.0016	1.00153	1.00156							
MMF7u	Beryllium	1	0.0031	1.00475	1.00432	1.00454	PMF27	Polythene	1	0.0024	1.01178	1.01116	1.01148							
MMF7v	Beryllium	1	0.003	1.00313	1.00344	1.0031	PMF28	Steel	1	0.0024	1.00307	1.00323	1.00346							
MMF7w	Beryllium	1	0.0028	1.00281	1.00283	1.00265	PMF29	None	1	0.0022	0.99636	0.9956	0.99571							
							PMF30	Carbon	1	0.0023	1.00259	1.00242	1.00253							
							PMF31	Polythene	1	0.0023	1.00617	1.0058	1.00599							
							PMF32	Steel	1	0.0023	1.00113	1.00075	1.00077							
							PMF41	DU	1	0.0016	1.0051	1.00571	1.00664							
							SMF08	Np/HEU	1.0026	0.0034	0.99609	0.9964	0.99697							