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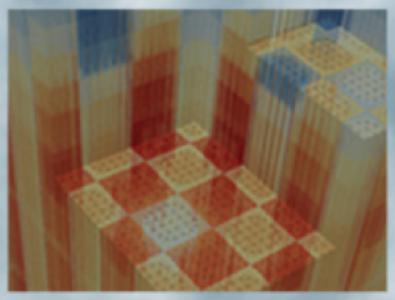
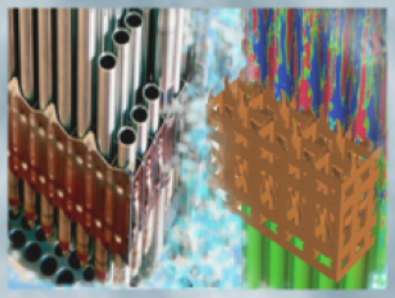
CASL-U-2017-1399-000

Energy Deposition Analysis of VERA Progression Problems Using MCNP6





Revision 0

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REVISION LOG

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Executive Summary

The current energy deposition model in the CASL neutronics code MPACT assumes all the fission energy is deposited locally. This approximation limits the accurate representation of the heating source distribution in the reactor core, which is essential for the thermal/hydraulic coupling calculations. There has been ongoing work to develop improved models in MPACT to account for the energy deposition distribution of gamma rays, including direct fission gamma (prompt and delayed) and the gamma rays from neutron capture. Also, the neutron/photon coupling transport calculation has been considered as a potential capability to be added in MPACT to provide high-fidelity heating calculations. In order to provide a reference solution for these gamma heating models, MCNP has been used in this work to develop a set of energy deposition benchmark problems, based on the elective VERA Progression Problems, including single pin cells, 2-D assemblies and 2-D quarter core cases.

Analysis of the benchmark results shows that the direct coolant heating fraction of 2.6% used in MPACT/CTF coupled calculation is a reasonable approximation for a fresh whole core calculation, but it would be desirable to allow the burnup dependence of this fraction. As suggested by the results of 2-D assembly calculations, the energy deposited in the non-fuel regions is non-trivial, e.g., the energy deposited in an AIC control rod is approximately 1/4 of that in a fuel pin. By comparing the fission rate distribution with the gamma heat distribution, the possible approach of a simplified gamma smearing scheme (without solving the gamma transport) can be investigated using the benchmark results, which is under development in another RTM milestone(L3:RTM.XSN.P15.01). For the future interest of developing deterministic neutron/photon coupled transport calculation in MPACT, the data presented in this benchmark problem can also be used for verification.

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1 Introduction

The energy released per fission is an important quantity in reactor core analysis. Due to the transport of fission neutrons and gamma rays (prompt, delayed and capture gammas), the fission energy carried by these particles can deposit their energy away from the place where the fission event occurs. Therefore, the spatial distribution of energy deposition should be determined by coupled neutron and photon transport calculations. To investigate the energy deposition behavior for CASL applications, MCNP6 was adopted in this work to create a set of energy deposition benchmark problems based on VERA Progression Problems [1], ranging from a single pin cell, to various 2-D assembly cases, and finally a few 2-D quarter core problems. A well-defined scheme for energy deposition tally for MCNP5 [2] is used in this study.

The rest of the report is organized as follows. The theory of fission energy release as well as the related tallies in MCNP will be discussed in Section 2. In Section 3, the cases investigated in this study are described first. A pin cell case is analyzed to verify the correctness of our MCNP model for energy deposition tally. Finally, the results of energy deposition are discussed in two aspects: the energy deposition fractions in different materials and the spatial distribution of fission rate, total heating and gamma heating. Note in Section 3, only the essential data are included for discussing the two aspects. More detailed benchmark results in terms of various energy forms are available in Appendix A.

2 Theory

2.1 Energy Release Per Fission

Throughout the project, we are interested in the energy release per fission that is defined as following:

$$E/fission = \frac{Energy}{\Sigma_f \phi} = \frac{Energy}{N \sigma_f \phi} \tag{1}$$

in which σ_f is microscopic fission cross section, N is number density of target nucleus and ϕ is neutron flux. Multiplication of all the three terms gives fission rates. The tally scheme for energy deposition calculation discussed in the next section is adapted from the previous experience of a VHTR with MCNP5 [2].

2.2 MCNP6 Tallies

2.2.1 Fission Rate

As mentioned in section 2.1, fission rate is defined by multiplication of N, σ_f and ϕ. MCNP6 provides native support for flux tally by f4 card. "F4:n < cell number > " in input files tallies the total scalar flux inside that cell. Besides, the built-in tally multiplier feature(FM card) allows multiplying the flux by number densities and a specific cross section(e.g. fission

cross section for fission rate purpose). These functions combined give fission rate of cells. For example,

f14:n 5
fm14:n (-1.0 20002 -6)

indicates tally number 14. Tallies whose id's ending with 4 are flux tallies. "5" on f card indicates it is a tally of cell 5. "-1.0" in fm card means multiplying the results by total number density of the current cell. "20002" is material number, and "-6" defines a fission tally. "20002" and "-6" combined indicates "(microscopic) fission cross section of material 20002". The whole f and fn set means "tally the flux times fission cross section of cell number 5", which is the fission reaction rate.

Internally, F4 tally is a track length estimate of cell flux in MCNP. Given the definition of average scalar flux,

$$\begin{aligned}\bar{\phi_v} &= \frac{1}{V}\int dV \int dE \int dt \int d\Omega \psi(\vec{r},\hat{\Omega},E,t) \\ &= \frac{1}{V}\int dV \int dE \int d\Omega \int dt v n(\vec{r},\hat{\Omega},E,t) \\ &= \frac{1}{V}\int dV \int dE \int ds N(\vec{r},E,t)\end{aligned} \tag{2}$$

where Ω is the directions particles traveling, ψ is angular flux, v is particle velocity. The quantity $dEdsN(\vec{r},E,t)$ can be treated as track length density due to neutrons in dE. Therefore, the average flux can be calculated by summing track lengths and integrating over E. As a result, MCNP estimates the value by summing WT/V of all particles in a cell, where W is particle weight and T is track length [4].

2.2.2 Energy Deposition

This section discusses how MCNP6 was used to calculate different forms of energy deposition, numerator of equation 1 in other words. Energy deposition tally is done by f6 and f7 tally cards. For the energy forms listed from section 2.2.2.1 to 2.2.2.5, fission fragments plus neutrons, prompt gamma and capture gamma are tallied directly by MCNP6, while the energy deposition from delayed gamma and beta are scaled, as described in their subsections.

F6 Tally: This tally card does track length estimate of energy deposition, which is physically expressed as equation 3 below:

$$\begin{aligned}H &= \frac{\rho_a}{m}\int dE \int dt \int dV \int d\Omega \sigma_t(E) H(E) \psi(\vec{r},\hat{\Omega},E,t) \\ &= \frac{\rho_a}{m}\int dE \sigma_t(E) H(E) \int dV \int d\Omega \int dt v n(\vec{r},\hat{\Omega},E,t) \\ &= \frac{\rho_a}{m}\int dE \sigma_t(E) H(E) \int dV \int ds N(\vec{r},E,t)\end{aligned} \tag{3}$$

in which σ_t is total cross section, H(E) is heating number and ρ_a is atom density.

Similar to Section 2, MCNP estimates this by summing $WT\sigma_t(E)H(E)\frac{\rho_a}{m}$, W is particle weight and T is track length, of all the particles. Specific forms of H(E) depend on types of particles to be tallied, which will be covered in section 2.2.2.1 and 2.2.2.2 [4].

F7 Tally: This tally card does track length estimate of fission energy deposition, which is physically expressed as equation 4 below:

$$\begin{aligned} H &= \frac{\rho_a}{m} Q \int dE \int dt \int dV \int d\Omega \sigma_f(E)\psi(\vec{r},\hat{\Omega},E,t) \\ &= \frac{\rho_a}{m} Q \int dE \sigma_f(E) \int dV \int d\Omega \int dt v n(\vec{r},\hat{\Omega},E,t) \\ &= \frac{\rho_a}{m} Q \int dE \sigma_f(E) \int dV \int ds N(\vec{r},E,t) \end{aligned} \tag{4}$$

and this will be estimated by summing $WT\sigma_f(E)Q\frac{\rho_a}{m}$. σ_f is fission cross section, Q is fission heating Q value, other are the same as those in equation 3 [4].

2.2.2.1 Fission Fragments and Neutrons

F6n card alone tallies energy deposited by fission fragments and neutrons in a certain cell. The fission neutron energy given by ENDF is the average energy of neutrons from a fission event. MCNP F6 tally does not count the energy of neutrons from fission directly. Instead, the neutron energy is tallied when the neutron interacts with an isotope through other reactions excluding fissions. For thermal systems, most of the neutron energy is deposited during slowing-down and the average absorption energy of neutrons is in the order of 0.1MeV, so the neutron energy for most LWR applications should be close to the fission neutron energy from ENDF. Thus, we can essentially compare it with ENDF value to verify the correctness of our MCNP models.

F6 neutrons: Starting from f6 tally equation 3, the heat deposited by fission fragments and neutrons uses the heating number in the following form [4]:

$$H(E) = E - \sum_i p_i(E)[\bar{E}_{i,out}(E) + \bar{E}_{i,\gamma}(E) - Q_i]$$

$p_i(E)$ = probability of reaction i at neutron incident energy E
$\bar{E}_{i,out}(E)$ = average exiting neutron energy for reaction i at neutron incident energy E
$\bar{E}_{i,\gamma}(E)$ = average exiting gamma energy for reaction i at neutron incident energy E
Q_i = Q-value of reaction i

(5)

2.2.2.2 Prompt Gamma Gammas are all tallied by f6p card, in which "p" stands for "photons". For F6p alone, it tallies the total energy deposited by prompt gamma and capture gamma. And prompt gamma can be distinguished if "PIKMT" card is included to pick up only MT=18, which includes fission introduced prompt gammas only.

F6 photons: Starting from f6 tally equation 3, estimating heat deposited by photons uses heating number as the following form [4]:

$$H(E) = E - \sum_{i=1}^{3} p_i(E)[\bar{E}_{i,out}(E)]$$

$p_i(E)$ = probability of reaction i at gamma incident energy E

$\bar{E}_{i,out}(E)$ = average exiting neutron energy for reaction i at neutron incident energy E

$i = 1 \rightarrow$ Compton scattering

$i = 2 \rightarrow$ Pair production

$i = 3 \rightarrow$ Photoelectric absorption

(6)

2.2.2.3 Capture Gamma As discussed in Section 2.2.2.2, the first run with f6p alone can get prompt gamma + capture gamma and the second run with f6p + pikmt can distinguish prompt gamma. Subtracting the two values gives energy deposition of capture gamma, which is very problem dependent. It can range from 5 to 12 MeV/fission.

2.2.2.4 Delayed Gamma Unlike the previous three kinds of particles from section 2.2.2.1 to 2.2.2.3, delayed gamma tally is not supported by MCNP6. In this case, we obtained the delayed gamma energy deposition by scaling the energy deposited by prompt gamma, which assumes identical spatial distribution of delayed and prompt gamma energy deposition. The validity of this assumption is discussed in Appendix B. By using capture gamma and prompt gamma release data from ENDF library and weighting them by fission rate of each isotope, we can calculate the ratio capture gamma / prompt gamma of the whole problem domain. Then the delayed gamma depositions estimated by multiplying the ratio with prompt gamma distribution,

$$H_{\gamma d}(r) = H_{\gamma p}(r) * \frac{Q_{\gamma d}}{Q_{\gamma p}} \tag{7}$$

where Q's are library values and $H_{\gamma p}$ is prompt gamma deposition discussed in 2.2.2.2.

2.2.2.5 Beta Similar to delayed gamma, but beta is scaled from F7, which is the sum of fission products, neutrons and prompt gammas, instead of prompt gamma alone. F7 tallies are done through F7n card.

$$H_{\beta}(r) = H_{F7}(r) * \frac{Q_{\beta}}{Q_{F7}} \tag{8}$$

where Q's are library values and H_{F7} is obtained from F7 tally.

2.3 k-correction

For the realistic energy deposition calculation of critical systems, the equilibrium energy deposition can be tallied with the foregoing scheme. However, the VERA progression problems investigated in this study are mostly off the critical condition. Since the equilibrium energy deposition does not exist for a non-critical system, the fission rates tallied by MCNP should be divided by k_{eff} in order for a balanced equation. Therefore, the energy forms directly computed from fission rates (fission fragments, prompt and delayed gamma and beta) should be divided by k_{eff} accordingly, but the energy forms not directly from fission (neutron and capture gamma) shouldn't be adjusted. Thus, when computing the energy per fission, this correction is equivalent to multiplying the tallied energy from neutron and capture gamma by k_{eff}, but no correction is needed for the direct fission energy forms since k_{eff} is cancelled out when dividing the energy by fission rate[3].

This correction has been used to verify the MCNP energy deposition models against ENDF values. If the MCNP benchmark results are used in the future to verify the energy deposition calculation of deterministic codes, the correction is not necessary as long as the treatment is consistent between the results from MCNP and the deterministic code. Thus, the results included in this report are uncorrected except the pin cell results in Section 3.2 that are needed to verify the MCNP models using ENDF reference data.

3 Data and Analysis

3.1 Problem Descriptions

VERA Problem 1c is a pin cell case. As shown in Figure 1, the red area at the center represents the 3.1% uranium fuel rod, the green layer is Zircaloy-4 cladding and the outermost blue area is moderator. The fuel is at 900K and any other materials are at 600K. This case is adopted to investigate the burnup effects. Instead of running the depletion calculation with MCNP, isotopic 'snapshots' are generated at various burnups up to 60GWD/tU using MPACT, and the fuel compositions are fed into a series of MCNP input decks to perform the neutron/photon coupled calculations.

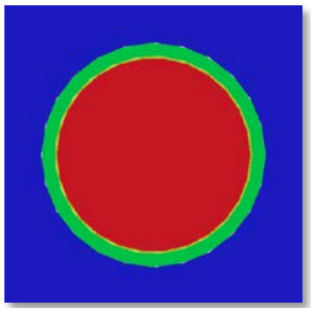

Figure 1: 1c: Layout

VERA Problem 2 presents a 17 by 17 fuel lattice with 264 fuel pins and 25 guide tubes. Specific description of each case of problem 2 is shown in Table 1 below and Figure 2.

Table 1: Problem 2 Overview

Problem Name	Descriptions
2b	264 3.1% fuel pins and 25 empty guide tubes.
2f	24 pyrex insertions in the guide tubes.
2g	24 AIC(Silver-Indium-Cadmium) control rods.
2h	24 B4C(Boron Carbide) control rods.
2m	128 of the fuel rods coated by IFBA(Integral Fuel Burnable Absorber, ZrB_2 for this case).
2p	24 of the fuel rods mixed homogeneously with Gadolinium integral burnable absorber (Gd_2O_3).

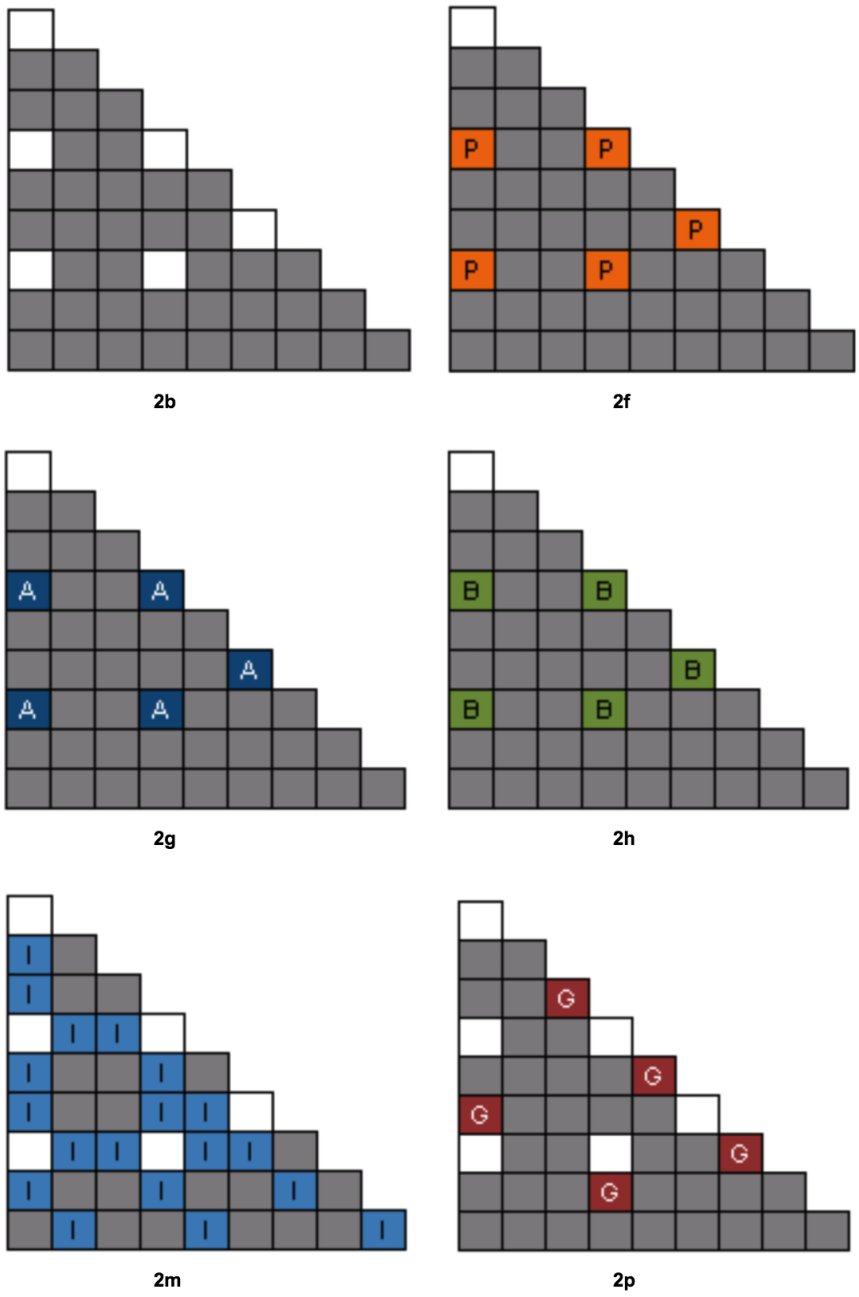

Figure 2: Case 2 Layouts

Problem 5 2D presents a quarter 2D 15 x 15 core consisting of the 17 by 17 assemblies mentioned in Problem 2. Various concentrations of fuel rods, pyrex insertions, AIC and B4C control rods, core baffle, barrel, vessel, and neutron pads are all included explicitly. This problem is adopted to investigate power distribution across the core and leakage on the boundary structural material.

Figure 3 is a quarter preview of p5's core lattice structure. On the left figure, the number on the top of each assembly indicates the enrichment of fuel rods in that assembly, and

the number on the bottom means number of pyrex insertions. And the right figure gives which assemblies have control rods. Problem 5a has all the control rods fully withdrawn, Problem 5b has AIC (Silver-Indium-Cadmium) control rods fully inserted and Problem 5c has B4C(Boron Carbide) control rods fully inserted.

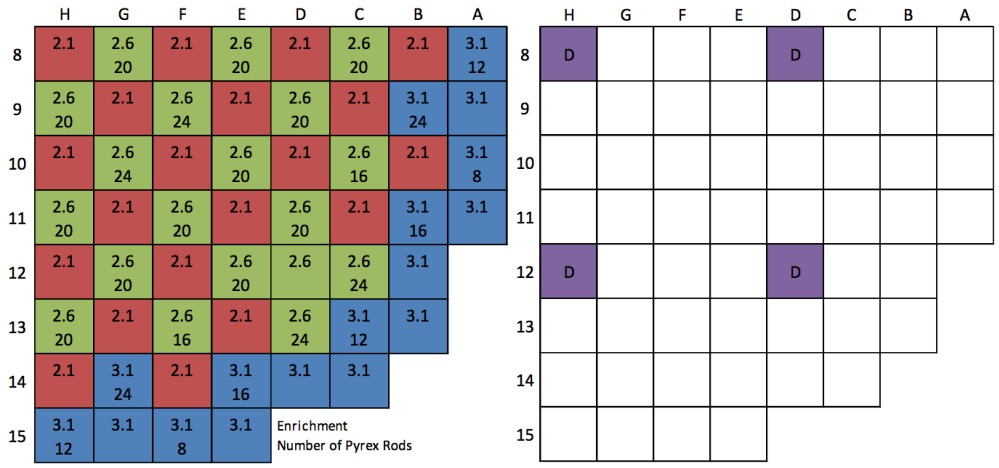

Figure 3: Case 5 layout

3.2 MCNP Model Verification

Problem 1c was firstly run to verify the correctness for our MCNP model of VERA problems. The case was run with reflective boundaries.

Table 2: 1c: Energy Deposition Summary(MeV/fission)

	n+fg	prompt gamma	capture gamma	delayed gamma	beta	total
mod	3.073e+00 +- 4.345e-04	3.156e-01 +- 4.464e-05	3.110e-01 +- 7.675e-05	3.089e-01 +- 4.369e-05	0	4.008e+00 +- 4.456e-04
he	2.156e-05 +- 3.050e-09	1.884e-06 +- 2.664e-10	1.842e-06 +- 4.564e-10	1.844e-06 +- 2.607e-10	0	2.713e-05 +- 3.106e-09
zirc	3.050e-02 +- 4.313e-06	5.674e-01 +- 8.024e-05	5.494e-01 +- 1.368e-04	5.553e-01 +- 7.853e-05	0	1.703e+00 +- 1.770e-04
U31	1.695e+02 +- 2.398e-02	5.686e+00 +- 8.042e-04	4.828e+00 +- 1.289e-03	5.565e+00 +- 7.871e-04	6.651e+00 +- 9.406e-04	1.923e+02 +- 2.406e-02
total	1.726e+02 +- 2.398e-02	6.569e+00 +- 8.094e-04	5.688e+00 +- 1.299e-03	6.430e+00 +- 7.922e-04	6.651e+00 +- 9.406e-04	1.980e+02 +- 2.406e-02
k-corrected	1.732e+02 +- 2.81e-02	6.569e+00 +- 8.094e-04	6.664e+00 +- 1.44e-03	6.430e+00 +- 7.922e-04	6.651e+00 +- 9.406e-04	1.995e+02 +- 2.822e-02
ENDF	173.97	6.57	-	6.33	6.65	-
Note: All the material abbreviations are material names from VERAIN files. So do the names in other figures and tables in this report.						

Table 2 summarizes each form of energy deposition in each material. As shown in the table, with k_{eff} correction, the simulation results are close to the ENDF reference, which affirms the correctness of our modeling.

3.3 Results of Energy Deposition

3.3.1 Heat Deposition by Material

In the MPACT and CTF coupled calculation, we assume that majority of the fission energy is deposited locally in the fuel rod, and only a small fraction (typically 2.6%) of the fission energy is directly deposited into the coolant subchannels around a fuel rod, which primarily

includes the neutron slowing-down energy and gamma energy deposited in the coolant. The heat sources from other materials, such as control rod, and structure materials are neglected. In this section, the heat deposition is investigated in terms of materials to verify the approximations used in MPACT and CTF coupled calculation.

Table 3: VERA Problem 2 Energy Deposited in each Material(MeV/fission)

	2b(UO2)	2f(Pyrex)	2g(AIC)	2h(B4C)	2m(IFBA)	2p(Gad)
fuel	1.917e+02 +- 1.970e-02	1.922e+02 +- 2.113e-02	1.933e+02 +- 2.213e-02	1.930e+02 +- 2.801e-02	1.923e+02 +- 2.113e-02	1.953e+02 +- 2.254e-02
he	2.499e-05 +- 2.234e-09	4.903e-05 +- 5.633e-09	3.293e-05 +- 3.191e-09	3.782e-05 +- 4.639e-09	2.684e-05 +- 2.559e-09	3.007e-05 +- 2.930e-09
mod	4.284e+00 +- 2.999e-04	4.971e+00 +- 3.767e-04	5.509e+00 +- 4.359e-04	5.775e+00 +- 5.951e-04	5.348e+00 +- 4.046e-04	5.697e+00 +- 4.474e-04
zirc	1.777e+00 +- 1.503e-04	1.828e+00 +- 1.640e-04	1.992e+00 +- 1.823e-04	1.907e+00 +- 2.229e-04	1.837e+00 +- 1.657e-04	2.258e+00 +- 2.089e-04
poison	0	9.583e-01 +- 2.383e-04	4.293e+00 +- 1.248e-03	2.267e+00 +- 7.116e-04	1.029e+00 +- 1.721e-04	0
others	0	1.696e-01 +- 4.036e-05	3.303e-01 +- 8.173e-05	2.998e-01 +- 9.808e-05	0	0
total	1.977e+02 +- 1.970e-02	2.001e+02 +- 2.113e-02	2.055e+02 +- 2.217e-02	2.032e+02 +- 2.803e-02	2.005e+02 +- 2.113e-02	2.032e+02 +- 2.255e-02

Table 4: VERA Problem 2 Energy Deposited in each Material in Percentage

	2b(UO2)	2f(Pyrex)	2g(AIC)	2h(B4C)	2m(IFBA)	2p(Gad)
fuel	96.93 +- 0.01 %	96.04 +- 0.01 %	94.10 +- 0.01 %	94.96 +- 0.02 %	95.90 +- 0.01 %	96.08 +- 0.02%
he	0.00 +- 0.00 %	0.00 +- 0.00 %	0.00 +- 0.00 %	0.00 +- 0.00 %	0.00 +- 0.00 %	0.00 +- 0.00 %
mod	2.17 +- 0.00 %	2.48 +- 0.00 %	2.68 +- 0.00 %	2.84 +- 0.00 %	2.67 +- 0.00 %	2.80 +- 0.00 %
zirc	0.90 +- 0.00 %	0.91 +- 0.00 %	0.97 +- 0.00 %	0.94 +- 0.00 %	0.92 +- 0.00 %	1.11 +- 0.00 %
poison	0	0.48 +- 0.00 %	2.09 +- 0.00 %	1.12 +- 0.00 %	0.51 +- 0.00 %	0
others	0	0.08 +- 0.00 %	0.16 +- 0.00 %	0.15 +- 0.00 %	0	0
total	100%	100%	100%	100%	100%	100%

Table 3 and 4 above show the material separated energy deposition information in absolute value and fraction respectively. As poisons are present, there is more energy deposited in regions other than fuel rods, due to the energy produced by neutron capture. A similar trend is also observed in 2p of gadolinium integrated fuel, because of the smearing effect of capture gamma over all material regions.

For the 2-D quarter core cases, in addition to the energy transport and deposition inside the core, energy leakage also occurs in these cases. Energy distribution data is attached in Table 5 and 6 below.

Table 5: VERA Problem 5 Energy Deposited in each Material(MeV/fission)

	5a	5b(AIC)	5c(B4C)
Control Rod	0	1.365E-01 +- 1.880E-04	6.130E-02 +- 5.947E-05
he	3.424E-05 +- 6.034E-09	3.443E-05 +- 6.105E-09	3.450E-05 +- 4.753E-09
mod	5.054E+00 +- 7.233E-04	5.073E+00 +- 7.401E-04	5.074E+00 +- 5.710E-04
pyrex-vera	3.790E-01 +- 1.464E-04	3.734E-01 +- 1.462E-04	3.727E-01 +- 1.133E-04
ss	6.310E-02 +- 2.648E-05	7.183E-02 +- 2.939E-05	7.000E-02 +- 2.237E-05
zirc	1.811E+00 +- 3.051E-04	1.815E+00 +- 3.081E-04	1.812E+00 +- 2.389E-04
Fuel Rod	1.920E+02 +- 2.756E-02	1.920E+02 +- 2.801E-02	1.920E+02 +- 2.174E-02
Outside Core	5.573E-01 +- 3.066E-04	6.577E-01 +- 3.292E-04	6.683E-01 +- 2.570E-04
total	1.999E+02 +- 2.758E-02	2.002E+02 +- 2.803E-02	2.002E+02 +- 2.803E-02

Table 6: VERA Problem 5 Energy Deposited in each Material in Percentage

	5a		5b(AIC)		5c(B4C)	
Control Rod		0	0.07 +-	0.00%	0.03 +-	0.00%
he	0.00 +-	0.00%	0.00 +-	0.00%	0.00 +-	0.00%
mod	2.53 +-	0.00%	2.53 +-	0.00%	2.54 +-	0.00%
pyrex-vera	0.19 +-	0.00%	0.19 +-	0.00%	0.19 +-	0.00%
ss	0.03 +-	0.00%	0.04 +-	0.00%	0.03 +-	0.00%
zirc	0.91 +-	0.00%	0.91 +-	0.00%	0.91 +-	0.00%
Fuel Rod	96.06 +-	0.01%	95.94 +-	0.02%	95.97 +-	0.02%
Outside Core	0.26 +-	0.00%	0.31 +-	0.00%	0.33 +-	0.00%
total		100.00%		100%		100%

As shown in these tables, about 0.3% of the energy released is deposited outside the core lattice area, including baffle, vessels, barrels and reflector regions. The energy deposition fractions of the materials inside the core are similar to the results from problem 2, i.e., the cases with control rods have slightly less energy deposited in fuel rods.

We also investigate the change of energy deposition fractions over fuel burnup by calculating the depletion snapshots of Problem 1c, as shown in Table 7. As burnup increases, less energy will be deposited in fuel rods and more will be deposited in structural materials and moderators. This is due to the intensive neutron captures from fission products, generating more gamma rays. For example, at 60 GWD/tU, more than 14 MeV of capture gamma may be produced per fission reaction, as compared to 5.83 MeV for a fresh fuel case.

Table 7: 1c Energy Deposited in Different Materials at Different Burnups Stages

	0(GWD/tU)	0.1(GWD/tU)	1(GWD/tU)	10(GWD/tU)	20(GWD/tU)	30(GWD/tU)	40(GWD/tU)	50(GWD/tU)	60(GWD/tU)
mod	2.02 +- 0.00 %	2.07 +- 0.00 %	2.10 +- 0.00 %	2.31 +- 0.00 %	2.51 +- 0.00 %	2.70 +- 0.00 %	2.87 +- 0.00 %	3.01 +- 0.00 %	3.13 +- 0.00 %
he	0.00 +- 0.00 %	0.00 +- 0.00 %	0.00 +- 0.00 %	0.00 +- 0.00 %	0.00 +- 0.00 %	0.00 +- 0.00 %	0.00 +- 0.00 %	0.00 +- 0.00 %	0.00 +- 0.00 %
zirc	0.86 +- 0.00 %	0.86 +- 0.00 %	0.87 +- 0.00 %	0.95 +- 0.00 %	1.01 +- 0.00 %	1.07 +- 0.00 %	1.12 +- 0.00 %	1.17 +- 0.00 %	1.21 +- 0.00 %
fuel	97.12 +- 0.02 %	97.07 +- 0.02 %	97.03 +- 0.02 %	96.75 +- 0.02 %	96.47 +- 0.02 %	96.23 +- 0.03 %	96.01 +- 0.03 %	95.82 +- 0.03 %	95.66 +- 0.03 %

From the aforementioned results, the 2-D assembly calculations indicate a variation of the coolant heating fraction (2.1-2.9%) due to the different poison types. For a whole core calculation, the 2.6% direct coolant heating fraction used in MPACT and CTF coupled calculation is a reasonable approximation according to Table 6, but it would be desirable to allow the burnup dependence of this fraction, as suggested by Table 7. More importantly, the energy deposited in the poison material regions is non-trivial as indicated in Table 4, especially for the cases with control rods. In the next section, the spatial heat distribution will be investigated to show the local heat source of these control rods.

3.3.2 Spatial Distribution

This section covers how different forms of energy are spatially distributed across assemblies(Problem 2) and cores(Problem 5). The fission rate, total heat deposition and gamma energy deposition are compared to study the smearing effect caused by gamma heating.

Figures 4 to 9 show the normalized fission rate, heat deposition and gamma deposition of Problem 2 cases with each block representing a pin cell. The normalization is done independently for the fission rate, total heat deposition and gamma energy deposition, such that the average of the 264 fuel pin cells is equal to unity. The normalization factor is then applied to the non-fuel pins as well.

For 2-D lattices, the fission rate distribution is mostly affected by the location of poisons. The energy deposition generally has the similar distribution patterns as fission rate, because the majority of the fission energy release is locally deposited. Due to the gamma smearing effect (non-local gamma deposition tends to flatten the gamma energy deposition), the overall energy deposition is slightly flatter than the fission rate distribution. As mentioned in the previous section, for some cases the energy deposited in the non-fuel regions is not negligible. For example, in Problem 2g(AIC), the energy deposited in an AIC control rod is approximately 1/4 of that of a fuel pin cell, indicating that the heat source from a control rod should be modeled in order to obtain the more accurate temperature distributions from the T/H calculation. This may require gamma transport capability in MPACT.

Also, we can compare the fission rate distribution with the gamma heating distribution to investigate the possible approach of a simplified gamma smearing scheme (without solving the gamma transport) in order to obtain a more consistent pin power distribution. This has been investigated in a separate effort [5].

0.000								
0.038								
0.165								
1.037	1.011							
1.035	1.011							
1.017	1.012							
1.037	1.014	1.014						
1.035	1.014	1.014						
1.017	1.012	1.012						
0.000	1.035	1.036	0.000					
0.038	1.034	1.034	0.038					
0.165	1.016	1.017	0.165					
1.037	1.011	1.013	1.041	1.032				
1.034	1.011	1.013	1.039	1.030				
1.014	1.009	1.009	1.016	1.013				
1.029	1.005	1.009	1.040	1.048	0.000			
1.028	1.006	1.009	1.037	1.045	0.038			
1.011	1.006	1.008	1.014	1.014	0.163			
0.000	1.024	1.025	0.000	1.033	1.014	0.975		
0.038	1.022	1.023	0.038	1.030	1.012	0.977		
0.163	1.007	1.006	0.163	1.006	1.000	0.989		
1.011	0.989	0.988	1.010	0.983	0.965	0.949	0.941	
1.011	0.990	0.989	1.009	0.985	0.968	0.953	0.945	
1.005	0.998	0.998	0.999	0.993	0.988	0.980	0.974	
0.977	0.974	0.972	0.974	0.966	0.954	0.947	0.941	0.949
0.979	0.976	0.975	0.976	0.969	0.958	0.951	0.945	0.952
0.995	0.992	0.990	0.990	0.985	0.982	0.977	0.974	0.973

From the top to tbe bottom: Normalized fission rate; heat deposition and total gamma

Maximum Standard deviations below:

Normalized fission rate: 1.52e-03

Normalized fuel heat: 1.31e-03

Normalized total gamma deposition: 8.77e-04

Figure 4: 2b(UO2): Comparison of Normalized Fission Rate, Heat Deposition and Gamma Deposition. Uncertainties are in Absolute Value.

0.000								
0.045								
0.171								
1.078	1.043							
1.070	1.038							
1.004	0.997							
0.971	0.992	0.973						
0.973	0.991	0.974						
0.984	0.983	0.976						
0.000	0.932	0.926	0.000					
0.088	0.937	0.930	0.086					
0.286	0.967	0.964	0.284					
0.925	0.958	0.955	0.911	0.926				
0.930	0.960	0.957	0.917	0.931				
0.967	0.972	0.970	0.963	0.970				
0.927	0.961	0.958	0.912	0.905	0.000			
0.932	0.963	0.960	0.918	0.913	0.088			
0.970	0.976	0.975	0.966	0.973	0.290			
0.000	0.942	0.941	0.000	0.934	0.965	1.035		
0.088	0.946	0.945	0.088	0.941	0.969	1.034		
0.288	0.979	0.979	0.289	0.990	1.002	1.023		
0.973	1.006	1.005	0.980	1.019	1.049	1.084	1.110	
0.975	1.005	1.004	0.982	1.018	1.046	1.079	1.104	
0.993	0.997	0.999	1.000	1.014	1.027	1.045	1.058	
1.046	1.054	1.055	1.057	1.075	1.092	1.115	1.136	1.153
1.042	1.049	1.051	1.052	1.070	1.086	1.108	1.129	1.144
1.010	1.013	1.014	1.018	1.029	1.043	1.056	1.069	1.077

From the top to tbe bottom: Normalized fission rate; heat deposition and total gamma
Maximum Standard deviations below:
Normalized fission rate: 1.85e-03
Normalized fuel heat: 1.58e-03
Normalized total gamma deposition: 9.85e-04

Figure 5: 2f(Pyrex): Comparison of Normalized Fission Rate, Heat Deposition and Gamma Deposition Uncertainties are in Absolute Value.

0.000								
0.048								
0.169								
1.074	1.037							
1.063	1.030							
0.987	0.982							
0.939	0.964	0.940						
0.942	0.964	0.943						
0.970	0.968	0.963						
0.000	0.884	0.875	0.000					
0.279	0.892	0.884	0.272					
0.777	0.952	0.950	0.774					
0.872	0.918	0.915	0.852	0.871				
0.881	0.923	0.921	0.863	0.882				
0.950	0.959	0.958	0.950	0.963				
0.877	0.927	0.921	0.856	0.851	0.000			
0.886	0.932	0.926	0.868	0.865	0.285			
0.955	0.964	0.963	0.954	0.970	0.808			
0.000	0.906	0.908	0.000	0.907	0.966	1.069		
0.284	0.914	0.915	0.285	0.917	0.971	1.065		
0.790	0.972	0.974	0.798	0.992	1.008	1.036		
0.963	1.005	1.011	0.977	1.042	1.095	1.155	1.200	
0.966	1.004	1.009	0.980	1.039	1.089	1.144	1.186	
0.992	0.998	1.002	1.005	1.023	1.038	1.066	1.084	
1.071	1.079	1.082	1.089	1.123	1.161	1.205	1.239	1.271
1.063	1.071	1.074	1.080	1.114	1.148	1.190	1.222	1.251
1.006	1.014	1.018	1.020	1.043	1.059	1.080	1.099	1.113

From the top to tbe bottom: Normalized fission rate; heat deposition and total gamma
Maximum Standard deviations below:
Normalized fission rate: 2.03e-03
Normalized fuel heat: 1.73e-03
Normalized total gamma deposition: 1.02e-03

Figure 6: 2g(AIC): Comparison of Normalized Fission Rate, Heat Deposition and Gamma Deposition. Uncertainties are in Absolute Value.

0.000								
0.049								
0.165								
1.062	1.023							
1.051	1.016							
0.972	0.967							
0.924	0.950	0.923						
0.927	0.950	0.926						
0.950	0.951	0.945						
0.000	0.863	0.854	0.000					
0.166	0.872	0.864	0.163					
0.336	0.933	0.929	0.333					
0.854	0.902	0.891	0.831	0.852				
0.864	0.907	0.897	0.843	0.864				
0.932	0.940	0.938	0.933	0.948				
0.858	0.910	0.903	0.837	0.837	0.000			
0.868	0.915	0.909	0.850	0.852	0.172			
0.940	0.952	0.951	0.940	0.962	0.353			
0.000	0.894	0.897	0.000	0.902	0.970	1.094		
0.171	0.902	0.906	0.171	0.913	0.975	1.090		
0.345	0.960	0.966	0.349	0.991	1.015	1.058		
0.959	1.002	1.012	0.980	1.051	1.115	1.181	1.241	
0.963	1.001	1.010	0.983	1.049	1.108	1.171	1.226	
0.990	0.994	1.003	1.005	1.032	1.054	1.093	1.119	
1.076	1.085	1.093	1.099	1.141	1.187	1.239	1.280	1.317
1.068	1.077	1.085	1.091	1.130	1.174	1.224	1.263	1.297
1.008	1.016	1.022	1.030	1.056	1.085	1.116	1.140	1.157

From the top to tbe bottom: Normalized fission rate; heat deposition and total gamma
Maximum Standard deviations below:
Normalized fission rate: 2.64e-03
Normalized fuel heat: 2.24e-03
Normalized total gamma deposition: 1.36e-03

Figure 7: 2h(B4C): Comparison of Normalized Fission Rate, Heat Deposition and Gamma Deposition. Uncertainties are in Absolute Value.

0.000								
0.045								
0.172								
0.982	1.038							
0.991	1.029							
1.003	1.005							
0.981	1.040	1.039						
0.989	1.031	1.030						
1.002	1.005	1.004						
0.000	0.985	0.983	0.000					
0.045	0.992	0.991	0.045					
0.172	1.003	1.001	0.171					
0.981	1.037	1.036	0.978	1.021				
0.989	1.028	1.027	0.986	1.013				
1.002	1.005	1.004	0.999	0.999				
0.981	1.038	1.035	0.970	0.969	0.000			
0.989	1.029	1.026	0.979	0.978	0.044			
1.002	1.004	1.003	0.998	0.997	0.170			
0.000	0.977	0.977	0.000	0.970	0.964	1.003		
0.045	0.986	0.985	0.045	0.979	0.973	0.997		
0.171	0.999	0.999	0.171	0.997	0.996	0.996		
0.973	1.016	1.030	0.978	1.013	1.014	0.946	1.014	
0.981	1.009	1.022	0.986	1.007	1.008	0.957	1.008	
0.997	0.998	1.001	1.000	0.998	0.998	0.993	0.999	
1.009	0.943	1.033	1.028	0.947	1.030	1.039	1.029	0.943
1.003	0.955	1.025	1.020	0.958	1.022	1.030	1.022	0.955
0.996	0.990	1.002	1.002	0.993	1.004	1.006	1.005	0.994

From the top to tbe bottom: Normalized fission rate; heat deposition and total gamma
Maximum Standard deviations below:
Normalized fission rate: 1.56e-03
Normalized fuel heat: 1.33e-03
Normalized total gamma deposition: 9.10e-04

Figure 8: 2m(IFBA): Comparison of Normalized Fission Rate, Heat Deposition and Gamma Deposition. Uncertainties are in Absolute Value.

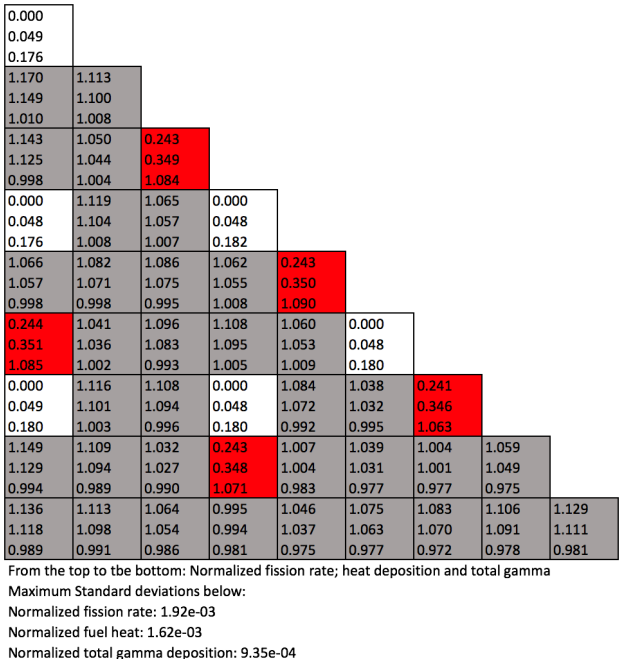

Figure 9: 2p(Gad): Comparison of Normalized Fission Rate, Heat Deposition and Gamma Deposition. Uncertainties are in Absolute Value.

For the 2-D quarter core cases, the energy distributions are tallied on the assembly level rather than fuel pin level. As shown in Figures 10-12, the assembly-wise gamma heat distribution is relatively flatter comparing to fission rate and heat deposition, but the gamma smearing effect is reduced across the assemblies with different enrichments. As discussed in [5], a single gamma smearing factor across the whole core is not possible, and the fission rate (primary source of gamma) effect should be included into the determination of gamma smearing factors. Also, for the assemblies near the reflector, the energy deposition is lower than one might expect from the smearing effect, and gamma heat is even more lower because of the leakage of gamma rays. As mentioned in section 3.3.1, approximately 0.3% of the total energy leaked out of the core, in which about two-thirds are carried away by gamma rays (see Tables 14-16).

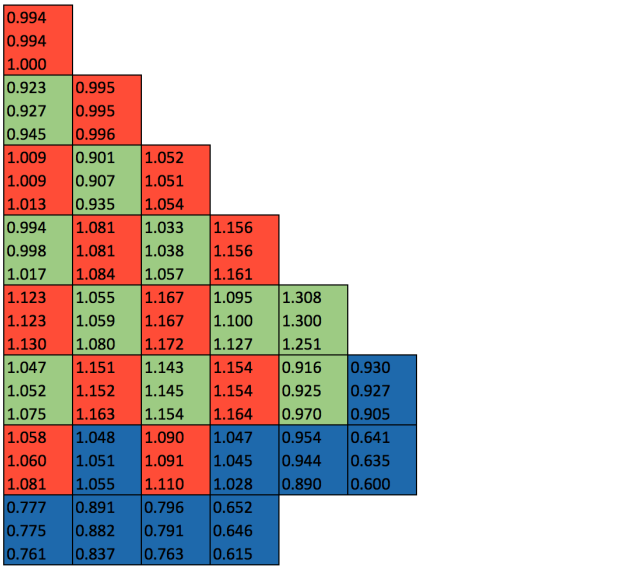

Figure 10: 5a-2d: Comparison of Normalized Fission Rate, Heat Deposition and Gamma Deposition. Uncertainties are given in absolute values.

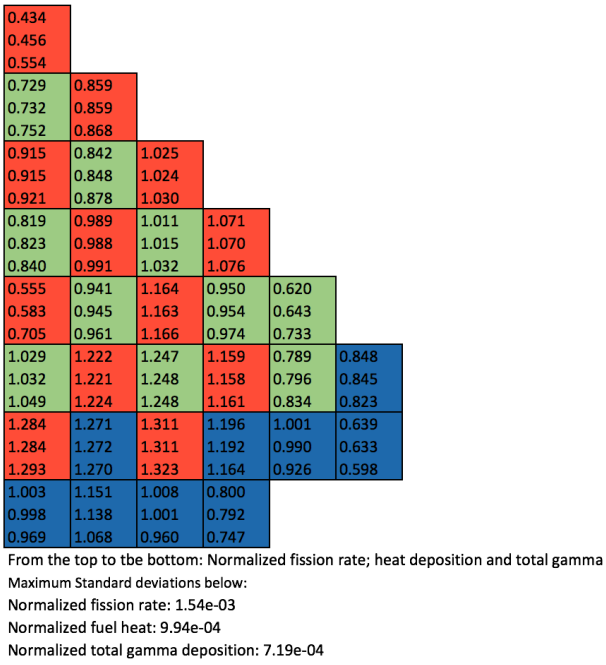

Figure 11: 5b-2d: Comparison of Normalized Fission Rate, Heat Deposition and Gamma Deposition. Uncertainties are given in absolute values.

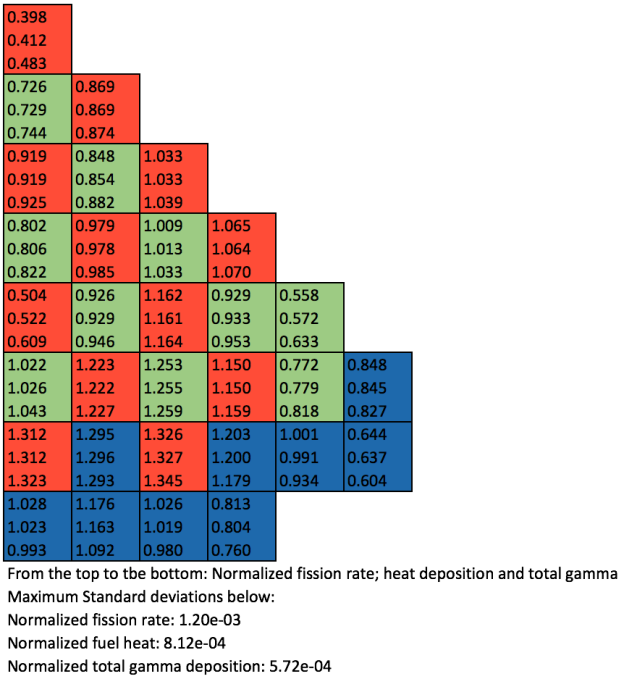

Figure 12: 5c-2d: Comparison of Normalized Fission Rate, Heat Deposition and Gamma Deposition. Uncertainties are given in absolute values.

4 Conclusions

In this work, a set of energy deposition benchmark problems were created based on the VERA Progression Problems. A well-defined scheme for energy deposition tally for MCNP5 has been used in this study for the energy deposition. The spatial distribution of energy deposition has been generated in terms of various energy forms available in MCNP calculation. These benchmark results will be useful to verify the ongoing development of energy deposition methods in MPACT.

Analysis of the benchmark results shows that the direct coolant heating fraction of 2.6% used in MPACT/CTF coupled calculation is a reasonable approximation for a fresh whole core calculation, but it would be desirable to allow the burnup dependence of this fraction. As suggested by the results of 2-D assembly calculations, the energy deposited in the non-fuel regions is non-trivial, especially for the cases with control rods. For example, in Problem 2g (AIC), the energy deposited in an AIC control rod is approximately 1/4 of that of a fuel pin cell, indicating that the heat source from a control rod should be explicitly modeled in order to obtain the more accurate temperature distributions from T/H calculation. By comparing the fission rate distribution with the gamma heating distribution, the possible approach of a simplified gamma smearing scheme (without solving the gamma transport) can be investigated using the benchmark results. Although the gamma heat is evenly smeared over the fuel pins of a 2-D assembly, the whole core calculation will require a more sophisticated gamma smearing scheme to account for the change of gamma source due to the fission rate difference in different assemblies, which is currently under development

in another RTM milestone(L3:RTM.XSN.P15.01). For the future interest of developing deterministic neutron/photon coupled transport calculation in MPACT, the data presented in this benchmark problem can also be used for verification.

Appendix A Benchmark Results

The detailed spatial distribution data of energy deposition by materials are provided in terms of energy forms, including fission fragments and neutron, beta, prompt gamma, delayed gamma, capture gamma, total gamma and total energy. These data are normalized such that the average fuel pin (for Problem 2) and the average assembly (for Problem 5 2D) energy deposition is equal to the overall energy deposition per fission, which is roughly 200MeV, and uncertainties are all given in absolute values. Also, the spatial integrated energy of each material is also included. The results of depleted cases of 1c are attached at the end.

m:5.96 z:1.53								
U:198.4 h:0.00 m:3.68 z:1.65	U:193.8 h:0.00 m:3.69 z:1.65							
U:198.4 h:0.00 m:3.68 z:1.66	U:194.4 h:0.00 m:3.69 z:1.65	U:194.4 h:0.00 m:3.69 z:1.65						
m:5.96 z:1.52	U:198.2 h:0.00 m:3.68 z:1.65	U:198.4 h:0.00 m:3.68 z:1.65	m:5.96 z:1.52					
U:198.3 h:0.00 m:3.68 z:1.65	U:193.8 h:0.00 m:3.68 z:1.65	U:194.1 h:0.00 m:3.68 z:1.64	U:199.2 h:0.00 m:3.68 z:1.65	U:197.6 h:0.00 m:3.67 z:1.65				
U:197.0 h:0.00 m:3.67 z:1.64	U:192.7 h:0.00 m:3.68 z:1.64	U:193.4 h:0.00 m:3.68 z:1.64	U:198.9 h:0.00 m:3.68 z:1.65	U:200.4 h:0.00 m:3.66 z:1.65	m:5.93 z:1.51			
m:5.94 z:1.51	U:196.0 h:0.00 m:3.67 z:1.64	U:196.2 h:0.00 m:3.67 z:1.64	m:5.93 z:1.51	U:197.5 h:0.00 m:3.66 z:1.64	U:194.1 h:0.00 m:3.66 z:1.63	U:187.0 h:0.00 m:3.66 z:1.62		
U:193.7 h:0.00 m:3.66 z:1.64	U:189.6 h:0.00 m:3.67 z:1.63	U:189.5 h:0.00 m:3.66 z:1.63	U:193.4 h:0.00 m:3.66 z:1.63	U:188.6 h:0.00 m:3.66 z:1.62	U:185.3 h:0.00 m:3.66 z:1.62	U:182.3 h:0.00 m:3.65 z:1.61	U:180.8 h:0.00 m:3.64 z:1.60	
U:187.5 h:0.00 m:3.67 z:1.63	U:186.9 h:0.00 m:3.66 z:1.63	U:186.6 h:0.00 m:3.66 z:1.62	U:186.9 h:0.00 m:3.66 z:1.62	U:185.5 h:0.00 m:3.66 z:1.61	U:183.4 h:0.00 m:3.65 z:1.61	U:182.0 h:0.00 m:3.65 z:1.60	U:180.9 h:0.00 m:3.64 z:1.60	U:182.3 h:0.00 m:3.63 z:1.60

Maximum Standard deviations below:

U:2.59e-01	h:2.85e-08	m:2.59e-03	z:1.90e-03

Legend:

U:U31	h:he	m:mod	z:zirc

Figure 13: 2b(UO2): Fuel Pin Number Normalized Total Energy Distribution Material Separated (MeV/fission)

m:4.49 z:0.03								
U:175.8 h:0.00 m:2.77 z:0.03	U:171.4 h:0.00 m:2.78 z:0.03							
U:175.7 h:0.00 m:2.78 z:0.03	U:171.9 h:0.00 m:2.78 z:0.03	U:171.9 h:0.00 m:2.78 z:0.03						
m:4.49 z:0.03	U:175.5 h:0.00 m:2.78 z:0.03	U:175.7 h:0.00 m:2.78 z:0.03	m:4.49 z:0.03					
U:175.7 h:0.00 m:2.77 z:0.03	U:171.4 h:0.00 m:2.78 z:0.03	U:171.7 h:0.00 m:2.78 z:0.03	U:176.5 h:0.00 m:2.77 z:0.03	U:175.0 h:0.00 m:2.77 z:0.03				
U:174.5 h:0.00 m:2.77 z:0.03	U:170.4 h:0.00 m:2.78 z:0.03	U:171.0 h:0.00 m:2.78 z:0.03	U:176.3 h:0.00 m:2.77 z:0.03	U:177.7 h:0.00 m:2.76 z:0.03	m:4.47 z:0.03			
m:4.47 z:0.02	U:173.5 h:0.00 m:2.77 z:0.03	U:173.8 h:0.00 m:2.77 z:0.03	m:4.47 z:0.03	U:175.0 h:0.00 m:2.76 z:0.03	U:171.8 h:0.00 m:2.77 z:0.03	U:165.2 h:0.00 m:2.77 z:0.03		
U:171.4 h:0.00 m:2.77 z:0.03	U:167.6 h:0.00 m:2.77 z:0.03	U:167.4 h:0.00 m:2.77 z:0.03	U:171.2 h:0.00 m:2.77 z:0.03	U:166.6 h:0.00 m:2.77 z:0.03	U:163.6 h:0.00 m:2.77 z:0.03	U:160.8 h:0.00 m:2.77 z:0.03	U:159.5 h:0.00 m:2.76 z:0.03	
U:165.6 h:0.00 m:2.77 z:0.03	U:165.1 h:0.00 m:2.77 z:0.03	U:164.8 h:0.00 m:2.77 z:0.03	U:165.1 h:0.00 m:2.77 z:0.03	U:163.8 h:0.00 m:2.77 z:0.03	U:161.8 h:0.00 m:2.77 z:0.03	U:160.6 h:0.00 m:2.76 z:0.03	U:159.6 h:0.00 m:2.76 z:0.03	U:160.9 h:0.00 m:2.75 z:0.03

Maximum Standard deviations below:

U:2.58e-01	h:2.75e-08	m:2.35e-03	z:5.17e-05

Legend:

U:U31	h:he	m:mod	z:zirc

Figure 14: 2b(UO2): Fuel Pin Number Normalized Energy by Fragments and Neutrons (MeV/fission)

m:0.51 z:0.52								
U:5.72 h:0.00 m:0.31 z:0.57	U:5.68 h:0.00 m:0.31 z:0.56							
U:5.73 h:0.00 m:0.31 z:0.57	U:5.69 h:0.00 m:0.31 z:0.57	U:5.68 h:0.00 m:0.31 z:0.57						
m:0.51 z:0.52	U:5.72 h:0.00 m:0.31 z:0.56	U:5.72 h:0.00 m:0.31 z:0.57	m:0.51 z:0.52					
U:5.71 h:0.00 m:0.31 z:0.57	U:5.67 h:0.00 m:0.31 z:0.56	U:5.66 h:0.00 m:0.31 z:0.56	U:5.72 h:0.00 m:0.31 z:0.56	U:5.70 h:0.00 m:0.31 z:0.56				
U:5.68 h:0.00 m:0.31 z:0.56	U:5.66 h:0.00 m:0.31 z:0.56	U:5.66 h:0.00 m:0.31 z:0.56	U:5.71 h:0.00 m:0.31 z:0.56	U:5.70 h:0.00 m:0.31 z:0.56	m:0.50 z:0.51			
m:0.50 z:0.51	U:5.66 h:0.00 m:0.31 z:0.56	U:5.66 h:0.00 m:0.31 z:0.56	m:0.50 z:0.51	U:5.65 h:0.00 m:0.31 z:0.56	U:5.60 h:0.00 m:0.31 z:0.56	U:5.53 h:0.00 m:0.31 z:0.55		
U:5.63 h:0.00 m:0.31 z:0.56	U:5.59 h:0.00 m:0.31 z:0.56	U:5.60 h:0.00 m:0.31 z:0.56	U:5.61 h:0.00 m:0.31 z:0.56	U:5.56 h:0.00 m:0.31 z:0.55	U:5.52 h:0.00 m:0.31 z:0.55	U:5.46 h:0.00 m:0.30 z:0.55	U:5.44 h:0.00 m:0.30 z:0.54	
U:5.57 h:0.00 m:0.31 z:0.56	U:5.55 h:0.00 m:0.31 z:0.56	U:5.55 h:0.00 m:0.31 z:0.55	U:5.54 h:0.00 m:0.31 z:0.55	U:5.52 h:0.00 m:0.31 z:0.55	U:5.48 h:0.00 m:0.30 z:0.55	U:5.46 h:0.00 m:0.30 z:0.55	U:5.43 h:0.00 m:0.30 z:0.54	U:5.43 h:0.00 m:0.30 z:0.54

Maximum Standard deviations below:

U:7.61e-03	h:5.21e-09	m:4.95e-04	z:9.24e-04

Legend:

U:U31	h:he	m:mod	z:zirc

Figure 15: 2b(UO2): Fuel Pin Number Normalized Prompt Gamma Distribution (MeV/fission)

m:0.47 z:0.47								
U:4.48 h:0.00 m:0.29 z:0.51	U:4.47 h:0.00 m:0.29 z:0.51							
U:4.47 h:0.00 m:0.29 z:0.51	U:4.46 h:0.00 m:0.29 z:0.51	U:4.47 h:0.00 m:0.29 z:0.51						
m:0.47 z:0.47	U:4.47 h:0.00 m:0.29 z:0.51	U:4.48 h:0.00 m:0.29 z:0.51	m:0.47 z:0.47					
U:4.45 h:0.00 m:0.29 z:0.51	U:4.45 h:0.00 m:0.29 z:0.51	U:4.46 h:0.00 m:0.29 z:0.50	U:4.47 h:0.00 m:0.29 z:0.51	U:4.48 h:0.00 m:0.29 z:0.51				
U:4.48 h:0.00 m:0.28 z:0.50	U:4.44 h:0.00 m:0.29 z:0.50	U:4.47 h:0.00 m:0.29 z:0.51	U:4.47 h:0.00 m:0.29 z:0.51	U:4.49 h:0.00 m:0.29 z:0.51	m:0.47 z:0.47			
m:0.47 z:0.47	U:4.45 h:0.00 m:0.29 z:0.51	U:4.44 h:0.00 m:0.29 z:0.50	m:0.47 z:0.47	U:4.47 h:0.00 m:0.29 z:0.51	U:4.45 h:0.00 m:0.29 z:0.50	U:4.41 h:0.00 m:0.28 z:0.50		
U:4.48 h:0.00 m:0.29 z:0.51	U:4.44 h:0.00 m:0.28 z:0.50	U:4.44 h:0.00 m:0.28 z:0.50	U:4.42 h:0.00 m:0.28 z:0.50	U:4.43 h:0.00 m:0.28 z:0.50	U:4.40 h:0.00 m:0.28 z:0.50	U:4.40 h:0.00 m:0.28 z:0.50	U:4.36 h:0.00 m:0.28 z:0.50	
U:4.42 h:0.00 m:0.28 z:0.50	U:4.43 h:0.00 m:0.28 z:0.50	U:4.40 h:0.00 m:0.28 z:0.50	U:4.39 h:0.00 m:0.28 z:0.50	U:4.38 h:0.00 m:0.28 z:0.50	U:4.39 h:0.00 m:0.28 z:0.50	U:4.37 h:0.00 m:0.28 z:0.50	U:4.37 h:0.00 m:0.28 z:0.50	U:4.37 h:0.00 m:0.28 z:0.50

Maximum Standard deviations below:

U:1.57e-02	h:7.70e-09	m:1.06e-03	z:1.91e-03

Legend:

U:U31	h:he	m:mod	z:zirc

Figure 16: 2b(UO2): Fuel Pin Number Normalized Capture Gamma Distribution (MeV/fission)

m:0.50 z:0.51								
U:5.59 h:0.00 m:0.31 z:0.55	U:5.55 h:0.00 m:0.31 z:0.55							
U:5.60 h:0.00 m:0.31 z:0.55	U:5.56 h:0.00 m:0.31 z:0.55	U:5.55 h:0.00 m:0.31 z:0.55						
m:0.50 z:0.51	U:5.59 h:0.00 m:0.31 z:0.55	U:5.59 h:0.00 m:0.31 z:0.55	m:0.50 z:0.51					
U:5.58 h:0.00 m:0.31 z:0.55	U:5.54 h:0.00 m:0.31 z:0.55	U:5.53 h:0.00 m:0.31 z:0.55	U:5.59 h:0.00 m:0.30 z:0.55	U:5.56 h:0.00 m:0.30 z:0.55				
U:5.55 h:0.00 m:0.30 z:0.55	U:5.53 h:0.00 m:0.30 z:0.55	U:5.53 h:0.00 m:0.30 z:0.55	U:5.58 h:0.00 m:0.30 z:0.55	U:5.57 h:0.00 m:0.30 z:0.55	m:0.49 z:0.50			
m:0.49 z:0.50	U:5.53 h:0.00 m:0.30 z:0.55	U:5.53 h:0.00 m:0.30 z:0.55	m:0.49 z:0.50	U:5.52 h:0.00 m:0.30 z:0.55	U:5.47 h:0.00 m:0.30 z:0.54	U:5.41 h:0.00 m:0.30 z:0.54		
U:5.50 h:0.00 m:0.30 z:0.55	U:5.46 h:0.00 m:0.30 z:0.54	U:5.47 h:0.00 m:0.30 z:0.54	U:5.48 h:0.00 m:0.30 z:0.54	U:5.43 h:0.00 m:0.30 z:0.54	U:5.39 h:0.00 m:0.30 z:0.54	U:5.34 h:0.00 m:0.30 z:0.53	U:5.31 h:0.00 m:0.30 z:0.53	
U:5.45 h:0.00 m:0.30 z:0.54	U:5.42 h:0.00 m:0.30 z:0.54	U:5.42 h:0.00 m:0.30 z:0.54	U:5.42 h:0.00 m:0.30 z:0.54	U:5.39 h:0.00 m:0.30 z:0.54	U:5.36 h:0.00 m:0.30 z:0.54	U:5.33 h:0.00 m:0.30 z:0.53	U:5.30 h:0.00 m:0.30 z:0.53	U:5.30 h:0.00 m:0.29 z:0.53

Maximum Standard deviations below:

U:7.44e-03	h:5.09e-09	m:4.83e-04	z:9.02e-04

Legend:

U:U31	h:he	m:mod	z:zirc

Figure 17: 2b(UO2): Fuel Pin Number Normalized Delayed Gamma Distribution (MeV/fission)

m:1.48 z:1.50								
U:15.80 h:0.00 m:0.91 z:1.63	U:15.70 h:0.00 m:0.91 z:1.63							
U:15.79 h:0.00 m:0.91 z:1.63	U:15.70 h:0.00 m:0.91 z:1.63	U:15.70 h:0.00 m:0.91 z:1.62						
	U:15.78 h:0.00 m:0.91 z:1.63	U:15.80 h:0.00 m:0.91 z:1.63						
m:1.47 z:1.50			m:1.47 z:1.50					
U:15.74 h:0.00 m:0.90 z:1.62	U:15.66 h:0.00 m:0.90 z:1.62	U:15.66 h:0.00 m:0.90 z:1.62	U:15.78 h:0.00 m:0.90 z:1.62	U:15.74 h:0.00 m:0.90 z:1.62				
U:15.70 h:0.00 m:0.90 z:1.62	U:15.62 h:0.00 m:0.90 z:1.61	U:15.65 h:0.00 m:0.90 z:1.62	U:15.75 h:0.00 m:0.90 z:1.62	U:15.76 h:0.00 m:0.90 z:1.62	m:1.46 z:1.48			
	U:15.64 h:0.00 m:0.90 z:1.62	U:15.62 h:0.00 m:0.90 z:1.61		U:15.63 h:0.00 m:0.90 z:1.61	U:15.53 h:0.00 m:0.89 z:1.60	U:15.35 h:0.00 m:0.89 z:1.59		
m:1.46 z:1.49			m:1.46 z:1.48					
U:15.60 h:0.00 m:0.90 z:1.61	U:15.48 h:0.00 m:0.90 z:1.60	U:15.50 h:0.00 m:0.89 z:1.60	U:15.51 h:0.00 m:0.89 z:1.60	U:15.41 h:0.00 m:0.89 z:1.60	U:15.32 h:0.00 m:0.89 z:1.59	U:15.20 h:0.00 m:0.88 z:1.58	U:15.10 h:0.00 m:0.88 z:1.57	
U:15.44 h:0.00 m:0.89 z:1.60	U:15.40 h:0.00 m:0.89 z:1.60	U:15.36 h:0.00 m:0.89 z:1.60	U:15.35 h:0.00 m:0.89 z:1.59	U:15.28 h:0.00 m:0.89 z:1.59	U:15.23 h:0.00 m:0.89 z:1.58	U:15.16 h:0.00 m:0.88 z:1.58	U:15.10 h:0.00 m:0.88 z:1.57	U:15.10 h:0.00 m:0.88 z:1.57

Maximum Standard deviations below:

U:1.57e-02	h:7.63e-09	m:1.06e-03	z:1.90e-03

Legend:

U:U31	h:he	m:mod	z:zirc

Figure 18: 2b(UO2): Fuel Pin Number Normalized Total Gamma Distribution (MeV/fission)

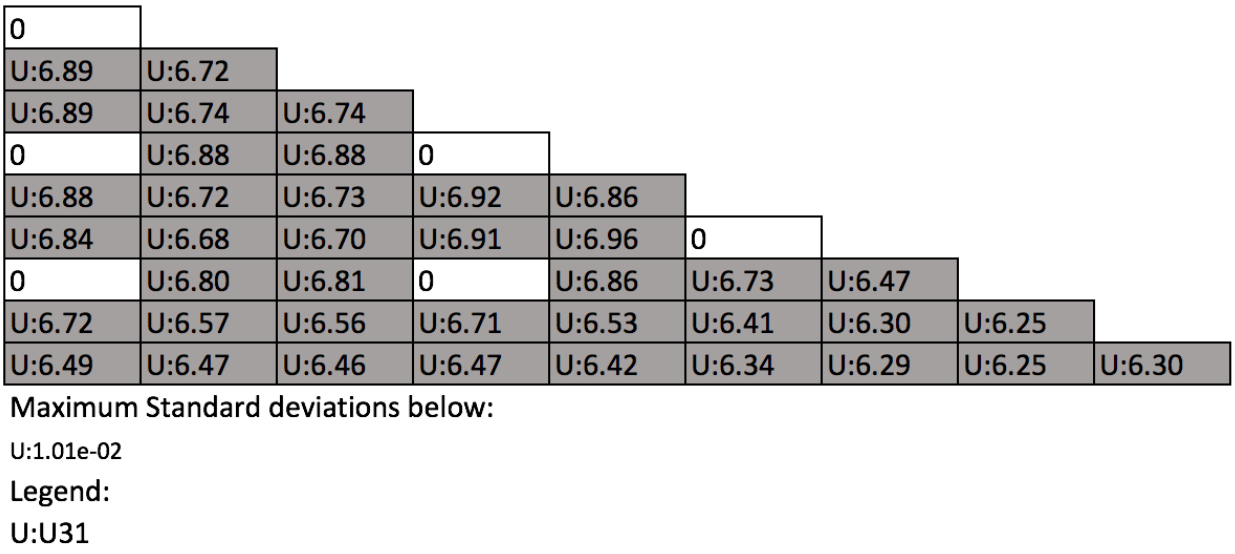

Figure 19: 2b(UO2): Fuel Pin Number Beta Distribution (MeV/fission)

Table 8: 2b(UO2): Energy Deposition Summary

	n+fg	prompt gamma	capture gamma	delayed gamma	beta	total	
U31	1.695e+02 +- 1.964e-02	5.608e+00 +- 6.248e-04	4.441e+00 +- 9.416e-04	5.479e+00 +- 6.103e-04	6.642e+00 +- 7.696e-04	1.917e+02 +- 1.970e-02	
he	1.957e-05 +- 2.165e-09	1.874e-06 +- 2.453e-10	1.714e-06 +- 4.312e-10	1.831e-06 +- 2.396e-10	0	2.499e-05 +- 2.234e-09	
mod	3.236e+00 +- 2.895e-04	3.612e-01 +- 3.808e-05	3.339e-01 +- 5.763e-05	3.529e-01 +- 3.720e-05	0	4.284e+00 +- 2.999e-04	
zirc	2.965e-02 +- 3.724e-06	6.060e-01 +- 7.032e-05	5.493e-01 +- 1.137e-04	5.920e-01 +- 6.869e-05	0	1.777e+00 +- 1.503e-04	
total	1.728e+02 +- 1.964e-02	6.576e+00 +- 6.299e-04	5.325e+00 +- 9.502e-04	6.423e+00 +- 6.153e-04	6.642e+00 +- 7.696e-04	1.977e+02 +- 1.970e-02	

m:7.32 z:1.55								
U:206.0 h:0.00 m:4.52 z:1.67	U:199.8 h:0.00 m:4.52 z:1.67							
U:186.9 h:0.00 m:4.46 z:1.66	U:190.5 h:0.00 m:4.48 z:1.65	U:187.1 h:0.00 m:4.45 z:1.64						
h:0.00 m:3.46 p:10.56 s:1.85 z:1.53	U:179.8 h:0.00 m:4.42 z:1.63	U:178.5 h:0.00 m:4.41 z:1.63	h:0.00 m:3.44 p:10.35 s:1.84 z:1.52					
U:178.5 h:0.00 m:4.41 z:1.63	U:184.3 h:0.00 m:4.44 z:1.63	U:183.8 h:0.00 m:4.44 z:1.63	U:175.9 h:0.00 m:4.40 z:1.62	U:178.6 h:0.00 m:4.41 z:1.63				
U:178.8 h:0.00 m:4.43 z:1.64	U:184.9 h:0.00 m:4.47 z:1.64	U:184.4 h:0.00 m:4.46 z:1.64	U:176.1 h:0.00 m:4.43 z:1.63	U:175.1 h:0.00 m:4.42 z:1.65	h:0.00 m:3.51 p:10.55 s:1.88 z:1.56			
h:0.00 m:3.49 p:10.58 s:1.87 z:1.55	U:181.6 h:0.00 m:4.47 z:1.65	U:181.4 h:0.00 m:4.47 z:1.65	h:0.00 m:3.50 p:10.59 s:1.87 z:1.55	U:180.5 h:0.00 m:4.49 z:1.67	U:186.0 h:0.00 m:4.56 z:1.69	U:198.8 h:0.00 m:4.66 z:1.72		
U:187.3 h:0.00 m:4.52 z:1.67	U:193.1 h:0.00 m:4.55 z:1.67	U:193.0 h:0.00 m:4.56 z:1.68	U:188.7 h:0.00 m:4.55 z:1.69	U:195.8 h:0.00 m:4.61 z:1.70	U:201.2 h:0.00 m:4.68 z:1.73	U:207.7 h:0.00 m:4.75 z:1.75	U:212.4 h:0.00 m:4.81 z:1.77	
U:200.5 h:0.00 m:4.61 z:1.69	U:201.8 h:0.00 m:4.62 z:1.70	U:202.1 h:0.00 m:4.63 z:1.70	U:202.4 h:0.00 m:4.65 z:1.71	U:205.8 h:0.00 m:4.68 z:1.72	U:209.1 h:0.00 m:4.74 z:1.75	U:213.3 h:0.00 m:4.79 z:1.77	U:217.3 h:0.00 m:4.84 z:1.79	U:220.4 h:0.00 m:4.85 z:1.80

Maximum Standard deviations below:

U:3.14e-01	h:2.25e-07	m:3.29e-03	p:1.23e-02	s:1.84e-03	z:2.15e-03

Legend:

U:U31	h:he	m:mod	p:pyrex	s:ss	z:zirc

Figure 20: 2f(pyrex): Fuel Pin Number Normalized Total Energy Distribution Material Separated (MeV/fission)

m:5.66 z:0.03								
U:182.8 h:0.00 m:3.50 z:0.03	U:176.9 h:0.00 m:3.50 z:0.03							
U:164.7 h:0.00 m:3.45 z:0.03	U:168.2 h:0.00 m:3.47 z:0.03	U:165.1 h:0.00 m:3.45 z:0.03						
h:0.00 m:2.66 p:9.33 s:0.06 z:0.03	U:158.1 h:0.00 m:3.42 z:0.03	U:157.0 h:0.00 m:3.42 z:0.03	h:0.00 m:2.65 p:9.13 s:0.06 z:0.03					
U:156.9 h:0.00 m:3.42 z:0.03	U:162.4 h:0.00 m:3.45 z:0.03	U:162.0 h:0.00 m:3.45 z:0.03	U:154.5 h:0.00 m:3.41 z:0.03	U:157.0 h:0.00 m:3.42 z:0.03				
U:157.1 h:0.00 m:3.43 z:0.03	U:162.9 h:0.00 m:3.47 z:0.03	U:162.4 h:0.00 m:3.46 z:0.03	U:154.6 h:0.00 m:3.43 z:0.03	U:153.6 h:0.00 m:3.42 z:0.03	h:0.00 m:2.70 p:9.30 s:0.06 z:0.03			
h:0.00 m:2.69 p:9.34 s:0.06 z:0.03	U:159.7 h:0.00 m:3.46 z:0.03	U:159.5 h:0.00 m:3.46 z:0.03	h:0.00 m:2.70 p:9.34 s:0.06 z:0.03	U:158.4 h:0.00 m:3.47 z:0.03	U:163.6 h:0.00 m:3.53 z:0.03	U:175.6 h:0.00 m:3.61 z:0.03		
U:164.9 h:0.00 m:3.50 z:0.03	U:170.5 h:0.00 m:3.53 z:0.03	U:170.4 h:0.00 m:3.54 z:0.03	U:166.2 h:0.00 m:3.53 z:0.03	U:172.8 h:0.00 m:3.57 z:0.03	U:177.8 h:0.00 m:3.63 z:0.03	U:183.8 h:0.00 m:3.68 z:0.03	U:188.2 h:0.00 m:3.73 z:0.03	
U:177.4 h:0.00 m:3.58 z:0.03	U:178.6 h:0.00 m:3.58 z:0.03	U:178.9 h:0.00 m:3.59 z:0.03	U:179.2 h:0.00 m:3.60 z:0.03	U:182.2 h:0.00 m:3.63 z:0.03	U:185.2 h:0.00 m:3.67 z:0.03	U:189.0 h:0.00 m:3.71 z:0.03	U:192.6 h:0.00 m:3.74 z:0.03	U:195.5 h:0.00 m:3.75 z:0.03

Maximum Standard deviations below:					
U:3.13e-01	h:2.18e-07	m:3.03e-03	p:1.22e-02	s:6.09e-05	z:5.95e-05
Legend:					
U:U31	h:he	m:mod	p:pyrex	s:ss	z:zirc

Figure 21: 2f(pyrex): Fuel Pin Number Normalized Energy by Fragments and Neutrons (MeV/fission)

m:0.55 z:0.50								
U:5.60 h:0.00 m:0.34 z:0.55	U:5.53 h:0.00 m:0.34 z:0.54							
U:5.39 h:0.00 m:0.33 z:0.54	U:5.39 h:0.00 m:0.33 z:0.53	U:5.33 h:0.00 m:0.33 z:0.53						
h:0.00 m:0.25 p:0.39 s:0.56 z:0.48	U:5.27 h:0.00 m:0.32 z:0.53	U:5.24 h:0.00 m:0.32 z:0.52	h:0.00 m:0.25 p:0.38 s:0.56 z:0.47					
U:5.26 h:0.00 m:0.32 z:0.52	U:5.30 h:0.00 m:0.33 z:0.53	U:5.28 h:0.00 m:0.32 z:0.52	U:5.21 h:0.00 m:0.32 z:0.52	U:5.24 h:0.00 m:0.32 z:0.52				
U:5.28 h:0.00 m:0.33 z:0.53	U:5.33 h:0.00 m:0.33 z:0.53	U:5.33 h:0.00 m:0.33 z:0.53	U:5.25 h:0.00 m:0.32 z:0.52	U:5.25 h:0.00 m:0.33 z:0.52	h:0.00 m:0.26 p:0.39 s:0.57 z:0.49			
h:0.00 m:0.26 p:0.39 s:0.57 z:0.49	U:5.35 h:0.00 m:0.33 z:0.53	U:5.35 h:0.00 m:0.33 z:0.53	h:0.00 m:0.26 p:0.39 s:0.57 z:0.49	U:5.37 h:0.00 m:0.33 z:0.53	U:5.49 h:0.00 m:0.34 z:0.55	U:5.69 h:0.00 m:0.35 z:0.56		
U:5.45 h:0.00 m:0.33 z:0.54	U:5.50 h:0.00 m:0.34 z:0.54	U:5.52 h:0.00 m:0.34 z:0.55	U:5.49 h:0.00 m:0.34 z:0.55	U:5.60 h:0.00 m:0.34 z:0.55	U:5.73 h:0.00 m:0.35 z:0.57	U:5.87 h:0.00 m:0.36 z:0.58	U:5.98 h:0.00 m:0.37 z:0.59	
U:5.65 h:0.00 m:0.35 z:0.56	U:5.64 h:0.00 m:0.35 z:0.56	U:5.66 h:0.00 m:0.35 z:0.56	U:5.70 h:0.00 m:0.35 z:0.56	U:5.76 h:0.00 m:0.35 z:0.57	U:5.88 h:0.00 m:0.36 z:0.58	U:5.97 h:0.00 m:0.36 z:0.59	U:6.06 h:0.00 m:0.37 z:0.60	U:6.11 h:0.00 m:0.37 z:0.60

Maximum Standard deviations below:

U:9.23e-03	h:2.67e-08	m:6.00e-04	p:6.30e-04	s:8.06e-04	z:1.03e-03

Legend:

U:U31	h:he	m:mod	p:pyrex	s:ss	z:zirc

Figure 22: 2f(pyrex): Fuel Pin Number Normalized Prompt Gamma Distribution (MeV/fission)

m:0.58 z:0.52								
U:4.95 h:0.00 m:0.35 z:0.56	U:4.99 h:0.00 m:0.35 z:0.56							
U:5.02 h:0.00 m:0.35 z:0.57	U:5.01 h:0.00 m:0.35 z:0.56	U:5.02 h:0.00 m:0.35 z:0.56						
h:0.00 m:0.29 p:0.47 s:0.68 z:0.56	U:4.97 h:0.00 m:0.35 z:0.56	U:4.98 h:0.00 m:0.35 z:0.56	h:0.00 m:0.29 p:0.46 s:0.68 z:0.55					
U:4.99 h:0.00 m:0.35 z:0.57	U:5.00 h:0.00 m:0.35 z:0.56	U:5.02 h:0.00 m:0.35 z:0.56	U:5.04 h:0.00 m:0.35 z:0.57	U:5.09 h:0.00 m:0.35 z:0.57				
U:5.00 h:0.00 m:0.35 z:0.56	U:5.01 h:0.00 m:0.35 z:0.56	U:5.00 h:0.00 m:0.35 z:0.56	U:5.00 h:0.00 m:0.35 z:0.57	U:5.11 h:0.00 m:0.36 z:0.58	h:0.00 m:0.29 p:0.48 s:0.69 z:0.56			
h:0.00 m:0.29 p:0.47 s:0.68 z:0.56	U:5.03 h:0.00 m:0.35 z:0.57	U:5.02 h:0.00 m:0.36 z:0.57	h:0.00 m:0.29 p:0.47 s:0.69 z:0.56	U:5.15 h:0.00 m:0.36 z:0.58	U:5.12 h:0.00 m:0.36 z:0.58	U:5.06 h:0.00 m:0.36 z:0.57		
U:5.04 h:0.00 m:0.36 z:0.57	U:5.02 h:0.00 m:0.36 z:0.57	U:5.02 h:0.00 m:0.35 z:0.57	U:5.07 h:0.00 m:0.36 z:0.57	U:5.09 h:0.00 m:0.36 z:0.57	U:5.03 h:0.00 m:0.36 z:0.57	U:5.05 h:0.00 m:0.36 z:0.57	U:5.05 h:0.00 m:0.36 z:0.57	
U:4.94 h:0.00 m:0.35 z:0.56	U:5.00 h:0.00 m:0.35 z:0.57	U:4.99 h:0.00 m:0.35 z:0.56	U:4.96 h:0.00 m:0.36 z:0.56	U:5.02 h:0.00 m:0.36 z:0.57	U:5.01 h:0.00 m:0.36 z:0.57	U:5.04 h:0.00 m:0.36 z:0.57	U:5.08 h:0.00 m:0.36 z:0.58	U:5.10 h:0.00 m:0.36 z:0.58
Maximum Standard deviations below:								
U:1.82e-02	h:5.84e-08	m:1.26e-03	p:1.36e-03	s:1.84e-03	z:2.15e-03			
Legend:								
U:U31	h:he	m:mod	p:pyrex	s:ss	z:zirc			

Figure 23: 2f(pyrex): Fuel Pin Number Normalized Capture Gamma Distribution (MeV/fission)

m:0.54 z:0.49								
U:5.48 h:0.00 m:0.33 z:0.54	U:5.41 h:0.00 m:0.33 z:0.53							
U:5.28 h:0.00 m:0.32 z:0.52	U:5.28 h:0.00 m:0.32 z:0.52	U:5.22 h:0.00 m:0.32 z:0.52						
h:0.00 m:0.25 p:0.38 s:0.55 z:0.47	U:5.17 h:0.00 m:0.32 z:0.51	U:5.14 h:0.00 m:0.32 z:0.51	h:0.00 m:0.25 p:0.37 s:0.55 z:0.47					
U:5.16 h:0.00 m:0.32 z:0.51	U:5.20 h:0.00 m:0.32 z:0.51	U:5.18 h:0.00 m:0.32 z:0.51	U:5.10 h:0.00 m:0.32 z:0.51	U:5.14 h:0.00 m:0.32 z:0.51				
U:5.17 h:0.00 m:0.32 z:0.52	U:5.23 h:0.00 m:0.32 z:0.52	U:5.22 h:0.00 m:0.32 z:0.52	U:5.14 h:0.00 m:0.32 z:0.51	U:5.15 h:0.00 m:0.32 z:0.51	h:0.00 m:0.25 p:0.38 s:0.56 z:0.48			
h:0.00 m:0.25 p:0.38 s:0.56 z:0.48	U:5.24 h:0.00 m:0.32 z:0.52	U:5.25 h:0.00 m:0.32 z:0.52	h:0.00 m:0.25 p:0.38 s:0.56 z:0.48	U:5.26 h:0.00 m:0.32 z:0.52	U:5.38 h:0.00 m:0.33 z:0.54	U:5.57 h:0.00 m:0.34 z:0.55		
U:5.34 h:0.00 m:0.33 z:0.53	U:5.39 h:0.00 m:0.33 z:0.53	U:5.41 h:0.00 m:0.33 z:0.54	U:5.38 h:0.00 m:0.33 z:0.54	U:5.48 h:0.00 m:0.34 z:0.54	U:5.61 h:0.00 m:0.34 z:0.56	U:5.75 h:0.00 m:0.35 z:0.57	U:5.85 h:0.00 m:0.36 z:0.58	
U:5.53 h:0.00 m:0.34 z:0.55	U:5.53 h:0.00 m:0.34 z:0.54	U:5.54 h:0.00 m:0.34 z:0.55	U:5.58 h:0.00 m:0.34 z:0.55	U:5.64 h:0.00 m:0.35 z:0.56	U:5.76 h:0.00 m:0.35 z:0.57	U:5.85 h:0.00 m:0.36 z:0.58	U:5.93 h:0.00 m:0.36 z:0.58	U:5.99 h:0.00 m:0.37 z:0.59

Maximum Standard deviations below:

U:9.04e-03	h:2.61e-08	m:5.87e-04	p:6.17e-04	s:7.90e-04	z:1.01e-03

Legend:

U:U31	h:he	m:mod	p:pyrex	s:ss	z:zirc

Figure 24: 2f(pyrex): Fuel Pin Number Normalized Delayed Gamma Distribution (MeV/fission)

m:1.66 z:1.52								
U:16.03 h:0.00 m:1.02 z:1.64	U:15.93 h:0.00 m:1.02 z:1.64							
U:15.70 h:0.00 m:1.01 z:1.63	U:15.68 h:0.00 m:1.01 z:1.62	U:15.57 h:0.00 m:1.00 z:1.61						
h:0.00 m:0.79 p:1.23 s:1.80 z:1.51	U:15.41 h:0.00 m:1.00 z:1.60	U:15.37 h:0.00 m:0.99 z:1.60	h:0.00 m:0.79 p:1.22 s:1.78 z:1.49					
U:15.41 h:0.00 m:1.00 z:1.60	U:15.50 h:0.00 m:1.00 z:1.60	U:15.48 h:0.00 m:0.99 z:1.60	U:15.35 h:0.00 m:0.99 z:1.59	U:15.47 h:0.00 m:0.99 z:1.60				
U:15.45 h:0.00 m:1.00 z:1.61	U:15.57 h:0.00 m:1.00 z:1.61	U:15.56 h:0.00 m:1.00 z:1.61	U:15.40 h:0.00 m:1.00 z:1.60	U:15.51 h:0.00 m:1.00 z:1.62	h:0.00 m:0.81 p:1.25 s:1.82 z:1.53			
h:0.00 m:0.80 p:1.24 s:1.81 z:1.52	U:15.61 h:0.00 m:1.01 z:1.62	U:15.62 h:0.00 m:1.01 z:1.62	h:0.00 m:0.80 p:1.25 s:1.82 z:1.52	U:15.79 h:0.00 m:1.02 z:1.64	U:15.98 h:0.00 m:1.03 z:1.66	U:16.32 h:0.00 m:1.05 z:1.68		
U:15.83 h:0.00 m:1.02 z:1.64	U:15.91 h:0.00 m:1.02 z:1.64	U:15.94 h:0.00 m:1.02 z:1.65	U:15.94 h:0.00 m:1.03 z:1.66	U:16.17 h:0.00 m:1.04 z:1.67	U:16.37 h:0.00 m:1.05 z:1.69	U:16.67 h:0.00 m:1.07 z:1.72	U:16.88 h:0.00 m:1.08 z:1.74	
U:16.12 h:0.00 m:1.04 z:1.66	U:16.17 h:0.00 m:1.04 z:1.67	U:16.18 h:0.00 m:1.04 z:1.67	U:16.24 h:0.00 m:1.05 z:1.68	U:16.42 h:0.00 m:1.06 z:1.69	U:16.65 h:0.00 m:1.07 z:1.71	U:16.85 h:0.00 m:1.08 z:1.74	U:17.06 h:0.00 m:1.09 z:1.75	U:17.20 h:0.00 m:1.10 z:1.77

Maximum Standard deviations below:

U:1.82e-02	h:5.83e-08	m:1.26e-03	p:1.36e-03	s:1.84e-03	z:2.15e-03

Legend:

U:U31	h:he	m:mod	p:pyrex	s:ss	z:zirc

Figure 25: 2f(pyrex): Fuel Pin Number Normalized Total Gamma Distribution (MeV/fission)

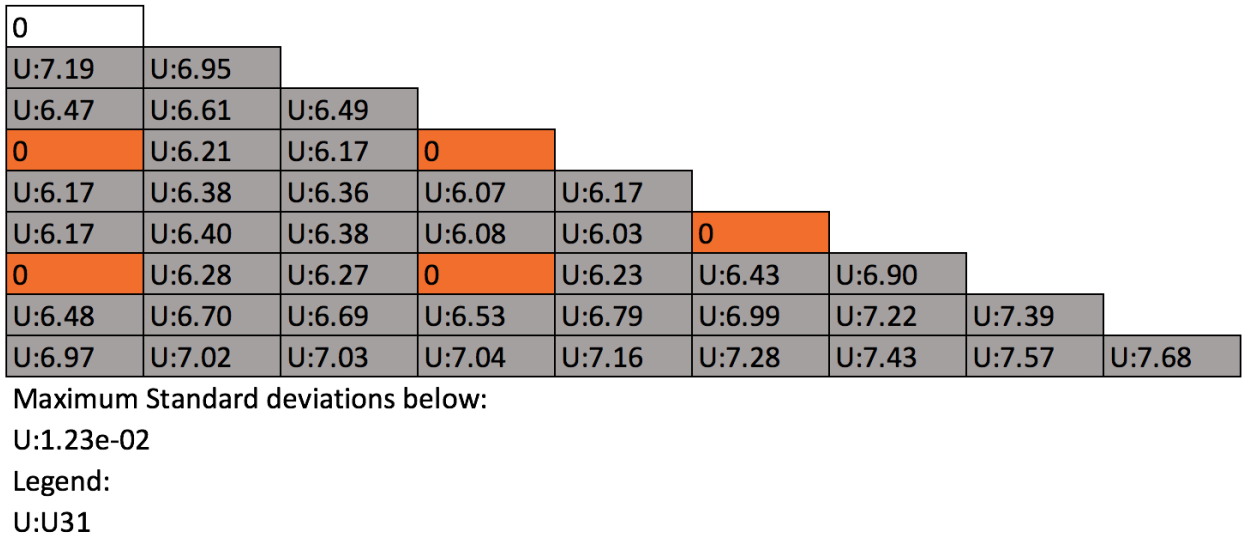

Figure 26: 2f(pyrex): Fuel Pin Number Normalized Beta Distribution (MeV/fission)

Table 9: 2f(pyrex): Energy Deposition Summary

	n+fg	prompt gamma	capture gamma	delayed gamma	beta	total
U31	1.696e+02 +- 2.106e-02	5.518e+00 +- 6.600e-04	5.029e+00 +- 1.016e-03	5.406e+00 +- 6.467e-04	6.663e+00 +- 8.279e-04	1.922e+02 +- 2.113e-02
he	3.932e-05 +- 5.448e-09	3.160e-06 +- 5.866e-10	3.451e-06 +- 1.175e-09	3.096e-06 +- 5.747e-10	0	4.903e-05 +- 5.633e-09
mod	3.850e+00 +- 3.660e-04	3.696e-01 +- 4.189e-05	3.895e-01 +- 6.671e-05	3.621e-01 +- 4.105e-05	0	4.971e+00 +- 3.767e-04
pyrex	8.456e-01 +- 2.364e-04	3.537e-02 +- 1.196e-05	4.269e-02 +- 2.540e-05	3.465e-02 +- 1.172e-05	0	9.583e-01 +- 2.383e-04
ss	5.186e-03 +- 1.207e-06	5.157e-02 +- 1.548e-05	6.228e-02 +- 3.403e-05	5.052e-02 +- 1.516e-05	0	1.696e-01 +- 4.036e-05
zirc	3.392e-02 +- 4.421e-06	5.927e-01 +- 7.435e-05	6.205e-01 +- 1.267e-04	5.807e-01 +- 7.285e-05	0	1.828e+00 +- 1.640e-04
total	1.743e+02 +- 2.107e-02	6.567e+00 +- 6.658e-04	6.144e+00 +- 1.027e-03	6.434e+00 +- 6.523e-04	6.663e+00 +- 8.279e-04	2.001e+02 +- 2.113e-02

m:7.97 z:1.64								
U:206.1 h:0.00 m:4.93 z:1.78	U:199.5 h:0.00 m:4.93 z:1.78							
U:182.0 h:0.00 m:4.86 z:1.78	U:186.4 h:0.00 m:4.88 z:1.77	U:182.2 h:0.00 m:4.85 z:1.77						
a:46.81 h:0.00 m:3.77 s:3.57 z:1.70	U:172.1 h:0.00 m:4.81 z:1.76	U:170.5 h:0.00 m:4.80 z:1.76	a:45.52 h:0.00 m:3.76 s:3.55 z:1.69					
U:169.9 h:0.00 m:4.81 z:1.76	U:178.2 h:0.00 m:4.84 z:1.76	U:177.7 h:0.00 m:4.85 z:1.76	U:166.3 h:0.00 m:4.80 z:1.76	U:170.0 h:0.00 m:4.84 z:1.78				
U:170.9 h:0.00 m:4.84 z:1.77	U:179.9 h:0.00 m:4.88 z:1.77	U:178.9 h:0.00 m:4.88 z:1.77	U:167.2 h:0.00 m:4.84 z:1.77	U:166.7 h:0.00 m:4.86 z:1.80	a:47.65 h:0.00 m:3.89 s:3.71 z:1.76			
a:47.68 h:0.00 m:3.84 s:3.63 z:1.73	U:176.4 h:0.00 m:4.91 z:1.80	U:176.6 h:0.00 m:4.92 z:1.80	a:47.74 h:0.00 m:3.87 s:3.67 z:1.74	U:176.8 h:0.00 m:4.98 z:1.84	U:187.5 h:0.00 m:5.09 z:1.85	U:206.2 h:0.00 m:5.26 z:1.88		
U:186.7 h:0.00 m:5.00 z:1.82	U:194.2 h:0.00 m:5.05 z:1.82	U:195.3 h:0.00 m:5.07 z:1.83	U:189.3 h:0.00 m:5.07 z:1.84	U:201.1 h:0.00 m:5.17 z:1.86	U:210.8 h:0.00 m:5.28 z:1.89	U:221.8 h:0.00 m:5.40 z:1.93	U:230.0 h:0.00 m:5.50 z:1.96	
U:205.9 h:0.00 m:5.12 z:1.83	U:207.5 h:0.00 m:5.13 z:1.84	U:208.1 h:0.00 m:5.16 z:1.85	U:209.3 h:0.00 m:5.19 z:1.85	U:215.8 h:0.00 m:5.28 z:1.89	U:222.7 h:0.00 m:5.37 z:1.91	U:230.9 h:0.00 m:5.47 z:1.95	U:237.2 h:0.00 m:5.55 z:1.98	U:243.0 h:0.00 m:5.59 z:2.00

Maximum Standard deviations below:

U:3.46e-01	a:6.60e-02	h:3.85e-08	m:3.80e-03	s:3.88e-03	z:2.43e-03

Legend:

U:U31	a:aic	h:he	m:mod	s:ss	z:zirc

Figure 27: 2g(AIC): Fuel Pin Number Normalized Total Energy Distribution Material Separated (MeV/fission)

m:6.21 z:0.03								
U:182.1 h:0.00 m:3.85 z:0.03	U:175.8 h:0.00 m:3.84 z:0.03							
U:159.3 h:0.00 m:3.77 z:0.03	U:163.5 h:0.00 m:3.80 z:0.03	U:159.5 h:0.00 m:3.77 z:0.03						
a:37.33 h:0.00 m:2.89 s:0.10 z:0.03	U:150.0 h:0.00 m:3.73 z:0.03	U:148.5 h:0.00 m:3.72 z:0.03	a:36.07 h:0.00 m:2.88 s:0.10 z:0.03					
U:147.9 h:0.00 m:3.73 z:0.03	U:155.8 h:0.00 m:3.77 z:0.03	U:155.3 h:0.00 m:3.77 z:0.03	U:144.5 h:0.00 m:3.73 z:0.03	U:147.8 h:0.00 m:3.75 z:0.03				
U:148.8 h:0.00 m:3.76 z:0.03	U:157.3 h:0.00 m:3.80 z:0.03	U:156.3 h:0.00 m:3.80 z:0.03	U:145.2 h:0.00 m:3.76 z:0.03	U:144.5 h:0.00 m:3.76 z:0.03	a:37.77 h:0.00 m:2.98 s:0.11 z:0.03			
a:38.02 h:0.00 m:2.95 s:0.11 z:0.03	U:153.8 h:0.00 m:3.81 z:0.03	U:154.0 h:0.00 m:3.82 z:0.03	a:37.98 h:0.00 m:2.97 s:0.11 z:0.03	U:153.9 h:0.00 m:3.86 z:0.03	U:163.8 h:0.00 m:3.96 z:0.04	U:181.4 h:0.00 m:4.11 z:0.04		
U:163.3 h:0.00 m:3.89 z:0.03	U:170.5 h:0.00 m:3.93 z:0.03	U:171.4 h:0.00 m:3.95 z:0.04	U:165.6 h:0.00 m:3.94 z:0.04	U:176.7 h:0.00 m:4.03 z:0.04	U:185.8 h:0.00 m:4.13 z:0.04	U:195.9 h:0.00 m:4.23 z:0.04	U:203.5 h:0.00 m:4.31 z:0.04	
U:181.6 h:0.00 m:4.00 z:0.04	U:183.0 h:0.00 m:4.01 z:0.04	U:183.5 h:0.00 m:4.03 z:0.04	U:184.6 h:0.00 m:4.06 z:0.04	U:190.5 h:0.00 m:4.12 z:0.04	U:196.8 h:0.00 m:4.20 z:0.04	U:204.4 h:0.00 m:4.28 z:0.04	U:210.1 h:0.00 m:4.34 z:0.04	U:215.5 h:0.00 m:4.37 z:0.04

Maximum Standard deviations below:

U:3.45e-01	a:6.49e-02	h:3.77e-08	m:3.52e-03	s:1.28e-04	z:6.83e-05

Legend:

U:U31	a:aic	h:he	m:mod	s:ss	z:zirc

Figure 28: 2g(AIC): Fuel Pin Number Normalized Energy by Fragments and Neutrons (MeV/fission)

m:0.52 z:0.48								
U:5.39 h:0.00 m:0.32 z:0.52	U:5.28 h:0.00 m:0.32 z:0.51							
U:5.08 h:0.00 m:0.31 z:0.50	U:5.10 h:0.00 m:0.31 z:0.50	U:5.02 h:0.00 m:0.31 z:0.49						
a:2.06 h:0.00 m:0.23 s:0.82 z:0.43	U:4.93 h:0.00 m:0.30 z:0.49	U:4.90 h:0.00 m:0.30 z:0.49	a:2.04 h:0.00 m:0.23 s:0.82 z:0.42					
U:4.89 h:0.00 m:0.30 z:0.48	U:4.96 h:0.00 m:0.30 z:0.49	U:4.96 h:0.00 m:0.30 z:0.49	U:4.84 h:0.00 m:0.30 z:0.48	U:4.87 h:0.00 m:0.30 z:0.48				
U:4.95 h:0.00 m:0.30 z:0.49	U:5.03 h:0.00 m:0.31 z:0.50	U:5.02 h:0.00 m:0.31 z:0.50	U:4.93 h:0.00 m:0.30 z:0.49	U:4.90 h:0.00 m:0.30 z:0.49	a:2.11 h:0.00 m:0.24 s:0.85 z:0.45			
a:2.11 h:0.00 m:0.24 s:0.85 z:0.44	U:5.07 h:0.00 m:0.31 z:0.50	U:5.08 h:0.00 m:0.31 z:0.50	a:2.12 h:0.00 m:0.24 s:0.85 z:0.45	U:5.12 h:0.00 m:0.31 z:0.51	U:5.38 h:0.00 m:0.33 z:0.53	U:5.74 h:0.00 m:0.35 z:0.56		
U:5.27 h:0.00 m:0.32 z:0.52	U:5.34 h:0.00 m:0.32 z:0.53	U:5.37 h:0.00 m:0.33 z:0.53	U:5.37 h:0.00 m:0.33 z:0.53	U:5.55 h:0.00 m:0.34 z:0.54	U:5.79 h:0.00 m:0.35 z:0.57	U:6.05 h:0.00 m:0.37 z:0.59	U:6.22 h:0.00 m:0.38 z:0.61	
U:5.57 h:0.00 m:0.34 z:0.55	U:5.59 h:0.00 m:0.34 z:0.55	U:5.63 h:0.00 m:0.34 z:0.55	U:5.71 h:0.00 m:0.35 z:0.56	U:5.81 h:0.00 m:0.35 z:0.57	U:6.03 h:0.00 m:0.36 z:0.59	U:6.20 h:0.00 m:0.37 z:0.61	U:6.34 h:0.00 m:0.38 z:0.62	U:6.47 h:0.00 m:0.39 z:0.63

Maximum Standard deviations below:

U:9.74e-03	a:3.84e-03	h:4.47e-09	m:6.27e-04	s:1.45e-03	z:1.14e-03

Legend:

U:U31	a:aic	h:he	m:mod	s:ss	z:zirc

Figure 29: 2g(AIC): Fuel Pin Number Normalized Prompt Gamma Distribution (MeV/fission)

m:0.72 z:0.66								
U:6.17 h:0.00 m:0.45 z:0.71	U:6.30 h:0.00 m:0.46 z:0.73							
U:6.43 h:0.00 m:0.48 z:0.76	U:6.39 h:0.00 m:0.47 z:0.75	U:6.46 h:0.00 m:0.47 z:0.75						
a:5.41 h:0.00 m:0.42 s:1.83 z:0.82	U:6.43 h:0.00 m:0.48 z:0.76	U:6.45 h:0.00 m:0.48 z:0.76	a:5.42 h:0.00 m:0.43 s:1.83 z:0.82					
U:6.46 h:0.00 m:0.48 z:0.76	U:6.49 h:0.00 m:0.47 z:0.76	U:6.48 h:0.00 m:0.48 z:0.76	U:6.56 h:0.00 m:0.49 z:0.78	U:6.73 h:0.00 m:0.49 z:0.79				
U:6.44 h:0.00 m:0.48 z:0.76	U:6.45 h:0.00 m:0.47 z:0.75	U:6.46 h:0.00 m:0.47 z:0.75	U:6.46 h:0.00 m:0.49 z:0.77	U:6.79 h:0.00 m:0.51 z:0.80	a:5.69 h:0.00 m:0.44 s:1.92 z:0.85			
a:5.48 h:0.00 m:0.43 s:1.84 z:0.82	U:6.49 h:0.00 m:0.48 z:0.77	U:6.51 h:0.00 m:0.48 z:0.76	a:5.56 h:0.00 m:0.43 s:1.87 z:0.83	U:6.72 h:0.00 m:0.50 z:0.80	U:6.51 h:0.00 m:0.48 z:0.76	U:6.30 h:0.00 m:0.46 z:0.73		
U:6.44 h:0.00 m:0.48 z:0.76	U:6.43 h:0.00 m:0.47 z:0.75	U:6.44 h:0.00 m:0.47 z:0.75	U:6.48 h:0.00 m:0.48 z:0.76	U:6.45 h:0.00 m:0.47 z:0.75	U:6.25 h:0.00 m:0.46 z:0.72	U:6.23 h:0.00 m:0.45 z:0.72	U:6.18 h:0.00 m:0.45 z:0.71	
U:6.12 h:0.00 m:0.45 z:0.71	U:6.24 h:0.00 m:0.45 z:0.72	U:6.20 h:0.00 m:0.45 z:0.72	U:6.09 h:0.00 m:0.45 z:0.70	U:6.30 h:0.00 m:0.45 z:0.72	U:6.12 h:0.00 m:0.45 z:0.71	U:6.16 h:0.00 m:0.45 z:0.71	U:6.22 h:0.00 m:0.45 z:0.71	U:6.21 h:0.00 m:0.45 z:0.71

Maximum Standard deviations below:

U:2.02e-02	a:1.16e-02	h:9.62e-09	m:1.40e-03	s:3.88e-03	z:2.43e-03

Legend:

U:U31	a:aic	h:he	m:mod	s:ss	z:zirc

Figure 30: 2g(AIC): Fuel Pin Number Normalized Capture Gamma Distribution (MeV/fission)

m:0.52 z:0.47								
U:5.29 h:0.00 m:0.32 z:0.51	U:5.19 h:0.00 m:0.31 z:0.50							
U:4.99 h:0.00 m:0.30 z:0.49	U:5.01 h:0.00 m:0.30 z:0.49	U:4.93 h:0.00 m:0.30 z:0.48						
a:2.02 h:0.00 m:0.23 s:0.81 z:0.42	U:4.84 h:0.00 m:0.30 z:0.48	U:4.81 h:0.00 m:0.29 z:0.48	a:2.00 h:0.00 m:0.22 s:0.80 z:0.42					
U:4.80 h:0.00 m:0.29 z:0.48	U:4.88 h:0.00 m:0.30 z:0.48	U:4.88 h:0.00 m:0.30 z:0.48	U:4.75 h:0.00 m:0.29 z:0.47	U:4.78 h:0.00 m:0.29 z:0.47				
U:4.86 h:0.00 m:0.30 z:0.48	U:4.94 h:0.00 m:0.30 z:0.49	U:4.93 h:0.00 m:0.30 z:0.49	U:4.84 h:0.00 m:0.30 z:0.48	U:4.81 h:0.00 m:0.29 z:0.48	a:2.08 h:0.00 m:0.23 s:0.83 z:0.44			
a:2.07 h:0.00 m:0.23 s:0.83 z:0.43	U:4.98 h:0.00 m:0.30 z:0.49	U:4.99 h:0.00 m:0.31 z:0.49	a:2.08 h:0.00 m:0.23 s:0.83 z:0.44	U:5.03 h:0.00 m:0.31 z:0.50	U:5.28 h:0.00 m:0.32 z:0.52	U:5.63 h:0.00 m:0.34 z:0.55		
U:5.18 h:0.00 m:0.32 z:0.51	U:5.25 h:0.00 m:0.32 z:0.52	U:5.27 h:0.00 m:0.32 z:0.52	U:5.27 h:0.00 m:0.32 z:0.52	U:5.45 h:0.00 m:0.33 z:0.53	U:5.68 h:0.00 m:0.35 z:0.56	U:5.94 h:0.00 m:0.36 z:0.58	U:6.11 h:0.00 m:0.37 z:0.60	
U:5.47 h:0.00 m:0.33 z:0.54	U:5.49 h:0.00 m:0.33 z:0.54	U:5.53 h:0.00 m:0.33 z:0.54	U:5.61 h:0.00 m:0.34 z:0.55	U:5.71 h:0.00 m:0.35 z:0.56	U:5.93 h:0.00 m:0.36 z:0.58	U:6.09 h:0.00 m:0.37 z:0.60	U:6.23 h:0.00 m:0.38 z:0.61	U:6.35 h:0.00 m:0.38 z:0.62

Maximum Standard deviations below:

U:9.57e-03	a:3.77e-03	h:4.39e-09	m:6.15e-04	s:1.43e-03	z:1.12e-03

Legend:

U:U31	a:aic	h:he	m:mod	s:ss	z:zirc

Figure 31: 2g(AIC): Fuel Pin Number Normalized Delayed Gamma Distribution (MeV/fission)

m:1.76 z:1.61								
U:16.85 h:0.00 m:1.09 z:1.75	U:16.76 h:0.00 m:1.09 z:1.75							
U:16.51 h:0.00 m:1.09 z:1.75	U:16.50 h:0.00 m:1.08 z:1.74	U:16.41 h:0.00 m:1.08 z:1.73						
a:9.49 h:0.00 m:0.88 s:3.46 z:1.67	U:16.20 h:0.00 m:1.08 z:1.73	U:16.15 h:0.00 m:1.07 z:1.72	a:9.46 h:0.00 m:0.88 s:3.45 z:1.66					
U:16.15 h:0.00 m:1.08 z:1.73	U:16.33 h:0.00 m:1.08 z:1.73	U:16.32 h:0.00 m:1.08 z:1.73	U:16.15 h:0.00 m:1.08 z:1.73	U:16.39 h:0.00 m:1.08 z:1.74				
U:16.25 h:0.00 m:1.08 z:1.73	U:16.42 h:0.00 m:1.08 z:1.74	U:16.40 h:0.00 m:1.08 z:1.74	U:16.22 h:0.00 m:1.08 z:1.73	U:16.49 h:0.00 m:1.10 z:1.77	a:9.87 h:0.00 m:0.91 s:3.60 z:1.73			
a:9.66 h:0.00 m:0.90 s:3.52 z:1.70	U:16.54 h:0.00 m:1.10 z:1.76	U:16.57 h:0.00 m:1.10 z:1.76	a:9.76 h:0.00 m:0.90 s:3.56 z:1.71	U:16.88 h:0.00 m:1.12 z:1.80	U:17.17 h:0.00 m:1.13 z:1.82	U:17.66 h:0.00 m:1.15 z:1.85		
U:16.90 h:0.00 m:1.11 z:1.79	U:17.01 h:0.00 m:1.11 z:1.79	U:17.08 h:0.00 m:1.12 z:1.80	U:17.12 h:0.00 m:1.13 z:1.81	U:17.45 h:0.00 m:1.14 z:1.83	U:17.72 h:0.00 m:1.15 z:1.85	U:18.21 h:0.00 m:1.18 z:1.89	U:18.51 h:0.00 m:1.20 z:1.92	
U:17.16 h:0.00 m:1.12 z:1.79	U:17.31 h:0.00 m:1.12 z:1.80	U:17.37 h:0.00 m:1.13 z:1.81	U:17.40 h:0.00 m:1.13 z:1.81	U:17.81 h:0.00 m:1.15 z:1.85	U:18.09 h:0.00 m:1.17 z:1.88	U:18.46 h:0.00 m:1.19 z:1.91	U:18.79 h:0.00 m:1.21 z:1.94	U:19.03 h:0.00 m:1.22 z:1.96

Maximum Standard deviations below:

U:2.02e-02	a:1.16e-02	h:9.60e-09	m:1.40e-03	s:3.88e-03	z:2.43e-03

Legend:

U:U31	a:aic	h:he	m:mod	s:ss	z:zirc

Figure 32: 2g(AIC): Fuel Pin Number Normalized Total Gamma Distribution (MeV/fission)

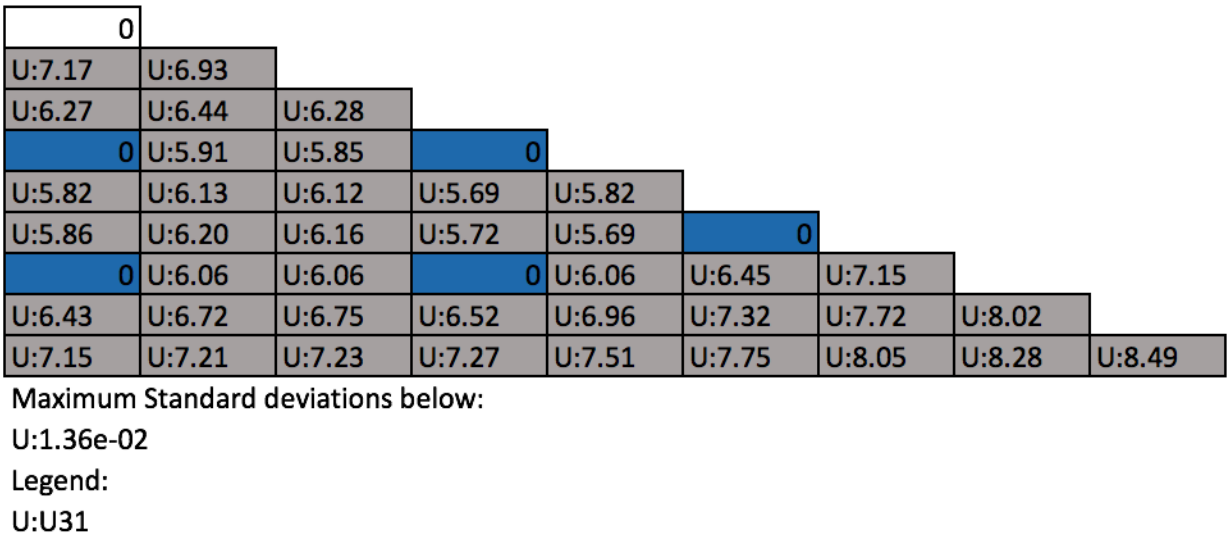

Figure 33: 2g(AIC): Fuel Pin Number Beta Distribution (MeV/fission)

Table 10: 2g(AIC): Energy Deposition Summary

	n+fg	prompt gamma	capture gamma	delayed gamma	beta	total
U31	1.696e+02 +- 2.206e-02	5.373e+00 +- 6.765e-04	6.393e+00 +- 1.191e-03	5.278e+00 +- 6.646e-04	6.681e+00 +- 8.692e-04	1.933e+02 +- 2.213e-02
aic	3.414e+00 +- 1.226e-03	1.903e-01 +- 7.209e-05	5.019e-01 +- 2.143e-04	1.869e-01 +- 7.082e-05	0	4.293e+00 +- 1.248e-03
he	2.668e-05 +- 3.120e-09	1.831e-06 +- 2.694e-10	2.617e-06 +- 5.568e-10	1.799e-06 +- 2.647e-10	0	3.293e-05 +- 3.191e-09
mod	4.286e+00 +- 4.243e-04	3.554e-01 +- 4.275e-05	5.186e-01 +- 8.014e-05	3.492e-01 +- 4.199e-05	0	5.509e+00 +- 4.359e-04
ss	9.552e-03 +- 2.500e-06	7.635e-02 +- 2.741e-05	1.694e-01 +- 7.209e-05	7.501e-02 +- 2.693e-05	0	3.303e-01 +- 8.173e-05
zirc	3.793e-02 +- 5.073e-06	5.701e-01 +- 7.528e-05	8.241e-01 +- 1.486e-04	5.601e-01 +- 7.395e-05	0	1.992e+00 +- 1.823e-04
total	1.774e+02 +- 2.210e-02	6.565e+00 +- 6.864e-04	8.407e+00 +- 1.224e-03	6.449e+00 +- 6.743e-04	6.681e+00 +- 8.692e-04	2.055e+02 +- 2.217e-02

m:8.29 z:1.56								
U:203.4 h:0.00 m:5.12 z:1.69	U:196.5 h:0.00 m:5.12 z:1.68							
U:178.7 h:0.00 m:5.04 z:1.67	U:183.3 h:0.00 m:5.06 z:1.67	U:178.5 h:0.00 m:5.03 z:1.66						
b:24.57 h:0.00 m:3.89 s:3.22 z:1.58	U:167.8 h:0.00 m:4.98 z:1.65	U:166.2 h:0.00 m:4.97 z:1.64	b:23.97 h:0.00 m:3.88 s:3.19 z:1.57					
U:166.2 h:0.00 m:4.98 z:1.65	U:174.7 h:0.00 m:5.03 z:1.65	U:172.8 h:0.00 m:5.02 z:1.65	U:162.0 h:0.00 m:4.98 z:1.65	U:166.0 h:0.00 m:5.02 z:1.67				
U:167.0 h:0.00 m:5.03 z:1.66	U:176.3 h:0.00 m:5.07 z:1.67	U:175.1 h:0.00 m:5.07 z:1.67	U:163.2 h:0.00 m:5.03 z:1.67	U:163.6 h:0.00 m:5.07 z:1.70	b:25.32 h:0.00 m:4.06 s:3.38 z:1.66			
b:25.21 h:0.00 m:3.99 s:3.30 z:1.62	U:173.6 h:0.00 m:5.11 z:1.70	U:174.3 h:0.00 m:5.13 z:1.71	b:25.27 h:0.00 m:4.03 s:3.34 z:1.64	U:175.6 h:0.00 m:5.21 z:1.75	U:187.9 h:0.00 m:5.36 z:1.79	U:210.6 h:0.00 m:5.57 z:1.85		
U:185.6 h:0.00 m:5.22 z:1.74	U:193.3 h:0.00 m:5.28 z:1.74	U:195.1 h:0.00 m:5.30 z:1.75	U:189.5 h:0.00 m:5.31 z:1.76	U:202.6 h:0.00 m:5.43 z:1.80	U:214.1 h:0.00 m:5.58 z:1.84	U:226.5 h:0.00 m:5.74 z:1.90	U:237.4 h:0.00 m:5.87 z:1.94	
U:206.4 h:0.00 m:5.37 z:1.76	U:208.3 h:0.00 m:5.39 z:1.77	U:209.8 h:0.00 m:5.42 z:1.78	U:210.8 h:0.00 m:5.47 z:1.80	U:218.7 h:0.00 m:5.57 z:1.84	U:227.3 h:0.00 m:5.70 z:1.89	U:237.1 h:0.00 m:5.83 z:1.94	U:244.6 h:0.00 m:5.93 z:1.98	U:251.4 h:0.00 m:5.98 z:2.01

Maximum Standard deviations below:

U:4.50e-01	b:3.66e-02	h:5.93e-08	m:5.14e-03	s:4.62e-03	z:3.12e-03

Legend:

U:U31	b:b4c	h:he	m:mod	s:ss	z:zirc

Figure 34: 2h(B4C): Fuel Pin Number Normalized Total Energy Distribution Material Separated (MeV/fission)

m:6.62 z:0.03								
U:180.1 h:0.00 m:4.10 z:0.04	U:173.6 h:0.00 m:4.10 z:0.04							
U:156.8 h:0.00 m:4.03 z:0.04	U:161.1 h:0.00 m:4.05 z:0.04	U:156.6 h:0.00 m:4.03 z:0.04						
b:23.51 h:0.00 m:3.09 s:0.11 z:0.03	U:146.5 h:0.00 m:3.98 z:0.04	U:145.0 h:0.00 m:3.98 z:0.04	b:22.92 h:0.00 m:3.08 s:0.11 z:0.03					
U:145.0 h:0.00 m:3.98 z:0.04	U:153.0 h:0.00 m:4.03 z:0.04	U:151.2 h:0.00 m:4.03 z:0.04	U:141.0 h:0.00 m:3.98 z:0.04	U:144.6 h:0.00 m:4.02 z:0.04				
U:145.7 h:0.00 m:4.02 z:0.04	U:154.4 h:0.00 m:4.06 z:0.04	U:153.3 h:0.00 m:4.06 z:0.04	U:142.0 h:0.00 m:4.02 z:0.04	U:142.1 h:0.00 m:4.05 z:0.04	b:24.21 h:0.00 m:3.21 s:0.12 z:0.03			
b:24.13 h:0.00 m:3.16 s:0.12 z:0.03	U:151.7 h:0.00 m:4.08 z:0.04	U:152.2 h:0.00 m:4.09 z:0.04	b:24.17 h:0.00 m:3.19 s:0.12 z:0.03	U:153.1 h:0.00 m:4.16 z:0.04	U:164.6 h:0.00 m:4.28 z:0.04	U:185.7 h:0.00 m:4.45 z:0.04		
U:162.7 h:0.00 m:4.17 z:0.04	U:170.0 h:0.00 m:4.22 z:0.04	U:171.6 h:0.00 m:4.24 z:0.04	U:166.3 h:0.00 m:4.24 z:0.04	U:178.4 h:0.00 m:4.34 z:0.04	U:189.1 h:0.00 m:4.46 z:0.04	U:200.4 h:0.00 m:4.59 z:0.04	U:210.5 h:0.00 m:4.68 z:0.04	
U:182.5 h:0.00 m:4.30 z:0.04	U:184.1 h:0.00 m:4.31 z:0.04	U:185.4 h:0.00 m:4.34 z:0.04	U:186.4 h:0.00 m:4.37 z:0.04	U:193.5 h:0.00 m:4.45 z:0.04	U:201.3 h:0.00 m:4.55 z:0.04	U:210.2 h:0.00 m:4.65 z:0.04	U:217.1 h:0.00 m:4.73 z:0.04	U:223.3 h:0.00 m:4.76 z:0.04
Maximum Standard deviations below:								
U:4.49e-01	b:3.65e-02	h:5.77e-08	m:4.81e-03	s:1.76e-04	z:9.36e-05			
Legend:								
U:U31	b:b4c	h:he	m:mod	s:ss	z:zirc			

Figure 35: 2h(B4C): Fuel Pin Number Normalized Energy by Fragments and Neutrons (MeV/fission)

m:0.53 z:0.48								
U:5.42 h:0.00 m:0.33 z:0.53	U:5.33 h:0.00 m:0.32 z:0.52							
U:5.15 h:0.00 m:0.32 z:0.51	U:5.15 h:0.00 m:0.32 z:0.51	U:5.09 h:0.00 m:0.31 z:0.50						
b:0.30 h:0.00 m:0.24 s:0.89 z:0.46	U:5.00 h:0.00 m:0.31 z:0.50	U:4.97 h:0.00 m:0.31 z:0.49	b:0.30 h:0.00 m:0.24 s:0.88 z:0.45					
U:4.99 h:0.00 m:0.31 z:0.50	U:5.06 h:0.00 m:0.31 z:0.50	U:5.03 h:0.00 m:0.31 z:0.50	U:4.93 h:0.00 m:0.31 z:0.49	U:4.98 h:0.00 m:0.31 z:0.50				
U:5.04 h:0.00 m:0.31 z:0.50	U:5.13 h:0.00 m:0.32 z:0.51	U:5.10 h:0.00 m:0.31 z:0.51	U:5.01 h:0.00 m:0.31 z:0.50	U:5.05 h:0.00 m:0.31 z:0.51	b:0.31 h:0.00 m:0.25 s:0.94 z:0.48			
b:0.31 h:0.00 m:0.25 s:0.92 z:0.47	U:5.16 h:0.00 m:0.32 z:0.52	U:5.17 h:0.00 m:0.32 z:0.52	b:0.31 h:0.00 m:0.25 s:0.93 z:0.48	U:5.27 h:0.00 m:0.33 z:0.53	U:5.54 h:0.00 m:0.34 z:0.55	U:5.93 h:0.00 m:0.36 z:0.59		
U:5.40 h:0.00 m:0.33 z:0.54	U:5.44 h:0.00 m:0.33 z:0.54	U:5.48 h:0.00 m:0.34 z:0.54	U:5.49 h:0.00 m:0.34 z:0.54	U:5.70 h:0.00 m:0.35 z:0.56	U:5.95 h:0.00 m:0.36 z:0.59	U:6.23 h:0.00 m:0.38 z:0.61	U:6.44 h:0.00 m:0.39 z:0.63	
U:5.67 h:0.00 m:0.35 z:0.56	U:5.69 h:0.00 m:0.35 z:0.56	U:5.73 h:0.00 m:0.35 z:0.56	U:5.81 h:0.00 m:0.35 z:0.57	U:5.97 h:0.00 m:0.36 z:0.58	U:6.21 h:0.00 m:0.37 z:0.61	U:6.42 h:0.00 m:0.39 z:0.63	U:6.60 h:0.00 m:0.40 z:0.64	U:6.72 h:0.00 m:0.40 z:0.66

Maximum Standard deviations below:					
U:1.28e-02	b:7.26e-04	h:6.30e-09	m:8.48e-04	s:1.97e-03	z:1.44e-03
Legend:					
U:U31	b:b4c	h:he	m:mod	s:ss	z:zirc

Figure 36: 2h(B4C): Fuel Pin Number Normalized Prompt Gamma Distribution (MeV/fission)

m:0.61 z:0.56								
U:5.42 h:0.00 m:0.38 z:0.61	U:5.50 h:0.00 m:0.38 z:0.61							
U:5.56 h:0.00 m:0.39 z:0.62	U:5.57 h:0.00 m:0.38 z:0.62	U:5.59 h:0.00 m:0.38 z:0.62						
b:0.46 h:0.00 m:0.32 s:1.34 z:0.64	U:5.57 h:0.00 m:0.38 z:0.62	U:5.56 h:0.00 m:0.38 z:0.62	b:0.46 h:0.00 m:0.32 s:1.33 z:0.64					
U:5.58 h:0.00 m:0.38 z:0.62	U:5.58 h:0.00 m:0.38 z:0.62	U:5.59 h:0.00 m:0.38 z:0.62	U:5.68 h:0.00 m:0.39 z:0.63	U:5.86 h:0.00 m:0.39 z:0.65				
U:5.59 h:0.00 m:0.39 z:0.62	U:5.64 h:0.00 m:0.39 z:0.63	U:5.67 h:0.00 m:0.39 z:0.63	U:5.64 h:0.00 m:0.39 z:0.63	U:5.95 h:0.00 m:0.40 z:0.66	b:0.49 h:0.00 m:0.34 s:1.41 z:0.68			
b:0.47 h:0.00 m:0.33 s:1.36 z:0.65	U:5.67 h:0.00 m:0.39 z:0.64	U:5.76 h:0.00 m:0.39 z:0.64	b:0.48 h:0.00 m:0.34 s:1.39 z:0.66	U:5.98 h:0.00 m:0.41 z:0.66	U:5.87 h:0.00 m:0.41 z:0.66	U:5.82 h:0.00 m:0.41 z:0.65		
U:5.72 h:0.00 m:0.40 z:0.64	U:5.72 h:0.00 m:0.39 z:0.63	U:5.79 h:0.00 m:0.40 z:0.64	U:5.80 h:0.00 m:0.40 z:0.65	U:5.85 h:0.00 m:0.40 z:0.64	U:5.71 h:0.00 m:0.40 z:0.64	U:5.81 h:0.00 m:0.41 z:0.65	U:5.85 h:0.00 m:0.41 z:0.66	
U:5.50 h:0.00 m:0.39 z:0.62	U:5.61 h:0.00 m:0.39 z:0.63	U:5.61 h:0.00 m:0.39 z:0.63	U:5.59 h:0.00 m:0.39 z:0.63	U:5.71 h:0.00 m:0.40 z:0.64	U:5.73 h:0.00 m:0.40 z:0.64	U:5.84 h:0.00 m:0.41 z:0.65	U:5.87 h:0.00 m:0.41 z:0.66	U:5.91 h:0.00 m:0.42 z:0.66

Maximum Standard deviations below:

U:2.61e-02	b:1.68e-03	h:1.46e-08	m:1.78e-03	s:4.61e-03	z:3.13e-03

Legend:

U:U31	b:b4c	h:he	m:mod	s:ss	z:zirc

Figure 37: 2h(B4C): Fuel Pin Number Normalized Capture Gamma Distribution (MeV/fission)

m:0.52 z:0.48								
U:5.33 h:0.00 m:0.32 z:0.52	U:5.25 h:0.00 m:0.32 z:0.51							
U:5.07 h:0.00 m:0.31 z:0.50	U:5.07 h:0.00 m:0.31 z:0.50	U:5.01 h:0.00 m:0.31 z:0.50						
b:0.29 h:0.00 m:0.24 s:0.88 z:0.45	U:4.92 h:0.00 m:0.30 z:0.49	U:4.89 h:0.00 m:0.30 z:0.49	b:0.29 h:0.00 m:0.23 s:0.87 z:0.44					
U:4.91 h:0.00 m:0.30 z:0.49	U:4.98 h:0.00 m:0.31 z:0.49	U:4.95 h:0.00 m:0.30 z:0.49	U:4.86 h:0.00 m:0.30 z:0.49	U:4.90 h:0.00 m:0.31 z:0.49				
U:4.96 h:0.00 m:0.31 z:0.50	U:5.05 h:0.00 m:0.31 z:0.50	U:5.02 h:0.00 m:0.31 z:0.50	U:4.94 h:0.00 m:0.31 z:0.50	U:4.97 h:0.00 m:0.31 z:0.50	b:0.31 h:0.00 m:0.25 s:0.92 z:0.47			
b:0.30 h:0.00 m:0.25 s:0.91 z:0.46	U:5.08 h:0.00 m:0.32 z:0.51	U:5.09 h:0.00 m:0.32 z:0.51	b:0.31 h:0.00 m:0.25 s:0.91 z:0.47	U:5.19 h:0.00 m:0.32 z:0.52	U:5.45 h:0.00 m:0.34 z:0.54	U:5.84 h:0.00 m:0.36 z:0.58		
U:5.31 h:0.00 m:0.33 z:0.53	U:5.36 h:0.00 m:0.33 z:0.53	U:5.40 h:0.00 m:0.33 z:0.53	U:5.40 h:0.00 m:0.33 z:0.54	U:5.61 h:0.00 m:0.34 z:0.56	U:5.86 h:0.00 m:0.36 z:0.58	U:6.13 h:0.00 m:0.37 z:0.60	U:6.34 h:0.00 m:0.38 z:0.62	
U:5.58 h:0.00 m:0.34 z:0.55	U:5.60 h:0.00 m:0.34 z:0.55	U:5.64 h:0.00 m:0.34 z:0.55	U:5.72 h:0.00 m:0.35 z:0.56	U:5.87 h:0.00 m:0.36 z:0.58	U:6.11 h:0.00 m:0.37 z:0.60	U:6.32 h:0.00 m:0.38 z:0.62	U:6.50 h:0.00 m:0.39 z:0.63	U:6.62 h:0.00 m:0.40 z:0.64

Maximum Standard deviations below:					
U:1.26e-02	b:7.15e-04	h:6.21e-09	m:8.35e-04	s:1.94e-03	z:1.42e-03
Legend:					
U:U31	b:b4c	h:he	m:mod	s:ss	z:zirc

Figure 38: 2h(B4C): Fuel Pin Number Normalized Delayed Gamma Distribution (MeV/fission)

m:1.67 z:1.53								
U:16.17 h:0.00 m:1.02 z:1.65	U:16.08 h:0.00 m:1.02 z:1.65							
U:15.78 h:0.00 m:1.01 z:1.64	U:15.79 h:0.00 m:1.01 z:1.63	U:15.70 h:0.00 m:1.00 z:1.62						
b:1.06 h:0.00 m:0.80 s:3.11 z:1.55	U:15.48 h:0.00 m:1.00 z:1.61	U:15.42 h:0.00 m:0.99 z:1.60	b:1.05 h:0.00 m:0.80 s:3.08 z:1.54					
U:15.47 h:0.00 m:1.00 z:1.61	U:15.62 h:0.00 m:1.00 z:1.61	U:15.57 h:0.00 m:1.00 z:1.61	U:15.47 h:0.00 m:1.00 z:1.61	U:15.74 h:0.00 m:1.01 z:1.64				
U:15.59 h:0.00 m:1.01 z:1.63	U:15.81 h:0.00 m:1.01 z:1.64	U:15.80 h:0.00 m:1.01 z:1.64	U:15.59 h:0.00 m:1.01 z:1.63	U:15.96 h:0.00 m:1.03 z:1.67	b:1.11 h:0.00 m:0.84 s:3.27 z:1.63			
b:1.08 h:0.00 m:0.83 s:3.19 z:1.59	U:15.92 h:0.00 m:1.03 z:1.66	U:16.02 h:0.00 m:1.03 z:1.67	b:1.10 h:0.00 m:0.84 s:3.22 z:1.61	U:16.44 h:0.00 m:1.06 z:1.71	U:16.85 h:0.00 m:1.08 z:1.75	U:17.59 h:0.00 m:1.12 z:1.81		
U:16.44 h:0.00 m:1.05 z:1.70	U:16.52 h:0.00 m:1.05 z:1.70	U:16.67 h:0.00 m:1.06 z:1.72	U:16.68 h:0.00 m:1.07 z:1.73	U:17.16 h:0.00 m:1.09 z:1.76	U:17.52 h:0.00 m:1.12 z:1.80	U:18.17 h:0.00 m:1.16 z:1.86	U:18.62 h:0.00 m:1.19 z:1.90	
U:16.75 h:0.00 m:1.07 z:1.73	U:16.90 h:0.00 m:1.08 z:1.74	U:16.98 h:0.00 m:1.08 z:1.74	U:17.12 h:0.00 m:1.10 z:1.76	U:17.56 h:0.00 m:1.12 z:1.80	U:18.05 h:0.00 m:1.15 z:1.85	U:18.57 h:0.00 m:1.18 z:1.90	U:18.97 h:0.00 m:1.20 z:1.94	U:19.25 h:0.00 m:1.22 z:1.96

Maximum Standard deviations below:

U:2.61e-02	b:1.68e-03	h:1.46e-08	m:1.78e-03	s:4.61e-03	z:3.12e-03

Legend:

U:U31	b:b4c	h:he	m:mod	s:ss	z:zirc

Figure 39: 2h(B4C): Fuel Pin Number Normalized Total Gamma Distribution (MeV/fission)

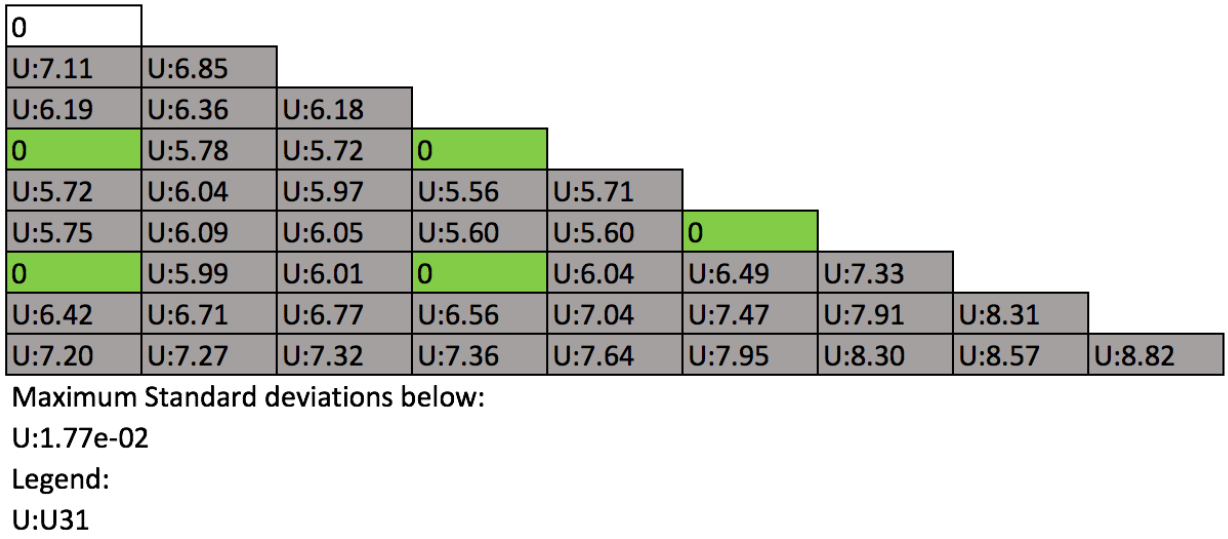

Figure 40: 2h(B4C): Fuel Pin Number Beta Distribution (MeV/fission)

Table 11: 2h(B4C): Energy Deposition Summary

	n+fg	prompt gamma	capture gamma	delayed gamma	beta	total
U31	1.697e+02 +- 2.793e-02	5.496e+00 +- 8.789e-04	5.709e+00 +- 1.439e-03	5.411e+00 +- 8.652e-04	6.697e+00 +- 1.106e-03	1.930e+02 +- 2.801e-02
b4c	2.168e+00 +- 7.107e-04	2.796e-02 +- 1.355e-05	4.298e-02 +- 3.069e-05	2.753e-02 +- 1.334e-05	0	2.267e+00 +- 7.116e-04
he	3.137e-05 +- 4.554e-09	2.033e-06 +- 3.773e-10	2.419e-06 +- 7.109e-10	2.001e-06 +- 3.715e-10	0	3.782e-05 +- 4.639e-09
mod	4.613e+00 +- 5.825e-04	3.670e-01 +- 5.564e-05	4.333e-01 +- 9.381e-05	3.613e-01 +- 5.478e-05	0	5.775e+00 +- 5.951e-04
ss	1.045e-02 +- 3.358e-06	8.315e-02 +- 3.695e-05	1.243e-01 +- 8.318e-05	8.186e-02 +- 3.638e-05	0	2.998e-01 +- 9.808e-05
zirc	4.067e-02 +- 6.767e-06	5.886e-01 +- 9.810e-05	6.987e-01 +- 1.752e-04	5.795e-01 +- 9.657e-05	0	1.907e+00 +- 2.229e-04
total	1.765e+02 +- 2.794e-02	6.562e+00 +- 8.869e-04	7.008e+00 +- 1.455e-03	6.461e+00 +- 8.732e-04	6.697e+00 +- 1.106e-03	2.032e+02 +- 2.803e-02

m:7.36 z:1.56								
U:189.2 h:0.00 i:2.15 m:4.55 z:1.70	U:199.1 h:0.00 m:4.58 z:1.69							
U:188.9 h:0.00 i:2.15 m:4.55 z:1.69	U:199.5 h:0.00 m:4.58 z:1.69	U:199.2 h:0.00 m:4.58 z:1.69						
m:7.36 z:1.56	U:189.6 h:0.00 i:2.16 m:4.55 z:1.69	U:189.3 h:0.00 i:2.16 m:4.54 z:1.69	m:7.34 z:1.56					
U:189.0 h:0.00 i:2.15 m:4.55 z:1.69	U:198.8 h:0.00 m:4.58 z:1.70	U:198.7 h:0.00 m:4.57 z:1.69	U:188.3 h:0.00 i:2.14 m:4.53 z:1.69	U:195.9 h:0.00 m:4.53 z:1.68				
U:188.9 h:0.00 i:2.15 m:4.55 z:1.69	U:199.1 h:0.00 m:4.59 z:1.69	U:198.5 h:0.00 m:4.58 z:1.69	U:186.9 h:0.00 i:2.13 m:4.53 z:1.69	U:186.8 h:0.00 i:2.12 m:4.51 z:1.68	m:7.32 z:1.54			
m:7.37 z:1.56	U:188.3 h:0.00 i:2.14 m:4.56 z:1.69	U:188.2 h:0.00 i:2.14 m:4.55 z:1.69	m:7.35 z:1.55	U:187.0 h:0.00 i:2.12 m:4.53 z:1.68	U:185.9 h:0.00 i:2.11 m:4.56 z:1.68	U:192.7 h:0.00 m:4.60 z:1.69		
U:187.4 h:0.00 i:2.13 m:4.57 z:1.68	U:195.1 h:0.00 m:4.59 z:1.68	U:197.6 h:0.00 m:4.60 z:1.68	U:188.4 h:0.00 i:2.14 m:4.57 z:1.69	U:194.6 h:0.00 m:4.60 z:1.69	U:194.8 h:0.00 m:4.63 z:1.69	U:182.6 h:0.00 i:2.06 m:4.63 z:1.69	U:194.8 h:0.00 m:4.66 z:1.69	
U:193.8 h:0.00 m:4.59 z:1.68	U:182.1 h:0.00 i:2.06 m:4.59 z:1.68	U:198.2 h:0.00 m:4.62 z:1.69	U:197.2 h:0.00 m:4.62 z:1.69	U:182.8 h:0.00 i:2.07 m:4.60 z:1.69	U:197.6 h:0.00 m:4.65 z:1.69	U:199.2 h:0.00 m:4.67 z:1.70	U:197.5 h:0.00 m:4.67 z:1.70	U:182.2 h:0.00 i:2.05 m:4.63 z:1.69

Maximum Standard deviations below:

U:2.65e-01	h:3.16e-08	i:3.89e-03	m:3.47e-03	z:2.14e-03

Legend:

U:U31	h:he	i:ifba	m:mod	z:zirc

Figure 41: 2m(IFBA): Fuel Pin Number Normalized Total Energy Distribution Material Separated (MeV/fission)

m:5.67 z:0.03								
U:166.6 h:0.00 i:2.14 m:3.52 z:0.03	U:176.0 h:0.00 m:3.54 z:0.03							
U:166.3 h:0.00 i:2.14 m:3.51 z:0.03	U:176.4 h:0.00 m:3.54 z:0.03	U:176.1 h:0.00 m:3.54 z:0.03						
m:5.68 z:0.03	U:166.9 h:0.00 i:2.15 m:3.52 z:0.03	U:166.7 h:0.00 i:2.15 m:3.51 z:0.03	m:5.66 z:0.03					
U:166.4 h:0.00 i:2.14 m:3.51 z:0.03	U:175.8 h:0.00 m:3.55 z:0.03	U:175.6 h:0.00 m:3.54 z:0.03	U:165.8 h:0.00 i:2.13 m:3.50 z:0.03	U:173.1 h:0.00 m:3.50 z:0.03				
U:166.3 h:0.00 i:2.14 m:3.52 z:0.03	U:176.0 h:0.00 m:3.55 z:0.03	U:175.5 h:0.00 m:3.54 z:0.03	U:164.4 h:0.00 i:2.11 m:3.50 z:0.03	U:164.3 h:0.00 i:2.11 m:3.48 z:0.03	m:5.66 z:0.03			
m:5.69 z:0.03	U:165.8 h:0.00 i:2.13 m:3.53 z:0.03	U:165.7 h:0.00 i:2.12 m:3.52 z:0.03	m:5.67 z:0.03	U:164.6 h:0.00 i:2.11 m:3.50 z:0.03	U:163.5 h:0.00 i:2.09 m:3.53 z:0.03	U:170.0 h:0.00 m:3.57 z:0.03		
U:164.9 h:0.00 i:2.12 m:3.53 z:0.03	U:172.3 h:0.00 m:3.55 z:0.03	U:174.6 h:0.00 m:3.56 z:0.03	U:165.8 h:0.00 i:2.13 m:3.54 z:0.03	U:171.8 h:0.00 m:3.56 z:0.03	U:172.0 h:0.00 m:3.59 z:0.03	U:160.4 h:0.00 i:2.04 m:3.60 z:0.03	U:172.0 h:0.00 m:3.62 z:0.03	
U:171.1 h:0.00 m:3.56 z:0.03	U:160.0 h:0.00 i:2.04 m:3.56 z:0.03	U:175.2 h:0.00 m:3.59 z:0.03	U:174.3 h:0.00 m:3.58 z:0.03	U:160.6 h:0.00 i:2.05 m:3.57 z:0.03	U:174.6 h:0.00 m:3.61 z:0.03	U:176.1 h:0.00 m:3.63 z:0.03	U:174.5 h:0.00 m:3.63 z:0.03	U:160.0 h:0.00 i:2.03 m:3.59 z:0.03

Maximum Standard deviations below:

U:2.65e-01	h:3.06e-08	i:3.89e-03	m:3.25e-03	z:5.76e-05

Legend:

U:U31	h:he	i:ifba	m:mod	z:zirc

Figure 42: 2m(IFBA): Fuel Pin Number Normalized Energy by Fragments and Neutrons (MeV/fission)

m:0.56 z:0.51								
U:5.55 h:0.00 i:0.01 m:0.34 z:0.55	U:5.62 h:0.00 m:0.35 z:0.56							
U:5.55 h:0.00 i:0.01 m:0.34 z:0.55	U:5.63 h:0.00 m:0.35 z:0.56	U:5.61 h:0.00 m:0.34 z:0.55						
m:0.56 z:0.51	U:5.56 h:0.00 i:0.01 m:0.34 z:0.55	U:5.54 h:0.00 i:0.01 m:0.34 z:0.55	m:0.55 z:0.50					
U:5.54 h:0.00 i:0.01 m:0.34 z:0.55	U:5.63 h:0.00 m:0.34 z:0.56	U:5.61 h:0.00 m:0.34 z:0.55	U:5.51 h:0.00 i:0.01 m:0.34 z:0.55	U:5.56 h:0.00 m:0.34 z:0.55				
U:5.55 h:0.00 i:0.01 m:0.34 z:0.55	U:5.62 h:0.00 m:0.34 z:0.56	U:5.61 h:0.00 m:0.34 z:0.55	U:5.50 h:0.00 i:0.01 m:0.34 z:0.55	U:5.49 h:0.00 i:0.01 m:0.34 z:0.54	m:0.55 z:0.50			
m:0.55 z:0.50	U:5.53 h:0.00 i:0.01 m:0.34 z:0.55	U:5.52 h:0.00 i:0.01 m:0.34 z:0.55	m:0.55 z:0.50	U:5.49 h:0.00 i:0.01 m:0.34 z:0.54	U:5.49 h:0.00 i:0.01 m:0.34 z:0.54	U:5.55 h:0.00 m:0.34 z:0.55		
U:5.50 h:0.00 i:0.01 m:0.34 z:0.55	U:5.58 h:0.00 m:0.34 z:0.55	U:5.60 h:0.00 m:0.34 z:0.55	U:5.53 h:0.00 i:0.01 m:0.34 z:0.55	U:5.57 h:0.00 m:0.34 z:0.55	U:5.58 h:0.00 m:0.34 z:0.55	U:5.50 h:0.00 i:0.01 m:0.34 z:0.55	U:5.60 h:0.00 m:0.35 z:0.55	
U:5.58 h:0.00 m:0.34 z:0.55	U:5.47 h:0.00 i:0.01 m:0.34 z:0.55	U:5.62 h:0.00 m:0.35 z:0.55	U:5.61 h:0.00 m:0.34 z:0.56	U:5.51 h:0.00 i:0.01 m:0.34 z:0.55	U:5.63 h:0.00 m:0.35 z:0.56	U:5.66 h:0.00 m:0.35 z:0.56	U:5.64 h:0.00 m:0.35 z:0.56	U:5.49 h:0.00 i:0.01 m:0.34 z:0.55

Maximum Standard deviations below:

U:8.27e-03	h:3.76e-09	i:1.18e-05	m:5.85e-04	z:9.94e-04

Legend:

U:U31	h:he	i:ifba	m:mod	z:zirc

Figure 43: 2m(IFBA): Fuel Pin Number Normalized Prompt Gamma Distribution (MeV/fission)

m:0.58 z:0.53								
U:5.09 h:0.00 i:0.01 m:0.36 z:0.57	U:5.01 h:0.00 m:0.35 z:0.56							
U:5.08 h:0.00 i:0.01 m:0.36 z:0.57	U:4.99 h:0.00 m:0.35 z:0.56	U:5.01 h:0.00 m:0.36 z:0.56						
	U:5.09 h:0.00 i:0.01 m:0.36 z:0.57	U:5.10 h:0.00 i:0.01 m:0.36 z:0.57	m:0.58 z:0.53					
U:5.09 h:0.00 i:0.01 m:0.36 z:0.57	U:5.00 h:0.00 m:0.35 z:0.56	U:5.00 h:0.00 m:0.35 z:0.56	U:5.11 h:0.00 i:0.01 m:0.35 z:0.57	U:5.02 h:0.00 m:0.35 z:0.56				
U:5.09 h:0.00 i:0.01 m:0.36 z:0.57	U:5.00 h:0.00 m:0.35 z:0.56	U:4.99 h:0.00 m:0.35 z:0.56	U:5.11 h:0.00 i:0.01 m:0.36 z:0.57	U:5.13 h:0.00 i:0.01 m:0.36 z:0.57	m:0.58 z:0.53			
m:0.58 z:0.53	U:5.08 h:0.00 i:0.01 m:0.35 z:0.57	U:5.10 h:0.00 i:0.01 m:0.36 z:0.57	m:0.58 z:0.53	U:5.13 h:0.00 i:0.01 m:0.36 z:0.57	U:5.10 h:0.00 i:0.01 m:0.36 z:0.57	U:4.99 h:0.00 m:0.36 z:0.56		
U:5.11 h:0.00 i:0.01 m:0.36 z:0.57	U:4.99 h:0.00 m:0.35 z:0.56	U:4.98 h:0.00 m:0.35 z:0.56	U:5.09 h:0.00 i:0.01 m:0.36 z:0.57	U:5.00 h:0.00 m:0.35 z:0.56	U:4.97 h:0.00 m:0.35 z:0.56	U:5.03 h:0.00 i:0.01 m:0.35 z:0.57	U:4.96 h:0.00 m:0.35 z:0.56	
U:4.95 h:0.00 m:0.35 z:0.56	U:5.03 h:0.00 i:0.01 m:0.35 z:0.57	U:4.97 h:0.00 m:0.35 z:0.56	U:4.97 h:0.00 m:0.35 z:0.56	U:5.01 h:0.00 i:0.01 m:0.35 z:0.57	U:4.98 h:0.00 m:0.35 z:0.56	U:4.94 h:0.00 m:0.35 z:0.56	U:4.97 h:0.00 m:0.35 z:0.56	U:5.04 h:0.00 i:0.01 m:0.36 z:0.57

Maximum Standard deviations below:

U:1.69e-02	h:8.01e-09	i:2.59e-05	m:1.25e-03	z:2.15e-03

Legend:

U:U31	h:he	i:ifba	m:mod	z:zirc

Figure 44: 2m(IFBA): Fuel Pin Number Normalized Capture Gamma Distribution (MeV/fission)

m:0.55 z:0.50								
U:5.44 h:0.00 i:0.01 m:0.34 z:0.54	U:5.51 h:0.00 m:0.34 z:0.55							
U:5.44 h:0.00 i:0.01 m:0.34 z:0.54	U:5.52 h:0.00 m:0.34 z:0.55	U:5.50 h:0.00 m:0.34 z:0.54						
m:0.55 z:0.50	U:5.45 h:0.00 i:0.01 m:0.34 z:0.54	U:5.43 h:0.00 i:0.01 m:0.34 z:0.54	m:0.54 z:0.49					
U:5.43 h:0.00 i:0.01 m:0.34 z:0.54	U:5.52 h:0.00 m:0.34 z:0.55	U:5.50 h:0.00 m:0.34 z:0.54	U:5.40 h:0.00 i:0.01 m:0.33 z:0.54	U:5.45 h:0.00 m:0.33 z:0.54				
U:5.43 h:0.00 i:0.01 m:0.34 z:0.54	U:5.51 h:0.00 m:0.34 z:0.54	U:5.50 h:0.00 m:0.34 z:0.54	U:5.39 h:0.00 i:0.00 m:0.33 z:0.54	U:5.38 h:0.00 i:0.01 m:0.33 z:0.53	m:0.54 z:0.49			
m:0.54 z:0.49	U:5.42 h:0.00 i:0.01 m:0.34 z:0.54	U:5.41 h:0.00 i:0.01 m:0.33 z:0.54	m:0.54 z:0.49	U:5.38 h:0.00 i:0.00 m:0.33 z:0.53	U:5.38 h:0.00 i:0.01 m:0.33 z:0.53	U:5.44 h:0.00 m:0.34 z:0.54		
U:5.39 h:0.00 i:0.01 m:0.33 z:0.54	U:5.47 h:0.00 m:0.34 z:0.54	U:5.49 h:0.00 m:0.34 z:0.54	U:5.42 h:0.00 i:0.01 m:0.33 z:0.54	U:5.46 h:0.00 m:0.34 z:0.54	U:5.47 h:0.00 m:0.34 z:0.54	U:5.39 h:0.00 i:0.01 m:0.34 z:0.54	U:5.48 h:0.00 m:0.34 z:0.54	
U:5.46 h:0.00 m:0.34 z:0.54	U:5.37 h:0.00 i:0.01 m:0.34 z:0.54	U:5.51 h:0.00 m:0.34 z:0.54	U:5.50 h:0.00 m:0.34 z:0.54	U:5.40 h:0.00 i:0.01 m:0.34 z:0.54	U:5.52 h:0.00 m:0.34 z:0.55	U:5.55 h:0.00 m:0.34 z:0.55	U:5.53 h:0.00 m:0.34 z:0.55	U:5.38 h:0.00 i:0.01 m:0.34 z:0.54

Maximum Standard deviations below:

U:8.10e-03	h:3.68e-09	i:1.16e-05	m:5.73e-04	z:9.74e-04

Legend:

U:U31	h:he	i:ifba	m:mod	z:zirc

Figure 45: 2m(IFBA): Fuel Pin Number Normalized Delayed Gamma Distribution (MeV/fission)

m:1.68 z:1.53								
U:16.09 h:0.00 i:0.02 m:1.04 z:1.66	U:16.14 h:0.00 m:1.04 z:1.66							
U:16.06 h:0.00 i:0.02 m:1.04 z:1.66	U:16.14 h:0.00 m:1.04 z:1.66	U:16.12 h:0.00 m:1.04 z:1.66						
m:1.68 z:1.53	U:16.09 h:0.00 i:0.02 m:1.03 z:1.66	U:16.07 h:0.00 i:0.02 m:1.03 z:1.66	m:1.68 z:1.53					
U:16.07 h:0.00 i:0.02 m:1.03 z:1.66	U:16.15 h:0.00 m:1.04 z:1.66	U:16.12 h:0.00 m:1.03 z:1.66	U:16.02 h:0.00 i:0.02 m:1.03 z:1.65	U:16.04 h:0.00 m:1.03 z:1.65				
U:16.07 h:0.00 i:0.02 m:1.03 z:1.66	U:16.13 h:0.00 m:1.04 z:1.66	U:16.10 h:0.00 m:1.03 z:1.66	U:16.01 h:0.00 i:0.02 m:1.03 z:1.65	U:15.99 h:0.00 i:0.02 m:1.03 z:1.65	m:1.66 z:1.51			
m:1.68 z:1.53	U:16.03 h:0.00 i:0.02 m:1.03 z:1.65	U:16.03 h:0.00 i:0.02 m:1.03 z:1.66	m:1.68 z:1.52	U:15.99 h:0.00 i:0.02 m:1.03 z:1.65	U:15.97 h:0.00 i:0.02 m:1.03 z:1.65	U:15.98 h:0.00 m:1.03 z:1.65		
U:16.00 h:0.00 i:0.02 m:1.03 z:1.65	U:16.03 h:0.00 m:1.03 z:1.65	U:16.07 h:0.00 m:1.03 z:1.65	U:16.03 h:0.00 i:0.02 m:1.03 z:1.66	U:16.03 h:0.00 m:1.03 z:1.65	U:16.02 h:0.00 m:1.03 z:1.66	U:15.91 h:0.00 i:0.02 m:1.04 z:1.66	U:16.04 h:0.00 m:1.04 z:1.66	
U:15.99 h:0.00 m:1.03 z:1.65	U:15.87 h:0.00 i:0.02 m:1.03 z:1.65	U:16.09 h:0.00 m:1.04 z:1.66	U:16.08 h:0.00 m:1.04 z:1.66	U:15.92 h:0.00 i:0.02 m:1.03 z:1.65	U:16.13 h:0.00 m:1.04 z:1.66	U:16.16 h:0.00 m:1.04 z:1.67	U:16.13 h:0.00 m:1.04 z:1.67	U:15.91 h:0.00 i:0.02 m:1.04 z:1.66

Maximum Standard deviations below:

U:1.69e-02	h:7.99e-09	i:2.58e-05	m:1.25e-03	z:2.14e-03

Legend:

U:U31	h:he	i:ifba	m:mod	z:zirc

Figure 46: 2m(IFBA): Fuel Pin Number Normalized Total Gamma Distribution (MeV/fission)

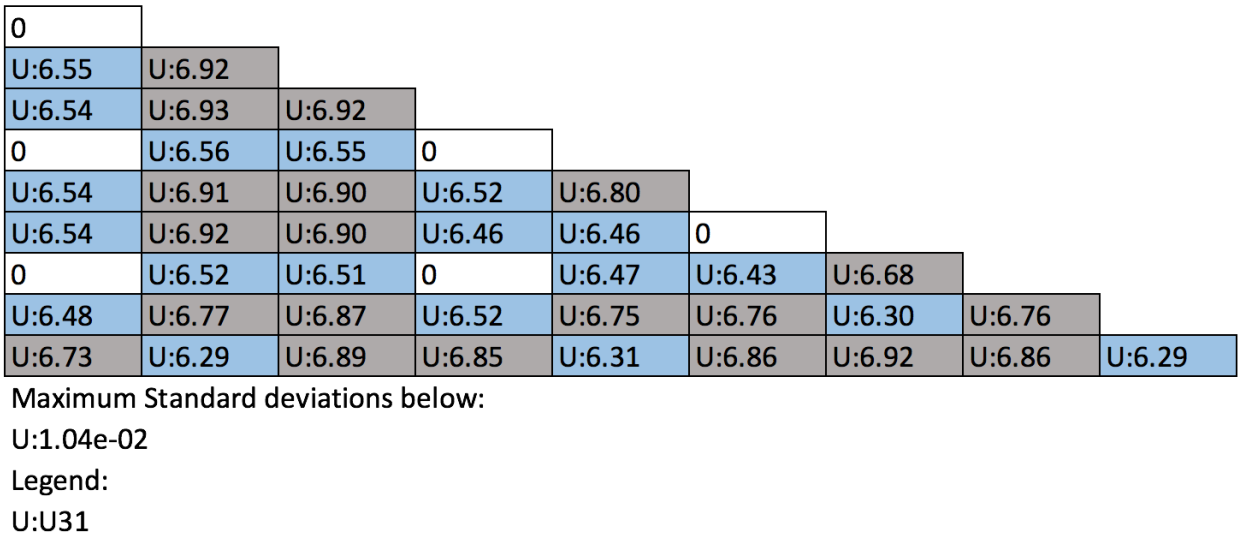

Figure 47: 2m(IFBA): Fuel Pin Number Normalized Beta Distribution (MeV/fission)

Table 12: 2m(IFBA): Energy Deposition Summary

	n+fg	prompt gamma	capture gamma	delayed gamma	beta	total
U31	1.696e+02 +- 2.106e-02	5.564e+00 +- 6.673e-04	5.035e+00 +- 1.031e-03	5.453e+00 +- 6.540e-04	6.665e+00 +- 8.280e-04	1.923e+02 +- 2.113e-02
he	2.159e-05 +- 2.493e-09	1.746e-06 +- 2.499e-10	1.798e-06 +- 4.548e-10	1.712e-06 +- 2.449e-10	0	2.684e-05 +- 2.559e-09
ifba	1.022e+00 +- 1.721e-04	2.486e-03 +- 4.988e-07	2.641e-03 +- 1.009e-06	2.437e-03 +- 4.889e-07	0	1.029e+00 +- 1.721e-04
mod	4.140e+00 +- 3.931e-04	4.005e-01 +- 4.549e-05	4.153e-01 +- 7.157e-05	3.925e-01 +- 4.459e-05	0	5.348e+00 +- 4.046e-04
zirc	3.401e-02 +- 4.468e-06	5.994e-01 +- 7.538e-05	6.155e-01 +- 1.276e-04	5.875e-01 +- 7.388e-05	0	1.837e+00 +- 1.657e-04
total	1.748e+02 +- 2.107e-02	6.566e+00 +- 6.731e-04	6.068e+00 +- 1.041e-03	6.436e+00 +- 6.597e-04	6.665e+00 +- 8.280e-04	2.005e+02 +- 2.113e-02

m:7.97 z:1.90								
h:0.00 m:4.94 u:225.4 z:2.06	h:0.00 m:4.93 u:215.4 z:2.08							
h:0.00 m:4.90 u:220.5 z:2.03	h:0.00 m:4.88 u:204.1 z:2.08	g:63.42 h:0.00 m:4.83 z:2.41						
m:7.89 z:1.89	h:0.00 m:4.88 u:216.3 z:2.07	h:0.00 m:4.85 u:206.8 z:2.09	m:7.84 z:1.95					
h:0.00 m:4.85 u:206.9 z:2.06	h:0.00 m:4.88 u:209.7 z:2.06	h:0.00 m:4.88 u:210.4 z:2.04	h:0.00 m:4.85 u:206.3 z:2.10	g:63.54 h:0.00 m:4.80 z:2.42				
g:63.75 h:0.00 m:4.81 z:2.40	h:0.00 m:4.87 u:202.6 z:2.08	h:0.00 m:4.89 u:212.1 z:2.04	h:0.00 m:4.87 u:214.4 z:2.07	h:0.00 m:4.82 u:206.0 z:2.09	m:7.80 z:1.93			
m:7.88 z:1.94	h:0.00 m:4.90 u:215.7 z:2.06	h:0.00 m:4.88 u:214.2 z:2.04	m:7.82 z:1.94	h:0.00 m:4.83 u:209.8 z:2.04	h:0.00 m:4.83 u:201.8 z:2.07	g:62.80 h:0.00 m:4.82 z:2.35		
h:0.00 m:4.93 u:221.3 z:2.03	h:0.00 m:4.93 u:214.3 z:2.02	h:0.00 m:4.87 u:200.6 z:2.05	g:63.17 h:0.00 m:4.80 z:2.37	h:0.00 m:4.84 u:196.1 z:2.04	h:0.00 m:4.88 u:201.6 z:2.01	h:0.00 m:4.89 u:195.5 z:2.02	h:0.00 m:4.94 u:205.2 z:2.00	
h:0.00 m:4.97 u:219.0 z:2.02	h:0.00 m:4.95 u:214.9 z:2.03	h:0.00 m:4.90 u:206.2 z:2.03	h:0.00 m:4.85 u:194.0 z:2.04	h:0.00 m:4.87 u:202.8 z:2.01	h:0.00 m:4.91 u:208.1 z:2.00	h:0.00 m:4.94 u:209.4 z:1.99	h:0.00 m:4.97 u:213.6 z:1.99	h:0.00 m:5.00 u:217.7 z:2.00

Maximum Standard deviations below:

g:5.06e-02	h:3.71e-08	m:3.72e-03	u:3.28e-01	z:2.61e-03

Legend:

g:g18	h:he	m:mod	u:u31	z:zirc

Figure 48: 2p(Gad): Fuel Pin Number Normalized Total Energy Distribution Material Separated (MeV/fission)

m:5.93 z:0.03								
h:0.00 m:3.67 u:198.3 z:0.03	h:0.00 m:3.65 u:188.8 z:0.03							
h:0.00 m:3.64 u:193.8 z:0.03	h:0.00 m:3.59 u:178.0 z:0.03	g:41.44 h:0.00 m:3.44 z:0.03						
m:5.84 z:0.03	h:0.00 m:3.61 u:189.6 z:0.03	h:0.00 m:3.56 u:180.5 z:0.03	m:5.73 z:0.03					
h:0.00 m:3.57 u:180.8 z:0.03	h:0.00 m:3.61 u:183.4 z:0.03	h:0.00 m:3.62 u:184.2 z:0.03	h:0.00 m:3.55 u:180.1 z:0.03	g:41.46 h:0.00 m:3.41 z:0.03				
g:41.72 h:0.00 m:3.44 z:0.03	h:0.00 m:3.58 u:176.6 z:0.03	h:0.00 m:3.63 u:185.9 z:0.03	h:0.00 m:3.59 u:187.9 z:0.03	h:0.00 m:3.53 u:179.8 z:0.03	m:5.71 z:0.03			
m:5.78 z:0.03	h:0.00 m:3.63 u:189.1 z:0.03	h:0.00 m:3.61 u:187.8 z:0.03	m:5.72 z:0.03	h:0.00 m:3.57 u:183.7 z:0.03	h:0.00 m:3.55 u:176.0 z:0.03	g:41.22 h:0.00 m:3.47 z:0.03		
h:0.00 m:3.69 u:194.7 z:0.03	h:0.00 m:3.68 u:188.0 z:0.03	h:0.00 m:3.60 u:174.9 z:0.03	g:41.43 h:0.00 m:3.44 z:0.03	h:0.00 m:3.57 u:170.7 z:0.03	h:0.00 m:3.63 u:176.1 z:0.03	h:0.00 m:3.63 u:170.2 z:0.03	h:0.00 m:3.70 u:179.6 z:0.03	
h:0.00 m:3.73 u:192.5 z:0.03	h:0.00 m:3.70 u:188.6 z:0.03	h:0.00 m:3.64 u:180.4 z:0.03	h:0.00 m:3.58 u:168.8 z:0.03	h:0.00 m:3.63 u:177.3 z:0.03	h:0.00 m:3.68 u:182.3 z:0.03	h:0.00 m:3.71 u:183.7 z:0.03	h:0.00 m:3.75 u:187.6 z:0.03	h:0.00 m:3.77 u:191.4 z:0.03

Maximum Standard deviations below:

g:4.61e-02	h:3.60e-08	m:3.41e-03	u:3.27e-01	z:6.38e-05

Legend:

g:g18	h:he	m:mod	u:u31	z:zirc

Figure 49: 2p(Gad): Fuel Pin Number Normalized Energy by Fragments and Neutrons (MeV/fission)

m:0.58 z:0.53								
h:0.00 m:0.36 u:5.93 z:0.58	h:0.00 m:0.35 u:5.79 z:0.57							
h:0.00 m:0.36 u:5.90 z:0.58	h:0.00 m:0.34 u:5.66 z:0.56	g:4.31 h:0.00 m:0.33 z:0.50						
m:0.57 z:0.52	h:0.00 m:0.35 u:5.75 z:0.56	h:0.00 m:0.34 u:5.61 z:0.55	m:0.55 z:0.50					
h:0.00 m:0.34 u:5.67 z:0.56	h:0.00 m:0.35 u:5.70 z:0.56	h:0.00 m:0.35 u:5.73 z:0.56	h:0.00 m:0.34 u:5.57 z:0.55	g:4.22 h:0.00 m:0.32 z:0.49				
g:4.36 h:0.00 m:0.33 z:0.50	h:0.00 m:0.34 u:5.61 z:0.55	h:0.00 m:0.35 u:5.74 z:0.56	h:0.00 m:0.34 u:5.69 z:0.55	h:0.00 m:0.33 u:5.52 z:0.54	m:0.54 z:0.49			
m:0.56 z:0.51	h:0.00 m:0.35 u:5.75 z:0.56	h:0.00 m:0.35 u:5.74 z:0.56	m:0.55 z:0.50	h:0.00 m:0.34 u:5.63 z:0.55	h:0.00 m:0.34 u:5.50 z:0.54	g:4.27 h:0.00 m:0.32 z:0.49		
h:0.00 m:0.36 u:5.93 z:0.58	h:0.00 m:0.35 u:5.84 z:0.57	h:0.00 m:0.34 u:5.60 z:0.55	g:4.29 h:0.00 m:0.32 z:0.50	h:0.00 m:0.34 u:5.51 z:0.54	h:0.00 m:0.34 u:5.62 z:0.55	h:0.00 m:0.34 u:5.57 z:0.55	h:0.00 m:0.35 u:5.73 z:0.57	
h:0.00 m:0.36 u:5.95 z:0.58	h:0.00 m:0.36 u:5.85 z:0.58	h:0.00 m:0.35 u:5.66 z:0.56	h:0.00 m:0.34 u:5.52 z:0.55	h:0.00 m:0.34 u:5.60 z:0.55	h:0.00 m:0.35 u:5.71 z:0.56	h:0.00 m:0.36 u:5.82 z:0.57	h:0.00 m:0.36 u:5.87 z:0.58	h:0.00 m:0.36 u:5.95 z:0.59

Maximum Standard deviations below:

g:6.55e-03	h:4.32e-09	m:6.52e-04	u:9.57e-03	z:1.11e-03

Legend:

g:g18	h:he	m:mod	u:u31	z:zirc

Figure 50: 2p(Gad): Fuel Pin Number Normalized Prompt Gamma Distribution (MeV/fission)

m:0.89 z:0.81								
h:0.00 m:0.55 u:7.34 z:0.87	h:0.00 m:0.58 u:7.54 z:0.91							
h:0.00 m:0.55 u:7.14 z:0.85	h:0.00 m:0.60 u:7.69 z:0.93	g:11.74 h:0.00 m:0.73 z:1.38						
m:0.92 z:0.83	h:0.00 m:0.58 u:7.62 z:0.92	h:0.00 m:0.62 u:7.85 z:0.96	m:1.02 z:0.93					
h:0.00 m:0.59 u:7.55 z:0.92	h:0.00 m:0.58 u:7.51 z:0.91	h:0.00 m:0.57 u:7.40 z:0.88	h:0.00 m:0.63 u:7.94 z:0.98	g:12.01 h:0.00 m:0.76 z:1.42				
g:11.69 h:0.00 m:0.72 z:1.37	h:0.00 m:0.60 u:7.75 z:0.94	h:0.00 m:0.56 u:7.34 z:0.88	h:0.00 m:0.60 u:7.67 z:0.93	h:0.00 m:0.63 u:8.04 z:0.98	m:1.01 z:0.93			
m:0.99 z:0.90	h:0.00 m:0.58 u:7.52 z:0.91	h:0.00 m:0.57 u:7.41 z:0.89	m:1.01 z:0.92	h:0.00 m:0.58 u:7.55 z:0.91	h:0.00 m:0.61 u:7.82 z:0.95	g:11.43 h:0.00 m:0.71 z:1.34		
h:0.00 m:0.54 u:7.00 z:0.84	h:0.00 m:0.54 u:7.08 z:0.85	h:0.00 m:0.59 u:7.55 z:0.92	g:11.55 h:0.00 m:0.72 z:1.35	h:0.00 m:0.59 u:7.58 z:0.92	h:0.00 m:0.56 u:7.26 z:0.88	h:0.00 m:0.57 u:7.34 z:0.89	h:0.00 m:0.54 u:7.01 z:0.84	
h:0.00 m:0.52 u:6.88 z:0.82	h:0.00 m:0.54 u:7.12 z:0.85	h:0.00 m:0.56 u:7.36 z:0.88	h:0.00 m:0.59 u:7.51 z:0.92	h:0.00 m:0.56 u:7.28 z:0.88	h:0.00 m:0.54 u:7.11 z:0.84	h:0.00 m:0.52 u:6.81 z:0.81	h:0.00 m:0.51 u:6.82 z:0.81	h:0.00 m:0.51 u:6.74 z:0.80

Maximum Standard deviations below:

g:2.06e-02	h:1.72e-08	m:1.64e-03	u:2.02e-02	z:2.61e-03

Legend:

g:g18	h:he	m:mod	u:u31	z:zirc

Figure 51: 2p(Gad): Fuel Pin Number Normalized Capture Gamma Distribution (MeV/fission)

m:0.58 z:0.53								
h:0.00 m:0.35 u:5.90 z:0.57	h:0.00 m:0.35 u:5.76 z:0.56							
h:0.00 m:0.35 u:5.88 z:0.57	h:0.00 m:0.34 u:5.63 z:0.55	g:4.29 h:0.00 m:0.32 z:0.50						
	h:0.00 m:0.34 u:5.72 z:0.56	h:0.00 m:0.34 u:5.58 z:0.55	m:0.54 z:0.49					
h:0.00 m:0.34 u:5.64 z:0.55	h:0.00 m:0.35 u:5.68 z:0.56	h:0.00 m:0.35 u:5.71 z:0.56	h:0.00 m:0.34 u:5.54 z:0.54	g:4.20 h:0.00 m:0.32 z:0.49				
g:4.33 h:0.00 m:0.33 z:0.50	h:0.00 m:0.34 u:5.58 z:0.55	h:0.00 m:0.35 u:5.72 z:0.56	h:0.00 m:0.34 u:5.66 z:0.55	h:0.00 m:0.33 u:5.50 z:0.54	m:0.54 z:0.49			
	h:0.00 m:0.35 u:5.73 z:0.56	h:0.00 m:0.34 u:5.71 z:0.56	m:0.54 z:0.50	h:0.00 m:0.34 u:5.60 z:0.55	h:0.00 m:0.33 u:5.48 z:0.54	g:4.25 h:0.00 m:0.32 z:0.49		
h:0.00 m:0.35 u:5.91 z:0.58	h:0.00 m:0.35 u:5.82 z:0.57	h:0.00 m:0.34 u:5.57 z:0.55	g:4.27 h:0.00 m:0.32 z:0.49	h:0.00 m:0.34 u:5.48 z:0.54	h:0.00 m:0.34 u:5.60 z:0.55	h:0.00 m:0.34 u:5.54 z:0.55	h:0.00 m:0.35 u:5.71 z:0.56	
h:0.00 m:0.36 u:5.92 z:0.58	h:0.00 m:0.35 u:5.82 z:0.57	h:0.00 m:0.35 u:5.63 z:0.56	h:0.00 m:0.34 u:5.49 z:0.54	h:0.00 m:0.34 u:5.57 z:0.55	h:0.00 m:0.35 u:5.68 z:0.56	h:0.00 m:0.35 u:5.79 z:0.57	h:0.00 m:0.36 u:5.84 z:0.57	h:0.00 m:0.36 u:5.92 z:0.58

Maximum Standard deviations below:

g:6.52e-03	h:4.30e-09	m:6.49e-04	u:9.53e-03	z:1.11e-03

Legend:

g:g18	h:he	m:mod	u:u31	z:zirc

Figure 52: 2p(Gad): Fuel Pin Number Normalized Delayed Gamma Distribution (MeV/fission)

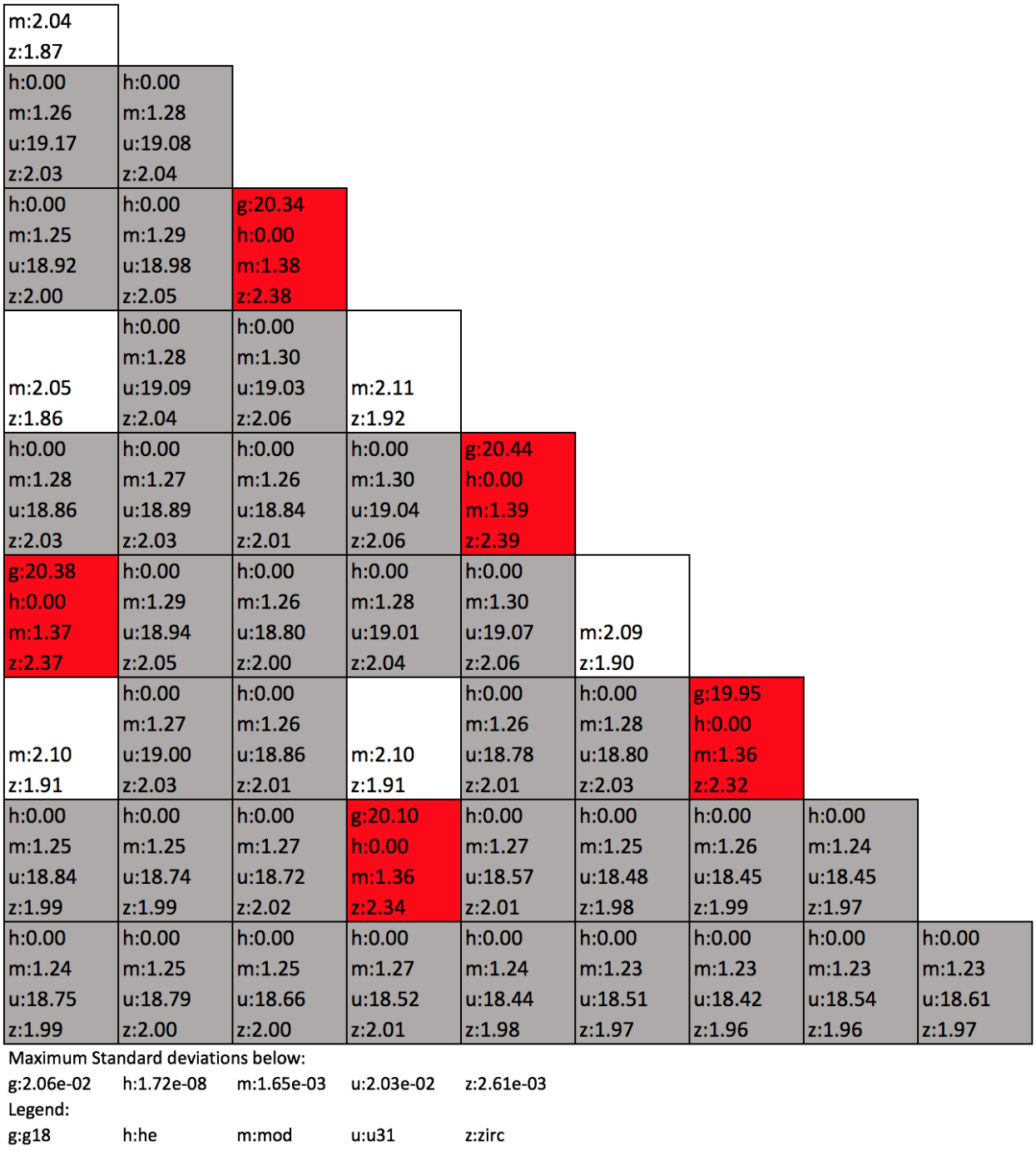

Figure 53: 2p(Gad): Fuel Pin Number Normalized Total Gamma Distribution (MeV/fission)

0								
u:7.92	u:7.54							
u:7.74	u:7.11	g:1.64						
0	u:7.58	u:7.21	0					
u:7.22	u:7.33	u:7.36	u:7.19	g:1.64				
g:1.66	u:7.05	u:7.42	u:7.51	u:7.18	0			
0	u:7.55	u:7.50	0	u:7.34	u:7.03	g:1.63		
u:7.78	u:7.51	u:6.99	g:1.64	u:6.82	u:7.03	u:6.80	u:7.17	
u:7.69	u:7.53	u:7.20	u:6.74	u:7.08	u:7.28	u:7.34	u:7.49	u:7.65

Maximum Standard deviations below:

g:1.83e-03 u:1.30e-02

Legend:

g:g18 u:u31

Figure 54: 2p(Gad): Fuel Pin Number Normalized Beta Distribution (MeV/fission)

Table 13: 2p(Gad): Energy Deposition Summary

	n+fg	prompt gamma	capture gamma	delayed gamma	beta	total
g18	3.769e+00 +- 9.188e-04	3.899e-01 +- 1.250e-04	1.060e+00 +- 3.881e-04	3.881e-01 +- 1.244e-04	1.495e-01 +- 3.645e-05	5.757e+00 +- 1.014e-03
he	2.320e-05 +- 2.833e-09	1.859e-06 +- 2.833e-10	3.162e-06 +- 6.328e-10	1.850e-06 +- 2.819e-10	0	3.007e-05 +- 2.930e-09
mod	4.208e+00 +- 4.303e-04	4.017e-01 +- 4.904e-05	6.877e-01 +- 1.013e-04	3.998e-01 +- 4.880e-05	0	5.697e+00 +- 4.474e-04
u31	1.658e+02 +- 2.244e-02	5.177e+00 +- 6.829e-04	6.743e+00 +- 1.239e-03	5.152e+00 +- 6.797e-04	6.623e+00 +- 8.982e-04	1.895e+02 +- 2.252e-02
zirc	3.453e-02 +- 4.813e-06	6.013e-01 +- 8.089e-05	1.023e+00 +- 1.748e-04	5.984e-01 +- 8.051e-05	0	2.258e+00 +- 2.089e-04
total	1.738e+02 +- 2.247e-02	6.569e+00 +- 7.007e-04	9.514e+00 +- 1.314e-03	6.538e+00 +- 6.973e-04	6.772e+00 +- 8.989e-04	2.032e+02 +- 2.255e-02

U21:191.7 h:0.00 m:5.30 z:1.83							
U26:178.1 h:0.00 m:4.67 p:0.82 s:0.13 z:1.71	U21:191.9 h:0.00 m:5.29 z:1.82						
U21:194.5 h:0.00 m:5.38 z:1.85	U26:174.1 h:0.00 m:4.60 p:0.95 s:0.16 z:1.69	U21:202.8 h:0.00 m:5.60 z:1.92					
U26:191.8 h:0.00 m:5.02 p:0.88 s:0.14 z:1.84	U21:208.4 h:0.00 m:5.75 z:1.98	U26:199.4 h:0.00 m:5.23 p:0.92 s:0.15 z:1.91	U21:222.9 h:0.00 m:6.16 z:2.12				
U21:216.6 h:0.00 m:5.98 z:2.06	U26:203.5 h:0.00 m:5.33 p:0.93 s:0.15 z:1.96	U21:225.0 h:0.00 m:6.21 z:2.14	U26:211.4 h:0.00 m:5.56 p:0.98 s:0.16 z:2.04	U26:251.2 h:0.00 m:6.43 z:2.27			
U26:202.1 h:0.00 m:5.30 p:0.93 s:0.15 z:1.95	U21:222.1 h:0.00 m:6.15 z:2.12	U26:220.3 h:0.00 m:5.73 p:0.80 s:0.13 z:2.09	U21:222.6 h:0.00 m:6.16 z:2.12	U26:177.3 h:0.00 m:4.77 p:0.98 s:0.16 z:1.76	U31:178.7 h:0.00 m:4.46 p:0.44 s:0.08 z:1.64		
U21:204.3 h:0.00 m:5.70 z:1.98	U31:202.0 h:0.00 m:5.05 p:0.98 s:0.18 z:1.90	U21:210.4 h:0.00 m:5.86 z:2.03	U31:201.3 h:0.00 m:5.00 p:0.65 s:0.12 z:1.86	U31:182.8 h:0.00 m:4.45 z:1.61	U31:122.9 h:0.00 m:2.99 z:1.09		
U31:149.4 h:0.00 m:3.70 p:0.37 s:0.06 z:1.38	U31:170.8 h:0.00 m:4.17 z:1.52	U31:152.8 h:0.00 m:3.75 p:0.25 s:0.04 z:1.38	U31:125.1 h:0.00 m:3.05 z:1.12				

Maximum Standard deviations below:

U21:1.82e-01	U26:2.04e-01	U31:1.81e-01	he:4.60e-08	mod:3.77e-03	pyrex-vera:1.59e-03	ss:2.64e-04	zirc:1.74e-03

Legend:

U21:U21	U26:U26	U31:U31	h:he	m:mod	p:pyrex-vera	s:ss	z:zirc

Figure 55: 5a-2d: Assembly Number Normalized Total Energy Distribution Material Separated (MeV/fission)

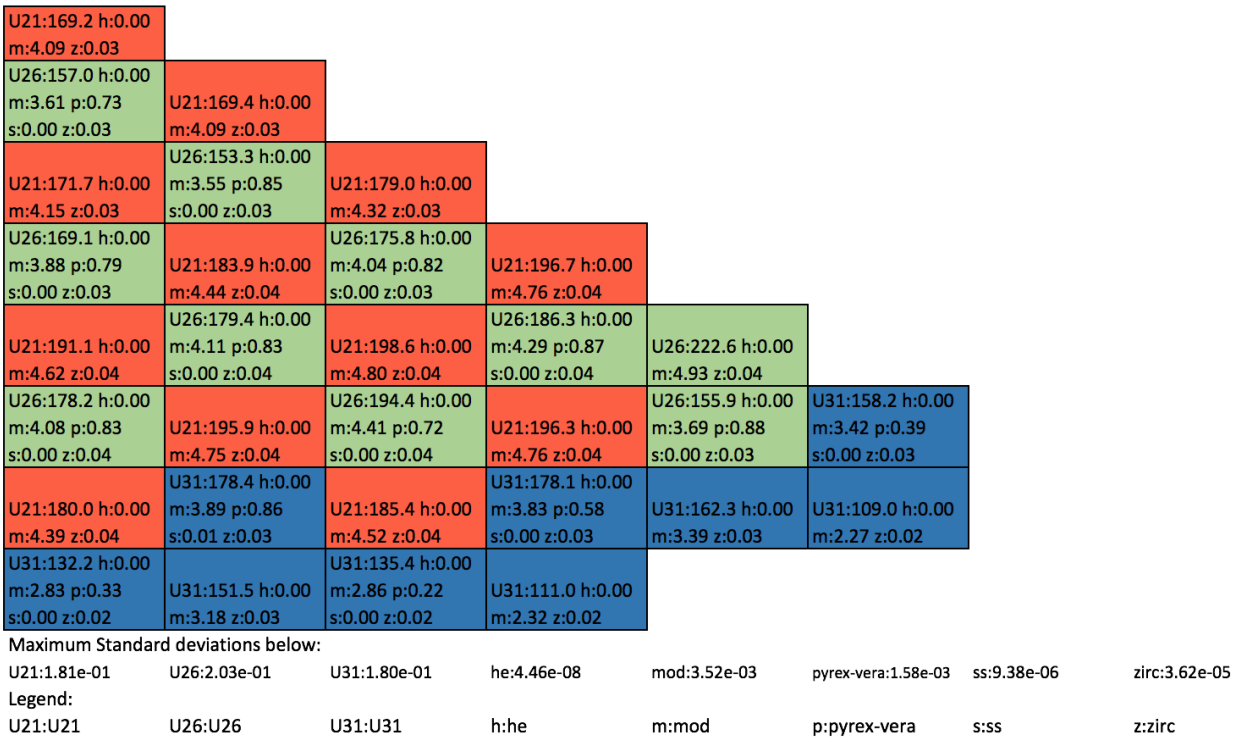

Figure 56: 5a-2d: Assembly Number Normalized Energy by Fragments and Neutrons (MeV/fission)

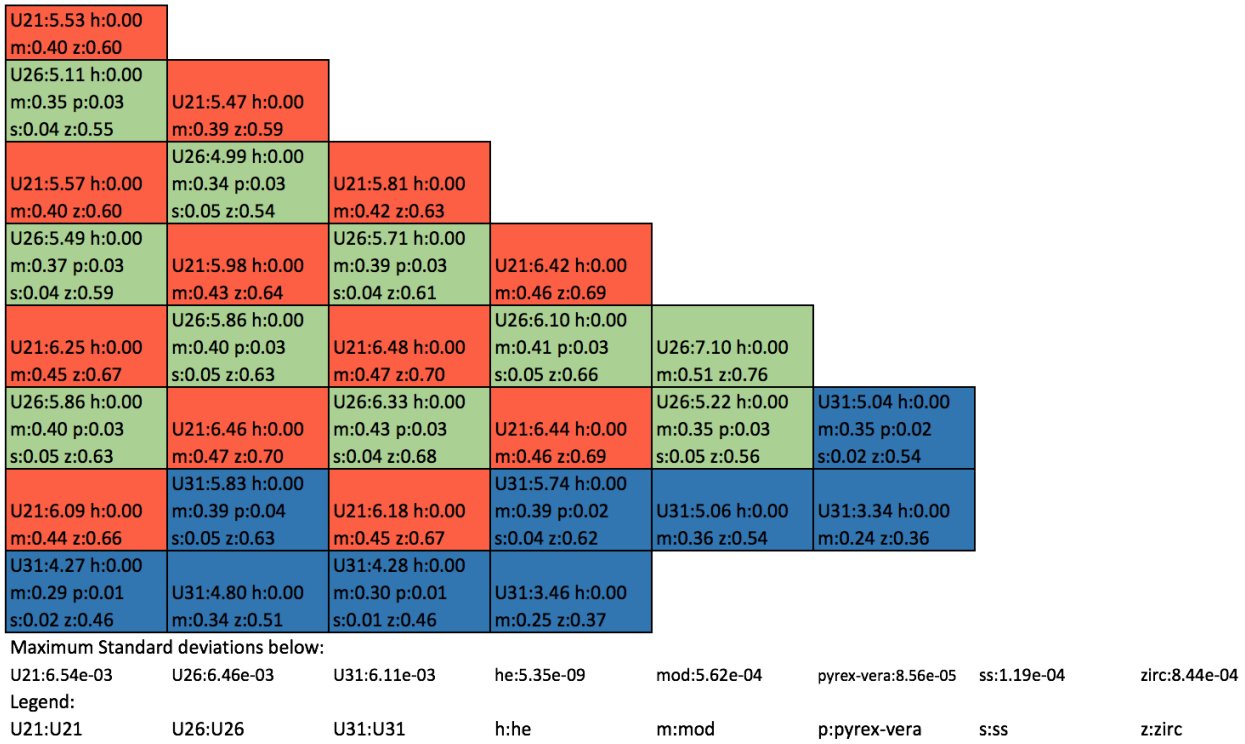

Figure 57: 5a-2d: Assembly Number Normalized Prompt Gamma Distribution (MeV/fission)

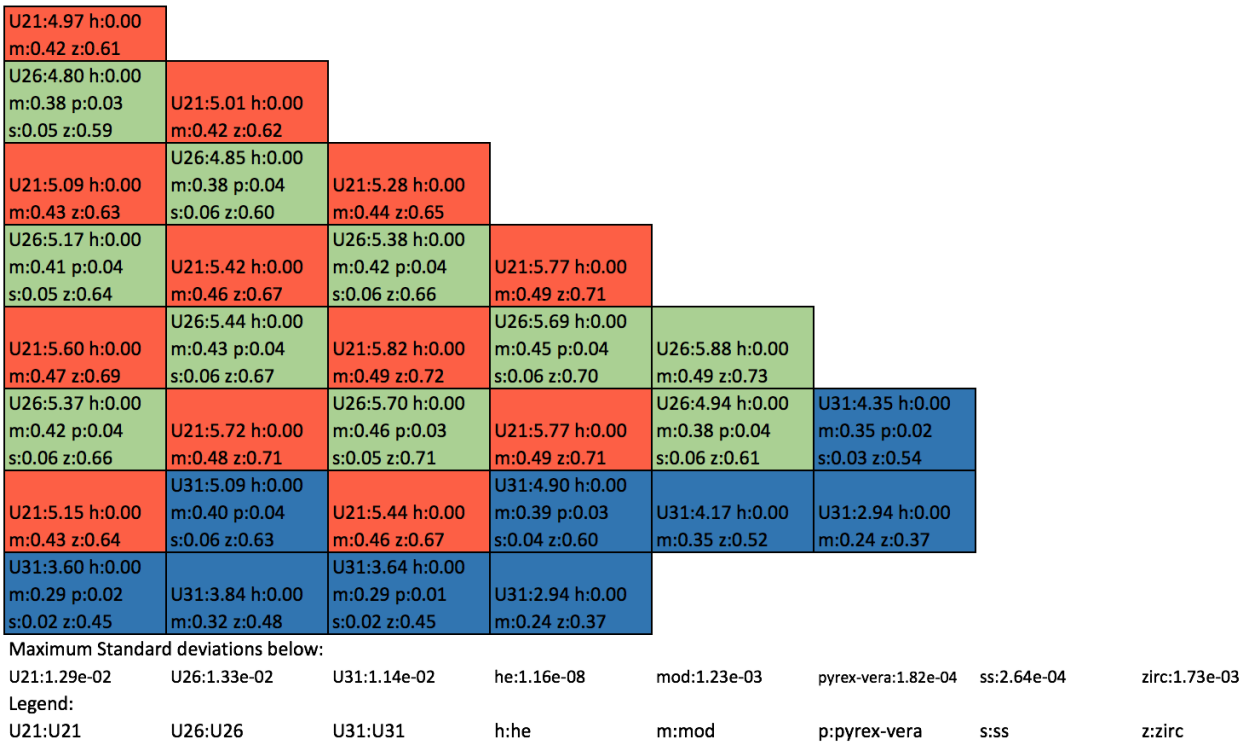

Figure 58: 5a-2d: Assembly Number Normalized Capture Gamma Distribution (MeV/fission)

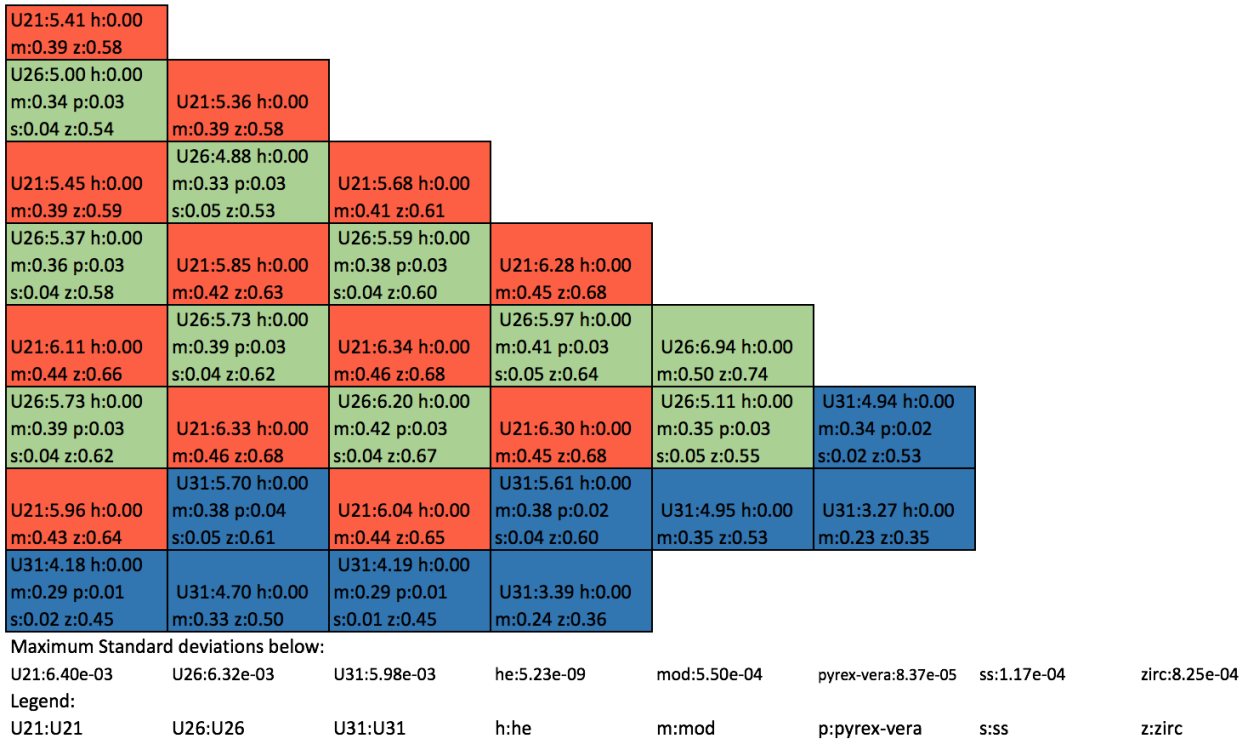

Figure 59: 5a-2d: Assembly Number Normalized Delayed Gamma Distribution (MeV/fission)

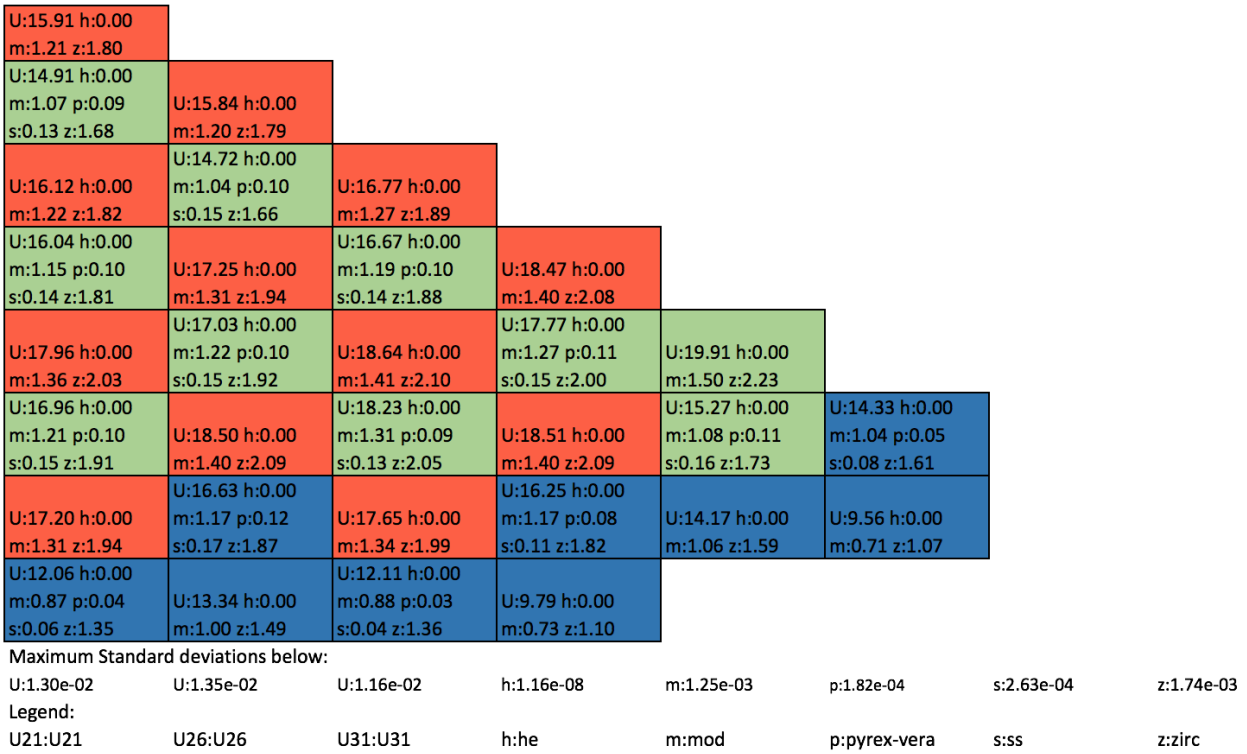

Figure 60: 5a-2d: Assembly Number Normalized Total Gamma Distribution (MeV/fission)

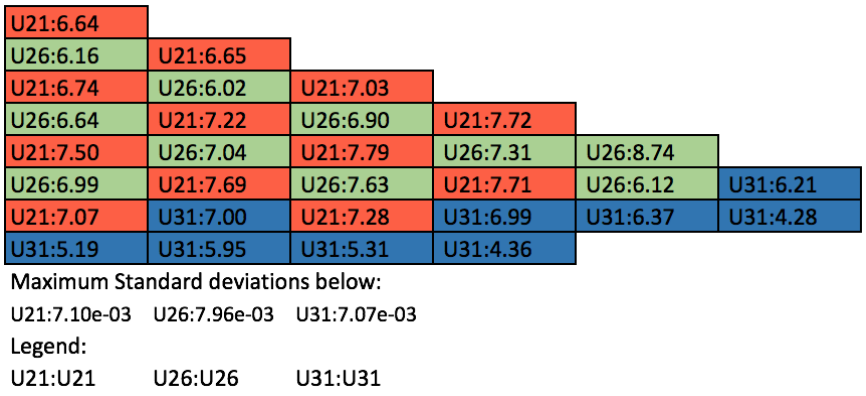

Figure 61: 5a-2d: Assembly Number Normalized Beta Distribution (MeV/fission)

Table 14: 5a-2d: Energy Deposition Summary

	n+fg	prompt gamma	capture gamma	delayed gamma	beta	total
he	2.720E-05 +- 5.858E-09	2.321E-06 +- 6.086E-10	2.450E-06 +- 1.167E-09	2.271E-06 +- 5.956E-10	0	3.424E-05 +- 6.034E-09
mod	3.891E+00 +- 6.942E-04	3.857E-01 +- 8.908E-05	4.000E-01 +- 1.603E-04	3.774E-01 +- 8.718E-05	0	5.054E+00 +- 7.233E-04
pyrex-vera	3.370E-01 +- 1.452E-04	1.312E-02 +- 7.135E-06	1.606E-02 +- 1.553E-05	1.284E-02 +- 6.983E-06	0	3.790E-01 +- 1.464E-04
ss	1.858E-03 +- 8.255E-07	1.913E-02 +- 1.013E-05	2.339E-02 +- 2.235E-05	1.872E-02 +- 9.916E-06	0	6.310E-02 +- 2.648E-05
zirc	3.228E-02 +- 6.496E-06	5.925E-01 +- 1.345E-04	6.066E-01 +- 2.401E-04	5.798E-01 +- 1.316E-04	0	1.811E+00 +- 3.051E-04
Fuel Rod	1.695E+02 +- 2.746E-02	5.509E+00 +- 9.507E-04	4.902E+00 +- 1.702E-03	5.391E+00 +- 9.303E-04	6.655E+00 +- 1.078E-03	1.920E+02 +- 2.756E-02
Outside Core	1.458E-01 +- 1.191E-04	5.793E-02 +- 6.646E-05	2.969E-01 +- 2.668E-04	5.669E-02 +- 6.504E-05	0	5.573E-01 +- 3.066E-04
total	1.739E+02 +- 2.747E-02	6.577E+00 +- 9.666E-04	6.245E+00 +- 1.747E-03	6.436E+00 +- 9.460E-04	6.655E+00 +- 1.078E-03	1.999E+02 +- 2.758E-02
Portion(%)	86.99 +- 0.02	3.29 +- 0.00	3.12 +- 0.00	3.22 +- 0.00	3.33 +- 0.00	100.00

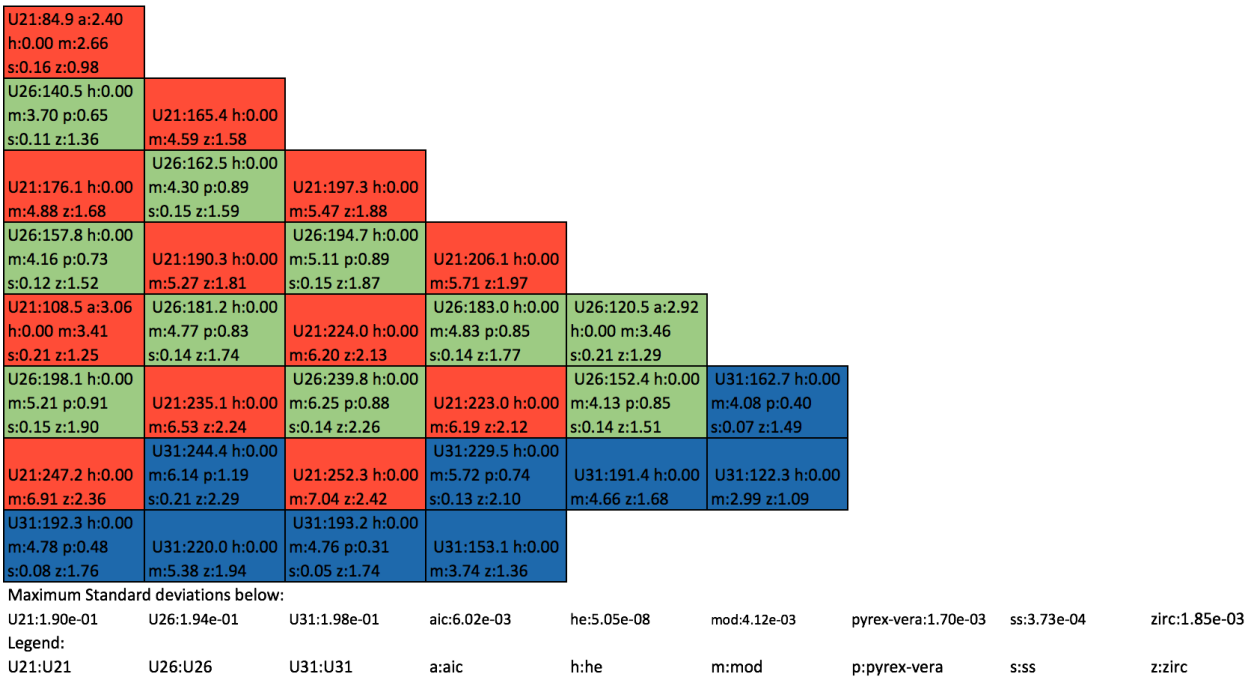

Figure 62: 5b-2d: Assembly Number Normalized Total Energy Distribution Material Separated (MeV/fission)

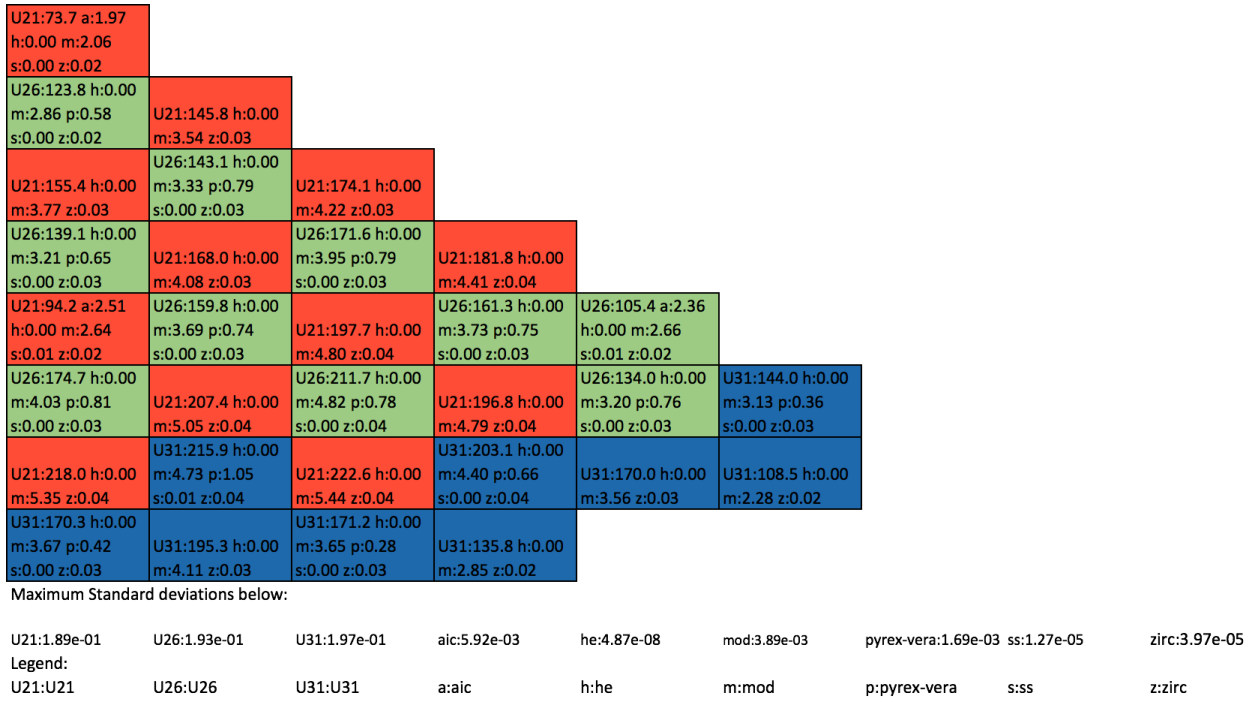

Figure 63: 5b-2d: Assembly Number Normalized Energy by Fragments and Neutrons (MeV/fission)

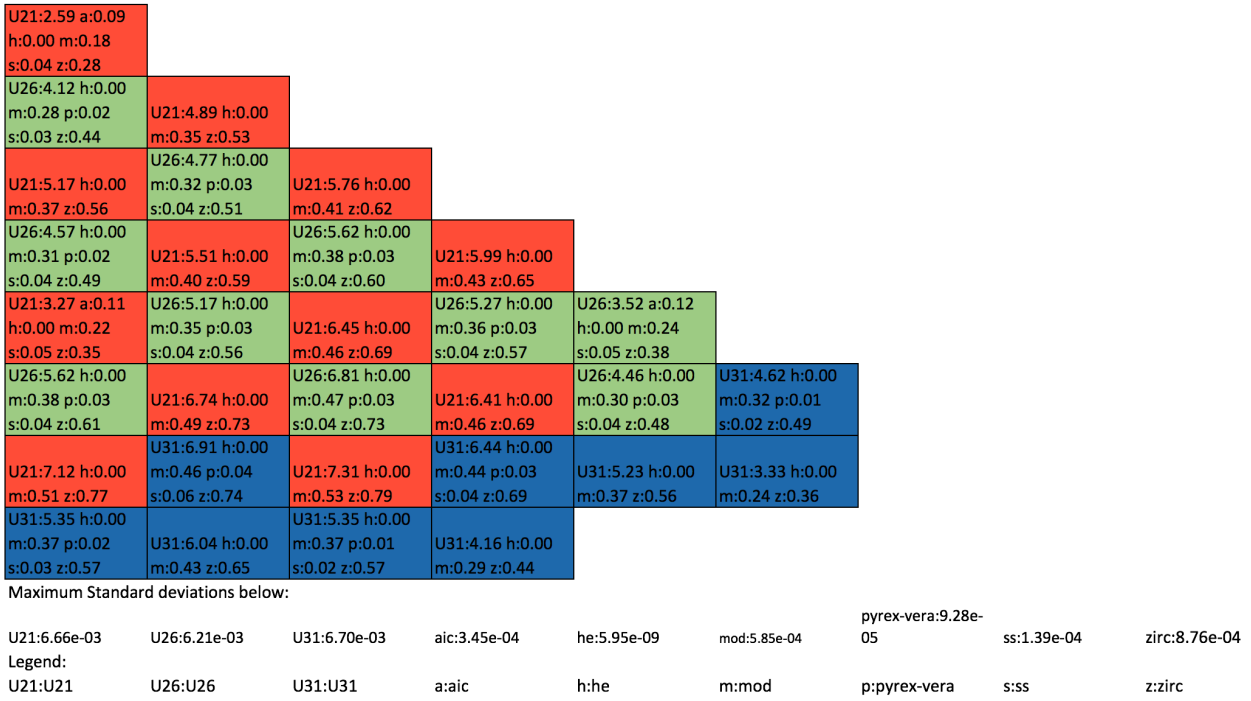

Figure 64: 5b-2d: Assembly Number Normalized Prompt Gamma Distribution (MeV/fission)

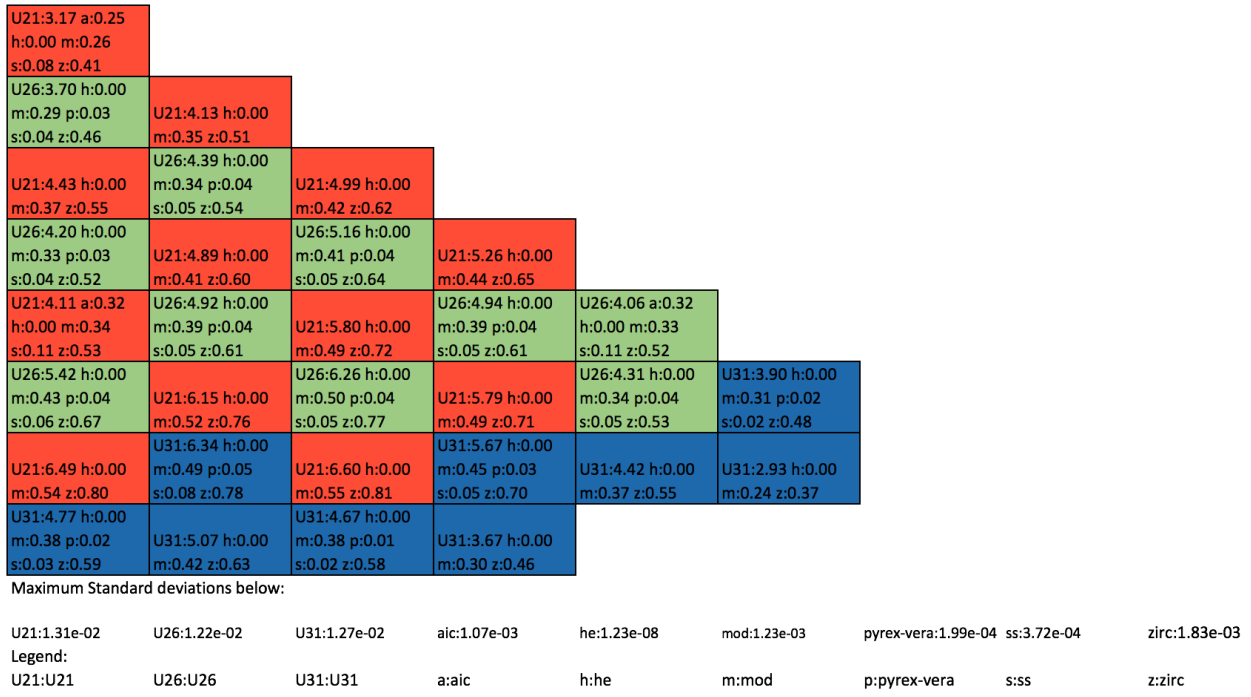

Figure 65: 5b-2d: Assembly Number Normalized Capture Gamma Distribution (MeV/fission)

U21:2.54 a:0.09 h:0.00 m:0.17 s:0.04 z:0.28								
U26:4.04 h:0.00 m:0.27 p:0.02 s:0.03 z:0.43	U21:4.79 h:0.00 m:0.34 z:0.52							
U21:5.07 h:0.00 m:0.36 z:0.55	U26:4.67 h:0.00 m:0.31 p:0.03 s:0.04 z:0.50	U21:5.64 h:0.00 m:0.41 z:0.61						
U26:4.48 h:0.00 m:0.30 p:0.02 s:0.03 z:0.48	U21:5.39 h:0.00 m:0.39 z:0.58	U26:5.51 h:0.00 m:0.37 p:0.03 s:0.04 z:0.59	U21:5.87 h:0.00 m:0.42 z:0.63					
U21:3.20 a:0.11 h:0.00 m:0.22 s:0.05 z:0.35	U26:5.06 h:0.00 m:0.34 p:0.03 s:0.04 z:0.54	U21:6.31 h:0.00 m:0.45 z:0.68	U26:5.16 h:0.00 m:0.35 p:0.03 s:0.04 z:0.56	U26:3.45 a:0.12 h:0.00 m:0.23 s:0.05 z:0.37				
U26:5.51 h:0.00 m:0.37 p:0.03 s:0.04 z:0.59	U21:6.59 h:0.00 m:0.47 z:0.71	U26:6.66 h:0.00 m:0.46 p:0.03 s:0.04 z:0.72	U21:6.28 h:0.00 m:0.45 z:0.68	U26:4.37 h:0.00 m:0.29 p:0.03 s:0.04 z:0.47	U31:4.52 h:0.00 m:0.31 p:0.01 s:0.02 z:0.48			
U21:6.97 h:0.00 m:0.50 z:0.75	U31:6.76 h:0.00 m:0.45 p:0.04 s:0.06 z:0.73	U21:7.15 h:0.00 m:0.52 z:0.77	U31:6.30 h:0.00 m:0.43 p:0.03 s:0.04 z:0.68	U31:5.12 h:0.00 m:0.36 z:0.55	U31:3.26 h:0.00 m:0.23 z:0.35			
U31:5.24 h:0.00 m:0.36 p:0.02 s:0.02 z:0.56	U31:5.91 h:0.00 m:0.42 z:0.63	U31:5.23 h:0.00 m:0.36 p:0.01 s:0.02 z:0.56	U31:4.07 h:0.00 m:0.29 z:0.44					

Maximum Standard deviations below:

U21:6.52e-03	U26:6.07e-03	U31:6.56e-03	aic:3.37e-04	he:5.82e-09	mod:5.73e-04	pyrex-vera:9.08e-05	ss:1.36e-04	zirc:8.57e-04

Legend:

U21:U21	U26:U26	U31:U31	a:aic	h:he	m:mod	p:pyrex-vera	s:ss	z:zirc

Figure 66: 5b-2d: Assembly Number Normalized Delayed Gamma Distribution (MeV/fission)

U:8.31 a:0.43 h:0.00 m:0.61 s:0.16 z:0.97								
U:11.86 h:0.00 m:0.85 p:0.07 s:0.10 z:1.34	U:13.82 h:0.00 m:1.05 z:1.56							
U:14.67 h:0.00 m:1.11 z:1.65	U:13.83 h:0.00 m:0.98 p:0.10 s:0.14 z:1.56	U:16.39 h:0.00 m:1.24 z:1.85						
U:13.25 h:0.00 m:0.95 p:0.08 s:0.11 z:1.49	U:15.78 h:0.00 m:1.19 z:1.78	U:16.29 h:0.00 m:1.16 p:0.10 s:0.14 z:1.83	U:17.13 h:0.00 m:1.30 z:1.93					
U:10.58 a:0.55 h:0.00 m:0.78 s:0.20 z:1.23	U:15.16 h:0.00 m:1.08 p:0.09 s:0.13 z:1.71	U:18.56 h:0.00 m:1.40 z:2.09	U:15.37 h:0.00 m:1.10 p:0.09 s:0.13 z:1.73	U:11.03 a:0.56 h:0.00 m:0.80 s:0.21 z:1.27				
U:16.55 h:0.00 m:1.18 p:0.10 s:0.14 z:1.87	U:19.48 h:0.00 m:1.48 z:2.20	U:19.73 h:0.00 m:1.42 p:0.09 s:0.14 z:2.22	U:18.48 h:0.00 m:1.40 z:2.08	U:13.14 h:0.00 m:0.93 p:0.09 s:0.14 z:1.49	U:13.04 h:0.00 m:0.94 p:0.05 s:0.07 z:1.46			
U:20.58 h:0.00 m:1.56 z:2.32	U:20.01 h:0.00 m:1.41 p:0.14 s:0.21 z:2.25	U:21.06 h:0.00 m:1.60 z:2.38	U:18.41 h:0.00 m:1.32 p:0.09 s:0.13 z:2.07	U:14.77 h:0.00 m:1.10 z:1.65	U:9.52 h:0.00 m:0.71 z:1.07			
U:15.36 h:0.00 m:1.11 p:0.05 s:0.08 z:1.73	U:17.02 h:0.00 m:1.27 z:1.91	U:15.25 h:0.00 m:1.11 p:0.04 s:0.05 z:1.71	U:11.90 h:0.00 m:0.89 z:1.34					

Maximum Standard deviations below:

U:1.33e-02	U:1.24e-02	U:1.29e-02	a:1.07e-03	h:1.24e-08	m:1.24e-03	p:1.99e-04	s:3.72e-04	z:1.85e-03

Legend:

U21:U21	U26:U26	U31:U31	a:aic	h:he	m:mod	p:pyrex-vera	s:ss	z:zirc

Figure 67: 5b-2d: Assembly Number Normalized Total Gamma Distribution (MeV/fission)

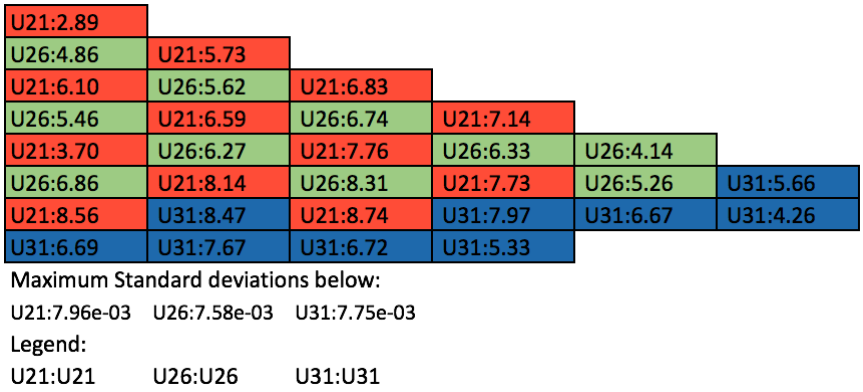

Figure 68: 5b-2d: Assembly Number Normalized Beta Distribution (MeV/fission)

Table 15: 5b-2d: Energy Deposition Summary

	n+fg	prompt gamma	capture gamma	delayed gamma	beta	total
aic	1.112E-01 +- 1.845E-04	5.406E-03 +- 1.036E-05	1.460E-02 +- 3.258E-05	5.292E-03 +- 1.014E-05	0	1.365E-01 +- 1.880E-04
he	2.739E-05 +- 5.930E-09	2.311E-06 +- 6.151E-10	2.466E-06 +- 1.172E-09	2.262E-06 +- 6.021E-10	0	3.443E-05 +- 6.105E-09
mod	3.910E+00 +- 7.114E-04	3.838E-01 +- 8.934E-05	4.034E-01 +- 1.614E-04	3.757E-01 +- 8.745E-05	0	5.073E+00 +- 7.401E-04
pyrex-vera	3.319E-01 +- 1.451E-04	1.297E-02 +- 7.140E-06	1.588E-02 +- 1.553E-05	1.269E-02 +- 6.989E-06	0	3.734E-01 +- 1.462E-04
ss	2.103E-03 +- 9.204E-07	2.107E-02 +- 1.101E-05	2.803E-02 +- 2.501E-05	2.063E-02 +- 1.077E-05	0	7.183E-02 +- 2.939E-05
zirc	3.253E-02 +- 6.630E-06	5.908E-01 +- 1.358E-04	6.138E-01 +- 2.424E-04	5.783E-01 +- 1.329E-04	0.000E+00	1.815E+00 +- 3.081E-04
Fuel Rod	1.695E+02 +- 2.790E-02	5.497E+00 +- 9.485E-04	4.951E+00 +- 1.706E-03	5.379E+00 +- 9.284E-04	6.656E+00 +- 1.101E-03	1.920E+02 +- 2.801E-02
Outside Core	1.748E-01 +- 1.279E-04	6.721E-02 +- 7.167E-05	3.500E-01 +- 2.863E-04	6.578E-02 +- 7.016E-05	0.000E+00 +- 0.000E+00	6.577E-01 +- 3.292E-04
total	174.10 +- 0.03	6.58 +- 0.00	6.38 +- 0.00	6.44 +- 0.00	6.66 +- 0.00	200.20 +- 0.03
Portion(%)	86.96 +- 0.02	3.29 +- 0.00	3.18 +- 0.00	3.22 +- 0.00	3.32 +- 0.00	100.00

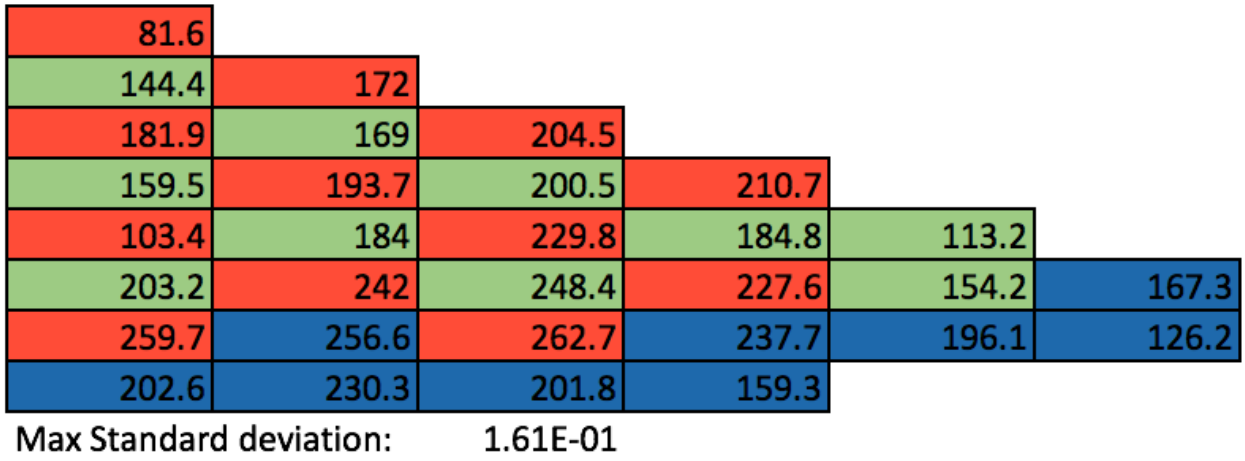

Figure 69: 5c-2d: Assembly Number Normalized Total Energy Distribution Material Separated (MeV/fission)

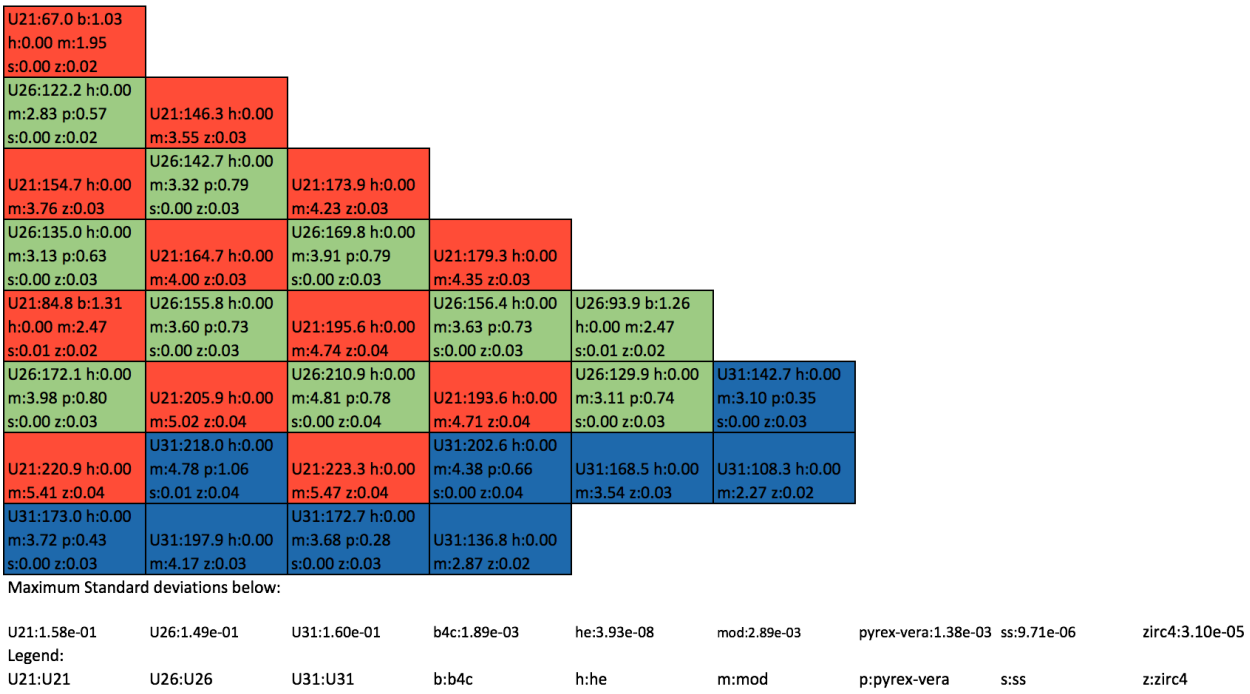

Figure 70: 5c-2d: Assembly Number Normalized Energy by Fragments and Neutrons (MeV/fission)

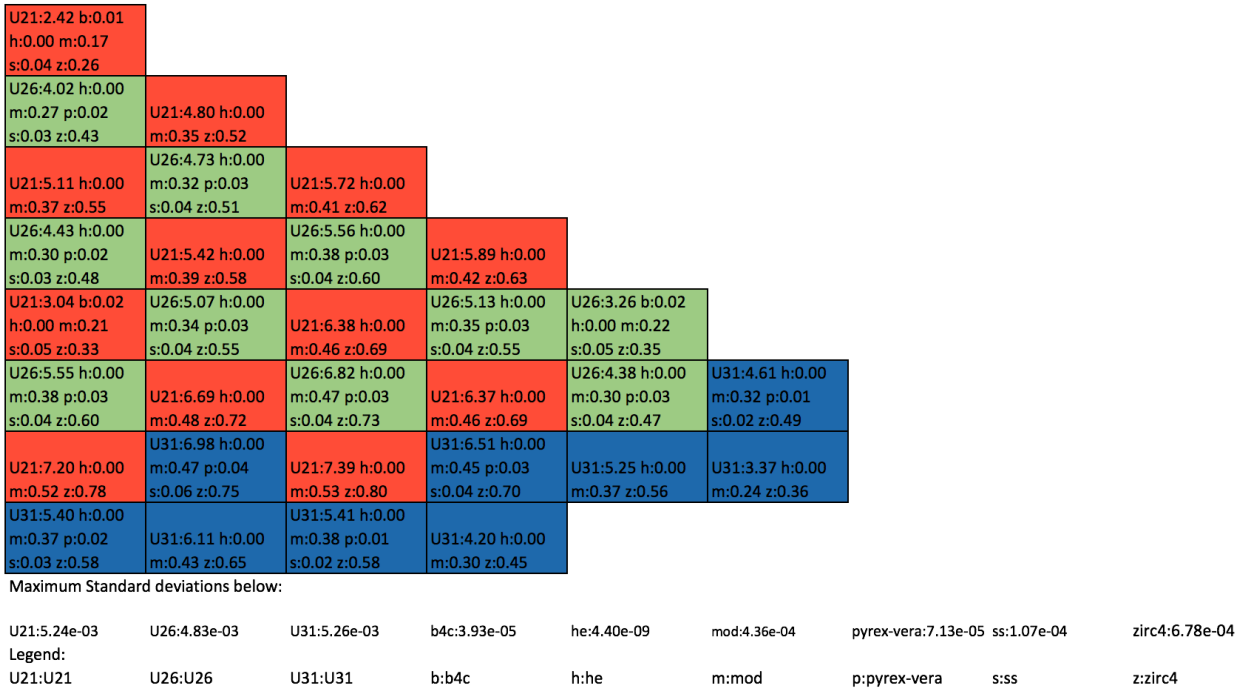

Figure 71: 5c-2d: Assembly Number Normalized Prompt Gamma Distribution (MeV/fission)

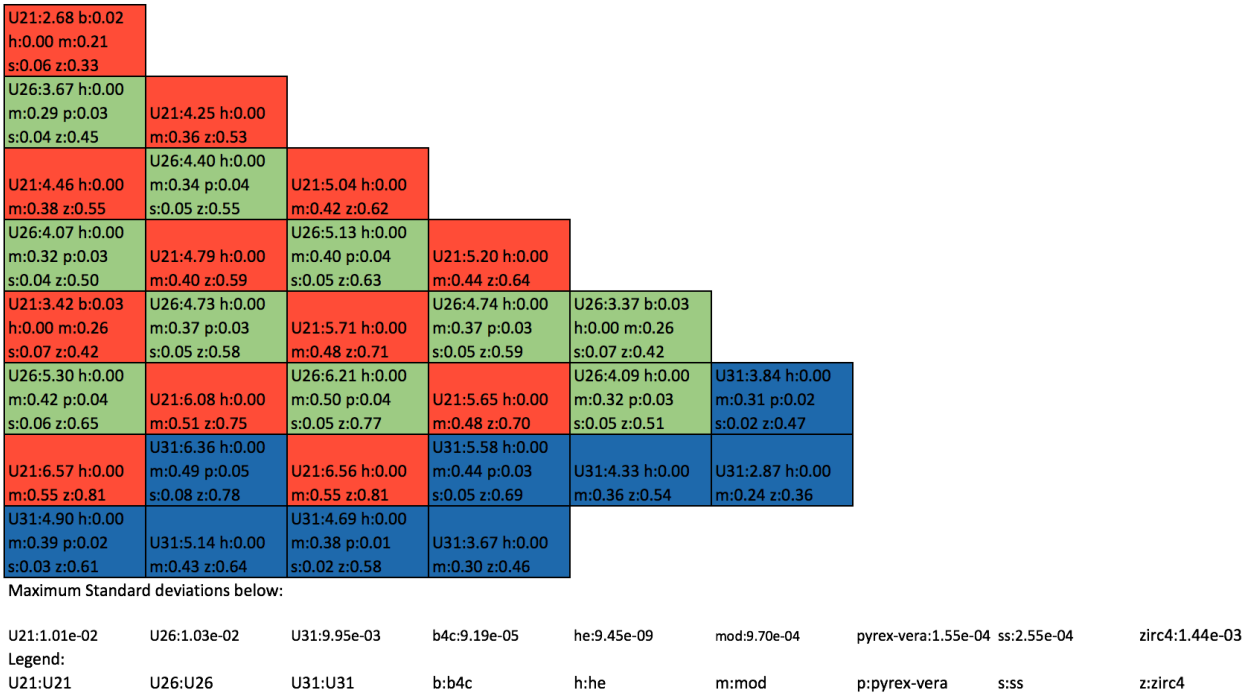

Figure 72: 5c-2d: Assembly Number Normalized Capture Gamma Distribution (MeV/fission)

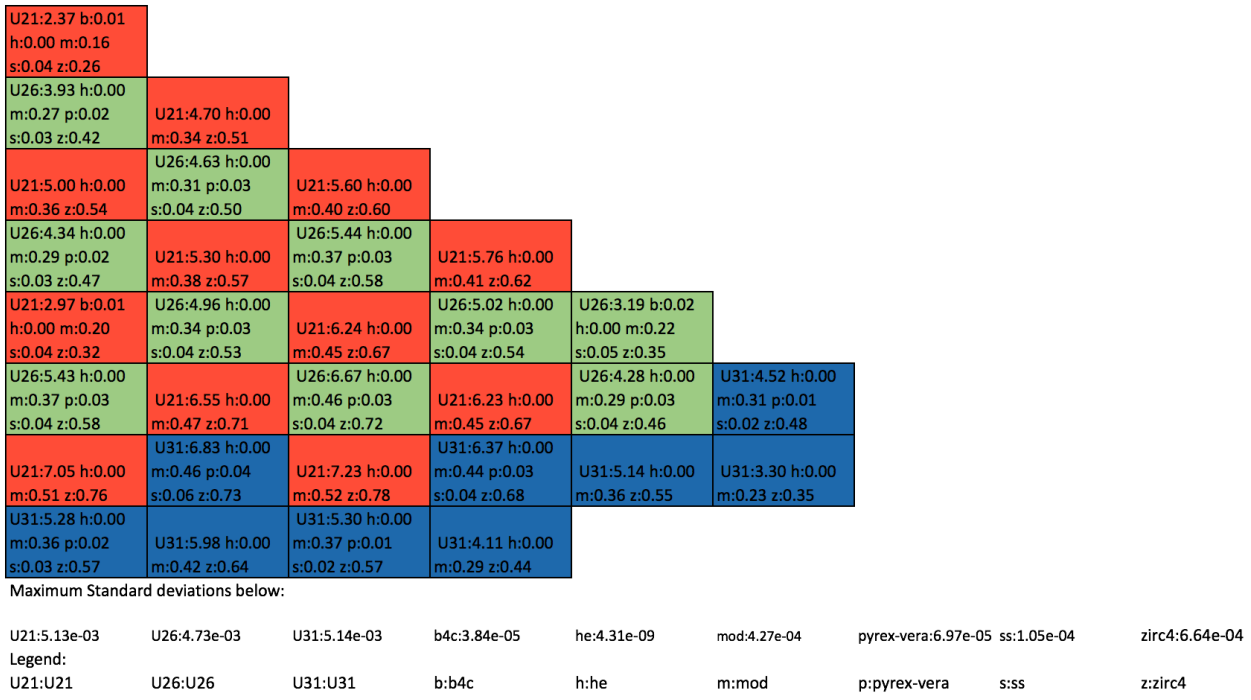

Figure 73: 5c-2d: Assembly Number Normalized Delayed Gamma Distribution (MeV/fission)

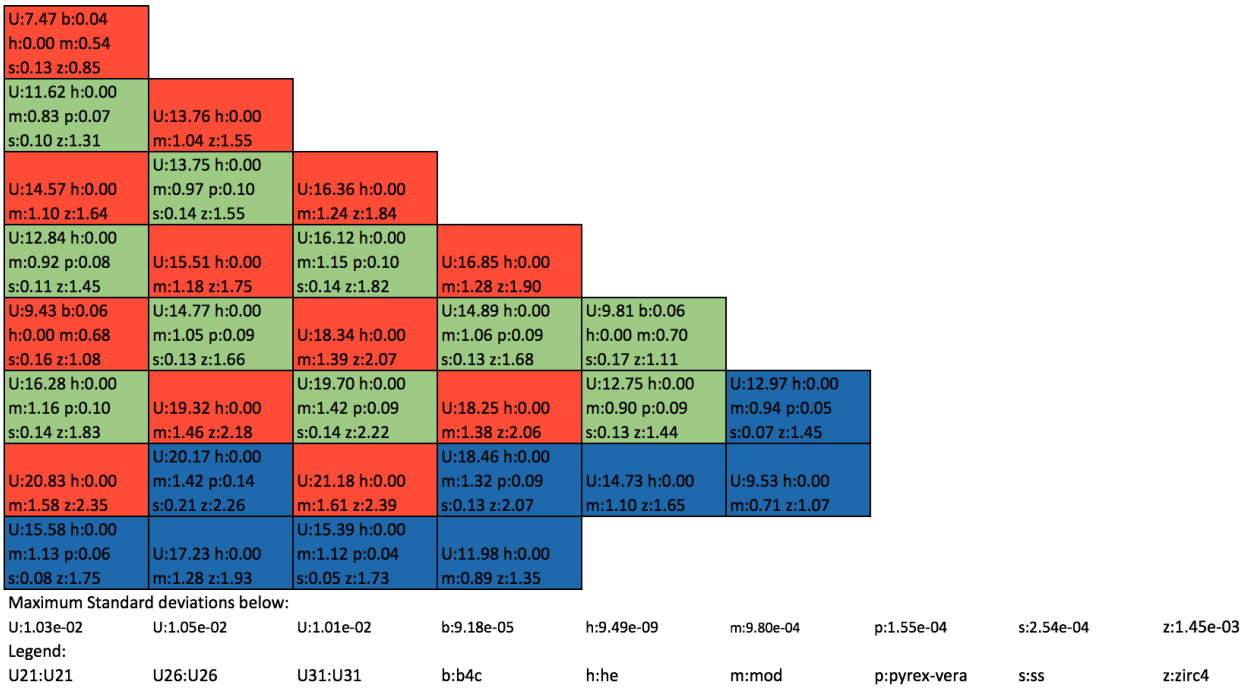

Figure 74: 5c-2d: Assembly Number Normalized Total Gamma Distribution (MeV/fission)

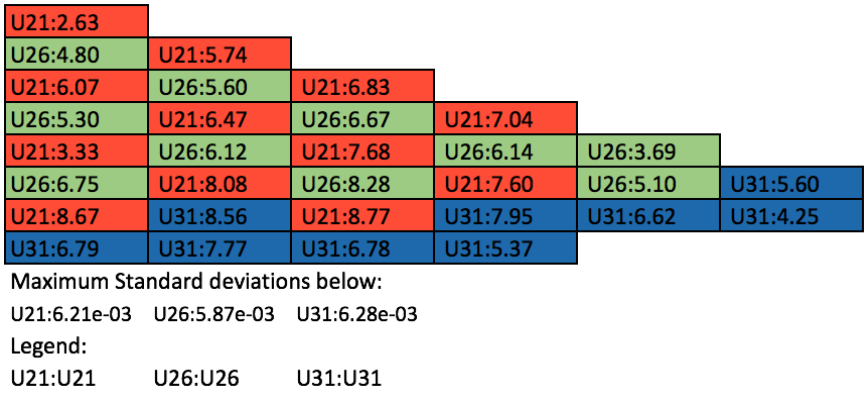

Figure 75: 5c-2d: Assembly Number Normalized Beta Distribution (MeV/fission)

Table 16: 5c-2d: Energy Deposition Summary

	n+fg	prompt gamma	capture gamma	delayed gamma	beta	total	Portion(%)
b4c	5.872E-02 +- 5.938E-05	7.199E-04 +- 1.168E-06	1.158E-03 +- 2.777E-06	7.047E-04 +- 1.143E-06	0	6.130E-02 +- 5.947E-05	0.03 +- 0
he	2.746E-05 +- 4.617E-09	2.315E-06 +- 4.768E-10	2.453E-06 +- 9.081E-10	2.266E-06 +- 4.667E-10	0	3.450E-05 +- 4.753E-09	0 +- 0
mod	3.913E+00 +- 5.489E-04	3.842E-01 +- 6.934E-05	4.004E-01 +- 1.238E-04	3.761E-01 +- 6.788E-05	0	5.074E+00 +- 5.710E-04	2.54 +- 0
pyrex-vera	3.313E-01 +- 1.124E-04	1.293E-02 +- 5.501E-06	1.579E-02 +- 1.203E-05	1.266E-02 +- 5.385E-06	0	3.727E-01 +- 1.133E-04	0.19 +- 0
ss	2.089E-03 +- 7.155E-07	2.100E-02 +- 8.555E-06	2.636E-02 +- 1.888E-05	2.056E-02 +- 8.374E-06	0	7.000E-02 +- 2.237E-05	0.03 +- 0
zirc4	3.254E-02 +- 5.148E-06	5.913E-01 +- 1.055E-04	6.091E-01 +- 1.878E-04	5.788E-01 +- 1.032E-04	0.000E+00	1.812E+00 +- 2.389E-04	0.91 +- 0
Fuel Rod	1.695E+02 +- 2.167E-02	5.499E+00 +- 7.372E-04	4.923E+00 +- 1.315E-03	5.383E+00 +- 7.216E-04	6.657E+00 +- 8.504E-04	1.920E+02 +- 2.174E-02	95.97 +- 0.02
Outside Core	1.775E-01 +- 9.762E-05	6.879E-02 +- 5.614E-05	3.546E-01 +- 2.245E-04	6.733E-02 +- 5.495E-05	0.000E+00 +- 0.000E+00	6.683E-01 +- 2.570E-04	0.33 +- 0.00
total	1.741E+02 +- 2.792E-02	6.578E+00 +- 9.651E-04	6.376E+00 +- 1.755E-03	6.438E+00 +- 9.447E-04	6.656E+00 +- 1.101E-03	2.002E+02 +- 2.803E-02	100.00
Portion(%)	86.96 +- 0.02	3.29 +- 0.00	3.18 +- 0.00	3.22 +- 0.00	3.32 +- 0.00	100.00	

Table 17: 1c Energy Deposited in Different Materials at 0.1 GWD/tU

	n+fg	prompt gamma	capture gamma	delayed gamma	beta	total	Heat Deposition Portion
mod	3.164e+00 +- 4.474e-04	3.155e-01 +- 7.055e-05	3.186e-01 +- 1.452e-04	3.089e-01 +- 6.907e-05	0	4.107e+00 +- 4.806e-04	2.07 +- 0.00 %
he	2.228e-05 +- 3.151e-09	1.883e-06 +- 4.210e-10	1.887e-06 +- 8.638e-10	1.844e-06 +- 4.122e-10	0	2.790e-05 +- 3.320e-09	0.00 +- 0.00 %
zirc	3.146e-02 +- 4.449e-06	5.672e-01 +- 1.268e-04	5.628e-01 +- 2.591e-04	5.553e-01 +- 1.242e-04	0	1.717e+00 +- 3.141e-04	0.86 +- 0.00 %
fuel	1.700e+02 +- 2.404e-02	5.685e+00 +- 1.271e-03	4.949e+00 +- 1.633e-03	5.566e+00 +- 1.245e-03	6.654e+00 +- 9.410e-04	1.928e+02 +- 2.417e-02	97.07 +- 0.02 %
total	1.731e+02 +- 2.404e-02	6.567e+00 +- 1.279e-03	5.830e+00 +- 1.660e-03	6.430e+00 +- 1.253e-03	6.654e+00 +- 9.410e-04	1.986e+02 +- 2.418e-02	100%

Table 18: 1c Energy Deposited in Different Materials at 1.0 GWD/tU

	n+fg	prompt gamma	capture gamma	delayed gamma	beta	total	Heat Deposition Portion
mod	3.217e+00 +- 4.549e-04	3.156e-01 +- 7.058e-05	3.343e-01 +- 1.483e-04	3.067e-01 +- 6.858e-05	0	4.173e+00 +- 4.885e-04	2.10 +- 0.00 %
he	2.274e-05 +- 3.216e-09	1.884e-06 +- 4.212e-10	1.981e-06 +- 8.823e-10	1.830e-06 +- 4.093e-10	0	2.843e-05 +- 3.386e-09	0.00 +- 0.00 %
zirc	3.204e-02 +- 4.532e-06	5.678e-01 +- 1.270e-04	5.906e-01 +- 2.647e-04	5.517e-01 +- 1.234e-04	0	1.742e+00 +- 3.185e-04	0.87 +- 0.00 %
fuel	1.702e+02 +- 2.408e-02	5.690e+00 +- 1.272e-03	5.188e+00 +- 1.658e-03	5.529e+00 +- 1.236e-03	6.610e+00 +- 9.348e-04	1.933e+02 +- 2.422e-02	97.03 +- 0.02 %
total	1.735e+02 +- 2.408e-02	6.574e+00 +- 1.281e-03	6.113e+00 +- 1.685e-03	6.387e+00 +- 1.244e-03	6.610e+00 +- 9.348e-04	1.992e+02 +- 2.422e-02	100%

Table 19: 1c Energy Deposited in Different Materials at 10 GWD/tU

	n+fg	prompt gamma	capture gamma	delayed gamma	beta	total	Heat Deposition Portion
mod	3.629e+00 +- 5.132e-04	3.171e-01 +- 7.090e-05	4.421e-01 +- 1.704e-04	2.937e-01 +- 6.567e-05	0	4.682e+00 +- 5.493e-04	2.31 +- 0.00 %
he	2.611e-05 +- 3.692e-09	1.892e-06 +- 4.230e-10	2.622e-06 +- 1.013e-09	1.752e-06 +- 3.918e-10	0	3.238e-05 +- 3.872e-09	0.00 +- 0.00 %
zirc	3.644e-02 +- 5.154e-06	5.724e-01 +- 1.280e-04	7.796e-01 +- 3.038e-04	5.302e-01 +- 1.186e-04	0	1.919e+00 +- 3.504e-04	0.95 +- 0.00 %
fuel	1.721e+02 +- 2.433e-02	5.728e+00 +- 1.281e-03	6.791e+00 +- 1.828e-03	5.306e+00 +- 1.186e-03	6.359e+00 +- 8.992e-04	1.962e+02 +- 2.448e-02	96.75 +- 0.02 %
total	1.757e+02 +- 2.434e-02	6.617e+00 +- 1.289e-03	8.013e+00 +- 1.861e-03	6.129e+00 +- 1.194e-03	6.359e+00 +- 8.992e-04	2.028e+02 +- 2.449e-02	100%

Table 20: 1c Energy Deposited in Different Materials at 20 GWD/tU

	n+fg	prompt gamma	capture gamma	delayed gamma	beta	total	Heat Deposition Portion
mod	4.036e+00 +- 5.707e-04	3.192e-01 +- 7.138e-05	5.375e-01 +- 1.906e-04	2.874e-01 +- 6.427e-05	0	5.180e+00 +- 6.093e-04	2.51 +- 0.00 %
he	2.924e-05 +- 4.135e-09	1.905e-06 +- 4.259e-10	3.191e-06 +- 1.134e-09	1.715e-06 +- 3.835e-10	0	3.605e-05 +- 4.326e-09	0.00 +- 0.00 %
zirc	4.066e-02 +- 5.750e-06	5.775e-01 +- 1.291e-04	9.470e-01 +- 3.395e-04	5.200e-01 +- 1.163e-04	0	2.085e+00 +- 3.815e-04	1.01 +- 0.00 %
fuel	1.733e+02 +- 2.451e-02	5.763e+00 +- 1.289e-03	8.199e+00 +- 1.987e-03	5.188e+00 +- 1.160e-03	6.242e+00 +- 8.828e-04	1.987e+02 +- 2.467e-02	96.47 +- 0.02 %
total	1.774e+02 +- 2.452e-02	6.659e+00 +- 1.297e-03	9.684e+00 +- 2.025e-03	5.996e+00 +- 1.168e-03	6.242e+00 +- 8.828e-04	2.060e+02 +- 2.468e-02	100%

Table 21: 1c Energy Deposited in Different Materials at 30 GWD/tU

	n+fg	prompt gamma	capture gamma	delayed gamma	beta	total	Heat Deposition Portion
mod	4.409e+00 +- 9.860e-04	3.215e-01 +- 1.159e-04	6.223e-01 +- 2.458e-04	2.840e-01 +- 1.024e-04	0	5.637e+00 +- 1.028e-03	2.70 +- 0.00 %
he	3.206e-05 +- 9.067e-09	1.918e-06 +- 6.916e-10	3.694e-06 +- 1.462e-09	1.694e-06 +- 6.109e-10	0	3.936e-05 +- 9.230e-09	0.00 +- 0.00 %
zirc	4.450e-02 +- 1.259e-05	5.821e-01 +- 2.099e-04	1.096e+00 +- 4.372e-04	5.142e-01 +- 1.854e-04	0	2.237e+00 +- 5.194e-04	1.07 +- 0.00 %
fuel	1.743e+02 +- 4.929e-02	5.791e+00 +- 1.638e-03	9.440e+00 +- 2.688e-03	5.116e+00 +- 1.447e-03	6.179e+00 +- 1.748e-03	2.008e+02 +- 4.944e-02	96.23 +- 0.03 %
total	1.787e+02 +- 4.930e-02	6.695e+00 +- 1.655e-03	1.116e+01 +- 2.734e-03	5.914e+00 +- 1.462e-03	6.179e+00 +- 1.748e-03	2.087e+02 +- 4.946e-02	100%

Table 22: 1c Energy Deposited in Different Materials at 40 GWD/tU

	n+fg	prompt gamma	capture gamma	delayed gamma	beta	total	Heat Deposition Portion
mod	4.749e+00 +- 1.062e-03	3.233e-01 +- 1.166e-04	6.979e-01 +- 2.657e-04	2.817e-01 +- 1.016e-04	0	6.052e+00 +- 1.106e-03	2.87 +- 0.00 %
he	3.460e-05 +- 9.787e-09	1.929e-06 +- 6.956e-10	4.143e-06 +- 1.580e-09	1.681e-06 +- 6.060e-10	0	4.235e-05 +- 9.956e-09	0.00 +- 0.00 %
zirc	4.794e-02 +- 1.356e-05	5.858e-01 +- 2.112e-04	1.229e+00 +- 4.722e-04	5.104e-01 +- 1.840e-04	0	2.373e+00 +- 5.493e-04	1.12 +- 0.00 %
fuel	1.750e+02 +- 4.951e-02	5.810e+00 +- 1.643e-03	1.054e+01 +- 2.911e-03	5.062e+00 +- 1.432e-03	6.138e+00 +- 1.736e-03	2.026e+02 +- 4.967e-02	96.01 +- 0.03 %
total	1.798e+02 +- 4.952e-02	6.719e+00 +- 1.661e-03	1.247e+01 +- 2.961e-03	5.855e+00 +- 1.447e-03	6.138e+00 +- 1.736e-03	2.110e+02 +- 4.969e-02	100%

Table 23: 1c Energy Deposited in Different Materials at 50 GWD/tU

	n+fg	prompt gamma	capture gamma	delayed gamma	beta	total	Heat Deposition Portion
mod	5.047e+00 +- 1.129e-03	3.253e-01 +- 1.173e-04	7.641e-01 +- 2.835e-04	2.806e-01 +- 1.012e-04	0	6.417e+00 +- 1.174e-03	3.01 +- 0.00 %
he	3.685e-05 +- 1.042e-08	1.941e-06 +- 6.998e-10	4.538e-06 +- 1.686e-09	1.674e-06 +- 6.036e-10	0	4.500e-05 +- 1.060e-08	0.00 +- 0.00 %
zirc	5.099e-02 +- 1.442e-05	5.897e-01 +- 2.126e-04	1.346e+00 +- 5.036e-04	5.087e-01 +- 1.834e-04	0	2.495e+00 +- 5.767e-04	1.17 +- 0.00 %
fuel	1.757e+02 +- 4.969e-02	5.828e+00 +- 1.648e-03	1.150e+01 +- 3.107e-03	5.027e+00 +- 1.422e-03	6.111e+00 +- 1.728e-03	2.041e+02 +- 4.986e-02	95.82 +- 0.03 %
total	1.808e+02 +- 4.970e-02	6.743e+00 +- 1.666e-03	1.361e+01 +- 3.161e-03	5.816e+00 +- 1.437e-03	6.111e+00 +- 1.728e-03	2.131e+02 +- 4.988e-02	100%

Table 24: 1c Energy Deposited in Different Materials at 60 GWD/tU

	n+fg	prompt gamma	capture gamma	delayed gamma	beta	total	Heat Deposition Portion
mod	5.287e+00 +- 1.182e-03	3.271e-01 +- 1.179e-04	8.188e-01 +- 2.983e-04	2.802e-01 +- 1.010e-04	0	6.713e+00 +- 1.229e-03	3.13 +- 0.00 %
he	3.868e-05 +- 1.094e-08	1.951e-06 +- 7.035e-10	4.863e-06 +- 1.774e-09	1.671e-06 +- 6.025e-10	0	4.716e-05 +- 1.112e-08	0.00 +- 0.00 %
zirc	5.343e-02 +- 1.511e-05	5.931e-01 +- 2.138e-04	1.443e+00 +- 5.298e-04	5.080e-01 +- 1.832e-04	0	2.597e+00 +- 6.002e-04	1.21 +- 0.00 %
fuel	1.762e+02 +- 4.983e-02	5.840e+00 +- 1.652e-03	1.229e+01 +- 3.270e-03	5.002e+00 +- 1.415e-03	6.092e+00 +- 1.723e-03	2.054e+02 +- 5.001e-02	95.66 +- 0.03 %
total	1.815e+02 +- 4.984e-02	6.760e+00 +- 1.670e-03	1.455e+01 +- 3.326e-03	5.790e+00 +- 1.430e-03	6.092e+00 +- 1.723e-03	2.147e+02 +- 5.003e-02	100%

Appendix B Delayed Gamma Spectrum

In the current MCNP energy deposition model developed for VERA Progression Problems, the delayed beta and gamma energy depositions are scaled by normalizing the MCNP tallied spatial distributions (prompt fission Q value and prompt gamma energy) to the ENDF entries of delayed modes. This approximation could affect the accuracy of the energy deposition model in two aspects: (1) the amount of delayed energy release as a function of time. We have verified that time dependence of delayed energy has marginal effect on the nominal reactor operation calculation with depletion. The time dependence on the fast transient problems (such as RIAs) is under investigation; (2) the spatial distribution of the gamma energy deposition. The current scaling approach assumes the spatial distribution of delayed gamma energy deposition is identical to that of prompt gamma energy deposition. This is true only when the delayed gamma spectrum resembles the prompt gamma spectrum, which is discussed as follows.

First, Refs. [6, 7] show that the equilibrium delayed gamma spectrum and prompt gamma spectrum of U-235 fairly resemble each other. It is also interesting to investigate the delayed gamma spectrum as a function of time, which can be done by depletion codes to provide the radiation source terms. In Figs. 76 and 77, we compare the prompt gamma spectrum obtained from ENDF/B-VII.1, with the delayed gamma spectra at various times followed by a fission event of U-235. These delayed gamma spectra data are obtained from Refs. [8] and [9] by calculations using CINDER and ORIGEN, respectively. The spectra of prompt and delayed gammas are normalized such that they are integrated to unity over gamma energy. Note the spectra lower than 0.1MeV are not shown in these plots because: (1) the prompt gamma spectrum less than 0.1MeV obtained in ENDF data is questionable by missing peaks indicated from Ref. [9]; (2) as computed from the CINDER and ORIGEN data, the number of delayed photons is produced with similar amount between the two energy ranges, 0-0.1MeV and 0.1-1MeV, so the heating energy produced by the photons in 0-0.1MeV is an order lower than the photons in 0.1-1MeV. Given the little potential contribution to heating calculation, efforts of further investigating the spectra differences can be saved in the energy range of 0-0.1MeV.

Although the spectral data of delayed gamma are available in different energy bins and time ranges between CINDER and ORIGEN results, they are roughly consistent if comparing at the same delayed times up to 10^4 s. It is also noted that the spectra of delayed gamma are generally softened as time increases. At early times (less than 1000s), the delayed gamma spectra are more likely to resemble the prompt gamma spectrum. Since more than three-fourths of the total delayed gamma energy is released within 1000s after a fission, with majority of heat contributed from short-lived FPs, it shouldn't be a bad approximation to assume a similar spectra of delayed gamma as prompt gamma, even during the period that the equilibrium delayed gamma is not achieved (such as core startup or power change).

In addition, Fig. 78 shows a same comparison for Pu-239, which is also available from CINDER calculations [8]. The same conclusion can be drawn from the spectra comparison

between prompt and delayed gammas for Pu-239.

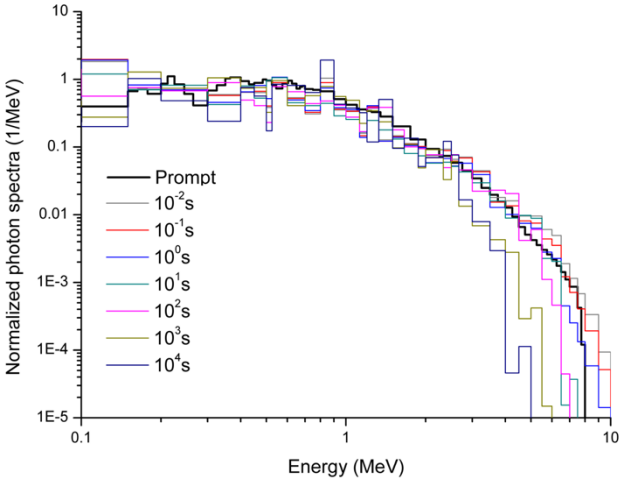

Figure 76: Comparison of delayed gamma spectra (CINDER) at various time after a U-235 fission event with prompt gamma spectrum from ENDF/B-VII.1 (MF=15, MT=18). The data of delayed gamma spectra is from CINDER calculations in Ref. [8]

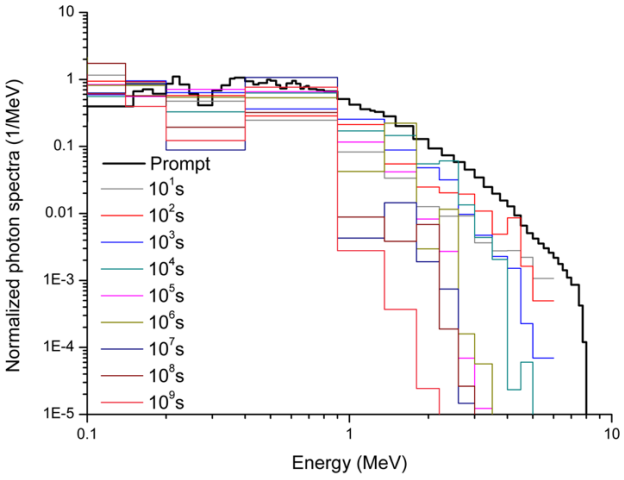

Figure 77: Comparison of delayed gamma spectra (ORIGEN) at various time after a U-235 fission event with prompt gamma spectrum from ENDF/B-VII.1 (MF=15, MT=18). The data of delayed gamma spectra is from ORIGEN calculations in Ref. [9]

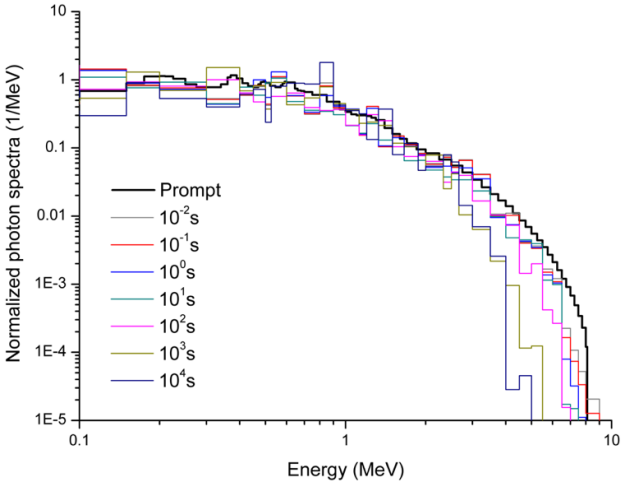

Figure 78: Comparison of delayed gamma spectra (CINDER) at various time after a Pu-239 fission event with prompt gamma spectrum from ENDF/B-VII.1 (MF=15, MT=18). The data of delayed gamma spectra is from CINDER calculations in Ref. [8]

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