(U) Update to the ENDF-102 MF 1 MT 458 Components of Energy Release Due to Fission

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1.5. Components of Energy Release Due to Fission (MT=458)

The energy released in fission is carried by fission fragments, neutrons, gammas, betas (+ and –), and neutrinos and anti-neutrinos. The term fragments includes all charged particles that are emitted promptly, since for energy-deposition calculations, all such particles have short ranges and are usually considered to lose their energy locally. Neutrons and gammas transport their energy elsewhere and need to be considered separately. In addition, some gammas and neutrons are delayed, and in a shut-down assembly, one needs to know the amount of energy tied up in these particles and the rate at which it is released from the metastable nuclides or precursors. The neutrino energy is lost completely in most applications, but is part of the Q- value. As far as the betas are concerned, prompt betas, being charged, deposit their energy locally with the fragments, and their prompt energies are correctly included with the fragment energies.

Components of fission energy release

ET Total energy; sum of all the partial energies that follow.

EFR Kinetic energy of the fragments

ENP Kinetic energy of the prompt fission neutrons

END Kinetic energy of the delayed fission neutrons

EGP Total energy released by the emission of prompt gamma rays

EGD Total energy released by the emission of delayed gamma rays

EB Total energy released by delayed betas

ENU Energy carried away by the neutrinos

ER Total energy less the energy of the neutrinos (ET - ENU)

Total energy (ET) release per fission should equal the true Q value. equal to the pseudo-Q in File 3 for MT=18

Original Format

```
[MAT, 1, 458 /   ZA,  AWR,    0,    0,    0,    0]HEAD
[MAT, 1, 458 /  0.0,  0.0,    0,    0,   18,    9/
                EFR, dEFR,  ENP, dENP,  END, dEND,
                EGP, dEGP,  EGD, dEGD,   EB,  dEB,
                ENU, dENU,   ER,  dER,   ET,  dET]LIST
[MAT, 1,   0 /  0.0,  0.0,    0,    0,    0,    0]SEND
```

Energy Dependence

The δE_i's are given by the following:

$$
\begin{aligned}
\delta \mathrm{ET} &= -\left(1.057 E_{inc} - 8.07\left(\bar{\nu}(E_{inc} - \bar{\nu}(0)\right)\right) \\
\delta \mathrm{EB} &= 0.075 E_{inc} \\
\delta \mathrm{EGD} &= 0.075 E_{inc} \\
\delta \mathrm{ENU} &= 1.000 E_{inc} \\
\delta \mathrm{EFR} &= 0 \\
\delta \mathrm{ENP} &= -\left(1.307 E_{inc} - 8.07\left(\bar{\nu}(E_{inc}) - \bar{\nu}(0)\right)\right) \\
\delta \mathrm{EGP} &= 0
\end{aligned}
$$

Early energy dependence:

$$E_i\,(0) = E_i\,(E_{inc}\,) + \mathrm{d}E_i$$

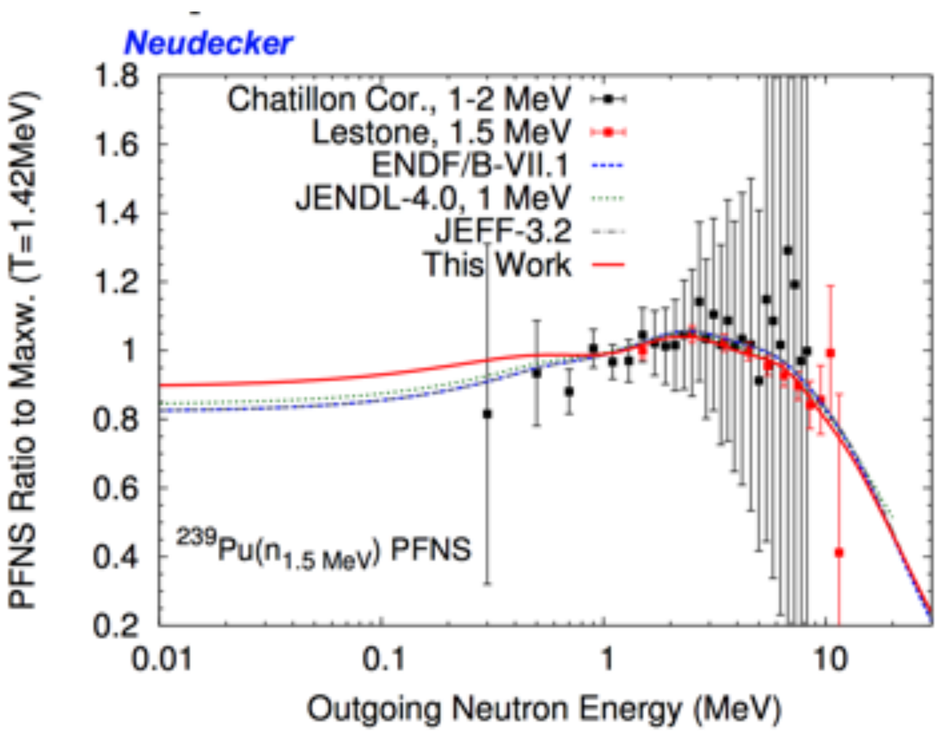
Though many processing codes -- most notably NJOY -- used a different parameterization to compute these values, particularly fission fragment TKE

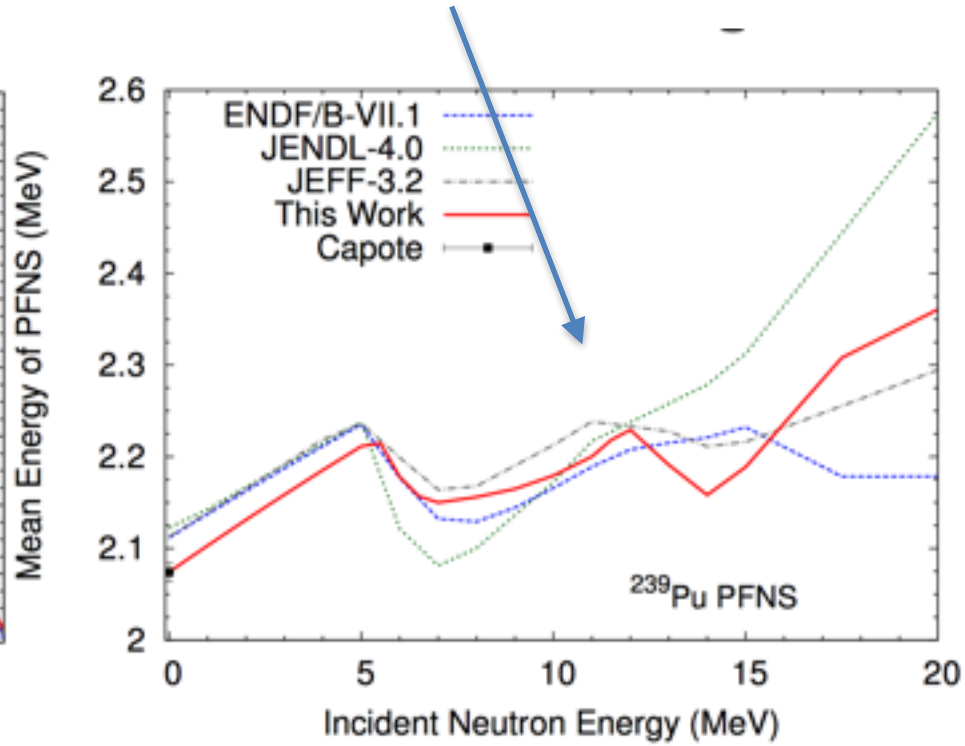
Polynomial Format

```
[MAT, 1, 458 /   ZA,  AWR,    0,    0,    0,    0]HEAD
[MAT, 1, 458 /  0.0,  0.0,    0,   NL,NL*18, NL*9/
                EFR, dEFR,  ENP, dENP,  END, dEND,
                EGP, dEGP,  EGD, dEGD,   EB,  dEB,
                ENU, dENU,   ER,  dER,   ET,  dET
                a1, ..., aN for each component   ]LIST
[MAT, 1,   0 /  0.0,  0.0,    0,    0,    0,    0]SEND
```

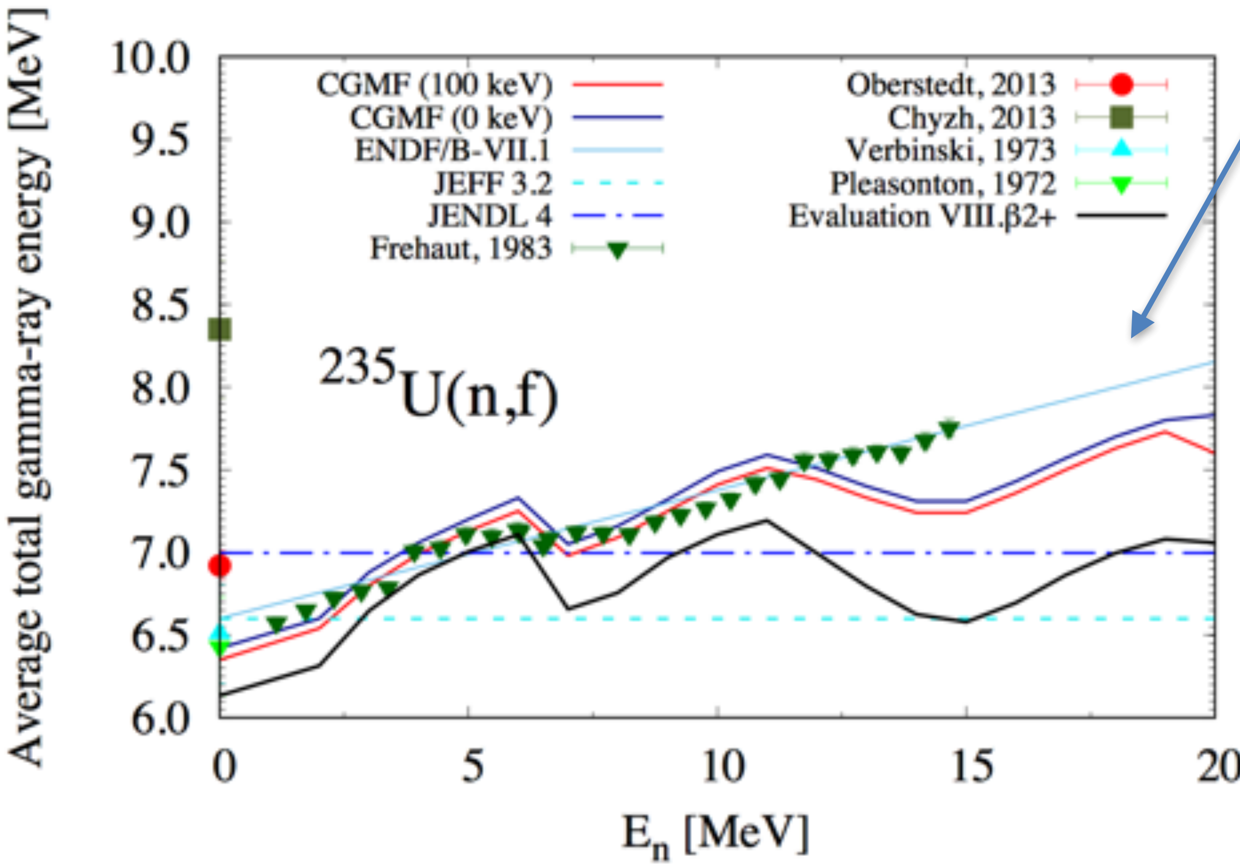
This was as bad an idea for energy released as it was for nubar.

Prompt neutron energy (ENP) is not a constant nor polynomial energy dependence.

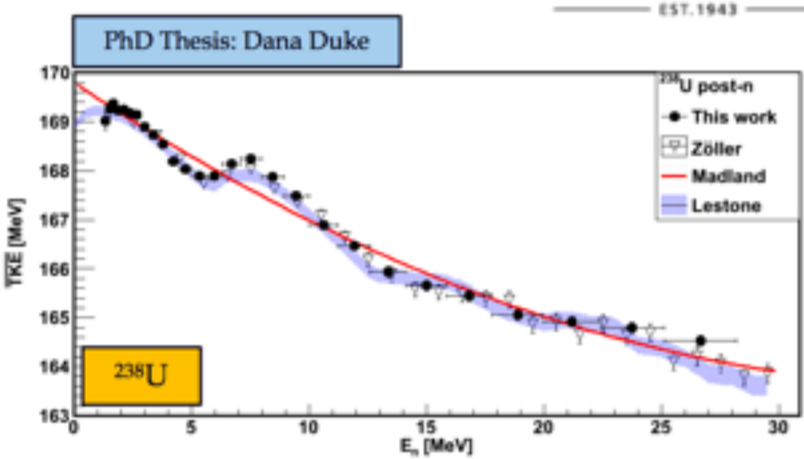


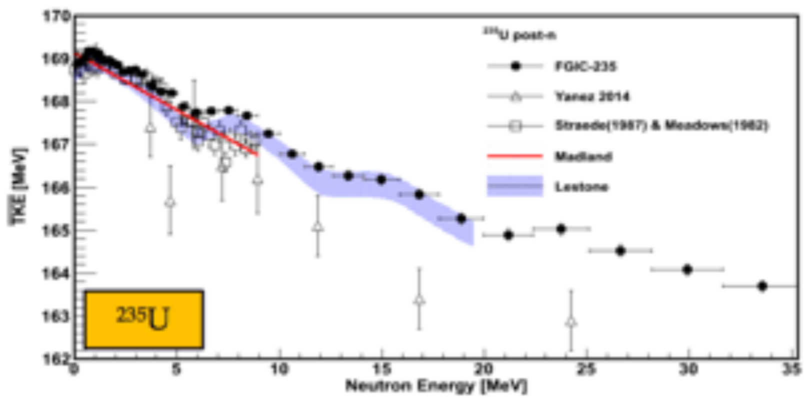


Prompt gamma energy (EGP) is not a constant nor polynomial energy dependence.



Fission fragment energy (TKE) is not a simple polynomial shape





We require a TAB1 record to store real x,y values for these data. This will also enable covariances (MF31/33-like) for these data.

Data are published in Meierbachtol, K. *et al.*, PRC 94, 034611 (2016); Duke, D. *et al.*, PRC 94, 054604 (2016);

Proposed Change to the Format

```
[MAT, 1, 458 /   ZA,  AWR,    0,    0,  NED,    0]HEAD
[MAT, 1, 458 /  0.0,  0.0,    0,    0,   18,    9/
                EFR, dEFR,  ENP, dENP,  END, dEND,
                EGP, dEGP,  EGD, dEGD,   EB,  dEB,
                ENU, dENU,   ER,  dER,   ET,  dET]LIST
[MAT, 1, 458 /  0.0,  0.0,  FCI,    0,   NR,   NP/
                Eint
                FER(E)                            ]TAB1
        ... remaining NED TAB1 sections ...
[MAT, 1,   0 /  0.0,  0.0,    0,    0,    0,    0]SEND

NED     - Number of Energy Dependent sections
FCI     - Fission Component ID (give each component an index)
FER(E)  - Energy dependent Fission Energy Release (FER)
```

Why NED TAB1 sections? Why not just mandate 9 entries?

- Many of these have no data. Why put more weight behind arbitrary energy dependence estimates.
- Average energy for delayed data may need more than one entry. This allows for a time constant to be given (maybe use C1, where 0. indicates time independent)

Can it be used?

- You've seen plots of these values in presentations this week

- These data are used to compute KERMA
  - Processing codes will have to know how to read, or at least skip, these data

- NJOY already allows an arbitrary TAB1 input in HEATR to override the internal energy dependence
  - Can easily extract these data from an evaluation and pass them into the code in this manner
  - Should be able to update quickly to use them directly