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EVALUATED DELAYED NEUTRON PRECURSOR DATA

by

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Based on energetics, ~ 270 fission products should be delayed neutron precursors. Of these, ~ 85 have measured and evaluated emission probabilities (Pn's) and ~ 34 have measured spectra data; the latter account for 80% or more of the total $\bar{\nu}_d$. Although the measurements are probably adequate for most reactor applications,[1,2] complete data sets are needed for ENDF/B and for fission product yield evaluations. This paper briefly describes the use of systematics and nuclear models used to produce a complete set of data for 272 precursors and presents aggregate summation calculations needed to produce the conventional six-time-group approximations.[3]

Unmeasured Pn values are calculated using a fit of the 85 evaluated measurements[4] to the Herrmann-Kratz systematic equation:[5]

$$Pn = a[(Q_\beta - S(n)/Q_\beta - K]^b \tag{1}$$

where

$K = 0$ for even-even precursors

$= 13/A^{1/2}$ odd precursors

$= 26/A^{1/2}$ odd-odd precursors

Q_β = total beta decay energy of the precursor

$S(n)$ = neutron separation energy of daughter

a,b = fitting parameters based on measured spectra.

For unmeasured spectra we have used a statistical model code, BETA,[6] and a simple evaporation model:

$$N(E) = CE \exp(-E/T) \tag{2}$$

where

$$[Q_\beta - S(n)] \simeq a\, T^2 \tag{3}$$

a = fitting parameter $\simeq (2/3)A$

A = mass number of precursor

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This simple model has the virtue of having a general shape similar to most measured precursor spectra and especially so in the energy range where most neutrons are emitted. It is used for cases in which no spectra have been measured. The BETA model code requires, in addition to mass values, the energy levels, spins, and parities of the precursor, daughter, and granddaughter; such detail is usually incomplete, so calculations must use added level values from systematics. The BETA code results are used only to augment 30 of the 34 measured spectra; here it is possible to normalize the calculations to a small range of the measurements.[7]

Figure 1 shows a typical measured spectrum[8] and its comparison with the two models. The measured spectrum extends to ~ 2.5 MeV; however, for ^{94}Rb, there are likely neutrons emitted up to 3.5 MeV and more neutrons are probable at energies below ~ 100 keV than indicated by this measurement or by the models. The actual evaluated spectrum used for ^{94}Rb is an augmentation of this measurement using adjusted BETA model values above 2.5 MeV and recent low energy measurements[9] below 0.2 MeV.

All measured precursor spectra were similarly examined and augmented, as needed, and the data file was extended, as indicted, to include Pn values and spectra for 272 precursors. These data, as well as other decay parameters, were then used in summation calculations for several fuels for both the total $\bar{\nu}_d$ and spectra. Figure 2 illustrates a temporal comparison for the delayed neutrons vs time for three fuels. These results have been approximated into six groups for the equilibrium $\bar{\nu}_d$ and a companion paper describes the six-group approximation for the corresponding spectra.[3,10]

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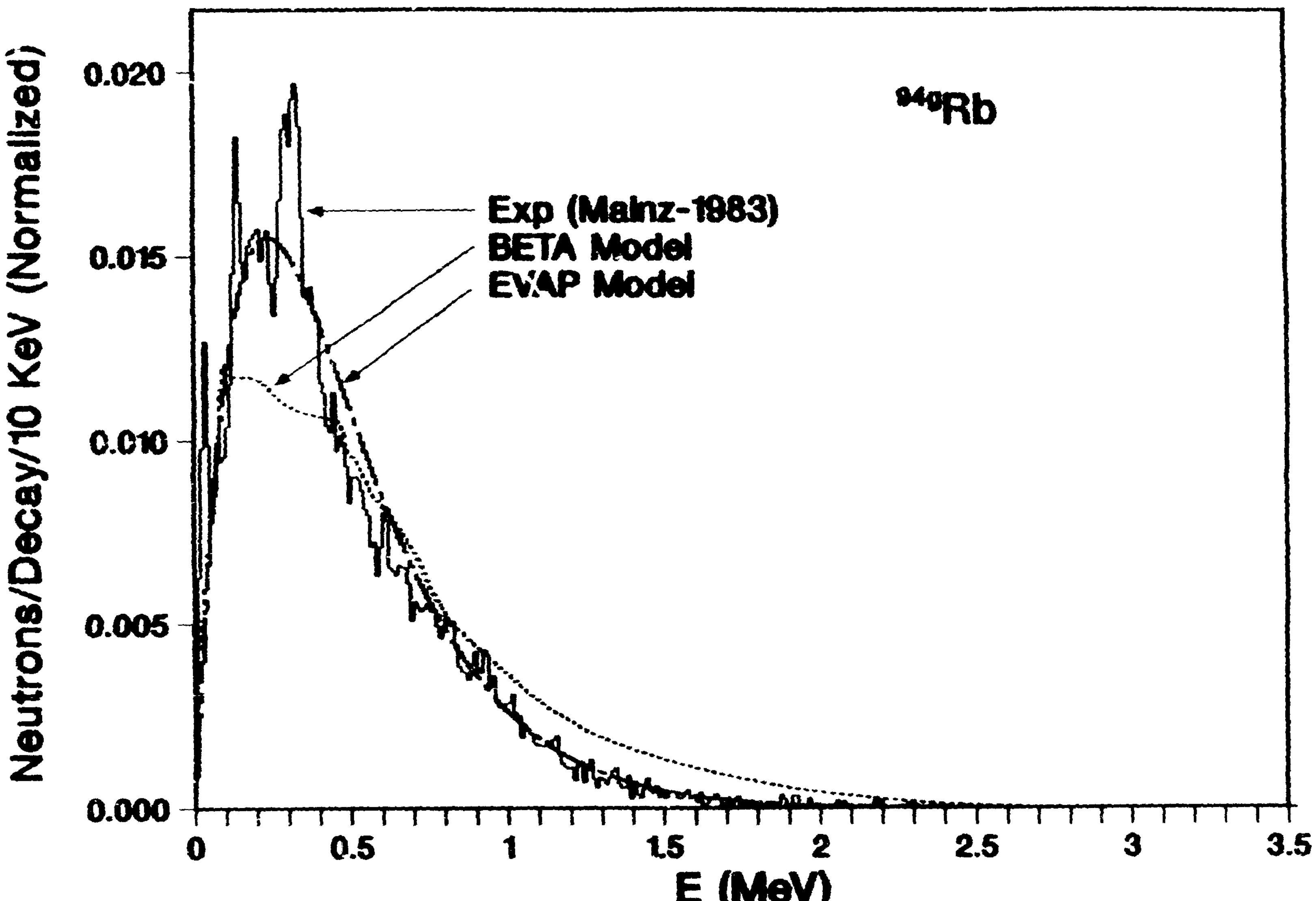

Fig. 1 Delayed Neutron Spectra for Nuclide ^{94g}Rb

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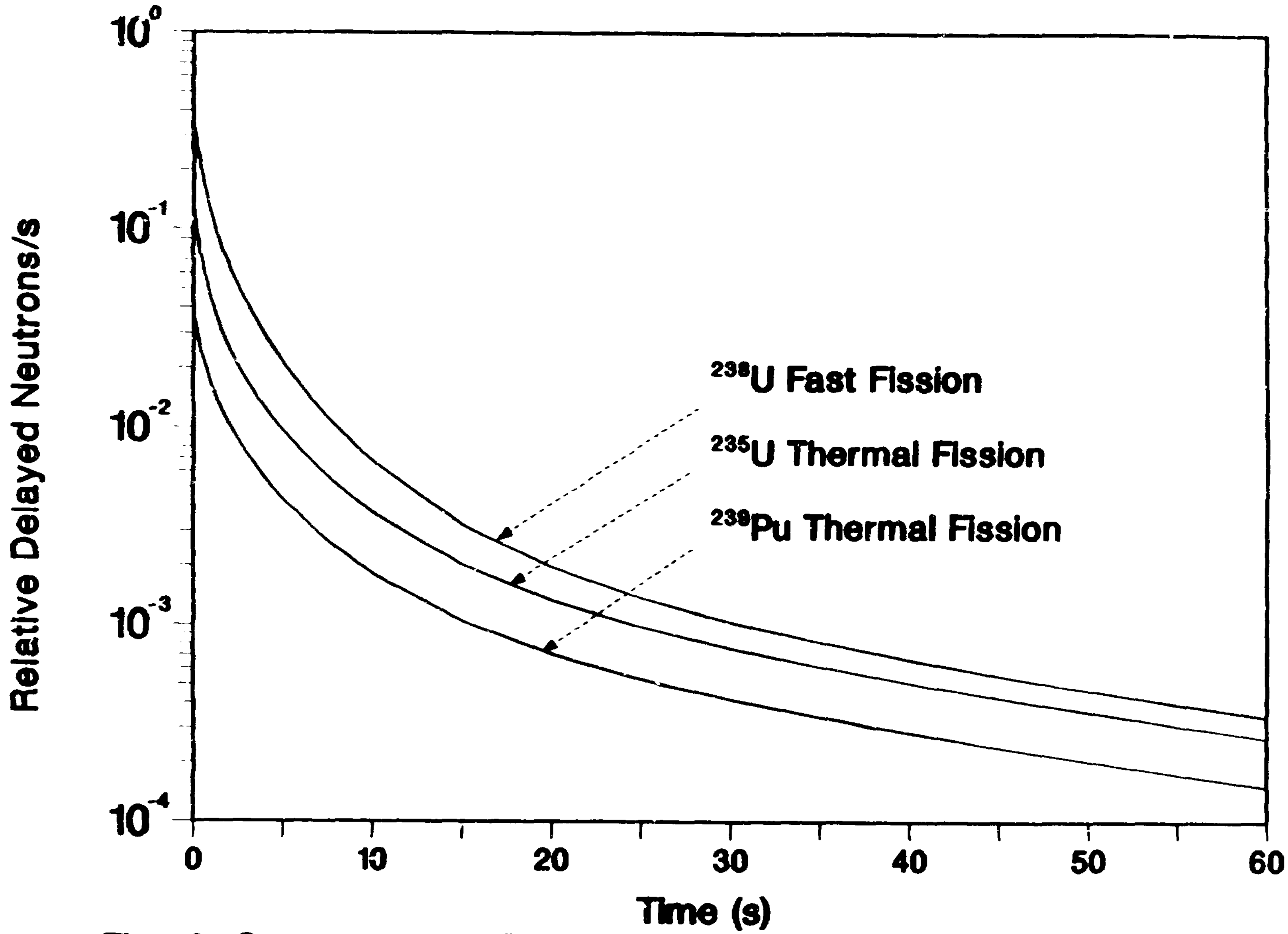

Fig. 2 Comparison of Total ν_d/s Following a Fission Pulse

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