USNRDL-TR-1093
3 October 1966

BETA SPECTRA. III. Spectra of U^{235} Fission Products at Selected Times after Fission

by

O. L. Hogan*

AD 645105

FACILITY FORM 602

N67-26173
(ACCESSION NUMBER)
58
(PAGES)
ad645105
(NASA CR OR TMX OR AD NUMBER)
CR 84001
(THRU)
0
(CODE)
24
(CATEGORY)

DDC
JAN 17 1967

U.S. NAVAL RADIOLOGICAL DEFENSE LABORATORY

SAN FRANCISCO • CALIFORNIA • 94135

NUCLEAR APPLICATIONS BRANCH
D. L. Love, Head

NUCLEAR TECHNOLOGY DIVISION
R. Cole, Head

ADMINISTRATIVE INFORMATION

The work reported was part of a project sponsored by the Space Nuclear Propulsion Office under AEC contract AT(49-5)-2505(2).

*Former NRDL employee.

DDC AVAILABILITY NOTICE

Distribution of this document is unlimited.

Eugene P. Cooper
Eugene P. Cooper
Technical Director

D. C. Campbell, CAPT USN
Commanding Officer and Director

ABSTRACT

Composite beta spectra for mixed fission products of U^{235} have been computed as the weighted sum of the theoretical beta spectra of the individual emitters. Reactor operating times used were: 0, 30, 60, 120, 240, 480, and 960 seconds, and 1 year. Sixteen decay times between 10^3 and 10^8 seconds were used. Results are graphically presented and are considered accurate to within 15 % for decay times less than 10^4 seconds, and to within 5 % for times greater than 10^4 seconds.

SUMMARY

Problem

Particles from reactor excursions represent a hazard when in contact with tissue because of the beta rays emitted from the fission products in the particle. For the determination of this hazard, the number and energy of the beta rays must be known. The problem is to calculate these emitted beta energy spectra from particles at selected times after fission for reactors with various histories.

Findings

Beta energy spectra from point source particles irradiated by both thermal and fission neutrons were computed at 16 decay times for each of 8 different reactor times.

I. INTRODUCTION

A possible hazard situation exists from the emitted beta rays of fission products in debris particles produced by a nuclear reactor excursion or re-entry burn up. To calculate this hazard it is necessary to know the beta energy spectrum of the mixtures of fission products present at any given time after a particular reactor history.

The beta spectra were computed, rather than measured experimentally, because only by computation could a spectrum be conveniently obtained for any desired reactor operating time and decay time. The composite spectra are generated as the weighted sum of the spectra of individual beta emitters, by a method that has been presented previously.[1] The individual negatron spectra have been presented in an earlier phase of this work.[2] The weighting factors for the nuclide abundances were computed at the desired times using a fission product abundance program.[3]

Degradation of the spectra due to self-absorption by the debris is not treated, for the present. Thus the plots presented in this report represent the beta energy distributions which would be emitted from infinitesimally small debris particles. The effect of a finite, spherical source of high-Z material, such as U^{235}, is treated in a forthcoming report.*

Other efforts[4-6] have been made to compute composite beta spectra, but the methods employed involved approximations in degrees of forbiddenness which make the error in the spectra indeterminate and quite possibly large.

II. COMPUTATION AND METHOD OF PRESENTATION

A. Outline of the Computation

The beta spectra are computed from the Fermi theory[7] with a correction due to Konopinski[8] for unique first-forbidden transitions. The

*O. L. Hogan, "Beta Spectra IV. Degraded Beta Spectra from a Finite Spherical Source", USNRDL-TR- (in preparation).

equations used for the one or more beta transitions of individual beta emitters are derived in Ref. 1.

Composite spectra, S(E,t), of a collection of beta-emitting nuclides are generated as the weighted sum over all of the j nuclides in the mixture:

$$S(E,t) = \sum_j A_j(t) \cdot B_j(E) \qquad (1)$$

where $A_j(t)$ = the activity of the jth nuclide at the time, t*
$B_j(E)$ = beta spectrum

Expected and median energies are presented with each spectrum. The expected energy is defined as:

$$\langle E \rangle = \frac{\int_0^{E_o\,max} E \cdot S(E,t) \cdot dE}{\int_0^{E_o\,max} S(E,t) \cdot dE} \qquad (2)$$

The median energy is that value of the energy such that half of the betas are of greater energy and half are of less energy. Its value appears as the upper limit, $E_{1/2}$, on the first integral in the defining equation:

$$\int_0^{E_{1/2}} S(E,t)\, dE = 1/2 \int_0^{E_o\,max} S(E,t) \cdot dE \,. \qquad (3)$$

B. Presentation of the Spectra

Spectra have been computed at arbitrarily selected times after reactor shut-down for 8 reactor operating times, and 2 fission types. The 2 fission types are U^{235} with thermal neutrons and U^{235} with fission neutrons.

Not all of the spectra computed have been presented. In situations where plotted spectra for U^{235} thermal and U^{235} fission look alike, only the U^{235} thermal spectra are presented.

*The program from which abundances are obtained is described in Ref. 3.

The spectra are presented (Appendix II) in plotted form only. For many kinds of hazard analysis, the accuracy these provide is adequate.* The original plots were 5 in. x 8 in., prepared on a Calcomp (Model 570) automatic plotter, which is accurate to 0.01 inch. An idea of the reproducibility may be gained from examination of the spectra shown in Appendix II, each of which was traced 3 times.

The total numbers of beta particles per second for each of the spectra computed are presented in Tables 1 (Thermal Neutron) and 2 (Fission Neutron), Appendix I.

The expected and median energies for each of the spectra computed are presented in Tables 3 (Thermal Neutron) and 4 (Fission Neutron), Appendix I. Despite the fact that these values appear on the plots, separate tabulation is presented in order to emphasize the trends and similarities among the values.

III. TIME POINTS CHOSEN

Two times are important in determining the characteristics of the spectra: (1) the length of time the reactor operated before shutdown, or excursion, and (2) the length of the decay time since reactor operation ceased. The reactor operating times are shown in Table 1, below; the decay times in Table 2.

Table 1

Reactor Operating Times (sec)
0
30
60
120
240
480
960
1 year

*For very careful work, however, more accurate values of the spectra may be had by repeating the computations described in II.A. and thus obtaining numerical lists of the spectrum values.

Table 2

Decay Times (sec)	
1×10^3	1×10^5
2×10^3	2×10^5
4×10^3	4×10^5
7×10^3	7×10^5
1×10^4	1×10^6
2×10^4	4×10^6
4×10^4	1×10^7
7×10^4	1×10^8

Short operating times were chosen because they seemed the most probable times for an operating nuclear reactor in space. The 1-year operating time, which represents steady-state, is added as a point for comparison.

For the facilitation of the intercomparison of spectra, all reactor operation powers were adjusted so that 1 megawatt-second had been produced, or 3.3×10^{16} fissions, had occurred, by the end of the operating time.

The decay times were chosen to permit easy graphical interpolation.

IV. SOURCES OF ERROR

Two sources contribute to the possible error in the composite beta spectra presented in this report: (1) uncertainty in the nuclear data (i.e. half-lives, end-point energies, forbiddenness assignments), and (2) lack of data for nuclides known to be beta-emitters.

Uncertainty in the nuclear data usually produces only relatively small errors, up to about 5 % in the value of the ordinate of an individual spectrum at any point. This error becomes less significant in the weighting and summing process, which makes the contribution of that nuclide only a small percentage of the total value of the spectrum.

Omission of certain nuclides for which adequate input data to prepare spectra are lacking may produce non trivial errors. Fortunately, the beta-emitters for which data are not known are in most cases of short half-life. In the present calculations this error is estimated

at 15 % or less for decay times shorter than 10^3 seconds and not greater than 5 % for times greater than 10^4 seconds. Table 5 in Appendix I lists the nuclides responsible for this error.

V. SUMMARY

Composite beta spectra for mixed fission products from U^{235} thermal-neutron fission and U^{235} fission-neutron fission have been computed for various combinations of reactor operating times and decay times. Results of the computations are presented graphically. Expected and median energies, and the beta emission rates for the various situations, are tabulated separately.

REFERENCES

1. O. L. Hogan, M. A. Hogan, "Beta Spectra I. FORTRAN Program for Composite Spectra," U. S. Naval Radiological Defense Laboratory, USNRDL-TR-1033, 28 March 1966.

2. O. L. Hogan, P. E. Zigman, J. L. Mackin, "Beta Spectra II. Spectra of Individual Negatron Emitters," U. S. Naval Radiological Defense Laboratory, USNRDL-TR-802, 16 December 1964.

3. M. A. Hogan, J. K. Crawford, V. Goddard, "Computer Program for Calculating Fission Product Abundances," U. S. Naval Radiological Defense Laboratory, USNRDL-TR-921, 15 October 1965.

4. R. B. Heller, "Energy and Time Beta Ray Spectra of Fission Products of U^{235} by Fission Neutrons and U^{238} by 12 Mev Neutrons," The Pentagon Weapon Systems Evaluation Group, WSEG Memorandum No. 19, 1961.

5. R. B. Heller, Shanti Chakravarty, Joan Frawley, M. Silver, "Energy and Time Beta Spectra of Fission Products," Nucleonics, 23:92 (1965).

6. J. E. Dieckhoner, "Prediction of the Time Dependent Beta Spectrum from a Nuclear Weapon Detonation," Masters Thesis, School of Engineering, Air Force Institute of Technology, Air University, August 1965.

7. E. Fermi, "Versuch einer Theorie der Beta-Strahlen. I." Z. Physik 88:161 (1934).

8. E. J. Konopinski, M. E. Rose, "The Theory of Nuclear β-Decay," in K. Siegbahn, ed., Alpha-Beta- and Gamma-Ray Spectroscopy, North Holland Publishing Co., Amsterdam, 1965, p. 1351, ff.

APPENDIX I

BETA ABUNDANCES AND ENERGIES FROM U^{235} FISSION PRODUCTS AT SELECTED TIMES AFTER CESSATION OF FISSION FOR SELECTED REACTOR OPERATING TIMES

TABLE 1

Negatrons Per Second Per Megawatt-Second from U^{235} Thermal-Neutron Fission

Time After Fission (sec)	Reactor Running Time							
	Instantaneous Fission	30 sec	60 sec	120 sec	240 sec	480 sec	960 sec	1 year (steady-state)
0		9.077×10^{13}	7.851×10^{13}	6.630×10^{13}	5.289×10^{13}	3.909×10^{13}	2.732×10^{13}	3.426×10^{9}
1×10^{3}	1.202×10^{13}	1.189×10^{13}	1.177×10^{13}	1.152×10^{13}	1.107×10^{13}	1.029×10^{13}	9.032×10^{12}	2.579×10^{9}
2×10^{3}	6.705×10^{12}	6.655×10^{12}	6.606×10^{12}	6.510×10^{12}	6.327×10^{12}	5.987×10^{12}	5.406×10^{12}	2.296×10^{9}
4×10^{3}	2.987×10^{12}	2.973×10^{12}	2.959×10^{12}	2.931×10^{12}	2.877×10^{12}	2.775×10^{12}	2.595×10^{12}	2.012×10^{9}
7×10^{3}	1.476×10^{12}	1.472×10^{12}	1.468×10^{12}	1.461×10^{12}	1.447×10^{12}	1.419×10^{12}	1.369×10^{12}	1.816×10^{9}
1×10^{4}	9.904×10^{11}	9.888×10^{11}	9.872×10^{11}	9.841×10^{11}	9.779×10^{11}	9.659×10^{11}	9.430×10^{11}	1.702×10^{9}
2×10^{4}	4.817×10^{11}	4.813×10^{11}	4.810×10^{11}	4.802×10^{11}	4.788×10^{11}	4.759×10^{11}	4.703×10^{11}	1.488×10^{9}
4×10^{4}	2.368×10^{11}		2.366×10^{11}	2.364×10^{11}	2.360×10^{11}	2.353×10^{11}	2.338×10^{11}	1.278×10^{9}
7×10^{4}	1.250×10^{11}			1.249×10^{11}	1.247×10^{11}	1.245×10^{11}	1.240×10^{11}	1.115×10^{9}
1×10^{5}	8.009×10^{10}				7.997×10^{10}	7.985×10^{10}	7.960×10^{10}	1.021×10^{9}
2×10^{5}	3.258×10^{10}				3.255×10^{10}	3.253×10^{10}	3.248×10^{10}	8.619×10^{8}
4×10^{5}	1.499×10^{10}					1.498×10^{10}	1.497×10^{10}	7.274×10^{8}
7×10^{5}	8.789×10^{9}						8.783×10^{9}	6.206×10^{8}
1×10^{6}	6.198×10^{9}							5.514×10^{8}
4×10^{6}	1.392×10^{9}							2.955×10^{8}
1×10^{7}	4.827×10^{8}							1.549×10^{8}
1×10^{8}	1.394×10^{7}							1.126×10^{7}

Note: Wherever values are omitted they are understood to be identical with the instantaneous-fission values.

Table 2

Negatrons Per Second Per Megawatt-Second from U^{235} Fission Neutron Fission

Time After Fission (sec)	Reactor Running Time							
	Instantaneous Fission	30 sec	60 sec	120 sec	240 sec	480 sec	960 sec	1 year (steady-state)
0		9.041×10^{13}	7.869×10^{13}	6.665×10^{13}	5.321×10^{13}	3.931×10^{13}	2.743×10^{13}	3.396×10^{9}
1×10^{3}	1.198×10^{13}	1.185×10^{13}	1.173×10^{13}	1.148×10^{13}	1.103×10^{13}	1.024×10^{13}	8.984×10^{12}	2.546×10^{9}
2×10^{3}	6.655×10^{12}	6.605×10^{12}	6.556×10^{12}	6.460×10^{12}	6.276×10^{12}	5.937×10^{12}	5.354×10^{12}	2.264×10^{9}
4×10^{3}	2.924×10^{12}	2.909×10^{12}	2.895×10^{12}	2.867×10^{12}	2.813×10^{12}	2.710×10^{12}	2.529×10^{12}	1.985×10^{9}
7×10^{3}	1.413×10^{12}	1.409×10^{12}	1.406×10^{12}	1.398×10^{12}	1.384×10^{12}	1.358×10^{12}	1.308×10^{12}	1.795×10^{9}
1×10^{4}	9.465×10^{11}	9.450×10^{11}	9.436×10^{11}	9.406×10^{11}	9.348×10^{11}	9.236×10^{11}	9.022×10^{11}	1.686×10^{9}
2×10^{4}	4.777×10^{11}	4.774×10^{11}	4.770×10^{11}	4.764×10^{11}	4.750×10^{11}	4.723×10^{11}	4.670×10^{11}	1.478×10^{9}
4×10^{4}	2.413×10^{11}	2.412×10^{11}	2.411×10^{11}	2.410×10^{11}	2.406×10^{11}	2.398×10^{11}	2.383×10^{11}	1.266×10^{9}
7×10^{4}	1.281×10^{11}		1.280×10^{11}	1.280×10^{11}	1.278×10^{11}	1.276×10^{11}	1.270×10^{11}	1.100×10^{9}
1×10^{5}	8.204×10^{10}		8.201×10^{10}	8.198×10^{10}	8.191×10^{10}	8.179×10^{10}	8.154×10^{10}	1.003×10^{9}
2×10^{5}	3.315×10^{10}		3.314×10^{10}	3.313×10^{10}	3.312×10^{10}	3.310×10^{10}	3.305×10^{10}	8.406×10^{8}
4×10^{5}	1.510×10^{10}			1.509×10^{10}	1.509×10^{10}	1.509×10^{10}	1.508×10^{10}	7.043×10^{8}
7×10^{5}	8.714×10^{9}			8.713×10^{9}	8.712×10^{9}	8.711×10^{9}	8.708×10^{9}	5.874×10^{8}
1×10^{6}	6.053×10^{9}			6.052×10^{9}	6.052×10^{9}	6.051×10^{9}	6.050×10^{9}	5.293×10^{8}
4×10^{6}	1.322×10^{9}							2.846×10^{8}
1×10^{7}	4.660×10^{8}							1.502×10^{8}
1×10^{8}	1.367×10^{7}							1.105×10^{7}

Note: Wherever values are omitted they are understood to be identical with the instantaneous-fission values.

TABLE 3

U^{235} Thermal-Neutron Fission, Expected and Median Energies

Time After Fission (sec)	Reactor Running Time															
	Instantaneous Fission		30 sec		60 sec		120 sec		240 sec		480 sec		960 sec		1 year (steady-state)	
	E_{ex}*	E_{med}**	E_{ex}	E_{med}	E_{ex}	E_{med}	E_{ex}	E_{med}	E_{ex}	E_{med}	E_{ex}	E_{med}	E_{ex}	E_{med}	E_{ex}	E_{med}
0			1.470	1.391	1.432	1.335	1.388	1.279	1.339	1.224	1.285	1.162	1.229	1.093	.803	.562
1×10^3	1.051	.870	1.050	.869	1.049	.868	1.047	.865	1.043	.860	1.038	.853	1.031	.843	.664	.431
2×10^3	1.014	.821					1.013	.820	1.012	.818	1.010	.816	1.007	.812	.619	.391
4×10^3	.981	.783					.980	.782	.979	.781	.977	.779	.972	.774	.566	.347
7×10^3	.924	.720					.923	.719	.922	.717	.920	.715	.916	.710	.523	.316
1×10^4	.881	.665					.880	.664	.880	.663	.878	.662	.876	.568	.498	.298
2×10^4	.809	.573					.808	.572	.808	.572	.807	.571	.806	.570	.448	.267
4×10^4	.714	.501					.713	.501	.713	.501	.713	.501	.712	.500	.396	.235
7×10^4	.598	.431											.597	.430	.358	.210
1×10^5	.517	.381											.516	.380	.339	.196
2×10^5	.389	.283											.388	.282	.318	.176
4×10^5	.304	.203											.304	.202	.314	.166
7×10^5	.287	.186													.318	.161
1×10^6	.289	.188													.322	.157
4×10^6	.315	.175													.341	.125
1×10^7	.318	.114													.379	.111
1×10^8	.461	.146													.435	.146

Note: Wherever values are omitted they are understood to be identical with the instantaneous fission values.

* See eqn. 2 in text.

**See eqn. 3 in text.

TABLE 4

U^{235} Fission-Neutron Fission, Expected and Median Energies

Time After Fission (sec)	Instantaneous Fission		Reactor Running Time: 30 sec		60 sec		120 sec		240 sec		480 sec		960 sec		1 year (steady-state)	
	E_{ex}*	E_{med}**	E_{ex}	E_{med}	E_{ex}	E_{med}	E_{ex}	E_{med}	E_{ex}	E_{med}	E_{ex}	E_{med}	E_{ex}	E_{med}	E_{ex}	E_{med}
0			1.467	1.387	1.429	1.331	1.383	1.273	1.332	1.216	1.277	1.151	1.219	1.078	.800	.558
1×10^3	1.034	.844	1.033	.842	1.032	.841	1.030	.838	1.026	.834	1.020	.826	1.013	.817	.661	.428
2×10^3	.998	.798	.997	.798	.997	.797	.997	.797	.996	.796	.994	.794	.992	.791	.618	.390
4×10^3	.974	.774			.973	.773	.973	.773	.972	.772	.971	.770	.967	.767	.566	.347
7×10^3	.926	.721					.925	.720	.924	.719	.922	.716	.918	.712	.525	.316
1×10^4	.883	.666					.883	.665	.882	.664	.880	.662	.878	.658	.500	.300
2×10^4	.807	.572					.806	.572	.806	.572	.805	.571	.804	.570	.451	.269
4×10^4	.715	.507							.715	.506	.714	.506	.713	.505	.399	.237
7×10^4	.605	.437									.604	.437	.603	.436	.359	.210
1×10^5	.525	.385											.524	.385	.339	.195
2×10^5	.393	.283											.392	.283	.316	.174
4×10^5	.306	.204													.311	.163
7×10^5	.288	.187													.314	.157
1×10^6	.289	.188													.317	.153
4×10^6	.311	.170													.334	.120
1×10^7	.311	.110													.371	.107
1×10^8	.449	.137													.423	.137

Note: Wherever values are omitted they are understood to be identical with the instantaneous fission values.
* See eqn. 2 in text.
**See eqn. 3 in text.

TABLE 5

Beta-Emitting Fission Product Nuclides Not Included in the Composite Spectra

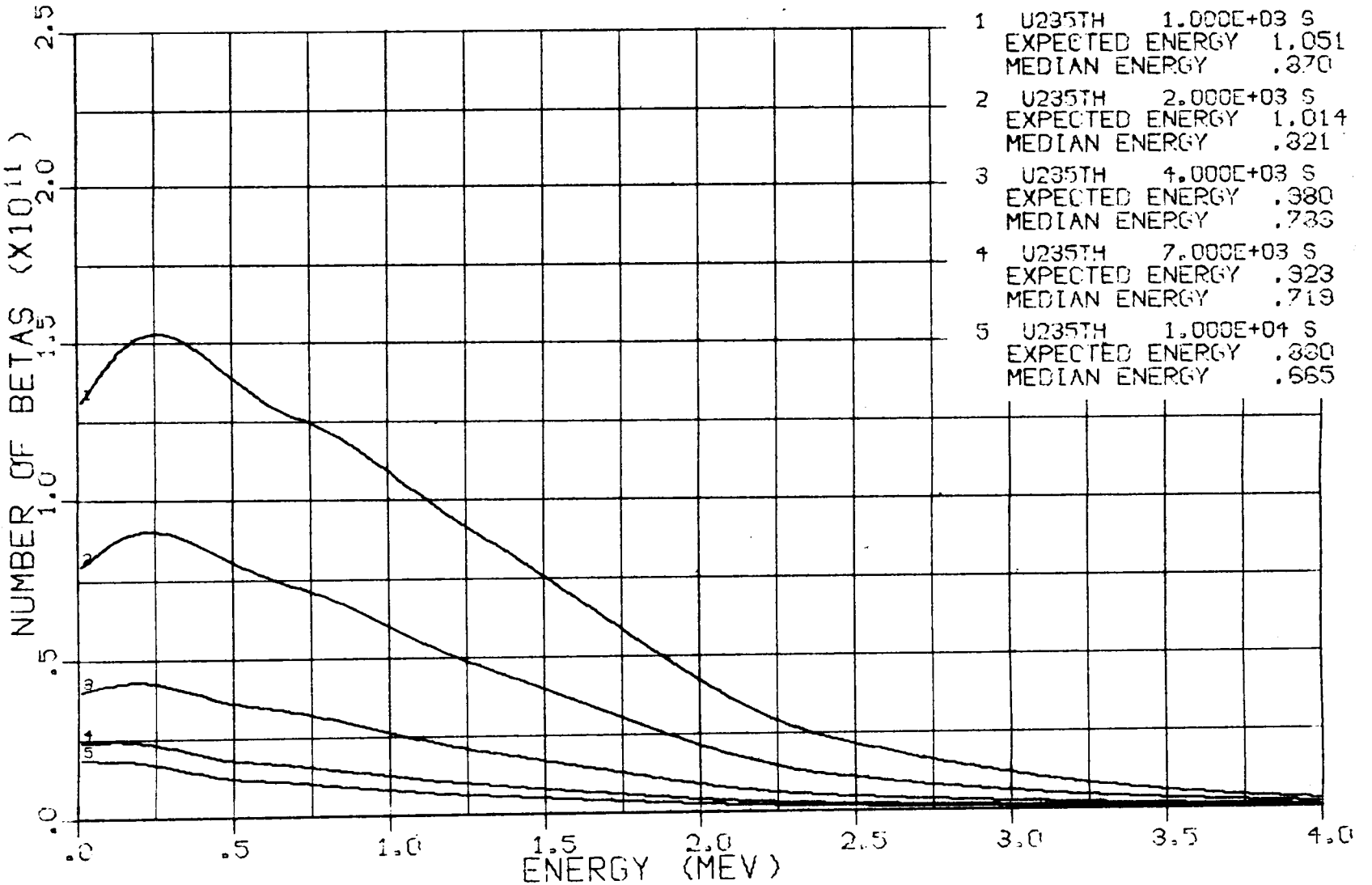
	$T_{1/2}$			$T_{1/2}$
As 80	36 s		Sn 126	2×10^5 y
Se 83	25 m		Sn 127	2.1 h
Se 84	3 m		Sn 128	57 m
Rb 90	2.9 m		Sn 129	1.8 h
Sr 93	8.2 m		Sn 130	2.6 m
Sr 94	1.3 m		Sn 131	1.3 m
Y 95	10.5 m		Sn 132	1.0 m
Nb 98	51 m		Sb 131	23 m
Nb 100	3 m		Sb 132	3.1 m
Nb 100A	11.5 m		Sb 133	2.7 m
Nb 101	1.0 m		Te 134	42 m
Mo 105	2 m		I 136	85 s
Tc 105	10 m		Xe 139	41 s
Pd 111A	5.5 h		Cs 140	66 s
Ag 113	5.3 h		Ba 142	11 m
Cd 117	50 m		Ce 147	1.2 m
Cd 119	11 m		Ce 148	0.7 m
Cd 120	1 m		Pr 147	12 m
			Pr 148	2 m

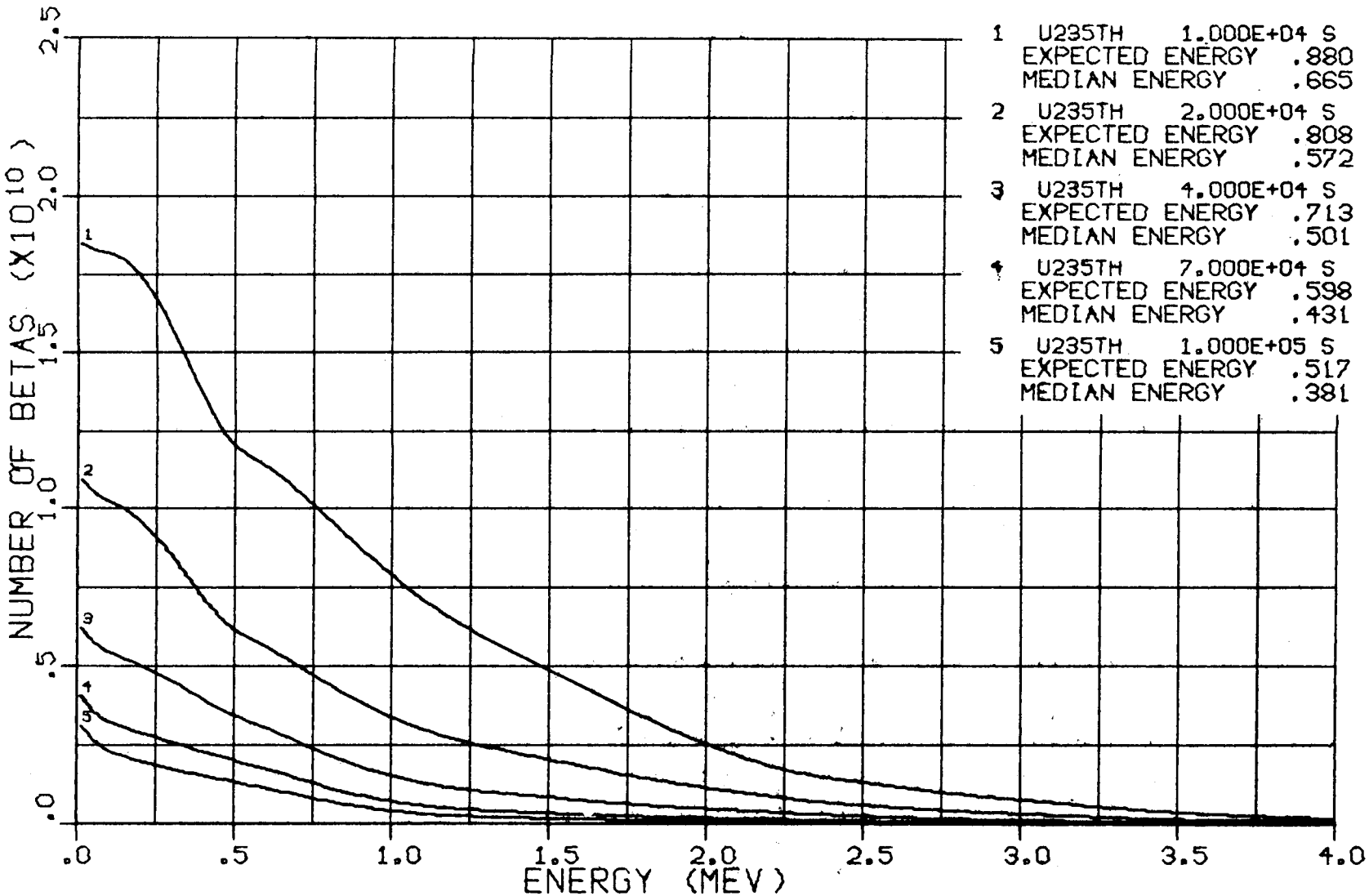
Note: Omission of the spectra of the 10 nuclides underlined is the principal source of error in the composite spectra at short decay times (10^3-10^4 seconds). See section IV.

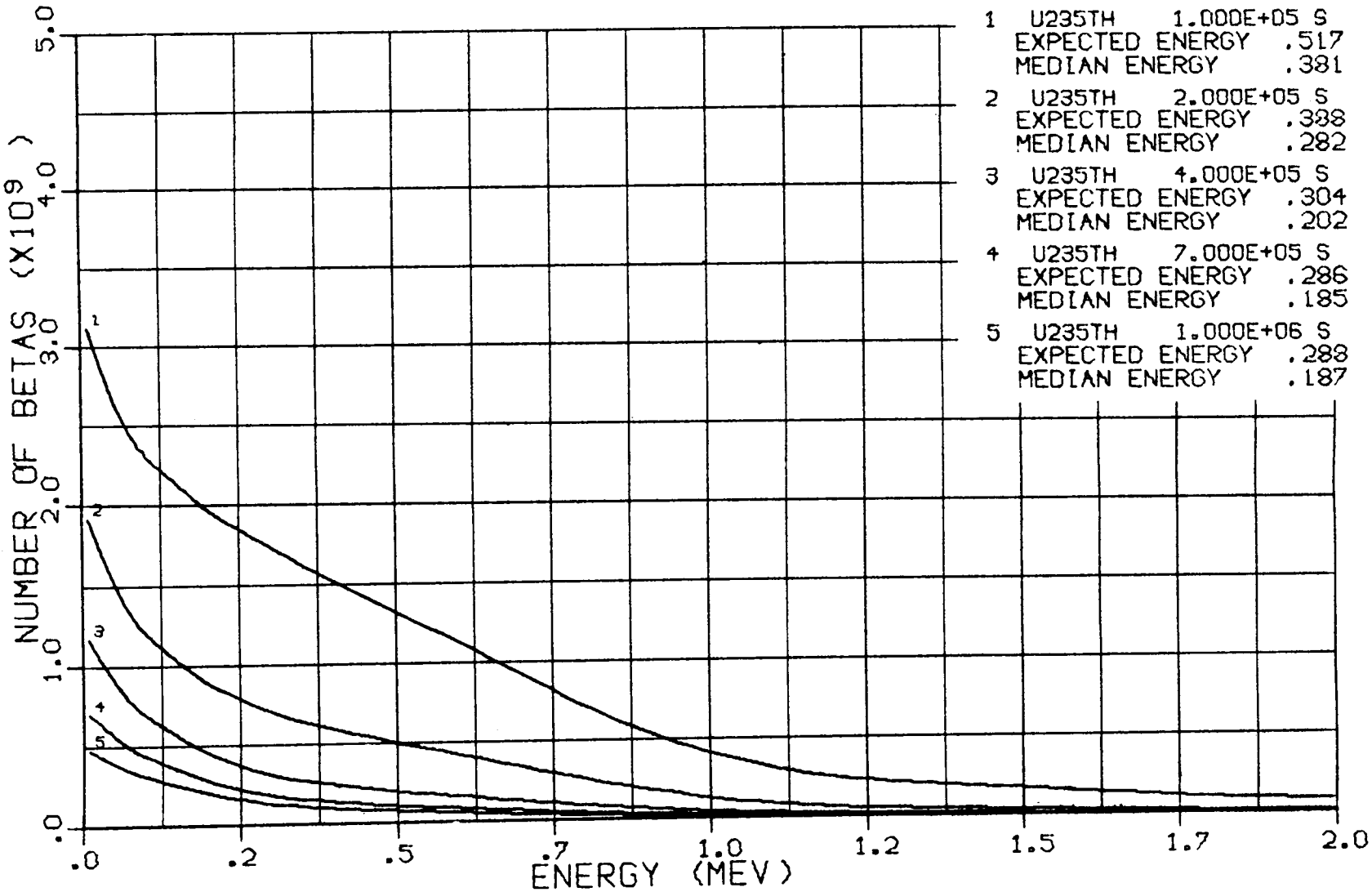
APPENDIX II

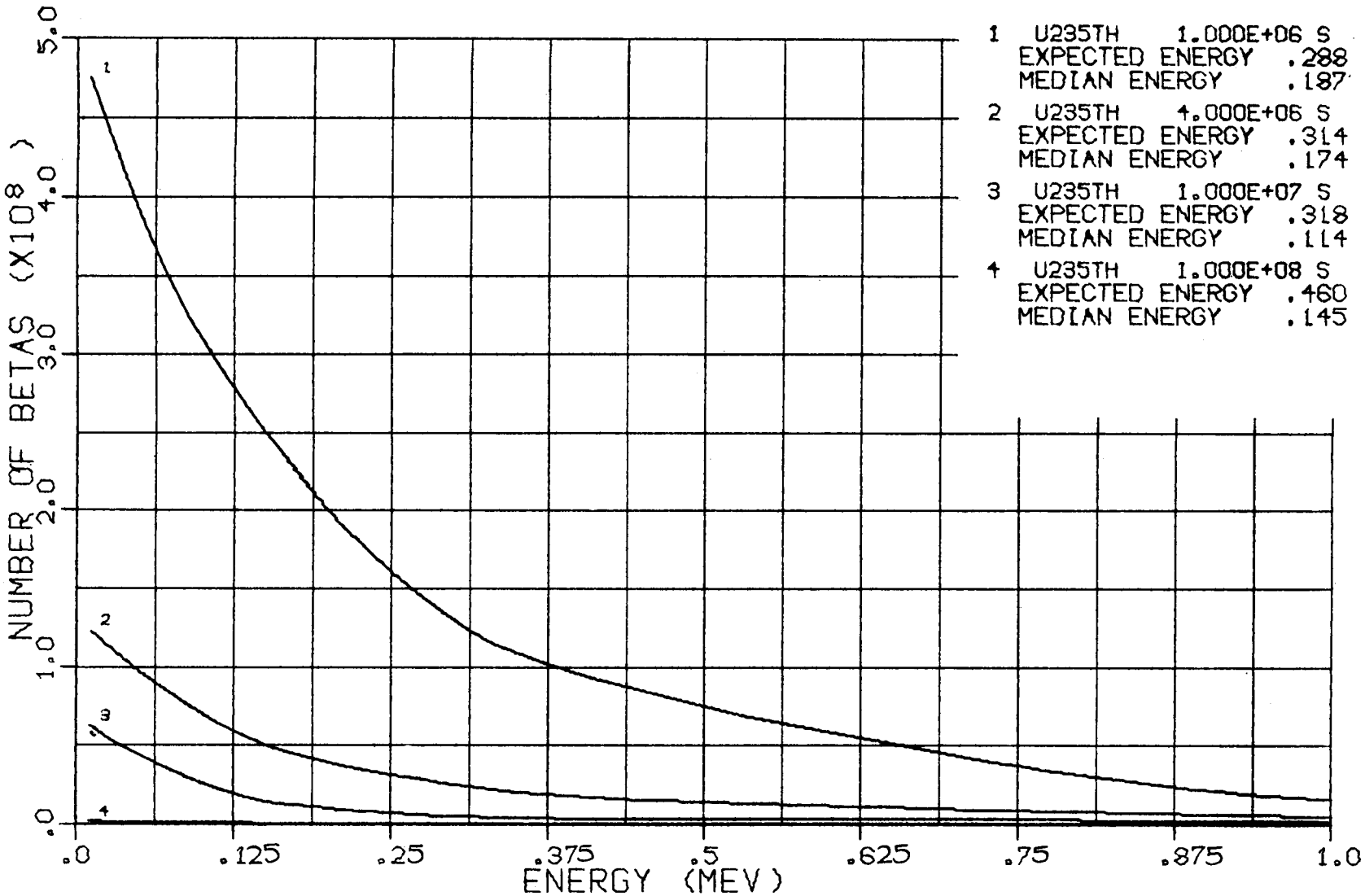
COMPOSITE BETA SPECTRA OF U^{235} FISSION PRODUCTS AT SELECTED TIMES AFTER FISSION

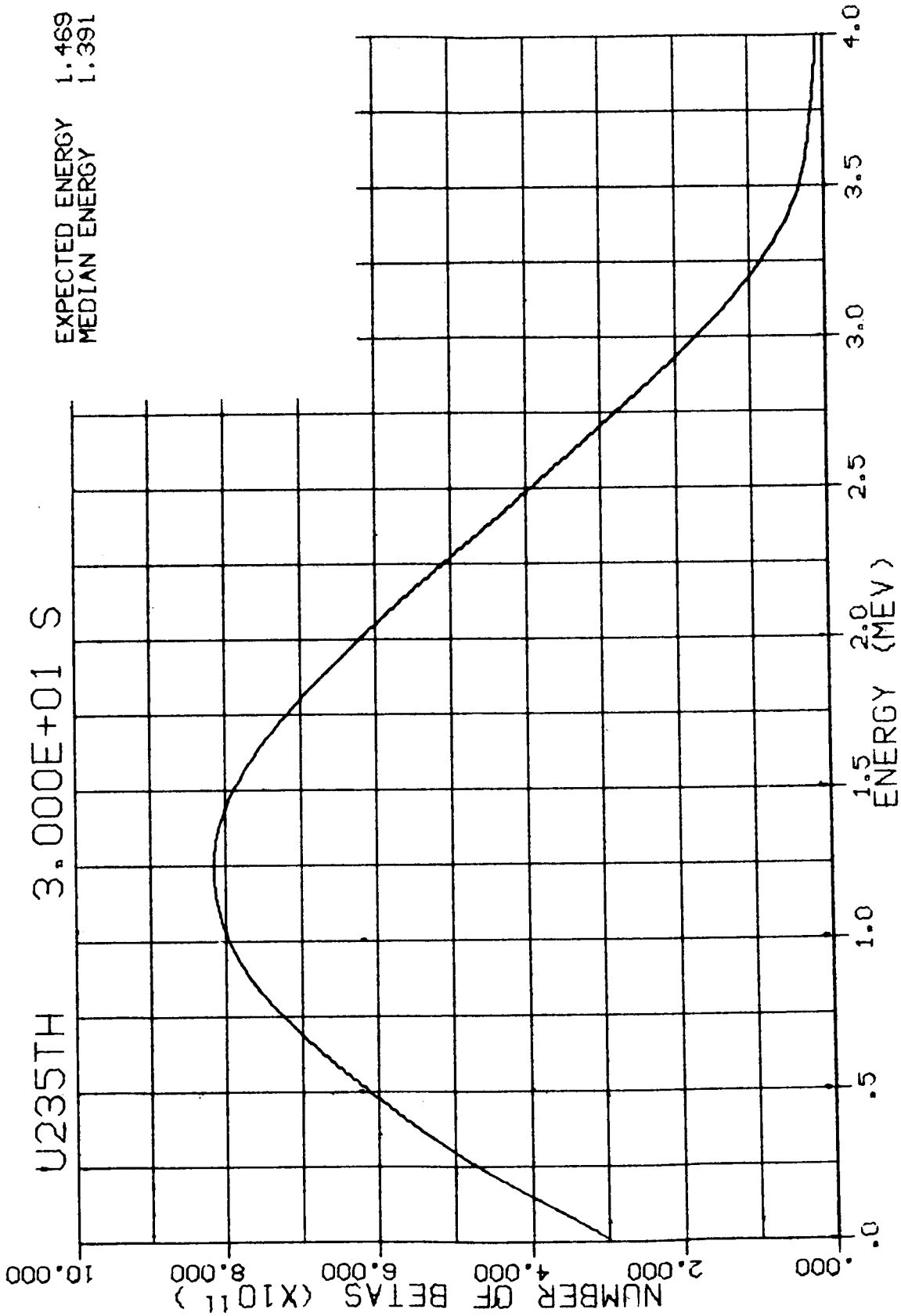
The time after fission and the reactor running time are contained in the numbers on the figures, appearing after U235TH for U^{235} thermal neutron fission and after U235FI for U^{235} fission neutron fission. For example, curve 1 of Figure 1 reads 1.000 + 03 s. The 1.....+ 03 refers to a time after fission of 1×10^3 seconds, and the 000 refers to a reactor running time of 0 seconds (instantaneous fission). See Tables 3 and 4 for a tabular sequence of these times.

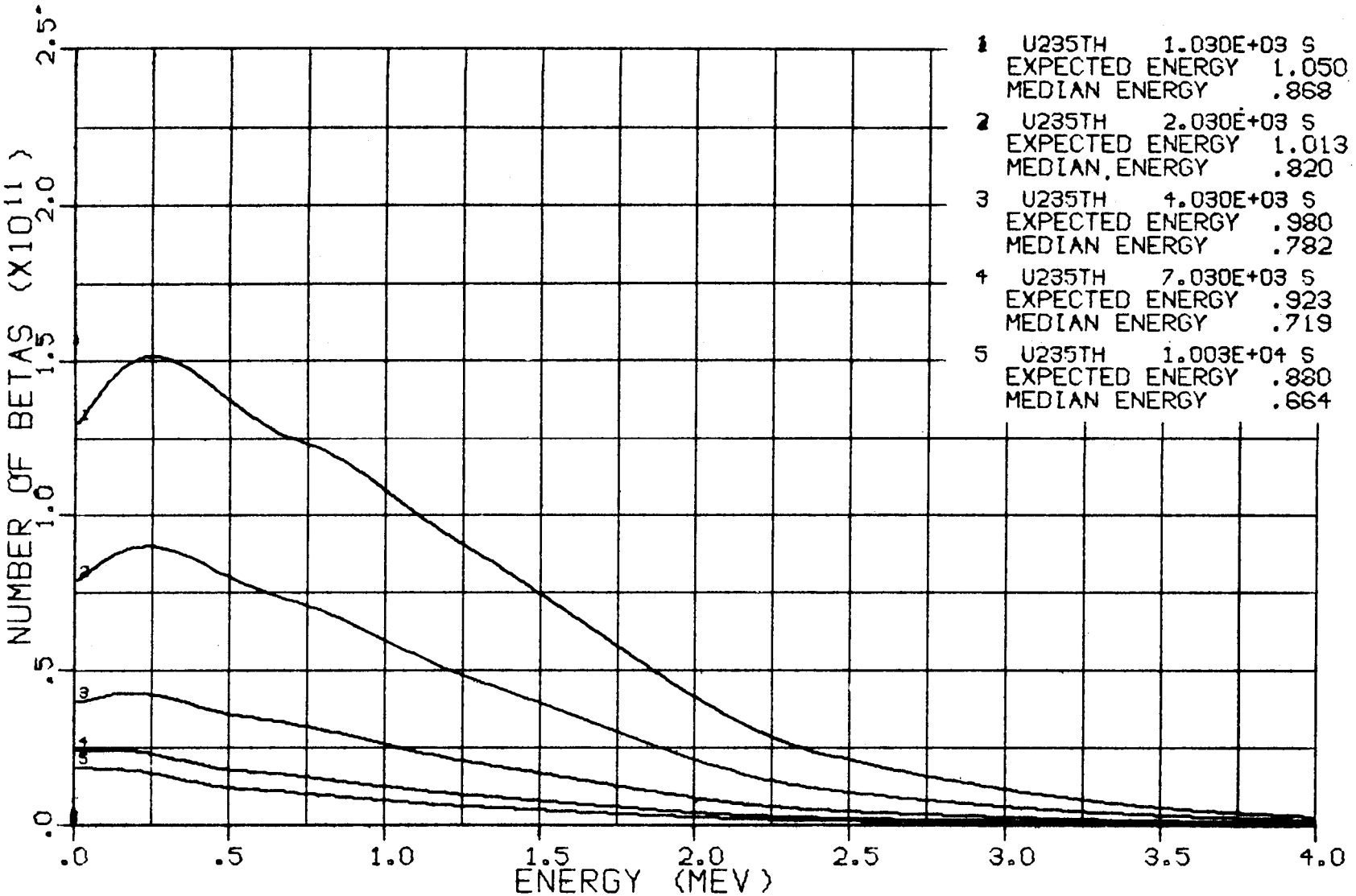

1 U235TH 1.000E+03 S
EXPECTED ENERGY 1.051
MEDIAN ENERGY .870
2 U235TH 2.000E+03 S
EXPECTED ENERGY 1.014
MEDIAN ENERGY .821
3 U235TH 4.000E+03 S
EXPECTED ENERGY .880
MEDIAN ENERGY .733
4 U235TH 7.000E+03 S
EXPECTED ENERGY .823
MEDIAN ENERGY .719
5 U235TH 1.000E+04 S
EXPECTED ENERGY .880
MEDIAN ENERGY .665
NUMBER OF BETAS (X10^11)
ENERGY (MEV)
.0
.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0

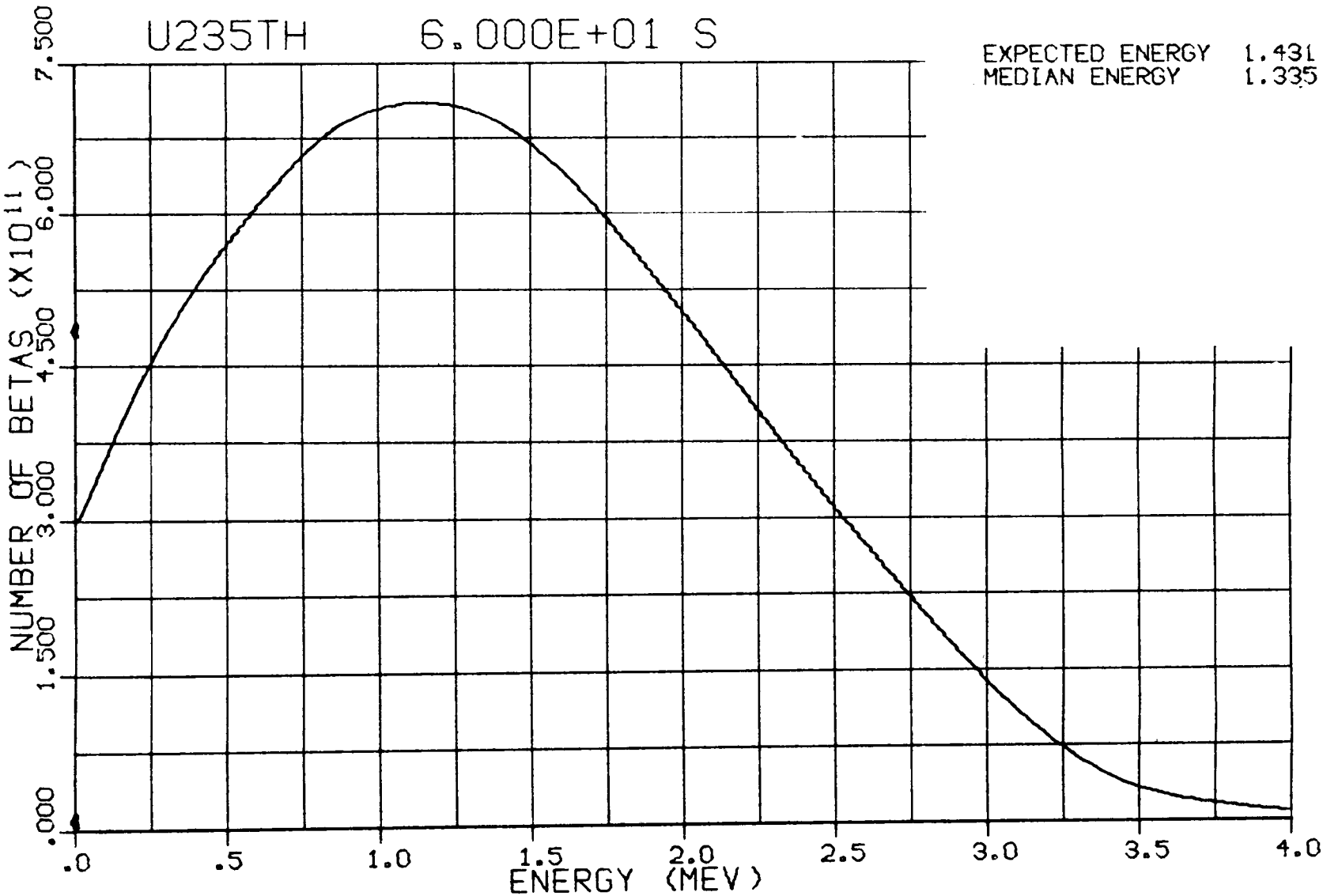

1 U235TH 1.000E+04 S
EXPECTED ENERGY .880
MEDIAN ENERGY .665
2 U235TH 2.000E+04 S
EXPECTED ENERGY .808
MEDIAN ENERGY .572
3 U235TH 4.000E+04 S
EXPECTED ENERGY .713
MEDIAN ENERGY .501
4 U235TH 7.000E+04 S
EXPECTED ENERGY .598
MEDIAN ENERGY .431
5 U235TH 1.000E+05 S
EXPECTED ENERGY .517
MEDIAN ENERGY .381
NUMBER OF BETAS (X10^10)
ENERGY (MEV)
.0
.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0

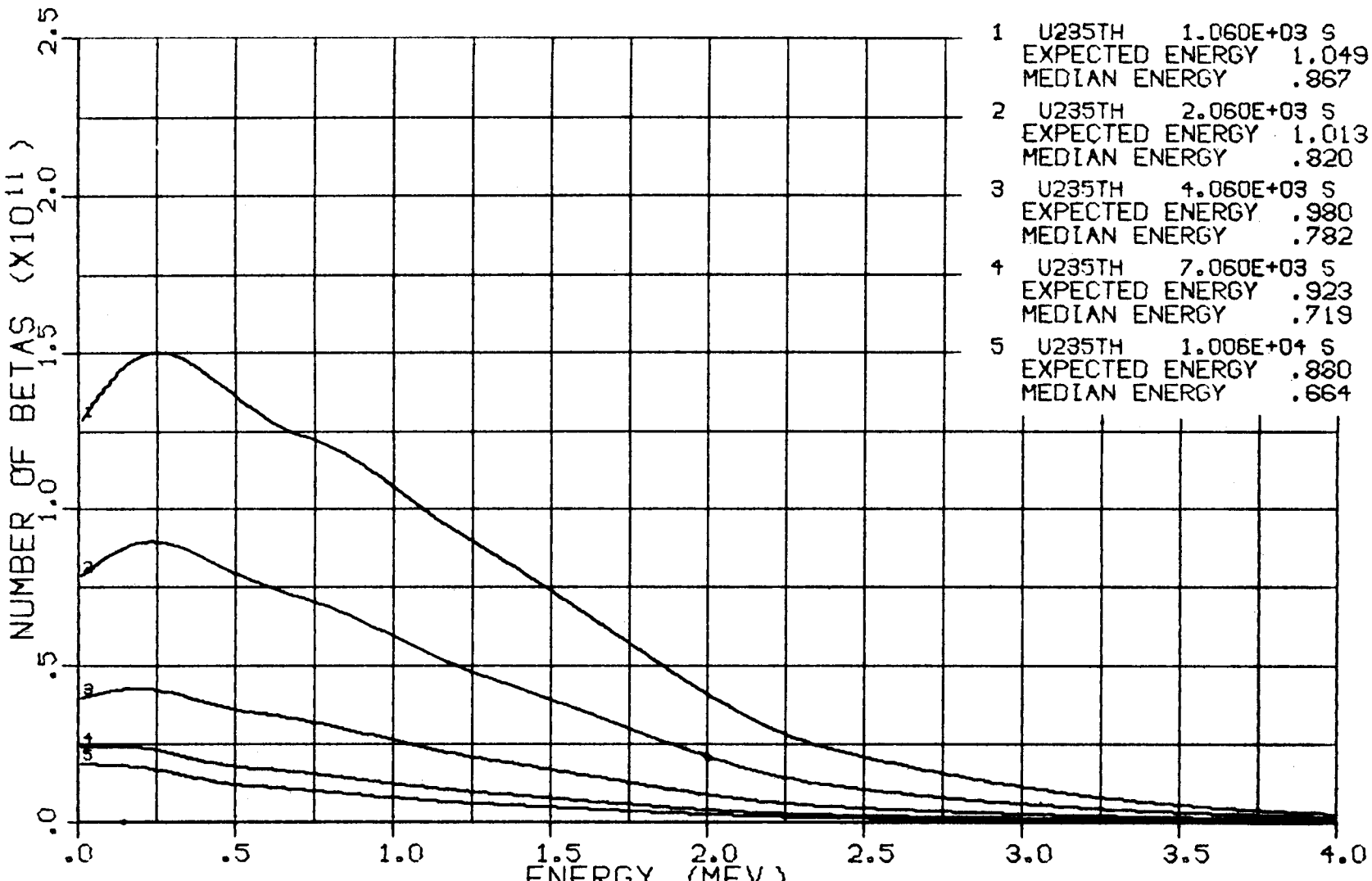

1 U235TH 1.000E+05 S
EXPECTED ENERGY .517
MEDIAN ENERGY .381
2 U235TH 2.000E+05 S
EXPECTED ENERGY .338
MEDIAN ENERGY .282
3 U235TH 4.000E+05 S
EXPECTED ENERGY .304
MEDIAN ENERGY .202
4 U235TH 7.000E+05 S
EXPECTED ENERGY .286
MEDIAN ENERGY .185
5 U235TH 1.000E+06 S
EXPECTED ENERGY .288
MEDIAN ENERGY .187
NUMBER OF BETAS (X10^9)
5.0
4.0
3.0
2.0
1.0
.0
.0
.2
.5
.7
1.0
1.2
1.5
1.7
2.0
ENERGY (MEV)

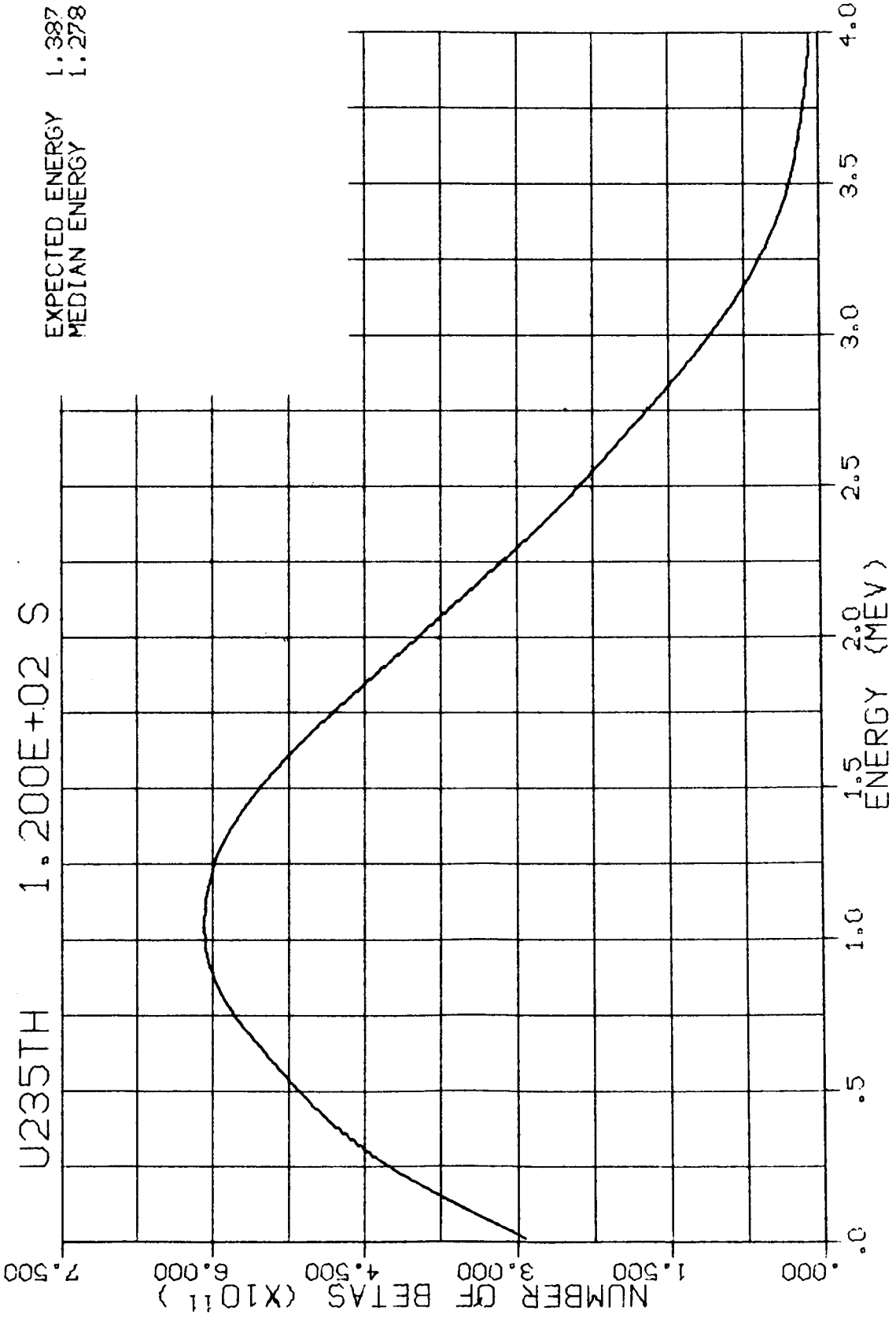

1 U235TH 1.000E+06 S
EXPECTED ENERGY .288
MEDIAN ENERGY .187
2 U235TH 4.000E+06 S
EXPECTED ENERGY .314
MEDIAN ENERGY .174
3 U235TH 1.000E+07 S
EXPECTED ENERGY .318
MEDIAN ENERGY .114
4 U235TH 1.000E+08 S
EXPECTED ENERGY .460
MEDIAN ENERGY .145
NUMBER OF BETAS (X10^8)
ENERGY (MEV)
.0
1.0
2.0
3.0
4.0
5.0
.125
.25
.375
.5
.625
.75
.875
1.0

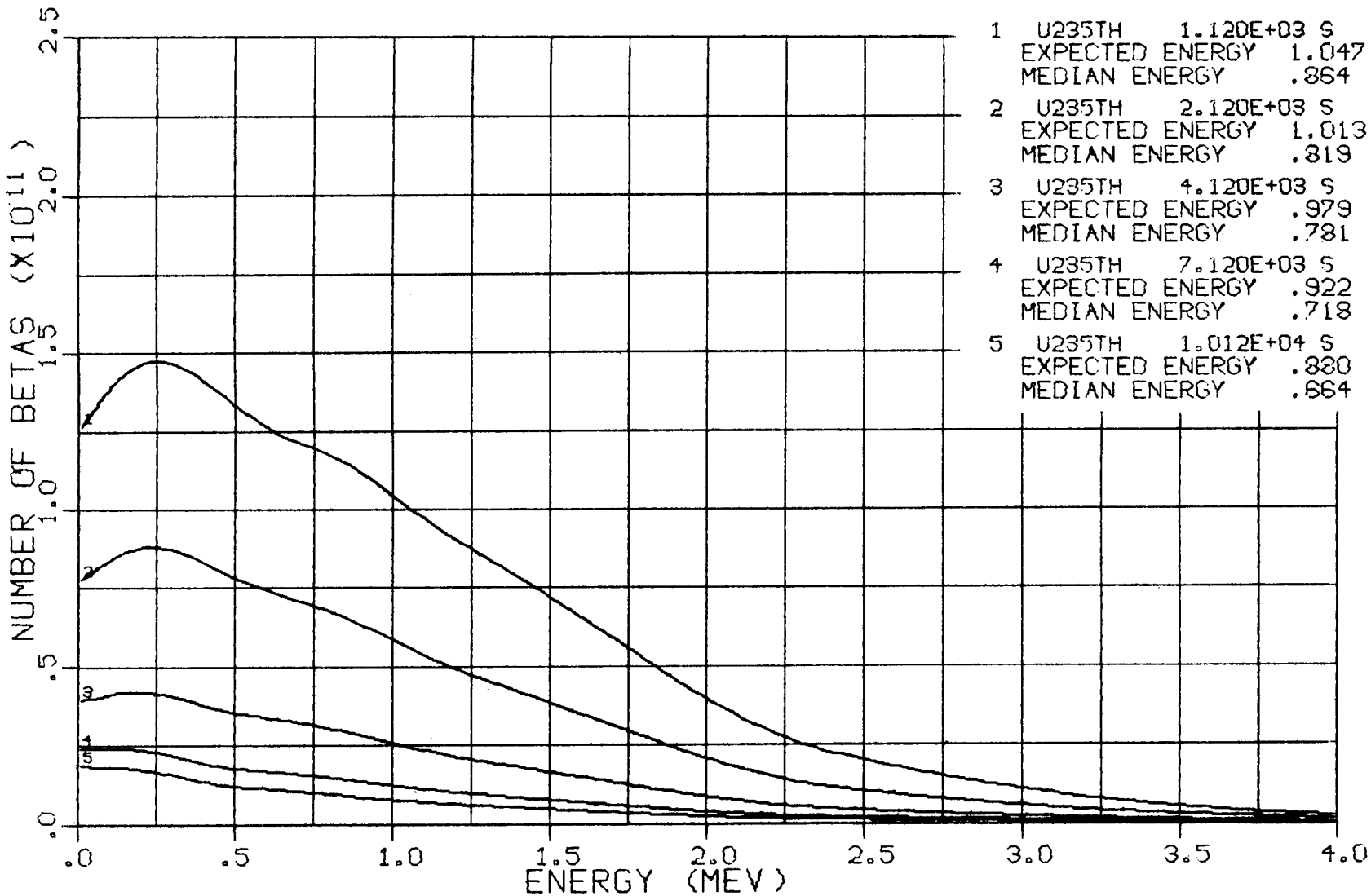

U235TH 3.000E+01 S
EXPECTED ENERGY 1.469
MEDIAN ENERGY 1.391
NUMBER OF BETAS (X10^11)
10.000
8.000
6.000
4.000
2.000
.000
.0
.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
ENERGY (MEV)

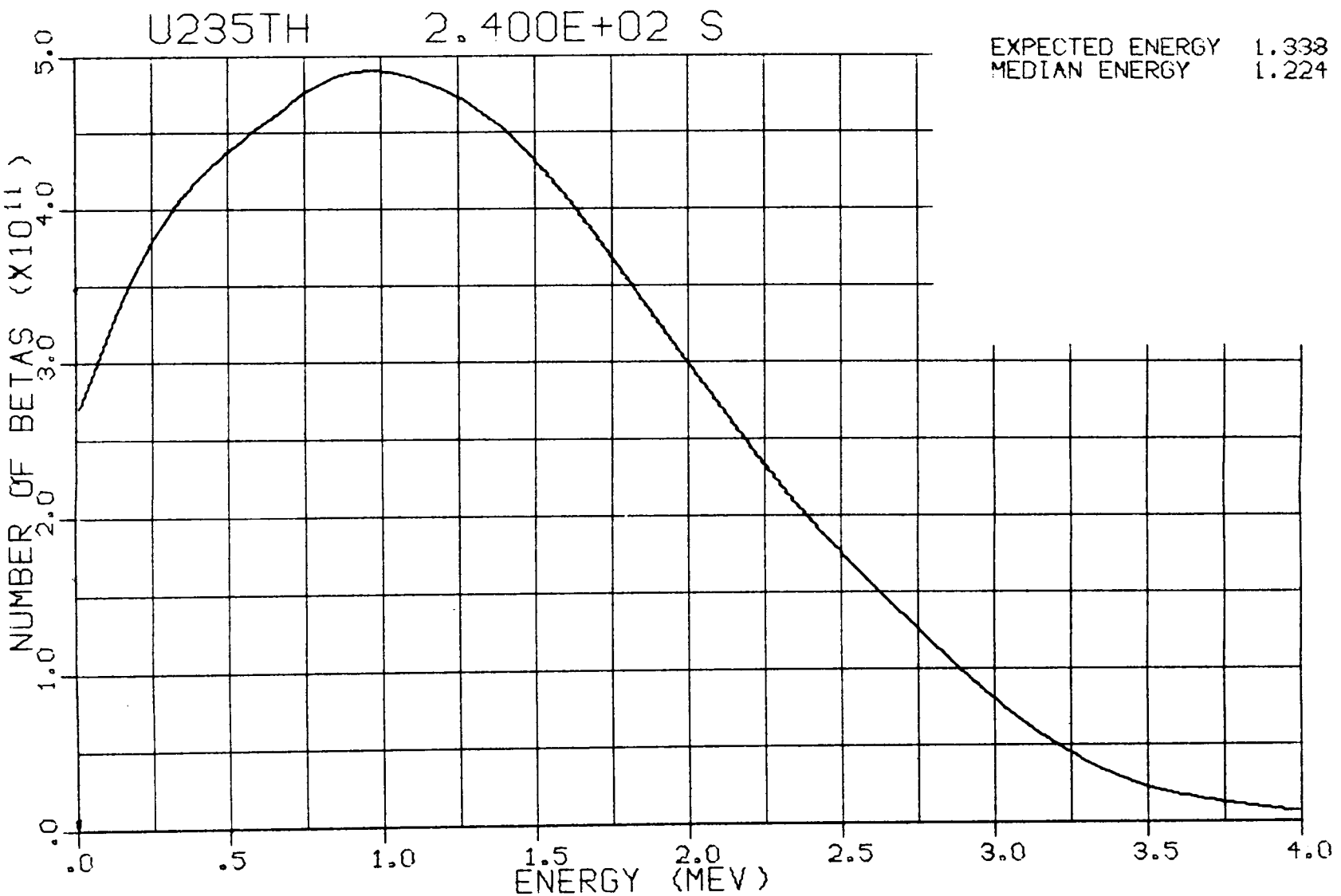

1 U235TH 1.030E+03 S
EXPECTED ENERGY 1.050
MEDIAN ENERGY .868
2 U235TH 2.030E+03 S
EXPECTED ENERGY 1.013
MEDIAN ENERGY .820
3 U235TH 4.030E+03 S
EXPECTED ENERGY .980
MEDIAN ENERGY .782
4 U235TH 7.030E+03 S
EXPECTED ENERGY .923
MEDIAN ENERGY .719
5 U235TH 1.003E+04 S
EXPECTED ENERGY .880
MEDIAN ENERGY .664
NUMBER OF BETAS (X10^11)
ENERGY (MEV)
.0
.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0

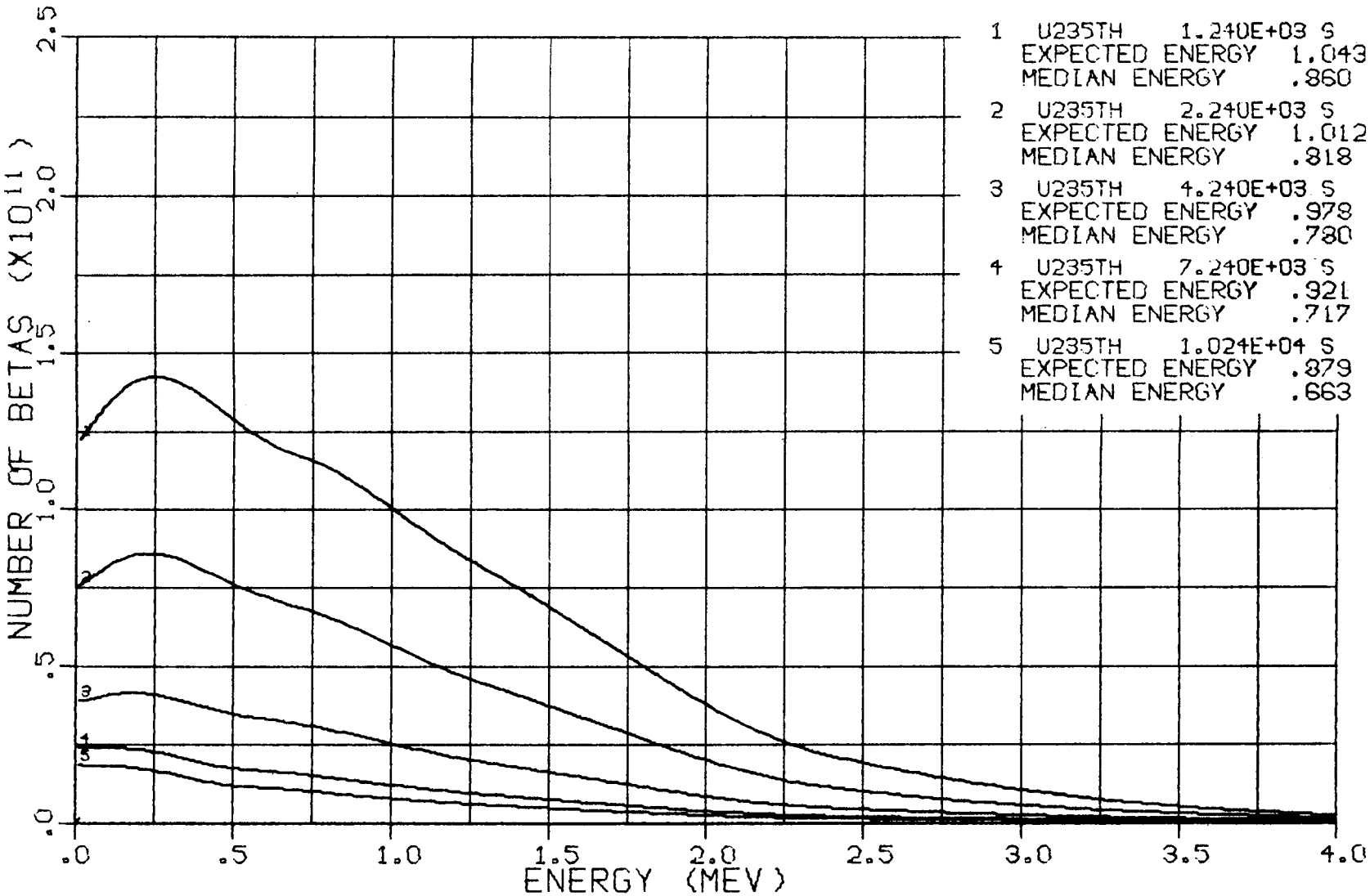

U235TH 6.000E+01 S
EXPECTED ENERGY 1.431
MEDIAN ENERGY 1.335
NUMBER OF BETAS (X10^11)
.000
1.500
3.000
4.500
6.000
7.500
.0
.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
ENERGY (MEV)

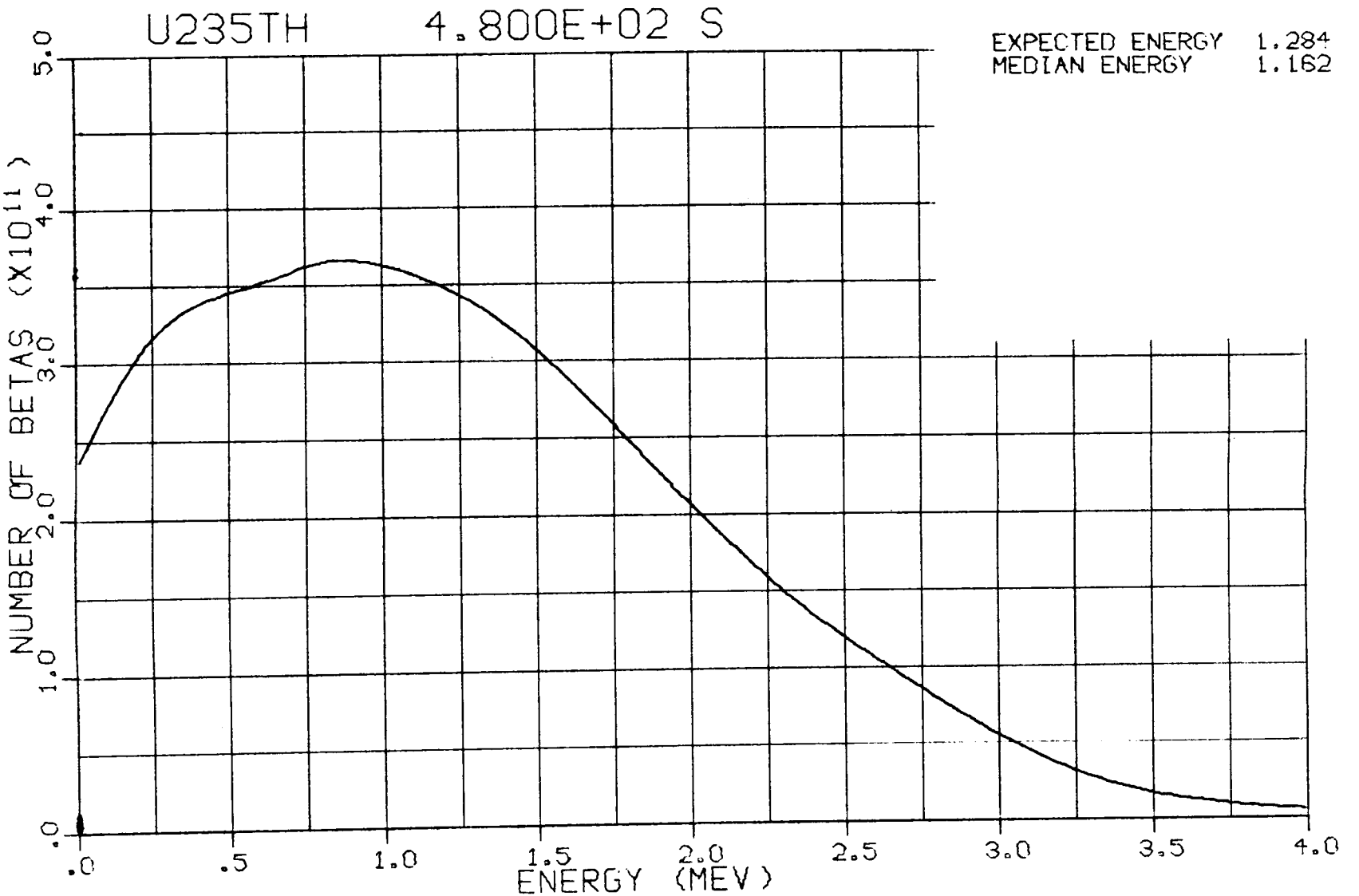

1 U235TH 1.060E+03 S
EXPECTED ENERGY 1.049
MEDIAN ENERGY .867
2 U235TH 2.060E+03 S
EXPECTED ENERGY 1.013
MEDIAN ENERGY .820
3 U235TH 4.060E+03 S
EXPECTED ENERGY .980
MEDIAN ENERGY .782
4 U235TH 7.060E+03 S
EXPECTED ENERGY .923
MEDIAN ENERGY .719
5 U235TH 1.006E+04 S
EXPECTED ENERGY .880
MEDIAN ENERGY .664
NUMBER OF BETAS (X10^11)
ENERGY (MEV)
.0
.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0

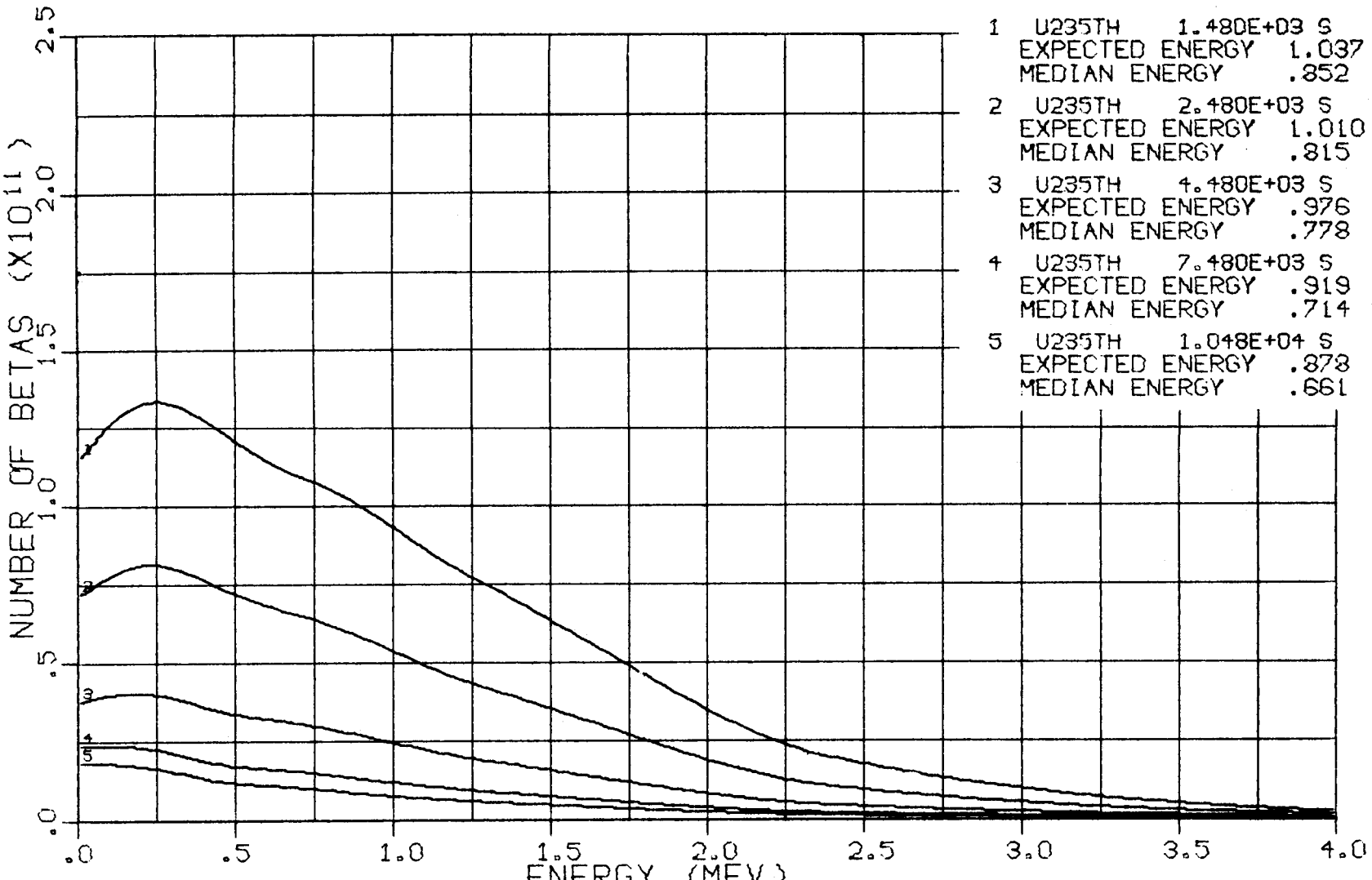

U235TH 1.200E+02 S
EXPECTED ENERGY 1.387
MEDIAN ENERGY 1.278
NUMBER OF BETAS (X10^11)
7.500
6.000
4.500
3.000
1.500
.000
.0
.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
ENERGY (MEV)

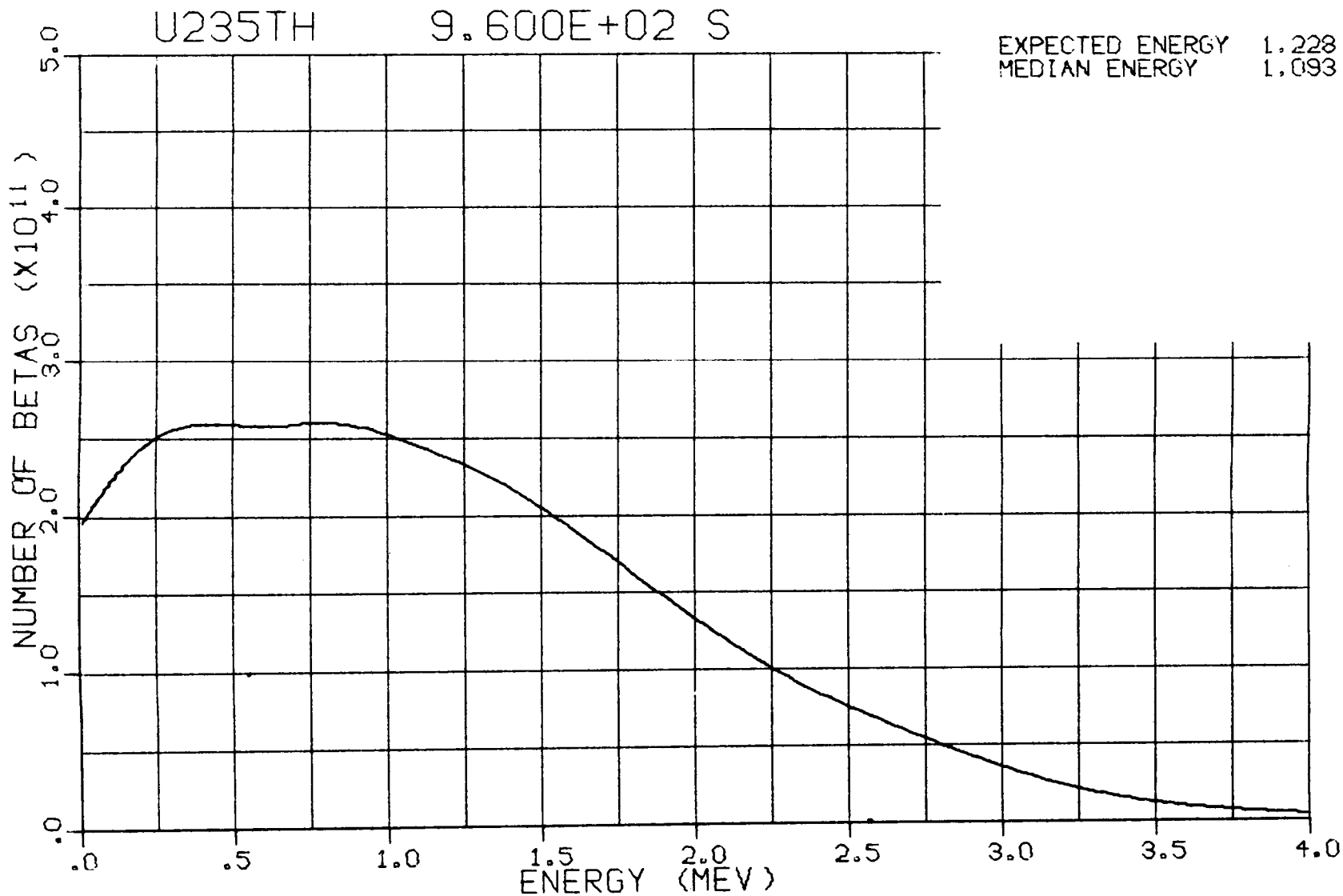

1 U235TH 1.120E+03 S
EXPECTED ENERGY 1.047
MEDIAN ENERGY .864
2 U235TH 2.120E+03 S
EXPECTED ENERGY 1.013
MEDIAN ENERGY .819
3 U235TH 4.120E+03 S
EXPECTED ENERGY .979
MEDIAN ENERGY .781
4 U235TH 7.120E+03 S
EXPECTED ENERGY .922
MEDIAN ENERGY .718
5 U235TH 1.012E+04 S
EXPECTED ENERGY .880
MEDIAN ENERGY .664
NUMBER OF BETAS (X10^11)
ENERGY (MEV)
.0
.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0

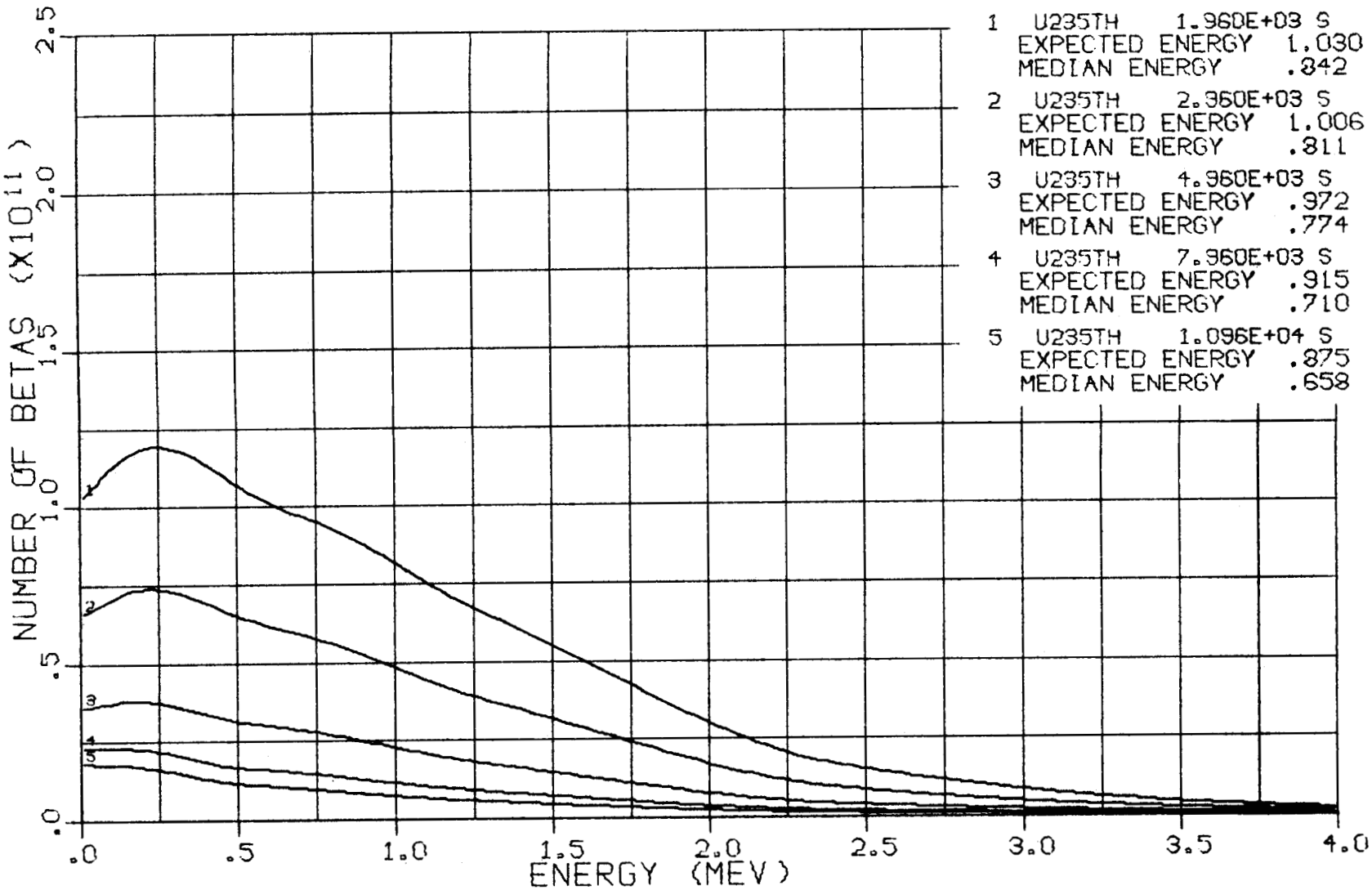

U235TH 2.400E+02 S
EXPECTED ENERGY 1.338
MEDIAN ENERGY 1.224
NUMBER OF BETAS (X10^11)
5.0
4.0
3.0
2.0
1.0
.0
.0
.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
ENERGY (MEV)

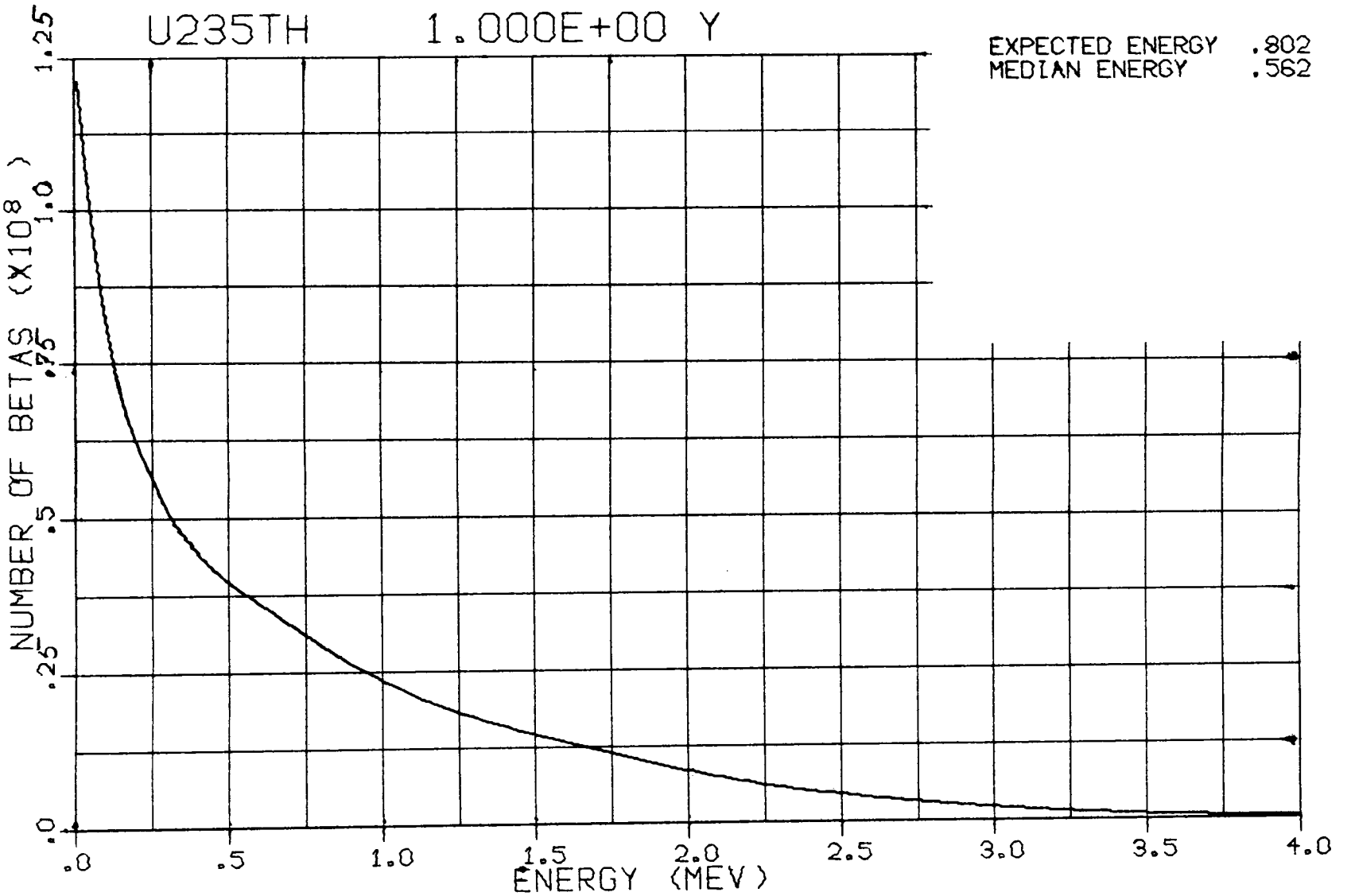

1 U235TH 1.240E+03 S
EXPECTED ENERGY 1.043
MEDIAN ENERGY .860
2 U235TH 2.240E+03 S
EXPECTED ENERGY 1.012
MEDIAN ENERGY .818
3 U235TH 4.240E+03 S
EXPECTED ENERGY .978
MEDIAN ENERGY .780
4 U235TH 7.240E+03 S
EXPECTED ENERGY .921
MEDIAN ENERGY .717
5 U235TH 1.024E+04 S
EXPECTED ENERGY .879
MEDIAN ENERGY .663
NUMBER OF BETAS (X10^11)
ENERGY (MEV)
.0
.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0

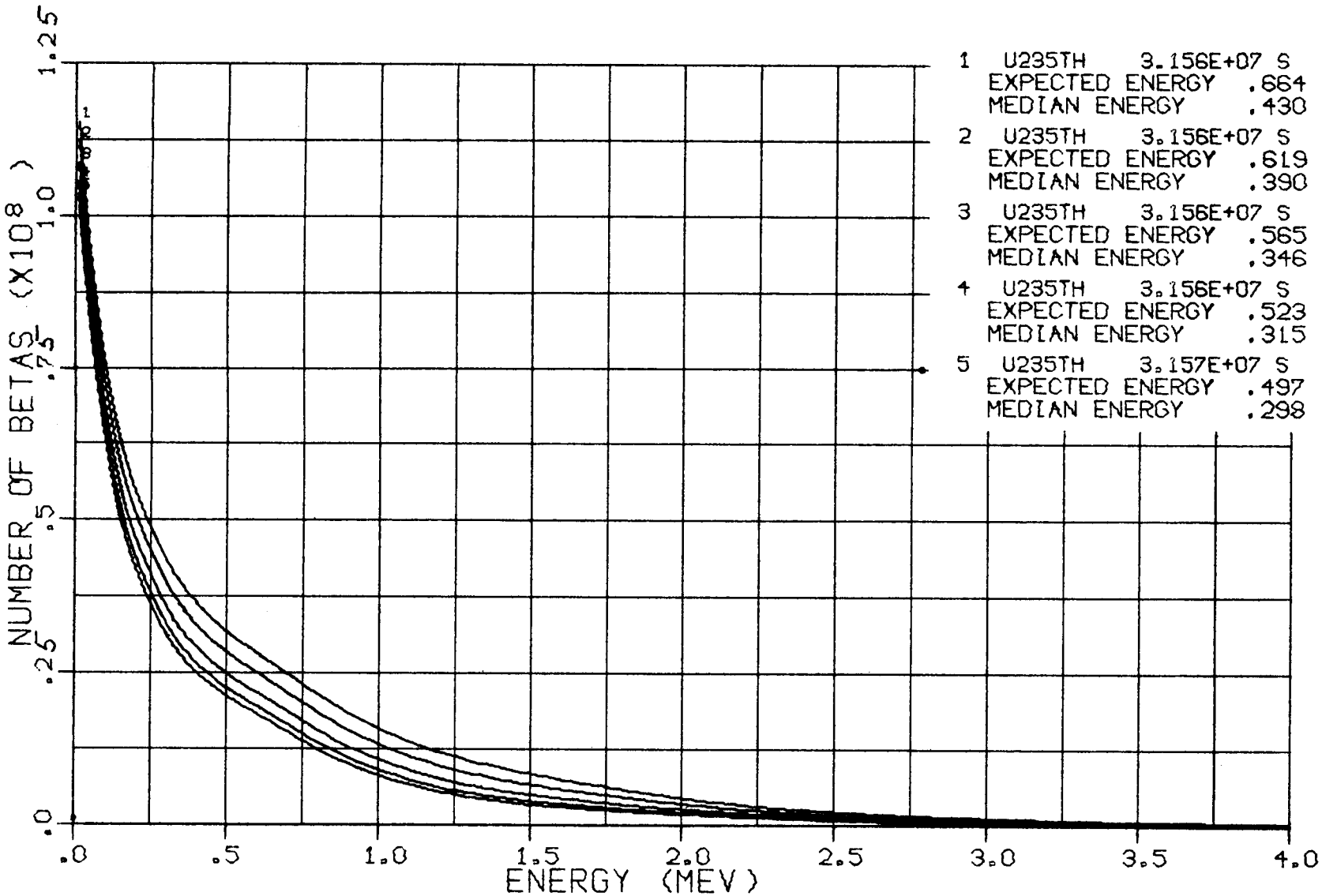

U235TH 4.800E+02 S
EXPECTED ENERGY 1.284
MEDIAN ENERGY 1.162
NUMBER OF BETAS (X10^11)
5.0
4.0
3.0
2.0
1.0
.0
.0
.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
ENERGY (MEV)

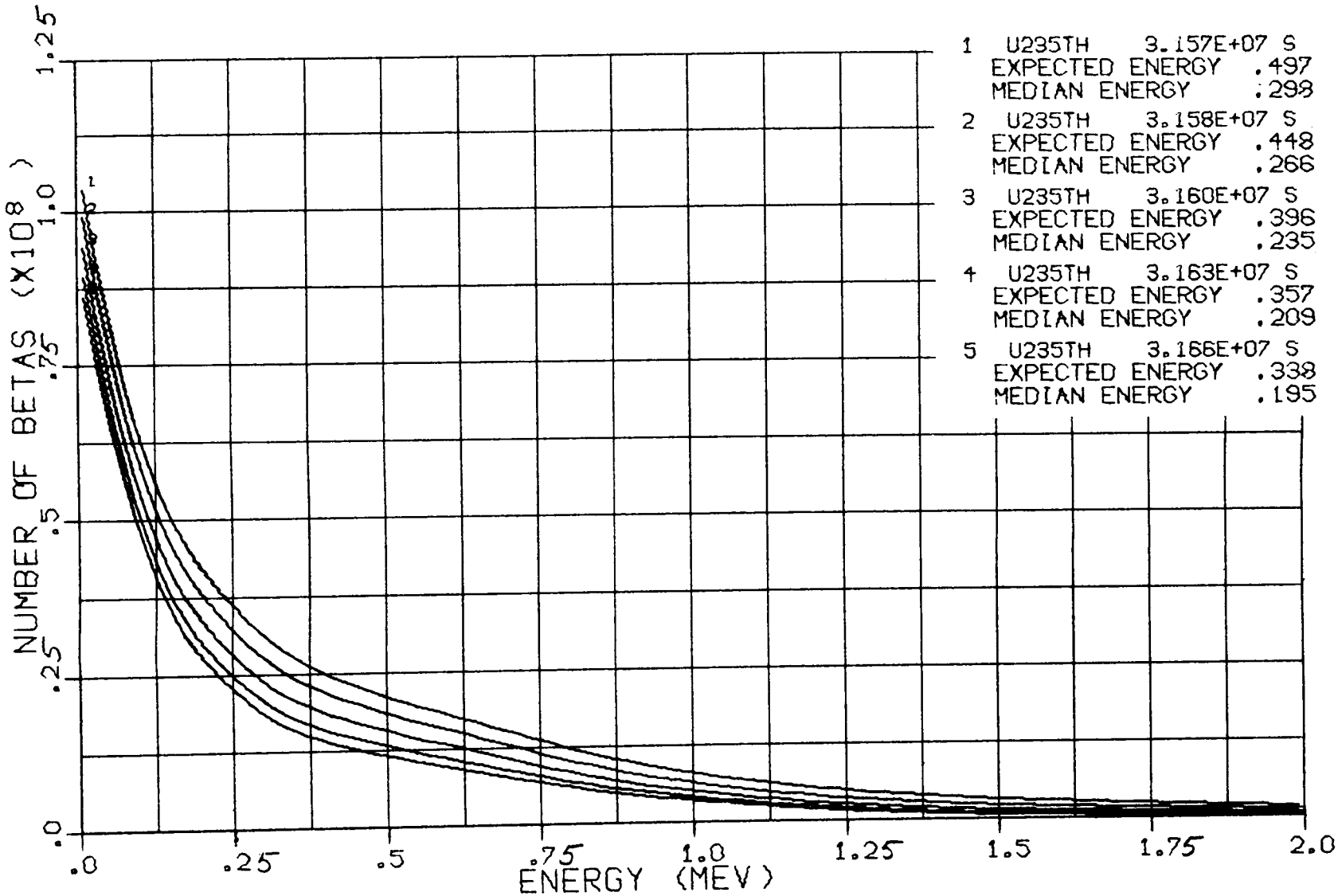

1 U235TH 1.480E+03 S
EXPECTED ENERGY 1.037
MEDIAN ENERGY .852
2 U235TH 2.480E+03 S
EXPECTED ENERGY 1.010
MEDIAN ENERGY .815
3 U235TH 4.480E+03 S
EXPECTED ENERGY .976
MEDIAN ENERGY .778
4 U235TH 7.480E+03 S
EXPECTED ENERGY .919
MEDIAN ENERGY .714
5 U235TH 1.048E+04 S
EXPECTED ENERGY .878
MEDIAN ENERGY .661
NUMBER OF BETAS (X10 11)
ENERGY (MEV)
.0
.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0

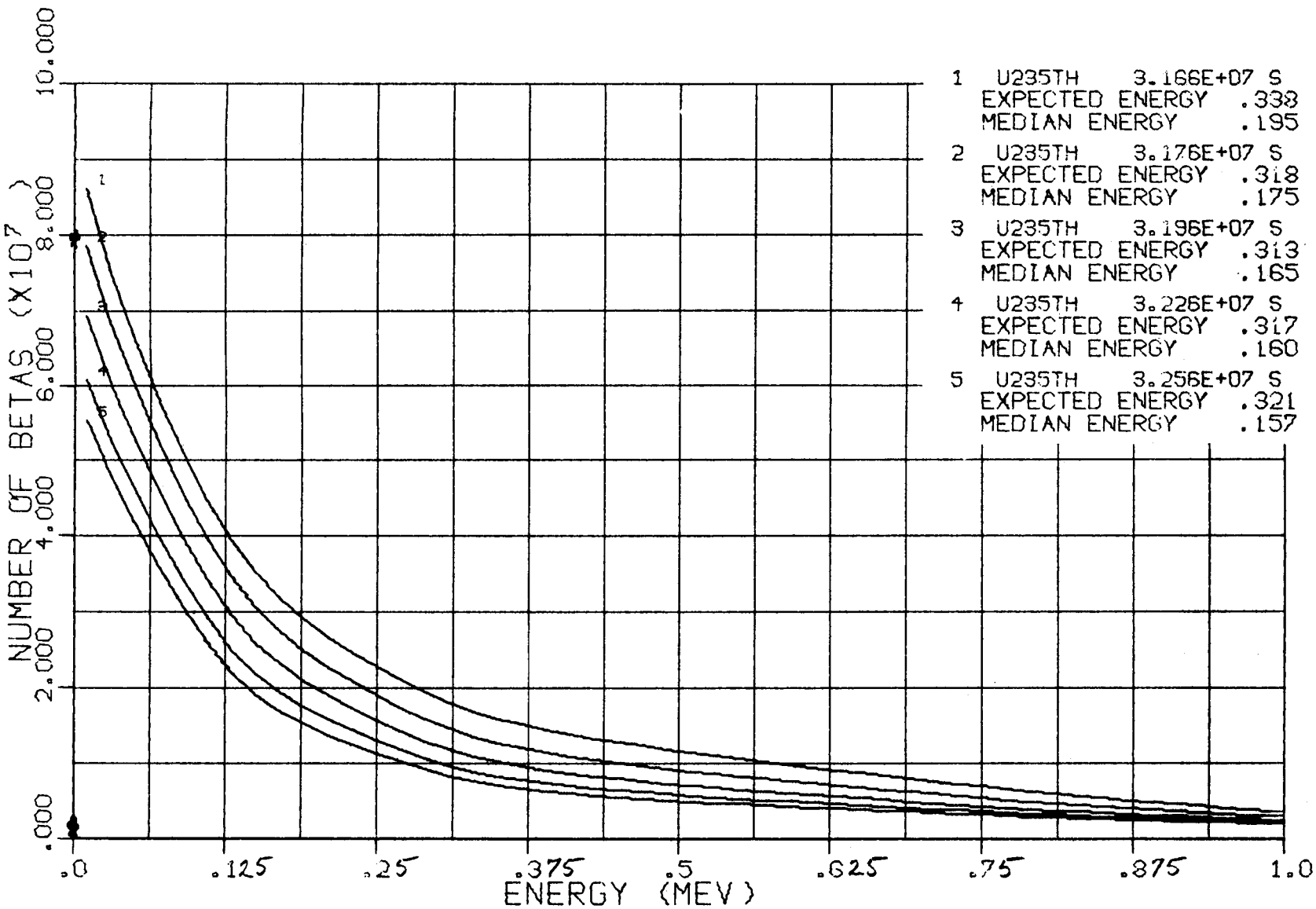

U235TH 9.600E+02 S
EXPECTED ENERGY 1.228
MEDIAN ENERGY 1.093
NUMBER OF BETAS (X10^11)
5.0
4.0
3.0
2.0
1.0
.0
.0
.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
ENERGY (MEV)

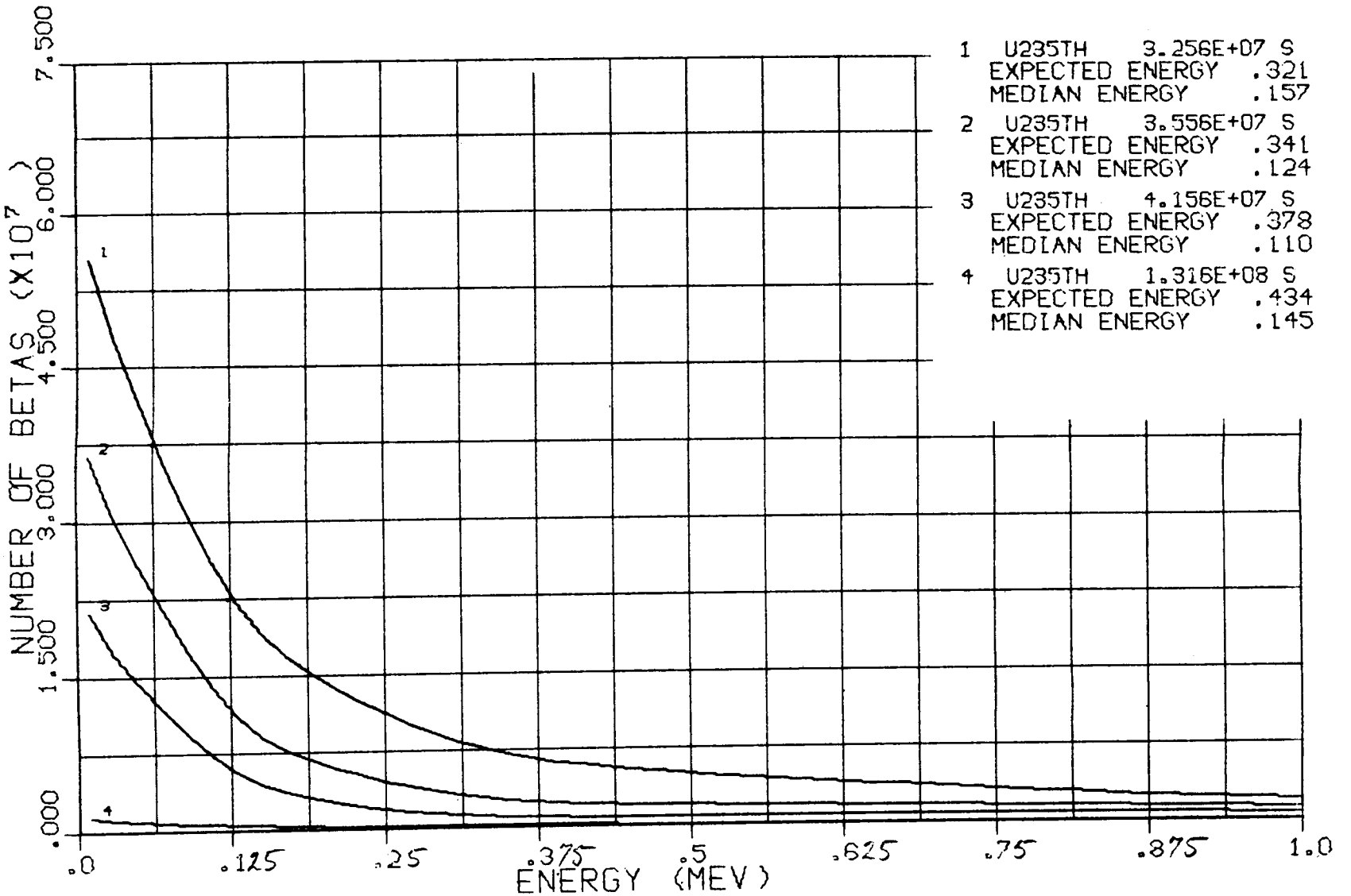

1 U235TH 1.960E+03 S
EXPECTED ENERGY 1.030
MEDIAN ENERGY .842
2 U235TH 2.960E+03 S
EXPECTED ENERGY 1.006
MEDIAN ENERGY .811
3 U235TH 4.960E+03 S
EXPECTED ENERGY .972
MEDIAN ENERGY .774
4 U235TH 7.960E+03 S
EXPECTED ENERGY .915
MEDIAN ENERGY .710
5 U235TH 1.096E+04 S
EXPECTED ENERGY .875
MEDIAN ENERGY .658
NUMBER OF BETAS (X10^11)
ENERGY (MEV)
.0
.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0

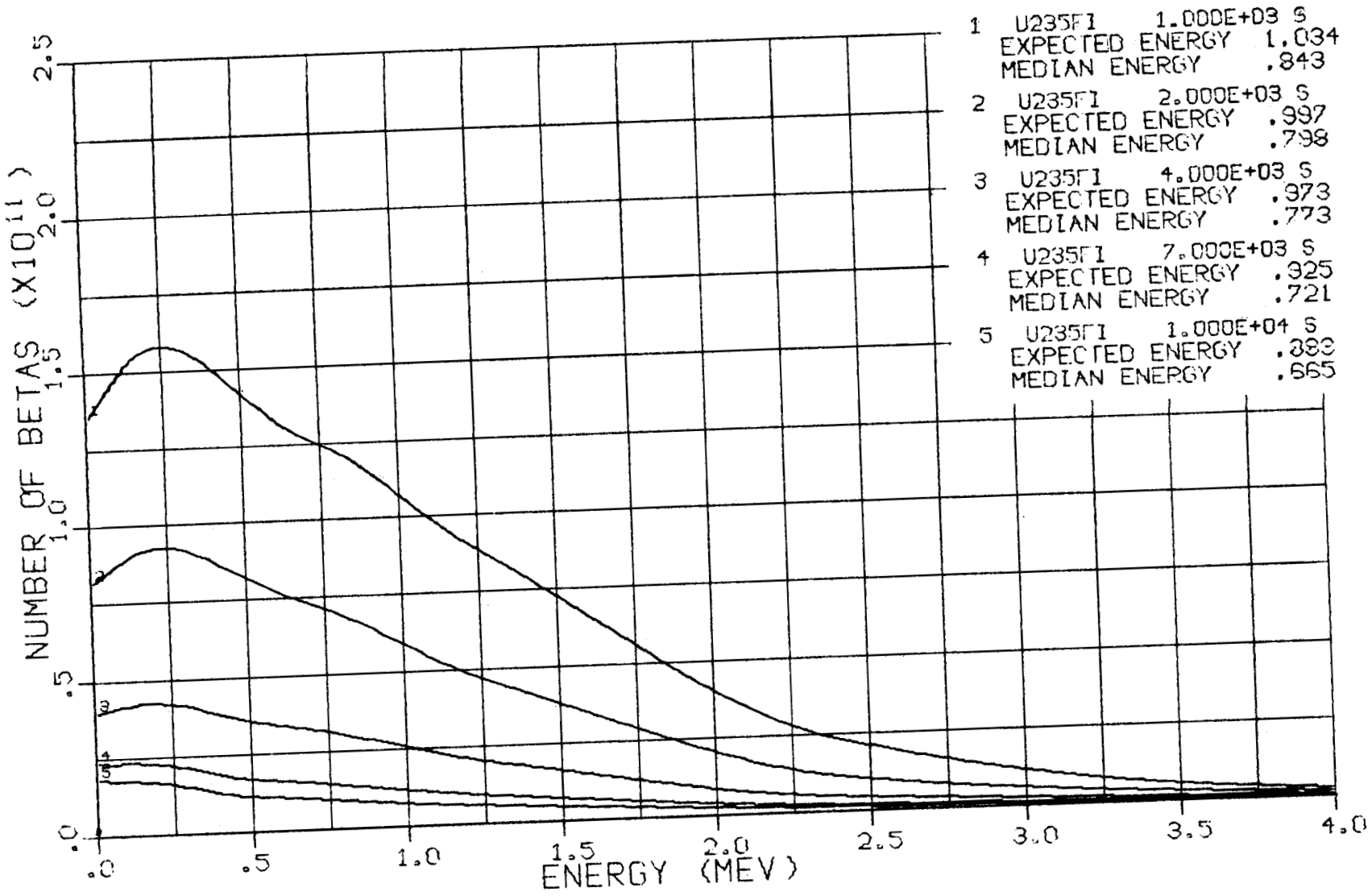

U235TH 1.000E+00 Y
EXPECTED ENERGY .802
MEDIAN ENERGY .562
NUMBER OF BETAS (X10^8)
1.25
1.0
.75
.5
.25
.0
.0
.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
ENERGY (MEV)

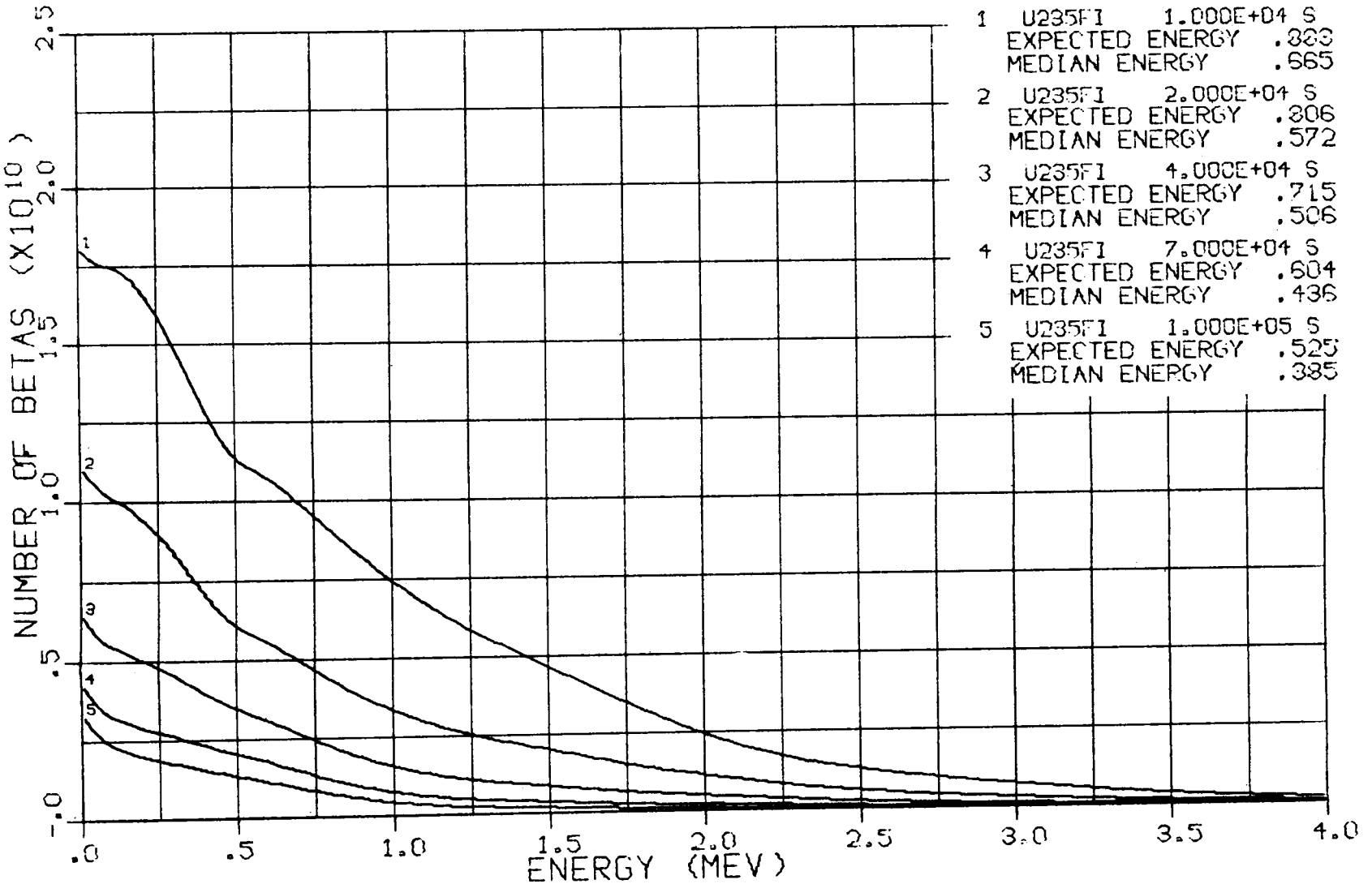

1 U235TH 3.156E+07 S
EXPECTED ENERGY .664
MEDIAN ENERGY .430
2 U235TH 3.156E+07 S
EXPECTED ENERGY .619
MEDIAN ENERGY .390
3 U235TH 3.156E+07 S
EXPECTED ENERGY .565
MEDIAN ENERGY .346
4 U235TH 3.156E+07 S
EXPECTED ENERGY .523
MEDIAN ENERGY .315
5 U235TH 3.157E+07 S
EXPECTED ENERGY .497
MEDIAN ENERGY .298
NUMBER OF BETAS (X10^8)
ENERGY (MEV)
.0
.25
.5
.75
1.0
1.25
.0
.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0

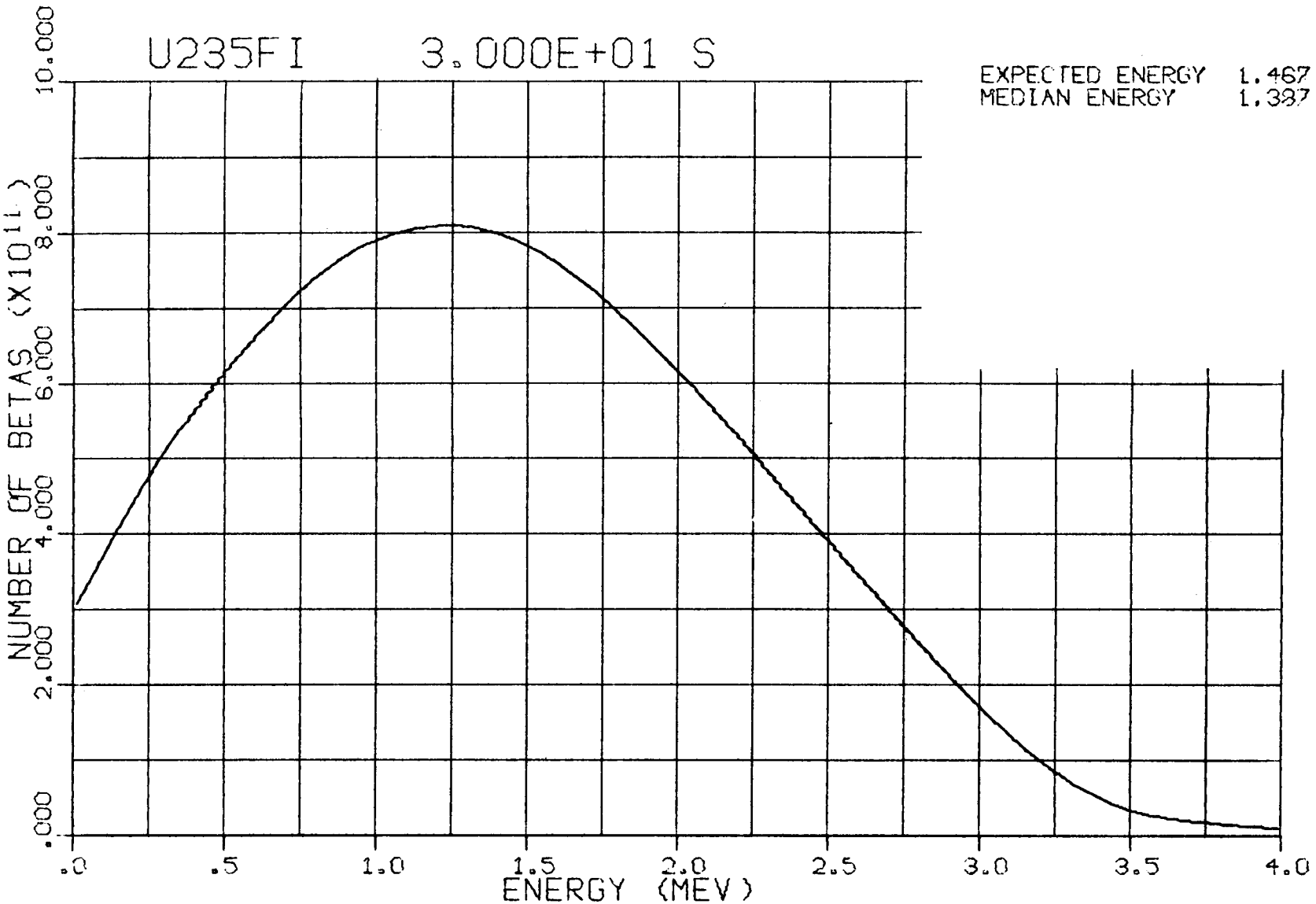

1 U235TH 3.157E+07 S
EXPECTED ENERGY .497
MEDIAN ENERGY .298
2 U235TH 3.158E+07 S
EXPECTED ENERGY .448
MEDIAN ENERGY .266
3 U235TH 3.160E+07 S
EXPECTED ENERGY .396
MEDIAN ENERGY .235
4 U235TH 3.163E+07 S
EXPECTED ENERGY .357
MEDIAN ENERGY .209
5 U235TH 3.166E+07 S
EXPECTED ENERGY .338
MEDIAN ENERGY .195
NUMBER OF BETAS (X10^8)
ENERGY (MEV)
.0
.25
.5
.75
1.0
1.25
1.5
1.75
2.0

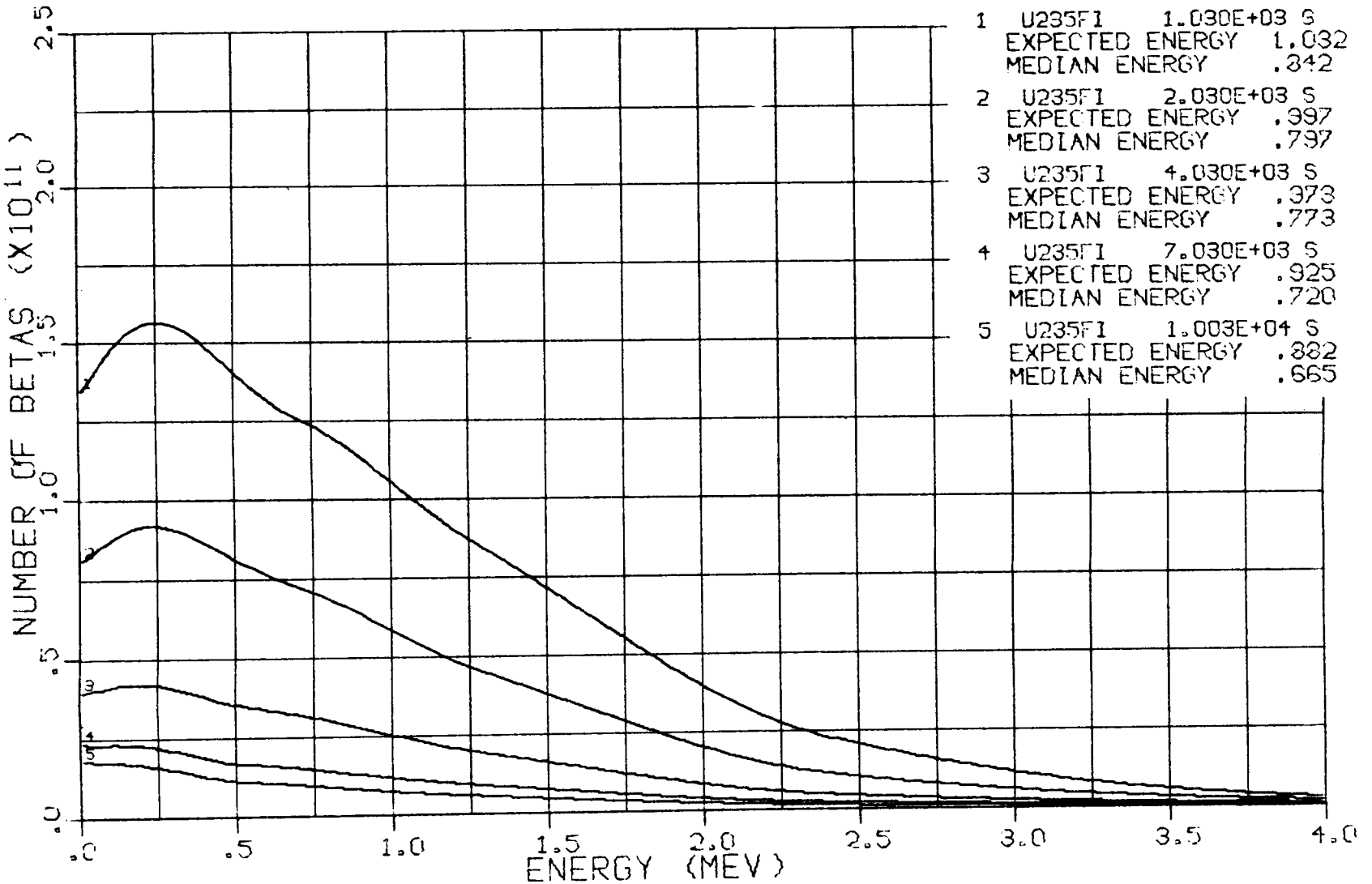

1 U235TH 3.166E+07 S
EXPECTED ENERGY .338
MEDIAN ENERGY .195
2 U235TH 3.176E+07 S
EXPECTED ENERGY .318
MEDIAN ENERGY .175
3 U235TH 3.196E+07 S
EXPECTED ENERGY .313
MEDIAN ENERGY .165
4 U235TH 3.226E+07 S
EXPECTED ENERGY .317
MEDIAN ENERGY .160
5 U235TH 3.256E+07 S
EXPECTED ENERGY .321
MEDIAN ENERGY .157
NUMBER OF BETAS (X10^7)
10.000
8.000
6.000
4.000
2.000
.000
.0
.125
.25
.375
.5
.625
.75
.875
1.0
ENERGY (MEV)

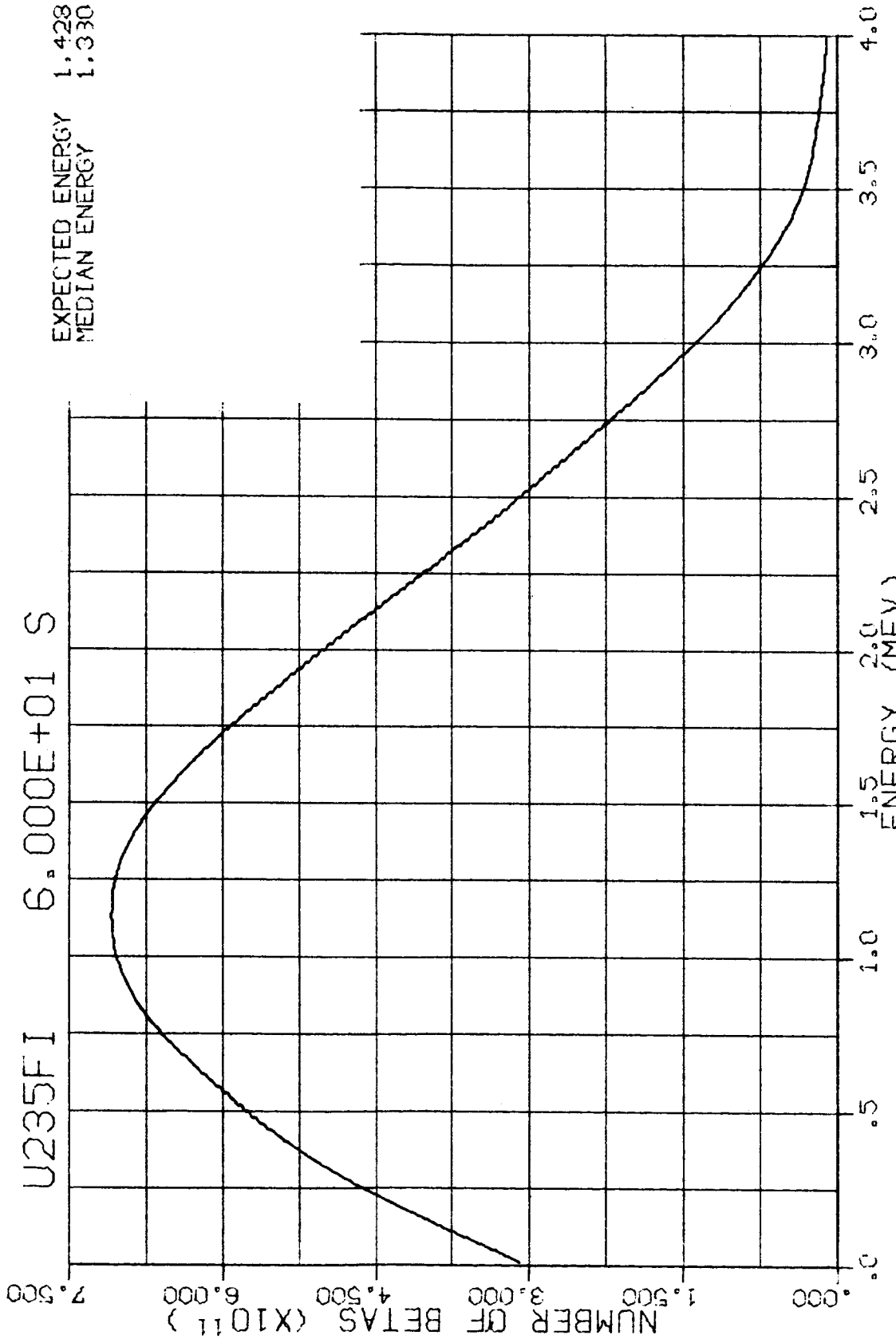

1 U235TH 3.256E+07 S
EXPECTED ENERGY .321
MEDIAN ENERGY .157
2 U235TH 3.556E+07 S
EXPECTED ENERGY .341
MEDIAN ENERGY .124
3 U235TH 4.156E+07 S
EXPECTED ENERGY .378
MEDIAN ENERGY .110
4 U235TH 1.316E+08 S
EXPECTED ENERGY .434
MEDIAN ENERGY .145
NUMBER OF BETAS (X10^7)
7.500
6.000
4.500
3.000
1.500
.000
.0
.125
.25
.375
.5
.625
.75
.875
1.0
ENERGY (MEV)

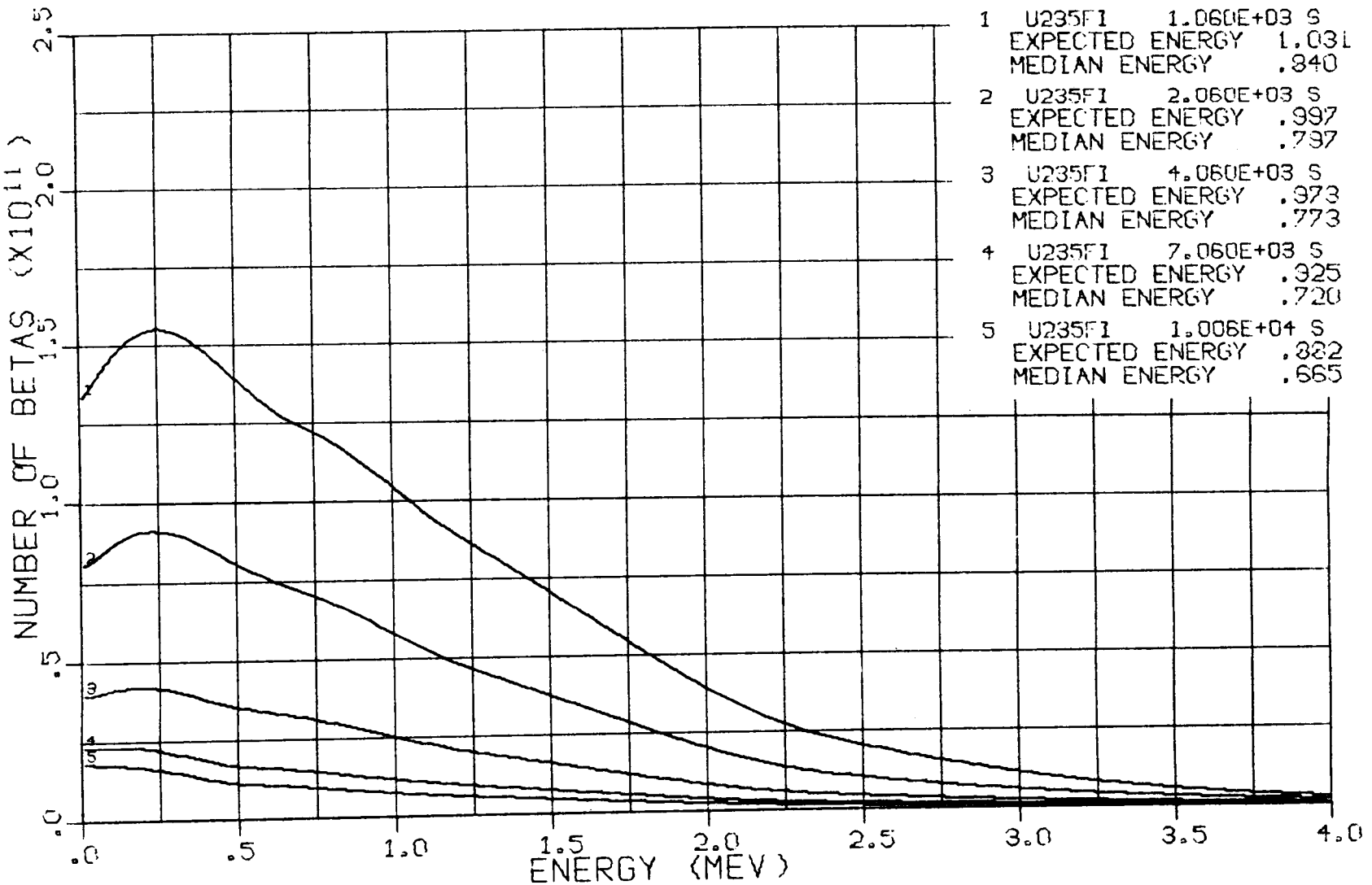

1 U235FI 1.000E+03 S
EXPECTED ENERGY 1.034
MEDIAN ENERGY .843
2 U235FI 2.000E+03 S
EXPECTED ENERGY .997
MEDIAN ENERGY .798
3 U235FI 4.000E+03 S
EXPECTED ENERGY .973
MEDIAN ENERGY .773
4 U235FI 7.000E+03 S
EXPECTED ENERGY .925
MEDIAN ENERGY .721
5 U235FI 1.000E+04 S
EXPECTED ENERGY .883
MEDIAN ENERGY .665
NUMBER OF BETAS (X10^11)
ENERGY (MEV)
0.0
.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0

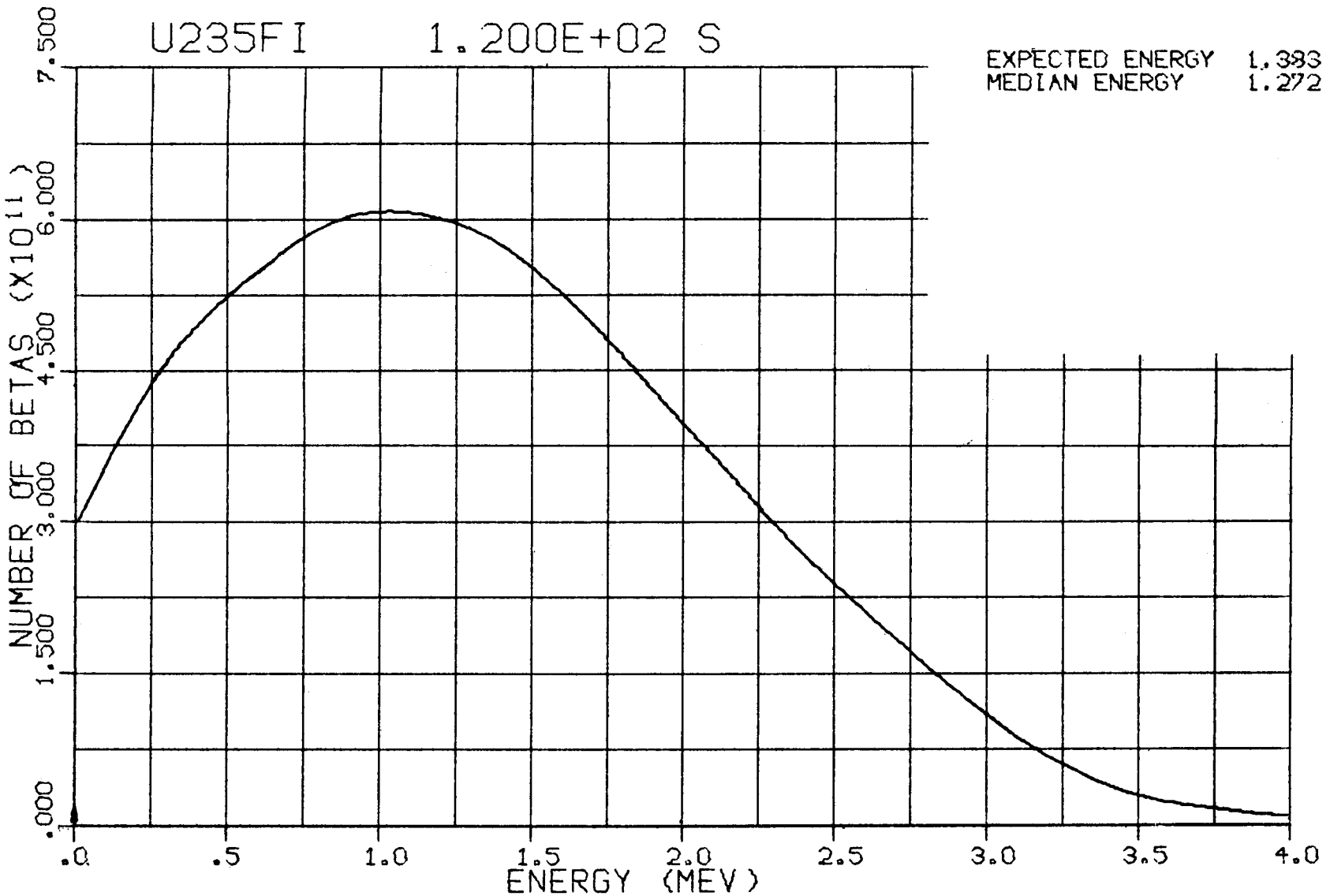

1 U235FI 1.000E+04 S
EXPECTED ENERGY .883
MEDIAN ENERGY .665
2 U235FI 2.000E+04 S
EXPECTED ENERGY .806
MEDIAN ENERGY .572
3 U235FI 4.000E+04 S
EXPECTED ENERGY .715
MEDIAN ENERGY .506
4 U235FI 7.000E+04 S
EXPECTED ENERGY .604
MEDIAN ENERGY .436
5 U235FI 1.000E+05 S
EXPECTED ENERGY .525
MEDIAN ENERGY .385
NUMBER OF BETAS (X10^10)
ENERGY (MEV)
-.0
.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0

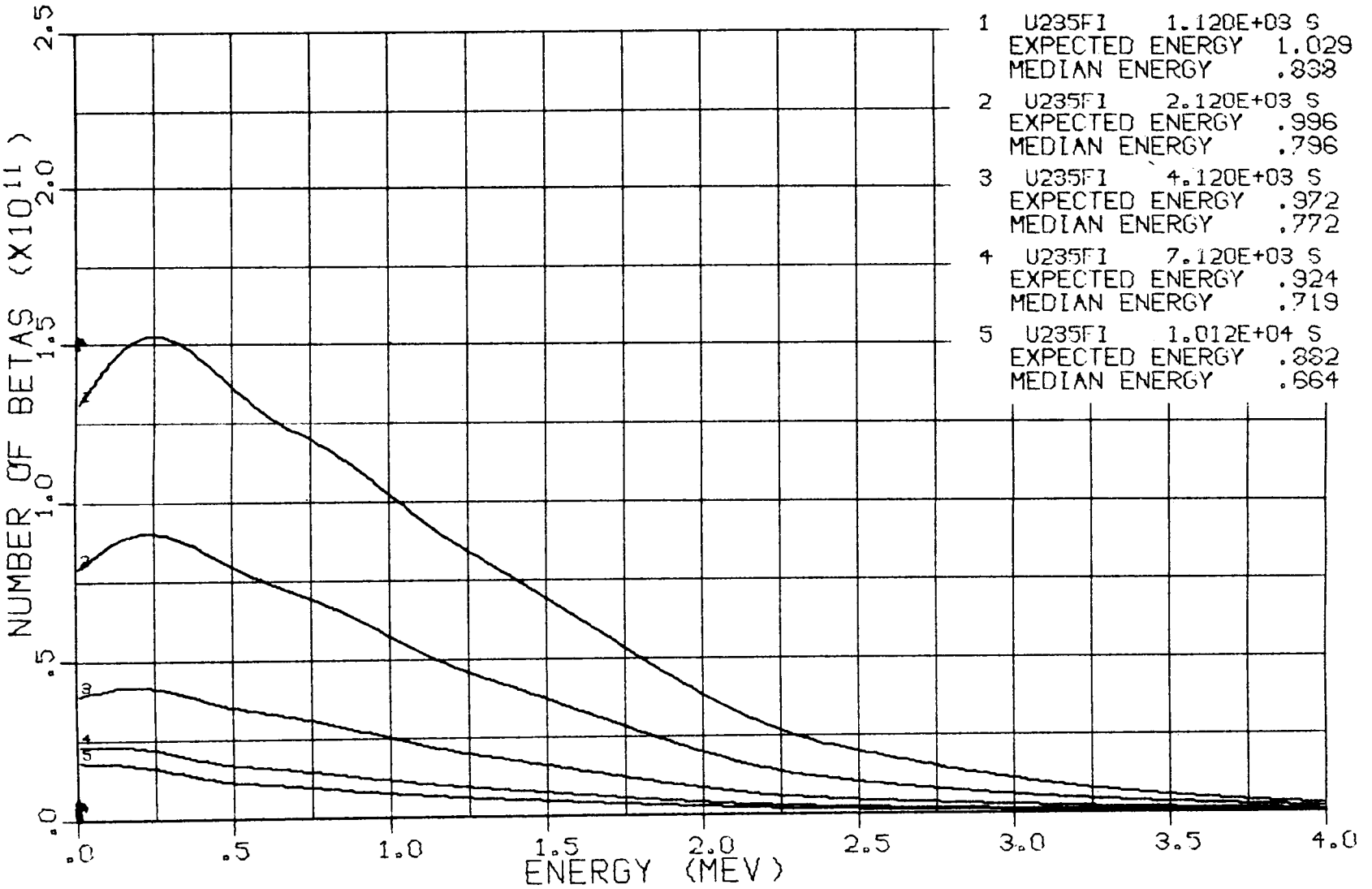

U235FI 3.000E+01 S
EXPECTED ENERGY 1.467
MEDIAN ENERGY 1.387
NUMBER OF BETAS (X10^11)
10.000
8.000
6.000
4.000
2.000
.000
.0
.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
ENERGY (MEV)

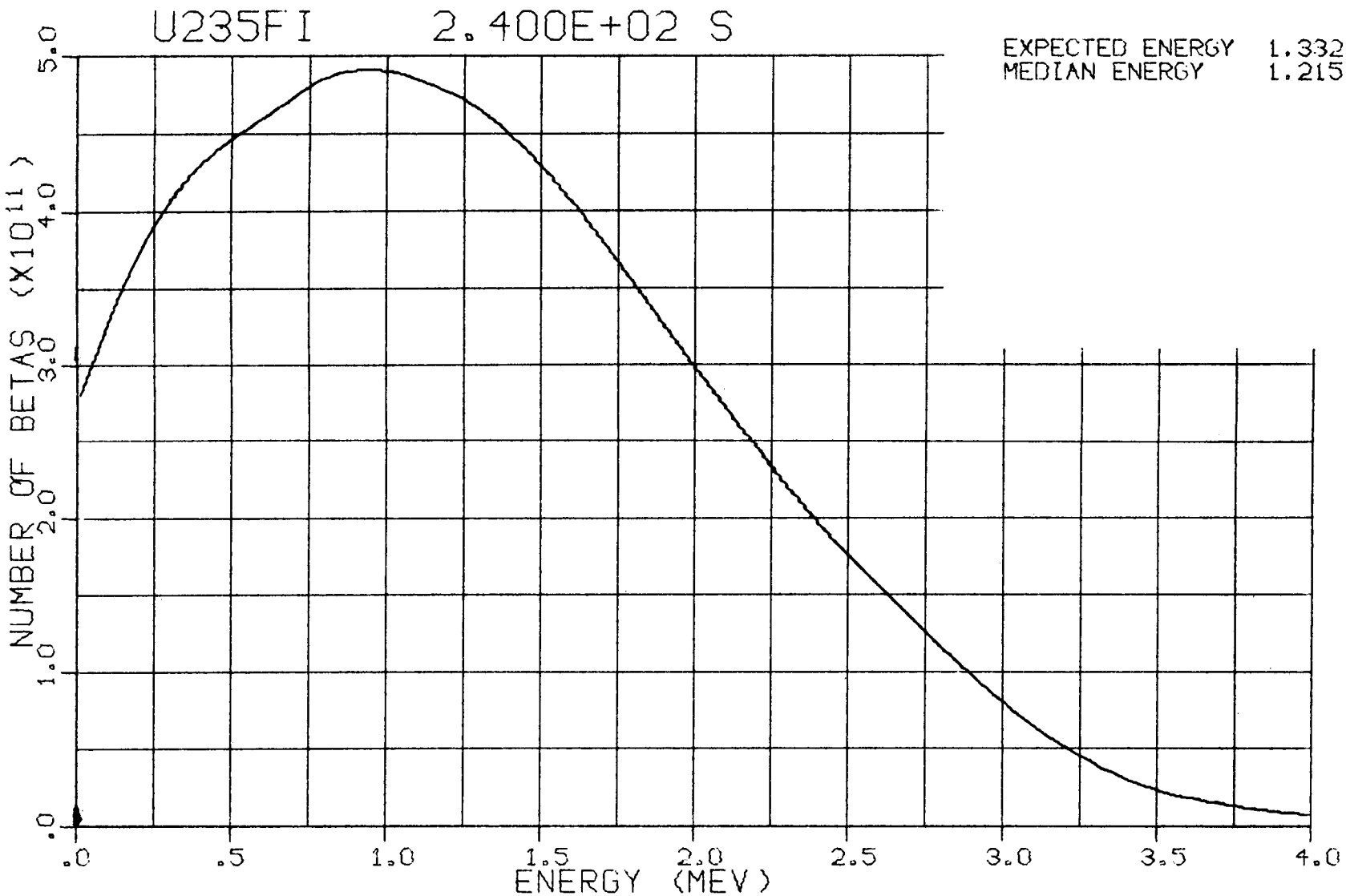

1 U235FI 1.030E+03 S
EXPECTED ENERGY 1.032
MEDIAN ENERGY .842
2 U235FI 2.030E+03 S
EXPECTED ENERGY .997
MEDIAN ENERGY .797
3 U235FI 4.030E+03 S
EXPECTED ENERGY .973
MEDIAN ENERGY .773
4 U235FI 7.030E+03 S
EXPECTED ENERGY .925
MEDIAN ENERGY .720
5 U235FI 1.003E+04 S
EXPECTED ENERGY .882
MEDIAN ENERGY .665
NUMBER OF BETAS (X10^11)
ENERGY (MEV)
.0
.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0

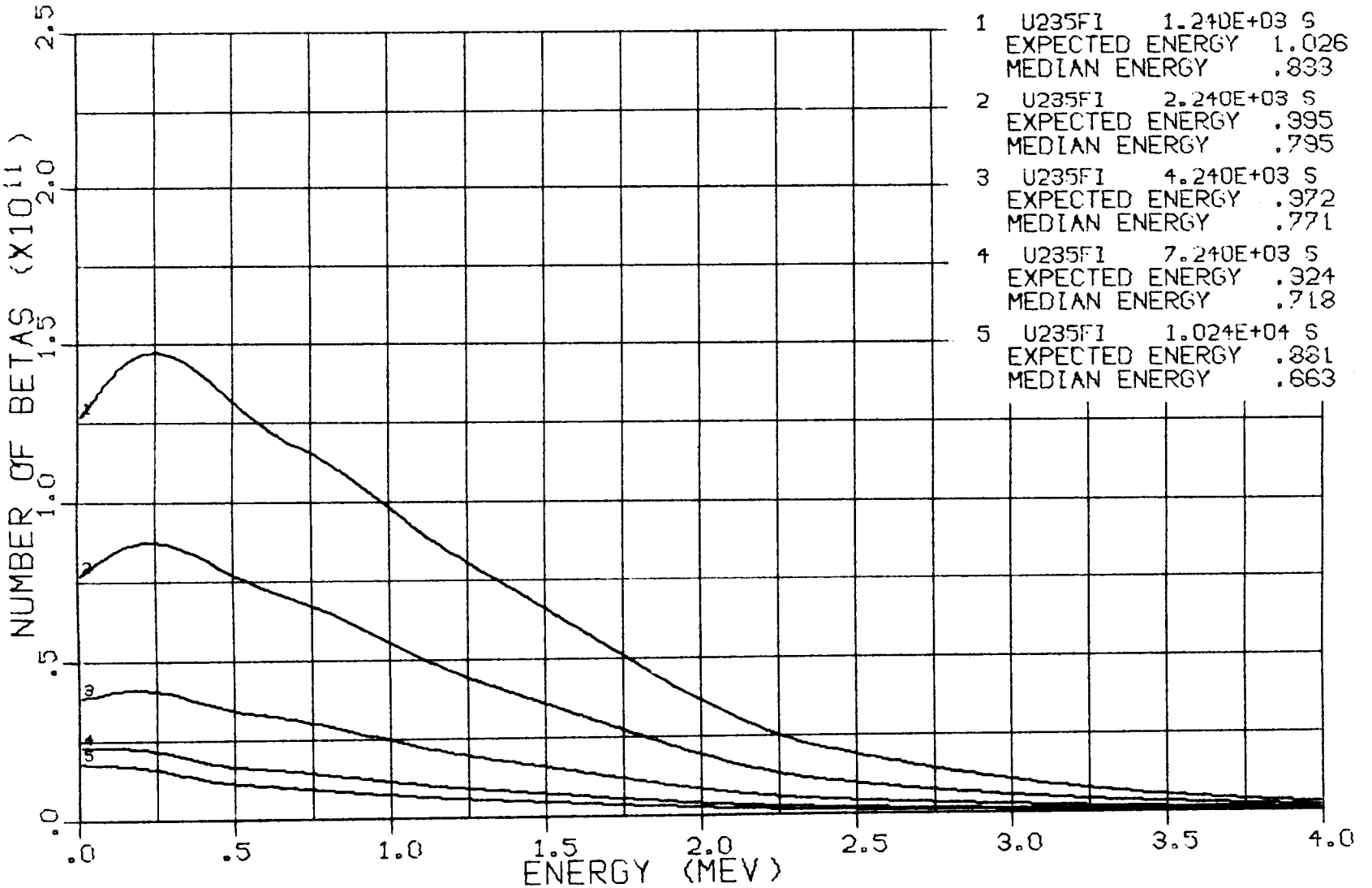

U235FI 6.000E+01 S
EXPECTED ENERGY 1.428
MEDIAN ENERGY 1.330
NUMBER OF BETAS (X10^11)
ENERGY (MEV)
.000
1.500
3.000
4.500
6.000
7.500
.0
.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0

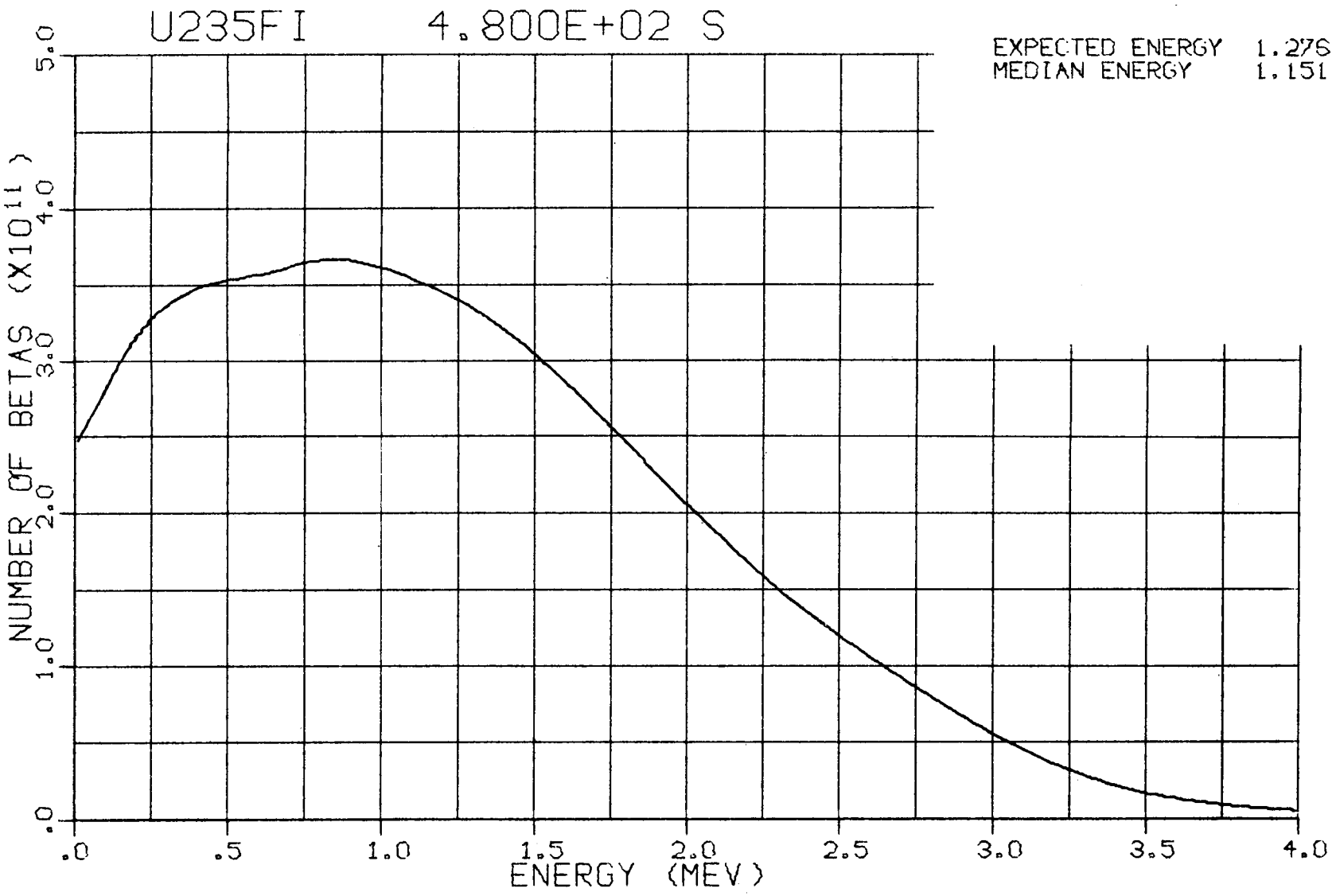

1 U235FI 1.060E+03 S
EXPECTED ENERGY 1.031
MEDIAN ENERGY .840
2 U235FI 2.060E+03 S
EXPECTED ENERGY .997
MEDIAN ENERGY .797
3 U235FI 4.060E+03 S
EXPECTED ENERGY .973
MEDIAN ENERGY .773
4 U235FI 7.060E+03 S
EXPECTED ENERGY .925
MEDIAN ENERGY .720
5 U235FI 1.006E+04 S
EXPECTED ENERGY .882
MEDIAN ENERGY .665
NUMBER OF BETAS (X10^11)
ENERGY (MEV)
.0
.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0

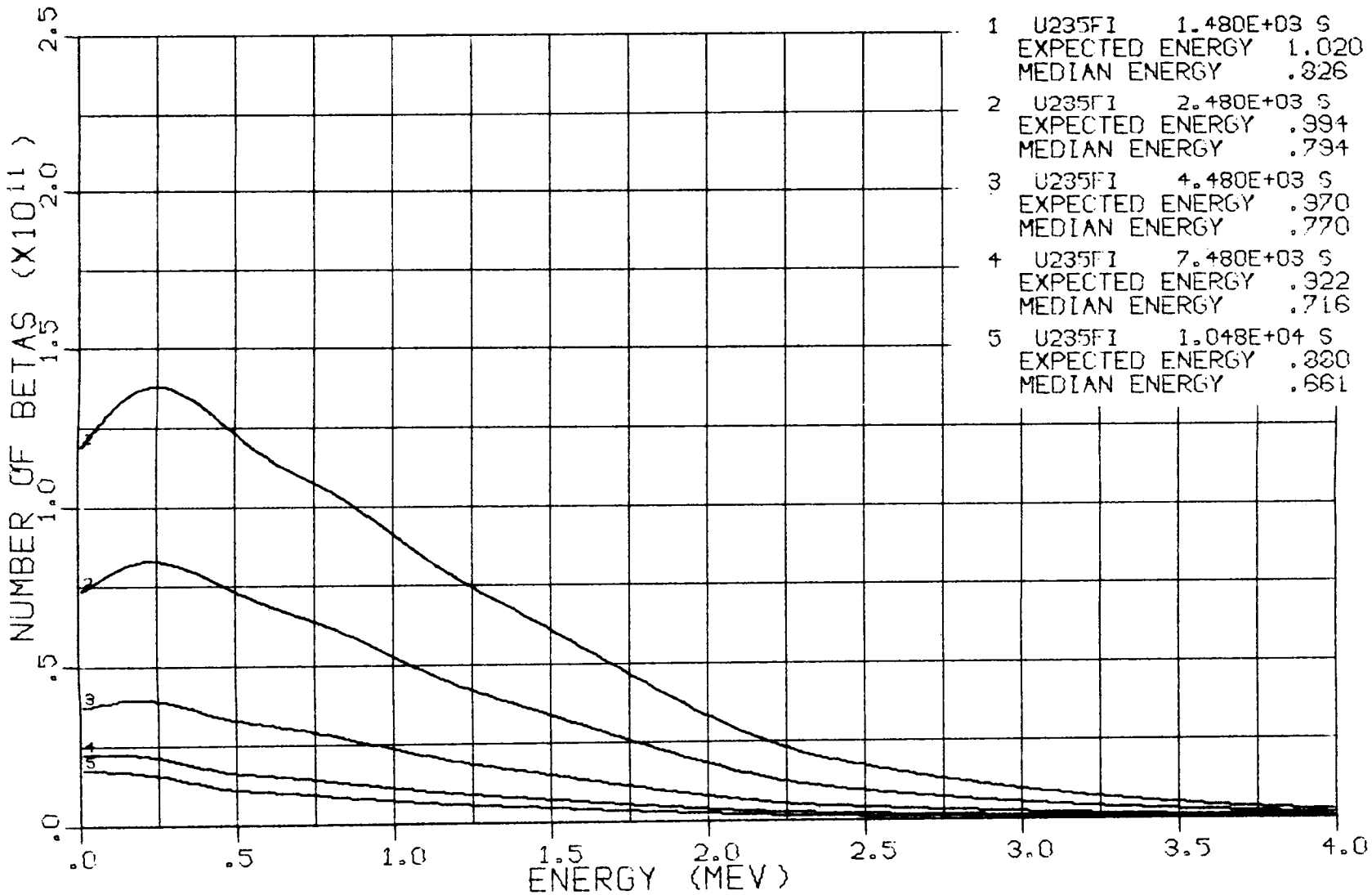

U235FI 1.200E+02 S
EXPECTED ENERGY 1.383
MEDIAN ENERGY 1.272
NUMBER OF BETAS (X10^11)
7.500
6.000
4.500
3.000
1.500
.000
.0
.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
ENERGY (MEV)

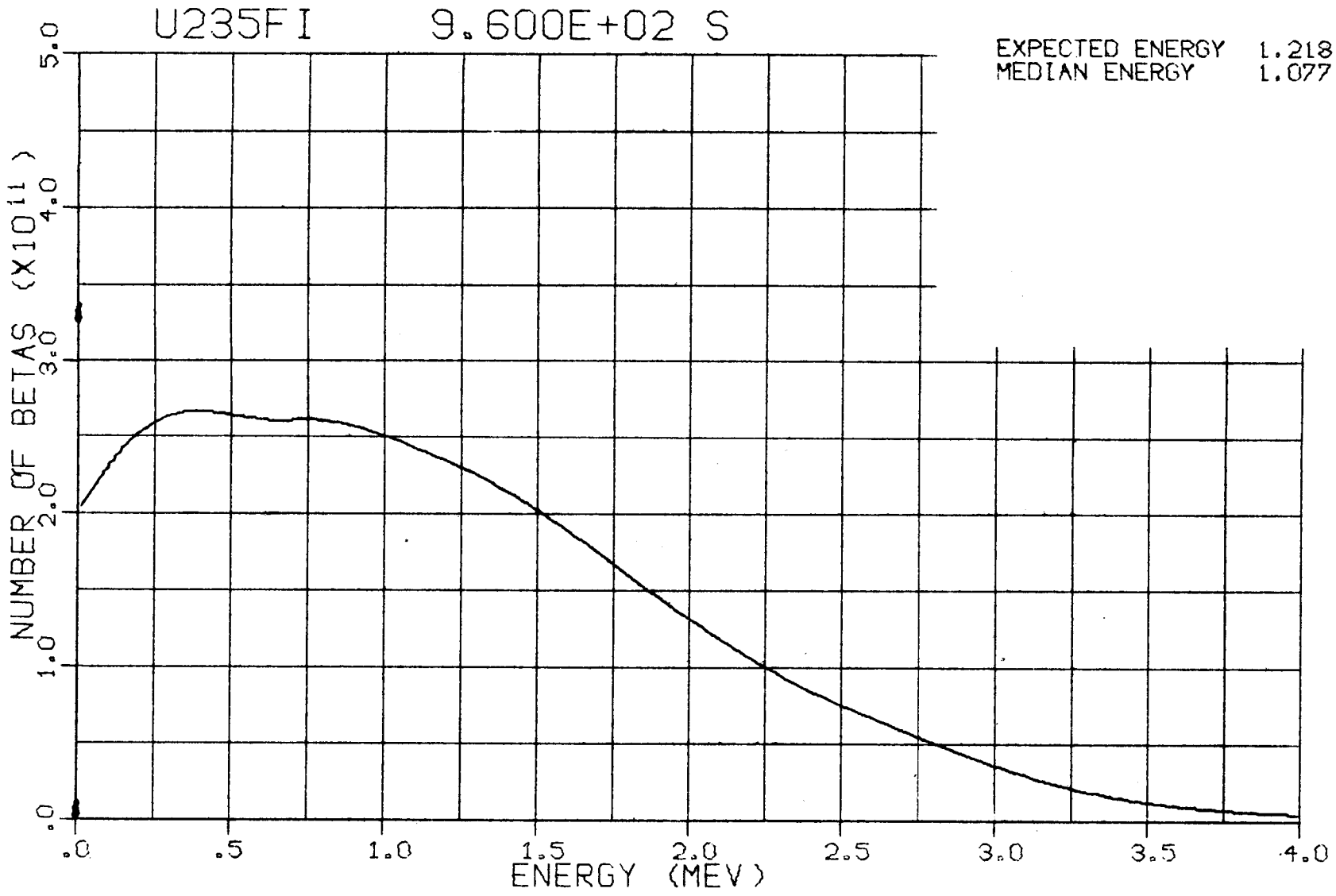

1 U235FI 1.120E+03 S
EXPECTED ENERGY 1.029
MEDIAN ENERGY .838
2 U235FI 2.120E+03 S
EXPECTED ENERGY .996
MEDIAN ENERGY .796
3 U235FI 4.120E+03 S
EXPECTED ENERGY .972
MEDIAN ENERGY .772
4 U235FI 7.120E+03 S
EXPECTED ENERGY .924
MEDIAN ENERGY .719
5 U235FI 1.012E+04 S
EXPECTED ENERGY .882
MEDIAN ENERGY .664
NUMBER OF BETAS (X10^11)
ENERGY (MEV)
.0
.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0

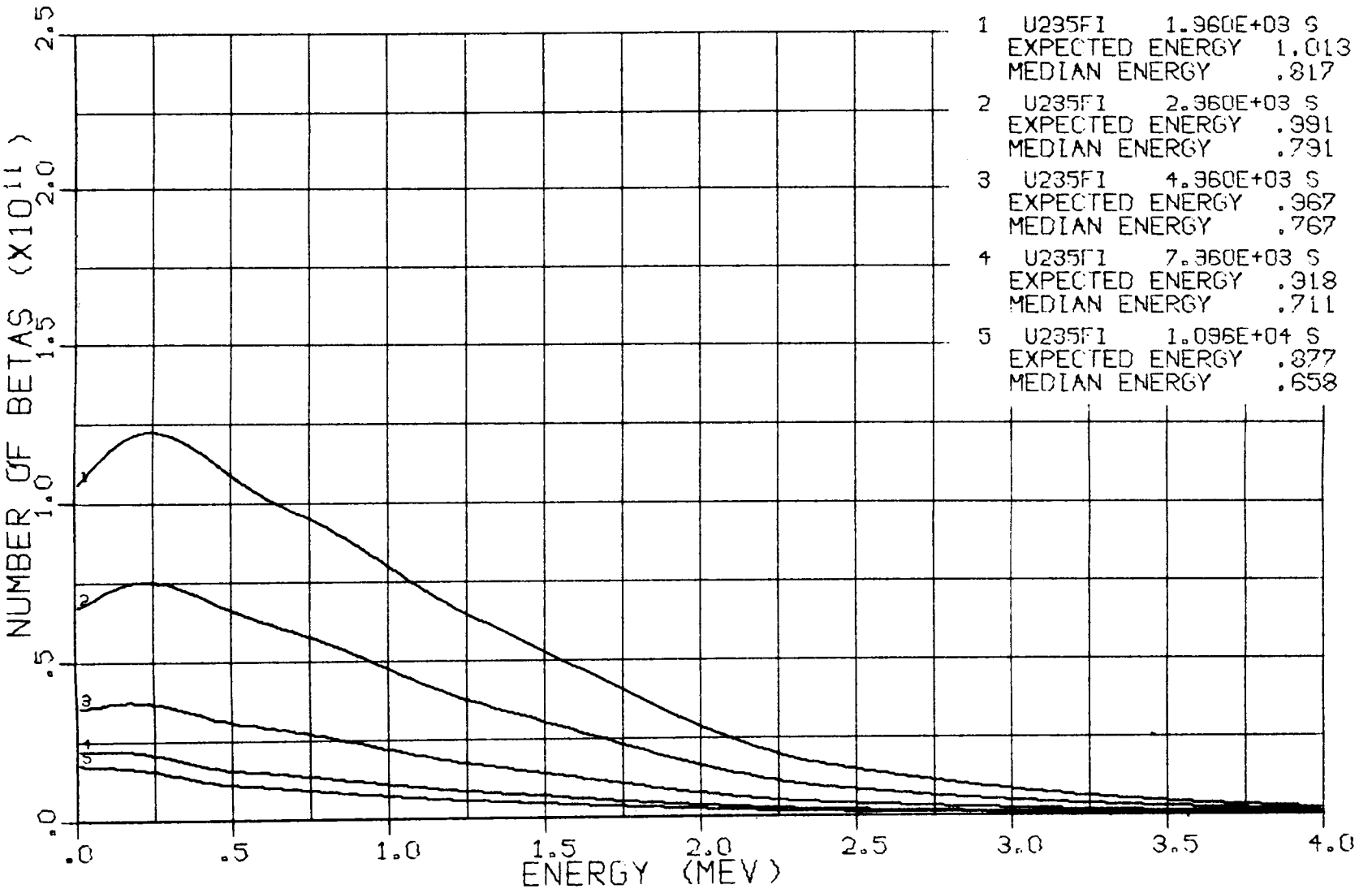

U235FI 2.400E+02 S
EXPECTED ENERGY 1.332
MEDIAN ENERGY 1.215
NUMBER OF BETAS (X10^11)
5.0
4.0
3.0
2.0
1.0
.0
.0
.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
ENERGY (MEV)


1 U235FI 1.240E+03 S
EXPECTED ENERGY 1.026
MEDIAN ENERGY .833
2 U235FI 2.240E+03 S
EXPECTED ENERGY .995
MEDIAN ENERGY .795
3 U235FI 4.240E+03 S
EXPECTED ENERGY .972
MEDIAN ENERGY .771
4 U235FI 7.240E+03 S
EXPECTED ENERGY .924
MEDIAN ENERGY .718
5 U235FI 1.024E+04 S
EXPECTED ENERGY .881
MEDIAN ENERGY .663
NUMBER OF BETAS (X10^11)
ENERGY (MEV)
.0
.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0


U235FI 4.800E+02 S
EXPECTED ENERGY 1.276
MEDIAN ENERGY 1.151
NUMBER OF BETAS (X10^11)
5.0
4.0
3.0
2.0
1.0
.0
.0
.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
ENERGY (MEV)


1 U235FI 1.480E+03 S
EXPECTED ENERGY 1.020
MEDIAN ENERGY .826
2 U235FI 2.480E+03 S
EXPECTED ENERGY .994
MEDIAN ENERGY .794
3 U235FI 4.480E+03 S
EXPECTED ENERGY .970
MEDIAN ENERGY .770
4 U235FI 7.480E+03 S
EXPECTED ENERGY .922
MEDIAN ENERGY .716
5 U235FI 1.048E+04 S
EXPECTED ENERGY .880
MEDIAN ENERGY .661
NUMBER OF BETAS (X10^11)
ENERGY (MEV)
.0
.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0


U235FI 9.600E+02 S
EXPECTED ENERGY 1.218
MEDIAN ENERGY 1.077
NUMBER OF BETAS (X10^11)
5.0
4.0
3.0
2.0
1.0
.0
.0
.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
ENERGY (MEV)


1 U235FI 1.960E+03 S
EXPECTED ENERGY 1.013
MEDIAN ENERGY .817
2 U235FI 2.960E+03 S
EXPECTED ENERGY .991
MEDIAN ENERGY .791
3 U235FI 4.960E+03 S
EXPECTED ENERGY .967
MEDIAN ENERGY .767
4 U235FI 7.960E+03 S
EXPECTED ENERGY .918
MEDIAN ENERGY .711
5 U235FI 1.096E+04 S
EXPECTED ENERGY .877
MEDIAN ENERGY .658
NUMBER OF BETAS (X10^11)
ENERGY (MEV)
.0
.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0

INITIAL DISTRIBUTION

Copies

NAVY

1	Commander, Naval Material Command (MAT 3241)
2	Commander, Naval Ship Systems Command (SHIPS 2021)
1	Commander, Naval Facilities Engineering Command (FAC 042)
1	Director, Naval Research Laboratory
1	Supt., Naval Postgraduate School, Monterey
1	NRDL Laboratory Representative (Attmore)

ARMY

1	Chief of Research and Development (Atomic Office)
1	Commander, Nuclear Defense Laboratory
1	CO, Engineer Research and Development Laboratory
1	USACDC Institute of Nuclear Studies
1	Postattack Research Division, OCD (Greene)

AIR FORCE

1	CO, Air Force Weapons Laboratory, Kirtland AFB (WLRB)
1	Director, Air University Library, Maxwell AFB
1	Hq., Air Force Systems Command (SCIZN) (Nuclear Safety Branch)

OTHER DOD ACTIVITIES

1	Director, Defense Atomic Support Agency
1	Commander, TC/DASA, Sandia Base (TCDV)
20	Defense Documentation Center

AEC ACTIVITIES AND OTHERS

1	Atomic Energy Commission, Dir. of Res. (Pierce)
1	Division of Isotope Development, AEC (Kern)
1	Division of Reactor Development and Technology, AEC (Seiken)
2	Isotopic Power Systems Branch, AEC (Rock, Carpenter)
1	New York Operations Office, AEC (Harley)
1	Reactor Division of Safety Standards, AEC (Dinunno)
1	Space Electric Power Office, AEC (Dix)

10	Space Nuclear Propulsion Office, AEC (Decker)
1	Lockheed Missiles and Space Co. (Plank)
1	Los Alamos Scientific Laboratory (Langham)
1	Los Alamos Scientific Laboratory (King)
1	Martin Company (Harvey)
1	Massachusetts Institute of Technology (Brownell)
1	Mound Laboratory (Grove)
1	Lewis Research Center, SNPO (Ordin)
1	National Aeronautics and Space Administration (Code RNS) (Kerr)
1	Nuclear Rocket Development Station (Erickson)
1	NUS Corporation (Goldman)
1	Oak Ridge National Laboratory (Fish)
2	Pacific N. W. Laboratory (Thompson, Kornberg)
1	Radd Associates (Radd)
1	Sandia Corporation (Blake, Hansen)
1	San Francisco State College (Sheehan)
1	Stanford Research Institute (Miller)
1	Planning Research Corporation (Harris)
1	Westinghouse Astronuclear Laboratory (Faulkner)
15	Division of Technical Information Extension, Oak Ridge

USNRDL

35	Technical Information Division

DISTRIBUTION DATE: 17 January 1967

UNCLASSIFIED
Security Classification

DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) U.S. Naval Radiological Defense Laboratory San Francisco, California 94135	2a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED 2b. GROUP

3. REPORT TITLE

BETA SPECTRA. III. SPECTRA OF U^{235} FISSION PRODUCTS AT SELECTED TIMES AFTER FISSION

4. DESCRIPTIVE NOTES *(Type of report and inclusive dates)*

5. AUTHOR(S) *(Last name, first name, initial)*

Hogan, Ora L.

6. REPORT DATE 17 January 1967	7a. TOTAL NO. OF PAGES 58	7b. NO. OF REFS 8
8a. CONTRACT OR GRANT NO. SNPO AEC contract AT(49-5)-2505(2) b. PROJECT NO. c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) USNRDL-TR-1093 9b. OTHER REPORT NO(S) *(Any other numbers that may be assigned this report)*	

10. AVAILABILITY/LIMITATION NOTICES

Distribution of this document is unlimited.

SNPO NASA AEC

11. SUPPLEMENTARY NOTES	12. ~~SPONSORING MILITARY ACTIVITY~~ Space Nuclear Propulsion Office Atomic Energy Commission Washington, D.C. 20545

13. ABSTRACT

Composite beta spectra for mixed fission products of U^{235} have been computed as the weighted sum of the theoretical beta spectra of the individual emitters. Reactor operating times used were: 0, 30, 60, 120, 240, 480, and 960 seconds, and 1 year. Sixteen decay times between 10^3 and 10^8 seconds were used. Results are graphically presented and are considered accurate to within 15 % for decay times less than 10^4 seconds, and to within 5 % for times greater than 10^4 seconds.

DD FORM 1 JAN 64 1473

UNCLASSIFIED
Security Classification

14. KEY WORDS	LINK A ROLE	LINK A WT	LINK B ROLE	LINK B WT	LINK C ROLE	LINK C WT
Beta spectra						
Fallout						
NERVA						
Fission products						

INSTRUCTIONS

1. ORIGINATING ACTIVITY: Enter the name and address of the contractor, subcontractor, grantee, Department of Defense activity or other organization *(corporate author)* issuing the report.

2a. REPORT SECURITY CLASSIFICATION: Enter the overall security classification of the report. Indicate whether "Restricted Data" is included. Marking is to be in accordance with appropriate security regulations.

2b. GROUP: Automatic downgrading is specified in DoD Directive 5200.10 and Armed Forces Industrial Manual. Enter the group number. Also, when applicable, show that optional markings have been used for Group 3 and Group 4 as authorized.

3. REPORT TITLE: Enter the complete report title in all capital letters. Titles in all cases should be unclassified. If a meaningful title cannot be selected without classification, show title classification in all capitals in parenthesis immediately following the title.

4. DESCRIPTIVE NOTES: If appropriate, enter the type of report, e.g., interim, progress, summary, annual, or final. Give the inclusive dates when a specific reporting period is covered.

5. AUTHOR(S): Enter the name(s) of author(s) as shown on or in the report. Enter last name, first name, middle initial. If military, show rank and branch of service. The name of the principal author is an absolute minimum requirement.

6. REPORT DATE: Enter the date of the report as day, month, year; or month, year. If more than one date appears on the report, use date of publication.

7a. TOTAL NUMBER OF PAGES: The total page count should follow normal pagination procedures, i.e., enter the number of pages containing information.

7b. NUMBER OF REFERENCES: Enter the total number of references cited in the report.

8a. CONTRACT OR GRANT NUMBER: If appropriate, enter the applicable number of the contract or grant under which the report was written.

8b, 8c, & 8d. PROJECT NUMBER: Enter the appropriate military department identification, such as project number, subproject number, system numbers, task number, etc.

9a. ORIGINATOR'S REPORT NUMBER(S): Enter the official report number by which the document will be identified and controlled by the originating activity. This number must be unique to this report.

9b. OTHER REPORT NUMBER(S): If the report has been assigned any other report numbers *(either by the originator or by the sponsor)*, also enter this number(s).

10. AVAILABILITY/LIMITATION NOTICES: Enter any limitations on further dissemination of the report, other than those imposed by security classification, using standard statements such as:

(1) "Qualified requesters may obtain copies of this report from DDC."

(2) "Foreign announcement and dissemination of this report by DDC is not authorized."

(3) "U. S. Government agencies may obtain copies of this report directly from DDC. Other qualified DDC users shall request through _____."

(4) "U. S. military agencies may obtain copies of this report directly from DDC. Other qualified users shall request through _____."

(5) "All distribution of this report is controlled. Qualified DDC users shall request through _____."

If the report has been furnished to the Office of Technical Services, Department of Commerce, for sale to the public, indicate this fact and enter the price, if known.

11. SUPPLEMENTARY NOTES: Use for additional explanatory notes.

12. SPONSORING MILITARY ACTIVITY: Enter the name of the departmental project office or laboratory sponsoring *(paying for)* the research and development. Include address.

13. ABSTRACT: Enter an abstract giving a brief and factual summary of the document indicative of the report, even though it may also appear elsewhere in the body of the technical report. If additional space is required, a continuation sheet shall be attached.

It is highly desirable that the abstract of classified reports be unclassified. Each paragraph of the abstract shall end with an indication of the military security classification of the information in the paragraph, represented as *(TS), (S), (C), or (U)*.

There is no limitation on the length of the abstract. However, the suggested length is from 150 to 225 words.

14. KEY WORDS: Key words are technically meaningful terms or short phrases that characterize a report and may be used as index entries for cataloging the report. Key words must be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location, may be used as key words but will be followed by an indication of technical context. The assignment of links, roles, and weights is optional.