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SPONTANEOUS-FISSION NEUTRONS OF CALIFORNIUM-252 AND CURIUM-244

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March 14, 1955

Further measurements of the multiplicities of prompt neutrons from the spontaneous fission of Cf^{252} and Cm^{244} have been made in a large cadmium-loaded scintillator.[1] The electronics have been improved and more cadmium has been added. The moderated neutrons are now captured with a mean life of 10 microseconds and the pulses are photographed from an oscilloscope sweep 30 microseconds long. Using the average number of neutrons per spontaneous fission of Cf^{252}, $\bar{\nu} = 3.53 \pm 0.15$ (probable errors shown throughout),[2] we found the efficiency for detecting one neutron to be $\epsilon = 0.772 \pm 0.034$. The ratio $\bar{\nu}\ Cf^{252}/\bar{\nu}\ Cm^{244} = 1.35 \pm 0.01$ has been obtained, giving $\bar{\nu}\ Cm^{244} = 2.62 \pm 0.11$. Higgins et al.[3] have measured $\bar{\nu}\ Cm^{244} = 2.60 \pm 0.12$.

If F(n) is the observed multiplicity distribution, the true distribution, P(ν), is obtained from

$$P(\nu) = \sum_{n=\nu}^{n=n_{max}} F(n)\, \frac{n!}{\nu!(n-\nu)!}\, \epsilon^{-n}(\epsilon - 1)^{n-\nu}.$$

The observed numbers of fissions of each nuclide giving ν neutrons are shown in Table I. Also given are the value of P(ν) (normalized so that $\sum_{\nu} P(\nu) = 1$) obtained after correcting the data for backgrounds of 0.0052 and 0.0084 neutron per fission for the Cf^{252} and Cm^{244} respectively.

Table I. Observed and true (calculated) neutron multiplicity distributions from 16,200 spontaneous fissions of Cm^{244} and 14,749 spontaneous fissions of Cf^{252}.

ν =	0	1	2	3	4	5	6	7	8
Cm^{244} Observed	999	4259	5814	3750	1174	188	16		
Cm^{244} P(ν)	0.010 ±0.006	0.136 ±0.022	0.318 ±0.018	0.339 ±0.016	0.158 ±0.020	0.035 ±0.006	0.004 ±0.001		
Cf^{252} Observed	312	1922	4216	4612	2648	836	170	29	4
Cf^{252} P(ν)	0.001 ±0.002	0.035 ±0.012	0.150 ±0.028	0.315 ±0.021	0.308 ±0.022	0.143 ±0.021	0.038 ±0.008	0.008 ±0.002	0.002 ±0.001

The normalized value of F(n) and P(ν) for Cm^{244} and Cf^{252} are shown in Fig. 1 and Fig. 2.

The average number of neutrons from the spontaneous fission of Pu^{240} has been measured at Los Alamos.[4,5,6] Preliminary results from a comparison of Cf^{252} (3925 fissions) and Pu^{240} (4610 fissions) indicate that the $\bar{\nu}$'s for Cf^{252} and Cm^{244} used above to determine the efficiency are too low. Based on the $\bar{\nu}$ for Pu^{240}, with a statistical error of 5 percent given, we obtain $\bar{\nu}$ Cf^{252} = 4.04 ± 0.14 and $\bar{\nu}$ Cm^{244} = 3.01 ± 0.11. Our efficiency for neutron detection would be reduced to ϵ = 0.671 ± 0.023 and the calculated points of the multiplicity distributions shifted toward higher multiplicities. The multiplicity distributions based on ϵ = 0.671 are given in Table II. Measurements concerning this discrepancy are continuing.

Table II. Calculated neutron multiplicity distributions based on ϵ = 0.671.

ν=	0	1	2	3	4	5	6	7	8
Cm^{244} P(ν)	-0.004	+0.071	+0.247	+0.382	+0.233	+0.062	+0.010		
Cf^{252} P(ν)	-0.002	+0.008	+0.060	+0.244	+0.372	+0.225	+0.073	+0.014	+0.007

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1. D. A. Hicks, J. Ise, Jr., and R. V. Pyle, Phys. Rev. 97, 564 (1955). The calculated multiplicity distribution given in this reference is incorrect because of an error in the published value of $\bar{\nu}$ Cf^{252} (see reference 2).
2. W. W. T. Crane, G. H. Higgins, and S. T. Thompson, Phys. Rev. 97, 242 (1955) and erratum submitted to the Physical Review.
3. G. H. Higgins, W. W. T. Crane, and Stewart Gunn, submitted to the Physical Review.
4. E. Segrè, LA-491 (1946).
5. W. W. Carter, LA-1582 (1952).
6. H. C. Martin, James Terrel, and B. C. Diven via private communication from R. F. Taschek.

LEGENDS FOR FIGURES

Fig. 1 Neutron number distribution arising from the spontaneous fission of Curium-244. Probable errors are shown.

Fig. 2 Neutron number distribution arising from the spontaneous fission of Californium-252. Probable errors are shown.

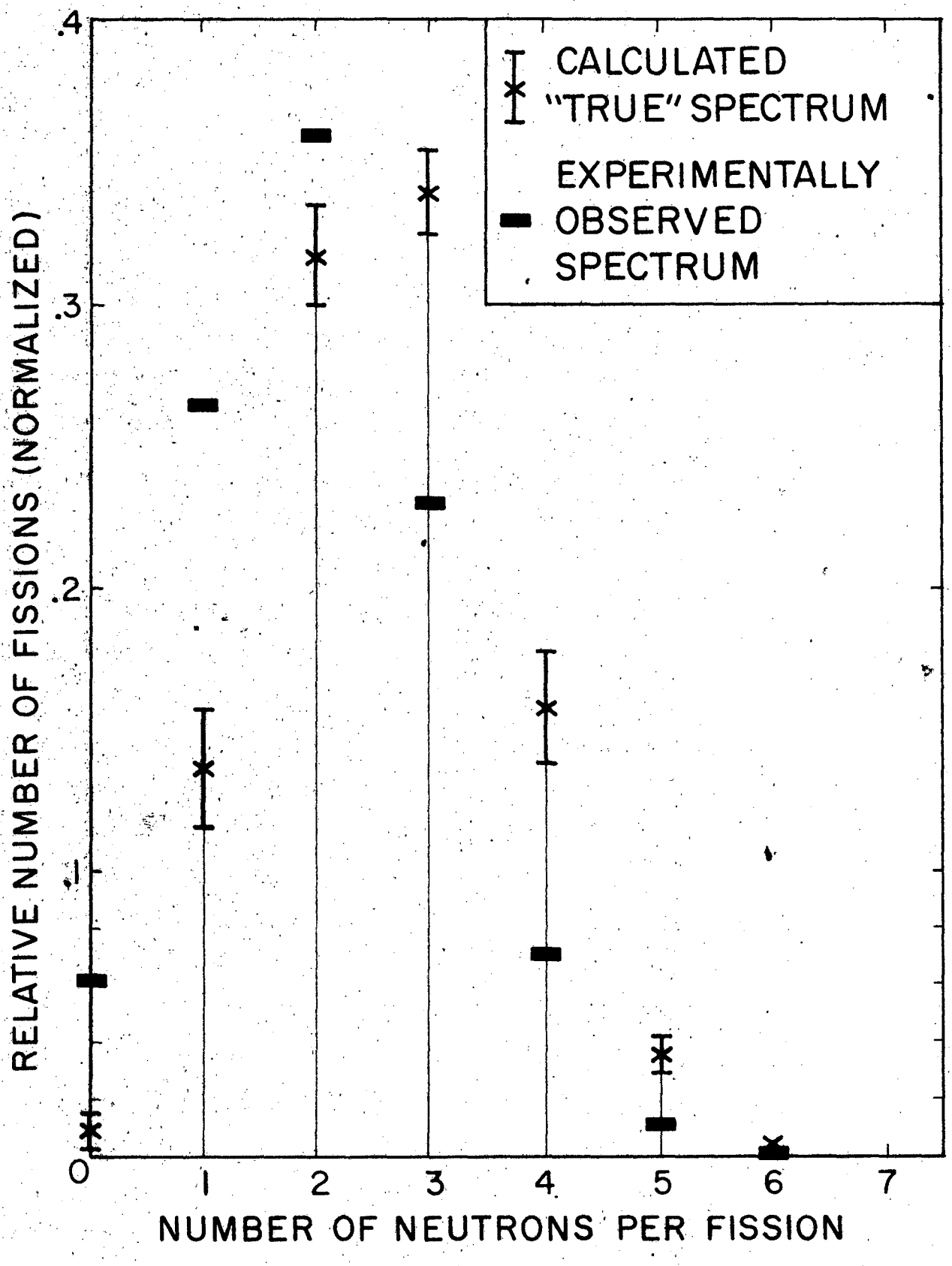
CALCULATED "TRUE" SPECTRUM
EXPERIMENTALLY OBSERVED SPECTRUM
RELATIVE NUMBER OF FISSIONS (NORMALIZED)
.4
.3
.2
.1
0
1
2
3
4
5
6
7
NUMBER OF NEUTRONS PER FISSION

Fig. 1

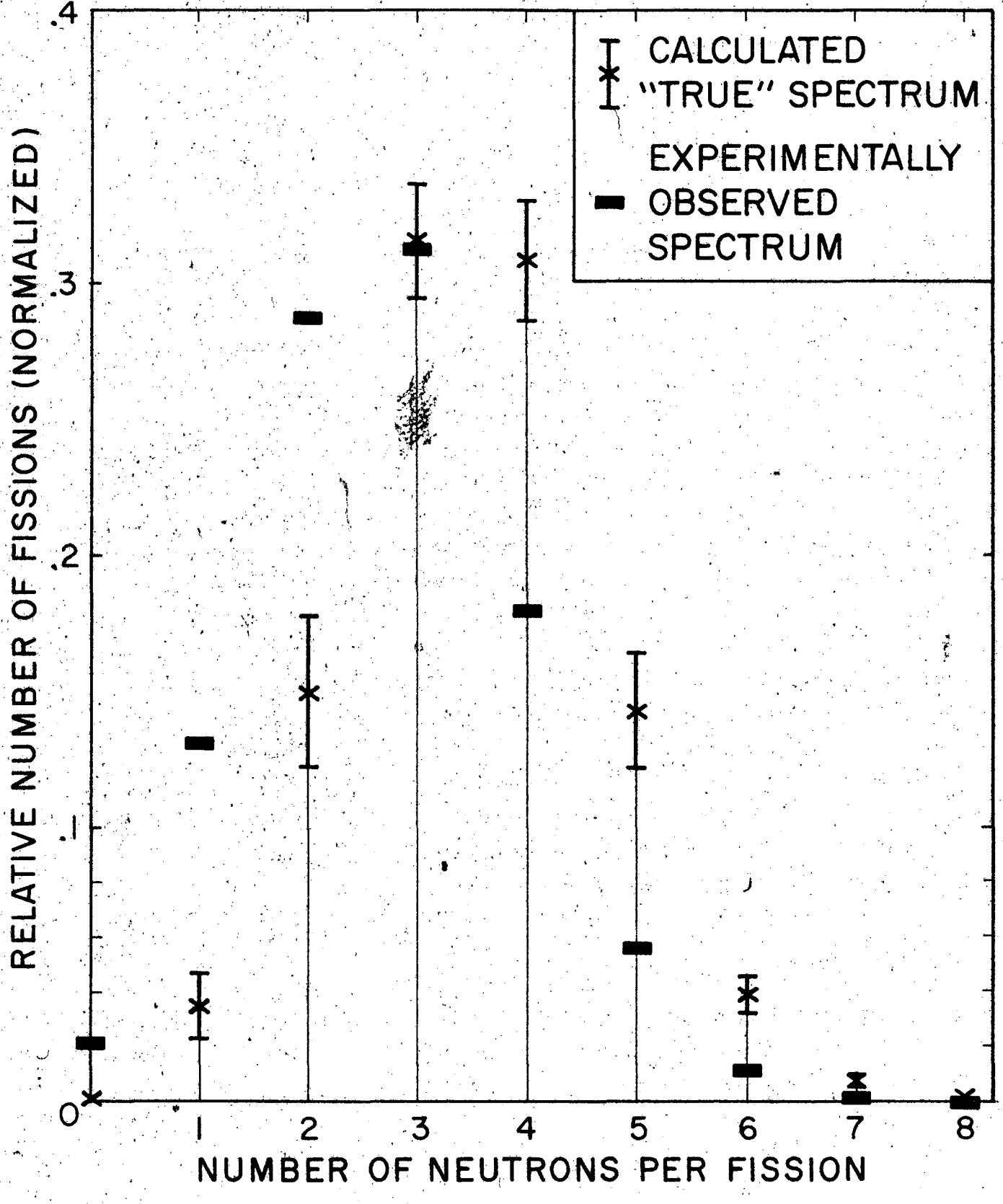
CALCULATED "TRUE" SPECTRUM
EXPERIMENTALLY OBSERVED SPECTRUM
RELATIVE NUMBER OF FISSIONS (NORMALIZED)
.4
.3
.2
.1
0
1
2
3
4
5
6
7
8
NUMBER OF NEUTRONS PER FISSION

Fig. 2