# Correlation between Fission-Channel Effects and Fragment Kinetic Energies*

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A measurement of the relative yield of fission events associated with the highest–kinetic-energy fragments has been made for several resonances in $^{235}U$. The results show that this yield is strongly correlated with $K$, the fission-channel quantum number.

Pattenden and Postma[1] have recently reported a measurement of fission-fragment anisotropies observed in the irradiation of aligned $^{235}U$ nuclei by neutrons, in the energy region below 100 eV. The quantity reported by Pattenden and Postma is $A_2$, the leading coefficient in the Legendre expansion describing the anisotropy, which depends strongly on $K$, the quantum number usually assumed to be connected with fission channels. It has been noted[2,3] that the Pattenden-Postma results are strongly correlated with variations in the mass distribution of the fragments, as determined by Cowan *et al.*,[4] and with the relative yield of high–kinetic-energy heavy fragments from fission induced by low-energy (< 1 eV) neutrons, as measured by Moore and Miller.[5] It is expected that correlations also should exist between $A_2$ and fragment kinetic energies, and between $A_2$ and $\bar{\nu}$, the number of neutrons emitted per fission, for higher-energy resonances. Previously available data[6-8] have not shown that such a significant correlation exists, however.

The measurement reported in the present paper was an attempt to determine the relative yield of the highest–kinetic-energy fragments across various resonances in $^{235}U$, to assist in multilevel analysis of different fission-channel contributions. The experiment was carried out as follows: A thin rolled foil (7–8 mg/cm$^2$) of $^{235}U$ was placed in a back-to-back gas scintillation fission chamber, which was positioned in a neutron beam at the Rensselaer Polytechnic Institute electron linear accelerator. Time-of-flight spectra were recorded for both singles and coincidences (between the two halves of the chamber) in different sections of memory of an on-line data acquisition computer. The fission foil was thick enough to eliminate the possibility of observing coincidences except for those fission events associated with the highest kinetic energy release; the coincidence-to-singles ratio was about 0.1%.

The statistical accuracy of the data was so low, however, that significant results were obtained for only a few of the largest resonances. The observed ratio of coincidences to singles for these resonances, compared with the $A_2$ coefficients reported by Pattenden and Postma,[1] is shown in Table I and plotted in Fig. 1 for these five resonances. The correlation coefficient, given by the expression

$$r = \left[\sum_{i=1}^{m}(x_i - \bar{x})(y_i - \bar{y})\right] \times \left[\sum_{i=1}^{m}(x_i - \bar{x})^2 \sum_{i=1}^{m}(y_i - \bar{y})^2\right]^{-1/2},$$

is found to be 0.97. Even with a sample of only

TABLE I. Relative yield of high–kinetic-energy fragments and $A_2$ values from the work of Pattenden and Postma (Ref. 1) for selected resonances in $^{235}U$. Errors are statistical only.

| Neutron energy (eV) | Relative yield of high-energy fragments | $A_2$ [a] |
|---|---|---|
| 56 | 0.0138 ± 0.0014 | −1.96 ± 0.10 |
| 35 | 0.0205 ± 0.0015 | −0.99 ± 0.07 |
| 19.3 | 0.0146 ± 0.0011 | −1.82 ± 0.06 |
| 12.4 | 0.0176 ± 0.0011 | −1.17 ± 0.08 |
| 8.8 | 0.0143 ± 0.0009 | −1.78 ± 0.05 |

[a] A 10% correction, suggested in Ref. 1, has not been applied.

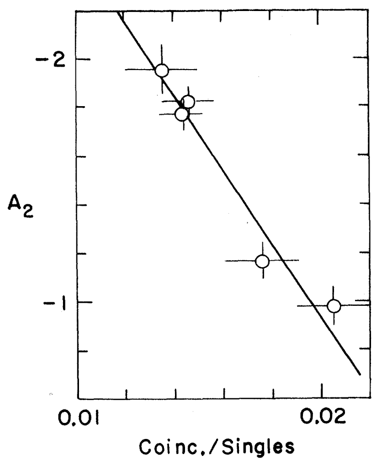


FIG. 1. $A_2$, as reported by Pattenden and Postma (Ref. 1), versus relative yield of high-energy fragments, as revealed by the coincidence-to-singles ratio.

five values or three degrees of freedom in a bivariate distribution, this corresponds to a significance level (probability that a random bivariate sample would give this result) of much less than 1%. It can be concluded that fission-channel properties are correlated with fragment kinetic energies and thus, presumably, also with $\bar{\nu}$. The effects observed in the present experiment on $^{235}$U can be compared with similar work (of considerably higher quality) reported by Felvinci and Melkonian[9] for $^{233}$U. The importance of indirect methods such as this for determining fission-channel properties for $^{239}$Pu, which does not permit direct determination by nuclear alignment studies, should also be pointed out.

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[1]N. J. Pattenden and H. Postma, Nucl. Phys. A167, 225 (1971).

[2]N. J. Pattenden, private communication (1971).

[3]M. S. Moore, in *Statistical Properties of Nuclei,* edited by J. B. Garg (Plenum, New York, 1972), p. 55.

[4]G. A. Cowan, B. P. Bayhurst, R. J. Prestwood, J. S. Gilmore, and G. W. Knobeloch, Phys. Rev. C 2, 615 (1970).

[5]M. S. Moore and L. G. Miller, in *Proceedings of the Symposium on the Physics and Chemistry of Fission, Salzburg, 1965* (International Atomic Energy Agency, Vienna, Austria, 1965), Vol. I, p. 87.

[6]E. Melkonian and G. K. Mehta, in *Proceedings of the Symposium on the Physics and Chemistry of Fission, Salzburg, 1965* (International Atomic Energy Agency, Vienna, Austria, 1965), Vol. II, p. 355.

[7]S. Weinstein, R. Reed, and R. C. Block, in *Proceedings of the Second International Atomic Energy Symposium on the Physics and Chemistry of Fission, Vienna, Austria, 1969* (International Atomic Energy Agency, Vienna, Austria, 1969), p. 477.

[8]Yu. V. Ryabov, So Don Sik, N. Chikov, and N. Yaneva, Joint Institute for Nuclear Research Report No. P3-5297, 1970 (to be published).

[9]J. P. Felvinci and E. Melkonian, in *Proceedings of the Third Conference on Neutron Cross Sections and Technology, Knoxville, Tennessee, 1971,* edited by R. L. Macklin, CONF-710301 (U. S. AEC Division of Technical Information Extension, Oak Ridge, Tenn., 1971), p. 855.

# Determination of Nuclear Spectroscopic Factors by Dispersion Relations*

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The spectroscopic factors for $d \to np$ and $^4\mathrm{He} \to n\,^3\mathrm{He}$ are studied using dispersion relations. It is found that the large distortions represented by the cuts, which have previously prevented dispersion relations from being a practical tool for nuclear physics, can be handled using the conformal mapping techniques of Cutkosky. The method could have general applicability for nuclear physics.

The most accurate determination of coupling constants in particle physics has been achieved via dispersion relations.[1] Soon after they were developed for nucleon-nucleon scattering, forward dispersion relations were derived for composite systems, and application was made to neutron-deuteron scattering[2] for the calculation of spectroscopic factors,[3] the nuclear analog of coupling constants. There have been a number of attempts since then to use dispersion relations in