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RATIOS OF BETA-DELAYED PARTICLE BRANCHES AND THE ROLE OF THE FLUCTUATION FUNCTION

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ABSTRACT

The ratios between the delayed-proton and the delayed-alpha branches from the precursors ^{113}Xe and ^{115}Xe have been measured to be 830 ± 50 and 1100 ± 300. It is shown that they are influenced by fluctuation effects.

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The beta decay of nuclei very far from the line of beta stability usually is complex and populates many excited levels. For a description of this process, it is therefore useful to start from a statistical picture and to introduce average quantities such as level densities and strength functions and also the probabilities of fluctuations around the averages. The elements of such a treatment [1] can be taken from the theory of neutron resonance reactions [2]. In the present paper, we wish to point to a contribution to the intensities due to fluctuation effects.

Until now, the most conspicuous effect of the fluctuations has been the fine structure observed in the spectra of beta-delayed gamma-rays, protons and neutrons [1,3-9]. This fine structure arises mainly from the Porter-Thomas fluctuations [10] in the transition probabilities, whereas fluctuations in the level spacings are of less importance [11]. Fluctuations may, however, also affect the intensities, especially in cases where only a few channels are open. As it is customary in nuclear statistical calculations to replace the fluctuating variables by their mean values, it becomes convenient to define [1,2] a fluctuation function S(a,b,..) by

$$\langle f(x,y,..;a,b,..)\rangle = S(a,b,..) \cdot f(1,1,..;a,b,..) \qquad (1)$$

where f denotes a function of the intensity variables, the parameters x,y,.. are statistical variables with mean values unity, and a,b,.. are constants.

Consider as an example the competition between two particle branches with intensities x and y, and gamma-ray emission, for which we assume the <u>total</u> width to be constant. The branching ratio for particle x from a single state is then of the form $f = x/(s + ay + b)$, and the fluctuation function corresponding to the average over many states will behave as shown in fig. 1. It is seen that in the limit of large b, corresponding to predominance of gamma decay of the states, the fluctuation function is unity. This, approximately, is the situation for the Cs precursors, which we use for comparison below. In the other limit, where b is zero, the analytical expression is $S(a) = (1 + a)/(1 + a^{\frac{1}{2}})$ so that for large a, the intensity of x behaves as $a^{-\frac{1}{2}}$. This corresponds to a strong enhancement of the weak particle branch.

A good case for demonstrating this enhancement effect is provided by the light xenon isotopes, for which a weak branch of beta-delayed alphas was expected to compete with the emission of beta-delayed protons. Experiments on $^{113,115}Xe$ were therefore carried out at the on-line isotope separators at G.S.I. [12] and at CERN [13], respectively. For the CERN experiments, a new target consisting of 7 g/cm^2 of lanthanum carbide was used. This target was connected to the ion source by a cooled transfer line, which allowed only gases to pass. At G.S.I. the activity was produced by irradiation of a 3 mg/cm^2 ^{58}Ni target with 290 MeV ^{58}Ni ions. The proton and alpha spectra of the mass-separated radioactivity were recorded by a ΔE-E counter telescope, and led to the experimental branching ratios given in the last column of table 1. For comparison, table 1 also includes the value for the isotope ^{118}Cs, taken from the work of D'Auria et al. [14].

Calculations of the absolute intensities of beta-delayed particles can be made rather accurately in a statistical model [15,1]. Even better agreement is obtained if only the ratios between proton and alpha intensities are considered [16], since in this case errors in the shape of the beta strength function and in the absolute value of the level density to a good approximation vanish in the final ratio. In the present work we include for the first time the correction for fluctuation effects (eq. 1). As the complete expressions for the particle intensities are relatively complicated, it was found most convenient to evaluate the effects of fluctuations in a Monte-Carlo calculation, that is directly from the left side of (1). The results of calculations without and with fluctuation corrections are shown in table 1.

It is seen from table 1 that the inclusion of the fluctuation corrections considerably improves the agreement with experiment for the xenon isotopes, and that the result for ^{118}Cs, which agreed well before, remains essentially unaltered. We take this as a strong indication that fluctuation effects decrease the proton-alpha ratios in $^{113,115}Xe$ by factors of 0.2 and 0.5, respectively, and as a reminder that the S(a,b,..) correction occasionally may be important. The existence of the correction itself is founded on well-established properties of complex nuclear spectra, and hardly requires experimental proof.

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Table 1

Proton-to-alpha intensity ratios in beta-delayed particle emission

Precursor	Calculated b_p/b_α		Experiment b_p/b_α
	Without fluctuating widths	With fluctuating widths	
^{113}Xe	3500	640	830 ± 50
^{115}Xe	2600	1450	1100 ± 300
^{118}Cs	18.9	18.7	17.2 ± 0.3

Figure caption

Fig. 1 : The fluctuation function for the branching ratio for particle "x" : $f = x/(x + ay + b)$. Here, x and y are assumed to be Porter-Thomas distributed random variables with mean value unity, and a and b are constants. Other cases of fluctuation functions are discussed in ref. [1].

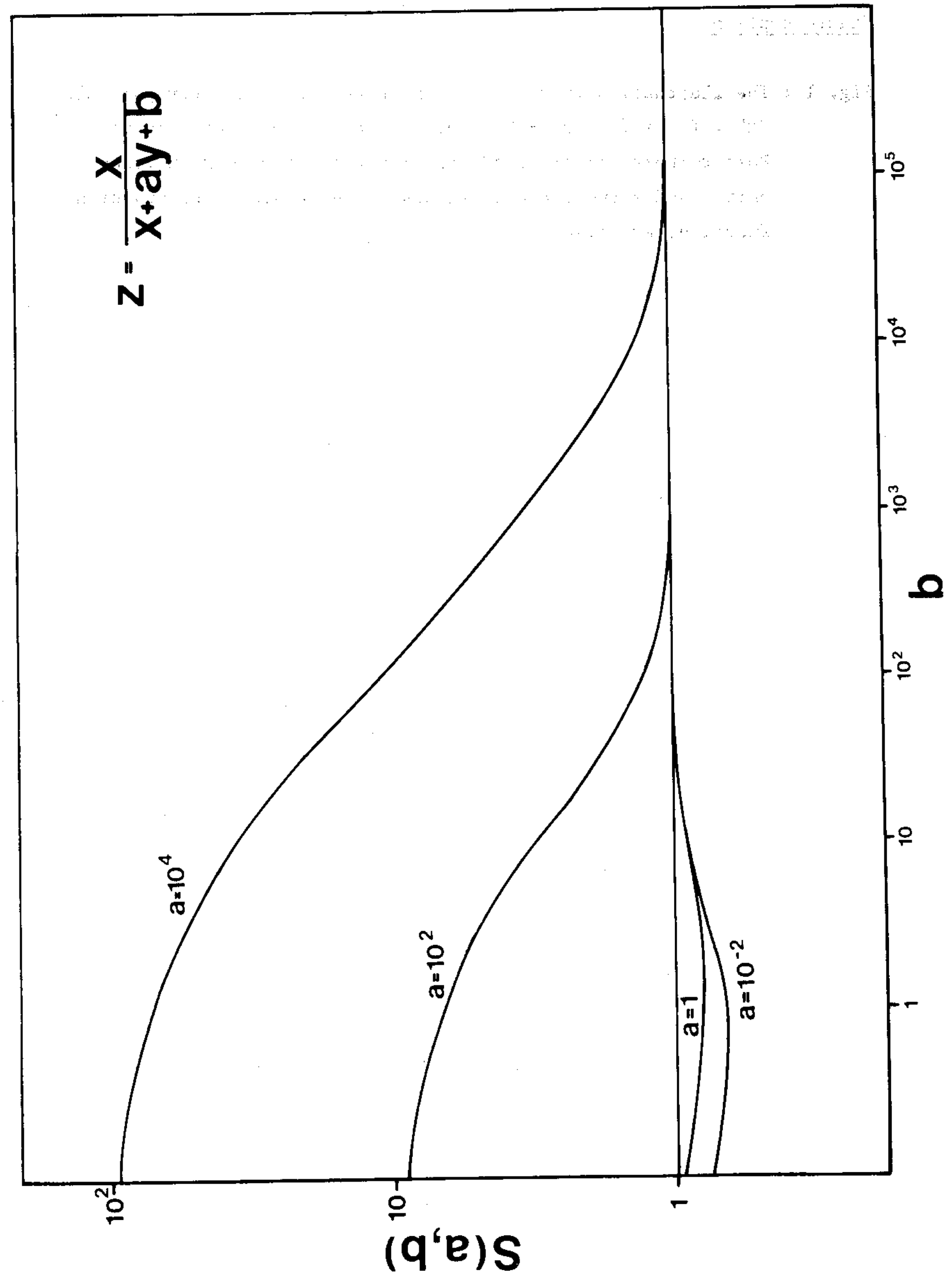

Fig. 1

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