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LETTER OF INTEREST

SIN-ISOLDE

BETA DELAYED PARTICLE EMISSION: AVERAGE AND STATISTICAL ASPECTS OF NUCLEAR STRUCTURE

E. Hagberg[a], P.G. Hansen[b], J.C. Hardy[a], B. Jonson[c],
S. Mattsson[c], G. Nyman[e], H.L. Ravn[c],
E. Roeckl[d], D. Schardt[c], P. Tidemand-Petersson[d],

The ISOLDE Collaboration
CERN, Geneva, Switzerland

a) Atomic Energy of Canada Ltd., Chalk River Nuclear Laboratories, Chalk River, Ontario, Canada.

b) Institute of Physics, University of Aarhus, Aarhus, Denmark.

c) CERN-ISOLDE, CERN, Geneva, Switzerland.

d) GSI, Darmstadt, Federal Republic of Germany.

e) Department of Physics, Chalmers University of Technology, Göteborg, Sweden.

Beta-delayed particle emission: average and statistical aspects of nuclear structure

One of the main fields of research at ISOLDE is experimental investigations of beta delayed particle emission. These studies have until now covered delayed protons [1-4], delayed alphas [5,6,7] and in recent years also delayed neutrons. One may say that these decay modes are typical of nuclei far from stability and they provide one of the main experimental tools for studying very unstable nuclear systems. This will certainly continue to be the case.

The particle emission processes, as such, are relatively well understood [1,2,8] and the main interest in continuing this type of exotic nuclear spectroscopy is to use the special features of the decay to learn about nuclear structure.

The particles are emitted from nuclear states that are typically at some MeV of excitation energy; in the case of medium weight and heavy nuclei these regions of excitation are characterized by high level densities. The particle spectra serve as a very sensitive probe of the properties of these states.

This letter mainly serves as a reminder that this research line will continue. To illustrate what we foresee as its most interesting outcome, we have chosen three examples:
(i) beta-strength functions; (ii) nuclear level densities;
(iii) lifetimes for highly excited nuclear states.

1. Beta-strength functions from delayed particle spectra

Beta-decay probabilities are normally thought of on a transition-by-transition basis, but with high level densities it is more natural to define the beta-strength function, S_β, as being related to the total probability per energy interval of final states in the daughter nucleus. In order to get a complete picture of the variation of the strength with energy for nuclei far from stability, the delayed-particle spectra play an important role. As an example of a case where the beta-strength function has been built up of a combination of different types of data we show in figure 1 the result for ^{49}K.

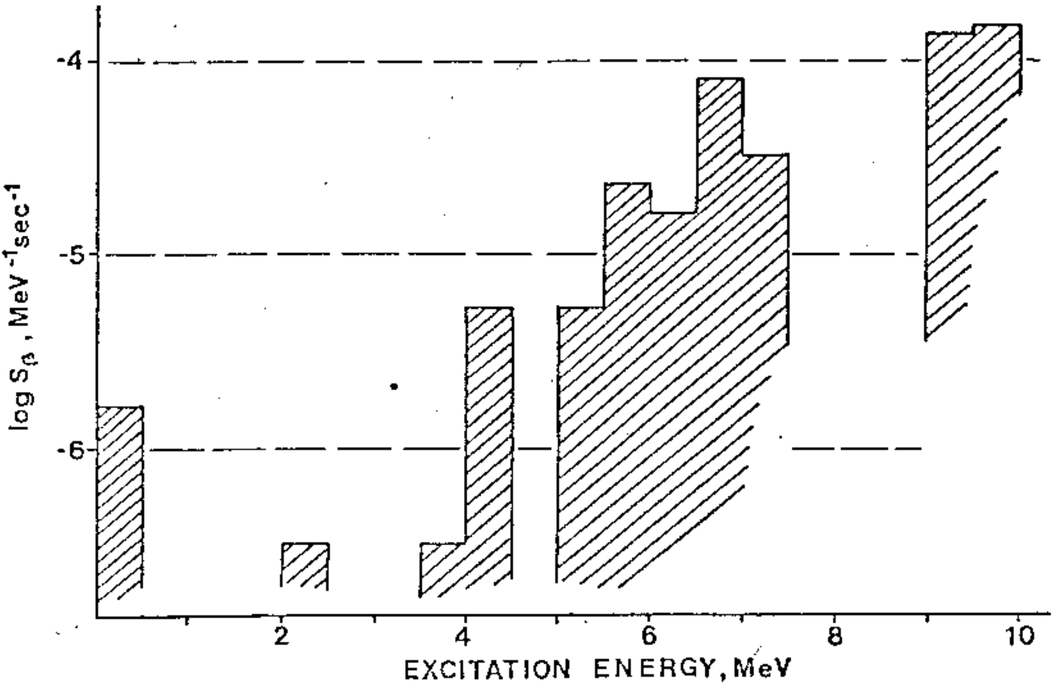

Fig. 1 The beta strength function for ^{49}K deduced from neutron and gamma-ray data.

In this case we have been able to construct the strength function up to 10 MeV by combining (i) gamma spectroscopy data, (ii) delayed neutron data (energy spectra and P_n value) and (iii) nγ coincidence data.

The special significance of this system lies, of course, in its proximity to the doubly-magic ^{48}Ca. It is possible that this nucleus will be useful as a model for understanding the microscopic origin of beta-strength.

We foresee that several new cases of this kind, on both sides of stability, will come within reach for experiments during the next couple of years and we shall continue our mapping of the strength functions. Also other doubly magic regions (Z,N=50,50 and Z,N=50,82) are of interest as well as the general behaviour of the β^--strength functions that we can extract from the beta-delayed neutron data.

2. Measurements of nuclear level densities

Spectra of delayed particles show, in the typical case, a broad hump with a super-imposed fine structure. This fine structure arises mainly from Porter-Thomas fluctuations in the transition probabilities, whereas fluctuations in the level spacings are of less importance. The intensity of the fluctuations in unresolved spectra from beta-delayed particle emitters can be related 2) to the nuclear level density at the excitation energy of the particle emitting states.

Analyses of this kind of data has until now only been completed in three cases, collected in figure 2. One interesting result is the extremely low value of the level density parameter for the isotope $^{99}_{47}$Ag. This is maybe the strongest evidence until now for the magicity of the as yet undiscovered $^{100}_{50}$Sn.

We shall continue to collect level density data and a major effort will be put on the neutron rich side of stability. With this information we may expect to arrive at a better understanding of the level density parameters in general and especially for the neutron rich isotopes that are of major interest in astrophysical calculations.

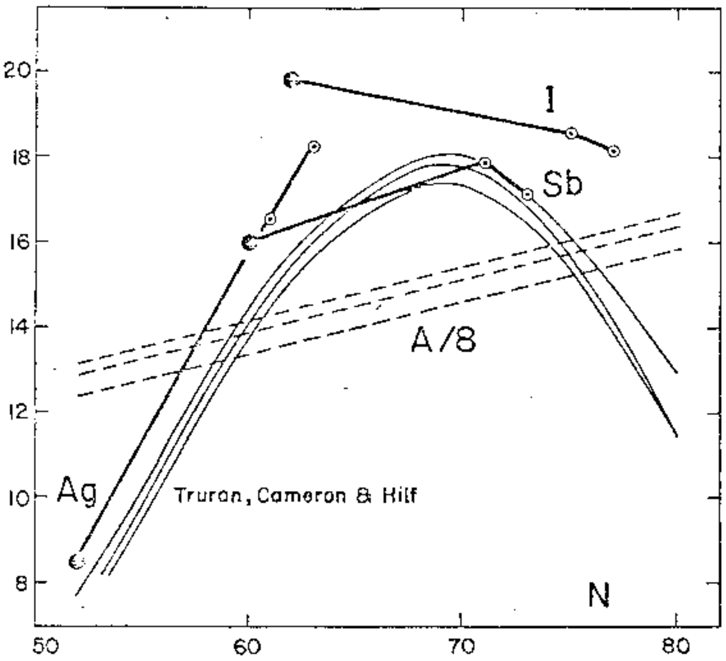

Fig. 2 *The level density parameter* $\underline{a}$ *(in* MeV^{-1}*) as a function of the neutron number N for the elements silver (Ag, Z = 47), antimony (Sb; = 51) and iodine (I, Z = 53). Experimental points are connected with heavy lines. The data points are from fluctuation analysis of beta-delayed proton spectra and the small ones from neutron resonance data. The curves correspond to predictions from a semi-empirical formula (Truran et al. ref. 10) and the dashed lines to the usual estimate* $\underline{a} = A/8$.

3. Average excited state lifetimes

In nuclei with A>50, delayed proton emission is usually preceeded by a significant electron capture component. Thus a K vacancy is created simultaneously with the population of a proton-unstable state. If the K X-ray is emitted before the proton its energy will be characteristic of the beta-decay daughter; if it is emitted after, it will correspond to the element one unit lower in Z. Consequently the intensity ratio of the two X-rays will provide a measure of the nuclear lifetime, since the atomic one is acurately known. Such lifetimes can be measured with particle X-ray coincidence techniques, and the data yield information on both γ-ray and proton partial widths as well as on the level density. As an illustration of this kind of data we show the results for

$^{73}\mathrm{Kr} \xrightarrow{\mathrm{EC}\ (\beta+)} {}^{73}\mathrm{Br}^{*} \xrightarrow{p} {}^{72}\mathrm{Se}$ in figure 3.

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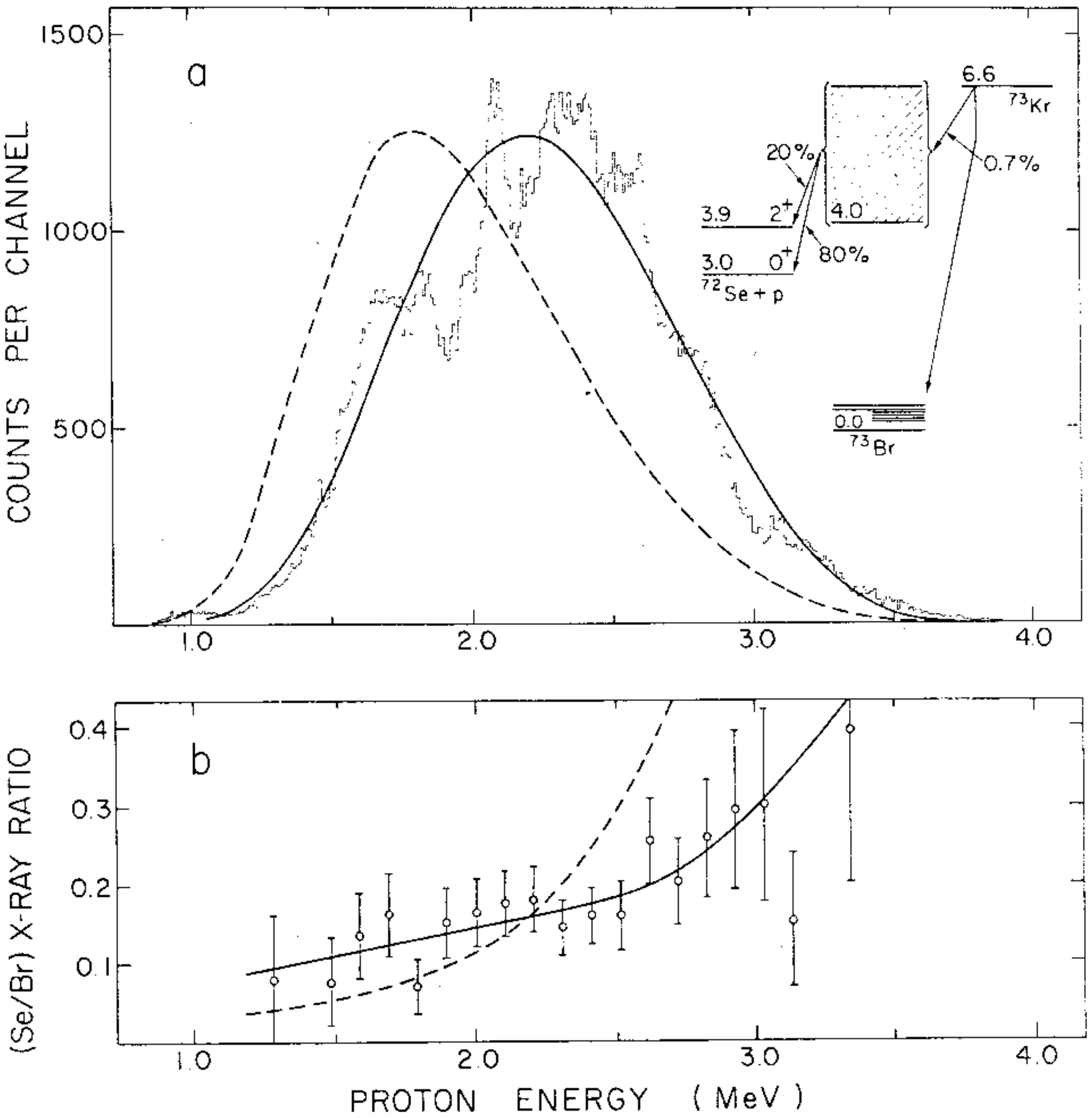

__Fig.3__ a) *Spectrum of protons observed following the devay of ^{73}Kr. In the simplified decay scheme, which is inset, all energies are given in MeV relative to the ^{73}Br ground state.*

b) *Ratio of X-rays from Se relative to those from Br, plotted as a function of coincident proton energy. The smooth curves in (a) and (b) are the results of calculations.*

This measurement technique yields direct information on the proton- and γ-decay widths of low-spin excited states, and as such is unique in the study of many exotic nuclei. We shall pursue these studies in order to relate present knowledge of near-stable nuclei to the more general geography of the entire nuclear chart. It is already evident that theories extrapolated from near stability do not correctly predict the behaviour of Γ_γ values.

4. Concluding remarks

The most recent experiment on the ^{73}Br lifetimes shows that a full understanding depends on obtaining data from a number of sources: particle intensities, fine structure, β-ray work, spectral shapes and lifetimes. In view of the fact that these experiments are complex and time consuming, the improvement in intensity offered by a SIN-ISOLDE installation is of considerable interest.

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