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BETA-DELAYED α EMISSION FROM $^{118,120}Cs$

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ABSTRACT

The isotopes ^{118}Cs ($T_{\frac{1}{2}}$ = 16 sec) and ^{120}Cs (58 sec) were found to have unresolved, bell-shaped α spectra extending from 7-10 MeV and 6-9 MeV, respectively. The branching ratios (in α/dis) are $(2.4 \pm 0.4) \times 10^{-5}$ and $(2.0 \pm 0.4) \times 10^{-7}$. The experiment confirms ^{120}Cs as a delayed-proton emitter with a proton branch of $(7 \pm 3) \times 10^{-8}$.

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Only a few cases of beta-delayed α emission are known [1]. In addition to light nuclei such as ^{8}Li, ^{8}B, ^{16}N, ^{20}Na, there are the classical cases $^{212,214}Bi$, where the low-lying excited levels of the polonium daughters owe their α instability to the very high Q_{α} values in this region. For extremely neutron-deficient nuclei, however, the high Q_{EC} and Q_{α} values will make beta-delayed α emission occur regularly throughout the nuclear chart. With their origin in regions of high level density (see insert in fig. 1), the α spectra are expected to appear as broad, unresolved distributions with shapes and intensities that reflect the beta population and the competition of p, α, and γ emission from the excited levels. This is exactly what makes the phenomenon interesting: it provides a way in which the distribution of α strength can be studied in an otherwise inaccessible energy region.

The isotope 3.6 sec ^{181}Hg, which is approximately 20 neutrons away from beta stability, was recently reported [2] to emit beta-delayed alphas, with a branching ratio of $(9 \pm 3) \times 10^{-8}$ α/dis. The data rate, however, was extremely low. As theoretical estimates indicate that in lighter nuclei the lower level densities and higher barrier penetrabilities may combine to give more favourable conditions, we have carried out a search in the isotopes of caesium, of which the odd-odd ones represent the best candidates.

Neutron-deficient caesium isotopes were produced in spallation reactions with 600 MeV protons from the reconstructed CERN Synchro-cyclotron (SC-2) impinging on a 20 cm thick target of molten lanthanum metal, and were subsequently mass-separated in the new ISOLDE Facility. References to technical papers describing the cyclotron and mass-separator reconstruction may be found in the paper by Ravn et al. [3], which also covers target and ion-source techniques. Even though the first tests had shown that the cyclotron was able to reach its design aim, an external beam of 5 μA, the present experiments were carried out with 30-100 nA in order to avoid excessive activation during the running-in period. Although this corresponds approximately to the proton beam intensity used at the old ISOLDE system there was already a substantial improvement in the caesium yields owing to improved focusing of the protons and also to the use of a 20 cm thick target instead of the 8 cm target used previously.

The radioactive ion beam of the mass of interest was directed into the experimental area and intercepted by a 20 $\mu g/cm^2$ carbon foil placed in front of a ΔE-E silicon counter telescope. Signals for particle identification and total energy were stored two-dimensionally, so that both proton events (from beta-delayed proton emission) and α events were recorded. After each measurement the carbon foil was removed and assayed for residual daughter activity from which the total number of atoms collected was obtained.

The half-lives of the light isotopes of caesium are well known [4-6], and ^{116}Cs [6,7], ^{118}Cs [5,6], and (tentatively) ^{120}Cs [5,6] are known to be delayed-proton emitters. The main new results are summarized below and in table 1.

<u>^{118}Cs.</u> The beta-delayed α spectrum shown in fig. 1 represents a branching ratio of $(2.4 \pm 0.4) \times 10^{-5}$ α/dis, determined on the basis of annihilation radiation from the β^+ decay of 3.5 min ^{118}Sb (β^+/dis = 0.755) [8], which is in equilibrium with ^{118}Te (6.0 d). The observed proton-to-alpha ratio is 16 ± 1, consistent with the previously determined [6] proton branching ratio of $(4.2 \pm 0.6) \times 10^{-4}$ p/dis.

<u>^{119}Cs.</u> A total of 10^9 atoms were collected during the experiment. No α events were recorded, so that with an upper limit of two events and a solid angle of 10.5% of 4π one obtains that any delayed α branch must be weaker than 2×10^{-8}.

<u>^{120}Cs.</u> The beta-delayed α spectrum shown in fig. 2 represents a total intensity of $(2.0 \pm 0.4) \times 10^{-7}$, determined on the basis of known γ-lines [9] in the EC,β^+ decay of ^{120}I (82 min). The growth and decay of this activity was followed for some hours; a consistent analysis of the data could, however, only be obtained by assuming that the intermediate ^{120}Xe has a half-life of 50 min instead of (40 ± 1) min as given in [10]. The p/α ratio for ^{120}Cs was found to be 0.36 ± 0.10. The proton branching ratio is thus $(7 \pm 3) \times 10^{-8}$.

<u>^{122}Cs.</u> No beta-delayed alphas were observed in a period in which $\simeq 10^{10}$ atoms were collected. Any delayed-alpha branch therefore must be weaker than 2×10^{-9}.

This experiment conclusively proves the existence of sizeable beta-delayed α branches in $^{118,120}Cs$. In a previous paper [2] we have shown how the α intensity (in the ^{181}Hg case) could be used to estimate the α strength function in the region of the α-emitting excited levels. A similar analysis for the caesium isotopes should await more data on spins and branching ratios (α and p) to final states. It may, however, be of interest to point to a possibly important difference between the mercury and caesium cases. While the total level widths for the former are dominated by the (non-fluctuating) gamma widths, one expects for the case of ^{118}Cs that the proton widths will dominate and that this will lead to important fluctuation corrections [11,12] to the calculated intensities. Thus, for the simplified case where protons and α's decay through only one channel each, and where the widths are, in the ratio $\Gamma_p/\Gamma_\alpha = X$, one calculates [13] an α branch of $(1 + X^{\frac{1}{2}})^{-1}$.

The present work represents a first result of the successful reconstruction and upgrading of the CERN Synchro-cyclotron; the authors would like to express their gratitude to the head of the Synchro-Cyclotron Division, Dr. E.G. Michaelis and to his collaborators. The new ISOLDE has benefited from contributions from many members of the Collaboration but is above all a result of the effort and skill of E. Kugler, H. Ravn, S. Sundell, L. Westgaard and the technical staff. One of us (P.T-P.) wishes to thank the Danish Nuclear Research Committee for a grant. The work has been financially supported by the Swedish Atomic Research Council.

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Table 1

Branching ratios for beta-delayed α emission from light Cs isotopes

Isotope	$T_{1/2}$ (sec)	$\frac{\alpha}{\text{dis}}$	$\frac{\text{Delayed p}}{\text{Delayed } \alpha}$
^{118}Cs	16.4 ± 1.2 [a)]	$(2.4 \pm 0.4) \times 10^{-5}$	16 ± 1
^{119}Cs	37.7 ± 1.0 [a)]	$< 2 \times 10^{-8}$	-
^{120}Cs	58.3 ± 1.8 [a)]	$(2.0 \pm 0.4) \times 10^{-7}$	0.36 ± 0.10
^{122}Cs	21.0 ± 0.7 [b)]	$< 2 \times 10^{-9}$	-

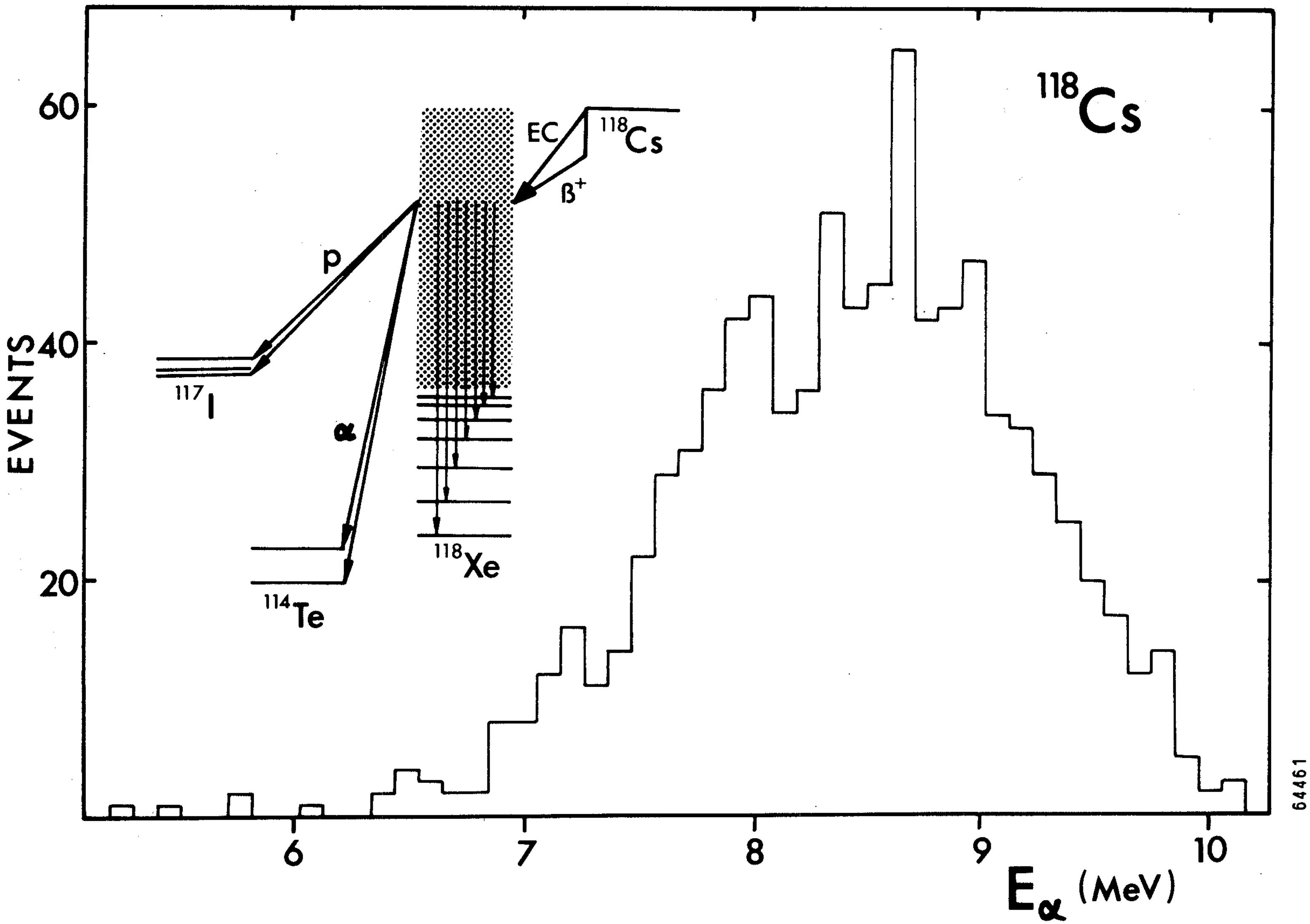
a) Ref. [5].

b) Ref. [4].

Figure captions

Fig. 1 : Beta-delayed α spectrum from ^{118}Cs. The spectrum represents the sum of results from three different runs. The telescope detector, consisting of a 27 μm, 100 mm^2 ΔE detector and a 500 μm, 450 mm^2 E detector, subtended a solid angle of 10.5% of 4π. The system resolution in these experiments corresponds to a FWHM of 55 keV for a monoenergetic α line. The inset shows a schematic representation of the ^{118}Cs decay.

Fig. 2 : Beta-delayed α spectrum from ^{120}Cs. The spectrum represents the sum of results from two different runs. The detector telescope used here was the same as for ^{118}Cs (see caption to fig. 1).



118Cs
EC
118Cs
β+
p
117I
α
114Te
118Xe
EVENTS
60
40
20
6
7
8
9
10
Eα (MeV)
64461

Fig. 1

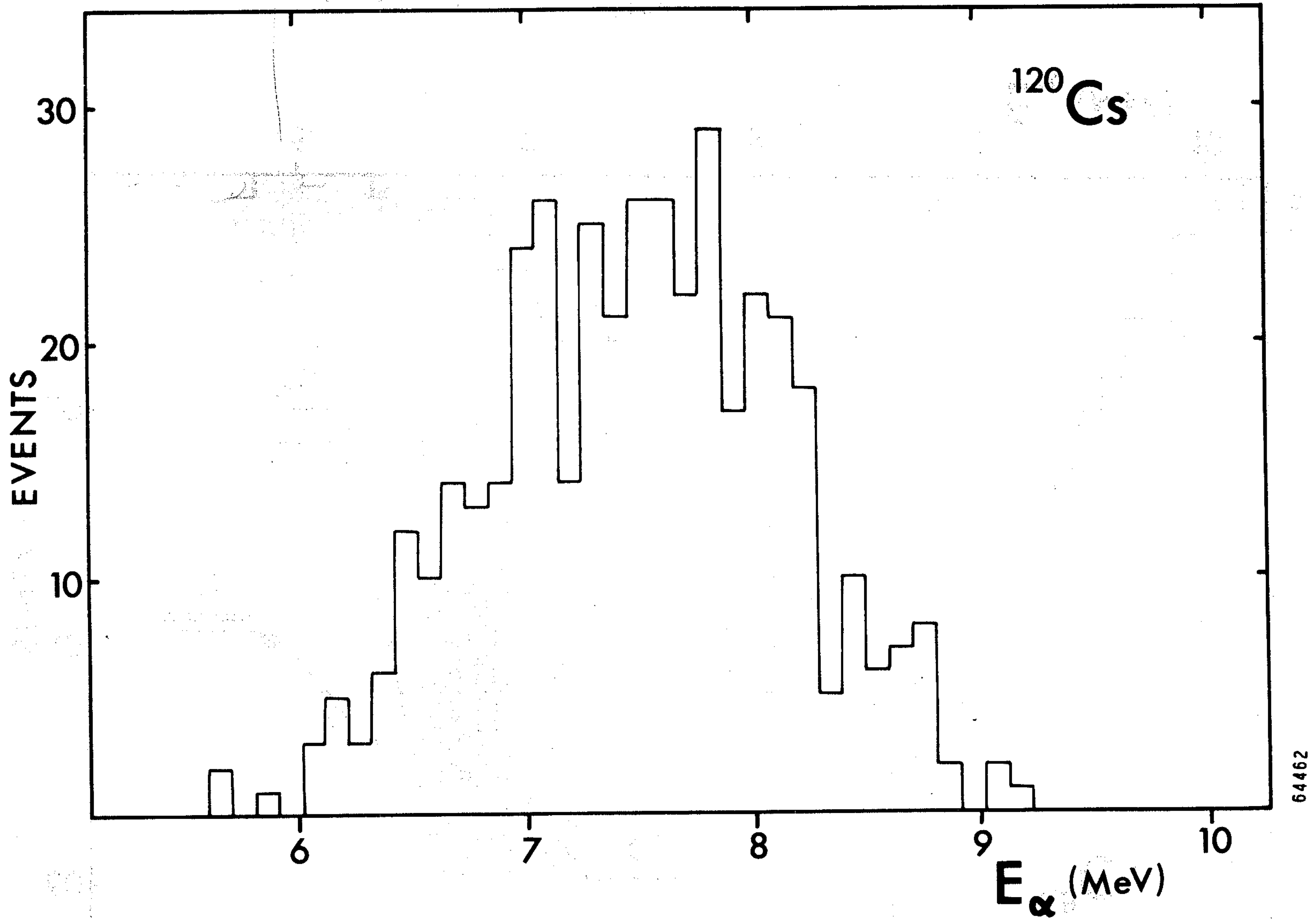


Fig. 2