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THE MUON CAPTURE RATE IN ^{232}Th AND ^{238}U STUDIED IN THE FISSION MODE

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ABSTRACT

The muon lifetime has been measured in the fission mode for muons captured in natural thorium and uranium. The results obtained are the following: $\tau_\mu(^{232}\mathrm{Th}) = 77.3 \pm 0.3$ ns and $\tau_\mu(^{238}\mathrm{U}) = (77.1 \pm 0.2)$ ns.

The results agree within the errors with values previously reported for the fission mode.

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Results from measurements[1-9] on the μ^- capture rate for actinide nuclei are, in general, compatible with the predictions of the Primakoff formula. It is, however, striking that their internal consistency is not very good (table 1). This fact has stimulated speculations that the measurements are not equivalent, either because the measured distributions also reflect other phenomena than simply the fate of the muon[10], or because they are due to muon capture not only on the target nucleus but also on fragments coming from prompt fission following nuclear excitation caused by muonic radiationless transitions[11]. It is evident from the table that in order to determine if the observed differences are significant, one has to improve considerably on the accuracy of the measurements.

It is also clear that such an improvement is most easily achieved by a measurement in the fission mode, for the following reasons:

1) much lower constant background of uncorrelated events, and
2) the absence of primary exponential background (long components), inherent in the measurements with e and γ registration. This type of background in the fission mode would come only from secondary processes (fission induced by neutrons emitted after muon absorption in light elements).

We report here on measurements performed with a multi-plate fast ionization chamber[12], used as target and fission detector. It obtained 100 aluminium foils forming the electrodes, with the fissile target material (natural thorium and uranium) deposited onto them. In both cases there was a total of 25 g of target material, with a thickness along the beam of about 600 mg/cm^2. A conventional counter telescope detected muons entering the target. To keep the background constant and low, events where two muons came too close together in time (± 10 μsec) were rejected.

The time distributions of fission events relative to the time of the μ-stop were measured with a time-to-digital converter (TDC). The error of the TDC calibration (performed using HP Electronic Counter type 5345 A) was estimated to be 2×10^{-4} and found negligible in comparison with other errors. The measured differential non-linearity (slope) was equal to $-(2.5 \pm 0.6) \times 10^{-5}$/ch, which introduces an uncertainty of the order 10^{-3} in our lifetime measurement.

The measured distributions were analysed using standard least square methods[13]. An exponential function with constant background was fitted to our results. The fitting was performed with two parameters (background equal to the one measured for negative times in the distributions) or with three parameters. Within the calculated errors, there was no difference between the values obtained for the parameters with the two methods. This also implies that the systematic error due to background from secondary processes is covered by the quoted errors. Therefore, for the final analysis we chose the two-parameter search with the background as measured.

In order to investigate the possibility of the presence of a short component in the measured time distributions, suggested by our own more extensive time correlation studies[14], the analysis was carried out for four different time intervals in the ^{238}U distribution: from +5, +18, +30, and +50 ns up to +345 ns. Evidently there is a trend in the resulting mean lifetime values, which for example in one of the measured distributions, grow from (76.30 ± 0.14) ns for 5 ns, through (76.82 ± 0.16) ns for 18 ns, up to (77.30 ± 0.18) ns for 30 ns. There is no difference between 30 ns and 50 ns, whereas the difference between 5 ns and 30 ns is (1.0 ± 0.25) ns.

Thus in order to make sure that we are not disturbed by a possible short component, we have chosen the results of the fit beginning from +30 ns shown in the table together with previously published data. In fig. 1 the measured time distributions and the resulting fits are shown.

There is an evident difference between the result of Kaplan et al.[8] and the current one for ^{238}U. On the other hand, the observed lifetime dependence on the fitted interval seems to indicate the presence of a short component in the measured (μ,f) distributions.

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Table 1

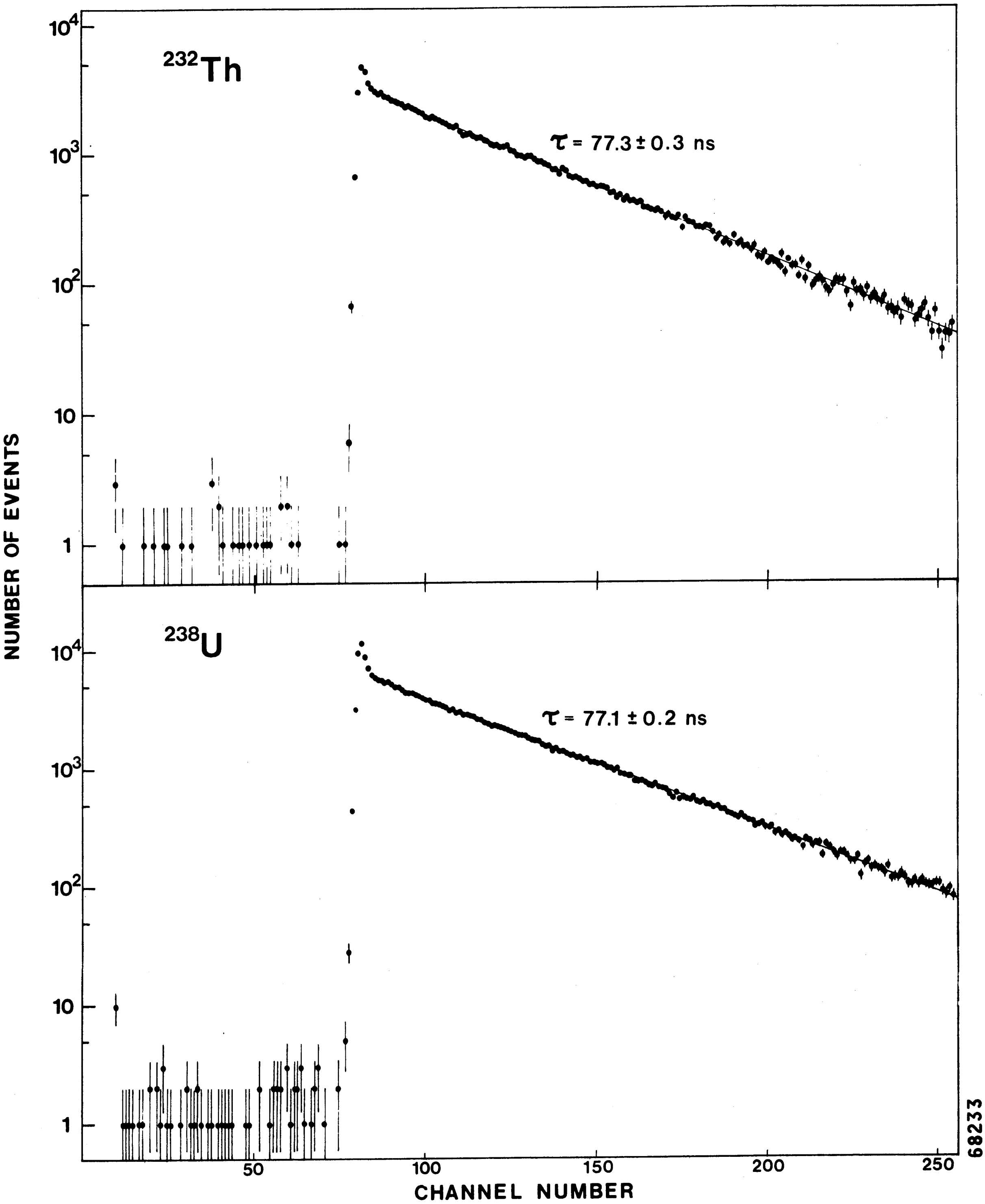
The muon capture mean lives for ^{232}Th and ^{238}U

Mode of registration	Mean lives τ_{μ}(ns)		Ref.
	^{232}Th	^{238}U	
e		88.0 ± 4	1
f	74.2 ± 5.6	75.6 ± 2.9	2
f		74.1 ± 2.8	3
f	87 ± 4	76.0 ± 1.0	4
f	84.0 ± 4.5		5
e	80.4 ± 2.0	81.5 ± 2.0	6
e	79.2 ± 2.0	73.5 ± 2.0	7
γ		79.1 ± 0.5	8
γ		78.6 ± 1.5	9
f	77.3 ± 0.3	77.1 ± 0.2	This work[a)]

a) Quoted results are means of several measurements, where in each case the distributions were fitted in the interval +30 ns to +345 ns.

Figure caption:

Fig. 1 : Time distributions of fission events relative to the time of the μ-stop for a) ^{232}Th and b) ^{238}U. One channel corresponds to 1.92 ns. The resulting mean lifetimes were obtained by fitting the experimental data in the time interval +30 ns to +345 ns.



NUMBER OF EVENTS
^{232}Th
τ = 77.3 ± 0.3 ns
^{238}U
τ = 77.1 ± 0.2 ns
10^4
10^3
10^2
10
1
50
100
150
200
250
CHANNEL NUMBER
68233

Fig. 1