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MEASUREMENT OF THE LIFETIME OF NEUTRAL CHARMED MESONS

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ABSTRACT

The lifetime of neutral charmed particles photoproduced in emulsion has been measured. The lifetime value presented here was obtained from a sample of 22 D^0 mesons, 18 of which have their charmed partner seen in emulsion. The sample is essentially background-free. The result obtained is

$$\tau_{D^0} = (2.11 {}^{+1.21}_{-0.63})\, 10^{-13}\, s.$$

The D^0 mass derived from 8 3C events is $m_{D^0} = 1856 \pm 36$ MeV/c^2.

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In the last years, different experiments have been performed to measure the lifetime of neutral D particles. Different beams were used: neutrino [1], hadron [2], and photon [3].

In this paper we present a sample of 22 neutral charmed-meson decays and give results on the lifetime estimate. The charmed particles are produced in photohadronic interactions with the emulsion nuclei.

Information on data-taking, scanning procedure, and event selection for experiment WA58 at CERN is given in the paper on the charged charmed-particle lifetime [4].

In order to find V^0-like decays (i.e. neutral charm-decay candidates), a volume scanning has been performed inside an angular region of $\pm 15°$ around the beam direction. The volume scanning has been done for primary events having at least one of the following characteristics:

i) one charm candidate already found;

ii) in the primary star, not all the tracks reconstructed by the TRIDENT program have been found.

All neutral secondary events with no visible recoil and an even number of minimum ionizing tracks are taken as candidates.

To avoid contamination due to electron pairs and to the few expected K^0_S or Λ^0 decays, we calculate the invariant mass of the events, assuming that they are (e^+e^-), or ($\pi^+\pi^-$), or ($p\pi^-$). If the mass is $m_{e^+e^-} < 0.1$ GeV/c^2, or $0.47 < m_{\pi\pi} < 0.53$ GeV/c^2, or $1.09 < m_{p\pi} < 1.15$ GeV/c^2, the event is rejected. Furthermore, in our sample the expected number of neutral secondary interactions simulating a charmed decay is estimated to be 0.1; so we accept a neutral candidate as a good one even if it is single, i.e. no charmed partner has been seen, if the event is not rejected by the above-mentioned checks.

The invariant mass of the charm candidate is computed, taking into account all possible decay modes compatible with its topology and with particle identification if any. If no 3C hypothesis succeeds, an unseen neutral particle is added. All the allowed 0C solutions have been taken into account. If in the 0C hypothesis the solution giving the highest momentum is not compatible with the over-all event energy, an upper limit compatible with it was imposed. For the 0C-fitted events, we attribute to the charmed particle a proper time that is the mean of the times corresponding to the allowed momenta.

Table 1 contains the 22 neutral mesons selected in the above-mentioned way. The list gives the decay length and the potential length*), the decay hypothesis, the charm momentum, the proper time, and the mass value in case of a 3C fit. Charged particles with unambiguous mass assignment are underlined, whilst undetected neutral particles are in brackets. Only for three neutral D's has the charmed partner not been seen.

The scanning efficiency for neutral secondary events is decreasing with the distance from the primary star. To evaluate the behaviour of the efficiency function, a volume scanning has been performed to find electron pairs from π^0 gamma conversion inside the emulsion, having an opening angle greater than 0.5° pointing to the interaction vertex and produced in a region of $\pm 15°$ around the beam direction. Despite the somewhat different topology, it seems reasonable to assume the same scanning efficiency for neutral charm decays. Each laboratory of the collaboration has determined its own efficiency as a function of the distance from the primary star and up to the maximum distance in which the volume scanning was performed. The efficiency curves can be fitted by a function of the type $\varepsilon(\ell) = \exp(-A\ell^2)$. In fig. 1, one of the experimental distributions is shown as an example. The efficiency function was folded in the likelihood function as follows:

$$L = \prod_{i=1}^{N} [\varepsilon_i(t) \exp(-t_i/\tau) / \int_{t_{i_{min}}}^{t_{i_{max}}} \varepsilon_i(t) \exp(-t_i/\tau)\, dt],$$

where $t_{i_{min}}$ and $t_{i_{max}}$ are the times corresponding to the minimum detectable length and to the potential length. The minimum length has been set at 20 μm except for event No. 21, where clear large-angle V^0 decay appears at a distance of 12 μm. The value which maximizes the L function is

$$\tau_{D^0} = (2.11 {}^{+1.21}_{-0.63}) \times 10^{-13} \text{ s}.$$

To evaluate the influence of the double solution events, the lifetimes have been calculated using all the minimum and all the maximum proper times. The resulting values are 1.4 and 2.9 $\times$ 10^{-13} s, respectively.

The D^0 rest mass in our sample turns out to be

$$m_{D^0} = 1856 \pm 36 \text{ MeV}.$$

In the other paper [4] we have presented the lifetime of charged D mesons and Λ_c^+ baryons:

$$\tau_{D^\pm} = (3.91 {}^{+2.35}_{-1.25}) \times 10^{-13} \text{ s}$$

and

$$\tau_{\Lambda_c^\pm} = (2.22 {}^{+1.34}_{-0.75}) \times 10^{-13} \text{ s}$$

were the results obtained.

The lifetime ratio turns out to be

$$\tau_{D^\pm}/\tau_{D^0} = 1.85 {}^{+1.54}_{-0.81},$$

in good agreement with the world average, as well as the Λ_c^+ lifetime value [5].

The $D^\pm$ and D^0 lifetimes appear to be lower than the world values. The differences may be attributed to the large errors still inherent in the present experiments devoted to measurements of charm lifetime.

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*) The potential length is the maximum scanning distance for the event or the available path in the emulsion, if lower.

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Table 1

	Decay length (μm)	Potential length (μm)	Hypothesis	p (GeV/c)	t (10^{-13} s)	Mass (MeV/c^2)	Partner
1	122.7	1000	$\bar{D}^0 \to \underline{K}^+\pi^+\pi^-\pi^-$	33.78	0.23	1870 ± 8	(a)
2	267	2000	$D^0 \to \pi^+\pi^-(\bar{K}^0)$ $D^0 \to \pi^+K^-(\pi^0)$	22.29–36.50 20.43–36.50	0.60 0.63		D^-
3	600	958	$\bar{D}^0 \to K^+\pi^-(\pi^0)$ $\bar{D}^0 \to \pi^+\pi^-(K^0)$	11.77–21.30 12.30–25.40	2.46 2.25		D^0
4	160	1089	$D^0 \to K^-\pi^+\pi^0$	17.55	0.57	1818 ± 104	$\bar{D}^0$
5	495	2000	$D^0 \to \pi^+\pi^-(\bar{K}^0)$ $D^0 \to \pi^+K^-(\pi^0)$	11.65–20.89 10.46–15.74	2.06 2.45		D^-
6	124	500	$\bar{D}^0 \to K^+\pi^+\pi^-\pi^-$	8.96	0.86	1844 ± 22	Λ_c^+
7	285	2000	$\bar{D}^0 \to \underline{\pi}^+\underline{\pi}^-(K^0)$	25.99–41.35	0.55		(a)
8	87	914	$\bar{D}^0 \to K^+\pi^+\pi^-\pi^-\pi^0$	14.80	0.37	1831 ± 31	D^+/Λ_c^+
9	239	500	$\bar{D}^0 \to \pi^+\underline{\pi}^-K^0(\pi^0)$	13.16–22.70	0.90		D^+
10	236	2000	$\bar{D}^0 \to K^+\pi^-(\pi^0)$ $\bar{D}^0 \to \pi^+\pi^-(K^0)$ $\bar{D}^0 \to \pi^+\pi^-\pi^0(K^0)$	6.25–16.75 6.72–16.75 14.81–16.75	1.61 1.53 0.93		Λ_c^+
11	279	1558	$\bar{D}^0 \to K^0\pi^+\pi^-(\pi^0)$	5.77–6.04	2.93		Λ_c^+
12	123	409	$\bar{D}^0 \to K^0\underline{\pi}^+\pi^+\pi^-\pi^-$	19.11	0.40	1887 ± 44	D^0
13	252	725	$D^0 \to \underline{K}^-\pi^+(\pi^0)$	15.43–25.29	0.82		$\bar{D}^0$
14	275	500	$\bar{D}^0 \to \underline{K}^+\pi^-(\pi^0)$	11.48–13.79	1.36		D^+/Λ_c^+
15	45,4	2000	$\bar{D}^0 \to K^+\pi^+\pi^-\pi^-$	19.93	0.14	1919 ± 42	D^0
16	623	2000	$D^0 \to \bar{K}^0\pi^-e^+(\nu)$	5.45–12.23	5.14		$\bar{D}^0$
17	498	1414	$\bar{D}^0 \to \underline{K}^+\underline{\pi}^-(\pi^0)$	15.87–21.10	1.71		Λ_c^+
18	23	500	$\bar{D}^0 \to K^+\underline{\pi}^-\pi^0$	37.65	0.04	1814 ± 139	Λ_c^+
19	330	424	$\bar{D}^0 \to K^+\pi^-(\pi^0)$ $\bar{D}^0 \to \pi^+\pi^-(K^0)$	4.55–8.36 5.04–10.28	3.48 3.03		D^+
20	32,5	1225	$D^0 \to \bar{K}^0\pi^+\pi^-(\pi^0)$	10.71–11.69	0.18		(a)
21	12	2000	$\bar{D}^0 \to \pi^+\pi^-K^0$	5.24	0.14	1867 ± 21	(a)
22	181	2000	$D^0 \to \pi^+\pi^-(\bar{K}^0)$	3.92–6.00	2.37		(b)

a) Charmed partner not seen.
b) V^0 under study.

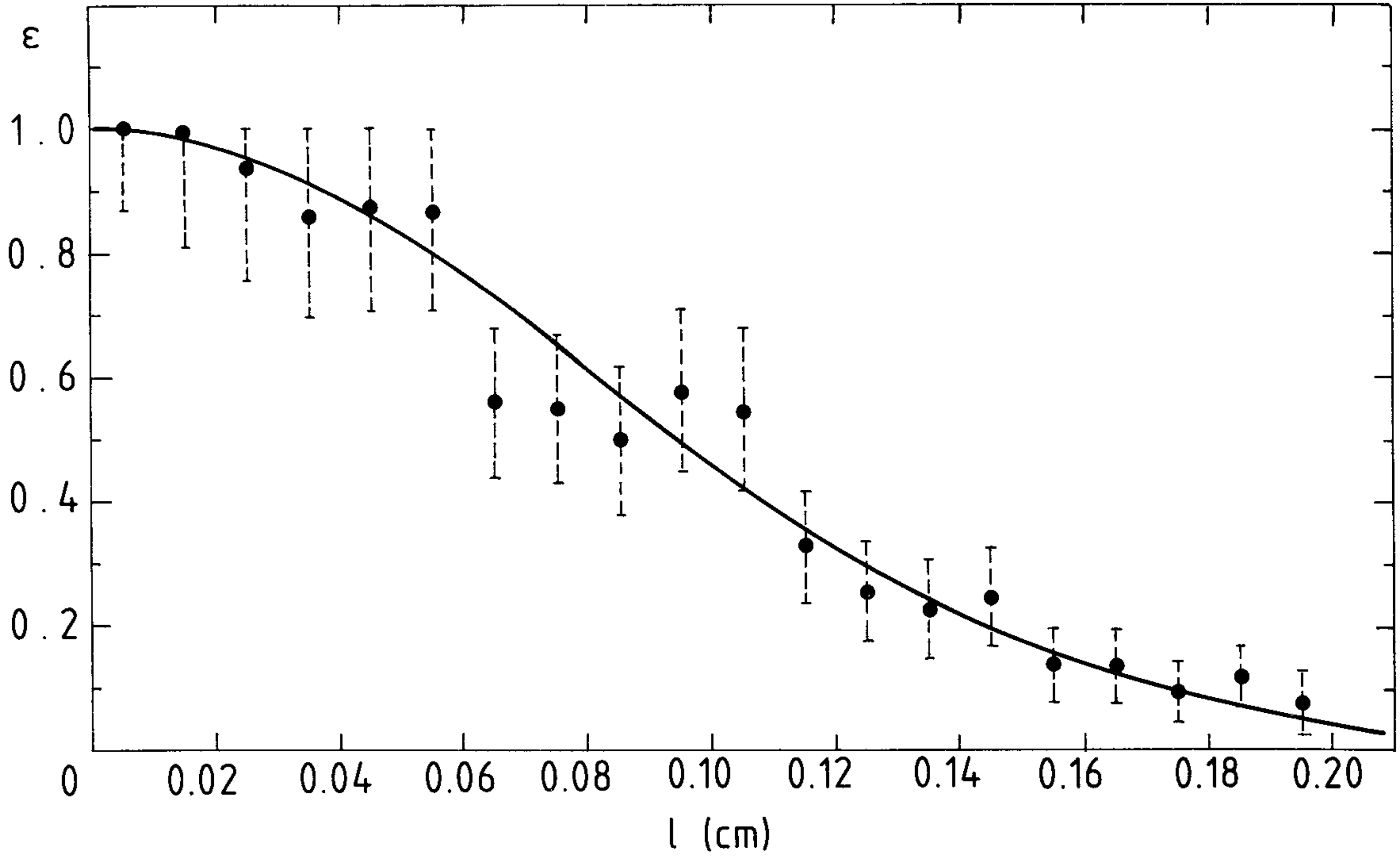

Fig. 1