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MEASUREMENT OF THE D_s^+ LIFETIME*

by

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ABSTRACT

We have observed 99 decays of the charmed strange meson, the D_s^+ (formerly called the F^+), into the $\phi\pi^+$ (61) and $\overline{K}^{*o}K^+$ (38) final states in the Fermilab photoproduction experiment E-691. We determine the lifetime to be $(.48^{+.06}_{-.05} \pm .02) \times 10^{-12}s$. Using our reported measurement of the D^o lifetime, we calculate the ratio $\tau(D_s^+)/\tau(D^o) = (1.10 \pm .15 \pm .04)$.

Key-words: Hadronic decays of mesons; Mesons and meson resonances.

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For some time it has been known that the D^+ lifetime is much longer than that of the D^o.[1] We recently published measurements of the D-meson lifetimes with the result $\tau(D^+)/\tau(D^o) = (2.44 \pm .14 \pm .08)$.[2] Many models, with quite different hypotheses, have been proposed to explain this large ratio. As the authors of those models point out, an important experimental test is a precise measurement of the lifetime of the D_s^+.[3] This paper presents results from the analysis of the D_s^+ lifetimes in E-691, a photoproduction experiment using the Fermilab Tagged Photon Spectrometer.

The TPS is a two-magnet spectrometer of large acceptance, with silicon microstrip detectors (SMD's), drift chambers, Cerenkov counters, and electromagnetic and hadronic calorimeters. The apparatus for this experiment has been described elsewhere.[4] The trigger required a total transverse energy (E_T) in the calorimeter of at least 2.2 GeV. The incident photon energy spectrum had approximately a bremsstrahlung form from $100 - 260$ GeV. The present results are based on an analysis of 45 million events, from a total sample of 100 million.

The analysis follows that used for the D-meson lifetimes.[2] Events were chosen which had three particles satisfying the particle identification assignment $K^+K^-\pi^+$. (Throughout the paper, the charge conjugate states are implicitly included.) We required the three charged tracks to form a good vertex, and the line of flight of the reconstructed charm candidate to pass within 75 μm of a reconstructed primary vertex candidate. Candidates which decayed at least a distance L downstream of the primary vertex were selected for the lifetime sample. The distance L was $6 - 10\sigma$, depending on decay mode, where σ is the error on the distance between primary and secondary vertices. The value of σ is typically $300\mu m$ for the average D momentum of 60 GeV/c. In the 20% of the events with multiple primary vertex candidates, L was calculated from the most downstream candidate, to be sure that it was downstream of any possible production point. The proper time was calculated from separation between the point a distance L downstream of the primary vertex and the location of the decay vertex. The fiducial region for decays was defined to end at the first SMD plane. We used only events for which the proper time corresponding to a decay at the end of this region, t_{max}, was greater than the maximum time used in the fit ($2.4ps.$).

The function

$$N \times f(t) \times 1/\tau \exp(-t/\tau) + B(t)$$

was used to fit the proper time distribution. In this expression $B(t)$ is the normalized time distribution for the background, as determined from the regions of the mass plot excluding the D^+ and D_s^+ region. The two parameters allowed to vary in the fit were N, the number of events in the charm signal, and τ, the charm lifetime. The function, $f(t)$, which was obtained from the Monte Carlo, corrects for effects of absorption, acceptance, resolution and efficiency.

For the lifetime analysis, we used only those events consistent with one of the two decay modes,

(A) $D_s^+ \rightarrow \phi\pi^+$ and

(B) $D_s^+ \rightarrow \overline{K}^{*o} K^+$

There are no events in common, since the two hypotheses are incompatible. For channel (A) we required the K^-K^+ mass to be in the interval 1.012 – 1.027 GeV/c^2. The angular distribution for the decay $\phi \rightarrow K^-K^+$ must be $dN/d(\cos\theta) = A\cos^2\theta$ where θ is the angle between the K^- and π^+ in the ϕ rest frame. We required $|\cos\theta| > 0.3$, which keeps 0.97 of the signal and 0.70 of the background. The minimum decay length chosen for this mode was $L = 6\sigma$. For channel (B) we required the $K^-\pi^+$ mass to be in the interval 0.845 – 0.945 GeV/c^2. This range misses some of the K^* events but minimizes the background. A minimum decay length of $L = 10\sigma$ was used in this channel. The requirement $|\cos\theta| > 0.3$ was also applied, where θ is the decay angle in the K^* rest frame.

The mass distributions for both channels are shown in Fig. 1. In each spectrum there are clear peaks for the D_s^+ decay and for the Cabibbo-suppressed D^+ decay.[5] The time distributions for events in the mass region 1.953 – 1.985 GeV/c^2 are shown in Fig. 2. There are 61 $D_s^+ \rightarrow \phi\pi^+$ decays and 38 $D_s^+ \rightarrow \overline{K}^{*o}K^+$ decays; the expected number of background events, as determined from the regions outside the D_s^+ and D^+, are 21 ± 3 and 15 ± 3 events respectively. The maximum likelihood fit gives a lifetime of $.49^{+.08}_{-.07}$ ps for channel (A) and $.46^{+.10}_{-.08}$ ps for channel (B). A joint fit to both distributions gives our best value for the D_s lifetime, $\tau(D_s^+) = (.48^{+.06}_{-.05} \pm .02)$ ps. The effect of including $f(t)$ in the fit was to shift the lifetime by $-.05$ ps, with an associated systematic error of $\pm.017$ ps. The systematic error due to the background subtraction is $\pm.012$ ps. The problem of $D^+ \rightarrow K^-\pi^+\pi^+$ or $\Lambda_c^+ \rightarrow pK^-\pi^+$ decays feeding into the D_s^+ sample is much reduced by using only the K^*K and $\phi\pi$ regions. Extensive studies using data and Monte Carlo events show that the number of events from both sources is about one event. Even this effect is reduced by the background subtraction, and the resulting contribution to the systematic error is negligible.

The D_s^+ lifetime we measure is almost twice as long as the published world average of $(.28^{+.16}_{-.07})$ ps.[6] Recent measurements are $.26^{+.16}_{-.09}$ ps,[7] $.35^{+.25}_{-.19}$ ps,[8] and $.36^{+.11}_{-.07}$ ps,[9] all of which are consistent with our result. For best comparisons with theoretical models of lifetimes and partial decay widths, the ratios of lifetimes are needed. Using our measurement of the D^o lifetime, $(.435 \pm .015 \pm .010)$ ps, we calculate $\tau(D_s^+)/\tau(D^o) = (1.10 \pm .15 \pm .04)$. Because the measurements were made in the same experiment with similar analyses, the systematic errors are small. Within the (mostly statistical) errors, the D_s^+ lifetime is consistent with the D^o lifetime, and a factor of two smaller than the D^+ lifetime, $(1.06 \pm .05 \pm .03)$ ps.

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FIGURE CAPTIONS

Fig. 1 Invariant mass spectra for two D_s^+ channels with vertex cuts as described in the text. (a) $D_s^+ \rightarrow \phi\pi^+$, $\phi \rightarrow K^+K^-$ and (b) $D_s^+ \rightarrow \overline{K}^{*o}K^+$, $\overline{K}^{*o} \rightarrow K^-\pi^+$.

Fig. 2 Proper time spectra for the two D_s^+ samples, in the same order as for Fig. 1. The data points are shown with background subtracted. The error bars represent the statistical error, including that on the background. The smooth curve follows the best fit as described in the text.

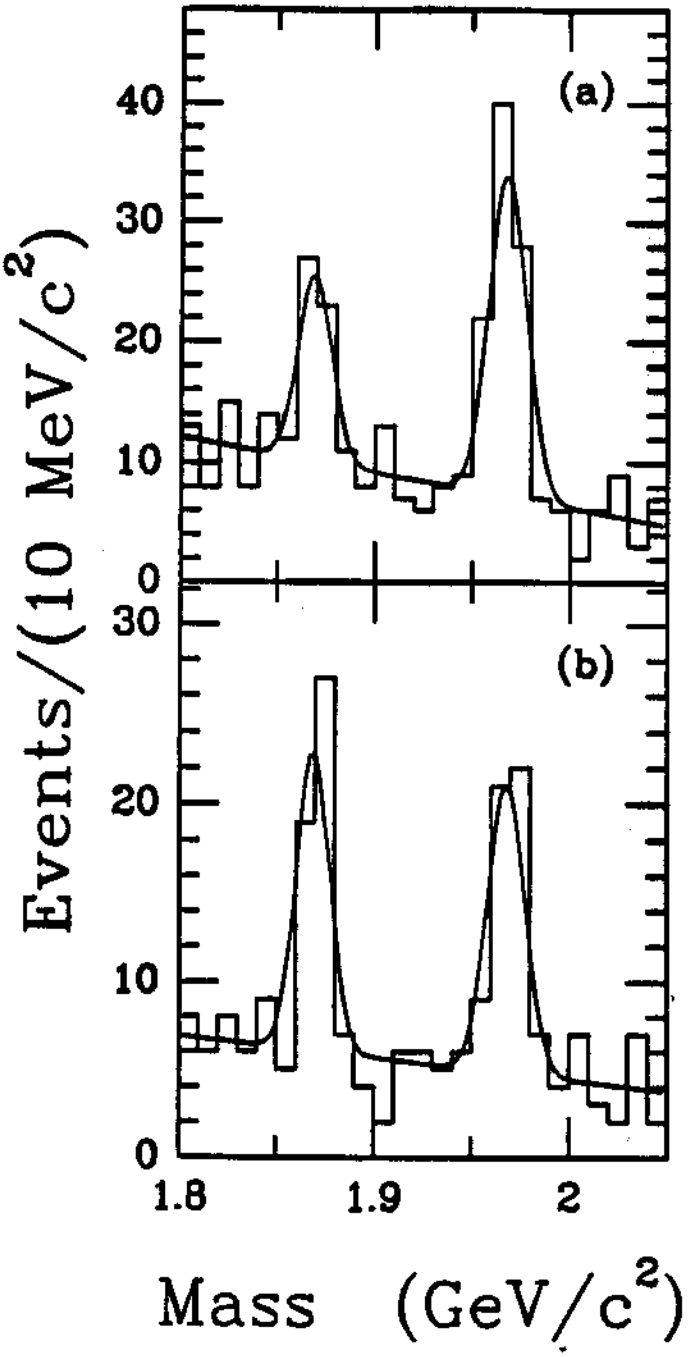

Fig. 1

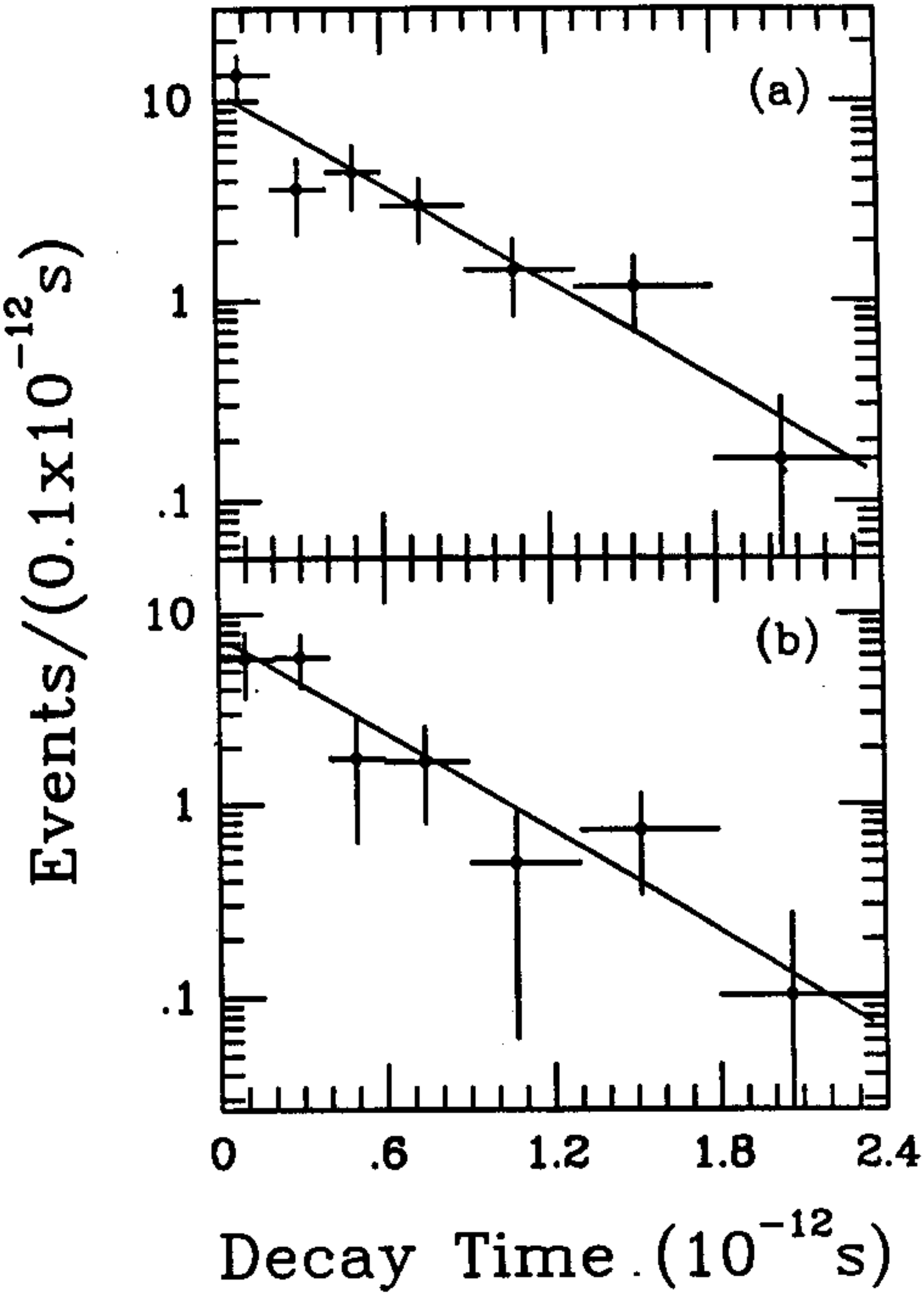

Fig. 2

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