

Measurement of the Λ_c^+ Lifetime*

The Tagged Photon Spectrometer Collaboration

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ABSTRACT

We observe 97 decays of the charmed baryon, the Λ_c^+ , into a $pK^-\pi^+$ final state in the Fermilab photoproduction experiment E-691. The mass is measured to be $2286.2 \pm 1.7 \pm 0.7$ MeV/ c^2 . The position of the production and decay vertices are reconstructed with the use of a silicon microstrip vertex detector. From these measurements, we determine the lifetime of the Λ_c to be $(.22 \pm .03 \pm .02) \times 10^{-12}$ s.

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The properties of charmed baryons have not been well determined. Past measurements of the Λ_c lifetime^{1,2} suggest a higher hadronic decay rate than for charmed meson states. A W -exchange mechanism allowing $cd \rightarrow su$ could account for this increased rate.³ The usual helicity suppression inhibiting this mechanism in mesons can be relieved by the presence of the extra quark in this baryon state. This paper presents a measurement of the Λ_c^+ lifetime from E-691, a photoproduction experiment using the Fermilab Tagged Photon Spectrometer (TPS). The analysis is similar to that used for our previously reported measurements of the D^0 , D^+ , and D_s^+ lifetimes.^{4,5}

The TPS is a large acceptance two-magnet spectrometer equipped with silicon microstrip detectors (SMD's), drift chambers, Čerenkov counters, and electromagnetic and hadronic calorimeters. The spectrometer has been described elsewhere.⁵ A 90 – 260 GeV bremsstrahlung photon beam (the average photon energy is 145 GeV) is directed into a 5 cm long beryllium target. The photoproduced charm states are detected and their decays reconstructed. The trigger requires a total transverse energy deposition in the calorimeters of at least 2.2 GeV and is highly efficient for charm. The present results are based on an analysis of our total data sample of 100 million events.

To extract the lifetime of the Λ_c we use those decays identified as $\Lambda_c^+ \rightarrow pK^-\pi^+$ and its charge conjugate. Events are selected on the basis of Čerenkov identification probabilities and vertex information. Combinations of three particles satisfying a joint $pK^-\pi^+$ Čerenkov particle identification probability of 50% or greater are selected. This requirement minimizes confusion from D^+ and D_s^+ decays in which one of the decay products is misidentified. We demand that the three charged tracks form a good vertex and that the line of flight of the reconstructed charm candidate pass within 80 μm of a reconstructed primary vertex candidate. The primary interaction vertex is required to lie within the beryllium target and the secondary decay vertex must be located before the first SMD plane. Charm candidates are selected from events in which the secondary decay

vertex is located at least a distance L_{min} downstream of the primary vertex position. The distance L_{min} chosen for this analysis is 8σ , where σ is the error (typically $300 \mu m$) on the distance between the primary and secondary vertices. About 20% of the events have multiple primary vertex candidates. In those cases L_{min} is calculated from the most downstream candidate, to insure that it is downstream of any possible production point and does not modify the exponential decay distribution. An adjusted proper time, $t = T - T_{min}$, is calculated from the point a distance L_{min} downstream of the selected primary vertex position to the observed decay vertex position: $t = (L_{decay} - L_{min})/c\beta\gamma$.

The function

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

is used to fit the adjusted 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 Λ_c^+ mass region. The two parameters allowed to vary in the fit are N , the number of events in the charm signal, and τ , the charm lifetime. The function $f(t)$, the acceptance correction function, is obtained from a Monte Carlo simulation of charm production and the detector. It includes multiple scattering, energy loss, secondary interactions, and the full complement of detector components. The Monte Carlo makes corrections for absorption, acceptance, resolution and efficiency. These corrections produce about a 5% effect on the measured lifetime.

The $pK^-\pi^+$ invariant mass distribution is shown in Fig. 1. A Gaussian fit to the signal and a linear fit to the background yields 97 ± 14 signal events over a background of 91 events. The signal width is consistent with a Monte Carlo signal width of $9.6 \text{ MeV}/c^2$. The fitted mass is $2285.6 \pm 1.7 \text{ MeV}/c^2$. We correct this mass for an observed shift of our measured D^+ mass of $1868.7 \pm 0.3 \text{ MeV}/c^2$ with respect to the reported world average measurement of $1869.3 \pm 0.6 \text{ MeV}/c^2$.¹ The corrected Λ_c mass measurement is $2286.2 \pm 1.7 \pm 0.7 \text{ MeV}/c^2$. The quoted systematic error is dominated by the uncertainty

in the world average D^+ mass.¹

The background subtracted time distribution for events in the mass region 2265.0 – 2305.0 MeV/ c^2 is shown in Fig. 2. The maximum likelihood fit gives a lifetime of $.22 \pm .03$ ps. The lifetime of background events within this region is about .16 ps. Contamination to the $pK^-\pi^+$ from misidentified D^+ and D_s^+ decays is determined to have a negligible effect on the observed lifetime ($+.005 \pm .005$ ps). Positive Čerenkov identification of the proton and kaon candidates practically eliminates this source of contamination. The effect of including $f(t)$ in the fit is to shift the lifetime by $-.01$ ps, with an associated systematic error of $\pm .01$ ps. The systematic error due to the background subtraction is estimated to be $\pm .02$ ps. In quadrature these errors contribute $\pm .02$ ps to the systematic error. All other variations of the lifetime are consistent with statistical fluctuations. The final measurement of the Λ_c lifetime is $.22 \pm .03 \pm .02$ ps where the first error is statistical and the second systematic.

This measured lifetime agrees with the reported world average of $(.23_{-.05}^{+.08})$ ps¹ and with more recent measurements.⁶ With this statistically improved measurement we determine the ratio of the Λ_c lifetime to the D^0 charmed meson lifetime measured by this experiment⁴ to be: $\tau(\Lambda_c)/\tau(D^0) = .52 \pm .07 \pm .05$. This short charm lifetime supports theoretical notions about its enhanced hadronic decay rate mentioned at the beginning of this paper and contributes to the difficulty in experimental observation of this charmed state.

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FIGURE CAPTIONS

1. $p K^- \pi^+$ mass distribution after analysis cuts. A Gaussian signal and linear background is superimposed.
2. Spectrum of decay time, t , for Λ_c events after background subtraction. The curve represents the best lifetime fit as described in the text.

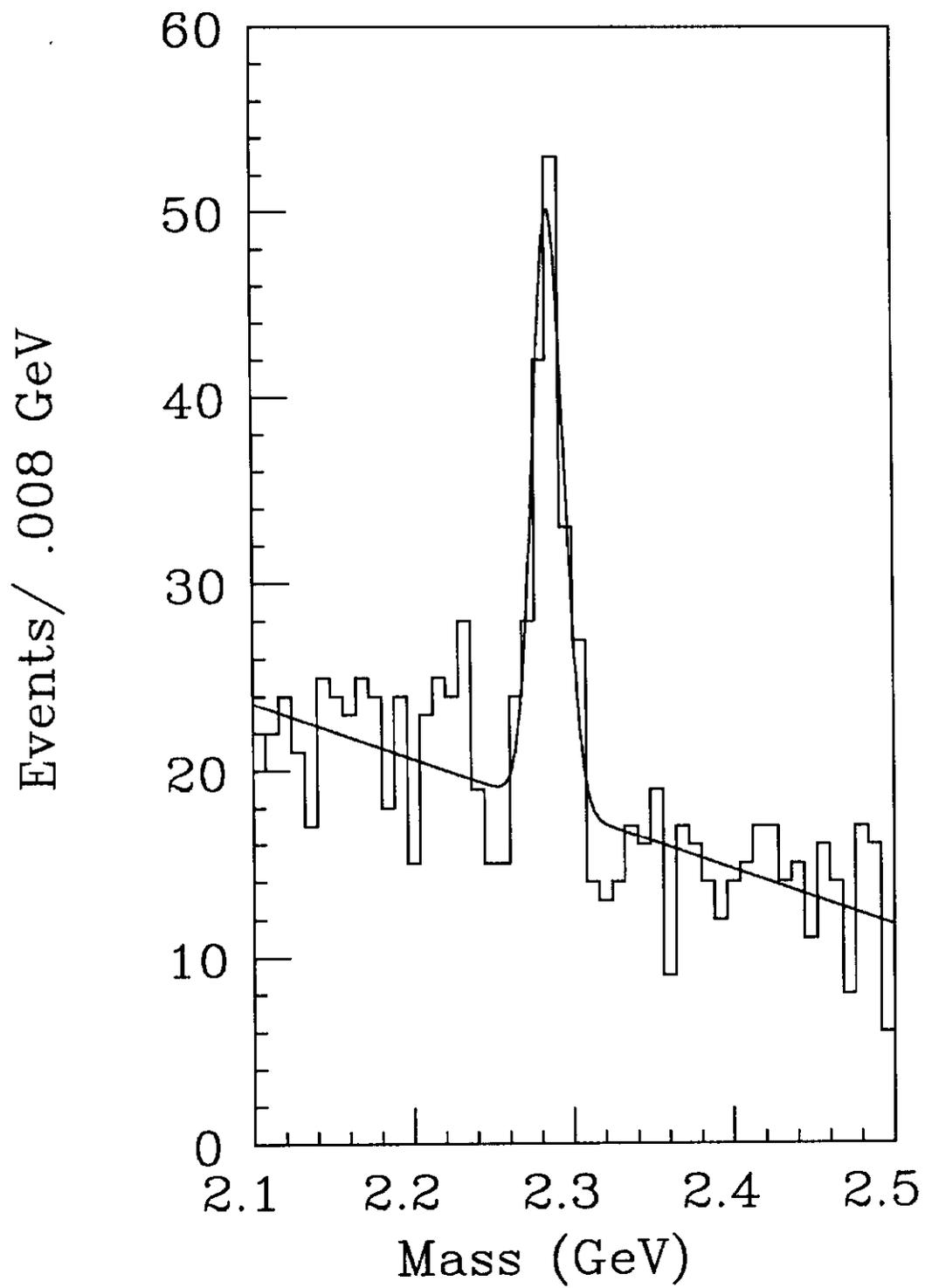


Figure 1

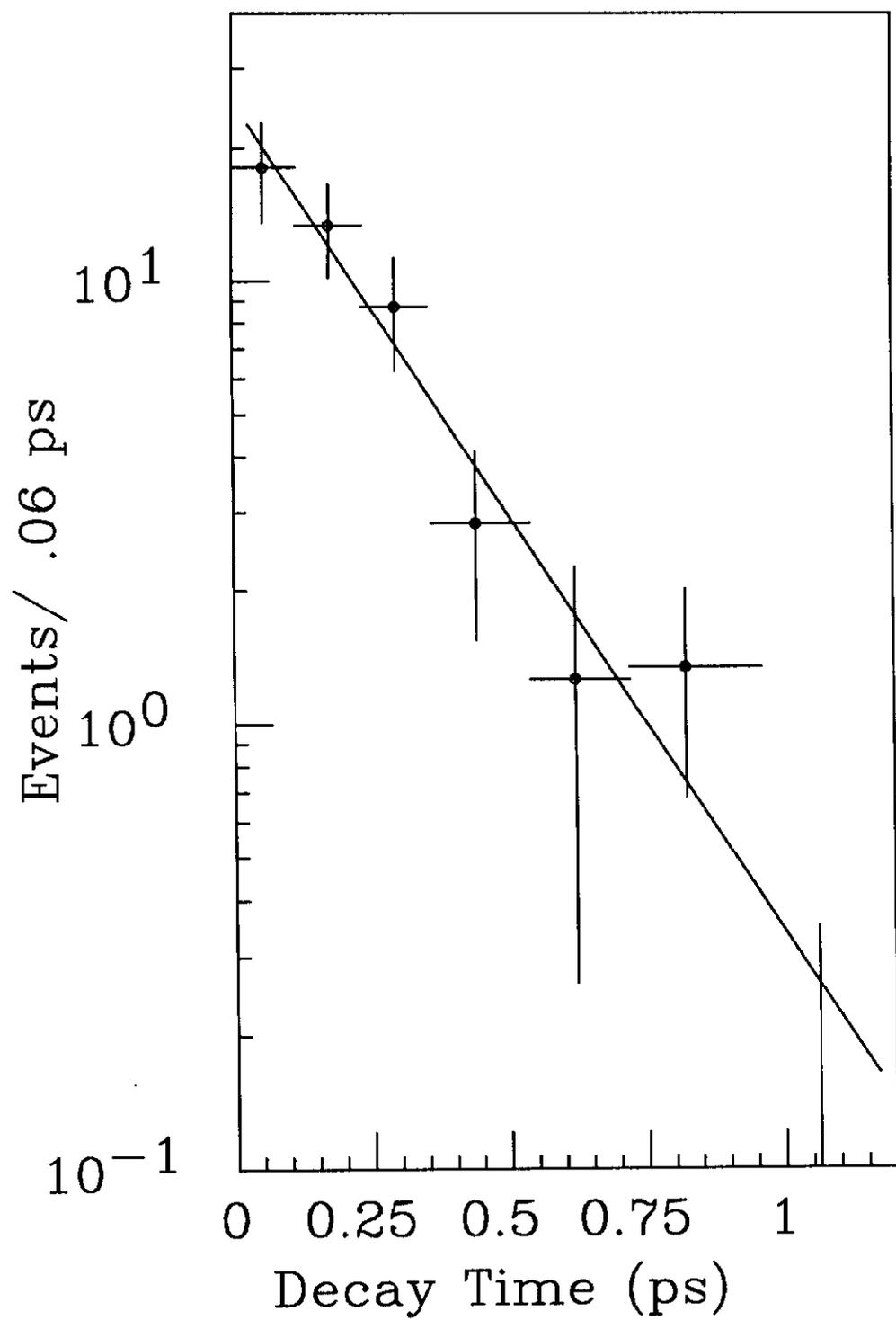


Figure 2