Preliminary Ξ_c^+ Lifetime Measurement from SELEX

U. Akgun (on behaf of the SELEX collaboration)[a]

[a]Department of Physics and Astronomy,
The University of Iowa, Iowa City, IA 52242-1479, USA

We report the results of a new Ξ_c^+ lifetime measurement from hadroproduction data taken by the SELEX (E781) experiment. Fermilab charged hyperon beam (Σ^-, π^- and p) at 600 GeV is used to produce charm particles in Cu and diamond targets. This measurement was made using decays into the $\Xi_c^+ \to \Xi^-\pi^+\pi^+$, $\Xi_c^+ \to p^+K^-\pi^+$, and $\Xi_c^+ \to \Sigma^+K^-\pi^+$ modes. We used binned maximum likelihood method and 301 ± 31 events yield a lifetime of $430 \pm 22 \pm 9$ fs.

1. Introduction and Event Selection

In this report we present the results of a new Ξ_c^+ lifetime measurement from hadroproduction data taken by the SELEX (E781) experiment at Fermilab. SELEX experiment has excellent particle identification capabilities therefore it is very efficient for studying charm baryons decays. Fermilab charged hyperon beam (Σ^-, π^- and p) at 600 GeV is used to produce charm particles in Cu and diamond targets. The details of the three-stage magnetic spectrometer is shown elsewhere [1]. High precision vertex detectors provide average proper-time resolution of 20 fs for the charm decays. The system of proportional chambers, drift chambers and silicon strip detectors measures the momentum with less than 1% resolution. Charged particle identification was done by a 10 m long Ring-Imaging Cerenkov (RICH) detector that separates π from K up to 165 GeV/c.

The charm interactions were selected by a scintillator trigger. The trigger for charm required at least 4 charged tracks after the targets as indicated by an interaction counter and at least 2 hits in a scintillator hodoscope after the second analyzing magnet. It accepted about 1/3 of all inelastic interactions. Triggered events were further tested in an online computational filter based on downstream tracking and particle identification information. The online filter selected events that had evidence of a secondary vertex from tracks completely reconstructed using the forward PWC spectrometer and the vertex silicon. The Monte Carlo generated decays were simulated and embedded into data events. To separate the charm signal from non-charm background we optimized the Monte Carlo sample over data sidebands by using the the following tools: (i) Decay vertex separation significance L/σ, where L is the spatial separation between the first and the second vertices, (ii) The charm baryon was reconstructed as the vector sum of its secondary tracks, the summation vector is extrapolated back to the primary vertex. Its misdistance with respect to the primary vertex is used, (iii) The secondary vertex tracks are extrapolated back to the z_{prim}. We used the second largest misdistance with respect to primary vertex, (iv) Sum of the squared transverse momentum of the secondary particles with respect to the charm track, (v) We also required a minimum momentum cut for the π^+, which helps to reject the soft pions that cause high background.

Optimising these variables yield; 157 ± 21 $\Xi_c^+ \to \Xi^-\pi^+\pi^+$ events (see Figure 2-a), 98 ± 17 $\Xi_c^+ \to p^+K^-\pi^+$ events (see Figure 2-b), and 46 ± 11 $\Xi_c^+ \to \Sigma^+K^-\pi^+$ events (see Figure 2-c). The shaded areas in the Figure 2 are estimated reflections from $\Lambda_c^+ \to \Sigma^-\pi^+\pi^+$ and $\Lambda_c^+ \to \Sigma^+\pi^-\pi^+$, respectively. The shapes are determined by Monte Carlo simulations and the areas are normalized to the observed number of signal events in Λ_c^+ data. We calculated to have 12 $\Lambda_c^+ \to \Sigma^-\pi^+\pi^+$ events under the $\Xi_c^+ \to \Xi^-\pi^+\pi^+$

signal, due to misidentification of Σ^- as Ξ^-, and 23 $\Lambda_c^+ \rightarrow \Sigma^+\pi^-\pi^+$ events under the signal of $\Xi_c^+ \rightarrow \Sigma^+K^-\pi^+$ decay channel due to misidentification of π^- as K^-.

A fit to the total Ξ_c^+ mass distribution using a Gaussian for signal and a linear function for background yields 301 ± 31 reconstructed Ξ_c^+ and a Gaussian σ of 8.8 MeV/c^2 (see Figure 2-d).

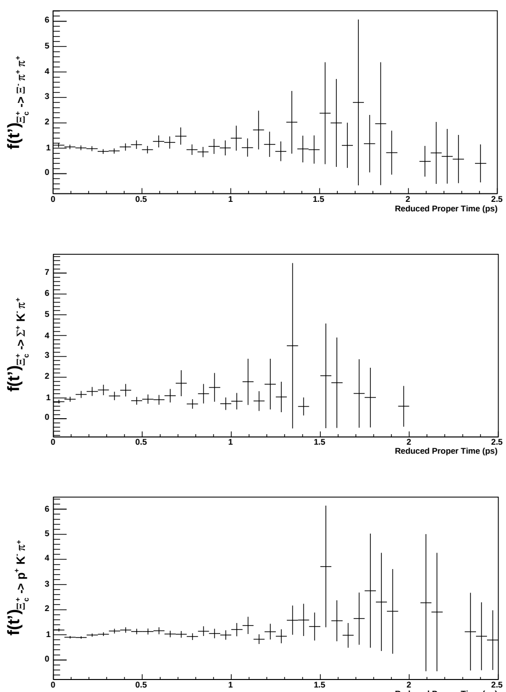

Figure 1. Applied correction functions for $\Xi_c^+ \rightarrow \Xi^-\pi^+\pi^+$ (top), $\Xi_c^+ \rightarrow \Sigma^+K^-\pi^+$ (middle), and $\Xi_c^+ \rightarrow p^+K^-\pi^+$ (bottom)

2. Analysis Technique

The average longitudinal error, σ_z, on the primary and the secondary vertices for $\Xi_c^+ \rightarrow \Xi^-\pi^+\pi^+$ sample are 358 μm and 539 μm respectively, which gives combined error of 647 μm. In $\Xi_c^+ \rightarrow \Xi^-\pi^+\pi^+$ signal region the average momentum is 213 GeV/c, corresponding to a time resolution of 25 fs, about 5% of the $\tau_{\Xi_c^+}$. Since the bin-smearing effects are small we used binned maximum likelihood fitting technique to determine the Ξ_c^+ lifetime. This fit was applied to a reduced proper time distribution;

$$t' = t - t_{min} = \frac{L - N\sigma_L}{\beta\gamma c} \tag{1}$$

Where, N is the significance of the detachment cut which has been adopted. A correction function, f(t'), is applied to all data to take into account the factors dependent on the detector resolution and systematic effects. The correction function is obtained from bin by bin ratio of simulated events' reduced proper time distributions before and after the reconstruction code (see Figure 1). The reflection events from Λ_c^+ decays are taken into account and the Λ_c^+ lifetime, $\tau_{\Lambda_c^+}$, is set to 200 fs [2].

The probability density was performed by the function;

$$P(t') = N_s(1 - (m+n)S(t')f(t') + mB(t') + nR(t')) \tag{2}$$

Where;

$$S(t') = \frac{e^{-t'/\tau_{\Xi_c^+}}}{\tau_{\Xi_c^+}} \tag{3}$$

$$B(t') = e^{-t'/\tau_{Bckg}} \frac{\alpha}{\tau_{Bckg}} + (1-\alpha)\frac{C}{t'_{max}} \tag{4}$$

and

$$R(t') = \frac{e^{-t'/\tau_{\Lambda_c^+}}}{\tau_{\Lambda_c^+}} \tag{5}$$

N_s is the total number of events having a mass ± 20 MeV/c^2 around the mean mass of the signal peak. $\tau_{\Xi_c^+}$, τ_{Bckg},and $\tau_{\Lambda_c^+}$ are the lifetimes of Ξ_c^+, background events, and reflection (Λ_c^+) events, respectively. The reduced proper time distribution of the sibeband events are fitted to exponential plus a constant term, C. α is the ratio of exponential within this background fit. The variables m and n are the percentages of the background and reflection events under the signal, respectively. f(t') is the corresponding correction function. The behavior of the background events in

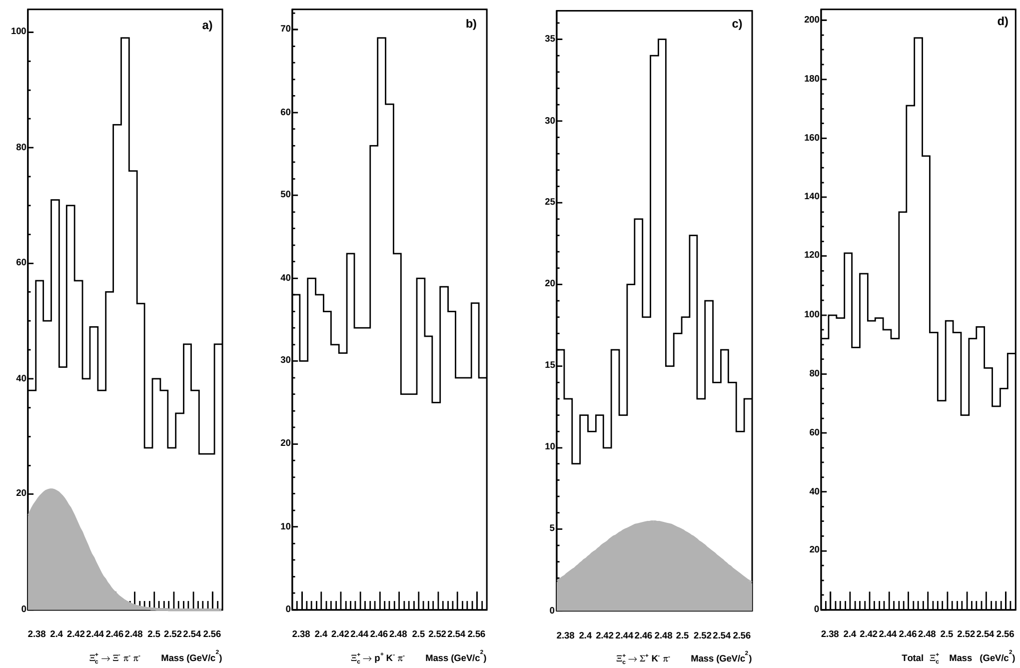

Figure 2. a) $\Xi_c^+ \to \Xi^-\pi^+\pi^+$ mass distribution after the cuts. The shaded area is the estimated reflection from $\Lambda_c^+ \to \Sigma^-\pi^+\pi^+$ decay channel. b) $\Xi_c^+ \to p^+K^-\pi^+$ mass distribution after the cuts. c) $\Xi_c^+ \to \Sigma^+K^-\pi^+$ mass distribution after the cuts. The shaded area is the estimated reflection from $\Lambda_c^+ \to \Sigma^+\pi^-\pi^+$decay channel. d) Total mass distribution, the gaussian fit yields 301 ± 31 Ξ_c^+ events.

the signal region is assumed to be the same with the sideband region events. For $\Xi_c^+ \to \Xi^-\pi^+\pi^+$ decay channel, since the reflection events are localized on left side of the mass peak, we chose the sideband region from 2.50 GeV/c^2 to 2.54 GeV/c^2, away from the effects of the possible reflection events. For $\Xi_c^+ \to p^+K^-\pi^+$ decay channel, two symmetric sideband regions, from 2.424 GeV/c^2 to 2.444 GeV/c^2 and from 2.484 GeV/c^2 to 2.504 GeV/c^2 are chosen. For $\Xi_c^+ \to \Sigma^+K^-\pi^+$ decay channel the reflection is distributed all over the mass region, so we cannot find a sideband region that is not contaminated by the possible reflection. The events from two symmetric mass regions, from 2.434 GeV/c^2 to 2.454 GeV/c^2 and from 2.494 GeV/c^2 to 2.514 GeV/c^2 are chosen as sideband events.

Finally, the Maximum Likelihood Function is the Landau probability of finding s_i events in i^{th} reduced proper time bin while we are expecting P_i events for all of the bins.

$$L = \Pi_{i=1}^{i=nbins} \frac{P_i^{s_i} e^{P_i}}{s_i!} \qquad (6)$$

Where nbin is 40; total number of reduced proper time bins. Since we have three independent data sets, we analyzed them separately, and took the weighted average, the total lifetime for Ξ_c^+ is found to be $430 \pm 22\ fs$.

Table 1
Lifetimes and event numbers of different decay channels.

Ξ_c^+ Decay Channel	Event Number	Lifetime (fs)
$\Xi^-\pi^+\pi^+$	157 ± 21	420 ± 28
$\Sigma^+K^-\pi^+$	46 ± 11	465 ± 76
$p^+K^-\pi^+$	98 ± 17	429 ± 39
Total	301 ± 31	430 ± 22

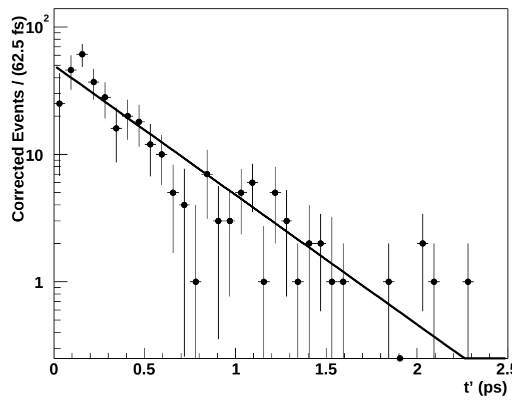

Figure 3. Corrected, sideband subtracted reduced proper time distribution for the 301 ± 31 events. The fit line shows the measured Ξ_c^+ lifetime, 430 fs.

3. Systematic Errors

The systematic study has been done by using Monte Carlo simulations and 157±21 events from $\Xi_c^+ \to \Xi^-\pi^+\pi^+$ decay. The bin size selection of the reduced proper time distribution contributes 4 fs to systematics. The X_f distribution for our data gives 3.6±0.7 as X_f power. We produced the MC samples with different X_f powers and measured lifetime with the correction functions coming from these samples. The systematical error contribution from X_f power selection is 7 fs. The Correction Function is fitted to different powers of polynomials, this variation yields 4 fs systematical errors to our measurement. The systematical errors due to the selection of the sidebands, and choosing different t_{max} values of reduced proper time distributions are negligible. Adding these contributions in quadrature gives a total systematic uncertainty of 9 fs. The Monte Carlo corrected, sideband subtracted reduced proper time distribution of the signal events, and lifetime fit are shown in Figure3.

4. Summary

This report presents SELEX's preliminary measurement of the Ξ_c^+ lifetime using three different decay modes, with a combined sample of 301 ± 31 events. We used binned maximum likelihood method and measured the lifetime to be $430 \pm 22 \pm 9$ fs, where the first error is statistical and the second is systematical. Our measurement systematical and statistical uncertainities are better than those of the world average. This measurement give a ratio $\tau_{\Xi_c^+}/\tau_{\Lambda_c^+} = 2.15 \pm 0.1$, using the Λ_c^+ lifetime of PDG $(200 \pm 6fs)$.

REFERENCES

1. U. Akgun, Ph.D. thesis, The University of Iowa, 2003.
2. Particle Data Group, S. Eidelman*et al.*, Physics Letters B, 592, 2004.