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MEASUEREMENT OF THE Ω_c^0 LIFETIME

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ABSTRACT

We report a precise measurement of the Ω_c^0 lifetime. The data were taken by the SELEX experiment (E781) spectrometer using 600 GeV/c Σ^-, π^- and p beams. The measurement has been done using 79 $\pm$ 16 reconstructed Ω_c^0 from a total sample of 107 $\pm$ 22. The lifetime of the Ω_c^0 is measured to be $(74 \pm 16(stat.))$ fs using $\Omega^-\pi^+\pi^-\pi^+$ and $\Omega^-\pi^+$ decay modes. The mass of the Ω_c^0 is measured to be $(2706.5 \pm 2.1 \pm 1.2)$ MeV/c^2.

1 Introduction

Several experiments [1, 2, 3, 4, 5] in the last years have detected the Ω_c^0 ground state. Recently at Fermilab the photoproduction experiment FOCUS (E831) reported an observation of a sample of 64 Ω_c^0 events and they measured its lifetime [6]. They report also, in an earlier publication [5], the Ω_c^0 lifetime

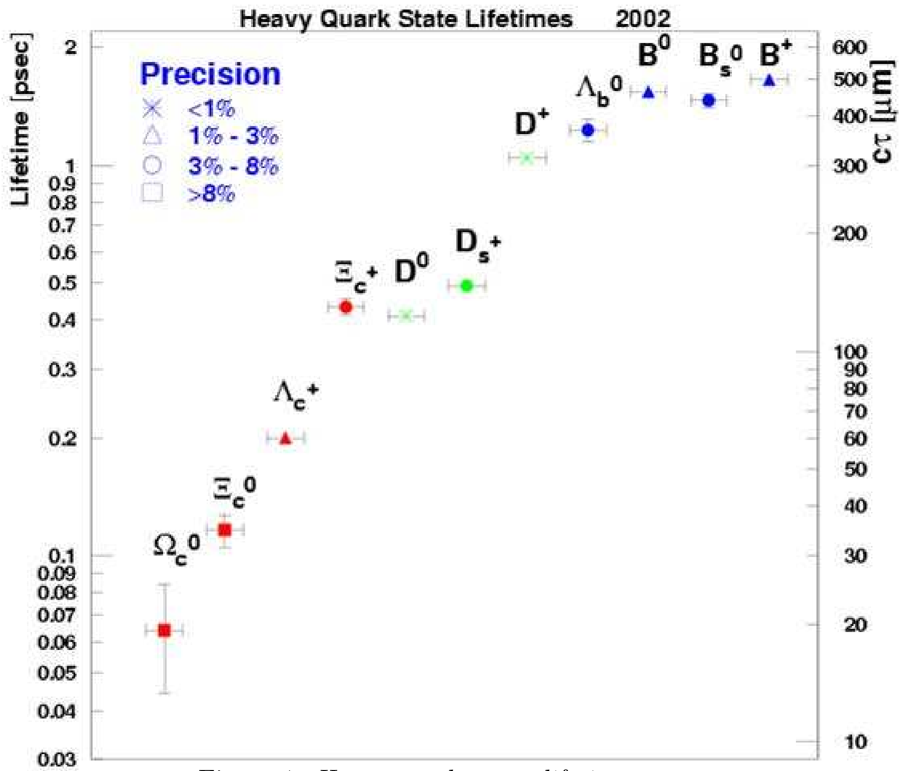

Figure 1: *Heavy quark states lifetimes.*

measurement. The experiment WA89 reported 200 Ω_c^0 events in several decays modes and a measurement of lifetime of $55^{+13}_{-11}{}^{+18}_{-23}$ fs from two decays modes only [7]. A qualitative hierarchy of lifetime has been predicted [8]. Fig. 1 shows the charmed baryon and meson lifetime is spread in a range of 50-1000 fs in strong contrast with the B mesons. Clearly additional measurements of lifetime as well the branching ratios with more statistical accuracy are needed to test theoretical models [9]. In this talk we report the results of a new measurement of the lifetime based on data from the hadroproduction experiment SELEX (E781) at Fermilab (throughout this article, charge conjugate states are assumed). The measurement is based on a subsample of 79 $\pm$ 16 fully reconstructed Ω_c^0 from a sample of 15.2 $\times 10^9$ hadronic triggers.

The SELEX detector at Fermilab is a 3-stage magnetic spectrometer. The negatively charged 600 GeV/c beam contains nearly equal fractions of Σ and π. The positive beam contains 92% protons. Beam particles are identified by a Transition Radiation detector. The spectrometer was designed to study charm production in the forward hemisphere with good mass and decay vertex resolution for charm momenta in the range 100-500 GeV/c. Five interaction targets (2 Cu and 3 C) had a total target thickness of 4.2% λ_{int} for protons. The targets are spaced by 1.5 cm. Downstream of the targets are 20 silicon planes with a strip pitch of 20-25 μm oriented in X, Y, U and V views. The scattered-particle spectrometers have momentum cutoffs of 2.5 GeV/c and 15 GeV/c respectively. A Ring-Imaging Cerenkov detector (RICH) [10], filled with Neon at room temperature and pressure, provides single track ring radius resolution of 1.4% and 2σ K/π separation up to about 165 GeV/c. A layout of the spectrometer can be found elsewhere [11, 12].

2 Data set and charm selection

The charm trigger is very loose. It requires a valid beam track, at least 4 charged secondaries in the forward 150 mrad cone, and two hodoscope hits after the second bending magnet from tracks of charge opposite to that of the beam. We triggered on about 1/3 of all inelastic interactions. A computational filter linked PWC tracks having momenta $>$ 15 GeV/c to hits in the vertex silicon and made a full reconstruction of primary and secondary vertices in the event. An event was written to tape if it was inconsistent with having come from a single vertex. This filter passed 1/8 of all interaction triggers and had about 50% efficiency for otherwise accepted charm decays. The experiment recorded data from 15.2 $\times 10^9$ inelastic interactions and wrote about 10^9 events to tape using both positive and negative beams.

In the full analysis the vertex reconstruction was repeated with tracks of all momenta. Again, only events inconsistent with having a single primary vertex were considered. The RICH detector identified charged tracks above 25 GeV/c. Results reported here come from a second pass reconstruction through the data, using a production code optimized for speed and cascade Reconstruction. To separate the signal from the non charm background we require that: (i) the spatial separation L between the reconstructed production and decay vertices exceeds 6 times the combined error σ_L, each decay track, extrapolated to the primary vertex z position, must miss by a transverse distance length $t \geq$

Ω_c^0	$Mass$(MeV/c^2)	Signal
$\Omega^-\pi^+\pi^+\pi^-$	2708.0 ± 4.5	44 ± 14
$\Omega^-\pi^+$	2707.1 ± 2.4	35 ± 12
$\Xi^- K^+\pi^-\pi^+$	2702.8 ± 8	28 ± 12
Average	$2706.5 \pm 2.1 \pm 1.2$	107 ± 22

Table 1: *Invariant mass results and signal yields for the two Ω_c^0 modes analyzed.*

2.5 times its error σ_t, (iii) each decay track, extrapolated to the *kink* vertex z position, must miss by a transverse distance length $t \geq 300$ μm ,(iv) decays must occur within a fiducial region and (v) the total transverse momentum of pions from $\Omega^-\pi^+\pi^-\pi^+$ decay must be greater than 0.35 GeV/c to the Ω_c^0 direction. These cuts optimize the ratio signal background. There are 107 $\pm$ 22 events Ω_c^0 candidates that pass these cuts and they are summarized in Table I and the mass spectrum is shown in Fig. 1. We divide them into three decay channels: , $\Omega^-\pi^+\pi^-\pi^+$, $\Omega^-\pi^+$, $\Xi^- K^-\pi^+\pi^+$. The invariant mass is measured to be 2706.5 $\pm$ 2.1 $\pm$ 1.2 MeV/c^2, 2.7 σ above the PDG mass value [13]. No dependence of mass value on momentum is found. We know that our mass resolution is quite accurate because the previous charm invariant masses, D,D_s and Λ_c agree well with word average [14]. The systematic error was obtained by comparing the SELEX measured mass value to the current PDG average. It results an offset < 1 MeV/c^2. π/K misidentification causes a reflection of Ξ_c under the Ω_c^0 peak. The sample was selected requiring a minimum π momentum of 8 GeV/c to reduce misidentification in the RICH as well as the fake invariant mass combination. We formed the invariant mass distribution of these events when one pion is interpreted as a K meson and Ξ^- as Σ^-. At most one of the two possible reflections per event falls into the Ω_c^0 mass window. We count the misidentified Ξ_c in the Ω_c^0 sample by fitting the Ω_c^0 mass distribution within $\pm$ 20 MeV/c^2 interval around the Ω_c^0 mass . The resultant misidentified Ω_c^0 is less than 2 events.

3 Lifetime evaluation using a maximum likelihood fit

The average longitudinal error σ_z on the primary and secondary vertices is 270 μm and 500 μm, which gives a combined error of 570 μm. In the Ω_c^0 sample, the average momentum is 250 GeV/c, corresponding to a time resolution of

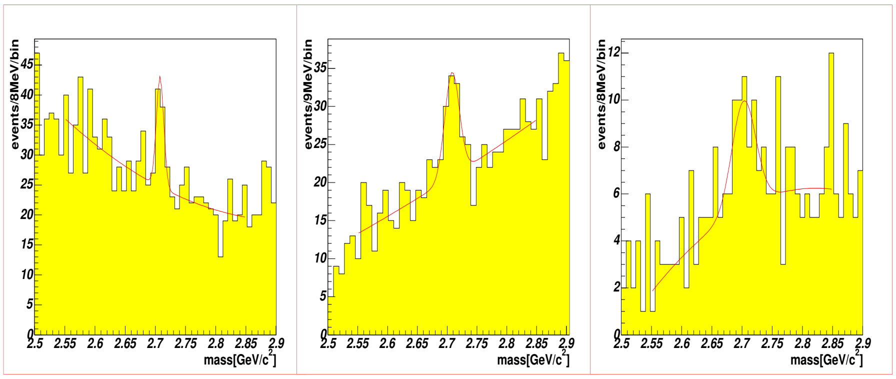

Figure 2: *From left to right: Invariant mass of $\Omega^-\pi^+$, $\Omega^-\pi^+\pi^-\pi^+$ and $\Xi^-K^-\pi^+\pi^+$ respectively. The yield is reported in Table 1.*

16 fs, about 22% of $\tau_{\Omega_c^0}$. Because bin-smearing effects are small, we used a binned maximum likelihood fitting technique to determine the Ω_c^0 lifetime. The fit was applied to a reduced proper time distribution, $t^* = M(L - L_{min})/pc$ where M is the known charm mass [13], p the reconstructed momentum, L the measured vertex separation and L_{min} the minimum L for each event to pass all the imposed selection cuts. L_{min} is determined event-by-event. We fitted all events with $t^* < 600$ fs in the mass range $2.630 < M(\Omega_c^0) < 2.760$ GeV/c^2, $\pm\ 2.5\sigma$ from the Ω_c^0 central mass value.

To evaluate the mean lifetime we used a maximum likelihood method. The probability density was performed by the function :

$$f(\tau_{\Omega_c^0},\ \tau_{Bck1},\ \tau_{Bck2},\ \alpha,\ \beta;\ t^*) = (1-\alpha)N_S\frac{e^{-t^*/\tau_{\Omega_c^0}}}{\epsilon(t^*)\tau_{\Omega_c^0}} + \alpha N_S B(t^*) \qquad (1)$$

where

$$B(t^*) = \beta\frac{e^{-t^*/\tau_{Bck1}}}{\tau_{Bck1}} + (1-\beta)\frac{e^{-t^*/\tau_{Bck2}}}{\tau_{Bck2}} \qquad (2)$$

The function is the sum of a term for the Ω_c^0 exponential decay corrected by the acceptance function $\epsilon(t^*)$ plus a background function $B(t^*)$ consisting of two exponentials to describe the strong decays and charm decays respectively.

Its parameters were determined from the Ω_c^0 sideband t^* distribution. The mass range of the sideband background windows, $2.610 < M(\Omega_c^0) < 2.630$ GeV/c^2 and $2.760 < M(\Omega_c^0) < 2.780$ GeV/c^2 was twice the signal mass window.

The fitted parameters are: $\tau_{\Omega_c^0}$ (Ω_c^0 lifetime), τ_{Bck1}, τ_{Bck2} (background lifetimes), α (background fraction in the signal region) and β (background splitting function). N_S is the total number of events in the signal region.

The proper-time-dependent acceptance $\epsilon(t^*)$ is independent of spectrometer features after the first magnet, e.g., RICH efficiency and tracking efficiency. These efficiencies affect only the overall number of events detected. The proper time distribution of these events depends crucially on vertex reconstruction. To evaluate $\epsilon(t^*)$ we generated 2×10^6 events by Monte Carlo simulation. The acceptance $\epsilon(t^*)$, does not differ significantly from unity and it is rather constant. Fig. 3 shows the overall fits to the data distributions as a function of reduced proper time for $\Omega^-\pi^+\pi^-\pi^+$ and $\Omega^-\pi^+$ decay modes.

We measure an average lifetime $\tau_{\Omega_c^0} = 74 \pm 16$ fs. The uncertainties are statistical only, evaluated where $-\ln\mathcal{L}$ increases by 0.5; the evaluation of systematic error is in progress.

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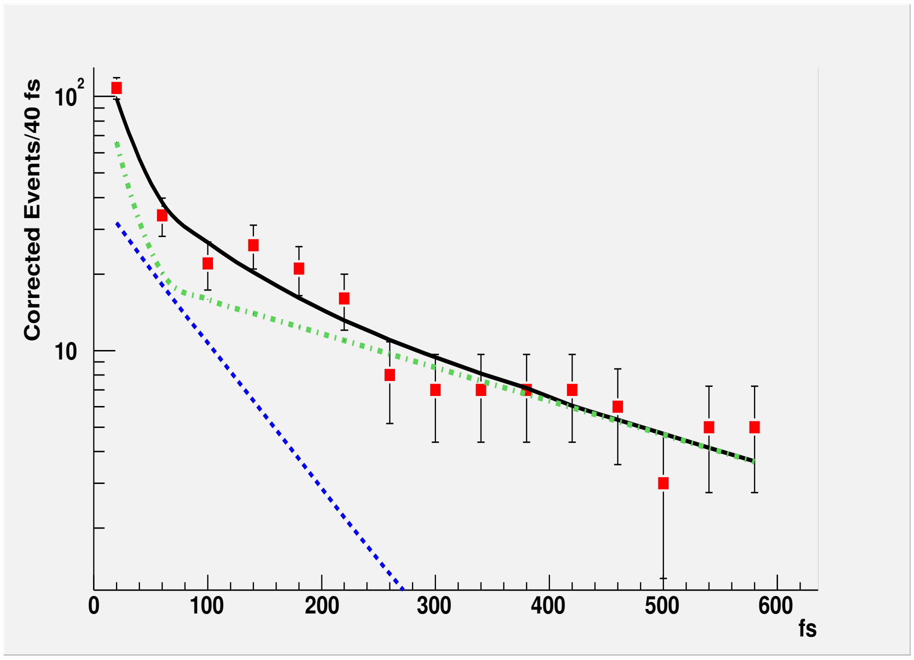

Figure 3: *Corrected reduced proper time distribution for $\Omega^-\pi^+\pi^+\pi^-$ and $\Omega^-\pi^+$ (squares) and result from the maximum likelihood fit (solid curve). The dashed dot curve shows the fitted background. The dashed curve shows the ${\Omega_c}^0$ lifetime.*

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