Fermi National Accelerator Laboratory

FERMILAB-Conf-93/164-E

E687

Charm Baryon Production and Decays in E687

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June 1993

Talk Presented at the *28th Recontres de Moriond, QCD and High Energy Hadronic Interactions*, Les Arc, Savoie, France, March 20-27, 1993

CHARM BARYON PRODUCTION AND DECAYS IN E687

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Abstract

Preliminary analysis of Charm Baryons from the Fermilab high energy photoproduction experiment E687 is presented. The results include the first observation of $\Omega_c^0 \rightarrow \Omega^- \pi^+$.

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In this paper I present and discuss new results on charm baryon lifetimes from Fermilab photoproduction experiment E687. The data were collected in 1990 and 1991 using the E687 spectrometer which is described elsewhere.[2)]

The "problem" of the difference between the D^0 and D^+ lifetimes is well known. Whereas the simple spectator model predict equal lifetimes for all weakly decaying charm hadrons, the measured lifetimes of the D^+ and D^0 differ by a factor $\tau(D^+)/\tau(D^0) = 2.54 \pm 0.07$.[3)] Since the ratio of semileptonic rates ($\Gamma(D^+)/\Gamma(D^0) = 0.88 \pm 0.17$)[3)] is consistent with unity and the purely leptonic rates are negligible, this suggests differences between the hadronic decays of the D^+ and D^0.

Two solutions proposed to account for this lifetime difference are: (i) destructive interference effects in the decay of the D^+; and (ii) a large W-exchange contribution to the decay of the D^0. Detailed theoretical studies of (i) and (ii) are still somewhat inconclusive due to difficulties in reliably accounting for soft gluon effects in the decay.[4)] Although the situation is certainly not clear, our understanding should improve with more experimental data on charm hadronic decays, both for the branching ratios of exclusive modes and also for the lifetimes of the weakly decaying charm baryons, Λ_c^+, Ξ_c^+, Ξ_c^0 and Ω_c^0.

There are at least three published predictions for the hierarchy of lifetimes for the charm baryons. Guberina, Rückl and Trampetić[5)] predict the hierarchy $\tau(\Omega_c^0) \approx \tau(\Xi_c^0) < \tau(\Lambda_c^+) < \tau(\Xi_c^+)$ using calculations on the quark level that include W-exchange and light quark interference effects as well as hard gluon QCD corrections. A similar calculation by Voloshin and Shifman[6)] where non-perturbative soft gluon effects are partially taken into account gives a different hierarchy $\tau(\Omega_c^0) < \tau(\Xi_c^0) < \tau(\Xi_c^+) \approx \tau(\Lambda_c^+)$ The third prediction comes from a phenomenological analysis of Gupta and Sarma[7)] where no interference is assumed but large W-exchange contributions are included. They predict $\tau(\Lambda_c^+) \lesssim \tau(\Xi_c^0) < \tau(\Omega_c^0) < \tau(\Xi_c^+)$.

We have made new measurements on the lifetimes of the Λ_c^+, Ξ_c^+ and Ξ_c^0 charm baryons using the decay modes $pK^-\pi^+$, $\Xi^-\pi^+\pi^+$ and $\Xi^-\pi^+$ respectively. We also see some evidence for the decay $\Omega_c^0 \to \Omega^-\pi^+$, but we do not have a lifetime measurement for Ω_c^0 yet. Care has been taken in studying systematic effects in our analyses and our measured lifetimes are given in table 1. Due to the lack of space available for this paper, the details of the analy-

Table 1. Measurements of charm baryon lifetimes.

	E687[8] (10^{-13} s)	E691[9] (10^{-13} s)	NA14[10] (10^{-13} s)	NA32[11] (10^{-13} s)	E400[12] (10^{-13} s)	WA62[13] (10^{-13} s)
$\tau(\Lambda_c^+)$	$2.15\pm0.16\pm0.08$ $pK^-\pi^+$	$2.2\pm0.3\pm0.2$ $pK^-\pi^+$	$1.8\pm0.3\pm0.3$ $pK^-\pi^+$	$1.96^{+0.23}_{-0.20}$ $pK^-\pi^+$		
$\tau(\Xi_c^+)$	$4.1^{+1.1}_{-0.8}\pm0.2$ $\Xi^-\pi^+\pi^+$			$2.0^{+1.1}_{-0.6}$ $\Xi^-\pi^+\pi^+$ $\Sigma^+K^-\pi^+$	$4.0^{+1.8+1.0}_{-1.2-1.0}$ $\Sigma^0K^-\pi^+\pi^+$ $\Lambda^0K^-\pi^+\pi^+$	$4.8^{+2.9}_{-1.8}$ $\Lambda^0K^-\pi^+\pi^+$
$\tau(\Xi_c^0)$	$1.01^{+0.25}_{-0.17}\pm0.05$ $\Xi^-\pi^+$			$0.82^{+0.59}_{-0.30}$ $\Xi^-\pi^+$		

ses are not presented here; the reader is referred to our recent publications.[8] Table 1 also shows other measurements that dominate the current lifetime world averages. It should be noted that the ACCMOR (NA32) collaboration either quotes exactly zero systematic errors (for Λ_c^+ and Ξ_c^0) or does not discuss systematic errors at all (Ξ_c^+).

Only experiments E687 and NA32 have measured lifetimes for all the three charm baryons Λ_c^+, Ξ_c^+ and Ξ_c^0. These are shown in figure 1. For the NA32 result for Ξ_c^+ the mean values for the two modes they used, $\Xi^-\pi^+\pi^-$ and $\Sigma^+K^-\pi^+$, are also shown. In my opinion, the $\Sigma^+K^-\pi^+$ mode may suffer from background due to Čerenkov misidentification ($\Lambda_c^+ \to \Sigma^+\pi^-\pi^+$) at a level beyond what they accounted for. The E687 and NA32 results do agree within statistical errors, though the E687 results favors a hierarchy of $\tau(\Xi_c^0) < \tau(\Lambda_c^+) < \tau(\Xi_c^+)$ whereas the NA32 results favors $\tau(\Xi_c^0) < \tau(\Lambda_c^+) \approx \tau(\Xi_c^+)$.

Combining the E687 results with the current world averages[3] gives:

$$\tau(\Lambda_c^+)/\tau(\Xi_c^0) = 2.06^{+0.34}_{-0.50};\ \tau(\Xi_c^+)/\tau(\Lambda_c^+) = 1.73^{+0.39}_{-0.26};\ \tau(\Xi_c^+)/\tau(\Xi_c^0) = 3.56^{+0.95}_{-0.98}.$$

These results favor the hierarchy of Guberina, Rückl and Trampetić, though of course more statistical precision is required before a conclusive lifetime hierarchy can be reached. With better data on the charm baryon lifetimes including that of the Ω_c^0, one should be able to extract the relative contributions due to spectator, W-exchange and interference, and maybe also determine whether soft gluon effects are important for charm baryon decays.

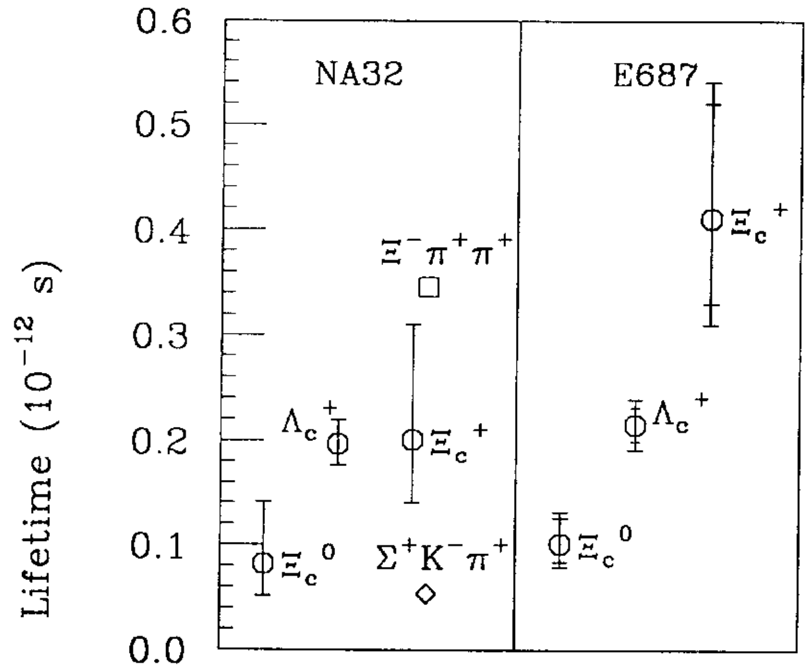

Figure 1. Comparison of lifetime hierarchies for charm baryons measured by E687[8] and NA32[11]. For the NA32 results only the statistical error is given. For the E687 results, the inner error bar gives the statistical error and the outer error bar the systematic error.

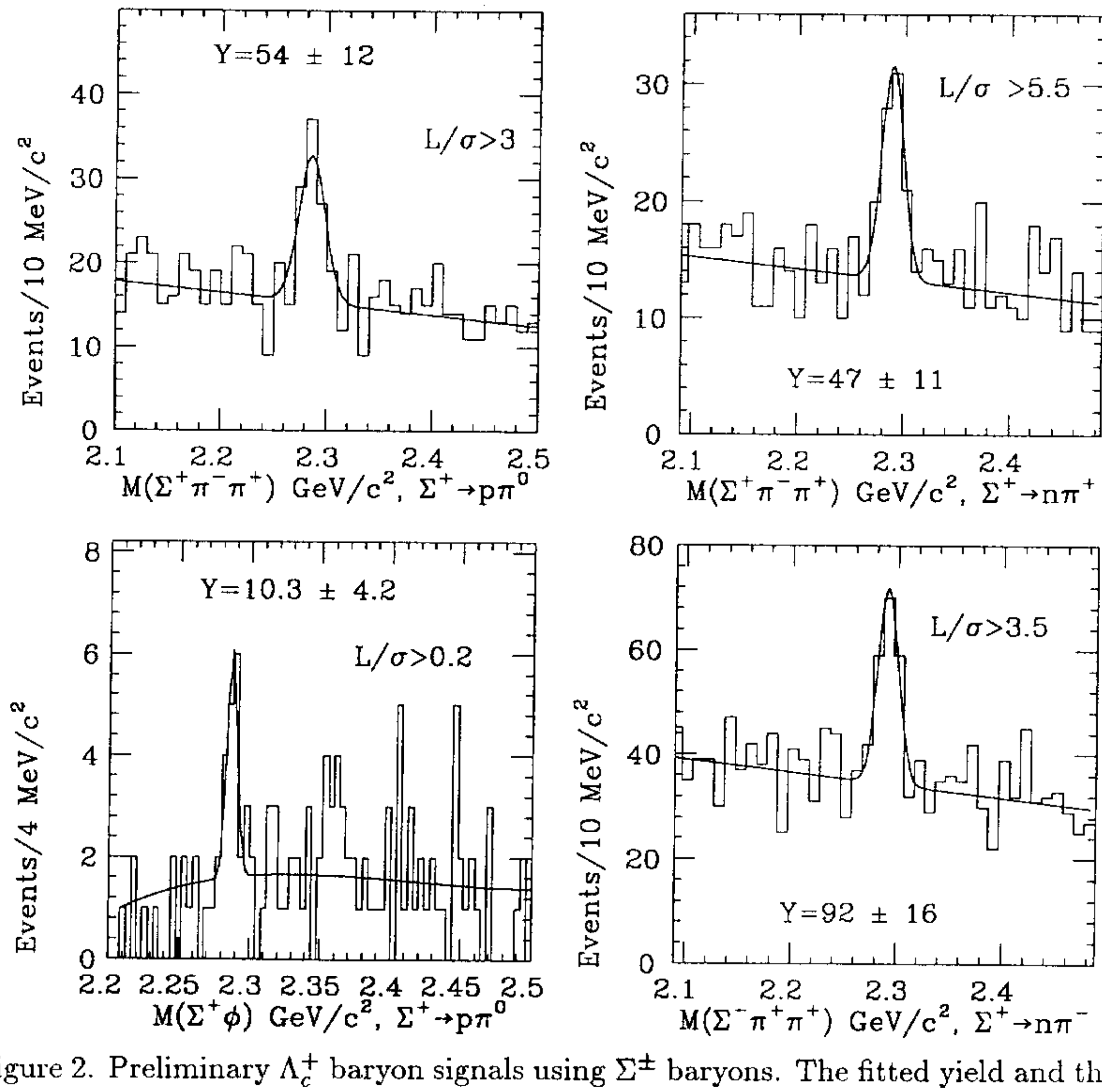

Figure 2. Preliminary Λ_c^+ baryon signals using $\Sigma^\pm$ baryons. The fitted yield and the cut on L/σ_L is given for each plot. L is the 3-dimensional distance between the primary and secondary vertices and σ_L is the error on L.

In order to improve our measurements of charm baryons we are investigating charm baryon decay modes involving $\Sigma^{\pm}$ baryons. The $\Sigma^{\pm}$ baryons are reconstructed kinematically. Figure 2 shows some preliminary charm baryon signals involving $\Sigma^{\pm}$ baryons.

We see a significant difference between the numbers of reconstructed D and $\overline{\mathrm{D}}$ in E687. Defining the asymmetry for D mesons as $A(\mathrm{D}) = \frac{(N_{\overline{\mathrm{D}}}-N_{\mathrm{D}})}{(N_{\overline{\mathrm{D}}}+N_{\mathrm{D}})}$, and using $\mathrm{D}^0 \to K^-\pi^+, K^-\pi^+\pi^+\pi^-$ and $\mathrm{D}^+ \to K^-\pi^+\pi^+$, we find $A(\mathrm{D}) = 3.58 \pm 0.77\%$, and $A(\mathrm{D}^{*+}) = 9.59 \pm 1.06\%$, where in the latter we only used D^0 decays. We interpret this difference as due to the larger associated production of $\overline{\mathrm{D}}\Lambda_c^+$ compared to $\mathrm{D}\overline{\Lambda_c^+}$. It is unknown to us why the difference is larger for spin 1 D^* mesons. Note that the result for $A(\mathrm{D})$ includes all reconstructed D mesons, so we are studying whether the total asymmetry in D production is due solely to an asymmetry in D^* production. Using $\mathrm{D}_s^+ \to \phi\pi^+$ we find $A(\mathrm{D}_s) = -2.49 \pm 5.20\%$ which is consistent with unity, and using $\Lambda_c^+ \to pK^-\pi^+$ we find $A(\Lambda_c) = -12.26 \pm 7.32\%$, which is consistent with enhanced $\overline{\mathrm{D}}\Lambda_c^+$ production. This direct evidence for enhanced $\overline{\mathrm{D}}\Lambda_c^+$ associated production is weak. However, if it is the sole cause of the difference in numbers of D and $\overline{\mathrm{D}}$, then with sufficient statistics we can use this to determine the number of associated produced Λ_c^+ and hence the absolute branching ratio of the $\Lambda_c^+ \to pK^-\pi^+$.

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1) and the E687 collaboration, please see reference 8).

2) P.L. Frabetti *et al.*, Nucl. Instrum. Methods Phys. Res., Sect. A **320**, 519 (1992).

3) Particle Data Group, K. Hikasa *et al.*, Phys. Rev. D **45**, No. 11, Pt. II (1992).

4) R. Rückl, "Comments on the differing lifetimes of charm hadrons". Proc. 23rd Int. Conf. on High Energy Physics, Berkeley, July 16-23, 1986, p.797; and reference section of 7).

5) B. Guberina, R. Rückl and J. Trampetić, Z. Phys. C **33**, 297 (1986).

6) M. B. Voloshin and M. A. Shifman, Sov. Phys. JETP **64**, 698 (1986).

7) V. Gupta and K. V. L. Sarma, Int. Jour. Mod. Phys. A **5**, 879 (1990).

8) P.L. Frabetti *et al.*, Phys. Lett. B**300**, 190 (1993); Phys. Rev. Lett. **70**, 1381 (1993); Phys. Rev. Lett. **70**, 1755 (1993); Phys. Rev. Lett. **70**, 2058 (1993).

9) J. C. Anjos *et al.*, Phys. Rev. Lett. **60**, 1379 (1988).

10) M. P. Alvarez *et al.*, Z. Phys. C**47**, 539 (1990).

11) S. Barlag *et al.*, Phys. Lett. B**218**, 374 (1989); Phys. Lett. B**233**, 522 (1989); Phys. Lett. B**236**, 495 (1990).

12) P. Coteus *et al.*, Phys. Rev. Lett. **59**, 1530 (1987).

13) S. F. Biagi *et al.*, Phys. Lett. B**150**, 230 (1985).