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# Laboratori Nazionali di Frascati


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A. Zallo:


## E687 RECENT RESULTS ON CHARM BARYON DECAYS


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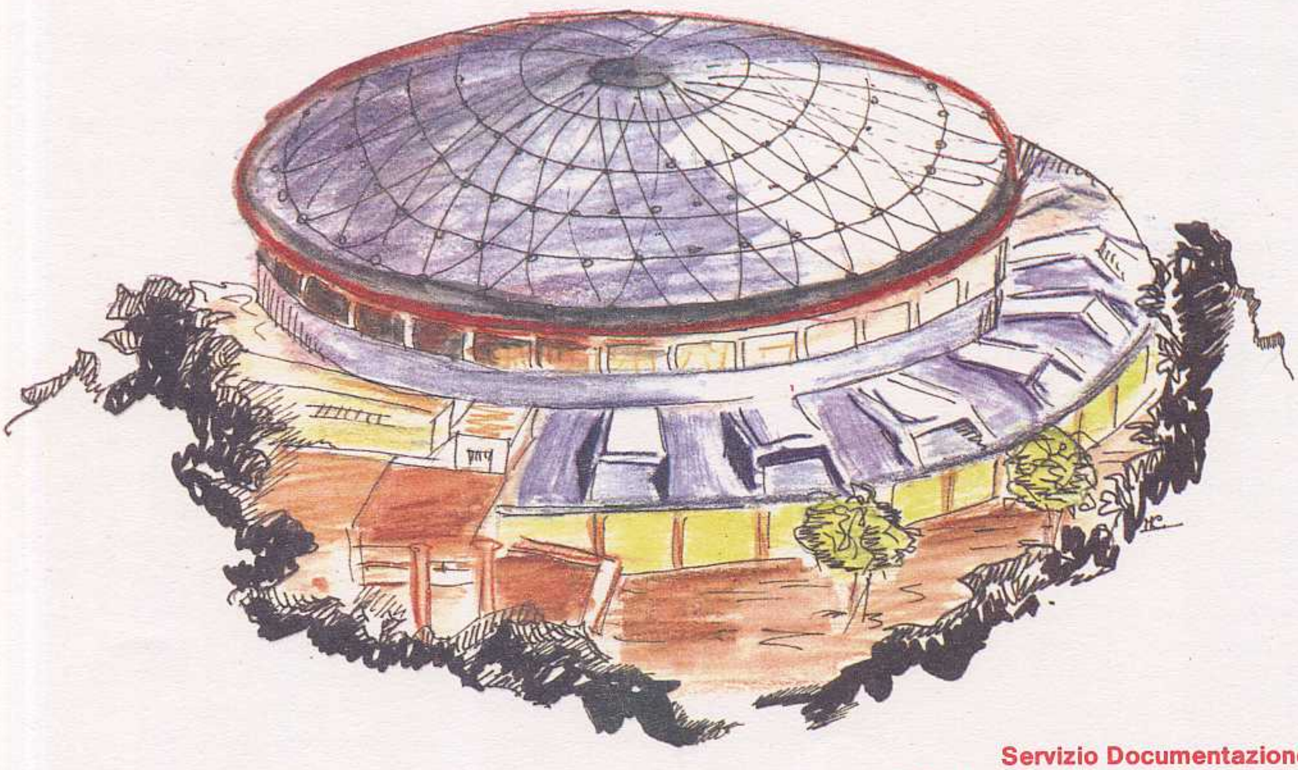


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# E687 RECENT RESULTS ON CHARM BARYON DECAYS

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**ABSTRACT**

New results from the Fermilab photoproduction experiment E687 on charmed baryon decays are presented. The measurements of $\Lambda_c$,$\Xi_c^+$, $\Xi_c^0$ lifetimes and of the Cabibbo suppressed decay $\Lambda_c^+ \to pK^-K^+$ are described.Preliminary results of charm baryon decays involving $\Sigma^\pm$ with $\Sigma^+ \to p\pi^0$ or $\Sigma^\pm \to n\pi^\pm$ are also given.

## 1 Introduction

Charmed baryons decays,unlike the charmed mesons, are not colour or helicity suppressed. This makes the investigation of the contribution of W-exchange diagrams possible.Charmed baryons are three body systems; interference effects due to the presence of identical quarks should be important; also important are the soft and hard gluon QCD corrections.All that makes the study of these decays a nice tool to test theoretical models, in particular the

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Table 1: Charm baryon lifetimes

| | $\tau(\Lambda_c^+)$ $(10^{-13}s)$ | $\tau(\Xi_c^+)$ $(10^{-13}s)$ | $\tau\ (\Xi_c^0)$ $(10^{-13}s)$ |
|---|---|---|---|
| E687 | $2.15 \pm 0.16 \pm 0.08$ $(pK^-\pi^+)$ | $4.1^{+1.1}_{-0.8} \pm 0.2$ $(\Xi^-\pi^+\pi^+)$ | $1.01^{+0.25}_{-0.17} \pm 0.05$ $(\Xi^-\pi^+)$ |
| NA32 | $1.96^{+0.23}_{-0.20}$ $(pK^-\pi^+)$ | $2.0^{+1.1}_{-0.6}$ $(\Xi^-\pi^+\pi^+)$ $(\Sigma^+K^-\pi^+)$ | $0.82^{+0.59}_{-0.30}$ $(\Xi^-\pi^+)$ |

QCD strong interaction sector.
The Fermilab photoproduction experiment E687 has collected in 1990 and 1991 more than 500 millions of events and reconstructed more than 100K charmed decays using the E687 spectrometer described in[1]. The E687 charmed baryon results presented here refer to $\Lambda_c$,$\Xi_c^+$, $\Xi_c^0$ lifetime measurements, measurement of the Cabibbo suppressed decay $\Lambda_c^+ \rightarrow pK^-K^+$, $\Lambda_c^+$ decays with $\Sigma^\pm$ in the final state. The details of the analysis are not given because of lack of space.The reader is referred to recent E687 publications [2].

## 2 $\Lambda_c$,$\Xi_c^+$, $\Xi_c^0$ lifetime measurements

There exist at least three theoretical models that predict different hierarchies of the charmed baryon lifetimes.For Guberina et al. [3]

$$\tau(\Omega_c^0) \simeq \tau(\Xi_c^0) < \tau(\Lambda_c^+) < \tau(\Xi_c^+)$$

Voloshin and Shifman[4] predict

$$\tau(\Omega_c^0) < \tau(\Xi_c^0) < \tau(\Xi_c^+) \simeq \tau(\Lambda_c^+)$$

For Gupta and Sarma [5]

$$\tau(\Lambda_c^+) \leq \tau(\Xi_c^0) < \tau(\Omega_c^+) < \tau(\Xi_c^+).$$

These models have relatively large theoretical uncertainties ($\simeq 1.2-1.5$). E687 has measured [2] the $\Lambda_c$,$\Xi_c^+$,$\Xi_c^0$ lifetimes looking at the decay modes $\Lambda_c^+ \longrightarrow pK^-\pi^+$, $\Xi_c^+ \longrightarrow \Xi^-\pi^+\pi^+$, $\Xi_c^0 \longrightarrow \Xi^-\pi^+$. Only another experiment[6],the CERN NA32, has measured the lifetimes for all the three charm baryons. The E687 and NA32 results are shown in Table 1. From this table we see that E687 favors the Guberina et al. hierarchy though more statistical precision is required. For a comparison with the NA32 results the reader is referred to reference [7].

## 3 Measurement of the Cabibbo suppressed decay $\Lambda_c^+ \rightarrow pK^-K^+$

The main difficulty in the measurement of the Cabibbo suppressed decay $\Lambda_c^+ \rightarrow pK^-K^+$ is the large background coming from the decays $D^+ \rightarrow K^+K^-\pi^+$, $D_s^+ \rightarrow K^+K^-\pi^+$ if a pion

Table 2:

| channel | $\Lambda_c^+ \to pK^-\pi^+$ | $\Lambda_c^+ \to pK^-K^+$ |
|---|---|---|
| $L/\sigma_L$ | $> 6.0$ | $> 6.0$ |
| mass($MeV/c^2$) | $2286.0 \pm 1.0$ | $2284.0 \pm 3.0$ |
| raw yield | $775.7 \pm 66.0$ | $30.3 \pm 8.7$ (Width fixed) |

is misidentified by the Cerenkov as a proton and from the decay $\Lambda_c^+ \to pK^-\pi^+$ if a pion is misidentified as a kaon. The E687 detector has succeeded [8] in measuring this decay because of the very good particle identification and vertex reconstruction capabilities. The proton and/or the like-sign kaon ($K^+$) is required to be unambiguously identified, while the unlike sign kaon ($K^-$) is loosely required to be kaon-consistent. A quantitative Monte Carlo estimate has shown that the contribution in the $\Lambda_c$ region coming from these decays is negligible (less than one entry).

To improve the signal to noise ratio two other analysis conditions are imposed to the $\Lambda_c^+ \to pK^-\pi^+$ candidates:

a) the total momentum of the decay prongs is required to be greater than 50 GeV/c because the Monte Carlo shows very low acceptance for $\Lambda_c$ baryons produced with momentum less than $\sim$ 40 GeV/c

b) the proper time of the decay is required to be less than five times the nominal $\Lambda_c$ lifetime. This cut retains 98% of the $\Lambda_c$ events while rejecting 14% and 45% (respectively) of the longer-living reflections from $D_s^+$ and $D^+$ mesons.

The signal yield obtained is given in Table 2,together with the mass measured and the ratio of the vertex separation between primary and secondary vertices $L$ and its error $\sigma_L$.This ratio $L/\sigma_L$ constitutes the most powerful tool in extracting the charm signal from the background [2].

The branching ratio measured is:

$$\frac{\Gamma(\Lambda_c^+ \to pK^-K^+)}{\Gamma(\Lambda_c^+ \to pK^-\pi^+)} = 0.096 \pm 0.029 \pm 0.010.$$

E687 finds also a statistically weak signal for $\Lambda_c^+ \to p\phi$ with a yield $Y(p\phi) = 6.1 \pm 2.8$ and a background of $Y(sb) = 2.0 \pm 1.8$, which allows to quote an upper limit of the branching ratio of the resonant component to the inclusive $\Lambda_c^+ \to pK^-K^+$ of

$$\frac{\Gamma(\Lambda_c^+ \to p\phi)}{\Gamma(\Lambda_c^+ \to pK^-K^+)} \leq 0.58$$

at 90% confidence level.

Fig.1 shows clean signals of the decays $\Lambda_c^+ \to pK_s^0, \pi^+\pi^-$ and $\Lambda_c^+ \to pK_s^0$. These results are preliminary and their analysis is in progress.

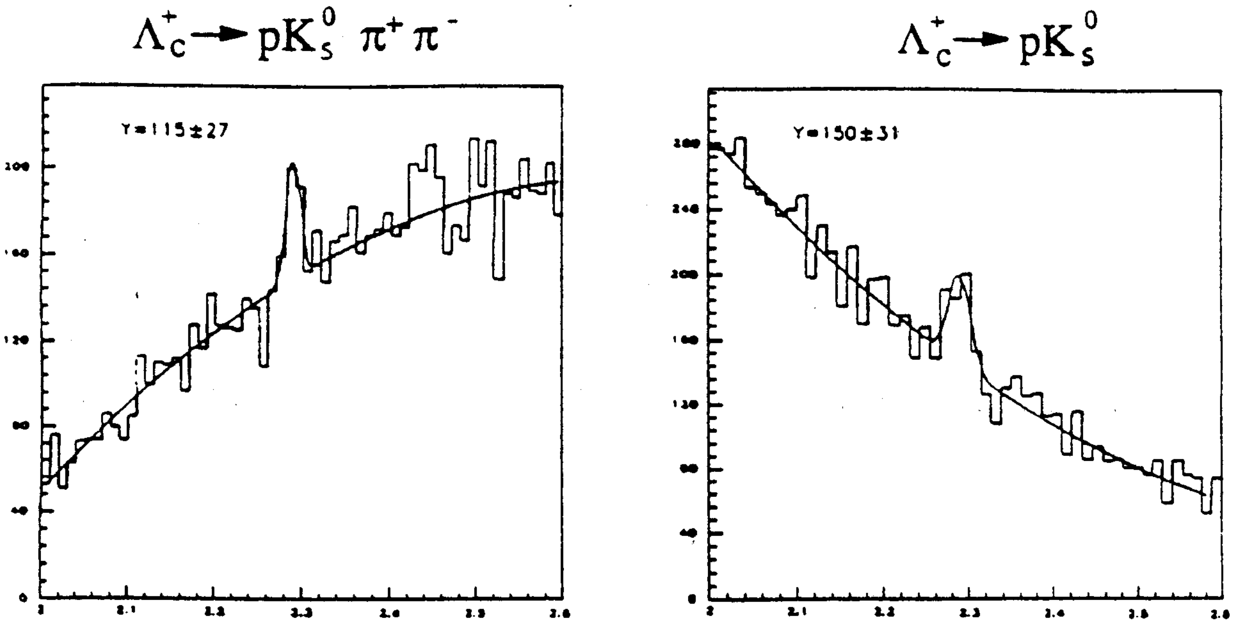


Figure 1: Invariant mass distribution for $\Lambda_c^+ \rightarrow pK_s^0\pi^+\pi^-, pK_s^0$.These results are preliminary.

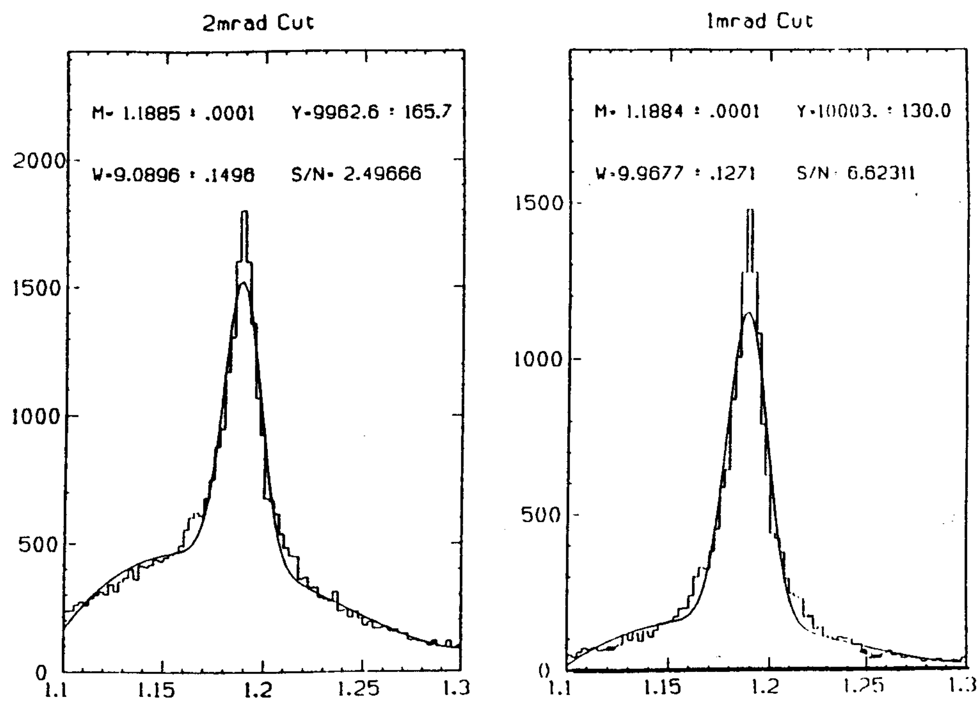


Figure 2: $\Sigma^+ \rightarrow p\pi^0$ invariant mass distribution for two different requirements on the matching of the $p\pi^0$ vector with the $\Sigma^+$ track.

Table 3: $\Lambda_c^+$ decays with $\Sigma^+ \rightarrow p\pi^0$

| channel | $\Sigma^+\pi^+\pi^-$ | $\Sigma^+\phi$ |
|---|---|---|
| $L/\sigma_L$ | $> 2.5$ | $> 0.3$ |
| mass($MeV/c^2$) | $2286.2 \pm 3.4$ | $2288.0 \pm 2.1$ |
| raw yield | $65.8 \pm 14.6$ | $7.8 \pm 3.8$ |

# 4 $\Lambda_c^+$ decays with $\Sigma^\pm$ in the final state

E687 has presented preliminary results on the branching ratio[9]

$$\frac{\Gamma(\Lambda_c^+ \rightarrow \Sigma^+\phi \rightarrow p\pi^0\phi)}{\Gamma(\Lambda_c^+ \rightarrow \Sigma^+\pi^+\pi^- \rightarrow p\pi^0\pi^+\pi^-)}$$

where the $\Sigma^+$ is detected through the decay $\Sigma^+ \rightarrow p\pi^0$. E687 has reconstructed the $\pi^0$'s requiring that the $p\pi^0$ momentum matches well the $\Sigma^+$ track direction.Fig.2 shows the $\Sigma^+ \rightarrow p\pi^0$ invariant mass distribution for two different requirements on the matching of the $p\pi^0$ vector with the $\Sigma^+$ track. The measurement of the $\pi^0$ is not essential, because the knowledge of the $\Sigma^+$ direction and of the proton momentum gives,assuming the particle nominal masses, the $\Sigma^+$ momentum.
More precisely the $\Sigma^+$ decay can be recognized as a kink between an unlinked track reconstructed by the microvertex and an unlinked proton track detected by the spectrometer. The spectrometer measures the proton momentum and the vertex detector the $\Sigma$ direction; the $\Sigma$ momentum is obtained with a twofold ambiguity; selecting the solution with the higher primary vertex confidence level the ambiguity is eliminated. The results obtained are collected in Table 3. The branching ratio measured

$$\frac{\Gamma(\Lambda_c^+ \rightarrow \Sigma^+\phi \rightarrow p\pi^0\phi)}{\Gamma(\Lambda_c^+ \rightarrow \Sigma^+\pi^+\pi^- \rightarrow p\pi^0\pi^+\pi^-)} = 0.160 \pm 0.086 \pm 0.048$$

is in good agreement with previous results[10].

E687 has also done the first observation of $\Lambda_c^+ \rightarrow \Sigma^-\pi^+\pi^+$. This decay has the same topology of the decay $\Sigma^+ \rightarrow p\pi^0$ and the same procedure is used to measure the momentum. To reduce the background, the hit point on both the electromagnetic calorimeter and the hadronic calorimeter is located and a hadronic shower is searched in an annular radius of $\simeq$ 17 cm.The E/P between the energy E released in the annular region and the neutron momentum P is estimated. The candidate is accepted if $0.3 < E/P < 1.7$. Finally using the E687 candidate-driven vertex algorithm[2] the $\Sigma^-(\pi\pi)_{like}$ combinations are selected. A similar analysis is done for $\Sigma^+$ decays in order to obtain the $\Sigma^+(\pi\pi)_{unlike}$ combinations.
Fig.3 shows clean signals of these decays. From their analysis E687 gets the following preliminary value

$$\frac{\Gamma(\Lambda_c^+ \rightarrow \Sigma^+\pi^+\pi^-)}{\Gamma(\Lambda_c^+ \rightarrow \Sigma^-\pi^+\pi^+)} = 1.86 \pm 0.55 \pm 0.07$$

of the branching ratio.

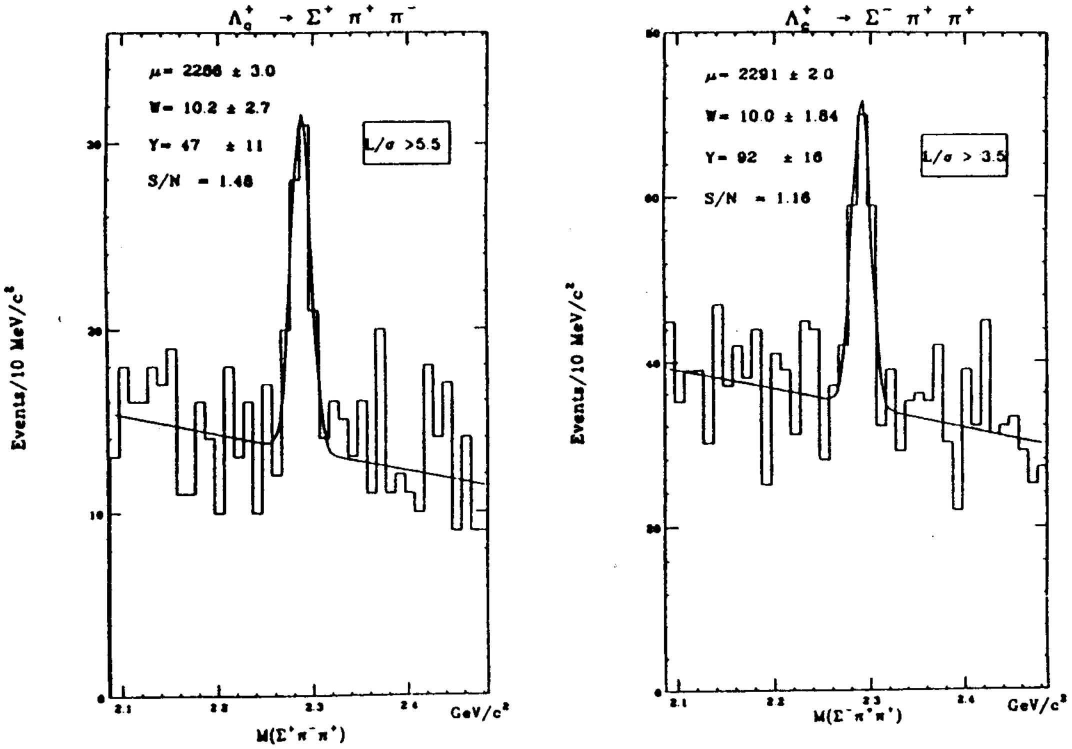


Figure 3: Invariant mass distribution for $\Lambda_c^+ \to \Sigma^+\pi^+\pi^-, \Sigma^-\pi^+\pi^+$. These results are preliminary.

# 5 Conclusions

E687 is proving to have good reconstruction capabilities for a large variety of charm baryons decay channels. The lifetimes of many charmed baryons have been measured with great precision. The Cabibbo suppressed decay $\Lambda_c^+ \to pK^-K^+$ has been measured. The first strong evidence for the $\Lambda_c^+$ decay to $\Sigma^-\pi^+\pi^+$ has been obtained. The reconstruction of charm baryon decays with $\pi^0$ is starting.

# References


[1] P. L. Frabetti *et al.*, Nucl. Instr. and Meth. in Phys. Res.,Sect. **A320**, 519 (1992).

[2] P. L. Frabetti *et al.*, Phys. Rev. Lett. **70**,1381 (1993), Phys. Rev. Lett. **70**,1755 (1993), Phys. Rev. Lett. **70**,2058 (1993).

[3] B. Guberina *et al.*, Z. Phys. **C33**, 297 (1986).

[4] M. B. Voloshin *et al.*, Sov. Phys. JETP **64**, 698 (1986).

[5] V. Gupta *et al.*, Int. Jour. Mod. Phys. **A5**, 879 (1990).

[6] S. Barlag *et al.*, Phys. Lett. **B218**, 374 (1989), Phys. Lett. **B233**, 522 (1989), Phys. Lett. **B236**, 495 (1990).

[7] Harry W. K. Cheung, Fermilab-CONF-93-164-E,June 1993.

[8] P. L. Frabetti *et al.*, Fermilab-PUB-93-183-E,July 1993, submitted to Phys. Lett. B.

[9] B. G. Cheon, American Physical Society,Vol.**38**,No. 2 ,1038 (1993).

[10] S. Barlag *et al.*, Phys. Lett. **B283**, 465 (1992).
CLEO collaboration,presented at the 7th DPF meeting,November 1992.