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# SEMILEPTONIC $\Lambda_c^+$ DECAYS WITH THE MARK II AT PEP*

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ABSTRACT

Semileptonic $\Lambda_c^+$ decays have been observed in 29 GeV $e^+e^-$ annihilation. We observe the channels $\Lambda_c^+ \rightarrow e^+\Lambda X$ and $\Lambda_c^+ \rightarrow \mu^+\Lambda X$. The production rate for $\Lambda_c^+$, times $\mathrm{Br}(\Lambda_c \rightarrow l^+\Lambda\mathrm{X})$ of $0.0031 \pm 0.0012 \pm 0.0010$ per hadronic event for electrons, and $0.0024 \pm 0.0024 \pm 0.0007$ per hadronic event for muons. When combined with the Lund model prediction for $\Lambda_c^+$ production, this gives semileptonic branching ratios of roughly 5%, about what is expected. When combined with the UCLA model prediction for $\Lambda_c^+$ production, this gives semileptonic branching ratios of 17% and 13% for electrons and muons, somewhat higher than expected.

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The experimental results on semileptonic charmed baryon decays are very sparse; the only previous measurements are from Mark II at SPEAR.[1] Semileptonic $\Lambda_c^+$ decays are interesting because they may be easily compared with charmed meson semileptonic decays, providing a tests of baryonic form factors.

In high energy $e^+e^-$ annihilation, $\Lambda_c^+$ production provides a strong test of fragmentation models; the predictions of the Lund[2] and UCLA[3] models differ by a factor of three.

We have measured $\sigma(e^+e^- \rightarrow \Lambda_c X) \cdot \mathrm{Br}(\Lambda_c \rightarrow l\Lambda X)$, for both electrons and muons. $\Lambda_c^+$ are seen via their decay to a $\Lambda$ plus a lepton, plus unobserved particles. The $\Lambda$ are required to come from the origin and have with a momentum of at least 1.5 GeV/c. Electrons are required to have a momentum of at least 1.5 GeV/c and muons are required to have a momentum of at least 2.0 GeV/c. The leptons are required to be in the same hemisphere as the $\Lambda$. The invariant mass of the combinations are shown in Figure 1, separately for right sign ($l^+\Lambda$ , $l^-\bar{\Lambda}$) and wrong sign ($l^+\bar{\Lambda}$, $l^-\Lambda$ ). There are 17 right sign events and 5 wrong sign events in the region below the $\Lambda_c^+$ mass of 2.28 GeV/c$^2$. Above 2.28 GeV/c$^2$, there are slightly more wrong sign events.

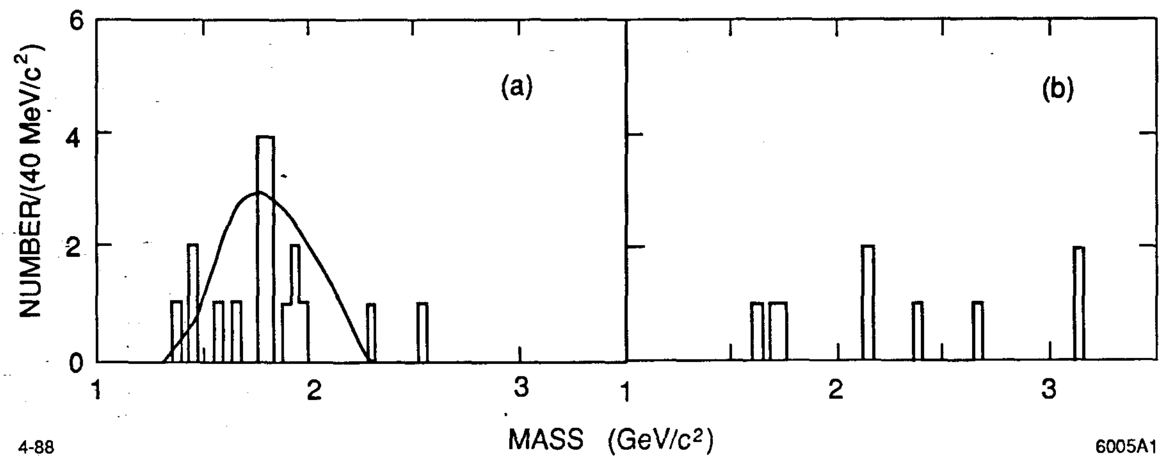


Fig. 1. Right sign ($\Lambda\ l^+$, $\bar{\Lambda} l^-$) and wrong sign ($\Lambda\ l^-$, $\bar{\Lambda} l^+$) combinations.

The background for the $\Lambda_c^+$ signal comes from a variety of sources. In order of decreasing importance, they are:

1. $K_s$ and random track combinations misidentified as $\Lambda$.
2. Fake leptons: misidentified electrons, $\pi/K$ decays, and hadron punchthrough.
3. Random background: A real $\Lambda$ plus a real lepton, from incoherent sources.
4. $\Lambda$ plus leptons, both from the same $b$ decay. The most likely form for this is a $B$ hadron decaying to a lepton plus a $\Lambda_c^+$, with the $\Lambda_c^+$ subsequently decaying to a $\Lambda$. This produces a wrong sign combination. Less common are $B$ mesons decaying to a lepton plus a baryon plus an $\bar{\Lambda}$, leading to a right sign event. The $b$ decay background is peaked at higher mass than $\Lambda_c^+$ decays, and the wrong sign excess seen at high masses may be from $b$ decays. Because $b$ decays are rarer than charm decays, and because of the higher average $b$ mass, this background source is small.

Since most of the background populates the right and wrong sign plots equally, the wrong sign combinations provide a measurement of the background.

The efficiency to detect a $\Lambda_c^+$ depends on the exact decay modes. Some modes that one could consider are: $l\nu\Lambda$, $l\ \nu\Sigma^0$, $l\ \nu\Sigma^{*0}$, $l\ \nu\Lambda\pi^0$, and $l\nu\Lambda(\pi\pi)^0$. Other modes are Cabbibo suppressed, or otherwise limited. We can eliminate all of these modes except $l\nu\Lambda$ on various theoretical grounds. The $\Lambda_c^+$ is isospin 0. The modes containing a single $\Sigma$ or $\Lambda\pi^0$ are isospin 1, and should be heavily suppressed. We can also compare with $D$ meson semileptonic decays. In $D$ meson semileptonic decays, the hadronic part of the final state is overwhelmingly a single particle.[4]

In $\Lambda_c^+$ semileptonic decays, the charmed quark emits a $W$, changing to a strange quark. In the baryon, the strange quark will have a large perpendicular momentum. Any extra quark production should occur between the strange quark and the nonstrange quarks. In that case, the final state would not include a $\Lambda$.

Two final hints come from the data. A search for the decay model $\Lambda\pi^+\pi^-$ yielded no candidates. From this, I conclude that the two-pion decay mode is negligible. Finally, the data shown in Figure 1 is in reasonable agreement with the Lund prediction for $l\nu\Lambda$, indicating that the decay is not dominated by other final states.

In what follows, we will take $\Lambda_c^+ \rightarrow l\nu\Lambda$ to be the dominant mode, and allow for other decay modes as systematic errors.

Figure 2 shows the (wrong sign) background subtracted momentum spectrum of the $\Lambda$ + lepton pairs. The normalized Lund model prediction is superimposed.

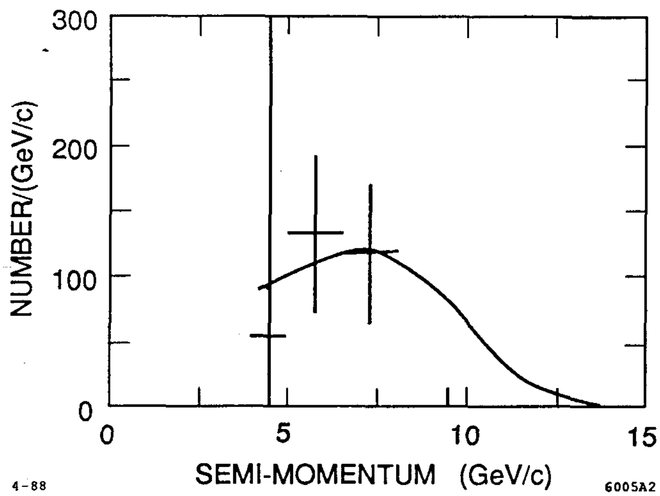


Fig. 2. Momentum of the $\Lambda$ + lepton combination. The solid curve is the Lund model prediction, normalized to the data in the 4 to 8 GeV/c region.

We also measure the total production rate. With radiative corrections, we find for the electron subsample (11 signal, 2 background):

$$\sigma(e^+e^- \rightarrow \Lambda_c X) \cdot \mathrm{Br}(\Lambda_c \rightarrow e\Lambda X) = 1.2 \pm 0.5 \pm 0.4 \text{ pb},$$

or $0.0031 \pm 0.0012 \pm 0.0010$ per hadronic event.

For the muons (6 signal, 3 background),

$$\sigma(e^+e^- \rightarrow \Lambda_c X) \cdot \mathrm{Br}(\Lambda_c \rightarrow \mu\Lambda X) = 1.0 \pm 1.0 \pm 0.3 \text{ pb},$$

or $0.0024 \pm 0.0024 \pm 0.0007$ per hadronic event.

To put these numbers in perspective, it is useful to consider some Monte Carlo predictions. The Lund model,[2] for example, predicts that at 29 GeV, 0.06 $\Lambda_c^+$ should be produced per-hadronic event. With this assumption, we find $Br(\Lambda_c \rightarrow e\Lambda X) = 5.1 \pm 2.0 \pm 1.7\%$ and $Br(\Lambda_c \rightarrow \mu\Lambda X) = 4.0 \pm 4.0 \pm 1.2\%$.

We can also consider the predictions of the UCLA model.[3] Since the UCLA model bases hadron production rates on their mass, and since $\Lambda_c^+$ are heavy, the predicted rate is much lower, 0.018 $\Lambda_c^+$ per hadronic event. This yields $Br(\Lambda_c \rightarrow e\Lambda X) = 17 \pm 7 \pm 6\%$ and $Br(\Lambda_c \rightarrow \mu\Lambda X) = 13 \pm 13 \pm 4\%$.

These rates can be compared with the Mark II/SPEAR measurements of $Br(\Lambda_c \rightarrow eX) = 4.5 \pm 1.7\%$ and $Br(\Lambda_c \rightarrow e\Lambda X) = 1.1 \pm 0.8\%$.

These results were found by measuring the increased rate of proton and $\Lambda$ production in $e^+e^-$ annihilation as the $e^+e^-$ energy was increased above the $\Lambda_c^+$ production threshold.

Table 1. Charmed particle semileptonic branching ratios and lifetimes.

| Particle | Br(e X) | Lifetime ($10^{-13}$s) |
|---|---|---|
| $D^+$ | 18.2 ± 1.7 | 10.5 ± 0.3 |
| $D^0$ | 7.0 ± 1.1 | 4.3 ± 0.1 |
| $\Lambda_c^+$ | ? | 1.9 ± 0.2 |

These numbers may also be compared with the comparable figures for $D$ meson semileptonic decays shown in Table 1. Neglecting the hadronic form factors, the charmed particle lifetimes should be proportional to the semileptonic branching ratios. Hadronic effects should be of order two or three, so, $Br(\Lambda_c \rightarrow e\Lambda X)$ should be small, probably less than 10%. So, it appears that the UCLA model prediction for $\Lambda_c^+$ production is low, while the Lund model prediction is reasonable.

One interesting application of this $\Lambda_c^+$ signal is to search for $\Sigma_c \rightarrow \Lambda_c\pi$, for both $\Sigma_c^{++}$ and $\Sigma_c^0$, using the same $\Delta$m technique used to find $D^*$. Because of the missing neutrino, the $\Delta$m band is much wider than for $D^*$. However, because of the purity of the $\Lambda_c^+$ signal, the technique works. Unfortunately, with the limited statistics present, the resulting upper limits are uninteresting.

In conclusion, we have observed semileptonic $\Lambda_c^+$ decays in 29 GeV $e^+e^-$annihilation.

## REFERENCES


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