RESULTS ON $\Lambda^+_c$, $D^+_c$, $D^0$, $D^+$ DECAY PROPERTIES
FROM THE NA32 EXPERIMENT
(ACCMOR Collaboration)

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ABSTRACT

Results on the decay modes of the $\Lambda^+_c$ baryon and $D^+_c$, $D^0$, $D^+$ mesons and charge conjugates produced in 230 GeV $\pi^-$Cu interactions are presented. A dedicated trigger for selection of $\Lambda^+_c \rightarrow pK^-\pi^+$, $D^+_c \rightarrow K^+K^-\pi^+$ was used. A high resolution vertex detector consisting of charge coupled devices and silicon microstrip detectors allowed the selection of very clean samples of $\Lambda^+_c$ and $D^+_c$. We obtained as well a large sample of $D^0$ and $D^+$. In a preliminary analysis, a total of 1200 charmed particles in 20 different channels are fully reconstructed. Preliminary results on branching ratios are given.

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1. **INTRODUCTION**

An experiment to measure $\Lambda_c^+ \rightarrow pK^-\pi^+$ and $D_s^+ \rightarrow K^+K^-\pi^+$ produced in hadronic interactions was started in 1985 with the ACCMOR spectrometer at the CERN SPS. It is a continuation of the NA32 experiment [1] with a Cu target, a modified vertex detector and a dedicated trigger. For the first time charge-coupled devices, CCDs [2], are used as vertex detectors. They provide high-resolution space points for secondary tracks close to the target. A modified version of the FAMP trigger [3] was used to trigger on events containing a pair of opposite sign kaons and/or protons. During 1985 and 1986, a total of 17.1 million triggers have been recorded. We present here results from the preliminary analysis of over 98% of the data sample. Very clean samples of $\Lambda_c$, $D_s^+$, $D^0$ and $D^{+*}$ are obtained and results on various branching ratios are presented.

2. **THE EXPERIMENT**

The experiment was located in the H6 beam of the North Area at the CERN SPS. A negative beam with a momentum of 230 GeV/c was used. Two CEDAR Cerenkov counters served for tagging incident pions and kaons (96% and 4% respectively).

Hadronic charm decays into charged particles are fully reconstructed with the large acceptance spectrometer [4] and the vertex detector. The spectrometer consists of two magnets and 48 planes of drift chambers arranged in 4 groups. Three multicellular Cerenkov counters are used to identify $\pi$, $K$, $p$ in the momentum range 4-80 GeV/c.

The trigger had two levels and used various components of the spectrometer [5]. The first level trigger used the geometrical correlation between elements of two scintillator arrays with cells of two Cerenkov counters to select events with at least two particles of opposite charge below the threshold of the Cerenkovs (8 thresholds of the Cerenkovs were 6.5 GeV/c and 12 GeV/c respectively). The second level trigger used a fast microprocessor (FAMP) which combined the information of 5 proportional chambers and the hardware signal from the first level trigger to check whether the selected particles have momenta in the range of the Cerenkov thresholds compatible with kaons and protons. Compared to an interaction trigger, the trigger increased the sensitivity by a factor 3.

A schematic view of the vertex detector [5] is shown in Fig. 1. It consists of 2 parts: a beam telescope with 7 silicon microstrip detectors (MSDs) and a vertex telescope with 2 CCDs at 10 and 20 mm behind the target and 8 MSDs starting at 65 mm behind the target.

*) particles stand for particles and antiparticles.
Capacitive charge division readout is used for the MSDs. Their characteristics are summarized in Table 1.

The CCDs have pixels of $22 \, \mu m \times 22 \, \mu m$ and measure space points with a precision of $\sigma_x = \sigma_y \sim 5 \, \mu m$ (x is the horizontal coordinate, y the vertical and z along the beam). A short 2.5 mm Cu target is used so that secondary vertices can be observed in vacuum close to the primary vertex.

3. DATA ANALYSIS

The aim of the data analysis is the search for charm decay vertices with or without a $K^0/\Lambda^0$. It is carried out in five steps.

First, for all events tracks are reconstructed in the drift chambers of the large acceptance forward spectrometer.

In the second step, the beam track and all other tracks are reconstructed in the beam and vertex telescope, respectively. The reconstruction of the tracks is made independently of the drift chamber track information. Then, the drift chamber tracks and the tracks in the vertex telescope are matched. Unassociated drift chamber tracks are used as a loose guidance in an attempt to recover tracks out of complex clusters of signals in the vertex telescope. Particle identification is made using the information of the Čerenkov hodoscopes. The reconstruction of the primary vertex is performed using all tracks found except tracks with a large impact parameter (the distance of closest approach in space of a track to the primary vertex), i.e. with a probability of less than 1% for belonging to the primary vertex. Figures 2a and 2b show the calculated error distributions in x, y and z of the fitted primary vertices (x/y is the horizontal/vertical coordinate, z is along the beam axis). Figure 3 shows the calculated impact parameter distribution of all tracks. It has been checked that the error distributions correspond to properly normalized $\chi^2$ distribution.

The third step selects events which have a primary vertex inside the Cu target and a candidate for a secondary vertex for reduction of the data sample, and amounts to a loose preselection of charm decays. Candidate events should have at least two tracks not originating from the primary vertex (as defined under step two) or contain one such a track and a $V^0$ candidate reconstructed with the drift chamber track elements. The data sample is reduced by about a factor seven.

The fourth step searches for secondary vertices and selects events containing at least one good secondary vertex which is constructed from the tracks not originating from the primary vertex (as defined under step two). Further, tracks which were originally used in the fit of the primary vertex are checked for compatibility with any of the secondary vertices.
Frequently, this leads to multiple interpretations of the event which are all used in the final physics analysis. These vertices should have a probability of better than 99%, for which the data sample is reduced by about a factor four. The calculated precision of the distance between primary and secondary vertices is shown in Fig. 4, which corresponds again to a properly normalized $\chi^2$ distribution.

In the last step, the secondary vertices are scanned for fully reconstructed charm decays checking all combinations compatible with the particle identification. Also "wrong sign" combinations are formed for background studies. Decay channels with $K^0$ or $\Lambda^0$ are studied as well. Further, special channels involving missing $\pi^0$s are investigated. It is this new approach of the search for secondary vertices that enables us to discover some rare decay modes. Secondary vertices inside the Cu target are excluded to remove possible secondary interactions. For the remaining events a final track recovery is attempted using guidance from the available secondary vertices, and $V^0$s are reconstructed in the drift chambers using the secondary vertices as production points. For each combination of particles in the secondary vertex the total momentum vector of the decay track is calculated which should originate with 99% probability from the primary vertex to be kept as a valid combination. For combinations with $K^0$s and $\Lambda^0$s, this condition is replaced by an impact parameter cut of less than 50 $\mu$m with respect to the primary vertex for this vector.

4. CHARM SIGNALS

We present preliminary results based on the analysis of 16.7 million triggers. Fig. 5 shows the 8 observed $D^0$ decay channels. A fit to the data yields 146 $D^0 \rightarrow K^-\pi^+$, 448 $D^0 \rightarrow K^-\pi^+\pi^+$, 16 $D^0 \rightarrow K^-K^+$, 16 $D^0 \rightarrow \pi^+\pi^-\pi^+$, 17 $D^0 \rightarrow K^0\pi^+\pi^-$, 10 $D^0 \rightarrow K^0K^+$ and 9 $D^0 \rightarrow K^0K^+$ events. We observe a new Cabibbo suppressed decay mode $D^0 \rightarrow K^-\pi^-\pi^-$ with 27 events. Figure 6 shows the 3 observed $D_S^+$ decay modes: 66 $D_S^+ \rightarrow K^+K^-\pi^+$, 14 $D_S^+ \rightarrow K^+\pi^+\pi^+\pi^-$ and 5 events in a new decay mode $D_S^+ \rightarrow K^+K^+K^-\pi^-$. Figure 7 and Fig. 6a show the 4 observed $D^+$ decay channels: 256 $D^+ \rightarrow K^-\pi^+\pi^+$, 48 $D^+ \rightarrow K^+K^+\pi^+$, 14 $D^+ \rightarrow K^0\pi^+\pi^+\pi^-$ and 15 events in a new decay mode $D^+ \rightarrow K^-\pi^+\pi^+\pi^-$. Finally, Fig. 8 shows the 5 $\Lambda_c$ decay modes: 135 $\Lambda_c^+ \rightarrow pK^-\pi^+$ and 12 $\Lambda_c^+ \rightarrow pK^0\pi^+\pi^-$. We also have indications for 2 new decay modes: 3 $p\phi$ events in a Cabibbo suppressed $\Lambda_c$ decay mode and 4 $pK^-\pi^+\pi^+\pi^-$ events in a 5-prong decay mode. We looked for the decay $\Lambda_c^+ \rightarrow \Sigma^+\pi^+\pi^+$, $\Sigma^+ \rightarrow p\pi^0$, where the $\Sigma$ decay is recognized as a kink between a track in the CCD+MSD planes and a forward-going track in the drift chambers, identified as a $p$ or $K/p$ in the Cerenkov counters. The precision on the minimum distance of the 2 tracks is $\sim 1$ mm and the precision on the kink angle is $\sim 0.4$ mr. Each valid kink gives 2 solutions
for the $\Sigma$ momentum. We then looked for a good vertex outside the copper target formed by a "$\Sigma$" track and 2 $\pi$ tracks, requiring all tracks to be displaced from the primary vertex. We found 32 events for $\Sigma^+\pi^+\pi^-(+c.c.)$ and only 1 for the "wrong charge" $\Sigma^+\pi^-\pi^-(+c.c.)$. In the first sample 27 vertices have an impact parameter less than 30 $\mu m$. Figure 8e shows their invariant mass with 1 entry for each $\Sigma$ momentum solution. A clear peak is seen at the $\Lambda_c$ mass. The accumulation of events at 2.03 GeV corresponds to the second momentum solution. The signal corresponds to 11 events with $|M-2.285 \text{ GeV}| < 4 \sigma_M$. One decay $\Lambda_c^+ \rightarrow \Sigma^+\pi^+\pi^-$, $\Sigma^+ \rightarrow n\pi^+$, has been reported so far [9].

5. ACCEPTANCE CALCULATIONS

In order to extract ratios of branching ratios (Br), each channel has to be corrected for the acceptance of the trigger and the selection criteria. Acceptance curves are determined by a Monte-Carlo calculation for all channels.

The Monte-Carlo program generates a primary pair of charmed particles

$$\pi^+ p \rightarrow CDX$$

for a chosen charmed particle C (where C can be a $\Lambda_c^+$, $D_s^+$ or a D-meson) and its associated partner $\bar{D}$. We have assumed no correlation between the pair of charmed particles. The required decay mode of C is then generated assuming a phase space distribution of its decay tracks or the relevant resonant components and the associated $\bar{D}$ decays into $K^+$ and anything according to the branching ratios given in [11]. The lifetime of the charmed particle C is derived from an exponential distribution with a world averaged mean lifetime [11] and in the case of $\Lambda_c$, as measured in this experiment [8]. The decay tracks are merged with interaction tracks X which are tracks read in from real interaction events. To balance momentum, the interaction tracks closest in momentum to the C and the $K^+$ (if any) from the $\bar{D}$ decay are removed. The geometrical acceptance, the trigger and event selection criteria are then applied in the Monte Carlo program:

1) Geometrical cuts

a) All the decay tracks have to be seen in at least the first five planes of the MSDs, except for $K^0$ or $\Lambda^0$ decay tracks

b) All tracks are tracked through the spectrometer magnets. They have to traverse at least the first group of drift chambers.

c) Any kaon or proton in the decay tracks must traverse the second magnet and be seen in the drift chambers downstream. The kaon and proton interaction and the kaon decay probabilities are also taken into account.
2) Trigger simulation

a) Hardware trigger signals for all the tracks are generated and the first level online trigger condition has to be fulfilled.

b) The FAMP algorithm is simulated and at least a pair of kaons and/or protons candidates of opposite charge has to be found within the momentum range used by FAMP.

3) Simulation of offline selection

a) The decay vertex has to be outside the copper target.

b) The separation of the decay vertex and of the decay tracks from the primary vertex are checked with cuts that are applied during the real event selection in data analysis.

Figure 9 shows the acceptance of the spectrometer for some examples of decay modes as a function of $x_F$, the longitudinal momentum of the charge particle in the centre of mass system divided by the maximum possible value.

It has to be emphasized that our trigger selected preferentially any decay with a pair of kaons and/or protons of opposite charge in the final state. Hence, for decays with a single kaon in the decay products, in order to satisfy the trigger condition, one needs either a pion misidentified by the trigger as a kaon/proton or the kaon from the decay of the associated charm partner. The acceptance is not very sensitive to the presence of a second kaon: by varying the branching ratio of $\mathcal{D} \rightarrow K^+ + X$ from 0 to 100%, the total acceptance for $\mathcal{D}$ mesons changes by $\pm 20\%$. We have checked that impact parameters and momentum distributions as produced in the Monte Carlo program agree well with all our experimental distributions. We quote systematic errors that cover uncertainty in the lifetime, in the $x_F$ and $p_T^\pi$ production characteristics and further refinements in the description of the apparatus. This introduces 15% uncertainty on the ratios of branching ratios. An additional 20% uncertainty has to be added for channels containing a $\phi^0$.

6. RESULTS

Tables 2-5 summarize our results for the $D^0$, $D^+_S$, $D^+$ and $\Lambda^+_c$ decay modes respectively. We measure ratios of branching ratios and normalize to the Cabibbo favoured decay modes $D^0 \rightarrow K^-\pi^+$, $D^0 \rightarrow K^-\pi^+\pi^-\pi^+$, $D^+ \rightarrow K^-\pi^+\pi^+$, $D^+_S \rightarrow \phi\pi^+$ and $\Lambda^+_c \rightarrow pK^-\pi^+$. All values quoted are still preliminary.

Table 2 summarizes our results for the $D^0$ decay modes. Our values compare reasonably well with other known measurements. For the new Cabibbo suppressed decay
mode $D^0 \to K^+K^-\pi^+\pi^-$, we studied the resonant component $D^0 \to \phi\pi^+\pi^-$. We measure the ratio $\text{Br}(D^0 \to \phi\pi^+\pi^-)/\text{Br}(D^0 \to K^+K^-\pi^+\pi^-) = 0.97 \pm 0.36$.

Table 3 summarizes our results for the $D_s^+ \to K^+K^-\pi^+$ decay mode. For the $D_s^+ \to K^+K^-\pi^+$ decay mode, we have studied the $\phi\pi^+$ and $K^{*0}K^+$ resonant components. They are shown in Fig. 10, together with the non-resonant component. Our values compare reasonably well with other experiments (last column in the table). We observe the $D_s^+ \to K^+K^-\pi^+\pi^-\pi^-$ decay mode and studied the $\phi\pi^+\pi^+\pi^-$ resonant component. We measure $\text{Br}(D_s^+ \to \phi\pi^+\pi^-)/\text{Br}(D_s^+ \to K^+K^-\pi^+\pi^-) = 0.4 \pm 0.2$. We observe a new decay mode: $D_s^+ \to K^{*0}K^+$ where $K^{*0}$ decays to $K^-\pi^+$ and $K^{*+}$ to $K^0\pi^+$. The ratio $\text{Br}(D_s^+ \to K^{*0}K^+)/\text{Br}(D_s^+ \to \phi\pi^+)$ is predicted by Bauer et al. [10] to be $1.2$. This value is in agreement within error with our measured value.

Table 4 summarizes our results for the $D^+$ decay modes. We measure the ratio $\text{Br}(D^+ \to K^-\pi^+\pi^+\pi^-)/\text{Br}(D^+ \to K^-\pi^+\pi^+)$ to be $0.053 \pm 0.017$ for this new 5-prong decay mode. For the Cabibbo suppressed $K^+K^-\pi^+$ decay mode, we studied the $\phi\pi^+$ and $K^{*0}K^+$ resonant components (Fig. 10). Our values are in reasonable agreement with values measured by other experiments. We also measured the ratio $\text{Br}(D^+ \to K^{*0}\pi^+\pi^+\pi^-)/\text{Br}(D^+ \to K^-\pi^+\pi^+)$ in agreement again with the MARK III values.

Finally, Table 5 summarizes our results for the $\Lambda_c$ decay modes. We studied the $pK^{*0}$ and $\Delta^{++}K^-$ resonant components in the $pK^-\pi^+$ decay mode. Figure 11 shows the invariant $K^-\pi^+$ and $p\pi^+$ mass spectra. A clear $K^{*0}$ peak appears; we measure $\text{Br}(\Lambda_c^+ \to pK^{*0})/\text{Br}(\Lambda_c^+ \to pK^-\pi^+)$ to be $0.31 \pm 0.07$ in agreement with a MARK II measurement. No clear $\Delta^{++}$ signal is seen in the $p\pi^+$ invariant mass spectrum. If we interpret the small excess of events as a signal, it would correspond to $\text{Br}(\Lambda_c^+ \to \Delta^{++}K^-)/\text{Br}(\Lambda_c^+ \to pK^-\pi^+) = 0.15 \pm 0.08$ but we prefer to quote an upper limit of $0.28$ at 90\% C.L. Relative branching ratios to the $pK^-\pi^+$ decay mode are given for the two new decay modes: $pK^-\pi^+\pi^+\pi^-$ and $p\rho$. Our measurement for the $pK^{*0}\pi^+\pi^-$ channel is in agreement with experiments. We have not calculated yet the acceptance for the $\Sigma^+\pi^+\pi^-$ decay mode for which special cuts have been applied. We estimated that it should be roughly of the same order of magnitude as the $pK^-\pi^+$ mode.

7. CONCLUSION

We have reconstructed the decays of 1200 charmed particles in 20 different decay modes: 8 $D^0$ decay modes, 3 $D_s^+$ decay modes, 5 $D^+$ decay modes and 5 $\Lambda_c^+$ decay modes. We give preliminary values for ratios of branching ratios.
REFERENCES


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Table 2

$D^0$ Decay Modes

(Errors are statistical only. The systematic error is 15% for ratios of branching ratios of decays to charged particles and 35% for ratios of branching ratios of decays involving a $K^0$. The acceptances quoted do not include branching ratios for $K^0$, $\phi$ or $K^*$ decays)

<table>
<thead>
<tr>
<th>Decay Mode</th>
<th># of events</th>
<th>Acceptance</th>
<th>Measurement</th>
<th>Other experiments</th>
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<tr>
<td>$K^-\pi^+\pi^-\pi^+$</td>
<td>448.5±22.2</td>
<td>0.028</td>
<td>$\frac{\text{Br}(D^0 \to K^-\pi^+)}{\text{Br}(D^0 \to K^+\pi^-\pi^+)} = 0.51 \pm 0.05$</td>
<td>0.47±0.06&lt;sup&gt;a&lt;/sup&gt;</td>
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<td>$K^-\pi^+$</td>
<td>146.5±12.4</td>
<td>0.018</td>
<td>$\frac{\text{Br}(D^0 \to K^-\pi^+\pi^-)}{\text{Br}(D^0 \to K^+\pi^-\pi^+)} = 0.040 \pm 0.009$</td>
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<tr>
<td>$K^-K^+\pi^+\pi^-$</td>
<td>26.9±6.1</td>
<td>0.042</td>
<td>$\frac{\text{Br}(D^0 \to K^-K^+\pi^-)}{\text{Br}(D^0 \to K^+\pi^-\pi^+)} = 0.039 \pm 0.012$</td>
<td>0.16±0.065&lt;sup&gt;a&lt;/sup&gt;</td>
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<tr>
<td>$\phi\pi^+\pi^-$</td>
<td>16.8±5.0</td>
<td>0.055</td>
<td>$\frac{\text{Br}(D^0 \to \phi\pi^+\pi^-)}{\text{Br}(D^0 \to K^-\pi^+\pi^-)} = 0.055 \pm 0.021$</td>
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<tr>
<td>$\pi^+\pi^-\pi^+\pi^-$</td>
<td>15.8±6.1</td>
<td>0.018</td>
<td>$\frac{\text{Br}(D^0 \to \pi^+\pi^-\pi^+\pi^-)}{\text{Br}(D^0 \to K^-\pi^+\pi^-)} = 0.122 \pm 0.018&lt;sup&gt;a&lt;/sup&gt;$</td>
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<tr>
<td>$K^+K^-$</td>
<td>15.6±4.5</td>
<td>0.022</td>
<td>$\frac{\text{Br}(D^0 \to K^+K^-)}{\text{Br}(D^0 \to K^-\pi^+)} = 0.087 \pm 0.026$</td>
<td>1.49±0.39&lt;sup&gt;a&lt;/sup&gt;</td>
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<td>$K^0\pi^+\pi^-$</td>
<td>16.5±4.5</td>
<td>0.010</td>
<td>$\frac{\text{Br}(D^0 \to K^0\pi^+\pi^-)}{\text{Br}(D^0 \to K^-\pi^+)} = 0.61 \pm 0.17$</td>
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<td>$K^0K^+K^-$</td>
<td>8.5±3.2</td>
<td>0.028</td>
<td>$\frac{\text{Br}(D^0 \to K^0K^+K^-)}{\text{Br}(D^0 \to K^-\pi^+)} = 0.11 \pm 0.04$</td>
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<tr>
<td>$K^0\phi$</td>
<td>4.8±2.4</td>
<td>0.036</td>
<td>$\frac{\text{Br}(D^0 \to K^0\phi)}{\text{Br}(D^0 \to K^-\pi^+)} = 0.10 \pm 0.05$</td>
<td>0.20±0.13&lt;sup&gt;a&lt;/sup&gt;</td>
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<td>$K^0K^+\pi^-$</td>
<td>9.5±3.8</td>
<td>0.015</td>
<td>$\frac{\text{Br}(D^0 \to K^0K^+\pi^-)}{\text{Br}(D^0 \to K^-\pi^+)} = 0.24 \pm 0.10$</td>
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<td>$K^*K^+$</td>
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<td>0.27±0.13&lt;sup&gt;b&lt;/sup&gt;</td>
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<sup>a</sup> value derived from the MARK III data using their statistical error only [7].

<sup>b</sup> value derived from the MARK II data using their statistical error only [7],[11].
### Table 3

**D_s^+ Decay Modes**

(Errors are statistical only. The systematic error is 15% for ratios of branching ratios of decays to charged particles and 35% for ratios of branching ratios of decays involving a K_0^*. The acceptances quoted do not include branching ratios for K_0^*, φ, or K* decays)

<table>
<thead>
<tr>
<th>Decay Mode</th>
<th># of events</th>
<th>Accep tance</th>
<th>Measurement</th>
<th>Other experiments</th>
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<tr>
<td>φπ^+</td>
<td>20.3±4.9</td>
<td>0.048</td>
<td>( \frac{\text{Br}(D_s^+ \to K^* K^+)}{\text{Br}(D_s^+ \to φπ^+)} = 0.89±0.32 )</td>
<td>1.03±0.3a)</td>
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<td>K^*0K^+</td>
<td>16.6±4.5</td>
<td>0.032</td>
<td>( \frac{\text{Br}(D_s^+ \to K K^{*0} K)}{\text{Br}(D_s^+ \to φπ^+)} = 0.96±0.32 )</td>
<td>0.74±0.12±0.06b)</td>
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<tr>
<td>(K^+K^-π^+)</td>
<td>28.3±6.4</td>
<td>0.035</td>
<td>( \frac{\text{Br}(D_s^+ \to K K^{*0} π_{\text{n.r.}})}{\text{Br}(D_s^+ \to φπ^+)} = 0.23±0.07±0.07b)</td>
<td>1.44±0.37c)</td>
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<tr>
<td>φπ^+π^+π^-</td>
<td>9.2±3.4</td>
<td>0.057</td>
<td>( \frac{\text{Br}(D_s^+ \to φπ^+π^-)}{\text{Br}(D_s^+ \to φπ^+)} = 0.39±0.17 )</td>
<td>0.77±0.31±0.15b)</td>
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<td>K^+K^-π^+π^-</td>
<td>4.8±2.8</td>
<td>0.051</td>
<td>( \frac{\text{Br}(D_s^+ \to K K^{*0} π_{\text{n.r.}})}{\text{Br}(D_s^+ \to φπ^+)} = 0.11±0.07 )</td>
<td>0.41±0.13±0.11c)</td>
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<td>K^<em>0K^</em>+</td>
<td>5.2±2.4</td>
<td>0.017</td>
<td>( \frac{\text{Br}(D_s^+ \to K^* K^*)}{\text{Br}(D_s^+ \to φπ^+)} = 2.3±1.2 )</td>
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a) value derived from the MARK III data using their statistical error only [7].
b) E691 data [7].
c) ARGUS data [7].
Table 4

D³ Decay Modes

(Errors are statistical only. The systematic error is 15% for ratios of branching ratios of decays to charged particles and 35% for ratios of branching ratios of decays involving a K⁰. The acceptances quoted do not include branching ratios for K⁰, φ or K* decays)

<table>
<thead>
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<th># of events</th>
<th>Acceptance</th>
<th>Measurement</th>
<th>Other experiments</th>
</tr>
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<tbody>
<tr>
<td>K⁻π⁺π⁺</td>
<td>256.0±16.5</td>
<td>0.032</td>
<td>Br(D⁺ → K⁻π⁺π⁺π⁺) / Br(D⁺ → K⁻π⁺π⁺) = 0.053±0.017</td>
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</tbody>
</table>
| K⁻π⁺π⁺π⁻ | 14.9±4.7    | 0.035      | Br(D⁺ → φπ⁺) / Br(D⁺ → K⁻π⁺π⁺) = 0.053±0.016 | 0.084±0.021±0.011 a)
| φπ⁺       | 13.6±4.1    | 0.065      | Br(D⁺ → φπ⁺) / Br(D⁺ → K⁻π⁺π⁺) | 0.103±0.014±0.009 b) |
| K⁺K⁻π⁺   | 9.8±3.8     | 0.047      | Br(D⁺ → K⁺K⁻π⁺π⁺) / Br(D⁺ → K⁺π⁺π⁺) = 0.038±0.015 | 0.048±0.021±0.011 a)
| non. res.  | 24.9±7.0    | 0.050      | Br(D⁺ → K⁺K⁻π⁺π⁺) / Br(D⁺ → K⁺π⁺π⁺) = 0.062±0.018 | 0.059±0.026±0.009 a) |
| K⁰π⁺π⁺π⁻ | 13.5±4.7    | 0.015      | Br(D⁺ → K⁰π⁺π⁺π⁻) / Br(D⁺ → K⁺π⁺π⁺) = 0.33±0.12 | 0.73±0.20 c) |

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a) MARK III data [7].
b) E691 data [7].
c) value derived from the MARK III data using their statistical error only [7].
Table 5

Λ_c Decay Modes

(Errors are statistical only. The systematic error is 15% for ratios of branching ratios of decays to charged particles and 35% for ratios of branching ratios of decays involving a K^0. The acceptances quoted do not include branching ratios for K^0, φ or K^* decays)

<table>
<thead>
<tr>
<th>Decay Mode</th>
<th># of events</th>
<th>Acceptance</th>
<th>Measurement</th>
<th>Other experiments</th>
</tr>
</thead>
<tbody>
<tr>
<td>pK^-π^+</td>
<td>135.6±12.3</td>
<td>0.030</td>
<td>$\frac{Br(\Lambda_c \rightarrow pK^*)}{Br(\Lambda_c \rightarrow pK^-\pi^+)} = 0.31±0.07$</td>
<td>0.18±0.10(^a)</td>
</tr>
<tr>
<td>pK^*0</td>
<td>29.2±5.8</td>
<td>0.031</td>
<td>$\frac{Br(\Lambda_c \rightarrow \Delta^{++}K^-)}{Br(\Lambda_c \rightarrow pK^-\pi^+)} &lt; 0.28@90%CL$</td>
<td>&lt;0.59@90%CL(^b)</td>
</tr>
<tr>
<td>Δ^{++}K^-</td>
<td>18.4±9.4</td>
<td>0.027</td>
<td>$\frac{Br(\Lambda_c \rightarrow \Delta^{++}K^-)}{Br(\Lambda_c \rightarrow pK^-\pi^+)}$</td>
<td>0.17±0.07(^a)</td>
</tr>
<tr>
<td>pK^-π^+π^+π^-</td>
<td>4.0±2.0</td>
<td>0.039</td>
<td>$\frac{Br(\Lambda_c \rightarrow pK^-\pi^+\pi^-)}{Br(\Lambda_c \rightarrow pK^-\pi^+)} = 0.022±0.011$</td>
<td>&lt;0.42@90%CL(^b)</td>
</tr>
<tr>
<td>pφ</td>
<td>3.6±2.1</td>
<td>0.026</td>
<td>$\frac{Br(\Lambda_c \rightarrow p\phi)}{Br(\Lambda_c \rightarrow pK^-\pi^+)} = 0.062±0.036$</td>
<td></td>
</tr>
<tr>
<td>pK^0π^+π^-</td>
<td>11.5±4.1</td>
<td>0.012</td>
<td>$\frac{Br(\Lambda_c \rightarrow pK^0π^+π^-)}{Br(\Lambda_c \rightarrow pK^-\pi^+)} = 0.62±0.23$</td>
<td>&lt;1.9@90%CL(^b)</td>
</tr>
<tr>
<td>Σ^+π^+π^-</td>
<td>11</td>
<td></td>
<td></td>
<td>1.3±1.0(^c)</td>
</tr>
</tbody>
</table>

\(^a\) MARK II data [7].
\(^b\) ARGUS data [7].
\(^c\) CLEO data [7].
Figure Captions

Fig. 1  
Side view of the vertex detector.
B1-B7 : silicon microstrip detectors for reconstruction of beam;
T : 2.5 mm Cu-target ; CCDs : charge-coupled devices ; I : interaction counter ;
V1-V8 : silicon microstrip detectors (orientations shown are with respect to
horizontal plane).

Fig. 2  
Error distributions of the fitted primary vertices (z-axis is beam direction).

Fig. 3  
Impact parameter distribution of all tracks with respect to primary vertex.

Fig. 4  
Distribution of errors on decay length.

Fig. 5  
Invariant mass distributions for the $D^0$ decay channels :
a) $K^-\pi^+$, b) $K^-\pi^+\pi^-\pi^+$, c) $K^+K^-$, d) $\pi^+\pi^-\pi^+\pi^-$,
e) $K^0\pi^+\pi^-$,
f) $\bar{K}^0K^+$, g) $K^0K^-\pi^+$, h) $K^-\pi^+\pi^-$, i) $\phi\pi^+\pi^-.$

Fig. 6  
Invariant mass distributions for the $D^+_s$ decay channels :
a) $K^+K^-\pi^+$, b) $K^+K^-\pi^+\pi^+\pi^-$, c) $K^+\bar{K}^-$, d) $\phi\pi^+\pi^+\pi^-.$

Fig. 7  
Invariant mass distributions for the $D^+$ decay channels :
a) $K^-\pi^+\pi^+$, b) $K^-\pi^+\pi^+\pi^+\pi^-$, c) $K^0\pi^+\pi^+\pi^-.$

Fig. 8  
Invariant mass distributions for the $\Lambda^+_c$ decay channels :
a) $pK^-\pi^+$, b) $pK^-\pi^+\pi^+$, c) $p\phi$, d) $pK^-\pi^+\pi^-\pi^+\pi^-$, d) $\Sigma^+\pi^+\pi^-.$

Fig. 9  
Acceptance as a function of $x_F$ for some decay modes as indicated in the figure.

Fig. 10  
Invariant $K^+K^-\pi^+$ mass distribution for events with a $m_{K^+K^-}$ within $\pm 9$ MeV from
the $\phi$ mass a), with a $m_{K^-\pi^+}$ within $\pm 75$ MeV from the $K^*0$ mass b) and the
remaining events c).

Fig. 11  
a) Invariant $K^-\pi^+$ mass for the $\Lambda_c \rightarrow pK^-\pi^+$ decays
b) Invariant $p\pi^+$ mass for the $\Lambda_c \rightarrow pK^-\pi^+$ decays.
active areas:

CCD : 8.8 x 24 mm$^2$
- ⇔ 42900 pixels

MSD : 36 x 24 mm$^2$
- ⇔ 1200 strips

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**Fig. 1**

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**Fig. 2**

**a)**
\[ \langle \sigma_x \rangle = 2.3 \mu m \]
\[ \langle \sigma_y \rangle = 2.0 \mu m \]

**b)**
\[ \langle \sigma_z \rangle = 70 \mu m \]

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**Fig. 3**

\[ \langle i.p. \rangle = 7.9 \mu m \]

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**Fig. 4**

\[ \langle \sigma_{\Delta z} \rangle = 186 \mu m \]
Figure 9