M. Basile et al.: A MEASUREMENT OF TWO RESONANT CONTRIBUTIONS IN THE \( \Lambda_c^+ \) BRANCHING RATIOS

Estratto da:
A Measurement of Two Resonant Contributions in the $\Lambda_c^+$ Branching Ratios.


CERN - Geneva, Switzerland
Istituto di Fisica dell'Università - Bologna, Italia
Istituto di Fisica dell'Università - Perugia, Italia
Istituto Nazionale di Fisica Nucleare - Sezione di Bologna, Italia
Istituto Nazionale di Fisica Nucleare - Laboratori Nazionali di Frascati, Italia

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Summary. — The contribution of two resonant states $\Delta^{++}$ and $K^{*0}$ to the $\Lambda_c^+$ decay has been measured. The world average is given.

1. — Introduction.

The purpose of this paper is to report on a study of the contributions to the decay $\Lambda_c^+ \rightarrow pK^-\pi^+$ of the two well-known resonant states

\begin{equation}
K^{*0} \rightarrow K^-\pi^+ \quad \text{and} \quad \Delta^{++} \rightarrow p\pi^+.
\end{equation}

The experiment has been performed by using, as the $\Lambda_c^+$ production reaction, high-energy pp collisions at the CERN Intersecting Storage Rings (ISR). The reaction investigated was

\begin{equation}
pp \rightarrow \Lambda_c^+ + \text{e}^- + \text{anything},
\end{equation}

at a total pp c.m. energy of $\sqrt{s} = 62$ GeV.

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Fig. 1. - Top view of the SFM detector, showing the MWPCs and the external apparatus for particle identification: i) \( C_i \) \((i = 0, \ldots, 5)\) are gas threshold Čerenkov counters, ii) \( SW_i \) \((i = 2, \ldots, 5)\) are lead/scintillator sandwiches, iii) \( LG_i \) \((i = 3, 4)\) are lead glass counters. Notice that only coincidences \( C_0 C_5 \) or \( C_3 C_4 \) associated to a minimum energy release (> 600 MeV) in the electromagnetic shower detectors \((LG_0, SW_2 \text{ or } LG_4, SW_4)\) were used in the "electron" trigger.
2. – Experimental set-up.

The experimental set-up consists of a system of multiwire proportional chambers (MWPCs) in a large-volume, 10 kG magnetic field, produced by the Split-Field Magnet (SFM). There are also gas Čerenkov counters and electromagnetic shower detectors for electron trigger, plus a large assembly of time-of-flight (TOF) counters for particle identification (p, K, π). Figure 1 shows a schematic lay-out of the set-up, which has been described in detail elsewhere (1).

3. – Data analysis.

From a sample of proton-proton collisions with an electron produced at 90° we obtained (2) a clear signal of the charmed baryon $Λ_c^+$ decaying via the channel $pK^+π^−$.

Firstly, the events were analysed in order to reduce the background contribution to genuine electron events. The contamination from charged hadrons simulating electrons was reduced to the 2% level. Background electrons from Dalitz π² and γ decays and from external γ-conversions were rejected to the 30% level via pulse-height analysis with a dE/dx chamber placed near the intersection region.

From the sample of events left, we selected those with at least one positive particle with $x = 2p_x/\sqrt{s} > 0.3$ and an error on the measured momentum $Δp/p < 30\%$. In these events the positive particle with the highest $x$ has been assumed to be a proton. In the invariant mass, $pK^+π^−, K^+(π^−)$ is any negative (positive) track not identified as an $\bar{p}$ or $π^−$ (p or $K^+$) by the time of flight. All possible combinations are entered into the mass plot, provided they satisfy the following conditions:


a) all particles are fitted to the vertex and have a momentum uncertainty \( \Delta p/p < 30\% \),

b) both \( K^- \) and \( \pi^+ \) are in the same rapidity hemisphere as that of the proton,

c) the rapidity of both the \( K^- \) and the \( \pi^+ \) is greater than 1.0.

In order to enhance the \( \Lambda_c^+ \) signal, we have imposed one of the following conditions on the hemisphere opposite to that of the \( \Lambda_c^+ \):

i) either the presence of a leading system of charged particles with 
\[
x_{\text{total}} = \sum_{i=1}^{n} x_i > 0.5, \text{ where } x = 2p_t/\sqrt{s};
\]

ii) or a signature for a leading system escaping detection, i.e. \( x_{\text{total}} < 0.1 \).

The above sum \( \sum_{i=1}^{n} \) is extended to all particles fitted to the vertex and with \( \Delta p/p < 30\% \). The results are shown in fig. 2.

![Graph](image)

**Fig. 2.** Mass distribution of \( pK^-\pi^+ \) combinations selected as described in the text. The solid line is a fit to the mass spectrum with \( e^+ \) trigger. This shape represents the background.
In order to study the resonant contributions to the decay $\Lambda_c^+ \rightarrow pK^-\pi^+$
from

$$\Lambda_c^+ \rightarrow K^\ast np \quad \text{and} \quad \Lambda_c^+ \rightarrow \Delta^{++}K^-,$$

the mass spectra for $K^-\pi^+$ and $p\pi^+$ have been studied in three different mass
ranges for the $pK^-\pi^+$ mass spectrum. These are indicated in table I.

Figure 3 shows the results. Above (fig. 3a)) and below (fig. 3c)) the $\Lambda_c^+$
mass range, the $K^-\pi^+$ and $p\pi^+$ mass spectra do not show any enhancement.

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**Fig. 3.** – Invariant-mass spectra for $K^-\pi^+$ and $p\pi^+$ combinations as a function of three
different cuts in the $pK^-\pi^+$ mass: a) $2.18 < m(pK^-\pi^+) < 2.28$ GeV/$c^2$ (below $\Lambda_c^+$),
b) $2.28 < m(pK^-\pi^+) < 2.38$ GeV/$c^2$ (in the $\Lambda_c^+$ peak), c) $2.38 < m(pK^-\pi^+) < 2.48$ GeV/$c^2$
(above $\Lambda_c^+$). The full-line histograms refer to $e^-$ triggers; the dashed-line histograms
refer to $e^+$ triggers. The solid lines are fits to these mass spectra with $e^+$ triggers.
This is not the case in fig. 3b), which corresponds to the $\Lambda_+^*$ mass range. Here we observe a peak in the mass spectrum of both the $K\pi^+$ and the $p\pi^+$, at mass values corresponding to $K^{*0}$ and $\Delta^{++}$, respectively.

<table>
<thead>
<tr>
<th>Table I. – Mass ranges of $pK^-\pi^+$ (GeV/c²).</th>
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<tbody>
<tr>
<td>below $\Lambda_+^*$</td>
</tr>
<tr>
<td>in the $\Lambda_+^*$ peak</td>
</tr>
<tr>
<td>above $\Lambda_+^*$</td>
</tr>
</tbody>
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Notice that the dashed-line histograms correspond to mass spectra with $e^-\pi^+$-triggered events. Here there is no evidence for any resonant state. This is another proof that, in order to have a clean $\Lambda_+^*$ signal, the $e^-$ trigger is needed. In fact, the associated production of $\Lambda_+^*$ with an anticharmed particle requires the presence of an $e^-$ and not of an $e^\pm$. The $e^-\pi^+$-triggered events were used to draw the shape of the background in the $e^-\pi^+$-triggered spectra.

4. – Results.

From the number of events above background in the $K^{*0}$ and $\Delta^{++}$ peaks and from the total number of observed $\Lambda_+^*$, the following branching ratios are obtained:

\[
\frac{\Lambda_+^* \to K^{*0}p}{\Lambda_+^* \to pK^-\pi^+} = 0.28 \pm 0.16,
\]

\[
\frac{\Lambda_+^* \to \Delta^{++}K^-}{\Lambda_+^* \to pK^-\pi^+} = 0.40 \pm 0.17.
\]

<table>
<thead>
<tr>
<th>Table II. – Branching ratios of $K^{<em>0}$, $\Delta^{++}$ resonant contributions to the $\Lambda_+^</em> \to pK^-\pi^+$ decay channel.</th>
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</thead>
<tbody>
<tr>
<td>$K^{*0}p/pK^-\pi^+$</td>
</tr>
<tr>
<td>SPEAR (Mark II) (5)</td>
</tr>
<tr>
<td>ISR (SAJOT) (4)</td>
</tr>
<tr>
<td>ISR (this experiment)</td>
</tr>
<tr>
<td>world average</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>$\Lambda_+^* \to (\Delta^{++}K^- + K^{*0}p)$</td>
</tr>
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The interest in these measurements is due to the fact that only two results \(^{3,4}\) are available so far. Table II summarizes the present knowledge of these branching ratios. The world average is also given.

- **RIASSUNTO**

Analizzando un campione di interazioni protone-protone ad un'energia totale nel centro di massa di 62 GeV, è stata studiata la produzione associata del barione incantato \(\Lambda_c^+\) con una particella antincantata che decade semileptonicamente. È stato misurato il contributo dei due stati risonanti \(\Delta^{++}\) e \(K^{*0}\) al decadimento del \(\Lambda_c^+\) nel canale \(\Lambda_c^+ \rightarrow pK^-\pi^+\).

Измерение двух резонансных вкладов в отношении ветвей \(\Lambda_c^+\).

Резюме (*) — Измеряется вклад двух резонансных состояний \(\Delta^{++}\) и \(K^{*0}\) в распад \(\Lambda_c^+\). Приводится «мировое» среднее.

(*) Переведено редакцией.