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30 March 1990MEASUREMENT OF THE REACTION $\bar{p}p \rightarrow \bar{\Lambda}\Sigma^0 + \text{c.c.}$ at 1.695 GeV/c

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ABSTRACT

The reaction $\bar{p}p \rightarrow \bar{\Lambda}\Sigma^0$ together with its charge conjugate channel (c.c.) has been measured at LEAR. The incident $\bar{p}$ momentum was 1.695 GeV/c, corresponding to an excess energy above threshold of 14.8 MeV. Results are given for the production cross-section and the differential cross-section as well as for the polarization. Comparisons are made with theoretical calculations and with the reaction $\bar{p}p \rightarrow \bar{\Lambda}\Lambda$.

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1. INTRODUCTION

The study of production of antihyperon-hyperon pairs in $\bar{p}p$ collisions close to reaction threshold has been motivated by the possibility of extracting information at the quark level from these reactions. Features such as the measured angular distributions and polarizations could provide information about the underlying dynamical processes. In a simple quark picture, the process is governed by annihilation and creation of quark pairs, in particular the creation of antistrange-strange quark pairs. In the framework of the static quark model, the non-participating spectator quarks form an $I = S = 0$ pair in the Λ , whereas they have $I = S = 1$ in the Σ^0 .

So far, theoretical work has concentrated on the channel $\bar{p}p \rightarrow \bar{\Lambda}\Lambda$, for which data have been published by our collaboration [1, 2]. 'Quark-based' models as well as models based on meson exchanges [3] have been used successfully to describe the differential cross-sections and the polarizations. In fact, the two approaches give very similar results.

In this context, the reaction $\bar{p}p \rightarrow \bar{\Lambda}\Sigma^0 + \text{c.c.}$ is of particular interest. The long-ranged $K(494)$ exchange is suppressed: $SU(3)$ relations give $g^2_{KN\Sigma^0}/g^2_{KNA} = 1/27$. As a consequence, the short-ranged $K^*(892)$ exchange becomes more important since $g^2_{K^*\Sigma^0}/g^2_{K^*\Lambda} \approx 0.8$. One might hope that this feature would make the reaction dynamics of $\bar{p}p \rightarrow \bar{\Lambda}\Sigma^0 + \text{c.c.}$ more sensitive to quark effects [4] and thus help to distinguish between the various theoretical approaches.

In certain 'quark-based' models, the ratios of cross-sections for different hyperon channels have been predicted [5–7]. The ratios, rather than absolute values, are calculated to eliminate uncertainties in the treatment of initial-state and final-state interactions.

In this paper we present a measurement of the reaction $\bar{p}p \rightarrow \bar{\Lambda}\Sigma^0 + \text{c.c.}$ made by the PS185 Collaboration at LEAR. The measurement was performed at an antiproton momentum of 1.695 GeV/c. This corresponds to an excess energy, $\epsilon = \sqrt{s} - (m_{\Sigma^0} + m_{\Lambda})$, of 14.8 MeV, the reaction threshold being at $p_{\text{thr}} = 1.653$ GeV/c. Differential and total cross-sections as well as polarizations have been obtained and are presented below.

2. EXPERIMENT AND DATA ANALYSIS

The PS185 detector is a forward decay spectrometer and consists of four basic components: a trigger-active target system made of four CH₂ and one carbon cell, each sandwiched between and surrounded by veto scintillators; stacks of multiwire proportional chambers and drift chambers for the reconstruction of charged particle tracks; a scintillator hodoscope for trigger purposes; and a solenoidal magnet enclosing drift chambers for baryon-number identification. The arrangement is described in more detail in refs. [1] and [2].

The data evaluation was restricted to events showing two 'neutral vees' ($2V^0$) in the chamber stacks. After applying geometrical and kinematical cuts, the event candidates were subjected to a kinematic fitting procedure, in which the hypotheses $\bar{p} p \rightarrow \bar{\Lambda} + \Sigma^0 \rightarrow \bar{\Lambda} + \Lambda \gamma \rightarrow \bar{p} \pi^+ + p \pi^- \gamma$ and $\bar{p} p \rightarrow \bar{\Lambda} \Lambda \rightarrow \bar{p} \pi^+ + p \pi^-$ were compared with each other. The incoming beam momentum vector was kept constant at its average value in order to reduce the number of free parameters (the γ -rays from the Σ^0 decay were not measured in this experiment). Global χ^2 -minimization was made in a 14-dimensional space [8]. The efficiency of reconstructing events was 60% and was determined by analysing Monte Carlo data isotropically distributed.

For the final analysis, the only events kept were those having a reduced $\chi^2 < 4.6$ for the $\bar{\Lambda} + \Sigma^0$ hypothesis, and where the $\bar{p} p \rightarrow \bar{\Lambda} \Lambda$ hypothesis would give a χ^2 -value at least 50% larger. Out of the 1714 events remaining after identification of baryons and antibaryons, 221 came from the carbon target cell. The numbers indicate a 25% contamination in our data from reactions on carbon in the CH₂ target cells. This is a factor of 3 higher than in the $\bar{\Lambda} \Lambda$ case at the same momentum [9], and is due to the fact that the reaction $\bar{p} C \rightarrow \bar{\Lambda} \Lambda + X$ can more easily mimic the $\bar{p} p \rightarrow \bar{\Lambda} \Sigma^0$ reaction. The background coming from the $\bar{p} p \rightarrow \bar{\Lambda} \Lambda$ reaction is reduced to 3% after the applied χ^2 -cuts. This has been corrected for in the angular distribution.

Another uncertainty arises from the difficulty in distinguishing the reaction $\bar{p} p \rightarrow \bar{\Lambda} \Sigma^0$ from its charge conjugate $\bar{p} p \rightarrow \bar{\Sigma}^0 \Lambda$. A Monte Carlo study gives the probability of misidentification to be 30%. Such an error in identifying which Λ is directly produced and which one comes from the Σ^0 decay will result in a shift in the assignment of the centre-of-mass angle. The effect is proportional to the ratio of momenta, p_γ/p_Λ , and gives typically an error of 0.1 in the assignment of $\cos(\Theta^{\text{cm}})$. This will result in a certain smearing of the angular distribution. The effect can be quantified using Monte Carlo generated events and has been corrected for [10].

3. RESULTS

The differential cross-section obtained is plotted in fig. 1. Numerical values of the corrected angular distribution are given in table 1. The errors are statistical only. Systematic errors are estimated to be 5%. The angular binning corresponds to the size of the smearing in $\cos(\Theta^{\text{cm}})$, which is due to the misidentification of events as explained in the previous section.

The general features that are known from the $\bar{\Lambda}\Lambda$ angular distributions are also recognized in the $\bar{\Lambda}\Sigma^0 + \text{c.c.}$ channel: a forward rise and a flat distribution at backward angles. This indicates a strong $L > 0$ production close to threshold, as observed in the $\bar{\Lambda}\Lambda$ channel at the same excess energy [1]. The forward rise occurs at a reduced four-momentum transfer of $t' \approx -0.15$ $(\text{GeV}/c)^2$, in agreement with what has already been observed for the $\bar{\Lambda}\Lambda$ channel [3]. A theoretical prediction by Kohno and Weise [4] is also shown in fig. 1. The agreement is reasonable in the forward region.

The polarization of the Λ has been evaluated from the self-analysing weak decay [1]. The Σ^0 polarization, P_{Σ^0} , has been extracted from the decay distribution of the daughter Λ [11],

$$I(\Theta) = 1 - [\alpha_{\Lambda} P_{\Sigma^0} \cos(\Theta_p)]/3,$$

where Θ_p is measured between the proton momentum vector in the Λ rest frame and the normal of the scattering plane, and α_{Λ} is the Λ decay-asymmetry parameter. When calculating the polarizations, systematic errors are included, with the exception of the above-mentioned ambiguity in $\bar{\Sigma}^0\Lambda$ and $\bar{\Lambda}\Sigma^0$ identification. The extracted Σ^0 polarization is shown in fig. 2a together with a prediction from Kohno and Weise [4], and in fig. 2b for the directly produced Λ . In both cases we have averaged over the antihyperon and hyperon polarizations. In view of the large errors it is difficult to draw conclusions from the polarizations.

It is of interest to compare the channels $\bar{\Lambda}\Sigma^0$ and $\bar{\Lambda}\Lambda$ with each other. In fact, there exists one $\bar{\Lambda}\Lambda$ measurement [1] at almost the same excess energy, $\epsilon = 14.6$ MeV, compared to $\epsilon = 14.8$ MeV in this measurement. The two differential cross-sections are compared in fig. 3. Their shapes are very similar. In table 2 the Legendre polynomial coefficients from fits to the data are given.

The total cross-section extracted for the reaction $\bar{p}p \rightarrow \bar{\Lambda}\Sigma^0 + \text{c.c.}$ at 1.695 GeV/c is (7.53 ± 0.35) μb . The error in the absolute normalization is 5% and comes mainly from uncertainties in the Monte Carlo corrections. The result from this experiment is plotted in fig. 4 together with the world data on $\bar{\Lambda}\Lambda$ and $\bar{\Lambda}\Sigma^0 + \text{c.c.}$ production in the LEAR momentum range [1, 2, 9, 12–16].

The present result makes it possible to compare the measured ratio of cross-sections, $\sigma(\bar{\Lambda}\Sigma^0)/\sigma(\bar{\Lambda}\Lambda)$, with predictions from 'quark-based' models, taking $\sigma(\bar{\Lambda}\Sigma^0)$ to be one half of the measured $\sigma(\bar{\Lambda}\Sigma^0 + \text{c.c.})$. The comparison, which can be made either at the same $\bar{p}$ momentum or at the same excess energy, is shown in table 3. The predicted ratios are a factor of 5 too large at 1.695 GeV/c. Even when taking into account, that the difference in phase space gives a factor of 2.3, the predicted ratio is still a factor of 2 off. It might be argued that, being relatively close to the $\bar{\Lambda}\Sigma^0$ threshold, a more sensible comparison should be made at the same excess energy for the two reaction channels [6]. In such a way the final-state interaction of the outgoing antihyperon-hyperon pair would be better compensated for when evaluating the ratio of cross-sections. As can be seen from table 3, this indeed compares more favourably with the theoretical predictions. The difference in phase space, in this latter case, is a 10% effect.

In conclusion, we have measured the differential cross-section of the reaction $\bar{p} p \rightarrow \bar{\Lambda}\Sigma^0 + \text{c.c.}$ close to threshold. The angular distribution is very similar to the one measured previously for the reaction $\bar{p} p \rightarrow \bar{\Lambda}\Lambda$ at the corresponding excess energy, and is rather well described by a prediction made by Kohno and Weise [4]. The ratio $\sigma(\bar{\Lambda}\Sigma^0)/\sigma(\bar{\Lambda}\Lambda)$ is in fair agreement with predictions from 'quark-based' models, provided the comparison is made at the same excess energy.

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Table 1

Differential cross-section of the reaction $\bar{p} p \rightarrow \bar{\Lambda} \Sigma^0 + \text{c.c.}$ at 1.695 GeV/c.

$\cos(\Theta^{\text{cm}})$	$d\sigma/d\Omega$ [$\mu\text{b/sr}$]	Error [$\mu\text{b/sr}$]
-1.00 to -0.75	0.314	0.092
-0.75 to -0.50	0.376	0.056
-0.50 to -0.25	0.328	0.065
-0.25 to 0.00	0.267	0.044
0.00 to 0.25	0.290	0.058
0.25 to 0.50	0.494	0.080
0.50 to 0.75	0.976	0.080
0.75 to 1.00	1.832	0.178

Table 2

Legendre polynomial coefficients from angular distribution fits of the reactions $\bar{p} p \rightarrow \bar{\Lambda} \Lambda$ and $\bar{p} p \rightarrow \bar{\Lambda} \Sigma^0 + \text{c.c.}$ at excess energies $\epsilon = 14.6$ MeV and $\epsilon = 14.8$ MeV, respectively.

Legendre coefficients	$\bar{p} p \rightarrow \bar{\Lambda} \Lambda$ $\epsilon = 14.6$ MeV	$\bar{p} p \rightarrow \bar{\Lambda} \Sigma^0 + \text{c.c.}$ $\epsilon = 14.8$ MeV
a_0	1.05 ± 0.04	0.61 ± 0.03
a_1/a_0	0.77 ± 0.07	1.12 ± 0.14
a_2/a_0	0.60 ± 0.09	1.16 ± 0.18
a_3/a_0	0.27 ± 0.10	0.68 ± 0.28

Table 3

The experimental ratio $\sigma(\bar{\Lambda}\Sigma^0)/\sigma(\bar{\Lambda}\Lambda)$ compared with theoretical predictions. The relation $\sigma(\bar{\Lambda}\Sigma^0) = \sigma(\bar{\Lambda}\Sigma^0 + \text{c.c.})/2$ has been used.

$\sigma(\bar{\Lambda}\Sigma^0)/\sigma(\bar{\Lambda}\Lambda)$		Reference
Experiment:	0.054 ± 0.003 0.29 ± 0.02	PS185: $p_{\bar{p}} = 1.695 \text{ GeV}/c$, this work and [9] PS185: $\epsilon \approx 14.7 \text{ MeV}$, this work and [1] ^{a)}
Theory:	0.259 0.236 0.259	H. Genz and S. Tatur [5] H. Rubinstein and H. Snellman [6] M. Kohno and W. Weise [7]

^{a)} The values of table 1 in ref. [1] for $\sigma_{\bar{\Lambda}\Lambda}$ should read 13.0 ± 0.5 at $1.4765 \text{ GeV}/c$ and 25.1 ± 0.7 at $1.5075 \text{ GeV}/c$.

Figure captions

- Fig. 1 Differential cross-section in the centre-of-mass system for the reaction $\bar{p} p \rightarrow \bar{\Lambda} \Sigma^0 + \text{c.c.}$ at 1.695 GeV/c. The solid line is a theoretical calculation by Kohno and Weise at 1.7 GeV/c [4].
- Fig. 2 a) Combined $\bar{\Sigma}^0$ and Σ^0 polarization. The solid line is a theoretical calculation by Kohno and Weise at 1.7 GeV/c [4].
b) Combined $\bar{\Lambda}$ and Λ polarization for the directly produced Λ . The data are not corrected for misidentification of Λ and Σ^0 , as discussed in the text.
- Fig. 3 Comparison of the measured differential cross-sections for the reactions $\bar{p} p \rightarrow \bar{\Lambda} \Sigma^0 + \text{c.c.}$ and $\bar{p} p \rightarrow \bar{\Lambda} \Lambda$ at excess energies of 14.8 MeV and 14.6 MeV [1], respectively.
- Fig. 4 Compilation of available data on $\bar{p} p \rightarrow \bar{\Lambda} \Lambda$ and $\bar{p} p \rightarrow \bar{\Lambda} \Sigma^0 + \text{c.c.}$ in the momentum range of LEAR. The data points are taken from this experiment and from refs. [1, 2, 9, 12–16]. The threshold momenta $p_{\text{thr}}(\bar{\Lambda} \Lambda) = 1.435 \text{ GeV/c}$ and $p_{\text{thr}}(\bar{\Lambda} \Sigma^0 + \text{c.c.}) = 1.653 \text{ GeV/c}$ are indicated with arrows.

Fig. 1

Fig. 2

Fig. 3

Fig. 4