CROSS SECTIONS FOR EXCLUSIVE CHANNELS IN $\bar{p}p$ REACTIONS AT 12 GeV/c

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ABSTRACT

The data obtained in an exposure of BEBC to an r.f. separated beam of antiprotons at 12 GeV/c are used to derive exclusive cross sections for reactions having one or more neutral strange particles in the final state. Particular attention is given to the estimation of the background. An upper limit of the cross section for the inclusive production of the charmed meson D^* is also given.

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1. INTRODUCTION

Very few data exist on the production of neutral strange particles in $\bar{p}p$ interactions above the energy threshold for charmed meson and baryon states production. In the quark models, similarities are expected in the production mechanisms of strange and charmed states, as the role of the s quark for the strange states is the analogue of the role of the c quark for the charmed states.

Inclusive results relevant to these questions were presented in a previous analysis of $\bar{p}p$ interactions at 12 GeV/c beam momentum, using pictures obtained during an exposure of the Big European Bubble Chamber (BEBC) to a radio-frequency separated antiproton beam [1]. We present here results on exclusive reactions leading to at least one neutral strange particle. We also give an upper limit for the production of charmed states.

The selection of the data sample is briefly described in sect. 2. In sect. 3, the method of event identification is presented, with particular emphasis on final states involving one missing neutral particle. Sect. 4 contains our results on exclusive cross sections. In sect. 5 a method for the selection of charm states is used which allows to derive an upper limit for their production cross section with a higher sensitivity than that of a previous search [2].

2. MEASUREMENT AND SELECTION OF THE EVENTS

The events studied show at least one V^0 , a neutral strange particle decay. After measurement and processing through the Hydra system of programs and following experimental procedures described previously [1], the sample retained for this analysis, passing the selection criteria described below, is given in table 1.

The measurement errors on the momentum, azimuth angle ϕ and dip angle λ of the tracks, as obtained by the geometry program, were calibrated using the pulls and probability distributions of the kinematical fit of the V^0 decays, and of the 4C fits. The events with large measurement errors were rejected, as well as those with beam parameter

values incompatible with the beam nominal values^(*) or with the kinematic probability at the V^0 vertex less than 0.01 (these rejected events, $\approx 9\%$ and $\approx 5\%$ of the sample respectively, are not included in table 1). Topology dependent corrections for V^0 decay outside the fiducial region or loss near the vertex, and scanning and measurement efficiency were taken into account.

The measurement of energy loss along the charged tracks was used to restrict their mass assignments in the further analysis. Details of this experimental procedure were presented elsewhere [2,3].

3. PROCEDURE

3.1 Method

Using the results of the V^0 decay kinematic fitting, a kinematic fit was performed also at the main vertex, assigning to each track the masses allowed by quantum number conservation (baryon number, strangeness, charge), within the mass range restricted as indicated above. Each allowed permutation of masses between the tracks is called here a "hypothesis".

3.1.1 Events without missing neutral particle

The events satisfying a 4C fit with probability greater than 10^{-4} were satisfactorily retained. When ambiguities occurred between hypothesis corresponding to mass permutations (denoted here "self ambiguous fits"), all hypothesis with kinematical probability lower than 0.25 times the best 4C kinematical probability were rejected.

3.1.2 Events with one missing neutral particle

A similar procedure was applied to the 1C events. However, most of them could not be unambiguously identified by the kinematical fit, due to the frequent presence of tracks with relatively high momenta. Instead of

(*) The beam nominal values have been determined with errors $\Delta p \approx 60 \text{ MeV/c}$, $\Delta \lambda \approx 1.4 \text{ mrad}$, $\Delta \phi \approx 1.2 \text{ mrad}$.

using the 1C fits for the events with one missing neutral particle, the following method was preferred with, as main purpose, the evaluation of the number of events actually belonging to each 1C hypothesis.

At first, an examination was made of the distributions of missing mass squared (MM^2) and of missing energy (EM). The distributions were constructed for each reaction channel using all hypotheses, i.e. all 4C, 1C and 0C candidates. The number of events was evaluated in the relevant MM^2 and EM regions taking into account the experimental resolution of these quantities. In particular, the resolution of MM^2 was determined as a function of MM^2 and of the number of tracks, either using the propagation of the measurement errors on the track parameters, or by an examination of the MM^2 histograms in the regions corresponding to expected neutral particles. The two estimations were found to be compatible.

Then, a background subtraction was made. The background, assumed to be flat^(*), was evaluated by extrapolation from the nearby regions. The number of events above the background was determined in intervals of MM^2 equal to 1, 2 and 3 times the MM^2 resolution, checking the compatibility of these three determinations assuming gaussian distributions.

The background in these distributions is essentially due to a wrong mass assignment to one or more tracks, (i.e. permutational) and to events with more than one neutral particle in the final state. Smaller contributions are due to events with a track badly measured (such as an incident track too short to be recognized as non-beam). A further effect of the background is to increase the width of the signal of the missing particles especially for events with many tracks, where the number of possible mass permutations is large.

The background can be appreciably reduced, for the channels with several charged π 's and a missing π^0 , by rejecting the events with a missing energy higher than a certain cut-off value. This is because the

(*) This assumption was checked by studying the behaviour of the MM^2 distributions for false hypothesis, not conserving hypercharge, baryonic number etc. simulated appropriately.

background increases as the missing energy EM increases^(*). The value of the cut-off was chosen, and an appropriate correction was made, by assuming that the single particle energy distributions of charged and neutral pions were similar. As an example of the effect of the cut $EM < 1.2 \text{ GeV}$, it can be seen, by comparing figs 1 and 2(a)-(b), that the similarity of the momentum distributions of the $K^\pm$ and K^0 in the $K^\pm 3\pi K_S^0 \pi$ reaction is improved.

The distributions in MM^2 and EM were examined for each reaction channel, both in the form of histograms and ideograms (to reduce the effect of statistical fluctuations) for two methods of event weighting.

The first was obtained by considering only permutations of the same reaction channel, assigning to each hypothesis a weight equal to the inverse of the number of self ambiguous fits. The second was obtained by assigning to each hypothesis a weight equal to the inverse of the total number of hypothesis including those of the other reaction channels. An example of the difference between these two distributions can be seen in figs 3(a) and 3(b). It was checked that the two methods gave compatible results. Whenever the two methods gave different results, a mean value was taken, and the error was suitably increased.

Finally, for the events with a seen $\Lambda(\bar{\Lambda})$ and the missing neutral particle identified (as above) as a γ , the $\Lambda(\bar{\Lambda})\gamma$ effective mass was studied to identify $\Sigma^0(\bar{\Sigma}^0)$ production and decay.

3.1.3 Events with more than one missing particle

Events not included in the previous two categories 4C and 1C were interpreted as multineutrals (OC), after checking that the measured missing mass MM was higher, within measurement errors, than the relevant sum of missing particle masses, and that the missing energy EM was positive.

(*) In fact, the missing momentum does not change appreciably for this wrong mass assignment and the variation ΔMM^2 in MM^2 is $\Delta MM^2 = -2EM \sum_i (\Delta m_i / E_i)$, where Δm_i is the difference in mass assignment in track i, E_i the corresponding energy and the sum goes over the tracks with wrong mass assignment. Therefore, for an event with large EM, e.g. with several charged π 's and more missing π^0 's (great MM^2), a small value of MM^2 can be obtained, interpreting some tracks as kaons or protons.

The events which failed all categories (5%) were checked individually. A small number ($\approx 10\%$ of the 4C sample) was assigned to the 4C fit sample, as their failure could be traced to underestimated measurement errors.

3.2 Experimental checks and discussion

The following experimental checks were performed in order to test the method of analysis.

As a first check, the method was used for some typical 4C channels, where the level of ambiguity is low and the background of misidentified events can be neglected. The results are reported in table 2, which shows also the corresponding number of 4C fits obtained by the kinematical analysis alone. The agreement is satisfactory.

By contrast, in table 3(a)-(c) the same comparison is made for 1C channels. The number of events assigned to each channel by our method are consistently lower than those coming from kinematics alone. However, it can be observed that almost all kinematic 1C fits are ambiguous with other fits. As further evidence we also report in table 3(a,b,c) the weighted number of fits obtained assigning to each fit a weight equal to the inverse of the total number of 1C fits of the event, ignoring the multineutral fits (which will lead to an overestimate of the weighted number).

The consistently higher number of 1C fits can be understood by remarking that the first step of our method is mathematically related^(*) to the requirement of a one-constraint fit, but that the second step of background subtraction is not performed by the kinematical fit. Thus, an identification of events uniquely based on the relatively loose one

(*) The kinematical fit minimizes, subject to the constraints of energy and momentum conservation, the quantity $\chi^2 = \sum_{i,k} (x_i^f - x_i^m) G_{ik} (x_k^f - x_k^m)$, where G_{ik} is the inverse measurement error matrix, x_i^m are the measured components of momentum, x_i^f are the adjusted values and the sum goes over all components of all measured tracks. In the case 1C of one missing neutral particle of mass m_0 , $\chi^2 \approx \left[\frac{MM - m_0}{\sigma(MM)} \right]^2$.

kinematical constraint necessarily includes misidentified background events. This contamination is particularly high in the present experiment where, as already indicated, the background arising from permutations and multineutral final states is high.

The contamination of the 1C fits by other channels can be estimated by looking at some momentum or angular distributions. For example, in the reaction $K^{\pm} 3\pi K_s^0 \pi^0$ using all 1C fits (prob. > 1%), the $K^{\pm}$ energy distribution (fig. 1(a)) is very different from that of the K_s^0 (fig. 1(b)); the same applies for the $\pi^{\pm}$ and π^0 energy distributions (figs 1(c)-(d)).

As a second check that we are evaluating the correct number of events, we compare the number of events with only one strange particle observed (1C fits) with the number predicted from the corresponding 4C channel where both neutrals are observed. A good agreement between these numbers of events is obtained with our method. Some examples are reported in table 3(d).

4. CROSS SECTIONS

In tables 4, 5 and 6 we present the inclusive topological cross sections for $K^{n(\dagger)}$, Λ and $\bar{\Lambda}$ production respectively. The K^n annihilation cross sections were determined with the following working hypothesis: (i) the $K_1^0 K_2^0$ and $K_1^0 K_1^0$ productions are equal (no indication for ϕ production was observed on the 1C fits); (ii) the fraction of annihilation events for the 0C events is equal to that of the 1C + 4C events. In figs 4 and 5 the cross sections for the 4C and 1C channels are shown.

The following characteristics are observed:

- (a) Both the K_{seen}^n and the Λ_{seen} ($\bar{\Lambda}_{\text{seen}}$) are associated more to $K^{\pm}$ than to K^n and the corresponding ratios increase as the topology n increases.
- (b) In the annihilation processes 4C (1C) the largest cross sections are observed for the channel $K^{\pm} 5\pi K_{\text{seen}}^0$ (π^0).

(†) By K^n is denoted either K^0 or $\bar{K}^0$, and by K_1^0 , K_2^0 the K_{short}^0 , K_{long}^0 respectively, K_{1s}^0 denotes seen K_{short}^0 .

- (c) In the non-annihilation processes $4C$ ($1C$) the channels $K^+ p \Lambda \pi \pi(\pi^0) + CC$ predominate where $m = 0, 2, 4$, the corresponding cross section having a maximum for $m = 2$. For the other processes with kaons, nucleons and Λ the cross section decreases as m increases.

5. CROSS SECTION UPPER LIMITS FOR CHARMED PARTICLE PRODUCTION

Results from e^+e^- [4] and $\nu p(n)$ [5] experiments show that charmed mesons are produced almost as frequently in the D^{*+} as in the D states. The decay $D^{*+} \rightarrow \pi D$ can then be used to separate the charmed signal from background, by using the fact that the mass difference $M(D^{*+}) - M(D) = 0.145$ MeV can be measured more accurately than the individual effective masses $M(D^{*+})$ or $M(D)$, because of some cancellation of experimental errors, and noting also that this small mass difference occurs in a region where the permutational background is very small.

This method has been used with some success in neutrino experiments [5], both for identification of the D^{*+} and of the charmed baryon Σ_c^+ , where a similar situation occurs for the decay $\Sigma_c^+ \rightarrow \Lambda_c^+ \pi$ [6].

In our data, the production of charmed particles D^{*+} and Σ_c^+ decaying into D^0 and Λ_c^+ respectively was studied by looking at the invariant mass distributions $K^0 m \pi$ and $\Lambda m \pi$ with $m = 2, 3, 4$ on which were imposed the conditions:

- (a) $M[K^0 m \pi] - M[K^0 (m-1) \pi] = 0.145 \pm 0.005$ GeV,
 (b) $M[\Lambda m \pi] - M[\Lambda (m-1) \pi] = 0.168 \pm 0.003$ GeV,

corresponding to the mass differences $D^{*+} - D^0$ and $\Sigma_c^+ - \Lambda_c^+$. The errors reflect both the present knowledge of the mass difference derived from other experiments^(*), and our experimental resolution.

(*) The published values are $M(D^{*+}) - M(D^0) = (0.1453 \pm 0.0004)$ GeV and $M(\Sigma_c^+) - M(\Lambda_c^+) = (0.168 \pm 0.003)$ GeV [5-7].

No event satisfying the condition (b) has been found. In fact, our incident energy of 12 GeV/c corresponds to the threshold for the reactions

$$\bar{p}p \rightarrow \Sigma_c \bar{\Sigma}_c, \text{ and } \bar{p}p \rightarrow \Lambda_c \bar{\Sigma}_c \pi + \text{CC} .$$

Further, no signal is observed (fig. 6) for the reactions

$$\begin{aligned} \bar{p}p &\rightarrow D^{*+} X \\ &\hookrightarrow D^0 (\bar{D}^0) \pi^\pm \\ &\hookrightarrow \bar{K}^0 \pi^+ \pi^- . \end{aligned}$$

Assuming the following branching ratios

$$\begin{aligned} D^{*+} &\rightarrow D^0 \pi^+ \quad (60 \pm 15)\% \\ D^0 &\rightarrow \bar{K}^0 \pi^+ \pi^- \quad (4.4 \pm 1.1)\% \end{aligned}$$

and the statistical sensitivity of our experiment (5.5 ev/ μb) the upper limit calculated at 90% confidence level is

$$\sigma_u(\bar{p}p \rightarrow D^{*+} X) < 19 \mu\text{barn} .$$

This value is appreciably smaller than the value obtained for D production in the same experiment [2]

$$\sigma_u(\bar{p}p \rightarrow D^+ X) < 320 \mu\text{barn} ,$$

underlining the experimental sensitivity gained by the use of the stringent condition (a).

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TABLE CAPTIONS

- Table 1 Sample of events used in the analysis.
- Table 2 Channels without missing neutral particles (4C fits). Notation: the index s (lower case) denotes a seen decay. The K_{1s}^0 denotes a seen K_{short}^0 .
- Table 3 (a) Channels with one missing neutral particle. Notation: K^n denotes either $\bar{K}^0$ or K^0 . K_{1s}^0 denotes a seen K_{short}^0 .
(b) Channels with one missing neutral particle (continued).
(c) Channels with one missing neutral particle (continued).
(d) Comparison between expected and observed number of events in selected channels. Notation: Λ_s denotes a seen Λ . Λ_n denotes an unseen Λ . Similarly for Σ .
- Table 4 Semi-inclusive topological cross sections for K_s^0 production.
- Table 5 Semi-inclusive topological cross sections for Λ production.
- Table 6 Semi-inclusive topological cross sections for $\bar{\Lambda}$ production.

TABLE 1

Topology	1 V^0	2 V^0
0	496	187
2	1551	356
4	1364	148
6	571	41
8	63	2

TABLE 2

Channel	No. of 4C fits prob. > 1%	No. of events accepted by our method
$\pi^+ \pi^- \Lambda_s^- \bar{\Lambda}_s^-$	16	16 ± 4
$p \pi^- \bar{\Lambda}_s^- K^0_{1s}$	13	12 ± 4
$\bar{p} \pi^+ \Lambda_s^+ K^0_{1s}$	11	9 ± 3
$K^+ p \Lambda_s^-$	28	24 ± 5
$K^- p \bar{\Lambda}_s^-$	22	20 ± 5
$K^\pm \pi^\mp K^0_{1s}$	1	1 ± 1
$4\pi K^0_{1s} K^0_{1s}$	3	$3 \pm \sqrt{3}$
$K^\pm 3\pi K^0_{1s}$	16	13 ± 4
$p p K^\pm \pi^\mp K^0_{1s}$	10	8 ± 3
$\pi^+ \pi^- K^+ p \Lambda_s^-$	34	34 ± 6
$\pi^+ \pi^- K^- p \bar{\Lambda}_s^-$	32	29 ± 6
$K^\pm 5\pi K^0_{1s}$	31	31 ± 5
$\bar{p} 4\pi K^+ \Lambda_s^+$	6	5 ± 2
$p 4\pi K^- \bar{\Lambda}_s^-$	7	7 ± 3
$\bar{p} 3\pi K^0_{1s} \Lambda_s^+$	3	$3 \pm \sqrt{3}$
$p 3\pi K^0_{1s} \bar{\Lambda}_s^-$	6	$5 \pm \sqrt{5}$
$4\pi \Lambda_s^- \bar{\Lambda}_s^-$	5	$6 \pm \sqrt{6}$

TABLE 3(a)

Channel	Number of fits 1C				Number of events accepted by our method
	prob.>1%	prob.>1% weighted ignor. the multineu-tral fits	prob.>25%	prob.>25% weighted ignor. the multineu-tral fits	
$K^{\pm} \pi^{\mp} K^0_{1S} \pi^0$	16	10	6	5	5 ± 3
$K^+ \bar{p} \Lambda^0_S \pi^0(\gamma)$	72	57	49	44	43 ± 7
$K^- \bar{p} \bar{\Lambda}^0_S \pi^0(\gamma)$	61	42	38	30	35 ± 7
$\pi^+ \pi^- K^0_{1S} K^n$	16	6	7	4	6 ± 3
$K^+ K^- K^0_{1S} K^n$	22	12	7	5	$1 \pm \frac{2}{1}$
$\pi^+ \bar{p} \Lambda^0_S K^n$	66	42	37	28	11 ± 5
$\pi^- \bar{p} \bar{\Lambda}^0_S K^n$	56	30	33	21	18 ± 7
$\bar{p} \bar{p} K^0_{1S} K^n$	27	21	13	12	7 ± 3
$K^+ \bar{p} K^0_{1S} n + CC$	55	33	32	24	14 ± 5
$K^+ \pi^- \bar{\Lambda}^0_S \bar{n}$	51	40	31	27	16 ± 5
$K^- \pi^+ \bar{\Lambda}^0_S n$	45	23	25	17	10 ± 4
$\pi^+ \pi^- \bar{\Lambda}^0_S \bar{\Lambda}(\bar{\Sigma}_0)$	68	51	38	34	20 ± 7
$\pi^+ \pi^- \bar{\Lambda}^0_S \Lambda(\Sigma_0)$	61	36	29	20	12 ± 5
$\pi^+ \bar{p} K^0_S \Lambda(\Sigma_0) + CC$	96	74	50	43	16 ± 6
$\bar{p} \bar{p} \bar{\Lambda}^0_S \bar{\Lambda}(\bar{\Sigma}_0)$	9	9	6	6	$0 + 2$
$\bar{p} \bar{p} \bar{\Lambda}^0_S \Lambda(\Sigma_0)$	5	5	1	1	$0 + 1$

TABLE 3(b)

Channel	Number of fits 1C				Number of events accepted by our method
	prob.>1%	prob.>1% weighted ignor. the multineu-tral fits	prob.>25%	prob.>25% weighted ignor. the multineu-tral fits	
$K^{\pm} 3\pi K_{1S}^0 \pi^0$	131	92	75	60	46 ± 9
$KKK\pi K_{1S}^0 \pi^0$	98	48	55	32	18 ± 9
$p\bar{p}K\pi K_{1S}^0 \pi^0$	90	32	47	24	23 ± 7
$K^{\pm} p 2\pi \Lambda_S \pi^0(\gamma)$	85	65	59	50	56 ± 10
$K^{\pm} p 2\pi \bar{\Lambda}_S \pi^0(\gamma)$	92	63	56	42	66 ± 10
$4\pi K_{1S}^0 K^n$	65	22	31	12	12 ± 4
$2K2\pi K_{1S}^0 K^n$	136	75	66	46	$0 + 5$
$p\bar{p}2\pi K_{1S}^0 K^n$	68	19	34	15	5 ± 7
$p\bar{p}K^+ K^- K_{1S}^0 K^n$	11	1	2	1	$0 + 1$
$3\pi p \Lambda_S K^n$	47	21	23	13	9 ± 7
$3\pi p \bar{\Lambda}_S K^n$	36	11	19	6	8 ± 7
$pK^- 2\pi K_{1S}^0 \bar{n} + CC$	228	131	127	80	9 ± 4
$pK^+ 2\pi K_{1S}^0 \bar{n} + CC$	112	35	40	16	$0 + 2$
$K^+ 3\pi \Lambda_S \bar{n}$	47	27	25	19	15 ± 7
$K^- 3\pi \bar{\Lambda}_S n$	60	26	26	13	9 ± 7
$p3\pi K_{1S}^0 \bar{\Lambda}(\bar{\Sigma}_0) + CC$	201	104	117	73	$0 + 4$
$4\pi \Lambda_{1S} \bar{\Lambda}(\bar{\Sigma}_0)$	37	18	21	13	7 ± 5
$4\pi \bar{\Lambda}_S \Lambda(\Sigma_0)$	43	17	19	12	4 ± 4
$2K2\pi \Lambda_S \bar{\Lambda}(\bar{\Sigma}_0)$	31	20	21	8	3 ± 3
$2K2\pi \bar{\Lambda}_S \Lambda(\Sigma_0)$	43	21	19	13	3 ± 3

TABLE 3(c)

Channel	Number of fits 1C				Number of events accepted by our method
	prob.>1%	prob.>1% weighted ignor. the multineu-tral fits	prob.>25%	prob.>25% weighted ignor. the multineu-tral fits	
$K5\pi K^0_{1S} \pi^0$	183	140	116	97	105 ± 14
$3K3\pi K^0_{1S} \pi^0$	148	87	89	59	34 ± 11
$K^+ p 4\pi \Lambda_S \pi^0 (\gamma)$	11	8	7	6	11 ± 4
$K^- p 4\pi \bar{\Lambda}_S \pi^0 (\gamma)$	9	6	6	5	9 ± 3
$6\pi K^0_{1S} K^n$	53	16	26	9	8 ± 5
$2K4\pi K^0_{1S} K^n$	135	73	76	46	$0 + 10$
$p \bar{p} 4\pi K^0_{1S} K^n$	12	4	4	2	3 ± 3
$\bar{p} 5\pi \Lambda_S K^n$	5	3	4	3	$1 \pm \frac{1}{2}$
$p 5\pi \bar{\Lambda}_S K^n$	5	2	2	1	$2 \pm \frac{1}{2}$
$p K^- 4\pi K^0_{1S} \bar{n} + CC$	47	29	15	11	20 ± 7
$K^+ 5\pi \Lambda_S \bar{n}$	5	3	1	1	$0 + 2$
$K^- 5\pi \bar{\Lambda}_S n$	11	8	6	4	6 ± 3
$p 5\pi K^0_{1S} \bar{\Lambda}(\bar{\Sigma}_0) + CC$	32	16	13	7	$0 + 5$
$6\pi \Lambda_S \bar{\Lambda}(\bar{\Sigma}_0)$	3	1	1	0	$0 + 1$
$6\pi \bar{\Lambda}_S \Lambda(\Sigma_0)$	3	2	2	1	1 ± 1
$2K4\pi \Lambda_S \bar{\Lambda}(\bar{\Sigma}_0)$	2	2	1	1	$0 + 1$
$2K4\pi \bar{\Lambda}_S \Lambda(\Sigma_0)$	7	6	4	4	$0 + 1$

TABLE 3(d)

Channel		Expected fraction	No. of fits weighted prob.>1%	No. of events accepted by our method
$\pi^+ \pi^- \Lambda \bar{\Lambda} (\bar{\Sigma})$	$\pi^+ \pi^- \Lambda_s \bar{\Lambda}_s (\bar{\Sigma}_s^0)$	0.41	26	26 ± 6
	$\pi^+ \pi^- \Lambda_s \bar{\Lambda}_n (\bar{\Sigma}_n^0)$	0.23	51	20 ± 7
	$\pi^+ \pi^- \Lambda_s \bar{\Lambda}_n (\Sigma_n^0)$	0.23	36	12 ± 5
$2\pi^+ 2\pi^- \Lambda \bar{\Lambda} (\bar{\Sigma})$	$2\pi^+ 2\pi^- \Lambda_s \bar{\Lambda}_s (\bar{\Sigma}_s^0)$	0.41	10	9 ± 3
	$2\pi^+ 2\pi^- \Lambda_s \bar{\Lambda}_n (\bar{\Sigma}_n^0)$	0.23	18	7 ± 5
	$2\pi^+ 2\pi^- \Lambda_s \bar{\Lambda}_n (\Sigma_n^0)$	0.23	17	4 ± 4
$\pi^+ \pi^- p \Lambda K^0 + CC$	$\pi^+ \pi^- p \Lambda_s K_{1s}^0 + CC$	0.43	34	28 ± 6
	$\pi^+ \pi^- p K_{1s}^0 \Lambda_n + CC$	0.24	74	16 ± 6
$3\pi^+ p \Lambda K^0 + CC$	$3\pi^+ p \Lambda_s K_{1s}^0 + CC$	0.43	15	12 ± 4
	$3\pi^+ p K_{1s}^0 \Lambda_n + CC$	0.24	104	2 ± 4

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FIGURE CAPTIONS

- Fig. 1 Reaction channel $K^{\pm}3\pi K_1^0\pi^0$, distributions obtained using all hypotheses 1C fitting with probability $> 1\%$:
- (a) $K^{\pm}$ energy;
 - (b) K_1^0 energy;
 - (c) $\pi^{\pm}$ energy;
 - (d) π^0 energy.
- Fig. 2 Distributions for the reaction channel $K^{\pm}3\pi K_1^0\pi^0$ obtained using all hypothesis 1C fitting with probability $> 1\%$ and selecting the hypothesis where the missing energy was < 1.2 GeV:
- (a) $K^{\pm}$ energy;
 - (b) K_1^0 energy.
- Fig. 3 Ideogram of the missing mass squared for the reaction channel $K^{\pm}5\pi K_1^0(\pi\pi^0)$ obtained by giving to each hypothesis:
- (a) a weight equal to the inverse of the number of hypotheses of the same channel;
 - (b) a weight equal to the inverse of the total number of hypotheses including those of the other channels.
- Fig. 4 (a) Cross sections for annihilation channels with a K_1^0 .
 (b) Cross sections for non-annihilations channel with a K_1^0 .
- Fig. 5 Cross section for non-annihilation channels with a $\Lambda(\Sigma)$.
- Fig. 6 Distributions obtained imposing the condition $M[K^0\pi\pi] - M[K^0(\pi\pi)\pi] = 0.145 \pm 0.005$:
- (a) mass $K^0\pi^+\pi^-$;
 - (b) mass $K^0\pi^{\pm}\pi^{\pm}$.

Fig. 1

(a)

(b)

Fig. 2

(a)

(b)

Fig. 3

(a)

(b)

Fig. 4

Fig. 5

Fig. 6