сообщения
объединенного
института
ядерных
исследований
дубна

E1 - 12345

E.Balea, C.Coca, V.M.Karnaukhov,
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E.Balea,[1] C.Coca,[1] V.M.Karnaukhov,
G.Kellner,[3] A.Mihul,[2] V.I.Moroz

STRANGE-PARTICLE CROSS SECTIONS FROM FOUR-PRONG π p INTERACTIONS AT 16 GeV/c

1 Central Institute of Physics, Bucharest
2 University of Bucharest
3 CERN, Geneva

Баля Е. и др.

E1 - 12345

Сечения образования странных частиц в четырехлучевых $\pi^- p$ -взаимодействиях при 16 ГэВ/с

В работе, выполненной на материале ~100000 фотоснимков с двухметровой водородной пузырьковой камеры ЦЕРН, представлены результаты исследования эксклюзивных четырехлучевых $\pi^- p$ -взаимодействий со странными частицами при импульсе первичных π^--мезонов 16 ГэВ/с.
Обсуждаются вопросы, связанные с вычислением поправок и сечений. Сечения определены только для тех конечных состояний, где есть хотя бы один зарегистрированный в камере V^0 -распад.
Для некоторых реакций проведено сравнение с сечениями, полученными в других экспериментах при различных импульсах первичных π^- -мезонов.

Работа выполнена в Лаборатории вычислительной техники и автоматики ОИЯИ.

Сообщение Объединенного института ядерных исследований. Дубна 1979

Balea E. et al.

E1 - 12345

Strange-Particle Cross Sections from Four-Prong $\pi^- p$ Interactions at 16 GeV/c

Cross sections are given for production of final states with strange particles from four-prong $\pi^- p$ interactions at 16 GeV/c. A brief comparision of our results with the values obtained in other experiments of different π^--momenta is presented too.

The investigation has been performed at the Laboratory of Computing Techniques and Automation, JINR.

Communication of the Joint Institute for Nuclear Research. Dubna 1979

1. INTRODUCTION

In this paper we present the results of the investigation of the exclusive four-prong $\pi^- p$ interactions with strange particle production at a primary momentum of 16 GeV/c.

The data presented here are based on a sample of about 100.000 pictures taken at CERN using 2m hydrogen bubble chamber exposed to a negative pion beam.

The methodical questions concerning scanning, measurements and the treatment of the neutral decay can be found elsewhere [1]. Details concerning the applied procedure of data processing, especially about the separation of the hypotheses and the selection criteria used, as well as, some results concerning the classification of four-prong events in different groups using a smaller sample of events are given in [2]. Therefore, we will discuss here only the problems directly connected with corrections to our raw data and determination of the cross sections. Cross sections are given only for those final states involving at least an observed V^0-decay.

2. CORRECTIONS TO DATA

In order to obtain cross sections the raw data was corrected as follows.

1. Scanning. A correction of 1.01 was made for the scanning losses.

2. Fit probability. A probability cut-off of 0.5% for both 4 constraint (4c) and (1c) channels

was used. The number of various channels was corrected to allow for this cut-off.

3. Measurement. Any event failing to give good reconstructuion program output or satisfactory FIT or NON-FIT hypotheses after three measurement was labelled as "unmeasurable". Unmeasured and unmeasurable events were allocated in a manner proportional to the passing events. The pass rate was about 80%.

4. Ambiguous fits. When an event was fitted by acceptable (4c) and (1c) hypotheses, the 1c fits were rejected. When it was the case, the events were examined on the scanning table to ensure consistency with observed bubble densities and resolve ambiguities. A maximum of three hypotheses per event has been accepted into data summary tape. Each ambiguous event remaining was weighted by the inverse of the number of acceptable ambiguous hypotheses.

Table 1 shows summary weights for ambiguous (more than three hypotheses per event) events at different particular channels.

Table 1

Summary weights for ambiguous (more than three hypotheses per enent) events at different particular channels.

Channel	$\sum_i W_i$
$\pi^+\pi^+\pi^-\pi^-K^\circ(\Lambda)$	1.0
$p\pi^+\pi^-\pi^-K^\circ(K^\circ)$	1.5
$K^+\pi^+\pi^-\pi^-K^\circ(n)$	1.4
$\pi^+\pi^+K^-\pi^-K^\circ(n)$	1.9
$pK^+\pi^-\pi^-K^\circ(\pi^\circ)$	1.7
$p\pi^+\pi^-K^-K^\circ(\pi^\circ)$	2.4

5. Detection. a) In order to allow for loss of events due to imposing the minimum length cut-off decaying particles and their escape from the finite fiducial volume, each observed decaying particle ($K^\circ, \Lambda, \bar{\Lambda}, \Sigma^+, \Sigma^-$) was given a weight

$$W_1 = [\exp(-\frac{L_{min}}{L_0 \cos\alpha}) - \exp(-\frac{L_{pot}}{L_0})]^{-1},$$

where L_{pot} is the distance from the production vertex to the edge of the decay fiducial volume along the particle direction. L_{min} is the minimum projected cut-off length appropriate to the type of particle. In this experiment the limits were fixed at L_{min} =0.3 cm for K°, Λ and $\bar{\Lambda}$ and L_{min} =0.2 cm for $\Sigma^\pm$'s, in the observation plane. L_0 is mean decay length and α is the particle dip angle. b) In addition, a weight W_θ corrects for those $\Sigma^\pm$ events which failed the cut on projected decay angle. W_θ was determined in the same way as for Ξ^-'s [3]. c) For each unseen neutral strange particle but inferred from the energy momentum conservation, the fitted hypothesis is weighted by

$$W_2 = \frac{1 - b_0}{1 - b_0 + b_0 \exp(-L_{pot}/L_0)}$$ (semi-potential weight),

where b_0 is the branching fraction into charged decay product [4]. d) Each V°-particle was further weighted by $1/b_0$ or $1/(1-b_0)$ such as the particle was observed or not in the effective region.

Table 2 shows sample averaged values for the weights of the individual strange particles.

Table 2

Sample averaged weights for either visible (fitted decay) or invisible (inferred from energy momentum conservation) strange particles

$W(\Lambda)_{viz}$ = 1.73	$W(K^\circ)_{inv}$ = 1.48
$W(\Lambda)_{inv}$ = 2.59	$W(\bar{\Lambda})_{viz}$ = 1.84
$W(K_S)_{viz}$ = 1.63	$W(\Sigma^-)_{viz}$ = 1.81
$W(K_S)_{inv}$ = 2.63	$W(\Sigma^+)_{viz}$ = 2.42
$W(K^\circ)_{viz}$ = 3.26	

Because of the small probability of $K^{\pm}$ decaying in the bubble chamber no weight was assigned to it. Events with visible $K^{\pm}$ were not used for cross section determination.

The weight for any fit was the product of the weights of the constituent strange particles.

3. CROSS SECTION RESULTS

The cross sections have been calculated by normalization on the total $\pi^- p$ cross section at 16 GeV/c interpolated from measurements obtained in counter experiments /5/. The sample of events used here corresponds to a "cross section per event" of 0.1896 ± 0.0095 μb/event.

The hypotheses attempted in this experiment involved at least a V°-decay observed. The reactions tried and topologies sought are given in table 3. The hypotheses with Σ° production have not tried and therefore we could expect a contamination in the Λ-channels from the Σ°-channels.

Table 3 lists our results for the cross sections along with the initial number of events used in each channel.

For some reactions the determination of the cross sections is somewhat complicated since a certain reaction can appear under several topologies. For instance, the cross section for $\Lambda K^\circ \pi^+ \pi^+ \pi^- \pi^-$ can be calculated using the events with one visible Λ or those events with one visible K°, or those events with both strange particles visible. This gave several independent values for the cross section. The number listed in table 3, for the cross section of this reaction is a weighted average of two values obtained as: first, summing up the weighting factors of all observed K° decays (from events with one K° visible and with both Λ and K° visible) yields a cross section of 27.5 ± 4.6 μb; secondly from the sum of the weighting factors of all Λ decays, a value of 26.5 ± 3.3 μb was found.

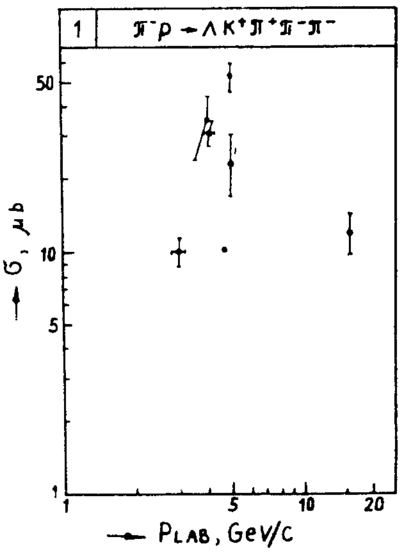
The $K^\circ_S K^\circ_S$ cross sections come directly from events with both K°'s visible in the bubble chamber. The cross section for $K^\circ_S K^\circ_L$ channel is

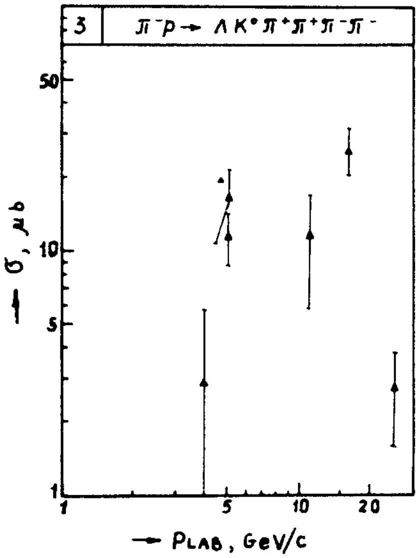
Table 3

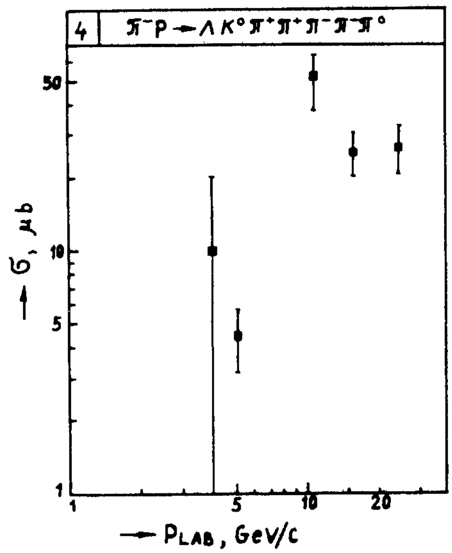
Number of events observed and cross sections for various channels

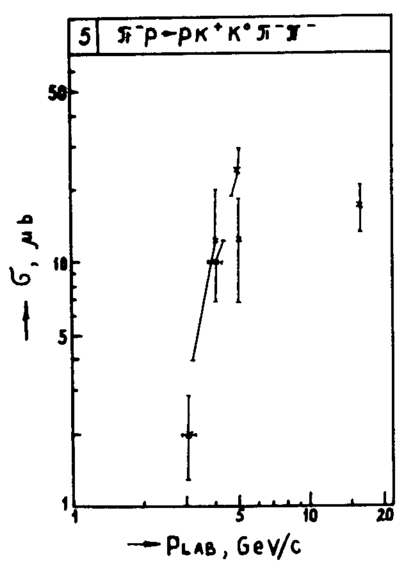
Channel	Decay observed	Total hyp.	No of unambiguous events	No of events	Fraction expected for given topology	Cross section (μb)
$\Lambda K^+\pi^+\pi^-\pi^-$	Λ	29	29	29	2/3	11.9 ± 2.3
$\Lambda K^+\pi^+\pi^-\pi^-\pi^0$	Λ	170	134	152	2/3	62.4 ± 5.2
	K^0_s,Λ	6	6	6	2/9	
$\Lambda K^0\pi^+\pi^+\pi^-\pi^-$	K^0_s	43	20	29.5	1/9	27.0 ± 5.6
	Λ	77	40	58.5	4/9	
$\Lambda K^0\pi^+\pi^+\pi^-\pi^-\pi^0$	K^0_s,Λ	18	18	18	2/9	24.2 ± 5.7
$pK^+K^0\pi^-\pi^-$	K^0_s	27	18	22.5	1/3	17.6 ± 3.7
$pK^+K^0\pi^-\pi^-\pi^0$	K^0_s	94	47	69.2	1/3	53.6 ± 6.4
$pK^-K^0\pi^+\pi^-$	K^0_s	29	20	24.5	1/3	19.1 ± 3.8
$pK^-K^0\pi^+\pi^-\pi^0$	K^0_s	186	123	152.7	1/3	118.6 ± 9.5
$nK^+K^0\pi^+\pi^-\pi^-$	K^0_s	71	43	52.5	1/3	40.7 ± 5.6
$nK^-K^0\pi^+\pi^+\pi^-$	K^0_s	69	42	53.5	1/3	41.6 ± 5.7
$nK^0K^0\pi^+\pi^+\pi^-\pi^-$	$2K^0_s$	13	12	12.5	1/9	31.6 ± 8.9
$pK^0K^0\pi^+\pi^-\pi^-\pi^0$	$2K^0_s$	12	11	11.5	1/9	29.1 ± 8.9
$pK^0_sK^0_s\pi^+\pi^-\pi^-$	$2K^0_s$	6	6	6	4/9	3.7 ± 1.5
$pK^0_sK^0\pi^+\pi^-\pi^-$	K^0_s	108	65	84.2	4/9	-
$pK^0_sK^0_L\pi^+\pi^-\pi^-$	K^0_s	-	-	76.2*	2/3	29.3 ± 4.0
$pK^0K^0\pi^+\pi^-\pi^-$	$1K^0_s$ or $2K^0_s$	114	71	90.2	5/9	40.6 ± 4.3
$\bar{\Lambda}pnK^-\pi^+\pi^-$	$\bar{\Lambda}$	1	1	1	2/3	$0.4^{+1.0}_{-0.4}$
$\bar{\Lambda}\Lambda pK^+K^-\pi^-$	$\bar{\Lambda}$	1	1	1	2/9	$1.1^{+2.6}_{-0.9}$
$\bar{\Lambda}\Lambda nK^+K^-\pi^+\pi^-$	$\bar{\Lambda}$,Λ	1	1	1	4/9	$0.8^{+1.7}_{-0.6}$
$\bar{\Lambda}\Sigma^-p\pi^+\pi^-\pi^0$	$\bar{\Lambda}$,Σ^-	2	2	2	2/3	1.6 ± 1.1
$\bar{\Lambda}\Sigma^-pK^+K^0\pi^-$	$\bar{\Lambda}$,Σ^-	1	1	1	4/9	$1.2^{+2.8}_{-1.0}$
$\bar{\Lambda}ppK^-K^0K^0\pi^-$	$\bar{\Lambda}$, $1K^0_s$	1	1	1	4/27	$2.1^{+4.9}_{-1.8}$
$\bar{\Lambda}\Sigma^+n\pi^+\pi^-\pi^-$	$\bar{\Lambda}$,Σ^+	1	1	1	2/3	$1.2^{+2.8}_{-1.0}$

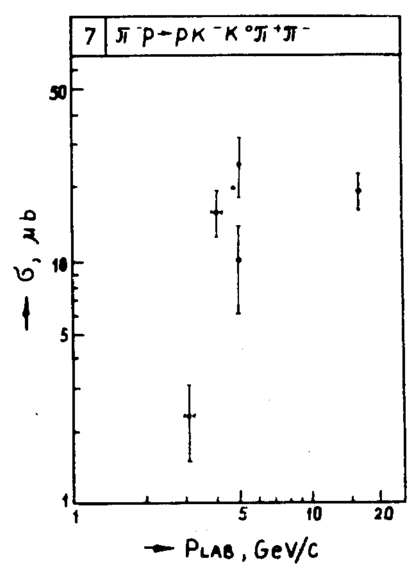
* Number determined from K^0-events after subtracting off $K^0_sK^0_s$-events.











Figs. 1-5. Cross section for various channels in $\pi^- p$ reactions as function of incident momentum.

Table 4

Comparison of strange particle cross sections (in μb) for various channels at different π^- momenta

	Reaction \ Beam momentum (GeV/c)	2.9-3.3 /6/	3.8-4.2 /6/	4 /7/	4.65 /8/	5 /9/	5 /10/	11 /11/	16	25 /12/
1	$\pi^- p \to \Lambda K^+\pi^+\pi^-\pi^-$	10.1±1.3	30±3.8	33±10(Λ/Σ^0)	10(Λ/Σ^0)	51±7(Λ/Σ^0)	22.6±7.0		11.9±2.3	
2	$\to \Lambda K^+\pi^+\pi^-\pi^-\pi^0$			12±6(Λ/Σ^0)	50(Λ/Σ^0)	34±5	21±7		62.4±5.2	
3	$\to \Lambda K^0\pi^+\pi^+\pi^-\pi^-$			3±3(Λ/Σ^0)	20(Λ/Σ^0)	12±3	16.9±5.6	12±6(Λ/Σ^0)	27.0±5.6	2.8±1.2 (Λ/Σ^0)
4	$\to \Lambda K^0\pi^+\pi^+\pi^-\pi^-\pi^0$			10±10(Λ/Σ^0)			4.4±1.3	49±13	24.2±5.7	25.6±6.2(Λ/Σ^0)
5	$\to pK^+K^0\pi^-\pi^-$	2.0±0.8	9.7±2.6	12±8		24±6	12.7±6.0		17.6±3.7	
6	$\to pK^+K^0\pi^-\pi^-\pi^0$					7±4	8.1±4.0		53.6±6.4	
7	$\to pK^-K^0\pi^+\pi^-$	2.3±0.8	15.8±3.4		20	10±4	24.8±7.0		19.1±3.8	
8	$\to pK^-K^0\pi^+\pi^-\pi^0$				40		14.8±6.0		118.6±9.5	
9	$\to nK^+K^0\pi^+\pi^-\pi^-$					6±4	16.8±6.5		40.7±5.6	
10	$\to nK^-K^0\pi^+\pi^+\pi^-$					5±3	16.2±6.0		41.6±5.7	
11	$\to pK^0_sK^0_s\pi^+\pi^-\pi^-$					7±4		7±3	3.7±1.5	
12	$\to pK^0K^0\pi^+\pi^-\pi^-$				30		1.0±1.0		40.6±4.3	
13	$\to pK^0K^0\pi^+\pi^-\pi^-\pi^0$							9.4±$(K^0_sK^0_s)$	29.1±8.9	
14	$\to nK^0K^0\pi^+\pi^+\pi^-\pi^-$							5±3$(K^0_sK^0_s)$	31.6±8.9	

determined from the events with one visible K^0 after subtracting off those single V^0-events which are $K^0_SK^0_S$.

The cross section for $pK^0K^0\pi^+\pi^-\pi^-$ has been calculated in the standard way from the events in which both or only one neutral K^0 was visible (the probability that in the reaction at least one neutral K^0 decayes as a K^0_S into charged particles is 5/9).

In view of the large quantity of data published on the cross sections it is perhaps surprising that we can compare so few of our cross sections in any meaningful way with the existing data. The brief comparison we present is therefore intended as a guide to the reliability of our data rather than as comments on the variation of cross section with energy.

Table 4 gives a compilation of cross sections for various reactions obtained in different experiments. Moreover, for some reactions in table 4 the variation of the cross section with incident beam momentum is also shown in figs 1-5.

We wish to express our thanks to the CERN for providing us the photographs. We would also like to thank the scanning, measuring and computing staffs in our Laboratories.

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Received by Publishing Department
on March 28 1979.