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NEUTRAL STRANGE PARTICLE PRODUCTION

IN $\bar{p}$ Ne REACTIONS AT 607 MeV/c

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Abstract. - The Λ^0 and K_S^0 production cross sections have been measured at 607 MeV/c for the reaction $\bar{p} + \text{Ne} \rightarrow V^0 + X$ ($V^0 = \Lambda^0, K_S^0$). The Λ^0/K_S^0 production ratio is found to be $(2.3 \pm .7)$. The data favour the hypothesis that K_S^0 are emitted from $\bar{p}N$ sources while Λ^0 are produced in multinucleon systems. The rapidity distributions of negative tracks in Λ^0 and non-strange events are different from that in K_S^0 events.

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Great interest has been attached to the effect of collective multi-nucleon processes and phenomena of high nuclear temperature. The most intriguing aspect is the possibility, under appropriate conditions, that a collection of nucleons could be transformed into a quark-gluon plasma. One of the signals should be an enhanced strange particle production. A process which deposits considerable energy into a nucleus is the absorption of an antiproton. The first experimental data on Λ^0 production in $\bar{p}$ interactions with complex nuclei were published by Condo et al.¹⁾ and by Miyano et al.²⁾.

In this letter we report the study of the reaction:

$$\bar{p} + \text{Ne} \rightarrow V^0 + X \quad (V^0 = \Lambda^0 \text{ or } K_S^0)$$

from an exposure of a $(90 \times 70 \times 18) \text{ cm}^3$ self shunted streamer chamber in a magnetic field. The chamber provided a natural Ne gas target at atmospheric pressure exposed to the low energy $\bar{p}$ beam of the LEAR facility³⁾. Λ^0 and K_S^0 are observed through their charged decay modes. Each annihilation with at least one associated V^0 candidate was fully measured and processed through the HYDRA geometry and kinematic programs. Figures 1 and 2 show the effective mass plots of Λ^0 and K_S^0 respectively. 79 events were recognized as Λ^0 (Σ^0) and 55 as K_S^0 . No distinction could be made between Λ^0 and Σ^0 .

From the decay length distributions of Λ^0 and K_S^0 displayed in figures 3 and 4 we can estimate the total yield of Λ^0 and K_S^0 . The figures reveal a substantial loss of V^0 in the first 2-3 cm from the production vertex. A reasonable assumption about these

losses (as a function of the decay length, hereby introducing one free loss parameter), enables us to make a fit to the distributions as shown in figures 3 and 4 ($\chi^2=5.5$ for 9 degrees of freedom). In this way we obtain a weight for each event as a function of momentum, lifetime, fiducial volume and the fitted loss parameter. Thus, also taking into account the neutral decay modes a detection efficiency of 29% for Λ^0 and 48% for K_S^0 has been inferred. Through repeated scan and measurements the scanning efficiency turns out to be 98%. In Table I we report the particle yield, the corresponding production cross section and rates for a sample of 7622 annihilations, produced by $9.4 \cdot 10^6 \bar{p}$ (all errors are statistical). For comparison we display the production ratios measured in a number of other experiments at several energies. It can be noted that our emission probability of Λ^0 , $(1.95 \pm .43)\%$, confirms that obtained by Condo et al.¹⁾ on complex nuclei below 450 MeV/c (in that experiment the K_S^0 production was not measured or detected). Moreover, the ratio $R = \sigma(\Lambda^0)/\sigma(K_S^0)$ is about 2, close to that measured with high statistics at 4 GeV/c by Miyano et al.²⁾. On the contrary, in deuterium $R \approx .2$ ⁴⁾.

Figures 5 and 6 show rapidity distributions of Λ^0 and K_S^0 . In order to show the influence of weighting both unweighted and weighted distributions have been drawn. The corrections due to weighting is largest for Λ^0 because on average the momentum of Λ^0 is smaller than that of K_S^0 . In Table II we report some kinematical quantities for events with and without Λ^0 and K_S^0 (all errors are statistical). The weighted average rapidity of Λ^0 is $\langle y \rangle = (.07 \pm .03)$. We define a reference frame moving with a velocity $\beta = (.07 \pm .03)$ in the laboratory frame. This new frame, in which the average rapidity $\langle y^* \rangle = 0$,

coincides with the C.M. frame of the system $\bar{p}$ together with 5-15 nucleons. This result is consistent with that deduced for $\bar{p}$ of 4 GeV/c²). The weighted angular distribution of Λ^0 in the $(\bar{p}, 15N)$ C.M. frame, moving with $\beta \approx .04$ in the laboratory frame, is isotropic within errors (fig.7a). The weighted average rapidity of K_S^0 is $(.33 \pm .07)$ indicating a pronounced preference of forward production relative to the $\bar{p}$ beam direction. For K_S^0 $\langle y^* \rangle = 0$ if $\langle y \rangle = (.33 \pm .07)$, which implies an interacting system $(\bar{p}, 1N)$ to be compared to a system $(\bar{p}, 3N)$ deduced at higher energy²⁾. The angular distribution of K_S^0 is consistent within errors with isotropy in the $(\bar{p}, 1N)$ C.M. frame (fig.7b). The rapidity distributions of negative tracks (mostly pions) produced in primary vertices are different for annihilations with associated Λ^0 and for those with associated K_S^0 (fig.8). The negative tracks emitted together with the Λ^0 are more forwardly directed than those emitted together with the K_S^0 . The rapidity is on average $(.31 \pm .08)$ for Λ^0 events and $(-.01 \pm .06)$ for K_S^0 events. In the same figure we display the rapidity of negative tracks produced in annihilations without observed Λ^0 or K_S^0 . The average rapidity is now $(.25 \pm .02)$. For comparison the distribution of π^- rapidity from $\bar{p}p$ annihilations at 607 MeV/c has been drawn. This curve is based on the model of Orfanidis et al.⁵⁾ and on phase space. The average charged prong multiplicities at the production vertices with associated V^0 are $\langle M \rangle = (6.1 \pm .3)$ for Λ^0 and $M = (5.5 \pm .3)$ for K_S^0 . These values are both higher than that for $\bar{p}p$ events⁶⁾. We can conclude that in $\bar{p}Ne$ annihilations at 607 MeV/c the data favour

the hypothesis that K_S^0 and Λ^0 production mechanism are similar to those described by Miyano et al. for $\bar{p}Ta$ annihilations at 4 GeV/c²). This agreement, with that found for the Λ^0 and K_S^0 angular distributions, suggests an evaporative character²⁾ of the emission mechanism independent of the $\bar{p}$ energy. However, in our case the Λ^0 are produced with kinetic energies still lower than that of ref.2, and considerable below the values expected if a phase transition to a quark-gluon plasma has occurred^{7,8)}. Moreover, the rapidity distributions of the negative tracks for Λ^0 and non strange events differ from those for K_S^0 events.

Further investigations of neutral strange particle production in $\bar{p}$ annihilations are in progress using different light targets and lower $\bar{p}$ energies (down to stopping $\bar{p}$).

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Table I - K_S^0 and Λ^0 Production Rates ($R = \sigma(\Lambda^0)/\sigma(K_S^0)$).

	Λ^0	K_S^0	R
Detected events	43	31	
Corrected no.of events	149 ± 34	65 ± 13	
<u>Production rates (%)</u>			
Ne (607.7 MeV/c)	$1.95 \pm .43$	$.85 \pm .17$	
C,Ti,Ta,Pb ¹) (450 MeV/c)	$1.9 \pm .4$	-	
<u>prod^(mb)</u>			
Ne (607.7 MeV/c)	12.3 ± 2.8	5.4 ± 1.1	$2.3 \pm .7$
Ta ²⁾ (4 GeV/c)	193 ± 12	82 ± 6	$2.4 \pm .3$
H ^{2,4)} (1 GeV/c)	$\sim .25\%$	$\sim 1.6\%$	$\sim .16$

Table II - Kinematical quantities from events with and without Λ^0 or K_S^0

	$\langle p \rangle$	$\langle p_T \rangle$	$\langle p_L \rangle$	$\langle y \rangle$
Neg.tracks from events without Λ and K_S^0	(334 ± 4)	(289 ± 5)	(106 ± 6)	$(.25 \pm .02)$
<u>Λ^0 events</u>				
Λ^0 fitted but unweighted	(365 ± 22)	(263 ± 17)	(116 ± 29)	$(.10 \pm .03)$
Λ^0 fitted and weighted	(298 ± 25)	(216 ± 20)	(76 ± 26)	$(.07 \pm .03)$
Neg.tracks from prim.vertices	(297 ± 27)	(259 ± 29)	(111 ± 32)	$(.31 \pm .08)$
<u>K_S^0 events</u>				
K_S^0 fitted but unweighted	(508 ± 24)	(331 ± 25)	(239 ± 41)	$(.37 \pm .07)$
K_S^0 fitted and weighted	(482 ± 25)	(318 ± 25)	(212 ± 4)	$(.33 \pm .07)$
Neg.tracks from prim.vertices	(270 ± 26)	(304 ± 35)	(3 ± 24)	$(-.01 \pm .06)$

Figure Captions.

Fig.1 - Effective masses of K_S^0 (a) and Λ^0 (b) of the events selected as Λ^0 by the kinematic program: a) $\langle m_{K_S^0} \rangle = (382 \pm 10) \text{ MeV}/c^2$;
b) $\langle m_{\Lambda^0} \rangle = (1125 \pm 9) \text{ MeV}/c^2$.

Fig.2 - Effective masses of K_S^0 (a) and Λ^0 (b) of the events selected as K_S^0 by the kinematic program: a) $\langle m_{K_S^0} \rangle = (508 \pm 15) \text{ MeV}/c^2$;
b) $\langle m_{\Lambda^0} \rangle = (1267 \pm 20) \text{ MeV}/c^2$.

Fig.3 - Decay length distribution of the events selected as Λ^0 :
—— fitted distribution;
- - - - corrected distribution.

Fig.4 - Decay length distribution of the events selected as K_S^0 :
—— fitted distribution;
- - - - corrected distribution.

Fig.5 - Rapidity distribution of Λ^0 :
—— unweighted;
- - - - weighted.

Fig.6 - Rapidity distribution of K_S^0 :
—— unweighted;
- - - - weighted.

Fig.7 - Angular distribution of Λ^0 (a) and K_S^0 (b):
a) —— in a frame moving with $\beta = .04$,
- - - in a frame moving with $\beta = .07$;
b) —— in a frame moving with $\beta = .33$.

Fig.8 - Rapidity distribution of negative tracks at production vertices:
—— K_S^0 associated;
- - - Λ^0 associated;
-.-.- events without Λ^0 or K_S^0
-o-o- model for $\bar{p}p$ annihilation.

FIG. 1

FIG. 2

FIG. 3

FIG. 4

FIG. 5

FIG. 6

FIG. 7

FIG. 8