STUDY OF K_s^0 , Λ AND $\bar{\Lambda}$ PRODUCTION IN S-W COLLISIONS AT 200 GeV/c PER NUCLEON

The WA85 Collaboration

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Abstract

Results on K_s^0 production at central rapidity in sulphur-tungsten interactions are presented. The selection procedure used to identify K_s^0 particles through their decay to two charged pions is described. The m_T spectra for K_s^0 , Λ and $\bar{\Lambda}$ and the relative production rates K_s^0/Λ and $K_s^0/\bar{\Lambda}$, calculated in the kinematic region $p_T > 1$ GeV/c and $2.5 \leq y_{LAB} \leq 3.0$, are discussed.

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Heavy ion collisions provide, at present, the only way to study hadronic matter under extreme conditions of energy density in the laboratory. A new state of matter, the Quark Gluon Plasma (QGP), is expected to be created in central heavy ion collisions at relativistic energies. To investigate the possibility of QGP formation, many signals have been suggested as useful probes. In particular, the production of strangeness has been suggested to be of importance in understanding the dynamics of hadronic matter in relativistic heavy ion collisions [1, 2]. This is due to the much shorter chemical equilibration time expected in a QGP compared to that in a Hadron Gas (HG) [1, 2]. Very little is known about the time constant of hadronization; in particular, mesons and baryons can be produced by different hadronization mechanisms, so that their relative abundances may not follow the laws of relative chemical equilibrium. Therefore it is also interesting to study strange meson production in order to compare with the production of strange baryons.

The CERN WA85 experiment [3] was designed to detect strange particle decays in relativistic heavy ion interactions in the central rapidity region with medium to high p_T ($p_T > 1$ GeV/ c). The layout of the experiment has already been described in previous publications [4]. Here we just recall that its main component is a set of seven multiwire proportional chambers (MWPC) spanned over about 1.3 m length inside the OMEGA magnet, starting at 2.3 m from the target; the chamber cathodes have a modified butterfly shape [5] which allows them to detect only central rapidity, medium to high p_T particles.

From this experiment we have already published results on hyperon (Λ , Ξ , Ω), antihyperon and charged kaon production in central sulphur-tungsten interactions at 200 GeV/ c per nucleon [6, 7]. In this letter we present results on K_s^0 production and the relative yields K_s^0/Λ and $K_s^0/\bar{\Lambda}$ ¹⁾ in the rapidity interval $2.5 \leq y_{LAB} \leq 3.0$ and $p_T > 1$ GeV/ c . The results presented are based on 60 million sulphur-tungsten events.

Neutral strange particles have been identified by studying their decays into two charged particles, a topology called V^0 . The selections used to identify V^0 s are described as follows. Any pair of oppositely charged particles gives a V^0 candidate if:

- (a) the distance of closest approach between the two tracks is less than 1 cm,
- (b) the angle between the vector momentum of the V^0 and its apparent line of flight from the centre of the target is less than 0.75° ,
- (c) each track has at least four space points and traces through all seven MWPCs,
- (d) the momentum of the V^0 is greater than 6.5 GeV/ c , and
- (e) the reconstructed decay vertex and the other intersection of the two tracks in the bend plane projection are both in the fiducial interval of 125 to 230 cm from the target.

The meaning of the last condition is the following: the two tracks, traced in the magnetic field, normally cross twice in the bend plane (horizontal in the OMEGA magnet). Due to extrapolation errors, sometimes the vertical separation of the two tracks is not sufficient to recognize which of the two crossings is the true decay point of the V^0 (see condition (a)). Selecting one of them as the actual V^0 vertex could produce a bias in the

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¹⁾ Since in our experiment it is not possible to recognize the electromagnetic decay $\Sigma^0 \rightarrow \Lambda\gamma$, wherever in this letter we write $\Lambda(\bar{\Lambda})$, we mean the sum $\Lambda + \Sigma^0(\bar{\Lambda} + \bar{\Sigma}^0)$.

particle yield because of the possible swapping of ‘good’ and ‘wrong’ crossings. This is particularly relevant for K_s^0 , for which the separation distance between the two crossings in the bend plane is larger than for Λ s (up to 80 cm, in the 1.8T OMEGA magnetic field, independently of the V^0 momentum). Criterion (e) is robust against confusion between the two crossings, can be taken into account in the acceptance correction and does not affect the mass or momentum of the V^0 . In addition, it safely excludes the possibility that two oppositely charged tracks coming from the target cross again in the fiducial volume, simulating a V^0 . This criterion, important for good K_s^0 selection, has also been applied to Λ s for purpose of comparison. More details about this procedure can be found in ref. 6.

To identify K_s^0 , Λ and $\bar{\Lambda}$, we require, in addition:

- (f) $q_T > 0.01$ GeV/ c , where q_T is the transverse momentum of the decay tracks with respect to the V^0 momentum. This selection removes the contamination coming from $\gamma \rightarrow e^+e^-$ conversions,
- (g) $|\alpha| < 0.45$ for K_s^0 candidates ²⁾, to eliminate Λ and $\bar{\Lambda}$ contamination,
- (h) $0.45 < |\alpha| < 0.60$ for Λ and $\bar{\Lambda}$ candidates, in order to reduce the contamination from K_s^0 . An example of the Podolanski-Armenteros plot, where the meaning of the above selections is demonstrated, can be seen in fig.2b of ref. 9.

The $\pi^+\pi^-$, $p\pi^-$ and $\bar{p}\pi^+$ invariant mass spectra obtained are shown in figs.1a,b,c, respectively. The shaded parts of fig.1b and fig.1c show the K_s^0 reflection in $p\pi^-$ and $\bar{p}\pi^+$ mass spectra. Selecting Λ and $\bar{\Lambda}$ candidates in a 50 MeV mass interval centred on the Λ mass [10] makes the K_s^0 contamination negligible (about 1 % in both cases). The K_s^0 candidates have been taken in a 100 MeV mass interval centred on the K_s^0 mass [10] and are free from Λ and $\bar{\Lambda}$ contamination due to condition (g) above. The final sample consists of 10 697 K_s^0 , 22 521 Λ and 5 452 $\bar{\Lambda}$ candidates.

The kinematic region of good acceptance for K_s^0 is different from that for Λ and $\bar{\Lambda}$ due to the different masses. In order to make a comparison, the yields and the transverse mass distributions have been computed in the overlapping region, namely $2.5 \leq y_{LAB} \leq 3.0$ and $p_T > 1$ GeV/ c .

The transverse mass ($m_T = \sqrt{p_T^2 + m^2}$) distributions of K_s^0 , Λ and $\bar{\Lambda}$ are shown in fig.2. The distributions have been corrected for acceptance, unseen decay modes and reconstruction efficiency. The Λ and $\bar{\Lambda}$ distributions have also been corrected for feed-down from Ξ ($\bar{\Xi}$) decays; the method has been described in a previous publication [11]. The spectra in fig.2 have been fitted with the expression

$$\frac{1}{m_T^{3/2}} \frac{dN}{dm_T} = A e^{-\beta m_T}.$$

The inverse slopes $1/\beta$ obtained are 219 ± 3 MeV for K_s^0 , 239 ± 3 MeV for Λ and 237 ± 4 MeV for $\bar{\Lambda}$, where the errors are statistical only. The inverse slope for K_s^0 is compatible within one standard deviation with those for K^+ and K^- , already published

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²⁾ α is the Podolanski-Armenteros [8] variable $\alpha = (q_L^+ - q_L^-)/(q_L^+ + q_L^-)$; q_L^+ and q_L^- represent the positive and negative track momenta projected on the V^0 momentum.

by our collaboration [7], and slightly smaller than for hyperons.

Table 1 shows the relative yields K_s^0/Λ and $K_s^0/\bar{\Lambda}$ calculated in the full $y_{LAB} - p_T$ region used in this analysis and also for two different m_T intervals: $m_T > 1.5$ GeV, which is the threshold value for Λ ($\bar{\Lambda}$), and $m_T > 1.9$ GeV for comparison with Λ ($\bar{\Lambda}$) and Ξ ($\bar{\Xi}$) previously studied [4].

In ref. 12 a prediction is made for the production ratio K_s^0/Λ as a function of the ratio $\bar{\Lambda}/\Lambda$, in the framework of a thermal fireball model, assuming meson-baryon chemical equilibrium. Using the $\bar{\Lambda}/\Lambda$ value of 0.25 ± 0.02 obtained in the kinematic region used for the present analysis (with $m_T > 1.9$ GeV/ c and $2.5 \leq y_{LAB} \leq 3.0$), a K_s^0/Λ ratio between 0.12 and 0.14 is predicted, according to different assumptions about the central fireball (HG or QGP), its temperature and collective flow. Our results show a significantly higher ratio than that predicted. However, as pointed out in ref. 12, due to the difference in the hadronization processes baryons and mesons do not need to be in chemical equilibrium relative to each other although chemical equilibrium may be established separately. Thus, the difference between the predicted K_s^0/Λ ratio and the one observed in our experiment can be interpreted as an indication for an off-equilibrium ratio of mesons to baryons in the strange sector.

The NA35 collaboration have published results concerning K_s^0 and Λ ($\bar{\Lambda}$) production in ultrarelativistic nucleus-nucleus collisions at 200 GeV/ c per nucleon [13]. Although their results are not directly comparable to ours because of different kinematic windows, a similar analysis [14] to that in ref. 12 has been carried out on S-S data from NA35. This analysis also indicates that strange mesons and baryons are not in full chemical equilibrium relative to each other.

In conclusion, we have reported results on the production of $K_s^0 \rightarrow \pi^+\pi^-$ in central SW collisions at 200 GeV/ c per nucleon. The inverse slope of the m_T distribution is found to be 219 ± 3 MeV, compatible with the values found for K^+ and K^- [7]. The relative yields K_s^0/Λ and $K_s^0/\bar{\Lambda}$ have been calculated in the three kinematic regions $2.5 \leq y_{LAB} \leq 3.0$ with $p_T > 1$ GeV/ c , $m_T > 1.5$ GeV and $m_T > 1.9$ GeV, respectively.

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Table

Table 1. Meson to baryon production rates in SW interactions at 200 GeV/ c per nucleon.

Ratio	$p_T > 1 \text{ GeV}/c$ $2.5 < y_{LAB} < 3.0$	$m_T > 1.5 \text{ GeV}$ $2.5 < y_{LAB} < 3.0$	$m_T > 1.9 \text{ GeV}$ $2.5 < y_{LAB} < 3.0$
K_s^0/Λ	1.43 ± 0.10	0.25 ± 0.02	0.22 ± 0.02
$K_s^0/\bar{\Lambda}$	6.45 ± 0.61	1.16 ± 0.08	0.87 ± 0.09

Figure captions

Figure 1. The invariant mass spectra of a) $(\pi^+\pi^-)$, b) $(p\pi^-)$ and c) $(\bar{p}\pi^+)$ after the selections described in the text.

Figure 2. Transverse mass distributions for K_s^0 , Λ and $\bar{\Lambda}$ candidates. The K_s^0 data have been divided by 2 in order to avoid graphical overlap with the others.

Figure 1.

Figure 2.