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CHARGED KAON PRODUCTION IN S-W COLLISIONS AT 200 GeV/c PER NUCLEON

The WA85 Collaboration

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Abstract

Results on central production of charged kaons in sulphur-tungsten interactions have been obtained by the WA85 Collaboration. The procedure used to select K^+ and K^- particles, identified through their decay to three charged pions, is described. The m_T spectra for K^+ and K^- and the ratio $\frac{K^+}{K^-}$, calculated in the kinematic region $p_T \geq 0.9$ GeV/c and $2.3 \leq y_{LAB} \leq 3.0$, are presented.

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Heavy ion collisions provide at present the only way to study hadronic matter under extreme conditions 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].

The CERN WA85[3] experiment was designed to detect strange particle decays in relativistic heavy ion interactions in the central rapidity region with medium to high p_T. In previous papers we have presented results on the production of strange baryons and antibaryons with 1, 2 and 3 units of strangeness in SW interactions at 200 GeV/c per nucleon[4].

The study of strange meson production in heavy ion experiments is also interesting. A comparison between the m_T spectra for K^+ and K^- could be a probe for the collision dynamics[5]. In a baryon-rich environment, where the abundance of the u and d quarks is greater than that of the $\overline{u}$ and $\overline{d}$ quarks, $K^+(u\overline{s})$ should be formed earlier than $K^-(\overline{u}s)$ in the hadronization process, giving rise to different m_T spectra[5]. In addition, the production ratio $\frac{K^+}{K^-}$ will provide information on the excess of u quarks with respect to $\overline{u}$, and hence on the baryochemical potential in the system.

In this paper we present results on the production of charged kaons in SW collisions at 200 GeV/c per nucleon, at central rapidity ($2.3 \leq y_{LAB} \leq 3.0$) and $p_T \geq 0.9$ GeV/c. The results presented are based on 60 million SW events taken in 1990. The layout of the experiment has been described in previous publications[4].

K^+ and K^- mesons have been identified by studying their decay into three charged pions:

$$K^\pm \rightarrow \pi^\pm \pi^+ \pi^-$$

The $c\tau$ for this decay is 370.9 cm and the branching fraction is 5.59%[6].

To select a three-prong decay topology we have applied the following two-step procedure. In each event, having at least three tracks reconstructed in at least four MultiWire Proportional Chambers (out of seven)[3], we first looked for all the combinations of two tracks with opposite charge and found the point of closest approach in space, i.e. the vertex of a 'pseudo' V^0; we then added a third track and did a global fit using all three tracks. This procedure has been used because we had already processed the full data sample through the reconstruction programs to find V^0 topologies.

Each V^0 candidate found in the first step was accepted for further analysis if satisfied the condition

$$m(\pi^+\pi^-) < 0.45 \text{ GeV},$$

which rejects pion pairs which cannot come from a $K^\pm$. Each of the remaining charged tracks of the events was then added one by one to the pseudo V^0 and a further minimization in space was done using all three tracks. A vertex was rejected if $d^2_{close} > 4$ cm^2, where

$$d^2_{close} = \sum_{i=1}^{3}[(y^i_{trk} - y_{vtx})^2 + (z^i_{trk} - z_{vtx})^2].$$

In addition, the vertex position was required to be in the fiducial interval of 100 to 230 cm from the target.

The $\pi^{\pm}\pi^{+}\pi^{-}$ invariant mass spectrum obtained is shown in fig.1a. A clear peak in the $K^{\pm}$ mass region is present. The combinatorial background, estimated by mixing tracks from three different events, is also shown.

To reduce the background, further selections were applied. To exclude tracks coming from the target, we required for each track an impact parameter at the target plane in the bending direction

$$| y_{imp} - y_{targ} | > 5 \text{ cm}.$$

Then, to ensure that the $K^{\pm}$ candidates come from an interaction in the target, we require

$$| y_{K^{\pm}} - y_{targ} | < 1.5 \text{ cm},$$

$$| z_{K^{\pm}} - z_{targ} | < 1.5 \text{ cm},$$

where $y_{K^{\pm}}$ and $z_{K^{\pm}}$ are the impacts of the candidates at the target plane.

Finally, the condition

$$| \alpha | < 0.45$$

(α being the Armenteros-Podolanski[7] 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), was applied to both opposite charged track combinations to eliminate Λ contamination.

Fig.1b shows the d^2_{close} distribution for the $K^{\pm}$ candidates after the selections described above. Events with $d^2_{close} > 0.75 \text{ cm}^2$ have been rejected. The corresponding mass distributions are shown in fig.2. For the final analysis we selected K^+ and K^- in a 60 MeV mass interval centred on the K mass, which gave 603 K^+ and 385 K^- candidates. Applying the same selection criteria to the background events of fig.1a gave 5 events in the K^+ mass interval and 3 events in the K^- mass interval.

Fig.3 shows a K^+ decay reconstructed in our apparatus.

The transverse mass ($m_T = \sqrt{p_T^2 + m^2}$) distributions of K^+ and K^- calculated in the rapidity interval $2.3 \leq y_{LAB} \leq 3.0$ are shown in fig.4. The distributions are fully corrected for acceptance, unseen decay modes and reconstruction efficiencies. They have been fitted using the expression

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

The inverse slopes $1/\beta$ obtained are 211 $\pm$ 12 MeV for K^+ and 198 $\pm$ 13 MeV for K^-, respectively, where the errors are statistical only. The inverse slopes are compatible with each other within one standard deviation.

The ratio of the K^+ to K^- yields in the kinematic region $p_T \geq 0.9$ GeV/c and $2.3 \leq y_{LAB} \leq 3.0$ is

$$\frac{K^+}{K^-} = 1.67 \pm 0.15.$$

Comparing the production yields of K^+ and K^- with that of K^o_s in the same experiment[8] gives

$$\frac{K^+ + K^-}{2K^o_s} = 1.07 \pm 0.03.$$

Results on charged kaon production in high energy nucleus-nucleus interactions have been previously reported by other collaborations[9, 10, 11] and are summarized in table 1. None of them is directly comparable to ours because of the different kinematic regions of acceptance and/or the different interacting nuclei. In addition, the parametrizations used in each experiment to fit the m_T distributions are slightly different. Although the inverse slopes for K^+ and K^- are compatible, the general pattern points toward a slightly higher value for K^+ in each experiment.

We have also compared our ratio K^+/K^- to those obtained in proton-proton and proton-tungsten collisions at the same beam energy, medium p_T and central rapidity, in a Fermilab experiment[12]. In ref.[12] the yields have been measured at several fixed p_T values, of which only p_T=1.54 GeV/c belongs to our accepted kinematic window. In order to compare our results with the proton data, we have calculated K^+/K^- at p_T=1.54 GeV/c from the fits of the m_T distributions shown in fig.4. The value obtained is compatible with those computed from the data published in ref.[12], as shown in the last rows of table 1.

In conclusion, we have reported results on the production of charged kaons in central SW interactions at 200 GeV/c per nucleon identified by their decay $K^\pm \rightarrow \pi^\pm\pi^+\pi^-$. The inverse slopes of the m_T distributions have been measured to be 211 $\pm$ 12 MeV for K^+ and 198 $\pm$ 13 MeV for K^-. The relative production ratio $\frac{K^+}{K^-}$ is 1.67 $\pm$ 0.15 in the kinematic region $p_T \geq 0.9$ GeV/c and $2.3 \leq y_{LAB} \leq 3.0$. Comparison with other heavy ions and proton experiments have been discussed.

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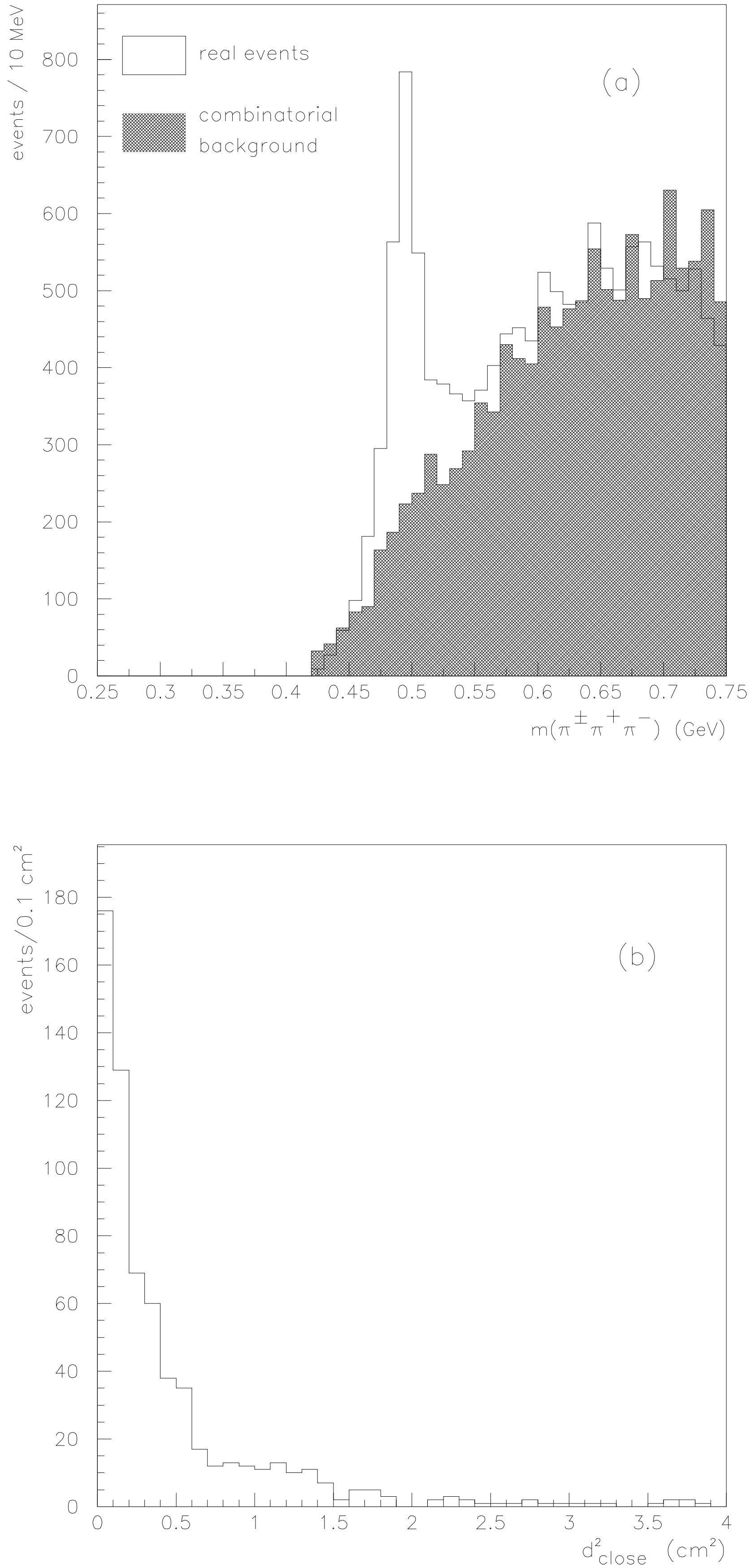
Tables

Table 1. Values of $1/\beta$ and ratio K^+/K^- calculated by different experiments. The beam energy is 200 GeV/c per nucleon in each case. The details of the analysis and the parametrizations used to fit the m_T distributions for NA34, NA35 and NA44 experiments are described in ref.[9, 10, 11], respectively. The K^+/K^- ratio in S+Ag interactions (NA35) have been computed from the data published in ref.[10]. The K^+/K^- ratios in proton-proton and proton-tungsten collisions have been computed from the data published in ref.[12].

Experiment	y_{LAB} - p_T(GeV/c)	$1/\beta$ (MeV)	K^+/K^-
NA34 S+W ref.[9]	$1.0<y_{LAB}<1.5$ $0.2<p_T<0.6$	268 ± 91 K^+ 136 ± 56 K^-	-
NA35 S+Ag ref.[10]	$0.4<y_{LAB}<2.2$ $0<p_T<1$	222 ± 26 K^+ 163 ± 25 K^-	2.16 ± 0.44
NA44 S+Pb preliminary ref.[11]	$3.0<y_{LAB}<3.4$ $0<p_T<0.7$	203 ± 6 K^+ 193 ± 6 K^-	-
WA85 S+W	$2.3<y_{LAB}<3.0$ $p_T>0.9$	211 ± 12 K^+ 198 ± 13 K^-	1.67 ± 0.15
	$2.3<y_{LAB}<3.0$ $p_T=1.54$	- -	1.90 ± 0.33
Fermilab p+p ref.[12]	$y_{LAB}=3.2$ $p_T=1.54$	- -	2.11 ± 0.21
p+W ref.[12]	$y_{LAB}=3.2$ $p_T=1.54$	- -	2.24 ± 0.19

Figure caption

Figure 1a. The $\pi^{\pm}\pi^{+}\pi^{-}$ invariant mass spectra, after the selections described in the text.
Figure 1b. d^2_{close} distribution for real data.
Figure 2. The $\pi^{+}\pi^{+}\pi^{-}$ and $\pi^{+}\pi^{-}\pi^{-}$ invariant mass spectra for kaon candidates.
Figure 3. A K^{+} decay fully reconstructed: a) horizontal view (bending plane), b) vertical view. The dashed lines represent the MWPCs.
Figure 4. Transverse mass distributions for K^{+} and K^{-}.



events / 10 MeV
real events
combinatorial background
(a)
m(π±π+π−) (GeV)
events/0.1 cm²
(b)
d²close (cm²)

Figure 1.

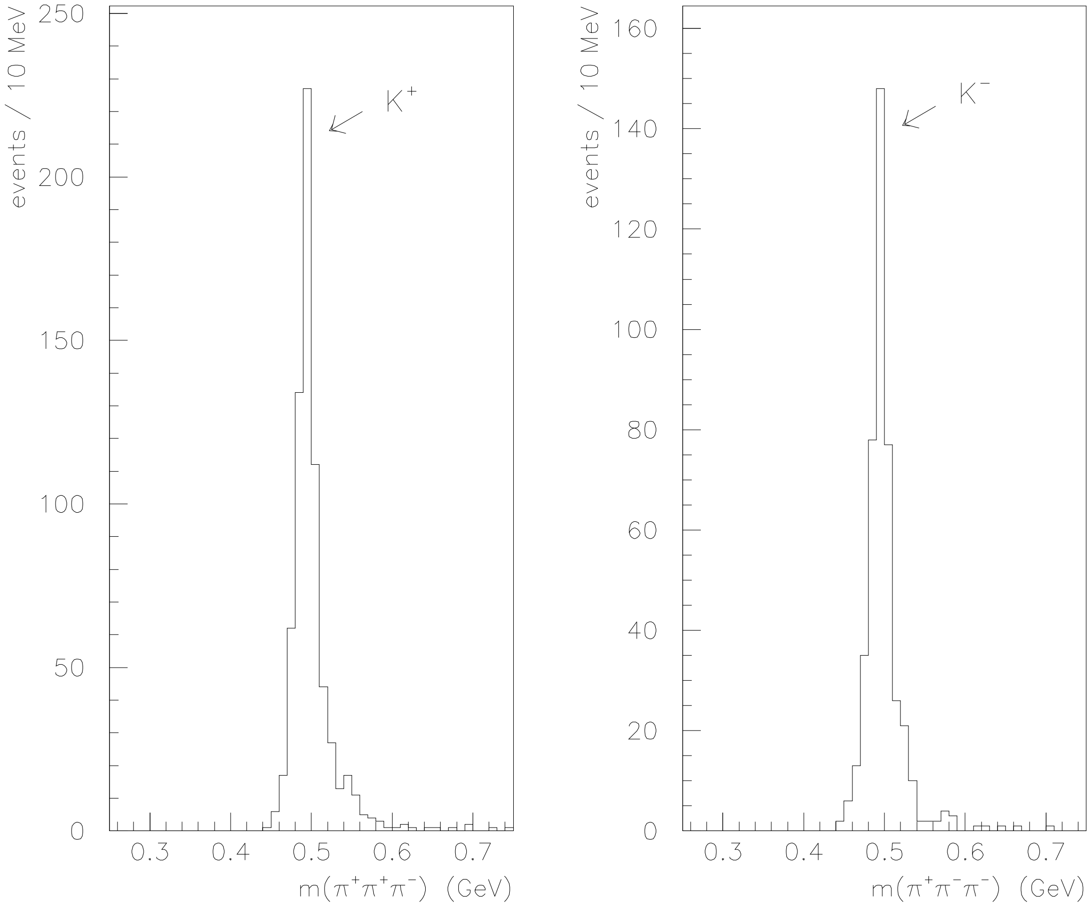
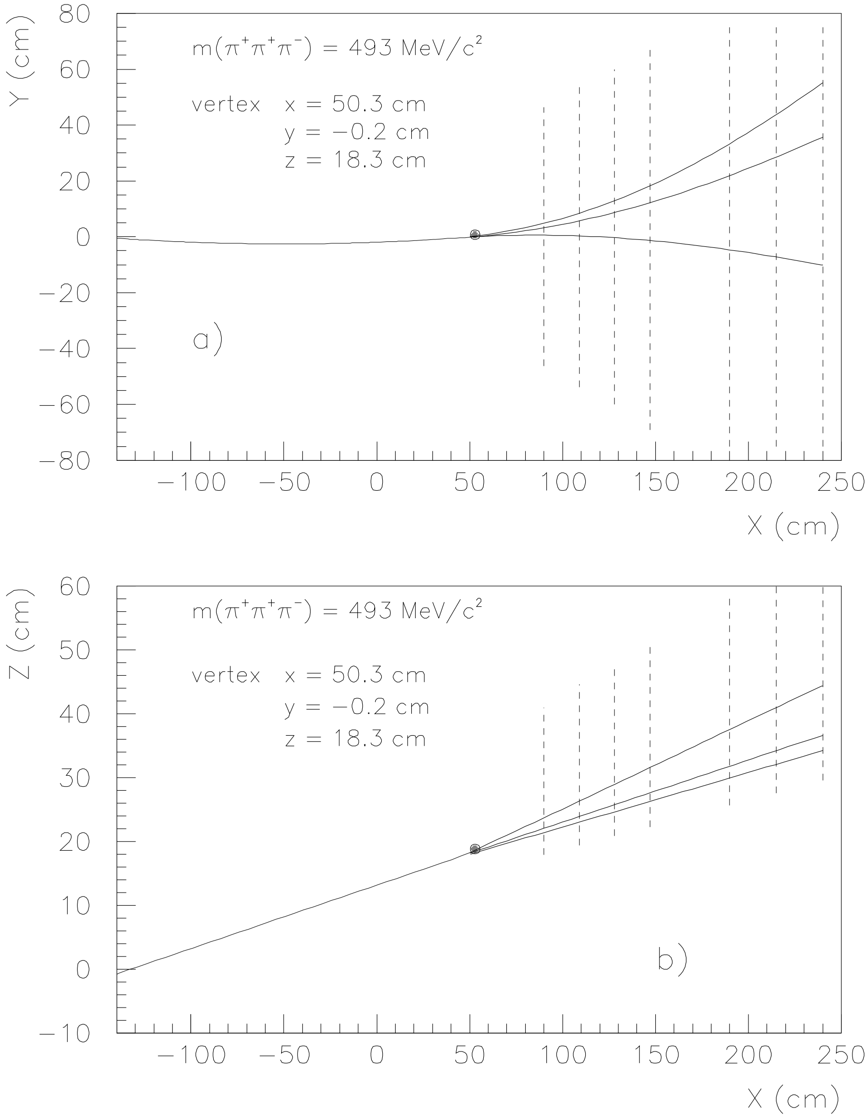

events / 10 MeV
250
200
150
100
50
0
0.3
0.4
0.5
0.6
0.7
K$^+$
m($\pi^+\pi^+\pi^-$) (GeV)
events / 10 MeV
160
140
120
100
80
60
40
20
0
0.3
0.4
0.5
0.6
0.7
K$^-$
m($\pi^+\pi^-\pi^-$) (GeV)

Figure 2.



m(π⁺π⁺π⁻) = 493 MeV/c²
vertex x = 50.3 cm
y = −0.2 cm
z = 18.3 cm
a)
Y (cm)
X (cm)
m(π⁺π⁺π⁻) = 493 MeV/c²
vertex x = 50.3 cm
y = −0.2 cm
z = 18.3 cm
b)
Z (cm)
X (cm)

Figure 3.

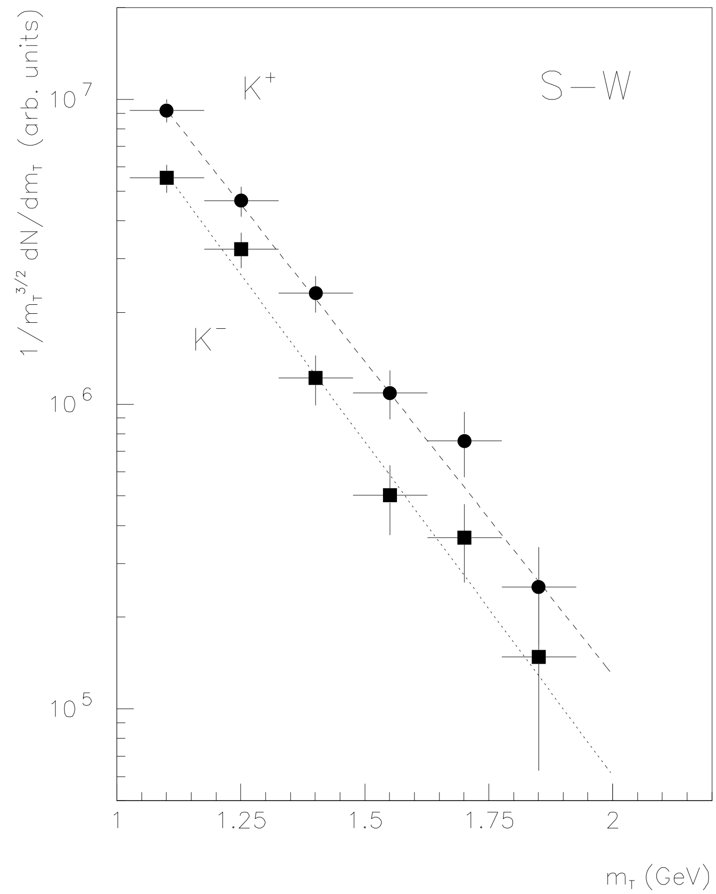


Figure 4.