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KAON AND PION PRODUCTION CROSS SECTIONS IN p + C, d + C AND C + C COLLISIONS AS A FUNCTION OF PROJECTILE ENERGY FROM 2.5 TO 8.1 GeV/NUCLEON

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New experimental data were obtained for pion and kaon production by proton, deuteron and carbon ions on carbon target at different incident energies from 2.5 to 8.1 GeV. The laboratory production angle was 24°; and momentum, 0.8 GeV/c.

The investigation has been performed at the Laboratory of High Energies, JINR.

Сечения рождения каонов и пионов в p + C, d + C и C + C столкновениях как функция энергии налетающих частиц в диапазоне энергий 2,5—8,1 ГэВ/нуклон

А.А.Балдин и др.

Получены новые экспериментальные данные по рождению пионов и каонов в p + C, d + C и C + C реакциях при различных энергиях налетающих частиц в диапазоне 2,5—8,1 ГэВ/нуклон. Измерения вторичных частиц проводились с импульсом 0.8 ГэВ/с под углом 24°.

Работа выполнена в Лаборатории высоких энергий ОИЯИ.

1. Introduction

An experimental study of pion, kaon and antiproton production by relativistic heavy ions on nuclei provides the unique possibility for the investigation of nuclear matter and interaction mechanisms because the phenomenon is so complicated that no theory has yet been successful in interpreting all the experimental data. Particle production in nucleus-nucleus collisions at values of kinetic energy per nucleon lower and near the threshold in nucleon-nucleon collision provides an interesting probe of possible collective phenomena. Much efforts have been made to find

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a signal of quark-gluon plasma phase in heavy ion reactions via k/π ratios. To clarify the reactions mechanism it is interesting to understand the systematics of the underlying processes with a variety of projectiles and at different beam energies.

In our previous publications [1,2,3] we have presented the spectra of kaons and the first observation of antiprotons in the reaction $^{12}C + A$ at 3.65 GeV/nucleon for laboratory production angle 24°. Recently subthreshold kaon and antiproton production in $^{28}Si + ^{28}Si$ collisions at 2.1 and 1.65 GeV/nucleon [4,5] and at highly relativistic momentum 14.6 GeV/nucleon [6,7] have been reported. However, it is interesting to compare data for $A + A$ and $p + A$ collisions at different projectile energies.

Now we report on a recent experiment in which we measured kaon and pion production in the reactions $p + ^{12}C$, $d + ^{12}C$ and $^{12}C + ^{12}C$ in the similar kinematics as a function of projectile energy.

2. Experimental Method

The measurements were carried out on the magnetic channel of «KASPIY» of INR (Moscow), installed on the extracted beam of the relativistic nuclei of the Laboratory of High Energies, JINR (Dubna). Magnetic channel «KASPIY» consists of two dipole and four quadrupole magnets with acceptance 9.8 msr·%. For particle identification time-of-flight (TOF) system included scintillation counters was used. The suppression of pion background was performed by two plexiglas Cherenkov counters. In addition the amplitude information from TOF scintillators was analyzed. We reconstructed all tracks passed through the system by a set of proportional chambers for phase space analysis. The incident ions intensities were about $5 \cdot 10^8$ particles for carbon beam, 10^9 particles for proton and deuteron beams per spill. The Laboratory momentum was 0.8 GeV/c. The target thickness was 8 g/cm. Figure 1 shows the quality of the data for positive secondaries produced in the reaction $d + ^{12}C$ at 2.5 GeV/nucleon. At the top, the TOF spectrum for positive particles vetoed by Cherenkov counters is shown. At the bottom, this TOF spectrum with amplitude from one of counters is presented. The experimental data were corrected for meson decay, multiple scattering, adsorption in the target and counters. The data were normalized to previously measured pion cross section [1,8,9]. The absolute accuracy of cross sections normalization is about 20%. The experimental data of the ratios of invariant cross sections are presented in Table 1. Table 2 includes meson invariant cross sections.

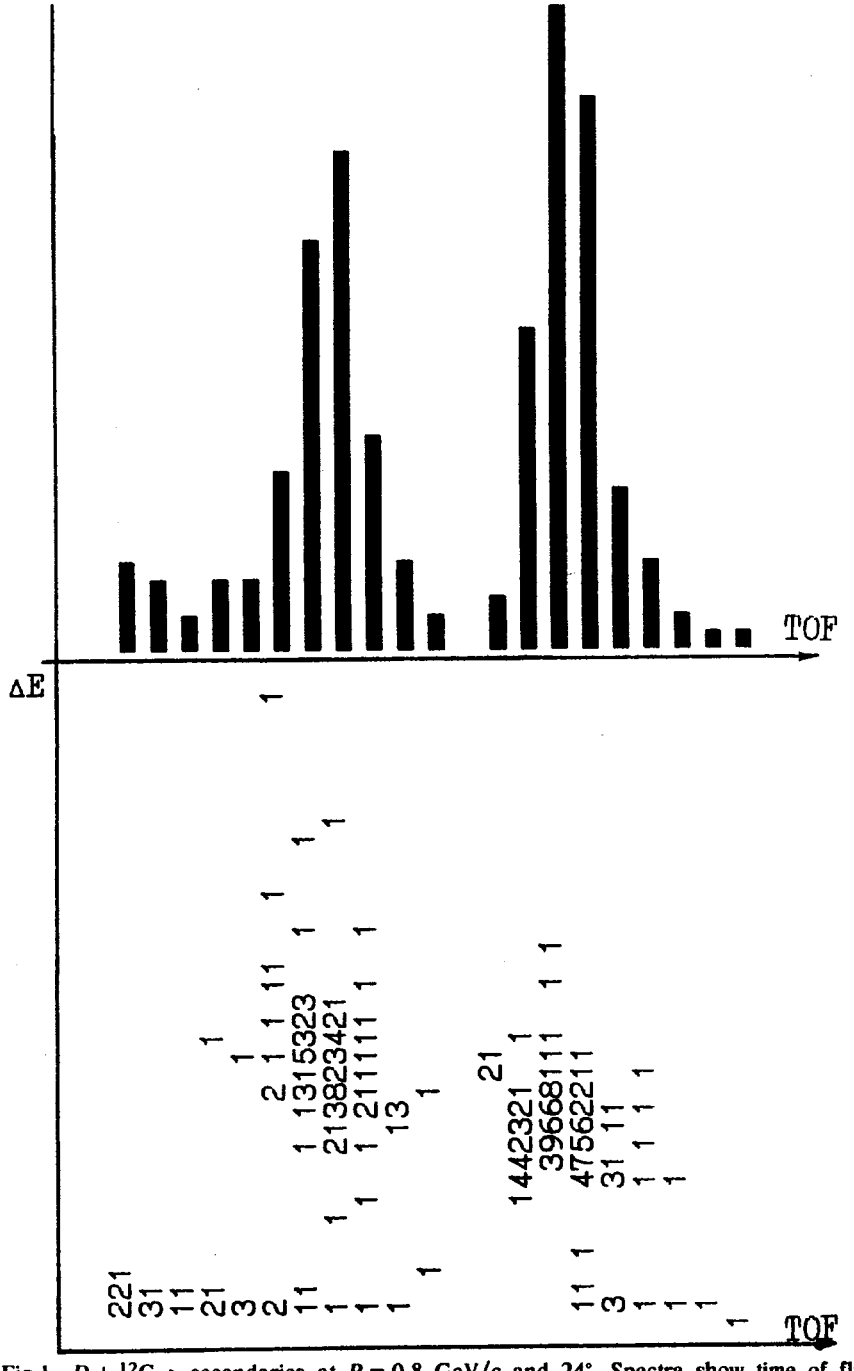

Fig.1. $D + {}^{12}C \rightarrow$ secondaries at $P = 0.8$ GeV/c and 24°. Spectra show time of flight for positives vetoed by Cherenkov counters (top). The TOF-ΔE analysis of this spectra (at the bottom)

Table 1

Ekin GeV/n	React	$\frac{k^-}{\pi^-}$	$\frac{k^+}{\pi^+}$	$\frac{\pi^-}{\pi^+}$	$\frac{k^-}{k^+}$
2.5	P+C	$(3.0\pm0.7)*10^{-4}$	$(2.6\pm0.2)*10^{-2}$	0.35±0.02	$(4.2\pm0.9)*10^{-3}$
	D+C	$(5.7\pm0.6)*10^{-4}$	$(3.1\pm0.1)*10^{-2}$	0.86±0.6	$(2.0\pm0.2)*10^{-2}$
	C+C	$(1.2\pm0.3)*10^{-3}$	$(3.4\pm0.2)*10^{-2}$	1.00±0.03	$(3.3\pm0.8)*10^{-2}$
3.0	D+C	$(1.6\pm0.14)10^{-3}$	$(4.1\pm0.1)*10^{-2}$	0.86±0.06	$(3.4\pm0.3)*10^{-2}$
	C+C	$(2.6\pm0.2)*10^{-3}$	$(5.0\pm0.4)*10^{-2}$	1.00±0.04	$(5.2\pm0.5)*10^{-2}$
3.65	P+C	$(2.6\pm0.4)*10^{-3}$	$(4.5\pm0.2)*10^{-2}$	0.68±0.05	$(3.8\pm0.6)*10^{-2}$
	D+C	$(3.6\pm0.5)*10^{-3}$	$(5.0\pm0.2)*10^{-2}$	0.93±0.06	$(6.6\pm0.5)*10^{-2}$
	C+C	$(4.5\pm0.4)*10^{-3}$	$(5.9\pm0.3)*10^{-2}$	1.00±0.04	$(7.6\pm0.3)*10^{-2}$
4.5	P+C	$(4.3\pm0.5)*10^{-3}$	$(6.0\pm1.0)*10^{-2}$	0.74±0.05	$(5.3\pm0.5)*10^{-2}$
6.0	P+C	$(7.9\pm0.2)*10^{-3}$	$(0.9\pm0.1)*10^{-1}$	0.90±0.6	$(7.9\pm0.4)*10^{-2}$
8.1	P+C	$(1.0\pm0.2)*10^{-2}$	$(1.1\pm0.2)*10^{-1}$	1.00±0.6	$(0.91\pm0.3)10^{-1}$

The ratio of invariant cross sections.

Table 2

Ekin GeV/n	React	π^-	π^+	k^-	k^+
2.5	P+C	12 ± 5	34 ± 14	$(4.1\pm1.7)*10^{-3}$	1.0±0.3
	D+C	90	100	$(4.1\pm1.4)*10^{-2}$	2.4±0.6
	C+C	350	350	$(4.6\pm1.0)*10^{-1}$	13.8±2.0
3.0	D+C	90	100	$(1.2\pm0.2)*10^{-1}$	3.5±0.6
	C+C	350	350	1.4±0.4	16.0±3.0
3.65	P+C	24 ± 4	35 ± 7	$(7.1\pm2.2)*10^{-2}$	1.6±0.3
	D+C	100 ± 10	100 ± 10	$(3.1\pm0.6)*10^{-1}$	4.3±1.3
	C+C	350 ± 20	350 ± 20	1.8±0.3	24.0±3.0
4.5	P+C	32 ± 5	43 ± 8	$(1.5\pm0.3)*10^{-1}$	2.2±0.5
6.0	P+C	46 ± 5	51 ± 10	$(4.1\pm0.8)*10^{-1}$	5.2±1.5
8.1	P+C	66 ± 5	66 ± 7	$(7.6\pm0.7)*10^{-1}$	8.4±1.3

The invariant cross section $\frac{E}{p^2}\cdot\frac{d^2\sigma}{dPd\Omega}$ (mb/sr Gev^2/c^3).

3. Analysis of Data

Data from Table 1 and data from [4,5] are shown in Figs.2 and 3 as a function of a projectile kinetic energy per nucleon. Assuming the dominant role of single pion production at low energy and taking into

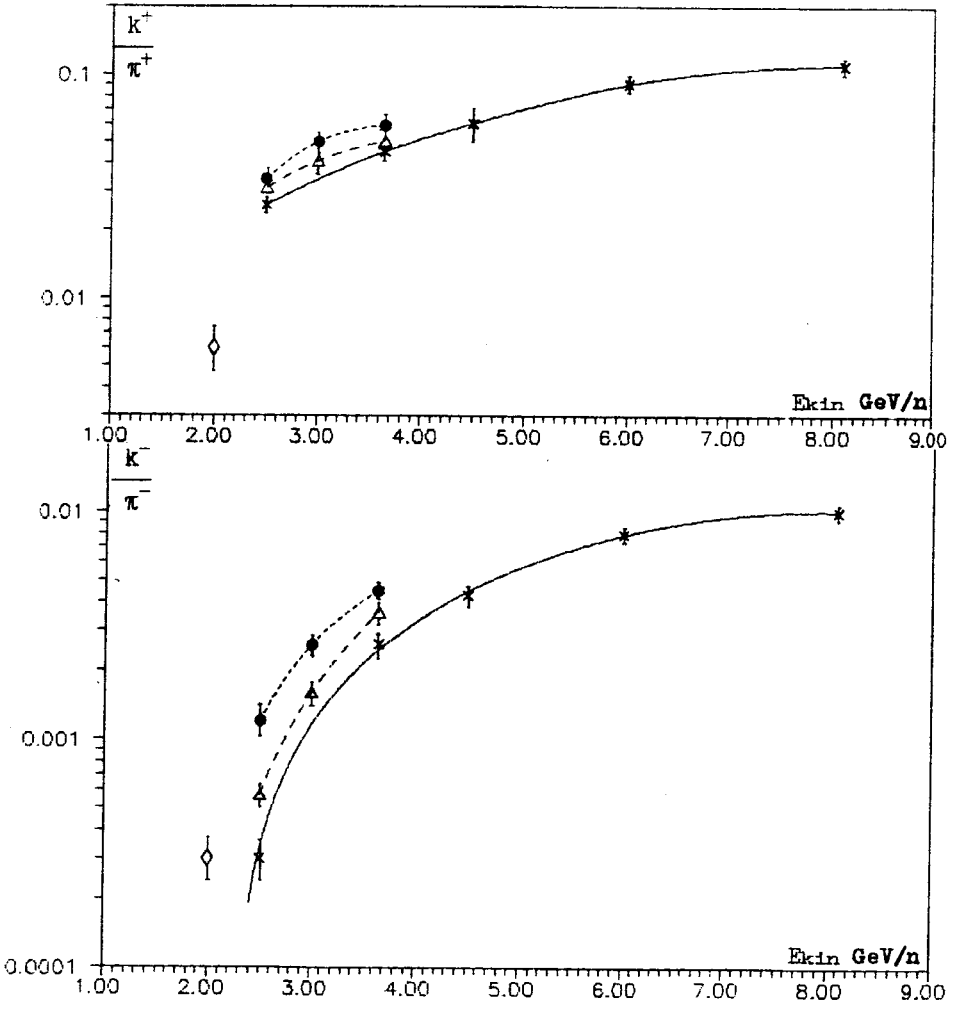

Fig.2. The ratio of invariant cross sections k^+/π^+ (top) and k^-/π^- (bottom) as a function of projectile kinetic energy per nucleon. This experiment: ×× — p + C — 24°, 0.8 GeV/n; ΔΔ — d + C — 24°, 0.8 GeV/n; •• — C + C —24°, 0.8 GeV/n. From ref.[4]: ◇ ◇ — Si + Si — 0°, 0.93 GeV/n

account isotopic relations for p + A collisions one can expect the ratio $\pi^-/\pi^+ = 0.4$. This value is in agreement with our data at $E = 2.5$ GeV.

In the past few years much work has been done for studying asymptotic properties of hadron-hadron collisions (see, for example, [10]). It is interesting to see asymptotic behavior of the π^-/π^+, K^-/K^+, K^-/π^- and K^+/π^+ ratios of the invariant cross section beginning from about 5 GeV/nucleon. According to the Brookhaven data [6,7] for central Si + Au collision at 14.6 Gev/c/nucleon the K^-/π^- and K^+/π^+ ratios are 0.018 and 0.2; and for P + Be, 0.075 and 0.016, respectively. To extract the ratios from [7] for P + Be at 14.6 GeV/c we took meson cross-sections at the same kinematic conditions as in our experiment.

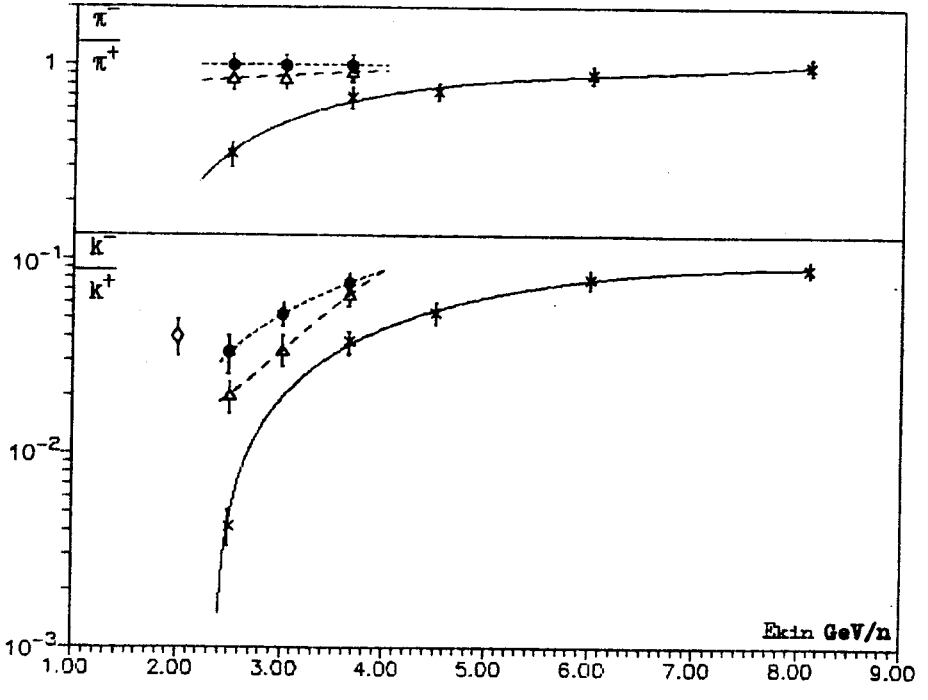

Fig.3. The ratio of invariant cross sections π^-/π^+ (top) and k^-/k^+ (bottom) as a function of projectile kinetic energy per nucleon. This experiment: ×× — $p + C \to k, \pi$, 24°, 0.8 GeV/n; ΔΔ — $d + C \to k, \pi$, 24°, 0.8 GeV/n; •• — $C + C \to k, \pi$, 24°, 0.8 GeV/n. From ref.[4]: ◇◇ — Si + Si $\to k$.. 0°, 0.93 GeV/n.

Our experimental data had covered the range between Berkeley and Brookhaven energies and we hope that it will be interesting to compare the different theoretical models.

In order to take into account the dependence of production cross sections on the atomic numbers of projectile and target nuclei an extended analysis of our data will be performed on the basis of the parton model with mass corrections [11].

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