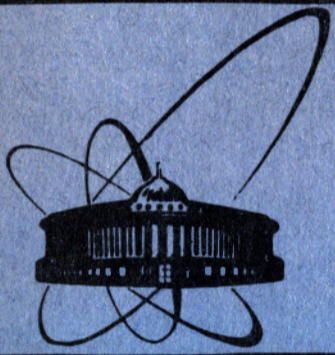

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E1-84-703

INVESTIGATION OF INCLUSIVE PROCESSES $\pi^- A \to \pi^- X$ AND $\pi^- A \to p_{backwards} X$ AT 40 GeV/c

Submitted to XXII International Conference on High Energy Physics (Leipzig, 1984)

1984

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1. The study of inelastic hadron-nucleus interactions at high energy is of considerable interest both from the theoretical and experimental points of view. This is due to a unique opportunity to obtain information on strong interactions of hadrons which cannot be obtained by studying only hadron-hadron interactions. In particular, study of the inclusive reaction $hA \to hX$ in the projectile hadron fragmentation region yields, apart from the opportunity to verify the model conceptions on the quark structure of the hadron, information on the character of the interaction between the newly produced particles and nucleons of a nucleus.

The reaction

$$\pi^- A \to \pi^- X \qquad (1)$$

was studied when analysing the experimental data obtained from the 5-metre magnet spark spectrometer of JINR at the 40 GeV/c pion beam of the Serpukhov PS accelerator. The scheme and geometry of the experiment were equivalent to those of the diffraction dissociation experiment [1], except for the trigger which was used in the inclusive version. Production of secondary fast negative pions was measured over the Feynman range $0.1 \leq x_F < 0.9$ and the transverse momentum range $P_T < 1$ GeV/c. Information on the targets used in the experiment is given in Table 1. Targets were placed in front of the first spark chamber plane as far as 70 cm from it; the full acceptance angle of the spectrometer was 30°. A multiwire proportional chamber in the spectrometer volume covered the above-mentioned acceptance and discriminated events when more than one charged particle from the target entered the spectrometer volume.

Over 4000 inelastic interaction events for 4 targets were measured at HPD JINR (Dubna). Further processing of the track information was performed by means of the modified ROMEO programme which in addition to the geometry reconstruction includes also the event vertex (the point of interaction) fit routine [3]. Estimation of efficiency of track finding by means of such an automatised processing procedure in the afore-mentioned kinematic region showed that track losses did not exceed 2%.

Figure 1 shows square momentum distributions for negative pions from reaction (1). Solid curves are the result of fitting of these distributions by the function $a \cdot \exp(-bP_T^2)$. The values

Table 1

Targets used in the experiment on studying process (1)

Target	*A*	*Thickness, g/cm²*
C	12.0	4.28
Al	27.0	3.25
Cu	63.5	1.70
Pb	207.2	1.14

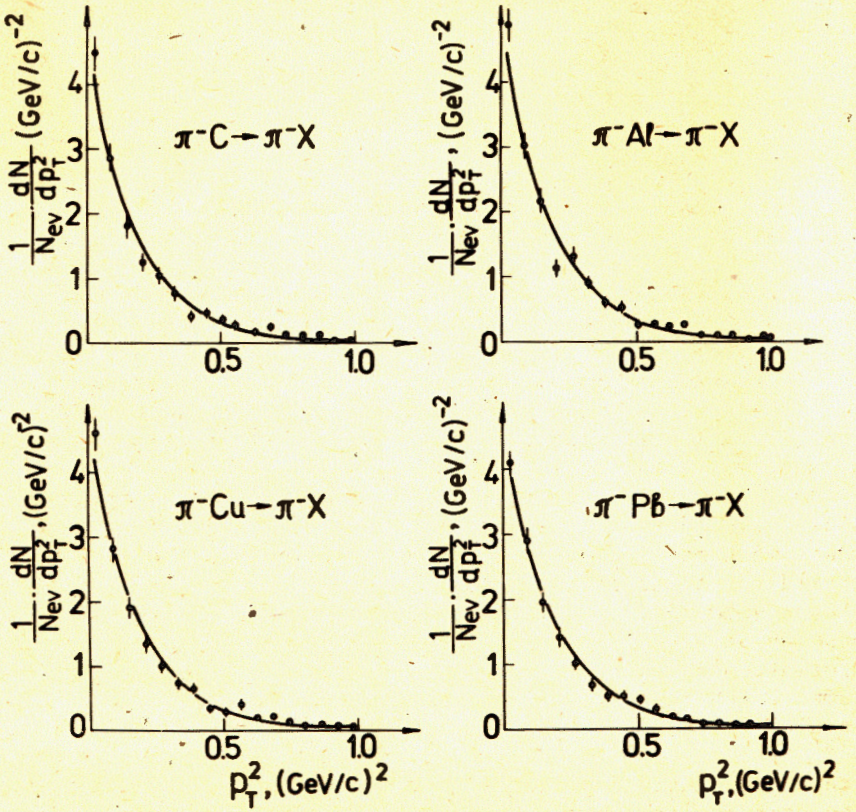


Fig.1. Distributions over the square of the transverse momentum for the inclusive process on C, Cu, Al, Pb nuclei at 40 GeV/c.

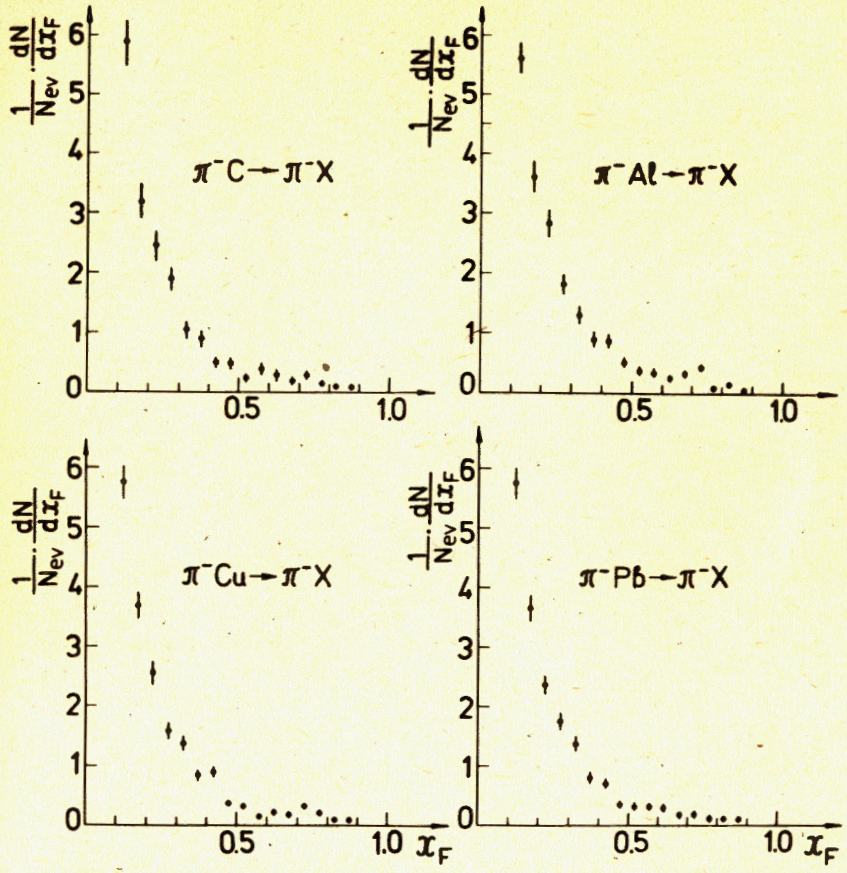


Fig.2. $\frac{1}{N_{ev}}\cdot\frac{dN}{dx_F}(\pi^-A\to\pi^-X)$ *functions of* X_F *for four target nuclei at 40 GeV/c.*

Table 2

Results of approximation of the distribution $\rho_A(x_F) \equiv \equiv \frac{1}{N_{ev}}\cdot\frac{dN}{P_T^2}$ *by the function* $a\cdot\exp(-bP_T^2)$

Target	*C*	*Al*	*Cu*	*Pb*
b, $(GeV/c)^{-2}$	5.4±0.3	5.2 ± 0.2	5.2 ± 0.2	5.3 ± 0.3
a, GeV^{-2}	4.6 ± 0.3	4.9 ± 0.3	4.6 ± 0.2	4.5 ± 0.2
χ^2/DF	1.37	2.08	1.96	0.99

Table 3

Comparison of the AQM predictions with the experimental values of ratios $\rho_{A_i}(0.5)/\rho_{A_j}(0.5)$

$\rho_{A_i}(0.5)/\rho_{A_j}(0.5)$	*Experiment* [1]	*AQM* [2]
Cu/Al	0.89 ± 0.06	0.84
Pb/Al	0.86 ± 0.05	0.65
Pb/Cu	0.96 ± 0.06	0.75

[1] *Experimental values of* ρ_A *(0.5) have been calculated for the interval* $0.2 \leq x_F < 0.8$.

[2] *Only ratios for* $A \geq 27$ *are calculated here, since there is no approximation for light nuclei in Ref.* [2].

of parameters "a" and "b", obtained in the fitting, and the ratio χ^2/DF are given in Table 2.

Distributions for C and Pb are well fitted by the chosen function, but this function describes distributions for Al and Cu targets much worse. One can see from Fig.1 and Table 2 that the form of P_T^2 distributions and values of the parameter "b" do not depend practically on the atomic number of the target.

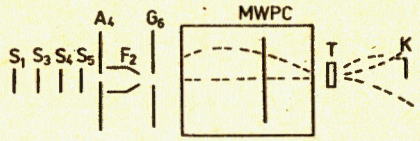
Figure 2 presents X_F-dependence of $\frac{1}{N_{ev}} \cdot \frac{dN}{dx_F}$ distributions (N_{ev} is the number of inelastic events). Noteworthy is the fact that the distributions for different nuclear targets are much alike. At the same time the additive quark model (AQM) [2] predicts some A-dependence of inclusive distributions for nuclei in the $x_F = 0.5$ neighbourhood. Table 3 allows one to compare our experimental results with the AQM predictions. It is seen that for values of the atomic number corresponding to copper and aluminium the AQM predictions coincide with our experimental data while for larger A the quark model disagrees with the experimental results.

2. The inclusive reaction

$$\pi^- + A \to p_\downarrow + X \qquad (2)$$

with proton emission to the backward hemisphere was measured at the projectile pion momentum 40 GeV/c on C, Cu and Pb nuclei in two angular intervals of proton emission: 120° ÷ 160° and 155° ÷ 175°. The scheme of measurements is shown in Fig.3.

Fig.3. Experimental lay-out for the study of the reaction $\pi^- A \to p_\downarrow X$. S_1, S_3, S_4, S_5, G_6, $\bar{A}_4$, $\bar{F}_2$, $\bar{K}$ *are scintillation counters, MWPC is the multiwire proportional chamber.*



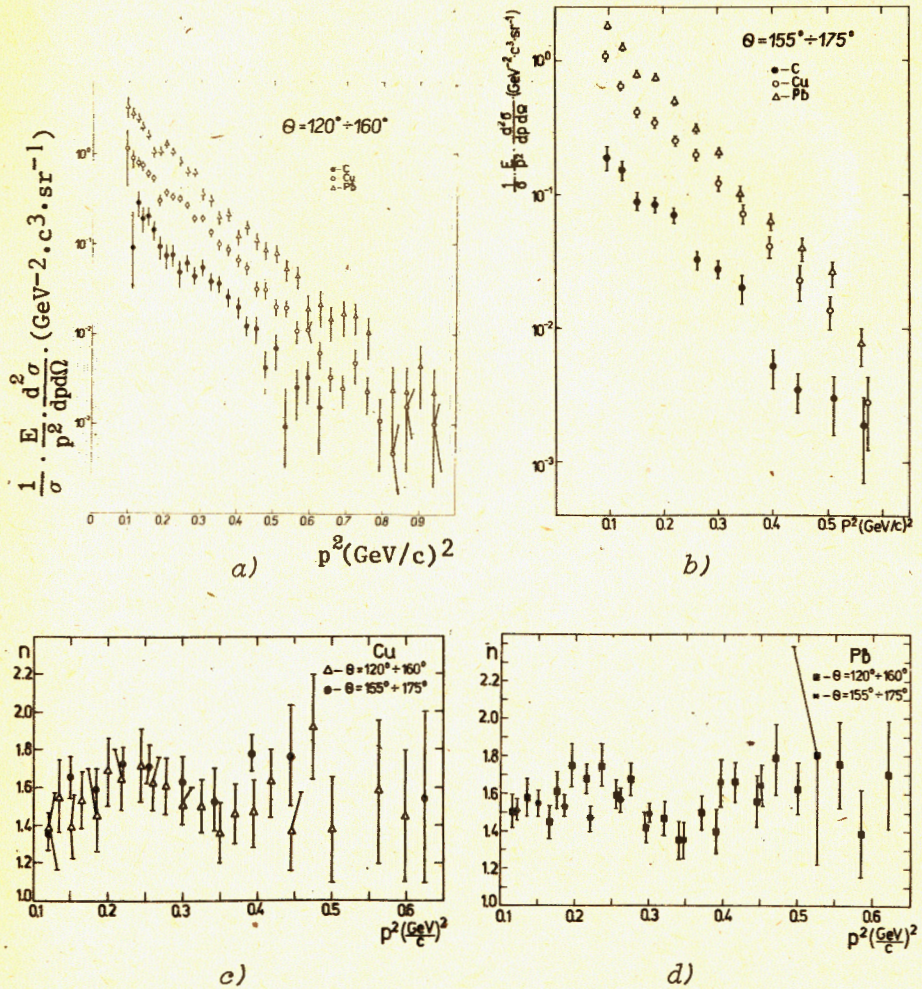


Fig.4. Momentum distributions of protons in the reaction $\pi^- A \to p_\downarrow X$ *for the proton emission angles 120° ÷ 160° and 155° ÷ 175°.*

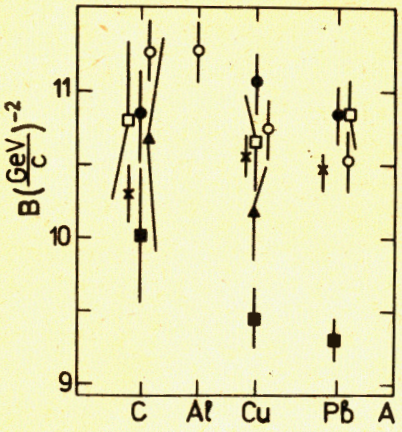


Fig.5. The slope parameter B vs the atomic number of the target nucleus. 1) The present paper: ■ and □ – for the angular intervals $120° \leq \theta \leq 160°$ and $155° \leq \theta \leq 175°$, respectively, at P > 0.3 GeV/c; ▲ – for the interval $120° \leq \theta \leq 160°$, P > 0.48 GeV/c. 2) Data of Ref.[4]: × – for the reaction $\pi^- A \to p_\downarrow X$ at P = 5 GeV/c; ● – for the reaction $pA \to p_\downarrow X$ at P_p = 8.5 GeV/c. 3) ○ – data of Ref.[5] for the reaction $pA \to p_\downarrow X$ at P_p = 8.9 GeV/c.

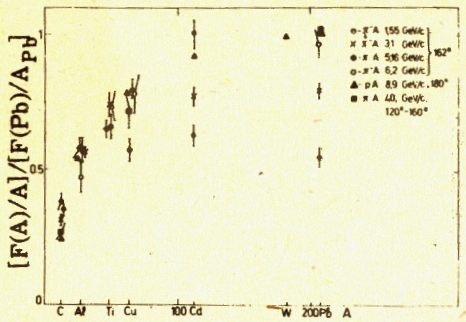


Fig.6. Invariant cross sections, normalised to the nucleon, plotted against the atomic number. Data for π^- mesons (P = =1.55 ÷ 6.2 GeV/c) are normalised to the cross section on lead at P = 5.1 GeV/c.

About 40000 stereopictures were scanned and then measured at the SAMET and AELT-2/160 devices. A special version of the programme-system MIS [3], earlier used to study coherent production of π^- mesons on nuclei, was made to analyse the results of measurements.

The invariant differential cross sections for reaction (2) $F = \frac{E}{P^2} \cdot \frac{d^2\sigma}{dPd\Omega}$, where E and P are the total energy and the momentum of the proton, respectively, were obtained by subtracting the spectra of negative particles from the spectra of positive particles with allowance for corrections for the geometrical efficiency and ionization losses. The invariant cross sections normalised to σ_{abs} are shown in Fig.4.

The slope parameters B obtained from parametrisation of the invariant cross sections

$$\frac{1}{\sigma_{abs}} \cdot \frac{E}{P} \cdot \frac{d^2\sigma}{dPd\Omega} = C \cdot \exp(-BP^2)$$

are shown in Fig.5 as a function of the target atomic number. Values of the slope parameters B [4,5], obtained at other momenta of projectile particles in reactions (2) and $p + A \to p_\downarrow + X$ (3), are shown in the same figure for comparison. One can see that B is almost independent of the atomic number of a target nucleus, but depends on the proton emission angle θ (increases with the increasing θ).

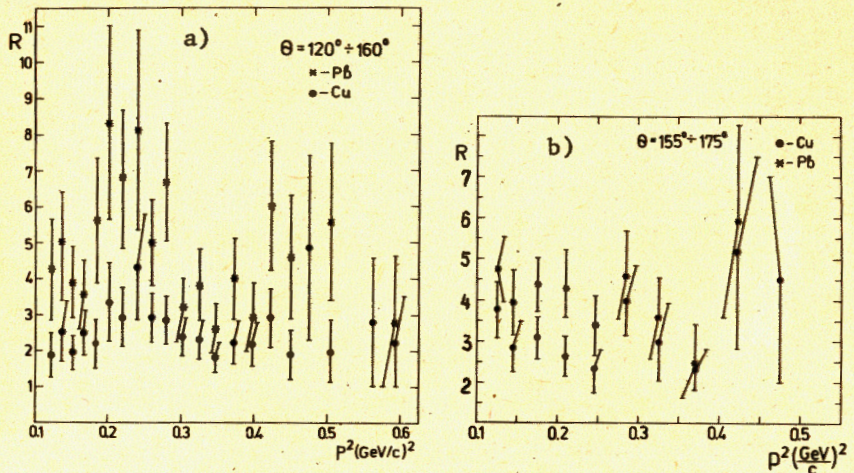


Fig.7. Dependence of a) $R = (F_A/A)/(F_C/A_C)$ and b) $n = \ln(F_A/F_C)/\ln(A/A_C)$ on the square momentum of protons emitted to the backward hemisphere for the reaction $\pi^- A \to p_\downarrow X$.

A-dependences of the invariant cross sections normalised to the nucleon $\frac{F}{A} = \frac{1}{A} \cdot \frac{E}{P^2} \cdot \frac{d^2\sigma}{dPd\Omega}$ for reactions (2) and (3) are similar and vary weakly in a wide range of the π^--meson momenta from 5 to 40 GeV/c. This can be seen from Fig.6 where results from Refs. [6,7] are presented for comparison.

Comparison of dependence of quantities $R = (F_A/A)/(F_C/A_C)$ and $n = \ln(F_A/F_C)/\ln(A/A_C)$ on the proton momenta (Fig.2) with the invariant cross sections (Fig.4) allows a conclusion that there are, seemingly, irregularities in behaviour of the cross sections and these irregularities grow as the atomic number of the target nucleus becomes smaller.

Analysis of the obtained data allows the following conclusions for processes (1) and (2):

1. For reaction (1), inclusive distributions (normalized to the number of inelastic events) with production of negative pions in the fragmentation region of projectile particles is practically independent of the atomic number.

2. The slope parameter of the square momentum distribution for process (1) is $b = 5.2 \div 5.4$ and also does not show A-dependence.

3. The additive quark model describes satisfactorily our experimental data on the ratio of x_F-distributions of negative pions in the region near $x_F = 0.5$ for Cu and Al targets, but disagree with the experimental results for larger A.

4. For reaction (2) with proton emission to the backward hemisphere, the slope parameter B weakly depends on the atomic number of the target nucleus.

5. The slope parameter B depends on the proton emission angle θ and increases with the increasing θ.

6. A-dependences of the invariant cross-section normalized per nucleon for reactions (2) and (3) are similar and vary weakly in the momentum range of projectile π^--mesons from 5 to 40 GeV/c.

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Received by Publishing Department
on November 1, 1984.

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E1-84-703

Исследование инклюзивных процессов $\pi^- A \to \pi^- X$ и $\pi^- A \to P_{назад} X$ при 40 ГэВ/с

Проведено изучение инклюзивных процессов $\pi^- A \to \begin{cases} \pi^- X \\ P_{назад} X \end{cases}$ для ядер-мишеней: C, Al, Cu, Pb при 40 ГэВ/с. Для реакции $\pi^- A \to \pi^- X$ получены инклюзивные спектры отрицательных пионов в области $0,1 \leq x_F < 0,9$. Результаты сравниваются с предсказаниями аддитивной кварковой модели. Процесс $\pi^- A \to P_{назад} X$ исследован в области импульсов вторичных протонов 0,3 ÷ 1 ГэВ/с. Измерены инвариантные сечения вылета протонов в заднюю полусферу в интервале углов 120°–175°. Обсуждается зависимость инвариантного сечения этого процесса от атомного номера мишени.

Работа выполнена в Лаборатории ядерных проблем ОИЯИ.

Препринт Объединенного института ядерных исследований. Дубна 1984

Abrosimov A.T. et al.

E1-84-703

Investigation of Inclusive Processes $\pi^- A \to \pi^- X$ and $\pi^- A \to P_{backwards}$ at 40 GeV/c

The study of the inclusive processes $\pi^- A \to \begin{cases} \pi^- X \\ P_{backward} X \end{cases}$ is performed for nuclear targets: C, Al, Cu, Pb at 40 GeV/c. Inclusive spectra of negative pions are obtained in the region $0.1 \leq x_F \leq 0.9$. The results are compared with the quark model predictions. The process $\pi^- A \to P_{backward} X$ is studied in the 0.3÷1 GeV/c region of secondary protons. Invariant cross sections of proton flying out in the back hemisphere are measured for the 120°÷175° angle interval. The A-dependence of the invariant cross section for this process is discussed.

The investigation has been performed at the Laboratory of Nuclear Problems, JINR.

Preprint of the Joint Institute for Nuclear Research. Dubna 1984