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CHARGED PARTICLE MULTIPLICITIES IN 40 GeV/c HADRON-NUCLEUS INTERACTIONS WITH AND WITHOUT A HIGH $P_\perp$ TRIGGER

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E.G.Boos, A.M.Mosienko, N.A.Pokrovsky
Institute for High Energy Physics, Alma-Ata

G.Bohm, W.Friebel, U.Gensch, R.Leiste, A.Meyer, T.Naumann, D.Pose, H.Roloff, C.Spiering, A.-E.Schwindt
Institute for High Energy Physics, Berlin

E.Denes, L.Diosy, T.Gemesy, L.Jenik, J.Krasnovszky, Gy.Pinter, I.Wagner
Central Research Institute for Physics, Budapest

A.V.Bannikov, H.Barwolff, J.Böhm, A.Derlicki, W.Dominik, Ya.V.Grishkevich, I.Farago, B.A.Khomenko, N.N.Khovanskij, Z.V.Krumstein, Yu.P.Merekov, G.Nyitrai, V.I.Petrukhin, K.Piska, K.Safarik, H.-J.Schreiber, J.Sedlak, G.A.Shelkov, L.G.Tkachev, V.V.Tokmenin, L.S.Vertogradov, S.Vyskocil, S.Zellar
Joint Institute for Nuclear Research, Dubna

V.N.Salomatov
Institute of Physics and Technics, Dushanbe

T.Soukup, A.Valkarova, S.Valkar, P.Zavada
Institute of Physics and Nuclear Center of Charles University, Prague

V.Krysteva, V.N.Penev, A.I.Shklovskaja
Institute for Nuclear Research and Nuclear Energy, Sofia

L.L.Gabunia, E.Sh.Ioramishvili, A.B.Ivanova, A.K.Javrishvili, A.I.Kharchilava, T.A.Lomtadze, L.Sh.Mandjavidze, E.S.Mailjan, L.A.Razdolskaja, L.B.Shalamberidze, L.D.Tchikovani
Institute of Physics, Tbilisi

J.G[illegible], L.Ropelewski, J.Zakrzewski
Inst[illegible] of Experimental Physics Warsaw University, Warsa[illegible]

1. INTRODUCTION

The study of hadron-nucleus interactions may yield, in principle, information on the space-time development of the formation of produced hadrons not accessible by investigating hadron-hadron interactions. The data published so far, however, don't allow a unique interpretation. To discriminate between different models one needs data over a wide A-range, with various beam particles at various energies. In general, full phase space information is requested. On the other hand, there could be phase space regions where certain aspects of models are distinguished better than integrating over full phase space, for instance, regions with one of the secondary particles having a high transverse momentum.

In this paper, we report results on multiplicities of charged particles, produced from interactions of π^-, K^- and $\bar{p}$ on nuclei at 40 GeV/c.

The targets were mounted in the 5 m streamer chamber RISK. In contrast to counter experiments [1,2], this technique is characterized by a very good multitrack efficiency, nearly 4π solid angle coverage, slow particle identification by ionization and charge determination. Ranging from $A = 7$ to $A = 207$ the six nuclei in our experiment give a reasonable basis for the study of A-dependent effects. This is in favour to emulsion data which are based on mixtures of nuclei and to the published results of bubble and streamer chamber experiments [3-8], which use 2 nuclei at most. Most of the bubble chamber data are interactions on C and Ne which are rather close in their A-number.

In section 2, we present results obtained from π^-, K^-, $\bar{p}$ interactions on Li, C, S, Cu, CsI and Pb targets selected with a minimum bias trigger. (Experimental details as well as preliminary results on the π^-/K^- sample were published elswhere [9]).

In section 3 preliminary multiplicity data from π^- interactions on C, Cu, and Pb targets are reported, which are selected with a high $P_\perp$ trigger ($P_\perp \geq 1.5$ GeV/c).

2. MULTIPLICITY CHARACTERISTICS

2.1. KNO Scaling of Negative Particles

It is well-known that the multiplicity distribution of hadron-hadron interactions at high energies ($E \gtrsim 30$ GeV/c) can be described by

$$\langle n^- \rangle \sigma_n / \sigma_{inel} = \psi (n^- / \langle n^- \rangle),$$

where ψ is a universal function; it is independent of the beam energy or the nature of the incoming particle (KNO scaling /10/). In Fig.1 our multiplicity data for π^-, K^- and $\bar{p}$ nucleus interactions (with A ranging from 7 to 207) are shown. The superimposed curve which is the result of a fit to pp data in the Serpukhov and FNAL/SPS energy region describes reasonably well our data. That indicates that KNO scaling holds independent of the target mass up to the heaviest nuclei number. Similar results were also obtained in refs. /5,8,11/.

2.2. Average Number of Protons

In experiments with π^+ and π^- beams on Neon /6/ the average multiplicity of fast ($P \gtrsim 800$ MeV/c) protons was extracted and found to be rather high.

In our experiment protons with momenta ≤ 500 MeV/c were identified by ionization. To get a measure for the number of fast protons, we introduce the average charge contribution from the nucleus, Q , $Q = N^+ - N^- + 1$ for a negative beam. By subtraction of the number of identified protons from Q we get $Q_R = N^+ - N^- + 1 - N_p$, the relativistic nuclear charge contribution which should be dominated by the fast protons (In fact, our interpolated value Q_{Neon} agrees within 10% with the overall number of protons published for $\pi^\pm$Ne interactions).

The average number of identified protons, $\langle N_p \rangle$, behaves as A^α with $\alpha = (0.63 \pm 0.02)$, independent of the nature of the primary particle, whereas $\langle Q_R \rangle$ goes with $A^{0.40}$.

The high α-value for $\langle N_p \rangle$ indicates that the protons with $p \lesssim 500$ MeV/c are dominated by cascading. The A-dependence of Q_R is much weaker but still remarkably stronger than $A^{0.25}$ to $A^{0.30}$ (which would mean proportionality to $\bar{\nu}$). Consequently, even for fast protons cascading effects are not negligible.

In Fig.2 we present the dependence of $\langle Q \rangle$ and $\langle N_p \rangle$ on $\bar{\nu}$. For π^-A and K^-A interactions, $\langle Q \rangle$ respectively $\langle N_p \rangle$ are similar one to another whereas for $\bar{p}$A interactions both quantities increase weaker with $\bar{\nu}$. The difference may be due to the annihilation channels in the $\bar{p}$ case. Within the Glauber-Gribov model, the effective number of interactions within the nucleus

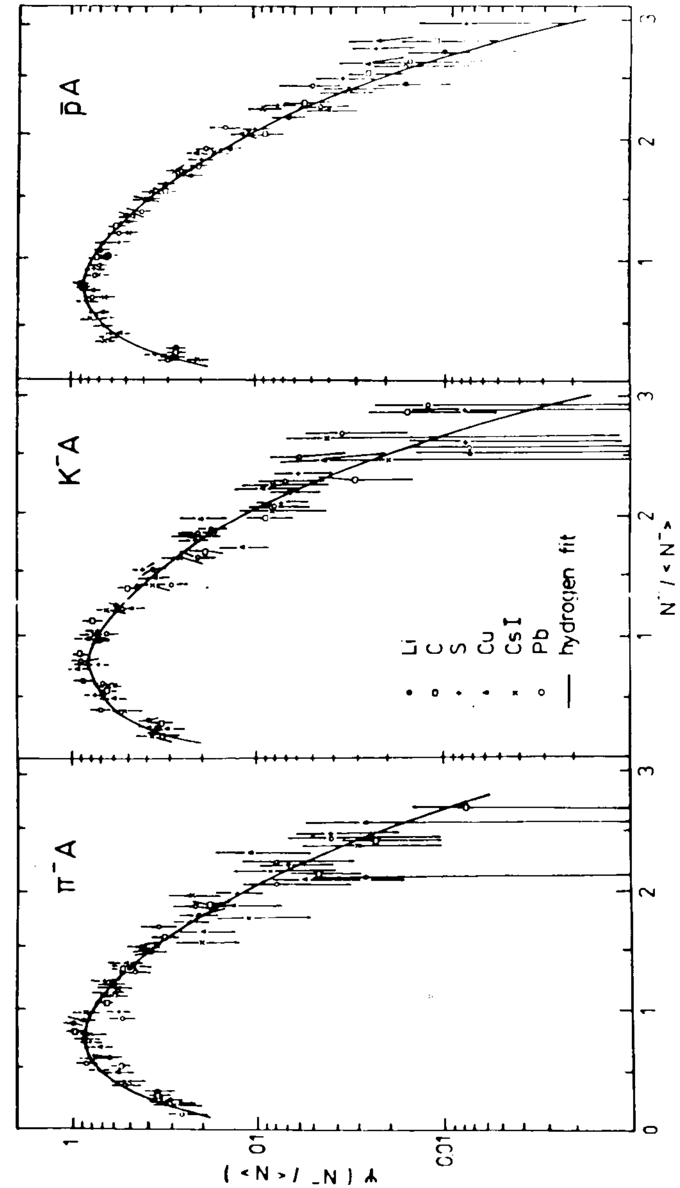

Fig.1. The KNO scaling distribution of negative particles for π^-A, K^-A and $\bar{p}$A interactions.

is determined as the ratio $\bar{\nu}_{eff} = \bar{\nu}/\bar{\nu}_a$ [14], where $\bar{\nu}_a = A\sigma^a_{\bar{p}p}/\sigma^a_{\bar{p}A}$ is the correction for the annihilation channels. The ratio of the annihilation and the inelastic cross sections, $\sigma^a_{\bar{p}A}/\sigma^{inel}_{\bar{p}p}$ calculated within the Glauber-Gribov model (with $\sigma^a_{\bar{p}p}$ = 5.6 mb taken as the difference of $\bar{p}p$ and pp cross sections at 40 GeV/c [12]), is shown in the following table.

Table

A	H	Li	C	S	Cu	Cs I	Pb
$\sigma^a_{\bar{p}A}/\sigma^{inel}_{\bar{p}A}$	0.15	0.21	0.24	0.30	0.35	0.40	0.44
$\bar{\nu}_{eff}$	1.0	1.4	1.6	2.0	2.5	2.7	3.0

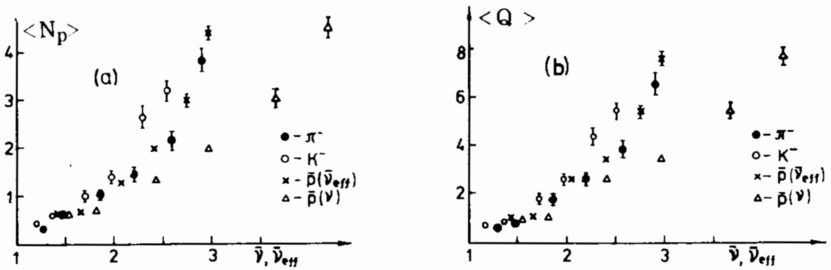

Fig.2. The average multiplicities of indentified protons $\langle N_p \rangle$ and of fast protons approximated by $\langle Q \rangle$ as functions of $\bar{\nu}$ ($\bar{\nu}_{eff}$).

As can be seen, the annihilation part of the inelastic cross section increases with the target mass. Therefore, $\langle Q \rangle$ and $\langle N_p \rangle$ for $\bar{p}A$ interactions should be presented as functions of $\bar{\nu}_{eff}$ instead of $\bar{\nu}$. As is seen in Fig.2, the $\bar{p}$ data fall on the same curve as the π^- data when plotted versus $\bar{\nu}_{eff}$.

2.3. Normalized Multiplicities of Negatively Charged Secondaries

In an earlier publication [9], we observed the unique behaviour of the normalized multiplicity of negative particles produced in π^-A and K^-A interactions, $R^- = \langle n^-_{hA}\rangle/\langle n^-_{hp}\rangle$, when plotted versus $\bar{\nu}$. As one can see from Fig.3 the antiproton data show a similar behaviour as the π^-, K^- data, however, with some deviations at large $\bar{\nu}$. This holds for plotting R^- versus $\bar{\nu}$ as well as versus $\bar{\nu}_{eff}$. The increase of $R^-(\bar{p})$ compared with $R^-(\pi^-, K^-)$

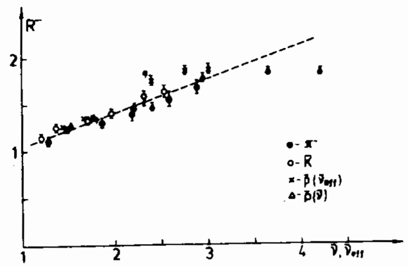

Fig.3. The normalized negative multiplicity $R^- = \langle n^-(hA)\rangle/\langle n^-(hp)\rangle$ as a function of $\bar{\nu}$ and $\bar{\nu}_{eff}$. The straight line shown was obtained by fitting the π^-, K^- data with the parametrization $R = a + b\bar{\nu}$.

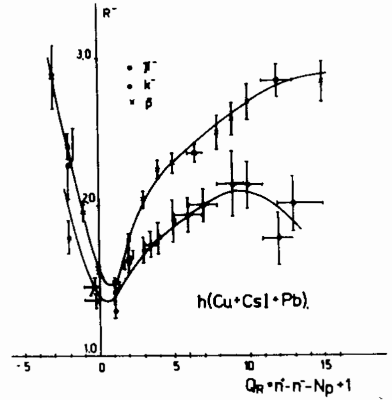

Fig.4. The normalized negative multiplicity R^- as a function of $Q_R = n^+ - n^- - N_p + 1$.

at large $\bar{\nu}_{eff}$ eventually may be explained by the stronger contribution of annihilation channels for the heavier nuclei and by the higher mean multiplicity in annihilation processes.

In fig.4 for h^-(Cu + CsI + Pb) events R^- is shown as a function of $Q_R = N^+ - N^- + 1 - N_p$. The curves shown are to guide the eye. Obviously, the $\bar{p}$ -data give higher R^--values as the π^-/K^- data. For high Q_R, R^- approaches ~ 2 in the meson case and ~ 3 for antiprotons. This is in qualitative agreement with the predictions of the additive quark model AQM [13]. So, for $Q_R \geq \bar{\nu}$, Q_R seems to be suited to measure, at least indirectly, the number of collisions in individual events.

3. MULTIPLICITIES FOR π^-A EVENTS HAVING A SECONDARY PARTICLE WITH $P_\perp \geq 1.5$ GeV/c

For this part of the experiment we used C, Cu, and Pb targets with thickness of ~ 0.7% nuclear absorbtion lengths. The target was mounted near the entrance window in the streamer chamber. The high $P_\perp$ trigger was formed by two proportional chambers (1.0x0.5 m^2 each) with two-dimensional readout. The chambers were positioned in the magnetic field above the streamer chamber covering for emitted particles from the target an angle interval of $12° < \theta < 17°$ in the lab.system or $85° < \theta^* < 135°$ in the

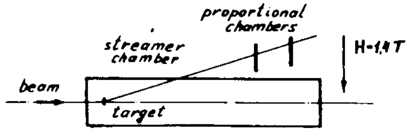

Fig.5. Sketch of the $P_\perp$ trigger configuration.

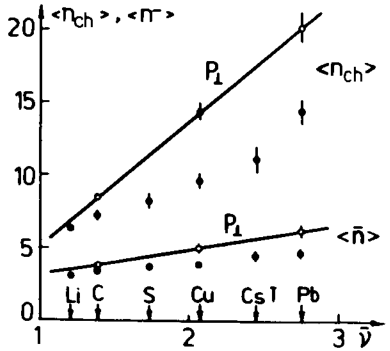

Fig.6. The average multiplicity of all charged particles and of the negative particles, $\langle n_{ch} \rangle$ and $\langle n^- \rangle$, as functions on $\bar{\nu}$. Full circles: minimum bias events. Open circles: $P_\perp$ events.

CMS. (See Fig.5). The chambers measure the coordinates y_1 and y_2 transverse to beam and magnetic field. A trigger matrix in (y_1, y_2) selects positively and negatively charged particles with $P_\perp > P_\perp$ (threshold). The threshold in $P_\perp$ was variable, ranging from 1 to 1.5 GeV/c. For $P_\perp \geq 1.5$ GeV/c the efficiency was 5-6%.

Here we present preliminary data for $P_\perp \geq 1.5$ GeV/c. Figure 6 shows the $\bar{\nu}$ -dependence of the charged multiplicity $\langle n_{ch} \rangle$ and the multiplicity of the negative particles $\langle n^- \rangle$ for normal events and for $P_\perp$ -events. The comparison of the $P_\perp$ events with the normal events reveals that more particles are produced in high $P_\perp$ interactions and that this difference grows with $\bar{\nu}$. For negatively charged particles the excess in the $P_\perp$ -data compared to the normal events (minimum bias) grows up to ~ 1.5 units only for Pb. The main contribution of charged multiplicity excess is due to positive particles. The behaviour of the protons is illustrated in Figs. 7 and 8 which show the ν -dependence of $\langle Q_R \rangle = \langle n^+ - n^- + 1 - N_p \rangle$ (as defined in sect. 2.2) and of the mean number of identified protons $\langle N_p \rangle$. As for the negative tracks, the number of fast and slow protons turns out to be higher in $P_\perp$ events than in minimum bias events. The multiplicity excess of the protons strongly grows with increasing target mass.

The data are still too raw to draw definite conclusions or even to discriminate between models. On the other hand, there should be no difficulties to explain the $P_\perp$ multiplicities as due to multiple scattering giving rise for a high $P_\perp$ track.

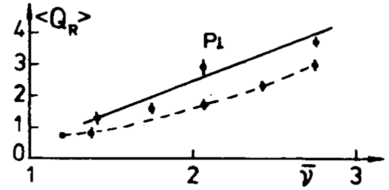

Fig.7. The average multiplicity of fast protons approximated by $\langle Q_R \rangle$ as a function of $\bar{\nu}$. Full circles: minimum bias events. Open circles: $P_\perp$ events.

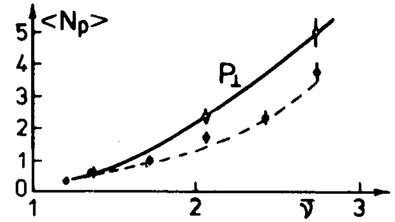

Fig.8. The average multiplicity of identified protons as a function of $\bar{\nu}$. Full circles: minimum bias events. Open circles: $P_\perp$ events.

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Боос Э.Г. и др. E1-83-449

Множественное рождение адронов в адрон-ядерных взаимодействиях при 40 ГэВ в неупругих взаимодействиях и в событиях с $P_{\perp} \approx 1{,}0-2{,}0$ ГэВ/с

Исследовалось множественное рождение адронов в π^-, K^-, $\bar{p}$ - ядро взаимодействиях при импульсе $P = 40$ ГэВ/с. Чистые ядерные мишени Li, C, S, Cu, CsI, Pb помещались внутри чувствительного объема пятиметровой стримерной камеры РИСК. Показана справедливость КНО-скейлинга, в том числе и для тяжелых ядер. Определен вклад взаимодействий налетающей частицы с группой нуклонов mN ядра. Во взаимодействиях π -ядро с триггерной частицей обоего знака, имеющей $P_{\perp}$ в интервале 1-2 ГэВ/с, $\theta^* \approx 90^{\circ}$, определена множественность, которая оказалась существенно выше, чем в обычных неупругих взаимодействиях.

Работа выполнена в Лаборатории ядерных проблем ОИЯИ.

Препринт Объединенного института ядерных исследований. Дубна 1983

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Charged Particle Multiplicities in 40 GeV/c Hadron-Nucleus Interactions with and without a High $P_{\perp}$ Trigger

Interactions of 40 GeV/c negative pions, kaons and antiprotons with nuclei of Li, C, S, Cu, CsI, and Pb were investigated. The nuclear targets were placed in the visible volume of the 5-meter streamer chamber RISK. KNO scaling holds for all nuclei including the heaviest. Searching for a measure of ν, the number of collisions, we found the relativistic net charge to be best suited to separate events with definite ν. Events with a charged particle produced in the transverse momentum range $P_{\perp} \approx 1.5-2.0$ GeV/c at $\theta^* \approx 85-135$ were selected. Their charged particle multiplicity is significantly higher than that for normal soft hadron-nuclei interactions.

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

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