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CHARGED PARTICLE MULTIPLICITIES IN π^--AND K^--MESON INTERACTIONS WITH NUCLEI IN A STREAMER CHAMBER AT 40 GeV/c

RISK-Collaboration

(Berlin-Budapest-Dubna-Prague-Sofia-Tbilisi-Warsaw)

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Submitted to ЯФ

An investigation of high energy particle collisions with nuclei is expected to yield information on the mechanism of the elementary interaction [1]. It is important here to obtain experimental data based on a large number of target nuclei, including the heaviest ones, for different types of incident particles, with information on the reaction products being as complete as possible. Until recently, the multiple production of particles in hadron-nucleus interaction has been studied mainly with nuclear emulsions and bubble chambers. These methods have not only some advantages, such as precise localization of an interaction vertex, high spatial resolution and low threshold for detection of low-energy secondary particles, but also some limitations. Among them, there is the restriction to some target nuclei only and the low rate of the event collection. The results obtained in the experiments with spark chambers and scintillation counters are of greater statistical significance [2-4]. In these cases, however, the charges and the momenta of secondary particles are not determined and it is necessary to introduce corrections, sometimes with the use of theoretical models.

In this paper, results are presented on the interactions of π^--mesons and K^--mesons of 40 GeV/c momentum with pure nuclear targets placed in the streamer chamber of the JINR magnetic spectrometer RISK. The detection of events with such a set-up makes it possible to define the charges and momenta of secondary particles. Also, one can work with a non-separated beam of particles impinging simultaneously on several targets under the conditions of a near 4π-geometry. These targets can be made 2 to 4 times thinner than those used in other electronic experiments, ensuring low values of corrections for secondary effects.

1. EXPERIMENTAL SET-UP

The main part of the RISK spectrometer was a large three-gap streamer chamber (4.7x0.9x0.8) m^3 [5], placed inside a magnetic field of about 1.5 T (Fig.1). A high-voltage pulse with an amplitude of ±400 kV and duration of ~20 ns was produced and formed with a bipolar Marx generator and a Blumlein line [6].

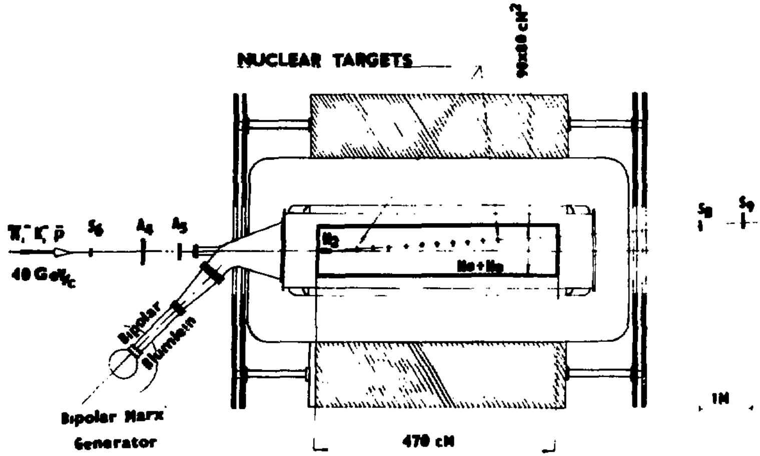
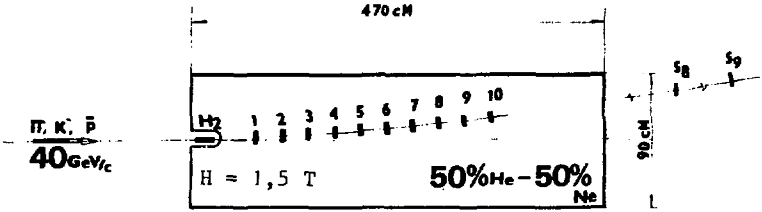


Fig.1. Location of the streamer chamber in the magnet SP-136. S_6, A_4, A_5, S_8, S_9 - scintillation counters.

The chamber was filled with a gas mixture consisting of 50% Ne and 50% He at atmospheric pressure. A memory time of 1-2 μs was achieved through a small admixture of SF_6. The sensitive volume of the chamber was viewed by 8 objectives (4 stereo pairs), each equipped with two-stage image intensifiers, and registered onto 4 films /7/. Besides, the events registered by the streamer chamber were directly controlled visually by means of a television monitor. The operation mode of the spectrometer main systems was controlled with a microprocessor system MICAM /8/ which had a direct access to the CAMAC dataway and was connected to the ES 1040 /9/ interface.

The chamber was exposed to an unseparated beam of negative particles with a mean momentum of 40 GeV/c and a spread of $\Delta P/P \sim 1.5\%$. The decomposition of the beam into π^-, K^-, $\bar{p}$ was 100:1.8:0.3. A beam telescope consisting of 6 scintillation counters and 4 threshold Cherenkov counters identified any incoming particle. The admixture of π^--mesons for the K^--meson trigger was about 1%. The transverse dimensions of the beam in the chamber region were (2x1.5) cm^2 and the beam angular dispersion was $\sim$2 mrad.

Eleven targets were placed in the visible volume of the chamber (Fig.2). The total thickness of all targets corresponded approximately to 8.3% of the π-meson absorption length.El-



	LIQUID HYDROGEN	NUCLEAR TARGETS									
N° of TARGET		1	2	3	4	5	6	7	8	9	10
MATERIAL	H_2	C	Pb	S	Li	Pb	CH_2	Cu	C	CsI	C
THICKNESS /MM/	198	6,87	0,90	7,20	17,01	0,48	9,65	0,98	7,04	3,38	3,12

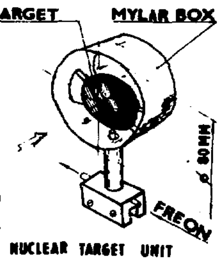


Fig.2. Construction of a nuclear target unit, thicknesses and location of the targets in the streamer chamber.

liptic nuclear targets were mounted inside mylar cylinder boxes through which a flow of freon-12 was maintained. The distance between the targets was 30 cm.

A scintillator telescope consisting of two counters $S_8 S_9$ and placed behind the chamber vetoed non-interacting beam particles as well as negative secondary particles with $|t| \lesssim 0.05\ (GeV/c)^2$. Such a set-up rejected most of the elastic peak, whereas only about 3% of the inelastic events were lost [11].

2. ANALYSIS

In this paper we present results obtained for two samples of 2200 π^--meson-nucleus and 1400 K^--meson-nucleus interactions. For each event, the total number of charged particles, n_{ch}, and the number of all positively and negatively charged particles, n^+ and n^-, respectively, were determined. Due to optical distortions of the image intensifiers, we had to use special templates for an estimation of the charge sign of very fast particles. These templates had been prepared through photographing the fiducial grid located over the streamer chamber. We recorded also, by means of a corresponding template, the number of fast charged particles with momenta $\gtrsim$500 MeV/c, n_F^+ and n_F^-, respectively. The validity of our results was tested by a comparison with the results from geometrical reconstruction of 100 measured events. We failed to define the sign of the charge by means of the template for 2% of particles. The charge sign for them was assigned randomly with equal probability. The average number of primary tracks for one frame turned out to be 1.3. In rare cases, one could observe interactions of more than one primary in a frame. For K^--meson interactions such frames were rejected.

Low energy δ -electrons with a kinetic energy of $\lesssim$5 MeV look like straight tracks following the direction of the magnetic field. They are observed in 5% of events and can be easily recognized among the short tracks of heavier particles which usually have some curvature and can take any direction. The positive and negative electrons, e^+ and e^-, of $\lesssim$60 MeV/c were identified at a scanning stage by their ionization. Their number turned out to be less than 0.5% of the total number of charged particles.

The average multiplicity values were corrected for e^+e^- pairs from π^0-decays, secondary interactions of charged particles within the target, and V^0 decaying close to the interaction point. Since the targets were thin, the corrections appeared to be small, e.g., the corrections in the average total multiplicities for the C and Pb targets are approximately ~4% and ~8%, respectively.

We have excluded from our data 0-prong and 1-prong events. Both topologies have rather low detection efficiency. The 1-prong-sample is contaminated by elastic events and Coulomb scattered beam tracks. A contribution from the coherent nuclear production events, not rejected by the trigger, has been excluded on the basis of the analysis of the multiplicity distribution of the total number of charged particles and the comparison with the cross sections from ref. [10].

By Monte-Carlo calculations we have found that, averaged over all targets, about 95% of all protons with momenta less than 180 MeV/c do not leave the targets, i.e., most of the evaporation products stop within the targets. We have not made a correction for the high momentum tail of evaporation products, which contaminates the sample of slow positive tracks.

3. RESULTS

In figs.3 and 4, we show, respectively, the average multiplicities of all charged particles, $\langle n_{ch} \rangle$, and of negatively charged particles, $\langle n^- \rangle$, as a function of a $\bar{\nu}$ parameter. This parameter, defined as the mean number of inelastic collisions of the incident hadron within a nucleus is given by $\bar{\nu} = A\sigma_{hp}/\sigma_{hA}$; where σ_{hp} (σ_{hA}) is the absorption cross section of hadron h on hydrogen (nucleus A). For calculations, we have taken the parametrization given by Denisov et al., $\bar{\nu} \sim A^{0.246}$ /11/ and the inelastic $\pi^-(K^-)$-meson cross sections are taken from the HERA compilations /12/.

The errors given in these figures are purely statistical. Possible systematical errors related to the target location in the chamber, to the number of flares in events with a high multiplicity and to picture quality have been estimated to be smaller than 10%.

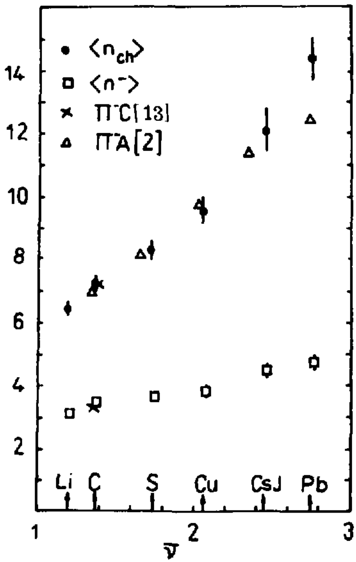


Fig.3. Mean multiplicities of charged and negatively charged particles, $\langle n_{ch} \rangle$ and $\langle n^- \rangle$, as a function of $\bar{\nu}$ for π^--meson-nucleus interactions at 40 GeV/c.

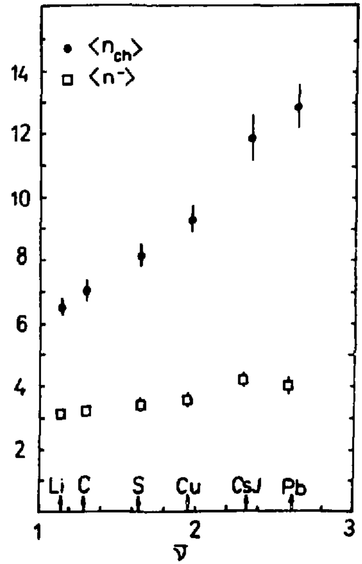


Fig.4. Mean multiplicities of charged and negatively charged particles, $\langle n_{ch} \rangle$ and $\langle n^- \rangle$, as a function of $\bar{\nu}$ for K^--meson-nucleus interactions at 40 GeV/c.

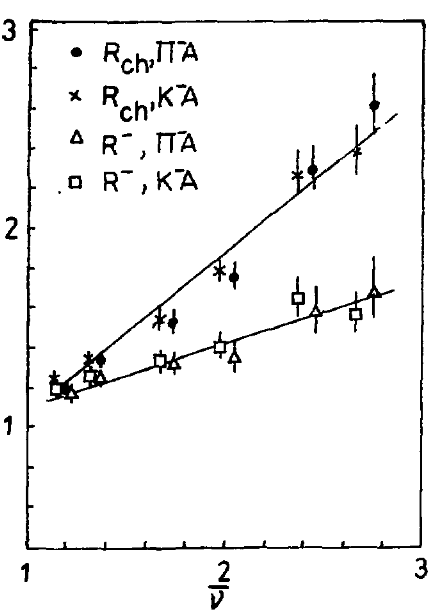


Fig.5. Normalized multiplicity distributions of charged and negatively charged particles, R_{ch} and R^-, as a function of $\overline{\nu}$.

Our π^--meson data agree well with the π^--carbon results from the propane bubble chamber experiment at 40 GeV/c [13]. Furthermore, they fit the interpolation between neon-hydrogen bubble chamber experiments at 30 and 50 GeV/c, respectively [14,15]. With the exception of the Pb nucleus, our data coincide within the errors with the data from a scintillation counter experiment at 37.5 GeV/c [2]. Due to the lack of other data no comparison is possible for our K^--meson results.

Fig.5 shows for both π^-A and K^-A collisions the dependence on the $\overline{\nu}$ parameter of the normalized multiplicities $R^- = \langle n^-\rangle_A/\langle n^-\rangle_p$ and $R^{ch} = \langle n_{ch}\rangle_A/\langle n_{ch}\rangle_p$. The linear fit corresponds to $R^- = (0.78\pm0.06)+(0.32\pm0.04)\overline{\nu}$ and $R^{ch} = (0.78\pm0.10)+(0.85\pm0.06)\overline{\nu}$.

In figs.3-4 one recognizes the big difference between the behaviour of $\langle n_{ch}\rangle$ and $\langle n^-\rangle$. While $\langle n_{ch}\rangle$ increases by a factor of about 2.5 when going from hydrogen to lead, $\langle n^-\rangle$ only grows by a factor of 1.6. Moreover, the slope of R^- vs. $\overline{\nu}$ is remarkably smaller than that of R^s vs. $\overline{\nu}$ for shower particles with $\beta \geq 0.85$, 0.062 ± 0.01, produced in π^-, K^+, p and $\bar{p}$ interactions with nuclei at 50 GeV/c [14]. On the other hand, the slope for R^{ch} is much higher than that for R^s.

In fig.6 we show the difference of the mean values of the numbers of fast positively and negatively charged particles, $\langle n_F^+\rangle - \langle n_F^-\rangle$, produced in π^-A and K^-A interactions, as a function of $\overline{\nu}$. The term $(1-Z/A)$, added to $\langle n_F^+\rangle - \langle n_F^-\rangle$ takes into account the number of protons and neutrons in the nucleus*. The

*For scattering on neutrons one has a trivial charge difference $n^+ - n^- = -1$.

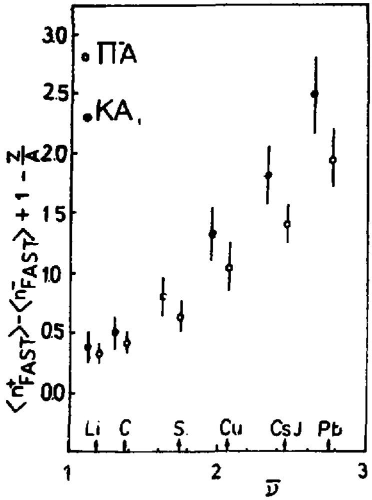


Fig.6. $\bar{\nu}$-dependence of the difference between mean multiplicities of fast (P ≥500 MeV/c) positively and negatively charged particles in π^-,K^--nucleus interactions at 40 GeV/c. Shown is the sum of $(\langle n^+_F\rangle - \langle n^-_F\rangle)$ and a correction factor $(1-Z/A)$, accounting for the excess of neutrons in nuclei.

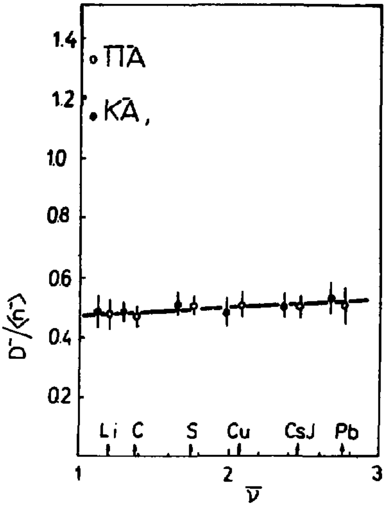


Fig.7. $D^-/\langle n^-\rangle$ for negatively charged particles as a function of $\bar{\nu}$ for π^-, K^--nucleus interactions at 40 GeV/c.

faster growth with the $\bar{\nu}$-parameter of $\langle n^+_F\rangle$ as compared to $\langle n^-_F\rangle$ is apparent. The excess of positive fast particles, reaching the value of about 2 for lead, is approximately equal to ~1/3 the number of protons produced with momenta P ≤ 500 MeV/c (see Figs.3 and 4).

Finally, in fig.7 we present the ratio of the dispersion $D = \sqrt{\langle (n^-)^2\rangle - \langle n^-\rangle^2}$ and the mean value of the multiplicity distribution, $\langle n^-\rangle$, for negatively charged particles produced in π^-A and K^-A collisions, respectively. The dependence of $D^-/\langle n^-\rangle$ on the $\bar{\nu}$-parameter can be approximated as $D^-/\langle n^-\rangle = (0.49\pm0.03) + (0.03\pm0.01)(\bar{\nu}-1)$ which points out to the independence of $D^-/\langle n^-\rangle$ ratio on the target mass. Our data are consistent with the approximation of $D^- = (0.53\pm0.02)\langle n^-\rangle - (0.05\pm0.03)$ obtained for π^-C and π^-Ne bubble chamber data in the energy interval from 4 to 50 GeV [15].

4. CONCLUSIONS

The study of the multiparticle production in meson-nucleus interactions shows that the growth of the charged particle multiplicity with the mass of a nucleus is predominantly achieved by positively charged particles. Even at momenta $p > 500$ MeV/c there is an excess of positive particles, presumably protons, compared to the negative ones. The average number of these excess particles is equal to $\sim 1/3$ of the number of protons leaving the nucleus with momenta $P \lesssim 500$ MeV/c.

The mean number of negatively charged particles, contrary to the positive ones, grows slowly with an increasing atomic number, $\langle n^- \rangle \sim A^{0.10}$, $\langle n^+ \rangle \sim A^{0.24}$.

The ratio $D^-/\langle n^- \rangle$ in π-meson and K^--meson nucleus collisions is nearly independent of the $\bar{\nu}$-parameter.

As a continuation of this work we are analyzing $\bar{p}A$ data. They will be presented later together with enriched π^-A and K^-A samples.

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