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CHARGED PARTICLE SPECTRA IN $\pi^- p$, $\pi^- d$ AND $\pi^- C$ INTERACTIONS AT 38 GeV/c WITH SINGLE-PARTICLE HIGH P_T TRIGGER

RISK Collaboration

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Interactions of 38 GeV/c negative pions with hydrogen, deuterium and carbon nuclei were studied with 5m streamer chamber placed in magnetic field (RISK spectrometer[1,2]). The trigger electronics selected the events with at least one charged particle with transverse momentum higher than preset threshold ($\gtrsim$ 1.0 GeV/c) and polar angle between 12° and 22° (85°- 120° in pion-nucleon center of mass system) covered by the multi-wire proportional chamber telescope (fig. 1). More detailed description of the spectrometer and trigger can be found elsewhere[3,4].

Following preliminary results are based on the geometrical reconstruction (determination of the momenta and production angles of the charged secondaries) of 1407 ^{2}H-events, 862 ^{2}D-events and 2325 ^{12}C-events with transverse momentum of trigger particle higher than 1 GeV/c.

The charged particle multiplicities of studied events are higher than those of the normal (without trigger) inelastic ones (table I). On the other hand, the fraction of total momentum carried by the neutral secondaries in studied events does not depend on target nuclei and is equal to 0.40 ± 0.01. This value is close to the neutral particle inelasticity in normal π^-p and π^-C interactions[5,6] which is 0.36 ± 0.01. The average rapidities of the secondary particles are lower and widths of rapidity distributions are narrower than corresponding values for normal events (table II). In table III the average transverse momenta of charged secondaries associated to the high p_T trigger particle are shown. One can see that for all targets the average transverse momentum of secondaries with charge opposite to the trigger particle's one is greater than in the case of like charges. This is more pronounced for π^-p and π^-d interactions, for π^-C interactions the difference in the transverse momenta decreases and in π^-Pb interactions[3] the difference disappears at all. At the same time, average transverse momenta of the secondaries with the same charge as one of the trigger particle are close to the values obtained for normal π^--nucleus interactions.

Table I. Average multiplicities of negative charged particles

π^-p		π^-n		π^-C	
$p_T>1.0$ GeV/c	all /5/	$p_T>1.0$ GeV/c from π^-d	all /5/	$p_T>1.0$ GeV/c	all /6/
3.46±0.08	2.81±0.02	4.02±0.09	3.04±0.03	4.13±0.06	3.16±0.03

Table II. Mean rapidities $\langle y_{lab}\rangle$ of charged particles

		π^-		π^+	
		$\langle y_{Lab}\rangle$	σ_y	$\langle y_{Lab}\rangle$	σ_y
π^-p	$p_T>1.0$ GeV/c	2.39±0.02	1.04	2.16±0.02	0.95
π^-d	$p_T>1.0$ GeV/c	2.34±0.02	1.04	2.11±0.03	1.00
π^-C	$p_T>1.0$ GeV/c	2.01±0.01	1.10	1.65±0.01	1.06
	all /6/	2.46±0.01	1.75	2.05±0.01	1.45

Table III. Mean transverse momenta of charged particles associated to the trigger particle with $p_T>1.0$ GeV/c

nucleus		$p_T>1.0$ GeV/c		"normal" /5,6/	
	trigger	π^+	π^-	π^+	π^-
H	+	0.379±0.007	0.381±0.006	0.384±0.002	0.367±0.002
	-	0.419±0.012	0.359±0.011		
D	+	0.364±0.008	0.384±0.007	0.362±0.008	0.344±0.006
	-	0.404±0.013	0.348±0.012	(π^-n - interactions)	
C	+	0.365±0.004	0.354±0.004	0.378±0.001	0.354±0.001
	-	0.389±0.005	0.349±0.005		
Pb /3/	+	0.360±0.003	0.302±0.004		
	-	0.364±0.005	0.293±0.007		

The transverse momentum distributions of associated charged socondaries can be reasonably fitted in the region $p_T>0.4$ GeV/c to the exponential behaviour $dN/dp_T \sim e^{-B\cdot p_T}$ (table IV). The slopes B obtained for negative charged particles are systematically higher than those obtained for positive charged ones and they tend to increase with atomic weight. This is in agreement with behaviour of the mean transverse momenta of the associated particles, averaged over both signs of trigger particle's charge. On the other side the slopes of the exponents fitted to the high-momentum ($p_T>1.4$ GeV/c) part of trigger particle's p_T-spectra have an opposite tendency, they decrease from hydrogen to lead.

In the azimuthal plane (perpendicular to the beam direction) the associated particles are produced mainly in the direction opposite to the trigger particle's one (fig. 2) and this effect is more pronounced for associated particles with higher transverse momenta ($p_T>0.6$ GeV/c). The asymmetry for the carbon target is smaller than for the hydrogen and deuterium ones. The asymmetry increases for "quasi-free" interactions on carbon (the net charge of event = 0 or = -1) but also in this case it is lower than the asymmetry in π^-p and π^-d events. Corresponding values of the asymmetry coefficients

$$A = \frac{N(\phi>\pi/2) - N(\phi<\pi/2)}{N(\phi>\pi/2) + N(\phi<\pi/2)}$$

(ϕ - the azimuthal angle between associated and trigger particles) are shown in table V. There is cited also the result obtained for π^-p events at 40 GeV/c in the propane bubble chamber, with at least one charged secondary of transverse momentum higher than 0.8 GeV/c. No discrepancies are seen between the bubble chamber data and ours

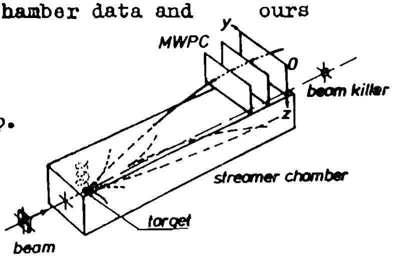

Fig.1. Experimental set-up.

if one takes into account the different kinematical regions of trigger particles and the contamination of "quasi-free π^-p" events on carbon in propane.

Table IV. Slopes B of transverse momentum distributions ($dN/dp_T \sim e^{-B \cdot p_T}$)

		$p_T > 0.4$ GeV/c	"trigger" $p_T > 1.4$ GeV/c
nucleus	charge	B	B
H	+	3.49±0.14	4.23±0.32
	-	3.77±0.14	
D	+	3.62±0.21	4.13±0.39
	-	3.71±0.17	
C	+	3.84±0.02	4.01±0.13
	-	4.07±0.09	
Pb [3]	+	3.79±0.17	3.20±0.24
	-	3.94±0.13	

Table V. Asymmetry coefficients A of azimuthal angle distributions for associated particles

nucleus	H	D	C	$C_{Q=0,-1}$	π^-p [7] propane
all particles	0.29±0.02	0.27±0.02	0.17±0.01	0.21±0.01	0.24±0.01
$p_T > 0.6$ GeV/c for associated particles	0.66±0.03	0.64±0.04		0.48±0.02	

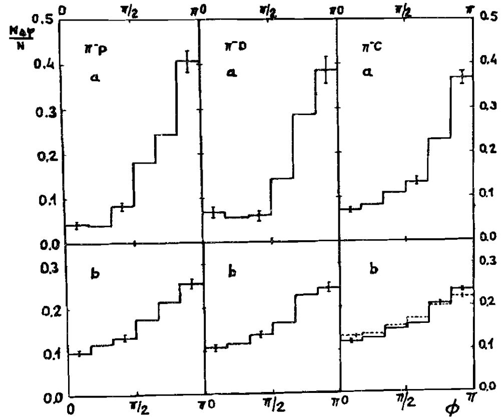

Fig.2. Distributions of associated particles in azimuthal angle between them and triggering particle (averaged over the signs of associated and trigger particle's charge): a - event with net charge = 0,-1, associated $p_T >$ 0,6 GeV/c, b - events with net charge = 0,-1 (dashed line - all events in π^-C interactions).

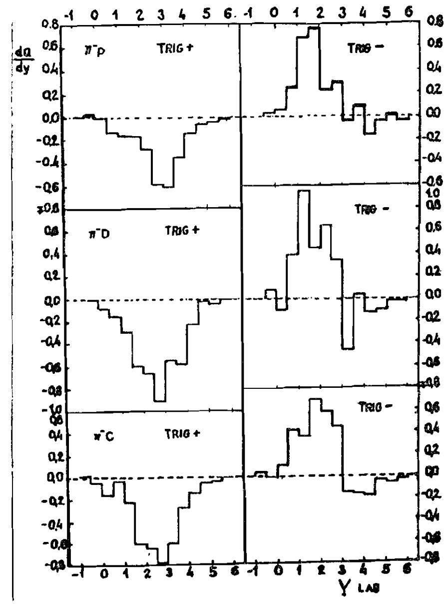

Fig.3. Mean net charge of associated particles versus rapidity in laboratory frame (rapidity of c.m.s. = 2.2)

The azimuthal distributions of associated particles for particular nuclear target do not depend within the statistical errors on the sign of either trigger or associated particle's charges. Therefore in fig. 2 the net distributions for both charges of trigger and associated particles are demonstrated. Nevertheless the mean net charge of the associated particles in events is not uniformly distributed and depends on the particular rapidity interval and on the sign of trigger particle's charge. In fig. 3 the dependence of mean charge of associated secondaries on their rapidity is shown. One can see that the charge of trigger particle is compensated mainly in the central rapidity region ($y_{LAB} \sim 1 \div 3$).

In table VI, it is shown, how the mean charge of associated particles is distributed with respect to the direction of trigger particle in different rapidity intervals. The mean charges of associated secondaries produced in the central rapidity region ($|\Delta y = y - y_{TRIG}| < 1$) towards the trigger particle in azimuth ($\langle Q_{TW} \rangle$) and away from it ($\langle Q_{AW} \rangle$) and the mean charges in the beam ($\Delta y > 1$) and target ($\Delta y < -1$) fragmentation regions ($\langle Q_{BEAM} \rangle$ and $\langle Q_{TARG} \rangle$ respectively) are presented and also the mean charge in the "trigger jet" $\langle Q_{TJET} \rangle = Q_{TRIG} + \langle Q_{TW} \rangle$ (Q_{TRIG} – charge of trigger particle) and the sum of the mean charges in the "anti-trigger jet" and in the beam fragmentation region $\langle Q_{AW} \rangle + \langle Q_{BEAM} \rangle$ are calculated. It is remarkable, that the difference exists in behaviour of the mean charge distributions in the events with opposite charges of trigger particles. The absolute value of the mean charge in the beam fragmentation region is much higher for the interactions with positive charged trigger than for the interactions with negative charged one. In addition, the mean charge of the "trigger jet" $\langle Q_{TJET} \rangle$ in the events with positive trigger is approximately equal to $\langle Q_{AW} \rangle + \langle Q_{BEAM} \rangle$. At the same time, in the events with negative trigger $\langle Q_{TJET} \rangle$ is markedly greater than the sum of the mean charges in

Table VI. Mean net charge of associated particles from two hemispheres of azimuthal angle (toward to trigger and away from it) in different rapidity intervals $\Delta y = y - y_{TRIG}$

		$\pi^- p$		$\pi^- d$		$\pi^- C$	
		trig +	trig –	trig +	trig –	trig +	trig –
$\lvert\Delta y\rvert < 1$	$\langle Q_{TW} \rangle$	–(0.19±0.05)	+(0.31±0.10)	–(0.40±0.06)	+(0.24±0.10)	–(0.32±0.05)	+(0.17±0.06)
	$\langle Q_{AW} \rangle$	–(0.28±0.05)	+(0.43±0.12)	–(0.40±0.08)	+(0.39±0.15)	–(0.41±0.07)	+(0.46±0.07)
$\Delta y > 1$	$\langle Q_{BEAM} \rangle$	–(0.58±0.05)	–(0.04±0.01)	–(0.47±0.07)	–(0.16±0.11)	–(0.47±0.04)	–(0.18±0.05)
$\Delta y < -1$	$\langle Q_{TARG} \rangle$	–(0.10±0.05)	+(0.07±0.05)	–(0.08±0.05)	+(0.09±0.07)	–(0.10±0.04)	+(0.14±0.04)
	$\langle Q_{TJET} \rangle$	+(0.81±0.05)	–(0.69±0.10)	+(0.60±0.06)	–(0.76±0.10)	+(0.68±0.05)	–(0.85±0.06)
$\langle Q_{AW} \rangle + \langle Q_{BEAM} \rangle$		–(0.85±0.07)	+(0.39±0.12)	–(0.87±0.11)	+(0.23±0.19)	–(0.88±0.08)	+(0.28±0.09)

the "anti-trigger jet" and in the beam fragmentation region. One could try to understand this fact in the simplified framework of a hard collision of the independent valence quarks from the interacting hadrons. The positive charged trigger hadron is produced basically in the fragmentation of the positive charged quark or diquark from nucleon, hence the mean charge in the "trigger jet" is between 2/3 ÷ 1 and due to the hard scattering one of the pion valence quarks will fragment as the "anti--trigger jet" and second remains in the beam fragmentation region, therefore the sum of the mean charges in these two regions will be close to -1. The mean charge in the "trigger jet" with the negative trigger particle is determined by the charges of fragmentating $\bar{u}$ or d valence quarks from the incident π^--meson, so the mean charge will be close to -1/2 and the sum of the charges of recoiling quark (or diquark) from target and spectator quark from projectile will be close to zero. In the $\pi^- n$ interactions, the difference between the mean charges in the events with positive and negative trigger particles would be greater than in the $\pi^- p$ interactions and that is seen indeed in the experimental data. Although such simple model is in agreement with general characteristics of the data, the predicted absolute values differ from the experimental ones, at least for the interactions with negative trigger. The mean charge in the beam fragmentation region for these events is predicted by such simple model to be between -1/2 ÷ -1/3, but the experimental values are close to zero. The mean negative charge in the "trigger jet" is correspondingly higher than the predicted one. Probably, these discrepancies are due to the assumption of independent interaction and fragmentation of quarks and could disappear in more realistic model (e.g. Lund model).

In addition to the events, in which the high transverse momentum charged particle was produced promptly at the interaction point, the spectrometer also selected the events

accompanied by a neutral strange particle of the transverse momentum higher than 0.8 GeV/c which produced via its decay at least one triggering secondary particle (V^0-trigger). In the sample of $\sim$ 3000 events (a part of the total statistics of $\pi^- p$, $\pi^- d$ and $\pi^- C$ interactions) about 80 events with V^0-trigger were found. It was revealed in the analysis of the effective mass distributions for triggering V^0-particles, that marked part of them ($\sim$30%, without taking into account the trigger acceptance, losses caused by the inefficiency of registration and identification ambiguity) is due to Λ^0-hyperon decay. It seems to show, that one cannot neglect the contribution of the target nucleon diquark scattering in the study of underlying mechanism responsible for the high transverse momentum particle production in the central rapidity region at 40 GeV incident pion energy.

The presented results do not exclude a remarkable contribution of hard scattering to the pion-nucleon interactions at the energy of some tens GeV. On the other side, they lead to the assumption that the multiple-scattering mechanism contributes to the nuclear production of the high transverse momentum particles. The last conclusion is favoured by the indications that with increasing number of nucleons in the target nucleus, the slopes of the transverse momentum spectra for trigger particles and the azimuthal correlation between trigger particle and associated ones, both decrease, whereas the number of identified, knocked-out from nucleus, protons and non-compensated positive charge, both increase /4/.

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