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CHARACTERISTICS OF THE SECONDARY PARTICLES FROM $\pi^- C$ INTERACTIONS AT 40 *GeV/c* IN DIFFERENT NUCLEAR MATTER PHASES

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ABSTRACT

In this paper we have presented the angular and momentum characteristics of the secondary particles from $\pi^- C$– interactions at 40 GeV/c in different phase transition regions of nuclear matter.

INTRODUCTION

The investigation of the multiparticle production in hadron-nucleus, nucleus-nucleus interactions at high energies and large momentum transfers is very important for understanding the strong interaction mechanism and inner quark-gluon structure of nuclear matter.

During the last years the possibility of the observing of the collective phenomena such as the cumulative particle production [1], the production of nuclear matter with high densities, the phase transition from the hadronic matter to the quark-gluon plasma state is widely discussed in the literature [2-5, 11-14].

According to the different ideas and models, if exist these phenomena in the nature, then they will be observed in the hadron-nucleus and nucleus-nucleus interactions at high energies and large momentum transfers and should be influenced to the dynamics of interaction process and would be reflected in the angular and momentum characteristics of the reaction products.

To study the phase transition of nuclear matter we must choose the variables corresponding to this physical process. In the theoretical calculations are mainly used the effective temperature T, the density of nuclear matter ρ / ρ_0 or the quark chemical potential μ. But the variables ρ and μ are not fully determined experimentally and their values are usually remained model dependently.

In our previous paper [13] we are proposed to study the phase transition process of nuclear matter to use the variable called "the cumulative number", n_c instead of the variable ρ(or μ).

The cumulative number, n_c in the fixed target experiments is determined by the next formula:

$$n_c = \frac{P_a * P_C}{P_a * P_b} \cong \frac{E_c - P_{II}^c}{m_p}$$

Here P_a, P_b and P_c are the four dimensional momenta of the incident particle, target and the considering secondary particles correspondingly. E_c is the energy and P_{II}^c is the longitudinal momentum of the considering secondary particle, m_p is the proton mass. From this formula we see that this variable is a relativistic invariant and can be fully determined experimentally without model dependent. This variable (n_c) may be

interpreted as minimal target mass, which is required for producing of the given secondary particle. We would like to stress that the connection of the variable and the four momentum transfer *t* is determined by the next formula [13].

$$t = -Q^2 = -(P_a - P_b)^2 = -m_a^2 - m_b^2 + 2E_a \cdot \frac{m_p}{m_p} \cdot (E_c - P_{II}^c) \cong S_{\pi^- p} \cdot n_c \quad (2)$$

Where $S_{\pi^- p}$ is the total energy square of $\pi^- + p$- interaction and is determined by the next formula:

$$S_{\pi^- p} = (P_{\pi^-} + P_p)^2 = m_\pi^2 + m_p^2 + 2E_{\pi^-} \cdot m_p \cong 2E_{\pi^-} \cdot m_p \quad (3)$$

In the fixed target experiment $S_{\pi^- p}$ is a constant and in our case

$$S_{\pi^- p} \cong 2 \cdot E_\pi - m_p \cong 75 Gev^2$$

The transverse energy spectra of the secondary particles in the different intervals are approximated by exponential functions of the next form:

$$\frac{1}{2 \cdot E_t} \frac{\Delta N}{\Delta E_t} \sim e^{-b \cdot E_t}, \qquad E_t = \sqrt{{p_t}^2 + m^2} \quad (4)$$

The effective temperature *T* is determined as the inverse of the slope parameters *b*,

$$T = \frac{1}{b} \quad (5)$$

EXPERIMENTAL METHOD

The experimental material was obtained with the help of Dubna 2-meter propane (C_3H_8) bubble chamber exposed by π^-– mesons with momentum *40 GeV/c* from Serpukhov accelerator. According to the advantage of the bubble chamber experiment, all distributions in this paper are obtained in the condition of 4 π geometry of secondary particles.

The average error of the momentum measurements is ~12% and the average error of the angular measurements is ~0.6˚.

All secondary negative particles are taken as π^-- mesons. The average boundary momentum from which π^--mesons were well identified in the propane bubble chamber is ~70 *MeV/c*. In connection with the identification problem between energetic protons and π^+-mesons, protons with momentum more than ~1 *GeV/c* are included to the π^+-mesons.

The other experimental details are described in [8,9].

8791 $\pi^- C$ interactions are used in this analysis.

PHASE DIAGRAMS FOR π^-–MESONS AND PROTONS

In our paper [13] we are presented the dependences between temperature T and cumulative number for negative pions (Fig.1) and protons (Fig.2) from $\pi^- C$- interactions at 40 *GeV/c*. Our analysis showed that dependence of the temperature *T* on the variable n_c (or *t*), the strongly interacting matter may occur in three different phases for π^- mesons: hadronic, thermodynamic equilibrium and quark-gluon plasma (QGP) and in two different phases for

protons: thermodynamical equilibrium and QGP states.

The main goal of this paper is to present the angular and momentum characteristics of negative pions and protons from $\pi^- C$ interactions in these different phases.

In the case of protons as mentioned above we are worked in the momentum interval from ~0,150 *GeV/c* to ~1,0 *GeV/c* and the protons with momentum $P_p > 1$ *GeV/c* which gives the main contribution to the hadronic phase are included inside π^+ mesons as mixture. This methodical difficulty may be the main reason of why we don't see the hadronic phase for the secondary protons.

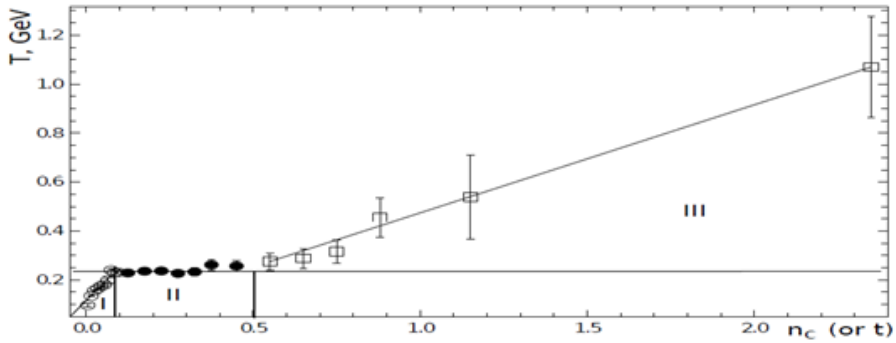

Figure 1: Shows the phase diagram of π^--mesons produced from $\pi^- C$-interaction at 40GeV/c.

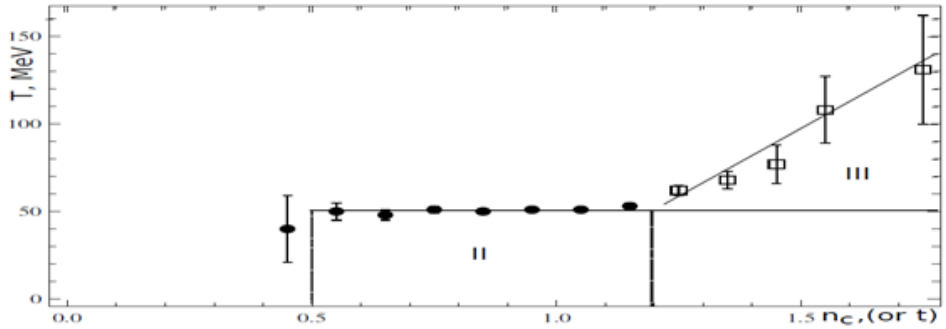

Figure 2: Shows the phase diagram of protons produced from $\pi^- C$-interaction at 40GeV/c.

$\pi^- + C \rightarrow \pi^- + X$ ANALYSIS

To do the comparative analysis, the angular and momentum characteristics of the all secondary π^- - mesons from $\pi^- C$– interactions at 40 *GeV/c* are presented on Fig.3. The average values of these distributions are given in table 1.

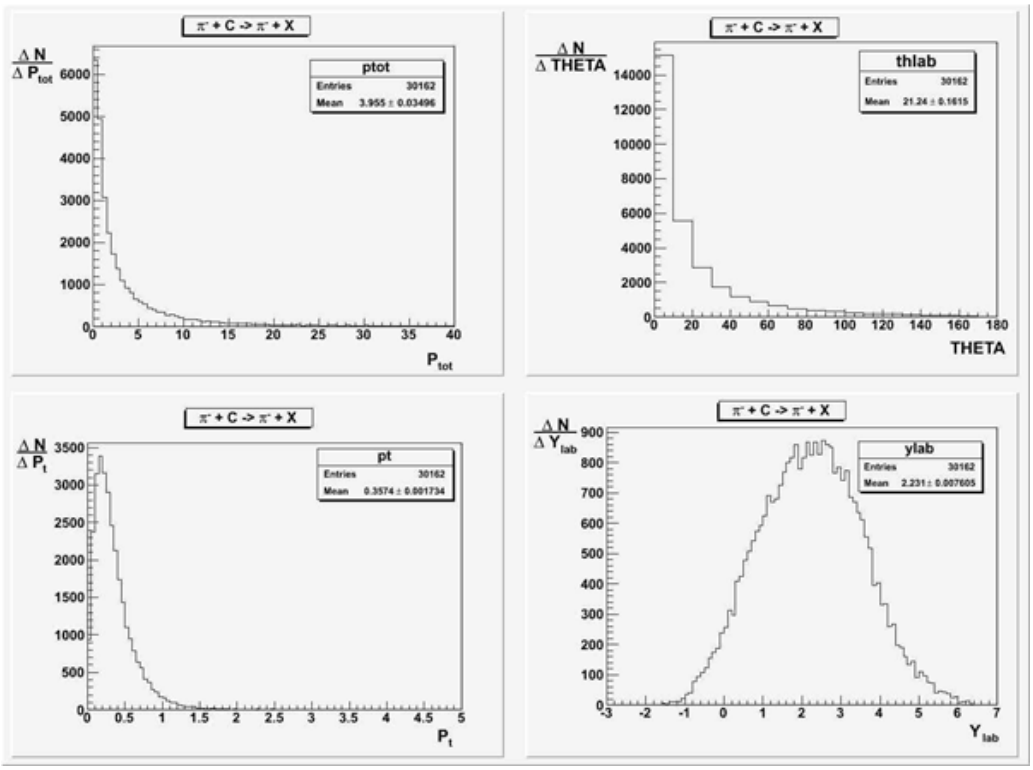

Fig.3 shows the momentum (P_{tot}), angular (Theta), transverse momentum (P_t) and rapidity (Y_{lab}) distributions for all π^-–mesons from π^-C interactions at 40 GeV/c.

Table 1 (for π^- mesons)

Average characteristics	Number of π^- mesons	$<P_{tot}>$ (Gev/c)	$<TH_{lab}>$ (in degrees)	$<P_t>$ (Gev/c)	$<Y_{lab}>$
All π^- mesons	30162	3,955 ± 0.035	21,24 ± 0,16	0,357 ± 0,002	2,231 ± 0,008
π^- mesons with $n_c \leq$ 0.08 and T < 0.200 Gev	19702	5,431 ± 0,039	7,00 ± 0,05	0,313 ± 0,002	2,924 ± 0.020
π^- mesons with 0.08 $\leq n_c \leq$ 0.5 and T ≈ 0,220 Gev	9879	1,174 ± 0,012	45,15 ± 0,45	0,419 ± 0,004	0,987 ± 0,010
π^- mesons with $n_c >$ 0.5 and T ≥ 0,220 Gev	581	1,547 ± 0,064	97,44 ± 4,00	0,930 ± 0,038	-0,115 ± 0,005

Fig.4 shows the angular and momentum distributions (total momentum P_t, angle transverse momentum and rapidity Y_{lab}) of π^- mesons which correspond to the hadronic phase (the I region with $n_c \leq$0,07, T < 0,200).

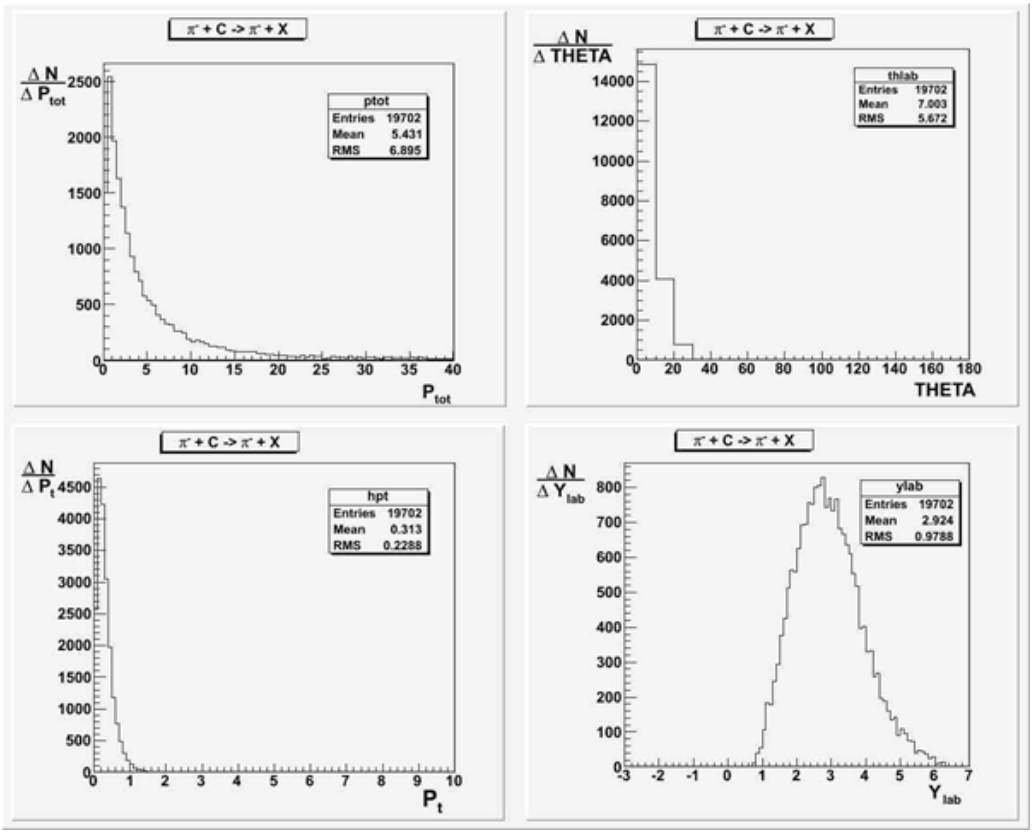

Fig.4 shows the angular and momentum characteristics of π^--mesons in the hadronic phase (I region).

Angular and momentum distributions of π^- mesons which correspond to the phase transition region from the hadronic matter to the QGP phase for which the temperature T remains practically constant (the II region with $0{,}07 > n_c \leq 0{,}5$, $T \approx 0{,}220$ *GeV*) are shown on Fig.5.

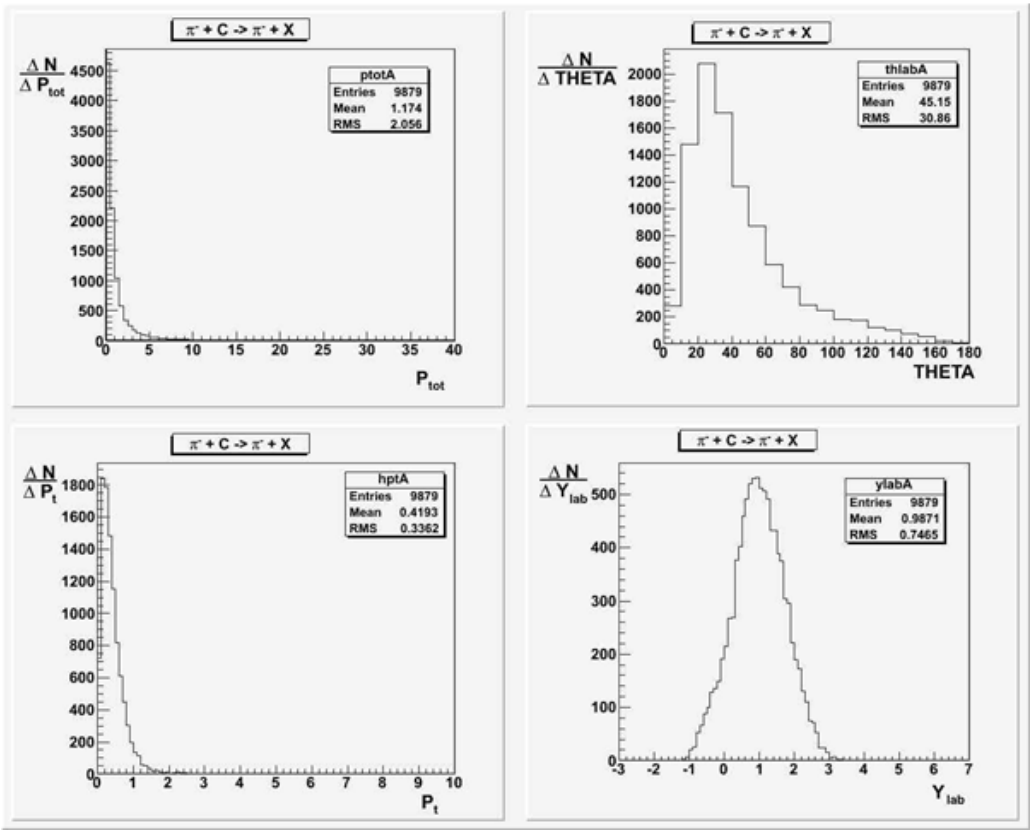

Fig.5 shows the angular and momentum characteristics of π^--mesons in the mixed phase (II region).

Fig.6 shows the same distributions of π^--mesons which belong to the QGP state (the III region with n ≥ 0,5, $T \geq 0{,}220$ *GeV*). For π^--mesons produced in this region we are obtained $\langle Y_{lab} \rangle$ = -0,115 ± 0,005 and $\langle P_t \rangle$ = 0,930 ± 0,038 *GeV/c*. So we would like to stress that π^--mesons only produced in the target fragmentation region with comparatively large transverse momentum are included in this region.

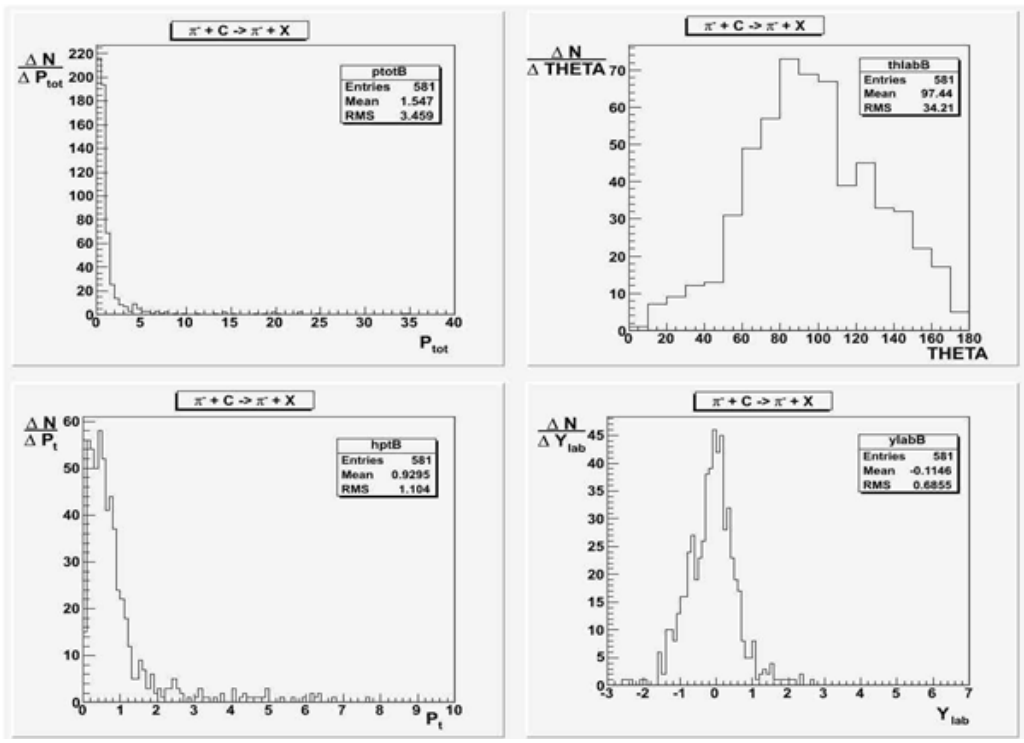

Fig.6 shows the angular and momentum characteristics of π^- -mesons in the QGP phase (III region).

First of all we would like to stress that the exact separation of the transition regions from the hadronic matter to the mixed phase and from the mixed phase to the QGP should be considered carefully. This separation procedure needs more detailed studies.

π^-+C→ P+X ANALYSIS

With the goal of comparison, the angular and momentum characteristics of all secondary protons from π^-C - interactions at 40 *GeV/c* are presented on Fig.7.

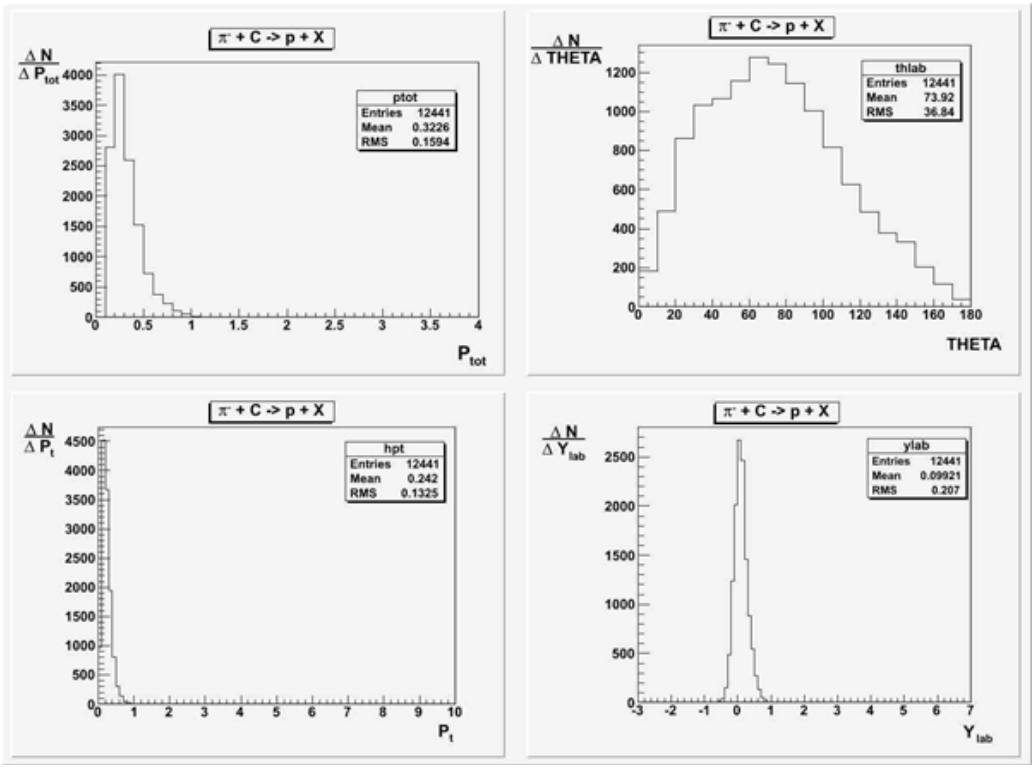

Fig.7 presents the momentum (P_{tot}), angular (Theta), transverse momentum (P_t) and rapidity (Y_{lab}) distributions of all protons from $\pi^- C$ interactions at 40 GeV/c.

Fig.8 shows the corresponding angular and momentum characteristics of protons in the mixed phase (the II region).

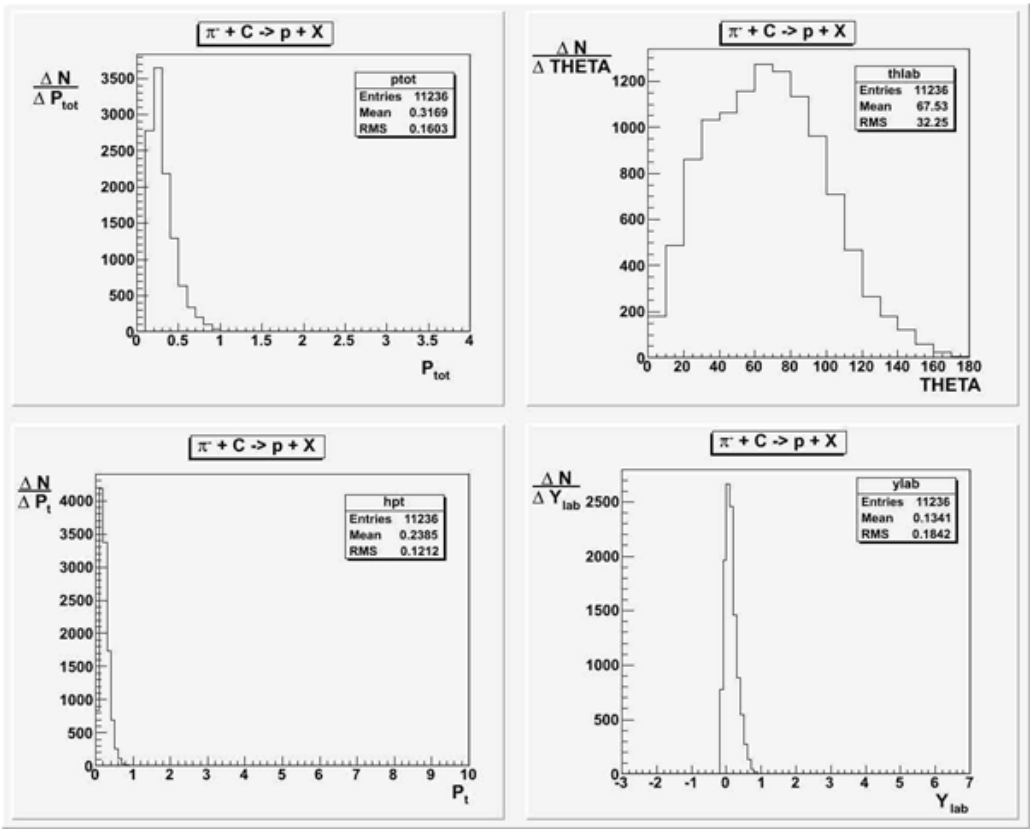

Fig.8 shows the angular and momentum characteristics of protons in the mixed phase (II region).

Table 2 shows average values of angular and momentum characteristics of all protons and protons in the two other different regions.

Table 2 (for protons)

Average characteristics	Number of protons	$<P_{tot}>$ (Gev/c)	$<TH_{lab}>$ (in degrees)	$<P_t>$ (Gev/c)	$<Y_{lab}>$
all protons	12441	0,323 ± 0.003	73,92 ± 0,66	0,242 ± 0,002	0,099 ± 0,001
protons with $n_c \leq 1.2$ and $T \approx 0.050$ Gev	11236	0,317 ± 0,003	67,53 ± 0,64	0,238 ± 0,002	0,134 ± 0,001
protons with $n_c > 1.2$ and $T \geq 0.050$ Gev	1205	0,376 ± 0,011	133,4 ± 3,84	0,275 ± 0,008	-0,223 ± 0,006

Fig. 7, 8 and Table 2 show that average values of the angular and momentum characteristics of protons in the mixed phase show small differences in comparison with data for all protons. Of course this is connected with the fact that about 90 % of protons produced in the mixed phase.

Fig. 9 and Table 2 show that $< P_{tot} >$, $< P_t >$ and $< TH_{lab} >$ in the III region are increased and $< Y_{lab} >$ is decreased in comparison with the data for all protons and protons in the III region, in other words, protons which produced at large momentum transfers, t, are included in this region.

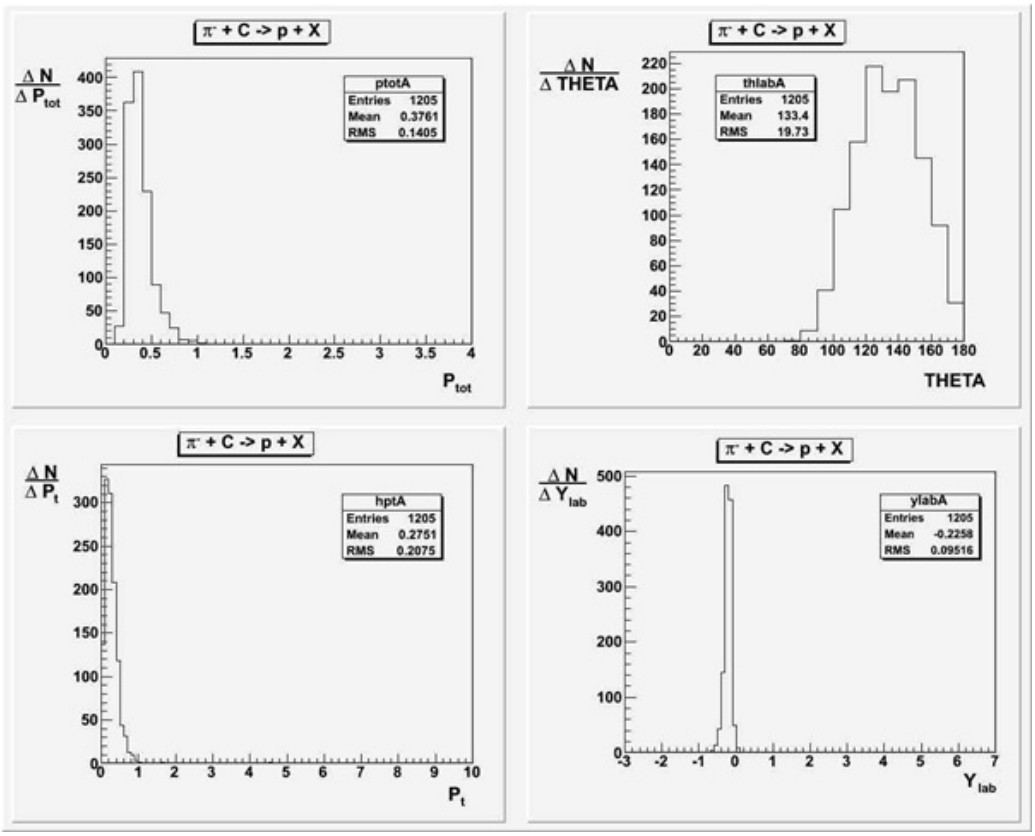

Fig.9 shows the angular and momentum characteristics of protons in the QGP phase (III region)

CONCLUSION

Our analysis showed that angular and momentum characteristics of π^-- mesons and protons from $\pi^- C$ interactions at 40 are different in every region.

We note that π^-- mesons which produced in the projectile fragmentation region give the main contribution to the hadronic phase and π^-- mesons produced only in the target fragmentation region with large transverse momentum are included to quark-gluon plasma (QGP) phase. All other π^--mesons with average characteristics between I and III regions are included to the mixed phase with the constant temperature $T=T_c$.

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