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SOME ANGLE DEPENDENT CHARACTERISTICS OF CHARGED SHOWER PARTICLES PRODUCED AT HIGH ENERGIES

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The angular distributions of showers in lab. and c.m. systems have been studied for various effective target thickness. Also the variation of particle number densities in lab. and c.m. systems has been given as a function of $\bar{\nu}$. It is observed that the particle density decreases with effective target mass in the most forward region in laboratory system whereas it shows an increasing trend in the c.m. system. The results seem to agree with CTM type of pictures of interaction. Some results on variation of R_A with $\bar{\nu}$ in different η-intervals have also been presented.

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1. *Introduction*

Study of the interactions with emulsion nuclei caused by elementary particles is expected to provide substantial information about the interaction with intranuclear matter. It has often been suggested [1, 2] that the multiplicity of grey prongs, N_g ($0.3 \leqslant \beta < 0.7$), in high-energy hadron-emulsion nucleus reactions is a good measure of the number of collisions, ν, inside the struck nucleus. On the basis of this suggestion, ν-N_g correlations for the disintegrations of CNO, AgBr and Em-nuclei induced by both pion and proton projectiles have been studied [3, 4]. These correlations have been used to analyze the hadron-nucleus data owing to the fact that (*i*) the peripheral and the more central collisions occurring in hadron-nucleus collisions may be distinguished if the number of the nucleons of target nucleus hit by the incident hadron is known as the number of nucleons participating in these reactions depends on the impact parameter [1], (*ii*) the central collision events may give an idea of the average behaviour of various features of the parameters involved in h-A collisions at higher energies [5].

Our main interest in the present study is to investigate the dependence of the number of particles density in the rapidity space and mean normalized multiplicity, on the average number of intranuclear collisions, $\bar{\nu}$, of the projectile. In order to study the characteristics of hadron-nucleus interactions as a function of ν, there are two experimental possibilities. One method is to vary the atomic number of target nucleus [6]. According to this approach the average number of hadron-nucleon collisions inside the nucleus of atomic number

A is given as

$$\bar{\nu}_A = A\sigma^{\text{inel}}_{\text{h-p}}/\sigma^{\text{inel}}_{\text{h-A}}, \tag{1}$$

where $\sigma^{\text{inel}}_{\text{h-p}}$ and $\sigma^{\text{inel}}_{\text{h-A}}$ are the hadron-proton and hadron-nucleus inelastic cross-sections respectively. The other method is to select the events based on the number of collisions of the projectile inside a given target nucleus. Since a given N_g-value corresponds to certain ν-value, it provides determination of effective ν in individual events and therefore any ν-dependent characteristic may be studied in more detailed fashion when this method of estimating ν is used. It has been reported [7] that the dispersion $D(\bar{\nu}_{N_g})$ of the distribution ν_{N_g} is close to $0.6\sqrt{\bar{\nu}_{N_g}}$ and is considerably smaller than the dispersion of the ν_A-distribution, $D(\bar{\nu}_A) \simeq 0.7\,\bar{\nu}_A$. Furthermore, a considerable range in the possible values of $\bar{\nu}$ is obtained using this method even with a not very heavy nucleus.

2. *Experimental details*

Details of stacks, scanning procedure, selection criteria, methods of measurements, etc., may be found in our earlier publications [8, 9].

The type of events used in the present analyses is given in Table I.

TABLE I

Projectile	Type of interaction	No. of events
50 GeV, π^-	$N_h \geqslant 2$	873
340 GeV, π^-	$N_h \geqslant 0$	1087
400 GeV, p	$N_h \geqslant 0$	673

3. *Determination of* ν

The number ν gives the thickness of the target as observed by the impinging hadron in units of the mean free path of the projectile in nuclear matter. Various models [3, 4] have been proposed to determine the dependence of $\bar{\nu}$ on N_g. According to the Stenlund--Otterlund model [4], the relation connecting $\bar{\nu}$ with N_g is

$$\bar{\nu}(N_g) = C_0 + C_1 N_g^{1/2} + C_2 N_g + C_3 N_g^{3/2}. \tag{2}$$

For the present study the values of the coefficients C_0, C_1, C_2 and C_3 for particular kind of projectile and target are taken from Ref. [4]. The overall average value of ν estimated by this method agrees well with the values obtained by method using Eq. (1).

4. *Dependence of* η*-spectrum on effective target thickness*

The pseudorapidity variable, η, is defined as

$$\eta = -\ln \tan \theta/2, \tag{3}$$

where θ is the angle of emission of secondary charged shower particles with respect to the beam direction in laboratory frame.

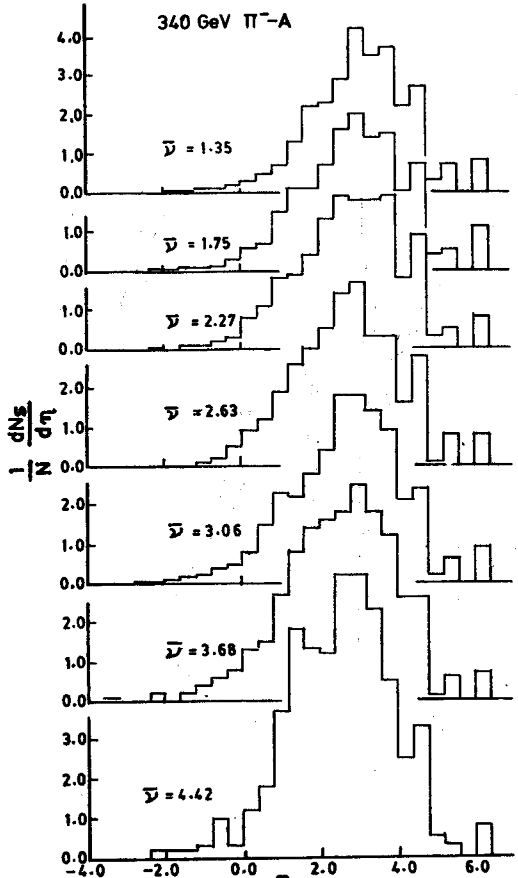

Fig. 1

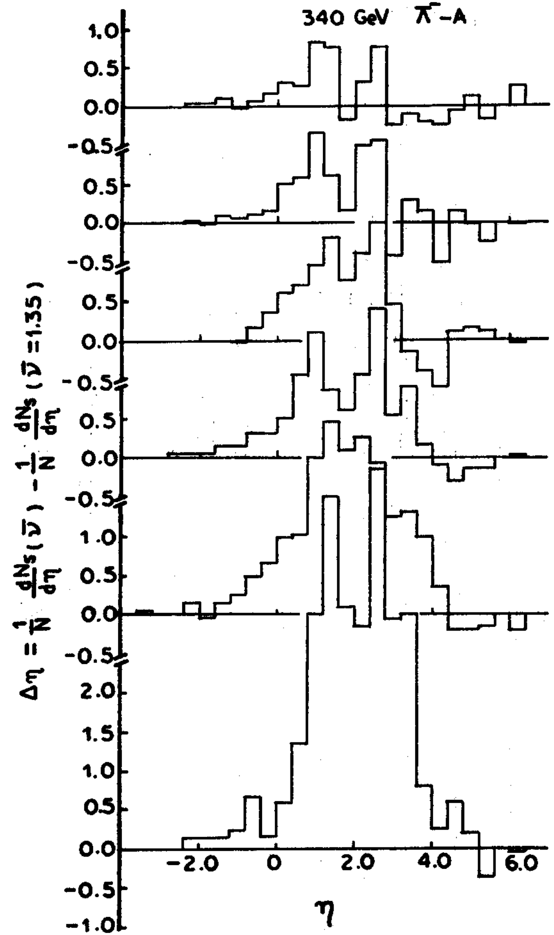

Fig. 2

Fig. 1. η-distributions of shower particles produced in emulsion interactions at 340 GeV for different nuclear thickness $\bar{\nu}$

Fig. 2. $\Delta\eta$-distributions at 340 GeV

To study the dependence of the η-spectrum on ν, the events have been divided into seven groups of ν. The η-distributions of shower particles for different values of $\bar{\nu}$ for 340 GeV pion-nucleus interactions are exhibited in Fig. 1. To see the change in the distributions with ν we have also plotted difference distributions which are shown in Fig. 2. Furthermore, the normalized particle number densities in the rapidity space, $\varrho(\eta) = \frac{1}{N}\frac{dN_s}{d\eta}$ as a function of $\bar{\nu}$ in various η-intervals are plotted in Fig. 3a–c respectively for 340, 50 GeV π^--nucleus and 400 GeV p-nucleus interactions. From these figures (Figs. 1–3) following conclusions may be drawn:

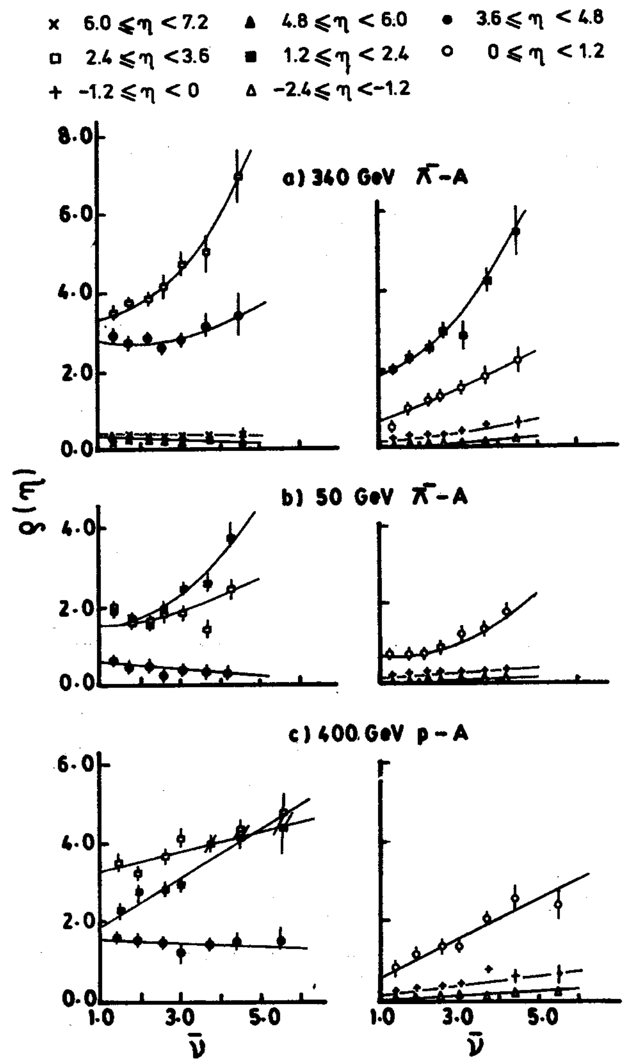

Fig. 3. Particle number densities $\varrho(\eta)$ for different η-bins as functions of $\bar{\nu}$. The lines are just to guide the eye

(*i*) A decrease in the produced particle multiplicity in very forward region (large η) with increasing $\bar{\nu}$ is observed, i.e. $\varrho(\eta)$ decreases with increasing $\bar{\nu}$ for all the three energies considered.
(*ii*) An increase in the multiplicity of charged secondaries produced at small η-values with increasing $\bar{\nu}$ is observed. A moderate enhancement of particle production in the target fragmentation region is observed whereas most of the produced particles are appearing in the pionization or central rapidity region.
(*iii*) The plot of $\varrho(\eta)$ vs $\bar{\nu}$ is not always linear.

These features of pseudorapidity distributions for different effective target thickness are the same as those observed in experiments where variation of $\bar{\nu}$ is obtained by changing the atomic number of target nucleus [10] and also agree fairly well with the prediction of some of the models [1, 5].

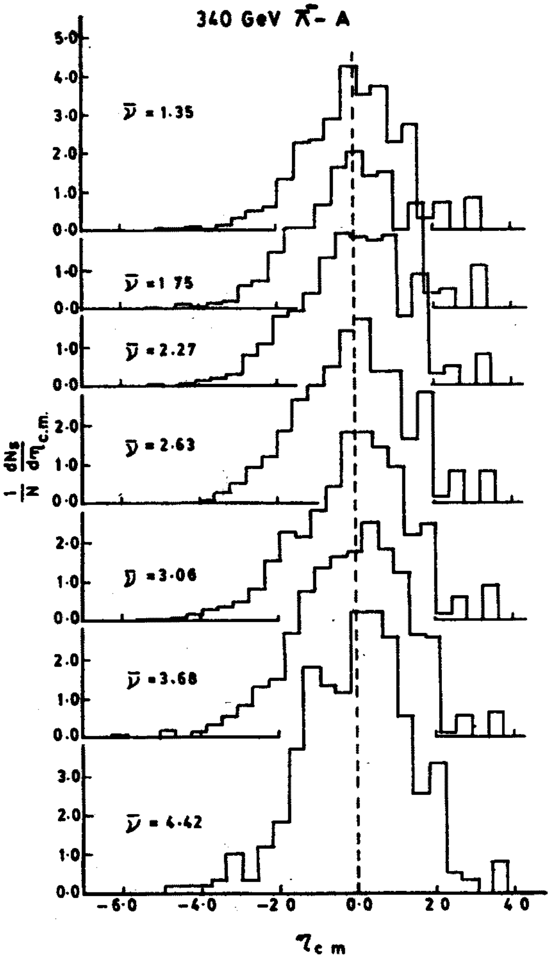

Fig. 4. $\eta_{c.m.}$-distributions of shower particles at 340 GeV

5. *Dependence of $\eta_{c.m.}$-distribution on $\bar{\nu}$*

The pseudorapidity distributions of showers in the centre of mass system, defined by the incident particle and the $\bar{\nu}$-nucleons, have been obtained and given in Fig. 4 for different values of $\bar{\nu}$. The values of $\eta_{c.m.}$ have been calculated by

$$\eta_{c.m.} = \eta_{lab} + \ln\sqrt{\frac{1-\beta}{1+\beta}}, \tag{4}$$

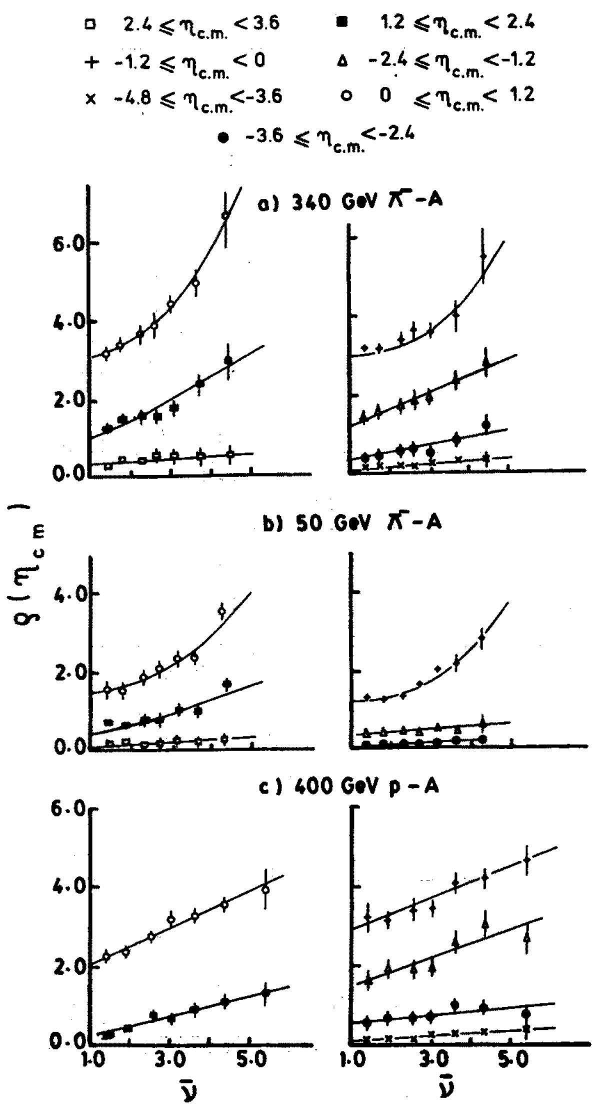

Fig. 5. Variation of $\varrho(\eta_{c.m.})$ as a function of $\bar{\nu}$ in different $\eta_{c.m.}$-intervals. The lines are discussed in Fig. 3

where $\beta = \frac{P_i}{E_i + \bar{\nu} M_p}$; E_i, P_i are the energy and momentum of the incident particle in laboratory-system and M_p is the nucleon mass. Furthermore, the normalized particle number densities in c.m. system, $\varrho(\eta_{c.m.})$ as a function of $\bar{\nu}$ in various $\eta_{c.m.}$-bins have been plotted in Fig. 5a–c for 340, 50 GeV π^--A and 400 GeV p-A interactions. From these figures following conclusions may be drawn:

(*i*) The average values of $\eta_{c.m.}$ for all the distributions lie around $\eta_{c.m.} = 0$ irrespective of the values of $\bar{\nu}$.

(*ii*) The produced particle multiplicity increases with increasing $\bar{\nu}$ for all values of $\eta_{c.m.}$, i.e., $\varrho(\eta_{c.m.})$ increases with $\bar{\nu}$ in all $\eta_{c.m.}$-intervals for all the three energies considered in the present study.

(*iii*) The $\eta_{c.m.}$-distribution is almost symmetrical about $\eta_{c.m.} = 0$, i.e., the variations of $\varrho(\eta_{c.m.})$ with $\bar{\nu}$ in the intervals $1.2 \leqslant \eta_{c.m.} < 2.4$, $0.0 \leqslant \eta_{c.m.} < 1.2$ are similar to the variations in the intervals $-2.4 \leqslant \eta_{c.m.} < -1.2$ and $-1.2 \leqslant \eta_{c.m.} < 0.0$ respectively.

(*iv*) In the most forward region of rapidity space, while the produced particle density seems to increase with $\bar{\nu}$ in the c.m. distributions, its values seem to decrease with $\bar{\nu}$ in lab. distributions. The increase in particle density agrees with a CTM type [5] picture where a higher ν-value means higher c.m. energy. The decrease in particle density with increasing ν at all energies in lab. distribution may be interpreted as kinematic effect: the lower ν means the higher velocity of c.m. system and thus more particles collimated in a given angular interval.

Thus, all the above features seem to be in agreement with the CTM-predictions [5].

6. *Mean normalized multiplicity in η-intervals*

Mean normalized multiplicity, R_A may be defined as:

$$R_A = \frac{\langle N_s \rangle}{\langle N_{ch} \rangle}, \tag{5}$$

where $\langle N_s \rangle$ is the average number of charged shower particles produced in hadron-nucleus interactions, $\langle N_{ch} \rangle$ is the average number of charged particles produced in hadron-hadron collisions.

Variation of R_A with $\bar{\nu}$ in different η-intervals have been studied at 50, 340 and 400 GeV which is shown in Fig. 6. Following observations can be made on the basis of this figure:

(*i*) The value of R_A increases with decreasing η-bin values.

(*ii*) The value of R_A remains constant with increasing $\bar{\nu}$ in very forward region ($\eta > 3.6$) and its value is always less than unity.

(*iii*) The parameter R_A increases with $\bar{\nu}$ for $\eta \leqslant 2.0$.

Thus, the cascadings at large angles (low rapidity region) and the absorption at large η corresponding to small angle have been observed. This could be interpreted in terms of multiple scattering suffered by projectile inside the target nucleus, so as it manages to produce particles in dispersed fashion. These findings are in agreement with those obtained by Vegni [11] in optical spark chamber experiment for π^--A interactions at 40 GeV.

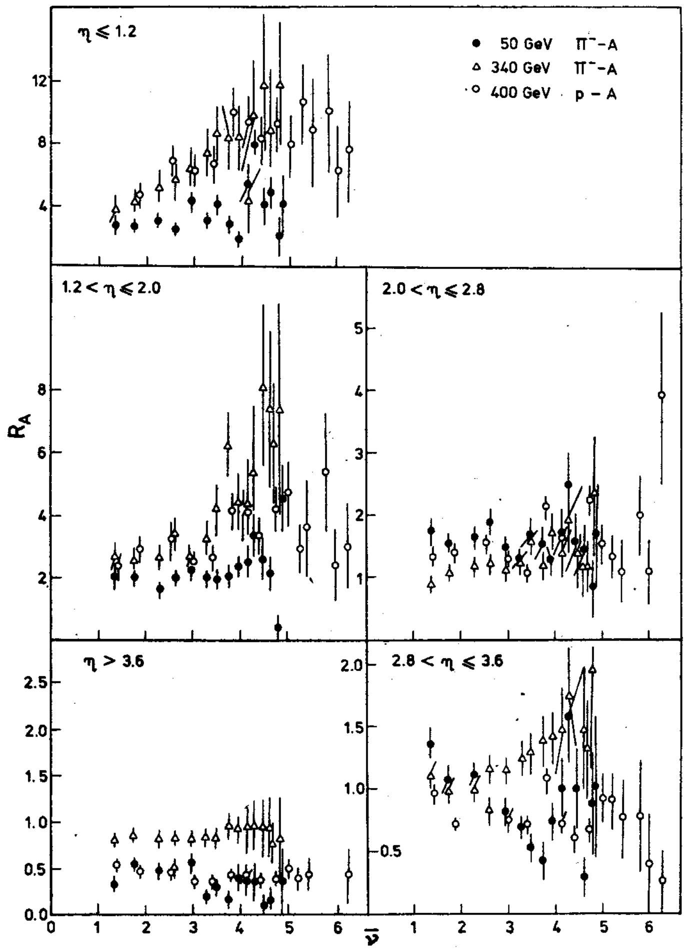

Fig. 6. R_A vs $\bar{\nu}$ in different η-intervals

REFERENCES

[1] K. Gottfried, *Phys. Rev. Lett.* **32**, 957 (1974).
[2] J. Babecki, G. Nowak, Report 970/PH, Kraków 1977.
[3] B. Anderson et al., *Phys. Lett.* **B73**, 343 (1978).
[4] E. Stenlund, I. Otterlund, *Nucl. Phys.* **B198**, 407 (1982).
[5] Y. Afek et al., Proc. — Topical Meeting on Multiparticle Production on Nuclei at Very High Energies, Trieste 1976.
[6] H. Khushnood et al., *Can. J. Phys.* **61**, 1120 (1983).
[7] R. Hołyński et al., *Acta Phys. Pol.* **B17**, 201 (1986).
[8] M. Irfan et al., *Nuovo Cimento* **A24**, 354 (1974).
[9] Tauseef Ahmad et al., *Acta Phys. Pol.* **B20**, 701 (1989).
[10] C. Halliwell et al., *Phys. Rev. Lett.* **39**, 1499 (1977) and references therein.
[11] G. Vegni, Proc.-Int. Conf. High Energy Phys., Vol. 2, Geneva 1979.