ANGULAR DISTRIBUTION OF SHOWER PARTICLES PRODUCED IN THE COLLISIONS OF 20-GeV/c AND 300-GeV NEGATIVE PIONS WITH EMULSION NUCLEI*

C. O. Kim, S. N. Kim, I. G. Park, and C. S. Yoon
Department of Physics, Korea University, Seoul 132, KOREA

ABSTRACT

For 435 accelerator-produced π^- jets of 20-GeV/c[1] and 300 GeV[2,3] in nuclear emulsion, $\langle\eta(\theta)\rangle$'s have been individually calculated for each jet, where $\eta(\theta)$ is a kinematic parameter introduced by one of us in 1967 in order to approximate the LS(laboratory system) rapidity, $\eta = \text{arctanh}\ (\beta \cos \theta)$.[4] By taking further averages by dividing the samples into groupings of the LS energy $E_\pi = m_\pi \cosh \eta_\pi$, N_h, the number of heavy prongs with LS velocity $\beta < 0.7$, and n_s, the number of charged shower particles with LS velocity $\beta \gtrsim 0.7$, $\langle\langle\eta(\theta)\rangle\rangle$ have been obtained. By use of the KNO (Koba-Nielsen-Olesen) scaling variable, $\xi = n_s/\langle n_s\rangle$,[5] we find good fit of our data to the regression function,

$$\langle\langle\eta(\theta)\rangle\rangle - \eta_\pi/2 - \tfrac{1}{2}\ln\ (m_\pi/m_p) = A + B/\xi, \quad (1)$$

where m_p is the proton mass.

1. Introduction. With the use of the samples of 3987 accelerator-produced proton jets of 30 - 400 GeV, one of us reported that the regression function,

$$\langle\langle\eta(\theta)\rangle\rangle - \eta_p/2 = A' + B'/\xi\ , \quad (2)$$

fits the angular data well, where the constants, A' and B' do not have any dependence on E_p ($= m_p \cosh \eta_p$).[6] In fact, Eq. (2) as well as Eq. (1) stem from the "scaling" asymmetry parameter R by Tavernier:[7,8]

$$R \equiv m_t \sinh\ (\langle\eta\rangle - \eta_t)/m_b \sinh\ (\eta_b - \langle\eta\rangle), \quad (3)$$

where m_b, m_t, η_b, η_t are masses and "initial" rapidities of beam and target, respectively. By putting, in the LS, $\eta_t = 0$, $m_t = \nu m_p$, $\langle\eta\rangle = \langle\langle\eta(\theta)\rangle\rangle$, the RHS of Eqs. (1) and (2) become equal to $\frac{1}{2}\ln\ (R/\nu)$, which can be represented by the LHS of Eqs. (1) and (2). Thus, the present paper is the similar analysis to Ref. 6, with the samples of 318 jets[1] of 20 GeV/c π^- and 117 jets[2,3] of 300 GeV π^-.

2. Experimental Material and Methods. Two stacks of glass-backed plates of Ilford K 5 nuclear emulsion of the size, 7.5 x 8 x 0.06 cm^3 (A stack, 21 plates; B stack, 20 plates)

*Research supported partly by the Korea Science and Engineering Foundation (1984 - 87).

were exposed "horizontally" to 300 GeV π^- beam at Fermilab in 1978 with a track density of about 3 x 10^4 particles/cm^2. The along-the-track scanning method was employed in order to find 207 inelastic events in tracing 100.374 m of the primary tracks; this gives the mean free path of 300 GeV π^- in Ilford K 5 nuclear emulsion, 48.5 ± 3.4 cm. Among these events, by following the procedure taken by Refs. 2 and 3, 126 interactions, whose origins were located more than 50 μm away either from the air surface or from the glass furface inside the processed emulsion plates, were subjected the analysis of counting the numbers of tracks to obtain $\langle N_h \rangle = 7.0 \pm 0.4$ and $\langle n_s \rangle = 13.2 \pm 0.6$. Further, we performed angular measurements to the charged shower particles of 117 interactions among the 126 interactions by applying the reference-track method of Ref. 6. The material and experimental procedure concerning the 20-GeV/c pion jets were reported in Ref. 1.

3. Dependence of $\langle\langle \eta(\theta) \rangle\rangle$. The LS emission angles of the charged shower particles were converted to $\eta(\theta)$ (Ref. 4) and for each jet $\langle \eta(\theta) \rangle$'s were calculated. Then, by grouping the 435 jets into subgroups, according to E_π, N_h = 0, 1, 2-4, 5-8, ≥9, n_s = 1, 2, 3, ..., 9, 10-14, 15-19, ..., $\langle\langle \eta(\theta) \rangle\rangle$ were calculated. As noticed in Refs. 1, 4, and 6, the trends shown in the values of $\langle\langle \eta(\theta) \rangle\rangle$, as a function of n_s and N_h, are:

(i) For $n_s \gg \langle n_s \rangle$ (i. e., $\xi \gg 1$), $\langle\langle \eta(\theta) \rangle\rangle$ becomes unreasonably larger. (Small $x_T = p_T/m$ effect.)
(ii) As N_h increases, $\langle\langle \eta(\theta) \rangle\rangle$ becomes smaller. (Nuclear target effect.)

As shown in Figs. 1 (a) - (e) and the values of A, B and χ^2/DF (and also A', B' and χ^2/DF for the 3987 proton jets of 30-400 GeV in parentheses) in Table I, our angular data of 435 π^- jets fit Eq. (1) rather well. The solid-line curves show

TABLE I. The values of A and B obtained by the least-squares fits for the 435 π^- jets (and those for the 3987 proton jets to Eq. (2)).

N_h	A (A')	B (B')	χ^2/DF
0	-0.18 ± 0.11 (-0.22 ± 0.03)	0.35 ± 0.09 (0.22 ± 0.02)	0.04 (1.63)
1	-0.08 ± 0.28 (-0.36 ± 0.05)	0.24 ± 0.20 (0.27 ± 0.04)	8.26 (1.35)
2-4	-0.38 ± 0.08 (-0.48 ± 0.03)	0.41 ± 0.06 (0.27 ± 0.03)	1.39 (1.87)
5-8	-0.53 ± 0.21 (-0.66 ± 0.05)	0.43 ± 0.25 (0.34 ± 0.06)	2.55 (1.46)
≥ 9	-1.12 ± 0.005 (-1.03 ± 0.03)	0.75 ± 0.004 (0.48 ± 0.02)	4.12 (2.38)

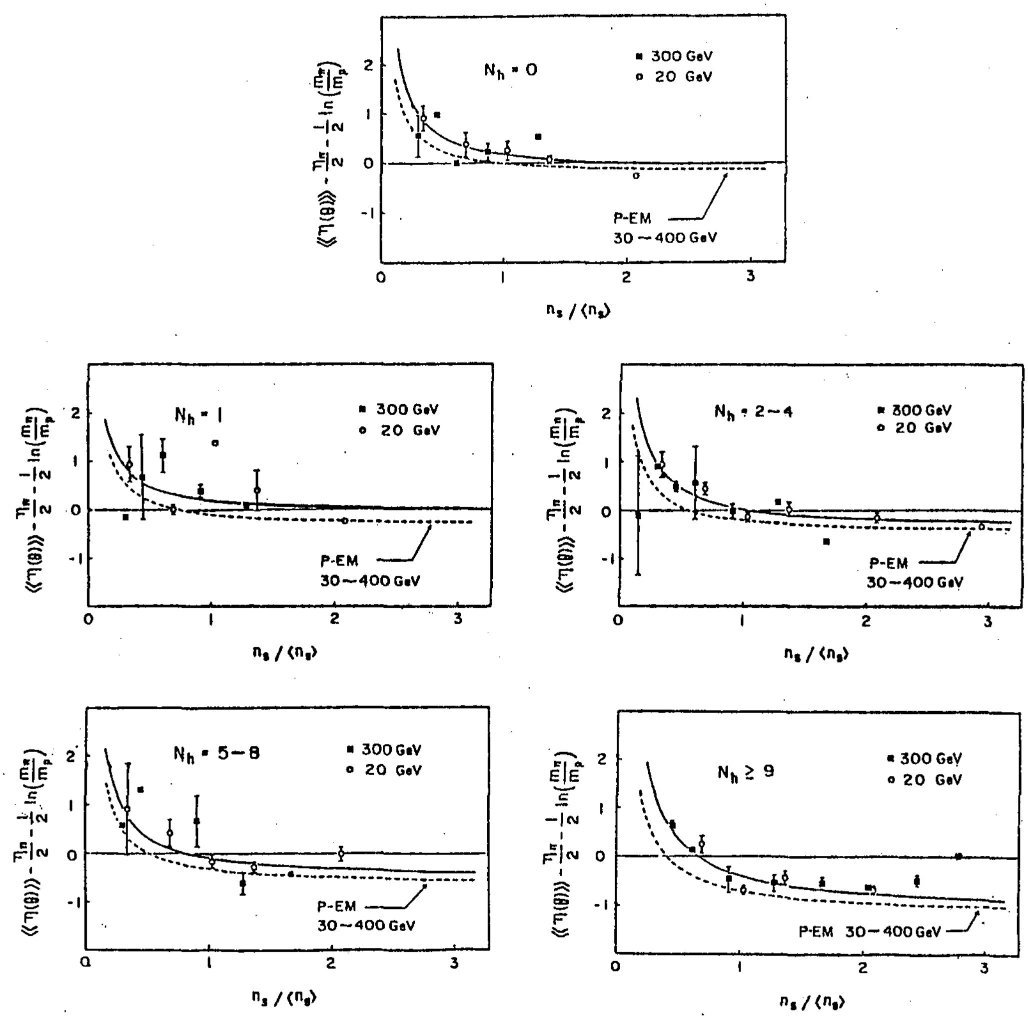

Fig. 1. Dependence of $\langle\langle\eta(\theta)\rangle\rangle$, according to Eq. (1) for the pion jets (solid-line curves) and to Eq. (2) for the proton jets (broken-line curves), for (a) $N_h = 0$, (b) for $N_h = 1$, (c) for $N_h = 2\text{-}4$, (d) for $N_h = 5\text{-}8$, and for $N_h \geq 9$.

the values of $\langle\langle\eta(\theta)\rangle\rangle - \eta_\pi/2 - \frac{1}{2}\ln(m_\pi/m_p)$ versus ξ, and the broken-line curves show the values of $\langle\langle\eta(\theta)\rangle\rangle - \eta_p/2$ versus ξ for proton jets of 30 - 400 GeV.

4. Discussion and Conclusion. As E. Gibbs et al.[9] first noted, the N_h dependence of A, listed in Table I, can be fitted by the regression function,

$$A = \alpha(1 + \gamma N_h)/(1 + \delta N_h), \qquad (4)$$

where the results are $\alpha = -0.152 \pm 0.001$, $\gamma = 0.520 \pm 0.004$, and $\delta = 0.020 \pm 0.005$ with $\chi^2/DF = 0.4/2$.[6] And as in Ref. 6, N_h-dependence of B, listed in Table I, can be fitted well by the regression function,

$$B = \kappa + \zeta N_h, \qquad (5)$$

where the results are $\kappa = 0.33 \pm 0.05$ and $\zeta = 0.025 \pm 0.03$ with $\chi^2/DF = 0.4/3$. Altogether, with the use of the data of angular measurements of 435 accelerator-produced jets of E_π = 20 and 300 GeV, we have obtained the empirical formula,

$$\langle\langle\eta(\theta)\rangle\rangle - \gamma_\pi/2 - \tfrac{1}{2}\ln(m_\pi/m_p) = (-0.152 \pm 0.001)\frac{[1 + (0.520 \pm 0.004)\,N_h]}{[1 + (0.020 \pm 0.05)\,N_h]} + \{(0.33 + 0.05) + (0.025 \pm 0.03)\,N_h\}/\xi.$$

We find the value of ν in Ref. 6 is almost in accord between the one obtained from the proton jets and the other obtained from the pion jets. But there exists some difference between the values of R of Refs. 7 and 8, which is indeed scaling, for proton and pion jets, reflecting the fact that pion jets do not have two surviving baryons but one.[4,6]

REFERENCES.

[1] E. R. Goza, S. Krzywdzinski, C. O. Kim, and J. N. Park, Phys. Rev. 2, 1838 (1970).

[2] M. Jurić, Dj. Krmpotić, O. Adamović, V. Gerc, L. Rak, J. Lory, D. Schune, Tsai-Chü, B. Willot, K. P. Hong, C. O. Kim, S. N. Kim, K. A. Moon, R. Schmidt, I. Otterlund, G. Baumann, M. Lopez Agüera, R. Niembro, A. Ruiz, E. Villa, Z. Phys. C 22, 131 (1984).

[3] Lj. Simić, O. Adamović, M. Jurić, J. Lory, D. Schune, Tsai-Chü, B. Willot, K. P. Hong, C. O. Kim, and K. A. Moon, Nuovo Cimento 82A, 327 (1984).

[4] C. O. Kim, Phys. Rev. 158, 1261 (1967).

[5] Z. Koba, H. B. Nielsen, and P. Olesen, Nucl. Phys. B40, 317 (1972).

[6] C. O. Kim, Phys. Rev. D 31, 513 (1985).

[7] S. P. K. Tavernier, Nucl. Phys. B105, 241 (1976).

[8] S. P. K. Tavernier and M. Gijsen, Phys. Rev. D 16, 2818(1977).

[9] E. Gibbs et al., Phys. Rev. D 10, 783 (1974).