SINGLE PARTICLE MOMENTUM AND ANGULAR DISTRIBUTIONS IN HADRON-HADRON COLLISIONS AT ULTRAHIGH ENERGIES

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1. Introduction. The forward-backward charged multiplicity distribution $P(n_F, n_B)$ of events in the 540 GeV $\bar{p}p$ collider has been extensively studied by the UA5 Collaboration. It was pointed out that the distribution with respect to $n = n_F + n_B$ satisfies approximate KNO scaling and that with respect to $Z = n_F - n_B$ is binomial [1]. The geometrical model of hadron-hadron collision interprets [2] the large multiplicity fluctuation as due to the widely different nature of collisions at different impact parameters b. For a single impact parameter b, the collision in the geometrical model should exhibit stochastic behavior. This separation of the stochastic and non-stochastic (KNO) aspects of multiparticle production processes gives conceptually a lucid and attractive picture of such collisions [3], leading to the concept of partition temperature T_p and the single particle momentum spectrum to be discussed in detail below.

2. Description of Model. Assuming the separation of stochastic from non-stochastic aspects of collision to remain valid as $n\to\infty$, we expect [1] that the distribution in the two-dimensional $(n_F/\bar{n})-(n_B/\bar{n})$ plane would become more and more concentrated in a narrow region. For 540 GeV $\bar{p}p$ collisions this region is in the form of an ellipse as shown in Fig. 1(a). When $\bar{n}$ becomes large, it becomes thinner and eventually collapses into a line segment (Fig. 1(b)). This line segment is a collection of points, at each of which $n_F \simeq n_B$ and both n_F and n_B fluctuate only to the extent of $\sqrt{n_F}$ (i.e., like a stochastic distribution). For example, if $n = 2\times10^6$, then n_F could easily be as small as 0.5×10^6 or as large as 2×10^6. But in either case, one can predict that $n_B \simeq n_F$ with fractional

errors of the order $(\bar{n})^{-\frac{1}{2}} \sim 10^{-3}$.

Accepting this picture for very high energies, we see that for fixed n_F, the distribution of n_B is stochastic. How then is the energy partitioned in the backward hemisphere? We shall assume that the energy partition for each hemisphere for a fixed $z = (n_F + n_B)/\bar{n}$ is also stochastic but subject to a number of conditions: (a) that the total energy of all outgoing particles on each side is $E_0 h$, (b) Bloch-Nordsieck factor d^3p/E for each particle, and (c) transverse momentum (p_T) cutoff factor $g(p_T)$. In other words, the probability distribution for central particles on each side will be taken as

$$\delta(\sum_i E_i - E_0 h) \prod_i (d^3 p_i/E_i)\, g(p_{Ti}) \qquad (1)$$

where $E_0 = \sqrt{s}/2$, $E_0(1-h)$ = total energy of all leading particles, and $i = 1,2,\cdots$ ranges over all the particles (positive, negative, and neutral) on one side minus the leading particles. h is a parameter that describes the fraction of E_0 that fragments into <u>all</u> particles in the central region.

Now the mathematical problem (1) is well-known in statistical mechanics as describing a microcanonical ensemble. By the well-known Darwin-Fowler method the single particle distribution of such an ensemble is given by the canonical ensemble:

$$dn = K\ (d^3p/E)\ g(p_T)\ \exp(-E/T_p) \qquad (2)$$

where T_p will be called the partition temperature and K is a normalization constant. Notice that all particles, positive, negative, and neutral, kaons, nucleons as well as pions, share the same T_p.

<u>3. Comparison with Experimental Angular Distribution at 540 GeV.</u> As Fig. 1(a) shows, at the 540 $\bar{p}p$ collider, the distribution is still an ellipse. We shall nevertheless test the validity of (2) at 540 GeV by evaluating the single particle angular distribution from it. We write

$$dn/d\eta = 2\pi K \sin^2\theta \int_0^{E_0 h} p^2 (dp/E)\, g(p\sin\theta) \exp(-E/T_p) \qquad (3)$$

where η = pseudo-rapidity, $\cosh\eta = \csc\theta$, and

$$g(p\sin\theta) = \exp(-\alpha p\sin\theta). \qquad (4)$$

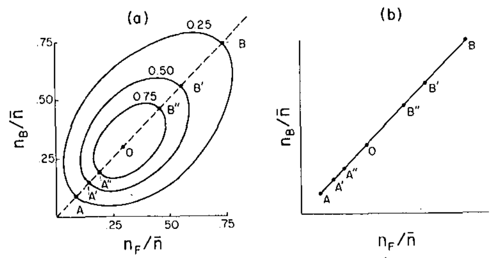

Fig. 1 Schematic diagram for forward-backward multiplicity distribution at very high energies. (a) The contour lines represent $P(n_F, n_B)$ at constant fractions of its maximum value at $\sqrt{s}$ = 540 GeV where $\bar{n} \simeq 29$. (b) The same contour lines degenerate to straight lines for extremely large $\bar{n}$.

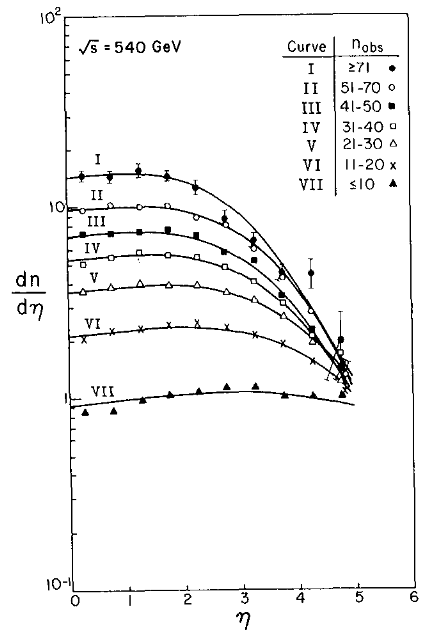

Fig. 2 Calculated and experimental dn/dη vs. η at $\sqrt{s}$ = 540 GeV.

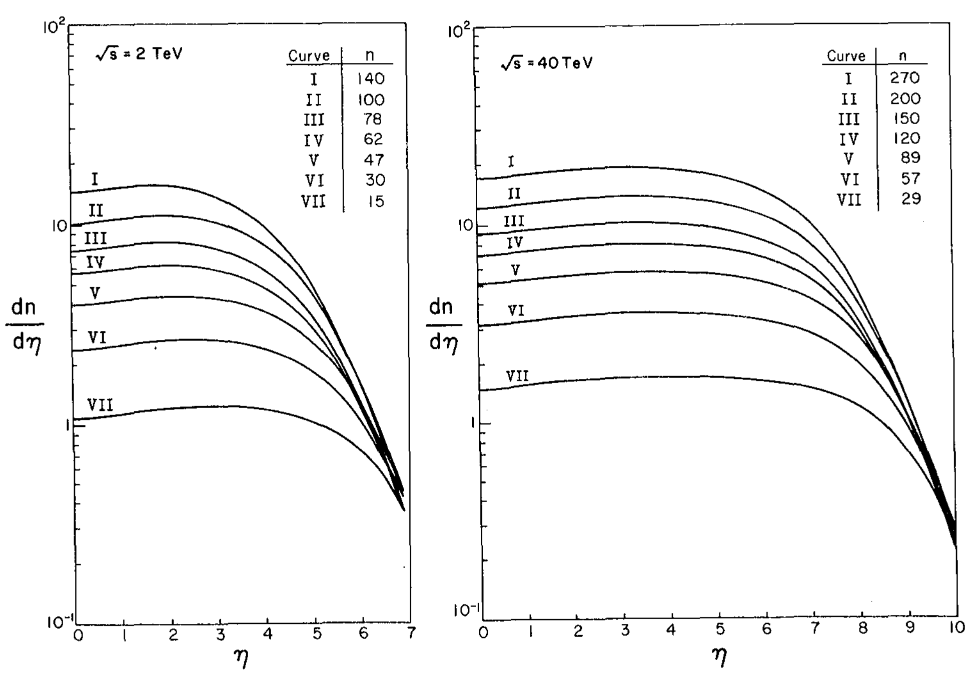

Fig. 3 Calculated dn/dη versus η at $\sqrt{s}$ = 2 TeV and 40 TeV.

We take α to be equal to 5.25(GeV/c)$^{-1}$. Only pions are included in this calculation. The angular distribution is evaluated from (3) and compared with the results [4] of UA5 in Fig. 2. It is found that the UA5 curve for each multiplicity n is well fitted by (3) for one value of T_p. We emphasize that there are no adjustable parameters in this computation, the cutoff α having been taken from experiments [5] concerning p_T distributions. The parameter h and normalization constant K are both determined from the curves themselves.

We conclude that the angular distribution (3) that results from (2) is in excellent agreement with experiment. Furthermore, we believe (2) would give a complete description of the single particle momentum distribution for central particles.

4. Extrapolation to Higher Energies. We made extrapolations of the angular distribution to $\sqrt{s}$ = 2 TeV (Tevatron) and 40 TeV (SSC). The assumptions made in these computations are as follows: (i) The values of α for these energies are taken to be 5.0 and 4.4 (GeV/c)$^{-1}$, respectively [5]. (ii) The parameter h is taken to be a function of the KNO variable $z = n/\bar{n}$ only. (iii) The values of $\bar{n}_{ch}$ for these energies are taken to be 41 and 78, respectively, by extrapolation. The results are presented in Fig. 3.

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