RISING PLATEAU FROM LONGITUDINAL PHASE-SPACE

A. BIAŁAS* AND A. KOTAŃSKI

Institute of Physics, Jagellonian University, Cracow**

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Longitudinal phase-space is used to study the energy dependence of the plateau in the rapidity distribution of particles produced in p-p collisions at laboratory momenta above 100 GeV. The density of particles emitted at 90° in cms shows a fast rise until 10000 GeV and then approaches the asymptotic limit very slowly. This rise accounts for a large fraction of the experimentally observed increase.

It is now well established that the Feynman scaling is not reached even up to the highest ISR energies [1, 2]. The density of particles in the central region of the rapidity plot increases approximately logarithmically with cms energy. In the present paper we argue that this increase can be partly understood in the uncorrelated cluster production model. In other words, a large part of the effect follows from the transverse momentum cut-off and the increase of available phase-space with energy.

The influence of phase-space on the density of particles in the central region has already been discussed. For instance, as stated in Ref. [3], in the multiperipheral cluster production model the rise of the plateau can be explained by the $t_{\min}$ effects. This explanation, however, depends on the detailed dynamical assumptions [4]. Therefore, it seems interesting to see how much of the rise is due to the simple kinematics and this motivates the present paper.

The uncorrelated jet model [5] has been used to describe the particle spectra by several authors [6]. In the present calculation the square of the matrix element for the production of N clusters in pp collision is taken as

$$|T_N|^2 = \frac{\lambda^N}{N!}(E_a+p_a^{\parallel})f_a(p_a^{\perp})(E_b-p_b^{\parallel})f_b(p_b^{\perp})\prod_{k=1}^{N} f(q_k^{\perp}). \tag{1}$$

Here λ is a constant determined from the average multiplicity, E_a, E_b, p_a, p_b are energies and momenta of the leading particles, f_a and f_b are the functions providing the transverse

* Also at the Institute of Nuclear Physics, Cracow.

** Address: Instytut Fizyki UJ, Reymonta 4, 30-059 Kraków, Poland.

momentum cutoff for the leading particles. The transverse cutoff for the clusters is supplied by $f(q_k^{\perp})$ which satisfy the normalization condition

$$\int f(q_k^{\perp})d^2q_k^{\perp} = 1. \tag{2}$$

The main results of the uncorrelated jet model are insensitive to the detailed form of the cutoff functions [7]. In our calculations we take[1]

$$f_a(p^{\perp}) = f_b(p^{\perp}) = \text{const } x \exp(-p^{\perp 2}/c^2),$$

$$f(q^{\perp}) = \frac{1}{\pi\kappa^2}\exp(-q^{\perp 2}/\kappa^2). \tag{3}$$

The single particle density is then expressed in terms of the phase-space integrals C_λ as follows

$$\frac{1}{\sigma}\frac{d\sigma}{d^2q^{\perp}dy} = \lambda f(q^{\perp})\frac{C_\lambda(P-q)}{C_\lambda(P)}, \tag{4}$$

where y is the cluster rapidity, P is the total four-momentum, q is the cluster four momentum and

$$C_\lambda(R) = \sum_{n=0}^{\infty}\int\frac{d^3q_1}{E_1}\cdots\frac{d^3q_n}{E_n}\frac{d^3p_a}{E_a}\frac{d^3p_b}{E_b}|T_n|^2\delta^4\left(R-\sum_{k=1}^{n}q_k-p_a-p_b\right). \tag{5}$$

The main technical problem here is the calculation of C_λ. We have used the method developed by de Groot [7, 8]. The results were checked by the Monte Carlo program of Jadach [9].

Fig. 1 shows the average multiplicity $\langle n\rangle$ of clusters as a function of incident momentum. It is seen that above $p_{lab} = 100$ GeV the average multiplicity is well described by the formula

$$\langle n\rangle = \lambda \ln\frac{s}{s_0}, \tag{6}$$

where $s = P^2$ and s_0 is a constant which depends on λ and on the average transverse cluster mass $M^{\perp}$. This relation allows us to determine both λ and $M^{\perp}$ from the experiment. Using the data from Ref. [10] and assuming that one π^- is emitted from each cluster we obtain $\lambda = 1.0$, $M^{\perp 2} = 2.0$ GeV^2.

Once we know the values of λ and $M^{\perp}$, we can calculate the cluster density. The results at $y = 0$ in the cms are compared with the data[2] from Ref. [1] in Fig. 2. It is seen

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[1] We have checked that very similar results are obtained for the exponential cutoff $\exp(-\beta q^{\perp})$.

[2] In Ref. [1] the data are given only in the region of $p^{\perp}$ from 0.045 GeV/c. The authors give also fits to their data using various functional forms of $p^{\perp}$ dependence. Since the $p^{\perp}$-integral values of the plateau density are needed for the comparison with the model, we have integrated the two best fits given in Ref. [1].

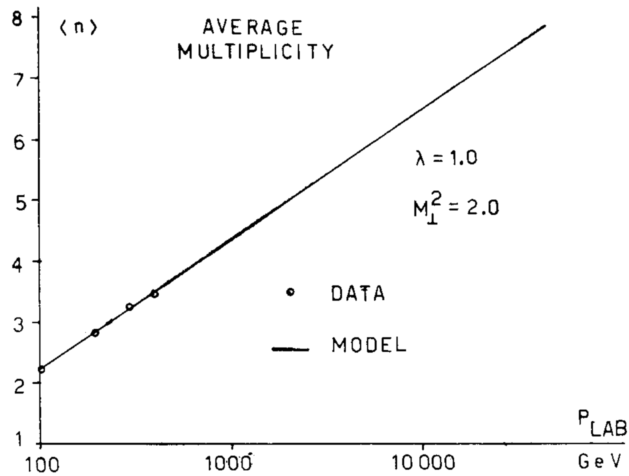

Fig. 1. Average multiplicity as calculated from the model vs. incident energy. The experimental data are taken from Ref. [10]

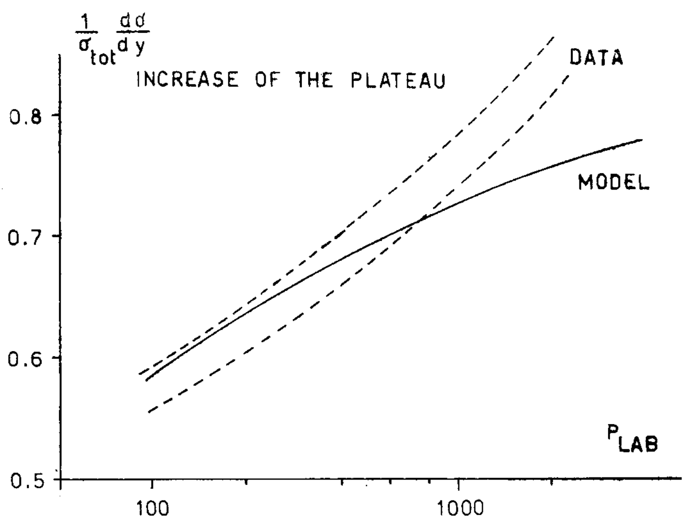

Fig. 2. The particle density in the rapidity variable at 90° of cms production angle, integrated over $p^\perp$. The broken lines are obtained by integrating the fits of Ref. [1] over $p^\perp$, as described in the text. The upper curve is for $As^\alpha \exp(B\mu^\perp)$ and the lower curve is for $As^\alpha \exp(Bp^\perp + Cp^{\perp 2})$. The continuous line is the result of our calculation

that the calculated density increases between $p_{lab} = 100$ GeV and 2000 GeV by a factor of about 1.3. This increase is not sufficient to explain the data of Ref. [1] where a factor of ~ 1.45 is observed in the same momentum range. It should be emphasized, however, that the calculated increase is quite substantial and should be taken into account in the analysis of the data.

We conclude that the uncorrelated jet model can explain a large fraction of the observed increase with energy of the density of particles produced in the central region of rapidity. We consider this to be a success of the model taking into account that the only dynamical ingredients of the model are: (*i*) the limitation of transverse momenta, (*ii*) the clustering of produced particles and (*iii*) the leading particle effect.

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REFERENCES

[1] K. Guettler et al. British-Scandinavian-MIT Collaboration, *Phys. Lett.* **64B**, 111 (1976).
[2] L. Michejda, *Nucl. Phys.* **B35**, 287 (1971).
[3] L. Caneschi, *Nucl. Phys.* **B68**, 77 (1974).
[4] M. Le Bellac, K. Zalewski, private communication.
[5] L. Van. Hove, *Rev. Mod. Phys.* **36**, 655 (1964).
[6] Th. W. Ruijgrok, *Nucl. Phys.* **B27**, 45 (1971); E. H. de Groot, Ph. D. Thesis, Utrecht 1971; J. Benecke, private communication.
[7] E. H. de Groot, *Nucl. Phys.* **B48**, 295 (1972).
[8] J. Benecke, Proceedings of the XVIII Int. Conf. on High Energy Physics, Tbilisi 1976, p. A3-12 and preprint MPI-PAE/PTh 28/76, Munich 1976.
[9] S. Jadach, *Comput. Phys. Commun.* **9**, 297 (1975).
[10] P. Stix, T. Ferbel, *Phys. Rev.* **D15**, 358 (1977).
[11] D. R. O. Morrison, *Proc. R. Soc.* **A335**, 461 (1973).