EVIDENCE FOR STRONG CORRELATIONS IN HIGH ENERGY NON-DIFFRACTIVE MULTIPLE PRODUCTION PROCESSES*

By J. Bartke, A. Zalewska and K. Zalewski

Institute of Nuclear Physics, Cracow**

(Received April 13, 1973)

It is pointed out that the recent data on topological cross-sections in pp collisions indicate not only the presence of a diffractive component, but also strong correlations in the pionization process itself.

The study of multiplicity distributions for particles produced in high energy hadron-hadron collisions yields valuable data for testing models [1]. The prong number distributions in pp interactions at the Serpukhov and NAL energies have been successfully fitted [2], [3], [4] using the two-component model [5]. In this approach a model for pionization is applied to predict the multiplicity distributions obtained after subtracting the diffractive contributions. The success of the two-component model depends of course on the quality of the model chosen to describe pionization. Thus *e. g.* Karczmarczuk [6] has shown recently that the uncorrelated jet model is unable to fit the high multiplicity tail of the prong number distribution. Consequently, if diffractive processes contribute to low multiplicity channels only, the uncorrelated jet model is unsuitable for the two-component model.

In this note the simple remark is made that any model for pionization, which predicts

$$f_2^{\text{ch}} = \langle (\langle n_{\text{ch}} \rangle - n_{\text{ch}})^2 \rangle - \langle n_{\text{ch}} \rangle \approx -Q \tag{1}$$

fails to fit the data. In formula (1) n_{ch} is the number of charged particles (prong number) in the final state, the brackets $\langle\ \rangle$ denote averaging over the non-diffractive events, Q denotes the total charge in the final state counted in elementary charge units, and the correlation parameter f_2 [1] is defined by the first equality in formula (1). The second equality in formula (1) would hold exactly, if the multiplicity distribution for the charged particles produced in the process were strictly Poissonian. This would correspond [1] to a completely

* Part of this work has been presented at the III International Colloquium on Multiparticle Reactions, Zakopane 1972.

** Address: Instytut Fizyki Jądrowej, Kawiory 26a, 30-055 Kraków, Poland.

uncorrelated production of charged particles. We show, however, by numerical examples that many of the so-called weakly correlated models also predict (1) and are consequently ruled out by the data.

The argument is as follows. From charge conservation the number of negative particles is

$$n_- = \tfrac{1}{2}(n_{ch} - Q). \tag{2}$$

Consequently the correlation parameter f_2 for negative particles, which is the one usually compared with experiment, is given by the formula

$$f_2^- = \tfrac{1}{4} f_2^{ch} - \tfrac{1}{2}\langle n_-\rangle + \tfrac{1}{4} Q \approx -\tfrac{1}{2}\langle n_-\rangle, \tag{3}$$

where the approximate equality follows from (1). Thus the correlation parameter f_2 is negative and increases in absolute value with increasing $\langle n_-\rangle$. The fits to the experimental

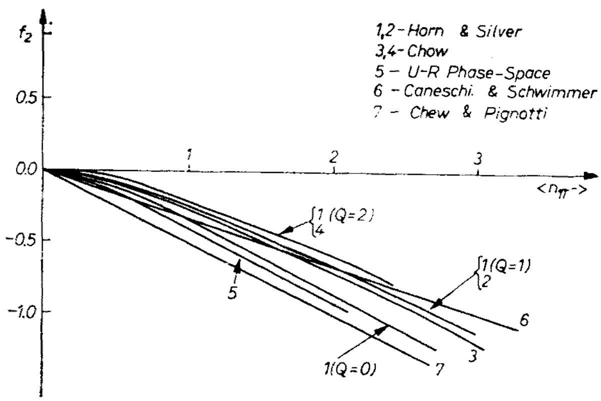

Fig. 1. For negative pions produced in pp collisions the correlation parameter f_2 is plotted against the average multiplicity. The curves are the predictions of the weakly correlated models described in the Appendix

data within the framework of the two-component model give, at least in the high energy region, $f_2^- \geqslant 0$ [2], [3], [4]. Thus prediction (3) corresponds to a too narrow prong multiplicity distribution in the non-diffractive component.

In Fig. 1 the values of f_2^- predicted by nine weakly correlated models are presented. The models are defined in the Appendix. They are based on different physical assumptions, but, as may be seen from the figure, give similar predictions for the dependence of f_2^- on $\langle n_-\rangle$. This observation indicates that the correlation parameter f_2 is not very sensitive to the details of the model, but rather reflects the general assumptions about the strength of the correlations. All the models considered here give results similar to prediction (3) and consequently share the disease caused by assumption (1).

To summarize: the weakly correlated models considered in this paper give prong number distributions which are much narrower than those required to fit the experimental data. In order to fit the data both the production of high multiplicities and the production of low multiplicities must be enhanced. Within the framework of the two-component model the low multiplicities are easily supplied by the diffractive processes. In order to reproduce the high multiplicities distribution, however, it is necessary to guess some correlations in the non-diffractive process itself. Most of the successful two-component models [2], [3] fit the data assuming strong correlations in pairs of oppositely charged particles (local charge conservation [14]) and no correlation between the pairs. Harari and Rabinovici [4], however, find evidence for additional correlations between pairs. At high energies these correlations give an additional enhancement to high multiplicity events. It is an interesting question whether an extrapolation from the present data will agree with higher energy data. *A priori* it is not improbable that with increasing energy more and more complicated correlations within the pionization component will have to be included. The ISR data should shed some light on this problem.

The authors thank Professor A. Białas for his valuable collaboration in the initial stages of this work. They are also grateful do Dr L. Caneschi for an exchange of letters concerning the predictions of the multiperipheral models, and to Dr K. Fiałkowski for reading the manuscript.

APPENDIX

In this Appendix the models used for the computation of the curves shown in Fig. 1 are described. For simplicity it is assumed that pions only are produced.

Let us write the cross-section for the inelastic process, in which n_+ positive pions, n_- negative pions and n_0 neutral pions are produced, in the form

$$P(n_+, n_-, n_0) = N \frac{\bar{n}^{(n_+ + n_- + n_0)}}{(n_+ + n_- + n_0)!} W(n_+, n_-, n_0). \tag{A1}$$

Here N is a normalization constant, $\bar{n}$ is a function of energy and the weights $W(n_+, n_-, n_0)$ are in some models normalized by the condition

$$\sum_{n_+, n_-, n_0} W(n_+, n_-, n_0) = 1 \tag{A2}$$

for $n_+ + n_- + n_0 = n$.

We have considered the following models.

i) The model proposed by Kastrup [7] and developed by Horn and Silver [8]:

$$W(n_+, n_-, n_0) = \frac{(n_+ + n_- + n_0)!}{n_+! n_-! n_0!} \varepsilon(n_+, n_-, n_0). \tag{A3}$$

The factor ε ensures charge conservation. It is equal one for a given value of $\bar{Q} = n_+ - n_-$, and zero otherwise. There are three variants of this model corresponding to $\bar{Q} = 0, 1, 2$.

ii) A similar model, where the non-zero value of ε equals a constant C, and C is determined from the normalization condition (A2). This ensures that the distribution of total multiplicities is Poissonian. Here again there are three possibilities corresponding to $\bar{Q} = 0, 1, 2$. We have calculated an average over them.

iii) The model described by Chow [9] and Chow and Rix [10].

$$W(n_+, n_-, n_0) = C\frac{1+2(n_+-n_-)-(n_+-n_-)^2}{n_+!n_-!n_0!} \times$$

$$\times 2^{-(n_+ + n_-)} \int_{-1}^{+1} (1+x)^{n_+ + n_- + 2} x^{n_0} dx \tag{A4}$$

for $0 \leqslant n_+ - n_- \leqslant 2$ and zero otherwise. Here the constant C is found from condition (A2) and the charge branching ratios are taken from the statistical model [11]. Since isospin is explicitly included, one avoids the three variants.

iv) This model uses formula (A4) with $C = 1$.

v) This model uses formula (A4) with

$$C = D[(n_+ + n_- + n_0 + 1)!]^{-1}, \tag{A5}$$

where the constant D is determined from condition (A2). This is equivalent to the use of ultrarelativistic phase space integrals instead of the Poisson distribution for the total multiplicities.

vi) Model H from Ref. [12]. In this model for high energies

$$f_2 \approx -\tfrac{1}{2}\langle n_- \rangle. \tag{A6}$$

vii) The model of Chew and Pignotti [13] named model A in Ref. [12]. In this model at high energies

$$f_2 \approx -\tfrac{1}{3}\langle n_- \rangle. \tag{A7}$$

REFERENCES

[1] A. H. Mueller, *Phys. Rev.*, **D4**, 150 (1971).
[2] K. Fiałkowski, H. I. Miettinen, *Phys. Letters*, **43B**, 61 (1973).
[3] C. Quigg, J. D. Jackson, *On a Two-Component Interpretation of Multiplicity Distributions*, NAL preprint, October 1972.
[4] H. Harari, E. Rabinovici, *Phys. Letters*, **43B**, 49 (1973).
[5] K. G. Wilson, Cornell preprint CLNS – 131 (1970), unpublished.
[6] J. Karczmarczuk, *Nuovo Cimento Letters*, **6**, 524 (1973).
[7] A. H. Kastrup, *Nuclear Phys.*, **B1**, 309 (1967).
[8] D. Horn, R. Silver, *Phys. Rev.*, **D2**, 2082 (1970).
[9] G. Y. Chow, *Nuovo Cimento Letters*, **3**, 545 (1970).
[10] G. Y. Chow, J. Rix, *Phys. Rev.*, **D2**, 139 (1970).
[11] F. Cerulus, *Nuovo Cimento*, **19**, 528 (1961).
[12] L. Caneschi, A. Schwimmer, *Phys. Rev.*, **D3**, 1588 (1971).
[13] G. F. Chew, A. Pignotti, *Phys. Rev.*, **176**, 2112 (1968).
[14] C. P. Wang, *Phys. Rev.*, **180**, 1463 (1969).