MUON-PROTON COLLISIONS
EXHIBITING LEADING PARTICLE EFFECT

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The data on charged hadronic multiplicities as well as on the dispersion in $\mu^+ p$ collisions at the cms energies from 4 to 20 GeV are considered in the frame of the quantum statistical bosonic approach including the influence of the leading particle effect. The experimental results on the dispersions cannot be explained within the original KNO scaling hypothesis nor with the energy independent leading particle effect. Starting from the requirement that the theoretical dispersions should be equal to the observed ones (at all published energies) we arrive at a good theoretical representation of the observed KNO like density distribution. At the same time, the variation of the average charged multiplicity with energy implies the oscillation of the parameter measuring the leading particle effect.

1. INTRODUCTION

The European Muon Collaboration on the NA 9 experiment at the SPS at CERN has published recently the data on the secondary charged hadronic multiplicities as well as on the dispersions $D_2$ in $\mu^+ p$ collisions at the cms energies from 4 to 20 GeV [1]. The aforementioned multiplicities are usually presented in the form of the KNO plot,

\[
\langle n \rangle P(n) = \psi(z = n/\langle n \rangle) \text{ vs. } z
\]

where $\psi$ should be independent of the energy.

In the frame of the KNO scaling hypothesis [2] the dispersions $D_2$, \n
\[
D_2 = \langle n^2 \rangle - \langle n \rangle^2)^{1/2}
\]

depend linearly on the average multiplicity $\langle n \rangle$,

\[
D_2 = \text{const. } \langle n \rangle.
\]

Even if there can be found [1] relatively good representation of the observed multiplicities in terms of the KNO variables, rel. (1), the observed dispersions $D_2$ do not fall on the linear dependence (3) involving an energy independent constant. This constant usually contains the parameters specifying the concrete form of the KNO scaling distribution. It is possible to preserve rel. (3) if the multiplicative constant is changed with the average multiplicity (i.e. with the energy); however, in this case the variation of the energy implies the variation of the KNO scaling curve.

The leading particle effect introduced by Wroblewski [3] in the analysis of the pp collisions data leads to the expression

\[
D_2 = \text{const. } (\langle n \rangle - z)
\]

where $z$, the measure of this effect [4], in the case of the hadron-hadron collisions
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fulfils the inequality $0 \leq \alpha \leq 2$. For the lepton-hadron collisions under consideration we take

$$0 \leq \alpha \leq 1.$$  

(5)

Bearing in mind the published values of $\langle n \rangle$ and $D_2$, the effort to preserve rel. (4) with energy independent both the multiplicative constant as well as the measure of the leading particle effect $\alpha$ [5] at all energies observed in [1], leads to the value $\alpha \leq -1$ which does not fulfil the inequality (5) and therefore this case will be not considered here anymore.

2. QUANTUM STATISTICAL BOSONIC MODEL INVOLVING THE INFLUENCE OF THE LEADING PARTICLE EFFECT

To describe the observed values of the dispersions $D_2$ as well as of the corresponding density distribution in the $\mu^+p$ collisions under consideration, we adopt the quantum statistical bosonic model including the influence of the leading particle effect. In a simplified version of this approach the outgoing particle (lepton) is characterized by a pure M-mode coherent field while the charged particles produced in this collision are characterized by a superposition of the M-mode stochastic and coherent fields. The average number of charged particles $\langle n \rangle$, produced in this collision consists of two parts, $\langle n \rangle = \langle n_T \rangle + \langle n_C \rangle$ where $\langle n_T \rangle$ represents the mean occupation number of the stochastic (thermal) field, $\langle n_C \rangle$. $\alpha^2$ represents the mean occupation number of coherent component of the superposition while that of the purely coherent field is $\alpha = \langle n_C \rangle . (1 - \alpha^2)$. The full occupation number in coherent fields is $\langle n_C \rangle . \alpha^2 + \langle n_C \rangle . (1 - \alpha^2) = \langle n_C \rangle$.

In this case, instead of rel. (1) the following relation is taken into account,

$$\langle n \rangle - \alpha P(n) = \psi(z_a) = (n - \alpha)[(\langle n \rangle - \alpha)]$$  

(6)

where $P(n)$ is the probability to observe $n$ charged particles and the scaling function $\psi$ is expressed in the form [6]

$$\psi(z_a) = M(1 + R_2^2) \cdot (\xi_a/R_2)^M \cdot \exp \left[ -M(\xi_a^2 + R_2^2) \right] \cdot I_{M-1}(2MR_2\xi_a)$$  

(7)

where $R_2^2 = (\langle n_C \rangle/\langle n_T \rangle)(1 - \alpha/\langle n_C \rangle)$ and

$$\xi_a = [z_a \cdot (1 + R_2^2)]^{1/2}.$$  

(8)

In rel. (7), $I_p(x)$ represents the modified Bessel function of the first kind. We note that the scaling function (7) depends only on two parameters, $M$ and $R_2$ while $\alpha$, the measure of the leading particle effect as well as the average multiplicity $\langle n \rangle$ are contained only in the variable $z_a$ (compare rel. (6)) entering rel. (8).

Having fixed the fundamental set of parameters

$$\langle n \rangle, \quad R_2, \quad \alpha$$  

(9)

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