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ON THE UNIVERSAL DESCRIPTION OF SEMI-INCLUSIVE π° PRODUCTION IN 5-205 GeV/c π^{-}p INTERACTIONS

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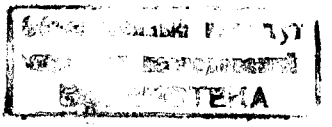

The inclusive approach suggested in [1,2] has been found to be greatly fruitful for the study of the multiparticle production processes. One of the most interesting results obtained in the framework of this approach is the scaling law of Koba, Nielsen and Olesen (the KNO-scaling) [3]. For simultaneous production of k kinds of secondary particles it states that

$$\langle n_1\rangle\langle n_2\rangle\ldots\langle n_k\rangle \frac{\sigma(n_1,n_2,\ldots,n_k)}{\sigma_{in}} \underset{s\to\infty}{\to} \psi\left(\frac{n_1}{\langle n_1\rangle}, \frac{n_2}{\langle n_2\rangle}, \ldots, \frac{n_k}{\langle n_k\rangle}\right), \quad (1)$$

where s is a total c.m.s. energy squared; $n_i(\langle n_i\rangle)$, multiplicity (average multiplicity) of i-th kind of particles; $\sigma(n_1, n_2, \ldots, n_k)$, cross section for the simultaneous production of n_1, $n_2, \ldots, n_k$ particles; σ_{in}, total inelastic cross section; ψ, the function independent explicitly of energy.

The analysis of data on charged particle multiplicity has revealed that the KNO-scaling holds within few per cent at high energies ($\gtrsim$ 50 *GeV*)[4]. Moreover, the phenomenologically motivated modification of the KNO-scaling seems to work starting from few *GeV* [5]. It should be pointed out that relation (1) has been derived under assumptions not fulfilled at present accelerator energies. The experimental evidence for the early onset of the apparent KNO-scaling can be therefore treated either as the existence of a more general regularity or as a transitory coincidence of the data violated with a further increase of energy.

The simultaneous analysis of neutral and charged particle production within the framework of relation (1) gives an additional possibility for the more detailed study of KNO-scaling. However, there are practically no data on multiplicity distributions of neutral particles dominated by neutral pions.

There are available only data on the semi-inclusive cross sections of the neutral particle production $\sigma_n(j) = \sigma_n \langle n_j \rangle_n$ (σ_n are topological cross sections, $\langle n_j \rangle_n$ is the average multiplicity of the j-th kind of neutral particles in the given topology).

Taking into account this situation Dao and Whitmore have shown /6/ that the application of relation (1) particularly for the description of $\sigma_n(\pi^\circ)$ results in the scaling relation

$$\frac{\langle n \rangle \sigma_n(\pi^\circ)}{\langle n_0 \rangle \sigma_{in}} = F\left(\frac{n}{\langle n \rangle} = z, s\right) \underset{s \to \infty}{\to} \phi(z), \qquad (2)$$

where $\langle n \rangle$ ($\langle n_0 \rangle$) is the average multiplicity of charged particles (π°-mesons), $\phi(z)$ is a function explicitly independent of energy.

The function $\psi(z)$ in the case of charged particles is normalized by the conditions

$$\int_0^\infty \psi(z)dz = \int_0^\infty z\psi(z)dz = 2. \qquad (3)$$

It can be shown that the analogous integrals for the function $\phi(z)$ are equal to

$$I_1 = \int_0^\infty \phi(z)dz = 2,$$
$$I_2 = \int_0^\infty z\phi(z)dz = 2\left[1 + \lim_{s\to\infty} \frac{f_2^{oc}}{\langle n \rangle \langle n_0 \rangle}\right], \qquad (4)$$

where $f_2^{oc} = \langle n_0 n \rangle - \langle n_0 \rangle \langle n \rangle$ is the correlation integral.

Since there is a strong positive correlation between neutral pions and charged particles at high energies, $I_2 > 2$.

The scaling prediction (2) has been examined by using pp-data above 50 *GeV/c* and $\bar{p}p$ data at 15 *GeV/c* /6/. All these data were satisfactorily fitted by a single curve parametrized in the form of

$$\phi(z) = a_0 \exp\left(\sum_{\ell=1}^{4} a_\ell z^\ell\right), \qquad (5)$$

where a_ℓ ($\ell = 0, \ldots, 4$) are parameters.

The approximation of $\pi^- p$ data at 40 *GeV/c* /7/ with function (5) has given results similar (in a sense of parameter values) to those of ref. /6/. Scaling relation (2) holds for neutral strange particle production at high energies too /8/. The similarity of the function $\phi(z)$ for π°, K°_S and Λ° has been observed /9/.

In order to investigate the problem of universality of the scaling law (2) within a wider range of energy we have analysed data on π° yields in $\pi^- p$-interactions at the momenta of 5, 18.5 /10/, 25 /11/, 40 /12/, 100 /13/ and 205 /14/ *GeV/c*. The data at 5 *GeV/c* are based on our recent results obtained using the JINR one-meter propane bubble chamber (see, ref. /15/ and quoted refs. there).

Figure 1 shows the experimental distributions $F(z, s)$ for $\pi^- p$ – interactions in comparison with the curve obtained from fitting the pp and $\bar{p}p$ data /6/.

The following features have been revealed in the analysis of these distributions:

- good agreement of $\pi^- p$ data at the momenta of $p_{\pi^-} \geq 40$ *GeV/c* with the pp-curve;
- the systematic deviations of the data from that curve at the momenta below 40 *GeV/c*;
- increase of these deviations with the decrease of energy;
- the shape of the $F(z, s)$ distributions practically independent of energy.

These regularities observed in the behaviour of experimental data give a reason to suppose that the analytical description of the difference of the $F(z,s)$ distributions may be achieved introducing an energy dependent z-axis shift. Therefore, we introduce the new variable

$$z_1 = z + \frac{a}{\langle n \rangle^\beta}, \qquad (6)$$

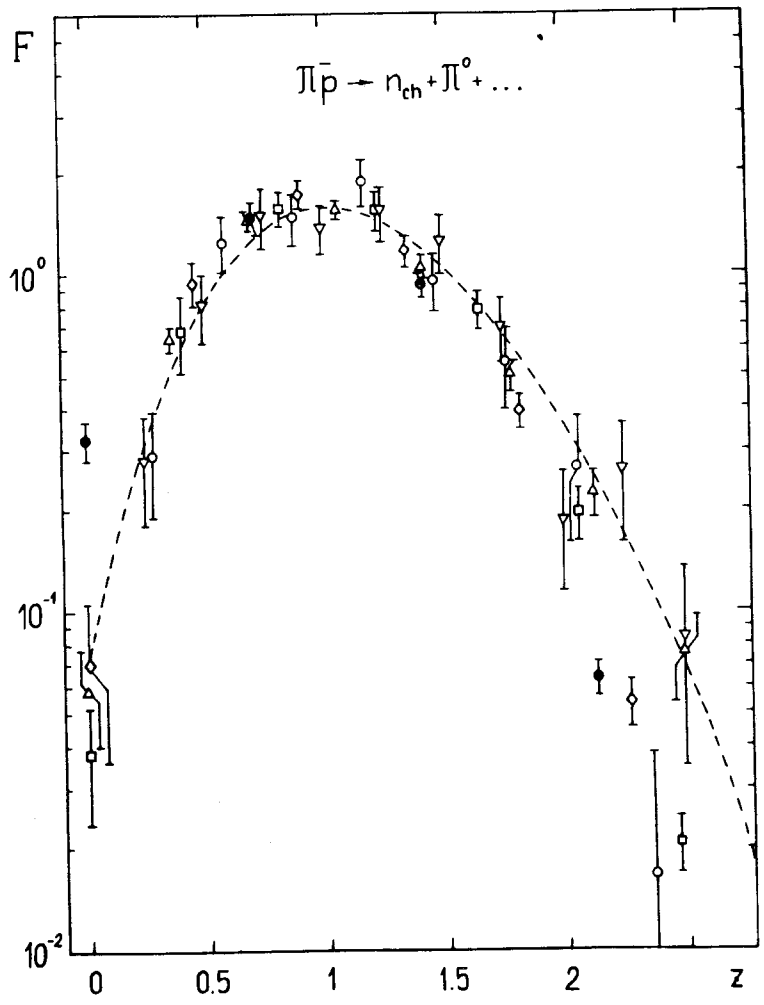

Fig. 1. Plot of $\langle n \rangle \sigma_n (\pi^0) / \langle n_0 \rangle \sigma_{in}$ *versus* $z = n/\langle n \rangle$ *for* $\pi^- p$ *collisions at 5 GeV/c - ●, 18.5 GeV/c - ◇, 25 GeV/c - □, 40 GeV/c - △, 100 GeV/c - ○, and 205 GeV/c - ▽. The curve shows the results of fitting the* pp *and* $\bar{p}p$ *data* /6/.

where α, β are energy independent parameters. Note that in asymptotics $z_1 \to z$. Taking additionally into account that the cross sections of inelastic processes with a small charged multiplicity decrease rapidly with increasing energy* and assuming analogous behaviour in the asymptotic region let us choose the following parametrization of the function $\phi(z_1)$:

$$\phi(z_1) = b_0 z_1 \exp\left(\sum_{\ell=1}^{m} b_\ell z_1^\ell\right), \qquad (7)$$

where $b_\ell (\ell = 0, \ldots, m)$ are parameters.

Under these assumptions we have achieved a universal description of all the $\pi^- p$ data in the 5-205 *GeV/c* momentum region. The best results of the least squares fit have been reached by using $\beta = 2$. In this case with $m = 2$ we have the statistically reasonable fit ($P(\chi^2) = 0.22$) of all the existing experimental data in the interval $z_1 < 2.6$ by the function (7) with the following parameter values: $b_0 = 0.68 \pm 0.08$, $b_1 = 2.55 \pm 0.16$, $b_2 = -1.65 \pm 0.05$, $\alpha = 1.81 \pm 0.18$. The values of the normalization integrals (4) are equal to $I_1 = 1.96$ and $I_2 = 2.20$. Increasing the number of free parameters m in (7) leads to no statistically significant improvement of results.

The experimental distributions $F(z_1, s)$ together with the obtained curve $\phi(z_1)$ are shown in *Fig. 2.*

The agreement of the $\phi(z_1)$ function with an individual experimental distributions is illustrated by the quantities "χ^2/ the number of points" which (in order to increase energy) are equal to 5.4/4, 1.2/6, 5.7/7, 16.2/8, 8.2/8, 7.6/10. The values quoted indicate the successful choice of the $\phi(z_1)$ function parametrization.

Let us summarize the basic results of this paper.

1. The analysis of experimental data indicates the similarity of the $F(z, s)$ distributions for $\pi^- p$ interactions in the energy region of 5-205 *GeV.*

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* For example, the topological cross section σ_0 falls two orders of magnitude if the energy increases from 5 to 205 *GeV.*

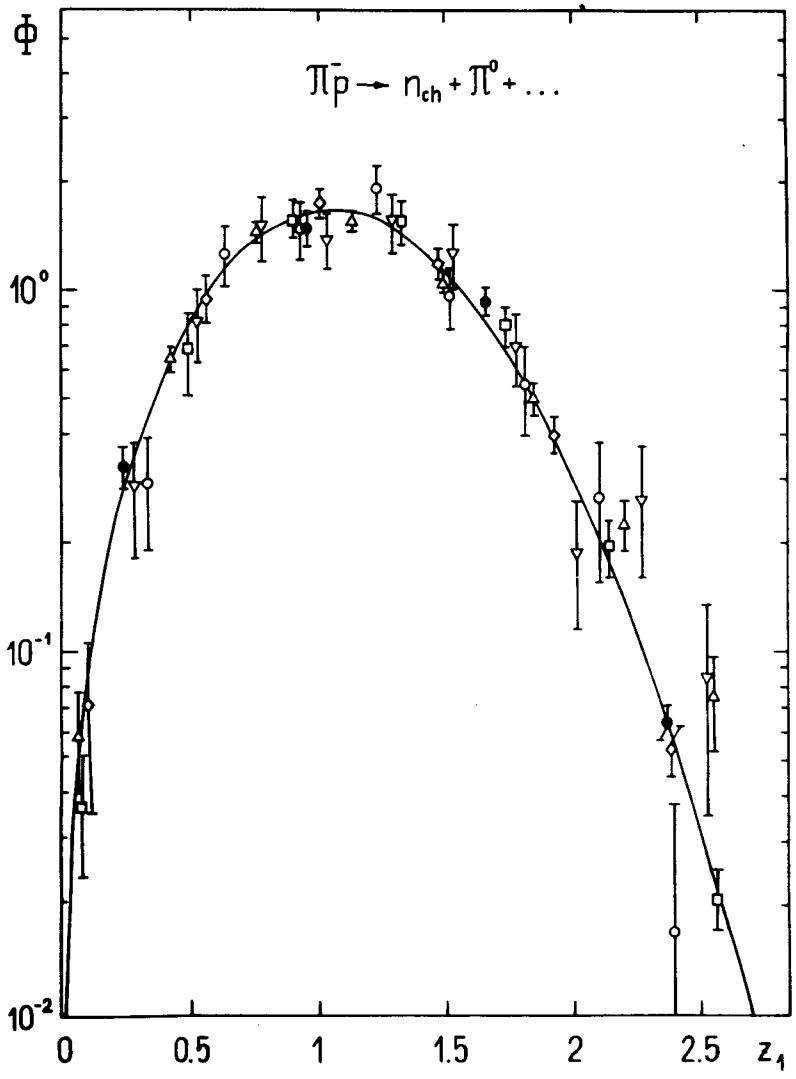

Fig. 2. Plot of $\langle n\rangle\sigma_n(\pi^\circ)/\langle n_0\rangle\sigma_{in}$ *versus* $z_1 = z + a/\langle n\rangle^2$ *for* $\pi^- p$ *collisions. The symbols used for experimental points are the same as in fig. 1. The curve shows the best fit of* $\pi^- p$ *data by the function (7) with* $m = 2$.

2. The suggested scale transformation $z_1 = z + \frac{a}{\langle n\rangle^2}$ has given the possibility of the universal description of all available $\pi^- p$ data.

3. Under the assumption that the function $\phi(z_1)$ should reflect the $F(z,s)$ asymptotic form our results can be interpreted as the quantitative description ($\sim\langle n\rangle^{-2}$) of the possible way by which the $F(z,s)$ distribution approaches asymptotics.

In conclusion it is worth noting that the performed analysis evidences in favour of the multiparticle production study at the moderate energies, too.

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