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ON SIMULTANEOUS DESCRIPTION OF ELASTIC SCATTERING AND INCLUSIVE PROCESSES

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Аннотация.

Саврин В.И., Семенов С.В., Тюрин Н.Е.
О совместном описании упругого рассеяния и инклюзивных процессов. Серпухов, 1975.
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С помощью формулы, полученной ранее в рамках модели независимого рождения частиц, вычисляется инклюзивное распределение по поперечному импульсу вторичной частицы. Результаты вычислений сравниваются с экспериментальными данными.

Abstract

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Inclusive distribution in transverse momentum of a secondary particle is calculated with the help of the formula obtained earlier within the framework of particle independent production model. The calculation results are compared with the experimental data.

Multiple production of particles is a characteristic feature of elementary particle interaction at high energies. Even when describing elastic scattering of two particles we cannot neglect multiple production of particles. Moreover, within the limits of high energies these are just the processes that become decisive in the course of two-particle reactions.

Let us treat unitary conditions for partial amplitude of elastic scattering of two hadrons.

$$\mathrm{Im}\, f_\ell(p) = p^2 |f_\ell(p)|^2 + \frac{1}{4p}\, \eta_\ell(p)\,, \qquad (1)$$

where p is the incident particle momentum in the c.m.s., and η_ℓ is an explicit contribution of all inelastic channels in interaction of two hadrons. There are experimental indications to the fact that within the limits of high energies $p \to \infty$ the amplitude of elastic scattering becomes pure imaginary. From relation (1) it can easily be seen that in this case the amplitude f_ℓ is mainly determined by the contribution of inelastic channels η_ℓ /1/.

The presence of multiparticle intermediate states in unitary condition results in the fact, that elastic scattering phases become complex and we speak about absorption at elastic scattering. The imaginary part of the phase is connected with the contribution of inelastic channels via a simple relation:

$$\mathrm{Im}\,\delta_\ell = -\frac{1}{4}\ln(1-\eta_\ell) \qquad (2)$$

In the case of a pure absorption the phases δ_ℓ are totally defined by the functions η_ℓ.

When there are inelastic processes interaction between two hadrons is described by a complex potential. Within the limits of high energies this potential is fully determined by the contribution of inelastic channels to unitary condition /2/.

Thus we see that owing to unitary condition, there exists a sufficiently tight connection between the production processes and elastic scattering. However this connection is too general and is of little importance for concrete calculations, that might be checked experimentally. Indeed, the state of things even in the future when we will know the experimental values for the amplitudes of all the possible inelastic channels in the given reaction can hardly be imagined. In this sense the magnitude η_ℓ is practically unobservable. However we managed to estimate theoretically the dependence of contributions of separate channels of the given reaction[3] on ℓ basing on probabilistic treatment of scattering.

Some years ago within the framework of the model of independent emission of mesons[4] there was obtained another connection between elastic and inelastic processes that is of quite a different nature as the one considered above. The imaginary part of the scattering phase was connected with the mean number of mesons, produced in collision of two nucleons at the state with the given angular momentum ℓ .

$$\mathrm{Im}\, \delta_\ell = \frac{1}{4}\bar{n}_\ell \tag{3}$$

Additional model notions of dynamics of nucleon interaction presented in ref.[5] allowed us to present formula (3) in the following form:

$$\mathrm{Im}\, \delta(b) = \frac{1}{4}\, g^2(\frac{1}{2}b) \tag{4}$$

where $g(\xi)$ is hadronic matter distribution on nucleon in the plane perpendicular to the direction of motion, and b is the impact parameter, that can be treated as equal to ℓ/p within the high energy limits.

Thus we got a possibility to connect the phases of elastic scattering with the internal structure of interacting hadrons. Some other connection between these characteristics was proposed by Chou and Yang[6]. However as we will see now formula (4) turns out to be more convenient in describing both elastic and inelastic collisions. The thing is that in the framework of the model considered here transverse momentum inclusive distribution of one of the produced particles is also connected with the matter distribution on nucleon through the following formula

$$\frac{d\sigma}{d\vec{\varkappa}} = \frac{1}{(2\pi)^2}\,\bar{g}^2(\varkappa) \tag{5}$$

where $\vec{\varkappa}$ is a transverse momentum, and

$$\bar{g}(\varkappa) = \int d\vec{\xi}\, e^{-i\vec{\varkappa}\vec{\xi}}\, g(\xi) \tag{6}$$

$\vec{\xi}$ is a two-dimensional vector in the plane, perpendicular to the direction of motion.

Having compared formulae (4) and (5) we have

$$\mathrm{Im}\,\delta(b) = \left(\frac{1}{2}\int \varkappa d\varkappa J_o\left(\frac{1}{2}b\varkappa\right)\sqrt{\frac{d\sigma}{d\vec{\varkappa}}}\right)^2 \tag{7}$$

Here we have assumed, that $\frac{d\sigma}{d\vec{\varkappa}}$ depends on $|\vec{\varkappa}|$ only. Thus we have obtained the relation that expresses the imaginary part of elastic scattering phase through inclusive distribution, i.e. the characteristics of multiple production processes. On the contrary to the contribution of inelastic channels to unitary condition inclusive reaction can directly be measured in experiment.

In the framework of the formulae enlisted here we may solve a reversal problem on calculating transverse momentum distribution for a given imaginary phase of elastic scattering in inclusive one-particle process.

Having performed some simple transformations we will obtain

$$\frac{d\sigma}{d\varkappa} = \left(\frac{1}{2}\int b\,db\,J_o\left(\frac{1}{2}\varkappa b\right)\sqrt{\operatorname{Im}\delta(b)}\;\right)^2 \qquad (8)$$

Thus if we are able to reconstruct the scattering phase, as the function of incident momentum p and impact distance $b = \ell/p$ from the experimental data on elastic scattering of two hadrons at high energies, then with formula (8) we will know momentum distribution of the secondary particle, produced in collision of these hadrons. It is worth noticing that because of ambiguities of normalization factor in the expression for distribution density of secondaries in the general case, the RHS of formula (8) will contain a multiplier dependent on energy.

The results on the experimental check of relation(8) in the domain of small momentum transfers are presented in figs. 1-3. The points in the figs. stand for the values integrated over transverse momentum of inclusive cross section in $pp \to \pi^- X$ reaction, P lab. being 102 GeV/c (taken from ref./7/). Solid lines illustrate the inclusive cross section, calculated with (8).

The results of different models of elastic pp scattering are taken as expressions for the phase. In ref./8/ elastic pp scattering phase at high energies was obtained by summing the diagrams of quantum electrodynamics. Here $\mathrm{Im}\,\delta(b) = a(s)\,e^{-\lambda\sqrt{b^2+x_o^2}}$ ($\lambda = 0.6$; $x_o = 3.9$). The corresponding inclusive distribution is presented in fig. 1. The inclusive cross section calculated with the help of the scattering phase obtained within the framework of the generalised Chou Yang model [9] is presented in fig. 2.

$$\mathrm{Im}\,\delta(b) = \varkappa(s)\,\frac{1}{48}\,\mu^2(\mu b)^3 K_3(\mu b)$$

where μ is the corresponding coefficient of the dipole formula for proton electromagnetic formfactor ($\mu^2 = 0.71$ GeV/c. In ref. [10] elastic scattering of proton was analyzed within the framework of quasipotential model, that takes into account particle interaction structure. The form of the quasipontial has been obtained from the study of scattering problem in strong coupling theory [11, 12]

$$V(r) = g^2(s)\int_a^{\infty}\frac{d\beta}{\beta^2/2}\exp\left(-\beta m^2 - \frac{M^2}{4\beta}\right) \tag{9}$$

here m is the mass of field quantum, a characterises the velocity of the exponential fall off of the particle formfactor [12]. Quasipotential (9) contains two pictures of interaction: field quantum m exchange in the case of large relative distances $r > r_o = 2ma$ when it is reduced to the Yukava potential $V(r) \sim G\frac{e^{-mr}}{r}$ and overlapping of structures in the case of small distances $r < r_o$, when a particle formfactor is essential and the potential takes a Gaussian form $V(r) \sim G' e^{-\frac{r^2}{4a}}$. The scattering phases on quasipotential (9) are presented in the form

$$\delta(b) = g_o(s) \int_a^\infty \frac{d\beta}{\beta} \exp\left(-\beta m^2 - \frac{b^2}{4\beta}\right) \qquad (10)$$

and also has two behaviour modes at large and small impact parameters. Fig. 3 gives an idea of inclusive distribution calculated with (8) with phase (10). It is worth noticing that when the phase is chosen in form (10) with the parameters a and m fixed at $S =$ $= 2800$, we have the most satisfactory agreement with experiment. Thus as we see different models of proton elastic scattering provide us with expressions for the phase, that gives a satisfactory description for inclusive spectrum of secondaries within the framework of the model of meson emission. Here the role of unitary condition becomes very evident. Under a certain assumption on interaction dynamics this condition allows one to obtain a concrete expression for connection between elastic and inelastic processes at high energies.

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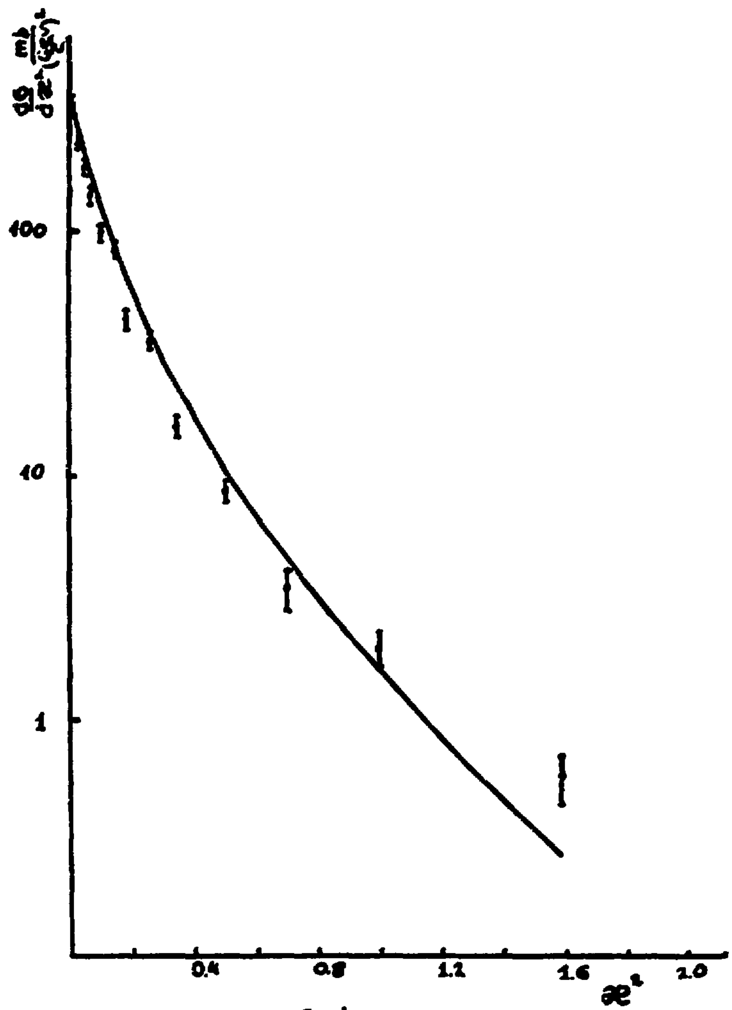
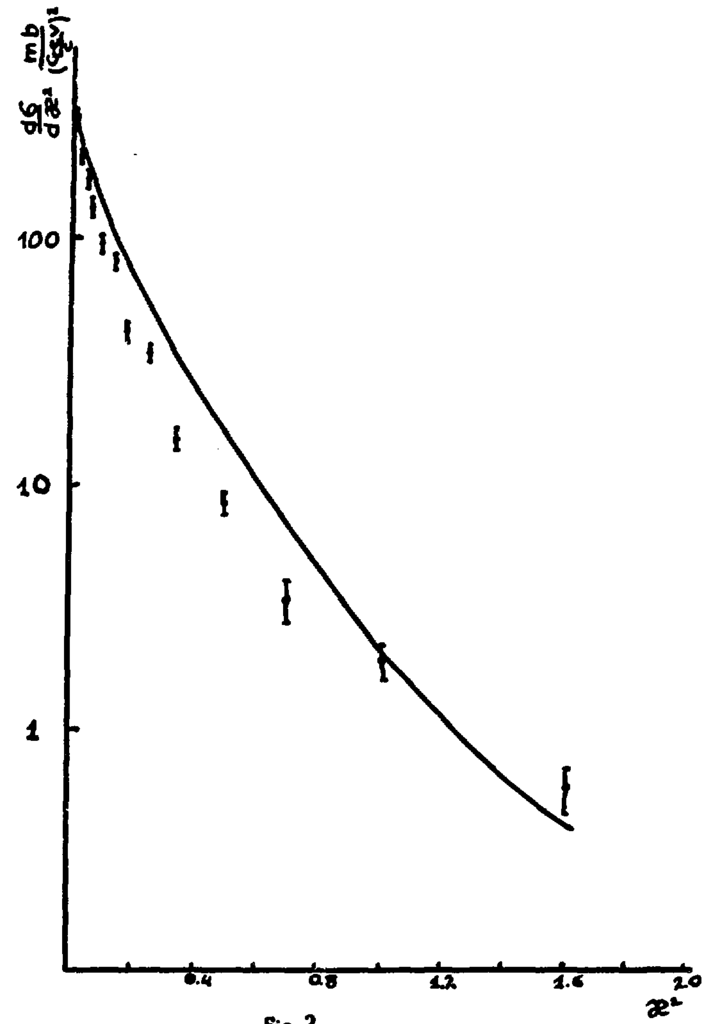


Fig. 1



$\frac{d\sigma}{d\varkappa^2}$ $\frac{mb}{(GeV)^2}$
100
10
1
0.4
0.8
1.2
1.6
2.0
$\varkappa^2$

Fig. 2

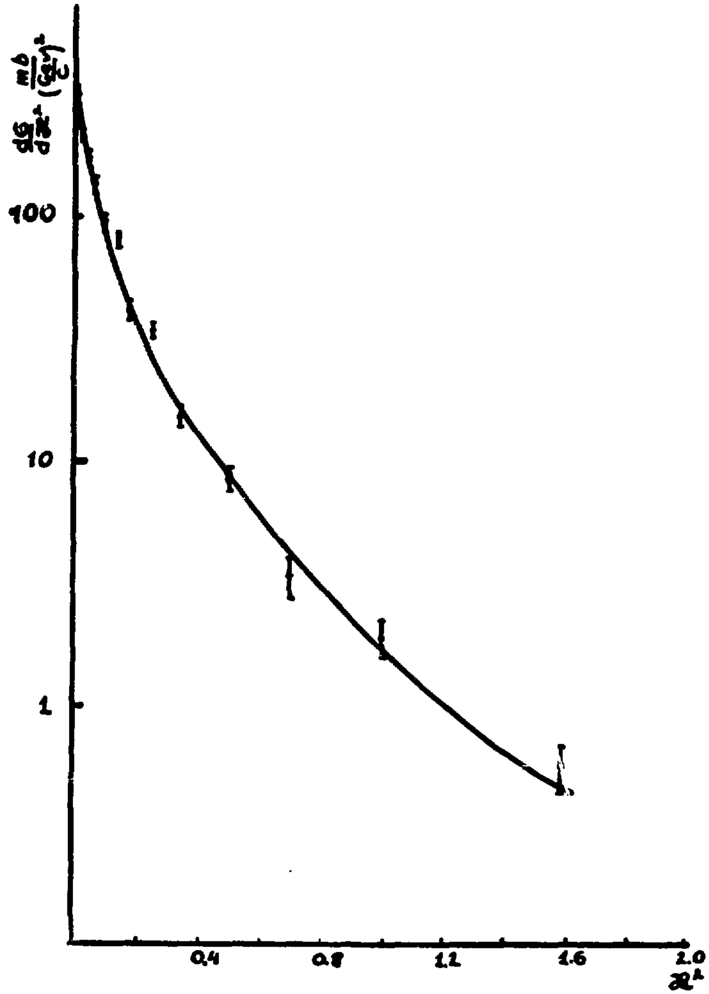


Fig.3

Цена 7 коп.

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