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Physics

Description of Multiparticle Production of Charged Particles by Gluon-Dominance Model in Hadron-Hadron and Hadron-Nucleus Collisions

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ABSTRACT. The parameters of Gluon-Dominance Model (GDM) for π^- mesons and charged particles are obtained in the multiplicity distributions of hadron-hadron and hadron-nucleus interactions. We have made an attempt to give a description of different processes of multiparticle production by means of a unifed approach based on quark-gluon picture using phenomenological hadronization. We have obtained agreement of GDM with experimental data in a very wide energy range. *© 2011 Bull. Georg. Natl. Acad. Sci.*

Key words: *nucleon, nucleus, collision, multiplicity distributions, quark-gluon picture.*

Multiparticle production (MP) is one of the important branches in high-energy physics [1]. Modern accelerators have made possible an intensive and detailed study of multiparticle processes. Multiplicity is the number of secondaries n in the process of MP,

$$A + B \rightarrow a_1 + a_2 + ... + a_n, \qquad (1)$$

Multiplicity distribution (MD) Pn is the ratio of cross section σ_n to $\sigma = \sum_n \sigma_n$, $P_n = \sigma_n/\sigma$.

To describe the MD we have used the probability of producing n charged particles in Gluon-Dominance Model (GDM). GDM studies MP in lepton and hadron processes. It is based on the quantum chromodynamics (QCD) and phenomenological scheme of hadronization (transformation of quarks and gluons into hadrons). The model describes well MDs and their moments. It has revealed an active role of gluons in MP, it also has confirmed the fragmentation mechanism of hadronization e^+e^- annihilation and its change to recombination mechanism in hadron and nucleus interactions. The GDM explains the shoulder structure of MDs. The agreement with Au + Au peripheral collision data for hadron-pion ratio has been also obtained with this model. Development of GDM allows one to study the multiplicity behavior of proton-antiproton ($p\bar{p}$)-annihilation at tens of GeV.

An investigation of heavy-ion collisions (HIC) at high energies gives strong evidence of quark-gluon plasma production [2]. The behavior of bulk variables at lower energies and also a detailed study of hadron interactions provide us with understanding of the production mechanism of this new state. At present this analysis is realized at SPS (CERN) [3]. The basic problem of HIC is to describe the systems consisting of partons or hadrons. Experiments at RHIC have confirmed this collective behavior [4]. In the case of hadron interaction the newly formed medium, named quark-gluon plasma (QGP), will not have such a plenty of constituents. We consider that the evaporation of single partons from separate hot pots (cluster sources) in the system of colliding hadrons, leads to the secondary-particles production. This conception was taken as the basis of the GDM [5-12]. It is supposed that after the inelastic collisions the energy of the initial im-

Table.

Parameters of Gluon-Dominance Model in the p(p,Al,Au) collisions at the energy 360 GeV[15], pp (40,50,205,360) GeV/c [12, 13], p(p, K,p) 250 GeV/c [14] and in the K^+(Al,Au) 250 GeV/c [15] collisions.

Interactions, Momentum GeV/c	<m>	N	$<n^h>$	χ^2/ndf
(p,Al) → h, 360	2.05 ± 0.36	1.000 ± 0.002	0.74 ± 0.12	5/10
(p,Au) → h, 360	3.59 ± 0.10	1.000 ± 0.001	0.83 ± 0.10	7/10
(π,p) → ch, 250	6.06 ± 0.82	7.27 ± 2.30	2.41 ± 0.16	2/13
(K,p) → ch, 250	5.96 ± 1.22	5.26 ± 2.02	2.35 ± 0.31	1/13
(p,p) → ch, 250	5.75 ± 0.51	5.37 ± 1.38.	2.28 ± 0.14	2/13
(π,p) → ch, 40	3.65 ± 0.18	2.66 ± 0.09	1.53 ± 0.10	3.3/9
(π,p) → ch, 50	3.83 ± 0.11	2.95 ± 0.03	1.85 ± 0.03	7/9
(π,p) → ch, 205	4.75 ± 0.14	3.90 ± 0.19	2.19 ± 0.05	2/12
(π,p) → ch, 360	5.66 ± 0.72	5.42 ± 1.62	2.07 ± 0.17	2/12
(K,Al) → π^-, 250	4.94 ± 0.20	2.97 ± 0.15	1.62 ± 0.07	3/17
(K,Au) → π^-, 250	6.56 ± 0.72	5.23 ± 1.71	1.78 ± 0.16	3/17
(pp) → ch, 360	6.02 ± 0.47	7.17 ± 1.38	2.74 ± 0.13	1/13

pact particles is transformed to the intrinsic energy. Several quarks and gluons become free and form a quark-gluon system (QGS). Partons which can produce hadrons are named the active ones. Two schemes were proposed [6, 7]. In the first scheme the parton fission inside the QGS is taken into account (the scheme with a branch). If we are not interested in what is going on inside QGS, we come to the scheme without a branch. Reserve quarks remained inside of the leading particles. All of the newly born hadrons were formed by active gluons. The Poisson distribution was chosen as the simplest MD for active gluons which appeared for the first time after the collision. The number of these gluons plays the role of the impact parameter for nucleus. At the second stage some of the active gluons can leave QGS ("evaporate") and transform to real hadrons. For hadronization a subnarrow binomial distribution was added as follows:

$$P_n(s) = \sum_{m=0}^{M} C_{mN}^{n} (\exp(-\overline{m})\overline{m}^{m}/m!)(\overline{n}^{h}/N)^{n}(1-\overline{n}^{h}/N)^{mN-n}, \quad (2)$$

$(P_2 = \exp(-\overline{m}))$, where s is c.m.s. energy squared, C_{mN}^{n} is binomial coefficient, m and $\overline{m}$ are the number of secondary gluons and their mean multiplicities. In sum (2) we constrain the maximal possible number of evaporated gluons equal to M=6; $\overline{n}^{h}$ and N have the meaning of average multiplicitiy and maximum possible number of secondary hadrons formed from the gluon at the stage of hadronization.

Comparison (2) with experimental data [13-17] (see Figures 1-4) gives the GDM parameters values presented in Table. Expression (2) describes well the experimental data [13-17] from 40 to 360 GeV/c. The mean gluon multiplicity $\overline{m}$ has a tendency to rise. It is surprising that gluon parameters of hadronization (N, $\overline{n}^{h}$) remain constant without considerable deviations in spite of the indirect finding: N≈1-6 and $\overline{n}^{h} \approx 1$. Therefore we can draw a conclusion about the universality of gluon hadronization in hadron-nucleus collisions in the rather wide energy region.

As is shown by the analysis, (2) gives a good description of hadron-hadron (hh) and hadron-nucleus (hA) interactions.

In [18, 19] MP is described by means of clan mechanism and emphasizes the gluon nature of clan. GDM allows to give a concrete content for clan. The clan model uses the logarithmic distribution in a single clan.

At the SPS energy the shoulder structure appears in MD [18, 19]. As was mentioned in the branch scheme, the gluon fission is strengthened at higher energies. The independent evaporation of gluon sources of hadrons may be realized as single gluons as groups from two and more fission gluons. Following [20] such groups are named clans.

The specific feature of GDM is the dominance of active gluons in MP. We expect the emergence of many of them in nuclear collisions at RHIC and the formation of a new kind of matter (QGP) at high energy. The QGS can be a candidate for this. According to GDM, the active gluons are a basic source of secondary hadrons. As is shown in Figs. 1-4, GDM explains experimental data [13-17] well and gives the following parameter values (see Table).

GDM describes well MDs of pp at (250, 360) GeV, π^-p at (40, 50, 205, 250, 360)GeV/c, K p at the 250 GeV/c and (p,K) (Al,Au) interactions at the (250, 360) GeV/c (see Table and Figures 1-4). The maximum possible number of

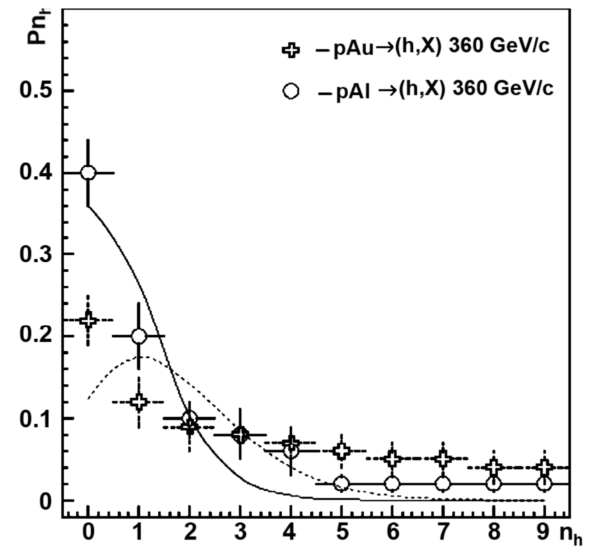

Fig. 1. The multiplicity distributions of charged particles in p(Al,Au)→(ch,X) at 360 GeV/c. The curves are the result of the approximation of experimental data by GDM.

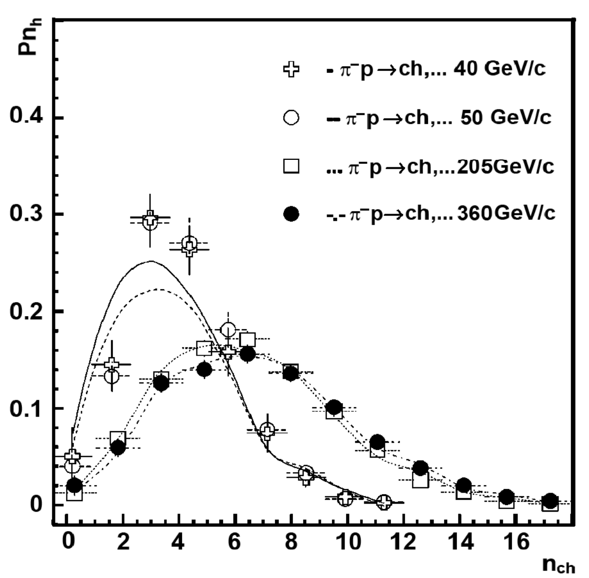

Fig. 2. The multiplicity distributions of charged particles in π p at (40, 50, 205 and 360) GeV/c. The curves are the result of the approximation of experimental data by GDM.

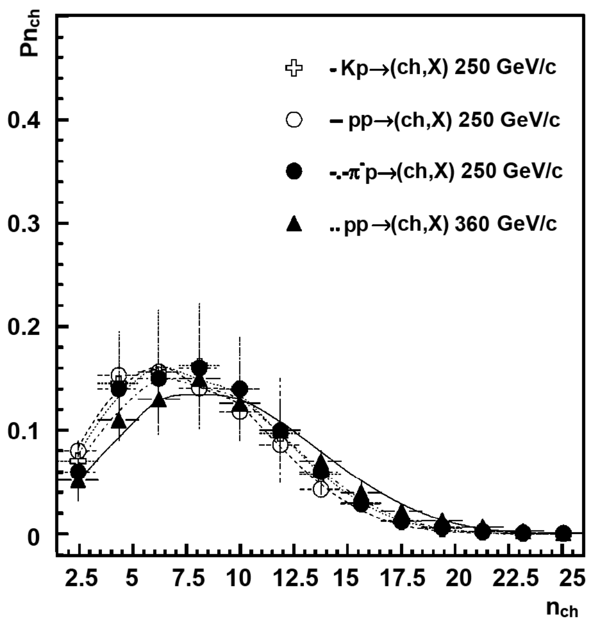

Fig. 3. The multiplicity distributions of charged particles in p(p,k,π)→(ch,X) at 250 GeV/c and in pp→(ch,X) at 360 GeV/c collisions. The curves are the result of the approximation of experimental data by GDM.

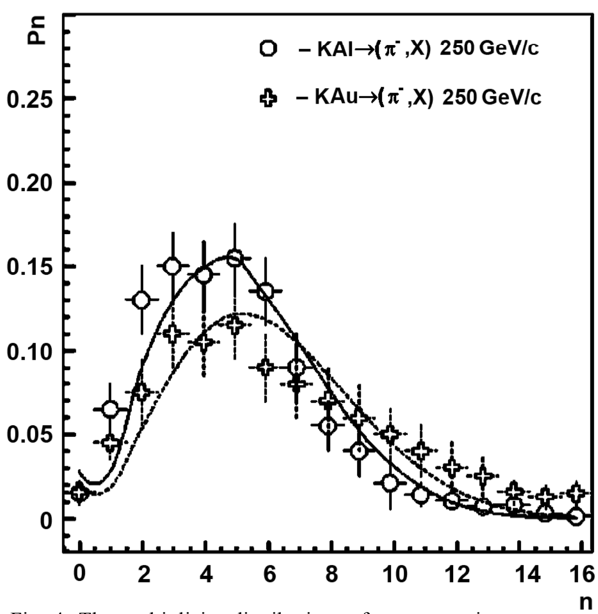

Fig. 4. The multiplicity distributions of π^- mesons in K(Al,Au)→(π^-,X) at 250 GeV/c. The curves are the result of the approximation of experimental data by GDM.

secondary hadrons formed from the active gluons N and their mean multiplicity $\bar{n}^h$ increases slowly depending on the energy of the initial particles. The growth of $\bar{n}^h$ in pp interactions indicates a possible change of hadronization mechanism of gluons in comparison with $p\bar{p}$ annihilation (see [11-12]).

The parameter of hadronization $\bar{n}^h$ has a tendency to increase weakly. We consider that parameter $\bar{n}^h$ has a limiting value (like saturation). For hadron and nuclear processes a lot of quark pairs from gluons appear almost simultaneously and recombine to various hadrons [21-25]. The value $\bar{n}^h$ becomes bigger, ≈2, which indicates the transition from the fragmentation mechanism to the recombination one.

In our research we see that:

1. At the same energy the mean multiplicity of the active gluons $\bar{m}$, the maximal possible number of secondary hadrons formed from one active gluon at the second stage N, and their mean multiplicity $\bar{n}^h$ are higher in

the pA collisions than in the hadron-hadron interactions.

2. With the growth of the energy of colliding pair the mean multiplicity of the active gluons $\overline{m}$ increases slowly in all interactions.

We have obtained an agreement of Gluon-Dominance Model with experimental data in hadron-hadron and hadron-nucleus collisions in a very wide energy domain.

The specific feature of GDM is the dominance of active gluons in MP. We expect the emergence of many of them in nucleus collisions and the formation of a new kind of matter (QGP) at high energy.

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ფიზიკა

ადრონ-ადრონულ და ადრონ-ბირთვულ დაჯახებებში დაბადებული დამუხტული ნაწილაკების მრავლობითობის განაწილებების შესწავლა გლუონური დომინანტობის მოდელით

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** ი. ჯავახიშვილის სახ. თბილისის სახელმწიფო უნივერსიტეტის მაღალი ენერგიების ფიზიკის ინსტიტუტი, თბილისი*

(წარმოდგენილია აკადემიის წევრის ა. ხელაშვილის მიერ)

შესწავლილია ადრონ-ადრონულ და ადრონ-ბირთვულ დაჯახებებში დაბადებული π-მეზონებისა და დამუხტული ნაწილაკების მრავლობითობის განაწილებები გლუონური დომინანტობის მოდელის თანახმად. ამ პროცესებში მრავლობითი დაბადება აღწერილია კვარკ-გლუონური მიდგომის ბაზაზე ფენომენოლოგიური ადრონიზაციის გამოყენებით. მიღებულია გლუონური დომინანტობის მოდელის თანხმობა ექსპერიმენტულ მონაცემებთან ენერგიის ფართო არეში.

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