საქართველოს მეცნიერებათა ეროვნული აკადემიის მოამბე, ტ. 15, №1, 2021
BULLETIN OF THE GEORGIAN NATIONAL ACADEMY OF SCIENCES, vol. 15, no. 1, 2021

Physics

p - Protons and π - Mesons Produced in (p,d,He,C)(CTa) Collisions at the (4.2,10) AGeV/c

Liana Abesalashvili[*] and Lali Akhobadze[*]

[*]*Institute of High Energy Physics, Ivane Javakhishvili Tbilisi State University, Georgia*

(Presented by Academy Member Anzor Khelashvili)

The parameters of Gluon-Dominance Model (GDM) for p - protons and π^- - mesons are obtained in the multiplicity distributions of hadron-nucleus and nucleus-nucleus interactions. We made an attempt to give description of different processes of multiparticle production by means of the unified approach based on quark-gluon picture using phenomenological hadronization. We obtained agreement of Gluon Dominance Model with experimental data in hadron-nucleus and nucleus-nucleus collisions in a very wide energy domain. *© 2021 Bull. Georg. Natl. Acad. Sci.*

Protons, pions, quarks, gluons, quark-gluon plasma

Multiparticle Production (MP) is one of the important branches in high energy physics. Multiplicity distribution (MD) P_n is the ratio of cross-sections.

To describe the Multiplicity distribution (MD) we used the probability of producing of n charge particles in Gluon Dominance Model (GDM). GDM studies multiparticle production (MP) in lepton and hadron processes. It is based on the QCD and phenomenological scheme of hadronization. The model describes good multiplicity distributions and their moments. It revealed an active role of gluons in multiparticle production, it also confirmed the fragmentation mechanism of hadronization in e^+e^- annihilation and its change to recombination mechanism in hadron and nucleus interactions. The GDM explains the shoulder structure of multiplicity distributions. Heavy ion collisions (HIC) at high energies study strong evidences of quark-gluon plasma (QGP) production. The behavior of bulk variables at lower energies and also a detailed study of hadron interactions supply with understanding of the production mechanism of this new state. The basic problem of HIC is to describe the systems, consisting of partons or hadrons. In the case of the hadron interaction the new 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 (claster sources) in the system of coliding hadrons, leads to the secondary particles production. This conception was taken as the basis of the Gluon Dominance Model [1-4]. It is supposed that after the inelastic collisions the part of the energy of the initial impact particles is transformed to the inside energy. Several quarks and gluons become free and form quark-gluon system (QGS). Partons, which can produce hadrons, are named the active ones. Two schemes were proposed. 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 inside QGS, we come to the scheme without a branch. For the hadronization a sub narrow binomial distribution was added as follows:

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

$(P_2=\exp(-\bar{m}))$, where C^{n-2} – binomial coefficient, m and <m> are the mass of secondary gluons and their mean multiplicites. In sum (1) we constrain the maximal possible number of the evaporated gluons equal to $M=6$. n^h and N have the meaning of average multiplicity and a maximum possible number of the secondary hadrons formed from the gluon at the stage of hadronization.

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. The QGS can be a candidate for this. In 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 logaritmic distribution (LD) in a single clan.

At the SPS energy the shoulder structure appears in MD. As it 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 [5] such groups are named clans.

Table 1. Parameters of Gluon Dominance Model in the (p, d, He, C) (C, Ta) collisions at the energy E_L=2.3 and 4.3 GeV

	2.3 *AGeV*				4.3 *AGeV*			
	<m>	N	$<n>^h$	χ^2/ndf	<m>	N	$<n>^h$	χ^2/ndf
PC	5.98±0.79	1.45±0.07	0.16±0.06	3.5/4	5.40±0.11	3.21±0.15	0.68±0.03	7/4
dC	5.35±0.35	3.06±0.38	0.67±0.10	26/5	5.22±0.11	3.76±0.76	1.57±0.11	2/5
HeC	5.82±0.30	2.84±0.56	0.71±0.13	7/6	6.03±0.21	0.41±0.10	0.15±0.03	2.6/6
CC	5.81±0.32	0.65±0.13	0.15±0.03	5.4/5	4.12±0.14	1.20±0.15	0.69±0.07	2.3/8
PTa	6.12±0.31	2.78±0.48	0.30±0.05	26/4	4.08±0.08	6.05±0.47	1.44±0.08	4/5
dTa	6.14±0.44	2.14±0.77	0.17±0.04	28/5	4.29±0.13	4.21±0.53	1.36±0.14	8.7/6
HeTa	4.20±0.17	1.76±0.24	0.67±0.09	15/6	4.08±0.26	1.70±0.36	0.90±0.18	4/8
CTa	4.43±0.54	4.44±2.17	1.35±0.60	4/7	5.70±0.75	1.00±0.05	0.97±0.02	12/11

Table 2. Parameters of Gluon Dominance Model in the (d, He) Ta, (F, Mg) C collisions at the energy E_L=4.3 and 5.2 GeV

	<m>	N	$<n>^h$	χ^2/ndf
dTa, 5.2AGeV	3.56±0.21	4.45V1.19	1.81±0.48	3.6/7
HeTa,5.2AGeV	4.34±0.71	0.87±0.04	0.63±0.04	7.4/8
FC, 4.3AGeV	4.59±2.18	2.64±2.11	0.80±0.33	1/8
MgC, .3AGeV	6.02±1.34	4.62±2.72	0.71±0.13	9.4/7

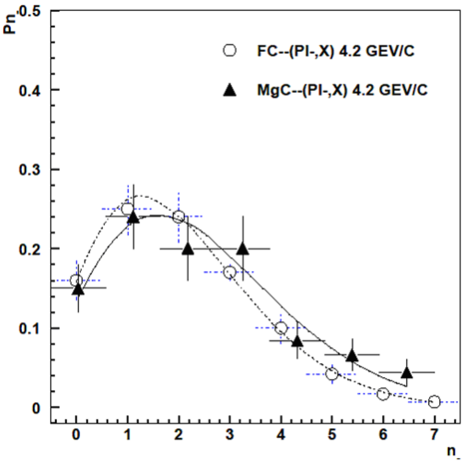

Fig. 1. The multiplicity distributions of π-mesons in (F, Mg) C collisions at E=4.3 GeV energy. The curves are the result of the approximation of experimental data by GDM.

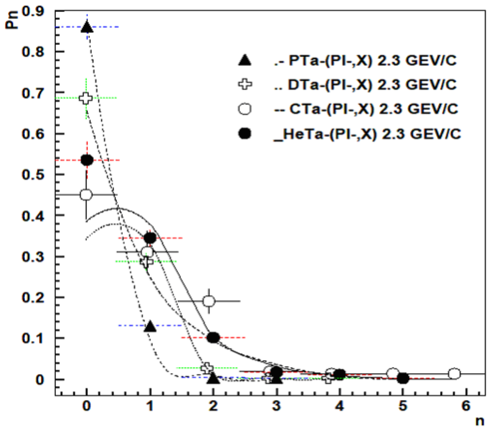

Fig. 2. The multiplicity distributions of π-mesons in (He, C, d, p) Ta collisions at E=2.3 GeV energy. The curves are the result of the approximation of experimental data by GDM.

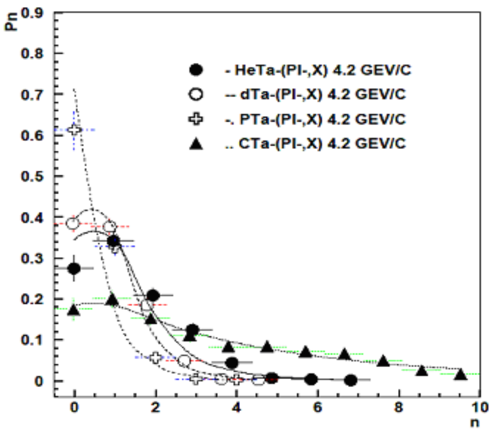

Fig. 3. The multiplicity distributions of π -mesons in (He, C, d, p) Ta collisions at E=4.2 GeV energy. The curves are the result of the approximation of experimental data by GDM.

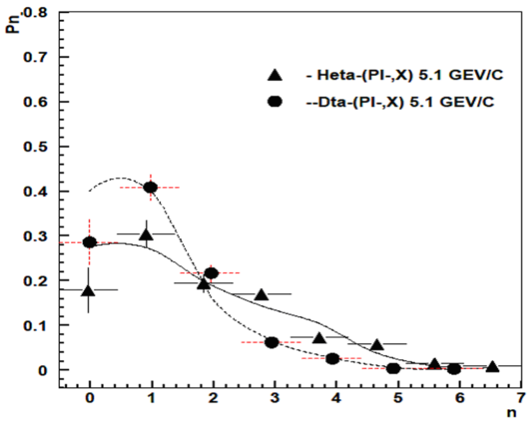

Fig. 4. The multiplicity distributions of π-mesons in (He, C) Ta collisions at E=5.2 GeV energy. The curves are the result of the approximation of experimental data by GDM.

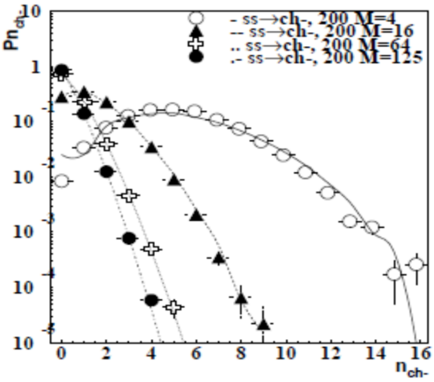

Fig. 5. The multiplicity distributions of charged particles in (S, S)→ch 200 GeV/c. The curves are the result of the approximation of experimental data by GDM.

The experimental data are obtained at two-metre propane bubble chamber PBC-500 and two-metre spectrometer SKM-200 High-Energy Laboratory of JINR (Dubna) [6].

At the E_L= (2.3, 4.3, 5.2) AGeV energy (p,d,He,C)(C,Ta) and (F,Mg)C collisions the analysis gives better description by Gluon Dominance Model (GDM).

The comparison (1) with experimental data nucleus-nucleus and hadron-nucleus collisions at (40÷360) GeV/c [6] gives the following parameter values (Tables 1,2). The expression (1) describes well the experimental data (Figs. 1-5). The mean gluon multiplicity m has a tendency to rise, but slower than the logaritmic one. It is surprising that gluon parameters of hadronization (N, n^h) remain constant without considerable deviations in spite of the indirect finding: $N\sim 2\div 5$ and $n^h\sim$(01÷2.5). Therefore (Tables 1,2) we can draw the conclusion about the universality of gluon hadronization in hadron-nucleus and nucleus-nucleus collisions in the rather wide energy region. As is shown by the analysis (1) gives better description of (40÷360) GeV/c pp, (π-p), p(Al,Au), K(p,Al,Au), (S,O) (Al,Au).

Conclusion

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

2. At the same energy the mean multiplicity of the active gluons $\overline{m}$, the maximal possible number of the secondary hadrons formed from one active gluons at the second stage N, and their mean multiplicity $\overline{n}^h$ are higher in the pA collisions, than in the hadron-hadron interactions.

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

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.

ფიზიკა

p - პროტონებისა და π - მეზონების დაბადება (p,d,He,C)(CTa) დაჯახებებში (4.2,10) AGeV/c

ლ. აბესალაშვილი და ლ. ახობაძე

ივანე ჯავახიშვილის სახ. თბილისის სახელმწიფო უნივერსიტეტი, მაღალი ენერგიების ფიზიკის ინსტიტუტი, თბილისი, საქართველო

(წარმოდგენილია აკადემიის წევრის ა. ხელაშვილის მიერ)

შესწავლილია ადრონ–ბირთვულ და ბირთვ-ბირთვულ დაჯახებებში დაბადებული p - პროტონებისა და π - მეზონების მრავლობითობის განაწილებები გლუონური დომინანტობის მოდელით. მრავლობითი დაბადება აღწერილია კვარკ–გლუონური მიდგომის ბაზაზე ფენომენოლოგიური ადრონიზაციის გამოყენებით. მიღებულია გლუონური დომინანტობის მოდელის თანხმობა ექსპერიმენტულ მონაცემებთან.

REFERENCES

1. Kokoulina E.S. (2006) Gluon dominance model., e-Print: hep-ph/0511111 [hep-ph] *AIP Conf. Proc.* **828**: 81.
2. Kokoulina E., Kutov A., Nikitin V. (2011) Analysis of high multiplicity events. *Phys.Part.Nucl.Lett.* **8**: 855-859.
3. Abesalashvili L.N., Akhobadze L.T. (2007) Description of multiparticle production by gluon dominance model. e-Print: arXiv: 0711.4461 [hep-ph].
4. Abesalashvili L.N. and Akhobadze L.T. (2009) Description of multiparticle production of charged particles by gluon dominance model in hadron-hadron and hadron-nucleus collisions. *Phys.Atom. Nucl.* **72**:97-104**.**
5. Giovannini A. and Ugocioni R. (2005) Clan structure analysis and new physics signals in pp collisions at LHC *J.Phys.Conf.Ser.* **5:** 190-198.
6. Abesalashvili L.N. et. al. (1972) Raspredelenie po mnozhestvennosti vtorichnykh chastits v Π^-P, Π^-n, Π^-C vzaimodeistviiakh pri impulse P=40 GeV/C (in Russian).

Received October, 2020