DESCRIPTION OF MULTIPARTICLE PRODUCTION
BY GLUON DOMINANCE MODEL

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ABSTRACT

The obtained \( \pi^- \) and charged multiplicity distribution parameters of Gluon Dominance Model explain the experimental data in nucleus-nucleus, p nucleus, pd, pp, p antip and \( \pi^- (p,n) \) interactions. We have undertaken an attempt to give description in different processes of multiparticle production by means of a unified approach based on quark-gluon picture using the phenomenological hadronization. We have obtained agreement of GDM with experimental data in a very wide energy range.

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

$$A + B \rightarrow a_1 + a_2 + \cdots + a_n$$

(1)

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

To describe the MD we have used the probability of producing of $n$ charge particles in the Gluon Dominance Model (GDM). GDM studies multiparticle production in lepton and hadron processes. It is based on the QCD and phenomenological scheme of hadronization. The model describes well multiplicity distributions and their moments. It has revealed an active role of gluons in multiparticle production, it also has 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. The agreement with Au+Au peripheral collisions data for hadron-pion ratio has been obtained with this model. Development of GDM allows one to study the multiplicity behavior of p+antip annihilation at tens of GeV.

Heavy ion collisions (HIC) at high energies study strong evidences of quark-gluon plasma (QGP) production [2]. 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. 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 the hadron interaction the new formed medium, named quark-gluon plasma (QGP), won’t 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 Gluon Dominance Model [5-10]. 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 [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 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 multiplicity distribution for active gluons which appeared for the first time after the collision. The number of these gluons fulfills the role of the impact parameter for nucleus. On the second stage some of active gluons can leave QGS (”evaporate”) and transform to real hadrons. For the hadronization a sub narrow binomial distribution (BD) was added as follows:

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

\[
(P_2=\exp(-\overline{m})), \text{ where } C_{mN}^{n-2} \text{ - binomial coefficient, } m \text{ and } \overline{m} \text{ are the number of secondary gluons and their mean multiplicites. In sum (2) we constrain the maximal possible number of the evaporated gluons equal to } M = 6. \overline{n} \text{ and } N \text{ have the meaning of average multiplicity and a maximum possible number of secondary hadrons formed from the gluon at the stage of hadronization.}

The comparison (2) with experimental data [8, 11÷25] (see Fig.1÷9 and tables 6÷12), gives the following parameter values (see Tables 1÷5). The expression (2) describes well the experimental data [8, 11÷25] from 4 GeV/c to 900 GeV (e.g. Fig. 1÷9 ). The mean gluon multiplicity \( \overline{m} \) has a tendency to rise, but slower than the logarithmic one. It is surprising that gluon parameters of hadronization ( \( N, \overline{n} \) ) remain constant without considerable deviations in spite of the indirect finding: \( N \sim 3÷4 \) and \( \overline{n} \sim 1 \). Therefore we can draw a conclusion about the universality of gluon hadronization in nucleus-nucleus collisions in the rather wide energy region.

As is shown by the analysis (2) gives better description of \( \pi^- (p,n) \), \( p(p,\text{antip,d,nucleus}) \) and light nuclei collisions than for heavy nuclei.

In [26] 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 (LD) in a single clan.

At the SPS energy the shoulder structure appears in MD [13]. 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 [26] such groups is named clans.
The specific feature of GDM is the dominance of active gluons in MP. We expect the emergence of many of them in nucleus 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.

In conclusion one can show GDM may explain experimental data [8, 11÷25] (see Fig. 1÷9 and tables 6÷12) and gives the following parameter values (see Tables 1÷5).

GDM describe well MD pp interactions at the region of (50÷800 GeV/c, 62 GeV) (see Table 3 and fig.5), (π−,p) interactions at the region of (40÷360 GeV/c (see Table 2 and fig 4). The maximum possible number of secondary hadrons formed from the active gluons N, their mean multiplicity $\bar{n}^h$ increase slowly. A growth of $\bar{n}^h$ in pp interactions indicates a possible change mechanism of hadronization of gluons in comparison with (p antip) annihilation (see Table 4 and figure 6).

The parameter of hadronization $(\bar{n}_{ch})^h$ has a tendency to increase weakly. We consider that parameter $(\bar{n}_{ch})^h$ goes to the limiting value (like saturation). For hadron and nucleus processes a lot of quark pairs from gluons appear almost simultaneously and recombine to various hadrons [27]. The value $\bar{n}^h$ becomes bigger $\sim(2÷3)$, that indicates to 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 gluons at the second stage N and their mean multiplicity $\bar{n}^h$ is higher in the nucleus-nucleus collisions and annihilation processes, than in the hadron-hadron interactions.

2. With the growth of the energy of colliding particles the mean multiplicity of the active gluons $\bar{m}$ increase slowly in all interactions.

We have obtained agreement of Gluon Dominance Model (GDM) with experimental data in (p antip) annihilation, pp, ($\pi^−, (p,n)$), pd and nucleus-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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**FIGURE CAPTIONS**

**Fig.1.** The multiplicity distributions of $\pi^-$ mesons in ((He,d,C),Ta) collisions at 4.2 GeV/c/nucleon. The curves are the result of the approximation of experimental data by sum (2) of Gluon Dominance Model.

**Fig.2.** The multiplicity distributions of $\pi^-$ mesons in ((He,C),C) collisions at 4.2 GeV/c/nucleon. The curves are the result of the approximation of experimental data by sum (2) of Gluon Dominance Model.

**Fig.3.** The multiplicity distributions of $\pi^-$ mesons in ((He,C),Prop) collisions at 4.2 GeV/c/nucleon. The curves are the result of the approximation of experimental data by sum (2) of Gluon Dominance Model.

**Fig.4.** The multiplicity distributions of charged particles in ($\pi^-$,p)→(ch,X) at (40, 50, 205 and 360) GeV/c. The curves are the result of the approximation of experimental data by sum (2) of Gluon Dominance Model.

**Fig.5.** The multiplicity distributions of charged particles in (p,p)→(ch,X) at (50,300 and 800) GeV/c. The curves are the result of the approximation of experimental data by sum (2) of Gluon Dominance Model.

**Fig.6.** The multiplicity distributions of charged particles in (p,antip)→(ch,X) at (14.75 and 22.4) GeV/c. The curves are the result of the approximation of experimental data by sum (2) of Gluon Dominance Model.

**Fig.7.** The multiplicity distributions of charged particles (\(\pi^-,n\))→(ch,X) at the momentum of 40 GeV/c/nucleon and (p,(p,n,d))→(ch,X) at the momentum of 300 GeV/c/nucleon. The curves are the result of the approximation of experimental data by sum (2) of Gluon Dominance Model.

**Fig.8.** The multiplicity distributions of $\pi^-$ mesons in (p,(Ar,Xe))→($\pi^-$,X) collisions at 200 GeV/c/nucleon. The curves are the result of the approximation of experimental data by sum (2) of Gluon Dominance Model.

**Fig.9.** The multiplicity distributions of charged particles in (p,(Ar,Xe))→(ch,X) collisions at 200 GeV/c/nucleon. The curves are the result of the approximation of experimental data by sum (2) of Gluon Dominance Model.
Table 1. Parameters of gluon dominance model (GDM) (He,d,C)Ta→(π−,X), (C,Ta)→(ch,X), (He,C)→(π−,X) and (He,C)Prop→(π−,X) at the momentum of 4.2 GeV/c/nucleon.

| AP, AT   | m̄     | N     | n̄h   | χ²/ndf | χ²/N_{exp} |
|----------|--------|-------|-------|--------|------------|
| (He,Ta)  | 2.34±0.12 | 10.21±2.54 | 3.99±0.49 | 17/5    | 17/8       |
| (d,Ta)   | 2.82±0.22  | 12.50±4.92  | 4.42±0.69  | 10/3    | 10/6       |
| (C,Ta)→(π−,X) | 2.81±0.08 | 5.03±0.27 | 1.97±0.10 | 8/6     | 11/6       |
| (C,Ta)→(ch,X) | 3.84±0.13 | 5.92±0.38 | 2.23±0.13 | 14/12   | 14/15      |
| (He,C)   | 2.89±0.21  | 10.23±3.04  | 5.40±0.49  | 11/3    | 11/6       |
| (C,C)    | 2.34±0.13  | 12.40±5.90  | 5.14±1.49  | 15/5    | 15/8       |
| (He,Prop) | 1.93.67±0.31 | 10.07±4.28 | 5.74±1.96 | 5/3     | 5/6        |
| (C,Prop) | 2.86±0.12  | 12.49±5.26  | 5.13±2.01  | 14/5    | 14/8       |

Table 2. Parameters of gluon dominance model (GDM) (π−,p)→(ch,X) at the momentum of (40, 50, 205 and 360) GeV/c.

| AP, AT   | m̄     | N     | n̄h   | χ²/ndf | χ²/N_{exp} |
|----------|--------|-------|-------|--------|------------|
| 40 GeV/c | 1.41±0.10 | 2.00±0.01 | 1.36±0.06 | 6/6    | 6/9        |
| 50 GeV/c | 2.61±0.68  | 1.00±0.01  | 0.74±0.20  | 3/5    | 3/8        |
| 205 GeV/c | 4.29±0.12 | 2.84±0.43 | 0.81±0.15 | 10/7   | 10/10      |
| 360 GeV/c | 4.34±0.17 | 4.47±1.22 | 0.90±0.02 | 4.4/8  | 4.4/11     |

Table 3. Parameters of gluon dominance model (GDM) (p,p)→(ch,X) at (50,200,205,300,400 and 800) GeV/c and at 62 GeV.

| AP, AT   | m̄     | N     | n̄h   | χ²/ndf | χ²/N_{exp} |
|----------|--------|-------|-------|--------|------------|
| 50 GeV/c | 2.35±0.60 | 2.00±0.17 | 1.46±0.09 | 6/4    | 6/7        |
| 200 GeV/c | 3.13±0.26 | 1.91±0.25 | 0.97±0.06 | 14/7   | 14/10      |
| 205 GeV/c | 2.91±0.21 | 2.01±0.16 | 1.01±0.05 | 16/8   | 16/11      |
| 300 GeV/c | 3.35±0.29 | 5.27±3.03 | 1.21±0.09 | 13/9   | 13/12      |
| 400 GeV/c | 2.24±0.91 | 2.28±0.11 | 1.31±0.06 | 19/12  | 19/15      |
| 800 GeV/c | 2.66±0.16 | 2.25±0.07 | 1.29±0.04 | 16/13  | 16/16      |
| 62 GeV   | 2.33±0.11 | 3.23±0.17 | 1.95±0.08 | 24/15  | 24/18      |
Table 4. Parameters of gluon dominance model (GDM) 
\((p,\text{antip})\rightarrow (\text{ch},X)\) at the momentum of \((14.75, 22.4)\ \text{GeV}/c\) and at \((200, 900)\ \text{GeV}\).

\(A_P\) Projectile \(p\) and \(A_T\) target \(\text{antip}\)

| \(A_P, A_T\)     | \(\bar{m}\)   | \(N\)     | \(\bar{n}^h\) | \(\chi^2/\text{ndf}\) | \(\chi^2/N_{exp}\) |
|------------------|---------------|-----------|----------------|------------------------|---------------------|
| 14.7 GeV/c       | 2.20±0.18     | 2.05±0.10 | 1.21±0.04      | 1/9                    | 1/12                |
| 22.4 GeV/c       | 2.26±0.18     | 2.01±0.05 | 1.33±0.05      | 8/8                    | 8/11                |
| 200 GeV          | 3.59±0.17     | 3.00±0.20 | 1.67±0.05      | 45/16                  | 45/19               |
| 900 GeV          | 5.68±0.01     | 4.11±0.70 | 1.27±0.01      | 13/8                   | 13/11               |

Table 5. Parameters of gluon dominance model (GDM) 
\((\pi^-,n)\rightarrow (\text{ch},X)\) at the momentum of 40 GeV/c, 

\((p,(\text{Ar,Xe}))\rightarrow (\text{ch},X), (p,(\text{Ar,Xe}))\rightarrow (\pi^-,X)\) at the momentum of 200 GeV/c 

and \((p,(n,d))\rightarrow (\text{ch},X)\) at the momentum of 300 GeV/c/nucleon.

\(A_P\) Projectile and \(A_T\) target

| \(A_P, A_T\)     | \(\bar{m}\)   | \(N\)     | \(\bar{n}^h\) | \(\chi^2/\text{ndf}\) | \(\chi^2/N_{exp}\) |
|------------------|---------------|-----------|----------------|------------------------|---------------------|
| \((\pi^-,n)\rightarrow (\text{ch},X)\)40 | 1.45±0.12     | 2.71±0.13 | 1.67±0.13      | 6/5                    | 6/8                 |
| \((p,n)\rightarrow (\text{ch},X)\)300 | 2.44±0.13     | 2.41±0.11 | 1.40±0.01      | 13/9                   | 13/12               |
| \((p,d)\rightarrow (\text{ch},X)\)300 | 2.65±0.12     | 3.33±0.15 | 2.14±0.01      | 10/9                   | 10/12               |
| \((p,\text{Ar})\rightarrow (\text{ch},X)\)200 | 3.40±0.10     | 5.00±0.43 | 3.27±0.01      | 43/17                  | 43/20               |
| \((p,\text{Xe})\rightarrow (\text{ch},X)\)200 | 5.64±0.33     | 4.83±0.02 | 3.19±0.03      | 58/11                  | 58/14               |
| \((p,\text{Ar})\rightarrow (\pi^-,X)\)200 | 2.25±0.14     | 2.51±0.14 | 1.58±0.1       | 31/19                  | 31/22               |
| \((p,\text{Xe})\rightarrow (\pi^-,X)\)200 | 2.32±0.11     | 3.00±0.02 | 1.98±0.02      | 31/19                  | 31/22               |
Table 6. Experimental results the multiplicity distributions of $\pi^-$ mesons and of charged particles in ((He,d,C)Ta) collisions at 4.2 GeV/c/nucleon [20]

| Mult | (d,Ta)   | (He,Ta) | (C,Ta) | (C,Ta)$\rightarrow$(ch,X) | Mult | (C,Ta) |
|------|----------|---------|--------|---------------------------|------|--------|
| n    | $P_n \pm dP_n$ | $P_n \pm dP_n$ | $P_n \pm dP_n$ | $P_n \pm dP_n$ | n    | $P_n \pm dP_n$ |
| 0    | .384±.02 | .274±.032 | .174±.026 | .053±.01 | 24   | .017±.005 |
| 1    | .376±.02 | .341±.022 | .194±.015 | .094±.01 | 25   | .012±.005 |
| 2    | .185±.02 | .208±.018 | .122±.012 | .087±.01 | 26   | .010±.004 |
| 3    | .048±.01 | .124±.014 | .100±.01  | .068±.009| 27   | .009±.004 |
| 4    | .004±.002| .043±.012 | .083±.01  | .054±.008| 28   | .013±.004 |
| 5    | .002±.001| .006±.0025| .083±.01  | .046±.008| 29   | .009±.004 |
| 6    | .001±.001| .003±.0015| .071±.01  | .034±.007| 30   | .011±.004 |
| 7    | 0.      | .001±.001 | .066±.008 | .026±.007| 31   | .013±.004 |
| 8    | 0.      | .049±.008 | .029±.007 | .007±.004| 32   | .007±.004 |
| 9    | 0.      | .015±.007 | .029±.007 | .007±.004| 33   | .007±.004 |
| 10   | 0.      | .016±.007 | .028±.007 | .011±.004| 34   | .011±.004 |
| 11   | 0.      | .011±.005 | .019±.007 | .008±.004| 35   | .008±.004 |
| 12   | 0.      | .009±.005 | .025±.006 | .010±.004| 36   | .010±.004 |
| 13   | 0.      | .004±.003 | .023±.006 | .008±.004| 37   | .008±.004 |
| 14   | 0.      | .009±.008 | .023±.006 | .006±.003| 38   | .006±.003 |
| 15   | 0.      | .001±.001 | .019±.005 | .009±.004| 39   | .009±.004 |
| 16   | 0.      |          | .017±.005 | .006±.004| 40   | .006±.004 |
| 17   | 0.      |          | .023±.005 | .008±.004| 41   | .008±.004 |
| 18   | 0.      |          | .015±.005 | .003±.002| 42   | .003±.002 |
| 19   | 0.      |          | .021±.005 | .008±.004| 43   | .008±.004 |
| 20   | 0.      |          | .012±.005 | .005±.003| 44   | .005±.003 |
| 21   | 0.      |          | .009±.005 | .004±.002| 45   | .004±.002 |
| 22   | 0.      |          | .014±.005 | .004±.002| 46   | .004±.002 |
| 23   | 0.      |          | .010±.005 | .003±.003| 47   | .003±.003 |
Table 7. Experimental results the multiplicity distributions of $\pi^-$ mesons in (C,C), ((C,He)Prop) and (He,C) collisions at 4.2 GeV/c/nucleon [21]

| Mult | (C,C) $P_n \pm dP_n$ | (C,Prop) $P_n \pm dP_n$ | (He,Prop) $P_n \pm dP_n$ | (He,C) $P_n \pm dP_n$ |
|------|-----------------|-----------------|-----------------|-----------------|
| 0    | 0.177±0.08     | 0.417±0.04    | 0.482±0.055    | 0.349±0.018    |
| 1    | 0.375±0.04     | 0.327±0.025   | 0.369±0.045    | 0.419±0.028    |
| 2    | 0.256±0.03     | 0.153±0.015   | 0.108±0.035    | 0.166±0.017    |
| 3    | 0.097±0.02     | 0.053±0.008   | 0.030±0.02     | 0.048±0.009    |
| 4    | 0.063±0.02     | 0.034±0.005   | 0.01±0.007     | 0.015±0.005    |
| 5    | 0.024±0.006    | 0.013±0.003   | 0.002±0.0017   | 0.003±0.0015   |
| 6    | 0.005±0.0025   | 0.0028±0.0015 | 0.002±0.0017   | 0.003±0.0015   |
| 7    | 0.003±0.0015   | 0.0014±0.0007 | 0.002±0.0017   | 0.003±0.0015   |
Table 8. Experimental results the multiplicity distributions of charged particles in \((\pi^-, n)\) collisions at 40 GeV/c \([15,17-18]\), \((\pi^-, p)\) collisions at 40 GeV/c \([15,17-18]\) and at \((50, 205\text{ and } 360)\text{GeV/c}\) \([22]\)

| Mult | \((\pi^-, n)_{40}\) | \((\pi^-, p)_{40}\) | 50 GeV/c | Mult | 205 GeV/c | 360 GeV/c |
|------|----------------|----------------|---------|------|----------|----------|
| n    | \(\text{Pn} \pm \text{dPn}\) | \(\text{Pn} \pm \text{dPn}\) | \(\text{Pn} \pm \text{dPn}\) | n    | \(\text{Pn} \pm \text{dPn}\) | \(\text{Pn} \pm \text{dPn}\) |
| 0    | 0.              | 0.050±0.030   | 0.007±0.001 | 0    | 0.012±0.005 | 0.020±0.010 |
| 1    | 0.100±0.03      | 0.          | 0.          | 2    | 0.069±0.005 | 0.059±0.009 |
| 2    | 0.              | 0.145±0.025  | 0.133±0.013 | 4    | 0.146±0.007 | 0.126±0.009 |
| 3    | 0.271±0.03      | 0.          | 0.          | 6    | 0.162±0.008 | 0.140±0.009 |
| 4    | 0.              | 0.296±0.025  | 0.291±0.015 | 8    | 0.171±0.008 | 0.156±0.009 |
| 5    | 0.259±0.03      | 0.          | 0.          | 10   | 0.138±0.007 | 0.136±0.008 |
| 6    | 0.              | 0.263±0.025  | 0.270±0.013 | 12   | 0.091±0.003 | 0.101±0.005 |
| 7    | 0.199±0.04      | 0.          | 0.          | 14   | 0.046±0.004 | 0.065±0.004 |
| 8    | 0.              | 0.158±0.025  | 0.181±0.009 | 16   | 0.026±0.007 | 0.035±0.002 |
| 9    | 0.107±0.04      | 0.          | 0.          | 18   | 0.013±0.002 | 0.020±0.001 |
| 10   | 0.              | 0.074±0.020  | 0.078±0.006 | 20   | 0.004±0.002 | 0.010±0.001 |
| 11   | 0.05±0.03       | 0.          | 0.          | 22   | 0.0011±0.0004 | 0.004±0.001 |
| 12   | 0.              | 0.028±0.009  | 0.033±0.007 | 24   | 0.0012±0.0004 | 0.002±0.001 |
| 13   | 0.013±0.01      | 0.          | 0.          | 26   | 0.0012±0.0004 | 0.001±0.0005 |
| 14   | 0.              | 0.008±0.004  | 0.006±0.002 | 28   | 0.        | 0.0002±0.0001 |
| 15   | 0.003±0.001     | 0.          | 0.          | 30   | 0.        | 0.0001±0.0001 |
| 16   | 0.              | 0.002±0.001  | 0.003±0.0015 |  |      |        |
| 17   | 0.001±0.001     | 0.          | 0.          |      |  |        |
| 18   | 0.              | 0.001±0.0005 | 0.003±0.003 |      |  |        |
| 19   | 0.001±0.001     | 0.          | 0.          |      |  |        |
| 20   | 0.              | 0.001±0.0003 | 0.          |      |  |        |
| 22   | 0.              | 0.0002±0.0002 | 0.          |      |  |        |
Table 9. Experimental results the multiplicity distributions of charged particles in (p,p) collisions at 62 GeV and at (50,200,205,400,800) GeV/c [14,23-24]

| Mult | (p,p) 50 | 62 GeV | 200 GeV/c | 205 GeV/c | 400 GeV/c | 800 GeV/c |
|------|----------|--------|-----------|-----------|-----------|-----------|
| n    | Pn±dPn   | Pn ± dPn | Pn ± dPn | Pn ± dPn | Pn ± dPn | Pn±dPn    |
| 2    | .158±.014 | .047±.015 | .075±.015 | .107±.015 | .082±.020 | .045±.015 |
| 4    | .249±.010 | .093±.015 | .175±.010 | .170±.007 | .140±.010 | .120±.020 |
| 6    | .212±.009 | .103±.015 | .200±.010 | .212±.008 | .156±.010 | .150±.020 |
| 8    | .133±.006 | .113±.015 | .200±.010 | .177±.007 | .174±.010 | .160±.020 |
| 10   | .054±.003 | .115±.010 | .145±.010 | .135±.006 | .143±.010 | .150±.020 |
| 12   | .013±.002 | .112±.010 | .100±.010 | .105±.005 | .116±.010 | .120±.020 |
| 14   | .005±.001 | .108±.010 | .005±.005 | .052±.003 | .085±.010 | .100±.020 |
| 16   | 0.        | .085±.010 | .025±.005 | .027±.002 | .040±.010 | .080±.015 |
| 18   | 0.        | .065±.005 | .013±.004 | .010±.001 | .029±.010 | .040±.015 |
| 20   | 0.        | .053±.005 | .005±.002 | .005±.001 | .017±.009 | .025±.008 |
| 22   | 0.        | .035±.006 | 0.        | .002±.001 | .010±.005 | .015±.007 |
| 24   | 0.        | .027±.003 | 0.        | 0.        | .004±.002 | .016±.008 |
| 26   | 0.        | .020±.003 | 0.        | .009±.0005| .004±.0015|           |
| 28   | 0.        | .010±.003 | 0.        | .005±.0003| .002±.0006|           |
| 30   | 0.        | .006±.002 | 0.        | .009±.0005| .0008±.0003|           |
| 32   | 0.        | .005±.002 | 0.        | .009±.0005| .0008±.0003|           |
| 34   | 0.        | .003±.002 | 0.        | .009±.0005| .0008±.0003|           |
| 36   | 0.        | .002±.001 | 0.        | .009±.0005| .0008±.0003|           |
Table 10. Experimental results the multiplicity distributions of charged particles in (p, antip) collisions at (14.75[8,25], 22.4[16]) GeV/c and at (200, 900) GeV[13]

| Mult | 14.75 GeV/c | 22.4 GeV/c | 200 GeV | 900 GeV |
|------|-------------|------------|----------|----------|
|      | Pn ± dPn    | Pn ± dPn   | Pn ± dPn | Pn ± dPn |
| 0    | 0.050±0.030 | 0.017±0.010| 0.        | 0.       |
| 2    | 0.250±0.080 | 0.225±0.055| 0.011±0.008| 2.010±0.0015|
| 4    | 0.080±0.025 | 0.362±0.045| 0.045±0.009| 4.030±0.006|
| 6    | 0.300±0.090 | 0.242±0.024| 0.064±0.006| 6.060±0.006|
| 8    | 0.200±0.060 | 0.109±0.015| 0.080±0.006| 8.074±0.007|
| 10   | 0.050±0.020 | 0.036±0.009| 0.100±0.010| 14.087±0.008|
| 12   | 0.008±0.002 | 0.010±0.004| 0.098±0.009| 16.090±0.009|
| 14   | 0.001±0.005 | 0.002±0.001| 0.102±0.008| 24.080±0.008|
| 16   | 0.0002±0.0001| 0.0001±0.0001| 0.098±0.006| 34.060±0.006|
| 18   | 0.        | 0.        | 0.094±0.006| 40.040±0.004|
| 20   | 0.        | 0.        | 0.086±0.006| 48.030±0.003|
| 22   | 0.        | 0.        | 0.088±0.006| 50.010±0.002|
| 24   | 0.        | 0.        | 0.076±0.007| 0.        |
| 26   | 0.        | 0.        | 0.072±0.007| 0.        |
| 28   | 0.        | 0.        | 0.045±0.008| 0.        |
| 30   | 0.        | 0.        | 0.050±0.008| 0.        |
| 32   | 0.        | 0.        | 0.028±0.009| 0.        |
| 34   | 0.        | 0.        | 0.010±0.005| 0.        |
| 36   | 0.        | 0.        | 0.005±0.002| 0.        |
Table 11. Experimental results the multiplicity distributions of charged particles in ((p,p),(p,n),(p,d))$^{[22]}$, (p,Ar) and (p,Xe)$\rightarrow$ ($\pi^-$,X)$^{[24]}$

| Mult | (p,p) 300 | (p,n) 300 | (p,d) 300 | (p,Ar) 200 | (p,Xe) 200 GeV/c |
|------|----------|----------|----------|-----------|-----------------|
| n    | Pn ± dPn | Pn ± dPn | Pn ± dPn | Pn ± dPn | Pn ± dPn |
| 0    | 0.       | 0.       | 0.       | 0.        | .025±.015 |
| 1    | 0.       | 0.       | 0.       | 0.        | 0.           |
| 2    | .063±.015| .061±.015| .040±.015| .027±.008| .060±.020 |
| 3    | 0.       | .121±.012| .110±.015| 0.        | .080±.020 |
| 4    | .130±.010| 0.       | .130±.015| .035±.006| .075±.020 |
| 5    | 0.       | .138±.011| 0.       | 0.        | .115±.020 |
| 6    | .139±.011| 0.       | .120±.010| 0.        | .117±.020 |
| 7    | 0.       | .147±.015| 0.       | .041±.006| .110±.020 |
| 8    | .161±.015| 0.       | 0.       | 0.        | .075±.020 |
| 9    | 0.       | .130±.013| .094±.007| 0.        | .060±.020 |
| 10   | .135±.014| 0.       | 0.       | .057±.006| .052±.020 |
| 11   | 0.       | .107±.008| 0.       | 0.        | .045±.010 |
| 12   | .101±.013| 0.       | .073±.007| 0.        | .035±.008 |
| 13   | 0.       | .067±.007| 0.       | .045±.006| .025±.007 |
| 14   | .062±.010| 0.       | 0.       | 0.        | .020±.006 |
| 15   | 0.       | .044±.006| .058±.007| 0.        | .015±.006 |
| 16   | .036±.008| 0.       | 0.       | .038±.006| .013±.006 |
| 17   | 0.       | .018±.005| 0.       | 0.        | .012±.006 |
| 18   | .010±.005| 0.       | .048±.007| 0.        | .011±.006 |
| 19   | 0.       | .006±.002| 0.       | .029±.006| .010±.006 |
| 20   | .009±.004| 0.       | .029±.005| 0.        | .010±.006 |
| 21   | 0.       | .0063±.003| .015±.006| 0.        | .010±.006 |
| 22   | .003±.0015| 0.       | .006±.003| .028±.006| .012±.007 |
| 23   | 0.       | .002±.001| 0.       | 0.        | 0.          |
| 24   | .002±.001| 0.       | 0.       | 0.        | 0.          |
| 25   | 0.       | 0.       | 0.       | .011±.006| 0.          |
| 27   | 0.       | 0.       | 0.       | 0.        | 0.          |
| 28   | 0.       | 0.       | 0.       | .016±.006| 0.          |
| 29   | 0.       | 0.       | 0.       | 0.        | 0.          |
| 31   | 0.       | 0.       | 0.       | .009±.004| 0.          |
| 34   | 0.       | 0.       | 0.       | .008±.004| 0.          |
| 37   | 0.       | 0.       | 0.       | .007±.004| 0.          |
| 40   | 0.       | 0.       | 0.       | .006±.003| 0.          |
Table 12. Experimental results the multiplicity distributions of charged particles in \((p,Xe)\) and \((p,Ar)\rightarrow(\pi^-,X)\) collisions [24]

| Mult | \((p,Xe)\)ch 200 | Mult | \((p,Xe)\)ch 200 | Mult | \((p,Ar)\rightarrow(\pi^-,X)\) 200 GeV/c |
|------|-----------------|------|-----------------|------|-----------------|
| n    | Pn ± dPn        | n    | Pn ± dPn        | n    | Pn ± dPn        |
| 0    | 0.              | 31   | 0.014±0.006     | 0    | 0.025±0.015     |
| 1    | 0.              | 34   | 0.017±0.006     | 1    | 0.              |
| 2    | 0.019±0.008     | 37   | 0.011±0.005     | 2    | 0.080±0.020     |
| 3    | 0.              | 40   | 0.011±0.005     | 3    | 0.100±0.020     |
| 4    | 0.027±0.007     | 43   | 0.011±0.005     | 4    | 0.130±0.020     |
| 5    | 0.              | 46   | 0.008±0.004     | 5    | 0.150±0.020     |
| 6    | 0.              | 49   | 0.007±0.004     | 6    | 0.120±0.020     |
| 7    | 0.035±0.007     | 52   | 0.005±0.003     | 7    | 0.100±0.020     |
| 8    | 0.              | 55   | 0.004±0.003     | 8    | 0.070±0.020     |
| 9    | 0.              | 58   | 0.003±0.002     | 9    | 0.050±0.020     |
| 10   | 0.033±0.006     | 60   | 0.003±0.002     | 10   | 0.035±0.010     |
| 11   | 0.              | 61   | 0.              | 11   | 0.030±0.010     |
| 12   | 0.              | 62   | 0.              | 12   | 0.025±0.006     |
| 13   | 0.035±0.006     | 63   | 0.              | 13   | 0.013±0.006     |
| 14   | 0.              | 64   | 0.              | 14   | 0.011±0.006     |
| 15   | 0.              | 65   | 0.              | 15   | 0.010±0.006     |
| 16   | 0.033±0.006     | 66   | 0.              | 16   | 0.011±0.006     |
| 17   | 0.              | 67   | 0.              |      |                 |
| 18   | 0.              | 68   | 0.              |      |                 |
| 19   | 0.027±0.006     | 69   | 0.              |      |                 |
| 20   | 0.              | 70   | 0.              |      |                 |
| 21   | 0.              | 71   | 0.              |      |                 |
| 22   | 0.023±0.006     | 72   | 0.              |      |                 |
| 23   | 0.              | 73   | 0.              |      |                 |
| 24   | 0.              | 74   | 0.              |      |                 |
| 25   | 0.018±0.006     | 75   | 0.              |      |                 |
| 26   | 0.              | 76   | 0.              |      |                 |
| 27   | 0.              | 77   | 0.              |      |                 |
| 28   | 0.016±0.006     | 78   | 0.              |      |                 |
| 29   | 0.              | 79   | 0.              |      |                 |
| 30   | 0.              | 80   | 0.              |      |                 |
Figure 1: The multiplicity distributions of $\pi^-$ mesons in ((He,d,C),Ta) collisions at 4.2 GeV/c/nucleon.
Figure 2: The multiplicity distributions of $\pi^-$ mesons in ((He,C),C) collisions at 4.2 GeV/c/nucleon.
Figure 3: The multiplicity distributions of $\pi^-$ mesons in ((He,C),Prop) collisions at 4.2 GeV/c/nucleon.
Figure 4: The multiplicity distributions of charged particles in $(\pi^-, p) \rightarrow (ch, X)$ at (40, 50, 205 and 360) GeV/c.
Figure 5: The multiplicity distributions of charged particles in (p,p)→(ch,X) at (50,300 and 800) GeV/c.
Figure 6: The multiplicity distributions of charged particles in (p,antip)→(ch,X) at (14.75 and 22.4) GeV/c.
Figure 7: The multiplicity distributions of charged particles ($\pi^-, n$) → (ch, X) at the momentum of 40 GeV/c/nucleon and (p, (p, n, d)) → (ch, X) at the momentum of 300 GeV/c/nucleon.
Figure 8: The multiplicity distributions of $\pi^-$ mesons in \((p,(Ar,Xe)) \rightarrow (\pi^-,X)\) collisions at 200 GeV/c/nucleon.
Figure 9: The multiplicity distributions of charged particles in $(p,(Ar,Xe))\rightarrow(ch,X)$ collisions at 200 GeV/c/nucleon.