High Energy Physics and Nuclear Physics

Volume 18, Number 4

Analysis of the New Data of Transverse Energy Distributions in High Energy p-A Collisions Based on Geometrical Model

Liu Bo and Zhao Weiqin

(Institute of High Energy Physics, Chinese Academy of Sciences, Beijing, China)

Based on the two geometrical pictures, namely the independent N-N collision and participant-picture, the new data of transverse energy distributions in high energy p-A collisions recently published by HELIOS are analyzed. The influence of the choices of various model parameters is discussed, and the results are compared to those in A-A collisions.

Key words: quark-gluon plasma, geometrical model, transverse energy distribution.

1. INTRODUCTION

While deeply studying relativistic heavy ion collisions, one realizes that analyses and discussions of high energy hadron-nucleus (h-A) interactions are needed in order to study both h-A and A-A processes by using a unified model to see whether essential changes appear. The new matter-quark-gluon plasma (QGP) can hardly be formed in h-A collisions due to the limited region of interactions. Therefore, by comparing the h-A data with the A-A data, one may be able to judge whether QGP is formed in A-A process. However, previous results in h-A collisions were measured at the experimental conditions different form those in relativistic heavy ion collisions. It is very

Received on January 25, 1994. Supported by the National Natural Science Foundation of China.

difficult to compare the results in p-A collisions with those in A-A interactions and give a unified description. Therefore, the observable in h-A collisions are measured recently by the collaborations of relativistic heavy ion collisions under the same conditions as those in A-A collisions. The measurements of transverse energy distributions in different pseudorapidity ranges in high energy p-A collisions by HELIOS collaboration [1] is one example of them. These new data can be used to test various models describing relativistic heavy ion collision process.

At present, there are many models based on various physics assumptions. Although their complexities of calculation are quite different, the explanations for global observable, such as transverse energies, multiplicity distributions, etc. are very close. In fact, these observable mainly depend on geometrical and statistical nature, but not sensitive to the details of models. Among various models, although the geometrical and statistical model [2] seems to be rough, the assumption of this model is simple and the picture is clear, which is helpful to understand the main reason of the results.

In this paper, two kinds of different geometrical models are used: independent N-N collision and participant pictures [3], to discuss the new data on transverse energy distributions in h-A collisions measured recently by HELIOS group. We take different forms of transverse energy distribution for the sources and compare the results with those in A-A collisions. We analyze the influence of the parameters on the results and compare with those obtained by the experimental group.

2. DESCRIPTION OF MODELS

2.1. Collision Geometry

Consider a collision of a hadron h with a nuclear target A. The probability for an inelastic hadron-nucleon collision at an impact parameter b is given by

$$T_A(b) = \sigma_{in}\int_{-\infty}^{\infty}\rho_A(b,z)\mathrm{d}z, \tag{1}$$

where σ_{in} is the inelastic hadron-nucleon cross section and $\rho_A(b, z)$ is the single particle density in the target nucleus A. The probability for the hadron h colliding with ν target nucleons averaged over b is given by

$$W(\nu) = \frac{\int \mathrm{d}^2b\binom{A}{\nu}T_A(b)^\nu\{1 - T_A(b)\}^{A-\nu}}{\int \mathrm{d}^2b\{1 - [1 - T_A(b)]^A\}}. \tag{2}$$

The transverse energy distribution in h-A process can be expressed as

$$\frac{\mathrm{d}\sigma^{hA}}{\mathrm{d}E_T} = C(A)\sum_{\nu=1}^{A} W(\nu)F_\nu(E_T), \tag{3}$$

where $C(A)$ is the normalization parameter related to A, and it corresponds to the total inelastic cross section in h-A process. $F_\nu(E_T)$ in Eq. (3) is the transverse energy distribution with inelastic collision number ν.

2.2. Determination of the Transverse Energy Distribution $F_\nu(E_T)$ with collision number ν.

The transverse energy distributions can be obtained by folding the contributions from independent sources based on the models and the form for the transverse energy distribution of each source is determined by the assumption of the model.

Within the framework of the independent N-N collision model the collision between the projectile and each target nucleon are the independent sources for producing transverse energy distributions. The transverse energy distribution from each source is assumed to be

$$f_N(E_T) = \frac{\alpha^\alpha E_T^{\alpha-1}}{\varepsilon_0^\alpha \Gamma(\alpha)} e^{-\alpha E_T/\varepsilon_0}, \tag{4}$$

where α is a parameter provided by the model and ε_0 is the mean value of transverse energy provided by each source. Considering ν collisions of the incident hadron with target nucleons, the transverse energy distributions provided by the ν independent sources can be written as

$$F_\nu^{(N)}(E_T) = \int \prod_{i=1}^{\nu} [dE_i f_N(E_i)] \delta\left(E_T - \sum_{i=1}^{\nu} E_i\right). \tag{5}$$

In the independent participant model the incident hadron and colliding nucleons are both independent sources which provide the transverse energy distributions. The transverse energy distribution provided by each target nucleon ε_A assumed to be

$$f_A(E_T) = \frac{\alpha^\alpha E_T^{\alpha-1}}{\varepsilon_A^\alpha \Gamma(\alpha)} e^{-\alpha E_T/\varepsilon_A}. \tag{6}$$

The transverse energy distribution contributed from the incident hadron is taken as

$$f_h(E_T) = \frac{\alpha^\alpha E_T^{\alpha-1}}{\varepsilon_h^\alpha \Gamma(\alpha)} e^{-\alpha E_T/\varepsilon_h}. \tag{7}$$

The transverse energy distributions for $\nu + 1$ sources in ν collisions can be expressed as

$$F_\nu^{(P)}(E_T) = \int \prod_{i=1}^{\nu} [dE_i f_\nu(E_i)] dE_h f_h(E_h) \delta\left(E_T - \sum_{i=1}^{\nu} E_i - E_h\right). \tag{8}$$

The mean transverse energies ε_h and ε_A provided by the incident hadron and target nucleons may take different values since the transverse energy distributions are measured at a certain pseudorapidity range. Substituting Eq. (5) or (8) into Eq. (3), the transverse energy distributions in h-A process can be obtained.

3. RESULTS AND DISCUSSIONS

In order to compare the results of p-A process directly with those in A-A collisions, recently, HELIOS collaboration remeasured the transverse energy distributions in p-A interactions in a pseudorapidity range of $-0.1 < \eta < 2.9$ [1] under the same conditions as the measurements in A-A collisions [4]. In this paper we analyze the data of p-A interactions by the formula in Section 2. The single particle density in target nuclei is taken to be Wood-Saxon distribution and the parameters are taken from [6]. The nucleon-nucleon inelastic cross section is taken to be 30 mb.

The results in Fig. 1 are given by independent N-N collision model. The mean transverse energy provided by each source in Fig. 1 is taken as $\varepsilon_0 = 1.9$ GeV. The solid lines are results of $\alpha = 2$ and the dashed lines are the results of $\alpha = 1$ in Fig. 1.

The results in Fig. 2 are given by independent participant model. The contributions from target nucleon sources are dominant and the contribution from the incident hadron is small since the pseudorapidity range $-0.1 < \eta < 2.9$. is in the target fragmentation region. So $\varepsilon_A = 1.9$ GeV and

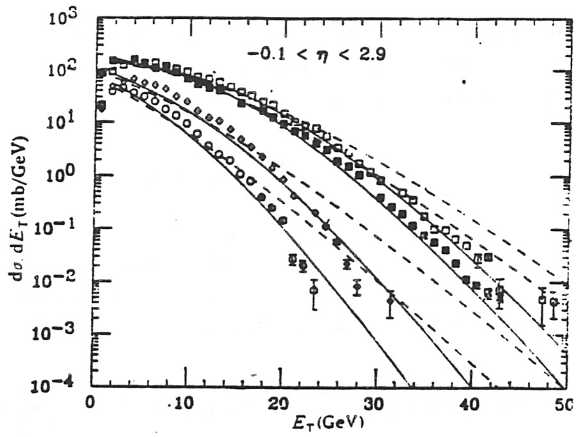

Fig. 1
Comparison between N-N collision picture predictions and the experimental distributions for various targets. ○ Al, ◇ Cu, ■ W, □ U.

$\varepsilon_h = 0.5$ GeV are taken in our calculations. The solid lines are results of $\alpha = 2$ and the dashed lines are results of $\alpha = 1$ in Fig. 2.

The normalization parameter $C(A)$ in Eq. (3) can be obtained by summing over the experimental differential cross sections for each nucleus, i.e.,

$$C(A) = \sum_i \left(\frac{d\sigma^{hA}}{dE_T}\right)_i^{exp} \cdot \Delta E_T(i) \tag{9}$$

The total hadron-nucleus inelastic cross section can be calculated based on the multiple scattering picture:

$$\sigma_A = \int d^2b\{1 - [1 - T_A(b)]^A\} \tag{10}$$

The comparisons between the experimental cross sections in Eq. (9) and total inelastic cross section by the multiple scattering picture in Eq. (10) for various target nuclei are given in Table 1. Table 1 shows that the experimental values are generally less than theory values. So we take the experimental values $C(A)$ as the normalization parameter in our calculations.

Figures 1 and 2 show that the results of $\alpha = 2$ are in good agreement with the experimental data. Both N-N collision and participant pictures show that the obtained transverse energy distributions are closely related to the form of the distribution chosen for each independent source. The results for $\alpha = 2$ are obviously improved comparing to that for $\alpha = 1$. The values of α reflect the physical origin of the transverse energy distribution of each source. The analysis in [2] shows that the transverse energy distribution of $\alpha = 2$ is produced by two independent sources which randomly provide excitation energies, and $\alpha = 1$ denotes one energy source. Therefore, the results in p-A collisions are similar to that in p-p collisions, i.e., the complicated energy sources are provided by N-N collisions or participants and the choice of the form for transverse energy distribution of each source is important. However, in A-A collisions the number of sources is quite large and it has a big fluctuation at different impact parameters. The form for transverse energy distributions in A-A collisions are mainly determined by the geometry effect. The effect of the form of transverse energy distribution for

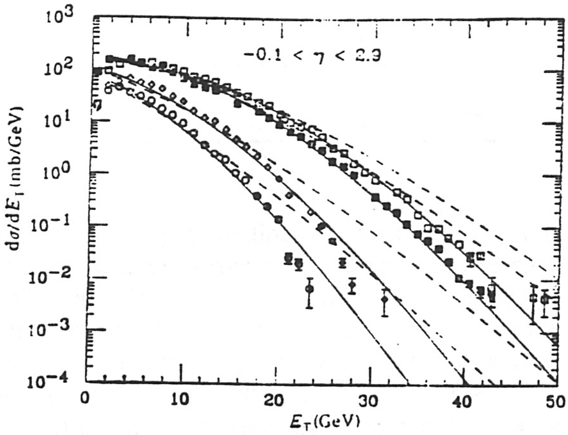

Fig. 2
Comparison between participant picture predictions and the experimental distributions for various targets. ○ Al, ◇ Cu, ■ W, □ U.

each source is covered by collision geometry. So the transverse energy distributions produced in A-A collisions are not sensitive to the form of the transverse energy distribution for each source [7].

On the other hand, the difference of the source numbers provided by N-N collision and participant pictures in p-A process is only one and the results by the two pictures are similar. Especially, in target fragmentation region ($-0.1 < \eta < 2.9$), the transverse energies are mainly provided by target fragmentation. So the mean transverse energies provided by each source in the two pictures are almost the same. We take the same value ε_0 for mean transverse energy of each source for various nuclei in N-N collision model. Figure 1 shows that the results will be improved if a small ε_0 is taken. This result is different from that of [1]. Our results can be explained as follows: the importance of the secondary collisions is increased when target nucleus becomes heavier, therefore, effective mean transverse energy provided by each source can be increased for models without secondary collisions [4]; on the other hand, the transverse energies contributed from the successive collisions decrease due to the energy loss in each collision. Due to the cancellation of these two effects, ε_0 value is almost not changed as target nucleus becomes heavier.

The results show that these two effects in p-A collisions are roughly equal, the effect of secondary collisions is slightly stronger. The distributions of number of collisions at a certain σ_{in} are determined from the geometry of target nucleus in our work and the variance of ε_0 as a function of target nucleus is completely determined by the experimental transverse energy distributions. Reference [1] pointed out that the value of ε_0 increases with increasing A of the target nucleus and that this case is consistent with that in A-A collisions. However, the value of ε_0 in [1] is somewhat arbitrary since the number of collisions at zero impact parameter is taken to be an adjustable parameter. The value of ε_0 may decrease with increasing A of the target nucleus if the number of collisions is taken to be a larger value for heavy nuclei. This may be the reason that the tendency of ε_0 in [1] is different from our results.

The case in A-A collisions is very different, based on the same geometrical considerations. The number of independent sources provided by the two pictures are very different. Therefore, the values of mean transverse energy contributed from each source also differ greatly. The assumption in N-N collision pictures is that each collision contributes on the average the same transverse energy. Because the number of independent sources in N-N collision picture is overestimated, the value of ε_0 obviously

Table 1
Total inelastic cross sections for p-A processes.

A	^{27}Al	^{63}Cu	^{184}W	^{238}U
$C(A)$ (mb)	287	522	1525	1595
σ_A (mb)	395	752	1573	1805

decrease with increasing A. The results in A-A collisions by participant picture is consistent with that in p-A collisions. The mean transverse energy contributed from each independent source in A-A collisions increases slightly due to the stronger secondary collisions effect [3].

Our analyses show that the transverse energy distributions in p-A and A-A processes are mainly determined from the geometrical effect. Results in p-A process are not sensitive to the choice of the two pictures, but they are sensitive to the form of transverse energy distribution of each source. The geometrical effect is more important and results are not sensitive to the form of transverse energy distribution of each source in A-A collisions. Due to the numbers of sources in A-A collisions provided by N-N collision and participant pictures are very different, the mean transverse energy contributed from each source is quite different, and the roles of secondary collisions and energy loss are more obvious in A-A processes.

REFERENCES

[1] T. Akesson *et al.* (HELIOS Collab.), *Z. Phys.*, **C58** (1993), p. 239.

[2] Liu Lian Son and Meng Tachung, *Phys. Rev.*, **D27** (1983), p. 2640; Cai Xu *et al.*, *Phys. Rev.*, **D33** (1986), p. 1287; Liu Lian Son, Meng Tachung and Peng Hongan, *Phys. Rev.*, **D37** (1988), p. 3327.

[3] Chao Wei Qin, Liu Bo and Miao Bixia, *Chinese Jour. Nucl. Phys.*, **12** (1990), p. 229; Miao Bixia and Chao Wei Qin, *Nucl. Phys.*, **A494** (1989), p. 620.

[4] Chao Wei Qin and Liu Bo, *Commun. Theor. Phys.*, **18** (1992), p. 185.

[5] T. Akesson *et al.* (HELIOS Collab.), *Z. Phys.*, **C38** (1988), p. 38; *Phys. Lett.*, **B214** (1988), p. 295.

[6] C. W. Jager *et al.*, *Atomic Data and Nuclear Data Table*, **14** (1974), p. 479.

[7] A. D. Jackson and H. Boggild, *Nucl. Phys.*, **A470** (1987), p. 669.