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A Monte-Carlo Generator of Chou-Yang Geometrical Model

Ding Linkai, Chi Xinyu, Zhu Qingqi, Jing Cailiu and Jing Guiru

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

Using an approximate energy conservation method, a Monte-Carlo generator which produces exclusive processes of Chou-Yang geometrical model is constructed. Using this generator the model is easily compared with experimental data and it receives a positive support. In principle, the method used is applicable to any models with a given inclusive momentum distribution.

1. INTRODUCTION

A good hadronic interaction model should be consistent with various experimental distributions. It is not an easy task to compare a theoretical model with experimental data under different trigger or selective conditions. However, if a Monte-Carlo generator of the model which produces exclusive processes is available, any kind of comparisons will become easier.

The major problem of constructing a Monte-Carlo generator is to create the multipartical final state by a random sampling method in which every particle ought to obey a given momentum distribution and all particles should follow the energy-momentum conservation. In case of a large number of secondary particles produced, it is very difficult, if not impossible, to solve this problem precisely. Some authors used an empirical method [1,2] which conserves energy approximately and applied extensively to the simulation of superhigh energy cosmic ray interactions. The effectiveness and applicability of this method are strictly demonstrated in Ref. 3. Here we extend this method to the case in which correlation between the longitudinal and transverse momenta exists, construct a Monte-Carlo generator of Chou-Yang model [4] and compare the model more extensively with S$\bar{p}$pS collider data.

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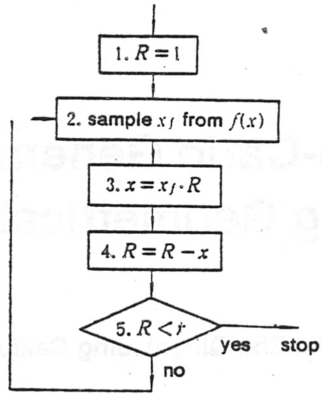

FIG. 1 Flow chart of Method A.

2. A BRIEF DESCRIPTION OF METHOD (HEREAFTER ABBREVIATED AS METHOD A)

If the fractional momenta $x = 2p_{11}/\sqrt{S}$ of secondary particles obey a given inclusive distribution *p(x)* where $\sqrt{S}$ is the total energy in c.m. system and p_{11} the longitudinal momentum of the secondary particle; we sample x_f from $f(x) = xp(x)$ rather than from p(x) directly as shown in step-2 of the flow chart in Fig. 1, time x_f by a positive number *R* (step-3) to obtain *x* needed, subtract *x* from *R* and let *R* be always the remaining available total fractional momentum (step-4), repeat step-2,3,4 to produce next *x*,.... The multiplicity *n* of the secondary particles is controlled by a predetermined small positive number r.

When the procedure of method A goes to "stop", we have $\sum^{n} x = 1 - r \simeq 1$ as *r* is always taken from 1% to 1‰, which means approximate longitudinal momentum conservation. In the simulation of superhigh energy cosmic ray interactions, it is just the approximate energy conservation because $p_{11} \approx E$.

In Ref. 3 it is proved that when $p(x) = (1-x)^m/x$ ($m \geq 0$), method A is absolutely correct. In case of *p(x)* being mono-descendent functions, the method is always precise enough, though not strictly established.

Here we applied the method to the longitudinal momentum sampling of Chou-Yang model.

3. MONTE-CARLO GENERATOR OF CHOU-YANG MODEL

It is noticed that starting from the inclusive momentum distribution of Chou-Yang model [4]

$$E\frac{dn}{dp^3} = K\exp(-\alpha p_T)\exp(-E/T_P) \tag{1}$$

the calculated pseudorapidity distribution

TABLE 1
The Parameters for Non-diffractive Processes at $\sqrt{s}$ = 540 GeV

n_{obs}	n_{cal}	$K(\mathrm{GeV}^{-2})'$	$T_P(\mathrm{GeV})$	$\alpha(\mathrm{GeV}/c)^{-1}$	h
>71	101.0	60.0	5.4	4.10	0.65
51—70	69.0	48.0	6.4	4.33	0.51
41—50	55.0	34.0	7.0	4.50	0.41
31—40	46.0	29.0	8.0	4.77	0.37
21—30	32.8	25.0	9.6	5.10	0.31
11—20	21.2	14.0	18.0	5.44	0.28
<10	11.7	5.5	200.0	5.69	0.25

n_{obs}, labeling the different charged multiplicity intervals, is different from the true charged multiplicity by a factor of about 1.25 due to experimental corrections (see Ref. 8). For a given charged multiplicity n, α is determined by the experimental correlation between $\langle p_T\rangle$ and n [5]. T_P, h and K are mainly determined by $dn/d\eta$ curves.

$$\frac{dn}{d\eta} = 2\pi K \sin^2\theta \int_0^{p_{max}} \frac{p\,dp}{E} \exp(-\alpha p \sin\theta)\exp(-E/T_P) \tag{2}$$

is in remarkable agreement with S$\bar{p}$pS data [4]. In (1) and (2), α is a parameter related to the mean transverse momentum $\langle p_T\rangle$, T_P, called partition temperature, it is related to the multiplicity n, K is a normalization constant and other quantities take the normal meaning. In formula (1), E plays the correlation role between the transverse momentum p_T and parallel momentum p_{11}. If we want to produce a good pseudorapidity distribution by Monte-Carlo method, the correlation between p_T and p must be treated carefully besides energy conservation.

Our procedure is as follows. Sample p_{11} from

$$\frac{dn}{dp_{11}} = 2\pi K \int_0^{p_{T\max}} p_T e^{-\alpha p_T} \frac{e^{-E/T_p}}{E}\, dp_T \tag{3}$$

according to method A, where $p_{T\max}$ takes an appropriate large value (no need to take a very large one due to the steepness of p_T distribution), substitute the sampled p_{11} into the joint distribution of p_T and p, and sample p_T from

$$\left.\frac{dn}{dp_T dp_{11}}\right|_{p_{11}=p_{11}^0} \propto \left. 2\pi K p_T e^{-\alpha p_T} \frac{e^{-E/T_p}}{E}\right|_{p_{11}=p_{11}^0} \tag{4}$$

then the correlation between p_T and p_{11} has been incorporated.

We modified the model parameters for the following reasons: 1) α = 5.25 GeV^{-1} gives a smaller $\langle p_T\rangle$ in $|\eta|$ at $\sqrt{s}$ = 540 GeV, which is only about 0.35 GeV/c that is smaller than the experimental datum. Instead, α = 4.9 gives 0.38 GeV/c. 2) In order to reproduce the correlation between multiplicity n and $\langle p_T\rangle$ observed in S$\bar{p}$pS experiment [5], we

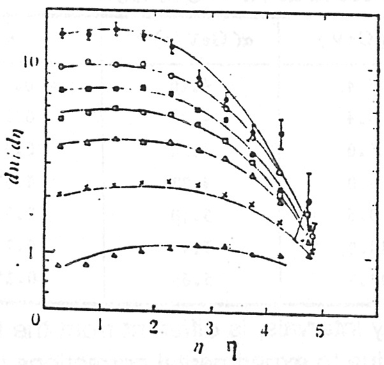

FIG. 2 $dn/d\eta$ vs η at $\sqrt{s}$ = 540 GeV. The curves are from the Monte-Carlo generator described in the text. The data points are taken from Ref. 5 which correspond to $n_{obs} > 71$; n_{obs} = 51–70, 41–50, 31–40, 21–30, 11–20; $n_{obs} < 10$ from top to bottom respectively.

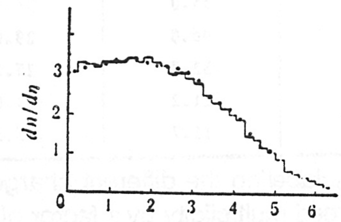

FIG. 3 $dn/d\eta$ vs η at $\sqrt{s}$ = 540GeV for the mean multiplicity. The dot points are data taken from Ref. 5 while the histogram is from the Monte-Carlo generator.

assume that the parameter α takes different values at different n (or different impact parameter b) just like the partition temperature T_P. As specified in Ref. 4, the cutoff α is taken from the experiments concerning p_T distribution, so we think this modification is not inconsistent with the original model consideration. The modified parameters are listed in Table 1.

In this Monte-Carlo generator, the distribution of multiplicity variable $Z = n/\langle n \rangle$ is taken from an approximate KNO scaling which fits the S$\bar{p}$pS data [6]. The forward

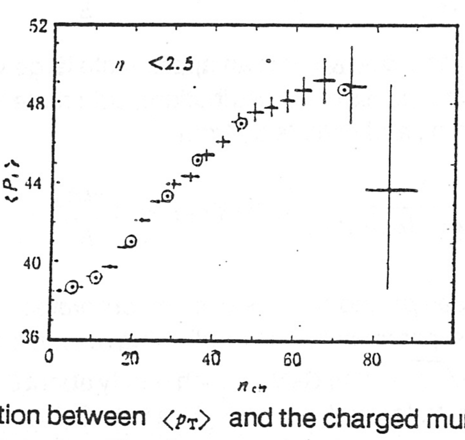

FIG. 4 The correlation between $\langle p_T \rangle$ and the charged multiplicity n with $|\eta| < 2.5$ at $\sqrt{s}$ = 540GeV. The data are taken from Ref. 5 while ⊙ are given from the Monte-Carlo generator.

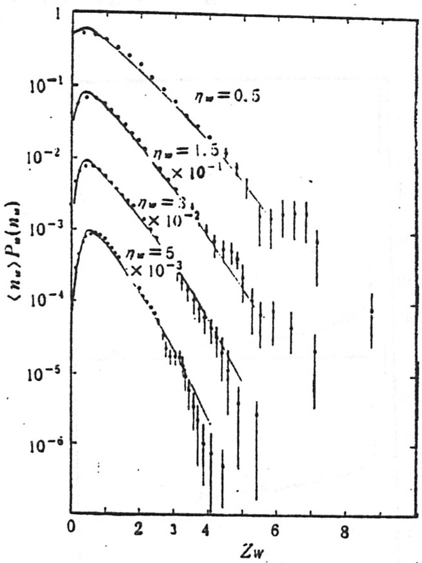

FIG. 5 The charged multiplicity distribution in the pseudorapidity window W at ($\sqrt{s}$ = 540 GeV). $|\eta| < \eta_W$ = 0.5, 1.5, 3.0 and 5.0. $Z_W = n_W/\langle n_W \rangle$. The data are taken from Ref. 9 and the curves are from the Monte-Carlo generator.

multiplicity n_F is sampled from the binomial distribution $C^{n/2}_{n_F/2}$ [7] and the backward multiplicity $n_B = n - n_F$. In a certain case, n_F and n_B are usually not the same, so T_P, and inelasticity h in forward and backward directions are also not the same.

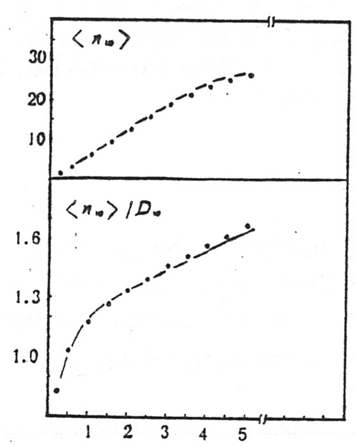

FIG. 6 The mean charged multiplicity $\langle n_W \rangle$ and the ratio $\langle n_W \rangle / D_W$ in different pseudorapidity windows at $\sqrt{s}$ = 540 GeV as functions of η_W where $D_W = (\langle n_W^2 \rangle - \langle n_W \rangle^2)^{1/2}$. The data are taken from Ref. 9 while the curves are the results from the Monte-Carlo generator.

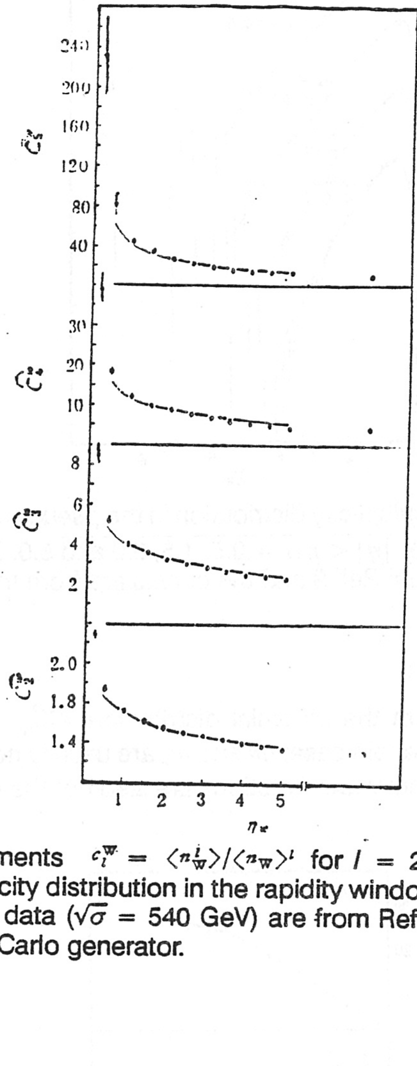

FIG. 7 The moments $c_l^W = \langle n_W^l \rangle / \langle n_W \rangle^l$ for l = 2, 3, 4 and 5 of the charged multiplicity distribution in the rapidity window $|\eta| < \eta_W$ as functions of η_W. The data ($\sqrt{\sigma}$ = 540 GeV) are from Ref. 9 while the curves from the Monte-Carlo generator.

4. RESULTS

The resultant pseudorapidity distributions by this Monte-Carlo generator in different charged multiplicity intervals and their comparisons with data are shown in Fig. 2. Fig. 3 is the comparison for the mean multiplicity. It can be seen that the agreement is perfect. The correlation between $\langle p_T \rangle$ and n is reproduced naturally due to the improved α values as shown in Fig. 4.

To check the model more extensively, the multiplicity distributions within different rapidity windows have been analyzed for the Monte-Carlo sample and compared with the data. The results are shown in Fig. 5. In Figs.6 and 7, the Monte-Carlo-simulated mean multiplicities, dispersions as well as higher moments in different rapidity intervals are compared with those measured. Furthermore, the results of the long-range correlation between forward and backward charged multiplicities, n_F and n_B, in three different rapidity intervals are shown in Fig. 8. All of these comparisons have provided positive support to the model.

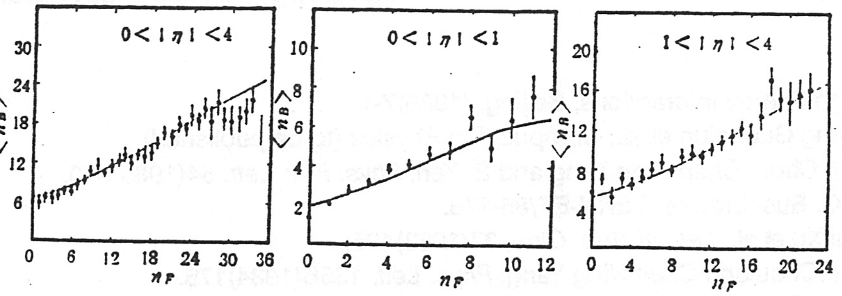

FIG. 8 The dependence of $\langle n_B \rangle$, averaged value of the backward charged multiplicity n_B, on the forward charged multiplicity n_F is shown in three different pseudorapidity intervals at $\sqrt{s} = 540$ GeV. Data are taken from Ref. 10. Curves are the results from the Monte-Carlo generator.

It is well known that there exists a long tail in the single particle p_T distribution at S$\bar{p}$pS collider energies, which deviates from an exponential distribution significantly. It is expected that the tail which can be well explained by QCD hard parton scattering [2] cannot be reproduced by the present model, but some improvement in the p_T distribution can be made by using new α parameters.

5. SUMMARY

Using the Monte-Carlo generator, Chou-Yang geometrical model was checked and supported by many experiments. If we disregard the azimuthal effect induced by jet processes, as well as those small probable events of large p_T particles, in the sense of statistical average, Chou-Yang model is good enough to describe the angular and momentum distribution of the non-diffractive hadronic multiparticle production processes.

This article presents the advantages of the Monte-Carlo generator of a theoretical model in comparing with the experimental data. The approximation in energy-momentum conservation did not seem to affect the results greatly. In principle, the method used here is applicable to other models with given single particle inclusive distributions.

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