HOW TO ACCOUNT FOR THE INTERFERENCE CONTRIBUTIONS IN MONTE CARLO SIMULATIONS

Yu.M. Shabelski

Petersburg Nuclear Physics Institute,
Gatchina, St.Petersburg 188350 Russia

Abstract

The diagram technique allows one to calculate the correction factors which can be used in Monte Carlo simulation of some processes. This is equivalent to the calculation with accounting for all or some part of the interference contributions. The example is presented for the simplest case of inelastic deuteron-deuteron interactions.

E-mail: shabel@vxdesy.desy.de
We will consider the discussed problem for the concrete case of intranuclear cascade model with Monte Carlo simulation of events. This model is rather popular until now, especially at not very high energies [1, 2]. It is well-known that all interference contributions are lost in such simulation because in the Monte Carlo method we can add probabilities but not amplitudes. In many cases it leads to not so large errors because the interference contributions are not dominated. However until now it was not possible even to estimate their role qualitatively.

In the present paper we will show that it is possible, as a minimum in some special cases, to calculate the correction factors. Use of them is equivalent to the account, as a minimum, some part of interference contributions.

Let us consider for simplicity the deuteron-deuteron interaction at energy a little smaller than 1 GeV per nucleon. In this situation only one secondary pion can be produced in each nucleon-nucleon interaction, and a secondary nucleon after the first inelastic collision practically cannot produce another pion because it has no enough energy. So the main source of pion production in the considered case is the process of one-nucleon pair inelastic interaction, Fig. 1a. Double-nucleon pair interaction has smaller probability, the process of Fig. 1b gives some correction to the cross section of one pion production whereas the process of Fig. 1c is qualitatively different because it leads to the two pion production in one event.

There exist also a lot of processes with elastic rescattering of secondary nucleons and pions but they cannot change the pion multiplicity (except of the case of pion absorption by secondary nucleon).

Let us consider now the processes of Fig. 1 from the point of view of unitarity condition. The modulo squared amplitude of Fig. 1a is shown as a cut of elastic $dd$ scattering amplitude in Fig. 2a. If the cross section determined by the imaginary part of the amplitude Fig. 2a is equal to $\Delta_1$, the cross section of the process Fig. 1a is equal to

$$\sigma_{1a} = \Delta_1 \frac{\sigma_{NN}^{inel}}{\sigma_{NN}^{tot}}$$

(we neglect the difference in $pp$, $pn$ and $nn$ cross sections for simplicity).

The modulo squared amplitudes of Fig. 1b and 1c correspond to the cuts of another diagram of $dd$ elastic scattering amplitude which are shown in Fig. 2b and 2c. The only difference between them is that in the case of Fig. 1b we should take one cutted nucleon-nucleon blob with inelastic intermediate state and another one with elastic $NN$ scattering, whereas in the case of Fig. 1c the inelastic intermediate states in both cutted blobs should be taken. So if the contribution of the diagram Fig. 2b (2c) to the total $dd$ cross section

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is equal to $\Delta_2$, the cross sections of the processes Fig. 1b and 1c are

$$\sigma_{1b} = 4\Delta_2 \frac{\sigma_{in\ell}^{NN}}{\sigma_{tot}^{NN}} \frac{\sigma_{el}^{NN}}{\sigma_{tot}^{NN}}$$

(2)

and

$$\sigma_{1c} = 2\Delta_2 \frac{\sigma_{in\ell}^{NN}}{\sigma_{tot}^{NN}} \frac{\sigma_{in\ell}^{NN}}{\sigma_{tot}^{NN}}$$

(3)

respectively. Factor two in both these Eqs. come from the AGK cutting rules [3, 4] and another factor two in Eq. (2) comes from combinatoric.

The diagram Fig. 1c can not interfere with another diagrams of Fig. 1 because it contain two pions in the final state. However the diagrams of Fig. 1a and 1b can interfere that corresponds to the intermediate state of elastic $dd$ amplitude shown in Fig. 2c. In accordance with AGK cutting rules this contribution to cross section is

$$\sigma_{1a,1b} = -4\Delta_2 \frac{\sigma_{in\ell}^{NN}}{\sigma_{tot}^{NN}}$$

(4)

This cross section can be calculated inside the Monte Carlo code via the value of $\sigma_{1c}$ (or the correspondent number of events) :

$$\sigma_{1a,1b} = -2\sigma_{1c} \frac{\sigma_{tot}^{NN}}{\sigma_{in\ell}^{NN}}$$

(5)

So we should multiply all distributions, histograms, multiplicities, etc., coming from the sum of events from Fig. 1a and Fig. 1b processes by the factor

$$R = \frac{\sigma_{1a} + \sigma_{1b} - \sigma_{1a,1b}}{\sigma_{1a} + \sigma_{1b}} < 1$$

(6)

and only after that add the events from the processes of Fig. 1c. In particular one can see that the mean multiplicity of produced pions will increase because we add smaller number of one-pion events with the same number of two-pion events.

The similar calculations can be fulfilled with the help of the same AGK cutting rules for more realistic cases of hadron-nucleus and nucleus-nucleus interactions and possibly in some another cases. Of course there exist many another interference contributions connected, say, with final state interactions, etc. which will be not accounted by the similar way. However sometimes these contributions can be not essential. So one can see that the combination of Monte Carlo code which allow one to calculate, say, some angular distributions of produced pions, and AGK cutting rules gives the possibility to increase the accuracy of calculations. Possibly the similar approach can be used in another cases where Monte Carlo simulations are used.
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**Figure captions**

Fig. 1. Diagrams for pion production in not high energy deuteron-deuteron interactions.

Fig. 2. The intermediate states of elastic $dd$ amplitude which correspond (a, b and c) to the modulo squares of the diagrams of Fig. 1 and (d) to the interference of amplitudes Fig. 1a and 1b.

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