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# Upper Limit of the Yield of Di-omega in Central Au-Au Collision at $\sqrt{s_{\mathrm{nn}}}=200\mathrm{GeV}$ with HIJING*

SHAN Qing WU Jian[1)] WANG Xiao-Lian CHEN Hong-Fang ZHANG Yi-Fei
ZHANG Zi-Ping SHAO Ming

(Department of Modern Physics, University of Science and Technology of China, Hefei 230026, China)

**Abstract** According to the theoretical calculations on the cross section, the $(\Omega\Omega)_{0^+}$ 's production including both the electromagnetic interaction process and the two-step process is studied with HIJING package. The production of the $(\mathrm{N}\Omega)_{022}$ is also simulated and calculated in this paper. The upper limit of the production rate of the $(\Omega\Omega)_{0^+}$ in the electromagnetic interaction process is $(1.097\pm0.293)\times10^{-10}$ per central Au-Au collision event at $\sqrt{s_{\mathrm{nn}}}=200\mathrm{GeV}$, while $(\mathrm{N}\Omega)_{022}$ is $(0.894\pm0.005)\times10^{-4}$.

**Key words** dibaryon, upper limit, production rate, $(\Omega\Omega)_{0^+}$ , $(\mathrm{N}\Omega)_{022}$

## 1 Introduction

As is well known, in the ordinary strong interaction world there are only baryons consisting of three valence quarks and mesons of a quark-antiqurak pair. However, for more than 20 years people have discussed and explored the possible existence of some multiquark states[1—5], not only because it provides a good place to examine the quantum chromodynamics (QCD) theory and to display the quark-gluon behavior in short distance, but also the very existence of such systems would open a new area for studying many new physical phenomena we have not known before.

Recently, with the development of the experiment in the relativistic heavy ion collisions, it provides a chance for searching these multiquark states. According to the prediction of the chiral $SU(3)$ quark model and the analysis in symmetry of the dibaryon system, $(\Omega\Omega)_{0^+}$ is found to be a favorable candidate for searching dibaryon[6]. It's a deeply bound state with binding energy around 100MeV, carrying two negative charge units. It can only exist through weak decay, and thus has quite a long mean lifetime of $\sim10^{-10}$s[7]. All of these interesting properties could make it easily identifiable experimentally in the heavy ion collision process. In this paper, a nuclear-nuclear collision simulation package (HIJING[8]) is used to calculate the production rate of the $(\Omega\Omega)_{0^+}$ including both the electromagnetic interaction process and the two-step process in 100GeV/$n$ Au-Au central collisions. Because of the lack of space information of particles in HIJING, only the upper limit of the production rate of the $(\Omega\Omega)_{0^+}$ is given. The upper limit of the $(\mathrm{N}\Omega)_{022}$ is also presented.

## 2 Simulation, calculation and result

### 2.1 The electromagnetic interaction process

Two free Ωs can form a $(\Omega\Omega)_{0^+}$ through the electromagnetic interaction process, such as $\Omega+\Omega\rightarrow(\Omega\Omega)_{0^+}+\gamma$. Four million events in Au-Au central collision at 100GeV/$n$ are generated with HIJING. The switch of all the decays is shut down while other switches are all set to the default in HIJING. Events

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1) E-mail: wujian@ustc.edu.cn

with at least two free Ωs of the same charge are selected. The number of such events is found to be 4184. The distributions of the rapidity and the transverse-momentum of these free Ω are showed in Fig. 1.

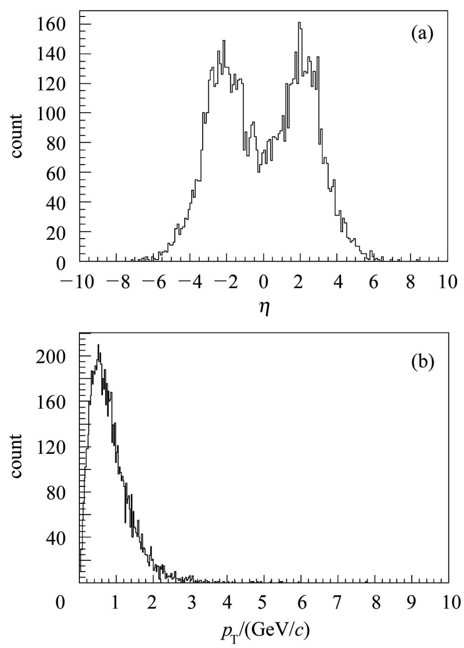

Fig. 1. The distributions of the rapidity (a) and transverse momentum (b) of free Ωs.

Then a further kinetic cut is applied to these events, requiring that the relative momentum of two free Ω be within 100 to 400MeV. Only 14 events pass the cut. The free Ωs in each event are assumed to collide for the second time, thus they might form $(\Omega\Omega)_{0^+}$ through the electromagnetic interaction process. According to the theoretical calculation, the cross sections of the $(\Omega\Omega)_{0^+}$ are 0.3μb and 1.6μb for the relative momentum of 100MeV and 400MeV respectively[9]. Here, the total cross section of the Ω+Ω is taken as the same as that of the pp collisions where $\sigma_{\mathrm{pp}} = 48+0.522(\ln p_{\mathrm{lab}})^2+(-4.51)\ln p_{\mathrm{lab}}$[10]. Thus we have $\sigma_{\Omega\Omega} \approx \sigma_{\mathrm{pp}} = 38.3$mb. On the other hand, we use a simple linearity $\sigma = \dfrac{13}{3000}\times p_{\Omega} - \dfrac{0.4}{3}$ to calculate the cross section of $(\Omega\Omega)_{0^+}$ for different relative momentum $p_{\Omega}$. So the production rate of the $(\Omega\Omega)_{0^+}$ through the electromagnetic interaction process can be calculated by

$$x=\frac{\sum\sigma_{(\Omega\Omega)_{0^+}}}{N\times\sigma_{\Omega\Omega}}=\frac{n\times\overline{\sigma}_{(\Omega\Omega)_{0^+}}}{N\times\sigma_{\Omega\Omega}},$$

where $\overline{\sigma}_{(\Omega\Omega)_{0^+}}$ means the average cross section and $N$ means the number of the events which are generated by HIJING.

From our simulation, we get $x=(1.097\pm0.293)\times10^{-10}$ for $(\Omega\Omega)_{0^+}$ 's production rate and it is rather low. The error is only statistical and limited by low event number.

### 2.2 The two-step process

Besides the electromagnetic interaction, the two-step process is also of interest. The first step is $\mathrm{N}+\Omega\rightarrow(\mathrm{N}\Omega)_{022}+\gamma$, or $\mathrm{N}+\Omega\rightarrow(\mathrm{N}\Omega)_{022}+\pi$, and the second step is an exchange reaction as: $\Omega+(\mathrm{N}\Omega)_{022}\rightarrow(\Omega\Omega)_{0^+}+\mathrm{N}$. Similar to the electromagnetic interaction process, two million events are generated for the two-step process study. The setting of HIJING and events are the same as those for the electromagnetic interaction. The difference is that now the relative momentum of one free Ω and one Nucleon is 200 to 500MeV. 244 events satisfy the upper conditions and the first step is possible to happen in these events and thus $(\mathrm{N}\Omega)_{022}$ might be formed. Fig. 2 shows the distributions of the rapidity and transverse momentum of nucleon.

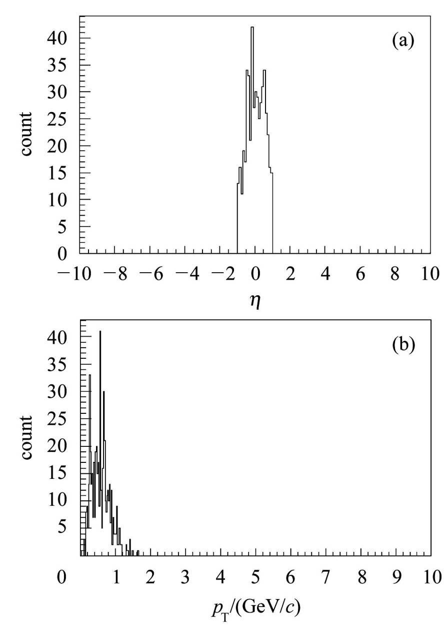

Fig. 2. The distributions of the rapidity (a) and transverse momentum (b) of nucleons.

According to the theoretical calculation we can see that the cross sections of the $(\mathrm{N}\Omega)_{022}$ are 50μb and 170μb for the relative momentum of 200MeV and

500MeV respectively in the first step, while the cross sections of the $(\Omega\Omega)_{0^+}$ are 50mb and 20mb for the relative momentum of 50MeV and 100MeV respectively in the second step[11]. Similar to the calculation in the electromagnetic interaction process, the total cross section of the $\mathrm{N}+\Omega$ is still taken as the same as the total cross section of the pp collisions in high energy. We still use the simple linearity $\sigma=0.4\times p-30$ to calculate the cross section of $(\mathrm{N}\Omega)_{022}$ for different relative momentum $p$.

Similarly, we can also calculate the production rate of $(\mathrm{N}\Omega)_{022}$ and get a result of $x=(3.963\pm0.254)\times 10^{-7}$. The error is also due to the statistical contribution only. If the second step is considered, the production rate of $(\Omega\Omega)_{0^+}$ is still rather low. But because of the lack of space information in HIJING, we can only deal with the first step.

### 2.3 The production rate of $(\mathrm{N}\Omega)_{022}$

When we simulate the two-step process, the production rate of $(\mathrm{N}\Omega)_{022}$ is also calculated. The method is the same as the simulation of the first step and the difference is that the second step does not need to be considered. So only events with one free $\Omega$ is requested in this simulation. Only neutrons are included in the simulation and we find 36690 events in a $1.2\times10^6$ sample. The distributions of the rapidity and the transverse momentum of neutron are showed in Fig. 3.

According to the algorithm in the previous section, the production rate of $(\mathrm{N}\Omega)_{022}$ rate can be calculated and the result is $x=(0.894\pm0.005)\times10^{-4}$. The production rate of $(\mathrm{N}\Omega)_{022}$ is much larger than that of $(\Omega\Omega)_{0^+}$ .

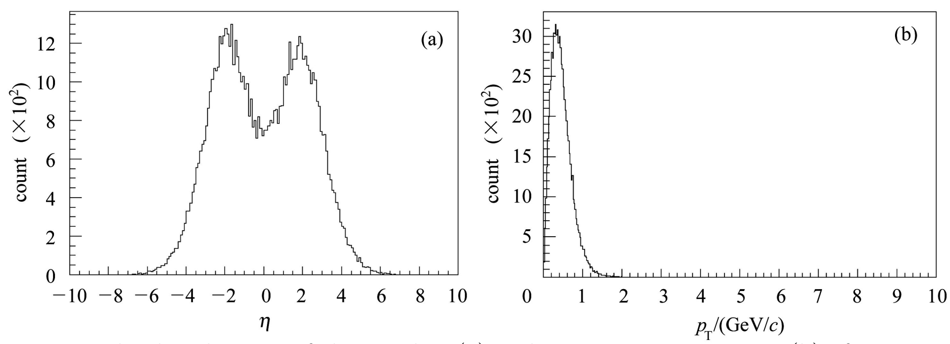


Fig. 3. The distributions of the rapidity (a) and transverse momentum (b) of neutrons.

## 3 Discussion

From the result of the simulation we can see that the production rate of $(\Omega\Omega)_{0^+}$ which is generated through both the electromagnetic interaction process and the two-step process is rather low. In addition, the production rate of $(\mathrm{N}\Omega)_{022}$ is also calculated and it is much larger. The result shows that the upper limit of the production rate of the $(\Omega\Omega)_{0^+}$ is about $(1.097\pm0.293)\times10^{-10}$ per central Au-Au collision event at $\sqrt{s_{\mathrm{nn}}}=200\mathrm{GeV}$ in the electromagnetic interaction process, while the upper limit of the production rate of the $(\mathrm{N}\Omega)_{022}$ is about $(0.894\pm0.005)\times10^{-4}$ for the same event.

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# $\sqrt{s_{\mathrm{nn}}}=200\mathrm{GeV}$ 下 Au-Au 中心碰撞中 Di-omega 产额上限的蒙特卡罗模拟*


单卿　伍健[1)]　汪晓莲　陈宏芳　张一飞　张子平　邵明

(中国科学技术大学近代物理系　合肥　230026)



**摘要**　根据现有的关于 $(\Omega\Omega)_{0^+}$ 的生成截面的理论计算, 利用 HIJING 事例产生器研究了 $\sqrt{s_{\mathrm{nn}}}=200\mathrm{GeV}$ 下 Au-Au 中心碰撞中 $(\Omega\Omega)_{0^+}$ 和 $(\mathrm{N}\Omega)_{022}$ 产生过程, 分别对 $(\Omega\Omega)_{0^+}$ 的电磁作用产生过程和两步产生过程中的第一步过程进行了 $(\Omega\Omega)_{0^+}$ 产率的计算, 给出了 $(\Omega\Omega)_{0^+}$ 产额的上限. 对于电磁作用过程, 其产率为 $(1.097\pm0.293)\times10^{-10}$. 同时我们也对 $(\mathrm{N}\Omega)_{022}$ 进行了初步的模拟, 初步给出了它的产率为 $(0.894\pm0.005)\times10^{-4}$.



**关键词**　双重子　上限产额　$(\Omega\Omega)_{0^+}$　$(\mathrm{N}\Omega)_{022}$



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1) E-mail: wujian@ustc.edu.cn