Diomega Production in Relativistic Heavy Ion Collisions

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Based on chiral SU(3) model, it was recently found that two Ω can form a diomega bound state $(\Omega\Omega)_{0+}$ with a binding energy of about 116 MeV and a root mean square distance of about 0.84 fm between them [1]. Because of the large strangeness, $(\Omega\Omega)_{0+}$ is not likely to be produced in proton-proton collisions. On the other hand, the enhanced production of Ω in relativistic heavy ion collisions would increase the possibility of forming such an exotic bound state. Based on a multiphase transport model (AMPT) [2], which gives a pronounced Ω production from multi-step strangeness-exchange reactions between antikaons and hyperons [3], we have estimated the probability of diomega production in heavy ion collisions at RHIC [4].

For diomega production from collisions between omegas, we have considered both the electromagnetic process $\Omega+\Omega\rightarrow(\Omega\Omega)_{0+}+\gamma$ and the strong interaction process $\Omega+\Omega\rightarrow(\Omega\Omega)_{0+}+\eta$ with their cross sections taken from Ref. [5], where they are evaluated using an effective Lagrangian. For the process $\Omega+\Omega\rightarrow(\Omega\Omega)_{0+}+\gamma$, the maximum cross section is found to be ~1.6 μb at $p_\Omega \approx 0.5 GeV$, while that for the process $\Omega+\Omega\rightarrow(\Omega\Omega)_{0+}+\eta$, which requires a threshold $p_\Omega > 0.88\, GeV$ due to finite η mass, reaches a maximum value of 5.5 μb at $p_\Omega \sim 1.1\, GeV$. Because of the mismatch between the large initial and small final relative momenta between the two omegas in the reaction $\Omega+\Omega\rightarrow(\Omega\Omega)_{0+}+\eta$, which involves only strong interactions, its cross section is only slightly larger than that for the reaction $\Omega+\Omega\rightarrow(\Omega\Omega)_{0+}+\eta$, which involves a much weaker electromagnetic interaction.

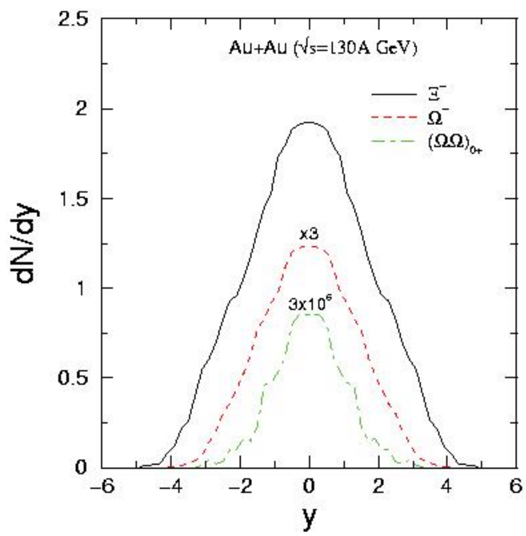

Figure 1: Rapidity distributions of cascade, omega , and diomega for Au+Au collisions at the RHIC energy of 130 AGeV at an impact parameter of less than 3 fm in the AMPT model.

In Fig. 1, we show the rapidity distribution of the multi-strange baryons Ξ and Ω, along with that of $(\Omega\Omega)_{0+}$. The rapidity distribution of particles with increasing strangeness content gradually become narrower as these particles are successively produced from their parent that collide more frequently at small rapidities where the baryon density is high.

The above study gives a lower bound on the diomega production probability, as there might be other production channels. If these diomega production cross sections are large, then diomegas may reach chemical equilibrium with omegas in heavy ion collisions. We have found that the AMPT results for K^+/π^+, $\bar{p}/p$, and K^-/K^* ratios, which are about 0.18, 0.65, and 0.89, respectively, at midrapidity in Au+Au collisions at energy $\sqrt{s}=130\,AGeV$, can be approximately described in the statistical model [6, 7] with a temperature $T\sim 170\,MeV$, baryon chemical potential $\mu_b\sim 37\,MeV$, and strange chemical potential $\mu_s\sim 10\,MeV$. If we assume that diomegas are also in chemical equilibrium with omegas, the ratio $(\Omega\Omega)_{0+}/\Omega^-$ is then 7.4×10^{-5}. With the omega number of about 0.41 at midrapidity, this leads to a diomega production probability of $\sim 3.0\times 10^{-5}$ per event, which is two orders of magnitude higher than that obtained in our transport model.

Diomega production in heavy ion collisions can also be studied using the coalescence model [8] based on the omega phase space distribution at freeze out as obtained in the AMPT model. For central Au+Au collisions at $\sqrt{s}=130\,GeV$, the yield of $(\Omega\Omega)_{0+}$ at midrapidity is found to be 2.6×10^{-5} and is comparable to that from the thermal model. The similar results obtained from both the thermal and coalescence models are not surprising as it was shown in Ref. [9] that the two models are equivalent when matter is in thermal and chemical equilibrium and the binding energy of the composite particle is much smaller than the temperature. Since the AMPT model predicts a hadronic matter at freeze out that is close to thermal and chemical equilibrium, the diomega yield from the coalescence model thus should be similar to that given by the thermal model.

Our estimate for the production probability of $(\Omega\Omega)_{0+}$ are well within the limits of the present detectors used at RHIC energies. Therefore, this exotic object can, in principle, be detected in present and future experiments. The observation of which could provide useful information of the unknown $\Omega-\Omega$ interaction strength. Our study thus opens up the intriguing possibility of detecting the new dibaryon $(\Omega\Omega)_{0+}$ in heavy ion collisions at the RHIC energies.

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