Abstract

Quark Gluon Plasma (QGP), a phase of QCD matter, was the temporary state that all matter had in the universe, microseconds after its creation, which has been produced in high energy nucleus-nucleus collisions at the Super Proton Synchrotron (SPS), the Relativistic Heavy Ion Collider (RHIC) and the Large Hadron Collider (LHC). In those experiments, one important probe of the QGP is the bound state of charm and anticharm quarks, called J/Ψ. Due to the conservation of charmness and momentum, the charm and anticharm quarks are produced with strong correlation in both coordinate and momentum space. In this study, we use the Parton Cascade Model to study the effect of initial charm and anticharm correlation on J/Ψ production within the QGP. We find that correlation will enhance the production of J/Ψ. Increasing the number of partons will increase this effect, and increasing the number of charm-anticharm quark pairs will decrease this effect. With all cross sections set at 4 nb, the ratios of the yield of J/Ψ between the correlated and uncorrelated cases at SPS, RHIC, and LHC energies were about 9, 15, and 6, respectively.

Method

Parton Cascade Model (PCM):
- Classical trajectories in phase space
- Randomization of position and momentum of partons
- Relativistic Kinematics

\[ \frac{\partial}{\partial t} - \frac{\vec{p}}{E} \frac{\partial}{\partial \vec{r}} \] \[ f_i(\vec{p}, \vec{r}, t) = \sum_{\text{processes}} C(\vec{p}, \vec{r}, t) \]

Collision Condition:

\[ d \leq \sqrt{\frac{\sigma}{\pi}} \]

Figure 3: If the distance between two partons is small enough, then they collide. Sigma is the cross section.

\[ c + g \rightarrow c + g \quad \bar{c} + g \rightarrow \bar{c} + g \]
\[ c + \bar{c} \rightarrow J/Ψ \quad J/ψ + g \rightarrow c + \bar{c} \]

Figure 4: These are the processes considered in the simulation.

Simulation Conditions

Uncorrelated

Correlated

Results 1

Figure 5: A ratio of actual to expected error. A value close to 1 is ideal.

Results 2

Figure 6: Initial conditions with uncorrelated (left) and correlated (right) charm quarks. In the uncorrelated case, the charm quarks and gluons are independently produced with random positions and momenta in the fireball. In the correlated case, the only difference is that each pair of charm and anticharm quarks are produced at the same position and with opposite transverse momentum.

Results 3

Figure 7-8: The first figure represents the time evolution of the yield of J/Ψ at SPS energy in an event with one pair of correlated and uncorrelated charms. The second figure represents the ratio of the amount of J/Ψ produced between the correlated and uncorrelated cases for 3 beam energies.

Conclusions and Future Studies

According to our simulation, these results show that the initial correlation of charm and anticharm quarks will increase the number of J/Ψ produced in heavy ion collisions. Also, they show that increasing the number of partons will increase this effect, while increasing the number of quark pairs will decrease this effect. More realistic initial parton distributions and varying cross sections will be considered in the future.

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