Study of heavy quark pair production in high energy proton-nucleus collisions within the Color Glass Condensate framework

論文の内容の要旨

Study of heavy quark pair production in high energy proton-nucleus collisions within the Color Glass Condensate framework

（カラーグラス凝縮の枠組みに基づく高エネルギー陽子原子核衝突における重クォーク対生成の研究）

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Understanding cold nuclear matter (CNM) effects such as parton saturation effect, nuclear parton distribution function, and energy loss in nuclear medium is important problem for studying ultrarelativistic nucleus-nucleus (AA) collisions to produce the quark-gluon plasma (QGP). The CNM effects are should be studied in high energy proton-nucleus (pA) collisions. In this paper, we investigate quarkonium and open heavy flavor meson productions in pA collisions at RHIC and LHC energies within the Color Glass Condensate (CGC) framework in order to study parton saturation effects in the target nucleus. The reason to focus on the heavy quark system is that the heavy quark pair is produced only in the initial gluon scattering. This means that the heavy quark is an ideal probe to investigate the QGP and heavy ion collision physics, while we can study the gluon structure in high energy hadron and the nucleus through the heavy quark productions.

The heavy quark pair production cross section from the CGC in pA collisions is obtained by Blaizot, Gelis and Venugopalan [J.P. Blaizot, F. Gelis, R. Venugopalan, Nucl. Phys. **A 743**, 57 (2004).], where a pA collision is treated as a dilute-dense system and the cross section is evaluated at the leading order in strong coupling constant and color charge density of valence parton in the proton ρ_p, but in all orders in the color charge density of valence parton in the nucleus $g^2\rho_A = O(1)$ because ρ_A should be proportional to

approximately $A^{1/3}$ with A being an atomic mass number. The CGC framework systematically includes multiple scattering of valence partons in the eikonal approximation and the resummation of large $\alpha_s \ln(1/x)$ correction at small Bjorken's x, which is important in high energy hadronic interactions. Actually the quantum evolution equation resums the $\alpha_s \ln(1/x)$ correction in the gluon distribution in the hadron.

We use the unintegrated gluon distribution at small x in the proton obtained by solving the Balitsky-Kovchegov equation with running coupling correction (rcBK). In this study, the initial condition for the rcBK equation in the proton is constrained by global fitting of HERA data compared with McLerran-Venugopalan model which includes only multiple scattering effect of a dipole off the heavy nucleus. For the heavy nucleus, multi-parton functions are relevant to heavy quark pair production and given by solving the rcBK equation with use of appropriate initial condition in large-N_c limit. When we focus on the minimum bias event, we replace the initial saturation scale of the gluon distribution in the proton by that in the nucleus. This initial saturation scale indeed depends on the impact parameter in the nucleus and we introduce nuclear thickness function to study the impact parameter dependence.

For quarkonium production, we firstly employ the color evaporation model and use appropriate heavy quark fragmentation function for open heavy flavor meson production. We show the transverse momentum spectrum and nuclear modification factor ($R_{\rm pA}$) of the quarkonium (J/ψ, $\Upsilon(1S)$) and the heavy meson (D, B) productions at collider energy. The important result is that the our CGC calculation shows the strongly suppression of the $R_{\rm pA}$ at RHIC and further suppression of $R_{\rm pA}$ at the LHC. We next discuss the transverse momentum, rapidity, and initial saturation scale dependence of the $R_{\rm pA}$, the transverse momentum broadening, and furthermore the azimuthal angle correlation of open heavy flavor meson pair.

Subsequently, we discuss the impact parameter dependence of the quarkonium production. by using the Glauber model with simple thickness function. As to the $R_{\rm pA}$, we actually find our computations reproduce the data for minimum bias event and central collisions event at RHIC but can not describe the peripheral data.

Finally, we discuss the quarkonium production within non-relativistic QCD (NRQCD)

effective field theory. Quarkonium production mechanism is not fully understood even in proton-proton collisions, then model dependence of quarkonium production is important study. In this framework, both the color singlet and octet channel productions are treated in a unified way. We notice that the color singlet production depends on the quadratic correlator in the target nucleus, and this may bring enhancement effect of the quarkonium production although the J/ψ production cross section itself in our model in this paper is smaller than inclusive J/ψ production data at RHIC. This effect brings a possibility what we should do in our future work.