学位論文要旨

Measurement of low transverse-momentum direct photons
in Cu+Cu collisions at √sNN = 200 GeV
（核子対あたり重心系衝突エネルギー200GeV
銅+銅原子核衝突における低横運動量直接光子の測定）

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The measurement of direct photons in the experiments of relativistic heavy-ion collisions is an essential tool for exploring the hot and dense matter created by the collisions. The hot-dense matter, called Quark-Gluon Plasma, is a new state of matter in which quarks and gluons are deconfined from nucleons. Quarks and gluons interact only by the strong force with each other, while photons interact with the electromagnetic force. Direct photons are defined by the photons that they do not arise from the hadron decays. Direct photons can carry the QGP information because they leave the medium without interaction with other particles. Thus, they are an excellent probe into the characteristics of the hot-dense matter. At the low transverse-momentum region, the thermal photons emitted from the hot-dense matter are supposed to be the dominant contribution. They are expected to reflect the thermodynamic properties. Therefore, measurements of low-transverse momentum direct-photons are essential to understand the characteristic of QGP.

The PHENIX experiment at the Relativistic Heavy Ion Collider (RHIC) has carried out the low transverse-momentum direct photon measurement in *p*+*p*, *d*+Au, and Au+Au collisions. Furthermore, the ALICE experiment at the Large Hadron Collider (LHC) has measured the direct photon in Pb+Pb collisions with higher collision energy than RHIC. Spectra and yields of the direct photons are measured in the above experiments, and thermal properties are studied within a wide range of system size and collision energy.

We have measured the low transverse-momentum direct photons by the virtual photon method in Cu+Cu collisions with the center-of-mass energy per nucleon pairs of 200 GeV taken at the PHENIX experiment in the year 2005. The virtual photon converts to low mass electron pair through internal conversion; therefore, we measure quasi-real virtual photons appeared as a low invariant mass of electron pairs. The virtual photons are statistically extracted as excess above hadronic sources from a large amount of background. The most crucial part of this analysis is background subtraction to tackle the virtual photon component extraction. We execute to estimate the uncorrelated background by the elliptic-flow adjusted mixed-event method. Moreover, we carry out the well-tuned Monte Carlo simulations to estimate the correlated backgrounds.

Finally, the direct photon component is successfully extracted as the direct photon fraction by comparing the invariant mass distribution between foreground electron pairs and background contributions.

The direct photon fractions, which are the direct to inclusive photon ratio, are measured as a function of transverse momentum for three collision centralities, minimum bias, 0 - 40%, and 40 - 94% centrality events. The direct photon spectra are calculated by converting from the direct photon fractions. The spectra are compared to the N_{coll} scaled *p+p* results, and the excess yields are observed in Cu+Cu collisions. The excess yields are parameterized by an exponential function, and the inverse slope gives an effective temperature T_{eff} = 285±53(stat)±57(syst) MeV/c for minimum bias events. The integrated direct photon yield called the rapidity density is calculated from the summing spectra as a function of N_{part}. The rapidity densities for Cu+Cu collisions are compared to the Au+Au results to discuss the centrality and the collision system size dependences of the direct photon production. The Cu+Cu data provide the results in low N_{part} region. A power-law function can describe the N_{part} dependence. The rapidity densities are also compared to the results from lower to higher collision energies with several collision nuclei as a function of charged-particle multiplicity, $dN_{ch}/d\eta$. The power-law function can describe the multiplicity dependence. It supposes that the low transverse-momentum direct photons are originated in the hadron gas phase and near the QGP-hadron gas phase transition.

In conclusion, we measure low transverse-momentum direct photons in Cu+Cu collisions at $\sqrt{s_{NN}}$ = 200 GeV via the virtual photon method with the PHENIX detector at RHIC. The Cu+Cu results provide the collision system size dependence of the direct photon production, especially in small N_{part} region. The Cu+Cu and Au+Au results follow the same scaling, and there seems to be no qualitative change in the photon sources for different collision system size. The scaling can describe the wide range of the collision energies, and it suggests that the source of the low transverse-momentum direct photons is near the transition from QGP to hadron phase.