Measurement of light vector mesons via di-electron decays in Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV and measurability in central Pb+Pb collisions at $\sqrt{s_{NN}}$ = 5.5 TeV
(核子対当たり重心系エネルギー200 GeV 金+金衝突における電子対崩壊を用いた低質量ベクトル中間子測定と核子対当たり重心系エネルギー5.5 TeV 鉛+鉛中心衝突における測定可能性)

中宮義英

High-energy heavy-ion collisions provide a unique opportunity to liberate quarks and gluons from nucleons and cause the QCD phase transition from hadronic matter to quark-gluon matter.

The mass modification of hadrons is one of the important signatures of the QCD phase transition, because their masses are strongly related to chiral condensate which is a prominent order parameter characterizing the QCD phase structure.

Light vector mesons such as ϕ, ω and ρ meson can be "standard candles" to study the properties of quark-gluon matter produced in heavy-ion collisions. The mass modification inside quark-gluon matter is potentially visible because their lifetimes are supposed to be comparable with the duration of the thermal equilibrium state. In addition, electron-positron pairs, which are referred as "di-electrons", decaying from light vector mesons are clear probe because they carry the original information in quark-gluon matter without strong interaction with hadronic matter in the relatively later stage of the system evolution.

Experimentally the signals of the mass modification are extracted from the mass spectrum shape of light vector mesons. In addition, the branching ratios between different decay channels can change by the effect of the mass modification, especially the comparison between $\phi \rightarrow e^+e^-$ and $\phi \rightarrow K^+K^-$ is important because di-kaon decays are expected to be suppressed even in case of small mass modification due to the small Q value.

The production of ϕ and ω mesons in Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV has been studied in the PHENIX experiment at Relativistic Heavy Ion Collider. The invariant yield as a function of transverse momentum with the range of $0 < p_T < 4$ GeV/c has been measured, and the measurement covers the transverse momentum range of $0 < p_T < 8$ GeV/c for ϕ mesons and $0 < p_T < 20$ GeV/c for ω mesons by combining with different decay channels.

The transverse momentum spectra of light vector mesons are systematically studied in different collision geometries, that is, from peripheral to central Au+Au collisions. The characteristics of the spectrum shape are investigated with semi-empirical functions. In addition, the scaling properties of the spectra are studied via the number of binary collisions and the number participant nucleons provided by the Glauber model.

The mass modification is discussed from the viewpoints of the mass spectrum shape and the branching ratio. As a result, the signature of the mass modification cannot be extracted from the mass spectrum shape of light vector mesons due to the poverty of the signal-to-background ratio and the statistical significance with current statistics. The yield fraction between $\phi \rightarrow e^+e^-$ and $\phi \rightarrow K^+K^-$ is turned out to be as same as that in normal vacuum within errors. In conclusion, any symptom of the mass modification is not observed in Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV.

The feasibility study of di-electron measurement in central Pb+Pb collisions at $\sqrt{s_{NN}} = 5.5$ TeV has been performed with the numerical simulation. The simulation takes the key aspects of heavy-ion collisions and experimental issues relevant to di-electron measurement into account and provides a guideline to be applicable to a concrete detector design with the wide range of experimental parameters. Measurability is evaluated by the signal-to-background ratio and the statistical significance as a function of the amount of detector materials, the rejection power of background hadrons, the coverage of the detection system and the detection efficiency of electrons.

The results of the simulation study suggest that there are realizable parameter ranges to measure light vector mesons via di-electrons with the reasonable significance level for a realistic luminosity in central Pb+Pb collisions at $\sqrt{s_{NN}} = 5.5$ TeV.