論文の内容の要旨

Canonical approach to finite density QCD (正準集合の方法を用いた有限密度格子 QCD 計算)

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Although it is well known that QCD has a rich phase structure at finite temperature and density, the investigations based on first-principles calculations are limited in a small density region due to so-called a sign problem. However, in finite temperature and density QCD systems, a lot of physically interesting targets such as the early Universe, neutron stars and quark matters have been waiting to be explored. Therefore, it can be said that it is quite meaningful to seek methods for accurate computation of thermodynamic quantities at a large baryon chemical potential values. This also is an urgent subject in the fields of particle and nuclear physics. The canonical approach which is studied in this thesis corresponds to a fugacity expansion of a grand canonical partition function and it could have a potential to overcome the sign problem. This is because it can avoid the sign problem in principle. However, it is reported that it has its particular numerical instabilities and it is somewhat unclear whether it can produce reliable results. Taking this situation into consideration, in this thesis, the validity of the canonical approach is discussed and pressure, baryon number density, and baryon susceptibility at finite density are calculated through lattice QCD simulation based on the canonical approach. The results are also compared with those obtained using the multi--parameter reweighting method and the Taylor expansion method which are considered as a valid method for finite density QCD at a small baryon chemical potential on a lattice. The results obtained by the canonical approach are found to be in very good agreement in the regions where the errors of the multi-parameter reweighting method and Taylor expansion method are under control. Moreover, it is also found that the validity range of the canonical approach is wider than the multi-parameter reweighting method and Taylor expansion method. A multiple precision calculation used in the Fourier transformation to calculate canonical partition functions contributes to this result.