ABSTRACT

Title: *Study of transport properties of strongly interacting matter in a magnetic field*

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In Heavy Ion Collisions (HIC) at experimental facilities such as the Large Hadron Collider (LHC) at CERN and Relativistic Heavy Ion Collider (RHIC) at BNL two highly energetic beams of heavy ions like Au-Au, Pb-Pb are collided to produce a system of strongly interacting matter at high density and/or temperature known as Quark gluon plasma (QGP) which is a deconfined system of quarks and gluons. This hot and dense nuclear matter may reach local thermodynamic equilibrium, exhibiting specific thermodynamic and transport properties. If the interaction between quarks and gluons is sufficiently strong to maintain local thermodynamic equilibrium in the subsequent phases, these phases will also exhibit distinct transport properties. Experimentally, only energy and momentum of particles post-freeze-out are measurable, necessitating the modeling of HIC starting from initial state of two Lorentz-contracted heavy ion nuclei, the formation and thermalization of the QGP, its evolution, the phase transition to the hadronic phase, and the evolution of the hadronic phase. The evolution of this system can be studied using hydrodynamics. Hydrodynamic simulations of relativistic HICs are performed using computational methods and matched with the observed momentum distribution of particles from experiments. STAR data on the elliptic flow of charged hadrons in Au+Au collisions at $\sqrt{s} = 200$ GeV per nucleon pair suggest that the matter produced in HIC behaves more like a strongly interacting liquid than a weakly interacting gas. This observation necessiates the use of dissipative hydrodyanmics. Transport coefficients which go as an input to hydrodyanmic equations measure the dissipative processes occurring in strongly interacting matter, driven by collisions among constituents. Thus, the scattering cross-section is an important dynamical input to the transport coefficients. We know that in HICs, the hadronic phase attains a temperature in the range 100 MeV $\lesssim T \lesssim 150$ MeV. Hence it becomes important to consider the thermal effects in the presence of background magnetic field in the calculations of cross section to provide a more realistic picture. In the first part of the thesis, the temperature and density dependence of the relaxation times, thermal conductivity, shear viscosity and bulk viscosity for a hot and dense gas consisting of pions, kaons and nucleons have been evaluated in the kinetic theory approach in the ambit of Relaxation Time Approximation (RTA). The in-medium cross-sections for $\pi\pi$, πK and πN scatterings have been obtained by using complete propagators for the exchanged ρ, σ, K^* and Δ excitations derived using thermal field theoretic techniques. Notable deviations have been observed in the temperature dependence of these transport coefficients when compared with corresponding calculations using vacuum cross-sections usually employed in the literature. The value of the specific shear viscosity η/s is found to be in agreement with available estimates. Apart from high temperature and/or density, in non-central heavy ion collision a strong magnetic field of the order of several m_π^2 or larger is produced at RHIC and LHC due to the collision geometry. The magnetic field being comparable to the typical QCD scale can have a direct influence on the strongly interacting matter. Though, the magnetic field is very transient (few fm/c), the finite electrical conductivity of the medium sustains the magnetic field for a longer time. In the presence of magnetic field the transport coefficients become anisotropic. Thus, in the second part of the thesis, the electrical and Hall conductivities in a uniform magnetic field are evaluated for an interacting pion gas using kinetic theory in the RTA framework. The in-medium cross sections vis-a-vis the relaxation time for $\pi\pi$ scattering are obtained using a one-loop modified thermal propagator for

the exchanged ρ and σ mesons using thermal field theoretic techniques. Use of the in-medium scattering cross-section is found to produce a significant effect on the temperature dependence of both electrical and Hall conductivities compared to the case where vacuum cross-section is used. The calculated electrical conductivity has been shown to be sufficient for causing a significant delay in the decay of the external magnetic field in a HIC. In the third part of the thesis we have considered the magnetic field influence on the relaxation time through the cyclotron frequency and magnetic field dependent cross-section unlike the second part where we considered only the thermal medium effects on the relaxation time. We have evaluated the electrical conductivity and shear viscosity of a interacting pion gas in a thermo-magnetic medium using the kinetic theory in the RTA method. The medium modified relaxation time is obtained from the corresponding in-medium $\pi\pi \rightarrow \pi\pi$ scattering cross-section calculated using the thermo-magnetic ρ propagator. It is observed that the average relaxation time shows a $1/T^4$ variation with temperature for a fixed value of magnetic field. The relaxation time shows a mild oscillatory variation with respect to the magnetic field. It is also observed that the medium dependent scattering cross-section causes a considerable amount of influence on the electrical conductivity and shear viscosity compared to its vacuum counterpart. Thus, the studies performed in this thesis indicates that incorporation of in-medium effects (both thermal and magnetic) are essential for the realistic hydrodynamic modelling of the HIC and also the estimated electrical conductivity points out that a weak magnetic field can be present in the later stage of a HIC (in hadronic phase) and could be phenomenologically relevant.

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