According to Quantum Chromodynamics (QCD), colored quarks and anti-quarks are the fundamental particle which always remain confined within a colorless hadrons via strong force mediated by another colored object called, gluon. Heavy ion collision (HIC) at relativistic energies provides an opportunity to study QCD at finite temperature and densities. Calculations based on Lattice QCD predict at high temperatures and/or densities the hadronic matter melts down to a state of quarks, anti-quarks and gluons. Such a deconfined state of thermal system is called Quark Gluon Plasma (QGP).

Relativistic Heavy Ion Collider (RHIC) at BNL and Large Hadron Collider (LHC) at CERN are two experimental facilities where QGP may be created for a short duration of time. Collision between nuclei at ultra relativistic energies produce charged particles either in hadronic or partonic state depending on the collision energy. Interaction among these charged particle produce electromagnetic (EM) radiation - real and virtual photons (dileptons). Electromagnetic (EM) probes - dileptons and photons - are considered to be very efficient tool for detection of QGP, because of their nature of interaction - they do not suffer final state re-scattering, hence provide clean signature of each stages of the evolving fireball.

The hot and dense matter expected to be formed in the partonic phase after ultra-relativistic heavy ion collisions dynamically evolve in space and time due to high internal pressure. Consequently, the system cools and reverts to the hadronic matter from the partonic phase. Just after the formation, the entire energy of the system is thermal in nature and with progress of time some part of the thermal energy gets converted to the collective (flow) energy. In other words, during the expansion stage the total energy of the system is shared by the thermal as well as the collective degrees of freedom. The collective motion is sensitive to the Equation of State (EoS) of the system, hence estimation of collectivity will shed light on the nature of the system.

The collective parameters extracted using hadronic spectra have hardly any information about the interior of the matter, as the parameters of collectivity extracted from the hadronic spectra are limited to the evolution stage where the collectivity ceases to
exist. In contrast to hadrons, EM probes are produced and emitted from each space time points. Therefore, estimating flow from the EM probes will shed light on the space-time evolution of the collectivity in the system. We study the evolution of collective motion, both radial and elliptic flow of the system formed in HIC at relativistic energies by using photons and lepton pairs.

The transverse momentum ($p_T$) distribution of photons reflect the temperature of the source as their productions from a thermal source depend on the temperature ($T$) of the bath through the thermal phase space factors of the participants of the reaction that produces the photon. However, the thermal phase space factor may be changed by several factors - e.g. the transverse kick due to flow received by low $p_T$ photons from the low temperature hadronic phase will mingle with the high $p_T$ photons from the partonic phase, making the task of detecting and characterizing QGP more difficult. For dilepton the situation is, however, different because in this case we have two kinematic variables - out of these two, the $p_T$ spectra of lepton pairs is affected but the $p_T$ integrated invariant mass ($M$) spectra is unaltered by the flow. From $p_T$ integrated $M$ distribution of lepton pairs, we infer that lepton pairs with $M (> m_\phi)$ originate from the early time, providing information of partonic phase and pairs with $M < m_\rho$ are chiefly produced at late times giving information of the hadronic phase. Therefore, the study of the $p_T$ integrated $M$ distribution of lepton pairs can act as a chronometer of the heavy ion collisions. On the other hand, the $p_T$ distribution of dilepton for different $M$ windows can be used as flow meter, and a judicious selection of $p_T$ and $M$ windows will be very useful to characterize the QGP and the hadronic phases separately.

**Radial Flow**

(a) **Ratio of photon to dilepton spectra:** The photon and dilepton spectra produced in RHIC at relativistic energies have been studied. The initial condition have been constrained to reproduce the available experimental data. The calculations of spectra from thermal sources depend on the parameters like initial temperature ($T_i$), thermalization time ($\tau_i$), chemical freeze-out temperature ($T_{ch}$), kinetic freeze-out temperature ($T_f$), etc., which are not known unambiguously. To minimize the dependence of thermal
sources on these parameters, the importance of the ratio of the transverse momentum spectra of photons to dileptons has been emphasized to partially overcome some of these uncertainties. It may be mentioned here that in the limit of $M \to 0$, the lepton pairs (virtual photons) emerge as real photons. Therefore, the evaluation of the ratio of the $p_T$ spectra of photons to dileptons for various invariant mass bins along with a judicious choice of the $p_T$ and $M$ windows will be very useful to extract the properties of QGP as well as that of the hadronic phase. We have extracted the radial flow from the ratio of photon to dilepton spectra. The variation of average radial flow velocity with average temperature of the system and $\langle M \rangle$ has been studied for different collision energies. Within the ambit of the present analysis it is shown that the variation of the radial velocity with invariant mass is indicative of a phase transition from the initially produced partons to hadrons.

(b) Correlation Function of lepton pairs: The correlation functions of lepton pairs have also been evaluated with the same inputs which reproduce the experimental data from HIC. It has been shown that the HBT radii extracted from the correlation functions of lepton pairs can be used to estimate the temporal and spatial dimension of the system. The $M$ dependence of the HBT radii could be used to characterize source properties at various instances of evolution. In one of the first such calculations involving dileptons, we show that the mass dependence of radii extracted from the dilepton interferometry provide access to the development of collective flow with time.

Elliptic Flow

We study the variation of elliptic flow of thermal dileptons with transverse momentum and invariant mass of the pairs for Pb+Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV. The dilepton productions from quark gluon plasma (QGP) and hot hadrons have been considered including the spectral change of light vector mesons in the thermal bath. The space time evolution has been carried out within the framework of 2+1 dimensional ideal hydrodynamics with lattice+hadron resonance gas equation of state. We find that a judicious selection of invariant mass ($M$) window can be used to extract the collective properties of quark matter, hadronic matter and also get a distinct signature of medium
effects on vector mesons. We observe a reduction of elliptic flow \( v_2 \) for \( M \) beyond \( \phi \) mass, which if observed experimentally would give the measure of \( v_2 \) of the partonic phase. We also observe that the magnitude of the elliptic flow at LHC is significantly larger than at RHIC collision condition.