Dilepton Interferometry : a tool to charecterize different phases of collision in HIC

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One of the most efficient way to obtain direct experimental information on the space-time struc- ture of the particle emitting source created in a Relativistic Heavy Ion Collision is through two-particle intensity (Hanbury-Brown-Twiss (HBT)) interferometry [1]. A new measurement of studying the mass dependence of the dilepton interferometry in relativistic heavy-ion collision experiments as a tool to characterize the partonic phase is proposed. Compared to real photons, the virtual photon (dilepton) can be used more effectively to study specific stages of evolution in heavy-ion collisions because of the additional kinematic variable, the invariant mass (M).

The interferometry of the dilepton pairs actually reflect correlations between two virtual photons. The analysis then concentrates on computing the Bose-Einstein correlation (BECF) function for two identical particles defined as,

$$C_2(\vec{k_1},\vec{k_2}) = \frac{P_2(\vec{k_1},\vec{k_2})}{P_1(\vec{k_1})P_1(\vec{k_2})} \tag{1}$$

where $\vec{k_i}$ is the three momentum of the particle i and $P_1(\vec{k_i})$ and $P_2(\vec{k_1},\vec{k_2})$ represent the one- and two- particle inclusive virtual photon transverse momentum (k_T) spectra respectivly. given by

$$P_1(\vec{k}) = \int d^4x\ \omega(x,k) \tag{2}$$

$$\begin{aligned} P_2(\vec{k_1},\vec{k_2}) &= P_1(\vec{k_1})P_1(\vec{k_2}) \\ &+ \int d^4x_1 d^4x_2\ \omega(x_1,K) \\ &\times\omega(x_2,K)\ \cos(\Delta x^\mu \Delta k_\mu) \quad (3) \end{aligned}$$

where $K=(k_1+k_2)/2$, $\Delta k_\mu = k_{1\mu}-k_{2\mu}=q_\mu$, x and k are the four co-ordinates for position and momentum variables respectively and $\omega(x,k)$ is the source function related to the thermal emission rate of virtual photons per unit four volume, R as follows:

$$\omega(x,k) = \int_{M_1^2}^{M_2^2} dM^2\, \frac{dR}{dM^2 d^2k_T dy} \tag{4}$$

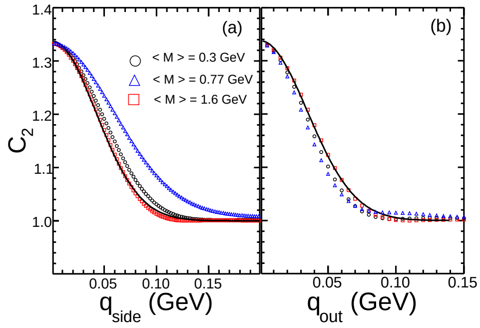

FIG. 1: Correlation function for dilepton pairs as a function of q_{side} (a) and q_{out} (b) for three values of $\langle M\rangle$.

The correlation function, C_2 for different invariant mass windows as a function of q_{side} and q_{out} has been calculated. The q_{side} and q_{out} which are related to transverse momentum of individual pair expressed as follows: $q_{out} = (k_{1T}^2 - k_{2T}^2)/f(k_{1T},k_{2T})$ and $q_{side} = (2k_{1T}k_{2T}\sqrt{1-\cos^2(\Delta\psi)})/f(k_{1T},k_{2T})$

where

$$f(k_{1T},k_{2T}) = \sqrt{k_{1T}^2 + k_{2T}^2 + 2k_{1T}k_{2T}\cos(\Delta\psi)} \tag{5}$$

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The source dimensions can be obtained by parameterizing the calculated correlation function with the empirical (Gaussian) form

$$C_2 = 1 + \lambda \exp(-R_i^2 q_i^2). \tag{6}$$

where the subscript i stand for *out* and *side* and λ represents the degree of chaoticity of the source. For a fully chaotic source $\lambda = 1$. A representative fit to the correlation functions are shown in Fig. 1 (solid lines).

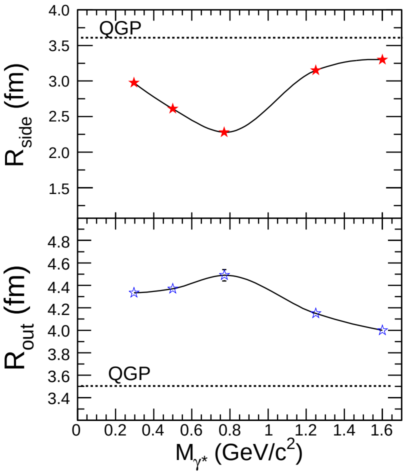

FIG. 2: R_{side} and R_{out} as a function of $\langle M \rangle$. The dashed line shows the corresponding values for the QGP phase.

While the radius (R_{side}) corresponding to q_{side} is closely related to the transverse size of the system and considerably affected by the collectivity, the radius (R_{out}) corresponding to q_{out} measures both the transverse size and duration of particle emission. The extracted R_{side} and R_{out} for different M are shown in Fig. 2. The R_{side} (R_{out}) shows non-monotonic dependence on M [3], it drops (rises) with increase (decreases) in M finally again approaching the QGP value for M $\geqslant m_\phi$ resulting in a dip (bump) around M $\sim m_\rho$. In a geometrical picture, as the system expands radially a rarefaction wave moves toward the center of the cylindrical geometry as a consequence the radial size of the emission zone decreases with time. Therefore, the size of the emission zone is larger at early times and smaller at late time. So the high $\langle M \rangle$ regions which are dominated by the early partonic phase and where the collective flow has not been developed fully have a larger R_{side}. In comparison, the lepton pairs with $M \sim m_\rho$ are emitted from the late hadronic phase where the size of the emission zone is smaller due to larger collective flow giving rise to a smaller R_{side}. These get reflected as a dip in the variation of R_{side} with $\langle M \rangle$ around the ρ-mass region (Fig. 2 upper panel). Thus the variation of R_{side} with M can be used as an efficient tool to characterize various phases of matter. The dip in R_{side} at $\langle M \rangle \sim m_\rho$ is due to the contribution dominantly from the hadronic phase. However, R_{out} probes both the transverse dimension and the duration of emission. Although the flow is larger in hadronic phase but as it can probe the duration of emission which is large for hadronic phase because the expansion is slower in this phase for the EoS used in the present work. The larger duration compensates the reduction of R_{out} due to flow in the hadronic phase resulting in a bump in R_{out} in this region of M (Fig. 2 lower panel).

In summary, the dilepton pair correlation functions has been evaluated for Au+Au collisions at RHIC energy. The additional kinematic variable, M for dilepton pairs make it a more useful tool for characterizing the different phases of the matter formed in heavy ion collisions compared to the HBT interferometry with real photon.

References

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