Probing elliptic flow of QCD matter by lepton pairs

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The strong collectivity of the medium formed in high energy heavy-ion collisions is quantified through the elliptic flow, v_2, which measures the azimuthal correlation of produced particle with respect to the reaction plane. The initial spatial anisotropy in heavy-ion collisions gets converted to anisotropy in momentum space due to interactions among the constituents of the matter. Therefore, v_2 may be treated as a measure of the momentum anisotropy. v_2 measurements at RHIC and LHC have been used to establish the collectivity at the partonic phase, constrain the equation of state and extract the transport properties of the QCD matter.

In the present work, we have studied the invariant mass (M) and transverse momentum (p_T) dependence of v_2 as probed by lepton pairs originating from the quark gluon plasma and hot hadrons. We evaluate v_2 at mid-rapidity for Pb+Pb collisions at $\sqrt{s_{NN}} =$ 2.76 TeV in 30-40% collision centrality using 2+1D ideal hydrodynamics [1]. Through this study we have further expanded the scope of v_2 to separately study the properties of partonic phase at high $M(> m_\phi\ )$ and hadronic hadronic phase ($M \sim M_\rho$). In addition we find that v_2 is sensitive to the medium effects [2] at low M ($< m_\rho$) region. We choose dileptons as they are subjected to electromagnetic interaction and are not distorted by final state interaction in a strongly coupled medium. As a result, once produced they travel unscathed carrying information from each space-time point of the system formed in ultra relativistic heavy-ion collisions. The choice of the above mass ranges can be understood from the invariant yield mass spectra shown in Fig. 1. The figure shows the dilepton yields from quark mater and hadronic matter with and without medium effects. One observes that for the mass range $M > M_\phi$ the yields are dominated by contribution from partonic phase, while for the mass range $M_\rho < M < M_\phi$ the contribution from hadronic phase dominates and for the $M < M_\rho$ the dilepton yields increases substantially when medium effects are included. Further, unlike real photon, dileptons are are massive. Thus with the availability of an additional kinematic variable M along with p_T one expects that the high mass dilepton originate form the early time providing information of the partonic phase and low mass dileptons predominantly produced in late time providing information about hadronic phase. Therefore the M distribution can be act as chronometer of the heavy ion collision [3]. Therefore, it is clear that appropriate choice of M window will help in estimating the flow for different phase of the matter. That is estimating flow from the EM probes will shed light on the time evolution of the collectivity in the system .

The elliptic flow of dilepton [4], v_2, is defined as

$$v_2(p_T, M) = \langle cos2\phi \rangle = \frac{\sum_{i=Q,H} \int cos(2\phi) \left(\frac{dN^{\gamma^*}}{d^2p_T dM^2 dy}|_{y=0} \right)_i d\phi}{\sum_{i=Q,H} \int \left(\frac{dN^{\gamma^*}}{d^2p_T dM^2 dy}|_{y=0} \right)_i d\phi} \quad (1)$$

where, ϕ is the azimuthal angle of the dilepton pair, Q and H corresponds to the quark and hadronic contributions. The invariant yields at mid-rapidity ($\frac{dN^{\gamma^*}}{d^2p_T dM^2 dy}|_{y=0}$) are obtained assuming a net baryon free and ideal fluid.

Fig. 2 shows the p_T dependence of v_2 probed by lepton pairs originating from quark matter

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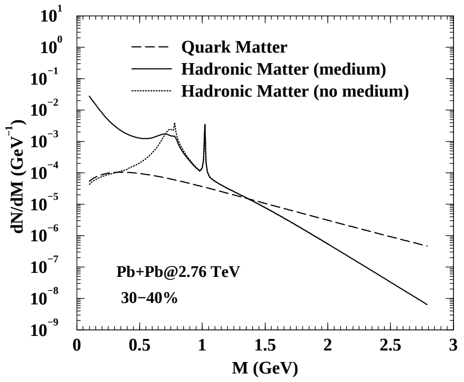

FIG. 1: Invariant mass distribution of lepton pairs from quark matter and hadronic matter (with and without medium effects).

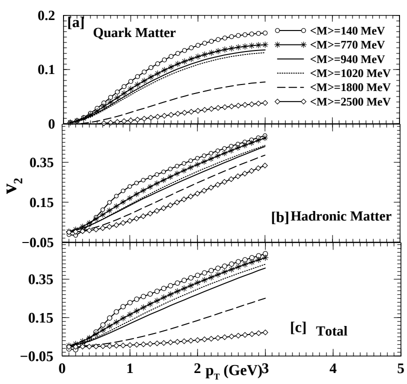

FIG. 2: Elliptic flow of lepton pairs from quark matter and hadronic matter and total.

(upper panel) hadronic matter (middle panel) and total (lower panel). The v_2 increases with increase in p_T and attains maximum value at $p_T \sim 2-3$ GeV. Higher mass dilepton pairs have smaller v_2, this trend is what is expected from hydrodynamical evolution. In general we find the p_T differential v_2 from hadronic contribution is larger than the corresponding contribution from partonic phase. However for the total v_2 the contribution from hadronic and partonic phases are weighted by the respective dN/dM contributions.

In Fig. 3 we depict the the variation of $v_2(p_T)$ for $\langle M\rangle$=500 MeV with and without medium effects on the ρ spectral function. $\langle M\rangle$=500 MeV is selected because the in-medium broadening of ρ enhances the lepton pair production in this region of M (see Fig. 1). We observe that medium effect causes an enhancement of the p_T differential v_2 at high p_T .

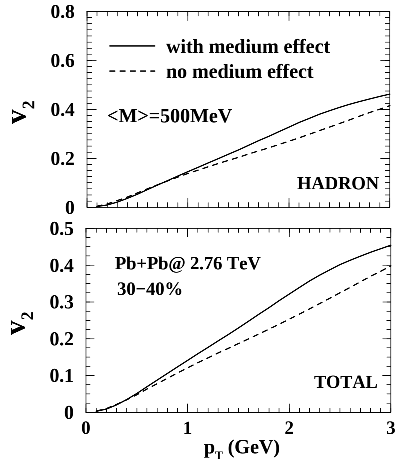

FIG. 3: Variation of dilepton elliptic flow as function of p_T from hadronic matter (with and without medium effects) and total.

Our study shows that $v_2(M, p_T)$ provides rich information about the collective evolution of QCD matter formed in heavy ion collision. Further details of $v_2(M)$ and comparison to corresponding results for hadrons at similar masses will be presented.

References

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