Consequences of Elliptic Flow in Relativistic Heavy Ion Collisions

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Introduction

The recent observation of large elliptic flow of hadrons at the Relativistic Heavy Ion Collider (RHIC) has provided a significant evidence of the formation of QGP, a hot and dense new state of matter by colliding heavy nuclei at relativistic energies. The elliptic flow parameter v_2 is a powerful fundamental observable which furnishes strong indication of collectivity and early thermalization in the system. Photons are known among the most efficient probes of heavy ion collision study as they are emitted from the entire lifetime of the system and do not suffer any final state interactions. The elliptic flow of electromagnetic radiation, produced in relativistic heavy ion collisions has been explored in detail in this thesis work.

1. Thermal photon v_2 at RHIC

We give a first prediction of the elliptic flow of thermal photons produced in 200A GeV Au+Au collisions at RHIC considering ideal hydrodynamic expansion of the plasma [1]. We show that the flow parameter v_2 at large p_T or at early times, reflects the momentum anisotropies of the initial partonic phase [see Fig. 1]. The dependence of photon v_2 on collision centrality, proper time τ, changing initial and final conditions has been investigated in detail. We show that the initial spatial eccentricity scaled elliptic flow of photons from different phases remains almost independent of the collision centrality upto a very large value of impact parameter. It has been shown recently that, thermal photon v_2 decides the

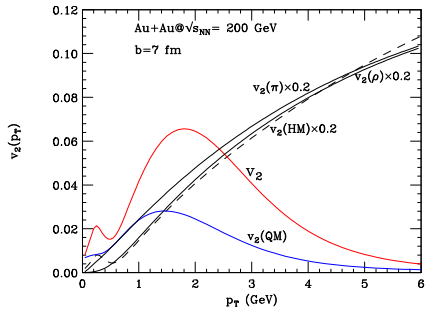

FIG. 1: Thermal photon elliptic flow at RHIC.

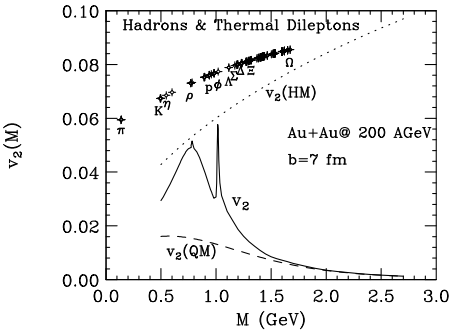

FIG. 2: Thermal dilepton elliptic flow at RHIC.

nature of the direct photon v_2 in the intermediate and low p_T range as the contribution to v_2 from all other sources of photons are almost negligible in that p_T range. This observation makes our findings even more interesting and efforts are on to obtain the experimental photon v_2 results from PHENIX accurately. In addition we give a prediction for photon v_2 at LHC, which shows a relatively large QGP phase contribution to v_2 compared to RHIC, as the initial temperature as well as radial flow at LHC is much larger than RHIC.

2. Thermal dilepton v_2 at RHIC

The study of virtual photons or dileptons as

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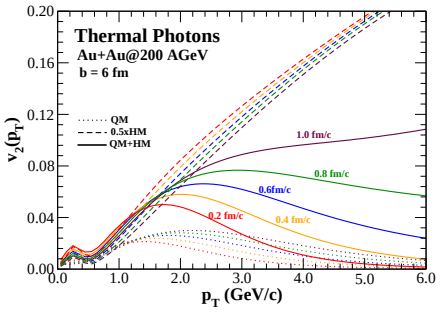

FIG. 3: Photon $v_2(p_T)$ at different τ_o.

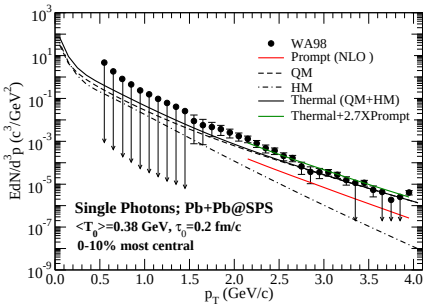

FIG. 4: Reanalysis of single photon SPS data.

a probe of heavy ion collisions is more advantageous compared to real photons as the invariant mass M of dileptons can be used along with transverse momentum p_T, to access the different stages of the expanding system. We show that the $v_2(M)$ for thermal dileptons at RHIC exhibits a very rich structure [Fig. 2] depending on the relative contributions from the quark matter and hadronic matter phases [2]. The thermal dilepton v_2 is completely dominated by the hadronic matter contribution for $M \leq M_\phi$, whereas beyond the ϕ mass, sum v_2 tracks the v_2 from quark matter. The p_T spectra and $v_2(p_T)$ of thermal dileptons at the resonance (ρ, ω, ϕ) masses as well as at large M values along with the centrality dependence of dilepton v_2 are investigated in detail.

3. τ_0 from photon v_2

A correct estimation of the initial formation time τ_0 of the plasma, beyond which its evolution can be described by fluid dynamics, is very much essential to study the properties of QGP produced in heavy ion collisions. We show that the thermal photon elliptic flow is quite sensitive to the initial formation time of the plasma. The value of τ_0 can be obtained precisely from experimental determination of photon v_2 at RHIC [3]. At smaller τ_0, QGP contribution increases at large p_T, which has a smaller v_2 [Fig 3]. As the photon v_2 is dominated by QGP v_2 for $p_T \geq 1$ GeV, sum v_2 decreases at smaller τ_0.

4. Reanalysis of single photon SPS data

The WA98 single photon data, which is considered as an important landmark in heavy ion collision study using electromagnetic probes, has been reanalyzed by incorporating several new improvements in theory of prompt and thermal photon production [4]. A quantitative explanation of the data is obtained by combining thermal photons along with properly normalized prompt contribution [Fig. 4]. We also show that photon v_2 at SPS energy can be very useful to distinguish between the with and without phase transition scenarios.

In conclusion, azimuthal anisotropy of electromagnetic radiations is investigated in detail. Elliptic flow of thermal photons and dileptons is found to reflect a clear signature of the initial partonic phase which is formed soon after the collision and is of a completely different nature compared to the elliptic flow of hadrons. We show that thermal photon v_2 can be used to estimate the initial formation time of the plasma precisely and photon v_2 at SPS energy can distinguish between the with and without phase transition scenarios.

References

[1] R. Chatterjee *et al.*, Phys Rev. Lett. **96**, 202302 (2006).
[2] R. Chatterjee *et al.*, Phys. Rev. C **75**, 054909 (2007).
[3] R. Chatterjee and D. K. Srivastava, Phys. Rev. C **79**, 021901(R) (2009).
[4] R. Chatterjee, D. K. Srivastava, and S. Jeon, Phys. Rev. C **79**, 034906 (2009).