Thermal photon production from shadowed Glauber model initial condition

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The idea of nucleon shadowing was first introduced by R. J. Glauber in order to explain why the total cross section of π meson with deuteron is smaller compared to the sum of the corresponding cross sections with free neutron and proton at very high energy [1]. Shadowing was considered for heavy ion collisions in [2]. The authors indicated that the inclusion of shadowing in the Monte Carlo Glauber initial conditions required as input for the hydrodynamical calculations reproduces the hadronic observables better, compared to the case, where such shadowing effect is ignored.
Apart from the hadronic probes, direct photons (dominant part at low p_T are the thermal photons) are also important probes for heavy ion collisions as they carry signatures of the entire evolutionary time line of a fireball. However, the reported discrepancies between the theoretical predictions and experimental observations of the elliptic flow of direct photons have put this perspective in question, the disagreement being better known as the "photon v_2 puzzle".
In this report, we study the effects of initial state shadowing on the thermal photon observables. We also explore whether this inclusion resolves the "photon v_2 puzzle".
We start firstly with the conventional Monte Carlo Glauber initial condition (MCG) and then we consider the same model after inclusion of shadowing (shMCG). We then study the differential spectra and elliptic flow of thermal photons using these two initial conditions as described below.

For the collision of two nuclei the beam axis is considered along the z axis and the plane perpendicular to the beam axis is the transverse plane. The initial entropy distributions for a single event on this plane is obtained using this following equation [3]:

$$s(x,y) = K \sum_{i=1}^{N_s} w_i(\Theta_i)\, f_i(x,y) \qquad (1)$$

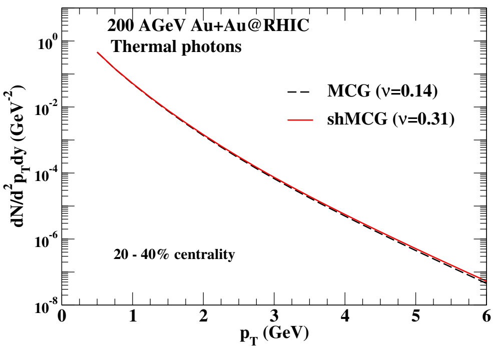

FIG. 1: Thermal photon spectra from MCG and shMCG initial conditions for 20-40% Au+Au@200A GeV collisions at RHIC [3].

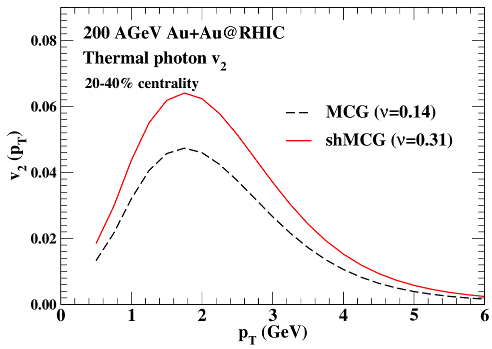

FIG. 2: Thermal photon v_2 from MCG and shMCG initial conditions for 20-40% Au+Au@200A GeV collisions at RHIC [3].

*Electronic address: pingaldg@vecc.gov.in where Θ_i is a binary variable which labels the type of the source. $w_i(\Theta_i)$ decides the weight to be given to the i^{th} source for entropy deposition. For MCG, if the i^{th} source is a collision then $\Theta_i = 0$ and $w_i = \nu$. On the other hand, if the i^{th} source is a participant then $\Theta_i = 1$ and $w_i = (1 - \nu)$. Hence each participant (or collision) in the case of MCG is given an equal weight. However in shMCG, weights are obtained according to the recipe given in [2], where they can be different for various participants (or collision). K in Eq.1 is a proportionality constant and $f_i(x, y)$ is a normalized distribution function for the i^{th} source which is taken as follows:

$$f_i(x, y) = \frac{1}{2\pi\sigma^2}\, e^{-\frac{(x-x_i)^2+(y-y_i)^2}{2\sigma^2}} \qquad (2)$$

where σ is a free parameter taken as 0.4 fm. The value of K, ν and λ (a parameter used in shMCG) are determined after reproducing the final charged particle multiplicity and its probability distribution. The initial entropy density profile for our hydrodynamical calculations is constructed for both the cases (MCG and shMCG) by taking initial state average over N random events (where events obey the distribution $dN/db \propto b$) of a particular centrality class.

We consider a (2+1) dimensional ideal hydrodynamical model to study the evolution of the system produced in $20 - 40\%$ central Au+Au @200A GeV collisions at RHIC. The initial thermalization time (τ_0) is considered as 0.17 fm. The spectra and elliptic flow of thermal photons are calculated using state of the art photon rates, where QGP rates are taken from [4] and the rates from different hadronic channels are taken from [5].

FIG. 1 shows the differential p_T-spectra of thermal photons for MCG and shMCG initial conditions. The p_T spectrum has been found to be independent of our choice of the initial condition. However, the elliptic flow coefficient ($v_2(p_T)$) is significantly different for these two cases (FIG. 2). We see a substantial increase in $v_2(p_T)$ for the shMCG initial condition compared to the MCG initial condition within the p_T range $1 - 3$ GeV and the peak value of $v_2(p_T)$ is about 35% larger compared to the MCG case. It is shown in [2] that for a collision of two nuclei, shadowing will act more on those nucleons at the interior than those at the boundary of a nucleus. Effectively, this increases the eccentricity of the ellipsoidal overlapped zone for the shMCG case compared to the MCG case. This results in a larger elliptic flow of thermal photons for the prior.

Finally, we conclude that initial state shadowing increases the initial spatial anisotropy henceforth the elliptic flow of thermal photons. The spectra and elliptic flow of hadrons are also calculated in the same formalism for a detailed comparison. However, a complete calculation considering the initial state shadowing along with the event by event fluctuations would be useful to get the accurate effect of shadowing on the thermal photon spectra and v_2.

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