Investigation of high $p_t$ events in Nucleus-Nucleus collisions using the Hijing event generator

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In recent years lot of interest has been observed in the nucleus-nucleus collisions at RHIC energies in phenomena related to high $p_t$ physics [1]. The suppression of high $p_t$ particles and disappearance of back-to-back jets compared to the scaling with number of binary nucleon-nucleon collisions indicates that a nearly perfect liquid is produced in these collisions. Results on self shadowing of high $p_t$ events are presented using hadron multiplicity associated to high $p_t$ and unbiased events in nucleus-nucleus collisions [2] obtained from the hijing event generator.

I. INTRODUCTION AND THEORY

It has been shown by Cunqueiro, Deus and Pajares [2] that the difference between the multiplicity associated to high $p_t$ events and unbiased multiplicity is given by the normalised variance of the unbiased multiplicity indicating thereby the self-shadowing of the high $p_t$ events. We here reproduce some of the equations of ref.[2] for the sake of clarity. In hadron-nucleus collisions, the inelastic unbiased cross section is defined as:

$$\sigma^{hA}(b) = \sum_{n=1}^{A} \binom{A}{n} (\sigma T(b))^n (1 - \sigma T(b))^{A-n}$$

where $\sigma T(b)$, the collision probability, is further divided into two classes viz., a collision giving rise to high $p_t$ particle termed as events of type C with cross-section $\sigma_C$ and rest of the events without high $p_t$ particle i.e., non-C type events with cross-section $\sigma_{NC}$. Thus :

$$(\sigma T(b))^n = \sum_{i=0}^{n} \binom{A}{n} (\sigma_C)^i (\sigma_{NC})^{n-i} T(b)^n,$$

The final cross section for events of type C must contain at least one elementary $\sigma_C$ in the sum [3] i.e.,

$$\sigma_C^{hA} = \sum_{n=1}^{A} \sigma_C^{n-i} \sigma_{NC}^{n-i} T(b)^n X (1 - (\sigma_C + \sigma_{NC})T(b))^{A-n}$$

$$= 1 - (1 - \sigma_C T(b))^A$$

This equation shows that C-events are self-shadowed, in the sense that their cross section depends only on their cross section in nucleon-nucleon collision. This is also true for nucleus-nucleus collisions [4, 5]. Taking $\alpha_C$ as the probability for an elementary collision to be of type C, $N(\nu)$ total
number of events, and $N_C(\nu)$ total number of events of type C, the probability distribution for C type events with $\nu$ collisions in the limit of small $\alpha_c$ can be written as [2]:

$$P_C(\nu) = \frac{\alpha C \nu N(\nu)}{\sum \nu N_C(\nu)} = \frac{\nu N(\nu)}{\nu \sum \nu N(\nu)} = \frac{\nu P(\nu)}{<\nu>} \quad (5)$$

It was proposed [2] that if the total multiplicity $P(n)$ is obtained by the convolution of the elementary multiplicity distributions $p(n)$, the total dispersion $D$ is related to the dispersion $d$ and multiplicity $\bar{n}$, of the distribution of elementary interaction as

$$D^2 < n >^2 = <\nu^2> - <\nu>^2 + \frac{d^2}{<\nu>\bar{n}^2} \quad (6)$$

As in nucleus-nucleus collision $\nu$ is very high so neglecting $Ind$ term one gets:

$$D^2 < n >^2 = <\nu^2> - <\nu>^2 \quad (7)$$

Hence, normalized dispersion of the total multiplicity is approximated by the normalized dispersion of the number of elementary interactions. This argument is used to extend Eq. 5 to the multiplicity distribution [2] i.e.,

$$P_C(n) = \frac{n P(n)}{<n>} \quad (8)$$

which can be written as:

$$< n >_C - < n > = \frac{D^2}{<n>} \quad (9)$$

Therefore, the difference between the average multiplicity associated with high $p_t$ events and unbiased average multiplicity is given by the normalized variance of the unbiased multiplicity distribution if high $p_t$ events are self-shadowed.

II. RESULTS AND DISCUSSION

We generated one million Au+Au minimum bias events at $\sqrt{s_{NN}} = 200$ GeV and 100K Pb+Pb minimum bias events at $\sqrt{s_{NN}} = 11$ TeV using Hijing Event generator with default setting. The analysis was done in the range $1.0 < y < 1.0$ and $0^o \leq \phi \leq 360^o$ for different $p_t$ cuts. The centrality bins were calculated using the number of participants in a collision. We used eight equal spacing centrality bins of $N_{part}$ i.e., 0-50, 50-100, 150-200, 200-250, 250-300, 300-350, and 350-400 representing, respectively, as centralities 1, 2, 3, 4, 5, 6, 7, and 8 for Au+Au collisions. In case of Pb+Pb collisions we also used the centrality bin corresponding to $400 < N_{part} < 450$, representing the 9th centrality bin. Events having at least one high $p_t$ track are termed as “events of type C”. We have used different high $p_t$ cuts to check the self shadowing effects in these event samples.

Figure 1(left) shows the plot of normalized variance ($D^2/<N>$) of unbiased multiplicity distribution versus centrality bin for Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV. It is observed that normalized variance decreases monotonically with increasing centrality. Similar trend is observed for Pb+Pb collisions at $\sqrt{s_{NN}} = 11$ TeV (Fig.1 (right)). Non-monotonic decrease of normalized variance with increasing centrality is not observed for both Au+Au and Pb+Pb collisions.

From Eq. 9, we expect the ratio(R)

$$R = \frac{(< n >_C - < n >) <n>}{D^2} = 1$$
In Fig. 2(left), the ratio, R, is plotted versus centrality bin for Au+Au data for different $p_t$ cuts i.e., $p_t > 2$ GeV/c, $p_t > 3$ GeV/c, $p_t > 4$ GeV/c and $p_t > 5$ GeV/c. It is seen that for $p_t < 4$ GeV/c ratio decreases with increasing centrality whereas for $p_t > 4$ GeV/c it stays constant as expected from Eq. 10 for self-shadowing of high $p_t$ events. Fig. 2(right) exhibits similar plots for Pb+Pb collisions for $p_t > 6$ GeV/c, $p_t > 8$ GeV/c, $p_t > 10$ GeV/c and $p_t > 12$ GeV/c. Here also it is noticed that for $p_t < 10$ GeV/c ratio decreases with increase in centrality but almost stays constant for $p_t > 10$ GeV/c indicating thereby self shadowing effect for high $p_t$ events. It is observed that $p_t$ cut changes with change in the collision energy for observing self-shadowing effect.

An attempt has also been made to see if this trend is valid for photon multiplicity distributions.
which can be observed with Photon Multiplicity Detector (PMD) in STAR [6] at RHIC and in ALICE [7] at LHC. Here we have termed events as high $p_t$ if an event has at least one high $p_t$ charged particle and studied the photon multiplicity distributions for different $p_t$ cuts on charged particles as PMD does not carry the information about the momenta of photons. Fig. 3(left) displays the ratio for photons versus centrality bin for Au+Au collisions. Here again we observed similar trend as is seen in Fig. 2(left) for charged particles indicating that self shadowing effect can be studied using photon multiplicity distributions as well. In Fig. 3(right), we present the plot of ratio for photons versus centrality bin for Pb+Pb collisions which again indicates that high $p_t$ events are self shadowed.

III. SUMMARY

Au+Au at $\sqrt{s_{NN}}=200$ GeV and Pb+Pb at $\sqrt{s_{NN}}=11$ TeV Hijing events exhibits self shadowing effect for high $p_t$ events. It is observed that $p_t$ cut changes with change in the collision energy for observing self-shadowing effect. Photon multiplicity distribution also shows similar self-shadowing for high $p_t$ events. This can be checked using Photon Multiplicity Detector in STAR at RHIC and ALICE at LHC.

References

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