Hard scattering contribution to particle production in high energy heavy-ion collisions

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Introduction

Global observables like the multiplicity of produced charged particles and transverse energy, are the key observables used to characterize the properties of the matter created in heavy-ion collisions. In order to study the dependence of the charged particle density on colliding system, center of mass energy and collision centrality, there have been measurements starting few GeV to TeV energies at LHC. There is a need to understand the particle production contribution coming from the QCD hard processes, which scale with number of binary nucleon-nucleon collisions, $N_{\rm coll}$ and soft processes scaling with number of participant nucleons, $N_{\rm part}$.

Centrality dependence of $dN_{\rm ch}/d\eta$ can be parametrized by using a two component model to extract the information of the fraction of hard scattering contributing to the particle production [1]. This gives hard scattering component x as well as average charged particle multiplicity $n_{\rm pp}$ in pp collision as follows.

$$\frac{dN_{\rm ch}}{d\eta} = n_{\rm pp}\left((1-x)\frac{\langle N_{\rm part}\rangle}{2} + x\langle N_{\rm coll}\rangle\right) \quad (1)$$

The Method

For comparison of hard and soft components for different collision energies using two component model, the values of $\langle N_{\rm coll}\rangle$ are required. To calculate that, $\langle N_{\rm coll}\rangle$ for a given energy, is parametrized according to Eq. (2) in terms of $\langle N_{\rm part}\rangle$ using two new parameters, A and α.

$$N_{\rm coll} = A \times N_{\rm part}^{\alpha} \quad (2)$$

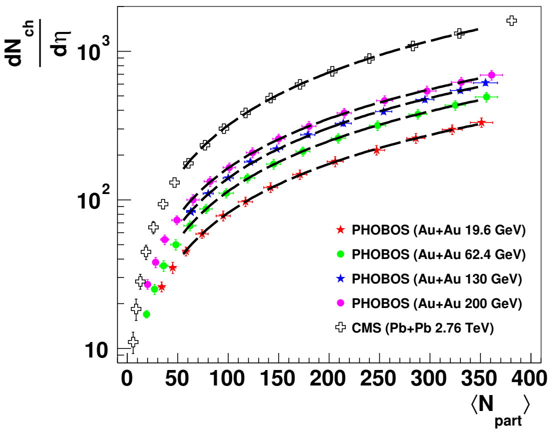

FIG. 1: Centrality dependence of $dN_{\rm ch}/d\eta$ for different RHIC energies (taken from PHOBOS experiment [2]) and for LHC energy (taken from CMS experiment [3]). Fitted lines are the corresponding two component model fittings to extract the x parameter.

Here, we use nuclear overlap model to calculate $\langle N_{\rm coll}\rangle$ and $\langle N_{\rm part}\rangle$ for a given energy, which uses a Glauber Monte Carlo approach. We have estimated the A and α parameters for different energies ranging from 19.6 GeV to 2.76 TeV. After getting the functional dependencies of $\langle N_{\rm coll}\rangle$ and $\langle N_{\rm part}\rangle$, we use the above two component model for various centrality data at different collision energies [2, 3] to estimate x and $n_{\rm pp}$. This is shown in Figure 1 and the extracted values of the hard scattering parameter x are shown in Figure 2 as a function of $\sqrt{s_{\rm NN}}$. A similar analysis is also done taking the centrality data for $dE_{\rm T}/d\eta$ for different $\sqrt{s_{\rm NN}}$ and the extracted x parameter is also shown in the same figure for a direct comparison. Modifying Eq. 1, one can obtain the two component model corresponding to $dE_{\rm T}/d\eta$ as follows

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$$\frac{dE_T^{AA}}{d\eta} = \frac{dE_T^{pp}}{d\eta}\left((1-x)\frac{\langle N_{part}\rangle}{2} + x\langle N_{coll}\rangle\right) \quad (3)$$

Results

Analysing the centrality data of $dN_{ch}/d\eta$ and $dE_T/d\eta$ from few GeV to TeV energies using Eq. 2, we find that the value of parameter, A shows a monotonic decrement with increasing of $\sqrt{s_{NN}}$, whereas the parameter α, shows a monotonic increment with increase of $\sqrt{s_{NN}}$. The value of these parameters have a noticeable impact on the hard scattering component x and average multiplicity density in pp collision, n_{pp}. Figure 1 shows the centrality dependence of $dN_{ch}/d\eta$ at midrapidity for different collision energies ranging from 19.6 GeV to 2.76 TeV. Two component approach is used for the above data sets to extract the hard scattering component, x, which is shown as a function of $\sqrt{s_{NN}}$ in Figure 2. The values of x are consistent for different energies within the experimental uncertainties. In Table. I, the values of average multiplicity density in pp collision n_{pp} and hard scattering component, x are given. n_{pp} shows a monotonic increment with increasing energy as expected. When we calculate N_{coll} as a function of N_{part} for different centre of mass energies it shows a monotonic increase. Although it is expected that x to increase with $\sqrt{s_{NN}}$, we don't observe that in heavy-ion collisions. This could be reasoned as suppression of high-p_T hadrons/jets in the dense medium created in heavy-ion collisions, which has been observed experimentally.

TABLE I: Hard scattering component x and n_{pp} for different $\sqrt{s_{NN}}$ (GeV).

	$\sqrt{s_{NN}}$	x	n_{pp}
Au Au	19.6	0.1018± 0.0515	1.3258± 0.15427
Au Au	62.4	0.1314± 0.0675	1.6976± 0.26269
Au Au	130	0.1175± 0.0391	2.1406± 0.21437
Au Au	200	0.0906± 0.0484	2.5641± 0.3529
Pb Pb	2760	0.1037± 0.0189	4.4220± 0.3169

Note that a similar analysis for $dN_{ch}/d\eta$ has been done in Ref. [4] for few energies. Our results both for $dN_{ch}/d\eta$ and $dE_T/d\eta$ are consistent with the above findings.

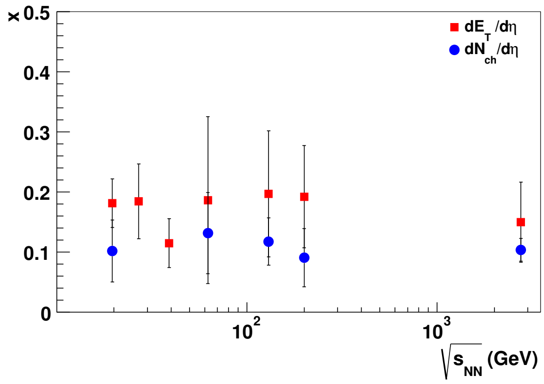

FIG. 2: The hard scattering component, x as a function of collision energy, showing a near energy independence behaviour in heavy-ion collisions.

Conclusions

The observation that the coefficient of the hard-scattering, *i.e.* x is not increasing with collisions energy, where as the fraction of N_{coll}/N_{part} has a monotonic increase and also the QCD cross sections do increase with energy, gives the evidence that the used two component model, fails to bring out the information about the hard-scattering contribution to particle production in a heavy-ion collision environment. This goes in line with the observation of suppression of high-p_T hadrons/jets in the dense medium created in heavy-ion collisions. This leaves out an open question to devise a method to study the relative contribution of hard/soft processes towards the particle production in heavy-ion collisions.

References

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