Pseudorapidity and Transverse energy density of charged particles in central collisions at RHIC and LHC energies

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Introduction

Quantum Chromodynamics (QCD), theory of strong interactions predicts a phase transition of nuclear matter to a deconfined system of quarks and gluons at extreme energy densities produced in heavy ion collision experiments. The properties of this matter are being experimentally investigated at the Super Proton Synchrotron (SPS), the Relativistic Heavy Ion Collider (RHIC) and the Large Hadron Collider (LHC) in different energy regime and for various colliding systems. The fraction of initial longitudnal energy which got converted into the energy carried away by the particles produced transverse to the beam axis of the colliding system, can be estimated with the help of mean transverse energy per unit pseudorapidity ($\frac{dE_T}{d\eta}$). The transverse energy density at midrapidity is a measure of the stopping power of nuclear matter produced. The pseudorapidiy and transverse energy density distributions usually provide information about the systematics of energy densities attained in various colliding systems. The centrality and collisional energy dependence of transverse energy density per unit pseudorapidity density provides the information about the conditions prior to thermal and chemical equilibrium.

Model description

We have used the idea of two-component model in modified Wounded Quark Model to calculate pseudorapidity distribution (Eq. 1) and used Hulthén function (Eq. 2) for expressing charge density of deuterium nuclei; where $a = 0.457$ fm^{-1} and $b = 2.35$ fm^{-1}. We have used the wood-saxon charge distribution for large nuclei (Eq. 3) ref [1–3].

$$\left(\frac{dn_{ch}}{d\eta}\right)^{AA}_{\eta=0} = \left(\frac{dn_{ch}}{d\eta}\right)^{pp}_{\eta=0}\left[(1-x)\,N_q^{AB} + xN_q^{AB}\nu_q^{AB}\right]. \quad (1)$$

$$\rho(r) = \rho_0\left(\frac{e^{-ar}+e^{-br}}{r}\right)^2, \quad (2)$$

$$\rho(b,z) = \frac{\rho_0}{1-exp(\frac{\sqrt{b^2+z^2}-R}{a})}, \quad (3)$$

For transverse energy density calculation we have used a simple relation with pseudorapidity density as follows:

$$\frac{dE_T}{d\eta} \cong \langle p_T\rangle \frac{dn_{ch}}{d\eta}. \quad (4)$$

where $\langle p_T\rangle$ is average transverse momentum calculated from different p_T distribution fit function for defferent colliding systems d-Au, Au-Au, Cu-Cu and Pb-Pb at RHIC and LHC energies respectively. We have used the Tsallis momentum distribution function along with its fitting parameter as given ref. [5] to calculate $d^2N_{ch}/dydp_T$ and finally put its value in following expression to obtain the average p_T [7] for each collisions considered in this article.

$$\langle p_T\rangle_{y=0} = \int dp_T p_T\left(d^2N_{ch}/dydp_T\right)/\int dp_T\left(d^2N_{ch}/dydp_T\right). \quad (5)$$

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Results and Discussions

In Table 1, We have shown pseudorapidity density calculation by modified WQM for various colliding systems at different energies and they are found to be well described by our model within given systematic and statistical error of experimental data. We see from table 1 that for small and large nuclei collisions like d-Au the pseudorapidity density is very low compared to large nuclei like Cu-Cu, Au-Au and Pb-Pb collisions; mentioning that the energy density of the fireball created in these collisions vary from small to large systems very well also since the centrality class we have taken; which is different in colliding systems so we can not demonstrate the suitable picture for that but the variations can be infer the fact for energy density.

TABLE I: Pseudorapidity density (GeV) at midrapidity ($\frac{dn_{ch}}{d\eta}$) for most central events by modified WQM for various colliding systems.

Sys.	$\sqrt{s_{NN}}$	C.B.(%)	Model	Expt.
d-Au	200	0-20	17.5	18.00 ± 1.27
Cu-Cu	200	0-10	173.2	176.35 ± 12.70
Au-Au	62.4	0-10	402	407.45 ± 35.25
Au-Au	200	0-12	622	623.9 ± 32.25
Pb-Pb	2760	0-5	1592	1601 ± 60.00

In Table 2: average p_T (GeV) is calculated for proton(anti-proton) spectrum for different colliding systems by Eq. 5 at midrapidity for most central events at RHIC and LHC energies. Further in Table 3: Transverse energy density (GeV) calculation is shown by Eq. 4 and compared with RHIC and LHC experimental data. We found that the calculated values not matches well with experimental data. Actually the calculated values underestimates for every colliding nuclei as well as at each energy. We found that as in Table: 2 average p_T values comes out to be low estimate by modified Tsallis fit [5]; So we have to considered a different momentum distribution fit for charged particles which calculates average p_T values suitable to describe transverse energy density.

TABLE II: Average transverse momentum (GeV) at midrapidity for most central events for different colliding systems.

Systems	$\sqrt{s_{NN}}$ (GeV)	Centrality Bin (%)	$\langle p_T \rangle$
d-Au	200	0-20	0.798
Cu-Cu	200	0-10	0.517
Au-Au	62.4	0-10	0.756
Au-Au	200	0-12	0.552
Pb-Pb	2760	0-5	0.676

TABLE III: $\frac{dE_T}{d\eta}$ for most central events of various colliding systems at RHIC and LHC energies. The centre of mass energies are in GeV scale for various collisions.

Sys.	$\sqrt{s_{NN}}$	C.B.(%)	Model	Expt.
d-Au	200	0-20	13.97	17.70 ± 1.50
Cu-Cu	200	0-10	89.54	153.35 ± 12.15
Au-Au	62.4	0-10	303.9	355.10 ± 21.40
Au-Au	200	0-12	343.34	548.85 ± 31.8
Pb-Pb	2760	0-5	1076.2	1601.05 ± 60.55

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