Transverse Energy Measurement in Au+Au Collisions by the STAR Experiment

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Transverse energy ($E_T$) has been measured with both of its components, namely hadronic ($E_{T\text{had}}$) and electromagnetic ($E_{T\text{em}}$) in a common phase space at mid-rapidity for 62.4 GeV Au+Au collisions by the STAR experiment. $E_T$ production with centrality and $\sqrt{s_{NN}}$ is studied with similar measurements from SPS to RHIC and is compared with a final state gluon saturation model (EKRT). The most striking feature is the observation of a nearly constant value of $E_T/N_{ch} \sim 0.8$ GeV from AGS, SPS to RHIC. The initial energy density estimated by the boost-invariant Bjorken hydrodynamic model, is well above the critical density for a deconfined matter of quarks and gluons predicted by lattice QCD calculations.

I. INTRODUCTION

Extreme conditions of high temperature and densities could be created in relativistic heavy ion collisions making a scenario to study the deconfined state of quarks and gluons called Quark Gluon Plasma (QGP). The interactions can be characterized in terms of the global variables like transverse energy and the charged particle multiplicity. These variables are closely related to the collisions geometry and are very important in understanding the global properties of the system created during heavy ion collisions. $E_T$ is the energy created transverse to the beam direction and is generated by the initial scattering of the partonic constituents of the incoming nuclei and probably also by the produced partons and hadrons [1, 2]. $E_T$ measurement gives an estimation of the initial Bjorken energy density ($\epsilon_{Bj}$) produced in the fireball and also helps in studying the particle production mechanism.

II. DATA ANALYSIS

We have analyzed the 62.4 GeV Au+Au minimum-bias STAR data for RHIC run 2004. The detectors used in this analysis include the Time Projection Chamber (TPC) and Barrel Electromagnetic Calorimeter (BEMC) in a common phase space (0 < $\eta$ < 1 and full azimuthal coverage). TPC uncorrected mid-rapidity multiplicity within $|\eta| < 0.5$ and $|V_z| < 30$ cm, is used for the centrality selection. The analysis method adopted here provides an independent event-by-event measurement of both the components of transverse energy i.e. $E_{T\text{had}}$ and $E_{T\text{em}}$. $E_{T\text{had}}$ is obtained from the TPC reconstructed tracks after taking into account the long-lived neutral hadrons which could not be detected by the TPC. $E_{T\text{em}}$ is estimated from the energy deposited in the calorimeter towers after correcting for the hadronic contaminations, by projecting hadronic tracks onto BEMC. The details of the transverse energy estimation procedure is discussed in Ref. [4, 5].

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III. RESULTS AND DISCUSSION

Figure 1 (left) shows the event-by-event minimum-bias $E_T$ and its components with the right figure showing $E_T$ distribution for all centrality classes which are gaussian in nature. The minimum-bias distributions show a peak and a sharp drop-off at low $E_T$ end corresponding to peripheral collisions. It reaches a broad plateau at the middle which corresponds to mid-central collisions. This is dominated by nuclear geometry. The higher values of $E_T$ correspond to the most central collisions having a “knee” leading to a fall off which is very steep for large acceptances and less for small acceptances. For the top 5% central collisions $< dE_T/d\eta > = 474 \pm 51 \text{ GeV}$. The variation of $< dE_T/d\eta >$ per $N_{part}$ pair as a function of centrality is shown in Figure 2 (left) for 62.4 GeV Au+Au collisions along with similar measurements from Pb+Pb 17.3 GeV at SPS [6] and Au+Au 130 [7], 200 GeV [8] at RHIC. The corresponding EKRT model [9] prediction for 62.4 GeV Au+Au collisions is shown by the dotted line. The data show a similar centrality behavior at different energies, whereas the EKRT model doesn’t agree with the data. For top central collisions, the variation of $< dE_T/dy >$ per $N_{part}$ pair as a function of $\sqrt{s_{NN}}$ is shown in Figure 2 (right) with similar measurements at other energies along with the EKRT model prediction which is shown by the thick line. $< dE_T/dy > / (0.5 N_{part})$ increases logarithmically with $\sqrt{s_{NN}}$. However, the EKRT model shows an underestimation of data at various energies.

In order to understand the systematic growth of transverse energy with $\sqrt{s_{NN}}$, the centrality
dependence of \( \langle dE_T/d\eta \rangle / \langle dN_{ch}/d\eta \rangle \) on energy density \( \epsilon_{Bj} \) and its extrapolation to LHC energy gives a value of 9.03 and the ratio shows a very slow increase with energy.

Next we have studied the Bjorken energy density \( \epsilon_{Bj} \) produced in the top central Au+Au collisions, which is shown in Figure 3 (left) along with similar data at other RHIC energies. The value of the energy density produced in top central Au+Au collisions at 62.4 GeV is found to be 3.65 ± 0.39 GeV fm\(^{-3}\) (taking formation time, \( \tau = 1 \) fm/c). This is well above the lattice QCD predictions \( \epsilon_{Bj} \) for a deconfined state of quarks and gluons. This figure shows an logarithmic increase of \( \epsilon_{Bj} \) and its extrapolation to LHC energy gives a value of 9.42 ± 0.55 GeV fm\(^{-2}\) c\(^{-1}\), based on the assumption that Bjorken model holds good at higher energies. We have shown the centrality dependence of \( \epsilon_{Bj} \) in Figure 3 (right), where one observes that higher energy densities are produced in more central collisions. Further more we have also studied the excitation functions of \( \langle dE_T/d\eta \rangle / (0.5N_{part}) \) and \( \langle dN_{ch}/d\eta \rangle / (0.5N_{part}) \) which show a logarithmic behavior. The details of which could be found elsewhere.

The electromagnetic fraction of the total transverse energy \( \langle dE_T^{em}/d\eta \rangle / \langle dE_T/d\eta \rangle \) for top central Au+Au collisions for 62.4 GeV, is studied as a function of \( \sqrt{s_{NN}} \), along with similar data from AGS-SPS to RHIC for different colliding species. This is shown in Figure 3 (left). The value of this ratio at 62.4 GeV is 0.32 ± 0.03 and the ratio shows a very slow increase with energy. This increase is consistent with the meson dominance of the matter at higher energies. Figure 3 (right) shows that this ratio is independent of the collision centrality.

IV. SUMMARY

The mid-rapidity measurement of \( E_T \) for 62.4 GeV Au+Au collisions is presented. The centrality and center of mass energy behavior of \( E_T \) production is studied and compared with...
similar data at other energies and with the EKRT gluon saturation model. The observation of a centrality and $\sqrt{s_{NN}}$ independent, nearly constant value of $E_T/N_{ch} \sim 0.8$ GeV from AGS, SPS to RHIC has been understood to be associated with freeze-out of the fireball. The initial energy density estimated by the boost-invariant Bjorken hydrodynamic model, is well above the lattice QCD value for a deconfined matter of quarks and gluons. Taking similar colliding species i.e. Au+Au, the $\epsilon_{Bj.\tau}$ has been predicted for LHC, based on the measurements at RHIC.

References

1. M. Jacob and P.V. Landshoff, *Mod. Phys. Lett.* A1, 657 (1986).
2. X.N. Wang, *Phys. Rep.* 280, 287 (1997).
3. K.J. Eskola, K. Kajantie, P.V. Ruuskanen and K. Tuominen, *Nucl. Phys.* B 570, 379 (2000).
4. J. Adams et al., STAR Collaboration, *Phys. Rev.* C 70, 054907 (2004).
5. Raghunath Sahoo, Ph.D. Thesis, 2007, STAR Collaboration, Preprint: 0804.1800 [nucl-ex].
6. M.M. Aggarwal et al., WA98 Collaboration, *Eur. Phys. J.* C 18, 651 (2001).
7. K. Adcox et al., PHENIX Collaboration, *Phys. Rev. Lett.* 87, 052301 (2001).
8. M. Gyulassy, *Lecture Notes in Physics*, 583, 37 (2001).
9. J. Cleymans, R. Sahoo, D.P. Mahapatra, D.K. Srivastava and S. Wheaton, *Phys. Lett.* B 660, 172 (2008) and Preprint: 0803.3940 [hep-ph], to appear in J. Phys. G: Nucl. Part. Phy.
10. J. Cleymans et al., *Eur. Phys. J.* Spec. Topics 155, 13 (2008).
11. J.D. Bjorken, *Phys. Rev.* D 27, 140 (1983).
12. F. Karsch, *Nucl. Phys.* A 698, 199c (2002).