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Two particle correlations at intermediate transverse momentum with identified trigger particles at LHC energy using AMPT model

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RHIC results on identified particle spectra in Au-Au collisions at $\sqrt{s} = 200$ GeV suggest that there exist a relative enhancement of baryons over mesons at intermediate transverse momentum (p_T). Hadronization models based on hydrodynamic expansion of equilibriated fireball and/or p-QCD motivated formalism of hardonization by parton fragmentation were found to be incompatible with this observation. A plausible explanation was offered by the models invoking recombination/coalescence of nearest neighbour partons in the phase space. Apparently such a recombination model would dis-favour any short ranged jet-like correlations. Interestingly, two-particle correlation measurements in region of baryon excess showcases evidence of small angle correlation typically associated with hadron formation by jet-fragmention. In this study we aim to understand the coexistance of anomalous baryon enhancement, a non perturbative process and jet-like correlations, a perturbative QCD motivated phenomena within the quark recombination model. It has been suggested that the quark recombination involving both minijet partons and partons from thermalized medium can account for both of these phenomena. Here we have performed identified particle correlation measurements and extracted the near-side yield at the p_T region of baryon enhancement in Pb-Pb 2.76 TeV from the string melting (SM) version of A Multiphase Transport model (AMPT) that implements quark coalescence as a mode of hadronization. Results obtained are compared and contrasted with the default version where hadronization is via the Lund string fragmentation.

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1. Introduction

At RHIC and LHC energies hadron yields at high p_T are found to be depleted in heavy-ion collisions relative to pp collisions at same energy [1]. This depletion is a suggestive of parton energy loss in a high density medium formed in heavy ion collisions. Loss of parton energy through jet-medium interaction tend to modify the fragmentation of high p_T partons compared to pp where fragmenation is most likely to be in vacuum. Medium induced modification of jet fragmentation may lead to significant change of particle compositions in jets [2]. The jet like structure associated with the baryon excess at intermediate p_T may be an indication that baryon enhancement in excess to elementary collisions might have originated from hard processes [3].

However, there are different approaches incorporating coalescence or recombination of 2 or 3 quarks to mesons and baryons respectively which seems to provide consistent explanation to most of the intermediate p_T phenomena [4]. Anomalous baryon to meson enhancement and the particle species dependence of nuclear modification factor (R_{AA}) are found to be successfully reproduced by such conjecture. The constituent quark scaling (NCQ) of identified hadrons v_2, a natural consequence of such formalism has also been confirmed by experiments at RHIC [5, 6].

RHIC results on conditional yield associated to baryon and meson triggers in Au-Au collisions at intermediate p_T have been found to be compatible with jet fragmentation. Enhancement has been observed in the near side yield from peripheral to central collisions which is consistent with parton energy loss scenario. However the yield associated to baryon trigger at intermediate p_T in most central collisions shows no enhancement rather it is suppressed. Such suppression has been attributed to baryon production from recombination of thermal quarks from the medium. Particles originating from the coalescence of thermal quarks are unlikely to have particles associated at small angles. Contribution of these particles to the trigger sample therefore dilutes the correlated near side yield referred to as the trigger dilution [7, 8].

Here we present centrality dependence of inclusive baryon to meson ratio and jet-like near side yield associated to identified leading hadrons at intermediate p_T from SM version of AMPT model that implements quark coalescence as a mode of hadronization. Detailed description of AMPT model and parameters can be obtained in the following references [9, 10]. Single inclusive baryon over meson yield is found to be enhanced in central collisions compared to peripheral. Per trigger yield associated to leading baryons as obtained from two particle correlation measurements are found to be suppressed at the most central collisions complying with the phenomena of trigger dilution.

2. Two Particle Correlation

The two particle correlation technique involves angular correlation between two classes of particles:`trigger` and `associated` [11]. The azimuthal angular difference, $\Delta\phi$ and pseudorapidity difference, $\Delta\eta$ are computed for each trigger-associated pair. Depending on the $\Delta\eta$ separation of trigger and associated pairs, correlation function can be grouped to short range and long range. The short range or jet-like correlation involves correlation among the particles that are close in phase space. The long range part arises out of the correlated pairs separated by large psuedorapidity mathematically represented in terms of Fourier harmonics. Such correlations are primarily

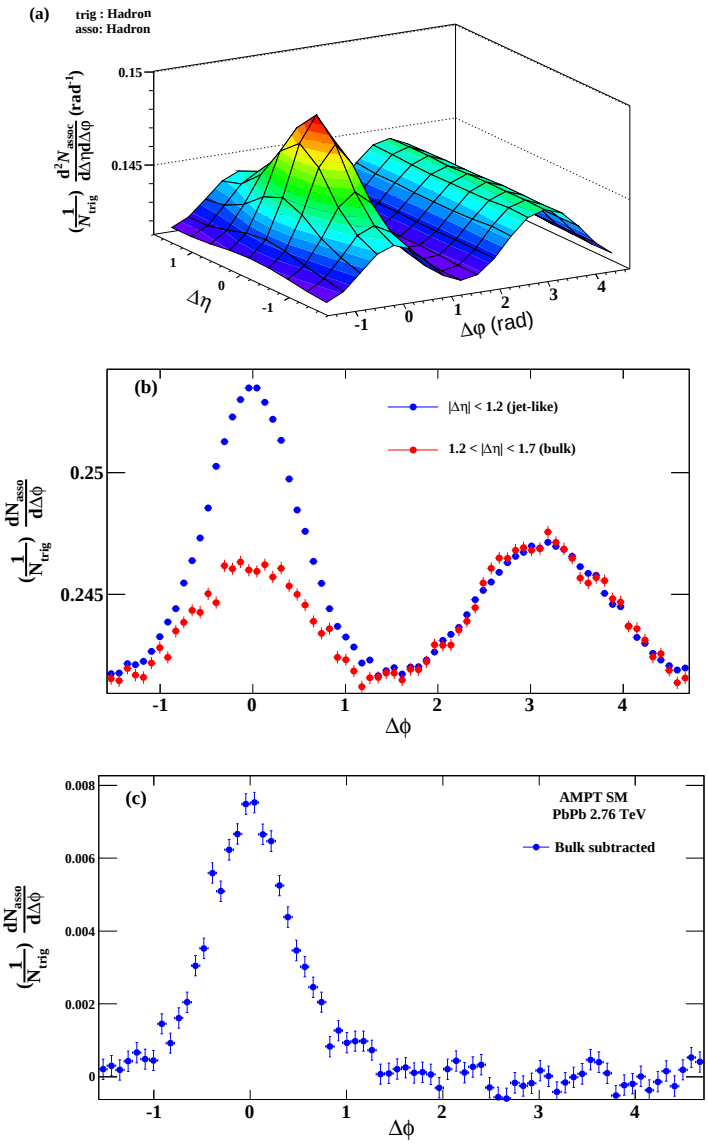

Figure 1: Two dimensional $\Delta\eta$ vs $\Delta\phi$ correlation function (a). Corresponding projection on $\Delta\phi$ axis for short range (jet) and long range (bulk) region (b) and bulk subtracted jet-like (c)

associated with the azimuthally anistropic emission of each particles relative to collision axis. The jet-like peak as obtained from short ranged correlation sits on a flow modulated background dominated by second Fourier harmonic component known as the elliptic flow. To obtain the near side jet-like yield, these flow modulated background need to be subtracted.

In this work, we aim to study the relative contributions from hard and soft processes to baryon excess at intermediate p_T. We have thus chosen the trigger baryon (protons) and the meson (pions) from the range $1.8 < p_T < 3.0$ GeV/c where baryon enhancement has been observed. The associated particles are charged hadrons in the range $1.0 < p_T < 1.8$ GeV/c. Correlation is obtained in 2 dimensional $(\Delta\phi, \Delta\eta)$ space pairing all trigger baryons and mesons with unidentified charged

hadrons in peripheral and central collisions. The Distribution of pairs in the same event can be represented mathematically as:

$$C(\Delta\eta,\Delta\phi) = \frac{d^2N}{d(\Delta\eta)d(\Delta\phi)}. \tag{2.1}$$

The correlation function obtained in *eqn*.1 needs to be corrected for detector in-efficiency and finite acceptance. In simulation we need to correct for finite acceptance only as we have restricted our trigger and associated particles in $|\eta| < 1$. The correlation function introduced above has been corrected by scaling the $C(\Delta\eta,\Delta\phi)$ by a correction factor:

$$B(\Delta\eta) = 1 - |\Delta\eta|/(2.\eta_{max}). \tag{2.2}$$

Uniform acceptance in azimuth ensures that no correction is required on $\Delta\phi$. The acceptance corrected associated yield, per trigger particle is defined as:

$$\frac{1}{N_{trigger}}\frac{d^2N}{d(\Delta\eta)d(\Delta\phi)} = \frac{C(\Delta\eta,\Delta\phi)}{B(\Delta\eta)}. \tag{2.3}$$

Where $N_{trigger}$ is the number of trigger particles in a centrality class and trigger p_T interval. We study near side small angle jet-like correlated yield by projecting the 2D correlation function on $\Delta\phi$ for $|\Delta\eta|$ <1.2. Near side peak is centered around $\Delta\eta = \Delta\phi = 0$ hence the yield is calculated integrating over the $\Delta\phi$ region of $|\Delta\phi| < \pi/2$.

A typical acceptance corrected 2D correlation function and its corressponding $\Delta\phi$ projections are shown in Fig 1. The short and long range projections are shown separately in Fig 1(b).

3. Results

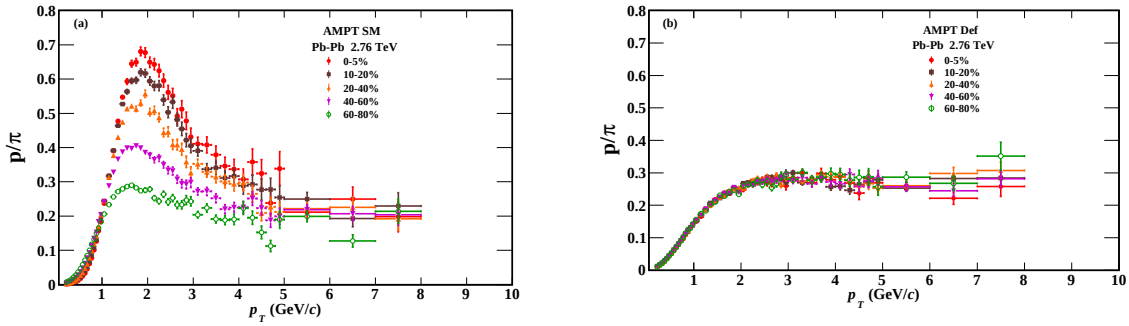

Figure 2: Inclusive proton over pion ratio from 60-80% to 0-5% centrality class from SM (a) and default (b) version of the AMPT model in Pb-Pb collisions at $\sqrt{s}$ = 2.76 TeV.

Fig. 2 shows inclusive proton to pion ratio from peripheral (60-80%) to central (0-5%) event classes of SM and default version of AMPT. The inclusive ratio in AMPT SM shows a clear enhancement in central events than peripheral. The ratio peaks around $p_T \sim 2$ GeV/c. In contrast, default version exhibits no enhancement in proton over pion ratio as a function of centrality. In this analysis the trigger p_T range of the identified particles are chosen in such a way that we capture the region where the enhancement in the ratio of single inclusive yield has a peak.

The centrality evolution of the ratio of near side yields for protons and pion triggers in SM and default version of AMPT ($Y^{p/\bar{p}}/Y^{\pi}$) are shown in Fig. 3. While the ratio is found to be nearly independent of centrality in default mode, in SM mode there is a gradual supperssion from peripheral to central events. It is worth mentioning that in the default version pion and proton triggered near side yields are almost same. This perhaps indicate that fragmenation is not biased by the choice of final state leading hadrons.

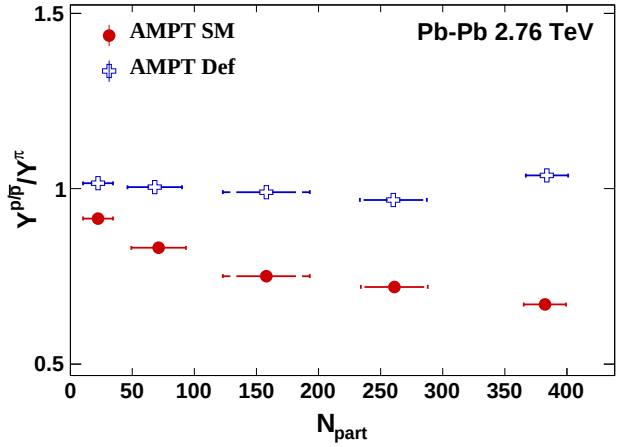

Figure 3: Ratio of near side jet like yield associated with proton and pion triggers at intermediate p_T from SM and default version of the AMPT model.

4. Discussions

The Two particle correlation study with identified leading hadrons in Pb-Pb collisions at 2.76 TeV have been performed on the events generated from the SM and the default version of AMPT . We have observed that the ratio of jet-like yield associated with proton and pion triggers at intermediate p_T from the SM version of AMPT features a gradual diminishing trend from peripheral to central events. The obeservation seems to be concordant with the phenomena of "trigger dilution". Such an effect is expected to happen if the mechanism of hadron formation involves recombination of thermalized quarks. As mentioned earlier that the proton production being favoured compared to pion within the coalescence approach, fraction of protons formed by the recombination of quarks from a thermalized medium are devoid of correlated partners. Though they are considered as triggers but they do not contribute to the total yield. Hence the per trigger yield for protons get mitigated. The chances of thermal recombination are more in central collisions, hence the trigger dilution is more prominent at the most central collision. Comparing with analogous measurements at RHIC indicate that the coalescence model has a better qualitative aggrement with the experimental results. However, proper tuning of the model to achieve quantative reproduciblity is more important for pinpointing the origin of baryon anomaly and extending it further towards understanding the mechanism of hadron formation at moderate p_T.

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