Signals of Transparency in p-p Collisions at RHIC and LHC

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Introduction

The ultra-relativistic p-p collisions at LHC energies have resulted in a number of observations signaling a close resemblance to a system with hydrodynamic flow effects formed in relativistic heavy-ion collisions. The p-p collisions also serve as a baseline for extracting the signals of QGP formation in heavy-ion collisions and are important to understand the particle production mechanism [1]. The value of chemical potential, specified in the framework of thermal models, is found to be lower in the p-p collisions than in heavy-ion collisions due to the low stopping power in p-p collisions [2] whereas it is larger in the case of heavy-ion collisions due to greater rapidity loss (drag) of the two colliding nuclear media. As one goes to LHC energies, the stopping further reduces giving rise to nearly zero net baryon density (or correspondingly zero baryon chemical potential) at mid-rapidity. Thus we believe that at LHC, the p-p collisions are almost completely transparent.

Model

Our analysis for the system formed in p-p collisions is based on our earlier proposed unified statistical thermal freeze-out model [3] wherein the momentum distributions of hadrons, emitted from within an expanding fireball in the state of local thermal equilibrium, are basically characterized by the Lorentz-invariant Cooper-Frye formula [4]. The baryonic chemical potential has been written as [3, 5] $\mu_B = a + by_0^2$ where y_0 (= cz) is the rapidity of the expanding hadronic fluid element along the beam axis (z-axis). The model essentially incorporates a longitudinal as well as transverse hydrodynamic flow. The transverse velocity component of the hadronic fireball, β_T is assumed to vary with the transverse coordinate r as $\beta_T(r) = \beta_T^s(\frac{r}{R})^n$, where n is an index and determines the profile of $\beta_T(r)$, β_T^s is the hadronic fluid surface transverse expansion velocity and $R = r_0\, exp\,(-\frac{z^2}{\sigma^2})$ [6]. The contributions from heavier decay resonances [7] are also taken into account. In the model we also impose the criteria of exact strangeness conservation in each region of the fireball which is assumed to be rapidly expanding in the transverse as well as longitudinal direction maintaining different baryon chemical potential. We have reproduced the rapidity and transverse momentum distributions of particle ratios in p-p collisions at three different LHC energies $\sqrt{S_{NN}}$ = 0.9 TeV, 2.76 TeV and 7.0 TeV and also at the highest RHIC energy $\sqrt{S_{NN}}$ = 200 GeV.

Results and Discussion

In figure 1, we have plotted the Λ-bar/Λ ratio with respect to the rapidity y at three different LHC energies $\sqrt{S_{NN}}$ = 0.9 TeV, 2.76 TeV and 7.0 TeV. The experimental data has been taken from ALICE experiment at LHC [8].The error bars represent the sum of statistical and systematic errors. The model parameters a, b and σ are found to be sensitive to the rapidity spectra. The extracted values have been shown in table 1.

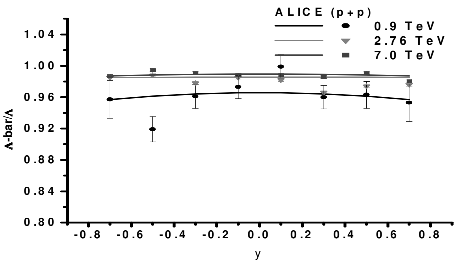

Fig. 1 Rapidity spectra of Λ-bar/Λ at LHC energies $\sqrt{S_{NN}}$ = 0.9 TeV, 2.76 TeV and 7.0 TeV.

Table 1: Model parameters extracted from rapidity spectra of Λ-bar/Λ at three different energies $\sqrt{S_{NN}}$ = 0.9 TeV, 2.76 TeV and 7.0 TeV.

$\sqrt{S_{NN}}$	*a (MeV)*	*b (MeV)*	σ *(fm)*
0.90 TeV	0.70	1.5	4.55
2.76 TeV	0.50	0.40	4.60
7.00 TeV	0.20	0.30	4.50

It is clear from the values of parameter *a* that the value of the baryonic chemical potential at mid-rapidity approaches to zero at higher energies and maintains a very small value throughout the mid-rapidity range of |y|<0.8, as is also evident from the value of parameter *b*. This vanishing baryonic chemical potential at mid-rapidity gives rise to the particle ratios to be consistent with unity as shown in figure 1. Also in figure 2, we have compared the rapidity spectra of pbar/p in p-p collisions at 2.76 TeV [8] with the same ratio produced in p-p collisions at $\sqrt{S_{NN}}$ = 200 GeV [9] in the mid-rapidity range |y|<0.8. We find that the ratio at $\sqrt{S_{NN}}$ = 2.76 TeV is consistent with unity over the given mid-rapidity range, thus indicating a vanishing chemical potential at mid-rapidity. The same ratio at $\sqrt{S_{NN}}$ = 200 GeV falls much below unity and tends to decrease for larger values of rapidity, thus indicating a significant chemical potential at mid-rapidity, see table 2. In other words there is only a partial transparency in p-p collisions at 200 GeV, whereas at 2.76 TeV a very high degree of nuclear transparency is observed.

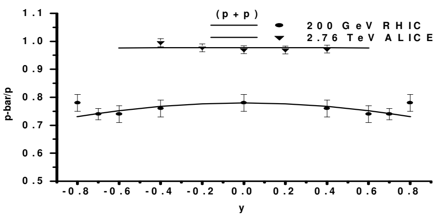

Fig. 2 Rapidity dependence of p-bar/p at 2.76 TeV and 200 GeV. Errors are statistical only.

$\sqrt{S_{NN}}$	*a (MeV)*	*b (MeV)*	σ *(fm)*
200GeV	20.0	9.0	4.20
2.76TeV	0.48	0.35	4.50

Table 2. Comparison of model parameters obtained from rapidity distributions of pbar/p in p-p collisions at $\sqrt{S_{NN}}$ = 200 GeV and 2.76 TeV.

In figure 3, we plot the transverse momentum distributions of particle ratios (pbar/p and Λbar/Λ) at the three LHC energies $\sqrt{S_{NN}}$ = 0.9 TeV, 2.76 TeV and 7.0 TeV. The experimental data has been taken from ALICE experiment at LHC [7]. The particle ratios are found to be consistent with unity in the given rapidity ranges, which supports our observation of nearly zero chemical potential at mid-rapidity at these LHC energies.

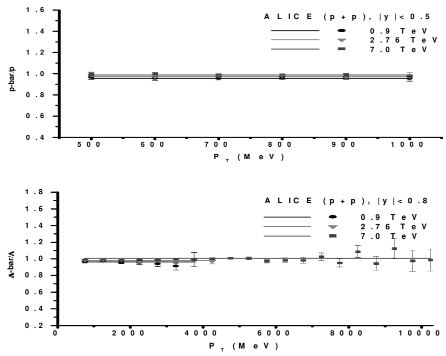

Fig. 3 Transverse momentum distribution of particle ratios at various LHC energies

Summary and Conclusion

We have successfully reproduced the transverse momentum and rapidity distributions of anti baryon to baryon ratios in p-p collisions at different LHC energies and the highest RHIC energy. We found no observed dependence on either rapidity or transverse momentum in the measured particle ratios for all the LHC energies. The ratios increase with increasing beam energy reaching almost unity for $\sqrt{S_{NN}}$ = 7.0 TeV. This indicates a vanishing chemical potential at mid-rapidity and hence a complete transparency in systems produced at LHC energies unlike at the RHIC energy.

References

[1] F. Becattini and U. Heinz, *Z. Phys. C* 76, (1997) 269
[2] J. Cleymans et al., arXiv: 1107.0450v1 [hep-ph] (2011)
[3] S. Uddin et al, *J. Phys.G* 39, (2012) 015012
[4] F. Cooper and G. Frye, *Phys. Rev. D,* 186-189 (1974)
[5] Uddin S *et al., Acta Phys. Pol.* B 41 (2010) 2433
[6] Koch P, Muller B and Rafelski J.*Phys. Rep.* 142 (1986) 187
[7] Saeed Uddin *et.al* arXiv:[hep- ph]/1407.6165 (2014)
[8] E. Abbas, (ALICE COLLABORATION), arXiv:1305.1562v1 [nucl-ex] (2013)
[9] I.G.Bearden *et al.* (BRAHMS Collaboration), *Phys. Lett. B,* arXiv:nucl-ex/0409002v2 (2004)