Thermal model description of hadronic ratios in pp collision at RHIC and LHC energies

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Introduction

The heavy ion collisions are performed to study strongly interacting matter where formation of quark gluon plasma (QGP) is expected. The QGP expands which is followed by hadronization. The system reaches chemical freeze-out when the density of the different particles do not change with time. Kinetic freeze-out is reached when the momentum distribution of the particles is frozen. The level of equilibrium of the system produced can be tested by analyzing the particle abundances (reflects the conditions at chemical freezeout) or their momentum spectra (reflects the conditions at kinetic freezeout).

The thermal statistical model [3] gives a good description of the hadronic yields obtained from experiments. In [1, 2], it is nicely described that the partons with low momentum have exponential distribution and recombine to form hadrons which is reflected in the lower region of p_T spectra of the yield of hadrons. The high p_T partons which are coming from hard scatterings are fragmented to form hadrons which has a power law distribution in hadronic spectra in the high p_T region.

Theoretical Approach

According to the statistical model, when the system is in thermal equilibrium [3], the number density of particles is given as:

$$n_i = -\frac{T}{V}\frac{\partial \ln Z}{\partial \mu} = \frac{g_i}{2\pi^2}\int_0^\infty \frac{p^2 dp}{\exp\left(\frac{E_i-\mu_B}{T}\right) \pm 1} \quad (1)$$

where T is the freeze-out temperature, μ_B is the baryon chemical potential, g_i is the degeneracy = $(2J_i + 1)$ and $E_i = \sqrt{p^2 + m_i^2}$. In Eqn. 1, + sign is for fermions and - sign is for bosons. Eqn. 1 has only two free parameter T and μ_B, which are obtained from fitting of the experimental data. The energies of light hadrons made from mass less quarks scale as [4]

$$f_{hadron}(E) \propto f^n(E/n) \quad (2)$$

where n is the number of quarks in the hadron. $n_{baryons}/n_{mesons} = 3/2 = 1.5$. This will have an effect on the yields of mesons and baryons. As less energy is required for meson production in comparison to baryon, we scale down the energy of baryons as $E_{mesons} = E_{baryons} \times n_{mesons}/n_{baryons}$. We define $b = n_{baryons}/n_{mesons}$ and include this parameter b in the denominator inside the exponential in Eqn. 1 to account for this.

Results

The data used in this work is obtained from the pp collision at $\sqrt{s}$ = 62.4 GeV, 200 GeV [5], 900 GeV [6, 7], 2.76 TeV and 7 TeV [7]. The data corresponding to ratios; π^-/π^+, K^-/K^+, $\bar{p}$/p, K^+/π^+, K^-/π^-, p/π^+, $\bar{p}/\pi^-$ at all energies are used in this work. In Fig. 1 the experimental and calculated ratios are plotted. The red circles are the experimental ratios and the blue lines are the theoretical values. The fitted parameters are given in the Table I :

We find that the T_f is lowest for 62.4 GeV and increases with $\sqrt{s}$. At and above 900 GeV T_f remains almost constant till 7 TeV. At low collision energy μ_B has the maximum value and with the increasing collision energy it decreases which is expected. At 7 TeV it is almost zero pointing to formation of baryon free system. The parameter b is same for all energies except the lowest energy where the baryon density is high. The value of b should be 1.5 but it is for massless quarks. Further,

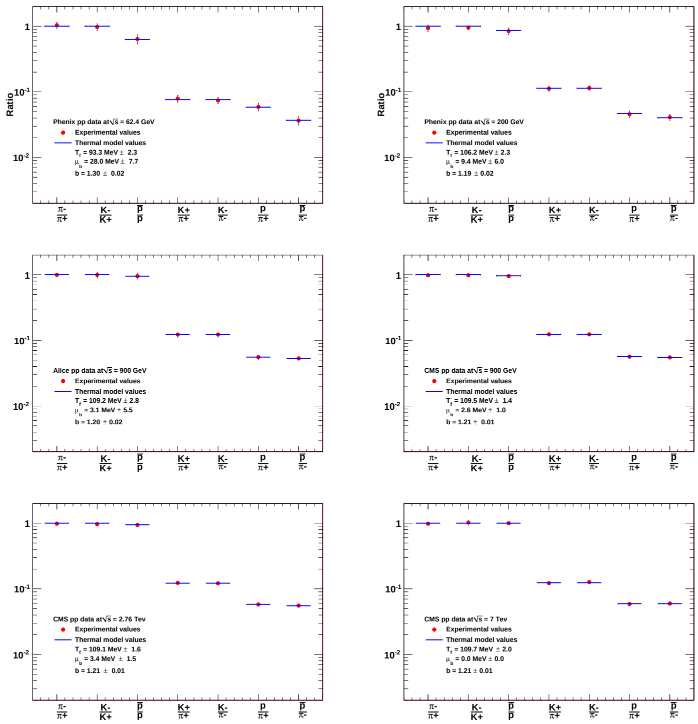

FIG. 1: Comparsion of the hadronic ratios from the experimental yield and from Thermal model.

TABLE I: Table for all the parameters

$\sqrt{s}$	T_f in MeV	μ_B in MeV	b
62.4 GeV	93.3 ± 2.3	28.0 ± 7.7	1.30 ± 0.02
200 GeV	106.2 ± 2.3	9.4 ± 6.0	1.19 ± 0.02
900 GeV	109.2 ± 2.8	3.1 ± 5.5	1.20 ± 0.02
900 GeV	109.5 ± 1.4	2.6 ± 1.0	1.21 ± 0.01
2.76 TeV	109.1 ± 1.6	3.4 ± 1.5	1.21 ± 0.01
7.0 TeV	109.7 ± 2.0	0.0 ± 0.0	1.21 ± 0.01

this scaling approach comes due to process of hadron formation by recombination which is good at intermediate p_T only.

Conclusion

In this work, we use the thermal model approach to describe the particle ratios produced in pp system at RHIC energies and the latest data of all three LHC energies. As a function of collision energy μ_B decreases as is expected and becomes zero at the highest LHC energies signaling a true baryon free regime. The freezeout temperature is almost constant for all LHC energies. We also introduced a parameter to account for different production mechanisms of mesons and baryons. Except at lowest energy this parameter is almost constant.

References

[1] R. Fries *et.al.* arXiv :0807.4939v1 (2008)
[2] R. Fries arXiv:nucl-th/0403036v1 (2004)
[3] A. Andronic *et.al.* Nucl. Phys. A. **772**, 467-199 (2006).
[4] arXiv : 0812.2104v2 [hep-ph] (2008)
[5] arXiv : 1102.0753v1
[6] arXiv : 1101.4110v3(hep-ex)
[7] CMS - PAS - FSQ- 12-014