Hadron productions using improved recombination model at $\sqrt{s_{NN}}$=2.76 TeV, LHC energy

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Introduction

Understanding hadron productions in relativistic heavy-ion collisions is highly contemporary. Several models have been developed to address the production at different domains of the hadron momentum (p_T)spectra. The region of the spectra with $p_T < 2$ GeV is well explained by hydrodynamics [1] and $p_T > 8$ GeV is explained through perturbative QCD [2–4]. Recombination model[5, 6] is another model which play an important role in the intermediate p_T region. But the model is not successful in explaining light meson productions and at low p_T.

In this work we tried to explain the pion and other hadron spectra at 2.76 TeV/A, LHC energy by improving the recombination model that explain even at low p_T region. Earlier, the Recombination model [5] has been used by the authors to describe the yields with partial success. The authors in [6] failed to produce low-p_T meson yields. In this work, we improve the Recombination model tailoring it to obtain a more satisfactory expression for the hadron yields and compared with the experimental data. We added a new confining term to take care of the quark confinement in the recombination probability.

Formalism

Starting with meson productions at midrapidity, the momentum spectra can be written

$$\begin{aligned} p^0 \frac{dN^M}{dp_T} &= \int \frac{dp_{T1}}{p_{T1}} \frac{dp_{T2}}{p_{T2}} (\mathcal{F}_{q_1\bar{q}_2}(p_{T1}, p_{T2}) \\ &\times \mathcal{R}^M_{q_1\bar{q}_2}(p_{T1}, p_{T2}; p_T)) \end{aligned} \quad (1)$$

$\mathcal{R}^M_{q_1\bar{q}_2}(p_{T1}, p_{T2}; p_T)$ is the probability of forming meson with transverse momentum $\{p_{Ti}\}$ and $\mathcal{F}_{q_1\bar{q}_2}(p_{T1}, p_{T2})$ is related to the parton distribution. 1 and 2 represent for the two recombining partons. The Recombination model considers the valence quarks to contribute to form a hadron and not the gluons.

Here we consider the recombination of thermal partons to produce the hadrons. We take,

$$\begin{aligned} &\mathcal{F}_{q_1\bar{q}_2}(p_{T1}, p_{T2}) = \mathcal{T}_1\mathcal{T}_2 \\ &R^M_{q_1 q_2}(p_{T1}, p_{T2}; p_T) = g_M \times \\ &\delta\left(\frac{\sqrt{m_1^2 + p_{T1}^2} + \sqrt{m_2^2 + p_{T2}^2}}{\sqrt{m_M^2 + p_T^2} + |B|} - 1\right) \\ &\times\delta(\frac{p_{T1}}{p_{T2}} - 1) \end{aligned} \quad (2)$$

Where, $\mathcal{T}_i = C_i \frac{p_T^{x+1}}{(\sqrt{p_T^2 + m_i^2})^x} e^{-\sqrt{p_T^2 + m_i^2}/T_i}$ tells about the thermal source of recombining quarks. g_M depends on meson type. Infact $C_1C_2g_M$ is a fitting parameter. Term B, appearing in the denomenator of delta function is the confinement energy i.e., the energy lost by the recombining quarks to form a hadron with lower energy. The expression for meson spectra is simplified to

$$\begin{aligned} p^0 \frac{d\bar{N}^M}{dp_T} &= \frac{C_1C_2}{4^x} g_M \int dz e^{-z/T} \\ &\times (\sqrt{m_M^2 + p_T^2} + |B|) \\ &\times \delta(z - \sqrt{m_M^2 + p_T^2} - |B|) \\ &\times \Big(\frac{(z^4 + (m_1^2 - m_2^2)^2}{z^3(z^4 - (m_1^2 - m_2^2)^2)^{x-1}} \\ &- \frac{2z^2(m_1^2 + m_2^2))^x}{z^3(z^4 - (m_1^2 - m_2^2)^2)^{x-1}}\Big) \end{aligned} \quad (3)$$

with $\sqrt{m_1^2 + p_{T1}^2} + \sqrt{m_2^2 + p_{T1}^2} = z$. Here x is

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a fitting parameter. For charged pion, $m_1 = m_u = 0.00216$ GeV, $m_2 = m_d = 0.00467$ GeV, $m_\pi = 0.13957$ GeV, $|B| = m_\pi - m_1 - m_2$.

Futher the expression for the meson productions was simplified with confining term and also taking centrality of collision into account. One can correlate above Eq.3 with following empirical parametrisation:

$$p^0 \frac{d\bar{N}^M}{dp_T} = A_h^0 \sqrt{s}^{b_h} N_{part}^{a_h} e^{-(\sqrt{p_T^2+m^2}+|B|)/T} \tag{4}$$

where $\sqrt{s}$ is the colliding energy in CM frame, N_{part} is the number of participants that vary in collisions of different centrality. A_h, b_h, a_h, B are new fitting parameters, which contain the information of $C_1, C_2, g_M, m_1, m_2, x, B$ of Eq.3.

Results

The results for pion production for various centralities are shown in Fig.1. The dots represent the experimental observationd from Pb+Pb collisions at $\sqrt{s_{NN}}$=2.76 TeV. The solid line is obtained from Eq.3. The extracted parameters are tabulated in Table-I. A_h is plotted with N_{part} in Fig.2 which shows linear behaviour.

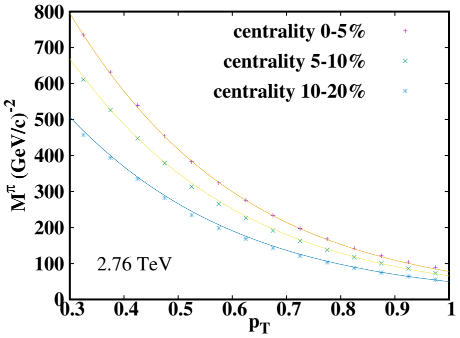

FIG. 1: pion p_T spectra at $\sqrt{s} = 2.76$ TeV. $M^\pi = \frac{d\bar{N}^\pi}{dp_T} = \frac{1}{2\pi p_T}\frac{dN^\pi}{dp_T}$ is the pion yield. Plot is for various centrality.

Summary and Conclusions

Here we emphasize on pion production as meson production at low p_T was not successfully explained earlier.

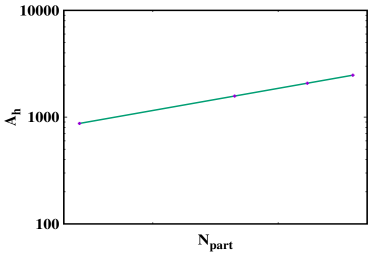

FIG. 2: Parameters of fit show some trends indicating the effectiveness of the constructed expression for yield.

$\sqrt{s}$ (TeV)	0.0624	0.2	2.76
T	0.238	0.258	0.292
a_π = 1.176			
b_π =0.12			
A^0_π =2.01			

TABLE I: Best fit for the parameters with the experimental results.

Results from improved recombination model explain the pion data nicely at low p_T. We have also calculated for other hadrons and compared with data from 2.76 TeV Pb+Pb collisions. The introduction of confinement energy and valence quark mass leads to good agreement with the pion data. The straight line trend of the log-log plots in Fig. 2 confirms that the simple parametric form is a good approximation for the hadron yield.

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