Hadron production in pp and p-Pb collisions: A mass dependent phenomenon

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We find from the existing experimental data that the relative rates of production of hadrons in the ultra-relativistic regime is influenced by both their hadronic masses and valance quark masses. Furthermore, the available data also indicate an energy dependence in the relative rates of production of hadrons. We parameterize the variations in yield ratios between any two hadrons with event charged multiplicity by a new function that gives an excellent fit to all the available data from pp and p–Pb collisions at LHC energies. We find that the variations are independent of all quantum numbers, but solely depends upon the masses of hadrons and masses of their valence quarks.

1. Introduction

ALICE observed in pp collisions at $\sqrt{s} = 7$ TeV that the p_{T} integrated yields of strange and multi-strange particles relative to π increase significantly with the charged-particle multiplicity [1]. The observed relative yield enhancements increase with the strange quark content in the hadrons. From the experimental data, we notice that the yield ratios between non-strange hadrons, such as p/π, or hadrons with the same strange content, such as Λ/K^0_s, show similar enhancements. For the first time, we find from the existing experimental data that the relative rates of production of hadrons in the ultra-relativistic regime is influenced by both their hadronic masses and valance quark masses. Furthermore, the available data also indicate an energy dependence in the relative rates of production of hadrons. We parameterize the variations in yield ratios, between any two hadrons (mesons or baryons, strange or non-strange particles), with event charged multiplicity by an empirical function that describes data from pp collisions [1, 5, 6] and p–Pb collisions [7, 8] at LHC energies. We find that the available data follow this hypothesis: the variations in yield ratios depend on masses of hadrons and masses of their valence quarks, and this is independent of any other quantum numbers. The function indicates the dominance of different hadron production mechanisms over $\langle \mathrm{d}N_{\mathrm{ch}}/\mathrm{d}\eta \rangle$.

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2. Results and Discussions

Figure 1 shows yield ratios p/π and $\Lambda/\mathrm{K}^0_{\mathrm{s}}$ in pp collisions at $\sqrt{s} = 7$ TeV and 13 TeV [5, 6], normalized by the respective values measured in the inclusive INEL > 0 pp collisions at $\sqrt{s} = 7$ TeV. Results from both the energies suggest the existence of multiplicity-dependence of normalised yield ratios between similar strange hadrons. Furthermore, the data may be indicating an energy dependence of relative rate of production of hadrons. This means the production rate of heavier hadrons increases faster than that of lighter hadrons. The ALICE data points are fitted up to $\langle \mathrm{d}N_{\mathrm{ch}}/\mathrm{d}\eta \rangle$ equals to 12 with three functions: (i) 1+ Log(x)/x, (ii) m∗x + c, (iii) y = 1. The fit results of function (i) show a logarithmic behaviour in the enhancement of the yield ratios towards lower $\langle \mathrm{d}N_{\mathrm{ch}}/\mathrm{d}\eta \rangle$. The fit χ^2/ndf values remain between 0.007 to 0.12. The fit results of function (ii) show the slope of the fit increase with energy. Finally, the fit results of function (iii) suggest the data is not consistent with unit in low $\langle \mathrm{d}N_{\mathrm{ch}}/\mathrm{d}\eta \rangle$. The fit χ^2/ndf values of the function increase by 25 to 350 times than those obtained from the function (i).

Figure 2 shows the multiplicity dependence

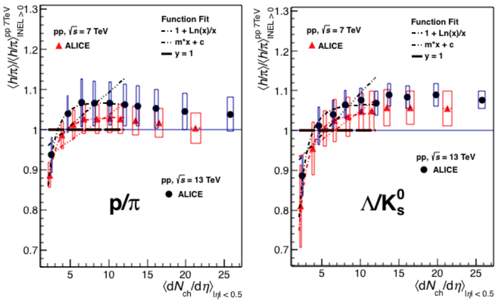

FIG. 1: The legends describe the nature of data points.

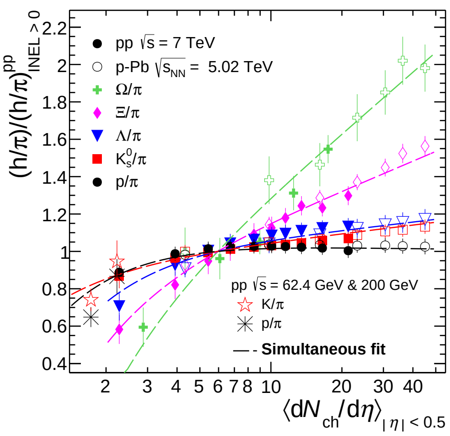

FIG. 2: The legends describe the nature of data points.

of primary yield ratios of hadrons to π, scaled by the respective values measured in the inclusive (INEL $>$ 0) pp collisions at $\sqrt{s}$ = 7 TeV. We have parameterized a function to describe this behaviour and examined how effectively this function can fit these 5 sets of data points simultaneously. Every line in Fig. 2 represents the curve predicted by our function that fits the corresponding data points. The empirical function is in the form

$$\frac{h/\pi}{(h/\pi)^{pp}_{IN>0}} = 1 + M_q \, log\left[\frac{\langle dN_{ch}/d\eta\rangle}{\langle dN_{ch}/d\eta\rangle^{pp}_{IN>0}}\right] + M_h \, log\left[\frac{\langle dN_{ch}/d\eta\rangle}{\langle dN_{ch}/d\eta\rangle^{pp}_{IN>0}}\right] \Big/ \langle dN_{ch}/d\eta\rangle, \quad (1)$$

$$M_q = a\left((M_{q,N})^b - (M_{q,D})^b\right) \; \& \quad M_h = c\,(M_{h,N} - M_{h,D})\,,$$

where $M_{q,N}$ ($M_{q,D}$) is twice the sum of masses of valence quarks of the hadron in the numerator (denominator), and $M_{h,N}$ ($M_{h,D}$) is twice the mass of hadron in the numerator (denominator). $(h/\pi)^{pp}_{IN>0}$ is the measured hadron to π ratio in (INEL $>$ 0) pp collisions, and a, b, c are free parameters having appropriate units. The fit describes available data well with χ^2/ndf = 0.38 for the best fit parameter values a = 1.35 ± 0.13, b = 1.84 ± 0.11 and c = 0.18 ± 0.034. There are two parts in the empirical function, which represents two different behaviours of yield enhancement. The first part depends on the masses of valence quarks, and it contributes substantially towards higher $\langle dN_{ch}/d\eta\rangle$. The second part depends on the hadron mass, and it contributes largely towards lower $\langle dN_{ch}/d\eta\rangle$. This may indicate that the increasing rate of a heavier hadron production with respect to a lighter one towards high $\langle dN_{ch}/d\eta\rangle$ is largely from quark coalescence and recombination mechanism, while in the low $\langle dN_{ch}/d\eta\rangle$ region, there is large suppression of heavier hadrons those come from fragmentation like processes, which says hadrons are mainly produced by excited string fragmentations or high p_T partonic jets.

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