

Research Article

A Comparative Study of K^\pm/π^\pm Ratio in Proton-Proton Collisions at Different Energies: Experimental Results versus Model Simulation

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A detailed study of energy dependence of K^+/π^+ , K^-/π^- and total kaon to pion multiplicity ratio $((K^+ + K^-)/(\pi^+ + \pi^-) = K/\pi)$ has been carried out in proton-proton (pp) collisions at $\sqrt{s} = 6.3, 17.3, 62.4, 200,$ and 900 GeV and also at $\sqrt{s} = 2.76$ TeV and 7 TeV in the framework of UrQMD and DPMJET III model. Dependence of K^+/π^+ and K^-/π^- on energy shows different behavior for UrQMD and DPMJET III model. The presence of the horn-like structure in the variation of K^+/π^+ and K^-/π^- with energy for the experimental data is supported by the DPMJET III model. Experimentally it has been observed that as energy increases, the total kaon to pion multiplicity ratio $((K^+ + K^-)/(\pi^+ + \pi^-) = K/\pi)$ increases systematically for pp collisions at lower energies and becomes independent of energy in LHC energy regime. Our analysis on total kaon to pion multiplicity ratio $((K^+ + K^-)/(\pi^+ + \pi^-) = K/\pi)$ with UrQMD data is well supported by the experimental results obtained by different collaborations in different times. In case of DPMJET III data, the saturation of K/π ratio at LHC region has not been observed.

1. Introduction

The study of nucleus-nucleus interactions at high energies has been a subject of major interest to the theoretical and experimental physicists. The nucleus-nucleus interaction can provide valuable information on the spatiotemporal development of multiparticle production process, which is one of the prime interests in view of recent developments of quantum chromodynamics. Along with the study of nucleus-nucleus collisions, a thorough understanding of proton-proton (pp) collisions is also necessary both as input to detailed theoretical models of strong interactions and as a baseline for understanding the nucleus-nucleus collisions at relativistic and ultrarelativistic energies. Soft particle production from ultrarelativistic pp collisions is also sensitive to the flavor distribution within the proton, quark hadronization, and baryon number transport. The measurement of charged particle transverse momentum spectra in pp collisions serves as a crucial reference for particle spectra in nucleus-nucleus

collisions. A proton-proton reference spectrum is needed for nucleus-nucleus collisions to investigate possible initial-state effects in the collision. The multiplicity distribution of particles produced in proton-proton (pp) collisions and the multiplicity dependence of other global event characteristics represent fundamental observables reflecting the properties of the underlying particle production mechanisms. In high-energy collisions along with the pions, kaons are also important as the strange particle production is a powerful probe into the hadronic interaction and the hadronization process in pp and heavy-ion collisions at relativistic energies. The study of K/π ratio in high-energy collisions is an important observable to be studied not only to address questions of the phase transition but also to obtain a better understanding of the pre-equilibrium dynamics, the hadronization processes, and dynamics of hadrons in the medium. It is well known that the strangeness enhancement in relativistic nucleus-nucleus collisions has been proposed as a signature of the Quark-Gluon Plasma (QGP) formation in the relativistic heavy-ion

collisions. The study of K/π ratio in pp collisions can provide a baseline to investigate the strangeness enhancement.

In this paper, we are presenting an analysis of energy dependence of K^+/π^+ , K^-/π^- and total kaon to pion multiplicity ratio $((K^+ + K^-)/(\pi^+ + \pi^-) = K/\pi)$ at $\sqrt{s} = 6.3, 17.3, 62.4, 200,$ and 900 GeV and also at $\sqrt{s} = 2.76$ TeV and 7 TeV in the framework of UrQMD and DPMJET III model in proton-proton (pp) collisions. We have also compared our results with available experimental results obtained so far. Before going into the details of the analysis it will be convenient for the readers to have brief introductions about the two models.

2. UrQMD and DPMJET III Model: A Brief Introduction

UrQMD model is a microscopic transport theory, based on the covariant propagation of all the hadrons on the classical trajectories in combination with stochastic binary scattering, colour string formation, and resonance decay. It represents a Monte Carlo solution of a large set of coupled partial integrodifferential equations for the time evolution of various phase space densities. The main ingredients of the model are the cross sections of binary reactions, the two-body potentials and decay widths of resonances. The UrQMD collision term contains 55 different baryon species (including nucleon, delta, and hyperon resonances with masses up to $2.25 \text{ GeV}/c^2$) and 32 different meson species (including strange meson resonances), which are supplemented by their corresponding antiparticle and all isospin-projected states. The states can either be produced in string decays, s -channel collisions, or resonance decays. This model can be used in the entire available range of energies from the Bevalac region to RHIC. For more details about this model, readers are requested to consult [1–3].

The Monte Carlo event generator DPMJET can be used to study particle production in high-energy nuclear collisions including photoproduction and deep inelastic scattering off the nuclei. It is a code system based on the Dual Parton Model and unifies all features of the DTUNUC-2, DPMJET-II, and PHOJET 1.12 event generators. DPMJET III allows the simulation of hadron-hadron, hadron-nucleus, nucleus-nucleus, photon-hadron, photon-photon, and photon-nucleus interactions from a few GeV up to the highest cosmic ray energies. DPMJET is an implementation of the two-component Dual Parton Model for the description of interactions involving nuclei. This model is based on the Gribov-Glauber [4–6] approach. Gribov theory of high-energy interactions of hadrons and nuclei is based on general properties of amplitudes in relativistic quantum theory and provides a unified approach to a broad class of processes. According to this theory, the Glauber approximation [6] to nuclear dynamics is valid in the region of not too high energies and should be modified at energies of RHIC and LHC. Gribov theory then allows determining the corrections to the Glauber approximation [6] for inclusive particle spectra by relating them to cross sections of large-mass diffraction. The technique has been applied to calculation of shadowing effects for structure functions of nuclei and

a good agreement with experimental data on these processes has been obtained. The same approach predicts a strong reduction of particle densities at superhigh energies as compared to predictions of the Glauber approximation [6]. Since its first implementations [7, 8] DPMJET model uses the Monte Carlo realization of the Gribov-Glauber multiple scattering formalism according to the algorithms of [9] and allows the calculation of total, elastic, quasielastic, and production cross sections for any high-energy nuclear collision. DPMJET III is a string model and the generalization of the string model to hadron-nucleus and nucleus-nucleus collisions was done by the Glauber-Gribov theory [4–6]. DPMJET III model treats both soft and hard scattering processes in a unified way. Soft processes are parametrized according to Regge-phenomenology whereas lowest order perturbative QCD is used to simulate the hard component. In DPMJET III model multiple parton interactions in each individual hadron/nucleon/photon-nucleon interaction have been described by the PHOJET event generator and the fragmentation of parton configurations is treated by the Lund model PYTHIA. For more details about the model, one can consult [10, 11].

3. Analysis and Results

We have generated ten thousand events using the UrQMD (UrQMD-3.3p1) [1–3] and DPMJET III (DPMJET 3.06) [10, 11] model in pp collisions at $\sqrt{s} = 6.3, 17.3, 62.4, 200,$ and 900 GeV and also at $\sqrt{s} = 2.76$ TeV and 7 TeV. However, as we are dealing with the RHIC and LHC data, these numbers cannot be taken as large. We have calculated the number of positive and negative kaons and the number of positive and negative pions from the generated output of the UrQMD and DPMJET III model for all the energies.

3.1. Energy Dependence Study of K^+/π^+ Ratio. The values of K^+/π^+ ratio have been calculated from the generated output of both UrQMD and DPMJET III model. Table 1 represents the values of K^+/π^+ ratio in pp collisions at $\sqrt{s} = 6.3, 17.3, 62.4, 200,$ and 900 GeV and also at $\sqrt{s} = 2.76$ TeV and 7 TeV. From Table 1 it is reflected that DPMJET III model simulated values of K^+/π^+ ratio are higher than their UrQMD counterparts up to $\sqrt{s} = 62.4$ GeV. From $\sqrt{s} = 200$ GeV, UrQMD simulated values of K^+/π^+ ratio overestimate the DPMJET III simulated values.

For comparison in Table 1 we have shown the experimental values of K^+/π^+ ratio obtained from different experimental works at $\sqrt{s} = 6.3$ GeV [12], $\sqrt{s} = 17.3$ GeV [13], $\sqrt{s} = 62.4$ GeV [14], $\sqrt{s} = 200$ GeV [15], and $\sqrt{s} = 7000$ GeV [16]. Pulawski presented [12] the experimental values of K^+/π^+ ratio at mid rapidity at $\sqrt{s} = 6.3$ GeV [12] in case of inelastic pp collisions for the data of NA61/SHINE collaboration. The study of NA61/SHINE collaboration [12] reflected that the energy dependence of K^+/π^+ ratio exhibits rapid changes in the SPS energy range. Pulawski pointed out that [12] the EPOS, UrQMD, Pythia 8, and HSD model failed to describe the NA61/SHINE experimental results satisfactorily. The values of K^+/π^+ ratio $\sqrt{s} = 62.4$ GeV and 7 TeV have been calculated from the dN/dy values at mid rapidity. The

TABLE 1: It represents the values of K^+/π^+ ratio in pp collisions at $\sqrt{s} = 6.3$ GeV to 7 TeV in the framework of UrQMD, DPMJET III, and the experimental values.

Energy \sqrt{s} GeV	UrQMD simulated value of K^+/π^+ ratio	DPMJET III model simulated value of K^+/π^+ ratio	Experimental values of K^+/π^+ ratio	Reference for the experimental values of K^+/π^+ ratio
6.3	$.049 \pm .001$	$.065 \pm .002$	$.081 \pm .002$	[12]
17.3	$.083 \pm .003$	$.095 \pm .003$	$.109 \pm .003$	[13]
62.4	$.101 \pm .002$	$.105 \pm .002$	$.097 \pm .002$	[14]
200	$.110 \pm .008$	$.099 \pm .005$	$.104 \pm .008$	[15]
900	$.122 \pm .004$	$.115 \pm .006$
2760	$.124 \pm .004$	$.116 \pm .006$
7000	$.124 \pm .005$	$.120 \pm .007$	$.126 \pm .006$	[16]

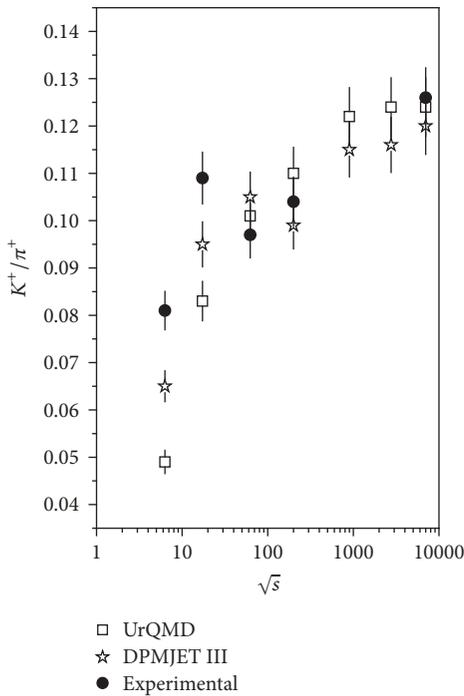


FIGURE 1: It represents the energy dependence of K^+/π^+ ratio in pp collisions at $\sqrt{s} = 6.3$ GeV to 7 TeV of the UrQMD, DPMJET III, and experimental analysis.

dN/dy values at mid rapidity at $\sqrt{s} = 62.4$ GeV and at $\sqrt{s} = 7$ TeV are $|\eta| < 0.35$ and $|\eta| < 0.5$, respectively. K^+/π^+ ratios at other energies have been estimated with the help of a high accuracy digitized plot analyzer.

In Figure 1 we have presented the variation of K^+/π^+ ratio with energy for pp collisions in case of UrQMD simulated, DPMJET III simulated, and the experimental values. From the figure it can be seen that for UrQMD simulation the values of K^+/π^+ ratio increase smoothly with energy and after reaching at $\sqrt{s} = 900$ GeV the ratio almost saturates, while in case of DPMJET III simulation the value of K^+/π^+ ratio shows a sudden decrease at $\sqrt{s} = 200$ GeV. After the sudden decrease the K^+/π^+ values begin to increase with energy. No prominent saturation of K^+/π^+ ratio has been observed

at LHC regime for DPMJET III model. The dependence of K^+/π^+ values with energy shows the presence of the horn-like structure in case of DPMJET III simulated events. The observed sudden decrease of K^+/π^+ ratio is completely absent in case of UrQMD simulation. The experimental studies of energy dependence of K^+/π^+ ratio also indicate that the K^+/π^+ values increase initially with energy, get a sudden drop at $\sqrt{s} = 62.4$ GeV, and go on increasing again signifying the presence of the horn-like structure.

3.2. Energy Dependence Study of K^-/π^- Ratio. In order to study the energy dependence of K^-/π^- ratio in pp collisions we have calculated the values of K^-/π^- ratio obtained from the simulation of pp collisions at $\sqrt{s} = 6.3$ GeV–7 TeV by UrQMD and DPMJET III model. Calculated values of K^-/π^- ratio for UrQMD and DPMJET III simulation have been presented in Table 2. From Table 2 it is seen that, from $\sqrt{s} = 900$ GeV, UrQMD simulated values of K^-/π^- ratio overestimate the DPMJET III simulated values. In the same table the values of K^-/π^- ratio calculated from the different publications at $\sqrt{s} = 6.3$ GeV [12], $\sqrt{s} = 17.3$ GeV [13], $\sqrt{s} = 62.4$ GeV [14], $\sqrt{s} = 200$ GeV [15], $\sqrt{s} = 900$ GeV [17], and $\sqrt{s} = 7000$ GeV [16] have also been presented. As in the case of K^+/π^+ ratio, the values of K^-/π^- ratio have been calculated from the values of dN/dy at mid rapidity at $\sqrt{s} = 62.4$ GeV ($|\eta| < 0.35$) and $\sqrt{s} = 7$ TeV ($|\eta| < 0.5$).

In Figure 2 we have depicted the variation of K^-/π^- ratio with energy for UrQMD simulated, DPMJET III simulated, and the experimental values. From Figure 2 it may be noted that the values of K^-/π^- ratio for the UrQMD simulated events are found to increase smoothly with energy and after reaching $\sqrt{s} = 900$ GeV, saturation of K^-/π^- ratio occurs. However in case of DPMJET III model a sudden drop of K^-/π^- ratio occurs at $\sqrt{s} = 900$ GeV. The ratio then begins to rise again presenting a horn-like structure as observed in case of the energy dependence of K^+/π^+ values. The experimental values of K^-/π^- ratio also get a sudden drop at $\sqrt{s} = 62.4$ GeV and increase again to construct a horn-like structure in the energy dependence of K^-/π^- values in pp collisions.

Thus it may be pointed out that the experimental study of energy dependence of both K^+/π^+ and K^-/π^- ratio shows a horn-like structure which is also shown by the DPMJET III model but UrQMD model fails to reproduce the horn-like

TABLE 2: It represents the values of K^-/π^- ratio in pp collisions at $\sqrt{s} = 6.3$ GeV to 7 TeV in the framework of UrQMD, DPMJET III, and the experimental values.

Energy \sqrt{s} GeV	UrQMD simulated value of K^-/π^- ratio	DPMJET III model simulated value of K^-/π^- ratio	Experimental values of K^-/π^- ratio	Reference for the experimental values of K^-/π^- ratio
6.3	$.026 \pm .001$	$.031 \pm .002$	$.038 \pm .001$	[12]
17.3	$.066 \pm .003$	$.077 \pm .003$	$.092 \pm .003$	[13]
62.4	$.093 \pm .004$	$.097 \pm .002$	$.081 \pm .005$	[14]
200	$.105 \pm .005$	$.116 \pm .005$	$.102 \pm .005$	[15]
900	$.120 \pm .007$	$.113 \pm .006$	$.121 \pm .013$	[17]
2760	$.123 \pm .005$	$.115 \pm .006$
7000	$.124 \pm .006$	$.119 \pm .007$	$.128 \pm .004$	[16]

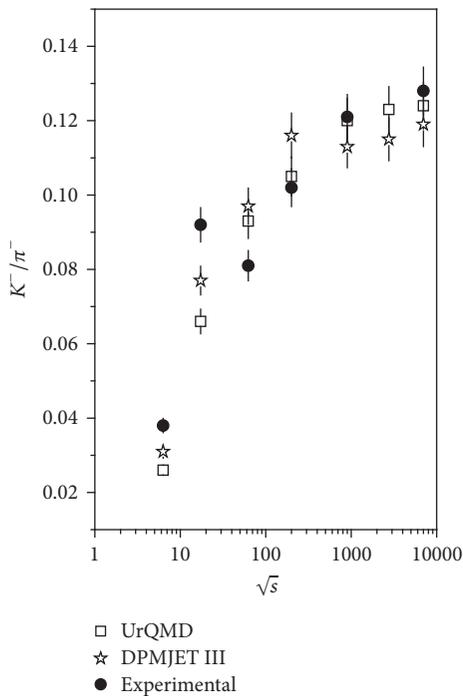


FIGURE 2: It represents the energy dependence of K^-/π^- ratio in pp collisions at $\sqrt{s} = 6.3$ GeV to 7 TeV of the UrQMD, DPMJET III, and experimental analysis.

structure. The observed difference in the energy dependence of K^+/π^+ and K^-/π^- ratio between UrQMD and DPMJET III model is due to the basic difference between the two models. It may be mentioned here that both UrQMD and DPMJET III are microscopic Monte Carlo models. UrQMD is a hadronic transport model and DPMJET III is based on string interaction. String models describe the collision through the exchange of colour or momentum between partons in the projectile and target. As a consequence of these exchanges, these partons become joined by colourless objects which are called string, ropes, or flux tubes. UrQMD is a semiclassical hadronic transport model based on the concepts of kinetic theory, in which the evolution of a heavy-ion collision is described by the propagation of

on-shell particles on relativistic trajectories in combination with a stochastic treatment of the individual particle scattering processes. The model offers an effective solution for the relativistic Boltzmann equation, where the collision term includes elastic and inelastic scatterings as well as resonance decays. To account for the quantum statistics, the hadrons are represented by Gaussian wave packets and effects such as Pauli blocking are included in this model.

It may be mentioned here that the horn-like structure of the experimental data occurs at different energy in comparison to the DPMJET III model for both K^+/π^+ and K^-/π^- ratio. In DPMJET III model at SPS energies two long strings with valence quarks at the end and SCET-soft sea quarks in the produced particles having a low K^\pm/π^\pm ratio are given by a parameter in PYTHIA. The cross section fits dictate how at higher energies the additional strings enter. Their partons are considered as something like a minijet extension of pQCD events at large transverse momentum P_T . There should be something like a continuous transition at a cutoff P_T . It means the particles at the sea string ends have a larger P_T and a larger K^\pm/π^\pm ratio. At an energy where the new strings just come in, they are short and the fraction of particles containing the string end partons is sizable. With increasing energies the strings get longer and their influence gets diluted (i.e., K^\pm/π^\pm gets again lower). In heavy-ion scattering the production of new chains is enhanced as each projectile nucleon meets several target nucleons and vice versa. The new typically shorter strings now lead to an increase in the K^\pm/π^\pm ratio. The string fusion (available in DPMJET III) and rescattering effects (presumably necessary) do not have a significant effect. There is some uncertainty in the parameterization of sea strings energies and the position of the horn is not a firm prediction.

Comparing Tables 1 and 2 it may be said that significant differences between the values of K^+/π^+ and K^-/π^- exist for both the models up to $\sqrt{s} = 200$ GeV. However, at the higher energy regime ($\sqrt{s} = 900$ GeV–7 TeV), no significant difference occurs between the values of K^+/π^+ and K^-/π^- for both UrQMD and DPMJET III model. In case of the experimental data it can be seen that from $\sqrt{s} = 200$ GeV the difference between the values of K^+/π^+ and K^-/π^- becomes insignificant. The difference between the K^+/π^+ and K^-/π^- values can be explained from the underlying physics of

TABLE 3: It represents the values of total kaon to pion multiplicity ratio $((K^+ + K^-)/(\pi^+ + \pi^-) = K/\pi)$ in pp collisions at $\sqrt{s} = 6.3$ GeV to 7 TeV in the framework of UrQMD and DPMJET III model along with the experimentally obtained values.

Energy \sqrt{s} GeV	Experimental value of K/π ratio	UrQMD model simulated Value of K/π ratio	DPMJET III model simulated value of K/π ratio	Reference for the experimental value
6.3	.045 ± .001	.046 ± .001	.052 ± .002	[18]
17.3	.082 ± .003	.075 ± .003	.087 ± .003	[13, 19, 20]
62.4	.094 ± .002	.097 ± .004	.101 ± .002	[14]
200	.103 ± .008	.108 ± .005	.109 ± .005	[15, 21]
900	.123 ± .004	.121 ± .007	.114 ± .006	[21]
2760	.124 ± .004	.123 ± .005	.116 ± .006	[16]
7000	.124 ± .005	.124 ± .006	.119 ± .007	[16]

kaon and antikaon production mechanism. Here it should be mentioned that there are two possible mechanisms of kaon production, the associated production mechanism and the pair production mechanism. According to the associated production mechanism only K^+ mesons are produced by the following two interactions: $N + N \rightarrow N + X + K^+$ and $\pi + N \rightarrow X + K^+$, where N is the nucleon and X is either Λ hyperons or Ξ hyperons. On the other hand pair production mechanism produces K^+ and K^- according to the interaction given by $N + N \rightarrow N + N + K^+ + K^-$. At the lower energy, the associated production mechanism dominates. As the energy increases, the pair production, which produces the same number of K^+ and K^- becomes more significant. At higher energy the antikaon excitation function is steeper than that of the kaon because of a higher threshold. So at higher energy the antikaon production cross section increases faster than that of kaon and the K^-/π^- ratio increases.

3.3. Energy Dependence Studies of Total Kaon to Pion Multiplicity Ratio. We have also calculated the total kaon to pion multiplicity ratio $((K^+ + K^-)/(\pi^+ + \pi^-) = K/\pi)$ at these different collision energies for the proton-proton collisions and presented the values in Table 3 for both UrQMD and DPMJET III simulated events. It can be noticed from the table that as energy increases, the K/π ratio increases initially for both UrQMD and DPMJET III model. At higher energy in the LHC range the kaon to pion ratio becomes almost independent of energy in case of UrQMD model. But for DPMJET III simulation the values of K/π go on increasing slowly with energy. No clear energy independency is observed for DPMJET III model in LHC energy regime. Moreover, the observed sudden decrease of K^+/π^+ and K^-/π^- values vanishes in case of total kaon to pion multiplicity ratio $((K^+ + K^-)/(\pi^+ + \pi^-) = K/\pi)$ in DPMJET III simulation. From Table 3 it can be noted that the UrQMD simulated values of kaon to pion ratio are higher than the DPMJET III simulated values as energy increases from $\sqrt{s} = 200$ GeV. At energy less than 200 GeV, however, DPMJET III model calculated values of kaon to pion ratio are higher in comparison to the UrQMD simulated values.

Experimental studies of total pion to kaon multiplicity ratio $((K^+ + K^-)/(\pi^+ + \pi^-) = K/\pi)$ in pp collisions have been reported by different collaborators in different times

over a wide range of energy. From the report of the NA61 collaboration [18] we have calculated the values of K/π ratio in pp collisions at $\sqrt{s} = 6.3$ GeV and presented the value in Table 3 along with the values obtained from our simulated analysis. From the study of NA49 collaboration [13, 19, 20] on pp collisions at $\sqrt{s} = 17.3$ GeV, we have calculated the values of K/π ratio. In the regime of RHIC data, we extracted the values of K/π ratio from the analysis of PHENIX collaboration [14] at $\sqrt{s} = 62.4$ GeV and from the analysis of STAR collaboration at $\sqrt{s} = 200$ GeV [15]. At $\sqrt{s} = 900$ GeV and $\sqrt{s} = 2.76$ TeV, the K/π ratio has been calculated from the study of ALICE Collaboration [21]. ALICE Collaboration [17] studied the pion, kaon, and proton production in pp collisions at $\sqrt{s} = 7$ TeV also. In that paper they calculated the values of K/π ratio in pp collisions. They have mentioned the values of K/π ratio in pp collisions at different energies studied earlier and presented a study of energy dependence. In [21] the values of K/π ratio at $\sqrt{s} = 200$ GeV and $\sqrt{s} = 900$ GeV have been mentioned in the text with proper references. The experimental values of K/π ratio at different energies have been calculated from the plot given in [16] with the help of a high accuracy digitized graphical software as mentioned earlier.

Experimentally calculated values of K/π ratio in pp collisions at $\sqrt{s} = 6.3, 17.3, 62.4, 200,$ and 900 GeV and also at $\sqrt{s} = 2.76$ TeV and 7 TeV have been taken from these literatures and presented in Table 3. From Table 3 it can be seen that the experimentally obtained values of K/π ratio increase initially with the increase of energy up to 200 GeV. At energy greater than 200 GeV the K/π ratio becomes independent of energy. Moreover, Table 3 reflects that the experimentally obtained total kaon to pion multiplicity ratio agrees well with their UrQMD counterpart qualitatively and quantitatively over the entire energy range.

In comparison to the UrQMD analysis, DPMJET III model calculated values of K/π ratio are higher than the experimental data up to 200 GeV. As we enter in the LHC region (900 GeV to 7 TeV) DPMJET III simulated values of K/π ratio are found to be lower than the corresponding experimental values. We have also studied the variation of K/π ratio with energy graphically for the experimental events, UrQMD simulated events, and DPMJET III simulated events. Figure 3 depicts the variation of kaon to pion ratio

with energy in case of pp collisions from 6.3 GeV to 7 TeV for experimental, UrQMD simulated, and DPMJET III simulated events. From Figure 3 it can be noticed that no horn-like structure is observed for the experimental data when the energy dependence of total kaon to pion multiplicity ratio is studied.

It may be mentioned here that Long et al. [22] utilized the parton and hadron cascade model PACIAE based on PYTHIA to investigate the kaon to pion ratio in pp collisions at RHIC and LHC energy. They found that the PACIAE model calculated values of K/π at $\sqrt{s} = 17.2, 200, \text{ and } 900 \text{ GeV}$ agree with the NA49 [13, 19, 20], STAR [15], and ALICE data [21, 23]. With the inclusion of the results for $\sqrt{s} = 2.36, 7 \text{ and } 14 \text{ TeV}$, it was found that the K/π ratio increases slightly from $\sqrt{s} = 0.2$ to 0.9 TeV and then saturates. Our study with UrQMD model predicts the same result. It should be mentioned here that ALICE Collaboration also in their published papers [21, 23] studied the energy dependence of K/π ratio in pp collisions.

4. Conclusions

To summarize we recall that we have presented a systematic study of K^+/π^+ , K^-/π^- , and $((K^+ + K^-)/(\pi^+ + \pi^-) = K/\pi)$ ratio in proton-proton collisions as a function of the bombarding energy from 6.3 GeV to 7 TeV using UrQMD model and DPMJET III model. Comparisons of the simulated results with the available experimental data have also been presented. Important findings of this analysis are given as follows:

- (1) Values of K^+/π^+ and K^-/π^- differ from each other in the lower energy regime ($\sqrt{s} = 6.3 \text{ GeV} - \sqrt{s} = 200 \text{ GeV}$) for both UrQMD and DPMJET III model simulation. The difference becomes insignificant in the LHC energy range ($\sqrt{s} = 900 \text{ GeV} - \sqrt{s} = 7 \text{ TeV}$). Experimental study also supports this observation. This observation can be explained on the basis of Kaon production mechanism.
- (2) In case of UrQMD model the values of K^+/π^+ , K^-/π^- , and $((K^+ + K^-)/(\pi^+ + \pi^-) = K/\pi)$ increase with energy initially and then saturate in the LHC energy regime. DPMJET III simulated ratio of K^+/π^+ , K^-/π^- , and $((K^+ + K^-)/(\pi^+ + \pi^-) = K/\pi)$ do not show any saturation at LHC region.
- (3) A horn-like structure is observed in case of DPMJET III simulation during the variation of K^+/π^+ and K^-/π^- with energy. The horn-like structure is found to be wiped out when the total kaon to pion multiplicity ratio $((K^+ + K^-)/(\pi^+ + \pi^-) = K/\pi)$ was considered. No horn-like structure has been observed in case of UrQMD simulation.
- (4) Comparison of our results with the experimental data of K^+/π^+ , K^-/π^- , and total multiplicity ratio $((K^+ + K^-)/(\pi^+ + \pi^-) = K/\pi)$ has also been presented whenever available. Experimental study of energy dependence of K^+/π^+ and K^-/π^- shows the presence of horn-like structure. No horn-like structure is observed in case of energy dependence of

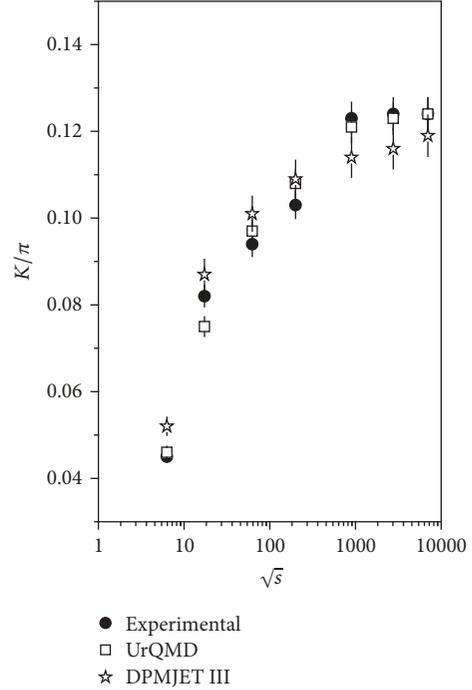


FIGURE 3: Variation of total kaon to pion multiplicity ratio $((K^+ + K^-)/(\pi^+ + \pi^-) = K/\pi)$ with energy \sqrt{s} in pp collisions at $\sqrt{s} = 6.3 \text{ GeV}$ to 7 TeV for the experimental data extracted from the papers of different collaborators, UrQMD model simulated values, and DPMJET III model simulated values.

total kaon to pion multiplicity ratio $((K^+ + K^-)/(\pi^+ + \pi^-) = K/\pi)$ for the experimental data.

- (5) The experimental data was found to exhibit energy dependence at the lower energy regime but the values of K^+/π^+ , K^-/π^- , and the K/π ratio become independent of energy as energy goes to the LHC range (900 GeV to 7 TeV). We have demonstrated that the experimentally obtained values of kaon to pion total multiplicity ratio (K/π values) are well reproduced by the UrQMD model. DPMJET III model simulated values of K/π ratio are little different from the experimental values of K/π ratio.

Conflicts of Interest

There are no conflicts of interest in publishing the paper.

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