International Journal of Modern Physics A
Vol. 31, No. 24 (2016) 1650136 (8 pages)

DOI: 10.1142/S0217751X16501360

Transverse momentum distribution of primary charged particles in the p–Pb interactions using HIJING 1.0

U. Tabassam,* Y. Ali,† M. Suleymanov,‡ A. S. Bhatti,§ J. B. Butt¶ and M. S. Amjad‖

Department of Physics, COMSATS Institute of Information Technology, Park Road, Islamabad, 44000, Pakistan

*uzma.tabassam@comsats.edu.pk
†yasir_ali@comsats.edu.pk
‡mais_suleymanov@comsats.edu.pk
§asbhatti@comsats.edu.pk
¶jamila.bashir@comsats.edu.pk
‖sohail_amjad@comsats.edu.pk

Received 12 February 2016
Revised 29 July 2016
Accepted 4 August 2016
Published 29 August 2016

The shape of the transverse momentum (p_T) distribution of primary charged particles in minimum bias (nonsingle-diffractive) p–Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV is studied in the pseudorapidity regions: $|\eta| < 0.3$, $0.3 < \eta < 0.8$ and $0.8 < \eta < 1.3$ and in the transverse momentum range $0.5 < p_T < 20$ GeV/c using simulated data produced with the HIJING 1.0 code. These are compared with the ALICE data measured by the ALICE detector at the LHC. In the model, the central and forward η-regions differ more than in the ALICE data and due to this fact HIJING 1.0 cannot describe well the high p_T region in the p_T distributions. The comparison of results from simulation implies that the HIJING 1.0 considered narrower pseudorapidity distribution for the charged particles than it is in the ALICE data. It cannot take into account satisfactorily leading effect due to the asymmetric p–Pb fragmentation.

Keywords: Transverse momentum; pseudorapidity; HIJING 1.0; leading effect; jet; fragmentation; p–Pb; 5.02 TeV; LHC.

PACS numbers: 12.38.Mh, 13.85.Ni

1. Introduction

In the ALICE paper,[1] the transverse momentum (p_T) distribution of primary charged particles is measured in minimum bias (nonsingle-diffractive) p–Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV with the ALICE detector at the LHC.[2,3] The p_T spectra were measured in the pseudorapidity regions in the center-of-mass system: $|\eta| < 0.3$, $0.3 < \eta < 0.8$ and $0.8 < \eta < 1.3$ and in the transverse momentum range $0.5 < p_T < 20$ GeV/c. It was observed that at high p_T, distributions of p–Pb collisions are similar to pp collisions, as expected in the absence of nuclear effects. There is an indication of a softening of the p_T spectrum when going from central to forward pseudorapidity region. That is a small effect, as seen in the ratios of the spectra at forward pseudorapidities to that at $|\eta| < 0.3$. DPMJET event generator[4] calculations well predict the measured $dN_{ch}/d\eta$ distribution in the laboratory reference system.[5] It is concluded in Ref. 1 that the data exhibit weak pseudorapidity dependence. There could be several reasons of this weak pseudorapidity dependence for the p_T distributions like: jet production and asymmetric fragmentation[1,6,7] of the projectiles-leading effect.[8–10]

The Heavy Ion Jet Interaction generator (HIJING 1.0) code can take into account jet production very well in hadron–nucleus collisions and give a clean picture of the jet fragmentation. In this paper, HIJING 1.0 is chosen as a generator of data for studying the p_T distribution of primary charged particles in p–Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV. The analysis based on the simulated data from the HIJING 1.0 code is done in the three mentioned pseudorapidity regions in the range of $0.5 < p_T < 20$ GeV/c. The data is compared with the ALICE data measured by the ALICE detector at the LHC.

In our simulation, we have used the Dubna version of the Monte Carlo model, HIJING 1.0.[11] This model combines the Lund model[12] for jet fragmentation[13] with Quantum Chromodynamics (QCD) inspired model for the multiple jet production.[14,15] Thus, it is possible to study jets in high energy pp, pA and AA collisions. The physics behind the program includes the multiple minijet production, soft excitation, nuclear shadowing of parton distribution functions and jet interaction in dense matter.[16,17] We have plotted the (p_T) distributions of primary charged particles at $\sqrt{s_{NN}} = 5.02$ TeV with 1×10^6 p–Pb events. We also studied the distributions by tuning the number of jets as well as for default jets (maximum number of hard nucleon–nucleon interactions as defined in HIJING 1.0 code).

2. Results and Discussion

We have selected primary charged particles like protons, antiprotons, K^+, K^-, π^+ and π^- mesons for analysis based on HIJING 1.0 code definitions. The number of jets were selected using parameter IHPR2(8) by selecting different variables. IHPR2(8): ($D = 10$) for maximum number of hard scattering per nucleon–nucleon interaction; IHPR2(8): ($D = 0$), for zero jet and IHPR2(8): ($D < 0$) for fixed jet production at its absolute value for each NN collision. All pions, kaons and protons are considered as primary particles, including the decays of strange hadrons, at variance to what is done by the ALICE experiment for the measurements.

Figure 1 shows the p_T distributions of the charged particles in minimum bias p–Pb collisions for different pseudorapidity (η) regions as mentioned above. The spectra of regions II and III are rescaled by the factor of 4 and 16, respectively. Similar p_T distributions are obtained from simulation of the HIJING 1.0 code and it is observed that the data from the model are systematically lower compared to

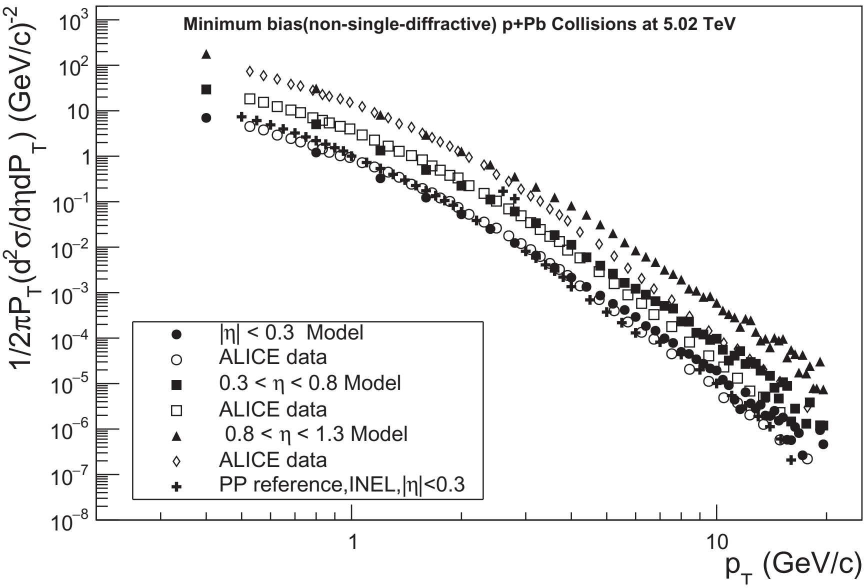

Fig. 1. Comparison of simulated and ALICE data transverse momentum (p_T) distributions of the primary charged particles in minimum bias p–Pb collisions for different pseudorapidity regions $|\eta| < 0.3$, $0.3 < \eta < 0.8$ and $0.8 < \eta < 1.3$, respectively. ALICE data are taken from Ref. 1.

the ALICE data. In order to compare the shapes of the simulated distributions generated from the code with the ALICE data;[a] the data were normalized to the values of charged particle distribution at $p_T = 2$ GeV/c. We took different normalization values of 2.0, 2.5 and 3.0 for regions I, II and III, respectively. One can see that after normalization the HIJING 1.0 code well describes the shape of the ALICE data for the first region till $p_T \approx 5$ GeV/c; for the second region till $\approx$ 4–5 GeV/c and for the last region till $\approx$ 2 GeV/c. For the last case, the deviation increases sharply with p_T due to jet production about 17%.

It is obvious that if we normalize the data at $p_T = 10$ GeV/c in Fig. 1, we would get results which will be similar to the interpolated results from the pp reference spectrum[1] Fig. 1. To test the idea we repeated all the work with 1×10^6 events for fixed number of jets: $0, 1, 2$ and also with default jets (maximum number of hard nucleon–nucleon interactions as defined in HIJING 1.0 code).

Figure 2 shows the p_T distribution of the charged particles with $|\eta| < 0.3$, and with different number of jets in an event. It is obvious that the deviation between the model and ALICE data changes with the number of jets. In case of 0 jets, the model could not describe the ALICE data both in the low and high p_T regions. For 1 and 2 jet events, clear fluctuations are observed in the high p_T area (which can

[a]The ALICE data (with and without errors) were taken from Ref. 1 using the HEPData; https://hepdata.net/record/37646; and pp reference spectra: http://hepdata.cedar.ac.uk/view/ins1190895.

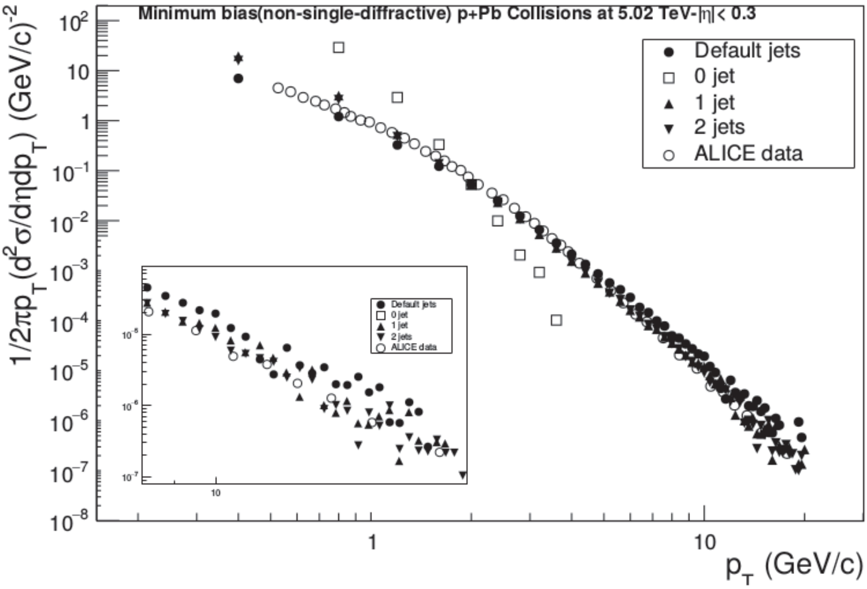

Fig. 2. Transverse momentum distributions of the primary charged particles in $|\eta| < 0.3$ for default, 0, 1 and 2 jets compared with ALICE data.[1]

be seen in the zoom in figure) while we find consistency between ALICE data and model at low p_T. One can say that in the $|\eta| < 0.3$ range the best approximation of the data by HIJING 1.0 can be reached in case of default jet. We can also conclude that in the high p_T region the model gives systematically higher results than the ALICE data. It may be due to absorption of charged particles by some dynamics which is not included in the HIJING 1.0 model.[14]

Figure 3 shows p_T distribution of the charged particles with η in the range $0.3 < \eta < 0.8$. Distributions coming from different number of jets are plotted against the ALICE data. The deviation is clear in the low p_T area.

Figure 4 depicts the distribution of charged particles in the region $0.8 < \eta < 1.3$. In this case, the model describes the low p_T area very well but has problems to describe the distribution at high p_T. We calculated the normalization factor at $p_T = 3.2$, which is 0.5 for $|\eta| < 0.3$ region, 1.5 for $0.3 < \eta < 0.8$ and 2.0 for $0.8 < \eta < 1.3$; this adjusts both distributions from model and ALICE data to a common scale.

So it seems that the HIJING 1.0 model can well describe the behavior of the charged particles with $|\eta| < 0.3$ (in the region of $p_T < 5$ GeV/c). Model has problem to describe the charged particles with $0.3 < \eta < 0.8$ and $0.8 < \eta < 1.3$. It means that HIJING 1.0 gives better description of the behavior of the charged particles from the central η region and has problem to describe the p_T behavior for the forward particles, which is the area of leading particles — projectiles fragments.

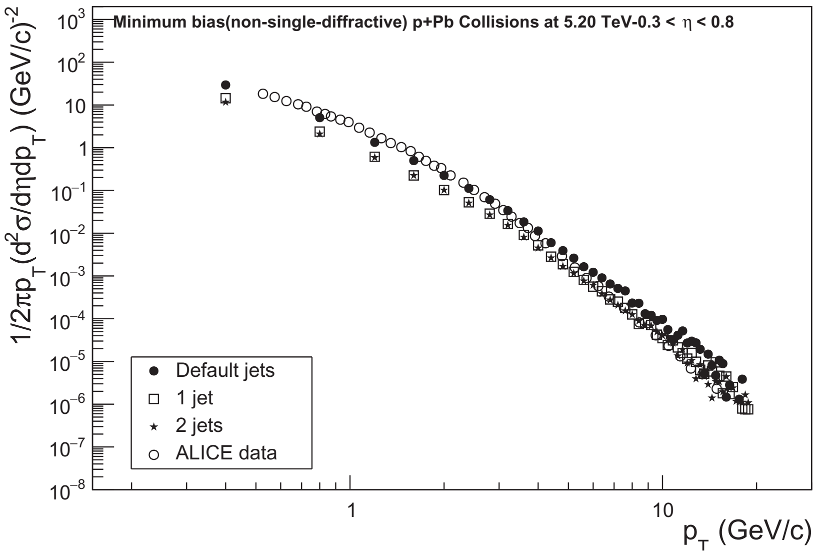

Fig. 3. Transverse momentum distributions of the primary charged particles in $0.3 < \eta < 0.8$ for default, 1 and 2 jets compared with ALICE data.[1]

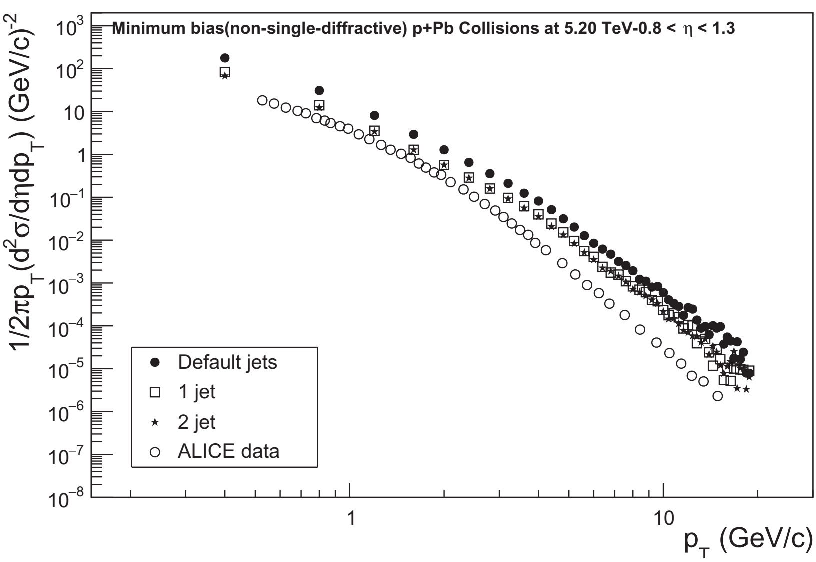

Fig. 4. Transverse momentum distributions of the primary charged particles in the region $0.8 < \eta < 1.3$ for default, 1 and 2 jets compared with ALICE data.[1]

For a more quantitative comparison, we plotted the ratios of spectra at forward pseudorapidities to that at $|\eta| < 0.3$ similar to Ref. 1 in Figs. 5 and 6.

The ratio of p_T distribution in pseudorapidity region II to pseudorapidity region I ($0.3 < \eta < 0.8/|\eta| < 0.3$) and the ratio of p_T distribution in pseudorapidity

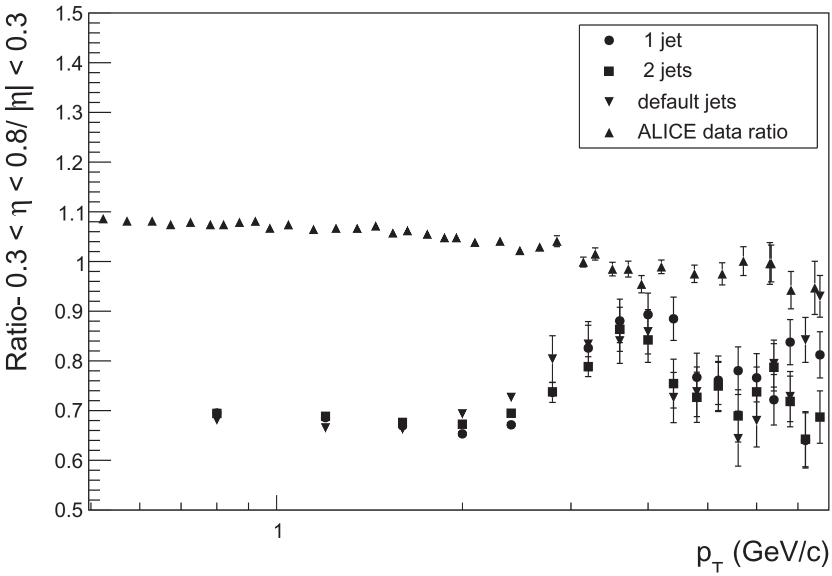

Fig. 5. The ratio of spectra $0.3 < \eta < 0.8/|\eta| < 0.3$ at forward pseudorapidity to that at $|\eta| < 0.3$.

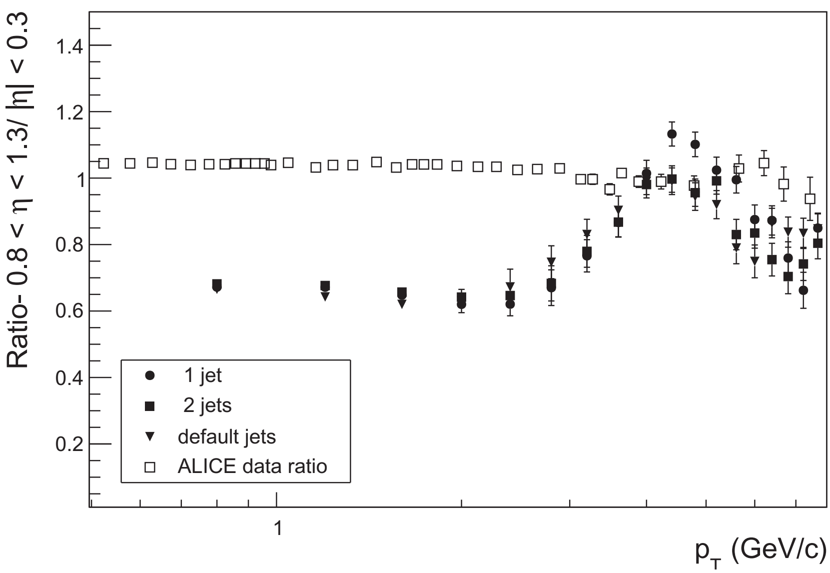

Fig. 6. The ratio of spectra $0.8 < \eta < 1.3/|\eta| < 0.3$ at forward pseudorapidity to that at $|\eta| < 0.3$.

region III to pseudorapidity region I ($0.8 < \eta < 1.3/|\eta| < 0.3$) are shown in Figs. 5 and 6, respectively.

Both figures represent the cases of 1 jet, 2 jet and default jet compared with the ALICE data ratio. We can see that: (i) the distributions looks similar to the ALICE data ratio up to ≈ 3 GeV/c but are lower compared to the ALICE data, between 3 GeV/c and 4 GeV/c, then the ratio increases and after 4 GeV/c it follows a similar trend as the ALICE data ratio; (ii) the results do not depend on the number of jets; and (iii) within statistical errors the ratios do not depend on the η regions. The reason that the simulated data is lower between 3 GeV/c and 4 GeV/c compared to the ALICE data is that the model generates a narrower pseudorapidity distribution than that observed in the ALICE data.

3. Conclusion

The results from the simulation are considered as an indication that the HIJING 1.0 model generates narrower η-distributions for the primary charged particles produced in the p–Pb interactions at $\sqrt{s_{NN}} = 5.02$ TeV. In the model, the central and forward η-regions differ significantly from the ALICE data and that is why the model could not describe well high p_T region in the p_T distributions. This is confirmed by the sharp increase of the ratio in the p_T region between 3 GeV/c and 4 GeV/c. The reason might be that in the ALICE data the transition from the central to the projectile fragmentation region occurs without changing the p_T distribution, while in the HIJING 1.0 code there exists some difference for the p_T distributions. We have discussed that in p–Pb interactions: (i) the charged particles with $|\eta| < 0.3$, $0.3 < \eta < 0.8$ and $0.8 < \eta < 1.3$ seem to be produced by the same dynamics, while the HIJING 1.0 code considers different mechanisms for central and fragmentation region particles; (ii) the central region is longer than $|\eta| < 0.3$, which is due to leading particle effect that results in the extension of the central area.

Acknowledgments

We would like to acknowledge the COMSATS Institute of Information Technology, Park Road, Islamabad Pakistan, which provided suitable platform and all possible facilities to perform the simulations and analysis.

References

1. ALICE Collab. (B. Abelev *et al.*), *Phys. Rev. Lett.* **110**, 082302 (2013).
2. http://aliceinfo.cern.ch/Public/Welcome.html.
3. ALICE Collab., *Int. J. Mod. Phys. A* **29**, 1430044 (2014).
4. S. Roesler *et al.*, arXiv:hep-ph/0012252.
5. ALICE Collab. (B. Abelev *et al.*), *Phys. Rev. Lett.* **110**, 032301 (2013).
6. M. Jacob *et al.*, *Phys. Rep.* **48**, 285 (1978).
7. ALICE Collab. (S. Aiola), *Nucl. Phys. A* **931**, 382 (2014).
8. J. Ranft, *Phys. Rev. D* **18**, 1491 (1978).
9. N. N. Nikolaev, *Phys. Lett. B* **70**, 95 (1977).
10. D. Drijard *et al.*, *Nucl. Phys. B* **156**, 309 (1979).
11. M. Gyulassy *et al.*, HIJING 1.0: A Monte Carlo program for parton and particle production in high energy hadronic and nuclear collisions, LBL-34246 (1997).

12. A. Bialas *et al.*, *Nucl. Phys. B* **291**, 793 (1987).
13. B. Andersson *et al.*, *Phys. Rep.* **97**, 31 (1983).
14. ALICE Collab. (M. Cannors), *Nucl. Phys. A* **931**, 1174 (2014).
15. D. Stump *et al.*, *J. High Energy Phys.* **10**, 046 (2003).
16. X.-N. Wanga *et al.*, *Nucl. Phys. A* **544**, 559c (1992).
17. M. Gyulassy *et al.*, *Phys. Rev. D* **45**, 844 (1992).