Available online at www.sciencedirect.com

ScienceDirect

Nuclear and Particle Physics Proceedings 273–275 (2016) 2752–2754

www.elsevier.com/locate/nppp

Transverse momentum distributions of baryons at LHC energies.

A.A. Bylinkin

Institute for Theoretical and Experimental Physics, Moscow, Russia

O.I. Piskounova

P.N.Lebedev Physical Institute, LPI, Moscow, Russia

Abstract

Transverse momentum spectra of protons and anti-protons from RHIC ($\sqrt{s}$ = 62 and 200 GeV) and LHC experiments ($\sqrt{s}$= 0.9 and 7 TeV) have been considered. The data are fitted in the low p_T region with the universal formula that includes the value of exponent slope as main parameter. It is seen that the slope of low p_T distributions is changing with energy. This effect impacts on the energy dependence of average transverse momenta, which behaves approximately as $s^{0.06}$ that is similar to the previously observed behavior of Λ-baryon spectra. In addition, the available data on Λ_c production from LHCb at $\sqrt{s}$ = 7 TeV were also studied. The estimated average $< p_T >$ is bigger than this value for protons proportionally to masses. The preliminary dependence of hadron average transverse momenta on their masses at LHC energy is presented.

Keywords High energy hadroproduction at LHC, transverse momentum distributions for baryons, average transverse momenta of baryons and mesons, QCD phenomenology models

1. Introduction

The transverse momentum distributions are the primary data that can be obtained in the study of hadron spectra at modern colliders. Interpretation of this distributions as in strongly theoretical perturbative QCD approaches as in various phenomenological models can shed a light upon the physics of hadroproduction processes at high energies. We apply the phenomenological approach based on the previous attempts of the description of p_T spectrum in the framework of Quark-Gluon String Model [1].

The model has described the data of previous colliders up to energies $\sqrt{s}$ = 200 GeV at the area of low p_T's that gives main contribution to the average value of transverse momenta. Recently Λ-baryon production has been studied [2] in terms of the QGSM. We suggest here to compare the latest data measured at LHC on proton production and to show the resulting average transverse momenta, $< p_T >$, as a function of c.m.s. energy, $\sqrt{s}$, of colliding protons. It seems interesting as well to compile the available data on $< p_T >$ at LHC energy for all sorts of hadrons and to present them as the function of produced hadron mass.

2. Models for the proton spectra

Let us first describe the QGSM approach, which has been applied for recent studies of Λ^0. According to this approach baryon production can be parameterized in the following way:

$$\frac{d\sigma}{p_T dp_T} = A_0 \exp[-B_0 \cdot (m_T - m_0)], \tag{1}$$

http://dx.doi.org/10.1016/j.nuclphysbps.2015.10.052

where, $m_T = \sqrt{p_T^2 + m_0^2}$, m_0 is the mass of the produced hadron and B_0 is the slope parameter for the considered energy. In the early paper [2], it was also shown that the value of the slope parameter B_0 becomes dependent on the collision energy.

Next, the widely used Tsallis parameterization [3, 4], which is known as giving rather good description of hadroproduction spectra, might be used. It can be expressed by the following formula:

$$\frac{d^2\sigma}{p_T dp_T} = \frac{A}{(1 + \frac{E_{Tkin}}{TN})^N} \qquad (2)$$

with a temperature-like parameter T and the power-like N. In this forumula (2) E_{Tkin} - is the transverse energy that can be calculated in the following way:

$$E_{Tkin} = \sqrt{p_T^2 + M^2} - M, \qquad (3)$$

with M equal to hte hadron mass.

Recently a two component model for hadroproduction has also been developed [5]. It was suggested to parameterize the large variety of charged particle spectra by a sum of an exponential (Boltzmann-like) and a power-law p_T distributions:

$$\frac{d\sigma}{p_T dp_T} = A_e \exp(-E_{Tkin}/T_e) + \frac{A}{(1 + \frac{p_T^2}{T^2 \cdot n})^n}, \qquad (4)$$

In [6, 7] it have been concluded, by the way, that spectra of baryon production can be described at high energies with only power-law term of the equation (4).

The results of these three approaches are shown in the figure 1 in the comparison with the available experimental data on proton production in pp collisions at different energies.

It should be noticed after all, that these three approaches have the exponential-like behavior in the low-p_T region and give a reasonable description of the experimental data. Therefore, for the analysis suggested in the present paper considering the mean transverse momentum $< p_T >$ of produced baryons one can use any of these models, since high-p_T particles (not measured by PHENIX and CMS) do not give a big contribution to the mean value.

If we take the experimental data, it is clearly seen in the shapes of transverse momentum dependences that the spectra of produced baryons become harder with the higher energies. Thus, it is interesting to study the variation of the mean transverse momentum $< p_T >$ with the collision energy in order to estimate the power of its growing.

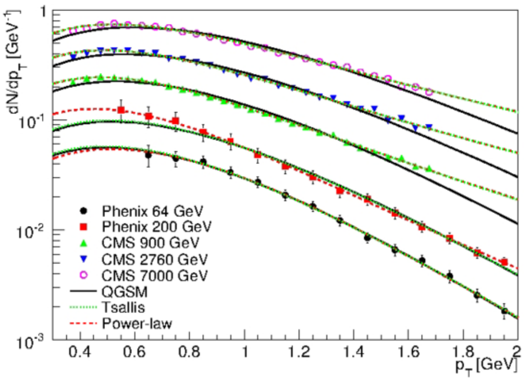

Figure 1:
Proton production spectra [9, 10] shown with arbitrary normalization together with various phenomenological approaches. Black solid line shows the QGSM (1), green pointed line - Tsallis-fit (2) and red dashed line - the power-law (4).

3. Mean transverse momenta

Let us now discuss the mean transverse momenta of produced baryons and look at its dependence on the collision energy, $\sqrt{s}$. It is reasonable also to compare the values calculated for the proton spectra with other available data on baryon production: Λ, Ξ [8] and Λ_c [11] spectra. Figure 2 shows such dependence for the available experimental data. The steep rise of the mean transverse momenta $< p_T >$ is seen as a function of energy $\sqrt{s}$. Remarkably, this rise can be parameterized by the same power-like $s^{0.055}$ behavior in case of all the species of produced baryons. These observations mean that the transverse distributions of baryons might be of the same nature and their variations are not dependent on the quark-composition of the baryon.

Remarkably, in the analysis of charged pion production [12] it was shown that the dependence of the $< p_T >$ extracted for the power-law term of (4) alone observes practically the same relation $s^{0.055}$ as a function of c.m.s. energy as in the present analysis.

Another interesting implication can be revealed from the comparison of the mean transverse momenta of various produced baryons at the certain collision energy as a function of their masses, shown in figure 3. Let us note that a linear dependence between the mean transverse momenta $< p_T >$ and the baryon mass M is observed. Remarkably, at $\sqrt{s}$ = 7 TeV the transverse momentum reaches the value of baryon mass, t.e.

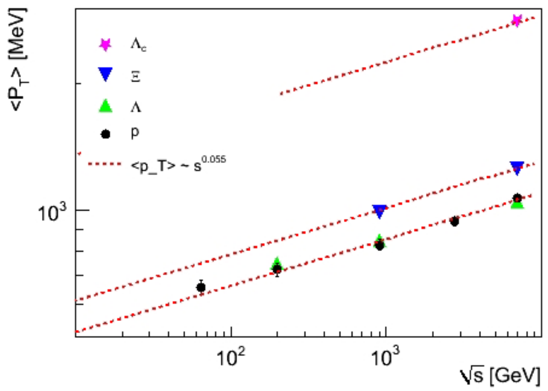

Figure 2:
Mean transverse momenta of charged baryons [9, 10, 8, 11] as a function of c.m.s energy $\sqrt{s}$. Lines show the power-law dependece $s^{0.055}$).

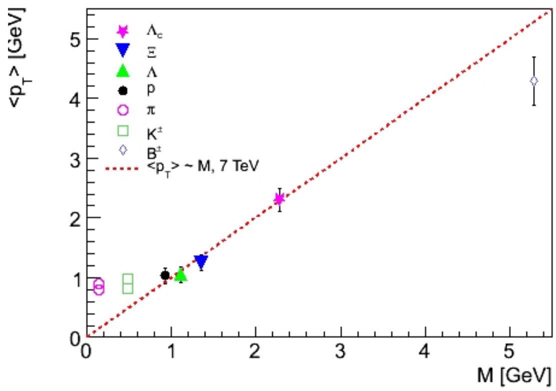

Figure 3:
Mean transverse momenta of charged baryons [10, 8, 11, 13] as a function of their mass at the energy $\sqrt{s}$ = 7 TeV. Red dashed line shows linear dependence.

$< p_T >\sim M$. Further measurements at LHC Run-II can shed light on whether or not the average transverse momentum expansion in the baryon production has a limit $< p_T >= M$.

It also might be interesting to compare $< p_T >$'s as a function of produced baryon mass M with the mass dependence of the mean transverse momenta that have been calculated from the description of charged meson production. Therefore, the points calculated for charged π, K, and B-mesons produced at the same c.m.s. energy $\sqrt{s}$ = 7 TeV are also shown in the figure 3.

4. Conclusion

Transverse momentum spectra of protons and antiprotons from RHIC ($\sqrt{s}$ = 62 and 200 GeV) and LHC experiments ($\sqrt{s}$= 0.9 and 7 TeV) have been described in the QGSM approach. This model is seems working for the up-to date collider energies, because spectra at low p_T are giving the main part of integral cross section.

The enhancement of power-low contribution into the spectra at high p_T 's causes the change of low p_T exponential slopes, so that mean transverse momenta are growing with energy. These average transverse momenta are also growing linearly if we are analyzing the spectra of different baryons in dependence on their masses. More data on heavy quark baryon (meson) spectra are wanted from LHC experiments.

Nevertheless, all this changes in hadroproduction spectra cannot be enough important to cause the knee in the primary proton spectra in cosmic rays at the energies in laboratory system correspondent to LHC energies.

5. Aknowledgements

Authors are sincerely thankful to Prof. K. Boreskov, to Prof. M.G. Ryskin and to Prof. A.A.Rostovtsev for numerous discussions and useful advises.

References

[1] A. B. Kaidalov and O. I. Piskunova, Z. Phys. C **30** (1986) 145.
[2] O. I. Piskounova, arXiv:1301.6539 [hep-ph]; O. I. Piskounova, arXiv:1405.4398 [hep-ph].
[3] C.Tsallis J.Statist.Phys 52 (1988), 479-487.
[4] C.Tsallis Braz.J.Phys. 29 (1999) 1-35.
[5] A. A. Bylinkin and A. A. Rostovtsev, Phys. Atom. Nucl. **75** (2012) 999 Yad. Fiz. **75** (2012) 1060; A. A. Bylinkin and A. A. Rostovtsev, arXiv:1008.0332 [hep-ph]; A. A. Bylinkin and A. A. Rostovtsev, Nucl. Phys. B **888** (2014) 65
[6] A. A. Bylinkin and A. A. Rostovtsev, Eur. Phys. J. C **72** (2012) 1961 [arXiv:1112.5734 [hep-ph]].
[7] A. A. Bylinkin and A. A. Rostovtsev, Eur. Phys. J. C **74** (2014) 2898 [arXiv:1203.2840 [hep-ph]].
[8] V. Khachatryan *et al.* [CMS Collaboration], JHEP **1105** (2011) 064 [arXiv:1102.4282 [hep-ex]].
[9] A. Adare *et al.* [PHENIX Collaboration], Phys. Rev. C **83** (2011) 064903 [arXiv:1102.0753 [nucl-ex]].
[10] V. Khachatryan *et al.* [CMS Collaboration], Phys. Rev. Lett. **105** (2010) 022002 [arXiv:1005.3299 [hep-ex]].
[11] RAaij *et al.* [LHCb Collaboration], Nucl. Phys. B **871** (2013) 1.
[12] A. A. Bylinkin, M. G. Ryskin, Phys. Rev. D **90** (2014) 017501 [arXiv:1404.4739 [hep-ph]].
[13] R. Aaij *et al.* [LHCb Collaboration], JHEP **1308** (2013) 117 [arXiv:1306.3663, arXiv:1306.3663 [hep-ex]].