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ON CORRELATORS FOR HIGH MULTIPLICITY EVENTS

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We present the results of the study of the energy correlators $K_2(n)$, $K_3(n)$ and their ratio $R_3(n)$ in dependence on the hadron multiplicity at the LHC. The PYTHIA generator has been used. The PYTHIA predicts that $R_3(n)$ is not dependent from multiplicity. The $K_2(n)$, $K_3(n)$ and $R_3(n)$ ratio can be studied at ATLAS.

The investigation of the very high multiplicity (VHM) events is a very important task for high energy physics [1]. The purpose of this study is to calculate the energy correlators $K_2(n,s)$, $K_3(n,s)$ and the ratio $R_3(n,s) = |K_3(n,s)|^{2/3}/|K_2(n,s)|$ as a function of hadron multiplicity at ATLAS [2]. The theory predicts that the $R_3(n,s)$ ratio has tendency to equilibrium for the VHM events [1].

We will call the very high multiplicity events the ones for which the condition $n(s) \gg \bar{n}(s)$ is fulfilled, where n is the number of hadrons in an event, $\bar{n}$ is the mean multiplicity of hadrons, and $\sqrt{s}$ is the c.m.s. energy. Figure 1 shows the distribution of $\langle n\rangle P(n)$, where $P(n) = \sigma_n/\sigma_{\rm tot}$, as a function of the secondary particles multiplicity represented in the units of the mean multiplicity. The points are the results of the E735 (FNAL) experiment at 1.8 TeV with $\langle n\rangle = 44$ [3]. The A region corresponds to the multiperipheral kinematics where $n \sim \bar{n}(s)$. The B region is the thermodynamical region corresponding to the approximation of the noninteracting gas where $n \to n_{\max}(s)$. The maximum possible number of hadrons is equal to $n_{\max}(s) = \sqrt{s}/m_\pi$, where m_π is the pion mass. The C region corresponds to the VHM events. The cross section of such a process is significantly smaller than $10^{-7}\sigma_{\rm tot}$ at 2 TeV. The thermodynamical description of the final state events in the high energy physics is possible at the fulfillment of the condition of Bogolyubov's principle of vanishing the correlators [4]: $R_l(n,s) = |K_l(n,s)|^{2/l}/|K_2(n,s)| \ll \ll 1$, where $l = 3, 4, \ldots$, $K_l(n,s)$ is the l-particle energy correlator for the n-particle event. Two and three particle correlators are defined as

$$K_2(n,s) = \langle\langle([\varepsilon_1;n,s] - \langle\varepsilon;n,s\rangle)([\varepsilon_2;n,s] - \langle\varepsilon;n,s\rangle)\rangle\rangle,$$

$$K_3(n,s) = \langle\langle([\varepsilon_1;n,s] - \langle\varepsilon;n,s\rangle)([\varepsilon_2;n,s] - \langle\varepsilon;n,s\rangle)([\varepsilon_3;n,s] - \langle\varepsilon;n,s\rangle)\rangle\rangle,$$

where ε_i is energy of i-particle and $\langle\varepsilon;n,s\rangle$ is the mean energy.

The PYTHIA has been used for this investigation [5]. For the simulation of the trigger events the hard processes have been used : $q_iq_j \to q_iq_j$, $q_i\bar{q}_i \to q_j\bar{q}_j$, $q_i\bar{q}_i \to gg$, $q_ig \to q_ig$, $gg \to q_i\bar{q}_i$, $gg \to gg$, where q are quarks and g are gluons. The main background for the VHM events at the LHC will be the soft processes. There will be ≈23 pp-interaction in the 25 ns of one interaction of bunches at the full LHC luminosity (10^{34} cm^{-2} s^{-1}). The time of the data collection will be 125 ns, for example for the electromagnetic calorimeter. Therefore, there will be written about 115 soft background events, which are called "pile-up", simultaneously with the trigger event. The inelastic processes have been used for the simulation of pile-up events.

Figure 2 (left) shows the results of calculations of the average energy and the correlators $\sqrt{K_2(n)}$, $\sqrt[3]{K_3(n)}$ in the GeV scale as a function of the hadrons multiplicity at 14 TeV. The values of $\sqrt{K_2(n)}$ have signs of $K_2(n)$. As can be seen the $K_2(n)$ and $K_3(n)$ tend to zero at $n_h \to 500$. The dependence of the $R_3(n)$ ratio on n_h is given in Fig. 2 (right). The PYTHIA predictions are given for the A region shown in Fig. 1. The average value of the $R_3(n)$ ratio does not depend on the hadron multiplicity and equals to 1.23. There is no tendency to equilibrium in this region. This can be understood as the PYTHIA is based on the multiperipheral model [1].

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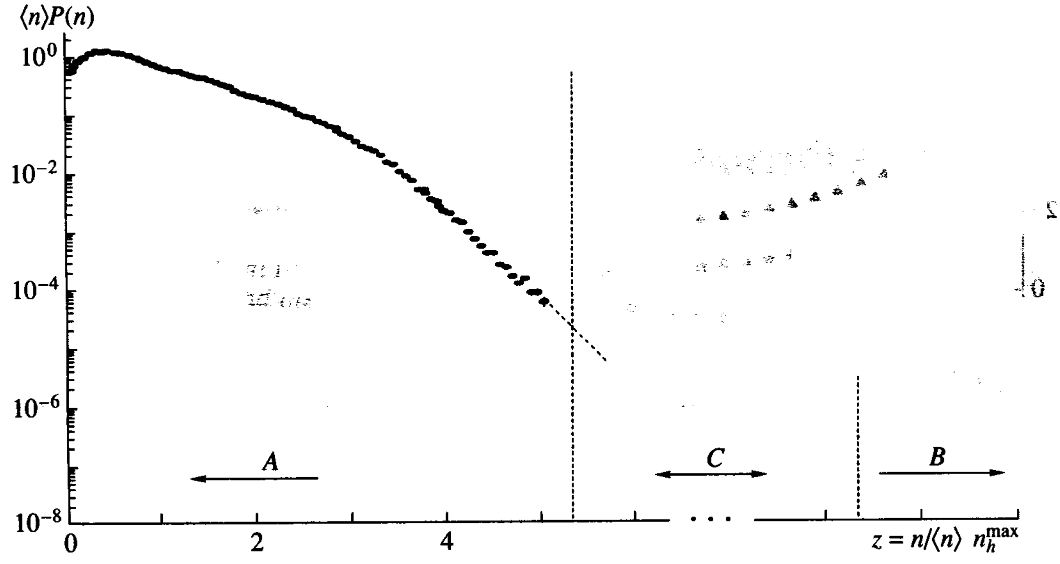

Fig. 1. Multiplicity distribution $\langle n\rangle P(n)$ in the KNO scaling form at 1.8 TeV.

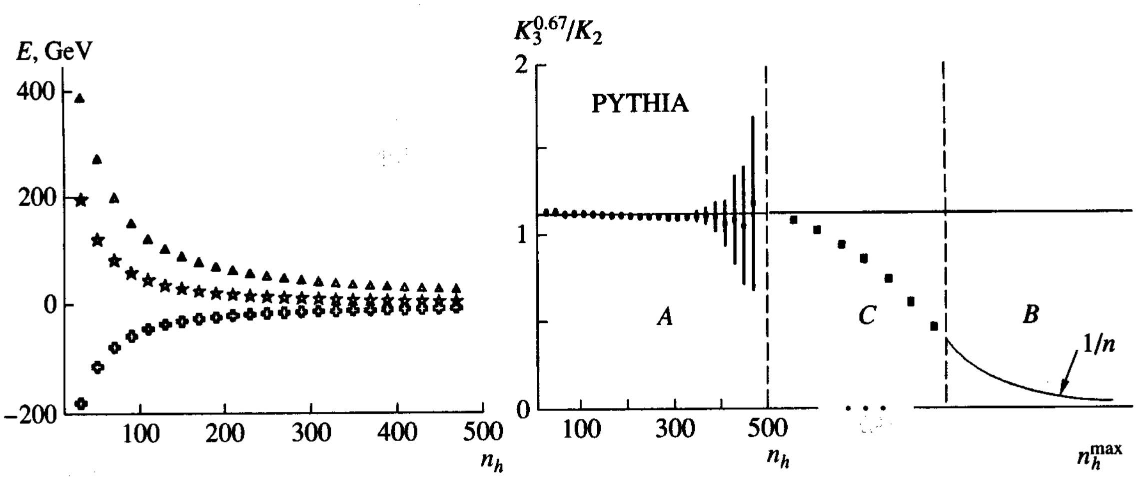

Fig. 2. The average energy (triangulars), the correlators $\sqrt{K_2(n)}$ (crosses), $\sqrt[3]{K_3(n)}$ (stars) on the left side and the $R_3(n)$ ratio (black circles) on the right side as a function of the multiplicity at 14 TeV. The black squares on the right side are the theory supposition for very high multiplicity region.

Harder events have been selected taking into account the experimental trigger conditions. The requirement on the transverse parton momentum $p_t^q \geq p_t^{q,\min}$ has been used, where $p_t^{q,\min} \geq 500$ GeV. This has led to the multiplicity increasing to $\approx$800. However, the tendency to equilibrium is not observed although the $R_3(n)$ ratio decreases to 1.1 for $p_t^q \geq$ ≥ 2000 GeV.

The investigation of behaviour of the VHM events is planned out on the ATLAS (LHC) [2] by using its calorimeter [6]. This calorimeter has beautiful energy resolution $\sigma/E = (42\%/\sqrt{E} + 1.8\%) \oplus 1.8/E$ in the barrel region [7]. Only charged particles with the transverse momentum more than $\approx$1.5–2 GeV reach the calorimeter because of the strong magnetic field (2 T) of the solenoidal magnet. Therefore, only hadrons with $p_t \geq 2$ GeV in the region $|\eta| \leq 2.5$ have been selected. The physics events satisfied the condition $p_t^q \geq p_t^{q,\min}$ for partons have been simulated for the decreasing of the background pile-up events. The obtained distributions of the correlators $K_2(n)$ and $K_3(n)$ as a function of multiplicity taking into account the pile-up are similar of the ones shown in Fig. 2 (left). As a result of using the cuts $p_t \geq 2$ GeV and $|\eta| \leq 2.5$ the maximum multiplicity decreases to $\approx$300 hadrons per event. As before, there is no tendency to equilibrium for the $R_3(n)$ ratio, $R_3(n) =$ $= 1.21$ for $p_t^q \geq 2000$ GeV. It is important to note, that

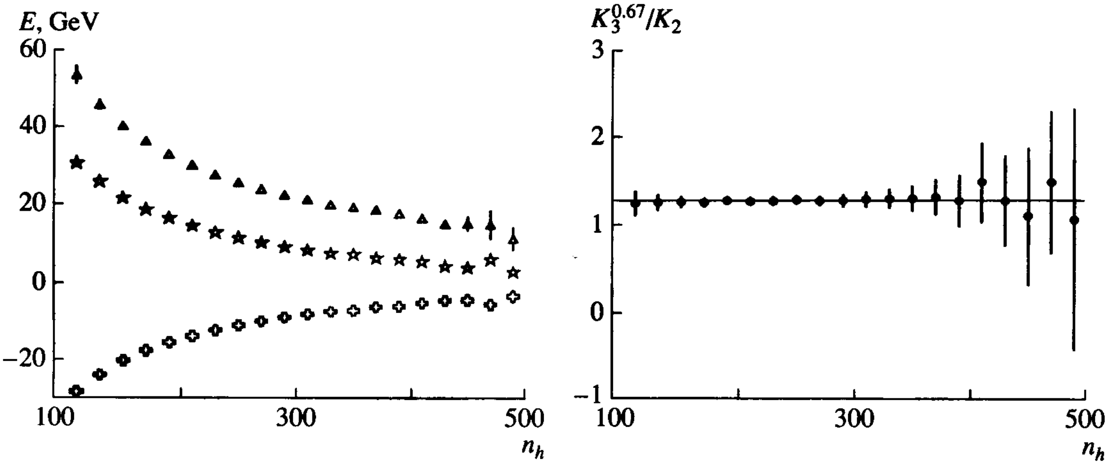

Fig. 3. The average energy (triangulars), the correlators $\sqrt{K_2(n)}$ (crosses), $\sqrt[3]{K_3(n)}$ (stars) on the left side and the $R_3(n)$ ratio (black circles) on the right side for energies in calorimeter towers as a function of the multiplicity at 14 TeV.

it is not necessary to take into account the detector acceptance because the correlations are small and equal for all particles in the VHM region.

It is assumed to use the calorimetric information for the determining of the energy correlators in the ATLAS experiment. There is the projective geometry for calorimeter towers. The initial transverse dimension of a hadronic calorimeter tower is equal to $\eta \times \phi = 0.1 \times 0.1$. The hadronic shower size is larger than one calorimeter tower size [8]. Signals from each tower have been used in the calculations separately. The ATLFAST programme [9] has been used for simulation.

Figure 3 (left) shows the dependence of the average energy and the energy correlators $\sqrt{K_2(n)}$, $\sqrt[3]{K_3(n)}$ for energy in calorimeter towers as a function of multiplicity of worked towers and using the cuts $p_t \geq 1.5$ GeV and $|\eta| \leq 3.5$. The values of the correlators lead to 5 GeV for $n_h \to 500$. The obtained distributions are also similar to the ones shown in Fig. 2 (left). The dependence of the $R_3(n)$ ratio as a function of worked towers is shown in Fig. 3 (right). There is no tendency to the decreasing of the $R_3(n)$ ratio at the n_h increasing. The value of this ratio is equal to 1.28 and coincides with the above obtained results (Fig. 2 (right)).

The results of the study of the energy correlators $K_2(n)$, $K_3(n)$ and their ratio $R_3(n)$ as a function of the hadron multiplicity at 14 TeV are represented. It is shown that the value of the ratio does not depend on multiplicity and it is slightly more than a unit. Thus, PYTHIA does not predict tendency to equilibrium, $R_3(n) \ll 1$, at high multiplicity. It is shown that the pile-up background and the changing of the particle energy to the registered ones in the ATLAS calorimeter towers have a negligible effect on the $R_3(n)$.

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