The midrapidity inclusive densities of different secondaries are calculated in the framework of the Quark–Gluon String Model. The transfer of baryon number in rapidity space due to the gluon string junction propagation leads to a significant effect on the net baryon production. The numerical results are in reasonable agreement with RHIC experimental data.

The Quark–Gluon String Model (QGSM) and the Dual Parton Model are based on the Dual Topological Unitarization and describe quantitatively many features of high energy production processes. The model parameters were fixed by comparison of the theoretical results with experimental data. In the present paper we compare the QGSM predictions with the experimental data on midrapidity yields $dn/dy$ ($|y| < 0.5$) for different secondaries produced in $pp$ collisions at RHIC energy ($\sqrt{s} = 200$ GeV).

High energy interactions are considered in the QGSM as taking place via the exchange of one or several Pomerons, all elastic and inelastic processes resulting from cutting through or between Pomerons. Inclusive spectra of hadrons are related to the corresponding fragmentation functions of quarks and diquarks, which are constructed using the Reggeon counting rules.

At very high energies and in the midrapidity region all fragmentation functions, which are usually written as $G^h_q(z) = a_h (1 - z)^\beta$ ($z$ is the fraction of a quark or diquark momentum carried out by the secondary hadron), are constants

$$G^h_q(z) = a_h ,$$

and they consistently lead to

$$\frac{dn}{dy} \sim g_h \cdot \left(\frac{s}{s_0}\right)^{\alpha_P(0)-1} \sim a_h \cdot \left(\frac{s}{s_0}\right)^{\alpha_P(0)-1} .$$
This corresponds to the one-Reggeon exchange diagram in Fig. 1a, which is the only diagram contributing to the inclusive density in the central region (AGK theorem). The main contribution at high energies comes from the case when both Reggeons in Fig. 1a are Pomerons. The intercept of the supercritical Pomeron $\alpha_P(0) = 1 + \Delta$, $\Delta = 0.139$, is used in the numerical calculations.

The diagram in Fig. 1a predicts equal inclusive yields for each particle and its antiparticle at very high energies. That is true for meson production, but at RHIC energies a numerically small difference in the positive and negative meson productions can exist. In the string models baryons are considered as configurations consisting of three connected strings (related to three valence quarks) called string junction (SJ)\(^{11,12}\). In the processes of secondary production the SJ diffusion in rapidity space leads to significant differences in the yields of baryons and antibaryons in the midrapidity region even at very high energies\(^{6,13,14,15,16,17,18,19,20}\).

There exist\(^{14}\) three different possibilities to obtain the net baryon charge. The first one is the fragmentation of the diquark giving rise to a leading baryon. A second possibility is to produce a leading meson in the first break-up of the string and a baryon in the subsequent break-up\(^{9,21}\). In these two cases the baryon number transfer is possible only for short distances in rapidity. In the third case, which takes place with rather small relative probability, both initial valence quarks recombine with sea antiquarks into mesons and a secondary baryon is formed by the SJ together with three sea quarks.

An example is shown in Fig. 1b where both valence quarks of the incident diquark annihilate with sea antiquarks into mesons $M$ and the baryon $B$ is produced rather far from the beam in rapidity space. The third valence quark of the incident baryon (not shown in Fig. 1b) independently fragments into a meson system. This process can be described by the Reggeon diagram shown in Fig. 1c which results in some corrections to the spectra of secondary baryons. As $\alpha_{SJ}$ is close to unity (we use $\alpha_{SJ} = 0.9$\(^{15}\)), the difference of the baryon and antibaryon yields in midrapidity region will vanish very slowly when the energy increases.

The normalization constants in Eq. (2) for pion production, $a_\pi$, kaon production, $a_K$, $B\bar{B}$ pair production, $a_{\bar{N}}$, and baryon production due to SJ diffusion, $a_N$, were determined\(^{1,2,5}\) from the experimental data at fixed target energies. Their values are:

$$a_\pi = 0.67, \ a_K = 0.21, \ a_{\bar{N}} = 0.18, \ a_N = 1.29.$$  (3)

The values of these parameters have not been modified for the present calculations, while the corresponding values for hyperons have been calculated by simple quark combinatorics\(^{22,23}\).
Table 1: The QGSM results for midrapidity yields $dn/dy$ ($|y| < 0.5$) for different secondaries at RHIC and LHC energies. The results for $\varepsilon = 0.024$ are presented only when different from the case $\varepsilon = 0$.

| Particle | RHIC ($\sqrt{s} = 200. \text{ GeV}$) | LHC ($\sqrt{s} = 14. \text{ TeV}$) | STAR Collaboration |
|----------|---------------------------------|---------------------------------|-------------------|
|          | $\varepsilon = 0$ | $\varepsilon = 0.024$ | $\varepsilon = 0$ | $\varepsilon = 0.024$ |
| $\pi^+$ | 1.27 | 2.54 |
| $\pi^-$ | 1.25 | 2.54 |
| $K^+$ | 0.13 | 0.14 $\pm$ 0.01 | 0.25 |
| $K^-$ | 0.12 | 0.14 $\pm$ 0.01 | 0.25 |
| $p$ | 0.0755 | 0.0861 | 0.177 | 0.184 |
| $\bar{p}$ | 0.0707 | 0.177 |
| $\Lambda$ | 0.0328 | 0.0381 | 0.0385 $\pm$ 0.0035 | 0.087 | 0.0906 |
| $\bar{\Lambda}$ | 0.0304 | 0.0351 $\pm$ 0.0032 | 0.0867 |
| $\Xi^-$ | 0.00306 | 0.00359 | 0.0026 $\pm$ 0.0009 | 0.0108 | 0.0112 |
| $\bar{\Xi}^+$ | 0.00298 | 0.0029 $\pm$ 0.001 | 0.0108 |
| $\Omega^-$ | 0.00020 | 0.00025 | * | 0.000902 | 0.000934 |
| $\bar{\Omega}^+$ | 0.00020 | * | 0.000902 |

$^{*}dn/dy(\Omega^- + \bar{\Omega}^+) = 0.00034 \pm 0.00019$

For sea quarks we have

$$p : n : \Lambda + \Sigma : \Xi^0 : \Xi^- : \Omega = 4L^3 : 4L^3 : 12L^2S : 3LS^2 : 3LS^2 : S^3.$$  \hspace{1cm} (4)

The strangeness suppression factor is given by the ratio $\lambda = S/L$, and $2L + S = 1$. Usually, in soft processes $\lambda$ is assumed to have a value $\lambda = 0.2-0.35$. Inside this range $\lambda$ should be considered as a free parameter. In the numerical calculation we have used the value $\lambda = S/L = 0.25$ that leads to the best agreement with the data\(^7\).

The calculated inclusive densities of different secondaries at RHIC, $\sqrt{s} = 200. \text{ GeV}$, and LHC, $\sqrt{s} = 14. \text{ TeV}$, energies are presented in Table 1, where one can see that the agreement of the QGSM calculations with RHIC experimental data\(^7\) is reasonably good.

In Fig. 2 we reproduce the experimental data on ratios of yields of different secondaries\(^7\) together with our calculations. Agreement is good except for the point of the $\bar{p}/\pi^-$ ratio. From the comparison of our results with experimental data presented in Table 1 and Fig. 2 we can conclude that the universal parameter $\lambda = 0.25$ describes the ratios of $\Lambda/p$, $\Xi/\Lambda$, and $\Omega/\Xi$ production in a reasonable way.

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Figure 2: Ratios of different secondaries produced in midrapidity region in \( pp \) collisions at \( \sqrt{s} = 200 \text{ GeV} \). Short horizontal solid lines show the results of the QGSM calculations.

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