The transverse mass spectra of Ω hyperons measured in Pb+Pb collisions at the SPS have been described by the STAR Collaboration. These data allow to test our model in the new energy regime. They also give a unique opportunity to extract parameters of the QGP hadronization at RHIC energies and consequently predict spectra of J/ψ and ψ′ mesons.

Within a hydrodynamical approach of the QGP hadronization the transverse mass spectrum of i-th hadron in the central rapidity region can be written as (see, e.g., Ref. [19]):

$$\frac{dN_i}{m_T dN_T dy} \bigg|_{y=0} = \frac{d_i \gamma_i^m}{\pi} \tau_H \frac{R_H^2}{\lambda_H} \int_0^1 \xi \, d\xi \, K_1 \left( \frac{m_T \cosh y_T \xi}{R_H} \right) I_0 \left( \frac{p_T \sinh y_T \xi}{R_H} \right),$$

where y is the particle longitudinal rapidity and y_T(ξ) = tanh⁻¹(v_T) is the fluid transverse rapidity, R_H and τ_H are, respectively, the transverse system size and proper time at the hadronization (i.e., at the boundary between the mixed phase and hadron matter), ξ = r/R_H is a relative transverse coordinate. The particle degeneracy and fugacity are denoted as d_i and λ_i, respectively, m_T = √p_T^2 + m_i^2 is the hadron transverse mass, K_1 and I_0 are the modified Bessel functions. Parameter γ_i in Eq. (1) (γ_S [20] for i = ρ, Ω and γ_C [14,15] for i = J/ψ, ψ′) describes a possible deviation of strange and charm hadrons from complete chemical equilibrium (n_i = 2 for φ, J/ψ, ψ′ and n_i = 3 for Ω).

The spectrum (1) is obtained under the assumption that the hydrodynamic expansion is longitudinally boost invariant and that the freeze–out occurs at constant longitudinal proper time τ = √t^2 - z^2 (t is the time and z is the longitudinal coordinate), i.e. the freeze–out time t is independent of the transverse coordinate r. In order to complete Eq. (1) the functional form of the transverse rapidity distribution of hadronizing matter y_T(ξ) has to be given. A linear flow profile, y_T(ξ) = y_T^{max} · ξ, used in our model is justified by the numerical calculations of Ref. [9].

Thus, in our model, the QGP hadronization is described by the following parameters: temperature T_H, “volume” τ_H R_H^2, maximum flow rapidity y_T^{max}, fugacities λ_i, and saturation factors γ_i. Note that the ρ, J/ψ, ψ′ have no conserved charges and λ_i = 1 for these particles. We use the fixed values of the parameters T_H = 170 MeV, γ_S = 1.0, λ_Ω = 1/λ_Ω = 1.09 (note that λ_i = exp[(μ_B - 3μ_S)/T], where μ_B and μ_S are, respectively, baryon and strange chemical potentials). These (average) values of the chemical freeze–out parameters have been found in the hadron gas analysis [4] of the full
set of the midrapidity particle number ratios measured in central Au+Au collisions at $\sqrt{s_{NN}} = 130$ GeV. The fit to the $m_T$-spectra of $\Omega^\pm$ hyperons [17] and $\phi$ mesons [18] measured in central (14% for $\Omega^\pm$ and 11% for $\phi$) Au+Au collisions at $\sqrt{s_{NN}} = 130$ GeV is shown in Fig. 1. The fit results are: $y_T^{\Omega_{\pm}} = 0.74 \pm 0.09$, $\tau_H R_H^{2\Omega_{\pm}} = 275 \pm 70$ fm$/c$ and $\chi^2/ndf \cong 0.46$. In the calculation of errors of the two free parameters of the model the uncertainties of $T_H$ ($\pm 5$ MeV), $\gamma_S$ ($\pm 0.05$) and $\lambda_{\Omega^\pm}$ ($\pm 0.06$) were taken into account.

Note that in Refs. [10–12] an additional factor $m_T^{1/2}$ was present in the r.h.s. of Eq. (2). It led to smaller values of $T^*$ when fitting the same spectrum. The $m_T$–spectrum (1) may, however, deviate significantly from a purely exponential one and its shape depends on the magnitude of the transverse flow and the mass of the particle. The normalization factors $C$ and the inverse slope parameters $T^*$ in different intervals of $m_T - m$ can be found from the $\phi$, $\Omega$, $J/\psi$ and $\psi'$ spectra given by Eq. (1) using the maximum likelihood method. The average values of $T^*$ for the $m_T$ domains of “low-$p_T$” ($m_T - m < 0.6$ GeV) and “high-$p_T$” (0.6 GeV < $m_T - m < 1.6$ GeV), discussed in Refs. [9,12], are shown in Fig. 2. The values of $T^*$ obtained by fitting the $\Omega^\pm$, $J/\psi$ and $\psi'$ data in Pb+Pb collisions at 158 A-GeV (see Ref. [11]) are also shown for comparison. The observed increase of $T^*$ with increase of the hadron mass is much stronger at RHIC than at SPS energies. It is caused by larger transverse flow velocity of hadronizing QGP at RHIC ($\bar{v}_T \cong 0.44$) than at SPS ($\bar{v}_T \cong 0.19$). The increase of $T^*$ is much more pronounced in “low-$p_T$” region than in “high-$p_T$” one. In our model the $m_T$–spectra of charmonia are extraordinary affected by the stronger transverse flow at RHIC due to enormous masses of these hadrons. Thus, the data on $J/\psi$ and $\psi'$ production in Au+Au collisions, soon to be obtained at RHIC, should allow to test the hypothesis of their formation at the QGP hadronization.

![FIG. 1. The hadron transverse mass spectra in Au+Au collisions at $\sqrt{s_{NN}} = 130$ GeV are shown. The points indicate experimental data for the $\Omega$ [17] and $\phi$ [18] measured by STAR. The model results are shown by full lines.

We note here that at present there exists an uncertainty in the estimates of the $\gamma_S$ factor, therefore, the predictions concerning charmonia multiplicities in Au+Au collisions at RHIC within statistical approaches significantly vary and their discussion goes beyond the scope of this letter.

![FIG. 2. The values of the inverse slope parameters $T^*$ for two different $(0.6$ GeV/$c < m_T < 4.6$ GeV) in Au+Au collisions at $\sqrt{s_{NN}} = 130$ GeV are shown. The points indicate experimental data for the $\Omega$ [17] and $\phi$ [18] measured by STAR. The model results are shown by full lines. The fit results are: $y_T^{\Omega_{\pm}} = 0.74$, $\tau_H R_H^{2\Omega_{\pm}} = 275 \pm 70$ fm$/c$ and $\chi^2/ndf \cong 0.46$. For comparison, the values of $T^*$ obtained by fitting the $\Omega^\pm$, $J/\psi$ and $\psi'$ data in Pb+Pb collisions at 158 A-GeV (see Ref. [11]) are also shown for comparison. The observed increase of $T^*$ with increase of the hadron mass is much stronger at RHIC than at SPS energies. It is caused by larger transverse flow velocity of hadronizing QGP at RHIC ($\bar{v}_T \cong 0.44$) than at SPS ($\bar{v}_T \cong 0.19$). The increase of $T^*$ is much more pronounced in “low-$p_T$” region than in “high-$p_T$” one. In our model the $m_T$–spectra of charmonia are extraordinary affected by the stronger transverse flow at RHIC due to enormous masses of these hadrons. Thus, the data on $J/\psi$ and $\psi'$ production in Au+Au collisions, soon to be obtained at RHIC, should allow to test the hypothesis of their formation at the QGP hadronization.

The “volume parameter” $\tau_H R_H^2 \equiv A(T_H)$ extracted from the fit to the $\Omega$ and $\phi$ spectra defines the line $\tau_H = A(T_H) \cdot R_H^{-2}$ in the $R_H^{-2}$–$\tau_H$ plane. The allowed region in the $R_H^{-2}$–$\tau_H$ plane can be estimated by varying the temperature parameter within its limits, $T_H = 165$ MeV and $T_H = 175$ MeV. The resulting lines are shown in Fig. 3. The transverse radius $R_H = 5 \div 7$ fm and the proper time $\tau_H = 8 \div 11$ fm$/c$ at the QGP hadronization can be estimated from the hydrodynamical calculations of [9] for central Au+Au collisions at $\sqrt{s_{NN}} = 130$ GeV (see Fig. 3 in Ref. [9]). These model boundaries and their intersection with the $R_H^{-2}$–$\tau_H$ region found in our analysis

![FIG. 3. The “volume parameter” $\tau_H R_H^2 \equiv A(T_H)$ extracted from the fit to the $\Omega$ and $\phi$ spectra defines the line $\tau_H = A(T_H) \cdot R_H^{-2}$ in the $R_H^{-2}$–$\tau_H$ plane. The allowed region in the $R_H^{-2}$–$\tau_H$ plane can be estimated by varying the temperature parameter within its limits, $T_H = 165$ MeV and $T_H = 175$ MeV. The resulting lines are shown in Fig. 3. The transverse radius $R_H = 5 \div 7$ fm and the proper time $\tau_H = 8 \div 11$ fm$/c$ at the QGP hadronization can be estimated from the hydrodynamical calculations of [9] for central Au+Au collisions at $\sqrt{s_{NN}} = 130$ GeV (see Fig. 3 in Ref. [9]). These model boundaries and their intersection with the $R_H^{-2}$–$\tau_H$ region found in our analysis.
FIG. 3. The lines \( \tau_{H} = A(T_{H}) \cdot R_{H}^{-2} \) of constant “volume parameter” \( A(T_{H}) \) are shown: \( T_{H} = 165 \text{ MeV} \) and \( T_{H} = 175 \text{ MeV} \) correspond to the lower and upper solid lines, respectively. The dashed area is the intersection of the \( R_{H}-\tau_{H} \) region between the \( T_{H} = 165 \text{ MeV} \) and \( T_{H} = 175 \text{ MeV} \) lines with the region of \( R_{H} = 5 \div 7 \text{ fm} \) and \( \tau_{H} = 8 \div 11 \text{ fm/c} \) estimated from Ref. [9].

Table I. The values of inverse slope parameters \( T_{*} \) for (anti)protons and (anti)lambdas in Au+Au collisions at \( \sqrt{s_{NN}} = 130 \text{ GeV} \) are presented. The experimental values are taken as the average ones over the STAR and PHENIX results (a difference in the results for particle and its anti-particle is small).

<table>
<thead>
<tr>
<th></th>
<th>( T_{low-p_T} ) (MeV)</th>
<th>( T_{high-p_T} ) (MeV)</th>
<th>Refs.</th>
</tr>
</thead>
<tbody>
<tr>
<td>DATA ( p, \bar{p} )</td>
<td>455 ± 105</td>
<td>290 ± 40</td>
<td>[23,25]</td>
</tr>
<tr>
<td>Hydro+RQMD</td>
<td>480</td>
<td>300</td>
<td>[9]</td>
</tr>
<tr>
<td>Single freeze-out</td>
<td>315</td>
<td>310</td>
<td></td>
</tr>
<tr>
<td>DATA ( \Lambda, \bar{\Lambda} )</td>
<td>505 ± 60</td>
<td>320 ± 30</td>
<td>[21,22]</td>
</tr>
<tr>
<td>Hydro+RQMD</td>
<td>440</td>
<td>310</td>
<td>[9]</td>
</tr>
<tr>
<td>Single freeze-out</td>
<td>360</td>
<td>330</td>
<td>[22]</td>
</tr>
</tbody>
</table>

Within our approach the \( m_T \)-spectra of \( \phi, \Omega, J/\psi, \psi' \) are assumed to be frozen at the space-time hyper-surface where the hadron phase starts. This assumption is justified by the small hadronic cross sections and large masses of these particles (in addition, the \( m_T \)-spectra of these hadrons are almost not affected by the resonance feeding). However, the \( m_T \)-spectra of many other hadrons are shown in Fig. 3.
atic) error was estimated to be a half of the difference between them.

Despite the large uncertainties, the data seem to favor the “QGP hydro + hadron cascade” model over the single freeze–out model. Additional data in the low-$p_T$ region and their theoretical analysis would be helpful to clarify presence of the hadron cascade stage and its influence on $T^*_{\text{low}-p_T}$ of (anti)protons and (anti)lambdas.

The results on $m_T$–spectra of charmonia in central Au+Au collisions at the RHIC energies are expected to be available soon. They should allow to test a statistical approach to the charmonia production at the QGP hadronization in high energy nuclear collisions. In particular, within this approach, we predict a strong (a few times) increase of the inverse slope parameter $T^*$ of the charmonia $m_T$–spectra at RHIC in comparison with that at SPS. The higher is the energy the larger inverse slope is expected due to increasing transverse flow of hadronizing QGP. Thus, at $\sqrt{s_{NN}} = 200$ GeV the increase of $T^*$ should become even more pronounced than at $\sqrt{s_{NN}} = 130$ GeV. Due to strong sensitivity of the charmonia spectra to the hadronization temperature and transverse flow velocity, their analysis should significantly improve our estimate of these parameters.

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