ABSTRACT: Hadron multiplicities — especially for strange particles — are calculated in the framework of the algebraic coalescence rehadronization model (ALCOR), which counts for redistribution of quarks into hadrons for relativistic heavy-ion collisions. The influence of Bjorken flow on the final hadronic composition are incorporated in the model. A comparison is made with the CERN SPS NA35 $S+S$ and $p+p$ experiments. The analysis of these experiments with ALCOR shows a strangeness enhancement for $S+S$ collisions and a possible formation of a sort of semi-deconfined state of the matter. Predictions for Pb+Pb collisions (NA49) are also presented.

Introduction

The strongly dynamical process of rehadronization from a thermal quark-gluon plasma or from any other type of prehadronic quark matter into the finally observed hadrons in a high-energy heavy-ion collision cannot be described in the framework of perturbative parton dynamics alone [1], [2] nor by using rate equations as in quarko- and hadrochemistry [3], [4]. Not only does the strength of the interaction leading to valence quark confinement into hadrons in the final state of this process rule out any expansion in terms of the QCD coupling constant $g^2/4\pi$, but also the fact that there are only color singlet hadrons renders a description using rate equations derived in the infinite volume limit to be unreliable. In this case there would always be a small fraction of free quarks present after a finite time has elapsed unless the hadronization cross section diverges after a finite time. In that case the use of rate equations is also unjustified.

The idea of redistributing all the quarks and antiquarks present in the quark matter at the latest stage of its evolution between color singlet final
states (hadrons) cures these two problems at the level of a phenomenological model. It describes the rehadronization as a sudden process. This assumption unfortunately cannot be checked in the framework of a quark number redistribution model. For this purpose a comparison with microscopic dynamical calculations will be necessary. If one then compares the predictions of such a simple redistribution of different quark flavors with experimental findings, especially with strange or charm to light hadron ratios, one may then have a basis for judging whether nontrivial collective phenomena at the quark level must be considered in these experiments.

In applying rehadronization models one has to supply as input the number of light and heavy valence quarks and antiquarks, all of which will be hadronized. This number can be obtained from theoretical models (e.g. string model [5], color rope model [6], thermodynamical models, etc.) or from a part of the observed data. In the latter case comparison of the predictions of the model with further experimental data may be used to prove or disprove the basic assumptions of that model. Here, applying the ALgebraic COalescence Rehadronization model, ALCOR [7], we shall follow the latter possibility.

The ALCOR model

The starting point of the ALCOR model is a state in which only those quarks and antiquarks which form the final hadrons are present in a local thermal equilibrium. We also assume that they are all present, so their number already account for some of the gluons fragmented earlier. This assumption is easily acceptable for the heavy quarks for which any meeting with their antiparticle is improbable due to their small specific density. In the case of light constituent quarks (counted after gluon fragmentation) the approximate entropy conservation during the rehadronization process leads to the conservation of their numbers. This picture was first formulated in the framework of the algebraic recombination model [8]. In this model the number of a given type of hadron produced is proportional to the product of the numbers of their constituting quarks. This picture was developed further by the introduction of gluon fragmentation [9]. We shall denote the number of produced $u, d, s$ quark pairs, just before the hadronization, by $N_{u,\text{pair}}, N_{d,\text{pair}}$ and $N_{s,\text{pair}}$, respectively. The strangeness production factor, $g_s$ is defined as $g_s = N_{s,\text{pair}} / (N_{u,\text{pair}} + N_{d,\text{pair}})$. (The definition of factor $f_s$ in Ref. [7] was different from that of $g_s$.)

In the ALCOR model we generalize this further by introducing the coalescence factors $C_M(i, j)$, $C_B(i, j, k)$ for each hadron type separately. In order to ensure that all quarks are included in hadrons in the final state we also introduce normalization factors $b(i)$ associated with each quark flavor when counting the quarks and antiquarks in hadrons. Furthermore, a spin degeneracy factor, $D^{(h)} = 2S_h + 1$, is also included. Here we shall consider the
simplest hadron multiplets conserving isospin symmetry. These are the spin 0 and spin 1 meson octets together with the \( \sigma \) and \( \omega \) isospin singlet meson states. The spin 1/2 octet and spin 3/2 decouplet baryons and anti-baryons are also included. Thus the numbers of a given sort of baryon or antibaryon, consisting of quarks with flavors \( i, j, k \), are given as

\[
N_{B}^{(h)}(i, j, k) = D^{(h)} C_{B}(i, j, k) b(i) b(j) b(k) N_{Q}(i) N_{Q}(j) N_{Q}(k),
\]

(1)

and the number of a given sort of meson is given as

\[
N_{M}^{(h)}(i, j) = D^{(h)} C_{M}(i, j) b(i) \bar{b}(j) N_{Q}(i) N_{Q}(j).
\]

(2)

Here \( N_{Q}(i) \) and \( N_{\bar{Q}}(i) \) are the number of quarks and antiquarks of type \( i \), respectively.

These constraints lead finally to the following system of equations (one for each quark and each antiquark flavor)

\[
N_{Q}(i) = \sum_{h} \sum_{j=1}^{N_{f}} D^{(h)} C_{M}(i, j) b(i) \bar{b}(j) N_{Q}(i) N_{\bar{Q}}(j)
\]

\[
+ \sum_{h} \sum_{j=1}^{N_{f}} \sum_{k=j}^{N_{f}} (1 + \delta_{i,j} + \delta_{i,k}) D^{(h)} C_{B}(i, j, k) b(i) b(j) b(k) N_{Q}(i) N_{Q}(j) N_{Q}(k),
\]

(4)

\[
N_{\bar{Q}}(i) = \sum_{h} \sum_{j=1}^{N_{f}} D^{(h)} C_{M}(i, j) \bar{b}(i) b(j) N_{Q}(i) N_{Q}(j)
\]

\[
+ \sum_{h} \sum_{j=1}^{N_{f}} \sum_{k=j}^{N_{f}} (1 + \delta_{i,j} + \delta_{i,k}) D^{(h)} C_{B}(i, j, k) \bar{b}(i) b(j) \bar{b}(k) N_{Q}(i) N_{Q}(j) N_{Q}(k).
\]

(5)

The number of independent equations in eqs.(4),(5) is equal to the number of independent \( b(i) \) and \( \bar{b}(i) \) factors. Note, that these \( 2N_{f} \) quantities are not adjustable parameters of the model, but they are normalization constants determined by eqs.(4-5).

**The Coalescence Factors**

Let us consider now two particles (quarks or antiquarks) of type (flavor) 'a' and 'b' which form a particle (hadron) 'h'. The rate equation describing this formation of particle 'h' as a one-way process is based on the number density
of particles 'a' and 'b' \((n_a, n_b)\) in the reaction volume \(V\) and on the specific cross section \(\sigma\) of the \(a + b \rightarrow h\) process:

\[
\frac{1}{V} \frac{d}{d\tau} (V n_h) = \langle \sigma v \rangle n_a n_b .
\] (6)

Here \(\langle \sigma v \rangle\) is the thermally averaged rate including the relative velocity \(v\) of the reacting partners. Starting such a process with no 'h' particles at the beginning the rate of change is initially constant — \(\langle \sigma v \rangle n_a(\tau_0)n_b(\tau_0)\) — thus the number of 'h' particles grows linearly. After a characteristic time \(\tau\) we have

\[
N_h = V n_h = \frac{\langle \sigma v \rangle \tau}{V} N_a N_b = C(a, b) N_a N_b
\] (7)

particles. In a sudden approximation we see the effect of different branching ratios due to competition between several possible reaction channels producing different types of particles (protohadrons). In this way a coalescence factor

\[
C(a, b) = \frac{\langle \sigma v \rangle \tau}{V}
\] (8)

can be defined for each hadron. These factors influence the relative distribution of strange quarks between strange mesons and singly or doubly, etc. strange baryons.

Considering the ratios of different hadron abundancies in the final state the proper time \((\tau)\) and volume \((V)\) dependence cancels, therefore the validity of the sudden approximation can not be checked by a direct comparison with experimental data. A long hadronization time, \(\tau\), on the other hand, would lead to chemical equilibrium between the hadrons. In this case the relative abundances would depend only on final state parameters and not on the branching ratios based on specific hadronization channels. It must be a very improbable coincidence if these two different assumptions about the rehadronization dynamics would lead to similar strange/non-strange hadron or meson/baryon ratios. Thus an indirect experimental check on the sudden approximation is provided.

We assume furthermore that the creation of a baryon from three quarks or an antibaryon from three antiquarks is a two-step process leading through an intermediate diquark formation in the corresponding color triplet or antitriplet state which forms the final baryon later on together with a third quark or antiquark. These diquarks must, however, be very unstable, short-lived clusters (spatial correlations), so they may decay before forming the baryon. We take into account this mechanism of baryon production by introducing the phenomenological baryon production parameter, \(g_B\).
Thus the coalescence factor of a three-quark hadron is calculated as

\[
C_B(a, b, c) = g_B \frac{1}{3} \{ C_M(a, b) C_M([a + b], c) +
+ C_M(a, c) C_M([a + c], b) + C_M(b, c) C_M([b + c], a) \}, \tag{9}
\]

where \( g_B \) is assumed to be flavor blind and we average on all combinatoric possibility to form a baryon \( N_B^{(h)}(a, b, c) \). Here the arguments \( a, b \) and \( c \) stand for any of the flavors \( u, d \) or \( s \) considered, respectively.

Note that the general scheme displayed in eqs.\((1 - 2)\), namely that the number of formed hadrons is proportional to the product of the numbers of initials, \( N_h = C(a, b) N_a N_b \), has also been conjectured in the framework of a relativistic coalescence model \([10]\). In this latter case, however, the coalescence factor, \( C'(a, b) \), has been obtained in another way: only an initial and final state wave function overlap in a Gaussian wave packet approximation was taken into account instead of using a transition matrix element inherent in the definition of the cross section involved in the ALCOR model.

There are two ingredients occurring in eq.\((8)\) which have not yet been discussed: i) the reaction volume, ii) the hadronization rate. The first is mainly restricted by the presence of a flow preventing some candidate valence quarks 'a' and 'b' from meeting to form a hadron 'h' if they are sitting in fluid cells which move away from each other so fast that the local thermal motion cannot overcome this relative velocity barrier.

In ref. \([11]\) the space-time and momentum-space evolution of the reaction at SPS energies was investigated using the SPACER model. It was found that the momentum distribution of the particles can be approximated by a local thermal distribution superimposed on a scaling flow in a finite space-time rapidity interval. We perform the calculation of the average reaction rate for this case.

**Hadronization Rate in the Presence of Flow**

In the presence of a flow we consider the relativistic Jüttner distribution

\[
f(x, p) = e^{-\beta p \cdot u(x)}
\]

with \( u_\mu(x) \) being the local four-velocity of the flow. Let us restrict ourselves in the following to a scaling longitudinal flow \([12]\). In this case the thermal averaging of the rate can be interpreted only locally: any rate equation of type eq.\((1)\) has to be reinterpreted in terms of reacting components from different coordinate rapidity ranges \( \eta_a \) and \( \eta_h \) respectively

\[
\frac{1}{V} \frac{d}{d\tau} (V n_h) = \int d\eta_a d\eta_h \langle \sigma v \rangle_{ab} n_a n_b. \tag{11}
\]
Clearly the total volume of the fireball increases due to a longitudinal scaling expansion like $V = \tau \pi R^2 \Delta \eta$ with total coordinate rapidity extension $\Delta \eta$ and transverse radius $R$. Assuming a space-time rapidity plateau for a finite interval in the number distribution of the reacting and produced components we arrive at a modified rate equation

$$\tau \frac{d}{d\tau} N_h = \frac{\lambda}{\pi R^2} N_a N_b.$$  \hspace{1cm} (12)

Here

$$\lambda = \int d(\eta_a - \eta_b) \langle \sigma v \rangle \Theta((p_a - p_b) \cdot (x_a - x_b))$$  \hspace{1cm} (13)

is the total rate of reactions between all possible coordinate rapidity cell pairs. The constraint $(p_a - p_b) \cdot (x_a - x_b) \geq 0$ reduces to the requirement that the relative velocity vector is oriented opposite to the relative position vector in the center of mass system of the colliding components 'a' and 'b'. This constraint is necessary because only those particles collide which have a relative velocity pointing towards each other.

The inclusion of this constraint after some algebraic manipulation leads to the general expression of the averaged rate

$$\lambda = \frac{\beta \int d\sqrt{s} \sigma(s) \lambda_{ab}(s) G(\beta \sqrt{s})}{8m_a^2 m_b^2 K_2(\beta m_a) K_2(\beta m_b)}$$  \hspace{1cm} (14)

where $\lambda_{ab}(s) = [s - (m_a + m_b)^2] [s - (m_a - m_b)^2]$ and $G(\beta \sqrt{s})$ is the thermal weight factor. In the presence of longitudinal scaling flow the latter can be written as an integral over relative coordinate rapidity $\eta = (\eta_a - \eta_b)$

$$G(\beta \sqrt{s}) = \int_{-\infty}^{\infty} d\eta \sqrt{s} \frac{K_0(\beta \sqrt{s} \text{ch} |\eta|) - K_0\left(\beta \sqrt{s} \text{ch} |\eta| + \beta \lambda_{ab}^{1/2}(s) \text{sh} |\eta|\right)}{\beta \lambda_{ab}^{1/2}(s) \text{ch} |\eta| \text{sh} |\eta|}.$$  \hspace{1cm} (15)

Investigating the integrand of eq.(15) one observes a finite width, $\delta \eta$, in the relative coordinate rapidity $\eta$. (This quantity, $\delta \eta$, is equal to the relative flow rapidity because of the Bjorken scaling assumption.) The finite width depends on temperature $T$, on the particle rest masses $m_a, m_b$, and on the considered energy scale $\sqrt{s}$ in a complicated manner.
Elementary Cross Sections

Finally, the most uncertain ingredient of the ALCOR hadronization model, the hadronization cross section will be discussed. Here, until the dynamical confinement mechanism in QCD has been explored, an analogy with the $p + A \rightarrow d + (A - 1)$ nuclear rearrangement (pick-up) reaction leading to deuteron formation may give some hints. Considering a final state in a Coulomb-like potential — a simplified picture of mesons at intermediate temperatures — a fusing cross section of

$$
\sigma = 16m_h^2 \sqrt{\pi} \rho^3 \frac{\alpha^2 a}{(1 + (k a)^2)^2}
$$

(16)

can be derived from the above mentioned analogy. Here $m_h$ is the rest mass of the meson, while $a = 1/(m_{ab}\alpha)$ is the Bohr radius of the bound $q\bar{q}$ state in a $V(r) = -\alpha/r$ Coulomb potential with $m_{ab}$ being the reduced mass of particles 'a' and 'b'. In our calculation we took $\alpha = 0.46$ and $T = 200$ MeV temperature in estimating hadronization cross sections at CERN SPS energy. The factor $\rho = 0.3$ fm occurring in eq.(16) accounts for the medium influencing the hadron formation and was taken to be equal to the Debye screening length in quark-gluon plasma at the above temperature. Finally $k$ occurring in eq.(16) is the magnitude of the relative momentum vector of particles 'a' and 'b' measured in their center of mass system $k = \lambda_{ab}(s)/2\sqrt{s}$.

Results

Well armed with the above theoretical considerations the redistribution of different flavor quarks and antiquarks into all possible hadrons can be calculated in the ALCOR model using practically only three parameters: i) the total number of quark-antiquark pairs, $N_{tot,(pair)} = N_{u,\text{pair}} + N_{d,\text{pair}} + N_{s,\text{pair}}$, which can be determined from the measured total charged multiplicity, ii) the parameter $g_B$ controlling the baryon formation and iii) the strangeness production factor $g_s$. The dependence of the final results on the other parameters (e.g. $T$, $\alpha$) within their physically acceptable interval is small. All further results, such as the number of hyperons, kaons, etc. are predictions of the ALCOR model.
|       | S+S   | DATA    | ALCOR  | HIJ.01 | RQMD  | QGSM  |
|-------|-------|---------|--------|--------|-------|-------|
| $h^-$ | 98 ± 3| 100.2   | 88.80  | 110.2  | 120.  |
| $\pi^+$|       |         |        |        |       |       |
| $\pi^0$ |     |         |        |        |       |       |
| $\pi^-$ | 91 ± 3| 88.14   | 79.60  |        |       |       |
| $K^+$  | 12.5 ± 0.4| 12.70  | 8.43   |        |       |       |
| $K^0$  |       |         |        |        | 6.36  |       |
| $K^-$  | 6.9 ± 0.4| 6.36   | 6.27   |        |       |       |
| $K_S^0$ | 10.50 ± 1.7| 9.53  | 7.23   | 10.0   | 7.4   |
| $p^+$  |       |         |        |        | 22.04 |       |
| $n^0$  |       |         |        |        | 22.04 |       |
| $\Sigma^+$ |  | 1.71   |        |        |       |       |
| $\Sigma^0$ |  | 1.71   |        |        |       |       |
| $\Sigma^-$ |  | 1.71   |        |        |       |       |
| $\Lambda^0$ |  | 8.54   | 4.58   | 7.76   | 4.7   |
| $Y^0 = \Sigma^0 + \Lambda^0$ | 9.4 ± 1.0| 10.25 |       |       |       |
| $\Xi^0$ |       | 1.13   |        |        |       |       |
| $\Xi^-$ |       | 1.13   | 0.04   |        |       |       |
| $\Omega^-$ |  | 0.19   |        |        |       |       |
| $\bar{p}$ |       | 2.35   |        |        |       |       |
| $\bar{n}$ |       | 2.35   |        |        |       |       |
| $\Sigma^-$ |  | 0.40   |        |        |       |       |
| $\Sigma^0$ |  | 0.40   |        |        |       |       |
| $\Sigma^+$ |  | 0.40   |        |        |       |       |
| $\Lambda^0$ |  | 1.98   | 0.86   | 0.35   |       |
| $\bar{Y}^0 = \Sigma^0 + \Lambda^0$ | 2.20 ± 0.4| 2.38 |       |       |       |
| $\Xi^0$ |       | 0.57   |        |        |       |       |
| $\Xi^+$ |       | 0.57   | 0.06   |        |       |       |
| $\Omega^+$ |  | 0.21   |        |        |       |       |

**Table 1:** Hadron multiplicities for $S + S$ collision observed experimentally and obtained in the ALCOR and in the HIJING, RQMD, QGSM models (early non-collective string model versions, taken from refs. [14][15]) at 200 GeV/nucleon bombarding energy.
Table 1 shows results for the S+S reaction at 200 GeV/nucleon bombarding energy together with the experimental data. Column 1 displays multiplicities observed in experiment NA35 [16], [17]. Column 2 contains the hadron multiplicities predicted by the ALCOR model. Adjusting the three above parameters of ALCOR one obtains fairly good agreement with the experimental data for particles $\pi^-, K^+, K^-, K^0_s, Y^0$, and $Y^0$. (Here we introduced the notation $Y^0 = \Lambda^0 + \Sigma^0$ and $Y^0 = \bar{\Lambda}^0 + \bar{\Sigma}^0$ for the measured neutral strange and anti-strange baryons.) We took into account that the number of participant nucleons was measured to be $N_{SS\text{partic}} = 51$ [18]. We used the parameters $N_{SS\text{tot,pair}} = 158.1$ with $g_s = 0.255$ for the strangeness production, and $g_B = 0.04$ for the baryon formation. For comparison we display some results of the HI-JING, RQMD and QGSM models in Columns 3, 4 and 5 taken from refs. [14] (early non-collective string model versions). Table 2 shows results for the strange baryon and anti-baryon ratios. Column 1 displays the experimental data [19] and Column 2 contains the ALCOR predictions. The agreement seems to be good.

| S+S | WA94 | ALCOR |
|-----|------|-------|
| $Y^0/Y^0$ | 0.23 ± 0.01 | 0.23 |
| $\Xi^-/\Xi^-$ | 0.55 ± 0.07 | 0.50 |
| $\Xi^-/Y^0$ | 0.09 ± 0.01 | 0.11 |
| $\Xi^-/Y^0$ | 0.21 ± 0.02 | 0.24 |

**Table 2:** Strange baryon and anti-baryon ratios measured by WA94 Collaboration [19] and obtained from ALCOR for $S + S$ collision at 200 GeV/nucleon bombarding energy.

From this experience we conjecture that the above rehadronization process is **locally quick:** the quarks and antiquarks (including the fragmented gluons) appear in hadrons according to simple kinematic rules and production branching ratios. This finding, however, does not settle the question whether quark matter with any degree of collectivity has been formed or other hadronization processes including strings or color ropes [18] are the source of this amount of quarks. Local thermal distribution of the different quark flavors and the presence of a longitudinal flow cannot, on the other hand, be excluded on the basis of this experimental data.
To obtain results for other reactions, we assume a scaling for the produced quark-antiquark pairs as

\[ N_{AA,\text{tot,pair}}(\sqrt{s}) = \left( \frac{N_{AA,\text{partic}}}{N_{SS,\text{partic}}} \right)^\alpha N_{SS,\text{tot,pair}}(\sqrt{s}) \]

(17)

where \( N_{AA,\text{partic}} \) are the number of participant nucleons in the A+A collision.

The scaling exponent \( \alpha \) may have the value \( \alpha = 1 \), or, for more collective production processes one expects \( \alpha = 4/3 \). Furthermore we shall use the values for \( g_B \) and \( g_s \) obtained above. If one of these parameters has to be changed in order to approve the correspondence of the calculated particle numbers with the experimental ones, than this change must have a physical interpretation.

| Hadron | p+n (exp) | ALCOR | p+p (exp) | ALCOR |
|--------|----------|-------|----------|-------|
| \( h^- \) | 3.23 ± 0.02 | 3.24 | 2.85 ± 0.03 | 2.87 |
| \( \pi^+ \) | 3.01 ± 0.04 | 3.03 | 3.22 ± 0.12 | 3.43 |
| \( \pi^0 \) | 3.06 ± 0.25 | 3.03 | 3.34 ± 0.24 | 3.01 |
| \( \pi^- \) | 3.01 ± 0.04 | 3.03 | 2.62 ± 0.06 | 2.67 |
| \( K^+ \) | 0.24 | 0.28 | 0.28 ± 0.06 | 0.28 |
| \( K^- \) | 0.17 | 0.12 | 0.18 ± 0.05 | 0.12 |
| \( K^0 \) | 0.20 | 0.20 | 0.17 ± 0.01 | 0.20 |
| \( p^+ \) | 1.00 ± 0.08 | 0.88 | 1.34 ± 0.15 | 1.10 |
| \( n^0 \) | 1.00 ± 0.08 | 0.88 | 0.61 ± 0.30 | 0.65 |
| \( Y^0 = \Sigma^0 + \Lambda^0 \) | 0.096 | 0.23 | 0.096 ± 0.01 | 0.22 |
| \( \bar{p}^- \) | (0.05) | 0.03 | 0.05 ± 0.02 | 0.03 |
| \( \bar{n}^0 \) | (0.05) | 0.03 | (0.05) | 0.03 |
| \( Y^0 = \Sigma^0 + \Lambda^0 \) | (0.013) | 0.019 | 0.013 ± 0.004 | 0.019 |

**Table 3:** Hadron multiplicities for \( p + n \) and \( p + p \) collision observed experimentally [20] and obtained in the ALCOR models at 200 GeV/nucleon bombarding energy. The numbers in square brackets are the average of the corresponding \( p + p \) and \( n + n \) results. The numbers in normal brackets are assumed values with 50% uncertainty [20].
With these assumptions we calculated the particle production also for nucleon-nucleon collisions namely for proton-proton and proton-neutron collisions at 200 GeV/nucleon energy. For this case, in order to get the number of strange hadrons correctly, we had to decrease the strangeness production factor. Table 3. shows the ALCOR results for $p + n$ and $p + p$ collisions together with the experimental values from Ref. \[20\]. In both cases we used the same parametrization, namely $N^{NN}_{\text{partic}} = 2$, $N^{NN}_{\text{tot, pair}} = 4.5$ with a decreased strangeness formation factor $g_s = 0.16$ and an unchanged baryon formation factor $g_B = 0.04$. The scaling exponent is $\alpha = 1.1$. (In the two cases only the flavour component of the incoming participant nucleons were different, i.e. $p + p$ and $p + n$, respectively.) One can observe, that the calculated meson and non-strange baryon numbers are not far from the measured ones. To achieve this we had to decrease the strangeness production factor, $g_s$, from its value in $S + S$ reaction. Thus we may conclude, that in the $S + S$ reaction the strangeness production is enhanced with respect to the nucleon-nucleon reaction by a factor of 1.6. Furthermore we may observe from Table 3., that the calculated $Y^0 = \Sigma^0 + \Lambda^0$ and $\bar{Y}^0 = \overline{\Sigma}^0 + \overline{\Lambda}^0$ numbers deviate essentially from the measured ones. Namely ALCOR overpredicts the production of these particles. This discrepancy can be interpreted by assuming that the hadronization mechanism in the $S + S$ reaction is different from that for the nucleon+nucleon reaction and this can be seen undoubtedly on strange baryon production. In fact, the ALCOR model assumes, that there may be quark exchanges between neighbouring excited objects (strongly packed strings, etc.) allowing larger role to the combinatoric possibilities. Thus one may describe this case as a formation of a semi-deconfined state of the matter. However, in nucleon-nucleon collision this effect is missing.

Using the parametrization of S+S collision and the above scaling law, we may make predictions for the Pb+Pb collision at 160 GeV/nucleon energy. In this case the number of participant nucleons is $N^{PbPb}_{\text{part}} = 390 \pm 10$ obtained from Monte-Carlo simulations \[21\]. We will use the mean value. During the extrapolation of the total number of produced quark-antiquark pairs from the S+S collision one needs to consider an energy rescaling. We will assume a logarithmic one:

$$\frac{N^{AA}_{\text{tot, pair}}(\sqrt{s_1})}{N^{AA}_{\text{tot, pair}}(\sqrt{s_2})} = \frac{\ln \sqrt{s_1}}{\ln \sqrt{s_2}} \quad (18)$$

This rescaling yields a $\approx 4\%$ correction and one obtains $N^{PbPb}_{\text{tot, pair}} = 1164$ in the linear case ($\alpha = 1$) and $N^{PbPb}_{\text{tot, pair}} = 2294$ in the more collective one ($\alpha = 4/3$). Table 4 displays the predictions of ALCOR for both scaling cases and the last column contains some results from HIJING taken from Ref. \[14\].
Table 4: Hadron multiplicities predicted by the ALCOR model assuming different scaling laws discussed in the text. For comparison, predictions of the HIJING model taken from ref. [14] are also selected.
Conclusion

We have applied the hadronization model, ALCOR, for the analysis of the experimental data of $p + p$, $p + n$ and $S + S$ collisions and for the prediction of hadron multiplicities in the $Pb + Pb$ collision at CERN SPS energy.

This model uses dynamical coalescence probabilities obtained from hadro-production reaction rate factors obtained on a one dimensional scaling flow background. The model is sensitive to only three free parameters: the total number of quark-antiquark pairs produced, an in-medium baryon formation factor $g_B$, and the strangeness production factor $g_s$, fitted to the experimental results of the reaction $S+S$. (The effect of changes in common factors are removed by the normalization constants.) With no further adjustment we have been able to describe several observed hadron multiplicities in agreement with the NA35 and WA94 experiments. We could clearly identify the strangeness enhancement in $S+S$ collision with respect to the nucleon-nucleon reaction.

Furthermore, for $p + p$ and $p + n$ collisions the ALCOR model could not reproduce the measured strange baryon and antibaryon numbers on the basis of $S + S$ collision. We interpret this discrepancy as a signature showing that the hadronization mechanism in the $S + S$ reaction differs from that for the nucleon-nucleon reaction. We infer from this comparison that in $S + S$ collision a sort of semi-deconfined state of the matter was formed which can be characterized by enhanced quark exchanges between neighbouring excited objects. This is a basic assumption in the ALCOR model.

We made detailed predictions for hadron multiplicities in a Pb+Pb reaction assuming two different scaling exponent. There is an agreement between the HIJING and the ALCOR model (in linear case, $\alpha = 1$) for prediction of total negative particle, pion and kaon multiplicities. However, the strange baryon and anti-baryon yields differ from the HIJING result. Now we look forward to compare these predictions with the results of the NA49 CERN SPS experiment to determine the details of hadronization processes. Possible agreement would support our statement about the formation of semi-deconfined state of the matter in high energy heavy ion collisions.

Acknowledgement

Discussions with T. Csörgő, M. Gazdzicki, K. Kadija, H. Sorge, H. Ströbele and X. N. Wang are acknowledged. This work was supported by the National Scientific Research Fund (Hungary), OTKA No.T014213 and by the U.S. - Hungarian Science and Technology Joint Fund, No. 378/93.
References

[1] X.N. Wang, M. Gyulassy, Phys. Rev. D44 3501 (1991)
[2] K. Geiger, B. Müller, Nucl. Phys. B369 600 (1992)
[3] T.S. Biró, J. Zimányi, Phys. Lett. B113 6 (1982)
[4] I. Montvay, J. Zimányi, Nucl. Phys. A316 490 (1979)
[5] K. Werner, Phys. Reports 232 87 (1993)
[6] T.S. Biró, J. Knoll, H.B. Nielsen, Nucl. Phys. B245 449 (1984)
[7] T.S. Biró, P. Lévai, J. Zimányi, Phys. Lett. B347 6 (1995)
[8] T.S. Biró, J. Zimányi, Nucl. Phys. A395 525 (1983)
[9] P. Koch, B. Müller, J. Rafelski, Phys. Report 142 167 (1986)
[10] J. Zimányi, P. Lévai, W. Greiner, U. Heinz, in preparation
[11] T. Csörgő, J. Zimányi, J. Bondorf, H. Heiselberg, Phys. Lett. B222 115 (1989)
[12] J.D. Bjorken, Phys. Rev. D27 140 (1982)
[13] e.g. L.I. Schiff, Quantum Mechanics, Chapt. 34, McGraw-Hill, New York, 1955
[14] V. Topor Pop at al., WA94 Coll., DFPD-94-NP-49 Preprint [hep-ph/9407262]
[15] N.S. Amelin, L.V. Bravina, L.P. Csernai, V.D. Toneev, K.K. Gudima, S.Yu. Sivoklokov, Phys. Rev C47 2299 (1993)
[16] J. Baechler et. al. Z. Phys. C58 367 (1993)
[17] NA35 Coll., T. Alber et al., IKF-HENPG/1-94 Univ. Frankfurt Preprint
[18] J. Bächler et al., NA35 Coll., Phys. Rev. Lett. 72 1419 (1994)
[19] WA94 Collaboration, data presented in S’95 by O. Villalobos-Bailie.
[20] M. Gazdzicki, O. Hansen, Nucl. Phys. A528 754 (1991)
[21] M. Gazdzicki, private communication.