

Baryon and Antibaryon production at RHIC energies in the Dual Parton Model

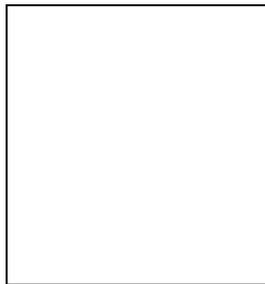
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We compute the mid-rapidity densities of pions, kaons, baryons and antibaryons in $Au-Au$ collisions at $\sqrt{s} = 130$ GeV in the Dual Parton Model supplemented with final state interactions, and we present a comparison with available data.

1 Description of the model

The rapidity density of a given type of hadron h produced in AA collisions at fixed impact parameter, is given by ^{1,2}

$$\begin{aligned} \frac{dN^{AA \rightarrow h}}{dy}(y, b) &= n_A(b) \left[N_{h, \mu(b)}^{qq^P - q^T}(y) + N_{h, \mu(b)}^{q_v^P - qq^T}(y) + (2k - 2) N_{h, \mu(b)}^{q_s - \bar{q}_s}(y) \right] \\ &+ (n(b) - n_A(b)) 2k N_{h, \mu(b)}^{q_s - \bar{q}_s}(y) . \end{aligned} \quad (1)$$

Here $n(b)$ is the average number of binary collisions and $n_A(b)$ is the average number of participant pairs at fixed impact parameter b . P and T denote projectile and target nuclei. k is the average number of inelastic collisions in pp and $\mu(b) = k\nu(b)$ with $\nu(b) = n(b)/n_A(b)$ the average total number of collisions suffered by each nucleon. At $\sqrt{s} = 130$ GeV we have $k = 2^2$. The $N_{h, \mu(b)}(y)$ in eq. (1) are the rapidity distributions of hadron h in each individual string. In DPM they are given by convolutions of momentum distribution and fragmentation functions ³.

It was shown in ² that eq. (1), supplemented with shadowing corrections, leads to values of charged multiplicities at mid-rapidities as a function of centrality in agreement with data, both at SPS and RHIC. Here we use the same shadowing corrections as in ref. ²

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Net Baryon Production ($\Delta B = B - \bar{B}$): In order to reproduce the stopping observed in Pb Pb collisions at SPS, we introduce a new mechanism (diquark breaking) based on the transfer in rapidity of the baryon junction^{4,5}. In an AA collision, this component gives the following rapidity distribution of the two net baryons in a single NN collision of AA ⁶

$$\left(\frac{dN_{DB}^{\Delta B}}{dy} \right)_{\nu(b)} = C_{\nu(b)} \left[Z_+^{1/2} (1 - Z_+)^{\nu(b)-3/2} + Z_-^{1/2} (1 - Z_-)^{\nu(b)-3/2} \right] \quad (2)$$

where $Z_{\pm} = \exp(\pm y - y_{max})$ and $\nu(b) = n(b)/n_A(b)$. $C_{\nu(b)}$ is determined from the normalization to two at each b .

In order to get the relative densities of each baryon and antibaryon species we use simple quark counting rules⁶. We denote the strangeness suppression factor by S/L (with $2L + S = 1$). If the baryon is made out of three sea quarks (which is the case of pair production) the relative weights are $I_3 = 4L^3 : 4L^2S : 12L^2S : 3LS^2 : 3LS^2 : S^3$ for $p, n, \Lambda + \Sigma, \Xi^0, \Xi^-$ and Ω , respectively. The various coefficients of I_3 are obtained from the power expansion of $(2L + S)^3$. For net baryon production there are two possibilities: one is to use I_3 which corresponds to the transfer of SJ without quarks. The other possibility corresponds to the transfer of the baryon junction plus one valence quark. In this case the relevant weights are given by I_2 , i.e. from the various terms in the expansion of $(2L + S)^2$. This second possibility is favored by data and it is considered in this work. In order to take into account the decay of $\Sigma^*(1385)$ into $\Lambda\pi$, we redefine the relative rate of Λ 's and Σ 's using the empirical rule $\Lambda = 0.6(\Sigma^+ + \Sigma^-)$ – keeping, of course, the total yield of Λ 's plus Σ 's unchanged. In this way the normalization constants of all baryon species in pair production are determined from one of them. This constant, together with the relative normalization of K and π , are determined from the data for very peripheral collisions. In the calculations we use $S = 0.1$ ($S/L = 0.22$).

Final State Interactions: The hadronic densities obtained above will be used as initial conditions in the gain and loss differential equations which govern final state interactions.

$$\tau \frac{d\rho_i}{d\tau} = \sum_{k\ell} \sigma_{k\ell} \rho_k \rho_{\ell} - \sum_k \sigma_{ik} \rho_i \rho_k . \quad (3)$$

The first term in the r.h.s. of (3) describes the production (gain) of particles of type i resulting from the interaction of particles k and ℓ . The second term describes the loss of particles of type i due to its interaction with particles of type k . In eq. (3) $\rho_i = dN_i/dyd^2s(y, b)$ are the particles yields per unit rapidity and per unit of transverse area, at fixed impact parameter. $\sigma_{k\ell}$ are the corresponding cross-sections averaged over the momentum distribution of the colliding particles.

The channels that have been taken into account in our calculations are

$$\pi N \leftrightarrow K\Lambda(\Sigma) , \quad \pi\Lambda(\Sigma) \leftrightarrow K\Xi , \quad \pi\Xi \leftrightarrow K\Omega \quad (4)$$

Of all possible charge combinations in these reactions, we have only kept those involving the annihilation of a light $q\bar{q}$ pair and production of an $s\bar{s}$ in the s -channel. We have also taken into account the strangeness exchange reactions

$$\pi\Lambda(\Sigma) \leftrightarrow KN , \quad \pi\Xi \leftrightarrow K\Lambda(\Sigma) , \quad \pi\Omega \leftrightarrow K\Xi . \quad (5)$$

as well as the channels corresponding to (4) and (5) for antiparticles.

2 Results

The calculations have been performed in the interval $-0.35 < y^* < 0.35$. In Fig. 1a-1d we show the rapidity densities of B, \bar{B} and $B - \bar{B}$ versus $h^- = dN^-/d\eta = (1/1.17)dN/dy$ and compare

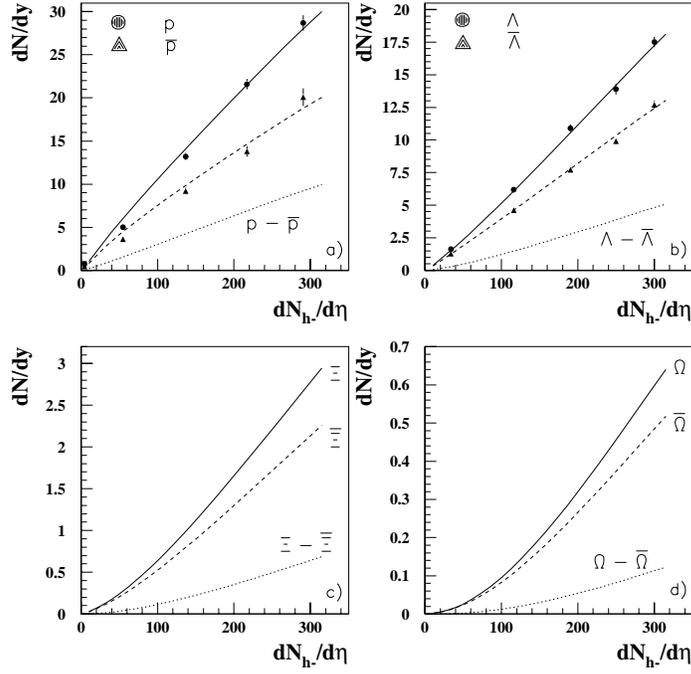


Figure 1: (a) Calculated values of rapidity densities of p (solid line), \bar{p} (dashed line), and $p - \bar{p}$ (dotted line) at mid rapidities, $|y^*| < 0.35$, are plotted as a function of $dN^-/d\eta$, and compared with PHENIX data⁷; (b) same for Λ and $\bar{\Lambda}$ compared to preliminary STAR data⁹; (c) same for Ξ^- and Ξ^+ ; (d) same for Ω and $\bar{\Omega}$.

them with available data^{7,8,9}. We see that, in first approximation, p , \bar{p} , Λ and $\bar{\Lambda}$ scale with h^- . Quantitatively, there is a slight decrease with centrality of p/h^- and \bar{p}/h^- ratios, a slight increase of Λ/h^- and $\bar{\Lambda}/h^-$ and a much larger increase for Ξ ($\bar{\Xi}$)/ h^- and Ω ($\bar{\Omega}$)/ h^- . In the DPM (before final state interaction) the rapidity density of charged particle per participant increases with centrality. This increase is larger for low centralities⁹. This has an important effect on both the size and the pattern of strangeness enhancement in our results. It explains why the departure from a linear increase of Ξ 's and Ω 's (concave shape) seen in Figs. 1c and 1d is also more pronounced for lower centralities.

The ratios \bar{B}/B have a mild decrease with centrality of about 15 % for all baryon species – which is also seen in the data¹⁰. Our values for $N^{ch}/N_{max}^{ch} = 1/2$ are : $\bar{p}/p = 0.69$, $\bar{\Lambda}/\Lambda = 0.72$, $\bar{\Xi}/\Xi = 0.79$, $\Omega/\bar{\Omega} = 0.83$ to be compared with the measured values⁸ :

$$\bar{p}/p = 0.63 \pm 0.02 \pm 0.06 \quad , \quad \bar{\Lambda}/\Lambda = 0.73 \pm 0.03 \quad , \quad \bar{\Xi}/\Xi = 0.83 \pm 0.03 \pm 0.05 \quad .$$

In Fig. 2a and 2b we plot the yields of B and \bar{B} per participant normalized to the same ratio for peripheral collisions versus n_{part} . The enhancement of B and \bar{B} increases with the number of strange quarks in the baryon. This increase is comparable to the one found at SPS between pA and central PbPb collisions – somewhat larger for antibaryons. Before final state interactions, all ratios K/h^- , B/h^- and \bar{B}/h^- decrease slightly with increasing centrality. This effect is rather marginal at RHIC energies and mid-rapidities. The final state interactions (4), (5) lead to a gain of strange particle yields. The reason for this is the following. In the first direct reaction (4) we have $\rho_\pi > \rho_K$, $\rho_N > \rho_\Lambda$, $\rho_\pi \rho_N \gg \rho_K \rho_\Lambda$. The same is true for all direct reaction (4). In view of that, the effect of the inverse reactions (4) is small. On the contrary, in all reactions (5), the product of densities in the initial and final state are comparable and

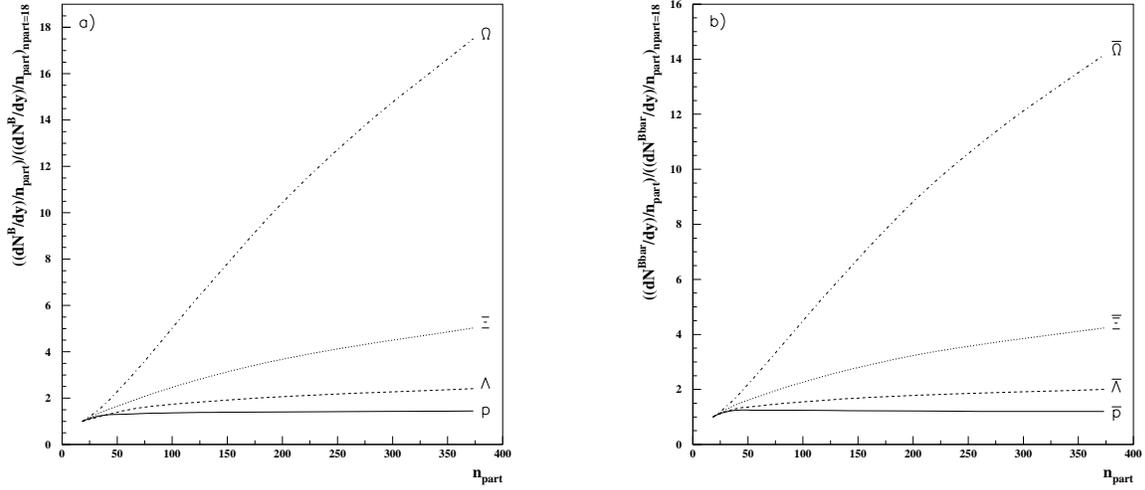


Figure 2: Calculated values of the ratios B/n_{part} (a) and \bar{B}/n_{part} (b), normalized to the same ratio for peripheral collisions ($n_{part} = 18$), are plotted as a function of n_{part} .

the direct and inverse reactions tend to compensate with each other. Baryons with the largest strange quark content, which find themselves at the end of the chain of direct reactions (4) and have the smallest yield before final state interaction, have the largest enhancement. Moreover, the gain in the yield of strange baryons is larger than the one of antibaryons since $\rho_B > \rho_{\bar{B}}$. Furthermore, the enhancement of all baryon species increases with centrality, since the gain, resulting from the first term in eq. (3), contains a product of densities and thus, increases quadratically with increasing centrality.

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References

1. A. Capella, U. Sukhatme, C.-I. Tan and J. Tran Thanh Van, Phys. Lett. **81B**, 68 (1979) ; Phys. Rep. **236**, 225 (1994).
2. A. Capella and D. Sousa, Phys. Lett. **B511**, 185 (2001).
3. A. Capella, C. A. Salgado and D.Sousa, nucl-th/0205014.
4. G. C. Rossi and G. Veneziano, Nucl. Phys. **B123**, 507 (1977).
5. B. Z. Kopeliovich and B. G. Zakharov, Sov. J. Nucl. Phys. **48**, 136 (1988) ; Z. Phys. **C43**, 241 (1989).
6. A. Capella and C. A. Salgado, New Journal of Physics **2**, 30.1-30.4 (2000) ; Phys. Rev. **C60**, 054906 (1999). A. Capella, E. G. Ferreira and C. A. Salgado, Phys. Lett. **B459**, 27 (1999) ; Nucl. Phys. **A661**, 502 (1999).
7. PHENIX coll., K. Adcox et al, nucl-ex/0112006, to be published by Phys. Rev. Lett.
8. STAR coll., C. Roy, nucl-ex/0111017, Proc. of the Int. Workshop on the Phys. of the QGP, Palaiseau (France), Sept. 01.
9. STAR coll., C. Adler et al, Phys. Rev. Lett. **87**, 262302 (2001).
10. STAR coll., C. Adler et al, Phys. Rev. Lett. **86**, 4778 (2001).