Net-Proton Rapidity Distributions in Relativistic Heavy-Ion Collisions

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Net-proton rapidity distributions in central relativistic heavy-ion collisions at SPS, RHIC and LHC energies have been investigated in a nonequilibrium-statistical Relativistic Diffusion Model [1] that has considerable predictive power regarding the mass- and energy dependence of the distribution functions. We have also suggested to use such distributions as a tool to probe saturation physics and in particular, geometric scaling [2]. Within the color glass condensate framework based on small-coupling QCD, net-baryon rapidity distributions are shown to exhibit geometric scaling.

We have two symmetric contributions, coming from the two beams. The contribution of the fragmentation of the valence quarks in the forward moving nucleus is

$$\frac{dN}{dy} = \frac{C}{(2\pi)^2} \int \frac{d^2p_T}{p_T^2}\, x_1 q_v(x_1, Q_f)\, \varphi\,(x_2, p_T)\,, \tag{1}$$

where $x_1 = p_T/\sqrt{s}\exp(y)$, $x_2 = p_T/\sqrt{s}\exp(-y)$ are the longitudinal momentum fractions carried, respectively, by the valence quark in the projectile and the soft gluon in the target. The factorization scale is set equal to the transverse momentum, $Q_f \equiv p_T$. The contribution of valence quarks in the other beam nucleus is added incoherently by changing $y \to -y$.

To show that the net-baryon distribution reflects the geometric scaling of the gluon distribution $\varphi\,(x_2, p_T)$, we perform the following change of variables:

$$x \equiv x_1, \quad x_2 \equiv x\, e^{-2y}, \quad p_T^2 \equiv x^2 s\, e^{-2y}. \tag{2}$$

Thus, we rewrite Eq. (1) as

$$\frac{dN}{dy}(\tau) = \frac{C}{2\pi} \int_0^1 \frac{dx}{x}\, x q_v(x)\, \varphi(x^{2+\lambda} e^{\tau}), \tag{3}$$

where $\tau = \ln(s/Q_0^2) - \ln A^{1/3} - 2(1+\lambda)\, y$ is the corresponding scaling variable. The value $\lambda = 0.2-0.3$ agrees with theoretical estimates based on next-to-leading order Balitskii-Fadin-Kuraev-Lipatov (BFKL) results. Hence, the net-baryon multiplicity in the peak region is only a function of a single scaling variable τ, which relates the energy dependence to the rapidity and mass number dependence. In the fragmentation region, the valence quark distribution is only very weakly dependent on Q_f.

Excellent agreement with RHIC data in Au + Au collisions at $\sqrt{s_{NN}} = 62.4$ GeV and 200 GeV [3] is found, in particular in the fragmentation regions. The mean rapidity loss is calculated and compared with data from SPS and RHIC. Corresponding results are obtained for net-kaon distributions. Predictions for net-proton rapidity spectra and the mean rapidity loss in central Pb + Pb collisions at LHC energies of $\sqrt{s_{NN}} = 5.5$ TeV are made.

References

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