What information can we obtain from the yield ratio π^-/π^+ in heavy-ion collisions ?

T.Osada and M.Biyajima
Department of Physics, Faculty of Science, Shinshu University, Matsumoto 390, Japan

Introduction: Significant enhancement of the pionic yield ratio π^-/π^+ in small m_T-m_π region in heavy-ion collisions is observed in [1, 2]. It may be caused by the Coulomb interaction between a charged pion and the central charged fragments (CCF) with effective charge $Z_{\rm eff}$ which consists of nearly stopping nucleons. Several authors[3, 4] also have argued this phenomenon due to the Coulomb interaction of $\pi^\pm$-CCF system. Using the zero-range Gamow factor, the yield ratio is analyzed by Shuryak[4]; $N^{\pi^-}/N^{\pi^+} = G(\eta_-)/G(\eta_+)$ where $G(\eta_\pm) = 2\pi\eta_\pm/[\exp(2\pi\eta_\pm) - 1]$ and $\eta_+ = Z_{\rm eff}\alpha\ m_\pi/p_r = -\eta_-$. To treat Coulomb interaction of $\pi^\pm$-CCF system rigorously, the Coulomb wave function $\psi(\mathbf{p}_r, \mathbf{r})$ of the two body system should be used. A pion source function $\rho_\beta(r)$ describing the finite interaction region also needs to introduce.

Theoretical formula of the yield ratio: The single particle spectra N^{π^+} in terms of $\psi(\mathbf{p}_r, \mathbf{r})$ and $\rho_\beta(r)$ is given in the following

$$\begin{aligned} N^{\pi^+}(\mathbf{p}_r, \beta) &= \int d^3\mathbf{r}\ \ \rho_\beta(r) \mid \psi(\mathbf{p}_r, \mathbf{r}) \mid^2 \\ &= G(\eta_+) \sum_{n=0}^{\infty}\sum_{m=0}^{\infty} \frac{(-i)^n (i)^m}{n+m+1} A_n(\eta_+) A_m(\eta_+)\ [\int_0^\infty dr r^{n+m+2}\ \rho_\beta(r)]\ (2p_r)^{n+m}, \quad (1) \end{aligned}$$

where $A_n(\eta_+) = \Gamma(i\eta_+ + n)/\{\Gamma(i\eta_+)(n!)^2\}$ and $\mathbf{p}_r$ is a relative momentum of pion in the rest frame of CCF. For concrete analysis two types of the source function are assumed: $\rho(r) = \mathcal{N}\exp(-r^2/2\beta)$ and $\rho(r) = \mathcal{N}\exp(-r/\beta)$. Finally the pionic yield ratio π^-/π^+ with fixed pions rapidity is given by

$$\pi^-/\pi^+ = \frac{N^{\pi^-}(m_T - m_\pi; \eta_-, \beta)}{N^{\pi^+}(m_T - m_\pi; \eta_+, \beta)}. \quad (2)$$

Analysis of experimental data and quasi-scaling in $N^{\pi^\pm}$: Using eq.(2) we analyze data of Pb+Pb at 158A GeV and Au+Au at 11A GeV in [1, 2]. In the present analysis of those data we find the following quasi-scaling behavior

$$N^{\pi^\pm}(m_T - m_\pi; \lambda\ \eta_\pm, \lambda\ \beta) \approx N^{\pi^\pm}(m_T - m_\pi; \eta_\pm, \beta), \quad (3)$$

where $\lambda > 0$. This quasi-scaling behavior makes separated estimation of $Z_{\rm eff}$ and β difficult. Figure 1 demonstrates that two sets of parameters give almost the same results. Here we define the following function,

$$S(\lambda\ \eta_\pm, \lambda\ \beta) \equiv \sum_{n=0}^{\infty}\sum_{m=0}^{\infty} \frac{(-i)^n (i)^m}{n+m+1} A_n(\eta_+) A_m(\eta_+)\ [\int_0^\infty dr r^{n+m+2}\ \rho_\beta(r)]\ (2p_r)^{n+m}. \quad (4)$$

Comparing coefficients of the Taylor expansion of the above function $S(\lambda\ \eta_\pm, \lambda\ \beta)$ with $1/G(\eta_\pm)$, we find that $S(\lambda\ \eta_\pm, \lambda\ \beta) \approx$ const.$\times 1/G(\eta_\pm)$. This means that the λ dependence of l.h.s. of eq.(3) cancels out in the product of $G(\eta_\pm)$ and $S(\lambda\ \eta_\pm)$. The cancellation of the λ dependence is cause of the quasi-scaling behavior seen in $N^{\pi^\pm}$.

Estimation of the baryon number density of the CCF: Combining results by