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A Blast-wave Model with two Freeze-outs

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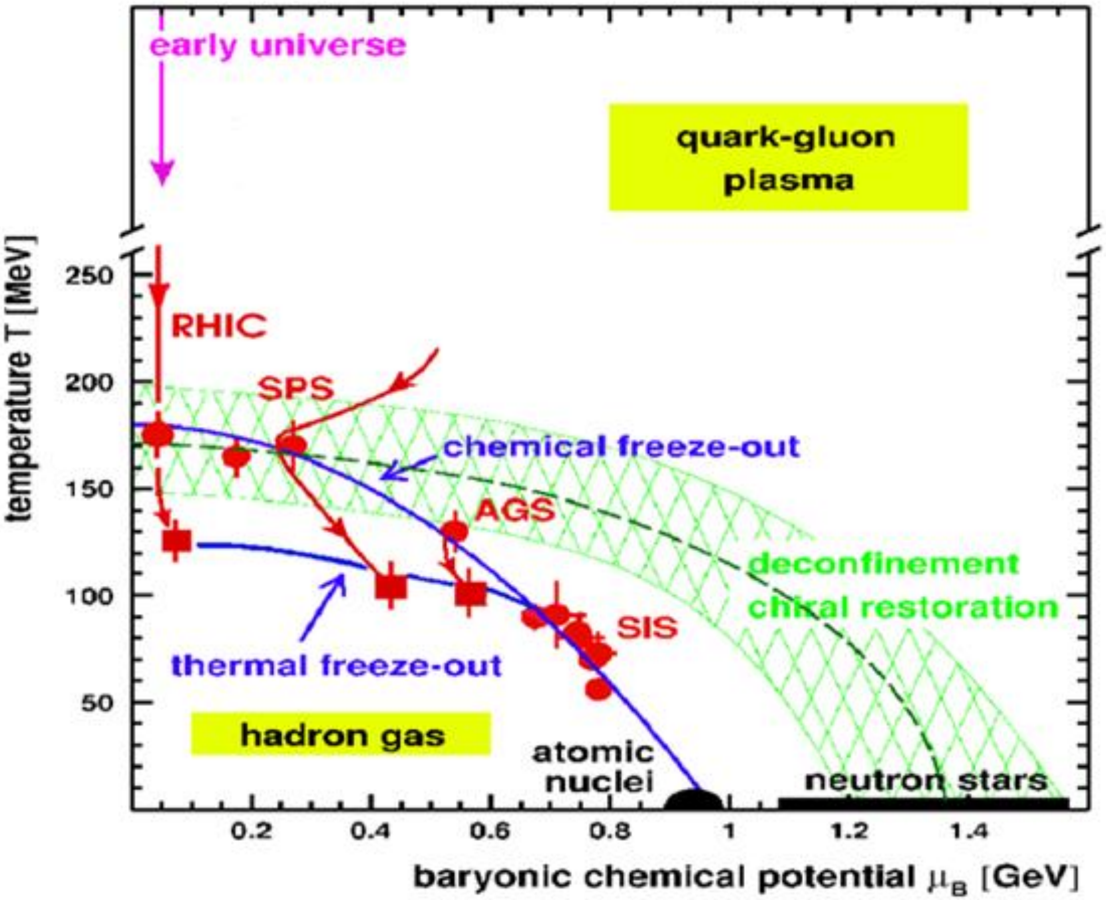
HIM 2011.12.10

Motivation



Chemical analysis of hadron ratios

$$R = e^{-(\mu_i - \mu_j)/T}$$

Thermal analysis of mt spectra of hadrons

$$e^{-\gamma(E-\beta P_L)/T}$$

$T_{ch} > T_{th}$

At Tch, chemical freeze-out occurs if inelastic collisions, which makes A+B->C+D, are not abundant. Then the numbers of each species, A,B,C, and D are not changing.

At Tth, thermal freeze-out occurs if elastic collisions are not abundant. Then, the momentum distribution is not changing any more.

Earlier chemical freeze-out and later thermal freeze-out.

$$T_{ch} > T_{th}$$

Models to incorporate the fact that $T_{ch} > T_{th}$ **in explaining the hadron production**

- **Hydrodynamic equation + Hadronic afterburner (UrQMD)**

Bass, Heinz+Bass

– at Tsw, generate hadrons via Monte Carlo Method

- **Hydrodynamic equation + Partial Chemical Equilibrium (PCE)**

Hirano, Teaney

– below Tch, fix Ni except for short lived resonances (eg. Delta) and solve for mui (13x13 matrix)

A Blast-wave model with two freeze-outs

Suk Choi, KSLee, PRC84, 064905(2011)

- **Chemical analysis at Tch**
  – Lorentz boosted thermal distribution is used.

- **Tch<T<Tth, number of thermal hadrons of each hadron species fixed.**

- **Approximation: Treat short lived hadrons as long lived ones, which causes small error but calculation becomes much simpler and fast.**

- **At Tth, thermal analysis of mt spectra**

- **Resonance contribution is carefully treated.**

Model Description

Cooper-Frye Formula

$$E\frac{d^3N}{d^3p} = \frac{g}{(2\pi)^3}\int_{\Sigma_f} p^\mu d\sigma_\mu(x) f(x,p)$$

$$f(x,p) = \exp(-\frac{p_\nu u_\nu(x) - \mu}{T})$$

For an ellipsoidally expanding fireball

$$\frac{d^2N_i^{th}}{m_T dm_T dy} = \frac{d_i V}{2\pi}\int_{-\eta_{max}}^{\eta_{max}} d\eta \int_0^{r_{max}(\eta)} r dr m_T \cosh(y-\eta) \times \exp(-\frac{m_T\cosh(y-\eta)\cosh\rho - \mu_i}{T}) I_0(\frac{p_T\sinh\rho}{T})$$

$$v_L = z/t$$

$$\eta = \tanh^{-1} z/t$$

$$r_{max}(\eta) = R_0\sqrt{1-\frac{\eta^2}{\eta_{max}^2}}$$

$$\rho(r) = \rho_0(r/r_{max})^\alpha$$

H. Dobler, J. Sollfrank, U. Heinz, P.L. B457,353(1999)

Chemical analysis

$$N_i^{th} = \int\int m_T dm_T dy \frac{d^2 N_i^{th}}{m_T dm_T dy}(T, \mu_i, \eta_{max}, \rho_0, R_0)$$

Chemical Potential $\mu_i = (n_q - n_{\bar{q}})\mu_q + (n_s - n_{\bar{s}})\mu_s$

Total Particle Number $N_i = N_i^{th} + N_i^{res}$

Thermal analysis

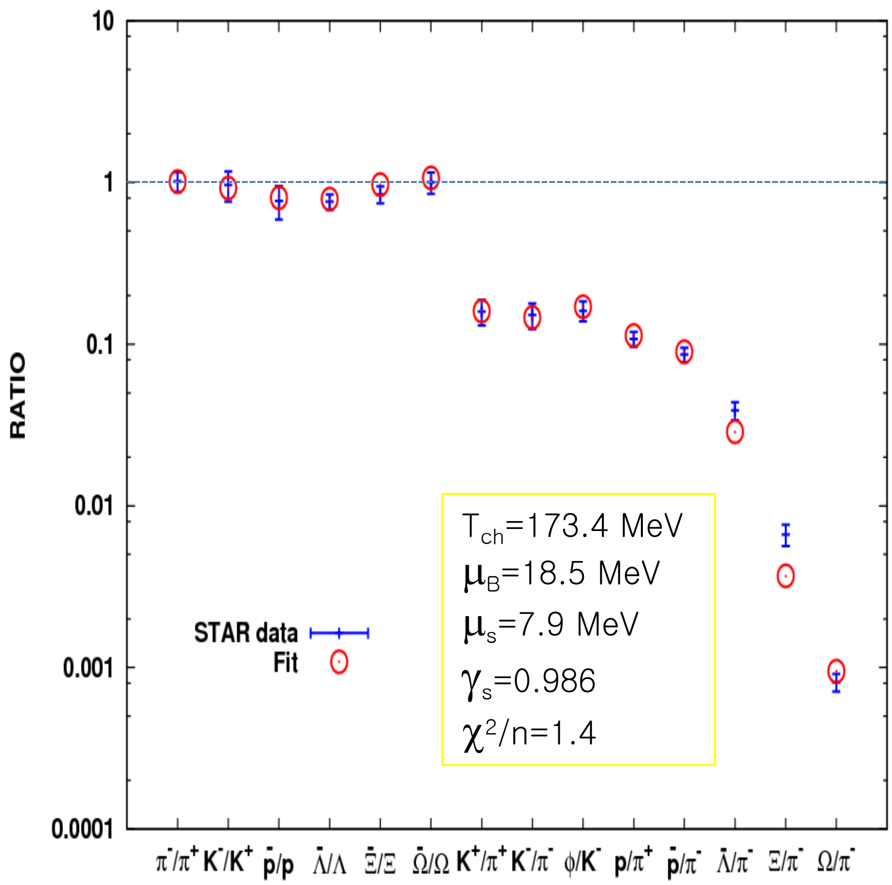
Transverse Mass Spectrum $$\frac{d^2 N_i}{m_T dm_T dy} = \frac{d^2 N_i^{th}}{m_T dm_T dy} + (\text{res. contr.})$$

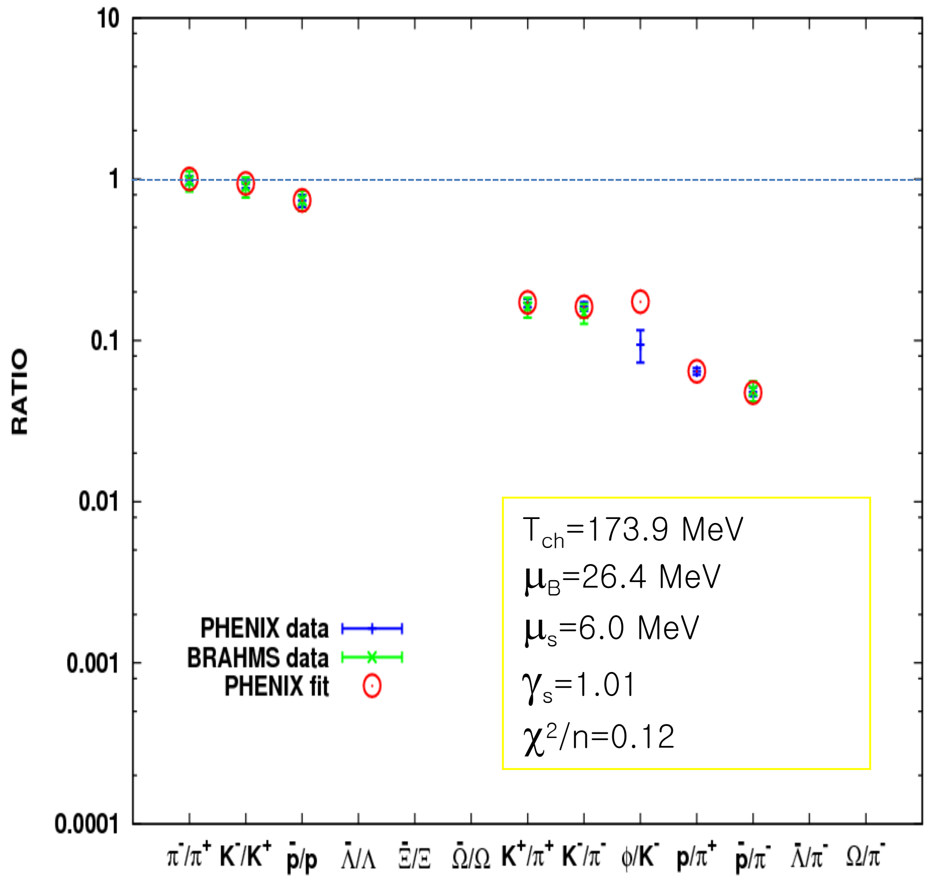
Chemical Potential **from particle ratios fixed at T_{ch}.**

$$\mu_i = \mu_\pi + T \ln\left[R_{i\pi} \frac{\int\int m_T dm_T dy (\frac{d^2 N_i'}{m_T dm_T dy})}{\int\int m_T dm_T dy (\frac{d^2 N_\pi'}{m_T dm_T dy})}\right] \qquad R_{i\pi} = N_i^{th}/N_\pi^{th}$$

the $'$ denotes that $\exp(\mu_i/T)$ is missing in this equation.

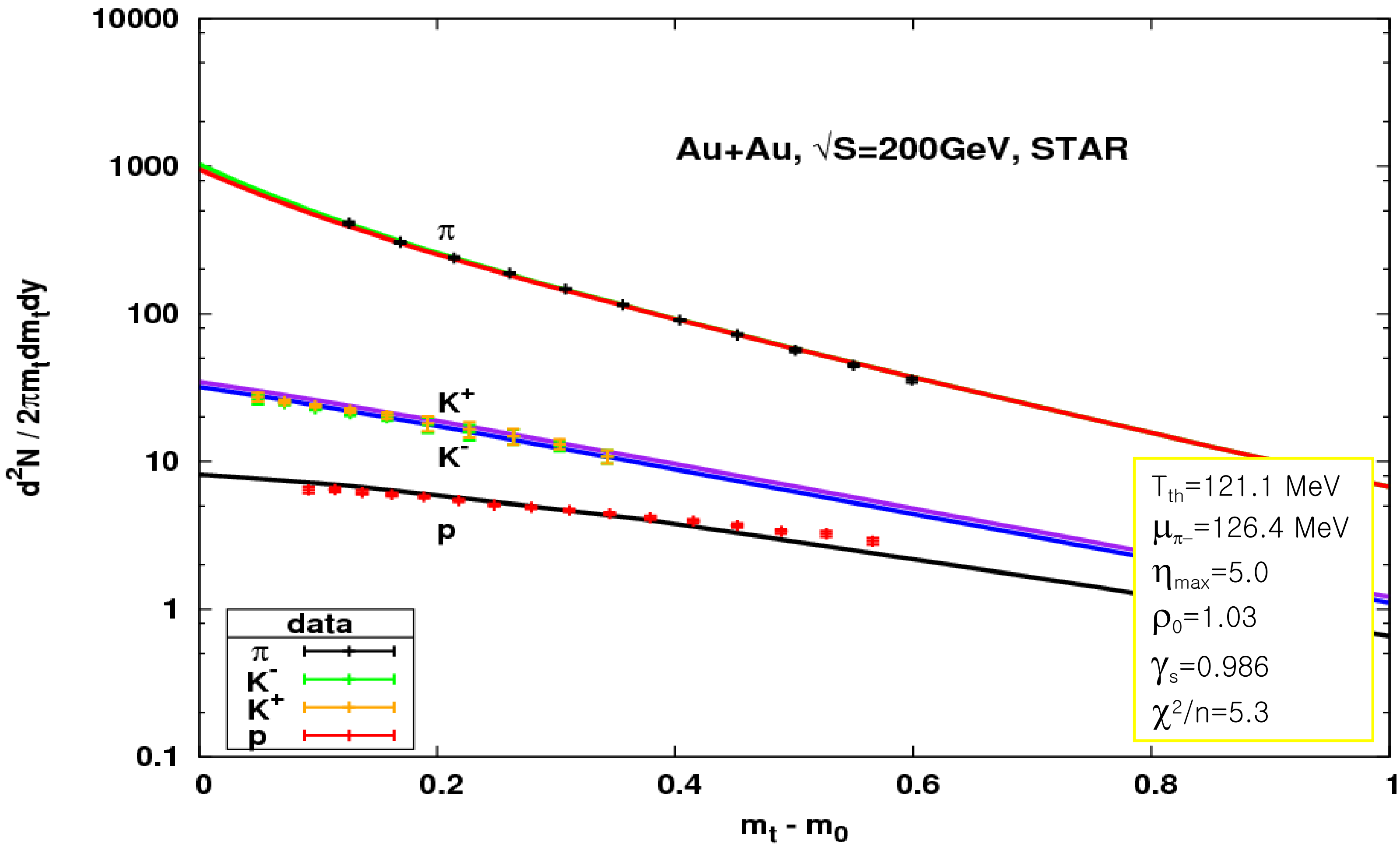
Results of chemical analysis



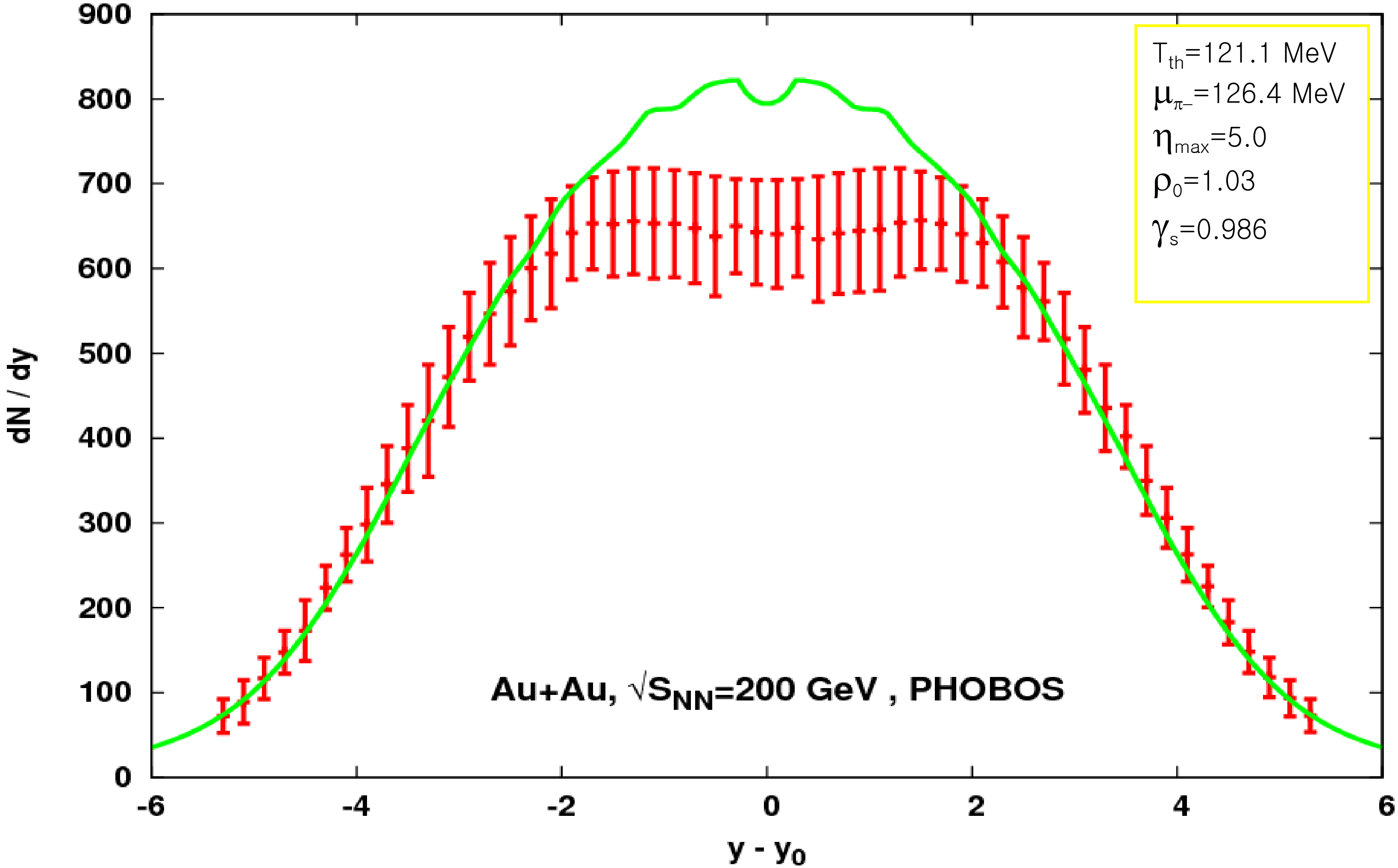


Weak decay contribution is properly included.

Result of thermal analysis



rapidity distribution dNch / dy



Conclusion

1. Within an expanding fireball model assuming two freeze-outs, both the yields, the magnitudes and slopes of the p_t spectra, and y-distribution of charged hadrons measured at RHIC are described.

2. Hadron ratios, mt spectra of pions, kaons and protons, and rapidity distribution of total charged hadrons are nicely fitted.

   Resonance contribution is important.

   For mt spectra, we have only one overall constant.

   Wide width of rapidity distribution is also nicely fitted by eta_max.

3. We are waiting for LHC data to analyze.