Two Freeze-out Model
in Relativistic Heavy ion Collisions

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Motivation

Two freeze-out Model

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Motivation

Chemical freeze-out from yields T_{ch} → **Thermal freeze-out from m_t spectra T_{th}**

$T_{ch} > T_{th}$

We want to fit both the yields, the magnitude and slopes of m_t spectra of various hadrons measured at RHIC with an expanding fireball model assuming two freeze-outs.

- Hydrodynamic equation + Hadronic afterburner (UrQMD)

  Heinz

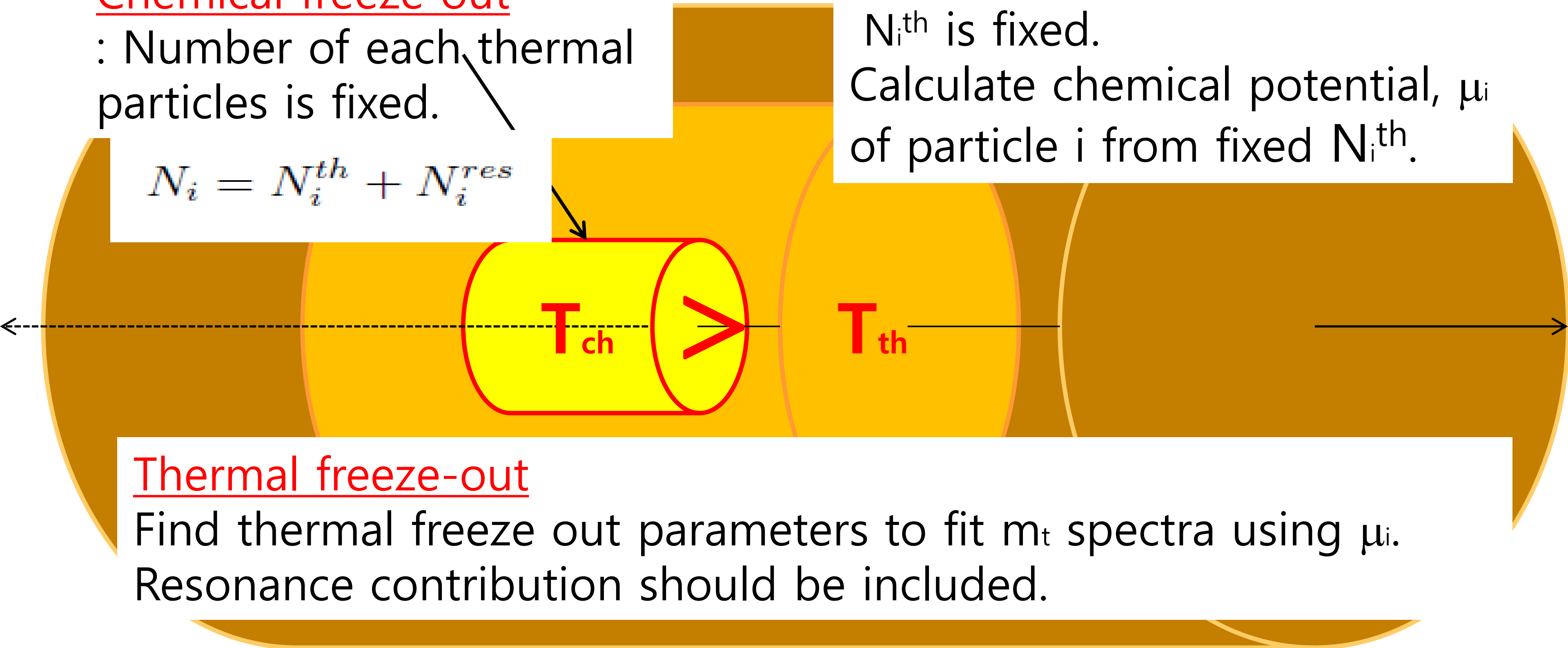
  - at Tsw, generate hadrons via Monte Carlo Method

- Hydrodynamic equation + Partial Chemical Equilibrium

  Hirano

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

Expanding fireball Model with two freeze-outs



Chemical freeze out

: Number of each thermal particles is fixed.

$$N_i = N_i^{th} + N_i^{res}$$

N_i^{th} is fixed.
Calculate chemical potential, μ_i of particle i from fixed N_i^{th}.

Thermal freeze-out

Find thermal freeze out parameters to fit m_t spectra using μ_i.
Resonance contribution should be included.

Hadron yields, slopes and magnitude of m_t spectra of various hadrons can be simultaneously explained within a single model.

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

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

$$v_L = z/t$$

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

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

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

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

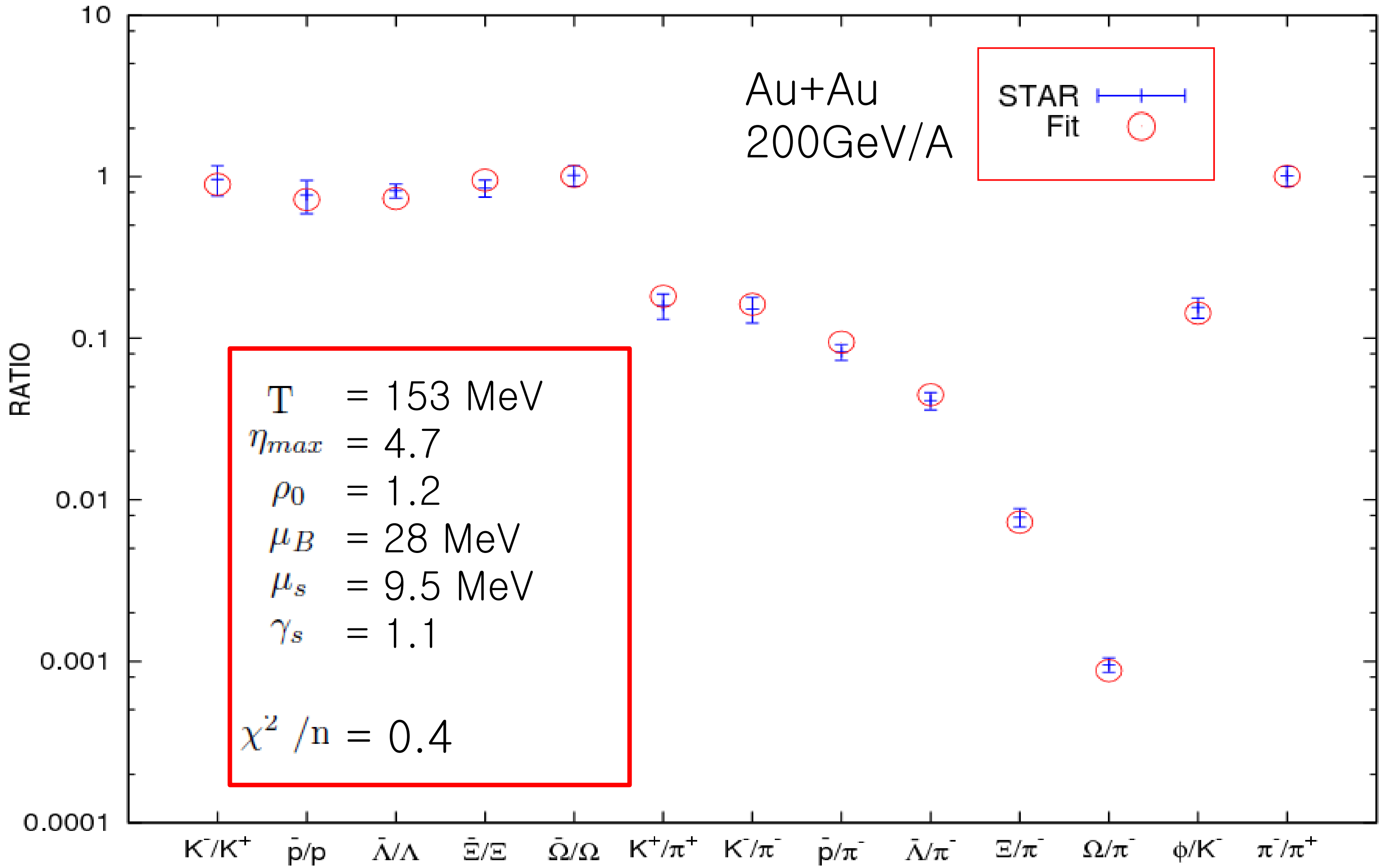
Transverse Mass Spectrum $$\frac{d^2 N_i}{m_T dm_T dy} = \frac{d^2 N_i^{th}}{m_T dm_T dy} + (\text{res. contr.})$$

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

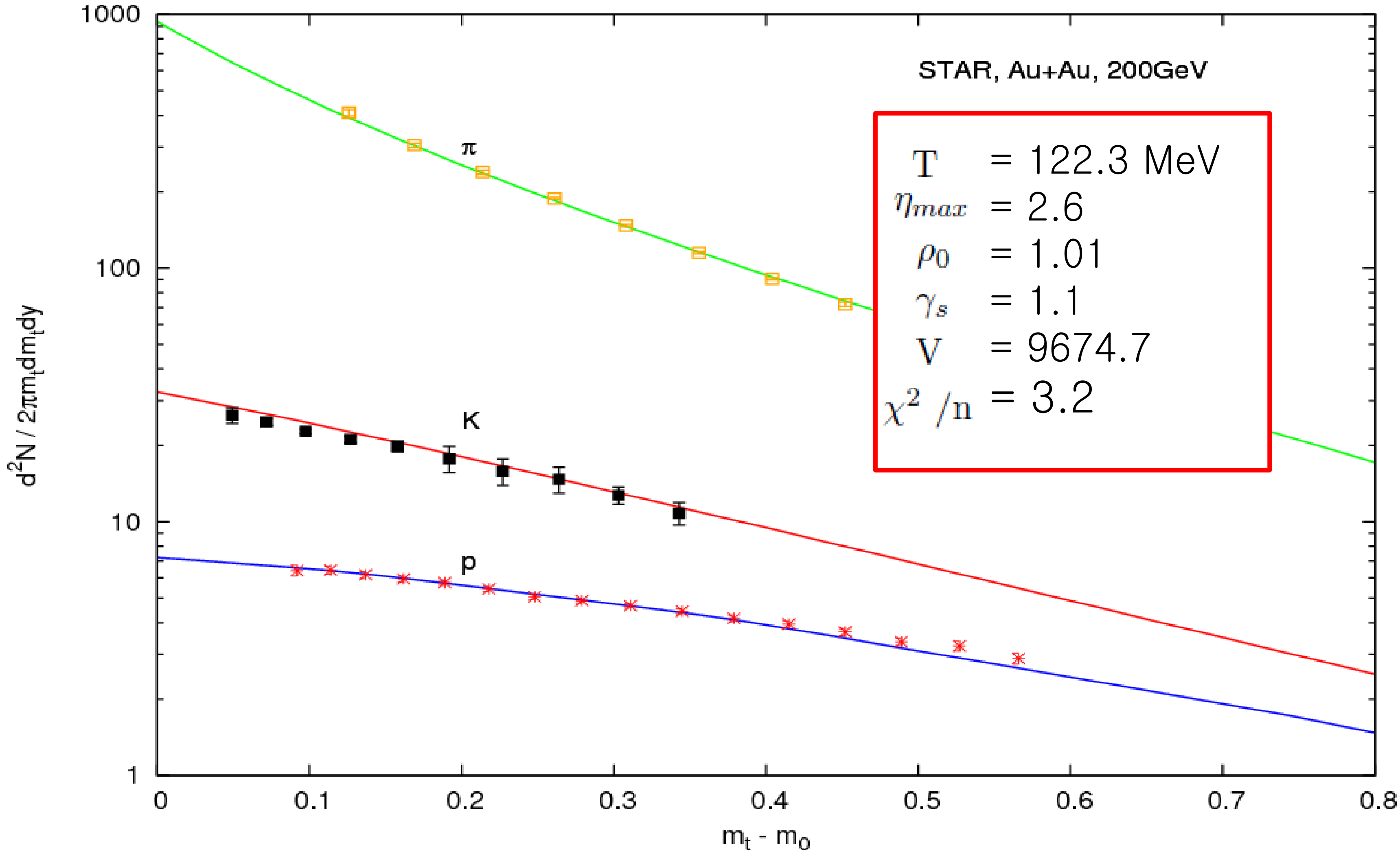
$$\mu_i = \mu_\pi + T \ln\left[R_{i\pi} \frac{\int\int m_T dm_T dy \left(\frac{d^2 N_i'}{m_T dm_T dy}\right)}{\int\int m_T dm_T dy \left(\frac{d^2 N_\pi'}{m_T dm_T dy}\right)}\right] \qquad R_{i\pi} = N_i^{th}/N_\pi^{th}$$

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

Chemical Freeze-out Result



Thermal Freeze-out Result



$T = 122.3$ MeV
$\eta_{max} = 2.6$
$\rho_0 = 1.01$
$\gamma_s = 1.1$
$V = 9674.7$
$\chi^2 / n = 3.2$

Conclusion

1. **In an ellipsoidally expanding fireball model, both the yields, magnitude and slopes of the p_t spectra at RHIC are described assuming two freeze-outs.**

2. **Particle p_t spectra are nicely fitted without arbitrary normalization. The resulting chemical freeze-out temperature is quite low, Tch – 153MeV.**

3. **We are waiting for LHC data to analyze.**