# Calculation of K*/K + and phi ratio assuming partial chemical equilibration at T_ch<T<T_th

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# Motivation and Goal

- Statistical model fits hadron ratios but over-predicts the ratios involving K* and phi.
- Due to their large inelastic cross sections, K* and phi do not chemically freeze-out at T_ch, but they do freeze-out later at T_th.
- At T_th, number of K* can be calculated from the numbers of pi and K+, and the number of phi from the numbers of K+ and K-.
- The results are comparable with ALICE data in Pb+Pb collisions at 2.76 TeV / A.

# Blast-wave model with two freeze-outs

**Chemical Freeze-out** at $T = T_{ch}$ : $N_i$'s fixed

$$\mu_i = (n_q - n_{\bar{q}})\mu_B/3 + (n_s - n_{\bar{s}})\mu_s$$

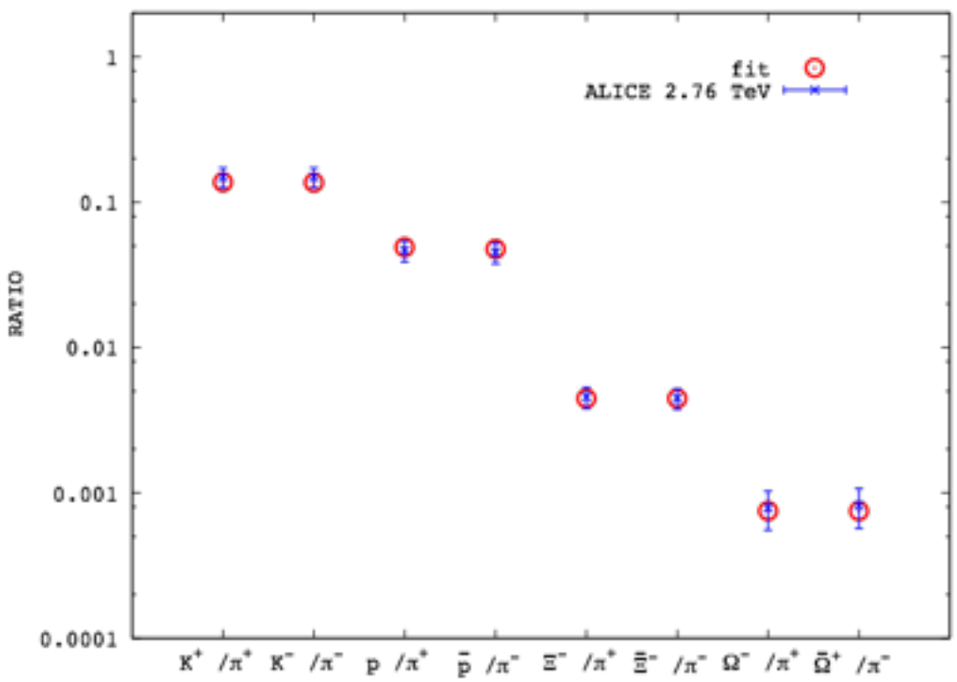
**Thermal Freeze-out** at $T = T_{th}$ : Momentum spectra calculated from

$$\frac{\mathrm{d}N_i^{th}}{m_T \mathrm{d}m_T} = \frac{d_i V_{eff}}{(2\pi)^2} \int_{-y_m}^{y_m} \mathrm{d}y \int_{-\eta_{max}}^{\eta_{max}} \mathrm{d}\eta \int_0^1 r' dr' m_T \cosh(y-\eta) \exp\left(-\frac{m_T \cosh(y-\eta)\cosh\rho - \mu_i}{T}\right) I_0\left(\frac{p_T \sinh\rho}{T}\right)$$

with $\mu_i$ caculated from $N_i$ as $\mu_i = T \ln[N_i / \int\int m_T \mathrm{d}m_T \mathrm{d}y (\frac{\mathrm{d}^2 N_i'}{m_T \mathrm{d}m_T \mathrm{d}y})]$ where the $'$ denotes that $\exp(\mu_i/T)$ is absent and calculate momentum spectra

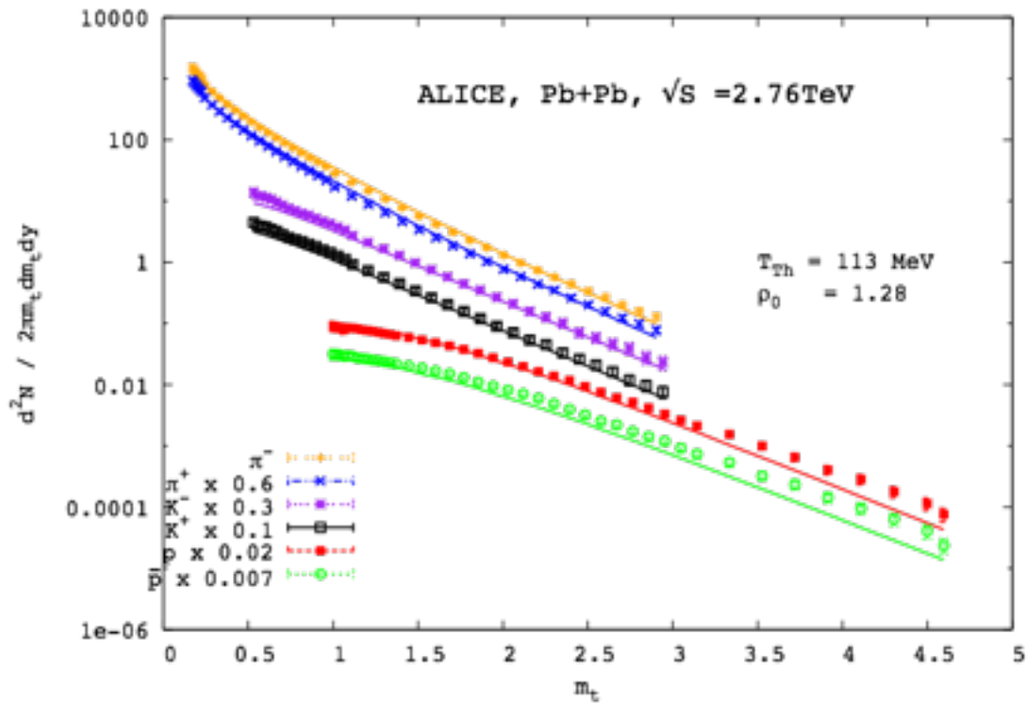
**Difference from usual blast-wave model : Relative magnitudes of $p_T$ spectra are already determined by $N_i$'s** , which is fixed at $T_{ch}$.

C. Choi, K.S.Lee, Phys.Rev.C84,064905(2011)




Chemical parameters fitted:
T=150 MeV
mu_B=0.37 MeV
mu_s=0.15 MeV
chi^2/N=0.9

Ratios only among pions, kaons, protons and anti-protons are fitted, whose pt spectrum is available




Thermal parameters fitted:
T=113 MeV
rho=1.28

C. Choi, K.S.Lee, Phys.Rev.C84,064905(2011)

# Partial Chemical Equilibrium

- Particles with large inelastic cross-section do not chemically freeze-out at T_ch but the reactions involved are chemically balanced  until at T_th.

$$K^* \rightleftharpoons \pi + K \qquad \phi \rightleftharpoons K^+ + K^-$$

- The numbers of K* and \phi can be calculated from the relation between chemical potentials at T_th.

$$\mu_{K^*} = \mu_\pi + \mu_K \qquad \mu_\pi = \mu_{K+} + \mu_{K-}$$

Assumption: Change in numbers of pion and kaons due to those reactions is negligible.

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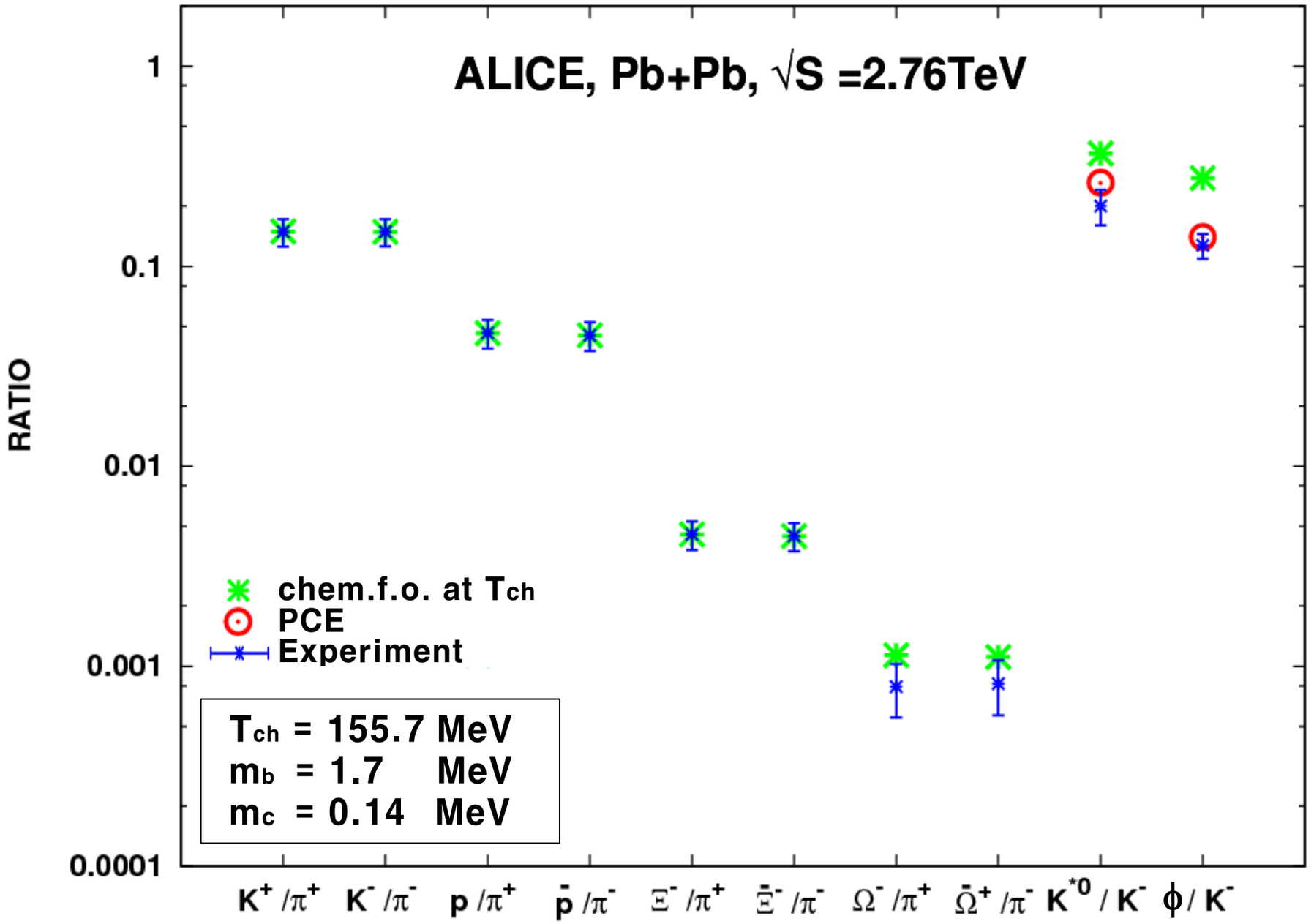
ALICE, Pb+Pb, √S =2.76TeV
RATIO
1
0.1
0.01
0.001
0.0001
chem.f.o. at Tch
PCE
Experiment
Tch = 155.7 MeV
mb = 1.7 MeV
mc = 0.14 MeV
K+ /π+
K- /π-
p /π+
p̄ /π-
Ξ- /π+
Ξ̄- /π-
Ω- /π+
Ω̄+ /π-
K*0 / K-
ϕ / K-

# Summary

Within blast-wave model which assumes two freeze-outs, namely the chemical and thermal freeze-out,

Reactions involving K* and \phi, which have large inelastic cross-sections, are assumed to be chemically balanced until T_th while other hadrons chemically freeze-out at T_ch (>T_th).

Thus calculated numbers of K* and \phi at T_th agrees with the measured ratios by ALICE collaboration.