Chemical and Kinetic Freeze-out Properties at RHIC

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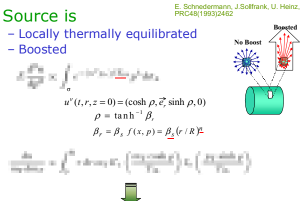
Blast Wave Model

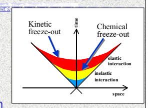
- Source is
  - Locally thermally equilibrated
  - Boosted

E. Schnedermann, J.Sollfrank, U. Heinz, PRC48(1993)2462



Compare p_T spectra to experimental data

Kinetic and Chemical Freeze-out



- Kinetic freeze-out
  - End of elastic interactions
  - Particle momenta are frozen
  - ⇔ Transverse momentum distribution

Ref. E. Schnedermann et al., PRC48(1993)2462

- Chemical freeze-out
  - End of inelastic interactions
  - Number of each particle species is frozen
  - ⇔ Particle ratios

Refs. J.Rafelski, PLB(1991)333; J.Sollfrank et al., PRC59(1999)1637

Model of Chemical Freeze-out

- Hadron resonance ideal gas

Refs. J.Rafelski PLB(1991)333; J.Sollfrank et al. PRC59(1999)1637

density of hadron i is

$$\rho_i = \gamma_s^{\langle s+\bar{s}\rangle_i} \frac{g_i}{2\pi^2} T_{ch}^3 \left(\frac{m_i}{T_{ch}}\right)^2 K_2(m_i/T_{ch})\, \lambda_q^{Q_i}\, \lambda_s^{s_i}$$

T_{ch} : chemical freeze-out temperature
μ_q : light-quark chemical potential
μ_s : strangeness chemical potential
γ_s : strangeness saturation factor

$\lambda_s = \exp(\mu_s/T_{ch})$, $Q_i = \langle u - \bar{u} + d - \bar{d} \rangle_i$
$\lambda_q = \exp(\mu_q/T_{ch})$, $s_i = \langle s - \bar{s} \rangle_i$

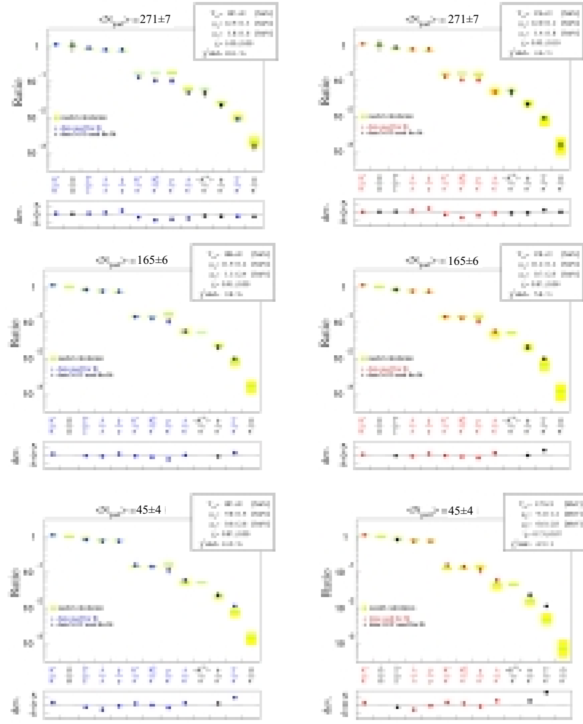
Relation to quantum number: Baryon $\mu_B = 3\mu_q$, Strangeness $\mu_S = \mu_q - \mu_s$

All resonances and unstable particles are allowed to decayed in the model

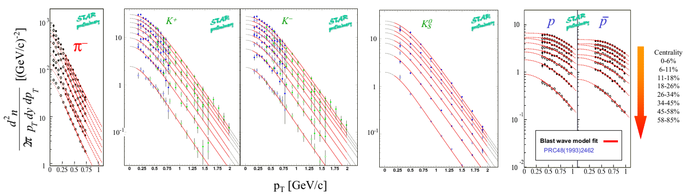
Compare particle ratios to experimental data

Common Chemical Freeze-out?

- Multi-Strange particles show earlier kinetic freeze-out
- How about Chemical Freeze-out?
  - Check two combinations of ratios for fit
    - with Ξ
    - without Ξ
- Particle ratios are obtained from recent STAR data
  - published / preprint / conference proceedings
  - some data are interpolated to adjust centrality ($\langle N_{part} \rangle$) to centrality bin of Ξ

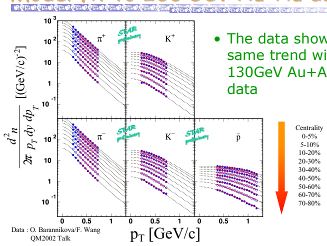


Model Fit to 130 GeV Data



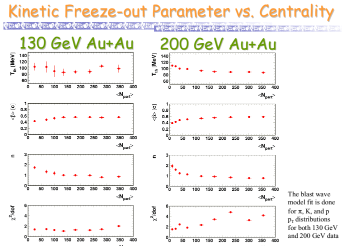
Blast wave model describes data very well

Model fit to 200 GeV Au+Au data

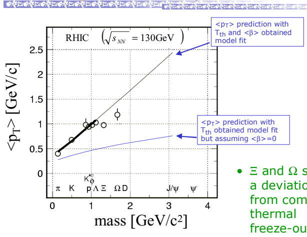


- The data show same trend with 130GeV Au+Au data

Kinetic Freeze-out Parameter vs. Centrality

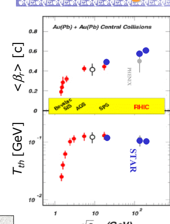


Mass Dependence of $\langle p_T \rangle$ (central data)



- Ξ and Ω show a deviation from common thermal freeze-out

Bombarding Energy Dependence

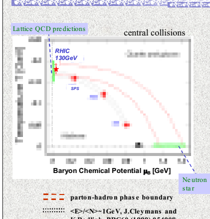


- From SPS to RHIC Energy
  - Increasing flow
  - Saturating temperature

Summary of Kinetic Freeze-out

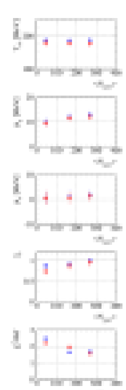
- The p_T distributions of π, K, and p are obtained as a function of centrality from RHIC-STAR at $\sqrt{s_{NN}}$=130GeV and 200 GeV Au+Au
- The blast wave model describes the data over all of centrality
- Within the blast wave model
  - As a function of centrality at RHIC
    - T_{th} ~ 100 MeV, goes down
    - $\langle \beta \rangle$ goes up and saturates (~0.55c (130GeV), 0.60c (200GeV))
    - Indication of change of flow profile
  - Beam energy dependence
    - Increasing flow
    - Saturating temperature

Summary of Chemical Freeze-out



- Beam energy dependence
  - Temperature increases
  - Baryon chemical potential decreases
- At RHIC
  - Being close to phase boundary
  - Fully strangeness equilibration (γ_s~1) at central collisions

Centrality Dependence of chemical freeze-out in 130GeV Au+Au Collisions



From the chemical freeze-out model

- T_{ch} ~ 175 MeV
- μ_q is increasing with centrality
  - Baryon transfer / Antibaryon absorbed?
- μ_s is close to zero
  - Close to phase boundary
  - Refs. PLB262(1991)333. PRC37(1988)1452, RC37(1988)1452
- γ_s is increasing with centrality
  - Fully strangeness equilibration in central collisions
- Deviation of multi-strangeness from non-strange/single-strangeness in peripheral collisions