Publication on system size dependence of strangeness production at 160 A GeV

Two approaches to study the transition into deconfinement:
Publication on
System size dependence of strangeness production ..... 

Draft for Letter circulated in editorial group
available from Claudia Höhne’s group directory
thought as a basis for discussion

Experimental data to be presented:
\[ \pi^+ K^- \phi \Lambda \bar{\Lambda} \] in C+C and Si+Si
discussed together with p+p S+S Pb+Pb

Main goal of the paper: to present an interpretation

Ideas:  
- QGP
- canonical suppression
  Hagedorn - Rafelski - Redlich

What is canonical suppression?

Application to our reactions
question: what is the nature of the thermally looking system?
what phase of an AA collision is to be identified with it?

- hadron gas picture: assumption: S determined in the hadronic phase
counter-evidence: correction factor \( \gamma_S + \phi \bar{\Lambda} \)

- partonic scenario:
  - plausible/necessary
to assume formation of coherent partonic subsystems
  by coalescence of resonances=strings=fireballs
  - statistical description of either the systems or their fragmentation
    (bridge to thermodynamics)
  - strangeness fraction determined here

Pühlhofer 290303
Semi-quantitative comparison

- theoretical saturation volume $V = (20 \pm 5) \, \text{fm}^3$
- expected size of coherent (sub-) volumes

AA collision, $A = 30$, $R = 3 \, \text{fm}$
CMS of the collision, $\gamma = 9$

volume containing the primary NN collisions
$\frac{2R}{\gamma} = 1 \, \text{fm}$

after longitudinal expansion by $\pm 1 \, \text{fm}$
$V = 80 \, \text{fm}^3$ at hadronization

total volume, not coherent because of rapidity spread

Estimate to be checked by UrQMD simulations (C. Höhne)

Outline of the discussion in the paper:

- assumption (no proof!): canonical suppression
- suggested model: formation of "coherent" partonic subsystems
- consistency between thermodynamic theory and estimated reaction volume
  no quantitative fit!
SIZE DEPENDENCE OF STRANGE PARTICLE PRODUCTION

\( \frac{K^+/\pi}{N_{\text{part}}} \)

\( \frac{K^-/\pi}{N_{\text{part}}} \)

\( \frac{\phi/\pi}{N_{\text{part}}} \)

\( \frac{\Lambda/N_{\text{part}}}{N_{\text{part}}} \)
CANONICAL SUPPRESSION / ENHANCEMENT

Given: an equilibrated relativistic system of "non-interacting" particles, $E, B, S, Q...$ fixed
Goal: particle composition (+ kinetic dist.)
Solution: statistical thermodynamics

- canonical or grand-canonical?
- (treatment of conservation laws)
- partition functions $\rightarrow$ observables

Aspect: strangeness production:
- treated as an additional phase canonically,
- the rest in grand-canonical approximation

Simplifying assumptions:
- Boltzmann statistics,
- only a single strange species, e.g. $K^\pm$
  (no resonances!)

Result: analytical formula ( Rafelski + Danos)

$$\langle n_{K^\pm} \rangle = \frac{I_1(14y)}{I_0(14y)} \cdot \sqrt[2]{4y}, \quad y = \left( \frac{VT^3}{2\pi^2} \right)^2 \left( \frac{m}{T} \right)^4 K_T \left( \frac{m}{T} \right)$$

$$\frac{y \gg 1}{(large \, V)} \quad \sqrt[2]{y} = \left( \frac{VT^3}{2\pi^2} \right)^2 \left( \frac{m}{T} \right)^4 K_T \left( \frac{m}{T} \right) \xrightarrow{y \gg 1} V \left( \frac{m}{T} \right)^3 e^{-\frac{m}{T}}$$

$$y \to 0 \quad y = \text{squark} \quad \rightarrow \quad e^{-2\frac{m}{T}}$$

$$\frac{\langle n_{K^\pm} \rangle}{\langle \pi \rangle} \sim \left. \frac{I_1(\ldots \, V)}{I_0(\ldots \, V)} \right|_{m, T} = \text{canonical suppression} f, \, \eta$$

\[\begin{array}{c}
\text{I}_0 \\
\text{I}_1
\end{array}\]
Fig. 1. The quenching factor \( \eta \) as a function of the reaction volume \( V \) in units of \( V_h = \frac{4}{3} \pi (1 \text{ fm})^3 \), for two temperatures. 
\[ = 4.2 \text{ fm}^3 \]

Fig. 2. Comparison of the quenching factors for hadronic and quark phases for \( T = 150 \text{ MeV} \).
Fig. 1. $K^+/\pi^+$ and $K^-/\pi^-$ ratios in a hadronic gas model as a function of the interaction volume normalized to the volume of the nucleon. The gas contains only particles having strangeness zero and $\pm 1$. Strangeness conservation is exact.

Cleymans, Redlich, Julicher
Z. Phys. C 51 (1991) 137

Fig. 1. Volume dependence of strange baryon densities normalized to their value calculated in $V_0 = \bar{V}_0 = 7.4$ fm$^3$ for $T = 168$ MeV and $\mu = 266$ MeV.

Hamisch, Toussj, Redlich
Comments (P. Seyboth, R. Stock, V. Friese)

- no proof of saturation behavior by the data
  however: given the present data + the theoretical ideas,
  saturation = most plausible scenario

- $N_W$ instead of $N_{\text{part}}$ on the abscissa

- inconsistencies of hadronic scenario:
  $\phi / \pi$ should not show canonical suppression
  $\Lambda / \pi$ should show stronger effect than kaons

- canonical suppression should act differently in partonic and in hadronic scenarios
  $m(K) = 500 \quad m(\pi) = 140 \quad m(s) = 460 \quad m(u/d) = 310 \text{ MeV}$ (constituent)

- not the partonic system itself (its $u : d : s : g$ ratio), but the **process** of hadronization is to be described in a statistical way! (contradiction to theoreticians)