

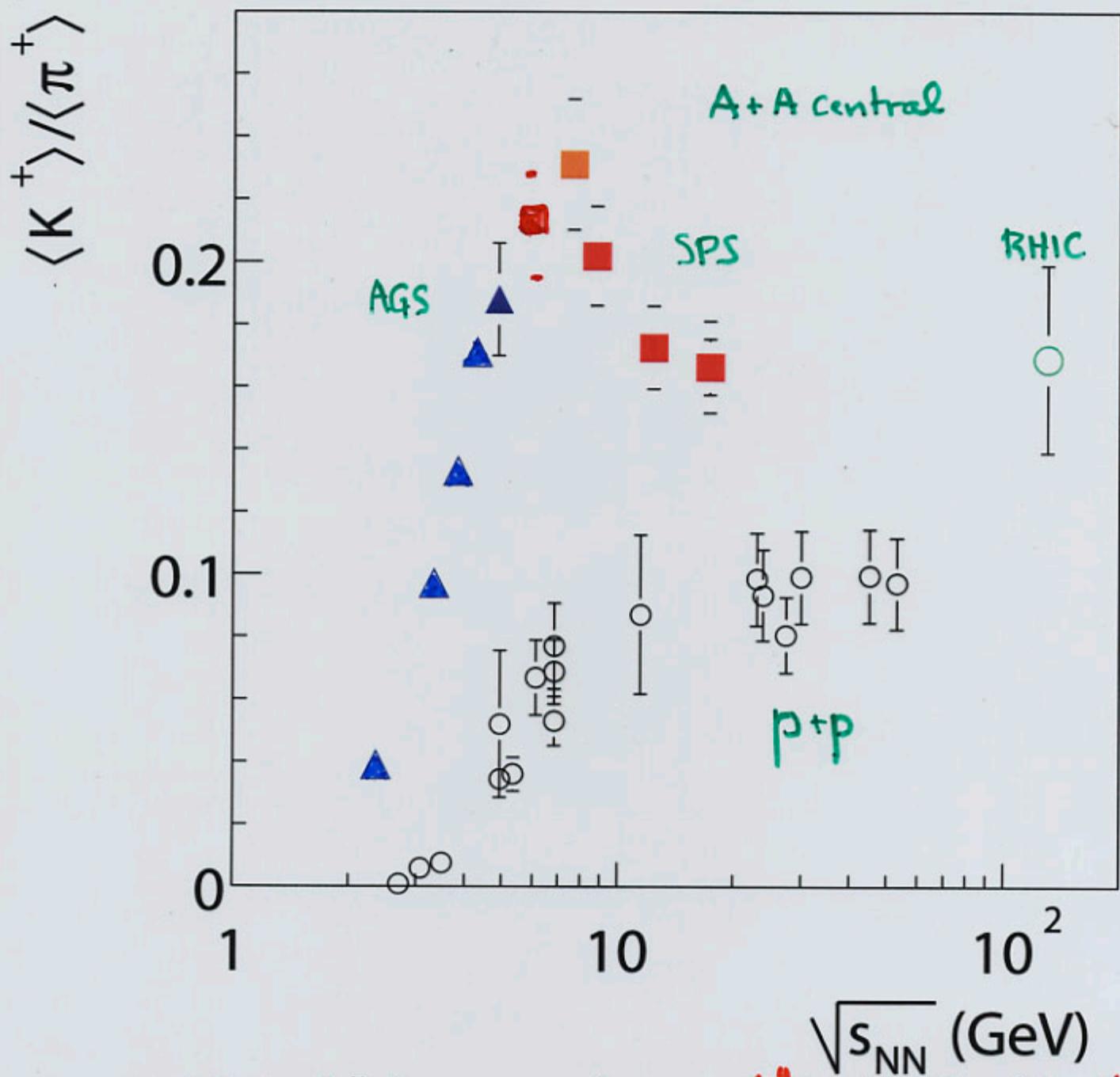
# NA49 Coll. Meeting 6. Oct. 2003

## Energy-Dependence of Strangeness Enhancement

R. Stock, University of Frankfurt

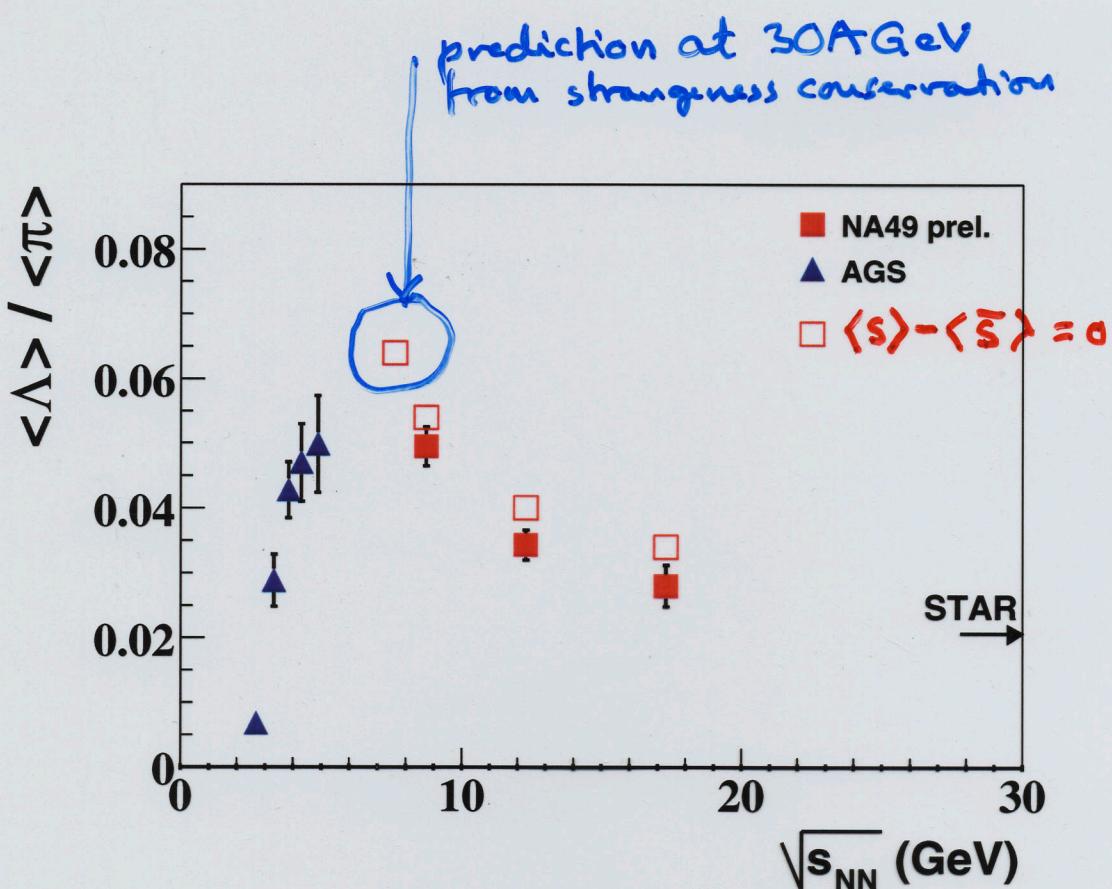
- Strangeness enhancement seen in  $K^+/\pi$ ,  $\Lambda/\pi$ :  
overall an effect of large hadronization volumes in A+A : transition canonical  $\rightarrow$  ground canonical ensemble (Tounsi + Redlich et al.)
- Sharp maximum in  $K^++\Lambda/\pi$  at  $\sqrt{s} \approx 6.5$  GeV  
beyond overall strangeness enhancement,  
not likely to be understood in transport or  
GC statistical models:  
we seem to require effect of a sharply local-  
ized mechanism ??
- New lattice QCD results for phase bound-  
ary at finite  $\mu_B$  (Bielefeld-Swansea)  
indicate strong net baryon density fluc-  
tuation at/near  $\mu_B \approx 450$  MeV,  $T \approx 155$  MeV.
- This "point" might just coincide with  
the turning point in the compression -  
expansion cycle of PbPb at  $\sqrt{s} \approx 6.5$  GeV  
corresponding to ca. 30 AGeV. System  
spends a relatively long time near fluc-  
tuation along phase boundary. At lower  
 $\sqrt{s}$  (AGS) the boundary is not reached; at  
higher  $\sqrt{s}$  (top SPS  $\rightarrow$  RHIC, LHC) it is rapidly  
overshot.
- Effect on the "associated"  $(K^++\Lambda)/\pi$  yield from  
QCD net baryon density fluctuation localized  
at  $\sqrt{s} \approx 6.5$  GeV by A+A dynamical evolution?
- Speculations on a nonlinear  $p_{ud} \rightarrow K^+\Lambda$  mecha-  
nism

# Energy dependence of strangeness enhancement



- Global "strangeness enhancement" in Pb+Pb / Au+Au over p+p
- "Strangeness enhancement" depends on  $\sqrt{s}$ !
- It has a sharp maximum at  $\sqrt{s}$  for low SPS energies
- We seem to need a "singularity" superimposed on a smooth background at this  $\sqrt{s}$ !

## Consequence for $\Lambda$ production



By requiring total strangeness  $= 0 \equiv s - \bar{s}$   
it follows from the  $K^+/\pi$  peak that  $\Lambda/\pi$   
also must have a corresponding peak!

i.e. the "associated production" channel  $K^+ + \Lambda$   
must share in the sharp overall strangeness  
enhancement peaks.

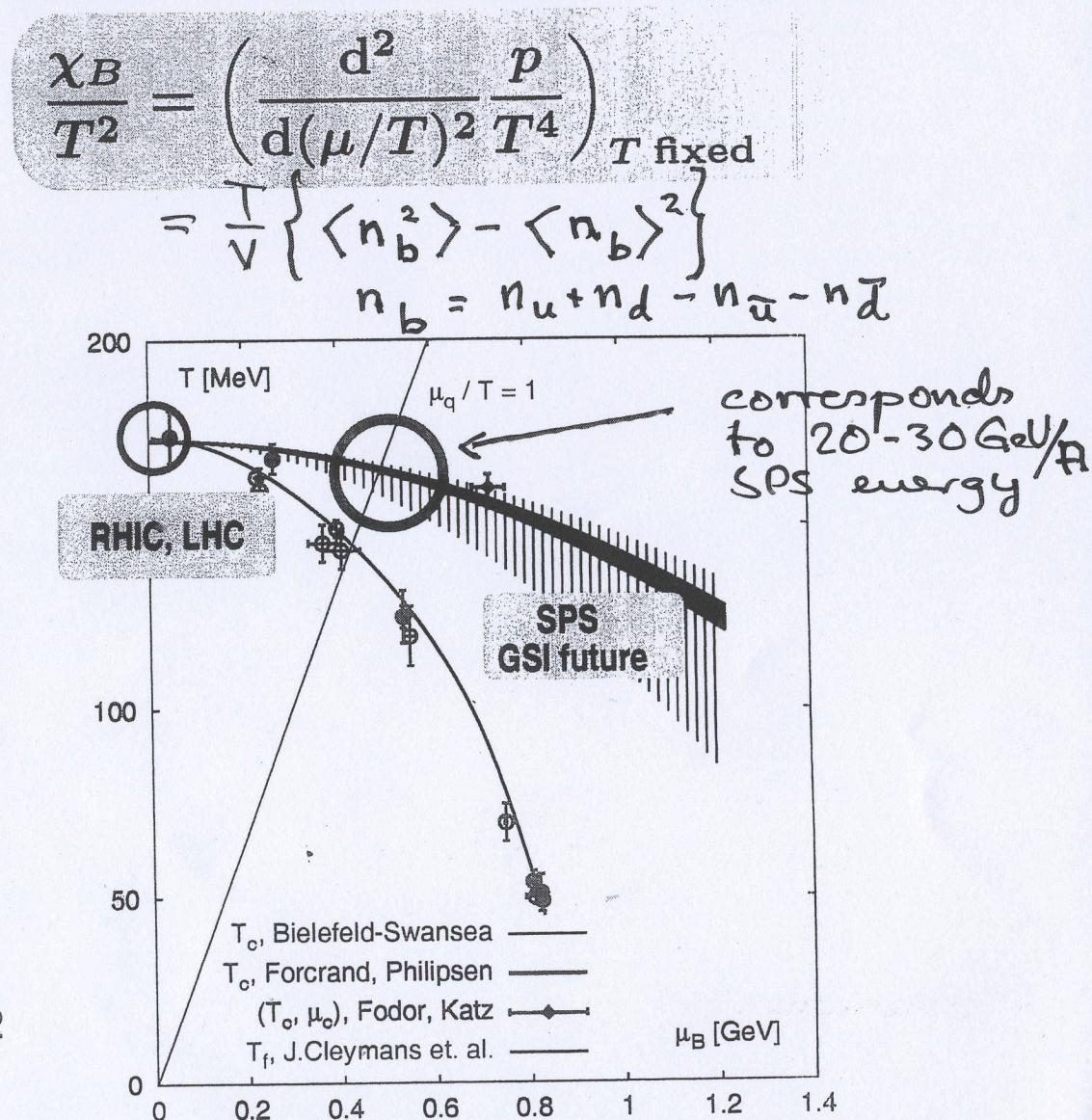
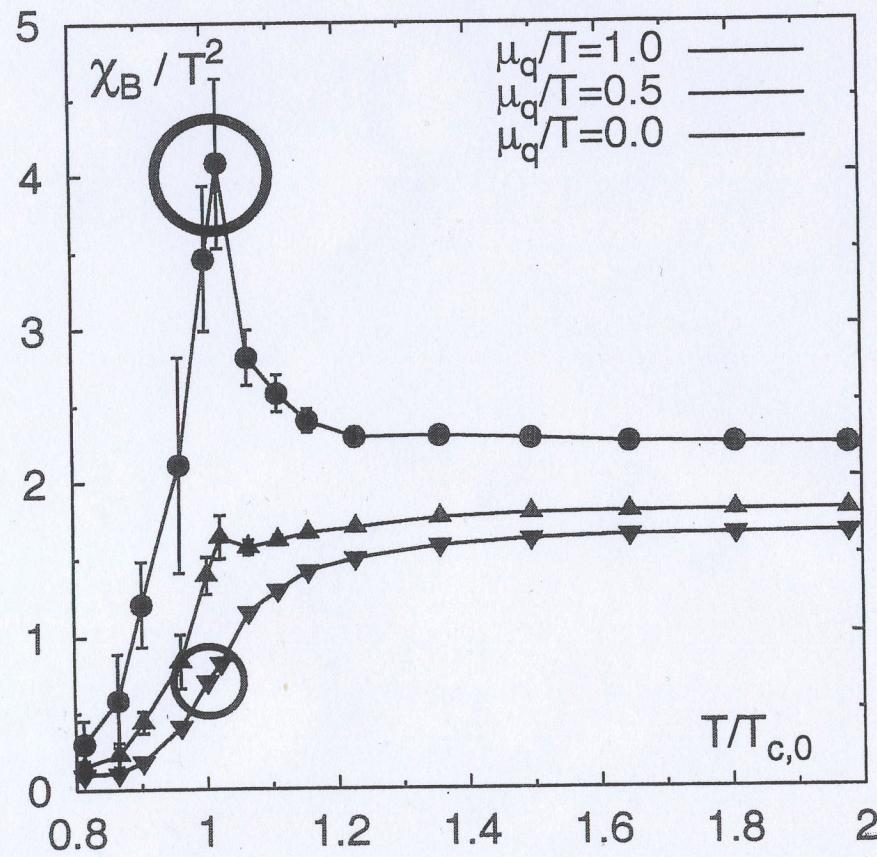
- ① We know that associated production mode depends critically on a high  $u+d$  net quark density (i.e. on a high baryochemical potential  $\mu_B$ )!  
Because  $K^+(\bar{s}u) + \Lambda(u\bar{d}s)$  contains 3 valence  $u+d$  quarks.
- ② In contrast to  $KK, \Lambda\bar{\Lambda}$  which have no net  $u,d$  content.

$\rightarrow \frac{\langle K^+ \rangle + \langle \Lambda \rangle}{\langle \pi \rangle}$  ratio driven by net  $u+d$  density. Fluctuation  
in this density (lattice QCD): effect on yield??!

hep-lat 0305 007

# Fluctuations of the baryon number density ( $\mu > 0$ )

baryon number density fluctuations:  
 (Bielefeld-Swansea, in preparation)



A possible connection between Lattice net baryon density fluctuation at/near  $\mu_B = 450 \text{ MeV}$  and associated  $K^+ + \Lambda$  production @  $V_s \approx 6.5 \text{ GeV}$

- The "associated production" channel  $u + u + d + s + \bar{s} \longleftrightarrow K^+(u\bar{s}) + \Lambda(u\bar{d})$  contains 3 net ud quarks, is thus driven by the net  $u+d$  quark density (high  $\mu_B$ ).
- This density fluctuates strongly at  $\mu_B \approx 450 \text{ MeV}, T = 155 \text{ MeV}$ : conditions that may just exactly be reached at  $V_s \approx 6.5 \text{ GeV}$  corresponding to  $30 \text{ GeV}/A$  in PbPb central collisions. Not reached below (AGS energies), far overshoot at top SPS  $\rightarrow$  RHIC.
- <sup>Bielefeld/Swansea</sup> Lattice QCD = large volume Grand Canonical ensemble of  $u, d, \bar{u}, \bar{d}, g$ : fluctuates, i.e.  $\rho(u - \bar{u}), \rho(d - \bar{d})$  fluctuates in sub-volumes whereas the total volume preserves fixed net baryon number total.
- In a PbPb central coll., this requires a large GC volume with conservation on average (globally).
- Ideal: we have seen that already STS exhibit Grand Canonical strangeness yields. The large PbPb volume may thus be seen as an ensemble of local STS size volumes, in which the local  $\rho(u\bar{d})$  fluctuates  $\uparrow$  or  $\downarrow$ , the overall proper  $\rho(u\bar{d})$  - baryon number being fixed on average over this ensemble.
- If the subvolumes hadronize separately locally, and if the relationship  $\rho(u\bar{d}) \rightarrow K^+ + \Lambda/\nu$  is nonlinear (like  $\rho^{4/3}$  or  $\rho^{3/2}$ ) we get an extra  $K^+ + \Lambda$  enhancement in central Pb+Pb: the "horn".

# A wild, preliminary guess:

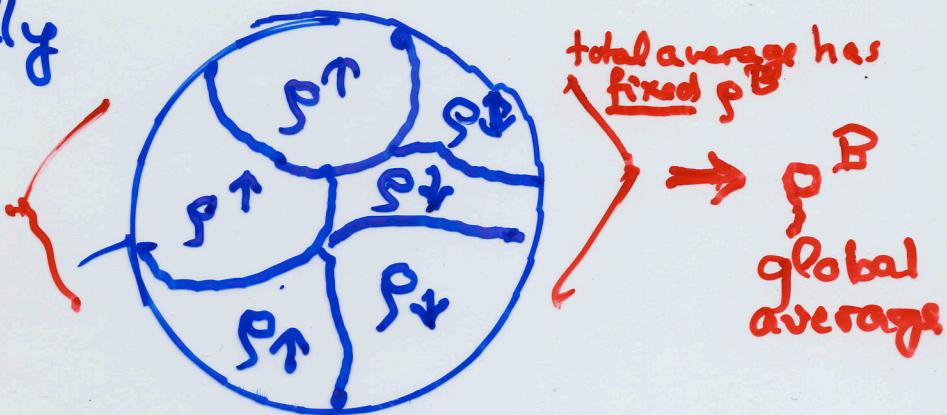
net baryon ( $u\bar{d}$ ) density fluctuations near critical QCD point  
enhance the  $K^+/\pi^+$  ratio

1. Lattice: large volume Grand Canonical ensemble of  $u, d, \bar{u}, \bar{d}, g$  at  $T \approx 160$  MeV
2. Bielefeld/Swansea: at  $\mu_Q = T$  strong fluctuation of  $\rho^B = \{\rho(u) + \rho(d) - \rho(\bar{u}) - \rho(\bar{d})\}$

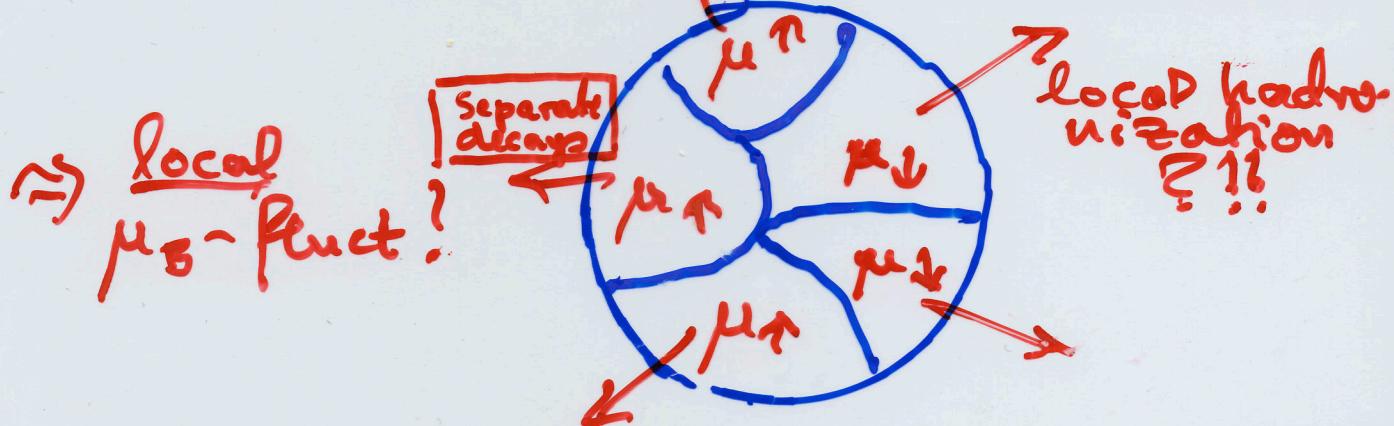
## 3. Symbolically

large volume in central Pb+Pb

↓  
subvolumes, by themselves already grand canonical, with locally  $\uparrow$  or  $\downarrow$   $\rho$  fluctuation



4. Assume  $\mu_B = \text{const} \rho_u^{2/3} \rho_{u-\bar{u}}^{2/3} \rho_d^{2/3} \rho_{d-\bar{d}}^{2/3}$  Fermi-gas



$$\rho_u \approx \rho_d \Rightarrow \mu_B = \text{const} \rho_u^{2/3} \rho_d^{2/3} = c \rho_Q^{4/3}$$

non-linear!

5. Consequence: "up" gains more than "down" takes away:

$$\frac{\langle K^+ \rangle}{\langle \pi^+ \rangle} \propto \frac{\langle \bar{s} \rangle}{\langle \bar{u} \rangle} \approx L^{-\{m_s - \mu_Q\}/T}$$

$$\frac{\langle \pi^- \rangle}{\langle \text{light} \rangle} \approx L^{-\{m_s - c \cdot \rho^{4/3}\}}$$

non linear ing!

?  $\rightarrow$  net increase in  $K^+/\pi^+, \pi^-/\pi^+$  by lattice fluct.?

An alternative idea concerning a non-linear relationship between  $\rho_{u,d}$  and  $K^+/\pi$ ,  $\Lambda/\pi$ :

### "Coalescence"



3 valence/net  
quarks

$\overset{\uparrow}{2}$  hadrons

$$\rho(u) \approx \rho(d) \quad \rho(K^+) \approx \rho(\Lambda)$$

$\Rightarrow$  Rate equilibrium at constant  $\rho(s) = \rho(\bar{s})$ :

$$\frac{\rho^3(\text{light quarks})}{\rho^2(K^+/\Lambda)} = f(E, V)$$

$$\Rightarrow \rho_{\text{equil.}}(K^+/\Lambda) \propto \left\{ \rho^{\text{equil.}}(u+d) \right\}^{3/2} \text{non-linear!}$$

Thus: In a large volume (Pb+Pb) grandcanonical lattice:  
a local high density of  $u, d$  will <sup>locally</sup> create more  $K^+, \Lambda/\pi$  than the corresponding local fluctuation to low density of  $u, d$  will take away?!

$\rightarrow$  output of  $\frac{K^+ + \Lambda}{\pi}$  will be higher than that expected for a non-fluctuating global, <sup>homogeneous</sup> hadronization volume

$\Delta$  a naive sketch only !!

