MULTIPLICITY FLUCTUATIONS

Also coupled to order parameter fluctuations. In fact their effect on multiplicity fluctuations is greater than on p_T fluctuations.

Stephanov KR Shuryak

BUT: large "background", due to impact parameter fluctuations.

Still, nonmonotonic variation with $\sqrt{s}$ would be suggestive.

BARYON, AND PROTON, NUMBER FLUCTUATIONS

Hatta Ikeda; Hatta Stephanov

- seen on the lattice → FIG
- should be loked for in experimental data

$\frac{\partial^2 \Omega}{\partial \mu_B^2}$ → B-fluctuations $\sim \xi^2$ + nonsingular

$\frac{\partial^2 \Omega}{\partial \mu_I^2}$ → no enhanced (u-d) fluctuations ~ nonsingular

Suggests $\frac{\mu_q}{T} \sim 1$ getting close to ●.

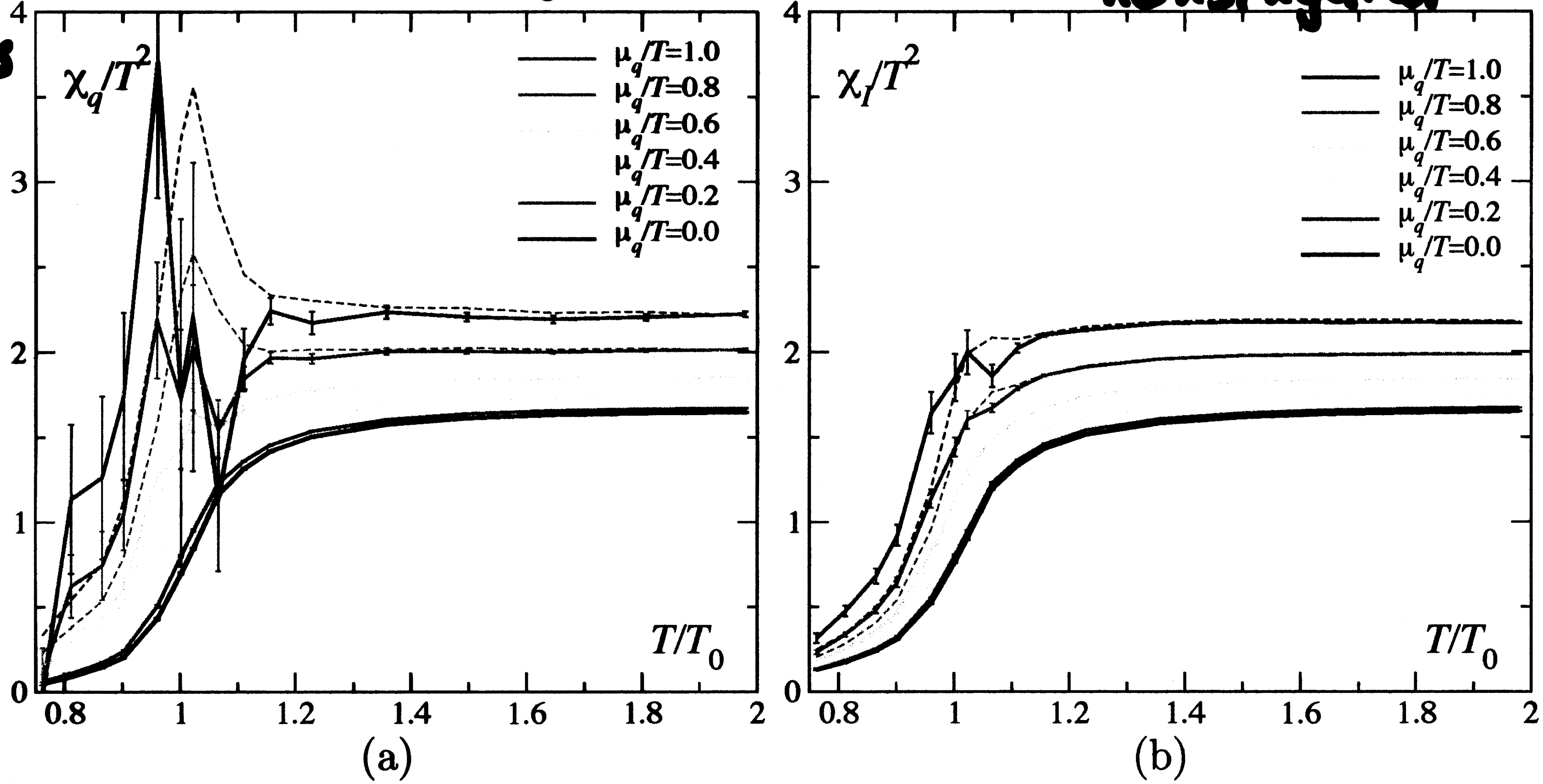


Figure 3.3: The quark number susceptibility χ_q/T^2 (left) and isovector susceptibility χ_I/T^2 (right) as functions of T/T_0 for various μ_q/T ranging from $\mu_q/T = 0$ (lowest curve) rising in steps of 0.2 to $\mu_q/T = 1$, calculated from a Taylor series in 6^{th} order. Also shown as dashed lines are results from a 4^{th} order expansion in μ_q/T.

(Because B fluctuates while isospin does not, proton fluctuations ~ B fluctuations)
Hatta Stephanov

Ejiri et al

PARTICLE RATIOS

NA 49

- Originally motivated by peak in $\langle K \rangle / \langle \pi \rangle$ at $\sqrt{s} = 7.6$ GeV.

  To better understand this, look at fluctuations of K/π ratio.

- Now motivated by observation that these fluctuations will better survive the late time hadron gas.

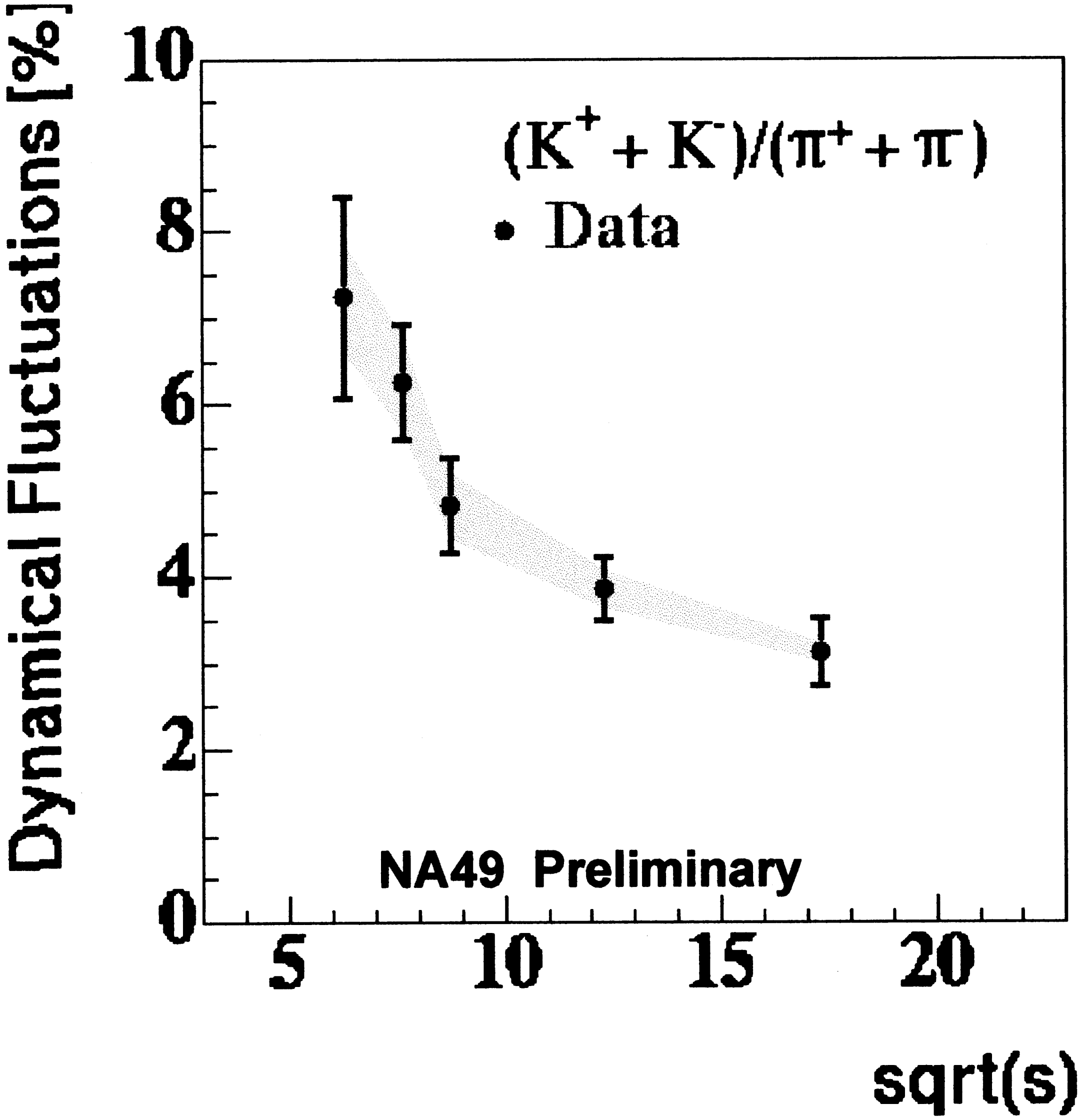
RESULT:

- Large K/π fluctuations at

  $\mu_B \sim 400 - 450$ MeV

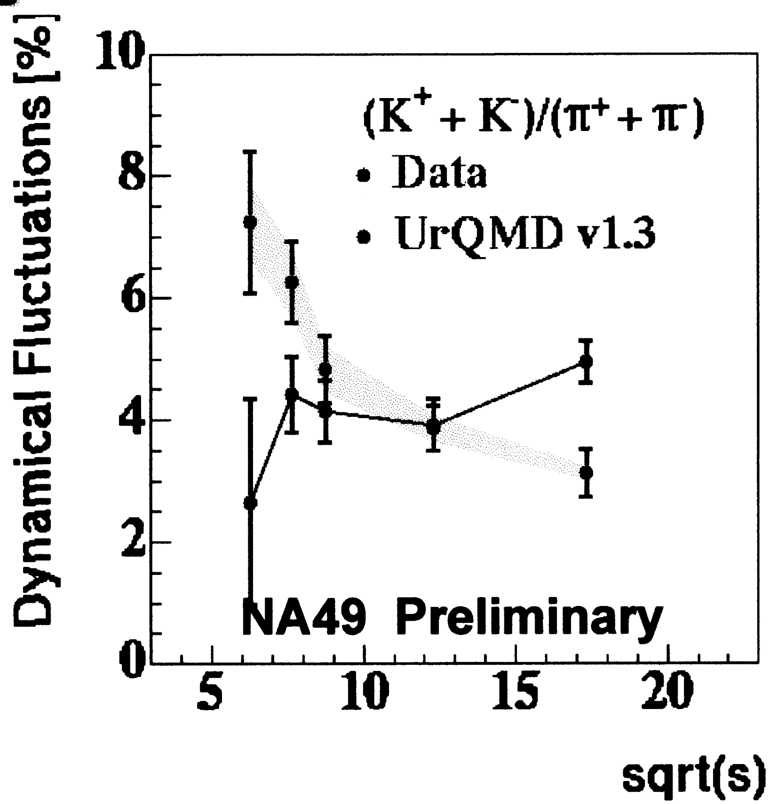
- Why no P/π fluctuations ???

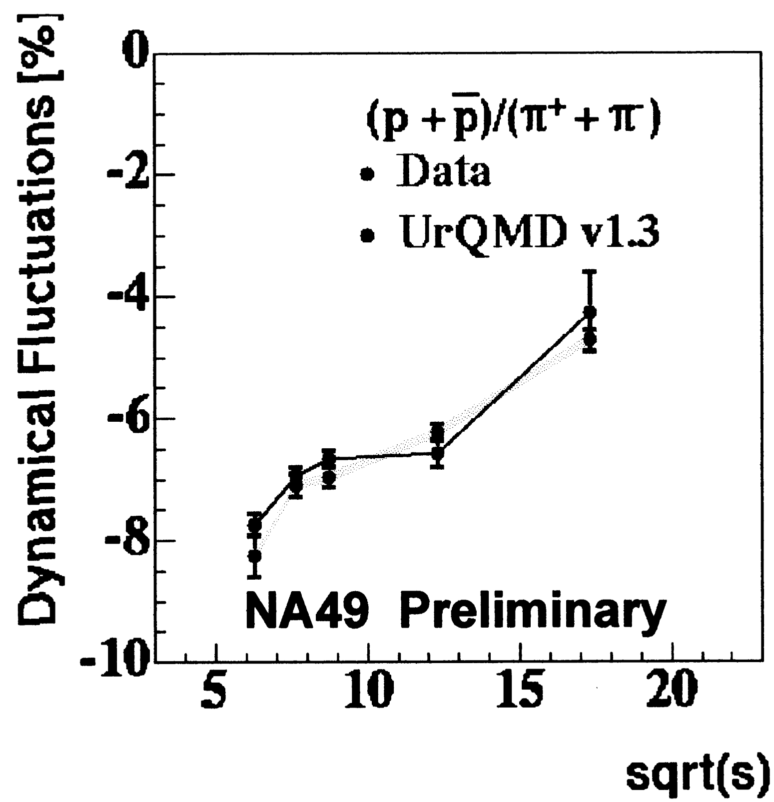
The E-by-E Kaon/Pion Ratio



Increased fluctuation signal at lower beam energies

Summary





- K/π fluctuations increase towards lower beam energy
  - **Significant enhancement over hadronic cascade model**
- p/π fluctuations are negative
  - **indicates a strong contribution from resonance decays**

Intriguing....

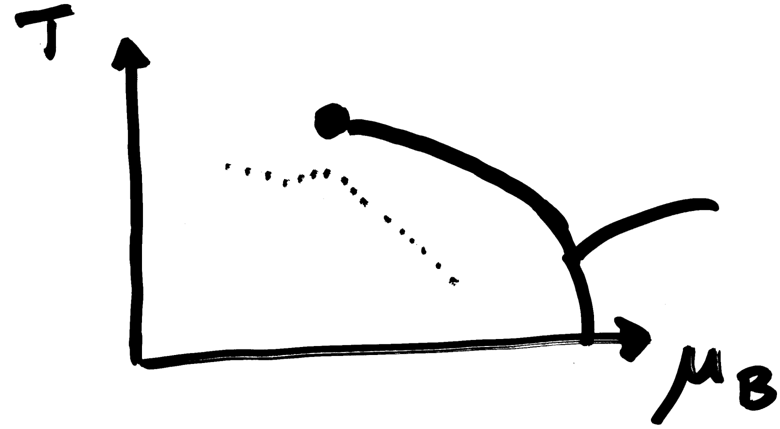
- Large event-by-event fluctuations in K/π at $\mu_B \sim 400-450$ MeV
- Are the K/π fluctuations dominated by low p_T π? Apparently not....
- Why no P/π fluctuations ???
- Koch Majumder Randrup suggest the K/π fluctuations due to hadronization of "blobs" left by a <u>first</u> <u>order</u> transition.
  - If so, expect non Gaussian fluctuations (vs. rapidity ?)
  - And, expect critical point at lower μ_B.
- At present, IMHO, these data are a very intriguing anomaly that is not well explained.

LINGERING AND FOCUSSING

Isentropic trajectories passing near the critical point on the phase diagram:

- Linger, due to enhanced C_V.
  - energy density, entropy density change at usual rate; T changes more slowly
  - likely a small effect, since C_V dominated by other modes, not by low p_T modes.
  - in principle, an elevated kinetic freezeout temperature

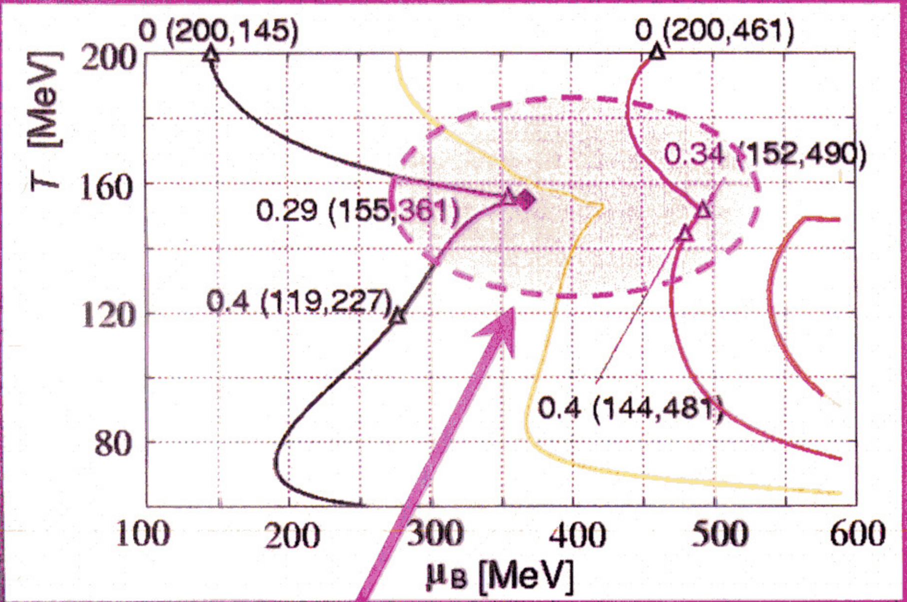
Stephanov
KR Shuryak



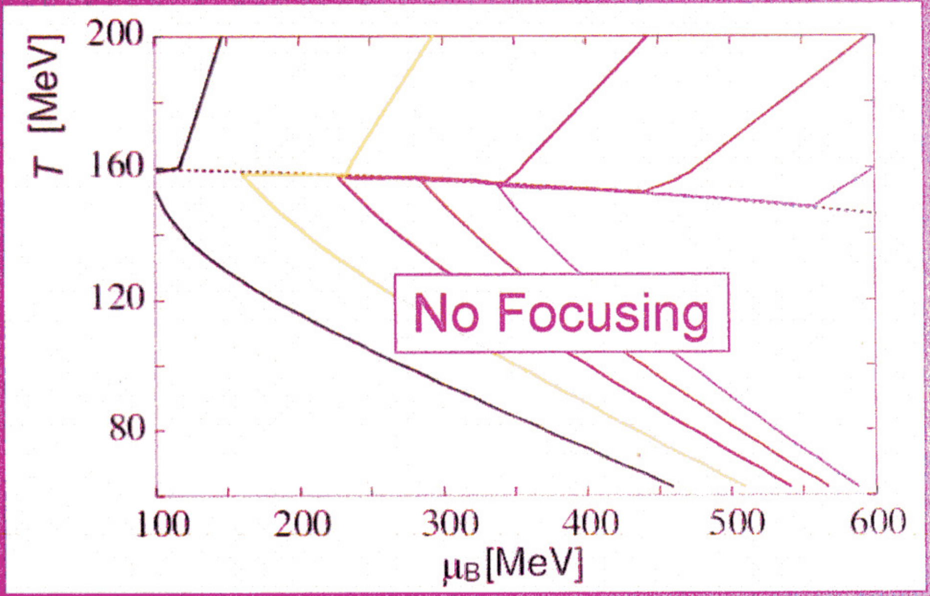
- are Focussed .... Stephanov KR Shuryak
  Asakawa Nonaka

With Large Critical Region

with CEP



without CEP (EOS in usual hydro calculation)



Focusing of Isentropic Trajectories

Excluded Volume Approximation
+ Bag Model EOS

used in most hydro calculations

M. Asakawa (Osaka University)

Focussing of trajectories that pass near the critical point:

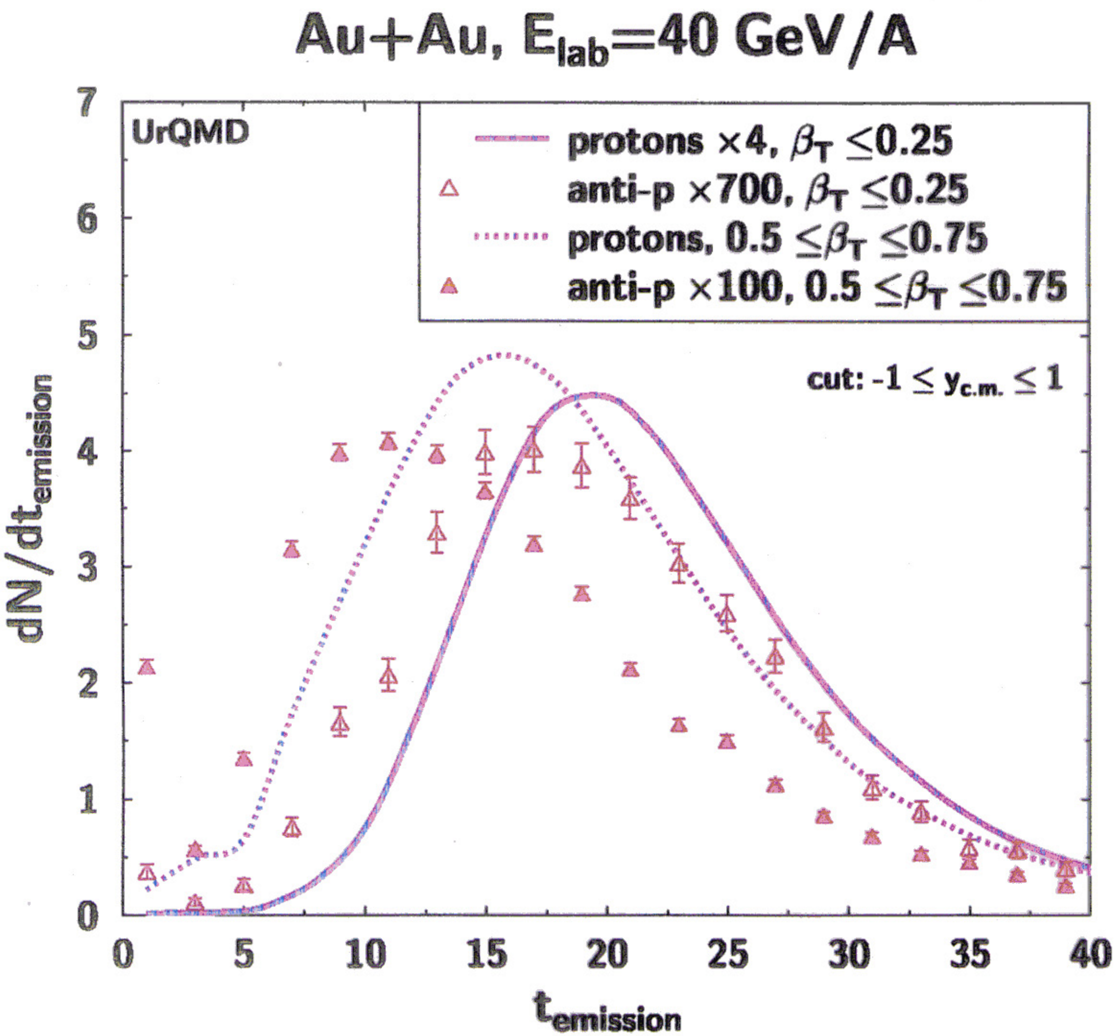
- is another argument that one need not take very small steps in μ_B.....
- has observable consequences that do not involve event-by-event fluctuations.

Asakawa Bass Muller Nonaka

Two key ideas:

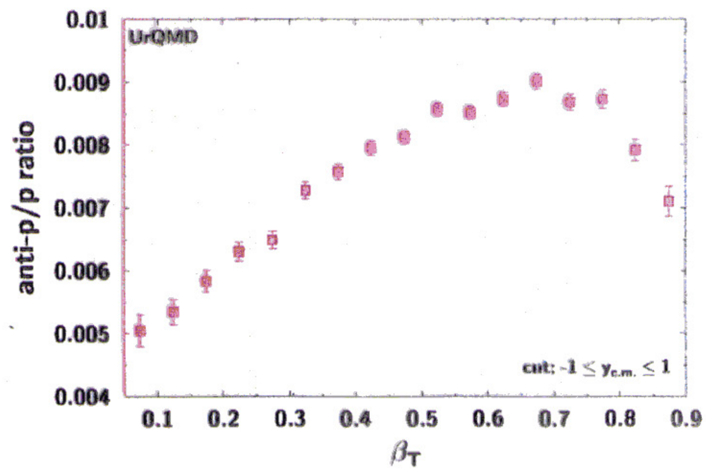
- Higher p_T p & $\bar{p}$ freezeout earlier
- Only for trajectories near critical point, higher p_T p & $\bar{p}$ freezeout at higher μ/T
  $\Rightarrow$ $\bar{p}/p$ ratio drops w p_T.

Emission Time Distribution

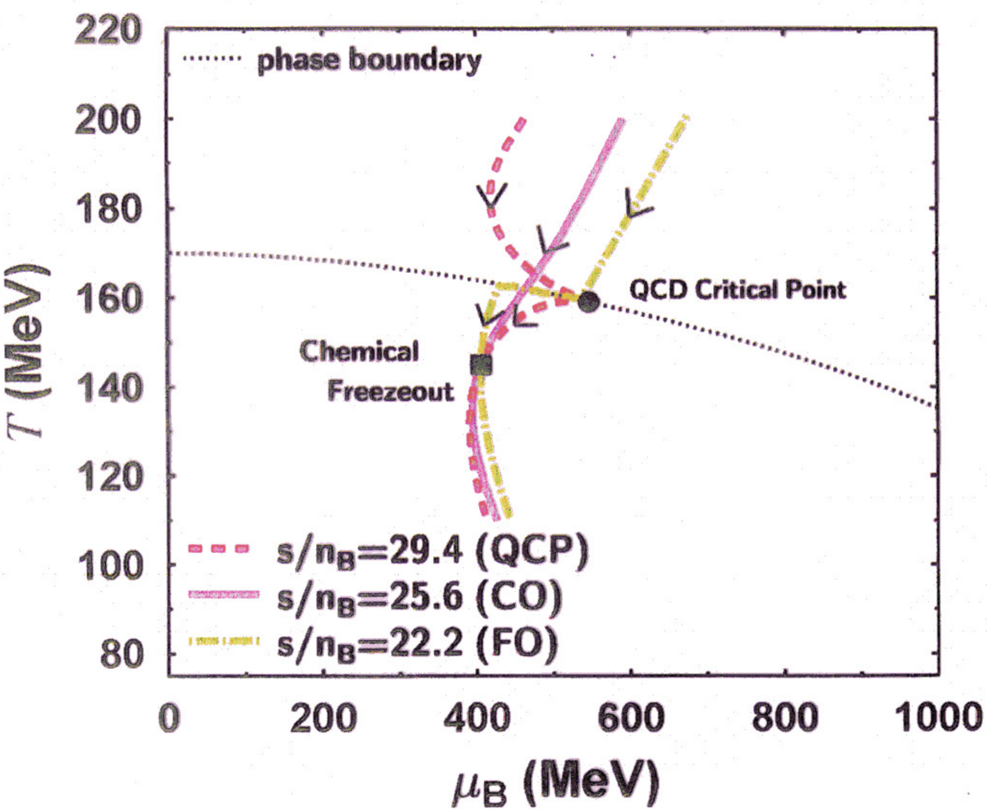


Emission Time

- Larger β_T, earlier emission
- No CEP effect (UrQMD)



Consequence



For a given chemical freezeout point, prepare three isentropic trajectories: w/ and w/o CEP

Along isentropic trajectory:

- FO, CO $\frac{\mu_B}{T}$ ↗
- QCP $\frac{\mu_B}{T}$ →

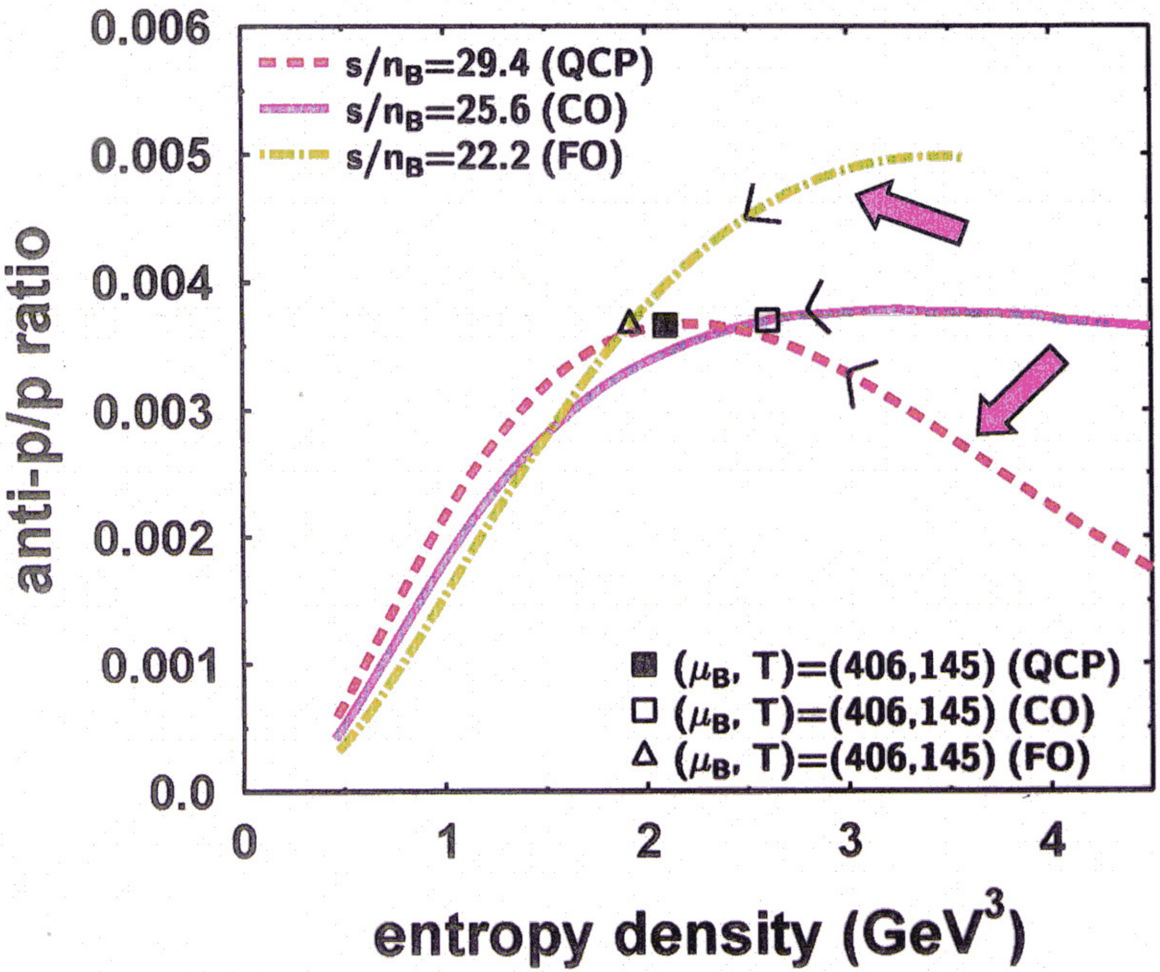
⇓ *Principle I*

As a function of $p_T(y_T)$:

- FO, CO $\frac{\mu_B}{T}$ ↘
- QCP $\frac{\mu_B}{T}$ ↗

➡ $\bar{p}/p$ ratio : near CEP steeper

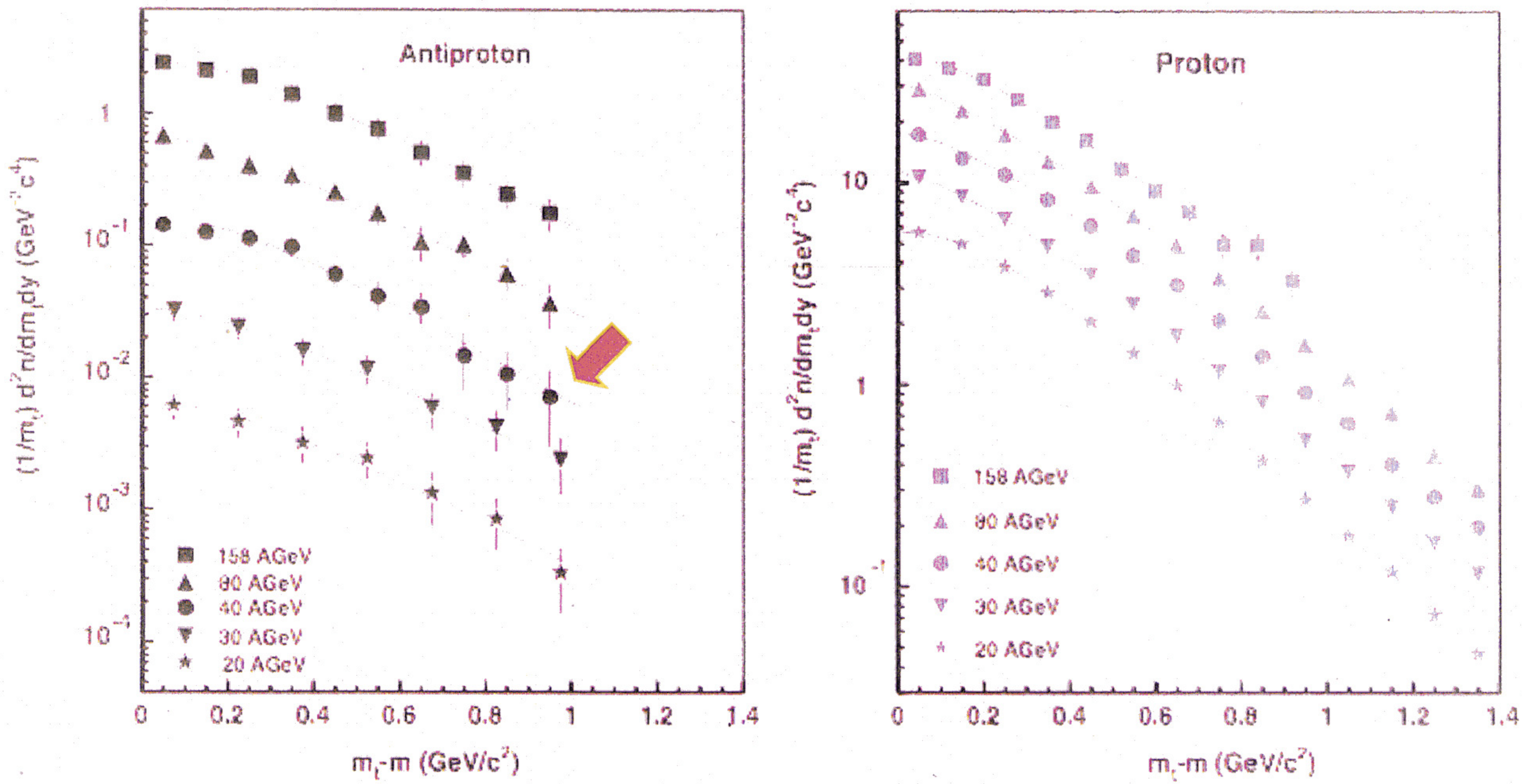
Evolution along Isentropic Trajectory



$$\bar{p}/p \sim \exp\left(-\frac{2\mu_B}{T}\right)$$

with CEP
steeper $\bar{p}$ spectra at high P_T

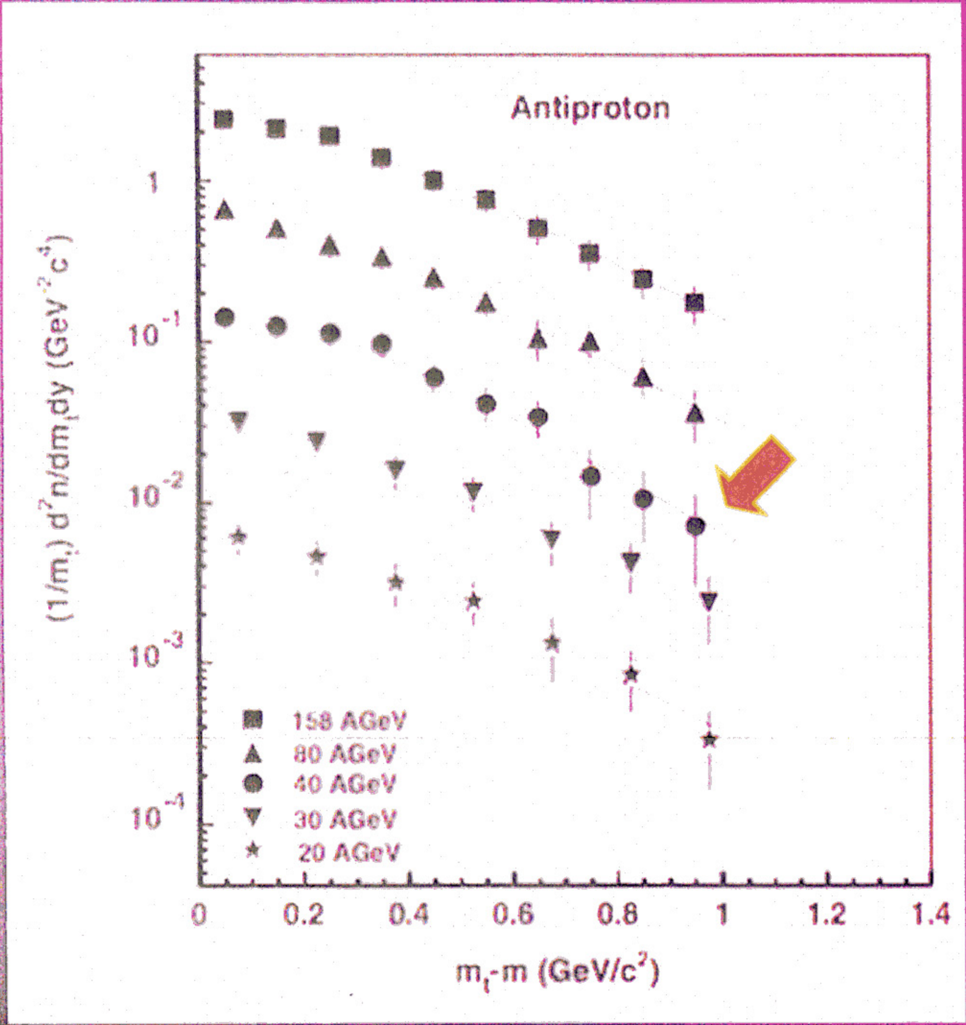
Effect on Spectra ?



steeper $\overline{p}$ spectra at high P_T

NA49, PRC73, 044910(2006)

Result of One Temperature Fit



NA49, PRC73, 044910(2006)

	E_{beam} (A GeV)	dn/dy	T (MeV)	$\langle m_t \rangle - m$ (MeV/c^2)
$\bar{p}$	158	1.66 ± 0.17	291 ± 15	384 ± 19
	80	0.87 ± 0.07	283 ± 30	385 ± 41
	40	0.32 ± 0.03	246 ± 35	355 ± 51
	30	0.16 ± 0.02	290 ± 45	395 ± 60
	20	0.06 ± 0.01	279 ± 64	394 ± 60
p	158	29.6 ± 0.9	308 ± 9	413 ± 13
	80	30.1 ± 1.0	260 ± 11	364 ± 16
	40	41.3 ± 1.1	257 ± 11	367 ± 16
	30	42.1 ± 2.0	265 ± 10	362 ± 14
	20	46.1 ± 2.1	249 ± 9	352 ± 13

- Only one experimental result for $\bar{p}$ slope
- Still error bar is large