Chemical fit at RHIC

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LBNL

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V.Koch, H.G.Ritter, N.Xu (LBNL),

Z.Xu (BNL),

and Organizers

Outlook

- Introduction
- Model
- Data
- Freeze-out parameters
- Model uncertainties
- Summary
- Open issues

Introduction

- Bulk properties of the heavy ion collisions
- Statistical approach for particle production
- Dynamical information – may be lost?
- Chemical freeze-out
  - occurs at an uniform condition? <E>/<N> ~ 1GeV
  - SIS (<1GeV), AGS (~5 GeV), SPS (~20 GeV), and RHIC (130 GeV)

The study for RHIC data

P. Braun-Munzinger,D.Magestro, K. Redlich, and J. Stachel, hep-ph/0105229

W. Florkwski, W. Broniowski, and M. Michalec, nucl-th/0106009

F. Becattini, workshop in Trento, June, 2001.

N. Xu and M. Kaneta, nucl-exp/0104021

Model

Hadron resonance ideal gas

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

Particle density of each particle

$$\rho_i = \gamma_s^{|s_i|} \frac{g_i}{2\pi^2} {T_{ch}}^3 \left(\frac{m_i}{T_{ch}}\right)^2 K_2(m_i/T_{ch})\ {\lambda_q}^{Q_i}\ {\lambda_s}^{s_i}$$

$$\lambda_q = \exp(\mu_q/T_{ch}), \quad \lambda_s = \exp(\mu_s/T_{ch})$$

- Q_i : 1 for u and d, -1 for $\bar{u}$ and $\bar{d}$
- s_i : 1 for s, -1 for $\bar{s}$
- g_i : spin-isospin freedom
- m_i : particle mass
- T_{ch} : Chemical freeze-out temperature
- μ_q : light-quark chemical potential
- μ_s : strangeness chemical potential
- γ_s : strangeness saturation factor

All resonances and unstable particles are decayed

Comparable particle ratios to experimental data

Model (cont.)

- Hadron resonance ideal gas
  - including higher mass resonances(≤1.7GeV)

π, η, ρ, ω, η', ϕ, $f_0(980)$, a_0 (980), $h_1(1170)$, b_1 (1235), a_1 (1260), $f_2(1270)$, f_1 (1285), $\eta(1295)$, $\pi(1300)$, $a_2(1320)$, $f_0(1370)$, $\eta(1440)$, $\omega(1420)$, f_1 (1420), $\rho(1450)$, f_0 (1500), f_1 (1510), $f_2'(1525)$, $\omega(1600)$, $\pi_2(1670)$, $\phi(1680)$, $\rho3(1690)$, $f_J(1710)$, $\rho(1700)$

p, n, N(1440), N(1520), N(1535), N(1650), N(1675), N(1680), N(1700)

$\Delta(1232)$, $\Delta(1600)$, $\Delta(1620)$, $\Delta(1700)$

K, K*, $K_1(1270)$, $K_1(1400)$, K*(1410), $K_0^*(1430)$, $K_2^*(1430)$, K*(1680)

Λ, $\Lambda(1450)$, $\Lambda(1520)$, $\Lambda(1600)$, $\Lambda(1670)$, $\Lambda(1690)$

Σ, $\Sigma(1385)$, $\Sigma(1660)$, $\Sigma(1670)$

Ξ, $\Xi(1530)$, $\Xi(1690)$

Ω

- For mid-rapidity, no requirement of
  - Strangeness neutrality
  - Charge/Isospin conservation

Ratio data

Central		Peripheral	
K^+/K^-	1.13 ± 0.01 ± 0.06 (STAR) 1.29 ± 0.07 ± 0.19 (PHENIX) 1.10 ± 0.08 ± 0.07 (PHOBOS) 1.12 ± 0.07 ± 0.06 (BRAHMS)	K^+/K^-	1.11 ± 0.02 ± 0.06 (STAR) 1.52 ± 0.16 ± 0.22 (PHENIX)
$\bar{p}/p$	0.61 ± 0.02 ± 0.06 (STAR) 0.61 ± 0.02 ± 0.07 (PHENIX) 0.60 ± 0.04 ± 0.06 (PHOBOS) 0.64 ± 0.04 ± 0.06 (BRAHMS)	$\bar{p}/p$	0.68 ± 0.03 ± 0.07 (STAR) 0.63 ± 0.03 ± 0.07 (PHENIX)
$\bar{\Lambda}/\Lambda$	0.70 ± 0.03 (STAR)	$\bar{\Lambda}/\Lambda$	0.88 ± 0.06 (STAR)
$\bar{\Xi}^+/\Xi^-$	0.82 ± 0.08 (STAR)		
π^-/π^+	0.95 ± 0.03 ± 0.05 (BRAHMS) 1.00 ± 0.01 ± 0.02 (PHOBOS)		
$\bar{p}/\pi^-$	0.080 ± 0.005 (STAR)	$\bar{p}/\pi^-$	0.050 ± 0.002 (STAR)
K^-/π^-	0.150 ± 0.004 (STAR)	K^-/π^-	0.101 ± 0.003 (STAR)
K^{*0}/h^- $\bar{K}^{*0}/h^-$	0.060 ± 0.007 ± 0.015 (STAR) 0.058 ± 0.006 ± 0.015 (STAR)	$\frac{(K^{*0}+\bar{K}^{*0})/2}{h^-}$	0.058 ± 0.010 ± 0.015 (STAR)

Red : the values from slide of QM2001
Blue: the values from figure in proceedings of QM2001
Black : PRL (including submitted)

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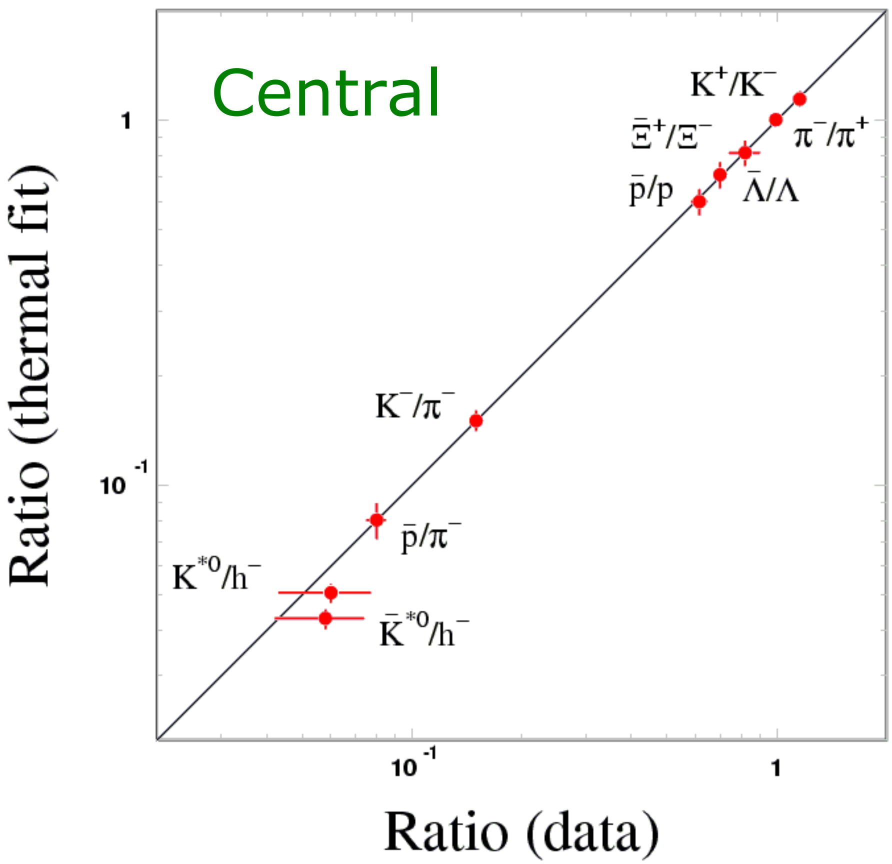
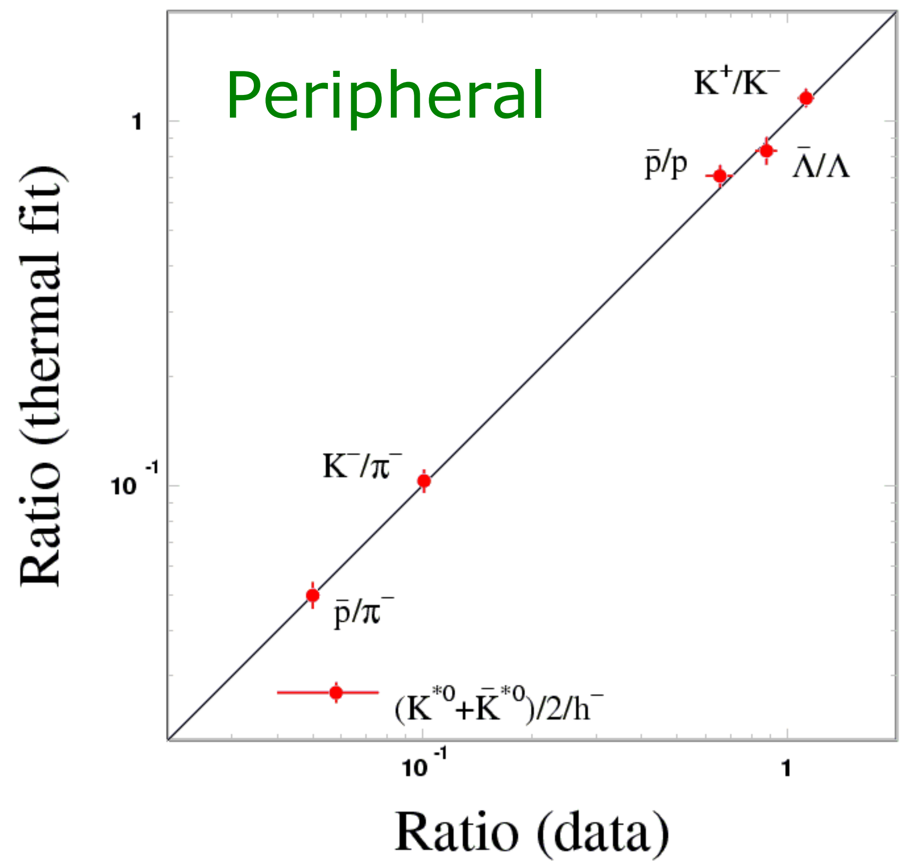
Freeze-out parameters

	Central	Peripheral
T_{ch} [MeV]	186 ± 8	147 ± 2
μ_q [MeV]	16.7 ± 1.7	8.8 ± 1.6
μ_s [MeV]	1.2 ± 2.4	-2.9 ± 3.0
γ_s	0.92 ± 0.04	0.60 ± 0.02
χ^2/dof	1.9/ 5	4.8/ 2
ε [MeV/fm^3]	$1160\pm^{450}_{340}$	$171\pm^{21}_{19}$
ρ [1/fm^3]	$0.99\pm^{0.32}_{0.25}$	0.21 ± 0.02
P [MeV/fm^3]	$184\pm^{69}_{52}$	31 ± 3

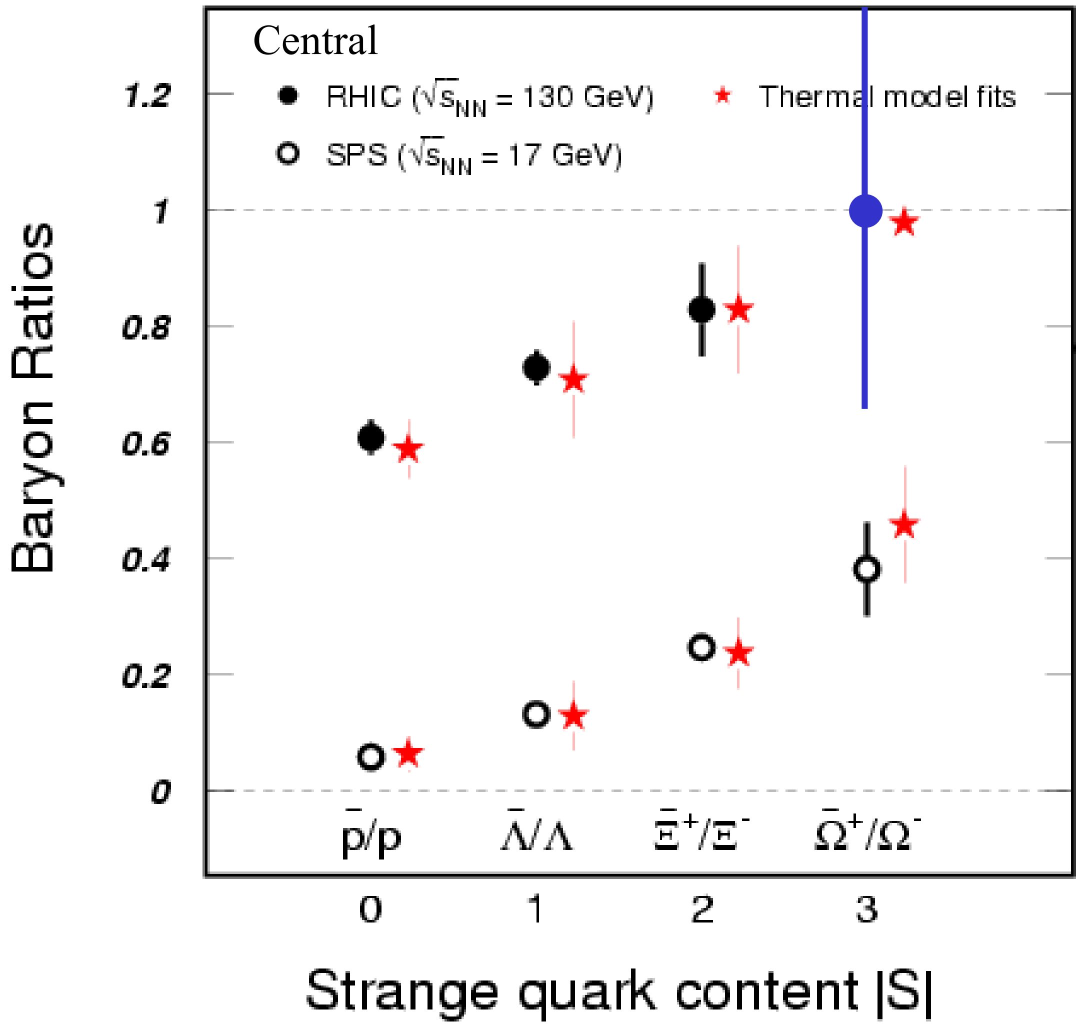
Note: The errors are estimated as $\chi^2_{min}+1$
The feed-down factor of 0.5 is assumed.

Ratios, experiment vs. model





Strange baryon ratios

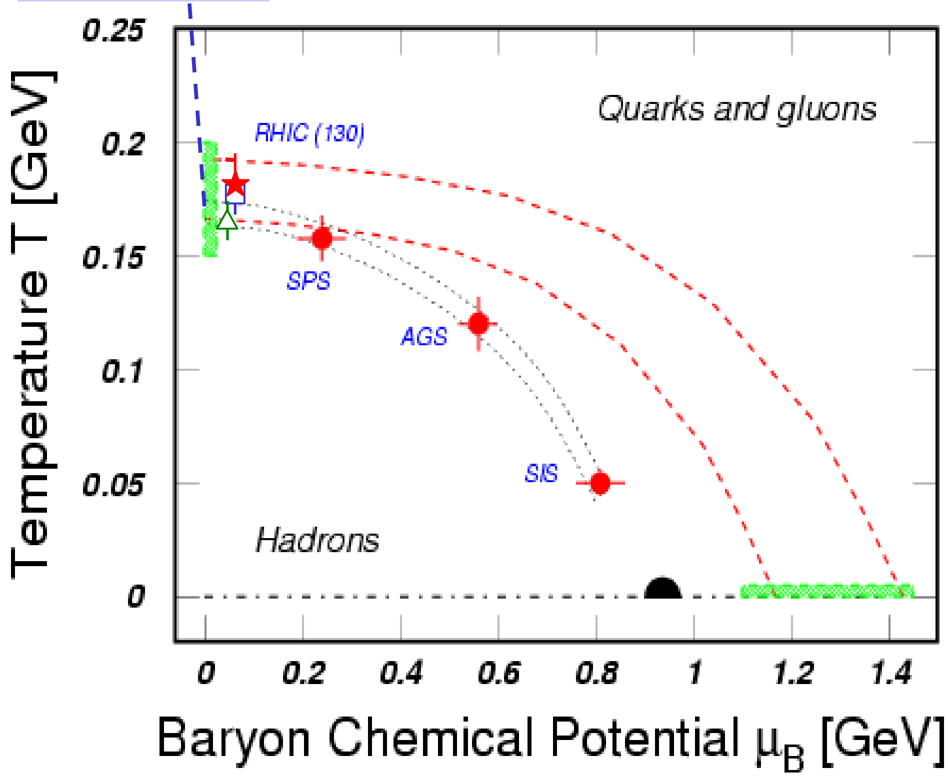


see also J. Zimanyi *et al*, hep-ph/0103156 (quark coalescence)

Systematics

Lattice QCD predictions

Central collisions



- ★ This analysis
- □ P.Braun-Munzinger et al.
- △ W. Florkowski et al.

Temperature increases with beam energy and being close to phase boundary

Neutron star

- - - parton-hadron phase boundary

:::::::::: <E>/<N>~1GeV, J.Cleymans and K.Redlich, PRC60 (1999) 054908

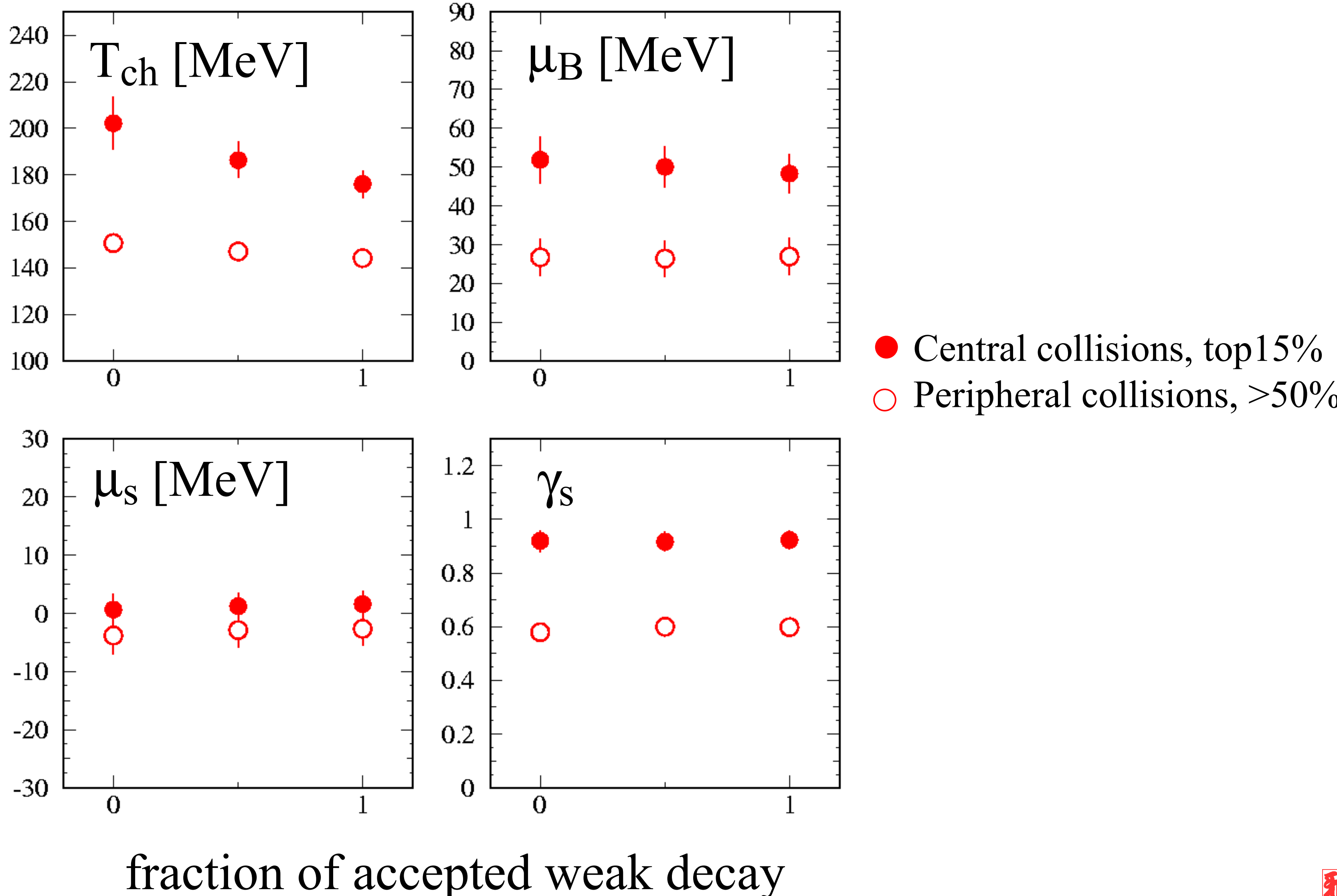
Model uncertainties

- Mass cut-off
- Boltzmann vs. Boson/Fermion } ⇐weak
- Weak decay feed-down
  - –Depend on particle species (i.e. c_τ)
  - –No equal opportunity to decayed particles
    - deferent p_T kick
  - –Depend on detector

•Test of the effect in case of

–fraction of accepted weak decay (f_W) =0, 0.5, 1.0

Feed-down effects



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Summary

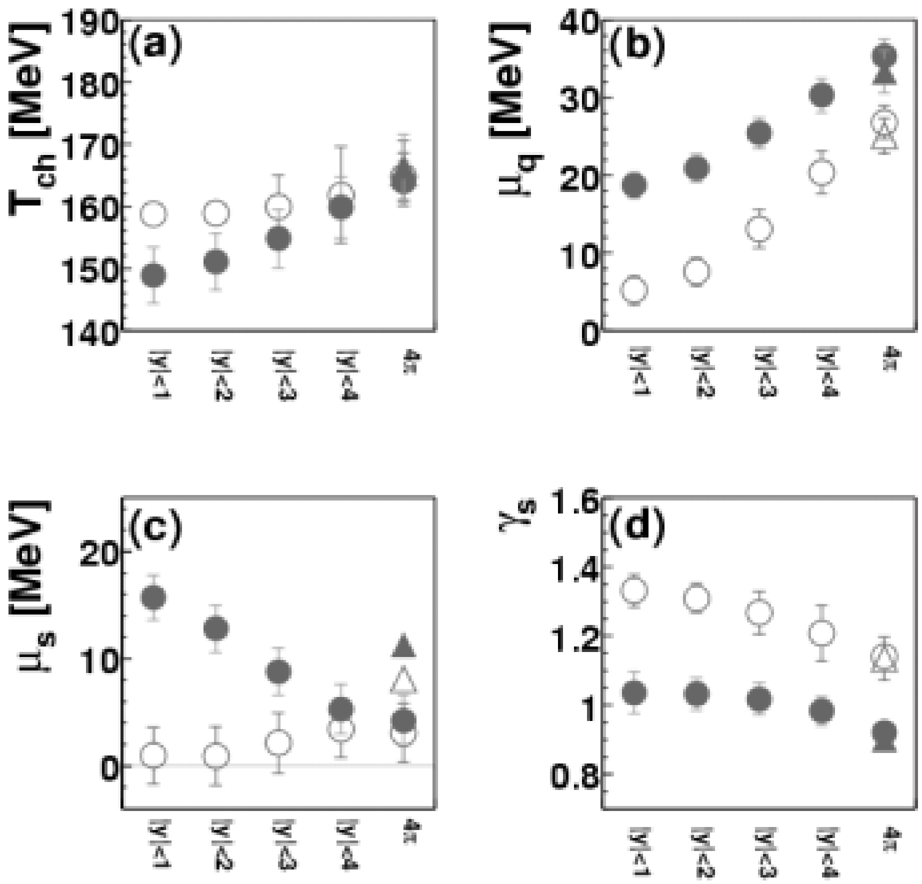
- Only mid-rapidity ratios used;
- With selected f_W the T_{ch} and μ are consistent with what expected;
- Centrality dependence;
- Systematic uncertainty needed to be evaluated;

Open issues

- Particle ratios are described by statistical model well
  - Dynamical information?
- Global vs. local equilibration
- Connection between T_{ch} and Lattice QCD T_c?

Test: rapidity dependence

Au + Au at 200 GeV (b≲3 fm)



● RQMD(v2.4)

○ NEXUS(V1.1)

(a) Temperature: Increasing as the rapidity width Δy open up;

(b) Baryon chemical potential: increase with Δy;

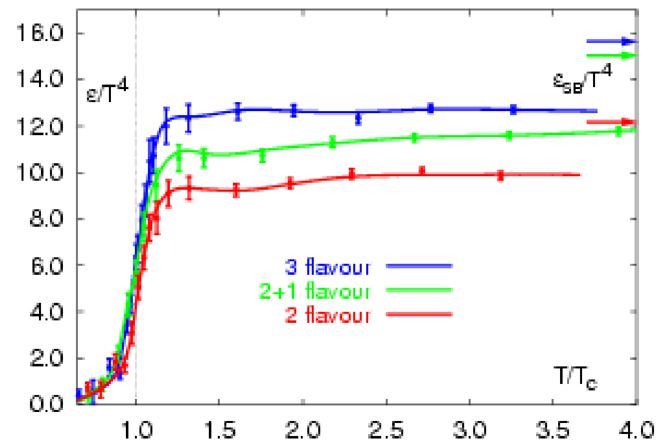
(c) Strange chemical potential: decrease with Δy;

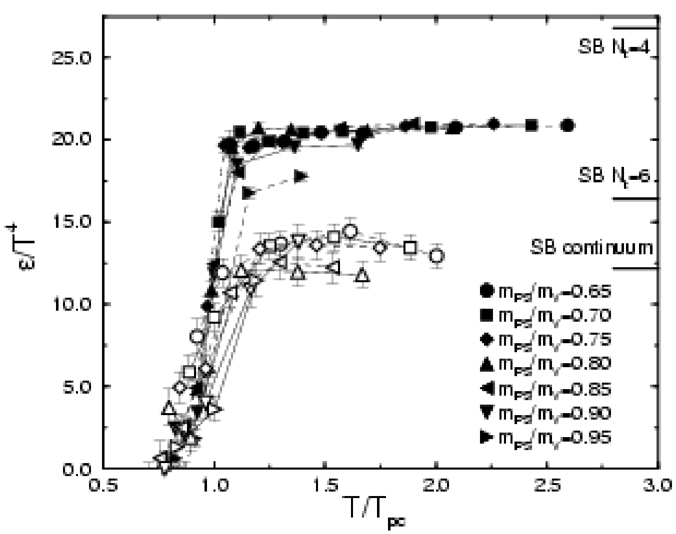
(d) Strange saturation factor: decrease with Δy;

Thermal parameters depend on the kinetic cuts!

J. Phys. G: Nucl. Part. Phys. 27 (2001) 589, M. Kaneta and N. Xu

Open issues





F. Karsch, hep-lat/0106019

1) Not fully ideal system at $4T_C$

2) Collective effects ?

3) ???