

Centrality and Rapidity Dependence of Chemical Freeze-out at RHIC

Refs. nucl-th/0405068 and hep-ph/0409071

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日本語

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English



日本語版

フリーズアウト

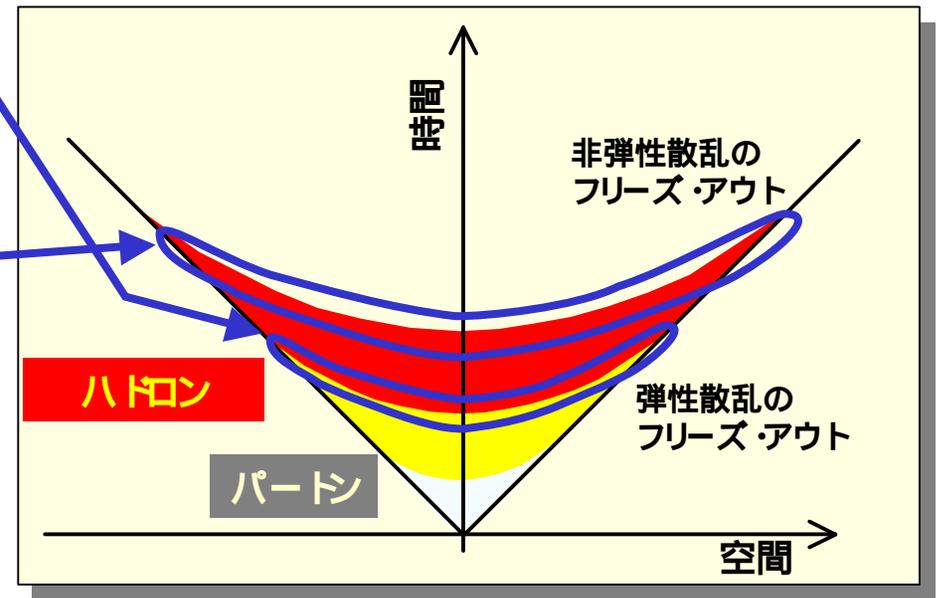
● 二種類のフリーズアウト

- 化学的

- 非弾性散乱の終わり
- 粒子(ハドロン)の数が固定される

- 熱的

- 弾性散乱の終わり
- 運動量分布が固定される



● 化学的フリーズアウト

- 衝突で生成されたハドロン・ガスでの熱平衡状態を仮定

- ここで“ハドロン”は u, d, s クォークからなるものを考える
- c は質量が重いので熱平衡に達していないと考える
 - しかし、この仮定は今や疑問視される
 - チャームの熱平衡がRHICで達成されているかも??

- このモデルはGSI-SIS, BNL-AGS, CERN-SPS ($\sqrt{s_{NN}} = 1-20\text{GeV}$)のデータに対してテストされてきた

- いくつかの独立したグループによるモデルあり

- モデルによる計算の違い(≒系統誤差) $\sim 10\%$

モデル

- 理想ハドロン・ガス モデル [PRC59 (1999) 1637を基にしている]
 - nucl-ex/0405068, JPG27 (2001) 589, NPA698 (2002) 306, PRC66 (2002) 044907 で使われている
- ハドロン i の密度

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

$$\lambda_s = \exp(\mu_s/T_{ch})$$

Q_i : uとdは1, \bar{u} と \bar{d} は-1

s_i : sに1, \bar{s} へは-1

g_i : スピン・アイソスピン自由度

m_i : ハドロン質量

T_{ch} : 化学フリーズ・アウト温度

μ_q : 軽いクォーク化学ポテンシャル

μ_s : ストレンジネス 化学ポテンシャル

γ_s : ストレンジネス飽和因子

- 質量が1.7GeV/c²までのレゾナンスを含むハドロンについて密度を計算
- 崩壊プロセスを適用
- そして実験データと比較
- このモデルで使われているハドロン達は

$\pi, \eta, \rho, \omega, \eta', \phi, f_0(980), a_0(980), h_1(1170), b_1(1235), a_1(1260), f_2(1270), f_1(1285), \eta(1295), \pi(1300), a_2(1320), f_0(1370), \eta(1440), \omega(1420), f_1(1420), \rho(1450), f_0(1500), f_1(1510), f_2'(1525), \omega(1600), \pi_2(1670), \phi(1680), \rho_3(1690), f_J(1710), \rho(1700)$
 $K, K^*, K_1(1270), K_1(1400), K^*(1410), K_0^*(1430), K_2^*(1430), K^*(1680)$

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

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

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

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

$\Xi, \Xi(1530), \Xi(1690)$

Ω

RHIC での実験グループ



小規模のコラボレーション (~100人)

BRAHMS, PHOBOS : 広い η しかし狭い方位角を覆う
大規模のコラボレーション (~500人)

STAR, PHENIX : 狭い η しかし広い方位角を覆う

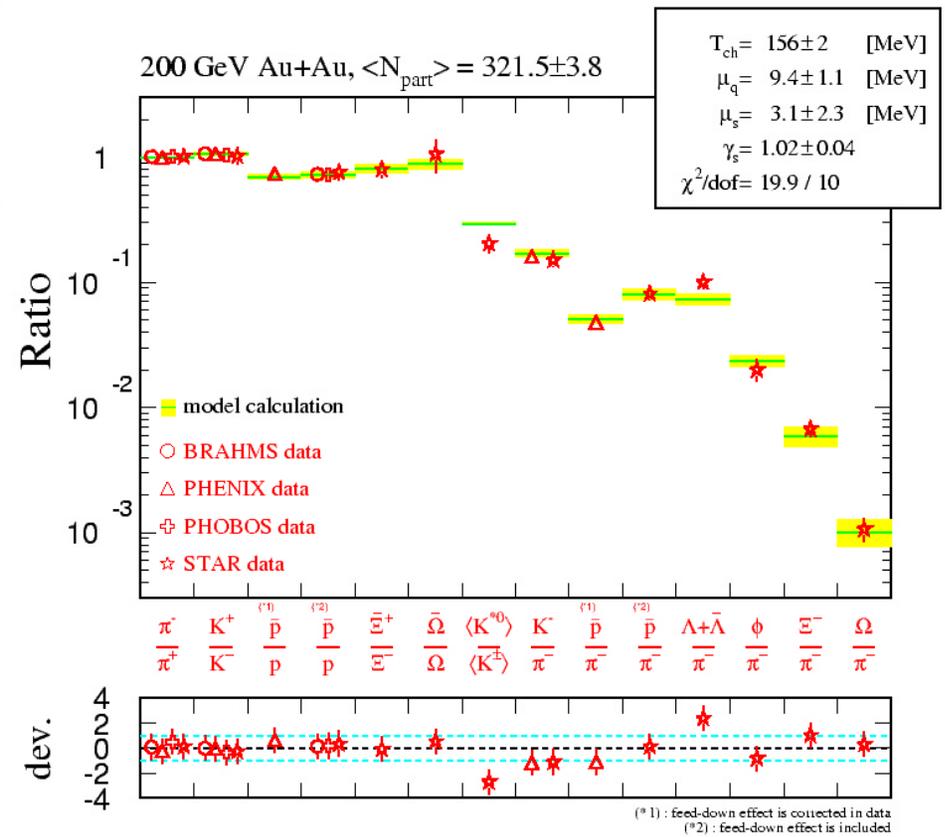
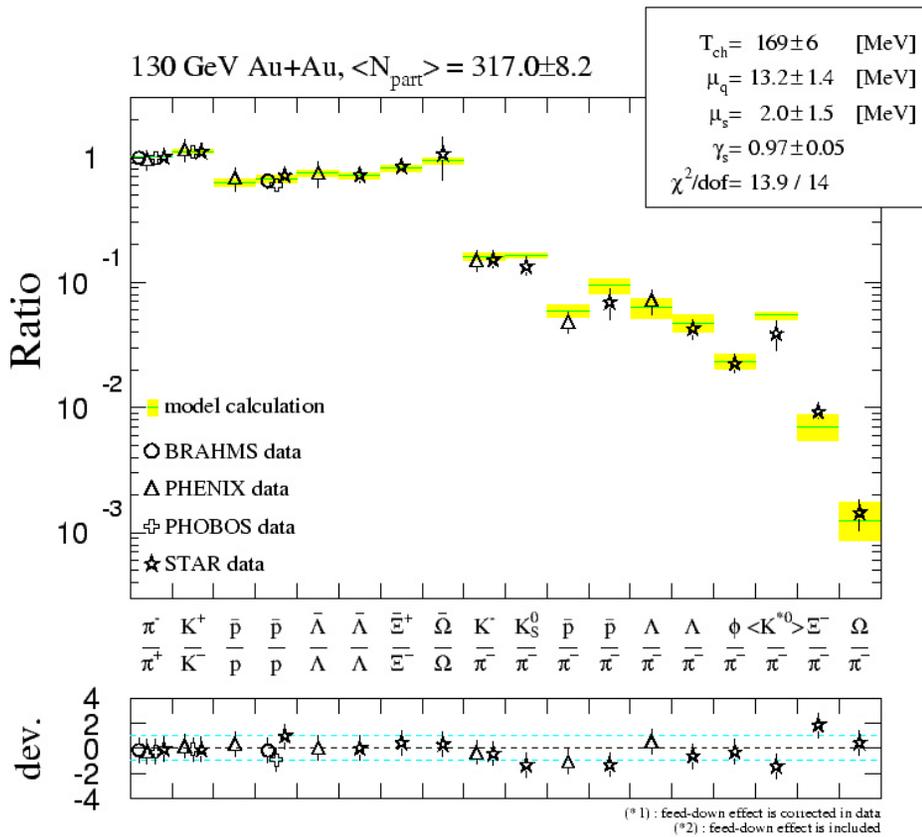
市場に出ているデータのまとめ

- 学術雑誌やプレプリントから
 - 重心系エネルギー130GeV と200GeVの金+金衝突
- 4つのRHICの実験
 - BRAHMS, PHOBOS, PHENIX, STAR
 - ハドロンデータは
 - 中心ラピディティでの、幾つかの中心衝突度依存のデータ
 - $\pi, \phi, K, K^*, p, \Lambda, \Xi, \Omega$
 - 中心衝突でのラピディティ分布
 - π, K, p
 - » ただし BRAHMSのデータのみで可
- 中心衝突度依存性を議論するために
 - 粒子比を $\langle N_{part} \rangle$ の関数として内挿
 - なぜなら、中心衝突度の定義は実験グループごとに違う
 - $\langle N_{part} \rangle$ は見積もられている
 - 違う実験グループのデータをまとめて同時にフィットするのには必要

Table from nucl-th/0405068

$\sqrt{s_{NN}}$	experiment	Refs.	dN/dy or ratio	centrality presented	
130 GeV	BRHAMS	[23]	π^- / π^+	(I) $\langle N_{part} \rangle$	
		[23]	\bar{p} / p	(I) $\langle N_{part} \rangle$	
	PHENIX	[24, 25]	π^+, π^-	(II) $\langle N_{part} \rangle$	
		[24, 25]	K^+, K^-	(II) $\langle N_{part} \rangle$	
		[24, 25]	p, \bar{p}	(II) $\langle N_{part} \rangle$	
		[25]	$\Lambda, \bar{\Lambda}$	(II) $\langle N_{part} \rangle$	
	PHOBOS	[26]	π^- / π^+	(III) $\langle N_{part} \rangle$	
		[26]	K^- / K^+	(III) $\langle N_{part} \rangle$	
		[26]	\bar{p} / p	(III) $\langle N_{part} \rangle$	
		STAR	[21]	π^-	(IV) $\langle N_{part} \rangle$
	[27]		K^+, K^-, K_S^0	(V)	$dN_{h-} / d\eta$
	[28]		\bar{K}^{*0} / K^{*0}	(IV)	
	[28]		$\langle K^{*0} \rangle$	(IV)	
	[29]		\bar{p}	(V)	
	[30]		\bar{p} / p	(V)	
	[31]		ϕ	(V)	
	[22]		$\Lambda, \bar{\Lambda}$	(VI)	
	[32, 33]		Ξ^-, Ξ^+	(V)	
	[33, 34]		Ω^-, Ω^+	(V)	
	200 GeV	BRAHMS	[35]	π^- / π^+	(I) $\langle N_{part} \rangle$
[35]			K^- / K^+	(I) $\langle N_{part} \rangle$	
[35]			\bar{p} / p	(I) $\langle N_{part} \rangle$	
PHOBOS		[36]	π^- / π^+	(III) $\langle N_{part} \rangle$	
		[36]	K^- / K^+	(III) $\langle N_{part} \rangle$	
		[36]	\bar{p} / p	(III) $\langle N_{part} \rangle$	
PHENIX		[37]	π^+, π^-	(II) $\langle N_{part} \rangle$	
		[37]	K^+, K^-	(II) $\langle N_{part} \rangle$	
		[37]	p, \bar{p}	(II) $\langle N_{part} \rangle$	
STAR		[38]	π^+, π^-	(VI) $\langle N_{part} \rangle$	
		[38]	K^+, K^-	(VI) $\langle N_{part} \rangle$	
		[38]	p, \bar{p}	(VI) $\langle N_{part} \rangle$	
		[39]	$\langle K^{*0} \rangle / \langle K^\pm \rangle$	(VI)	
		[40]	ϕ	(VI)	
		[41]	$\Lambda + \bar{\Lambda}$	(VI)	
		[42]	Ξ^-, Ξ^+	(VI)	
[34]	Ω^-, Ω^+	(VI)			

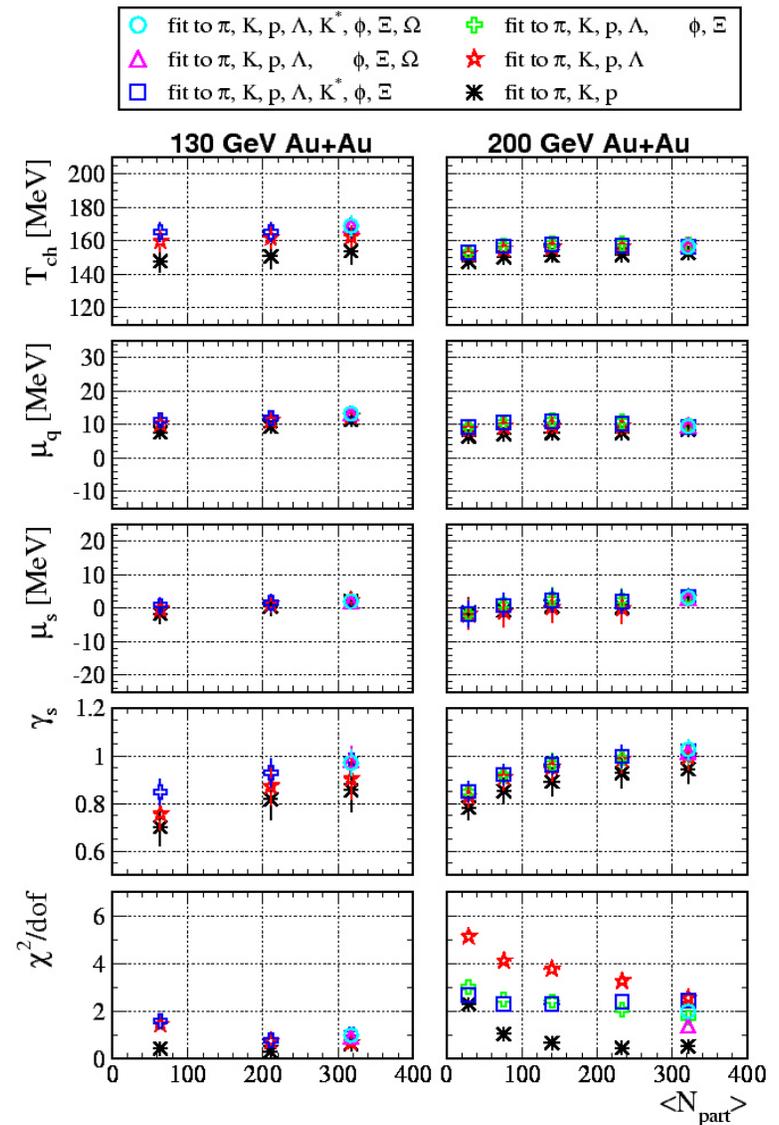
フィットの結果とデータの比較



- モデルはデータを良く(殆どの点で1標準偏差以内で)再現している
 - There are a few exception, but they are OK within 2 sigma

中心衝突度 ($\langle N_{part} \rangle$) 依存性

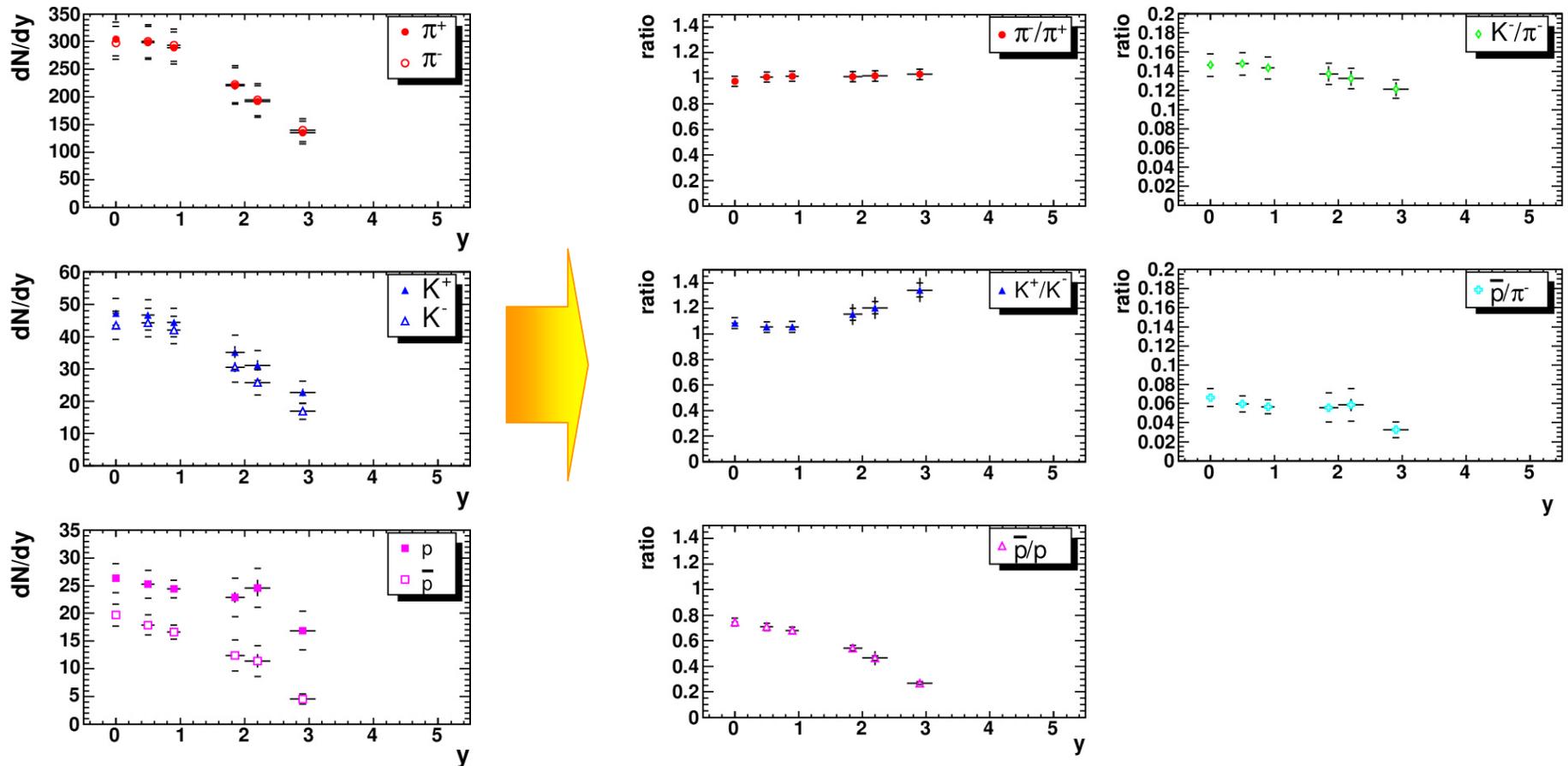
- 130 (200) GeV 金+金衝突度のデータを3 (5) に分ける
- フィットをするのに使うハドロンのお組み合わせ依存性も試した
 - 組み合わせは π, K, p から始める
 - スレンジネスハドロンを増やしていく
 - $|s|=1, |s|=2, |s|=3$
- T_{ch}, μ_q, μ_s
 - $\langle N_{part} \rangle$ への依存性は小さい
- γ_s
 - $\langle N_{part} \rangle$ と共に増加
 - RHICの中心衝突で **スレンジネスの完全な熱平衡**
- 組み合わせ依存性
 - スレンジネスを増やしていくと、パラメータの値が大きな方に変化
 - スレンジ量子数大きなものは、他のもの達と平衡に達していない?
 - あるいは単にモデルが良くないのか.....?



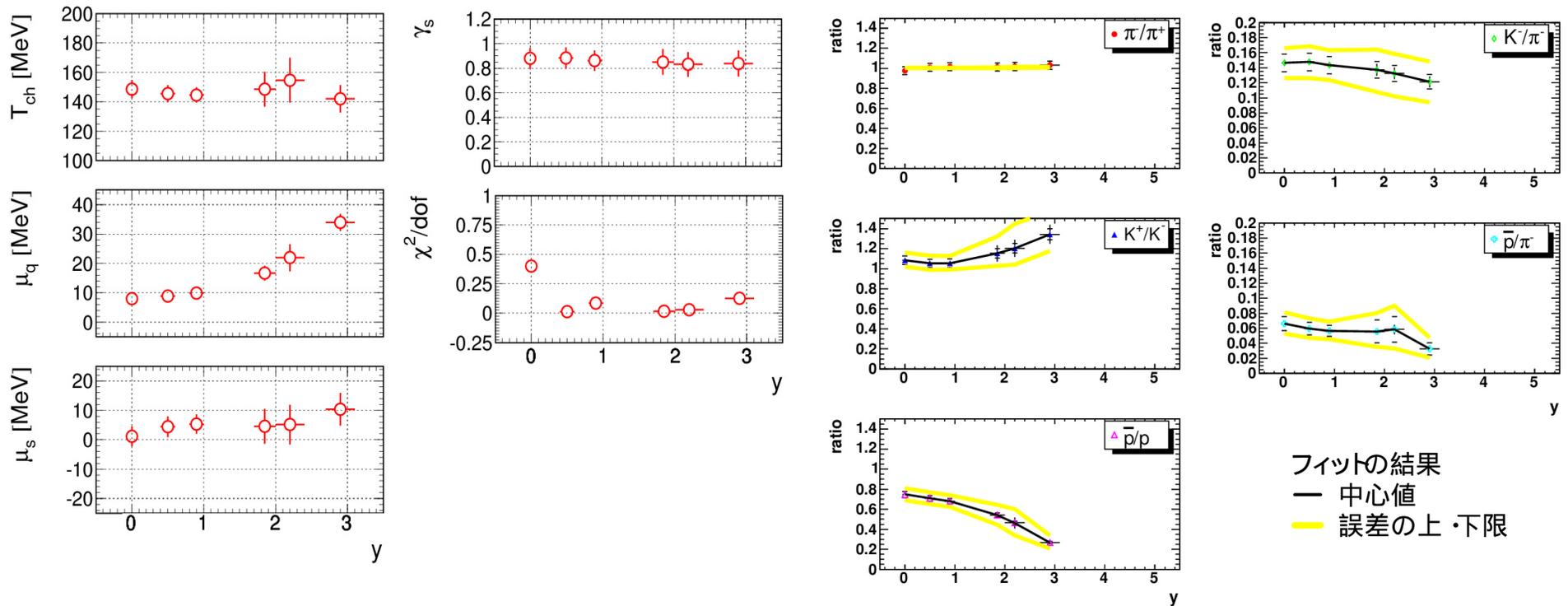
ラピディティ依存性

- 200 GeV 金+金 中心衝突での BRAHMSのデータから

π と K の dN/dy は陽子・反陽子と同じラピディティのビンになるように内挿した。データは[JPG30(2004)1129]より。



ラピディティ依存性



フィットの結果
 — 中心値
 — 誤差の上・下限

- T_{ch}, γ_s
 - $\langle N_{part} \rangle$ に対する依存性は少ない
 - ラピディティが 0 ~ 3 ($y_{beam} = 6$) にわたって ストレンジネスの熱平衡状態が達せられている
- μ_q, μ_s
 - $\langle N_{part} \rangle$ と共に増加
 - バリオン密度がラピディティと共に減少していることを反映している

- 中心衝突度依存性のところで議論したように
 - フィットを行うときに使うハドロン の組み合わせの依存性がある
 - ストレンジネス・ハドロン のデータが欲しい
 - しかし今の実験セットアップからは不可能。。。

まとめ

- 化学フリーズ・アウトモデルを最近のRHICのデータに当てはめた
- モデルはデータを良く再現している
- フィットの結果
 - 中心衝突度依存性
 - ストレンジネスの熱平衡状態 ($\gamma_s \sim 1$) がAu+Au中心衝突で達成
 - RHICのエネルギーのみで達成
 - AGS や SPS のエネルギーでは $\gamma_s < \sim 0.7$
 - ラピディティ依存性
 - $y=0 \sim 3$ の領域にわたってストレンジネスの熱平衡状態が達成されている可能性
- コメント
 - ハドロン・ガスが熱平衡状態にあるというのは仮定である
 - 熱平衡状態にあるガス \Rightarrow 熱平衡分布を示す : 常に正しい
 - 熱平衡分布 \Rightarrow 熱平衡に達してる : 常に正しいわけではない
 - 注意が必要



English Version

Outlook of This Talk

Outlook of This Talk

Chemical Freeze-out

- Freeze-out
 - Chemical
 - End of inelastic interaction
 - Number of particle is fixed
 - Kinetic
 - End of elastic interaction
 - Momentum distribution is fixed
- Chemical freeze-out model
 - Assuming thermalization of hadron gas created in the collisions
 - Here, "hadrons" consisted from u, d, s are taken care
 - Because c will not be thermalized due to the heavy mass
 - But this assumption is questionable now
 - Threshold down can be in RHIC?
 - Established by analyses to the data from GSI-SIS, BNL-AGS, CERN-SPS ($\sqrt{s}_{NN} = 1-20\text{GeV}$)
 - There are several independent group
 - Systematic error among models $\sim 10\%$

The Model

- Ideal hadron gas model based on RRC59 (1999) 1637
 - Used by RAL-EUHPC0306, JRC07 (2001) 589, NAPS09 (2002) 906, PHENIX (2002) 044907
- Density of hadron / is

$$\rho_i = \frac{g_i}{2\pi^2} \left(\frac{m_i}{T_H}\right)^2 K_2(m_i/T_H) \lambda_i^{q_i} \lambda_s^{s_i} \lambda_c^{c_i}$$
 - q_i = 1 for u and d , -1 for s and c , T_H = chemical freeze-out temperature
 - s_i = 1 for s , -1 for c , μ_H = light-quark chemical potential
 - c_i = quark-antiquark freedom, μ_s = strangeness chemical potential
 - m_i = particle mass, γ_s = strangeness saturation factor
- Compute particle densities for hadrons including resonances (mass $< 1.7\text{GeV}$)
- Apply decay calculation for all of hadrons
- And then we can obtain particle ratios to compare data
- Hadrons in this model are:
 - $\pi, K, \eta, \eta', \omega, \phi, \rho(770), \omega(980), \omega(1370), \omega(1450), \omega(1720), \omega(2350), \omega(2450), \omega(2750), \omega(3000), \omega(3930), \omega(4360), \omega(4775), \omega(5040), \omega(5570), \omega(5775), \omega(6170), \omega(6420), \omega(6750), \omega(7310), \omega(7670), \omega(8000), \omega(8330), \omega(8540), \omega(8700), \omega(8920), \omega(9160), \omega(9460), \omega(9750), \omega(10000), \omega(10200), \omega(10400), \omega(10600), \omega(10800), \omega(11000), \omega(11200), \omega(11400), \omega(11600), \omega(11800), \omega(12000), \omega(12200), \omega(12400), \omega(12600), \omega(12800), \omega(13000), \omega(13200), \omega(13400), \omega(13600), \omega(13800), \omega(14000), \omega(14200), \omega(14400), \omega(14600), \omega(14800), \omega(15000), \omega(15200), \omega(15400), \omega(15600), \omega(15800), \omega(16000), \omega(16200), \omega(16400), \omega(16600), \omega(16800), \omega(17000), \omega(17200), \omega(17400), \omega(17600), \omega(17800), \omega(18000), \omega(18200), \omega(18400), \omega(18600), \omega(18800), \omega(19000), \omega(19200), \omega(19400), \omega(19600), \omega(19800), \omega(20000)$

RHIC Experiments

Small collaborations (~100)
 BRAHMS, PHOBOS : Large η but small ϕ coverage
 Big collaborations (~500)
 STAR, PHENIX : Small η but large ϕ coverage

Data Summarized from the Market

- Data publication/preprint
 - 130GeV and 200GeV Au+Au collisions
- 4 RHIC experiments
 - BRAHMS, PHOBOS, PHENIX, STAR
 - Hadrons
 - Many centrality bins at mid-rapidity
 - $\eta = -0.5 \sim 0.5, A \pm 0.5$
 - Rapidity dependence at central collisions
- To discuss centrality dependence
 - Interpolation of particle ratios as a function of $\langle N_{part} \rangle$
 - Because centrality definition is independent among experiments
 - It is necessary for simultaneous fit from different experiments

Experiment	Collision System	Collision Energy	Centrality	Particle	Yield	Yield Error	Yield Ratio	Yield Ratio Error
BRAHMS	Au+Au	130 GeV	0-5%	p	1.2	0.1	1.2	0.1
					1.5	0.1	1.5	0.1
					2.0	0.1	2.0	0.1
					2.5	0.1	2.5	0.1
					3.0	0.1	3.0	0.1
					3.5	0.1	3.5	0.1
					4.0	0.1	4.0	0.1
					4.5	0.1	4.5	0.1
					5.0	0.1	5.0	0.1
					5.5	0.1	5.5	0.1
					6.0	0.1	6.0	0.1
					6.5	0.1	6.5	0.1
PHOBOS	Au+Au	130 GeV	0-5%	p	1.2	0.1	1.2	0.1
					1.5	0.1	1.5	0.1
					2.0	0.1	2.0	0.1
					2.5	0.1	2.5	0.1
					3.0	0.1	3.0	0.1
					3.5	0.1	3.5	0.1
					4.0	0.1	4.0	0.1
					4.5	0.1	4.5	0.1
					5.0	0.1	5.0	0.1
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					4.0	0.1	4.0	0.1
					4.5	0.1	4.5	0.1
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STAR	Au+Au	130 GeV	0-5%	p	1.2	0.1	1.2	0.1
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					3.5	0.1	3.5	0.1
					4.0	0.1	4.0	0.1
					4.5	0.1	4.5	0.1
					5.0	0.1	5.0	0.1
					5.5	0.1	5.5	0.1
					6.0	0.1	6.0	0.1
					6.5	0.1	6.5	0.1

Comparison of Fit Results to Data

- The model reproduce data within (almost) one sigma
 - There are a few exception, but they are OK within 2 sigma

Centrality ($\langle N_{part} \rangle$) Dependence

- 3 (S) centrality bins for 130 (200) GeV Au+Au
 - Start with x, K, p
 - Increasing strangeness hadrons
 - $|x|=1, |p|=2, |K|=3$
- Test of hadron combination dependence
 - Less sensitivity to $\langle N_{part} \rangle$
- T_{str} μ_H μ_s
 - Less sensitivity to $\langle N_{part} \rangle$
 - Increasing with $\langle N_{part} \rangle$
 - Reach full strangeness equilibration in central collisions at RHIC
- Combination dependence
 - With adding more strangeness, value of parameters increased
 - No equilibration of multi-strangeness with the others?
 - Or just model is involved...

Rapidity Dependence

- BRAHMS data in central 200 GeV Au+Au collisions
 - To have some rapidity range with proton, a cut $\epsilon < 20\%$ are superimposed from data (PHOBOS+PHENIX)

Rapidity Dependence

- Less sensitivity to $\langle N_{part} \rangle$
- Close to strangeness equilibration in central collisions over $y=0-3$ ($v_{str} \approx 6$)
- Increasing with $\langle N_{part} \rangle$
 - Reflect that baryon density is decreasing with y
- As discussed in page of centrality dependence
 - There is a particle combination dependence
 - More strangeness hadrons are needed
 - but it is almost impossible so far

Summary

- Chemical freeze-out model applied to recent RHIC data
- The model well describes data
- The fit results say
 - Centrality dependence
 - Strangeness equilibration ($v_s \approx 1$) in central collisions
 - It happen only RHIC energy
 - $\mu_s \approx 0.7$ at AGS and SPS energy
 - Rapidity dependence
 - Suggesting strange equilibration over $y < 3$
- Note
 - Thermalization in hadron gas is an assumption
 - Thermal source \Rightarrow Thermal distribution : always true
 - Thermal distribution \Rightarrow Thermal source : NOT always true
 - Be careful

Two kinds of Freeze-out

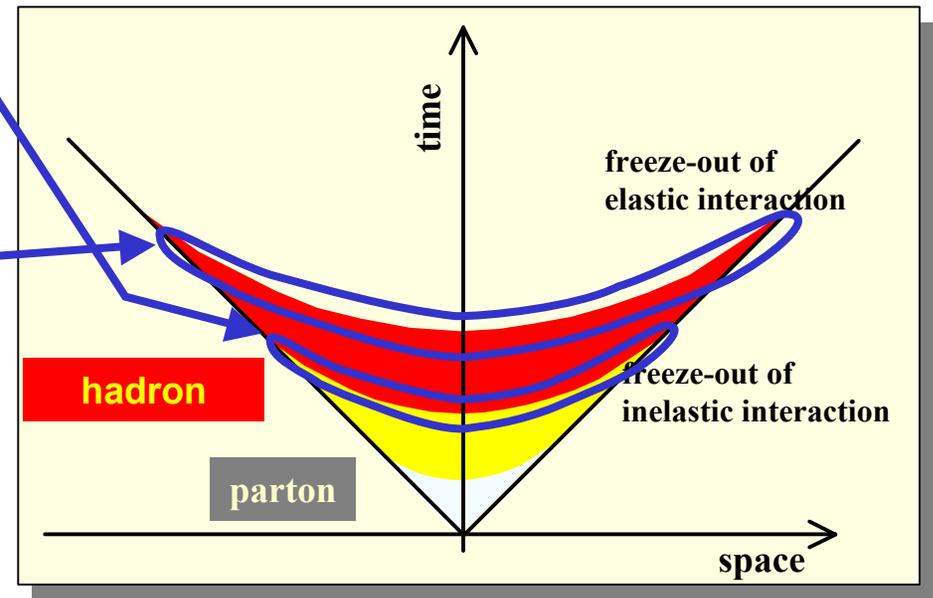
• Freeze-out

- Chemical

- End of inelastic interaction
- Number of particle is fixed

- Kinetic

- End of elastic interaction
- Momentum distribution is fixed



• Chemical freeze-out model

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- Here, "hadrons" consisted from u, d, s are taken care
- Because c will not be thermalized due to the heavy mass
 - But this assumption is questionable now
 - Thermalized charm can be in RHIC??

- Established by analyses to the data from GSI-SIS, BNL-AGS, CERN-SPS ($\sqrt{s_{NN}} = 1-20\text{GeV}$)

- There are several independent group

- Systematic error among models $\sim 10\%$

The Model

- Ideal hadron gas model based on PRC59 (1999) 1637
 - used in nucl-ex/0405068, JPG27 (2001) 589, NPA698 (2002) 306, PRC66 (2002) 044907
- Density of hadron i is

$$\rho_i = \gamma_s^{|s_i|} \frac{g_i}{2\pi^2} T_{ch}^3 \left(\frac{m_i}{T_{ch}} \right)^2 K_2(m_i/T_{ch}) \lambda_q^{Q_i} \lambda_s^{s_i} \quad \begin{aligned} \lambda_q &= \exp(\mu_q/T_{ch}), \\ \lambda_s &= \exp(\mu_s/T_{ch}) \end{aligned}$$

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

- Compute particle densities for hadrons including resonances (mass<1.7GeV)
- Apply decay calculation for all of hadrons
- And then we can obtain particle ratios to compare data
- Hadrons in this model are:

$\pi, \eta, \rho, \omega, \eta', \phi, f_0(980), a_0(980), h_1(1170), b_1(1235), a_1(1260),$
 $f_2(1270), f_1(1285), \eta(1295), \pi(1300), a_2(1320), f_0(1370), \eta(1440),$
 $\omega(1420), f_1(1420), \rho(1450), f_0(1500), f_1(1510), f_2'(1525),$
 $\omega(1600), \pi_2(1670), \phi(1680), \rho_3(1690), f_j(1710), \rho(1700)$
 $K, K^*, K_1(1270), K_1(1400), K^*(1410), K_0^*(1430), K_2^*(1430),$
 $K^*(1680)$

$p, n, N(1440), N(1520), N(1535), N(1650), N(1675),$
 $N(1680), N(1700)$
 $\Delta(1232), \Delta(1600), \Delta(1620), \Delta(1700)$
 $\Lambda, \Lambda(1450), \Lambda(1520), \Lambda(1600), \Lambda(1670), \Lambda(1690)$
 $\Sigma, \Sigma(1385), \Sigma(1660), \Sigma(1670)$
 $\Xi, \Xi(1530), \Xi(1690)$
 Ω

RHIC Experiments



Small collaborations (~100)

BRAHMS, PHOBOS : Large η but small ϕ coverage

Big collaborations (~500)

STAR, PHENIX : Small η but large ϕ coverage

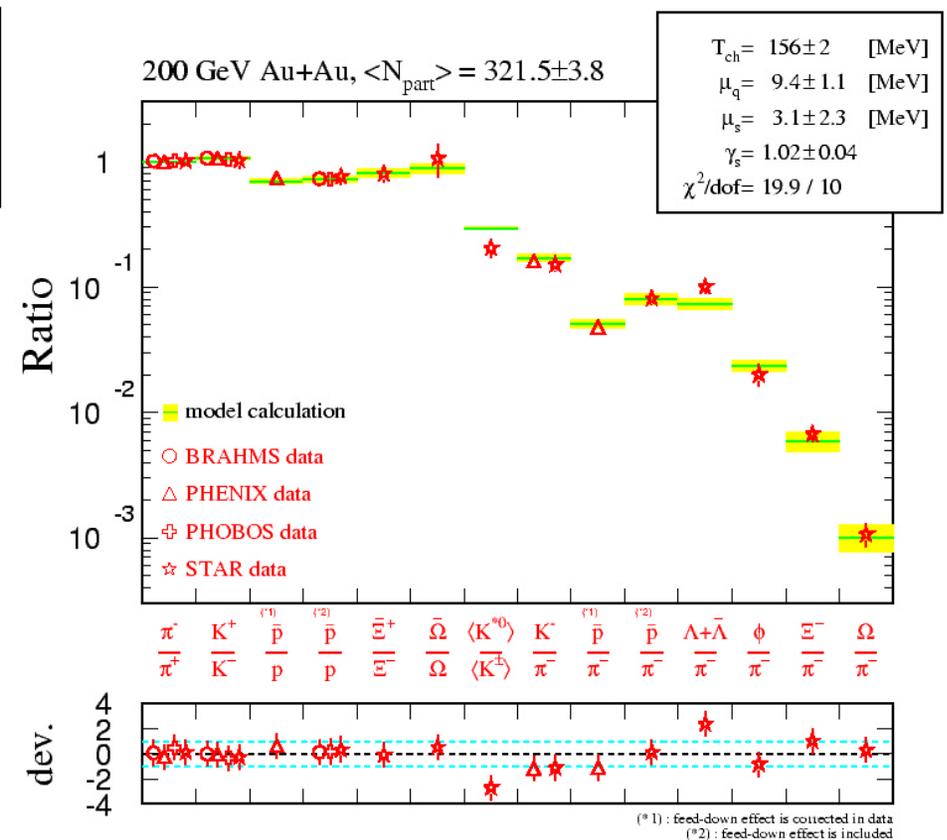
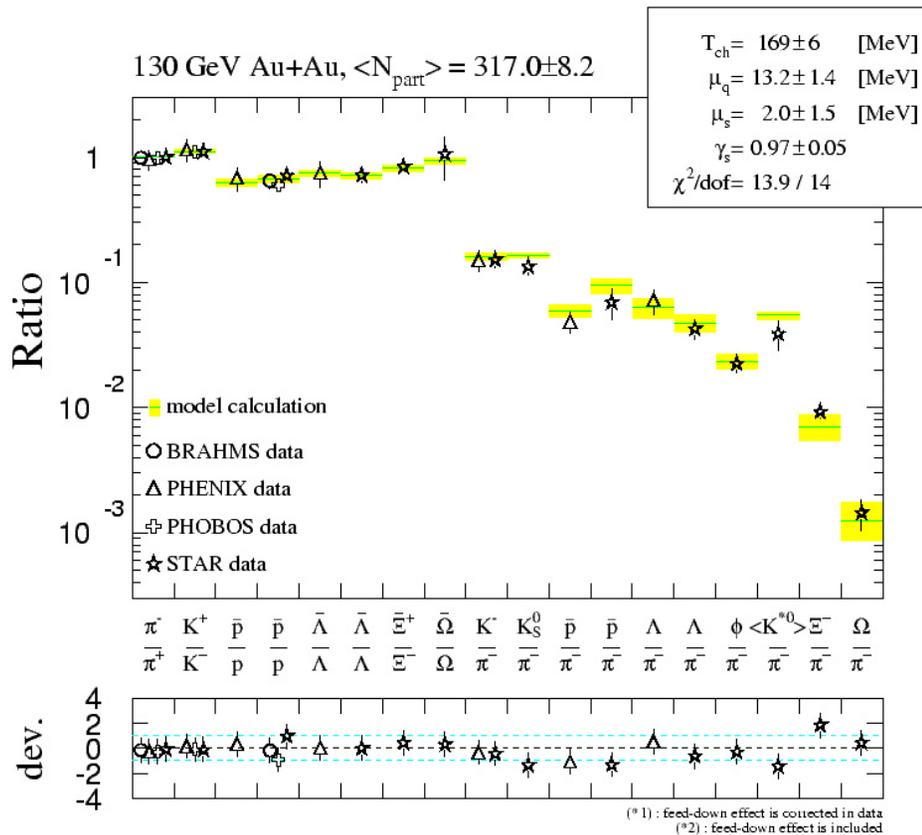
Data Summarized from the Market

- Data publication/preprint
 - 130GeV and 200GeV Au+Au collisions
- 4 RHIC experiments
 - BRAHMS, PHOBOS, PHENIX, STAR
 - Hadrons
 - Many centrality bins at mid-rapidity
 - $\pi, \phi, K, K^*, p, \Lambda, \Xi, \Omega$
 - Rapidity dependence at central collisions
 - π, K, p
 - » Note : only BRAHMS data
- To discuss centrality dependence
 - Interpolation of particle ratios as a function of $\langle N_{part} \rangle$
 - Because centrality definition is independent among experiments
 - It is necessary for simultaneous fit from different experiments

Table from nucl-th/0405068

$\sqrt{s_{NN}}$	experiment	Refs.	dN/dy or ratio	centrality presented	
130 GeV	BRAHMS	[23]	π^- / π^+	(I) $\langle N_{part} \rangle$	
		[23]	\bar{p}/p	(I) $\langle N_{part} \rangle$	
	PHENIX	[24, 25]	π^+, π^-	(II) $\langle N_{part} \rangle$	
		[24, 25]	K^+, K^-	(II) $\langle N_{part} \rangle$	
		[24, 25]	p, \bar{p}	(II) $\langle N_{part} \rangle$	
	PHOBOS	[25]	$\Lambda, \bar{\Lambda}$	(II) $\langle N_{part} \rangle$	
		[26]	π^- / π^+	(III) $\langle N_{part} \rangle$	
		[26]	K^- / K^+	(III) $\langle N_{part} \rangle$	
		[26]	\bar{p}/p	(III) $\langle N_{part} \rangle$	
		STAR	[21]	π^-	(IV) $\langle N_{part} \rangle$
	[27]		K^+, K^-, K_S^0	(V)	$dN_{h-} / d\eta$
	[28]		\bar{K}^{*0} / K^{*0}	(IV)	
	[28]		$\langle K^{*0} \rangle$	(IV)	
	[29]		\bar{p}	(V)	
	[30]		\bar{p}/p	(V)	
	[31]		ϕ	(V)	
	[22]		$\Lambda, \bar{\Lambda}$	(VI)	
	[32, 33]		Ξ^-, Ξ^+	(V)	
	[33, 34]		Ω^-, Ω^+	(V)	
	200 GeV	BRAHMS	[35]	π^- / π^+	(I) $\langle N_{part} \rangle$
			[35]	K^- / K^+	(I) $\langle N_{part} \rangle$
			[35]	\bar{p}/p	(I) $\langle N_{part} \rangle$
PHOBOS		[36]	π^- / π^+	(III) $\langle N_{part} \rangle$	
		[36]	K^- / K^+	(III) $\langle N_{part} \rangle$	
		[36]	\bar{p}/p	(III) $\langle N_{part} \rangle$	
PHENIX		[37]	π^+, π^-	(II) $\langle N_{part} \rangle$	
		[37]	K^+, K^-	(II) $\langle N_{part} \rangle$	
		[37]	p, \bar{p}	(II) $\langle N_{part} \rangle$	
STAR		[38]	π^+, π^-	(VI) $\langle N_{part} \rangle$	
		[38]	K^+, K^-	(VI) $\langle N_{part} \rangle$	
		[38]	p, \bar{p}	(VI) $\langle N_{part} \rangle$	
		[39]	$\langle K^{*0} \rangle / \langle K^\pm \rangle$	(VI)	
		[40]	ϕ	(VI)	
		[41]	$\Lambda + \bar{\Lambda}$	(VI)	
		[42]	Ξ^-, Ξ^+	(VI)	
[34]	Ω^-, Ω^+	(VI)			

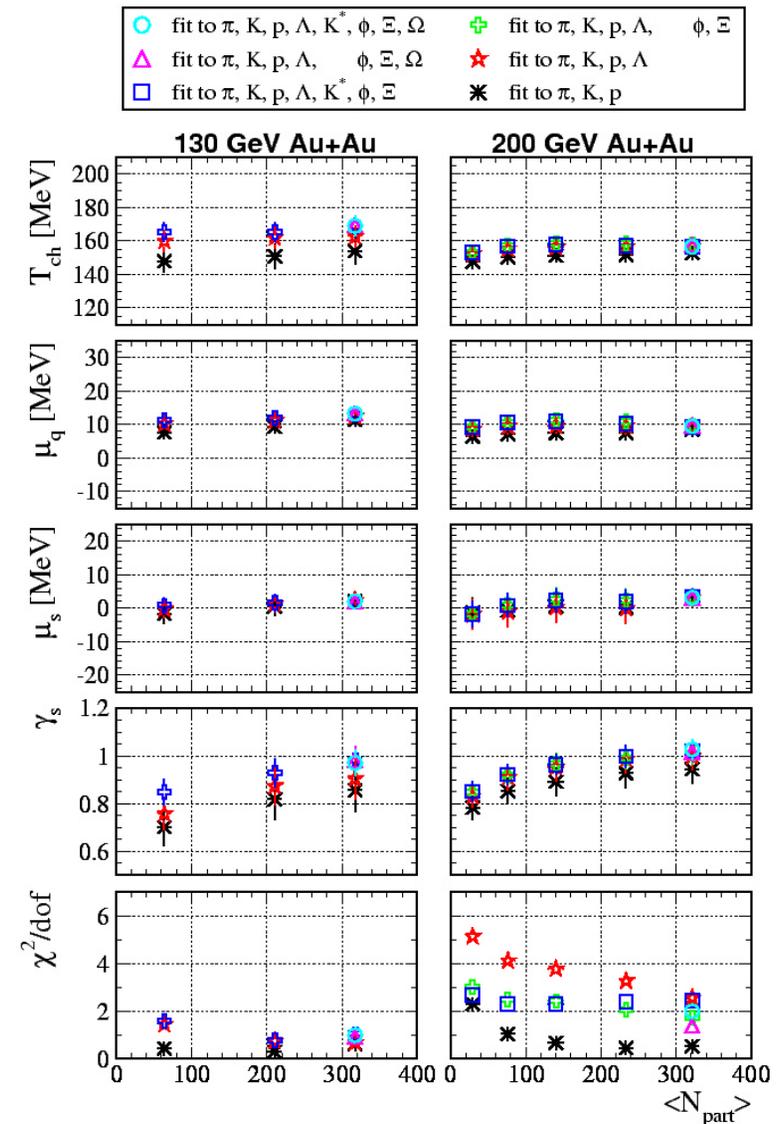
Comparison of Fit Results to Data



- The model reproduce data within (almost) one sigma
 - There are a few exception, but they are OK within 2 sigma

Centrality ($\langle N_{part} \rangle$) Dependence

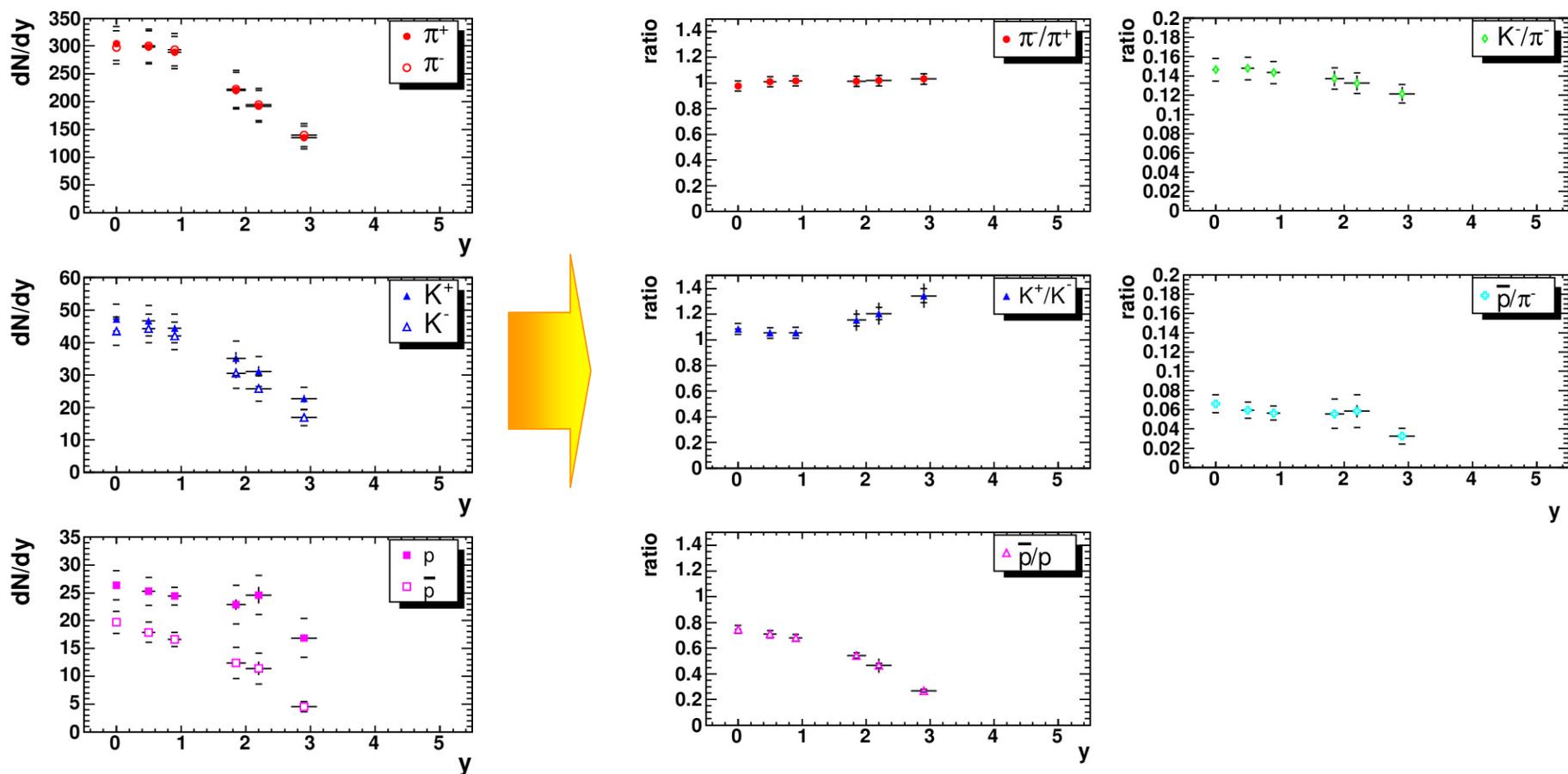
- 3 (5) centrality bins for 130 (200) GeV Au+Au
- Test of hadron combination dependence
 - Start with π, K, p
 - Increasing strangeness hadrons
 - $|s|=1, |s|=2, |s|=3$
- T_{ch}, μ_q, μ_s
 - Less sensitivity to $\langle N_{part} \rangle$
- γ_s
 - Increasing with $\langle N_{part} \rangle$
 - Reach full strangeness equilibration in central collisions at RHIC!
- Combination dependence
 - With adding more strangeness, value of parameters increased
 - No equilibration of multi-strangeness with the others?
 - Or just model is incorrect...?



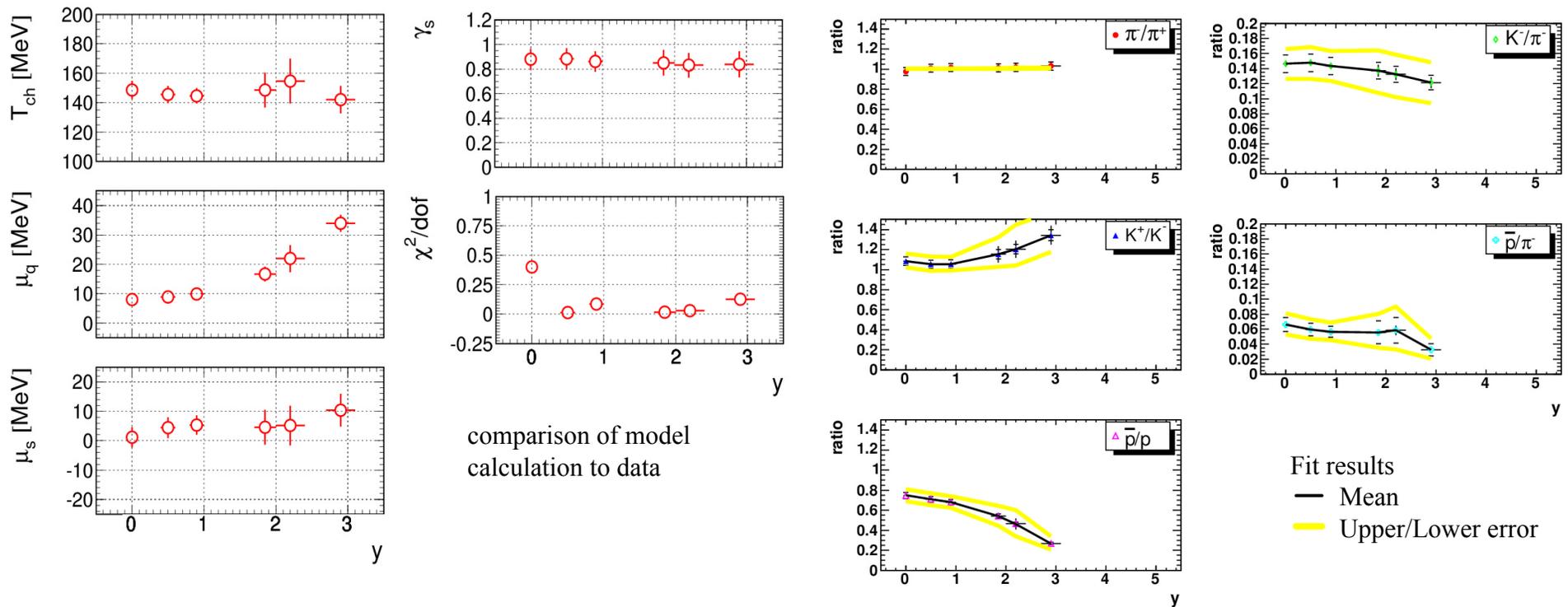
Rapidity Dependence

- BRAHMS data in central 200 GeV Au+Au collisions

To have same rapidity range with protons,
 π and K dN/dy are interpolated from data
 [JPG30(2004)1129]



Rapidity Dependence



- T_{ch}, γ_s
 - Less sensitivity to $\langle N_{part} \rangle$
 - Close to strangeness equilibration in central collisions over $y=0-3$ ($y_{beam}=6$)
- μ_q, μ_s
 - Increasing with $\langle N_{part} \rangle$
 - Reflect that baryon density is decreasing with y

- As discussed in page of centrality dependence
 - There is a particle combination dependence
 - More strangeness hadrons are needed
 - but it is almost impossible so far

Summary

- Chemical freeze-out model applied to recent RHIC data
- The model well describes data
- The fit results say
 - Centrality dependence
 - Strangeness equilibration ($\gamma_s \sim 1$) in central collisions
 - It happen only RHIC energy
 - $\gamma_s < \sim 0.7$ at AGS and SPS energy
 - Rapidity dependence
 - Suggesting strange equilibration over $y < 3$
- Note
 - Thermalization in hadron gas is an assumption
 - Thermal source \Rightarrow Thermal distribution : always true
 - Thermal distribution \Rightarrow Thermal source : NOT always true
 - Be careful



Backup