Thermal Production of particles at RHIC (Test of Chemical Freeze-out at RHIC)

Jun Takahashi for the STAR collaboration

SQM2008, Beijing, China

高橋純

Introduction:

- Strangeness chemical equilibration is achieved at RHIC, but …
  - To what extent?
  - Does it vary with system size?
  - Can we disentangle the canonical suppression?
  - What about the rapidity range?

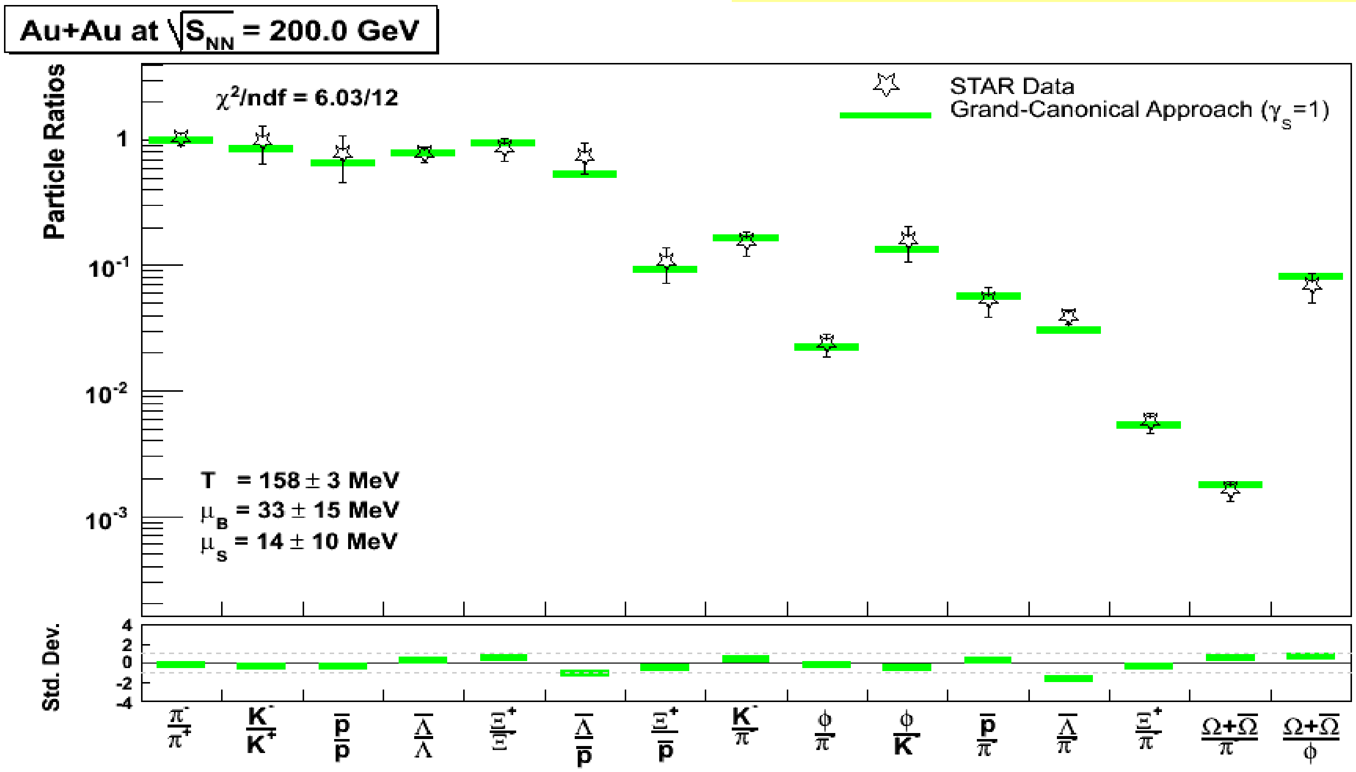
- STAR has a large amount of data, with different particles, at different centralities and in different collision systems.

Statistical Thermal Model

- Statistical Thermal Model (THERMUS)* was used fitting T_{ch}, μ_B, μ_S, and γ_S (strangeness saturation factor).
- Particles used in the fit:

π, K, p, Λ, Ξ, Ω and ϕ.

* Thermus, A thermal Model Package for Root
S. Wheaton & Cleymans, hep-ph/0407174

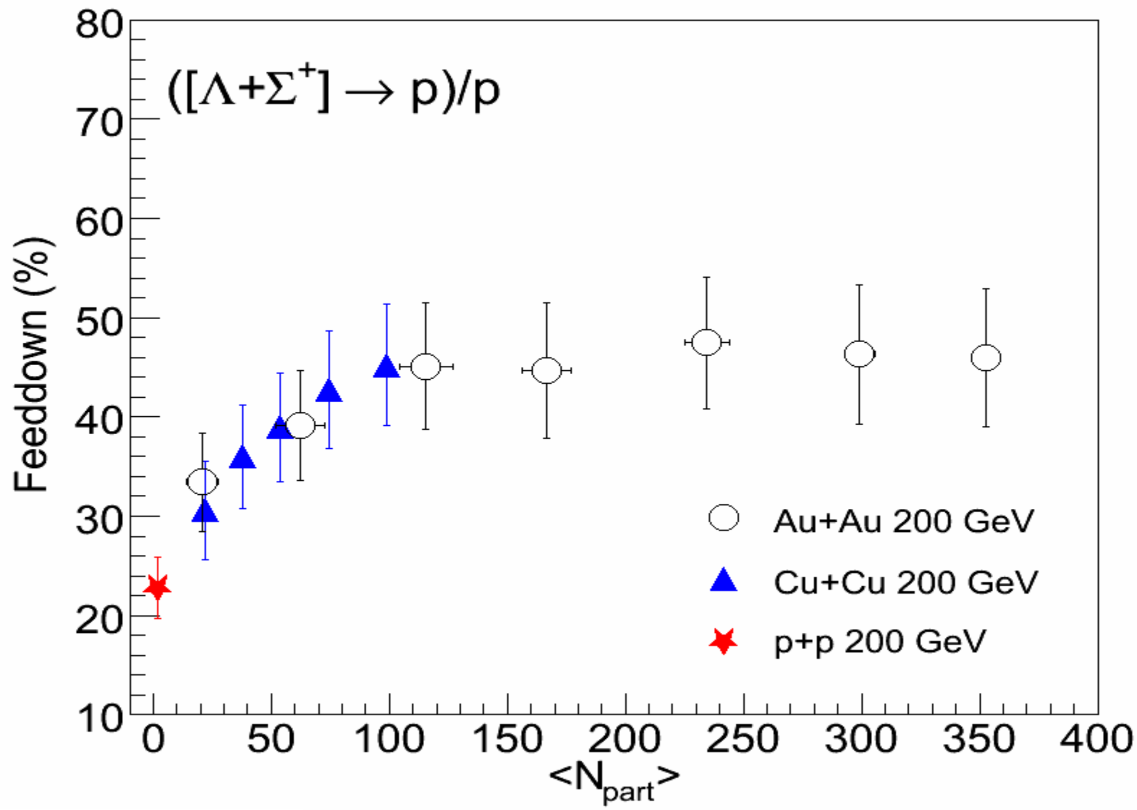


Feed-down corrections:

- Pion yields
  - Weak decay feed-down contributions are subtracted.
- Proton yields
  - Λ decay feed-down is subtracted, considering inclusive Λ´s.
  - Σ decay feed-down needs to be studied.
- Lambda yields
  - Ξ decay feed-down is subtracted.
  - Ω decay is negligible. ($\Omega/\Lambda \sim 0.01$)
- Ξ yields
  - Ω decay feed-down is negligible. BR 8.6 %

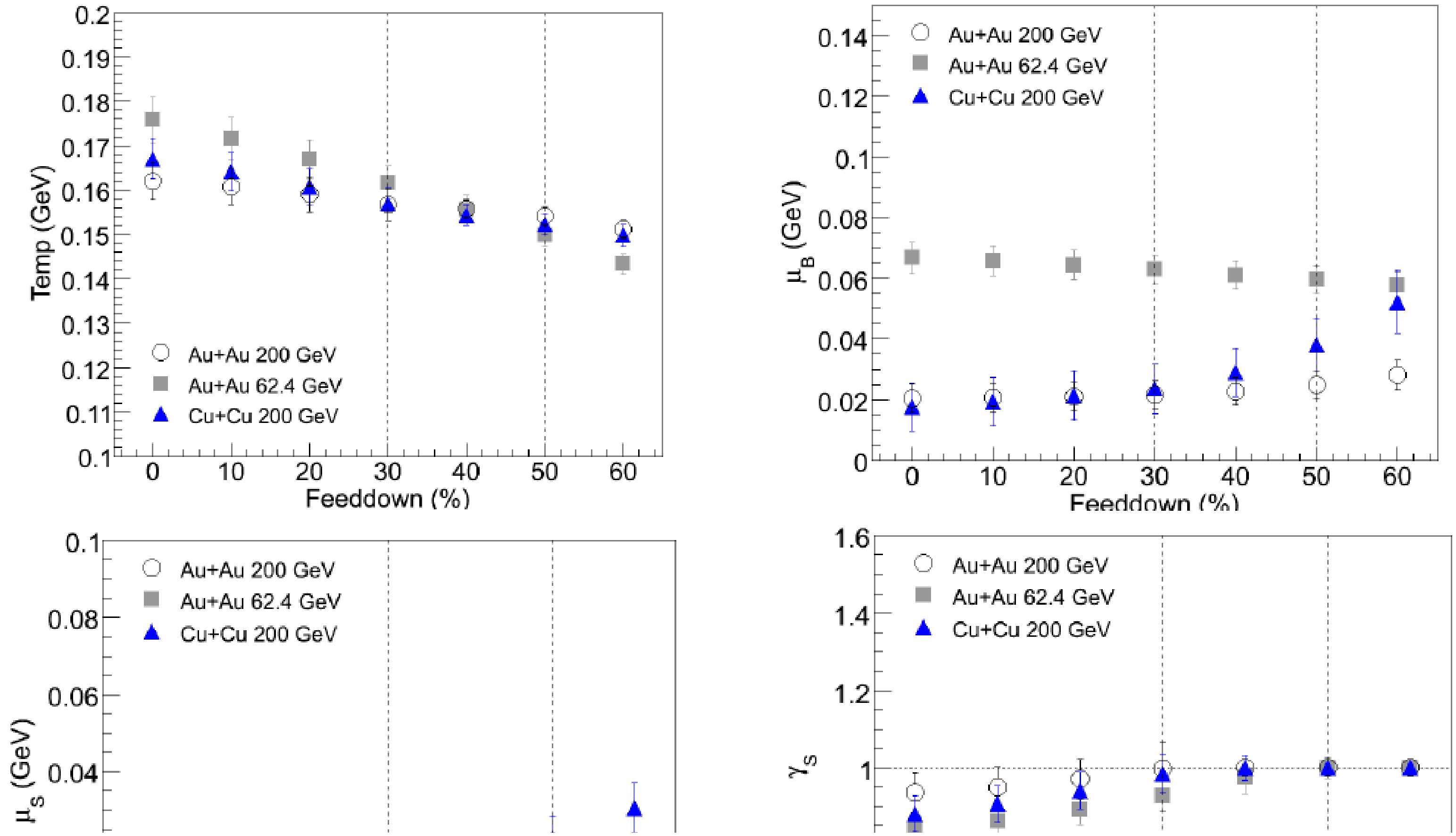
				ng Ratio
				±0,05)%
				±0,5)%
				±0,30)%
				±0,30)%
				±0,005)%
Ξ^-	$\rightarrow$	$\Lambda + \pi^-$	4,91 cm	(99,887±0,035)%
Ξ^0	$\rightarrow$	$\Lambda + \pi^0$	8,71 cm	(99,523±0,013)%
Ω	$\rightarrow$	$\Lambda + K^-$	2,461 cm	(67,8±0,7)%

Feed-down correction of protons from the Sigma



- Total correction to the protons is around 45%, due to Lambdas (Λ) and Sigmas (Σ).

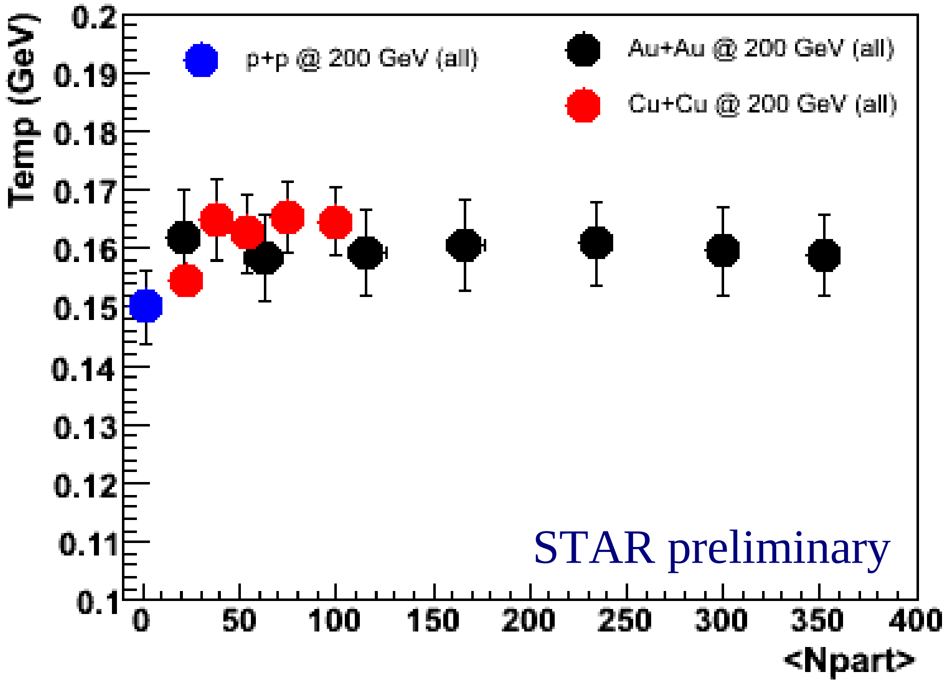
Effect of feed-down on thermal parameters



Thermal parameters has small variation in the range consistent with the feed-down correction uncertainty of the protons.

$$\Delta T = 5\ MeV\ (3\%),\ \Delta\mu_B = 0.005,\ \Delta\mu_S = \text{ negligible },\ \gamma_S = 1$$

Chemical freeze-out T_{ch} vs. system size

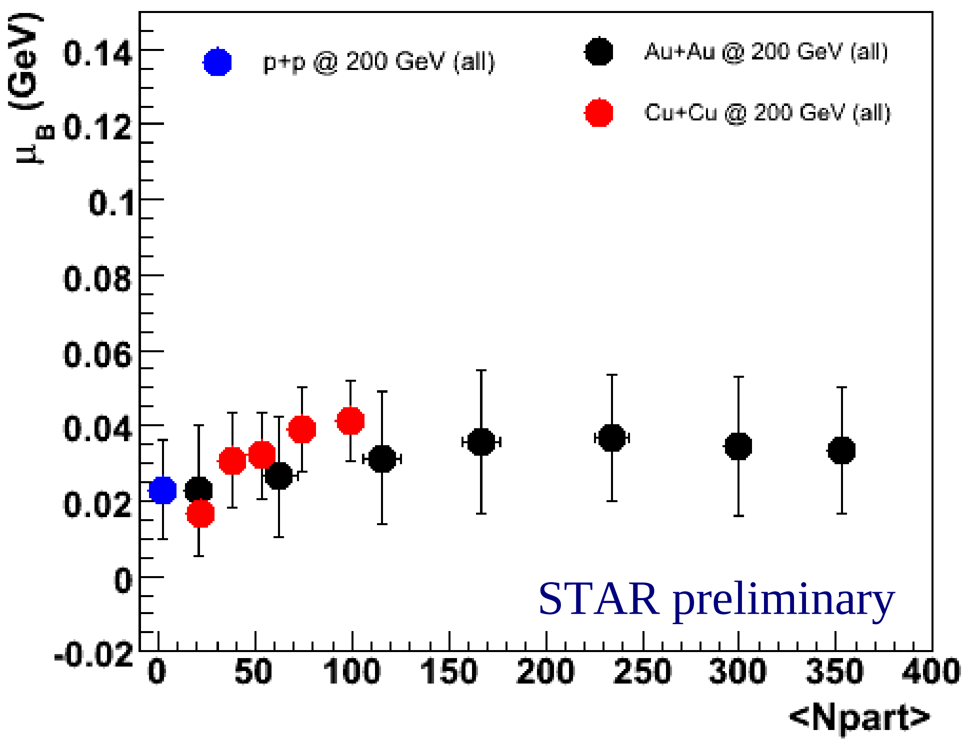


- Au+Au 200 GeV
  Temperature seems constant with system size.

- Cu+Cu 200 GeV
  Temperature is in agreement with Au+Au 200 GeV (within error bars).

Thermus, a thermal Model Package for Root
S. Wheaton & Cleymans, hep-ph/0407174

Baryon chemical potential μ_B vs. system size



- Baryon chemical potential μ_B is small.
- Small variation with system size.
- Cu+Cu 200 GeV baryon chemical potential seems to be in good agreement with Au+Au 200 GeV.

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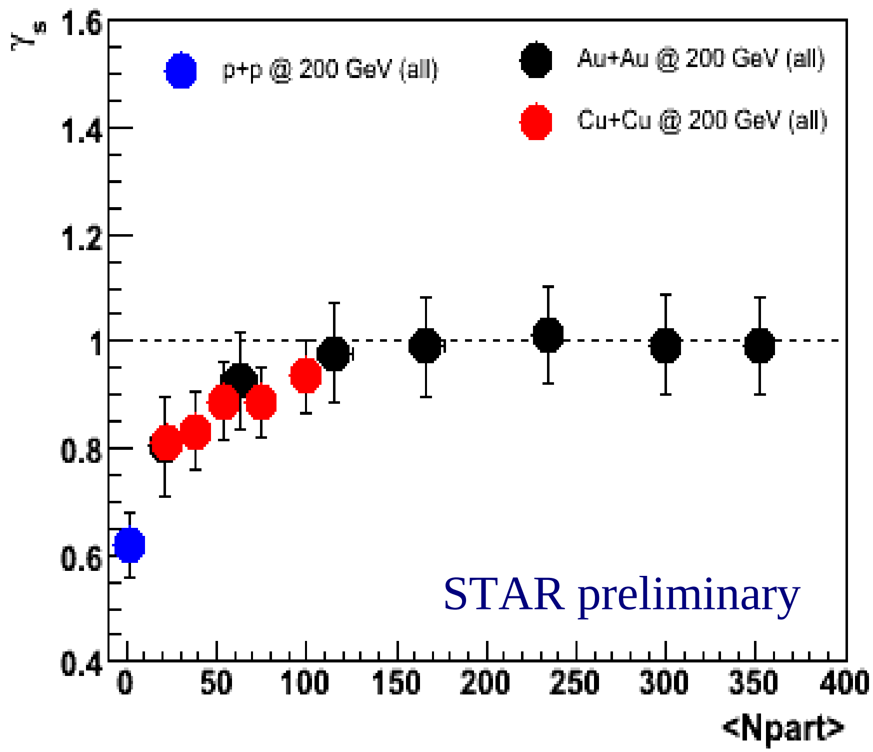
Strangeness saturation γ_s vs. system size



- Strangeness saturation constant, shows an increase with system size, reflecting the increase of strangeness enhancement.
- Cu+Cu 200 GeV data consistent with Au+Au 200 GeV result.
- Deviates from 1 for systems smaller than N_{part} < 100.

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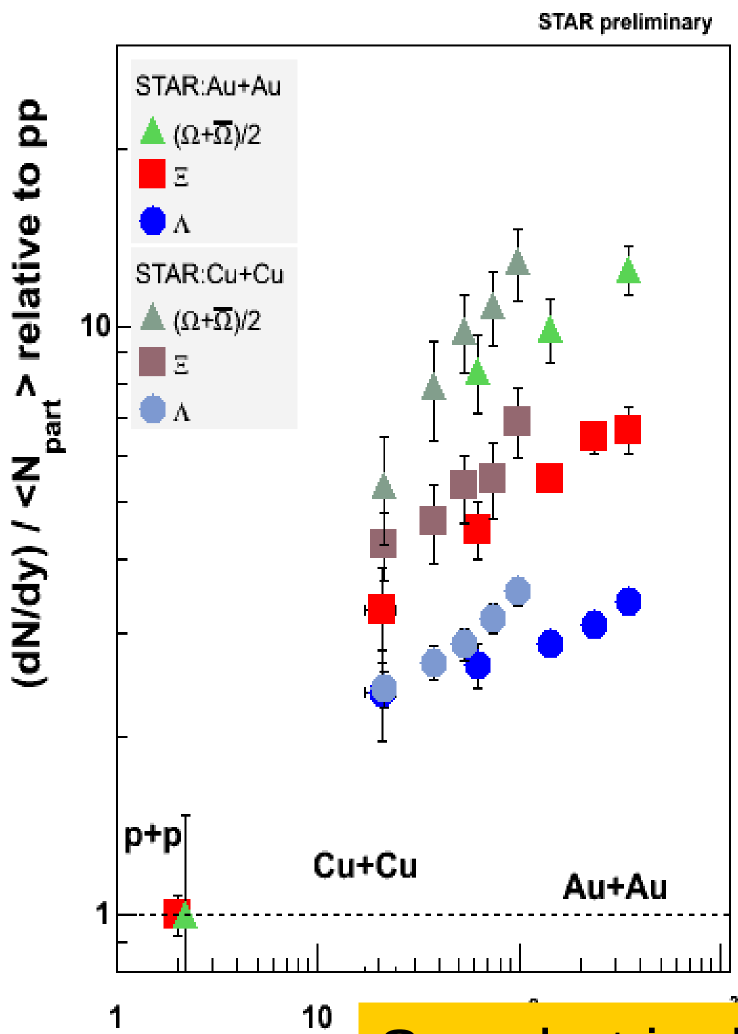
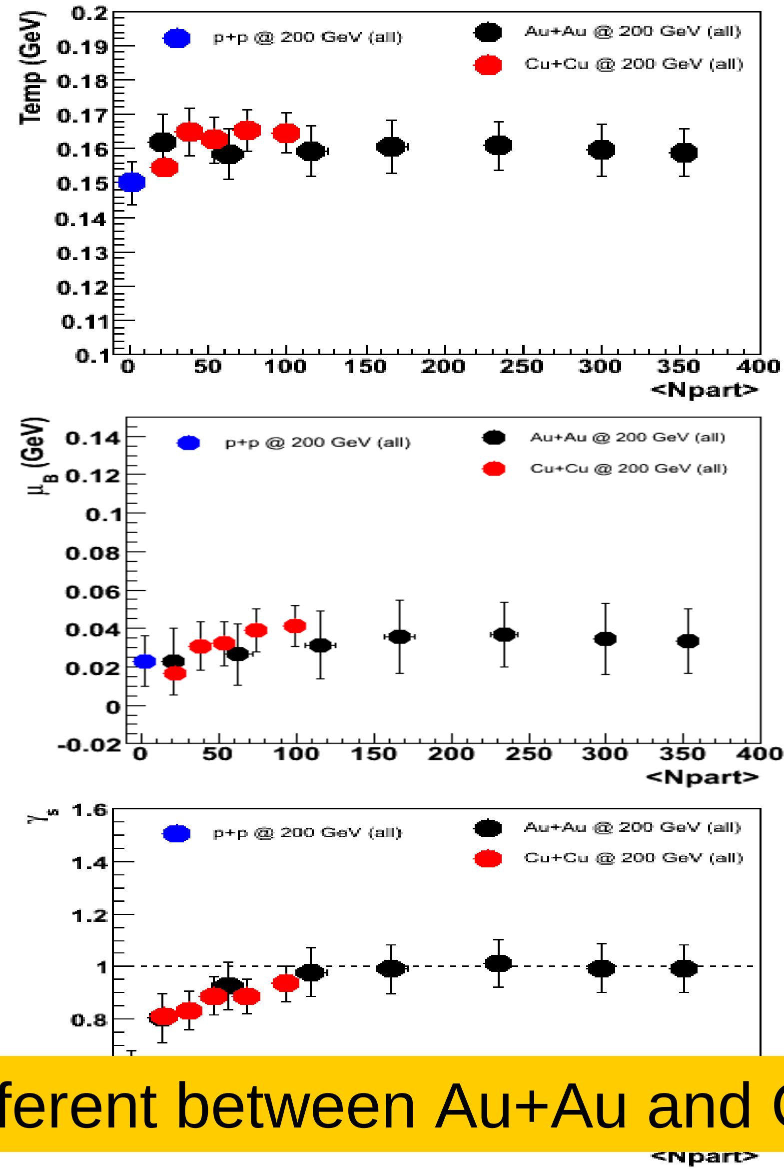
Cu+Cu vs Au+Au

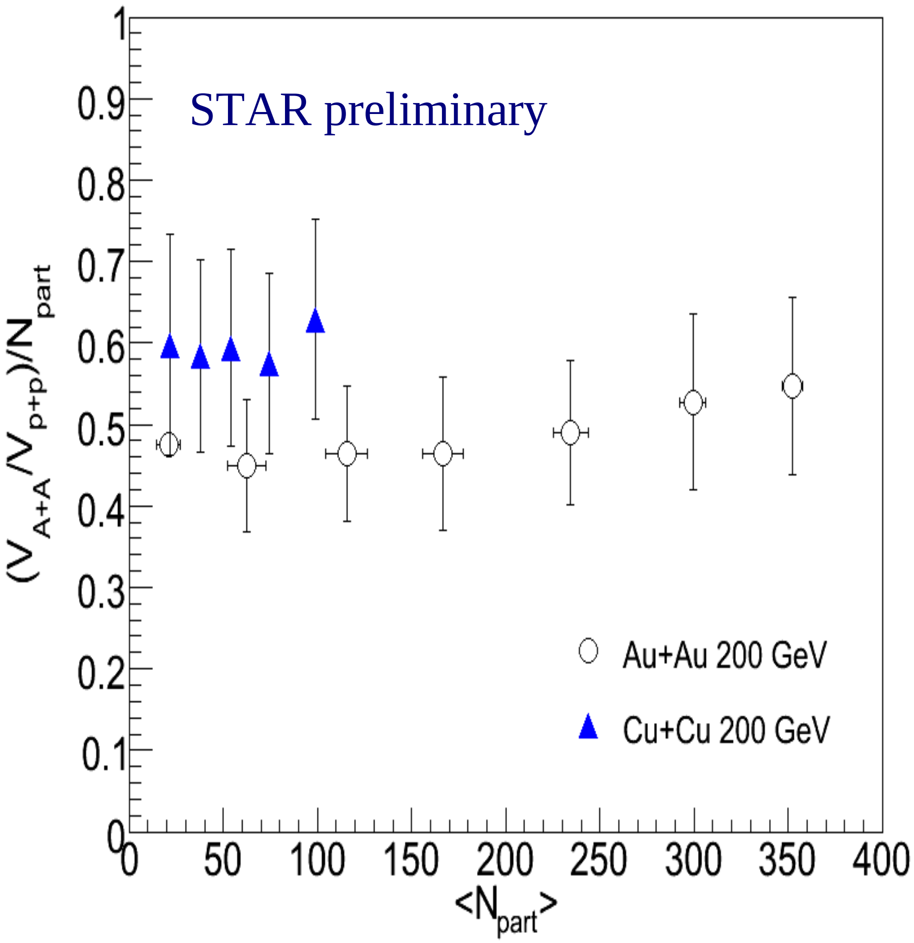




So, what is different between Au+Au and Cu+Cu?

From A. Timmins talk on monday

Chemical freeze-out volume vs. system size



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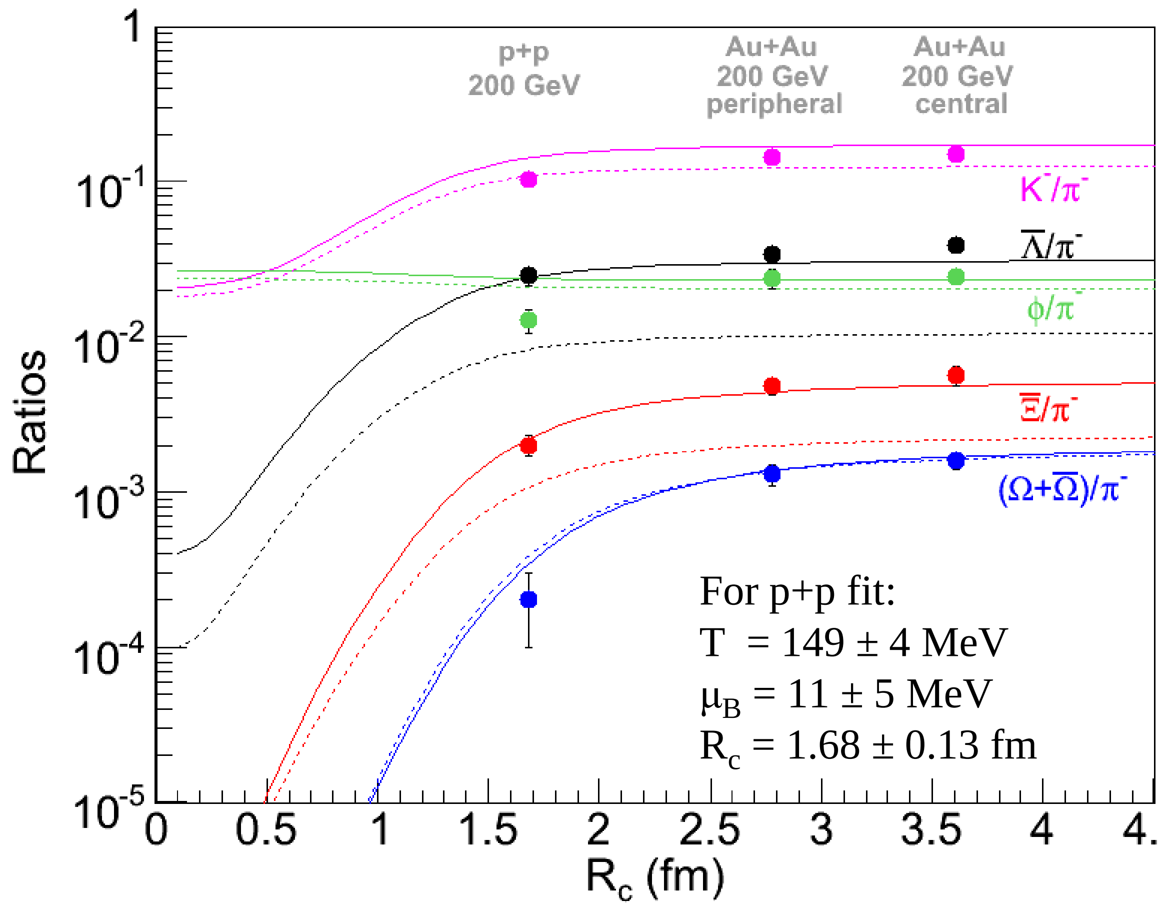
- Volume at Chemical freeze-out was determined using pion yields.
- Relative volume of the fireball at chemical freeze-out in Cu+Cu collision is higher than in Au+Au collision, for the same equivalent N_{part}.
- Higher strange particle yields observed in Cu+Cu compared to Au+Au (Ant. Timmins talk) is related to the volume at CF, so not to N_{part}.

Canonical Suppression effect

- How does strangeness production get affected by the canonical radius?
- Can we tell we have indication of canonical suppression?

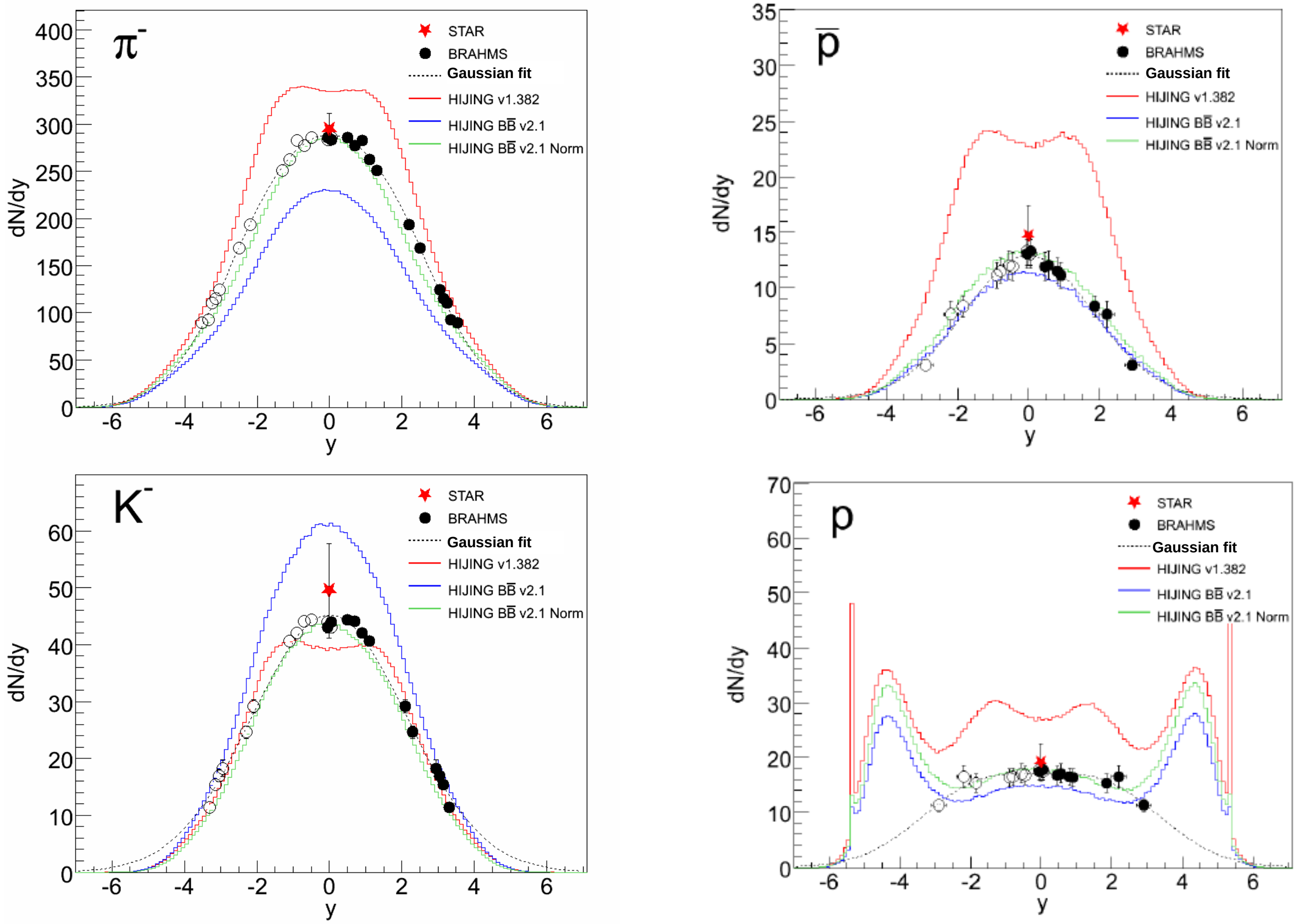


Data of most peripheral Au+Au collision is already in the saturated region, thus, not subject to canonical suppression !!!

It seems that in Strangeness Enhancement scenario, canonical suppression can only account for the initial increase from pp to most peripheral AuAu for open strange particles.

SPS: $R_c \approx 1.4$ (I. Kraus & K. Redlich hep-ph/0604242)

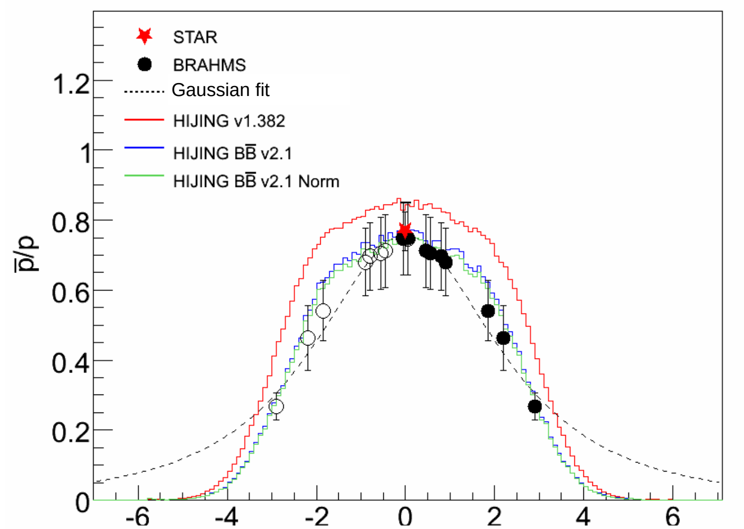
Rapidity distributions

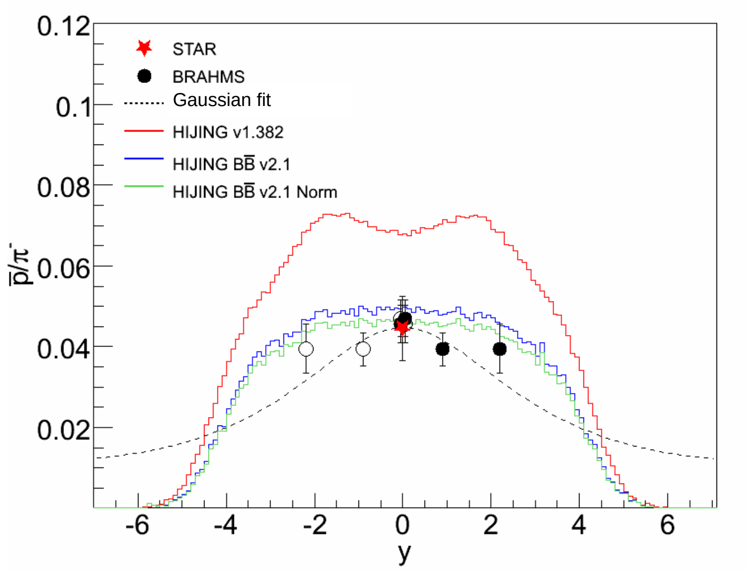


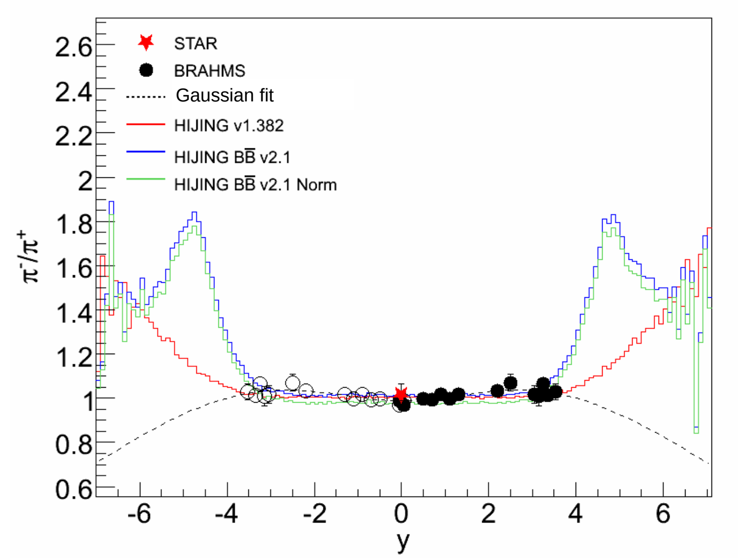
BRAHMS data: PRL94_162301 (2005) & PRL93_102301 (2004)
Hijing: X.N. Wang and M. Gyulassy: Comput. Phys. Commun., 83:307, 1994.

Ratios vs. Rapidity

- Hijing and Gaussian distributions describe quite well the particle ratio rapidity dependence for |y|<3.5 .
- But, different parameterizations disagree for |y|>4.







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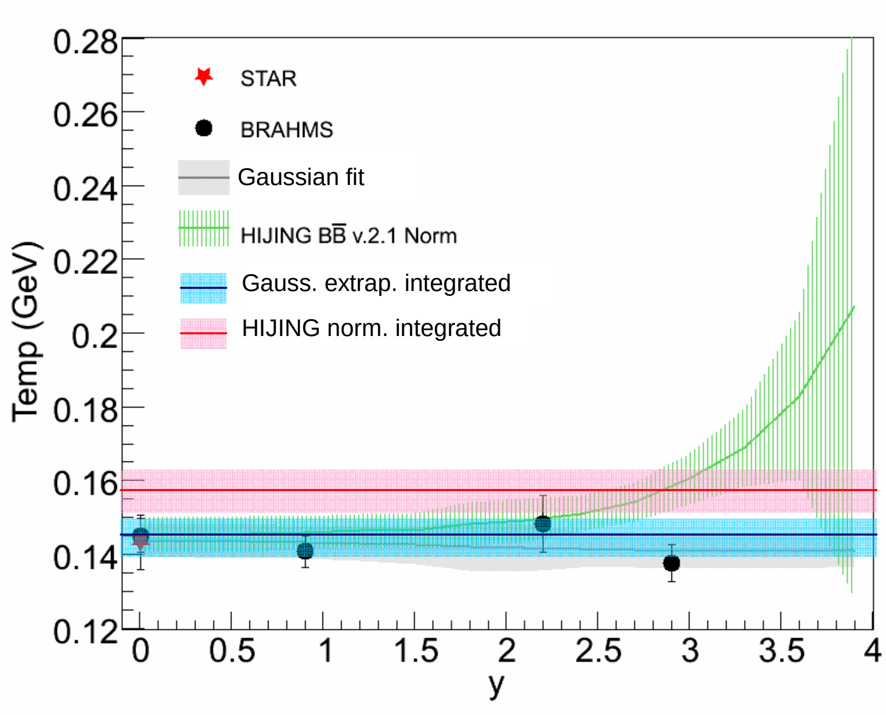
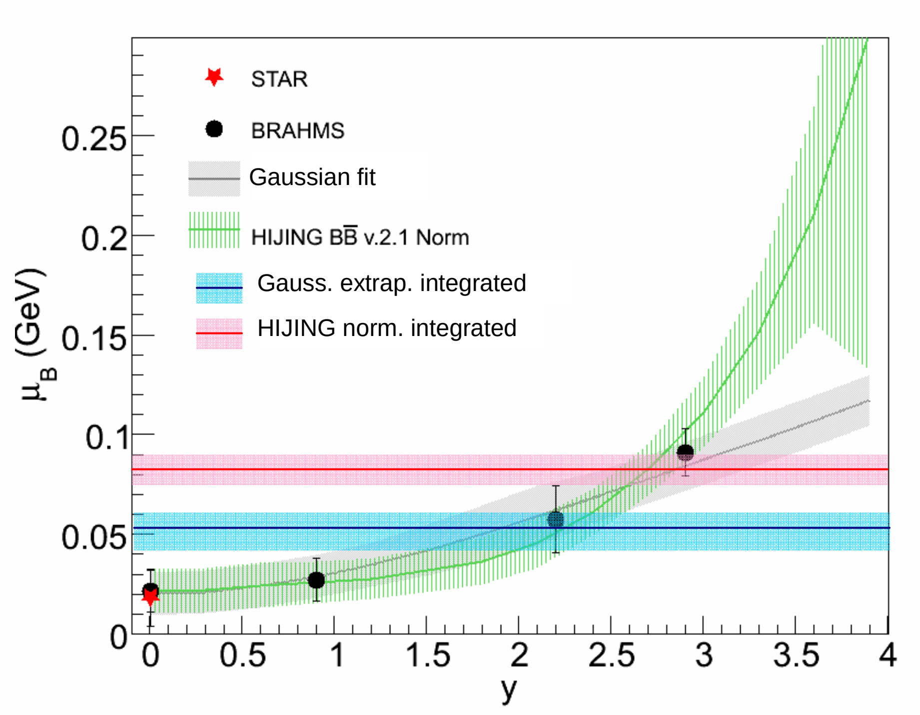
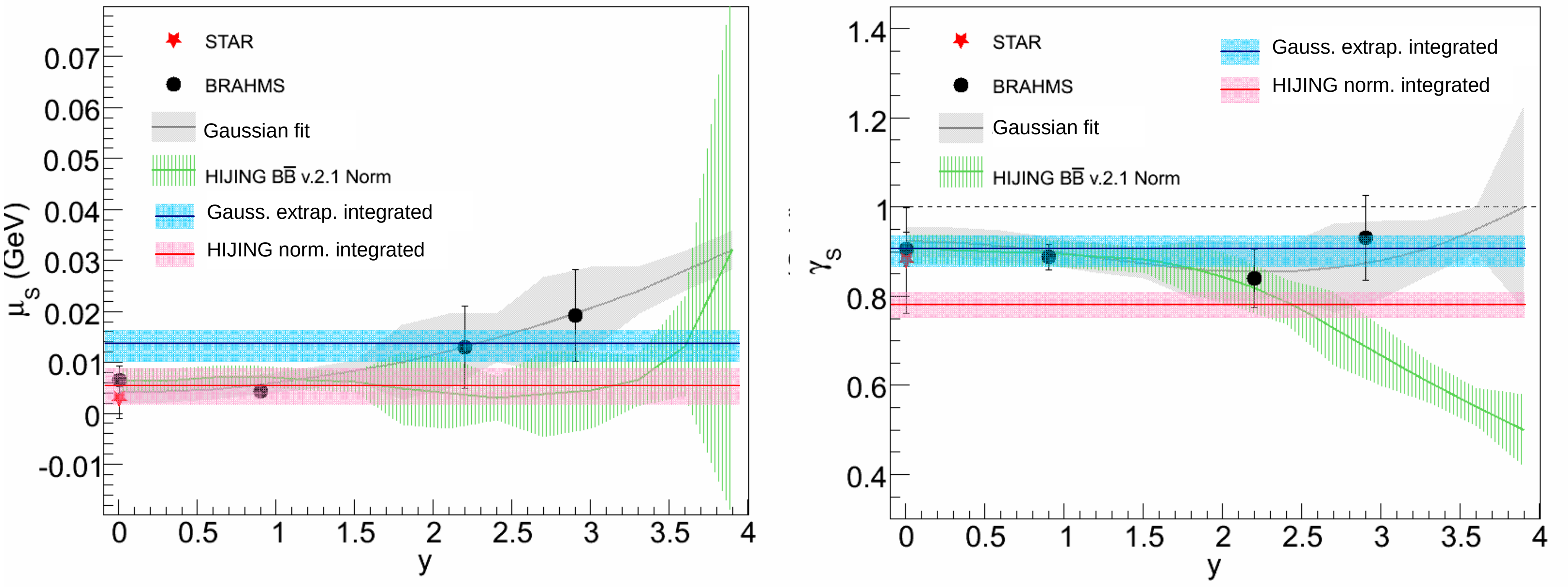
Thermal fit results vs. Rapidity





- Temperature constant up to y=3.
- μ_B shows increase with rapidity.
- For rapidity integr. yields using Gauss: $T=144\pm8$ MeV, $\mu_B=53\pm16$ MeV
- For rapidity integr. yields using Hijing: $T=156\pm8$ MeV, $\mu_B=79\pm19$ MeV

Thermal fit results vs. Rapidity

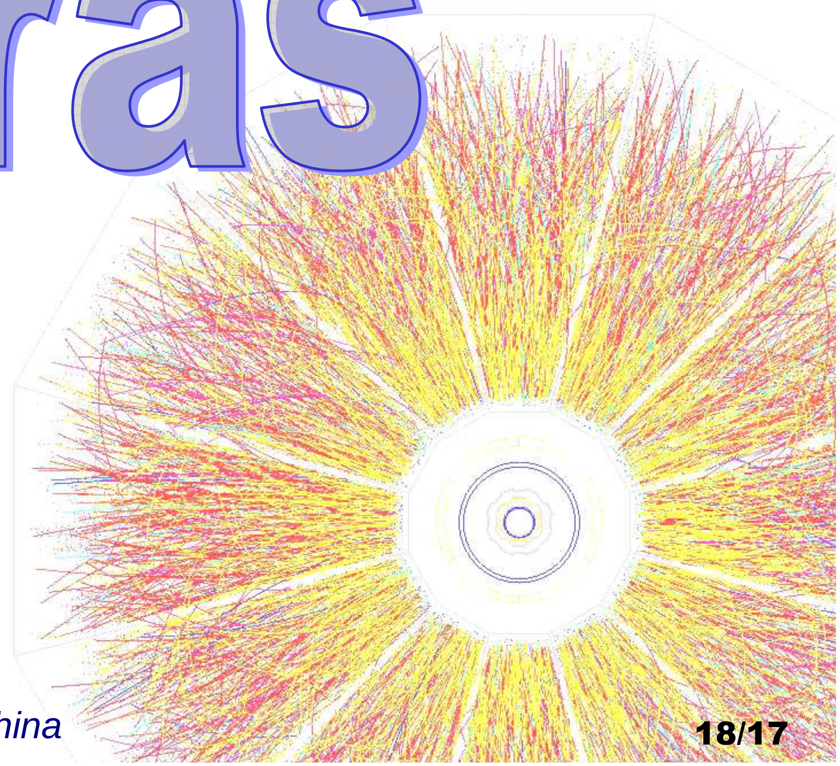


- μ_S shows increase with rapidity, Hijing extrapolation shows no variation with rapidity in the studied range.
- γ_S constant with rapidity, up to y=3.
- For rapidity integr. yields using Gauss: μ_S=14±4 MeV, γ_S=0.91 ±0.12
- For rapidity integr. yields using Hijing: μ_S=7±4 MeV, γ_S=0.79 ±0.12

Conclusions:

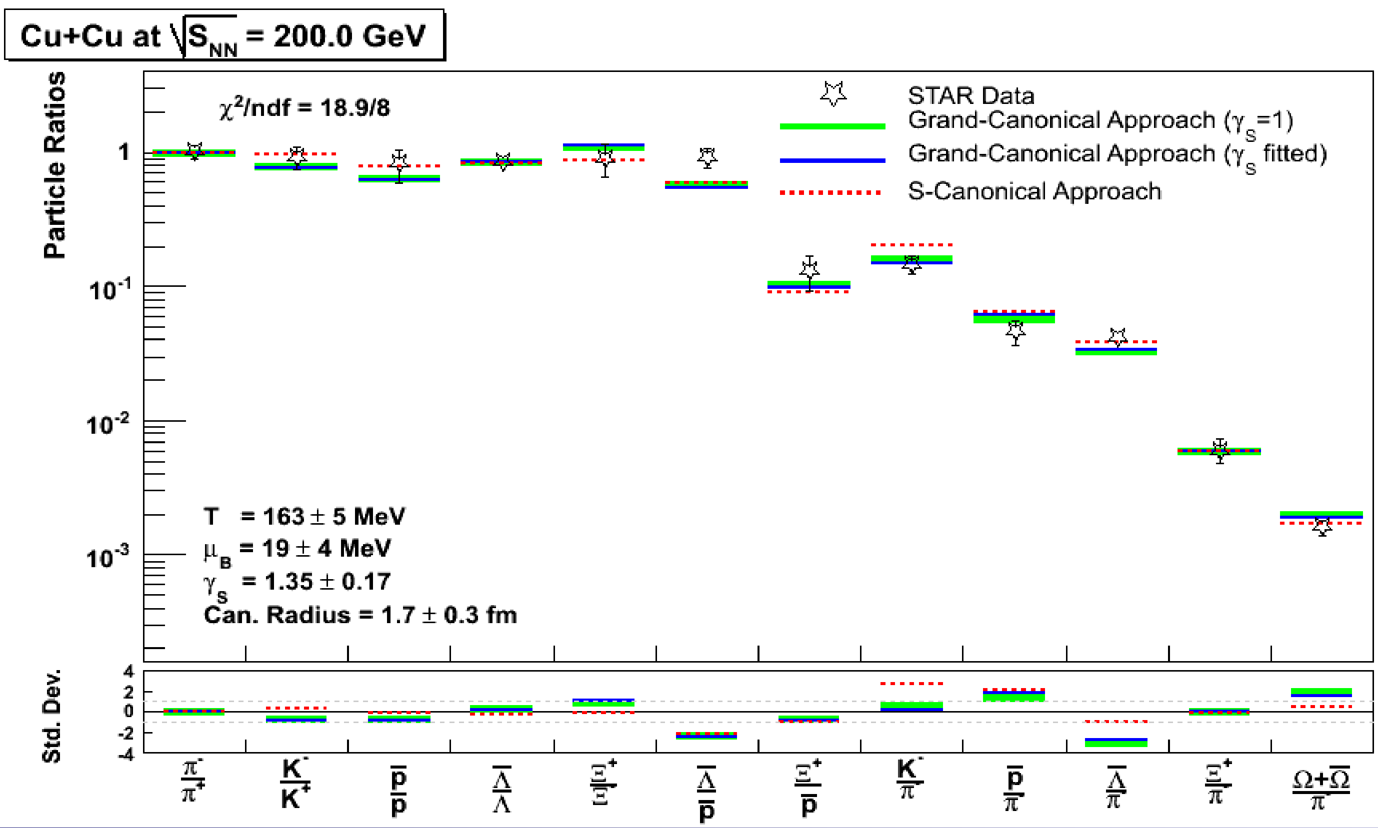
- **Strangeness is chemically equilibrated at RHIC energies.**
- **Thermal parameters are constant for a wide range:**
  - **Centrality:** System with N_{part}>100 is well described using GC approach with γ_s=1.
  - **Rapidity:** at RHIC energies, thermal fit Temperature constant up to Y=3; μ_B shows increase with rapidity.
- **Canonical** approach shows strong increase of strange particles with R_c, except for the phi-mesons. **Fits to Au+Au data results in R_c values where canonical suppression is no longer relevant**.
- **Cu+Cu and Au+Au**: Results of thermal model fits indicate that the **freeze-out volume formed in Cu+Cu collision is higher than that in Au+Au collisions** with the same initial condition.

Extras

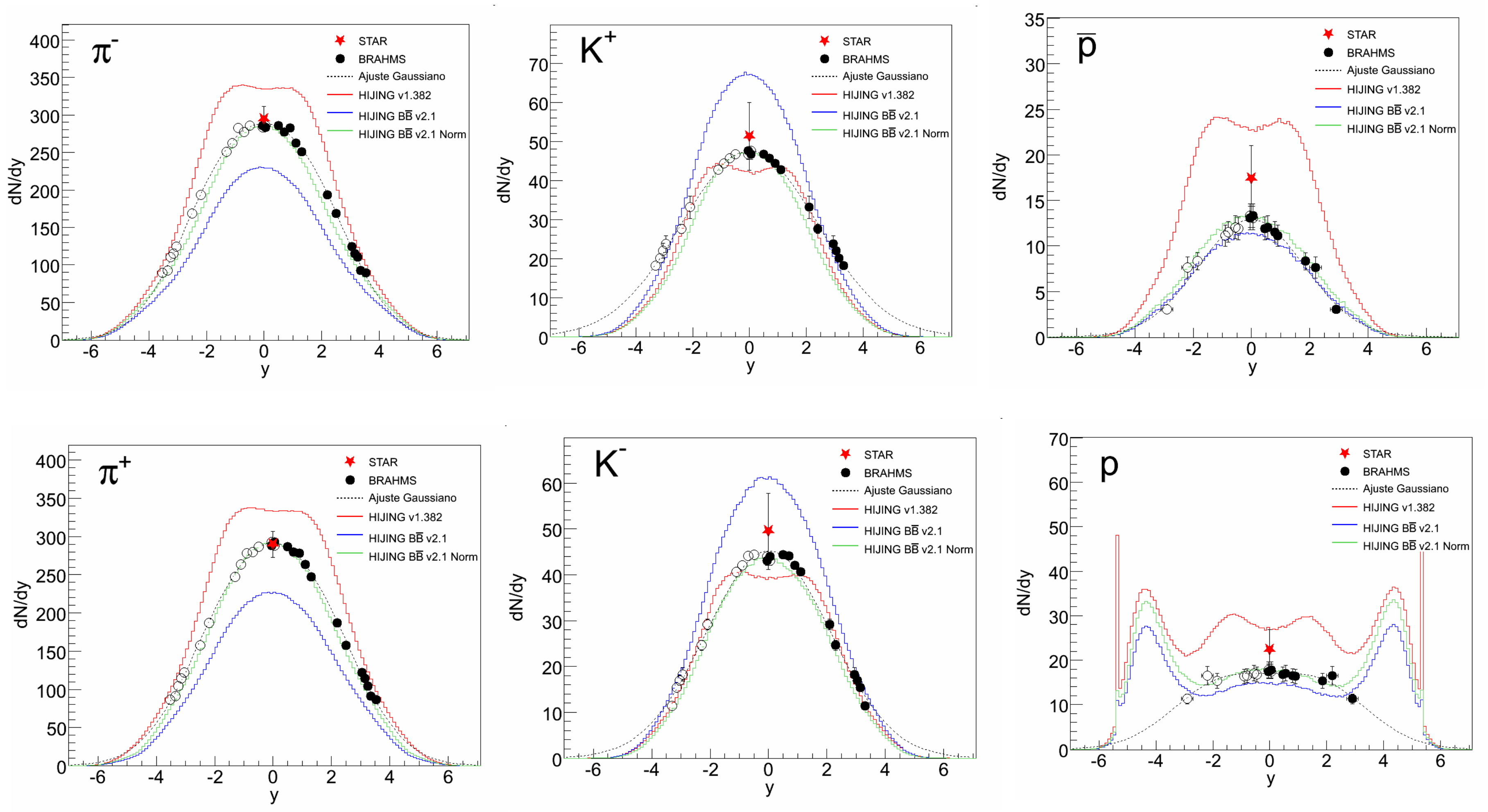


Comparing different thermal model conditions: Central Cu+Cu collision

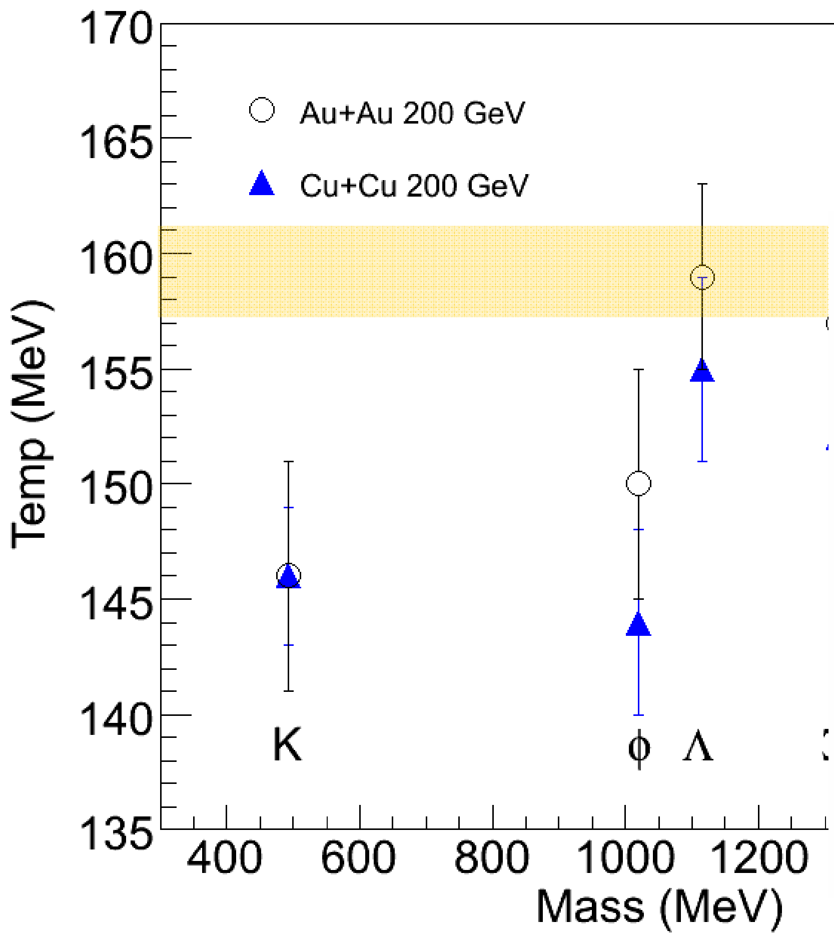
- Particles ratios still well described with GC ensemble.
- Canonical ensemble describes identical particle ratios, Lambdas and Omega better.



Rapidity distributions

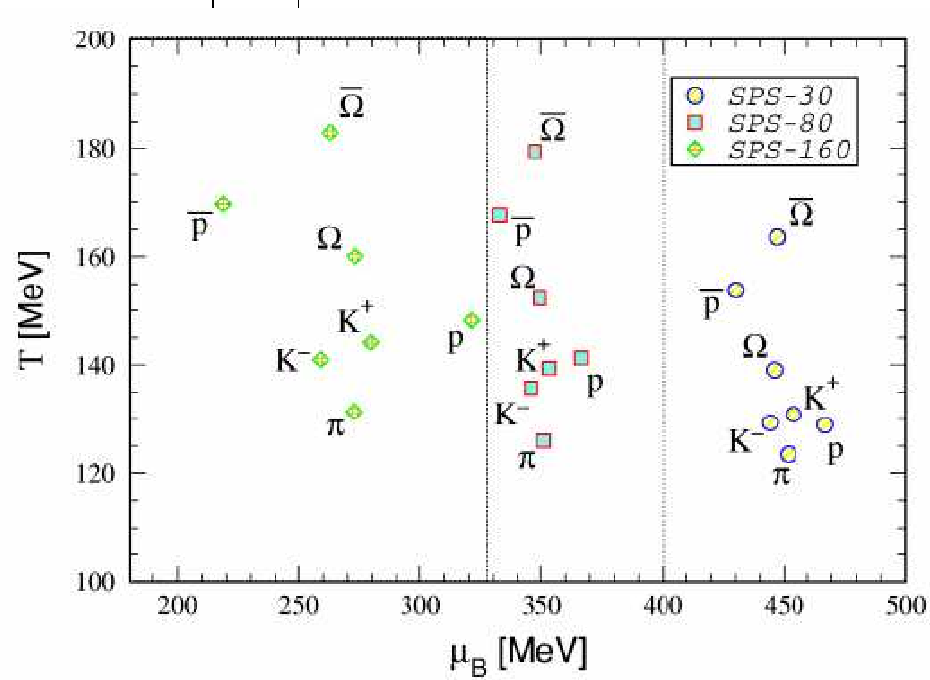


Varying the strange particle used in the thermal fit



Ratios built with:

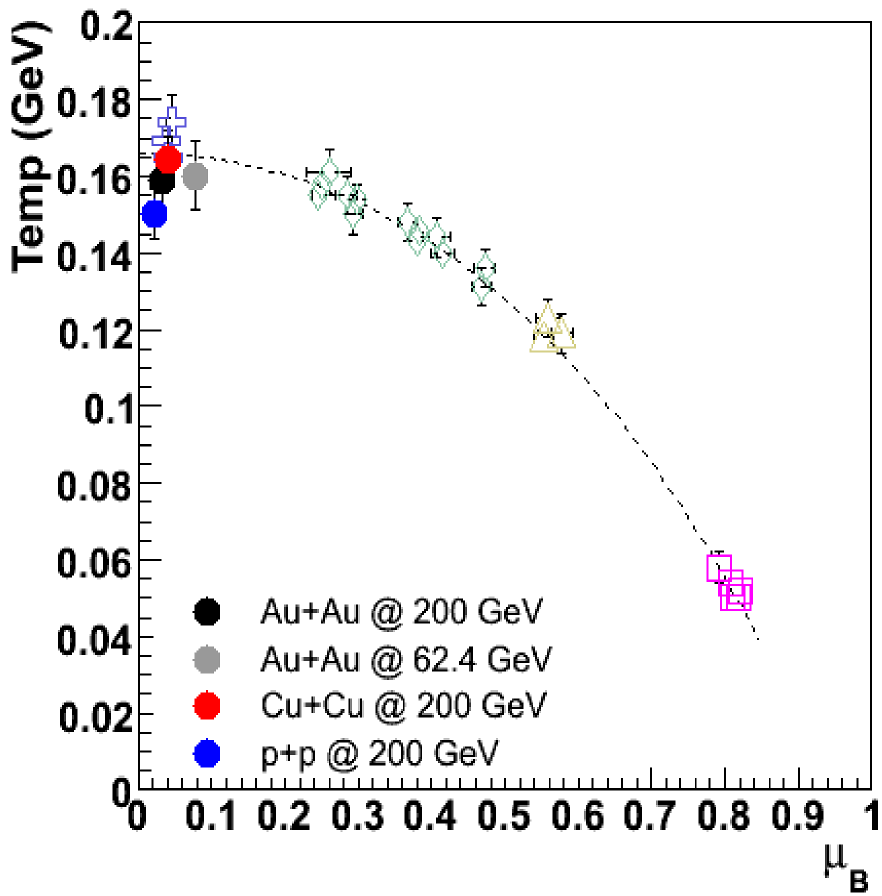
$$p, \bar{p}, \pi^-, \pi^+, S, \bar{S}$$



arXiv:nucl-th/0612033v1: Local and Global strangeness inhomogenuities at freeze-out conditions.
PRC_73_024902: Inhomogeneous freeze-out in relativistic heavy ion collisions.

Summary of thermal model study

- **Statistical Thermal** model fits reasonably well the particle ratios measured in STAR, indicating that data is consistent with a thermalized system.



- Au+Au 200 and 62 GeV: Centrality dependence of thermal fits show increase of γ_s parameter, consistent with strangeness enhancement seen in the data yields.
- Cu+Cu200 GeV: yields the same temperature and baryon chemical potential values obtained from the fit to Au+Au data.
- Strangeness Canonical approach seems to yield better agreement with our data.