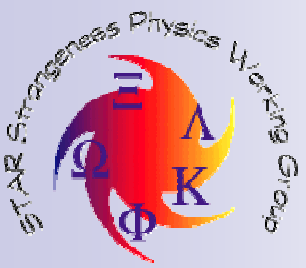


Strangeness production in STAR

Jun Takahashi for the STAR collaboration

Motivation

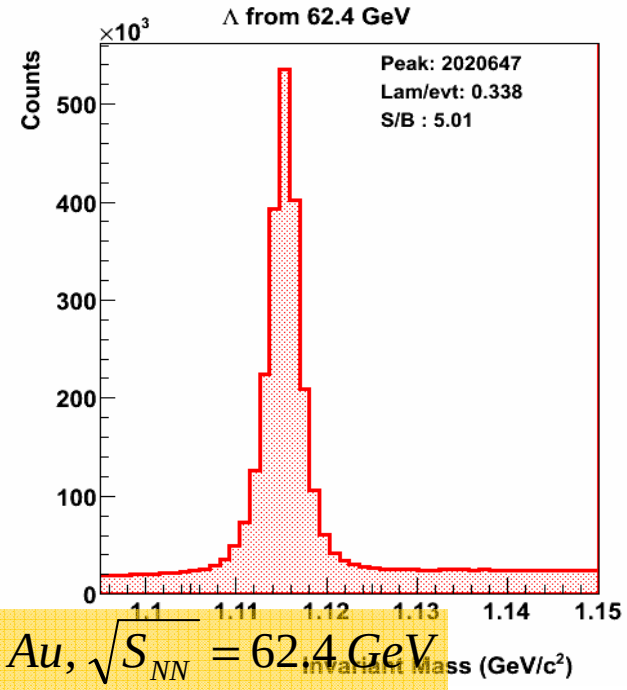
- In A+A:
  Strangeness production is expected to be enhanced !!!
- In p+p, and peripheral
  Strangeness production may be limited due to canonical suppression.

In this talk, we will discuss this problem by looking at:

- New Cu+Cu data vs Au+Au data.
- System size dependence.
- Chemical Equilibrium:
  Is strangeness equilibrated?
  What are the equilibrium properties?
  Does canonical approach describes data better?

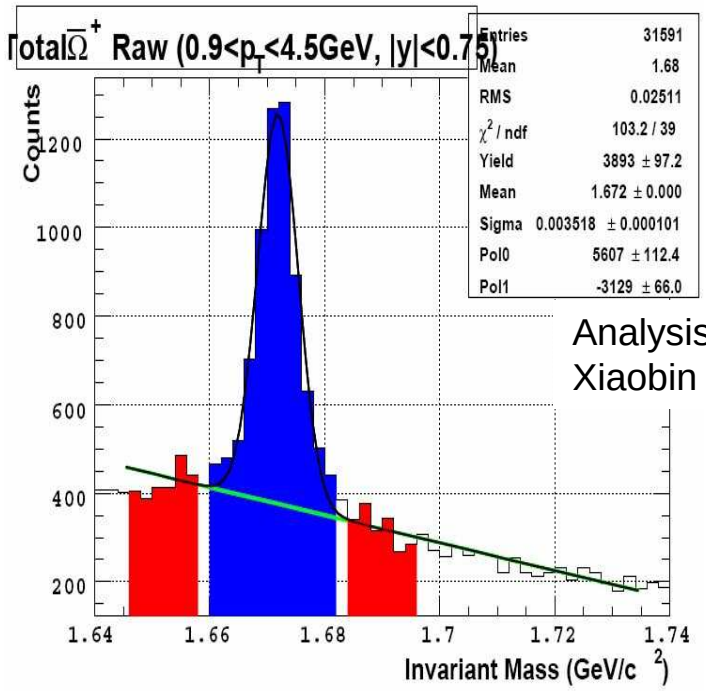
The STAR experiment

- Excellent detector reconstructing strange baryons.
- Large acceptance at mid-rapidity.
- Perfect for reconstructing strange particles through topology decay: Λ, Ξ, Ω.



$Au + Au, \sqrt{S_{NN}} = 62.4\,GeV$

$Cu + Cu, \sqrt{S_{NN}} = 200\,GeV$



Analysis done by Xiaobin Wang

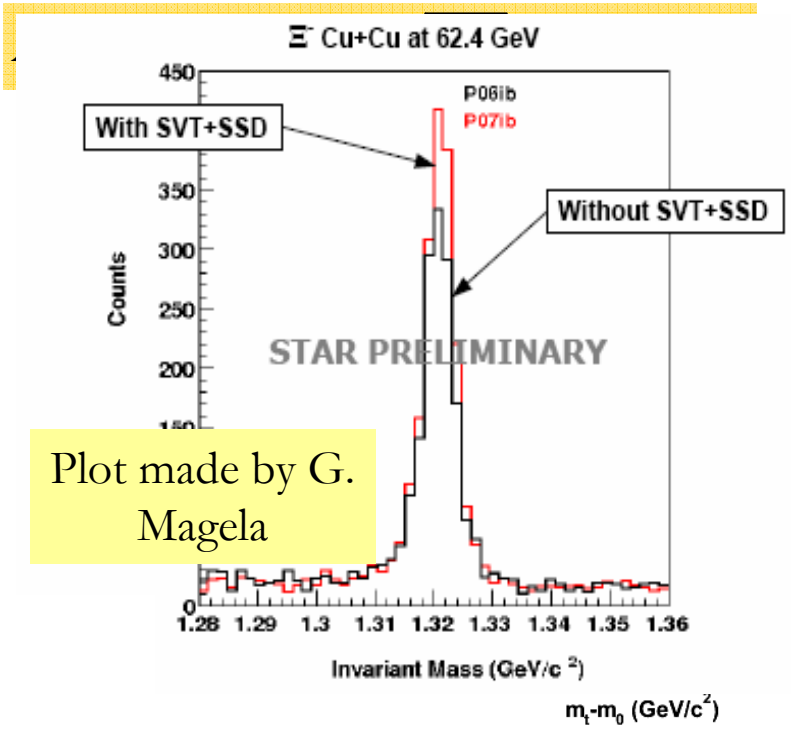
Data Analysis: Event centrality

- Event centrality determined by charged particle multiplicity.
- Collision geometrical parameters are inferred using Glauber Model.

Au+Au			Cu+Cu		
Cent	N_{part}	N_{Bin}	Cent	N_{part}	N_{Bin}
0-5	351.0 ± 3.0	1039 ± 79			
5-10	293 ± 7.	810 ± 58			
10-20	231 ± 3.2	574 ± 42			
20-40	139 ± 5.	278 ± 30	0-10	98.4 ± 1.0	185.7 ±5.9
40-60	59.0 ± 5.	82 ± 12	10-20	74.8 ± 2.5	126.7 ±6.7
			20-30	54.4 ± 2.8	81.5 ± 6.0
60-80	19.0 ± 3.5	19 ± 5	30-40	38.5 ± 2.5	51.0 ± 4.8
			40-60	21.9 ± 2.6	24.3 ± 3.9

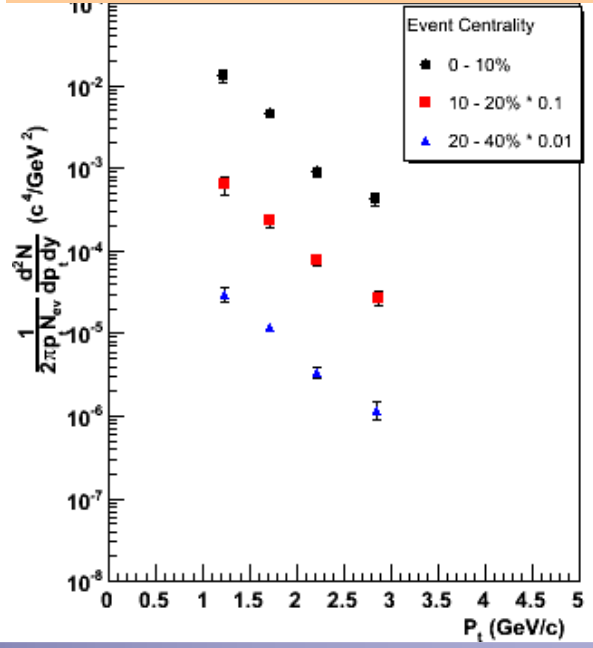
Data analysis: Total Yield

- Efficiency & acceptance and Feed-down correction.
- Total yield calculated from fit: Boltzmann, Exponential or Levi function.
- Extrapolated area is ~25% for Λ, 30% for Ξ and 35% for Ω.
- New 2007 data with STAR inner tracker (SVT+SSD) should reduce extrapolated area and improve systematic error.



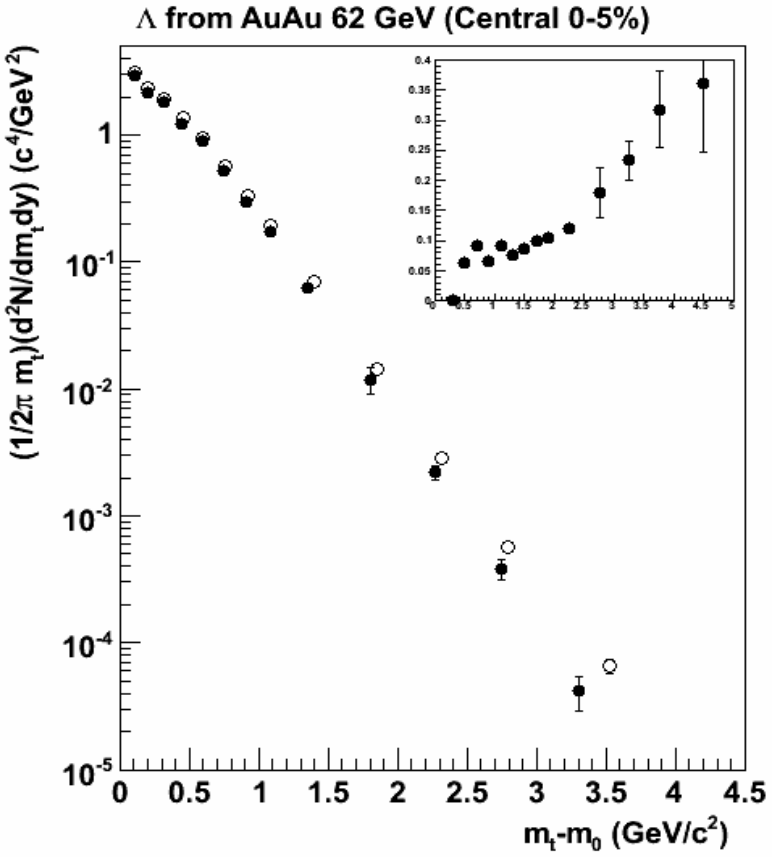
Plot made by G. Magela

$\Omega^- \ from \quad Cu+Cu, \sqrt{S_{NN}} = 62.4\ GeV$

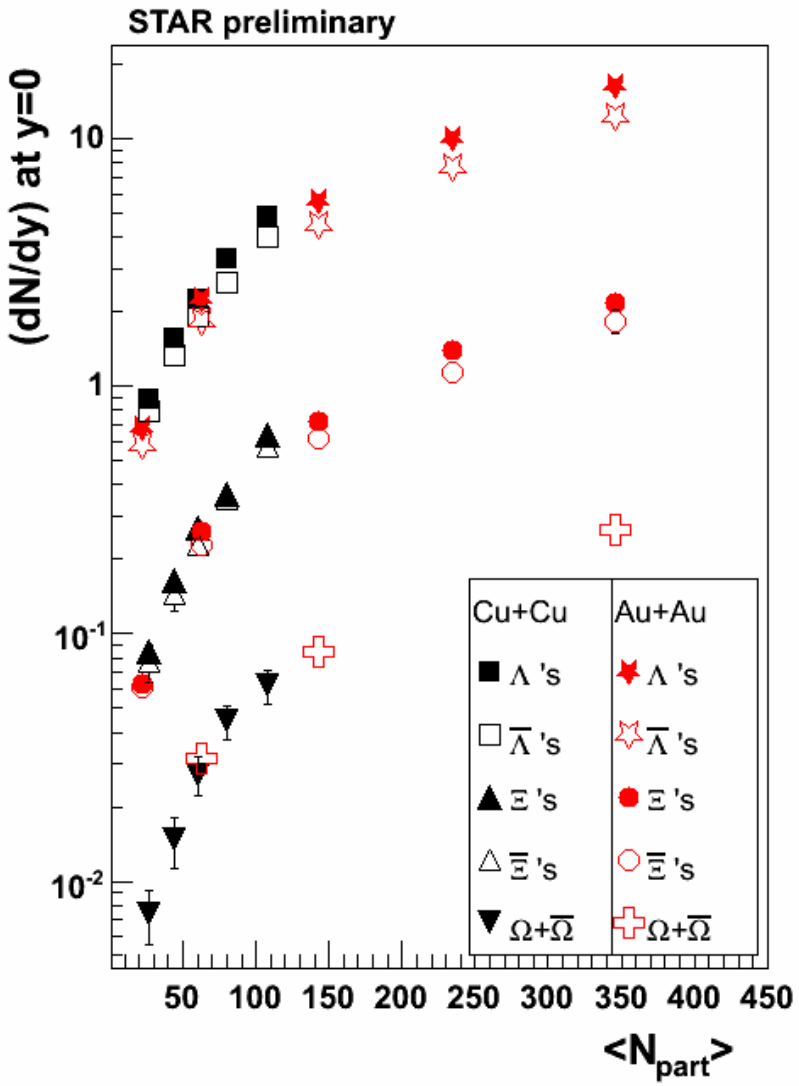


STAR data description for strange particles:

- Mainly, mid-rapidity yields (-1.0 <y <1.0)
- Pion yields are corrected for weak decay feed-down contributions.
- In papers, unless explicitly noted, Protons and Anti-protons are not corrected for weak decay feed-down corrections. This correction is estimated to be at maximum of 30%.
- Λ are corrected for Ξ feed-down.
- Ξ feed-down from Ω is negligible. BR 8.6 %



CuCu200 & AuAu200 Yields: Λ´s, Ξ´s and Ω´s



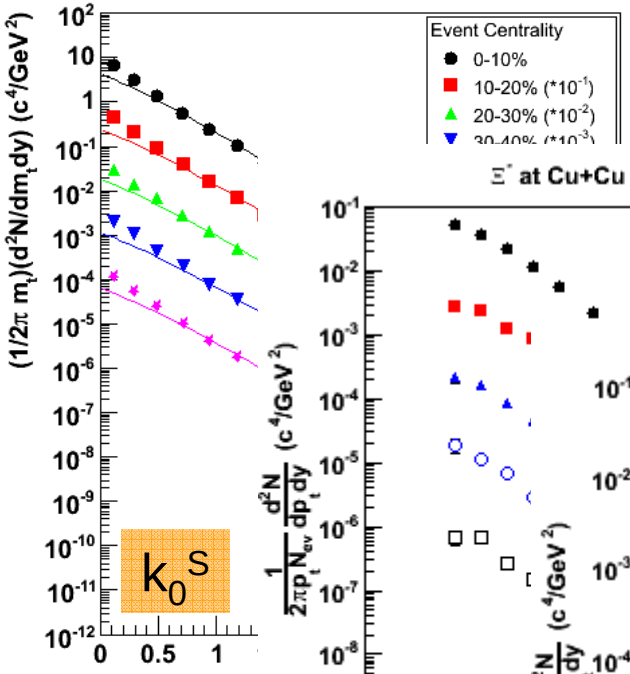
- Both Au+Au and Cu+Cu data show particle yields increase with system size.
- We use the number of collision participants for geometrical scaling.
- Cu+Cu strange baryons show higher yield relative to equivalent AuAu $\langle N_{part} \rangle$ centrality.

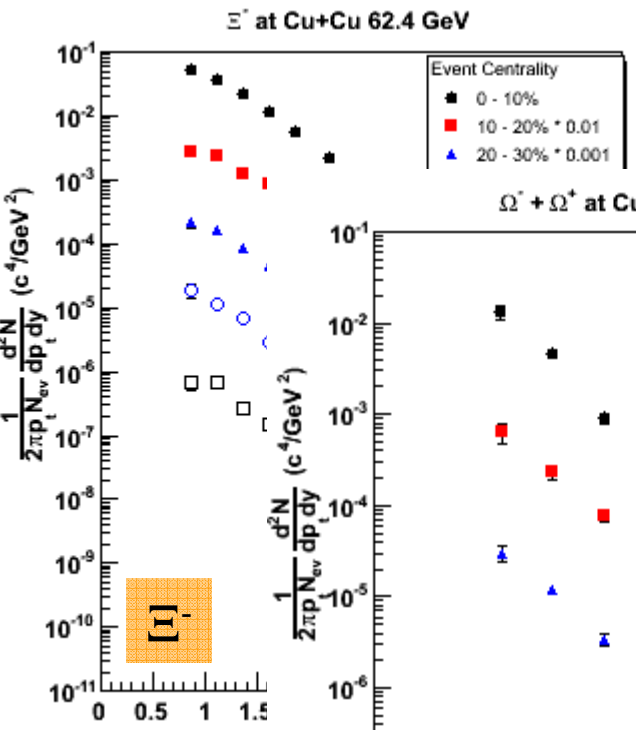
- Red symbols are for Au+Au 200GeV
- Black symbols are for Cu+Cu 200 GeV
- Solid symbols are for the particles
- Open symbols are for anti-particles.

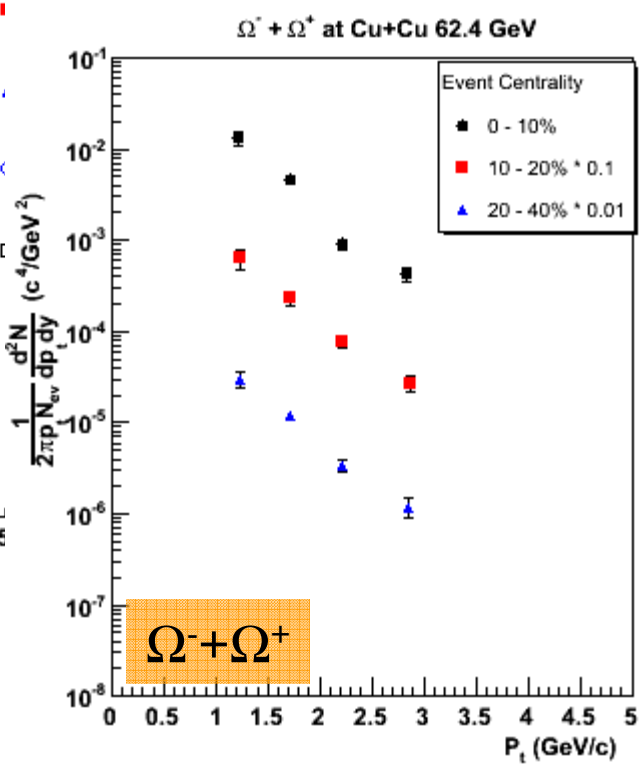
New Cu+Cu 62 GeV:

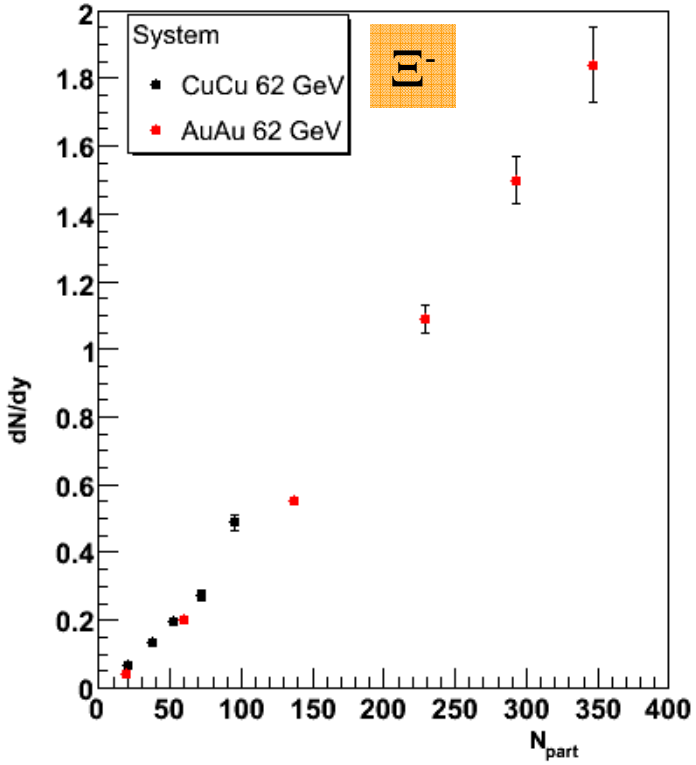
Very Preliminary data !!!

- Cu+Cu 62 GeV data seems to show same enhancement relative to Au+Au as seen in 200 GeV.



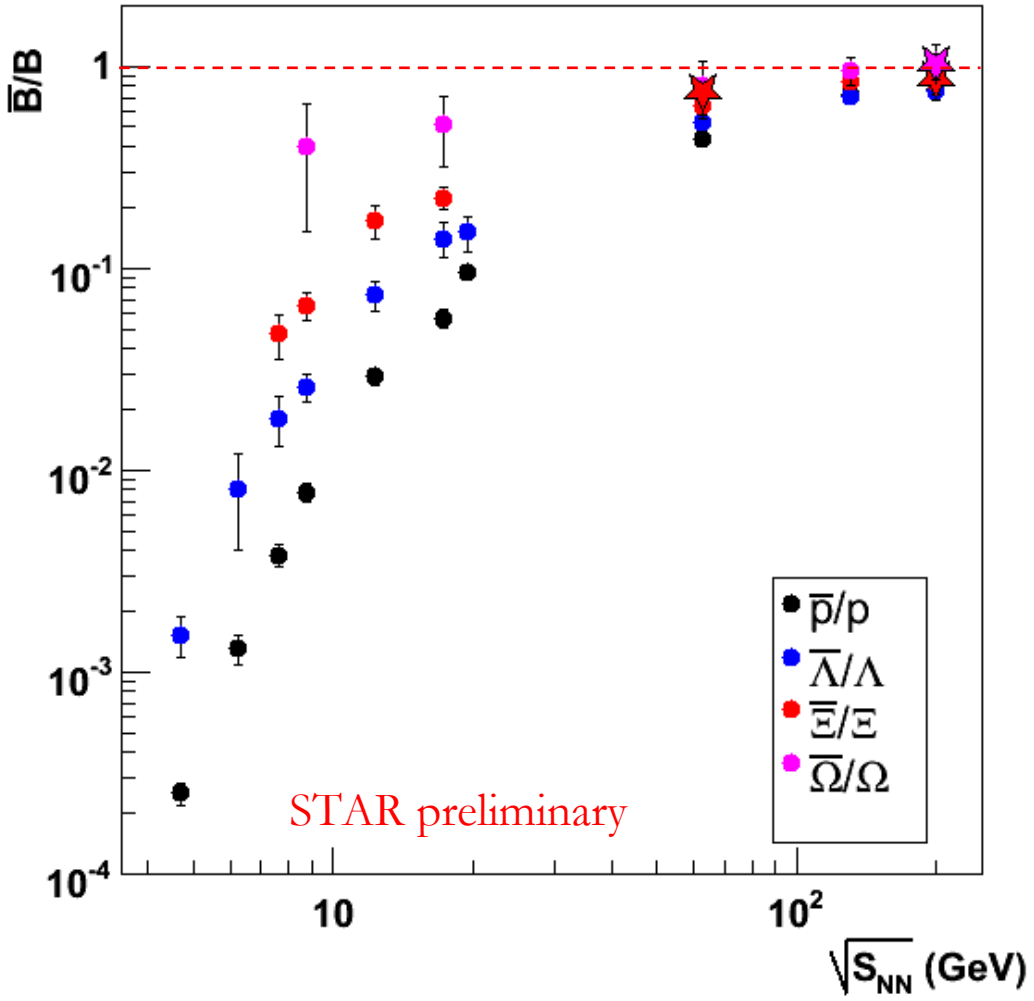






Analysis done by G.Magela & M. Munhoz

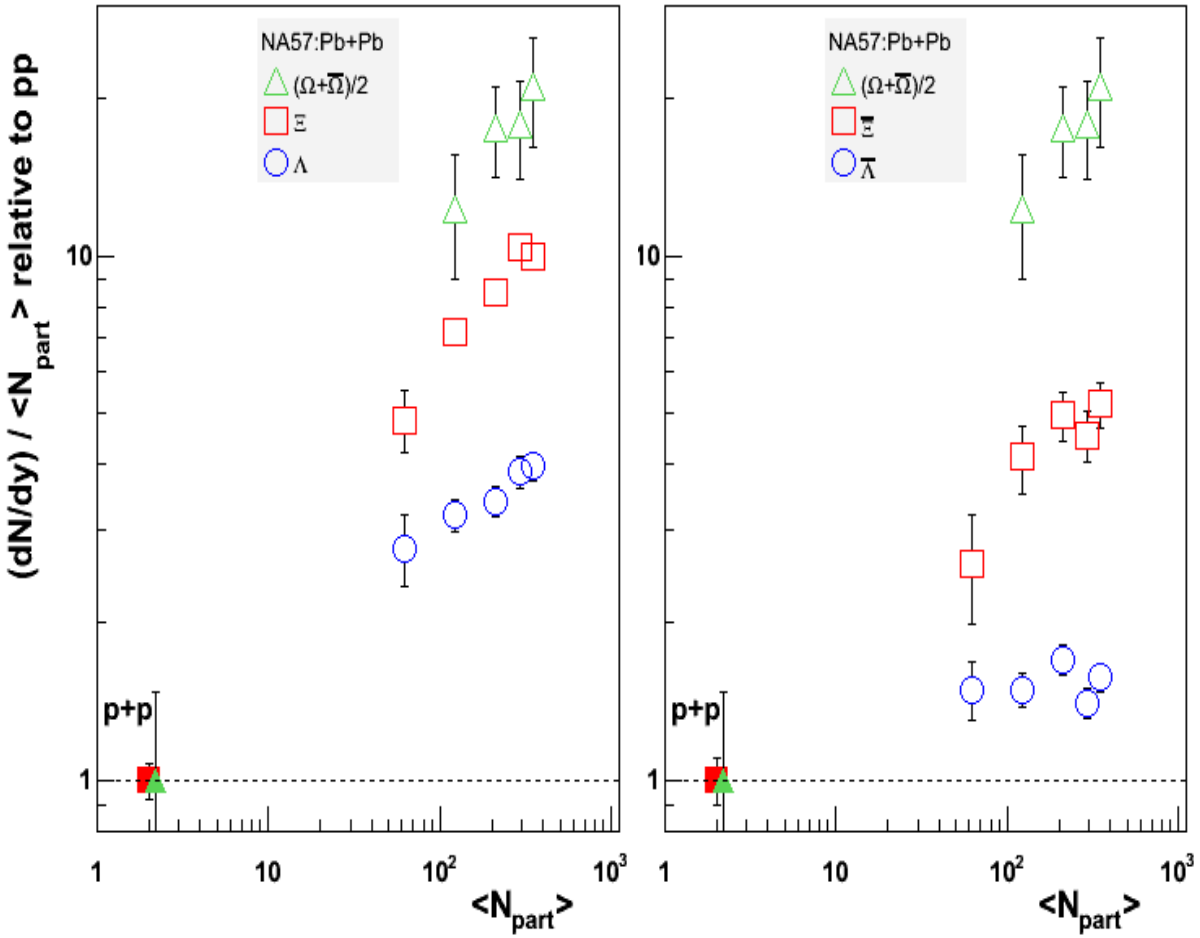
The new STAR data in the systematic



- New Cu+Cu data seems to follow systematic.
- Ratio seems to be the same, independent of the system size.

Strangeness Enhancement: SPS

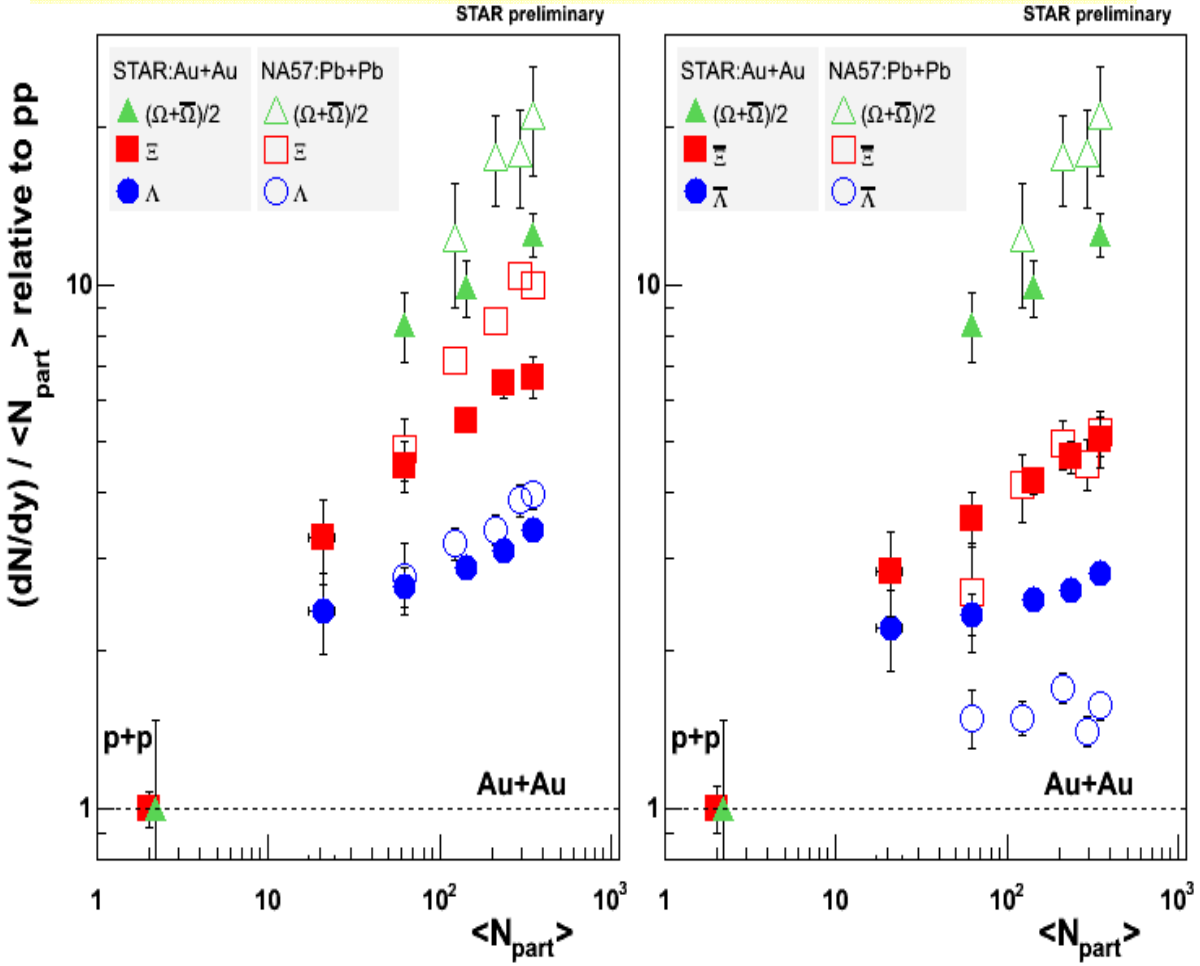
F.Antinori et al. (NA57 Collab.) Jorn. Phys. G, 32 (2006) 427-441



- Enhancement of strangeness production per participants in AA collisions, relative to pp.
- Enhancement observed already in the most peripheral bin.
- Relative enhancement hierarchy with number of strange quarks, as expected in a GC Thermal model scenario.
- Relative enhancement of strange baryons higher than anti-baryons. Expected due to non-zero net baryon number.

Strangeness Enhancement: SPS and RHIC

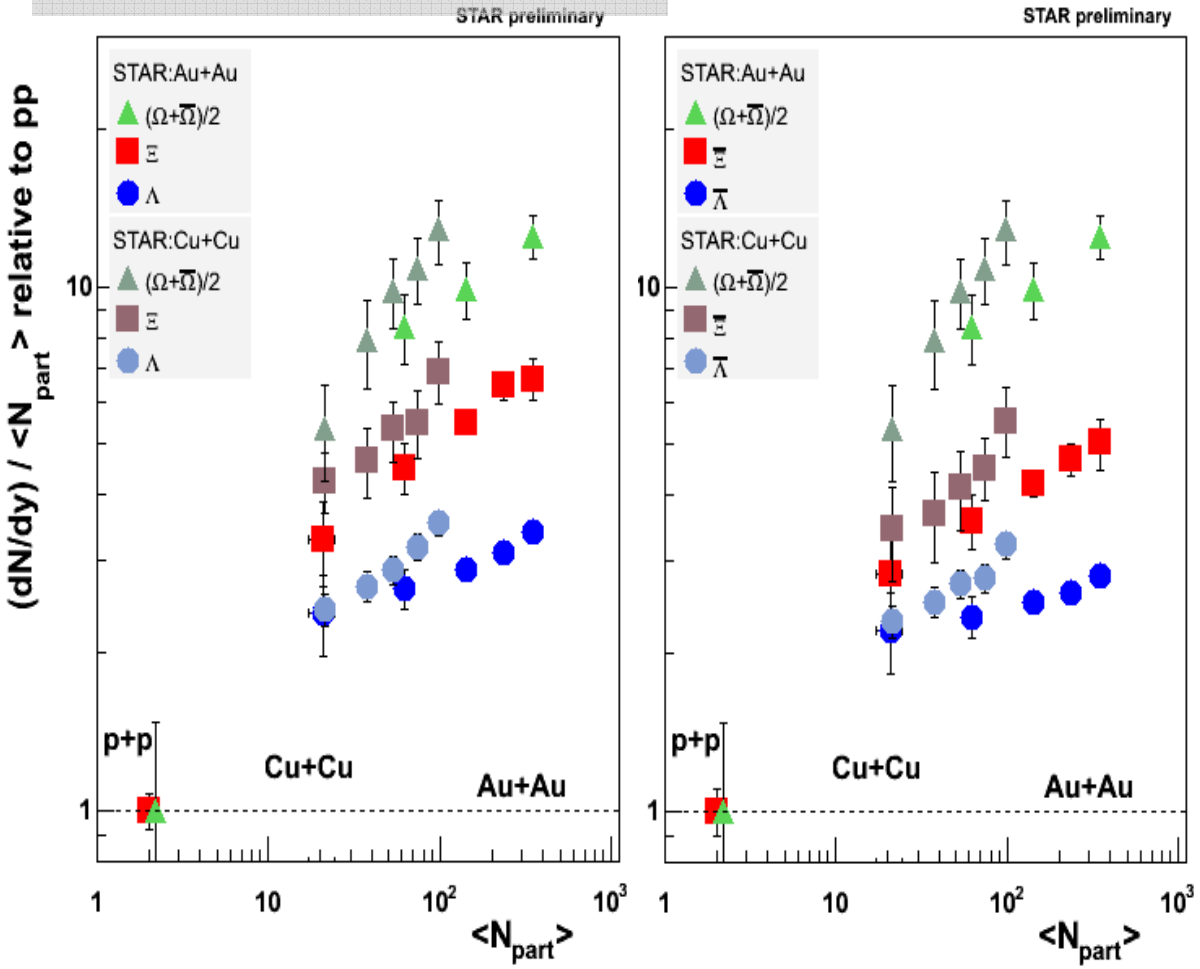
F.Antinori et al. (NA57 Collab.) Jorn. Phys. G, 32 (2006) 427-441



- RHIC Au+Au data also shows clear hyperons enhancement relative to pp.
- Strangeness enhancement show dependence with volume (N_{part}) which disagrees with GC thermal production.
- Relative enhancement seems to be slightly lower than in SPS.

Strangeness Enhancement: AuAu and CuCu

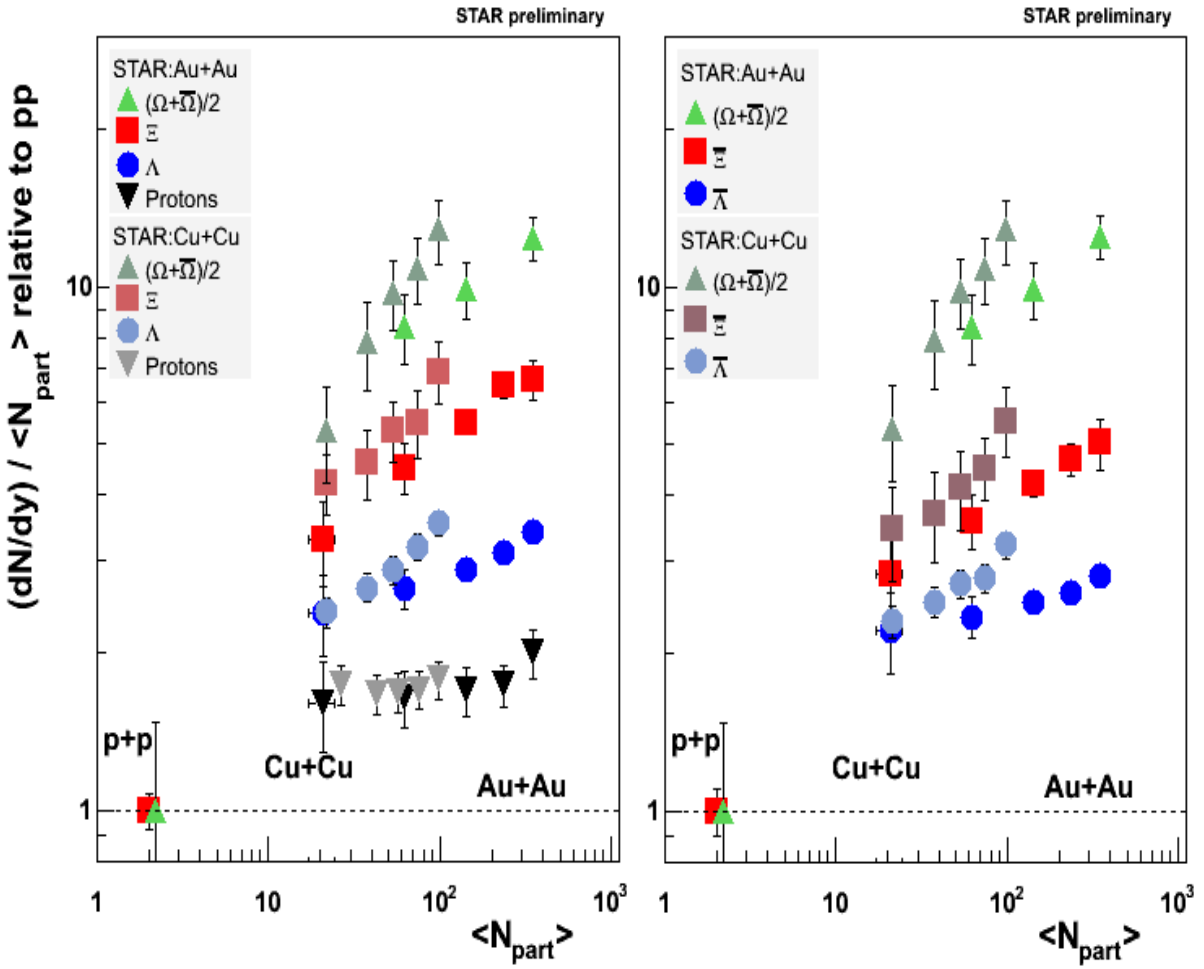
AuAu data published in nucl-ex/0705.2511



- Still see clear hyperon enhancement in Cu+Cu data.
- For Λ, Ξ, and Ω, Cu+Cu relative enhancement seems to be higher than in Au+Au.

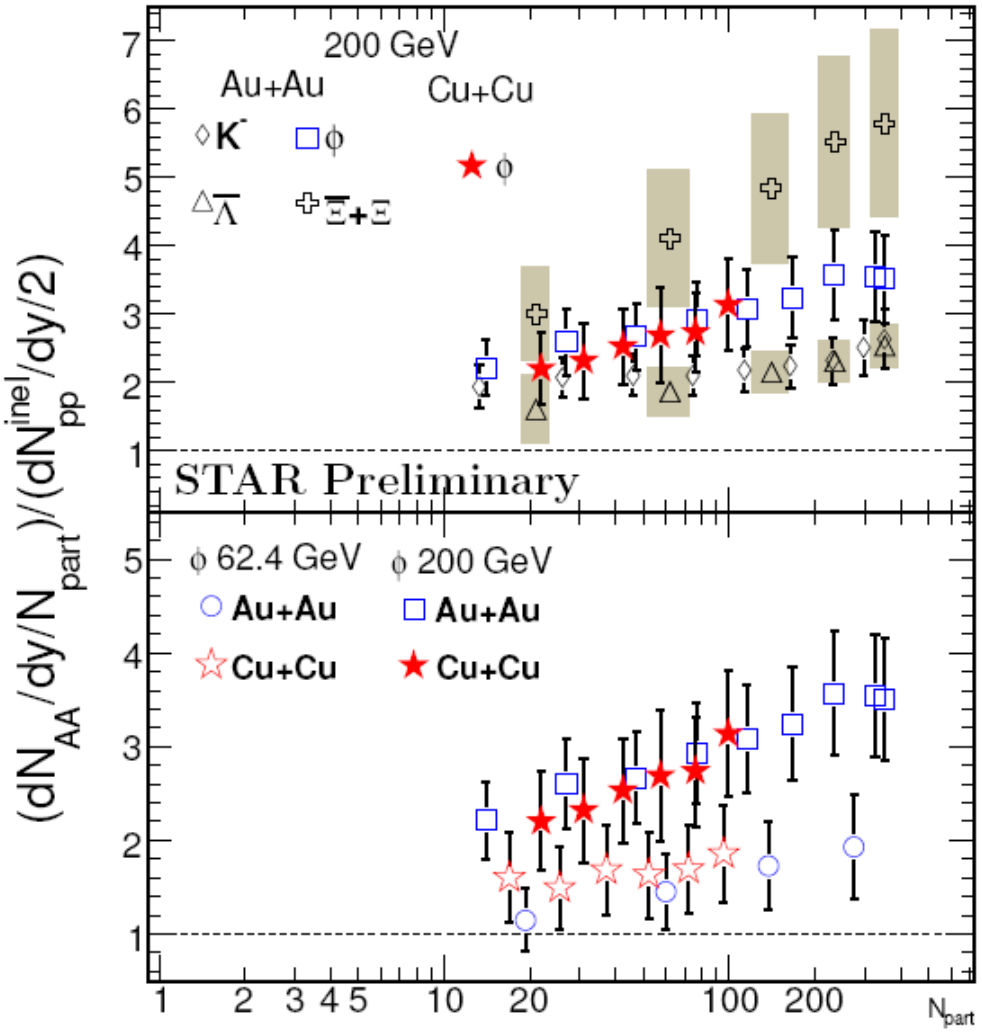
CuCu analysis from several people in STAR, in special A. Timmins, X. Wang, M. Munhoz
ref. QM2008 proceedings
ref. SQM2007 proceedings

How about the protons ?



- Protons also show relative enhancement in AuAu and CuCu relative to pp.
- Does NOT show higher relative yields in CuCu compared to AuAu.
- Flat with N_{part}.
- Can this be due to feed-down from Lambdas?

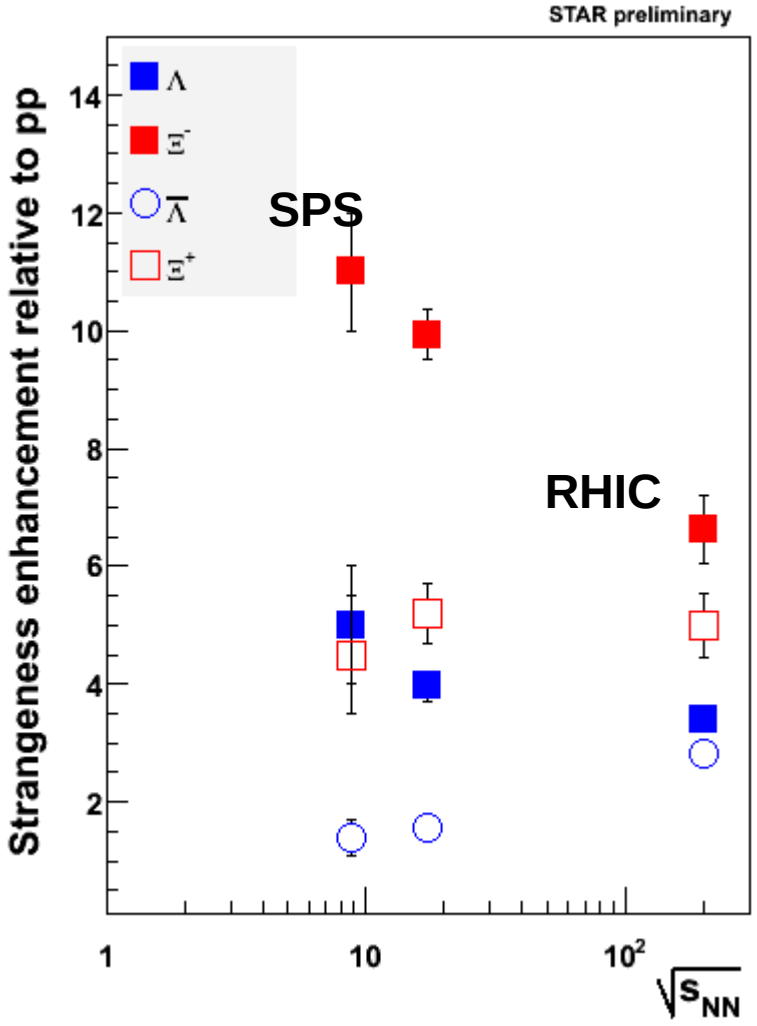
Strangeness Enhancement: ϕ´s



- ϕ also show relative enhancement in AuAu and CuCu relative to pp.
- But, show no relative enhancement of CuCu over AuAu as seen in the Λ, Ξ, and Ω.
- Could this be related to the fact that ϕ not subject to canonical suppression?

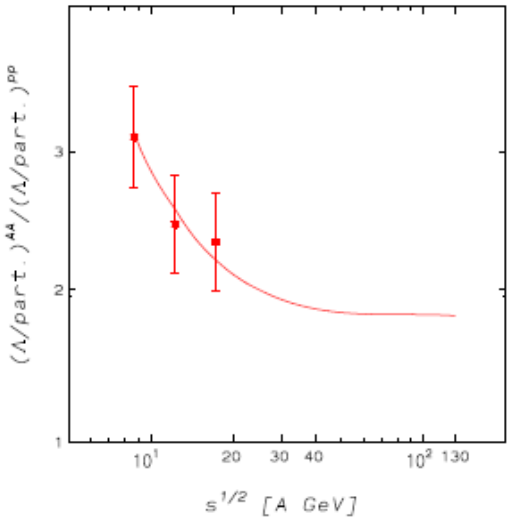
J.H. Chen, QM2008 proceedings, to be published.

Energy dependence of Relative strangeness enhancement



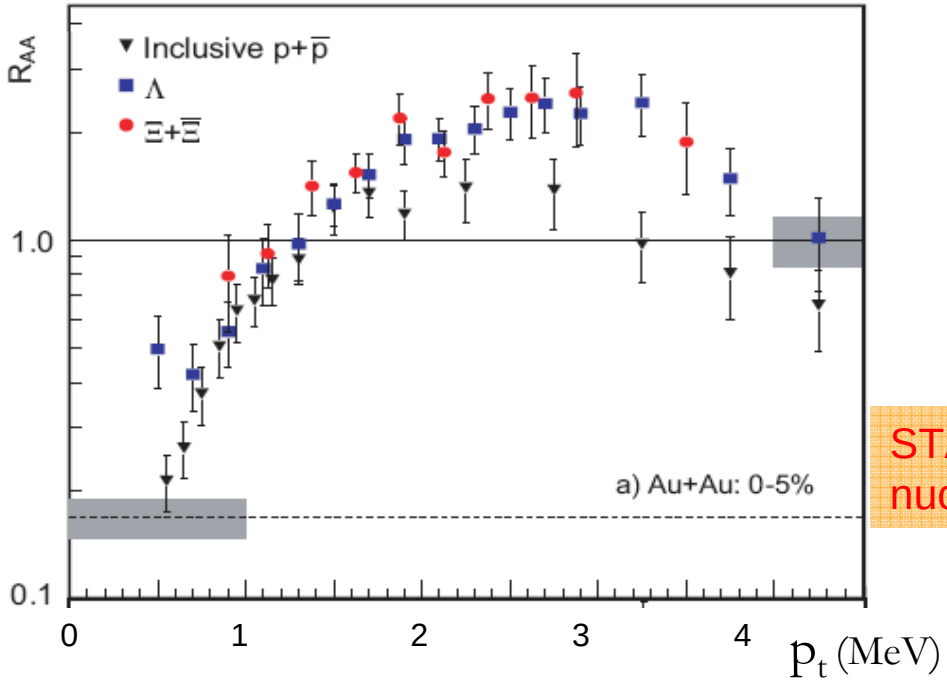
- Enhancement of particles seems to reduce with collision energy, which is in agreement with the canonical suppression scenario as proposed by A. Tounsi et. al.
  (Nucl. Phys. A 715, 565)

- But antiparticles seem to follow different trend.



Canonical suppression effect in the R_{AA}.

- Higher values of R_{AA} for strange particles.
- Effect of canonical suppression in strangeness production in p+p collisions extending to the intermediate p_T region.



STAR preliminary
nucl-ex/0705.2511

So, summarizing up to now:

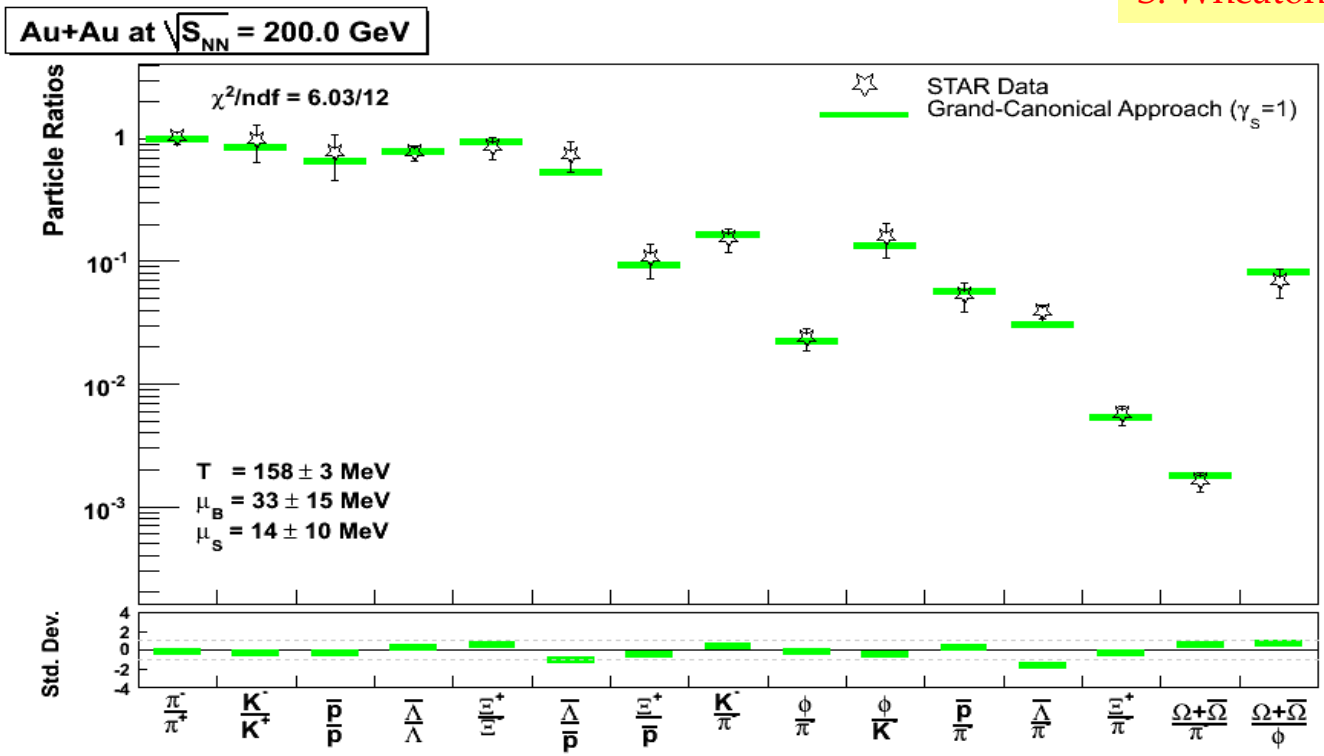
- Enhancement of Λ, Ξ, Ω yield per participant in AuAu and CuCu data relative to pp reference.
- Does it agree with thermal model with canonical suppression?
  - ☑ Strangeness enhancement with strange quark content hierarchy
  - ☑ Dependency with collision energy
  - ☑ Difference between Baryon and Anti-baryons due to net baryon density.
  - ☒ Not flat with N_{part} as predicted by the model.
  - ☒ CuCu show higher relative SE for Λ, Ξ, Ω when using N_{part}
  - ? φ´s does not show same behavior.
- Lets see what the thermal model tells us.

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:

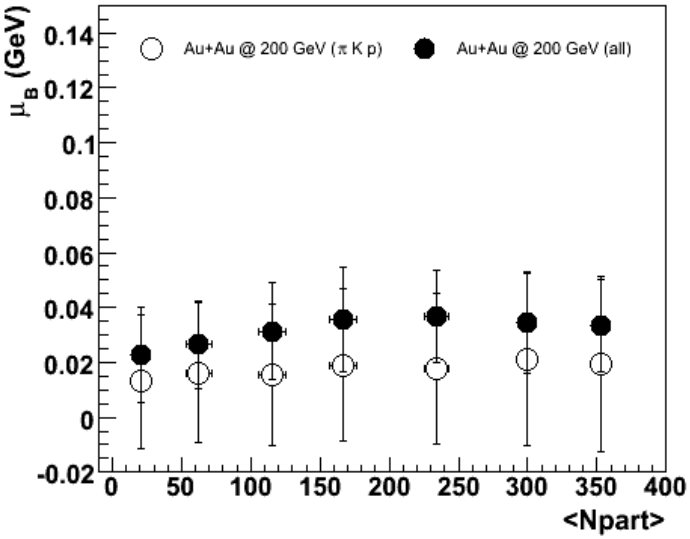
  π, K, p, Λ, Ξ, Ω and **ϕ**.
- Particles were corrected for weak decays.

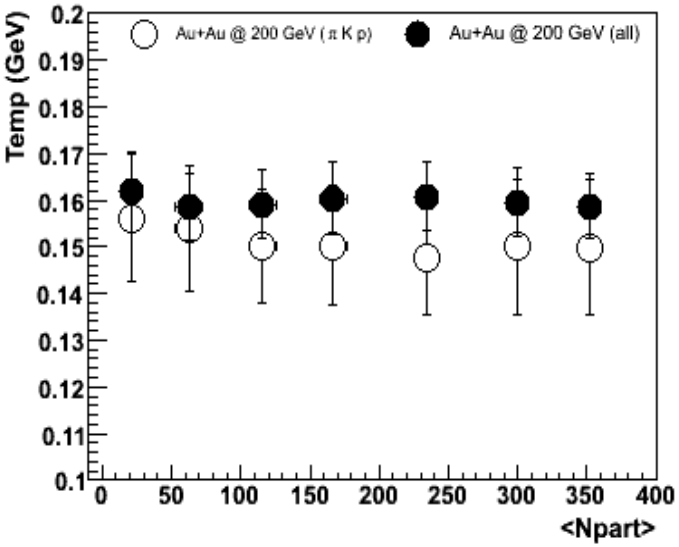
* Thermus, A thermal Model Package for Root
S. Wheaton & Cleymans, hep-ph/0407174

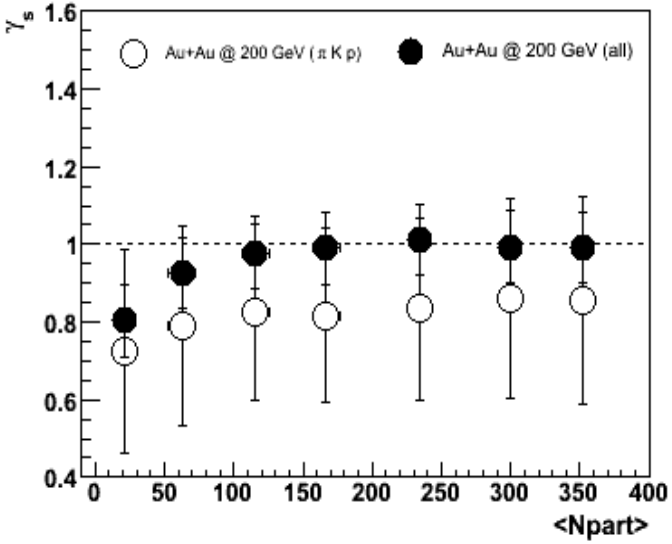


Including the multi-strange baryons in the Thermal fit

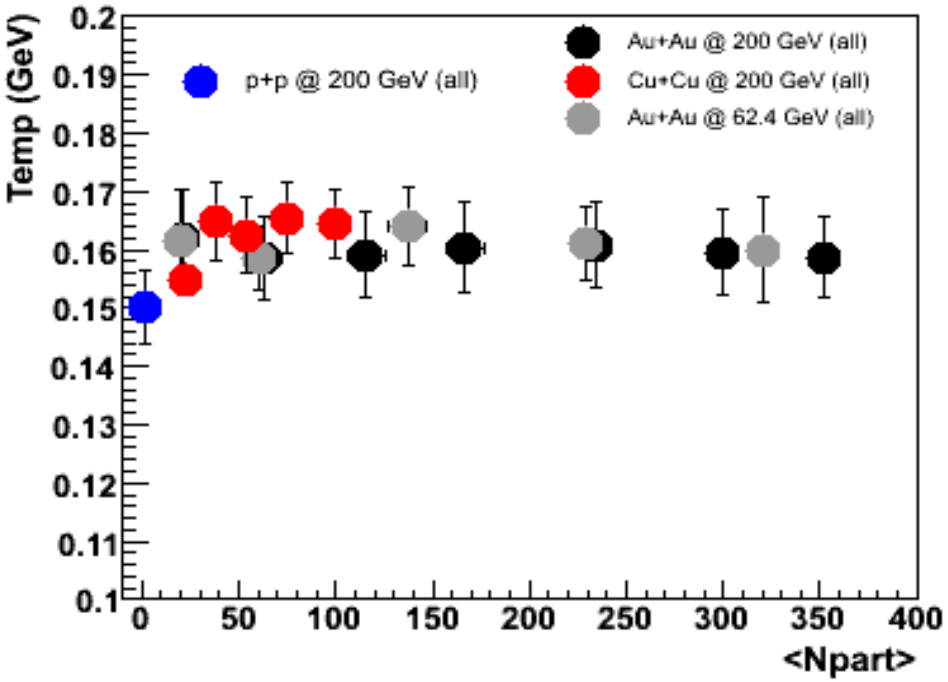
- Does it make a difference if we include the strange hyperons in the thermal fit?
- Values change slightly and fit errors are reduced. T=150 MeV → 165 MeV.
- Temperature and μ_B increase slightly.







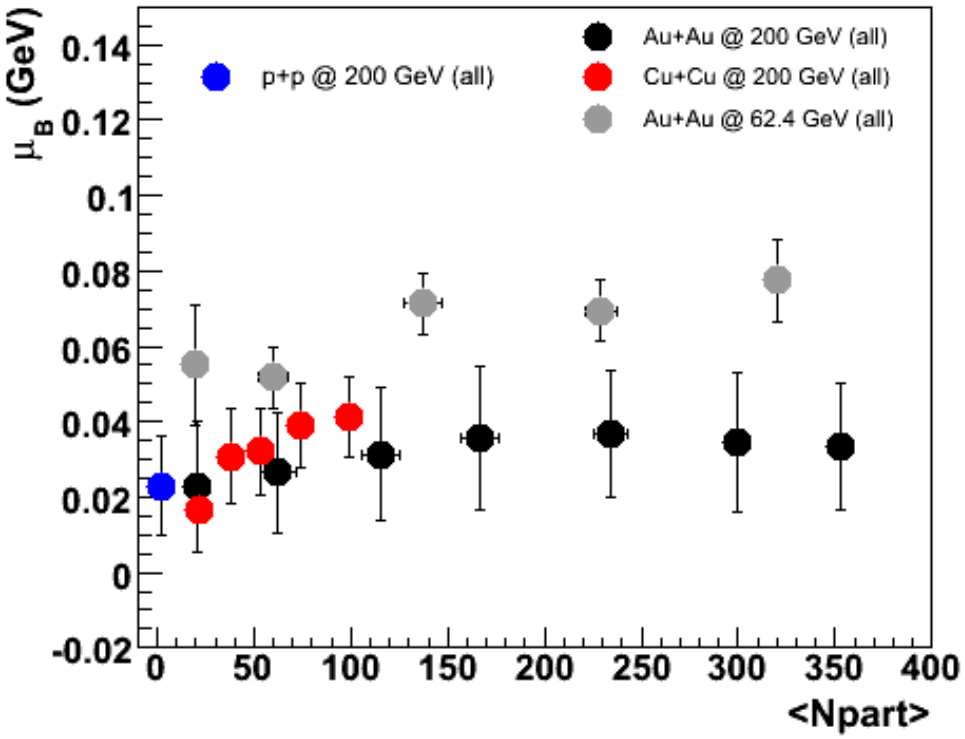
Statistical Thermal Model: T_{ch} vs. system size



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

- Temperature seems constant with system size for Au+Au 200 GeV.
- Cu+Cu 200 GeV temperature shows a higher value then compared to Au+Au data, but is in agreement within error bars.
- Au+Au 62 GeV data shows same temperature values of Au+Au 200 GeV and also no system size dependence can be observed within error bars.

Statistical Thermal Model: μ_B vs. system size



- Baryon chemical potential μ_B is small.
- Small variation with system size.
- Cu
  po
  ag
- Au
  val
  an
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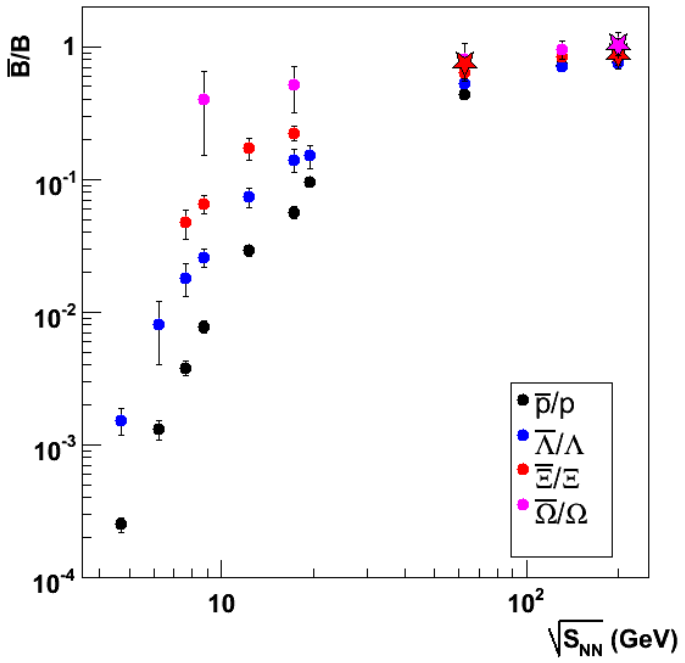
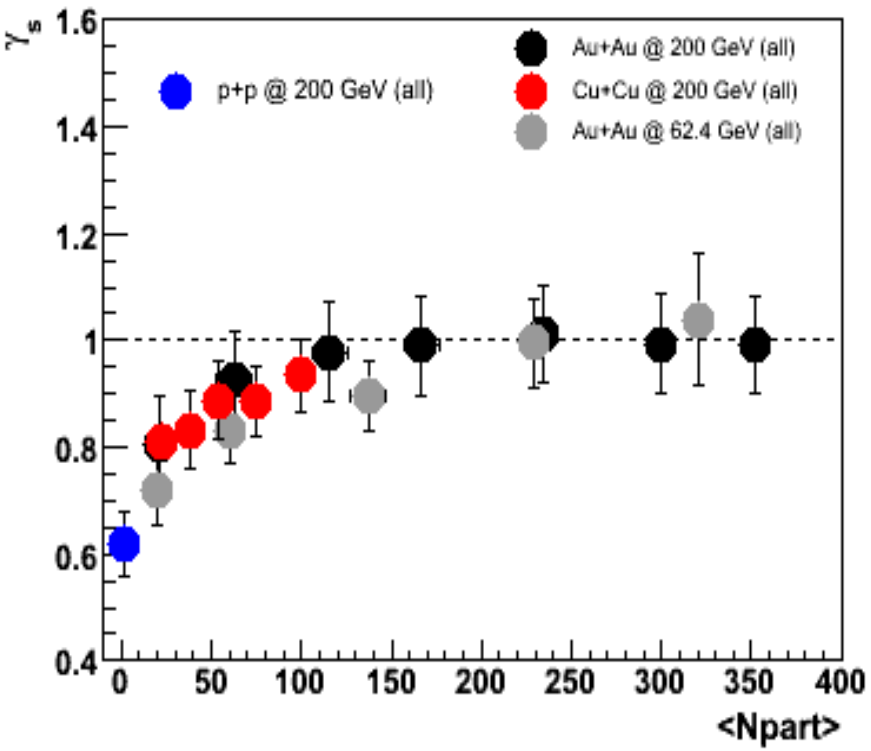


* Thermus, A thermal Model Package for Root
S. Wheaton & Cleymans, hep-ph/0407174

Statistical Thermal Model: Fit parameters vs. system size

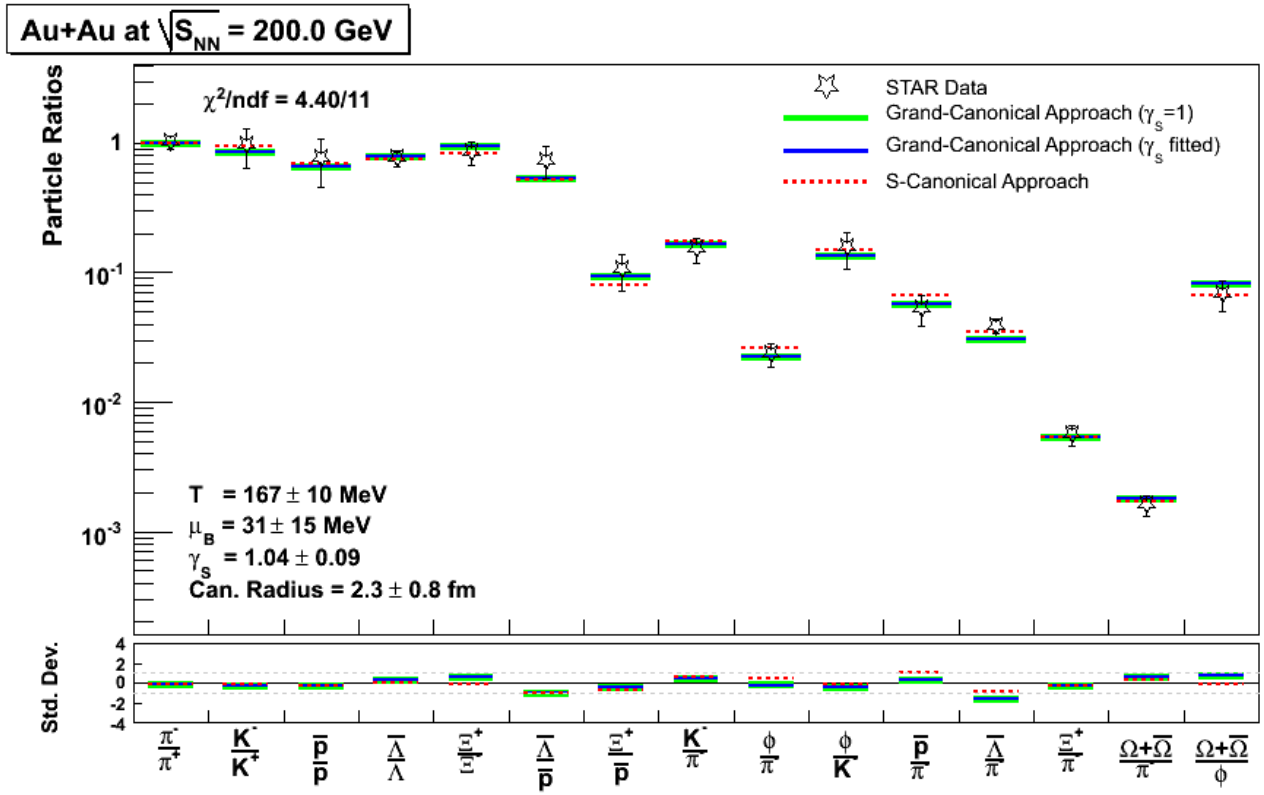


- Strangeness saturation constant, shows an increase with system size, reflecting the increase of strangeness enhancement.
- Cu+Cu 200 GeV data fits seems to yield a strangeness saturation constant consistent with 1.
- Au+Au 62 GeV data shows same values and behavior of Au+Au 200 GeV.

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

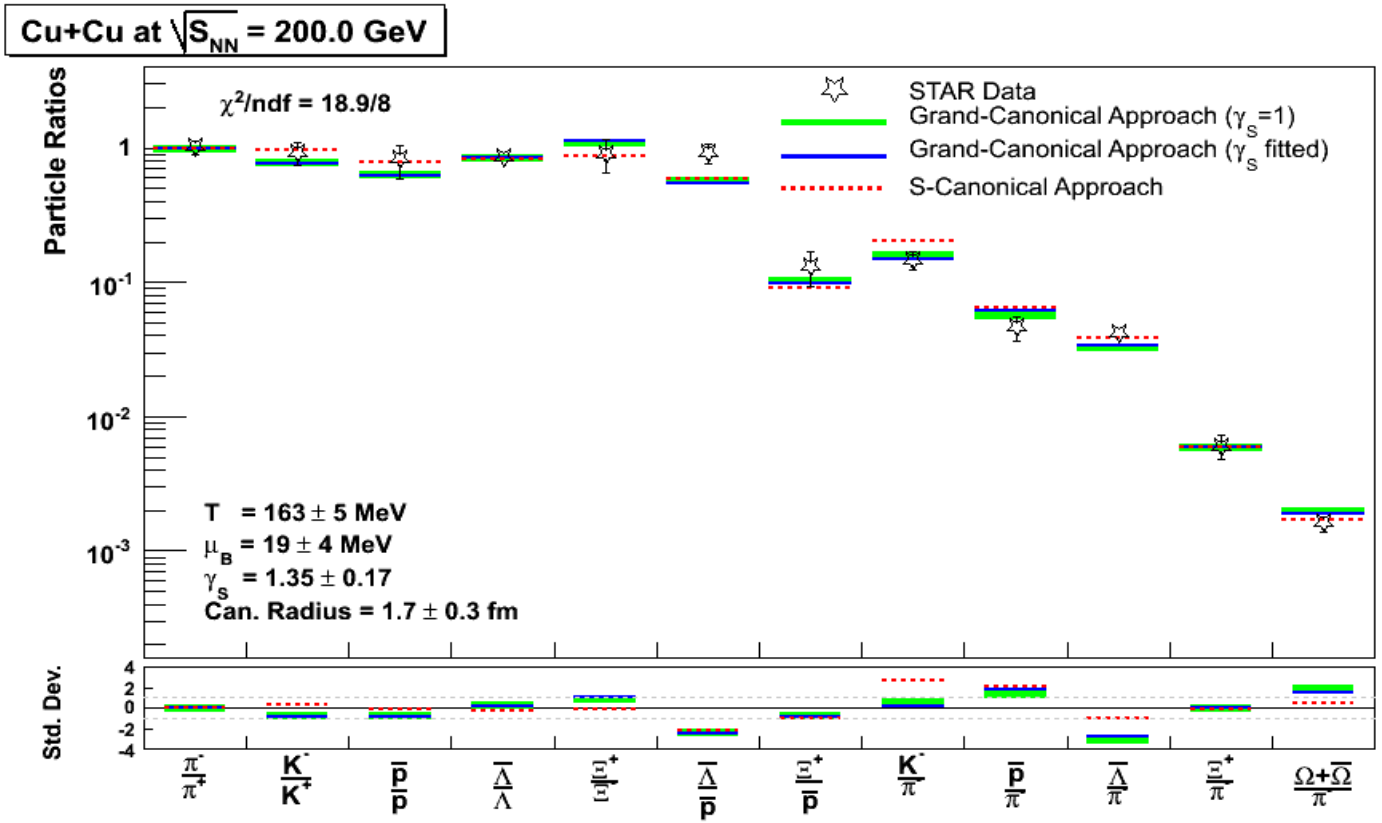
Comparing different Thermal Model conditions: Central Au+Au collision

- Particle ratios already described well with GC ensemble.
- γ_s is consistent with 1.
- Temperature increase with the strangeness canonical ensemble.



Comparing different thermal model conditions: Central Cu+Cu collision

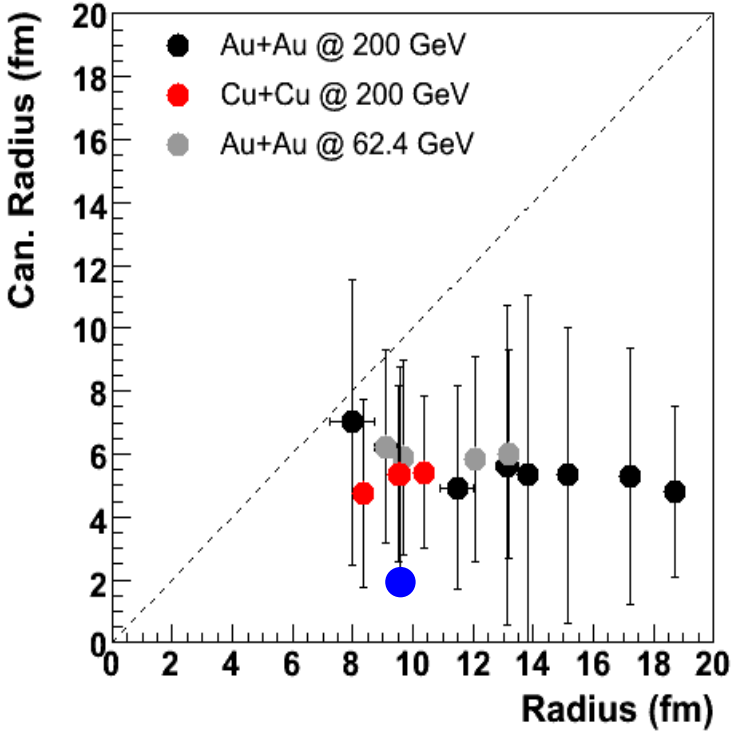
- Particles ratios still well described with GC ensemble.
- γ_s is lower than 1.
- Canonical ensemble describes data slightly better.

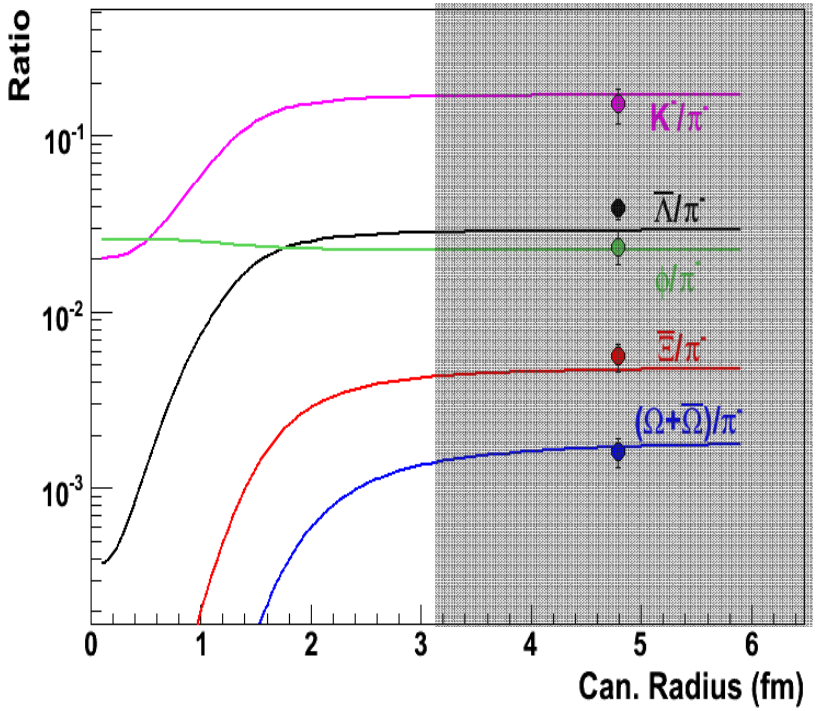


Strangeness canonical radius.

- How does the canonical volume change with event centrality?
- How do strangeness production get affected by the canonical radius?

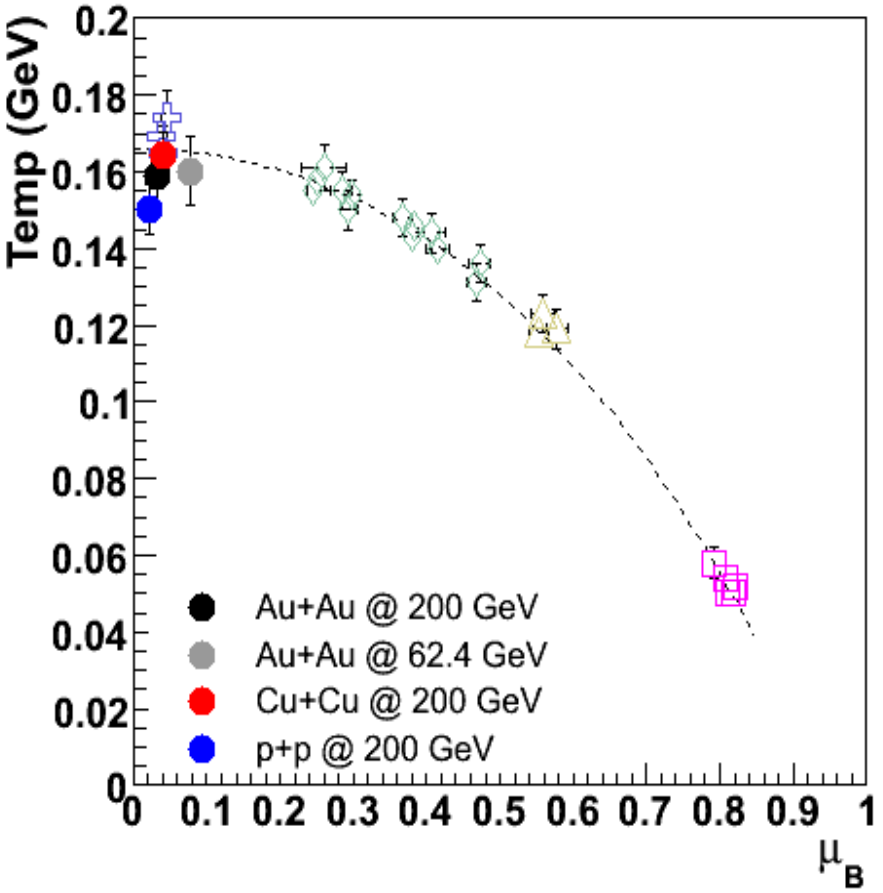
- SPS: $R_c \approx 1.4$ (I. Kraus & K. Redlich hep-ph/0604242)





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.

Conclusions

- **Strangeness Enhancement** in Au+Au and Cu+Cu relative to p+p data.
  - Still present in new Cu+Cu 200 GeV and Cu+Cu 62.4 GeV.
  - Enhancement characteristics show some agreement with canonical suppression scenario, but it is not enough to explain the observed enhancement.
  - Variation of strangeness canonical radius show enhancement of strange particles over pions.

- **New Cu+Cu** data was compared with Au+Au data scaled by N_{part} to study system size dependence.
  - Overall spectra shape seems to be consistent with the equivalent peripheral Au+Au collision.
  - Cu+Cu most central events show higher yield compared to the equivalent Au+Au peripheral collision.
  - Same thermal model parameters for both systems.

Thank you

The STAR Collaboration

University of Illinois at Chicago - Argonne National Laboratory Institute of High Energy Physics - University of Birmingham Brookhaven National Laboratory - California Institute of Technology - University of California, Berkeley - University of California, Davis - University of California, Los Angeles - Carnegie Mellon University - Creighton University – Nuclear Physics Inst., Academy of Sciences - Laboratory of High Energy Physics - Particle Physics Laboratory - University of Frankfurt - Institute of Physics, Bhubaneswar - Indian Institute of Technology, Mumbai - Indiana University Cyclotron Facility - Institut de Recherches Subatomiques de Strasbourg - University of Jammu - Kent State University - Institute of Modern Physics - Lawrence Berkeley National Laboratory - Massachusetts Institute of Technology - Max-Planck-Institut fuer Physics - Michigan State University - Moscow Engineering Physics Institute - City College of New York - NIKHEF and Utrecht University - Ohio State University - Panjab University - Pennsylvania State University - Institute of High Energy Physics - Purdue University – Pusan National University - University of Rajasthan - Rice University - Instituto de Fisica da Universidade de Sao Paulo - University of Science and Technology of China - Shanghai Institue of Applied Physics - SUBATECH - Texas A&M University - University of Texas, Austin - Tsinghua University - Valparaiso University – Variable Energy Cyclotron Centre, Kolkata - Warsaw University of Technology - University of Washington - Wayne State University - Institute of Particle Physics - Yale University - University of Zagreb -UNICAMP