Strangeness production as a function of system size and energy at RHIC

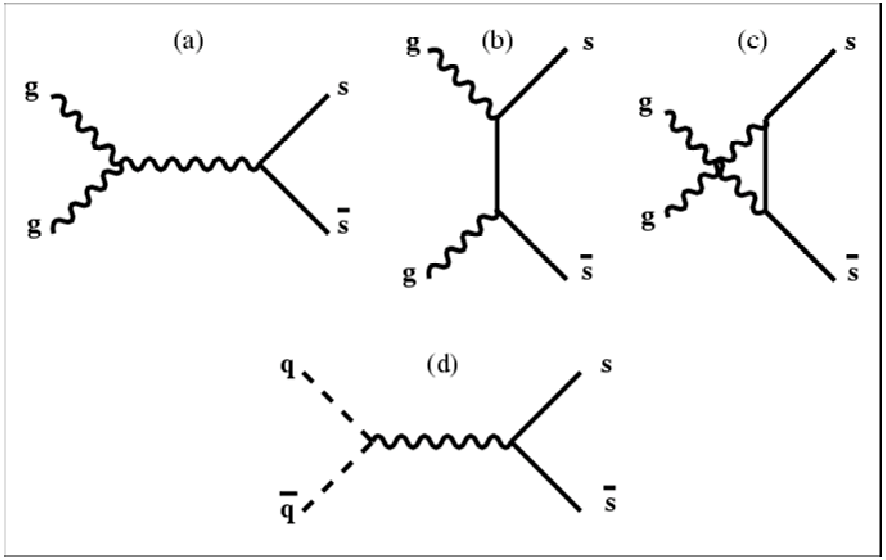
Matthew A. C. Lamont,
Brookhaven National Laboratory
for the STAR experiment

Talk Outline

- Strangeness as a signature of QGP formation
- Strangeness in p+p and Au+Au at RHIC
  - Bulk: strangeness enhancement
  - Intermediate p_T: identified baryons and mesons
- Strangeness in Cu+Cu NEW
  - What's different?
- Summary

Strangeness as a QGP signature

- In a de-confined medium, the dominant form of strange quark production is via gluon fusion (~80%)
- If chiral symmetry is restored, the strange quark mass is reduced to its "bare" value and its production is easier:



$q+\bar{q}\text{->}s+\bar{s}$: $E_{thresh} = 2m_s \sim 200$ MeV

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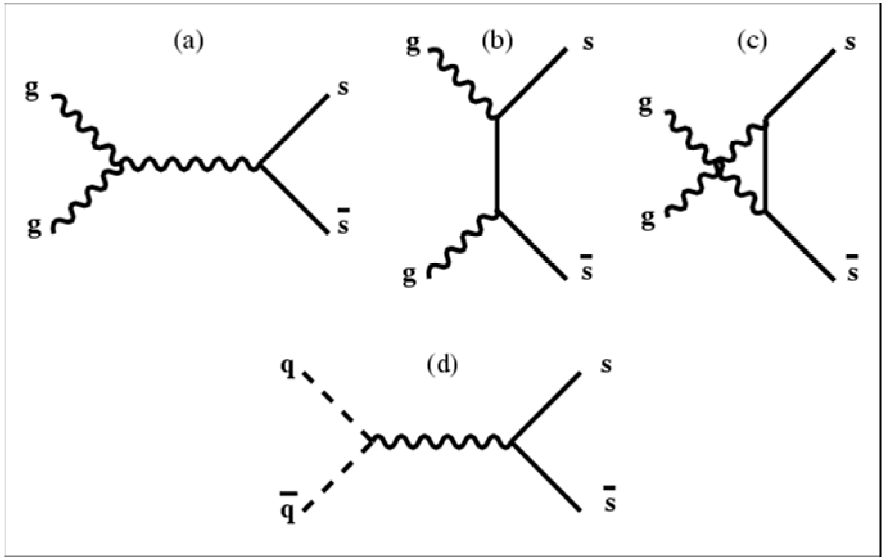

- In a hadronic system, there is a much greater energy penalty to produce strange quarks

$N+N \rightarrow \Lambda+K^{+}+N$	: $E_{thresh} \sim 700$ MeV (primary collisions)
$N+N \rightarrow N+N+\Lambda+\bar{\Lambda}$	: $E_{thresh} \sim 2200$ MeV (primary collisions)
$\pi+N \rightarrow \Lambda+K^{+}$	: $E_{thresh} \sim 530$ MeV (secondary collisions)
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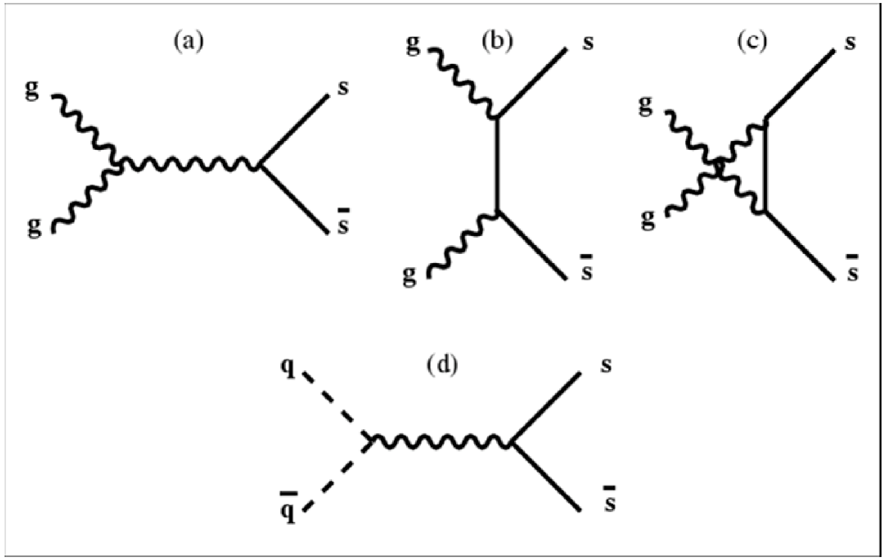

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- Therefore, in a de-confinement scenario, we expect a large strangeness enhancement which increases with the strangeness content of the particle

Müller and Rafelski, PRL 48, 1066 (1982)

Data Presented

	STAR				NA57	
CMS Energy (GeV)	p+p	d+Au	Au+Au	NEW Cu+Cu	p+Be	Pb+Pb
200	✔	✘	✔	✔		
130			✔			
62.4			✔	✘		
19.6			✘			
17.2					✔	✔

Low energy RHIC running - coming soon!

Strangeness at RHIC

Strangeness at STAR

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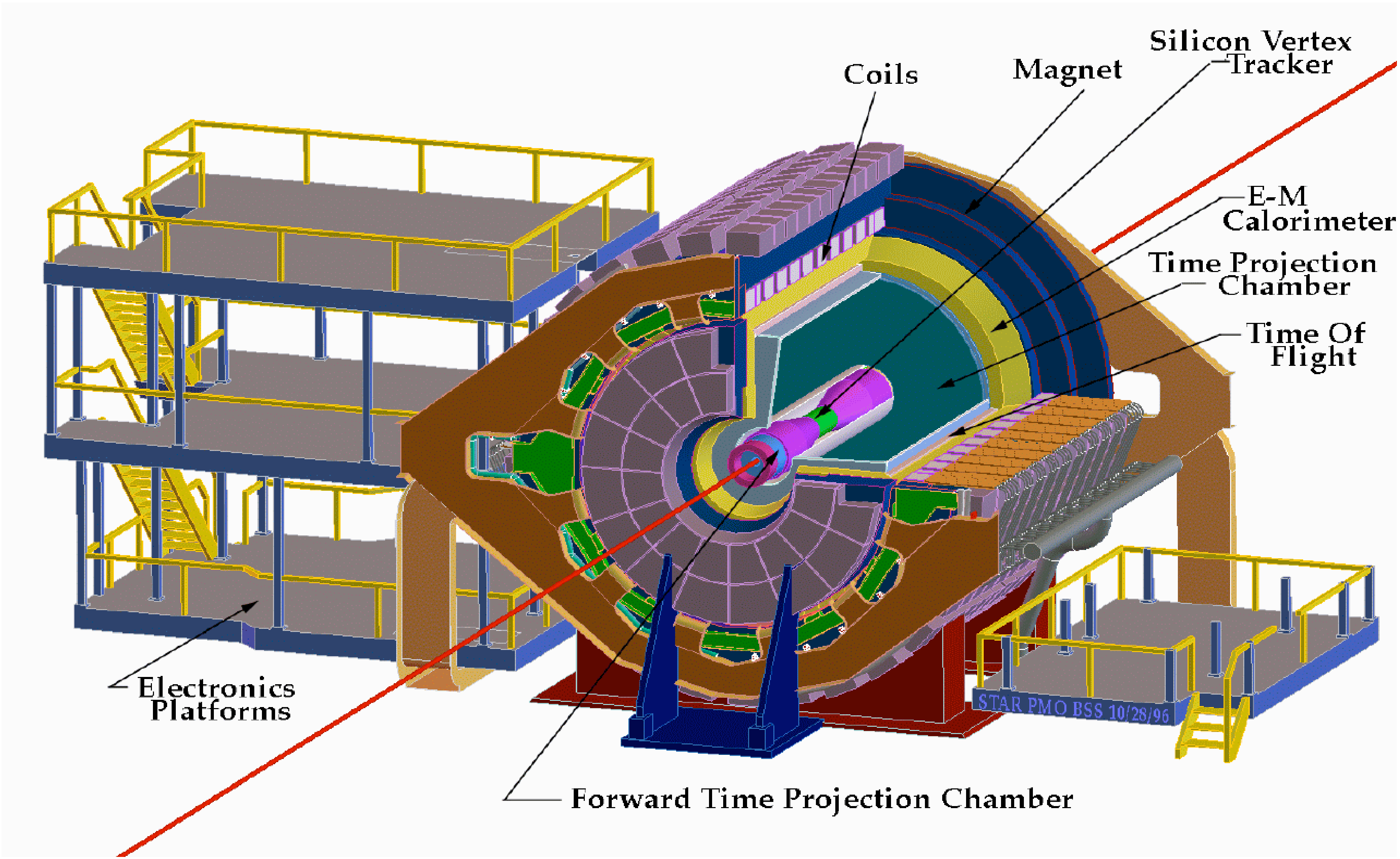
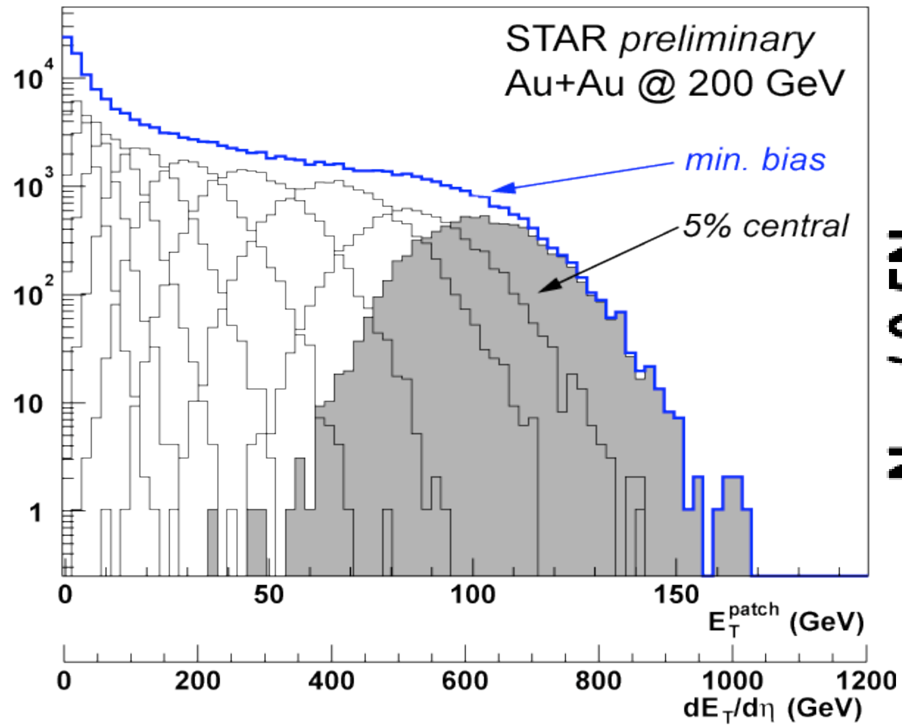
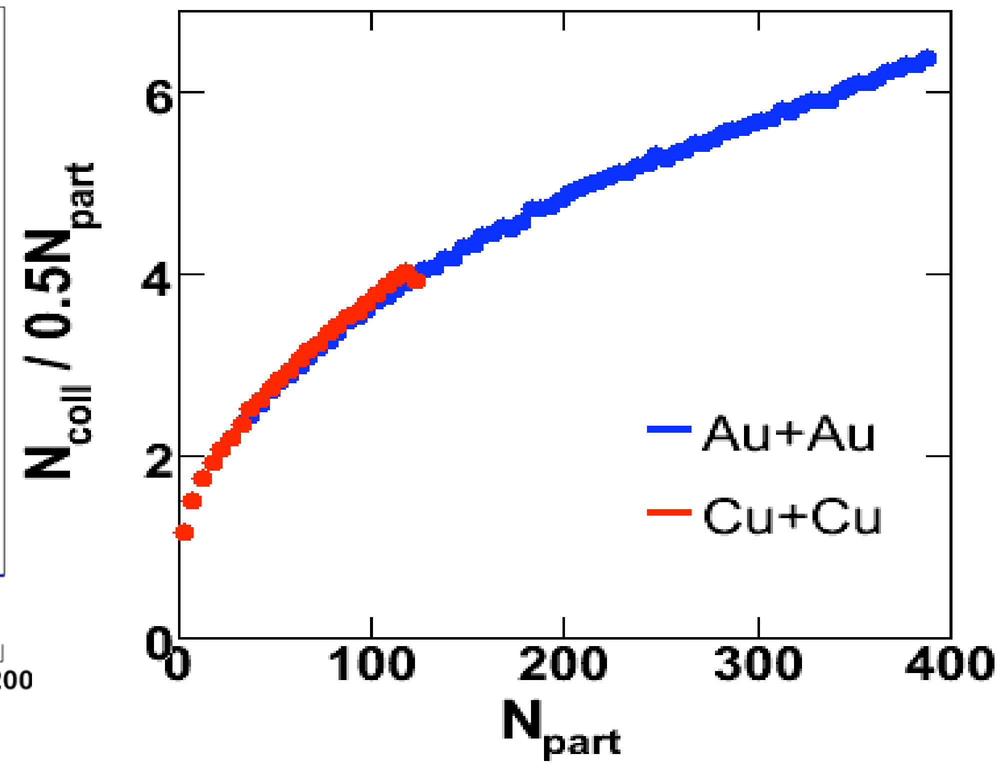


Calculating System Size

- Event centrality classes are defined based on the measured charge particle multiplicities.

- The equivalent number of particles that participate in the reaction N_{part} is calculated using the Glauber Model, that also provides the equivalent number of binary collisions N_{Coll} or N_{Bin}.





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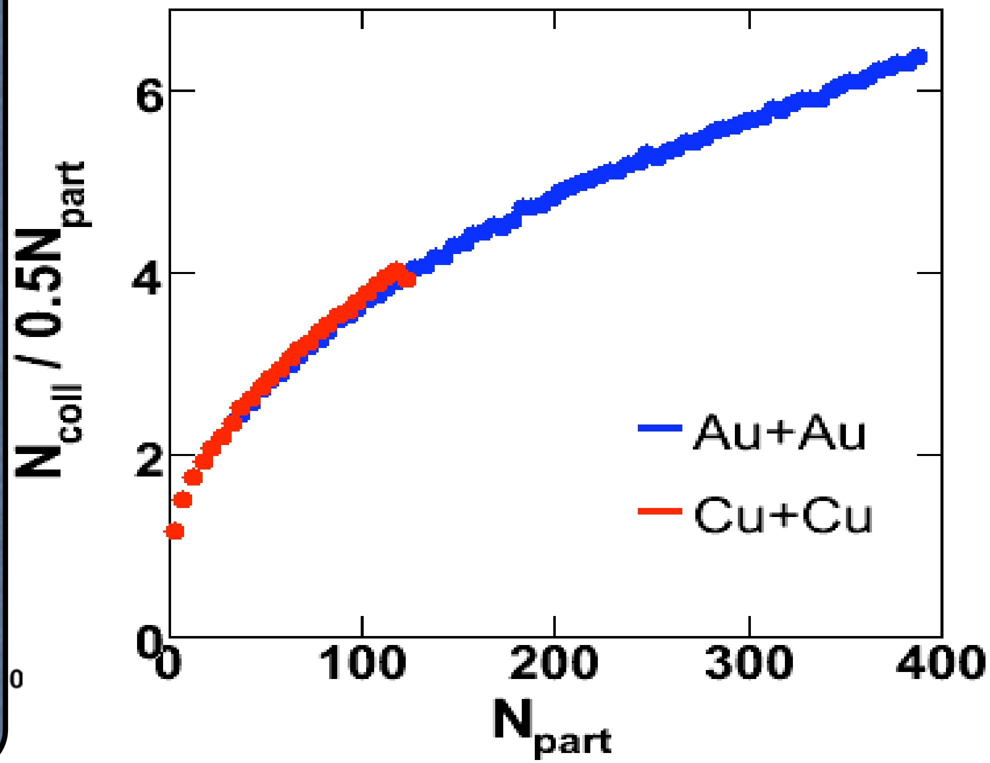
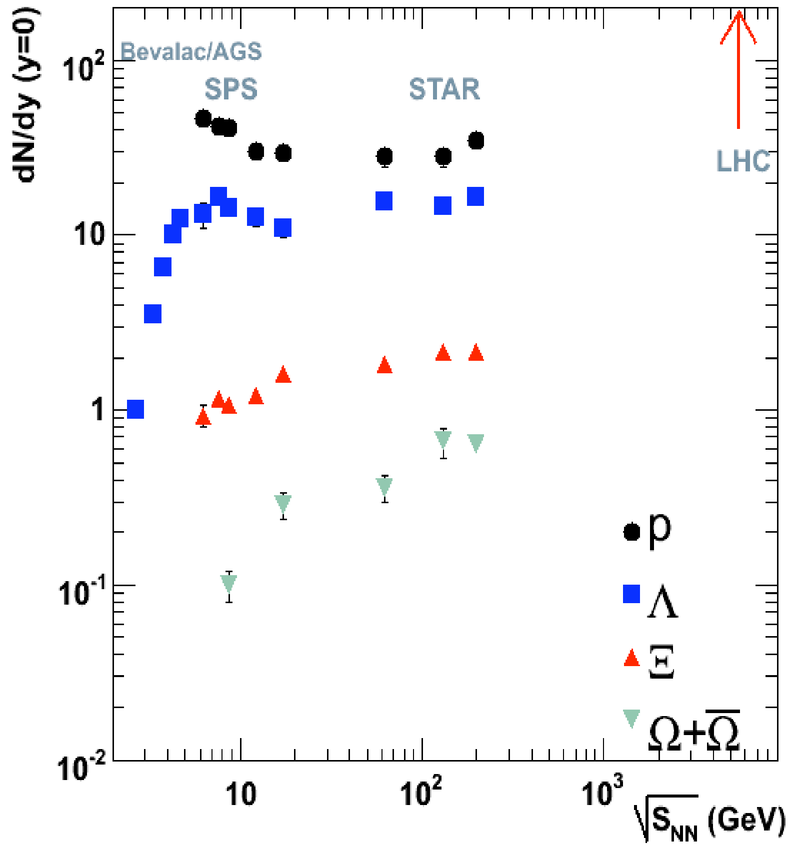
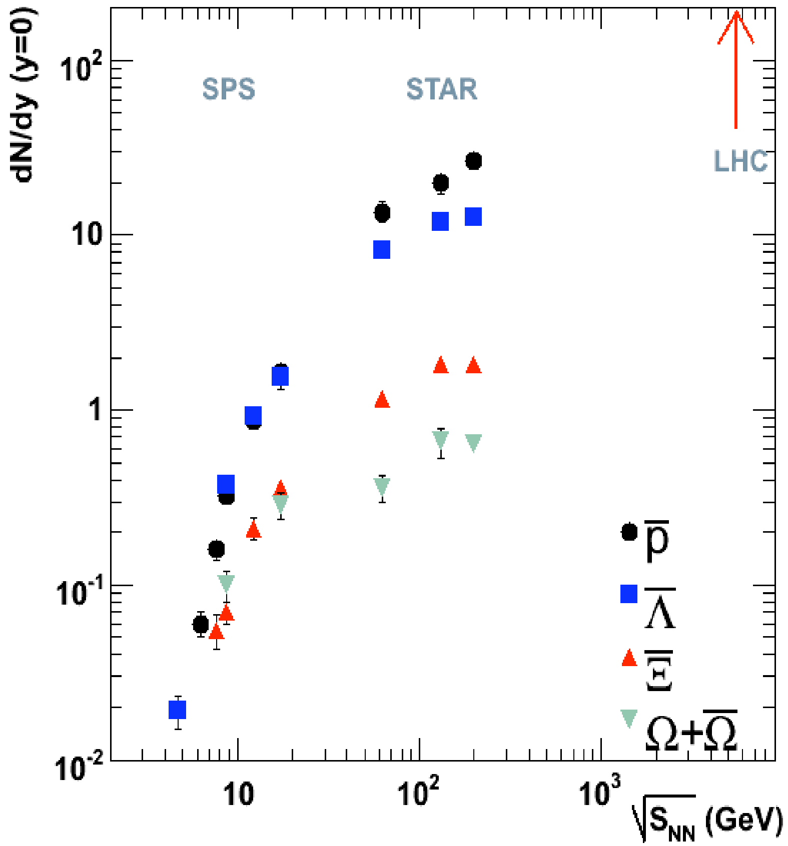
Cu+Cu data provides for more detailed extrapolation at lower N_{part}.



Yield Excitation Functions

SPS data from NA49
AGS data from E896 & E802





- Smooth interpolation of baryon and anti-baryon yields from the AGS and SPS to RHIC
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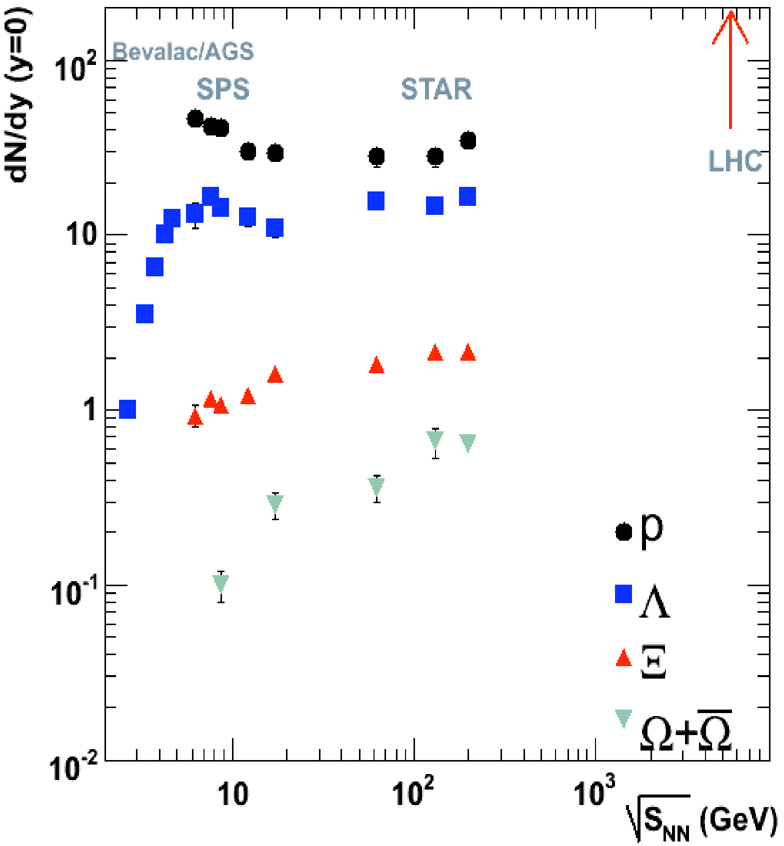

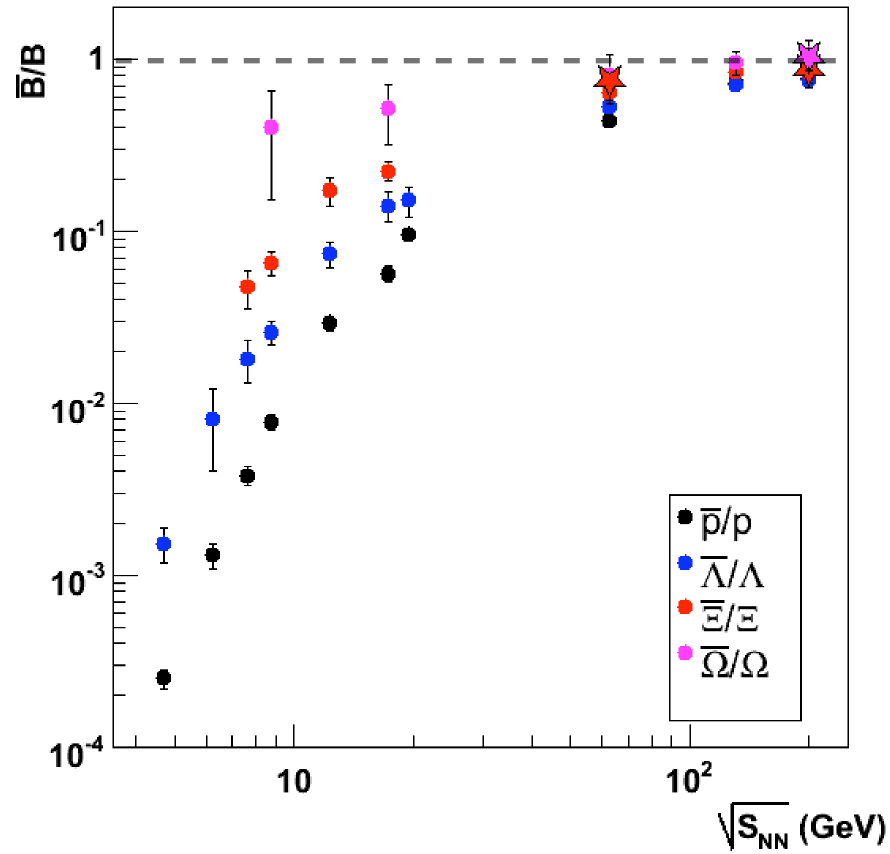

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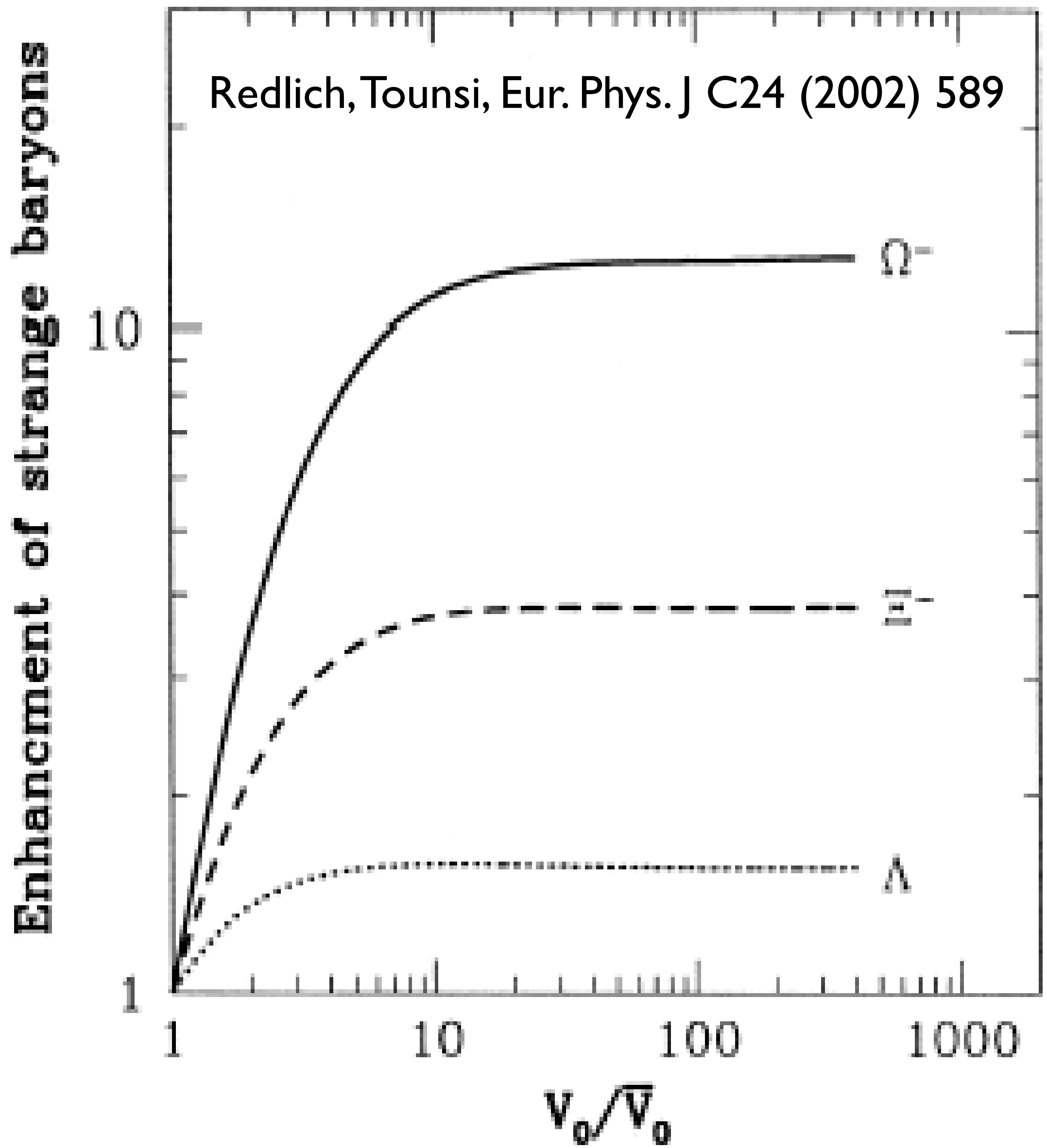
Strangeness Enhancement

Expect an increased enhancement with energy and with strangeness content of the baryon for a thermalised system



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Is the system thermalised?

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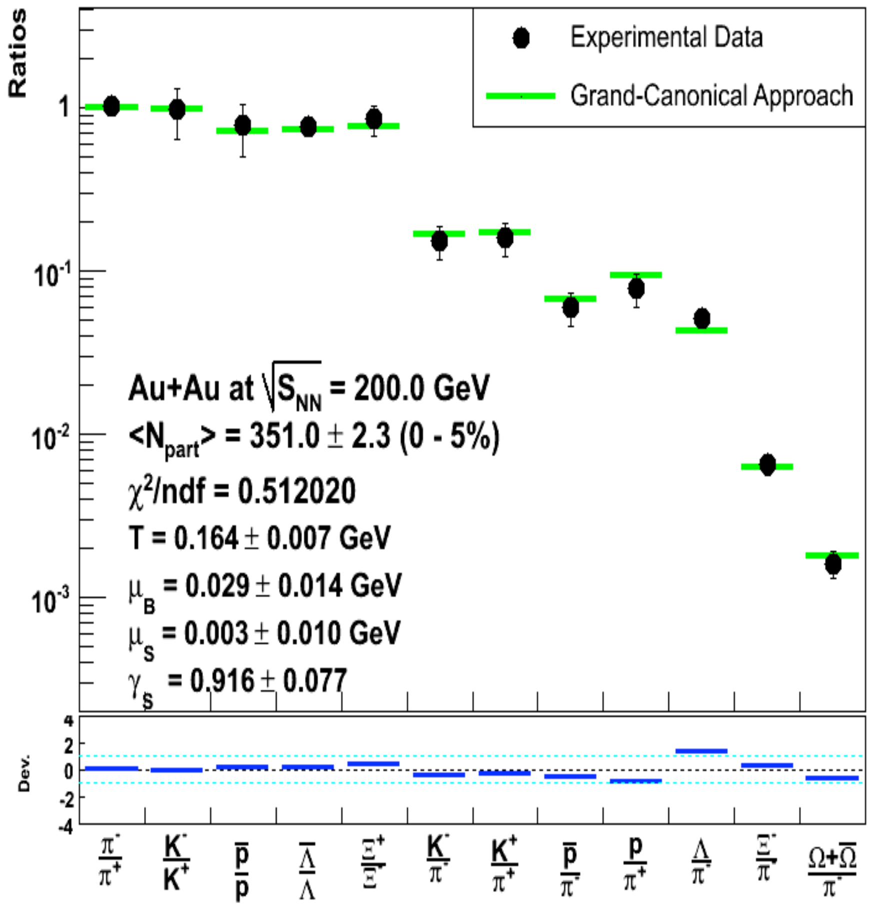

THERMUS model

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

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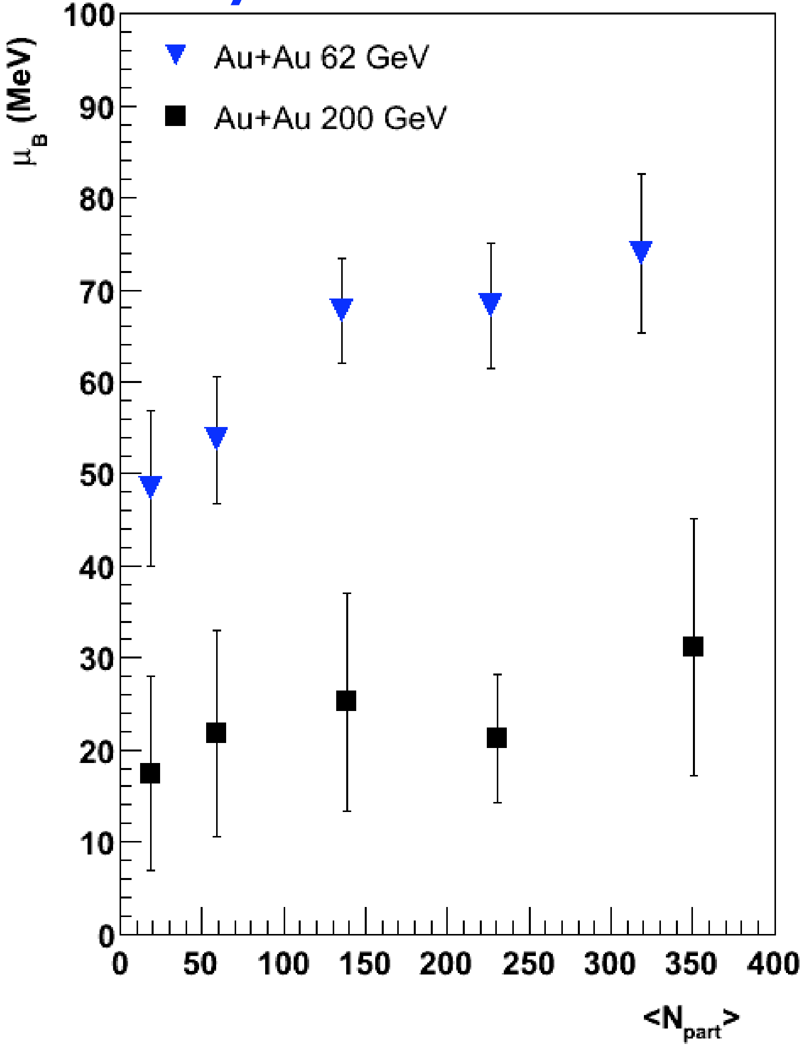

μ_B - Baryon Chemical Potential
small for 200 GeV data
increases at lower energies

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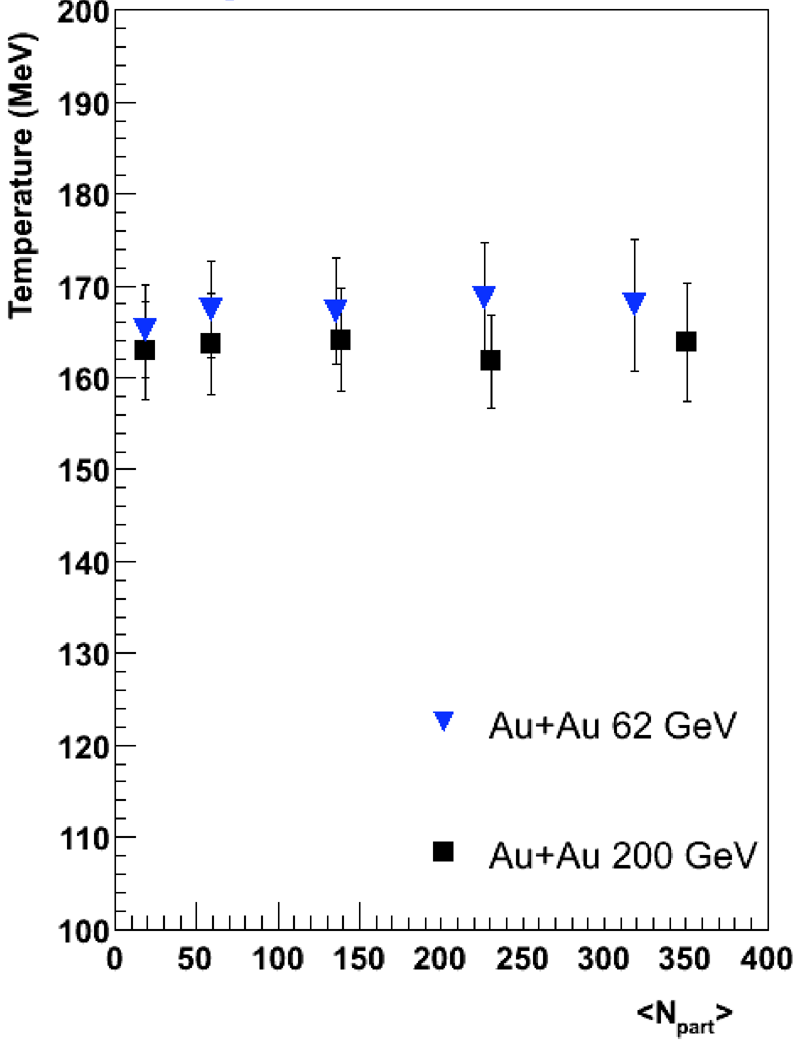

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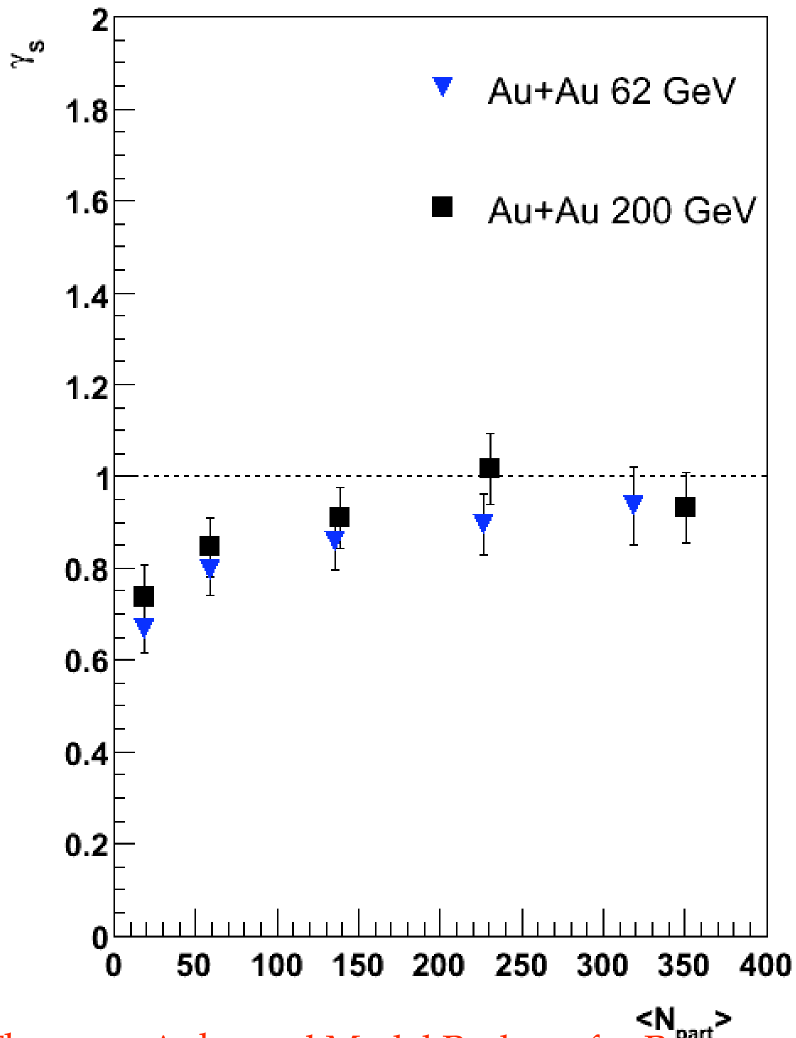

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μ_B - Baryon Chemical Potential
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T - Chemical Freeze-Out Temp
independent of centrality
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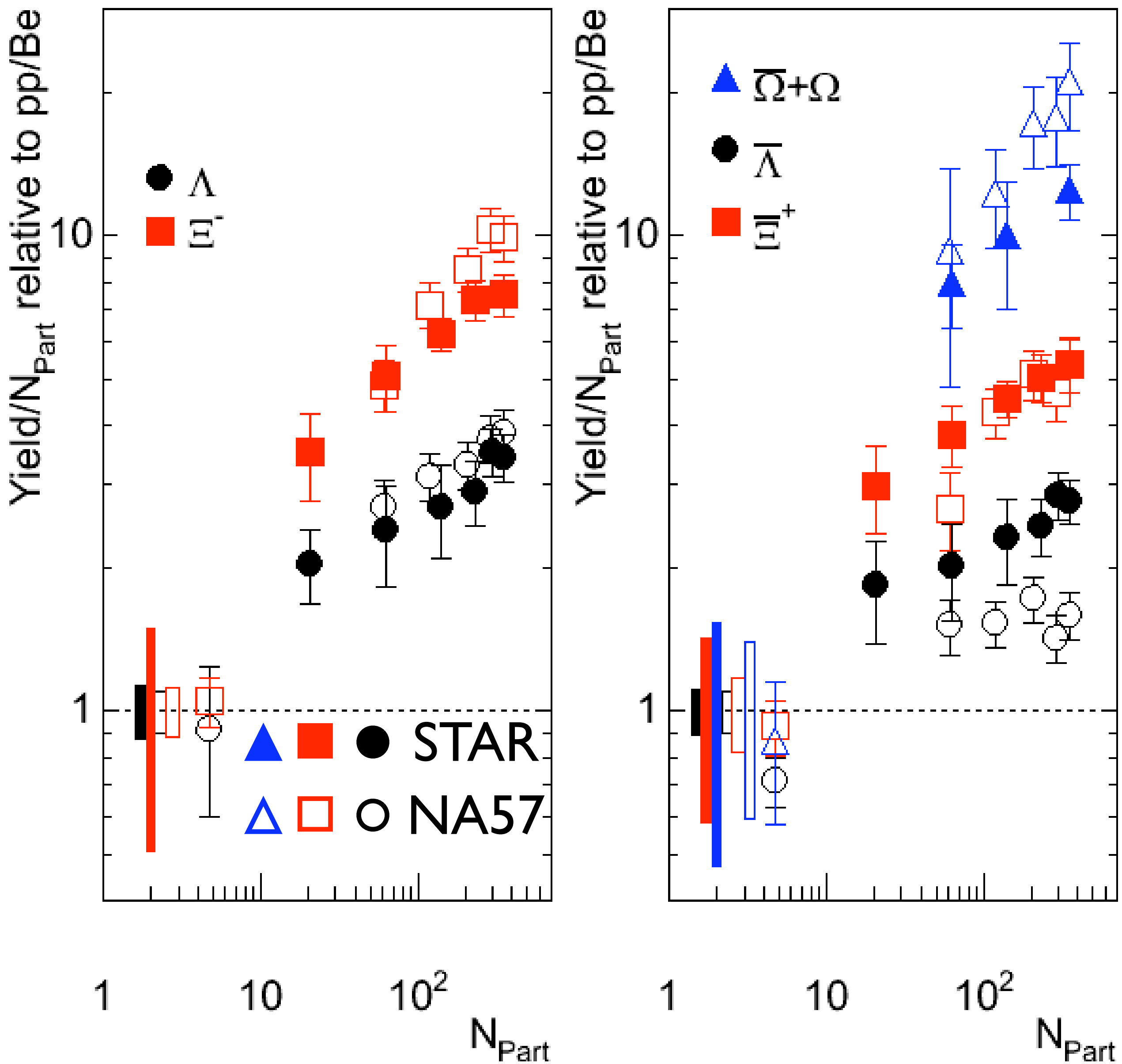
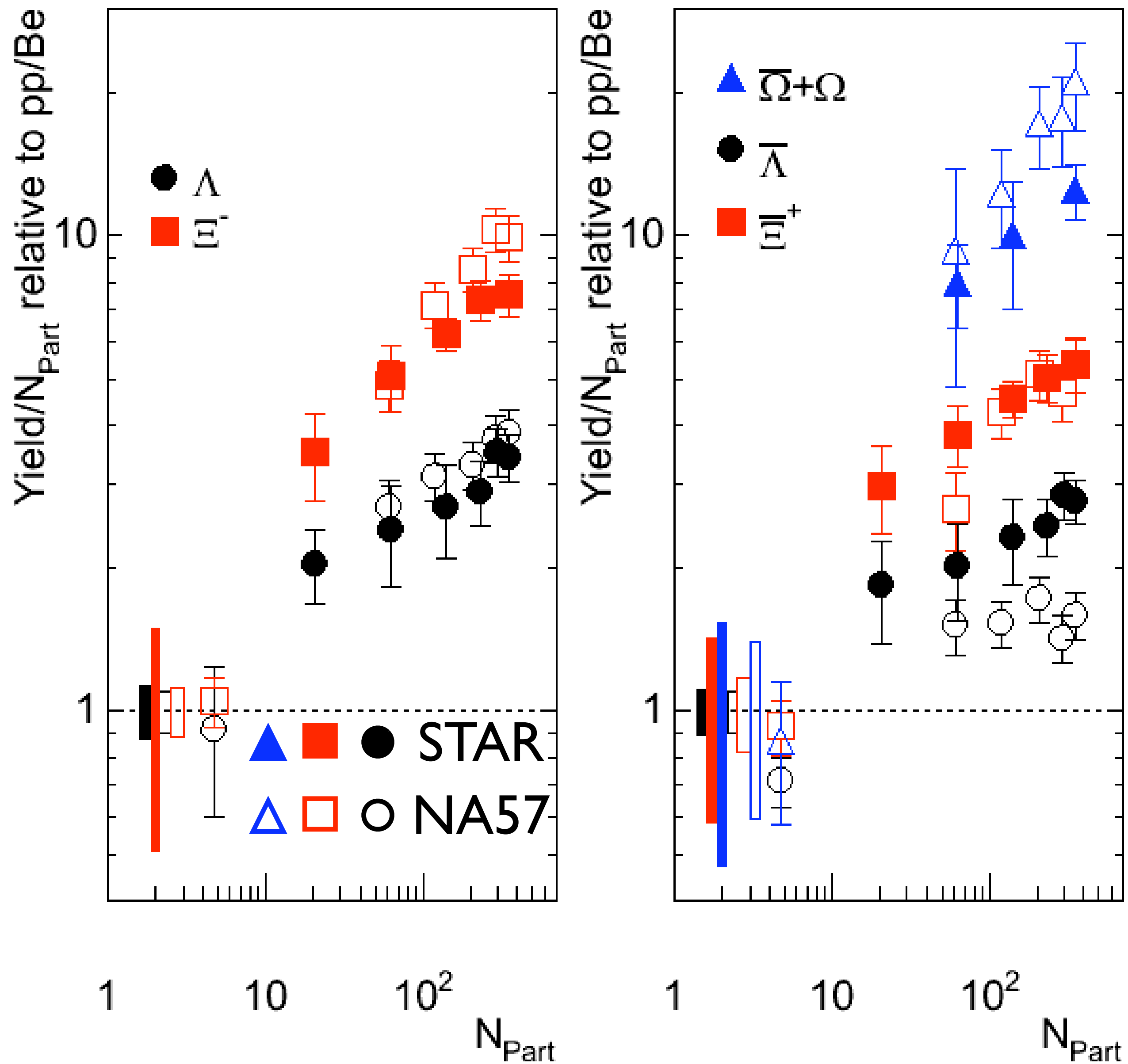
γ_s - Strangeness Saturation Factor
large values for all centralities
saturates at unity for most central data
~independent of energy

Strangeness Enhancement



Strangeness Enhancement

Enhancement at 200 GeV similar to SPS (17.2 GeV)



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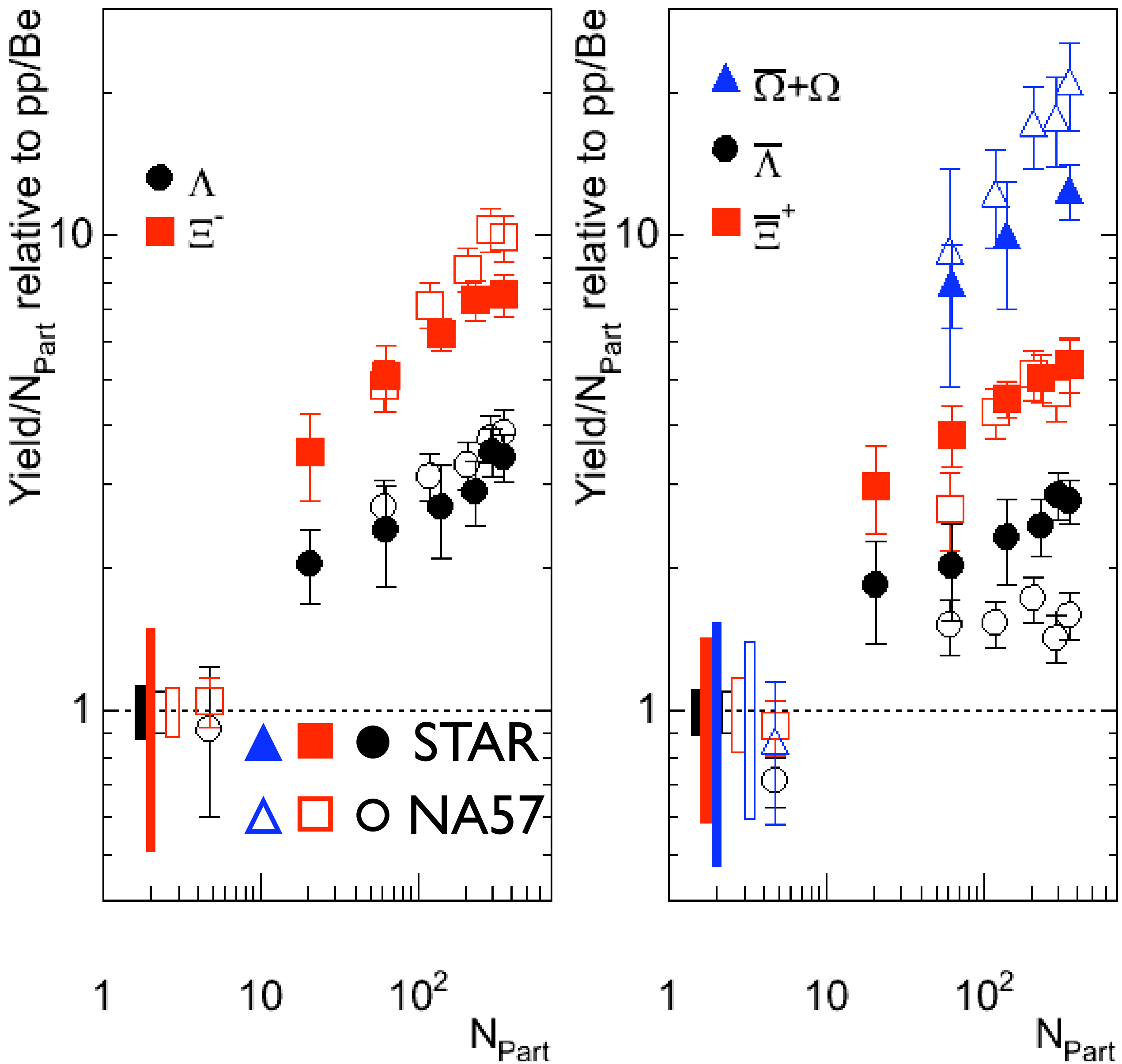
But we expected an increase with energy?

We have convoluted strangeness production in A+A and p+p(Be)

⇒ higher energies also

leads to reduction of strangeness suppression in p+p!!



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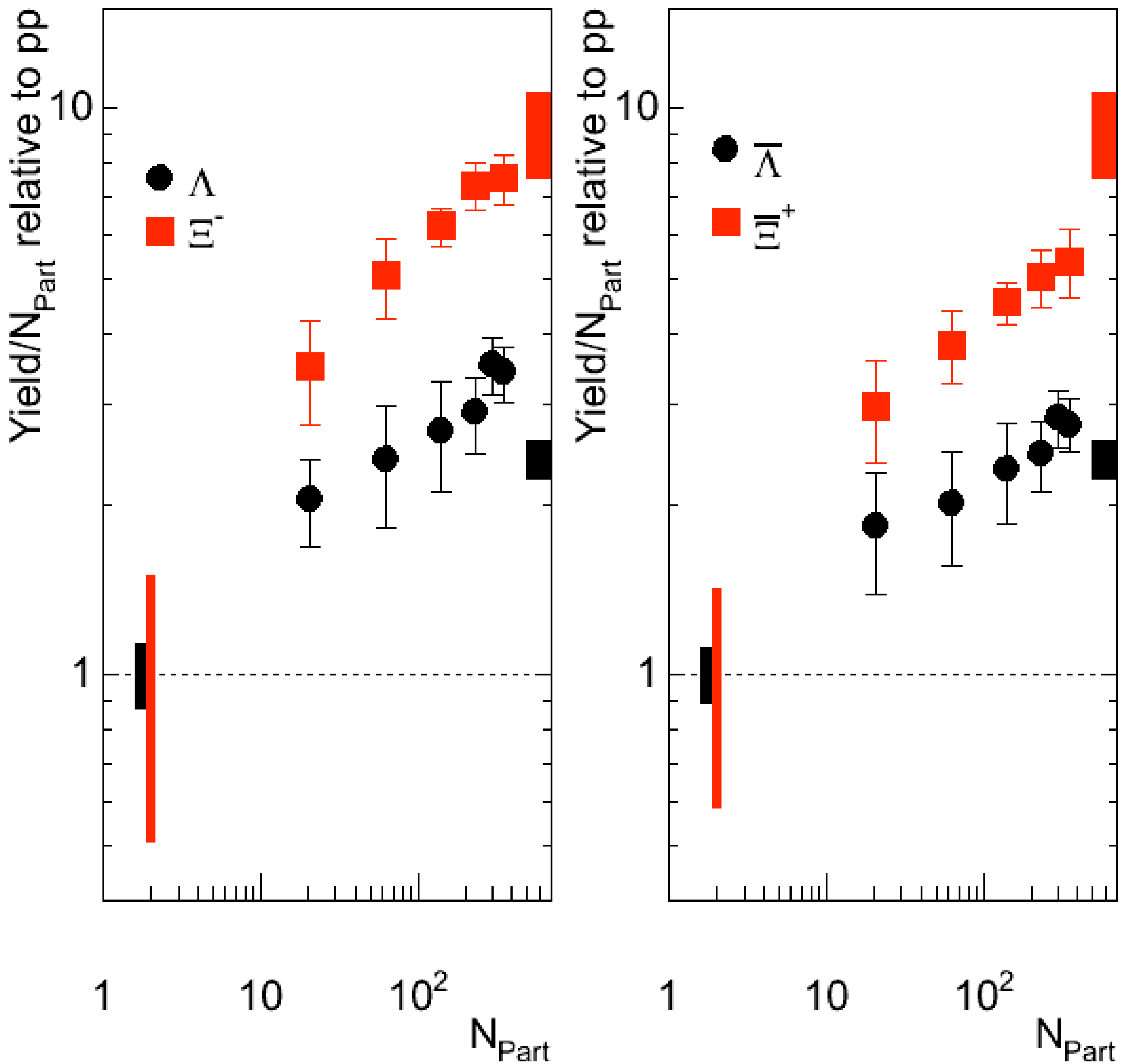
Temperature variations from 165 to 170 MeV



Thanks to K. Redlich !!

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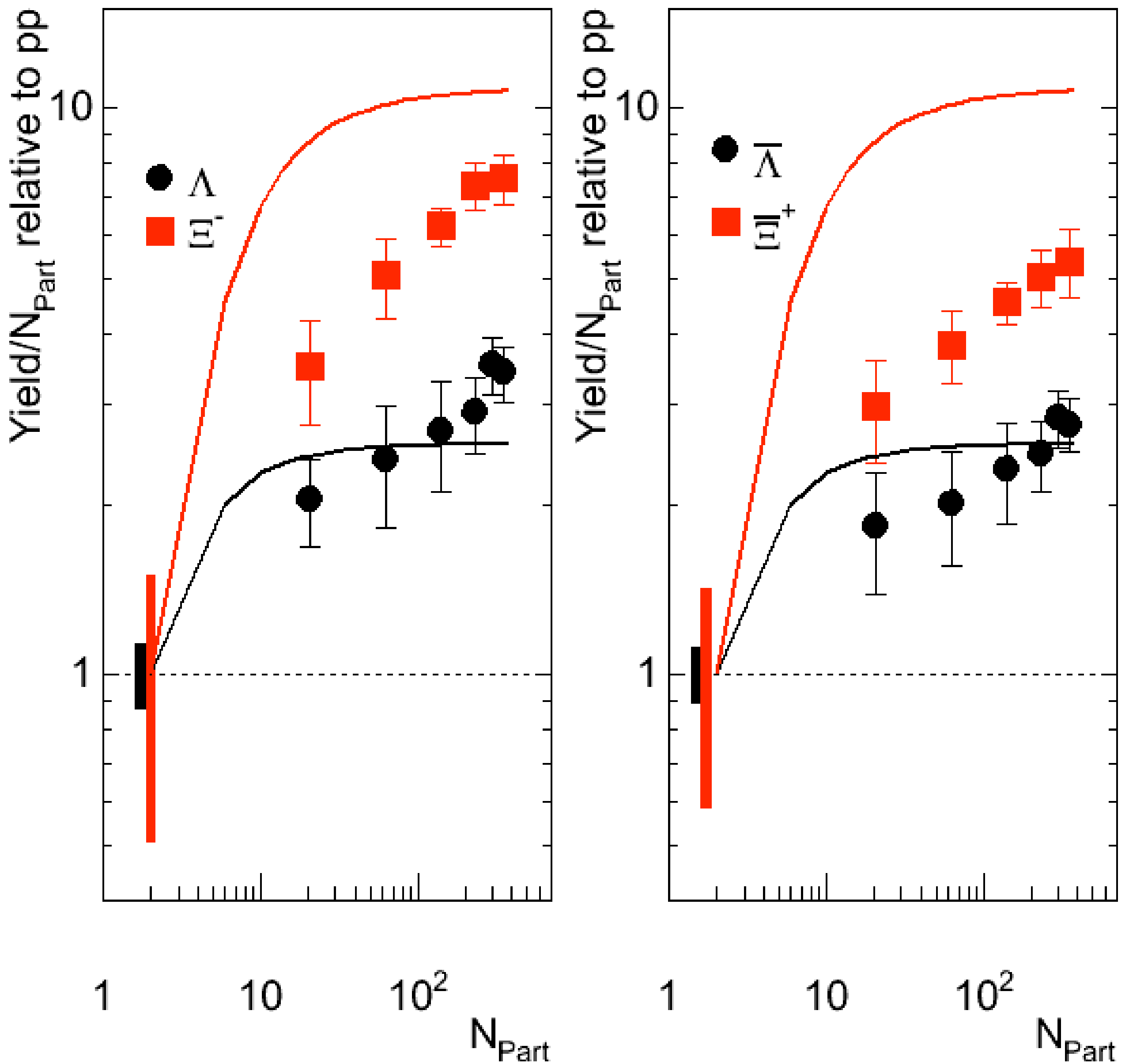
Assuming a constant T_{chem}:

$$V = A^{\alpha} V_0$$

$$A = N_{part}/2$$

$$V_0 = 4/3.\pi R^3$$

$\alpha = 1$ - scales with Volume



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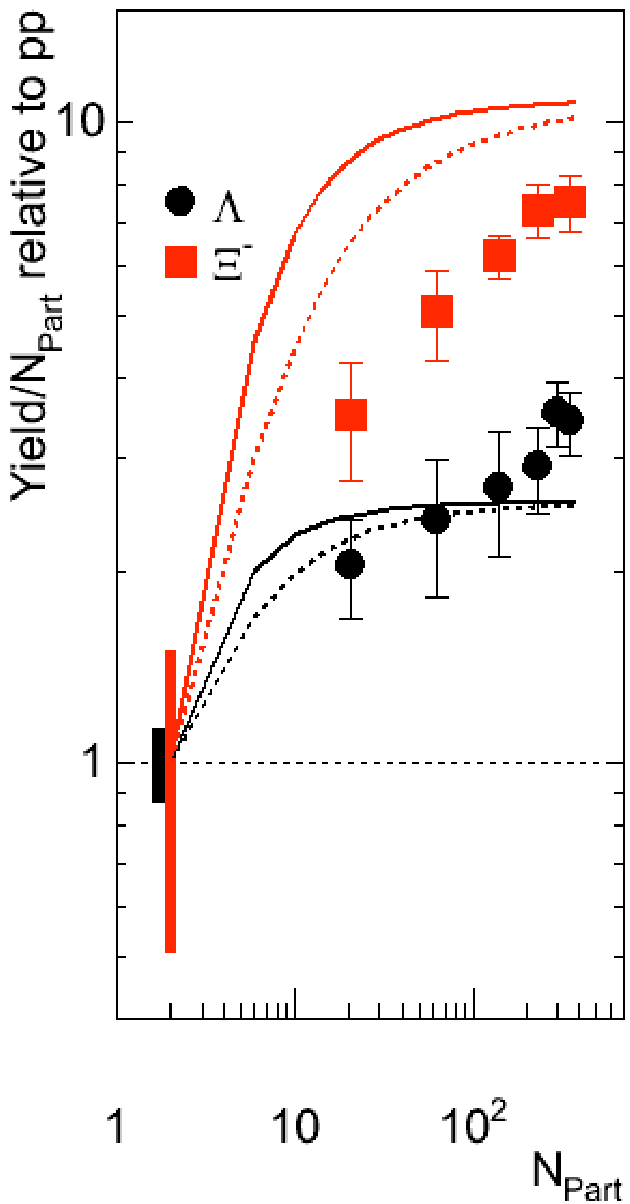

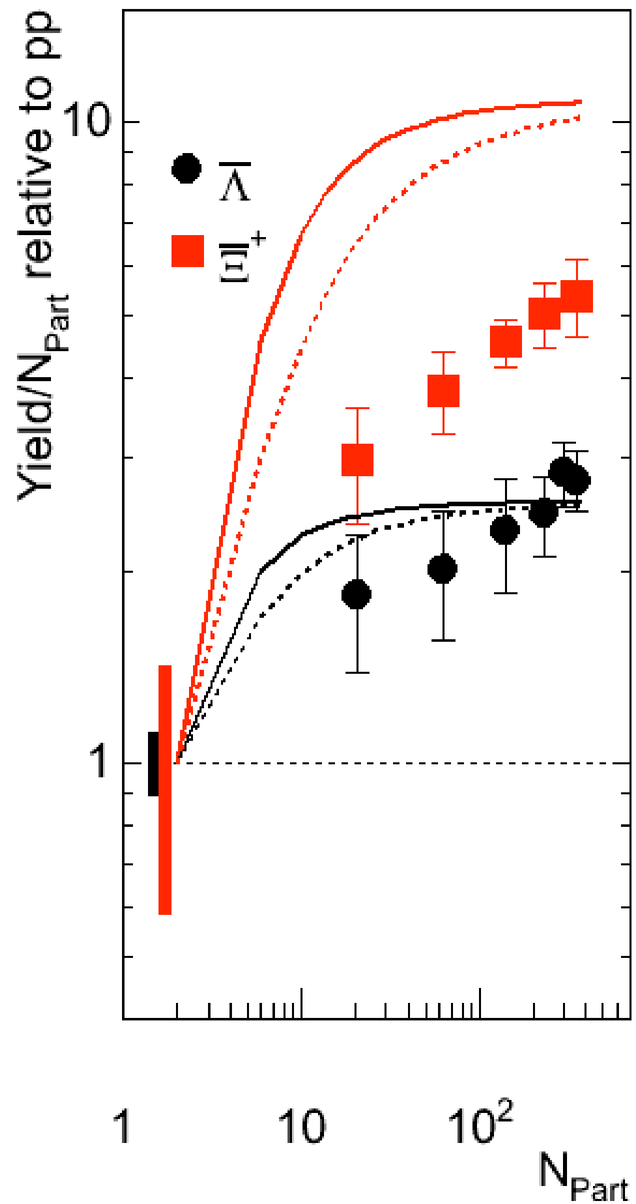

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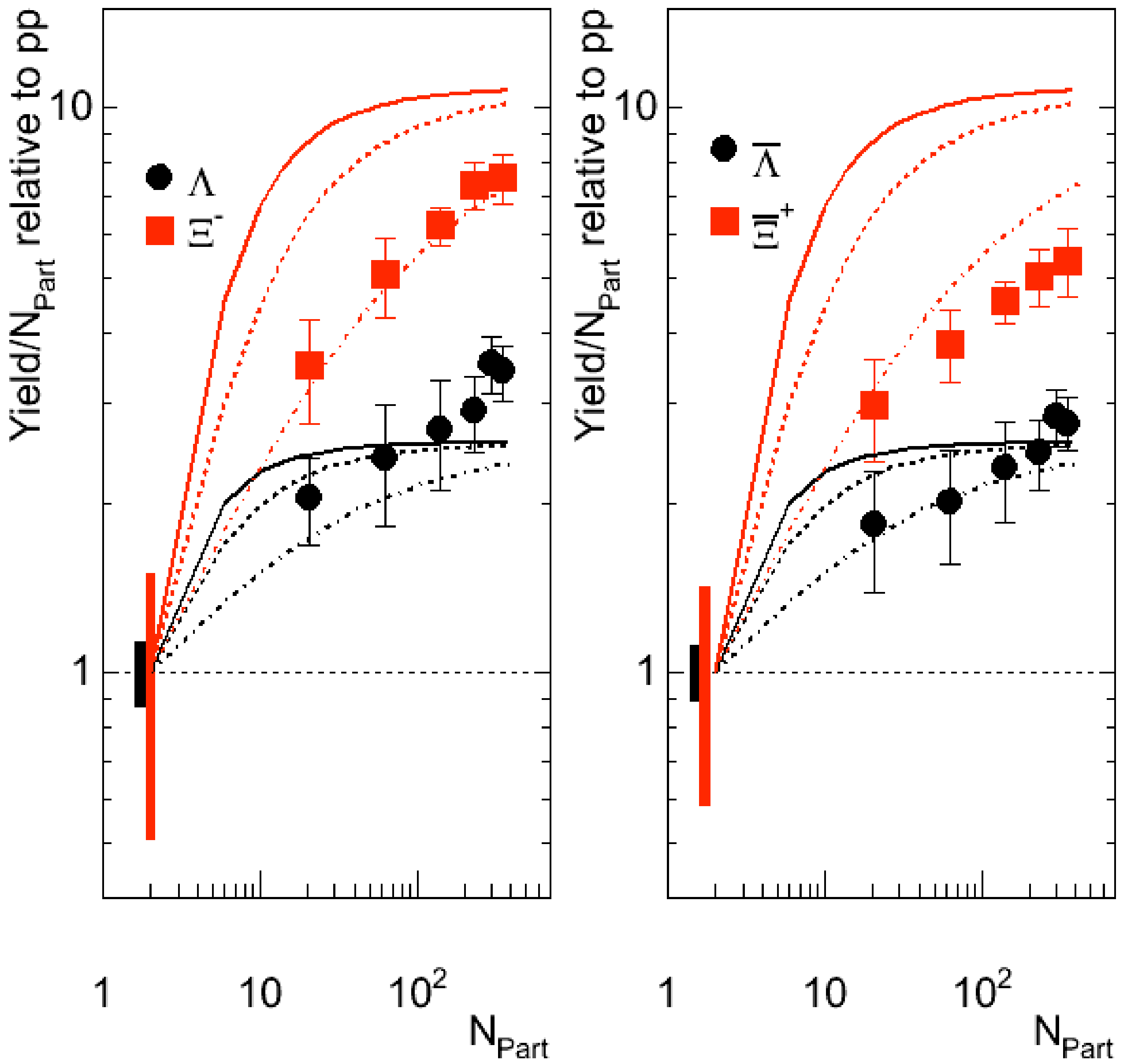

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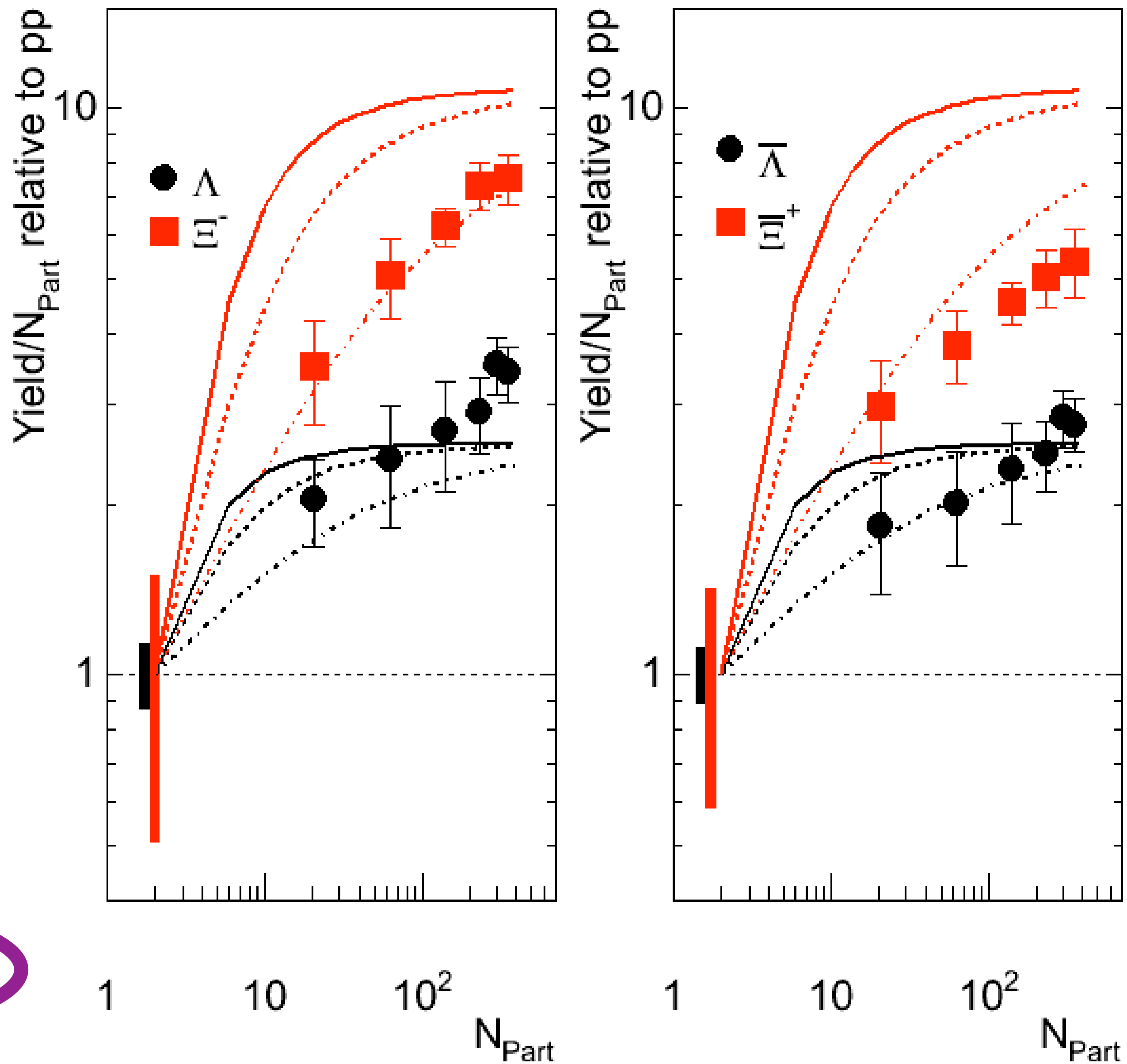

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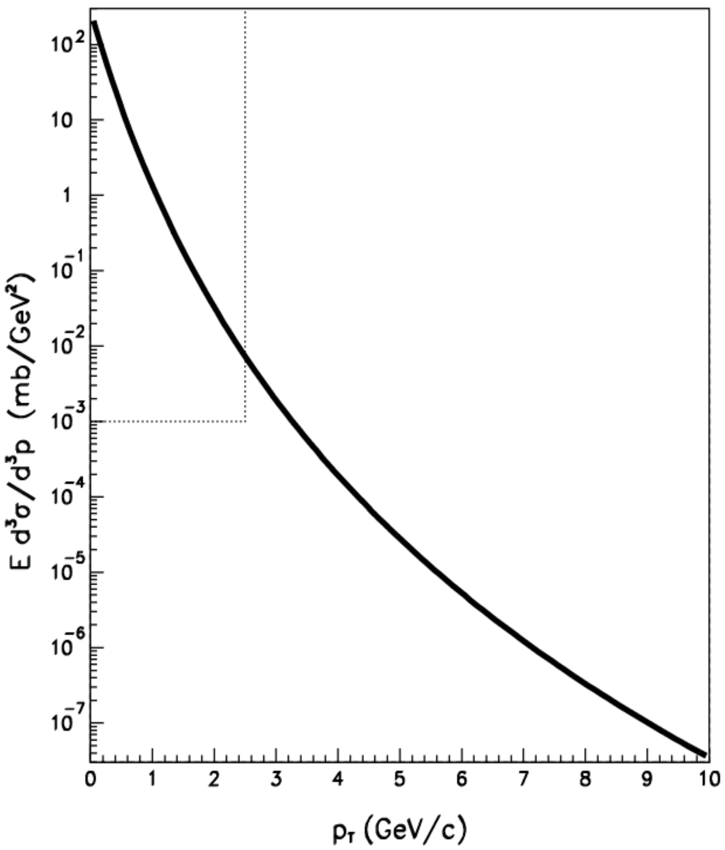
Particle Production vs p_T



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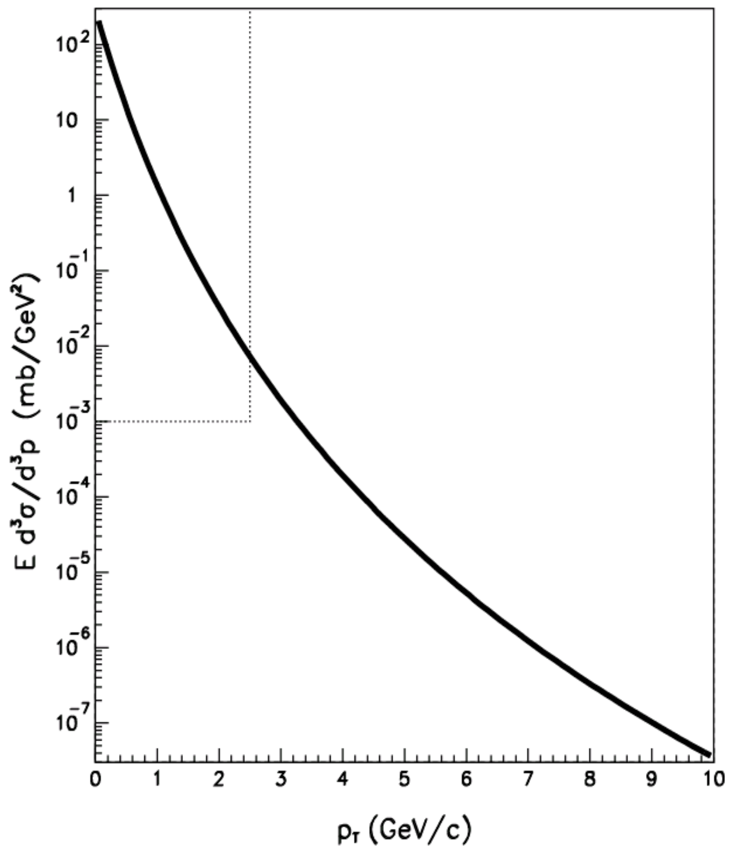
- ReCo models invoke the coalescence of low-p_T partons to form hadrons at intermediate p_T



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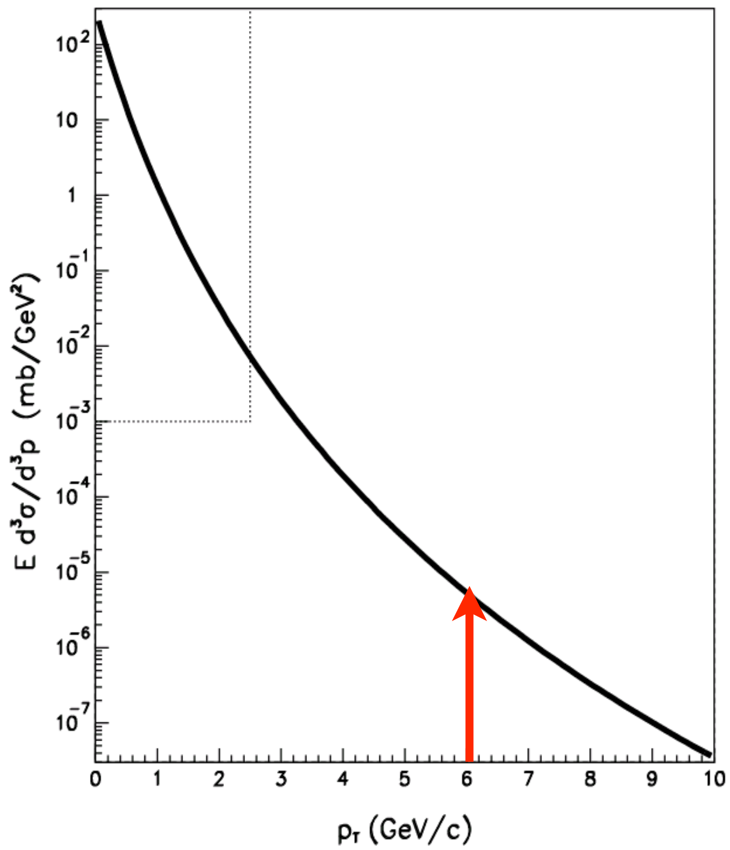

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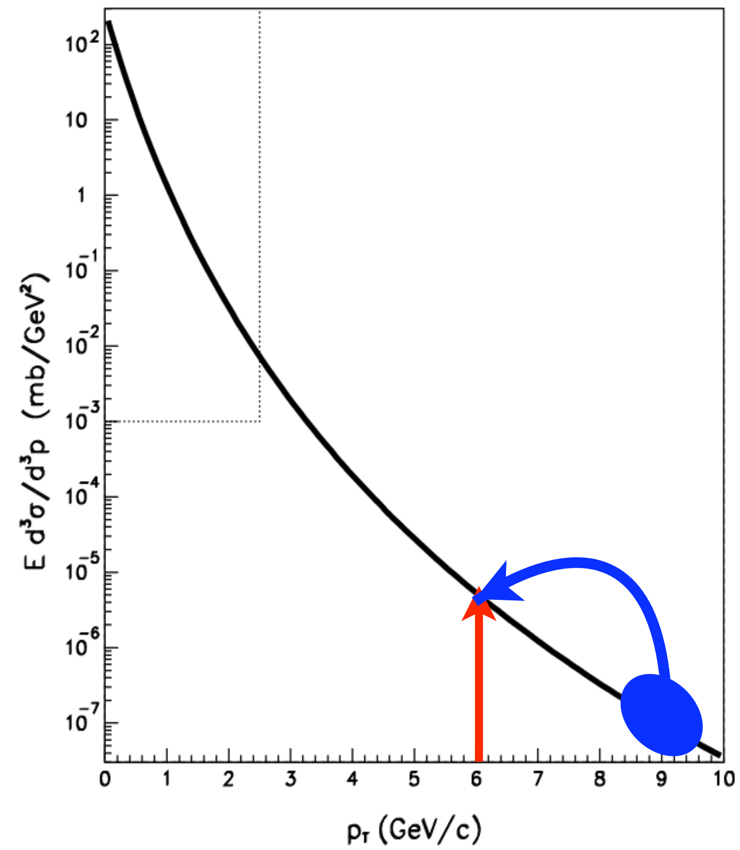

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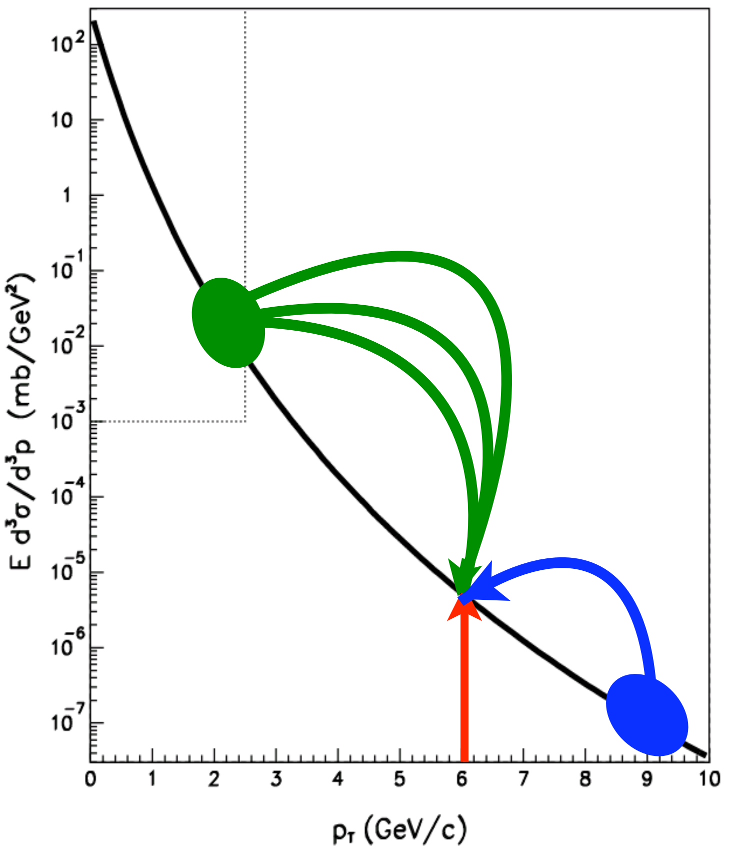

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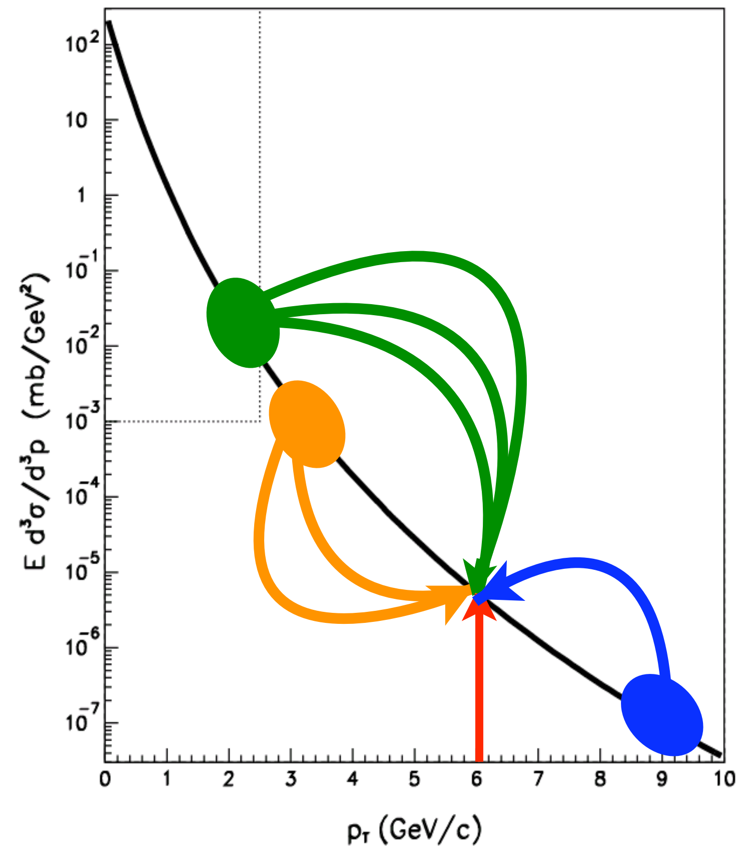

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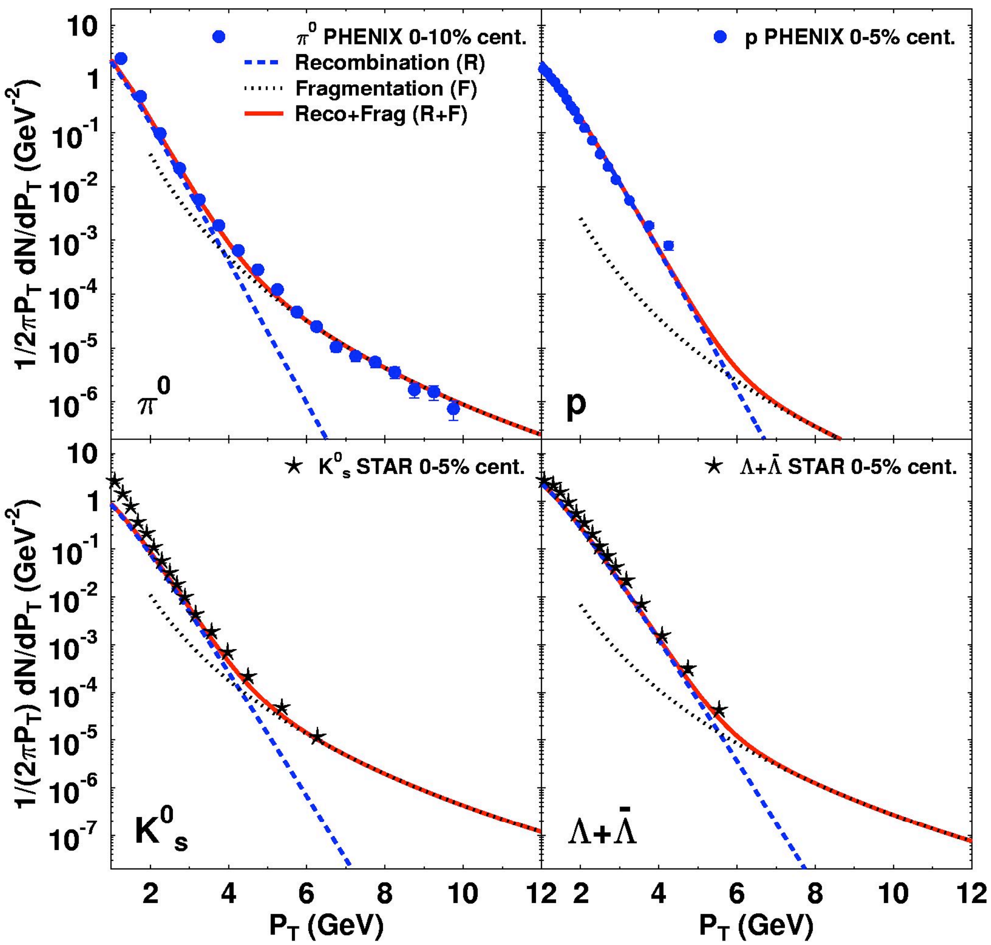

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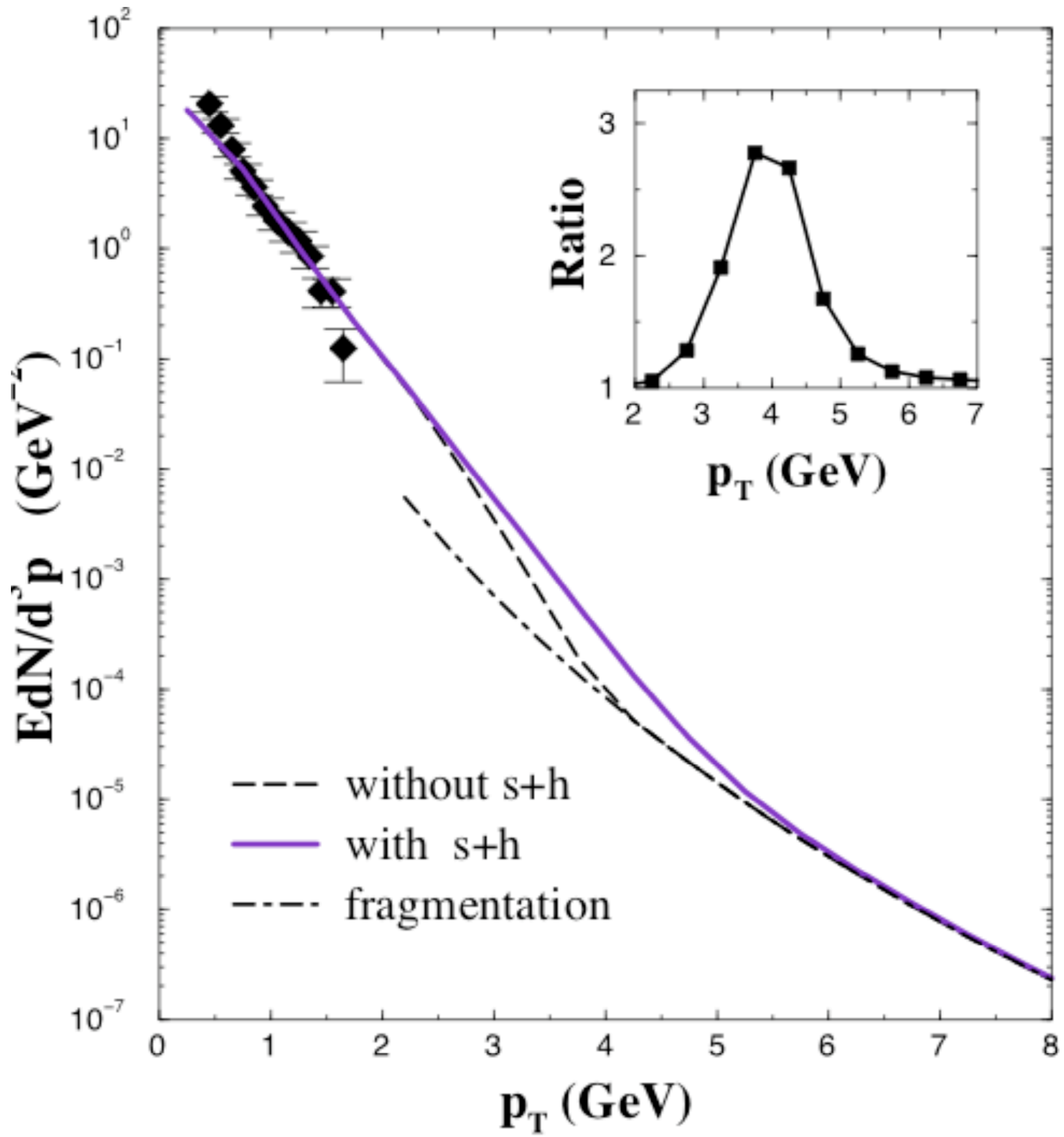
- Some models allow the recombination of soft and hard partons



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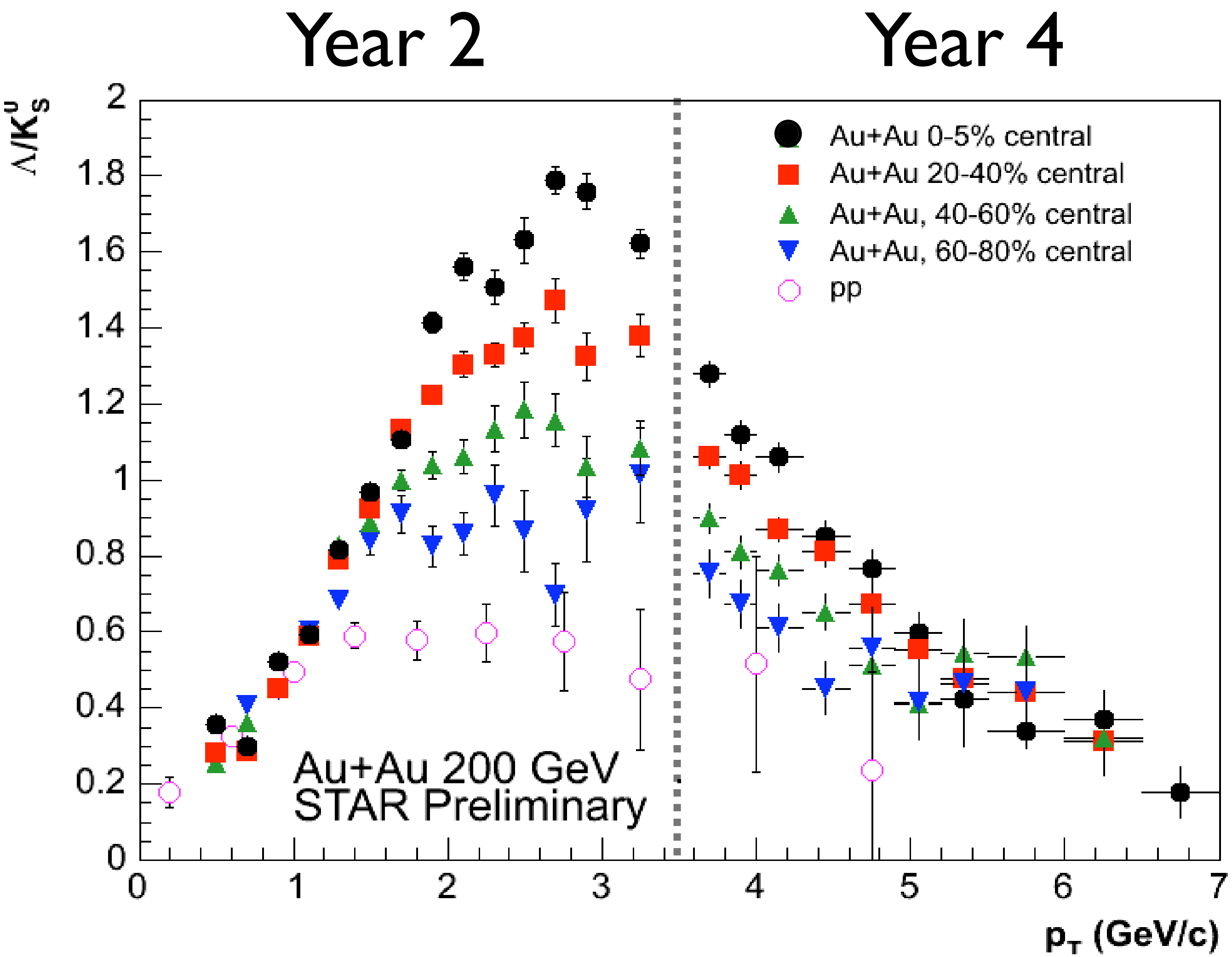

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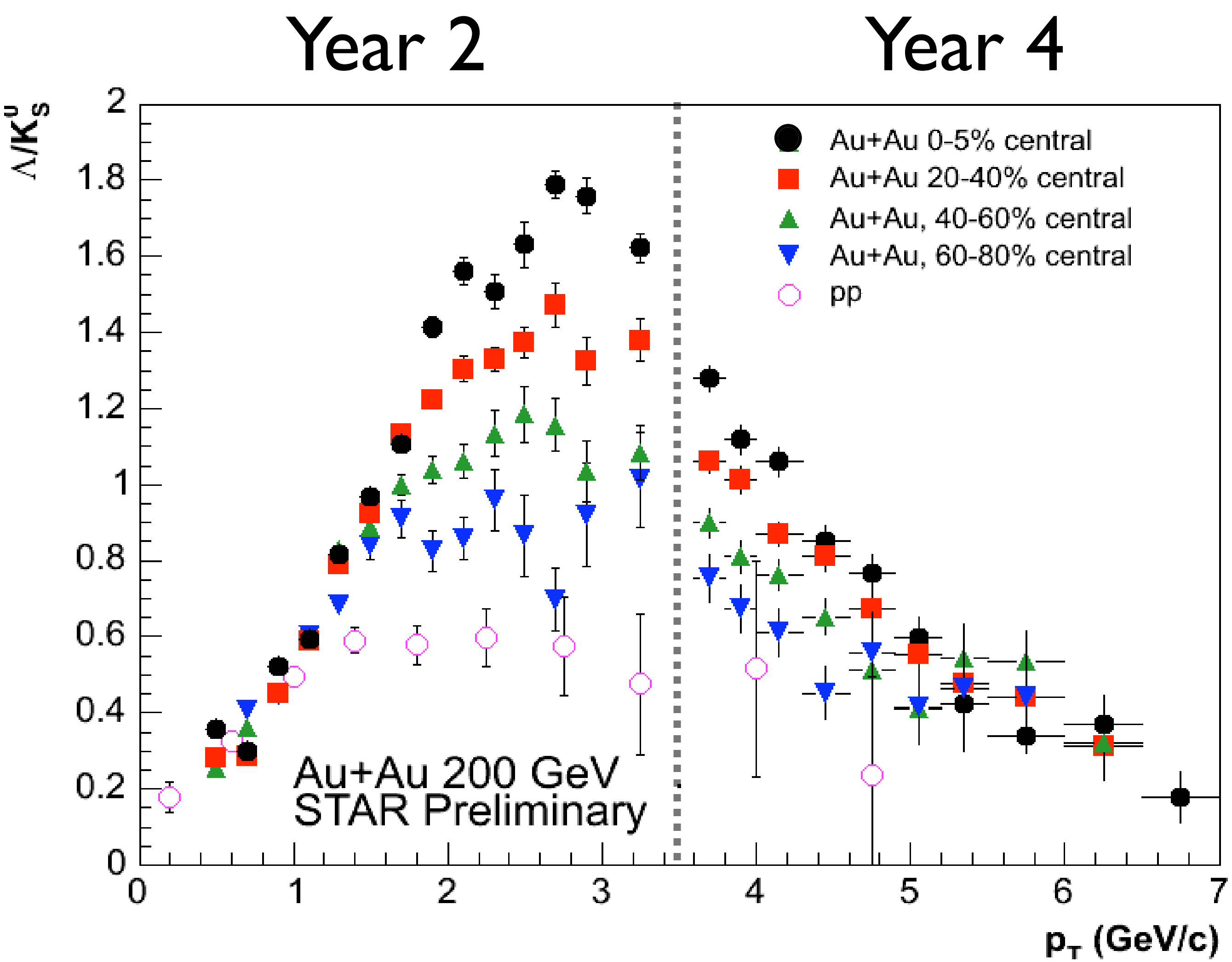

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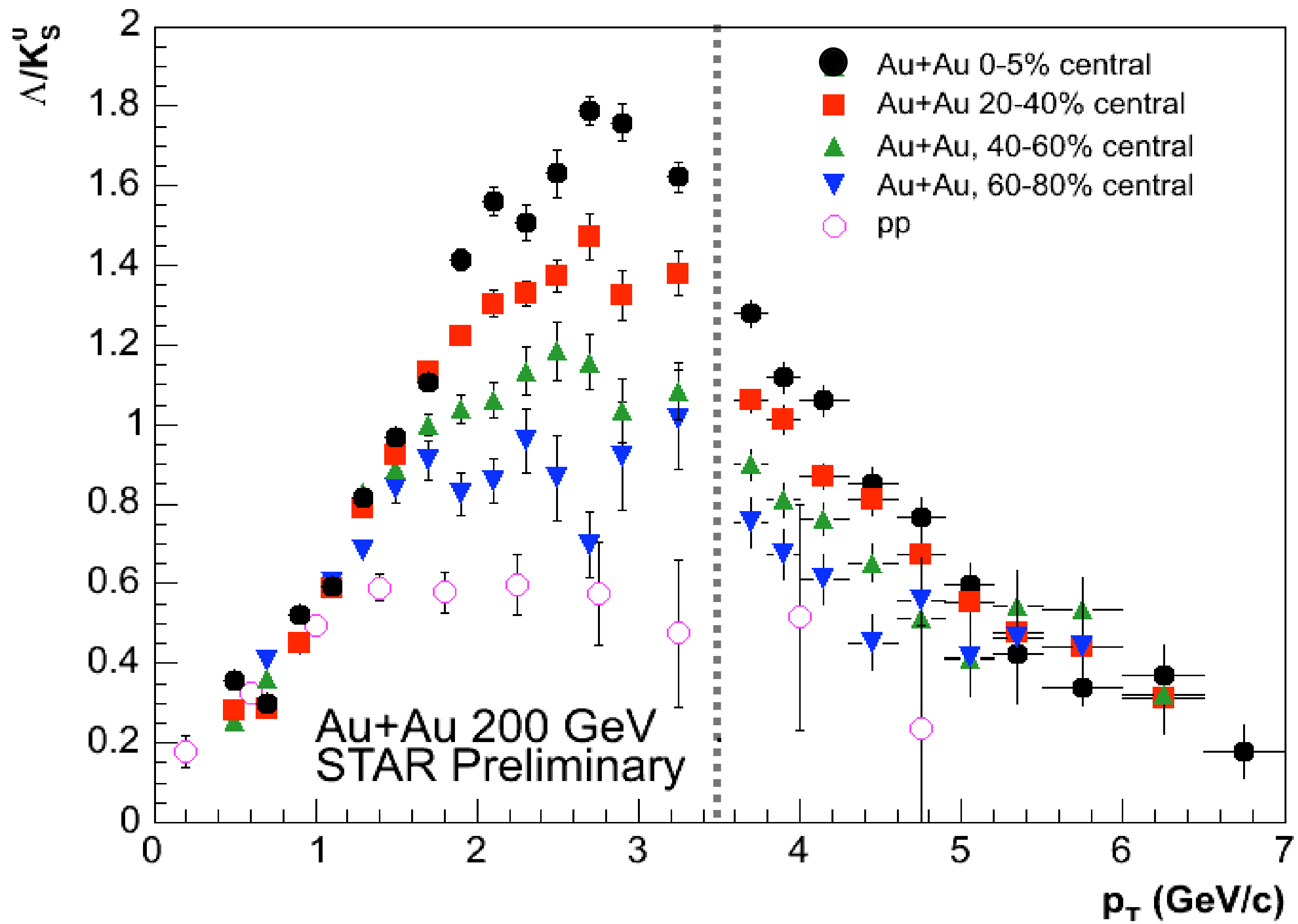
Year 2 Year 4



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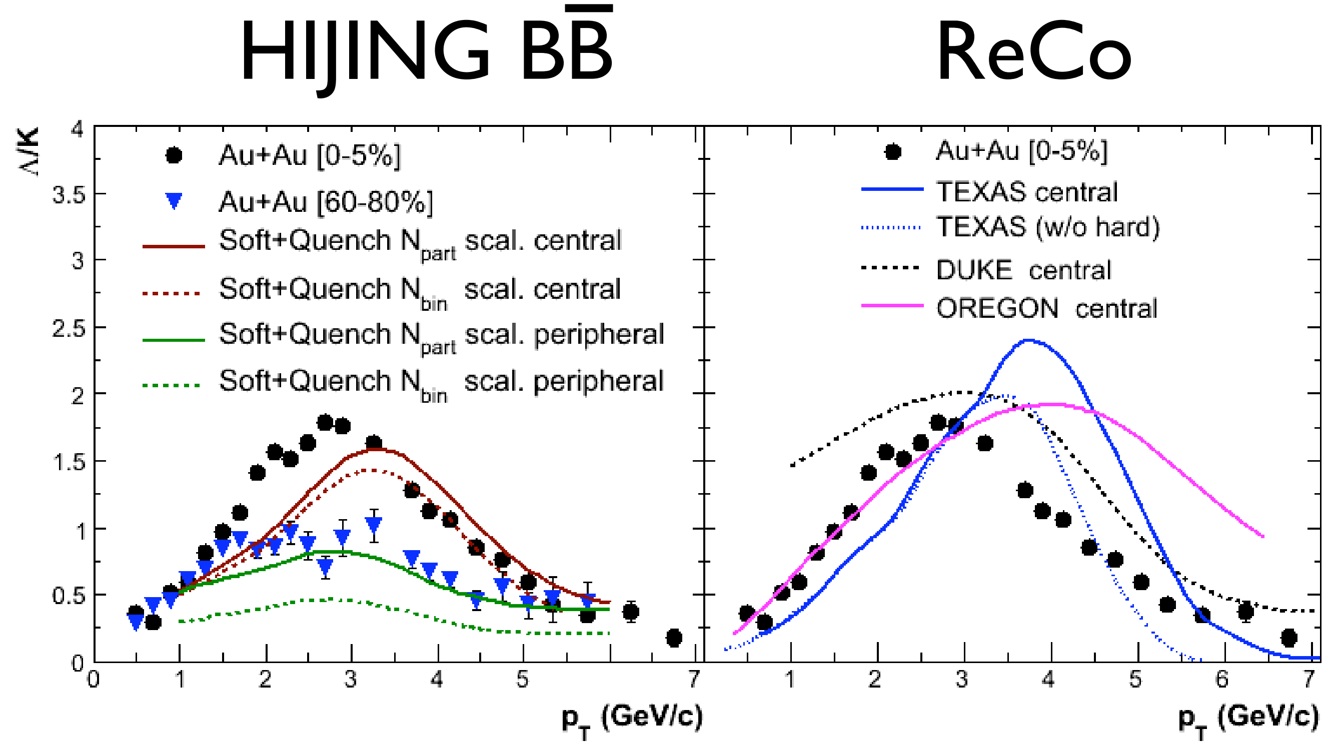

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For information on 2-particle correlations, see talk by Marek Bombara later this afternoon

System Size:

<table>
<tr><th colspan="4">Au+Au</th><th colspan="3">Cu+Cu</th></tr>
<tr><th>Centr.</th><th>N_{part}</th><th>N_{Bin}</th><th>dN_{ch}/dy</th><th>Centr.</th><th>N_{part}</th><th>N_{Bin}</th></tr>
<tr><td>0-5</td><td>351.0 ± 3.0</td><td>1039 ± 79</td><td>691 ± 49</td><td rowspan="3"></td><td rowspan="3"></td><td rowspan="3"></td></tr>
<tr><td>5-10</td><td>293 ± 7.</td><td>810 ± 58</td><td>558 ± 40</td></tr>
<tr><td>10-20</td><td>231 ± 3.2</td><td>574 ± 42</td><td>421 ± 30</td></tr>
<tr><td>20-40</td><td>139 ± 5</td><td>278 ± 30</td><td>238 ± 20</td><td>0-10</td><td>98.4 ± 1.0</td><td>185.7 ±5.9</td></tr>
<tr><td rowspan="2">40-60</td><td rowspan="2">59.0 ± 5.</td><td rowspan="2">82 ± 12</td><td rowspan="2">98 ± 10</td><td>10-20</td><td>74.8 ± 2.5</td><td>126.7 ±6.7</td></tr>
<tr><td>20-30</td><td>54.4 ± 2.8</td><td>81.5 ± 6.0</td></tr>
<tr><td rowspan="2">60-80</td><td rowspan="2">19.0 ± 3.5</td><td rowspan="2">19 ± 5</td><td rowspan="2">32 ± 10</td><td>30-40</td><td>38.5 ± 2.5</td><td>51.0 ± 4.8</td></tr>
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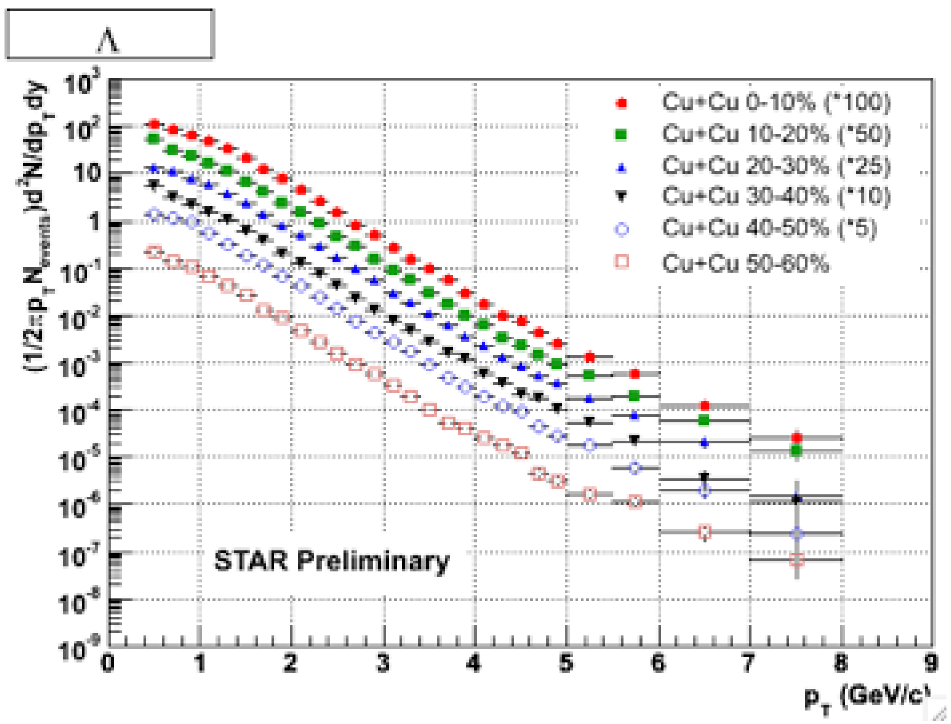
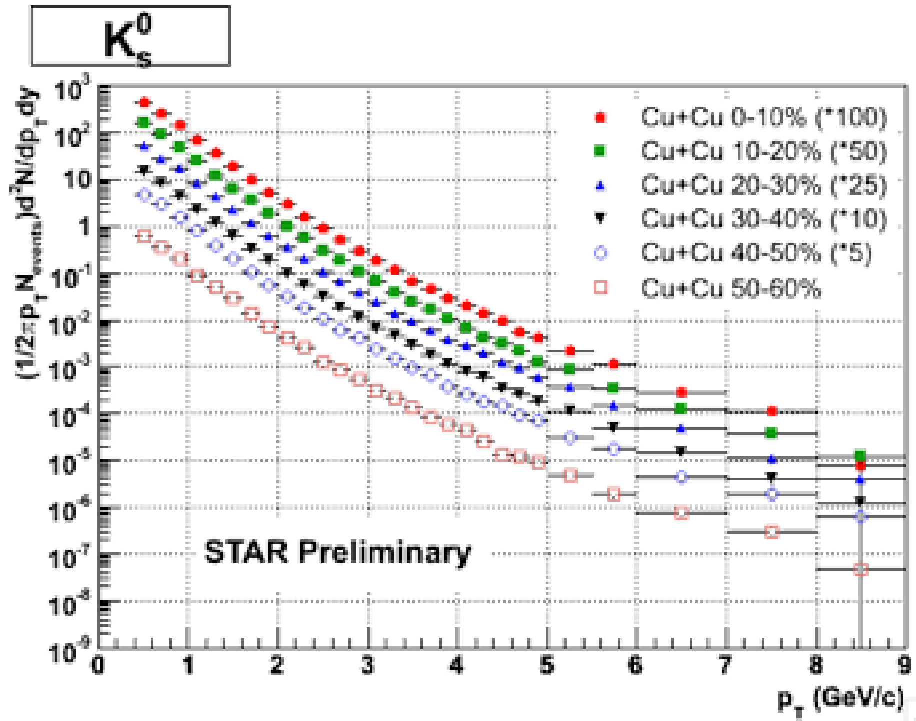
</table>

Cu+Cu Spectra





- 5×10^7 events analyzed
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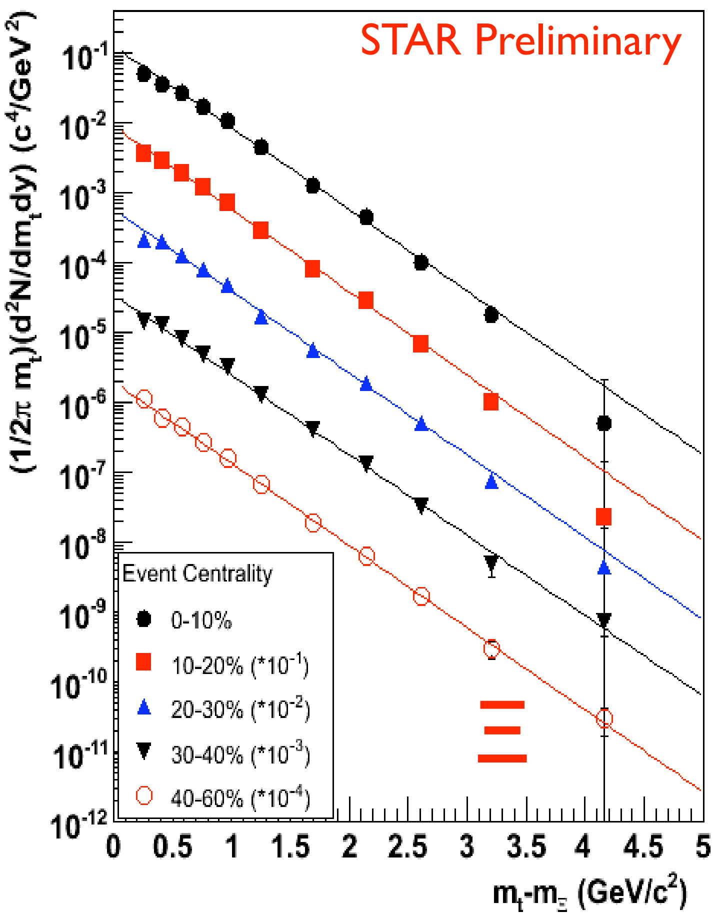

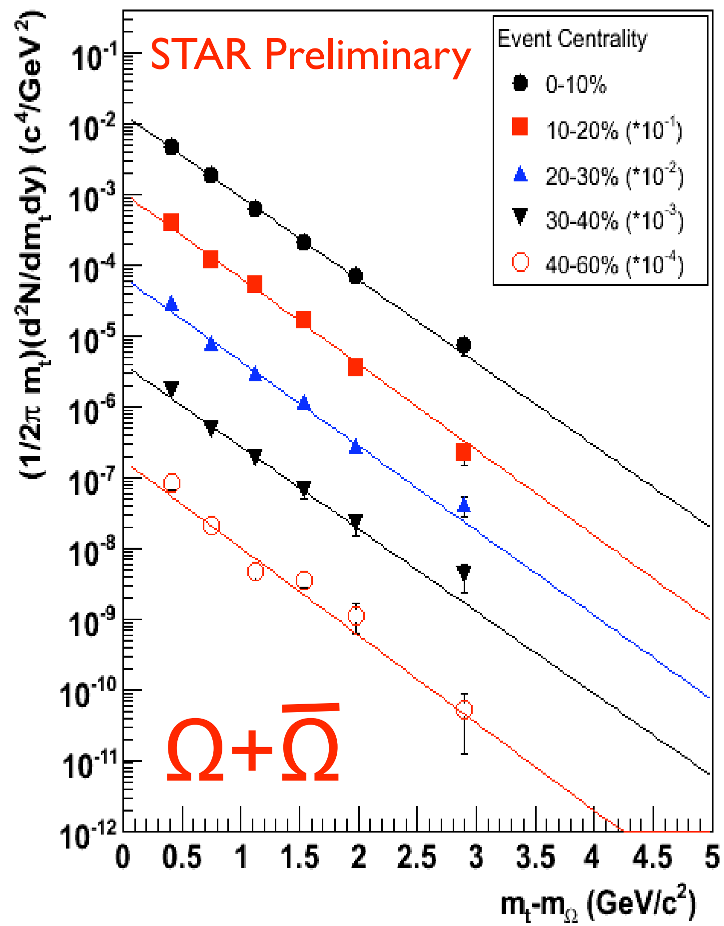

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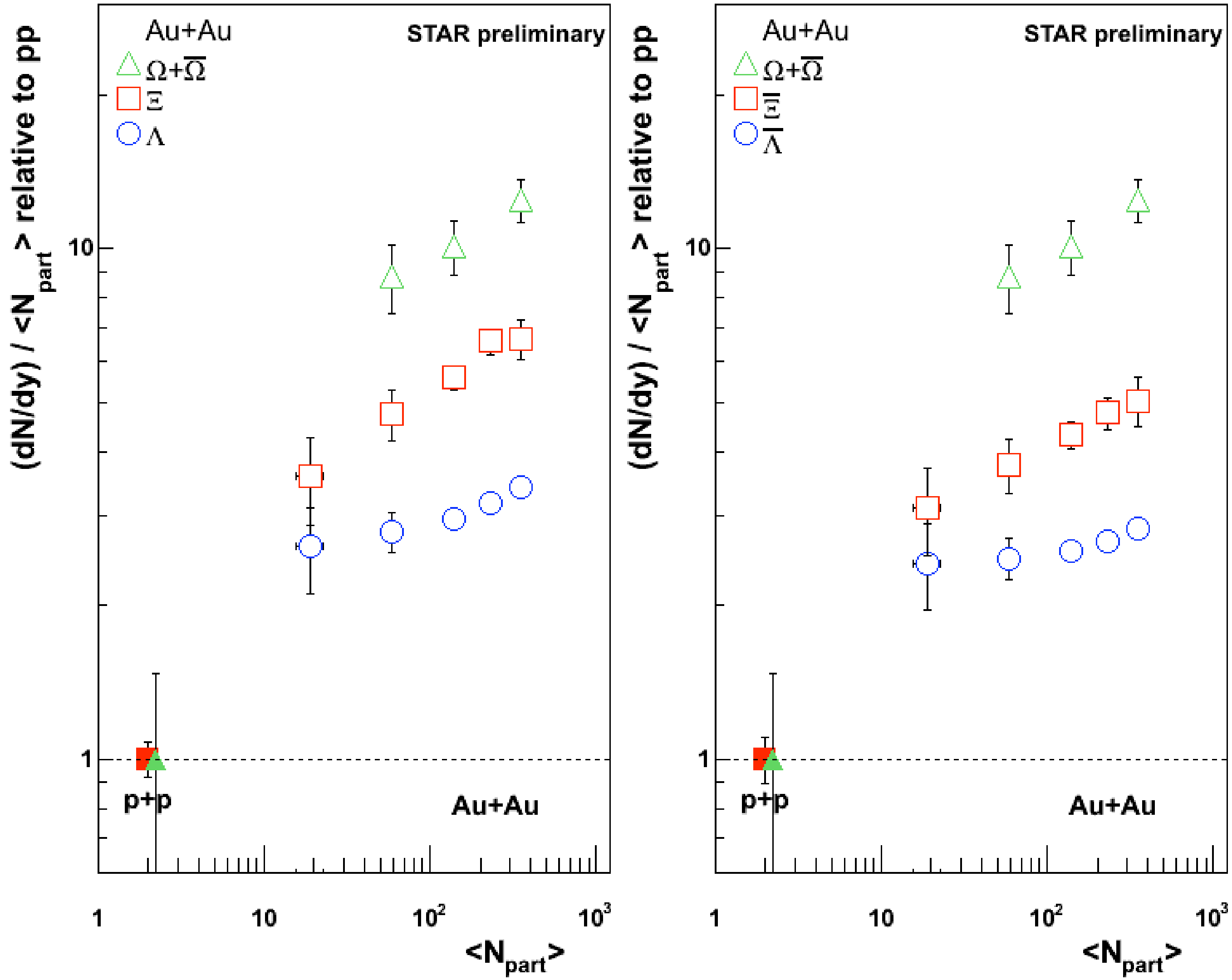
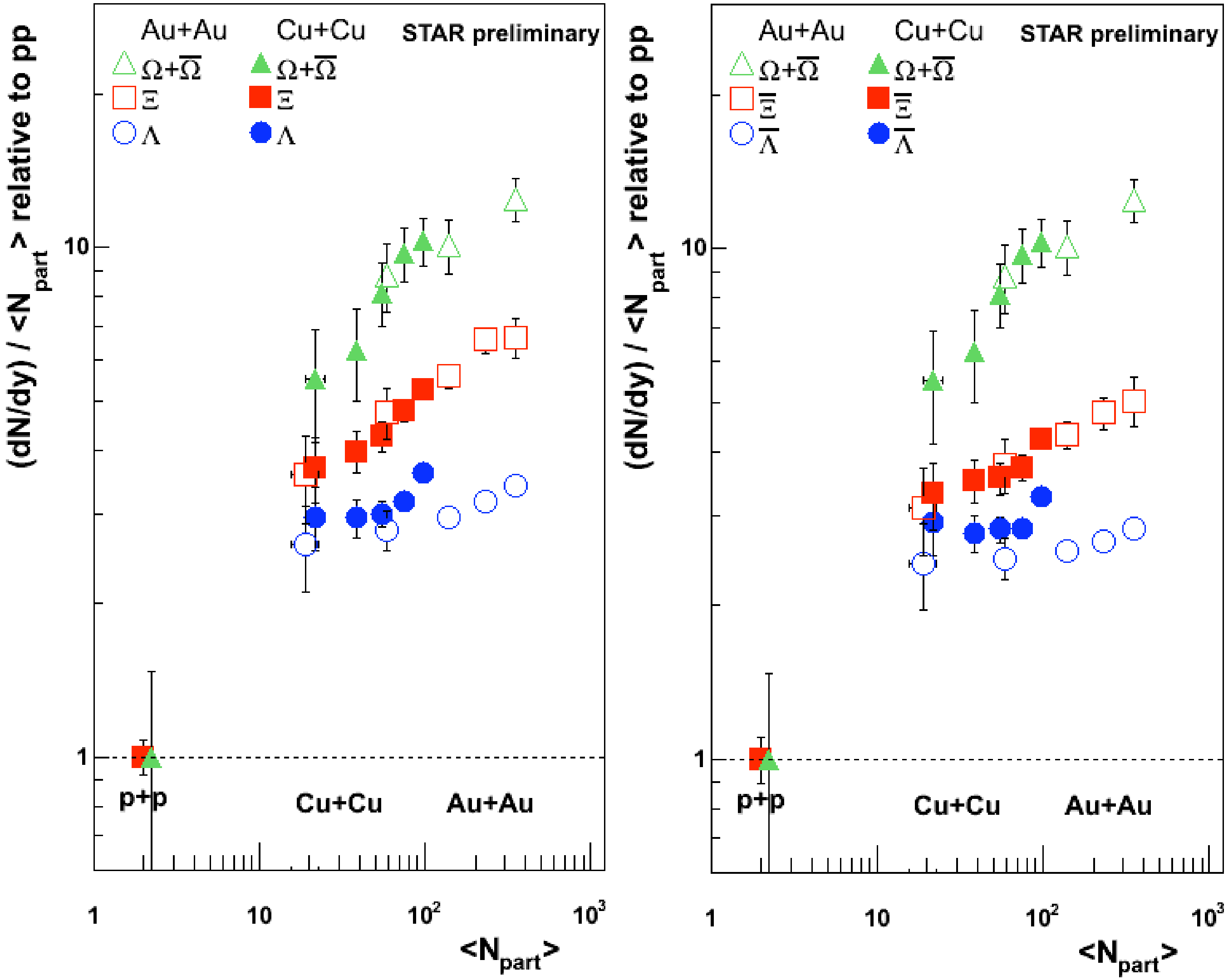
Strangeness Enhancement: Cu+Cu



Strangeness Enhancement: Cu+Cu

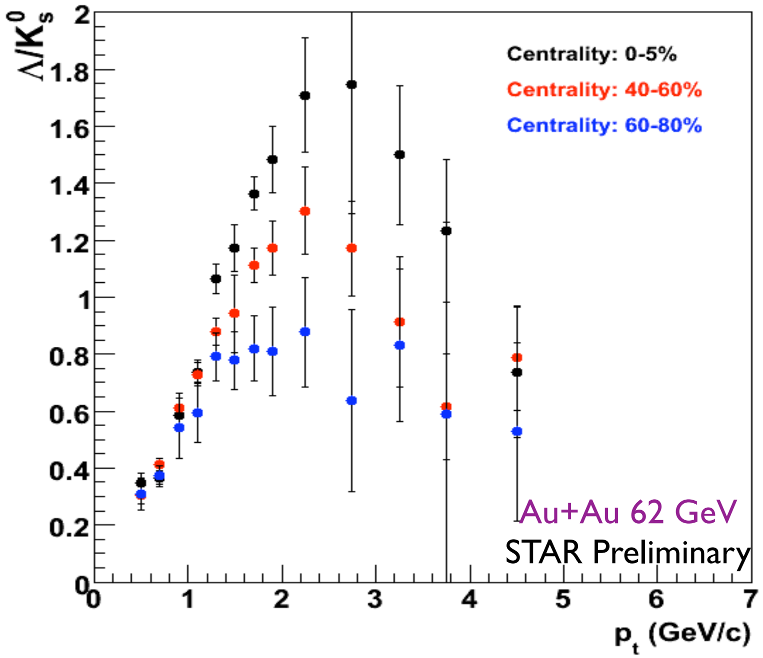
- Cu+Cu increases the fine detail at lower <N_{part}>
- Multi-strange:
  - Cu+Cu and Au+Au ~ same
- Singly-strange:
  - Cu+Cu yields higher than Au+Au for the same <N_{part}>

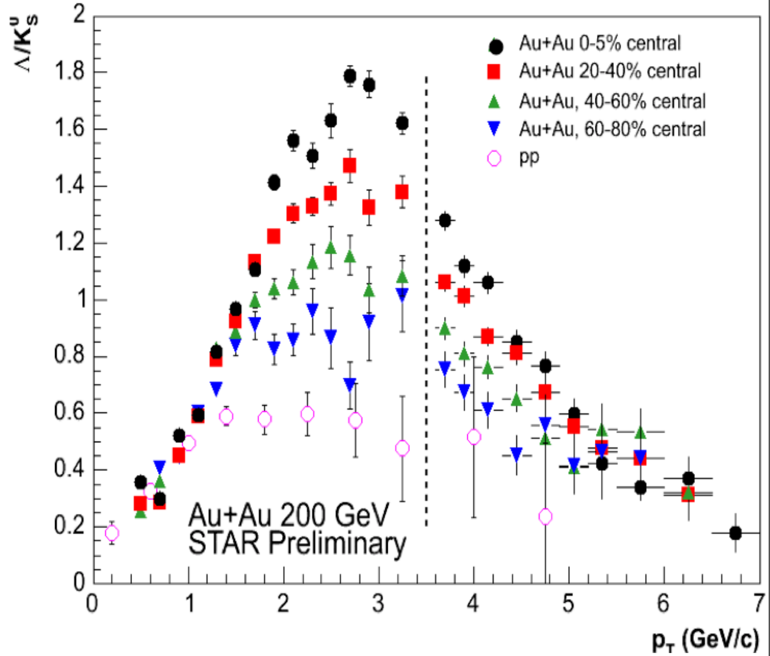


Different system geometries between central Cu+Cu (spherical) and peripheral Au+Au (ellipsoidal)

Intermediate p_T: Energy and system size dependence

- Baryon/meson ratio appears to be the same for both Au+Au energies (large error bars)
  - Despite the $\bar{\Lambda}/\Lambda$ ratio being different by 60%
- "Peak" value of enhancement at lower p_T for lower energy?





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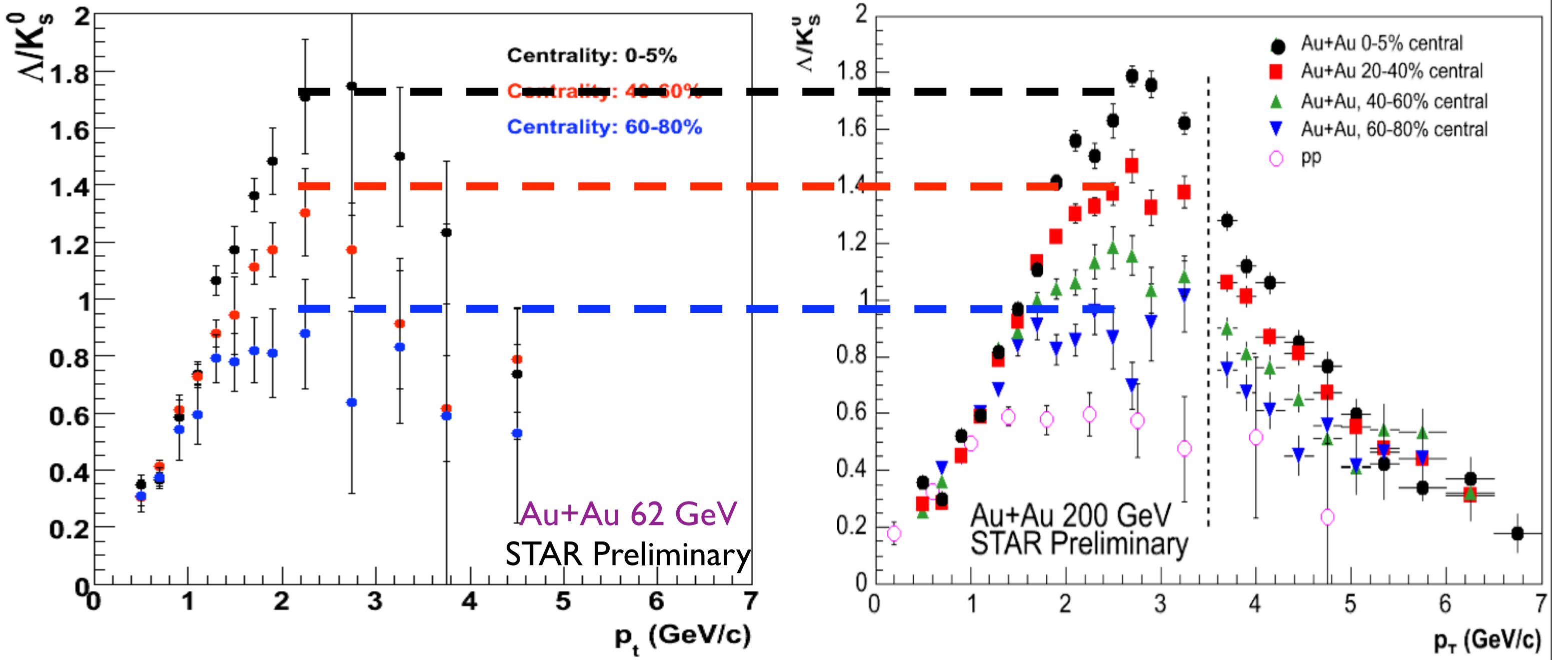

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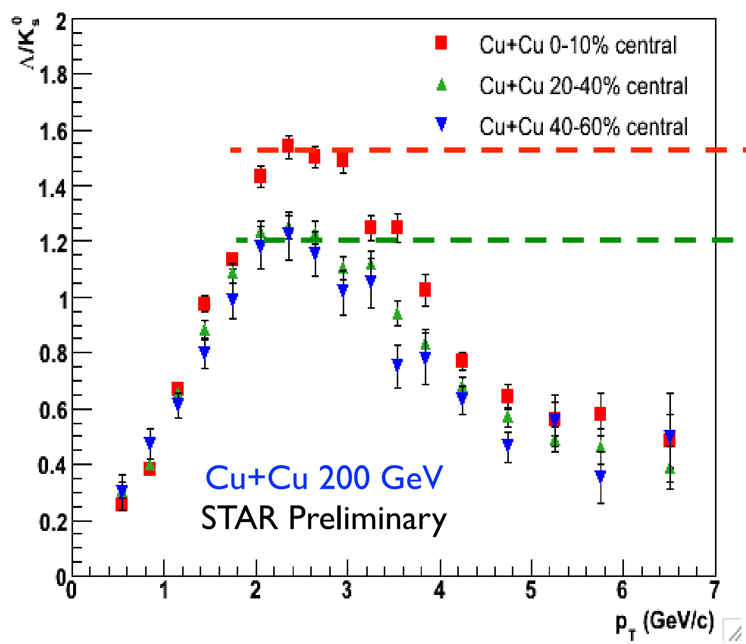

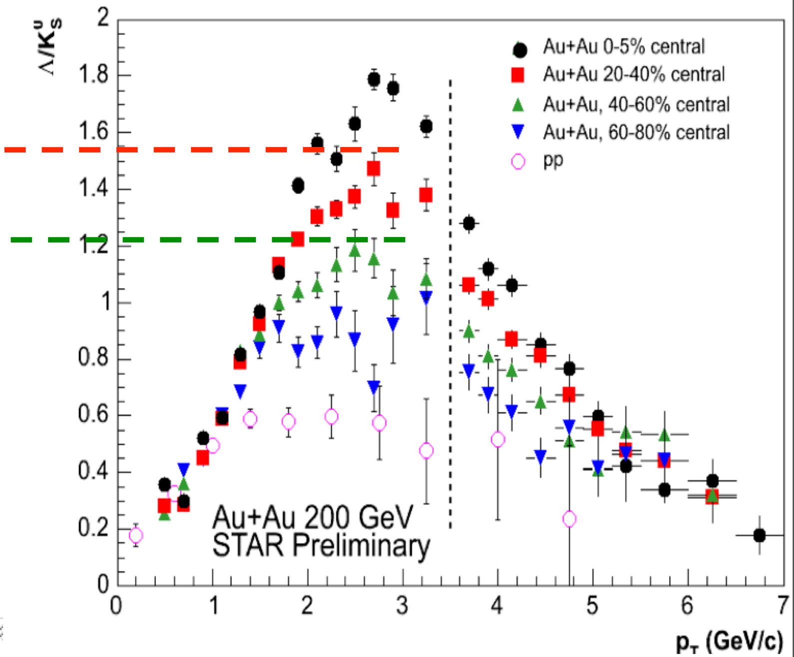

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  - Despite the $\overline{\Lambda}/\Lambda$ ratio being different by 60%
- "Peak" value of enhancement at lower p_T for lower energy?

- Again, similarities between Cu+Cu and Au+Au
  - both 200 GeV, no $\overline{\Lambda}/\Lambda$ differences
- "Peak" value of enhancement at lower p_T for smaller system

Intermediate p_T: Energy and system size dependence

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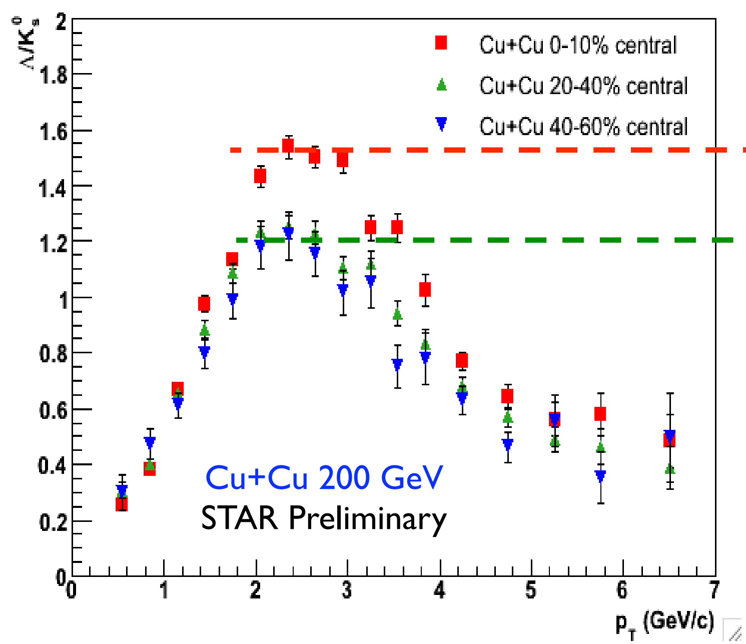
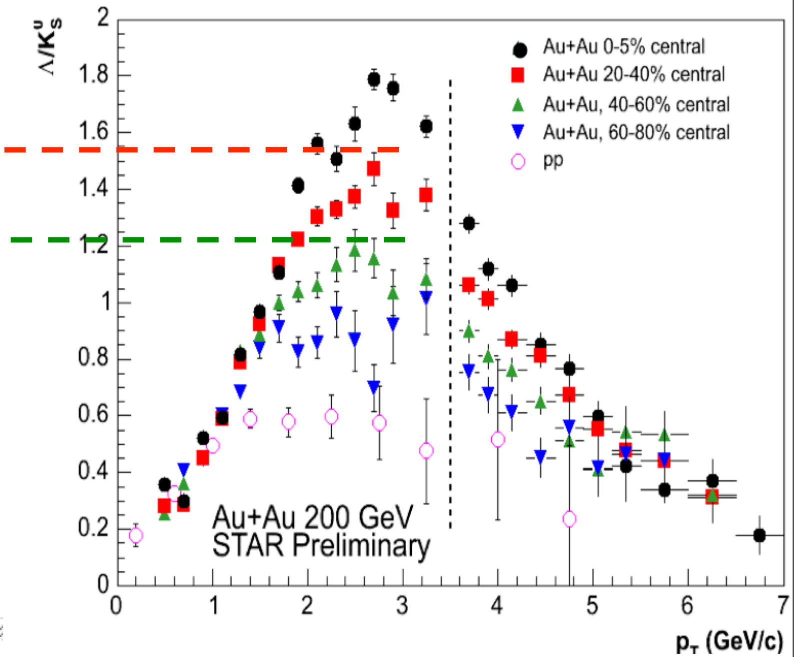
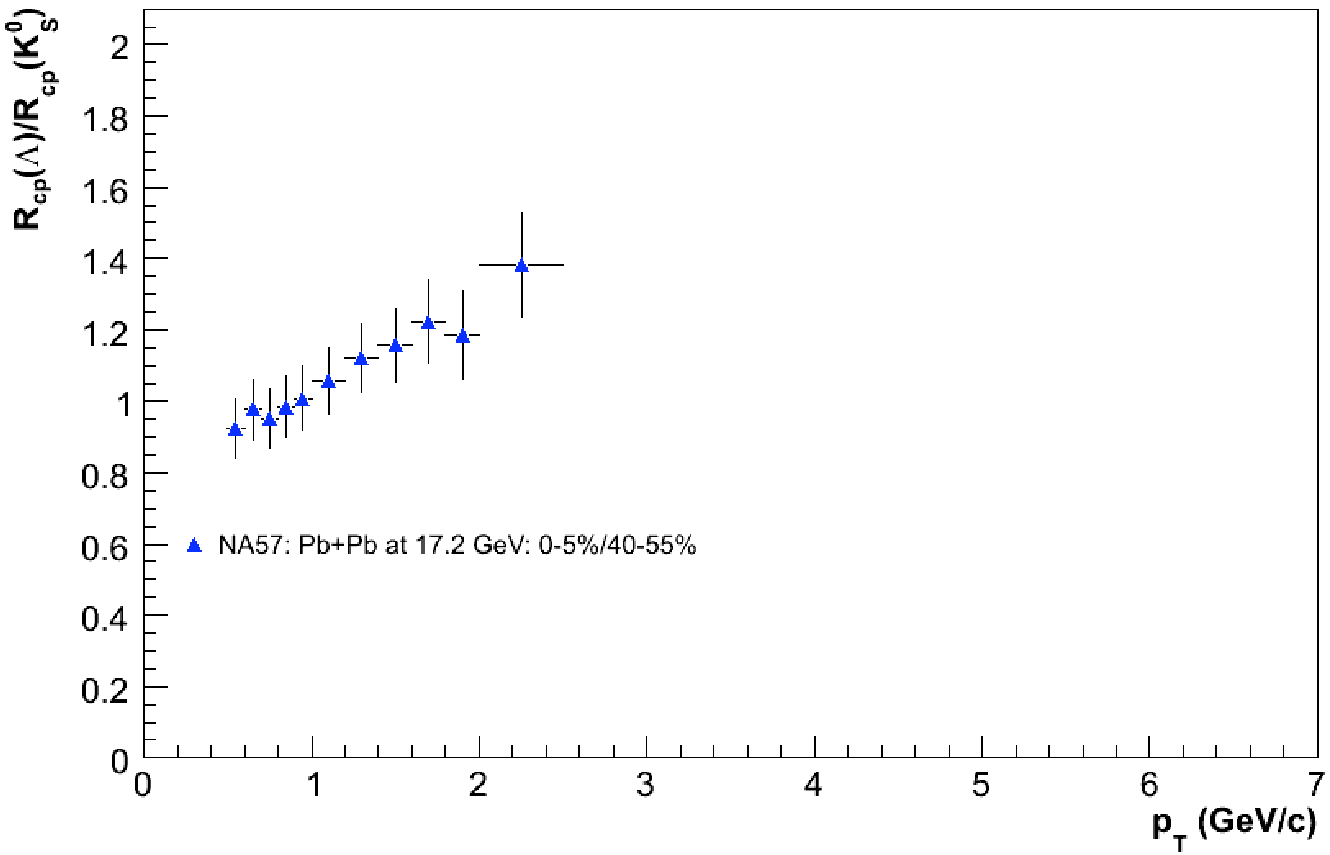




- Aga
  - be
- “Pea tem

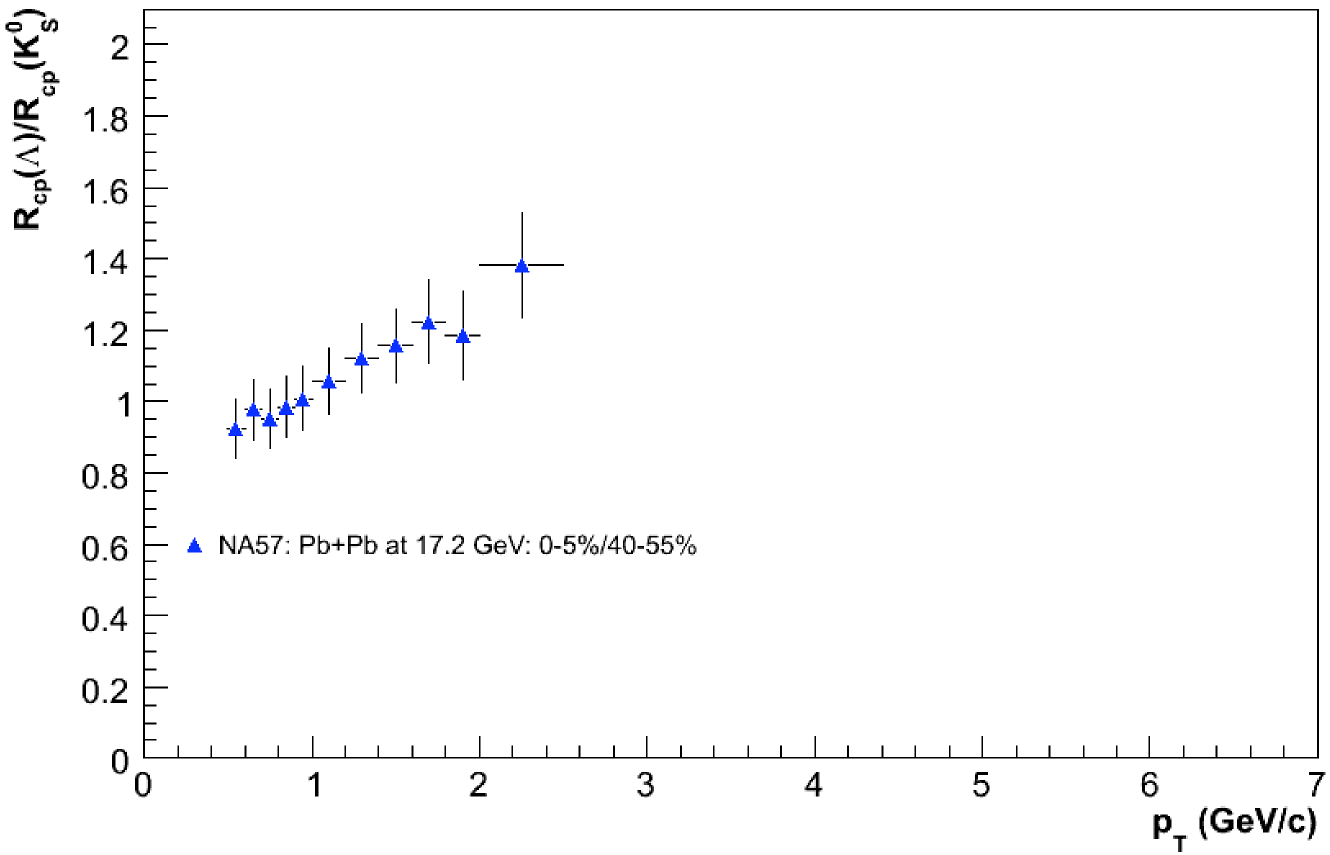
Difficult to make direct comparisons like this, what else can we do?

Intermediate p_T: Energy and system size dependence



Intermediate p_T: Energy and system size dependence

- Plot: Λ/K^0_S in central over peripheral
- Removes any baryon stopping effects between different energies.



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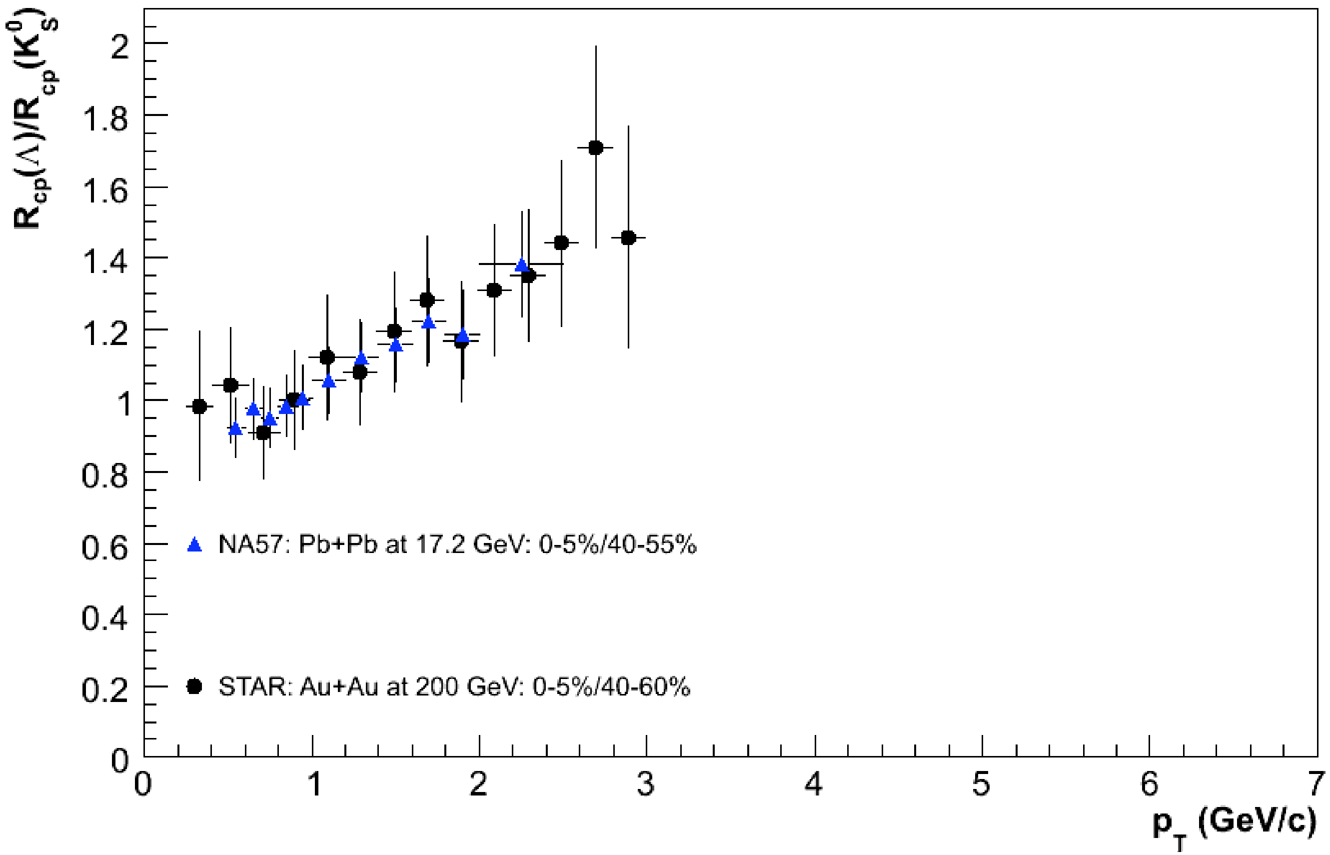

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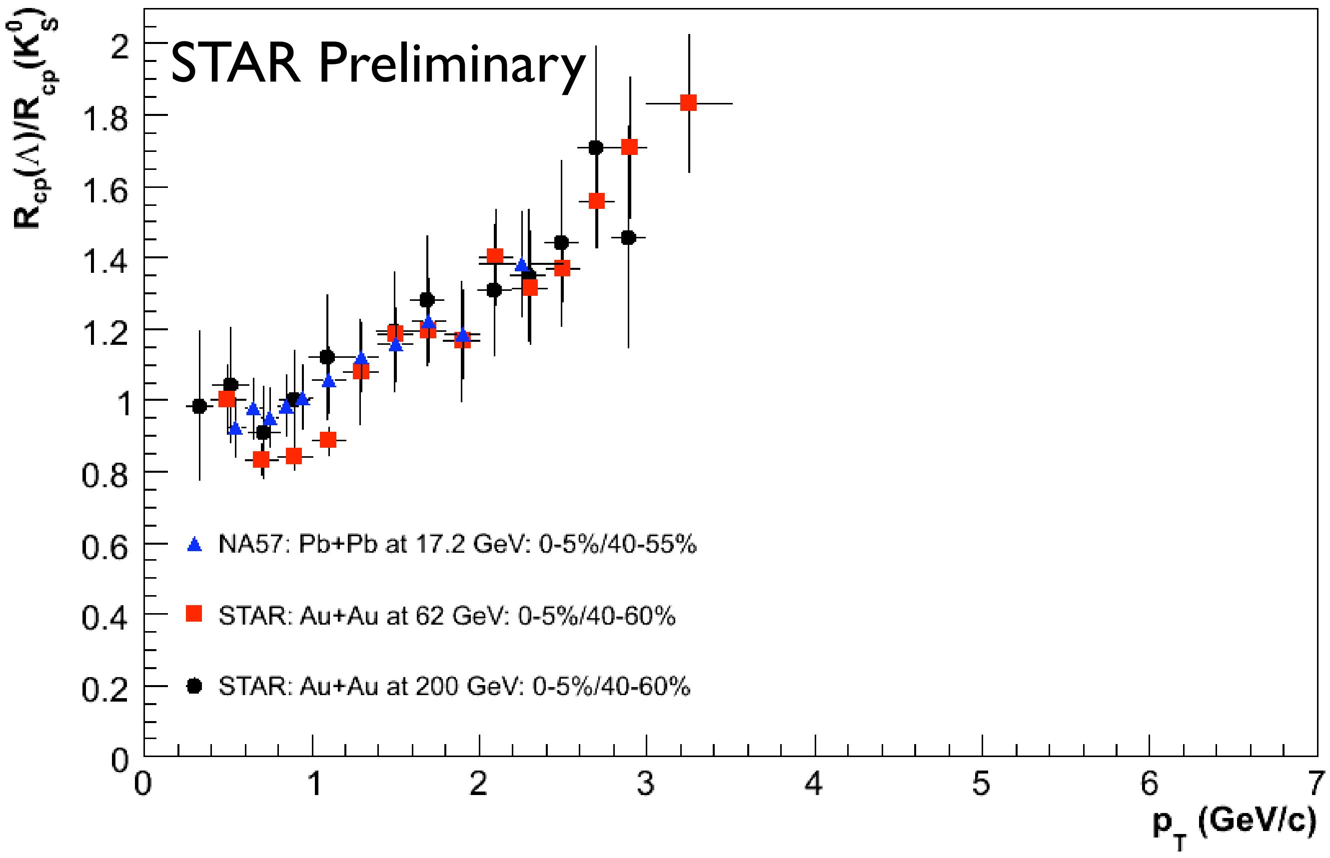

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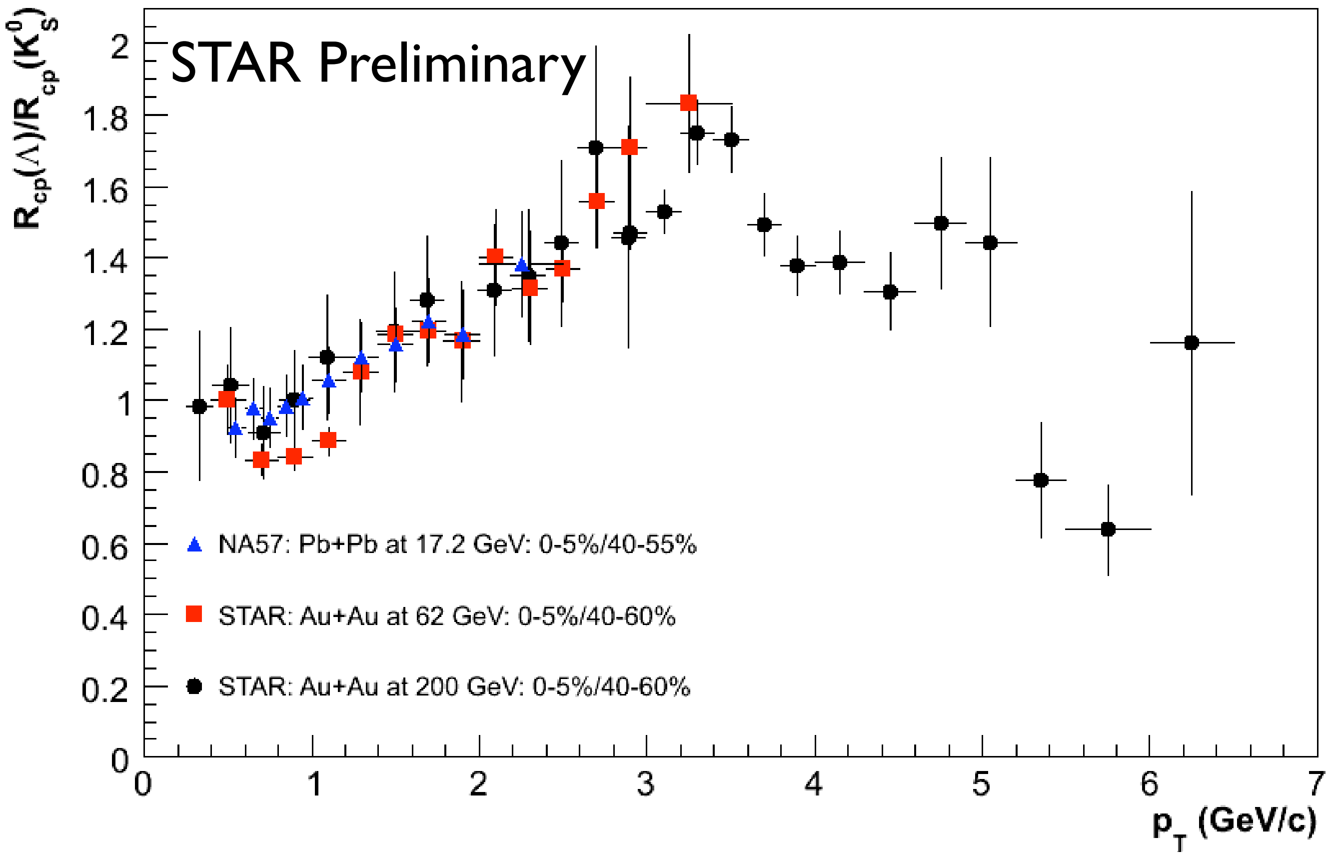
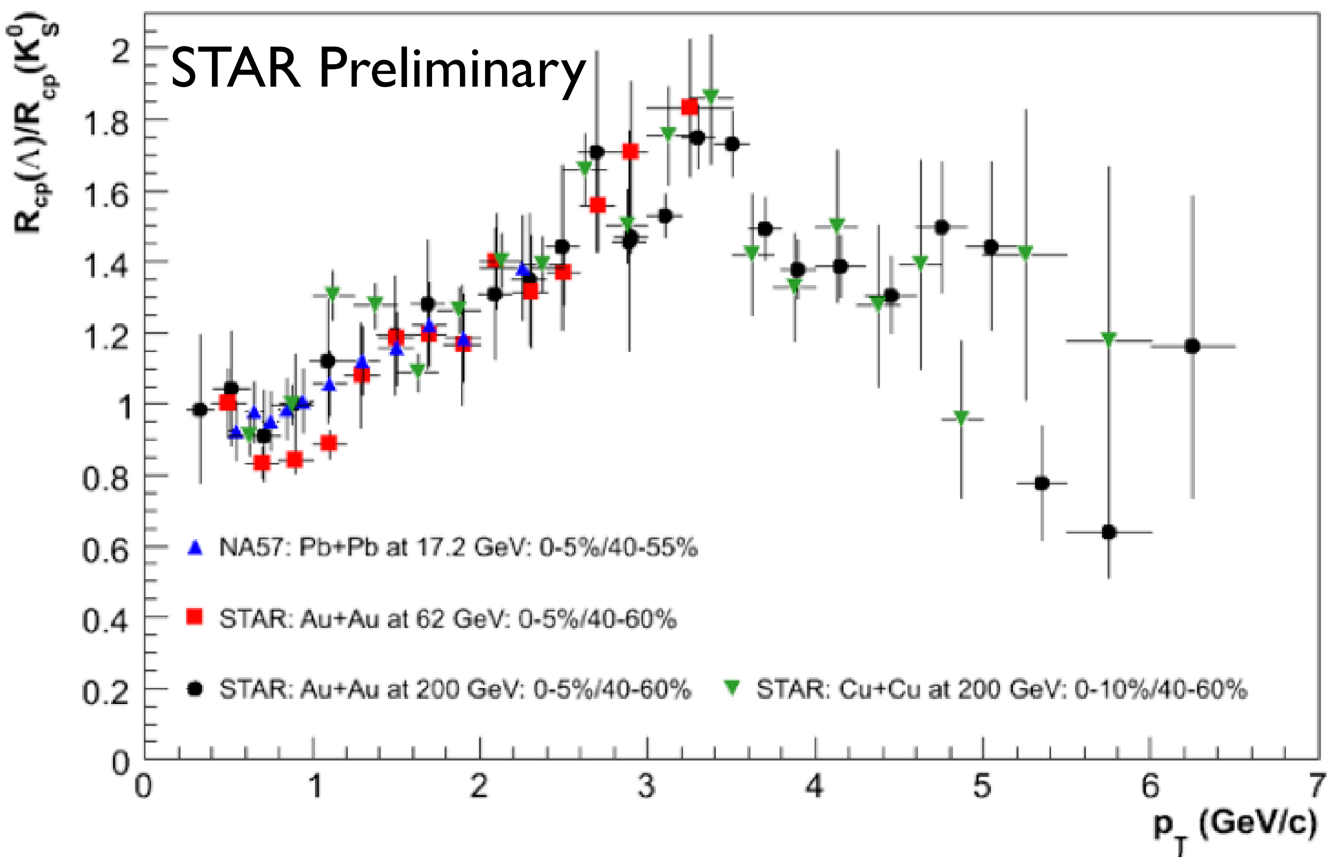


Intermediate p_T: Energy and system size dependence

- Plot: Λ/K^0_S in central over peripheral
- Removes any baryon stopping effects between different energies.
- Remarkable agreement between the different energies and systems
- Central <N_{part}>/ Peripheral <N_{part}> ~ 5 for both Cu +Cu and Au+Au



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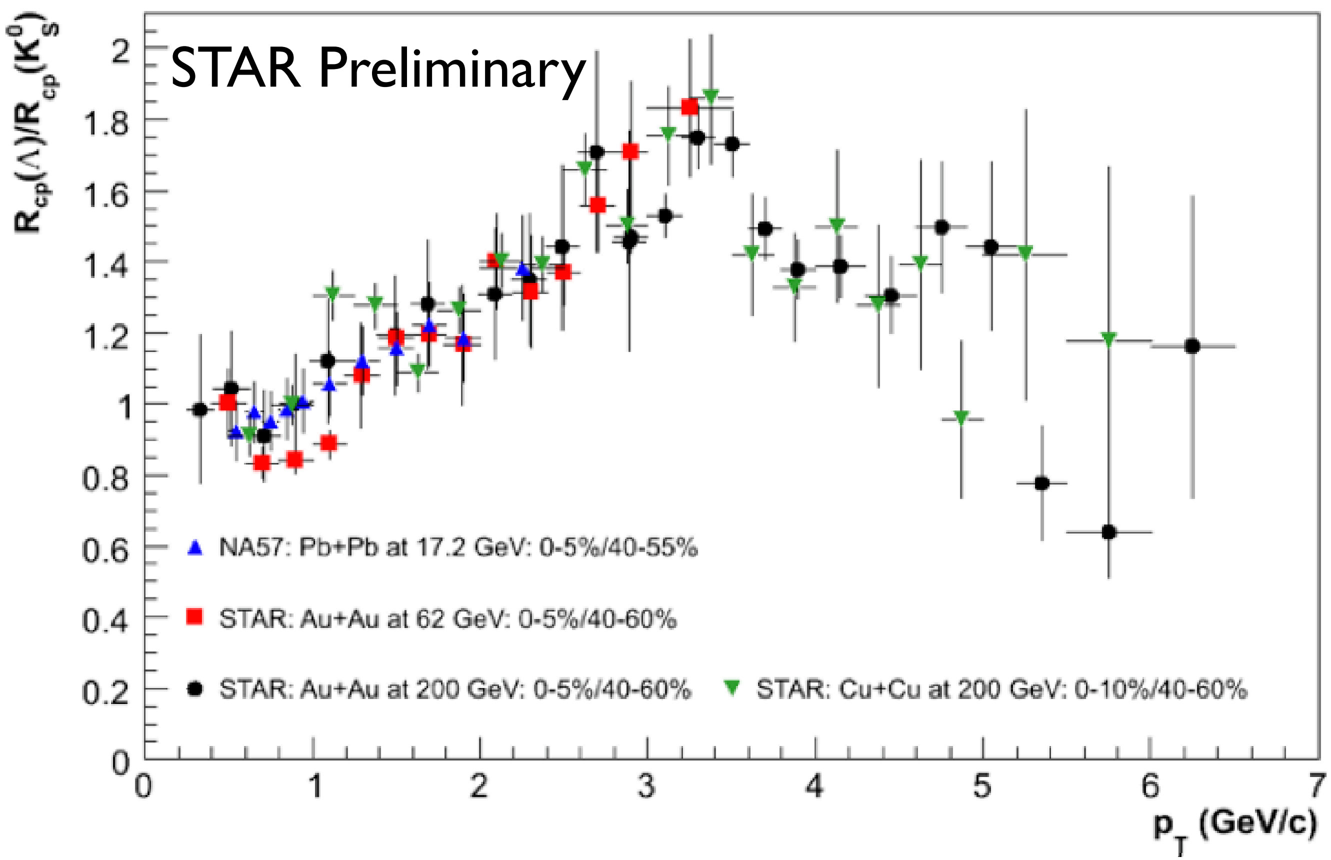
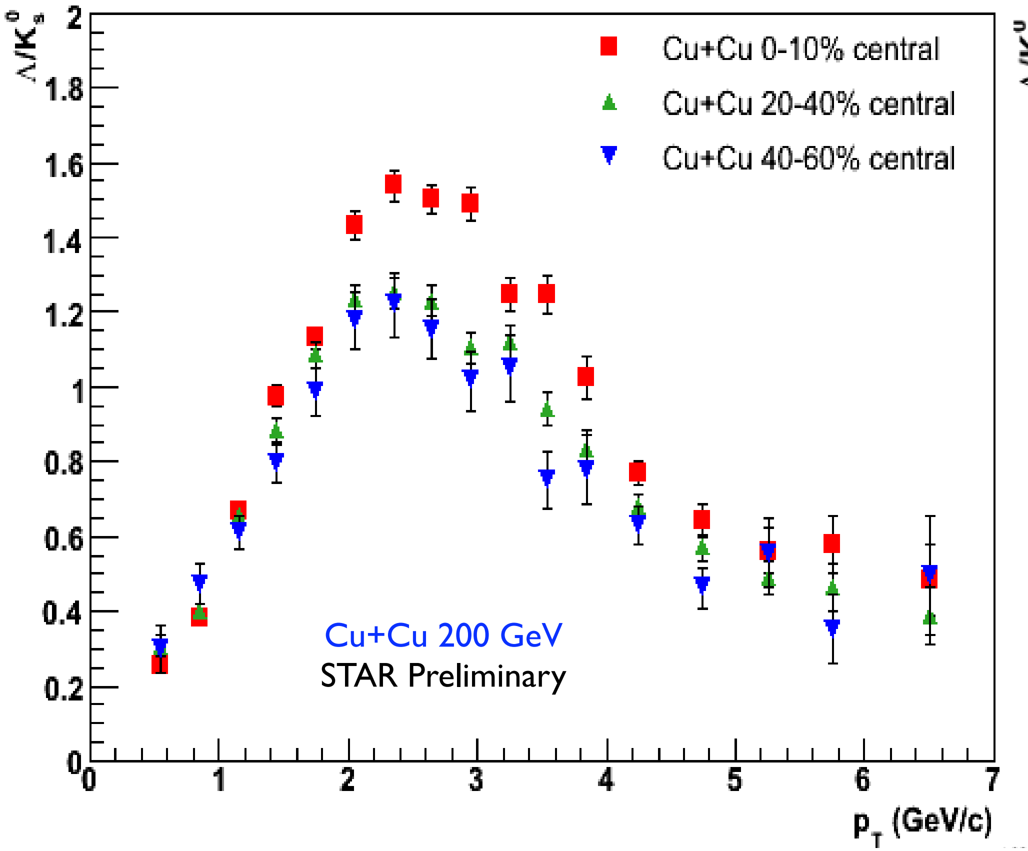
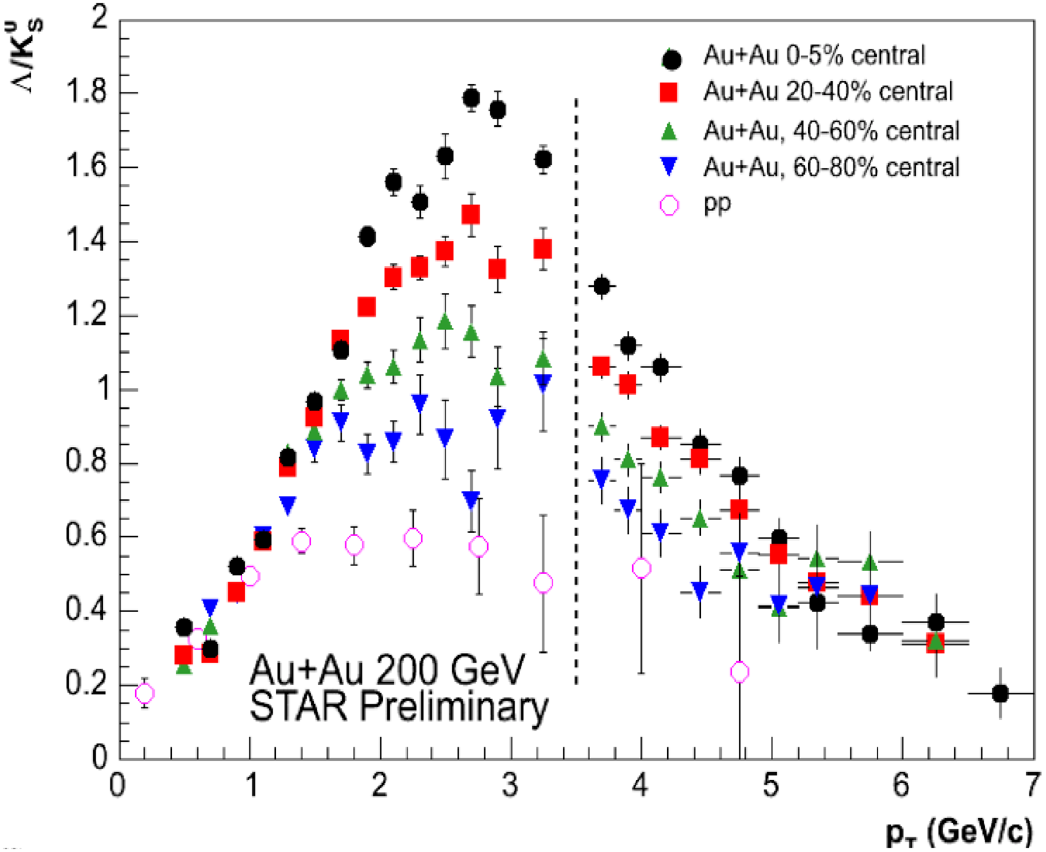


Same physics present in the different systems and energies?
- hydro at low p_T, ReCo at intermediate p_T ...

Integrated Λ/K^0_S ratios





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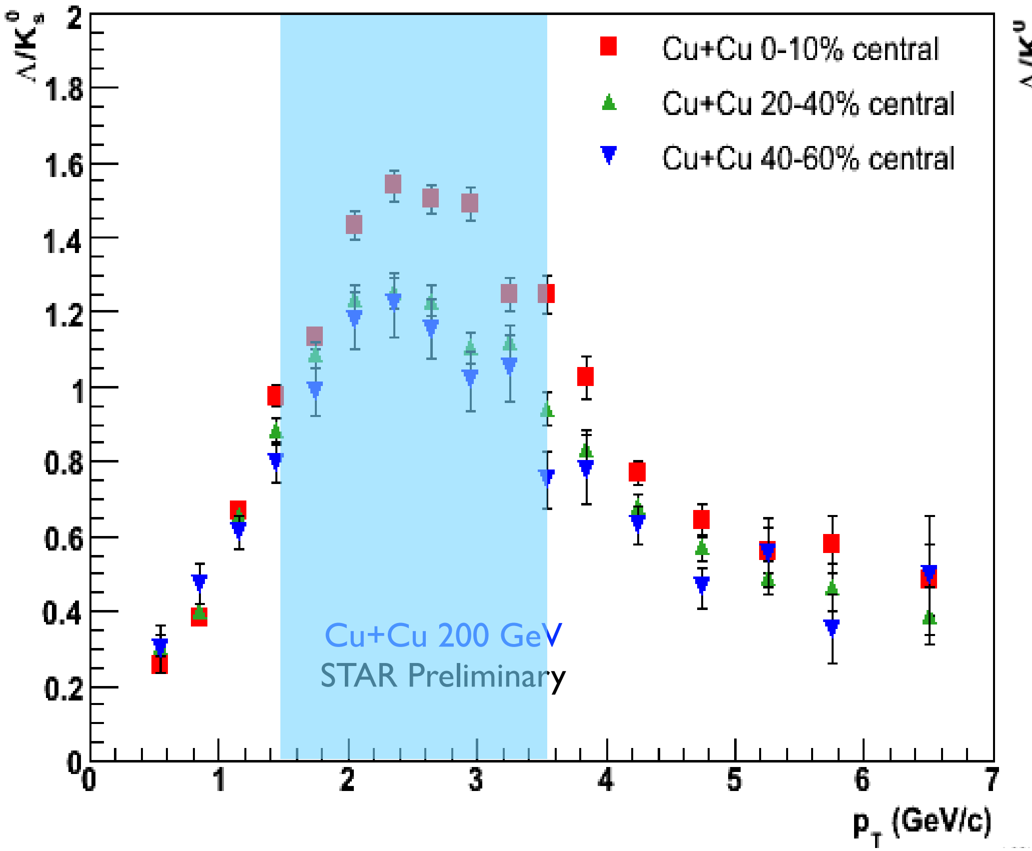

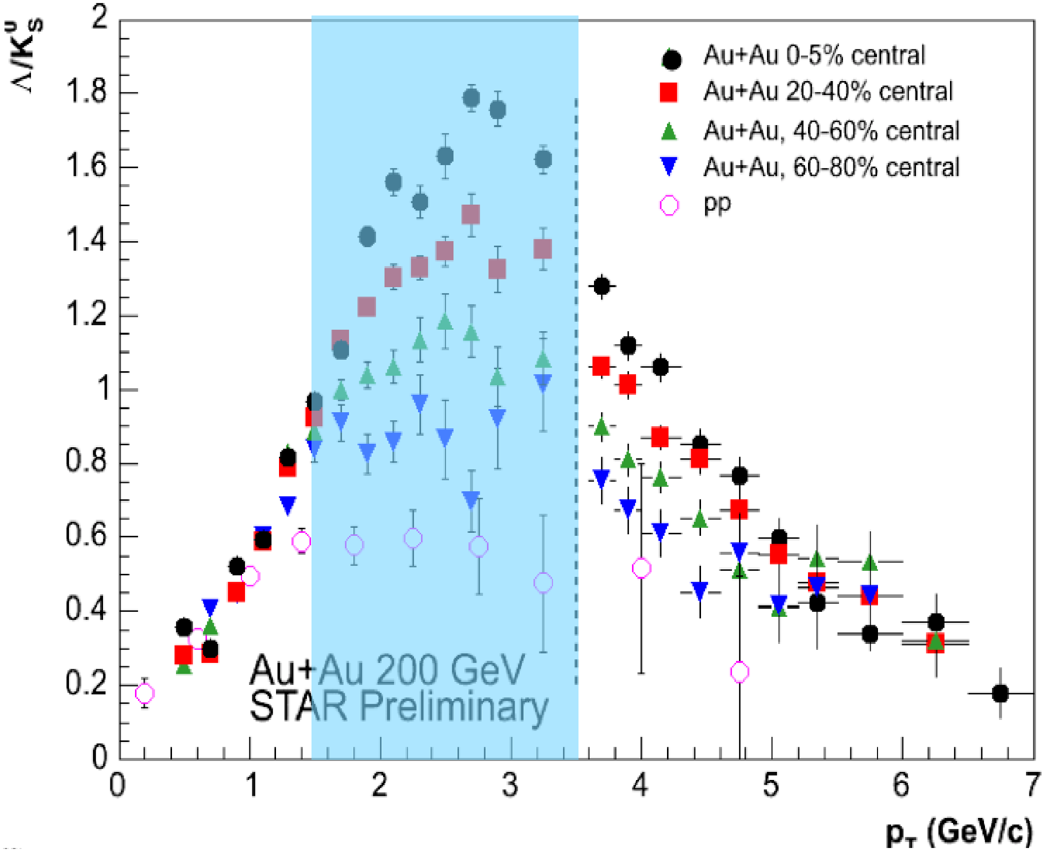

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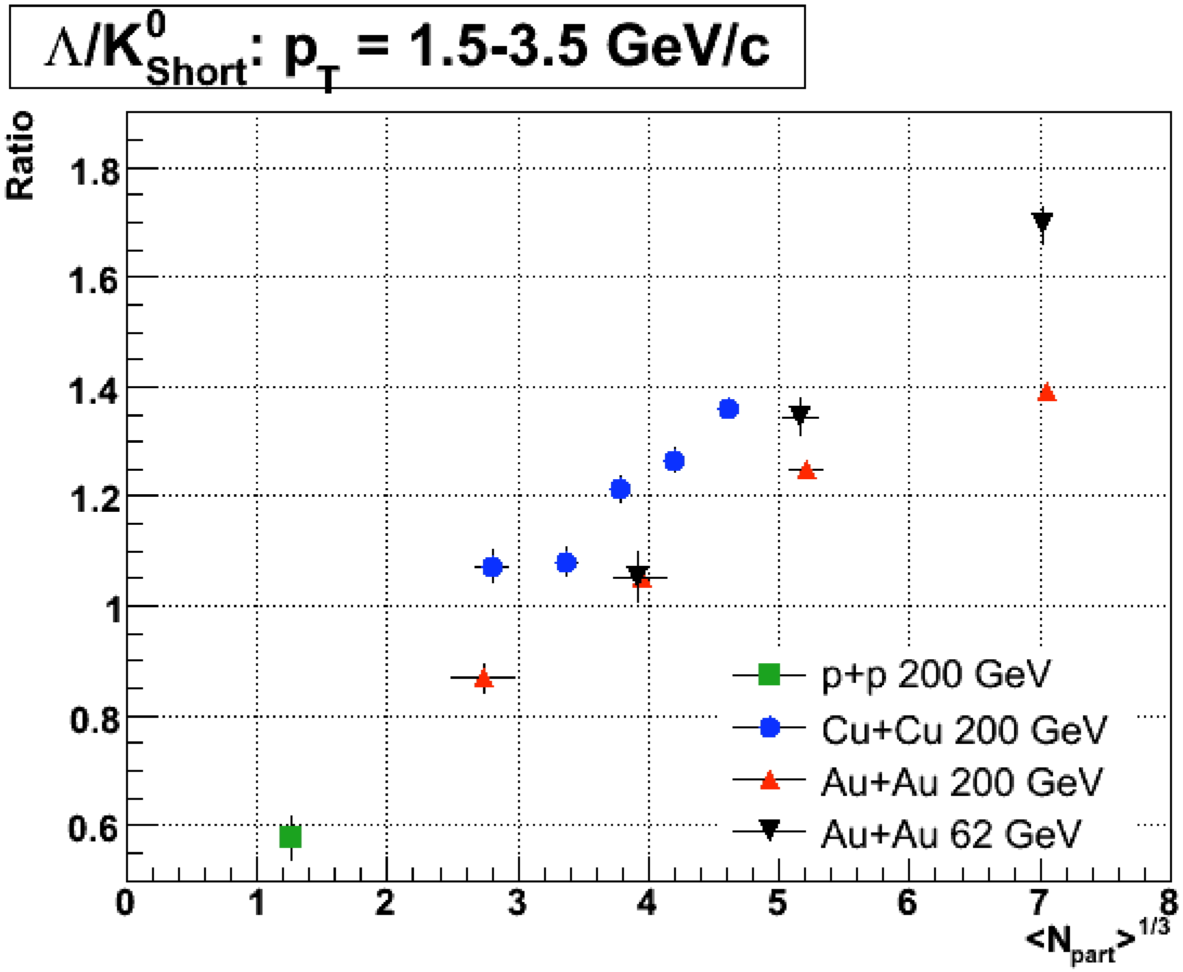

- Difference in Au+Au at 62 and 200 GeV due to baryon stopping
- Similar slopes for same $<N_{part}>$ - why the R_{CP} ratio plot showed no differences.

Greater enhancement in Cu+Cu than Au+Au - evidence of system size/shape dependence to yields?

Summary and Outlook

- Bulk physics:
  - Yield and ratio excitation functions show no surprises
  - Strangeness thermalised in most central data
  - Strangeness enhancement observed which is approximately independent of energy
    - Appear to scale with $A^{1/3}$ and not A
    - Small differences between Au+Au and Cu+Cu - simply geometry differences?
- Intermediate p_T (2-6 GeV/c):
  - Λ/K^0_S ratio exhibits large increase in A+A compared to p+p
  - R_{CP} plot showed little difference between energies and system sizes
    - Same physics processes, independent of A and $\sqrt{s}$?
  - Differences show up in integrated ratio
    - Cu+Cu > Au+Au - again simply geometry differences?
- Still to come: Cu+Cu data at 62.4 GeV, low energy runs