

SQM⁰⁹

INTERNATIONAL CONFERENCE
ON STRANGENESS IN QUARK MATTER



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UNICAMP

Multi-Strange Particle Production in Relativistic Heavy Ion Collisions at

$$\sqrt{s_{NN}} = 62.4 \text{ GeV}$$

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Motivation

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▪ Strangeness Enhancement

Strangeness enhancement observed at A+A collisions compared to p+p collisions has been proposed as one of the QGP signatures.

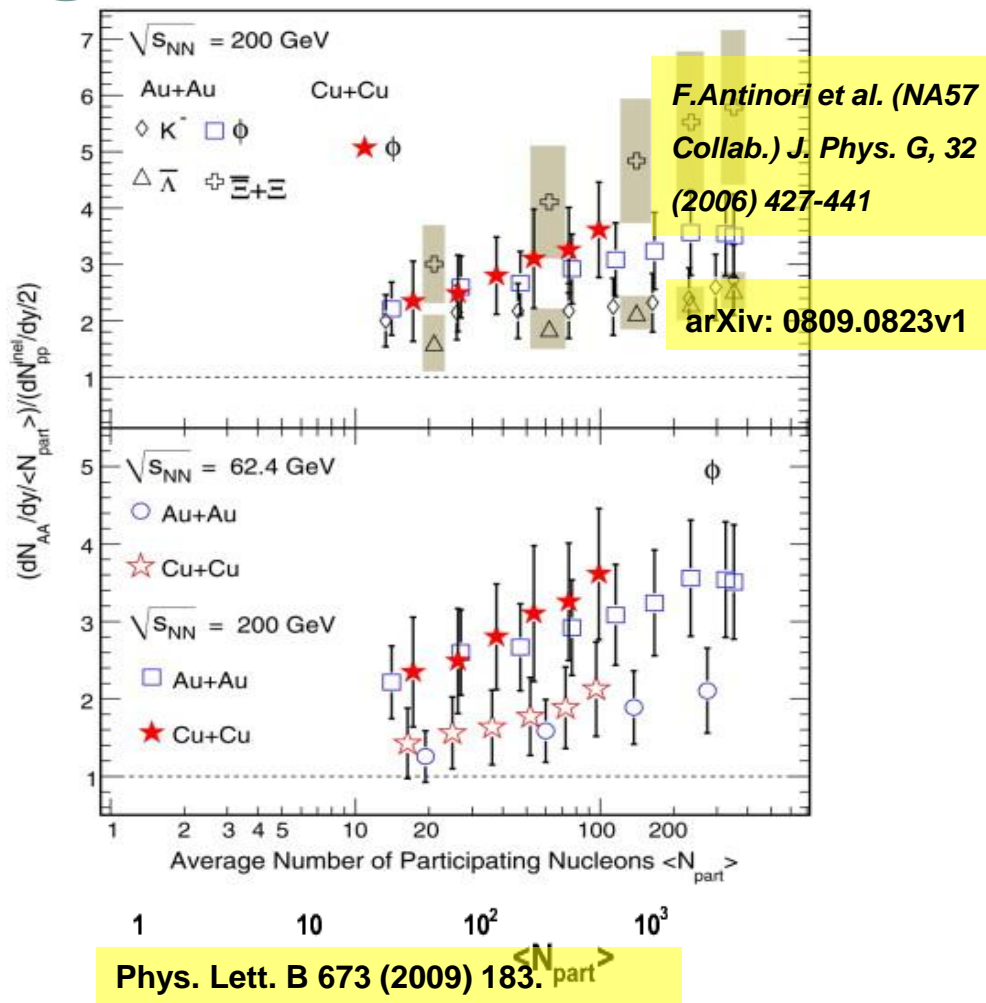
Experimental results:

▪ Λ , Ξ and Ω

- ✓ SPS (NA57: Pb+Pb 17.3 GeV).
- ✓ RHIC (STAR: Au+Au 200 GeV).

▪ ϕ :

- ✓ RHIC (STAR: Au+Au and Cu+Cu at 200 GeV and 62.4).



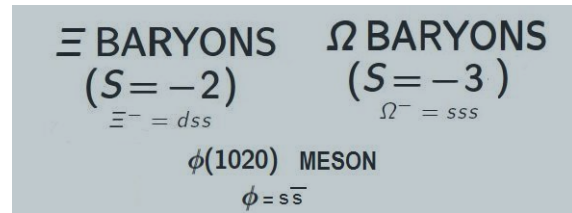
Motivation

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▪ Multi-Strange Particle

- Ξ and Ω measurements.
- Less influence of net-baryon density.

▪ Ω and ϕ are formed by pure s quark.



▪ Au+Au and Cu+Cu

- Allow us to understand the system size dependence.

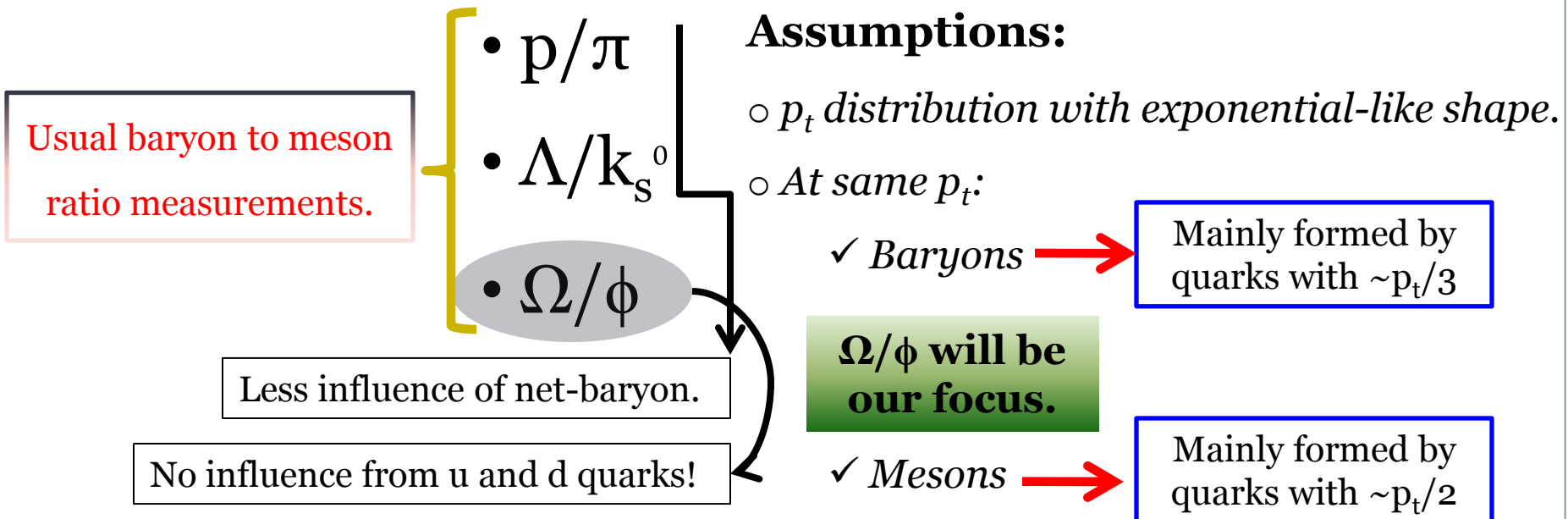
▪ 62.4 GeV Data

- Important connection between energy available at SPS (17.3 GeV) and top RHIC energy (200 GeV).
- RHIC beam energy scan of RHIC will cover the lower energy region.

Motivation

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*Enhancement of baryon to meson ratio at intermediate p_t can be interpreted as one of the possible signatures of **Parton Coalescence**.*



Motivation

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Previous results at 200 GeV.

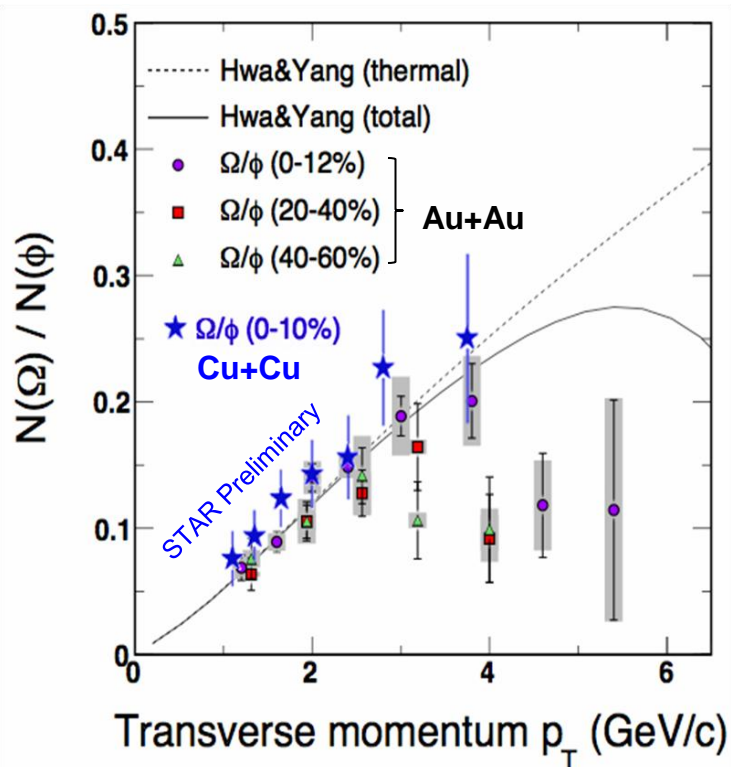


Fig. from: *J. Phys. G. Nucl. Part. Phys.* 35 (2008) 104074

- Hwa and Yand model can describe data for Au+Au at 200 GeV collisions for $p_t < 4$ GeV/c (linear dependence).

Prediction: $R_{\Omega/\phi}^{th}(p) \propto p$

Phys. Rev. C 75,
(2007) 054904

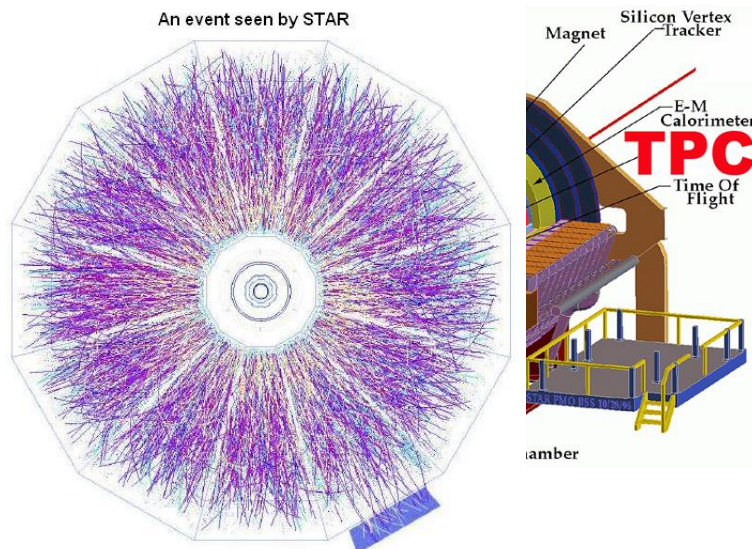
- Cu+Cu 200 GeV follows same trend at intermediate p_t compared to Au+Au.

➔ What is expected for 62.4 GeV?

➔ Is there any dependence with the energy of collision?

The STAR Experiment

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Data set used:

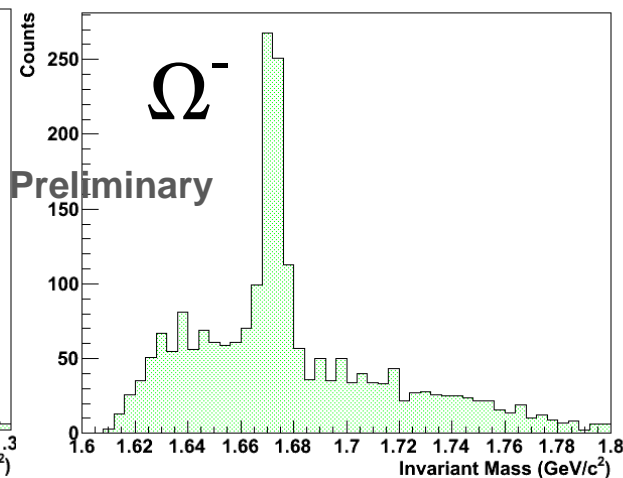
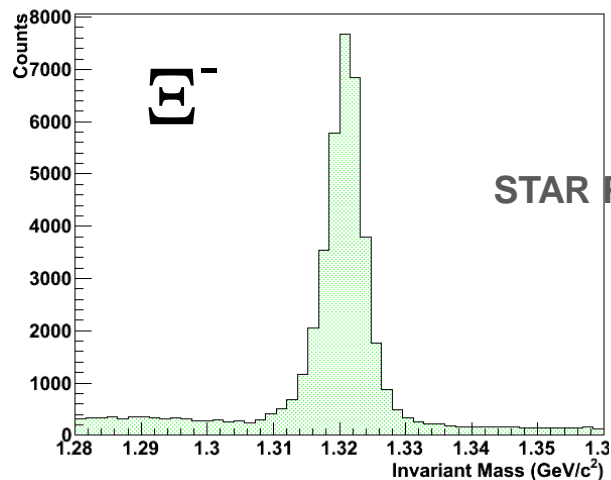
- ~7 M events from run 2004 (Au+Au 62.4 GeV).
- ~9 M events from run 2005 (Cu+Cu 62.4 GeV).

From each event:

- Charged particles (proton, pion and kaon) are identified using dE/dx .
- Λ , Ξ and Ω are reconstructed using their weak decay topology.

Cu+Cu 62.4 GeV

- Clear peak at invariant mass spectra for mid-rapidity ($|y| < 1$).



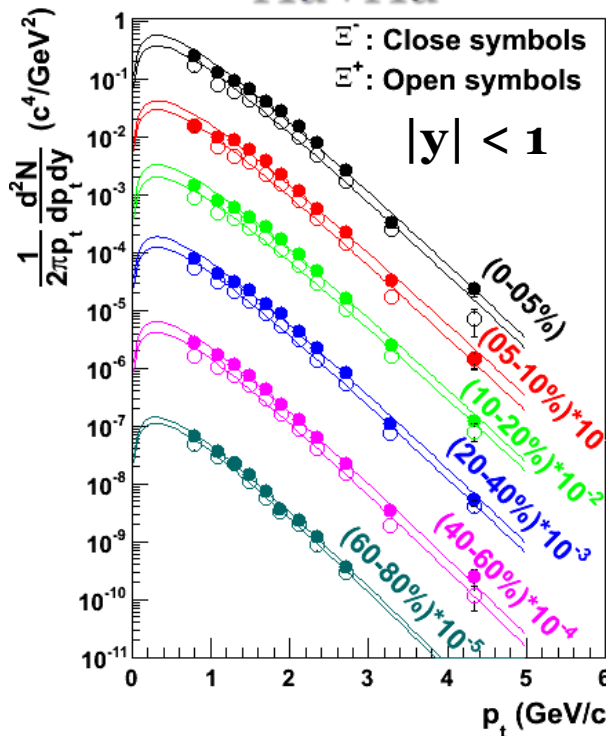
E^- and E^+ p_t Spectra at 62.4 GeV

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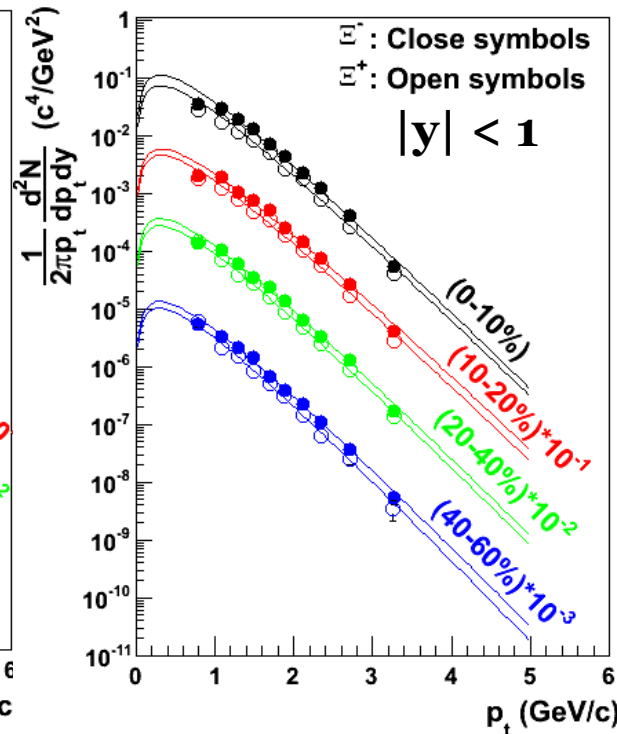
Transverse Momentum Spectra:

- Data corrected for efficiency and detector acceptance.
- Different centrality classes were studied.
- Boltzmann function was used to extract yields and the slope parameter.

Au+Au



Cu+Cu



- Both systems have similar slope parameter.

Most central collision

Au+Au: (336 ± 4) MeV

Cu+Cu: (322 ± 12) MeV

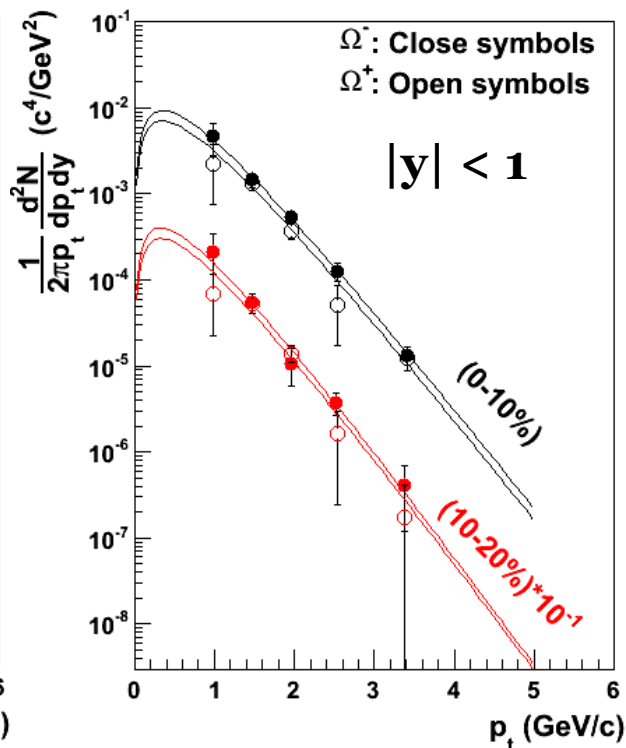
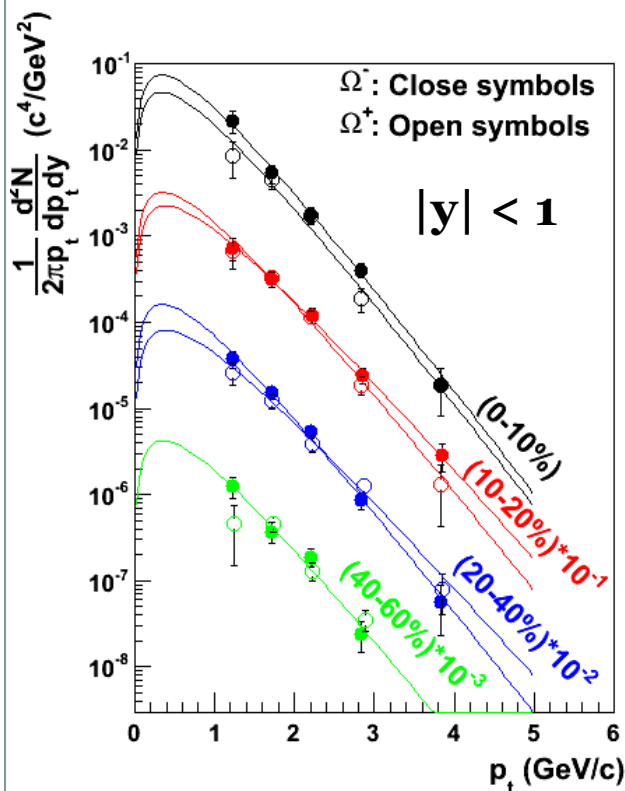
- Slope parameter shows no centrality dependence.

Ω^- and Ω^+ p_t Spectra at 62.4 GeV

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Au+Au

Cu+Cu



- Boltzmann function was used to fit spectra.

- Slope parameter has no difference between Au+Au and Cu+Cu.

Most central collision

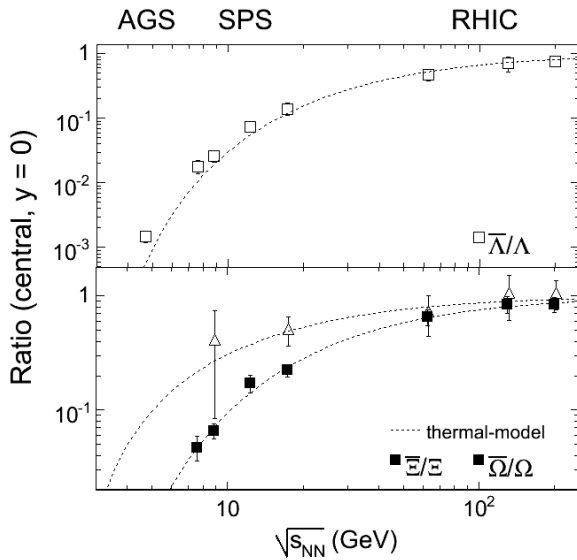
Au+Au: (347 ± 26) MeV

Cu+Cu: (353 ± 29) MeV

Strange Particle Ratios

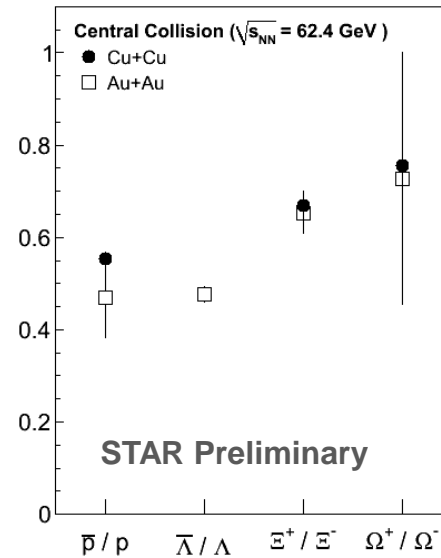
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• Anti-baryon to baryon ratio as function of center-of-mass energy of the collision.



62.4 GeV:
STAR
Preliminary

• Anti-baryon to baryon ratio as function of strange quark content.



- *Increases with quark content.*
- *No difference observed between Au+Au and Cu+Cu*

- ❖ Anti-particle to particle ratios increase with the energy of collision.
- ❖ Almost reach the unity for top RHIC energy.
- ❖ Follows the strange quark content hierarchy.

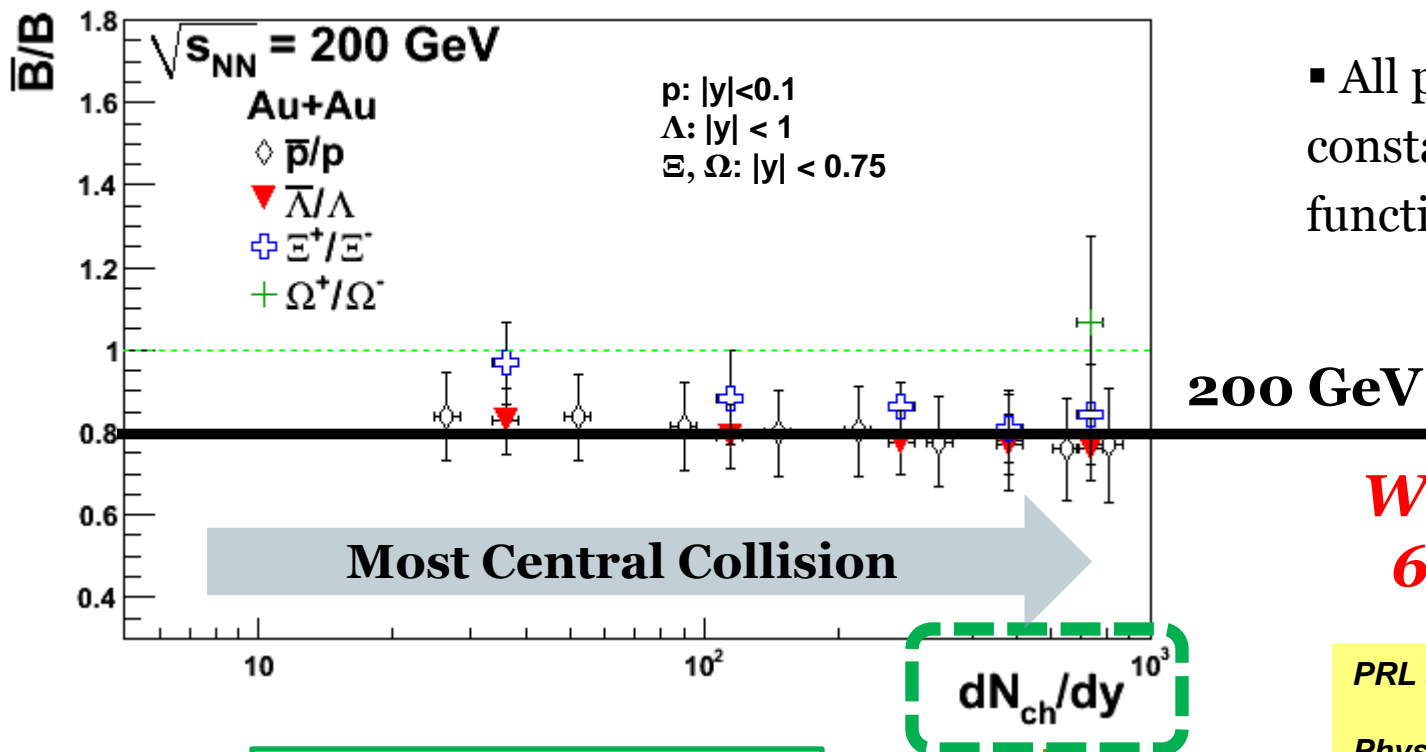
*Proton at Au+Au:
statistical and systematic
uncertainties*

*Other measurements
have only statistical
uncertainties.*

Strange Particle Ratios: Au+Au 200 GeV

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Anti-Baryon to Baryon Ratio vs Centrality



- All particles have constant behavior as function of centrality.

What about 62.4 GeV?

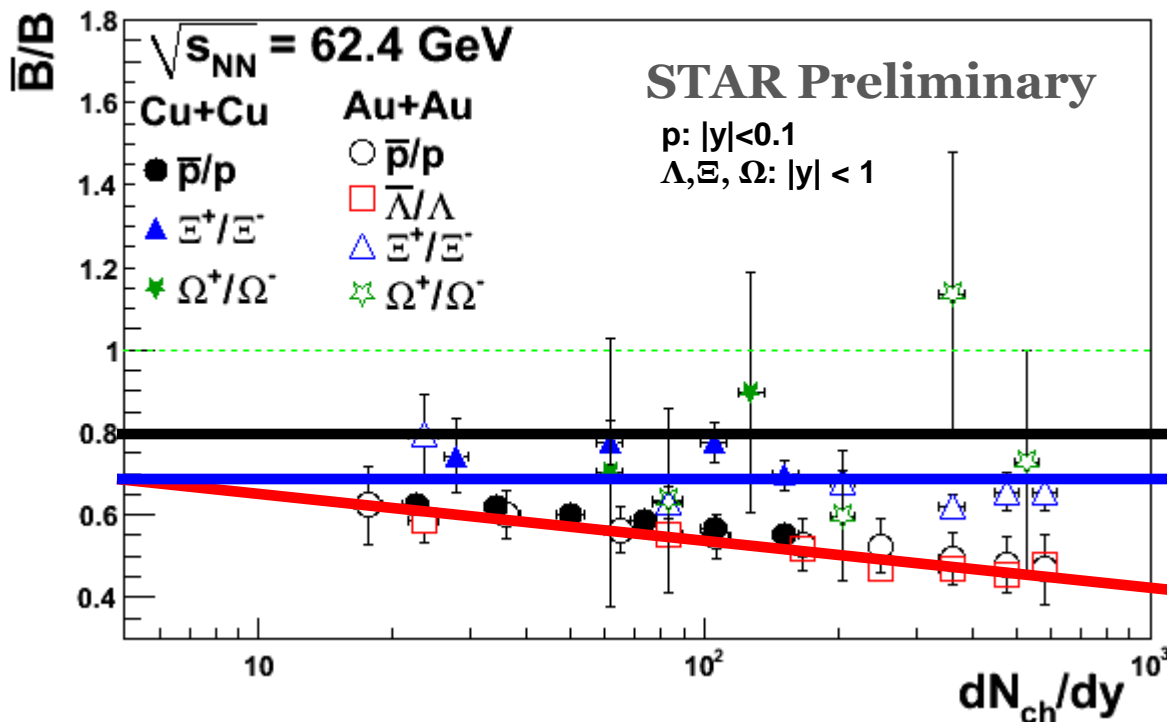
Multiplicity of charged particles per rapidity.

PRL 98, 062301 (2007).
 Phys. Rev. C 79, 034909 (2009).
 Nucl. Phys. A 715, 470c-473c (2003)

Strange Particle Ratios: 62.4 GeV

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Now at 62.4 GeV...



• **protons and Λ 's**

The ratios decrease slightly as the collisions become more central.

• **E**

No centrality dependence.

200 GeV

p, Λ

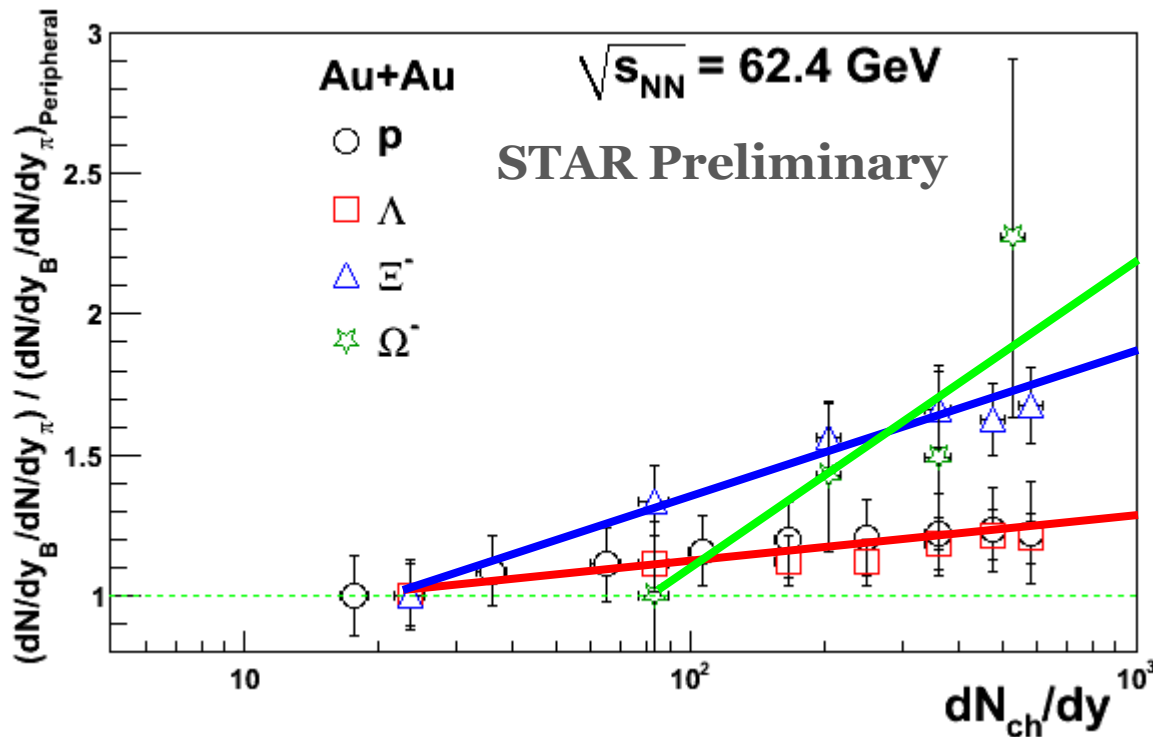
▪ Au+Au and Cu+Cu scales with dN_{ch}/dy .

- High net baryon density at lower energy.
- E and Ω have less influence of net baryon density.

Strangeness Enhancement: Au+Au

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- No results from p+p collisions at 62.4 GeV for Λ , Ξ and Ω .
- Pion yield was used as reference.
- Relative yield was normalized to the most peripheral bin.



□ Λ/π agrees with p/π within uncertainties.

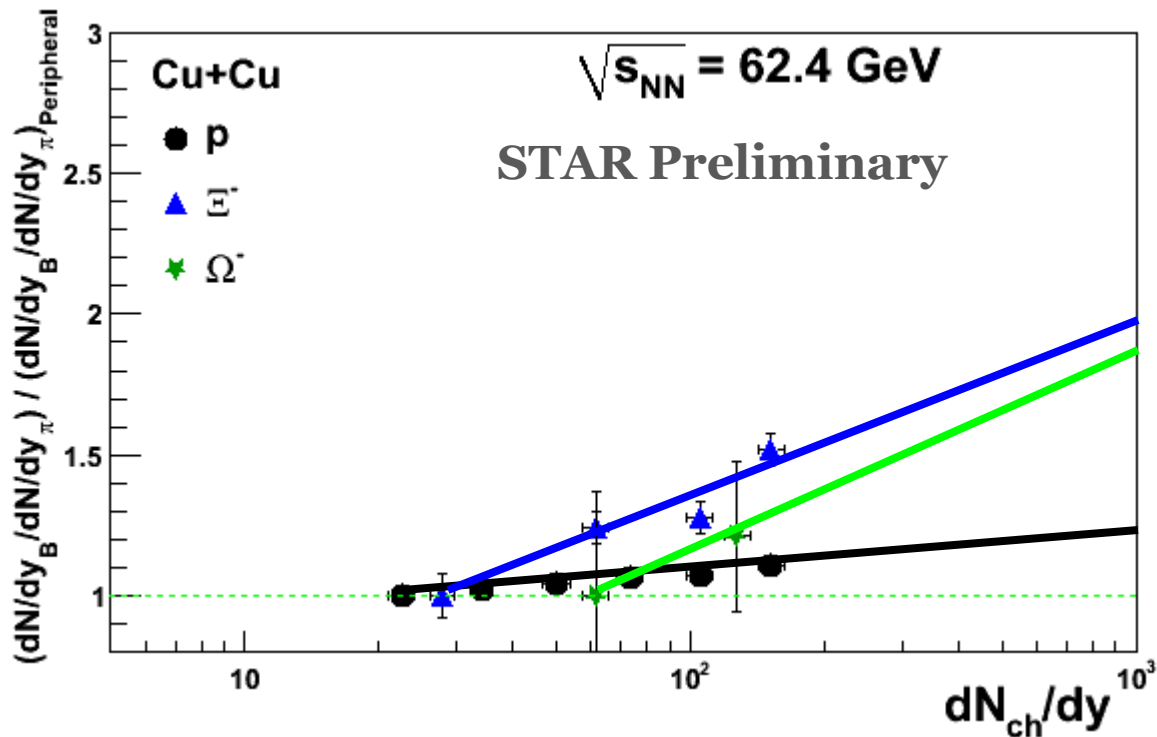
□ Multi-strange relative ratios show larger increase rate compared to p/π and Λ/π .

□ The enhancement rate seems to follow the hierarchy of strange quark content in both data set.

Strangeness Enhancement: Cu+Cu

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Now, at Cu+Cu...

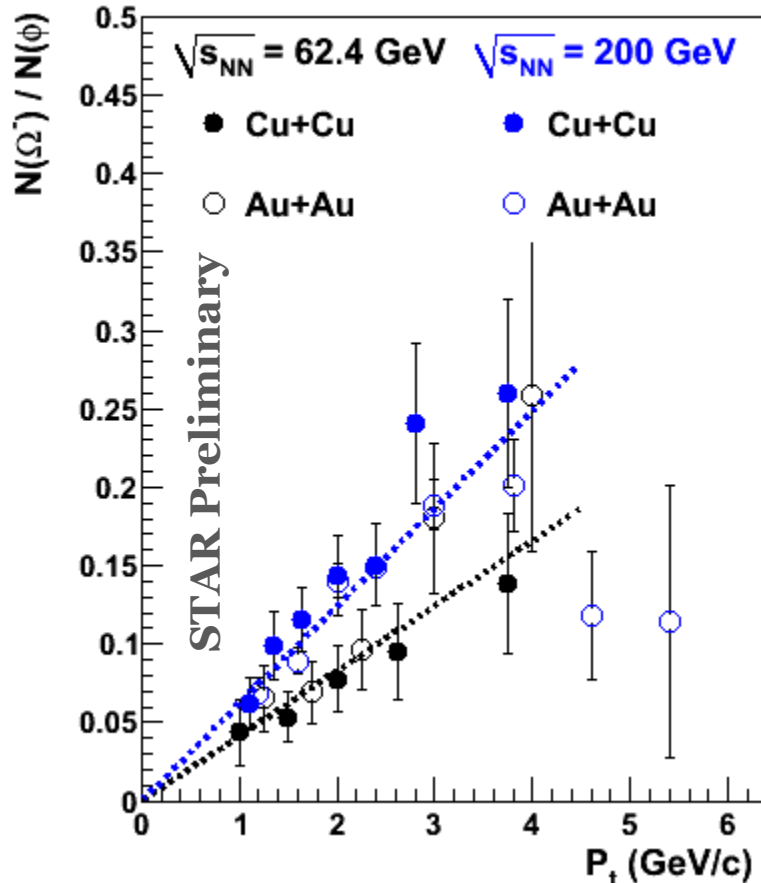


Same trend
compared to
Au+Au!

Ω/ϕ Ratio

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200 GeV and 62.4 GeV



- Cu+Cu and Au+Au follow same trend.
- For $p_t < 4 \text{ GeV/c}$, results show that Ω/ϕ ratio is linearly dependent of p_t .

$$R_{\Omega/\phi}^{th}(p_t) \cong A p_t$$

- For $p_t < 4 \text{ GeV/c}$, 200 and 62.4 GeV show same behavior, but have different slope (slope at 200 GeV is greater than 62.4 GeV).

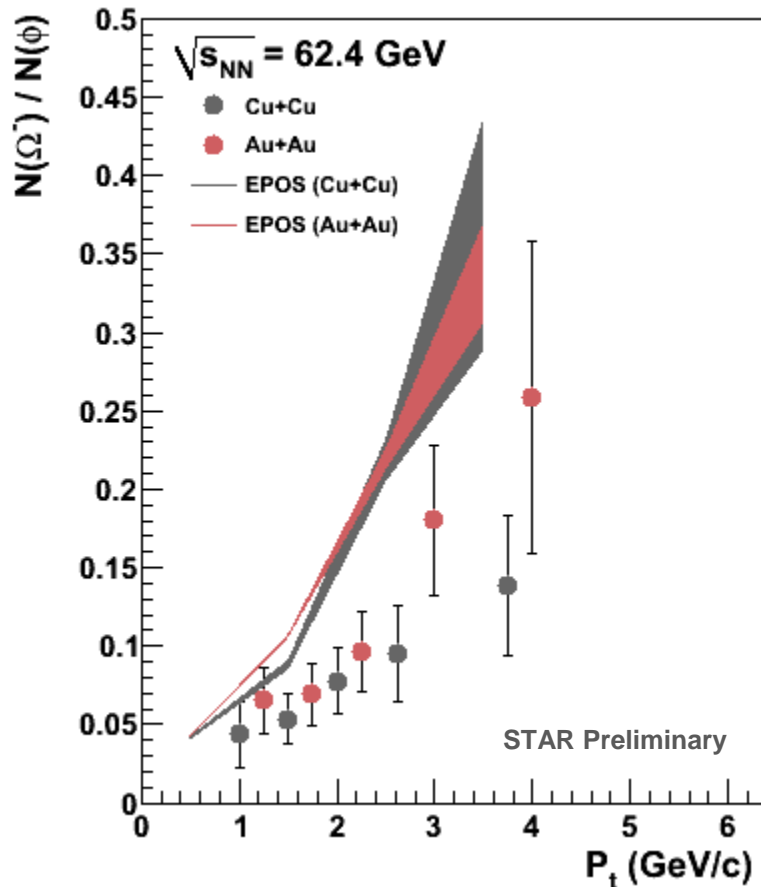
$$200 \text{ GeV: } A = 0.062 \pm 0.002$$

$$62.4 \text{ GeV: } A = 0.041 \pm 0.004$$

Ω/ϕ Ratio

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Comparison with EPOS



□ EPOS do not describe correctly data at 62.4 GeV.

□ EPOS show the linear dependence, but with different slope for $p_t < 4$ GeV/c at 62.4 GeV.

EPOS Reference:
Phys. Rev. C 74 (2006),
 044902

Summary

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- Multi-strange baryons have been measured from Cu+Cu and Au+Au 62.4 GeV collisions.
- Looking at strange particle ratios, we observe a dependence with centrality for proton and Λ 's for 62.4 GeV, but not for Ξ . This could be due to a higher net baryon density for collisions at lower energy.
- Multi-strange particle yields relative to pions show higher increase rate with centrality than protons and Λ 's.
- Ω/ϕ ratio at 62.4 GeV/A shows same trend compared with previous results at 200 GeV/A for intermediate p_t , but with lower linear constant.



Thank you!

Acknowledgment

