Tsinghua University

STAR

Strange Hadron Production in Au+Au Collisions at $\sqrt{s_{NN}} = 54.4$ GeV

- Motivation
- STAR detector
- Results
  - ✓ p_T spectra
  - ✓ Particle yields
  - ✓ Ω/ϕ ratio
  - ✓ Nuclear modification factor R_{cp}
  - ✓ Strange particles/pions ratio
- Summary

The 19th International Conference on Strangeness in Quark Matter

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SQM2021

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for the STAR Collaboration

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STAR

SQM 2021, 05.18.2021

Motivation

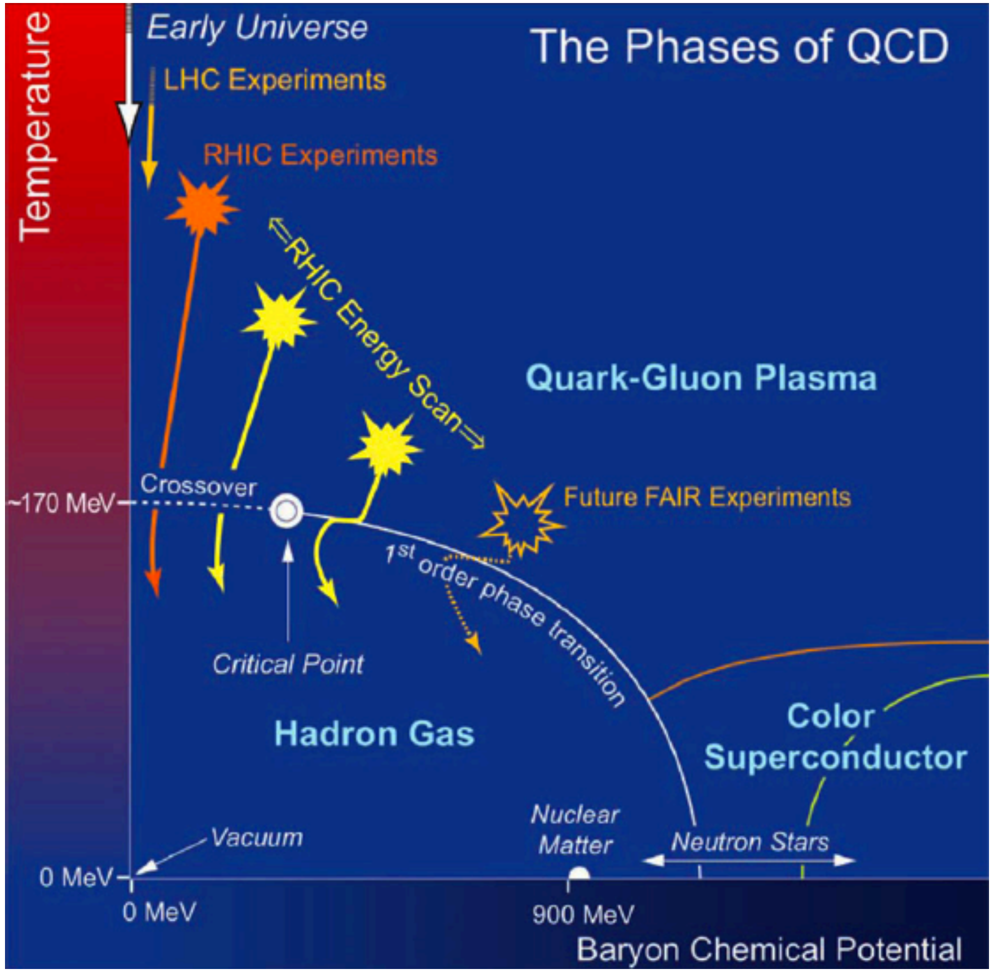
Goal: Mapping the QCD Phase Diagram

- Onset of deconfinement
- Phase boundary
- Critical point

➢ BES-I (completed) systematic study of Au+Au collisions at 7.7, 11.5, 14.5, 19.6, 27, 39, 54.4 and 62.4 GeV.

➢ BES-II (ongoing) Au+Au = 7.7 – 19.6 GeV.

➢ Fixed-Target (ongoing) Au+Au = 3.0 – 7.7 GeV, μ_B up to 720 MeV.



https://drupal.star.bnl.gov/STAR/starnotes/public/sn0598

Motivation

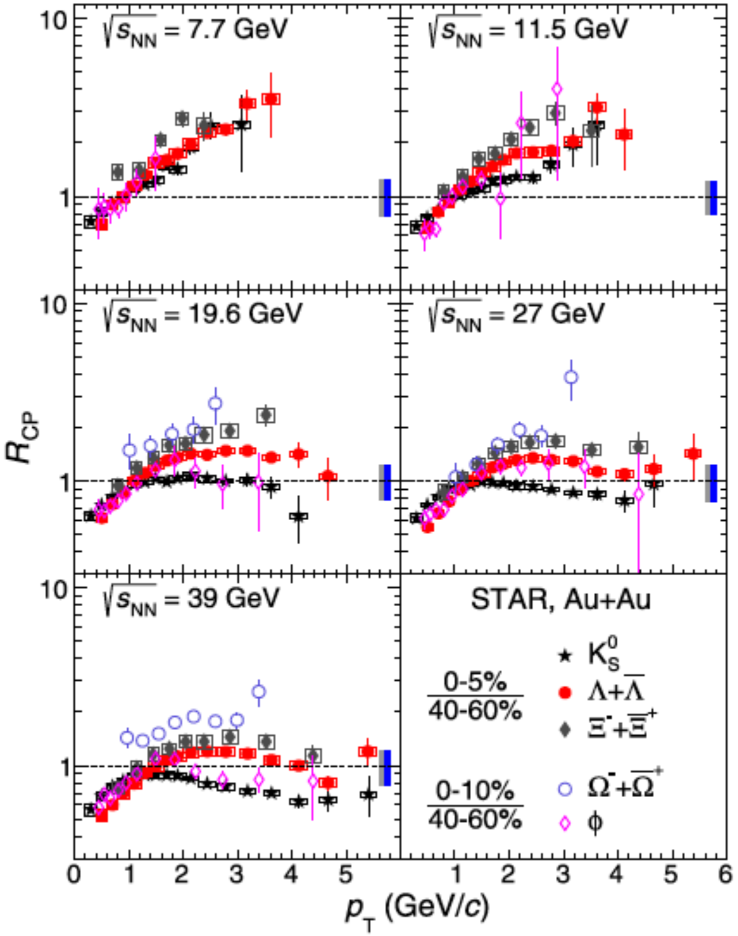
Multi-strange hadrons:

- Early freeze out
- Small hadronic interaction cross section

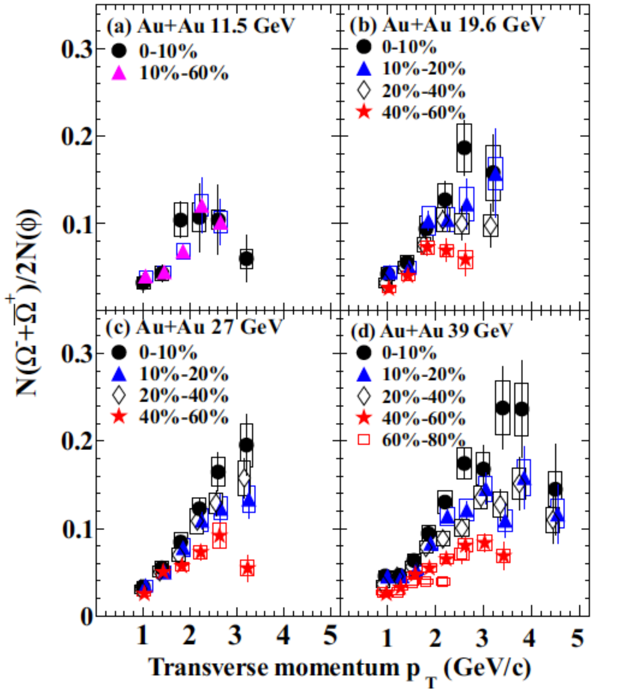
J. Rafelski and B. Muller, *PRL.56, 2334 (1986)*

STAR, NPA 757, 102(2005)

Sensitive probe to study the initial stage of the collision!



STAR, PRC 102, 034909 (2020)



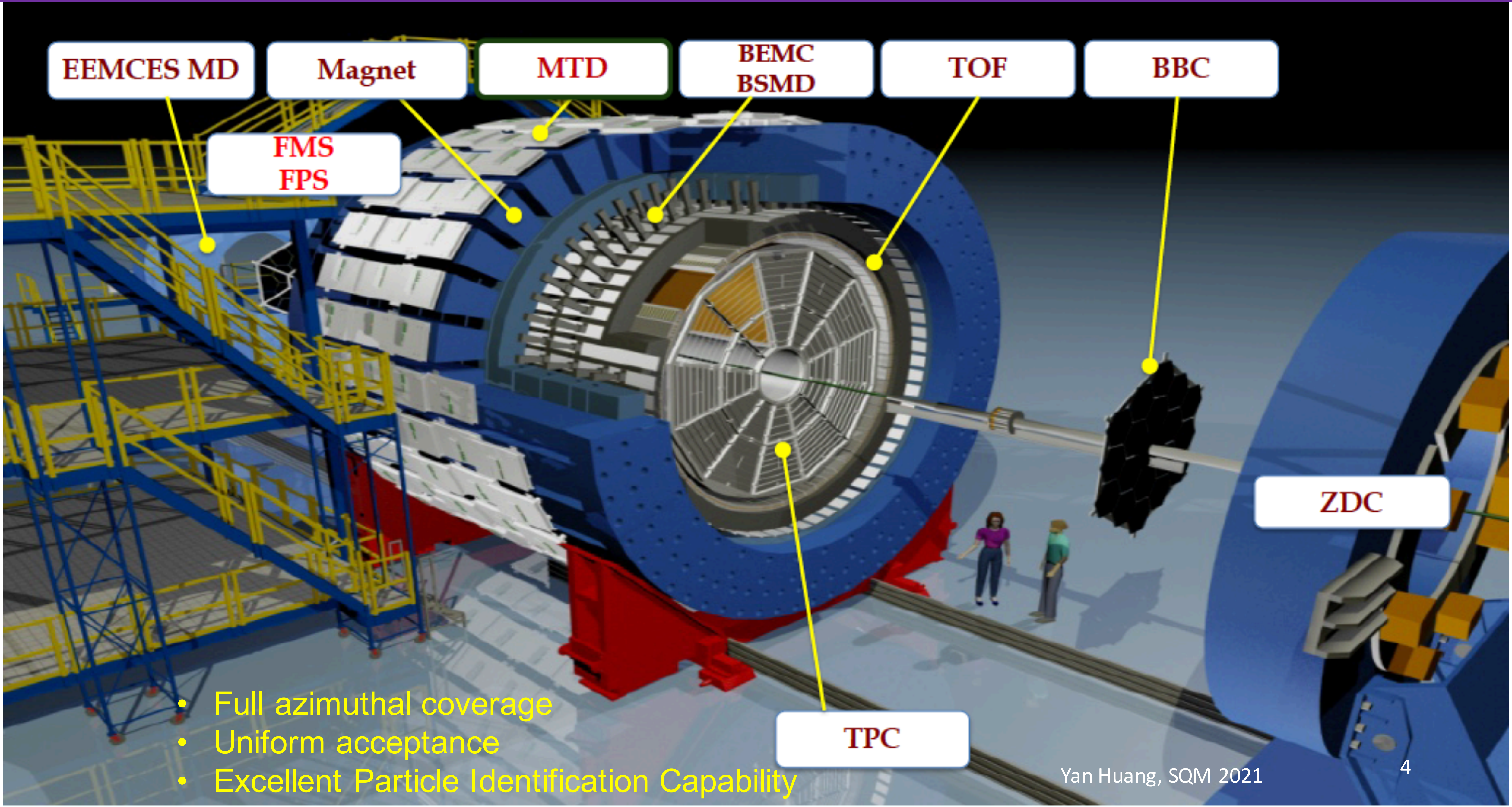
STAR Phys.Rev.C 93,021903(R),2016

- $R_{cp} < 1$ at high p_T : QGP → **parton energy loss**
- Different trends in baryon/meson: $p_T \approx 2.5$ GeV/c

→ **parton recombination**

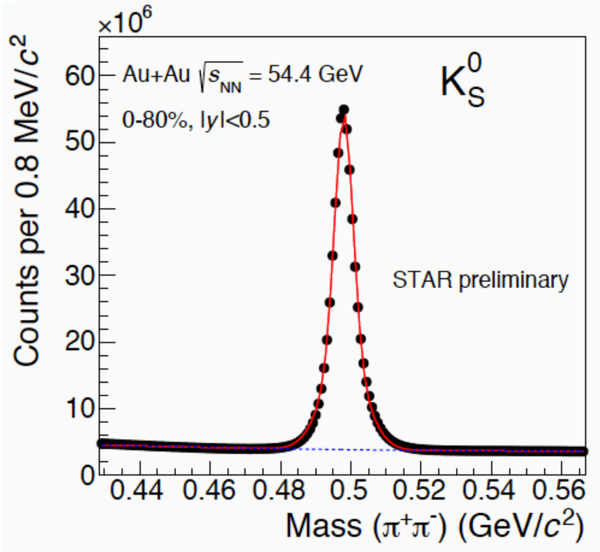
- Ω/ϕ ratio enhancement at intermediate p_T → hadron formation through parton recombination

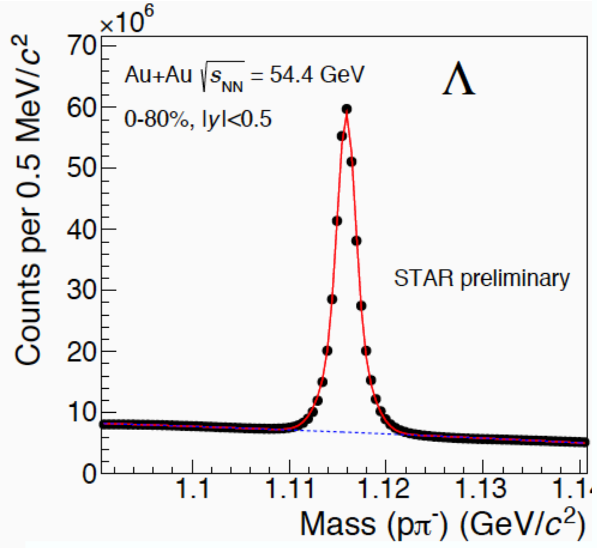
STAR detector

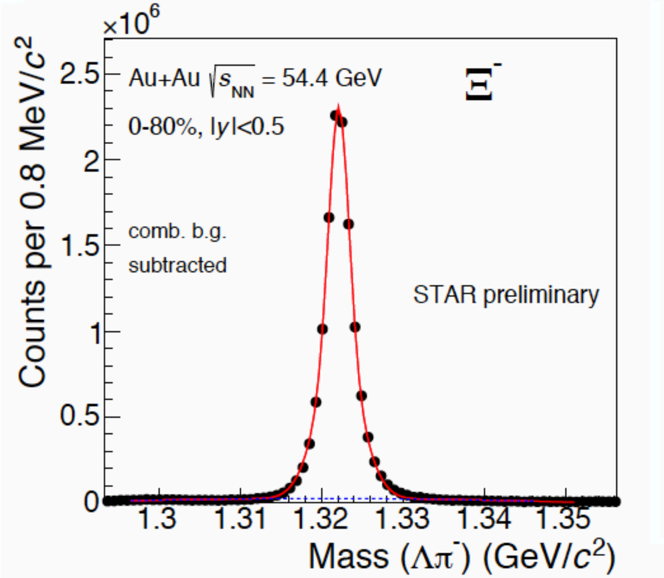


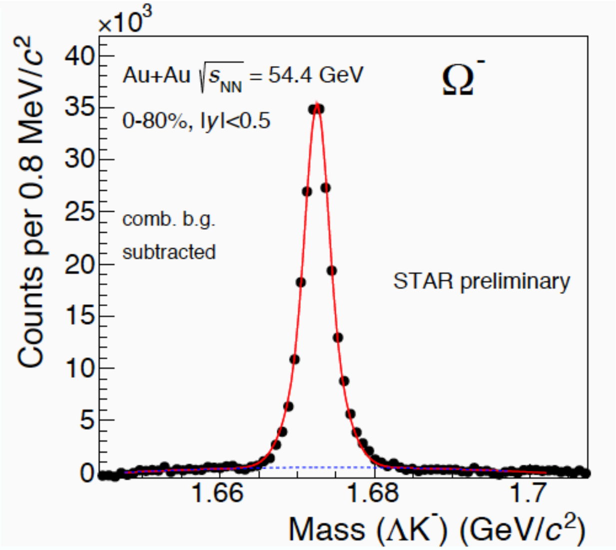
- Full azimuthal coverage
- Uniform acceptance
- Excellent Particle Identification Capability

Particle identification and reconstruction









$$K^0_S \rightarrow \pi^+ + \pi^- \ (B.R.\ 69.20\%)$$

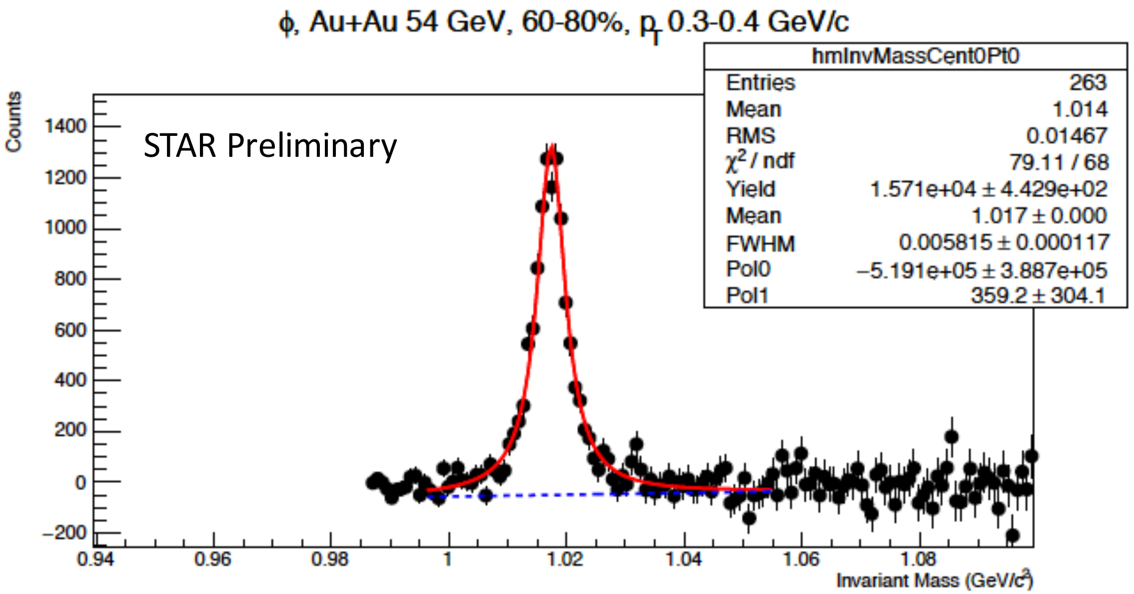
$$\Lambda(\bar{\Lambda}) \rightarrow p(\bar{p}) + \pi^-(\pi^+) \ (B.R.\ 63.9\%)$$

$$\Xi^-(\bar{\Xi}^+) \rightarrow \Lambda(\bar{\Lambda}) + \pi^-(\pi^+) \ (B.R.\ 99.9\%)$$

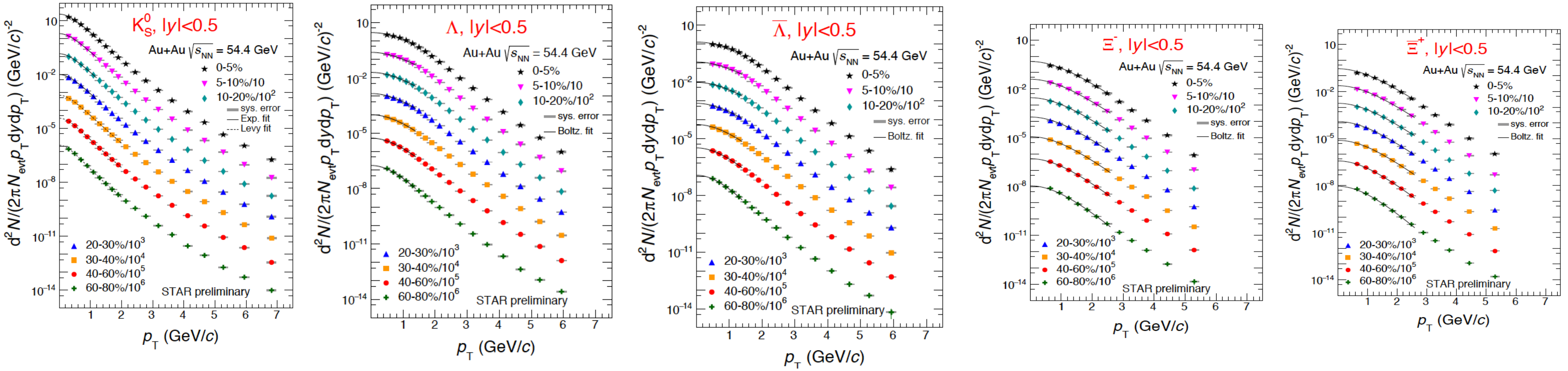
$$\Omega^-(\bar{\Omega}^+) \rightarrow \Lambda(\bar{\Lambda}) + K^-(K^+) \ (B.R.\ 67.8\%)$$

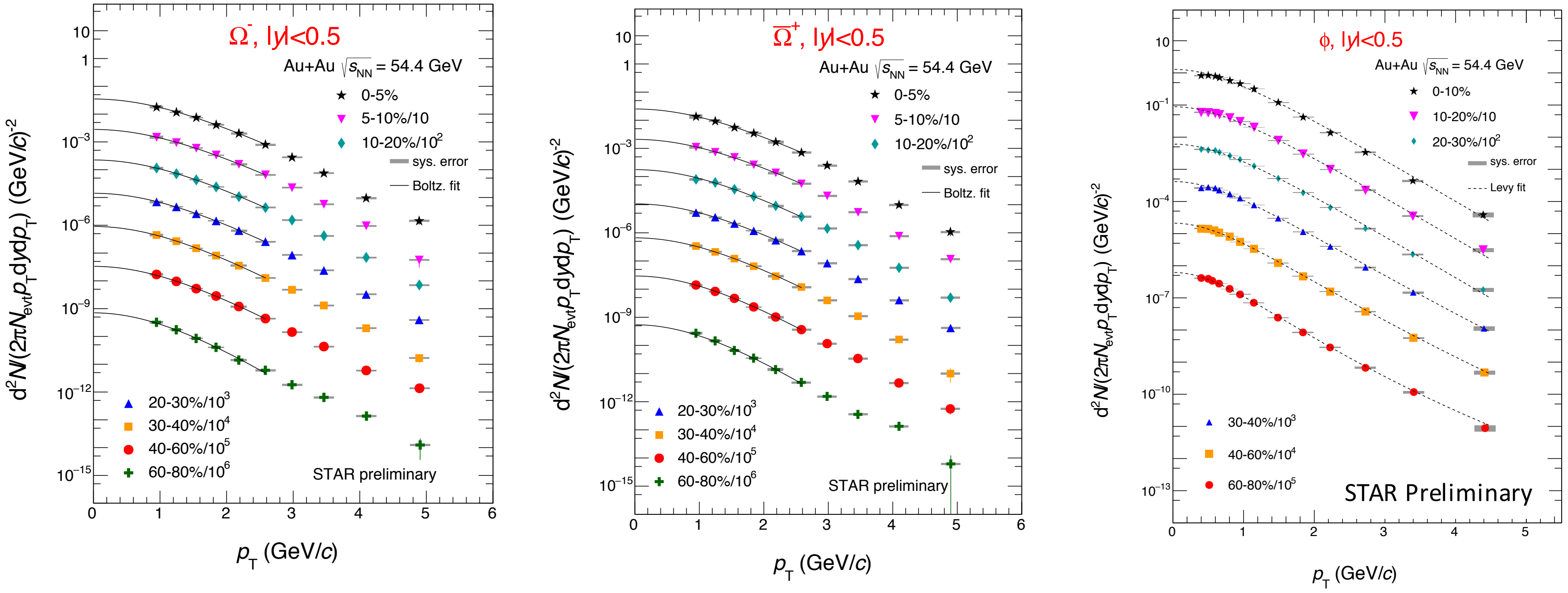
$$\phi \rightarrow K^+ + K^- (B.R.\ 49.2\%)$$

π, K, p are identified by dE/dx in TPC to reconstruct the secondary vertex.



p_T spectra

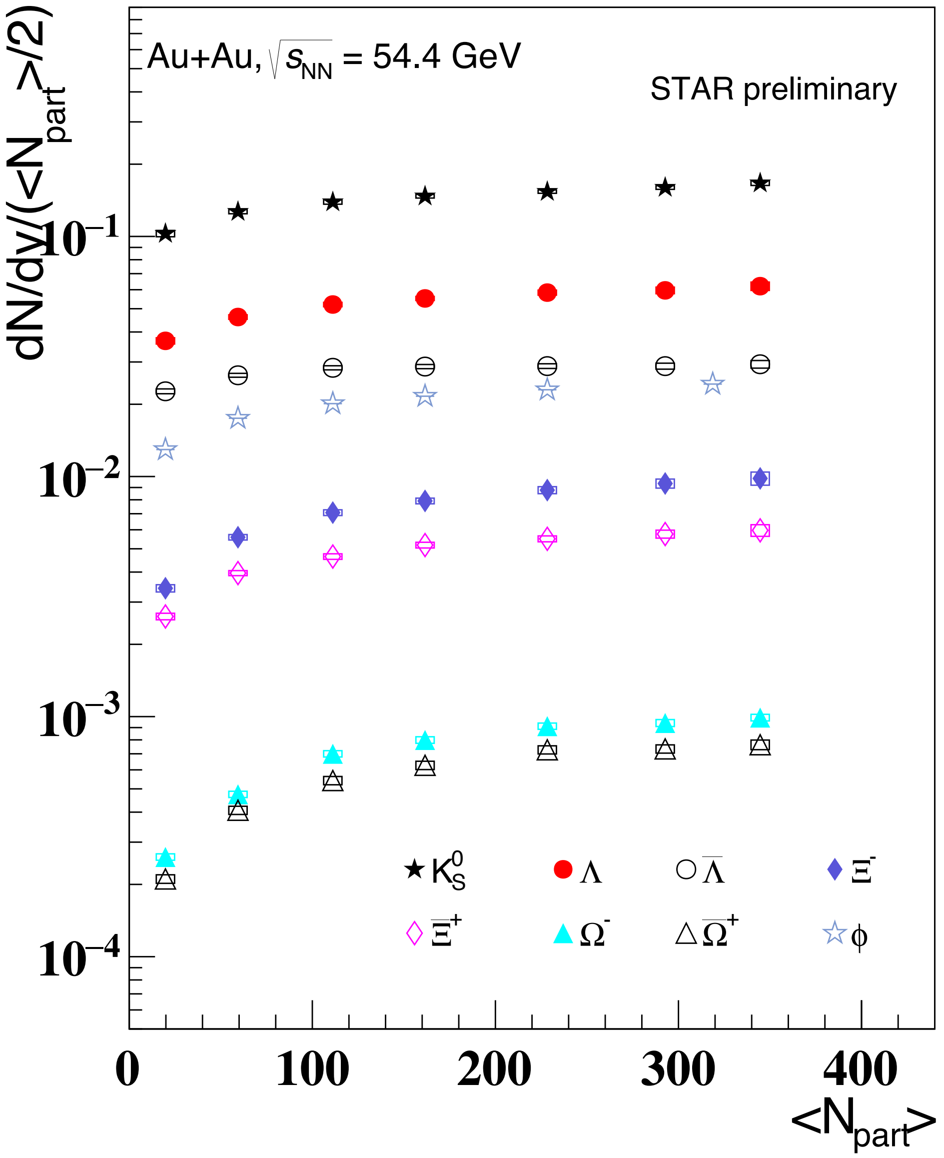




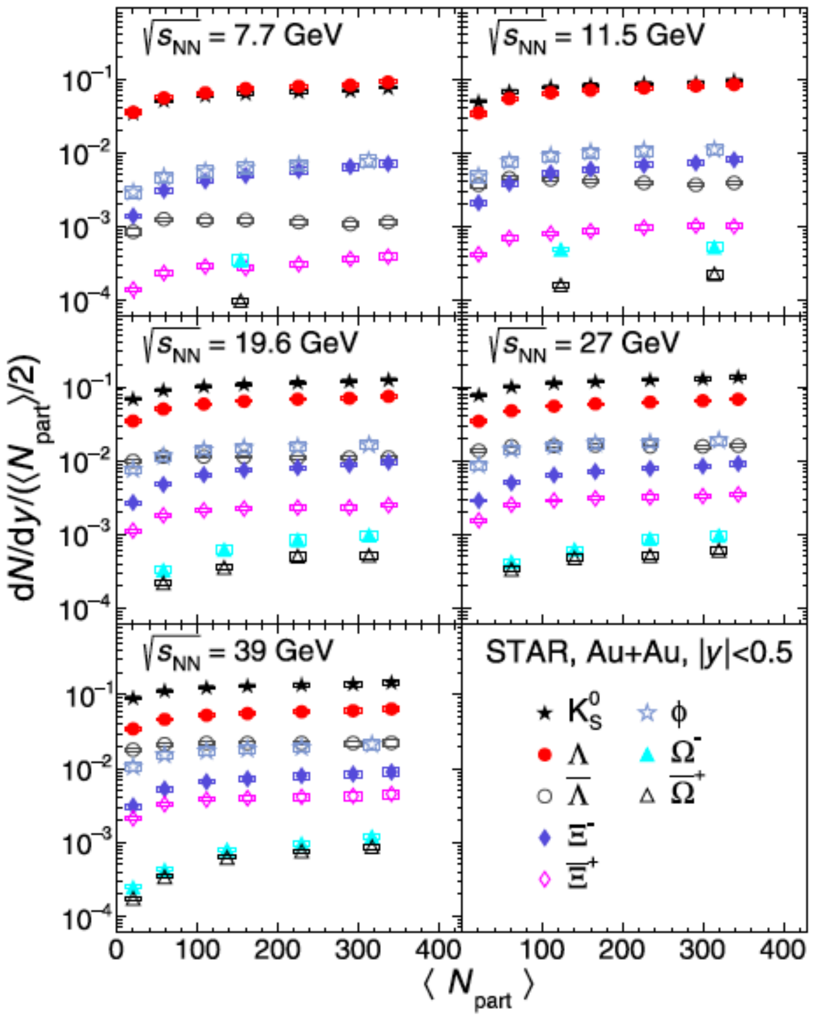
Low p_T extrapolation

- K_S^0, ϕ: m_T-exponential fit and levy function
- Λ, Ξ, Ω: boltzmann function
- Λs weak decay feed-down corrected

Particle yields



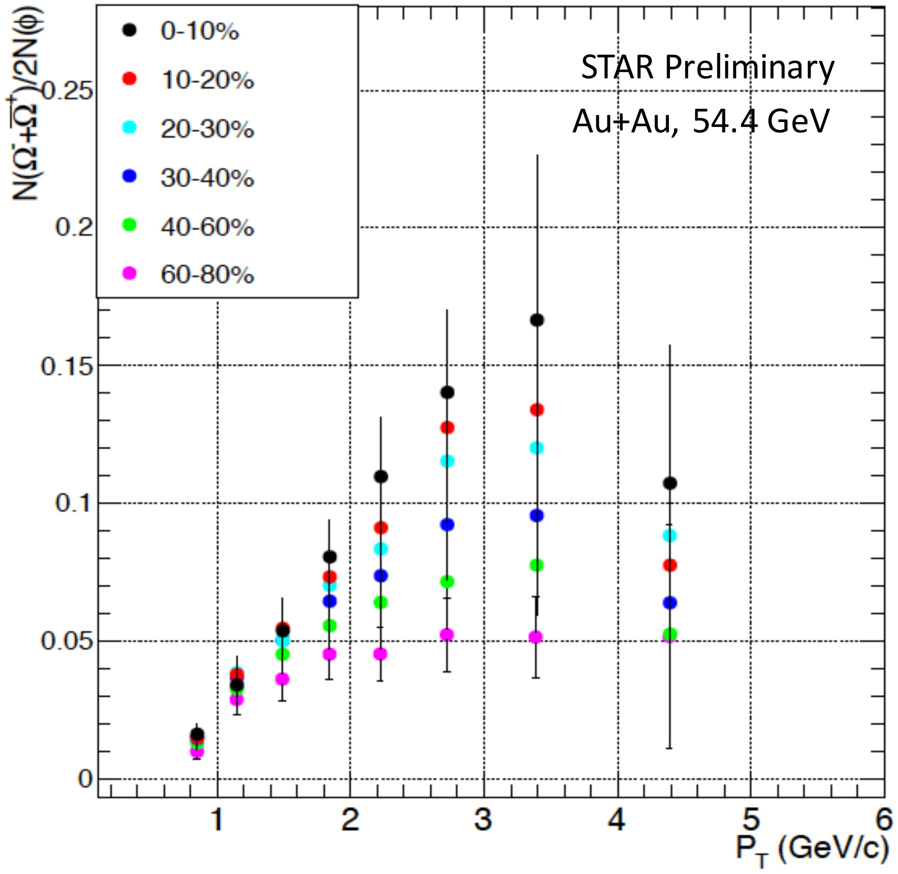
- K^0_S, Ξ, Ω, ϕ normalized yields: increase with average number of participant nucleons and energy.



STAR, PRC 102, 034909 (2020)

- Feed-down corrected $\bar{\Lambda}$ normalized yield: weak centrality dependence similar to other BES energies: possible annihilation processes on antibaryon production.

Ω/ϕ ratio



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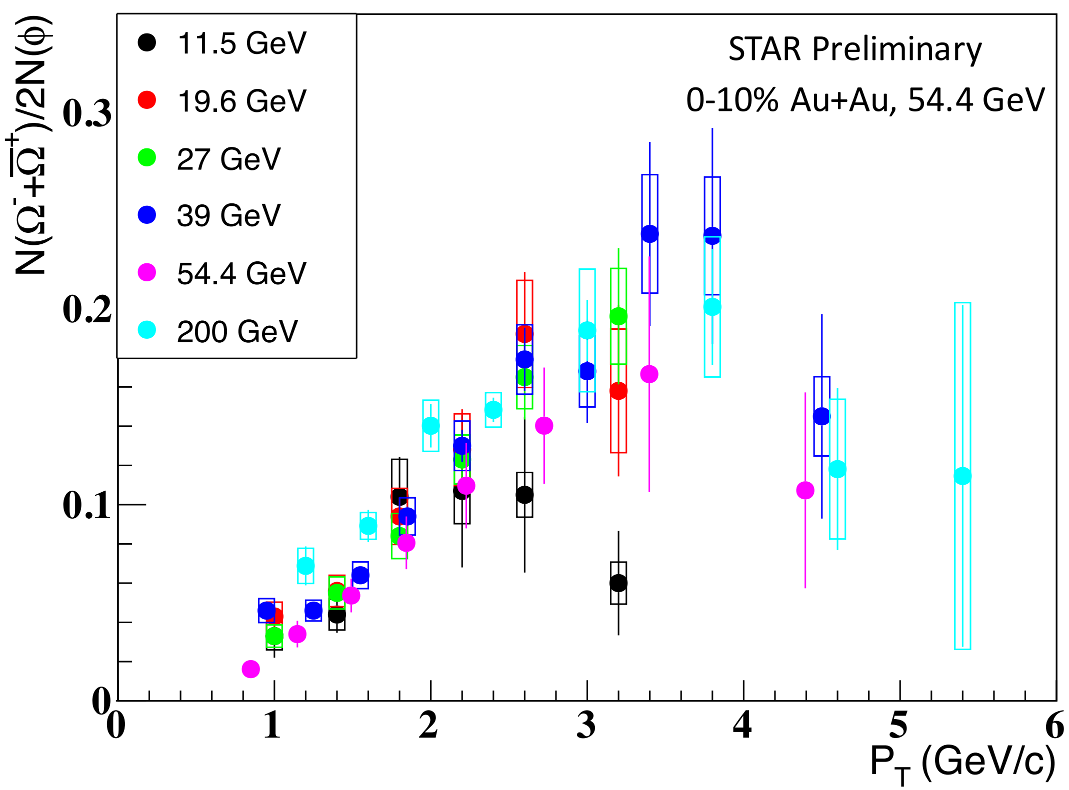
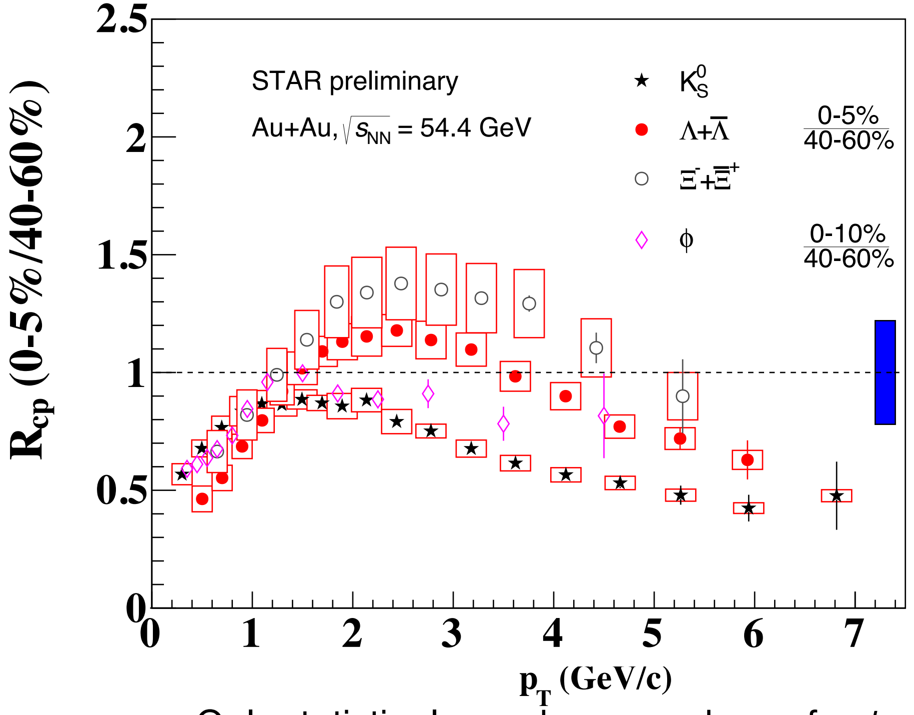


- Ω/ϕ ratio at $\sqrt{s_{NN}} = 54.4$ GeV: Enhancement at intermediate p_T
  → hadron formation through parton recombination.
- Need more statistics at $\sqrt{s_{NN}} = 11.5$ GeV to make a conclusion (BES-II).

Nuclear modification factor

$$R_{CP} = \frac{[(dN/dp_T)/\langle N_{coll}\rangle]_{central}}{[(dN/dp_T)/\langle N_{coll}\rangle]_{peripheral}}$$



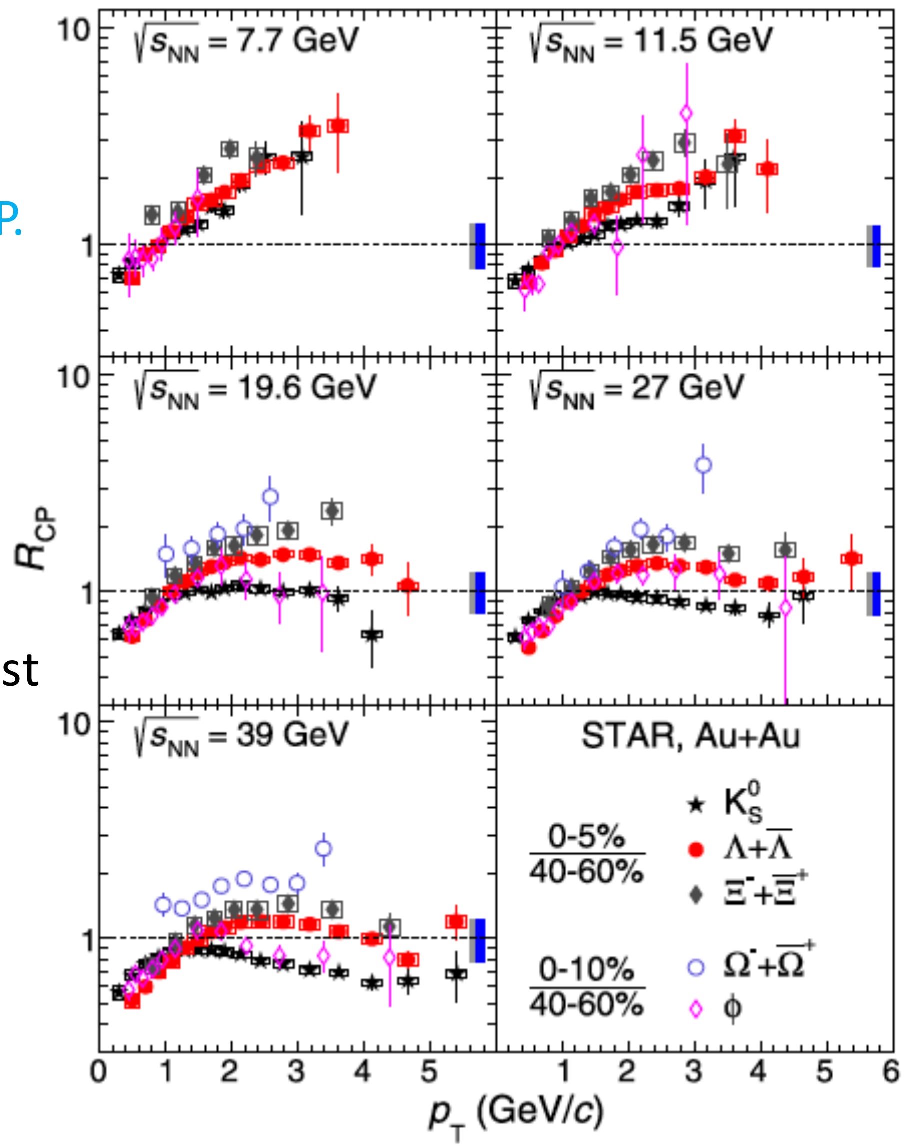
Only statistical error bars are shown for ϕ

$\sqrt{s_{NN}} = 54.4$ GeV:

- Strong suppression at high p_T: energy loss of scattered partons in QGP.
- Separation (baryon/meson) at intermediate p_T: parton recombination.

$\sqrt{s_{NN}} \leq 11.5$ GeV:

- No suppression at highest measured p_T.
- Need more statistics for high p_T (BES II).



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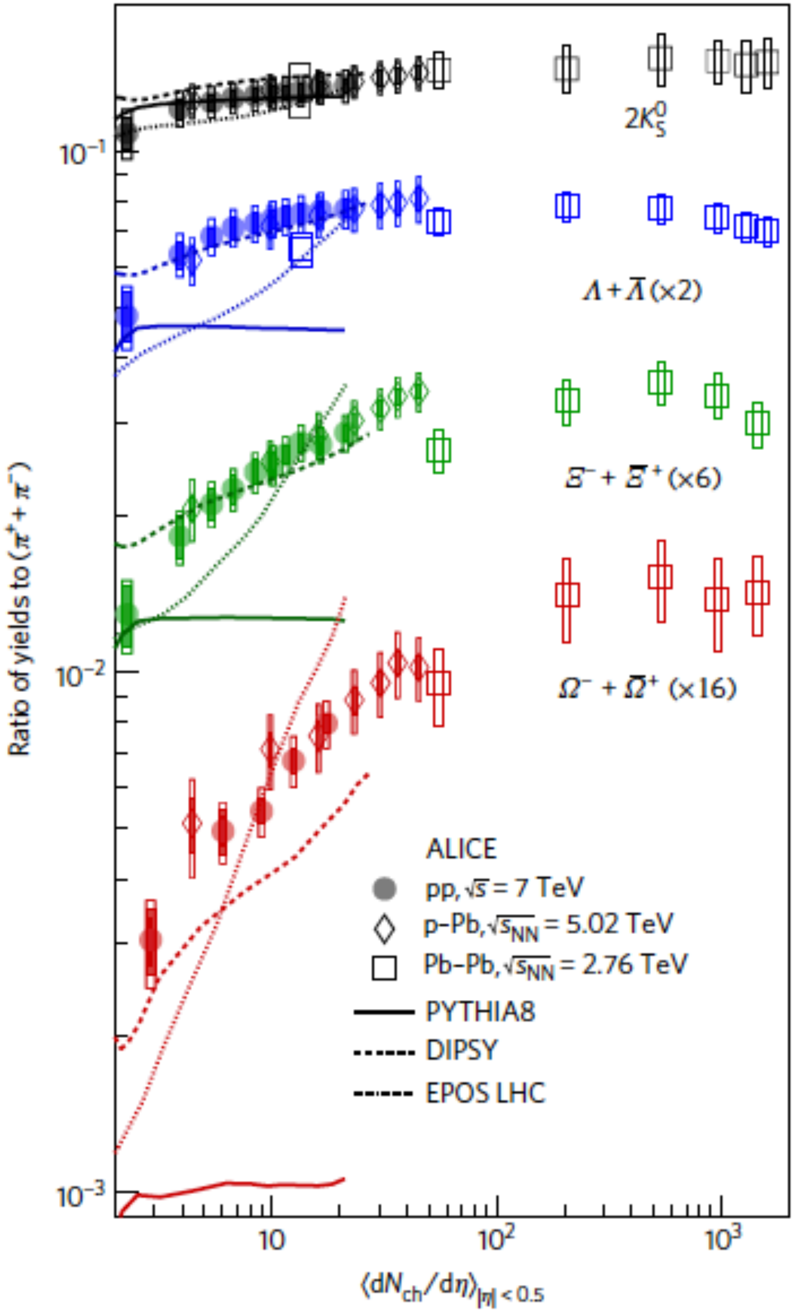
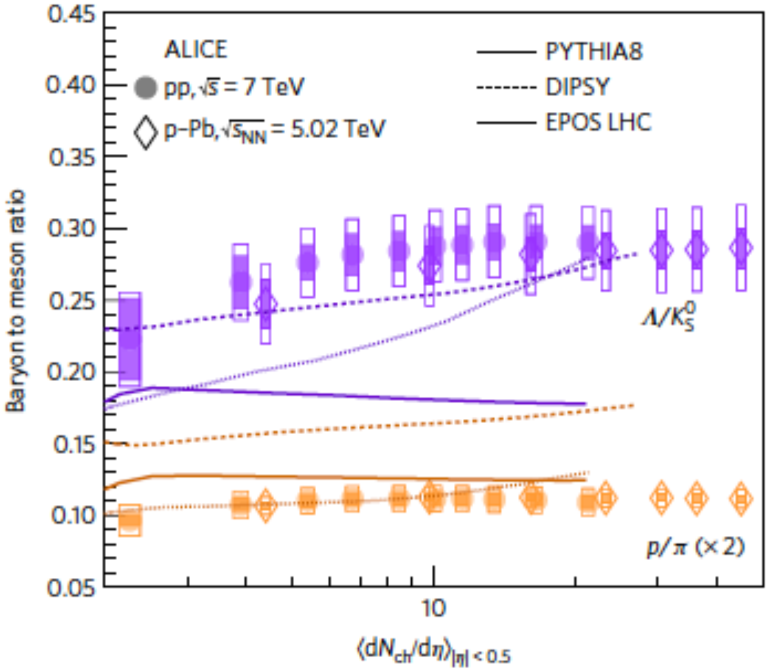
The energy evolution of strange hadron R_{cp} reflects the decreasing partonic effects with decreasing beam energies.

Strange particles/pions ratio



Enhanced production of multi-strange hadrons in high multiplicity proton–proton collisions. Nature Physics ***volume 13****, 535-539(2017)*

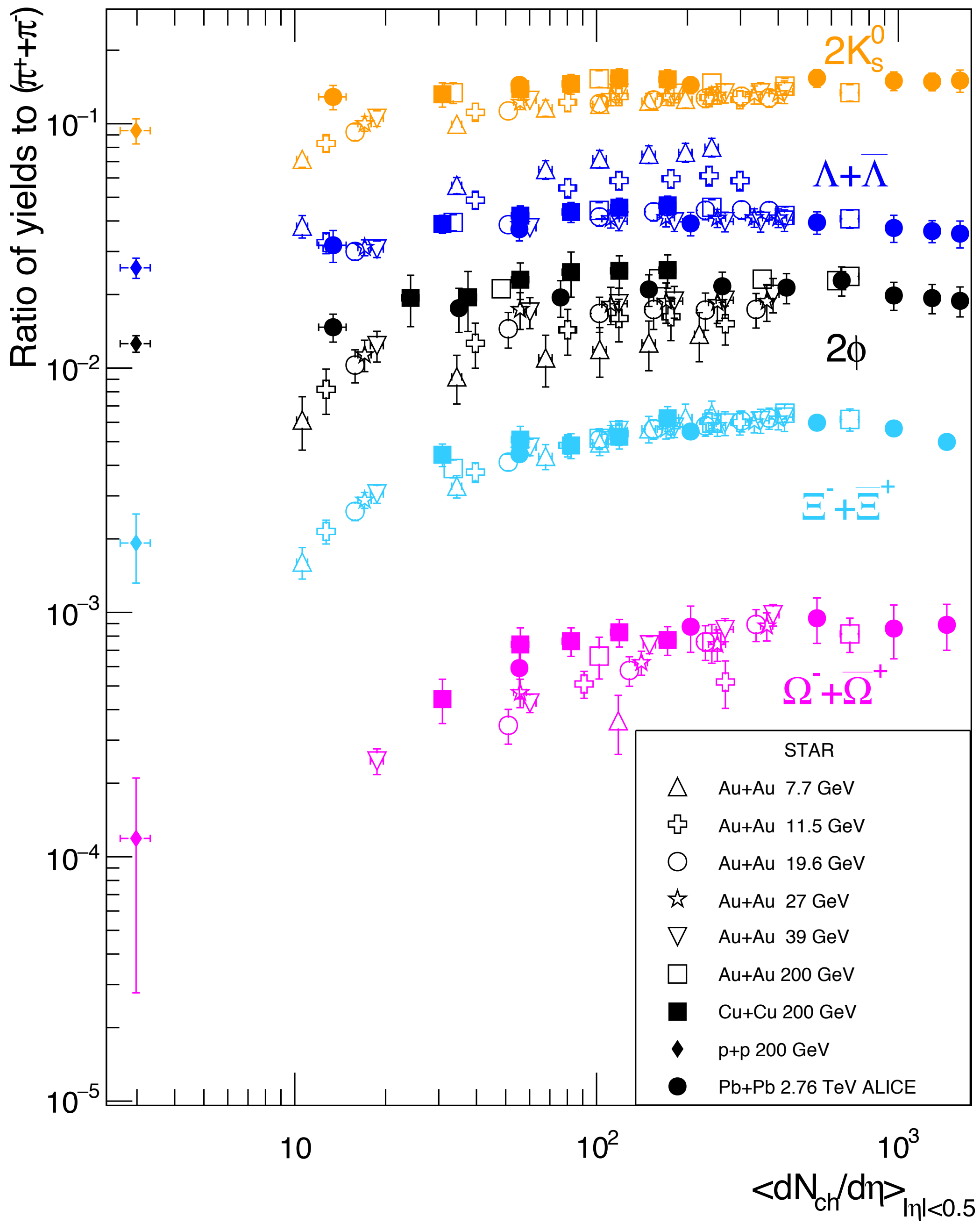
Particle ratios in pp and p–Pb are identical at the same $dN_{ch}/d\eta$, indicating that the final-state particle density might indeed be a good scaling variable between these two systems.



Particle yield ratios $\Lambda/K^0_S = (\Lambda + \bar{\Lambda})/2K^0_S$ and p/π =(p+p)/(π^+ +π^-) as a function of $\langle dN_{ch}/d\eta \rangle$.

This demonstrates that the observed enhanced production rates of strange hadrons with respect to pions is not due to the difference in the hadron masses.

Strange particles/pions ratio



- The function of yield ratios with $dN_{ch}/d\eta$ are system and energy independent, except Λ and ϕ.
- More statistics are needed for a firm conclusion for Ω.

$$\frac{dn}{dy} = \frac{\sqrt{M(1+\sinh^2 y)}}{\sqrt{1+M\sinh^2 y}}\frac{dn}{d\eta},$$

where $M = 1 + m^2/p_t^2$

$$p/E = \cosh\eta/\sqrt{1+m^2/p_t^2+\sinh^2\eta}.$$

$$dN_{ch}/d\eta = \sum dN_{ch}/d\eta\,(k^{\pm},\pi^{\pm},p,\bar{p})$$

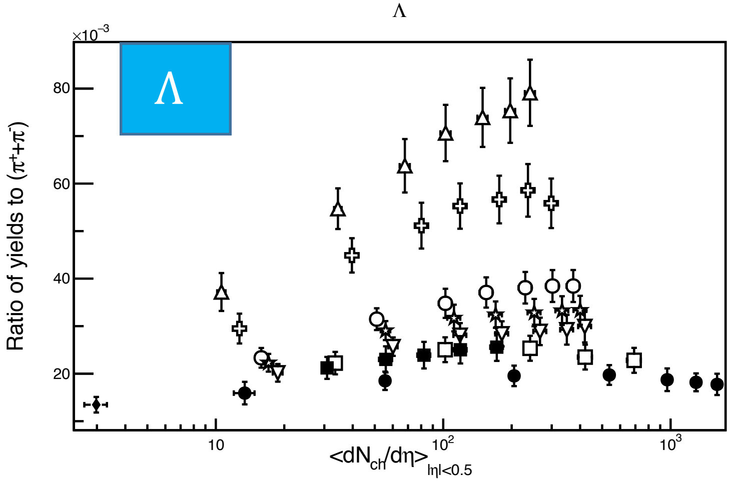
$$dN_{ch}/d\eta(\eta=0) \sim dN_{ch}/d\eta(|\eta|<0.5)$$

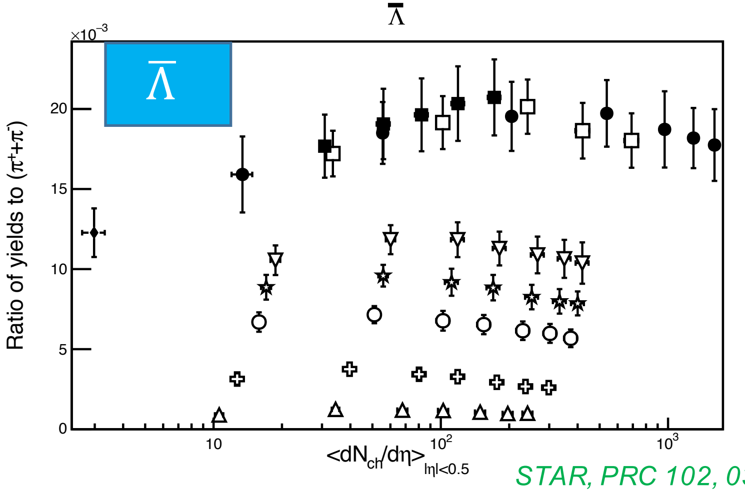
STAR, PRC 102, 034909 (2020)

STAR, PRC 96, 044904 (2017)

ALICE, PRC 88, 044910 (2013)

Strange particles/pions ratio





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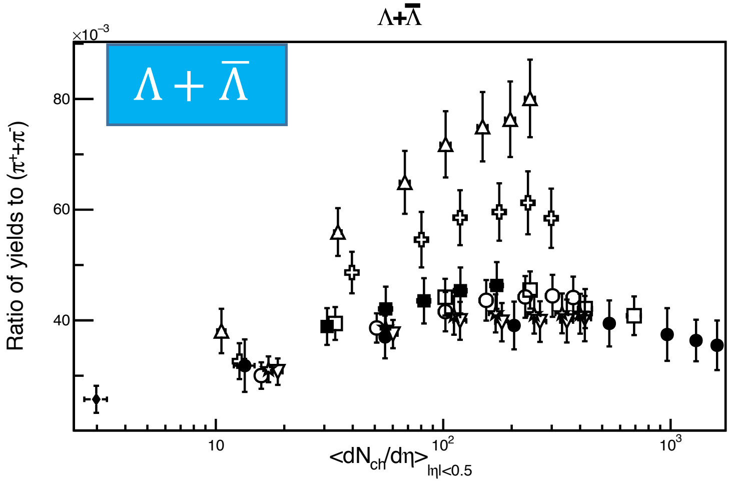

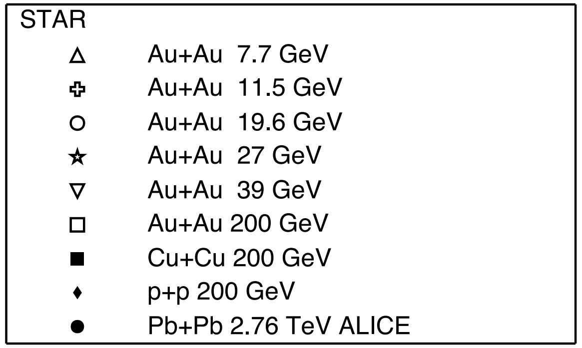

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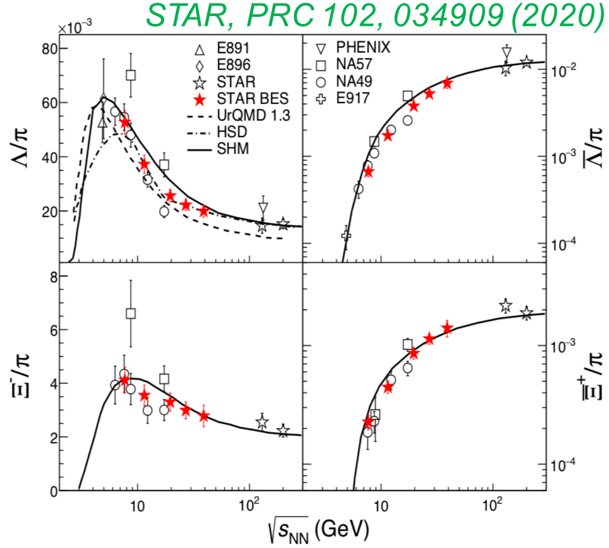
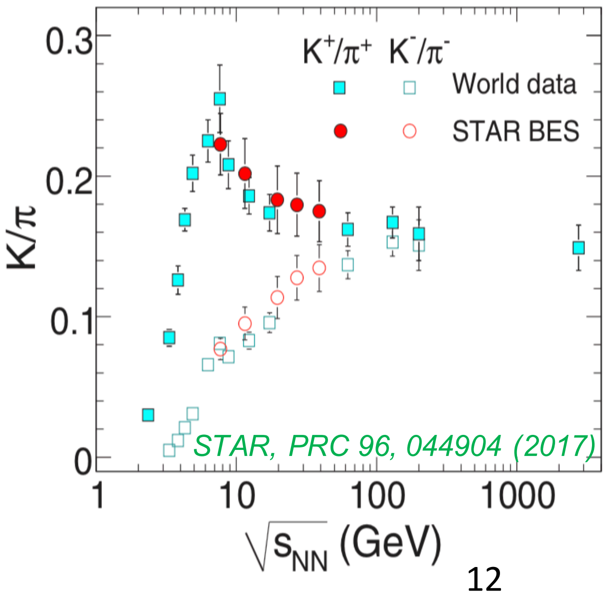


$NN \rightarrow N\Lambda K^+$



- Breaking of the scaling for Λs may be due to the (hadronic or equivalent partonic) associated process, which dominates Λ production at $\sqrt{s_{NN}} = 7.7$ and 11.5 GeV.
- There are significant peaks in both Λ/π and K^+/π^+ at $\sqrt{s_{NN}}$~7.7 GeV.

Summary

- K_S^0, Ξ, Ω, ϕ normalized yields: increase with average number of participant nucleons and energy.
- $\bar{\Lambda}$ normalized yield: weak centrality dependence for Au+Au collisions at $\sqrt{s_{NN}} = 54.4$ GeV,

  → Possible annihilation processes on antibaryon production.
- Nuclear modification factors: strong suppression at high p_T for $\sqrt{s_{NN}} = 54.4$ GeV,

  → Energy loss of parton in QGP.
- Rcp separation (baryon/meson) at intermediate p_T and Ω/ϕ ratio enhancement at intermediate p_T for $\sqrt{s_{NN}} = 54.4$ GeV,

  → Parton recombination.
- Yield ratios as a function of $dN_{ch}/d\eta$ are independent of system and energy for K_S^0 and Ξ.

Thanks for your attention!