APS | JOINT MARCH MEETING AND APRIL MEETING
Global Physics Summit
March 16–21, 2025, Anaheim, CA and virtual

Probing Baryon Transport Dynamics and Strangeness Production with Hyperon-kaon Correlations

Siyuan Ping (For the STAR Collaboration)
Fudan University

Outline

1. Baryon Number Transport

2. Hyperon-Kaon Correlation

3. p(d) + Au Collision

4. Hyperon reconstruction in STAR data

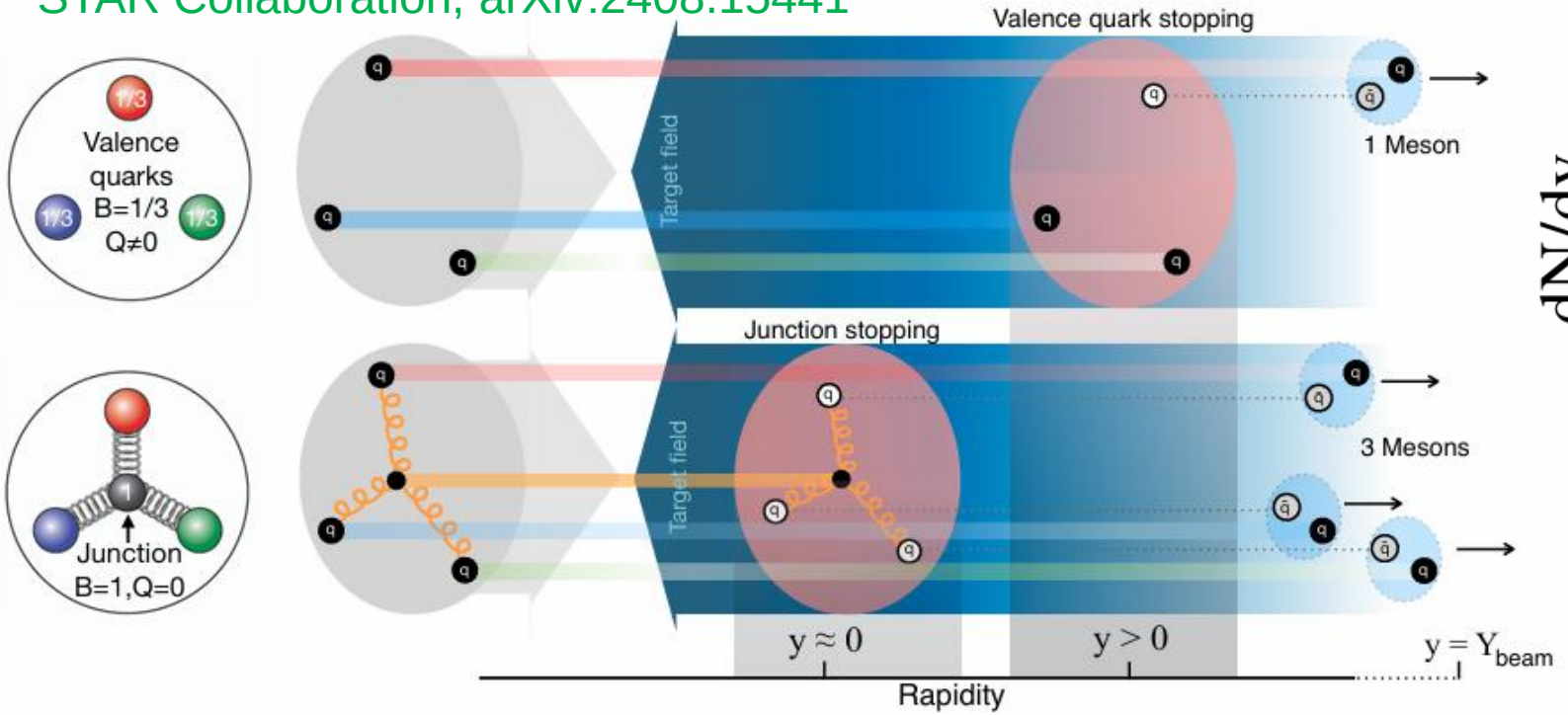
5. AMPT Result

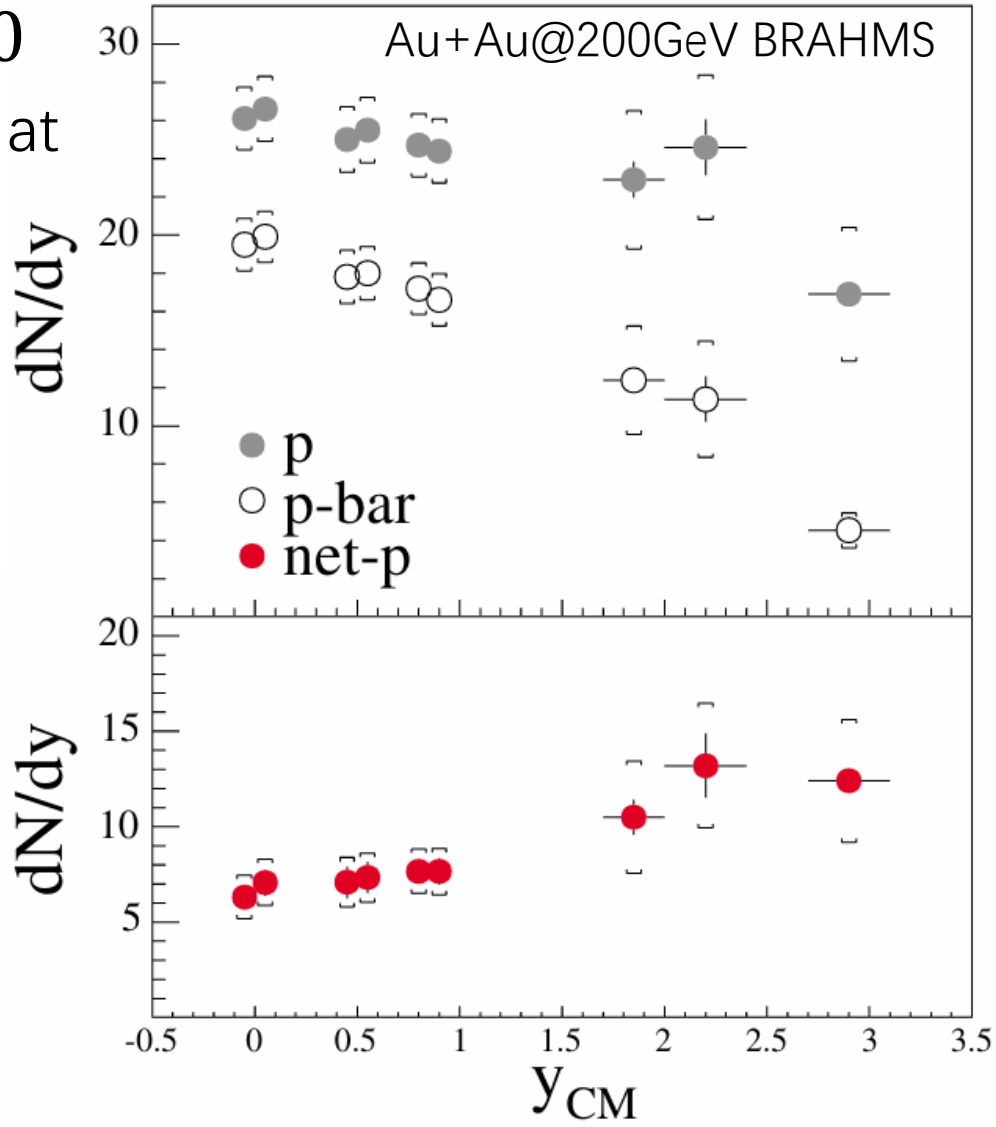
6. Summary and Outlook

Baryon Number Transport

- Baryons number transport from $|y_{Beam}|$ to $y{\sim}0$
  - Significant $N_{Baryon} > N_{anti-Baryon}$ at mid-rapidity at RHIC energies.
- Stopping scheme
  - Valence quark picture
  - Gluon-junction model

STAR Collaboration, arXiv:2408.15441

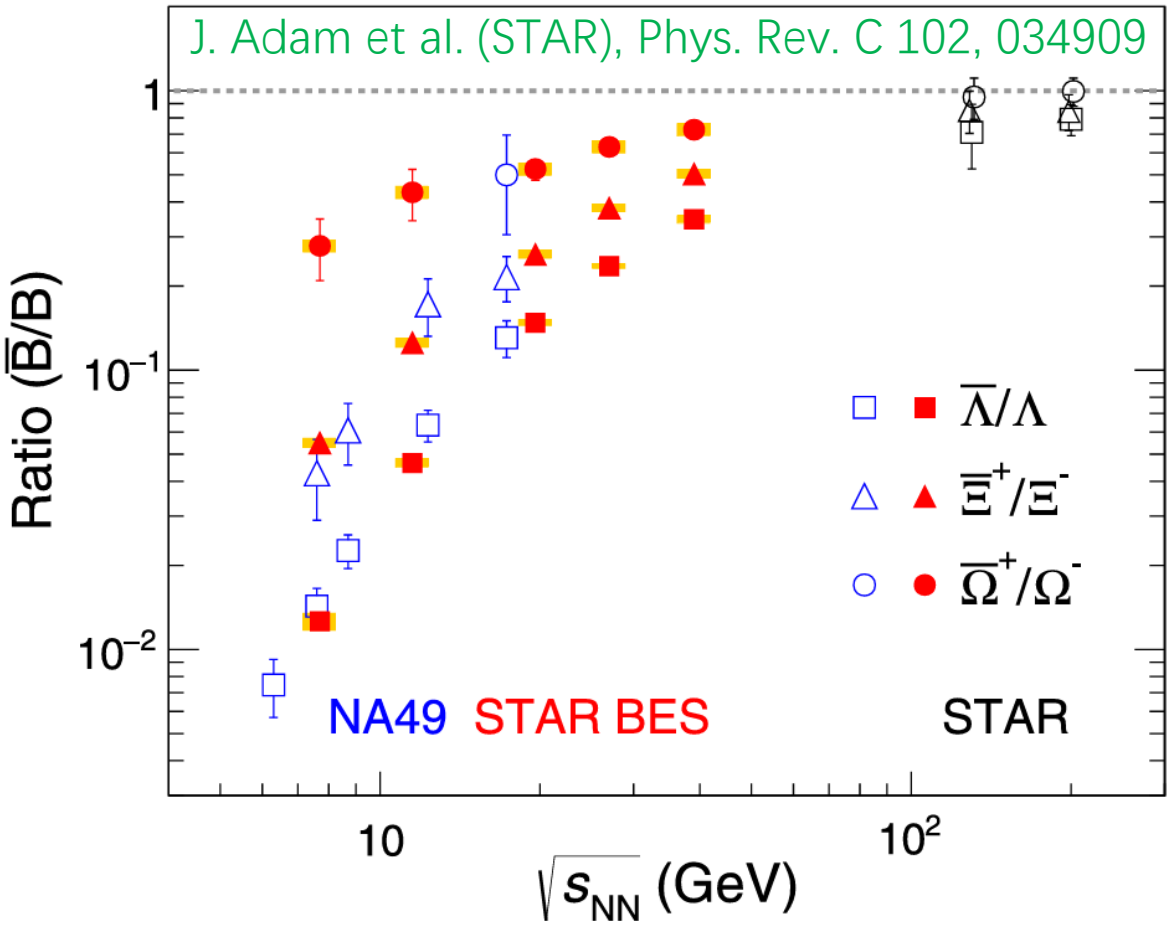




I. G. Bearden et al. (BRAHMS), Phy. Rev. Lett. 2004, 93(10):102301

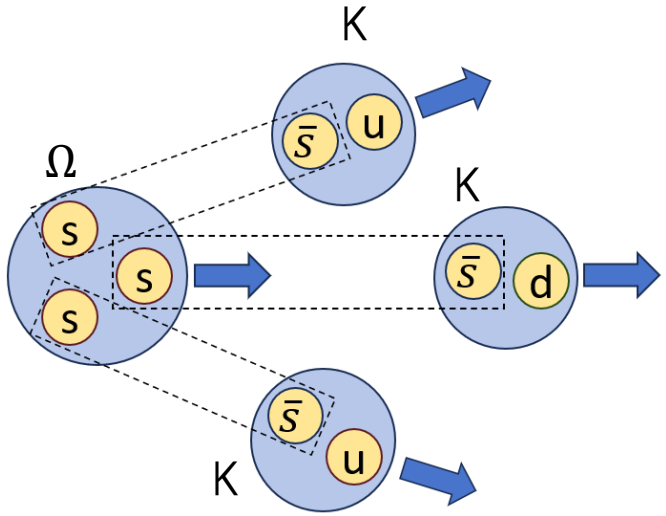
Hyperon-Kaon Correlation

- Baryons number transport from Proton/Neutron to Hyperon
  - Ratio Anti-Hyperon/Hyperon < 1
  - Strangeness conservation: Strange – Anti-Strange quarks are pair-produced



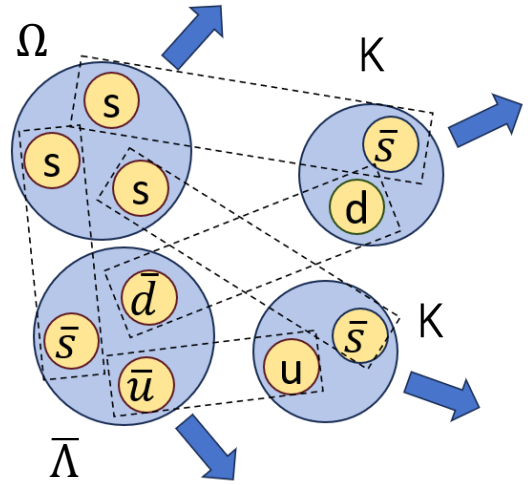
Kaon-Hyperon Correlation:

particles containing at least one valence strange quark:
More primordial production than from weak decays
compare to π and p



1: General associate production
Transport one Baryon Number

$\frac{K}{\Omega} = 3$

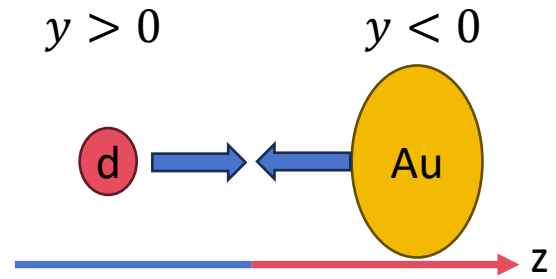


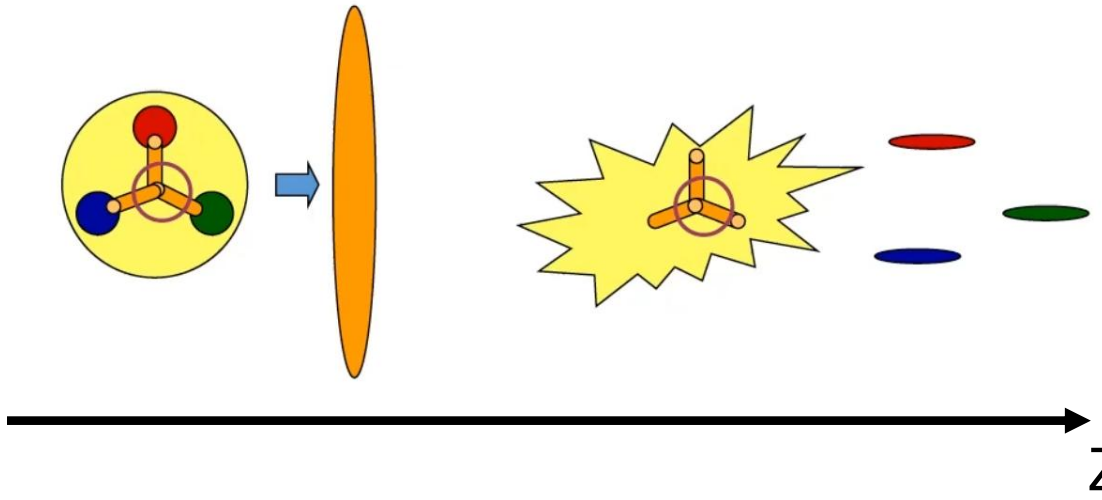
2: General pair production
Transport no Baryon Number

$\frac{K}{\Omega} = 1,2,3$

p(d) + Au Collision

- What we expect in p(d)+A asymmetric collisions
  - Asymmetric collisions
  - In Gluon-junction scheme:
    - Baryon number is carried by the gluon junction
    - Valence quark jets emerge with leading mesons
    - Hyperons in initial p/d hemi-sphere more likely carry baryons number from initial p/d
    - Clearer K-Hyperon correlation for hyperon which y>0
      - Difference Δy pair distribution between $hyperon_{y>0}$ and $hyperon_{y<0}$.





$$\bar{s}s \;-\; \bar{s}\bar{s}$$

$$C_{K\Lambda}(\Delta y) = \frac{1}{N_{\Lambda}} \frac{dN^{pairs}_{K^+\Lambda}}{d\Delta y} - \frac{1}{N_{\bar{\Lambda}}} \frac{dN^{pairs}_{K^+\bar{\Lambda}}}{d\Delta y}$$

$$\Delta y = \theta(y_{\Lambda})(y_K - y_{\Lambda}) + \theta(-y_{\Lambda})(y_{\Lambda} - y_K)$$

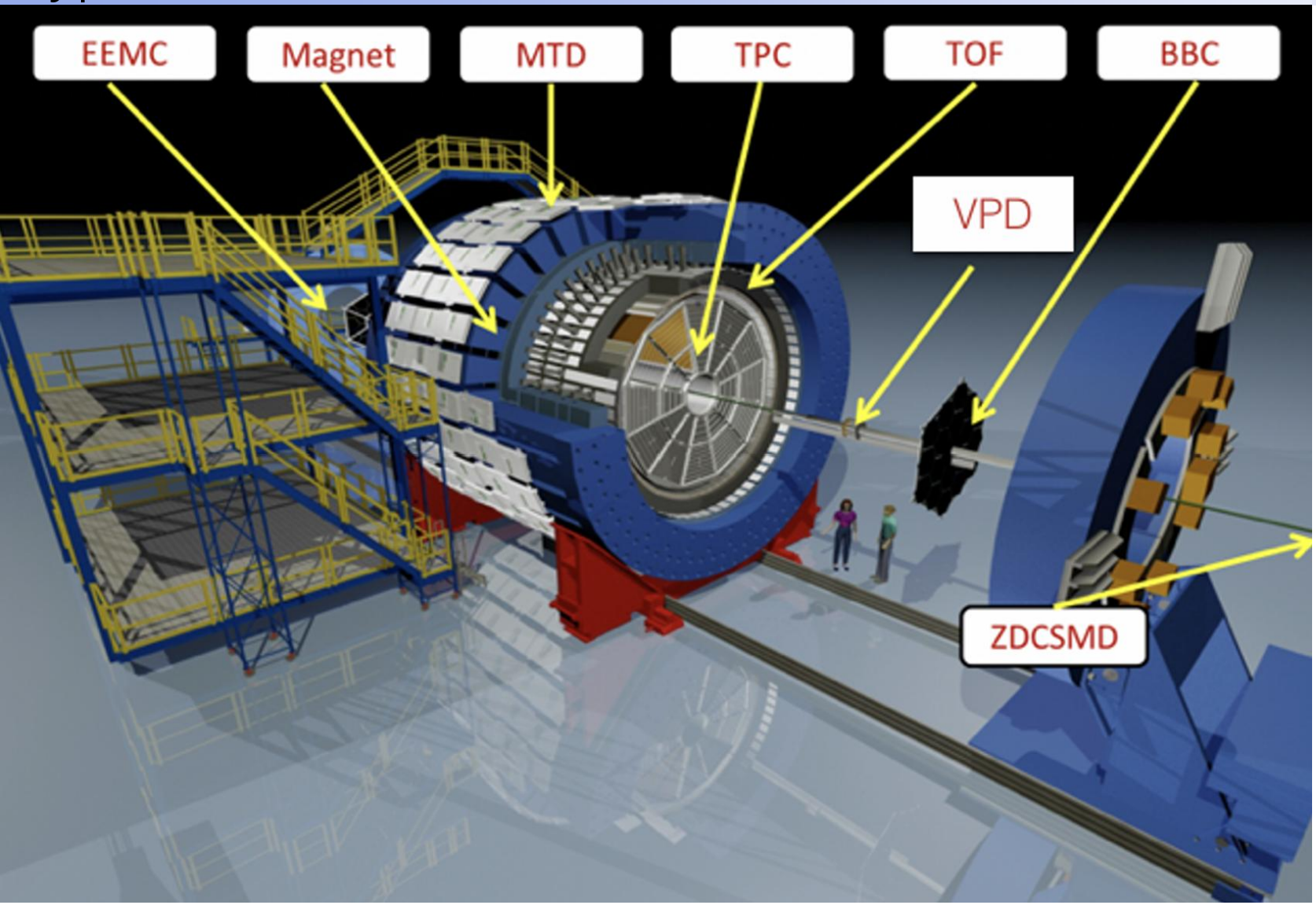
$$\theta(x) = \begin{cases} 1, x \geq 0 \\ 0, x < 0 \end{cases}$$

$\Delta y > 0$: Kaon emit faster; $\Delta y < 0$: Λ emit faster

Yielding information of average Kaon number per Lambda

Combinatorial background subtraction

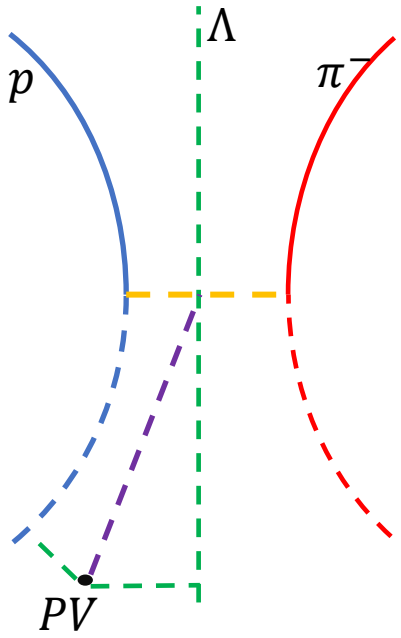
Hyperon reconstruction in STAR data

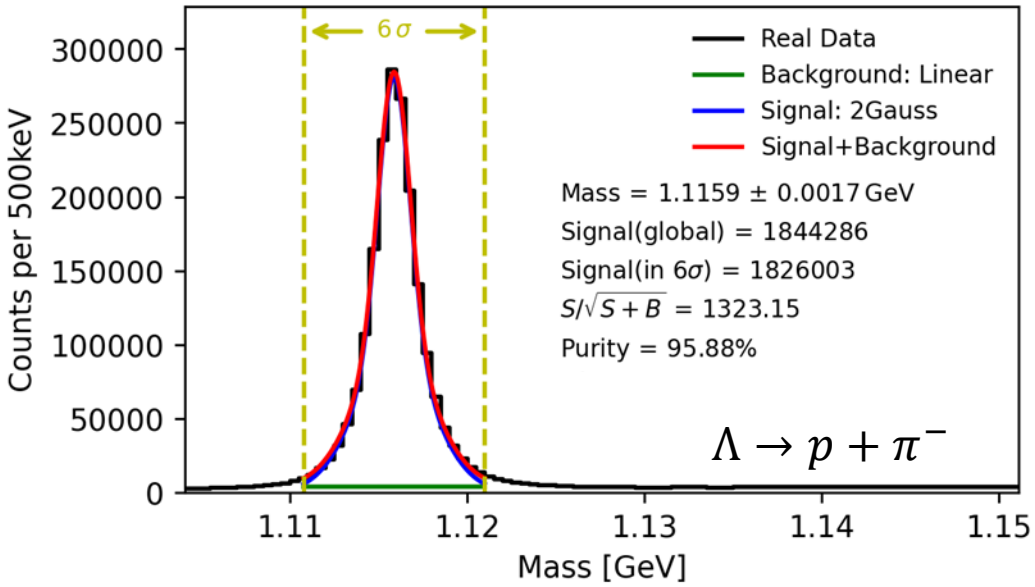


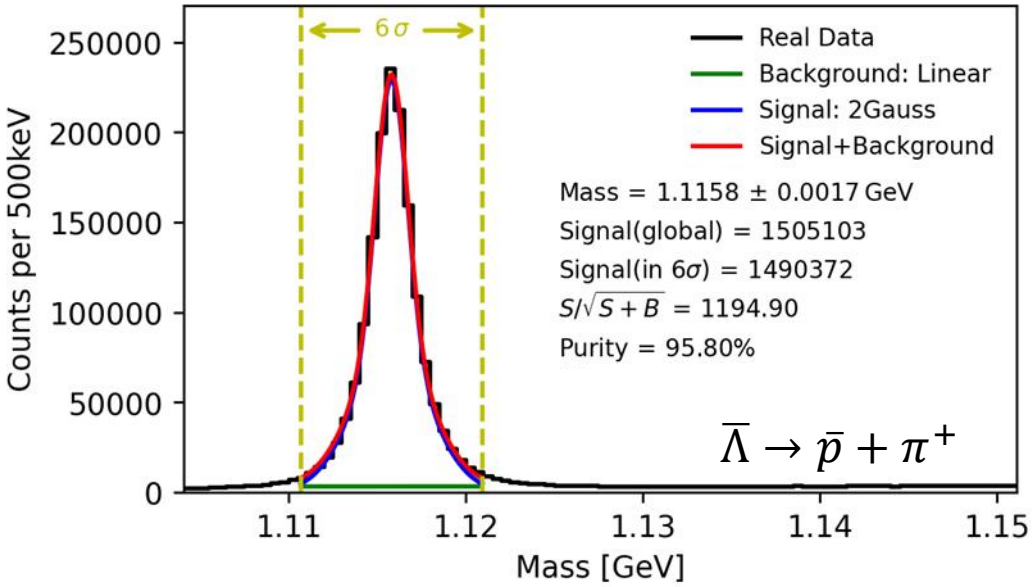
- Dataset:
  - d+Au@200GeV Run 21
- STAR Acceptance
  - TPC & TOF are used
  - $|y| < 1$
  - $|\eta| < 1$

Hyperon reconstruction in STAR data

- KFParticle Package was used in d+Au@200GeV Run 21:
  - Using dE/dx in the TPC for particle identification
  - **DCA** between daughter particles **< 0.5 cm**
  - the **distance** to the primary vertex from the decay vertex **> 1.0 cm**

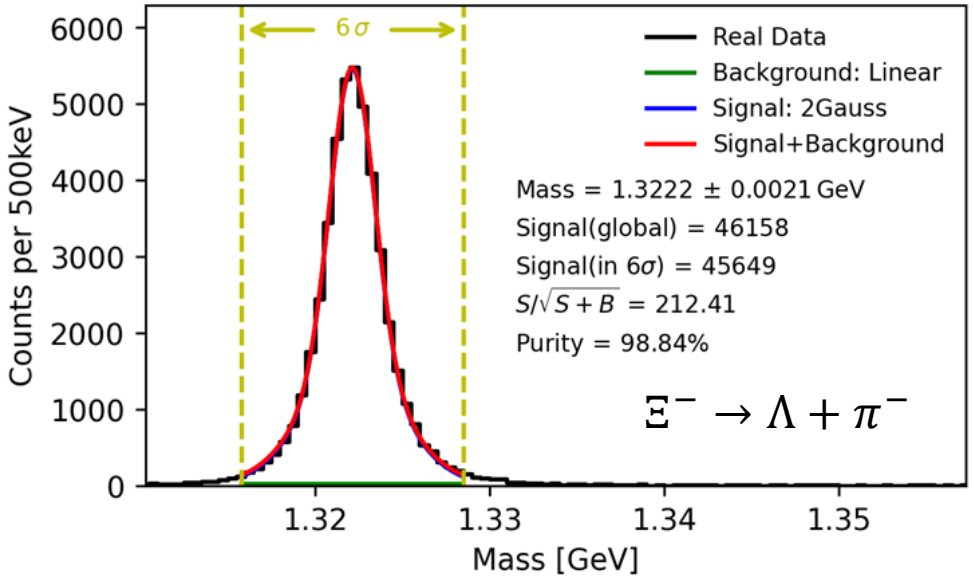


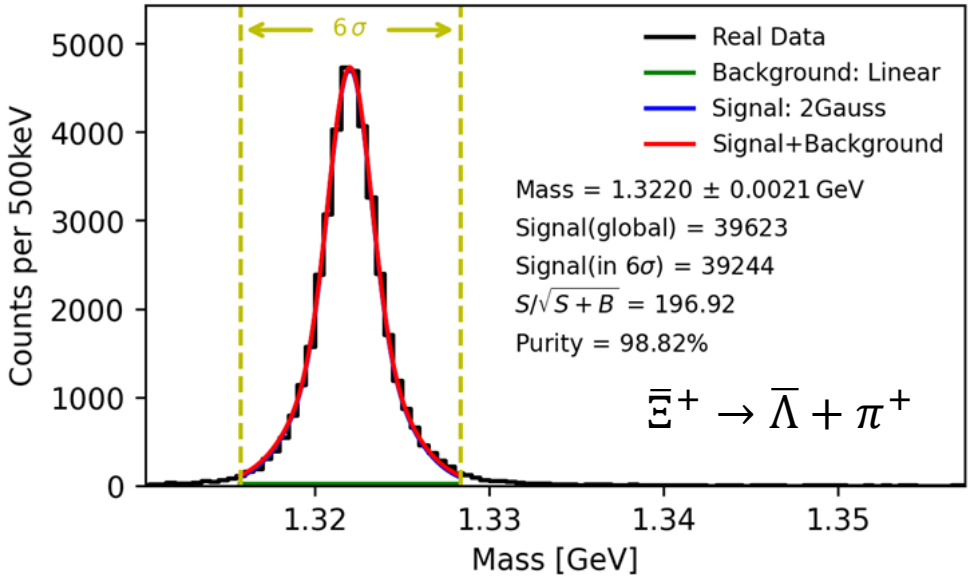


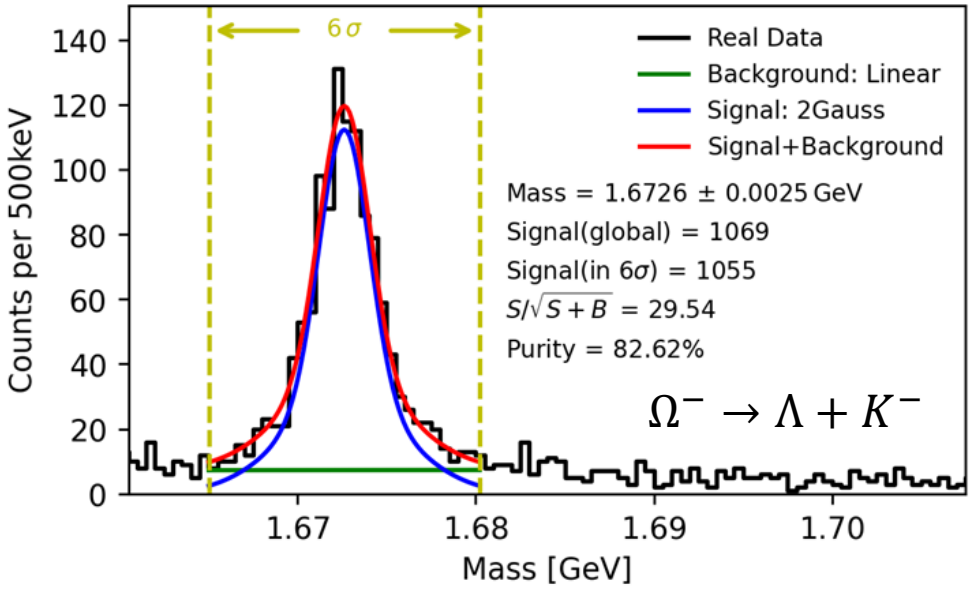


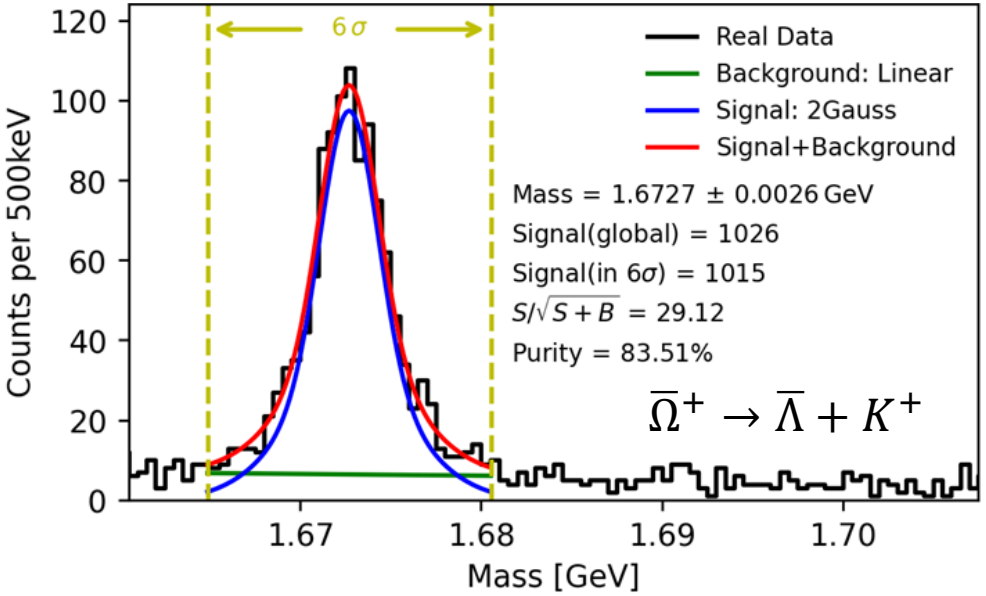
For more KFP introduction:
https://publikationen.ub.uni-frankfurt.de/opus4/frontdoor/deliver/index/docId/29538/file/GorbunovThesis.pdf

Hyperon reconstruction in STAR data



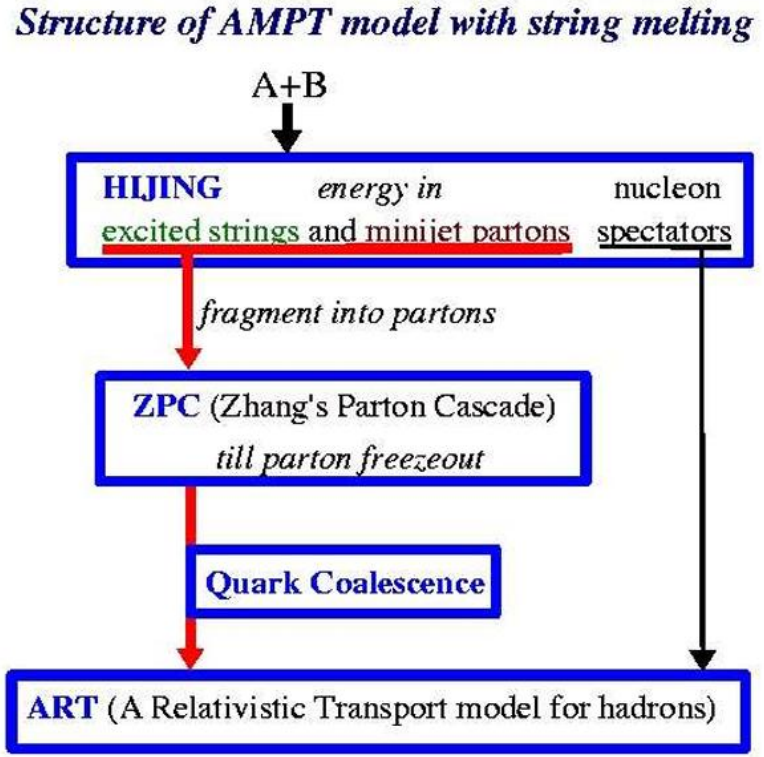






AMPT Result

- Simulation for reference:
  - A Multi-Phase Transport Model (AMPT)
  - Version: 2.25t7cu (StringMelting)
  - Transport models treat chemical and thermal freeze-out dynamically
  - Data Generated:
    - p+Au@39/62GeV
    - d+Au@200GeV
  - Guiding the experimental investigation
    - STAR acceptance adopted
      - $|y| < 1$
      - $|\eta| < 1$
    - AMPT has no Baryon junction:
      - As a benchmark for experimental studies



Z.W. Lin, C.M. Ko, B.A. Li, B. Zhang, S. Pal, Phys.Rev.C72:064901,2005

AMPT Result

- d+Au@200GeV

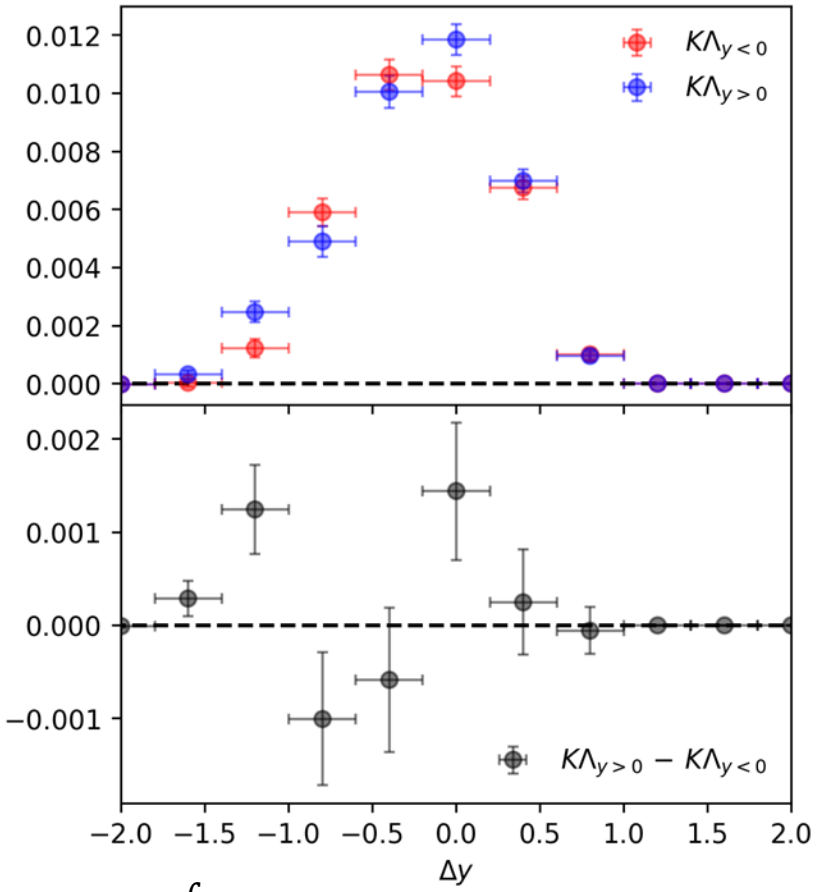
$$\Delta y = \theta(y_{Hyperon})(y_K - y_{Hyperon}) + \theta(-y_{Hyperon})(y_{Hyperon} - y_K)$$

$\Delta y > 0$: Kaon emit faster; $\Delta y < 0$: $Hyperon$ emit faster

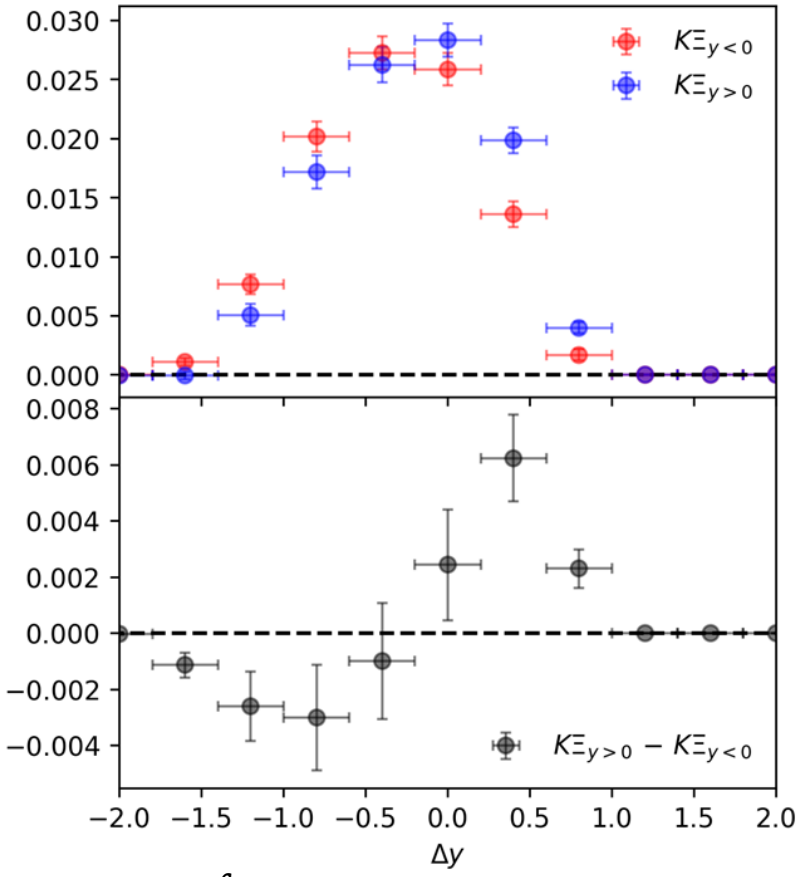
$$C_{K\Lambda}(\Delta y) = \frac{1}{N_\Lambda}\frac{dN^{pairs}_{K^+\Lambda}}{d\Delta y} - \frac{1}{N_{\bar\Lambda}}\frac{dN^{pairs}_{K^+\bar\Lambda}}{d\Delta y}$$

$$C_{K\Xi}(\Delta y) = \frac{1}{N_\Xi}\frac{dN^{pairs}_{K^+\Xi}}{d\Delta y} - \frac{1}{N_{\bar\Xi}}\frac{dN^{pairs}_{K^+\bar\Xi}}{d\Delta y}$$

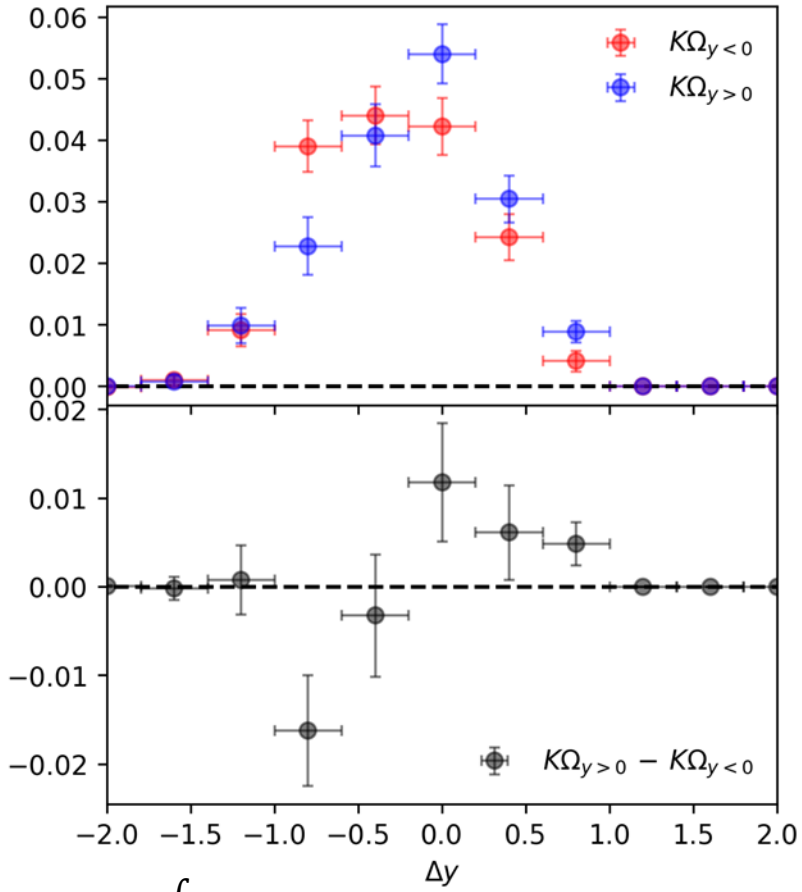
$$C_{K\Omega}(\Delta y) = \frac{1}{N_\Omega}\frac{dN^{pairs}_{K^+\Omega}}{d\Delta y} - \frac{1}{N_{\bar\Omega}}\frac{dN^{pairs}_{K^+\bar\Omega}}{d\Delta y}$$



$$\int C_{K\Lambda}(\Delta y)\, d\Delta y = 0.037 \pm 0.001$$



$$\int C_{K\Xi}(\Delta y)\, d\Delta y = 0.099 \pm 0.002$$



$$\int C_{K\Omega}(\Delta y)\, d\Delta y = 0.166 \pm 0.007$$

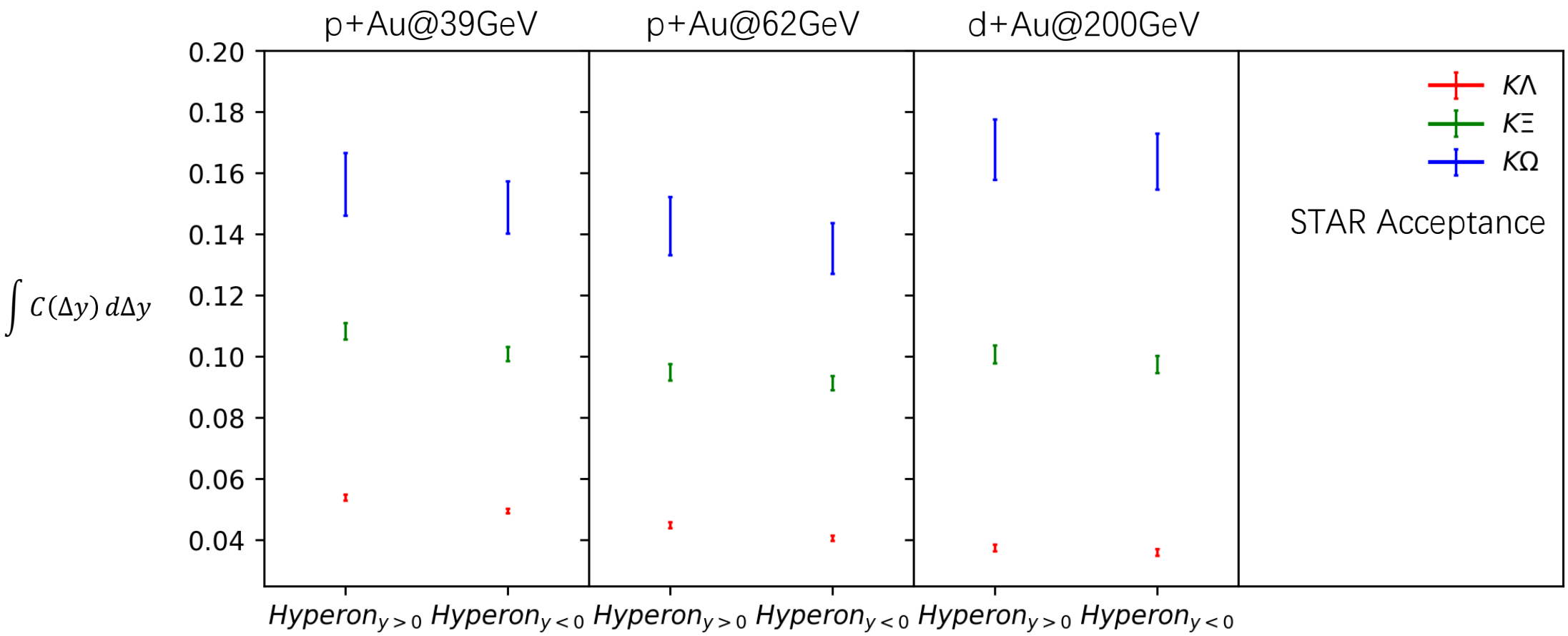
Summary and Outlook

- p(d)+A collision:
  - A new way to study to study baryon stopping and possible baryon junction interactions.
- Hyperon-Kaon correlation:
  - Sensitive probe of baryon number transport dynamics
- AMPT simulation:
  - StringMelting version
  - Hyperons with positive rapidity correlate faster emitted Kaons
    - Indicates stronger baryon stopping for initial deutron.
  - Positive $\int C_{K-Hyperon}(\Delta y)\, d\Delta y$:
    - $\int C_{K\Omega}(\Delta y)\, d\Delta y > \int C_{K\Xi}(\Delta y)\, d\Delta y > \int C_{K\Lambda}(\Delta y)\, d\Delta y$
    - A hint of baryon number transport to hyperons
- Analysis of d+Au STAR dataset is ongoing (Stay tuned!)

Thank you!

Back Up

AMPT Result


p+Au@39GeV
p+Au@62GeV
d+Au@200GeV
$\int C(\Delta y)\, d\Delta y$
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
KΛ
KΞ
KΩ
STAR Acceptance
$Hyperon_{y>0}$ $Hyperon_{y<0}$ $Hyperon_{y>0}$ $Hyperon_{y<0}$ $Hyperon_{y>0}$ $Hyperon_{y<0}$