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Light and strange hadron production and anisotropic flow measurement in Au + Au collisions at $\sqrt{s_{NN}}$ = 3 GeV from STAR experiment

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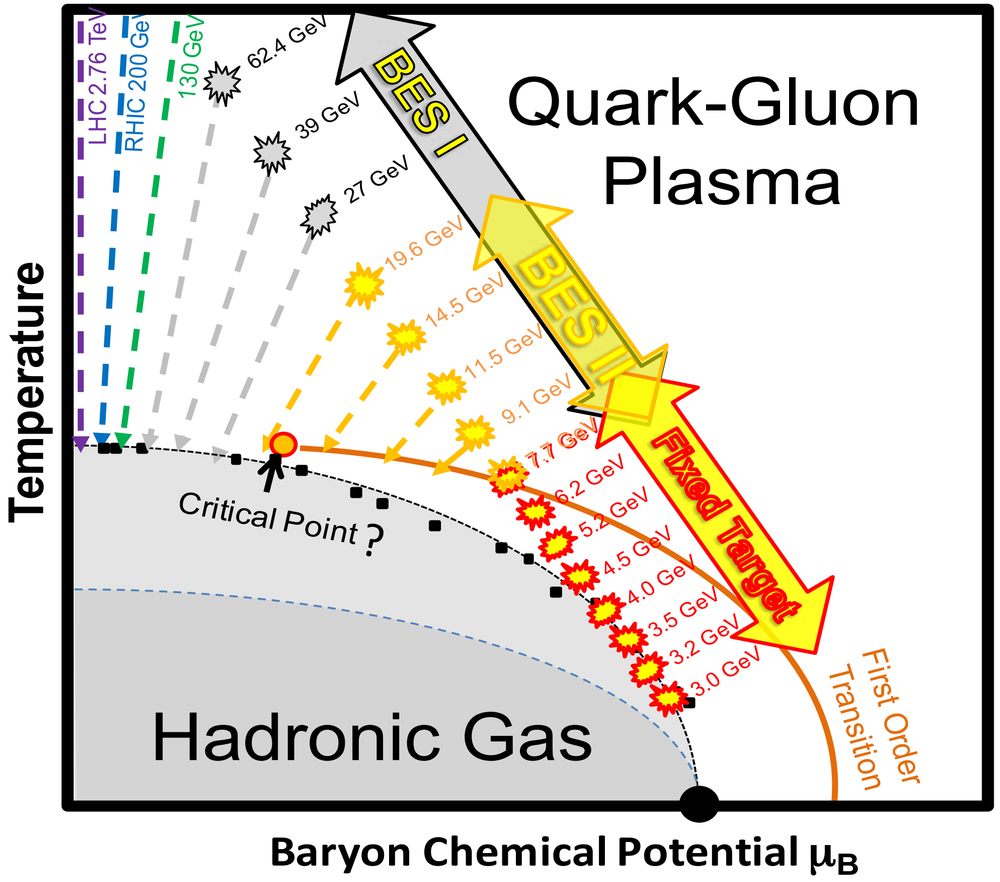
Ref:
M. Abdallah et al. (STAR Collaboration) 2108.00908
M. Abdallah et al. (STAR Collaboration) 2108.00924

Outline

- **Motivation**
- **STAR Fixed Target (FXT)**
- **Results of light and strange hadron production yields**
  - yield ratios
- **Results of light and strange hadron anisotropic flow**
  - v_1, v_2
- **Summary**

Introduction



- RHIC BES cover the intermediate baryon density region
  - Look for onset of de-confinement, phase boundary and locate critical point

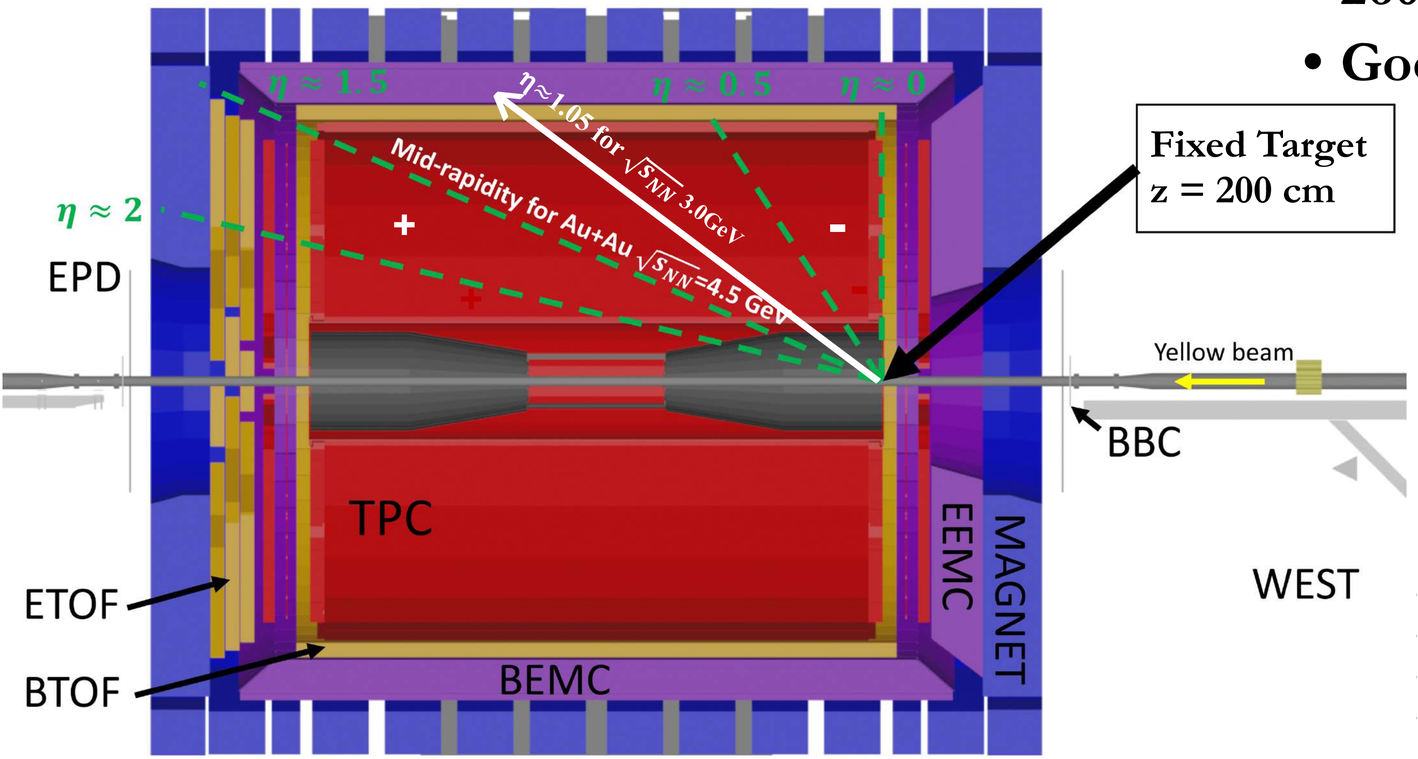
- STAR FXT mode $\sqrt{s_{NN}}$ = (3.0 - 13.7) GeV
  - High baryon chemical potential μ_B (~276 MeV up to ~ 720 MeV) allows us to study properties of high baryon density matter

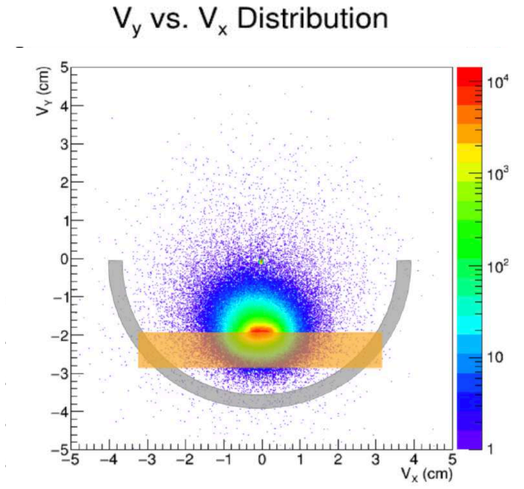
◉Particle production
  - Understand medium properties and different particle production mechanisms

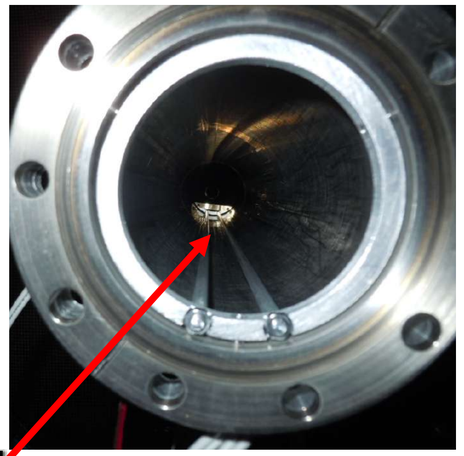
◉Collective flow
  - Study properties of the produced medium

FXT setup at STAR

- Target was installed at the edge of TPC
- 260M events for Au+Au FXT at $\sqrt{s_{NN}} = 3$ GeV
- Good mid-rapidity coverage







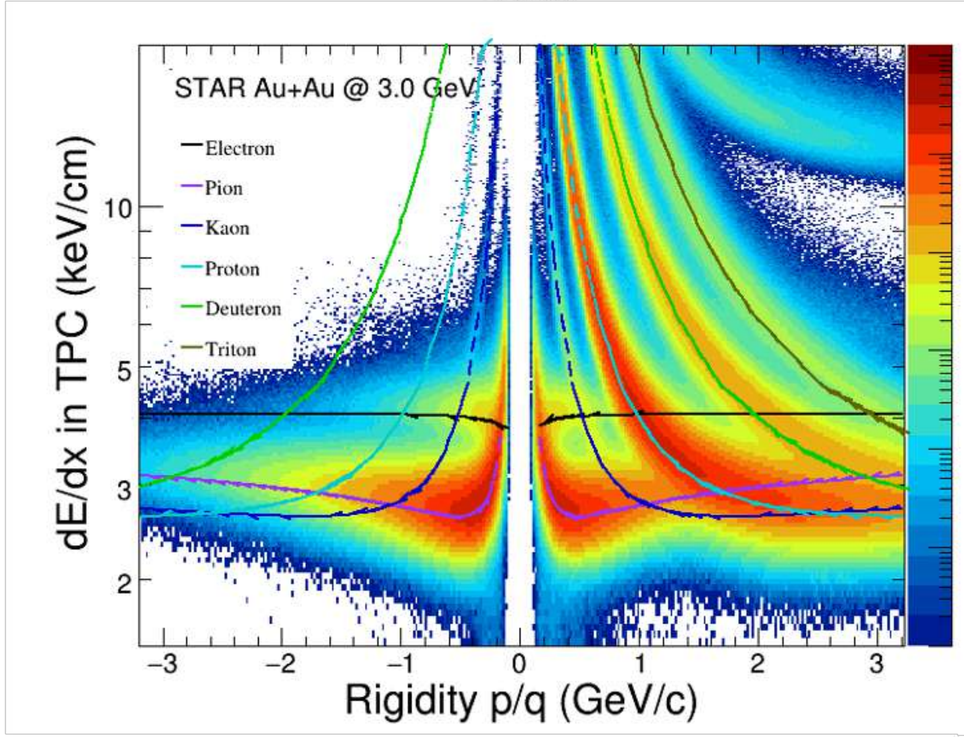
Beam pipe

Au-Target =0.25mm thickness
1% interaction probability

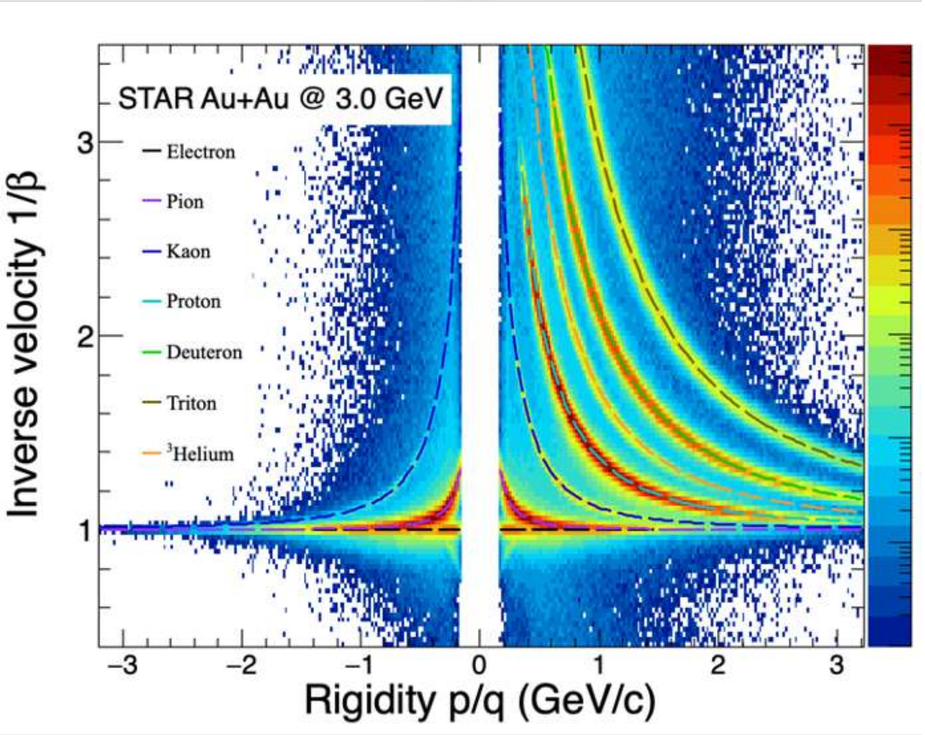
Conventions:
beam-going direction is the positive direction
In C.M. frame, $y_{target} = -1.045$ for the 3GeV collisions

PID at STAR FXT

TPC



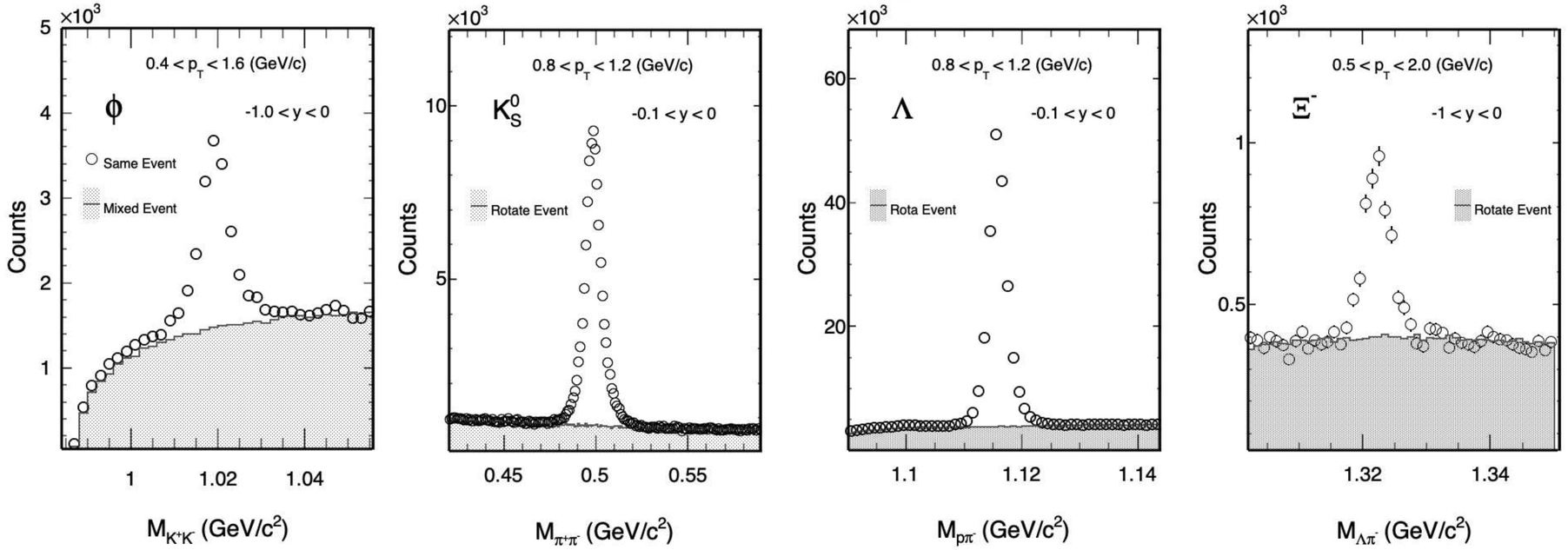
TOF



- TPC (dE/dx) and TOF (β) for pion, kaon and proton particle identification
- On average, "longer tracks" for FXT events than for collider events, better resolutions in FXT mode

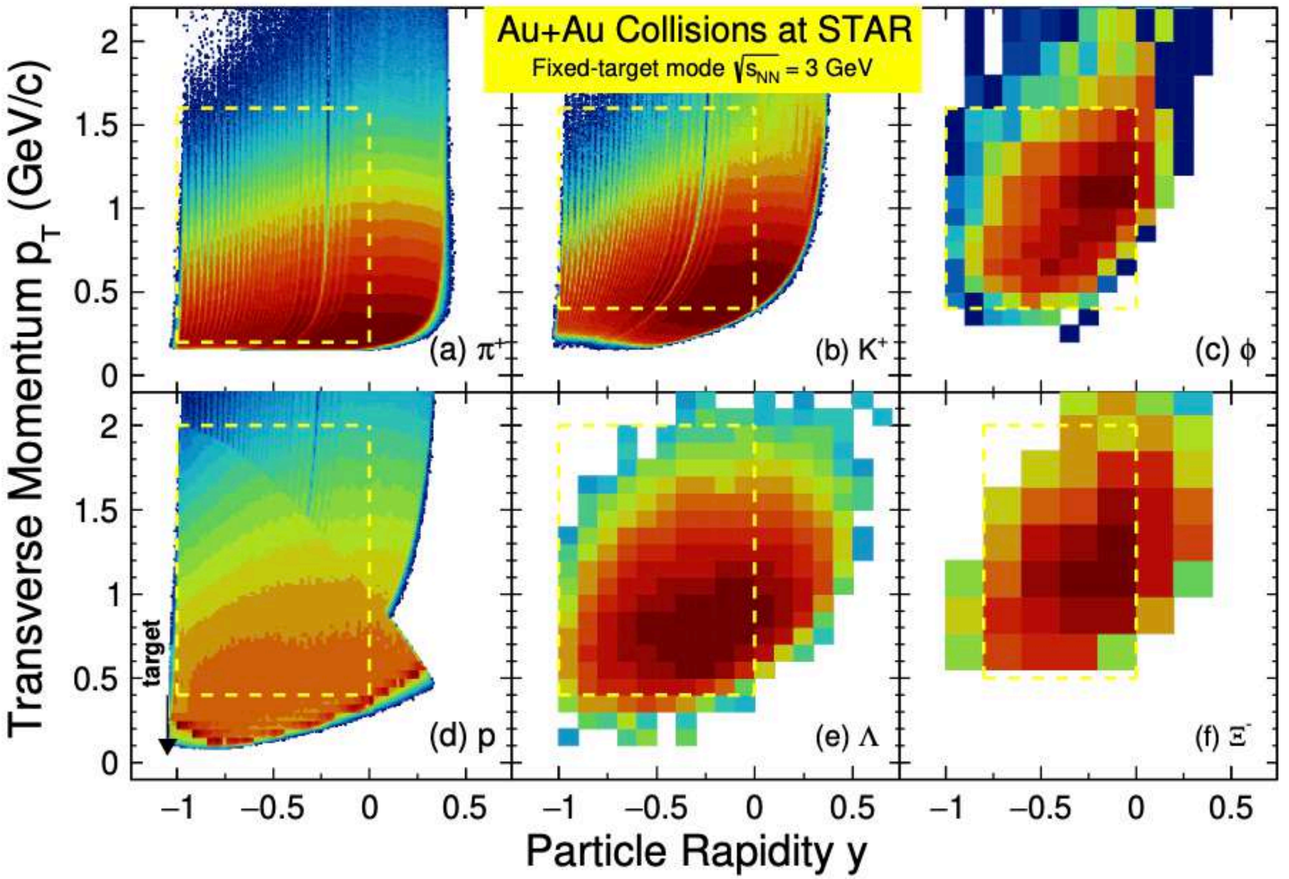
Particle reconstruction

STAR Au+Au @ 3 GeV



- **ϕ mesons are reconstructed in K^+K^- channel**
  - Background is obtained by using mixed-event technique
- **K^0_S, Λ and Ξ^- are reconstructed in $\pi^+\pi^-$, $p\pi^-$ and $\Lambda\pi^-$ channels respectively using KF particle package, good purity and efficiency is achieved**
  - Background is obtained by rotating daughter tracks

Particle acceptance



- **The acceptance plot measured from STAR at 3 GeV (TPC and TOF) for $\pi, K, p, K^0_S, \Lambda, \phi$ and Ξ^-**
  - Good mid-rapidity coverage

arXiv:2108.00908v1

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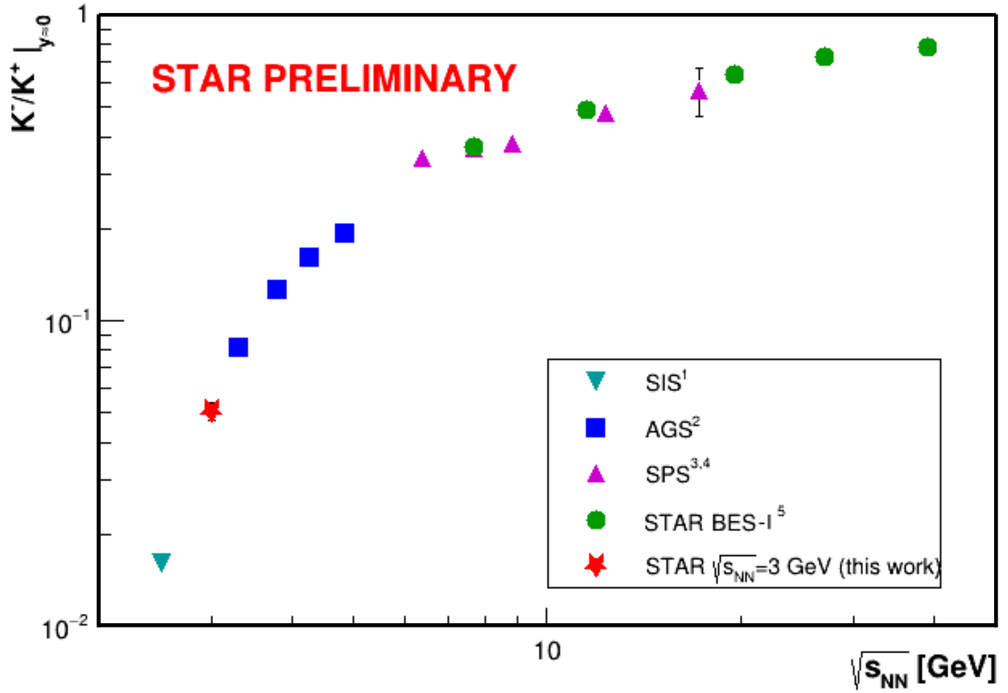
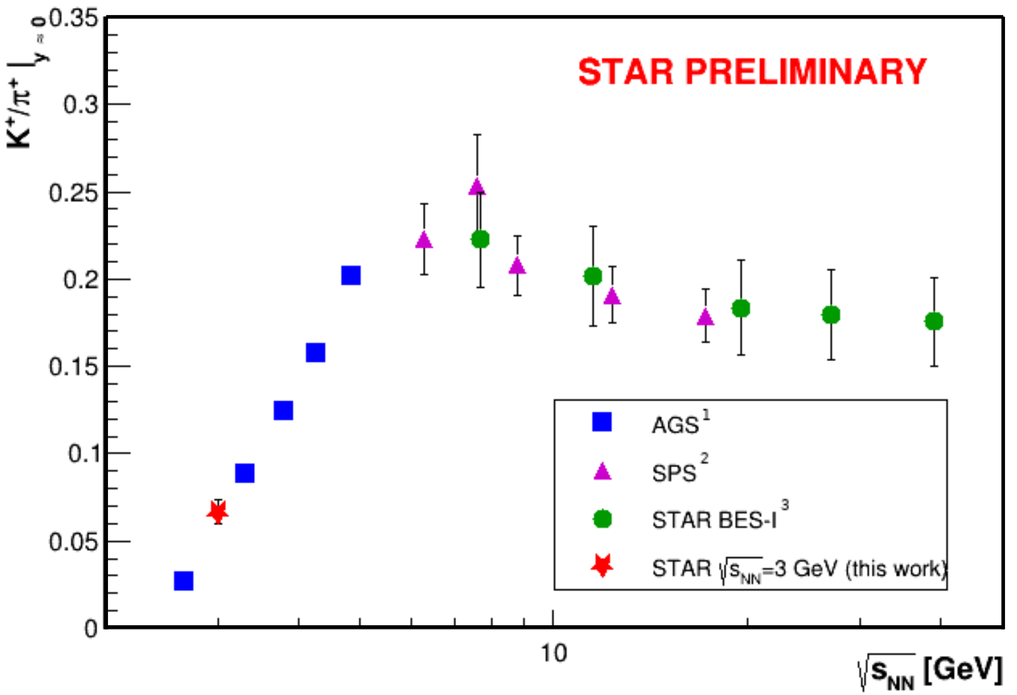
K^-/K^+ and K^+/π^+ ratio

Beam energy dependence of strangeness production

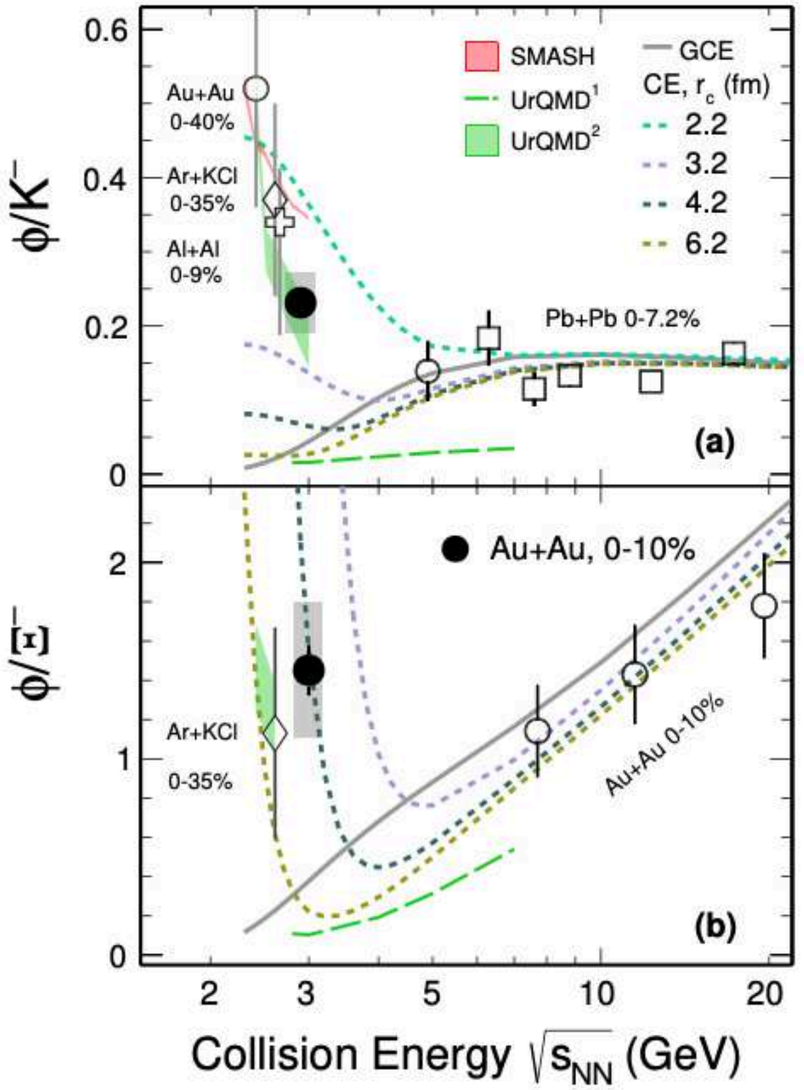




- K^-/K^+ ratio shows importance of K^+ production in association with the Λ $(N + N \rightarrow N + \Lambda + K)$
- K^+/π^+ ratio proposed by NA49 as a possible signal of onset of deconfinement. Statistical model describes the data
- Results at $\sqrt{s_{\mathrm{NN}}} = 3.0$ GeV follow the world trend

KaoS, J. Phys. G 28, 2011 (2002)
E866/E917, Phys. Lett. B490, 53 (2000)
NA49, Phys. Rev. C 77, 024903 (2008)
NA49, Phys. Rev. C 66, 054902 (2002)
STAR, Phys. Rev. C 96, 044904 (2017)
E866/E917, Phys. Lett. B476, 1 (2000)
A. Andronic et al., Phys. Lett. B, 673, 142 (2009)

ϕ/K^- and ϕ/Ξ^- ratio



- Grand canonical ensemble (GCE) and canonical ensemble (CE) calculations are quite different at low energy
- ϕ/K^- and ϕ/Ξ^- ratios favor CE treatment for strangeness and a small strangeness correlation length parameter, r_c, in 0–10% central Au+Au collisions
- The transport models including the resonance decays can reasonably describe both our measured ϕ/K^- ratio result at this energy and the trend of ϕ/Ξ^- at lower energies
- Suggest a significant change in the strangeness production at $\sqrt{s_{NN}}$ = 3 GeV compared to higher collision energies, indicating a change of EoS

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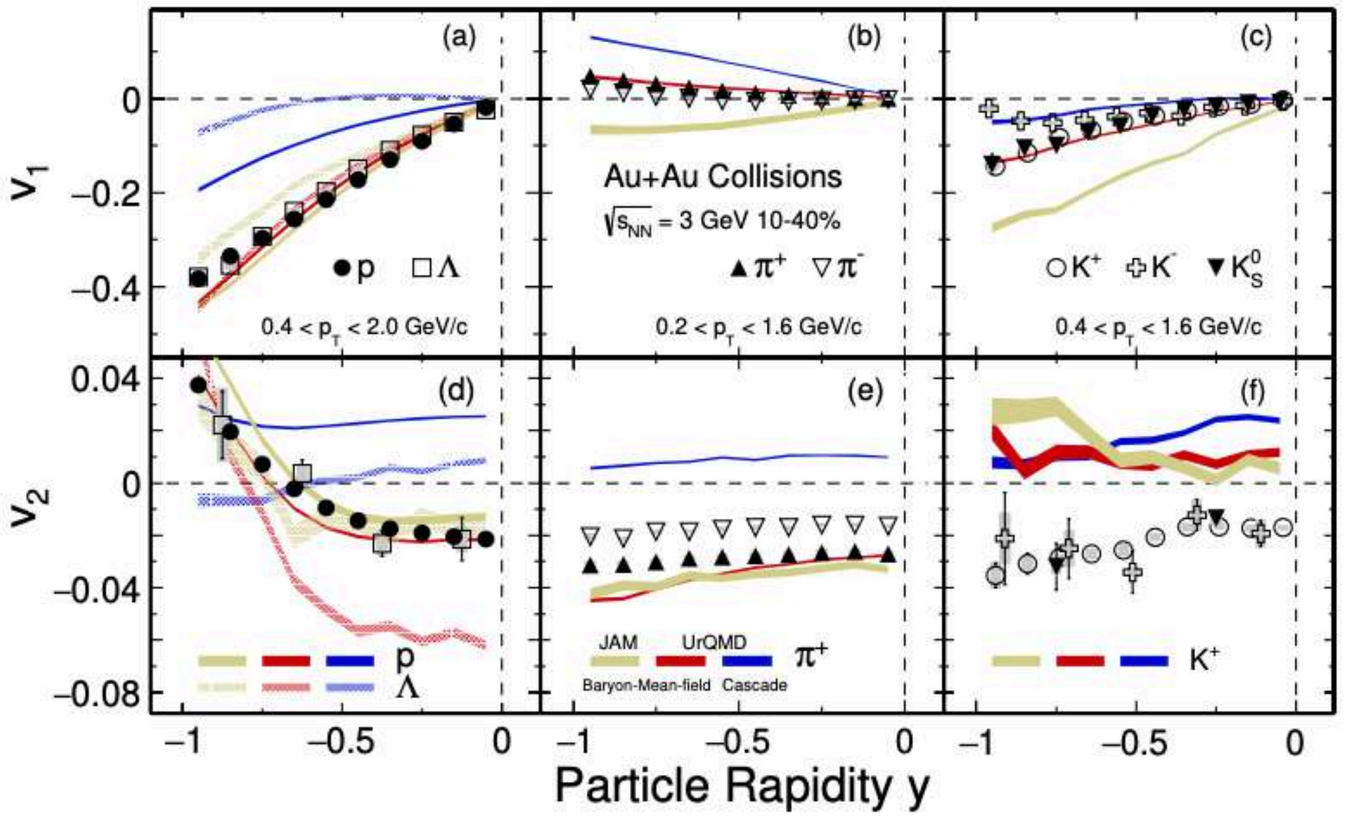
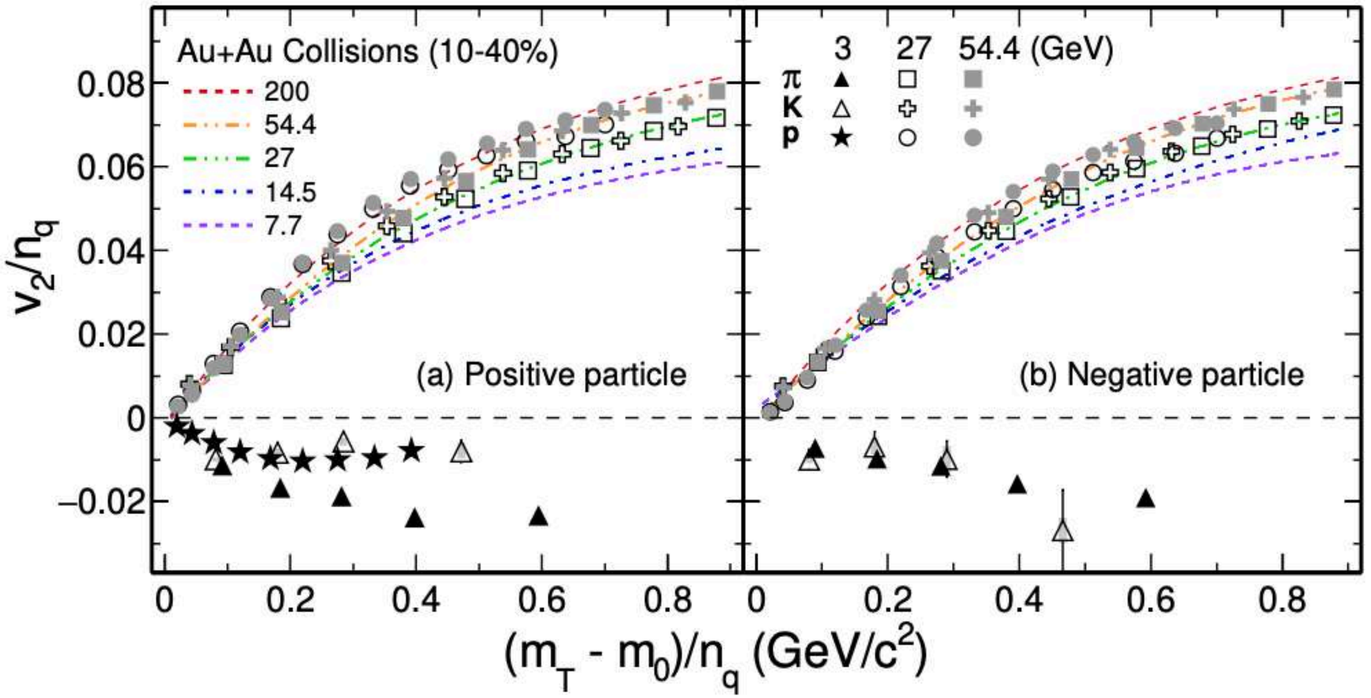
Rapidity dependence of v_1 and v_2



- The strength of the rapidity dependence of v_1 is proportional to the hadron mass
- All of the measured mid-rapidity ($|y| \leq 0.5$) hadrons show negative values of v_2
- The JAM and UrQMD calculations with baryonic mean-field potential qualitatively describe the data indicating hadronic dof dominates

arXiv:2108.00908v1

v_2 scaling properties



- The number of constituent quark (NCQ) scaling for v_2 holds down to 7.7 GeV Au+Au Collisions
  - different color dash line is the fit to data from 200 GeV - 7.7 GeV
  - consistent with the nature of partonic collectivity
- At 3 GeV, the measured v_2 for all particles are negative and the NCQ scaling breaks, especially for positive charged particles

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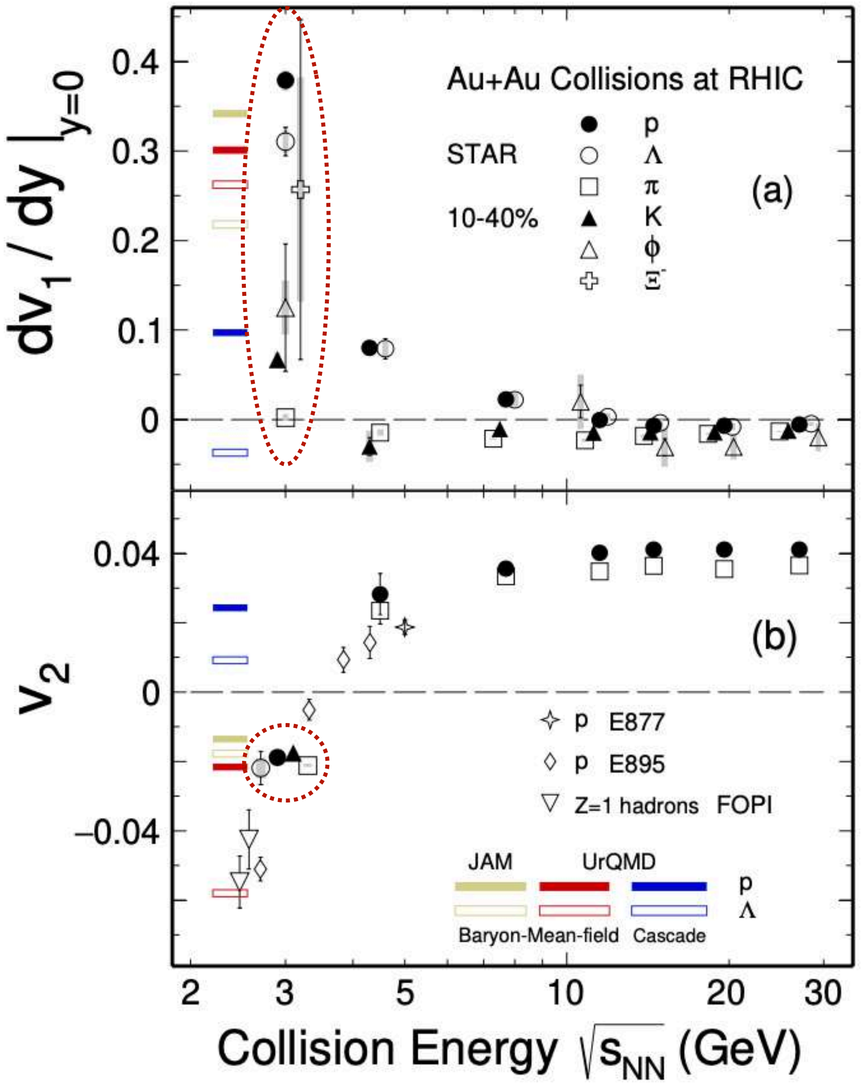
Energy dependence of v_1 and v_2



- Positive v_1 slope and negative v_2 for all measured particles in 3 GeV collisions. Opposite collective behaviors with that in high energy collisions
- Positive v_1 slope observed for kaons and ϕ-meson for the first time
- Results from JAM and UrQMD with baryonic mean-field potential qualitatively describe the measurement at 3GeV
- EoS dominated by the baryonic interactions at 3 GeV

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Summary

- Light and strangeness production in Au+Au 3 GeV collisions
  - Particle production mechanism may differ from that at high energy
  - ϕ/K^- and ϕ/Ξ^- show strong effect of canonical suppression, indicating a change of EoS
- Collectivity measurements in Au+Au 3 GeV collisions
  - The EoS dominated by baryonic interactions

➡ Hadronic interactions dominates the EOS in Au+Au collisions at 3 GeV!

Outlook
- Global thermal fit together with all other particles at 3 GeV on the way (T_{ch}, T_{kin}, μ_B)
- More than 2 billions events of 3 GeV Au+Au collisions have been collected. That will allow us to
  - Extract parameters of EOS
  - Analyze baryon correlation functions
  - Study di-electron pair productions in high baryon environment
  - Analyze hyper-nuclei production and collectivity
  - and more …

Backup