Directed Flow of Identified Particles in Au+Au Collisions at $\sqrt{s_{NN}}$ = 19.6 GeV

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Abstract

Determination of equation of state for nuclear matter at high baryon density region is one of the most important motivations for RHIC Beam Energy Scan program. Directed flow (v_1), which is the first harmonic coefficient in the Fourier expansion of the final state azimuthal distribution of produced particles relative to the collision reaction plane, is one of good probes to early stage of collision dynamics for its high sensitivity. STAR Beam Energy Scan program phase I (BES I) covers collision energies from $\sqrt{s_{NN}}$ = 7.7 GeV to 200 GeV. We observed that v_1 slopes ($dv_1/dy|_{y=0}$) at mid-rapidity region for net-proton and net-Λ show a minimum value when collision energy is around $\sqrt{s_{NN}}$ = 10-20 GeV [1]. The slope of ϕ mesons has a hint of sign change between 11.5 and 14.5 GeV [2]. With large statistics from BES II, we will present v_1 results of pions, kaons, protons, and ϕ mesons at $\sqrt{s_{NN}}$ = 19.6 GeV. The corresponding v_1 slopes will be studied as a function of transverse momentum, rapidity and collision centrality. The data will constrain the model calculations and provide important insights on the possible first order QCD phase transition.

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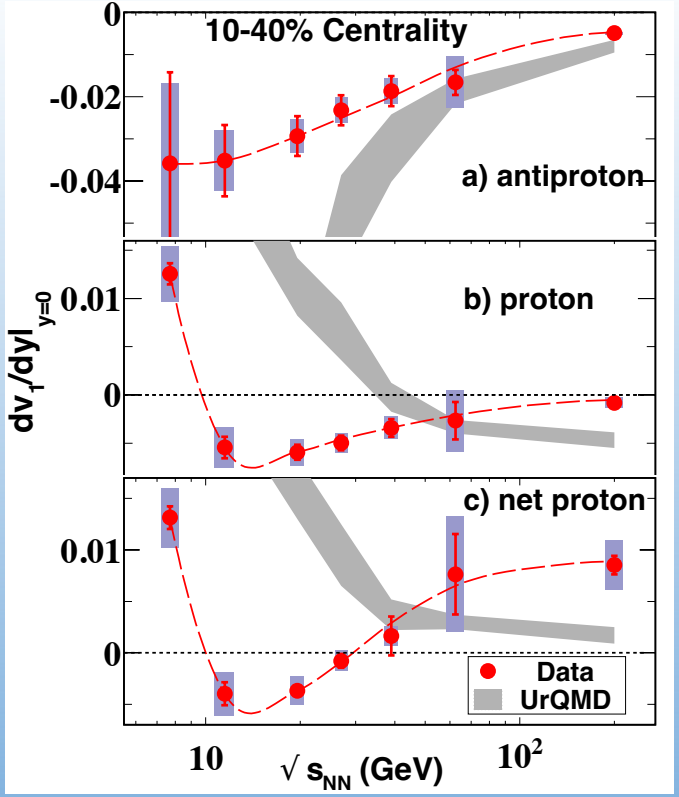
Motivation



- Hydrodynamic calculation with the first-order phase transition motivates the study. v_1 is predicted to be sensitive to the 1st order phase transition.

- The proton and net-proton slope(dv_1/dy) shows a minimum between 11.5 and 19.6 GeV. In addition, the net-proton slope changes sign twice between 7.7 and 39 GeV.
  → EoS softest point?

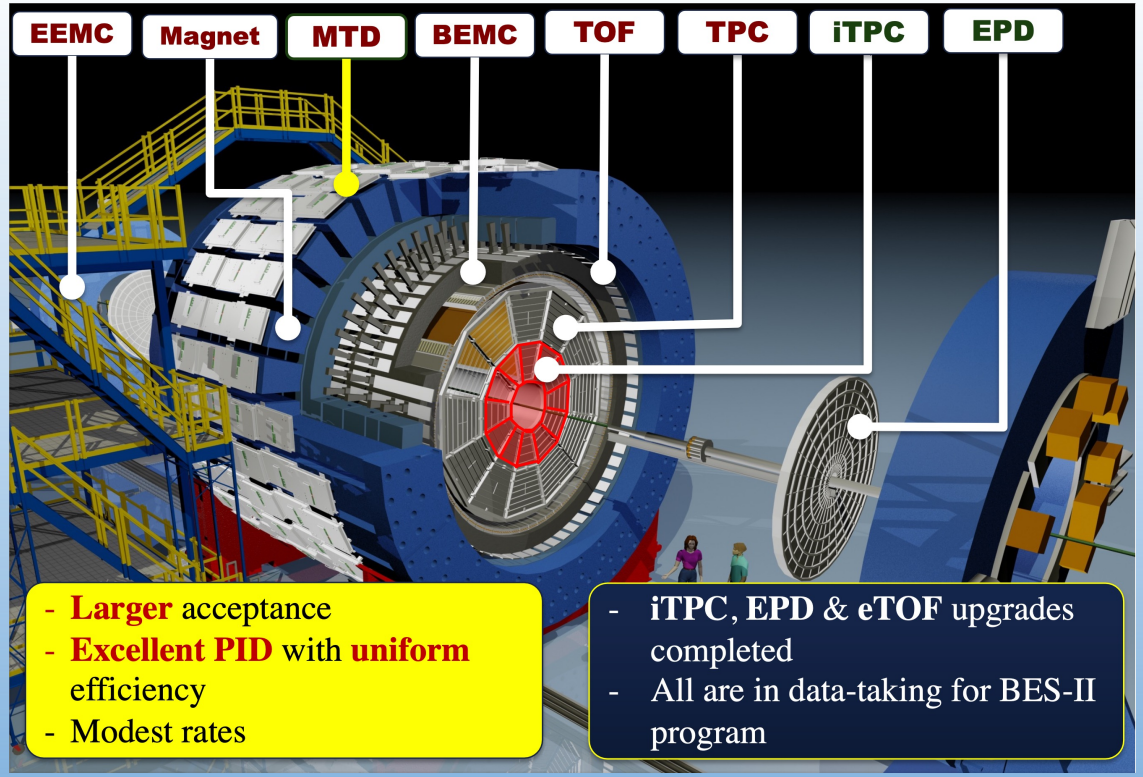
- The UrQMD model can not explain slope trend of net-proton, which shows a monotonic trend, with a positive slope at all energies.

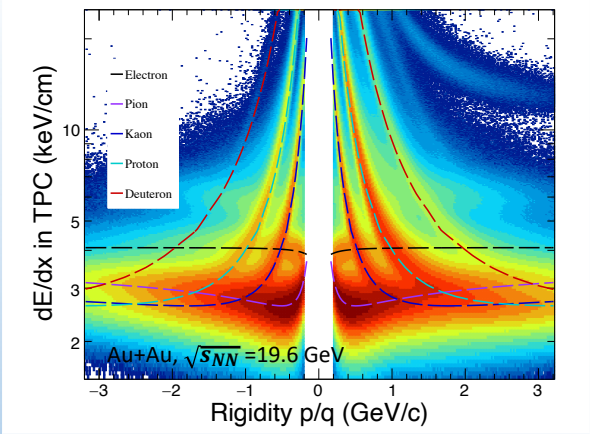
The slope of net-p is based on expressing the y dependence of v_1 for all protons as:

$$[v_1(y)]_p = r(y)[v_1(y)]_{\bar{p}} + [1 - r(y)][v_1(y)]_{\text{net-}p}$$

Where r(y) is the ratio of $\bar{p}$ to p.
Note that v_1(p) and v_1(net-p) converge in the limit of negligible $\bar{p}$ production.

Experiment setup





Solenoidal tracker detectors:

- Time Projection Chamber
  - Charged particle tracking
  - Particle identification
- Time Of Flight
  - Particle identification

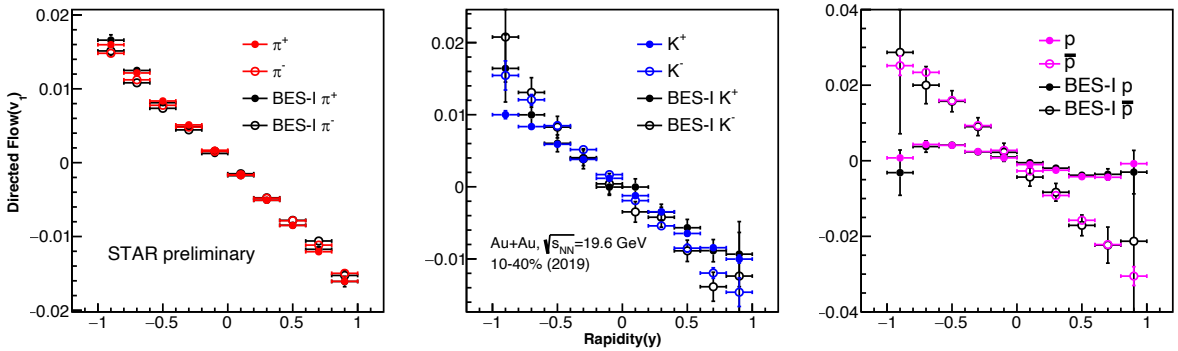
Event plane determination:

- Event Plane Detector
  - $2.1 < |\eta| < 5.1$

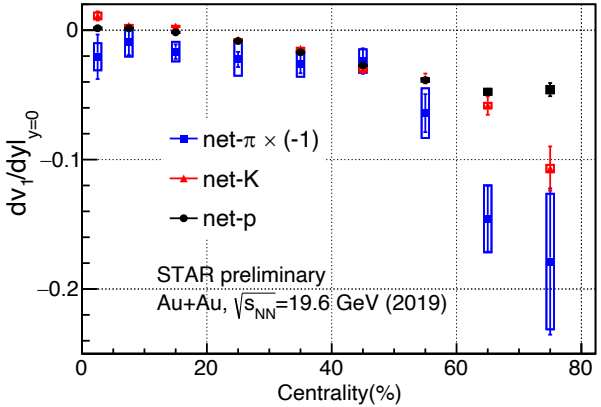
STAR

Results

Rapidity dependence of identified particles v_1 :



Centrality dependence of net-particles v_1 slope:

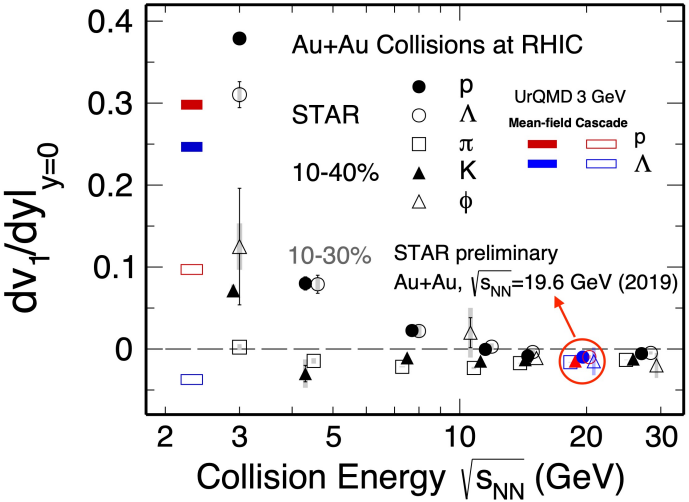


- The statistical error reduced by a factor 8 comparing to BES-I results.
- Larger v_1 slope for net-particles in more peripheral collisions.

Net-pion dv_1/dy is positive at all centralities. To facilitate plotting in the figure opposite, net-pion dv_1/dy is shown with reversed sign.

Summary

Energy dependence of v_1 slope:



- All particles show negative slope at 19.6 GeV, and positive slope at 3 GeV.
- The dominant degrees of freedom at 3 GeV are the interacting hadrons[3], unlike at 19.6 GeV.
- Further study with more BES-II energies could offer more information on the change of equation of state and possible phase transition.

Summary:

- v_1 measurements of identified particles from Au+Au collisions at 19.6 GeV.
- Centrality dependence of net-pion, net-kaon and net-proton v_1 slope.
- Quark degrees of freedom dominate at 19.6 GeV, in contrast to hadrons at lowest BES energy.

Outlook:

- v_1 measurements of more collision energies from BES-II: explore the QCD phase structure.

References:

[1] L. Adamczyk et al.(STAR Collaboration), Phys. Rev. Lett. 112, 162301 (2014).
[2] L. Adamczyk et al.(STAR Collaboration), Phys. Rev. Lett. 120, 062301 (2018).
[3] M. S. Abdallah et al.(STAR Collaboration), Phys. Lett. B 827 137003 (2022).