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

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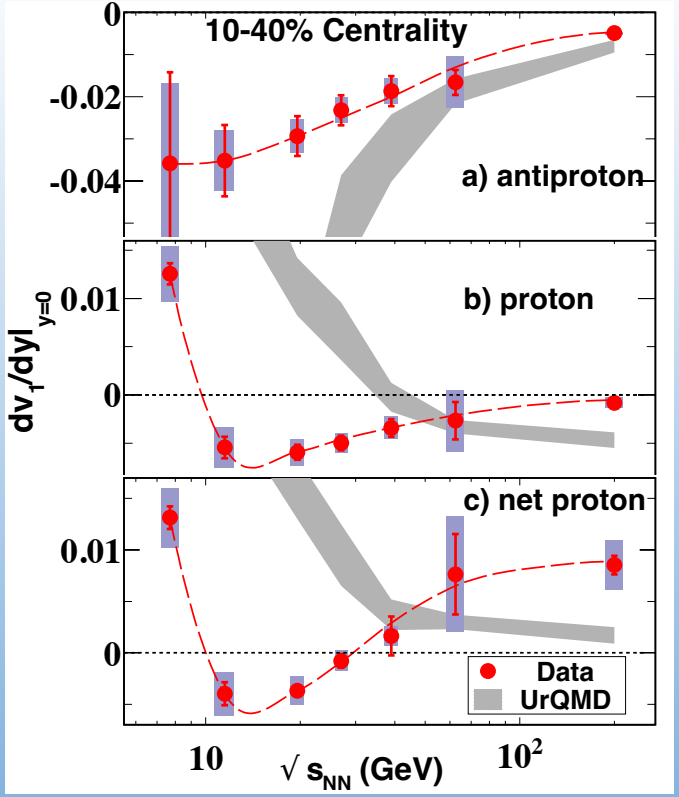
Abstract

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 into the nature of QCD phase transition.

Supported in part by the U.S. DEPARTMENT OF ENERGY Office of Science

Motivation



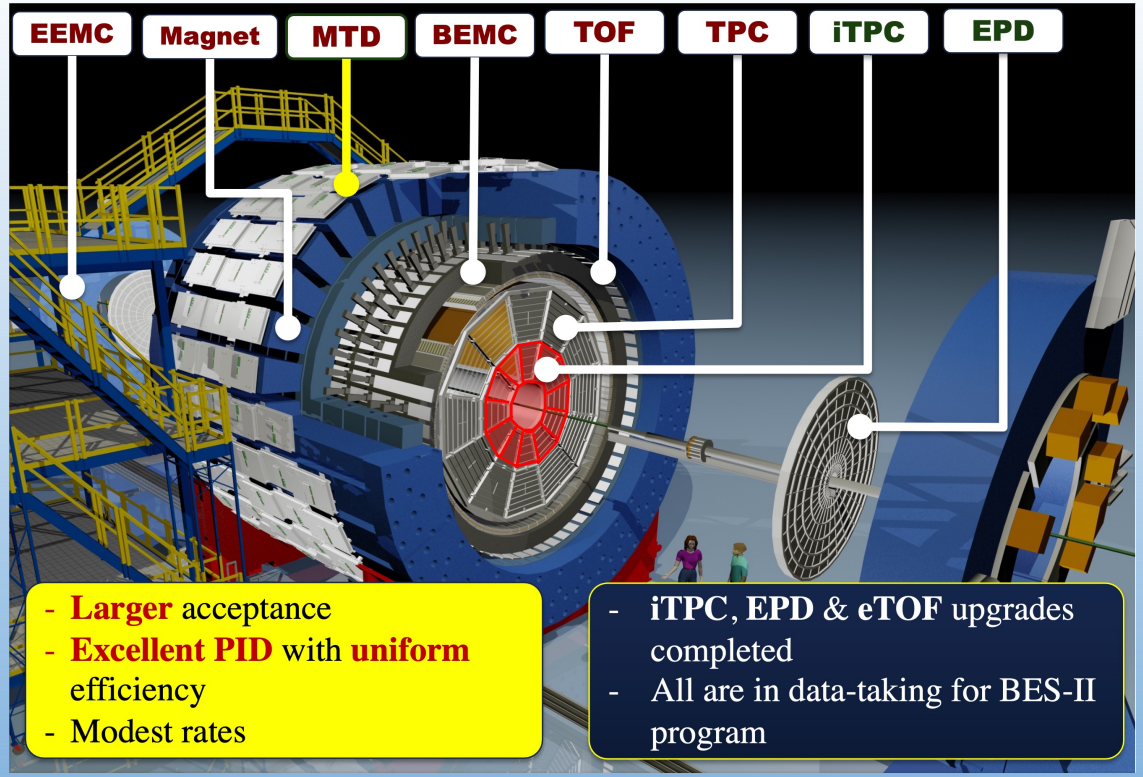
- v_1 is sensitive to the the QCD 1st order phase transition.
- The proton and net-proton show non-monotonic slope(dv_1/dy) as function of collision energy [1].
  - EoS softest point?
  - The UrQMD model can not reproduce the trend.

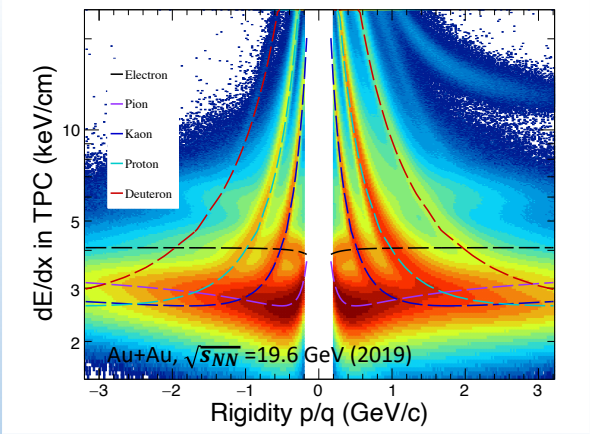
The slope of net-p is based on expressing the y dependence of v_1 for all protons as:

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

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 at lower energy.

Experimental setup





Solenoidal tracker detectors:

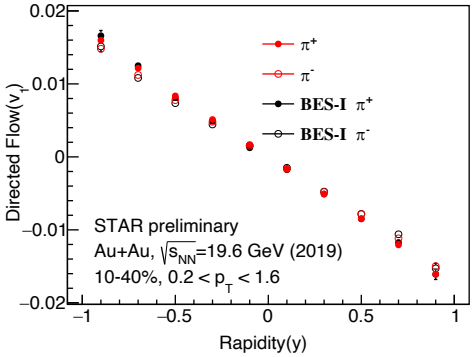
- Time Projection Chamber
  - Charged particle tracking
  - Particle identification
- Time Of Flight
  - Particle identification

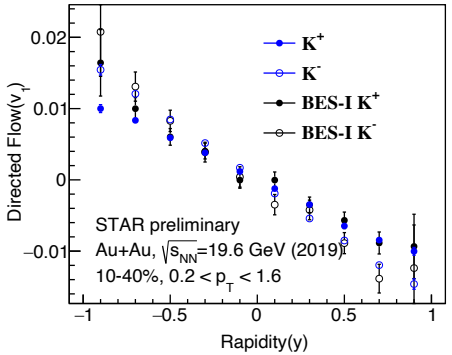
Event plane determination:

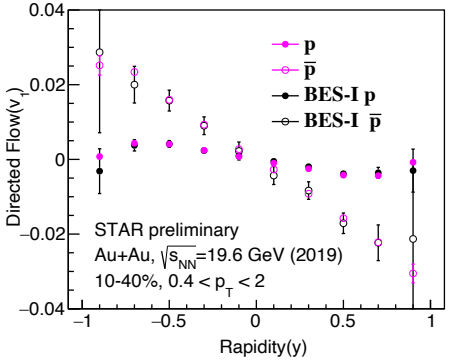
- Event Plane Detector
  - $2.1 < |\eta| < 5.1$

Results

Rapidity dependence of identified particle v_1 :

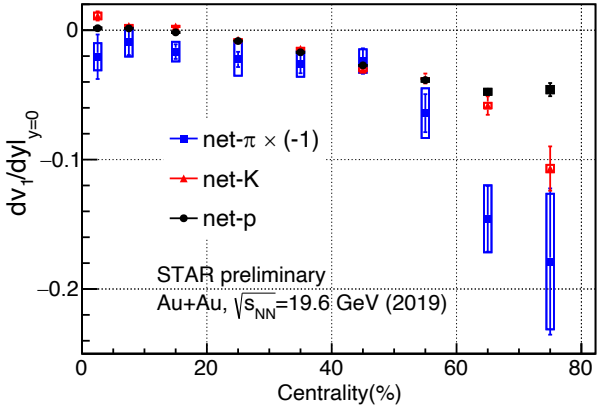






Centrality dependence of net-particles v_1 slope:

Error bar is statistical uncertainties.

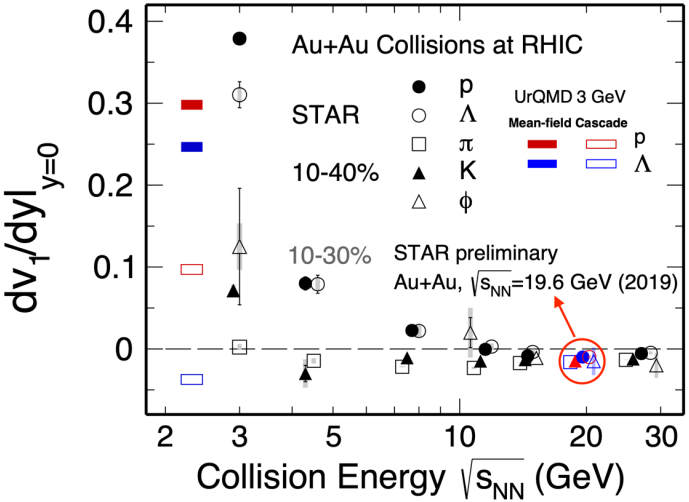


- The statistical uncertainties reduced by a factor 8 comparing to BES-I results, and event plane resolution improved by about 45% than BES-I.
- Larger magnitude of v_1 slope for net-particle in more peripheral collisions.

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 other 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 other 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).