Directed flow of ϕ mesons in Au+Au collisions at the second phase of beam energy scan (BES-II) program from STAR

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Outline

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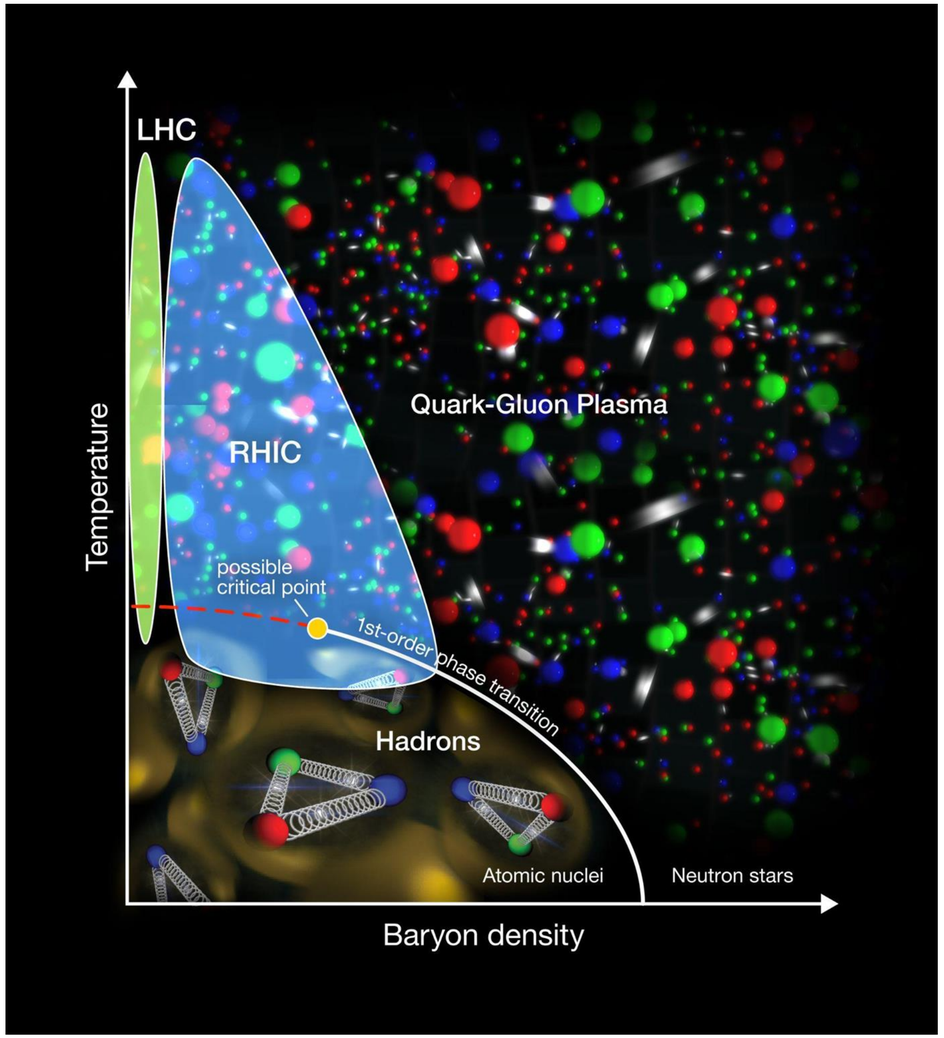
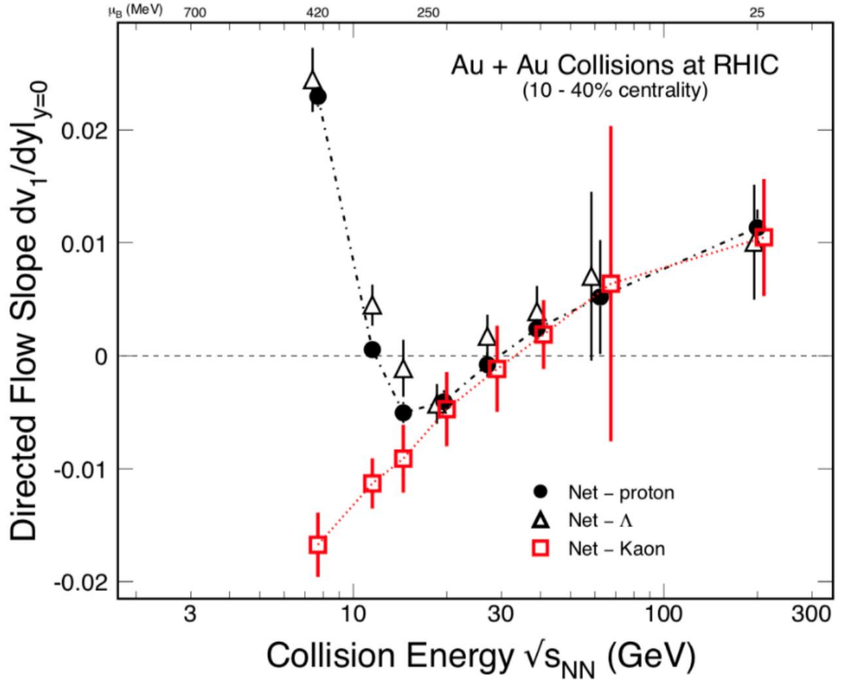
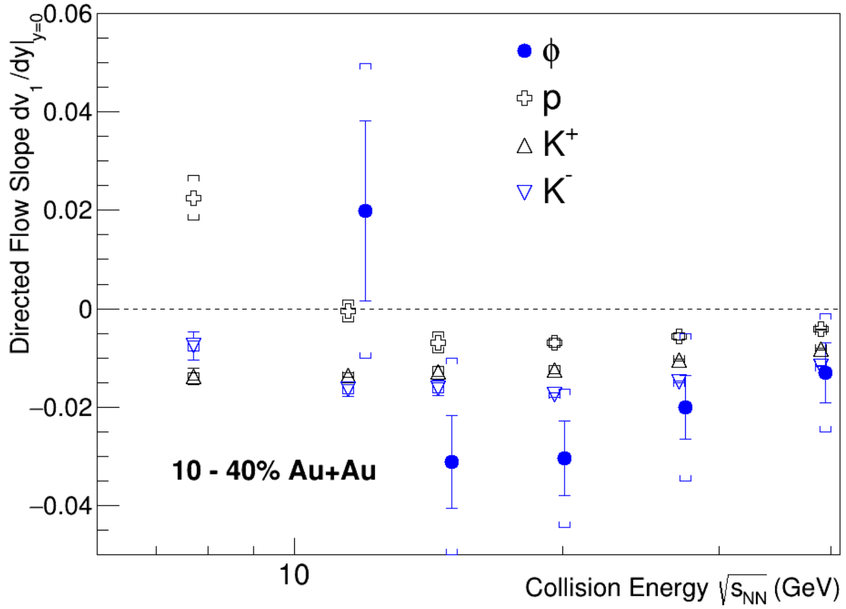


Image Credit: Successful RHIC Run 21 Completes Beam Energy Scan II | BNL Newsroom

Motivation

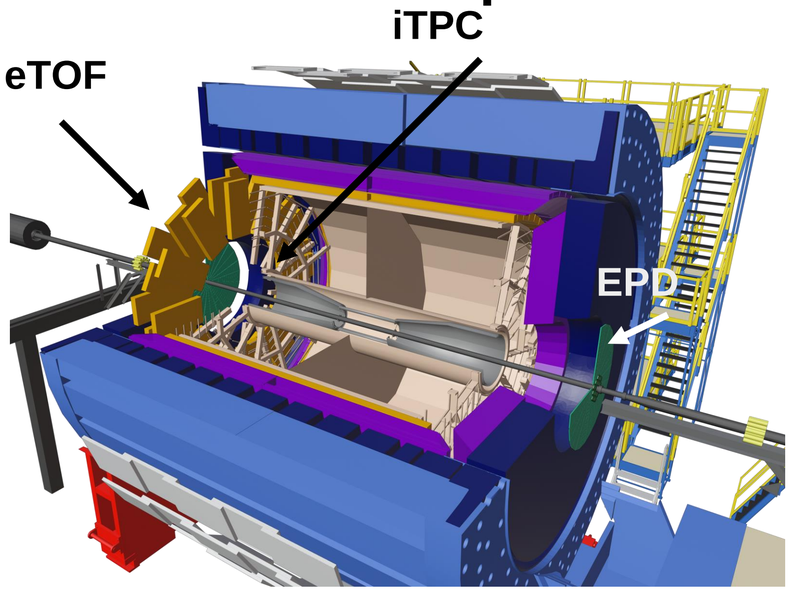
- From the STAR measurements using the first phase of RHIC Beam Energy Scan program (BES-I), the minimum of net-proton and net-Λ dv_1/dy may indicate the softest point of equation of state (EoS)[1].
- The ϕ-meson has small hadronic cross-section - sensitive to the early stages of collisions.
- STAR BES-I measurements also show a hint of sign change of ϕ-meson dv_1/dy around 11.5 GeV, with large uncertainties. What is the origin of sign-change for the ϕ-meson?

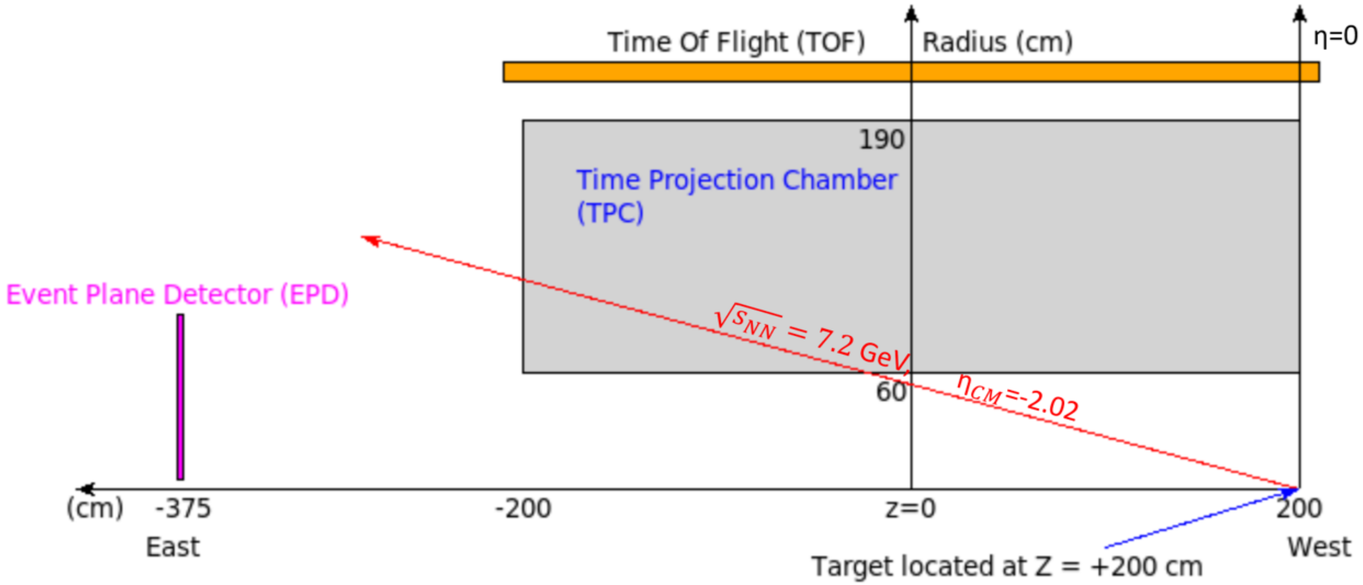




[1] L. Adamczyk et al. (STAR). *Phys. Rev. Lett. 120 062301*

Experiment Setup

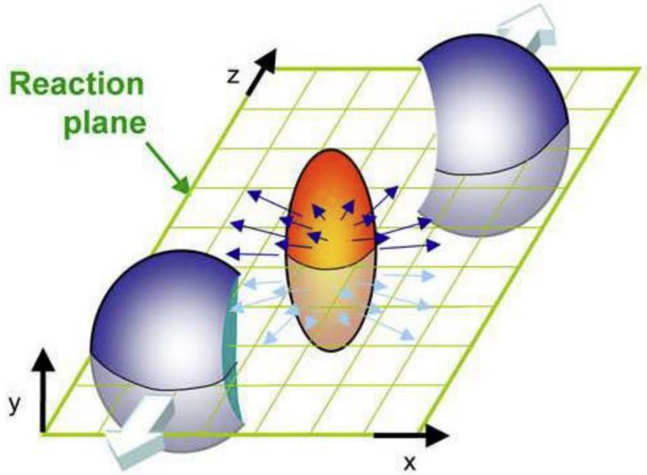


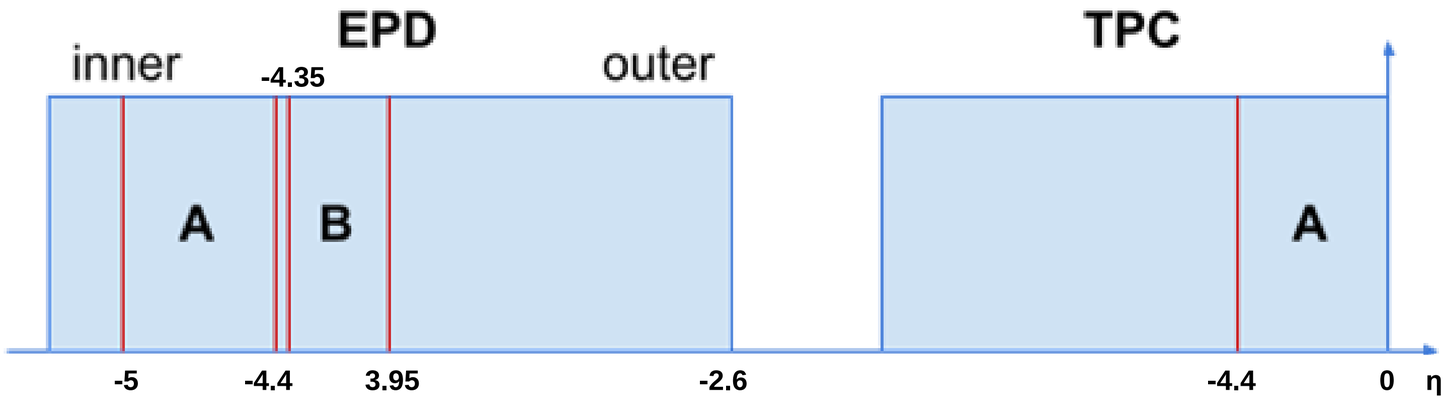


- Fixed-target program (FXT) at STAR enables physicists to scan a range of low collision energies that collider mode (COL) cannot reach ($\sqrt{s_{NN}}$ down to a minimum of 3 GeV)[2].
- In this talk, I will mainly share the details of the measurement in $\sqrt{s_{NN}}$ = 7.2 GeV Au+Au collisions in FXT mode, where the main detectors used are shown in the right-hand side figure.

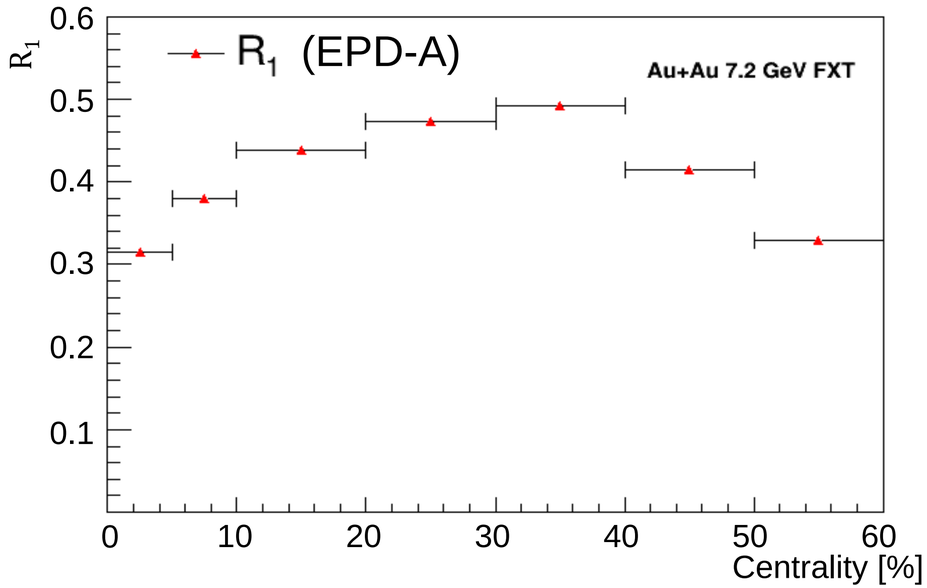
[2]G. Odyniec* for the STAR collaboration, *PoS(CORFU2018)151*

Event Plane Reconstruction





- 1st order event plane Ψ_1 is used to measure the directed flow.
- 3 subevent method is used to calculate the resolution R_1.
  - The η ranges for 3 subevents are [-5.0, -4.4] (EPD-A), [-4.35, -3.95] (EPD-B), [-0.6, 0] (TPC-A) to maximize the resolution of Ψ_1^{EPD-A}, which is used for the directed flow measurement.



Particle Identification

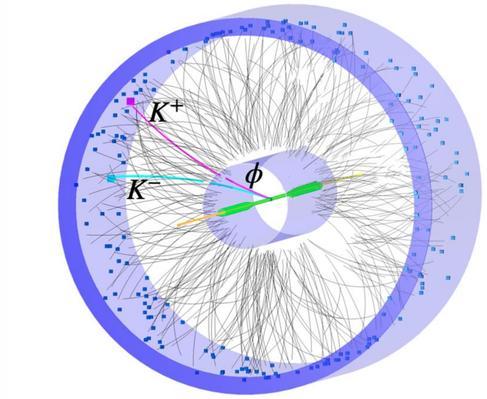
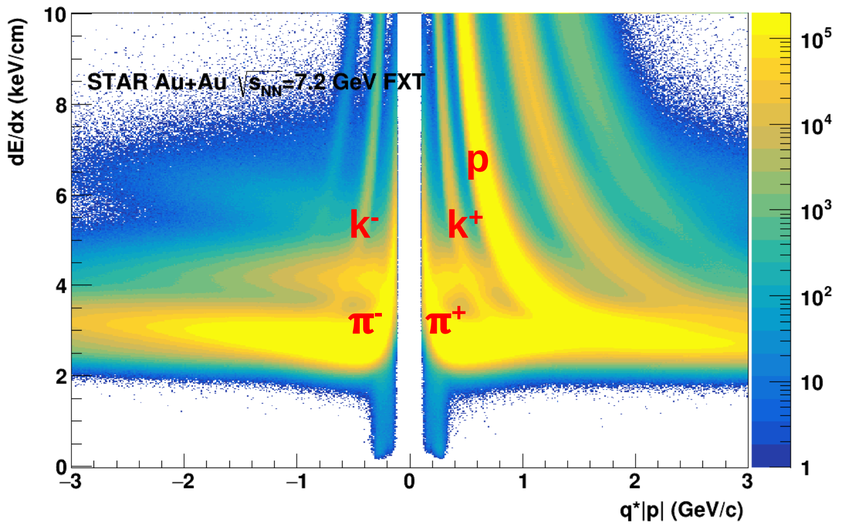
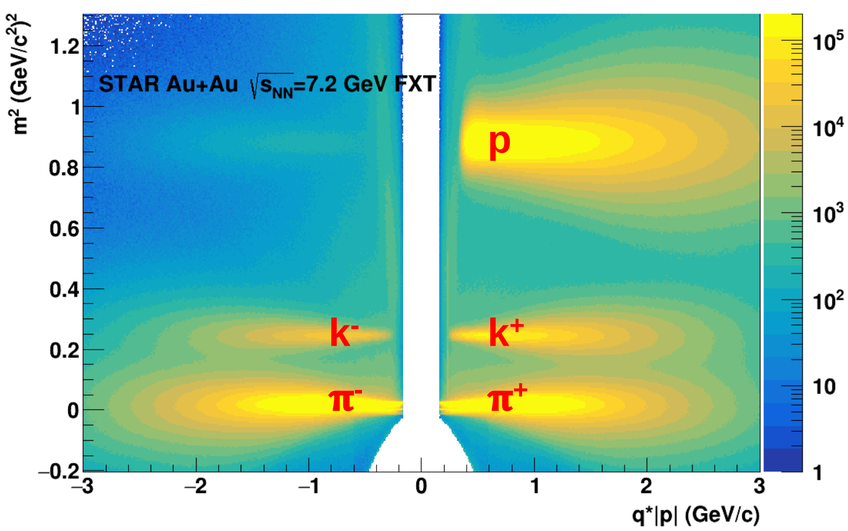
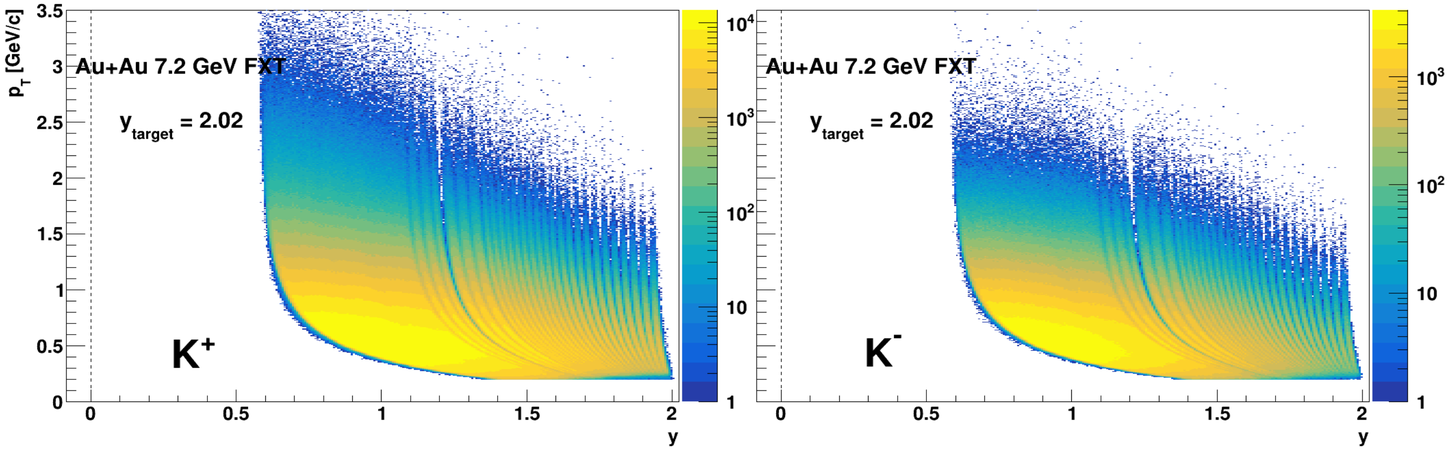


Image Credit: arxiv.org/pdf/2204.02302

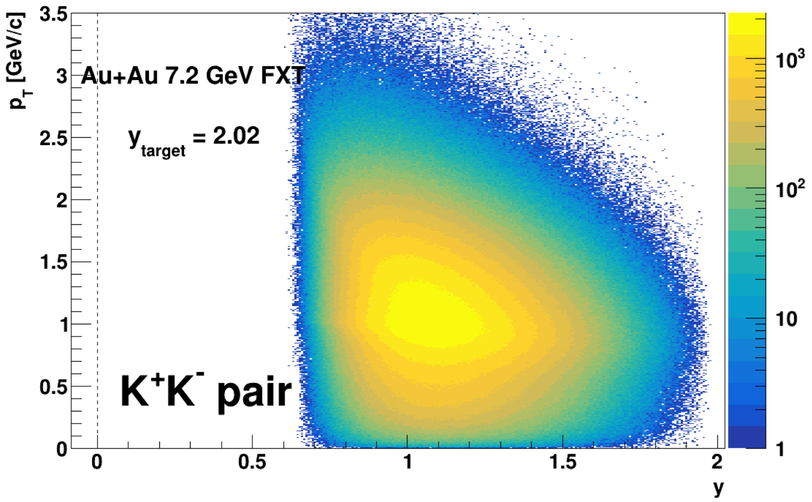




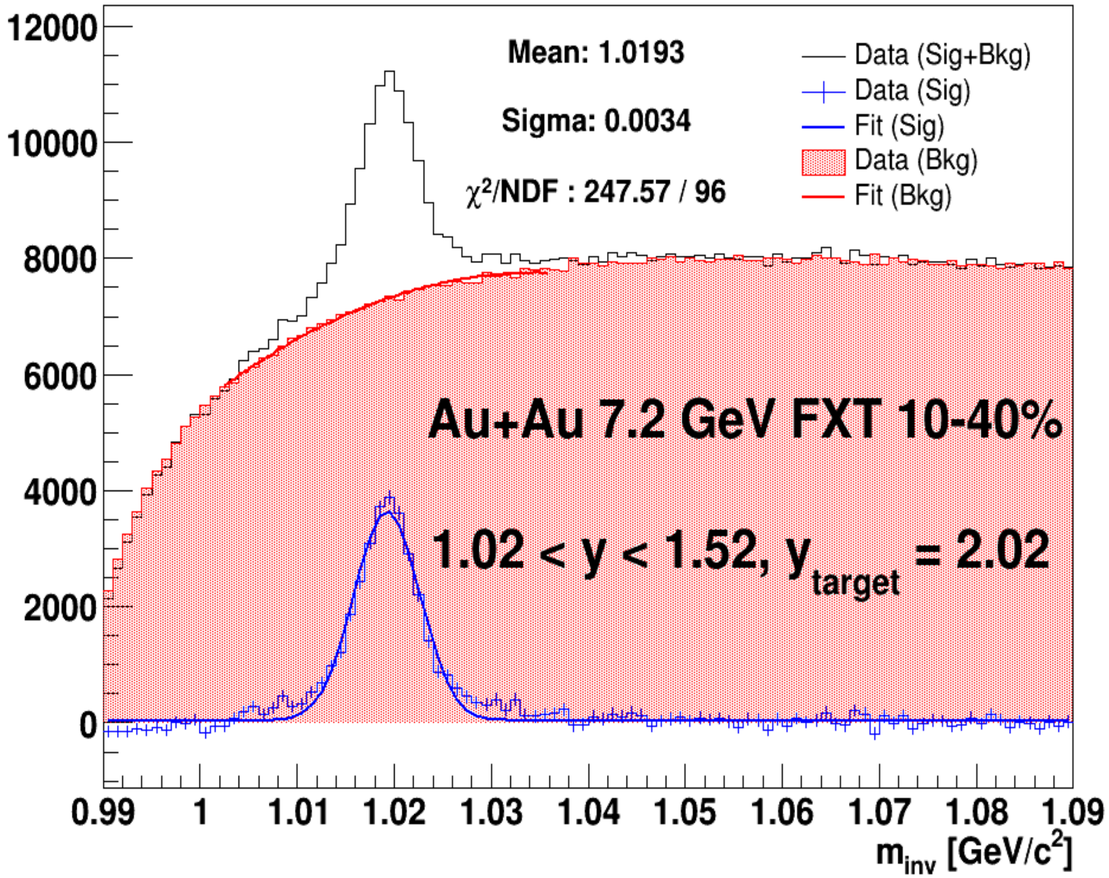


- ϕ mesons are reconstructed by K^+K^- pairs $(49.1 \pm 0.5\%)$, which are identified using dE/dx from TPC and $mass^2$ from TOF.
  - TPC $|n\sigma_{K^\pm}| < 2$
  - $0.16 < mass^2 < 0.32$ $(GeV/c^2)^2$
- Convention used in this analysis:
  $y = y_{Lab} - y_{mid}, y_{mid} = -2.02$

ϕ-meson reconstruction



ϕ-meson mass: $1019.461 \pm 0.016\ \mathrm{MeV}/c^2$

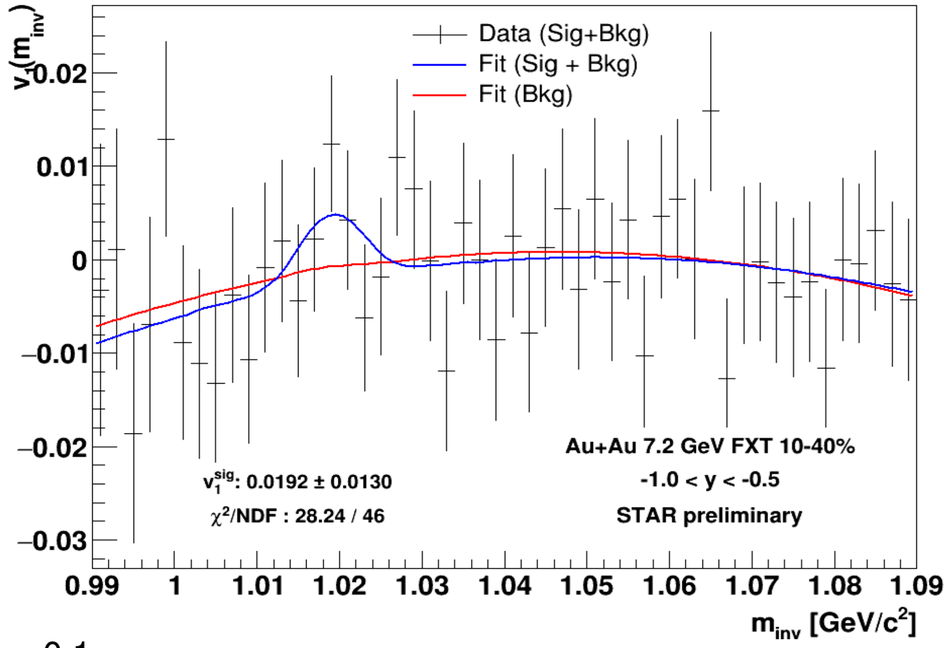


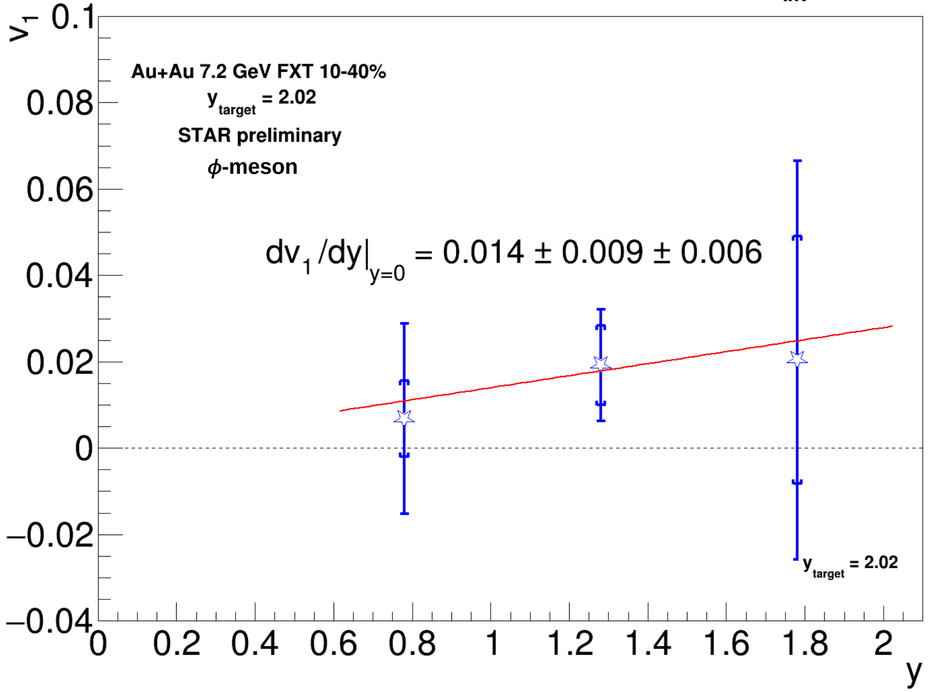
- We compare measurements of K^+K^- pairs from the same event data (Sig+Bkg) and mixed event data (Bkg), subtract Bkg to get ϕ-meson signal
- Fitting Function:
  - Sig : Gaussian + Constant
  - Bkg : 2nd order polynomial

Flow Extraction

- ϕ-meson v_1 is measured by the event plane method using EPD. v_1 corrected for the first-order event plane resolution R_1.
  - Sig + Bkg:
    $Y_R v_1^{Sig}(m_{inv}) + (1 - Y_R) v_1^{Bkg}(m_{inv})$
  - Bkg : $(1 - Y_R) v_1^{Bkg}(m_{inv})$
  - $Y_R = \frac{Yields(Sig)}{Yields(Sig)+Yields(Bkg)}$
  - v_1^{Bkg}: Estimated with 2^{nd} order polynomial

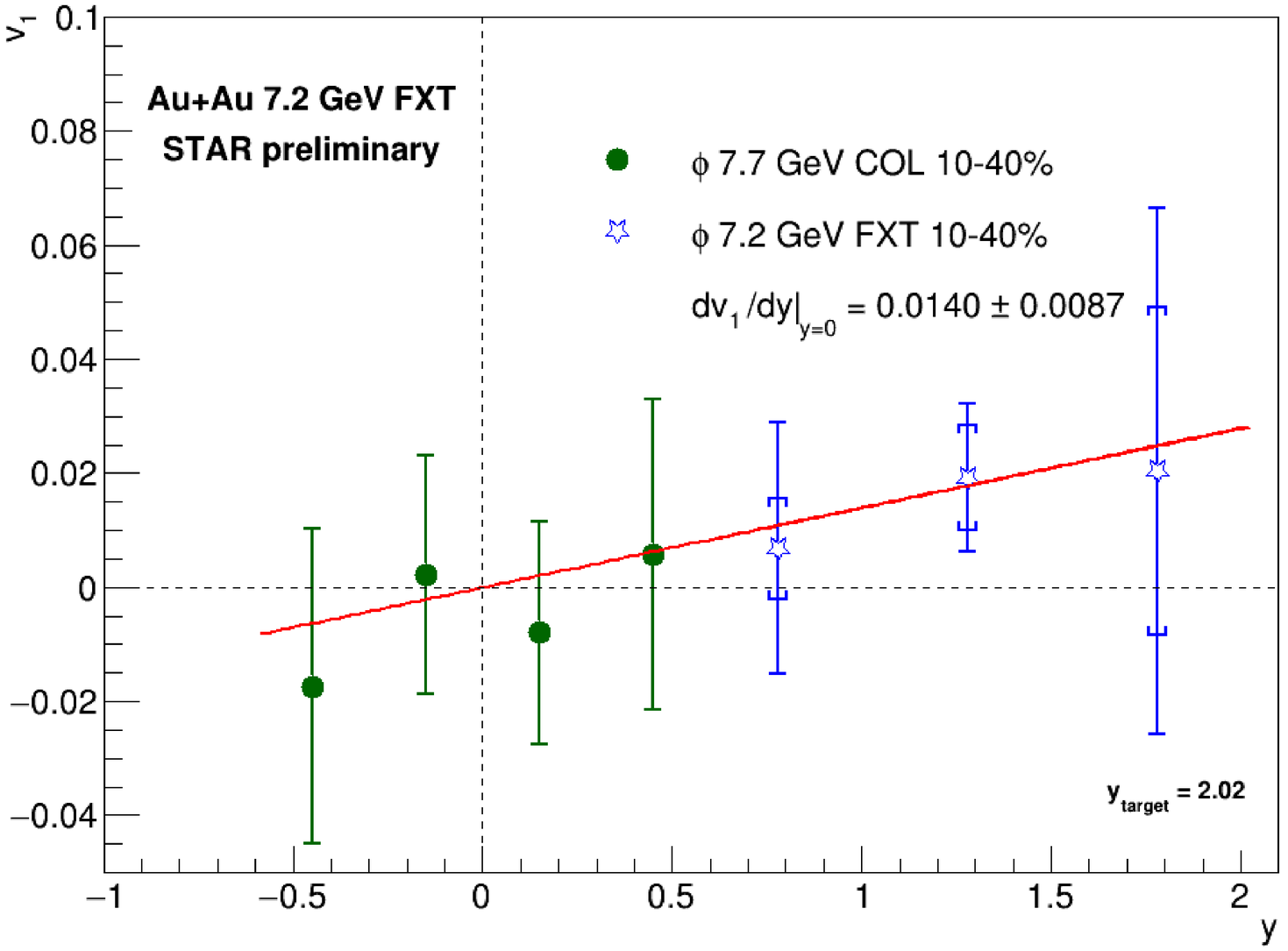
- Fitting function $f(y) = p_1 y$ is constrained to pass through the origin, where p_1 is the slope dv_1/dy.





Flow Extraction

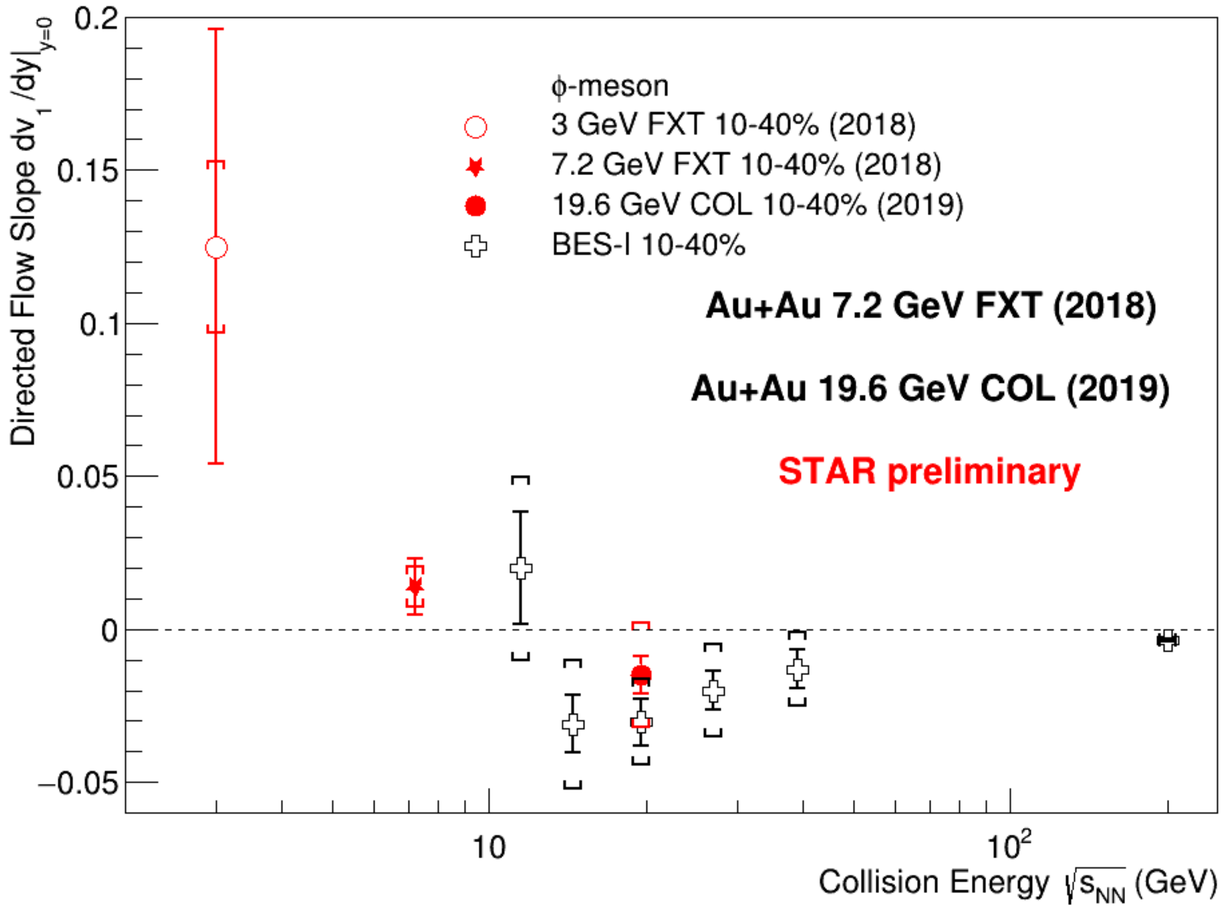
- Plot collider mode (COL) 7.7 GeV[1] and FXT 7.2 GeV ϕ-meson v_1 together.
- It shows good agreement between COL and FXT modes.
- FXT mode provides a wider lever arm in rapidity & improve the linear fit.



[1] L. Adamczyk et al. (STAR). *Phys. Rev. Lett. 120 062301*

Results and Summary

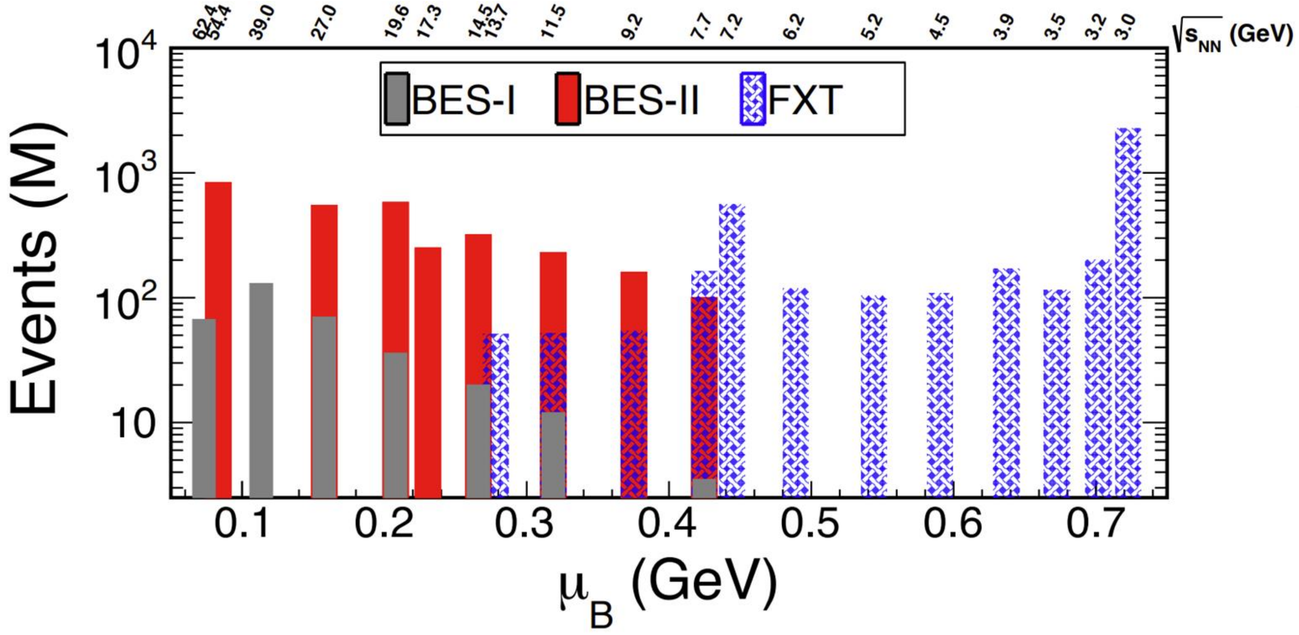
- As the collision energy decreases the $dv_1/dy|_{y=0}$ of ϕ-meson shows indication of sign change from negative to positive, with improved precision compared to the BES-I data.



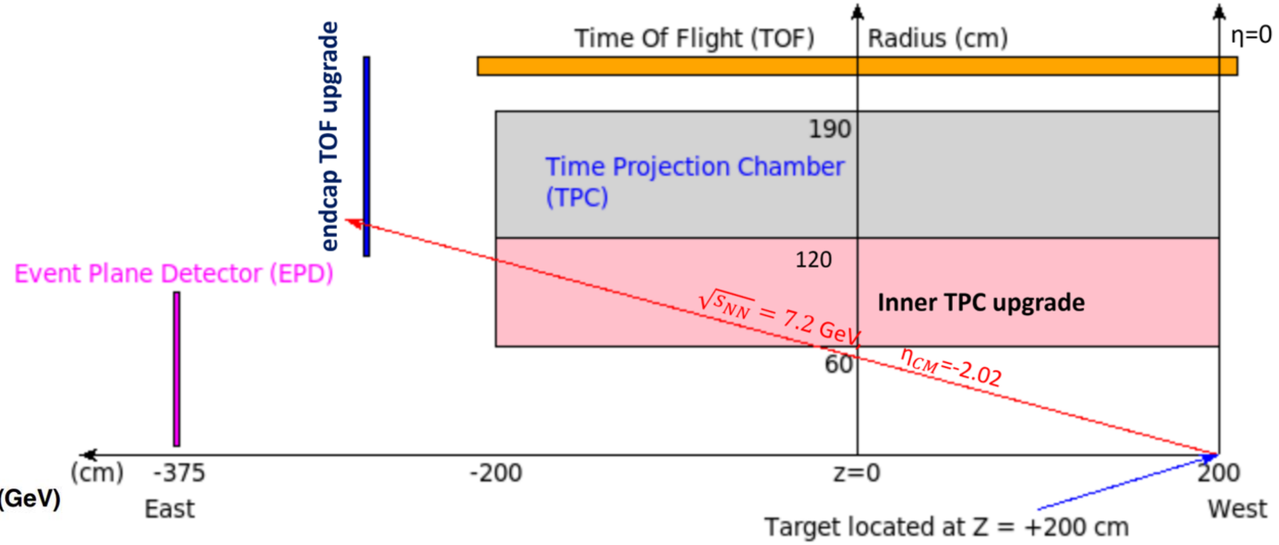
- The $dv_1/dy|_{y=0}$ of ϕ-meson at intermediate centrality (10-40%) shows sign turning positive around 10 GeV in Au+Au collisions.
- Results from fixed target and collider modes connect well in rapidity. At same collision energy, combining measurements from both FXT and COL modes can improve the flow measurements.
- A precise measurement of the ϕ-meson v_1 around $\sqrt{s_{NN}} = 10$ GeV will help probe the v_1 slope sign change, using more BES-II FXT data.

Outlook

- More FXT & COL datasets with upgraded detectors from STAR are in production, which will help to map out the trend of ϕ-meson flows at 3 - 19.6 GeV



P.Tribedy, STAR Highlights, Quark Matter 2022



- Datasets taken with eTOF and iTPC having PID coverage at mid-rapidity are in production and being analyzed now.