Measurement of path-length-dependent v_1 of high-p_T charged hadrons in Au+Au collisions by the STAR experiment

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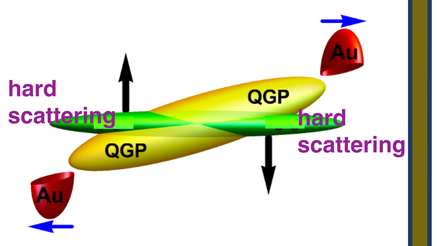
Abstract

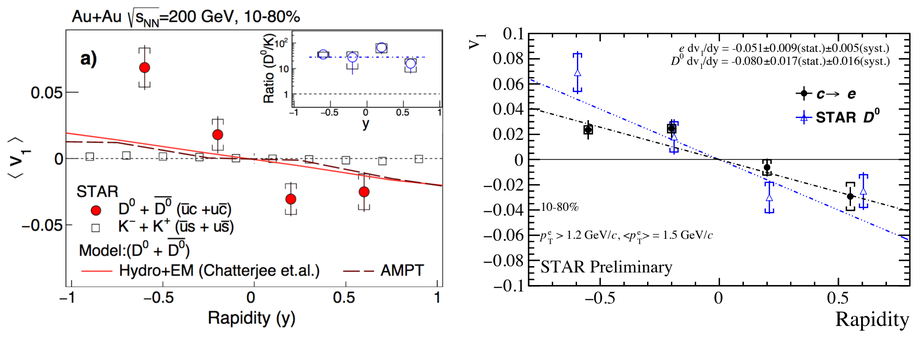
In heavy-ion collisions, the thermalized matter is tilted in the reaction plane as a function of rapidity, while the production profile of partons from hard scatterings is symmetric in rapidity [1,2]. This leads to a rapidity-odd asymmetry in medium path length traversed by the hard partons and results in a rapidity-odd directed flow (v1). Measurements of high-p_T hadron v_1 can provide valuable constraints on the initial longitudinal distribution of the fireball as well as the path-length-dependent momentum loss of the partons. A similar effect, producing significantly large directed flow for heavy flavor mesons, was predicted [3] and has been observed for D^0 mesons (at 3.4σ significance) by STAR [4] recently. In this poster, we present the first measurement of pseudorapidity and centrality dependence of the v_1 of high-p_T (>5 GeV/c) charged hadrons in Au+Au collisions at 200 GeV. The v_1 of charged hadrons change sign twice as a function of p_T and show large negative slope at high-p_T, similarly to D^0 mesons. The initial hard-soft asymmetry from the AMPT model calculations is found to show a similar centrality dependence as the v_1 of high p_T charged hadrons measured in data.

Introduction

- QGP bulk is tilted in rapidity, but hard scattering profile is symmetric
  - ➡ hard - soft asymmetry in initial state
- Induces (negative) v_1 for hard produced partons [1,2]
- Valuable probe to study path-length-dependent energy loss and initial conditions in longitudinal direction

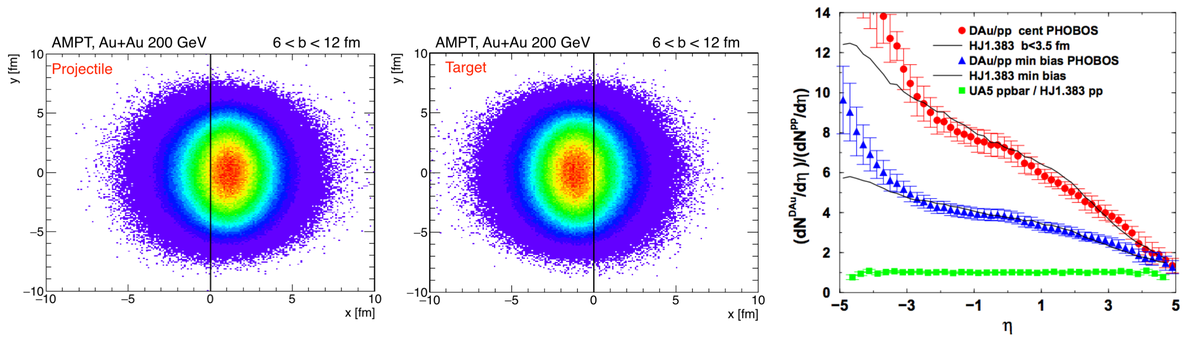


- Similar effect producing large v_1 observed for D^0 [4] and *e* from HF decay



Hard-soft asymmetry in initial state

- Nuclei are diffused, the radial density inside nucleus decreases going outwards (Wood-Saxon profile)
- When two nuclei collide, the participant nucleon distribution has a gradient along impact parameter, with opposite signs for projectile and target



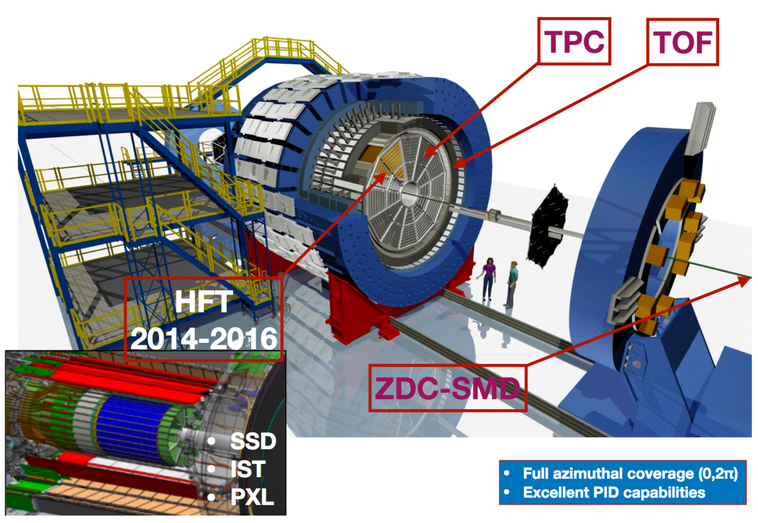
- Forward going participants emit preferentially in forward rapidity (and vice-versa)
- Gives rise to tilt of the initial density distribution in the reaction plane, as a function of rapidity [1]:

$$\epsilon(\tau_0) = \epsilon_0\{2[N_+(x,y)f_+(\eta_{||}) + N_-(x,y)f_-(\eta_{||})](1-\alpha) + 2\alpha N_{bin}(x,y)f(\eta_{||})\}/N_0$$

  N_+ and N_-: participant densities from the two nuclei
  $f_{+/-}$: rapidity asymmetric emission function from participant

- However, production profile of hard partons follow that of N_{binary} collisions and is symmetric in rapidity
- Causes asymmetry in medium path length for hard produced partons and large negative (relative to spectators) v_1

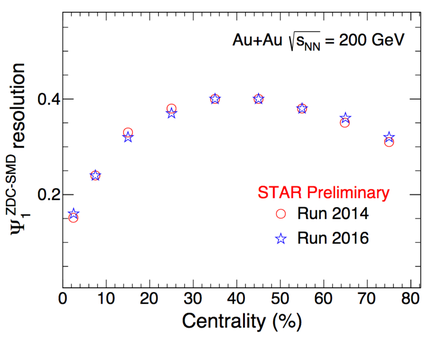
Experiment and Data Analysis



- Excellent tracking capabilities at midrapdity
- Charged tracks reconstructed using hits in Time Projection Chamber (TPC) and Heavy Flavor Tracker (HFT)
- About 2 billion MB events from RHIC runs in 2014 and 2016 are used in the analysis

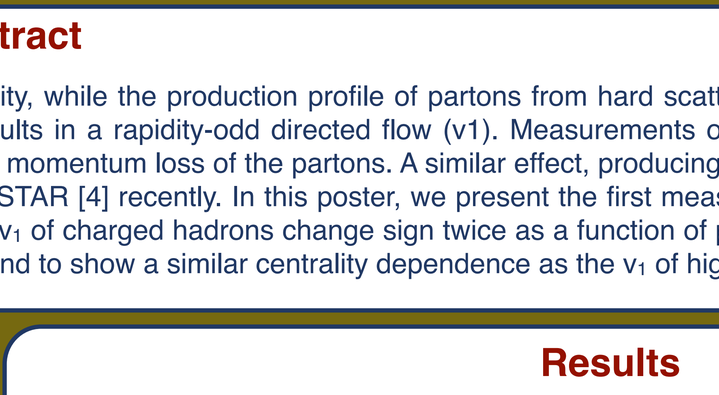
- Directed flow measured relative to the reaction plane (RP) determined from spectator neurtons using ZDC-SMD
- Measured signal corrected for event plane resolution

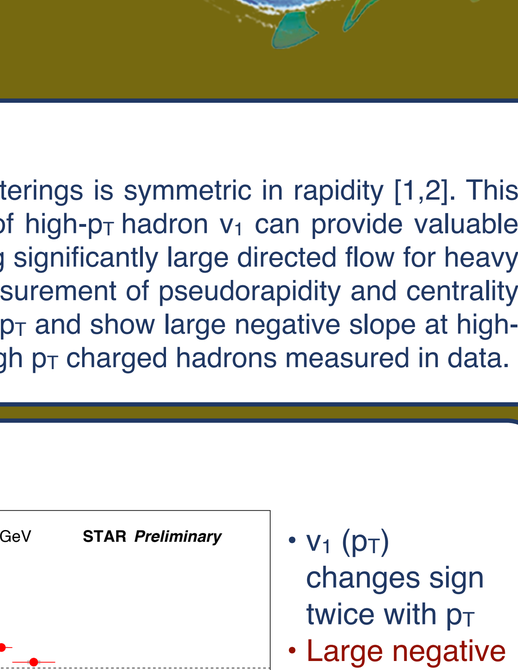
$$v_1 \sim \frac{\langle cos(\phi - \Psi_{1,ZDC})\rangle}{\mathrm{Res}\{\Psi_{1,ZDC}\}}$$

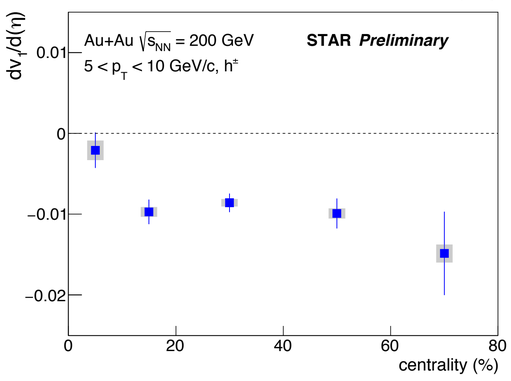


Results

- v_1 (p_T) changes sign twice with p_T
- Large negative v_1 at high p_T, similar to behavior seen for D^0



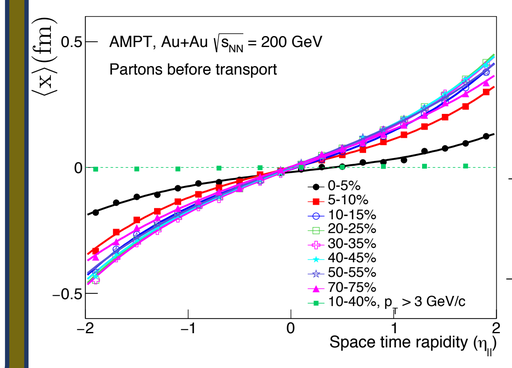


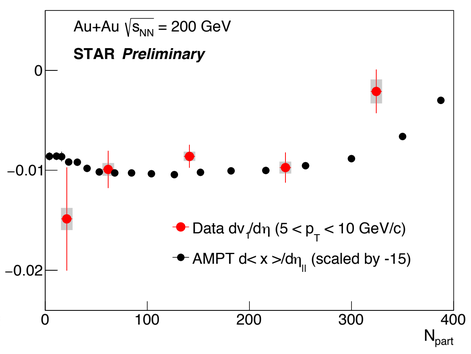


- Slope of $dv_1/d\eta$ shows weak centrality dependence in mid-central collisions
- Close to zero in central collisions where initial asymmetry is expected to be small

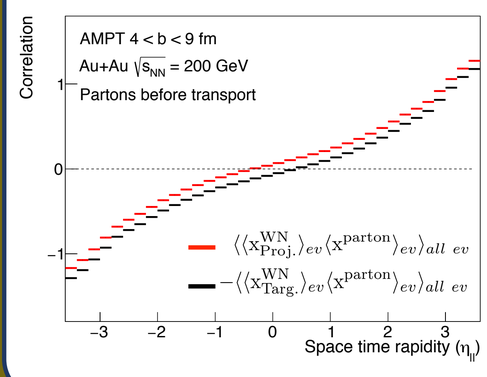
Model Comparisons

- AMPT has the diffuse geometry for nuclei and thus the initial asymmetry
- Calculate the average position of partons along the impact parameter direction, $\langle x \rangle$ Reflects the net density difference a high p_T parton sees as it passes through the bulk





- Weak centrality dependence of initial asymmetry in AMPT, drops only in most central
- Similar to that of high-p_T v_1 slope in data



Impact of initial state fluctuations

- Initial state fluctuations and model uncertainties on it a limiting factor in studying medium properties
- Study event-by-event correlation of initial parton asymmetry along x with that of wounded nucleons
- Contribution of fluctuations small compared to avg. component, particularly at large rapidities
- Can be accessed in data using even and odd components of v_1

Summary and Outlook

- Charged hadron v_1 changes sign twice as function of p_T. Large negative values at high p_T
- Weak centrality dependence for mid-central collisions. Consistent with zero in most central collisions
- Centrality dependence of initial asymmetry from AMPT shows similar trend as in data
- Contributions from fluctuations small compared to average component
- Makes a valuable observable to study path-length-dependent energy loss

References

[1] P. Bozek, I. Wyskiel. Phys. Rev. C. 81,054902 (2010)
[2] A. Adil, M. Gyulassy. Phys. Rev. C. 72,034907 (2005)
[3] S. Chatterjee, P.Bozek. Phys. Rev. Lett. 120,192301 (2018)
[4] Adam J *et al.* (STAR) Phys. Rev. Lett. 123, 162301 (2019)

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