

Measurement of directed flow at forward and backward pseudorapidity in Au+Au collisions at $\sqrt{s_{NN}} = 27$ GeV with the Event Plane Detector (EPD) at STAR

Xiaoyu Liu (liu.6566@osu.edu), the Ohio State University, *for the STAR Collaboration*

Abstract

The measurement of pseudorapidity (η) dependence of directed flow (v_1) can provide unique constraints on the three-dimensional initial conditions in heavy-ion collisions. In the year 2018, the Event Plane Detector (EPD, $2.1 < |\eta| < 5.1$) was installed in STAR and used for the Beam Energy Scan phase-II (BES-II) data taking. The combination of EPD and high statistics BES-II data enables us to extend the v_1 measurement to the forward and backward pseudorapidity regions. In this poster, I discuss the techniques for measuring v_1 with a scintillator detector like EPD, present results of v_1 in Au+Au collisions at $\sqrt{s_{NN}} = 27$ GeV and compare the results with the UrQMD model.



THE OHIO STATE
UNIVERSITY



Supported in part by the



U.S. DEPARTMENT OF
ENERGY

Office of
Science

Xiaoyu Liu / Quark Matter 2022



Directed flow

- In heavy ion collisions, the particle azimuthal distribution measured with respect to the reaction plane (Ψ_{RP}) is anisotropic and can be expanded into a Fourier series [1]:

$$\frac{dN}{d(\phi - \Psi_{RP})} = k \left\{ 1 + \sum_{n=1}^{\infty} 2v_n \cos[n(\phi - \Psi_{RP})] \right\}$$

- v_1 describes the collective sideward motion of produced particles and nuclear fragments. It carries information on the very early stages of the collision.
- In this analysis, v_1 was measured with respect to the first-order event plane (Ψ_1) from the Time Projection Chamber (TPC, $|\eta| < 1$, $0.15 < p_T < 2.0$ GeV/c) to avoid the momentum conservation effect.

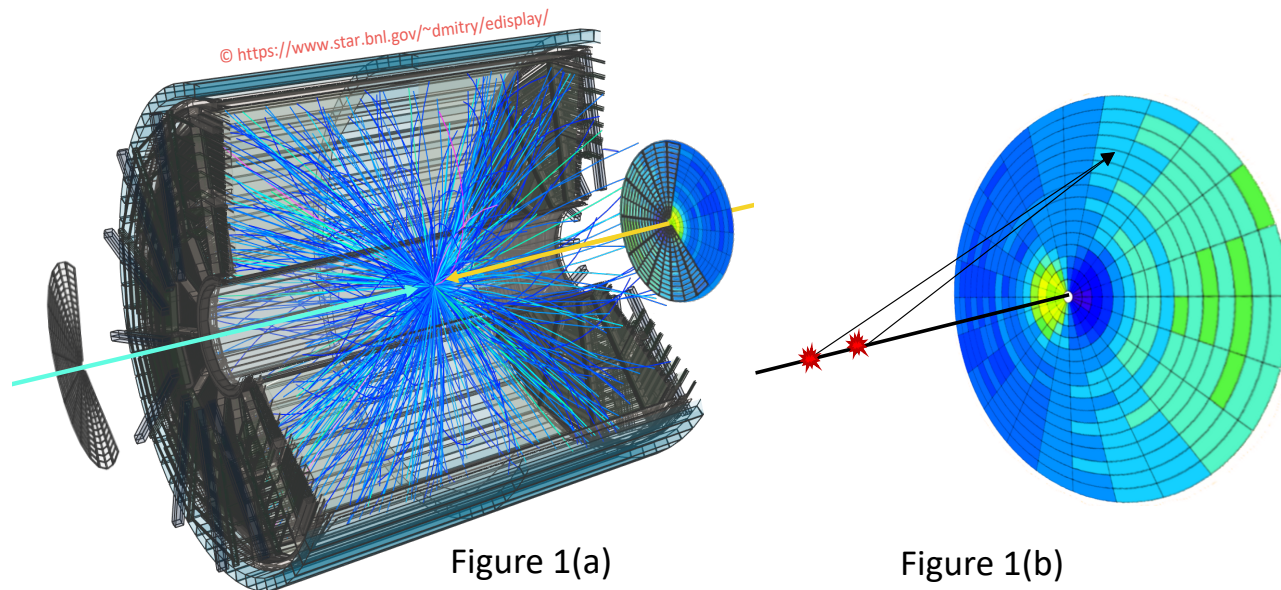
Figure 1(a): a sketch shows an event recorded by the TPC and the EPD; (b): the pseudorapidity (η) range of a EPD tile depends on the primary vertex position. The EPD acceptance is $2.1 < |\eta| < 5.1$ when $(V_x, V_y, V_z) = (0,0,0)$.

Event Plane Detector (EPD)

EPD has two wheels located on the east and west side of the STAR detector. Each wheel consists of 744 tiles [2]. Despite the high granularity, as a scintillator detector, EPD cannot count the exact number of particles hitting a tile in each event. Instead, the ADC value of each tile is recorded, and the signal depends on:

1. the number of particles hitting the tile,
2. the energy loss of each particle.

The number of particles, averaged over events, can be extracted from the ADC distributions.



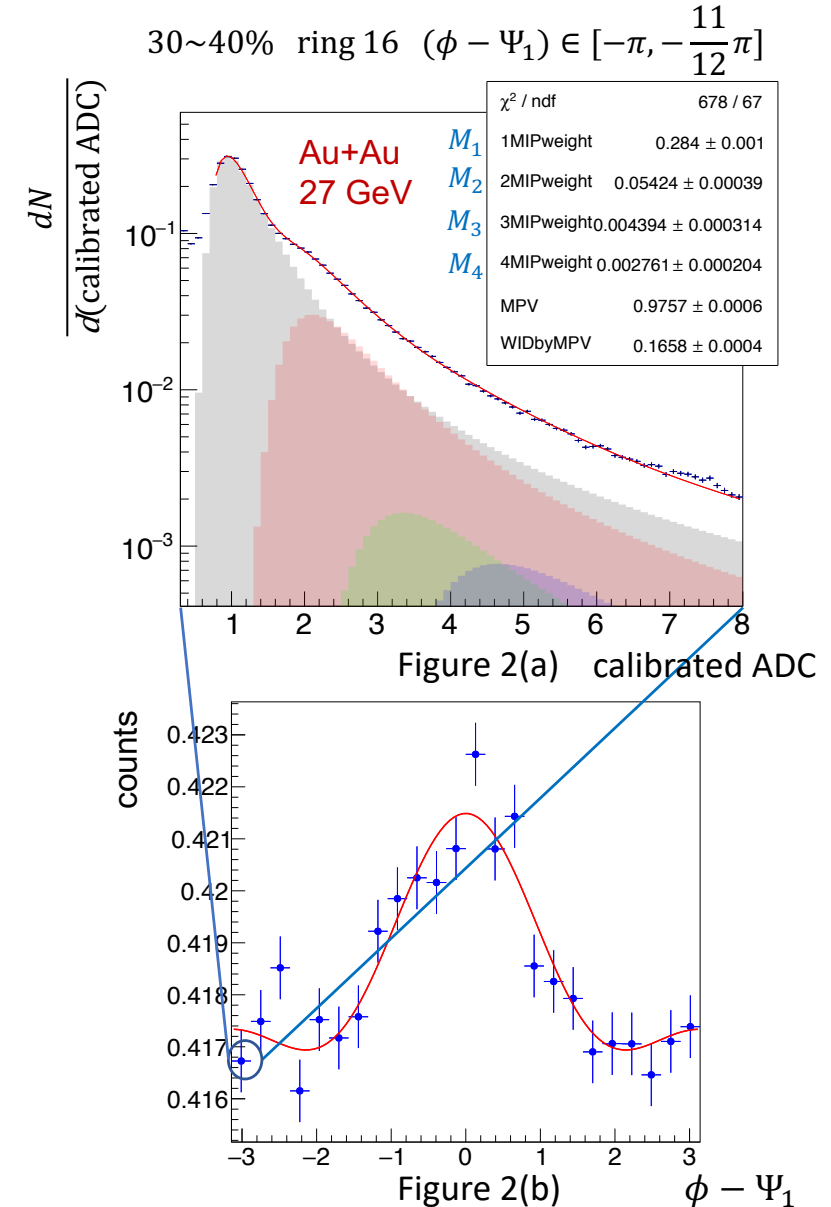
From EPD signal to v_1

When a minimum ionizing particle (MIP) goes through a scintillator detector, the energy loss follows a Landau distribution. The width of the Landau distribution only depends on the material and the thickness of the detector. When two MIPs go through the detector, the energy loss follows a convolution of the 1-MIP Landau distribution with itself, and so on. Therefore, the EPD ADC distribution is a sum of 1-, 2-, 3-,...MIP Landau distributions with different weights.

Figure 2(a) shows a fitted calibrated ADC distribution. ADC was scaled by a constant so the position (Most Probable Value) of the 1-MIP Landau distribution (grey peak) is around one. The i MIPweight (M_i) in the fitting parameters represents the fraction of the i -MIP events. Figure 2(b) shows a $\phi - \Psi_1$ distribution. Each point was calculated as:

$$N = \sum_{i=1}^{i=4} i \times M_i$$

Then, v_1 can be extracted by fitting the Fourier decomposition of the $\phi - \Psi_1$ distribution. Finally, v_1 is corrected for the event plane resolution and the influence from the STAR material budget.



Results

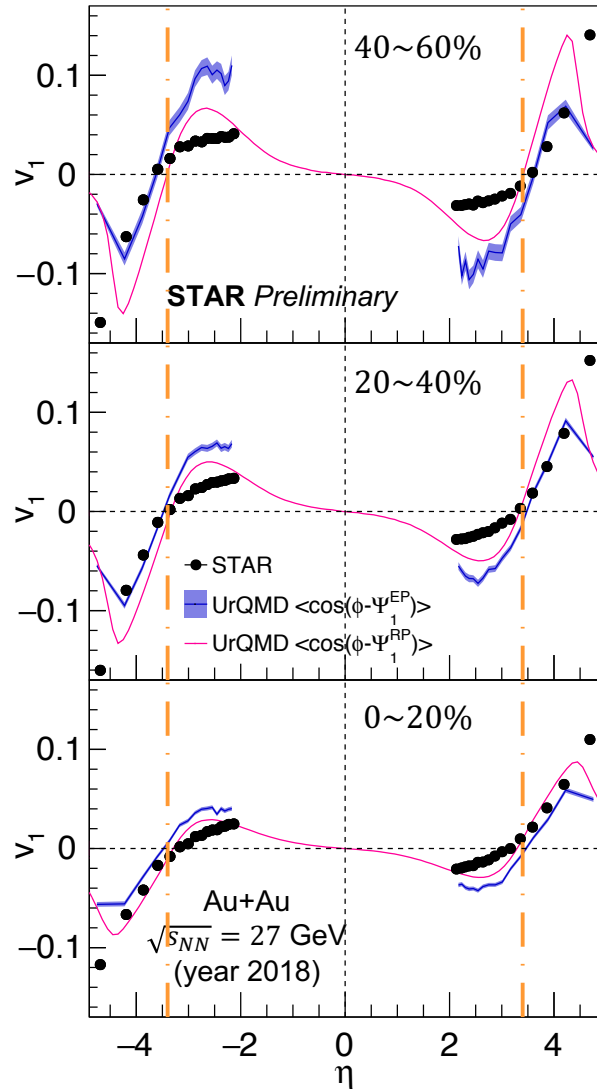


Figure 3(a)

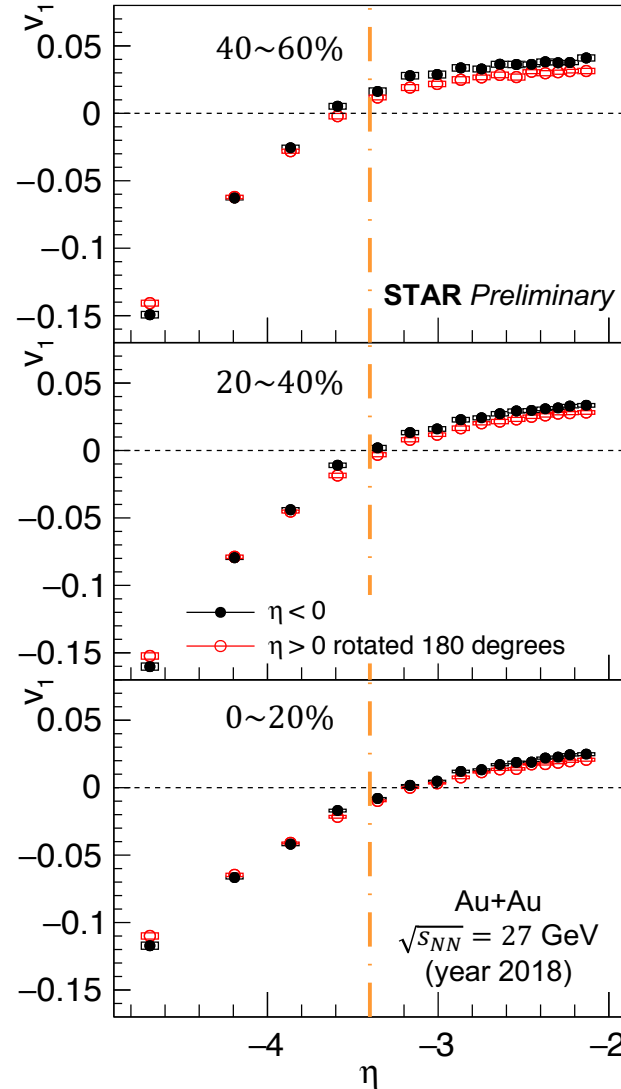


Figure 3(b)

- $v_1(\eta)$ has all corrections applied. Both statistical errors (smaller than markers) and systematic errors (boxes) are plotted. The dashed orange line corresponds to where the incident ions would lie on a rapidity scale.
- Figure 3(a) shows both the STAR measurement and the UrQMD simulation at three centralities. UrQMD particles are sampled 100 fm/c after the beginning of the collision.
- UrQMD $v_1(\eta)$ shows the same shape as the measured $v_1(\eta)$, although the values are different.
- Figure 3(b) zooms in to the backward η region. v_1 at forward η is also plotted after a 180-degree rotation about the origin. $v_1(\eta)$ changes sign near the beam rapidity.

Results

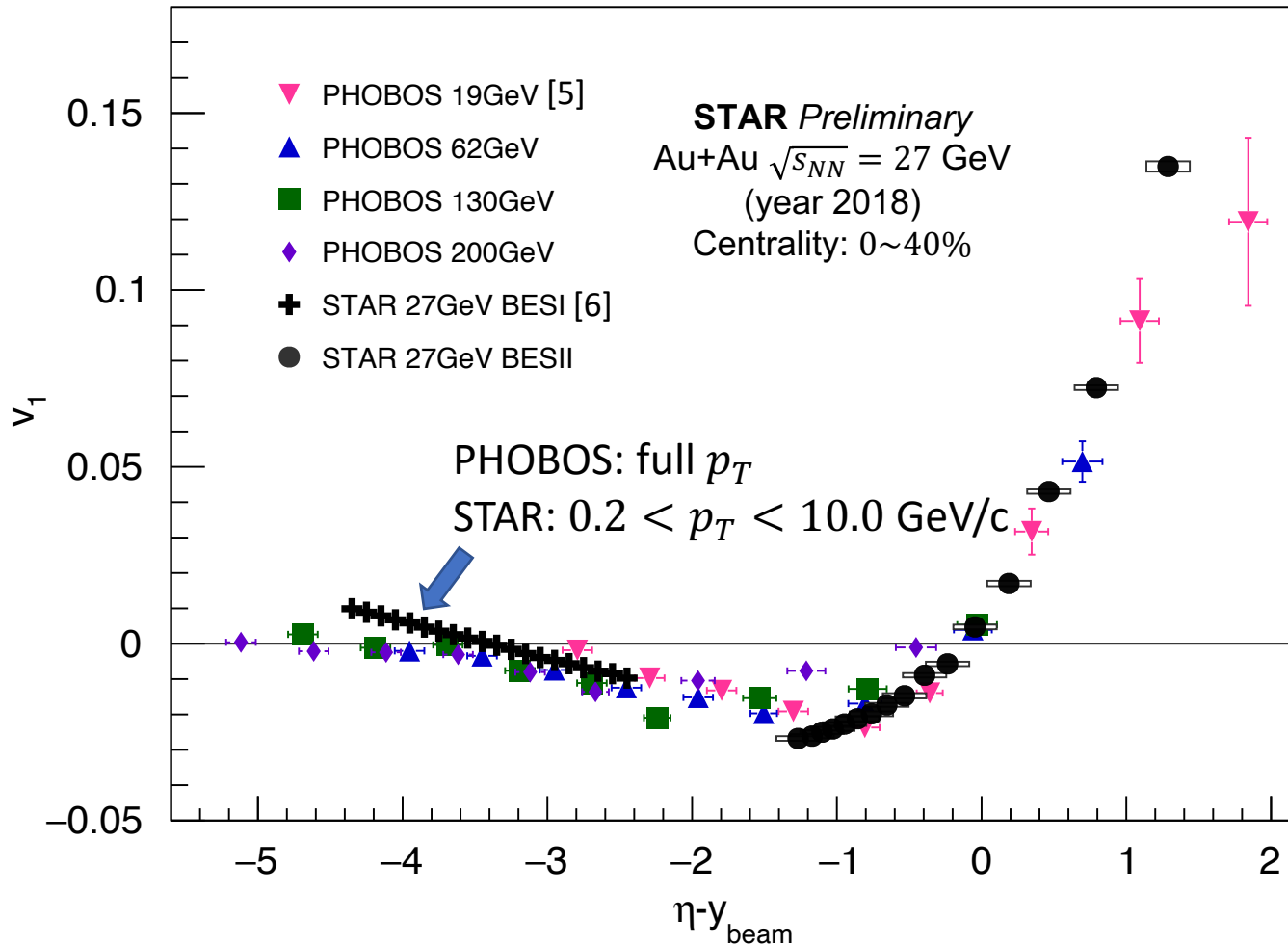


Figure 4: except for STAR BESII, all other data sets only have statistical errors plotted.

✓ $v_1(\eta - y_{\text{beam}})$ follows the pattern of limiting fragmentation [3].

Outlook

- Use the mixed harmonic method [4] to further study the non-flow effect.

Reference

- [1] Poskanzer, Arthur M., and Sergei A. Voloshin. *Physical Review C* 58.3 (1998): 1671
- [2] Adams, Joseph, et al. *Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment* 968 (2020): 163970.
- [3] STAR, *Phys. Rev. C* 73.3 (2006): 034903.
- [4] STAR, *Phys. Rev. C* 72.1 (2005): 014904.
- [5] PHOBOS, *Phys. Rev. Lett.* 97.1 (2006): 012301.
- [6] STAR, *Phys. Rev. C* 101.2 (2020): 024905.