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

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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 psuedorapidity 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.

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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]:

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

- 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.

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.

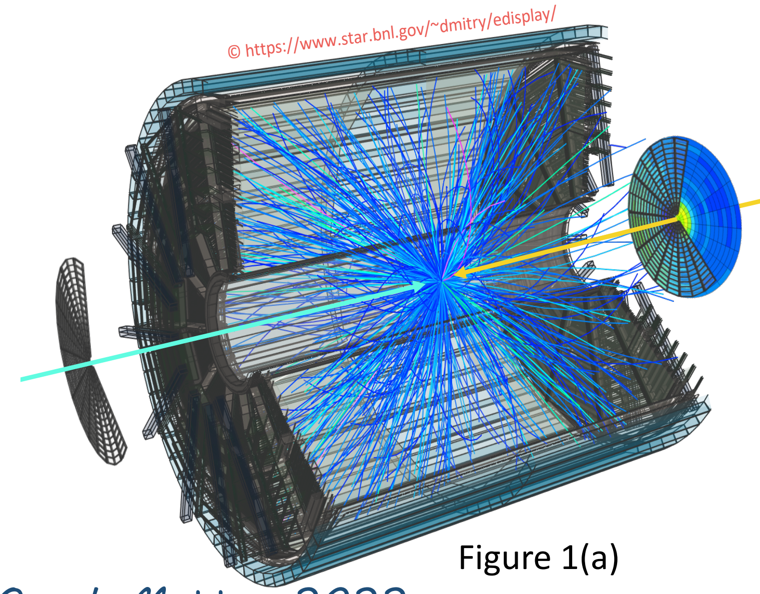

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Figure 1(a)

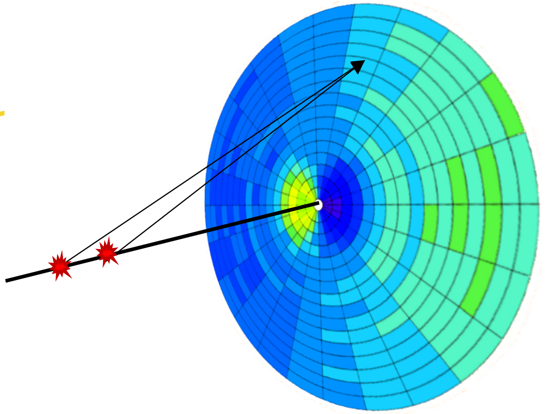

Figure 1(b)

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).

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 $\frac{d^2N}{d(\phi-\Psi_1)d\mathrm{nMip}}$ distribution. nMip is the calibrated ADC and the position (Most Probable Value) of the 1-MIP Landau distribution (grey peak) is around $\mathrm{nMip} = 1$. The iMIPweight (M_i) in the fitting parameters represents the fraction of the i-MIP events. Figure 2(b) shows a $\frac{dN}{d(\phi-\Psi_1)}$ distribution. Each point was calculated as:

$$\frac{dN}{d(\phi-\Psi_n)} = \sum_{i=1}^{i=4} i \times M_i$$

Then, v_1 can be extracted by fitting the Fourier decomposition of $\frac{dN}{d(\phi-\Psi_1)}$. Finally, v_1 is corrected for the event plane resolution and the influence from the STAR material budget.

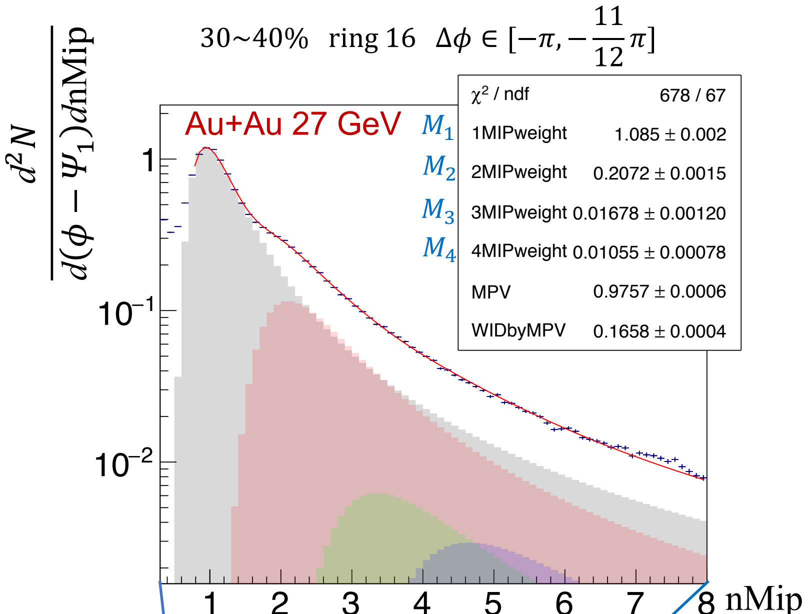

Figure 2(a)

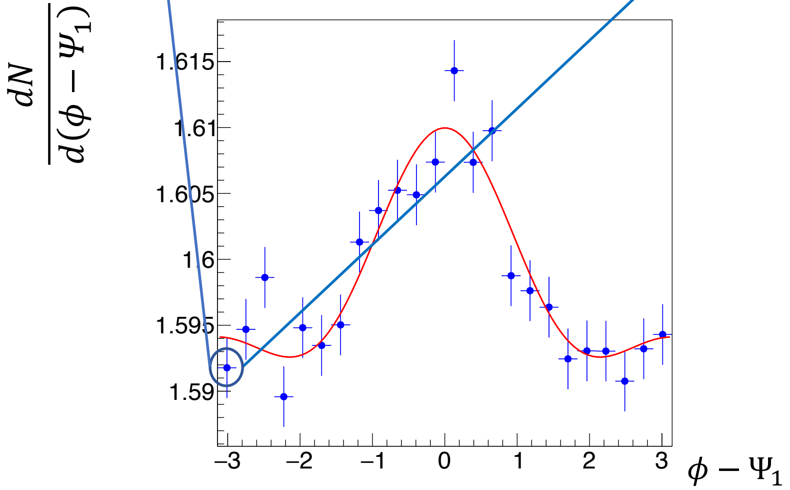

Figure 2(b)

Results

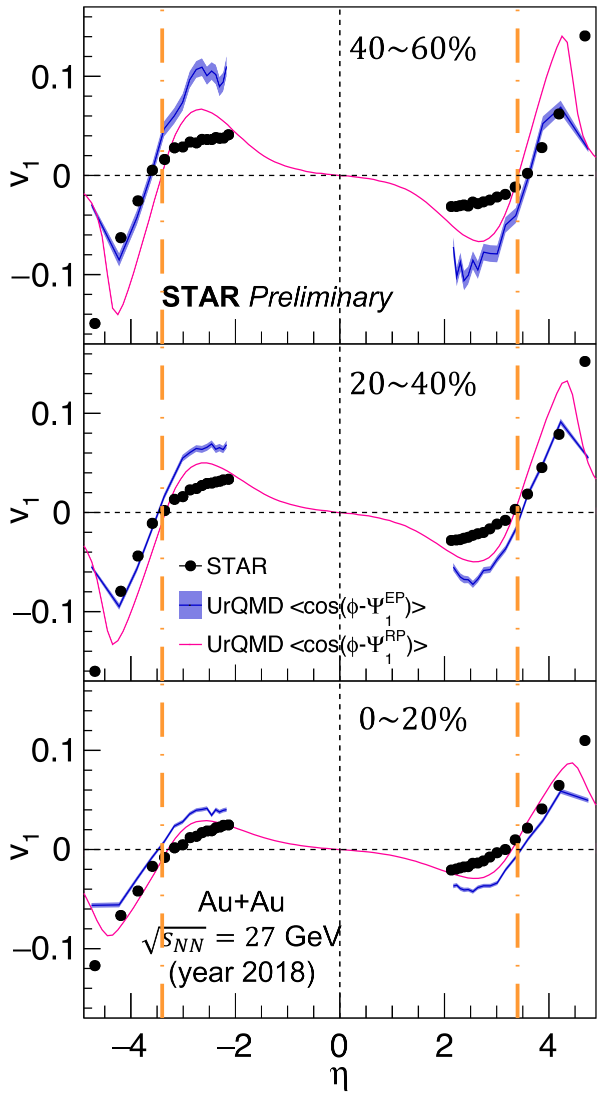

Figure 3(a)

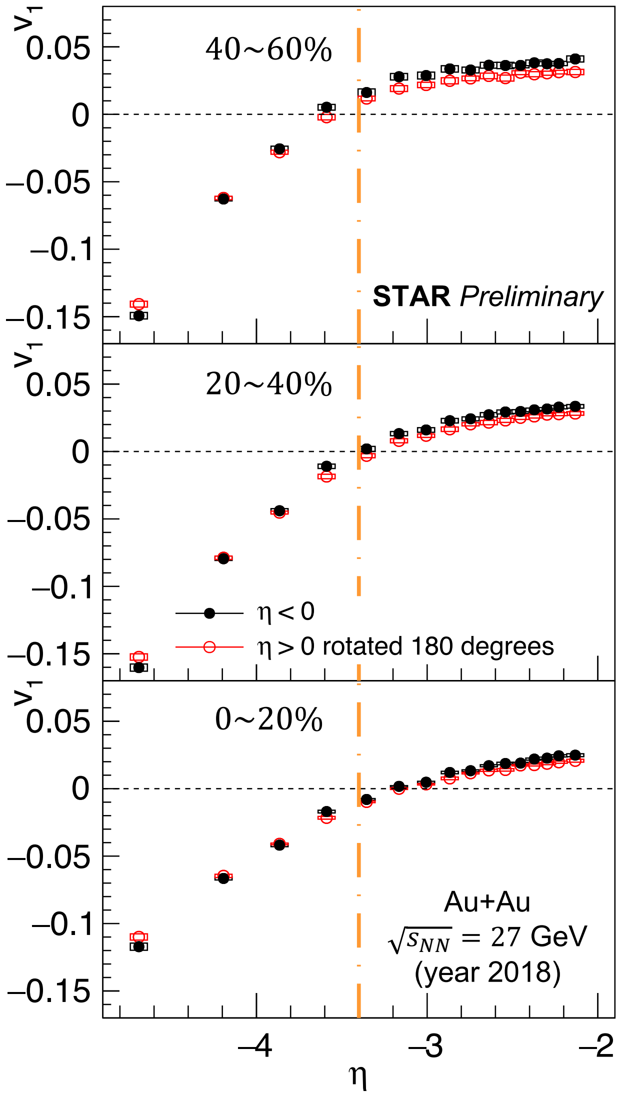

Figure 3(b)

- $v_1(\eta)$ 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 mesurement 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

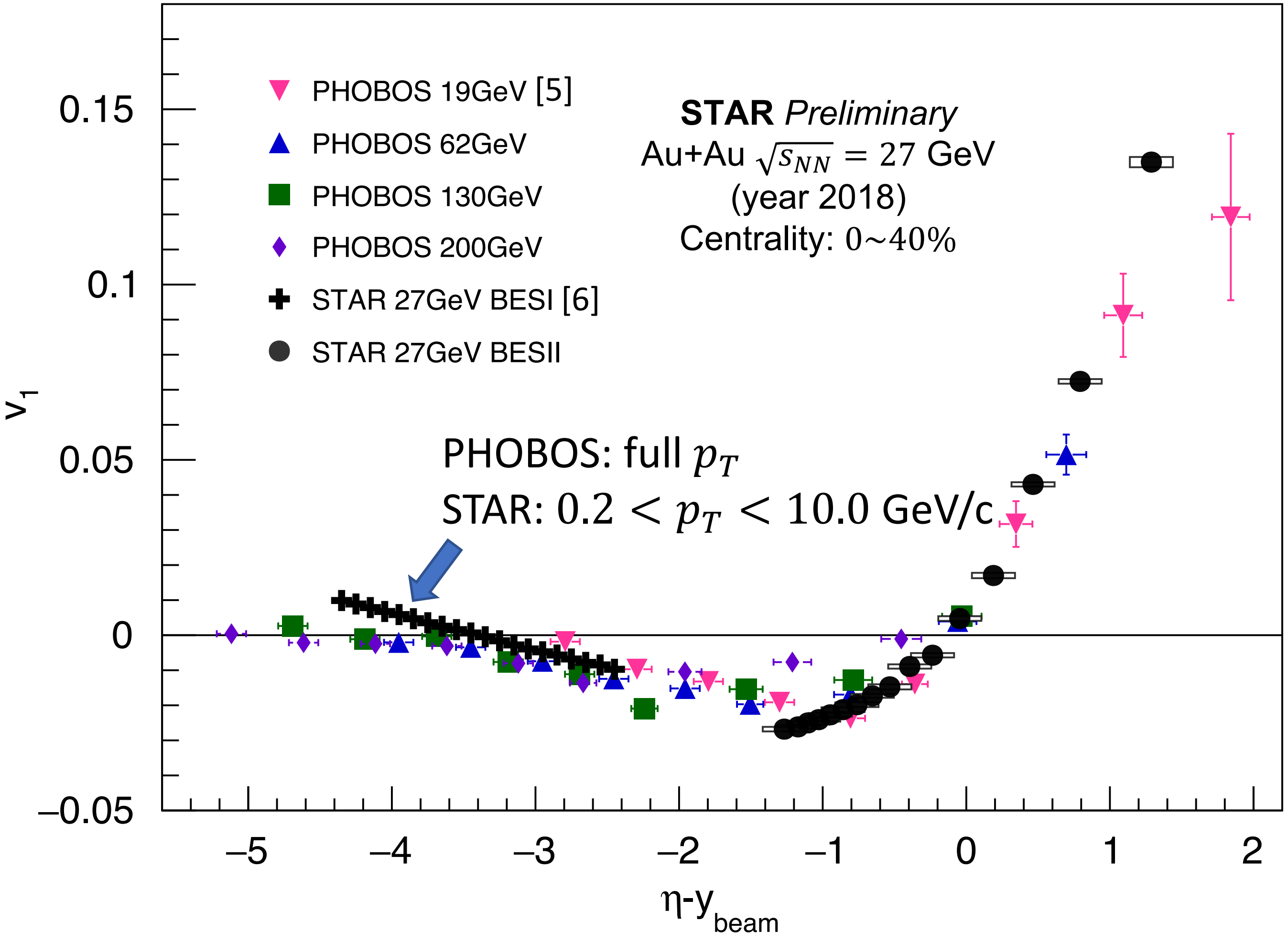

Figure 4: except for STAR BESII, all other data sets only have statistical errors plotted.

✓ $v_1(\eta - y_{\mathrm{beam}})$ 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*
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