v_n measurement with the Event Plane Detector at STAR

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for the STAR Collaboration

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Outline

- Event Plane Detector (EPD)
- Flow measurement using the ADC distribution of a scintillator detector
- EPD fast simulator
- UrQMD set up
- v_1 from UrQMD
- Summary and outlook

Event Plane Detector (EPD)

- EPD is a scintillator detector that consists of 744 tiles. The high granularity significantly increases the event plane resolution and makes the flow measurement in the EPD acceptance ($2.1 < |\eta| < 5.1$) possible.

- In the analysis, η of a hit tile is determined by a straight line between the primary vertex (PV) and a random point on the tile.

- EPD is not a tracking detector and CANNOT count the number of particles going through each tile.

- Instead, the ADC value of each tile is measured and it depends on:
  - number of particles hitting the tile,
  - energy loss of each particle (Landau distribution).

- The fraction of 0, 1, 2 … particles hitting the tile can be extracted from the ADC distribution.

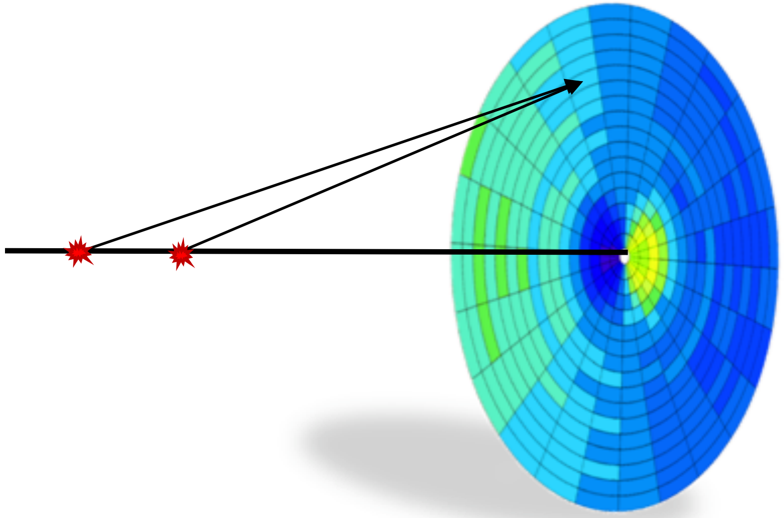


Figure 1 η range of a tile depends on the primary vertex (PV) . The EPD acceptance is $2.1 < |\eta| < 5.1$ when V_x, V_y, V_z = (0,0,0)

nMIP definition and Landau distribution

- nMIP is calibrated ADC: nMIP = constant × ADC
- The positon (MPV) of 1-MIP Landau (grey peak) is around nMIP=1
- The width (WID/MPV) of the 1-MIP Landau is about 0.16 for the scintillator whose thickness is 1.2 cm
- The nMIP distribution can be described by the sum of multi-MIP peaks (red curve) with only parameters:
  - MPV and WID/MPV of the 1-MIP peak
  - the fraction of 1-, 2-, 3-, 4-MIP events (i.e "nMIPweight" shown in the statistics box, they depend on the incident particle distribution)
- **Multi-MIP peaks (red, green, purple) are convolutions of the 1-MIP peak (grey):** No adjusted width or position

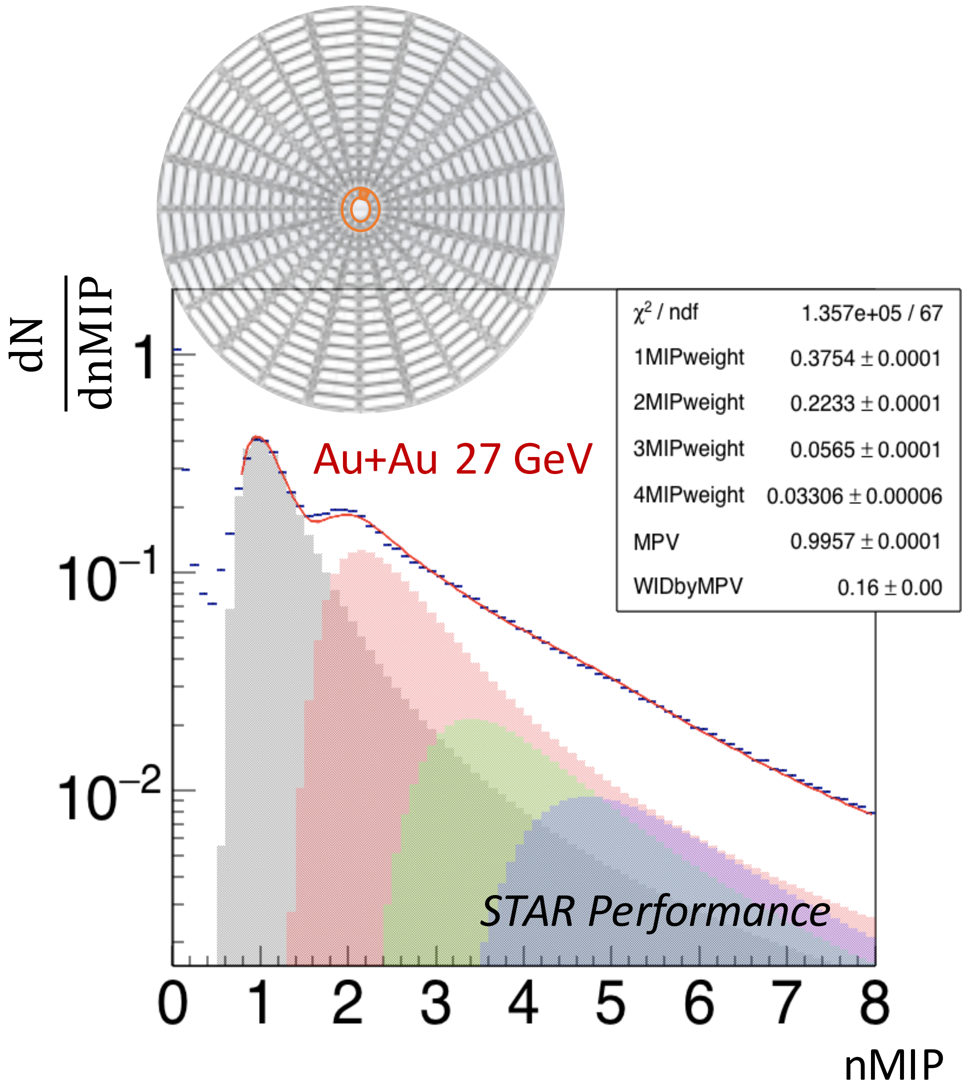


Figure 2 Averaged nMIP distribution over tiles in West Ring 1 and divided by the number of events (centrality: 30 ~ 40%). Red curve is the sum of Landaus

From nMIP to $dN/d(\phi-\Psi_n)$ and v_n

We divided the η and ϕ acceptance into ten and twelve bins respectively:

1. In a η region, for each ϕ bin j, produce $\frac{d^2N}{d(\phi-\Psi_n)dnMIP}(\phi_j)$ (normalized, i.e divided by the total number of events). Ψ_n is the n-th order event plane angle

2. Fit to extract the fraction of 1-,2-,...k-MIP events per collision in bin j (i.e $M_{1,j}$, $M_{2,j}$... $M_{k,j}$)

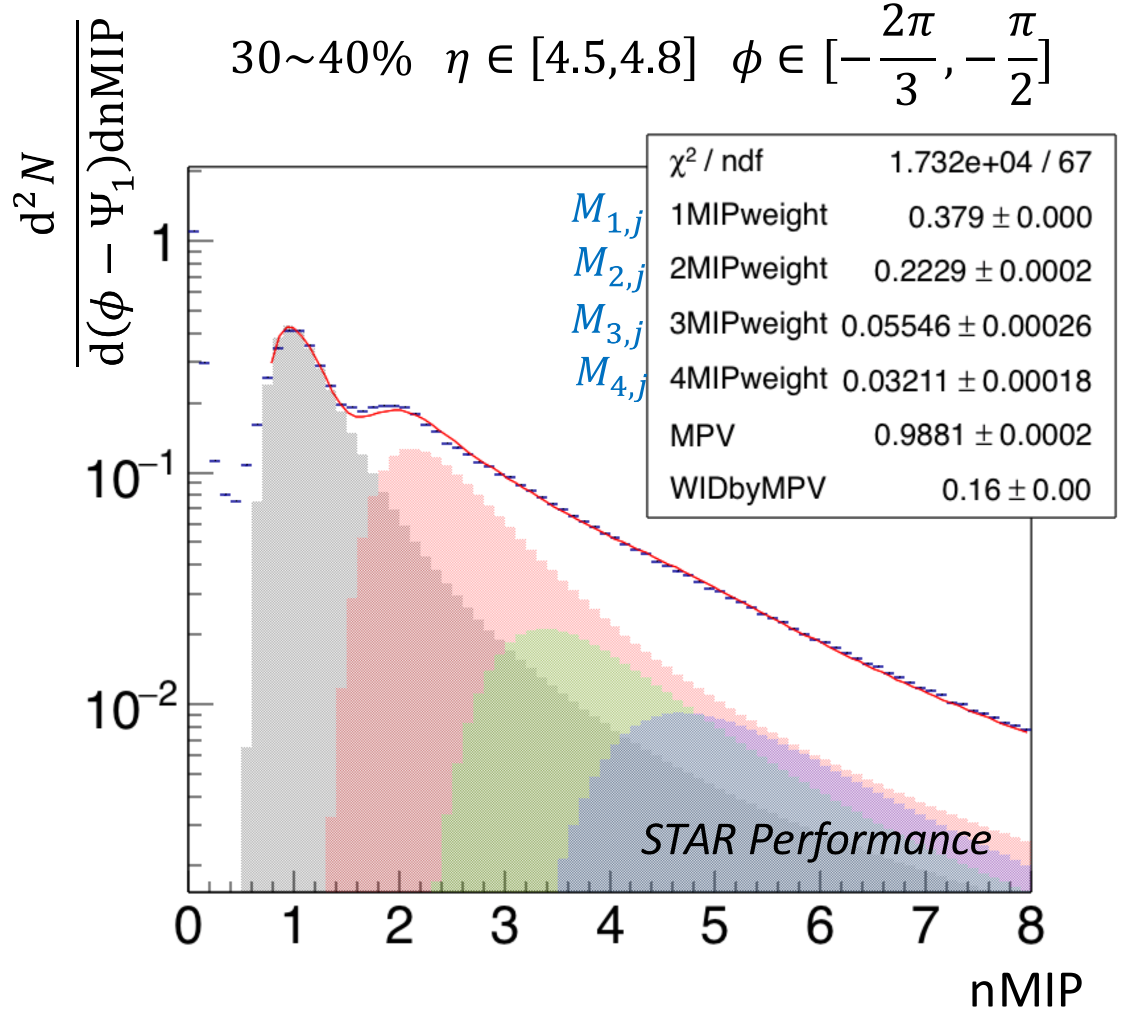
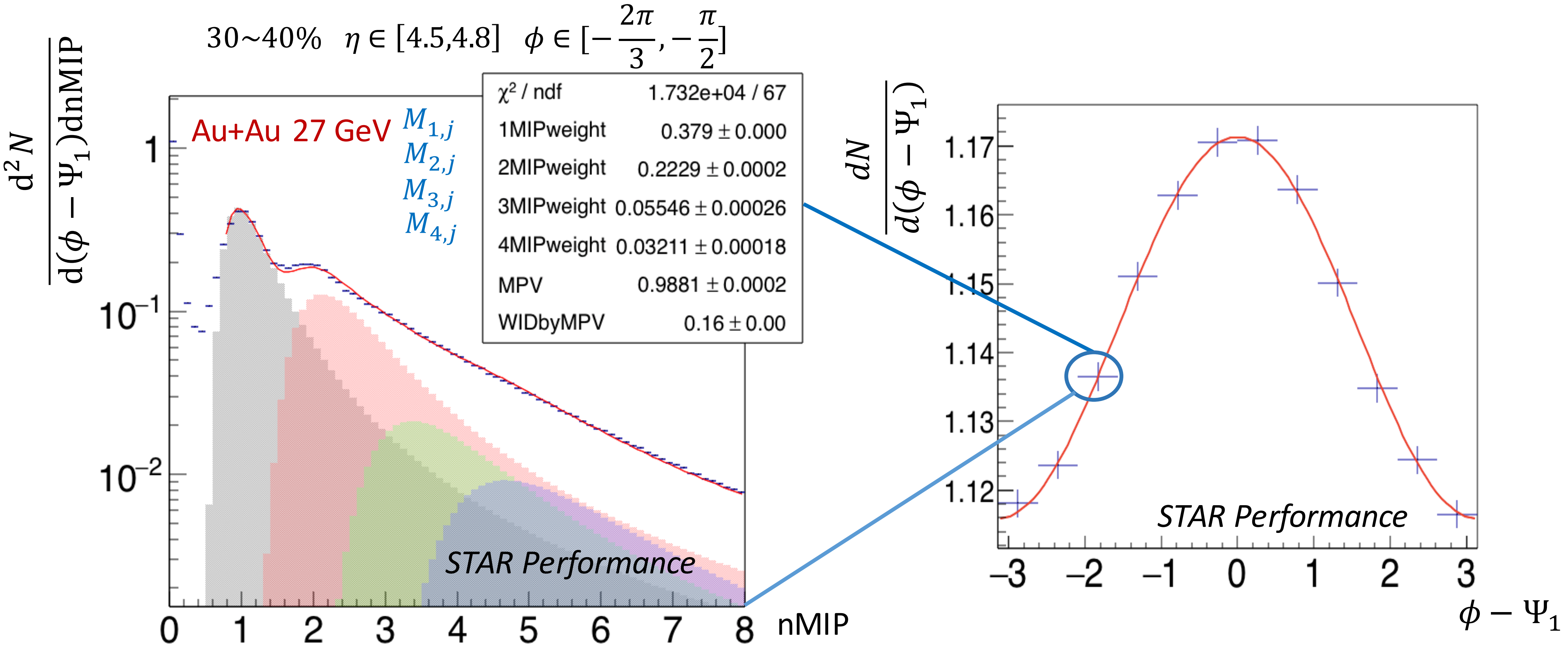


Figure 3 Normalized nMIP distribution for a single $\eta-\phi$ bin (centrality: $30\sim40\%$).

From nMIP to dN/dϕ and v_n



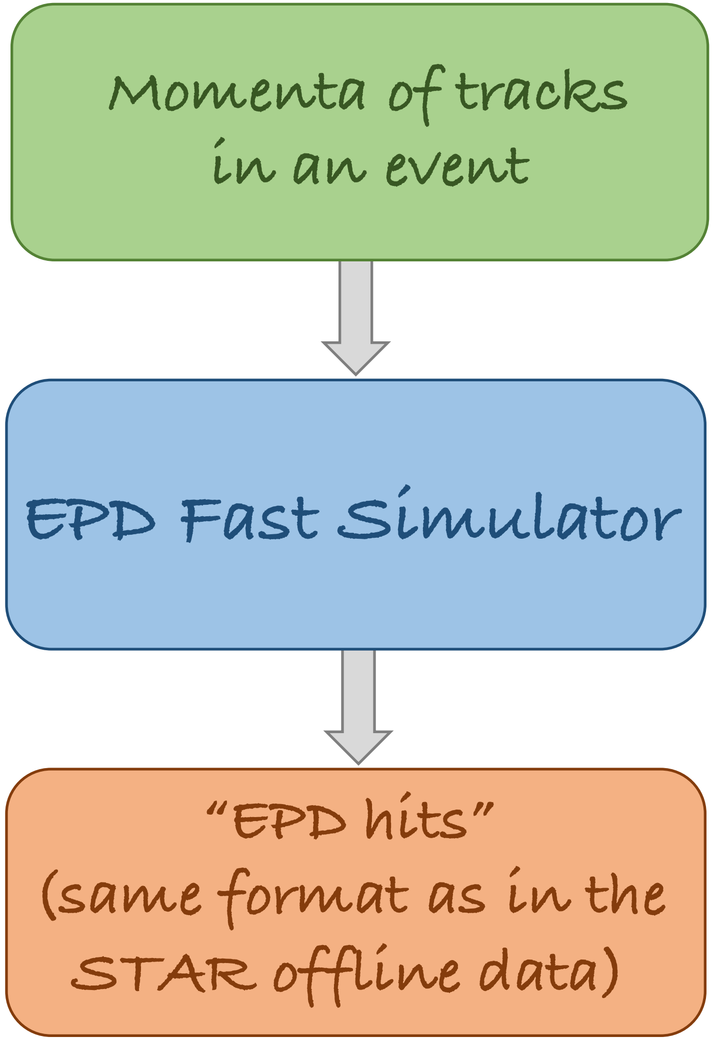
3. Sum over nMIP to get the $dN/d(\phi-\Psi_n)$: $\frac{dN}{d(\phi-\Psi_n)}(\phi_j) = \sum_{k=1}^{k=4} k \cdot M_{k,j}$
4. v_n can be estimated by fitting the Fourier decomposition of $\frac{dN}{d(\phi-\Psi_n)}$

EPD Fast Simulator

- The EPD Fast Simulator is not a full GEANT simulation but it can take the momenta of tracks in an event and convert them to the "EPD hits", each "EPD hit" contains the unique ID and nMIP value of the hit tile.

- The full geometry of EPD (including gaps) was included: the tracks falling out of the EPD acceptance will not end up in the EPD hits.

- Landau fluctuation of the energy loss was included:
  - When a particle falls in the acceptance of a EPD tile, the energy loss (dE) of the particle will be sampled using a Landau distribution ($\mathrm{MPV}=1$, $\mathrm{WID}/\mathrm{MPV}=0.16$)
  - Adding the dE of all the particles going through the tile, then the sum will be the nMIP value of this tile



UrQMD set up

- Goal: compare v_1(track) and v_1(EPDhit) to check the feasibility of the new method

- UrQMD setup:
  - 27 GeV Au+Au collisions
  - For each event, the reaction plane (RP) was chosen as a random angle in $[0, 2\pi]$
  - Primary vertex (PV) position is set to $V_x, V_y, V_z = (0,0,0)$
  - No pT cut was used

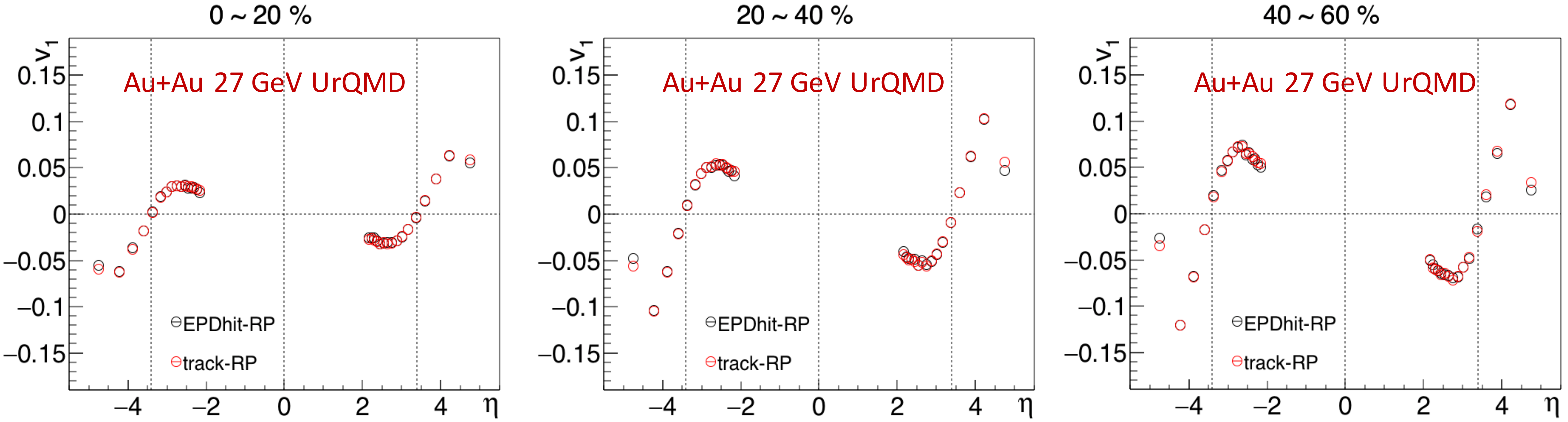
- v_1(track) was measured directly using the UrQMD tracks, while v_1(EPDhit) was measured using the "EPD hits" coming from the EPD fast simulator.

- Both v_1 was measured with respect to the RP

- Both measurements used twelve ϕ bins and v_1 was obtained by fitting $\mathrm{dN}/\mathrm{d}(\phi - \mathrm{RP})$ with:

$$k \times \{1 + 2v_1 \cos(\phi - \mathrm{RP}) + 2v_2 \cos[2(\phi - \mathrm{RP})]\}$$

v_1 from UrQMD



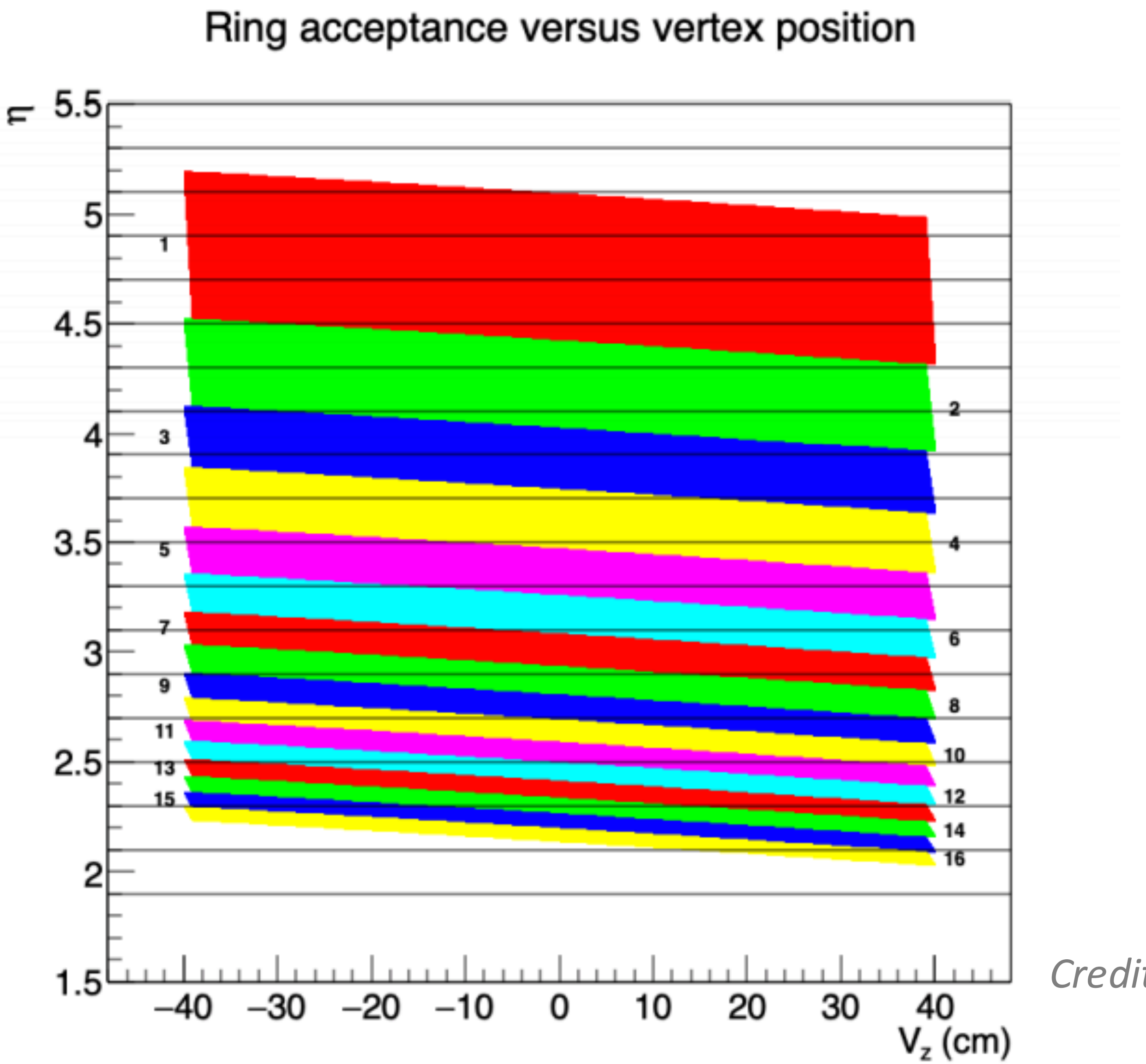
- 16 variable η bins corresponding to 16 EPD rings were used
- ✓ v_1(track) and v_1(EPDhit) are consistent within error bars
- ✓ The new method measures the flow in the EPD acceptance pretty well
- The simulation of STAR materials is needed to account for the residual detector effect

Summary and Outlook

- We developed a new method of measuring the flow with the nMIP (or ADC) distributions from a scintillator detector (EPD)
- Study with UrQMD and the EPD fast simulator showed the feasibility of this method although further corrections are needed
- Outlook:
  - Apply this method to the STAR offline data and measure $v_n(\eta)$ at forward η region
  - Study the influence of STAR materials on the flow measurement: one major advantage of this method is that we don't need the ADC distributions in the STAR simulation, which is not trivial to obtain.

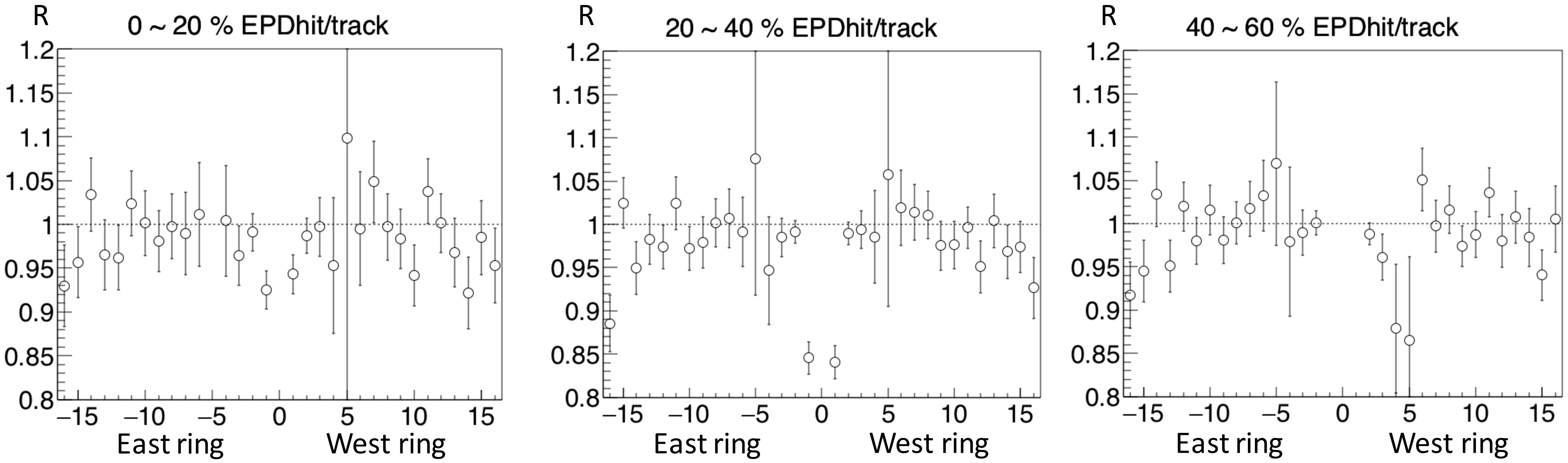
Backup

Ring acceptance vs. PV



Credit: Mike Lisa

Ratio between v_1(EPDhit) and v_1(track)



- In general, the ratios are consistent with one
- Small ratio for ring one in $20\sim40\%$ and $40\sim60\%$ is due to the poor dN/dnMIP fitting (big χ^2/ndf)
- The fitting of dN/dnMIP tends to be poorer when the number of particles is larger