



# Measurement of multi-particle cumulants in p+Au, d+Au, and <sup>3</sup>He+Au collisions with PHENIX



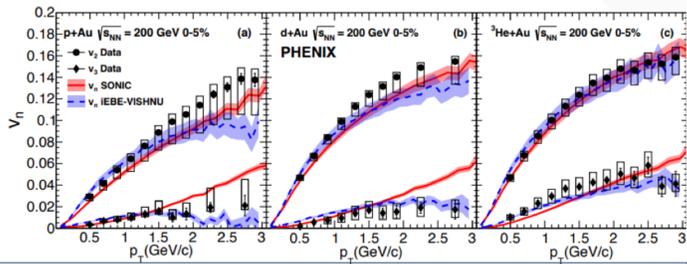
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## Motivation

The PHENIX experiment has collected data of p+Au, d+Au, and <sup>3</sup>He+Au collisions at 200 GeV, giving a unique set of initial geometries. Shown in Fig. 1 are measurements of elliptic and triangular flow in the three systems [1] that are compared with hydrodynamics calculations [2,3]. These calculations provide a simultaneous quantitative description of the data in all three systems, indicating that the observed collectivity is geometric in origin.

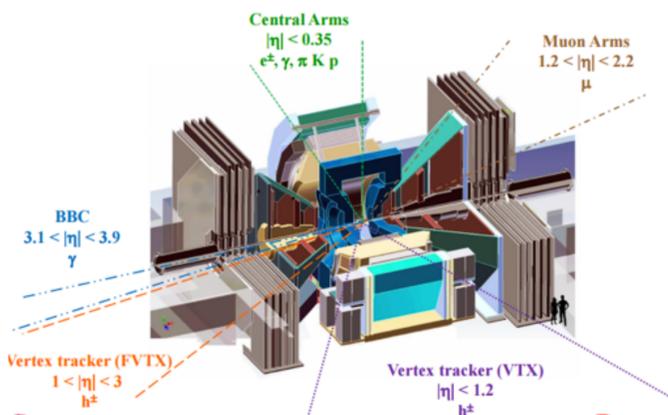


**Figure 1** PHENIX measurements of elliptic and triangular flow in p/d/<sup>3</sup>He+Au collisions [1] compared to hydrodynamic calculations.

Multi-particle correlations, including sub-event cumulants, are studied to investigate the role of possible non-flow correlations and the event-by-event flow fluctuations.

## Experimental Details

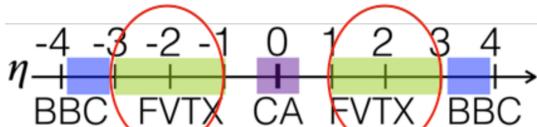
Data sets: 2,261M p+Au events, and 628M d+Au events  
Tracks are reconstructed in the Forward Silicon Vertex Tracker



**Figure 2** PHENIX Detector configuration for Run15/16

## Methods

### Multi-particle correlation method



$$\begin{aligned} \langle\langle 2 \rangle\rangle &= \langle\langle e^{in(\phi_1 - \phi_2)} \rangle\rangle \\ \langle\langle 4 \rangle\rangle &= \langle\langle e^{in(\phi_1 + \phi_2 - \phi_3 - \phi_4)} \rangle\rangle \\ c_2\{4\} &= \langle\langle 4 \rangle\rangle - 2 * \langle\langle 2 \rangle\rangle^2 \\ v_2\{4\} &= (-c_2\{4\})^{-1/4} \end{aligned}$$

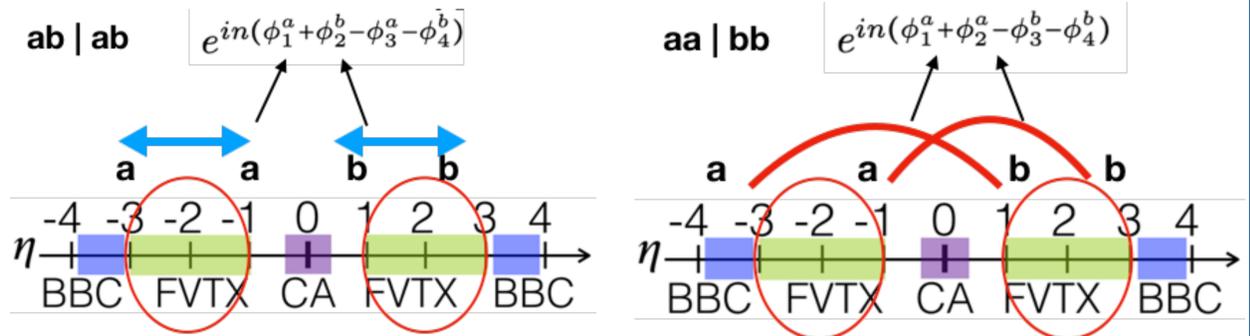
1. Multi-particle correlations suppress non-flow effectively
2. Multi-particle correlations also provide information about how flow fluctuates event-by-event

$$\begin{aligned} v_2\{4\}^2 &\approx v_2\{6\}^2 \approx \langle v_2 \rangle^2 - \sigma_{v_2}^2 \\ v_2\{2\}^2 &\approx \langle v_2 \rangle^2 + \sigma_{v_2}^2 + \delta v_2 \end{aligned}$$

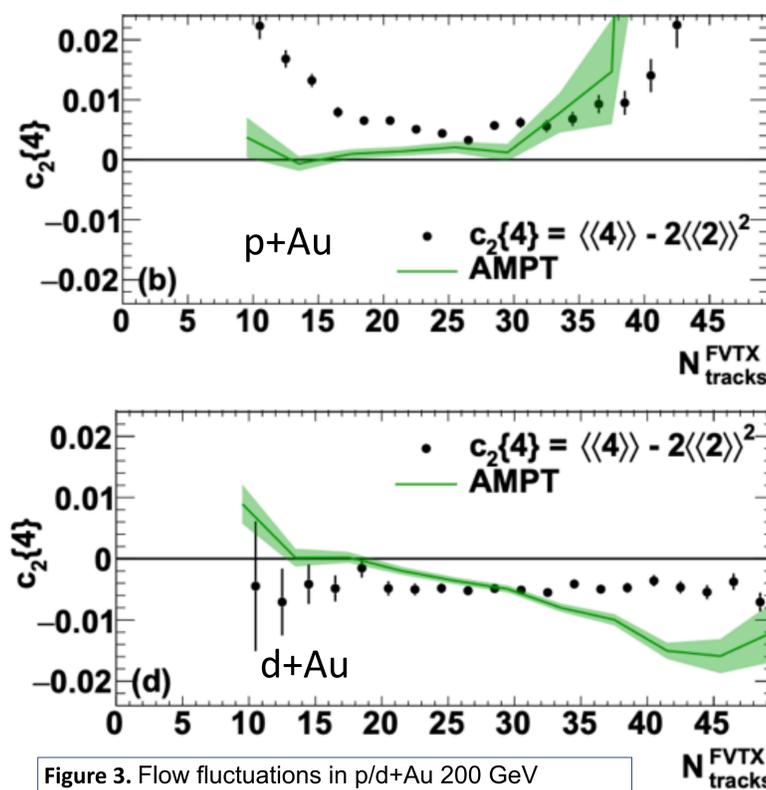
## Methods

### Sub-event cumulants method

1. Further suppress non-flow and investigate the role of fluctuations
2. Expected non-flow contributions:  $aa|bb < ab|ab < \text{standard method}$

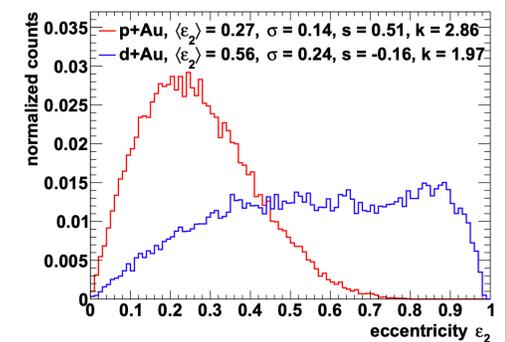


## Results



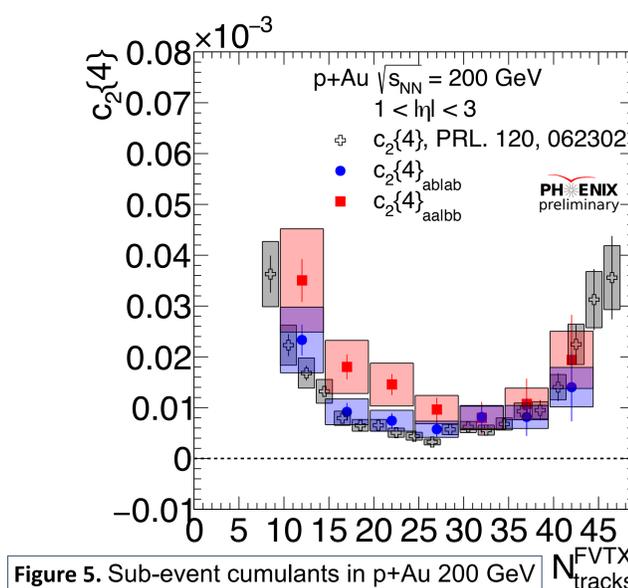
**Figure 3.** Flow fluctuations in p/d+Au 200 GeV

- Implies  $c_2\{4\}$  in p+Au is dominated by fluctuations
- AMPT (A Multi-phase transport model) describes the sign



**Figure 4.** MC Glauber initial eccentricity distribution in p/d+Au collisions

- Initial eccentricity distribution is highly non-Gaussian
- Fluctuations are highly non-trivial in small systems



**Figure 5.** Sub-event cumulants in p+Au 200 GeV

- Two sub-event  $c_2\{4\}$  in p+Au is still positive
- Confirms observed positive  $c_2\{4\}$  is due to fluctuations rather than nonflow in p+Au

## Conclusions

- **Initial geometry** is the driving force of the final-state correlations
- **Small variance limit** breaks in p+Au and in d+Au collisions
- **Flow fluctuations are significant in  $c_2\{4\}$**  in p+Au collisions confirmed by sub-event cumulant analysis