Event-by-Event Distributions of Flow Harmonics in U+U Collisions at $\sqrt{s_{NN}}$ = 193GeV

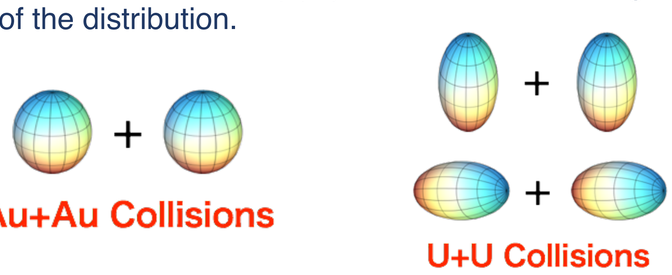
Maowu Nie, *for the STAR Collaboration*
Shanghai Institute of Applied Physics & Stony Brook University

Abstract

In this work, we present the study of Event-by-Event(EbyE) measurement of elliptic flow in U+U collisions with center-of-mass energy $\sqrt{s_{NN}}$ = 193GeV and in Au+Au collisions with $\sqrt{s_{NN}}$ = 200GeV. A comparison between the asymmetric U+U and a symmetric Au+Au system is shown in terms of the probability distributions of flow vector. The measured flow vector distributions are unfolded by a data-driven Bayesian Unfolding process to suppress non-flow and statistic fluctuation to obtain the true flow distributions[1]. From the probability distribution ($p(v_2)$), multi-particle cumulants of v_2 - $v_2\{2\}$, $v_2\{4\}$ and $v_2\{6\}$ are calculated. Comparing to Au+Au, $v_2\{4\} > 0$ and $v_2\{6\}<0$ in the most central U+U collisions indicates that the prolate shape of uranium increases the anisotropy in the final momentum space distributions of the observed particles. A splitting between $v_2\{6\}$ and $v_2\{4\}$ is observed for most centralities in Au+Au and U+U, which is a signature of non-Gaussian fluctuations.

Motivation

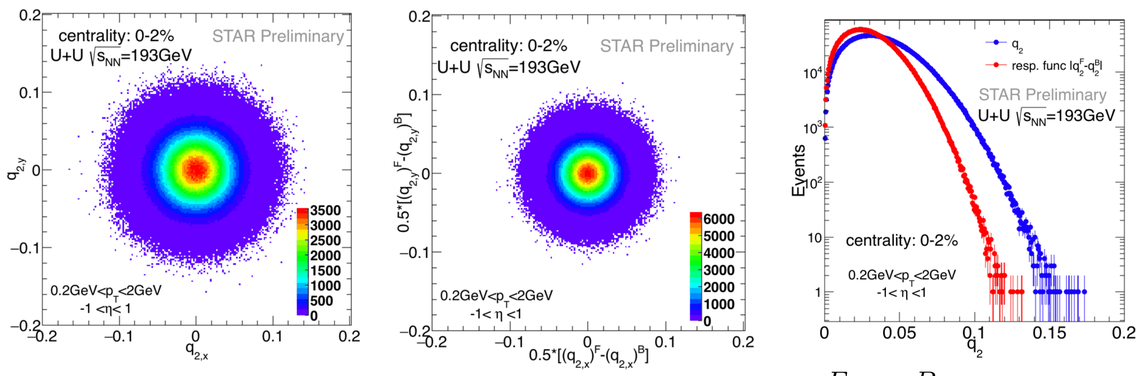
- Investigate the difference of initial condition fluctuation in deformed U+U and spherical Au+Au.
- Measure the full distribution of $p(v_n)$ distribution. We can get the $\langle v_n \rangle$ and σ ; the full shape of the distribution.



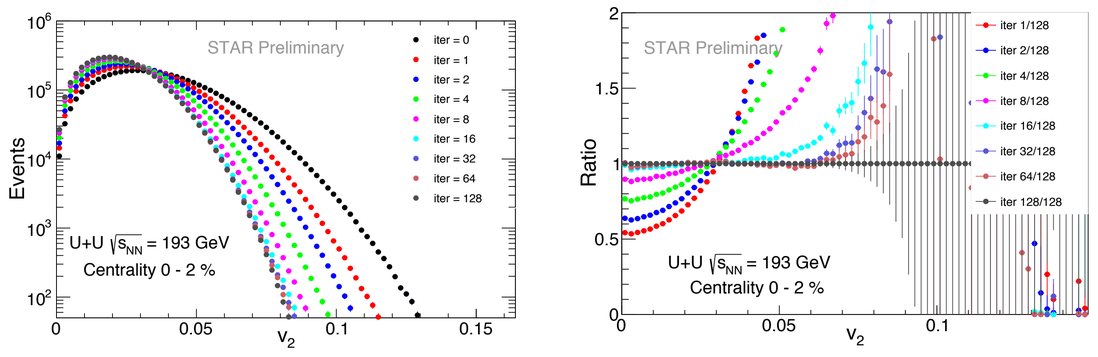
Methodology

- Bayesian unfolding → Obtain cause (v_n) from effect (q_n).

$$q_{n,x} = < cos(n\phi) >, q_{n,y} = < sin(n\phi) > \quad q_n = \sqrt{q_{n,x}^2 + q_{n,y}^2}$$

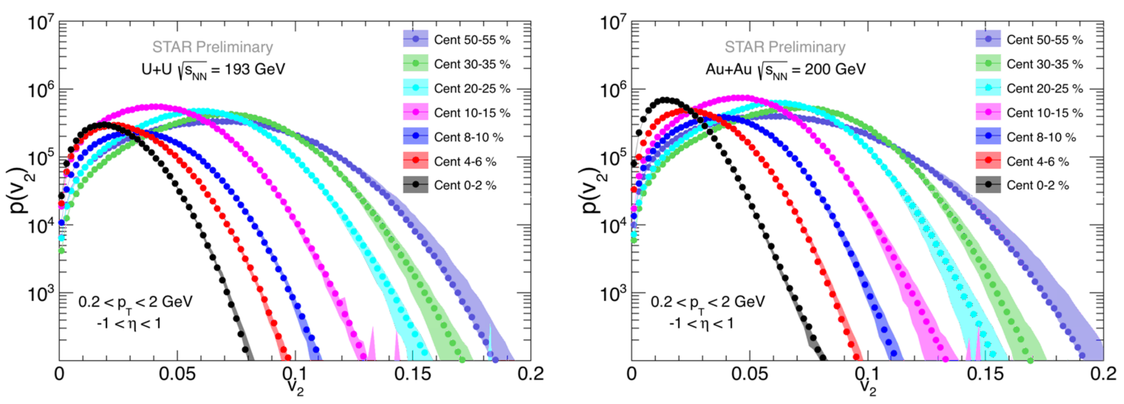


- Two sub-event to get the Response function: $RF = (\vec{q}_n^F - \vec{q}_n^B)/2$, the physical flow signal cancels, it contains mainly the effects of statistical smearing and non-flow.



- Bayesian Unfolding procedure: q_2 for iterations; Convergence after 8 iterations.
- Unfolded v_2 distribution → the underlying flow probability distribution.

Results - Probability distributions of EbyE v_2



- A comparison between the asymmetric U+U and a symmetric Au+Au system is shown in terms of the probability distributions of event-by-event flow vector.
- In Central region the shapes are different, which is also reflected in the cumulants

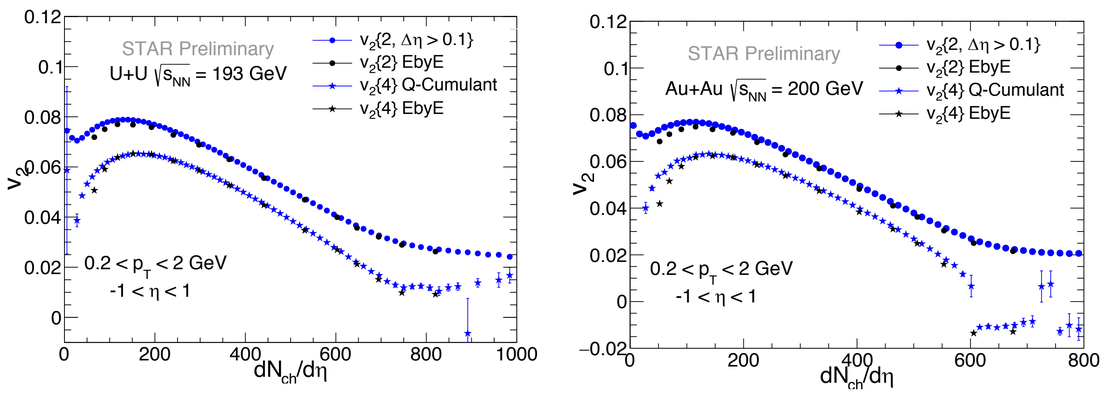
Results

The 2k[th]-order coefficient can be calculated analytically from the measured v_2 distributions.

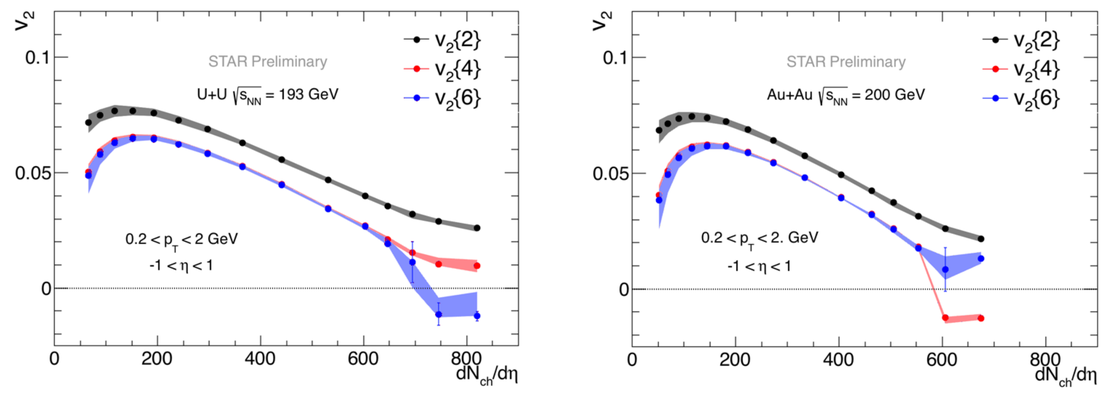
$$c_n\{2\} = \langle v_n^2 \rangle \qquad v_n\{2\} = sgn(c_n\{2\})(|c_n\{2\}|)^{1/2}$$

$$c_n\{4\} = \langle v_n^4 \rangle - 2\langle v_n^2 \rangle^2 \qquad v_n\{4\} = -sgn(c_n\{4\})(|c_n\{4\}|)^{1/4}$$

$$c_n\{6\} = \langle v_n^6 \rangle - 9\langle v_n^4 \rangle \langle v_n^2 \rangle + 12\langle v_n^2 \rangle^3 \qquad v_n\{6\} = sgn(c_n\{6\})\left(|\frac{c_n\{6\}}{4}|\right)^{1/6}$$

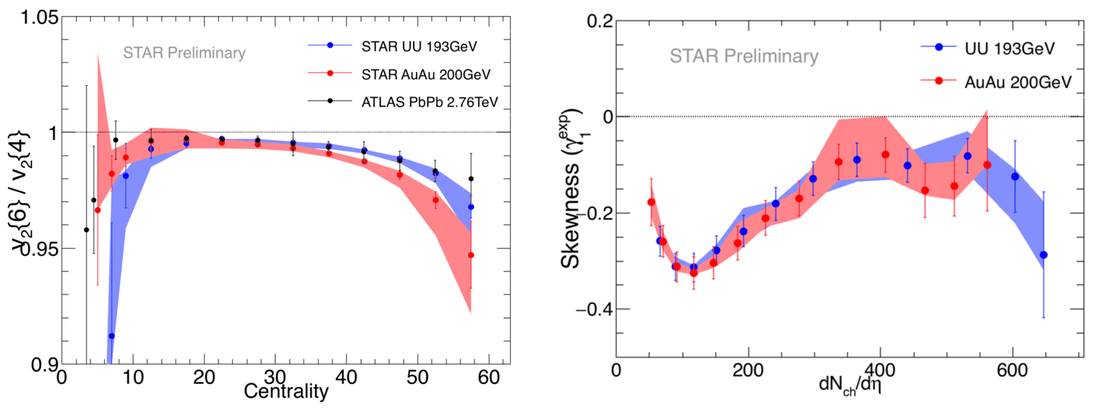


- The unfolding results are consistent with the STAR published results[2].



- In most central collision, for Au+Au, $v_2\{4\} < 0$ and $v_2\{6\} > 0$; for U+U, $v_2\{4\} > 0$ and $v_2\{6\} < 0$.
- The prolate shape of uranium increases the anisotropy in the final momentum space distributions of the observed particles.

Skewness with cumulants[3] $\gamma_1^{exp} = -6\sqrt{2}v_2\{4\}^2 \frac{v_2\{4\} - v_2\{6\}}{(v_2\{2\}^2 - v_2\{4\}^2)^{3/2}}$



- A fine splitting between $v_2\{4\}$ and $v_2\{6\}$ is observed for most centralities, which is a signature of non-Gaussian fluctuations.
- Comparing to Au+Au and Pb+Pb, the ratio in U+U is relatively smaller in most central region, which means the fluctuation is mainly due to the prolate shape.
- Negative skew corresponding to the hierarchy $v_2\{4\} > v_2\{6\}$, which lifting the degeneracy between higher-order cumulants.

Summary

- Measured event-by-event probability distribution of v_2 in U+U and Au+Au.
- In most central U+U $v_2\{4\} > 0$ and $v_2\{6\} < 0$, which is due to the prolate shape of uranium increases the anisotropy in the final momentum space distributions.
- A splitting between $v_2\{4\}$ and $v_2\{6\}$ is observed for most centralities in Au+Au and U+U, which is a signature of non-Gaussian fluctuations.
- Comparing to Au+Au and Pb+Pb, a relatively smaller ratio in the most central region indicates the fluctuation is mainly due to the prolate shape.

References

[1] Aad G *et al.* (ATLAS) 2013 *JHEP* **11** 183
[2] Adamczyk L *et al.* (STAR) 2015 *Phys. Rev. Lett.* **115** 22301
[3] Giacalone G *et al.* arXiv:1608.01823

The STAR Collaboration
drupal.star.bnl.gov/STAR/presentations