Multiparticle correlations from the direct calculation of cumulants using particle azimuthal angles

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Motivation
What is the smallest possible droplet of QGP?
- What is the smallest \(N_m\)?
- How to measure 6 and more particle correlations at \(N_m<100\)?

To understand how the nonflow affects multiparticle correlations, we propose calculating cumulants directly using particle azimuthal angles (Looping) in small systems.

Standard cumulant method
To avoid using nested loops, introduce the Q-vector [1]:
\[
Q_{h,n} = \sum_{i=1}^{M} e^{i(n\phi_1 + \phi_2 - \phi_3 - \phi_4)}
\]
\[
\langle Q_{h,n} \rangle = \frac{\langle Q_{h,n} \rangle}{M(M-1)} - 2 \frac{\langle Q_{h,n} \rangle}{M(M-1)(M-2)} - 2 \frac{\langle Q_{h,n} \rangle}{M(M-1)(M-2)(M-3)}
\]
Calculate Q-vectors in different subevents, then estimate cumulants and flow

Subevent cumulant method
Based on the standard method, introducing subevents [2]:
(a) Three subevents
\[
\langle Q_{n,m} \rangle = \frac{1}{M(M-1)(M-2)} \sum_{i=1}^{M} e^{i(n\phi_1 + \phi_2 - \phi_3 - \phi_4)}
\]
(b) Two subevents
\[
\langle Q_{n,m} \rangle = \frac{1}{M(M-1)} \sum_{i=1}^{M} e^{i(n\phi_1 + \phi_2 - \phi_3 - \phi_4)}
\]
Calculate Q-vectors in different subevents, then estimate cumulants and flow

Introducing the Looping method
- Need to study correlations vs. \(\eta\) gap
- Run out of statistics quickly
- Any solutions?
- Recall that the idea behind Q-cumulant method is to avoid using nested loops
- If we just loop over particle azimuthal angles, it is very easy to study the \(\eta\) gap dependence
- Also with much better statistics since it keeps all possible combinations

Current status
Have to redo it with eta gaps

Results
Cumulants
- Introducing subevents makes a huge difference
- Looping method removes much more nonflow

Symmetric Cumulants
\[
SC(n,m) = \langle (\phi_1 - \phi_2)^n (\phi_3 - \phi_4)^m \rangle
\]
\[
SC(n,m)_{k_l} = \langle (\phi_1 - \phi_2)^n (\phi_3 - \phi_4)^m \rangle
\]
Asymmetric Cumulants
\[
AC_{n,m(\eta)}(4) = \langle (\phi_1 - \phi_2)^n (\phi_3 - \phi_4)^m \rangle
\]
\[
AC_{n,m(\eta)}(4) = \langle (\phi_1 - \phi_2)^n (\phi_3 - \phi_4)^m \rangle
\]

Conclusions
Turn-on of flow is important for understanding the smallest possible droplet
The looping method is introduced to suppress nonflow in small systems
The method could also be used for Symmetric/Asymmetric Cumulants

References