EVENT SHAPE ANALYSIS IN ULTRARELATIVISTIC NUCLEAR COLLISIONS*

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(Received May 31, 2016)

We present a novel method for sorting events. So far, single variables like flow vector magnitude were used for sorting events. Our approach takes into account the whole azimuthal angle distribution rather than a single variable. This method allows us to determine the good measure of the event shape, providing a multiplicity-independent insight. We discuss the advantages and disadvantages of this approach, the possible usage in femtoscopy, and other more exclusive experimental studies.

DOI:10.5506/APhysPolBSupp.9.247

1. Introduction

Initial conditions in heavy-ion collisions fluctuate from event to event: there are different impact parameters and different initial energy-density distributions. Hot matter created in those collisions expands very fast in both longitudinal and transverse directions, initial inhomogeneities are translated into all orders of anisotropy of this expansion. The analysis of event shapes can help us identify events with similar initial conditions undergoing similar evolution. We present a novel study of event shapes using the algorithm proposed in [1]. This algorithm studies the *shape* of the distribution rather than a single variable. It compares, sorts and selects events according to *similarity* with each other.

2. The method

The method is thoroughly described in [2]. Here, it will be briefly described using a simple example. We generated 5000 events from a toy model. It generates azimuthal angles of pions from the distribution

* Presented at WPCF 2015: XI Workshop on Particle Correlations and Femtoscopy, Warszawa, Poland, November 3–7, 2015.

$$P_5(\phi) = \frac{1}{2\pi}\left(1 + \sum_{n=1}^{5} 2v_n \cos(n(\phi - \psi_n))\right) . \tag{1}$$

The parameters v_n are quadraticaly multiplicity dependent, details can be found in [2], multiplicity $M \in (300, 3000)$. This choice is motivated by the LHC data [3, 4].

For each event, we made an azimuthal angle histogram with 20 bins. Every event is then described by its record $\{n_i\}$. Since we are studying *angle* distribution, the choice of rotating single events is free. We will address this issue in the next section. The algorithm operates as follows [2]:

1. (Somehow rotate the events).
2. Order events according to a chosen variable.
3. Divide the sorted events into quantiles (deciles).
4. For every event calculate the probability that event with record $\{n_i\}$ belongs to event bin μ: $P(\mu|\{n_i\})$.
5. For every event calculate mean bin number $\bar{\mu}$ (values 1–10): $\bar{\mu} = \sum \mu P(\mu|\{n_i\})$.
6. Sort events according to $\bar{\mu}$.
7. If the new sorting changed the assignment of any events into event bins, return to (3). Otherwise the algorithm converged.

Events with a similar shape are organized by the algorithm so that they end up close together. There is no specific observable according to which the sorting proceeds. Moreover, the final arrangement of events is independent of the initial sorting.

3. Results

First, we tested the algorithm using events which include only v_1 and v_2. One of the methods used in event shape studies is *Event Shape Engineering* [5]. This method sorts the events according to a chosen observable, usually $q_2 = |\sum_{j=1}^{n} e^{2i\phi_j}|/M$. We were interested in verifying whether q_2 is truly a good measure for sorting events. As can be seen in Fig. 1, the correlation of $\bar{\mu}$ with v_2 is clearly better than correlation of $\bar{\mu}$ with q_2. This means v_2 is better observable for sorting events than q_2 in this simple case. As mentioned before, the rotation of each event can be arbitrary. Since in this simple case v_2 is clearly dominant, we decided to rotate events in a way that $\psi_2 = 0$.

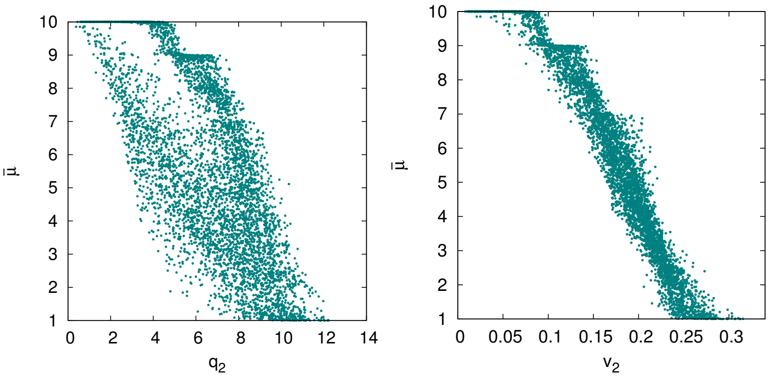

Fig. 1. Left: correlation of $\bar{\mu}$ with q_2 determined for each event. Right: correlation of $\bar{\mu}$ with v_2 determined for each event via the event plane method.

In order to test more realistic setting, we then generated events with all five orders of Eq. (1). The initial event rotation is not as simple as in the previous case. Interplay of harmonics comes into play. We rotated the events according to the bisector of ψ_3 and ψ_2. Moreover, we have to take care of the parity symmetry. Hence, the events are oriented so that ψ_2 is less than $\pi/2$ away from ψ_3 counterclockwise. The final event sorting is shown in Fig. 2. It turns out that v_2 is as bad for sorting events as q_2 and the sorting is not even dominated by v_3. Higher harmonics do not play any role at all. This suggests that event shape is determined by an interplay of several observables.

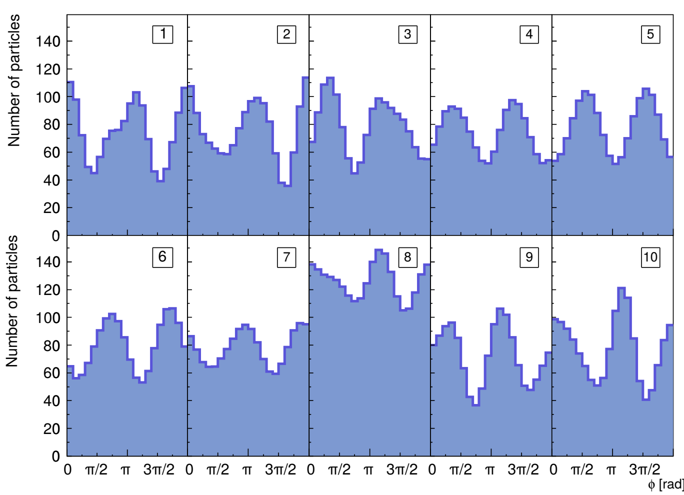

Fig. 2. Average histograms of the azimuthal angles for event bins 1–10, with event bins indicated in the panels.

4. Conclusions and outlook

The proposed sorting algorithm provides a novel method to identify events which have evolved similarly. Our results confirm the importance of elliptic and triangular flows for the event shape analysis.

Our approach can be useful in studies including mixed events technique. One could do, *e.g.*, a femtoscopic study of an exclusive group of events. This means that we could get as close as possible to single-event femtoscopic studies. *Event Shape Sorting* could provide a selection of events with similar momentum distributions which would make a suitable sample for event mixing. In the case of statistics in a single event being too small, one could take a sample of events with similar momentum distributions and reasonably expect that they also have the same sizes and undergo the same dynamics. Then, one could analyse the correlation function integrated over the whole selected event sample. The feasibility of such studies will be investigated in the future.

On the technical side, the required computational time is rather high, but since we have not optimised our algorithm yet, we expect the required CPU time to decrease significantly. We will also scrutinise the initial rotation of events.

Furthermore, we are currently studying a set of events obtained by AMPT. This will bring an insight into more realistic events. In spite of these difficulties, we believe that our method is worth applying in real data and that it will bring more detailed understanding of heavy-ion collisions dynamics.

Supported in parts by SGS15/093/OHK4/1T/14 (Czech Republic), APVV-0050-11, and VEGA 1/0469/15 (Slovakia).

REFERENCES

[1] S. Lehmann, A.D. Jackson, B. Lautrup, `arXiv:physics/0512238[physics.soc-ph]`.

[2] R. Kopečná, B. Tomášik, *Eur. Phys. J. A* **52**, 115 (2016).

[3] G. Aad *et al.* [ATLAS Collaboration], *Phys. Rev. C* **86**, 014907 (2012).

[4] G. Eyyubova [for the ALICE Collaboration], *EPJ Web Conf.* **70**, 00075 (2014).

[5] J. Schukraft, A. Timmins, S. Voloshin, *Phys. Lett. B* **719**, 394 (2013).