# Azimuthally sensitive femtoscopy with sorted events

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## 1. Motivation

In ultra-relativistic heavy-ion collisions each event evolves from different initial conditions. This leads to anisotropies in the final distributions of hadrons.

Some information may get lost if we average hadron distributions over events with fluctuating anisotropies. If events are aligned according to second-order or third-order event plane, only that order of anisotropies is seen in correlation radii. Can we see a more rich structure?

**What if we select pairs of particles from events which are similar and were likely to undergo similar evolution?**

We use Event Shape Sorting (ESS) [1] to sort events according to their shape and divide them into classes, in which events have similar shape.

## 2. Event Shape Sorting

We apply the method to histograms of azimuthal angles of hadron momenta.

**The algorithm:**

1. (Rotate the events appropiately)
2. Sort events arbitrarily, e.g. by their $v_2$ (initial sorting does not influence the final result)
3. Divide sorted events into $\omega$ classes (we use $\omega = 10$)
4. Determine average histograms in each class
5. For each event $i$ calculate Bayesian probability that it belongs to class $\mu$.
6. For each event calculate mean class number $\bar{\mu} = \sum_{\mu=1}^{10} \mu P(i|\mu)$
7. Sort events according to their values of $\bar{\mu}$
8. If order of events changed, return to 3. Otherwise sorting converged.
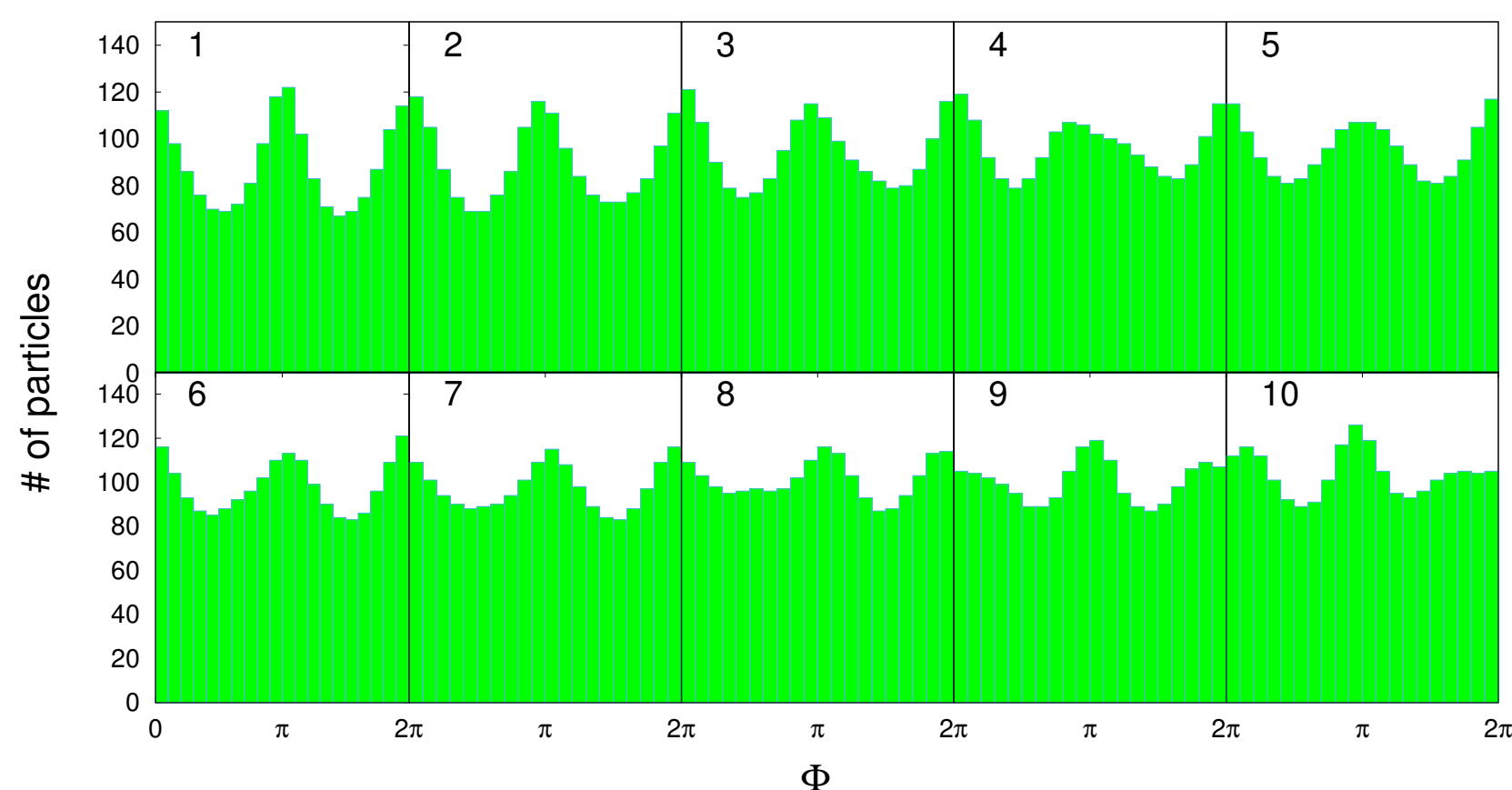
**Result of the algorithm: sorted events**



**Figure 1:** *Average shape of events in classes as a result of ESS. This result is from AMPT-LHC sample.*

Through this QR code you can view an animation showing how the process of Event Shape Sorting is changing average shape of events in classes during iterations (∼50MB).

## 3. Generated Events

We generated events using DRAGON [2] and AMPT [3] generators. We used three samples of simulated events:

- 150 000 DRAGON events with anisotropies $a_2, \rho_2 \in (-0.1; 0.1)$, $a_3, \rho_3 \in (-0.03; 0.03)$
- 10 000 AMPT events of AuAu collisions at RHIC energy $\sqrt{s_{NN}} = 200\,\mathrm{GeV}$, impact parameter 7-10 fm
- 10 000 AMPT events of PbPb collisions at LHC energy $\sqrt{s_{NN}} = 2760\,\mathrm{GeV}$, impact parameter 7-10 fm

## 4. Result of sorting

The effect of sorting can be seen in the evolution of coefficients $v_2$ and $v_3$ across classes. We can see that there is still bigger dependence on second order anisotropy, but in the last class the third order becomes high enough to overcome second order.
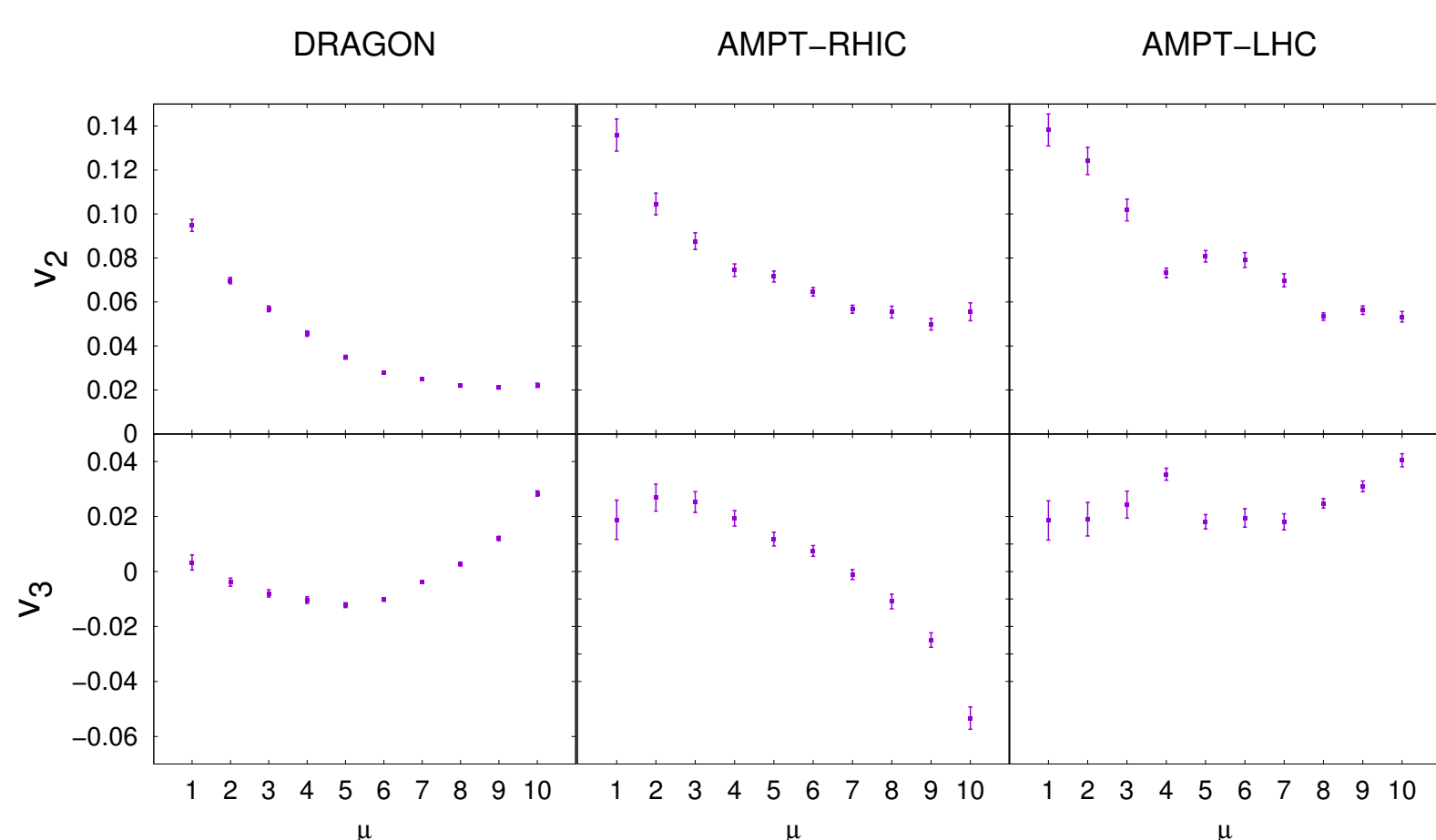


**Figure 2:** *Coefficients $v_2$ and $v_3$ of average histograms for three different samples of events. Negative $v_n$ means a shift of the corresponding event plane by $\pi/n$.*
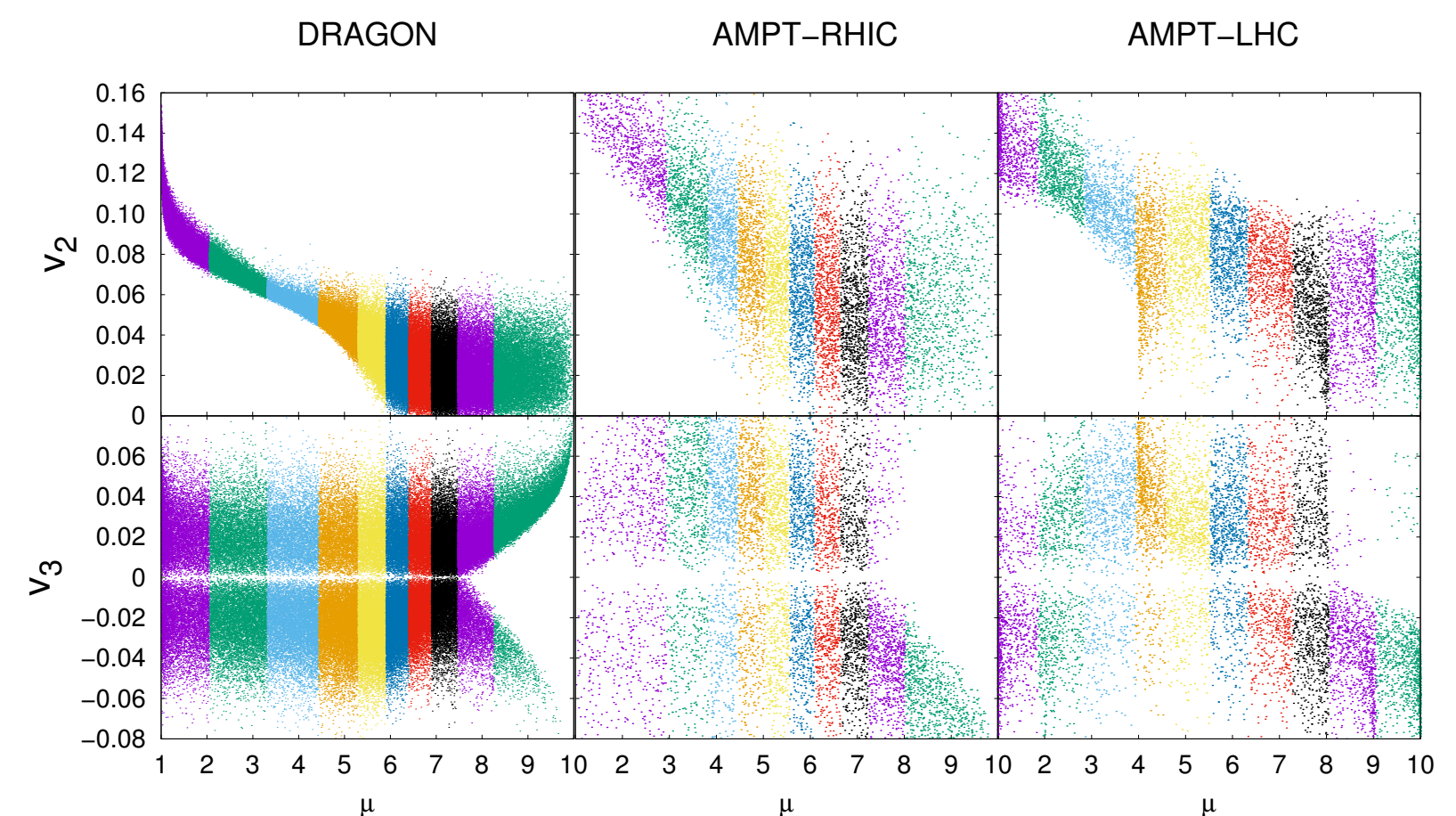


**Figure 3:** *Dependence of coefficients $v_2$ and $v_3$ of all events on mean class number. Negative $v_n$ means a shift of the corresponding event plane by $\pi/n$.*

## 5. Femtoscopy of similar events

We generated correlation functions for each class using CRAB [4]. Correlation function can be fit with 3D Gauss distribution to obtain correlation radii $R_i^2$. These radii are azimuthally dependent and can be decomposed into Fourier series. Then we can study second and third order anisotropy of correlation radii for each class.
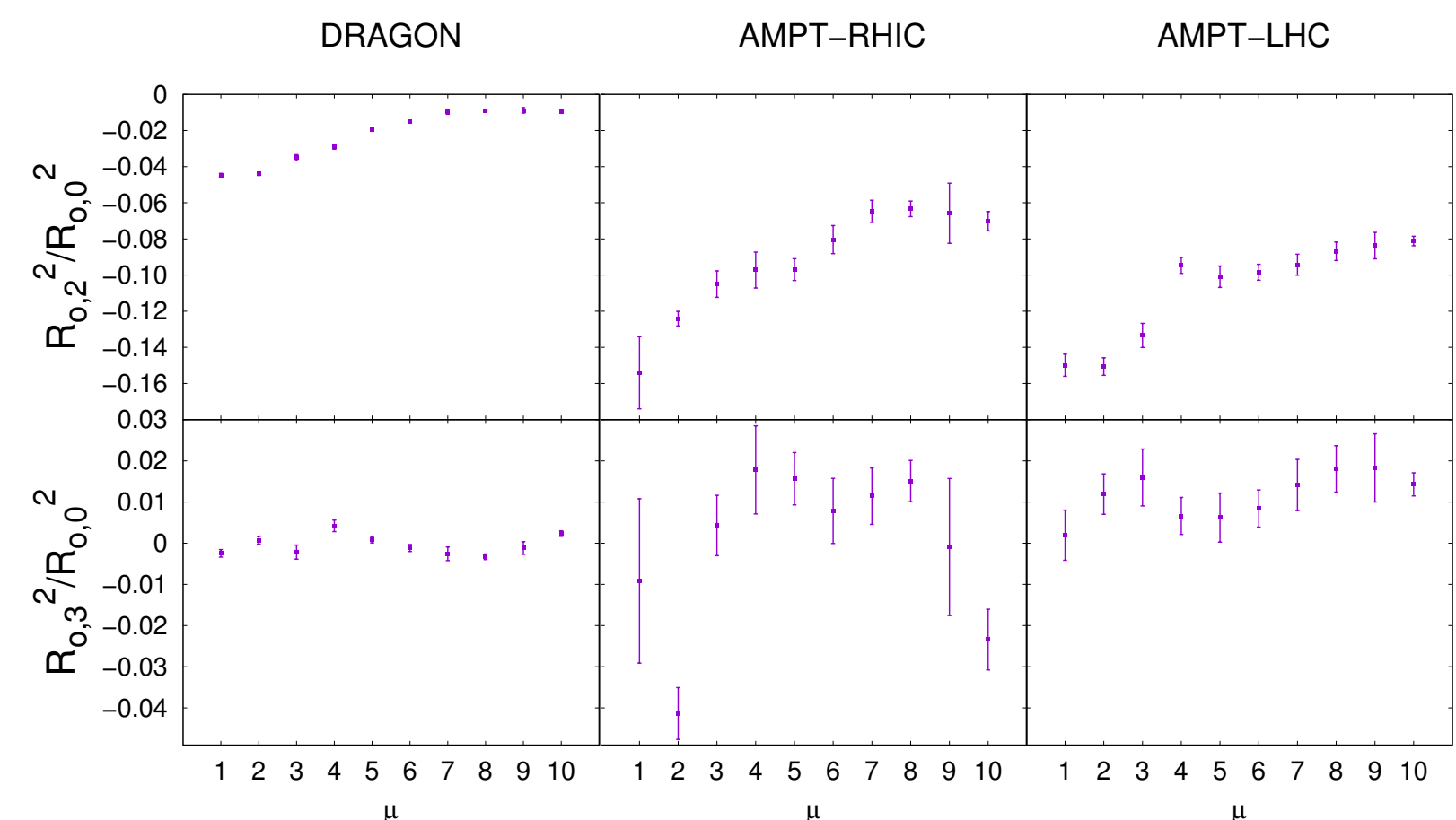


**Figure 4:** *Second and third-order Fourier coefficients scaled by zeroth-order coefficients of the correlation radius $R_o^2$, for sorted event classes.*
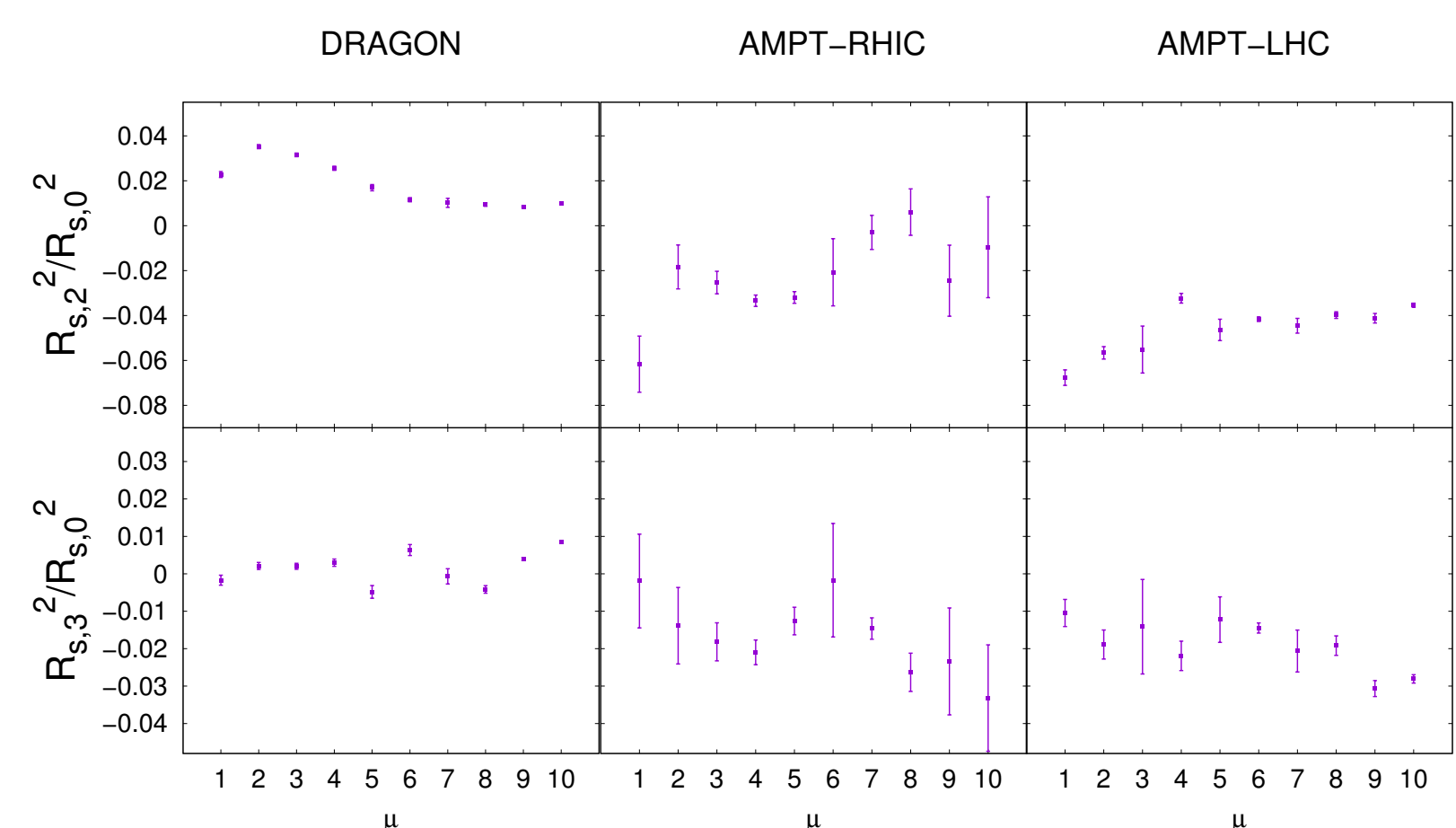


**Figure 5:** *Second and third-order Fourier coefficients scaled by zeroth-order coefficients of the correlation radius $R_s^2$, for sorted event classes.*

On these plots we can see different behavior of generators and also different behavior of events with different energy. We can also observe both orders of anisotropy in each class. While in first classes the second order is dominant, in the last class third order again overcome second order.

## 6. Conclusions

Event shape sorting can help to select events with similar shapes. Thanks to ESS we can calculate correlation functions of similar events, because events are chosen more exclusively, over which we take averages.

In classes of similar events we can observe both second and third order anisotropies of correlation radii at the same time. We can also see evolution of the shape of events and correlation radii across classes.

One could also try single-event femtoscopy, because the Event Shape Sorting allows to construct mixed-events background from similar events.

## References

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[2] B. Tomášik, Comp. Phys. Commun. **180** (2009) 1642

[3] Z.-W. Lin et al., Phys. Rev. C **72** (2005) 064901

[4] S. Pratt, [online] https://web.pa.msu.edu/people/pratts/freecodes/crab/home.html