Prospects of Event Shape Sorting

Jakub Cimerman, Boris Tomášik

3 December 2019

Have you ever been told by someone
"You're doing too much averaging in that analysis. You lose a lot of information about anisotropies and so on."?

No problem. I'll just use

Event Shape Engineering

But according to which variable I sort the events?

Have you recognized yourself in this?

Then we have a perfect tool for you

Have you recognized yourself in this?

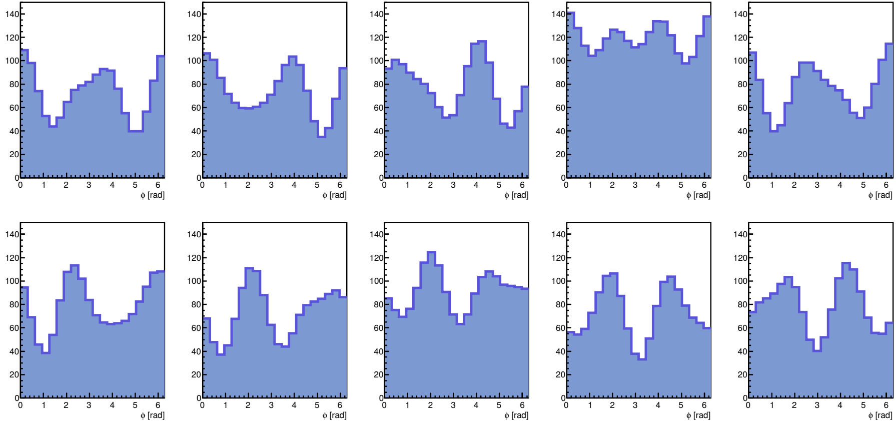
Then we have a perfect tool for you

Event Shape ~~Engineering~~ Sorting

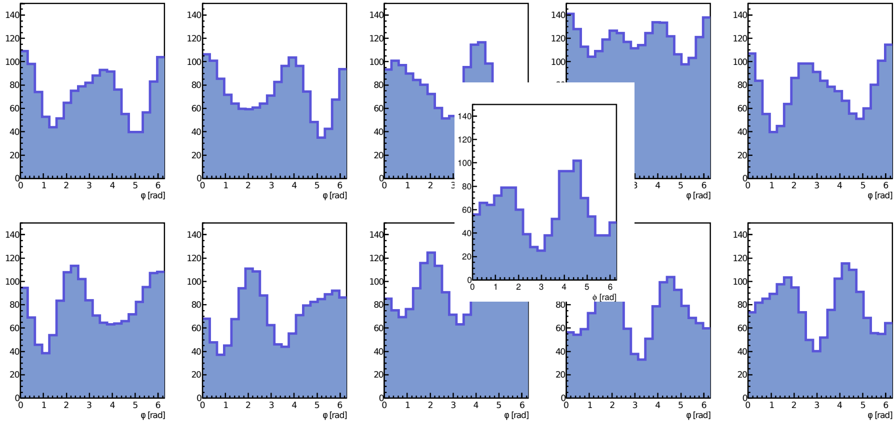
Event Shape Sorting vs Event Shape Engineering

- Both are sorting algorithms
- ESE sorts events according to one chosen property (q_2, q_3, $\ldots$), but all the other properties will be averaged out
- ESS sorts events according to similarity of their shapes in a more complex way, so you can see combination of anisotropies of different orders at the same time

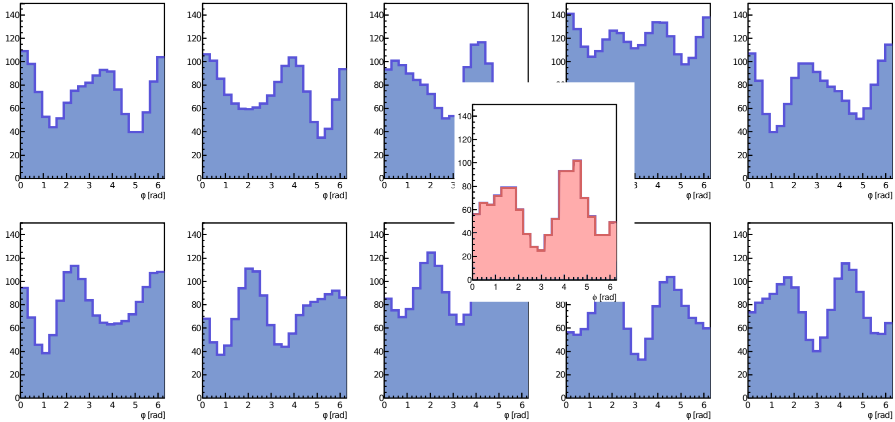
Event Shape Sorting Algorithm



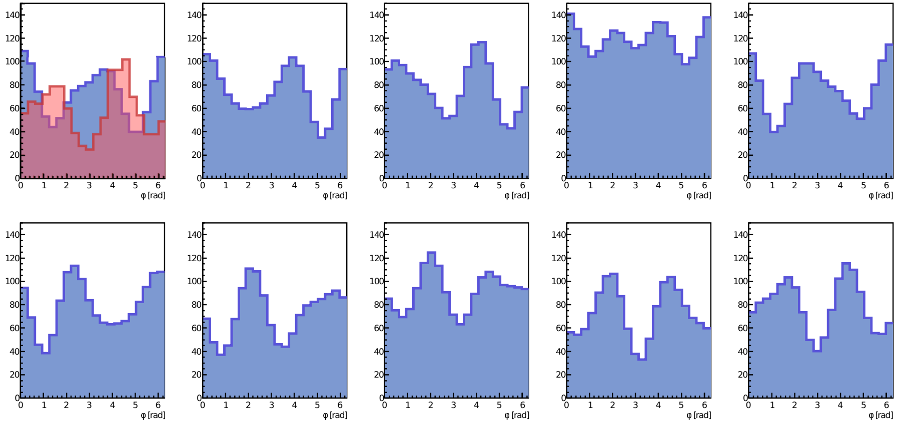
Event Shape Sorting Algorithm



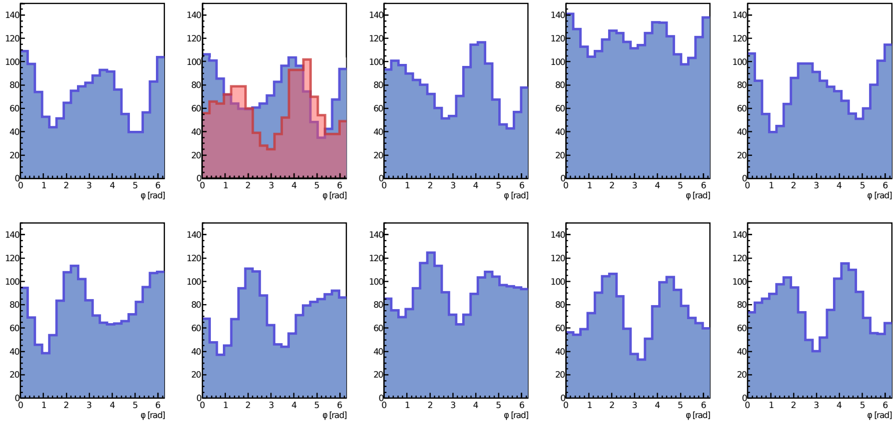
Event Shape Sorting Algorithm



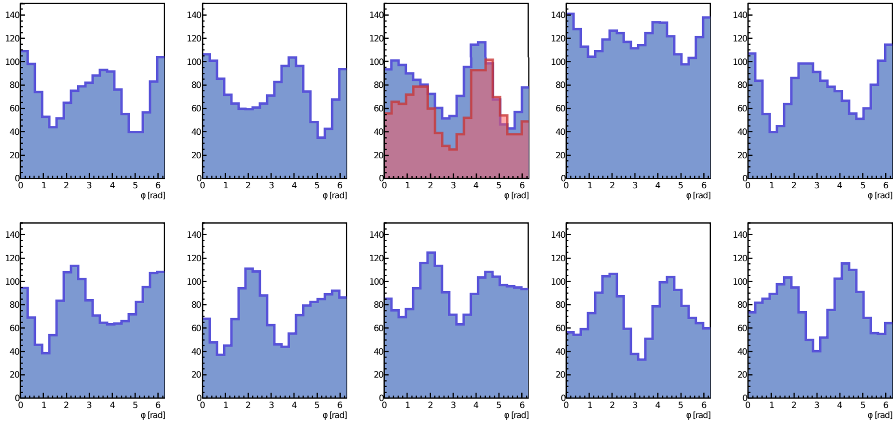
Event Shape Sorting Algorithm



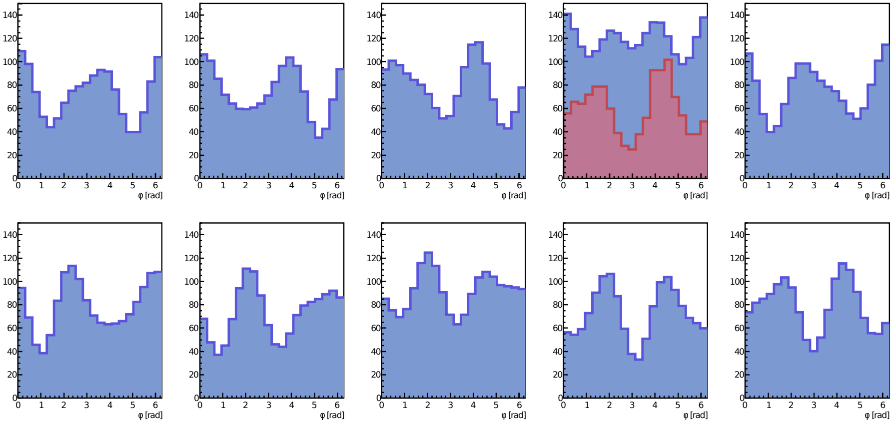
Event Shape Sorting Algorithm



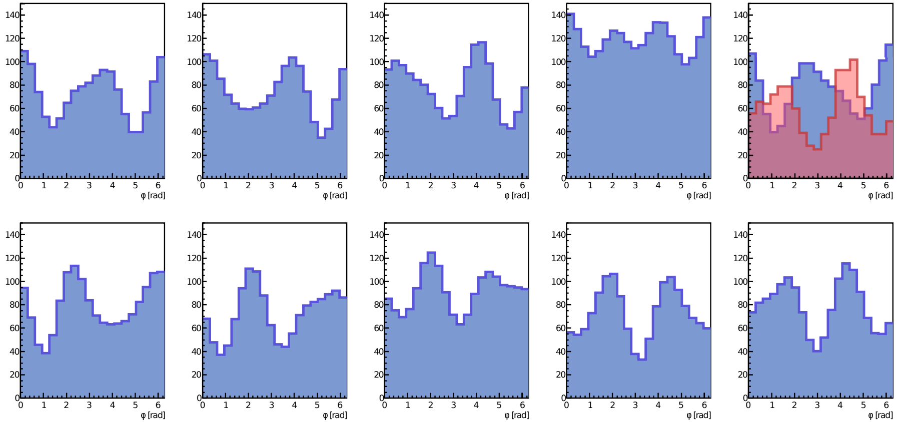
Event Shape Sorting Algorithm



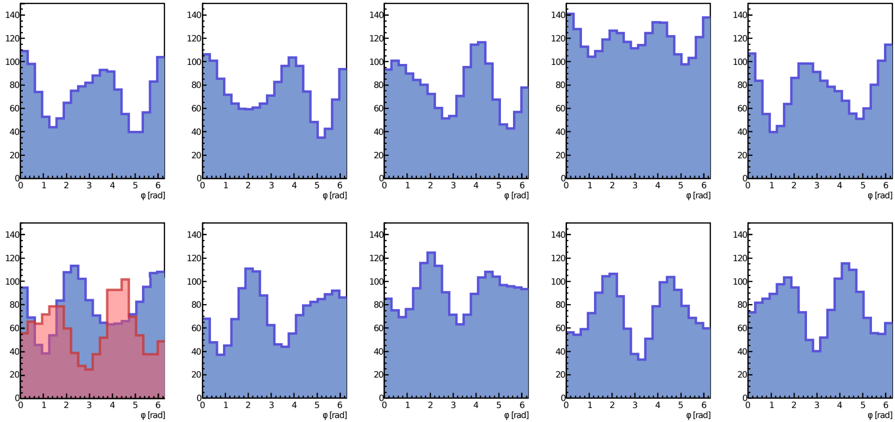
Event Shape Sorting Algorithm



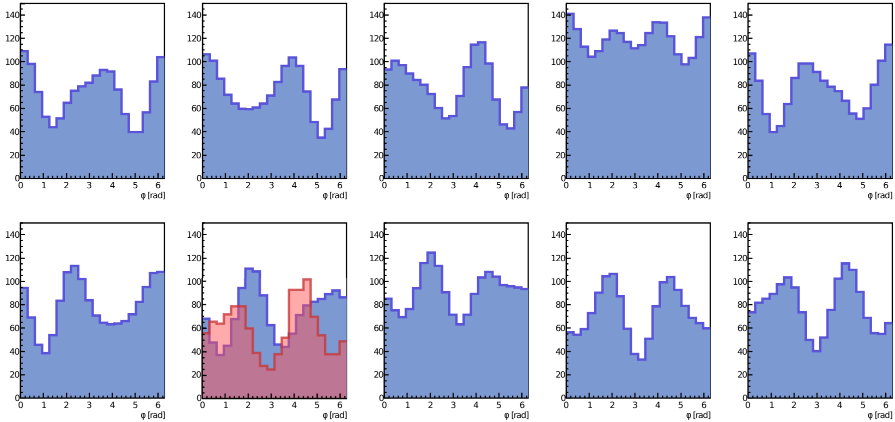
Event Shape Sorting Algorithm



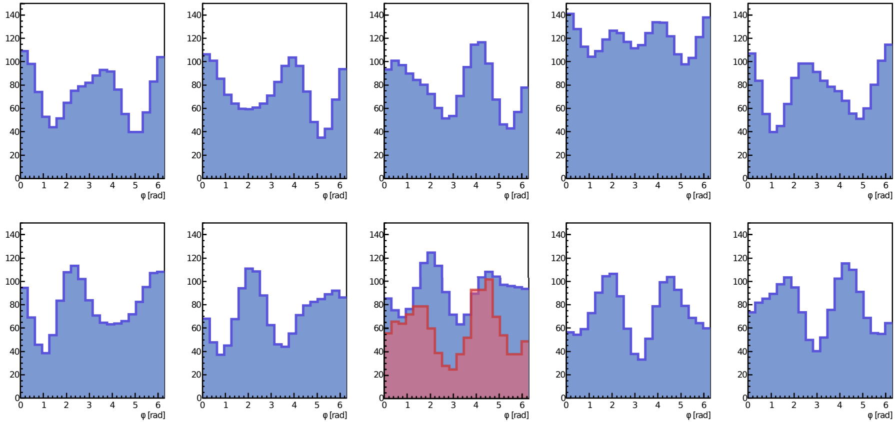
Event Shape Sorting Algorithm



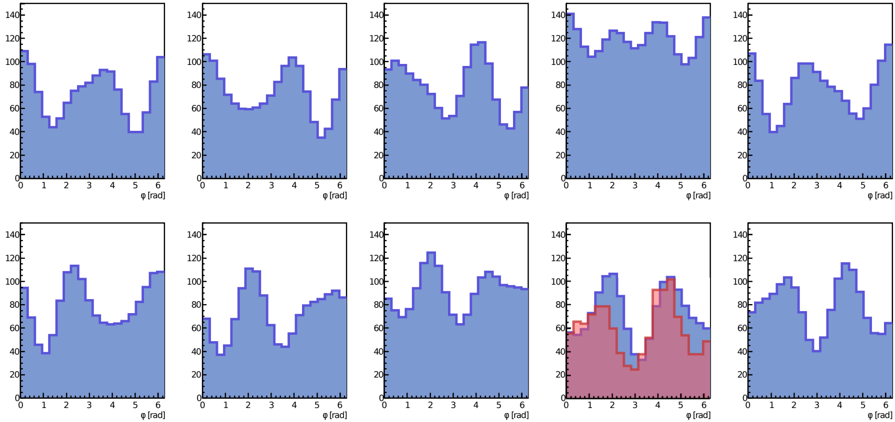
Event Shape Sorting Algorithm



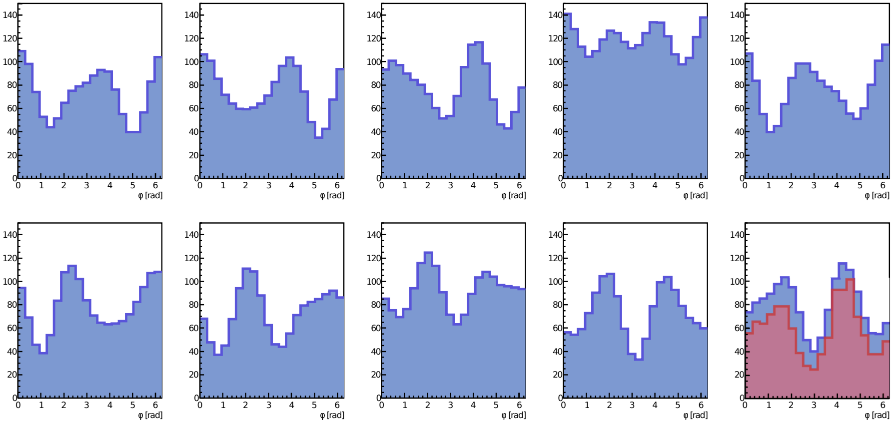
Event Shape Sorting Algorithm



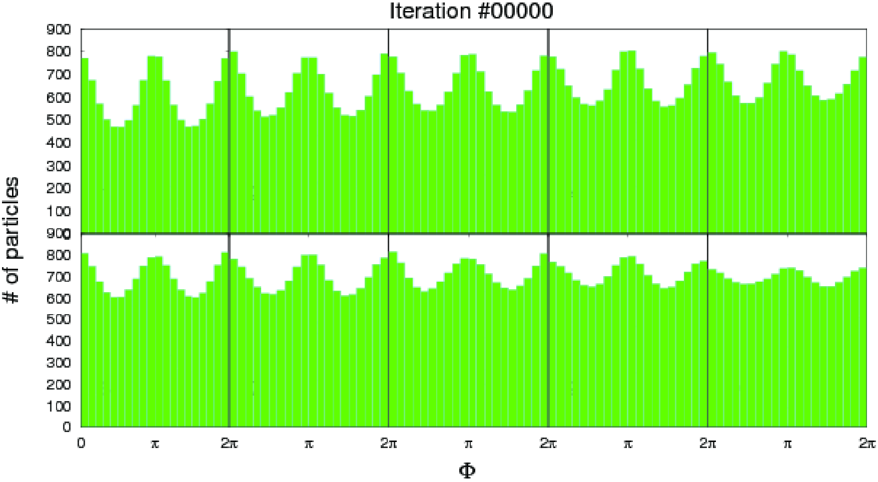
Event Shape Sorting Algorithm



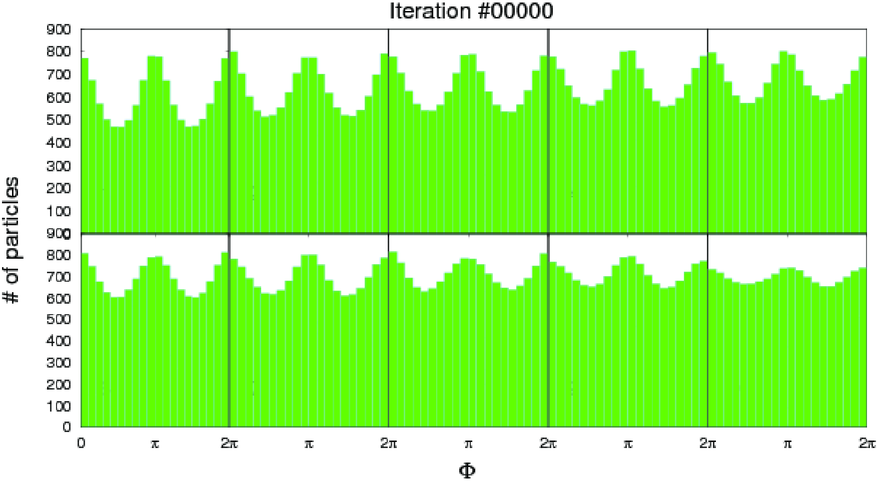
Event Shape Sorting Algorithm



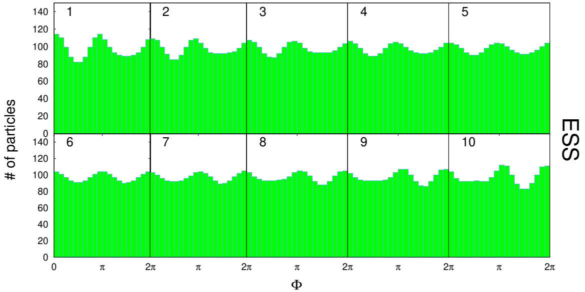
Animation of Event Shape Sorting

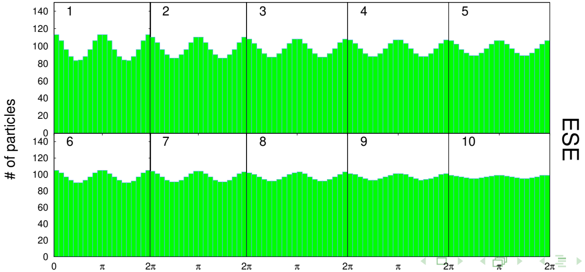


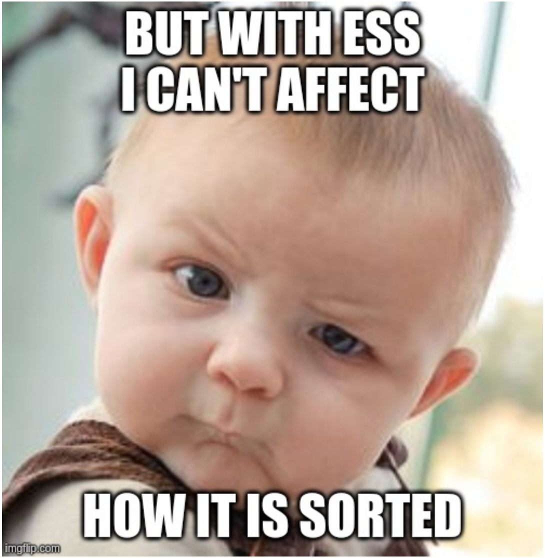
Animation of Event Shape Sorting



Results of Sorting: ESS vs. ESE






BUT WITH ESS
I CAN'T AFFECT
HOW IT IS SORTED
imgflip.com

But that is a good thing

But that is a good thing

ESS can find things you don't know are there

But that is a good thing

ESS can find things you don't know are there

Let's take a look at some example

Correlation between the Second and Third-Order Event Plane

- For uncorrelated event planes we get

$$\left\langle e^{i\{\theta_2-\theta_3\}_{min}} \right\rangle = \frac{\int_0^{\pi} \mathrm{d}\theta_2 \int_0^{\frac{2\pi}{3}} \mathrm{d}\theta_3 e^{i\{\theta_2-\theta_3\}_{min}}}{\int_0^{\pi} \mathrm{d}\theta_2 \int_0^{\frac{2\pi}{3}} \mathrm{d}\theta_3} = \frac{3}{\pi}$$

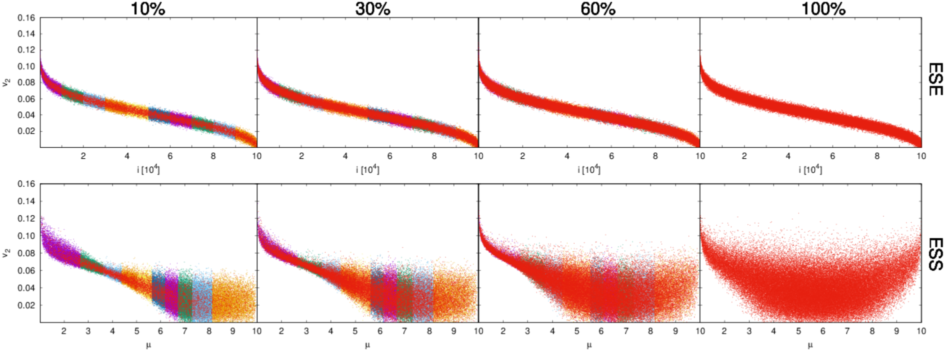
- The same value of the correlator can be obtained with event planes which only differ by one of two possible values

$$\left\langle e^{i\{\theta_2-\theta_3\}_{min}} \right\rangle = \frac{1}{2}\left(e^{i\delta_1} + e^{i\delta_2}\right) = \frac{3}{\pi}$$

$$\delta_{1,2} = \pm 0.301374$$

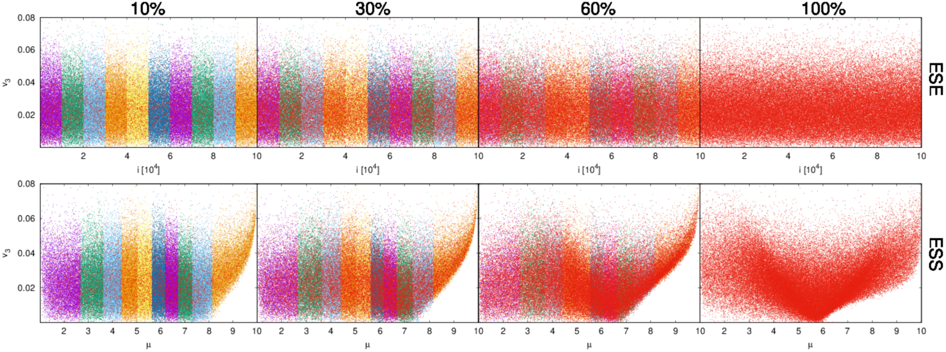
- To illustrate this, we generated 100 000 events using DRAGON with 10%, 30%, 60% and 100% events with correlated event planes

Amplitude of Second Order Anisotropy v_2



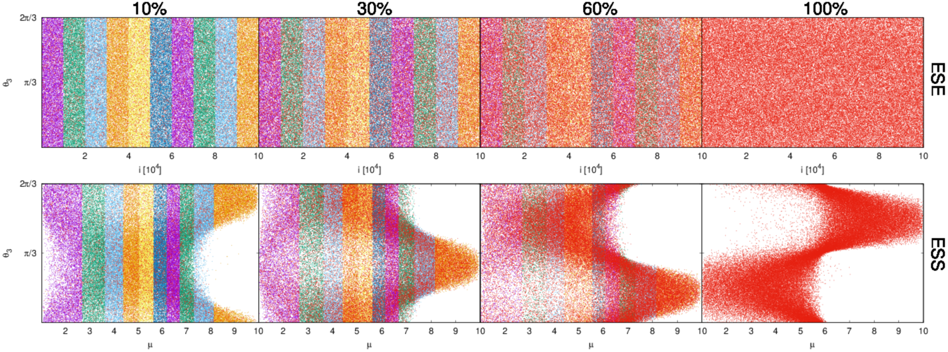
- Correlated events are tagged with red dots
- μ is the sorting variable in ESS algorithm

Amplitude of Third Order Anisotropy v_3



- Correlated events are tagged with red dots
- μ is the sorting variable in ESS algorithm

Angle of Rotation of the Third Order Plane θ_3



- Correlated events are tagged with red dots
- μ is the sorting variable in ESS algorithm

Conclusions

- We have shown the advantages of ESS against ESE
  - ESS takes into account both sedond- and third-order anisotropies at the same time, which ESE can not
  - ESS can find out some informations which can not be found using ESE

Backup slides

Event Shape Sorting algorithm

- 1. Split particles in each event into k azimuthal angle bins
- 2. Initial sorting according to $|\vec{q}_2|$
- 3. Calculate $P(i|\mu)$ for each angle bin in each class

$$P(i|\mu) = \frac{\sum_{\text{events in } \mu\text{-th class}} (n_i)_j}{\sum_{\text{events in } \mu\text{-th class}} N_j}$$

- 4. Calculate $P(\mu|\left\{n_i\right\}_j)$ for each event

$$P(\mu|\left\{n_i\right\}_j) = \frac{\prod_{i=1}^{k} P(i|\mu)^{(n_i)_j}}{\sum_{\mu'=1}^{\omega} \prod_{i=1}^{k} P(i|\mu')^{(n_i)_j}}$$

- 5. Calculate mean class number $\overline{\mu}$

$$\overline{\mu} = \sum_{\mu=1}^{\omega} \mu P(\mu|\left\{n_i\right\}_j)$$

- 6. Sort events according to $\overline{\mu}$
- 7. Repeat from step 3, until order of events stay unchanged

Statistical Fluctuations

- How statistical fluctuations influence the sorting?
- To find out we split the particles according to their pseudorapidity into reference particles $|\eta| < 0.4$ and test particles $0.5 < |\eta| < 0.8$
- This was done with three sets of simulated data
  - **DRAGON:** 150 000 events with anisotropies $a_2, \rho_2 \in (-0.1; 0.1)$, $a_3, \rho_3 \in (-0.03; 0.03)$
  - **UrQMD:** 100 000 events in Au+Au collisions, $\sqrt{s_{NN}} = 200$ GeV, impact parameter $b \in (7; 10)$ fm
  - **AMPT:** 10 000 events in Au+Au collisions, $\sqrt{s_{NN}} = 200$ GeV, impact parameter $b \in (7; 10)$ fm

Amplitude of Second Order Anisotropy v_2