Angular correlations of particle yield ratios

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Introduction

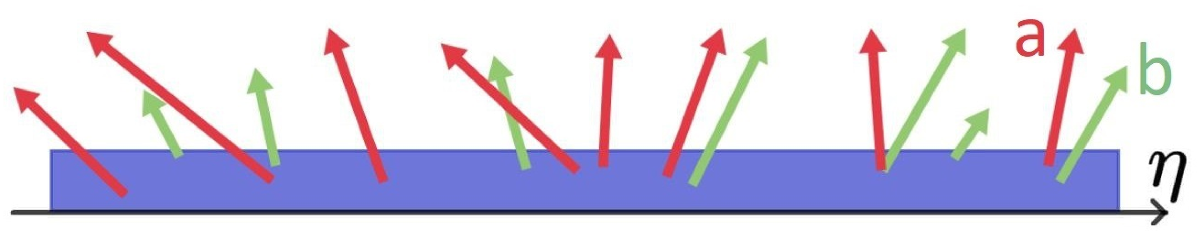
Event-by-event fluctuations are sensitive to phase transitions and other collective phenomena in systems formed in high-energy hadronic collisions. Recently proposed fluctuation observable [1], namely, the correlation coefficient between ratios of identified particle yields measured in two angular acceptance windows, has a number of useful properties. In this work we demonstrate them and show predictions from several models. These calculations will serve as baselines for the future measurements of this observable in real experimental data.

Fluctuations of ratio

Event-by-event fluctuations of the ratios of particles of different types, $r = n_a/n_b$, can be described by the *integrated* observable ν_{dyn} [2].

$$\nu_{\mathrm{dyn}} \equiv \nu - \nu_{\mathrm{stat}} = \frac{\langle n_a(n_a-1)\rangle}{\langle n_a\rangle^2} + \frac{\langle n_b(n_b-1)\rangle}{\langle n_b\rangle^2} - 2\frac{\langle n_a n_b\rangle}{\langle n_a\rangle\langle n_b\rangle}, \quad (1)$$

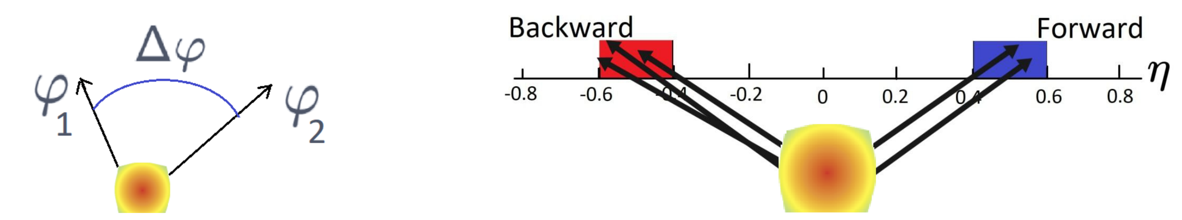
where $\nu \equiv \frac{\Delta r^2}{\langle r\rangle^2} \approx \left\langle\left(\frac{n_a}{\langle n_a\rangle} - \frac{n_b}{\langle n_b\rangle}\right)^2\right\rangle$, equals to $\nu_{\mathrm{stat}} = \frac{1}{\langle n_a\rangle} - \frac{1}{\langle n_b\rangle}$ with Poissonian distribution.



The particles are taken from the whole detector acceptance, so there are contributions from short-range effects (decays, jets).

Angular correlations

Example of a *differential* observable is pairwise correlation in azimuthal plane [3].

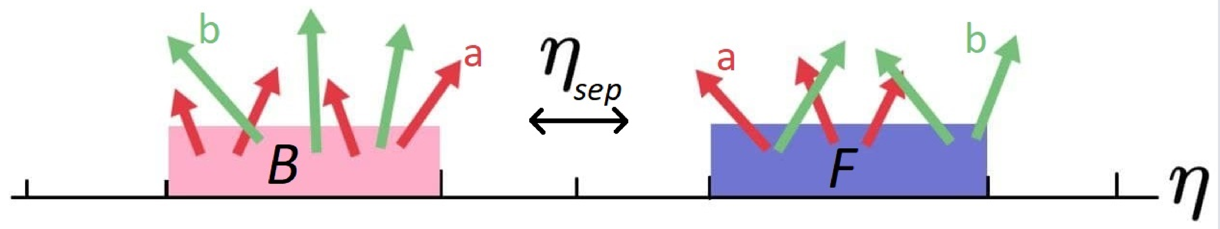


Another type of differential studies are the so-called forward-backward correlations. If particles are correlated in two separate rapidity intervals, they were probably produced in the initial state of a collision. Unfortunately, this quantity is sensitive to the fluctuations of system volume. This leads to trivial effects which can be overcome using strongly intensive quantities, such as ν_{dyn}, ν_{FB}.

Correlation of ratios in η intervals

The differential observable ν_{FB} [1] shows the correlation strength between the ratios in forward and backward rapidity intervals.

$$\nu_{\mathrm{FB}}^{a/b} = \frac{\langle r^F \cdot r^B\rangle}{\langle r^F\rangle \cdot \langle r^B\rangle} - 1 \approx$$
$$\frac{\langle n_a^F n_a^B\rangle}{\langle n_a^F\rangle\langle n_a^B\rangle} + \frac{\langle n_b^F n_b^B\rangle}{\langle n_b^F\rangle\langle n_b^B\rangle} - \frac{\langle n_a^F n_b^B\rangle}{\langle n_a^F\rangle\langle n_b^B\rangle} - \frac{\langle n_b^F n_a^B\rangle}{\langle n_b^F\rangle\langle n_a^B\rangle} \quad (2)$$

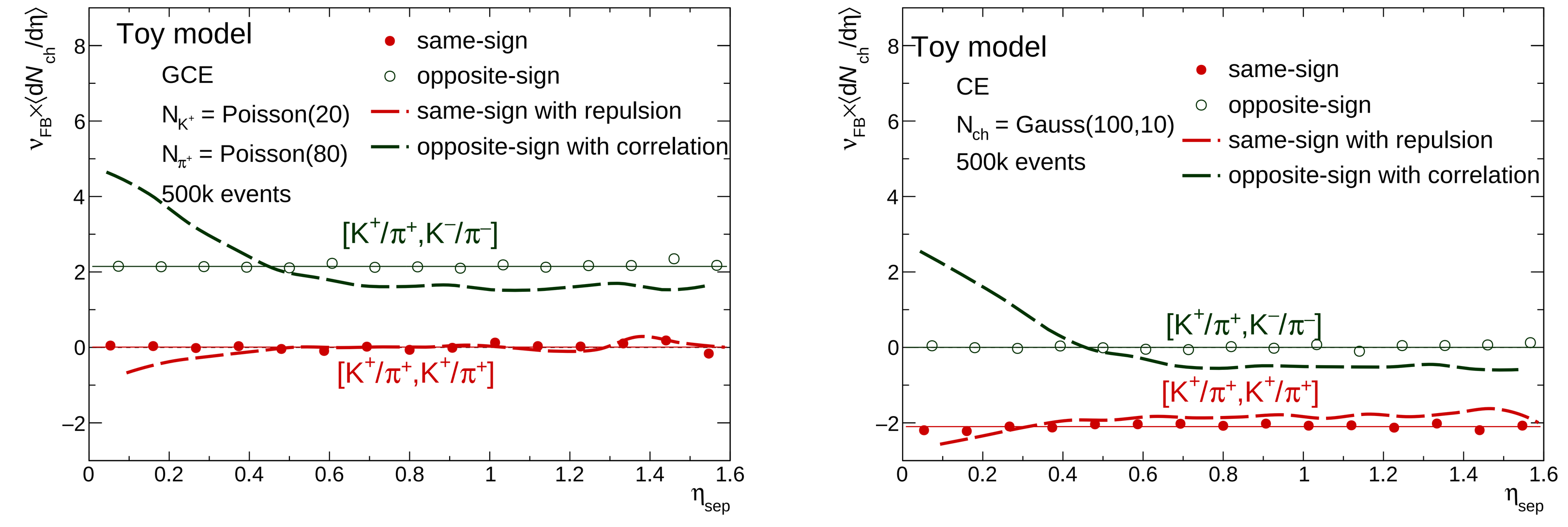


The properties of the ν_{FB} are the same as of the ν_{dyn}:

- = 0 if independent particle production, measures deviations from Poissonian behaviour;
- robust against volume fluctuations, efficiency losses;
- not affected by short-range effects (decays, jets) at large η_{sep} (not the case for the ν_{dyn}).

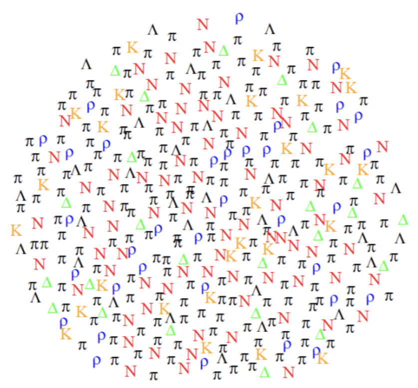
Toy model

Two ensembles, grand canonical (GCE) and canonical (CE), are emulated. In GCE pions and kaons are generated from Poisson distribution, while in CE they have strictly fixed fraction. Short-range correlations are simulated: repulsion for same-sign pairs (re-generation of η if values are close) and a higher probability to have close η for opposite-sign pairs.



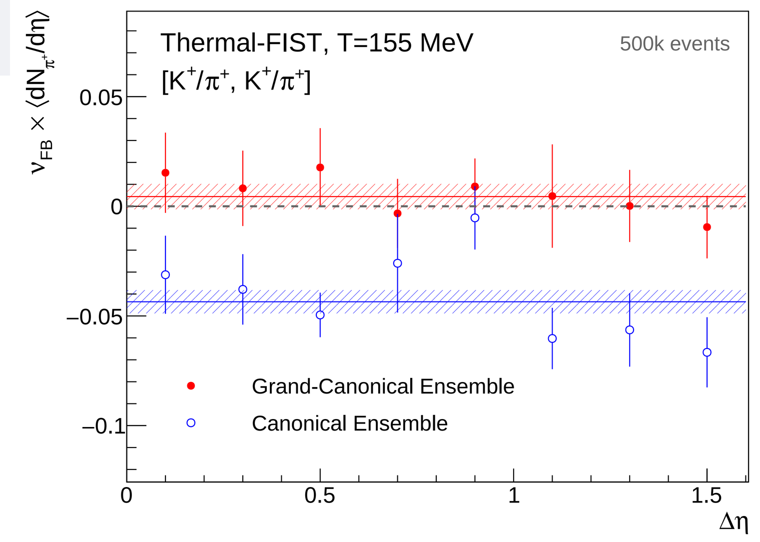
–Canonical suppression and positive impact from charge conservation is visible.

Thermal model



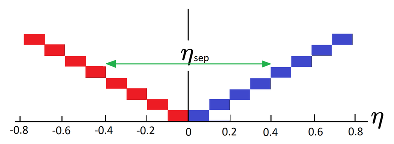
Thermal model equilibrated hadron resonance gas (HRG) at the chemical freeze-out stage. Thermal-FIST package [4] was used in Monte Carlo mode (HRG + radial flow + decays) for CE and GCE.

–The pattern of suppression for the CE is observed.

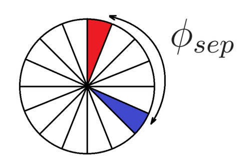


String-based models: HIJING (Pb–Pb) and PYTHIA (pp)

Rapidity windows



Azimuthal windows

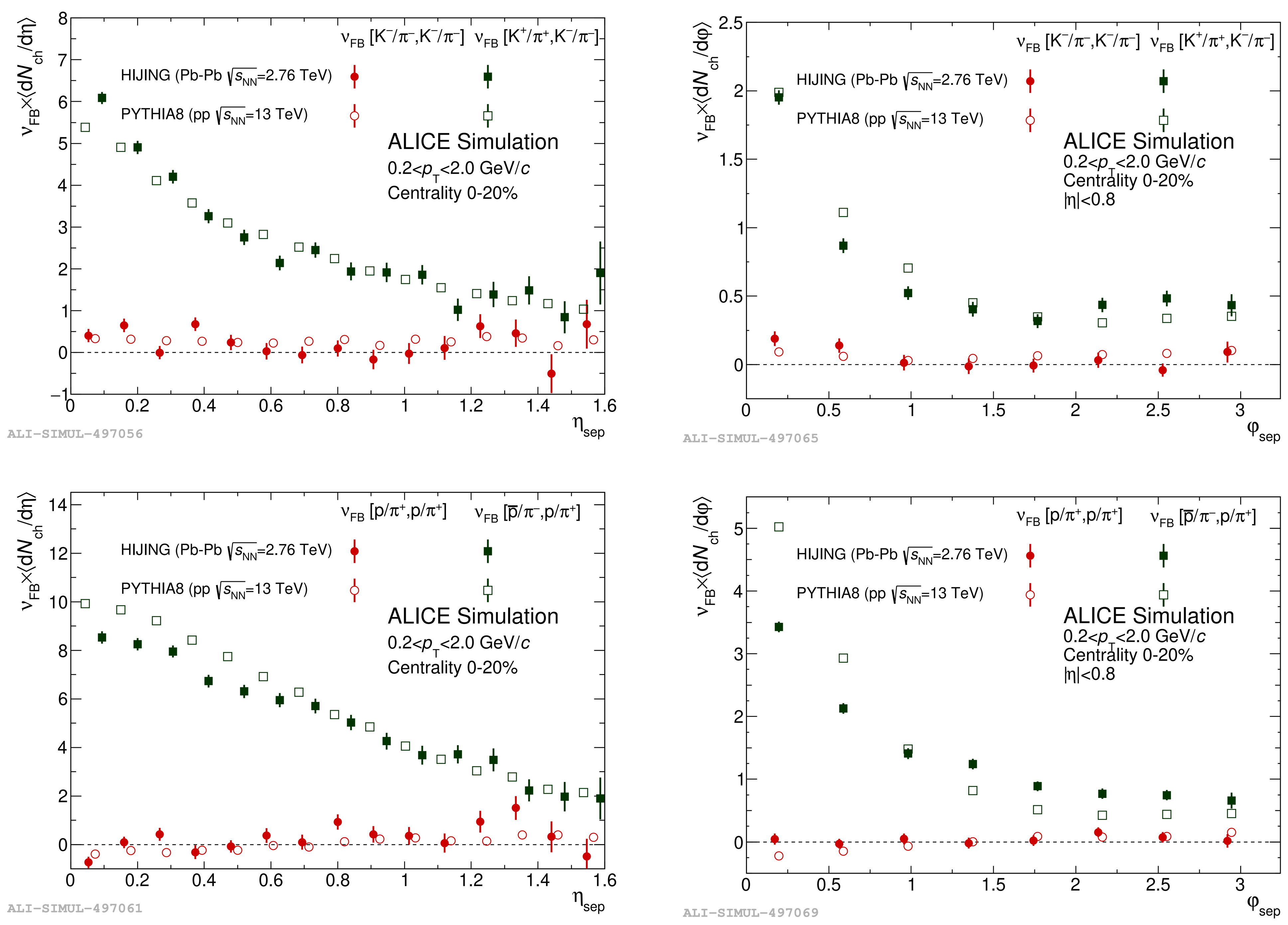


Calculations in MC generators, based on Lund string fragmentation, at LHC energies.

–Near-side peak for opposite-sign pairs.

–Same-sign pairs are nearly zero, which reflects binomial sampling of angles.

–Consistent results between HIJING and PYTHIA.



Conclusions and future plans

Angular correlations between ratios of identified particle yields in two rapidity (as well as azimuthal) windows were calculated in different models. It was shown that ν_{FB} is a robust observable, which allows to suppress contributions from short-range correlations. The canonical suppression lowers ν_{FB} values, while the charge conservation gives positive impact.

In the future, ν_{FB} will be calculated for data of Pb–Pb at $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV and pp at $\sqrt{s_{\mathrm{NN}}} = 13$ TeV collisions with ALICE detector.

References

[1] I. Altsybeev, *EPJ Web of Conferences*, vol. 204, 2019.

[2] C. Pruneau, S. Voloshin, and S. Gavin, *Phys. Rev.*, vol. C 66, p. 044904, 2002.

[3] ALICE Collaboration, *Eur. Phys. J.*, vol. C77, p. 569, 2017.

[4] V. Vovchenko and H. Stoecker, *Comput. Phys. Commun.*, vol. 244, p. 295, 2019.

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