Forward-backward correlations between intensive observables

V. N. Kovalenko and V. V. Vechernin
Saint Petersburg State University, Russia

The 2nd international conference on particle physics and astrophysics – ICPPA2016

1. Abstract and motivation

The study of the correlations between observables in two separated rapidity windows (the so-called forward-backward correlations) has been proposed [1] as a signature of the string fusion and percolation phenomenon [2], which is one of the collectively effects in ultrarelativistic heavy ion collisions. Later it was realized [3-5] that the investigations of the forward-backward correlations between intensive observables, such as e.g. mean-event transverse momenta, enable to obtain more clear signal about the initial stage of hadronic interaction, including the process of string fusion, compared to usual forward-backward multifragmentation. As an example the correlation between mean-event transverse momenta of charged particles in separated rapidity intervals is considered. We show that the abundance of this type of correlation is achieved only in heavy ion collisions at LHC, while in Au-Au collisions at RHIC and p-Pb at LHC the string density is not enough to provide a clear correlation coefficient for most central collisions.

We demonstrate that this type of correlation is promising for the observation of the signatures of string fusion in the initial stage of hadronic interaction in relativistic heavy ion collisions at LHC energy.

References


2. Forward-Backward Rapidity Correlations

The correlation coefficient:

\[ h_{\text{corr}} = \frac{\langle F(\eta)\cdot F(\eta') \rangle - \langle F(\eta) \rangle \langle F(\eta') \rangle}{\sqrt{\langle F(\eta)^2 \rangle - \langle F(\eta) \rangle^2} \cdot \sqrt{\langle F(\eta')^2 \rangle - \langle F(\eta') \rangle^2}} \]

For a correlation between relative variables, \( \frac{F(\eta')}{\sqrt{\langle F(\eta)^2 \rangle}} \): \( \frac{F(\eta)}{\sqrt{\langle F(\eta')^2 \rangle}} \):

\[ h_{\text{corr}} = \frac{\langle F(\eta)\cdot F(\eta') \rangle - \langle F(\eta) \rangle \langle F(\eta') \rangle}{\sqrt{\langle F(\eta)^2 \rangle - \langle F(\eta) \rangle^2} \cdot \sqrt{\langle F(\eta')^2 \rangle - \langle F(\eta') \rangle^2}} \]

Observe: \( F \), \( \eta \), \( \eta' \), the extensive variables \( h_{\text{cor}} \), \( h_{\text{corr}} \), the intensive variables

The Long-Range Multiplicities Correlations (SRC) \( h_{\text{cor}} \) at large \( R \)

The locality of the string interaction in rapidity is SRC - Short-Range Correlations.

The event-by-event variance in the number of unit pions (strings) \( R \), LRC.

3. Versions of string fusion

local fusion (overlaps)

\[ \langle F(\eta) \rangle = \frac{1}{N_v} \sum_{\nu} F(\eta^\nu) \]

global fusion (overlaps)

\[ \langle F(\eta) \rangle = \sum_{\nu} F(\eta^\nu) \]

4. Dipole-based MC SFM model

5. Centrality class width dependence of forward-backward correlations

6. Results in dipole-based MC SFM model

2. Forward-Backward Rapidity Correlations

The correlation coefficient:

\[ h_{\text{corr}} = \frac{\langle F(\eta)\cdot F(\eta') \rangle - \langle F(\eta) \rangle \langle F(\eta') \rangle}{\sqrt{\langle F(\eta)^2 \rangle - \langle F(\eta) \rangle^2} \cdot \sqrt{\langle F(\eta')^2 \rangle - \langle F(\eta') \rangle^2}} \]

For a correlation between relative variables, \( \frac{F(\eta')}{\sqrt{\langle F(\eta)^2 \rangle}} \): \( \frac{F(\eta)}{\sqrt{\langle F(\eta')^2 \rangle}} \):

\[ h_{\text{corr}} = \frac{\langle F(\eta)\cdot F(\eta') \rangle - \langle F(\eta) \rangle \langle F(\eta') \rangle}{\sqrt{\langle F(\eta)^2 \rangle - \langle F(\eta) \rangle^2} \cdot \sqrt{\langle F(\eta')^2 \rangle - \langle F(\eta') \rangle^2}} \]

Observe: \( F \), \( \eta \), \( \eta' \), the extensive variables \( h_{\text{cor}} \), \( h_{\text{corr}} \), the intensive variables

The Long-Range Multiplicities Correlations (SRC) \( h_{\text{cor}} \) at large \( R \)

The locality of the string interaction in rapidity is SRC - Short-Range Correlations.

The event-by-event variance in the number of unit pions (strings) \( R \), LRC.

The event-by-event fluctuations in the number of unit pions (strings) \( R \), LRC.

The linear regression (linear correlation): \( h_{\text{corr}} \) with \( h_{\text{cor}} \) and \( h_{\text{corr}} \) are independent of the volume fluctuations and the details of the centrality selection.

In figure 2 the calculations in a more realistic MC model with string fusion are shown [9, 10].

Note that the \( h_{\text{cor}} \) means averaging over tracks from all events.

The feature of the expression (7) for the coefficient of the pt-pT correlation in which it offers finite correlation is in dependence of \( \langle \text{pt}^2 \rangle \), i.e., independence of the variance of the number of particles formed during string fragmentation. This makes pt-pT correlations robust against volume fluctuations and the details of the centrality selection.

In figure 2 the calculations in a more realistic MC model with string fusion are shown [9, 10].

7. Mean pt-pT correlations in different models

The results show that non-monotonic behaviour of \( h_{\text{corr}} \) with centrality is achieved in heavy ion collisions at LHC, while in Au-Au collisions at RHIC and p-Pb at LHC the string density is not enough to provide a clear correlation coefficient for most central collisions.

The collision process is described in [12].

The relativistic transport model and string fusion process demonstrate significant centrality dependence of \( h_{\text{corr}} \), as well as its non-monotonic behaviour.

The comparison clearly shows that \( h_{\text{corr}} \) forward-backward correlation and its centrality dependence is sensitive to the initial stages of heavy ion collisions.

8. Summary and conclusions

The dependence of the correlation between mean-event transverse momenta on the collision centrality is obtained for different initial energies. It is shown that RHAHMC energy dependence reveals the decline of the correlation coefficient for most central collisions, reflecting the attenuation of color field fluctuations due to the string fusion at large string density.

The long-range correlation between intensive observables, being robust against the volume fluctuations and the details of the centrality determination, enables to obtain signatures of string fusion at the initial stage of hadronic interaction in relativistic heavy ion collisions at LHC energy.

It would be interesting to study forward-backward pt-pT correlations in fully event-by-event hydrodynamic models, like ESE/HERMIN or EKTM to extract the results.

The authors acknowledge Saint-Petersburg State University for the research grant 11.38.242.2015.