Forward-backward correlations with strange particles in PYTHIA

This content has been downloaded from IOPscience. Please scroll down to see the full text.
2016 J. Phys.: Conf. Ser. 668 012034
(http://iopscience.iop.org/1742-6596/668/1/012034)

View the table of contents for this issue, or go to the journal homepage for more

Download details:

IP Address: 195.19.236.163
This content was downloaded on 09/03/2016 at 13:23

Please note that terms and conditions apply.
Forward-backward correlations with strange particles in PYTHIA

I.G. Altsybeev¹, G.A. Feofilov¹, E. L. Gillies²

¹ Saint-Petersburg State University, RU
² University of Edinburgh, UK

E-mail: Igor.Altsybeev@cern.ch

Abstract. We present studies of strange particle yields and correlations in \(pp\) collisions in the PYTHIA8 event generator by studying forward-backward correlations. Several key processes that give rise to these correlative effects are identified and manipulated to probe the fundamental properties of strange particle emitting sources. The sensitivity of strange particle production and correlations to PYTHIA’s multiparton interaction, color reconnection, and explicit strangeness suppression are shown.

1. Introduction

Forward-backward (FB) correlations are a powerful tool for studying the initial stages of \(pp\) and AA collisions. FB correlations are studied in two intervals of pseudorapidity (\(\eta\)) which are selected one in the forward and another in the backward hemispheres in the center-of-mass system.

The FB correlation strength is characterized by the correlation coefficient \(b_{\text{corr}}\). This value is defined via a linear regression of the average value of a given quantity \(B\) measured in the backward hemisphere \((\langle B \rangle_F)\) as a function of value of another quantity \(F\) measured in the forward hemisphere. Note that \(F\) and \(B\) can describe the kinematic quantity or distinct quantities.

\[
\langle B \rangle_F = a + b_{\text{corr}} \cdot F.
\]

Taking \(F\) and \(B\) particle multiplicities, the relation (1) becomes \(\langle n_B \rangle_{nf} = a + b_{\text{corr}} \cdot n_F\), which was first experimentally observed in UA5 [1] and discussed in [2–4]. FB correlations between multiplicities have been recently studied in \(pp\) and Au-Au collisions by STAR [5] at RHIC, and in \(pp\) collisions by ATLAS [6] and ALICE [7] at LHC.

FB correlation studies are more informative when decoupled into short-range and long-range components [4,8]. Short-range correlations (SRC) are localized over a small range of \(\eta\), typically up to one unit. They are induced by various short-range effects like decays of clusters or resonances, jet and mini-jet induced correlations. Long-range correlations (LRC) extend over a wider range in \(\eta\) and originate from fluctuations in the number and properties of particle emitting sources, e.g. clusters, cut pomerons, strings, mini-jets etc. [4,8–11]. In ALICE paper [7], the “classical” approach to the long-range correlation analysis in two pseudorapidity intervals was expanded using additional azimuthal (\(\phi\)) sectors within these windows. This approach allows for a more thorough investigation of the SRC and LRC and their contributors, which can provide stronger constrains on phenomenological string models. Correlations with additional azimuthal segmentation of rapidity windows were also studied in PYTHIA6 [12].
2. Motivation for other variables in FB correlations
FB multiplicity correlations in pp collisions can be interpreted using the parametric string model [13] which implies event-by-event fluctuations in number of strings as independent particle emitters. However, independent emitters can not describe other types of correlations, such as a non-zero correlation between charged particle multiplicity and average transverse momentum \( \langle p_T \rangle \). This correlation (\( \langle p_T \rangle \)) in a single \( \eta \)-window This was first established at ISR energies in [14].

The correlation of the mean \( p_T \) of charged particles and other observables can be explained via collective effects relevant to the formation of particle emitting sources. In pp and \( p \bar{p} \) collisions, these collective effects were considered to be string fusion between quark-gluon strings [15,16]. Specifically, the multi-Pomeron exchange model provided a description of the experimentally measured growth in \( p_T \) with event multiplicity over a wide energy range of collision energies (0.3-1.8 TeV). It was shown [17] that the use of color reconnection in string-based PYTHIA model can produce the positive \( p_T \)-multiplicity correlation seen experimentally in pp collisions.

In string-based models, the Schwinger-like mechanism of string hadronization is used to obtain the production rate of \( q \bar{q} \) pairs with opposite transverse momenta \( p_T \). The rate is proportional to \( \exp \left( -\frac{\kappa}{8}(m^2 + p_T^2) \right) \), where \( \kappa \) is a string tension and \( m \) is a quark mass. This result can be used to estimate the relative production of different flavoured quarks and the \( p_T \) distribution. Collective effects could yield a higher effective string tension, as in the string fusion model [18-20] and the overlapping color ropes model in DIPSY event generator [21]. Larger string tension implies larger strangeness and baryon fractions as expected.

PYTHIA allows for multiple parton interactions (MPI) in pp events. This can cause non-negligible phase-space overlaps between final states from different MPI systems. The interaction between strings is implemented by color reconnection (CR), as proposed in [22]. In PYTHIA8 before reconnection, partons are connected in their respective MPI system. The color flow of two such systems can be fused such that the partons of the lower-\( p_T \) system are added to the strings defined by the higher-\( p_T \) system to give the smallest total string length. This is the default method in PYTHIA8. In the new CR model [23], junction structures are introduced in addition to the more common string-string reconnections. The new model has been tuned to reproduce measured ratios of kaons and hyperons such as \( \Lambda/K^0_s \) ratio. The use of junction structures introduces a slight enhancement of the strangeness and overall baryon production in this implementation.

3. Forward-backward correlations of strange particles in PYTHIA8
The effect of MPI and CR on FB correlations was studied in PYTHIA8. As shown in Fig. 1(a), the \( \langle p_T \rangle \) correlation between single \( \eta \)-window is preserved when considering two windows with large rapidity separation. When the color reconnection mechanism in PYTHIA8 is switched off the correlation drops to almost flat behavior as is shown in the Fig. 1(a) with open markers. Using the FB correlation approach, it is possible to examine string configurations and their interactions along \( \eta \)-range, accessible in an experiment, and also to get rid of short-range contributions coming from resonance decays, jets etc.

FB correlations involving strange particles can also be used to test string models. Fig. 1(b) shows that the \( \langle \Lambda/\bar{\Lambda} \rangle \) correlation function is affected by the choice of the CR model. At \( N_{ch}^p \approx 8 \), a “knee” can be seen in the correlation function. This indicates some threshold behavior incorporated in PYTHIA8. Fig. 2 compares the FB strange particle multiplicity correlation in \( \eta-\varphi \) windows, obtained in PYTHIA8. Specifically, it shows that the “plateau” level and the shapes of the near-side and away-side structures in this topology changes in the absence of CR.

The effective quark masses used in the Schwinger-mechanism are tuned the s/u ratio seen in experimental data. In PYTHIA, this implies an explicit suppression of strange quark production, \( u : d : s \approx 1 : 1 : 0.3 \) [24]. In Fig. 2(c), the particle multiplicity correlation topology in \( \eta-\varphi \) windows is shown for enhanced strangeness production with MPI turned off, revealing additional
4. Conclusions

A number of observables in pp and AA collisions can not be described by independently hadronizing particle emitters, indicating the presence of collective effects. To study this collectivity, conventional analysis of forward-backward correlations can be extended from charged particle multiplicities to other observables chosen in the windows in phase-space. Usage of the “intensive” variables in FB correlations like $\langle p_T \rangle$, $\Lambda/\pi$, $K/\pi$, as well as strange particle yields allows string interaction mechanisms in pp and AA collisions to be studied. To properly understand the underlying physics, the shape of the correlation function can be more informative than using the correlation coefficient $b_{\text{corr}}$ alone.

It was shown that different color reconnection models in PYTHIA8 change the behavior of modifications of the correlation coefficient $b_{\text{corr}}$. Additional figures can be found in attachments for these proceedings.
FB correlations. The newest CR scheme in PYTHIA8 gives more baryons and demonstrates different slopes of FB correlation functions. The correlations are also affected by MPI and explicit strangeness suppression in this generator.

Acknowledgements

This work is supported for I.A. and G.F. by the Saint-Petersburg State University research grant 11.38.242.2015.

References

[1] Alner G et al. 1987 UA5: A general study of proton-antiproton physics at $\sqrt{s} = 546$ GeV, Phys. Rep. 154, 247.
[2] Capella A and Tran Thanh Van J 1984 Long Range Rapidity Correlations in Hadron - Nucleus Interactions, Phys.Rev. D29, 2512.
[3] Fowler G, Friedlander E, Pottag F, Weiner R, Wheeler J, et al. 1988 Rapidity Scaling of Multiplicity Distributions in a Quantum Statistical Approach, Phys.Rev. D37, 3127.
[4] Capella A and Krzywicki A 1978 Unitarity Corrections to short range order: Long range rapidity correlations, Phys.Rev. D18, 4120.
[5] STAR Collaboration, Abelev B et al. 2009 Growth of Long Range Forward-backward Multiplicity Correlations with Centrality in Au+Au Collisions at $\sqrt{s_{NN}} = 200$ GeV, Phys.Rev.Lett. 103, 172301, arXiv:0905.0237.
[6] ATLAS Collaboration, Aad G et al. 2012 Forward-backward correlations and charged-particle azimuthal distributions in pp interactions using the ATLAS detector, JHEP 07 019, arXiv:1203.3100.
[7] Abelev 2009 et al. 2015 Forward-backward multiplicity correlations in pp collisions at $\sqrt{s} = 0.9, 2.76$ and $7$ TeV, JHEP 05 097.
[8] Capella A, Sukhatme U, C.-I. Tan and J. T. T. Van 1994 Dual parton model, Phys. Rep. 236, 225.
[9] Braun M, Pajares C and Vechernin V 2000 On the forward-backward correlations in a two stage scenario, Phys.Lett. B493 54.
[10] Armesto N, Ferreiro E and Pajares C 1994 Long and short range correlations and the search of the quark gluon plasma, Phys.Rev.Lett. 73 2813.
[11] Braun M, Kolevatov R, Pajares C and Vechernin V 2004 Correlations between multiplicities and average transverse momentum in the percolating color strings approach, Eur.Phys.J. C32 (2004) 535.
[12] Vechernin V 2015 Forward-backward correlations between multiplicities in windows separated in azimuth and rapidity, Nucl.Phys. A939 21, arXiv:1210.7588.
[13] Vechernin V and Kolevatov R 2007 On multiplicity and transverse-momentum correlations in collisions of ultrarelativistic ions, Phys.Atom.Nucl. 70 1797.
[14] Kovalenko V N, 2013 Modelling of exclusive parton distributions and long-range rapidity correlations for pp collisions at the LHC energy, Phys. Atom. Nucl. 76, 1189.
[15] Bierlich C, Gustafson G, Lonnblad L, Tarasov A, 2015 Effects of Overlapping Strings in pp Collisions, arXiv:1412.6259 [hep-ph].
[16] Lonnblad L 1996 Reconnecting coloured dipoles, Zeitschrift fur Physik C Particles and Fields, Volume 70, Issue 1, pp 107-113.
[17] Christiansen J R, Skands P Z 2015 String Formation Beyond Leading Colour, JHEP08 003, arXiv:1505.01681 [hep-ph].
[18] Buckley A et. al. 2011 General-purpose event generators for LHC physics, Phys. Rept. 504 145, arXiv:1101.2599 [hep-ph].