

Forward-backward Sphericity correlations in pp collisions at $\sqrt{s}=13$ TeV

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This report tried to determine the the Sphericity(S_0) correlation between forward-backward pseudorapidities in a Proton-Proton collision ("Beams:idA= 2212" and "Beams:idB= 2212"). The observable S_0 is investigated in the Monte Carlo Model Pythia 8.307 in order to better understand results from experimental data obtained in the ALICE detector at CERN. The aim of this experiment is to reproduce a simulation and use the features proposed by Pythia to find out the unexpected outcomes. The analysis is conducted using $(\Delta\eta)$ two particle correlations. The influence of the Multiple Parton Interactions on the general distribution of the tracks around the collision is also investigated.

I. INTRODUCTION

Until recently, the measurements used to constrain physics models of high energy particle collisions came primarily from experiments done at the previous generations of accelerators, such as the SPS, LEP, and the Tevatron. In particular, studies of "minimum-bias" and underlying-event physics have been widely used to constrain the poorly known nonfactorizable and non-perturbative aspects of Monte Carlo (MC) event generators. These generators are, in turn, used ubiquitously over a continually expanding range of energies and intensities, for both high- and low-Transverse momentum processes. MC "tunes" that rely exclusively on these older data sets are, however, becoming outmoded by a new generation of high-energy experiments, performed at the Large Hadron Collider (LHC). The extrapolation of previous results to the higher energies and large acceptances of the LHC experiments is associated with significant uncertainties, and the demands on both theoretical and experimental precision are becoming ever more stringent. The importance of reevaluating the physics models, and of retuning them in situ, has therefore been highlighted in several recent studies.

II. THEORY

A. Theoretical Background

The primary physics motivation for the present study is based on the concept of the chromoelectric flux tubes (quark-gluon strings or Pomerons exchanged between the colliding hadrons) - the objects stretched in rapidity that might be formed at the very early stages of hadron-hadron collisions. These colour strings may interact, and, in the case of sufficiently high density, string fusion may produce new strings of higher colour. This recent phenomenon of string fusion could be one of the mechanisms

leading to the QGP formation. It was shown that studying forwards-backward correlations of particle production in collisions of two nuclei at high energies may allow distinguishing between the string fusion, clusters formation and decay processes. The long-range correlations(LRC) between various observables, measured in sufficiently separated rapidity intervals, may appear as the signal relevant to string fusion. At the same time, the decay of clusters of particles and resonances is marked by increased short-range correlations(SRC). Recently, similar predictions for the LRC appeared also in the model of Color Glass Condensate and Plasma flux tubes , originating from forming so-called "glasma" flux tubes at early collision stages. However, these models (SFM and CGC) differ in the predictions of the behaviour of multiplicity correlation strength with the centrality of the collision. The presence of strong long-range backward-forward multiplicity correlations extended to several units of pseudorapidity, was demonstrated for the MC event generator.. In addition, the multiple parton interactions (MPI), considered by PYTHIA, might be also responsible for the fluctuation in the number of color strings, and, therefore, could be one of the potential contributors to the LRC. In all approaches shown above the LRC are produced by the fluctuating number of particle emitting sources (strings), formed in the collision, although the dynamical origin of the sources might be different. Therefore, the detailed experimental studies of the correlation strength and its rapidity structure are crucial for understanding of the physics of the hadron collision process in general.

B. Sphericity

Transverse sphericity:- In the present work, the mid-rapidity charged hadron transverse sphericity, S_0 , is used to characterize the events through the geometrical distribution of the p_T 's of the charged hadrons, which is by definition collinear and infrared safe. The restriction to the transverse plane avoids the bias from the boost along the beam axis. It is defined for a unit transverse vector

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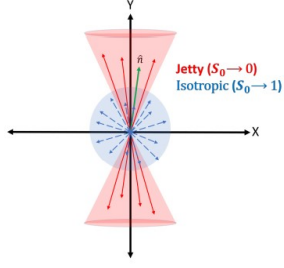


FIG. 1: A schematic picture showing transverse spherocity distribution of a hadronic collision.

$\hat{\mathbf{n}}$ which minimizes the ratio below:

$$S_0 = \frac{\pi^2}{4} \left(\frac{\sum_i |\vec{p}_{T_i} \times \hat{\mathbf{n}}|}{\sum_i p_{T_i}} \right)^2$$

By construction, the limits of the variable are related to specific configurations in the transverse plane

$$S_0 = \begin{cases} 0 & \text{"pencil-like" limit (hard events)} \\ 1 & \text{"isotropic" limit (soft events)} \end{cases}.$$

In this study, inelastic pp collisions were generated with Pythia 8.307 tune pp 14(Monash), this tune describes qualitatively many features of the LHC pp data. The event shape was computed considering only primary charged particles at mid-rapidity ($|\eta| < 1$) and in the transverse momentum interval $0.5 < p_T$ GeV/c. Transverse spherocity was only defined for events with more than two hadrons. Different observables like jet production and identified hadron production were studied at mid-rapidity for different S_0 and multiplicity (N_{ch}) intervals. Event shapes studied by experiments at LHC, e.g. ATLAS [24] and ALICE [25], have shown an interesting result: a good agreement between data and models is observed for the average event shape, while the event shape distributions exhibit large discrepancies. This is a very important message: the average measurements do not contain enough information, hence, care needs to be taken when extracting physics from models. For example, in the concrete case of the event generators reported in following references, they overestimate significantly the contribution of back-to-back jets events and underestimate the contribution of isotropic events at high multiplicity.

C. Experimental setup, event and track selection

Charged primary particles are reconstructed with the central barrel detectors combining information from the Inner Tracking System (ITS) and the Time Projection Chamber (TPC). Both detectors are located inside the 0.5 T solenoidal field.

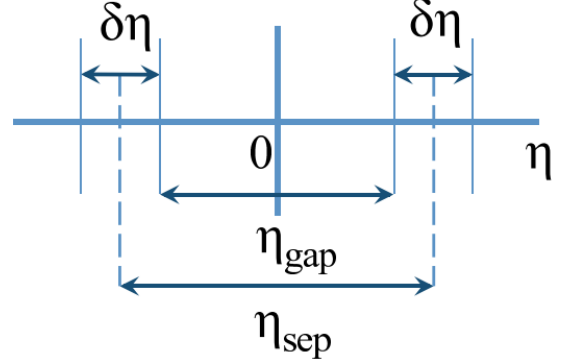


FIG. 2: Illustration of the variables $\delta\eta$, η_{gap} and η_{sep} used in the present analysis.

The ITS is composed of 3 different types of coordinate-sensitive Si-detectors. It consists of 2 silicon pixel innermost layers (SPD), 2 silicon drift (SDD) and 2 silicon strip (SSD) outer detector layers. The design allows for two-particle separation in events with multiplicity up to 100 charged particles per cm^2 . The SPD detector covers the pseudorapidity ranges $|\eta| < 2$ for inner and $|\eta| < 1.4$ for outer layers, acceptances of SDD and SSD are $|\eta| < 0.9$ and $|\eta| < 1$, respectively. All ITS elements have a radiation length of about $1.1\%X_0$ per layer. The ITS provides reliable charged particle tracking down to transverse momenta of 0.1 GeV/c, ideal for the study of low- p_T (soft) phenomena. The TPC has an acceptance of $|\eta| < 0.9$ for tracks which reach the outer radius of the TPC and up to $|\eta| < 1.5$ for tracks that exit through the endcap of the TPC.

For the present analysis, minimum bias pp events are used. The minimum-bias trigger required a hit in one of the forward scintillator counters (VZERO) or in one of the two SPD layers. In this way a uniform acceptance in the central pseudorapidity region $|\eta| < 0.8$ is ensured. The data samples for $\sqrt{s} = 13\text{TeV}$ comprise 1×10^6 events, respectively. Only runs with low probability to produce several separate events per one bunch crossing (so-called pile-up events) were used in this analysis.

To obtain high tracking efficiency and to reduce efficiency losses due to detector boundaries, tracks are selected with $p_T > 0.5\text{GeV}/c$ in the pseudorapidity range $|\eta| < 2.5$. Additionally, at least two hits in the ITS must be associated with the track. Tracks are also rejected if their distance of closest approach (DCA) to the reconstructed event vertex is larger than 0.3 cm in either the transverse or the longitudinal plane. For the chosen selection criteria, the tracking efficiency for charged particles with $p_T > 0.5\text{GeV}/c$ is about 80%.

The ALICE TPC is the main tracking detector of the central rapidity region. The TPC, together with the ITS, provides charged particle momentum measurement, particle identification and vertex determination with good

momentum and dE/dx resolution as well as two-track separation of identified hadrons and leptons in the p_T region below $10\text{GeV}/c$.

D. Forward-Backward Correlation

Forward-backward (FB) correlations are a powerful tool for studying the initial stages of pp collisions. FB correlations are studied in two intervals of pseudorapidity (η) which are selected one in the forward ($\eta > 0$) and another in the backward ($\eta < 0$) hemispheres in the center-of-mass system.

The FB correlation strength is characterized by the correlation coefficient b_{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 $\langle n_B \rangle_{n_F} = a + b_{\text{corr}} \cdot n_F$, which was first experimentally observed in UA5 and discussed in following references. FB correlations between multiplicities have been recently studied in pp and Au – Au collisions by STAR at RHIC, and in pp collisions by ATLAS and ALICE at LHC.

FB correlation studies are more informative when decoupled into short-range and long-range components. Short-range correlations (SRC) are localized over a small range of η , typically up to one unit. They are induced by various short-range effects like decays of clusters or resonances and jet and mini-jet induced correlations. Long-range correlations (LRC) extend over a broader range in η and originate from fluctuations in the number and properties of particle emitting sources, e.g. clusters, cut pomerons, strings, mini-jets etc. In the ALICE paper, the "classical" approach to the long-range correlation analysis in two pseudorapidity intervals was expanded using additional azimuthal (φ) sectors within these windows. This approach allows for a more thorough investigation of the SRC, LRC, and their contributors, which can provide more substantial constraints on phenomenological string models.

multiplicity of charged particles in another η interval ($p_T - n$). In our present analysis, we have explored first two types of FB correlation in detail. The FB correlation strength is measured in a coordinate system with origin $\eta = 0$ which is the collision vertex. Two η intervals are selected: one in the forward ($\eta > 0$) and another in the backward hemispheres ($\eta < 0$) in the center-of-mass system. FB Spherocity correlation coefficient b_{corr} (Spherocity) has been estimated using the following formula

of Pearson Correlation Coefficients.

$$b_{\text{corr}}(\text{Spherocity}) = \frac{\langle S_f S_b \rangle - \langle S_f \rangle \langle S_b \rangle}{\langle S_f^2 \rangle - \langle S_f \rangle^2},$$

Here, S_f and S_b are the Spherocities in F and B window respectively.

III. RESULTS

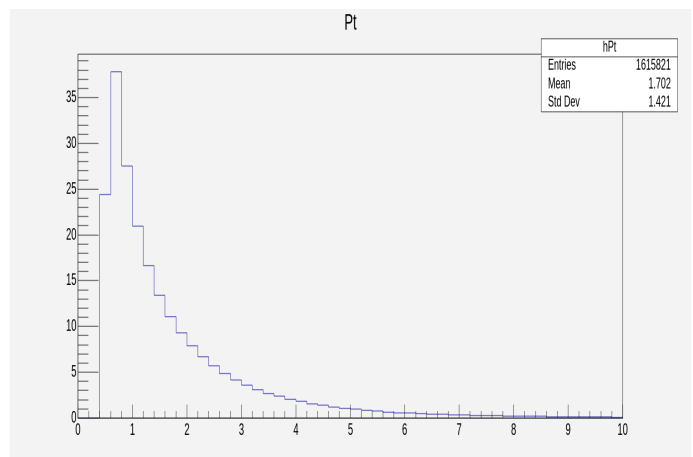


FIG. 3: Transverse Momentum Distribution

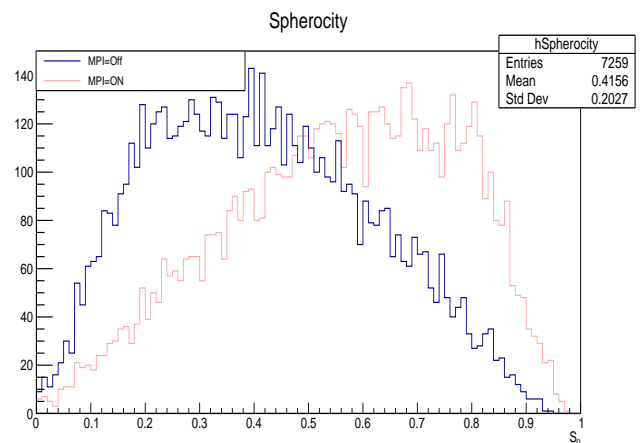


FIG. 4: Effect of MPI on Spherocity distribution

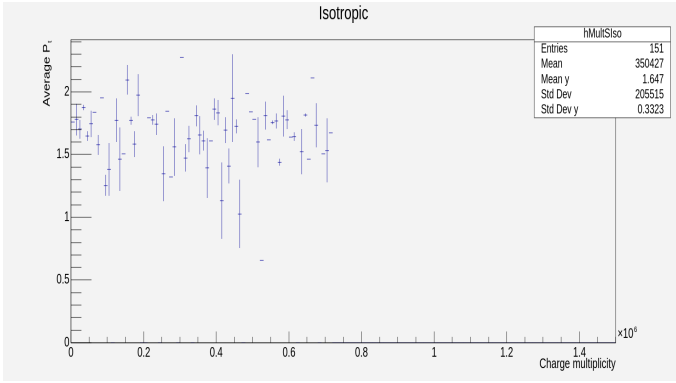


FIG. 5: Isotropic events distribution (events having $S_0 > 0.8$)

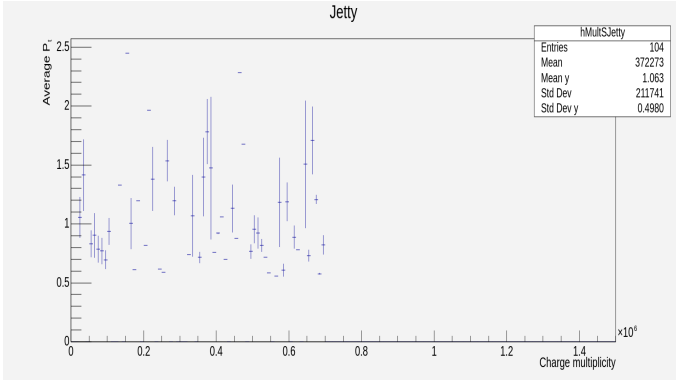


FIG. 6: Jetty events distributions (events having $S_0 < 0.2$)

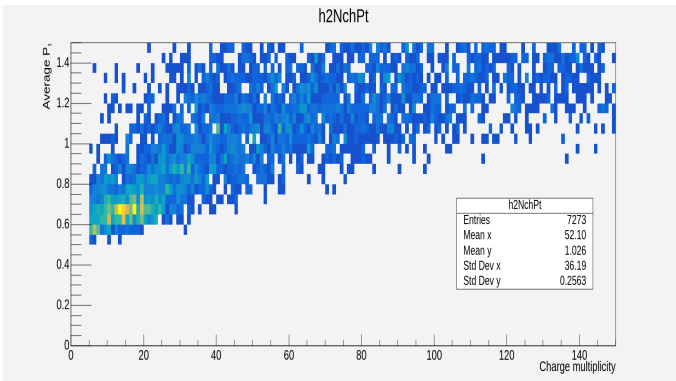


FIG. 7: 2-D Histogram of Sum of tracks and Average momentum

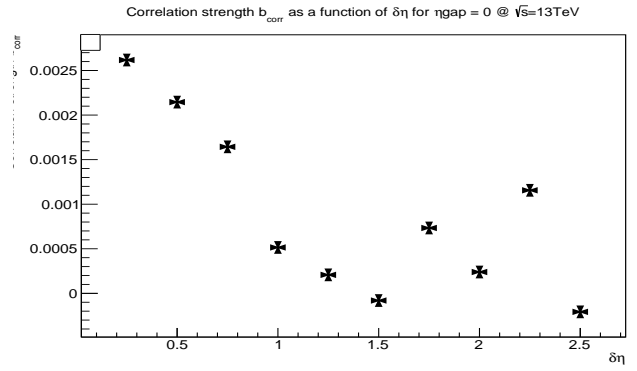


FIG. 8: Correlations between Sphericity in forwards-backwards pseudorapidity $\delta\eta$

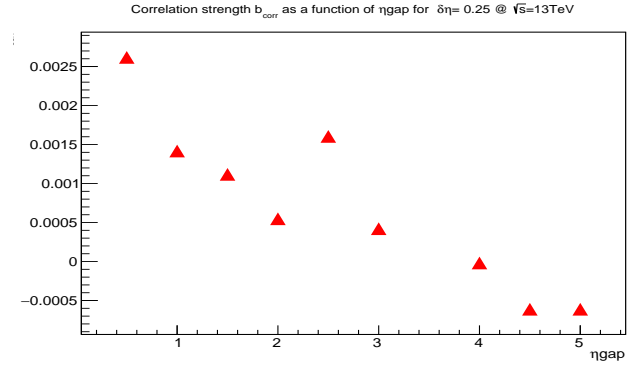


FIG. 9: Correlation strength b_{corr} as a function of η_{gap} for $\delta\eta = 0.25$ @ $\sqrt{s} = 13\text{TeV}$

IV. CONCLUSIONS

1. The transverse sphericity has been used to study the influence of the multiparton interactions on the final-state in pp collisions. It was demonstrated that the number of multi-parton interactions is strongly correlated with the Isotropic events, at least up to a point where a saturation of the number of multi-parton interactions occurs. The transverse sphericity selection allows for identifying and analysing two extreme cases: the jetty-like and the isotropic events at the two ends of the transverse sphericity spectrum. Different studies were done: jet production identified particle ratios and blast-wave analysis. The results show the benefits of the combined multiplicity and event shape analysis. We conclude that more widespread use of event shape variables in the data study may give us a much better understanding of the detail of the collisions.
2. it was observed that Pearson correlation coefficient b_{corr} was decreasing with increasing width of window ($\delta\eta$) and also decreasing with increasing η_{gap} .

However, fluctuations at end points were observed. it might be due to less number of data.

V. REFERENCES

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