Simulation studies of $\mathrm{R}_2\,(\Delta\eta, \Delta\varphi)$ and $\mathrm{P}_2\,(\Delta\eta, \Delta\varphi)$ correlation functions in p–p collisions with the PYTHIA and HERWIG models

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Introduction

Two- and multi- particle azimuthal correlation functions have confirmed the existence of anisotropic flow and quark scaling (approximate) of flow coefficients in A–A collisions at RHIC and LHC as well as reveals the presence of flow in smaller systems (e.g., p–A and high multiplicity p–p collisions). Measurements of two particle differential- number correlations, R_2, and transverse momentum correlations, P_2, have provided the collective nature of the azimuthal correlations observed in Pb–Pb collisions [1] . Centrality studies in A-A collisions show that near-side peak of both charge-independent (CI) and charge-dependent (CD) correlations is narrower for P_2 than in R_2 [2]. This correlator P_2 provides a more discriminating probe of the correlation structure of jets and their underlying events than the R_2. To understand, we performed this study in three p_{T} ranges $0.2 < p_{\mathrm{T}} \leq 2.0$ GeV/c, $2.0 < p_{\mathrm{T}} \leq 5.0$ GeV/c, and $5.0 < p_{\mathrm{T}} \leq 30.0$ GeV/c, using PYTHIA and HERWIG models for the charged hadrons in pp collisions at $\sqrt{s}$ = 2.76 TeV for both CI and CD.

Correlation functions definition

The R_2 and P_2 correlation functions are constructed by using single, $\rho_1(\eta, \varphi)$, - and two, $\rho_2(\eta_1, \varphi_1, \eta_2, \varphi_2)$, - particle densities as a function of the particle pseudo-rapidity η and azimuthal angle φ.

The R_2 is defined as a two-particle cumulant normalized by the product of single particle densities as follows

$$\mathrm{R}_2(\eta_1, \varphi_1, \eta_2, \varphi_2) = \frac{\rho_2(\eta_1, \varphi_1, \eta_2, \varphi_2)}{\rho_1(\eta_1, \varphi_1)\rho_1(\eta_2, \varphi_2)} - 1. \quad (1)$$

while the P_2 is defined as the ratio of differential correlator $\langle \Delta p_{\mathrm{T}} \Delta p_{\mathrm{T}} \rangle$ to the square of the average transverse momentum, p_{T}, to make it dimensionless like R_2, as follows

$$\mathrm{P}_2(\eta_1, \varphi_1, \eta_2, \varphi_2) = \frac{\langle \Delta p_{\mathrm{T}} \Delta p_{\mathrm{T}} \rangle(\eta_1, \varphi_1, \eta_2, \varphi_2)}{\langle p_{\mathrm{T}} \rangle^2} = \frac{1}{\langle p_{\mathrm{T}} \rangle^2} \times \frac{\int_{p_{\mathrm{T,min}}}^{p_{\mathrm{T,max}}} \mathrm{dp_{T,1}dp_{T,2}}\rho_2(\tilde{\mathrm{p}}_1, \tilde{\mathrm{p}}_2)\Delta \mathrm{p_{T,1}}\Delta \mathrm{p_{T,2}}}{\int_{p_{\mathrm{T,min}}}^{p_{\mathrm{T,max}}} \mathrm{dp_{T,1}dp_{T,2}}\rho_2(\tilde{\mathrm{p}}_1, \tilde{\mathrm{p}}_2)}.$$

where $\Delta p_{\mathrm{T,i}} = p_{\mathrm{T,i}} - \langle p_{\mathrm{T}} \rangle$ and $\langle p_{\mathrm{T}} \rangle$ is the inclusive mean transverse momentum [3] . The $\langle \Delta p_{\mathrm{T}} \Delta p_{\mathrm{T}} \rangle$ correlator is positive leading to positive value of P_2 whenever both particles are coming from higher (or lower) than the $\langle p_{\mathrm{T}} \rangle$, but it is negative when a low-p_{T} particle ($p_{\mathrm{T}} < \langle p_{\mathrm{T}} \rangle$) is accompanied by a high-p_{T} particle ($p_{\mathrm{T}} > \langle p_{\mathrm{T}} \rangle$) .

In this work, the correlators R_2 and P_2 are convoluted into the differences $\Delta\eta = \eta_1 - \eta_2$ and $\Delta\varphi = \varphi_1 - \varphi_2$ and shifted by $-\pi/2$ for convenience of representation in the figures according to

$$O(\Delta\eta, \Delta\varphi) = \frac{1}{\Omega(\Delta\eta)} \int O(\eta_1, \varphi_1, \eta_2, \varphi_2)\delta(\Delta\varphi - \varphi_1 + \varphi_2) \times \mathrm{d}\varphi_1 \mathrm{d}\varphi_2 \delta(\Delta\eta - \eta_1 + \eta_2)\mathrm{d}\eta_1 \mathrm{d}\eta_2.$$

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where $\Omega(\Delta\eta)$ represents the width of the acceptance in $\bar{\eta} = (\eta_1 + \eta_2)/2$ at a given value of $\Delta\eta$ [5]. The analysis of the R_2 and P_2 correlation functions are carried out for charge combination pairs $(+-)$, $(-+)$, $(++)$, and $(--)$ to yield charge-independent, $O^{\rm CI} = \frac{1}{2}[O^{+-} + O^{++} + O^{-+} + O^{--}]$, and charge-dependent, $O^{\rm CD} = \frac{1}{2}[O^{+-} - O^{++} + O^{-+} - O^{--}]$, correlation functions [4].

Results

Figure 1 represents the decreasing trend of near-side width of ${P_2}^{\rm CD}$ using PYTHIA with rising $p_{\rm T}$ owing to the angular ordering and Schwinger mechanism.

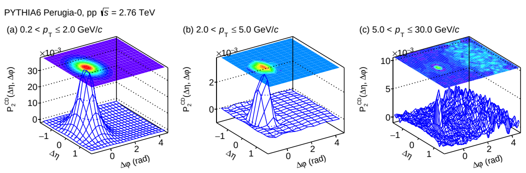

FIG. 1: Correlation functions ${P_2}^{\rm CD}$ of charged hadrons in three $p_{\rm T}$ ranges (a) $0.2 < p_{\rm T} \leq 2.0$ GeV/c, (b) $2.0 < p_{\rm T} \leq 5.0$ GeV/c, and (c) $5.0 < p_{\rm T} \leq 30.0$ GeV/c, obtained with PYTHIA for pp collisions at $\sqrt{s} = 2.76$ TeV.

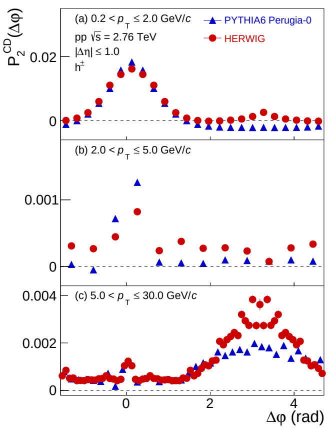

FIG. 2: The $\Delta\varphi$ projections of ${P_2}^{\rm CD}$ are calculated as averages of the 2-D correlations in the range $|\Delta\eta| \leq 1.0$.

Also, there is a finite away-side CD correlation in the $p_{\rm T}$ range $5.0 < p_{\rm T} \leq 30.0$ GeV/c due to quark-quark jets as quarks possess charge. This correlator ${P_2}^{\rm CD}$ will help to probe the internal structure of jets and the charge production ordering. Comparison of PYTHIA and HERWIG, in Fig 2, reveals different behavior of the two models as they use different hadronization model.

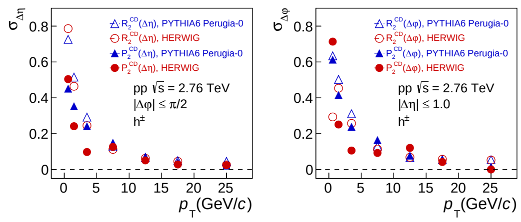

FIG. 3: Width of the near-side peak of CD correlation functions along $\Delta\eta$ (left panel), in the range $|\Delta\varphi| \leq \pi/2$, and along $\Delta\varphi$ (right panel), in the range $|\Delta\eta| \leq 1.0$, as function of $p_{\rm T}$.

To understand the trend, we performed this study in more refined $p_{\rm T}$ ranges. PYTHIA shows monotonic decrease of the width whereas HERWIG gives a more complicated behavior of the width as a function of $p_{\rm T}$ in both $\Delta\eta$ and $\Delta\varphi$ case as shown in Fig 3. We observed that P_2 width is broader than R_2 in some $p_{\rm T}$ ranges due to the angular ordering which is reverse in nature as stated [2]. Rigorous study will give distinction between quark-jets and gluon-jets in future.

References

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