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Multiplicity dependence of jet-like two-particle correlations in pp collisions at $\sqrt{s}$ = 7 and 13 TeV with ALICE

Igor Lakomov (for the ALICE Collaboration)

European Organization for Nuclear Research (CERN), CH-1211, Geneva 23, Switzerland

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Abstract

Two-particle correlations in relative azimuthal angle ($\Delta\phi$) and pseudorapidity ($\Delta\eta$) have been used to study heavy-ion collision dynamics, including medium-induced jet modification. Further investigations also showed the importance of Multiple Parton Interactions (MPI) in high-multiplicity pp collisions, which are often described by pQCD-inspired models. In these proceedings the latest ALICE measurements of two-particle correlations as a function of multiplicity in pp collisions are presented using the data from Run I and Run II at the LHC.

Keywords: ALICE, correlations, pp, MPI, event activity, multiplicity

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1. Introduction

Particle production in high-energy pp collisions at the LHC is expected to have a substantial contribution from Multiple Parton Interactions (MPI). This can be studied via the two-particle correlation technique, where pair yields are used to probe the parton fragmentation process and the contribution of MPI to particle production. Two-particle correlation functions are measured as a function of relative azimuthal angle ($\Delta\phi$) and pseudorapidity ($\Delta\eta$) between trigger and associated particles. The area around $\Delta\phi = 0$ is referred to as “near side”, while the area around $\Delta\phi = \pi$ is referred to as “away side”. In recent years, the LHC experiments have observed a near-side ridge (along $\Delta\eta$) in two-particle correlation functions in pp, p–Pb and Pb–Pb collisions at different energies. Surprisingly, the near-side ridge in small systems at high multiplicity resembles the ridge in Pb–Pb collisions. While in heavy-ion collisions the ridge is usually attributed to anisotropic flow, its origin in small systems is not well understood. Possible explanations include an (incoherent) superposition of MPI and/or final state collective effects. ALICE, being dedicated to study heavy-ion collisions at the LHC, also has an extensive pp physics program. In these proceedings the latest ALICE results from pp collisions on minijets, the near-side jet peak, and long-range correlations are presented.

2. Uncorrelated seeds and MPI

MPI processes contribute significantly to the particle production in pp collisions at LHC energies. Previously, it was shown by ALICE that in PYTHIA [1, 2] the number of MPI is proportional to the number of independent particle sources (number of uncorrelated seeds [3]), defined as follows: $\langle N_{\text{uncorrelated seeds}} \rangle =$

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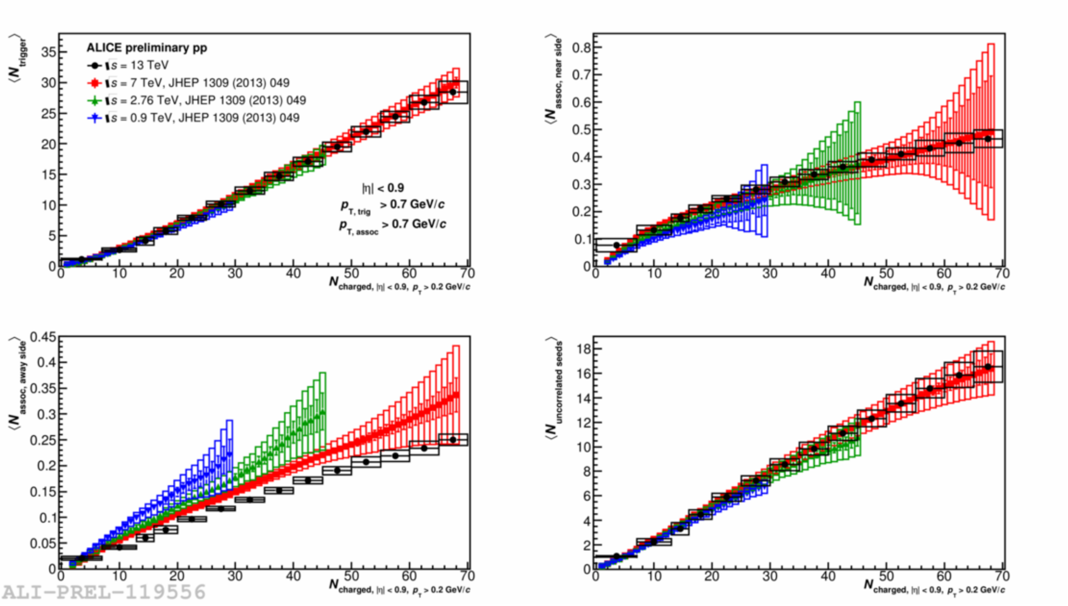

Fig. 1. Multiplicity dependence of the average number of trigger particles (top left), associated-particle yield on the near (top right) and away (bottom left) sides, and average number of uncorrelated seeds (bottom right) in pp collisions. Black circles are new measurements at $\sqrt{s}$ = 13 TeV, red squares, green triangles and blue triangles are results at $\sqrt{s}$ = 7 TeV, 2.76 TeV and 0.9 TeV, respectively, from [3].

$\frac{\langle N_{\mathrm{trigger}}\rangle}{1+\langle N_{\mathrm{assoc,\ near\ side}}\rangle+\langle N_{\mathrm{assoc,\ away\ side}}\rangle}$. Here $\left\langle N_{\mathrm{trigger}}\right\rangle$ is the average number of trigger particles per event, $\langle N_{\mathrm{assoc,\ near\ side}}\rangle$ and $\left\langle N_{\mathrm{assoc,\ away\ side}}\right\rangle$ are the associated-particle yields on the near and away side, respectively. This observable by construction is expected to have little sensitivity to autocorrelations. ALICE has measured $\langle N_{\mathrm{uncorrelated\ seeds}}\rangle$ in pp collisions at $\sqrt{s}$ = 0.9, 2.76 and 7 TeV [3] and in p–Pb at $\sqrt{s_{\mathrm{NN}}}$ = 5.02 TeV [4]. In all collision systems and energies, it was found to grow linearly with the multiplicity with a hint of slight saturation at high multiplicity in pp collisions. During Run II at the LHC, ALICE repeated the analysis in pp collisions at $\sqrt{s}$ = 13 TeV. Figure 1 shows preliminary results from this ongoing analysis: the multiplicity dependence of the average number of trigger particles, the associated-particle yield on the near and away sides, and the average number of uncorrelated seeds. The results for pp collisions at $\sqrt{s}$ = 13 TeV are consistent with the previous measurements at lower energies. All the four observables increase with increasing multiplicity. The average number of triggers, near-side associated-particle yield and number of uncorrelated seeds seem to have no energy dependence. The away-side particle yield demonstrates a decreasing trend with increasing energy. At high multiplicities the data show a deviation from the linear trend, which might be an indication of some limit in MPI, i.e. the number of MPI might not be proportional to the charged-particle multiplicity anymore. Further investigations with the full Run II statistics will help in understanding this behaviour.

3. Near-side jet peak in pp at $\sqrt{s}$ = 7 TeV

In order to evaluate long-range correlations (i.e. the ridge) in small systems a deeper understanding of short-range (mini-)jet-like structures is necessary. ALICE has studied the near-side jet peak at mid-rapidity in pp collisions at $\sqrt{s}$ = 7 TeV as a function of multiplicity. To reduce autocorrelations, the multiplicity is selected outside of the η region where the correlations are measured. The following procedure is used in these measurements to extract the near-side jet peak. The two-particle correlation function is projected onto $\Delta\eta$ and $\Delta\phi$. The near-side peak is then isolated and fitted with a generalized Gaussian:

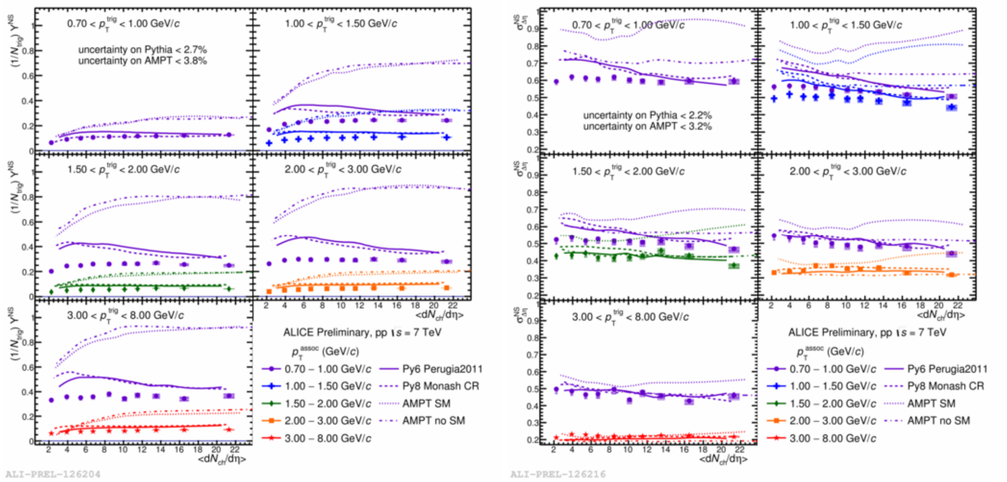

Fig. 2. Near-side peak yields (left) and widths (right) as a function of multiplicity in pp collisions at $\sqrt{s}$ = 7 TeV with comparison to MC models. See text for details.

$f_{\text{gen.Gauss}}(x) = \frac{\gamma\beta}{2\alpha\Gamma(1/\beta)} e^{-(|x|/\alpha)^{\beta}}$, where $x = \Delta\eta$ or $x = \Delta\phi$, respectively. The width of a generalized Gaussian is calculated as $\sigma = \sqrt{\frac{\alpha^2\Gamma(3/\beta)}{\Gamma(1/\beta)}}$. The left (right) panel of Fig. 2 shows the multiplicity dependence of the near-side peak yield (width in $\Delta\eta$) for different transverse momentum (p_T) ranges of the trigger and associated particles. The measured yields show a multiplicity dependence, especially at low multiplicity, while the widths suggest a very weak multiplicity dependence. The width value varies from 0.2 to 0.6 depending on the p_T range. These measurements set the scale for $\Delta\eta$ cuts that can be used to investigate long-range correlations in pseudorapidity. Both the yields and the widths are compared to different models, including AMPT [5], PYTHIA6 [1, 2] and PYTHIA8 [6]. The AMPT model drastically overestimates the near-side jet peak yields, and also shows much stronger multiplicity dependence of the yields than seen in the data. PYTHIA 6 and PYTHIA8 show a fair agreement with the data. In some p_T bins both PYTHIA models show a decreasing yield with increasing multiplicity, which is not observed in the data. The models also tend to overestimate the widths of the near-side jet peak at low p_T while at high p_T they are either in agreement or slightly below the data.

4. Long-range correlations in pp at $\sqrt{s}$ = 7 TeV

ALICE also measured long-range correlations ($1.87 < |\Delta\eta| < 2.2$) as a function of multiplicity in pp collisions at $\sqrt{s}$ = 7 TeV. In this analysis, the background is subtracted using a ZYAM-like (Zero Yield at Minimum) method where the yield is fixed to zero at $\Delta\phi = 0.8$. Figure 3 shows the corresponding correlation functions projected onto $\Delta\phi$ as a function of multiplicity. The near-side and away-side yields are evaluated in the following $\Delta\phi$ ranges: $|\Delta\phi| < 0.8$ and $2.4 < |\Delta\phi| < 3.9$. The background-subtracted yields are then summarized as a function of multiplicity in Fig. 4 for the away side and the near side. The data show a strong multiplicity dependence of the away-side yield but a smaller dependence of the near-side yield. An enhancement of the long-range yield on the near side is seen in the data at high multiplicity which is not reproduced by PYTHIA. The away-side yield is not described by PYTHIA for the multiplicity ranges under study.

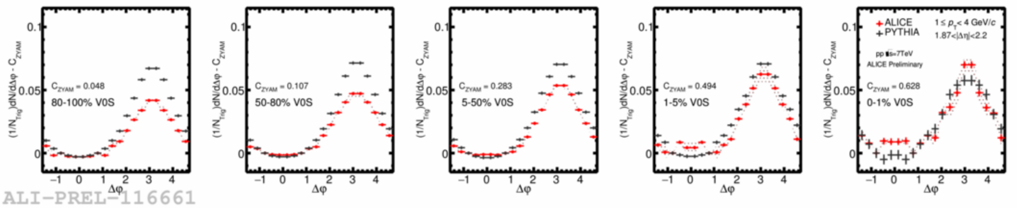

Fig. 3. Two-particle correlation functions projected onto $\Delta\phi$ in different multplicity bins in pp collisions at $\sqrt{s} = 7$ TeV. The data (red markers) are compared to PYTHIA (black markers). The multiplicity is increasing from left to right panel.

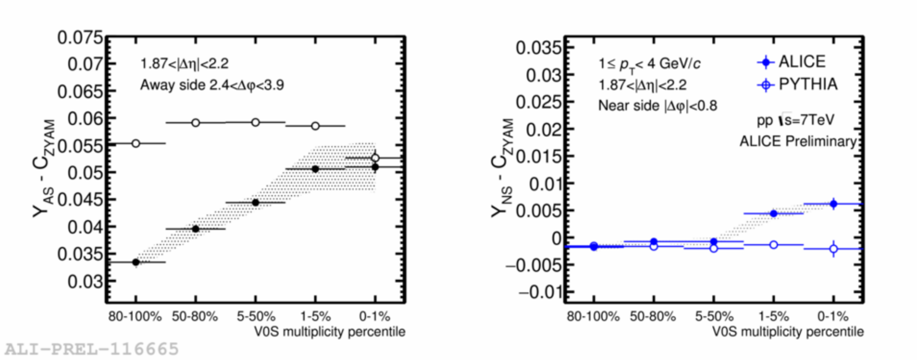

Fig. 4. Background-subtracted away-side (left) and near-side (right) yields as a function of multiplicity in pp collisions at $\sqrt{s} = 7$ TeV.

5. Conclusions

ALICE has performed three new multiplicity-dependent studies of two-particle correlations in pp collisions at $\sqrt{s} = 7$ and 13 TeV. The minijet analysis shows a strong energy dependence of the away-side yield. Measurements of the number of uncorrelated seeds suggest a hint of a non-linear dependence at high multiplicity which might be an indication of a limit in MPI. The near-side jet peak studies at $\sqrt{s} = 7$ TeV show little-to-no change in the peak widths as a function of multiplicity. The near-side widths are found to vary from 0.2 to 0.6 depending on the particle p_{T} range. These measurements provide guidance on the $\Delta\eta$ gap to be used for long-range correlations studies. Preliminary results on long-range correlations at $\sqrt{s} = 7$ TeV show an enhancement of the near-side yield for events with high multiplicity. Further studies of particle production in high-multiplicity pp collisions should improve our understanding of MPI.

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