PROCEEDINGS OF SCIENCE

Jets in pp and PbPb collisions at LHC energies simulated within the PYTHIA, HIJING and HYDJET++ models

O. Djordjić[ab], **J. Milošević**[*a]
[a]*University of Oslo, Oslo, Norway*
[b]*University of Banja Luka, Republic of Srpska, B&H*
E-mail: `jovan.milosevic@fys.uio.no`, `olja.dordic@fys.uio.no`

Preliminary results of two particle azimuthal correlations analysis for high-p_T charged pions from pp and $PbPb$ collisions at $\sqrt{s} = 14$ TeV and $\sqrt{s_{NN}} = 5.5$ TeV, respectively, generated using the PYTHIA, HIJING and HYDJET++ Monte Carlo codes are presented. Depending on the physics involved in the different models a rich structure in the near side and the away side peak is obtained. Jet properties strongly depend on the spatial position of the hard scattering within the overlapping region. Propagating through the dense medium causes the changes of jet features. Jet modifications are studied as a function of system size, centrality and transverse momentum of pions associated to the trigger particle. A narrow jet-like pattern at the near side is nearly unaffected by the medium, while a strong modification at the away side suggests energy transfer of the hard scattered parton to the medium formed in the collision. However, k_T broadening, as an initial state effect, also have an influence on modification of the away side peak.

High-pT Physics at LHC -09
February 4- 4 2009
Prague, Czech Republic

*Speaker.

PoS(High-pT physics09)044

1. Introduction

In elementary collisions production and fragmentation of jets is well described by perturbative QCD (pQCD). That knowledge is useful as a reference measurement in ultra-relativistic nucleus-nucleus collisions. Although in nucleus-nucleus collisions, the jets are produced in the hard scattering of the two incoming partons [1, 2, 3, 4], afterwards they interact with the dense medium created in such a collision. The effect of that interaction manifests as an energy loss ('jet-quenching') which leads e.g to a reduction of the correlated dihadron yields at high transverse momentum (p_T) and a broadening of the jet correlation [5, 6, 7].

The two-particle azimuthal ($\Delta\phi$) correlations method has been used in pp collisions at ISR energies ($\sqrt{s} = 63$ GeV) and below [8, 9, 10] where it is difficult to reconstruct jets. The same method is applicable in nucleus-nucleus collisions where the huge particle multiplicity makes direct jet reconstruction quite difficult. Such measurements reveal characteristic jet-like peaks at the near-side ($\Delta\phi \sim 0$) and at the away-side ($\Delta\phi \sim 2\pi$). Prior measurements at RHIC energies [11, 12, 13, 14] indicate strong modifications of the near- and the away-side peaks. In nucleus-nucleus collisions, the near-side peak is broadened and enhanced, while the away-side peak is suppressed with respect to pp collisions. The effect is especially pronounced for high-p_T particles in central collisions.

2. Simulated data and the applied method

We present here results on two-particle azimuthal correlations applied on simulated pp and $PbPb$ events at LHC energies. In the Table 1 is given statistics of simulated pp@14 TeV and $PbPb$@5.5 TeV minimum bias events. For the analysis are used charged pions emitted within the whole pseudorapidity (η) range. In PYTHIA [15] and HIJING [16] collective flow effects

Table 1: Statistics of the simulated minimum bias events used in the construction of the signal and the background distributions within PYTHIA, HIJING and HYDJET++ models.

	PYTHIA	HIJING	HYDJET++	b range [fm]
pp signal	14.0M	34.0M	-	0.0 - 1.25 [1]
pp BG	14.0M	40.0M	-	0.0 - 1.25
$PbPb$ signal	-	1.56M	16.0M	0.0 - 14.5
$PbPb$ BG	-	1.14M	10.0M	0.0 - 14.5

are not incorporated, while flow is included in HYDJET++ model [17]. Also, both HIJING and HYDJET++ models include a true collisional geometry, production and quenching of jets.

From the azimuthal difference $\Delta\phi = \phi_{trigg} - \phi_{assoc}$ between a leading (trigger) and associated particle taken within given p_T^{trigg} and p_T^{assoc} ranges one forms a signal $N_{corr}(\Delta\phi) = \frac{1}{N_{trigg}} \cdot \frac{dN_{corr}}{d\Delta\phi}$ and a background distribution $N_{mix}(\Delta\phi) = \frac{1}{N_{trigg}} \cdot \frac{dN_{mix}}{d\Delta\phi}$. Both distributions are normalized to the number of

[1] In pp collisions b is obtained via (a weak) correlation between its value and the charged pion multiplicity which is actually used in the analysis

trigger particles. The background distribution is obtained by mixing trigger and associated particle from different, but topologically similar, events. The correlation function $C(\Delta\phi)$ is constructed via a normalized ratio of the the signal and the background distributions

$$C(\Delta\phi) = \frac{\int N_{mix}(\Delta\phi)d(\Delta\phi)}{\int N_{corr}(\Delta\phi)d(\Delta\phi)} \cdot \frac{N_{corr}(\Delta\phi)}{N_{mix}(\Delta\phi)} \tag{2.1}$$

In the Eq. (2.1), the normalization is done in such a way that the area below the correlation function is equal to 2π.

Both, the signal $N_{corr}(\Delta\phi)$ and the background $N_{mix}(\Delta\phi)$ distribution could be affected by the pair efficiency of the detector. Constructing the ratio given in Eq. (2.1) that effect cancels. Therefore the correlation function contains only physical correlations. We fit $C(\Delta\phi)$ with a sum of two Gaussians, with free parameters corresponding to the areas ($C_{near/away}$) and widths ($\sigma_{near/away}$), centered at $\Delta\phi = 0$ (near side peak) and at $\Delta\phi = \pi$ (away side peak), and a constant function which assumes that the real and the mixed distributions are not modulated by an anisotropic flow effect

$$J(\Delta\phi) = C_0 + C_{near} \cdot G_{near}(\sigma_{near}, \Delta\phi) + C_{away} \cdot G_{away}(\sigma_{away}, \Delta\phi) \tag{2.2}$$

We know *a priori* it is true within PYTHIA and HIJING events due to the fact that there are no

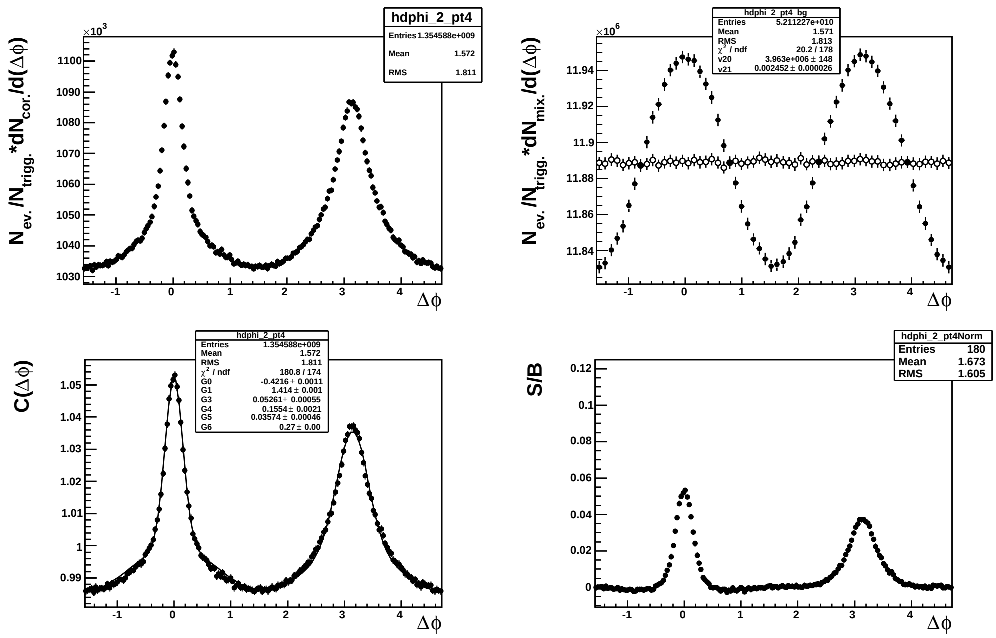

Figure 1: Top: A signal (left) and a background (right) distribution obtained using HYDJET++ simulations of $PbPb$@5.5 TeV minimum bias events with $2 < p_T^{assoc} < 4$ GeV/c. Bottom: The correlation function (left) preserved the shape of the signal. After the flow subtraction, only a Gaussian like signal is left (right).

flow effects present. But in the HYDJET++ model, as well as in the real experiment, it is not the case anymore. So $C(\Delta\phi)$ is described with a sum consisting of a jet $J(\Delta\phi)$ and an elliptic flow contribution

$$C(\Delta\phi) = b_0[1 + 2v_2^{trigg} v_2^{assoc} \cos(2\Delta\phi)] + J(\Delta\phi) \tag{2.3}$$

where b_0 is a new normalization coefficient.

At the top of Fig. 1 are shown signal and background distributions normalized to the number of trigger particles obtained within the HYDJET++ model. The signal distribution contains a cosine like elliptic flow modulation on top of which is positioned a Gaussian like jet signal. Demanding that the background distribution is calculated by mixing topologically similar events not only in the sense of the similar multiplicity, but also with the similar orientation of the reaction plane, the obtained background will reveal presence of the elliptic flow in the HYDJET++ model. As the mixed event distribution contains the information of the elliptic flow magnitude it can be measured by fitting it. The obtained contribution has been subtracted from the background distribution in order to get a flat one. The correlation function with precisely known flow contribution is then fitted with Eq. (2.3) in order to get the corresponding jet widths. Additionally, using the obtained fit parameters, we were able to calculate signal to background (S/B) ratio. Here S (B) stands for the signal (combinatorial background). The S/B is the area below the Gaussian divided by constant C_0 ($C_0 + b_0$) in order to correct it for the normalization (which value is always smaller than 1).

3. Results

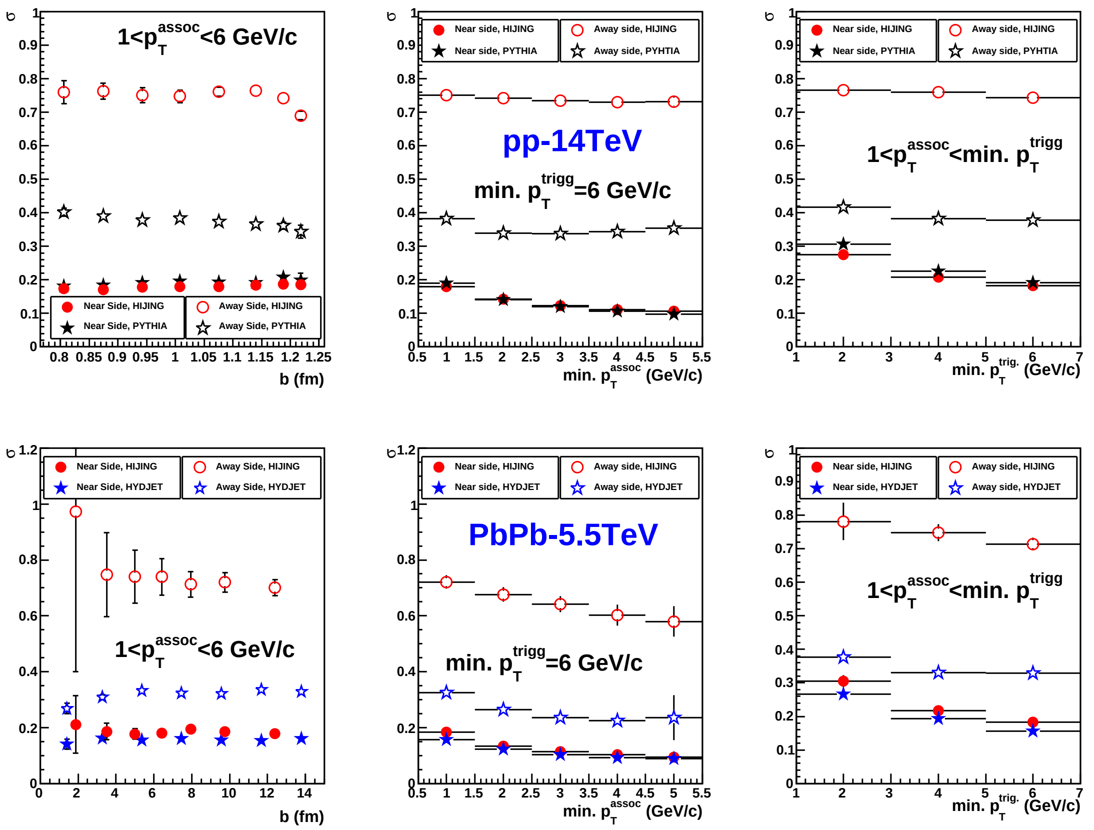

Figure 2: Top: The extracted widths of the near and away side peak in *pp*@14 TeV simulated within HIJING and PYTHIA *vs* impact parameter *b* (left), *min.* p_T^{assoc} (middle) and *min.* p_T^{trigg} (right). Bottom: The same as at the top but for *PbPb*@5.5 TeV simulated within HIJING and HYDJET++ model.

The analysis is performed for a few p_T^{trigg} selections (above 2, 4 and 6 GeV/c) correlated with associated particles with p_T^{assoc} satisfying $min.\ p_T^{assoc} < p_T^{assoc} < min.\ p_T^{trigg}$ condition. The obtained results, shown in Fig. 2, have a common feature. Independently of the colliding system and on the model used, the extracted widths (σ) do not depend on centrality. For both colliding systems the widths slowly decrease with increasing of the transverse momentum of the associated (trigger) particle p_T^{assoc} (p_T^{trigg}). Such dependencies suggest a surface emission of jets in analysed models. Based on the ratio of the σ's magnitudes between the away and the near side peak, one can conclude that jets produced within the HIJING model are strongly suppressed with respect to those formed in the PYTHIA and the HYDJET++ model. A comparison with the PHENIX results at RHIC [18] shows qualitatively the same behaviour of σ *vs* p_T^{assoc}. Although at higher incident energy, HIJING results show experimentally found strong broadening of the away side peak with roughly similar magnitudes.

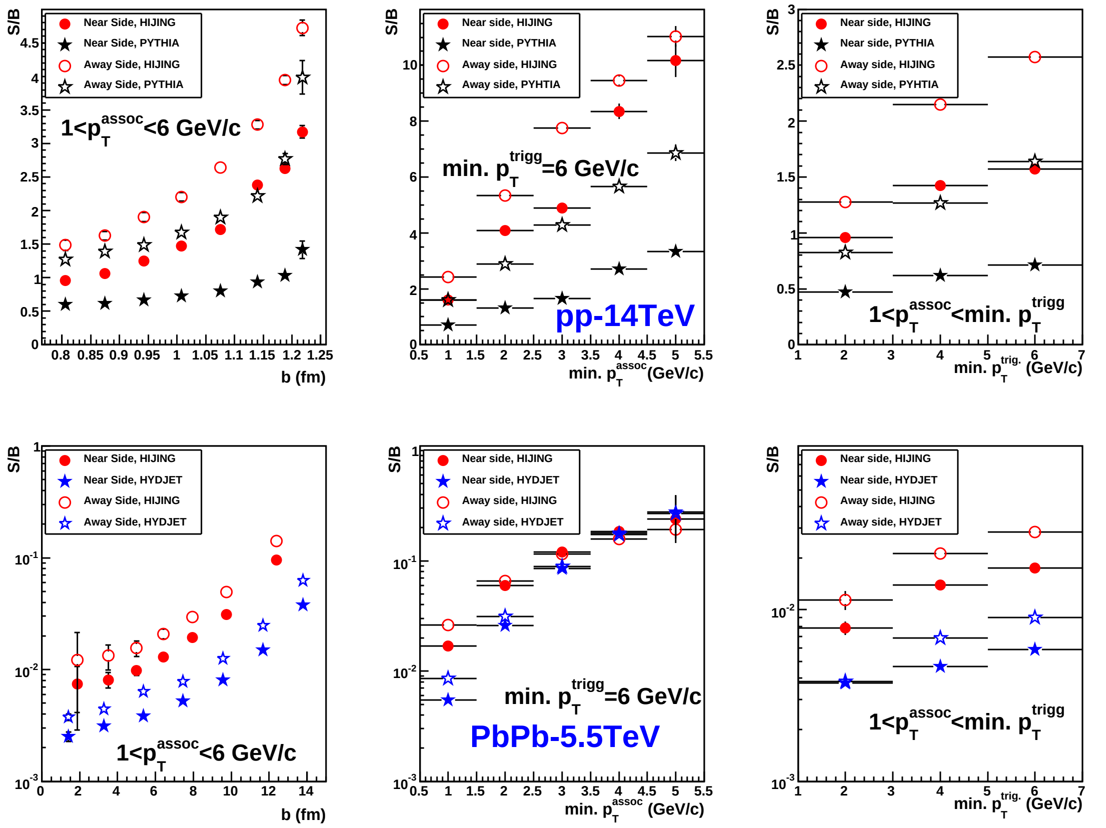

Figure 3: Top: The extracted signal to background ratio (S/B) of the near and away side peak in *pp*@14 TeV simulated within HIJING and PYTHIA *vs* impact parameter b (left), $min.\ p_T^{assoc}$ (middle) and $min.\ p_T^{trigg}$ (right). Bottom: The same as at the top but for *PbPb*@5.5 TeV simulated within HIJING and HYDJET++ model.

In Fig. 3 are shown the extracted values of the signal to background ratio (S/B) of the near and the away side peak. A common property of the obtained results, independently of the colliding system and of the model used, is that the value of S/B increases with increasing b as well as with both p_T^{assoc} and p_T^{trigg} transverse momenta. Qualitatively, the obtained results for pp events are rather similar to those corresponding to *PbPb* events. Quantitatively, the S/B values in *PbPb* events are roughly 2 orders of magnitudes smaller with respect to the ones in the case of pp collisions. It is a simple consequence of the fact that the multiplicity in *PbPb* events is 2 orders of magnitude higher with respect to the one in pp events giving correspondingly higher combinatorial background.

4. Conclusions

In this paper, two-particle azimuthal correlations constructed in pp and *PbPb* events at LHC energies generated using PYTHIA, HIJING and HYDJET++ model are studied. We presented the centrality and p_T dependence of the obtained jet widths and corresponding signal to background ratios. For both, pp and *PbPb* collisions and independently on the model used, the obtained widths do not depend on centrality and slowly decrease with increasing of the transverse momentum. Also, the signal to background ratios increase with increasing b and p_T. The obtained results are consistent with a simple point of view where more energetic particles more easily penetrate the dense medium with respect to the less energetic ones. A narrow jet-like pattern at the near side is nearly unaffected by the medium, while a strong modification at the away side suggests a possible energy transfer of the hard scattered parton to the medium formed in the collision in both pp and *PbPb* collisions simulated within the HIJING model. The k_T broadening also contributes to modification of the away side peak similarly to the one within the PYTHIA. The HYDJET++ model gives a correlation function which resembles the shape expected for vacuum fragmentation as seen within the PYTHIA simulation. Within the analysed models, the obtained results on σ *vs* b and σ *vs* p_T dependence suggest the surface emission of jets.

Acknowledgments

We would like to thank P. Christiansen and I. Lokhtin for useful comments and discussions. Thanking to I. Lokhtin I. Arsene we could perform the analysis within the HYDJET++ model too. This work has been supported by Norwegian Research Council (NFR).

References

[1] S. M. Berman, J. D.Bjorken, and J. B. Kogut, *Phys. Rev.* **D 4** (1971) 3388.

[2] J F. Owens and J. D. Kimel, *Phys. Rev.* **D 18** (1978) 3313.

[3] J. F. Owens, E. Reya, and M. Gluck, *Phys. Rev.* **D 18** (1978) 1501.

[4] R. P. Feynman, R. D. Field, and G. C. Fox, *Phys. Rev.* **D 18** (1978) 3320.

[5] R. Baier, Y. L. Dokshitzer, A. H. Mueller, S. Peigne and D. Schiff, *Nucl. Phys.* **B 484** (1997) 265;

[6] M. Gyulassy, I. Vitev, X. N. Wang, and B. W. Zhang, [nucl-th/0302077].

[7] A. Kovner and U. A. Wiedemann, [hep-ph/0304151].

[8] A. L. S. Angelis *et al.*, *Phys. Lett.* **B 97** (1980) 163.

[9] P. Darriulat *et al.*, *Nucl. Phys.* **B 107** (1976) 429.

[10] M. Della Negra *et al*., *Nucl. Phys.* **B 127** (1977) 429.

[11] A. Adler *et al.*, [STAR Collaboration], *Phys. Rev.* Lett. **90** (2003) 082302.

[12] J. Adams *et al*., [STAR Collaboration], *Phys. Rev.* **C 73** (2006) 064907.

[13] J. Adams *et al*., [STAR Collaboration], *Phys. Rev. Lett.* **95** (2005) 152301.

[14] S. S. Adler *et al*., [PHENIX Collaboration], *Phys. Rev. Lett.* **97** (2006) 052301.

[15] T. Sjöstrand, *Comp. Phys. Comm.* **82** (1994) 74.

[16] M. Gyulassy and X.-N. Wang, *Comp. Phys. Comm.* **83** (1994) 307.

[17] I. P. Lokhtin, L. V. Malinina, S. V. Petrushenko, A. M. Snigirev, I. Arsene and K. Tywoniuk, [hep-ph/0810.2082v1].

[18] S. S. Adler *et al*., [PHENIX Collaboration], *Phys. Rev.* **D 74** (2006) 072002.