Energy and rapidity dependence of J/ψ production as function of charged-particle multiplicity in different event shapes

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The search for collectivity in small systems (pp and p−A) is an emerging field of interest in the high-energy nuclear physics community. Recently, the discovery of collective-like phenomena [1, 2], strangeness enhancement in in high-multiplicity pp and p−A collisions [3] have made it intriguing topic of discussion. An understanding of small system collectivity from microscopic view point is necessary. These collective-like phenomona can be a result of thermalised medium that involves all the particles in the system, or it is just the effect of contributions from the processes like resonance decays, jets, underlying events (UE) etc. In the same direction, the multiplicity dependence study of J/ψ production at mid and forward-rapidities, performed by ALICE helps us to observe the effect of UE to J/ψ production. A faster than linear and approximately linear behavior has been observed at mid and forward-rapidities, respectively [4]. The faster than linear increase of J/ψ yield with multiplicity questions the role of phenomena like collectivity, contribution of higher fock states, percolation, color reconnection etc., in addition to the multipartonic interaction (MPI) [5–8] It has been speculated that different kinds of trend for multiplicity dependence of J/ψ at mid and forward rapidity might be due to auto-correlation and/or jet biases. In the present study, we have investigated different trends of multiplicity dependence of J/ψ production at mid-rapidity and forward rapidity through the transverse spherocity analysis. Adding a new variable called transverse spherocity [9], which describes the event shape, helps to investigate the particle production by isolating the hard and the soft components of the particle production and the importance of jets in high-multiplicity pp collisions. Using this tool, one can extensively study the contribution of jets to the observed structure by separating the isotropic and jetty events from the minimumbias ones. We have analyzed the J/ψ production at the mid-rapidity and forward rapidities via dielectron and dimuon channels, respectively using 4C tuned PYTHIA8 event generator [10]. The analysis has been performed in pp collisions at $\sqrt{s}$ = 5.02 and 13 TeV, to see the energy dependence of jet contribution to the multiplicity dependence study of J/ψ production.

Figure 1 represents the transverse momentum spectra of J/ψ at forward (left panel) and mid-rapidity (right panel) for integrated multiplicity at $\sqrt{s}$ = 5.02 TeV for different spherocity classes. The lower panel of the same figure represents the ratio of p_{T}-spectra for isotropic and jetty events with respect to spherocity integrated (S_0) events. It can be seen that the lower-p_T region is dominated by isotropic over the jetty events. However, this scenario gets reversed as we move towards higher p_T. At a particular point, termed as ‘crossing point’, the jetty events dominate over the isotropic events. Therefore, the study of the ‘crossing point’ is of great interest as far as a feasible boundary for dominance of the event type and hence the associated particle production mechanisms are concerned. The event shape study is carried out using transverse spherocity in different charged-particle multiplicity classes and the values for both en-

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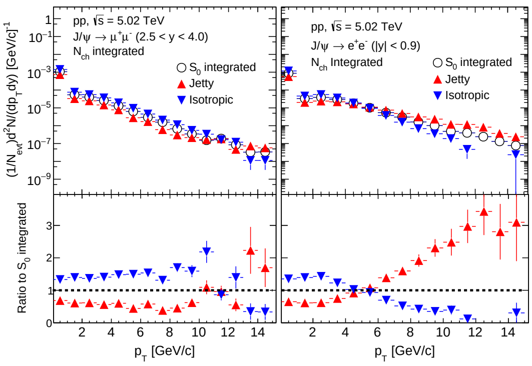

FIG. 1: The upper panel shows p_{T}-spectra of J/ψ for minimum bias pp collisions as a function of spherocity. Whereas, the lower panel shows the ratio of p_{T}-spectra for isotropic and jetty events w.r.t. S_0 integrated events. The blue inverted triangles are for isotropic events and red triangles are jetty events and open circles represent S_0 integrated events [11].

ergies at mid and forward rapidities are listed in Table I. It can be seen from the table that

TABLE I: The crossing point of jetty and isotropic events at forward and mid rapidity for pp collisions at $\sqrt{s}$ = 5.02 and 13 TeV.

Multiplicity	$\sqrt{s}$ = 5.02 TeV		$\sqrt{s}$ = 13 TeV	
N_{ch} bin	$\lvert y\rvert < 0.9$	2.5< y <4.	$\lvert y\rvert < 0.9$	2.5< y <4.
5-10	0.5	6.0	1.5	6.5
10-15	2.0	6.5	2.5	7.0
15-20	3.5	7.5	4.0	7.5
20-30	4.0	8.5	4.5	9.0
30-40	5.0	9.0	5.5	10.5
40-150	6.5	9.5	7.0	10.0

crossing point is shifted as a function of multiplicity in both rapidity region and there is significant variation in jetty events between mid and forward rapidity. The following important observations are drwan from the study of event shape, multiplicity and rapidity dependence of J/ψ production at $\sqrt{s}$ = 5.02 and 13 TeV:

1. The jet contribution to the J/ψ production is higher at mid-rapidity compared to forward rapidity, and is independent of $\sqrt{s}$.
2. The system formed in pp collisions contain dynamical effects, which leads to collective-like behaviour. The collectivity increases from low to high-multiplicity at mid-rapidity, irrespective of the dominance of the event type in J/ψ production, and is more prominent for jetty events compared to isotropic events.
3. The isotropic events are dominant throughout all the multiplicity bins at forward rapidities with a very little contribution from jetty events, and are independent of $\sqrt{s}$.

The observations drawn from the current study are able to explain the recent experimental results by ALICE [4]. Further, the spectral analysis of J/ψ at mid and forward-rapidity in different event shape and multiplicity classes has been done using Tsallis non-extensive statistics to draw the information about associated dynamical effect(s). The details of this work could be found in Ref. [11].

References

[1] W. Li [CMS Collaboration], J. Phys. G **38**, 124027 (2011).
[2] V. Khachatryan *et al.* [CMS Collaboration], JHEP **1009**, 091 (2010).
[3] J. Adam *et al.* [ALICE Collaboration], Nature Phys. **13**, 535 (2017).
[4] D. Thakur [ALICE Collaboration], PoS HardProbes **2018**, 164 (2019).
[5] S. G. Weber [ALICE Collaboration], Nucl. Phys. A **967**, 333 (2017).
[6] E. G. Ferreiro and C. Pajares, Phys. Rev. C **86**, 034903 (2012).
[7] B. Z. Kopeliovich, *et al.*, Phys. Rev. D **88**, 116002 (2013).
[8] D. Thakur, S. De, R. Sahoo and S. Dansana, Phys. Rev. D **97**, 094002 (2018).
[9] A. Ortiz, G. Paic and E. Cuautle, Nucl. Phys. A **941**, 78 (2015).
[10] T. Sjostrand, S. Mrenna and P. Z. Skands, Comput. Phys. Commun. **178** (2008) 852.
[11] A. Khatun, D. Thakur, S. Deb and R. Sahoo, arXiv:1909.03911 [hep-ph].