

## FURTHER RESULTS ON PERIPHERAL-TUBE MODEL FOR RIDGE CORRELATION\*

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*(Received January 25, 2013)*

Peripheral one-tube model has shown to be a nice tool for dynamically understanding several aspects of ridge structures in long-range two-particle correlations, observed experimentally and obtained also in our model calculations using NexSPheRIO code. Here, we study an extension of the model, to initial configurations with several peripheral tubes distributed randomly in azimuth. We show that the two-particle correlation is almost independent of the number of tubes, although the flow distribution becomes indeed strongly event dependent. In our picture, the ridge structures are causally connected not only in the longitudinal direction but also in azimuth.

DOI:10.5506/APhysPolBSupp.6.513

PACS numbers: 25.75.-q, 24.10.Nz, 25.75.Gz

### 1. Introduction

Ridge effect has been observed in long-range two-particle correlations. The main characteristic is a narrow  $\Delta\phi$  and a wide  $\Delta\eta$  correlation around the trigger. There is also some awayside structure: one or two ridges. Originally, the trigger was chosen a high- $p_T$ , presumably jet particle, but now data are available also for low- $p_T$  trigger or even without trigger.

In a previous work [1], we got the ridge structure in a purely hydrodynamic model. What is essential to producing ridges in hydrodynamic approach are event-by-event fluctuating initial conditions (IC) and besides

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\* Presented by Y. Hama at the International Symposium on Multiparticle Dynamics, Kielce, Poland, September 17–21, 2012. A similar talk has been given also at the WPCF2012, Frankfurt am Main, Germany, September 10–14, 2012.

very bumpy tubular structures in the IC. Nowadays, this kind of IC are being studied by several groups. We have been using NEXUS event generator [2] for producing such fluctuating IC. In a series of previous studies, starting from NEXUS events, and by doing 3D hydro calculations for Au+Au collisions at 200A GeV, we obtained some of the experimentally known properties such as (i) centrality dependence [3, 4]; (ii) trigger-direction dependence in non-central windows [3, 5]; and (iii)  $p_T$  dependence [4].

However, *what is the origin of ridges?* One may intuitively associate the long extension in  $\Delta\eta$  of the two-particle correlation with the tubular structures of IC. But *what about the structure in azimuth?* Trying to understand this property, we studied carefully the hydrodynamic evolution of the high-density fluid in the neighborhood of one peripheral high-energy tube, by introducing what we call *boost-invariant one-tube model* [3]. It turns out that such a high-energy peripheral tube expands strongly at early times, pushing the surrounding matter, causing deflection of the flow coming from inside, producing two-peak structure in the single particle azimuthal distribution,  $dN/d\phi$  (symmetric with respect to the tube position, in the case of central collisions). As a consequence, the two-particle correlation in  $\Delta\phi$  appears to have the characteristic shape with the main peak at  $\Delta\phi = 0$  (near-side ridge) and two symmetrical secondary maxima at  $\Delta\phi \sim \pm 2\pi/3$  (away-side ridges). See details in Refs. [3, 6].

This model has shown to be a nice tool for clarifying also some other aspects of ridge structures [7, 8], observed experimentally. We emphasize that it gives a unified description of the ridge structures, both near-side and away-side ones, and moreover, these structures are causally connected.

Now, what happens if there are more than one peripheral tube, as presumably occurs in a realistic set of initial conditions. This is the main topic of this paper.

## 2. Multi-tube model

In order to answer the question above, we extended the previous one-tube model to *multi-tube model*, considering 2, 3 or 4 peripheral tubes placed on top of an isotropic background as before. For simplicity, we took identical tubes, with Gaussian energy distribution, distributed randomly in azimuth at a constant distance  $r_0 = 5.4$  fm from the axis. Explicitly, the energy distribution is parametrized in a similar way as in Ref. [3], namely,

$$\epsilon = 12 \exp[-.0004r^5] + \sum_{i=1}^n \frac{34}{.845\pi} \exp\left[-\frac{|\mathbf{r} - \mathbf{r}_i|^2}{.845}\right], \quad (1)$$

where  $n = 1, 2, 3, 4$  is the number of peripheral tubes,  $|\mathbf{r}_i| = 5.4$  fm, and their azimuths are chosen randomly.

In what follows, we present preliminary results computed with only 50 random events in each case.

### 2.1. Fourier components of $dN/d\phi : v_n$

First, we computed the one-particle azimuthal distributions, decomposing them into Fourier components. In Fig. 1, we show how some of the Fourier coefficients  $v_n$  are distributed. As expected, they are widely spread and also show smaller values as compared to the one-tube case, where evidently they are sharply defined.

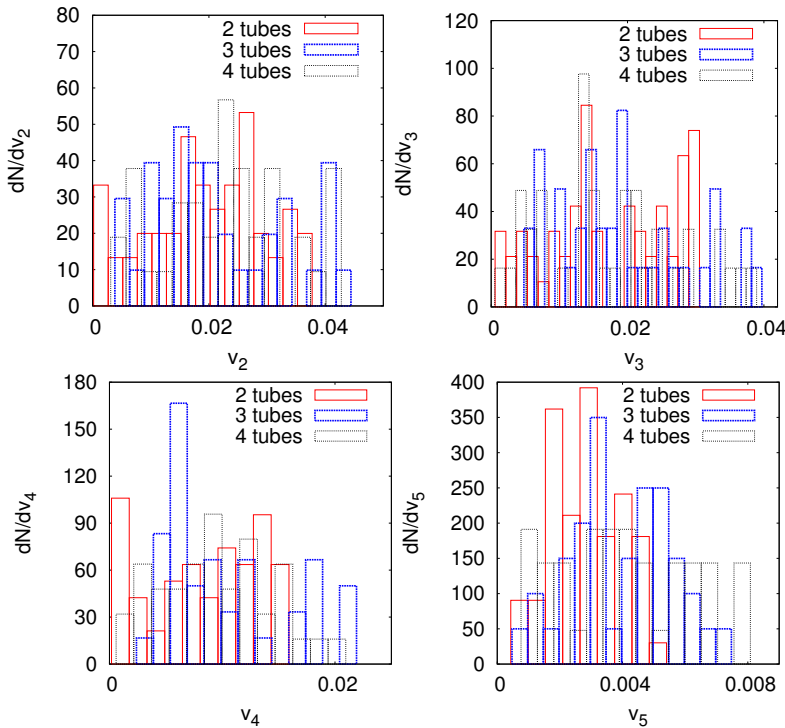


Fig. 1. (Color on-line) Distributions of some of the Fourier components  $v_n$  of the single-particle azimuthal distributions  $dN/d\phi$ , produced by 2-, 3- and 4-tube models. For comparison, the corresponding values for the one-tube model are, respectively,  $v_2 = 0.0569$ ,  $v_3 = 0.0740$ ,  $v_4 = 0.0479$  and  $v_5 = 0.0160$ .

### 2.2. Correlations among $\Psi_n$

Next, we computed the symmetry angle  $\Psi_n$  for each  $v_n$  component, in order to see whether they show some correlations among them. In Fig. 2, we

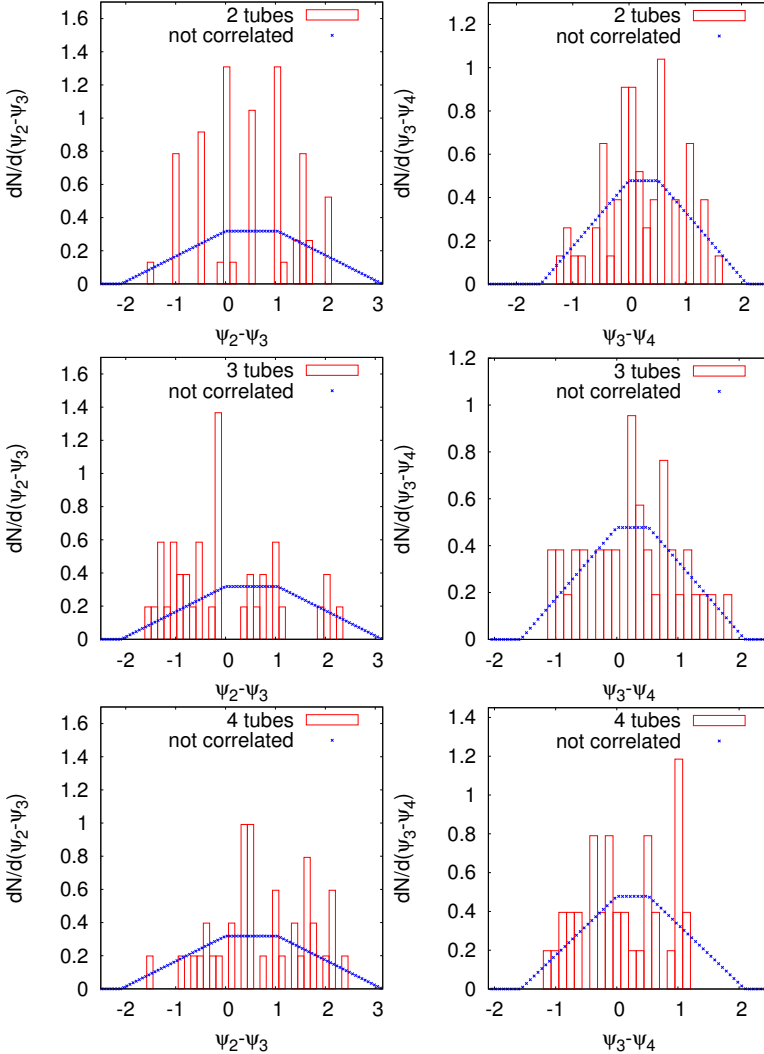


Fig. 2. (Color on-line) Distributions of  $\Psi_2 - \Psi_3$  and  $\Psi_3 - \Psi_4$ , computed for 2-, 3- and 4-tube models. The dotted lines represent the ideal distributions in the limit of infinite numbers of events.

show the differences  $\Psi_2 - \Psi_3$  and  $\Psi_3 - \Psi_4$  for the two-, three- and four-tube cases. As can be seen, the distributions of  $\Psi_m - \Psi_n$  are widely spread and consistent with no-correlation. For one-tube case, these differences have well defined values which are, respectively,  $\Psi_2 - \Psi_3$  (one-tube) =  $\pi/6$  and  $\Psi_3 - \Psi_4$  (one-tube) =  $\pi/12$ , corresponding precisely to the mid-points of the distributions shown there.

### 2.3. Two-particle correlations in $\Delta\phi$

Finally, we went on to the computation of the two-particle correlations, predicted by each  $n$ -tube model. Figure 3 shows the results. As expected, the two-particle correlation is almost independent of the number of peripheral tubes, showing that the interference arising from different tubes are already completely canceled with only 50 random events.

While in the one-tube case there is just one event, so  $dN/d\phi$  is uniquely defined, in the multi-tube cases the IC are fluctuating event-by-event, as given by Eq. (1), so the one-particle azimuthal distribution  $dN/d\phi$  varies from event to event, as implied by Figs. 1 and 2. However, as for the two-particle correlation, they give almost the same result as for the one-tube case. We understand that this coincidence indicates that *what determines the several structures of two-particle correlation is what each peripheral tube produces during the expansion of the bulk matter and has nothing to do with the global distribution of the matter at the initial time.*

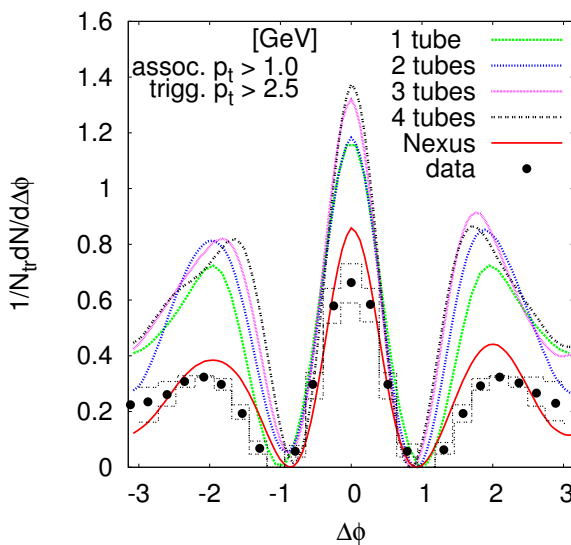


Fig. 3. (Color on-line) Two-particle correlations as functions of  $\Delta\phi$ , computed with 1-, 2-, 3- and 4-tube models. The results with NEXUS initial conditions and data [9] are shown for comparison. It should be mentioned that in NEXUS, both the tube size and their radial positions fluctuate and not maintained constant as in Eq. (1).

### 3. Conclusions

- Hydrodynamic approach with fluctuating IC, with tube-like structures, produces ridge structures in two-particle correlations at low and intermediate  $p_T$ .
- Peripheral-tube model (now extended to multi-tube configurations) is a nice tool for clarifying the ridge-formation mechanism.
- It gives a unified description of the ridge structures, both near-side and away-side ones.
- The mechanism of ridge production is local: what is important is each peripheral tube and not the global structure of the initial conditions.
- Because these structures are produced by each of the peripheral tubes, they are causally connected. The causal connection of the ridge, with respect to the longitudinal distribution, has been discussed elsewhere [10]. Now, we are sure that the ridge structures, including near-side and away-side ones, are entirely connected by causality.

A more detailed account of the present work is being prepared and will be published soon.

This work was partially supported by FAPESP (09/50180-0), FAPEMG and CNPq.

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