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THE RIDGE AS A SHADOWING EFFECT IN HYDRODYNAMICS

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The aim of this work is to clarify the origin of the in-plane/out-of-plane effect, in the two-particle correlation function, computed with the NexSPheRIO code, in Au + Au collisions at $200A$ GeV. We show that such an effect can be understood in terms of the shadowing effect caused by a peripheral high-energy-density tube.

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INTRODUCTION

In the previous publications [1, 2], we have applied the one-tube model in order to try to understand the NexSPheRIO results on two-particle correlation [1, 3], which are in good agreement with the main characteristics of the Au + Au data at RHIC [4–8]. The NexSPheRIO code is a junction of the event generator Nexus [9] and the hydrodynamic code SPheRIO [10]. We have argued that the ridge structure, in the NexSPheRIO scenario, is related to the tubular structures that characterize the Nexus initial conditions. In Fig. 1, an example of initial energy density distribution is shown.

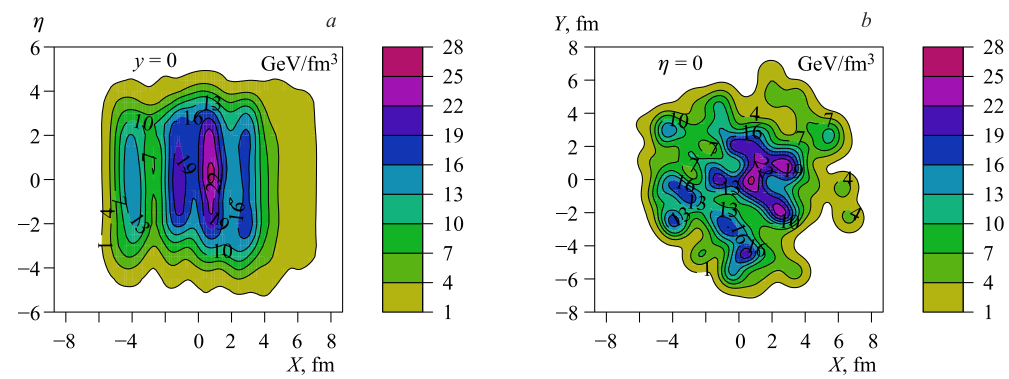

Fig. 1. Initial energy density distribution of a random Nexus event (central Au + Au collision at $200A$ GeV)

In particular, the existence of peripheral tubes is the crucial ingredient to produce ridges, for instance, the tube at $x \sim -4$ fm (see Fig. 1, *a*). In the one-tube model, the hydrodynamic expansion of the matter in the neighborhood of such a peripheral tube can be studied in detail.

In general, we observe, in the azimuthal distribution, a valley, flanked by peaks, at the angular position of the tube. This is the so-called shadowing effect in hydrodynamics.

An interesting behavior of the two-particle correlation function is observed by studying its dependence on the azimuthal angle ϕ_s of the trigger particle, with respect to the event plane [8]. In a mid-central window, the away-side structure in $\Delta\phi$ is a peak at π, if the trigger is close to the event plane, and it is split into two peaks, as ϕ_s goes closer to $\pi/2$. This is the so-called in-plane/out-of-plane effect. In the next Section, we show the in-plane/out-of-plane correlation computed with the NexSPheRIO code, in Au + Au collisions at $200A$ GeV. In Sec.2, the one-tube model is applied in order to understand the role of peripheral tubes in creating the near-side and away-side structures. Our conclusions are summarized in the final section.

1. NexSPheRIO RESULTS

In Fig. 2, our results on in-plane/out-of-plane correlation are shown in the 20–30% centrality window, for Au + Au collisions at $200A$ GeV. The away-side structure evolves from a double to a single ridge as the azimuthal angle of the trigger goes from 90 to 0° with respect to the event plane, just as observed in data [8].

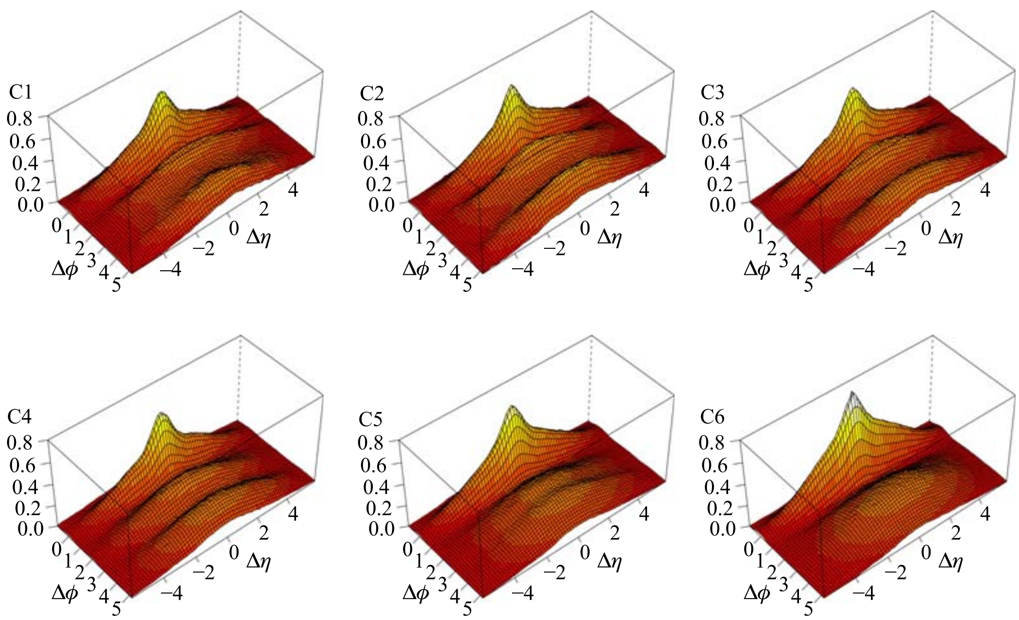

Fig. 2. In-plane/out-of-plane correlation computed with NexSPheRIO, in the 20–30% centrality window, for Au + Au collisions at $200A$ GeV. From top to bottom and left to right: C1 ($75 < \phi_s < 90°$), C2 ($60 < \phi_s < 75°$), C3 ($45 < \phi_s < 60°$), C4 ($30 < \phi_s < 45°$), C5 ($15 < \phi_s < 30°$), C6 ($0 < \phi_s < 15°$). ϕ_s is the azimuthal angle of the trigger with respect to the event plane

2. ONE-TUBE MODEL

In Fig. 3, *a*, an example of initial energy density distribution in the one-tube model is shown. The average of Nexus initial energy density, in the 20–30% centrality window, for Au + Au collisions at $200A$ GeV, is performed, in order to create a smooth background, and the peripheral tube (or hot spot) is placed at some point along the contour curve $\epsilon_{\text{bkgd}} \sim$ 1 GeV/fm^3 (close to the border). For the longitudinal expansion, Boost invariance is assumed and both the baryon density and the initial transverse velocity are assumed null. The tube has an energy content $E_{\text{tube}} \sim 7$ GeV/fm, which is compatible with the typical energy content of a peripheral Nexus tube, in the same centrality window (see Fig. 3, *b*). The energy content, or energy per unit of length ($E_{\text{tube}} \propto \epsilon \Delta r^2$), as we have shown [2], is a suitable parameter to characterize tubes, once the relevant factor in this model is the capacity of expansion of these objects.

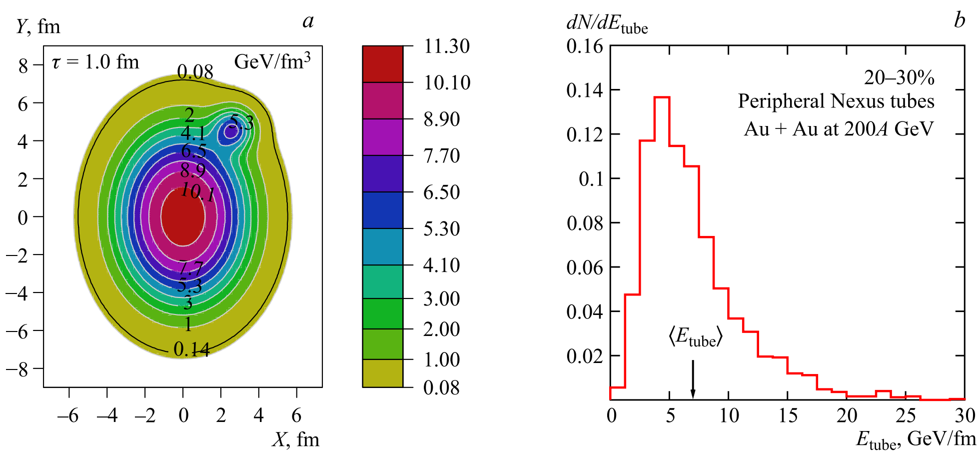

Fig. 3. *a*) Energy density distribution for the one-tube event with $\phi_{\text{tube}} = 60°$. The tube is placed on the contour curve $\epsilon_{\text{bkgd}} \sim 1$ GeV/fm^3. *b*) Energy-content distribution ($E_{\text{tube}} \propto \epsilon \Delta r^2$) of peripheral Nexus tubes, in the 20–30% centrality window. The tubes used in this plot were selected, in each event, from the transverse area limited by the ellipses $r_1 = 5.18/R_n$ and $r_2 = 5.81/R_n$, where $R_n = \sqrt{1.74 \cos(\phi - \Psi_n)^2 + \sin(\phi - \Psi_n)^2}$ and Ψ_n is the event plane angle of the nth event

In Fig. 4, *a*, the azimuthal distribution of the associated particles (top) and triggers (bottom) are shown. The solid lines refer to the one-tube event with $\phi_{\text{tube}} = 60°$ and the dashed lines to the average angular distribution. In the latter, the average is performed over a set of one-tube events with the tube randomly placed along the same contour curve. In both plots the behavior is similar: there is a lack of particles at the angular position of the tube (shadowing effect), at $\phi \sim \pi/3$, and an excess at $\phi \sim 0$ and $\phi \sim \pi/2$, in comparison with the average angular distribution. The two-particle correlation functions are shown in the same Fig. 4, *b*, for in-plane and out-of-plane triggers, respectively. The upper panels refer to the one-tube event with $\phi_{\text{tube}} = 60°$ (solid lines) and the average correlation (dashed lines). The difference between both functions is shown in the lower panels (resulting correlation). The symmetrical

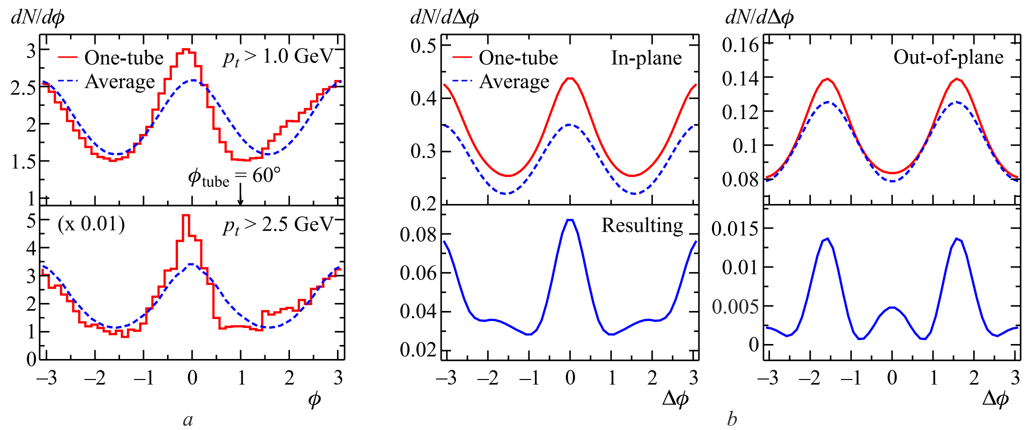

Fig. 4. *a*) Azimuthal distribution of the associated particles (top) and triggers (bottom). The solid lines refer to the one-tube event with $\phi_{\text{tube}} = 60^\circ$ and the dashed lines to the average angular distribution. *b*) Corresponding two-particle correlation functions (upper panels) and the resulting correlation (lower panels), for in-plane and out-of-plane triggers

one-tube events are included: 120, 240 and 300°, which makes the plots symmetrical with respect to the origin.

In the in-plane case, in which the azimuthal angle of the trigger goes from –15 to 15° (and from 165 to 195°), the two-particle correlation shows a peak at 0 and at π as a consequence of the excess of particles at $\phi \sim 0$. The excess of associated particles at $\phi \sim \pi/2$ gives rise to the local maximum point at $\Delta\phi \sim \pi/2$. In the out-of-plane case, the excess of associated particles at $\phi \sim 0$ gives rise to a peak at $\pi/2$ and at $-\pi/2$, once the azimuthal angle of the trigger goes from 75 to 105° (and from 255 to 285°). Finally, there is a central peak (lower) due to the excess of particles at $\phi \sim \pi/2$. This result shows that the near-side and away-side structure, the latter with one or two peaks, can be understood in terms of the hydrodynamic expansion of the matter in the neighborhood of a peripheral high-energy-density tube.

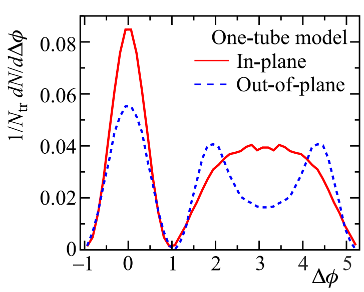

Fig. 5. The final in-plane/out-of-plane correlation in the one-tube model, normalized by the number of triggers

By moving the tube position along the contour curve $\epsilon_{\text{bkgd}} \sim 1$ GeV/fm^3, the position of peaks and valleys change. (For instance, a configuration with $\phi_{\text{tube}} = 0^\circ$ produces a valley at $\phi = 0$, in the azimuthal distribution.) However, when the two-particle correlation is integrated over tube position in order to obtain the final correlation for in-plane (or out-of-plane) triggers, certainly those configurations close to the example we chose ($\phi_{\text{tube}} = 60^\circ$) dominate, because they produce an excess of particles at $\phi \sim 0$ (in-plane) and $\phi \sim \pi/2$ (out-of-plane), in comparison with the averaged azimuthal distribution. So, the results obtained with this particular configuration can be used to understand the overall shape of the integrated correlation. In Fig. 5, such final in-plane/out-of-plane correlations are shown, normalized by the number of triggers.

CONCLUSION

We discussed the in-plane/out-of-plane effect in the NexSPheRIO scenario, for Au + Au collisions at $200A$ GeV. It was shown that the qualitative behavior of the correlation function is consistent with the data at RHIC. The one-tube model was applied in order to clarify the origin of the near-side and away-side structures. It was observed that the overall shape of the in-plane/out-of-plane correlations are reproduced by the model as a consequence of the hydrodynamic expansion of the matter in the neighborhood of a peripheral high-energy-density tube.

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