The background for Cherenkov gluons at RHIC and LHC energies

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The pseudorapidity distribution of centers of dense isolated groups of particles in HIJING model is determined. It can be considered as the background for Cherenkov gluons. If peaks over this background were found in experiment, they would indicate on new collective effects.

The search for collective effects in hadronic and nuclear high-energy reactions has always been one of the mainstreams of experimental and theoretical investigations. Among them, Cherenkov gluons [1,2] and Mach waves [3] were discussed a long time ago. Recently, the interest to them was revived [4–9] in connection with RHIC data [10] as reviewed in [4]. The common feature of these collective coherent processes is particle production concentrated on a cone with the polar angle θ defined by the condition

$$\cos\theta = \frac{c_w}{v} \ , \tag{1}$$

if the infinite medium at rest is considered. Here v is the velocity of the particle producing these waves, c_w is the phase velocity of gluons or sound in the medium. At high energies $v \approx c$ and c_w ranges from quite low values to a value slightly below c according to present estimates for both effects (see [4]). The lowest values of c_w are obtained for dilute media and low energy gluons, while larger c_w correspond to strong shock waves and high energy gluons. For gluons $c_w = c/n$ where n is their nuclear index of refraction. This index was estimated from experimental data on hadronic reactions [2,4]. The finite length of nuclear targets can change the estimate (1) [2,4].

The main experimental signature of both effects would be two peaks in the pseudorapidity distribution of particles produced in high energy nuclear collisions which are positioned in accordance with Eq. (1). The most picturesque image of these effects is the ring-like structure of events in the plane perpendicular to the direction of propagation of initiating them body.

The recently observed at RHIC [10] effect with two peaks in angular distribution about the direction of propagation of the companion jet was interpreted in [7] as Mach waves

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with $c_w = 0.33c$. In terms of Cherenkov gluons, it could be the emission of low energy gluons with nuclear index of refraction equal to 3.

Beside low energy gluons, the forward moving very high energy partons can produce high energy Cherenkov gluons. They would result in two peaks of the pseudorapidity distribution positioned at large c.m.s. angles. The emission angle in the target rest system is small but much larger than bremsstrahlung angles. There are numerous experimental indications in favor of this effect (see review in [4]). The first one of them was presented in [11].

The important problem of experimental search for this effect is the background due to ordinary processes. Its influence should be minimized. For doing this we propose to use the distinctive feature of production of high energy Cherenkov gluons. Namely, each gluon should produce a jet of particles which can be distinguished as a high density isolated group of particles. Separating such groups in experimental data one would increase the share of jets produced by Cherenkov gluons among all particles. By this choice we omit weakly correlated particles. Statistical fluctuations and hard QCD-jets are still accounted but their probability is lowered and pseudorapidity distribution is rather smooth. Therefore the role of background in the distribution of the centers of such groups becomes lower compared to the overall pseudorapidity distribution. Peaks corresponding to Cherenkov gluons should be more pronounced. If the peaks in the pseudorapidity plot of the centers of separated groups are found in experiment and fit the condition (1), then it favors the hypothesis about Cherenkov gluons. The positions of the peaks reveal the properties of hadronic matter.

To estimate the background we have used the HIJING model for central collisions ($b = 0$) for Au+Au collisions at RHIC energy $\sqrt{s}$=200A GeV and for Pb+Pb collisions at LHC energy $\sqrt{s}$=5500A GeV. 3500 events were generated in each case.

Then the spikes in individual HIJING events exceeding this distribution by more than one and two standard deviations have been separated. They can appear either as purely statistical fluctuations or as hard QCD-jets. Figs 1a and 2a show the examples of such events (each one for RHIC and LHC energies, correspondingly) plotted over the smooth inclusive pseudorapidity distributions.

Peaks exceeding the distributions are clearly seen. All simulated events have been plotted in such a way and centers of peaks defined. Finally, the distribution of the centers of these peaks is plotted. Figs 1b and 2b show these distributions for peaks exceeding the inclusive plot at RHIC and LHC energies by two or one standard deviations. It is seen that these distributions are flat with extremely small irregularities. This appeals to our expectations that statistical fluctuations and QCD jets do not have any preferred emission angle. They can be considered as background plots for experimental search for Cherenkov gluons which do have such preferred angle. If experimental data on group centers distribution show some peaks at definite pseudorapidity values over this background, this can be an indication on new collective effect, not considered in HIJING. These findings will add to those experimental facts in favor of this effect which existed before (they are reviewed in [4]).

To conclude, the pseudorapidity distributions of the centers of dense isolated groups of particles (jets) exceeding in individual events the inclusive distribution are plotted for events generated according to HIJING model at RHIC and LHC energies. They provide the background for further searches for such collective effects as Cherenkov gluons and Mach waves.

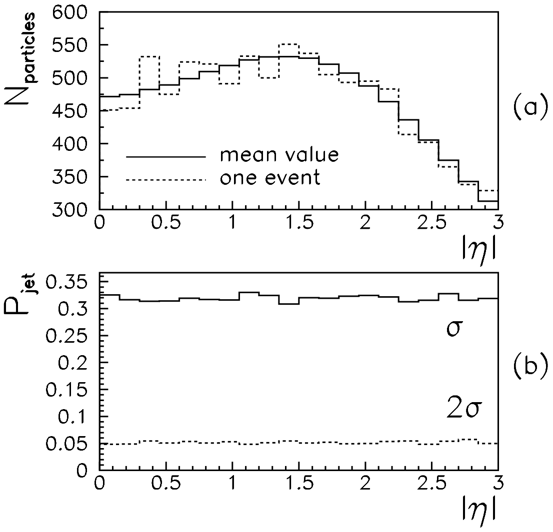

Figure 1. (a) The pseudorapidity distribution in one of HIJING events (dashed histogram) for central Au+Au collision at $\sqrt{s}$=200A GeV is plotted over the inclusive HIJING distribution (solid histogram), $N_{particles}$ — number of particles. Peaks over the inclusive plot are clearly seen. (b) The pseudorapidity distribution of the centers of dense isolated groups of particles similar to those shown in Fig. 1a and exceeding the inclusive plot by two and one standard deviations σ, P_{jet} — probability to find peak over mean + σ (2σ). This is the smooth background for further searches of collective effects.

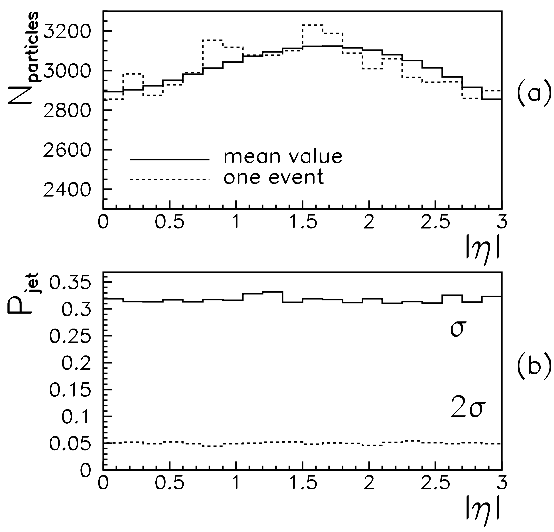

Figure 2. (a) The pseudorapidity distribution in one of HIJING events (dashed histogram) for central Pb+Pb collision at $\sqrt{s}$=5500A GeV is plotted over the inclusive HIJING distribution (solid histogram), $N_{particles}$ — number of particles. Peaks over the inclusive plot are clearly seen. (b) The pseudorapidity distribution of the centers of dense isolated groups of particles similar to those shown in Fig. 2a and exceeding the inclusive plot by two and one standard deviations σ, P_{jet} — probability to find peak over mean + σ (2σ). This is the smooth background for further searches of collective effects.

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