**EPJ manuscript No.**
(will be inserted by the editor)

# Evidence for creation of strong electromagnetic fields in relativistic heavy-ion collisions

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the date of receipt and acceptance should be inserted later

**Abstract.** It is proposed to identify a strong electric field created during relativistic collisions of asymmetric nuclei via observation of pseudorapidity and transverse momentum distributions of hadrons with the same mass but opposite charges. Calculation results within the Parton-Hadron String Dynamics model are given for Cu-Au collisions at the NICA energy of 9 GeV.

**PACS.** 2 5.75.-q, 25.75.Ag

It was demonstrated in Ref. [1] that charged particles created in relativistic heavy-ion collisions may produce extremely strong electromagnetic field strength. In particular, in peripheral Au-Au collisions at the energy $\sqrt{s_{NN}}$ =200 GeV in the very initial interaction state this strength reaches $B_y/m_\pi^2 \sim 5 = 5 \cdot 10^{18}$ Gauss, which exceeds every value reachable in the earth conditions and even may be higher than the fields created in magnetars. However, the subsequent analysis of Au+Au collisions in the range up to the top RHIC energy has observed no visible effect for global characteristics, in particular, for such a sensitive quantity as the elliptic flow. The reason of that is not a very short interaction time of the system, as could be naively expected, but rather a compensation effect between electric and magnetic components of acting electromagnetic forces, as found in Ref. [2]. Thus, the question of wether so strong electromagnetic fields are really created in high-energy nuclear collisions remains open.

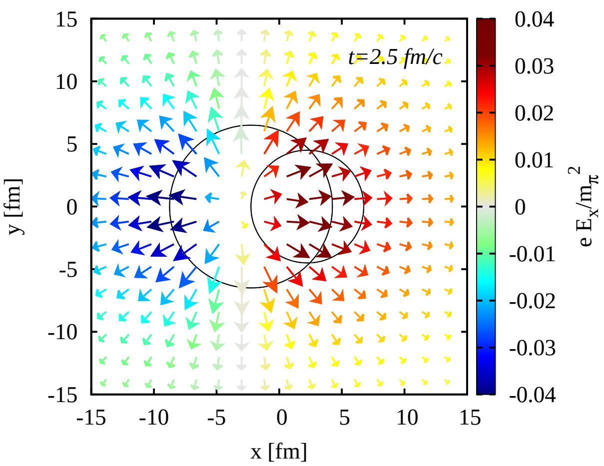


**Fig. 1.** Electric field generated in the transverse plane of Cu+Au collisions at $\sqrt{s_{NN}}$ =9 GeV, $b$ =4.5 fm and $t$ ==2.5 fm/c. The direction of arrows indicates the field direction projected onto the reaction plane and the length is proportional to the electromagnetic strength shown in color.

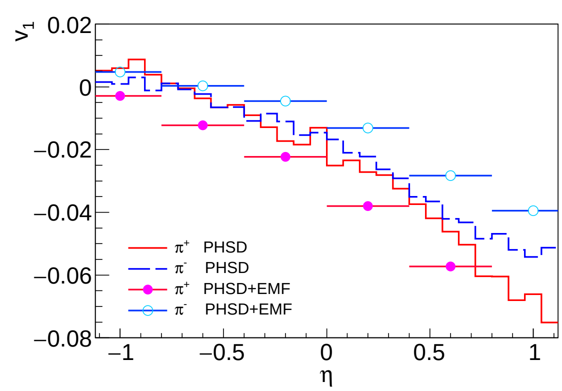


**Fig. 2.** Pseudorapidity distribution of positive and negative pions created in Cu+Au collisions at $\sqrt{s_{NN}}$ =9 GeV. Histograms are the result of the standard PHSD transport approach, points - electromagnetic force is additionally included.

Recently, it has been found that such compensation is absent in asymmetric collisions due to the difference in the number of protons in colliding nuclei [3]. In particular, in Cu+Au(200 GeV) collisions the directed flow (the first flow harmonic $v_1(\eta, p_t)$) exhibits the electric charged particle dependence. As follows from the results presented in Fig. 1, this effect can be observed at the NICA energy, too. Indeed, the strength of the induced electric field is strongly asymmetric within the region of overlapping nu-

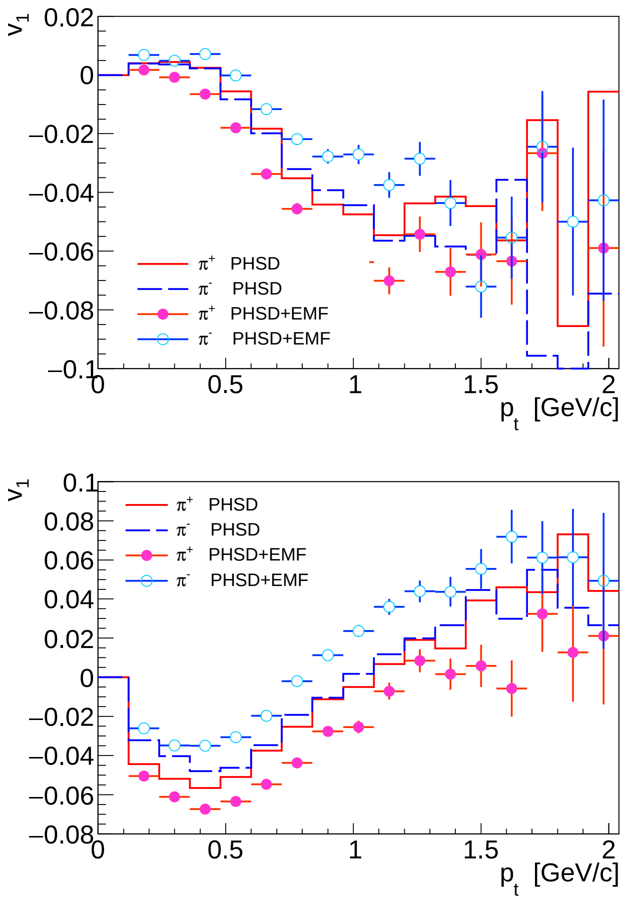


**Fig. 3.** Charge-dependent $p_t$ distributions of pions from asymmetric Cu+Au collisions at $\sqrt{s_{NN}}$ =9 GeV for backward (upper panel) and forward (bottom panel) emission. Notation as in Fig. 2.

clei, which may result in observable asymmetry of hadrons with opposite charges.

In this respect, on the basis of the Parton Hadron String Dynamics model [4] we calculated various characteristics of asymmetric Cu+Au collisions at the NICA energy $\sqrt{s_{NN}}$ =9 GeV. As is seen from Fig. 2, without accounting for the created electromagnetic field (EMF) the $\eta$ distributions for $\pi^+$ and $\pi^-$ are very close to each other (difference is coming only from different mean multiplicity of these pions) but the inclusion of the electromagnetic field results in a noticeable separation of these distributions. Note that the detector acceptance is taken into account here.

Transverse momentum distributions of the directed flow $v_1$ for pions is presented in Fig. 3. It is remarkable that $v_1(p_t)$ differs in the backward ($\eta < 0$) and forward ($\eta > 0$) directions. For $\eta < 0$ (the Au side) the low momentum ($p_t$ <1 GeV/c) pions are dominated while in the opposite direction the $p_t$ distribution is an increasing function with some minima at $p_t \sim 0.5$ GeV/c. In both cases the charge separation is well visible in Fig. 3 and it is getting larger for higher values of $p_t$.

Similar effects are seen for $K^+$ and $K^-$ mesons. But for a proton-antiproton pair it is not the case since the strong interaction of $p$ and $\bar{p}$ is quite different.

We propose to measure the pseudorapdity $v_1(\eta)$ and transverse momentum $v_1(p_T)$ distributions of the directed flow for identified pairs of hadrons (at least for $\pi^+, \pi^-$ and $K^+, K^-$ mesons) in the NICA energy range, which could first evidence a new physical effect – the formation of extremely strong electromagnetic fields in relativistic heavy-ion collisions. Realization of this experiment implies that two ions of different kind may interact in the collider. As an estimate shows, the planned luminosity $L = 10^{27} cm^{-2} s^{-1}$ resulting in the collision rate $(\sigma L \epsilon)$ =500 event/s makes feasible this experiment at the NICA collider.

## References

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