Directed flow from color glass condensate

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The initial state of nuclear collisions at very high energies is thought to be a phase of Quantum Chromodynamics (QCD) called the Color Glass Condensate (CGC) in which the dynamics is governed by semi-classical gluon fields. We have used a generalization of the McLerran-Venugopalan (MV) model and an expansion of the classical gluon field around the time of collision (t=0) to calculate the evolution of the energy momentum tensor in Color Glass Condensate.

In the past reporting period we have finished our calculation of energy flow of the gluon field in the early collision. We have confirmed that there is a flow component α that is driven by gradients of the energy density (a "hydrodynamic flow" behavior) while there is a second, "anomalous" component β which amplifies hydrodynamic flow in certain directions while quenching it in others. We have found an intuitive abelian analogue in which the hydrodynamic flow of gluon fields is a result of Ampere's and Faraday's Law while the anomalous flow component β results from Gauss' Law.

We find very interesting phenomenological consequences for this flow. While the hydrodynamic component α is even in rapidity the anomalous component β is odd in space-time rapidity η. This phenomenon leads to a significant tilt of the fireball around a vector perpendicular to the event plane. After a further hydrodynamic expansion a non-trivial directed flow (v_1) of particles survives. The sign and rapidity-dependence of this flow is consistent with directed flow reported by the STAR collaboration at RHIC. To our knowledge it is the first time that the fireball tilt and directed flow have been calculated from an effective theory derived from first principles (color glass condensate). There are other very intriguing consequences of β for asymmetric collision systems like Cu+Au. A careful phenomenological analysis could deliver further confirmation for the existence of color glass condensate at RHIC and LHC energies.

Figs. 1 and 2 show some typical flow patterns. The results of this work have been published in

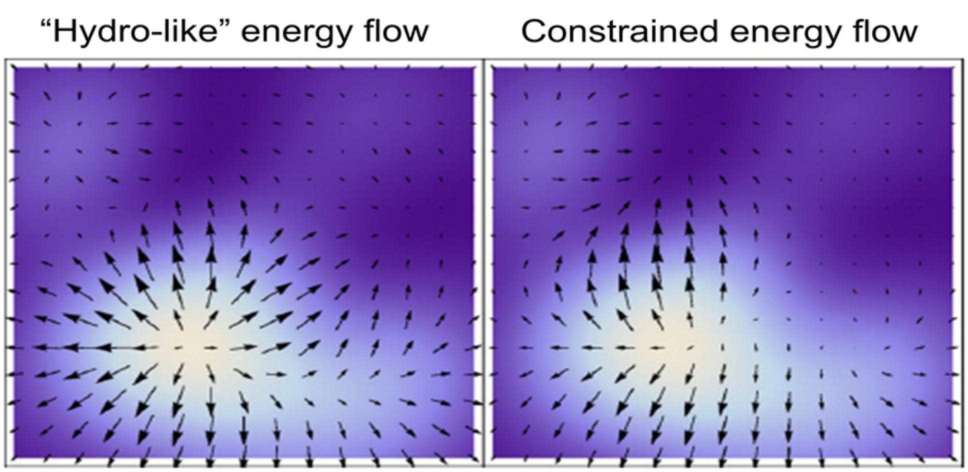

FIG. 1. The energy flow field (black arrows) in the transverse plane of the collision in a U(1) analogue, assuming random longitudinal (perpendicular to the plane) electric and magnetic fields which emerge from "seed fields" A_1 and A_2 as given by color glass. Background shading indicates energy density.Left: At η=0 there is only hydro-like flow. Right: The result at η=1 has contributions of β mixed in and shows a characteristic enhancement and quenching pattern of the flow field.

Ref.[1]. We are in the process of applying our results to the computation of initial conditions for hydrodynamics and important jet and heavy flavor observables.

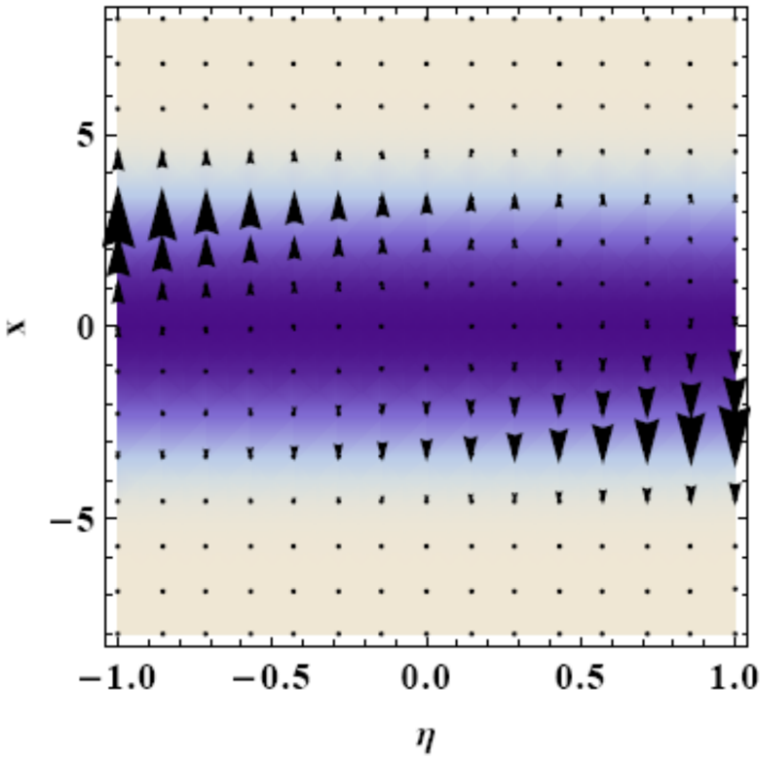

FIG. 2. The energy flow field of the classical gluon field (black arrows) in the x-η-plane at y=0 for a Au+Au collision at impact parameter b=6 fm. Energy density is indicated by shading [darker=larger energy density]. The directed flow that will lead to a tilting of the fireball is clearly visible.

[1] G. Chen and Rainer J. Fries, Phys. Lett. B **723**, 417 (2013).