Mach Cones and Two-Particle Correlations: The Origins in a Kinetic Transport Approach

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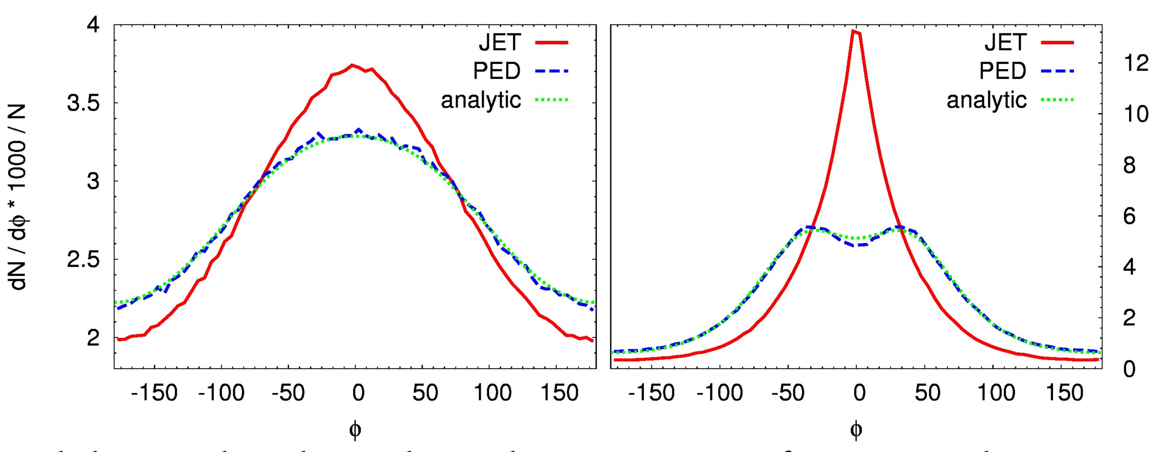
Motivation

Recent results of the Relativistic Heavy Ion Collider (RHIC) indicates the formation of a new state of matter, the quark-gluon plasma (QGP), which behaves like a nearly perfect fluid. Furthermore, jet-quenching is observed and recent measurements of two- and three particle correlations in heavy-ion collisions show a complete suppression of the away-side jet. For lower p_T surprisingly a double peak structure is observed, indicating the formation of Mach Cones [1].

Using the microscopic transport model BAMPS [2] (Boltzmann Approach for Multi-Parton Scatterings) we investigate the evolution of conical structures using different source terms and viscosities. We use a static box with T = 400 MeV and an ultrarelativistic gas. We address the question whether Mach Cones in the ideal hydro limit can generate a double peak structure as observed in the experiment.

Two Particle Correlations

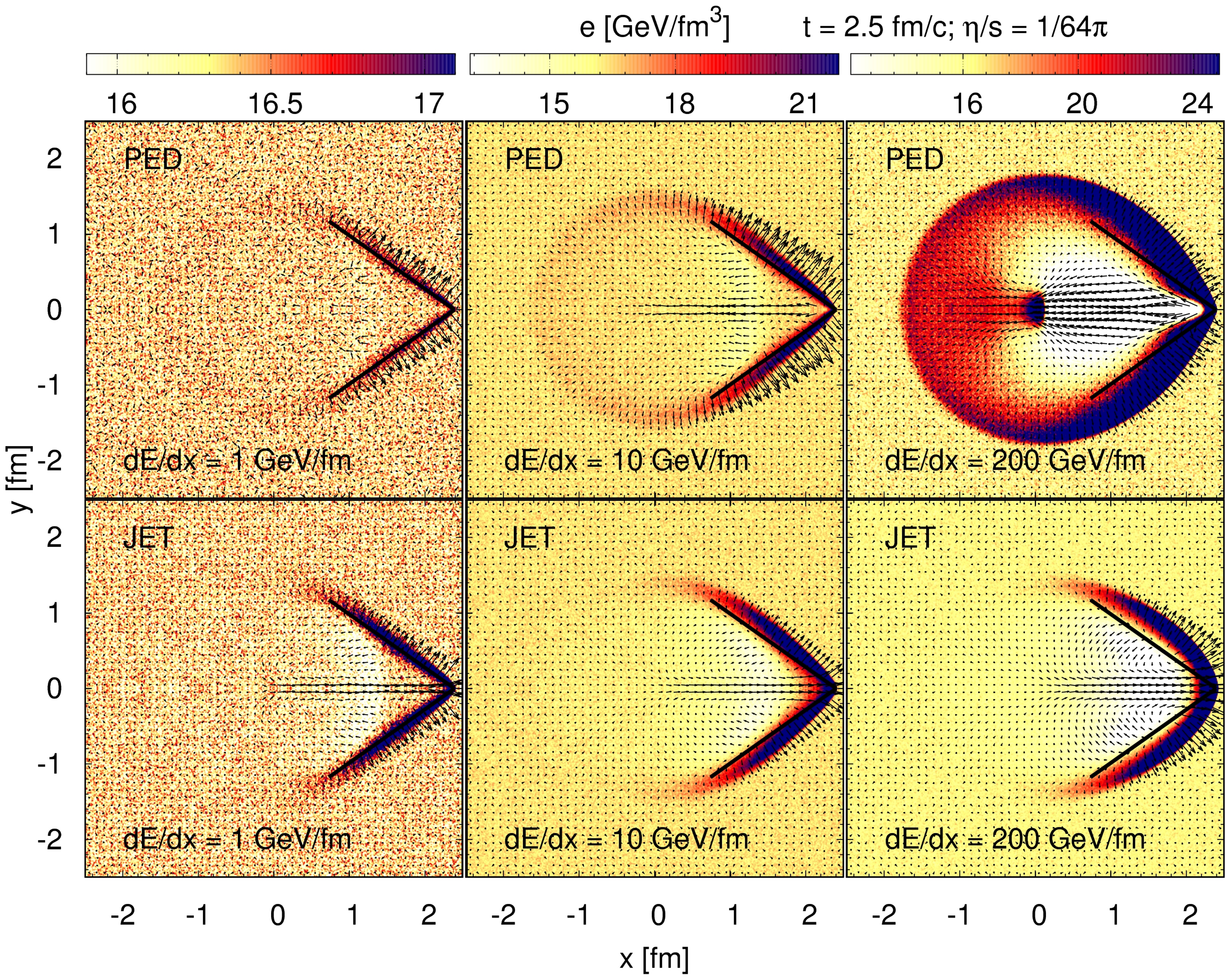
We extract the particle distribution $dN/(Nd\phi)$ from BAMPS calculation using both source terms and $\eta/s = 1/64\pi$. We compare them to a simple analytical calculation for a thermal particle distribution on the surface of a Mach Cone. In the left (right) panel we demonstrate the results for the energy deposition $dE/dx = 10$ ($dE/dx = 200$) GeV/fm. To get rid of the effects of the diffusion wake and the back region a lower energy density cut at $20\,\mathrm{GeV/fm^3}$ ($50\,\mathrm{GeV/fm^3}$) is applied.



Although the development of conical structures are observed in BAMPS calculations for different energy and momentum deposition scenarios, they are not necessary associated with double peak structures in the azimuthal particle distributions $dN/(Nd\phi)$. We find that a PED scenario and rather high energy deposition lead to a double peak structure, which otherwise can not be observed because of a strong diffusion wake and head shock. However, the PED scenario has no correspondence in heavy ion physics. On the other hand the JET scenario is a simplified model but nevertheless demonstrates that a double peak structure can not be produced by jets with energy and momentum deposition.

Mach Cones in the ideal hydro limit

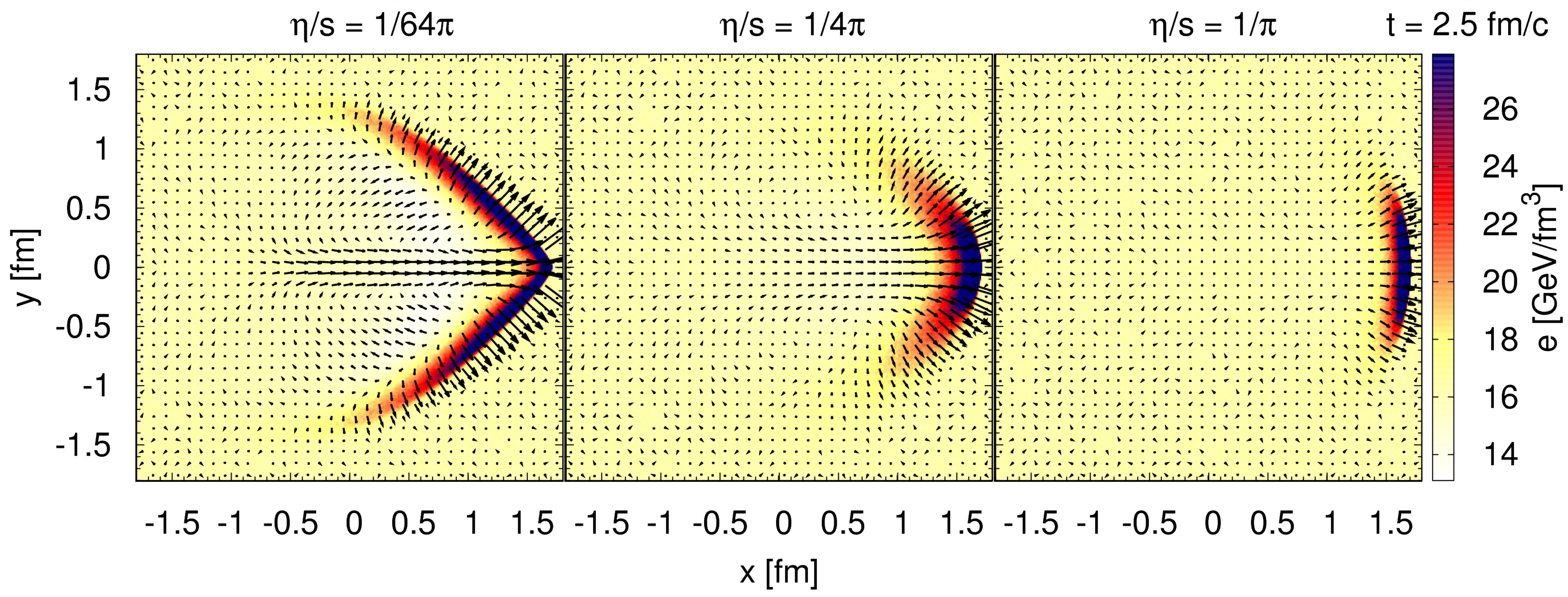
We employ **BAMPS** to show the shape of a Mach Cone for different source terms and different energy depositions to the medium, $dE/dx = 1, 10$ and 200 GeV/fm (from left to the right). The results are shown in the ideal hydro limit by keeping the viscosity over entropy density ratio to a very small value, $\eta/s = 1/64\pi$. The upper panel shows the pure energy deposition scenario (PED); the lower panel shows the propagation of a highly energetic jet (JET) depositing energy and momentum in x-direction. We show the energy density and velocity profile. The results are a snapshot of the evolution at $t = 2.5$ fm/c. In addition we show the analytical solution for the ideal Mach cone in the very weak perturbation case with the emission angle $\alpha = 54.72°$.



In all scenarios the development of a Mach Cone is found. In addition, a dependence of the Mach angle on the energy deposition is observed.

Mach Cones: Transition from Ideal to Viscous

For the JET scenario and $dE/dx = 10$ GeV/fm we show the transition from ideal to viscous Mach Cones by adjusting the viscosity to $\eta/s = 1/64\pi$, $1/8\pi$ and $1/\pi$ (from left to the right).



For larger viscosities we found a smearing out of the profile (middle) and vanishing Mach Cone signal (right).

Conclusion

We investigated for the first time, within a microscopic transport model, relativistic shocks in form of Mach Cones in the nearly perfect fluid limit using different source terms. We found a dependence of the Mach Cone angle on the energy deposition of the source. In addition, we also found viscous solutions of Mach Cones by adjusting the shear viscosity over entropy density ratio η/s. We observed a smearing out of the profile when η/s is large.

Whereas the demonstrated pure energy deposition scenario (PED) provides a double peak when the energy deposition is strong enough, the scenario, where also momentum deposition exists, simulated by a jet (JET), never leads to a double peak structure due to the strong diffusion wake and head shock. We conclude that the double peak structure is not the appropriate observable for the signal of a Mach Cone in heavy ion collisions.

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