Flow-Driven Conical Correlations in Heavy-Ion Collisions

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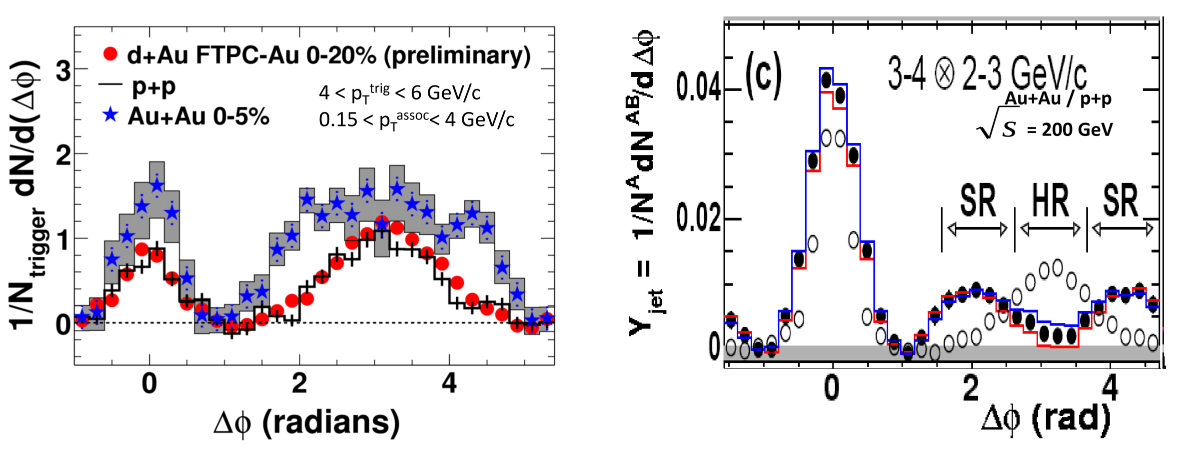
Motivation

RHIC data have shown that a hot and dense medium is created in heavy-ion collisions which is most likely the Quark-Gluon Plasma (QGP). It was found to behave like an almost perfect fluid and to be opaque to jets. This raises the possibility of probing the medium's properties by studying the energy deposited by the jet in the medium.

The experimental two-particle correlations (see Fig. 1) exhibit a double-peak structure at angles opposite to the trigger jet. It has been suggested that this structure is due to Mach cones [2].



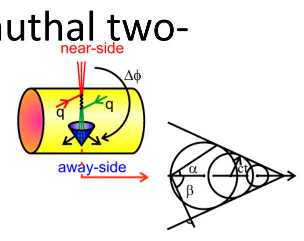


Fig. 1: Background-subtracted, p_T-weighted azimuthal two-particle correlations for p+p, d+Au and Au+Au collisions [1].

Idea

Mach cones lead to an excess of low-p_T hadrons being emitted at an angle of ϕ_M, given by Mach's law, $\cos\phi_M = c_s/v_{\rm jet}$. Measuring ϕ_M and $v_{\rm jet}$ would allow to extract c_s, the speed of sound of the medium and thus the QGP Equation of State (EoS).

Experimental Results

Experimental results (see Fig. 2) show that the away-side structure is relatively insensitive to p_T^{assoc}, but sensitive to p_T^{trig}, an effect that could not be explained in the Mach cone picture.

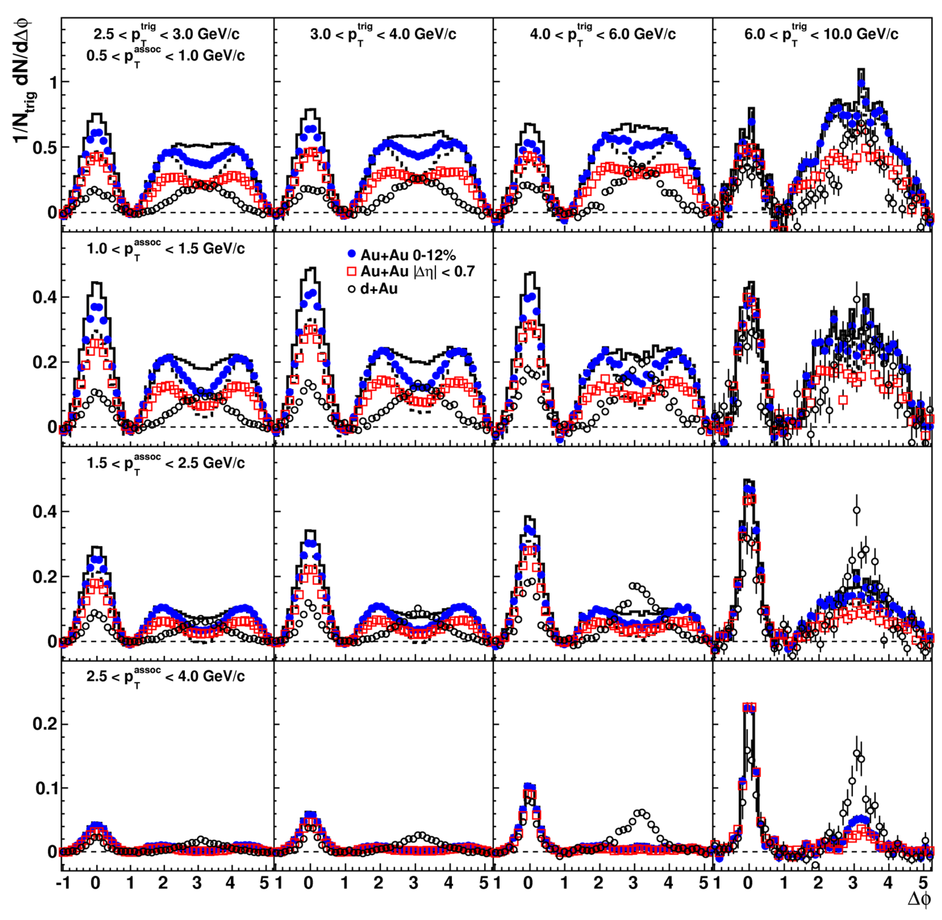


Fig. 2: Background-subtracted, p_T-weighted azimuthal two-particle correlations for Au+Au collisions as a function of p_T^{trig} and p_T^{assoc} [1].

Single jets

In a static medium, two factors impair the observation of conical correlations. The thermal smearing broadens the away-side peak for low p_T-particles and the momentum deposited by the jet leads to a diffusion wake (see Fig. 3) moving in the opposite trigger-jet direction which may overwhelm any signal from the Mach cone [3].

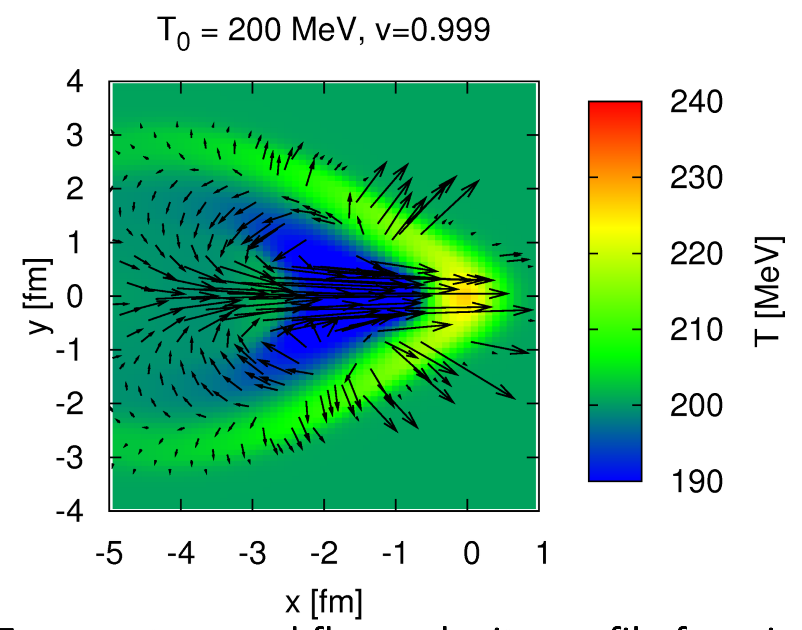


Fig. 3: Temperature and flow velocity profile for a jet depositing energy and momentum in a static medium [3].

Expanding Medium

In experiment, the trajectory of a jet is not known and one has to mimic the situation by taking into account many different jet trajectories.
We use (3+1)d ideal hydrodynamics to study the evolution of the jet according to $\partial_\mu T^{\mu\nu} = S^\nu$, close the system with an ideal gas EoS for gluons, and consider a transverse profile according to the Glauber model [4]. Assuming surface bias, we parameterize the different jet origins lying on a circle and convert the fluid into particles by applying an isochronous Cooper-Frye freeze-out prescription [4].

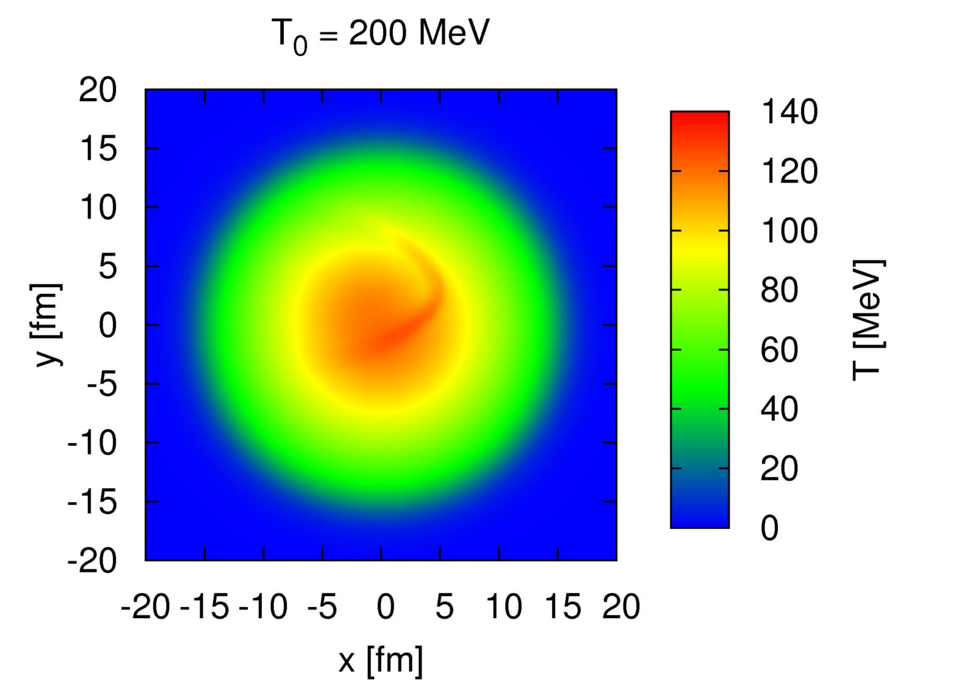


Fig. 4: Temperature profile of a non-central jet propagating through an expanding medium.

Fig. 4 shows that the wake created by a jet is deflected due to the interaction of the jet with the expanding background.
The averaging over those deflected wakes eventually leads to a double-peak structure on the away-side (see Fig. 5), where the dip is reduced for larger jet energies, corresponding to larger p_T^{trig} (cf. Fig.2).

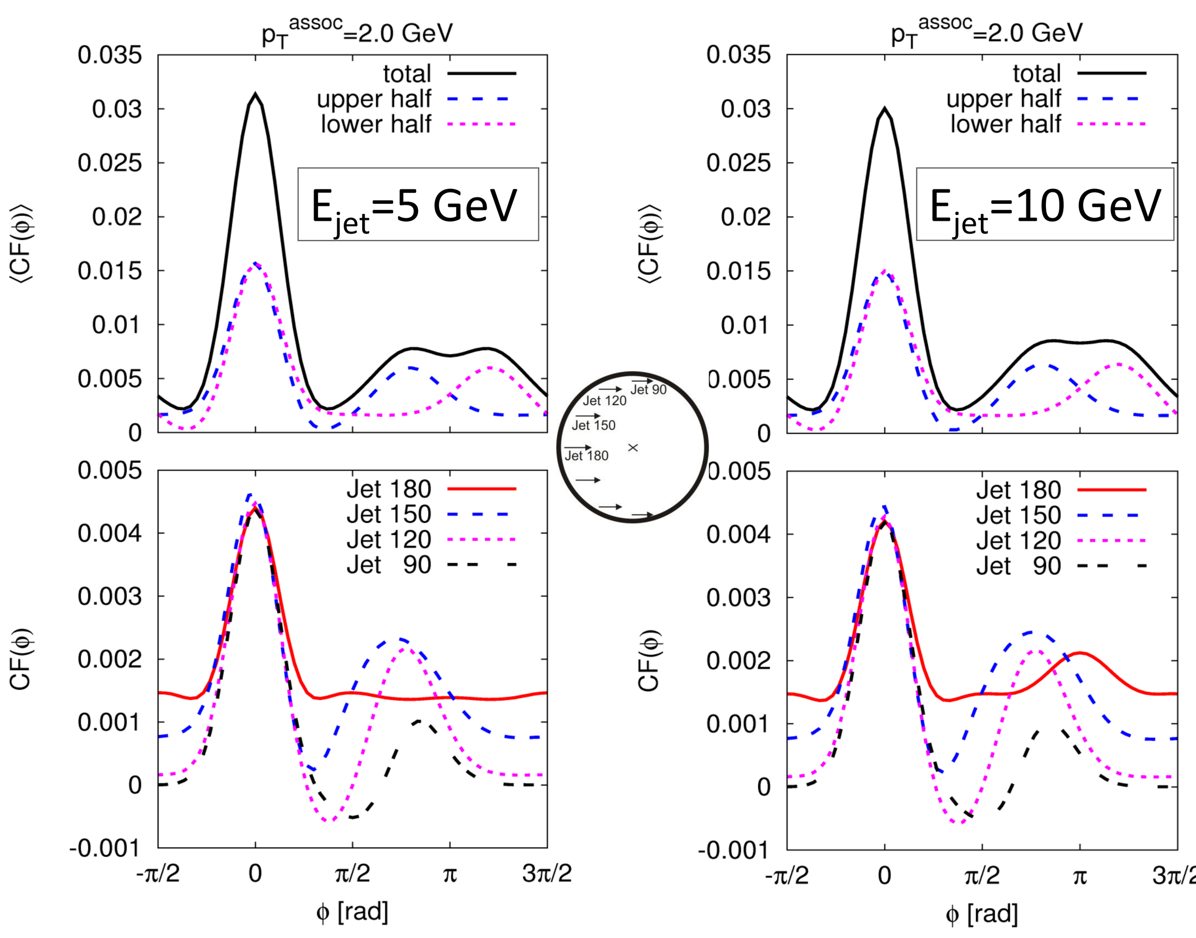


Fig. 5: Averaged (upper panel) and non-averaged (lower panel) two-particle correlation functions from different jet trajectories for a jet depositing an energy of 5 GeV (left) and 10 GeV (right) [4].

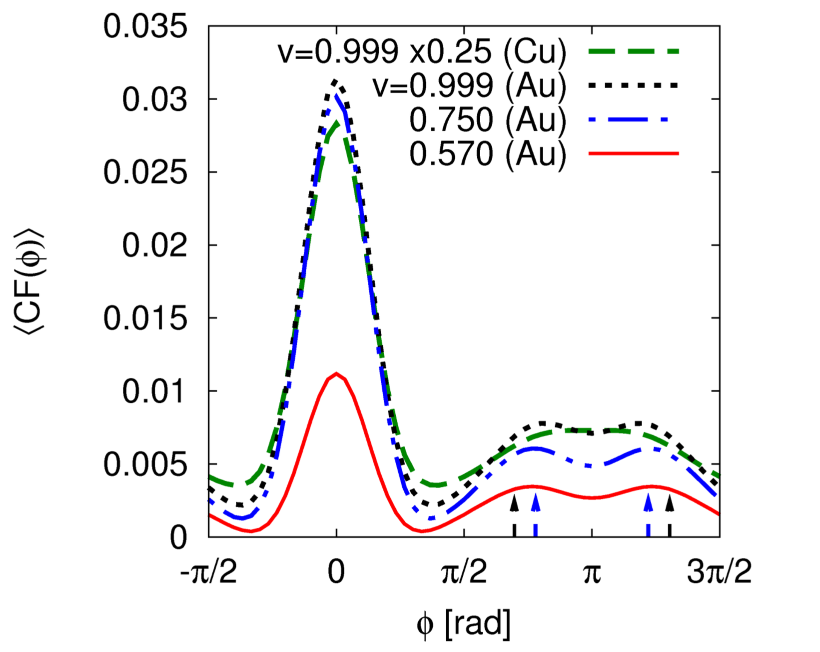


Fig. 6: Two-particle correlation functions for different jet velocities and system sizes [4].

Surprisingly enough, the same double-peak emission structures are found for different system sizes and jet velocities, even for subsonic jets where no Mach cone is created (see Fig. 6).

Fluctuating Initial Conditions

In Ref. [5], it was shown that the double-peak away-side structure can also be obtained by fluctuating initial conditions. We confirmed using a simple model that just one hot spot may result in a conical correlation. While both the hot spot event and the jet scenario show a double-peak structure for p_T^{trig} = 3.5 GeV, only the away-side structure of the jet scenario coalesces into one peak for a p_T^{trig} = 8.0 GeV as seen in experiment (see Fig. 7). One has to conclude that there is a superposition of jets and fluctuating initial conditions.

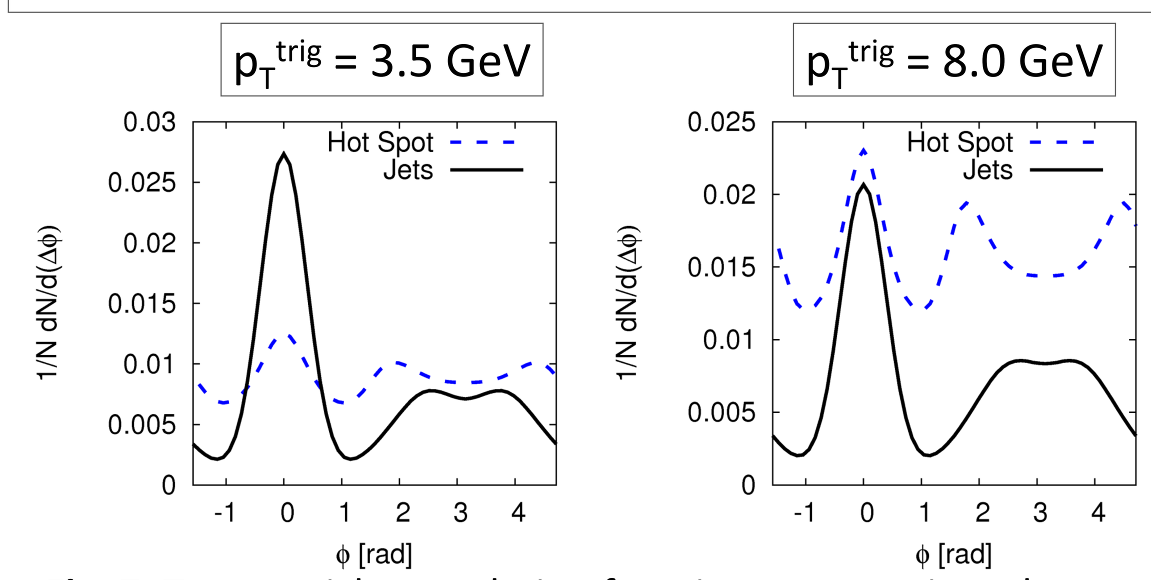


Fig. 7: Two-particle correlation functions, comparing a hot spot event and a jet scenario for a p_T^{assoc} = 2.0 GeV and two different p_T^{trig} [6].

Conclusions

The double-peak structure on the away side of soft-hard correlations could originate from the coupling of jet fragments to the background transverse collective flow. The apparent width of the away-side shoulder is "universal" in the sense that it is insensitive to the system size and similar for both supersonic and subsonic "jets", in contrast to the Mach cone scenario.

This prediction can be tested by comparing correlations induced by heavy-flavor tagged jets with those induced by light-flavor jets which will also clarify the impact of the initial state fluctuations.

References

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Unterstützt von / Supported by Alexander von Humboldt Stiftung / Foundation
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