Mach Cone induced by γ-triggered jet in heavy ion collisions

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1.Why?---Motivation!

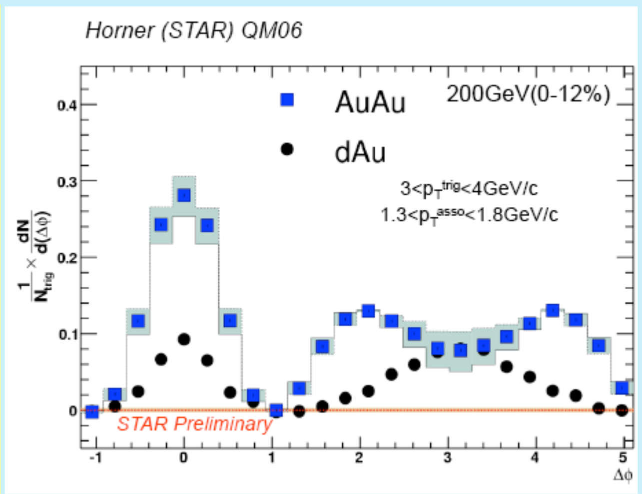
- Jet quenching, i.e., the suppression of high-PT hadrons' yield, the production of mono-jet, etc, has been observed in heavy ion collisions. This is one of the signals of production of QGP.

- In the meantime, lost energy and momentum of jet will be redistributed to medium by multiple scattering and eventually lead to collective medium excitations such as supersonic waves or Mach Cone.

✦Dihadron correlation in d-Au collisions shows a single-peak in the away side of the triggered high pT jet.

✦Dihadron correlation in central Au-Au collision shows a double-peak structure in the away side of the triggered high pT jet.

✦Double-peak structure in Au-Au collision also be observed in a multiple transport (AMPT) Monte Carlo



- Hydrodynamics with realistic energy-momentum deposition by jets and string calculations in the hydrodynamic regime failed to reproduce the conic structure in dihadron correlation.

2.How?---Parton Cascade Simulation!

- Starting with Boltzmann transport equation with elastic collision:

$$p_1 \cdot \partial f_1(p_1) = -\int dp_2 dp_3 dp_4 (f_1 f_2 - f_3 f_4)|M_{12\to 34}|^2 \times (2\pi)^4 \delta^4(P_1 + P_2 - P_3 - P_4)$$

$$dp_i \equiv \frac{d^3 p_i}{2E_i (2\pi)^3},\ |M_{12\to 34}|^2 = Cg^2(s^2+u^2)/(t+\mu^2)^2$$

$$f_i = 1/(e_i^p.u/T \pm 1)(i=2,4),\ f_i = (2\pi)^3 \delta^3(\vec{p}-\vec{p}_i)\delta^3(\vec{x}-\vec{x}_i)(i=1,3)$$

i=1,3: jet shower parton before and after scattering.
i=2,4: thermal parton before and after scattering.
u: flow velocity of medium.
C=1(9/4) for qg(gg) interaction.

- Time step Δt_i between scatterings is determined by

$P_i = 1 - exp[-\sum_j \Delta x_j \cdot u\ \sigma_i \rho(\vec{x}_j, t_j)]$ ρ: local energy density of medium

✦We call it linearized Boltzmann jet transport since we neglect scatterings between recoiled medium partons.

✦It's a good approximation when the medium excitation of propagating jet δf<<f.

3.What do we get?---Results!

• Uniform Medium:

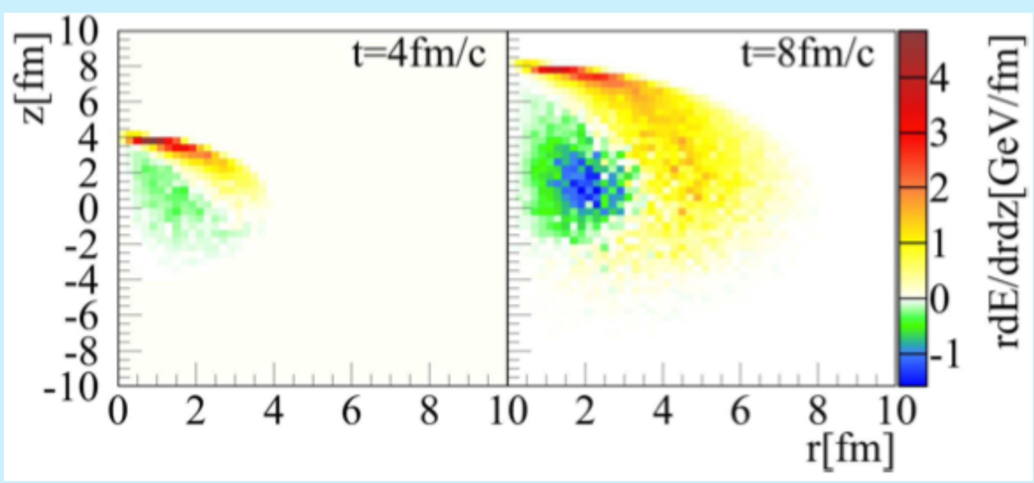
✦Initial conditions: $E_{jet} = 20\ \mathrm{GeV},\ T = 300\ \mathrm{MeV},\ \alpha_s = 0.5,\ \mu = 1.0\ \mathrm{GeV}$

✦Mach-cone-like medium excitation forms at later times.

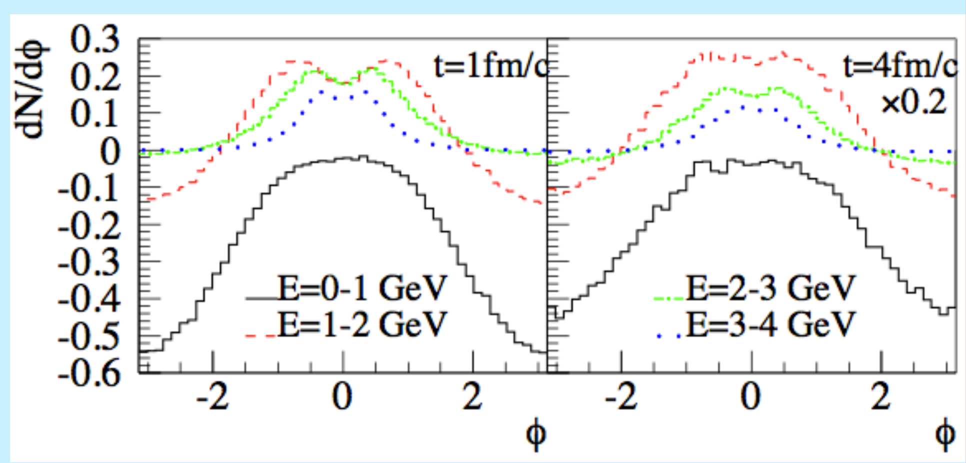
✦At early times, a double-peak structure is created by recoil thermal partons from the primary jet-medium scattering, which is given by the collision kernel in the Boltzmann equation.

✦At later times, the recoiled medium partons from the primary jet-medium interaction will scatter with other thermal partons, causing diffusion of the wake front. The final azimuthal distribution has only a broad single peak along the direction of the propagating jet.

Contour plot of energy density rdE/drdz of medium excitation induced by a quark which propagates in the z direction in a uniform gluonic medium.



The corresponding azimuthal parton distributions.



• Hydrodynamic Medium:

- 3+1D ideal hydrodynamics

T. Hirano, *et al.*, Phys. Lett. B **636**, 299 (2006).

$$(\tau, x, y, \eta)$$

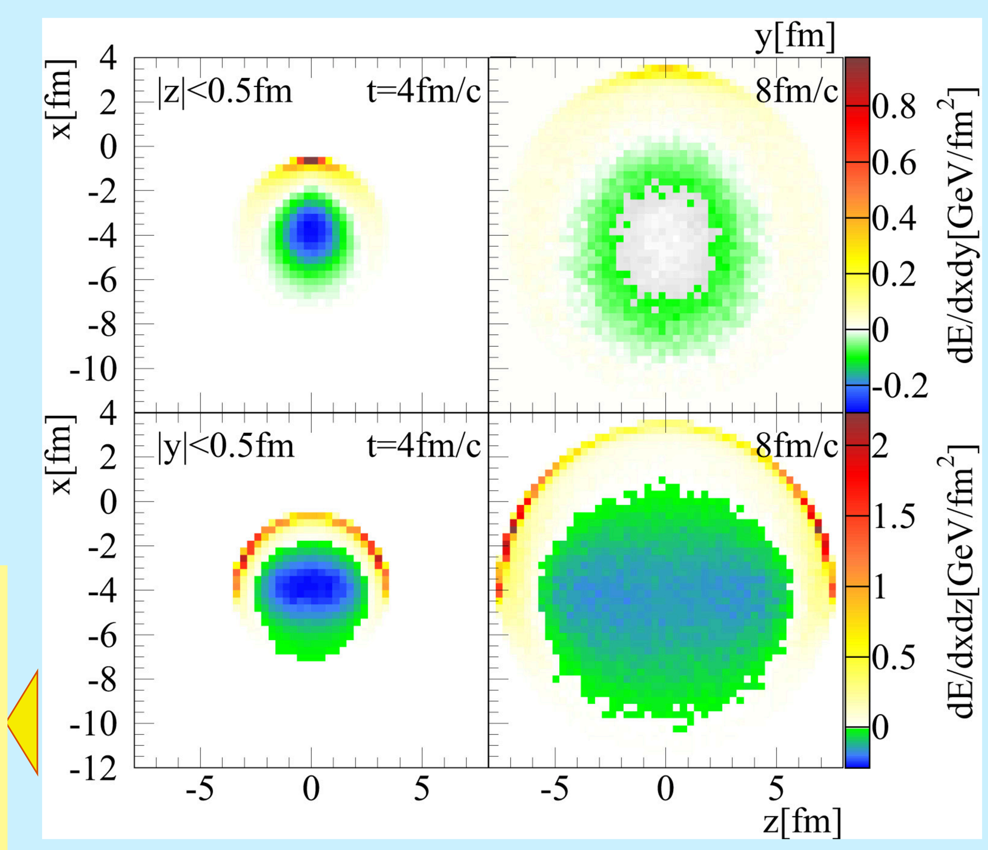
$$\varepsilon, T, f_{\mathrm{QGP}}, u$$

- Jet from HIJING by triggering a photon with energy $E_T^\gamma = 20\ \mathrm{GeV}$.

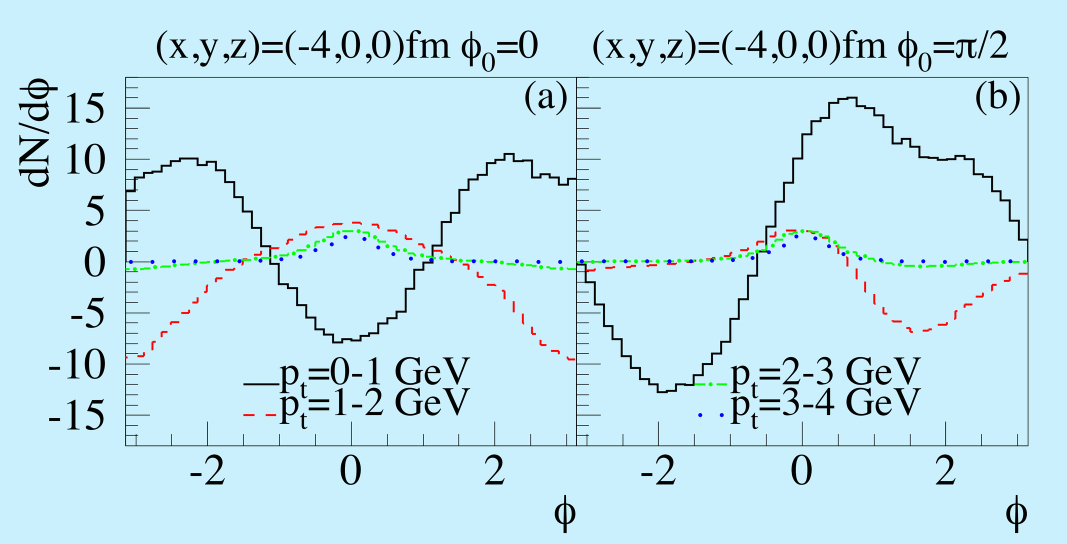
✦Compared to the case of a uniform medium, the shape of the medium excitation is distorted considerably by the transverse and longitudinal flow of the expanding medium.

✦The distortion depends on the direction of the jet propagation relative to the flow.

Contour plot in the transverse (x-y) and beam (x-z) plane of energy density excited by a quark jet shower with E = 20 GeV and initial position at (x,y,z) = (−4,0,0) fm that travels towards the center of the expanding medium.



The azimuthal distribution of medium and jet shower partons when the jet shower travels against (left) and perpendicular (right) to the transverse flow.

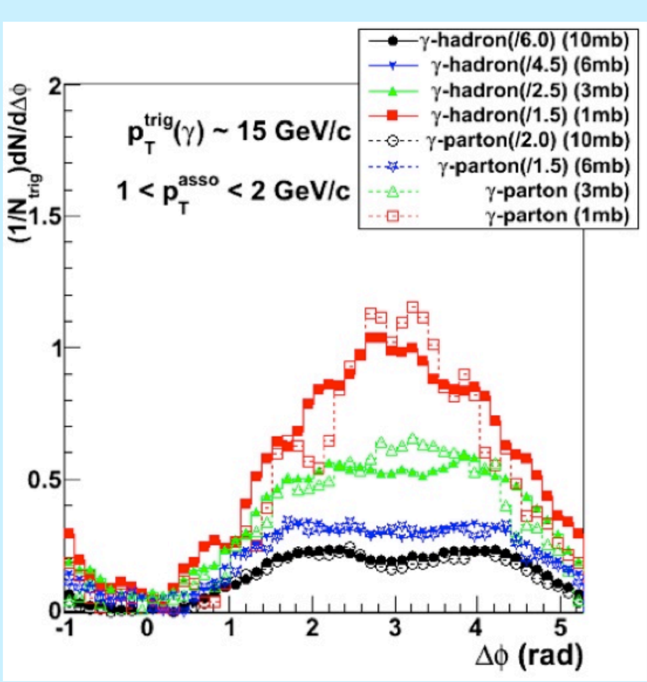


✦For a tangentially propagating jet shower (lower right), low pT partons from the jet shower and Mach-cone-like excitation are clearly deflected by both the density gradient and the radial flow, giving rise to the azimuthal distributions that peak at an angle away from the initial jet direction.

✦For jet showers that travel against the radial flow (lower left), the same deflection essentially splits the azimuthal distribution of low pT partons to become a double-peaked one.

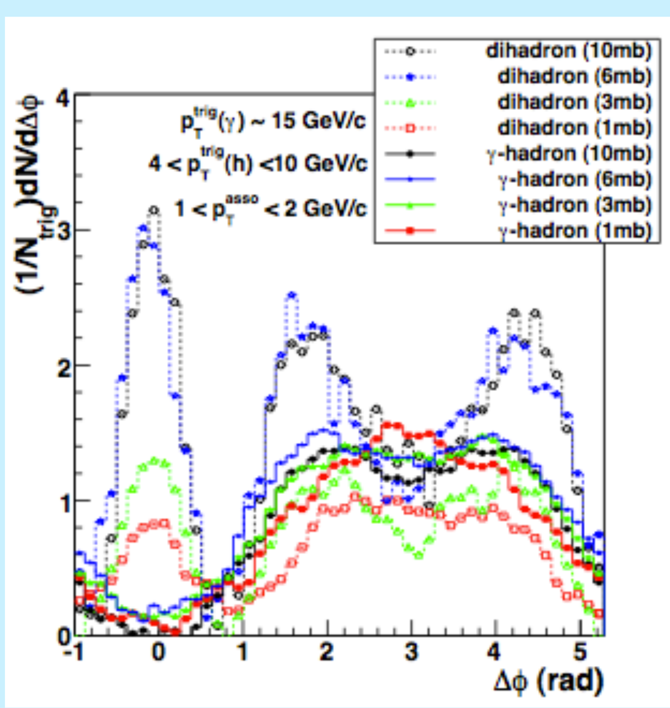
• Results from AMPT

γ-hadron and γ-parton azimuthal correlation from AMPT model calculation with different values of the parton cross section.



✦The differences between γ-hadron and γ-parton correlation before and after hadronization, are rather small in AMPT.

Dihadron and γ-hadron azimuthal correlation from AMPT model calculation with different values of the parton cross section.



✦The dihadron correlations develop a double-peak feature in the away side of the trigger as one increases the value of the parton cross section.

✦The amplitudes of double-peaks in dihadron correlations are much bigger than those of γ-hadron correlations for a given value of parton cross section.

4.What do we learn?---Conclusions!

✦Jet propagation in a uniform medium is found to form a Mach Cone like excitation at later times. However, it can not lead to a double-peak in azimuthal distribution.

✦Deflection of jet shower and Mach Cone in an expanding medium will lead to a double-peak azimuthal distribution.

✦Trigger bias between dihadron and γ-hadron correlation can lead to different expressions in the azimuthal distribution. As proved in ref. [4], harmonic flow and hot spots also have contributions to the double-peak structure in dihadron correlation.

✦Comparing dihadron and γ-hadron correlations will shed light on the dynamics of jet propagation and medium excitations, and the strength of the medium parton interaction.

5.Reference

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