Jet-induced medium excitation in γ-hadron correlation

Wei Chen

Collaborators:Shanshan Cao, Tan luo ,Longgang Pang , Xin-Nian Wang

Precision Spectroscopy of QGP Properties with Jets and Heavy Quarks

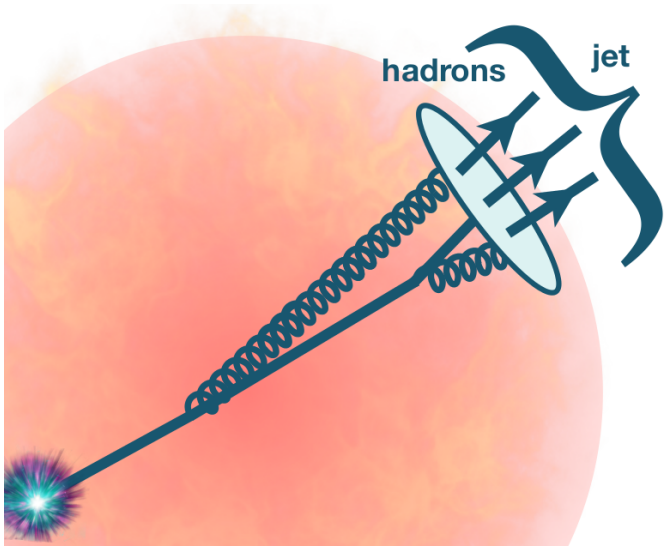
May 10, 2017

Outline

Introduction

jet tomography for the study of QGP

- suppression of leading hadrons
- dihadron and γ-hadron correlations
- jet specta modification
- dijet and γ-jet correlations
- jet profiles



from Yasuki Tachibana

How to determine the modification jet:

- energy loss of the leading shower partons
- the redistribution of the lost energy in the medium

we need a complete understanding of both **jet transport** and **jet-induced medium excitation**.

LBT model (Linear Boltzmann jet transport model)

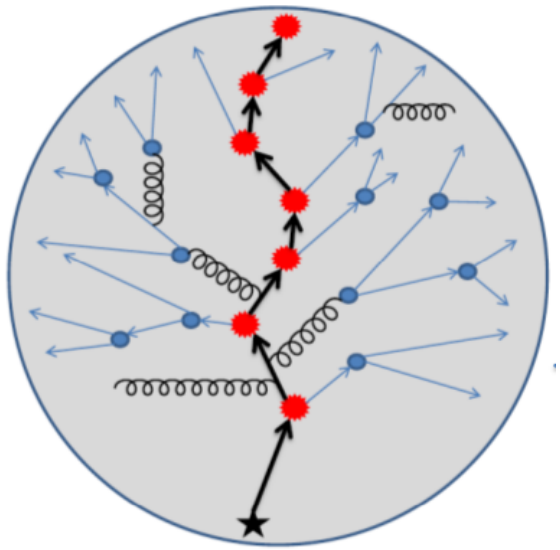
LBT model studys jet transport in QGP medium.

- jet transport is simulated according to a linear Boltzmann equation

$$p_1 \cdot \partial f_a(p_1) = -\int \frac{d^3p_2}{(2\pi)^3 2E_2} \int \frac{d^3p_3}{(2\pi)^3 2E_3} \int \frac{d^3p_4}{(2\pi)^3 2E_4} \sum_{b(c,d)} [f_a(p_1) f_b(p_2) - f_c(p_3) f_d(p_4)]$$

$$|M_{ab\to cd}| \times S_2(s,t,u)(2\pi)^4 \delta^4(p_1 + p_2 - p_3 - p_4) + radiation$$

- consider both elastic and inelastic processes
- keep track of jet shower parton and thermal recoiled parton
- take into account of back reaction and denote initial thermal partons in each scattering as "negative" partons
- assume propagation partons follow a classical trajectory
- linear approximation:neglect interaction between jet shower partons and recoiled partons



from Tan

Hanlin Li, etc Phys.Rev.Lett. 106, 012301

Xin-Nian Wang, Yan Zhu Phys.Rev.Lett. 111, 062301

Yayun He, Tan Luo, Xin-Nian Wang, Yan Zhu Phys.Rev. C91 (2015) 054908

CoLBT-Hydro model

Coupled Linear Boltzmann jet transport with 3+1D hydrodynamical model

CoLBT-Hydro model is used to simulate both the transport of jet shower partons and jet-induced medium excitation.

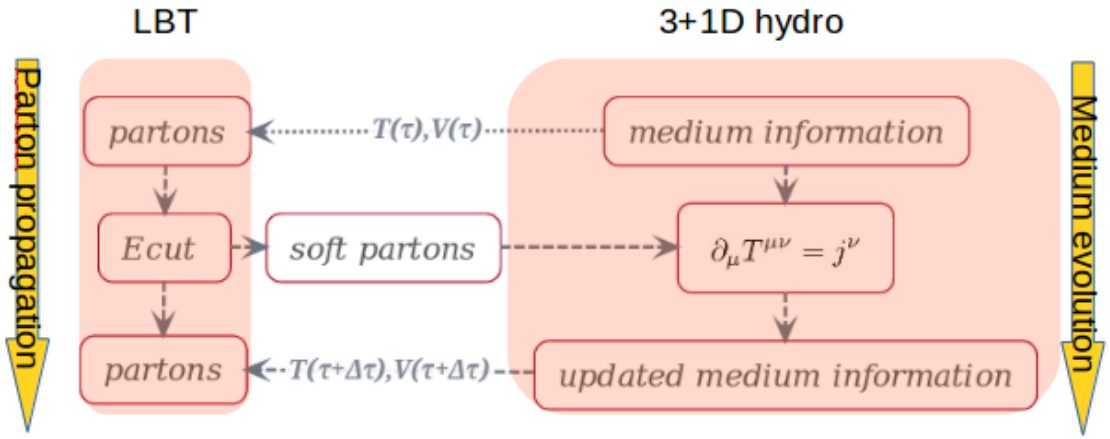


Figure : The structure of CoLBT-Hydro model

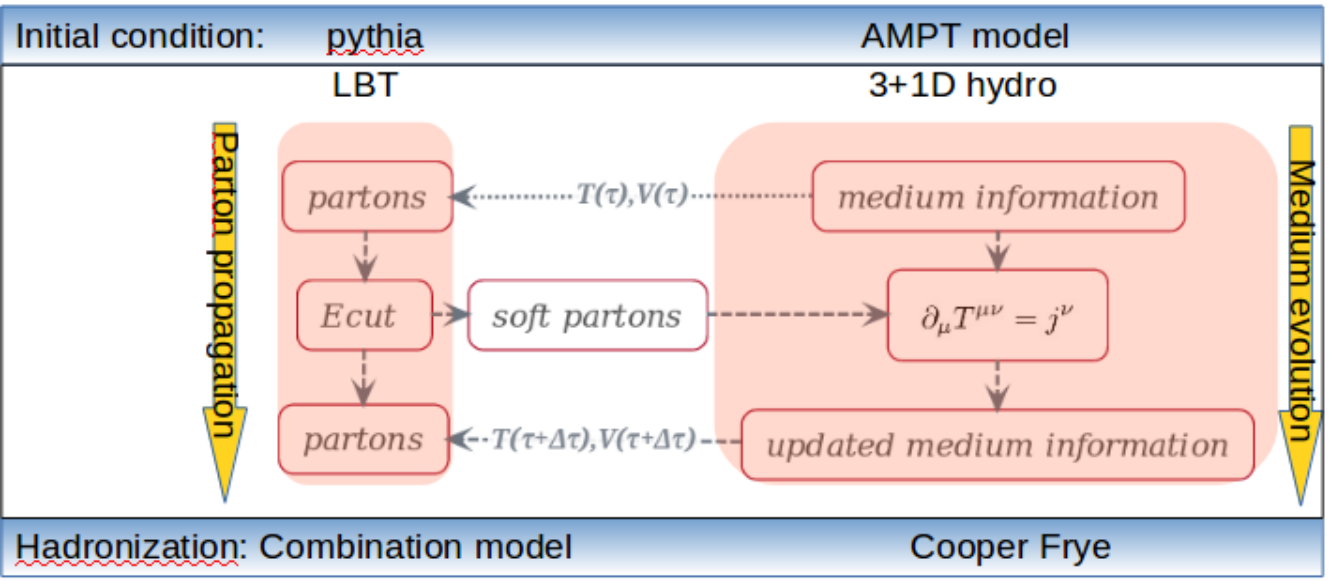
- The source term J^ν can be expressed by:

$$J^\nu = \sum_{i=1}^{n} \frac{P^\nu_{i(soft)}}{\Delta\tau} \delta^3(\vec{X} - \vec{X}_i) - \sum_{i=1}^{m} \frac{P^\nu_{i(neg)}}{\Delta\tau} \delta^3(\vec{X} - \vec{X}_i) \tag{1}$$

soft: partons with $p.u < Ecut$ neg: "negative" partons from back reaction

- **Assumption**:Instantaneous local thermalization of deposited energy and momentum

Initial condition and hadronization



Initial condition:

- hydro initial condition
- initial production positions o partons
- energy-momentum of jet par

different in each event

Figure : The structure of CoLBT-Hydro model

Hadronization:

- LBT part:
  1. Record all hard partons' information at $T < T_c$
  2. Put these information into recombination model from Texas A-M group
     Kyong Chol Han, Rainer J. Fries, Che Ming Ko J.Phys.Conf.Ser. 420 (2013) 012044
- Hydro part:Cooper-Frye formula

γ-hadron correlations with CoLBT-hydro

Modification of γ-hadron correlation: a good probe of parton energy loss in QGP medium.

- direct photons can be used to better measure the initial jet energy.

γ-hadron correlations in p+p collision:

- initial jet show partons for γ-jet events in p+p collision
- hadronization with recombination model.

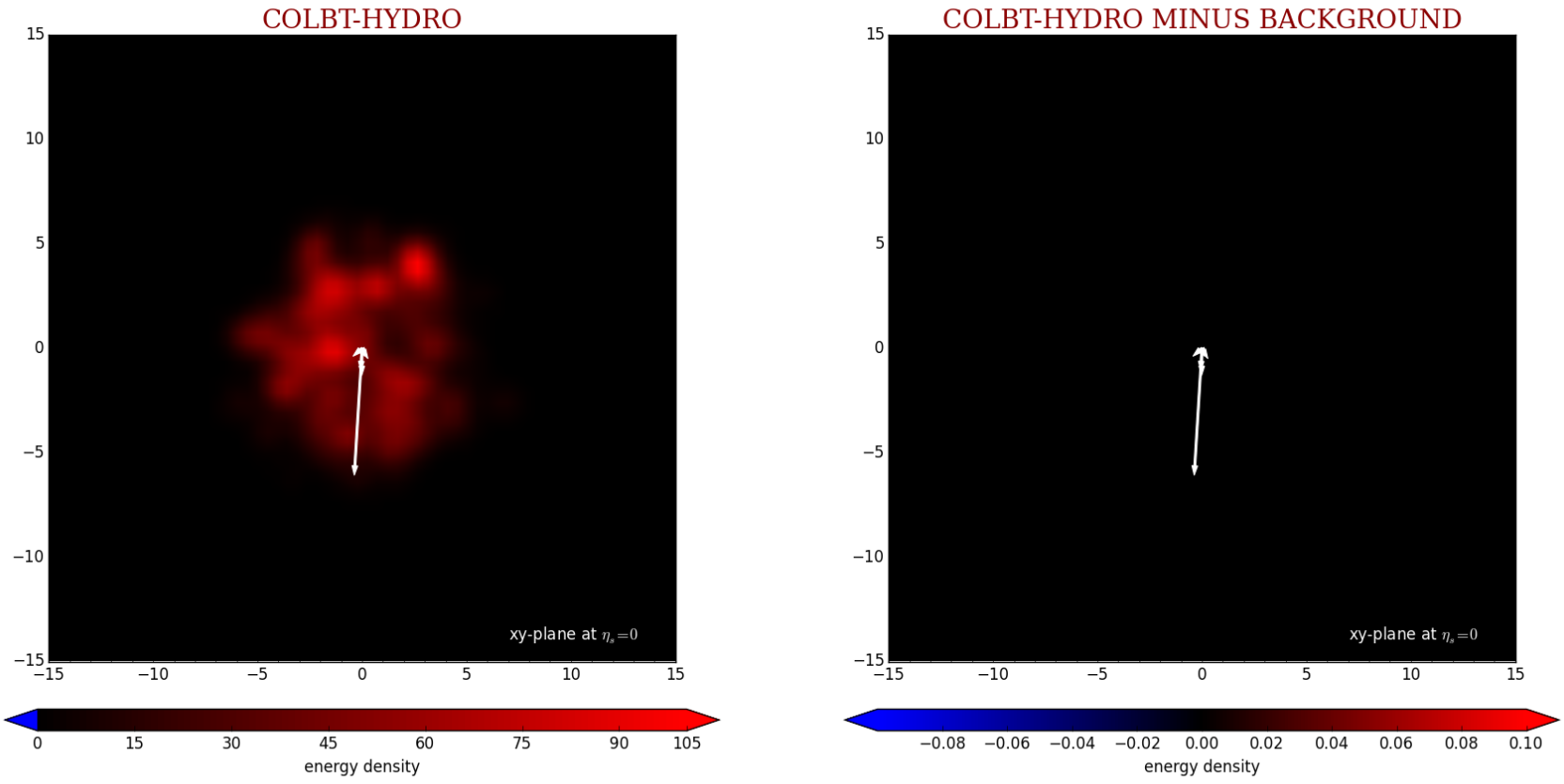
γ-hadron correlations in Au+Au collision:

- jet-medium interaction simulated in CoLBT-hydro
- background subtraction: hydro with γ-jet - hydro without γ-jet in the same initial condition.

We study in particular the evidence of jet-induced medium excitation in soft hadrons associated with the suppression of leading hadrons due to parton energy loss in γ-jet events of heavy-ion collisions.

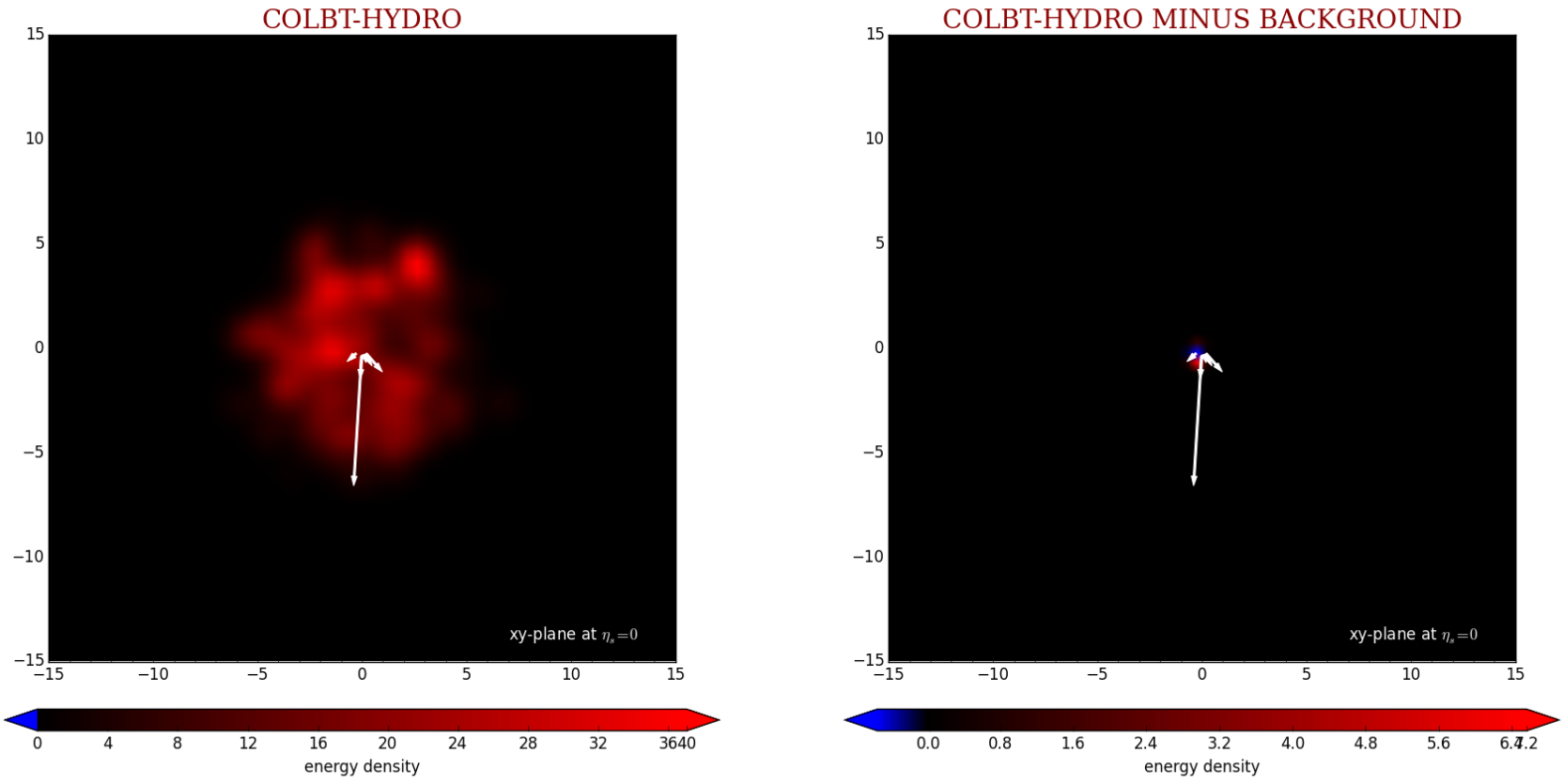
Jet propagation and jet-induced medium excitation

Jet propagation in hot medium at $\tau = 0.4 fm$



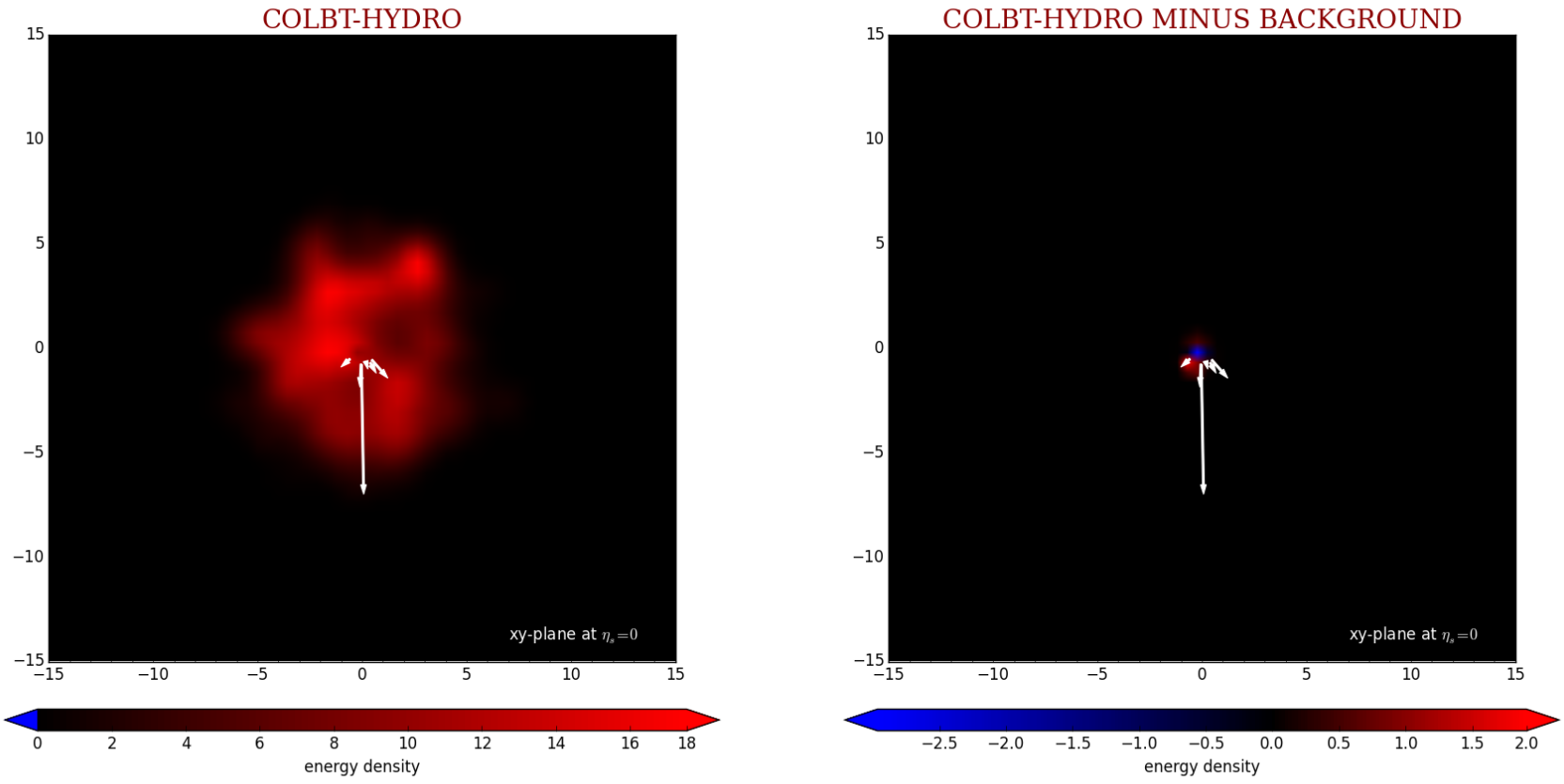
Jet propagation and jet-induced medium excitation

Jet propagation in hot medium at $\tau = 0.8 fm$



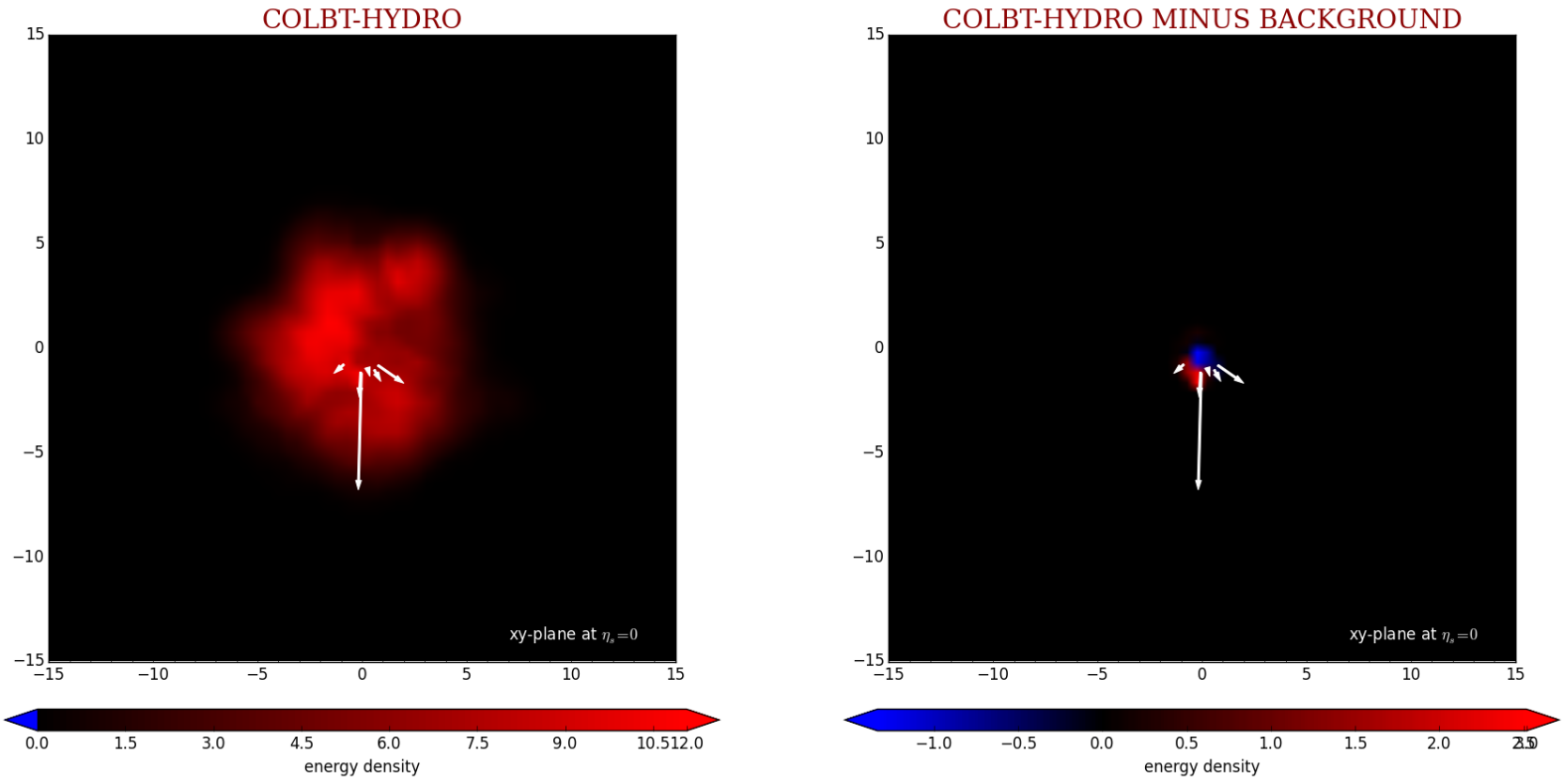
Jet propagation and jet-induced medium excitation

Jet propagation in hot medium at $\tau = 1.2 fm$



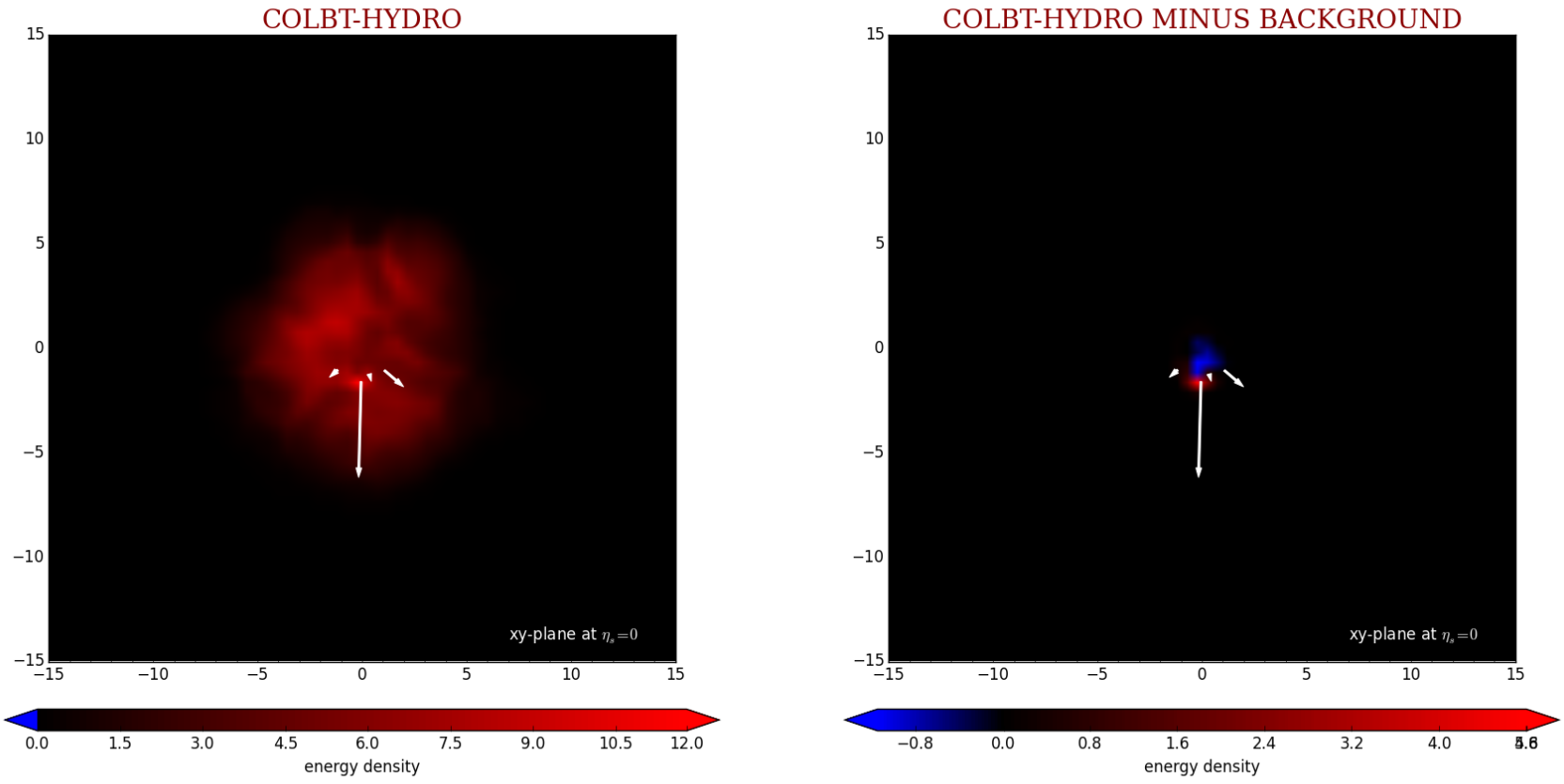
Jet propagation and jet-induced medium excitation

Jet propagation in hot medium at $\tau = 1.6 fm$



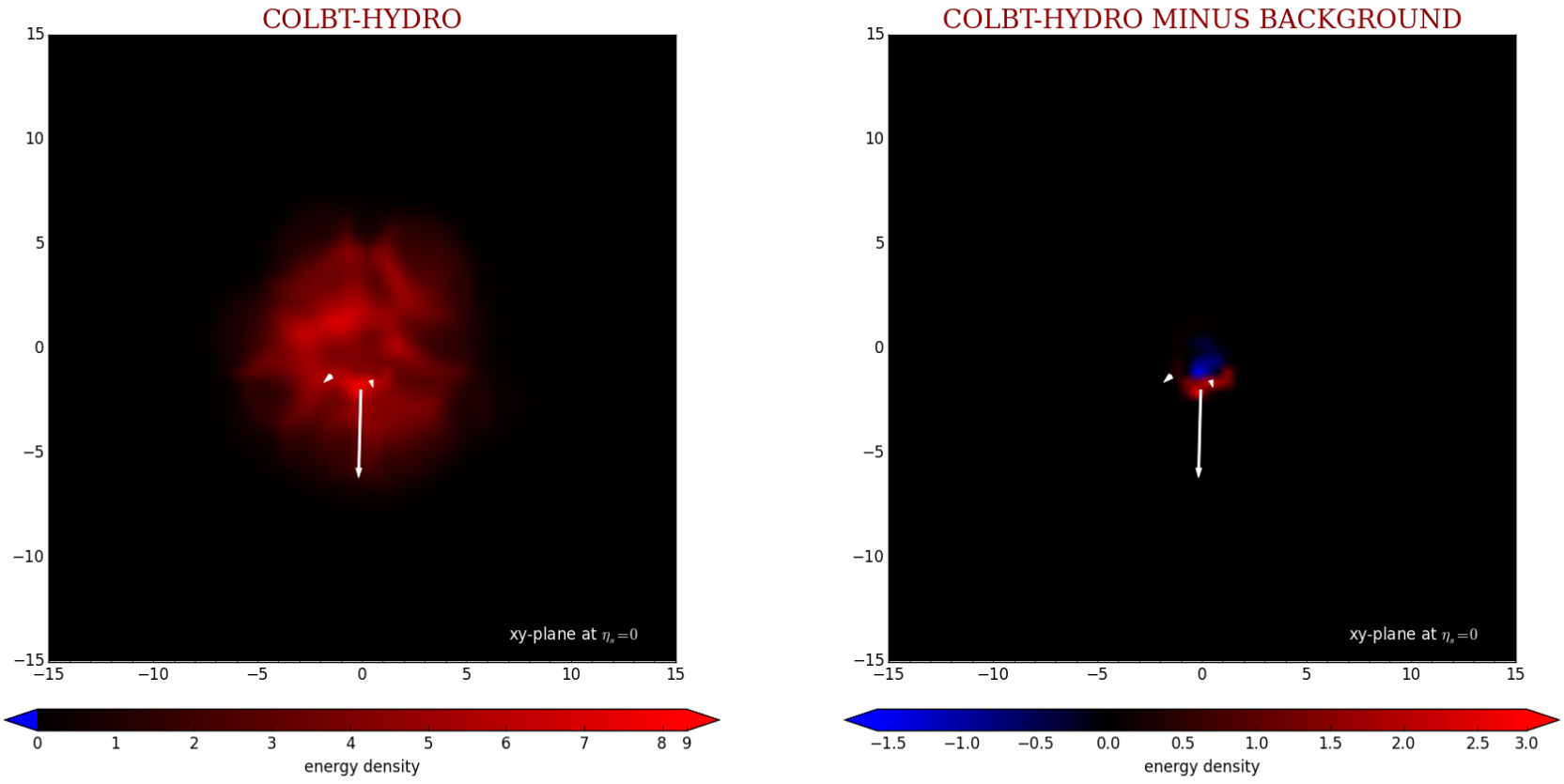
Jet propagation and jet-induced medium excitation

Jet propagation in hot medium at $\tau = 2.0 fm$



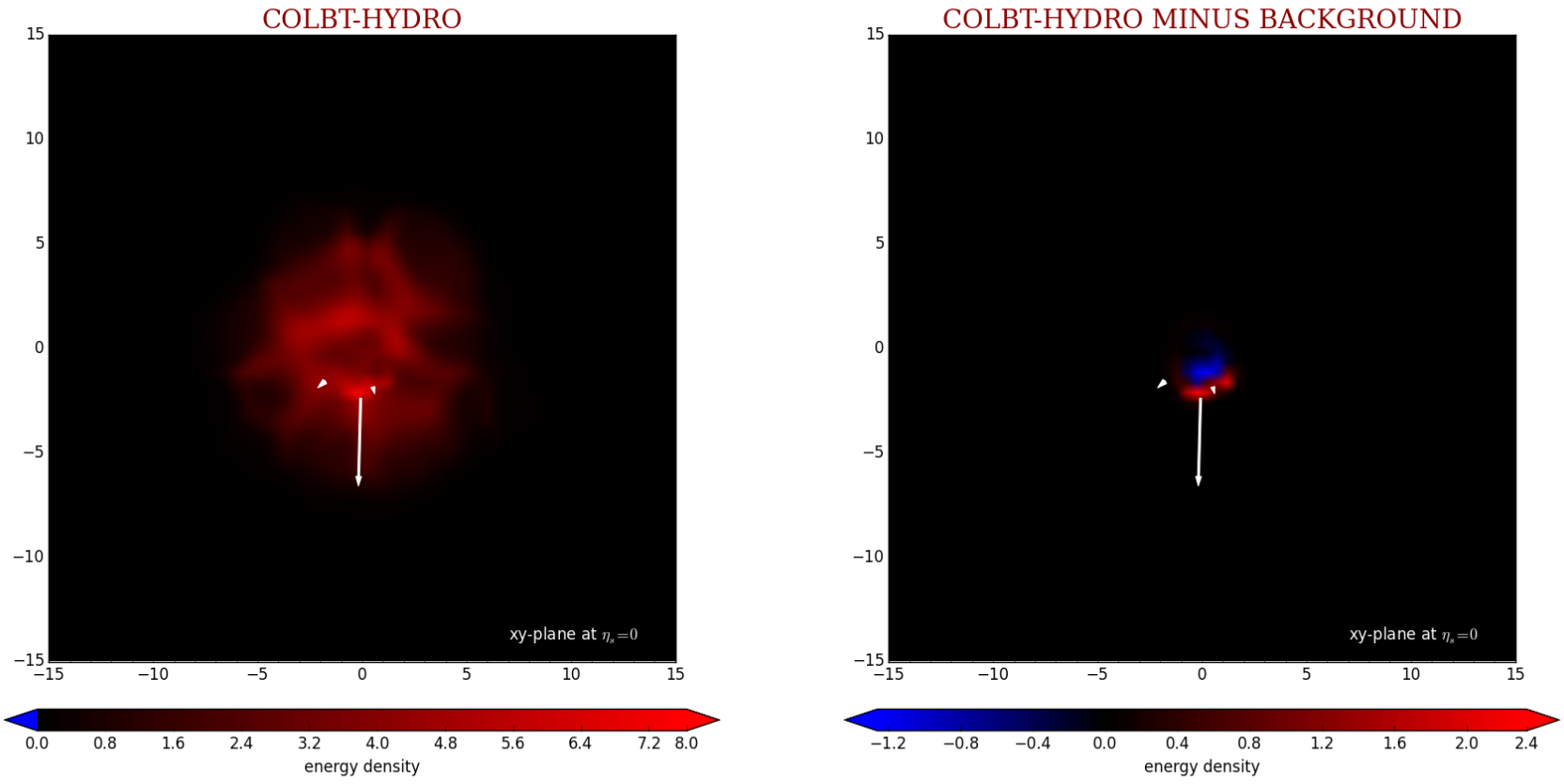
Jet propagation and jet-induced medium excitation

Jet propagation in hot medium at $\tau = 2.4 fm$



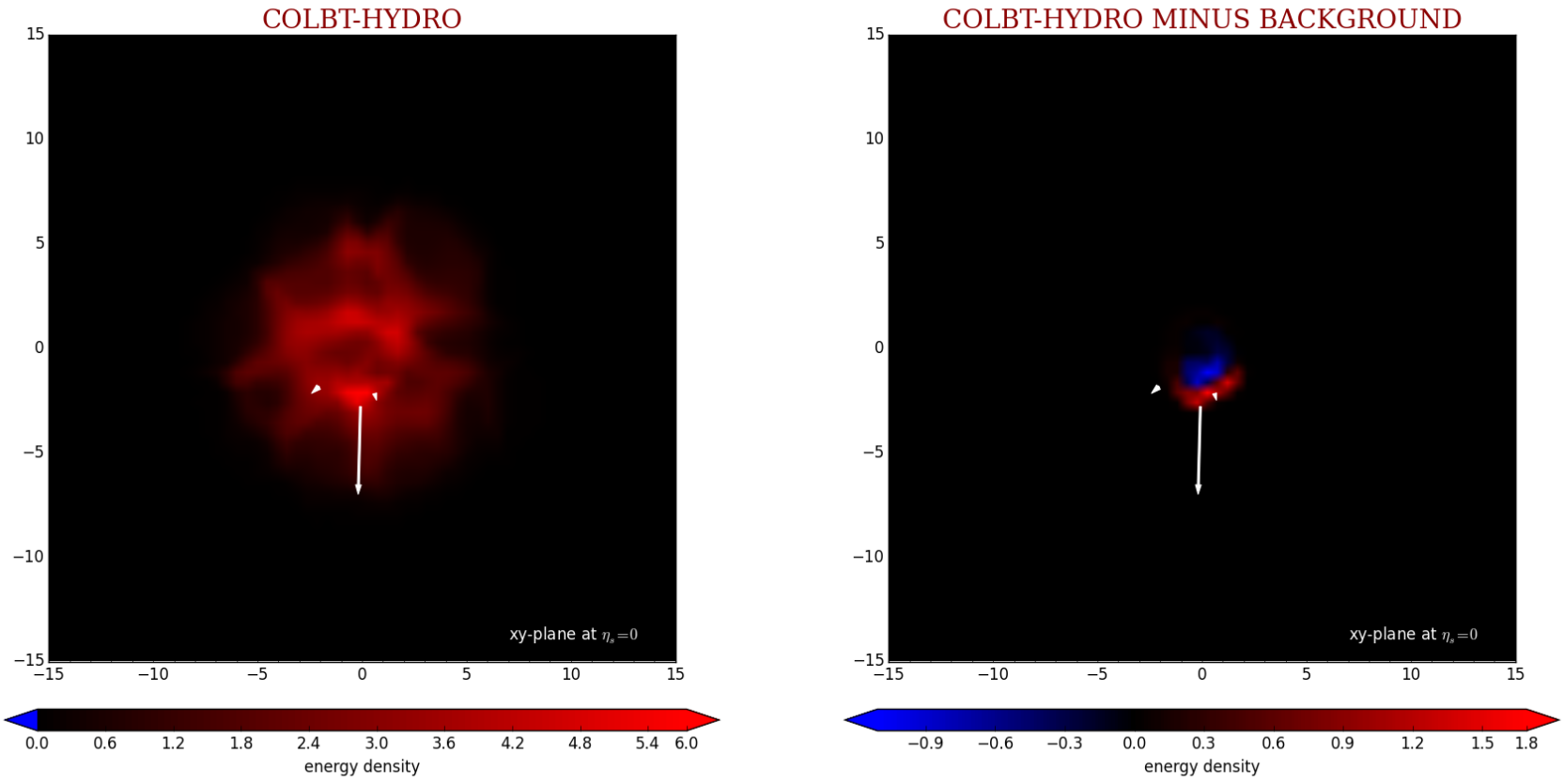
Jet propagation and jet-induced medium excitation

Jet propagation in hot medium at $\tau = 2.8 fm$



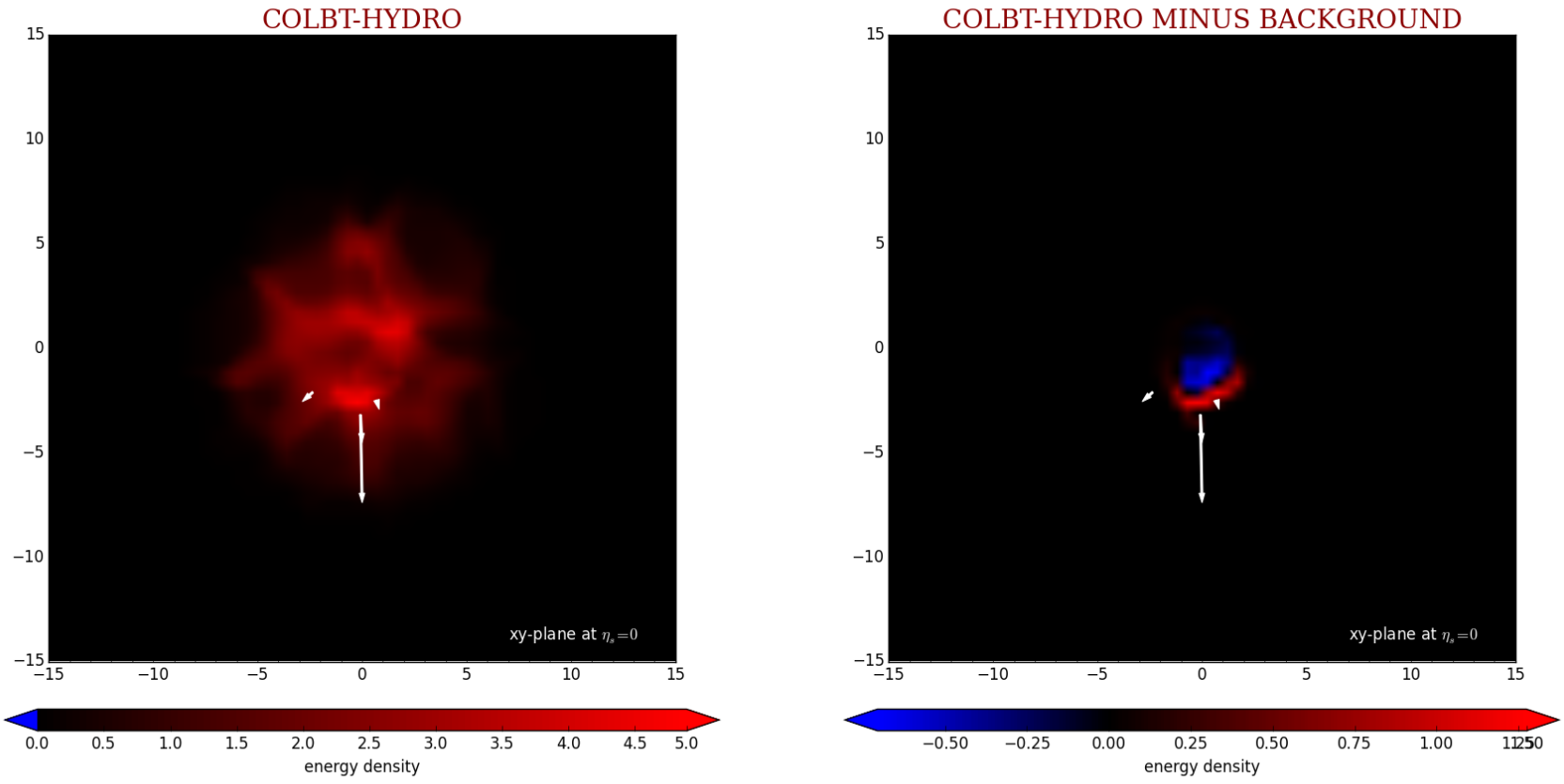
Jet propagation and jet-induced medium excitation

Jet propagation in hot medium at $\tau = 3.2 fm$



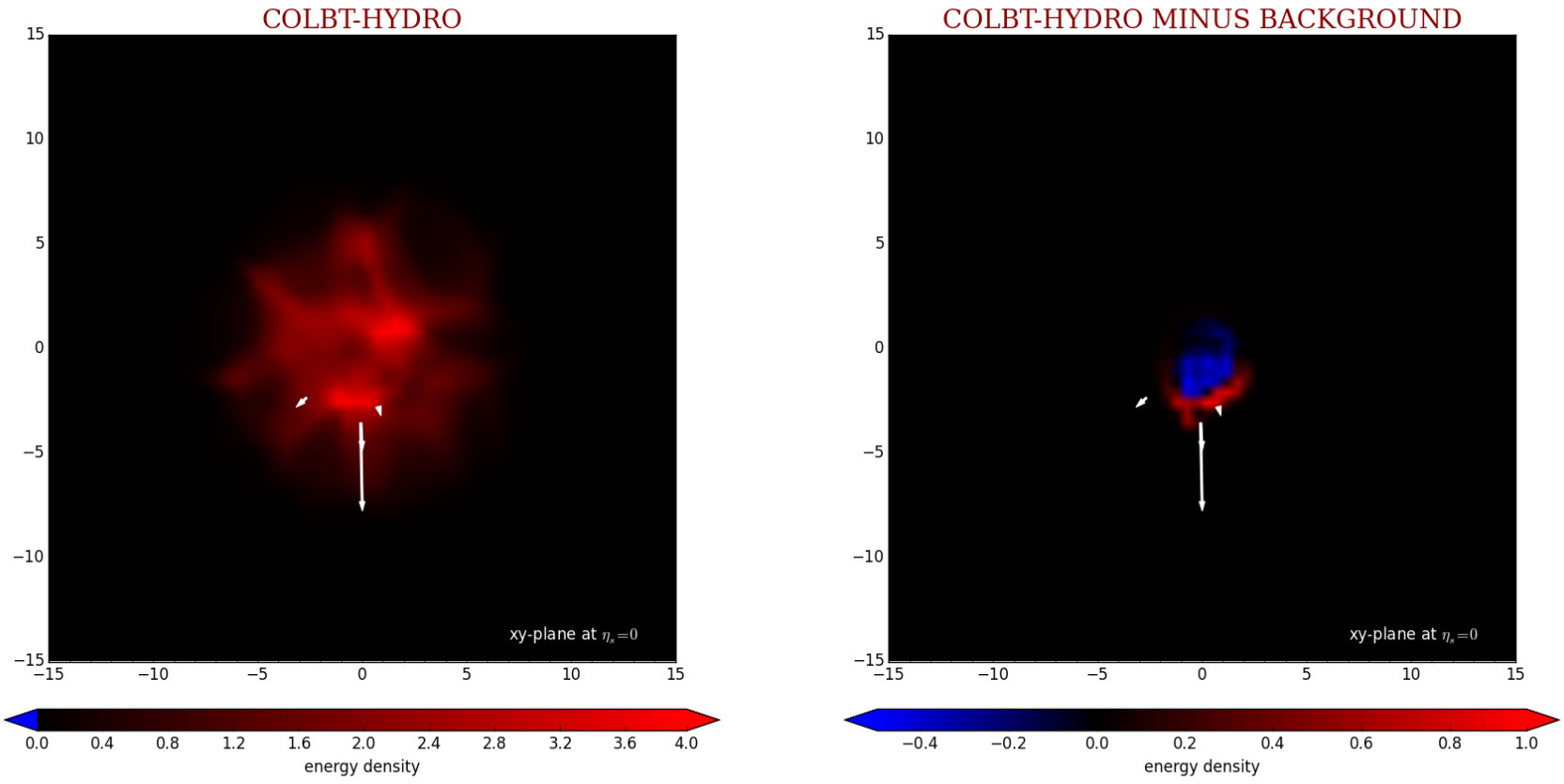
Jet propagation and jet-induced medium excitation

Jet propagation in hot medium at $\tau = 3.6 fm$



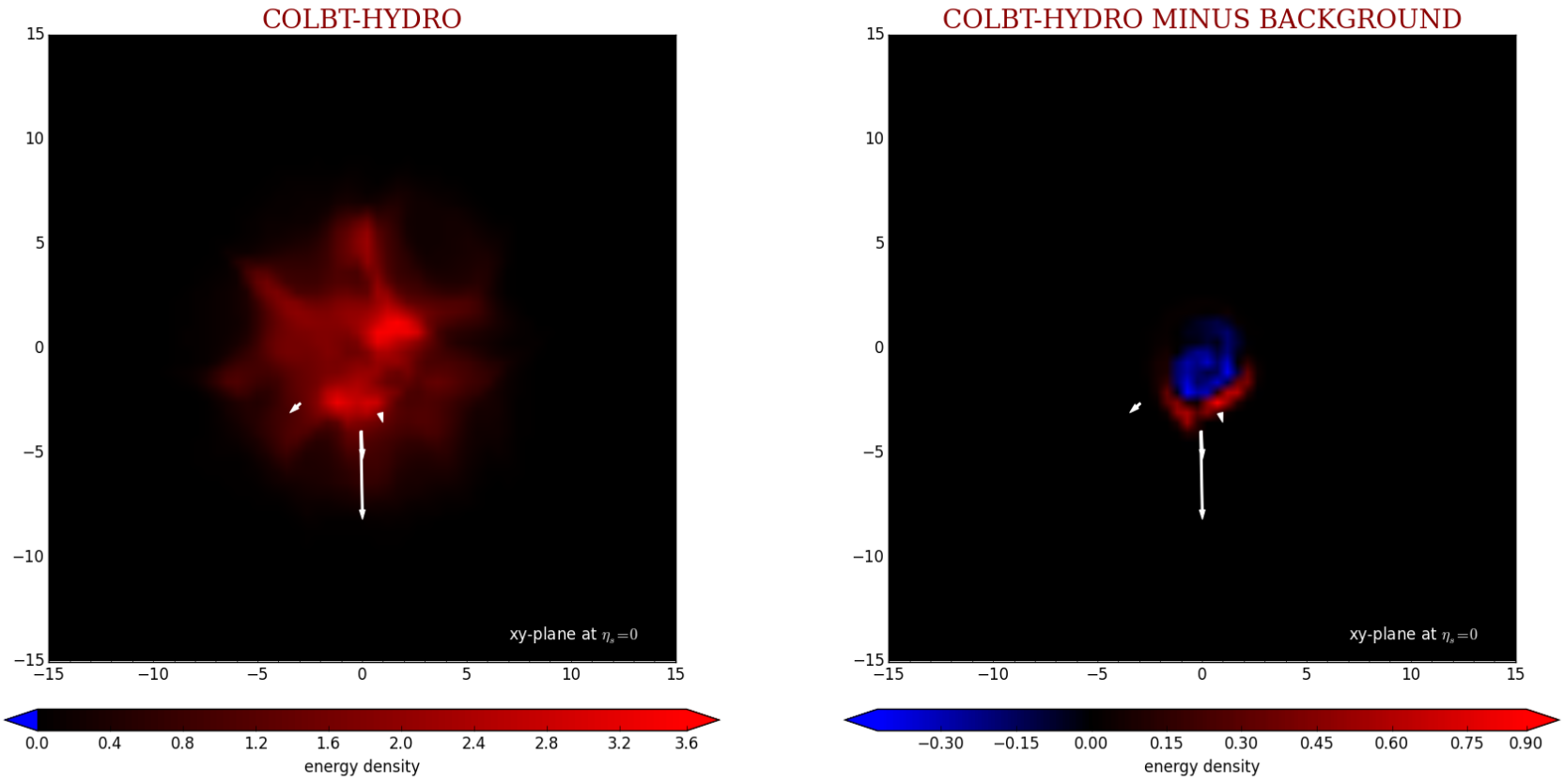
Jet propagation and jet-induced medium excitation

Jet propagation in hot medium at $\tau = 4.0 fm$



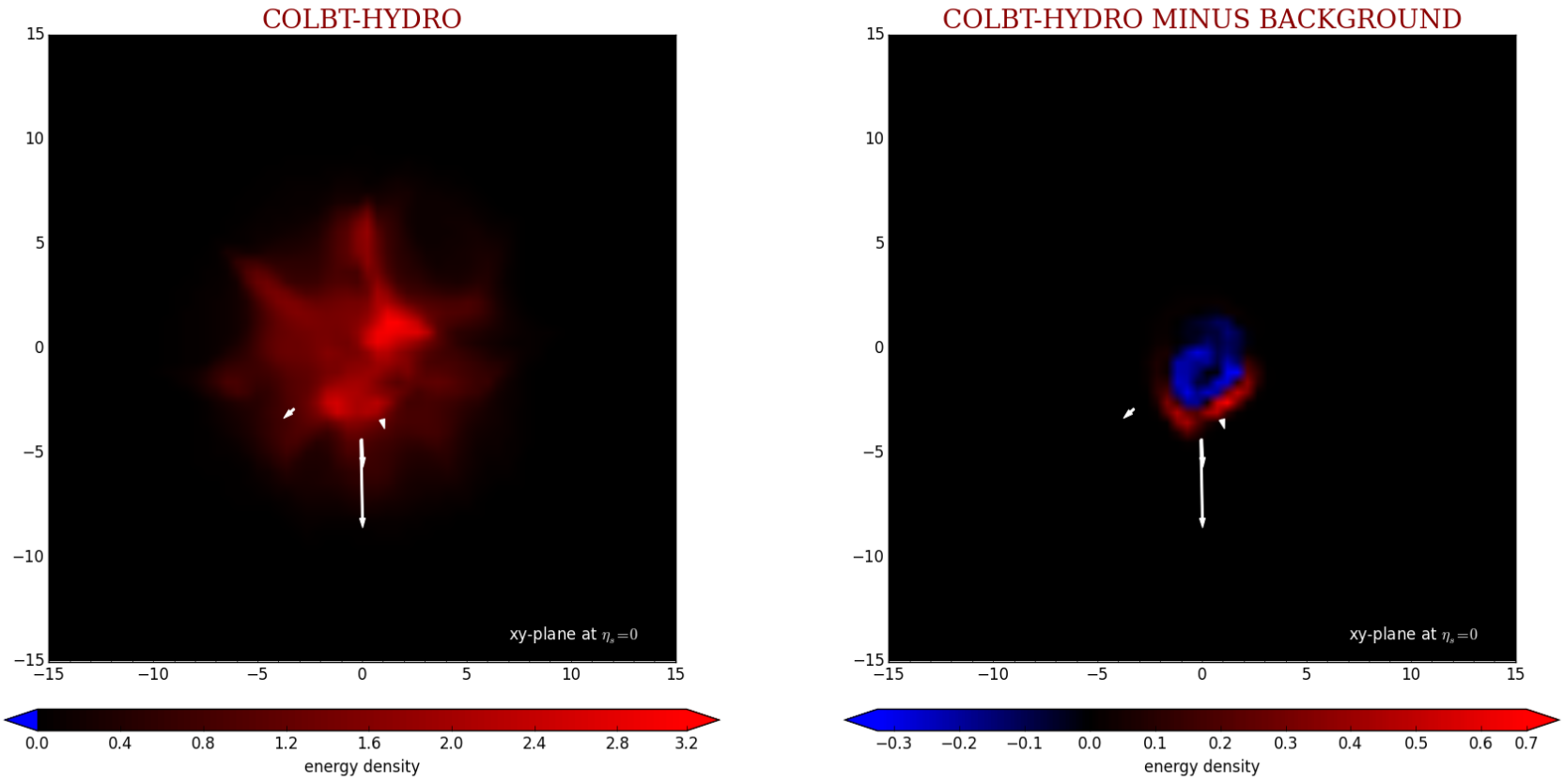
Jet propagation and jet-induced medium excitation

Jet propagation in hot medium at $\tau = 4.4 fm$



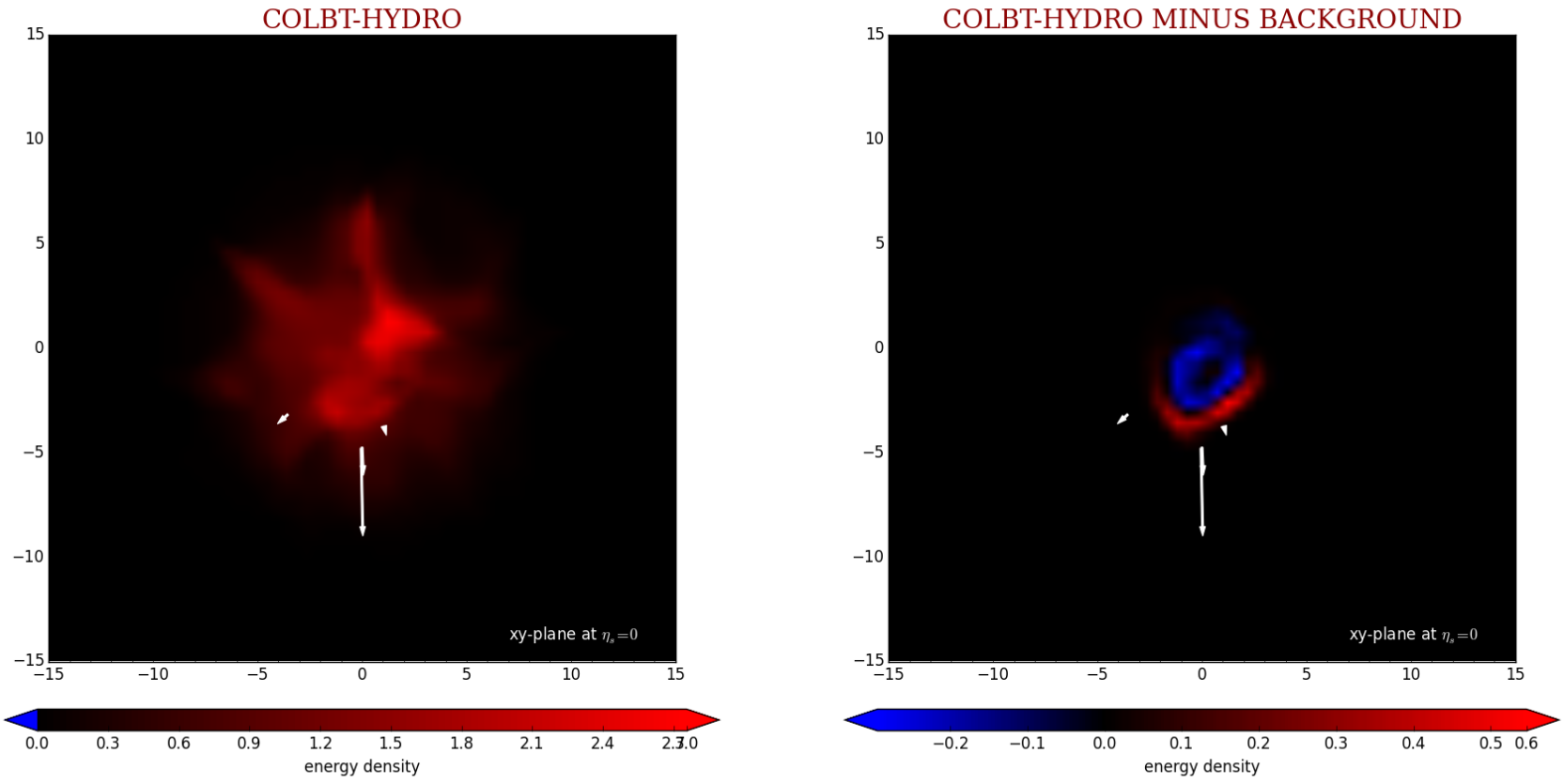
Jet propagation and jet-induced medium excitation

Jet propagation in hot medium at $\tau = 4.8 fm$



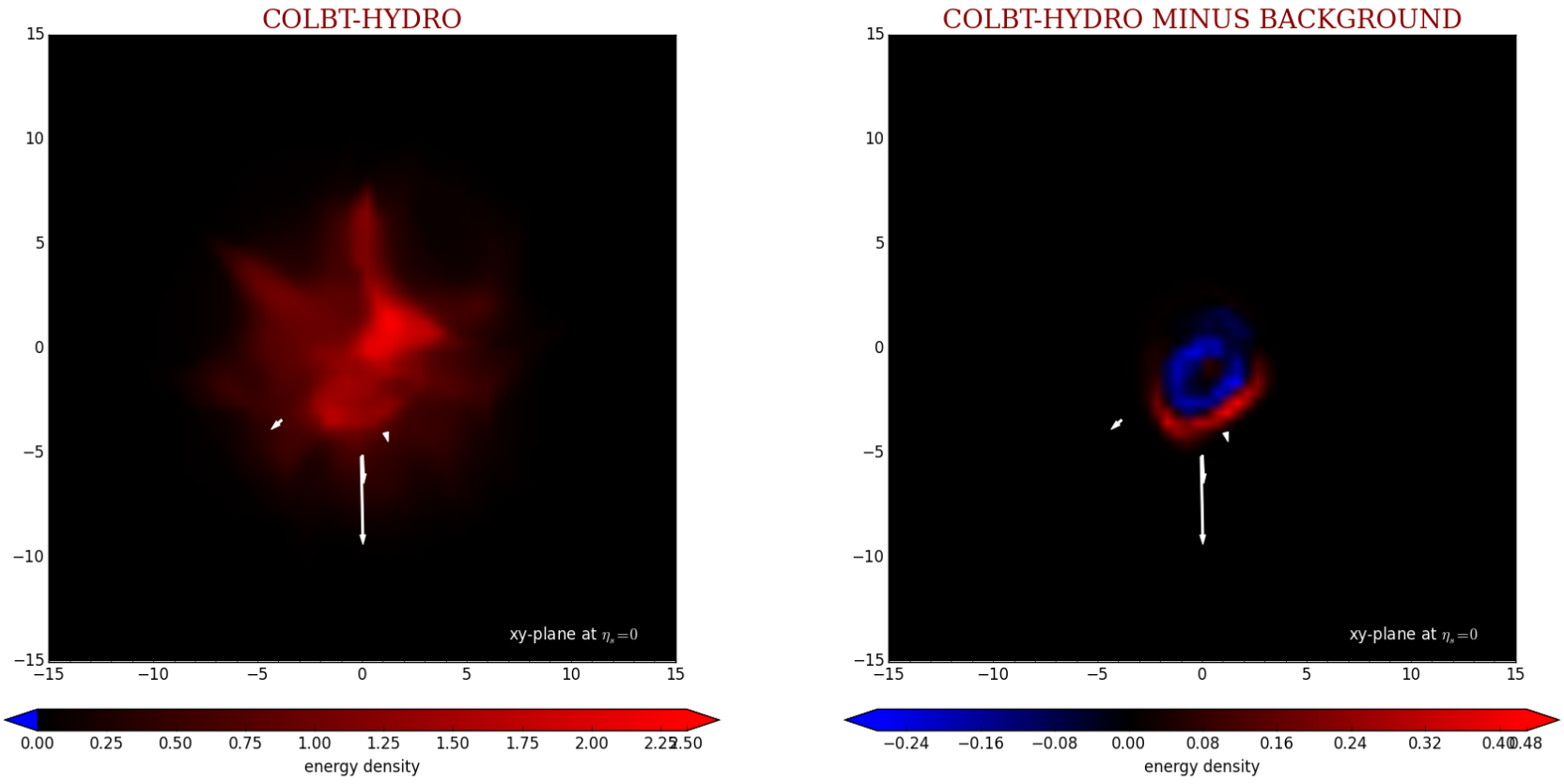
Jet propagation and jet-induced medium excitation

Jet propagation in hot medium at $\tau = 5.2 fm$



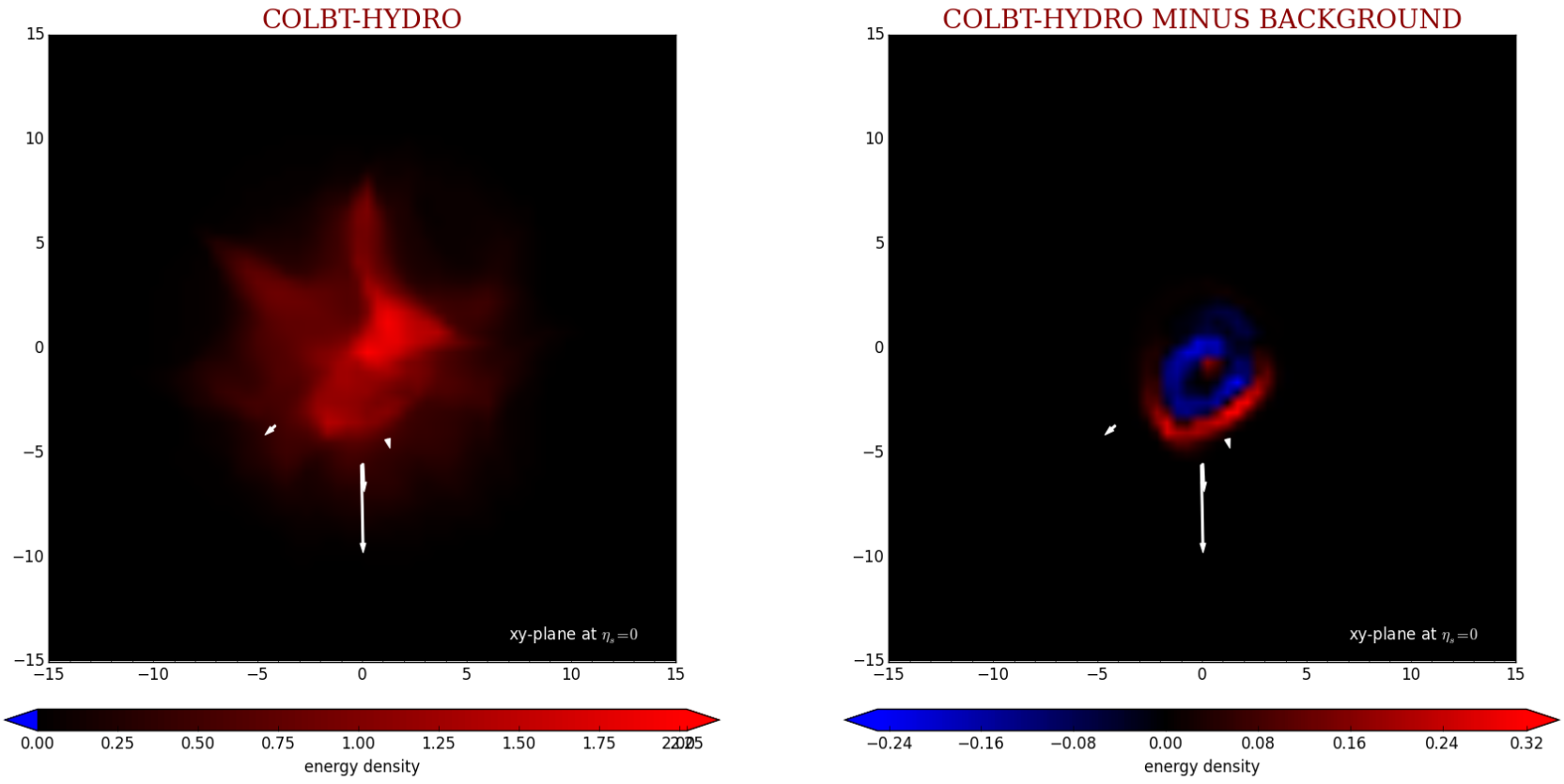
Jet propagation and jet-induced medium excitation

Jet propagation in hot medium at $\tau = 5.6 fm$



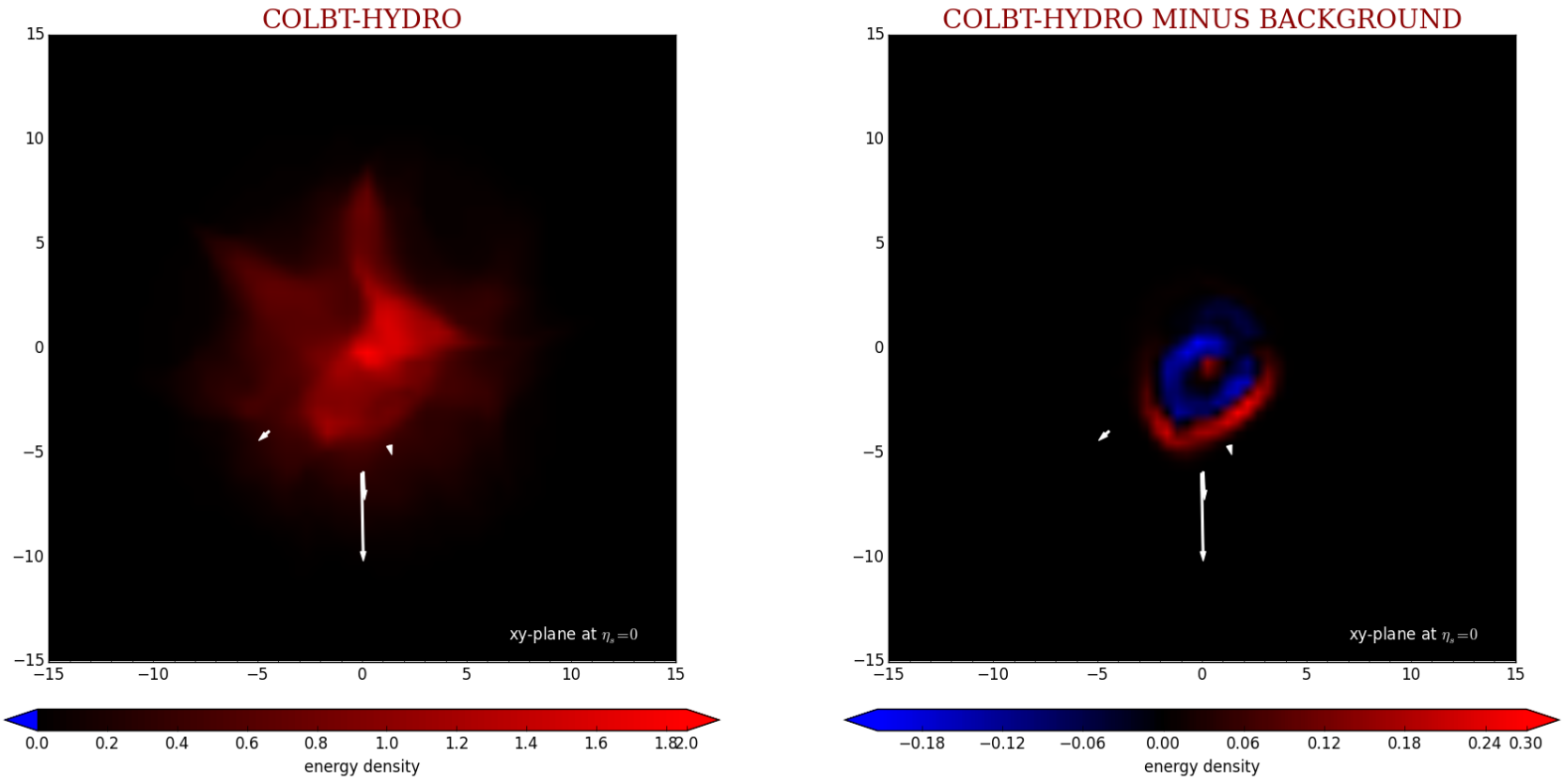
Jet propagation and jet-induced medium excitation

Jet propagation in hot medium at $\tau = 6.0 fm$



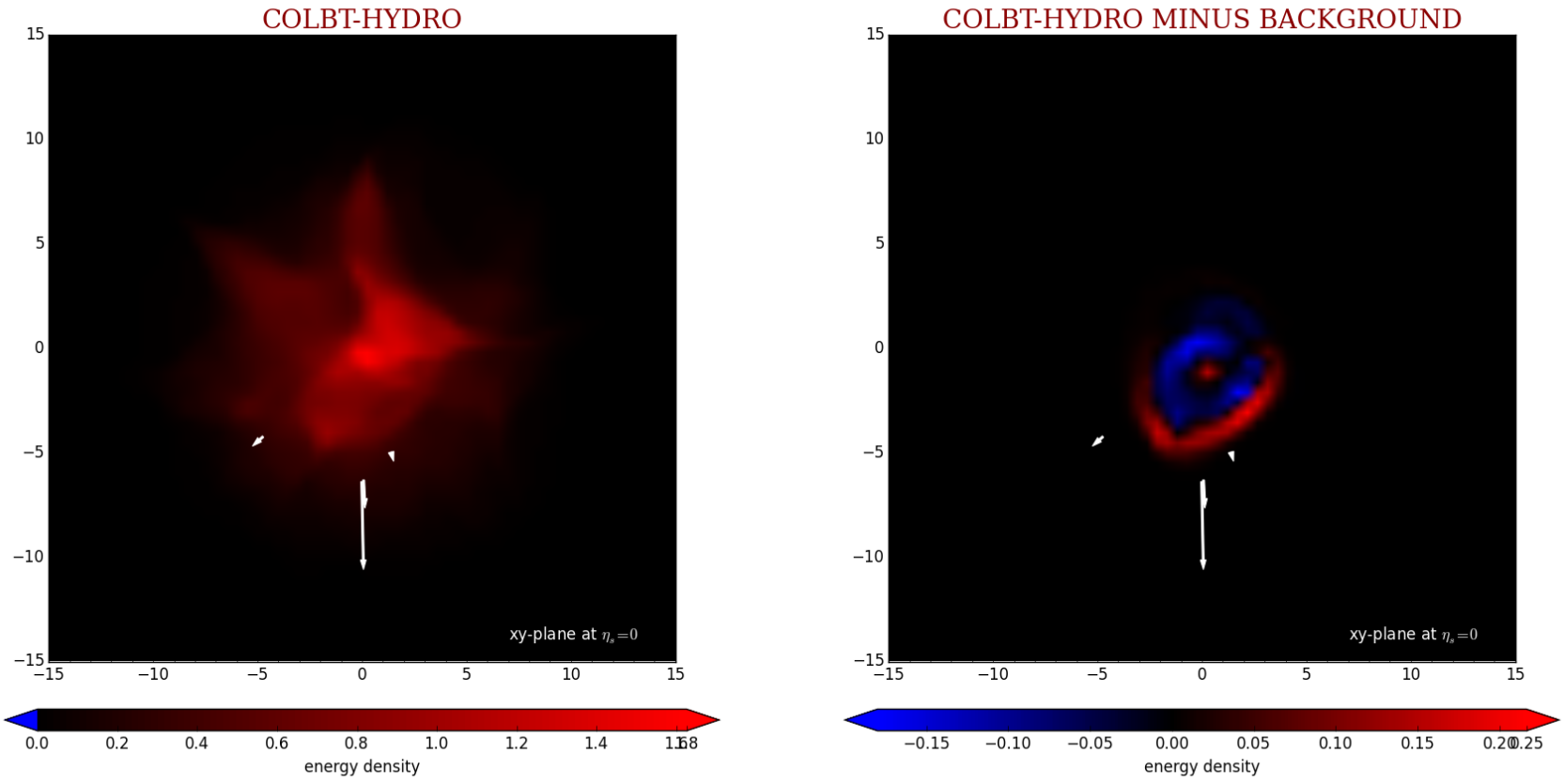
Jet propagation and jet-induced medium excitation

Jet propagation in hot medium at τ=6.4fm



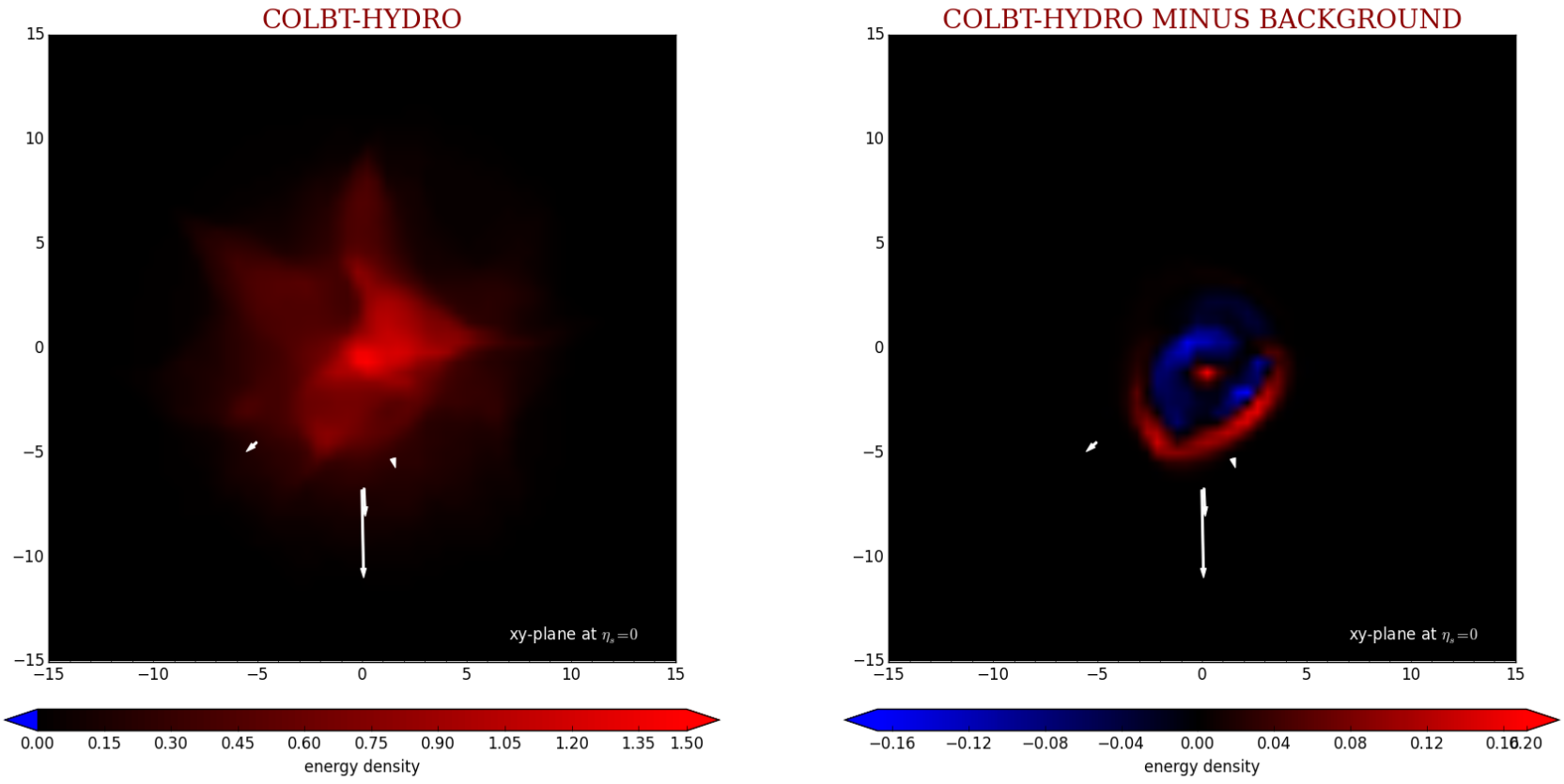
Jet propagation and jet-induced medium excitation

Jet propagation in hot medium at $\tau = 6.8 fm$



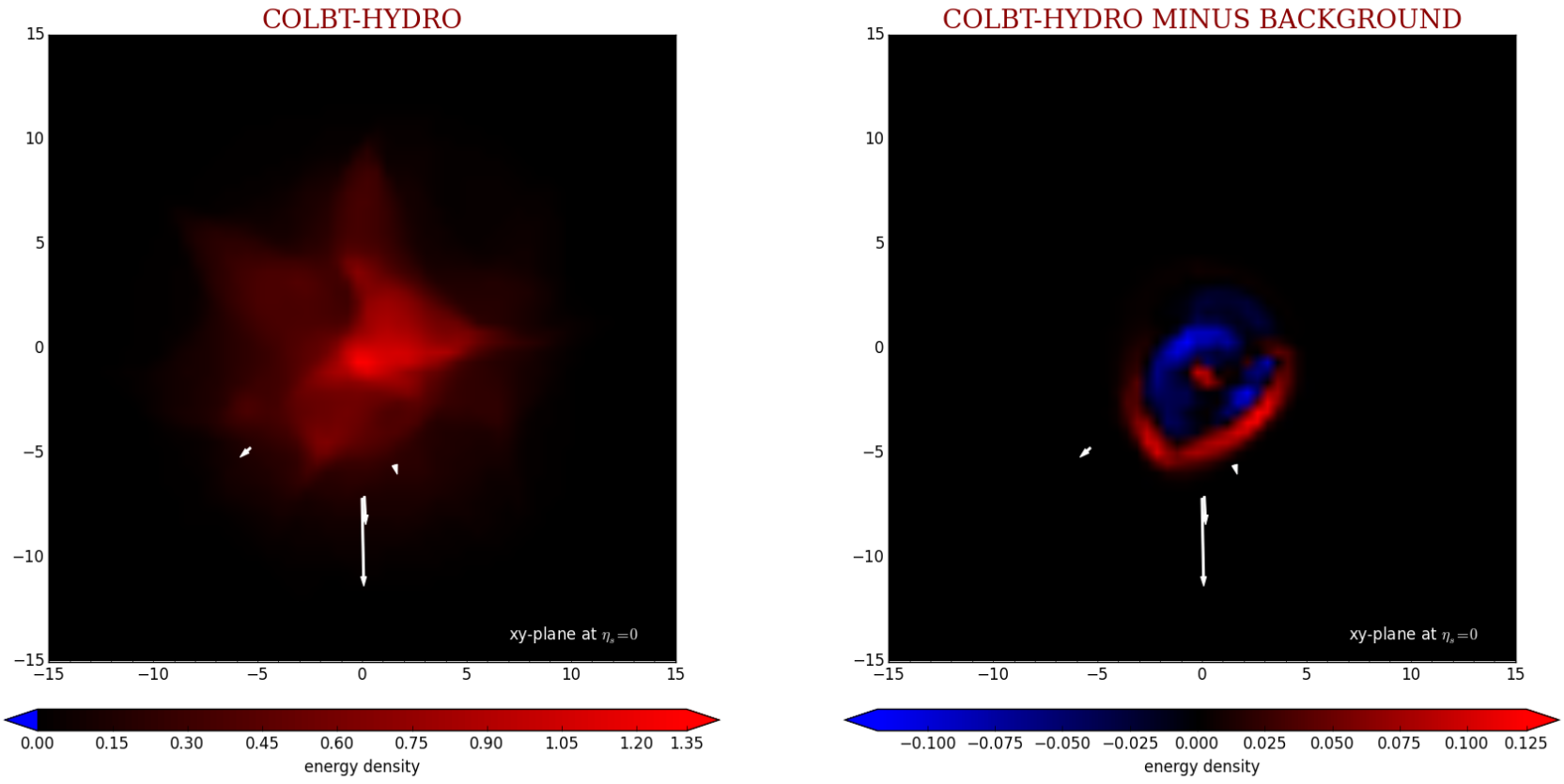
Jet propagation and jet-induced medium excitation

Jet propagation in hot medium at $\tau = 7.2 fm$



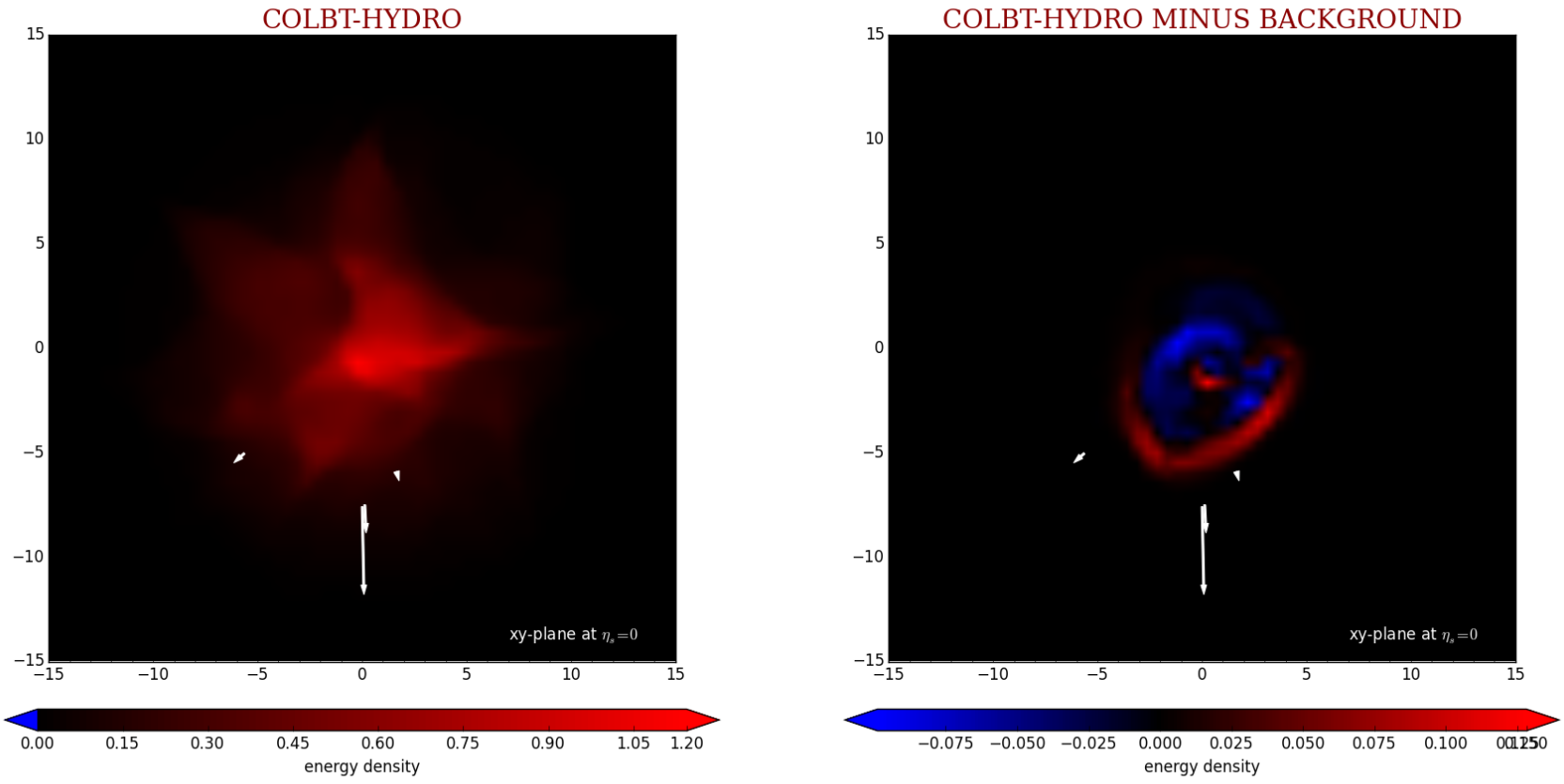
Jet propagation and jet-induced medium excitation

Jet propagation in hot medium at $\tau = 7.6 fm$

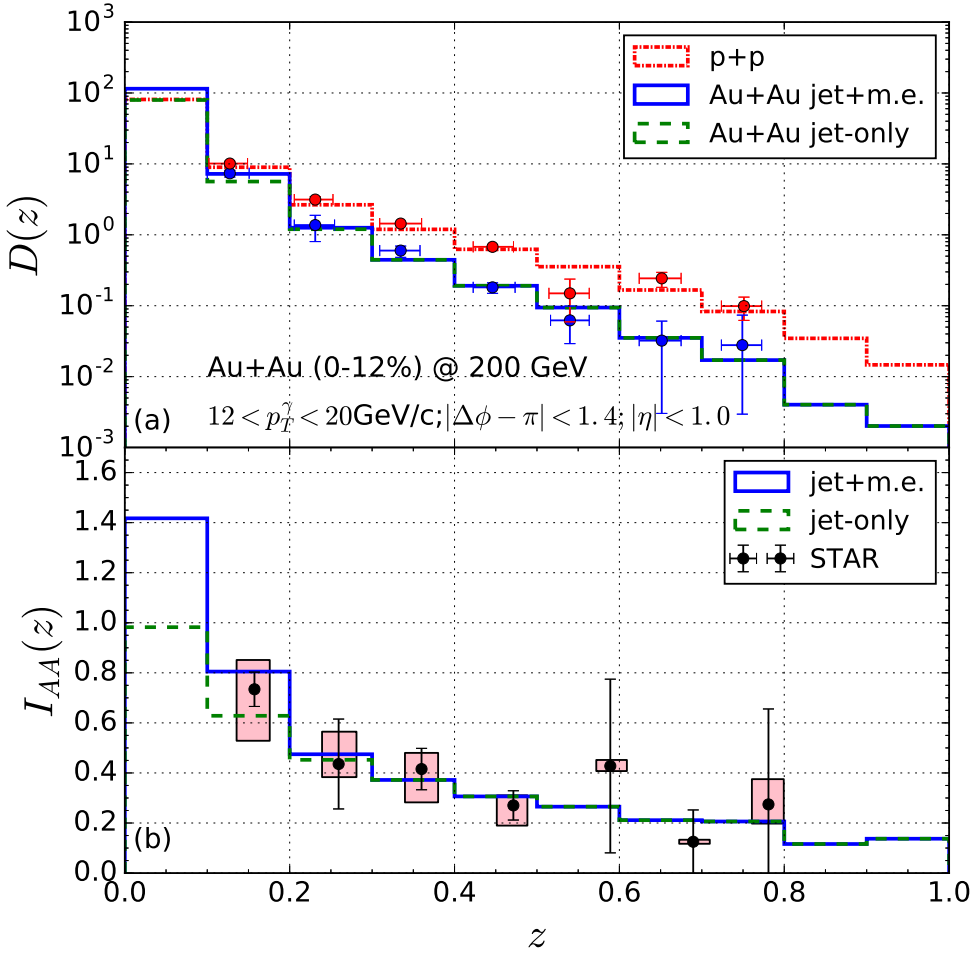


Jet propagation and jet-induced medium excitation

Jet propagation in hot medium at $\tau = 8.0 fm$



Medium modification of γ-triggered hadron yields in RHIC energy



Phys.Lett. B760 (2016) 689-696 STAR

In our calculation

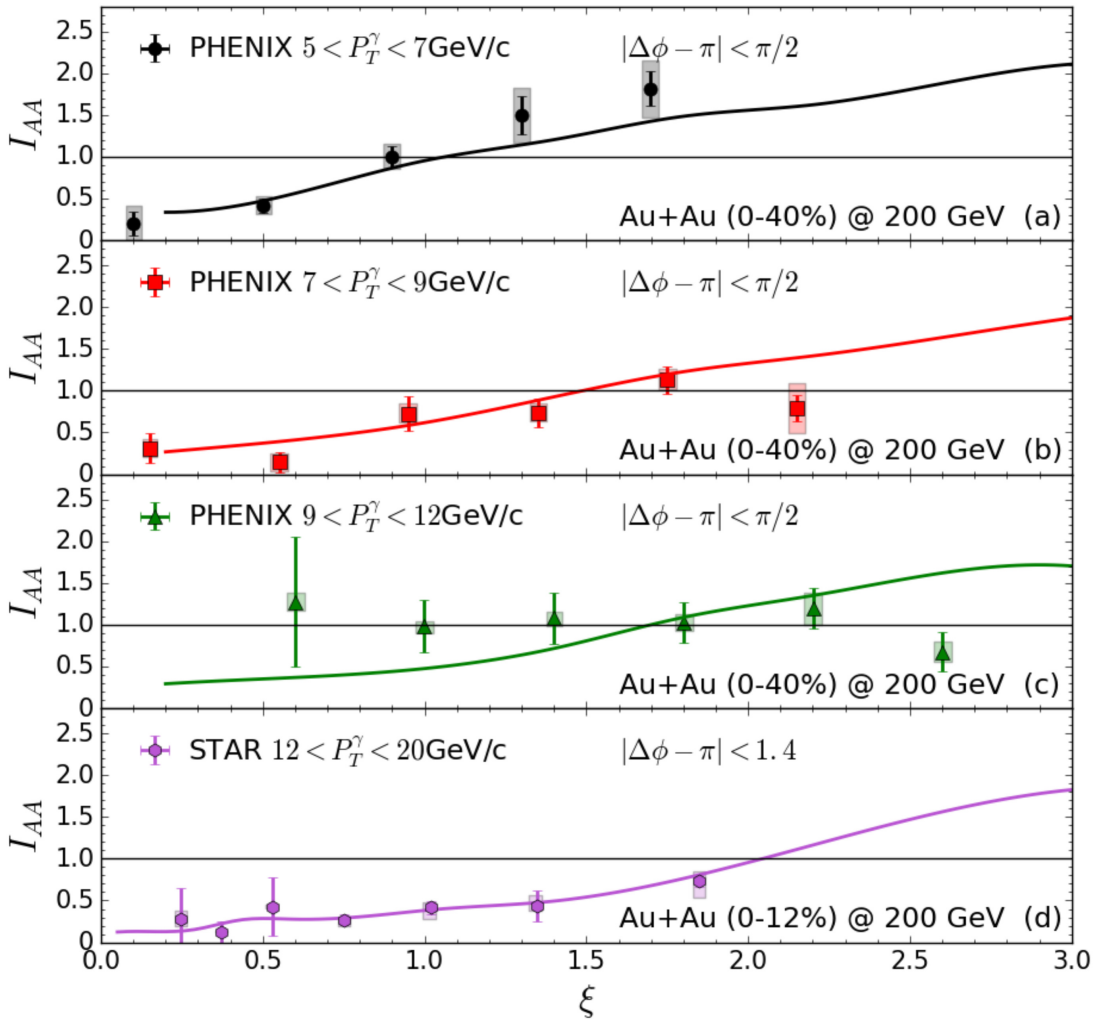
$$D(z) = \left.\frac{dN_h}{dydz}\right|_{LBT} + \left.\frac{dN_h}{dydz}\right|_{hydro}^{w/jet} - \left.\frac{dN_h}{dydz}\right|_{hydro}^{no/jet}$$

- the suppression of leading hadrons at intermediate and large z
  $\Leftarrow$ energy loss of hard partons
- enhancement of soft hadrons at small z
  $\Leftarrow$ jet-induced medium excitation
  ($\alpha_s = 0.3$ and $p_{cut}^0 = 2$GeV/c)

$$z \equiv p_T^h / p_T^\gamma$$

$$I_{AA}(z) = D_{AA}(z)/D_{pp}(z)$$

Medium modification of γ-triggered hadron yields in RHIC energy



With p_T^γ range increasing:

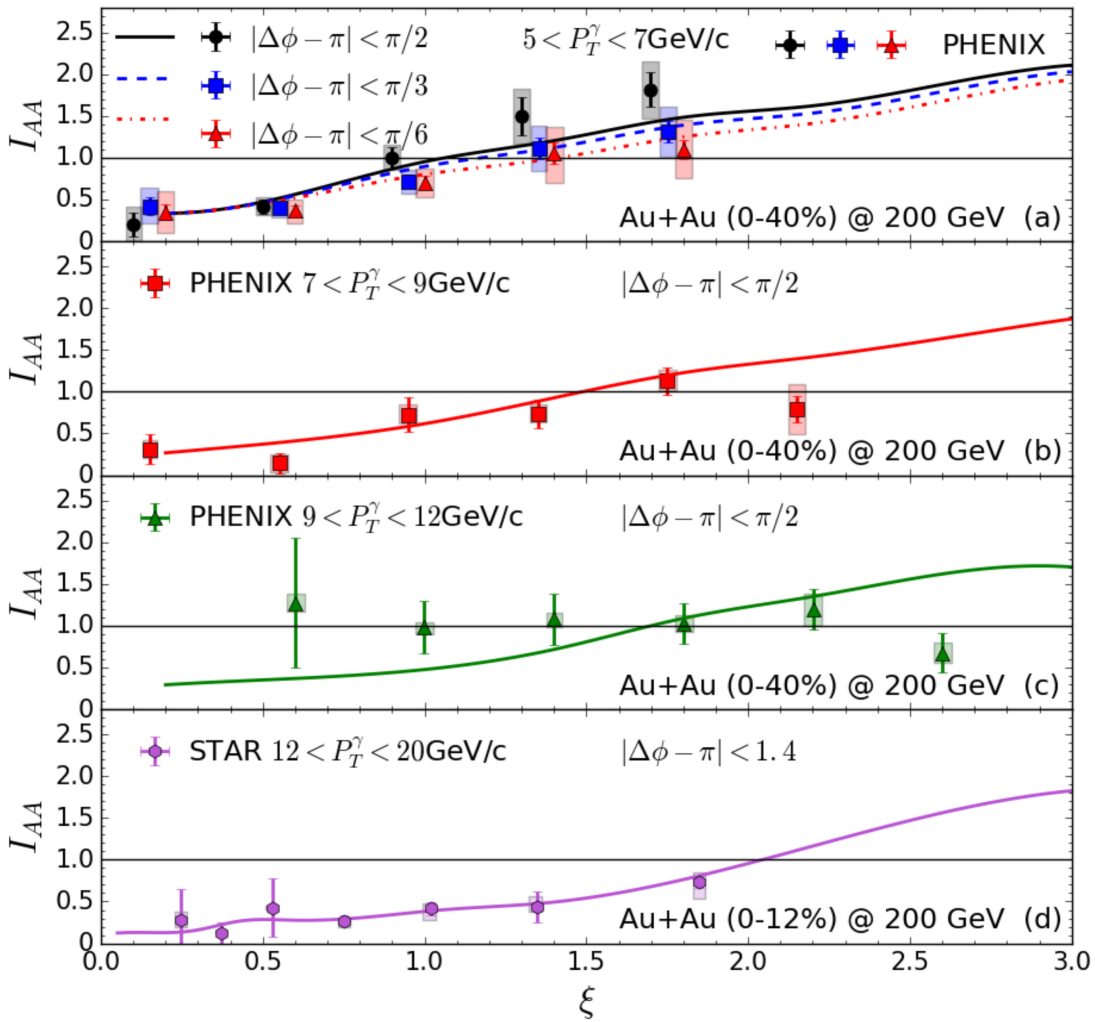
- Transition point from suppression to relative enhancement shifts to larger ξ
- Transition point corresponds to the fixed p_T range

$$\xi = log\frac{1}{z}$$

$$z \equiv p_T^h / p_T^\gamma$$

We can get that **enhancement at small ξ due to medium excitation.**

I_{AA} for diffrent away-side integration range

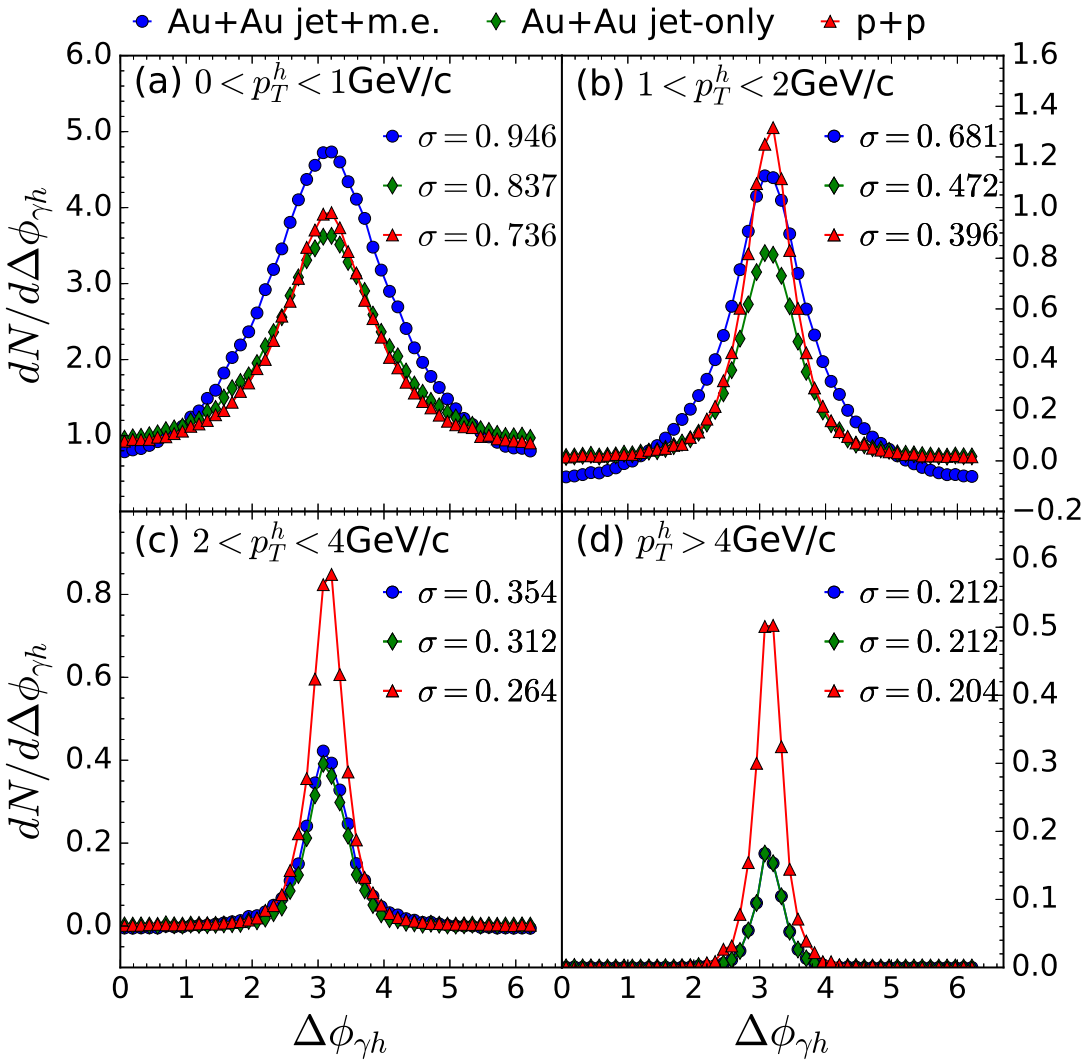


With azimuthal angle range decreasing:

1. the enhancement at high ξ becomes smaller
2. the point with I_{AA}=1 shifts to larger ξ

the soft hadron enhancement has significant contributions from both small and large azimuthal angle relative to the jet direction.

γ-hadron azimuthal correlation in RHIC energy



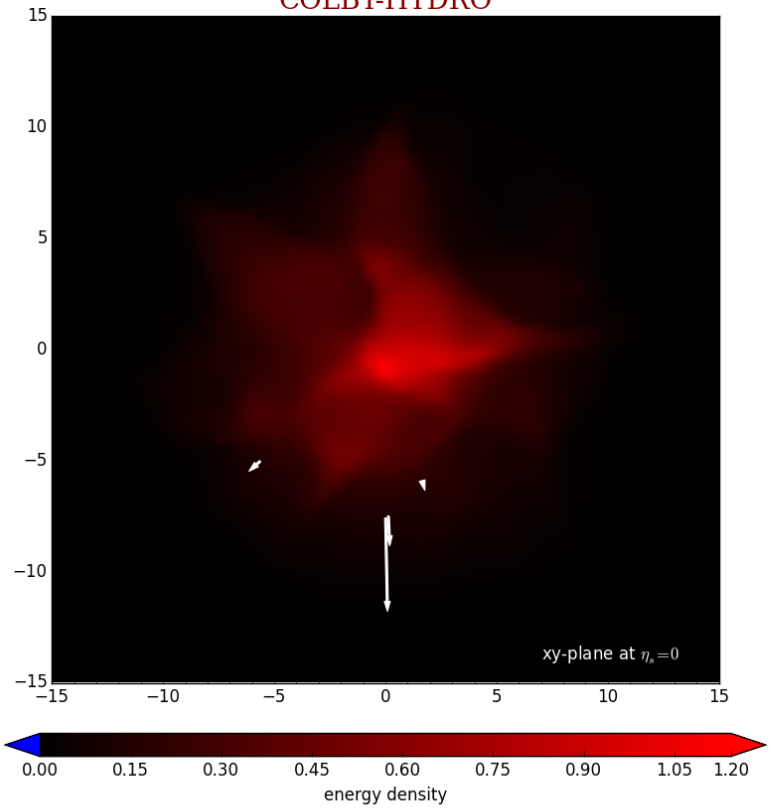
$AuAu200GeV0 \sim 12\%$
$12 < P_T^\gamma < 20GeV/c$
$|\Delta\phi - \pi| < 1.4; |\eta| < 1.0$
σ: gaussian width

- large suppression at large p_T range
- significant enhancement of hadron yields at small p_T range
- a broadened peak at small pt range
- smaller hadron yield in near side at small p_T range

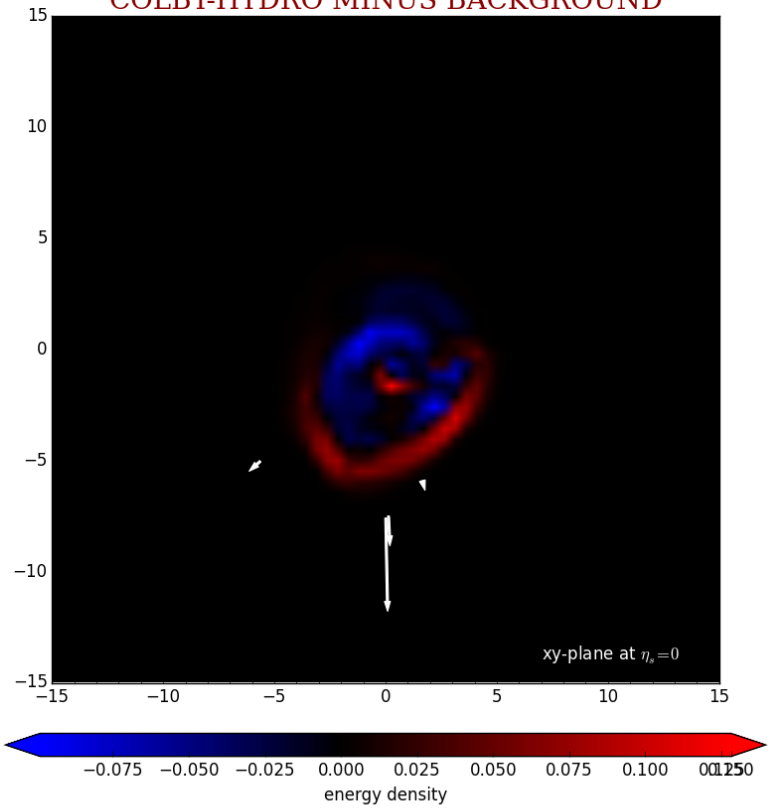
γ-hadron azimuthal correlation in RHIC energy

Jet propagation in hot medium at τ=8.0fm

COLBT-HYDRO



COLBT-HYDRO MINUS BACKGROUND



negative distribution at gamma direction is due to the effect of diffusion wake caused by the deposition of energy-momentum into the medium

Summary and outlook

- We develop CoLBT-Hydro model for simultaneous event-by-event simulations of jet propagation and hydrodynamic evolution of the bulk medium including jet-induced medium excitation.
- CoLBT-hydro describes well both the suppression of leading hadrons due to parton energy loss and enhancement of soft hadrons due to jet-induced medium excitation.
- The onset of soft hadron enhancement at a constant p_T^h with broadened angular distribution and depletion of soft hadrons in the γ direction

Outlook:

- 3+1D viscous hydro
- different jet type
- different collision energy and centrality

how is the lost energy redistributed in the medium