

Medium response made efficient: a linearized hydro approach

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Introduction

- High energy jets probe quark-gluon plasma (QGP), since QGP modifies jet production and jet substructure
- Jets lose energy when propagating through QGP
- The energy deposited by jets evolves in QGP, (partially) thermalizes to form jet wake and hadronizes into particles
- Some soft particles generated from the deposited energy get reconstructed into final jets
- Important to understand how medium responds to jet energy loss in order to use jets as probes
- Full hydrodynamic calculation of wake due to every parton in every jet in a sample of 100,000 jets is unfeasible. Jet wake from linearized hydrodynamics will suffice, and will modify Hybrid Model predictions for soft particles in jets in the direction indicated by data [1]
- Use the linearity of linearized hydrodynamics to speed up calculation of wake by 10,000 and of its hadronization by 100

Framework of linearized hydrodynamics

- Hydrodynamic equation in presence of external currents

$$\nabla_\mu T^{\mu\nu} = J^\nu, \quad (1)$$

- Expand to linear order in perturbation

$$\nabla_\mu T_{(0)}^{\mu\nu} = 0, \quad \nabla_\mu T_{(1)}^{\mu\nu} = J^\nu, \quad (2)$$

- External currents given by energy loss rate and jet moving direction

$$\int \tau dx dy d\eta_s J^\mu = \frac{d}{d\tau} \int \tau dx dy d\eta_s T_{(1)}^{\mu\nu} = \frac{dP^\mu}{d\tau}, \quad (3)$$

where $P^\mu = (E, \vec{v}E)$. Functional form of J^μ is chosen Gaussian

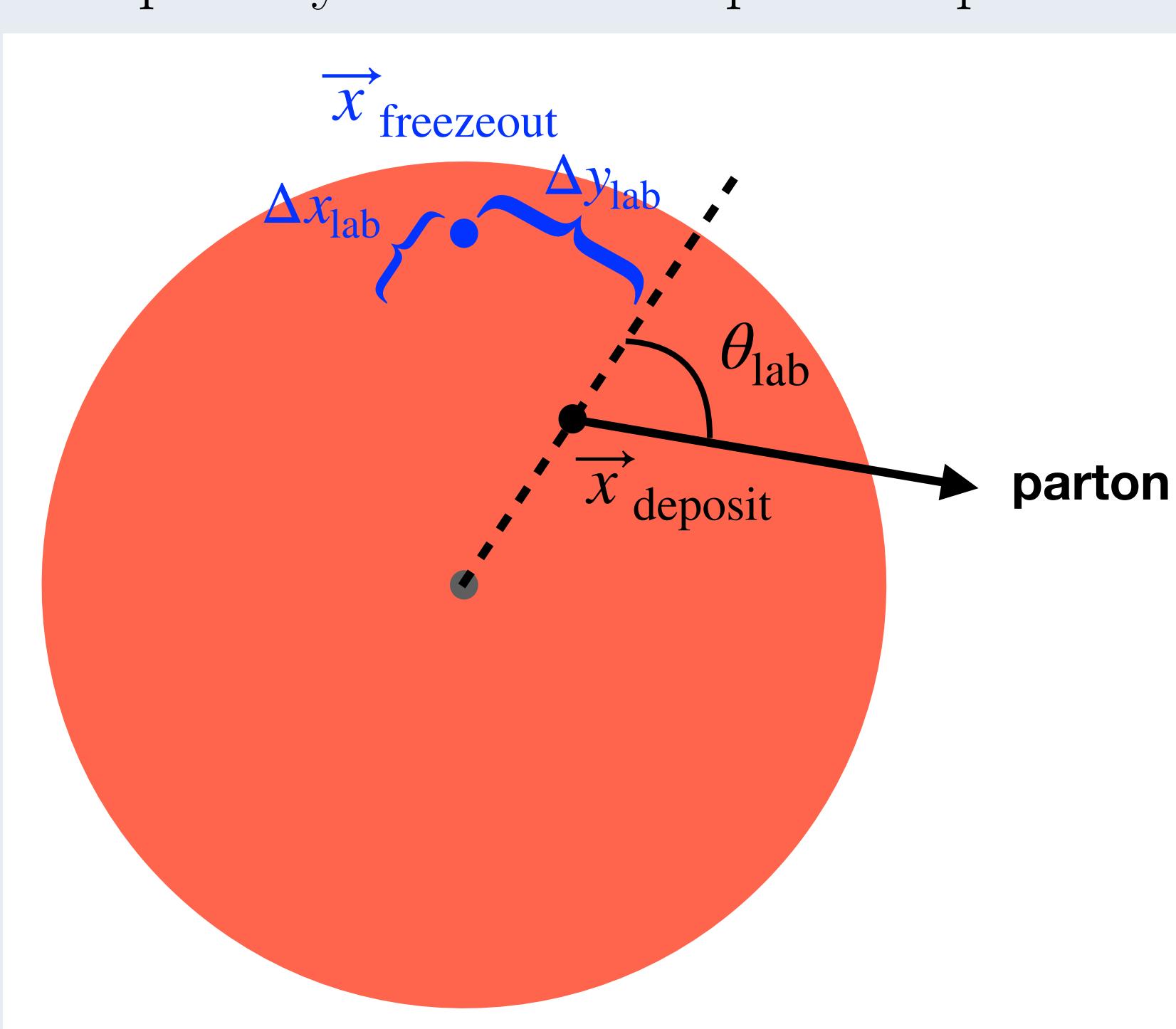
- Hadronization: Cooper-Frye formula

$$(2\pi)^3 E \frac{d\Delta N}{d^3 p} = \int d\sigma^\mu p_\mu f\left(\frac{u^\mu p_\mu}{T}\right) - \int d\sigma_0^\mu p_\mu f\left(\frac{u_0^\mu p_\mu}{T_0}\right), \quad (4)$$

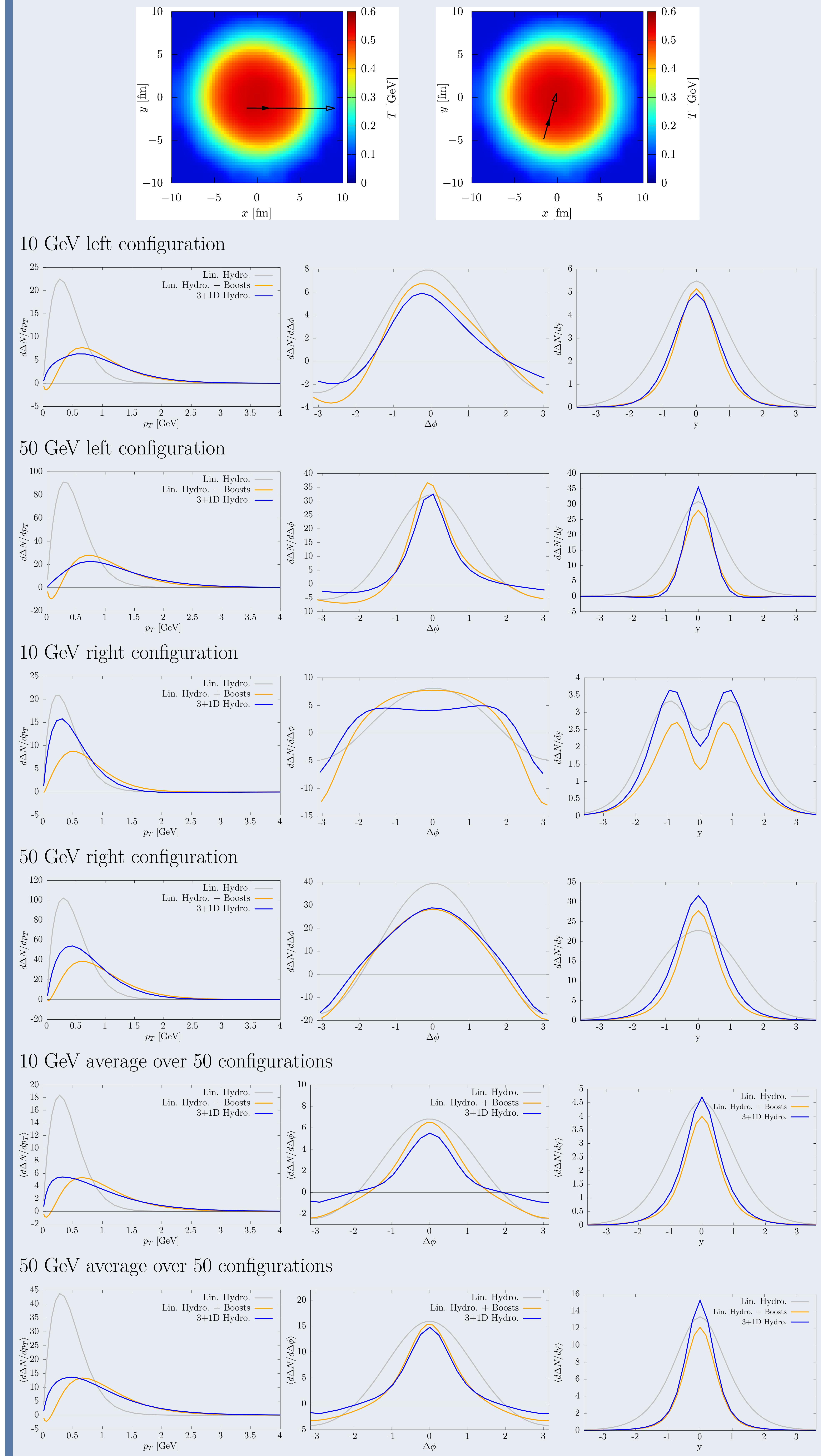
where $d\sigma$ and u are the freezeout hypersurface and flow velocity respectively, and 0 means unperturbed

Technical details

- Consider a blast wave model for the background flow $v\gamma = cr$ where $c \approx 0.12$. It well describes transverse flow at late times
- The blast wave model allows us to perform coordinate transformation into the transversely comoving frame, where we study linearized hydrodynamics on top of Bjorken flow
- We obtain template solutions to the linearized hydrodynamics, in response to 1 GeV deposition
- We discretize the jet trajectory and linearly superpose jet wake solutions on the freezeout hypersurface for each deposition point, **with proper coordinate transformation, rotations and boosts** ($\Delta\vec{x}_{\text{lab}} \rightarrow \Delta\vec{x}_{\text{co}}$, $\theta_{\text{lab}} \rightarrow \theta_{\text{co}}$)
- Apply the Cooper-Frye formula for particle production



Results



Reference

- [1] J. Casalderrey-Solana, J. G. Milhano, D. Pablos, K. Rajagopal and X. Yao, “Jet Wake from Linearized Hydrodynamics,” JHEP **05**, 230 (2021) [arXiv:2010.01140 [hep-ph]].