QGP TOMOGRAPHY: INFERRING BULK MEDIUM PROPERTIES FROM HIGH $p_\perp$ DATA

STEFAN STOJKU, INSTITUTE OF PHYSICS BELGRADE

IN COLLABORATION WITH: MAGDALENA DJORDJEVIC, JUSSI AUVINEN, MARKO DJORDJEVIC AND PASI HUOVINEN

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Introduction

- Bulk properties of QGP - traditionally explored with low-$p_\perp$ particles (99.9% of particles formed in a heavy-ion collision).
- Rare high energy particles traversing QCD medium - excellent probe of QGP properties.
- DREENA-A: theoretical predictions can be compared with a wide range of experimental data.

- The dynamics before thermalization time τ_0 not established
- τ_0 is an important parameter - affects evolution of the system, as well as interactions of high $p_\perp$ particles with the medium
- Conventional hydrodynamics approach: vary τ_0 and compare obtained distributions with data
- Low $p_\perp$ data provides only weak limits to the thermalization time: $\tau_0 = 0.59 \pm 0.41 fm/c \implies$ further constraints would be useful!

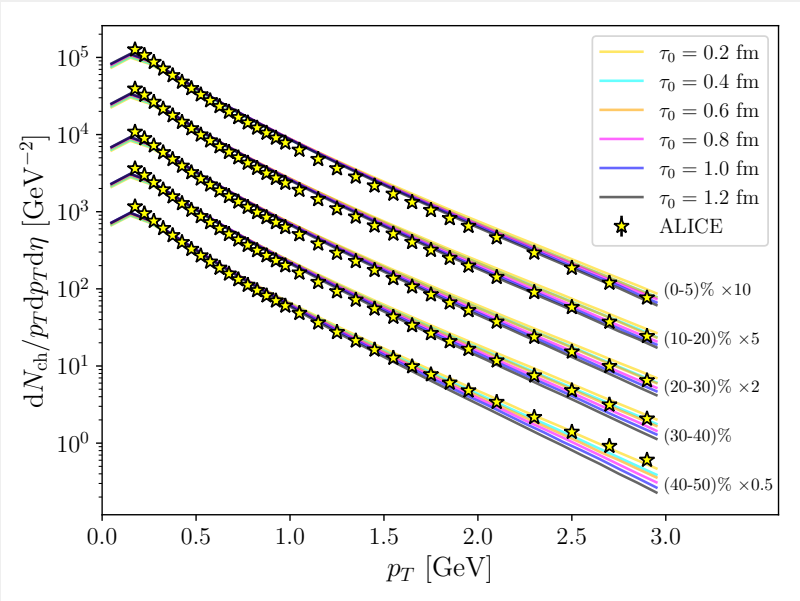
Model Description

- Our approach: how do high $p_\perp$ observables R_{AA} and v_2 depend on the QGP thermalization time τ_0?
- We describe the medium using 3+1D viscous hydro model

  E. Molnar, H. Holopainen, P. Huovinen and H. Niemi,Phys. Rev. C90, 044904 (2014).

- Bass *et al.* (2017): comparison of hydro low $p_\perp$ data insensitive to a wide range of τ_0 ($0.2fm < \tau_0 < 1.2fm$)
- Independently confirmed by our systematic analysis: 3+1D viscous hydro model run with six different τ_0:

  S. Stojku, J. Auvinen, M. Djordjevic, P. Huovinen and M. Djordjevic, arXiv:2008.08987 [nucl-th]



- Good agreement with low $p_\perp$ data confirms low sensitivity to τ_0.
- Can this indeterminancy be further constrained through high $p_\perp$ theory and data?

High $p_\perp$ Results for Various τ_0

- Next step: use DREENA-A to generate high $p_\perp$ data for all τ_0 (charged hadrons, $Pb + Pb$ @ $\sqrt{s_{NN}} = 5.01$ TeV)

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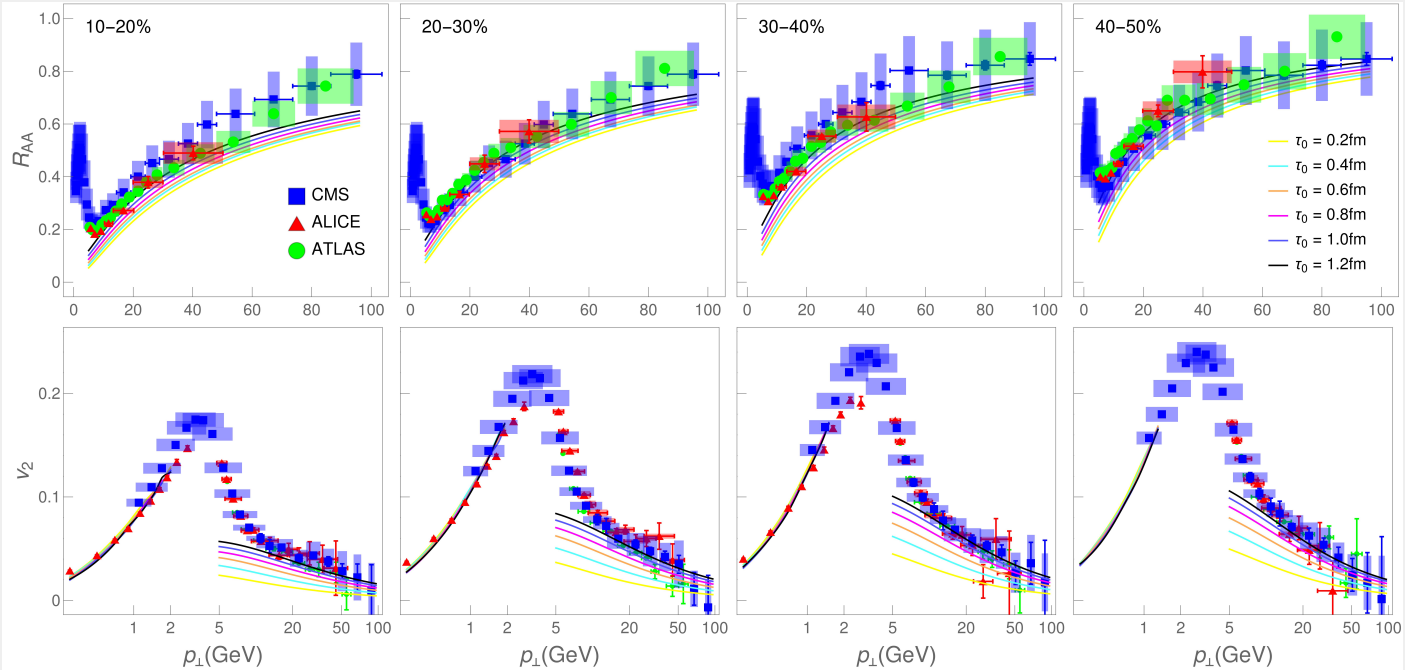

- Low $p_\perp$ v_2 is completely insensitive to different τ_0.
- On the other hand, high $p_\perp$ predictions can clearly be resolved against experimental data.
- Later thermalization time is clearly preferred by R_{AA} and v_2.

Heavy Flavor High $p_\perp$ Results for Various τ_0

- DREENA-A predictions for D mesons (full curves) and B mesons (dashed curves), $Pb + Pb$ @ $\sqrt{s_{NN}} = 5.01$ TeV

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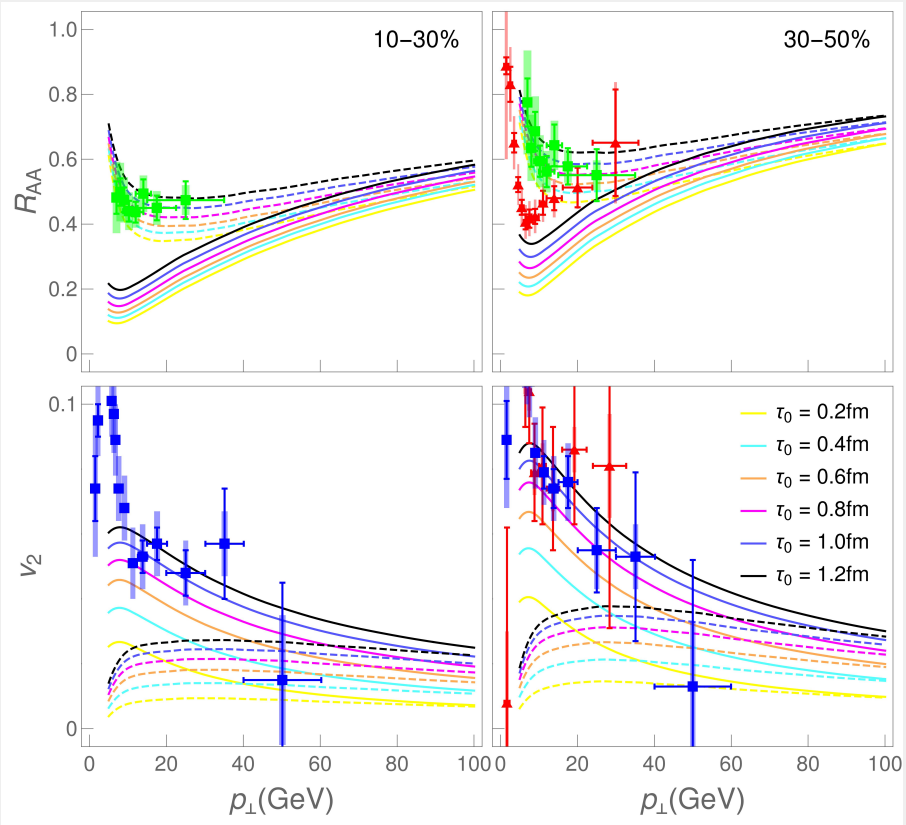
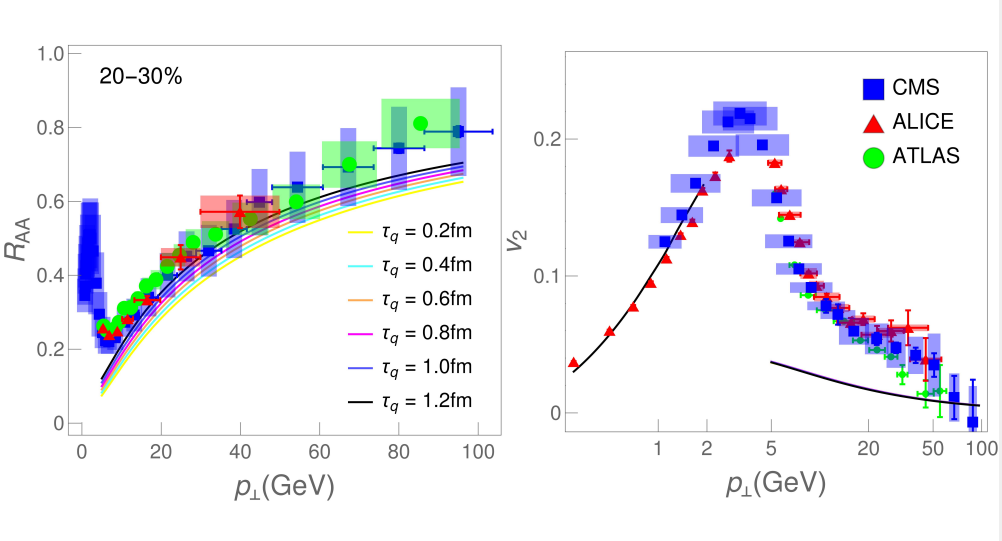


- D meson: ALICE (red triangles), CMS (blue squares)
- B meson: CMS non-prompt J/ψ (green circles)
- Heavy quarks are even more sensitive to τ_0.
- Later thermalization time is preferred.

Later Quenching Time?

- What if jet quenching starts later than QGP thermalization time (and subsequent medium evolution) τ_0?
- To test this scenario, we introduce quenching time $\tau_q \geq \tau_0$
- DREENA-A results generated on a temperature profile with $\tau_0 = 0.2$ fm, but τ_q in the range of = 0.2-1.2fm:

S. Stojku, J. Auvinen, M. Djordjevic, P. Huovinen and M. Djordjevic, arXiv:2008.08987 [nucl-th]



- v_2 surprisingly insensitive to τ_q!

Explaining the Observed Sensitivity

- ... of high $p_\perp$ observables R_{AA} and v_2 on τ_0 (and τ_q)
- We evaluated the average temperatures that partons experience while traversing the medium in the in-plane ($\phi = 0$) and out-of-plane ($\phi = \pi/2$) directions for various τ_0

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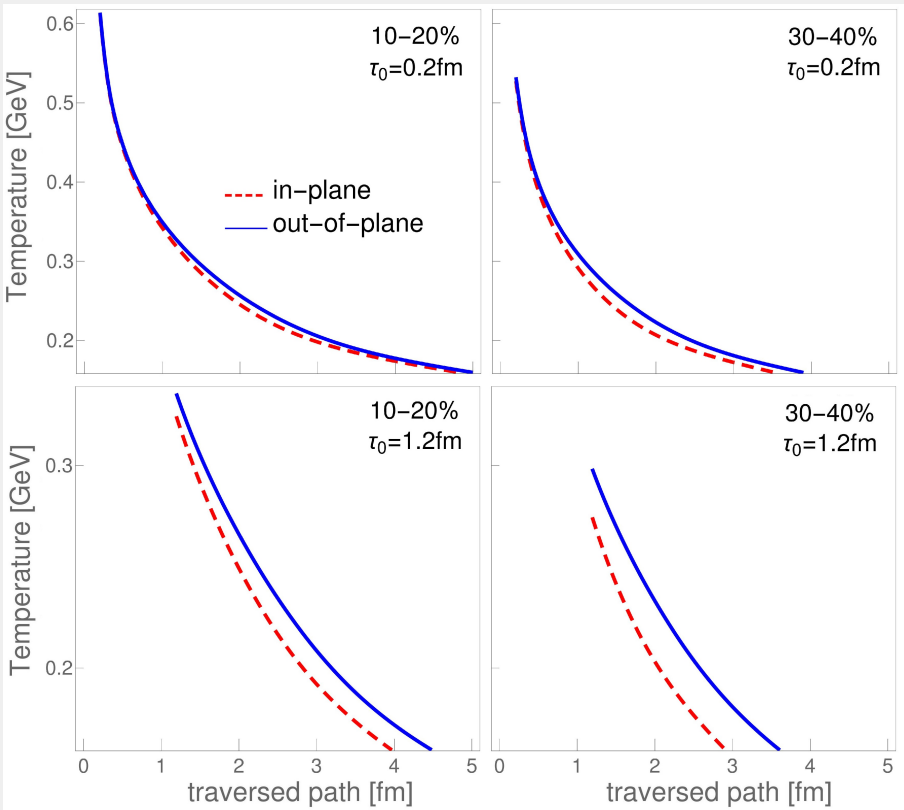

- As τ_0 increases $\Longrightarrow$ the difference between average in-plane and out-of-plane temperatures increases
- Recall that $v_2 \approx \frac{1}{2}\frac{R_{AA}^{in} - R_{AA}^{out}}{R_{AA}^{in} + R_{AA}^{out}}$

- Explains the observed dependence of v_2 on τ_0.

Conclusion and Acknowledgements

- We presented (to our knowledge) the first example of using high $p_\perp$ theory and data to constrain a parameter weakly sensitive to bulk medium evolution
- We demonstrated that experimental data favors later QGP thermalization time.
- This demonstrates synergy of low- and high-$p_\perp$ QGP physics, supporting our QGP tomography approach.

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