ANISOTROPY OF THE QGP DROPLET EXPLORED THROUGH HIGH-\( p_\perp \) DATA

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QGP TOMOGRAPHY

- **Our main goal:** use high-$p_\perp$ data to infer bulk properties of QGP.
- **Dynamical Radiative and Elastic ENergy Loss Approach:** our numerical framework capable of generating high $p_\perp$ predictions
  - High energy particles lose energy when they traverse QGP.
  - This energy loss is sensitive to QGP properties.
  - *We can realistically predict this energy loss.*
- High-$p_\perp$ probes are excellent tomography tools.
  - *We can use them to infer some of the bulk QGP properties.*
- **Initial spatial anisotropy:** one of the main properties of QGP. One of the major limiting factors for QGP tomography.
- **How to use high $p_\perp$ data to infer spatial anisotropy of QGP?**
- **We propose a novel approach,** based on inference from already available high-$p_\perp$ $R_{AA}$ and $v_2$ measurements.
Anisotropy

- We previously argued that at high-$p_\perp$, the ratio of elliptic flow parameter $v_2$ and $1 - R_{AA}$, where $R_{AA}$ is the nuclear suppression factor saturates, and reflects only the geometry of the system. This argument was based on analytic considerations and simple 1-dimensional medium expansion.


- We here study the behavior of $v_2/(1 - R_{AA})$ in a system that expands in both longitudinal and transversal directions.


- It has been experimentally observed that $v_2$ and $1 - R_{AA}$ are directly proportional at high $p_\perp$.

- Such relationship is equivalent to a $p_\perp$-independent ratio of $v_2$ and $1 - R_{AA}$.

- Can fluid dynamical calculations reproduce such proportionality? Can we relate this observation to a physical property of the system, namely to its anisotropy?
What happens when we include full medium evolution?

- **DREENA-A**: can accommodate any temperature profile and generate high-$p_{\perp} R_{AA}$ and $v_2$ predictions. Check out the poster by Dušan Žigić.
  

- We visualize the temperatures partons experience in the in-plane and out-of-plane directions for different initializations and evolutions.

\[ \langle T_x(t) \rangle = \frac{1}{N} \sum_{i=1}^{N} T(x_i + t, y_i, t) \]

\[ \langle T_y(t) \rangle = \frac{1}{N} \sum_{i=1}^{N} T(x_i, y_i + t, t) \]

- Does $v_2/(1 - R_{AA})$ saturate? Does this saturation carry information on the anisotropy of the system? What kind of anisotropy measure is revealed through high-$p_{\perp}$ data? We calculate $v_2/(1 - R_{AA})$ within DREENA-A framework:

  The phenomenon of $v_2/(1 - R_{AA})$ saturation is robust! How to explore if it contains information on the system anisotropy?
Next: Plot charged hadrons’ \( \nu_2/(1-R_{AA})[100\text{GeV}] \) vs. \( \Delta L/\langle L \rangle \)


Centrality classes: 10-20%, 20-30%, 30-40%, 40-50%

Surprisingly simple relation between \( \nu_2/(1-R_{AA}) \) and \( \Delta L/\langle L \rangle \).

Slope \( \approx 1 \).

\( \nu_2/(1-R_{AA}) \) carries information on the system anisotropy, through \( \Delta L/\langle L \rangle \).

Can we define a more direct measure of anisotropy? With an explicit dependence on time evolution?

We define \( jT \):

\[
jT(\tau, \phi) \equiv \frac{\int dx dy \ T^3(x + \tau \cos \phi, y + \tau \sin \phi, \tau) \ n_0(x,y)}{\int dx dy \ n_0(x,y)}
\]

\( jT \) is not azimuthally symmetric. We define its 2\(^{nd} \) Fourier coefficient \( jT_2 \):

\[
jT_2(\tau) = \frac{\int dx dy \ n_0(x,y) \int \phi \cos 2\phi \ T^3(x + \tau \cos \phi, y + \tau \sin \phi, \tau)}{\int dx dy \ n_0(x,y) \int \phi \ T^3(x + \tau \cos \phi, y + \tau \sin \phi, \tau)}
\]
A simple time-average of $jT_2$: jet-temperature anisotropy:


$$\langle jT_2 \rangle = \frac{\int_{\tau_0}^{\tau_{\text{cut}}} d\tau jT_2(\tau)}{\tau_{\text{cut}} - \tau_0}$$

- $\tau_{\text{cut}}$: the time when the center of the fireball has cooled to critical temperature $T_c$.
- $v_2/(1 - R_{AA})$ shows a linear dependence on $\langle jT_2 \rangle$, with a slope close to 1.
- Therefore, $v_2/(1 - R_{AA})$ carries information on this property of the medium.

We evaluated $\langle jT_2 \rangle$ from experimentally measured $R_{AA}(p_\perp)$ and $v_2(p_\perp)$: the fitted ratio was converted to $\langle jT_2 \rangle$.

All three experiments lead to similar values of $\langle jT_2 \rangle$.

Jet-temperature anisotropy provides an important constraint on bulk-medium simulations - they should be tuned to reproduce it.
Conclusions and acknowledgements

- High-$p_{\perp}$ theory and data - traditionally used to explore high-$p_{\perp}$ parton interactions with QGP.
- High-$p_{\perp}$ probes can become powerful tomography tools, as they are sensitive to global QGP properties (e.g. spatial anisotropy).
- A (modified) ratio of $R_{AA}$ and $v_2$ - a reliable and robust observable for straightforward extraction of spatial anisotropy.
- The saturation is directly proportional to jet-temperature anisotropy.
- It will be possible to infer anisotropy directly from LHC Run 3 data: an important constraint to models describing the early stages of QGP formation.
- Synergy of more common approaches for inferring QGP properties with high-$p_{\perp}$ theory and data.