DREENA framework as a multipurpose tool for QGP tomography

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DREENA framework

- **Dynamical Radiative and Elastic Energy loss Approach**

- fully optimized numerical procedure capable of generating high $p_{\perp}$ predictions
- includes:
  - parton production
  - multi gluon-fluctuations
  - path-length fluctuations
  - fragmentation functions

- keeping all elements of the state-of-the art energy loss formalism, while introducing more complex temperature evolutions
version C - Constant temperature medium

- natural first step
- simplest calculation:
  analytical integration possible in certain cases
- all other version need to have const T limit
- exploring the influence of medium evolution on both light and heavy flavour and different observables

• Charged hadrons, $Pb + Pb$, $\sqrt{s_{NN}} = 5.02$ TeV

for charged hadrons, qualitatively good agreement, but overestimation of $v_2$ data
DreonA-C

- D mesons, $Pb + Pb$, $\sqrt{s_{NN}} = 5.02$ TeV


For D mesons, qualitatively good agreement, but again overestimation of $v_2$ data.
• B mesons, $Pb + Pb$, $\sqrt{s_{NN}} = 5.02\, TeV$


for B mesons, our $\nu_2$ predictions are non-zero
Main conclusions for DREENA-C:

- good agreement with $R_{AA}$ data
- however, $v_2$ overestimates the data
- other models underestimate $v_2$ - $v_2$ puzzle
- overall good agreement with data given the simplicity of approximation

version B - 1D Bjorken evolution

- natural next step
- $T$ introduced through analytical expression, which is only a function of time
- differences in results should suggest the sensitivity of observables to different aspects of medium evolution
- limits prove the validity of models

• Charged hadrons, $Pb + Pb$, $\sqrt{s_{NN}} = 5.02$ TeV


very good joint agreement with both $R_{AA}$ and $v_2$ data
DREENA-B

- D mesons, \( Pb + Pb \), \( \sqrt{s_{NN}} = 5.02 \text{ TeV} \)


[Graph showing data points and fits for different bin ranges, indicating good joint agreement for D mesons as well]
• B mesons, $Pb + Pb$, $\sqrt{s_{NN}} = 5.02$ TeV


we predict non-zero $v_2$ for B mesons
• $Pb + Pb$, $\sqrt{s_{NN}} = 5.02$ TeV predictions for muons


好 agreement with the data
Main conclusions for DREENA-B:

- Takes medium evolution as a simple analytical expression that depends only on time.
- Explains high $p_{\perp}$ data for different probes and centralities.
- This form of time evolution is suitable for studying the influence of initial stages of QGP evolution on high $p_{\perp}$ observables.


- Yet, it can’t provide us with further information about the properties of QGP (shear viscosity, ...)

version A - Adaptive

- main goal of our research
- tool for exploiting high $p_{\perp}$ data for QGP tomography by employing advanced medium model (hydro, transport coefficients,...)
- DREENA-A introduces full medium evolution but not at the expense of simplified energy loss
- also capable to account for event-by-event fluctuations
Glb-eBCFit, $\tau_0 = 1.0$ fm

used in Molnar-Holopainen-Huovinen-Niemi 3d hydro - energy density based on a third-order polynomial of the BC from optical Glauber

Charged hadrons

Very good agreement with $R_{AA}$ and $v_2$ data!

For high-$p_\perp$ data, proper description of parton-medium interactions is more important than the medium evolution!
QGP properties

- Next goal: inferring QGP properties from high $p_{\perp}$ theory and data

- high energy particles lose energy
- energy loss sensitive to QGP properties
- predict the energy loss of high $p_{\perp}$ probes
- infer QGP properties:
  - initial spatial anisotropy
  - constrain the initial stages by high $p_{\perp}$ theory and data
  - path-length dependence of energy loss
Towards QGP tomography - DREENA-A

- Glb-eBC, $\tau_0 = 0.5$ fm
  - used in SONICv1.7 - energy density based on the BC density from optical Glauber

Charged hadrons

D mesons

B mesons
Towards precision QGP tomography - DREENA-A

- MCGLb-sMix, $\tau_0 = 0.6$ fm

used in **iEBE-VISHNU** - entropy density based on a mixture of wounded nucleon and BC densities from Monte Carlo Glauber

**Charged hadrons**

**D mesons**

**B mesons**
Towards precision QGP tomography - DREENA-A

Analized the sensitivity of high-$p_\perp$ $R_{AA}$ and $\nu_2$ data to different hydro temperature profiles.

Obtained notable sensitivity shows that high-$p_\perp$ theory/data can indeed be used to constrain the bulk QGP properties.

As a separate study, we also analized sensitivity of high-$p_\perp$ $R_{AA}$ and $\nu_2$ data to different initial stages.


$R_{AA}$ shows notable sensitivity to initial conditions, while $\nu_2$ is surprisingly insensitive to these conditions.

High-$p_\perp$ theory and data are suitable for QGP tomography, but both $R_{AA}$ and $\nu_2$ have to be tested simultaneously to infer the properties of this new form of matter!
Acknowledgements

Thank you for your attention!
Backup slides

- Charged hadrons, $Pb + Pb$, $\sqrt{s_{NN}} = 5.02\ TeV$
  
DREENA-C & DREENA-B
Backup slides

- B Meson, $Pb + Pb$, $\sqrt{s_{NN}} = 5.02$ TeV

DREENA-C
• Charged hadrons, \( Pb + Pb, \sqrt{s_{NN}} = 5.02 \, TeV \)
DREENA-C & DREENA-B & DREENA-A