QGP tomography with DREENA framework

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in collaboration with: Magdalena Djordjevic, Jussi Auvinen, Igor Salom, Marko Djordjevic and Pasi Huovinen

МИНИСТАРСТВО ПРОСВЕТЕ,
НАУКЕ И ТЕХНОЛОШКОГ РАЗВОЈА

DREENA framework

- **D**ynamical **R**adiative and **E**lastic **EN**ergy loss **A**pproach

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

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

version **C** - **C**onstant temperature medium

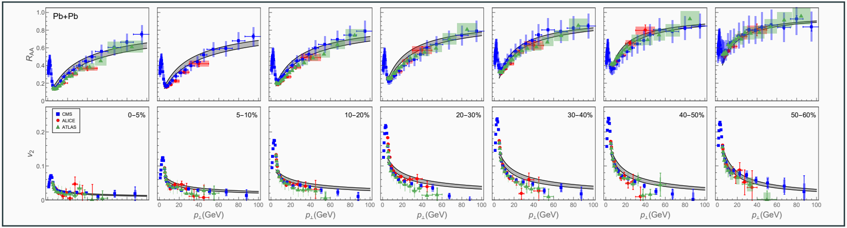
- natural first step
- simplest calculation:
  analytical integration possible in certain cases
- all other version need to have const T limit
- exploring the influence of medium evolution on both light and heavy flavour and different observables

D. Z., I. Salom, J. Auvinen, M. Djordjevic and M. Djordjevic, J. Phys. G **46**, no. 8, 085101 (2019).

DREENA-C

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

D. Z., I. Salom, J. Auvinen, M. Djordjevic and M. Djordjevic, J. Phys. G **46**, no. 8, 085101 (2019).

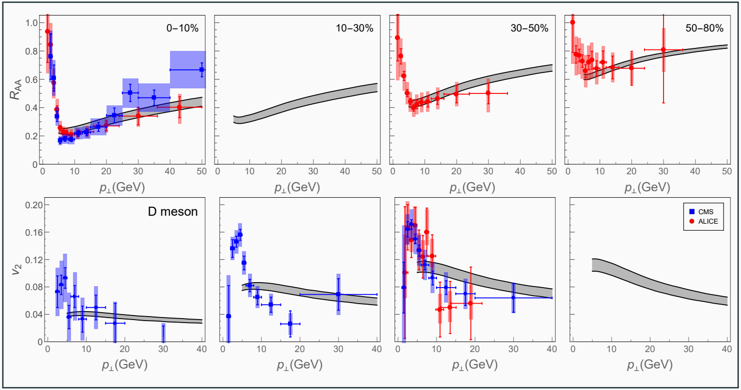


for charged hadrons, qualitatively good agreement, but overestimation of v_2 data

DREENA-C

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

D. Z., I. Salom, J. Auvinen, M. Djordjevic and M. Djordjevic, J. Phys. G **46**, no. 8, 085101 (2019).

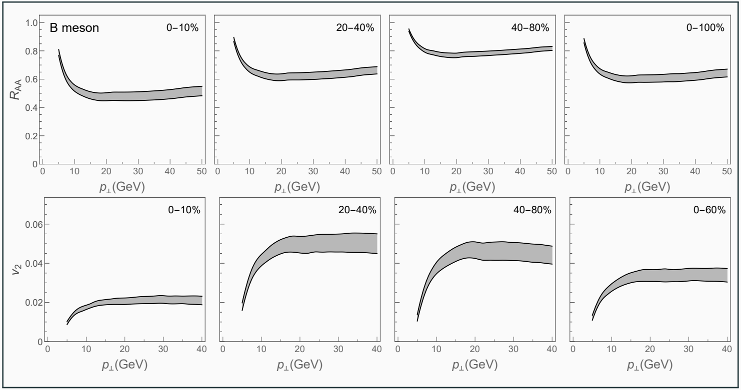


for D mesons, qualitatively good agreement,
but again overestimation of v_2 data

DREENA-C

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

D. Z., I. Salom, J. Auvinen, M. Djordjevic and M. Djordjevic, J. Phys. G **46**, no. 8, 085101 (2019).



for B mesons, our v_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

D. Z., I. Salom, J. Auvinen, M. Djordjevic and M. Djordjevic, J. Phys. G **46**, no. 8, 085101 (2019).

version **B** - 1D **B**jorken evolution

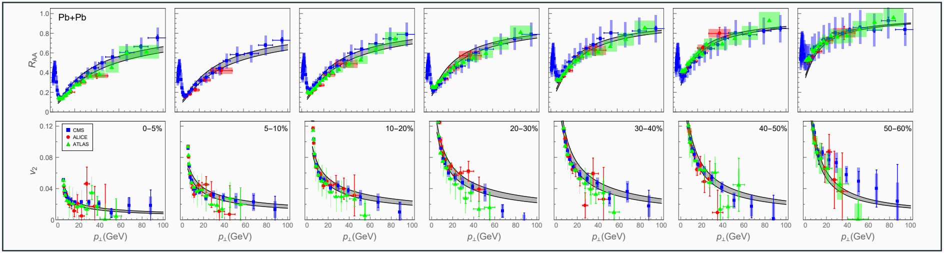
- natural next step
- T introduced through analytical expression, which is only a function of time
- differences in results should suggest the sensitivity of observables to different aspects of medium evolution
- limits prove the validity of models

D. Z., I. Salom, J. Auvinen, M. Djordjevic and M. Djordjevic, Phys. Lett. B **791**, 236 (2019).

DREENA-B

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

D Z., I. Salom, J. Auvinen, M. Djordjevic and M. Djordjevic, Phys. Lett. B **791**, 236 (2019).

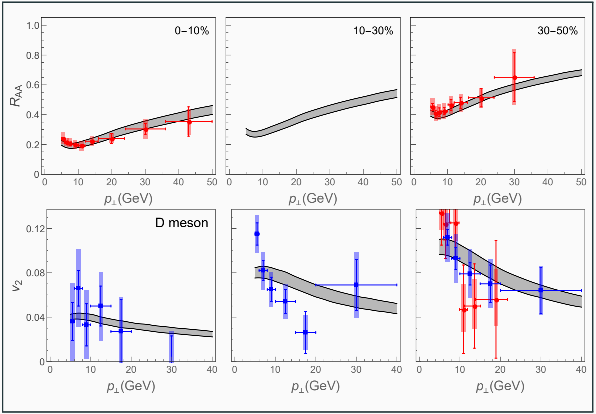


very good joint agreement with both R_{AA} and v_2 data

DREENA-B

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

D. Z., I. Salom, J. Auvinen, M. Djordjevic and M. Djordjevic, Phys. Lett. B **791**, 236 (2019).

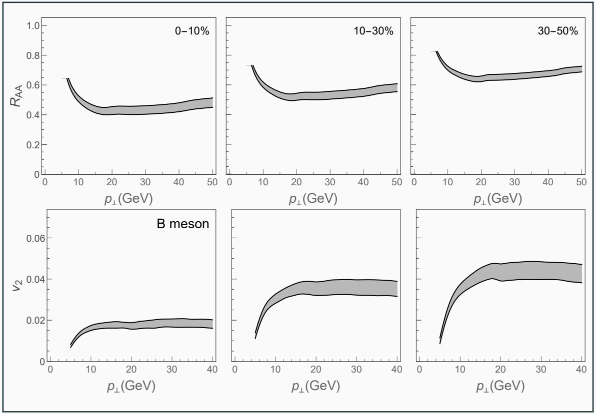


good joint agreement for D mesons as well

DREENA-B

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

D. Z., I. Salom, J. Auvinen, M. Djordjevic and M. Djordjevic, Phys. Lett. B **791**, 236 (2019).

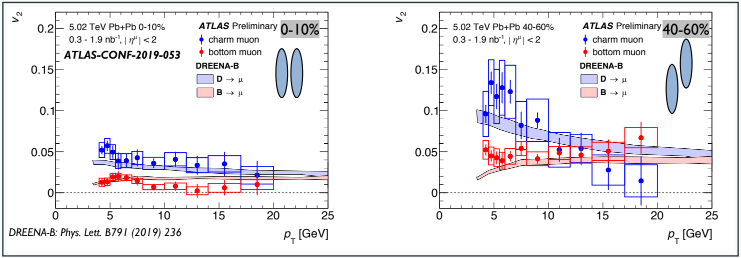


we predict non-zero v_2 for B mesons

DREENA-B

- $Pb + Pb$, $\sqrt{s_{NN}} = 5.02\,TeV$ predictions for muons

D. Z., I. Salom, J. Auvinen, M. Djordjevic and M. Djordjevic, Phys. Lett. B **791**, 236 (2019).



good agreement with the data

DREENA-B

Main conclusions for DREENA-B:

- takes medium evolution as a simple analitycal 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
  D. Z., B. Ilic, M. Djordjevic and M. Djordjevic, arXiv:1908.11866 [hep-ph]
- yet, it can't provide us with futher information about the properties of QGP (shear viscosity,...)

D. Z., I. Salom, J. Auvinen, M. Djordjevic and M. Djordjevic, Phys. Lett. B **791**, 236 (2019).

DREENA-A

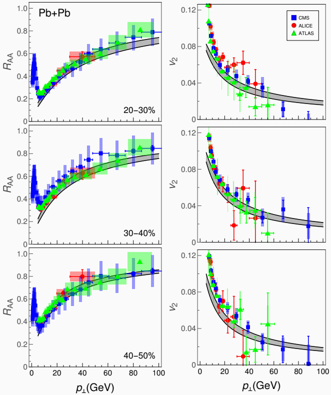
version **A** - **A**daptive

- 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

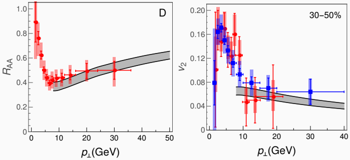
- Glb-eBCFit, $\tau_0 = 1.0$ fm

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

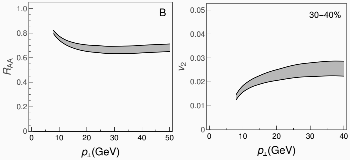
Charged hadrons



D mesons



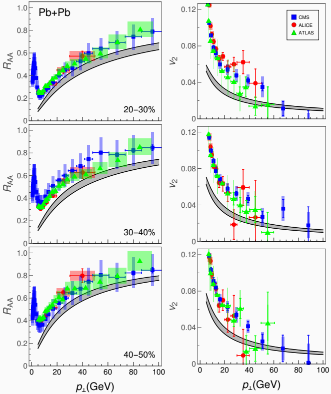
B mesons



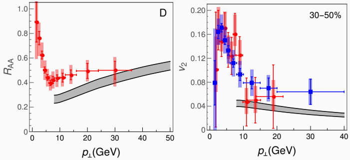
- Glb-eBC, $\tau_0 = 0.5$ fm

used in **SONICv1.7** - energy density based on the binary collision (BC) density from optical Glauber

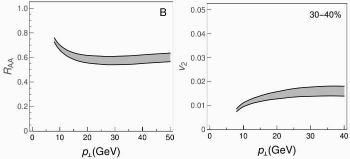
Charged hadrons



D mesons



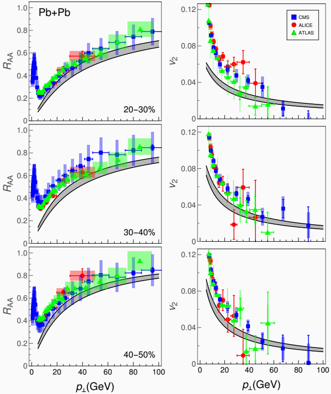
B mesons



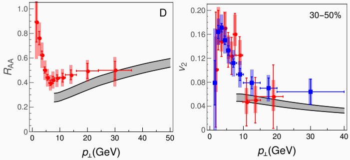
- MCGlb-sMix, $\tau_0 = 0.6$ fm

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

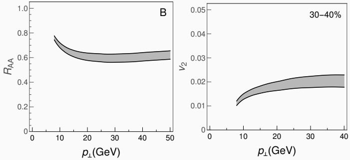
Charged hadrons



D mesons



B mesons



Main conclusions for DREENA-A:

- three different initial conditions were used to generate different temperature evolutions
- those temperature evolutions were then used to generate both R_{AA} and v_2 predictions for both light and heavy flavour
- some had better agreement with the high-$p_\perp$ data although all had good agreement with low-$p_\perp$ data
- low-$p_\perp$ predictions alone are not sensitive enough to extract QGP properties
- both low-$p_\perp$ and high-$p_\perp$ approaches are necessary to reliably extract QGP properties, i.e. for QGP tomography

Summary

- we introduce **DREENA** framework - computational implementation of **dynamical energy loss formalism**
- the main purpose of DREENA is to infer QGP properties
- developed three frameworks, based on <u>C</u>onstant T (DREENA-C), 1D <u>B</u>jorken (DREENA-B) and <u>A</u>daptive profile (DREENA-A)
- **DREENA-C** predictions overestimate v_2, while **DREENA-B** predictions are in good agreement with the data, yet it can not provide further information about QGP
- **DREENA-A** - unique framework that incorporates both state-of-the-art energy loss formalism and state-of-the-art medium evolution, which makes it an optimal framework for exploring the bulk QGP properties by high $p_\perp$ theory and data

Acknowledgements

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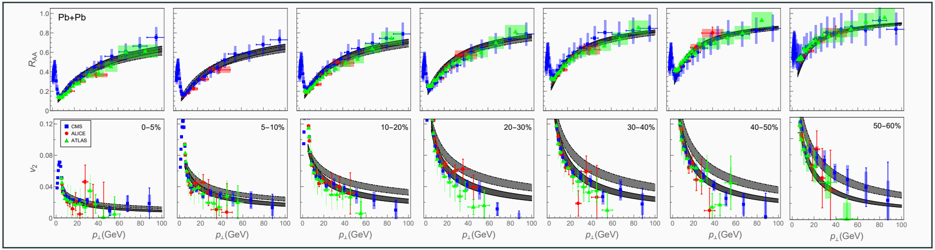
НАУКЕ И ТЕХНОЛОШКОГ РАЗВОЈА

Thank you for your attention!

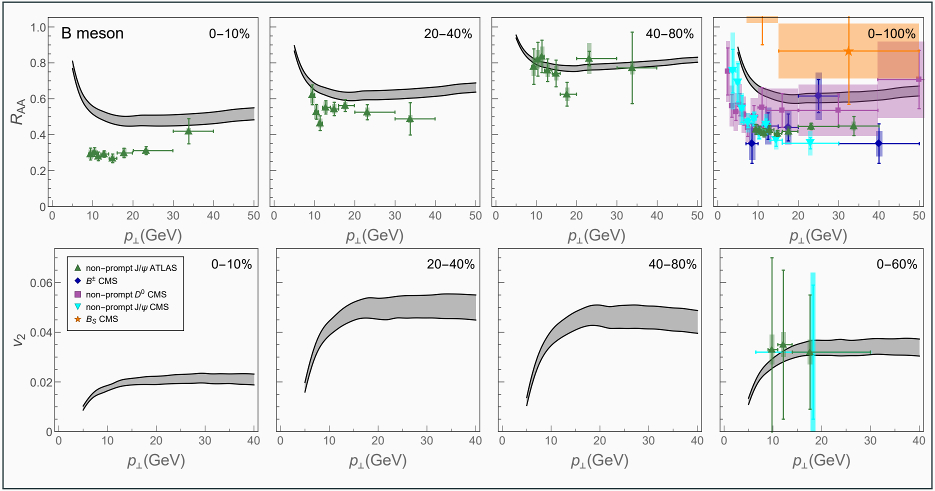
Backup slides

- 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



Backup slides

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