Towards QCD-assisted hydrodynamics for heavy-ion collisions

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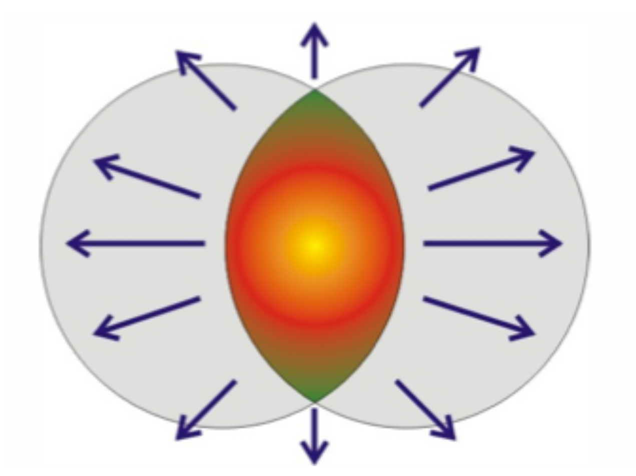
Motivation

- Heavy-ion collisions are well described by a dynamical evolution with a long hydrodynamical phase.
- The properties of the strongly coupled quark-gluon plasma are reflected in the equation of state (EoS) and the transport coefficients, most prominently by the shear and bulk viscosity over entropy density ratios $\eta/s(T)$ and $\zeta/s(T)$, respectively.
- In this work [1], the most recent QCD-based parameters are provided as input to the MUSIC framework. An $\eta/s(T)$ computed with a QCD based approach is used for the first time [2].



Description of the different phases

- **IP-Glasma** model is used to describe the initial energy density distribution [5,6]
  - realistic event-by-event fluctuations and non-zero pre-equilibrium flow

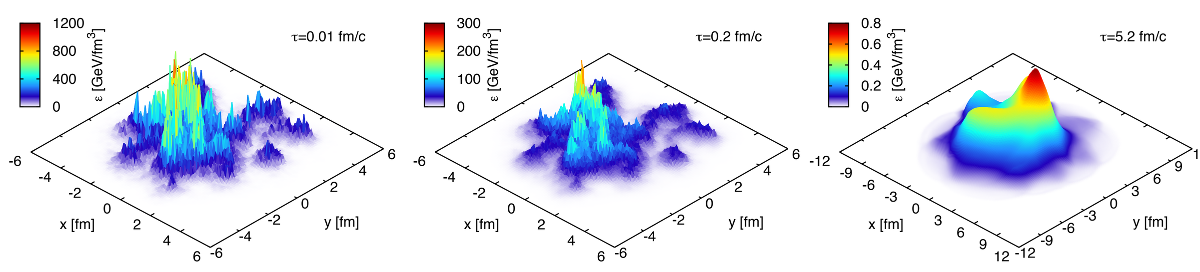
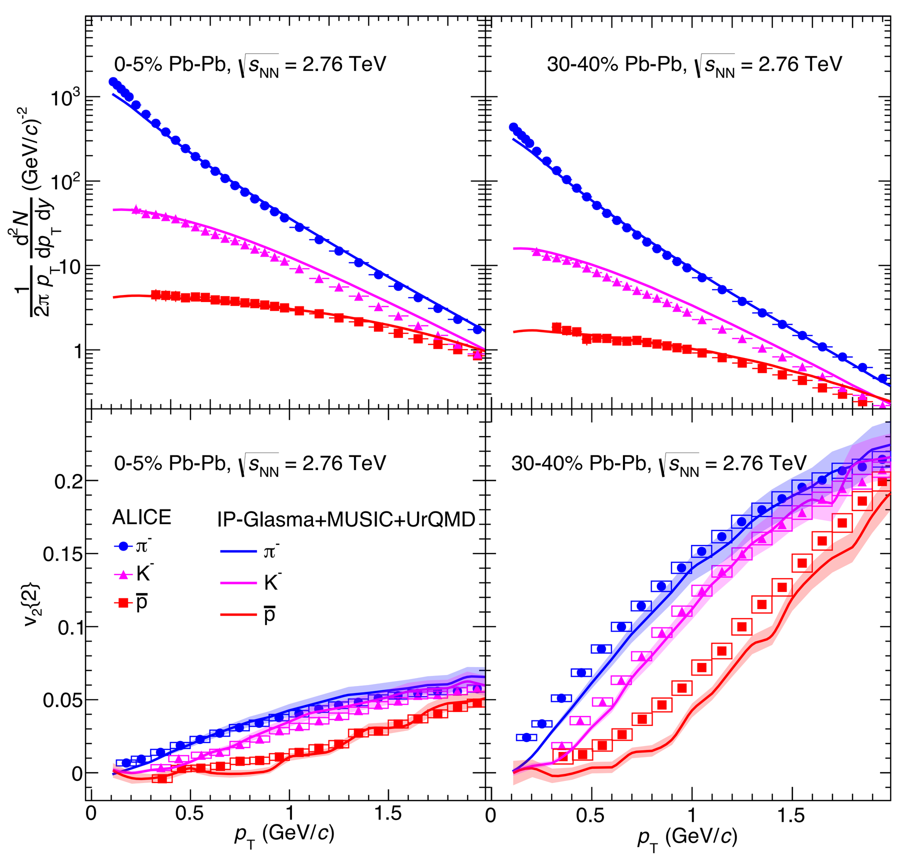


Figure taken from: Annu. Rev. Nucl. Part. Sci. 63 (2013) 123-151

- **MUSIC** code used to simulate the hydrodynamic phase
- **UrQMD** is used to describe the the dilute hadronic phase
  - T_{switch} = 145 MeV
- Particles are produced according to the **Cooper-Frye** equation
- **Out-of-equilibrium corrections** are included for both $\eta/s(T)$ and $\zeta/s(T)$

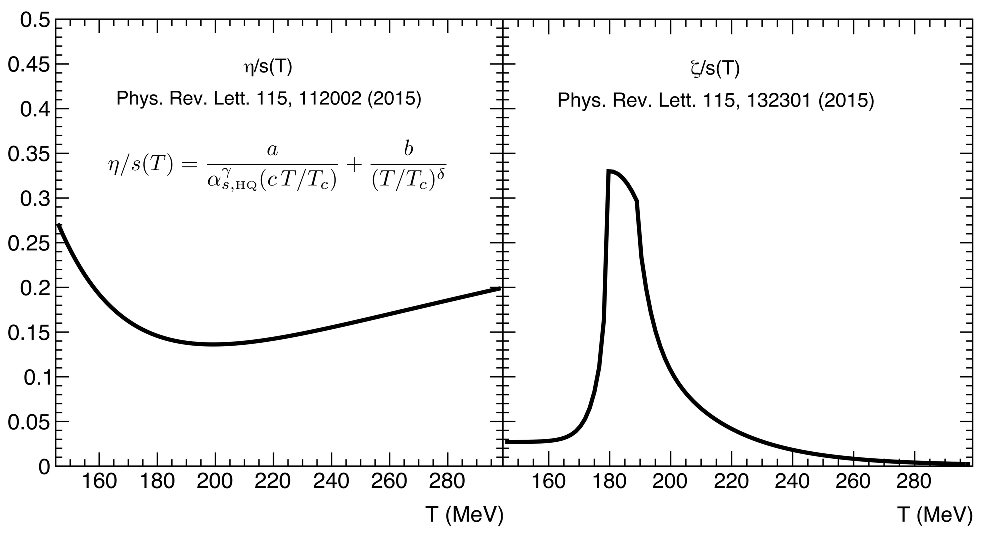
$$E\frac{dN_i}{d^3p} = \frac{gi}{(2\pi)^3}\int_\Sigma f_i(x,p)p^\mu d^3\sigma_\mu$$

p_T-differential observables



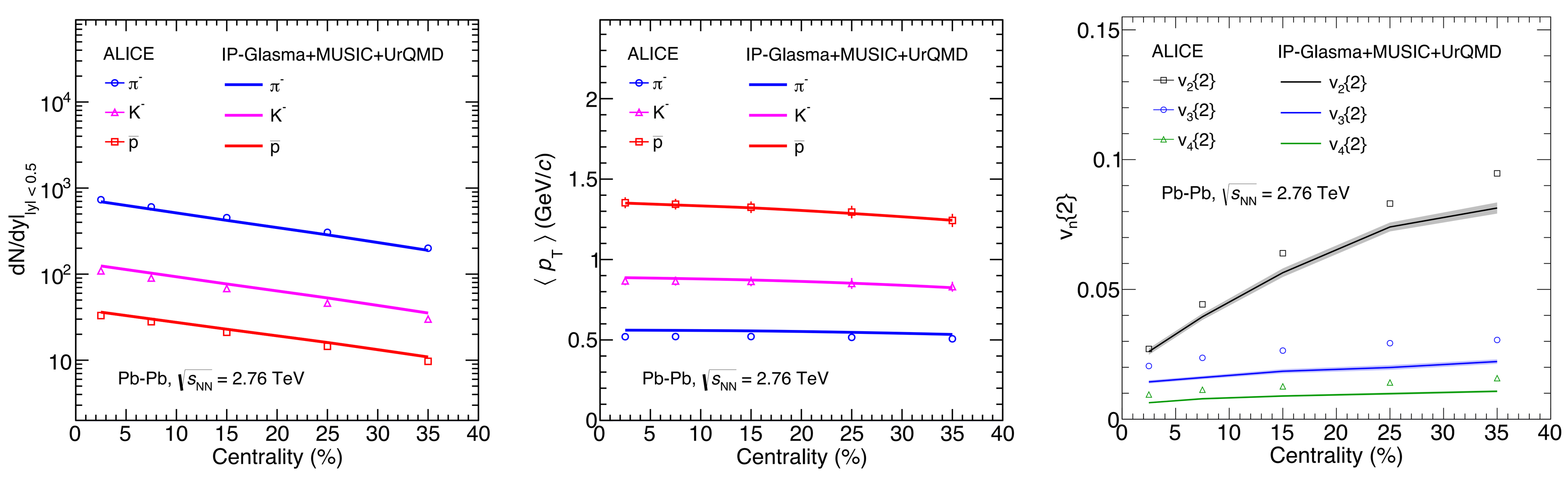
- Comparison of p_T **spectra** of identified hadrons
  - Insight about radial flow of the expanding system
- Comparison of p_T**-differential flow coefficients** of identified hadrons
  - interplay of radial and elliptic flow leads to the mass ordering of the v_n coefficients
  - v_n**{2} coefficients** are too suppressed at low p_T: important role played by the out-of-equilibrium correction from bulk viscosity

Inputs to the hydro simulation



- **EoS** from(2+1)-flavour Hot-QCD [3]
- $\mathbf{T_c}$ = 155 MeV
- $\boldsymbol{\eta}$**/s(T)** from a functional diagrammatical approach to QCD transport coefficients [2]
- $\boldsymbol{\zeta}$**/s(T)** from phenomenological parameterization [4]

Centrality-dependent observables

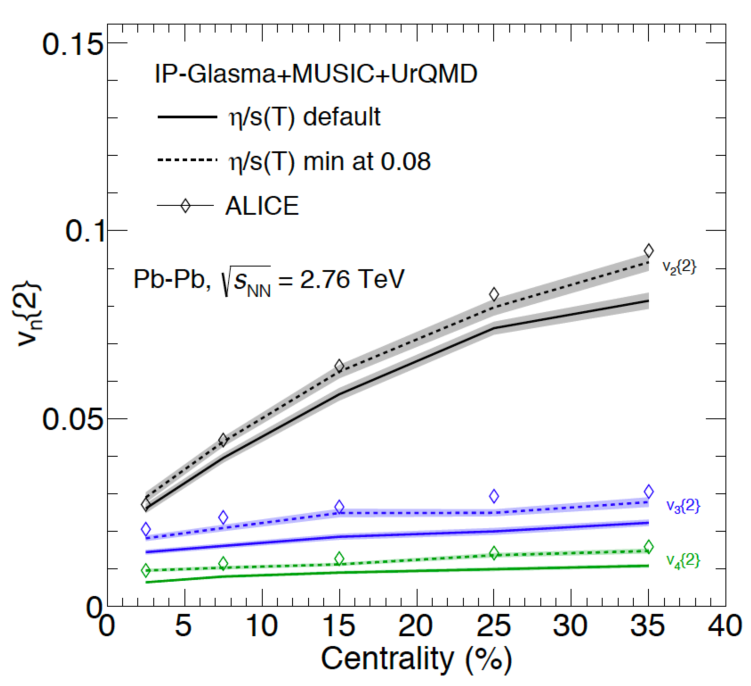


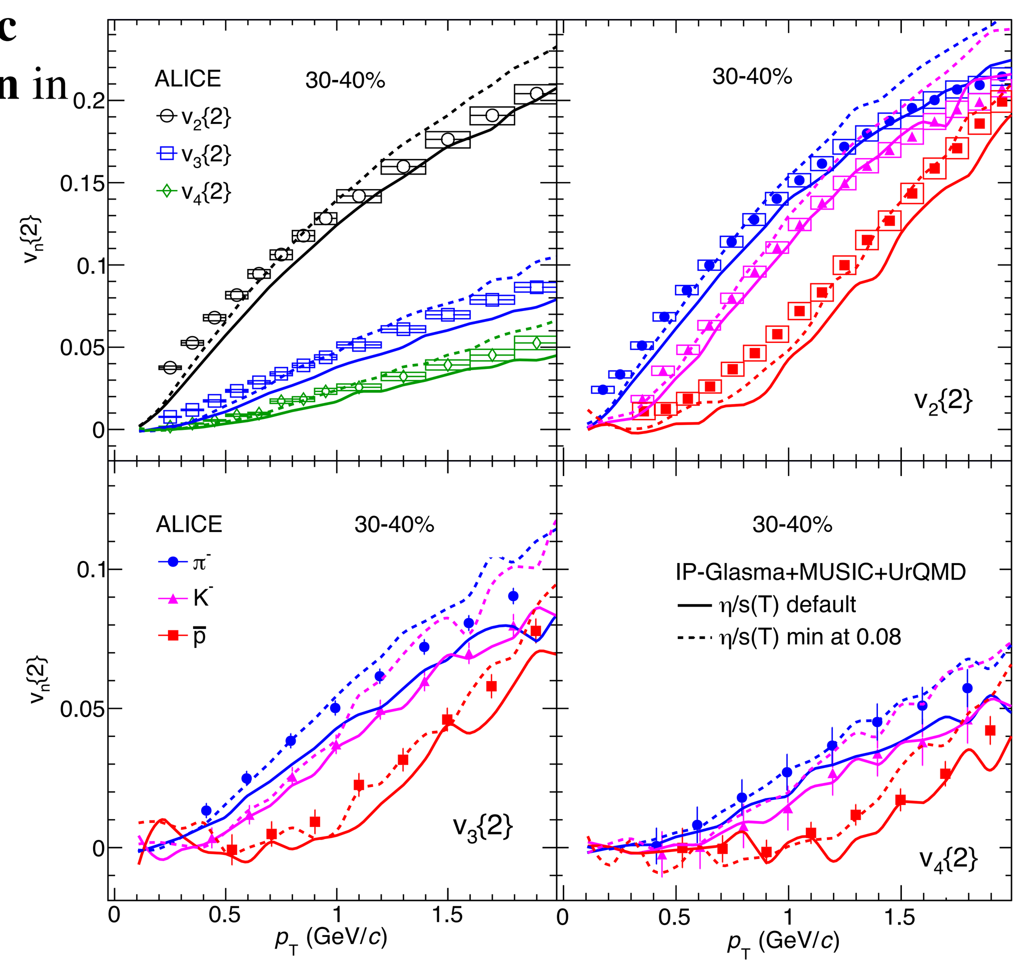
- **Pion, kaon and proton multiplicities** at mid-rapidity as a function of collision centrality for Pb-Pb collisions at 2.76 TeV obtained from the simulations are in good agreement with the experimental measurements performed by ALICE
- Good description of the **mean-p_T** for identified hadrons
  - **bulk viscosity** and the **UrQMD** phase play a crucial role in the simulation
- v_n**{2} coefficients** are too suppressed in the simulation, especially when moving to more peripheral collision centrality classes. This is because $\eta/s(T)$ is likely too large in the region below T = 200 MeV

Shifting the η/s(T) within the systematic

Estimate of the impact of the **systematic** error of $\eta/s(T)$: **shift the whole function** in order to have the **minimum at 0.08**

$$\eta/s(T) \to \eta/s(T) + d, \qquad d \in [-0.06, 0]$$





- Results of p_T-integrated v_n of our calculations are in agreement within the statistical uncertainties with the experimental measurements by ALICE
- $v_n\{2\}(p_T)$ coefficients for charged and identified hadrons obtained with the modified $\eta/s(T)$ deviate from the data at high p_T, but a better agreement with data is observed for p_T < 1 GeV/c, where most particles are produced

Conclusions

- In this contribution, we compare results from a hybrid model of IP-Glasma initial conditions, shear and bulk viscous hydrodynamics (MUSIC), and microscopic hadronic transport (UrQMD) with a wide range of integrated and differential measurements in Pb–Pb collisions at 2.76 TeV.
- The shear viscosity over entropy density ratio from a functional diagrammatical approach to QCD transport coefficients has been used for the first time
- **Outlook:** Usage of more transport coefficients computed from first principles and computation of flow harmonics for strange and multi strange hadrons

[1] arXiv:1805.02985
[2] Phys. Rev. Lett. 115, 112002 (2015)
[3] Phys. Rev. D 90, 094503 (2014)
[4] Phys. Rev. C 80, 064901 (2009)
[5] Phys. Rev. Lett. 108, 252301 (2012)
[6] Phys. Rev. C86, 034908 (2012)