Introduction

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Hadron and heavy-ion physics in a broader context

- Research fields touching/overlapping with particle physics, nuclear physics, ultra-cold gases, cosmology and gravitational wave physics
  $\rightarrow$ **A field at a crossing point** with a large number of interfaces

- Treating fundamental questions of physics:
  $\rightarrow$ transition from single to multi-body system description, thermalisation of (isolated) quantum systems
  $\rightarrow$ Transitions and interplay of dilute and dense descriptions, quantum and classical concepts validity and their transitions

- Facilities for neighboring fields without equivalence
  $\rightarrow$ hydrodynamic response to initial geometry: anistropic flow analysis
  $\rightarrow$ Large photon fluxes in clean environment: ultra-peripheral collisions
  $\rightarrow$ tests of standard model at moderate/low Q^2 as input for particle physics e.g. $\sin\theta_W$

Hadron and heavy-ion physics: physics track record in last years

- New signatures of deconfinement with quarkonium
  $\rightarrow$ breakdown of static picture of quarkonium prior to LHC
- Hydrodynamics established including fluctuations
  $\rightarrow$ nuclear structure, proton fluctuations
- Collectivity in small systems
  $\rightarrow$ breakdown of jet universality prior to LHC, advance thermalisation
- Depleted gluon density in the nucleus
  $\rightarrow$ constraints on saturation
- Jet quenching studies with full jets
  $\rightarrow$ new multi-scale probe program
- Energy-momentum tensor from theory & pheno
  $\rightarrow$ guidance of the experimental programs
- Lattice QCD for hadron structure
  $\rightarrow$ combined fits of experimental and lattice data
- Precision TMD fits
  $\rightarrow$ input to precision electro-weak HEP physics

Hadron and heavy-ion physics: instrumentation track record in last years

- new collision systems including asymmetric beyond LHC design
  $\rightarrow$ pPb, XeXe, OO, pO: enlarging physics case of LHC $\rightarrow$ saturation, nuclear physics, cosmic ray showers, thermalisation
- Large scale CMOS trackers
  $\rightarrow$ input to future instrumentation upon accelerators
- Large scale GPU usage
  $\rightarrow$ big data science connection profiting from technology advance
- first fixed-target collisions at LHC
  $\rightarrow$ opening new physics opportunities for QGP and hadron structure

Hadron and heavy-ion physics: basis of advance

Innovative & dynamic field embracing risk

$\rightarrow$ **in physics concepts & instrumentation**

Data-driven field: perspectives and paradigms change based on new data

New quality of conclusions based on quantitative research

- advance in instrumentation & diversity of collision systems/types
- facilitated by idealised set-ups
  $\rightarrow$ heavy-ion physics: large energy clear time-ordered space-time picture
  $\rightarrow$ hadron structure: lepton/photon-hadron collisions

Hadron and heavy-ion physics: open questions

- Saturation:
  At which collision energy required in description?
- Thermalisation:
  How fast and in which collision system?
- Hadrons from partons, hadronisation:
  How do partons transition in hadrons in different environments?
- Partons in Hadrons, properties:
  How does the mass and the spin and not only the charge emerge from partons?
- Properties of deconfined matter:
  Which speed of sound + transport of charges and energy-momentum?
- Phase transition characterisation:
  Chiral restoration/deconfinement, where and how in phase diagram?

$\rightarrow$ Our ideas are in many aspects qualitative or based on plausibility or single measurement types and not on redundant evidence

A summary plot for illustration from heavy-ion physics

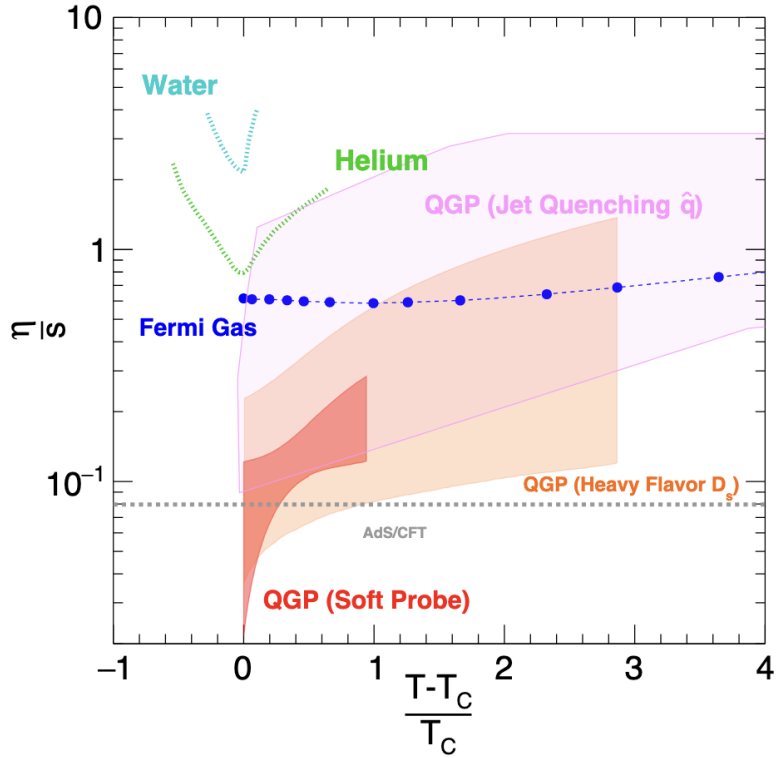

Figure 25: Compilation of the specific shear viscosity as a function of the temperature of the medium. To compare the properties of various media close to phase transition temperature, the temperature is normalized by the (pseudo-) critical temperature of the medium. A model-dependent translation of jet quenching parameter $\hat{q}$ and heavy quark diffusion coefficient D_s to specific shear viscosity is performed, and the results are shown as QGP (Jet quenching $\hat{q}$) and QGP (Heavy Flavor D_s) in the figure.

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Hadron and heavy-ion physics: more to come

Means to turn these ideas into textbook knowledge ... a biased list

- experimental extraction of the equation of state
- jet program with new measurement types
- new observables and larger kinematics for saturation physics
- exclusive physics with pQCD-save high Q^2 and high luminosity
- extension of deconfinement characterisation beyond vector state quarkonium decaying to dileptons and total heavy-quark production
- electromagnetic probes program in idealised set-up: chiral restoration and thermalisation
- interplay with gravitational waves in frequency domain of ground based interferometers (equation of state at high-mub) and pulsar time arrays (early universe cosmology for QCD transition)

New experimental facilities required
$\rightarrow$ QCD program of the HL-LHC
$\rightarrow$ Electron-ion collider

Hadron and heavy-ion physics in France

- around 130 permanent staff members in France organised within GDR QCD within CNRS/university/CEA
  $\rightarrow$ a large community
- 3 projects starting data taking in the 2030ies to be discussed today: ALICE3, EIC, LHCb U2

Goal of today's meeting

- Overview on planned contributions in the three major projects
  $\rightarrow$ ALICE3@HL-LHC, EPIC@EIC and LHCb U2@HL-LHC
  $\rightarrow$ focus on technical contributions
- reach out to full community
- Discussion on status with the directions of In2p3 and Irfu