Quark-Gluon Plasma Physics

6. Space-time evolution of the QGP
Basics of relativistic hydrodynamics
Evidence for collective behavior in heavy-ion collisions

- Shape of low-$\rho_T$ transverse momentum spectra for particles with different masses
- Azimuthal anisotropy of produced particles
- Source sizes from Hanbury Brown-Twiss correlations
- …
Evidence for radial flow

- Shape is different in pp and A-A
- Stronger effect for heavier particles

\[
\frac{1}{(2\pi p_T)} \frac{d^2N}{dp_T dy} \quad (\text{GeV/c})^2
\]

\[
\sqrt{s_{NN}} = 2.76 \text{ TeV}
\]

\[
p_T \quad (\text{GeV/c})
\]

\[
\begin{align*}
\text{pp} & \quad \text{Pb-Pb} \\
\times 300 & \quad 0-5\% \text{ central} \\
\circ \quad \text{\pi}^\pm & \quad \text{\textcolor{blue}{\textbf{K}}^\pm \times 0.1} \\
\square & \quad \text{\textcolor{red}{p}+\textcolor{red}{\bar{p}} \times 0.01}
\end{align*}
\]
Evidence for elliptic flow

Good explanation: Azimuthal variation of the flow velocity
Basics of relativistic hydrodynamics

Standard thermodynamics: $P$, $T$, $\mu$ constant over the entire volume

Hydrodynamics assumes local thermodynamic equilibrium: $P(x^\mu)$, $T(x^\mu)$, $\mu(x^\mu)$

Local thermodynamic equilibrium only possible if mean free path between two collisions much shorter than all characteristic scales of the system:

$$\lambda_{mfp} \ll L$$

This is the limit of non-viscous hydrodynamics.

4-velocity of a fluid element:

$$u = \gamma(1, \vec{\beta}), \quad u^\mu u_\mu = 1$$

$$\gamma = \frac{1}{\sqrt{1 - \beta^2}}$$
Number conservation

Mass conservation in nonrelativistic hydrodynamics:

\[ \frac{\partial \rho}{\partial t} + \nabla (\rho \vec{v}) = 0 \quad \text{[continuity equation]} \]

Lorentz contraction in the relativistic case: \( \rho \rightarrow n_\gamma = n u^0 \)

The continuity equation then reads:

\[ \frac{\partial (n u^0)}{\partial t} + \nabla (n \vec{u}) = 0 \]

The conservation of \( n \) can be written more elegantly as

\[ \partial_\mu (n u^\mu) = 0 \]

For a general 4-vector \( a \) we have:

\[ \partial_\mu \equiv \frac{\partial}{\partial x^\mu} = \left( \frac{\partial}{\partial t}, \nabla \right), \quad \partial^\mu \equiv \frac{\partial}{\partial x^\mu} = \left( \frac{\partial}{\partial t}, -\nabla \right), \quad \partial_\mu a^\mu = \left( \frac{\partial}{\partial t}, \nabla \right) \cdot (a^0, \vec{a}) = \frac{\partial a^0}{\partial t} + \nabla \vec{a} \]
Energy and momentum conservation

Analogous to the contravariant 4-vector $J^\mu = n u^\mu$ one can define conserved currents for the energy and the three moments components. These can be written as contravariant tensor:

$$ T^{\mu\nu} \quad \nu : \text{component of the 4-momentum} $$

$$ \mu : \text{component of the associated current} $$

$$ T^{\mu\nu} = \begin{pmatrix} \text{energy density} & \text{momentum density} \\ \text{energy flux density} & \text{momentum flux density} \end{pmatrix} $$

$T^{00}$: the energy density

$T^{0j}$: density of the $j$-th component of the momentum, $j = 1, 2, 3$

$T^{i0}$: energy flux along axis $i$

$T^{ij}$: flux along axis $i$ of the $j$-th component of the momentum

Examples: $T^{00} = \frac{\partial E}{\partial x \partial y \partial z} \equiv \varepsilon$, $T^{11} = \frac{\partial p_x}{\partial t \partial y \partial z}$

force in $x$ direction acting on an surface $\Delta y \Delta z$ perpendicular to the force $\rightarrow$ pressure
Equations of non-viscous hydrodynamics

Energy-momentum tensor in the fluid rest frame:

\[ T^\mu_\nu = \begin{pmatrix} \varepsilon & 0 & 0 & 0 \\ 0 & P & 0 & 0 \\ 0 & 0 & P & 0 \\ 0 & 0 & 0 & P \end{pmatrix} \]

rest frame: pressure is the same in all direction, constant energy density and momentum

For an arbitrary fluid velocity:

(without derivation)

\[ T^\mu_\nu = (\varepsilon + P) u^\mu u^\nu - Pg^\mu_\nu \]

Energy, momentum and baryon number conservation then be written as

\[ \partial_\mu T^\mu_\nu = 0 \quad \partial_\mu (n u^\mu) = 0 \]

5 equations for 6 unknowns:

\( (u_x, u_y, u_z, \varepsilon, P, n_B) \)
Ingredients of hydrodynamic models

- Equation of state (EoS) needed to close the system:
  \[ P(\varepsilon, n_B) \]

- Via the EoS hydrodynamics allows one to relate observables with QCD thermodynamics

- Initial conditions \((\varepsilon(x, y, z))\)
  - Glauber MC
  - Color glass condensate

- Transition to free-streaming particles
  - E.g. at given local temperature

Simple equations of state:

- **EOS I**: ultra-relativistic gas \(P = \varepsilon/3\)
- **EOS H**: resonance gas, \(P \approx 0.15 \varepsilon\)
- **EOS Q**: phase transition, QGP \(\leftrightarrow\) resonance gas
Cooper-Frye freeze-out formula

Particle spectra from fluid motion:

\[
E \frac{dN}{d^3p} = \frac{1}{2\pi p_T} \frac{d^3N}{dp_T dy d\varphi} = \int_{\Sigma_f} f(x, p) p^\mu d\Sigma_\mu
\]

In rest frame of the fluid cell: \( u^\mu = (1, 0, 0, 0) \sim p_\mu \cdot u^\mu = E \)
Longitudinal expansion: Bjorken's scaling solution (I)

The Bjorken model is a 1d hydrodynamic model (expansion only in $z$ direction). The initial conditions correspond to the one which one would get from free streaming particles starting at $(t, z) = (0, 0)$.

\[ \beta_z = \frac{z}{t} \]

proper time:
\[ \tau = \frac{t}{\gamma} = t \sqrt{1 - \beta_z^2} = \sqrt{t^2 - z^2} \]

Initial conditions in the Bjorken model:
\[ \epsilon(\tau_0) = \epsilon_0, \quad u^\mu = \frac{1}{\tau_0}(t, 0, 0, z) = \frac{x^\mu}{\tau_0} \]

In this case the equations of ideal hydrodynamics simplify to
\[ \frac{d\epsilon}{d\tau} + \frac{\epsilon + p}{\tau} = 0 \]
Longitudinal expansion: Bjorken's scaling solution (II)

For an ideal gas of quarks and gluons, i.e., for

\[ \varepsilon = 3p, \quad \varepsilon \propto T^4 \]

this gives

\[ \varepsilon(\tau) = \varepsilon_0 \left( \frac{\tau}{\tau_0} \right)^{-4/3}, \quad T(\tau) = T_0 \left( \frac{\tau}{\tau_0} \right)^{-1/3} \]

The temperature drops to the critical temperature at the proper time

\[ \tau_c = \tau_0 \left( \frac{T_0}{T_c} \right)^3 \]

The QGP lifetime is therefore given by

\[ \Delta \tau_{QGP} = \tau_c - \tau_0 = \tau_0 \left[ \left( \frac{T_0}{T_c} \right)^3 - 1 \right] \]
Mixed phase in the Bjorken model

Entropy conservation in ideal hydrodynamics leads in the case of the Bjorken model (independent of the equation of state) to

\[ s(\tau) = \frac{s_0 \tau_0}{\tau} \]

actually independent of the EOS, in case of an the ideal QGP:

\[ s = \frac{\varepsilon + p}{T} = \frac{4 \varepsilon}{3 T} = \frac{4 \varepsilon_0}{3 T_0} \frac{\tau_0}{\tau} \]

If we consider a QGP/hadron gas phase transition we have a first order phase transition and a mixed phase with temperature \( T_c \). The entropy in the mixed phase is given by

\[ s(\tau) = s_{\text{HG}}(T_c) \xi(\tau) + s_{\text{QGP}}(T_c)(1 - \xi(\tau)) = \frac{s_0 \tau_0}{\tau} \]

This equation determines the time dependence of \( \xi(\tau) \) and the time \( \tau_h \) at which the mixed phase vanishes:

\[ \xi(\tau) = \frac{1 - \tau_c/\tau}{1 - g_{\text{HG}}/g_{\text{QGP}}} \quad \implies \quad \tau_h = \tau_c \frac{g_{\text{QGP}}}{g_{\text{HG}}} \]

the hadron gas close to \( T_c \) can be described with \( g_{\text{HG}} \approx 12 \)
Temperature evolution in the Bjorken model

The graph shows the temperature evolution in the Bjorken model over time. The temperature $T_0 = 250$ MeV drops sharply to reach a plateau in the Quark-Gluon Plasma (QGP) phase. The critical temperature $T_c = 170$ MeV is indicated, and the final temperature $T_f = 150$ MeV is reached. The graph also indicates the transition between the QGP phase and the hadron phase (HHG).
Transverse expansion

Transverse expansion of the fireball in a hydro model (temperature profile)

2+1 d hydro: Bjorken flow in longitudinal direction

temperature in GeV

velocity vector
Temperature Contours and Flow lines

flow lines indicate motion of fluid cells
Hydrodynamic modeling of heavy-ion collisions: State of the art

- Equation of state from lattice QCD
- (2+1)D or (3+1)D viscous hydrodynamics
- Fluctuating initial conditions (event-by-event hydro)
- Hydrodynamic evolution followed by hadronic cascade

![Diagram showing event-by-event hydro: two different freeze-out surfaces](arXiv:1009.3244)
Initial conditions from gluon saturation models (I)

**Graph: Gluon Density**
- $Q^2 = 20$ GeV$^2$
- $Q^2 = 200$ GeV$^2$
- $Q^2 = 5$ GeV$^2$

Growth of gluons saturates at an occupation number $1/\alpha_s$. This defines a (semihard) scale $Q_s(x)$, i.e., a typical gluon transverse momentum.

\[
\frac{1}{2(N_c^2 - 1)} \frac{xG(x, Q_s^2)}{\pi R^2 Q_s^2} = \frac{1}{\alpha_s(Q_s^2)}
\]
Initial conditions from gluon saturation models (II)

- Color glass condensate:
  Effective field theory, which describes universal properties of saturated gluons in hadron wave functions

- CGC dynamics produces so-called glasma-field configurations at early times
  - Strong longitudinal chromoelectric and chromomagnetic fields screened on transverse distance scales \(1/Q_s\).

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Schenke, Tribedy, Venugopalan, PRL108, 252301 (2012)

Annu. Rev. Nucl. Part. Sci. 2010.60:463
Spectra and Radial flow
Comparison of $\pi$, $K$, $p$ spectra with hydro models
The blast-wave model: A Simple model to describe the effect of radial flow on particle spectra

Transverse velocity profile: \[ \beta_T(r) = \beta_s \left( \frac{r}{R} \right)^n \]

Superposition of thermal sources with different radial velocities:

\[
\frac{1}{m_T} \frac{dn}{dm_T} \propto \int_{0}^{R} r \, dr \, m_T \, l_0 \left( \frac{p_T \sinh \rho}{T} \right) K_1 \left( \frac{m_T \cosh \rho}{T} \right)
\]

\[ \rho := \text{arctanh}(\beta_T) \quad \text{"transverse rapidity"} \]

\[ l_0, K_1 : \text{modified Bessel functions} \]


Freeze-out at a 3d hyper-surface, typically instantaneous, e.g.:

\[ t_f(r, z) = \sqrt{\tau_f^2 + z^2} \]
Example: Radial Flow Velocity Profile from Blast-wave Fit to 2.76 TeV Pb-Pb Spectra (0-5%)

\[ \beta_T(r) = \beta_s \left( \frac{r}{R} \right)^n \]

\[ \langle \beta_T \rangle = 0.651 \]

\[ n = 0.712 \]

\[ \langle \beta_T \rangle = 0.651, \quad n = 0.712 \]

\[ \beta_s = 0.8 \]

arXiv:1303.0737
Example: Pion and Proton $p_T$ Spectra from blast-wave model

Parameters for 0-5% most central Pb-Pb collisions at 2.76 TeV, arXiv:1303.0737

Larger $p_T$ kick for particles with higher mass:

$$ p = \beta_{\text{source}} \gamma_{\text{source}} m + \text{"thermal"} $$
Local slope of $m_T$ spectra with radial flow

$m_T$ slopes with transverse flow for pions for fixed transverse expansion velocity $\beta_r$

$$\lim_{m_t \to \infty} \frac{d}{dm_T} \ln \left( \frac{1}{m_T} \frac{dn}{dm_T} \right) = -\frac{1}{T} \sqrt{\frac{1 - \beta_r}{1 + \beta_r}}$$

The apparent temperature, i.e., the inverse slope at high $m_T$, is larger than the original temperature by a blue shift factor:

$$T_{\text{eff}} = T \sqrt{\frac{1 + \beta_r}{1 - \beta_r}}$$
Blast-wave fit for CERN SPS data (NA49)

![Graph showing blast-wave fit for baryons and anti-baryons with fitted parameters: T=125 ± 3 MeV, β_T = 0.48 ± 0.01, χ^2/NDF=100/41 for baryons, and T=121 ± 3 MeV, β_T = 0.48 ± 0.01, χ^2/NDF=49/41 for anti-baryons.](image)
Blast-wave fit LHC

Works well for K and p

For pions, the contribution from resonance decays at low $p_T$ and hard scattering at high $p_T$ probably explains the discrepancy
$T$ und $\langle \beta \rangle$ for different centralities at RHIC and the LHC

10% larger flow velocities in central collisions at the LHC than at RHIC
Elliptic flow and higher flow harmonics
Azimuthal distribution of produced particles

\[
\frac{dN}{d\varphi} \propto 1 + 2 \sum_{n=1}^{\infty} v_n \cos[n(\varphi - \Psi_n)]
\]

Fourier coefficients:

\[ v_n(p_T, y) = \langle \cos[n(\varphi - \Psi_n)] \rangle \]

- \( v_2 \): elliptic flow
- \( v_3 \): triangular flow
- \( v_4 \)
- \( v_5 \)

\[ f(\varphi) = 1 + 2v_n \cos(n\varphi) \]
Origin of odd flow components

- $v_2$ is related to the geometry of the overlap zone
- Higher moments result from fluctuations of the initial energy distribution

Müller, Jacak, [http://dx.doi.org/10.1126/science.1215901](http://dx.doi.org/10.1126/science.1215901)
Hydrodynamic models: $v_2/\varepsilon$ approx. constant

Ideal hydrodynamics gives $v_2 \approx 0.2 - 0.25 \varepsilon$

$v_2/\varepsilon_x$

$\varepsilon_x$: initial eccentricity of the participants
How the $v_n$ are measured (1):
Event plane method (more or less obsolete by now)

Event flow vector $Q_n$
e.g., measured at forward rapidities:

$$Q_n = \sum_k e^{in\varphi_k} = |Q_n|e^{in\psi_{n,\text{rec}}} = Q_{n,x} + iQ_{n,y}$$

Event plane angle
reconstructed in a given event:

$$\psi_{n,\text{rec}} = \frac{1}{n}\text{atan2}(Q_{n,y}, Q_{n,x})$$

Reconstructed event plane angle fluctuates around “true” reaction plane angle.
The reconstructed $v_n$ is therefore corrected for the event plane resolution:

$$v_n = \frac{v_{n,\text{rec}}}{R_n}, \quad v_{n,\text{rec}} = \langle \cos[n(\varphi - \psi_{n,\text{rec}})] \rangle, \quad R_n = "\text{resolution correction}"$$

What the event plane methods measures depends on the resolution
which depends on the number of particles used in the event plane determination:

$$\langle v^\alpha \rangle^{1/\alpha} \quad \text{where} \quad 1 \leq \alpha \leq 2$$

Therefore other methods are used today where possible.
How the $v_n$ are measured (2):
Cumulants

Two-particle correlations:
\[
\langle \langle e^{i2(\varphi_1 - \varphi_2)} \rangle \rangle = \langle \langle e^{i2(\varphi_1 - \psi_{RP} - (\varphi_2 - \psi_{RP}))} \rangle \rangle,
\]
\[
= \langle \langle e^{i2(\varphi_1 - \psi_{RP})} \rangle \langle e^{-i2(\varphi_2 - \psi_{RP})} \rangle \rangle = \langle v_2^2 \rangle,
\]
if correlations are only due to collective flow

Cumulants:
\[
c_n\{2\} \equiv \langle \langle e^{in(\varphi_1 - \varphi_2)} \rangle \rangle = \langle v_n^2 \rangle,
\]
\[
c_n\{4\} \equiv \langle \langle e^{in(\varphi_1 + \varphi_2 - \varphi_3 - \varphi_4)} \rangle \rangle - 2 \langle \langle e^{in(\varphi_1 - \varphi_2)} \rangle \rangle^2 = \langle -v_n^4 \rangle.
\]

$c_n\{4\}$ is a measure of genuine 4-particle correlations, i.e., it is insensitive to two-particle non-flow correlations. It can, however, still be influenced by higher-order non-flow contributions.

\[
v_n\{2\}^2 := c_n\{2\}, \quad v_n\{4\}^4 := -c_n\{4\}.
\]
Non-flow effects

Not only flow leads to azimuthal correlations. Examples: resonance decays, jets, …

\[ v_n\{2\}^2 = \langle v_n^2 \rangle + \delta_n \]

Different methods have different sensitivities to nonflow effects. The 4-particle cumulant method is significantly less sensitive to nonflow effects than the 2-particle cumulant method.

Example:
\[ v_2 = 0, \quad v_2\{2\} > 0 \]
Elliptic flow of identified hadrons: Reproduced by viscous hydro with $\eta/s = 0.2$

Dependence of $v_2$ on particle mass ("mass ordering") is considered as strong indication for hydrodynamic space-time evolution.

Final results: arXiv:1405.4632
## Viscosity

### Pitch drop experiment, started in Queensland, Australia in 1927

<table>
<thead>
<tr>
<th>Date</th>
<th>Event</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>1927</td>
<td>Hot pitch poured</td>
<td></td>
</tr>
<tr>
<td>October 1930</td>
<td>Stem cut</td>
<td></td>
</tr>
<tr>
<td>December 1938</td>
<td>1st drop fell</td>
<td>8.1</td>
</tr>
<tr>
<td>February 1947</td>
<td>2nd drop fell</td>
<td>8.2</td>
</tr>
<tr>
<td>April 1954</td>
<td>3rd drop fell</td>
<td>7.2</td>
</tr>
<tr>
<td>May 1962</td>
<td>4th drop fell</td>
<td>8.1</td>
</tr>
<tr>
<td>August 1970</td>
<td>5th drop fell</td>
<td>8.3</td>
</tr>
<tr>
<td>April 1979</td>
<td>6th drop fell</td>
<td>8.7</td>
</tr>
<tr>
<td>July 1988</td>
<td>7th drop fell</td>
<td>9.2</td>
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<td>November 2000</td>
<td>8th drop[A]</td>
<td>12.3</td>
</tr>
<tr>
<td>April 2014</td>
<td>9th drop[B]</td>
<td>13.4</td>
</tr>
</tbody>
</table>

Meaningful comparison of different fluids: $\eta/s$

[https://en.wikipedia.org/wiki/Pitch_drop_experiment](https://en.wikipedia.org/wiki/Pitch_drop_experiment)
Shear and bulk viscosity

Shear viscosity

Acts against buildup of flow anisotropies ($v_2, v_3, v_4, v_5, \ldots$)

Bulk viscosity

Acts against buildup of radial flow
Higher flow harmonics are particularly sensitive to $\eta/s$

Major uncertainty in extracting $\eta/s$ from data: uncertainty of initial conditions
\( \eta/s \) from comparison to data

\[
\left\langle v_n^2 \right\rangle^{1/2}
\]

\begin{align*}
\text{ATLAS 20-30\%, EP} \\
\text{\( v_2 \)} & \quad \text{red} \\
\text{\( v_3 \)} & \quad \text{green dash} \\
\text{\( v_4 \)} & \quad \text{orange} \\
\text{\( v_5 \)} & \quad \text{blue dash}
\end{align*}

narrow: \( \eta/s(T) \)

wide: \( \eta/s = 0.2 \)

Current status (Pb-Pb at \( \sqrt{s_{NN}} = 2.76 \text{ TeV} \)):

\[
(\eta/s)_{QGP} \approx 0.2 = 2.5 \times \frac{1}{4\pi} \quad (20\% \text{ stat. err., } 50\% \text{ syst. err.})
\]
Universal aspects of the underlying physics

- Strongly-interacting degenerate gas of fermionic $^6\text{Li}$ atoms at 0.1 $\mu$K
- Cigar-shaped cloud initially trapped by a laser field
- Anisotropic expansion upon abruptly turning off the trap: Elliptic flow!
- $\eta/s$ can be extracted: [PhD thesis Chenglin Cao]

$$\left(\frac{\eta}{s}\right)^{^6\text{Li}}_{\text{gas}} \approx 0.4 = 5 \times \frac{1}{4\pi}$$

The ultimate goal is to unveil the universal physical laws governing seemingly different physical systems (with temperature scales differing by 19 order of magnitude)
Temperature-dependence of $\eta/s$ for different gases

$\eta/s$ appears to be minimal at a phase transition

QGP is a candidate for being the most perfect fluid

Conjectured lower bound from string theory

$$\eta/s|_{\text{KSS}} = \frac{1}{4\pi} \approx 0.08$$

in natural units

SI units: $$\eta/s|_{\text{KSS}} = \frac{\hbar}{4\pi k_B}$$

D meson $v_2$ in Pb-Pb: Heavy quarks seem to flow, too!

Given their large mass, it is not obvious that charm quarks take part in the collective expansion of the medium.
Collective flow in small systems?
Collectivity in small systems: 2-particle correlation in pp at $\sqrt{s} = 7$ TeV

No indication for collective effects in minimum bias pp collisions at 7 TeV
Radial flow in p-Pb?

Shape of spectra changes with \( dN_{ch}/d\eta \)

Increase of \( \langle p_T \rangle \) with \( dN_{ch}/d\eta \)

Effects which can be explained as resulting from radial flow
Results of blast-wave fits in p-Pb
Collectivity in small systems: Two-particle correlations in Pb-Pb collisions

50-60%

collective flow + jet correlations

near-side “ridge”
Collectivity in small systems:
Two-particle correlations in high-multiplicity pp and p-Pb collisions at the LHC

Flow-like two-particle correlation become visible in high-multiplicity pp and p-Pb collisions at the LHC

CMS N ≥ 110, 1.0 GeV/c < p_T < 3.0 GeV/c
p+p at √s = 7 TeV

(b) CMS pPb √s_NN = 5.02 TeV, 220 ≤ N_{trk}^{offline} < 260
1 < p_T^{trig} < 3 GeV/c
1 < p_T^{assoc} < 3 GeV/c
Comparison of $v_2$ in Pb-Pb and p-Pb for the same track multiplicity

- $v_2\{8\}$ measured: $v_2$ in p-Pb is a genuine multi-particle effect
- $v_2$ in p-Pb only slightly smaller than in Pb-Pb
Collectivity in small systems: Mass ordering in p-Pb collisions

$v_2$ from fit of two-particle correlation, jet-like correlation removed by taking the difference between central and peripheral p-Pb collisions

Consistent with hydrodynamic expansion of the medium also in p-Pb
Elliptic flow not only in high multiplicity pp collisions?

[Need to sort out apparent disagreement with CMS]
Summary/questions space-time evolution

- Hydrodynamic models provide an economic description of many observables (spectra, flow)
- Shear viscosity / entropy density ratio in Pb-Pb at $\sqrt{s_{NN}} = 2.76$ TeV from comparing hydrodynamic models to data:

$$\left(\frac{\eta}{s}\right)_{\text{QGP}} \approx 0.2 = 2.5 \times \frac{\eta}{s} \bigg|_{\text{min,KSS}} = 2.5 \times \frac{1}{4\pi}$$

- Appropriate theoretical treatment of thermalization and matching to hydrodynamics?
  - Strong coupling or weak coupling approach?
  - Weak coupling: Applicable at asymptotic energies, but still useful at current $\sqrt{s_{NN}}$
  - Strong coupling (string/gauge theory duality), see e.g. arXiv:1501.04952: Fast thermalization of the order of $1/T$, but too much stopping?
- Does one need hydrodynamics to explain collective effects in small system (pp, p-Pb)?