Initial conditions for fluid dynamics from a parton cascade model

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1. Motivation

We investigate the pre-equilibrium evolution of the QGP in ultrarelativistic heavy-ion collisions. We first parametrize the initial particle distribution function at $t = 0\,\mathrm{fm/c}$. Then the subsequent time-evolution of the distribution function, up to $t = 1\,\mathrm{fm/c}$, is modeled by solving the relativistic Boltzmann equation.

2. Parametrization

The initial single-particle distribution function reads as follows:

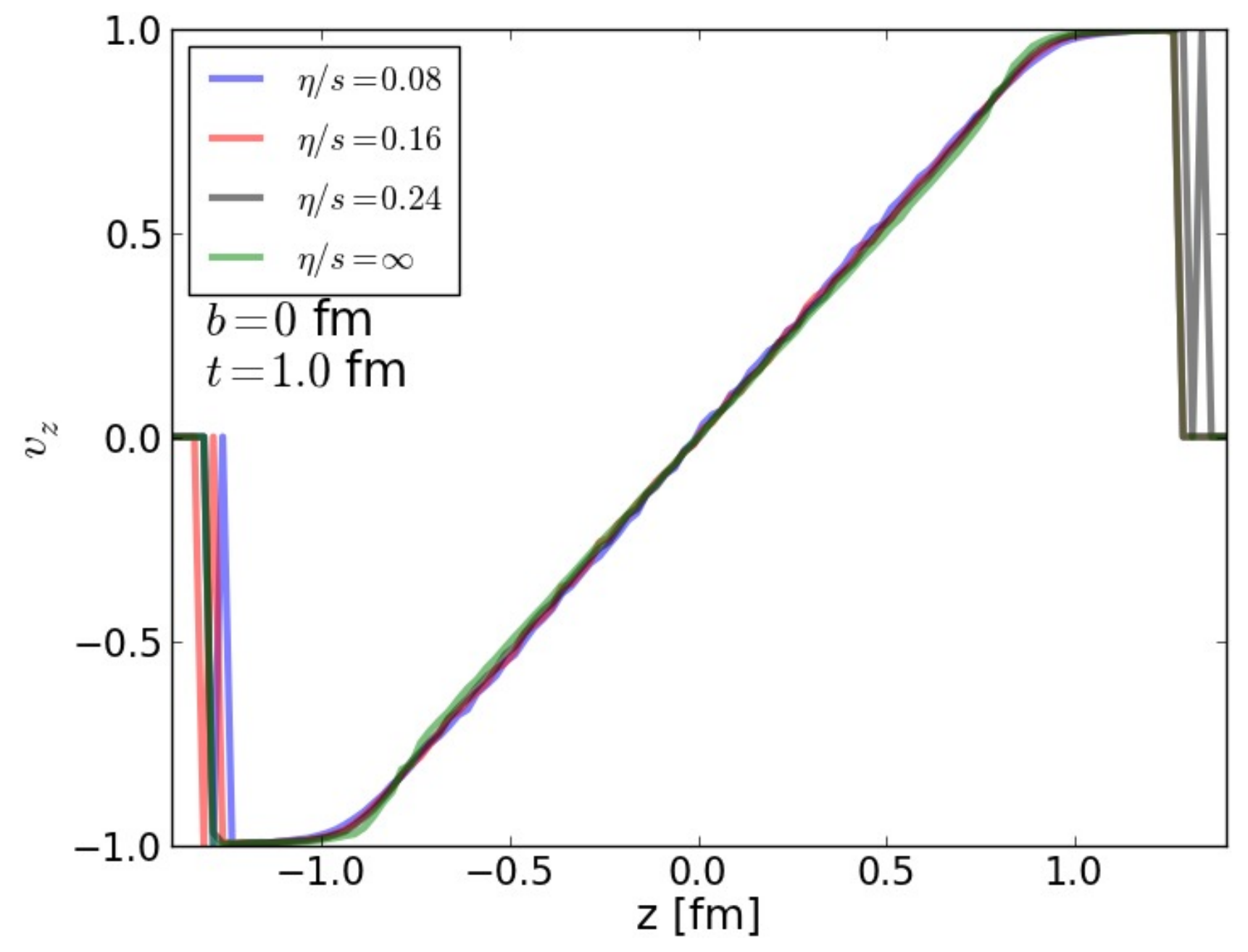
$$f(\mathbf{x},\mathbf{p}) = K\frac{1}{E}\left(\frac{Q^n}{Q^n+p_T^n}\right)^n e^{\left(-\frac{y^2}{\sigma_y^2}\right)}$$
$$\times e^{\left(-\frac{z^2}{\sigma_z^2}\right)} T_{\mathrm{A}}(\mathbf{x}_T-\frac{\mathbf{b}}{2})T_{\mathrm{B}}(\mathbf{x}_T+\frac{\mathbf{b}}{2})$$

- T_{A} and T_{B} are the nuclear thickness functions
- Parameters are: $Q = 0.6\,\mathrm{GeV}$, $n = 1.4$, $m = 5.5$, $\sigma_y = 2.25$ and $\sigma_z = 0.065\,\mathrm{fm}$
- The normalization: we use $K = 0.6$; for $\eta/s = 0.08$ and $\mathbf{b} = 0$, $e_{\max} = 30\,\mathrm{GeV/fm^3}$ at $0.6\,\mathrm{fm/c}$ and $z = 0\,\mathrm{fm}$

3. The Transport model BAMPS

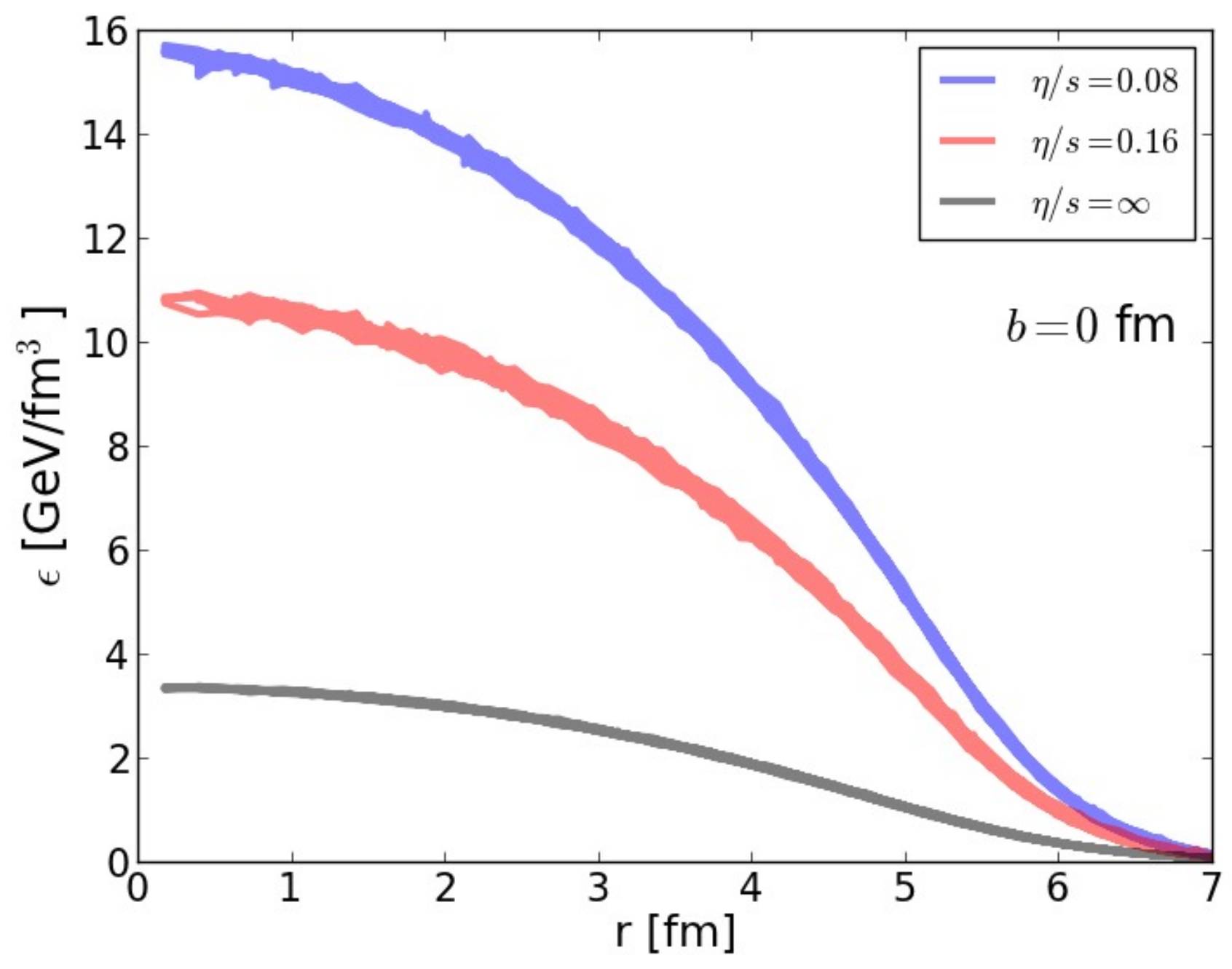
- The time evolution is solved by the Boltzmann approach for multi parton scatterings (**BAMPS**) [1] up to times of the order of $1\,\mathrm{fm/c}$
- Cross-section adjusted to give a constant η/s; we use two different impact parameters $\mathbf{b}$
- we consider only massless particles, binary collisions and an isotropic cross section

4. Scaling Flow

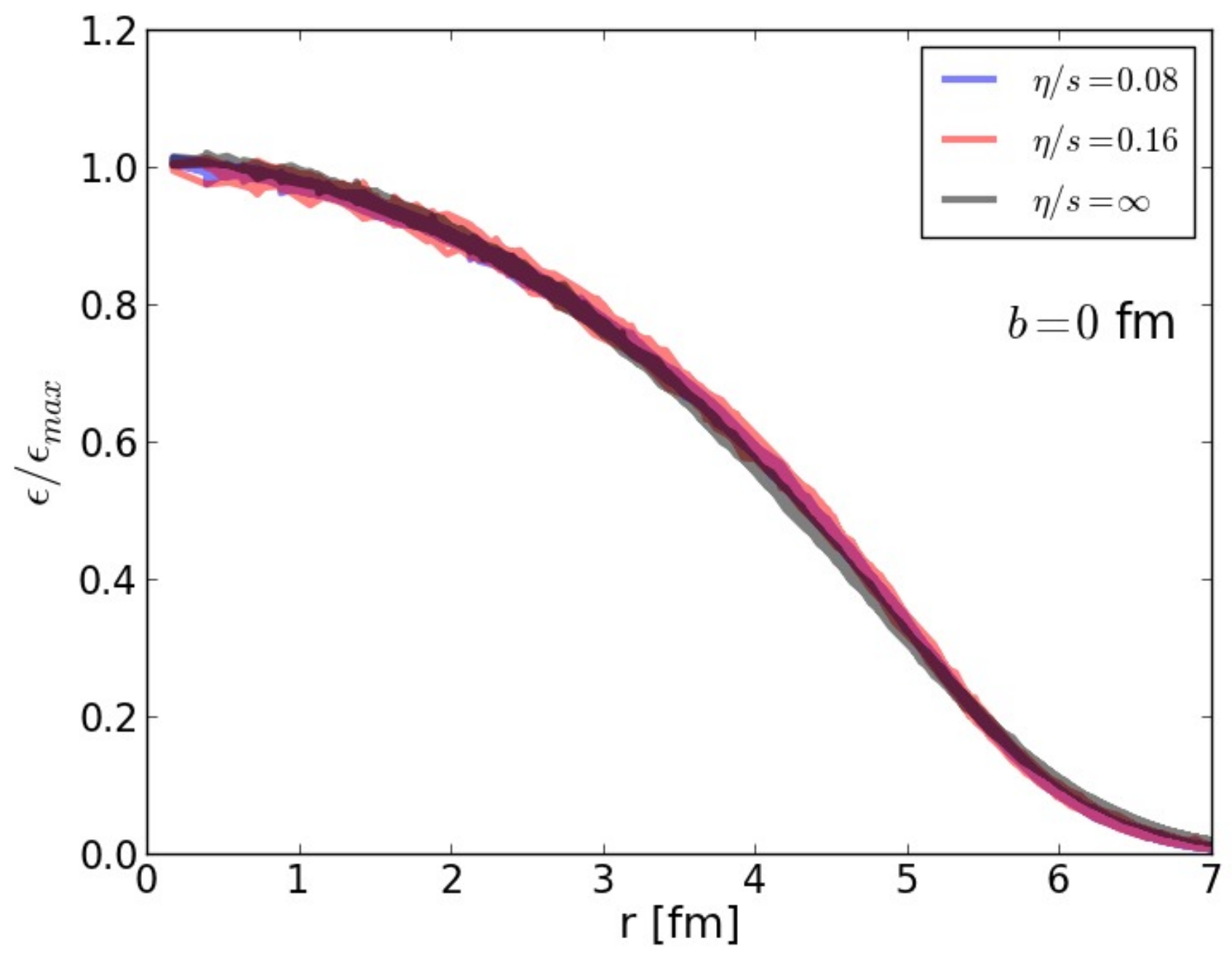


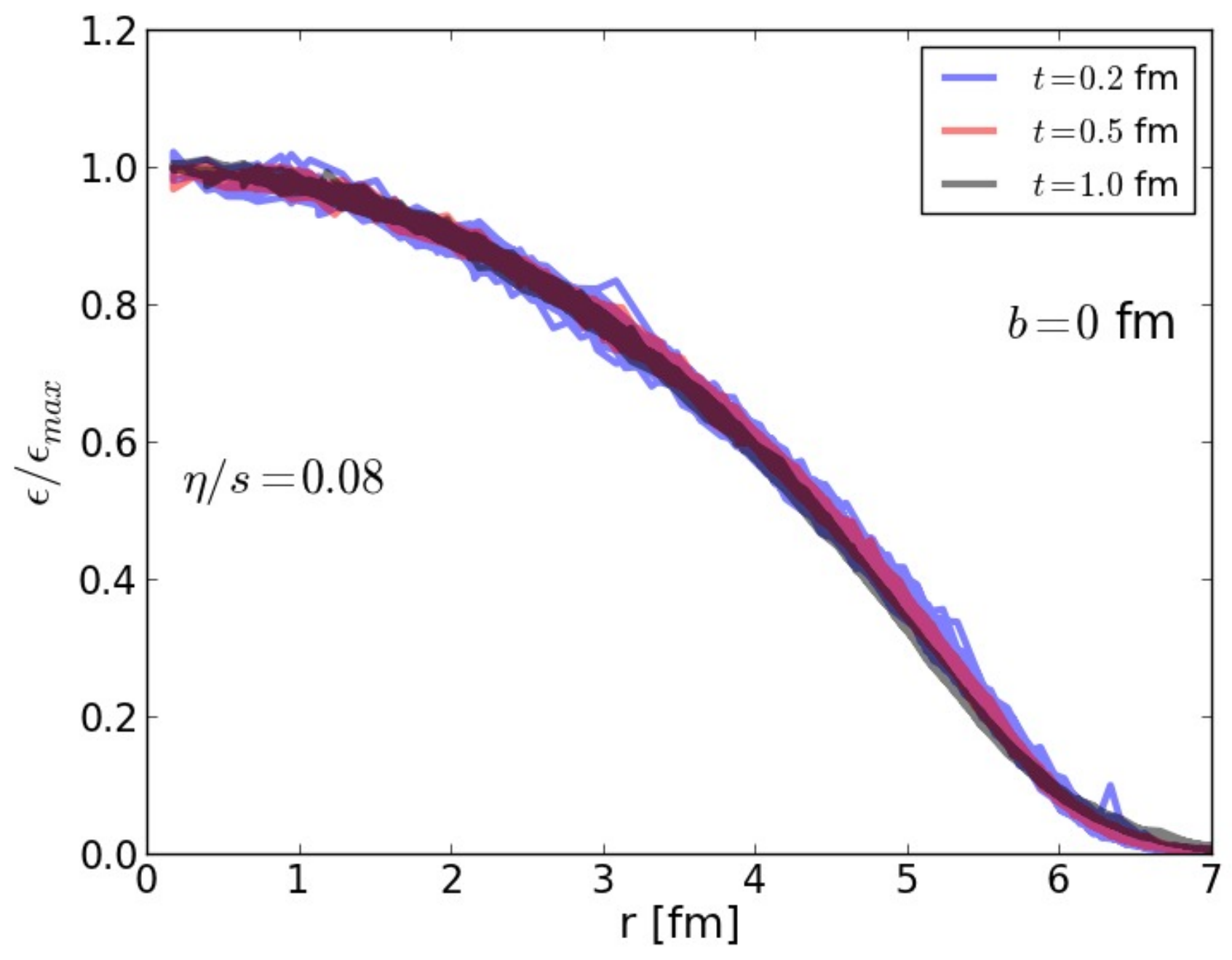
- Longitudinal velocity v_z at $r = 0\,\mathrm{fm}$ and $t = 1.0\,\mathrm{fm/c}$ and $\mathbf{b} = 0$
- Scaling flow ($v_z(z) = z/t$) reached for all choices of η/s

5. Energy Density



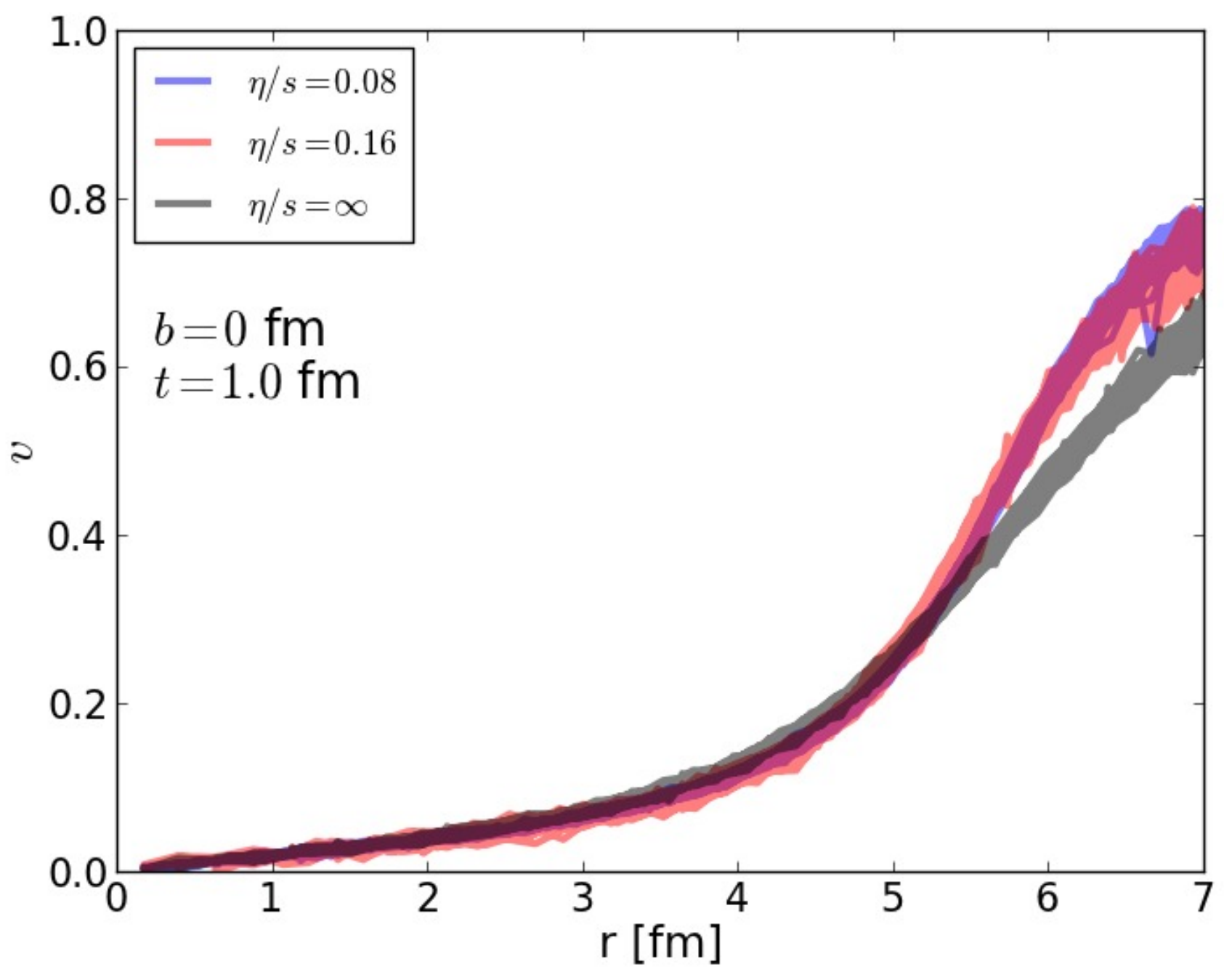
- energy density e at $\mathbf{b} = 0$ and $z = 0\,\mathrm{fm}$
- Strong dependence of $e_{\max}$ on the value of η/s
- The larger η/s, the faster energy density drops





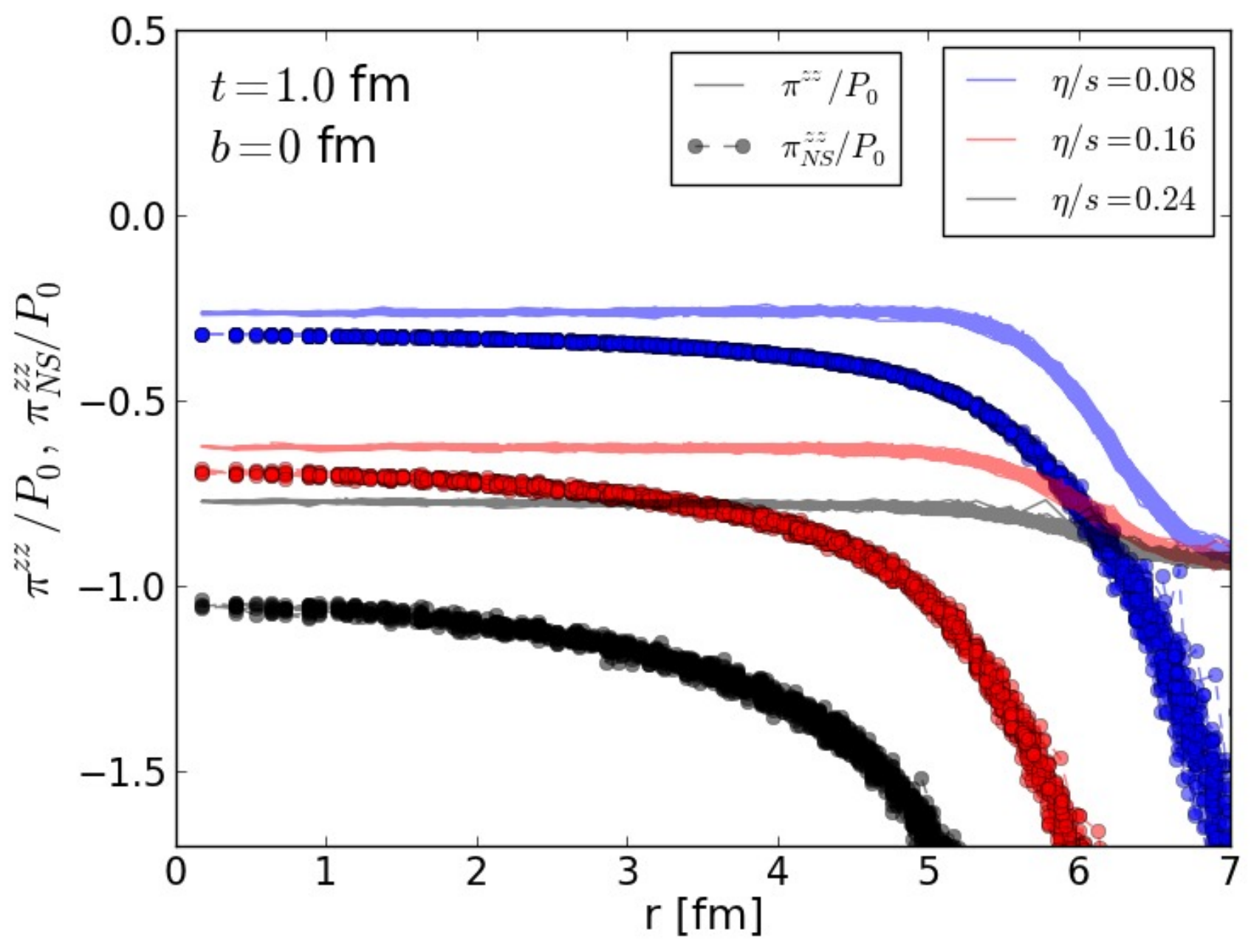
- Shape ($e/e_{\max}$) of the energy density profile at $t = 1.0\,\mathrm{fm/c}$ practically independent of η/s
- Shape of the profile practically unchanged between $t = 0\,\mathrm{fm/c}$ and $t = 1\,\mathrm{fm/c}$

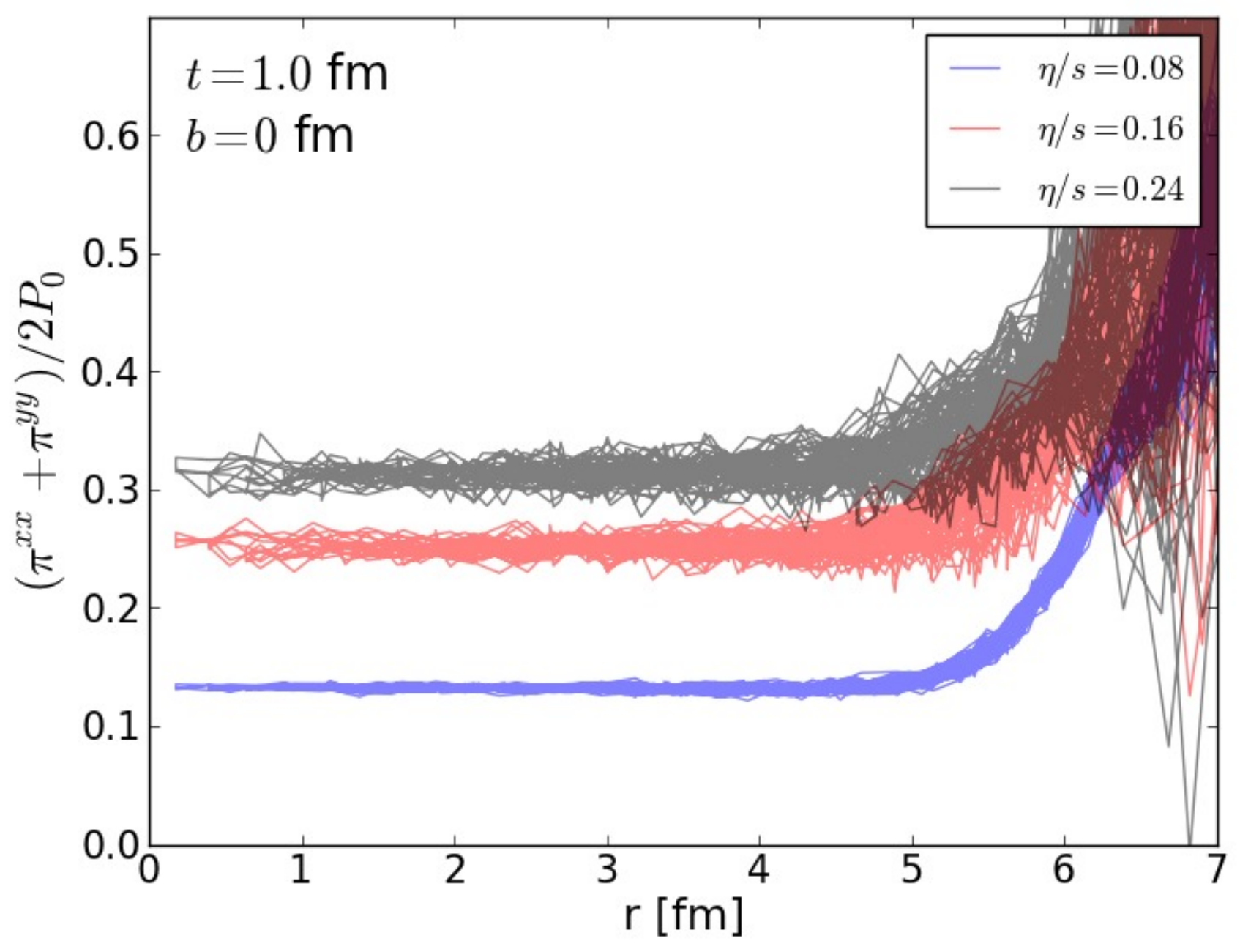
6. Transverse velocity



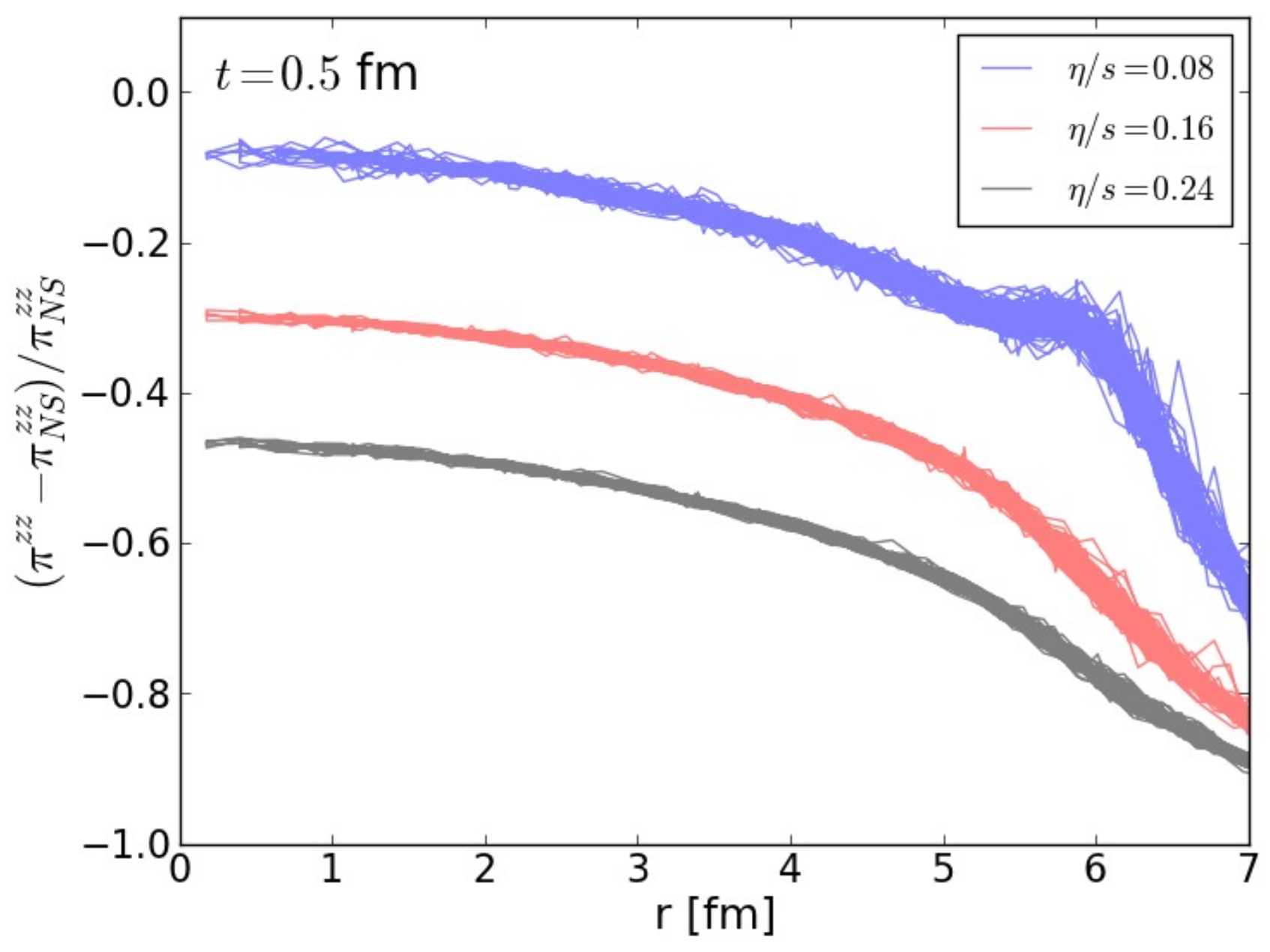
- Transverse velocity at $z = 0\,\mathrm{fm}$, $t = 1.0\,\mathrm{fm/c}$ and $\mathbf{b} = 0$
- Significant transverse velocity established (especially near the edges)
- Transverse velocity profiles almost independent of η/s

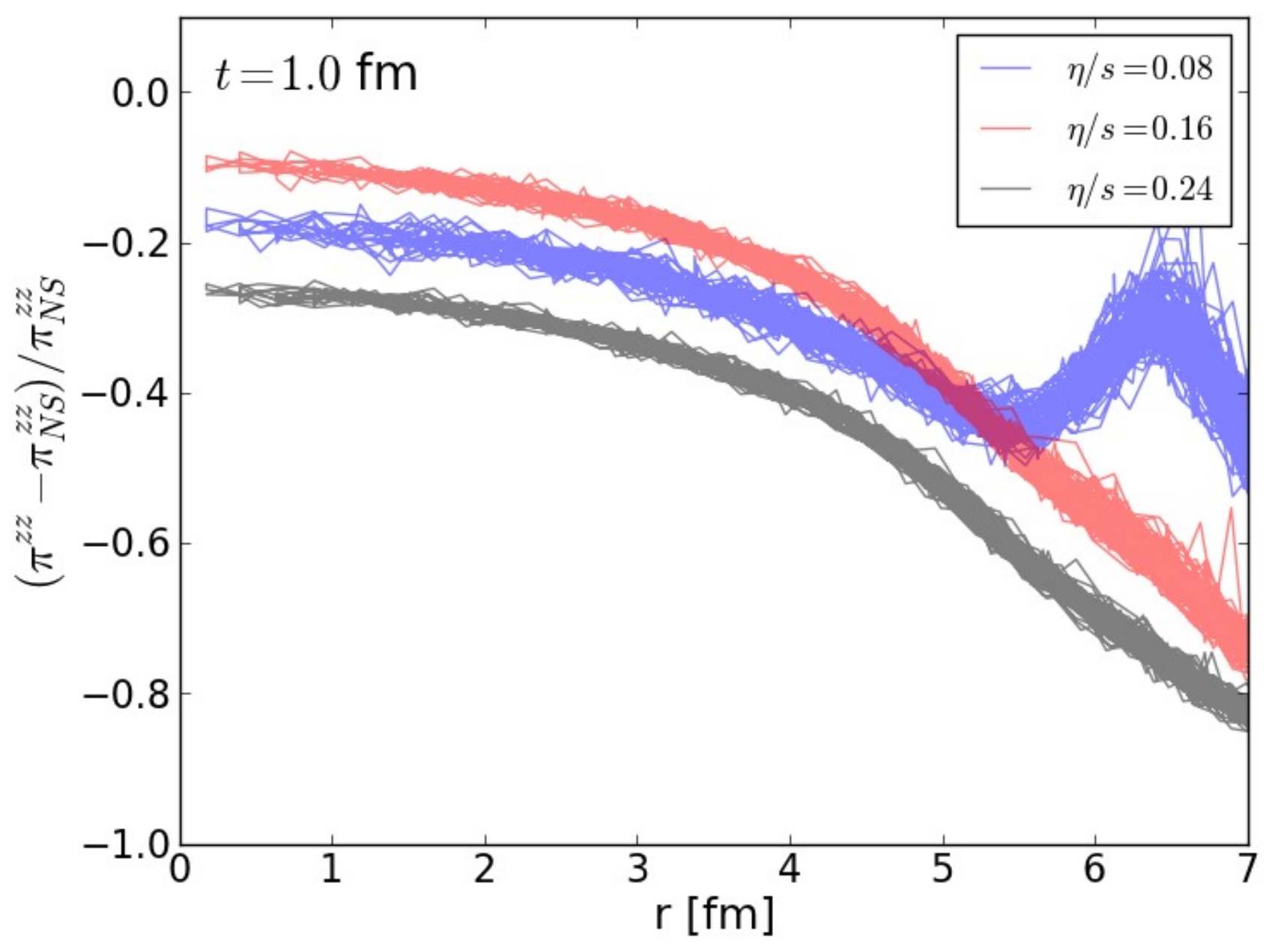
7. Shear-Stress Tensor





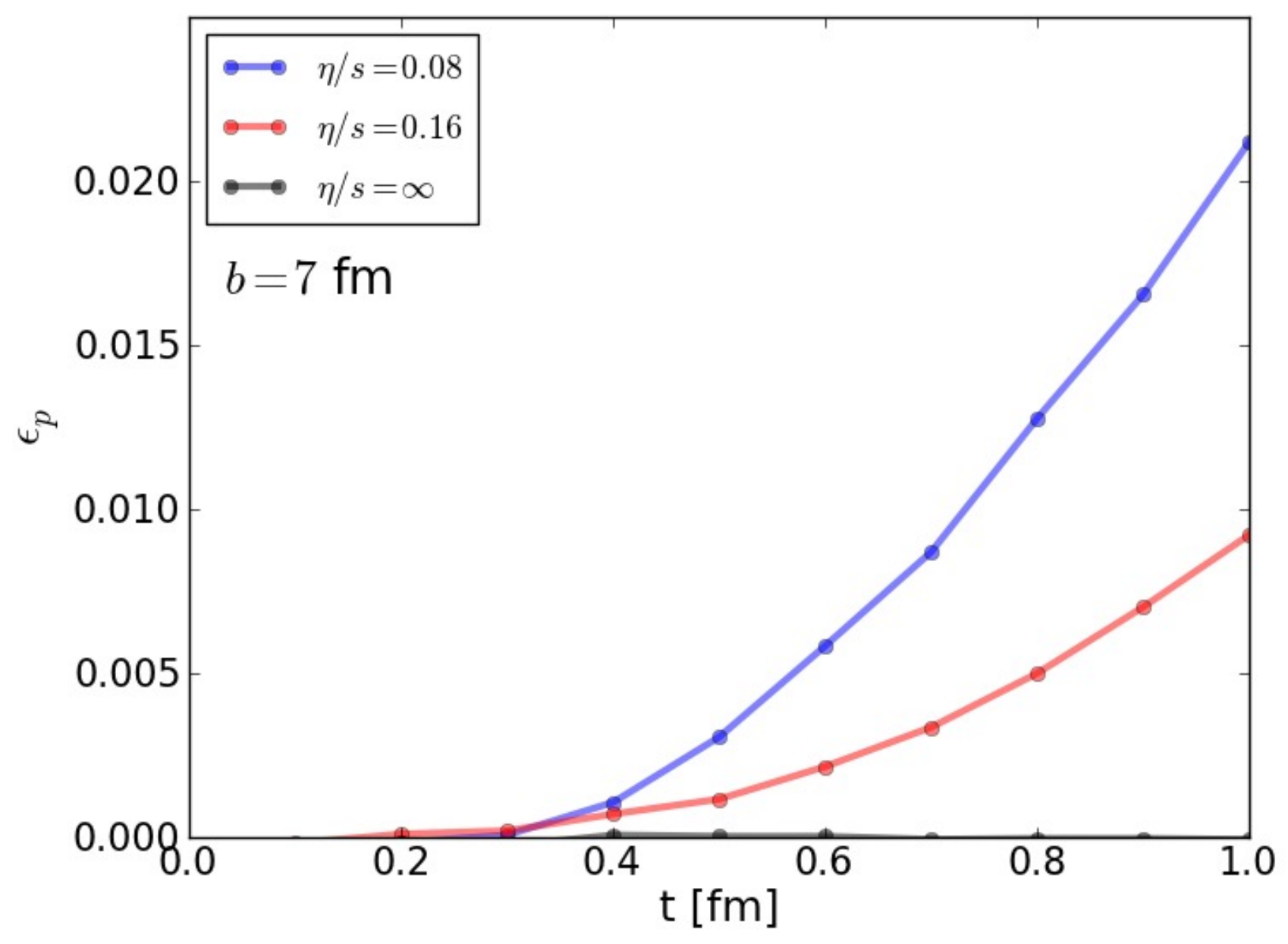
- Longitudinal and transverse components of the shear-stress tensor (over thermodynamic pressure) at $\mathbf{b} = 0$ and $z = 0\,\mathrm{fm}$ at $t = 1\,\mathrm{fm/c}$
- Strong deviations from the Navier-Stokes values (especially near the edges)
- NS-values overestimate the shear-stress tensor.

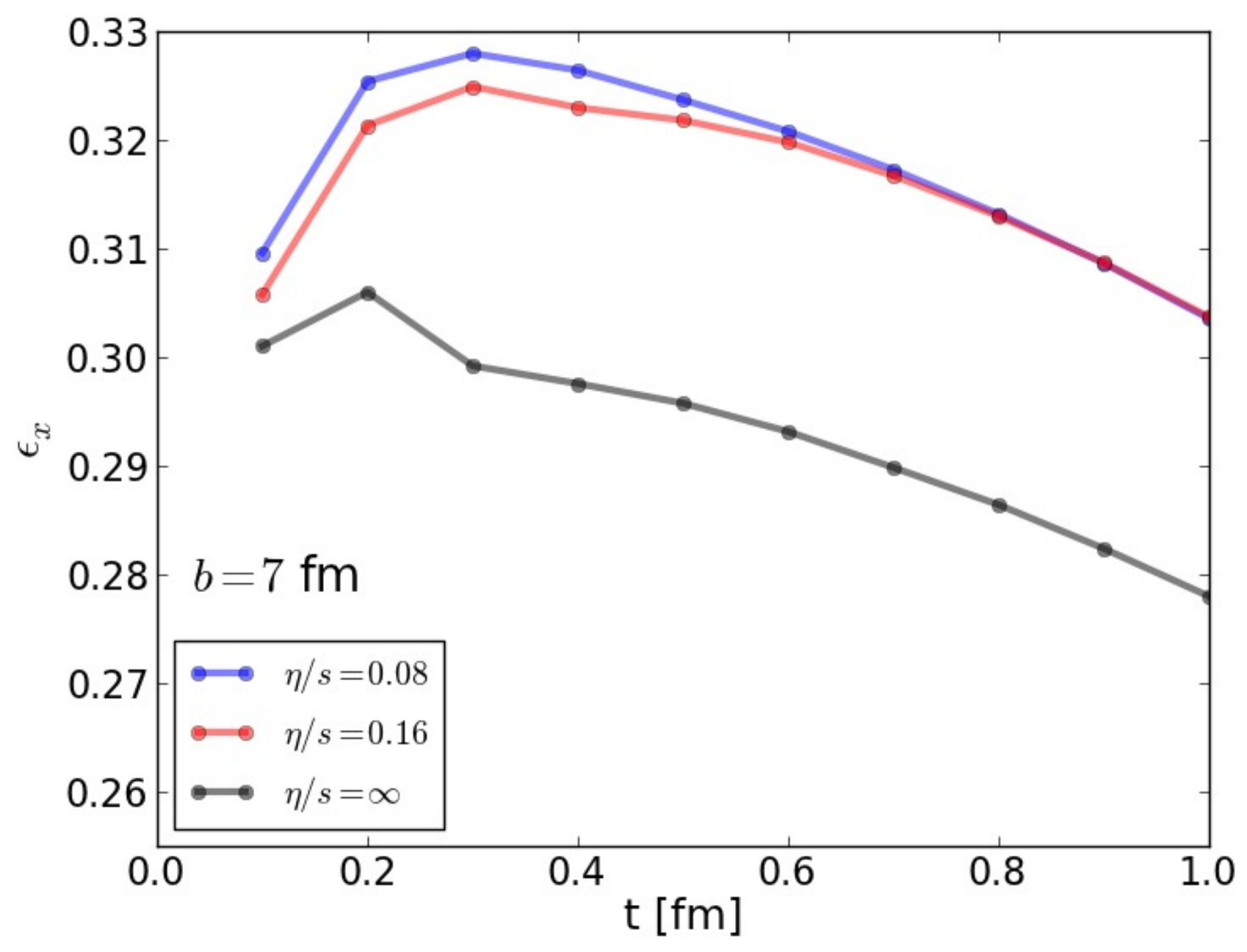




- Relative deviation from the NS-values at two different times

8. Eccentricities at early times





- time-evolution of momentum space ϵ_p and spatial ϵ_x eccentricities for non-central collisions $\mathbf{b} = 7$ at $t = 1\,\mathrm{fm/c}$

$$\epsilon_p = \frac{\int dxdy(T^{xx}-T^{yy})}{\int dxdy(T^{xx}+T^{yy})}$$
$$\epsilon_x = \frac{\int dxdy\, e(\tau,x,y)(y^2-x^2)}{\int dxdy\, e(\tau,x,y)(y^2+x^2)}$$

- Spatial eccentricity changes only slightly
- momentum eccentricity depends strongly on value of η/s (although transverse velocity almost independent of η/s)

Conclusions

- We studied the pre-thermal evolution of the QGP using BAMPS
- Transverse velocity and the shape of the energy density profile after the pre-equilibrium phase are practically independent of η/s
- The shear stress tensor developed in the first fm of evolution is non-zero and can deviate from the Navier-Stokes prediction
- For non-central collisions we found that a considerable momentum anisotropy can already be generated in the pre-thermal evolution of the QGP

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References

[1] Z. Xu and C. Greiner, Phys. Rev. C **71** (2005) 064901; Phys. Rev. C **76** (2007) 024911