Hydrodynamic modeling of QGP expansion using an exact solution of Riemann problem

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Strangeness in Quark Matter
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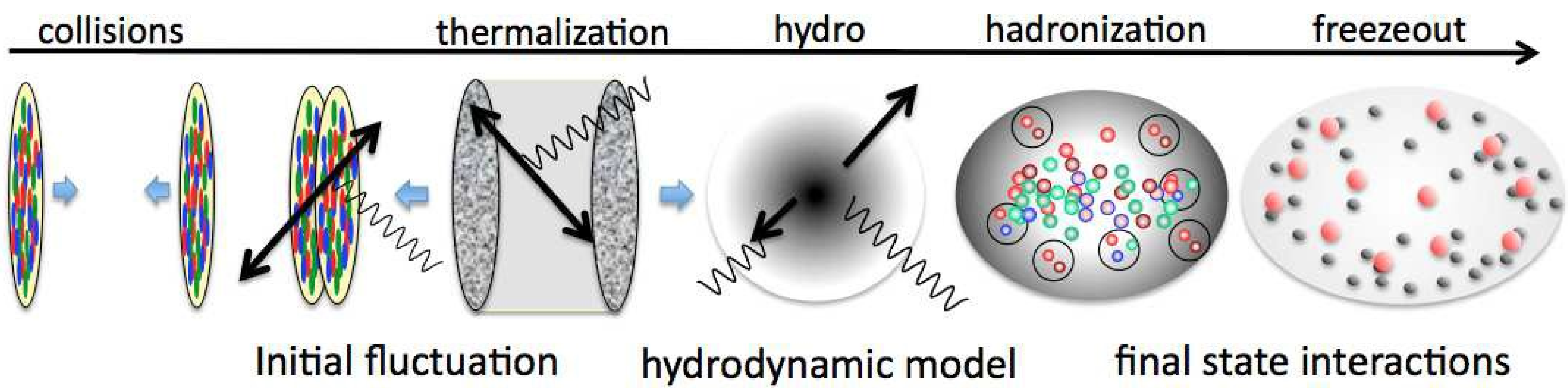
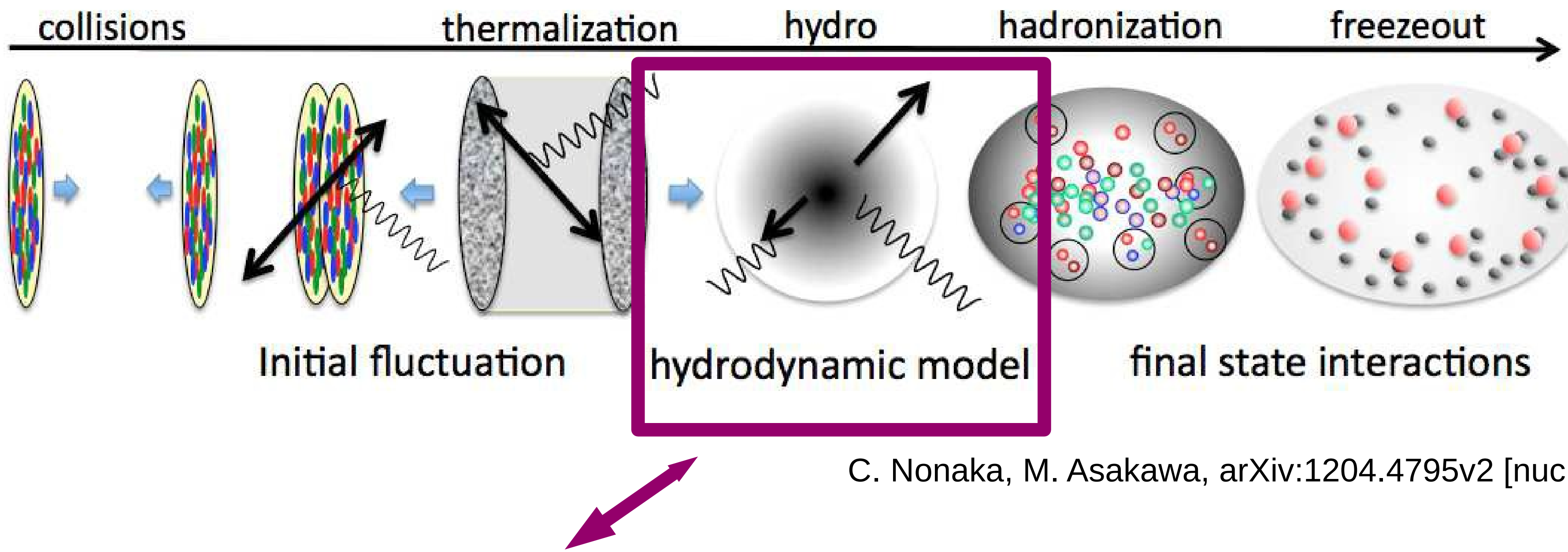
Hydrodynamic expansion



C. Nonaka, M. Asakawa, arXiv:1204.4795v2 [nucl-th]

Hydrodynamic expansion



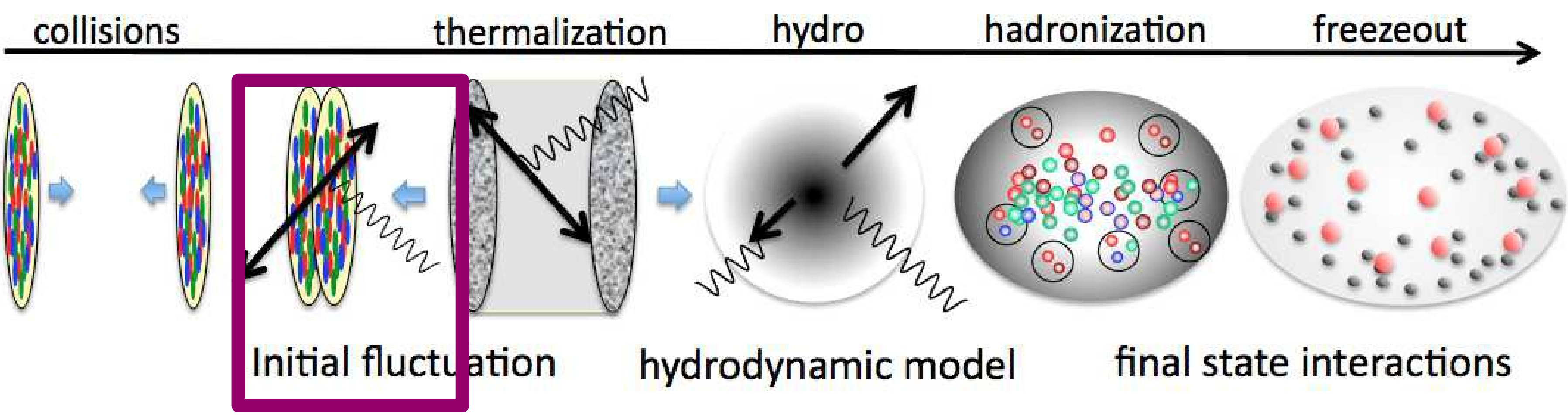
C. Nonaka, M. Asakawa, arXiv:1204.4795v2 [nucl-th]

$$\partial_\mu n^\mu = 0$$
$$\partial_\mu T^{\mu\nu} = 0$$
$$p = p(\epsilon, n)$$

Ideal hydrodynamics:

$$T^{\mu\nu}_{(0)} = (\epsilon + p) u^\mu u^\nu - p g^{\mu\nu}$$

Initial conditions



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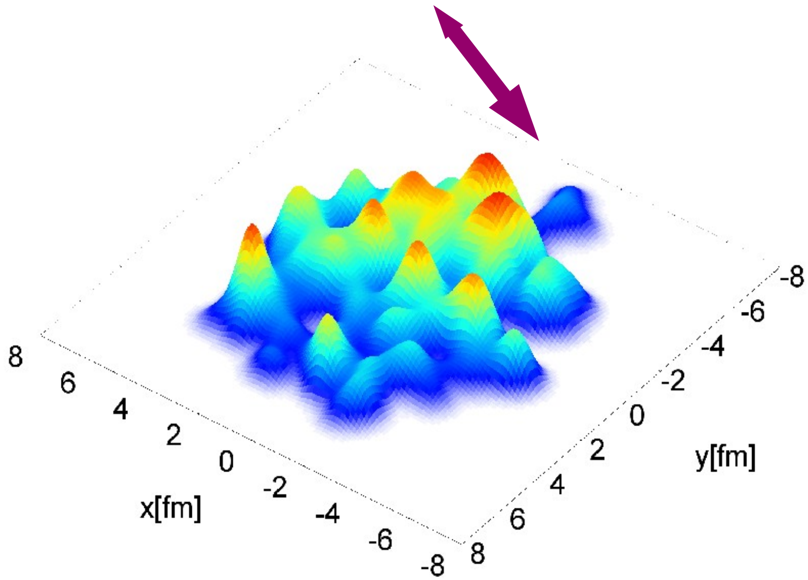
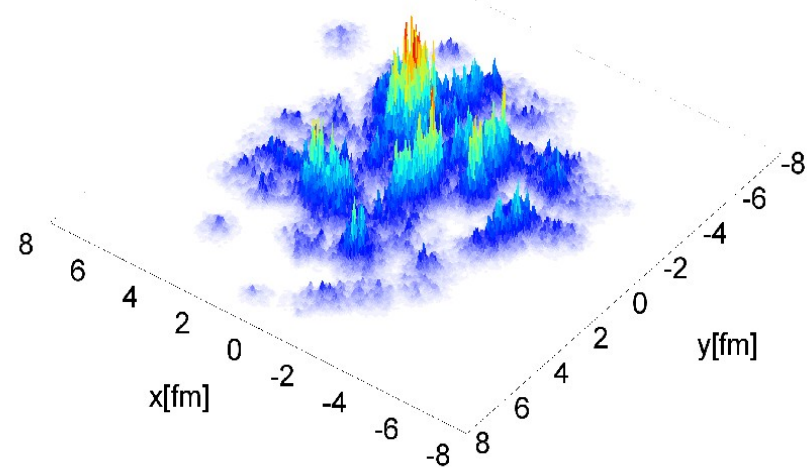


MC Glauber



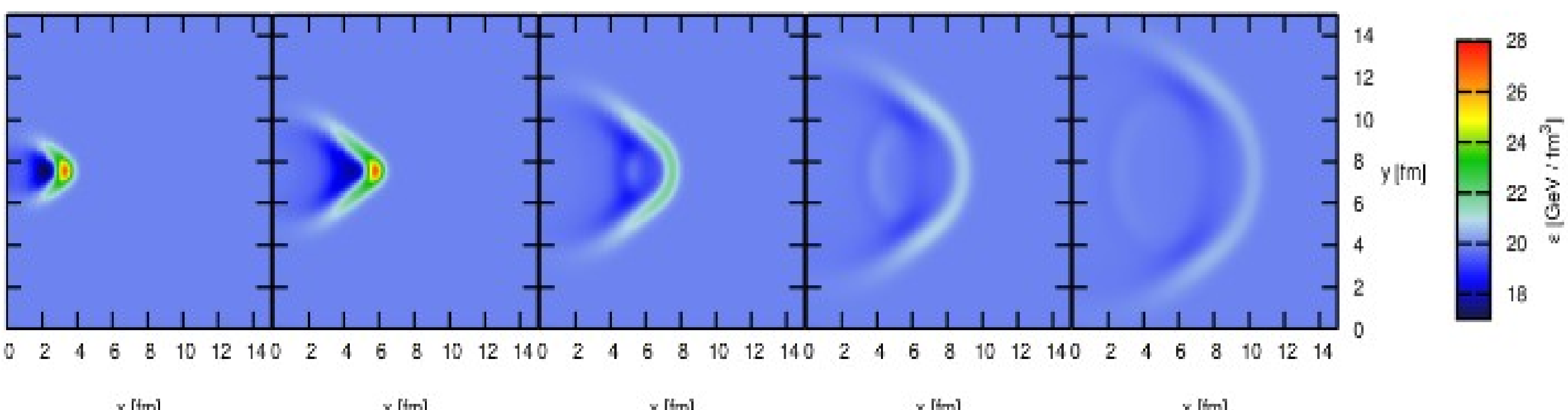
IP Glasma

B. Schenke et al., Phys. Rev. Lett. 108 (2012) 252301

Jets in the medium

- Response of the medium to jets
- Jet = a large deposition of energy and momentum into the liquid

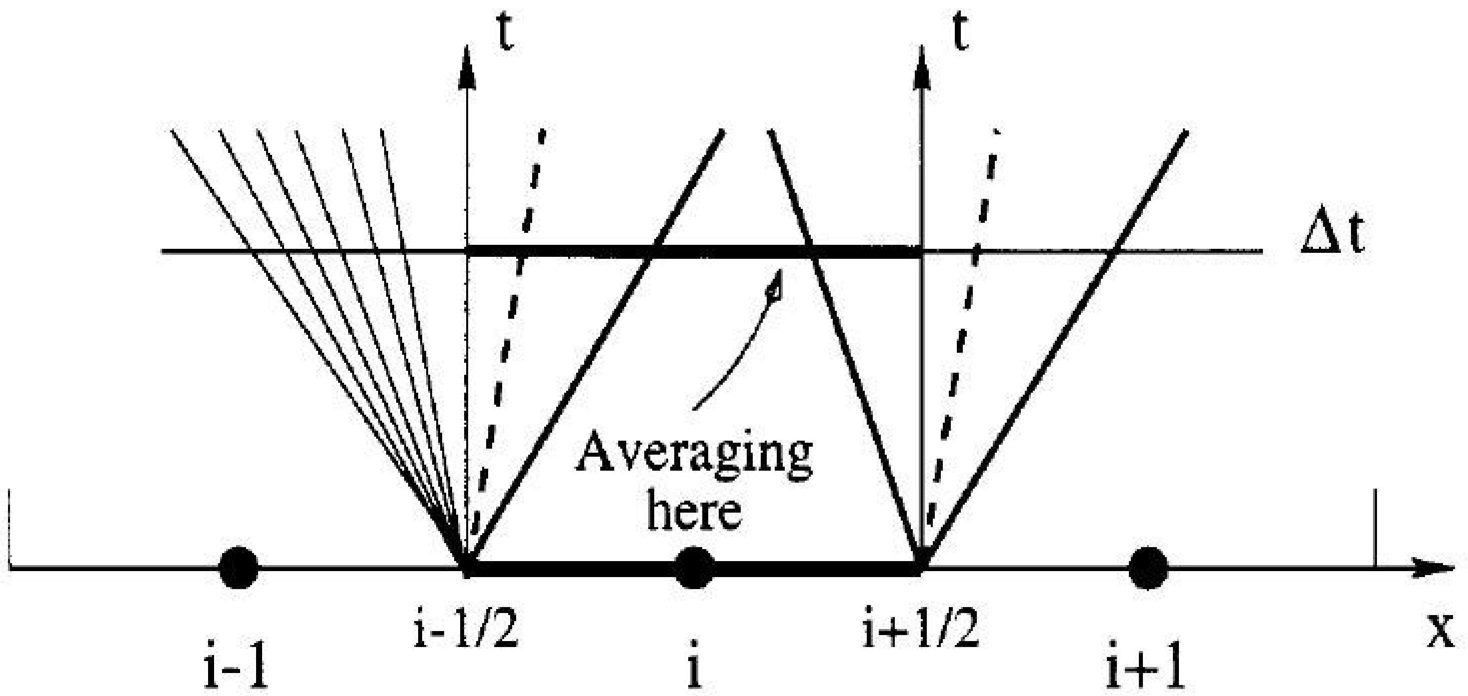
L. M. Satarov, H. Stoecker, I. N. Mishustin: Phys.Lett. B627 (2005) 64-70
J. Casaderrey-Solana, E. V. Shuryak, D Teaney: Nucl.Phys. A774 (2006) 577-580
B. Betz, J. Noronha et al.: Phys.Rev. C79 (2009) 034902



M. Schulc, B. Tomasik: J.Phys. G40 (2013) 125104

Numerical method

- Godunov method: computing the flow of conserved variables on cell boundaries

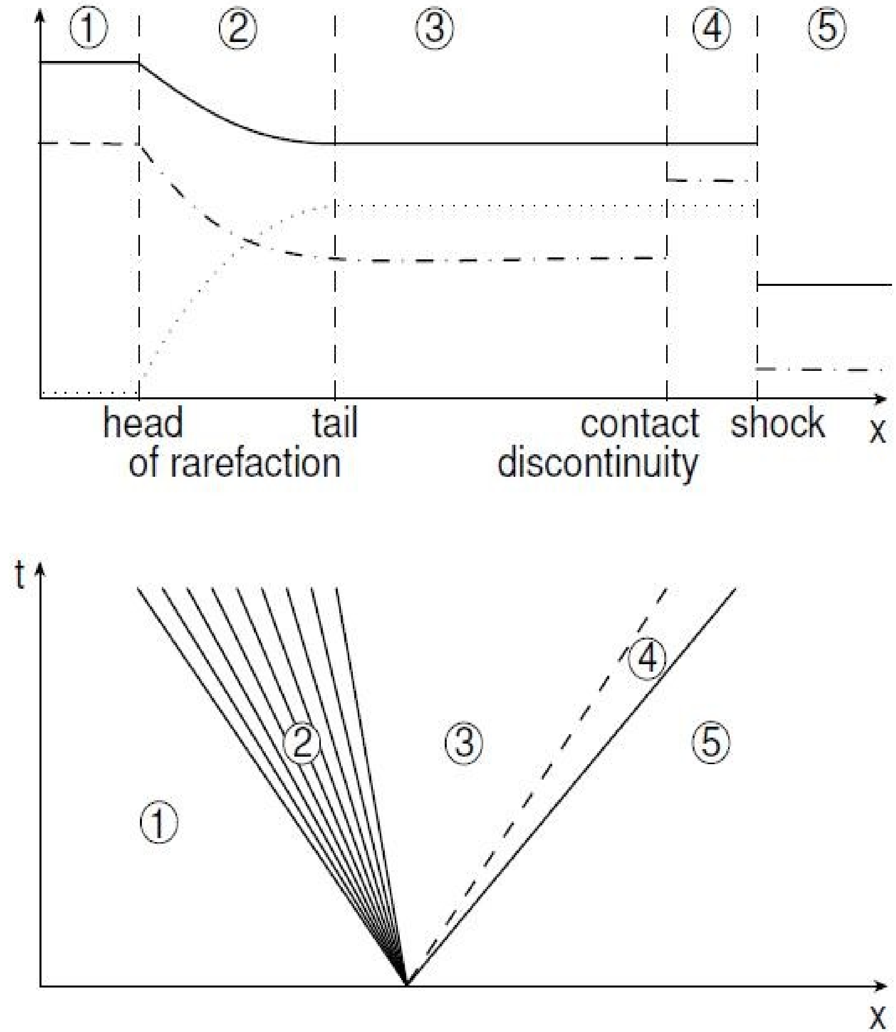


E. F. Toro: Riemann Solvers and Numerical Methods for Fluid Dynamics

Riemann problem

- Exact solution: reconstructing flow on both sides of the interface
- Shock/rarefaction wave
- Solving at the interface:

$$v_L^x(\epsilon_{new}) = v_R^x(\epsilon_{new})$$



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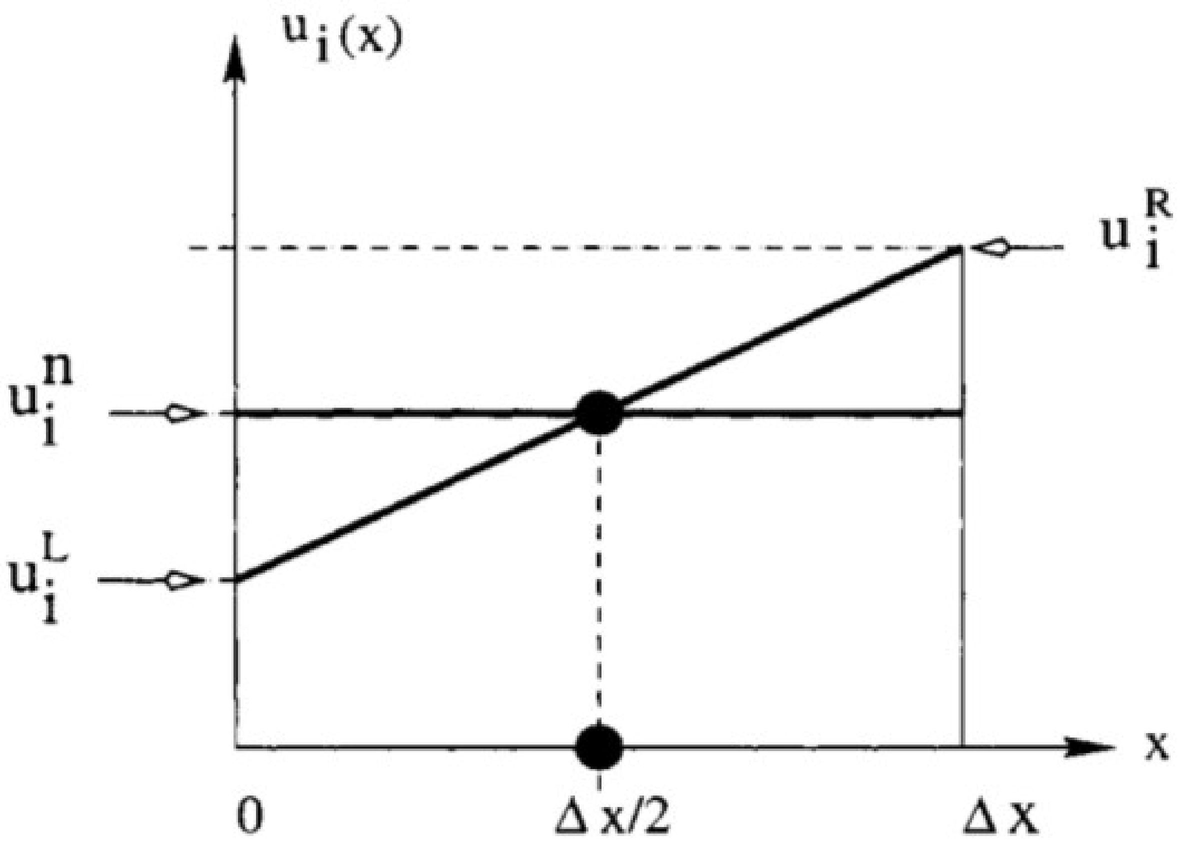
Linear reconstruction



Piece-wise linear reconstruction of data in one cell

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Testing the scheme

- Sound wave propagation: precision, numerical viscosity

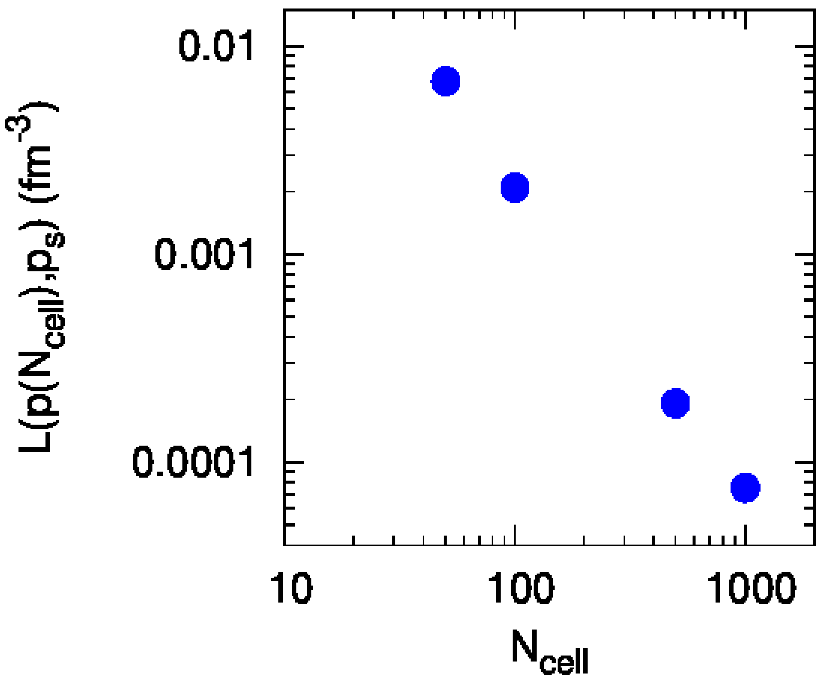
$$p_{init}(x) = p_0 + \delta p \sin(2\pi x/\lambda), v_{init}(x) = \frac{\delta p}{c_{s0}(e_0 + p_0)} \sin(2\pi x/\lambda)$$

$$p_0 = 10^3 fm^{-4}, \delta p = 10^{-1} fm^{-4}, \lambda = 2 fm$$

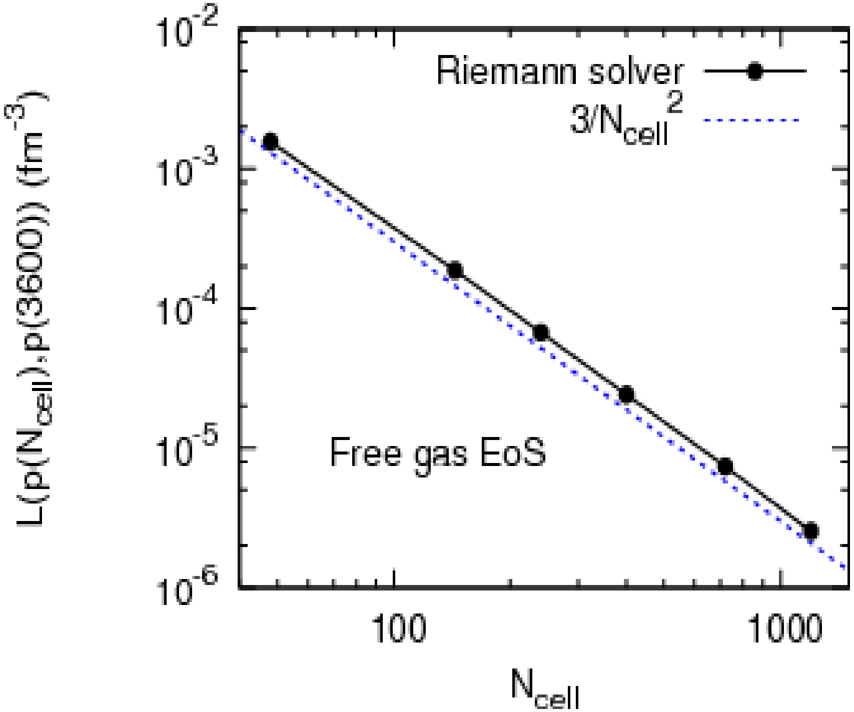
Sound wave propagation

L1 norm:

$$L(p(N_{cell}), p_s) = \sum_{i=1}^{N_{cell}} |p(x_i, \lambda/c_s; N_{cell}) - p_s(x_i, \lambda/c_s)| \frac{\lambda}{N_{cell}}$$



Our results

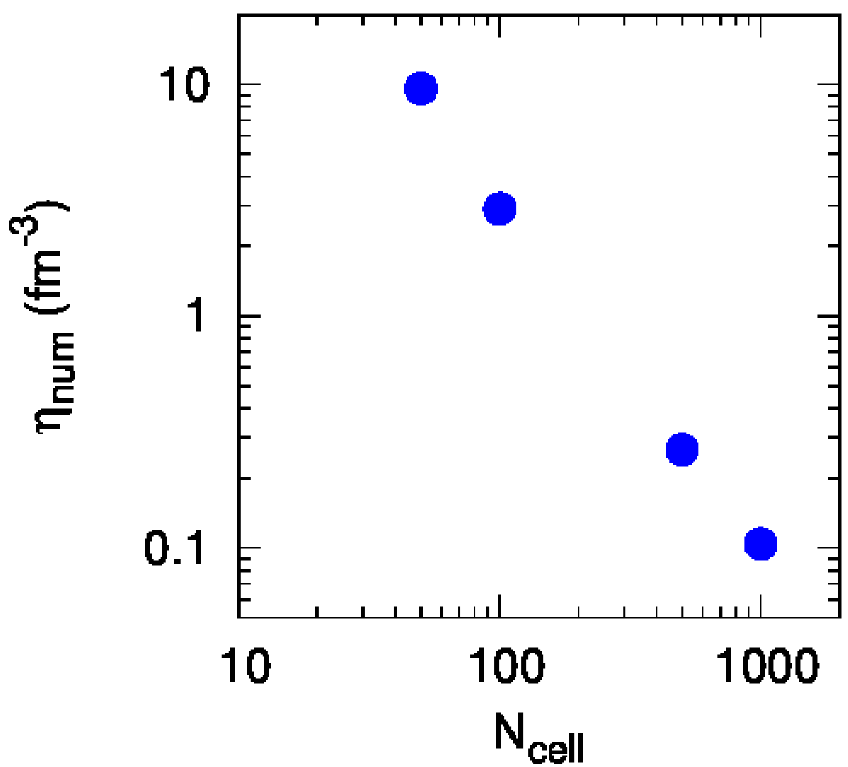


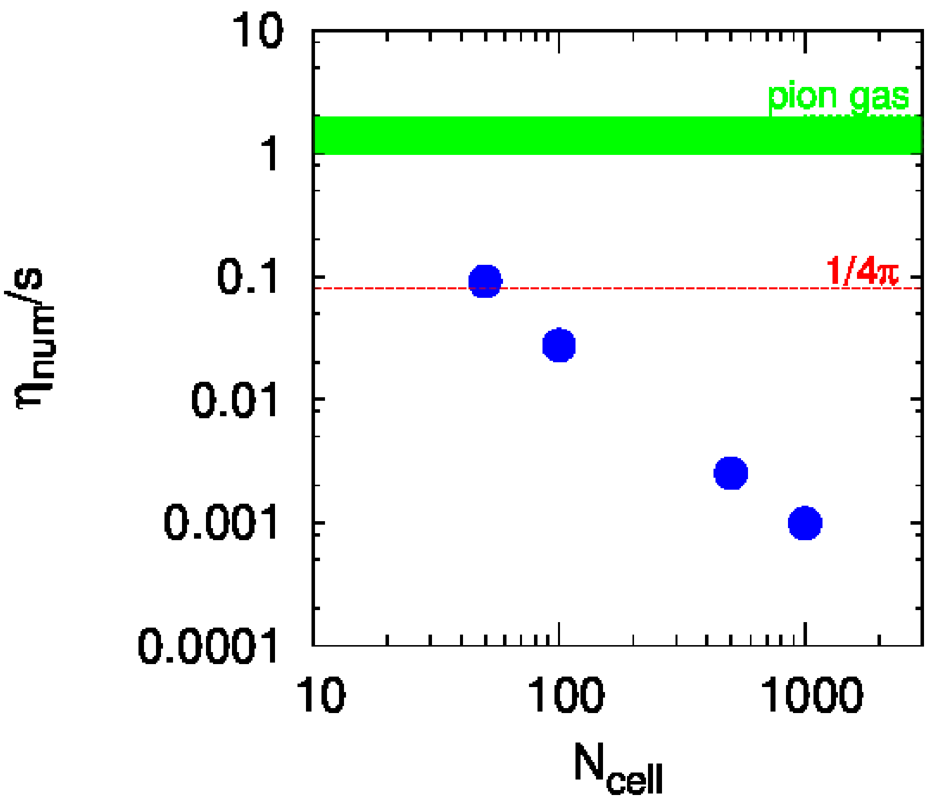
Y. Akamatsu et al., J. Comput. Phys. 256 (2014) 34

Sound wave propagation

Numerical viscosity:

$$\eta_{num} = \frac{-3\lambda}{8\pi^2} c_{s\,0}(e_0 + p_0) \ln\left[1 - \frac{\pi}{2\lambda\,\delta p} L(p(N_{cell}, p_s))\right]$$





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$$p_0=10^3 fm^{-4}, \delta p=10^{-1} fm^{-4}, \lambda=2 fm$$

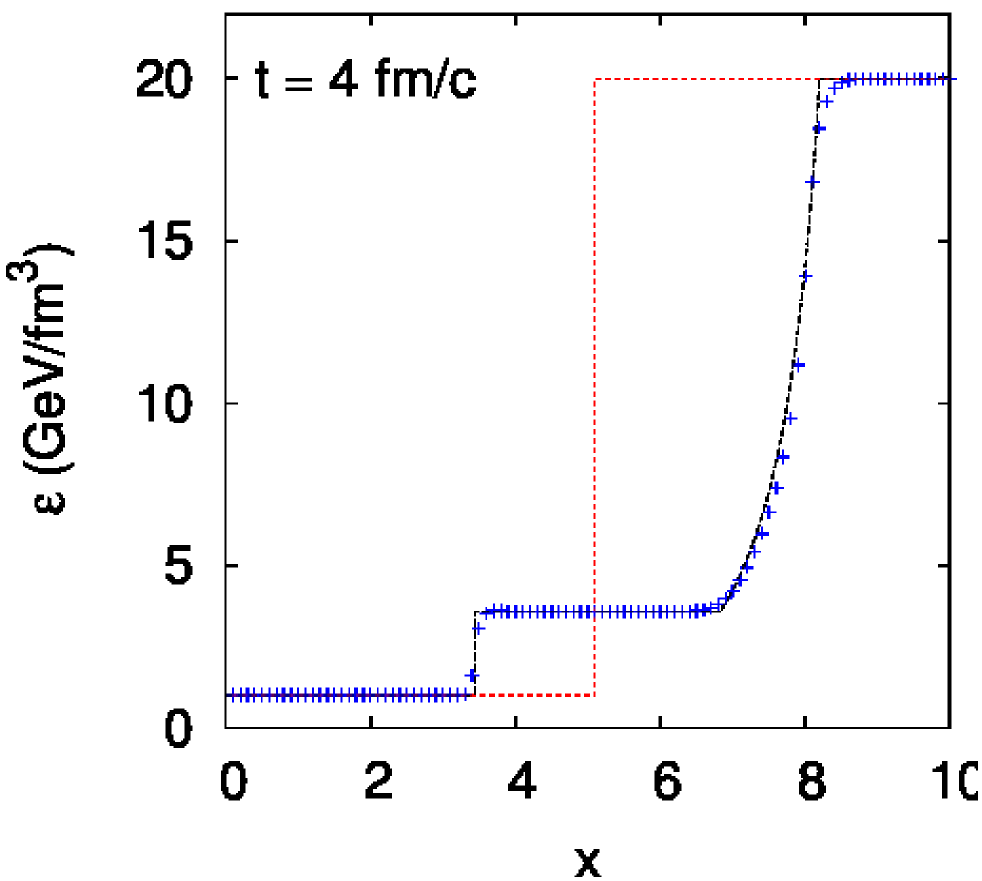
- Shock tube problem: initial discontinuity in energy density and tangential velocity

$$\varepsilon_L=1\, GeV\cdot fm^{-3}, \varepsilon_R=20\, GeV\cdot fm^{-3}$$

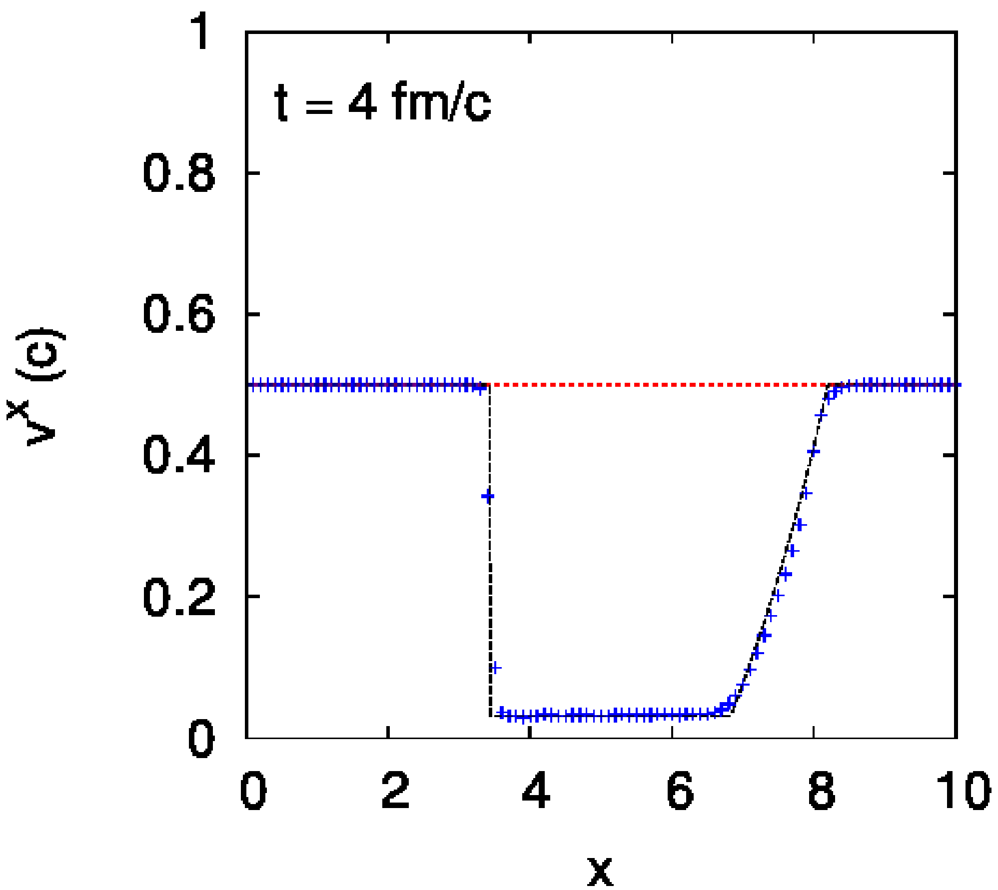
$$v_L^t=1/3c, v_R^t=1/2c$$

$$\lambda=10 fm, N_{cell}=100, \Delta t=0.04 fm.c^{-1}$$

Shock tube problem

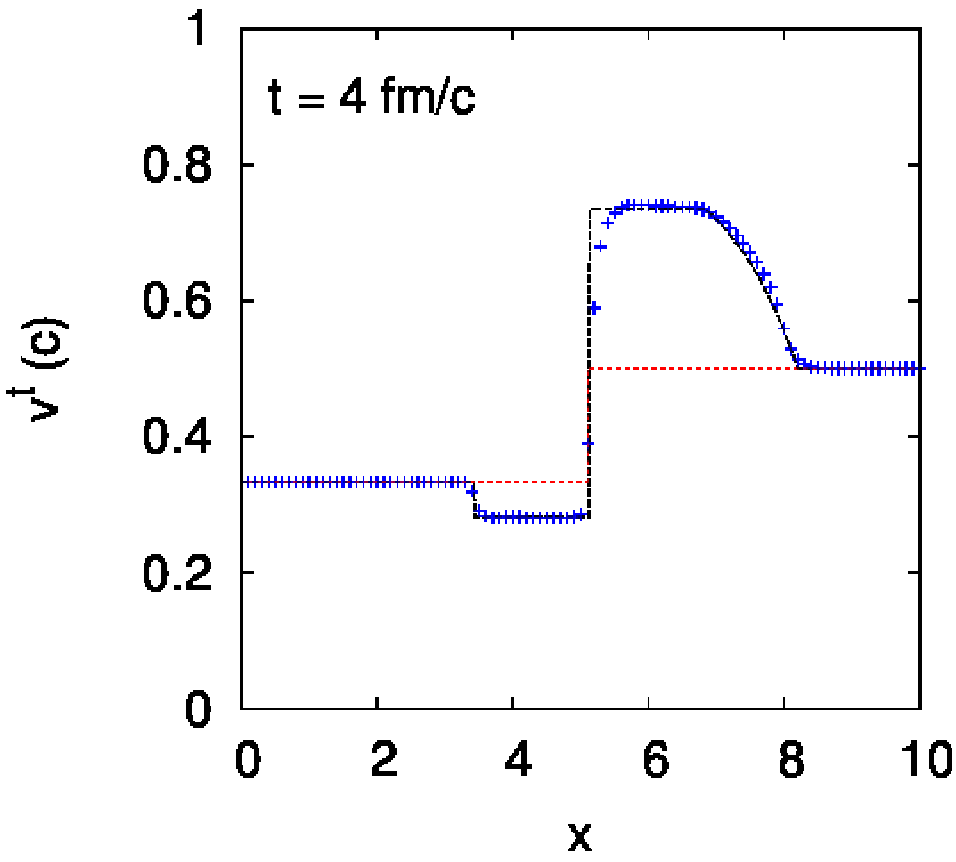


Energy density profile after 100 steps

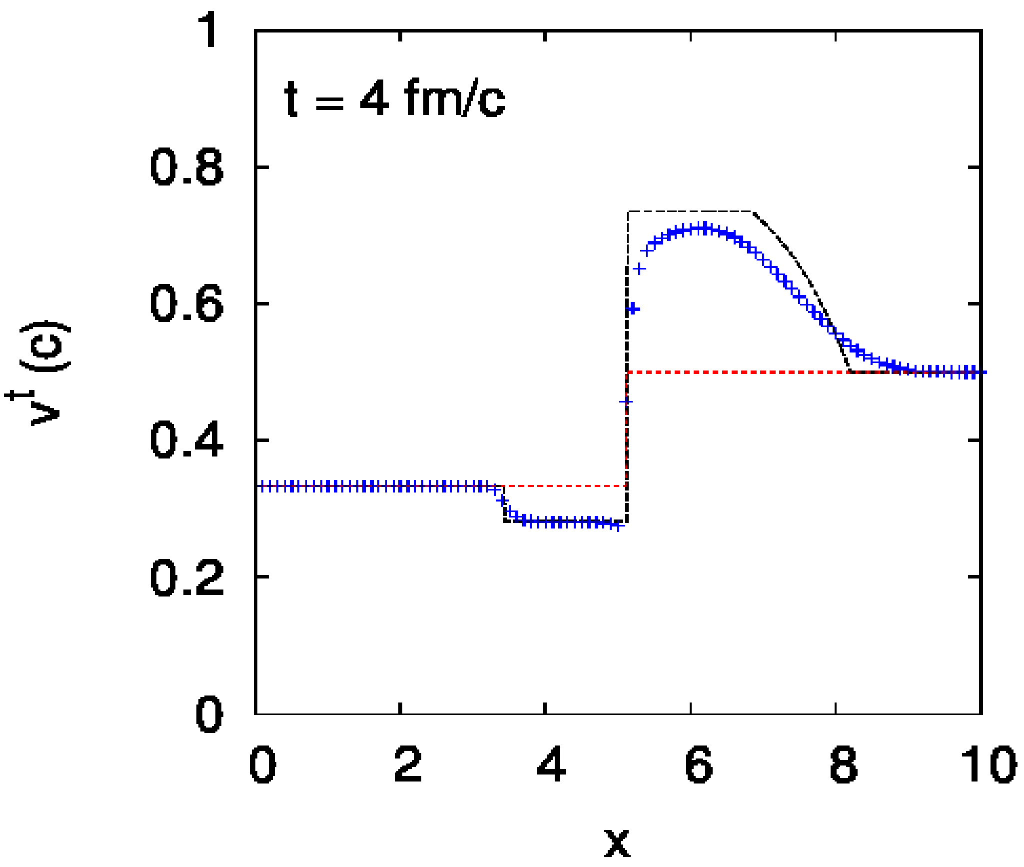


Normal velocity profile after 100 steps

Shock tube problem



Tangential velocity profile after 100 steps



Tangential velocity profile after 100 steps with linearization

Summary

- Ideal hydrodynamics code for quark-gluon plasma modeling
- Successfull testing in 1D
- Firsts tests in 2D
- Simulating jets penetrating the medium and the response of the medium to the energy deposited