Boost-invariant spin hydrodynamics with spin feedback effect

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We study one - dimensional and boost invariant expansion with second - order corrections in the spin polarization tensor to the energy-momentum tensor and baryon current without dissipative components. Consequently, we obtain feedback from spin dynamics on the hydrodynamic background which constrains possible spin polarization configurations. However, for a small magnitude of the spin polarization tensor (below unity in natural units), the permitted spin dynamics differ very little from that found in the case without the second-order corrections (Ref. [2]).

⇒ **Motivation:** theoretical description of the RHIC spin polarization data (Ref. [1]).

We use the form of polarization tensor with four - vectors decomposed in the orthonormal basis

$$\omega_{\mu\nu} = k_\mu U_\nu - k_\nu U_\mu + t_{\mu\nu}, \qquad t_{\mu\nu} = \epsilon_{\mu\nu\alpha\beta} U^\alpha \omega^\beta, \tag{1}$$

$$k^\mu = C_{kx} X^\mu + C_{ky} Y^\mu + C_{kz} Z^\mu, \qquad \omega^\mu = C_{\omega z} X^\mu + C_{\omega y} Y^\mu + C_{\omega z} Z^\mu, \qquad t^\mu = V_x X^\mu + V_y Y^\mu + V_z Z^\mu. \tag{2}$$

With the tensor forms calculated in Ref. [3] and Ref. [4], we consider the conservation laws for baryon number current, energy - momentum tensor, and spin tensor respectively and as a result, we obtain equations

$$\partial_\mu N^\mu = \frac{d\bar{n}}{d\tau} + \frac{\bar{n}}{\tau} = 0, \tag{3}$$

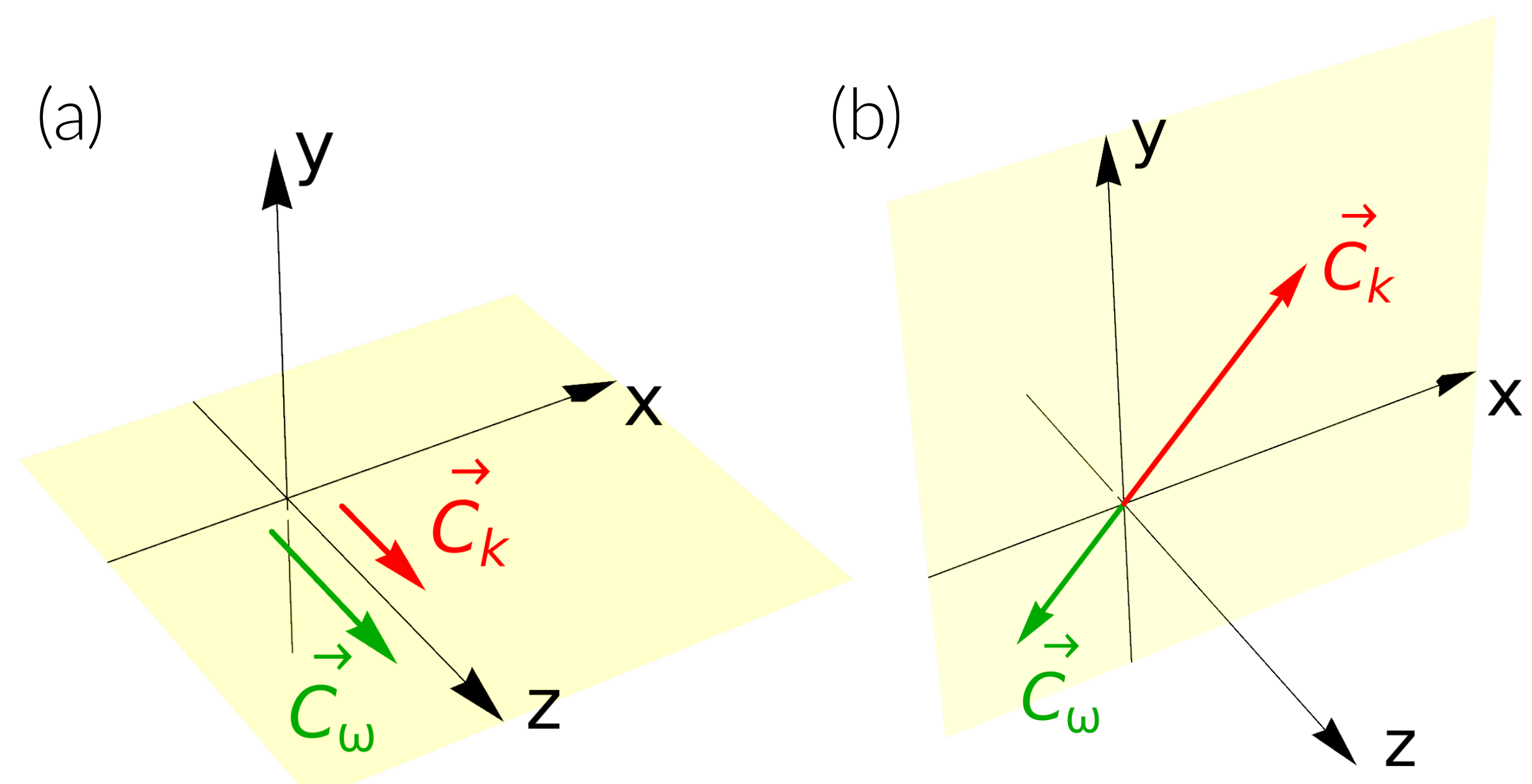

Figure 1: Schematic view for longitudinal (a) and transverse (b) configuration.

$$\partial_\mu T^{\mu\nu} = \left[\dot{\bar{\varepsilon}} + \frac{\bar{\varepsilon} + \bar{P}}{\tau} + \frac{P}{\tau}\left(C_{kz}^2 + C_{\omega z}^2\right)\right] U^\nu + \left[\left(\dot{P}_t + \frac{P_t}{\tau}\right) V_x + P_t \dot{V}_x\right] X^\nu$$
$$+ \left[\left(\dot{P}_t + \frac{P_t}{\tau}\right) V_y + P_t \dot{V}_y\right] Y^\nu + \left[\left(\dot{P}_t + \frac{P_t}{\tau}\right) V_z + P_t\left(\dot{V}_z + \frac{V_z}{\tau}\right)\right] Z^\nu = 0, \tag{4}$$

$$\begin{aligned}\partial_\lambda S^{\lambda,\mu\nu} = {} & \frac{1}{\tau}\left[A\left(k^\mu U^\nu - k^\nu U^\mu\right) + A_1 t^{\mu\nu}\right] + \dot{(A k^\mu)} U^\nu - \dot{(A k^\nu)} U^\mu \\ & + \dot{A}_1 t^{\mu\nu} + A_1 \dot{t}^{\mu\nu} + \frac{1}{2}\partial_\lambda A_3\left(t^{\lambda\mu} U^\nu - t^{\lambda\nu} U^\mu\right) \\ & + \frac{A_3}{2}\Big[\left(\partial_\lambda t^{\lambda\mu}\right) U^\nu + t^{\lambda\mu}\partial_\lambda U^\nu - \left(\partial_\lambda t^{\lambda\nu}\right) U^\mu - t^{\lambda\nu}\partial_\lambda U^\mu \\ & - \frac{U^\mu}{\tau} k^\nu + \Delta^{\lambda\mu}\partial_\lambda k^\nu + \frac{U^\nu}{\tau} k^\mu - \Delta^{\lambda\nu}\partial_\lambda k^\mu\Big] = 0.\end{aligned} \tag{5}$$

LONGITUDINAL CONFIGURATION

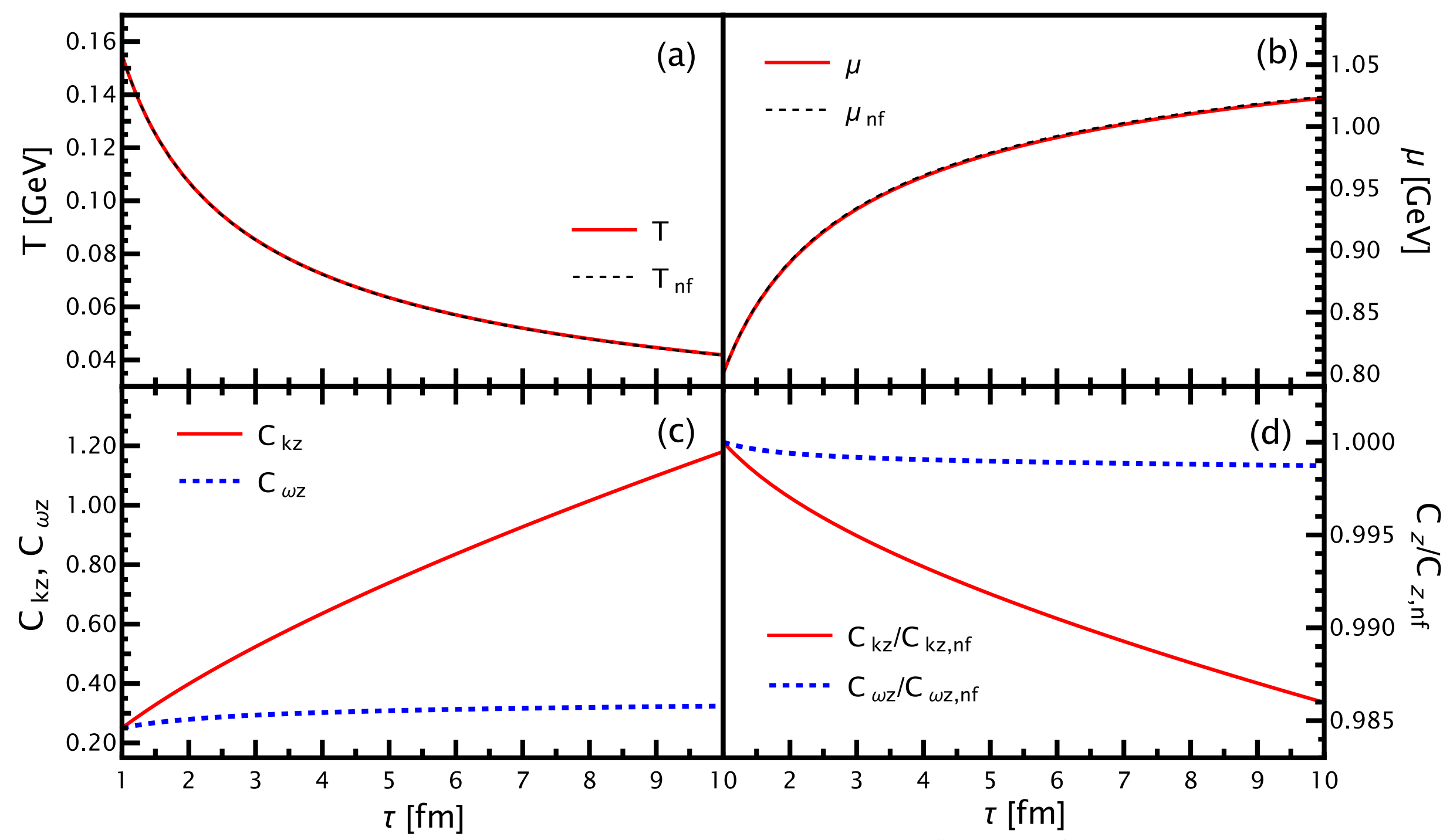

Figure 2: Longitudinal configuration with the initial values $C^0_{kz} = C^0_{\omega z} = 0.25$.

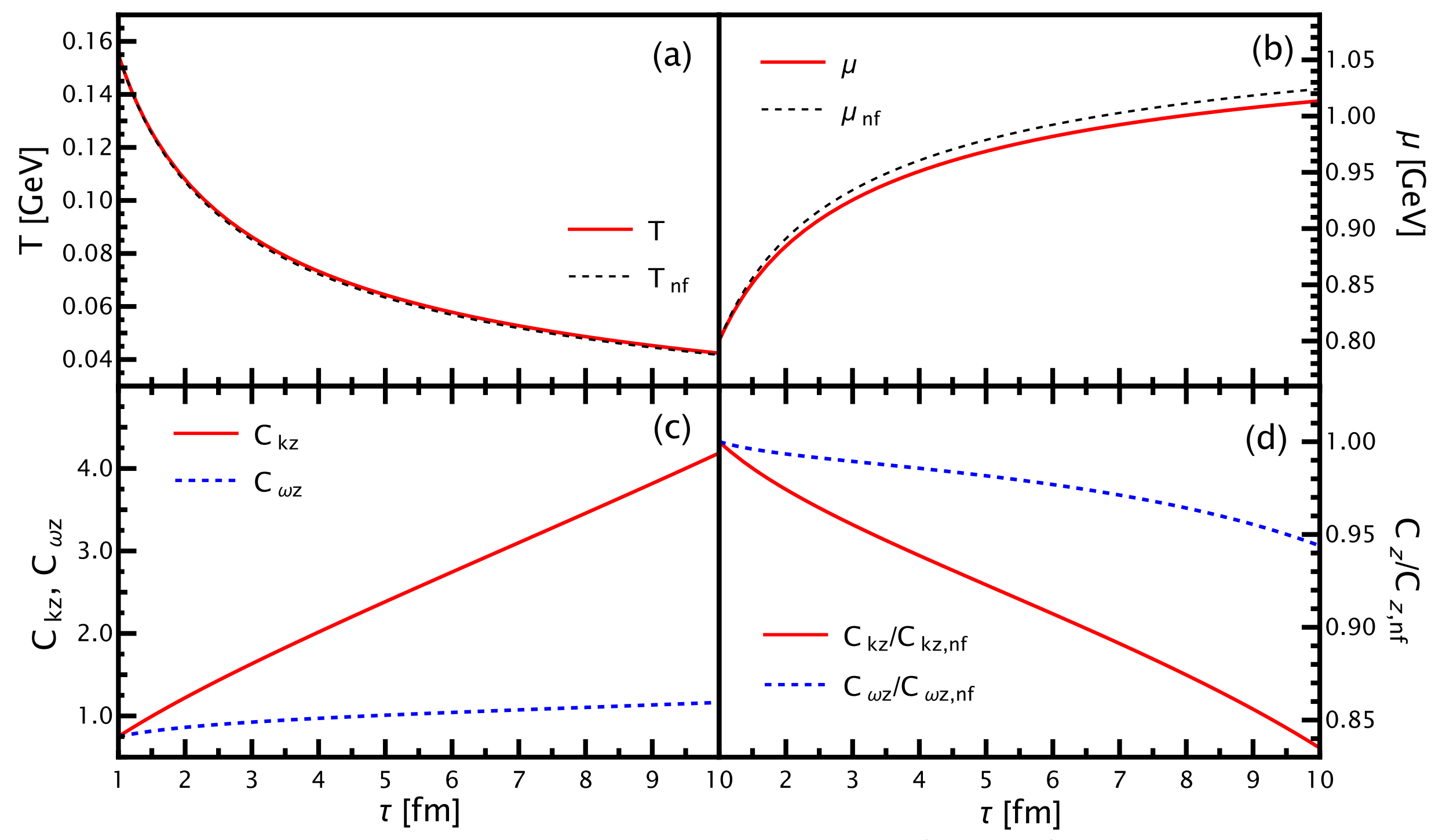

Figure 3: Longitudinal configuration with the initial values $C^0_{kz} = C^0_{\omega z} = 0.75$.

TRANSVERSE CONFIGURATION

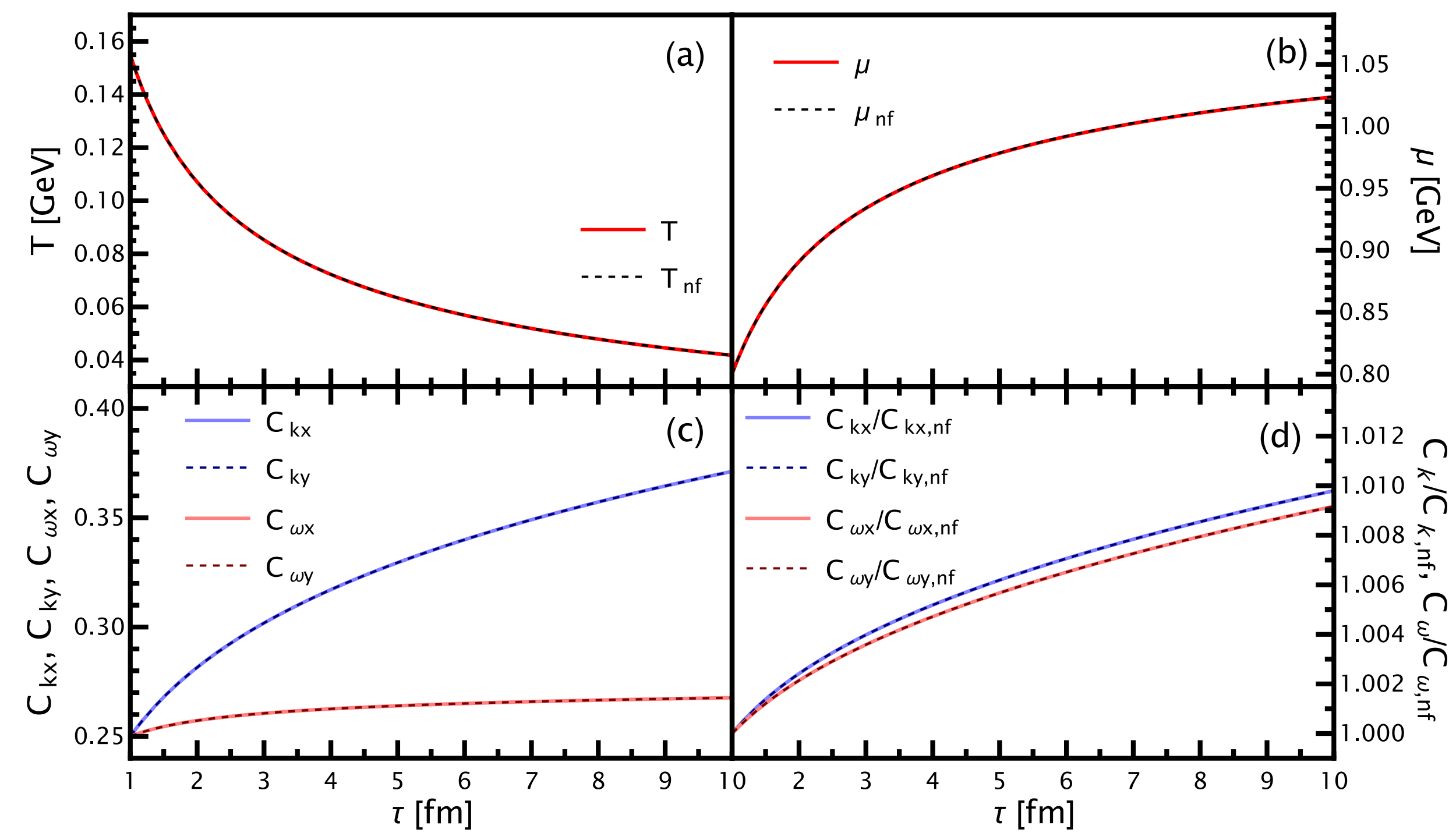

Figure 4: Transverse configuration with the initial values $C^0_{kx} = C^0_{ky} = C^0_{\omega x} = C^0_{\omega y} = 0.25$.

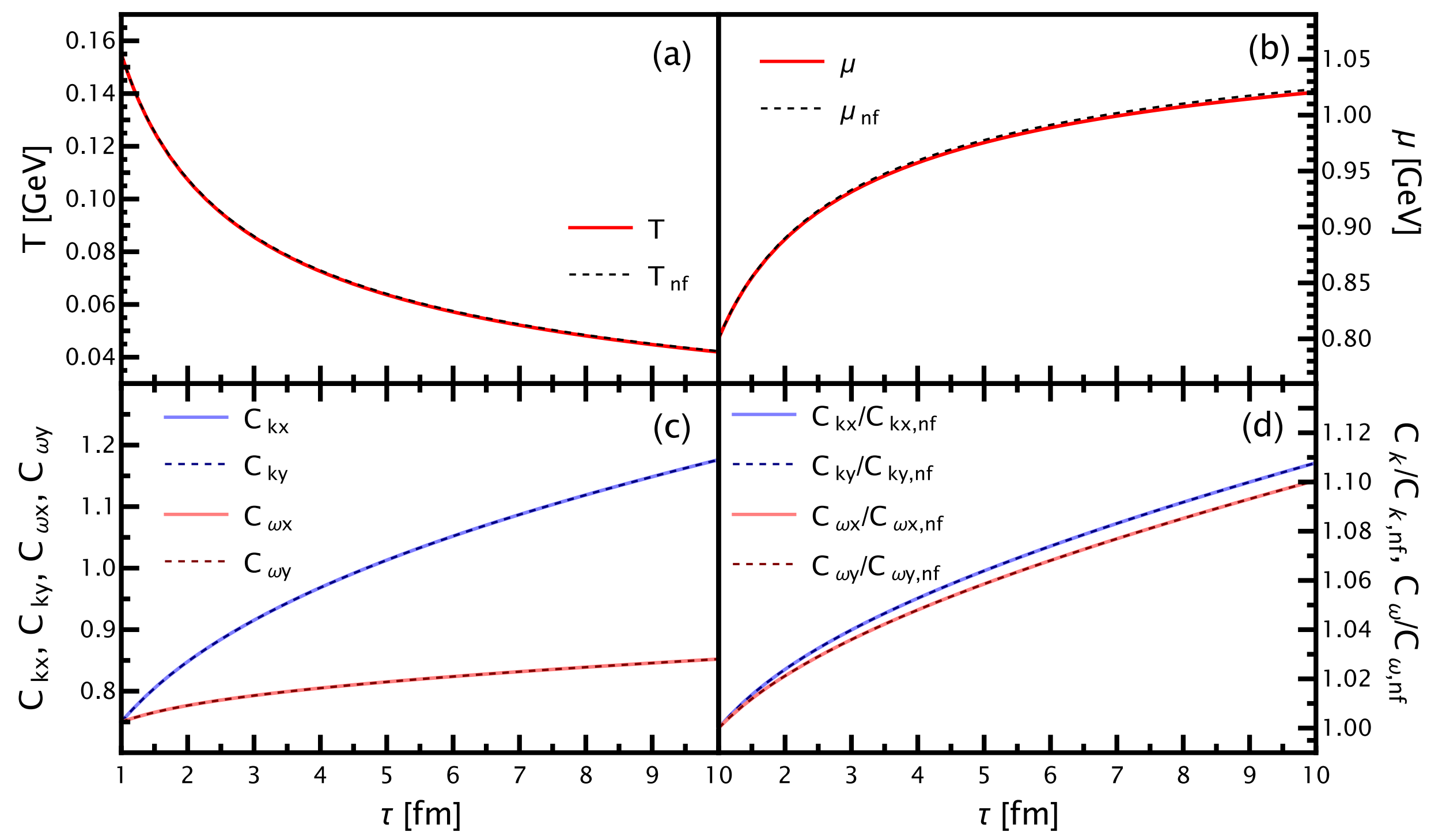

Figure 5: Transverse configuration with the initial values $C^0_{kx} = C^0_{ky} = C^0_{\omega x} = C^0_{\omega y} = 0.75$.

Panels describe proper-time dependence of (a) temperature T, (b) baryon chemical potential μ, (c) C coefficients and (d) their ratios to no-feedback results.

References

[1] Francesco Becattini, Michael Lisa, *Polarization and Vorticity in the Quark Gluon Plasma*, Ann. Rev. Nucl. Part. Sci. 70 (2020) 395-423, arXiv:2003.03640.
[2] W. Florkowski, A. Kumar, R. Ryblewski, and R. Singh, *Spin polarization evolution in a boost invariant hydrodynamical background*, Phys. Rev. C 99, 044910 (2019), arXiv:1901.09655.
[3] W. Florkowski and M. Hontarenko, *Generalized thermodynamic relations for perfect spin hydrodynamics*, (2024), arXiv:2405.03263.
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