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An initial state with local shear and vorticity for peripheral heavy ion collisions

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V.K. Magas, J. Gordillo, D.D. Strottman, Y.L. Xie and L.P. Csernai, ***arXiv:1712.00283 [nucl-th].***

Nuclei colliding at ultra-relativistic energies
with nonzero impact parameter
have a large initial angular momentum,
which is usually ignored
in the initial conditions assumed for hydro calculations

$$J_0 \sim Ab\sqrt{s}$$

Which potential output this may have?

J_0 → system rotation → v_1, HBT

J_0 → fluid shear → flow vorticity

Flow vorticity can be observed → Λ polarization

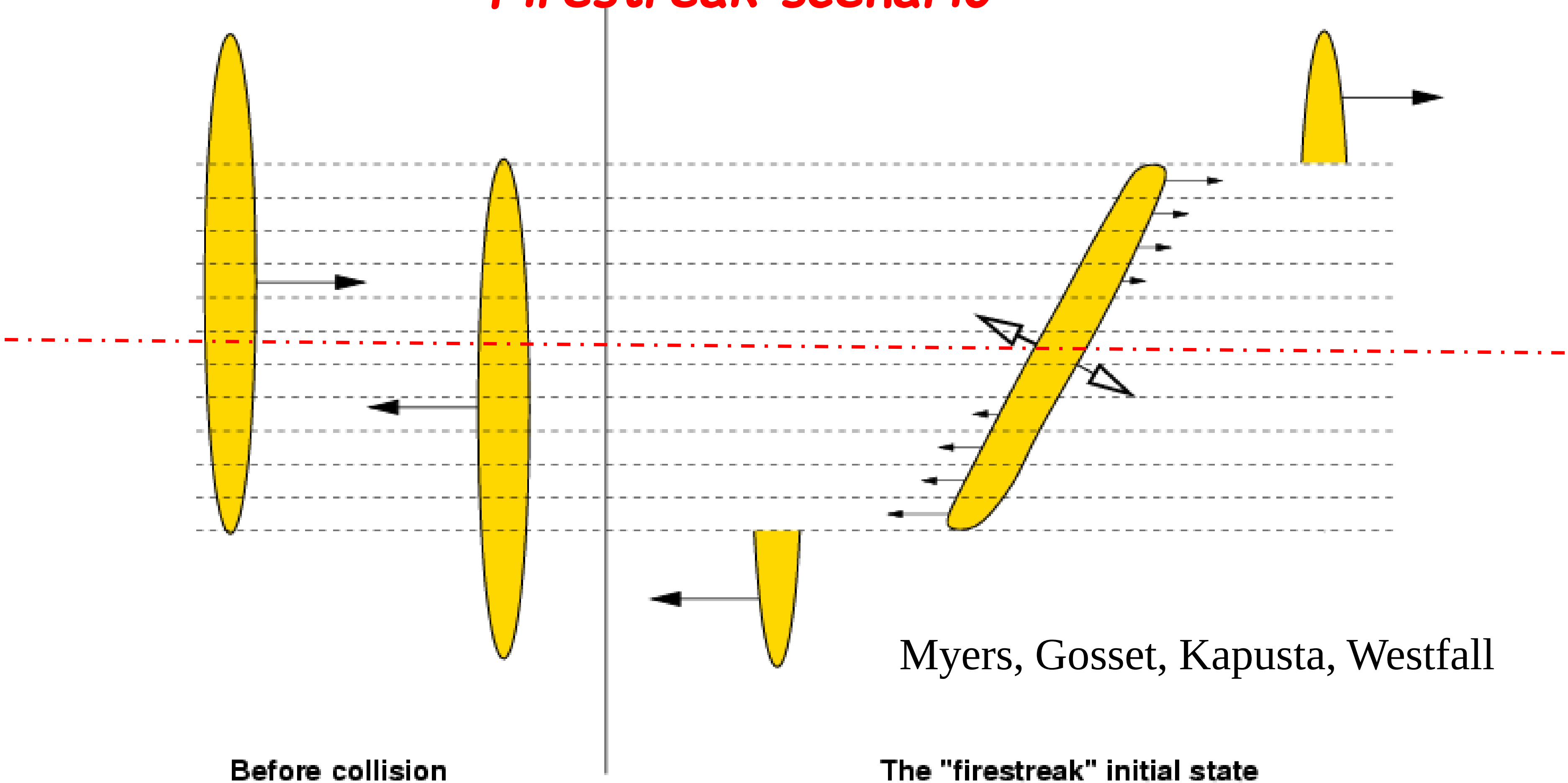
Yilong Xie talk QM'18

Objectives

To propose New Initial State for hydro, which
- conserves angular momentum;
- has fluid shear & vorticity;
- simulates recent parton cascade results

Nuclei colliding at ultra-relativistic energies with nonzero impact parameter have a large initial angular momentum

Firestreak scenario

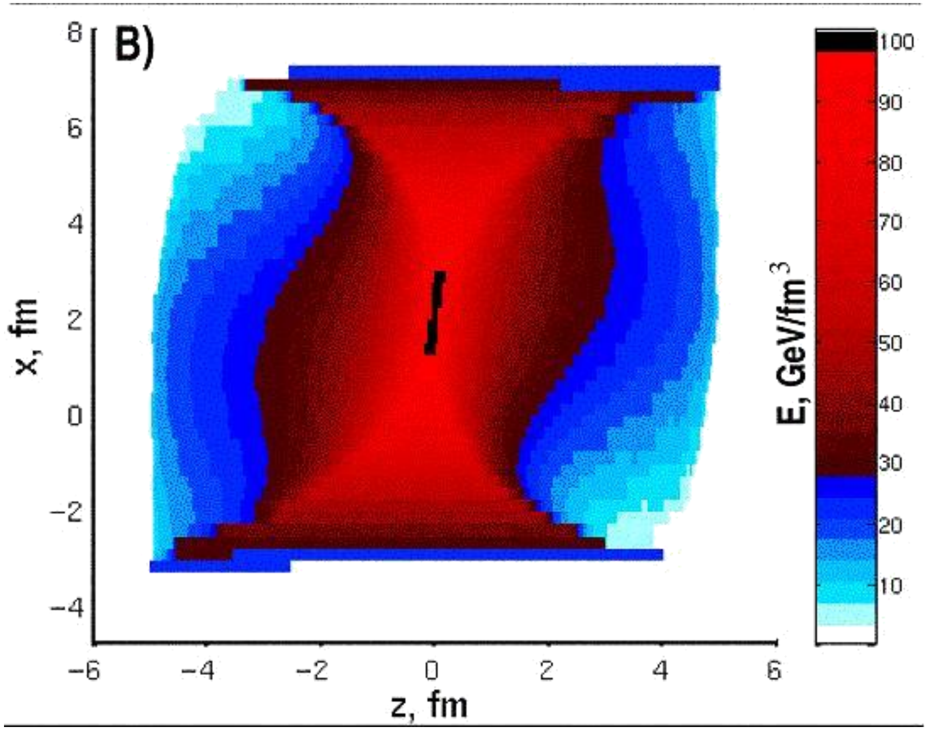


Myers, Gosset, Kapusta, Westfall

Symmetry axis = z-axis. Transverse plane divided into streaks

Initial state from Effective String Rope Model

Magas, Csernai, Strottman, PRC 64 (2001) 014901, NPA 712 (2002) 167



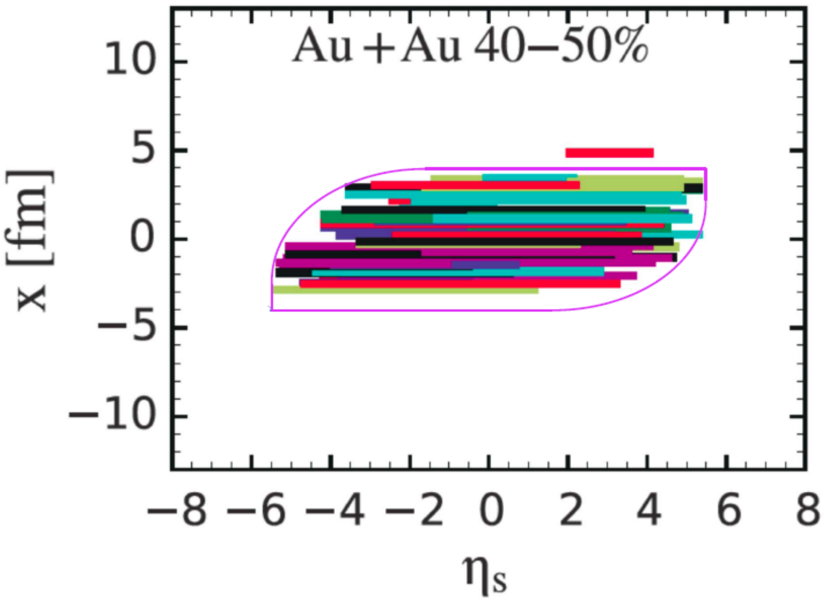
- Idealized: based on several rather strong assumptions

- Too complicated to be a toy model

-Only one free parameter, controlling string tension

- IS for hydro at rather late time of a few fm

Present parton kinetic models give different space-time configurations

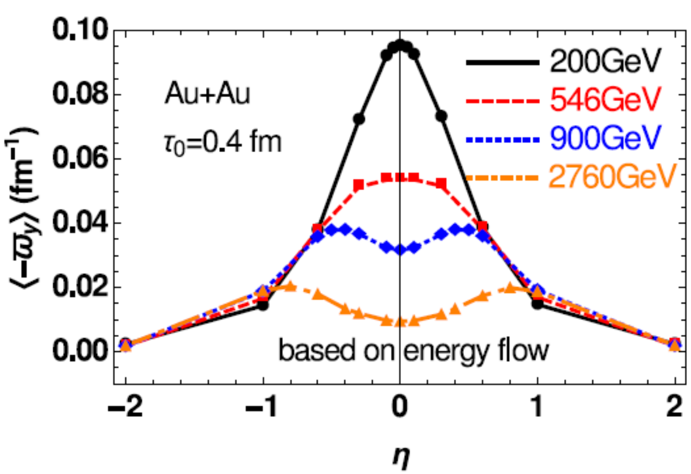


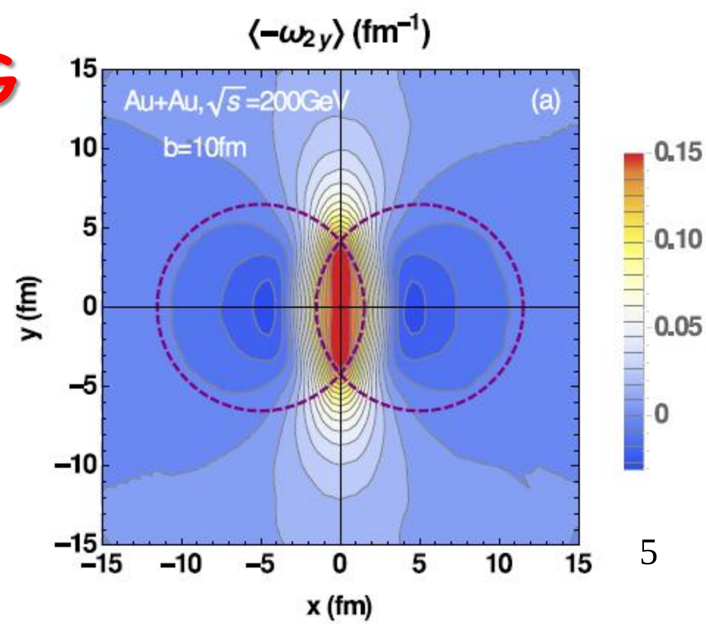
Long-Gang Pang, talk at Quark Matter 2015

A Multi-Phase Transport (AMPT) model

Wei-Tian Deng, and Xu-Guang Huang,
J.Phys.Conf.Ser. 779 (2017) no.1, 012070

HIJING





New Initial State in τ, η coordinates

Firestreak scenario

+ Bjorken boost invariant solution applied streak by streak in the transverse plane

$e_i(\tau_i),\ n_i(\tau_i)\ \ +$ in. cond. at $\tau_i = \tau_0$

For each streak "i":

$$\eta_{min,i} \leq \eta_i \leq \eta_{max,i}$$

$$< \eta_i >= \left(\eta_{min,i} + \eta_{max,i}\right)/2$$

$$\Delta\eta_i = \eta_{max,i} - \eta_{min,i}$$

Hypersurface τ=const

$$d^3\Sigma_\mu = \tau A u_\mu d\eta \qquad A = \Delta x \Delta y$$

Conservation laws at $\tau_i = \tau_0$

$$N_i = \tau_0 n_i(\tau_0) A \Delta\eta_i$$

$$E_i = 2\tau_0 e_i(\tau_0) A \sinh(\Delta\eta_i/2)\cosh(\eta_i)$$

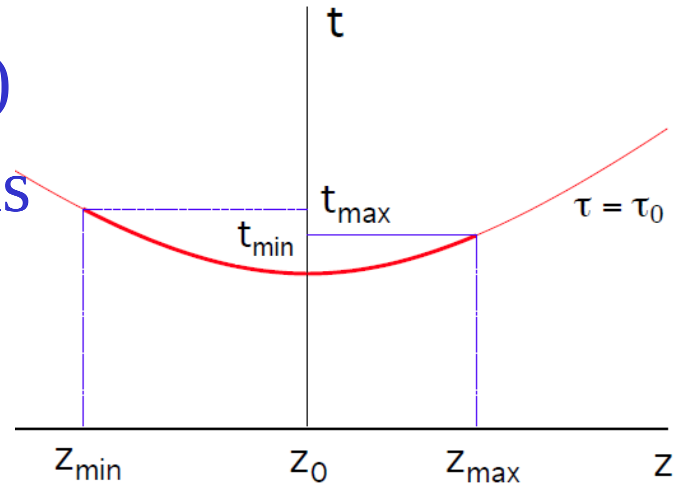
$$P_{iz} = 2\tau_0 e_i(\tau_0) A \sinh(\Delta\eta_i/2)\sinh(\eta_i) \Longrightarrow < \eta_i >= Atanh\left(\frac{P_{iz}}{E_i}\right)$$

New Initial State in τ, η coordinates

Each i-th streak has its own coor. (τ_i, η_i)

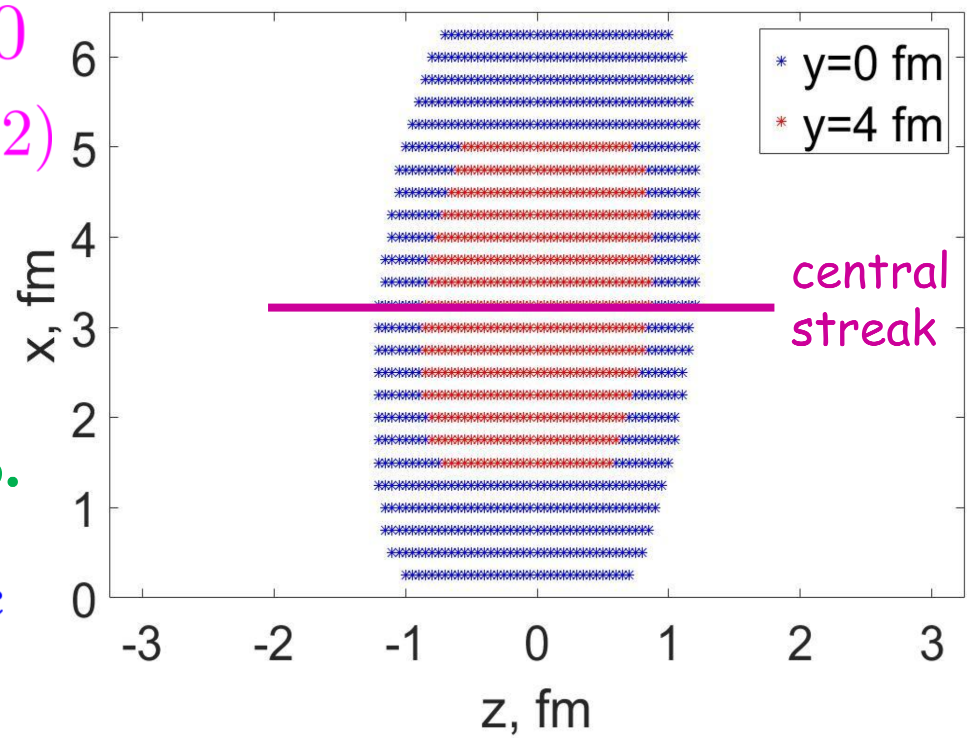
These are connected to the global (t,z) as

$$t - t_{0,i} = \tau_i \cosh \eta_i$$
$$z - z_{0,i} = \tau_i \sinh \eta_i$$



Central streak (y=0)

$$t_{0,c} = z_{0,c} = 0 \qquad < \eta_c >= 0$$
$$z_c^{max} = -z_c^{min} = \tau_0 sinh(\Delta\eta_c/2)$$



Model parameters:

$\tau_0,\ \Delta\eta_c$ **We can control the extension of the I.S.**

$$\Rightarrow \quad e_c(\tau_c = \tau_0) = e_c$$

New Initial State in τ, η coordinates

We require:

- $e_i(\tau_i = \tau_0) = e_c$ **To ensure compact I.S.**

$$\Longrightarrow \quad \Delta\eta_i = 2Asinh\left(\frac{E_i}{2\tau_0 e_c(\tau_0) A\cosh(<\eta_i>)}\right)$$

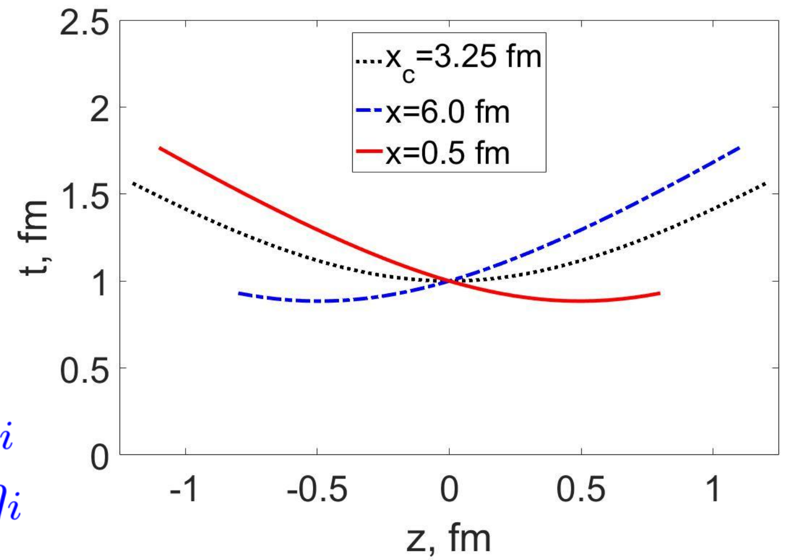
For each streak "i": $\eta_i \subset [<\eta_i> - \frac{\Delta\eta_i}{2}; <\eta_i> + \frac{\Delta\eta_i}{2}]$

The central rapidity point: $\eta_i =< \eta_i >$

- $z(\tau_i = \tau_0, \eta_i =< \eta_i >) = 0$
- $\tau_i(\eta_i =< \eta_i >) = \tau_0$

To combine different streaks in global I.S.

$$\Rightarrow \quad \{t_{0,i}, z_{0,i}\}$$



$$t = t_{0,i} + \tau_i \cosh\eta_i$$
$$z = z_{0,i} + \tau_i \sinh\eta_i$$

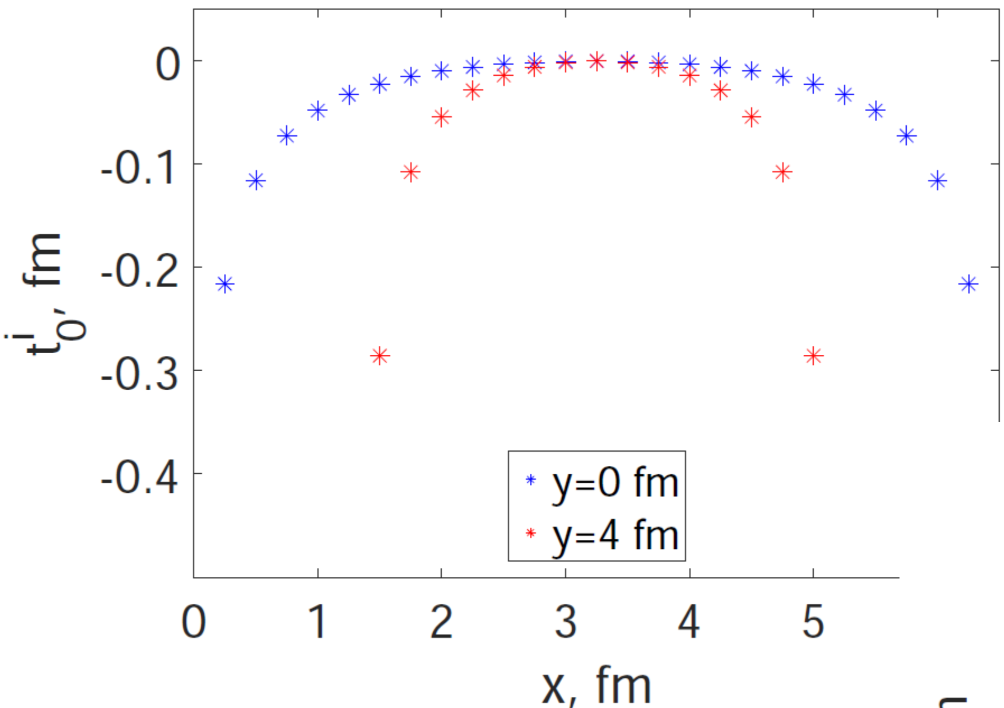
New Initial State in τ, η coordinates

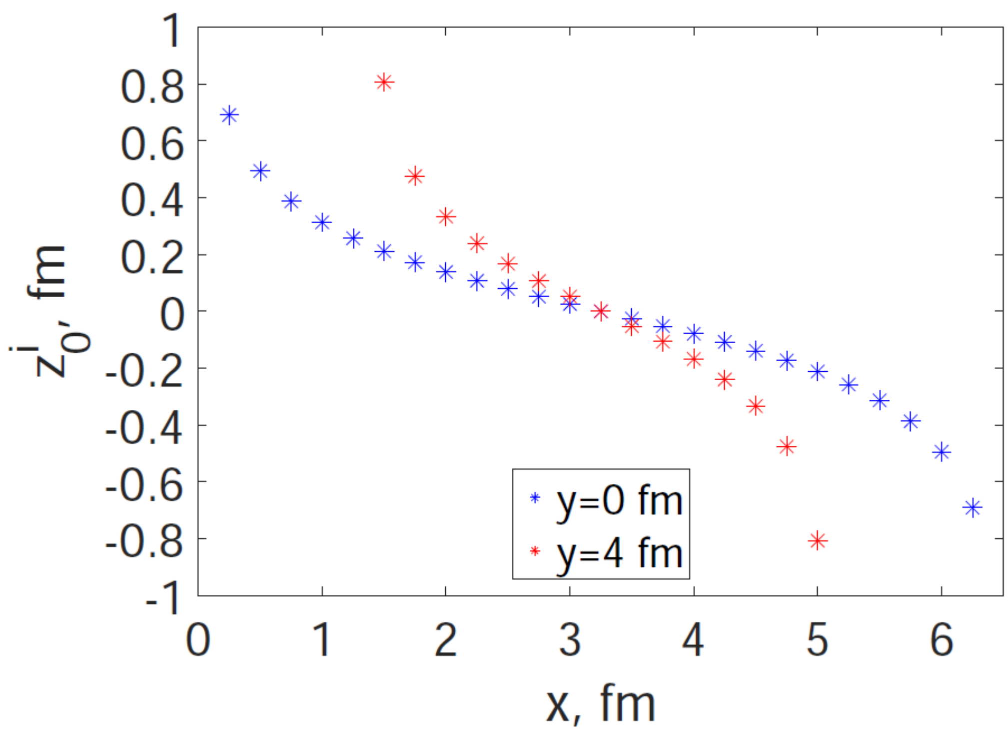
Au+Au, 100 + 100 GeV/nucl, b=R_{Au}

Model parameters:

$\Delta\eta_c = 2$

$\tau_0 = 1$ fm





Thus for each streak, i, we can get the origin of the τ=τ_0 hyperbola, $\{t_{0,i}, z_{0,i}\}$

Initial State for hydro at $t = t_{fin}$

Au+Au, 100 + 100 GeV/nucl, b=R_{Au}

Model parameters:

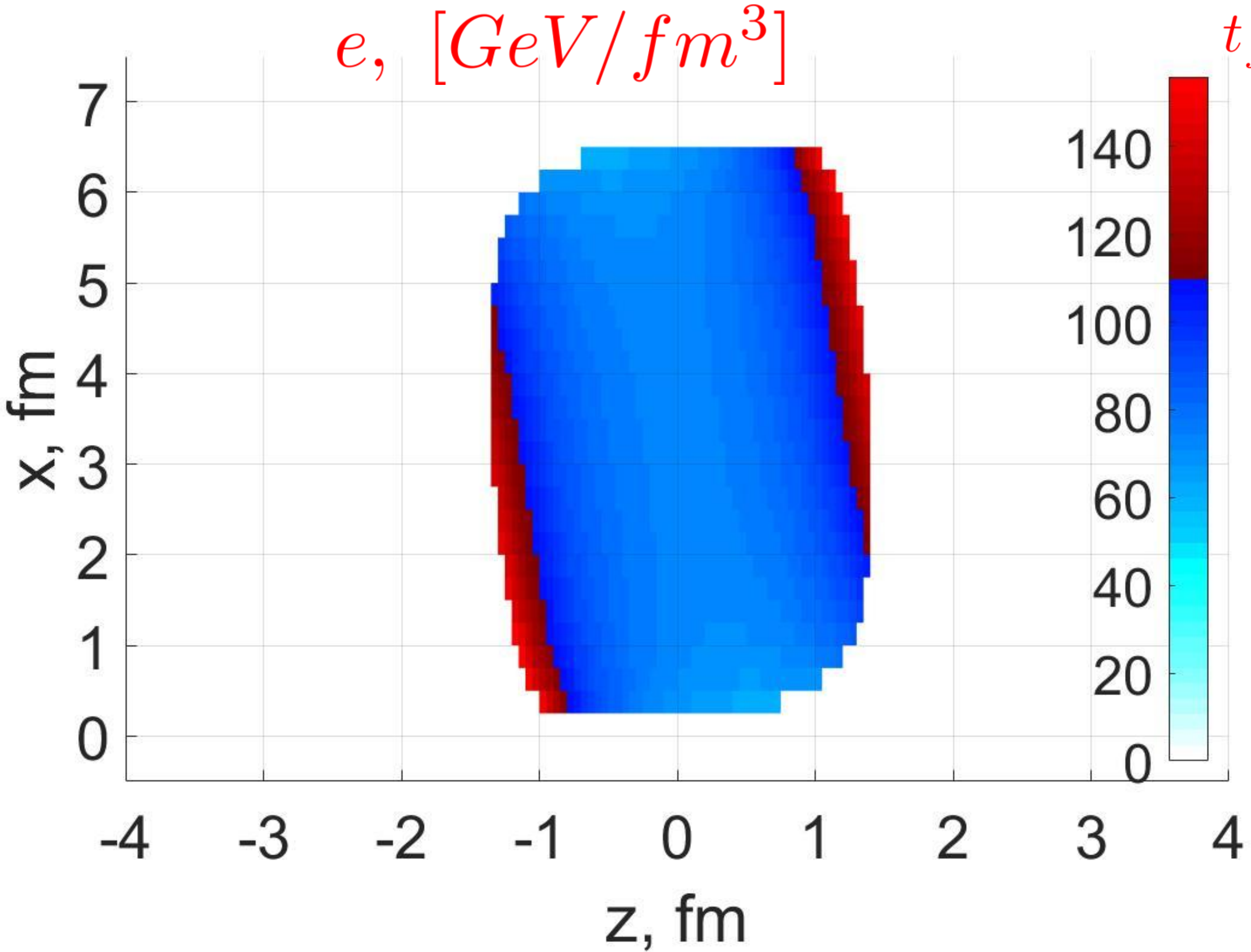
$\Delta\eta_c = 2$

$\tau_0 = 1$ fm

$t_{fin} = 1.78$ fm

minimal possible

all $\tau_i \geq \tau_0$



Initial State for hydro at $t = t_{fin}$

Au+Au, 100 + 100 GeV/nucl, b=R_{Au}

Fluid shear

Model parameters:

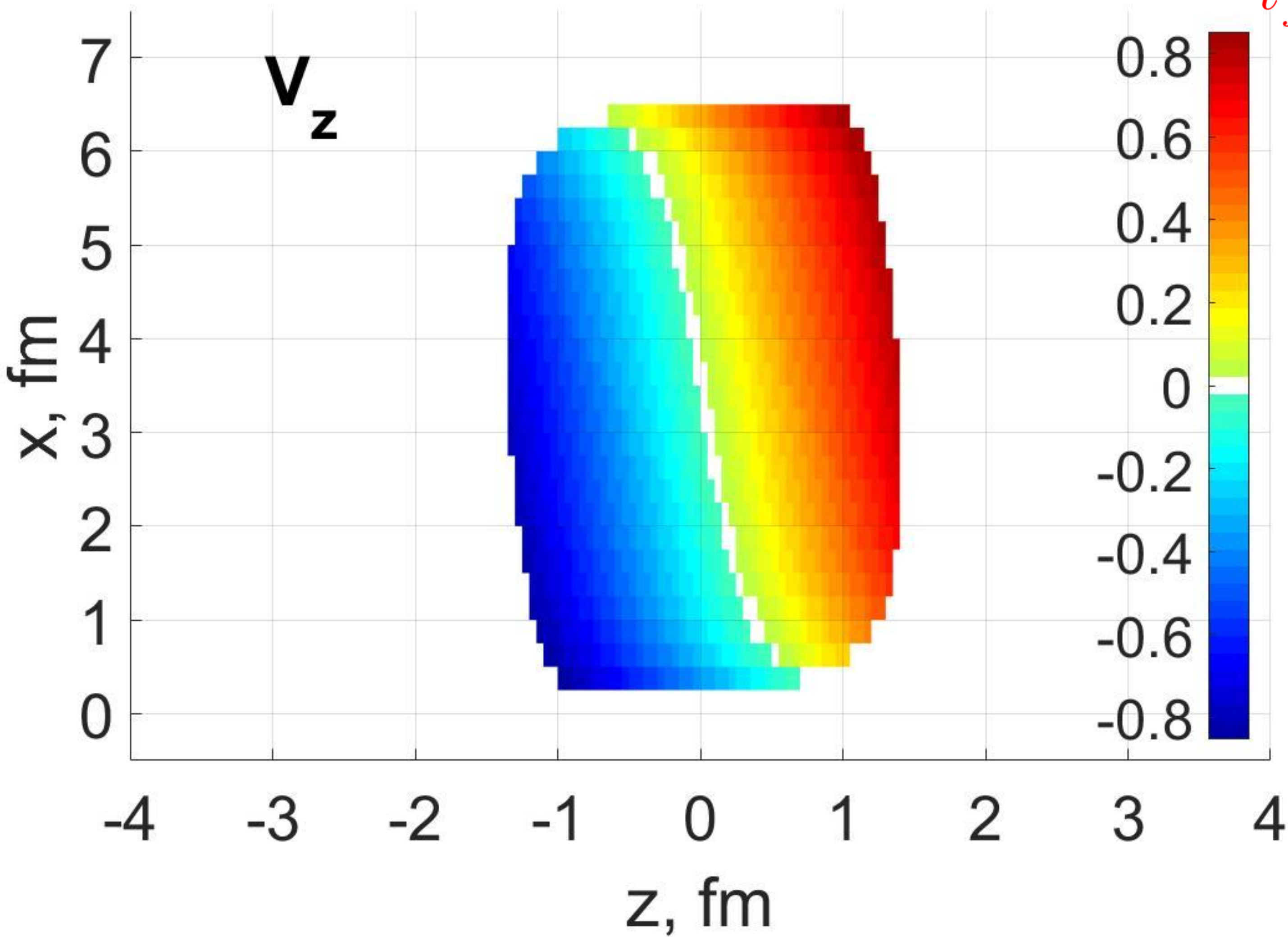
$\Delta\eta_c = 2$

$\tau_0 = 1$ fm

$t_{fin} = 1.78$ fm

minimal possible

all $\tau_i \geq \tau_0$



Initial State for hydro at $t = t_{fin}$

Au+Au, 100 + 100 GeV/nucl, b=R_{Au}

Model parameters:

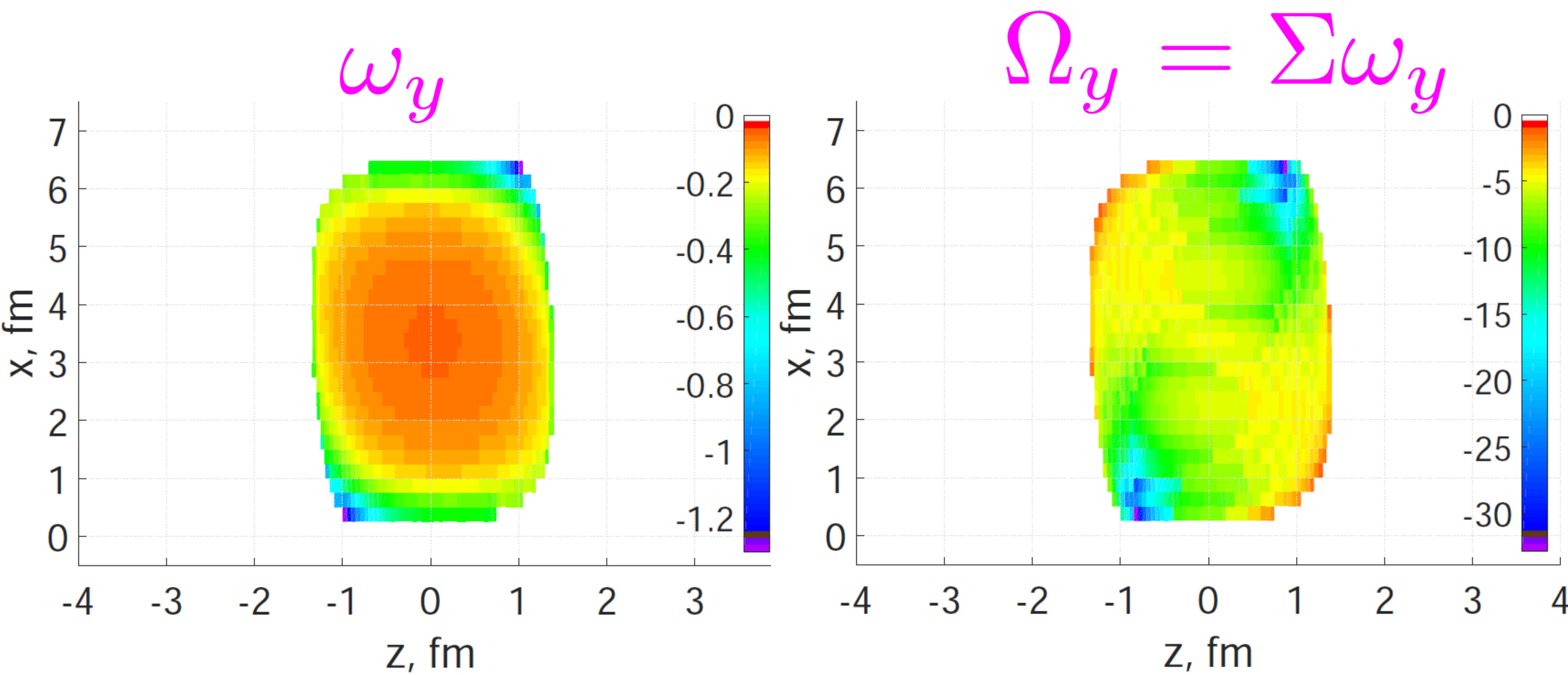
$\Delta\eta_c = 2$

$\tau_0 = 1$ fm

$t_{fin} = 1.78$ fm

Relativistic flow vorticity

$$\omega_y = \frac{1}{2}\left(\partial_z \gamma v_x - \partial_x \gamma v_z\right)$$



Conclusions

New Initial State for hydro is proposed

- Simple (toy model level), but non-trivial:
  - large initial angular momentum
  - fluid shear
  - flow vorticity

- I.S. has 2 free parameters to vary $\tau_0, \; \Delta\eta_c$

- I.S. can be given in both (τ,η) and (t,z) coordinates

- New I.S. in (t,z) can be easily combined with PIC 3+1D hydro code

- Work in progress