HBT in a non-boost invariant framework

— what's different?

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Introduction

Evolution model description

- Framework
- Caveats

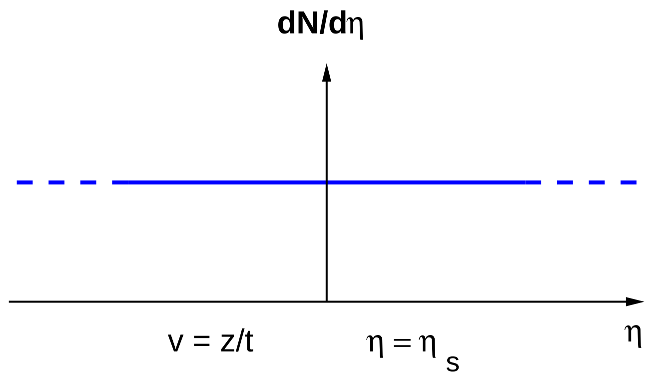
HBT correlation radii

- General remarks on η-dependence
- Three scenarios
- Results

Conclusions

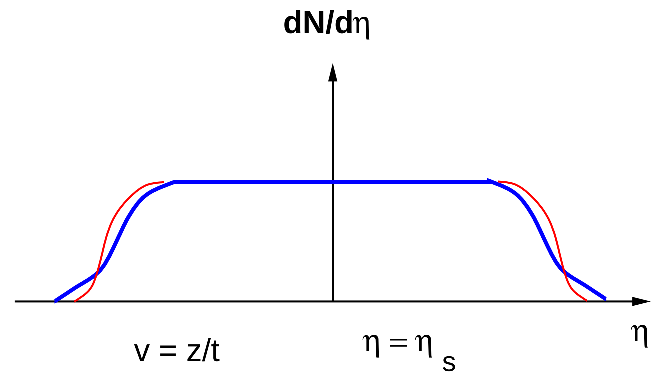
What is meant by boost-invariance?

asymptptic Bjorken solution



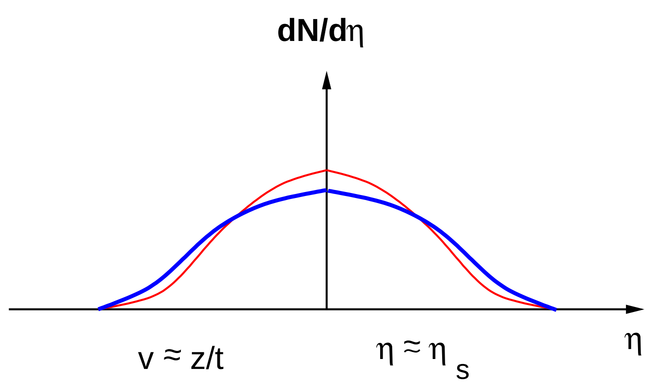
spectra and correlation radii same in LCMS

finite energy Bjorken solution



spectra and correlation radii same in LCMS
across finite rapidity interval ('plateau')

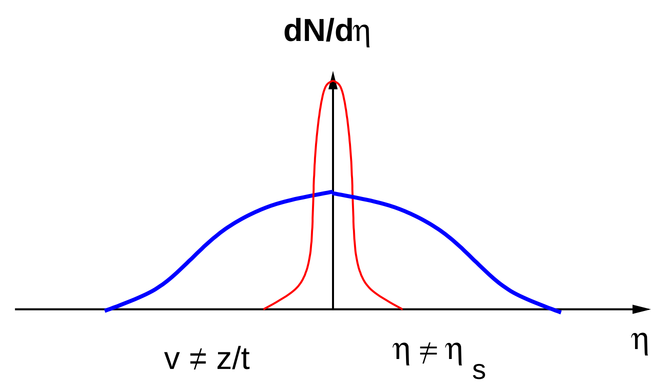
approximate scaling solution



expansion preserves dN/d η ('3d hydro')

spectra and correlation radii in LCMS depend on dN/dη

non−boost−invariant expansion



spectra and correlation radii in LCMS
depend on time evolution and on dN/d η

Fireball evolution

Starting point: entropy density

$$S = \int d^3x N R(r,\tau) H(\eta_s,\tau) \qquad \text{using}$$

$$R(r,\tau) = 1/\left(1+\exp\left[\frac{r-R_c(\tau)}{d_{\text{ws}}}\right]\right) \qquad H(\eta_s,\tau) = 1/\left(1+\exp\left[\frac{\eta_s-H_c(\tau)}{\eta_{\text{ws}}}\right]\right)$$

$R_c(\tau)$ expanding from R_0 to R_F
$\longrightarrow$ determines transverse flow field assuming $v_T(\tau,r) = r/R v_T^{max}(\tau)$

$H_c(\tau)$ from η_0 to η_f
$\longrightarrow$ non-Bjørken dynamics

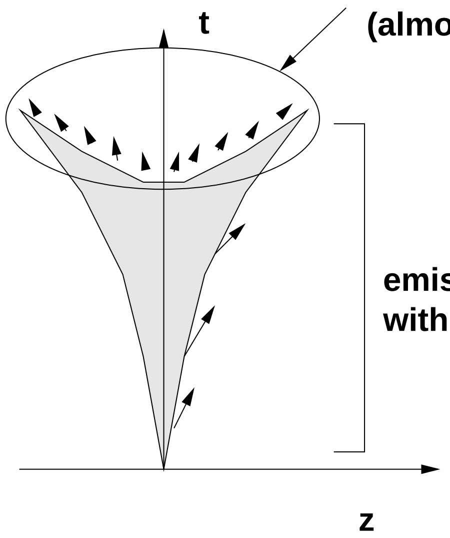
EOS from lattice QCD
$\longrightarrow T(\eta_s, r, \tau)$

Can be tuned quickly to simulate all of the scenarios shown previously

Fireball evolution

Hadron emission: Cooper-Frye formula

$$E\frac{d^3N}{d^3p} = \frac{g}{(2\pi)^3}\int d\sigma_\mu p^\mu \exp\left[\frac{p^\mu u_\mu - \mu_i}{T_f}\right] = d^4xS(x,p)$$



$$\frac{d^2N}{m_\perp dm_\perp dy} = \int_0^R A_i m_\perp K_1\left(\frac{m_\perp \cosh\rho}{T}\right) I_0\left(\frac{p_\perp \sinh\rho}{T}\right)$$

is based on

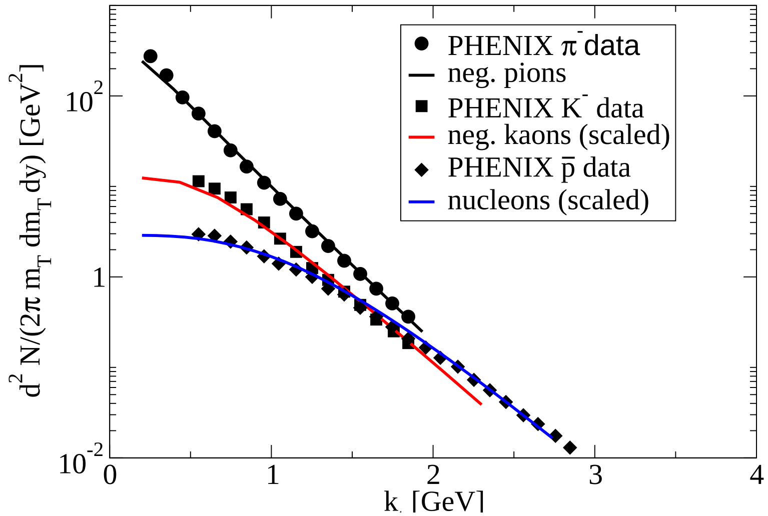
$$K_1(z) = \int_0^\infty \cosh\eta_s \exp[-z\cosh\eta]d\eta$$

for $\eta = \eta_s$ — in the general case, the integral has to be done numerically.

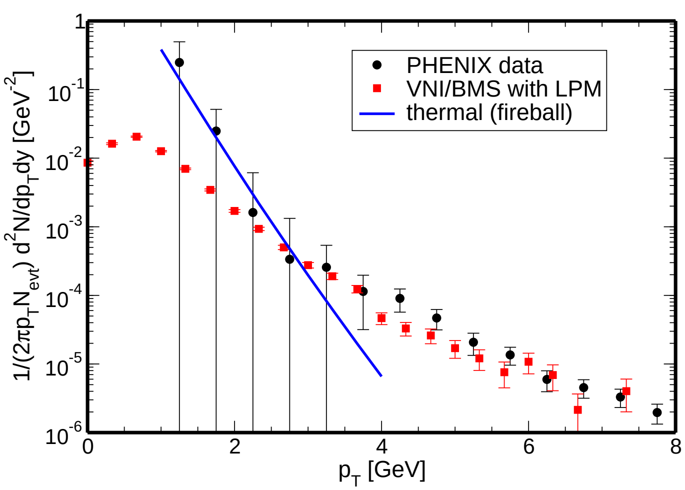
Differences to Blast Wave:

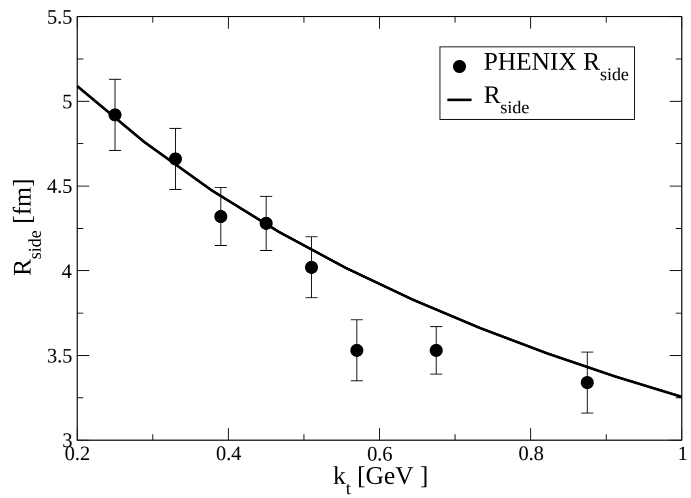
• $\eta \neq \eta_s$ • R_F and $v_\perp$ correlated • evolution from initial to final state
• spacelike emission hypersurface • explicit link to EOS

RHIC MODEL COMPARISON



- absolute normalization: entropy S_0 (input parameter)
- relative normalization: statistical hadronization (model prediction)
- spectral shape: evolution model result (fitted)
- missing: resonance decays (low k_t)





⇒ describes simultaneously m_t-spectra, HBT, R_{AA} and photon emission (so far)

Some caveats

Disclaimers:

• The framework describes *thermal* physics
⇒ not applicable in target/projectile fragmentation region
⇒ not applicable in dilute regions (large fraction of matter below T_F ab initio)
⇒ moderately constrained at forward rapidities, central collisions only!

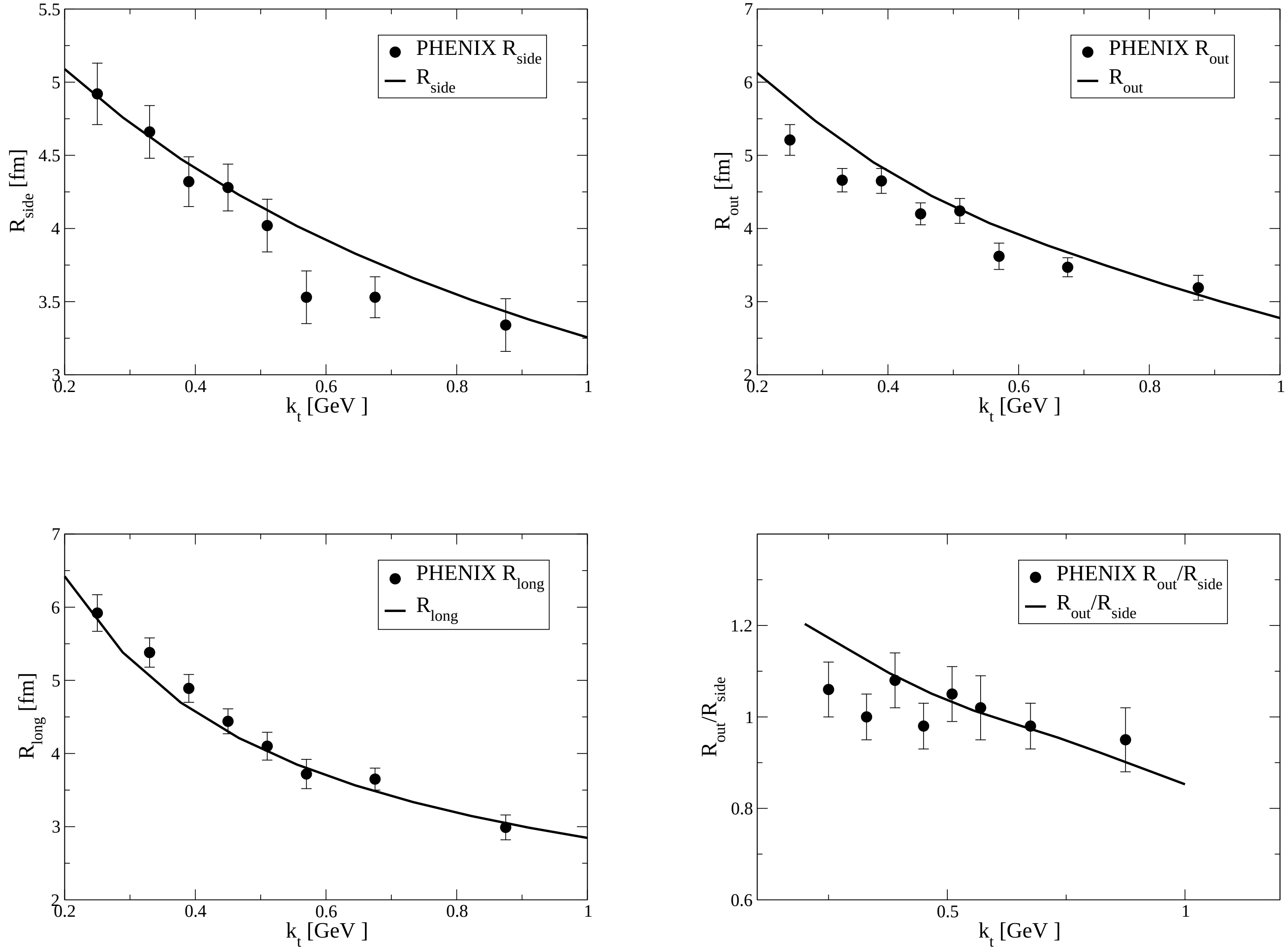
• HBT correlation radii are calculated as averages over the emission function

$$R^2_{side}(\mathbf{K}) = \langle \tilde{y}^2 \rangle(\mathbf{K})$$
$$R^2_{out}(\mathbf{K}) = \langle (\tilde{x} - \beta_\perp \tilde{t})^2 \rangle(\mathbf{K})$$
$$R^2_{long}(\mathbf{K}) = \langle (\tilde{z} - \beta_l \tilde{t})^2 \rangle(\mathbf{K})$$

$$\tilde{x}^\mu(K) = x^\mu - \langle x^\mu \rangle(K) \quad \text{with} \quad \langle f \rangle(K) = \frac{\int d^4x f(x) S(x,K)}{\int d^4x S(x,K)}$$

⇒ no explicit calculation of the correlator

HBT AT MIDRAPIDITY — THE STANDARD SCENARIO



Rapidity dependence of HBT

Two essential effects:

• 'trivial rapidity dependence induced by observed $dN/d\eta$
(for approximate scaling and non-Bjorken)
$\Rightarrow$ amount of thermalized matter determines the geometry

• time dependence of $dN/d\eta$
(for non-Bjorken)
$\Rightarrow$ matter radiates into different rapidities at different times

but. . .

• time dep. only visible if emission not dominated by sudden breakup

Three scenarios

Three different evolutions leading to the same $dN/d\eta$

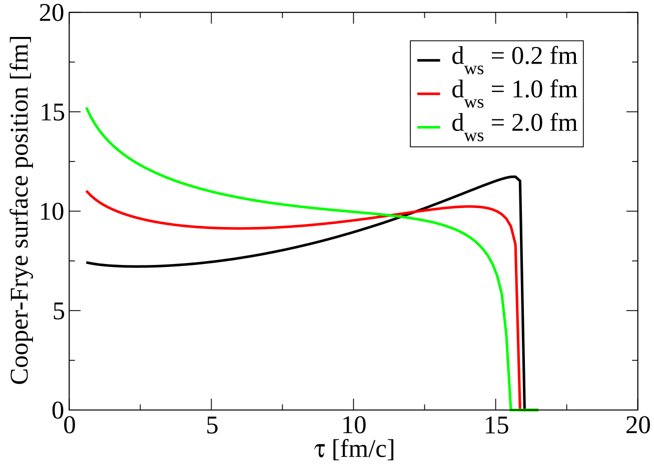
- approximate scaling solution (hadronic m_T, $dN/d\eta$, R_{side})

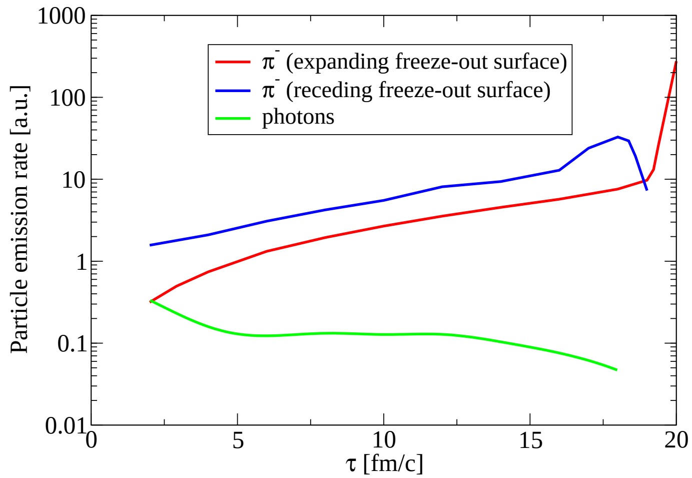
- non-Bjorken expansion with sudden breakup (hadronic m_T, $dN/d\eta$ and HBT at midrapidity)

- non-Bjorken expansion with continuous emission (hadronic m_T, $dN/d\eta$, R_{side}, R_{long})

$\Rightarrow$ study in comparison

SUDDEN BREAKUP VS. CONTINUOUS EMISSION





- dilute (Gaussian) surface: fireball shrinks

$\longrightarrow$ emission from spacelike surface dominant

- sharp (Box) surface: fireball expands

$\longrightarrow$ emission from timelike surface dominant

$\Rightarrow$ $dN/d\tau$ looks different in both cases!

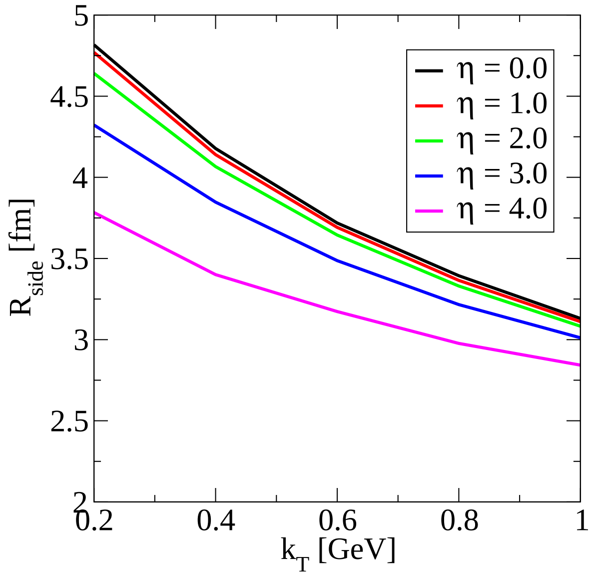
$\Rightarrow$ for the best fit $d_{ws} = 0.2$ fm, hadron emission can be seen as final breakup + corrections

$\Rightarrow$ for inward-burning solution R_{out}/R_{side} starts to get larger

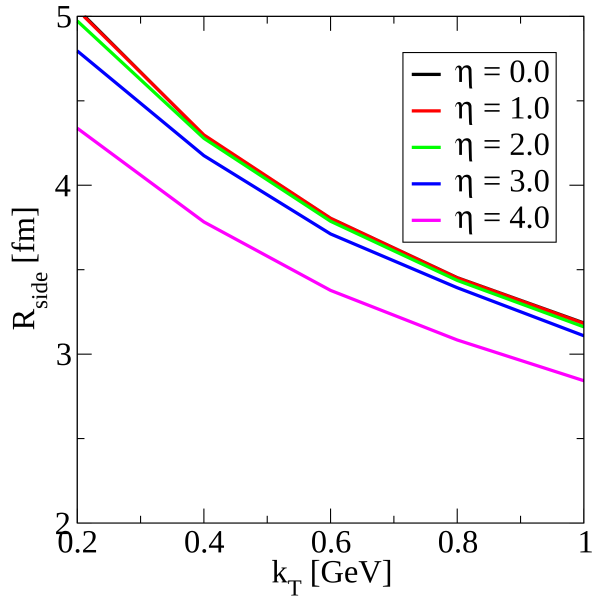
The measured R_{out}/R_{side} favours a sudden breakup solution

RAPIDITY DEPENDENCE OF R_{side}

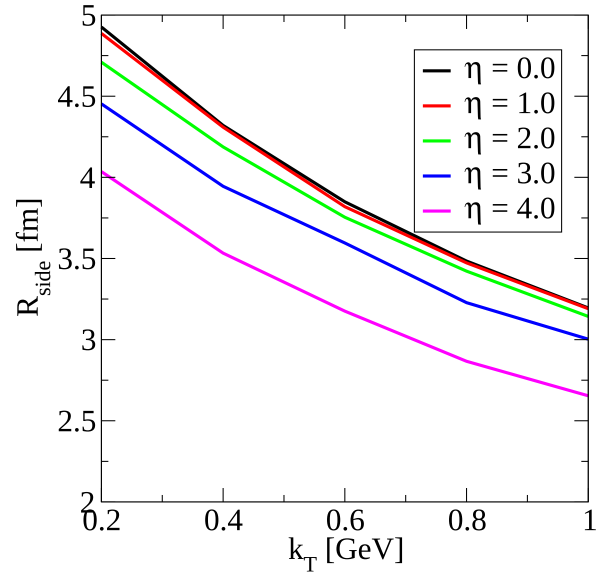
approx. scaling (1)



sudden breakup (2)



slow breakup (3)



Rapidity-independent physics:

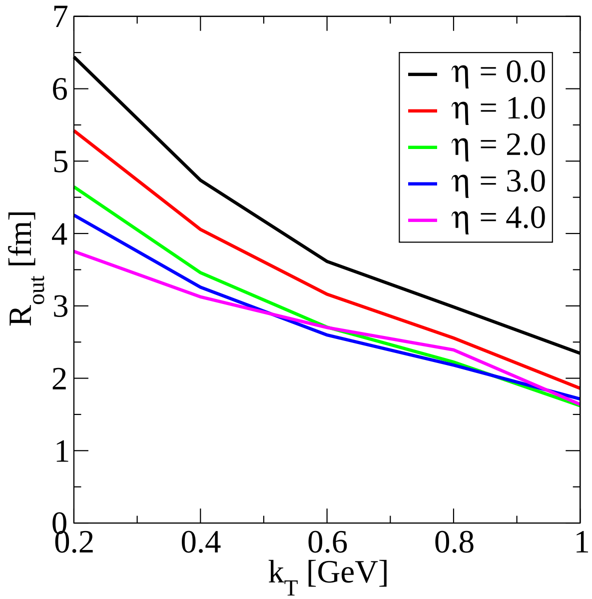
- (1): stronger longitudinal expansion than (2),(3) $\Rightarrow$ less transverse expansion at τ_F

Rapidity-dependent physics:

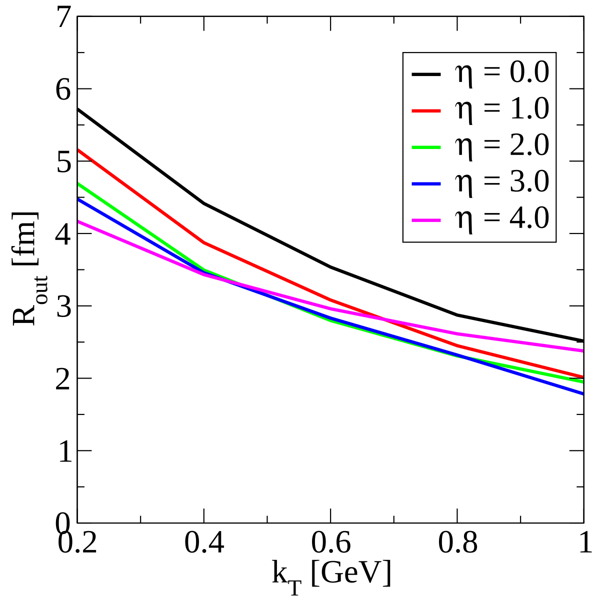
- forward region in (3) initially populated by thermal tail $\Rightarrow$ smaller scale

RAPIDITY DEPENDENCE OF R_{out}

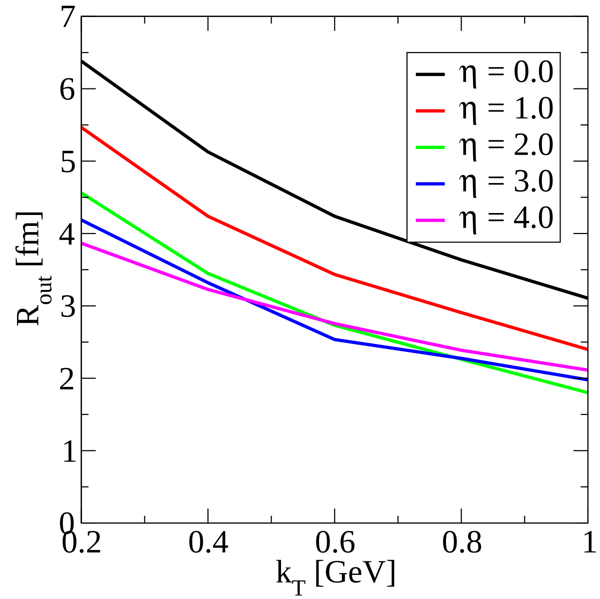
approx. scaling (1)



sudden breakup (2)



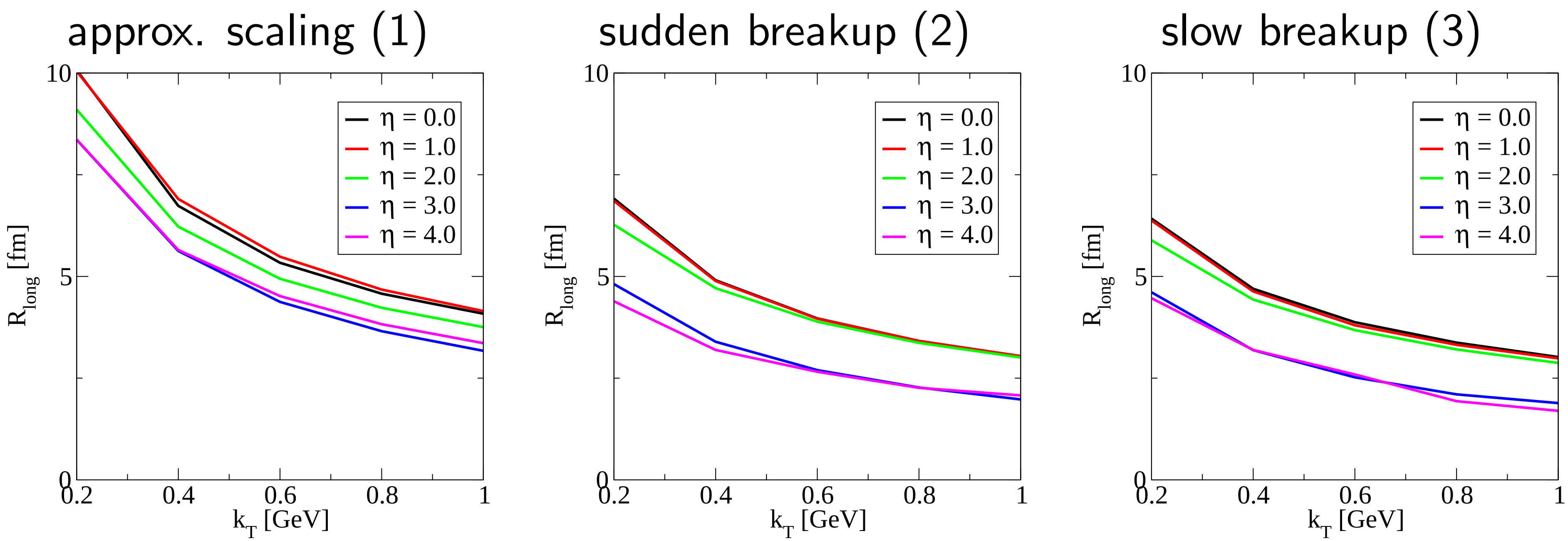
slow breakup (3)



Rapidity-independent physics:

- (3): negative $x - t$ correlation due to inward burning Cooper-Frye surface
- (1): negative $x - t$ correlation due to strong long. expansion and cooling

Rapidity dependence of R_{long}



Rapidity-independent physics:

- (1): strong long. expansion and mapping $\eta_s = \eta$
- (2),(3): $\eta_s < \eta$

Rapidity-dependent physics:

- (2),(3): sensitive to the 'drop' of thermalized matter distribution

Conclusions

HBT correlation radii $\Leftrightarrow$ interplay of many effects

- balance between longitudinal/transverse expansion
- relation between η and η_s
- temporal pattern of emission
- amount of thermalized matter per rapidity
- evolution history
- . . .

However:

If R_{out}/R_{side} implies sudden final breakup, the rapidity dependence of HBT correlations is dominated by the 'trivial' dependence on the measured $dN/d\eta$.

$\Rightarrow$ photons still see the whole evolution