Observables, forgó megoldások X = Z = R, Y esetében

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Our starting equations

Consider the non-relativistic hydrodynamical problem, as given by the continuity, Euler and energy equations:

$$\begin{aligned} \partial_t n + \nabla \cdot (n\mathbf{v}) &= 0\,, \\ \partial_t \mathbf{v} + (\mathbf{v} \cdot \nabla)\mathbf{v} &= -(\nabla p)/(mn)\,, \\ \partial_t \epsilon + \nabla \cdot (\epsilon \mathbf{v}) &= -p\nabla \cdot \mathbf{v}\,, \end{aligned}$$

v flow velocity field, n particle number, p pressure,
m particle mass, ϵ energy density

The closing Equation of State

$$p = nT\,, \qquad \epsilon = \kappa(T)nT,$$

T temperature, $\kappa(T)$ compressibility
for ideal gas 3/2

The Ansatz for the solution

self-similar, ellipsoidally symmetric density and flow profiles:

$$T(\mathbf{r},t) = T(t),$$

$$n(\mathbf{r},t) = n_0 \frac{V_0}{V} \exp\left\{-\frac{r_x^2}{2X^2} - \frac{r_y^2}{2Y^2} - \frac{r_z^2}{2Z^2}\right\}$$

$$\mathbf{v}(\mathbf{r},t) = \left(\frac{\dot{X}}{X} r_x + \omega r_z \, , \, \frac{\dot{Y}}{Y} r_y \, , \, \frac{\dot{Z}}{Z} r_z - \omega r_x\right)$$

where

$$(X,Y,Z) = (X(t), Y(t), Z(t))$$ $$V = XYZ,$$

is known from a long time

S.V. Akkelin, T. Csörgő, B. Lukács, Yu. M. Sinyukov and M. Weiner, Phys. Lett. **B505** (2001) 64.

The final ordinary differentialequation for the time propagation

$$X = Z \equiv R, \quad \dot{X} = \dot{Z} \equiv \dot{R},$$

$$R\ddot{R} - R^2\omega^2 = \ddot{Y}Y = \frac{T}{m_0},$$

$$\dot{T}\frac{d}{dT}(T\kappa(T)) + T\frac{\dot{V}}{V} = 0,,$$

$$\omega(t) = \omega_0 \frac{R_0^2}{R^2(t)}.$$

The time dependence of the temperature is

$$\frac{V_0}{V} = \exp\left[\kappa(T) - \kappa(T_0)\right] \exp \int_{T_0}^{T} \frac{dT'}{T'} \kappa(T')$$

Inital conditions

$$V_0 = V(t_0)$$

$$T_0 = T(t_0)$$

$$T = T_0 \left(\frac{V_0}{V}\right)^{1/\kappa}$$

The observables and the new solutions

the emission function at a constant freeze-out temperature

$$S(t,\mathbf{r}',\mathbf{k}') \propto \mathrm{e}^{-\frac{(x\mathbf{k}'-m\mathbf{v}')^2}{2mT_f}-\frac{r_x'^2}{2X_f^2}-\frac{r_y'^2}{2Y_f^2}-\frac{r_z'^2}{2Z_f^2}}\,\delta(t-t_f)$$

single particle spectrum

$$S \propto \exp\left\{-\frac{T_x r_x^2}{2T_f X_f^2}+\frac{p_x\dot{X}_f - p_z\omega_f X_f}{X_f T_f}r_x-\frac{p_x^2}{2mT_f}\right\}\times$$

$$\times\exp\left\{-\frac{T_y r_y^2}{2T_f Y_f^2}+\frac{p_y\dot{Y}_f}{Y_f T_f}r_y-\frac{p_y^2}{2mT_f}\right\}\times$$

$$\times\exp\left\{-\frac{T_z r_z^2}{2T_f Z_f^2}+\frac{p_z\dot{Z}_f + p_x\omega_f Z_f}{Z_f T_f}r_z-\frac{p_z^2}{2mT_f}\right\}$$

The observables and the new solutions

Using the new notation:

$$
\begin{aligned}
T_x &= T_f + m\left(\dot{X}_f^2 + \omega_f^2 Z_f^2\right), \\
T_y &= T_f + m\dot{Y}_f^2, \\
T_z &= T_f + m\left(\dot{Z}_f^2 + \omega_f^2 X_f^2\right).
\end{aligned}
$$

new terms from the rotation

The observables II

$$
\begin{aligned}
C(\mathbf{K}',\mathbf{q}') &= 1+\lambda \exp\left(-q_x'^2 R_x'^2 - q_y'^2 R_y'^2 - q_z'^2 R_z'^2\right), \\
\mathbf{K}' &= \mathbf{K}'_{12} = 0.5(\mathbf{k}'_1+\mathbf{k}'_2), \\
\mathbf{q}' &= \mathbf{q}'_{12} = \mathbf{k}'_1-\mathbf{k}'_2 = (q'_x, q'_y, q'_z), \\
R_x'^{-2} &= X_f^{-2}\left(1+\frac{m}{T_f}(\dot{X}_f^2 + Y_f^2\omega^2)\right), \\
R_y'^{-2} &= Y_f^{-2}\left(1+\frac{m}{T_f}\dot{Y}_f^2\right), \\
R_z'^{-2} &= Z_f^{-2}\left(1+\frac{m}{T_f}(\dot{Z}_f^2 + X_f^2\omega^2)\right).
\end{aligned}
$$

the two-particle BECF

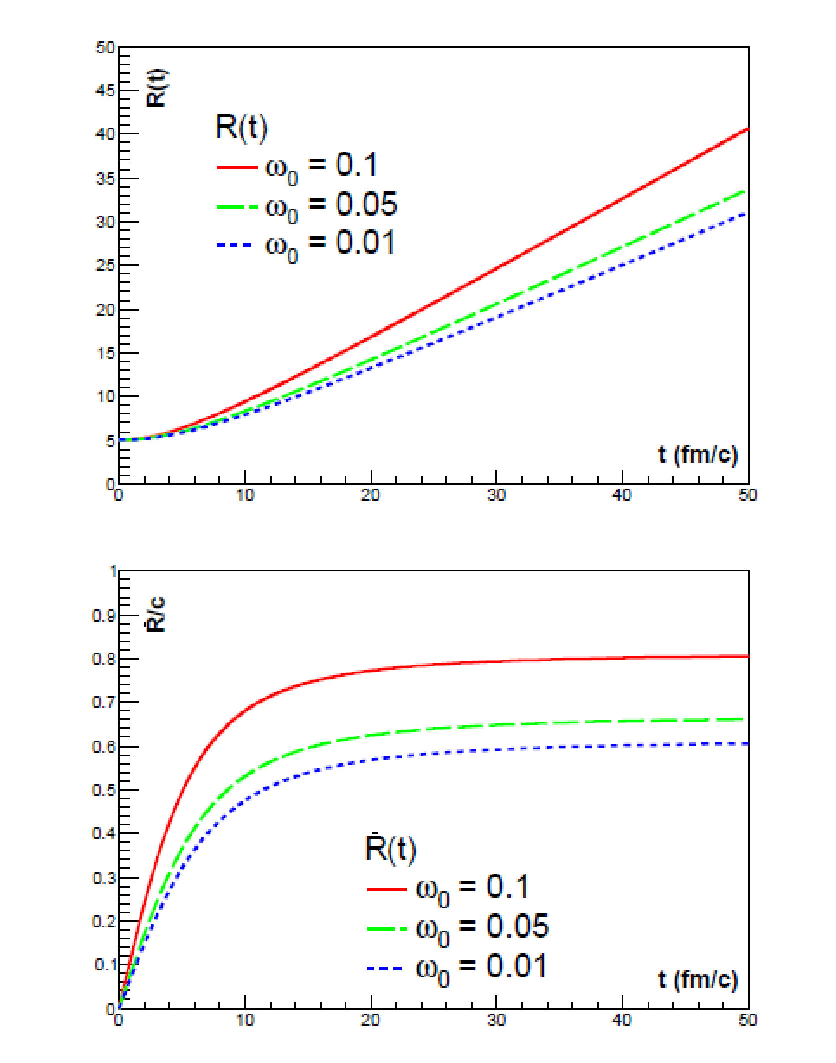
new terms from the rotation

$$
\begin{aligned}
C_2(\mathbf{K},\mathbf{q}) &= 1+\lambda \exp\left(-\sum_{i,j=\mathrm{s,o,l}} q_i q_j R_{ij}^2\right), \\
R_{\mathrm{s}}^2 &= R_y'^2 \cos^2\phi + R_x^2 \sin^2\phi, \\
R_{\mathrm{o}}^2 &= R_x^2 \cos^2\phi + R_y'^2 \sin^2\phi + \beta_t^2 \Delta t^2, \\
R_{\mathrm{l}}^2 &= R_z'^2 \cos^2\theta + R_x'^2 \sin^2\theta + \beta_{\mathrm{l}}^2 \Delta t^2, \\
R_{\mathrm{ol}}^2 &= 0 + \beta_t \beta_{\mathrm{l}} \Delta t^2, \\
R_{\mathrm{os}}^2 &= (R_x^2 - R_y'^2)\cos\phi \sin\phi, \\
R_{\mathrm{sl}}^2 &= 0.
\end{aligned}
$$

the transverse momentum of the measured pair

Results I

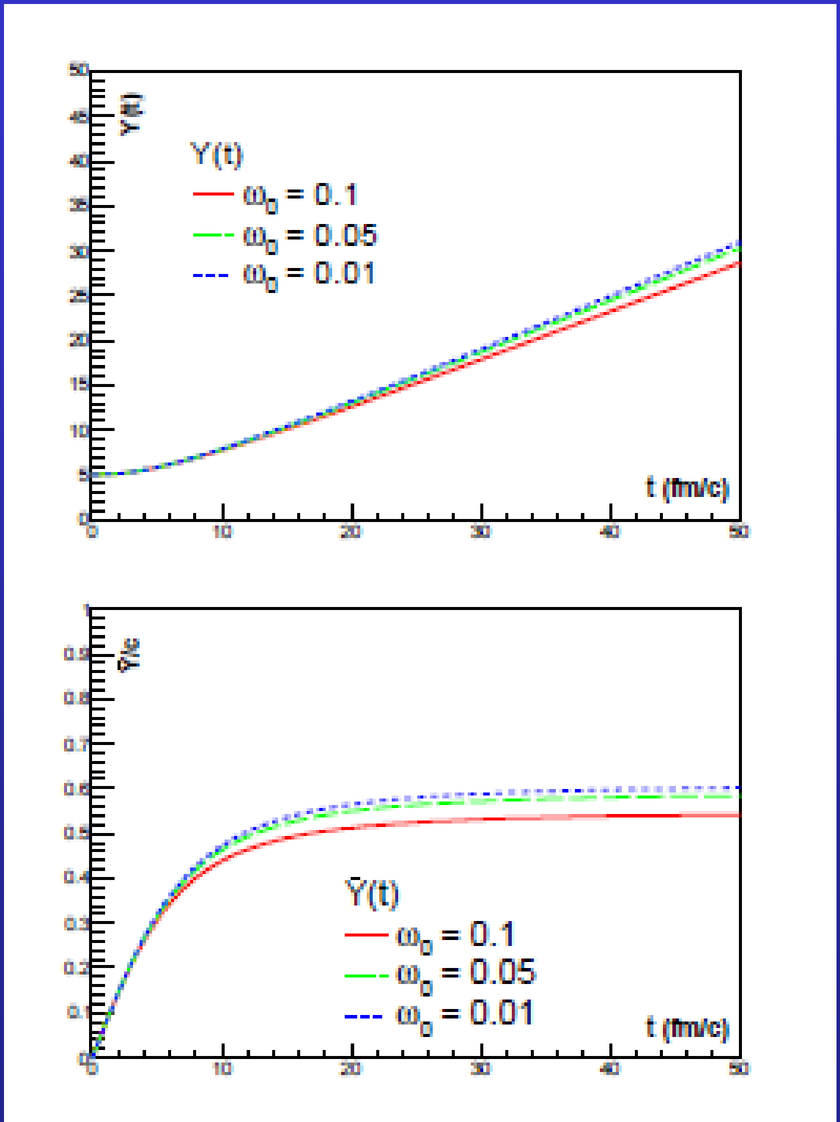
Time evolutions of the axes X(t) = Z(t) = R(t)



Inital conditions:
R_0 = 5 fm,
Y_0 = 5 fm

Results II

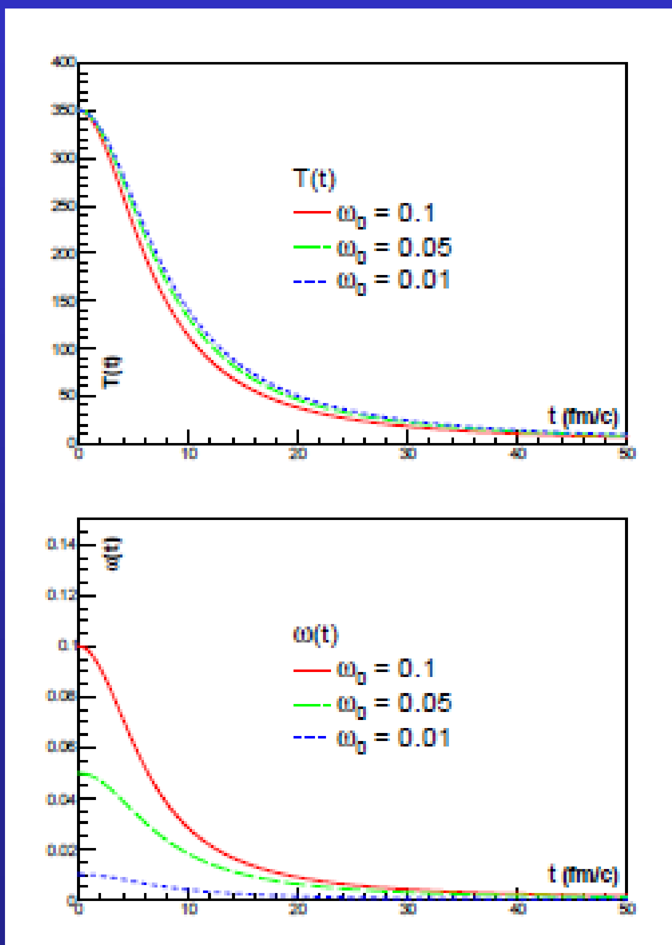
Time evolutions of the axes Y(t)



Inital conditions:
$R_0 = 5$ fm,
$Y_0 = 5$ fm

Results III

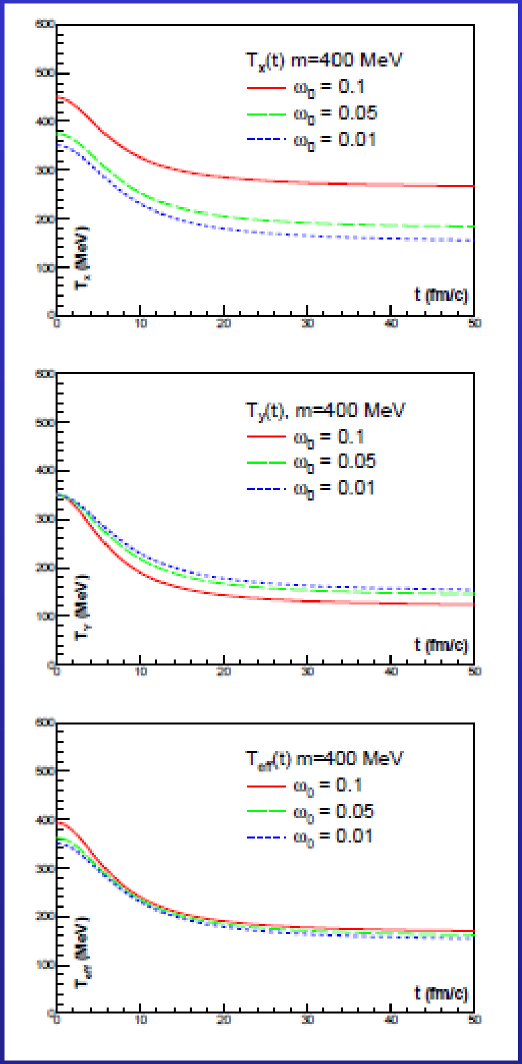
The time evolution of the temperature and the angular velocity



Inital conditions:
R_0 = 5 fm,
Y_0= 5fm
Kappa = 3/2
T_f = 140 MeV
at 8 – 10 fm/c

Results IV

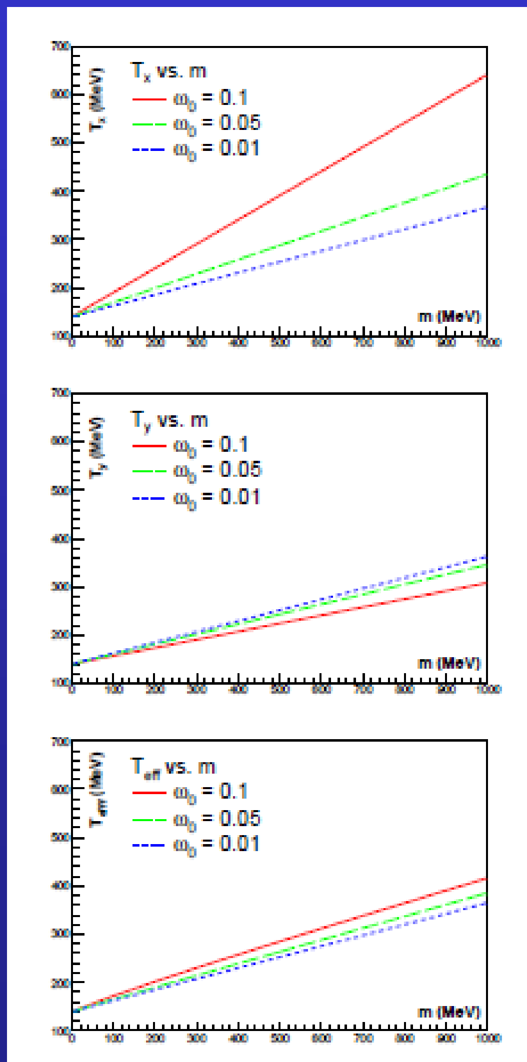
Freeze-out time dependence of the slope parameters   T_x = T _z



Inital conditions:
R_0 = 5 fm,
Y_0= 5fm
Kappa = 3/2
T_f = 140 MeV

Results V

The slope parameters T_x = T _z and the effective temperature

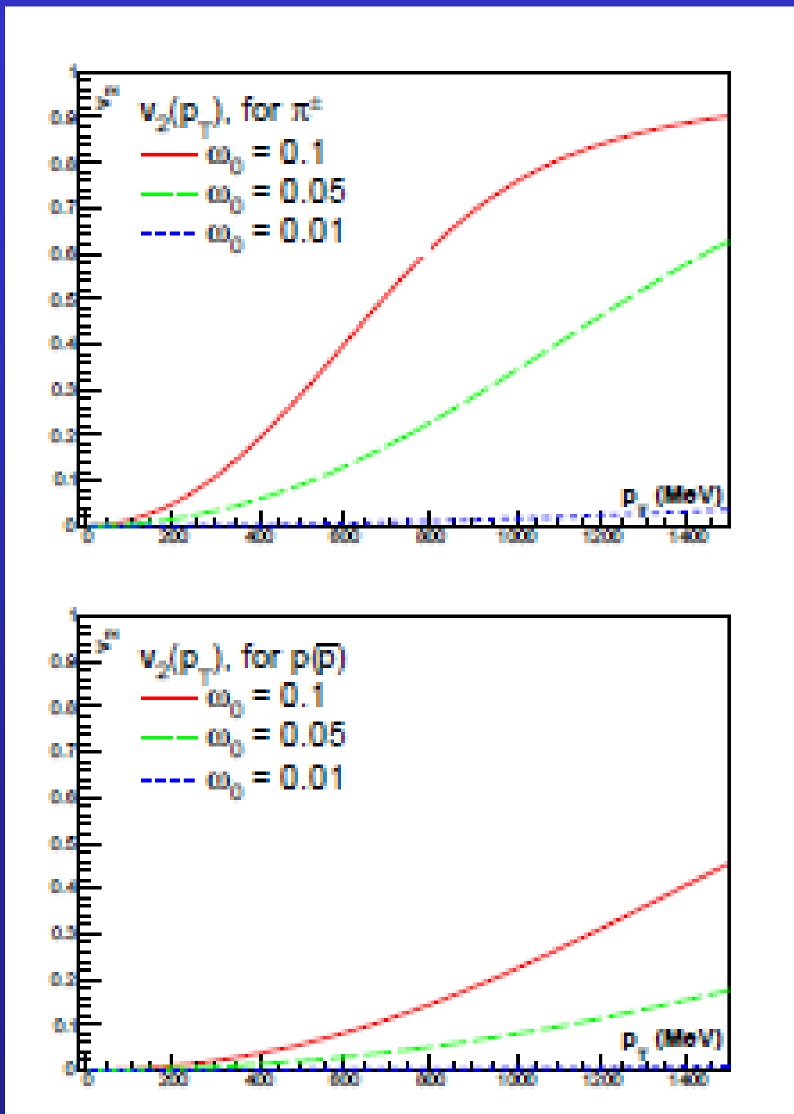


$$\frac{1}{T_{\mathrm{eff}}} = \frac{1}{2}\left(\frac{1}{T_x} + \frac{1}{T_y}\right)$$

Inital conditions:
R_0 = 5 fm,
Y_0= 5fm
Kappa = 3/2
T_f = 140 MeV

Results VI

V_2 for pions (upper) and protons (lower)



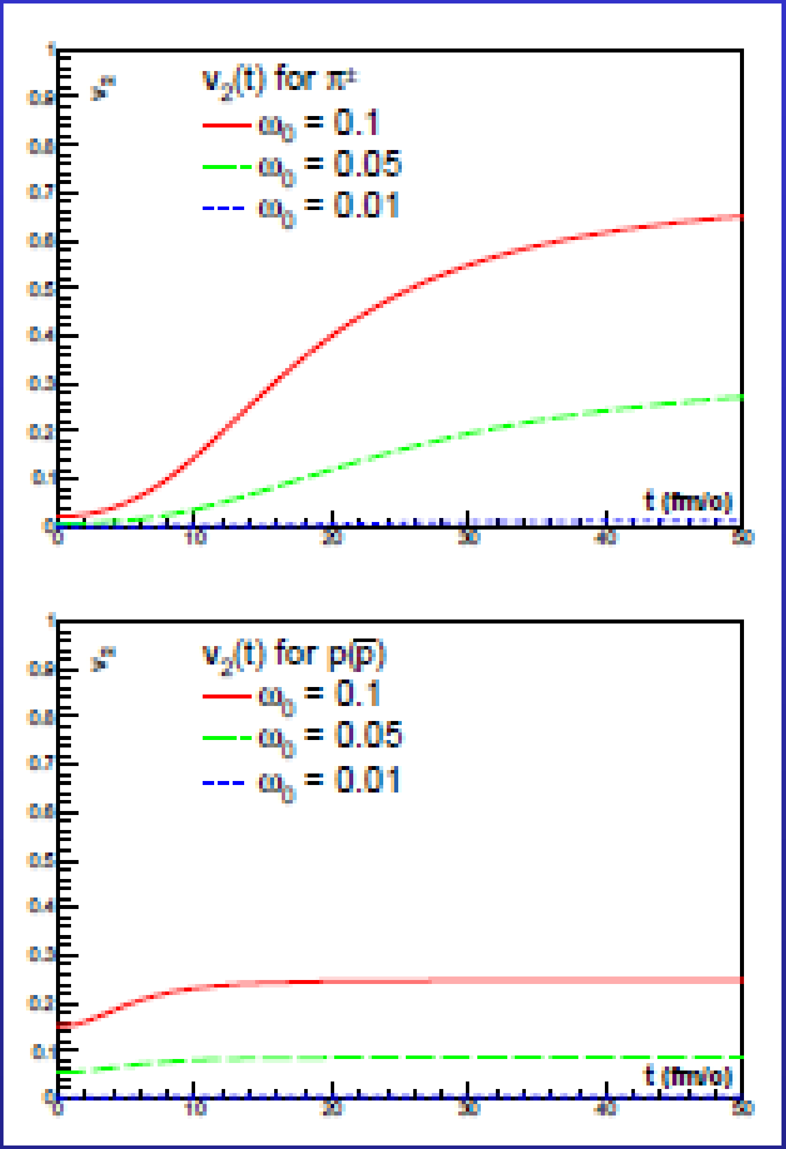
Inital conditions:
$R_0 = 5$ fm,
$Y_0 = 5$fm
Kappa = 3/2
T_f = 140 MeV 0

$$\frac{dn}{2\pi p_t dp_t dp_z} \propto \exp\left(-\frac{p_t^2}{2mT_{\rm eff}} - \frac{p_z^2}{2mT_z}\right) I_0(w)$$

$$\frac{dn}{dp_z p_t dp_t d\phi} = \frac{dn}{2\pi dp_z p_t dp_t}\left[1 + 2\sum_{n=1}^{\infty} v_n \cos(n\phi)\right]$$

$$v_{2n+1} = 0, \quad v_{2n} = \frac{I_n(w)}{I_0(w)}.$$

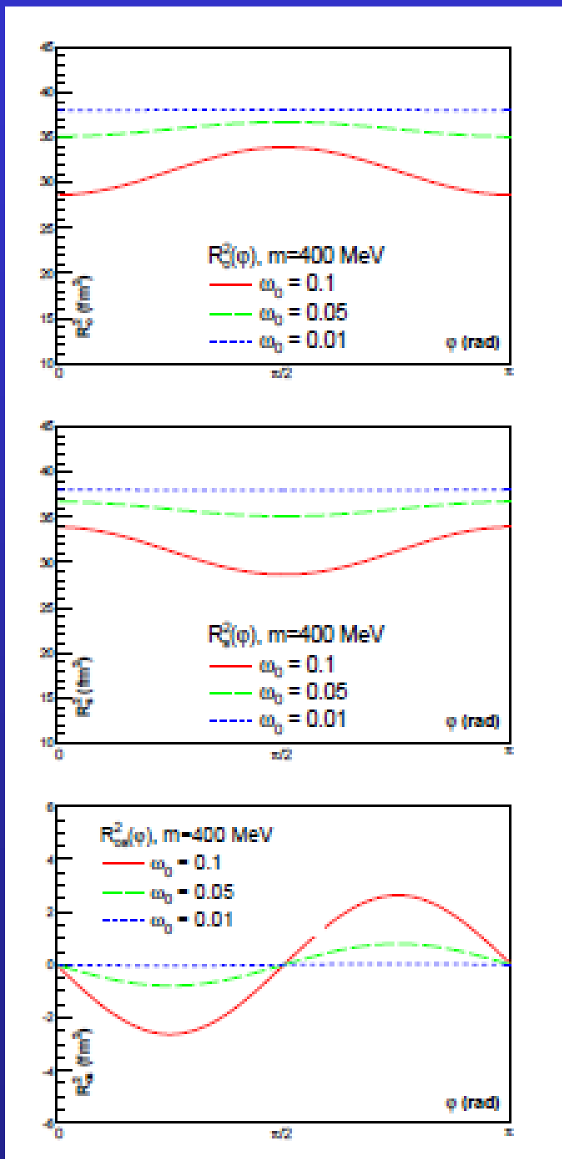
Results VII



The freeze-out time dependence of v_2 for pions (upper) and for protons (lower) at fixed p_T (300 MeV/c) and (1000 MeV/c)

Inital conditions:
R_0 = 5 fm,
Y_0= 5fm
Kappa = 3/2

Results VIII



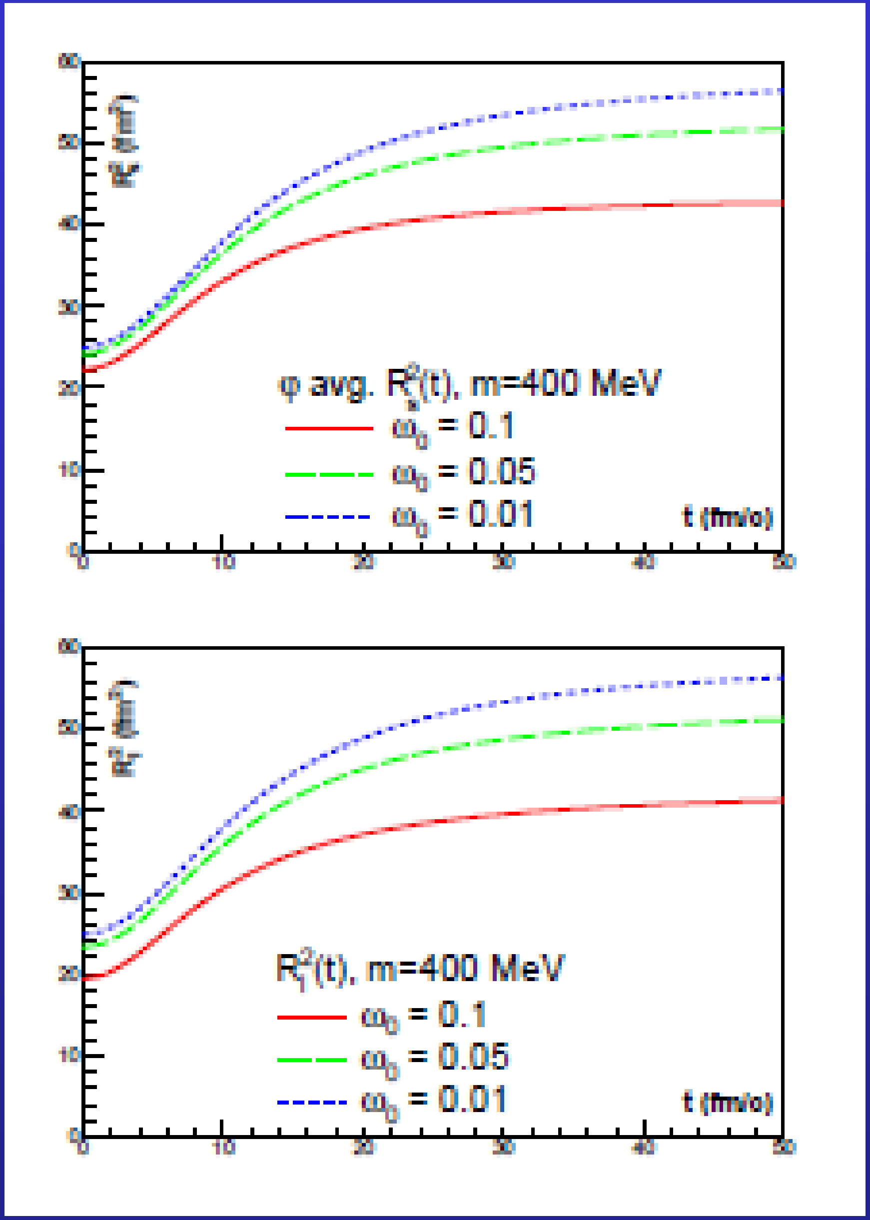
The HBT radius parameters
$R^2{}_0$ (upper panel)
$R^2{}_s$ (middel panel)
$R^2{}_{os}$ (lower panel)

$$\begin{aligned} C\left(\mathbf{K},\mathbf{q}\right) &= 1+\lambda \exp\left\{-q_x^2R_x^2-q_y^2R_y^2-q_z^2R_z^2\right\} \\ \mathbf{K} &= \mathbf{K}_{12} = \frac{1}{2}\left(\mathbf{p}_1+\mathbf{p}_2\right), \\ \mathbf{q} &= \mathbf{q}_{12} = \left(\mathbf{k}_1-\mathbf{k}_2\right), \end{aligned}$$

$$\begin{aligned} C_2\left(\mathbf{K},\mathbf{q}\right) &= 1+\lambda \exp\left(-\sum_{i,j=\mathrm{s,o,l}} q_i q_j R_{ij}^2\right) \\ R_\mathrm{s}^2 &= R_y^2\cos^2\phi + R_x^2\sin^2\phi\,, \\ R_\mathrm{o}^2 &= R_x^2\cos^2\phi + R_y^2\sin^2\phi + \beta_t^2\Delta t^2 \\ R_\mathrm{l}^2 &= R_x^2 + \beta_\mathrm{l}^2\Delta t^2, \\ R_\mathrm{ol}^2 &= \beta_t\beta_\mathrm{l}\Delta t^2, \\ R_\mathrm{os}^2 &= \left(R_x^2-R_y^2\right)\cos\phi\sin\phi\,, \\ R_\mathrm{sl}^2 &= 0. \end{aligned}$$

for m = 400 MeV

Results IX



Freeze-out time dependence of the azimuthal average of $R^s{}_2$ (upper) and $R^l{}_2$ (lower)

m = 400 MeV

Thank
You
for
Your
Attention!

Questions, Remarks, Comments?...