Reconstruction of space-time picture of particle production at RHIC

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- Observables in the Buda-Lund hydrodynamical model
- Fitting year-1 final PHENIX and STAR Au + Au $\sqrt{s_{NN}}$ = 130 GeV data
- Comparing with SPS Pb + Pb $\sqrt{s_{NN}}$ = 17.2 GeV results
- Conclusion

Buda-Lund hydrodynamical model

Basics

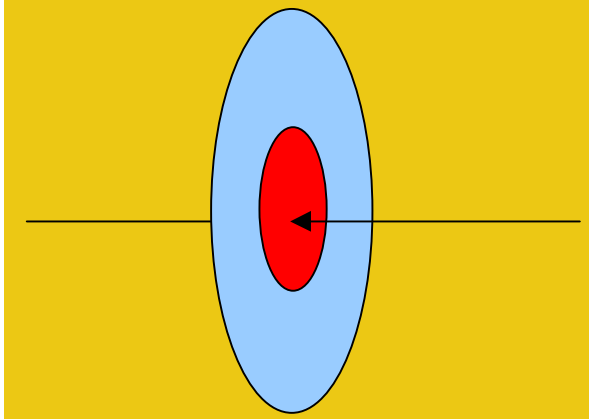
- **BL-H decouples the emission from the core and from the halo of resonances.**
- **BL-H couples the analysis of single-particle spectra and two-particle correlation data.**
- **BL-H introduces local fields (*temperature*, *flow*, *chemical potential*) by their 'means' and 'variances'.**

Buda-Lund hydrodynamical model

Observables:

1. Invariant double differential single-particle spectrum with core/halo correction:

$$N_1(\mathbf{k}) = \frac{d^2 n}{2\pi m_t dm_t dy} = \frac{g}{(2\pi)^3}\overline{E}\overline{V}\overline{C}\left[\exp\left(\frac{p\cdot u(\bar{x})-\mu(\bar{x})}{T(\bar{x})}\right)+s\right]^{-1}$$



Emission sources:

Collision core

Resonance halo

$$\overline{C} \propto \lambda_*(\mathrm{k}) = [N_{1core}(\mathrm{k})/N_1(\mathrm{k})]^2$$

Buda-Lund hydrodynamical model

2. Two-particle Bose-Einstein correlation function (HBT) radii

$$C_2(\Delta\mathbf{k},\mathbf{K}) = \frac{N_2(\mathbf{p_1},\mathbf{p_2})}{N_1(\mathbf{p_1})N_1(\mathbf{p_2})}$$

The **BL-H** invariant form:

$$C_2(\Delta\mathbf{k},\mathbf{K}) = 1+\lambda_* \Omega(Q_{||})\exp(-R_{||}^2 Q_{||}^2 - R_{=}^2 Q_{=}^2 - R_{\perp}^2 Q_{\perp}^2)$$

The **Bertsch-Pratt** form in LCMS (not invariant):

$$C_2(\Delta\mathrm{k},\mathrm{K}) = 1+\lambda_* \exp(-R_{side}^2 Q_{side}^2 - R_{out}^2 Q_{out}^2 - R_L^2 Q_L^2 - 2R_{outL}^2 Q_o Q_L)$$

Experimental data - > R_{BP} - > R_{BL-H} - > R_G

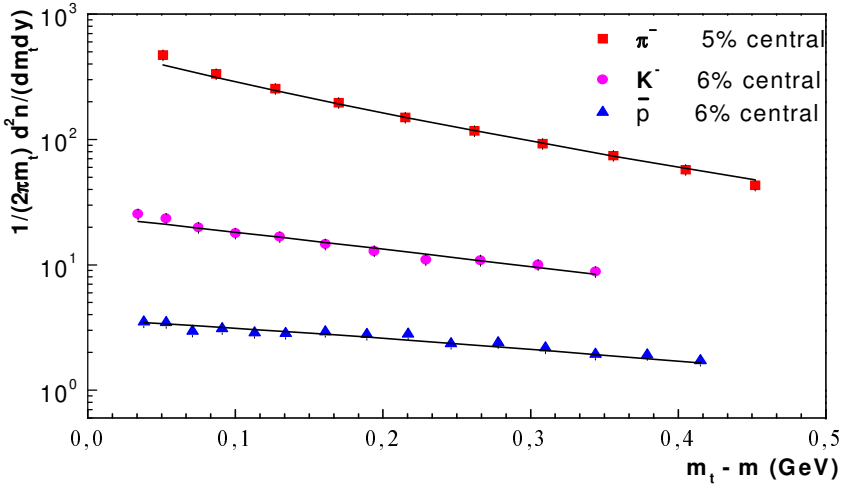
Buda-Lund hydrodynamical model

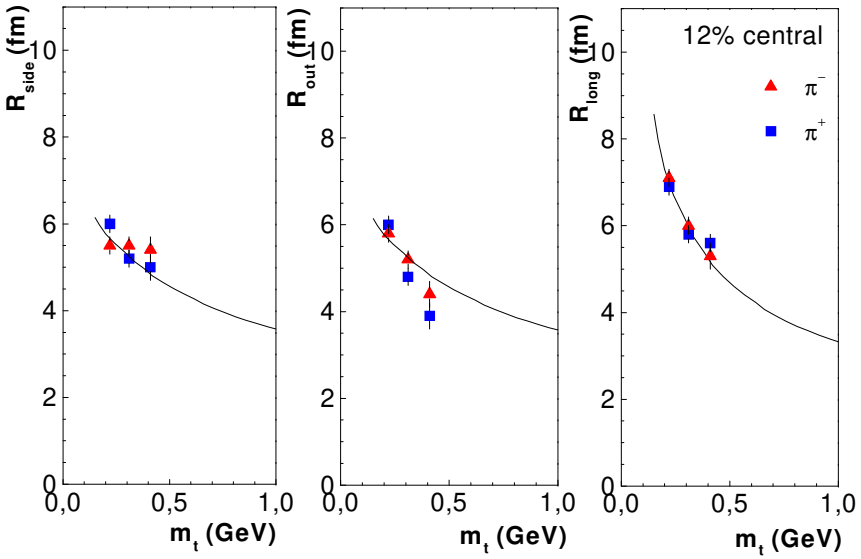
Free model parameters:

T_0	central freeze-out temperature
$\langle u_t \rangle$	average trasverse flow
R_G	transverse geometrical radius
τ_0	mean emission time
$\Delta\tau$	width of emission in proper time
$\Delta\eta$	width of space-time rapidity distribution
$\langle \Delta T/T \rangle_r$	average radial temperature decrease
$\langle \Delta T/T \rangle_t$	average temporal temperature decrease
μ_0	central chemical potential

References: Heavy Ion Physics 10 (1999) 1., hep-ph/9810314, hep-ph0001233

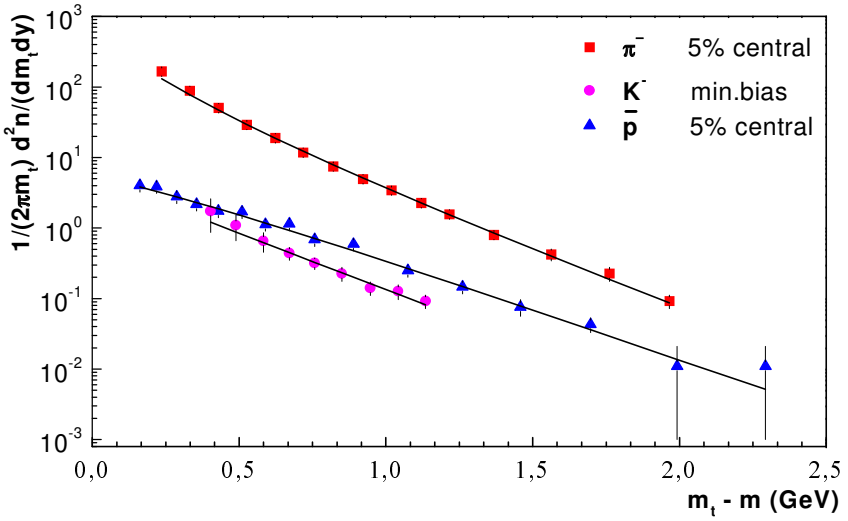
Fits to preliminary STAR data (HEP01 presentation)

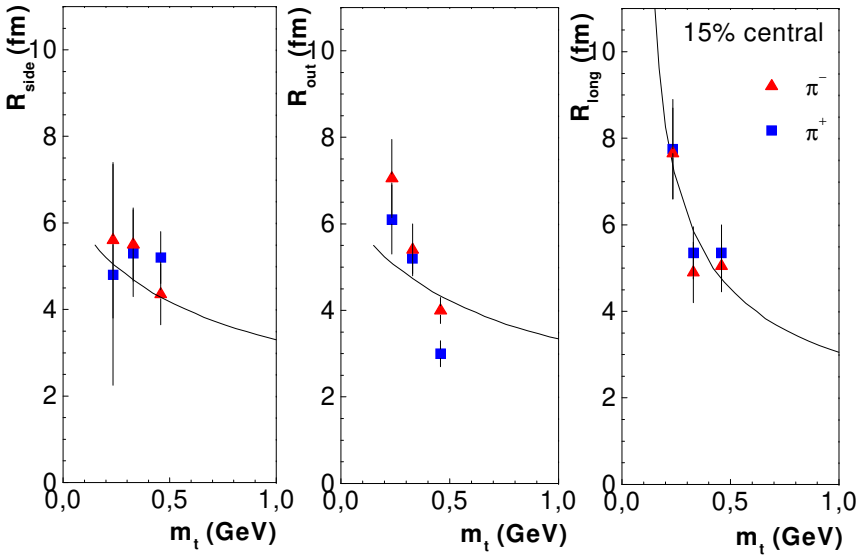




BL-H source parameters		
T_0	144	± 5 MeV
$\langle u_t \rangle$	0.86	± 0.1
R_G	8.0	± 0.5 fm
τ_0	8.9	± 0.5 fm/c
$\Delta\tau$	0.5	± 1.0 fm/c
$\Delta\eta$	1.0	± 0.1
$\langle \Delta T/T \rangle_r$	0.09	± 0.01
$\langle \Delta T/T \rangle_t$	1.6	± 0.4
$\mu_0^{\pi^-}$	0	fixed
$\mu_0^{K^-}$	46	± 11 MeV
$\mu_0^{\bar{p}}$	300	± 18 MeV

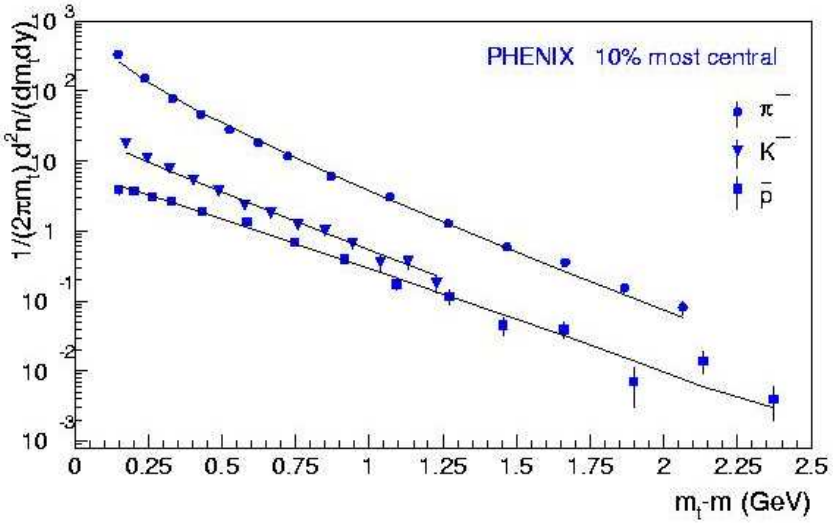
Fits to preliminary PHENIX data (HEP01 presentation)

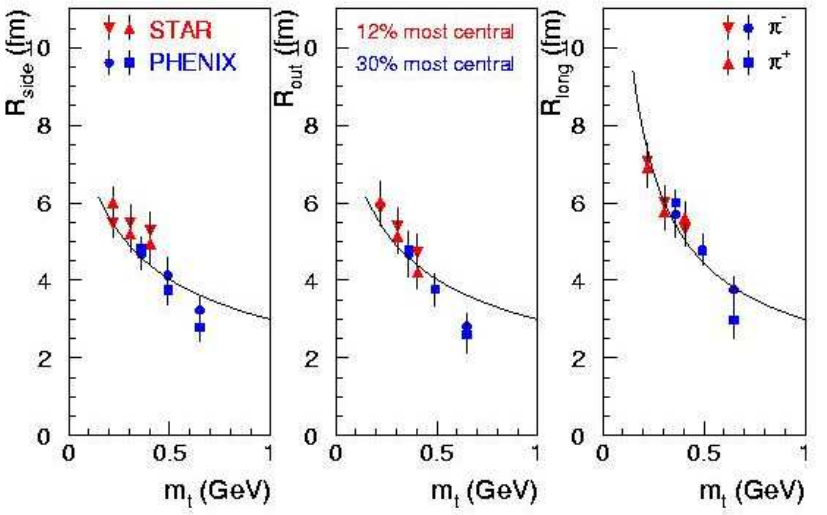




BL-H source parameters		
T_0	139	$\pm$ 5 MeV
$\langle u_t \rangle$	0.68	$\pm$ 0.3
R_G	6.6	$\pm$ 0.3 fm
τ_0	7.9	$\pm$ 0.3 fm/c
$\Delta\tau$	0.6	$\pm$ 1.2 fm/c
$\Delta\eta$	1.5	$\pm$ 0.1
$\langle \Delta T/T \rangle_r$	0.04	$\pm$ 0.01
$\langle \Delta T/T \rangle_t$	0.86	$\pm$ 0.09
$\mu_0^{\pi^-}$	0	Fixed
$\mu_0^{K^-}$	-	
$\mu_0^{\bar{p}}$	376	$\pm$ 38 MeV

Fits to year-1 final PHENIX and STAR data





BL-H source parameters	Fit I.	Fit II.
T_0 [MeV]	174 ± 12	140 fixed
$\langle u_t \rangle$	1.03 ± 0.14	0.98 ± 0.14
R_G [fm]	9.3 ± 1.0	9.2 ± 1.0
τ_0 [fm/c]	6.7 ± 0.3	7.6 ± 0.2
$\Delta\tau$ [fm/c]	0.2 ± 2.8	0.1 ± 1.4
$\Delta\eta$	2.5 fixed	2.5 fixed
$\langle \Delta T/T \rangle_r$	0.46 ± 0.16	0.17 ± 0.06
$\langle \Delta T/T \rangle_t$	3.0 ± 0.9	1.0 ± 0.2
$\mu_0^{\pi^-}$ [MeV]	0 fixed	0 fixed
$\mu_0^{K^-}$ [MeV]	50 ± 16	76 ± 9
$\mu_0^{\bar{p}}$ [MeV]	391 ± 35	422 ± 12
χ^2/NDF	84/69=1.22	100/70=1.43
CL	11.3%	1.1%

Comparing to SPS results

BL-H source parameters	Au+Au RHIC		Pb+Pb <SPS>		h+p SPS	
T_0 [MeV]	140	fixed	139	± 6	140	± 3
$\langle u_t \rangle$	0.98	± 0.14	0.55	± 0.06	0.20	± 0.07
R_G [fm]	9.2	± 1.0	7.1	± 0.2	0.88	± 0.13
τ_0 [fm/c]	7.6	± 0.2	5.9	± 0.6	1.4	± 0.1
$\Delta\tau$ [fm/c]	0.1	± 1.4	1.6	± 1.5	1.3	± 0.3
$\Delta\eta$	2.5	fixed	2.1	± 0.4	1.36	± 0.02
$\langle \Delta T/T \rangle_r$	0.17	± 0.06	0.06	± 0.05	0.71	± 0.14
$\langle \Delta T/T \rangle_t$	1.0	± 0.2	0.59	± 0.38	-	
$\mu_0^{\pi^-}$ [MeV]	0	fixed	-		-	
$\mu_0^{K^-}$ [MeV]	76	± 9	-		-	
$\mu_0^{\bar{p}}$ [MeV]	422	± 12	-		-	

Conclusion

The analysis of the 1st year final data of single-particle momentum distributions and Bose-Einstein correlation function radii of the RHIC experiments PHENIX and STAR show:

fastest transverse flow (0.98c)and

longest existence (7.6 fm/c) of the hydrodynamical phase

seen so far compared to lower energy SPS experiments.