Energy dependence of the slope parameter in heavy-ion collisions

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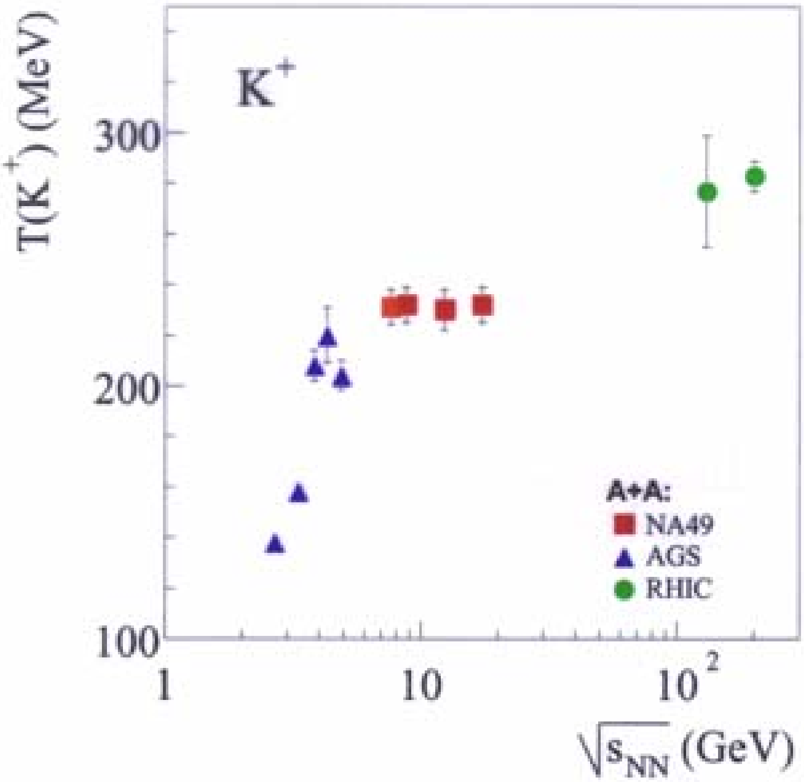
Plan of presentation:

1. Motivation
2. Method
3. Results
4. Conclusions



Ref. 1

A Characteristic Plateau in the Energy Dependence of the Apparent Temperature of Kaons in Central Pb+Pb Collisions at Low SPS Energies May Indicate Onset of Deconfinement

Within a hydrodynamical model approach the transverse momentum spectra of kaons are sensitive to the initial temperature and pressure of the created matter. In the transition region where a mixed phase exists these are independent of energy density (collision energy), whereas in the pure confined and deconfined phases both increase with the energy. This leads to the observed plateau (at low SPS energies) in the energy dependence of the apparent temperature T of kaons, which is commonly used to characterise the shape of the transverse momentum spectrum.

Ref. 2

Method of study

We solve the hydrodynamic equations in the following way.

Main ingredients:

- Initial conditions
- Equations of state
- Hydrodynamic code – **SPheRIO***   Ref. (1)
- Freeze-out conditions

$\Downarrow$

Computation of
$\frac{d\sigma}{dm_T} \Rightarrow T^*$

*Smoothed Particle hydrodynamical evolution of Relativistic heavy IOn collisions.

Initial conditions

1) Landau type:

$$
\begin{aligned}
\mathbf{v} &= 0, \\
V &= V_0/\gamma = \frac{4\pi}{3} r_0^3 A / \frac{\sqrt{s}}{2m} \\
E &= \eta\,(\sqrt{s} - m_n)\,A, \quad (\eta = 0.67), \\
\varepsilon &= \frac{E}{V} = \frac{\eta \rho_0\,(\sqrt{s} - m_n)\,\sqrt{s}}{2m_n}, \\
&\quad (\rho_0 = 0.11/fm^3).
\end{aligned}
$$

Ref. 3

~~2) Modified Landau:~~

$$
\begin{aligned}
u^\mu(z) &= \gamma(z)(1, 0, 0, v), \\
u^z(z) &= \frac{z}{z_m}\,\eta\sqrt{\gamma_0^2 - 1}, \qquad (z_m = R/\gamma_0) \\
E &= \int_{r^2 + \gamma_0^2 z^2 \le R^2} \Big[(\varepsilon + p)\gamma^2(z) - p\Big] dV, \\
&\quad (\varepsilon = \text{const.})
\end{aligned}
$$

2) Averaged NeXus: The fluid is spread over a large rapidity region.

Ref. 4

Equations of state

1) Ideal gas + QGP bag:

$$\begin{cases} p_h = \frac{\pi^2}{90} g_h T^4, \\ \varepsilon_h = \frac{\pi^2}{30} g_h T^4, \end{cases} \quad \begin{cases} p_q = \frac{\pi^2}{90} g_q T^4 - B, \\ \varepsilon_q = \frac{\pi^2}{30} g_q T^4 + B. \end{cases}$$

Ref. 3

2) Resonance gas + QGP bag:

Hadronic phase: made of resonances with mass$\leq$ 2.5 GeV/c^2, with volume correction taken into account. Ref. 5.

QGP:

$$\begin{cases} p_q = \frac{\pi^2}{90} g_q T^4 + \frac{3}{2}\left(T^2 \mu_q^2 + \frac{\mu_q^4}{2\pi^2}\right) - B, \\ \varepsilon_q = \frac{\pi^2}{30} g_q T^4 + \frac{9}{2}\left(T^2 \mu_q^2 + \frac{\mu_q^4}{2\pi^2}\right) + B, \\ s_q = \frac{2\pi^2}{45} g_q T^3 + 3T\mu_q^2, \\ n_q = 3\left(T^2 \mu_q^2 + \frac{\mu_q^3}{\pi^2}\right). \end{cases}$$

Freezeout conditions

We used the usual Cooper Frye prescription, just for the simplicity.

However, the freezeout temperature ($T_{f.o.}$) is **not** an intrinsic thermodynamic property of the fluid. It depends also on the system size.

A rough estimate gives (when $\sqrt{s} \to \infty$)

$$T_{f.o.} \propto (\sqrt{s})^{-1/12},$$

Ref. 9

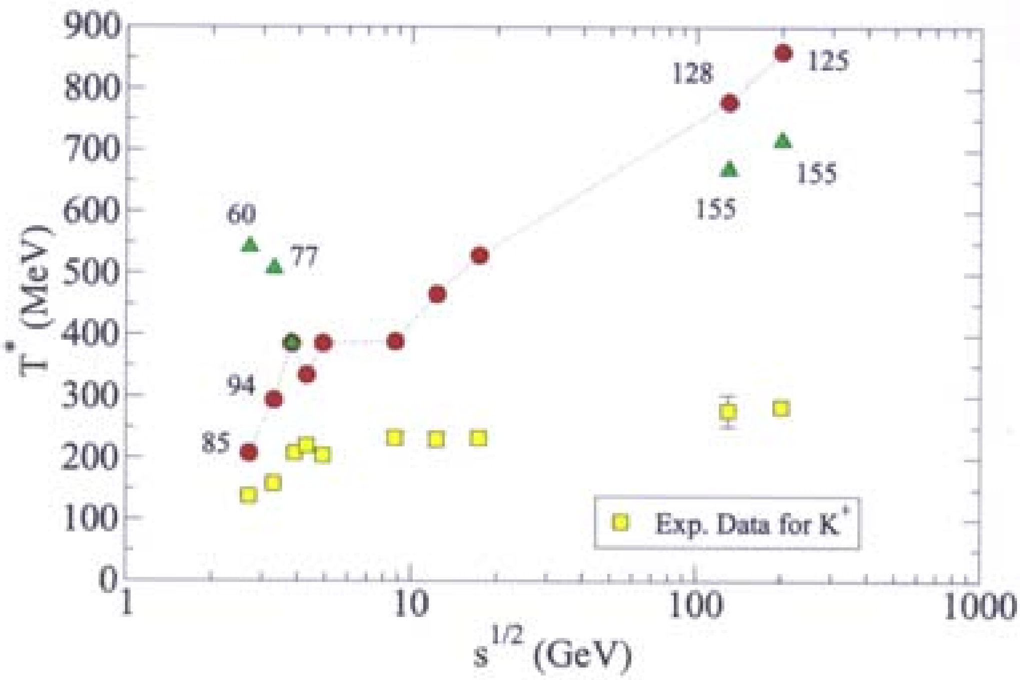
for a given pair of nuclei, and which is verified in pp and $\bar{p}p$ data analyses.

It has been reported that also in Au+Au (Pb+Pb), $T_{f.o.}$ seems to decrease with $\sqrt{s}$. Ref.10

Results with Landau initial conditions

$T_c = 160$ MeV

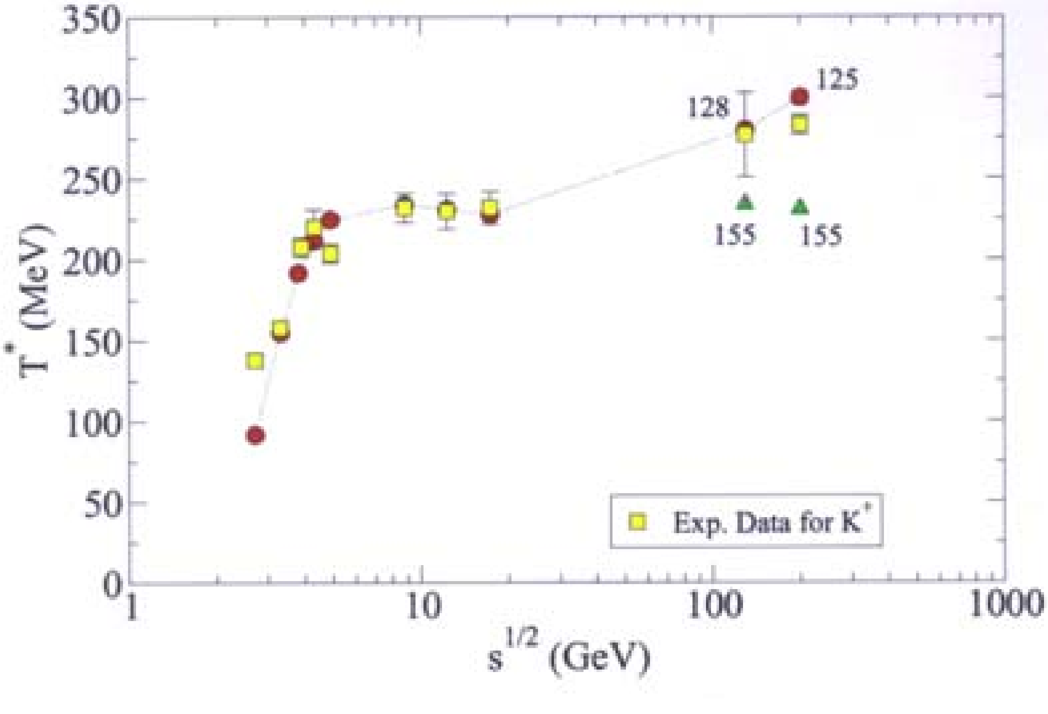
$\sqrt{s}$ (A·GeV)	T_0 (MeV)	ε_0 (GeV/fm^3)	T_{fo} (MeV)	$\bar{v}_T$	T^* (MeV)
2.7	112	0.110	85	0.427	208
			60	**0.716**	**542**
3.3	135	0.232	94	0.520	294
			77	**0.675**	**507**
3.8	151	0.361	97	0.590	386
			92	**0.631**	**386**
4.3	160	0.514	115	0.500	335
4.9	160	0.731	120	0.537	386
8.8	191	3.006	143	0.503	389
12.3	233	6.326	147	0.571	466
17.3	282	13	149	0.631	529
130	796	822	128	0.801	779
			155	**0.767**	**669**
200	989	1955	125	0.819	861
			155	**0.776**	**716**



Results with NeXus initial conditions

$T_c = 160$ MeV

$\sqrt{s}$ (A·GeV)	T_0 (MeV)	ε_0 (GeV/fm^3)	T_{fo} (MeV)	$\bar{v}_T$	T^* (MeV)
2.7	98	0.75	85	0.067	92
3.3	128	0.66	94	0.28	155
3.8	131	1.01	97	0.41	192
4.3	135	1.38	115	0.37	212
4.9	140	1.55	120	0.39	225
8.8	198	4.06	143	0.32	234
12.3	248	9.04	147	0.32	231
17.3	265	11.37	149	0.32	228
130	279	12.86	128	0.52	280
			155	**0.34**	**234**
200	277	12.48	125	0.56	300
			155	**0.34**	**231**



Conclusions

The Landau type initial conditions, given in small volume, cannot reproduce simultaneously the data on multiplicity, rapidity distributions and the transverse-momentum distributions.

This conclusion does not depend on the EoS of the hadronic phase.

Initial conditions, with spatially spread energy and velocity distributions (for example, NeXus-type), reproduce well all the main characteristics of data at high-energies, namely particle multiplicities, rapidity distributions and p_T spectra.

In this case, the increase of T^* in RHIC energy domain seems to be due mostly to the larger expansion in the hadronic phase rather than to that in the QGP phase.

Appearance of the plateau seems to indicate a deconfinement transition.

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