Transverse-momentum spectra in heavy-ion collisions at sqrt(sNN) = 2.76 TeV within chemical non-equilibrium model

Viktor Begun

Jan Kochanowski University, Kielce, Poland

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V.B., W. Florkowski, M. Rybczynski, 1312.1487, 1405.7252

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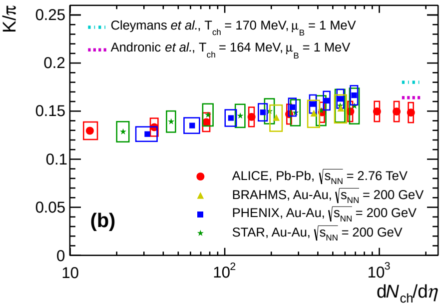
- Statistical models of hadron production became a cornerstone of our understanding of heavy-ion collisions
- The measured proton abundances at sqrt(S) 2.76 TeV at LHC did not agree with the predictions of the statistical models



B. Abelev *et al.*, [ALICE Collaboration] PRC 88 (2013)

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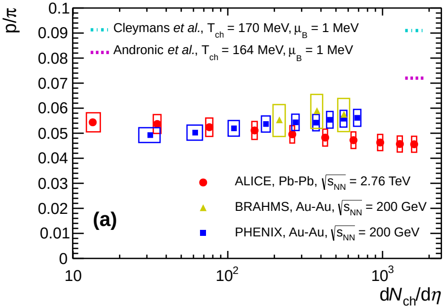

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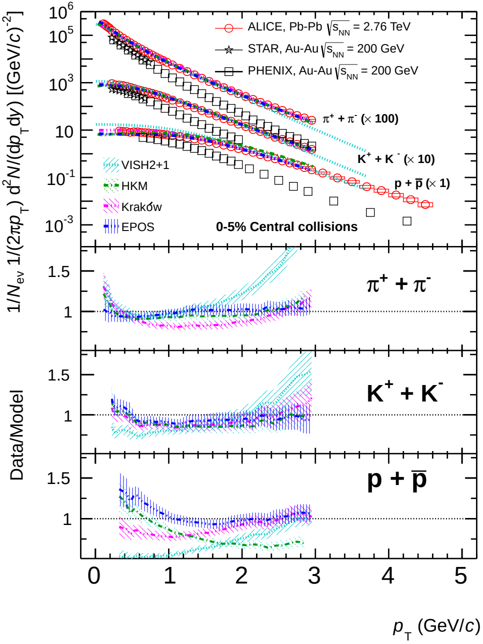

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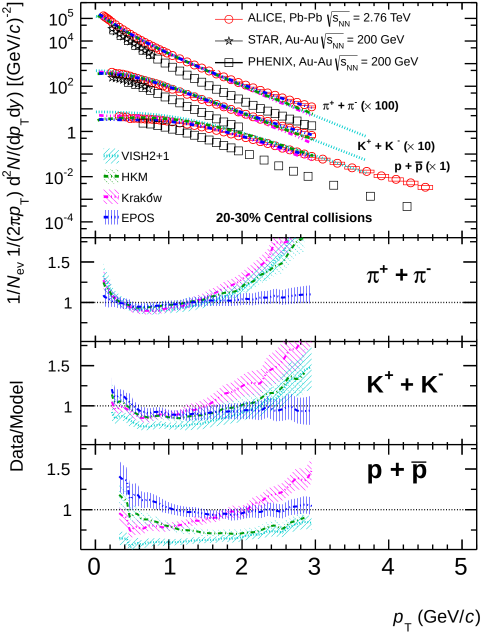

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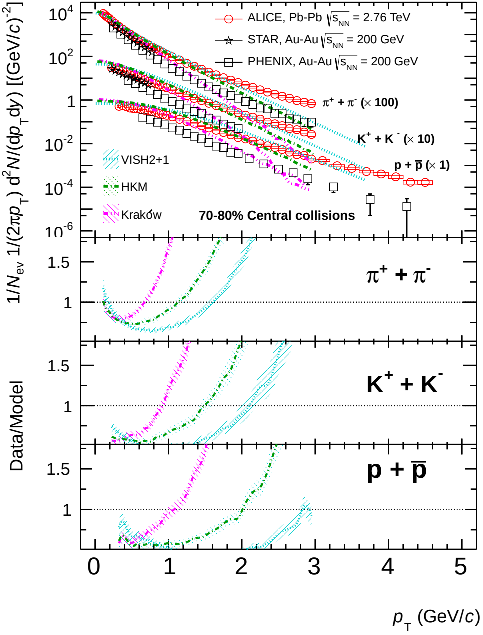

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The Cracow Model

- Transverse-momentum distributions are calculated from the Cooper-Frye formula:

$$\frac{dN}{dyd^2p_T} = \int d\Sigma_\mu p^\mu f(p \cdot u),$$

where $d\Sigma_\mu$ is an element of the freeze-out hypersurface and u^μ is the hydrodynamic flow at freeze-out

- The primordial distribution of the i-th hadron in the local rest frame has the form:

$$f_i \ = \ g_i \int \frac{d^3p}{(2\pi)^3} \frac{1}{\Upsilon_i^{-1} \exp(\sqrt{p^2 + m_i^2}/T) \mp 1}$$

where $\Upsilon_i = \gamma_q^{N_q^i + N_{\bar{q}}^i} \gamma_s^{N_s^i + N_{\bar{s}}^i}$. The N_j^i are the numbers of light (u, d) and strange (s) quarks and anti-quarks in the i-th hadron. We compare the non-equilibrium, $\gamma_j \neq 1$, and equilibrium, $\gamma_j = 1$ cases

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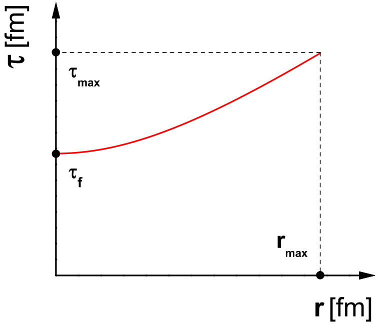

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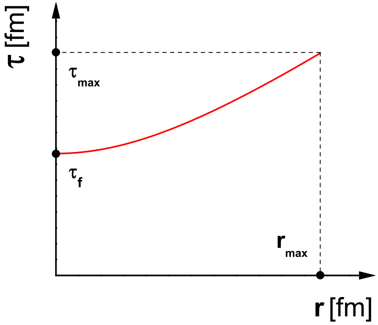

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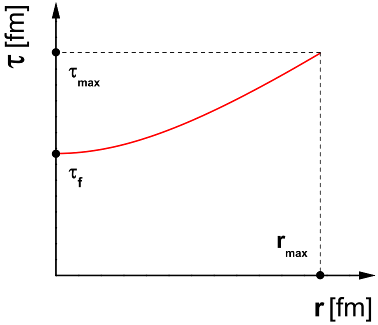

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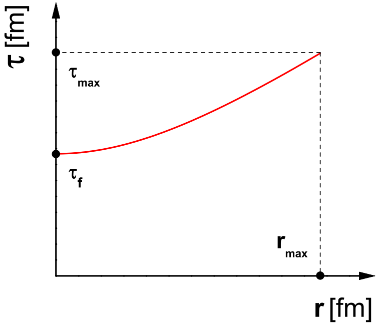

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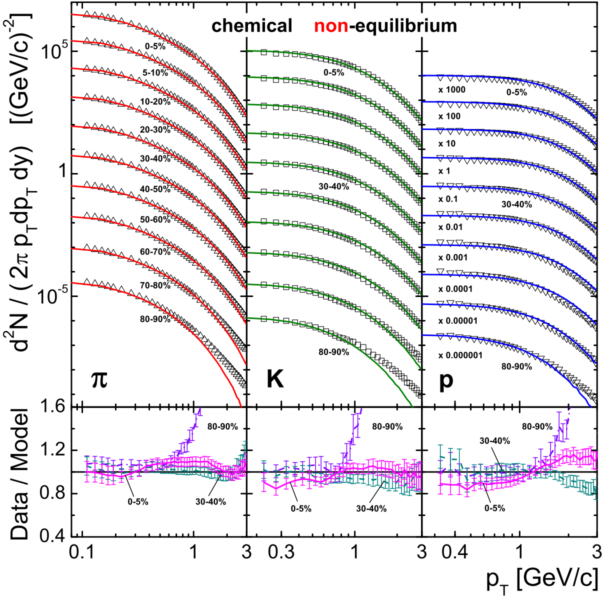

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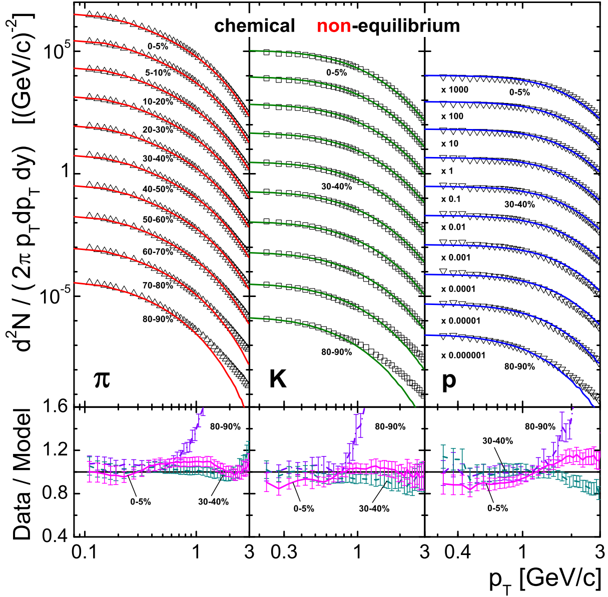

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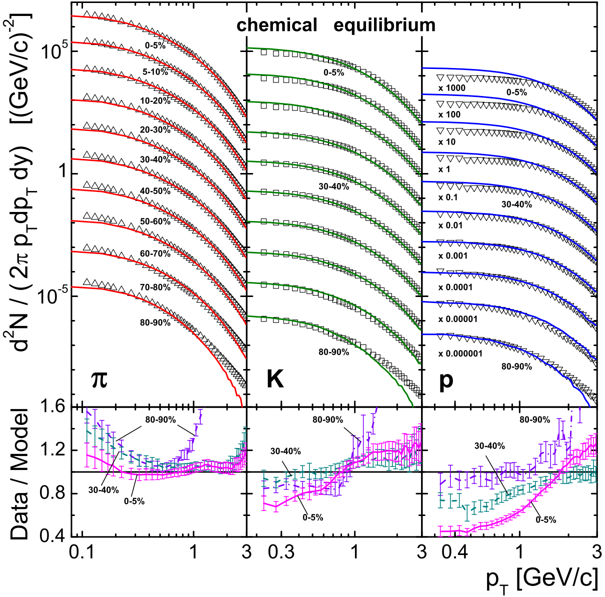

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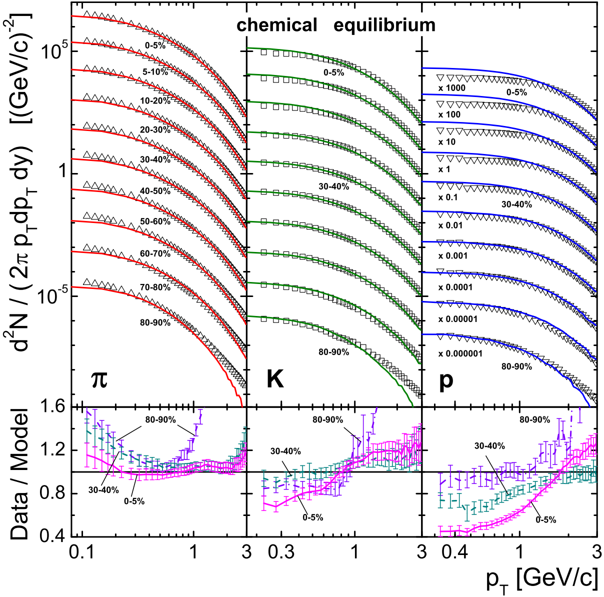

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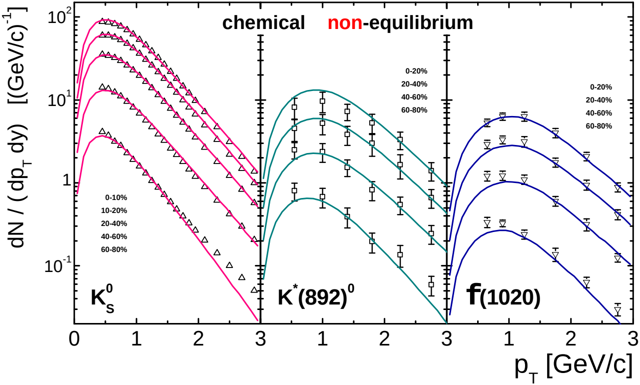
Light Strange particles

- Using exactly the same parameters, we have obtained an excellent description of K_S^0, K^{*0}, and ϕ



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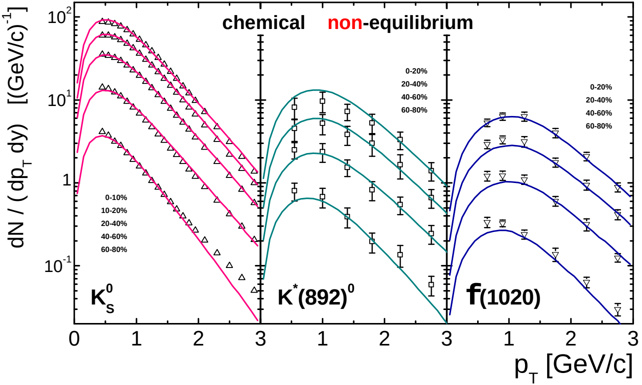

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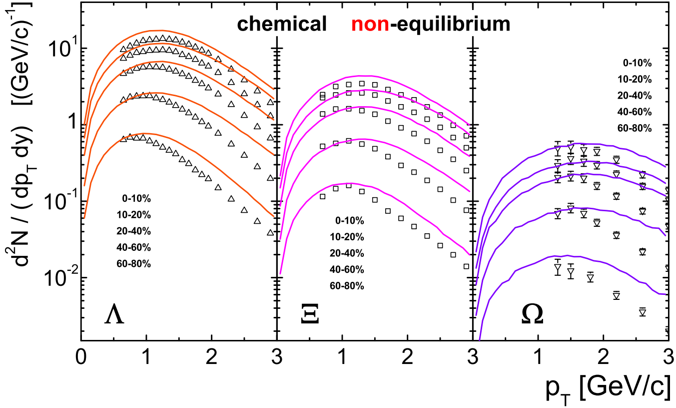

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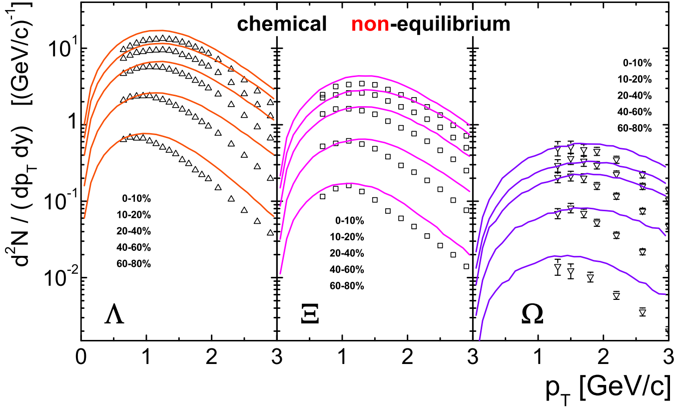

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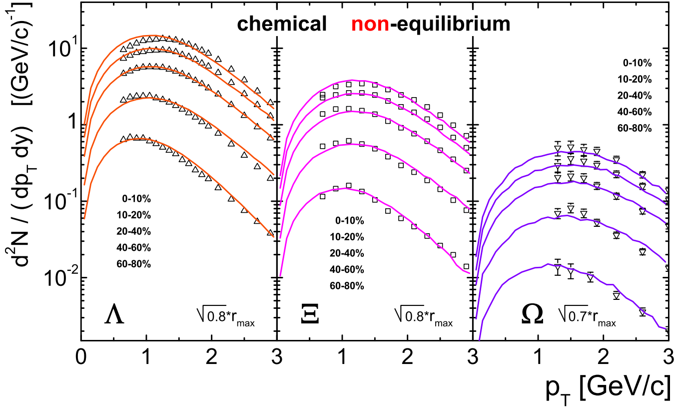

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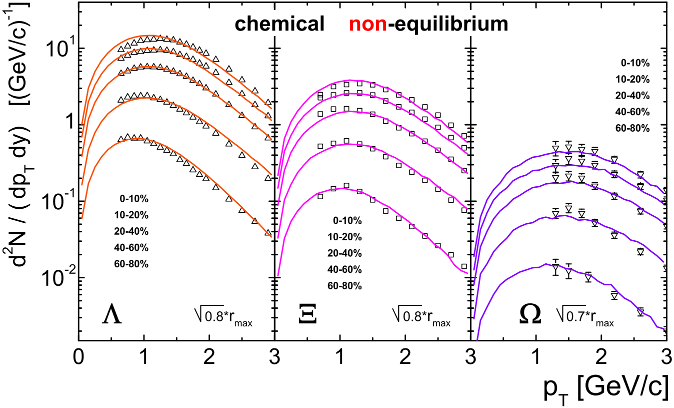

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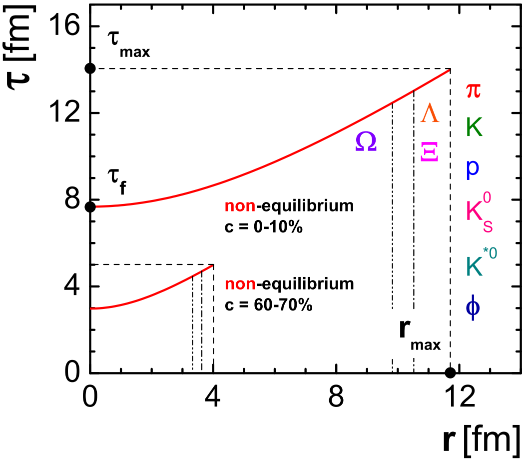
Freeze-out in Cracow Model at LHC

- In the center-of-mass frame at $z = 0$, the freeze-out starts in the center of the fireball at the time τ_f.

- Subsequently, it spreads out along the hyperbola $\tau(r) = \sqrt{\tau_f^2 + r^2} \leq \sqrt{\tau_f^2 + r_{\max}^2}$



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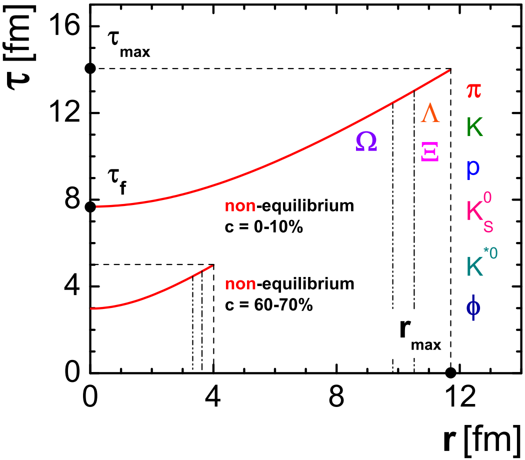

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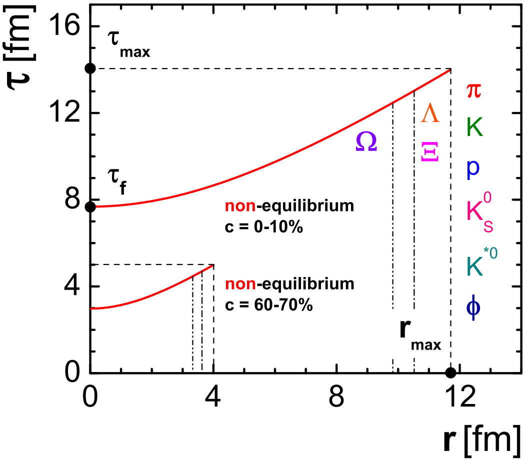

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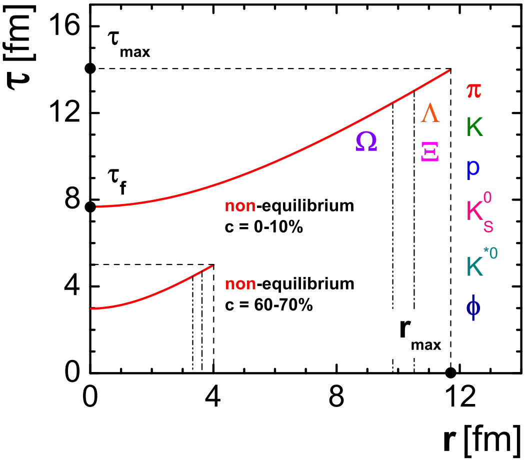

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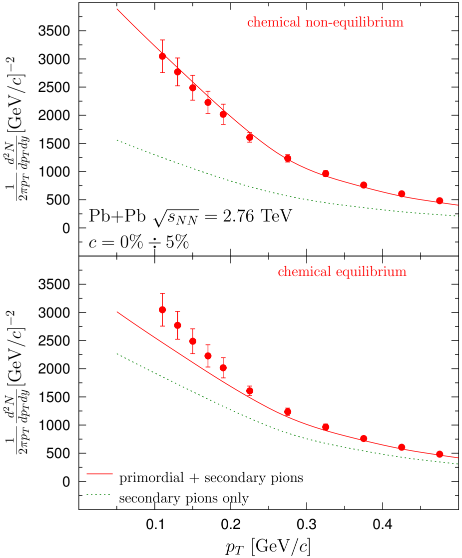
- The low p_T enhancement of pions can be explained only in non-equilibrium

- The value of γ_q that we use is equivalent to the pion chemical potential $\mu_\pi = 2T \ln \gamma_q \simeq 134$ MeV, which is very close to the π^0 mass, $m_{\pi^0} \simeq 134.98$



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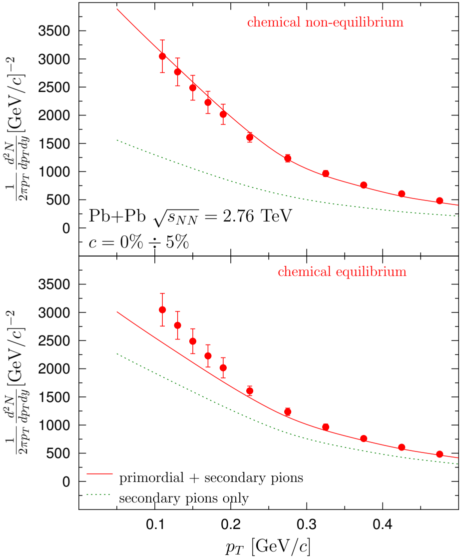

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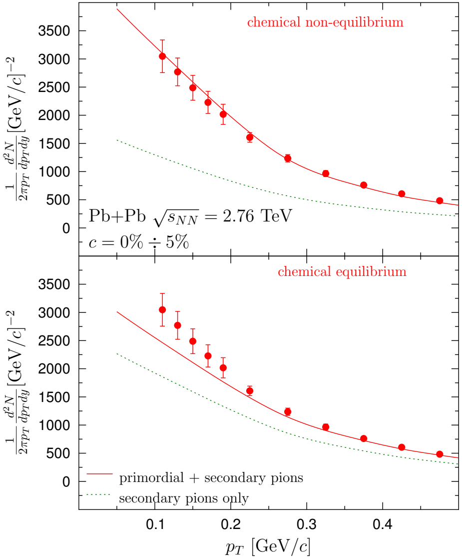

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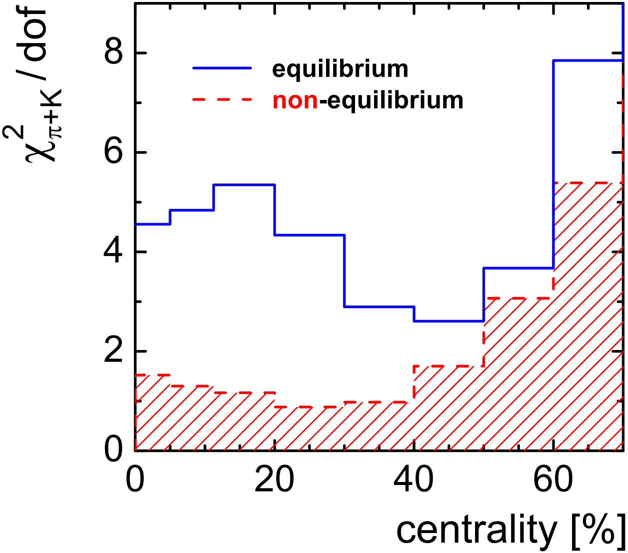
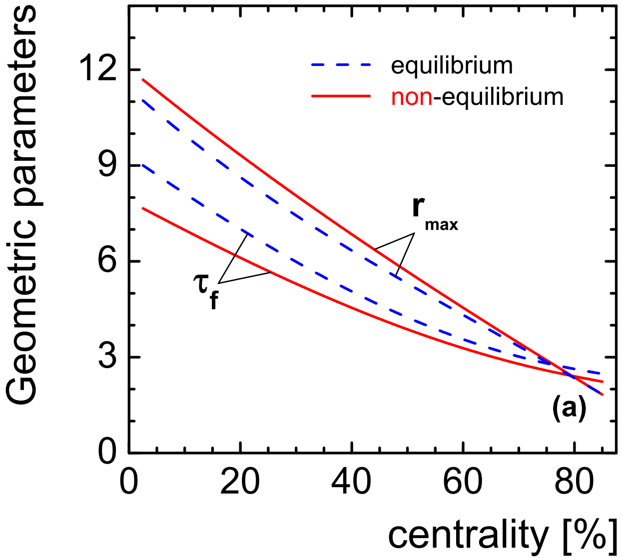
Conclusions:

- We connect the proton anomaly with the pion enhancement effect and show that the two problems may be **solved** naturally within the non-equilibrium Cracow single freeze-out model
- The obtained values of the non-equilibrium parameter γ_q are close to the pion condensation limit $(\gamma_q^{cond})^2 = e^{m_\pi / T}$
- It may be interpreted as a signature of the onset of **pion condensation** in ultra-relativistic heavy-ion collisions at LHC.

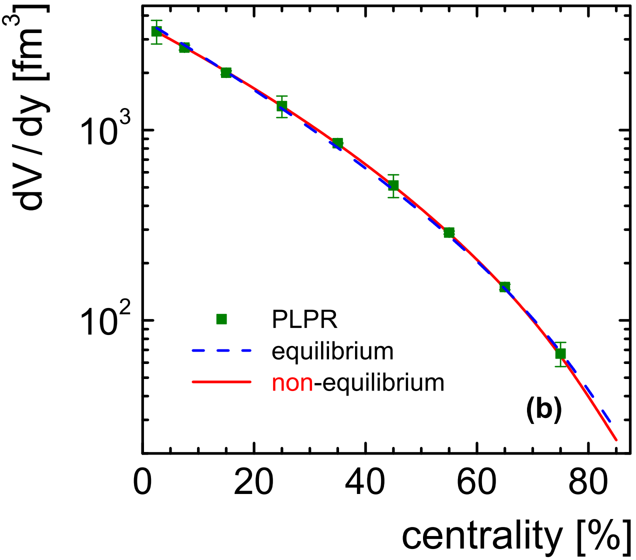
Extra Slides



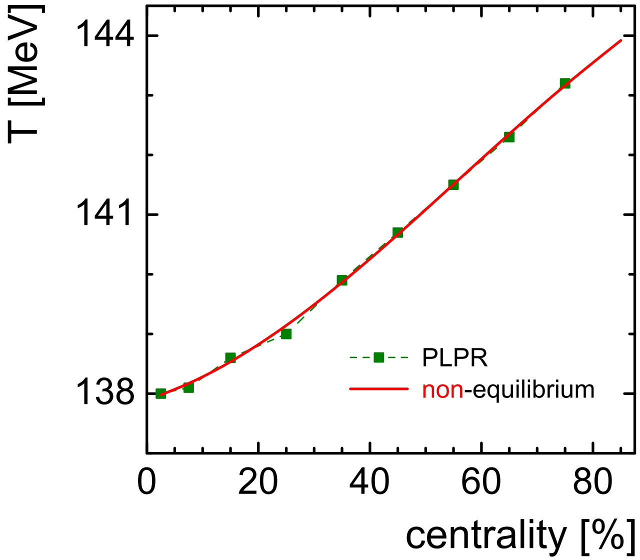
$\chi^2_{\pi+K}$ / dof
equilibrium
non-equilibrium
0
2
4
6
8
0
20
40
60
centrality [%]

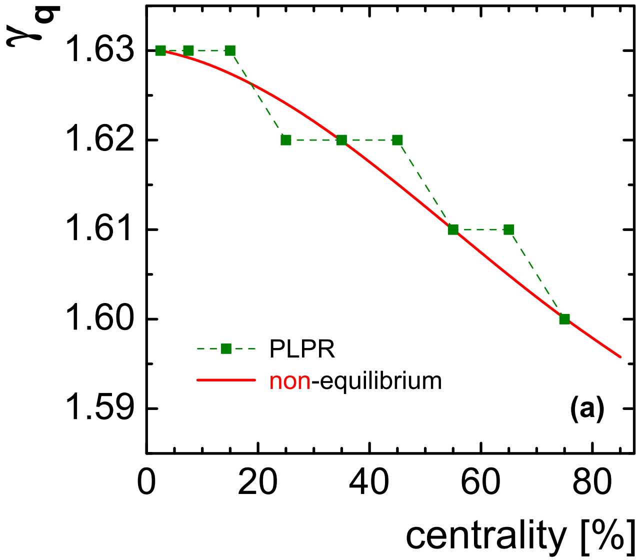


Geometric parameters
centrality [%]
equilibrium
non-equilibrium
r max
τ f
(a)
0
3
6
9
12
0
20
40
60
80

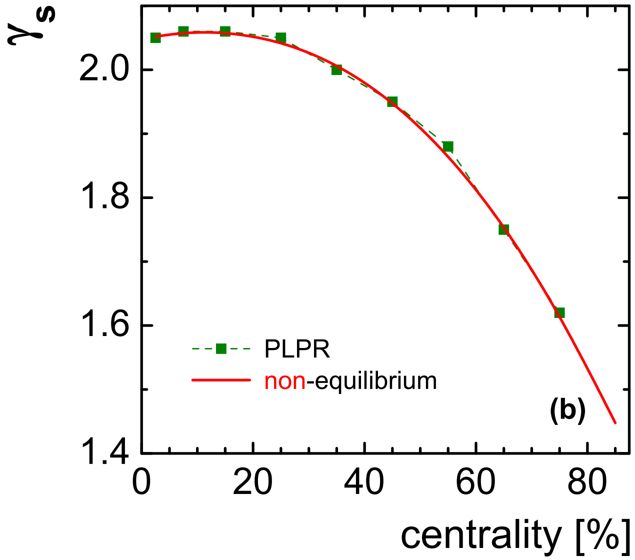


dV / dy [fm^3]
10^3
10^2
0
20
40
60
80
centrality [%]
PLPR
equilibrium
non-equilibrium
(b)


T [MeV]
144
141
138
0
20
40
60
80
centrality [%]
PLPR
non-equilibrium



γ_q
1.63
1.62
1.61
1.60
1.59
0
20
40
60
80
centrality [%]
PLPR
non-equilibrium
(a)



γ_s
2.0
1.8
1.6
1.4
0
20
40
60
80
centrality [%]
PLPR
non-equilibrium
(b)