Explanation of hadron pT spectra in heavy-ion collisions at sqrt(s)=2.76 TeV within chemical non-equilibrium statistical hadronization model

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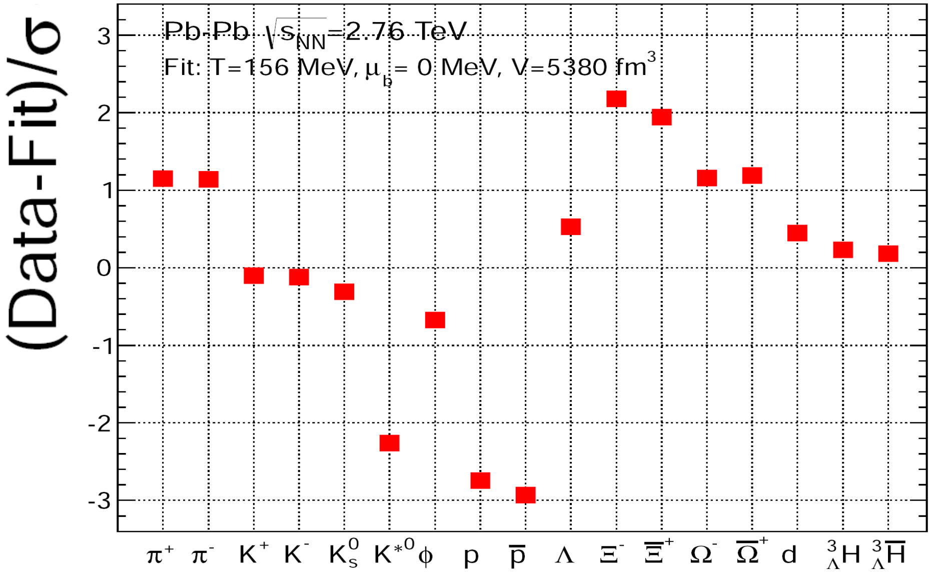
V.B., W. Florkowski, M. Rybczynski, arXiv: 1312.1487

Motivation

- 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 do not agree with the thermal model
- The low pt pion spectra show enhancement by about 25-50% with respect to the predictions of various models
- This is in contrast with the measurements at lower energies, for example, at RHIC

LHC data vs statistical models

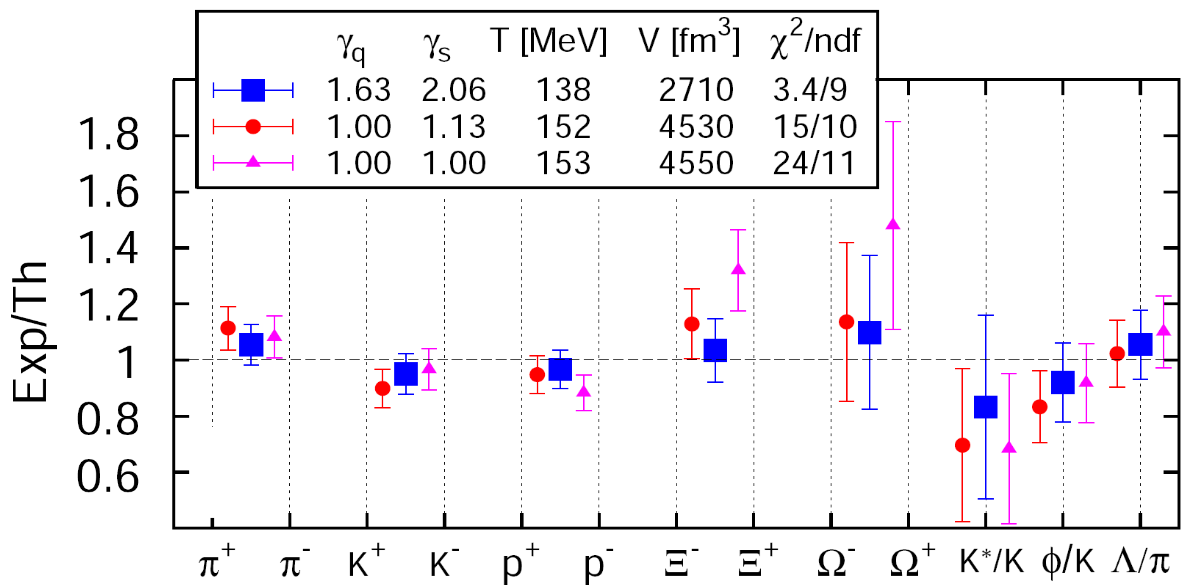


Stachel, Andronic, Braun-Munzinger, Redlich, arXiv:1311.4662

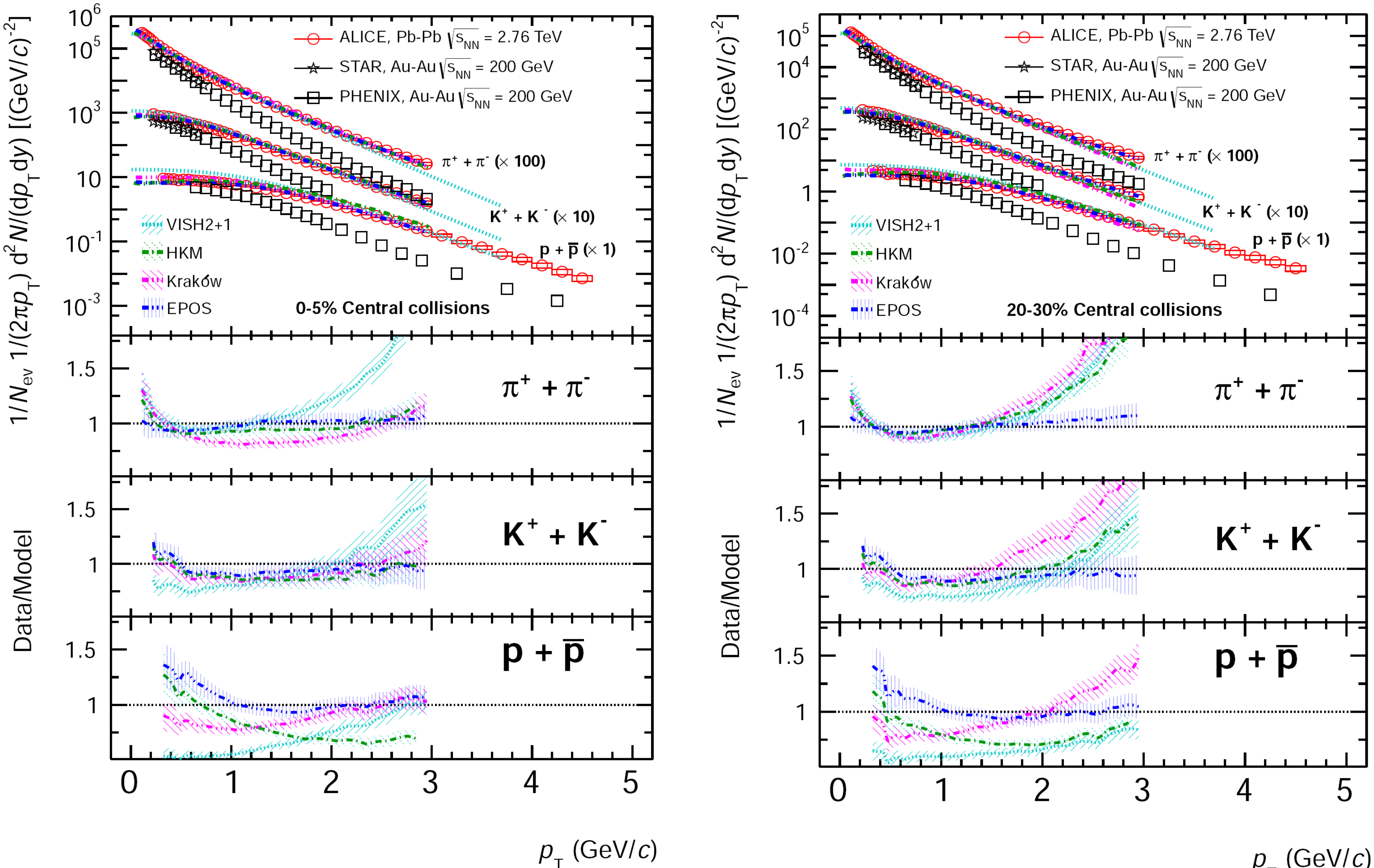
"...Excellent agreement with the statistical hadronization model has been achieved with exception of the (anti-)proton yields..."

"...We have shown that *only* the chemical non-equilibrium SHM describes very well all available LHC hadron production data..."

Petran, Letessier, Petracek, Rafelski, arXiv:1303.2098, PRC 2013



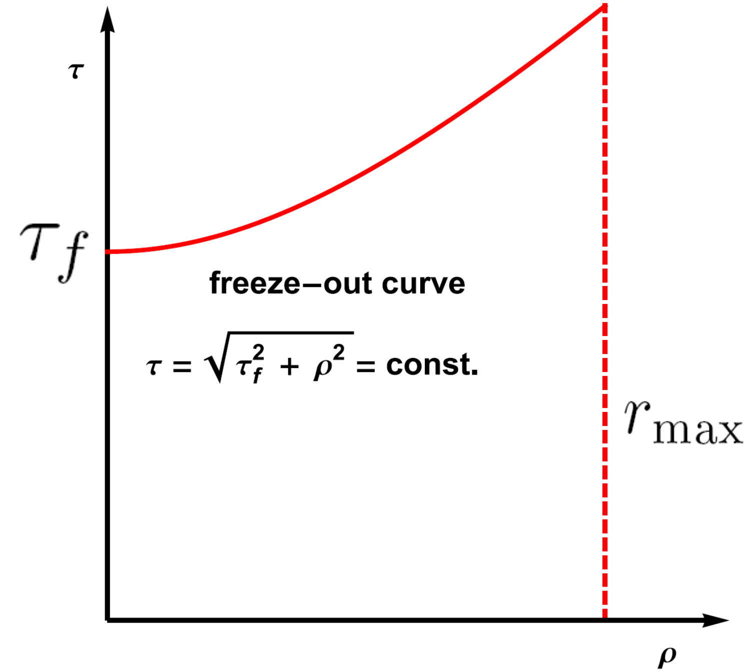
Low pt enhancement of spectra



ALICE Collaboration, arXiv: 1303.0737, PRC 2013

Krakow Single Freeze-Out Model

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



The freeze-out hypersurface Σ:

$$t^2 = \tau_f^2 + x^2 + y^2 + z^2, \quad x^2 + y^2 \leq r_{\max}^2$$

Flow at freeze-out has the Hubble form: $u^\mu = x^\mu / \tau_f$

The primordial distribution of the ith hadron in the local rest frame, where $u^\mu = (1,0,0,0)$, has the form:

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

Broniowski, Florkowski, Phys. Rev. Lett. 2001
Chojnacki, Kisiel, Florkowski, Broniowski, Comput. Phys. Commun. 2012

Non-equilibrium statistical model

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

If we neglect electric charge and charm then:

$$\Upsilon_i = (\lambda_q \gamma_q)^{N_q^i} (\lambda_s \gamma_s)^{N_s^i} (\lambda_{\bar{q}} \gamma_{\bar{q}})^{N_{\bar{q}}^i} (\lambda_{\bar{s}} \gamma_{\bar{s}})^{N_{\bar{s}}^i}$$

$$= \gamma_q^{N_q^i + N_{\bar{q}}^i} \gamma_s^{N_s^i + N_{\bar{s}}^i} \exp\left(\frac{\mu_B B_i + \mu_S S_i}{T}\right)$$

$$\frac{\text{baryon}(qqq)}{\text{meson}(q\bar{q})} \propto \frac{\gamma_q^3}{\gamma_q^2}$$

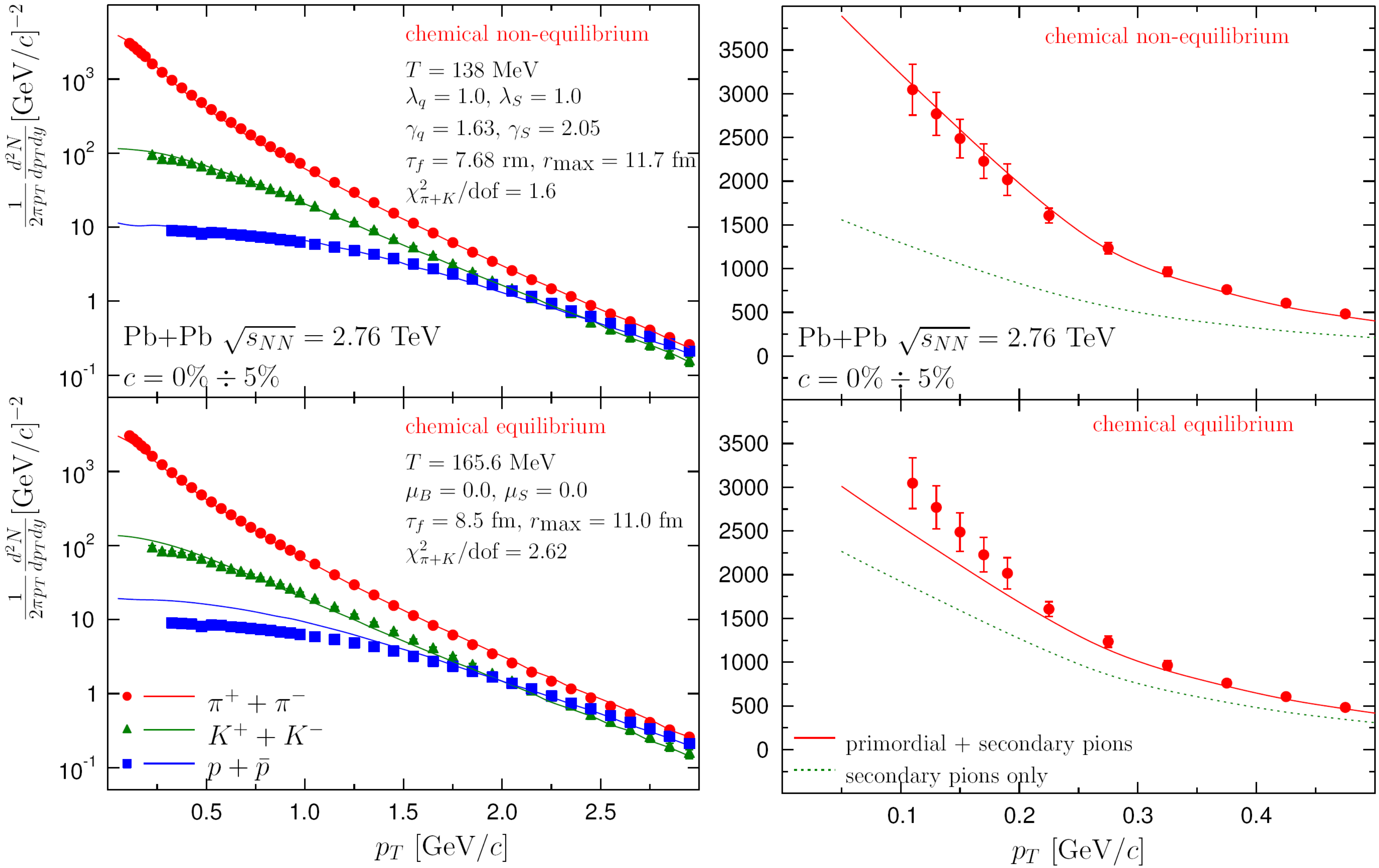
for non-strange baryon to meson ratio

There is an upper bound on γ_q and γ_s because of Bose–Einstein condensate which corresponds to a singularity in the distribution function f_i

$$\gamma_q^{\text{crit}} = \exp\left(\frac{m_{\pi^0}}{2T}\right)$$

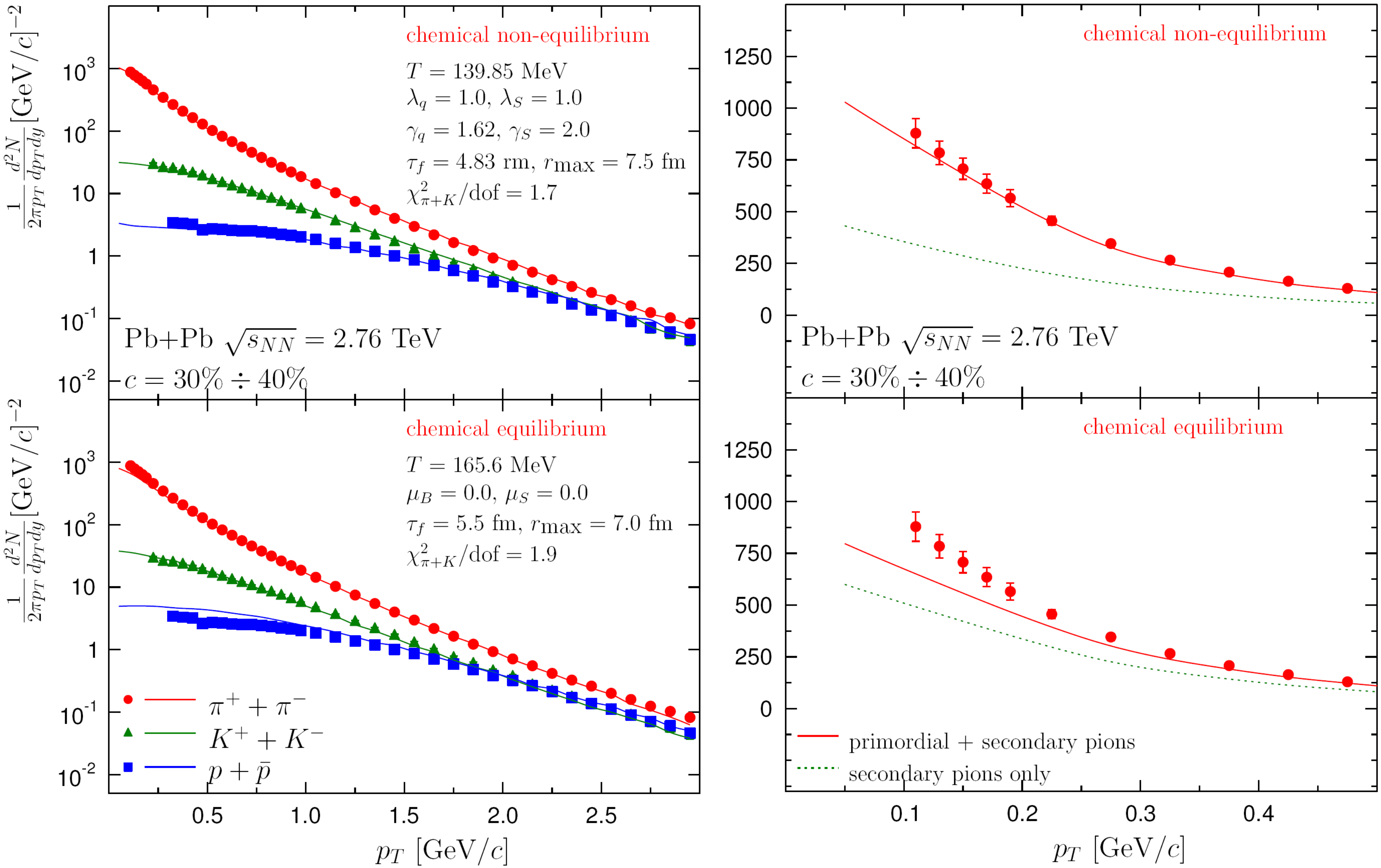
Petran, Rafelski, arXiv:1303.0913, PRC 2013
Petran, Letessier, Petracek, Rafelski, arXiv:1303.2098, PRC 2013

Spectra of pions, kaons, protons



V.B., W. Florkowski, M. Rybczynski, arXiv: 1312.1487

Spectra of pions, kaons, protons



V.B., W. Florkowski, M. Rybczynski, arXiv: 1312.1487

Conclusions:

- The non-equilibrium thermal model combined with the single-freeze-out scenario explains very well the spectra of pions, kaons, and protons

- It eliminates the proton anomaly and explains the low-pt enhancement of pions

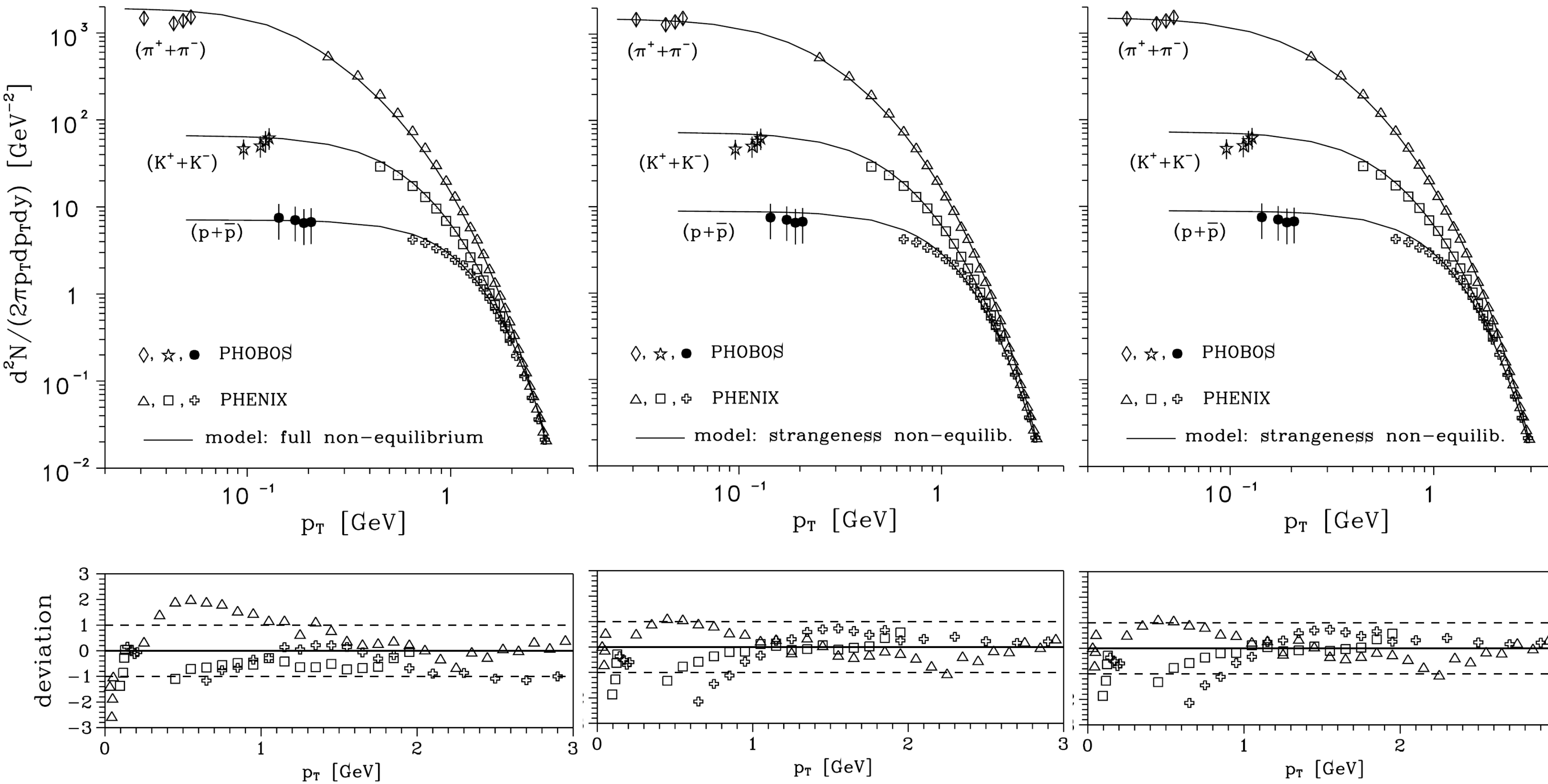
- This enhancement may be interpreted as a signature of the onset of pion condensation in heavy-ion collisions at the LHC energies

- It might be connected to the gluon condensation in the context of thermalization of the Quark-Gluon Plasma

- It would be interesting to measure the pion spectrum at smaller values of pt than those available at the moment

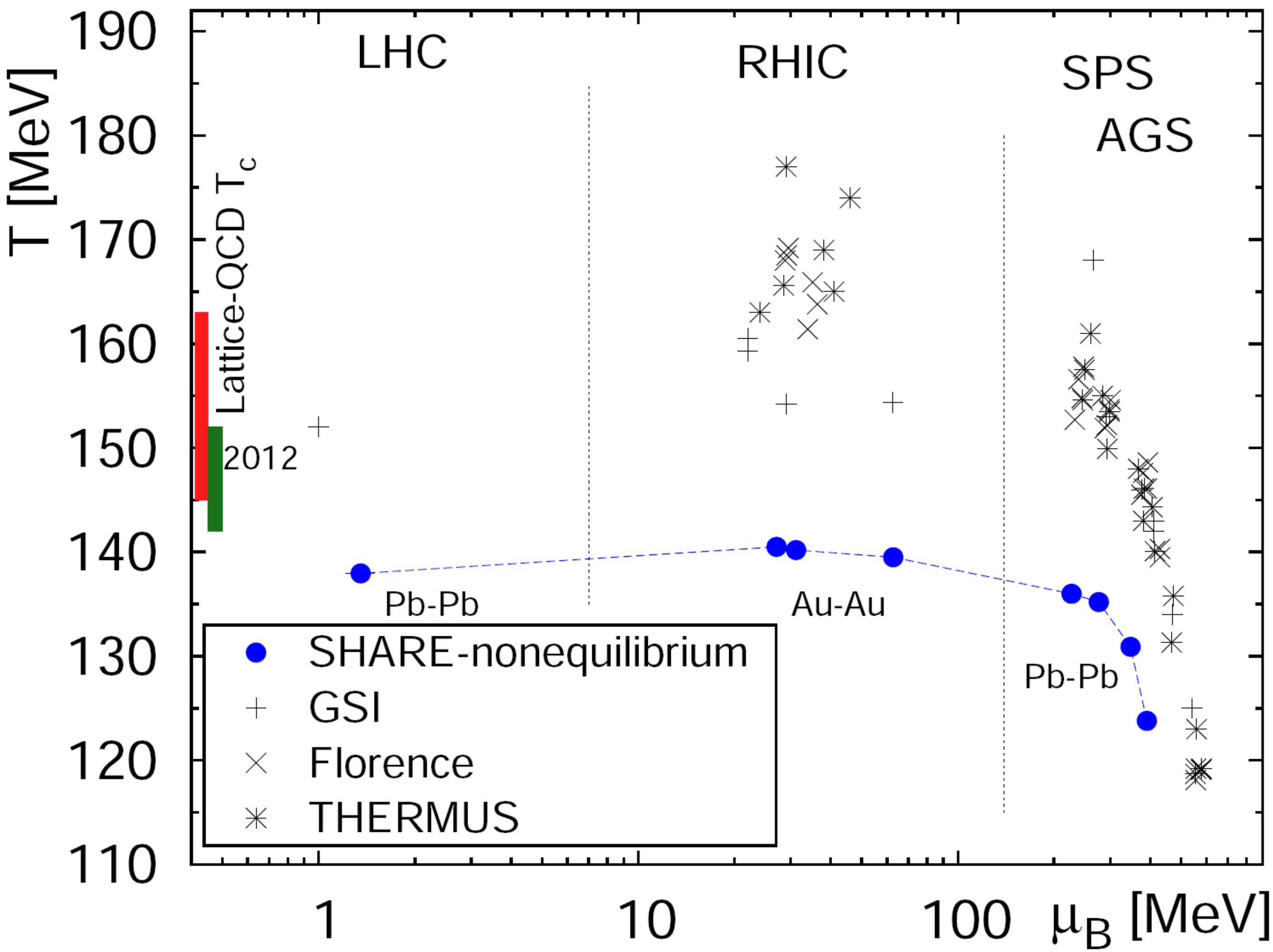
Thank you!

Non-equilibrium statistical model @ RHIC



Prorok, arXiv:nucl-th/0609041, PRC 2007

Non-equilibrium Phase Diagram



Petran, Letessier, Petracek, Rafelski, arXiv:1303.2098, PRC 2013