IMPACT OF HIGHER MASS-STATES ON THE FREEZE-OUT CONDITIONS IN HEAVY-ION COLLISION

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INTRODUCTION

The precision achieved by recent lattice simulations of QCD thermodynamics allows to extract quantitative predictions on the physic of ***Heavy Ion Collisions*** (HICs), which provide a new insight into our understanding of strong interactions.

For example one can study the chemical composition of strongly interacting matter and identify the degrees of freedom which populate the system in the vicinity of the QCD phase transition.

FLUCTUATIONS

Once the partition function $\mathcal{Z}$, which describes the system, is set, the moments of the multiplicity distribution for a conserved charge are related to the fluctuations χ of the same charge, defined as follows:

$$\chi_{lmn}^{BSQ} = \frac{\partial^{l+m+n}\left(\ln \mathcal{Z}/(VT^3)\right)}{\partial\left(\mu_B/T\right)^l \partial\left(\mu_S/T\right)^m \partial\left(\mu_Q/T\right)^n}$$

mean: $$M = \langle N \rangle = VT^3\chi_1,$$

variance: $$\sigma^2 = \langle(\delta N)^2\rangle = VT^3\chi_2,$$

skewness: $$S = \frac{\langle(\delta N)^3\rangle}{\sigma^3} = \frac{VT^3\chi_3}{(VT^3\chi_2)^{3/2}},$$

kurtosis: $$\kappa = \frac{\langle(\delta N)^4\rangle}{\sigma^4} - 3 = \frac{VT^3\chi_4}{(VT^3\chi_2)^2};$$

Such fluctuations can be calculated using various theoretical approaches, e.g. lattice QCD or the ***Hadron-Resonance Gas*** (HRG) model.

THE HRG MODEL

A system of interacting hadrons in the ground state can be described by a ***gas of non-interacting hadrons and resonances***.

We call chemical ***chemical freeze-out*** (FO) the point in the evolution of the system in the hadronic phase at which inelastic scatterings of hadron cease.

The good agreement of the HRG calculations with lattice data in the low temperature regime is commonly assumed as a signal of the realization of the confined phase.

PARTICLE LIST

There is basically no free parameter in the HRG model, the only uncertainty lying in the amount of states measured experimentally and listed by the ***Particle Data Group*** (PDG).

It has recently been proposed [1] to use the precise lattice QCD results for specific observables, and their possible discrepancy with the HRG model predictions, to infer the existence of higher mass, not yet measured, hadronic states.

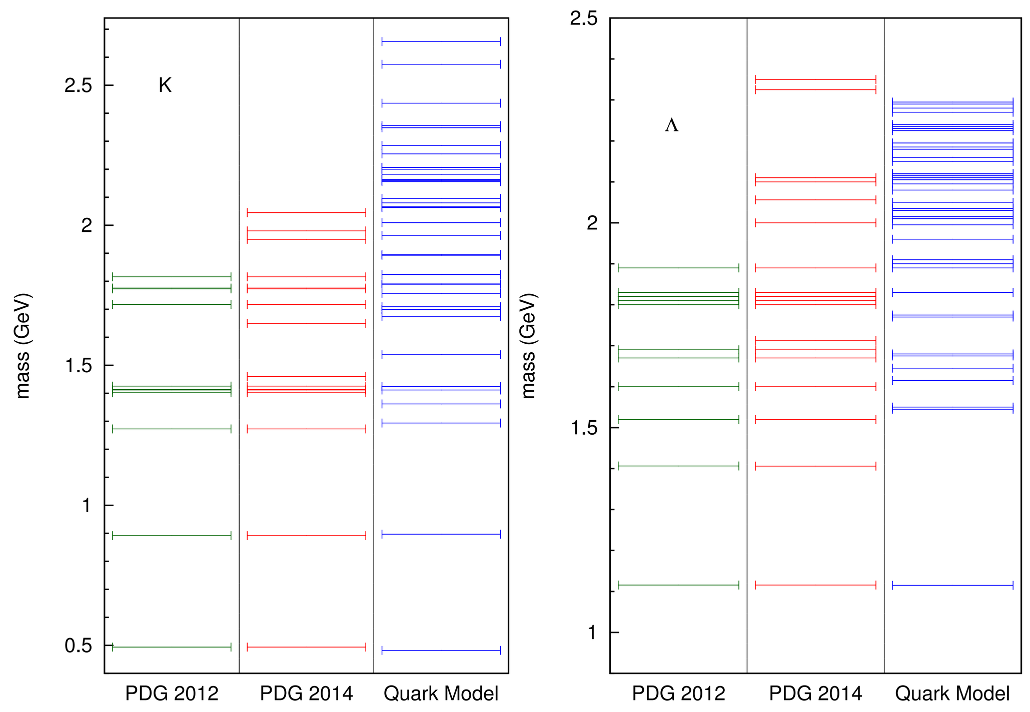
In order to do so, predictions from ***Quark-Model*** (QM) calculations for mesonic [2] and baryonic [3] states are used.

PREDICTED QM STATES

The QM reproduces reasonably well the known mass spectrum of both mesons and baryons, and gives a high number of new states, considering all the possible combinations of different quark-flavor, spin and quantum number configurations. However, the QM does not provide any information on the decay properties of such particles.

In recent years, the spectrum of experimentally verified particles has substantially improved, but the number of states is still considerably lower than the QM predictions. In particular, the strange sector contains about 3 times more particles in the QM list than in the PDG one.

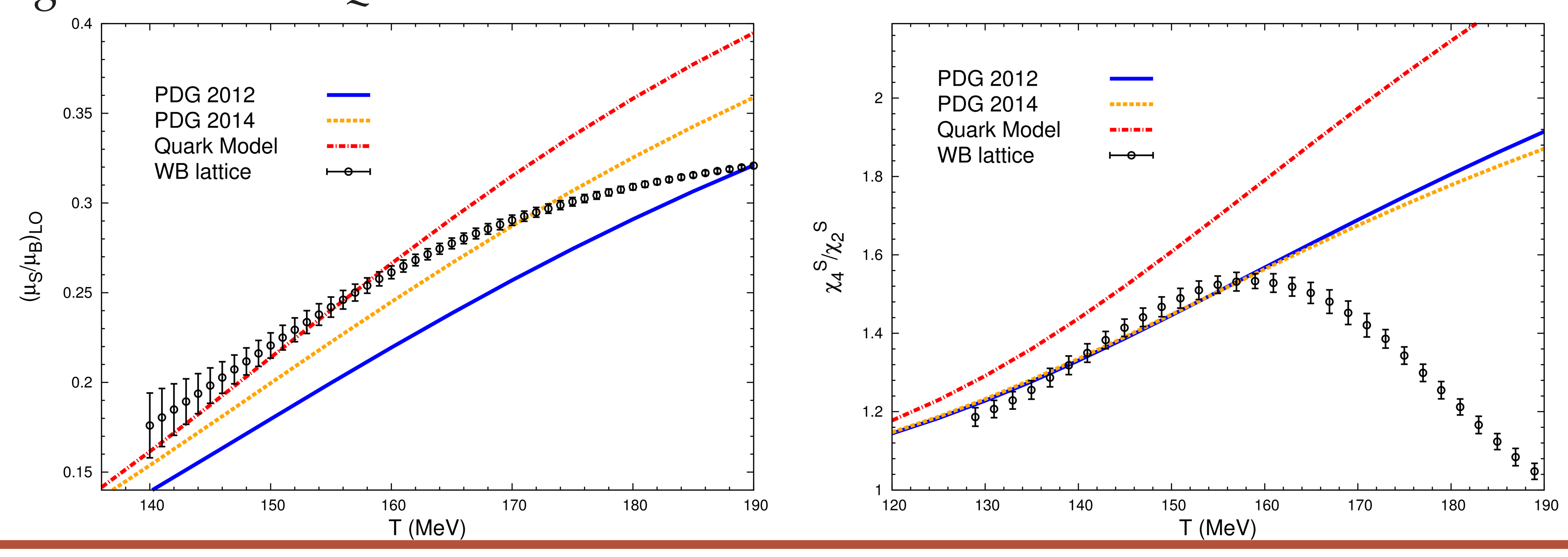
It is worth pointing out that the difference between the PDG2012 and PDG2014 is mainly due to the increase of 95% for the strange baryons, compared to an increase of about 45% for the strange mesons.



STRANGENESS-RELATED MULTIPLICITY FLUCTUATIONS

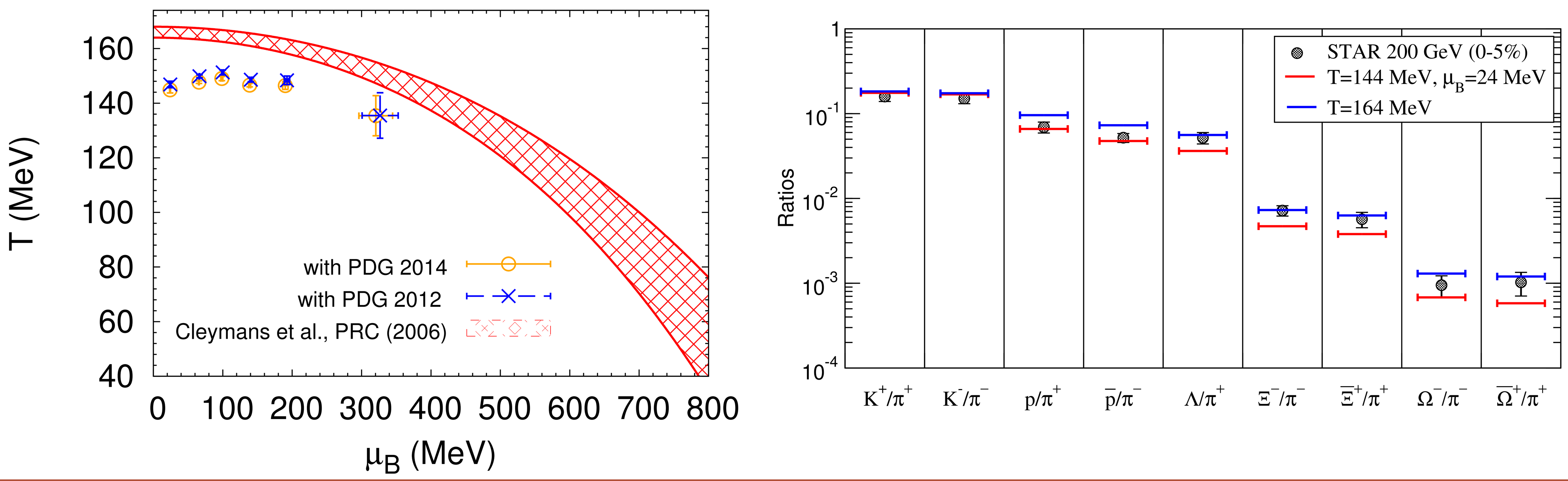
The QM is in good agreement with $\mu_S/\mu_B|_{LO}$ from [4], while both PDG spectra underestimate it. This quantity is particularly sensitive to the presence of strange baryons, and indeed it is worth noticing that the PDG2014 substantially improves the agreement with the lattice data with respect to the PDG2012.

The QM overestimates the $\chi_4/\chi_2|_{net-S}$ from [5]; for every particle species, this observable is proportional to their strangeness squared, suggesting an imbalance between multi- and single-strange sector in the QM.



THE FREEZE-OUT AND PARTICLE YIELDS

We performed the same analysis on net-proton and net-charge lower moments as done in [6], but using our PDG2014 which considerably improves the description of $\mu_S/\mu_B|_{LO}$; our findings are that the FO parameters are in agreement with the previous ones, preserving the tension on the shift in temperature needed for the yields in the light and strange sectors.



CONCLUSIONS

In [1] it is suggested that the use of the lattice result for $\mu_S/\mu_B|_{LO}$ will decrease the freeze-out temperature for strange particles and bring it close to the one needed for light particles. This study does not take into account the effects due to resonance decay.

We show that a reasonable extension of the mass spectrum, which improves the description of $\mu_S/\mu_B|_{LO}$ and takes into account resonance decay effects, has little influence on the FO. A study [7] of the multi-strange sector could constrain the QM higher-mass states predictions.

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