Particle ratios in Pb+Pb at SPS in a chiral $SU(3) \times SU(3)$ model^{B,G}

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Ideal gas model calculations have been used for a long time to calculate particle production in relativistic heavy ion collisions, (see e.g. [1, 2] and references therein). Fitting the particle ratios as obtained from those noninteracting gas calculations to the experimental measured ratios at SIS, AGS and SPS for different energies and different colliding systems yields a curve of chemical freeze-out in the $T-\mu$ plane. Now the question arises, how much the deduced temperatures and chemical potentials depend on the model employed. Especially the influence of changing hadron masses and effective potentials should be investigated, as has been done for example in [3, 4, 5, 6]. This is of special importance for the quest of a signal of the formation of a deconfined phase, i.e. the quark-gluon plasma. As deduced from lattice data [7], the critical temperature for the onset of a deconfined phase coincides with that of a chirally restored phase. Chiral effective models of QCD therefore can be utilized to give important insights on signals from a quark-gluon plasma formed in heavy-ion collisions.

We compare experimental measurements for Pb+Pb collisions at SPS with the results obtained from a chiral $SU(3)\times SU(3)$ model [6, 8]. This effective hadronic model predicts a chiral phase transition at $T \approx 150\,\mathrm{MeV}$. Furthermore the model predicts changing hadronic masses and effective chemical potentials, due to strong scalar and vector fields in hot and dense hadronic matter, which are constrained by chiral symmetry.
In [2] the noninteracting gas model was fitted to particle ratios measured in Pb+Pb collisions at SPS. The lowest χ^2 is obtained for $T = 168\,\mathrm{MeV}$ and $\mu_q = 88.67\,\mathrm{MeV}$. Using these values as input for the chiral model leads to dramatic changes due to the changing hadronic masses in hot and dense matter [6] and therefore the freeze-out temperature and chemical potential have to be readjusted to account for the in-medium effects of the hadrons in the chiral model. We call the best fit the parameter set that gives a minimum in the value of χ^2, with $\chi^2 = \sum_i \frac{\left(r_i^{exp} - r_i^{model}\right)^2}{\sigma_i^2}$. Here r_i^{exp} is the experimental ratio, r_i^{model} is the ratio calculated in the model and σ_i represents the error in the experimental data points as quoted in [2]. In all calculations μ_s was chosen such that the overall net strangeness f_s is zero. The best values for the parameters are $T = 144\,\mathrm{MeV}$ and $\mu_q \approx 95\,\mathrm{MeV}$. While the value of the chemical potential does not change much compared to the noninteracting gas calculation, the value of the temperature is lowered by more than 20 MeV. Using the best fit parameters a reasonable description of the particle ratios used in the fit procedure can be obtained (see fig.1, data from [2]).

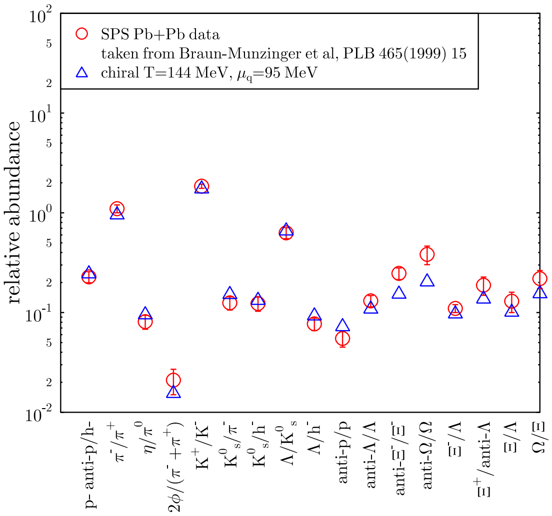

Figure 1: Particle ratios as predicted by the chiral $SU(3)\times SU(3)$ model ($T = 144\,\mathrm{MeV}$ and $\mu_q \approx 95\,\mathrm{MeV}, \mathrm{f_s} = 0$) compared to SPS Pb+Pb data (taken from [2]).

This shows, that in spite of the strong assumption of thermal and chemical equilibrium the obtained values for T and μ differ significantly depending on the underlying model, i.e. whether and how effective masses and effective chemical potentials are accounted for. Note that we assume implicitly, that the particle ratios are determined by the medium effects and freeze out during the late stage expansion - no flavor changing collisions occur anymore, but the hadrons can take the necessary energy to get onto their mass shall by drawing energy from the fields. Rescattering effects will alter our conclusion but are presumably small when the chemical potentials are frozen.

References

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