Chemical relaxation time of pions in hot hadronic matter *

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We have studied the thermal and chemical relaxation time scales of pions in hot hadronic matter with an effective chiral Lagrangian. From the explicit calculation we show that pions in hot hadronic matter are in a phase where elastic collisions rates are very fast compared to typical expansion rates of the system. For chemical equilibration the dominant contribution comes from the inelastic collision involving a_1 mesons. Comparing with previous calculations [1] based on chiral perturbation theory, the inclusion of the resonances has reduced the chemical relaxation time by about a factor of 10. When we neglect the formation time of these resonances, the resulting chemical relaxation time of pions is 10 fm/c at $T = 150$ MeV. This value is comparable to the size of the hot system produced the collision of large nuclei.

Given a system size of $5 \sim 10\,\text{fm}$ we obtain a thermal freeze-out temperature which is small compared to those extracted from experiments [2,3]. This might be due to flow effects which lead to smaller effective system sizes. If we take the thermal freeze-out temperature be about 150 MeV, then the freeze-out size of the system would be $2 \sim 3$ fm. On the other hand the chemical relaxation time for a system of this size would be $T = 170\,\text{MeV}$. This implies that chemical freeze-out of pions happens at considerably higher temperatures than thermal freeze-out.

We also have studied the effect of baryons on the chemical relaxation time of pions. Since the effect of baryons is suppressed by their large mass, we consider only low laying baryons, $N(938)$ and $\Delta(1236)$. To estimate the relaxation time we use the phenomenological cross section for $NN \rightleftharpoons N\Delta$. The effect of baryons is very small and can be neglected in SPS experiments.

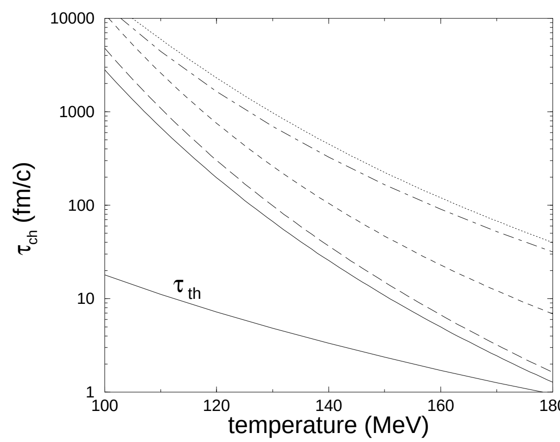

Figure 1: Chemical relaxation time of pions in hot hadronic matter. The reactions $\rho\rho \leftrightarrow \pi\pi$ (long dashed curve), $\pi\omega \leftrightarrow \pi\pi$ (dashed-dot curve), $\pi a_1 \leftrightarrow \pi\pi$ (dashed curve) and $\pi\pi\pi\pi \leftrightarrow \pi\pi$ (dotted curve) are considered. The solid curve represents the total relaxation time. These results are compared with the thermal relaxation time, τ_{th}.

However, it becomes important in AGS experiments where the baryon chemical potential is much larger than that in the SPS experiments.

We have extend the definition for the chemical relaxation time to a system of pions out of equilibrium with $\mu_\pi \neq 0$. In this case it is possible that the overpopulated pions will be reduced by the inelastic reactions involving vector and axial vector mesons. At $T = 150$ with $\mu_\pi = 100\,\text{MeV}$ the relaxation time is about 2 fm/c which is certainly comparable to the system size at freeze-out.

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[3] U. Heinz, Nucl Phys. A 566 (1994) 205c.

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