Upsilon Absorption in Hadronic Matter

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Because of its larger binding energy than that of J/Ψ , the critical energy density at which an K is dissociated in the quark-gluon plasma is also higher. One thus expects to see the effects of the quark-gluon plasma on the production of K only in ultra-relativistic heavy ion collisions such as at the BNL RHIC and the CERN LHC. However, to use K suppression as a signal for the quark-gluon plasma in heavy ion collisions requires the understanding of its absorption in hadronic matter as in the case of J/Ψ.

To evaluate the K absorption cross sections by hadrons, we have used a hadronic Lagrangian [1]. Starting from the free Lagrangian for pseudoscalar and vector mesons in the limit of SU(5) symmetry, we obtain their interaction Lagrangians via the minimal substitution. This gives rise to couplings not only among two pseudoscalar mesons with a vector meson (BBB^*, ΨBB, and ΔBB) but also among three vector mesons (KB^*B^* and ΔB^*B^*). Furthermore, there exists contact interactions among four particles (BKBB^*, ΔKBB, and ΔKB^*B^*). These interaction Lagrangians lead to the K absorption processes by mesons shown in Fig. 1.

The coupling constant $g_{BBB^*} = 10.3$ is determined from the QCD sum rules [2]. Using the vector meson dominance model gives the three-point coupling constants $g_{\Delta BB} = 2.52$ and $g_{KBB} = 13.3$, which has a ratio of about 5 and is almost a factor of three larger than that expected from SU(5) symmetry. For the coupling constants among three vector mesons, we use the SU(5) relations $g_{\Delta BB} = g_{\Delta B^*B^*}$ and $g_{KBB} = g_{KB^*B^*}$. The four-point coupling constants are determined from the three-point coupling constants via the SU(5) relations, i.e. $g_{BKB^*B^*} = g_{BBB^*}\, g_{KBB}$, $g_{\Delta KBB} = 2\, g_{\Delta BB}\, g_{KBB}$, and $g_{\Delta KB^*B^*} = g_{\Delta B^*B^*}\, g_{KB^*B^*}$.

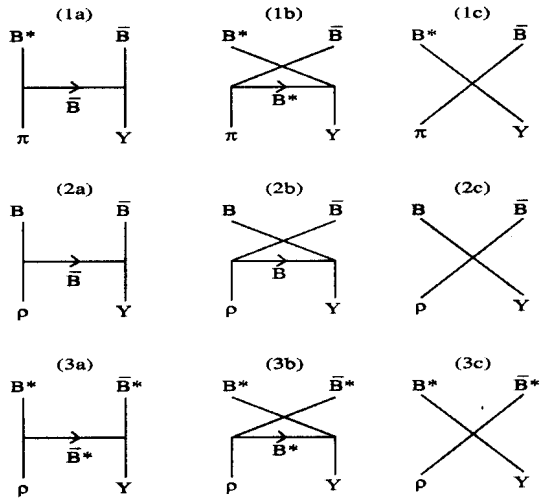

Figure 1: Diagrams for K absorption processes. (1a-c): BK $\rightarrow B^*\bar{B}$, (2a-2c): ΔK $\rightarrow B\bar{B}$, and (3a-3c): ΔK$\rightarrow B^*\bar{B}^*$. Diagrams for the process BK $\rightarrow B\bar{B}^*$ are similar to (1a)-(1c) but with each particle replaced by its anti-particle.

To take into account the composite nature of hadrons, we introduce at the three-point t channel and u channel vertices a monopole form factor $F(7,\mathbf{q}^2) = 7^2/(7^2 + \mathbf{q}^2)$, with a cutoff parameter 7 and the squared three momentum transfer q^2 in the center-of-mass frame. At four-point vertices, the form factor is taken to be the product of $F(7_1, <\mathbf{q}^2>)$ and $F(7_2, <\mathbf{q}^2>)$, where 7_1 and 7_2 are the two different cutoff parameters at the three-point vertices present in the process with the same initial and final particles and $<\mathbf{q}^2>$ is the average value of the squared three momentum transfers in t and u channels. For simplicity, we use the same value

for all cutoff parameters and choose them as either 1 or 2 GeV to show the uncertainties due to form factors.

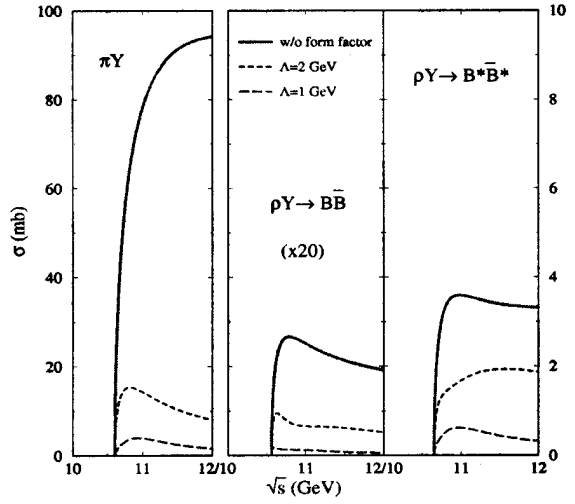

Figure 2: K absorption cross sections as functions of center-of-mass energy with and without form factors.

Fig. 2 shows the cross sections of K absorption by B and Δ mesons as functions of the center-of-mass energy $\sqrt{s}$. The cross section Φ_{BK} includes contributions from both BK $\rightarrow$ $B\bar{B}^*$ and BK $\rightarrow$ $B^*\bar{B}$, which have same cross sections. It is seen that the three K absorption cross sections have very different energy dependence near the threshold energy. Form factors are seen to strongly suppress the cross sections and thus cause large uncertainties in their values. However, the K absorption cross sections remain appreciable after including form factors at the interaction vertices. The values for

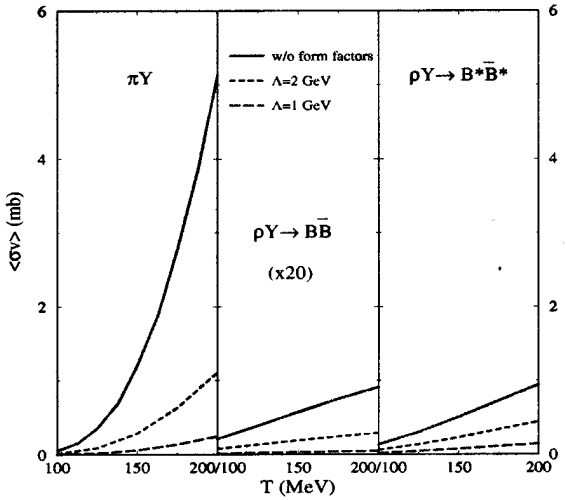

Figure 3: Thermal averages of the cross sections for K absorption as functions of temperature T with and without form factors.

Φ_{BK} and $\Phi_{\Delta K}$ are roughly 8 mb and 1 mb, respectively. Because of the large threshold of the reactions, the thermal average of these cross sections is only about 0.2 mb at a temperature of 150 MeV as shown in Fig. 3. Our results thus suggest that absorption by hadronic comovers is unimportant in high energy heavy ion collisions.

References

[1] Z. W. Lin and C. M. Ko, Phys. Lett. **B503**, 104 (2001).

[2] V. M. Belyaev, V. M. Braun, A. Khodjamirian and R. Ruckl, Phys. Rev. D **51**, 6177 (1995). Note that our coupling constants are a factor of $2\sqrt{2}$ smaller due to the difference in definitions.