J/ψ absorption in hadronic matter

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To understand J/ψ suppression in heavy ion collisions, which has been proposed as a possible signature for the formation of the quark-gluon plasma [1], it is important to know if J/ψ absorption by hadrons plays an important role. There are unfortunately no empirical information on the J/ψ absorption cross section by mesons such as pion and rho meson. Various approaches have thus been used in evaluating these cross sections. In the perturbative QCD approach based on the dissociation of charmonium bound states by energetic gluons inside hadrons [2], the dissociation cross section is found to increase monotonously with the hadron kinetic energy and has a value of only about 0.1 mb at 0.8 GeV. On the other hand, the quark-exchange model gives a cross section which is more than an order of magnitude larger [3, 4].

To further understand these cross sections, we have used instead a hadronic Lagrangian [5]. Starting from the free Lagrangian for pseudoscalar and vector mesons in the limit of SU(4) 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 (πDD^*, ψDD, and ρDD) but also among three vector mesons (ψD^*D^* and ρD^*D^*). Furthermore, there exists contact interactions among four particles ($\pi\psi DD^*$, $\rho\psi DD$, and $\rho\psi D^*D^*$). These interaction Lagrangians lead to the J/ψ absorption processes by mesons shown in Fig. 1.

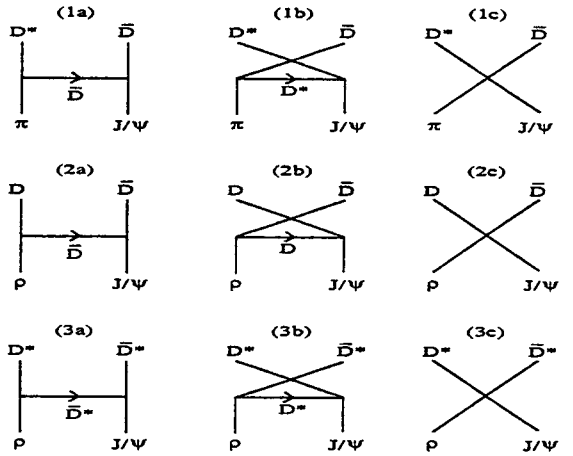

Figure 1: Diagrams for J/ψ absorption processes. (1a-1c): $\pi\psi \to D^*\bar{D}$, (2a-2c): $\rho\psi \to D\bar{D}$, and (3a-3c): $\rho\psi \to D^*\bar{D}^*$. Diagrams for the process $\pi\psi \to D\bar{D}^*$ are similar to (1a)-(1c) but with each particle replaced by its anti-particle.

The coupling constant $g_{\pi DD^*} = 4.4$ is determined from the D^* decay width. Using the vector meson dominance model gives the three-point coupling constants $g_{\rho DD} = 2.52$ and $g_{\psi DD} = 7.64$. The latter is almost a factor of two larger than that expected from SU(4) symmetry. For the coupling constants among three vector mesons, we use the SU(4) relations $g_{\rho DD} = g_{\rho D^*D^*}$ and $g_{\psi DD} = g_{\psi D^*D^*}$. The four-point coupling constants are determined from the three-point coupling constants via the SU(4) relations, i.e., $g_{\pi\psi DD^*} = g_{\pi DD^*}g_{\psi DD}$, $g_{\rho\psi DD} = 2\, g_{\rho DD}g_{\psi DD}$, and $g_{\rho\psi D^*D^*} = g_{\rho D^*D^*}g_{\psi D^*D^*}$.

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 $F(\Lambda, \mathbf{q}^2) = \Lambda^2/(\Lambda^2 + \mathbf{q}^2)$, with a cutoff parameter Λ and the

squared three momentum transfer $\mathbf{q}^2$ in the center-of-mass frame. At four-point vertices, the form factor is taken to be the product of $F(\Lambda_1, <\mathbf{q}^2>)$ and $F(\Lambda_2, <\mathbf{q}^2>)$, where Λ_1 and Λ_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.

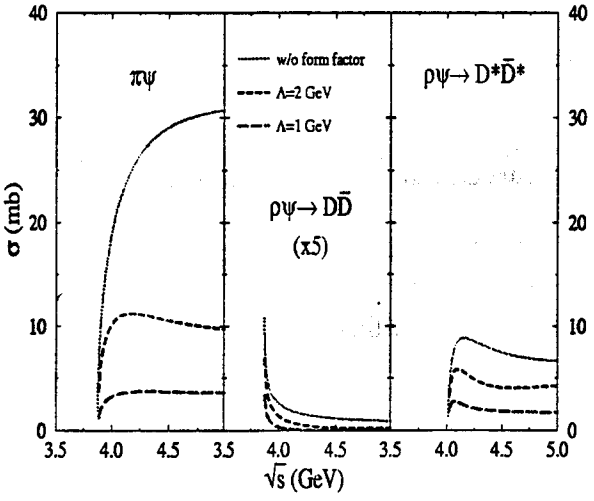

Figure 2: J/ψ absorption cross sections as functions of center-of-mass energy with and without form factors.

Fig. 2 shows the cross sections of J/ψ absorption by π and ρ mesons as functions of the center-of-mass energy $\sqrt{s}$. The cross section $\sigma_{\pi\psi}$ includes contributions from both $\pi\psi \to D\bar{D}^*$ and $\pi\psi \to D^*\bar{D}$, which have same cross sections. It is seen that the three J/ψ 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 J/ψ absorption cross sections remain appreciable after including the form factors at the interaction vertices. The values for $\sigma_{\pi\psi}$ and $\sigma_{\rho\psi}$ are roughly 7 mb and 3 mb, respectively, and are comparable to those used in phenomenological studies of J/ψ absorption by co-moving hadrons in relativistic heavy ion collisions [6, 7].

Our results for the J/ψ absorption cross sections by hadrons based on the meson-exchange model are consistent with those based on a similar approach [8] but are much larger than those from a previous study [9] which includes only the coupling among two pseudoscalar mesons with a vector meson. Our results are also comparable to that from the quark-exchange model [3, 4] but are much larger than that from the perturbative QCD approach [2].

References

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