Charm Meson Scattering in Hadronic Matter

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The study of charm meson production in ultrarelativistic heavy ion collisions is useful in searching for the signatures of the quark-gluon plasma, that is expected to be formed in the initial stage of ultrarelativistic heavy ion collisions. Since charm production from hadronic reactions is reasonably well described by the perturbative QCD, a change in the charm meson spectra may thus provide information on the properties of the quark-gluon plasma, as charm quarks produced in heavy ion collisions undergo strong radiative energy loss in the quark-gluon plasma. However, the interactions between resulting charm mesons and other hadrons may also affect the final charm meson spectra. To extract information about the properties of the quark-gluon plasma from the charm meson spectra thus requires a good understanding of the scattering of charm mesons in hadronic matter.

Recently, using an effective Lagrangian we have evaluated the scattering cross sections of charm mesons with pions, rhos, and nucleons [1]. Fig.1 shows the Feynman diagrams for charm meson interactions with the pion (diagrams 1 to 8), the rho meson (diagrams 9 and 10), and the nucleon (diagrams 11 to 13).

Coupling constants used in the calculations are taken to be $g_{\rho\pi\pi} = 6.1$, $g_{\pi DD^*} = 4.4$, $g_{\rho DD} = 2.8$ [2], $g_{\pi NN} = 13.5$, $g_{\rho NN} = 3.25$ and $\kappa_\rho = 6.1$. These values are close to those based on the $SU(4)$ symmetry. To

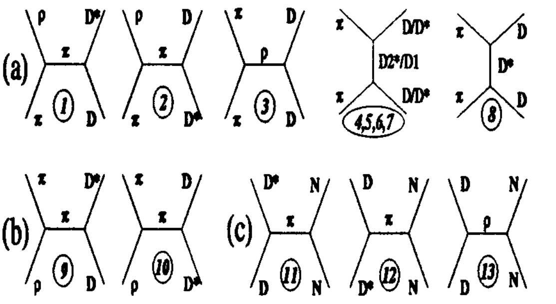

Figure 1: Feynman diagrams for (a) $D\pi$, (b) $D\rho$, and (c) DN scatterings.

take into account the structure of hadrons, we include form factors at the vertices. For t-channel processes, monopole form factors of the form $f(t) = (\Lambda^2 - m_\alpha^2)/(\Lambda^2 - t)$ are used, where Λ is a cut-off parameter [1] and m_α is the mass of the exchanged meson. To obtain finite cross sections for diagrams 2 and 9 ($D^*\pi \leftrightarrow D\rho$), which are singular as the intermediate mesons can be on-shell, we add an imaginary part of 50 MeV to the mass of the intermediate pion.

The thermal averaged cross section, $<\sigma v_{||}>$, is shown in Fig.2(a) for initial particles in a thermal bath at temperature T. Only the dominant scattering channels which have values above 1.1 mb are shown.

The effects of hadronic scattering on the charm meson transverse mass ($m_\perp$) spectrum can be characterized by the squared momentum transfer to a charm meson, i.e., $<\sigma v_{||} p_0^2>$. Fig.2(b) shows this thermal average for dominant scattering channels which have values above 0.75 mb·GeV^2. Averaging over D and D^*, we obtain for a hadronic matter at $T = 150$ MeV $<\sigma_i v_{||}\, p_0^2> \sim 1.1$, 1.5,

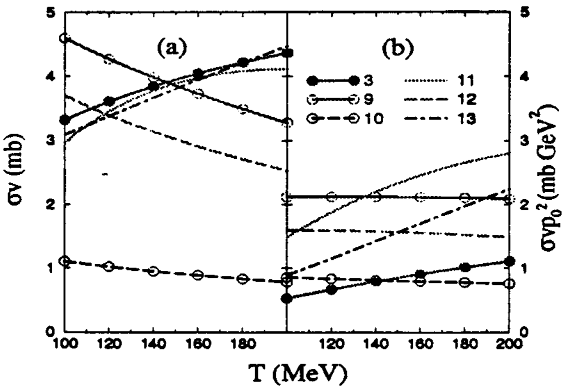

Figure 2: Thermal averages (a) $< \sigma v_{||} >$ and (b) $< \sigma v_{||} p_0^2 >$ for dominant charm meson scattering processes as functions of temperature. Numbers labeling the curves correspond to the diagram numbers in Fig. 1.

and 2.7 mb·GeV^2 for π, ρ and N scatterings with charm mesons, respectively.

For central Pb+Pb collisions at SPS energies, there are initially about 500 π, 220 ρ, 100 ω, 80 η, 180 N, 60 Δ, and 130 higher baryon resonances [3]. We assume that in the charm meson local frame the time evolution of hadron densities is inversely proportional to the proper time. Taking the initial time $\tau_0 = 1$ fm and neglecting omega, eta, delta, and higher baryon resonances, we obtain $\rho_0 \tau_0 \simeq 0.79$, 0.35, and 0.28 fm^{-2} for pion, rho, and nucleon, respectively. From the thermal averaged total square momentum transfer, $< p_S^2 > \simeq 0.61$ GeV^2, the parameter T_S, which characterizes the scattering strength and is given by $T_S \simeq < p_S^2 > /(3m_D)$ in the lowest-order approximation [1], has a value $T_S = 96$ MeV. Based on Monte Carlo simulations, T_S has been related to the inverse slope T_{eff} of the final charm meson $m_\perp$ spectrum as shown in Fig.6 of Ref. [4]. From that figure, we find that the charm meson T_{eff} increases from 160 MeV to about 235 MeV,

A hardened charm meson transverse mass spectrum increases the slope parameter of the transverse momentum spectrum of dileptons from the decay of charm mesons. From the energy cuts in the NA50 acceptance, a dimuon enhancement factor of about 2.1 is obtained if one uses the estimates from Ref. [4]. This offers another possible explanation for the observed enhancement of intermediate mass dileptons besides that due to dilepton production from secondary hadron scatterings [5].

To study more quantitatively the hadronic scattering effects on charm mesons, one needs to carry out a transport model calculation using the theoretical cross sections. Furthermore, for heavy ion collisions at RHIC energies, partonic rescattering effects on charm quarks also need to be included. Such studies are currently under way.

References

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