Transverse momentum spectra of J/ψ in heavy-ion collisions

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It has long been suggested [1] that the suppression of J/ψ mesons produced in primordial nucleon-nucleon collisions in ultrarelativistic heavy-ion collisions can be utilized to probe the Quark-Gluon Plasma (QGP). However, the suppression of this "direct component" can be masked by secondary J/ψ formation due to coalescence of charm and anticharm quarks (regenerated component) at the hadronization transition [2], if c-cbar pairs are produced copiously. Evidence for regeneration has been found at the Relativistic Heavy-Ion Collider (RHIC) [3], where the suppression turns out to be similar to SPS (Super Proton Synchrotron) energies although the temperature of the putative QGP at RHIC is higher.

Toward a more quantitative assessment of suppression and coalescence mechanisms, we have computed transverse momentum (p_t) spectra of charmonia ($\Psi = J/\psi, \chi_c, \psi'$) in a two-component approach (direct + regenerated component) [4]. For the direct component we solve a Boltzmann transport equation,

$$p^{\mu}\partial_{\mu} f_{dir}(\vec{x}_t, \vec{p}_t, \tau) = -E_{\psi} \cdot \Gamma(\vec{x}_t, \vec{p}_t, \tau) \cdot f_{dir}(\vec{x}_t, \vec{p}_t, \tau)$$

($f_{dir}(\vec{x}_t, \vec{p}_t, \tau)$: phase space distribution function of charmonia, E_{ψ}: energy of Ψ with 3-momentum modulus p, $\vec{x}_t$: spatial position of Ψ, $\Gamma(\vec{x}_t, \vec{p}_t, \tau)$: charmonium dissociation rates). The initial distributions, $f_{dir}(\vec{x}_t, \vec{p}_t, 0)$ incorporate nuclear absorption and Cronin effects, the latter being implemented by a Gaussian smearing of the initial p_t-spectra in elementary N-N collisions. The charmonium dissociation rates are evaluated using the quasi-free breakup mechanism *g(q)+Ψ→c+cbar+g(q)* [5] instead of the commonly employed gluo-dissociation [6], *g+Ψ→c+cbar*, which becomes inefficient for small binding energies. The momentum dependence of the dissociation rates is shown in Fig. 1. The direct component also includes the leakage effect, i.e. charmonia exiting the fireball are not subject to suppression.

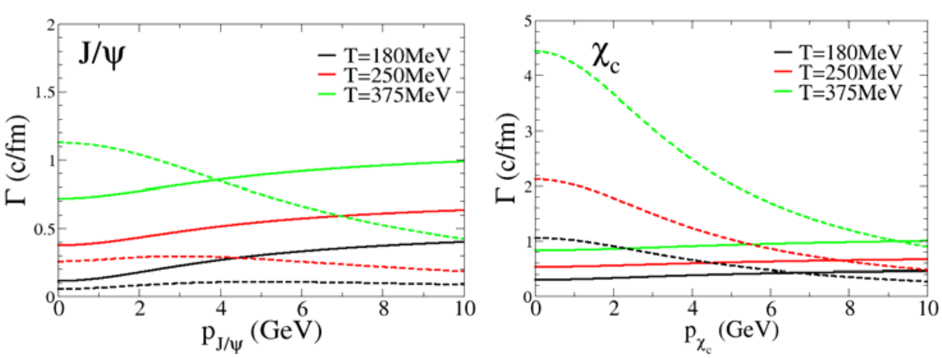

Figure 1. Comparison of the momentum dependence of quasifree (solid lines, in-medium binding energies) and gluo-dissociation rates (dashed lines, free binding energies) for J/ψ (left panel) and χ_c (right panel) at different temperatures.

For the regenerated charmonia we assume a local thermal distribution with p_t spectra given by the blastwave expression

$$f_{bw}(p_t) \propto m_t \int_o^R r dr K_1\left(\frac{m_t \cosh y_t}{T}\right) I_0\left(\frac{p_t \sinh y_t}{T}\right)$$

(R and y_t: radius and transverse rapidity of the fireball); the pertinent normalization (abundance), N_{coal}, is determined via a momentum-independent rate equation, $dN_{coal}/d\tau = -<\Gamma>\cdot(N_{coal} - R \cdot N_\psi^{eq})$ with $<\Gamma>=\Gamma(p=0)$ and N_ψ^{eq} being the charmonium equilibrium numbers from the statistical model with a correction factor $R = 1 - \exp(-\tau/\tau_c^{eq})$ to mimic incomplete kinetic equilibration of c-quarks in A-A collisions (τ_c^{eq} is the thermal relaxation time for c-quarks). Our results for J/Ψ transverse momentum spectra are represented by the nuclear modification factor, $R_{AA}(p_t)$ (the number of J/ψ's for a given p_t relative to that in p-p collisions times the number of binary collisions), for direct and regenerated components in Fig. 2 and compared to PHENIX data [3].

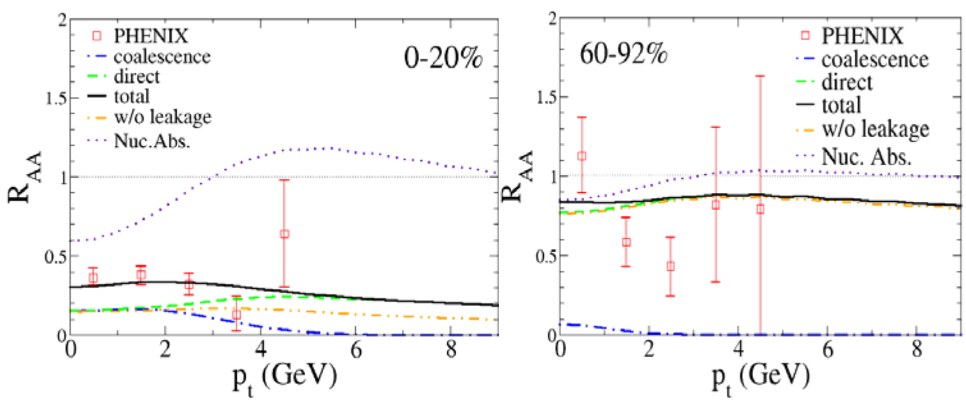

Figure 2. R_{AA} vs. p_t for central (left) and peripheral (right) Au-Au collisions at RHIC. PHENIX data [3] are compared to our calculations: initial primordial component (dotted line), including QGP and HG suppression (dashed line), and with leakage effect switched off (dash-double-dotted line); the coalescence contribution is given by the dash-dotted line.

By integrating R_{AA} (p_t) over p_t we obtain the centrality dependence of the inclusive J/ψ yield and their average squared transverse momentum, $<p_t^2>$, in Au-Au collisions, plotted in Fig. 3 vs. the number of participant nucleons, N_{part}. Our results are largely consistent with PHENIX data [3]. Future studies will address the full solution of the transport equation including the gain term with microscopic input for the charm-quark distribution functions.

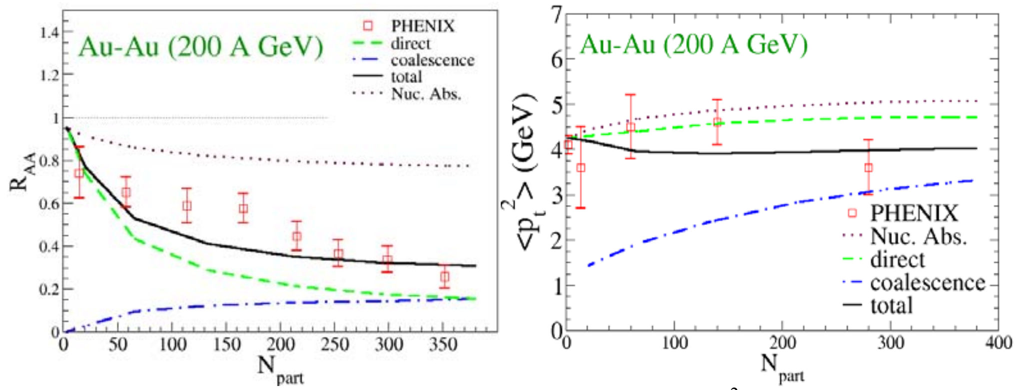

Figure 3. Results of the 2-component model for $R_{AA}(N_{part})$ and $<p_t^2>(N_{part})$ at RHIC, compared to PHENIX data [3]. The dotted line represnt the primordial input, while the dashed line additionally include QGP an HG suppression. The coalescence yield is represented by the dash-dotted line.

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