Evidence for ψ' Regeneration in Heavy Ion Collisions

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The study of hidden charm production is an important part of the heavy ion program. The standard approach to this problem [1] assumes that $c\bar{c}$ bound states are created *only* at the initial stage of the reaction and then partially destroyed at later stages due to interactions with the medium [2, 3, 4].

The idea of the statistical J/ψ production [5] triggered the development of an alternative approach [6, 7] — the statistical coalescence model (SCM): charmonia (as well as open charm hadrons) are formed at hadronization due to coalescence of charm quarks and antiquarks.

The standard approach (two its versions — the threshold suppression model [2] and comover model [3, 4]) demonstrates reasonable agreement with the data on J/ψ production in Pb+Pb collisions at SPS. Better agreement, but only for (semi)central collisions $N_p > 100$ (N_p is the number participant nucleons) can be obtained within the SCM [8].

It is interesting to check, which of the two scenarios is better suited for excited charmonium states. Recently the N50 collaboration presented new data on ψ' production in Pb+Pb collisions [9]. It appears that the both versions of the standard approach as well as SCM are able to fit the new ψ' data (see Fig. 1). But the observed ψ' suppression seems to be too weak to give reasonable values of the fit parameters of the standard scenario.

The free parameter of the threshold suppression model is the threshold density of the participant nucleons in the transverse plane at which the charmonium species under consideration is suppressed. The J/ψ data can be reasonably fitted with $n_{J/\psi} = 3.77\ ^{+0.09}_{-0.10}$ fm^{-2} for primary J/ψ's and $n_\chi = 1.95\ ^{+0.35}_{-0.45}$ fm^{-2} for excited charmonia (mostly χ-states) contributing up to 40% to the total J/ψ yield in p+p collisions. Because the ψ' is much weaker bound than any of the χ states, one would expect that its suppression begins at substantially lower density. It appears, however, that the ψ' data suggest approximately the same (or even larger) threshold for the ψ' suppression as for χ: $n_{\psi'} = 2.17\ ^{+0.33}_{-0.43}$ fm^{-2}.

The comover model does not alow to extract the suppression parameters for primary J/ψ and χ separately. The free parameter of the model is the *effective* suppression cross section averaged over all charmonium states that contribute to the production of the species under consideration. There is no obvious contradiction between the fit results for J/ψ and ψ': $\sigma^{co}_{J/\psi} = 1.01 \pm 0.05$ mb and $\sigma^{co}_{\psi'} = 2.84\ ^{+1.56}_{-0.79}$ mb, i.e. the comover dissociation cross section for ψ' is by a factor of about 3 larger than that for J/ψ. This ratio of the cross sections can be obtained, if one assumes that the matrix element of the reaction is approximately the same for J/ψ and ψ' [10] and the suppression is dominated by exothermic (e.g. $J/\psi + \rho \to D + D$) re-
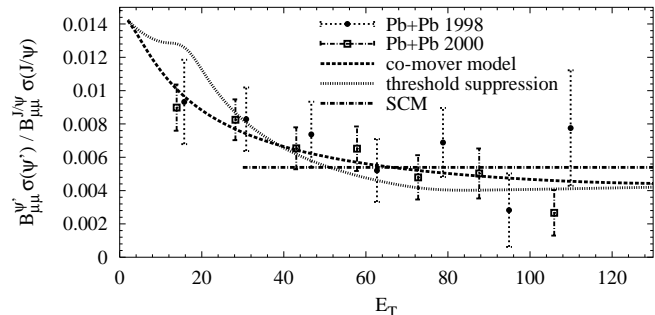

Figure 1: The ψ' to J/ψ ratio in Pb+Pb collisions at SPS.

actions. Still, model calculations of the matrix element predict much larger dissociation cross section for ψ' than for J/ψ [12]. If that is indeed so, then the only possible explanation of the observed ψ' yield is regeneration of ψ' at late stages of the reaction. As can be seen from Fig. 1 the new data (as well as the old ones [6, 11]) are consistent with the assumption that the ψ' to J/ψ ratio is nearly constant at $N_p > 100 - 150$. It is equal to the thermal value, corresponding to freeze-out temperatures $T = 150 - 170$ MeV, which agrees with the SCM. This suggest that excited charmonium states are likely to be produced at the final rather than at the initial stage of heavy ion reactions.

Measurement of the charmonium production in heavy ion collisions at lower energies, e.g. at the new GSI accelerator facility, would help to disentangle different charmonium production mechanisms.

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