X(3872) transport in heavy-ion collisions

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Ever since its discovery, the internal structure of the X(3872) particle has remained under debate [1]. The production of the X(3872) in heavy-ion collisions has been contemplated as an alternative probe of its internal structure. To investigate this conjecture, we perform transport calculations of the X(3872) through the fireball formed in nuclear collisions at the LHC [2].

We employ the thermal-rate equation approach that we have used before to interpret and predict a wide variety of charmonium and bottomonium observables [3–5]. Here, we focus on the time evolution of the X(3872) abundance in the hadronic phase of the fireball; it is governed by two transport parameters: the equilibrium limit and the inelastic reaction rate. The former provides an important benchmark as the long-time limit of the transport equation, while the latter encodes the structure effects through its coupling to the medium. Specifically, we consider two scenarios for the X(3872): a compact tetraquark state as a bound state of a colored diquark (cq) and its anti-diquark, and a hadronic molecular state as a loosely bound state of a D and D* meson. The width of the tetraquark is estimated to be in the range of Γ_{tetra}=40-80 MeV at an initial temperature of T_0=180 MeV, but much larger for the molecule, Γ_{mol}=300-500 MeV. The temperature dependence is assumed to decrease proportional to $(T/T_0)^3$. For the initial conditions, we assume the equilibrium limit for the tetraquark at the initial temperature (based on its formation with large reaction rates in the quark-gluon plasma), and zero for the molecule. The calculation of the temperature-dependent equilibrium limit throughout the hadronic includes a large number of charm-hadron states which largely affect the evaluation of the charm-quark fugacity (which figures squared for states containing $c\bar{c}$).

Our results, summarized in Fig. 1, show rather moderate differences in the yields within the two X(3872) structure scenarios, by around a factor of 2, which is smaller than in most coalescence model calculations which predict differences of up to two orders of magnitude. Moreover, contrary to coalescence models, the tetraquark yields are larger than those for the molecule, a direct consequence of

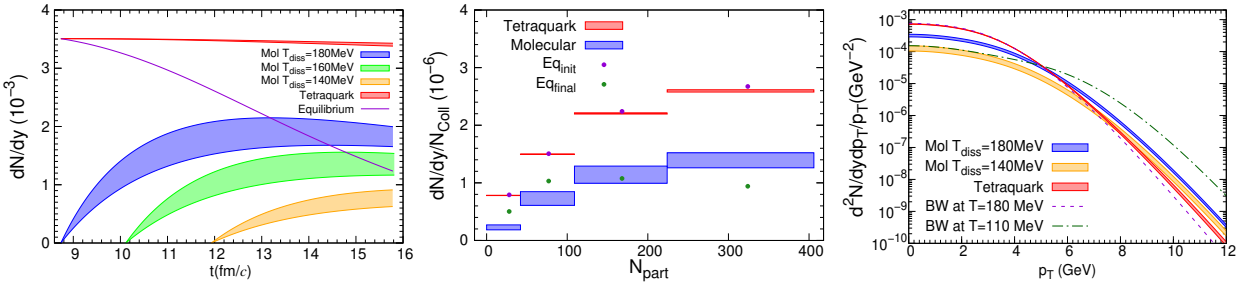

Fig. 1. Left panel: time evolution of the X(3872) equilibrium yield (solid line) and the solutions of the rate equation for the molecular (lower bands, for decreasing onset temperature of regeneration) and tetraquark (upper red band) scenarios in the hadronic phase of 0-20% Pb-Pb collisions at 5 TeV. Middle panel: centrality dependence of the production yields, normalized to the number of primordial NN collisions at each centrality (red bars: tetraquark scenario, blue bars: molecule scenario, symbols: equilibrium limit at chemical and thermal freezeout). Right panel: p_T-spectra in 0-20% central Pb-Pb collisions for the molecular (blue/orange band for T_{diss}=180/140MeV) and tetraquark (red band) scenarios, compared to blastwave spectra at chemical (dashed line) and thermal (dash-dotted line) freezeout.

the larger reaction rate for the molecule in connection with a decreasing equilibrium limit as the fireball cools down. Our calculations of the transverse-momentum (p_T) spectra provide additional constraints on the production time in the fireball evolution, with harder spectra indicating later production.

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