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Probing of exotic multiquark states in hadron and heavy ion collisions

The spectroscopy of charmonium-like mesons with masses above the 2_mD open charm threshold has been full of surprises and remains poorly understood [1]. The currently most compelling theoretical descriptions of the mysterious XYZ mesons attribute them to hybrid structure with a tightly bound cc\bar diquark [2] or cq(cq)\bar tetraquark core [3 - 5] that strongly couples to S-wave DD\bar molecular like structures. In this picture, the production of a XYZ states in high energy hadron collisions and its decays into light hadron plus charmonum final states proceed via the core component of the meson, while decays to pairs of open-charmed mesons proceed via the DD\bar component.

These ideas have been applied with some success to the XYZ states [2], where a detailed calculation finds a cc\bar core component that is only above 5% of the time with the DD\bar component (mostly D0D0\bar) accounting for the rest. In this picture these states are compose of three rather disparate components: a small charmonium-like cc\bar core with r_rms < 1 fm, a larger D+D- component with r_rms = ħ/(2μ+B+)ˆ1/2 ≈ 1.5 fm and a dominant component D0D0 with a huge, r_rms = ħ/(2μ0B0)ˆ1/2 > 9 fm spatial extent. Here μ+(μ0) and B+(B0) denote the reduced mass for the D+D- (D0D0\bar) system and the relevant binding energy |m_D + m_D - M_X(3872)| (B+ = 8.2 MeV, B0 < 0.3 MeV). The different amplitudes and spatial distributions of the D+D- and D0D0 components ensure that the X(3872) is not an isospin eigenstate. Instead it is mostly I = 0, but has a significant (˜ 25 %) I = 1 component.

In the hybrid scheme, XYZ mesons are produced in high energy proton-nuclei collisions via its compact (r_rms < 1 fm) charmonium-like structure and this rapidity mixes in a time (t ˜ ħ/δM) into a huge and fragile, mostly D0D0, molecular-like structure. δM is the difference between the XYZ meson mass and that of the nearest cc\bar mass pole core state, which we take to be that of the χc1(2P) pure charmonium state which is expected to lie about 20 ˜ 30 MeV above M_X(3872) [6, 7]. In this case, the mixing time, cτ_mix 5 ˜ 10 fm, is much shorter than the lifetime of X(3872) which is cτ_X(3872) > 150 fm [8].

The experiments with proton-proton and proton-nuclei collisions with √S_pN up to 27 Gev and luminosity up to 10ˆ32 cmˆ-2sˆ-1 planned at NICA may be well suited to test this picture for the X(3872) and other XYZ mesons [9]. In near threshold production experiments in the √S_pN ≈ 8 GeV energy range, XYZ mesons can be produced with typical kinetic energies of a few hundred MeV (i.e. with γβ ≈ 0.3). In the case of X(3872), its decay length will be greater than 50 fm while the distance scale for the cc\bar ⟶ D0D*0 transition would be 2 ˜ 3 fm. Since the survival probability of an r_rms ˜ 9 fm "molecular"inside nuclear matter should be very small, XYZ meson production on a nuclear target with r_rms ˜ 5 fm or more (A ˜ 60 or larger) should be strongly quenched. Thus, if the hybrid picture is correct, the atomic number de-pendence of XYZ production at fixed √S_pN should have a dramatically different behavior than that of the ψ', which is long lived compact charmonium state.

The current experimental status of XYZ mesons together with hidden charm tetraquark can-didates and present simulations what we might expect from A-dependence of XYZ mesons in proton-proton and proton-nuclei collisions are summarized.

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