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Probing of charmonium and exotics in hadron and heavy ion collisions

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The spectroscopy of higher lying charmonium states together with exotic mesons with masses above the $2m(D)$ open charm threshold has been full of surprises and remains poorly understood [1]. It is a good testing tool for the theories of strong interactions, including: QCD in both the perturbative and non-perturbative regimes, LQCD, potential models and phenomenological models. The experiments with antiproton-proton annihilation, proton-proton and proton-nuclei collisions are well suited for a comprehensive spectroscopy program, in particular, the spectroscopy of charmonium and exotics states. The currently most compelling theoretical descriptions of the mysterious XYZ mesons attribute them to hybrid structure with a tightly bound diquark [2] or tetraquark core [3 - 5] that strongly couples to S-wave molecular like structures. In this picture, the production of a XYZ states in high energy hadron collisions and its decays into light hadron plus charmonium final states proceed via the core component of the meson, while decays to pairs of open-charmed mesons proceed via the component. These ideas have been applied with some success to the XYZ states [2], where a detailed calculation finds a core component that is only about 5% of the time with the component (mostly) accounting for the rest. In this picture these states are composed of three rather disparate components: a small charmonium-like core with $r_{rms} < 1$ fm, a larger component with $r_{rms} \approx 1.5$ fm and a dominant component with a huge, $r_{rms} \approx 9$ fm spatial extent. 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 rapidly mixes in a time ($t \sim \hbar/\delta M$) into a huge and fragile, mostly, molecular-like structure. δM is the difference between the XYZ mass and that of the nearest mass pole core state, which we take to be that of the $\chi_{c1}(2P)$ pure charmonium state which is expected to lie about 20 ~ 30 MeV above $m(X(3872))$ [6, 7]. In this case, the mixing time, $\tau_{mix} \sim 5 \sim 10$ fm, is much shorter than the lifetime of $X(3872)$ which is $\chi\tau X(3872) > 150$ fm [8]. The near threshold production experiments in $\sqrt{s_{pN}} \sim 8$ GeV energy range with proton-proton and proton-nuclei collisions with $\sqrt{s_{pN}}$ up to 26 GeV and luminosity up to $10^{32} cm^{-2} s^{-1}$ planned at NICA may be well suited to test this picture for the $X(3872)$ and other exotic XYZ mesons [9]. Their current experimental status together with hidden charm tetraquark candidates and present simulations what we might expect from A-dependence of XYZ mesons in proton-proton and proton-nuclei collisions are summarized.

References

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