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A search for molecular-type hidden charm pentaquarks with an improved unitarization method

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The existence of the nucleonic pentaquark resonances $P_{c\bar{c}}(4312)^+$, $P_{c\bar{c}}(4380)^+$, $P_{c\bar{c}}(4440)^+$, $P_{c\bar{c}}(4457)^+$, $P_{c\bar{c}s}(4338)^0$ and $P_{c\bar{c}s}(4459)^0$, established by the LHCb collaboration, has been one of the major discoveries in hadron physics in the latest years. Most of these states (5 out of 6) can be understood as hadronic molecules, namely bound states of a sufficiently attractive meson-baryon interaction.

By unitarizing the scattering amplitude in the t-channel vector-meson exchange interaction model one can investigate the dynamically generated resonances. We revisited the procedure of the unitarized coupled-channel hidden gauge formalism, which has been a very successful approach in explaining many exotic hadrons in the charm and hidden charm sectors. The unitarization procedure requires the regularization of the meson-baryon loop function, commonly done using either a cut-off (G^{CO}) or dimensional regularization (G^{DR}). Although both schemes should yield similar results, some unphysical structures in the T-matrix were found that could not be associated to any resonance or bound state. We introduce a novel hybrid loop function (G^{HY}), which combines both dimensional and cut-off regularizations. This approach enables a cleaner analysis of the scattering amplitude by avoiding the generation of unphysical poles, while keeping the properties of the dynamically generated states unaltered. In particular, this improved procedure allows us to predict two new pentaquark states in the $S = -1$, $I = 1$ sector. These states are dynamically generated in a very specific way, via a strong non-diagonal attraction between the two heaviest meson-baryon channels. This mechanism is also related to the generation of the two predicted pentaquark states in the $S = -2$, $I = 1/2$ sector reported in PRL 130, 091903 (2023) and PRD 111, 054020 (2025). This effect was overlooked before, because other research groups were discouraged by the repulsive character of the diagonal kernel coefficients, and because the complex structure of the scattering amplitudes obtained with both G^{DR} and G^{CO} - with unphysical structures - has obscured these physical states.

We hope that our work would stimulate experiments looking for these new pentaquark states, the discovery of which would enrich the family of observed exotic baryons.

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