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Study of the pion-pion scatterings with a combination of all-to-all propagators and the HAL QCD method

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In this talk, we show recent developments in the HAL QCD method including quark annihilation processes. We apply the hybrid method for all-to-all propagators, which combines a low-mode spectral decomposition of the quark propagator and noisy estimators for remaining high modes, to the HAL QCD potential for the first time. Using this combination, we investigate the $I = 1, 2 \pi \pi$ scatterings at $m_{\pi} \approx 870$ MeV. From these studies, we confirm that the hybrid method works for the potential, but it is also revealed that it needs large numerical costs for sufficient precision if there are quark annihilation contributions. We also discuss a promising calculation strategy, which may achieve both small numerical costs and good precision.

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