

# XVth Quark Confinement and the Hadron Spectrum



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## Quarkonium Productions in $e^+e^-$ Collider with their QCD calculations up to NNLO

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☑ This talk presents the study on the next-to-next-to-leading-order (NNLO) QCD corrections to  $e^+e^- \rightarrow J/\psi + \eta_c$  and  $e^+e^- \rightarrow J/\psi + J/\psi$  at the  $B$  factories, based on our two published works:

☑ JHEP 02 (2024) 055 e-Print: 2311.04751 [hep-ph], and JHEP 02 (2023) 049, e-Print: 2212.03631 [hep-ph].

For  $e^+e^- \rightarrow J/\psi + \eta_c$  is enhanced by about 17%, and the perturbative series of the prediction shows the convergent behavior. It is also found that the contributions from bottom quark starts at the  $\alpha_s^3$ -order, which is about 2.4% of the total prediction. The renormalization scale  $\mu_R$  dependence of the cross section is reduced at the NNLO level, but the prediction is sensitive to the charm quark mass  $m_c$ . By considering the uncertainties caused by renormalization scale  $\mu_R$ , charm quark mass  $m_c$  and the NRQCD factorization scale  $\mu_\Lambda$ , our prediction shows agreement with the BBAR and BELLE measurements within errors.

For  $e^+e^- \rightarrow J/\psi + J/\psi$ , to obtain a reasonable estimation for the cross section, the square of the amplitude up to NNLO is used, and the result for total cross section and differential cross section could be compared with precise experimental measurement in future at the  $B$  factory.

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**Session Classification:** Heavy Quarks

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