Hadronic Physics Summer School 2016

8. Search for Exotic Quantum Numbers with a Future Detector

Hadron spectroscopy can reflect the dynamics of the strong interaction, especially those in the heavy quark sector. Due to their heavy quark mass, the heavy quarkonium can be well described by the non-relativistic quark model below the open charmed/bottomed threshold[1, 2]. For the states above threshold, some states predicted by the quark model are still missing and at the same time a lot of X, Y, Z states beyond the conventional quark model are observed [2, 3] . Since the charm quark mass is not as large as that for the bottom quark, the non-perturbative effect in the charm sector will be larger than that in the bottom sector. That is the reason why more exotic X, Y, Z candidates are observed in the charm sector, such as $X(3872)$, $Z_c(3900)$, $Z_c(4020)/Z_c(4025)$, $Z(4430)$, $Z_1(4050)$, $Z_2(4250)$, $Y(4260)$. So far, only two exotic candidates, i.e. $Z_b(10610)$ and $Z_b(10650)$, are observed in the bottom sector. Some of them might be a mixing state of the conventional $q\bar{q}$ configuration and the exotic configuration, since their quantum numbers, such as $J^{PC} = 1^{++}$, can be accessed in the two scenarios. As the result, searching for exotic states with the exotic quantum numbers, such as 1^{-+}, beyond the conventional quark model has been attracting large attention from both theoretical and experimental side. A good place to search for this kind of potential candidates is the heavy quarkonium sector, because the heavy quark spin symmetry (HQSS) guarantees that the exotic states in the same multiplet share the same low-energy parameters [4] which can be extracted from the well known channels. As proposed in Ref. [4], there could be a 1^{-+} exotic state with mass 3.915 GeV and strongly coupling to both the $D\bar{D}^*$ and the $D^*\bar{D}^*$ channels. Although it is tens of MeV above the $D\bar{D}^*$ threshold and can decay to $D\bar{D}^*$, one might not be able to scan its full line shape in the $D\bar{D}^*$ channel due to its small phase space. An alternative decay channel is the hidden charm channel, such as $1^{-+} \to J/\psi\pi^+\pi^-\pi^0 \to (\mu^+\mu^-)\pi^+\pi^-\pi^0$ and $1^{-+} \to \eta_c\pi^+\pi^-\pi^0\pi^0 \to (K\bar{K}\pi^0)\pi^+\pi^-\pi^0$. Since the later one has six hadrons (with two neutral pions) in the final state, it is not as easy to be reconstructed as the former one. We would expect that $J/\psi\pi^+\pi^-\pi^0$ channel is the best channel to search for this potential 1^{-+} exotic candidate.

The experimental search for this exotic state is challenging because of the many particles in the final state and the mixture of charged and neutral particles. How would an ideal detector look like to measure this exotic state? This is the question we want to address in this working group. How can we create these particles? What are the characteristics of the final states? What detectors do we need to measure them? How does the background look like?

References

[1] E. Eichten, K. Gottfried, T. Kinoshita, K. D. Lane and T. -M. Yan, Phys. Rev. D **17**, 3090 (1978) [Erratum-ibid. D **21**, 313 (1980)].

[2] N. Brambilla, S. Eidelman, P. Foka, S. Gardner, A. S. Kronfeld, M. G. Alford, R. Alkofer and M. Butenschn *et al.*, arXiv:1404.3723 [hep-ph].

[3] E. J. Eichten, K. Lane and C. Quigg, Phys. Rev. D **73**, 014014 (2006) [Erratum-ibid. D **73**, 079903 (2006)] [hep-ph/0511179].

[4] M. L. Du, U. G. Meißner and Q. Wang, arXiv:1608.02537 [hep-ph].