## Hadronic Physics Summer School 2014

### Hidden Charm: Search for the exotic $1^{-+}$ hidden charmonium at PANDA

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 quarknoium 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 $X, Y, Z$ particles are observed in the charm sector, such as $X(3872)$, $Z_c(3900)^{\pm}$, $Z_c(4020)/Z_c(4025)$, $Z(4430)$, $Z_1(4050)$, $Z_2(4250)$, $Y(4260)$. So far, only two exotic states, i.e. $Z_b(10610)$ and $Z_b(10650)$, are observed in the bottom sector. As a result, searching for the missing charmonia and exotic $X, Y, Z$ particles in the charm sector (which we call the hidden charm generally) and studying their production and decay mechanism will be one way to learn the non-perturbative aspect of QCD.

Comparing to the $e^+e^-$ colliders, the hadron colliders especial $p\bar{p}$ reactions such as PANDA[4] would be a good platform to study these hidden charm states. On the one hand, all the possible states with the quantum numbers predicted by the quark model can be directly formed in $p\bar{p}$ reaction and some states with exotic quantum numbers, such as $1^{-+}$, $0^{+-}\cdots$, can also be produced by recoiling some other known particles with proper quantum numbers. As a result, we can study the direct production of these exotic states which will help us distinguish these exotic states either as genuine states or the kinematical reflections[5]. On the other hand, there will be larger events accumulated in hadron colliders and one can get a perfect signal once the appropriate cuts are used. Due to these large events, we can also study the rare decays of the hidden charm states besides their normal decay modes.

**This group will focus on estimating the production rate of these exotic hidden charm states, such as $X(3872)$, $Z_c(3900)$ and a set of $1^{--}/1^{-+}$ exotic states[6] at PANDA**. Among them, the most interesting one is the hidden charm states with the exotic quantum number $1^{-+}$[6] which can give some hints about the non-perturbative QCD.

**With cross section estimates and branching ratios of prominent decay channels, experimental conditions for the detection of exotic states can be formulated and compared to the specifications and design goals of the PANDA apparatus**. Benchmark channels can be identified and experiments can be planned to measure the properties of the new states.

# References


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