Search for new particle at Belle experiment

The matter of our universe is made of quarks and leptons which are taken as elementary entities in particle physics. There are six quark types — named up, down, strange, charm, bottom, and top quarks. The quark model based on quark-antiquark mesons and three-quark baryons has been very successful in classifying the hadrons. And at the moment the most successful theoretical model describing the hadronic interactions between quarks is called as quantum chromodynamics (QCD). However, QCD does not forbid the existence of exotic hadronic states with other quark-gluon configurations, such as glueballs (with no quark), hybrids (with quarks and excited gluon), multi-quark states (with more than three quarks), and hadron molecules (bound state of two or more hadrons). It is a long history of searching for all these kinds of states. With the operations of high luminosity experiments, like BABAR, Belle, BESIII, many candidates for the exotic hadronic states, the so-called "XYZ" states, were observed. However, no solid conclusion was reached until now.

The unexpected observed X(3872) in $\pi^+\pi^- J/\psi$ invariant mass distribution from B mesons decays at Belle in 2003 kicked off the research prelude of XYZ states. Later the X(3872) was confirmed by CDF、D0、BABAR、LHCb and CMS experiments in different production or decay processes. Since the observation of the X(3872), its mass、width and quantum numbers of J^{PC} have been well measured, however, its nature properties are still unclear, which has been interpreted either as tetraquark state with a pair of charm-anticharm quarks and a pair of light quarks, molecular state of two charmed mesons, quark-glue hybrid, threshold enhancement or other configurations. Due to its narrow width and its mass is inconsistent with the theoretical prediction, it is called charmonium-like state, meanwhile its mass is close to the $D^{*0}\bar{D}^0$ mass threshold, it is regarded as a $D^{*0}\bar{D}^0$ molecule. According to the latest results from LHCb measurement, the prefer explanation is a mixture state of the charmonium state $\chi_{c1}^{'}(2P)$ and $D^{*0}\bar{D}^0$ molecule.

It is therefore natural to search for a similar state (called X_b hereafter) in the bottomonium system. The search for X_b supplies important information about the discrimination of a compact multiquark configuration and a loosely bound hadronic molecule configuration for the X(3872). The existence of the X_b is predicted in both the tetraquark model and those involving a molecular interpretation. The team of Prof. Chengping Shen from School of Physics and Nuclear Energy Engineering studied $\Upsilon(5S)\rightarrow\gamma\omega\Upsilon(1S)$ process to search for this new particle X_b in $\omega\Upsilon(1S)$ system based on a 118 fb^{-1} data sample collected with the Belle detector at 10.867 GeV. The below plot shows the $\omega\Upsilon(1S)$ invariant mass distribution. The dots with error bars are from data. No obvious X_b signal is observed from the expected mass region of 10.55 to 10.65 GeV/c^2. Assuming that the X_b mass is 10.6 GeV/c^2, the obtained product branching fraction is $Br(\Upsilon(5S)\rightarrow\gamma X_b)Br(X_b\rightarrow\omega\Upsilon(1S))< 2.9\times10^{-5}$ at 90% confidence level. Although no clear signal was observed, Prof. Shen observed new abnormal large hadronic decay modes of $\Upsilon(5S)\rightarrow\omega\chi_{bJ}\rightarrow\omega\gamma\Upsilon(1S)$, which indicates the existence of new possible intermediate state. So this research work supplies important information on the new hadron spectrum; which needs to be rechecked at BelleII in the future.

The above results were published in Physical Review Letters on behalf of Belle Collaboration. Prof. Shen is the only corresponding author, who also did some theoretical work trying to explain experimental results in collaboration with a few colleagues in University of Bonn. The theoretical paper was published in Physics Letters B.

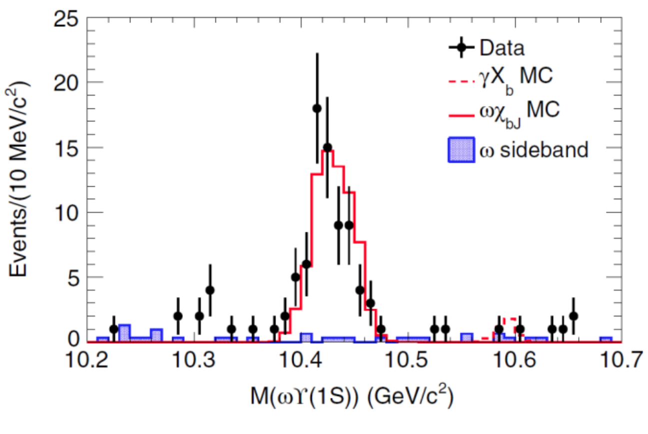

Figure: The $\omega\Upsilon(1S)$ invariant mass distribution.The dots with error bars are from data, the solid histogram is from the normalized contribution of e+e- $\rightarrow\omega\chi_{bJ}$ (J=0,1,2) from MC simulation. (Picture credits: Phys. Rev. Lett.).

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References

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