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First Results from BESIII

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We present the most recent results from the BESIII experiment. This review covers the studies of charmonium decays, light hadron spectroscopy and charm physics. Especially, the prospects for weak decays of charm mesons are addressed at the BESIII.

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1. Introduction

The Beijing Electron Collider has been upgraded (BEPCII) to a double ring collider with a design luminosity of $1 \times 10^{33}\text{cm}^{-2}\text{s}^{-1}$ at a center-of-mass energy of 3.78GeV. It is operating between 2.0 and 4.6 GeV in the center of mass. The BESIII experiment will be used to study the charm and τ physics. It is foreseen to collect on the order of 10 billion J/ψ events or 3 billion $\psi(2S)$ events per year according to the designed luminosity. About 32 million $D\overline{D}$ pairs and 2.0 million $D_S\overline{D}_S$ at threshold will be collected per year [1, 2]. In last summer, the peak luminosity of BEPCII had reached $3.2 \times 10^{32}\text{cm}^{-2}\text{s}^{-1}$, while, it reaches $5.2 \times 10^{32}\text{cm}^{-2}\text{s}^{-1}$ during this winter running on the $\psi(3770)$ peak.

During 2009, BESIII acquired a sample of 106 M ψ' events, or four times the CLEOc sample, and about 226 M J/ψ events, or about four times the BESII J/ψ sample. Results in this paper are based on these data sets. In 2010, about 910 pb^{-1} integrated luminosity was collected on the peak of $\psi(3770)$. Now BESIII is still taking data on the peak of $\psi(3770)$, we expect another 1.5 pb^{-1} luminosity will be ready this summer.

We report on the charm physics potential at the BESIII experiment which will make significant contribution to quark flavor physics this decade. The charm physics program includes studies of leptonic, semileptonic, hadronic charm decays, and tests for physics beyond the Standard Model. High precision charm data will enable us to validate forthcoming Lattice QCD calculations at the few percent level. These can then be used to make precise measurements of CKM elements, V_{cd}, V_{cs}, V_{ub}, V_{cb} and V_{ts}, which are useful to improve the accuracy of test of the CKM unitarity [1, 3].

2. Results for charmonium physics

In 2005, CLEOc [4] reported a measurement of the mass of the P-wave charmonium spin-singlet state h_c in $e^+e^- \to \psi' \to \pi^0 h_c$, $h_c \to \gamma\eta_c$, in which they used both inclusive and exclusive η_c decay events. In 2008, they repeated their analysis with 25 M ψ' events [5]. Combining results, they obtained $m(h_c)_{AVG} = 3525.2 \pm 0.18 \pm 0.12$ MeV/c^2 [5]. A precise determination of the mass is important to learn about the hyperfine (spin-spin) interaction of P wave states [6]. Using the spin weighted centroid of the ^3P_J states, $< m(^3P_J) >$, to represent $m(^3P_J)$, they obtained $\Delta m_{hf}(1P) = \ < m(^3P_J) > - m(^1P_1) = +0.08 \pm 0.18 \pm 0.12$ MeV/c^2. This is consistent with the lowest order expectation of zero.

The h_c state is also studied at BESIII with 106 M $\psi(2S)$ events accumulated in 2009 [7]. Clear signals are observed for $\psi(2S) \to \pi^0 h_c$ with and without the subsequent radiative decay $h_c \to \gamma\eta_c$. The absolute branching ratios $\mathscr{B}(\psi(2S) \to \pi^0 h_c) = (8.4 \pm 1.3 \pm 1.0) \times 10^{-4}$ and $\mathscr{B}(h_c \to \gamma\eta_c) = (54.3 \pm 6.7 \pm 5.2)\%$ are determined for the first time. The width for h_c state is determined to be $\Gamma(h_c) < 1.44$ MeV at the 90% C.L.. Measurements of $M(h_c) = 3525.40 \pm 0.13 \pm 0.18$ MeV and $\mathscr{B}(\psi' \to \pi^0 h_c) \times \mathscr{B}(h_c \to \gamma\eta_c) = (4.58 \pm 0.40 \pm 0.50) \times 10^{-4}$ are consistent with previous results by CLEOc [4].

BESIII has studied $\psi' \to \gamma\chi_{cJ}, \chi_{cJ} \to \pi^0\pi^0$ and $\eta\eta$, where π^0 and η decay to $\gamma\gamma$ [8]. The branching fractions are measured to be $\mathscr{B}(\chi_{c0} \to \pi^0\pi^0) = (3.23 \pm 0.03 \pm 0.23 \pm 0.14) \times 10^{-3}$ and $\mathscr{B}(\chi_{c2} \to \pi^0\pi^0) = (0.88 \pm 0.02 \pm 0.06 \pm 0.04) \times 10^{-3}$ [$\mathscr{B}(\chi_{c0} \to \eta\eta) = (3.44 \pm 0.10 \pm 0.24 \pm 0.20) \times 10^{-3}$ and $\mathscr{B}(\chi_{c2} \to \eta\eta) = (0.65 \pm 0.04 \pm 0.05 \pm 0.03) \times 10^{-3}$], respectively. These results are consistent with CLEOc measurements within error [9]. Improved measurements will allow refinement of theory [10].

3. Light hadron spectroscopy in charmonium decays

With 106 M $\psi(2S)$ and 226 M J/ψ events, BESIII experiment [11] confirmed the existence of the threshold enhancement in the $p\bar{p}$ invariant mass in $J/\psi \to \gamma p\bar{p}$ decay, with mass agrees with the BESII measurement [12], and the width less than 8 MeV at the 90% C.L.. We have not observed any enhancement in the decay of $\psi(2S) \to \gamma p\bar{p}$ at both BESII and BESIII experiments.

In an analysis of the $J/\psi \to \gamma\eta'\pi^+\pi^-$, three resonances are observed [13]. The $X(1835)$ has a mass of 1838 ± 3 MeV, in good agreement with BESII result [14], and a width of 180 ± 9 MeV, which is larger than the BESII measurement. The two new resonances are observed at 2124 MeV and 2371 MeV, respectively, with widthes about 100 MeV. The so called $X(1835)$ together with the two new resonances are possibly the excited or higher excited η or η' states [15, 16], the candidate for glueballs, the $p\bar{p}$ molecular states, and so on. A partial wave analysis is needed for further understanding of these new states.

In the $\eta\pi^+\pi^-$ invariant mass recoiling against an ω in $J/\psi \to \omega\eta\pi^+\pi^-$ decay, besides the observations of the known $f_1(1285)$ and $\eta(1405)$, a state at 1873 ± 11 MeV with a width of 82 ± 19 MeV is oberserved, it could be the hadronic production of the $X(1835)$ observed in $\eta'\pi^+\pi^-$ mode, although the mass difference is large. Again, a partial wave analysis is urgent to be implemented in order to understand the property of the new observation.

4. Potential of charm physics at BESIII

Many of the measurements related to charm decays have been done by other experiments such as BESII and CLEO-c, and many are also accessible to the B-factory experiments. What are BESIII's advantages to running at the open charm threshold?

BESIII will not be able to compete both BABAR and Belle in statistics on charm physics, especially on the rare and forbidden decays of charm mesons. However, data taken at charm threshold still have powerful advantages over the data at $\Upsilon(4S)$, which we list here [17]: 1) Charm events produced at threshold are extremely clean; 2) The measurements of absolute branching fraction can be made by using double tag events; 3) Signal/Background is optimum at threshold; 4) Neutrino reconstruction is clean; 5) Quantum coherence allow simple [18] and complex [19] methods to measure the neutral D meson mixing parameters and strong phase difference [20], and to check for direct CP violation.

For charm physics at BESIII, the first physics results will be the measurements of the leptonic and semileptonic decays of charm mesons. Measurements of the leptonic decays at BESIII will benefit from the fully tagged D^+ and D_S^+ decays available at the $\psi(3770)$ and at $\sqrt{s} \sim 4170$ MeV or ~ 4017 MeV [21]. The leptonic decay rates for D^+ and D_S^+ has been measured with a precision of 4.3% and 2.0 % with the final data from CLEOc. It should be noted that the $D^+ \to \tau^+\nu$ decay is reported by CLEOc with upper limit of 1.2×10^{-3} at 90% C.L. [22]. At BESIII, with 4 times (about 4 fb^{-1}) of the CLEOc's luminosity, significant gains on these measurements will be made if the systematic errors remain the same. This will allow the validation of theoretical calculations of the decay constants at the 1-2% level. The neutral D mixing and *CP* violation in charm sector using quantum correlation are all statistics-starved at CLEOc, improvement will be made at BESIII experiment.

5. Summary

Results have been presented based on BESIII samples of 106 M ψ' and about 226 J/ψ events. Many more results are to be expected in the future. In addition, BESIII acquired nearly $1fb^{-1}$ of data at the $\psi(3770)$ resonance in 2010, including approximately $75pb^{-1}$ of scan data around the $\psi(3770)$ peak. BESIII is still running at the $\psi(3770)$ peak in 2011. We expect another 1.5 fb^{-1} luminosity will be collected next summer. Decays of the $\psi(3770)$ produce quantum correlated $D\bar{D}$ pairs, which are ideal for mixing and CP violation studies, as well measurements of absolute branching fractions and studies of semi-leptonic decays. This sample allows BESIII to begin their charm physics program.

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