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The status and future plan of BESIII experiment

Weimin Song

College of Physics, Jilin University, Changchun, China, 130012

E-mail: `weiminsong@jlu.edu.cn`

Abstract.

BESIII experiment has been working for more than 10 years, and the BESIII Collaboration has published more than 300 physics results about charmed hadron, exotic hadron states, τ lepton and light hadrons. In this paper, the current performance of the detector will be mentioned, including the tracking system, particle identification system, and calorimeter system. The experiment will run for another 10 years, and the future plan of the experiment will be mentioned also.

1. Introduction to BEPCII and BESIII

"BEPCII" is short for Beijing Electron Positron Collider, and the "II" means the collider was upgraded to higher luminosity [1]. The centre of mass energy of the facility is between 2 to 5 GeV, and that is the reason why it is called a τ-charm factory. "BESIII" is short for BEijing Spectrometer , and the "III" means it was upgraded twice [2]. The cylindrical core of the BESIII detector covers 93% of the full solid angle and consists of a helium-based multilayer drift chamber (MDC), a plastic scintillator time-of-flight system (TOF), and a CsI(Tl) electromagnetic calorimeter (EMC), which are all enclosed in a superconducting solenoidal magnet providing a 1.0 T magnetic field. The solenoid is supported by an octagonal flux-return yoke with resistive plate counter muon identification modules interleaved with steel. The charged-particle momentum resolution at 1 GeV$/c$ is 0.5%, and the dE/dx resolution is 6% for electrons from Bhabha scattering. The EMC measures photon energies with a resolution of 2.5% (5%) at 1 GeV in the barrel (end cap) region. The time resolution in the TOF barrel region is 68 ps, while that in the end cap region is 110 ps. The end cap TOF system was upgraded in 2015 using multi-gap resistive plate chamber technology, providing a time resolution of 60 ps.

2. Recent results from BESIII

Starting physics data taking from 2009, BESIII has collected the largest electron positron collision data in the τ-charm region in the world, including 10 Billion J/ψ events, 2 Billion $\psi(2S)$ events, R scan data at about 100 centre of mass energies, 2.9 fb^{-1} data on the peak of $\psi(3770)$ and the so called "XYZ" data with centre of mass energy above the open charm threshold. With these data sets, the light hadron states, Charmonium decays and transitions, exotic states, charm meson decays, R value, hadron form factor, new physics beyond the Standard Model are studied. Some selected topics will be discussed in the following, and these are just the examples of the more than 300 papers published by the collaboration.

2.1. The study of X(1835)

A state named X(1835) was observed in the $\eta\prime\pi^+\pi^-$ final state when studying J/ψ radiative decays at BESII [3] , and it was confirmed with 0.2 Billion J/ψ data at BESIII [4]. The same channel was studied with 1.1 Billion J/ψ data at BESIII again [5], and a significant distortion of the $\eta\prime\pi^+\pi^-$ line shape near the $p\bar{p}$ mass threshold that could not be accommodated by an ordinary Breit-Wigner resonance function. Two models were used to fit the data, and the first one assumes a state couples strongly to $p\bar{p}$, while the second assumes there are two resonances. In the first model, the distortion was explained as the open channel effect, and in the second it was explained by the interference effect between the two resonances. In order to understand the nature of the states here, more data is needed, and more decay channels such as $\gamma\phi$ should be studied.

2.2. The study of Z_c states

When studying the $e^+e^- \to \pi^+\pi^- J/\psi$ at 4.26 GeV at BESIII in 2013, a structure called $Z_c(2900)^\pm$ was observed in the $J/\psi\pi^\pm$ invariant mass spectrum [6]. As it is not charge neutral, $Z_c(3900)^\pm$ could not be a Charmonium state, however it could decay to $J/\psi\pi^\pm$ final states which means that the $c\bar{c}$ component in it is large. This result has been cited fore more than 800 times, which could show how much interest it has attracted. The neutral partner $Z_c(2900)^0$ was discovered by studying the $e^+e^- \to \pi^0\pi^0 J/\psi$ channel [7]. The open charm decay mode of $Z_c(3900)$ was observed when studying $e^+e^- \to \pi^\pm(D\bar{D}^*)^\mp$ channel, and its quantum number is measured to be 1^+. Related channels, such as $e^+e^- \to \pi^+\pi^-\psi(3686)$ [8], $e^+e^- \to \pi^+\pi^-\psi(3770)$ [9], $e^+e^- \to \pi^+\pi^- h_c$ [10] are studied too.

2.3. Cross section enhancement near the threshold

The production cross sections of $e^+e^- \to B\bar{B}$ are measured as the function of the centre of mass energy, where B means baryon, such as proton [11], neutron [12], Λ [13], and Λ_c [14]. As shown by Figures 1 to 4, the cross section enhances just after the threshold, which tells us there is other dynamics beyond the phase space effect near the the threshold.

2.4. CMK matrix and decay constant measurement of Charm meson

By measuring the (semi)leptonic decay branching fractions of Charm meson, the decay constant or the related CKM matrix could be subtracted, such as $Br(D^+ \to \tau^+\nu_\tau)$ [15] and $Br(D^+ \to \eta\mu^+\nu_\mu)$ [16]. Thanks to the large statistics, the measurements could reach an unprecedented precision.

2.5. Others

The mass of τ lepton was measured by a scan method with the highest precision in the world [17]. As a fundamental parameter of Standard Model, τ mass is important for many tests, such as the lepton universality. Using Initial State Radiation (ISR) method, the cross section of $e^+e^- \to \pi^+\pi^-$ is measured [18], and it is an important input when calculating the anomaly magnetic moment of muon. The decay branching fractions of D^{*0} was measured with a recoil mass method to the highest precision [19]. Besides these, when analysing the huge data at BESIII, some data analysis methods were developed, such as the method to deal with the ISR correction in the cross section measurement [20].

3. Object performance and systematic uncertainty

In order to get great physics result, the detector performance should be understood carefully. At BESIII, the frequently used objects are charged tracks and photons, and for charged tracks, the particle identification (PID) is important for hadron physics. The integrated luminosity and centre of mass energy are almost used in all the publications.

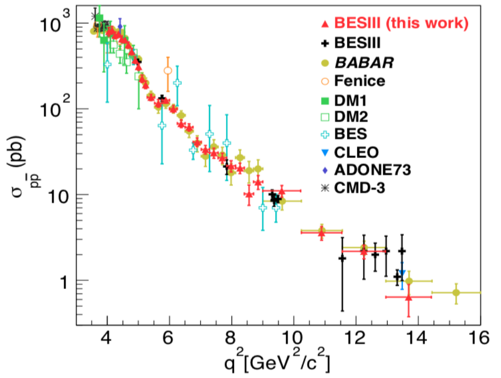

Figure 1. Cross section of $e^+e^- \to p\bar{p}$.

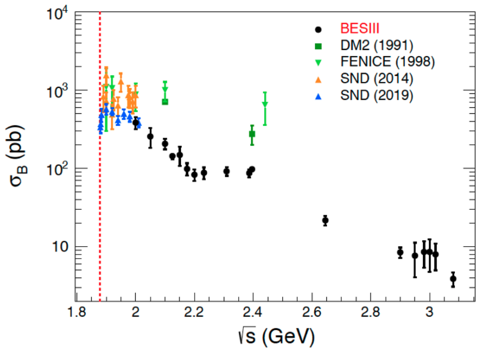

Figure 2. Cross section of $e^+e^- \to n\bar{n}$.

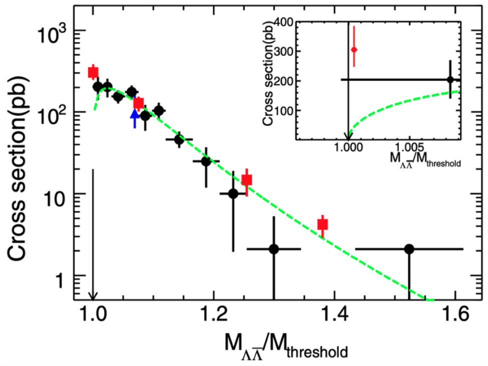

Figure 3. Cross section of $e^+e^- \to \Lambda\bar{\Lambda}$.

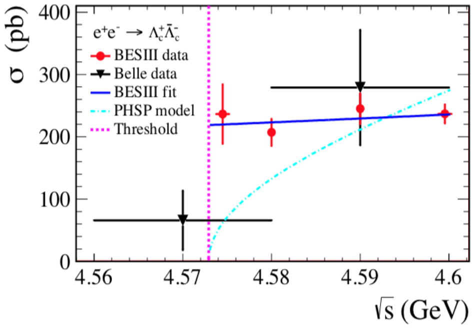

Figure 4. $e^+e^- \to \Lambda_c\bar{\Lambda}_c$.

- Charged track reconstruction: efficiency is lower for low momentum tracks, and could reach 98% after 500 MeV; difference between MC and data is within 1%;
- Photon reconstruction: efficiency is pretty flat around 99%; difference between MC and data is within 1%;
- PID: efficiency is high for low momentum, and decrease to 80% above 1.5 GeV; difference between MC and data is within 1%;
- Luminosity: measured with Bhabha process, uncertainty less than1% [21];
- Center of mass energy: measured with di-muon process, uncertainty less than 1% [22];

4. The future plan for BESIII

Even though we have so many publications, we do not solve the problems about the low energy QCD, but we either find some hints to the solutions or find more problems. That is the reason we want to continuum the running of BESIII detector for an other 10 years [23]. With the next 10 years, we will upgrade the detector, and the luminosity/energy of BEPCII will be expanded also; we will get more data sample, which means that we could perform more precisemeasurement; at the same time better understanding of the detector will be reached, which means smaller systematic uncertainty.

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