# Overveiw of the BES physics

WANG Yi-Fang(王贻芳)[1)]

(Institute of High Energy Physics, Chinese Academy of Sciences, Beijing 100049, China)

**Abstract** Recent physics results at Beijing Electron-Positron Collider (BEPC) are reviewed, especially on excited baryons. Substantial improvements are expected at the newly built BESIII experiment, which is operational since 2008. The detector performance is excellent and a total of 100 million ψ(2$S$) and 200 million J/ψ event are collected in 2009. Preliminary results shows that a new era of excited baryon physics will begin.

**Key words** Decays of J/ψ, charmonium, baryon

**PACS** 13.20.Gd

## 1 Introduction

The Beijing electron-positron collider (BEPC) was first built in 1984 and completed in 1989. The detector, called Beijing spectrometer (BES), was operational in 1991 and its upgrade, BESⅡ, was completed in 1997. Since then a series of data taking program was completed, including an energy scan from 2—5 GeV to measure $R$ values, a collection of 58 million J/ψ events, 14 million ψ′ events, and an integral luminosity of 35/pb at and near by the ψ(3770) resonance.

Physics results from BESⅡ ranging from charm physics, light hadron physics, charmonium physics to QCD studies. A total of more than 150 papers published since then. A few highlights from recent years are illustrated below.

A tau-charm collider running at 2—5 GeV range can produce a lot of resonances as shown in Fig. 1, facilitating many physics studies[1].

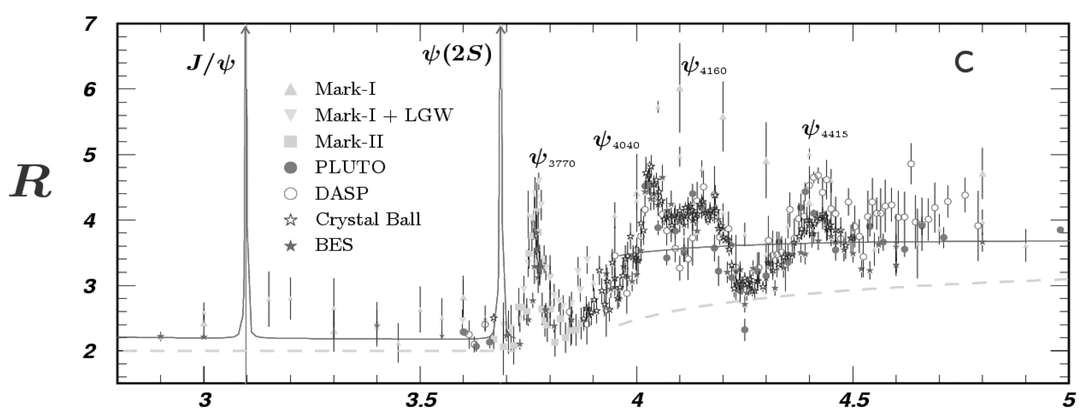


Fig. 1. $R$-value measurements compared with theoretical calculation(solid line).

A precision measurement of $R$-value from 2—5 GeV is essential to the Standard Model, since all radiative corrections need the input of vacuum polarization, which can only be obtained from measured $R$-values.

$R$-values are actually the hadronic production cross section, $\sigma(e^+e^- \rightarrow \text{hadrons})$, normalized to that of muons, $\sigma(e^+e^- \rightarrow \mu^+\mu^-)$. Fig. 1 shows the BESⅡ measurements in comparison with other experimental

Received 7 August 2009

1) E-mail: yfwang@ihep.ac.cn

results and theoretical calculations[1]. The precision is typically 6%, an improvement over previous results by a factor of 2.5. A recent measurement of $R$-values by BES II at a few discrete energy points reached a precision of about 3Such a measurement has profound implications to the prediction of Higgs mass, and g-2 experiments. At BESIII, we expect to improve the precision to the level below 2%.

Since the production cross section of J/ψ and ψ(2$S$) is the largest among all known resonances and their decays are kinematically favorable, J/ψ and ψ(2$S$) decays are ideal for the study of light hadron spectroscopy. In addition, the two-gluon process plays an important role, it is expected that glueballs shall have the largest production probability in J/ψ decays. At BES II, searching for new resonances has been performed and indeed, there are several seemingly non-conventional resonances observed.

For example, a threshold enhancement near the $p\bar{p}$ threshold with a very narrow width was observed[3]. At the similar mass region with similar width, a new resonance, called $X(1835)$, was observed in $J/\psi \to \gamma\eta'\pi^+\pi^-$ [4]. A very broad resonance with $J^{PC} = 1^{--}$ near the $K^+K^-$ threshold was observed in $J/\psi \to \gamma K^+K^-\pi^0$ [5]. This resonance seems too broad($\Gamma \sim 400$ MeV) to be a normal meson. Similar threshold enhancement was observed in many others channels such as $J/\psi \to \gamma\omega\phi$[6]. The fact that threshold enhancement was observed so frequently could be due to the favorable background conditions. At BESIII with more statistics and a much better energy resolution for photons, a detailed study of all possible resonances is possible and many remaining issues can be resolved.

J/ψ decay is also one of the ideal place to study excited baryons because of its well-defined initial states and relatively clean backgrounds. In fact, BES II confirmed several baryons and observed a few new ones. Fig. 2 shows the newly observed N(2050) from $J/\psi \to p\bar{n}\pi^-$ [7].

Physics at tau-charm region certainly has not been exhausted by BES II, and it is still limited by both statistic and systematic errors. In the ear of LHC, precision physics at relatively low energies is complementary in the virtual regime to that at high energies in the real world. In fact, charm physics is in the transition region between pQCD and non-pQCD, it is advantageous and actually crucial for the understanding of QCD and the testing of the Standard Model.

A major upgrade of BEPC was planed since late 90's and actually started in 2003. The accelerator, called BEPC II, will improve the luminosity by a factor of 100 to $10^{33}$ $cm^2 \cdot s^{-1}$. This is a double-ring machine with a large crossing angle of 22 mrad reutilizing the existing tunnel. A total of 93 bunches, each with a current of 10 mA, is circulating in the storage ring. A superconducting quadruple magnet close to the interaction point will focus the beam to its final dimension at the interaction point.

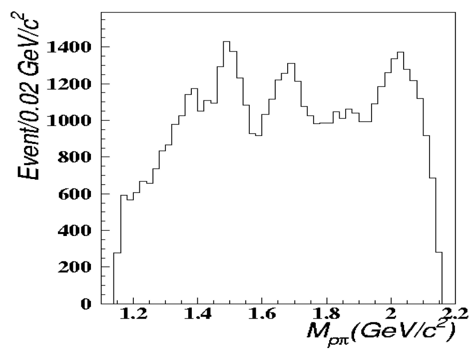


Fig. 2. Invariant mass spectrum of Pπ from BES II. A new baryon clearly seen at $M$ = 2050 MeV.

The new detector, call BESIII[8], as shown in Fig. 3, consists of the following components: 1) a main draft chamber (MDC) equipped with about 6500 signal wires and 22000 field wires arranged as small cells with 43 layers. The designed single wire resolution is 130 μm and the momentum resolution 0.5%@ 1 GeV; 2) an electromagnetic calorimeter made of 6240 CsI(Tl) crystals. The designed energy resolution is 2.5%@ 1 GeV and position resolution 6 mm@ 1 GeV; 3) a particle identification system using Time-Of-Flight counters made of 2.4 m long plastic scintillators. The designed resolution is 80 ps for two layers, corresponding to a K/π separation (2$\sigma$ level) up to 0.8 GeV; 4) a superconducting magnet with a field of 1 tesla; 5) a muon chamber system made of RPC.

A comprehensive study of physics at BESIII is completed in 2008 to summarize current status of tau-charm physics and physics reach of BESIII, including charm physics, charmonium physics, light hadron physics, QCD and tau physics[9]. Table 1 shows expected number of events in one year of data taking.

The BEPC II /BESIII construction was completed in 2008 and the full cosmic-ray test was performed in Mar. 2008. The detector was then moved to the interaction point and the first $e^+e^-$ collision event was seen by the detector on July 19, 2008. Since then a

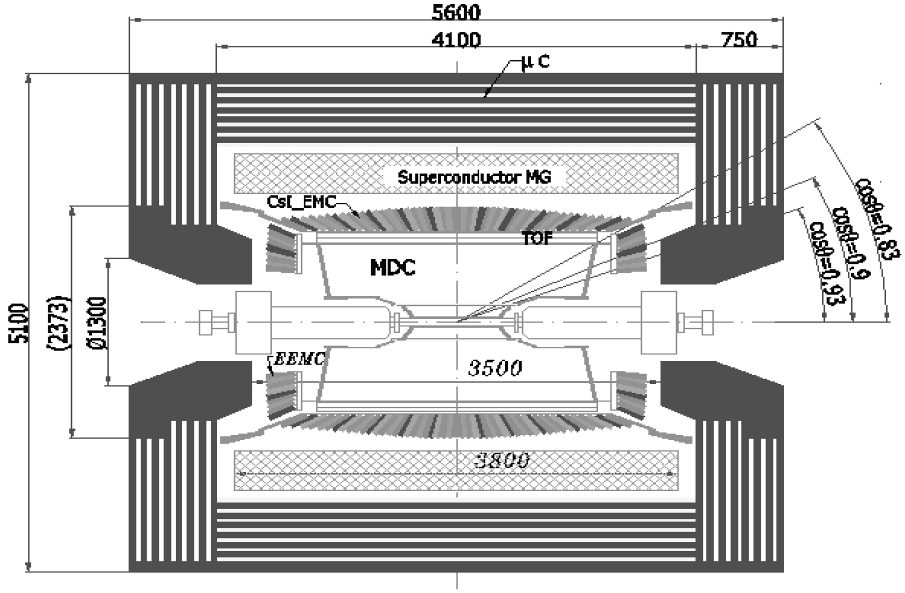


Fig. 3. The schematic view of the BESIII detector.

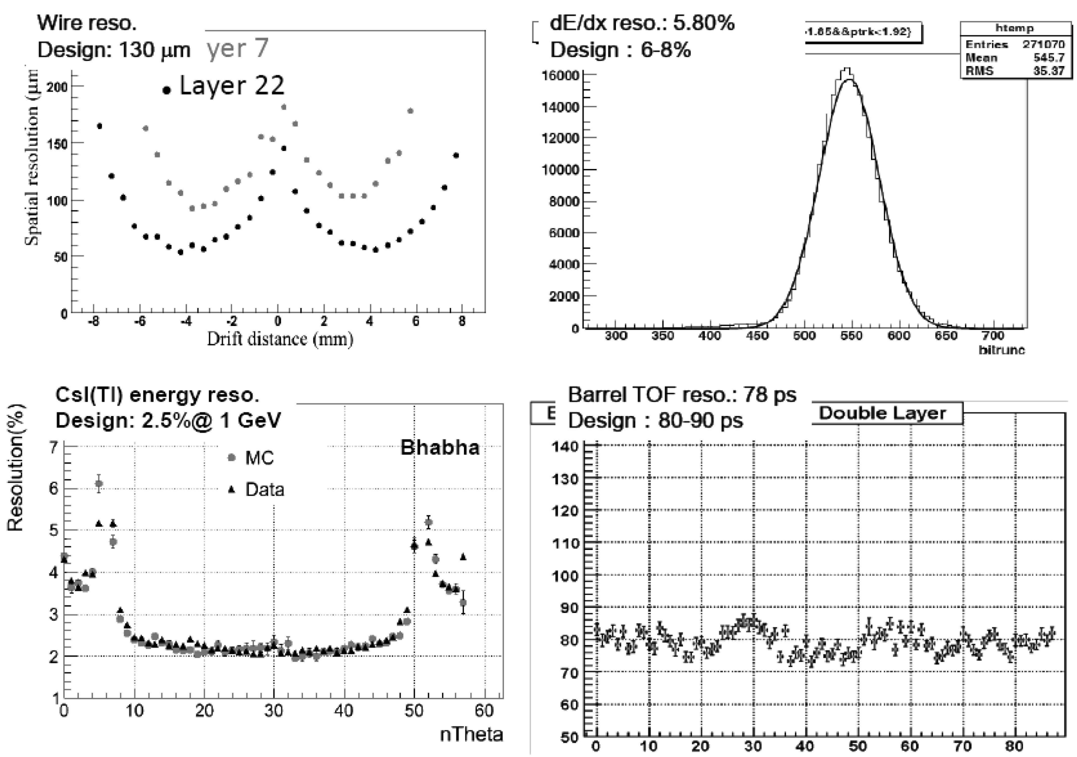


Fig. 4. Main parameters of the calibrated BESIII detector.

Table 1. Expected number of events in one year of data taking.

| event type | CMS/GeV | peak luminosity/$(10^{33}\text{cm}^{-2}\cdot\text{s}^{-1})$ | cross section (nb) | events/year |
|---|---|---|---|---|
| $J/\psi$ | 3.097 | 0.6 | ~3400 | $10\times10^9$ |
| $\tau$ | 3.670 | 1.0 | ~2.4 | $12\times10^6$ |
| $\psi'$ | 3.686 | 1.0 | ~640 | $3.0\times10^9$ |
| D | 3.770 | 1.0 | ~6.5 | $32\times10^6$ |
| $D_s$ | 4.040 | 0.6 | ~0.32 | $1.0\times10^6$ |
| $D_s$ | 4.160 | 0.6 | ~1.0 | $3.0\times10^6$ |

total of 13 million $\psi(2S)$ events was collected in 2008 and the detector was calibrated to be ready for physics. Fig. 4 shows the calibration results. Clearly, the detector is in a very good condition and all the design specifications have been satisfied.

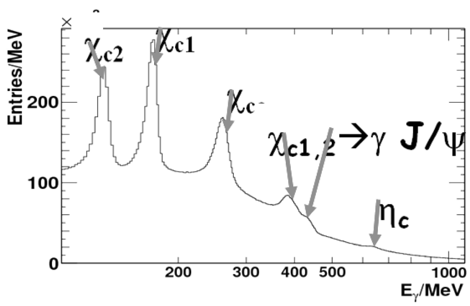


Fig. 5. Measured inclusive photon spectrum from $\psi(2S)$ decays.

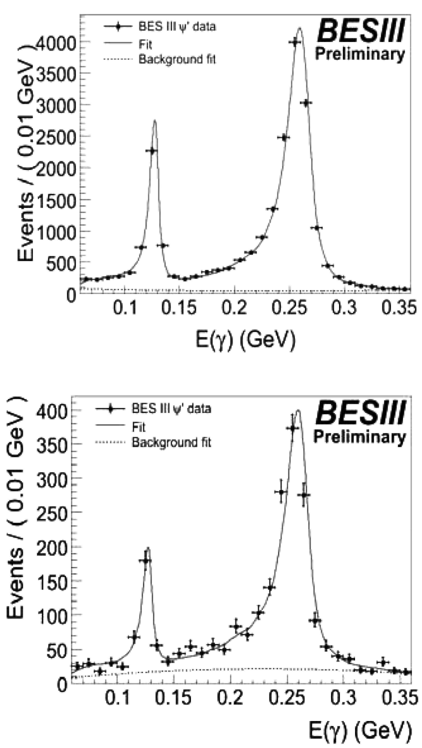


Fig. 6. Observed $\chi_{c0}$ and $\chi_{c2}$ signal from $\gamma\pi^0\pi^0$ (up) and $\gamma\eta\eta$ (down) channels.

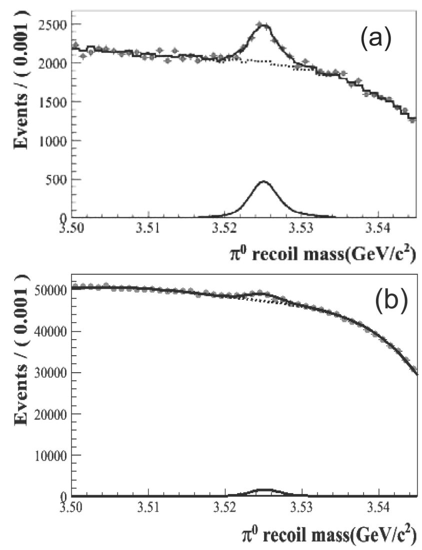


Fig. 7. $h_c$ observed in BESIII. (a) tagging the prompt photon in the $h_c$ decays; (b) tagging $\pi^0$ from $\psi(2S)$ decays.

Starting from March 2009, after a winter shutdown for maintenance and machine studies, BESIII successfully collected 100 million $\psi(2S)$ events, 42/pb continuum events at 3.65 GeV, and 200 million $J/\psi$ events. The peak luminosity was typically $2\times10^{32}$ $\text{cm}^{-2}\cdot\text{s}^{-1}$ at $\psi(2S)$. An energy scan of $\psi(2S)$ lineshape shows that the beam energy spread is about 1.45 MeV, and the effective peak cross section of $\psi(2S)$ is about 700 nb. The beam-related backgrounds was substantially reduced in comparison with that of 2008, thanks to the fine tuning of the beam parameters and the movable masks installed at 8m upstream of the beam from the interaction point. The data taking efficiency of the detector is more than 85%.

An initial physics program has been planned for the $\psi(2S)$ data set, including, but not limited to, the following topics:

1) Spin-singlet studies ($h_c,\eta_c,\eta_c'$, $\cdots$)

2) $\psi(2S)$ hadronic decays ($\rho\pi$ puzzle, new states, $\cdots$)

3) $\chi_c$ decays (search for new states and new decays, $\cdots$)

A first glance of the $\psi(2S)$ data shows that a lot of resonances can be clearly seen. Fig. 5 shows the inclusive photon spectrum from the electromagnetic calorimeter. Signals from the electromagnetic transition between charmonium states can be well identified and they demonstrate the impressive performance of the CsI(Tl) crystal calorimeter.

Preliminary physics results have been obtained, ranging from the confirmation of BESⅡ and CLEOc observations, to new observations. Fig. 6 shows the prompt photon spectrum from $\psi(2S)\rightarrow\gamma\pi^0\pi^0$ (up) and $\psi(2S)\rightarrow\gamma\eta\eta$ (down). Signals from $\chi_{c0}$ and $\chi_{c2}$ are observed and their branching ratios are measured.

The last member of the charmonium family below the open charm threshold called $h_c$ was observed by CLEOc in 2005[10] from $\psi(2S)$ decays to $\pi^0 h_c$, $h_c\rightarrow\gamma\eta_c$. Fig. 7 shows the BESⅢ observation of $h_c$ by tagging the prompt photon in the $h_c$ decays. By tagging $\pi^0$ from $\psi(2S)$ decays, clear signals can be also seen and branching fractions of $\psi(2S)\rightarrow\pi^0 h_c$, $h_c\rightarrow\gamma\eta_c$ can be individually measured.

In summary, BESⅡ made significant progress on tau-charm physics and BESⅡ will continue the trend. We expect a great leap in the next few years on charm physics, charmonium physics, light hadron physics and tau physics.

## References


1 Amsler C et al (Particle Data Group). Phys. Lett. B, 2008, **667**: 1

2 Ablikim M et al (BES collaboration). Phys. Lett. B, 2009, **677**: 239 [arXiv:0903.0900 [hep-ex]]

3 BAI J Z et al (BES collaboration). Phys. Rev. Lett., 2003, **91**: 022001 [arXiv:hep-ex/0303006]

4 Ablikim M et al (BES collaboration). Phys. Rev. Lett., 2005, **95**: 262001

5 Ablikim M et al (BES collaboration). Phys. Rev. Lett., 2006, **97**: 142002 [arXiv:hep-ex/0606047]

6 Ablikim M et al (BES collaboration). Phys. Rev. Lett., 2006, **96**: 162002 [arXiv:hep-ex/0602031]

7 Ablikim M et al (BES collaboration). Phys. Rev. Lett., 2006, **97**: 062001 [arXiv:hep-ex/0405030]

8 WANG Y F, hex-ex:0711.4199, talk given at Charm07

9 Physics at BES-Ⅲ. Eds. Chao K T, WANG Y F. Int. J. Mod. Phys. A, 2009, **24**(Supp.1)

10 Rubin P et al. Phys. Rev. D, 2005, **72**: 092004; Dobbs S et al. Phys. Rev. Lett., 2008, **101**: 182003