BEPCII and BESIII

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The Beijing Electron Collider is being upgraded (BEPCII) to a two-ring collider with a design luminosity of $1 \times 10^{33}$ cm$^{-2}$ s$^{-1}$ at a center-of-mass energy of 3.89 GeV. It will operate between 2 and 4.2 GeV in the center of mass. With this luminosity, the BESIII detector will be able to collect, for example, 10 billion $J/\psi$ events in one year of running. This will be a unique facility in the world opening many physics opportunities. BEPCII and BESIII are currently under construction, and commissioning of both is expected to begin in summer 2007.

1. Introduction

The Beijing Electron-Positron Collider (BEPC) at the Institute of High Energy Physics (IHEP) in Beijing has been, until recently, a unique facility running in the tau-charm center-of-mass energy region from 2 to 5 GeV with a luminosity at the $J/\psi$ peak of $5 \times 10^{30}$ cm$^{-2}$ s$^{-1}$. The Beijing Spectrometer (BESI [1] and BESII [2]) detector at the BEPC has operated since about 1990 and studied many physics topics, including a precision measurement of the tau mass [3] and a detailed R-scan [4], and obtained 58 million events at the $J/\psi$, 14 million at the $\psi'$, and over 30 pb$^{-1}$ at the $\psi''$.

In 2003, the Chinese Government approved the upgrade of the BEPC to a two-ring collider (BEPCII) with a design luminosity approximately 100 times higher than that of the BEPC. This will allow unprecedented physics opportunities in this energy region and contribute to precision flavor physics. In this paper, BEPCII and BESIII will be described, along with their status. Another paper presented at this conference will provide more detail on BESIII physics and on BESIII simulation studies [5].

Currently BESII has been removed from the interaction region. The BEPCII linac installation is complete and that of the storage ring started in March 2006. The installations of the muon counter and the super-conducting magnet into the BESIII detector are also complete.

2. BEPCII

BEPCII is a two-ring $e^+e^-$ collider that will run in the tau-charm energy region ($E_{cm} = 2.0 - 4.2$ GeV) with a design luminosity of $1 \times 10^{33}$ cm$^{-2}$ s$^{-1}$ at a beam energy of 1.89 GeV, an improvement of a factor of 100 with respect to the BEPC. This is accomplished by using multibunches and micro-beta. The upgrade uses the existing tunnel and some old magnets.

The 2024 meter long linac has been upgraded with new klystrons, a new electron gun, and a new positron source to increase its energy and beam current; it can accelerate electrons and positrons up to 1.89 GeV with a positron injection rate of 50 mA/min. Its installation was completed in the summer of 2005 (see Fig. [1]), and it reached most design specifications.

There are two storage rings with lengths of 237.5 meters. The collider has new superconducting RF cavities, power supplies, and control; superconducting quadrupole magnets; beam pipes; magnets and power supplies; kickers; beam instrumentation; vacuum systems; and control. The old dipoles are modified and used in the outer ring. Electrons and positrons will collide at the interaction point with a horizontal
crossing angle of 11 mrad and bunch spacing of 8 ns. Each ring has 93 bunches with a beam current of 9170 mA. The machine will also provide a high flux of synchrotron radiation at a beam energy of 2.5 GeV. The manufacture of major equipment such as magnets, superconducting RF cavities (with the cooperation of KEK and MELCO) and quadrupole magnets (with the cooperation of BNL), as well as the cryogenics system, is complete. Installation in the tunnel began in March 2006. Beam collisions are expected in summer of 2007.

3. BESIII

The BESIII detector consists of a beryllium beam pipe, a helium-based small-celled drift chamber, Time-Of-Flight counters for particle identification, a CsI(Tl) crystal calorimeter, a superconducting solenoidal magnet with a field of 1 Tesla, and a muon identifier using the magnet yoke interleaved with Resistive Plate Counters (RPC). Fig. 2 shows the schematic view of the BESIII detector, including both the barrel and endcap portions.

3.1. Main Drift Chamber

The main drift chamber (MDC) is 2.58 meters in length and has an inner radius of 63 mm and an outer radius of 0.81 m. The inner and outer cylinders are carbon fiber. As shown in Fig. 3, there is a short inner portion near the beam pipe, a stepped region, and a cone shaped outer region. The polar angle coverage is \( \cos \theta = 0.83 \) for a track passing through all layers, and \( \cos \theta = 0.93 \) for one that passes through 20 layers. The end-plates are machined with a hole position accuracy better than 25 microns. Altogether there are 43 layers of 25 micron gold plated tungsten wires; the field wires are 110 micron gold-plated aluminum. The cells are approximately square, and the size of the half-cell is 6 mm in the inner portion of the drift chamber and is 8.1 mm in the outer portion. The chamber will use a 60/40 \( \text{He/C}_3\text{H}_8 \) gas mixture.

The expected spatial, momentum, and \( dE/dx \) resolutions are \( \sigma_s = 130 \mu \text{m} \), \( \sigma_p/p = 0.5\% \) at 1 GeV/c, and \( \sigma_{dE/dx}/dE/dx \sim 6\% \), respectively. Beam tests performed with prototype electronics at KEK in a 1 T magnetic field yielded a spatial resolution better than 110 microns and \( dE/dx \) resolution better than 5\%. The readout uses the CERN HPTDC. The wiring of the drift chamber has been completed, and the electronics assembly of the chamber has started.
3.2. TOF

Outside the MDC is the time of flight (TOF) system, which is crucial for particle identification. It consists of a two layer barrel array of 88 50 mm x 60 mm x 2320 mm BC408 scintillators in each layer and endcap arrays of 48 fan shaped BC404 scintillators. Hamamatsu R5942 fine mesh phototubes will be used - two on each barrel scintillator and one on each endcap scintillator. Expected time resolution for kaons and pions and for two layers is 100 to 110 ps, giving a $2\sigma K/\pi$ separation up to 0.9 GeV/c for normal tracks. This has been confirmed in a beam test of a TOF counter using prototype electronics. The scintillator and phototubes for the TOF system will be delivered before summer 2006, and the system will be tested and ready for installation in January 2007. A laser TOF calibration system is being built by the University of Hawaii.

3.3. Calorimeter

The CsI(Tl) crystal calorimeter contains 6240 crystals. The typical crystal is $5 \times 5$ cm$^2$ on the front face and $6.5 \times 6.5$ cm$^2$ on the rear face with a length of 28 cm or 15 radiation lengths. Figure 4 shows a schematic of the assembly containing an aluminum plate with two photodiodes (Hamamatsu S2744-08) with 10 mm by 20 mm sensitive area and an aluminum box for the preamp mounted on the end of a crystal. The expected energy and spatial resolutions at 1 GeV are 2.5% and 0.6 cm, respectively.

The CsI(Tl) crystals are being produced at Saint-Gobain, Shanghai Institute of Ceramics, and Hamamatsu (Beijing). Most of the crystals have been delivered, and their size, light yield, uniformity, and radiation hardness are satisfactory. A beam test shows that the electronics noise from the preamplifier, main amplifier, charge digitizer, and 18 meters of cable was less than 1000 electrons equivalent per crystal, corresponding to about 220 keV of energy.

Figure 5 shows the prototype mechanical structure for mounting the crystals. The crystals are held by screws and there are no walls between crystals. Mechanical assembly will start soon and should be completed by the end of the year. By the end of the year, all electronics boards should be tested and installed.

3.4. Magnet

The BESIII super-conducting magnet is the first of its kind built in China. The vacuum cylinder and the supporting cylinder are made in China, in collaboration with the Wang NMR company of California, and the wiring of the super-conducting cable and later the epoxy cur-
Figure 5. Prototype of the mechanical structure for mounting the crystals.

Figure 6. The super-conducting magnet during the installation into the BESIII detector.

ing, assembly, and testing were all done at IHEP with advice from experts all over the world. The superconducting magnet is a 3.91 m long single layer solenoid with a 1 T magnetic field at a nominal current of 3650 A. The field in the MDC will have a uniformity better than 5 %, and it will be measured with an accuracy better than 0.25 %. The magnet is complete, and Fig. 6 shows its installation into BESIII. The magnet will be tested before summer, and the field mapping will be done with the super conducting quadrupoles in place using a computer controlled mapping machine before December 2006.

3.5. Muon Counter

The magnet return iron has 9 layers of Resistive Plate Chambers (RPC) in the barrel and 8 layers in the endcap to form a muon counter. The electrodes of the RPCs are made from a special phenolic paper laminate on bakelite, which has a very good surface quality. The gas used is Ar : $C_2H_2F_4 :$ Isobutane (50:42:8). Extensive testing and long term reliability testing has shown that the chambers have high efficiency, low dark current, and good long term stability.

All the RPCs for the muon identifier have been manufactured, tested, and installed, as shown in Fig. 7. The average dark current and noise level for all chambers installed after one weeks training is 1.6 $\mu$A/m$^2$ and 0.095 Hz/cm$^2$, respectively, for a high voltage corresponding to an average efficiency of 95 %. The spatial resolution obtained was 16.6 mm.

3.6. Trigger, Data Acquisition, and Offline Software

The trigger design is almost finalized; it is pipelined and uses FPGAs. Information from the TOF, MDC, and muon counter will be used. The maximum trigger rate at the $J/\psi$ will be about 4000 Hz with a good event rate of about 2000 Hz. All boards should be tested and installed by the end of 2006.

The whole data acquisition system has been tested to 8 kHz for an event size of 12 Kb, which is a safety margin of a factor of two. The expected bandwidth after level one is 48 Mbytes/s. The data acquisition system is 1000 times the performance of BESII.

The preliminary version of the BES Offline Software System (BOSS) is complete. A tremendous amount of work has been accomplished but much remains to be done. Simulation is based on Geant4. Figure 8 shows a BESIII event display. Figure 9 shows $D$ decays reconstructed from a simulated 50,000 $\psi''$ inclusive event sample. The beam constrained mass resolution for $D^0 \rightarrow K^-\pi^+$ is $\sigma_{BC} = 1.2 \text{ MeV}/c^2$. Simulation and reconstruction is done using BOSS.
4. Physics in the tau-charm energy region

The tau-charm energy region makes available a wide variety of interesting physics. Data can be taken at the \( J/\psi \), \( \psi(2S) \), and \( \psi(3770) \), at \( \tau \) threshold, and at a energy to allow production of \( D_s \) pairs, as well as for an R-scan.

In 2003, the construction of wiggler magnets at the CESR collider at Cornell was approved that would allow the energy of their machine to be lowered to compete with BES, and a test run was made with a single wiggler magnet. Since 2005, CESR has had a full complement of these magnets, and the luminosity of CLEOc is currently less than \( 1 \times 10^{32} \text{ cm}^{-2} \text{ s}^{-1} \). CLEOc is scheduled to finish data taking in 2008.

BEPCII and BESIII will begin commissioning in summer 2007. The design luminosity of BESIII is \( 1 \times 10^{33} \text{ cm}^{-2} \text{ s}^{-1} \). Clearly BESIII with higher luminosity will contribute greatly to precision flavor physics: \( V_{cd} \) and \( V_{cs} \) will be measured with a statistical accuracy of 1.6%. \( D^0 \bar{D}^0 \) mixing and CP violation will be searched for. Table 15 gives the numbers of events expected during one year of running at various energies. Huge \( J/\psi \) and \( \psi(2S) \) samples will be obtained. The \( \eta_C \), \( \chi_{CJ} \), and \( h_C \) can be studied with high statistics. The \( \rho \pi \) puzzle will be studied with better accuracy.
Table 1
Number of events expected for one year of running.

| Physics channel | Center-of-mass Energy (GeV) | Peak Luminosity \(10^{31} \text{ cm}^{-2} \text{ s}^{-1}\) | Physics cross section (nb) | Number of Events per year |
|-----------------|----------------------------|---------------------------------|---------------------------|---------------------------|
| \(J/\psi\)      | 3.097                      | 0.6                             | \(\sim 3400\)           | \(10 \times 10^9\)     |
| \(\tau\)        | 3.67                       | 1.0                             | \(\sim 2.4\)            | \(12 \times 10^6\)     |
| \(\psi(2S)\)    | 3.686                      | 1.0                             | \(\sim 640\)            | \(3.0 \times 10^9\)    |
| \(D\)           | 3.770                      | 1.0                             | \(\sim 5\)              | \(25 \times 10^6\)     |
| \(D_s\)         | 4.030                      | 0.6                             | \(\sim 0.32\)           | \(1.0 \times 10^6\)    |
| \(D_s\)         | 4.140                      | 0.6                             | \(\sim 0.67\)           | \(2.0 \times 10^6\)    |

Table 2 shows a comparison of the BESIII and CLEOc detectors.

| Detector | BESIII | CLEOc |
|----------|--------|-------|
| MDC \(\sigma_{xy} = 130 \mu m\) | 90 \mu m | 90 \mu m |
| \(\Delta P/P = 0.5\% \quad (@1 \text{ GeV/c})\) | 0.5 \% | 0.5 \% |
| \(\Delta E/E = 2.3\% \quad (@1 \text{ GeV})\) | 2.0 \% | 2.0 \% |
| EMC \(\sigma_{x} = 0.6/\sqrt{E} \quad \text{cm}\) | 0.5/\sqrt{E} \quad \text{cm} | 0.5/\sqrt{E} \quad \text{cm} |
| TOF \(\sigma_T = 100 - 110 \quad \text{ps}\) | Double layer | Rich |
| \(\mu\) counter | 9 layers | – |
| Magnet | 1 T | 1 T |

5. BESIII Collaboration

A BESIII collaboration meeting was held January 10 - 12, 2006 at IHEP in Beijing, China. More than one hundred collaborators from 21 institutions and six countries attended the meeting, including China, United States, Japan, Sweden, Germany, and Russia. This meeting was historic as the governance rules of the collaboration were approved and used for the first time. Under these rules, the Institutional Board (IB) was established and its chair was elected.

A conference CHARM2006 will be held in Beijing in June of this year to discuss the physics potential of BESIII, and a US-China workshop on BESIII collaboration will be held immediately afterwards. All interested parties are welcomed.

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