AN OVERVIEW OF THE BEPCII PROJECT

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Abstract

The BEPCII, as a natural extension of the BEPC (Beijing Electron-Positron Collider), is a double ring e-e^+ collider and a synchrotron radiation (SR) source with its outer ring, or SR ring. As an e-e^+ collider, the BEPCII operates in the beam energy region of 1-2.1 GeV with design luminosity of 1×10^{33}cm^{-2}s^{-1} at 1.89 GeV. As a light source, the SR ring operates at 2.5 GeV and 250 mA. The project started construction in the beginning of 2004. The upgrade of the injector linac completed in late 2004. The BEPC ring dismount started in July 2005. Installation of the storage ring components completed in October 2007. The commissioning is in progress. In the meantime, the BESIII detector was constructed, assembled and tested in the off-line position beside the interaction region (IR). This paper provides an overview of the BEPCII project.

GENERAL DESCRIPTION

The BEPCII serves the purposes of both high energy physics experiments and synchrotron radiation applications. The details of the BEPCII design can be found in its design report [1]. The goals of the BEPCII are shown in Table 1.

Table 1: The design goals of the BEPCII

Beam energy	12.1 GeV
Optimum energy	1.89 GeV
Luminosity	1×10^{33} cm^{-2}s^{-1} @189 GeV
Linac injector	Full energy inj.: 1.551.89 GeV Positron inj. rate ≥50 mA/min
Dedicated SR	250 mA @ 2.5 GeV

Serving as a collider, the BEPCII will operate in the beam energy region of 1.0-2.1 GeV so that its physical potential in τ-charm range is preserved. The design of the BEPCII aims at a high luminosity. The luminosity of an e^+-e collider is expressed as

$$L(\mathrm{cm}^{-2}\mathrm{s}^{-1}) = 2.17\times10^{34}(1+r)\xi_y \frac{E(GeV)k_b I_b(\mathrm{A})}{\beta_y^*(\mathrm{cm})},$$

where $r=\sigma_y^*/\sigma_x^*$ is the beam aspect ratio at the interaction point (IP), ξ_y the vertical beam-beam parameter, β_y^* the vertical β-function at IP, k_b bunch number in each beam and I_b the bunch current. The strategy for the BEPCII to reach the design luminosity is to apply multi-bunch collisions (k_b=93) with two rings and micro-β at IP with short bunches whose length is compatible to the β_y^* value. A multi-coil superconducting magnet is used on each side of the southern IP. The layout and installed double-ring accelerator units in the BEPCII tunnel are shown in Fig. 1.

The inner ring and the outer ring cross each other in the northern and southern IP's. The horizontal crossing angle between e^+ and e beams at the southern IP, where the detector locates, is 11×2 mrad to meet the requirement of sufficient separation but no significant degradation to the luminosity. In the northern crossing region, e^+ and e beams cross horizontally and a vertical bump is used for beam separation, so that the optics of the two rings remains symmetric. For the dedicated synchrotron radiation operation of the BEPCII, electron beams circulate in the outer ring with a pair of horizontal bending coils in SC magnets and in the northern IP a bypass is designed to connect two halves of the outer ring. The machine physics issues are discussed in Ref. [2].

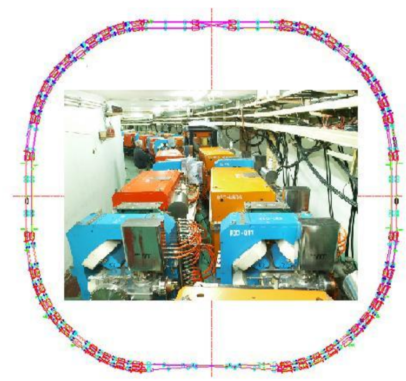

Figure 1: Layout and installed double-ring units.

The milestones of the BEPCII are as follows:

January 2004	Construction started
May 4, 2004	Dismount of 8 linac sections started
Dec. 1, 2004	Linac delivered e beams for BEPC
July 4, 2005	BEPC ring dismount started
March 2, 2006	BEPCII ring installation started
Nov. 13, 2006	Commissioning with conventional IR magnets started
Oct. 24, 2007	Commissioning with superconducting IR magnets started
Jan. 29, 2008	2×500 mA e^+e collision realized with luminosity higher than 1×10^{32}cm^{-2}s^{-1}

THE BEPCII ACCELERATORS

INJECTOR LINAC

The BEPC injector is a 202-meter electron/positron linac with 16 RF power sources and 56 S-band RF structures. The BEPCII requires the injector in two aspects. One is the full energy of e^+ and e beams injected into the storage rings, i.e. $E_{\mathrm{inj}} \geq 1.89$ GeV; the other is e^+ injection rate ≥ 50 mA/min. To realize the full energy top-off injection up to 1.89 GeV, the 30MW klystrons are replaced with the new 45-50 MW ones and the modulators upgraded with new pulse transformer oil tank assembly, PFN's, thyratrons, charging choke and DC power supplies. In order to compensate the RF phase drift due to various factors, an RF phasing system is developed.

The technical measures taken for increasing positron intensity in the BEPCII injector can be summarised as following: to increase the e^- beam current on e^+ target from 2.5A to 6A, the repetition rate from 12.5Hz to 50Hz, the bombarding energy for e^+ from 140MeV to 240MeV; to develop a new positron source to increase the yield from 1.4% to 2.7%, and to apply two-bunch injection scheme. Though the pulse length reduced from 2.5 ns to 1ns, the total gain factor of the e^+ intensity can be about 20 times higher than the BEPC. The new developed positron source is pictured in the Fig. 2.

Figure 2: The new developed positron source.

All the new hardware subsystems, including the electron gun, the 40MeV pre-injector, the 200MeV booster section and the positron source of the linac were installed in the summer 2004 after dismounting the old devices. Figure 3 shows the BEPCII injector linac.

Figure 3: The BEPCII injector linac.

It took less than one month to start up the machine and process the new systems before the linac provided electron beams for the dedicated SR operation of the BEPC storage ring starting from the beginning of the December 2004. The commissioning of the linac for e^+ beam has been carried out during the machine studies. The first e^+ beam of 50 mA was obtained at the linac end on March 19, 2005. The e^- beam current output from the gun is ~10A, and ~6A at the positron converter target which is the same as simulation. All of the 16 RF power sources were rebuilt, and stably work at 50pps. The new control and beam instrumentation systems make the machine commissioning and operation more convenient. The performance of the linac is listed in Table 2, showing that its design specification is reached.

Table 2: The results of the linac commissioning

	Unit		Measured	Design
Energy	GeV		1.89	1.89
Beam current	mA	e^+	63	37
		e^-	>510	500
Emittance	mm·mr	e^+	0.35	0.4
		e^-	0.1	0.1
Energy spread	%	e^+	0.30	0.5
		e^-	0.37	0.5
Repetition rate	Hz		50	50
Pulse length	ns		1.0	1.0
e^+ injection rate	mA/min.		50~80	>50

THE STORAGE RINGS

The BEPCII storage rings consist of two rings, i.e. the e^+ ring and the e^- ring. The two outer halves of the e^+ and e^- rings are used for the dedicated SR operation. Table 3 lists the main parameters of the BEPCII storage rings.

Table 3: Main Parameters of the BEPCII storage rings

Parameters	Unit	Collision	SR
Energy	GeV	1.89	2.5
Circumference	m	237.53	241.13
RF frequency	MHz	499.8	499.8
RF voltage	MV	1.5	1.5~3.0
Beam emittance	nm·rad	144	120
Bunch number		93	200-400
Beam current per ring	A	0.91	0.25
Injection energy	GeV	1.89	1.89
β-function at IP	m	1/0.015	–
Crossing angle	mrad	11× 2	–
Beam-beam Parameter		0.04	–
Luminosity	$cm^{-2}s^{-1}$	1.0×10^{33}	–

RF system

Two SC cavities are installed in the BEPCII with one cavity in each ring to provide RF voltage of 1.5 MV/ring. Each cavity is powered with a 250 kW klystron. The horizontal high power test shows the Q values of 5.4×10^8 and 9.6×10^8 at V_{rf}=2 MV for the west and east cavities respectively, higher than the design values of 5×10^8 at 2 MV. Figure 4 pictures the cavity in installation.

Figure 4: A superconducting cavity in installation.

Magnets and power supplies

The BEPCII will reuse 44 BEPC bends and 28 quads. In total 267 new magnets, including 48 bends, 89 quads, 72 sextupoles, 4 skew quads and 54 dipole correctors, need to be produced. Most magnets were fabricated in the IHEP workshop. The magnets were measured with both rotating coils and stretched wire. The results are in agreement with each other within 10^{-3}. Figure 5 pictures a quadrupole magnet in measurement with a rotating coil. There are 1 electric and 4 permanent wigglers in the storage rings serving as SR wavelength shifters. Among the 4 permanent wigglers, three are out-vacuum and one in-vacuum.

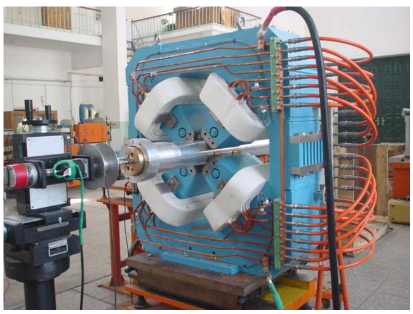

Figure 5: A quadrupole magnet in measurement.

To provide required flexibility for BEPCII operation with various modes, each arc quadruple is excited by an independent power supply. There are all together 345 power supplies in the storage rings. The power supplies have been installed, connected to the magnets and tested. Their current stability is better than 1×10^{-4}.

Vacuum System

The BEPCII imposes two challenges to the vacuum system, one is the vacuum pressure, and the other is the impedance. The designed dynamic vacuum pressure are 8×10^{-9} Torr in the arc and 5×10^{-10} Torr in the IR. Antechambers are chosen for the arc of both e^+ and e rings. For the e^+ ring, the inner surface of the beam pipe is coated with TiN in order to reduce the secondary electron yield (SEY). Measurement results show that the maximum SEY is 1.6-1.9 after the coating, seen in Fig. 6.

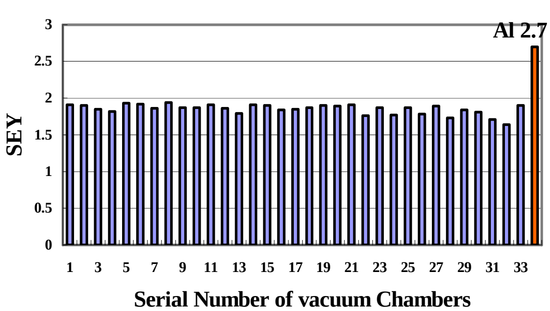

Figure 6: Measured SEY of TiN-coated chambers.

IR and SC Insertion Magnets

The IR has to accommodate competing and conflicting requirements from the accelerator and the detector. Many types of equipment including magnets, beam diagnostic instruments, masks, vacuum pumps, and the BESIII detector must co-exist in a crowded space. A special pair of superconducting insertion magnets (SIM's) is placed in the IR. Each SIM consists of a main and a skew quadrupoles, 3 compensation solenoids and 2 dipole coils, for squeezing the β-function at IP, compensating the detector solenoid and to serve as the bridge connecting outer ring for SR operation, respectively. The SIM's were installed into IR in Oct. 2007. Some special warm bore magnets in IR such as septum bending magnet and two-in-one quadrupoles have been manufactured, tested and installed. Figure 7 shows two SIM's and some warm magnets in the IR.

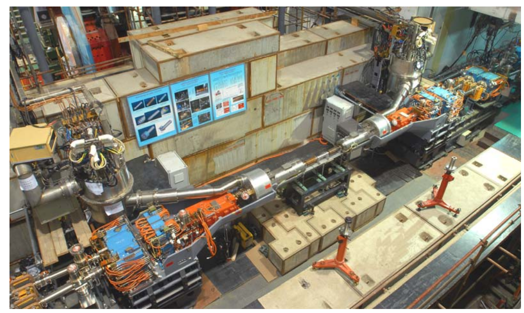

Figure 7: SIM's and some warm magnets installed in IR.

Instrumentation and Control

The instrumentation system consists of 136 beam position monitors (BPM's), 2 DCCT's, 2 bunch current monitors and 2 synchrotron radiation monitors. Transverse bunch-by-bunch feedback systems are equipped in order to damp coupled bunch instabilities. The control system is based on the EPICS environment, providing a friendly man-machine interface for operators. The instrumentation and control systems have been examined during the commissioning.

Cryogenics system

The BEPCII cryogenics system is composed of four sub-systems: the central cryogenic plant and three satellite cryogenic systems for the RF cavities, the SIM magnets, and the SSM detector solenoid. Two 500W refrigerators are equipped to cool the SC devices to 4.5K, one for the cavities and another for the magnets. The cavity side cryogenics has been in normal operation since mid-2006, while the magnet part since mid-2007 after problems of control Dewar, valve boxes and current leads were fixed.

Commissioning and Operation

The operation of the BEPC completed on July 4, 2005, and then dismount of the old ring started. The storage ring installation was completed in early November 2006 except the cryogenics of the magnets. It was decided to install conventional magnets in the IR to start storage ring commissioning (Phase 1) and SR operation. In the meantime, improvement of the cryogenics system and measurement of the SC magnets was carried out at the off-line position. The Phase 2 commissioning and SR operation with SIM's in the IR was started late Oct. 2007. By the end of the Jan. 2008, 2×500mA e^+-e^- beam collision was realized and the luminosity measured with zero-degree γ detector was higher than $1\times10^{32}cm^{-2}s^{-1}$. Details of the commissioning are presented in another paper of these proceedings [3].

BESIII DETECTOR

Design Consideration

A high quality detector with advanced technology comparable to BEPCII needs to be built in order to reach the physics goal of the project. Therefore a modern detector, the BESIII, is designed to meet the following requirements:

- Very good photon energy resolution, good angle resolution for photon measurement.
- Accurate 4-momenta measurement of low charged particles.
- Good hadron identification capabilities.
- A modern data acquisition system and the front-end electronics system based on the pipeline technique.

The choice of the detector components is based on physics requirements, existing experience, budgetary, schedule and etc. Figure 8 shows the schematics of the BESIII detector, which consists of main drift chamber (MDC), CsI crystal electromagnetic calorimeter (EMC), time of flight (TOF) counters, μ counters, SC solenoid magnet and beryllium beam pipe. Table 4 gives main parameters of the BESIII detector.

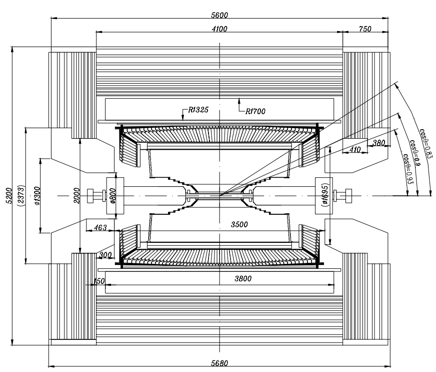

Figure 8: Schematic drawing of the BESIII detector.

Table 4: Main parameters of the BESIII detector

Sub-system	BESIII
MDC	σ_{xy} = 130μm
	$\Delta P/P$=0.5% @ 1GeV
	$\sigma_{dE/dx}$= (6-7) %
EMC	$\Delta E/E$=2.5%@1GeV
TOF detector	σ_T=100 ps (barrel), 110 ps (endcap)
μ counters	9 layers
Magnet	Superconducting, B=1.0 Tesla

Construction

On March 27, 2008, the BESIII beryllium beam pipe was successfully installed inside the MDC, which marks the full completion of the BESIII detector construction. In the past 4 years, all sub-detectors, the MDC, barrel and endcap TOF, barrel and endcap EMC, μ counters were produced, assembled and tested with DAQ, trigger and slow control systems. The SC magnet was constructed, tested and field measured at 1 Tesla and 0.9 Tesla. The software and physics preparation are in good shape. Figure 9 pictures the barrel EMC in installation.

Figure 9: Installation of the Barrel EMC.

On Feb. 14, 2008, the BESIII realized cosmic ray data acquisition (see Fig. 10) after all the sub-detectors were put into place, which indicated that BESIII had successfully finished initial tuning.

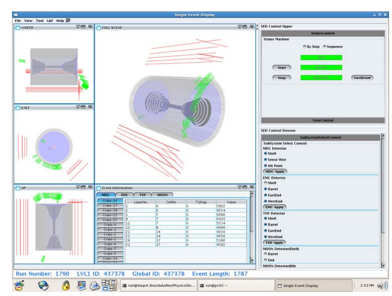

Figure 10: BESIII cosmic ray data acquisition.

Machine -Detector Interface

The interface between the BEPCII accelerator and the BESIII detector is intensively studied. With injection optimisation, the dose rate gets acceptable for pulling the BESIII detector into the IR. More collimators will be installed in the storage rings to reduce background during data acquisition. Some interlocks are introduced. Shielding and radiation background monitors will be installed in the detector. The details are given in Ref. [4].

PLAN AND SCHEDULE

The BESIII detector is scheduled to roll in the IR of the BEPCII in mid-April, 2008. The collider will be operated together with BESIII detector (Phase 3 commissioning) after the IR is reinstalled early June. It is expected that the luminosity would be high enough for the BESIII detector to start experiment by the end of 2008.

REFERENCES

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