THE PRESENT STATUS OF THE KEKB PROJECT

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Abstract

The Japanese B-Factory project at KEK (KEKB) is an 8 x 3.5 GeV, two-ring, electron-positron collider in the existing TRISTAN tunnel of 3000 m circumference. Large stored currents of 1.1 A in the electron ring and 2.6 A in the positron ring, a small β_y^* value at the interaction point (1 cm), and a high beam-beam tuneshift of 0.05 are required to achieve the luminosity goal of 10^{34} $cm^{-2}s^{-1}$. Electrons and positrons collide at a finite angle of ±11 mrad at the center of the BELLE detector. The construction of KEKB started in 1994 and it will be commissioned in JFY 1998.

1 INTRODUCTION

KEKB(B-Factory)[1,2] is an 8×3.5 GeV, two-ring, asymmetric, electron-positron collider aiming at detecting the CP-violation effect at B-mesons; the luminosity goal was set to be 10^{34} $cm^{-2}s^{-1}$ to reach this objective. Two rings of the KEKB (3.5 GeV low-energy ring, LER, for positrons, and 8 GeV high-energy ring, HER, for electrons) are installed in the existing TRISTAN tunnel of 3 km circumference and the infrastructure of TRISTAN will be maximally utilized. Taking advantage of the large tunnel size of TRISTAN, two rings are installed side by side; unnecessary vertical bending of trajectories that may increase the vertical emittance of the beams is minimized.

Figure 1 shows the layout of KEKB. KEKB has only one interaction point, IP, at Tsukuba experimental hall, where electron and positron beams collide at a finite angle of ±11 mrad at the center of the BELLE detector[3]. Electrons and positrons from the linac are injected into the rings at the Fuji straight section; this straight section is also used for installing RF cavities of LER. Cavities of HER are to be installed in straight sections at Nikko and Oho. These sections are also reserved for wigglers for LER.

To facilitate full-energy injection into the KEKB rings from linac and avoid acceleration of high-current beams, the upgrading of the present 2.5 GeV linac to 8 GeV is underway[4]. The upgrade is done by combining the main linac with the positron production linac, increasing the number of accelerating structures, replacing klystrons with high-power ones, and compressing RF pulses by SLEDs. The increase of the energy of electrons impinging on the positron production target from 250 MeV to 4 GeV multiplies positron intensity by 16; the injection time of positrons to LER is estimated to be 900 sec. A new 130-m tunnel for transport lines between the linac and KEKB rings will be constructed from December 1996 to September 1997. This tunnel bypasses the accumulation ring, AR, from KEKB.

2 BASIC DESIGN

2.1 Beam Parameters and Lattice Design

The main parameters of the KEKB accelerators are given in the references[1,2]. HER and LER have the same circumferences, emittances, and the β functions at IP. The large current, the large number of bunches, small bunch spacing, the small value of β function at IP and finite-angle crossing of beams are the salient features of KEKB.

Non-interleaved chromaticity correction scheme with the 2.5π phase advance per cell guarantees a large enough transverse dynamic aperture at injection both for LER and HER, and a large enough longitudinal (momentum) aperture to have a sufficiently long Touschek lifetime for LER[5]. The lattice is flexible enough to allow us to change the momentum compaction factor from -1×10^{-4} to 4×10^{-4} and the emittance from 50% to 200% of the nominal value. In LER a local chromaticity correction scheme at the IP straight section effectively corrects the large vertical chromaticity produced by the final focus quadrupole magnets and increase the Touschek lifetime.

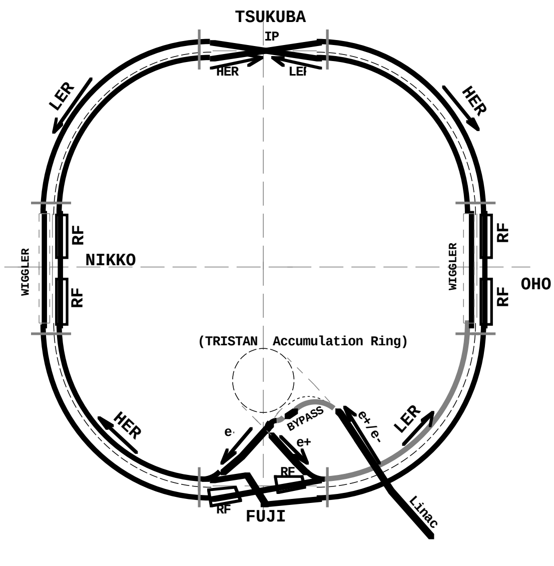

Fig. 1 Layout of KEKB

2.2 Finite-Angle Crossing Scheme

The finite-angle crossing scheme of ±11 mrad at KEKB make it possible to fill every bucket with beam without any concern on parasitic collisions, remove separation dipole magnets that would be necessary for a head-on collision and minimize the horizontal width of the Be vacuum pipe; the smaller beam pipe improves the vertex point resolution and permits efficient use of the luminosity. Computer simulation showed that the finite-angle crossing reduces usable areas in the ν_x-ν_y plane due to synchro-betatron resonance, and that if we make the ν_s(synchrotron tune) smaller than 0.02, a fair amount of areas in the ν_x-ν_y plane is still free from reduction of luminosity due to resonance[6].

In KEKB we use superconducting final-focus quadrupole magnets in order to have a flexibility of tuning. Superconducting solenoids placed in front of the quadrupoles can make the integrated solenoidal field nearly zero between the quadrupole pair. This cancellation is desirable for asymmetric colliders in order not to make the beams rotate by different angles by residual solenoidal field inside the detector. One superconducting solenoid and one final-focus quadrupole in each side of IP are contained in the same cryostat[7].

A superconducting crab cavity with a squashed shape operating in the TM110 mode is now under development in order to prepare for unpredictable beam-beam effects due to this finite-angle crossing[1]. In the last May the first 1/3 model cavity was cooled down to 4.2K.

3 HARDWARE SYSTEM

3.1 RF System

The RF accelerating cavity for the KEKB should have a structure by which higher-order modes (HOMs) in the cavity are damped to the level where the growth times of the coupled-bunch instabilities excited by HOMs become comparable to or longer than the damping time. The cavity should have enough stored energy in order to make the detuning frequency of the cavity due to beam loading small compared with the revolution frequency of the ring. We are now developing two types of cavities for KEKB. One is a normal conducting cavity called ARES and the other is a superconducting, single-cell, single-mode cavity.

3.2 ARES

ARES (accelerator resonantly coupled with energy storage) was devised in KEK and extensive R&D works are under way[8]. In ARES an accelerating cell is connected to an energy storage cell via a coupling cell; this effectively increases the stored energy of the system and makes ARES robust against the heavy beam loading. The system employs a $\pi/2$ mode where almost pure TM010 mode and almost pure TE013 mode are excited in the accelerating cell and the energy storage cell, respectively, and very little field is excited in the coupling cell. Two parasitic modes (0 and π modes) have a field in the coupling cell and can be damped rather easily by a coupler attached to it. In order to suppress HOMs, a choke-mode cavity[9] is used as the accelerating cell of ARES. Two prototype choke-mode cavities were delivered to KEK and successfully tested up to 110 kW of wall dissipation which corresponds to a gap voltage of 0.73 MV. One of the prototype choke-mode cavity was set at AR and could store a 110 mA, two-bunch electron beam at 2.5 GeV by supplying 0.5 MV accelerating voltage. Full ARES will be tested at AR in this fall.

3.3 Superconducting RF Cavity

A superconducting cavity has a large stored energy due to its high field gradient and is immune to the beam-loading. The superconducting cavity for KEKB is a single-cell cavity with two large-aperture beam pipes attached to the cell [10]. HOMs propagate toward the beam pipes, since their frequencies are above the cut-off frequencies of the pipes. The diameter of the one pipe (300 mm) is made larger than that of the other (220 mm) in order to make a few transverse modes otherwise trapped propagate. The iris between the cell and the larger beam pipe prevents the fundamental mode from propagating toward the beam pipe. HOMs are absorbed by ferrite HOM absorbers.

The first full-size superconducting cavity reached the field of 11.4 MV/m, which is comparable to the accelerating field of 13.1 MV/m obtained at a vertical cryostat test. From March 31 to April 2, 1996, we tested this prototype superconducting cavity with 2.5 GeV electron beam at AR; APS-type cavities of AR was detuned and only the superconducting cavity supplied accelerating voltage. The results are summarized as follows: (1) we could store 60 mA (single-bunch) for 10 hours with 2 MV (8.2 MV/m) without any RF trips; (2) 90 mA (single-bunch) for 30 minutes with 2 MV; (3) 70 mA(single-bunch) for 50 minutes with 2.5 MV (10.3 MV/m), (4) 110 mA (single-bunch) for 10 minutes with 2.33 MV (9.6 MV/m); (5) 100 mA (32 bunches) with 2.33 MV[11]. Full-scale test will be made in July and October-November of this year.

3.4 Bunch-by-Bunch Feedback System

Feedback systems that can damp the coupled-bunch oscillations of the beam with a bunch spacing of 2 ns are being developed [12]. Since the number of bunch is large (5000) and the bunch spacing is short (2 ns) at KEKB, the signal processing part of the system needs a lot of R&D. We are trying to develop a 2-tap FIR digital filter system as the kernel of the signal processing unit. The 2-tap FIR filter does not require any multiplication but a subtraction of two signals. This kind of filter can be composed of memory chips and simple CMOS logic

ICs without relying on DSP chips. By using 500 MHz ADC and DAC, two custom-made 4-bit GaAs 1:16 500-MHz demultiplexers and two 4-bit GaAs 16:1 500-MHz multiplexers, and having 16 parallel 2-tap FIR logics, we can construct a signal processing unit on a single board. Effectiveness of the 2-tap FIR logic to real beams was demonstrated by beam tests at AR by the use of a low speed 2-tap FIR logic CAMAC board; and the tests showed that the system could be applied for a wide range of the beam tune.

Prototype transverse and longitudinal pickups that can detect bunch oscillations for the 500 MHz bunch frequency have been completed. Drift tube type longitudinal kickers and strip line transverse kickers are now being developed.

4 BEAM STUDY

4.1 Beam Study at the TRISTAN AR

Series of long-term beam tests are planned to be held in 1996 by the use of AR: the first one from July 1st to July 22nd and the second from October 17th to December 2nd of 1996. We plan to store more than 500 mA electron beam in AR with a multibunch mode at 2.5 GeV. To accumulate this high current, the existing APS type RF cavities will be removed temporally from the ring and ARES cavities and a single-cell superconducting cavity for KEKB will be installed. The transverse and longitudinal feedback systems will also be tested.

This test will give us a good opportunity to study the fast-ion instability[13]. A transient digitizer system that can store the beam position of every bunch at every turn for more than 100 msec is under construction for this purpose.

4.2 Photoelectron Instability Study at BEPC

Synchrotron lights produced by a positron beam in a ring hit the wall of vacuum chamber and produce photoelectrons, which are attracted by the beam and eventually form a cloud of electrons around the beam. Excitation of a coupled-bunch instability by this cloud is called the photoelectron instability (PEI); however, there is only one experimental evidence[14] and more experiments are definitely needed. KEKB group is collaborating with BEPC group in Beijing and preparing a series of experiments on PEI at BEPC in 1996 and 1997[15].

5 MILESTONES

KEKB project started in 1994 and is going smoothly. Last December TRSTAN has terminated and all magnets have been removed from the tunnel. From December 1996 installation of KEKB magnets in the tunnel will start. Table 1 shows a tentative major milestones of the project.

Table 1 Tentative Milestones of KEKB

Date		Milestones
1994	April	start of construction
1995	July	bidding for LER main equipment
	Dec.	start of dismantling of TRISTAN
1996	March	end of dismantling
	June	bidding for HER main equipment and final focus superconducting quadrupoles
	July	beam test at AR
	Oct.	beam test at AR
	Nov.	beam test at AR
.	Dec.	start of bypass tunnel construction
	Dec.	start of installation of magnets
1997	Sep.	completion of bypass tunnel
1998	March	3.5 GeV positrons from linac
	May	LER commissioning
	Oct.	8 GeV electrons from linac
	Oct.	HER commissioning
1999	early	collision starts

ACKNOWLEDGEMENT

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