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DESIGN AND CONSTRUCTION OF THE PEP-II LOW-ENERGY RING

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Abstract

We describe the design and construction status of the Low-Energy Ring (LER) of the PEP-II project, a collaboration of SLAC, LBNL, and LLNL. In the past year we have optimized LER parameters and started component fabrication. By reusing the original PEP wigglers, we were able to simplify the design of the distributed wiggler photon dump, which must dissipate 260 kW of power. The number of RF stations (each comprising a klystron powering two 476-MHz cavities) was reduced from 4 to 3. We have begun fabrication of the arc vacuum system based on an extruded Al ante-chamber configuration with discrete photon stops and TSPs. The design of straight section vacuum components, to be fabricated from stainless steel pipe, is also completed. Quadrupoles and dipoles are provided under a collaborative agreement with IHEP (Beijing); correctors and skew quadrupoles are built domestically and sextupoles are refurbished from existing PEP magnets. LER commissioning will begin early in 1998.

1 INTRODUCTION

The PEP-II asymmetric *B* factory collider consists of two storage rings, a High-Energy Ring (HER) with 9 GeV electrons and a Low-Energy Ring (LER) with 3.1 GeV positrons. Main parameters for the LER are summarized in Table I. The requirements of the LER for a large circumference, a low energy, a large emittance, and a short bunch length make the lattice difficult, and substantial effort has been spent on its design. The high beam current requirement is also challenging.

Table I
PEP-II LER main parameters.

Energy [GeV]	3.1
Circumference [m]	2200
Emittance, *y/x* [nm-rad]	2.6/64
Beta function at IP, *y/x* [cm]	1.5/37.5
Beam-beam tune shift	0.03
RF frequency [MHz]	476
RF voltage [MV]	5.1
Bunch length, rms [cm]	1
No. of bunches	1658
Total current [A]	2.1
Energy loss per turn [MeV]	0.8

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Because the LER is an entirely new ring, all of its technical components must be newly designed and fabricated. LBNL is responsible for the arc magnets and supports, the arc vacuum system, and the transverse feedback system, LLNL for much of the interaction region (IR), the straight section vacuum systems, and the LER wiggler, and SLAC for both the RF and the longitudinal feedback systems. All three labs play a role in the areas of power supplies and diagnostics.

Construction began in January 1994 and will be completed in September 1998. Commissioning of the LER will begin in April 1998.

Here we describe the present status of the ring, focusing on design changes in the past year and on our progress at fabrication of the ring components. Information on the lattice design has been covered previously [1].

2 RECENT DESIGN CHANGES

Parameters of the LER have been stable for the past year. However, for cost reasons we have now decided to reuse the original PEP wiggler units in lieu of a new wiggler that based on alternating polarity dipoles. The three PEP wiggler units, each comprising a central "full" pole and two outer half poles, have less magnetic length than our baseline wiggler, but they operate at higher field (1.8 T vs. 1.6 T for our baseline case). Thus, the damping rate and emittance range are nearly unchanged from our earlier design. The wiggler units have been inspected, magnetically measured, and shown to be acceptable for use. This choice has also permitted some simplifications in the design of the wiggler photon dump [2], with concomitant savings in its design.

The RF configuration of the ring has been modified to eliminate one RF station, reducing the number of stations from four to three. To minimize beam-loading effects, we had already planned to operate only three stations, with the fourth serving as a "hot spare." No operational impact is expected in initial operation. If a station fails, the remaining stations can support nearly the full beam current at a somewhat increased bunch length. We envision adding a spare station in the future if operational experience shows a need for it.

In the past year, we have studied two different versions of the Q2 quadrupole, the outer member of the doublet in the IR. Because of the solenoidal fringe field from the *BABAR* detector, we considered a permanent magnet device that would be adjustable by means of counter-rotating rings. We discovered, however, that it would still be necessary to surround Q2 with an iron shield in order to reduce its fringing field on the nearby HER beam. Given this and the relative lack of adjustability of the permanent magnet design, we returned to a conventional iron-copper septum quadrupole design similar to that described in the Conceptual Design Report [3]. Iron shielding will be installed around the HER beam pipe to reduce the effects of Q2 fringe field.

We have optimized a few of the design details of the ring to reduce costs. We now require only one quadrupole core length (43 cm) throughout the ring (with the exception of the Q2 magnets in the IR). Different quadrupole coil configurations are used to better match power supply specifications for the long arc strings (15-turn) and short strings (58-turn).

3 MAGNETS AND SUPPORTS

Quadrupole and dipole magnets for the LER are being provided by a collaboration of LBNL and the Institute of High Energy Physics (IHEP) in Beijing. After a joint design of the quadrupole, IHEP has embarked on their fabrication and measurement. Magnetic field quality has been excellent, bettering the specified multipole tolerances by at least a factor of two. Figure 1 shows an LER arc quadrupole undergoing measurements at IHEP. To date, 46 of the required 320 production quadrupoles have been delivered to LBNL.

Design of the arc dipole magnets has also been completed, and the prototype magnet (see Fig. 2) field profile has been verified at IHEP and subsequently at LBNL. This magnet has been released for production, with complete delivery expected by August 1997.

Horizontal and vertical correctors are being fabricated in industry, with delivery of about 300 magnets due this summer.

LER sextupoles will make use of refurbished PEP cores. Long sextupoles (not needed for the HER) were split to provide the required lengths. New coils for these magnets were designed at LBNL and are now being fabricated commercially. These coils provide the clearance required for the LER magnet chamber extrusions. Due to spatial constraints, it is expected that a few sextupoles

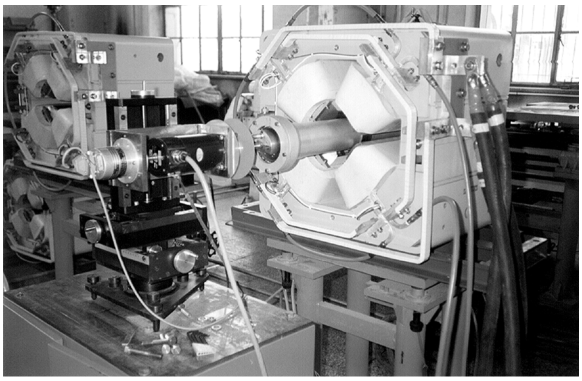

Figure 1. LER arc quadrupole at IHEP.

Figure 2. Prototype arc dipole at IHEP.

will have to include extra windings to provide a skew quadrupole field. A design for such a combined-function magnet is being studied, with encouraging results.

Support stands have been designed for both the arcs and straights. In the straights, these consists of rafts containing a dipole, quadrupole, corrector, and sometimes a sextupole. The raft is located atop the HER dipole, and is positioned with LER dipole centered above the HER dipole to keep the orbit geometry of the two rings closely similar. The "L" supports for the HER dipoles provide support for the LER raft also. In the straights, a similar, but simpler approach is followed. Here the quadrupole spacing of the two rings is typically not the same, so the LER supports are placed off to the side of the HER with the LER magnets cantilevered above the HER ring. Finite-element analysis shows that adequate stiffness and earthquake stability are maintained. Prototypes of both rafts have been installed in the PEP tunnel.

4 VACUUM SYSTEM

The LER arc vacuum system is based on aluminum extrusions. Spanning the region between arc rafts is a pumping chamber extrusion, about 6 m long and 45 cm wide, consisting of a large antechamber with a Glidcop photon stop, a titanium sublimation pump, and a lumped ion pump. All required chambers have now been produced and are being shipped to LBNL. Spanning the arc raft itself is a smaller magnet chamber extrusion having a slotted appendage for the photon beam to exit. These chambers are all delivered to LBNL and we are in the process of machining them to weld on the flanges. Flange welding will take advantage of the techniques and equipment developed at ANL for the APS project.

Because the LER must run an intense beam of positrons, we must be concerned with the possibility of the "electron-cloud" instability. Simulations suggest that to mitigate this we must avoid the high secondary electron emission characteristic of an aluminum beam pipe. Our plan is to coat the chamber with a low secondary emission material, TiN. Tests of the technique are under way. We have shown that diode sputtering is effective in putting the coating on. Optimization of the process is now being studied, including determining proper coating thickness, gas composition during sputtering, and longevity of the coating.

Design of the photon stop, which must absorb up to 15 kW of synchrotron radiation power from the two nearest upstream dipoles, is well along. We have demonstrated the required brazing techniques to join the Glidcop hot wall, with its serpentine water passages, to the copper backing plate. The beam surface of the hot wall is also grooved along the incoming photon direction to spread the incident power out longitudinally and thus reduce the peak power and thermal stresses. Finite-element calculations show the efficacy of the approach.

In the LER straights, we make use of the same technology used in the HER, water-cooled stainless steel pipes. Because of differences in the magnets between the two rings, some dimensions of the LER chambers differ from the HER chambers, but the components are otherwise identical.

One region of the LER where a different approach is called for is in the straight section containing the IR. Here the LER beam must be brought from above the HER beam into the HER plane. In this region there are many nonstandard components, including vertical bending magnets. Moreover, in the upstream portion of the line we face very stringent vacuum requirements to minimize detector backgrounds arising from beam-gas scattering. Here we have borrowed from the HER arc technology, using copper extrusions and non-evaporable getter (NEG) pumps to provide high linear pumping speed.

Another highly nonstandard region of the LER is the wiggler area. Here we must handle up to 260 kW of synchrotron radiation power from the wiggler on a distributed copper photon dump [2]. Design of the wiggler vacuum chamber is completed and machining of the large OFE copper sections is under way at LLNL. The vacuum system for this region consists of a novel NEG "washer" string with a tubular support. Regeneration is done with a calrod heater external to the vacuum system that can be replaced easily in case of failure.

5 RF AND FEEDBACK

The standard RF configuration now includes only 3 RF stations. LER components are identical to those in the HER, with the exception that an LER 1.2-MW klystron powers two cavities (vs. four in the HER). This difference is due to the lower voltage requirement in the LER along with the higher beam loading. Klystrons are being produced by Phillips. The first production tube was recently approved and fabrication of the remaining tubes is under way. RF cavities are being built within the collaboration, with the main manufacturing done at LLNL. The first batch of eight cavities is well along. Frequency tuning of the first cavity by machining the nose cones has begun. Window tests have demonstrated the required power throughput of 500 kW, though reproducibility of the window coating remains an issue. Initial tests of the tuner have also shown that some redesign will be needed to handle the high power reliably.

Work on the feedback systems is proceeding well. The main issue for the LER is heating of the longitudinal feedback kickers due to beam-induced power deposited in modes trapped just below cut-off. While it is likely that the HER kickers can be cooled radiatively, the higher LER beam current makes this problematical. The addition of beryllia standoffs to provide better thermal management is under study. This approach, if adopted, is expected to have only minor electromagnetic effects.

6 DIAGNOSTICS

Work is progressing on the beam position monitor (bpm) electronics, the DC current transformer (DCCT), and the bunch current monitor. Most LER bpms will be single plane (x-only at the QFs, y-only at the QDs). In key areas, such as the IR, dual-plane readouts are used. If need be, additional readout electronics to convert the bpms to dual-plane readout can easily be added later.

The DCCT uses a commercial core with a vacuum housing like that designed for the ALS. The device is already built and undergoing bench testing. The bunch current monitor uses a commercial flash ADC to digitize the current in individual bunches. This device is closely coupled to the injection system. The specification on the bunch filling uniformity for each ring is ±2%. The bunch current monitor information will be able to diagnose a poor bunch lifetime within the bunch train due to beam-beam related problems.

7 SUMMARY

The LER continues to progress well toward its commissioning target of April 1998. Designs have been completed for the major system components and production activities are in full swing. The dedication of the LER team, which spans the three collaborating laboratories, is a key ingredient in our successful efforts to date.

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