Conf-940618--112 SLAC-PUB-6564
LBL-34956
June 1994
(A)

The PEP-II Asymmetric *B* Factory: Design Details and R&D Results*

E. Bloom, H. DeStaebler, J. Dorfan, B. Feerick, T. Himel,
L. Klaisner, D. Nelson, E. Reuter, and J. Seeman
Stanford Linear Accelerator Center, Stanford University, Stanford, CA 94309

T. Elioff, D. Hunt, and M. Zisman
Lawrence Berkeley Laboratory, 1 Cyclotron Road, Berkeley, CA 94720

T. McCarville, K. van Bibber, and R. Yamamoto
Lawrence Livermore National Laboratory, Livermore, CA 94550

for the PEP-II Project Team

Abstract

PEP-II, a 9 GeV × 3.1 GeV electron-positron collider with a design luminosity of 3×10^{33} $cm^{-2}s^{-1}$ has now been approved for construction by SLAC, LBL and LLNL for the purpose of studying *CP* violation in the $B\bar{B}$ system. This upgrade project involves replacing the vacuum and RF systems of PEP, which will serve as the high-energy ring (HER), along with the addition of a new low-energy ring (LER) mounted atop the HER. Designs for both rings [1] are described, and the anticipated project construction schedule is indicated. Collider operation will begin at the end of 1998. An aggressive R&D program has been carried out to validate our design choices; key results in the areas of lattice design, vacuum, RF, and multibunch feedback are summarized.

1. INTRODUCTION

The design of the PEP-II Asymmetric *B* Factory project began in 1990 as a joint undertaking of SLAC, LBL, and LLNL. The design was updated and a new Conceptual Design Report (CDR) was completed in June 1993. In October 1993, the project was selected for funding and designated as a "Presidential Initiative." Since that time, project activities have focused on optimization and detailed design of key components and systems. As was done for the earlier R&D phase, project activities are subject to management review before commitment of major funds. In addition, a Machine Advisory Committee will be formed soon to advise laboratory and project management on technical issues. The overall technical status of the project is contained in a project-wide technical database (Oracle) that includes not only the parameter list (subject to formal configuration-control procedures) but detailed fabrication information on the technical subsystems (magnetic measurements, vacuum and magnet travelers, etc.), personnel information, documentation control, inventory control, ES&H information, and a component list.

*This work was supported by the Director, Office of Energy Research, Office of High Energy and Nuclear Physics, High Energy Physics Division of the U.S. Department of Energy, under Contract Nos. DE-AC03-76SF00515 (SLAC), DE-AC03-76SF00098 (LBL), and W-7405-Eng-48 (LLNL).

2. PROJECT OVERVIEW

A summary of the main PEP-II collider parameters is given in Table 1. Most noteworthy are the low beta functions at the interaction point (IP), the high beam currents, and the large number of bunches in each ring. We use head-on collisions at the IP; a crossing angle could be accommodated as a second phase. The main design challenges for PEP-II involve the vacuum, RF, and multibunch feedback systems. These areas have been the main focus of our R&D program.

The RF system [2] is based on highly damped room-temperature cavities, powered by newly developed 1.1-MW klystrons. This is a good technical choice for the PEP-II parameter regime, where very high gradients are not required. Compared with the CDR design, we have optimized the parameters such that the LER contains 5 klystrons powering 10 cavities and the HER contains 6 klystrons powering 24 cavities.

Even with highly damped cavities, feedback is needed to combat coupled-bunch instabilities. The PEP-II feedback systems (longitudinal and transverse) operate in the bunch-by-bunch (time-domain) mode. The longitudinal system is based on commercially available digital signal processing technology. Both systems have been tested at the ALS [3] and shown to give excellent performance.

Table 1
Main PEP-II collider parameters.

	HER	LER
Energy [GeV]	9.0	3.1
Circumference [m]	2200	2200
Emittance, x/y [nm-rad]	1.9/48	2.6/64
Beta function at IP, x,y [cm]	2.0/50.0	1.5/37.5
Beam-beam tune shift	0.03	0.03
RF frequency [MHz]	476	476
RF voltage [MV]	18.5	5.9
Bunch length, rms [cm]	1	1
No. of bunches	1658	1658
Total current [A]	1.0	2.1
Energy loss per turn [MeV]	3.6	1.1
Design luminosity [cm^{-2} s^{-1}]	3×10^{33}	

Presented at the Fourth European Particle Accelerator Conference (EPAC'94), London, England, June 27-July 1, 1994

To deal with high thermal loads and to minimize the photodesorbed gas load, the vacuum system for the HER [4] is based upon extruded copper chambers with conventional distributed ion pumps (DIPs). The possibility of augmenting the DIPs with non-evaporable getter (NEG) pumps is under study. Though the LER vacuum approach described in the CDR is similar to that of the HER, we are presently considering an alternative design (see below).

For its injector, PEP-II utilizes the SLC linac, damping rings, and positron target; the overall layout is shown in Fig. 1. Thus, we have a demonstrated ability to provide the required beams of electrons and positrons for topping off both rings in about 3 minutes. Both electron and positron beams will be extracted from the linac at their proper energies and transported to the storage rings in bypass lines (located within the linac housing) that connect to the existing PEP injection lines.

The PEP-II control system is based on the well-developed SLC control system software. The software and hardware will be upgraded and augmented as needed for PEP-II service.

2. PRESENT STATUS

At this stage of the project, the majority of the R&D activities are completed or will be so shortly. The results have been very successful and have validated the approaches outlined in the CDR.

2.1 Vacuum System

For the HER, the vacuum system R&D program has demonstrated sufficient pumping speed from the DIPs in tests at LLNL. Photodesorption experiments at NSLS [5] have shown adequately low desorption coefficients. Electron-beam welding and stretch-forming techniques to fabricate the chamber have been demonstrated. An e-beam welder is presently being acquired by the project for fabrication purposes, and a stretch-forming apparatus has been designed, fabricated and tested.

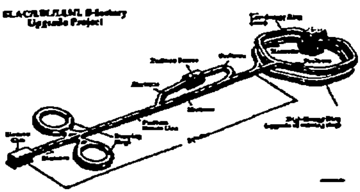

Figure 1. Overall layout of the PEP-II facility at SLAC.

For the LER, we are now examining a vacuum chamber configuration with an extruded aluminum antechamber having discrete copper photon stops and lumped titanium sublimation pumps (TSPs). Based on favorable experience at the ALS, this new approach offers considerably improved vacuum at comparable or lower cost than for the CDR design. Detailed design of the system is now under way. Taking advantage of the possibility of weaker wigglers (see Section 2.4) a simpler approach to the wiggler photon dump is also being studied. Several concepts are being considered, including a continuous dump with sloped antechambers on both sides of the beam chamber.

2.2 RF System

The RF cavity design [6] has also progressed significantly in the past year. Previous work on a low-power cavity model has demonstrated the efficacy of the higher-order-mode (HOM) damping technique. A high-power cavity is under construction, as is a high-power klystron. Both systems will be ready for testing early in 1995. The cavity is being fabricated from copper plate that is cold-formed into bowl-shaped shells. Cooling channels and ports for inserts are then machined into the body, which is covered with an electroformed outer shell. All inserts (tuner, coupler, HOM waveguides, etc.) will be made as separate subassemblies and e-beam welded into the cavity body. The 476-MHz, 1.1-MW klystron is being developed under a Cooperative Research and Development Agreement (CRADA) with Varian Corporation. We envision that some of these tubes will be made in industry and some at SLAC, where there is great experience in the manufacture of similar devices.

2.3 Feedback System

Great progress has been made in the design and testing of feedback system components. The ALS has been a very useful test-bed for this work. Its bandwidth requirement is twice that for PEP-II and it thus provides a severe test of our feedback system design. The prototype system has met its performance goals under realistic conditions, and we are fully confident of its ability to control the beam in the PEP-II rings.

2.4 Accelerator Physics

Progress has been made in optimizing the lattice designs for both rings. For the HER, an improved chromaticity correction scheme has been developed based on a "beta bump" to increase the separation of horizontal and vertical beta functions at sextupoles in the arcs adjacent to the IP. For the LER, a lattice with improved chromatic properties and a better geometrical layout has been developed, and both 72° and 90° phase advance cases have been studied. The present LER lattice has a reduced dependence on wigglers compared with the CDR design. The required emittance control can now be obtained with wigglers of about one-quarter the length called for in the CDR, though this comes at the expense of fully matched damping decrements in the two rings. (The shorter LER dipoles mentioned below would reduce the imbalance in damping rates in the two rings to a negligible level.)

Beam-beam simulations have shown little sensitivity to a change in LER damping rate at the level contemplated. Simulations have also been used to explore the luminosity lifetime of PEP-II by looking at the tails of the distributions by means on an algorithm [7] that enhances their population (compared with "brute-force" simulations) in a statistically significant way. These results also permit a detailed understanding of the loss mechanism associated with the beam-beam interaction.

2.5 Construction Activities

At present, about 50% of the existing PEP ring components have been removed from the tunnel. Removals will be completed by the end of 1994. Magnet refurbishment of the HER magnets, all of which are being reused, is in full production (see Fig. 2). The reinstallation of refurbished components on new C-supports will begin by the end of the year. These supports will carry both the HER dipoles and the girders for the LER above them. Other components to be reused, such as LIPs, are being stored for later refurbishment.

We are presently optimizing the designs of the LER quadrupole and dipole magnets. The new quadrupole design is based on a 2-piece core rather than the 4-piece core described in the CDR. The design of the dipole coil is also being optimized and, based on the updated lattice and vacuum chamber designs discussed above, the possibility of a somewhat shorter dipole magnetic length is being explored.

Fabrication of the injection line magnets is just beginning. These magnets will be installed in the linac housing next year during a scheduled SLC downtime.

3. SCHEDULE

We have adopted a phased approach for the PEP-II construction, beginning with the injector, moving on to the HER and finishing with the LER and interaction region IR. The advantage of this approach is that we can first test and optimize the injection process, then commission the HER and understand the issues associated with high currents and many bunches, and finally commission the LER and IR to deal with beam-beam behavior and detector backgrounds. Initial tests of the injector will commence in 1996. We plan to begin injecting into the HER in the summer of 1997 and to begin LER commissioning in early 1998.

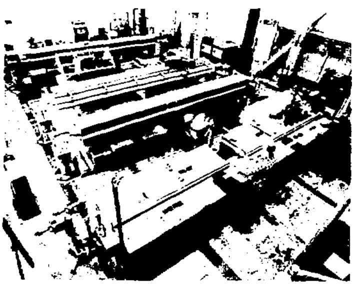

Figure 2. Refurbishment of PEP dipoles for use in the PEP-II HER.

4. SUMMARY

The PEP-II project has been undertaken by a collaboration of SLAC, LBL, and LLNL. We have a strong engineering and accelerator physics staff in place and progress on the project has been good. We are looking forward to a successful commissioning and the start of collisions in 1998.

5. ACKNOWLEDGMENTS

It is a pleasure to thank the many physicists and engineers who believed in the PEP-II project and who labored so long and hard to finally make it a reality. We also acknowledge the many fruitful interactions with our colleagues at KEK and Cornell who showed similar dedication in the pursuit of their respective projects.

6. REFERENCES

[1] PEP-II: An Asymmetric *B* Factory, Conceptual Design Report, SLAC-418, June 1993.

[2] H. Schwarz and R. Rimmer, "RF System Design for the PEP-II B Factory," these proceedings.

[3] J. Fox, N. Eisen, H. Hindi, I. Linscott, G. Oxoby, L. Sapozhnikov, and M. Serio, "Feedback Control of Coupled-Bunch Instabilities," in Proc. 1993 Particle Accelerator Conference, p. 2076.

[4] C. Perkins, *et al.*, "Vacuum System Design for the PEP-II B Factory High Energy Ring," these proceedings.

[5] C. Foerster, *et al.*, "Desorption Measurements of Copper and Copper Alloys for PEP-II," in Proc. of 12th Intl. Vacuum Conf., 8th Intl. Conf. on Solid Surfaces, Oct. 12–16, 1992, The Hague.

[6] R. Rimmer, *et al.*, "High-Power RF Cavity R&D for the PEP-II *B* Factory," these proceedings.

[7] J. Irwin, "Simulation of Tail Distributions in Electron-Positron Circular Colliders," SLAC-PUB-5743, 1992.