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PEP-II Design Update and R&D Results

William Barletta and Michael S. Zisman Accelerator & Fusion Research Division Lawrence Berkeley Laboratory, Berkeley, CA 94720 U.S.A. and Robert A. Bell and Jonathan M. Dorfan Stanford Linear Accelerator Center Stanford, CA 94309 U.S.A.

for the SLAC/LBL/LLNL PEP-II Design Group*

Abstract

We describe the present status of the PEP-II asymmetric B factory design undertaken by SLAC, LBL, and LLNL. Design optimization and changes from the original CDR are described. R&D activities have focused primarily on the key technology areas of vacuum, RF, and feedback system design. Recent progress in these areas is described. The R&D results have verified our design assumptions and provide further confidence in the design of PEP-II.

1. INTRODUCTION

The conceptual design for the PEP-II asymmetric *B* factory, carried out as a collaboration of SLAC, LBL, and LLNL, was completed in February, 1991 [1]. The design goal for PEP-II, which comprises a high-energy ring (HER) of 9 GeV e⁻ and a low-energy ring (LER) of 3.1 GeV e⁺, is to provide a luminosity of $\mathcal{L} = 3 \times 10^{33}$ cm⁻² s⁻¹. Since the conceptual design report (CDR) was completed, the design has continued to evolve and R&D is being carried out in the technological areas of vacuum, RF, and feedback. The main design changes and R&D results are summarized here.

2. DESIGN OVERVIEW

The two-ring PEP-II facility will be located in the 2200-m circumference PEP tunnel, with the new LER mounted atop the HER. The HER reuses most of the components from the existing PEP ring. The injector for the rings makes use of the present SLC injector, which routinely provides 3×10^{10} e[±] per pulse at 120 pps (compared with a PEP-II design requirement of $0.2-1 \times 10^{10}$ e[±] per pulse). With this injection system, the estimated top-off time for the operating collider is 3 minutes, and the time to fill the rings from zero current is about 6 minutes. A summary of the main PEP-II parameters is given in Table 1.

Table 1. Main PEP-II Parameters.		
	LER	HER
Energy, E [GeV]	3.1	9
Circumference, C [m]	2200	2200
$\varepsilon_{v}/\varepsilon_{x}$ [nm·rad]	2.6/64	1.9/48
β_y^*/β_x^* [cm]	1.5/37.5	2.0/50.0
50x.0v	0.03	0.03
f _{RF} [MHz]	476	476
V _{RF} [MV]	5.9	18.5
Bunch length, σ_t [mm]	10	10
Number of bunches, k_B	1658 [†]	1658†
Damping time, τ_{rv} [ms]	40.3	37.2
Total current, I [A]	2.14	0.99
U_0 [MeV/turn]	1.14	3.6
Luminosity [cm ⁻² s ⁻¹]	3×10^{33}	

[†]includes gap of ≈5% for ion clearing

3. DESIGN OPTIMIZATION

3.1 Lattice Design

The main changes with respect to the CDR design involve the LER lattice. To increase the emittance contribution and radiation damping from the arcs (thereby reducing the dependence on wigglers), the LER arc dipole length has been reduced from 100 cm to 45 cm. Increasing the width of the LER vacuum chamber to provide additional conductance has made this solution acceptable. The LER arcs now provide half of the required damping decrement and half of the required emittance for the LER.

We have also increased the symmetry of the LER by making the magnet arrangement mirror symmetric about the interaction point (IP), as described in Ref. [2]. We have examined the concept of "local" chromaticity correction in which sextupoles are located in the interaction region (IR) straight section itself to control the chromaticity generated by the IR quadrupoles. This approach reduces the higherorder chromaticity that must otherwise be controlled with the arc sextupoles alone. Finally, we reduced β_y^* and β_x^* in the HER to 2 cm and 50 cm respectively and the design

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luminosity is now reached with a lower current of 0.99 A in the HER and a smaller emittance of 64 nm rad in the LER.

Based on beam-beam simulations of the injection process [3], we have now adopted a vertical injection scheme for the rings. This keeps the injected beam well away from the stored beam in the other ring at the parasitic crossing points and thus minimizes the beam blowup during injection. Horizontal injection is still an acceptable option but leads to more blowup and thus potentially more detector background.

3.2 IR Design

The PEP-II IR design is based on an "S-bend" geometry, as illustrated in Fig. 1. Compared with the CDR design, we now have fewer magnets (2 vs. 3 IR quadrupoles) and a stronger B1 separation dipole (tapered for maximum strength and minimum interference with the detector solid angle). This configuration, in combination with the reduced emittance in the LER, leads to larger horizontal separation at the parasitic crossing points (11.8 σ vs. 7.6 σ). Only the Q1 quadrupole is common to both HER and LER. The Q2 magnet is a conventional septum quadrupole acting only on the low-energy beam.

As part of the IR design procedure, we have adopted criteria against which any proposed design is tested. For example, we design for an aspect ratio of $\sigma_y/\sigma_x \ge 0.04$. This minimizes the potential loss in luminosity associated with the beams being tilted at the IP. Another criterion is to use a "graded aperture" whereby the acceptance at the IR is 15 σ , that in the adjacent straight sections is 12.5 σ , and that in the arcs is 10σ . This ensures that particle losses will preferentially occur far from the detector. As with all *B* factory projects, we carry out extensive studies of detector backgrounds [4].



Fig. 1. PEP-II IR layout (anamorphic plan view).

4. R&D PROGRESS AND PLANS

R&D activities permit us to verify design choices and optimize design parameters. Results of the R&D activities are continually folded back into the project design. Examples of this include the down-sampling feature added to the multibunch feedback system [5], the detailed calculations of the higher-order mode (HOM) damping and thermal loading of the RF cavities [6], the simplified approach to the HER vacuum chamber design [7] and the improved support system resulting from shortcomings which were apparent from our mockup.

4.1 Vacuum System

We have carried out extensive photodesorption studies using the VUV ring at BNL [8]. Initial studies used copper bars to choose acceptable materials for the chamber, and subsequently an actual chamber was studied to examine fabrication and cleaning issues. Chamber production is being studied in detail to determine optimum fabrication, cleaning, and assembly techniques. We are also preparing a series of tests on the pumping speed of distributed ion pumps (DIPs) to optimize the pumping cell design and verify the pumping speed of our chosen configuration.

The status of this work [7] is that materials choices have been made (C10100 copper for the chamber body and C10300 copper for the cooling bar), and the required photodesorption coefficient, $\eta \le 2 \times 10^{-6}$, has been achieved after an equivalent PEP-II photon dose of only 25 A-hr. A DIP test facility, utilizing an actual PEP dipole, has been fabricated, with pumping tests to be completed in the next few months. Over 70 m of arc chamber extrusions, both dipole and quadrupole chambers, have been procured along with the cooling bar extrusions. The chambers meet tolerances and are acceptable in all respects. Electron-beam welding techniques have been developed for attaching the cooling bar to the chamber body. A fixture has been built which bends the dipole chambers to the required sagitta.

In the next six months, we plan to use the prototype HER extrusions to carry out a realistic fabrication sequence which will result in a complete arc cell vacuum assembly. Impedance measurements of the various chamber components will also be performed.

4.2 RF System

The R&D goals of the RF system program have included fabricating a low-power test cavity and measuring its HOM properties. In addition, tests to verify the efficacy of the proposed waveguide damping scheme have been carried out, resulting in damping of the most dangerous longitudinal HOM (TM011) to $Q \approx 30$ (compared with a desired reduction to Q < 70). A program of three-dimensional thermal and mechanical stress calculations for the RF cavity has been carried out in collaboration with the AECL Chalk River Laboratory (CRL) to devise a suitable cooling scheme for the high-power cavity [9]. This cavity is in final design with fabrication to commence soon. A high-power test stand that will be used for the cavity tests (150 kW design goal) and window tests (500 kW design goal) is now available, powered by a 500-kW modified PEP klystron retuned to 476 MHz. These tests will be carried out in the upcoming year. Considerable emphasis has been placed on the development of an RF feedback system to avoid driving coupled-bunch instabilities with the fundamental mode. A detailed simulation model of the RF feedback system has been carried out in collaboration with CRL and the results are very promising [10]. The design of a 1.2-MW, 476-MHz klystron is well under way, with materials on order for fabrication, and full-power testing planned in the next eighteen months.

4.3 Feedback System

The feedback system R&D in the past year has concentrated on optimizing the design of the longitudinal system. In addition to carrying out simulations with realistic parameters, actual system tests have been performed with beam, using the SPEAR ring at SLAC [11] and the Advanced Light Source (ALS) at LBL. These measurements verify that the system performs properly and understandably under "combat" conditions. In addition, the data have allowed us to verify, in detail, the validity of our simulation package. Our simulations have shown that the down-sampled design is both simple and effective, and that realistic noise and bunch-to-bunch coupling in pickup and kicker do not degrade system performance. At the present time a full prototype longitudinal and transverse systems are being designed. These prototypes will be installed and tested at the ALS beginning in November 1993.

4.4 Magnets and Supports

In the past year we have completed a full-cell hardware mockup of the PEP-II rings and performed mechanical stability and alignment tests. Based on this work, we intend to modify the LER support structure for better alignment line-of-sight. As mentioned, the vacuum system and its supports will be included in this setup. A prototype LER quadrupole will be fabricated and measured to ensure it meets field-quality requirements.

5. SUMMARY

Major progress has been made on the PEP-II design in the past year. Technical uncertainties have been successfully eliminated and no significant new problems have been uncovered. R&D activities are also well under way and have resulted in important design improvements. The issues being studied by the PEP-II team are of great interest to the entire new generation of colliders and storage rings, including B, Φ, τ -charm factories, hadron colliders (SSC, LHC) and new generation light sources.

The PEP-II project has a strong design team combined with an excellent site from which to mount it. We are looking forward to receiving soon the go-ahead to begin construction.

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