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PEP-II Asymmetric *B* Factory: R&D Results*

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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 been proposed by SLAC, LBL and LLNL as an upgrade of the existing PEP collider. An aggressive R&D program is now under way to validate the design choices. Progress and plans are described for the prototype low- and high-power RF cavities and the prototype 476-MHz, 500-kW klystron, and advances in the bunch-by-bunch longitudinal feedback system are indicated. Gas desorption tests (performed at BNL) on typical vacuum chamber materials are discussed. Progress in designing the IR is outlined and, finally, the tunnel mock-up is described.

1. INTRODUCTION

In early 1991, a conceptual design[1] for the PEP-II collider was submitted to the U.S. Department of Energy. Since that time, R&D activities aimed at optimizing the design and confirming design choices have been carried out. PEP-II will be housed in the PEP tunnel and will make use of the existing PEP magnets and infrastructure (Fig. 1); no conventional construction is required to build the facility. The collider will consist of two rings, a high-energy ring (HER) for 9 GeV electrons and a low-energy ring (LER) for 3.1 GeV positrons. To achieve the design luminosity, high beam currents (1–2 A) are needed. Our design approach is to maintain single-bunch parameters at values typical of today's colliders but to use a substantially larger number of bunches (1658 per ring). Because of the large bend radius of the PEP magnets (165 m), the synchrotron radiation losses are moderate in PEP-II. This permits the design to make use of relatively standard vacuum chamber approaches and well-understood room-temperature RF cavity technology. A list of main collider parameters appears in Table 1.

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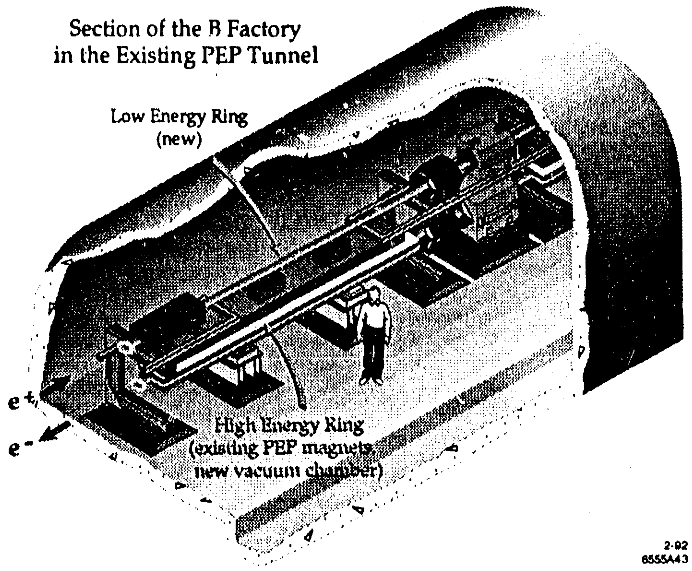

Fig. 1. Cutaway view of PEP-II tunnel.

Table 1. Main PEP-II Parameters

	LER	HER
Energy, E [GeV]	3.1	9
Circumference, C [m]	2200	2200
$\varepsilon_y/\varepsilon_x$ [nm·rad]	3.9/97	1.9/48
β_y^*/β_x^* [cm]	1.5/37.5	3.0/75.0
$\xi_{0x,0y}$	0.03	0.03
f_{RF} [MHz]	476	476
V_{RF} [MV]	9.5	18.5
Bunch length, σ_ℓ [mm]	10	10
Number of bunches, k_B	1658[a]	1658[a]
Damping time, $\tau_{x,y}$ [ms]	36.4	37.2
Total current, I [A]	2.14	1.48
U_0 [MeV/turn]	1.2	3.6
Luminosity [$cm^{-2}s^{-1}$]	3×10^{33}	

[a]Includes gap of ≈5% for ion clearing.

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2. RF System

The high circulating beam currents in the PEP-II rings excite strong wakefields in the RF cavities that couple the motion of the many bunches in each ring and lead to very strong instabilities. Two complementary approaches are used in PEP-II to deal with this effect. The first is to reduce the amount of HOM impedance by minimizing the number of installed RF cavities. The second is to damp the unwanted HOMs by means of broadband loads.[2]

In the PEP-II HER, the wall power (per cell) is 130 kW. To assess the thermal behavior, a three-dimensional computer model was generated. The thermal loads appear not to be excessive and can be handled with straightforward cooling techniques. We are now collaborating with Chalk River Laboratories in the design of a high-power test cavity to demonstrate a satisfactory cooling design. A model cavity will be available for testing by year's end.

For full-power tests on the high-power cavity model, a 500-kW klystron operating at 476 MHz is needed. The new klystron is based on a 353-MHz PEP klystron. It retains the gun structure of the original klystron but the accelerating structures are redesigned to reflect the higher frequency needed for PEP-II. The klystron will be part of a high-power stand to test both the cavity and the RF window (which must operate reliably at a 500-kW power level). The ultimate goal of this aspect of the R&D effort is to produce 1.2 MW klystrons that will each power two RF cavities in PEP-II.

With 20 RF cavities, the HOM impedance would give unmanageable instability growth rates in the PEP-II HER. To further reduce the growth rates, we use a broadband damping technique whereby the cavity body is penetrated by three waveguides to which damping loads are attached (see Fig. 2). Dimensions are selected such that the waveguides are beyond cutoff for the fundamental RF mode but allow the HOM fields to propagate. Our estimates[1] indicate that the Q of the fundamental is reduced by only about 5% when the strong TM011 mode is damped by a factor of 1000. Based on ARGUS calculations, a waveguide location has been selected that couples well to the expected HOM fields. A low-power prototype cavity (Fig. 2), in the final stages of fabrication, will be measured to ensure that no HOMs escape damping.

3. Feedback

Even after damping the cavity HOMs to $Q \approx 70$, longitudinal and transverse feedback systems are required. The longitudinal system proposed for PEP-II is based on a novel digital signal processing architecture described in Ref. 3. In optimizing the design of the system, we have adopted a down-sampling technique. With our chosen parameters, the kicker voltage is only updated every fourth turn for each bunch. This technique considerably reduces the amount and complexity of the feedback system processing hardware, with essentially no loss in system performance. Moreover, the down-sampling technique permits the PEP-II feedback system architecture to be applicable to many rings, including the ALS at LBL and DAFNE at Frascati. Both these projects are now collaborating

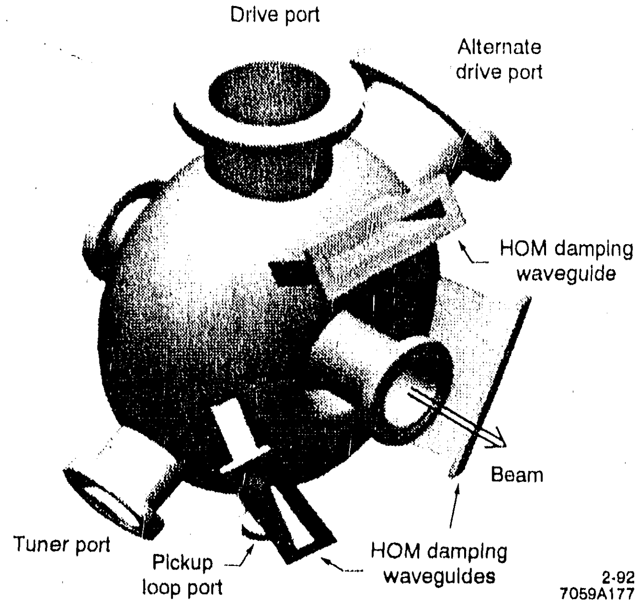

Fig. 2. Low-power PEP-II RF cavity prototype.

on various aspects of the feedback R&D program. A prototype longitudinal kicker has been fabricated and is undergoing wire measurements at LBL to examine its response.

In the transverse case, coupled-bunch instabilities are driven by the resistive-wall impedance rather than that from the RF cavity HOMs. In this case, down-sampling techniques are not applicable and we are focusing on a simpler analog approach.

4. Interaction Region

The interaction region R&D is aimed at optimization of the design presented in the CDR.[1] The updated design has simplified beam-separation optics, an increased level of engineering detail, and further elaboration of background simulations (now including the effect of the detector solenoid on lost-particle trajectories).

Simplification of the optics has resulted in fewer optical elements close to the interaction point (IP). Whereas the CDR design had eight permanent magnets (two dipoles and six quadrupoles) within ±2 m of the IP, the present design has only four (two dipoles and two quadrupoles). This permits more space for the placement of masks, pumps, trim coils for the permanent magnets, etc. The superconducting septum quadrupole used in the CDR design is now replaced by a room-temperature magnet. The level of engineering specification for the IR region is considerably more detailed.

Background simulations have been improved in several ways. The simulation of the scattering from masks has been made more realistic by including the tapered mask tip geometry. This reduces the synchrotron radiation backgrounds by about a factor of four compared with earlier estimates. The lost-particle backgrounds depend on details of the particle trajectories. Present simulations include the effect of the detector magnetic field. While significant, this can be fully compensated with small changes in the positioning of the IR magnetic elements. We also now include the background from the radiative Bhabha final state ($e^+e^-\gamma$). This process can greatly increase photon-induced backgrounds. Fortunately, the detector can be shielded against the radiative Bhabha background. Software tools for isolating the exact sources of lost-particle backgrounds are much improved. Background levels for the new IR design, like those in the CDR,[1] are well below the conservative limits set for detector performance.

5. VACUUM SYSTEM

Vacuum system R&D activities are in the areas of beam tests of desorption, development of a test setup for studying distributed ion pumping speed at low pressure, examining possible bellows designs and fabrication techniques, and optimizing fabrication techniques for the copper chambers.

Synchrotron radiation levels at PEP-II are about ten times those of PEP. To compensate for the resultant higher gas load and to provide a self-shielding beam environment, the PEP-II vacuum chambers will be constructed from copper. Copper is expected to desorb gas molecules ten times less copiously than aluminum. Because the chamber design relies crucially on the assumption of low desorption, we have embarked on a program of desorption measurements at BNL using photon beams from the National Synchrotron Light Source. These measurements are performed by a collaboration of LLNL and BNL scientists and engineers. Thus far, measurements have been completed on five different copper bars; measurements are currently under way on a cylindrical chamber fabricated in much the same way we envision for the actual PEP-II chambers. Present results, summarized in Table 2 and Fig. 3, demonstrate that adequately low photodesorption yields can be obtained with copper in a reasonable amount of running time.

The five bars summarized in Table 3 come from four different vendors and differ in their surface finish. The first two (C10100 and C15715) had machined surfaces, the other three bars (C10100, C10300 and C10700) had surfaces as prepared by the manufacturer. We see from Fig. 3 that the desorption yields drop to acceptable values with a relatively small dose. After 3×10^{23} accumulated photons, the bar was glow-discharge cleaned, resulting in a significant further reduction of desorption yield. These curves are typical of all samples, though the rate of cleanup of the samples differs. Note that no sample is seen to "bottom out," i.e., they all continue to clean up with increased dose. The measured desorption properties are fully compatible with the PEP-II specifications. These tests are continuing and will form the basis of the choice of PEP-II vacuum chamber material.

Table 2. Desorption yield (molecules per incident photon)

Sample	Accum. dose (photons/m)	CO	CO_2	CH_4
C10100	4.5×10^{23}	1×10^{-6}	6×10^{-7}	4×10^{-8}
C15715	4.5×10^{23}	3×10^{-6}	4×10^{-7}	6×10^{-8}
C10100	$\sim 2 \times 10^{23}$	9×10^{-6}	4×10^{-6}	4×10^{-7}
C10300	3.5×10^{23}	6×10^{-6}	2×10^{-6}	2×10^{-7}
C10700	3×10^{23}	9×10^{-6}	3×10^{-6}	2×10^{-7}

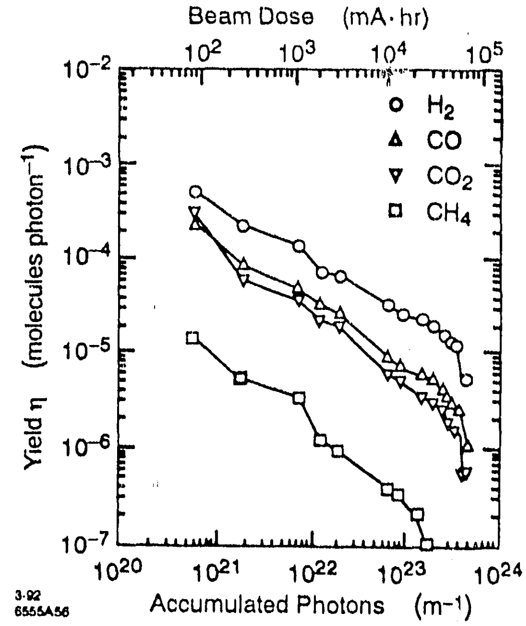

Fig. 3. Desorption coefficients for C10100 sample.

6. PEP-II SUPPORT SYSTEM MOCK-UP

A mock-up of the PEP-II two-ring support system has been set up. The supports have been built as currently conceived (see Fig. 1). A short section of PEP was demounted and the magnets refurbished in the manner anticipated for PEP-II. These magnets, which will be used for the HER, were incorporated into the mock-up. In addition, dummy magnets for the LER and dummy vacuum chambers were fabricated to simulate the proper space requirements and weight distribution. The mock-up spans three standard PEP-II half-cells. The purposes of the mock-up are to: validate the structural integrity and ease of fabrication; establish the level of refurbishment required for existing PEP components; establish optimal alignment procedures; address spatial conflicts; permit vibration measurements; and optimize installation procedures. This study has resulted in a decrease in the estimated time for the magnet removal process, with a concomitant cost savings.

7. SUMMARY

Great progress has been made at optimizing the design of PEP-II. R&D results have confirmed design expectations and indicated ways to simplify and improve the collider design. In the next year we look forward to completing the remaining R&D tasks and being ready to commence construction.

REFERENCES

[1] "An Asymmetric B Factory Based on PEP," Conceptual Design Report, LBL PUB-5303, SLAC-372, CALT-68-1715, UCRL-ID-106426, UC-IIRPA-91-01 (1991).

[2] R. Rimmer, et al., "Higher Order Mode Damping Studies on the PEP-II B-Factory RF Cavity," these proceedings.

[3] H. Hindi, et al., "Downsampled Signal Processing for a B Factory Bunch by Bunch Feedback System," these proceedings.

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