

STATUS AND FUTURE PLANS OF THE PEP-II B-FACTORY*

Y. Cai, J. Clendenin, F. J. Decker, M. Donald, S. Ecklund, R. Erickson, A. Fisher, S. Heifets, R. Holtzapple, R. Iverson, P. Krejcik, A. Kulikov, J. Nelson, A. Novokhatski, I. Reichel, J. T. Seeman, M. Stanek, M. Sullivan, J. Turner, U. Wienands, SLAC, Stanford, CA 94309, USA
C. Steier, M. Zisman, LBNL, Berkeley, CA 94720, USA
M. Biagini, INFN, Frascati, Italy
W. Kozanecki, Saclay, France

Abstract

The PEP-II e+e- collider [1,2,3,4] has been operating for two years with the BaBar detector at the energy of the Upsilon 4S resonance. The peak luminosity has reached $3.3 \times 10^{33}/\text{cm}^2/\text{s}$ with 693 bunches with a positron current of 1.5 A and an electron current of 0.8 A. PEP-II has delivered in excess of 38 fb^{-1} of data to BaBar. The beam-beam tune shift limits are approaching 0.05-0.07 horizontally and 0.03-0.05 vertically [5]. The electron cloud instability ECI enlarges the positron beam size at high currents but is reduced by a solenoidal field on the vacuum chambers [6]. The beam currents in PEP-II are being raised to increase the number of bunches and the luminosity. Over the next few years the luminosity goal for PEP-II is $10^{34}/\text{cm}^2/\text{s}$.

1 PEP-II COLLIDER

PEP-II is an e+e- collider with asymmetric energies (3.1 and 9 GeV, respectively) in a 2200 m tunnel at the Stanford Linear Accelerator Center. The collider produces B mesons to study a particle physics effect called CP violation as well as other physics topics. PEP-II was completed in 1998 with the first luminosity generated in July of that year. The installation of the BaBar Detector was finished in May 1999.

The overall layout of PEP-II is shown in Figure 1. The accelerator parameters and achievements of the High Energy Ring (HER) are listed in Table 1 and those for the Low Energy Ring (LER) in Table 2. The two beams collide at a single point in the IR2 hall where the BaBar detector is located. Beam parameters at the best luminosity are shown in Table 3. General PEP-II milestones are listed in Table 4.

The salient features of the PEP-II collider design are LER-above-the-HER rings, head-on collisions but with dipoles bends near the collision point, new copper RF cavities with HOM damping, strong bunch-by-bunch feedback systems, many bunches (1658), high stored charges (2.0A x 1.0 A), permanent magnet interaction region quadrupoles and dipoles, and use of the existing SLAC linac as an injector but with new transport lines.

The PEP-II run with BaBar is going very well. The luminosity reached 110% of design or $3.3 \times 10^{33}/\text{cm}^2/\text{s}$ on October 29, 2000, and an integrated luminosity day of 163% of design or 220 pb^{-1} occurred June 29, 2001. The total delivered integrated luminosity to date is 38 fb^{-1} . The peak luminosity and integrated luminosity plots over the past two years are shown in Figures 2 and 3.

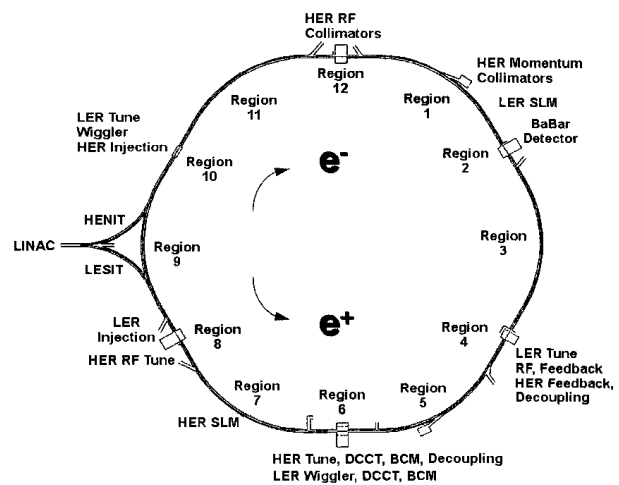


Figure 1: PEP-II B-Factory Overview

Table 1 PEP-II HER Parameters and Results

HER Parameter	Design	Achieved
Beam energy (GeV)	9.0	9.1
Number of bunches	1658	1658
Particles per bunch	2.1×10^{10}	5.6×10^{11}
Total current (mA)	750	920
Current per bunch (mA)	0.45	>12.
Bunch spacing (m)	1.26	0.63
Bunch length (mm)	11.0	12.0
$\Delta E/\text{turn}$ (MeV)	3.6	3.6
RF frequency (MHz)	476.	476.
Ion clearing gap (%)	5	5
RF voltage (MV)	14.0	14.0
Rel. energy spread (10^{-3})	0.61	0.61
Synchrotron tune	0.045	0.045
Betatron tune (ν_x/ν_y)	24.62/23.64	24.57/23.64

*Work supported in Department of Energy contract numbers DE-AC03-76SF00515 and DE-AC03-76-SF00098.

Table 2 PEP-II LER Parameters and Results

<u>LER Parameter</u>	<u>Design</u>	<u>Achieved</u>
Beam energy (GeV)	3.1	3.1
Number of bunches	1658	1658
Particles per bunch	5.9×10^{10}	3.2×10^{11}
Total current (mA)	2140	2141
Current per bunch (mA)	1.29	>7.
Bunch spacing (m)	1.26	0.63
Bunch length (mm)	10.0	12.
$\Delta E/\text{turn}$ (MeV)	0.75	0.68
RF frequency (MHz)	476.	476.
Ion clearing gap (%)	5	5
RF voltage (MV)	5.1	4.5
Rel. energy spread (10^{-3})	0.77	0.70
Synchrotron tune	0.033	0.032
Betatron tune (ν_x/ν_y)	38.57/36.64	38.65/36.58

2 ACCELERATOR PHYSICS

The peak luminosity was achieved using 693 bunches with 1550 mA of positrons and 850 mA of electrons. The bunches were spaced every four RF buckets in 35 short trains of 20 bunches each. There is a 5% ion clearing gap. The beta x and y at the collision point were 50 cm and 1.25 cm, respectively. The first e^+ bunch in each mini-train is under filled by about 10% to avoid blowing up its respective e^- bunch by the beam-beam force. That e^+ bunch is not enlarged as much by ECI as the other e^+ bunches.

Table 3 PEP-II Collision Parameters

<u>IR Parameter</u>	<u>Design</u>	<u>Present Operating</u>
C-M energy (GeV)	10.28	10.28
Crossing angle (mrad)	0.0	<0.1
Luminosity ($\times 10^{33}$)	3.00	3.30
Number of bunches	1658	693
HER current (mA)	750	850
LER current (mA)	2146	1550
Beam-beam parameter ($y+/-$)	0.03	0.055/0.028
Beam-beam parameter ($x+/-$)	0.03	0.069/0.059
β_y^*/β_x^* (cm/cm)	1.5/50.	1.25/50.
Optimum coupling (%)	3.0	2 to 6
Emittance (nm-rad) (y/x)	1.5/49.	3/30+, 2/50-
IP rms beam σ_y/σ_x (mm)	4.7/157.	5.0/147
$\Sigma_{x,y}$ (microns)(at low I)	6.7/222	6.7/207
Injection top-off time (min)	3	2
Injection full fill time (min)	10	8
Detector solenoid field (T)	1.5	1.5
Int. luminosity in 8 hours pb^{-1}	45	76
Int. luminosity in 24 hours pb^{-1}	135	220
Int. luminosity per week pb^{-1}	785	1048
Int. luminosity per month pb^{-1}	3300	3870
Total integrated luminosity thru 6/22/01		38 fb^{-1}

Table 4 PEP-II Milestones

<u>Date</u>	<u>Milestone or Commissioning</u>
1994 January	Start of PEP-II construction
1997 June 16	HER beam first stored
1998 July 16	LER beam first stored
1998 July 23	First collisions
1999 May 10	BaBar detector installed
1999 May 26	First hadronic events recorded
1999 June 15	Scan of the Upsilon 4S
1999 Sept 14	Luminosity peak of 1.35×10^{33}
2000 June 11	Integrated 150 pb^{-1} in one day
2000 Oct 29	Luminosity peak of 3.30×10^{33}
2001 June 29	Integrated 220 pb^{-1} in 24 hours
2001 June 29	Total delivered luminosity of 38 fb^{-1}

Several coasting beam fills with BaBar were tried with a bunch pattern having every other bucket filled. This bunch spacing is the design pattern (called the "by-2" pattern) having potential parasitic crossing effects. With full colliding currents and the by-2 bunch pattern the nominal peak luminosity was nearly achieved (90-95%) in a few hours. The main effect was to shift the vertical tune by about 0.01. This bodes well for the future when we will try for higher luminosity with more bunches.

Over the past year, a PEP-II vacuum bellows next to the beryllium vacuum chamber in the center of BaBar has developed elevated temperatures at the higher beam currents. Studies were made of the heating of this component under various beam conditions (current, bunch length, number of bunches, orbit offsets and angles). It is likely that the heating comes from HOM power from an abrupt transition crotch in the forward end of the IR.

The transverse size of the positron beam is enlarged at high currents by the electron cloud instability from multipacting electrons, as is now commonly seen in several accelerators. A solenoid capable of 30 gauss has been wrapped on the straight section vacuum chambers to suppress these electrons. A length of 600 m has been wound resulting in a luminosity increase of order 70% over the past year. With the present solenoids the beam size enlargement starts at about 1300 mA with four bucket spacing and is seen in both the vertical and horizontal planes. PEP-II is now embarking on a program to wind solenoids in the LER bending arcs to suppress multipacting and photo-electrons there. About 200 chambers (5 m each) need winding. 80 m is done so far.

The LER wiggler was turned off a year ago last February to reduce the LER beam size at the collision point to increase the luminosity. The luminosity increased about 40%. Most of the loss in luminosity with the wiggler on was traced to a strong induced x-y coupling. Nothing in the wiggler magnetic measurements data would indicate such a strong coupling. In addition to generating radiation, the wiggler changes the orbit length due to the trajectory wiggles and, thus, moves the beam orbit radially over all of LER. As a test during the

machine studies, a similar radial orbit shift was made by changing the RF frequency while looking at the x-y coupling. The lattice as designed should not couple the beams with a radial orbit shift. However, the RF frequency shift did change the coupling and about as much as the wiggler did. The coupling was traced to a changing vertical orbit in the interaction region which changes the beam position in the local sextupoles causing coupling.

The beams at the interaction point were measured to be tilted by about 1.5 degrees relative to the machine axis. There were also hints from the out of plane beam-beam deflection scans that the two beams were slightly tilted relative to each other.

Tests were made to center the minima of the IR y beta functions at the collision point by moving the waists with the IR quadrupoles while measuring the luminosity using the rf relative phase. The waists were found to be very nearly centered to a few mm.

3 PEP-II UPGRADES

In the three month 2000-2001 winter downtime, new equipment was installed to improve the performance capability of PEP-II. The third LER RF station was installed to allow the LER current to be raised from 1.8 A to 2.7 A. Two new LER movable collimators have been installed near the interaction point to improve the BaBar backgrounds at high currents. A shielding wall was installed in the PEP-II tunnel upstream of BaBar to remove “tunnel shine” from affecting the IFR detectors. Additional vacuum pumps were added to LER Arc 7 to improve the vacuum pressure. A new HER vacuum chamber from 10 to 20 m upstream of BaBar was installed to lower the average pressure to well below 1 nTorr. A new HER high power dump was installed. All these tasks were successful commissioned in spring 2001.

Several upgrade projects for summer 2002 have been started aiming at higher beam currents and an increased luminosity. Two new rf stations (fourth LER and sixth HER) have been started. These new stations will allow the

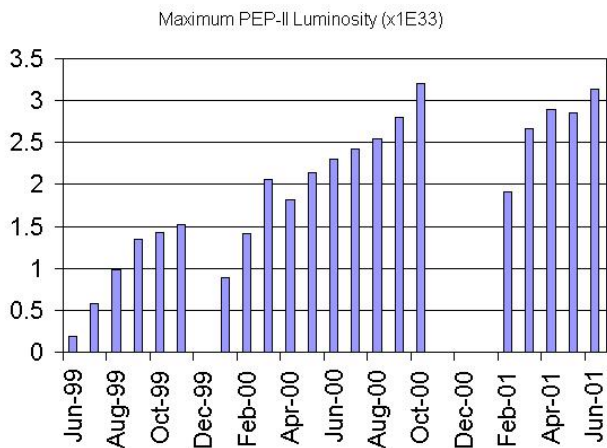


Figure 2 Peak luminosity in PEP-II during each month.

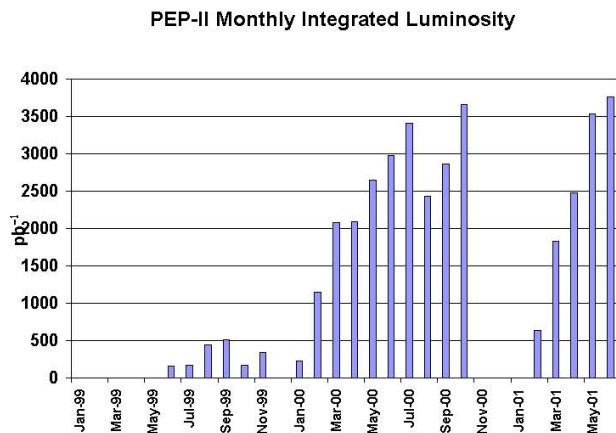


Figure 3: Monthly integrated luminosity delivered by PEP-II to BaBar.

currents to be raised by 20-30% in each ring. Construction has started on improved interaction region vacuum chambers to reduce the HOM heating near the IR.

4 PEP-II FUTURE PLANS

PEP-II is to run continuously through to the end of June 2002 with the hope of integrating 100 pb⁻¹. Then a three to four month down is needed to replace several vacuum chambers near the IR, install two new RF stations, and to repair the Instrumented Flux Return IFR of BaBar.

There are several longer range upgrade plans in place to raise the luminosity to 10³⁴ and, furthermore, the issues for 2 x 10³⁴ are under study. Several of the issues include understanding the empirical skew quadrupole adjustments to make smaller spot sizes, raising the LER and HER currents, reducing beam aborts from short radiation bursts in BaBar and from the RF system, lowering beta y* from 1.25 cm to 0.7 cm, reducing the electron cloud instability, replacing several hot vacuum chambers, and raising the number of bunches.

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