PROGRESS OF THE PEP-II B-FACTORY *

J. Seeman, M. Browne, Y. Cai, W. Colocho, F.-J. Decker, M. Donald, S. Ecklund, R. Erickson, A. Fisher, J. Fox, S. Heifets, R. Iverson, W. Kozanecki, P. Krejcik, A. Kulikov, A. Novokhatski, P. Schuh, H. Schwarz, M. Stanek, M. Sullivan, D. Teytelman, J. Turner, U. Wienands, Y. Yan, J. Yocky, SLAC, Stanford, CA 94309, USA;
M. Biagini, INFN, Frascati, Italy; M. Zisman, LBNL, Berkeley, CA 94720, USA

Abstract

PEP-II is an e^+e^- B-Factory Collider located at SLAC operating at the Upsilon 4S resonance. PEP-II has delivered, over the past five years, an integrated luminosity to the BaBar detector of over 131 fb^{-1} and has reached a luminosity of $6.11x10^{36}/cm^2/s$. Steady progress is being made in reaching higher luminosity. The goal over the next several years is to reach a luminosity of at least $2x10^{34}/cm^2/s$. The accelerator physics issues being addressed in PEP-II to reach this goal include the electron cloud instability, beam-beam effects, parasitic beam-beam effects, high RF beam loading, shorter bunches, lower betay*, interaction region operation, and coupling control. A view of the PEP-II tunnel is shown in Figure 1.

The present parameters of the PEP-II B-Factory are shown in Table 1 compared to the design. The present peak luminosity is 204% of design and the best integrated luminosity per month is 7.4 fb^{-1} that is 225% of design. The best luminosity per month is shown in Figure 2. The integrated luminosity over a month is shown in Figure 3 and the total integrated luminosity in shown in Figure 4.

The progress in luminosity has come from correcting the orbits, adding specific orbit bumps to correct coupling and dispersion issues, lowering the beta y* in the LER, and moving the fractional horizontal tunes in both rings to just above the half integer (<0.52).

Figure 1 View of the PEP-II tunnel.

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**seeman@slac.stanford.edu

Table 1: PEP-II May 2003 Parameters.

Parameter	PEP-II Design	PEP-II Present
Energy (GeV)	3.07x9	3.1x8.97
HER Vertical tune	23.64	23.57
HER Horizontal tune	24.62	24.516
LER Vertical tune	36.64	36.63
LER Horizontal tune	38.57	38.509
HER current (mA)	750	1100
LER current (mA)	2140	1750
Number of bunches	1658	939
Ion gap (%)	5	2.6
HER RF klystron/cav	5/20	7/24
HER RF volts (MV)	14.0	11.5
LER RF klystron/cav.	2/4	3/6
LER RF volts (MV)	3.4	3.2
β_y* (mm)	15-25	11
β_x* (cm)	50	35
Emittance (x/y) (nm)	49/2	21 to 49/3
σ_z (mm)	11	12
Lum hourglass factor	0.9	0.84
Crossing angle(mrad)	0	<0.5
IP Horiz. size Σ (μm)	222	150
IP Vert. Size Σ (μm)	6.7	6.8
HER Horizontal ξ_x	0.03	0.075
HER Vertical ξ_y	0.03	0.060
LER Horizontal ξ_x	0.03	0.065
LER Vertical ξ_y	0.03	0.048
Lumin. ($x10^{33}/cm^2/s$)	3.00	6.11
Int. Lum/month (fb^{-1})	3.3	7.4
Integ. Lumin. (fb^{-1})	100 (for CP)	131

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1 RUN 3 STATUS

PEP-II has been providing colliding beams for the BaBar detector since May 1999 [1-8]. The present run started in November 2002 and will end in June 2003. There will be a two month down this summer with beam starting again in September 2003. During the recent run, colliding beams occupied 70% of the time, 20% for repairs, and 10% for machine development and accelerator physics studies. About 87% of the data logged by BaBar was on the Upsilon 4S resonance and 13% off-resonance about 40 MeV lower. PEP-II has scanned the Upsilon 3S, shown in Figure 5. The highest luminosity in PEP-II is $6.11\text{x}10^{33}/\text{cm}^2/\text{s}$ with the corresponding parameters listed in Table 1. The horizontal beam size of the LER is enlarged at this peak luminosity by about 20%. Also, the vertical beam size of the HER is enlarged by about 20% at the peak luminosity. Both increases are due to the beam-beam effect. 365 pb^{-1} has been delivered in 24 hours. The present delivered luminosity to BaBar is 131 fb^{-1}.

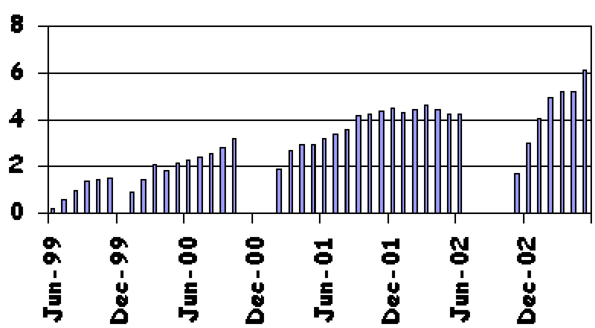

Figure 2 Peak luminosity each month since May 1999. The peak luminosity has reached $6.11\text{x}10^{33}/\text{cm}^2/\text{s}$.

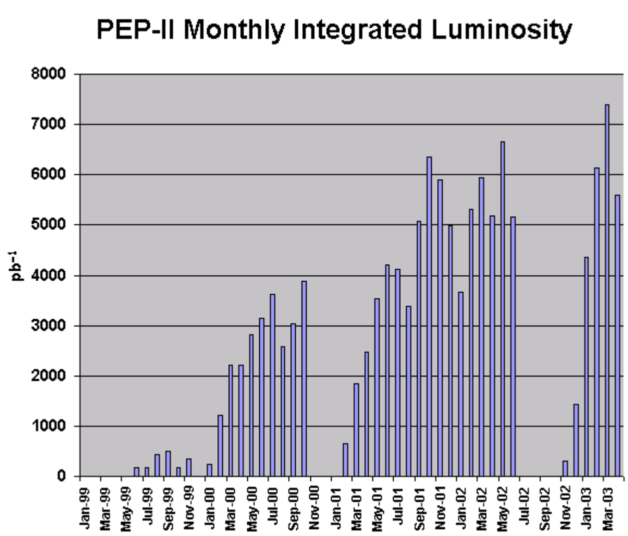

Figure 3 Integrated luminosity per month. In March 2003 PEP-II deliver 7.4 fb^{-1} and BaBar logged 7.2 fb^{-1}.

2 BEAM-BEAM INTERACTION

At low currents, the luminosity increases as the product of the electron and positron bunch charges. At higher currents the LER-x and HER-y beam sizes enlarge due to beam-beam and, perhaps, electron cloud effects in LER, thus, reducing the luminosity increase with current. The HER and LER bunch charges are appropriately balanced to produce near equal beam-beam effects. If there is a miss-balance, flip-flop effects can occur. The horizontal tunes of both rings were recently moved to just above the half integer (~0.52) and an immediate increase of about 20% in luminosity occurred. In order to move the LER to the half integer, the horizontal beta beats in the LER had to be fixed. Moving close to the half integer makes the beta beats worse. A computer algorithm (MIA) was created and recently has been made to work. The beta beats in the LER are below 10%. The HER still needs additional work and will be worked on soon.

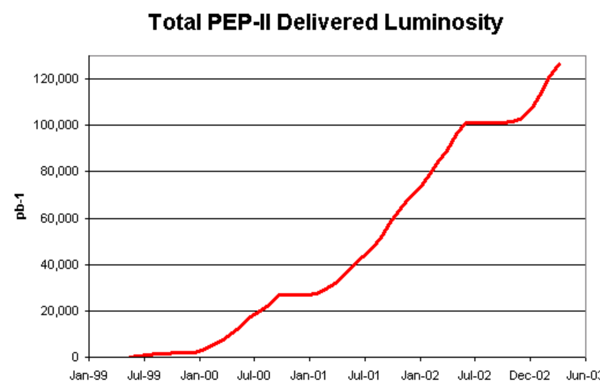

Figure 4 Total delivered integrated luminosity to BaBar by PEP-II. 131 fb^{-1} was delivered by May 2003.

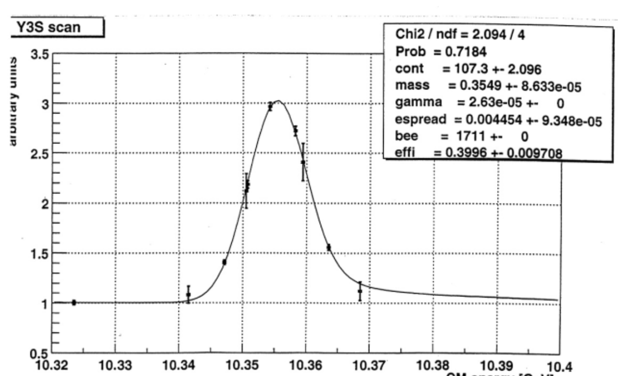

Figure 5 Energy scan of the Upsilon 3S resonance in November 2002.

Recently, PEP-II has been operated with bunches every three RF buckets but with mini-gaps after about 10 to 11 bunches to allow easy bunch number changes and to reduce small ECI effects. A plot of the bunch luminosity over the whole train is shown in Figure 6. There are no obvious signs of ECI over the train. With two bucket spacing, there are signs of electron cloud effects and parasitic beam-beam effects. To help reduce the ECI effects in the By-2 pattern, stronger solenoids will be added to the LER straight sections this coming summer. The parasitic crossing beam-beam effects are largest in the vertical plane where the vertical betas are much larger than the horizontal betas at the parasitic collisions displaced 63 cm from the IP on both sides. As the betay* is lowered the parasitic effects will become stronger. The exact limit of this effect is under study.

Beam-beam parameters from 0.048 to 0.075 are now routinely achieved in PEP-II that far exceed our design goal of 0.03.

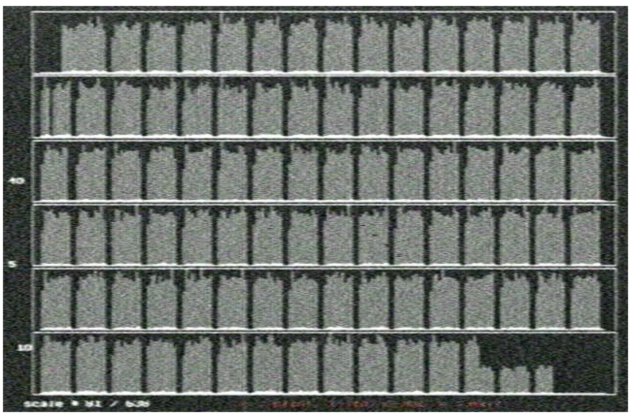

Figure 6 Bunch luminosity along the train with every 3rd RF bucket filled and a 2.6% ion gap at the end of the train. There are mini-gaps of about 5 RF buckets.

3 INTERACTION REGION HEATING

At the interaction point of PEP-II there is a Be chamber surrounded by a precision silicon strip detector SVT of BaBar. The Be chamber is double-walled with water cooling between. At present, the water removes about 1 kW of HOM and I^2R heat load. This 60 cm long chamber is connected to the nearby B1 dipole magnet chamber with a two convolution bellows on each end. In the summer of 2002, the IR support tube was removed and extra cooling of air and water added, new temperature instrumentation was added to the Be chamber bellows, a new Q2 crotch chamber with lower HOM generation was installed, and new higher power Q2 bellows were installed. The increased power capability of a factor of four to five should allow a factor of about four increase in luminosity. During recent operation, the new cooling techniques have performed according to specification.

4 FUTURE PLANS

PEP-II has an upgrade plan that is leading towards a luminosity of greater than $2\text{x}10^{34}$ in FY2006. Combining the equations for luminosity and the vertical beam-beam parameter, one derives the traditional luminosity scaling

$$L = 2.17 \times 10^{34} (1+r) \xi_y \left(\frac{EI}{\beta_y^*} \right) \ \text{cm}^{-2} \text{sec}^{-1} \qquad (1)$$

equation with r the y to x aspect ratio (~0.02), E the beam energy, I the beam current, and β_y* the vertical beta at the collision point. In order to get a factor of four above the present luminosity (to $2\text{x}10^{34}$), the currents will be raised about a factor of two, the tune shifts increased about 10% and β_y* reduced from 12 mm to about 7 mm. The number of RF stations in the LER will be increased from three to four in order in achieve about 3.6 A. The number of RF stations in the HER will be increased from seven to eight allowing a current of 1.6 A. The β_y* can be decreased to about 7 mm using the present IR quadrupole configuration but with extra permanent magnet quadrupole slices replacing some B1 dipole slices. Somewhat increased backgrounds are expected that are under study. The chromatic corrections will be more difficult but early tests indicate an acceptable dynamic aperture. To achieve near $4\text{x}10^{34}$ the β_y* must be lowered to about 5 mm and additional RF stations added to the HER and LER. In order to shorten the bunches, to reduce the hourglass effects, lower alpha lattices would be needed in the HER and LER or higher harmonic RF cavities to increase the effective RF voltage. The details of the $4\text{x}10^{34}$ upgrade will be evaluated in the next few months.

5 ACKNOWLEDMENTS

We wish to thank the Operations Group for their help.

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