RESULTS AND PLANS OF THE PEP-II B-FACTORY *

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Abstract

PEP-II is an e^+e^- B-Factory Collider located at SLAC operating at the Upsilon 4S resonance (3.1 GeV x 9 GeV). PEP-II has delivered, over the past five years, an integrated luminosity to the BaBar detector of about 240 fb^{-1} and has reached a luminosity of $9.21x10^{33}/cm^2/s$. Steady progress is being made in reaching higher luminosity. The goal over the next several years is to reach a luminosity of at least $2.4x10^{34}/cm^2/s$. 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 over three times the design and the best integrated luminosity per month is 16 fb^{-1} that is five times the design. The highest 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 Run 4 in shown in Figure 4.

The progress in integrated luminosity has come from correcting the orbits, lowering beta y*, moving the fractional horizontal tunes in both rings to just above the half integer (<0.52), and trickle injection of both beams.

Figure 1 View of the PEP-II tunnel.

Table 1: PEP-II June 2004 Parameters.

Parameter	**PEP-II Design**	**PEP-II Present**
HER Vertical tune	23.64	23.622
HER Horizontal tune	24.62	24.520
LER Vertical tune	36.64	36.564
LER Horizontal tune	38.57	38.512
HER current (mA)	750	1550
LER current (mA)	2140	2450
Number of bunches	1658	1588
Ion gap (%)	5	2
HER RF klystron/cav	5/20	8/26
HER RF volts (MV)	14.0	16.5
LER RF klystron/cav.	2/4	3/6
LER RF volts (MV)	3.4	3.8
β_y* (mm)	15-25	10.5
β_x* (cm)	50	32
Emittance (x/y) (nm)	49/2	31-59/1.4
σ_z (mm)	11	13
Lum hourglass factor	0.9	0.84
Crossing angle(mrad)	0	<0.1
IP Horiz. size Σ (μm)	222	170
IP Vert. Size Σ (μm)	6.7	7.2
HER Horizontal ξ_x	0.03	0.055
HER Vertical ξ_y	0.03	0.046
LER Horizontal ξ_x	0.03	0.053
LER Vertical ξ_y	0.03	0.064
Lumin. ($x10^{33}/cm^2/s$)	3.00	9.21
Int. Lum/month (fb^{-1})	3.3	16.02
Total Integ. Lumin. (fb^{-1})	100 (for CP violation)	240

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RUN 4 STATUS

PEP-II [1-8] has been providing colliding beams for the BaBar detector since May 1999. The present Run 4 started in September 2003 and will end in July 2004. There will be a two month down this summer with beam starting again in October 2004. During the recent run, colliding beams occupied 74% of the time, 20% for repairs, and 6% 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. The highest luminosity in PEP-II is $9.21 \times 10^{33}/cm^2/s$ with the corresponding parameters listed in Table 1. The horizontal beam size of the LER is enlarged at this peak luminosity by about 30%. 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. 710 pb^{-1} has been delivered in 24 hours. The present delivered luminosity to BaBar is about 240 fb^{-1}.

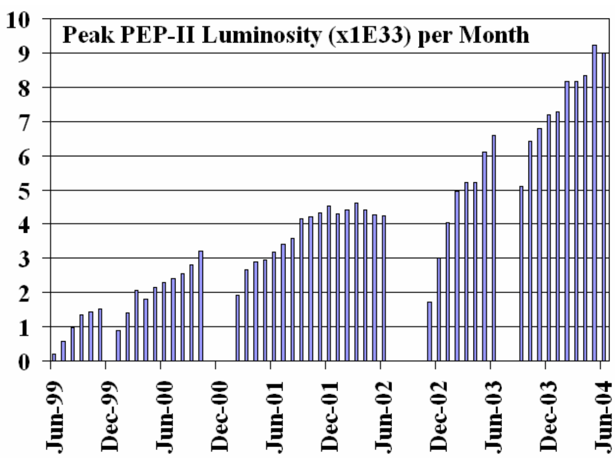

Figure 2 Peak luminosity each month since May 1999. The peak luminosity has reached $9.21 \times 10^{33}/cm^2/s$.

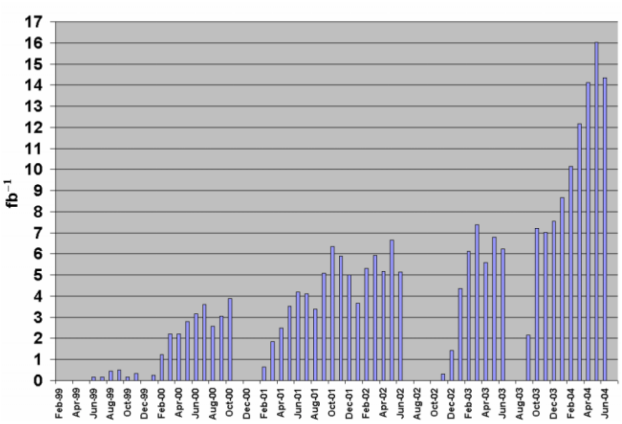

Figure 3 Integrated luminosity per month. In May 2004 PEP-II delivered 16 fb^{-1}.

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, interaction region parasitic collisions; 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 closer to the half integer (~0.51 to 0.52) and an increase of about 10% in luminosity occurred. In order to move the HER to the half integer, the horizontal beta beats in the HER 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 both rings are now below 50%.

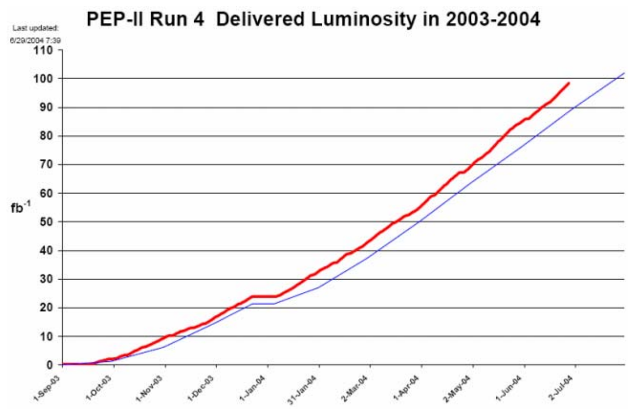

Figure 4 Delivered integrated luminosity to BaBar by PEP-II in Run 4: 100 fb^{-1} so far in Run 4 and a grand total of 240 fb^{-1} has been delivered from May 1999 to June 2004.

Figure 5 PEP-II's best day showing trickle injection and a 710 pb^{-1} integrated luminosity.

Since October 2003, PEP-II has operated with bunches every two RF buckets but with mini-gaps of a few RF buckets after about 66 bunches. 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. Any potential 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 but so far we see at most a few percent luminosity loss. Beam-beam parameters from 0.046 to 0.064 are now routinely achieved in PEP-II that far exceed our design goal of 0.03.

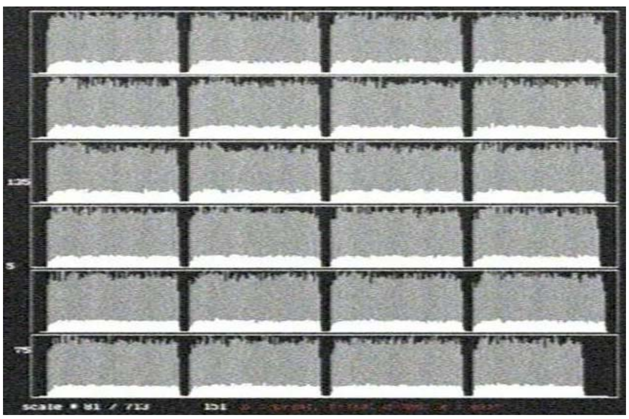

Figure 6 Bunch luminosity along the train with every 2nd RF bucket filled and a 2 % ion gap at the end of the train. There are mini-gaps of about 3 RF buckets.

CONTINUOUS (TRICKLE) INJECTION

A collaboration between the PEP-II accelerator operators and the BaBar detector operators have worked for several years to make injection losses small. After ten or so machine studies shifts spaced over a year and hard work in between, PEP-II and BaBar have reduced the backgrounds to an acceptable level to allow BaBar to take data continuously. Trickle injection for the positron ring of PEP-II was good enough for production data running at BaBar in November of 2003. The improved efficiency for data taking was about 30% within a few days. Trickle injection for positrons uses about three injection pulses per second from the SLAC linac, resulting in the positron current being stable to about 0.1% with BaBar recording better than 98% of the data. The electron ring at PEP-II was more difficult and studies continued until March 2004 before trickle injection was successful. About two linac pulses per second is all that is needed to keep the electron current stable to 0.1%. Since March 2004, both PEP-II rings are trickle injected with BaBar taking data. The SLAC linac was designed to allow up to 40 injected positron pulses and also 40 electron pulses each second in any order, although fewer pulses are actually needed. So PEP-II has true trickle injection with very steady currents and steady luminosity, see Figure 5. The overall improvement in efficiency jumped 10% with the second ring and to just over 40% with both rings together.

FUTURE PLANS

PEP-II has an upgrade plan that is leading towards a luminosity of greater than 2.4×10^{34} in FY2007. Combining the equations for luminosity and the vertical beam-beam parameter, one derives the traditional luminosity scaling

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

equation with r the y to x aspect ratio (~0.03), 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 three above the present luminosity (to 2.4×10^{34}), the currents will be raised about a factor of 1.5 to 2, the tune shifts increased about 10% and β_y* reduced from 12 mm to about 8 mm. The number of RF stations in the LER will be increased from three to five in order in achieve about 4.4 A. The number of RF stations in the HER will be increased from eight to ten allowing a current of 2.2 A. The β_y* can be decreased to about 8 mm using the present IR quadrupole configuration. Somewhat increased backgrounds are expected that are under study. The chromatic corrections will be more difficult but early tests indicate an acceptable dynamic aperture. In order to shorten the bunch length to reduce the hourglass effects, a lower alpha lattice will be needed in the HER. The details of the 2.4×10^{34} upgrade will be finalized over the next few months.

ACKNOWLEDMENTS

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