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PEP-II AND KEKB OPERATIONAL STATUS *

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Abstract

The present two B-Factories, PEP-II at SLAC in California and KEKB at KEK in Tsukuba, Japan, operate at the Upsilon 4S and have reached parameter levels unprecedented for e+e- colliders. They have provided very large data samples for their respective particle detectors, BaBar and BELLE. Luminosity has exceeded 1.5 x 10^{34}/cm^2/s. Beam currents have reached 2.5 A with 1600 positron bunches spaced by 4 nsec. Continuous injection with the detectors taking data has added significantly to data collection rates by about 40%. Bunch-by-bunch feedback systems damp strong longitudinal and transverse coupled bunch instabilities. The beam-beam interaction has allowed high tune shift levels even in the presence of parasitic crossing and crossing angle effects. Both B-Factory colliders have significant near term luminosity improvement programs.

PARAMETERS

PEP-II [1] is an e^+e^- asymmetric B-Factory Collider located at SLAC operating at 3.1 GeV x 9 GeV. PEP-II is shown in Figure 1 and 2 and its operating parameters are shown in Table 1. It has reached a luminosity of 9.21x10^{33}/cm^2/s and has delivered an integrated luminosity of 710 pb^{-1} in one day. PEP-II operates in continuous injection mode for both beams boosting the integrated luminosity. The peak positron current has reached 2.45 A in 1588 bunches. Steady progress is being made in reaching higher luminosity. The progress in luminosity has come from correcting the orbits, lowering β_y*, moving the fractional horizontal tunes in both rings to just above the half integer (<0.52), and trickle injection of both beams. The goal over the next several years is to reach a luminosity of 2.1x10^{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 [4], shorter bunches, lower β_y* interaction region operation, and coupling control. PEP-II has delivered an integrated luminosity to the BaBar detector of over 17 fb^{-1} in one month and more than 264 fb^{-1} since 1999.

KEKB [2] is an e^+e^- asymmetric B-Factory Collider located at the KEK laboratory in Tsukuba, Japan, operating at 3.5 GeV x 8 GeV. KEKB is shown in Figure 3 and 4 and its operating parameters are shown in Table 2. It has reached a luminosity of 15.6x10^{33}/cm^2/s and has delivered an integrated luminosity of 1116 pb^{-1} in one day. KEKB operates in continuous injection mode for both beams boosting the integrated luminosity. The peak positron current has reached 1.76 A in 1389 bunches. Steady progress is being made in reaching higher luminosity. The goal over the next several years is to reach a luminosity of 3.0x10^{34}/cm^2/s. The accelerator physics issues being addressed in KEKB to reach this goal include the electron cloud instability, primary beam-beam effects, and crab crossing cavities. KEKB has delivered, over the past six years, an integrated luminosity to the BELLE detector of over 26.5 fb -1 in one month and more than 420 fb^{-1} since 1999.

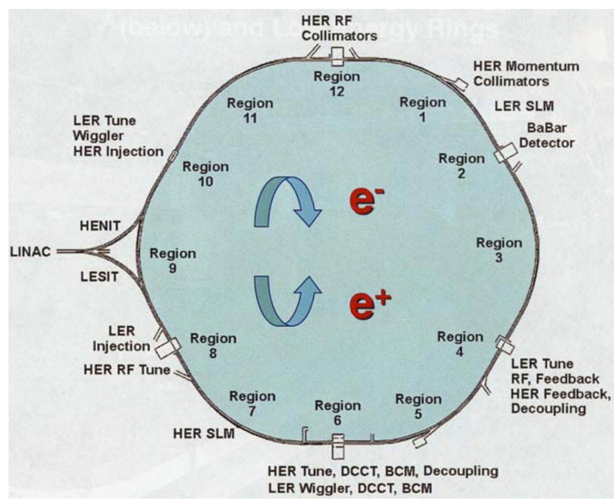

Figure 1. Overview of the PEP-II B-Factory.

Figure 2. Tunnel view of PEP-II

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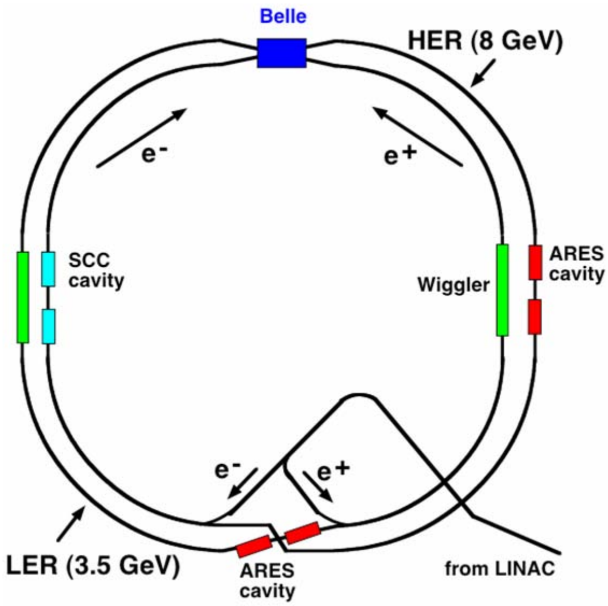

Figure 3 Overview of the KEKB B-Factory


Figure 4 Tunnel view of KEKB

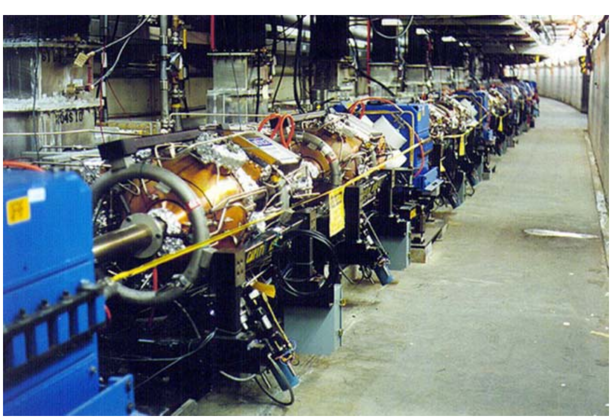
Figure 5 PEP-II RF Cavities

Table 1: PEP-II May 2005 Parameters 3.1 x 9 GeV.

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	1.8
HER RF klystron/cav	5/20	9/26
HER RF volts (MV)	14.0	15.5
LER RF klystron/cav.	2/4	4/8
LER RF volts (MV)	3.4	4.04
β_y* (mm)	15-25	11
β_x* (cm)	50	35-49
Emittance (x/y) (nm)	49/2	31-59/1.4
σ_z (mm)	11	11-12
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	7.3
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	17.04
Total Int. Lum. (fb^{-1})	30/year	> 262 total

RF SYSTEMS

The RF systems for PEP-II and KEKB are shown in Figures 5 through 7. PEP has only copper cavities. KEKB has copper cavities for the LER and copper and superconducting cavities for the HER. A world record for for e- current in SC cavities goes to KEKB HER at 1.24 A. The overall world record for (positron) beam current for any RF cavity goes to PEP-II LER at 2.45 A.

Table 2: KEKB May 2005 Parameters 3.5 x 8 GeV.

Parameter	KEKB Design	KEKB Present
HER Vertical tune	43.08	41.58
HER Horizontal tune	47.52	44.51
LER Vertical tune	45.08	43.55
LER Horizontal tune	45.52	45.51
HER current (mA)	1100	1242
LER current (mA)	2600	1763
Number of bunches	5000	1389
Ion gap (%)	2.3	2.3
HER RF klystron/cav	18/36	18/18
HER RF volts (MV)	20	15
LER RF klystron/cav	10/10	10/20
LER RF volts (MV)	5	8
β_y* (mm)	10	5.4-6.2
β_x* (cm)	33	56-59
Emittance (x/y) (nm)	18/0.36	18-24/0.4
σ_z (mm)	4.0	6
Hourglass factors	~0.75	~0.85
Crossing angle(mrad)	+/-11	+/-11
IP Horiz. size Σ (μm)	109	152
IP Vert. Size Σ (μm)	2.7	3.0
HER Horizontal ξ_x	0.039	0.074
HER Vertical ξ_y	0.052	0.056
LER Horizontal ξ_x	0.039	0.118
LER Vertical ξ_y	0.052	0.081
Lumin. ($x10^{33}/cm^2/s$)	10.0	15.6
Int. Lum/month (fb^{-1})	10	26.5
Total Int. Lum. (fb^{-1})	100/year	> 425 total

INTERACTION REGIONS

The PEP-II interaction region is shown in Figure 8 and the KEKB interaction region in Figure 9. PEP-II uses permanent magnets inside BaBar to allow the beams to collide head on. The KEKB interaction region allows the beams to travel straight into the collision point but then bend going out. The KEKB layout allows for lower backgrounds but with potentially more difficult beam-beam effects with a crossing angle of +/-11 mrad.

HALF INTEGER TUNES

Both PEP-II and KEKB operate with the horizontal tunes just above the half integer (~0.505-0.515) to take advantage of strong dynamic beta effects with current. This enhances the beam-beam tune shifts available. The vertical tunes are nearby at about (0.58-0.60).

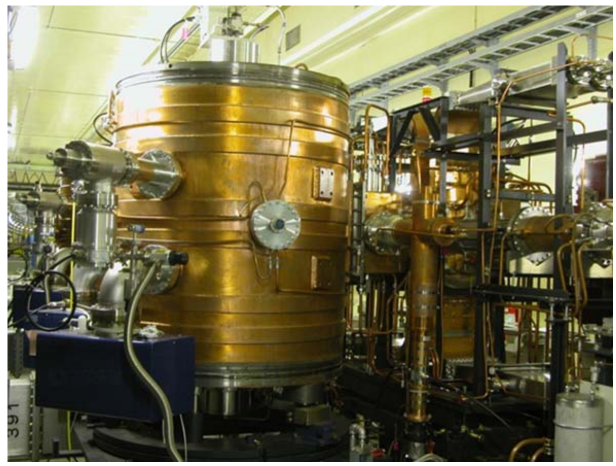

Figure 6 KEKB ARES Cavities

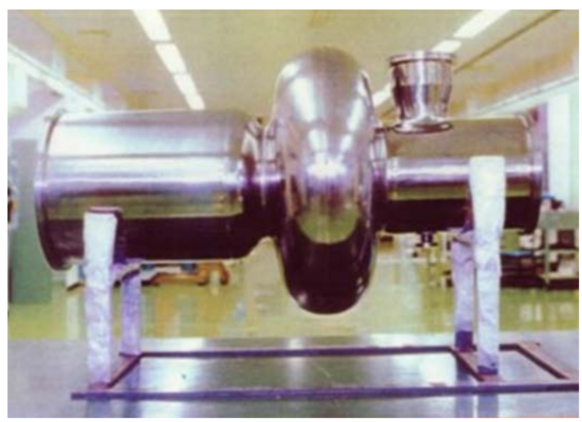

Figure 7 KEKB Superconducting Cavity

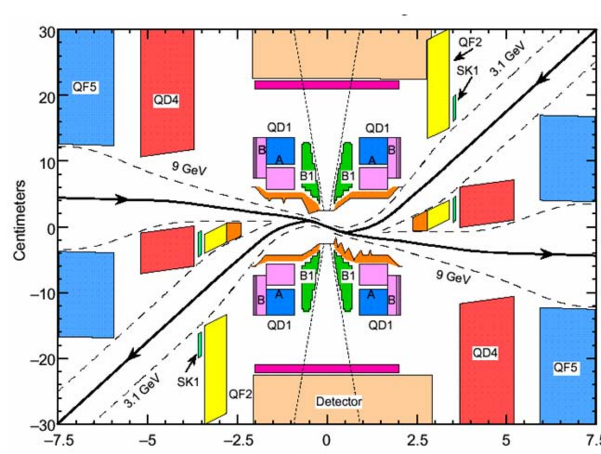

Figure 8 PEP-II Interaction Region

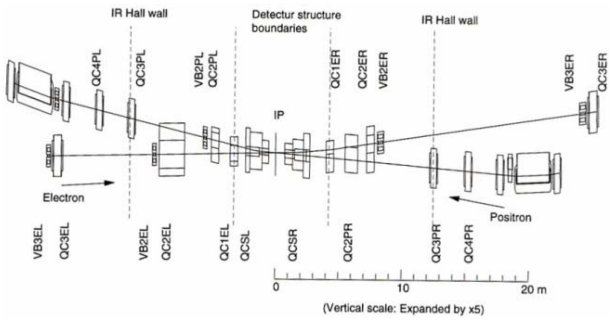

Figure 9 KEKB Interaction Region

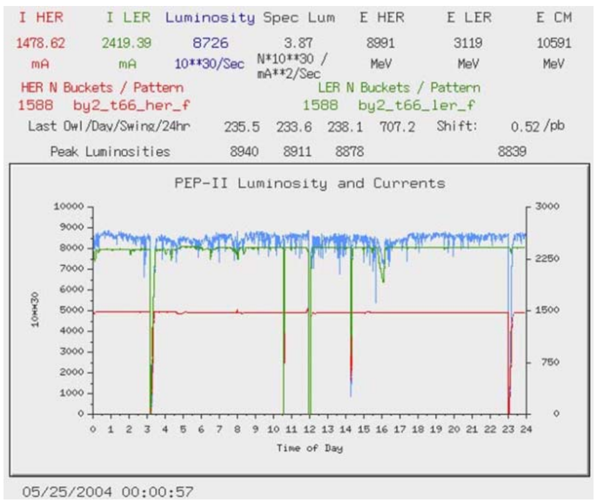

Figure 10 PEP-II trickle charge operation with constant currents and luminosity.

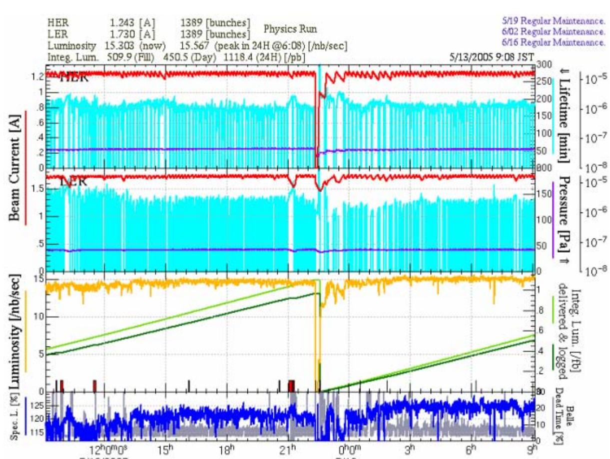

Figure 11 KEKB continuous injection operation.

CONTINUOUS (TRICKLE) INJECTION

Continuous injection [3] is an operational mode where the beams are topped off while the particle physics detector is running. Continuous injection for the LER in PEP-II was made to work with BaBar in November 2003. The continuous injection mode for the PEP-II HER was made to work in March 2004. PEP-II can inject with either beam type pulse-by-pulse producing very steady currents and steady luminosity. The injection rate is a few Hz. KEKB went to continuous injection for both rings in early 2004. The KEKB injector must switch back and forth between injection particle types about every 10 minutes. See Figures 10 and 11 for the two accelerators. The production rate for overall integrated luminosity improved by about 30 to 40% for both colliders.

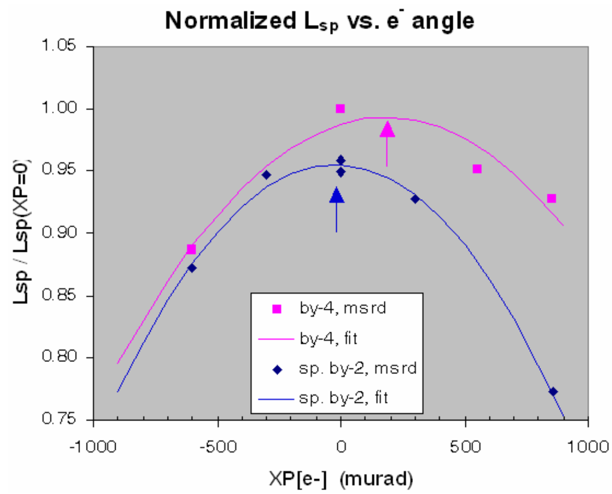

Figure 12 PEP-II luminosity with crossing angle with (lower) and without (upper) parasitic collisions at 0.63 m.

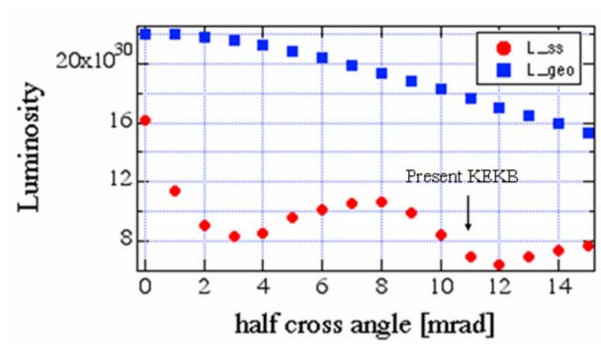

Figure 13 KEKB simulation of luminosity versus crossing angle indicating crab cavities will help the peak luminosity. Geometrical effects are shown above and strong beam-beam effects below [Ohmi, Tawada]

BEAM-BEAM INTERACTION

The beam-beam parameters have reached large values for both accelerators as can be seen in the two tables. These values are attributed to operation near the horizontal half integer, reduced damping times, and coupling and dispersion correction at the interaction point (IP). Parasitic collisions in PEP-II at 0.63 m from the IP reduce the peak luminosity about 5% as seen in Figure 12. [5, 6] The crossing angle in KEKB reduces the peak luminosity by about a factor of two as shown in the simulations in Figure 13. The plot indicates that adding crab cavities in KEKB may give a factor of two increase in luminosity.

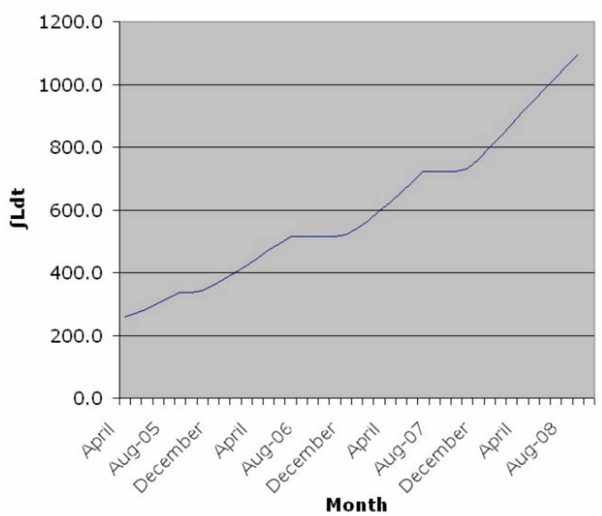

Figure 14. PEP-II projected integrated luminosity to 2008.

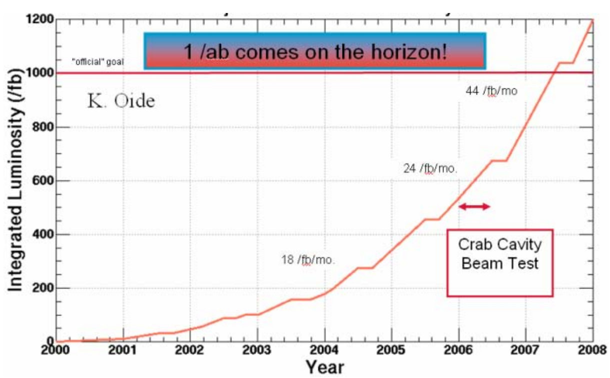

Figure 15. KEKB projected integrated luminosity to 2008.

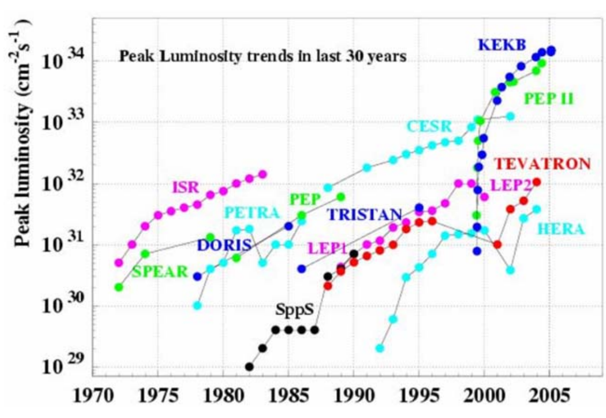

Figure 16. Peak luminosity versus year for various colliders. PEP-II and KEKB have produced a significant step. (K. Oide *et al.*)

FUTURE PLANS

Combining the equations for luminosity and the vertical beam-beam parameter, one derives the traditional luminosity parameterization:

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

with r the y to x aspect ratio (~0.03), E the beam energy, I the beam current, ξ_y the vertical tune shift, and β_y* the vertical beta at the collision point.

Over the next two years in PEP-II the currents will be raised about a factor of 1.5 to 2, the tune shifts increased about 10% and β_y* reduced from 11 mm to about 8.5 mm. The number of RF stations in the LER will be increased from four to five in order in achieve about 4.4 A. The number of RF stations in the HER will be increased from nine to ten allowing a current of 2.2 A. To shorten the bunch length to reduce the hourglass effects, a lower alpha lattice will be used in HER and a higher RF voltage. The peak luminosity should reach $2.1 \times 10^{34}/\mathrm{cm}^2/\mathrm{s}$ in 2007.

In January 2006 transverse (crab) cavities will be installed in KEKB to gain the luminosity indicated in Figure 13 giving hopefully a factor of two through ξ_y. This project upgrade is very interesting as this process has been studied for several decades and will be tested soon.

The expected integrated luminosities for PEP-II and KEKB until 2008 are shown in Figures 14 and 15, respectively. There is a good chance that both accelerators will exceed 1 ab^{-1} in 2008.

Figure 16 shows the yearly luminosity levels over the lifetimes of many collider projects. PEP-II and KEKB compare very favorably with the historical peak luminosities of similar machines and have set a new high standard by an order of magnitude. Future, order of magnitude, increases in luminosity could be obtained by upgrading these colliders to Super B-Factories [7, 8].

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