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e^+e^--Factories: PEP-II, KEKB, DAΦNE

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Abstract

In 1999 two B-factories, PEP-II and KEK, and a Φ-factory, DAΦNE , started their physics experiments. A status report of the three factories is presented. A description of the interaction regions, strongly influenced by the detector requirements, and of the machine background in the detectors is presented.

1 General Description

On the low energy and high luminosity frontier e^+e^--factories have been designed aiming at measuring CP violation effects in the B or Φ meson decays. For this objective a very high luminosity and high precision experiments are required.

A high increase of luminosity with respect to past generation colliders is obtained by increasing the number of bunches. The choice of many bunches requires high currents and two separate rings, in fact the two beams must cross only at one interaction point inside the detector and be separated elsewhere. The achievement of high currents implies many challenges: reduction of multibunch instabilities by means of feedbacks and HOM free RF cavities and very effective vacuum and injection systems. The separation scheme poses constraints on the optics of the interaction region and makes the optimisation of the collision parameters quite complex. Moreover, in two rings colliders, the beam-beam limit is very sensitive to machine coupling, which can be different for the two beams.

This choice is common to PEP-II [1], KEKB [2] and DAΦNE [3], while the layout and the separation scheme of the three rings are different. PEP-II is an asymmetric collider at 3.1 x 9.0 GeV, the Low Energy Ring (LER) is above the High Energy Ring (HER) and the two beams collide head-on in one interaction region dedicated to the BaBar [4] detector. KEKB is also asymmetric but the energies are 3.5 GeV and 8 GeV; the two rings are built side by side and the beams collide at an horizontal crossing angle of 22 mrad. There is one interaction region for the Belle [5] detector. DAΦNE is symmetric with a rather low energy (.51 GeV), the rings are horizontally separated with a crossing angle at the interaction point of 25 mrad. The KLOE [6] detector, dedicated to a CP violation experiment, is installed in one of the two interaction regions; the DEAR [7] experiment is installed in the second one and will be replaced later on by FINUDA [8]. The total length of each DAΦNE ring is the same as that of the interaction region of one of the B-factories and the lattice does not have a long arc with regular periodic cells. A comparison of the design parameters for the three colliders is shown in Table I. Let us point out that the number of bunches is very different between the three machines but the bunch distance, which is relevant for the luminosity, is nearly the same. Also the damping time is very similar for all the rings: a short damping time and high fluctuations in the energy losses are useful to reduce single beam instabilities and improve beam-beam performance. For DAΦNE the damping time in terms of the number of revolution turns is much longer with respect to the other machines. This means that even high order beam-beam resonances can affect luminosity performance.

Table 1
DAΦNE , PEP-II and KEKB Design parameters

	DAΦNE	PEP-II	PEP-II	KEKB	KEKB
		LER e^+	HER	LER	HER
Beam Energy (GeV)	.051	3.1	9.0	3.5	8.0
Circumference (m)	98		2199		3016
Crossing angle (mrad)	2x12.5		0		2x11
Luminosity ($cm^{-2}s^{-1}$)	$5\ 10^{32}$		$3\ 10^{33}$		10^{34}
Emittance (mm mrad)	1.0	.049	.049	.018	.018
Coupling	.01	.03	.03	.02	.02
$\beta_y{}^*/\beta_x{}^*$ (cm/cm)	4.5/450		1.5/50		1/33
Number of bunches	120		1658		5000
Particles/bunch	$9\ 10^{10}$	$6\ 10^{10}$	$2.8\ 10^{10}$	$3.3\ 10^{10}$	$1.4\ 10^{10}$
Bunch spacing (ns)	2.7		4.2		2.0
Bunch length (mm)	30	10	11	4	4
RF frequency (MHz)	368.		476.		509.
Damping time (ms) τ_ϵ	18	30	18	45	23

2 Status Report

2.1 PEP-II

The BaBar detector has been installed in May 1999. In August 1999 a peak luminosity L = 8.3 10^{32} $cm^{-2}s^{-1}$has been obtained after tuning the machine energy on the Y(4S).In May 2000 the highest luminosity at an e^+e^-collider, L=2.02 10^{33} $cm^{-2}s^{-1}$, has been achieved with 554 bunches and currents of 613 mA $e^-$and 1090 mA e^+, corresponding to a peak luminosity per bunch of twice the design value. The total integrated luminosity delivered to BaBar from June to November 1999 is 2 fb^{-1}; the same integrated luminosity has been collected between January 15 and March 13 2000. The integrated luminosity per day is 126 pb^{-1}; the peak e^-current in the HER is 920 mA and the peak e^+current in LER 1721 mA. The future perspectives are for an increase of the luminosity up to 3 10^{33} $cm^{-2}s^{-1}$in August and 10^{34} $cm^{-2}s^{-1}$by the end of 2002.

2.2 KEKB

The Belle detector has been installed in May 1999; in July a peak luminosity L = 2.9 10^{32} $cm^{-2}s^{-1}$was measured after an energy scan to set the machine on the Y(4S). In May 2000 the peak luminosity is L = 1.85 10^{33} $cm^{-2}s^{-1}$and the total integrated luminosity delivered to Belle is 3.3 fb^{-1}. The integrated luminosity per day is 89 pb^{-1}. In the two B-factories the luminosity has been continuously increased, since detector installation, mainly by reducing the machine coupling and the effective vertical beam size at IP, by tuning the working point in the betatron tune phase space and by increasing the current in multibunch operation.

2.3 DAΦNE

Before KLOE detector installation, in March 1999, the single bunch luminosity was L_0 = 1.6 10^{30} $cm^{-2}s^{-1}$. The ratio between vertical and horizontal emittances (coupling) was as low as $\kappa = .002$, well below the design value ($\kappa = .01$). After detector installation, the high integrated field of the KLOE solenoid introduced a strong coupling in the machine. The luminosity performance of the collider was reduced although the coupling was corrected down to the design value. A single bunch luminosity around L_0 = 2 10^{29} $cm^{-2}s^{-1}$was measured. In December 1999, four weeks were dedicated to KLOE experimental runs. The initial run luminosity, in multibunch mode, ranged between 3 and 5 10^{30} $cm^{-2}s^{-1}$.

During January and February 2000 a machine shutdown was dedicated to maintenance and setup of the cryogenic system for the magnetic measurements of the FINUDA solenoid. During this shutdown three major operations, beneficial to the machine performance, were executed: installation of a new computer control system, new injection kickers equipped with damping antennas for trapped modes and realignment of the KLOE low-β triplets.

Between March and May 2000 four weeks were dedicated to machine development. In DAΦNE the KLOE solenoid is compensated by means of two superconducting antisolenoids, which cancel the longitudinal field integral, and a rotation of the interaction region quadrupoles which compensates the coupling. A strong reduction of the coupling was obtained by adjusting the KLOE solenoid and antisolenoid fields, looking at the ratio of the vertical and horizontal beam sizes at the synchrotron light monitor. The final optimisation has been done by measuring the effective vertical beam size Σ_y at the interaction point by means of vertical scans of one beam with respect to the other at low bunch current. The measured value of Σ_y (18 μm) is consistent with the design parameters and a machine coupling of $\kappa = .005$. A new working point in the betatron phase plane (5.10, 5.14) was explored and a new optics with the design emittance and an improved chromaticity correction scheme was adopted. A peak single bunch luminosity $L_0 = 4.0\ 10^{29}\ cm^{-2}s^{-1}$was obtained.

The microwave instability which was limiting the single bunch current in many bunches operation has disappeared after the modifications performed during the shutdown. This will allow to increase the currents of the multibunch operation.

3 Interaction Regions

For all the factories there is a tight integration between the machine elements of the Interaction Region (IR) and the detector facilities. High field detector solenoids require a compensation scheme consisting of rotated quadrupoles, antisolenoids and skew quadrupoles. To obtain a very low value of the β_y* at the Interaction Point (IP) the magnetic elements are very close to the IP and immersed in the soleniod field. This prevents the use of conventional iron elements and requires the use of superconducting or permanent magnet elements. PEP-II has the first bend and first quadrupole made of permanent magnet, in KEKB the quadrupole and the antisolenoid next to the IP are superconducting and DAΦNE has permanent magnet quadrupoles in the low-β triplets. The separation scheme required for the two ring colliders makes the IR design more complex. KEKB and DAΦNE have adopted an horizontal crossing angle while PEP-II has head-on collision with a strong first bend.

Due to the high circulating currents machine background for the detectors is a critical issue. The different sources of background have been simulated and countermeasures have been taken to reduce the background to a level acceptable for the detectors. For the B-factories the main source of background is the synchrotron radiation which is reduced with proper masking in the IR. At the energy of DAΦNE the synchrotron radiation background is negligible and the main sources of background are the particles lost due to Touschek scattering. These have been reduced by increasing the vacuum chamber aperture in the IR and installing a properly designed system of beam scrapers. The particle losses due to beam-gas interaction are a background source common to the three factories and the cure is to reduce the residual gas pressure upstream of the IR as much as possible. The detector background is below the value acceptable for the experiments at the maximum luminosity achieved by the three factories and is improving according to the reduction of the gas pressure in the vacuum chamber.

4 Conclusions

The B-factories detectors are taking data at high luminosity with an acceptable background level and a further increase of luminosity is foreseen for the machines. DAΦNE single bunch luminosity has been increased by reducing the coupling and the control of the machine parameters has been improved in the recent shifts. Physics runs for KLOE will start in July.

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