B-FACTORIES

K. Wille
University of Dortmund, Postfach 500 500
Otto-Hahn-Straße, 4600 Dortmund 50, Germany

Abstract

For future experiments in the field of B-physics one has to outstrip the presently available data rates by a substantial margin. Therefore the required luminosity of the B-factories of the next generation should exceed values of $\mathcal{L} > 1\cdot10^{33}\ \mathrm{cm}^{-2}\ \mathrm{sec}^{-1}$. Currently several different concepts for e^+e^--colliders with extremely high luminosity are under discussion. Optimized storage rings use multiple bunches in each beam. The best results i.e. the highest luminosity require double rings. Because of the high circulating currents of $I_{beam} \geq 0.5$ A the problems of multi-bunch instabilities have to be solved using cavities with mode damping and effective feedback systems. Another problem is the reduction of background due to particle losses in the machine. The production of at least 10^7 B-mesons a year also makes a very effective injection necessary without the need of energy ramping in the storage rings. An interesting variation of the storage ring concept is the use of two rings with substantially different energies (12 GeV/2 GeV). This hetero-energetic system produces "flying B's" providing a new quality for measurements of CP violation. Some ideas of future B-factories are based on the linear collider concept. There are preliminary designs using superconductive cavity structures as well as such with high gradient linacs driven by relativistic high power klystrons. These machines are obviously longer term and technically more risky than the storage rings.

Introduction

The luminosity of an e^+e^--storage ring is given by

$$\mathcal{L} = f_o\, n\, \frac{N^+ N^-}{4\pi\sigma_x\sigma_z} \tag{1}$$

where $N^{\pm}$ are the number of particles per bunch, f_o the revolution frequency, n the number of bunches and σ_x and σ_z the horizontal and vertical beam size, respectively. Presently the best available luminosities of DORIS II are $\mathcal{L} = 2\cdot10^{31}\ \mathrm{cm}^{-2}\ \mathrm{sec}^{-1}$ and of CESR $\mathcal{L} \approx 1\cdot10^{32}\ \mathrm{cm}^{-2}\ \mathrm{sec}^{-1}$. The B-factories of the next generation, however, have to exceed these values by at least one order of magnitude. This requirement is substantially important for measurements of CP violation. Therefore we can define the design goal for the luminosity of a future B-factory :

$$\mathcal{L} \geq 1\cdot10^{33}\ \mathrm{cm}^{-2}\ \mathrm{sec}^{-1} \quad (\ @\ E_{CM} \approx 10\ \mathrm{GeV}\ )$$

This value corresponds to the production of $N_{b\bar{b}} \geq 10^7$ $B\bar{B}$'s per year. During the last three years several different types of B-factories have been investigated. A general view of the most important projects is shown in Fig. 1.

The existing facilities (CESR, DORIS II, VEPP 4) are storage rings with the two beams circulating in the same vacuum chamber. With one ring multibunch operation is possible using a "pretzel scheme" as developed for CESR. Two new projects (TRISTAN Accumulator Ring (KEK) [1] and the Stanford Beauty Factory SBF_o (SLAC) [2]) are based on this scheme. Higher luminosities are possible seperating both beams in two different rings. Only in the interaction region the both beams have the same orbit. Three projects have been suggested using the double ring concept i.e. PSI (SIN) project [3], SBF (SLAC) [2] and Cornell B-factory [4]. An interesting variation of storage ring colliders are the hetero-energetic devices using two rings with

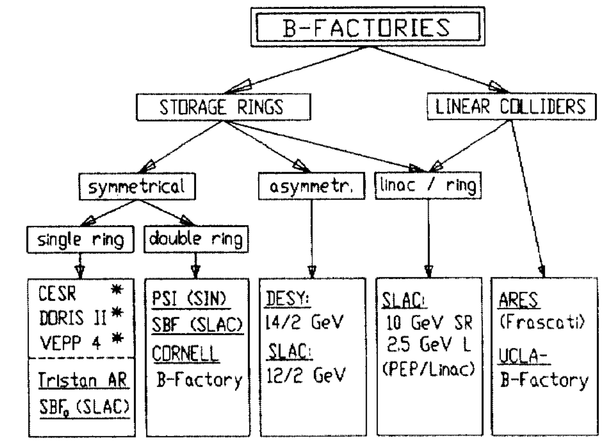

Fig. 1 General view of the most important B-factory projects presently investigated (* in operation)

different energies. These asymmetric machines have been investigated at DESY [5] and SLAC [6]. A completely different idea is to use two linacs accelerating beams with extremely low emittances. Two projects of linear colliders are proposed. One is the superconductive facility ARES [7] and the other the UCLA e^+e^- Linear Collider $B\bar{B}$ Factory Project [8] using high gradient linac structures. It is also possible to collide a high energy positron beam circulating in a storage ring with a low energy electron beam accelerated in a linac. Such scheme has been investigated at SLAC [9].

In this paper the advantages and problems of the different B factory concepts are discussed including the general physical and technical limitations. The principal design and the special features of the projects are presented.

e^+e^- Storage Rings

The luminosity of a storage ring expressed by eq. (1) is mainly limited by space charge effects between the colliding bunches. In linear approximation this effect causes the tune shift ΔQ which must not exceed a critical value. Therefore no beam currents higher than

$$I_{max}[\mathrm{mA}] = 698.5\ \frac{f_o E^3 \left(\sqrt{\epsilon_x\beta_x^*} + \sqrt{\epsilon_z\beta_z^*}\right)\sqrt{\epsilon_{x,z}}}{\beta_z^*}\ \Delta Q_{x,z} \tag{2}$$

are possible (energy E [GeV], emittance ϵ [m rad], betafunction β [m], f_o [sec^{-1}]). With the condition $\Delta Q_x = \Delta Q_z = \Delta Q$ the emittance coupling becomes $k = \epsilon_z/\epsilon_x = \beta_z^*/\beta_x^*$ and the luminosity is

$$\mathcal{L} = 1.51\cdot10^{32}\ \frac{n\, f_o\, E^4\, (\ 1 + k\ )\ \epsilon_x}{\beta_z^*}\ \Delta Q^2 \tag{3}$$

This is the maximum value in a storage ring only limited by space charge effects. From eq. (3) one can easily derive the design criteria for a high luminosity B factory.

The vertical betafunction β_z^* in the interaction point has to be very small and therefore a mini beta insertion is necessary. But one has to consider the fact that because of space charge limitations the betafunction must not be smaller than $\beta_z^* = 1.5\ \sigma_s$ (σ_s: bunchlength). Special lattices and beam optics have to provide the large required emittances ϵ_x. This, however, makes little sense if the dynamic aperture of the machine is too small to accept the respective beam cross sections. This problem must be solved by a careful design of chromaticity compensation. A crucial parameter is the maximum tune shift ΔQ for which in all e^+e^- storage rings values of 0.025 or larger have been measured. With good magnet alignment, effective orbit controls and sufficient dynamic aperture tune shifts of ΔQ = 0.05 or even higher are possible. But as found at DORIS I any crossing angle between the two beams causes a drastical decrease of the tune shift. To improve the performance of colliding beam storage rings one must use multible bunches in each beam. In order to get maximum flexibility of possible bunch numbers without reduction of the beam aperture one has to choose double rings.

A consequence of the large beam emittance and many bunches in the storage rings are high beam currents of at least 500 mA. Such high currents obviously will cause transverse and longitudinal instabilities found in different storage rings [10]. Therefore one has to apply all cures either to avoid instabilities or to add artificial damping by use of proper feedback systems. From this point of view an extremely smooth vacuum chamber without sudden changes of cross section has to be designed providing the required low chamber impedance. Another problems are the cavities. Because of the strong beam loading the shunt impedance of the cavities is not very important, but the problem of the instabilities is the real crucial point. Therefore one has to develope cavities with very effective mode damping. A reduced shunt impedance is tolerable under these conditions. At present, a cavity sized as the superconductive types with mode couplers, but made by normal conductive material as copper, seems to be the best solution [11]. Such design would combine the advantage of high mode damping with high reliability of conventional technique. Generally a double ring can store the high multy bunch currents of future B factories more stable than a single ring. In each ring there is only half of the total circulating current and for a given bunch spacing of one beam it is much easier to design a multy bunch feedback system.

Another problem due to the high beam currents is the background in particular in the vertex chambers. Therefore extremely good vacuum is required around the ring and carefully designed absorbers for synchrotron radiation have to be installed. But more critical are the high energy electrons with large betatron oscillations. These particles, driven by nonlinear resonances, may hit the vacuum chamber in the interaction region. To reduce this background to the possible minimum careful tracking calculations have to be done. Special scrapers installed in proper places may help to get rid of the unstable particles. Generally the background seems to be one of the fundamental problems of high luminosity B factories.

For high energy experiments the average luminosity per day $\langle\mathcal{L}\rangle_{day}$ is more important than the peak luminosity. Therefore the injection time t_I has to be as short as possible. With short injection times the duration of a run t_R for a given beam lifetime τ also becomes short. Because of the frequent injection the average current is high and consequently the average luminosity. Let

$$\mathcal{L}(t) = \mathcal{L}_0\, e^{-t/a\tau} \qquad \text{with} \qquad 0.5 < a < 1 \tag{4}$$

we get the maximum average luminosity per day

$$\langle\mathcal{L}\rangle_{day} = \frac{T\, a\, \tau\, \mathcal{L}_0}{t_R + t_I}\left(1 - e^{-t_R/a\tau}\right) \tag{5}$$

with the optimum running time

$$t_R = \frac{1}{2}\left(\sqrt{t_I^2 + 4a\tau t_I} - t_I\right). \tag{6}$$

T is the duration of one day.

To get very fast injection first of all a booster synchrotron is required which accelerates beams to the full working energy (E_{max} > 5 GeV). In addition an accumulator ring based on the concept of PIA at DESY [12] will increase the positron and electron intensity significantly. Finally a perfect control of all relevant injection parameters of the storage ring and the preaccelerators is needed. It should mentioned here that a high reliability of the entire B factory is of substantial importance concerning the B production rate of the facility.

Following eq. (5) and (6) the maximum possible average luminosity per day is achievable reducing t_I to negligible values. With other words, one should use a kind of "continious injection" which compensates the particle losses during a luminosity run within very short time intervalls. Then the average luminosity is identical with its peak value ($\langle\mathcal{L}\rangle = \mathcal{L}_0$). It is obvious that an injection with running detector will aggravate the background problems, but the benefit is significant. Therefore it seems to be worthwhile to start a program to develope a "continious injection" scheme.

Examples of Storage Rings

Following the design criteria mentioned above several storage ring projects have been suggested as B meson factories. In the following we will look at these projects.

The TRISTAN Accumulator Ring (single ring)

The KEK-group has studied plans to upgrade the accumulator ring for higher luminosity [1]. The most interesting idea is to turn the accumulator ring into a multibunch collider. The multibunch operation is done in a "pretzel" orbit scheme developed at CESR [13]. In order to make pretzel orbit horizontal beam separators will be used with a phase advance from one separator to the other of a half-integer. With this scheme bunch numbers between 1 and 9 are possible. To achieve high luminosity by decreasing the vertical β-function in the interaction point (I.P.) the quadrupoles will be placed closer to the I.P. at a distance of 1.4 m. With this configuration β_x = 1 m and β_z = 0.02 m will be possible. By use of new beam optics the emittance will increase by a factor of 3. If the tune shift limit is ΔQ = 0.03 which is a conservative assuption the expected luminosity with 4 buches per beam is $\mathcal{L} \approx 2 - 3\cdot10^{32}$ cm^{-2} sec^{-1}. This will provide an average value of $\langle\mathcal{L}\rangle_{day} \approx 8$ pb^{-1}/day.

The Stanford Beauty Factory SBF$_0$ (single ring)

E. Bloom has suggested an improvement to PEP, the Stanford Beauty Factory SBF$_0$, which would allow a multibunch operation with 9 – 15 bunches per beam at an energy of E_{cm} between 20 and 30 GeV [2]. A modified version of the pretzel scheme is used to seperate the beams outside the interaction point. Since there is not enough aperture in the arcs the beam separation is concentrated in the very long straight sections of 117 m. This scheme allows 15 bunches per beam placed in three groups of five bunches with each bunch in a group separated by 20 m from the next. At SBF$_0$ with the first vertically focusing quads 2.75 m distant from the I.P. betafuntcions of $\beta_z \approx 0.03$ m are possible. Scaled from the tune shift of ΔQ = 0.05 already achieved in PEP a value of ΔQ = 0.08 is assumed. The estimated luminosities for two beam energies and the corresponding beam currents are listed in the following table:

		5.4	12.5
E_{beam}	[GeV]	5.4	12.5
$\mathcal{L}_{peak}$	[cm^{-2} sec^{-1}]	$2.3\cdot10^{32}$	$1.32\cdot10^{33}$
I_{beam}	[mA]	76	179
$\langle\mathcal{L}\rangle_{day}$	[pb^{-1}]	6.8	38

The SIN B Factory (double ring)

A double ring optimized for high B meson production has been suggested by the Paul Scherrer Institut PSI (formerly SIN). It is a configuration with two seperated rings and combined insertions in the interaction regions as shown in Fig. 2.

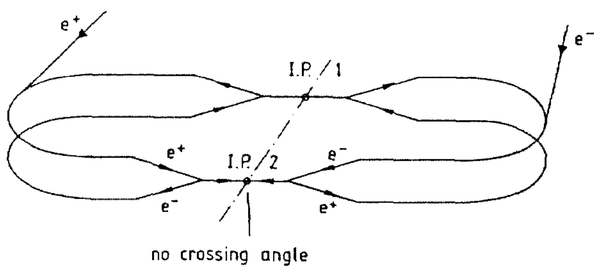

Fig. 2 Sketch of the SIN double ring with head on collision

To reduce the natural chromaticity of the machine a mini beta insertion is used with a very small distance of 0.7 m between the I.P. and the first focusing quadrupole. This quadrupole is a superconductive magnet because of the required high field gradient of $g = \partial B_z/\partial x \approx 30$ T/m. The focusing allows a variation of the vertical beta-function between $\beta_z^* = 1 - 5$ cm. For standard optics a value of $\beta_z^* = 3$ cm is chosen. A problem is the layout of the vertical beam separation at the end of the interaction region. One can use either electrostatic plates or fast RF-magnets. Since both techniques provide only a rather weak bending 8 m long elements have been chosen. Because of the vertical separation the minimum bunch spacing is 32 m. With the machine circumference of L = 648 m a maximum number of 20 bunches per beam is possible.

The beam optics has been carefully designed to get a large dynamic aperture. For the present lattice the dynamic aperture is almost as large as the aperture limited by the vacuum chamber. Therefore the required emittance of $8.3 \cdot 10^{-7}$ m rad is available without reduction of beam lifetime. The energy acceptance is larger than $\Delta E/E = 2$ %.

For maximum luminosity a current of I = 485 mA in each beam is assumed. The number of bunches depends on the energy and may be about n = 10 in most of the cases. Because of running costs the RF-power should not exceed values of $P_{RF} = 1050$ kW. In order to get rid of transverse and longitudinal instabilities cavities with effective mode damping and multibunch feedback systems are intended.

The maximum energy of the storage rings is E = 7 GeV. A booster synchrotron accelerates the electrons and positrons to an energy of E = 6 GeV which is limited to keep the costs low. On the other hand storage ring energies above 6 GeV are only possible with reduced currents and luminosities because of limited RF-power. Therefore it is not necessary to have a full energy injection above 6 GeV. Two 400 MeV linacs are used as preaccelerators and for positron production. An accumulator ring for both the positrons and the electrons is arranged between the linacs and the booster synchrotron.

The luminosity of the SIN B factory is shown in Fig. 3 as a function of energy. With the standard optics ($\beta_z^* = 3$ cm) and a tune shift of $\Delta Q = 0.03$ one gets curve (1) which is a moderate luminosity for the first year of operation. After some R&D and a better understanding of the machine curve (2) should be available with $\Delta Q = 0.04$

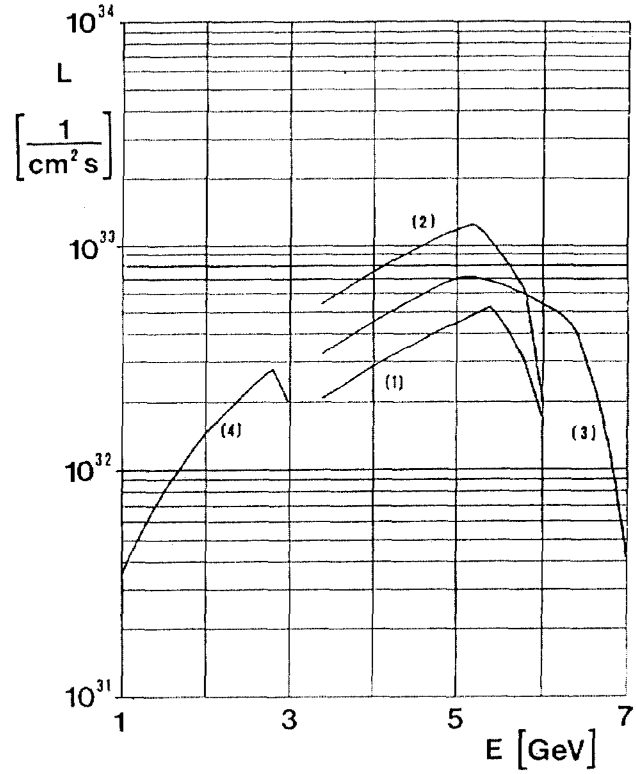

Fig. 3 The luminosity of the SIN B factory

and $\beta_z^* = 2$ cm. Curve (3) shows a special high energy mode and curve (4) is optimized for runs in the charm quark region. Higher luminosities than shown in curve (2) may be possible but this will be a long term program.

The Stanford Beauty Factory SBF (double ring)

There is another idea to convert PEP into a double ring B factory suggested by E. Bloom [2]. A second identical machine is put on top of the existing PEP. With the bunch spacing of 31 m, 70 bunches can be put uniformly in each ring. The maximum emittance limited by the aperture is $\epsilon_x = 1.2 \cdot 10^{-7}$ m rad. Wigglers are needed to bring the beam size to the aperture limit at E < 14.5 GeV. The maximum tune shift is assumed to be the same as for SBF_o i.e. $\Delta Q = 0.08$. A mini beta insertion provides a betafunction of $\beta_z^* = 3$ cm. The beam currents are larger than 0.5 A which is rather high for a large machine like PEP. Obviously this makes additional R&D necessary. The expected luminosities for SBF are listed in the next table:

E_{beam} [GeV]	5.4	12.5
$\mathcal{L}_{peak}$ [cm^{-2} sec^{-1}]	$1.1 \cdot 10^{33}$	$6.16 \cdot 10^{33}$
I_{beam} [mA]	354	835
$\langle\mathcal{L}\rangle_{day}$ [pb^{-1}]	32	177

The Cornell B Factory (double ring)

On a longer time scale, the Cornell group is beginning a design study for a B factory constructed at Cornell. The initial ideas are to lower the present CESR ring in the tunnel and place a second identical ring directly on top of it [4]. Both the RF cavities and the vacuum chambers would be of a new design to cope with the 1 A beam currents in each ring. Bunch spacing would be 10 to 20 meters to limit peak bunch currents and their large high order mode power requirements. This design would achieve peak luminosities in excess of $\mathcal{L} = 2 \cdot 10^{33}$ cm^{-2} sec^{-1} at two interaction regions with a vertical tune shift of $\Delta Q = 0.025$ and daily integrated luminosities in excess of 100 pb^{-1}.

Heteroenergetic Storage Rings

If one collides two beams of unequal energy, the center-of-mass will move and so will the decaying B mesons. One can see the vertices seperately and reconstruct the events with greater certainty. For these reasons some groups have begun studying the design of hereroenergetic colliding beam systems. In particular the studies are concentrated on a pair of storage rings, one operating at 12 to 14 GeV and the other at 2 GeV with their beams brought into collision in a shared straight section as shown in Fig. 4. This device has to be arranged

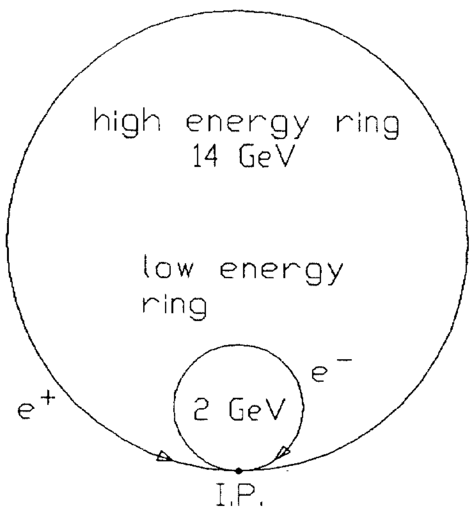

Fig. 4 Sketch of a heteroenergetic storage ring system

as a double ring. Since the two beams 1 and 2 have significantly different energies the luminosity of such a system becomes [6]

$$\mathcal{L} = \frac{\pi \gamma_{cm}^2 f_0 \Delta Q_1 \Delta Q_2 \sigma_x \sigma_z}{4\, r_e^2\, \beta_{z1}^*\, \beta_{z2}^*} \qquad (6)$$

with $\sigma_{x1} = \sigma_{x2} = \sigma_x$, $\sigma_{z1} = \sigma_{z2} = \sigma_z$ and $\gamma_{cm} = 4\, \gamma_1\, \gamma_2$. In addition to the general design criteria of storage rings mentioned above, one is faced with special problems due to the common focusing in the interaction region. It is impossible to focus both beams with the same set of mini beta quadrupoles. Therefore one has to separate the beams within the mini beta insertion by use of a bending magnet. This magnet, however, will produce strong synchrotron radiation which will hit the small vertex chamber in the I.P. causing background and heating problems. Therefore one has to develope a separation scheme with rather weak bending magnets and relatively long straight sections between the mini beta quadrupoles.

There are presently two heteroenergetic (or "asymmetric") storage rings being studied, one at DESY and the other at SLAC :

PETRA as a B-Factory

The idea is to run PETRA with 20 bunches at a beam energy of 14 GeV. A new small 2 GeV ring is added at the interaction region. Preliminary beam optics for both rings have been developed and a concept for beam separation has been proposed which seems to satisfy the background requirements [5]. The main important parameters of the study are given in the following table:

		PETRA 14 GeV	NEW RING 2 GeV
circumference	L [m]	2304.0	115.2
bending radius	ρ [m]	192.0	4.65
bunch number		20	1
betafunctions	β_x^* [m]	0.47	0.20
	β_z^* [m]	0.07	0.03
tune shifts	ΔQ_x	0.03	0.03
	ΔQ_z	0.03	0.03
beam current	I [mA]	60	179
beam power	P [kW]	1079.0	54.9

Based on these values the luminosity is calculated to be $\mathcal{L} = 1.00 \cdot 10^{32}$ cm^{-2} sec^{-1}.

PEP as an Asymmetric B Factory

A preliminary design for an asymmetric collision system between 12 GeV PEP electrons and 2 GeV positrons (or *vice versa*) in another new ring has been investigated by A.A. Garren [6]. The bunch number in PEP is 85 whereas the low energy ring has 6 bunches. The design is believed to be resonable from the standpoint of beam-beam and optics limitations. However, optimistic assumptions have been made and the most important of these are that the very high currents in both rings are achievable, that the synchrotron radiation from the separating dipole and quadrupoles can be masked, and that the required high field current septum magnet can be made. With a maximum tune shift of $\Delta Q = 0.05$ in both rings the luminosity is $\mathcal{L} = 5 \cdot 10^{32}$ cm^{-2} sec^{-1}.

Linear Colliders

A more speculative possibility is a linear collider using next generation technology. In contrast to the circular colliders linear colliders have some advantages. A mono- as well as a hetero-energetic operation is available with the same facility. The small beam size gives the possibility of a very small beam pipe to use vertex detectors. Also there is the hope to reach luminosity in excess of 10^{34} cm^{-2} sec^{-1}. Therefore there are some projects using linear colliders as B factories. A general sketch is shown in Fig. 5. Because of the pinch effect the

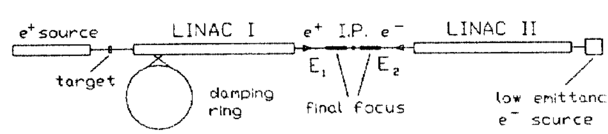

Fig. 5 Sketch of a linear collider

luminosity is enhanced by a factor H(D) where D is the disruption factor.

$$\mathcal{L} = f_0\, n\, \frac{N^+ N^-}{4\pi\sigma_x\sigma_z}\, H(D) \qquad 1 < H(D) < 6 \qquad (7)$$

$$D = \frac{r_e\, \sigma_s\, N}{\epsilon_n\, \beta^*}$$

The number of particles $N^{\pm}$ accelerated with a linac is limited by the RF power ($P_b = f_0\, n\, N^{\pm} E$) and by wake field instabilities. Another problems are the required high repetition rates $f_0 > 10$ kHz, the energy spread due to bremsstrahlung during collision, the production of high intensity low emittance positron beams using damping rings, the production of low emittance electron beams emitted from laser driven cathodes, and the final focus to get the extremely small spot size. The main problem, however, is in the moment the lack of experience with linear colliders. In the next future SLC at SLAC will hoprfully answer the most important questions.

The One-Racetrack ARES Project

U. Amaldi and G. Coignet have proposed a linear collider project which is manly based on two 500 m long superconductive linacs arranged like a racetrack [7]. The 500 MHz cavities have a gradient of E = 5 MeV/m. Each linac provides an energy gain of ΔE = 1.05 GeV. Several recirculators are used to guide the beams from one to the second linac. A very intense electron beam accelerated to 2.2 GeV produces positrons in a rotating target. The positron bunch is accelerated to 2.2 GeV and then injected into a damping ring. Electron bunches are produced almost simultaneously. It should mentioned here that ARES allows luminosity operation at various beam energies between 1.15 and 7.45 GeV. The parameters of the machine for B production are listed in the next table.

	high resolution $\Upsilon(4S)$	medium resolution $\Upsilon(5S)$
E_0 [GeV]	5.29	5.43
N^+	$2.5\cdot10^{10}$	$2.5\cdot10^{10}$
N^-	$8.0\cdot10^{10}$	$8.0\cdot10^{10}$
ϵ_n [m]	$2.0\cdot10^{-6}$	$2.0\cdot10^{-6}$
$\sigma_x = \sigma_z$ [μm]	1.0	0.6
σ_s^+ [mm]	3.0	1.0
σ_s^- [mm]	1.0	0.5
β^* [mm]	5.0	2.0
D^+	21	27
D^-	22	28
H(D)	7.7	7.3
f_0 [kHz]	10.0	10.0
P^+ [MW]	0.2	0.2
P^- [MW]	0.7	0.7
$\mathcal{L}$ [cm^{-2} sec^{-1}]	$1.3\cdot10^{33}$	$3.0\cdot10^{33}$

The UCLA e^+e^- Linear Collider Project

The design of a linear collider $B\bar{B}$ factory has been presented by D.B. Cline [8]. It is a very ambigious project using high gradient accelerating structures driven by 10 GHz relativistic klystrons. The gradient is assumed to be of the order of G = 150 MeV/m. The spot size is $\sigma \le 0.1$ μm which is not achievable with conventional focusing elements. Therefore a plasma lense with 2 cm focal length with a 5 GeV beam has been suggested. The most important parameters of the collider are:

energy	:	E = 5 - 7 GeV / beam
bunch number	:	n = 4
bunchlength	:	σ_s = 0.4 - 0.2 mm
spot size	:	$\sigma_{x,z}$ = 0.1 - 0.05 μm
emittance	:	$\epsilon_n = 3\cdot10^{-6}$ m rad
betafunction	:	β^* = 0.7 mm
no. of particles	:	$N = 3\cdot10^{10}$
energy spread	:	$\delta = 8\cdot10^{-3}$
beam power	:	P_b = 0.2 MW

The resulting luminosity of the UCLA-project is between $\mathcal{L} = 1\cdot10^{33} - 4\cdot10^{34}$ cm^{-2} sec^{-1}. It is obvious that this project needs a lot of basic R&D and will not be operational in the next few years.

Hybrid Colliders

P. Grosse-Wiesmann has investigated the possibility of colliding a linear accelerator electron beam with a positron beam stored in a circular storage ring [9]. With this scheme the advantages of a storage ring and a linac are combined. Intense positron currents are accumulated in a high energy low emittance storage ring using standard techniques. The low energy electron beam is produced by a laser driven cathode source and accelerated in a linac. In order to get beams with the rquired small spot size the betafunctions of the storage ring and the linac are β^* = 1 cm and β^* = 0.5 cm, respectively. The following table presents the most important parameters of the study:

	e^- (linac)	e^+ (SR)
energy E [GeV]	2.5	10.0
rep. rate f_r [MHz]	1.0	1.0
particles/beam N	$4\cdot10^{9}$	$1\cdot10^{12}$
power P [MW]	1.7	0.4
size σ [μm]	4.0	4.0

The expected luminosity of this hybrid collider is estimated to be $\mathcal{L} = 3.1\cdot10^{33}$ cm^{-2} sec^{-1}.

References

[1] H. Aihara et al., "Proposal for Study of B Physics by a Detector with Particle Identification and high Resolution Calorimetry at Tristan Accumulator ring", KEK, 1988

[2] E.D. Bloom, "B-Factories", SLAC-PUB-4604, 1988

[3] K. Wille, "Feasibility Study of a B Meson Factory", Paul Scherrer Institut (SIN), PR-88-01, 1988

[4] D.L. Hartill, Cornell University, private communication, 1988

[5] H. Nesemann, W. Schmidt-Parzefall, F. Willeke, "The Use of PETRA as a B-Factory", these proceedings

[6] J. Rees, "On the Luminosity of Heteroenergetic Colliding-Beam Storage Rings", SLAC/AP-67, 1988
A.A. Garren, "APIARY I, Asymmetric Particle Interactions Accelerator Research Yard", Lawrence Berkeley Laboratory, 1988

[7] U. Amaldi, G. Coignet, "A One Racetrack Superconducting Accelerator Complex for Bottom Quark and Nuclear Physics Studies", Proceedings of the Workshop on Heavy Quarks Factory, Courmayeur (Italy) 14-18 December 1987

[8] D.B. Cline, "The UCLA e^+e^- Linear Collider $B\bar{B}$ Factory Project", University of California, 1987

[9] P. Grosse-Wiesmann, "Colliding a Linear Electron Beam with a Storage Ring Beam", SLAC-PUB-4545, 1988

[10] see: J.L. Laclare, XIth. Intern. Conf. on High Energy Accelerators, Geneva, (1980)

[11] D. Proch, DESY, private communications.

[12] A. Febel, G. Hemmie, Internal Report DESY M-79/13 March 1979

[13] R. Littauer, IEEE NS-32, (1985) 1610.