DESIGN OF AN ASYMMETRIC SUPER-B FACTORY*

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Abstract

A Super Flavor Factory, an asymmetric energy e^+e^- collider with a luminosity of order 10^{36} cm^{-2}s^{-1}, can provide a sensitive probe of new physics in the flavor sector of the Standard Model. The success of the PEP-II and KEKB asymmetric colliders [1,2] in producing unprecedented luminosity above 10^{34} cm^{-2}s^{-1} has taught us about the accelerator physics of asymmetric e^+e^- colliders in a new parameter regime. Furthermore, the success of the SLAC Linear Collider [3] and the subsequent work on the International Linear Collider [4] allow a new Super-Flavor collider to also incorporate linear collider techniques. This note describes the parameters of an asymmetric Flavor-Factory collider at a luminosity of order 10^{36} cm^{-2}s^{-1} at the Y(4S) resonance and perhaps about 10^{35} cm^{-2}s^{-1} at the τ production threshold. Such a collider would produce an integrated luminosity of about 10,000 fb^{-1} (10 ab^{-1}) in a running year (10^7 sec) at the Y(4S) resonance.

1 DESIGN FROM PAST SUCCESSES

The construction and operation of modern multi-bunch e^+e^- colliders have brought about many advances in accelerator physics in the area of high currents, complex interaction regions, high beam-beam tune shifts, high power RF systems, controlled beam instabilities, rapid injection rates, and reliable uptimes (~95%):
1) Colliders with asymmetric energies can work.
2) Beam-beam energy transparency conditions are weak.
3) Interaction regions with two energies can work.
4) IR backgrounds can be handled successfully.
5) High current RF systems can be operated (3 A x1.8 A).
6) Beam-beam parameters can reach 0.06 to 0.09.
7) Injection rates are good and continuous injection is done in production.
8) The electron cloud effect (ECI) can be managed.
9) Bunch-by-bunch feedbacks at 4 nsec spacing work.

Lessons learned from SLC and subsequent linear collider studies (for ILC) and experiments (FFTB, ATF, ATF2) have also shown new successful concepts:
A) Small horizontal and vertical emittances can be produced in a damping ring with a short damping time.
B) Very small beam spot sizes and beta functions can be achieved at the interaction region.
C) Bunch length compression can be performed.

2 LUMINOSITY

The design of a 10^{36} cm^{-2}s^{-1} e^+e^- collider combines extensions of the design of the present *B* Factories and linear collider concepts to allow improved beam parameters to be achieved. The luminosity L in an e^+e^- collider is given by the expression

$$L = \frac{N^+N^-n_b f_c H_d}{4\pi\sigma_x\sigma_y} \qquad (1)$$

$$\sigma = \sqrt{\beta\varepsilon}$$

where n_b is the number of bunches, f_c is the frequency of collision of each bunch, N is the number of particles in the positron (+) and electron (-) bunches, H_d is the disruption enhancement factor from the collisions, σ is the beam size in the horizontal (x) and vertical (y) directions, ε is the beam emittance and β is the beta function (cm) at the collision point for each plane.

3 COLLIDER CONCEPTS STUDIED AT THE FIRST SUPER-B WORKSHOP

Schematic drawings of the Super-Flavor Factory as initially considered at the First Super-B workshop [5] is shown in Figure 1. A positron bunch from a 2 GeV damping ring is extracted and accelerated to 7 GeV in a superconducting (SC) linac. Simultaneously, an electron bunch is generated in a gun and accelerated in a separate SC linac to 4 GeV. The two bunches are prepared to collide in a transport line where the bunch lengths are shortened. These bunches are focused to a small spot at the collisions point and made to collide. The spent beams are returned to their respective linacs with transport lines where they return their energies to the SC accelerator. The 2 GeV positrons are returned to the damping ring to restore the low emittances. The spent electron beam is discarded. The process is repeated with the next bunch. It is expected that each bunch will collide about 120 times each second and that there will be about 10000 bunches. Thus, the collision rate is about 1.2 MHz. A small electron linac and a positron source are used to replenish lost positrons in the colliding process and natural beam lifetime. See Figure 1.
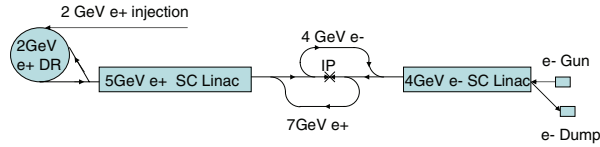
Figure 1 Former Linearly Colliding Super-F Factory

This scheme was necessary in order to save power for cooling the beams that are heavily disrupted after the collision. As shown in Fig.2, the vertical emittance growth in a single collision is about 300. Running the rings at low energy is the only mean to bring the power requirements for the facility to the 100MW levels.
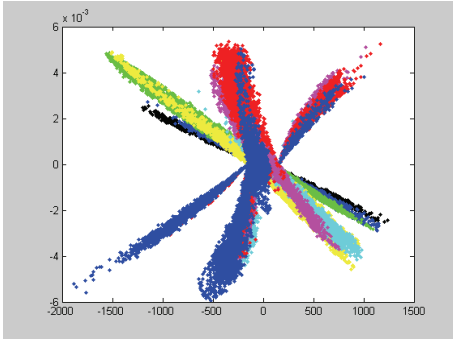

Figure 2 Plot of the (y,y') phase space after collision in the earlier design. Each color refers to one longitudinal bunch slice.

The scheme studied in [5] presents several complexities and challenging requirements for several subsystems. In particular the low energy required for the rings, in combination with the high current, low emittance, small energy spread and short bunch length, is more challenging than the already challenging solution studied for ILC.

4 DESIGN PROGRESS PRESENTED AT THE SECOND SUPER-B WORKSHOP

The IP parameters have been re-optimized in order to minimize the disruption due to the beam-beam forces. The proposed values, shown in Table 1, do produce a much smaller luminosity for a single pass, but the emittance blowup for a single crossing is of the order of a few parts in 10^3 and, thus, only modest damping is needed between collisions. The new scheme is shown in Table 1 and Figure 3. It is possible to increase the collision frequency, and collide continuously in the ring with near ILC requirements with very small blowup. The proposed parameters in the second column for the DR are nearly the ones proposed for ILC except the number of bunches is about 4 times larger. The required Final Focus is also exactly the one designed for ILC with the energy rescaled.
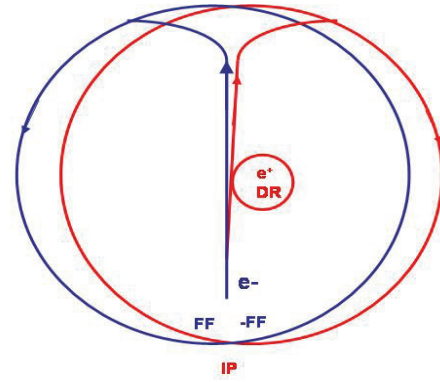
5 COLLISION PARAMETERS OPTIMIZATION

Figure 3 Super-Flavor Factory layout.

Table 1 Preliminary Super-F Factory collision parameters

	1st LNF Workshop Best Working Point	2nd LNF Workshop Best Working Point
σ_x^* (μm)	30 (1.0 σ_x betatron)	2.67
η_x (mm)	1.5 LER/-1.5 HER	0.0
σ_y^* (nm)	12.6	12.6
β_x^* (mm)	1.25	8.9
β_y^* (mm)	**0.080**	0.080
σ_z^* (mm)	0.100	6.0
σ_E^*	**2.x10^-2**	10^{-3}
σ_E _Lum	10^{-3}	$0.7x10^{-3}$
ε_x (nm)	0.8	0.8
ε_y (nm)	0.002	0.002
ε_z (μm)	2.0	4.0
θ_x (mrad)	Optional	2*20
σ_z_DR (mm)	4.0	6.0
σ_E_DR	**0.5x10^-3**	10^{-3}
N_{part} (10^{10})	**7.0**	2.0
$N_{bunches}$	12000	12000
I (A)	**6.7**	1.9
C_DR (km)	6.0	6.0
$\tau_{x,y}$ (ms)	10	20
N_{turns} bet.	50	1
f_{coll} (MHz)	12.0	650
$L_{singleturn}$	1.5	1.2
$L_{multiturn}$	1.1	1.0

The optimization for the "collisions in the ring" option [6] is based on the requirements to not have any need for bunch compression and acceleration. The needs to have small IP spot sizes, small beta functions and tune shifts are satisfied with the combination of small emittances and a crossing angle. The low emittances reduce the beam sizes; the second one simultaneously reduces the tune shift in both planes [7] and the longitudinal overlapping region. Since the interaction region now is short, it is possible to decrease the vertical beta to very small values, further decreasing the vertical size and tune shift. In addition, further minimization of the beam-beam nonlinearities can be performed [8] with a crab waist, to

greatly reduce the residual emittance blowup due to the crossing angle.

Beam-beam studies have been performed with the "GuineaPig" computer code by D. Schulte (CERN) [6, 9], which includes backgrounds calculations, pinch effect, kink instability, quantum effects, energy loss, and luminosity spectrum. The beams are tracked through the ring similarly to what is done in [10], and the emittances and luminosity are evaluated after equilibrium is reached. Fig.4 shows an example of such tracking.
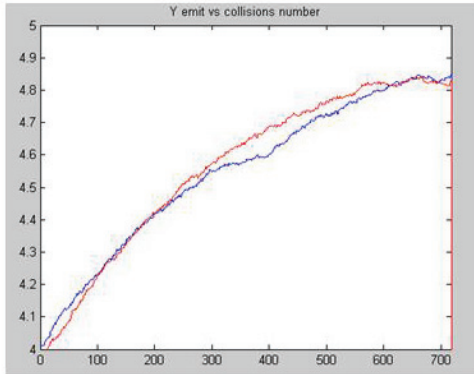

Figure 4 Vertical emittance vs turn number.

6 INTERACTION REGION PARAMETERS

The interaction region is being designed to leave about the same longitudinal free space as that presently used by *BABAR* but with superconducting quadrupole doublets as close to the interaction region as possible [11].

A preliminary design of the Final Focus, similar to the NLC/ILC ones, has been performed for the IP parameters in Table 1, second column. The total FF length is about 70 m and the final doublet is at 0.5m from the IP. A plot of the optical functions in the incoming half of the FF region is presented in Fig. 6. The need for a finite crossing angle at the IP greatly simplifies the IR design (Fig. 8), since the two beams are now naturally separated at the parasitic collisions.

7 POWER REQUIREMENTS

The power required by this collider is the sum of magnet and the accelerator operation. The present estimates indicate about 45 MW for the ring RF, 10 MW for the linac, and 10 MW for the ring magnets for 65 MW total.

8 SYNERGY WITH ILC

There are many similarities between this linear Super-B collider and the ILC. The project described here will capitalize on R&D projects that have been concluded or are on-going within the ILC collaboration. The damping ring and interaction region designs between the two projects are very similar.
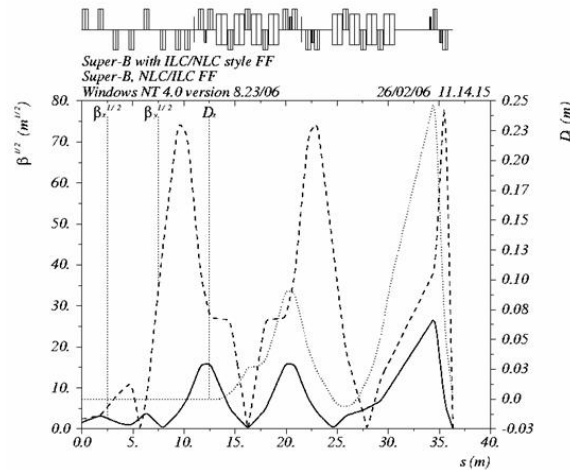

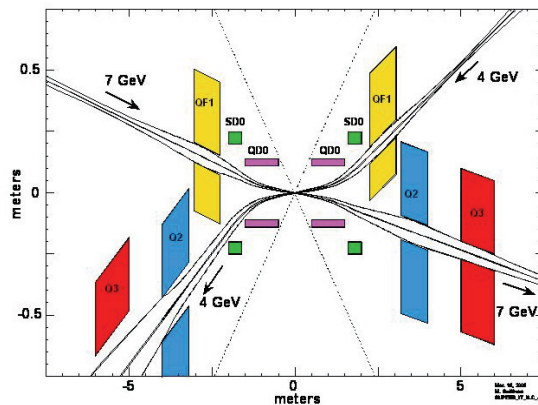Figure 6 Optical functions in half Final Focus region.

Figure 8 Plan view of a possible IR layout.

9 REFERENCES

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