CONCEPTUAL DESIGN OF A MULTIPURPOSE BEAUTY FACTORY BASED ON SUPERCONDUCTING CAVITIES

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Abstract: The conceptual design of a high luminosity ($10^{33} - 10^{34} \text{cm}^{-2} \text{s}^{-1}$) beauty factory ($W = 10\text{-}20 \text{ GeV}$) based on a superconducting linear collider with recirculators and damping rings is discussed in detail. Such an accelerator complex opens not only the possibility of performing interesting experiments in the energy range where $c\bar{c}$ and $b\bar{b}$ quark pairs are abundantly produced, but can be used as continuous linear accelerator for nuclear physics and can support competitive programs in the field of synchrotron light and power FEL's. Around it the new techniques needed for future high luminosity TeV linear colliders could be developed and, at a later stage, be used to build a Z-factory or a toponium-factory.

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1. INTRODUCTION

Most of our knowledge about the beauty (or bottom) quark sector has been obtained from experiments carried out at circular e^+e^- storage rings, with typical luminosities $L \simeq 10^{31} \text{cm}^{-2}\text{s}^{-1}$ [1]. The relevant accelerators are: CESR (Cornell) and DORIS II (Hamburg) running either at the Υ (4S) or at higher center of mass energies ($10.5 < W < 11 \text{ GeV}$), PEP (SLAC) and PETRA (DESY) running in the "continuum" ($20 < W < 47 \text{ GeV}$).

Recently the UA1 collaboration at the SppS (CERN) has reported the first indication of a possible $B^0 - \bar{B}^0$ mixing [2]. The presently running storage rings and the accelerators which are expected to come into operation soon (TeV 1 (FNAL), SLC (SLAC) and LEP (CERN)) will improve significantly our knowledge of b-quark physics [3]. On the other hand, the problem of $B^0_d - \bar{B}^0_d$ mixing, which is expected to be small, will very probably not be settled. An electron-positron collider with a luminosity $L \simeq 10^{33} \text{cm}^{-2}\text{s}^{-1}$ in the energy range $9 < W < 11 \text{ GeV}$ will thus be very useful. Such a collider should have an energy resolution of a few MeV to resolve the production of $B_d(\bar{b}d)$ and of $B_s(\bar{b}s)$, and also to take data just above the thresholds for the channels $B\bar{B}$, $B\bar{B}^*$, $B^*\bar{B}$ and $B^*\bar{B}^*$.

Another even more important issue, which most probably will still be pending for a long time, is the detection of a possible CP violation in B decays [4]. One can in principle search for CP asymmetries in semi-leptonic B decays by measuring the ratio of equal sign to opposite sign dimuons. But, in the standard model, the predicted value for this ratio is so small that some 10^9 B-mesons have to be produced, an unacceptably high number for the quoted machines. The search for CP violation looks much more promising in individual exclusive channels which have small branching ratios but where CP violation is expected to be large [5]. In order to study these exclusive channels one has to reconstruct a few tens $B(\bar{B})$ mesons and tag the associated $\bar{B}$ (B). This may be possible at the Υ (4S) but higher energies seem to be better for some channels, when taking into account tagging and reconstruction efficiencies [6]. An e^+e^- collider with $L \simeq 10^{34} \text{cm}^{-2}\text{s}^{-1}$ at a center of mass energy $W = 15\text{-}20 \text{ GeV}$ with an energy spread of a few hundred MeV, which can be reduced proportionally to the luminosity, will give other handles in the study of CP asymmetries.

The quoted luminosities both at low and high energy would also allow precise measurements of specific channels which could reveal the presence of new physics, in addition to much better determinations of lifetimes and weak interaction parameters.

In this paper we give a detailed account of the proposal for a new collider which allows these important physics cases to be pursued if some advanced technical issues can be solved. The proposal was made in an unpublished report [7] and presented at a dedicated special symposium [8].

The proposed linear collider, schematically shown in Fig. 1, uses state-of-the-art superconducting (SC) cavities and satisfies the above discussed requirements in energy ($10 \leq W \leq 20$ GeV), energy spread (10-300 MeV) and luminosity ($10^{33} - 10^{34} \text{cm}^{-2} \text{s}^{-1}$). Such accelerator offers the added advantage of being a multipurpose machine. A fraction of the first acceleration stage, combined with a wiggler system, can be used as a Free Electron Laser (FEL) to produce, for instance, intense infrared photon beams, as done at present with the SC linac of Stanford University [9]. The complete first stage would allow Nuclear Physics studies with a continuous electron beam of energy of the order of 2.5 GeV [10]. Each one of the electron (positron) damping rings is an interesting synchrotron light source. Moreover, when the full damping ring system is added, the complex can be used as $D-\bar{D}$ factory of large luminosity ($L \geq 3 \cdot 10^{32} \text{cm}^{-2} \text{s}^{-1}$), while the second acceleration stage is the $B-\bar{B}$ factory, which offers also the possibility of producing B 's with different boosts in the laboratory. Finally, the 5-10 GeV continuous electron beam can be used as a powerful electromagnetic probe of nuclear matter.

Such an accelerator complex, on top of its rich physics potentials, would allow the study and development of techniques needed for high luminosity linear colliders in the TeV energy range which make use either directly [11,13] or indirectly [14,15] of SC cavities. After completion of these developments, one could imagine to substitute the second acceleration stage with a linear collider based on a technology which could give larger gradients and thus reach, within a reasonable total length, energies of the order of (50+50) GeV. This opens the way to the construction of a Z^0 -factory and, maybe, even to a toponium factory, if such particle exists in the available energy range.

2. DESCRIPTION OF THE LINEAR COLLIDER

Fig.1 shows the scheme of the proposed collider. To minimize its cost we envisage to use a recirculation scheme both for the first stage (injector to the damping rings) and for the second stage (final acceleration). This solution is chosen because according to today estimates the recirculators cost less than the extra length of SC cavities, but this assumption, together with the optimum number of recirculators, has to be checked when more precise cost estimates will be available.

In the following we assume an accelerating gradient $G = 7 \text{ MV/m}$ and a quality factor $Q = 5 \cdot 10^9$. Such values have been obtained in prototype multicell cavities [16] at frequencies in the range 350-1500 GHz. The choice of the frequency is not critical in our application; when needed we shall use $f_{RF} = 350 \text{ GHz}$, the frequency of the cavities developed for LEP 200, and we shall comment on the effect of choosing $f_{RF} = 500 \text{ MHz}$. Low frequencies are preferred because the energy spread and the emittance of the bunches have to be very small, and wake field effects during acceleration depend strongly on f_{RF} . A subsidiary argument is that low frequencies are needed for the efficient powering of high gradient-high frequency copper structures with a superconducting low energy linac [14, 15].

For the $\Upsilon(4S)$ studies we aim at a luminosity $L = 10^{33} \text{ cm}^{-2} \text{ s}^{-1}$ with a final beam current comparable to what will be produced at the CEBAF accelerator. Since CEBAF will produce $200 \mu\text{A}$ at 4 GeV with four recirculators [10], we assume similar average currents. However, our peak current is equal to the SLC one and $\sim 10^4$ times larger than at CEBAF.

To run in the high-resolution mode on the $\Upsilon(4S)$ peak (at 10576 MeV), which at half height is about 25 MeV wide, one needs a r.m.s. energy spread smaller than 10 MeV. This implies a very small average beamstrahlung [17] fractional energy loss by the e^+ 's and e^- 's bunches: $\langle \epsilon \rangle \simeq 5 \cdot 10^{-4}$ at a beam energy $E \simeq 5 \text{ GeV}$. In the "continuum" the collider would run in the low resolution-high energy mode, for which one can instead accept $\langle \epsilon \rangle \simeq 10^{-2}$. For the invariant emittance ϵ_n we choose a value which is close to what the best synchrotron light source of the new generation aim at:

$$\epsilon_n \simeq 2 \cdot 10^{-6} \text{ m.}$$

Once the bunch energy $E = W/2$, the power of each beam P , the emittance ϵ_n and the fractional beamstrahlung loss $\langle \epsilon \rangle$ are given, all the other quantities defining the collider can be determined by fixing the disruption parameter D [17,18]. To take full advantage of the pinching effect [19] and have large luminosities, we assume $D \approx 15$ in both modes. This implies a large pinching of the bunches with a luminosity gain $H \approx 6.0$ [19]. The definitions and the values of the important parameters for both modes of running are collected in Table 1. We underline that the collider would run in the so called "classical regime", since the ratio of the photon critical energy to the bunch energy is $T < 1$. However, the high resolution beauty factory requires a small value for the average number of radiated photons N_γ , a quite unusual condition.

Table 1			
Parameters for the high resolution and low resolution modes of the beauty factory			
Quantity [Reference]	Symbol/Unit	High resolution mode	Low resolution mode
bunch energy	E/GeV	$5\text{-}6^*$	$6\text{-}10^*$
luminosity	$L/\text{cm}^{-2}\text{s}^{-1}$	10^{33}	10^{34}
power/beam	P/MW	0.5	1.5
bunch frequency	f/kHz	12	12
invariant emittance	ϵ_n/m	$2 \cdot 10^{-6}$	$2 \cdot 10^{-6}$
disruption parameter	D	16	13
pinch factor [19]	H	6	6
particles/bunch	N	$5 \cdot 10^{10}$	$8 \cdot 10^{10}$
bunch r.m.s. length	σ_z/mm	1.3	0.4
β -value at IP	β^*/mm	6.0	4.0
bunch r.m.s. radius	$\sigma_t/\mu\text{m}$	1.1	0.60
av.critical energy [17]	E_c/MeV	2.3	85
E_c/E	T	$4.5 \cdot 10^{-4}$	$8.5 \cdot 10^{-3}$
fractional energy loss	$\langle \epsilon \rangle$	$4.5 \cdot 10^{-4}$	$2.5 \cdot 10^{-2}$
av.number of photons [17]	N_γ	2.5	7.5
collision energy	W/GeV	10-12	12-20
fract. r.m.s. of W [17]	σ_W	$3.5 \cdot 10^{-4}$	$1.3 \cdot 10^{-2}$
r.m.s of $W = \sigma_W W$	$\Delta W/\text{MeV}$	3.4	125

* The other parameters are given for $E = 5 \text{ GeV}$ and $E = 10 \text{ GeV}$ respectively.

The large value of D implies that the particles perform radial oscillations during the bunch-bunch interaction, and that the angle of the radiated photons is about 15 mrad. In such conditions numerical calculations

are needed to accurately determine the average number of radiated photon N_γ and the fractional energy loss $\langle \epsilon \rangle$ [17]. Approximate expressions, which take into account the pinch effect, have been used in computing the values of Table 1 with the formulae given in Ref 15 and 18. Since the distribution of the c.m. energy W caused by the beamstrahlung radiation is not normal, the fractional r.m.s. value σ_W has a not well defined meaning [17]. Still in Table 1 we have computed the r.m.s. value ΔW of the energy W as if it was a gaussian distribution; this should not be forgotten when considering the numerical values of the parameter ΔW .

We note that, on purpose, the parameters σ_z , β^* and σ_t of the high resolution mode are similar to SLC ones [20]. The invariant emittance is instead ten times smaller, and the disruption parameter is ten times bigger. The bunch frequency is hundred times larger than in SLC, as allowed by the use of SC cavities which run continuously.

In the high luminosity-low resolution mode the emittance and the frequency are equal to the ones needed in the high resolution mode, while the other parameters are somewhat more demanding. In particular the bunch length is $\sigma_z = 0.4$ mm (instead of 1.3 mm) and the β -function at the interaction point has the value $\beta^* = 4.0$ mm (instead of 6.0 mm as at SLC). This is certainly feasible, especially in view of the small momentum spread achievable with SC cavities, which reduces the problem connected with the chromaticity of the final focus system.

In the scheme shown in Fig.1 we foresee to have electrons and positrons circulating in opposite directions both in the first and in the second acceleration stage. The counterrotating bunches have to be electrostatically separated in the arcs of the second stage. Moreover, quadrupole focusing has to be provided along the SC linacs and it could be that further calculations show that an easier solution is found when the two beams circulate in the same direction. This is a detail which does not modify our considerations.

3. POSITRON SOURCE AND DAMPING RINGS

Positron production is a serious problem, because of the low energy of the collider. It is known that one needs on average an electron of ≈ 25 GeV to produce a low energy e^+ to be accelerated [20]. Since this is not available, we need a SC linac at a 12 kHz repetition frequency and high current to produce enough positrons. With a ~ 150 MeV electron injector and a ~ 30 mA current, the power on the target is 5 MW. This certainly poses serious technical problems. Different types of positron sources are worthwhile studying.

The required invariant emittance ($\epsilon_n \approx 2 \cdot 10^{-6}$ m) is small and optimized damping rings (DR) are needed. We have chosen as damping energy $E_d \approx 2.4$ GeV to reduce the effect of intrabeam scattering [21]. By following the work done in connection with synchrotron light sources, we use the formulae which are valid for lattices of the Chasman-Green type [22] each module being formed by two bending magnets and five quadrupoles:

$$\begin{aligned}\epsilon_d/[m] &\approx 1.2 \cdot 10^{-11} (\gamma_d/N_d)^3 \\ \tau/[s \cdot T^2] &\approx 30/(\gamma_d B_d^2),\end{aligned}$$

where ϵ_d is the equilibrium emittance, γ_d is the γ -factor of the particles of energy E_d in the DR's, τ is the damping time, $N_d/2$ is the number of achromatic modules per ring, and B_d is the field in the bending magnets [15]. At $E_d = 2.4$ GeV, to get an equilibrium emittance $\epsilon_d \approx 10^{-6}$ the above equation implies $N_d \approx 100$ magnets. With $B_d = 1.6$ T the damping time is $\tau \approx 2.5 \cdot 10^{-3}$ s. The radius of curvature is $\rho_d \approx 5$ m, the average radius $R \approx 15$ m and the length of each bending magnet is about 30 cm, similar to the length of the magnets used in the FODO rings built for the SLC collider [20].

We can now compute the total number of damping rings. The ratio of the total length of the DR's ℓ_d to the average distance between the bunches ℓ_b in each DR is [18].

$$\ell_d/\ell_b = 2(t/\tau) f \tau \approx 300,$$

where t is the bunch waiting time in a DR, and we have taken $(t/\tau) \approx 5$. By putting in the DR's trains of 5 bunches at a distance $\lambda = 85$ cm ($f_{RF} = 350$ MHz) separated by about 10 m, $\ell_b \approx 2.7$ m and

$\ell_d \approx 800$ m. (This needs the development of very fast kickers.) To achieve the needed $f = 12$ kHz frequency, for damping the e^- and e^+ bunches one has to built 4+4 rings, each having a circumference $2\pi R \approx 100$ m. (Maybe two, or more, rings can be put one on top of the other by using the same iron for the return yoke, as done in the CERN Booster.) At any moment each ring contains $8 \times 5 = 40$ bunches and a refined feedback system is required for damping the multibunch instabilities.

The train operation of the rings implies that in the second acceleration stage 5 e^- and 5 e^+ bunches have to be accelerated from 2.4 GeV to a maximum of ≈ 10 GeV. In the high resolution mode the energy extracted by such a train is 0.3 J/m, to be compared with a stored energy of 90 J/m at 7 MV/m, if the frequency is 350 MHz. This corresponds to an energy difference between the first and the fifth e^+e^- collision of ≈ 8 MeV, which is small enough. At a RF frequency of 500 MHz this difference increases to ~ 15 MeV, still acceptable. From this point of view higher frequencies are not favored, but could be chosen if the number of bunches per train is smaller than 5 and the length of the DR's is increased. For completeness we note that the energy spread due to the finite length of each bunch when it is accelerated on the crest of the wave is completely negligible (less than 0.5 MeV at 350 GHz).

The intrinsic energy spread of the bunches extracted from the DR's has also to be taken into account. This is determined [15] by the properties of the DR's: $\sigma_E \approx 4.4 \cdot 10^{-7} \gamma_d / \sqrt{\rho_d} / [m] \approx 10^{-3}$, i.e. $\Delta E \approx 2$ MeV. In the high resolution mode to have a bunch length $\sigma_z \approx 1.3$ mm at the collision point (Table 1) and an energy spread definitely smaller than the width of the state Υ (4S) (FWHM = 25 MeV), one has to rotate the bunches in the longitudinal phase and have in the DR a bunch length ≤ 5 mm. This is possible with a total acceleration voltage/turn of ≤ 1 MV at 350 MHz.

4. USE OF THE FIRST STAGE AS $D\bar{D}$ FACTORY

The first acceleration stage and the DR's can be used to collide electron and positron bunches at energies $W \approx 4$ -5 GeV with luminosities roughly hundred times larger than what is today available at SPEAR (SLAC). Table 2 contains a possible list of parameters.

All parameters are very similar to the ones used for the B-factory running in the high resolution mode and the achievable luminosity is $L \approx 3 \cdot 10^{32} \text{cm}^{-2} \text{s}^{-1}$. The beamstrahlung width at the collision point is very small ($\Delta W \approx 0.1 \text{ MeV}$) and the energy resolution, dominated by the bunch energy spread after rotation in the longitudinal phase space, is so small ($\Delta W \leq 10 \text{ MeV}$) that narrow states can be effectively excited. Note that, by reducing σ_z and $\sigma_t \propto \sigma_z^{1/2}$, the luminosity could be increased above $3 \cdot 10^{32} \text{cm}^{-2} \text{s}^{-1}$ while keeping D constant.

Table 2	
Parameters for (2+2) GeV collisions	
Symbol/Unit	Value
E/GeV	2.0-2.5*
$L/\text{cm}^{-2} \text{s}^{-1}$	$3 \cdot 10^{32}$
P/MW	0.13
f/kHz	10
ϵ_n/m	$2 \cdot 10^{-6}$
D	17
H	6
N	$4 \cdot 10^{10}$
σ_z/mm	1.5
β^*/mm	5
$\sigma_t/\mu\text{m}$	1.6
E_c/MeV	0.17
τ	$8.5 \cdot 10^{-5}$
$\langle \epsilon \rangle$	$4.7 \cdot 10^{-5}$
N_y	1.4
W/GeV	4.0
σ_w	$4.5 \cdot 10^{-5}$
$\Delta W/\text{MeV}$ (due to beamstrahlung)	0.1

* The other parameters are given for $E = 2.0 \text{ GeV}$.

5. FACTORIES AROUND (50+50) GEV

The first acceleration stage and the DR system represent an unique source of low-emittance and high-frequency electron and positron bunches. As such it could be used as injector to a high-gradient

structure, which would accelerate the bunches to $\sim (50+50)$ GeV -- or even higher. Here we consider only the first case.

As shown in the first column of Table 3, the parameters are such that, at the Z^0 peak one could reach a luminosity which is more than 100 times higher than the one of LEP 100. For Z^0 production a large energy spread ($\Delta W \simeq 1$ GeV, r.m.s) can be accepted. Such a low resolution mode would give $\simeq 10^9$ Z^0 's/year, i.e. $\simeq 10^8$ $b\bar{b}$ /year. This rate, larger than what can be obtained at the beauty factory, may be enough to observe some CP-violation effect in the semileptonic decay of b-quarks.

A toponium factory would have less luminosity since, if the toponium mass turns out to be in the accessible energy range, one would like to run with $\Delta W \leq 20$ MeV. A possible set of parameters providing $L \simeq 2 \cdot 10^{32} \text{cm}^{-2} \text{s}^{-1}$ is given in the second column of Table 3.

Table 3		
Parameters for (50+50) GeV collisions		
Symbol/Unit	Low resolution collider (Z^0 -factory)	High resolution collider (toponium-factory)
E/GeV	50	50
$L/\text{cm}^{-2} \text{s}^{-1}$	$2.5 \cdot 10^{33}$	$2 \cdot 10^{32}$
P/MW	2.0	1.0
f/kHz	12	12
ϵ_n/m	$2 \cdot 10^{-6}$	$2 \cdot 10^{-6}$
D	4.5	4.8
H	6	6
N	$2 \cdot 10^{10}$	$1 \cdot 10^{10}$
σ_z/mm	0.7	5.0
β^*/mm	4	15
$\sigma_t/\mu\text{m}$	0.30	0.55
E_c/MeV	600	23
T	$1.2 \cdot 10^{-2}$	$4.7 \cdot 10^{-4}$
$\langle \epsilon \rangle$	$1.7 \cdot 10^{-2}$	$1.8 \cdot 10^{-5}$
N_γ	3.6	1.0
W/GeV	100	100
σ_w	$1.1 \cdot 10^{-2}$	$2.0 \cdot 10^{-4}$
$\Delta W/\text{MeV}$	1,100	20*

* This spread is small enough because $N_\gamma \simeq 1$ and in a large fraction of the collisions no photon is radiated. Note that the spread ΔW can be further reduced proportionally to L .

To have a small energy spread both colliders work in the classical regime ($T \ll 1$) with a small average number of radiated photons, as for the other colliders considered in this paper. The main difference is in the bunch length. For the low resolution Z^0 -factory the bunch length is $\sigma_z \approx 0.7$ mm. Such a value is compatible with the very large frequencies (30 GHz) considered at CERN for the copper structures powered by a low energy beam whose energy is replenished by superconducting cavities [14,15]. We underline that the 300 m of SC cavities used in the second acceleration stage of the bottomium factory (Fig. 1) are exactly what is needed for the driving beam powering a (500 + 500) meter long copper structure at 30 GHz, which would run at ≈ 100 MV/m and produce (50 + 50) GeV collisions with the quoted luminosities. If the gradient in the 350 GHz SC cavities would be as high as 15 MV/m, the acceleration gradient could be ≥ 200 MV/m.

For achieving the high energy resolution required for the toponium factory, the bunch has to be long ($\sigma_z \approx 5$ mm). This requires a long wavelength, i.e. a relatively small frequency ($f_{RF} = 350\text{-}500$ MHz). The toponium factory is thus a natural extension of the fully superconducting beauty factory described above. Of course, once built this collider could be used with short bunches as Z^0 -factory with a set of parameters similar to the ones appearing in the first column of Table 3.

6. COST ESTIMATE

We have made a first rough cost estimate of the accelerator complex schematically drawn in Fig.1. The costs of the DR's is estimated by using 35 kSF/m, which is more than twice the unit cost of the LEP magnet and RF systems: $800 \text{ m} \times 35 \text{ kSF/m} \approx 28 \text{ MSF}$. The costs of the SC cavities and cryostat are also assumed to depend only on length. With 230 kSF/m, as given for LEP 200 cavities in Ref 23, we get $230 \text{ kSF/m} \times 400 \text{ m} \approx 92 \text{ MSF}$. In a reasonable layout (Fig.1) there are about 500 m of recirculators. Using the same unit as for the DR's, we get about 18 MSF.

At 350 MHz and 7 MV/m ($R/Q = 260\Omega$ and $Q = 5 \cdot 10^9$) the cryogenic losses are ~ 40 W/m, i.e. the cryogenic power to be installed is $P_{\text{cryo}} = 15$ kW at 4.8 K, which corresponds to about 8 MW at room

temperature. The cost [23] of the cryogenic system is $C_{\text{cryo}} = 2.5 \text{ MSF } P_{\text{cryo}}^{3/5} \approx 13 \text{ MSF}$. Finally the cost of the RF-system can be estimated [23] at the unit price of 1.8 MSF/MW for a total of $\leq 3 \text{ MW}$, i.e. 6 MSF. For the focusing arcs we take 35 kSF/m for a total length of $\approx 200 \text{ m}$, i.e. 7 MSF.

Summing up the cost of the main components would be about $\approx 165 \text{ MSF}$. The electron gun and the positron source (which is certainly very expensive) will bring the material cost of such a collider to about 220 MSF. Manpower, controls, civil engineering and contingency are not included in this estimate.

7. CONCLUSIONS

We have shown that, by further developing some advanced technologies, it is possible to build an intense $b\bar{b}$ factory ($10 \leq W \leq 20 \text{ GeV}$, $L = 10^{33} - 10^{34} \text{ cm}^{-2} \text{ s}^{-1}$) based on a e^+e^- superconducting linear collider with recirculators [24]. In addition the first acceleration stage and the damping rings can be used as a $c\bar{c}$ -factory with a luminosity $\geq 3 \cdot 10^{32} \text{ cm}^{-2} \text{ s}^{-1}$.

The collider may use standard LEP 200 superconducting cavities (350 MHz), but a somewhat higher frequency is also possible. The damping rings are of the kind needed for the next generation of synchrotron light sources. The electron and positron bunches are brought to collision as in the SLC scheme and used only once. The high luminosity assumes that a high current, low energy ($\sim 150 \text{ MeV}$) electron linear accelerator (which has to be based on superconducting cavities) is used for positron production. The high power to be dissipated in the positron target is one of the main challenges of the proposed scheme. Novel ideas in the production of positrons are certainly worth pursuing.

This accelerator complex, which has very precise physics justifications, is unique because it opens the possibility of an interesting physics program in the energy range where $c\bar{c}$ and $b\bar{b}$ quark pairs are abundantly produced. As described in the Introduction, it produces continuous electron beams for nu-

clear physics experiments and can be used as intense synchrotron light source; it can also support a competitive program in the field of a high power FEL's. A fully superconducting toponium factory is a natural extension of the proposed beauty factory. Moreover, around such an accelerator one could develop the new techniques needed for future high luminosity TeV linear colliders, which later could be used to build, for example, a Z-factory.

In our opinion the construction of the accelerator complex described in this paper can be considered as part of a reasonable strategy to go from SLC to the future linear colliders of very large energies and luminosities, with the added advantage that it could be constructed in stages within a limited budget by a medium size laboratory.

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Fig. 1 Schematic drawing of the superconducting beauty factory. The first accelerator stage produces a 2.5 GeV electron beam which can be used for nuclear physics. A charm-factory is obtained by colliding the bunches extracted from the damping rings. (The different parts are not drawn to scale.)