PHYSICS PROSPECTS FOR A LINEAR COLLIDER B-$\bar{B}$ FACTORY

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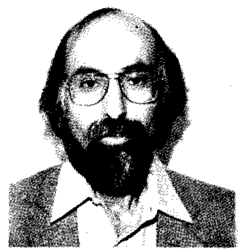

ABSTRACT. Physics motivation for a dedicated, high luminosity B-$\bar{B}$ factory is emphasised. B decays can give very useful information on some important parameters of the Standard Model (such as mixing angles) and clarify the role of QCD in weak decays. B decays are far cleaner than K decays so far as QCD corrections are concerned. The strength of some of the flavor-changing loop decays of B are also vastly enhanced over the corresponding decays of kaons making such loop decays invaluable for testing the full machinery of the Standard Model (SM) to one loop. Possibilty of observation of CP violation in a new arena remains the most tantalizing promise of a B factory. However, that would require $\geq 10^8$ B's. As such an e^+e^- linear collider B-$\bar{B}$ factory with a luminosity of $10^{34}/cm^2$ is highly desirable.

The outline of this talk[1] is as follows:

1. Introduction and Motivation.
2. SM Physics (without CP):
   (a) Tree graph decays and determination of CKM parameters.
   (b) Loop decays via electroweak penguins.
   (c) Loop decays via QCD penguins.
3. Observabilty of CP Non-Conservation in B Decays.
4. Non Standard Model Physics .... One Example.
5. Sources for B's: Incidental and Dedicated B factories.
6. Summary.

1. Introduction and Motivation.

In the past several years intense kaon factories have become available making it feasible to measure rare branching ratios down to the impressive level of 10^{-11}.[2] The need for a dedicated B factory may therefore hardly appear necessary. What we wish to point out here is that the B system is extremely rich and its rare decays have a lot of potential for excellent physics.

For one thing B decays are far cleaner from QCD corrections compared to K decays. Indeed there are two well known tests of strong corrections to weak amplitudes, namely, the lifetime difference between charged and neutral mesons and the semileptonic branching ratio. Experimentally it is already known that $0.5 \lesssim \tau_{B^+}/\tau_{B^0} \lesssim 2$ which is a far cry from the factor of 450 for the kaon case. Furthermore, the semileptonic branching ratio for B's is also roughly in accord with naive quark counting. These are important indications that effects of QCD corrections are not that important on b decays at least in so far as tree graph decays are concerned. Presumably, the fact that $m_b^2 >> m_s^2$ is at least in part responsible for the smallness of QCD corrections as a manifestation of the asymptotically free nature of QCD.

In the realm of loop decays the u quark in the flavor changing loop $b \to s$ transition essentially decouples because the u quark has such a small mass (compare to c and t quarks) and also because the CKM angle $V_{ub} << V_{cb} << V_{tb}$. This decoupling of the light u quark should make loop decays of b quarks short (and not long) distance dominated and therefore much more readily amenable to perturbative analysis.

Freedom from QCD corrections can be a very important consideration for electroweak experiments as the computational ability of the theoretical community in the realm of small momentum transfers is at such an abysmal state. A case in point is the situation regarding the CP violating parameter ε'/ε in neutral kaon decays. As of now there is no theoretical calculational scheme that can reliably calculate this quantity. As a result the heroic experimental effort[3)] which are now on the verge of measuring this quantity with an impressive accuraccy of one part in a thousand may tragically fail to have an impact on the SM unless the calculational situation improves.

Loop decays of b also have significantly larger BRs than the corresponding kaon decays. This happens as loop decays are often driven by the heaviest (virtual) quark in the loop, i.e. the top quark. Then the ratio of BR for $b \to s$ versus $s \to d$ transitions becomes:

$$|V_{ts}^{*} V_{tb}/V_{cb}|^{2} \;/\; |V_{td}^{*} V_{ts}/V_{us}|^{2} \simeq \lambda^{-8} \simeq 10^{5} .$$

Indeed BR $(B \to K\nu\bar{\nu}) \sim (1\text{-}70)*10^{-6}$ [4)] whereas for BR $(K \to \pi\nu\bar{\nu}) \simeq (1\text{-}3) \times 10^{-10}$.[5)] Thus loop decays of b may not be that rare and they provide an excellent probe for the short distance structure of the theory. These probes are the analogues of the precision tests such as the (g-2) of the muon except that in b decays they are more powerful as they test the full non-Abelian gauge theory structure including non-Abelian coupling and symmetry breaking mechanism of the SM. This is an important point and we shall elaborate on this in Section 3.

Being a member of the third family b quark is also likely to be much more sensitive to the parameters of the 4th generation than the s quark.

As $m_B^2 >> m_K^2$, B has a lot more final states available to it than the K. This has the important effect that restrictions imposed by the CPT theorem get watered down compare to the case in kaons in so far as tests of CP invariance are concerned. Thus CPT plus strong interactions selection rules require $BR(K^+ \to \pi^+\pi^o) = BR(K^- \to \pi^-\pi^o)$ so that two body decays of $K^{\pm}$ cannot be used for testing CP nonconservation. The large mass of the B makes it available to many more final states so that in contrast, e.g.

$$BR(B \to K\pi) - BR(\bar{B} \to \bar{K}\bar{\pi})$$

is a perfectly viable and indeed an interesting test of CP invariance.

Finally we take the opportunity to reiterate what has been repeatedly emphasized in the literature: b decays offer the only hope for observable

CP violating effects outside of the neutral kâon system at least if the SM with 3 generations is the correct explanation for the observed CP violation.[6] Analysis of the potential signatures strongly suggest that successful tests of CP would require $\gtrsim 10^8$ clean $B\bar{B}$ pairs in an e^+e^- environment.[7] Such fluxes seem difficult if not impossible to attain at circular machines and therefore a dedicated linear collider B factory would be very highly desirable.

2. Standard Model Physics (without CP violation).

(a) Tree Graph B Decays and Determination of CKM Parameters.

In the context of the SM the mixing angles like quark and lepton masses are input parameters whose value has to be obtained from experiment. Studies of b quark that proceed via simple tree graphs can shed light on two important CKM elements V_{ub} and V_{cb}. Measurements of B lifetime and semileptonic branching ratio have shown that V_{cb} is unexpectedly small. At the moment all the data also seems compatible with $V_{ub} = 0$. If that is really true that could have a profound effect as the SM with the known 3 generations will not be able to accomodate a CP violating phase. A determination of V_{ub} or at least a demonstration that it is nonvanishing is therefore extremely important.

In principle the simplest way to determine V_{ub} is via $B^\pm \to \tau^\pm + \nu_\tau$. The BR is estimated to be:[8,9]

$$BR\ (B \to \tau+\nu_\tau) \sim 4 \times 10^{-4}\ (f_B/.2\ \text{GeV})^2\ [5\ V_{ub}/V_{uc}]^2 \lesssim 4 \times 10^{-4}\ .$$

The decay thus monitors $V_{ub}{*}f_B$ where f_B is the pseudoscalar decay constant. Although this is a very tough measurment it may be feasible at a B factory. A possible mode for detection of τ is $\tau \to \nu_\tau\ e\nu_e$ but there are likely to be serious background problems with $B \to e\nu\pi^0$. A mode that seems to have a better chance of working is $\tau^\pm \to \nu_\tau\pi^\pm$. The overall signal would be a reconstructible B along with a $\pi^\pm$ with substantial missing energy. Expected # of events $\simeq$ 30/yr.[7] The main background of $\lesssim 10$ events/yr is from $B^\pm \to K_L\pi^0$. There are some other ways of measuring V_{ub}: (1) $B \to e\nu_e X_{\not{c}}$ where $X_{\not{c}}$ is a charmless inclusive final state. The expected inclusive BR ~ 10^{-3} (if $V_{ub}/V_{cb} \sim 1/5$). Dominant exclusive final states are likely to be $e\nu\pi^0$, $e\nu\rho^0$ .... These decays monitor V_{ub} times a semi-leptonic form factor. Such form factors appear measurable using lattice techniques.[10] (2) $B \to F+\phi$, $F+K\bar{K}$.[9] Such non-leptonic decays proceed through the annihilation graph and have an estimated BR of ~ 10^{-4}. (3) $B \to F+\pi$, $F+\rho$, $F+\pi\pi$ ... .[9] These tend to proceed through the spectator graph and have an inclusive BR of ~10^{-3}.

For the last two methods to yield V_{ub} would require knowledege of hadronic matrix elements. Again measurements of exclusive hadronic matrix elements may be feasible using lattice techniques.[10]

(b) Rare Decays via Electroweak Penguins.[11]

At the quark level the interesting modes are $b \to s\ell^+\ell^-$,[4,12,13] $b \to s\nu\bar{\nu}$,[4] $b \to s\gamma$.[14-17] They materialise, e.g., as $B \to Kee$, $KeeX$, $B_s \to \phi ee$ ... ; $B \to K\nu\bar{\nu}$ ... ; $B \to K^*\gamma$ ... etc.

Perhaps the cleanest and theoretically most interesting mode is $B \to Kee$ which has a well defined and reconstructible final state. The decay is interesting because it provides a test of the full machinery of the SM at the one loop level. If quarks with mass > m_W exist these decays ($b \to s\ell\ell$, $s\nu\bar{\nu}$) acquire special importance. In the limit of X_Q ($X_Q \equiv m_Q^2/m_W^2 \gg 1$) the formula for the rates take a very simple form:[4,18]

$$\sim \left| \frac{1}{4} X_Q + \frac{3}{4} \ln X_Q \right|^2$$

where (in the 't Hooft-Feynman gauge) the first contribution is due to Z exchange and the second one due to γ exchange. Presence of the first term due to Z exchange means that the rate grows as m_Q^4. Therefore the process becomes an excellent way of monitoring mass scales and mixing angles of heavy quarks. The growth of the rate with virtual quark mass as m_Q^4 is very remarkable. This somewhat counter intuitive behavior constitutes an evasion of the screening theorem of Appelquist and Carrazone[19] and arises due to the fact that the underlying spontaneously broken gauge theory has Yukawa coupling constants which are proportional to fermion masses. A similar phenomenon in K-$\bar{K}$ or B-$\bar{B}$ mixing occurs. However, those mixing effects are governed by amplitudes which grow as m_Q^2. The rates for $b \to s\ell\ell$, $s\nu\bar{\nu}$ go as $|\text{Amplitude}|^2$ and consequently grow as m_Q^4. The presence of the m_Q^4 term is a consequence of the fermion mass generating Higgs mechanism of the underlying SM and therefore measurments of these decays constitutes a very important test of the SM at its weakest sector, namely the symmetry breaking mechanism. The importance of these tests of the SM can therefore hardly be overemphasised.

The three generation result is given in Fig. 1. The current CLEO bound BR ($B \to Kee$) $\lesssim 10^{-4}$ translates into $m_t \lesssim 500$ GeV. So at the moment this bound on m_t does not compete favorably with that obtained from ρ

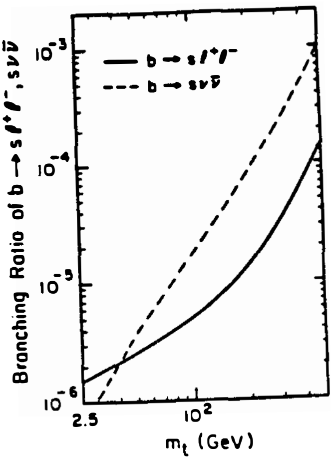

Fig. 1. BRs for the process $b \to s\ell^+\ell^-$, $s\nu\bar{\nu}$ in the 3-generation case. For the $b \to s\nu\bar{\nu}$, the 3-neutrino species have been summed over.

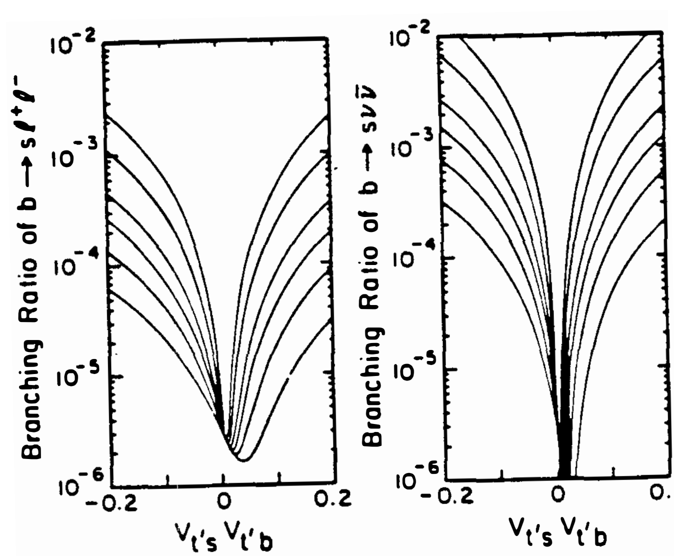

Fig. 2. The 4-generation BRS vs. $v_{t'} \equiv V^*_{t's} V_{t'b}$. We have used $V_{cb} = .05$, $m_t = m_L = 50$ GeV. Different curves from bottom to top are: $m_{t'} = 150$, 200, 250, 300, 400 and 500 GeV.

parameter and radiative corrections of $\sin^2\theta_W$ which now give $m_t \lesssim 200$ GeV.[20] However, the latter bounds are a result of over five years of theoretical and experimental effort whereas the bounds from B decays are at a stage of pre-infancy. As improvements in measurements of B decays become available and certainly as a dedicated B factory that we are advocating becomes available, these decays would start to compete very favorably with these other bounds.

The 4-generation result for $b \to s\ell^+\ell^-$ and $b \to s\nu\bar{\nu}$ is shown in Fig. 2. Here the controlling mixing angle is $v_{t'} \equiv V_{t'b}V^*_{t's}$. We have limited our considerations to $|v_{t'}| \leq .2$ and $150 \leq m_{t'} \leq 500$ GeV. We see that an order of magnitude enhancement over the three generation result is quite possible.

Another interesting loop decay is $b \to s\gamma$.[14-17] A significant fraction of the time this should materialize into the exclusive mode $B \to K^*\gamma$. For the three generation case the inclusive BR is $\sim 10^{-4}$ within a factor of two and is quite insensitive to the top mass. In 4 generation the BR can be much larger or appreciably smaller (because of cancellation between t and t' contributions) than the 3 generation case. This mode has the distinction of very likely becoming the first observable loop decay of the b quark.

(c) Loop Decays via QCD Penguins.[11,21]

At the quark level these decays proceed through $b \to sg^*$ where g^* is a gluon on or off its mass shell. At the hadron (inclusive) level this materializes into $B \to K+X_{\not{c}}$ where again $X_{\not{c}}$ stands to emphasize that the hadronic final state must be charmless. Denoting q as the 4-momentum of the gluon, the contributing processes can be of three types: (a) $q^2 > 0$, i.e. time-like gluon which leads to $g^* \to q\bar{q}$ (q = u,d,s for charmless final state) and $g^* \to gg$; (b) $q^2 < 0$, i.e. the space-like case. At the quark level this leads to a two-body decay; (c) $q^2 = 0$ which is the light-like case. Although this last process is lowest order in α_S, it is driven by the magnetic form factor alone and contributes much less than the $O(\alpha_S^2)$ process (a) as the electric form factor is much larger than magnetic. The contribution for these three case as well as the total is shown in Fig. 3. The total inclusive BR is fairly insensitive of the top quark mass and is 1-2%. For the 4 generation case (see Fig. 4) the BR ranges from .5% to 15%.

We thus see that at the inclusive[11,21-22] level these loop decays have fairly large BR. However, they would materialize mostly into multibody final states such as $K + 2\pi$, $K + 3\pi$ ... and to a lesser extent

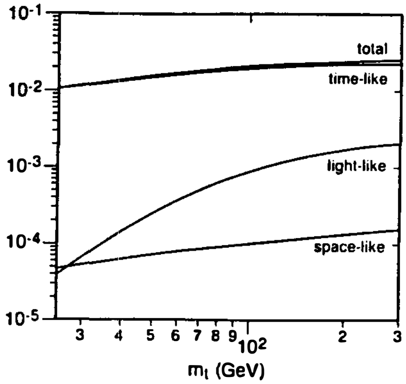

Fig. 3. The 3-generation case.

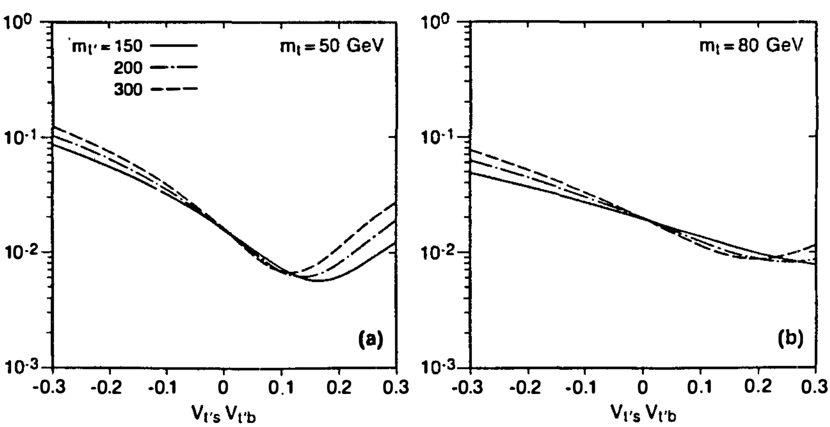

Fig. 4. The 4-generation case.

multikaon states. Decays into two-body charmless modes such as $K\pi$ are going to be suppressed (BR ~ 10^{-5}). The experimental challenge in detection of QCD penguins lie in finding a good way to veto against the presence of charm in such final states. If that could be overcome the interpretation is quite clear: BR ($B \to K+X_{\not{c}}$) less than .5% or greater than 5% cannot be accommodated by 3 generation SM, 5% $\lesssim$ BR $\lesssim$ 20% would strongly suggest the existence of 4 families and BR > 20% cannot be accommodated even with 4 families and would imply a breakdown of the SM.

Table 1 provides a summary of these rare loop decays (without CP): $b \to s\ell\ell$, $b \to s\nu\bar{\nu}$, and $b \to sg^*$ for 3 and 4 families along with the current experimental bound.

Table 1: Some of the Rare Decays of the b-quark.

Mode	(a) BR for 3-Generation	(b) BR for 4-Generation	(c) Current Experimental Limit
$b \to s\ell^+\ell^-$	$2 \times 10^{-6} - 2 \times 10^{-5}$	$2 \times 10^{-6} - 4 \times 10^{-4}$	$\lesssim 2 \times 10^{-4}$
$b \to s\nu\bar{\nu}$	$1 \times 10^{-6} - 7 \times 10^{-5}$	$10^{-6} - 3 \times 10^{-3}$	not available
$b \to s\gamma$	$8 \times 10^{-5} - 2 \times 10^{-4}$	$10^{-6} - 2 \times 10^{-3}$	$\lesssim 2 \times 10^{-3}$
$b \to sg^*$	1 - 3%	.5 - 15%	not available

(a) Ranges shown corresponds to m_t = 50 - 200 GeV.
(b) For 4-generation, ranges shown are obtained by taking 40 GeV $\lesssim m_t$ < m_W, $|v_{t'}|$ < .3 and 150 < $m_{t'}$ < 500 GeV.
(c) See the Talk by N. Horwitz at the 4th Family Meeting, Santa Monica (February 1987).

3. Observability of CP Non-Conservation in B Decays.

In B decays there are several mechanisms that can potentially contribute to observable CP violating effects. The simplest way to expose CP is through the asymmetry parameter[23)]

$$\Delta \equiv \frac{BR(B \to f) - BR(\bar{B} \to \bar{f})}{BR(B \to f) + BR(\bar{B} \to \bar{f})} .$$

For SM with 3 generations the numerator being CP violating has to be proportional to the invariant: $s_1 s_2 s_3 s_\delta$.[24)] This implies that Δ will tend to be enhanced provided the denominator has CKM suppression through mixing angles as well. A mechanism that necessarily introduces such a suppression involves modes such as $b \to sq\bar{q}$. Calculation of the amplitude to $O(\alpha_s^2)$ yields an absorptive part to the decay amplitude which is a necessary criteria for yielding non-vanishing CP asymmetry.[23] This mechanism is also fairly flexible: It can be used to expose CP in neutral as well as charged, in inclusive as well as exclusive modes. Such is not the case, for example, of the mass mixing or cascade mechanisms which are applicable only to neutral B's.[25]

In the following we will illustrate CP observability in B decays through a few interesting examples: $B \to K\pi$ ... . This mode is extremely interesting for its simplicity in reconstruction and furthermore as even for neutral B_d^o, $\bar{B}_d^o$ a simultaneous double tag is not necessary.[26,27] This is because, as one can easily convince oneself, e.g. $B_d^o \to K^+\pi^-$ but $\bar{B}_d^o \not\to K^+\pi^-$ to lowest order in weak and all orders in strong interactions. So a simple way to search for CP is to sit on $\Upsilon(4s)$ and count $K^-\pi^+$ versus $K^+\pi^-$ events (each with invariant mass that of B). The fact that a double tag is not necessary means a saving in tagging efficiency for the "other B" (i.e. the one not undergoing decay via $K\pi$ mode) of a factor $\simeq$ .1. Such a tag would obviously be needed if one tried to measure Δ for a self-conjugate mode such as $\pi^+\pi^-$. Of course, for charged $B^{\pm}$ one simply counts the number of, e.g. $K^+\pi^o$ versus $K^-\pi^o$ <u>or</u> $K_S^o\pi^+$ versus $K_S^o\pi^-$ decays of B's.

At the moment the calculation of the rate and the asymmetry contain significant uncertainties.[8] Part of the uncertainty is due to lack of knowledge of the relevant CKM parameters. The other major uncertainty arises from our inability to calculate the relevant hadronic matrix elements. Both of these sources of uncertainties would be largely removed as more data from B decays gets accumulated. In any event the estimated BR is most likely in the range of $5 \times 10^{-6} - 3 \times 10^{-5}$ and the asymmetry $\Delta \simeq 5$-35%. Using an estimated detection efficiency of .3, one finds that a B factory with 10^8 B's would be sensitive to $\Delta_S \gtrsim 40\%$ if BR is $\sim 5 \times 10^{-6}$ and $\Delta_S \gtrsim 5\%$ if the BR is at the more optimistic level of $3*10^{-5}$.[7]

In principle, inclusive decays especially that go via QCD penguins such as $B \to K+X_{\not{c}}$ versus $\bar{B} \to \bar{K}+X_{\not{c}}$ are (as discussed earlier) not that rare (BR ~ 1%) and could have asymmetries at the level of a few percent. However, the detection of such modes appears very difficult.

A more promising way to go would be via charmless modes $B \to K$ + a few π's, say $B \to K+3\pi$. The estimated BR being $\sim 10^{-3}$, a B factory would be sensitive to a modest asymmetry $\Delta_S \gtrsim 3\%$.[7]

Cascade decays $B_d \to D^o+X$ followed by $D^o \to K_S+Y$ has been repeatdly emphasised. The BR here is of order 0.1 and the expected asymmetry 1-5%.[28] These do require double tag and sitting on $\Upsilon(5s)$ [rather than $\Upsilon(4s)$] so that the rates for $B\bar{B}$ would be somewhat smaller (by about a factor of 3). Using a tagging efficiency of 10^{-2}, detection efficiency of .3, BR = .1 and rate of 10^8/3 yr., we arrive at a signal of 10^4 events/yr. with an estimated background of about 700. Thus the sensitivity of a 10^8 $B-\bar{B}$ factory would only be to $\Delta_S > 20\%$.[7] So this mode is likely to require $\gtrsim 10^9$ $B-\bar{B}$ [29] unless the anticipated CP asymmetry (1-5%) and/or the BR ~ .1% turnout to be too low.

It would therefore seem that 10^8 $B-\bar{B}$/yr. is a minimum requirement for CP studies. There is an important caviat in this statement which we want to stress: These estimates are based on the assumption that SM with 3-generations is the underlying explanation for the observed CP violation. This assumption could be wrong. Indeed there is no strong reason to believe that SM with 3-generation is the only source for CP non-conservation. Surprises may therefore be in store for us; hopefully they will be pleasant ones, i.e. asymmetry effects may turn out to be larger than SM based estimates.[30]

4. Non-Standard Model Physics ... One Example.

There are numerous applications of a B factory for probing non-SM physics ... left-right symmetric gauge theories, extended Higgs sector, supersymmetry etc. Due to lack of time, we will briefly outline only one example, that of horizontal gauge interactions.

An extremely interesting possibility is that CP violation may be linked to family gauge symmetry, that is, the exchange of horizontal gauge bosons (called "Rabbions") causes CP violation.[31] Indeed for simplicity, models can be constructed in which the SM has no CP violation phase. There is only one dominant CP phase and this arises in exchanges of horizontal gauge bosons.

As an illustration, we consider the right handed components of the three families in an adjoint representation of a horizontal $SU(2)_R$ gauge group. Thus $(e^-,\mu^-,\tau^-)_R$, $(d,s,b)_R$ and $(u,c,t)_R$ may be considered to have a horizontal charge (+,0,-) that distinguishes them.

K_L-K_S mass difference and the observed rate of CP non-conservation impose lower and upper bounds on the mass (M_R) of the Rabbions. Thus: 5 TeV $\lesssim M_R g_L/g_R \lesssim$ 65 TeV.

As usual, lepton number violating decays have BR that scale as $1/M_R^4$. In the simplest version of the model BR $(K_L \to \mu e) \gtrsim 10^{-10}$ - well within reach of current round of experiments. However, one must understand that in fact such predictions are highly dependent on assignments. If the fermion assignment is changed from the one given above to $(e,\tau,\mu)_R$, $(d,b,s)_R$, $(u,t,c)_R$ then $K_L \not\to \mu e$ whereas $B_{d,s} \to \tau e, \mu\tau$ and not μe.

Table 2 below gives the prdiction of the first assignment given above. There are relatively clean examples of two- and three-body decays of B with mixed lepton flavors. A B factory presumably should be able to place limits at the 10^{-7} level. A non-observation at the 10^{-7} level would imply $M_R \gtrsim 25$ TeV (assuming $g_L = g_R$). In comparison it may be useful to recall that at the SSC (with $\sqrt{s} = 40$ TeV and luminosity of $10^{40}/\text{cm}^2$) horizontal gauge bosons in this model will be observable for $M_R \lesssim 10$ TeV.[32] We thus see here one example of the B factory complementing the physics at the SSC.

Table 2: Lepton # Violating Decays of B Mesons.

Mode	BR
$B_d^o \to \mu e, \mu\tau$	Forbidden
$\to K\mu e, K\mu\tau$	$2 \times 10^{-5} - 8 \times 10^{-10}$
$B_u^\pm \to K^\pm\mu e, K\mu\tau$	" "
$B_s^o \to \mu e$	$4 \times 10^{-9} - 2 \times 10^{-13}$
$\to \mu\tau$	$1 \times 10^{-6} - 3 \times 10^{-11}$
$\to \phi\mu e, \phi\mu\tau$	$2 \times 10^{-15} - 8 \times 10^{-10}$

5. Sources for B's: Incidental and Dedicated B Factories.

Some information on B factories is given in Table 3 below. While hadronic machines (colliders and fixed target) are expected to have very large fluxes of B's, the overall environment is in general very "messy." Indeed at the SSC one anticipates as many as 10^{12} B's/yr would be produced.[8] After cuts, the number of useful B's that is left is about 10^8 and very preliminary investigations of the feasilibity of doing rare B physics with a specialized detector ("Taster") were undertaken at snowmass '86.[33] The background problem in the SSC environment may be difficult to surmount. Since the initial (pp) state is not self-conjugate under CP (unlike $\bar{p}p$ or e^+e^-) it means that simple CP noninvariance tests such as B^o

$\to K^+\pi^-$ versus $\overline{B}^o \to K^-\pi^+$ would require (in principle) a double tag as the rates for $pp \to \overline{B}^o + X$ need not equal $pp \to B^o + X$. Furthermore, some of the rare modes such as $B \to K\nu\overline{\nu}$ or $B \to \tau + \nu_\tau$ would be extremely difficult if not impossible.

Table 3: Sources of B Mesons.

Source	B's/yr	Remarks
CLEO (current)	$\sim 10^5$	$\sim 10^6$ (upgrade)
SLC/LEP	$\sim 10^5 - 10^6$	
TEVATRON	$\sim 10^7$	
SSC	$\sim 10^{12} \to 10^8$	
Dedicated (e^+e^-) circular collider B factory	$(.5-1)*10^7$ (?)	e.g. SIN proposal[34)]
Dedicated (e^+e^-) linear collider B factory	10^8 ?	e.g. BLC under consideration at UCLA[35)]

6. Summary.

We have tried to explain the importance of dedicated, clean, and e^+e^- based B factory. There is a wide spectrum of very useful physics that can be done at such a facility:

(a) At $\sim 10^6$ B's/yr, we will get important information on mixing angles and role of QCD on weak decays.

(b) With $10^6 - 10^7$ B's/yr, a B factory would provide nontrivial test of SM to one loop especially symmetry breaking mechanism (which is the weak point in the SM) and probe new mass scales.

(c) At 10^8 B's/yr, one can hope to see some evidence for CP nonconservation outside of the neutral kaon system for the first time. This remains the most tantalizing goal of a B factory.

The physics of B_s and B_c systems could also be very interesting. It would be useful to think of incorporating the necessary flexibility so that these may be doable at a B factory.[36)]

The machine(s) we are advocating here should not be thought of as a distraction from the SSC (and/or LHC) efforts. For one thing, B factory physics is complementary to the physics of super colliders. Besides these hadron colliders could use clues coming from B factories and other low energy experiments. In this regard, there is an important lesson to be learnt from the on-going search for the top quark at S$\bar{p}$pS by UAI. There is one and only one unknown parameter namely the top mass (m_t) and the hadron collider environment is so complicated that even placing a lower bound on m_t presents considerable difficulty. In the absence of a candidate theory (beyond the SM) which is relevant to the very large energy scale (much larger than S$\bar{p}$pS energies), searching for new physics at the SSC is likely to be a very difficult challenge. Success of supercolliders hinges on knowing what to look for as precisely as possible and important clues as to what to expect can be provided by a high luminosity B factory.

A clean source of $\gtrsim 10^8$ $B\bar{B}$/yr would lead to major progress in at least three areas:

1. Far better understanding of SM especially symmetry breaking, i.e. mechanism for fermion mass generation of fermion mass scales and of a new fermion family.
2. Family gauge symmetry, i.e. the generation puzzle.
3. Perhaps the most important area is that of CP nonconservation where there has been a frustrating deadlock for over two decades.

The physics arguments for such a machine are therefore very compelling so it should be pushed for as expeditiously as possible.

References and Footnotes.

1. This talk is based on extracts from a comprehensive article that is in preparation.
2. See the talks by R. Cousins and W. Morse in the *Proceedings of the 4th Family Meeting* held at Santa Monica (February 1987).
3. See the talks by G. Bock and M. Holder in the *Proceedings of the 4th Family Meeting* held at Santa Monica (February 1987).
4. G. Hou, R. Willey, and A. Soni, UCLA/86/TEP/43, to be published in Physical Review Letters.
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26. See Ref. 9 and references therein for the calculation of the rates.
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28. I. Bigi and A. Sanda (private communication) and Ref. 6.
29. This estimate for this cascade mode is also arrived at by J. D. Bjorken. See his talk in the *Proceedings of the 4th Family Meeting* in Santa Monica (February 1987).
30. There are some other works on CP violation in B meson decays that may be of interest: J. Bernabeu and C. Jarlskog, Z. Phys. C8, 233 (1981);

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36. Due to lack of space, we have focused here primarily on direct B physics. In fact a B factory would also entail a very rich spectrum of incidental physics. A 10^8 B facility would also yield $c\bar{c}$ jets, $\tau^+\tau^-$ pairs, and multihadron jets (of u,d,s quarks) each ~ 10^8. This is about three orders of magnitude more than the current available data allowing for high statistics study of charm and τ decays, hadronization studies, precise determination of $\Lambda_{\overline{MS}}$, search for Higgs, glueballs, and other resonances. See Ref. 1 for further details.