THRESHOLD $\bar{B}B$ FACTORIES*

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ABSTRACT

We review the requirements of $\bar{B}B$ Factories to facilitate the observation of rare B decays and the study of CP violation. Two advances are required over present colliding beam machines: (1) much higher luminosity, (2) collisions that increase the reconstruction efficiency and facilitate proper time measurements. The latter requirement can likelly be met by using asymmetric colliding beams (either circular or linear). The limitations on achievable luminosity in circular machines likely limits the maximum luminosity to $10^{33}\mathrm{cm}^{-2}\mathrm{sec}^{-1}$ (SIN Machine). Linear collider $\bar{B}B$ Factories offer the possiblitiy of greater luminosity but are still in the R&D stage. Examples of $\bar{B}B$ Factory designs at UCLA and Frascati are described.

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Outline

Introduction

There are two promising directions of study in K or B Physics: Rare Decays and CP Violation. A considerable effort is underway at BNL, CERN, and FNAL to study rare K decays and study CP violation in the K°_L system. Kaon factories at LAMPF and Canada are being designed to carry on this work. On the other hand the B system has hardly been studied but may have a greater sensitivity in both the rare decays and CP violation.

About two years ago at the Heidelberg Conference the concept of $\bar{B}B$ Factories was born[1,2,3]. This occured at about the same time as the announcement of substantial B° mixing by the UA1 group[4]. Later the ARGUS group reported large mixing in the B°_d system to the surprise of almost all theorists[5]. During the past two years several B factory design studies have started and one machine has been formally proposed for construction. Two workshops devoted to this idea have been held.

In this report we review the progress to date in these designs and indicate the areas where substantial uncertainty still exists and where R&D efforts are still required.

1. Rare B Decays

The large mass of the b quark and the strong coupling to the massive t quark increase the sensitivity of rare B decays to new physics such as the existence of a 4^{th} family of quarks. There are numerous examples of rare B decay calculations in the literature. One illuminative case is the decays

$$b \to s + \ell + \bar{\ell} \tag{1}$$

$$b \to s + \nu + \bar{\nu} \tag{2}$$

These decays can be contrasted with the decays

$$s \rightarrow d + \ell + \bar{\ell} \quad (3)$$
$$s \rightarrow d + \nu + \bar{\nu} \quad (4)$$

which are studied as

$$K^+ \rightarrow \pi^+ + e^+ + e^- \quad (5)$$
$$K^+ \rightarrow \pi^+ + \nu + \bar{\nu} \quad (6)$$

It is well known that the GIM breaking decay branching action for 6 is expected to appear at the level of about 10^{-10}. In contrast reactions (1) and (2) can display GIM breaking decay at the level of $10^{-5} - 10^{-7}$. Thus the B decays much more sensitive to non GIM effects than the corresponding K decays. A list of the current estimate for rare B decays is given in Table 1. [7]

2. CP Violations in B Decay

The coupling of the b quark to off diagonal K-M matrix elements is expected to enhance the level of CP violation in certain processes. (Those that favor the off diagonal elements such as $B^\circ \rightarrow \pi^+\pi^-$.) In addition it appears that B°_d mixing is larger than was originally expected, futher enhancing the chance for observing CP violation. Many theorists now believe that the future study of CP violation will be largely concentrated in the B decay sector.

Rare B decays may exhibit the largest CP violation. Thus high luminosity $\bar{B}B$ production is required. Table 1 indicates some B decays that may exhibit large CP violation and the estimated level. Another way to study CP violation is to observe the proper time behavior of the B°_d or B°_s system. This is described in some detail in Reference 8.

In order to derive an estimate of the number of $\bar{B}B$ pairs required to observe CP violation, we find

$$N \simeq \frac{1}{\alpha^2} \cdot \frac{1}{B_r} \cdot \frac{1}{Q} \cdot 10$$

where α is the CP violating asymmetry expected, B_r is the branching ratio of the decay mode and Q is a quality factor that includes the reconstruction efficiency and tagging efficiency for the other B (or $\bar{B}$). For present colliders Q is very small. It might be hoped that Q could reach 10^{-1} using a linear collider with a very small beam pipe and asymmetric energies. For example, with $\alpha = 10^{-1}$, $B_r = 10^{-4}$, $Q \sim 10^{-1}$ we find the number of events needed is 10^8. a more careful calculation has been carried out by Rosner, Sanda and Schmidt and the results are shown in Figure 1.[8]

3. Requirements in Luminosity and Reconstruction Efficiency

The currently proposed strategy for observing CP violation in the B sector is to select improbable or rare B decays and to search for a rate asymmetry or a deviation in the proper time distribution from the expected distribution with no CP violation. The former method required identification of the B or $\bar{B}$ in the same event, thus requiring good reconstruction efficiency. The second method requires accurate proper time measurement. Both methods constrain the parameters of the $\bar{B}B$ system. It is now recognized that the best solution to these problems is to operate colliding beam machines in asymmetric energy mode to give the $\bar{B}B$ system a net laboratory momentum. This will increase the γ of each B and thus the path length before decay, enhancing the proper time measurements. Furthermore, the Lorentz boost should increase reconstruction efficiency.

The major advantage of the asymmetric energies is to give a boost to the B and $\bar{B}$ systems as shown in figure 2.[9] In Figure 3 we show the decay lengths for symmetric colliding beam energies. In the vicinity of the Υ (4S) the decay length is very small. At higher energy the decay length increases, however, unfortunately the production $\bar{B}B$ cross section falls rapidly. Figure 4 shows the same decay lengths for the asymmetric case. Note that for the case of 2.5 GeV and 10 GeV the decay length increases to about 350 μm. The conbination of this long decay length and the very small beam pipe for a linear collider could result in a large Q factor.

The observation of the rare B decay (see Table 1) can only be carried out at an e^+ e^- machine. Studies are underway to determine if the boosted system offers an advantage.

A promising technique to measure the B_d°, B_s° mixing and to search for CP violation effects is to study time distribution. A recent study of the detector parameters has been carried out by Gratta, Schwarz and Zaccardelli. They define the necessary resolution in decay length measurements [9]

$$\sigma_{\mathrm{mix}} \leq \frac{1}{\mathrm{n}} \frac{2\pi}{X_{\mathrm{s,d}}} [\beta\gamma c\tau]$$

where $X_{s,d}$ are the mixing parameters, n is a quality of measurement factor and $\beta\gamma c\tau$ are well known. Figure 5 shows the results of a monte carlo generation of decays. For the boosted case they find

$$\sigma_{\mathrm{mix}} \leq 320\mu\mathrm{m} \text{ for } B_d^\circ - \bar{B}_d^\circ \text{ on the } \Upsilon(4S)$$

and

$$\sigma_{\mathrm{mix}}^{5S} \leq 40\mu\mathrm{m} \text{ for } B_s^\circ - \bar{B}_s^\circ \text{ for the } \Upsilon(5\mathrm{S})$$

These values are obtainable with present micro vertex detectors.

4. Limitations on Luminosity in Circular Colliders

We now describe the various approaches that have been considered for threshold $\bar{B}B$ factories. A summary of the limitations and possible goals in luminosity for these machines is shown in Figure 6. At present it seems that only a linear collider $\bar{B}B$ factory has the potential for leading to the observation of CP violation in the B system. However, as we shall see, this is still subject to a great deal of uncertainty which calls for a strong R&D program in this field.

Circular colliders have many advantages and several disadvantages for the production of large quantities of $\bar{B}B$ pairs. The major advantage is the ease of construction of circular machines after two decades of experience with such machines. The disadvantages are (1) relatively large beam pipe at the IP making proper time measurements difficult, (2) limitations on luminosity due to the maximum time shift allowed by the machine, (3) difficulty of operating the machines in an asymmetric energy mode. We note that the CESR machine at Cornell would eventually reach a luminosity of $5 \times 10^{32} \mathrm{cm}^{-2} \mathrm{sec}^{-1}$.[11]

The maximum luninosity that can be obtained in a circular machine is given by [10]

$$\mathcal{L}^{\max} \simeq (\mathrm{nf}) \times \epsilon_x \times \frac{(\Delta\nu)^2}{\beta^* y}$$

where nf is the number of bunches, σ_x is the natural horizontal emittance of the beam, $\Delta\nu$ is the linear tune shift and $\beta^* y$ is at the IP of the collider. There is strong evidence of a limitation of $\Delta\nu$ in existing machines. This likely limits $\mathcal{L}^{\max}$. $\Delta\nu$ will be partially limited by bunch crossing at regions other than the IP and this is one reason the SIN project will have two rings.[10] It is now generally considered that $\mathcal{L}^{\max}$ can not exceed $\sim 10^{33} \mathrm{cm}^{-2} \mathrm{sec}^{-1}$ due to these limitations.

5. Circular Collider $\bar{B}B$ Factroy : SIN Example

A complete design of a circular $\bar{B}B$ factory has been carried out by a SIN – West Germany group.

In order to overcome part of the time shift limitations the SIN machine will operate with two rings.[10] In addition, electrons and positrons will be injected into the collider at the final energy, thus avoiding the necessity of accelerating the electrons and positrons in the storage ring. This should also help raise the luminosity. A schematic of the machine is shown in Figure 7. The current design parameters are given in Table 3. a recent calculation of the luminosity prospects is shown in Figure 8. The initial luminosity of the machine would be $5 \times 10^{32}\text{cm}^{-2}\text{sec}^{-1}$ and this assumes 10 bunches per beam and a tune shift of $\Delta\nu \simeq 0.03$. Using 10 cavities per ring it will be possible to reach 6 GeV in each beam. A later improvement in the Beta function at the IP magnet alignment and assuming $\Delta\nu \sim 0.04$ and using 20 bunches can bring the luminosity to 10^{33} $\text{cm}^{-2}\text{sec}^{-1}$. From the recent SIN study it appears that this will likely be the maximum luminosity possible.[10]

6. Asymmetric Circular Colliders : PEP Example

A study of an asymmetric energy two storage ring circular collider has been carried out by a SLAC/LBL group.

A preliminary design of this machine has been carried out by A. Garren from LBL.12 A set of parameters for the 2 GeV or 12 GeV circular collider is given in Table 4. Note the maximum luminosity in this design is $5 \times 10^{32}\text{cm}^{-2}\text{sec}^{-1}$ and this assumes $\Delta\nu \simeq 0.05$ (a value larger than the SIN design). Bringing the beams into collision is a non trivial matter and a schematic of the Garren solution is shown in Figure 9. 12 One problem with this machine may be the large β that occures in parts of the machine due to the ultra low β^* at the IP. The lattice β function of the small machine is shown in Figure 10. While this machine may not exceed $5 \times 10^{32}\text{cm}^{-2}\text{sec}^{-1}$ luminosity, it may be valuable in the study of B decays due to the potentially larger reconstruction efficiency.

7. Linear Collider $\bar{\text{B}}$B Factories : R&D Questions

Linear collider $\bar{\text{B}}$B Factories seem to offer the possibility of very high luminosity (perhaps $10^{35}\text{cm}^{-2}\text{sec}^{-1}$ under very favorable circumstances). However, these machines are still in the R&D phase. Many questions need to be answered before we can be certain that high average luminosity is possible.

Two specific machine designs have been carried out

(1) A Superconducting recirculating linac $\bar{B}B$ Factory by a CERN – Frascati group [2]

(2) An Asymmetric submicron – High Gradient $\bar{B}B$ Factory by the UCLA group [3, 13]

These machines emphasize different parameters to achieve high luminosity. In the Frascati design the repetition rate of the machine is assumed to be 12 kilo Hertz putting a strain on the positron source.[2] In the UCLA design the emphasis is put on achieving very small spot size (about 0.1 μm) putting a severe constraint on the electron and positron source emittance and the final focus system.

At the 1987 UCLA $\bar{B}B$ Factroy Workshop, P. Wilson from SLAC worked out a set of parameters for a high luminosity $\bar{B}B$ factory.[14] Table 5 gives a list of the parameters. In this example it would be possible to reach a luminosity of $10^{34}cm^{-2}sec^{-1}$. The possibility of reaching this luminosity is perhaps a little greater now due to the recent calculation of Chen and Yokoyo on the disruption luminosity enhancement.

8. The Frascati Recirculating Superconducting B Factory Design

A schematic of the Frascati design is shown in Figure 11. The current design parameters are given in Table 5. Note that the luminosity of $10^{34}cm^{-2}sec^{-1}$ can be reached in the "low resolution mode". The machine will use superconducting cavities to accelerate the $e^{\pm}$. It is not clear if this can operate in an asymmetric energy mode. The machine will also serve the nuclear physics groups in Italy. To do this a complicated set of beam gymnastics are to be used, as shown in Figure 12. [15]

The Frascati collider is a very interesting type of $\bar{B}B$ factory. The use of Superconducting cavities allows a high repetition rate and this allows for high luminosity. There are several problems with this approach, one of which is the positron source and the target heating.[16]

A strong R&D program has been started at Frascati – CERN to solve many of these problems.

9. The UCLA Asymmetric – Submicron – High Gradient Linear Collider B Factory Design

The early $\bar{B}B$ factory design from the UCLA group is shown in Figure 13. a later design differs from this previous design by two changes

(1) The beam energies are asymmetric

(2) The positron problem is alleviated by recirculation of the e^+ and production using the 10 GeV e^- beam and is shown in Figure 14.

The parameters of the symmetric version of the UCLA $\bar{B}B$ factory are given in Table 6.[13] Note that the collider assumes very small spot size at the IP. We will now describe several aspects of the machine design.

There is reason to be optimistic about the high luminosity of a submicron -low energy collider. Recent calculation by Chen and Yokoya show that increasing the beam-beam disruption can produce a large enhancement in the luminosity provided the parameter[17]

$$A = \frac{\sigma_z}{\beta^*}$$

is kept small. Results from the calculations are shown in Figure 15a and 15b.[17] Note that $H_D \sim 25$ may be possible a factor of 4 above the earlier estimated limit. In order to keep A small and D large, it will likely require a very short focal length final focus. Such a lens may be provided by a plasma lens as shown in Figure 16.[18] An ANL/SLAC/UCLA group is developing such a lens for the SLC and this could be used for the UCLA $\bar{B}B$ factory.

It is likely that the achievement of utlra small spot sizes will require the shortest possible accelerator to avoid emittance blowup. High gradient Cu acceleration is possible as shown in Figure 17. A possible RF driver that could achieve the required power at 11.4 GHz is the Relativistic Klystron shown in Figure 18.[19] There have been recent breakthroughs in this technique by the SLAC/LLNL/LBL groups where a gradient of 130 MeV/ has recently been obtained at LLNL.[19]

Finally, the solution to the positron problem for the UCLA $\bar{B}B$ Factory may consist of partially reusing the positrons that have been produced by the 10 GeV e^- beam used after the collision.[13, 20] A schematic of this e^+ collider-source is shown in Figure 19. The details of this linac-damper are being worked out[13, 20].

Finally, the UCLA machine is imagined to be constructed on the University campus in Westwood, LA (see Figure 20). This mode of operation is likely appropriate to such an R&D machine.[13]

10. Conclusions

It is clear that the future study of rare B decays and CP violation require a very large luminosity $\bar{B}B$ factory. The e^+ e^- production of $\bar{B}B$ near threshold offers the cleanest environment to study B physics. In order to increase the reconstruction efficiency it will be necessary to operate the collider in an asymmetric mode. This is possible for both circular and linear colliders. Very likely the circular collider will have the same luninosity limitations as symmetric colliders.

Linear colliders appear to offer the greatest luminosity. They can be operated in an asymmetric mode as shown by the UCLA design. Furthermore, this is rather natural if the high energy beam is to be used to produce positrons as well.

There are several other important ideas in this field. The Novosibirsk group is designing a $\bar{B}B$ factory that is similar to the SLAC/SLC in that it would use a single linac to accelerate both e^+ and e^- and arcs to bring the particles into collision.[21]

A recent idea to use the Inverse Free Electron Laser as the accelerator has been put forward by C. Pellegrini. The IFEL is shown in Figure 21.[20] The potential advantage of this approach is that the IFEL can help keep the $e^\pm$ emittance small during the acceleration.

These and other ideas are likely to keep this field very lively and the R&D program very interesting.

We can compare the possible rare B decay physics that could result from the realization of a $\mathcal{L} \sim 10^{34}\mathrm{cm}^{-2}\mathrm{sec}^{-1}$ $\bar{B}B$ factory in Italy or at UCLA in Figure 22. The natural comparison is with π and K factories. Note , however, that the theoretical rates for many B decay processes are enhanced by a ratio of

$$(\frac{m_t}{m_c})^2 \sim \sigma(2000)$$

or more, which partially compensates for the expected ratio of K to B particles that can be produced per year of $\sim \frac{10^{14}}{10^9} \sim 10^5$. Furthermore, the detector and background limits could be different for the rare B and K decays partially overcoming this large rate advantage. Clearly the future of $\bar{B}B$ factories is assured.

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ESTIMATED RARE B DECAY BRANCHING RATIOS		
MODE	ESTIMATED BRANCHING RATIOS	CP ASYMMETRY
$B \to D^+D^-$	$\sim 10^{-3}$	
$B^\circ \to \Psi K_s$	$(4\times10^{-4})^* \to 2 \times 10^{-5}$	~ 0.2
$B \to K\pi$ **	$\sim 10^{-5}$	?
$B \to \pi\pi$	$\sim 10^{-5}$	> 0.05
$B \to \bar{p}p$	$\sim 10^{-5}$	~ 0.3
$B \to K\nu\bar{\nu}$	$\sim 10^{-7} - 10^{-6}$	–
$B \to Ke^+e^-$	$\sim 10^{-7} - 10^{-6}$	–
$B^\circ \to \mu^+\mu^-$	$\sim 10^{-8}$	
$B \to K\mu^\pm e^\pm$	?	

* Detection of $4K_s$ final state in the mode $4 \to \ell\bar{\ell}$, $K_s \to \pi\pi$ introduces an additional reduction in the effective branching ratio

** B $\bar{B}$ tagging may not be necessary – a rate difference between $K^+\pi^-$ and $K^-\pi^+$ could be sufficient to detect CP violation

Table 1. Estimated Rare B Decay Branching Ratio

TABLE 2						
	Υ(4S) Symmetric	Υ(4S) Boosted	PEP (25 GeV)		Z°	
	R = 1 cm	R = 1 cm	R = 1 cm	R = 4 cm	R = 1 cm	8 cm
$< P_\beta >$ GeV/c	0.3	5	9	9	20	20
$< \gamma\beta >$	0.08	1	1.7	1.7	20	20
$< \bar{b}b$ separation $>$	35	300	1020	1020	4200	4200
Impact parameter relative to beam collision	17	150	280	280	500	500
$< P_\pi >$ GeV/c	0.5	0.7	1.0	1.0	2.0	2.0
δ microns	21	18	15	60	11	11
Figure of merit M	1.6	8.3	18	4.5	45	5.7

Table 2. Parameters of the B Meson System and Figure of Merit for Different Types of $\bar{B}B$ Sources (From P. Oddone, Ref 9)

Table 3.				
			Standard Optics	Micro beta
Circumference	L [m]	:	648.0	
Number of bends		:	56	
Bending radius	R [m]	:	41.443	
Energy loss/turn	ΔE [MeV]	:	1.389	
Hor. betafunction	β_x^* [m]	:	1.00	1.0
Vert. betafunction	β_z^* [m]	:	0.03	0.015
Tune	Q_x	:	7.779	
	Q_z	:	9.279	
Chromaticity	ξ_x	:	-12.8	-12.9
	ξ_z	:	-19.3	-30.6
Number of sextupole families		:	2	
Compensated chromaticity	ξ_x	:	+1	
	ξ_z	:	+1	
Mom. comp. factor	α	:	$2.5 \cdot 10^{-2}$	
hor. emittance	ϵ_x [m·rad]	:	$5.5 \cdot 10^{-7}$	
min. vert. emittance	ϵ_z [m·rad]	:	$9.9 \cdot 10^{-10}$	
vert. emittance with 3% coupling	ϵ_z [m·rad]	:	$1.7 \cdot 10^{-8}$	
Energy spread	$\Delta E/E$	:	$6.6 \cdot 10^{-4}$	
Damping times	τ_x [msec]	:	16.5	
	τ_z [msec]	:	15.6	
	τ_z [msec]	:	7.6	
RF-frequency	f_{RF} [MHz]	:	500	
# of cavities		:	10	
max. number of bunches		:	20	
current	I [mA]	:	485	
RF-power	P_{RF} [kW]	:	1050	

Table 3. Parameters for the SIN $\bar{B}B$ Factory Project

APIARY 1 Parameters			26 February 1988		
		2 GeV		12 GeV	
Bunch spacing	S_B		25.88		
Number of bunches	B	6.0		85.0	
Particles/bunch	N_B	2.90×10^{11}		1.45×10^{11}	
Current	I	538.0		269.0	mA
Emittances	ϵ_z	0.3		0.01	μm
(design)	ϵ_y	0.03		0.01	μm
3-functions at IP	β_z^*	0.254		0.762	m
	β_o^*	0.0254		0.0762	m
	η^*	0		0	m
Beam-beam tune shifts	$\Delta\nu_z$	0.05		0.05	
	$\Delta\nu_z$	0.05		0.05	
Luminosity	$\mathcal{L}$		5×10^{32}		$cm^{-2}s^{-1}$
Peak β function values	$\hat{\beta}_z$	24.0		360.0	m
	$\hat{\beta}_y$	24.0		388.0	m
	$\hat{\eta}$	2.9		1.9	m
Tunes (unadjusted)	ν_z	4.60		22.95	
	ν_y	4.35		16.06	
Natural emittance	ϵ_{xo}	0.3214		0.301	μm
Circumference	2πR	155.3		2200.0	μm
Rigidty	B_ρ	6.671		40.03	T-m
Critical photon energy from first dipole	E_c	0.4		15.0	keV
Bend angle of first dipole	θ_1	50.0		8.0	mrad

TABLE 4. Parameters for an Asymmetric Collider (from A. Garren)

TABLE 5

Parameters for a 10 GeV

B-factory linear collider

$$E_o = 10\text{GeV}$$
$$\mathcal{L} = 10^{34}\text{cm}^{-2}\text{s}^{-1}$$
$$\text{L} = 100 \text{ m}$$
$$b = 4$$
$$\frac{\sigma_p}{\rho} = 2.0 \times 10^{-3}$$
$$\sigma_z = 0.30 \text{ mm}$$
$$\eta_b = 0.028$$
$$\text{N} = 2.2 \times 10^{10}$$
$$\sigma_\perp^* = 0.32\ \mu\text{m}$$
$$\text{D} = 9.0, \text{H}_\text{D} = 6$$
$$\Upsilon = 5 \times 10^{-3}$$
$$\delta_{c\ell} = 9 \times 10^{-3}$$
$$f_r = 11.1 \text{ KHz}$$
$$f_b = 44.4 \text{ KHz}$$
$$P_b = 1.6 \text{ MW}$$
$$\epsilon_n = 3.0 \times 10^{-6} \text{ rad}$$
$$\beta^* = 0.7 \text{ mm}$$
$$\langle N_p \rangle = 4.0$$
$$\frac{\sigma_w}{W} = 5 \times 10^{-3}$$

Table 5. Parameters for a 10 GeV B Factory Linear Collider. (P. Wilson)

Table 6.			
Mode:	High-resolution $\Upsilon(4S)$	Medium-resolution $\Upsilon(5S)$	Low-resolution 'continuum'
E_o (GeV)	5.29	5.43	7.5
W (GeV)	10.58	10.86	15.
$N^+(10^{10})$	2.5	2.5	5.0
$N^-(10^{10})$	8.0	8.0	8.0
$^\epsilon n$ $(10^{-6}m)$	2.0	2.0	2.0
$^\epsilon L$ + $(10^{-2}m)$	4.0	4.0	6.0
$^\epsilon L$ − $(10^{-2}m)$	1.0	1.0	1.0
$^\sigma z$ + (mm)	3.0	1.5	0.7
$^\sigma z$ − (mm)	1.0	0.5	0.5
β^* (mm)	5.0	2.0	2.0
$^\sigma x = {}^\sigma y$ (μm)	1.0	0.6	0.5
D^+	21	27	25
D^-	22	28	28
H_D [a)]	8.5	8.5	8.5
f_r (kHz)	10.	10.	10.
ΔW_b (MeV)	4	15	75
ΔW_L (MeV)	9	17	45
P^+ (MW)	0.2	0.2	0.6
P^- (MW)	0.7	0.7	1.
P_T^- (MW)[b)]	0.9	0.9	1.8
P_{mains} (MW)[c)]	18	18	20
L $(10^{33}cm^{-2}s^{-1})$	1.4	3.5	10

a) Computed using the expression given in Ref.
b) Power of a 2.2 GeV electron beam needed to produce the positrons.
c) Total power absorbed by the SC linacs.

Table 6. Parameter List for the One-Racetrack ARES Project

TABLE 7

Parameters of a Submicron Spot

$\bar{B}B$ Factory Collider

$$E_\circ = (5 \rightarrow 7)\text{GeV per beam}$$
$$\mathcal{L} = 10^{34}\text{cm}^{-2}\text{sec}^{-1}$$
$$L = 50 \rightarrow 75 \text{ m}$$
$$b = 4$$
$$\frac{\sigma_p}{\rho} = 3 \times 10^{-3}$$
$$\sigma_z = (0.4 \rightarrow 0.02) \text{ mm}$$
$$\eta_b = 0.03$$
$$N = 3 \times 10^{10}$$
$$\sigma_\perp = (0.14)\mu\text{m}$$
$$D = 36, \;\; H_D = 10$$
$$\Upsilon = 5 \times 10^{-3}$$
$$\delta = 8 \times 10^{-3}$$
$$f_r = 1 \text{ kHz}$$
$$f_b = 4 \text{ kHz}$$
$$P_b = 0.2 \text{ MW}$$
$$\epsilon_n = 3 \times 10^{-6}\text{m} - \text{RAD}$$
$$\beta^* = 0.07 \text{ mm}$$
$$\frac{\sigma_w}{w} = 4 \times 10^{-3}$$

Table 7. Parameters of a Submicron Spot $\bar{B}B$ Factory Collider

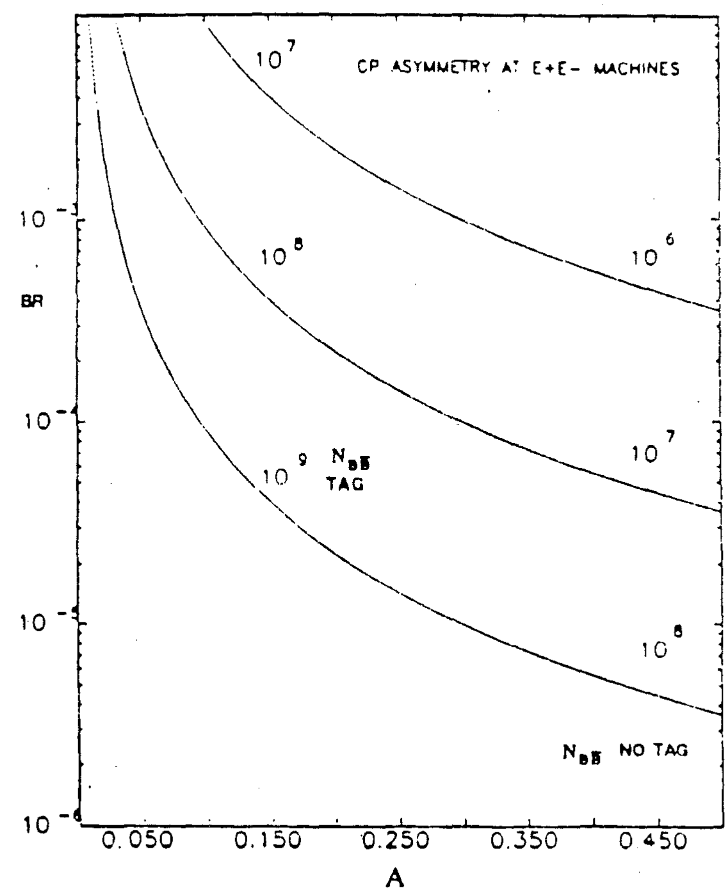

Figure 1. Number of B decays needed to see a CP violating asymmetry A in a process with branching ratio BR. Larger numbers assume a 10% tagging efficiency.

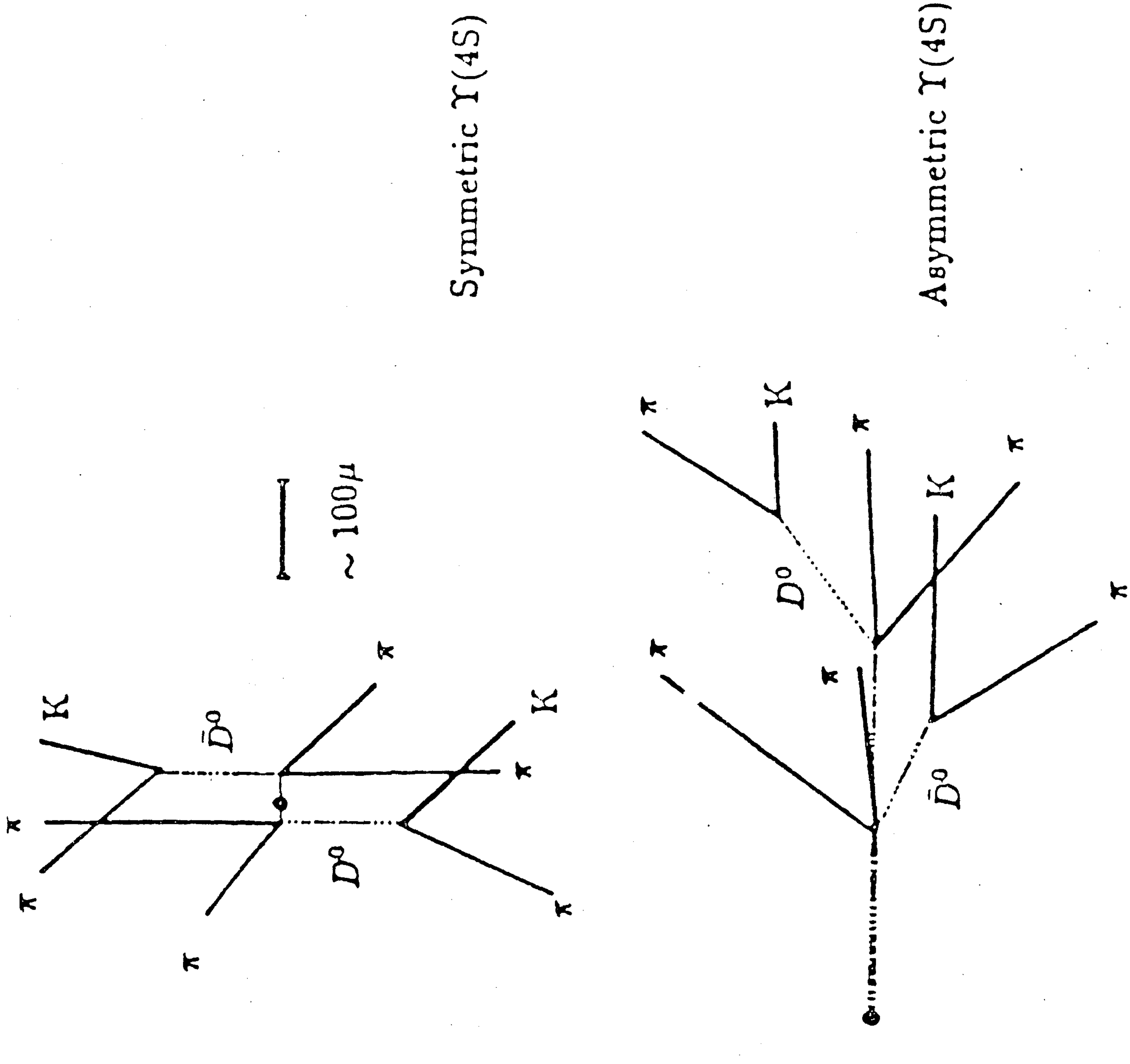

Figure 2. Lorentz Boost of the B̄B System for the Symmetric and Antisymmetric B̄B Factories

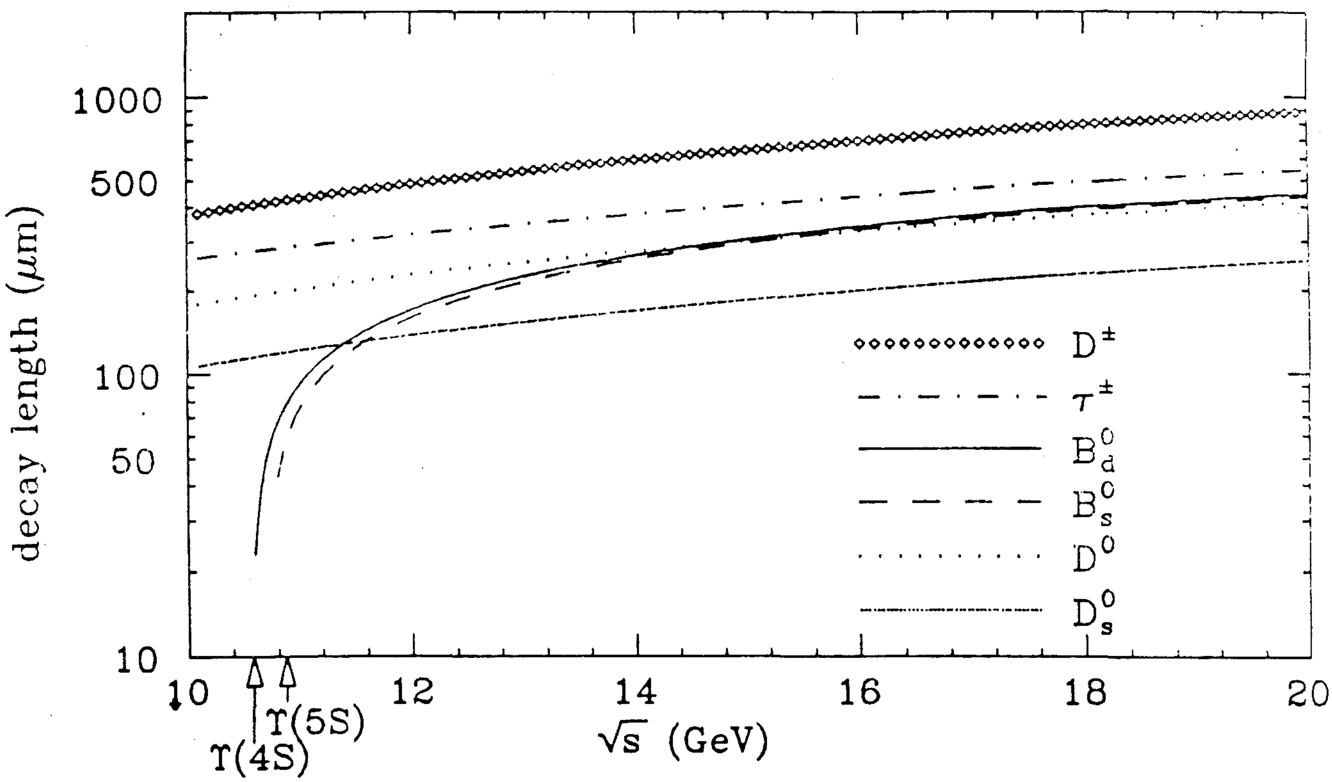

Figure 3. The mean decay length of D mesons, τ leptons and B mesons as a function of $\sqrt{s}$ using the values for their proper lifetimes and masses. The different fragmentation functions for the charm and the bottom quark have been taken into account. Note that for the B_s°, the values obtained for the mean decay length are very model dependent in the vicinity of the υ [5S] resonance. (Ref 9)

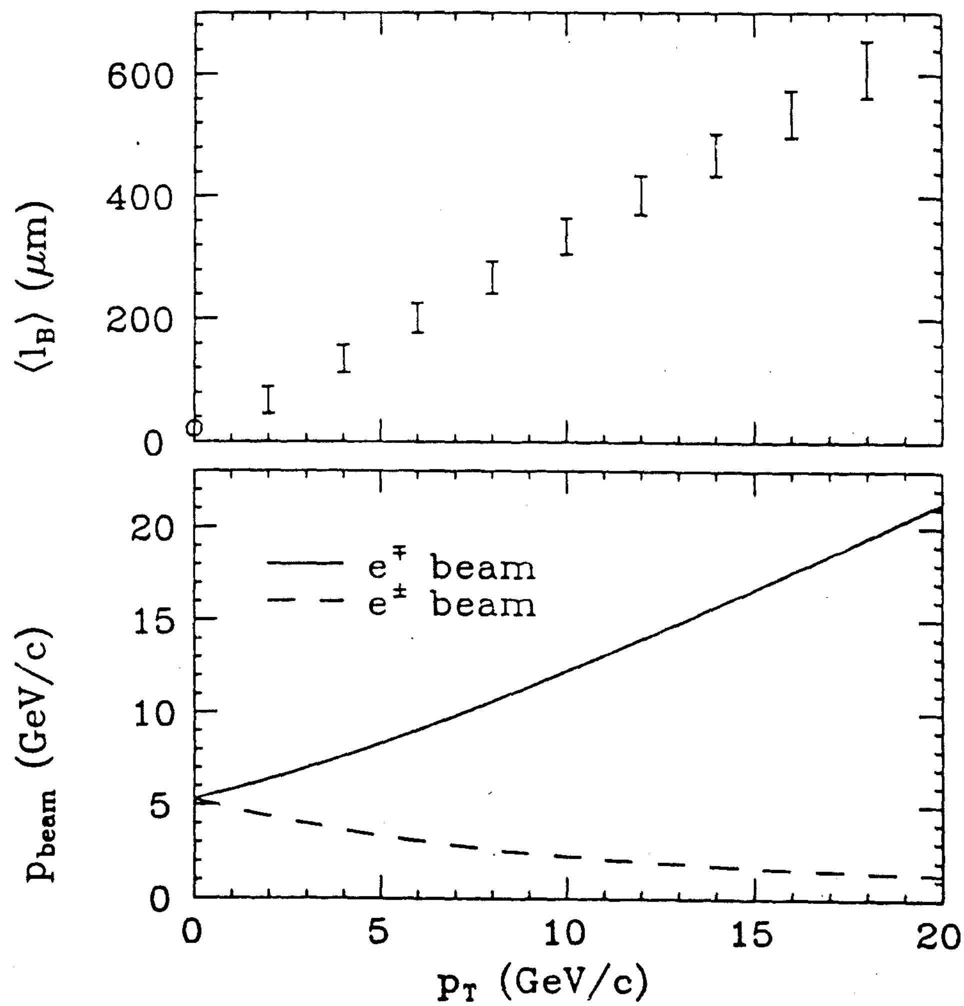

Figure 4. The expected decay length range of B mesons from a moving υ [4S] as a function of the momentum of the υ [4S] (p_υ). the two boundaries for the decay length range are given by the two extreme cases where the B meson is emitted from the υ [4S] antiparallel or parallel to the boost direction. Also shown are individual e^+ and e^- beam momenta necessary to create the υ [4S] resonance in the center of mass. (Ref 9)

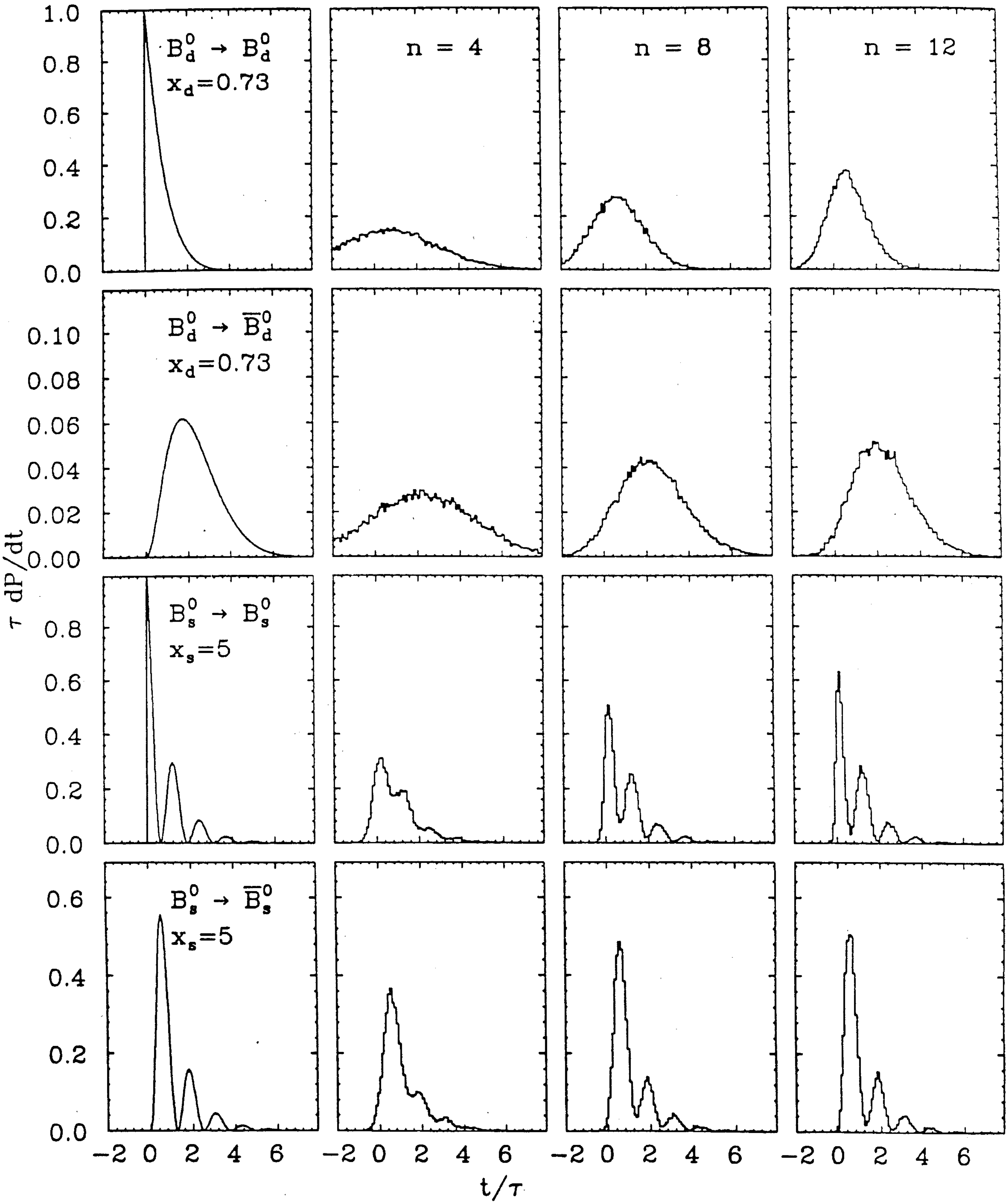

Figure 5. Monte Carlo generated mixing distributions for B_d° and B_s° mixing, smeared with thee different values of the assumed decay length resolution σ_{mix} (see text) using n=4, n=8, and n=12 for x_d=0.73 and x_s=scales for the individual distributions. (Ref 9)

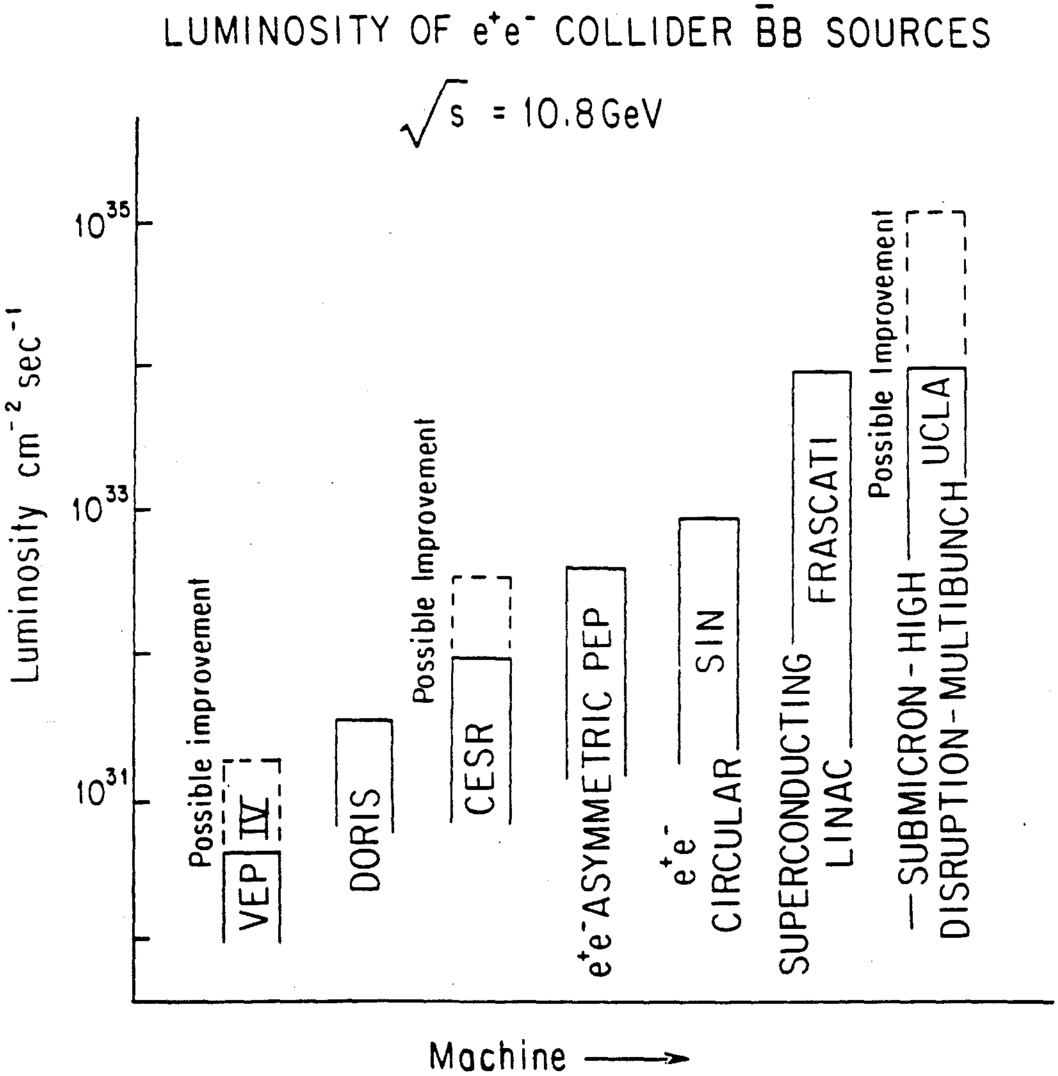

Figure 6. Overview of the Possible Luminosities For Circular and Linear Collider B̄B Factories compared with some existing colliders.

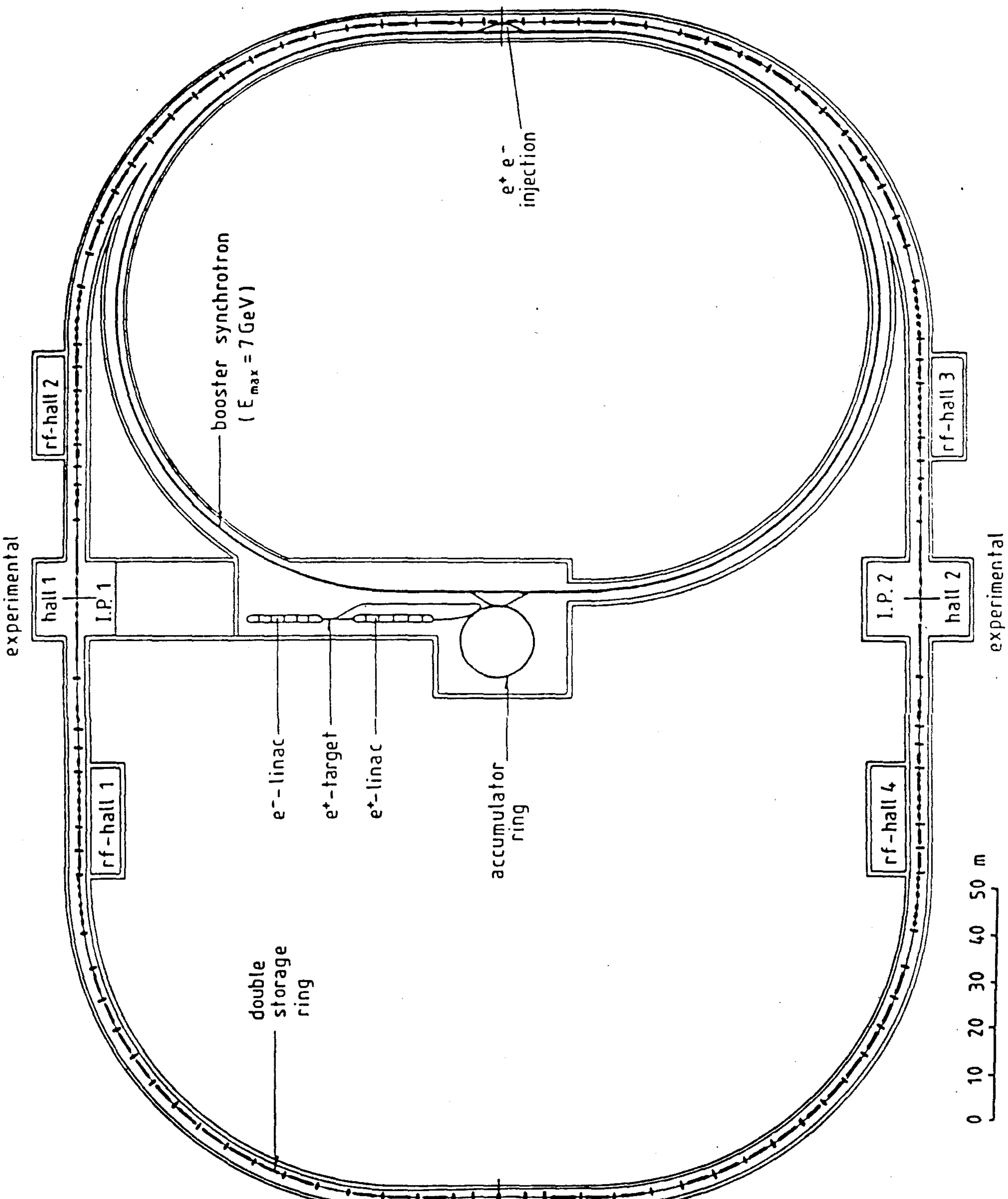

Figure 7. View of the SIN Circular Collider $\bar{B}B$ Factory

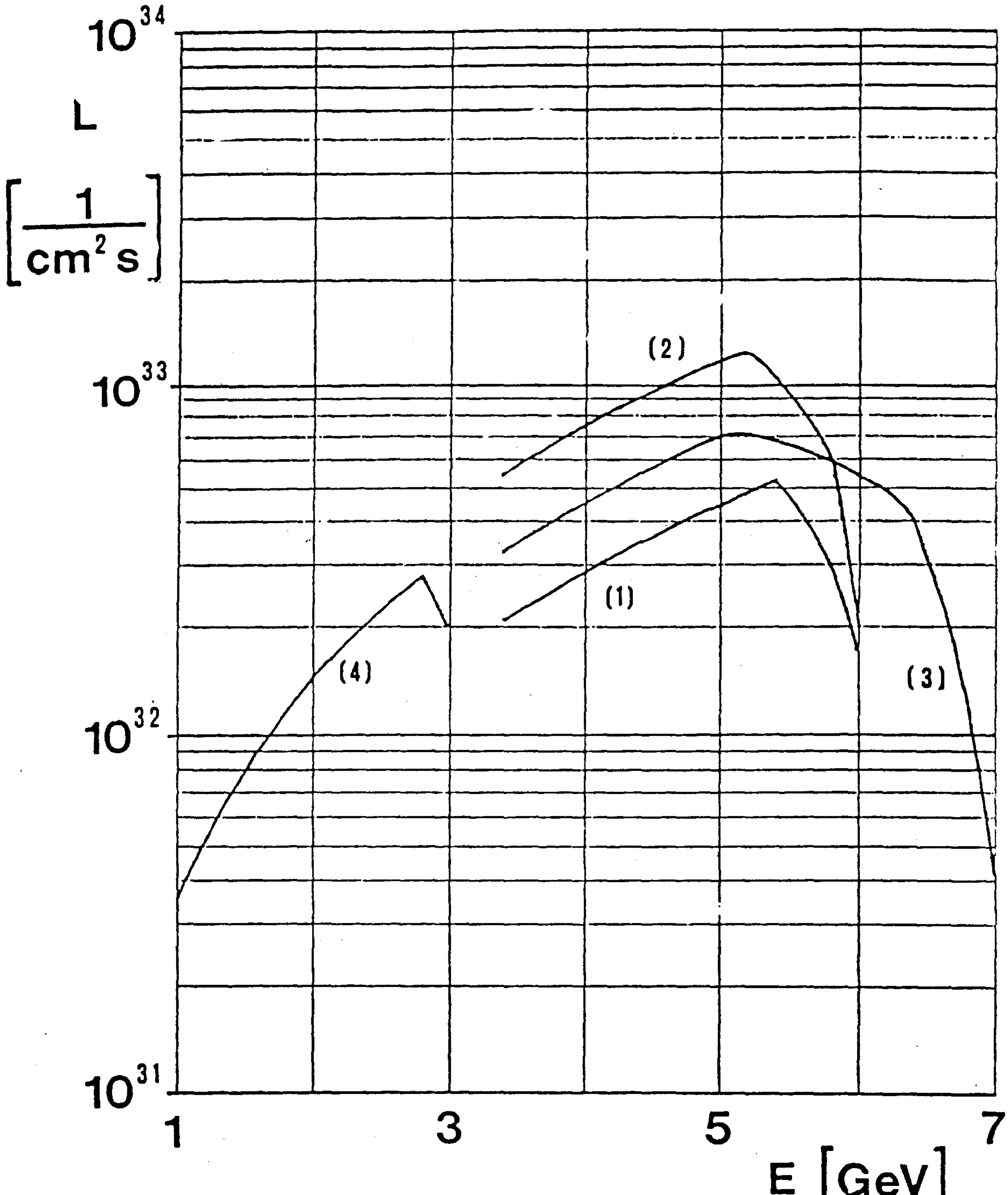

Figure 8. The luminosity of the SIN B meson factory. Curve (1): standard optics, $\Delta Q=0.03$, 10 cavities, 10 bunches, $P_{RF}=1050$ kW. Curve (2): $\beta_z^*=2$cm, $\Delta Q=0.04$, 10 cavities, 10 bunches, $P_{RF}=1050$ kW. Curve (3): $\beta_z^*=2$ cm, $\Delta Q=0.04$, 14 cavities, 6 bunches, $P_{RF}=1050$ kW. Curve (4): standard opt., $\Delta Q=0.03$, 2 one cell cavities, $P_{RF}=129$ kW. Above 5.3 GeV the luminosity can be increased through the installation of more RF power or superconductive cavities.

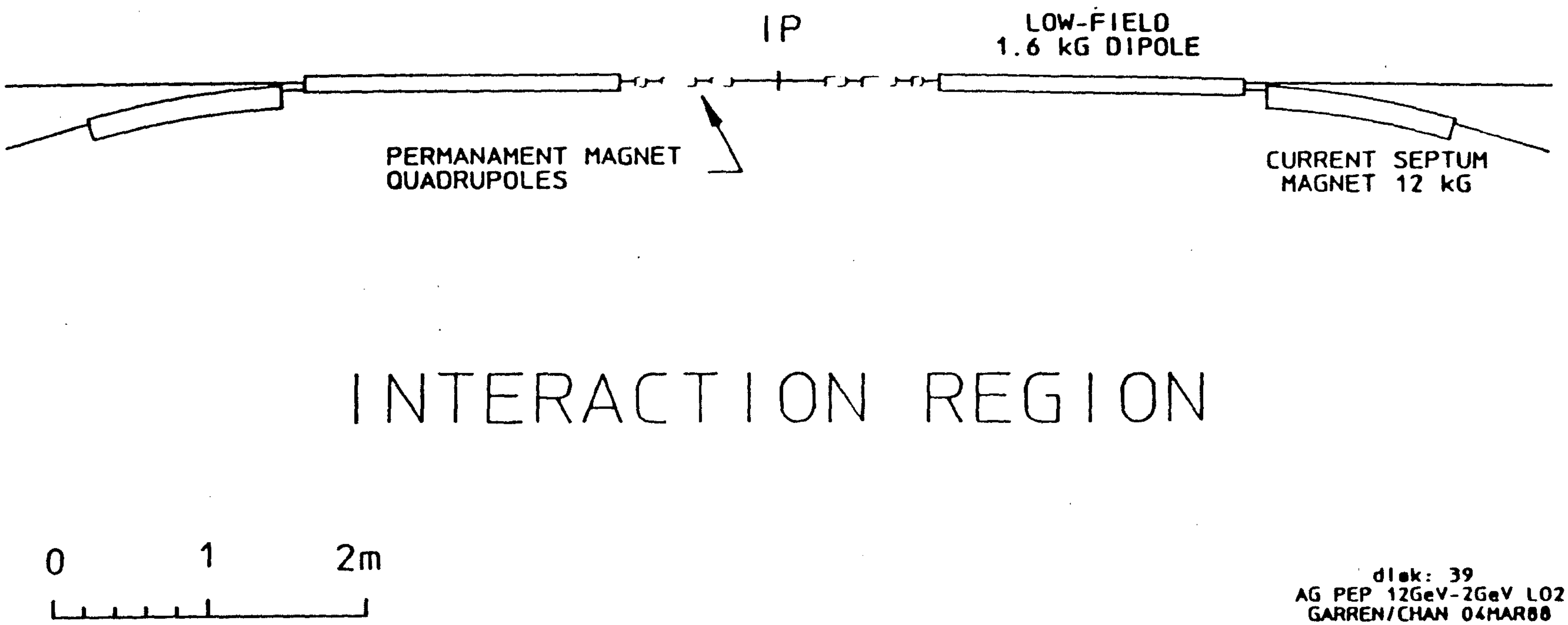

Figure 9. IR for the asymmetric e^+ e^- circular collider study (A. Garren)

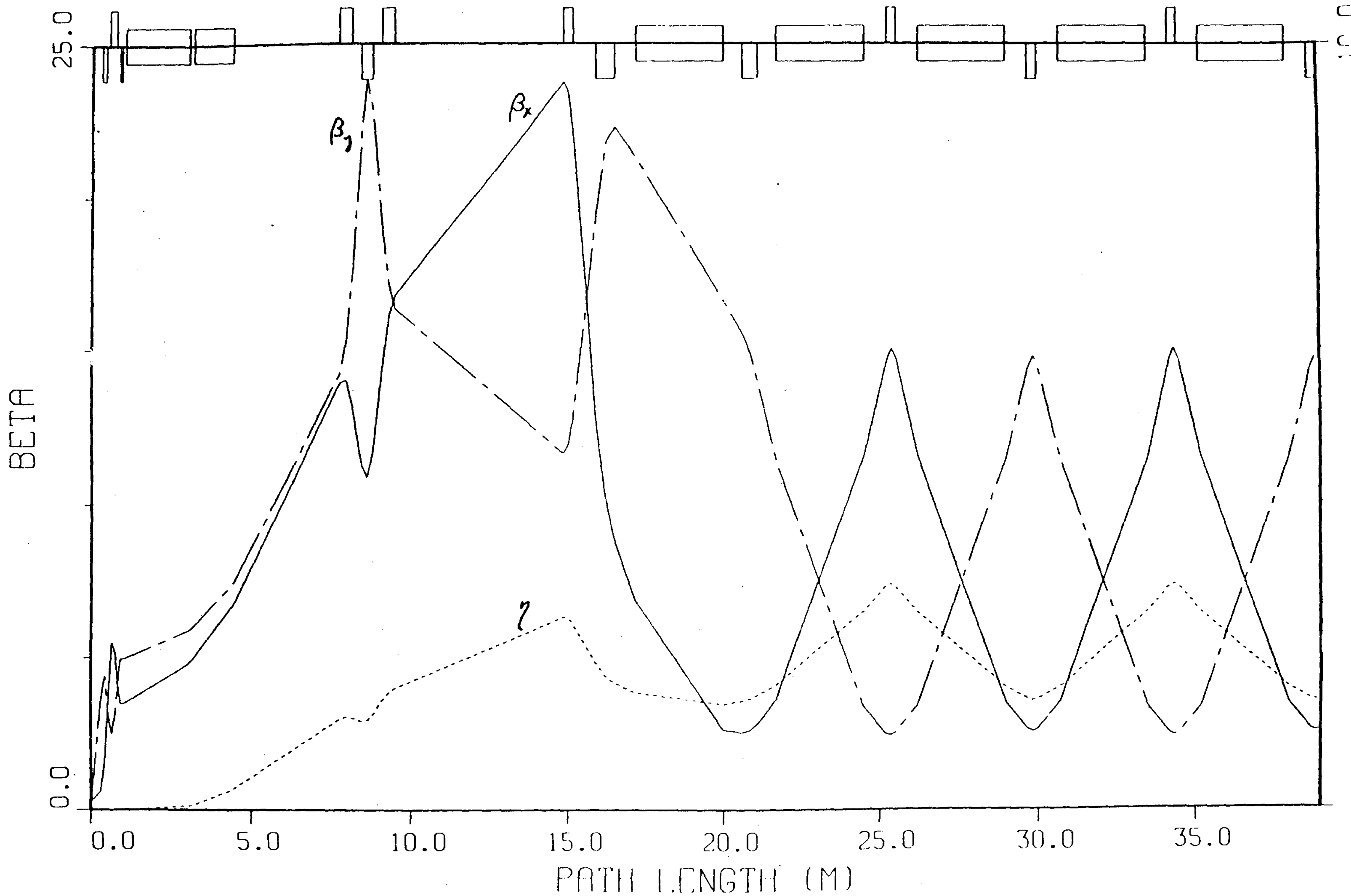

Figure 10. β and η Functions for the small ring in the asymmetric circular collider study (A. Garren)

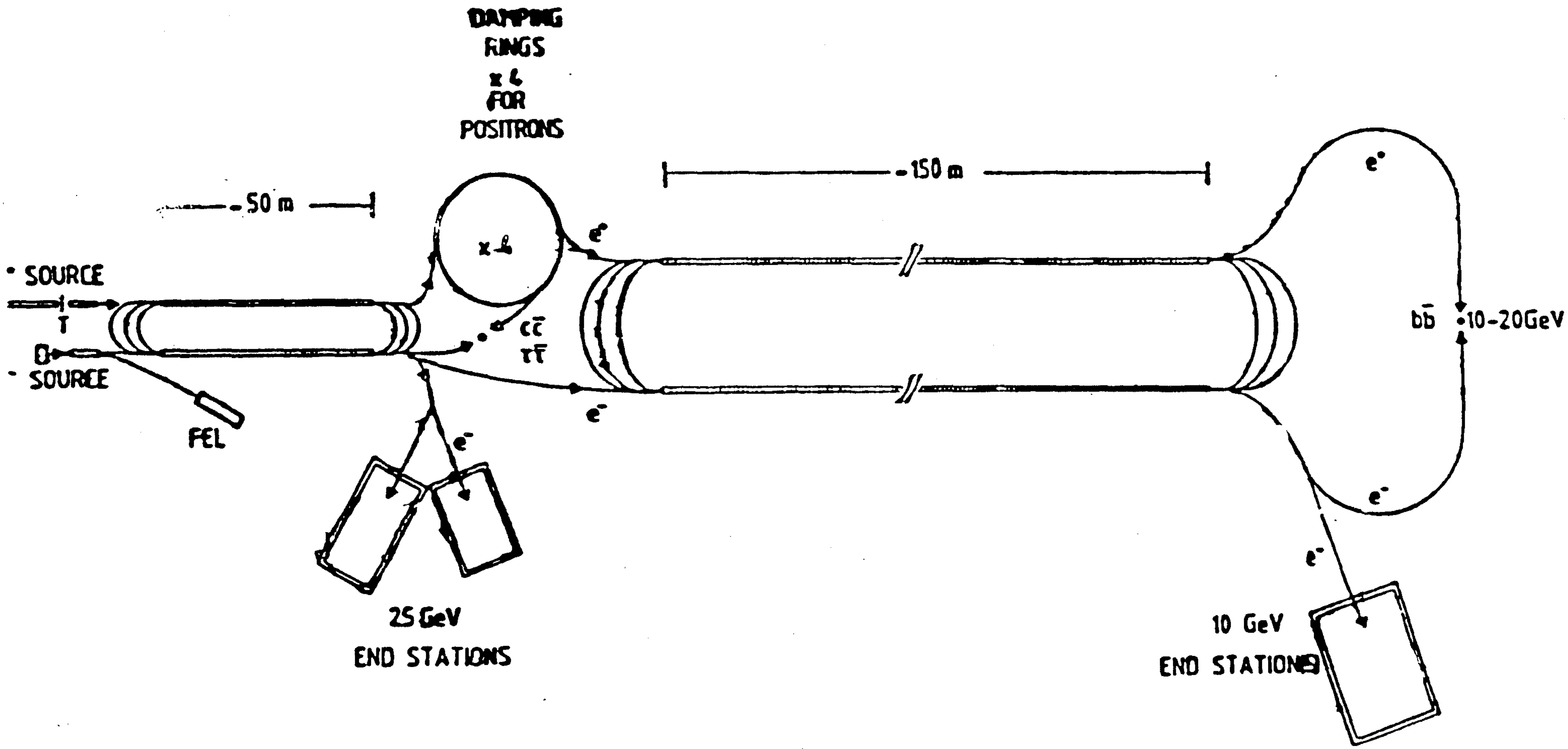

Figure 11. Early design of the Frascati B̄B Factory

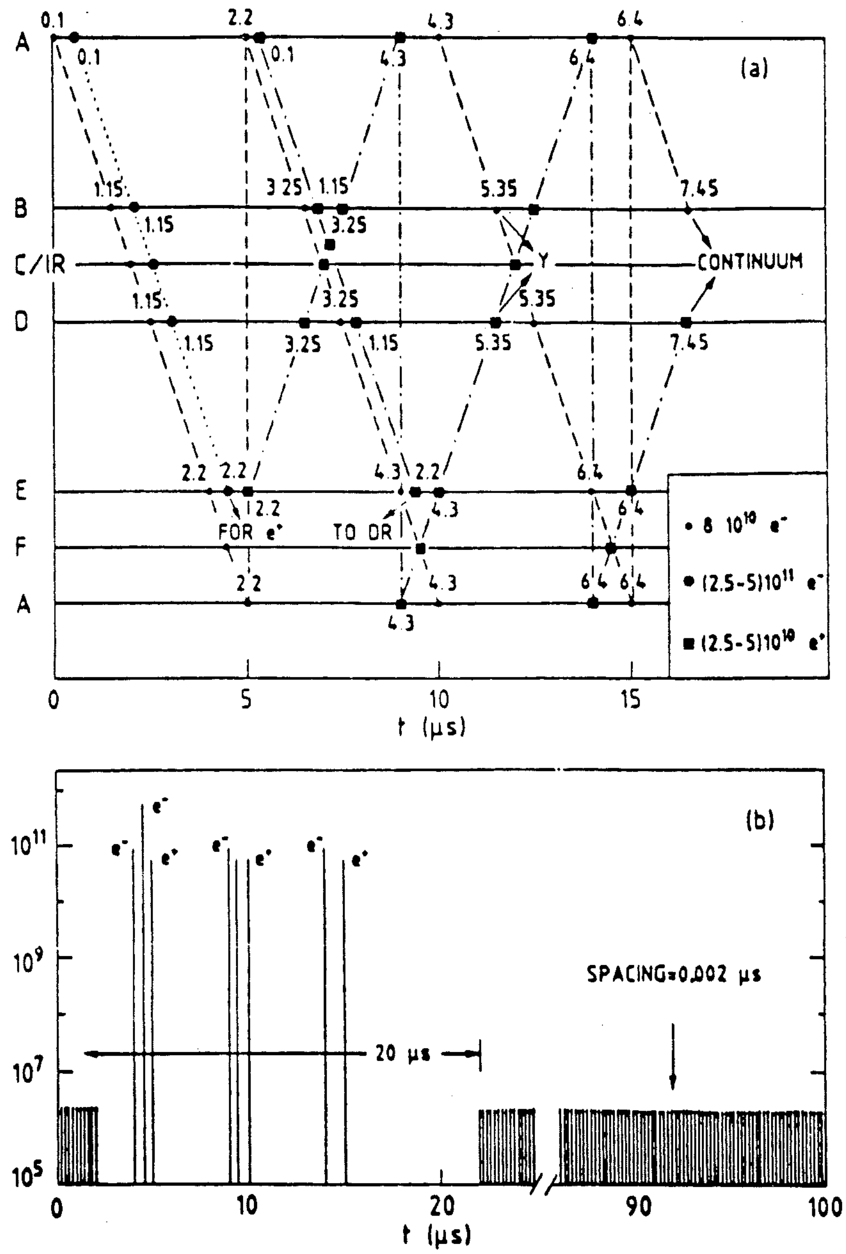

Figure 12. Some of the beam gymnastics for a later design of the Frascati machine.

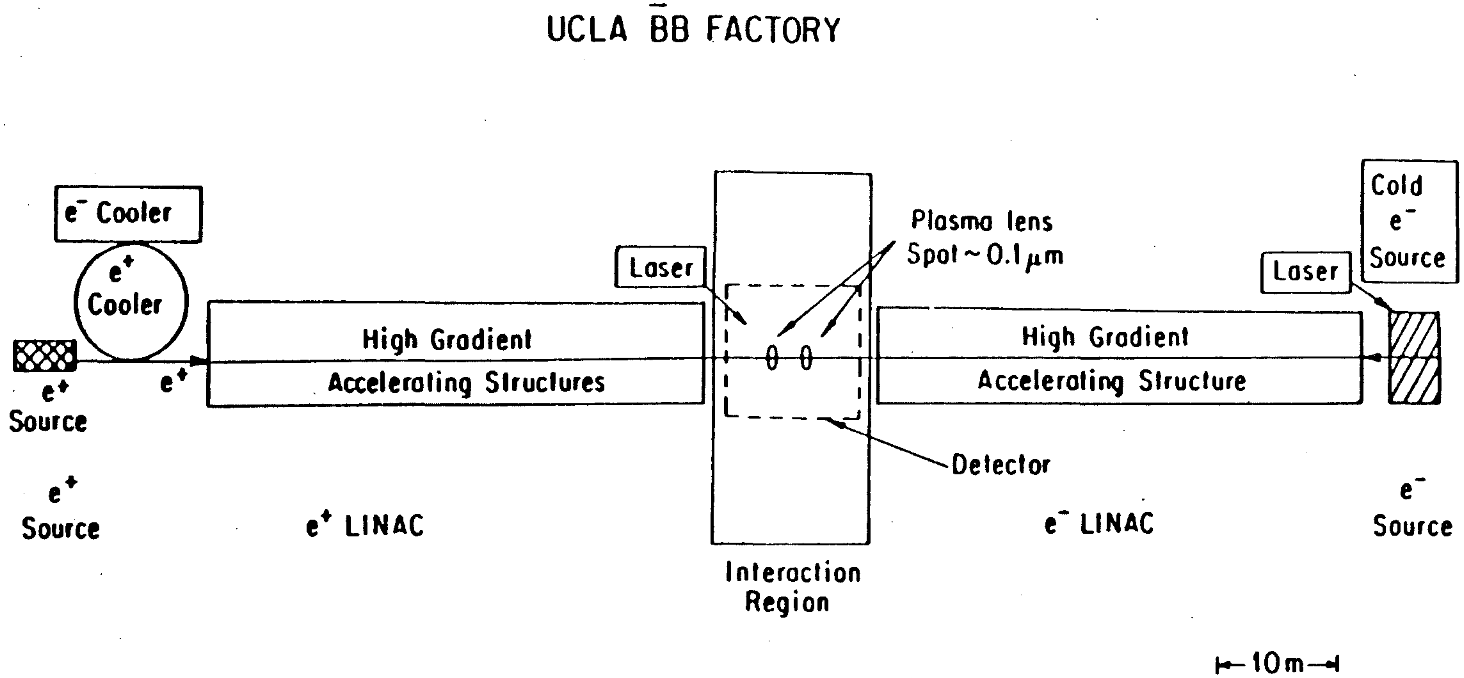

Figure 13. Early schematic design of the UCLA Linear Collider $\bar{B}B$ Factory

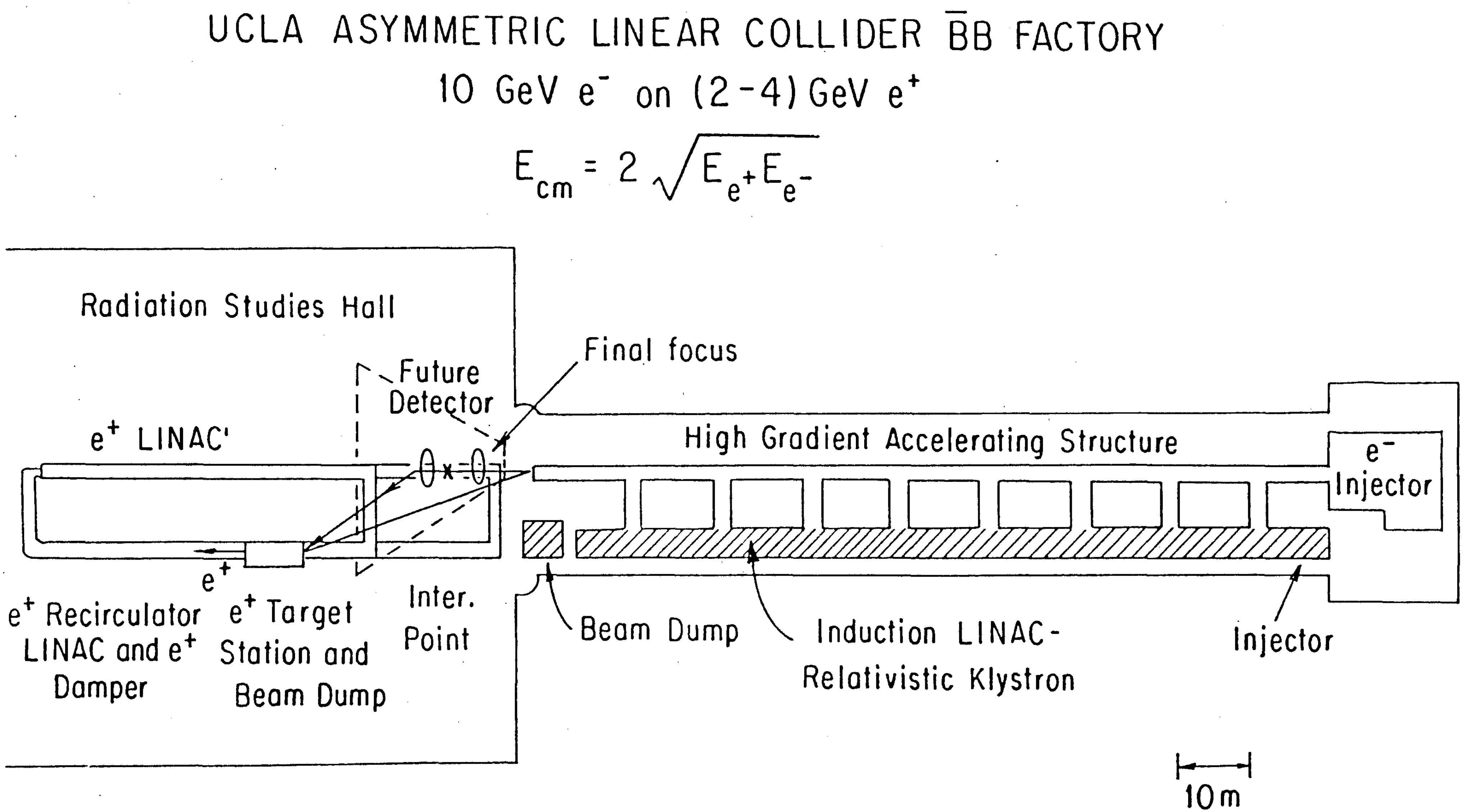

Figure 14. Most recent conceptual design of the UCLA $\bar{B}B$ Factory with Asymmetric Beam and a New Positron Source

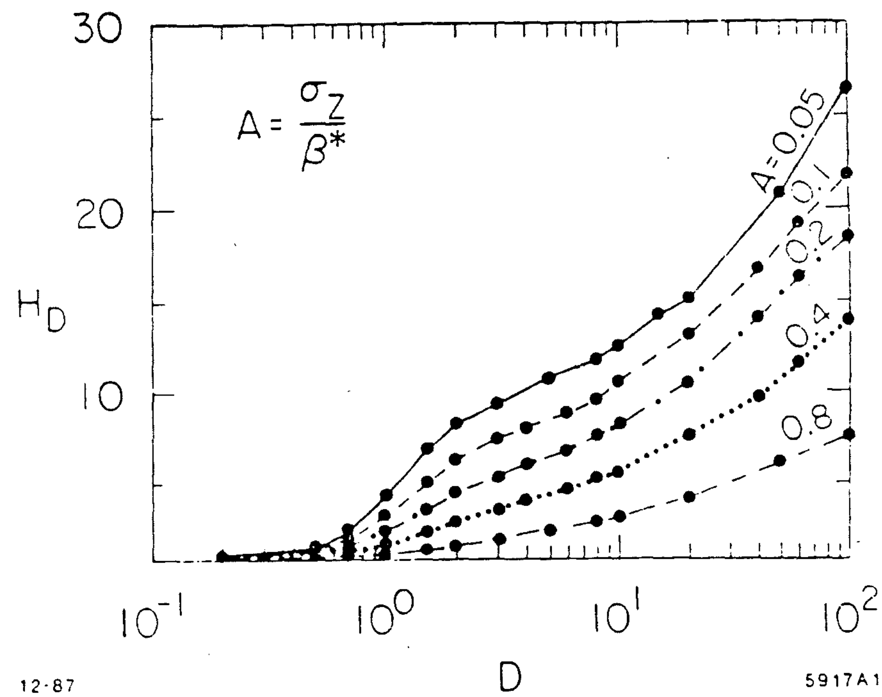

Figure 15a. Luminosity enhancement factor as a function of D, computed with five different values of A. The values are so chosen that they are equally separated on the logrithmic scale.

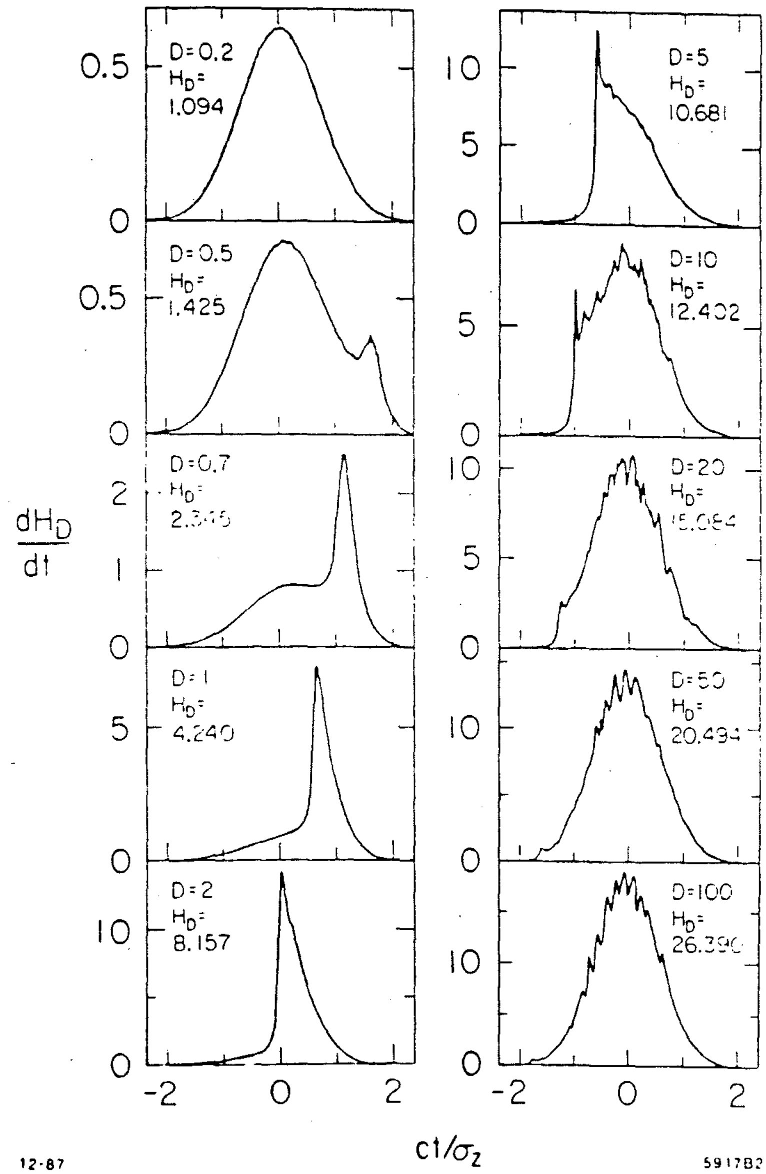

Figure 15b. Computer analysis on the time evolution of the luninosity enhancement factor H_D, at various different values of D. For very small and very large D's, dH_D/dt varies as a Gaussian function (although for large D regime there are small wiggles superimposed), while for medium values of D there is an obvious spike. (Ref 17)

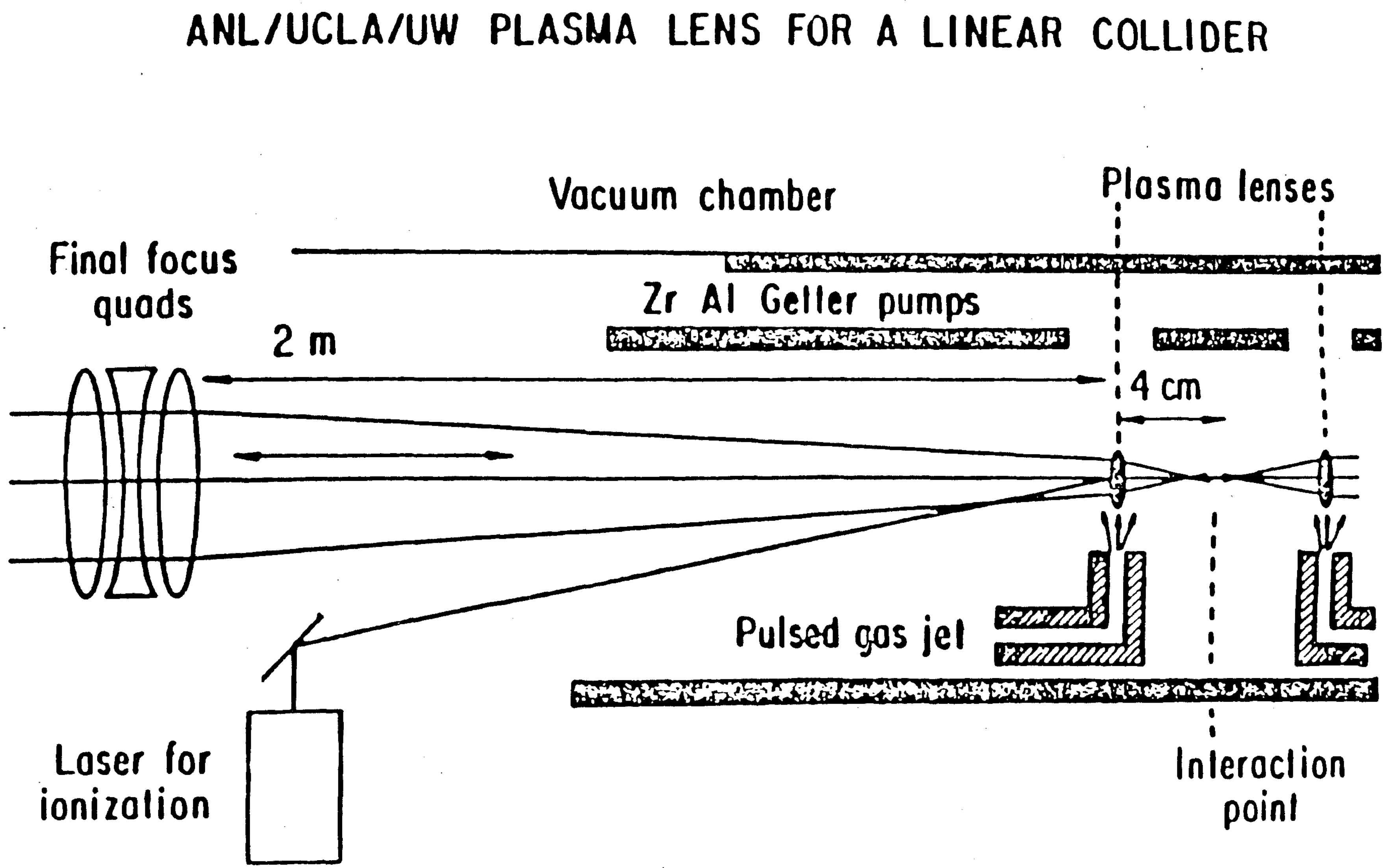

Figure 16. Design of a Plasma Lens by the ANL/SLAC/UCLA group (Ref 18)

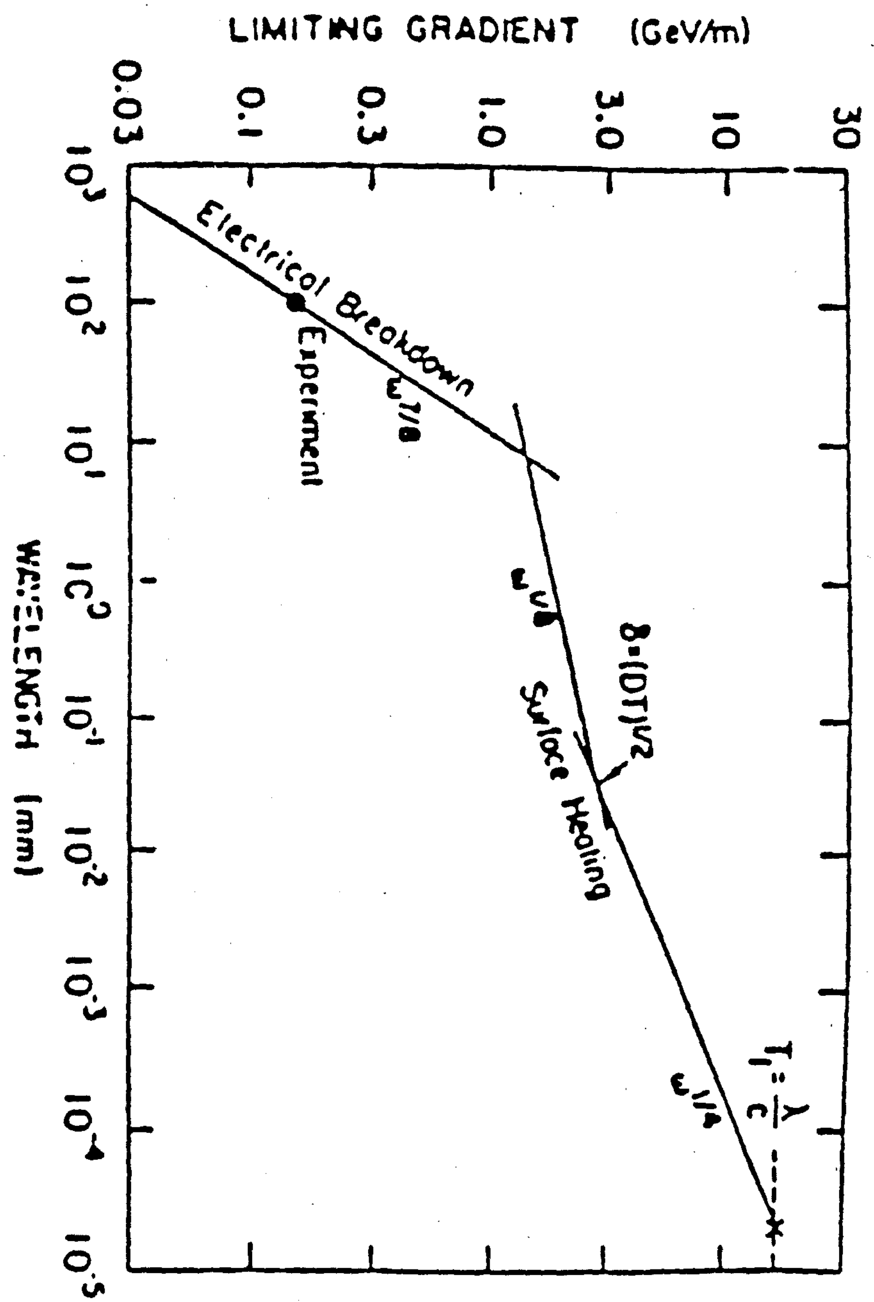

Figure 17. Limiting gradient for a Cu structure as a function of the RF wavelength of the driver source

Schematic of a relativistic klystron

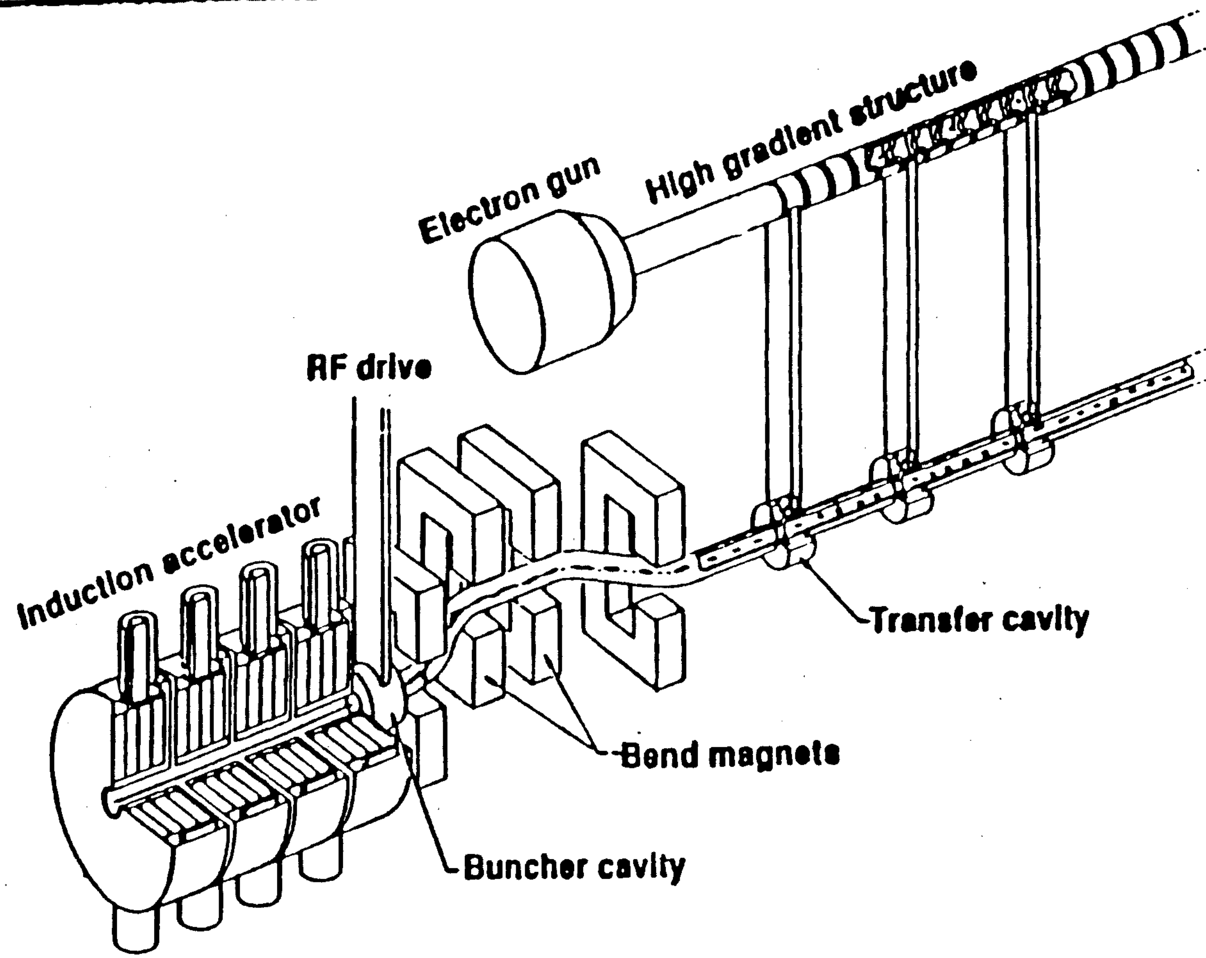

Figure 18. Schematic of the Relativistic Klystron being tested by the SLAC/LLNL /LBL groups

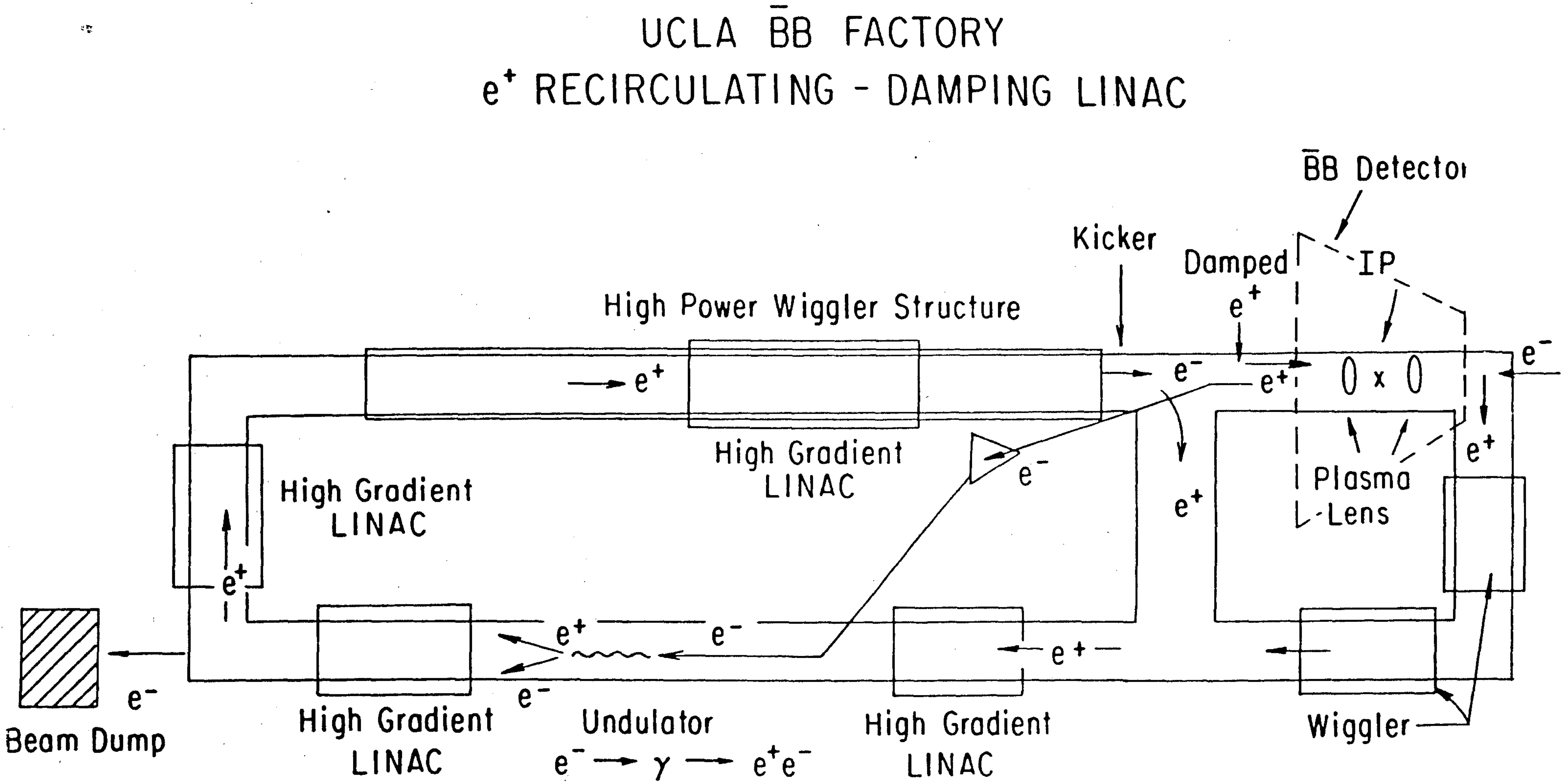

Figure 19. An e^+ Recirculating-Damping Linac for the UCLA $\bar{B}B$ Factory that partially solves the positron source problem.

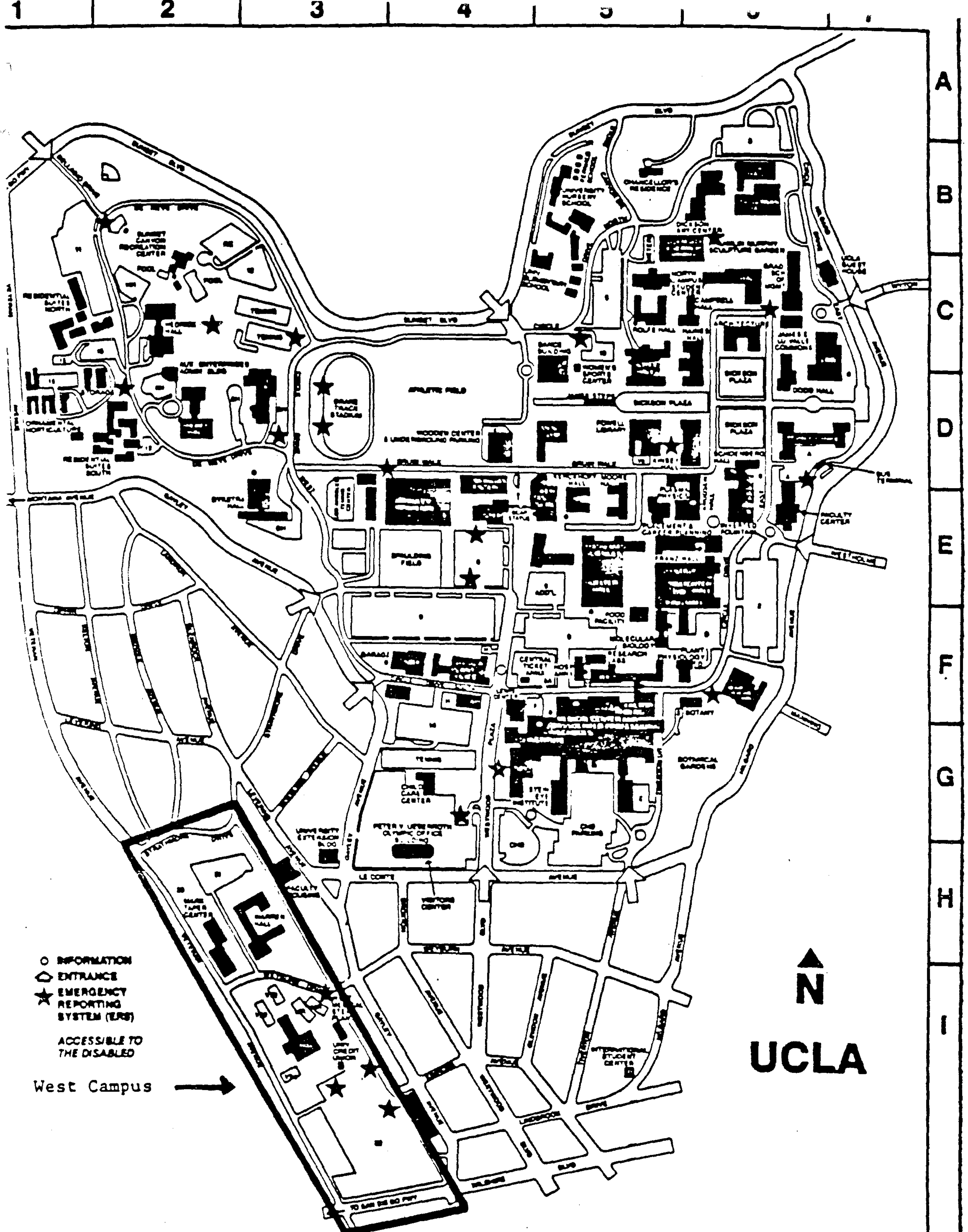

Figure 20. Possible site for the UCLA $\bar{B}B$ Factory in Westwood, Los Angeles

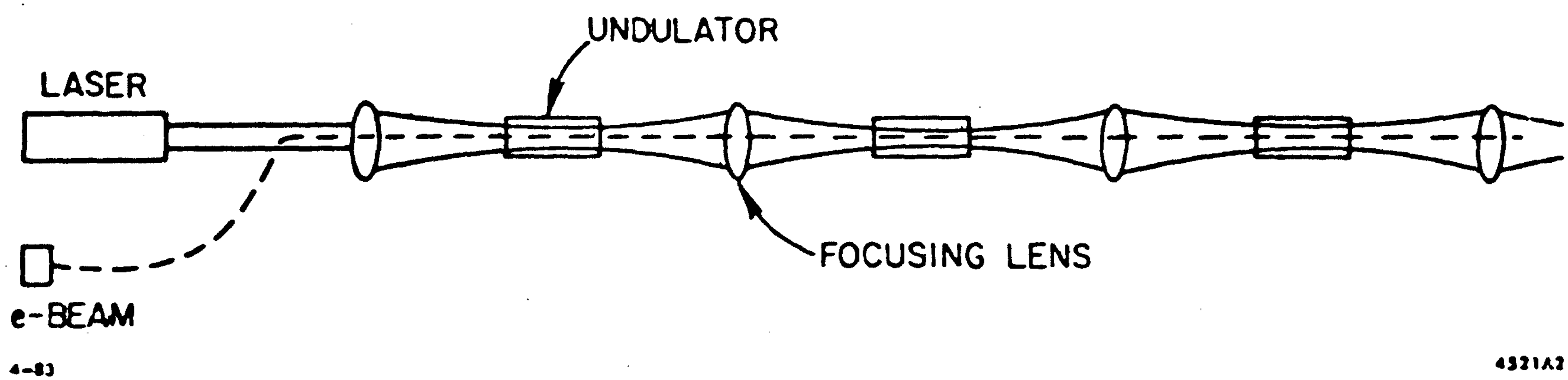

Figure 21. An IFEL Driven for a $\bar{B}B$ Factory (C. Pelligrini)

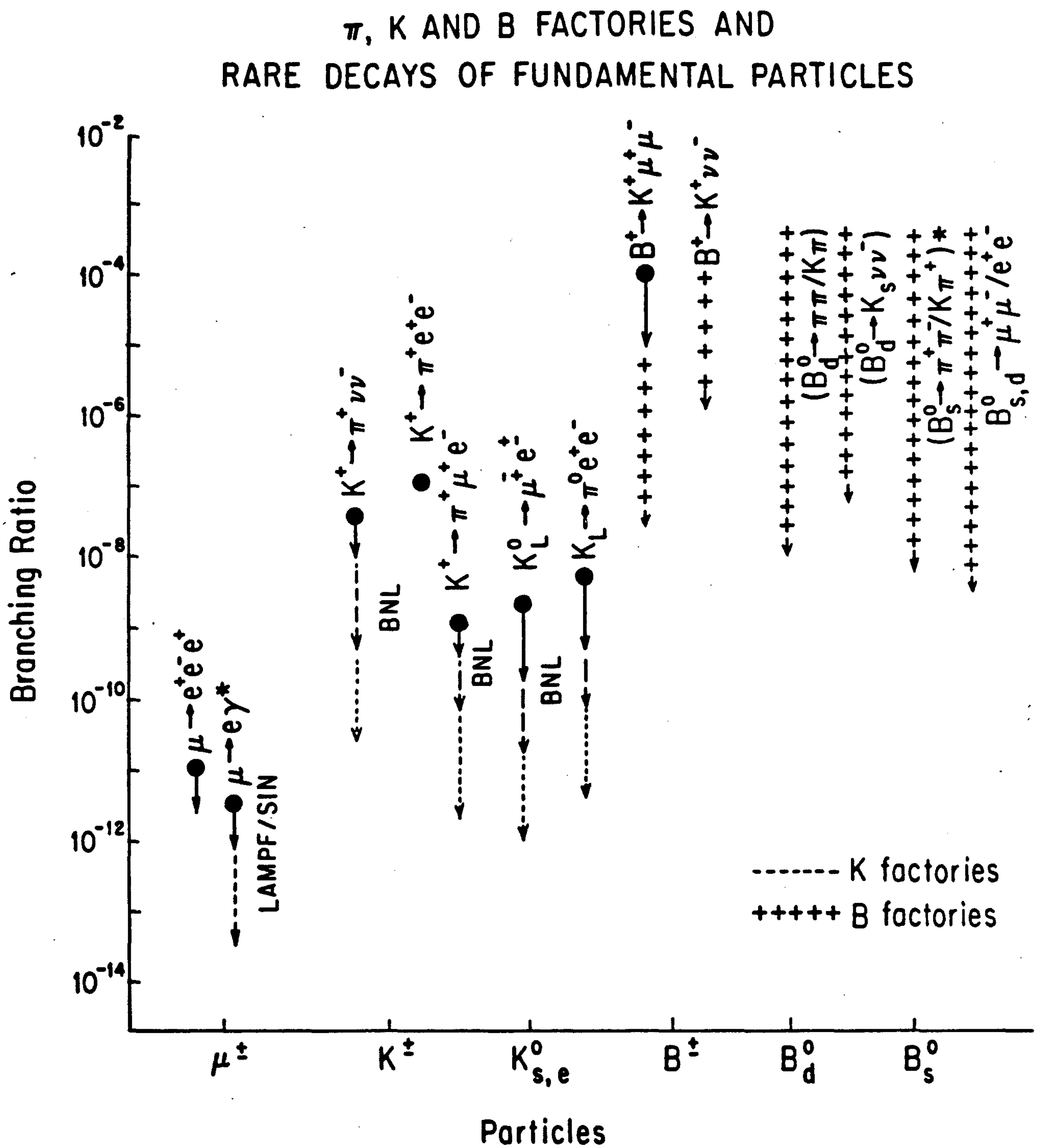

Figure 22. Comparison of the Range of Sensitivity of π, K and $\bar{B}$B Factories and some of the Interesting Decay Modes.