THE PROPOSED INJECTION SYSTEM FOR AN ASYMMETRIC B FACTORY IN THE PEP TUNNEL

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I. ABSTRACT AND INTRODUCTION

The proposed asymmetric energy B Factory to be built in the PEP tunnel at SLAC will require a highly effective and profuse source of low emittance electron and positron bunches. The B Factory will consist of two rings of equal size, a 9 GeV electron ring and a 3.1 GeV positron ring, each with 1658 bunches with total circulating currents of 1.5 and 2.1 amperes respectively. As the luminosity lifetime of the collider is expected to be about two hours, the injector should be capable of filling the rings in a small fraction of an hour. It turns out that with some simple modifications, the SLC linac with its damping rings and positron source is ideally suited to fulfill this function effectively. The overall injection system is described below.

II. SYSTEM SPECIFICATIONS AND DESCRIPTION

The specifications and required parameters of the injection system are shown in Table I. It is seen that each of the 1658 stored bunches will require about 5 x 10^{10} particles. In the topping-off filling mode (80→100%), assuming that each bucket receives about 5 single bunches from the injector with 50% filling efficiency, the linac will have to provide single bunches of 4×10^9 particles/bunch as compared to 2-5 x 10^{10} particles/bunch in the regular SLC mode. This should be very easy. In the full filling mode, the first 80% of each bucket will be filled, also with 5 linac bunches, but at the rate of 2×10^{10} particles/bunch, and the remaining 20% at the topping-off rate as above. Assuming that both rings are filled by alternate linac pulses, each at a 60 pps rate, it is easily seen that the filling operations will take on the order of 3 and 6 minutes respectively.

A schematic of the SLC injection system is shown in Fig. 1. The injector will consist of the first 19 sectors of the linac, the two damping rings and the positron source. The 3.1 GeV positrons will be extracted at the end of Sector 3 through a DC chicane which will let the electrons continue on, either to the end of Sector 7 for extraction at 9 GeV via a slowly pulsed magnet, or to Sector 19 at about 30 GeV for positron production. The remaining 11 sectors of the linac may be

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TABLE I

B FACTORY INJECTION SPECIFICATIONS AND PARAMETERS

Beam Energy:	
High-energy ring (HER) (e^-) [GeV]	9 [range: 8-10]
Low-energy ring (LER) (e^+) [GeV]	3.1 [range: 2.8-4]
Beam current:	
HER ring [A/$10^{10}e^-$]	1.48/6777
LER ring [A/$10^{10}e^+$]	2.14/9799
Particles per bunch:	
HER ring[$10^{10}e^-$]	4.1
LER ring [$10^{10}e^+$]	5.9
Linac repetition rate [pps]	60/120
Linac current [10^{10} $e^{\pm}$ per pulse]**	0.4-2
Invariant linac emittance [m-rad]	5×10^{-5}
Filling times:	
Topping-off (80-100%) [min]	3
Full Filling (0-100%) [min]	6
Magnet standardization time [min]	15
Ring circumference [m]	2199.318
Revolution period [μs]	7.336
Revolution frequency [kHz]	136.311
Bunch frequency [MHz]	476/2 = 238
Time between bunches [ns]	4.20
Harmonic number	3492
Number of bunches	1746 - 5%
(leaving 5% gap)	= 1658
Horizontal damping time:	
HER [ms]	38
LER with wigglers [ms]	36
LER without wigglers [ms]	150
Geometric beam emittance [nm-rad]:	
HER horizontal/vertical	48/1.9
LER horizontal/vertical	96/3.8

**Assuming 50% filling efficiency.

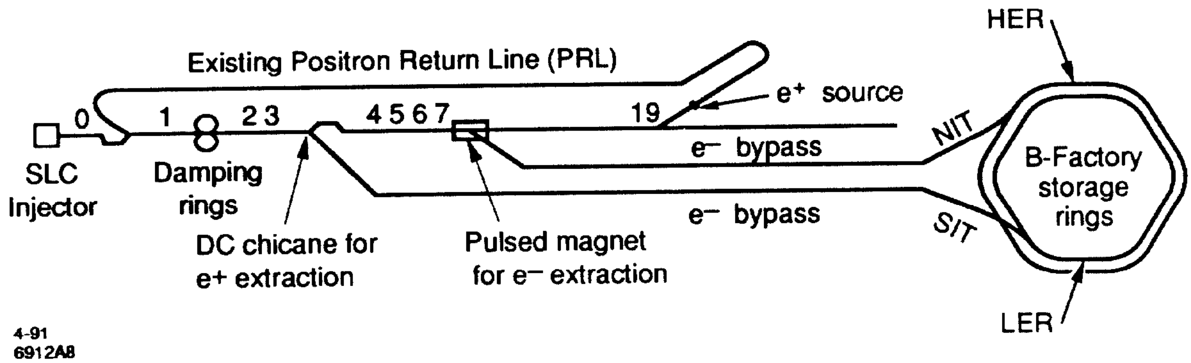

Fig. 1. Schematic of the B Factory $e^{\pm}$ injection system, based on use of the SLC linac with bypass lines. The numbers along the linac indicate the location (not to scale) of each sector. Each of the 30 sectors is 100 m long.

turned off. Once extracted, the respective bunches of electrons and positrons will be transmitted through two separate bypass lines to the existing NIT and SIT lines presently used to fill PEP from the end of the linac. The NIT and SIT lines are well instrumented and will not be described in this paper. The advantages of the system proposed here are numerous: a) it preserves all other High Energy Physics opportunities at SLAC; b) the bunches leave the linac at the desired energy, thereby eliminating the need for backphasing and minimizing wakefields in unnecessary accelerator structures; c) by alternating e^+ and e^- pulses at 60 pps, only one bunch will be stored at a time in each damping ring; d) no additional fast kickers (often unreliable) will be needed; e) between filling times, it will be possible to "park" e^+ and e^- bunches at a low rate in NIT and SIT Faraday cups to optimize readiness for filling on demand; f) finally, by selecting a ring RF frequency of 476 MHz, i.e., 1/6 of the linac RF frequency of 2856 MHz, synchronization will be greatly simplified.

The bypass lines will consist of 10 cm-diameter aluminum pipe (for adequate pumping speed) with 2.5 cm-diameter constrictions every 50m where a FODO array of quadrupoles and beam position monitors will be located. These apertures will be fully adequate since the low-emittance beams will have σ_r's of less than 1.5 mm. A cross-section of the linac housing with the overhead-suspended quadrupoles showing the respective tilts of the extraction planes is given in Fig. 2. The existing positron return line (PRL) is shown for reference in the upper right-hand corner. Table II gives a list of the components in the bypass lines. The matching quadrupoles are part of 360 degree-phase advance achromatic bends joining the linac to the bypass lines, and these to NIT and SIT.

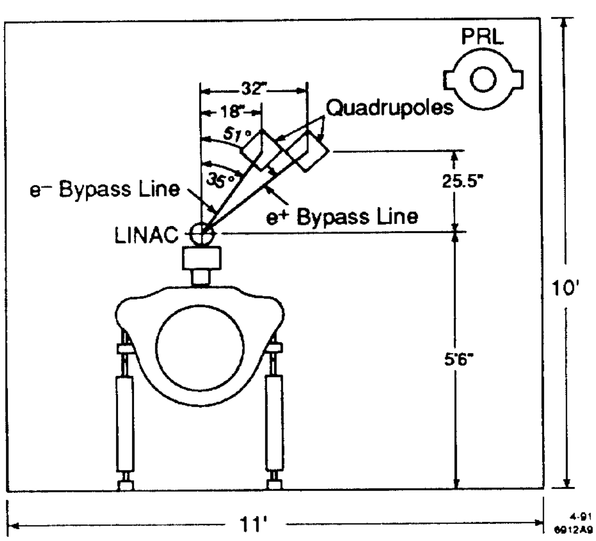

Fig. 2. Cross section of linac housing showing the location of the electron and positron FODO array quadrupoles. Note the tilts of the extraction planes.

TABLE II
LINAC BYPASS LINE COMPONENTS AND SPECIFICATIONS

	POSITRON LINE	ELECTRON LINE
Length (km)	~2.6	~2.2
Energy (GeV)	2.8-4	8-10
No. of quadrupoles		
Matching	24	24
FODO array	52	44
Steering correctors	64	56
Beam position monitors	64 (64 readouts)	56 (56 readouts)
Profile monitors	2	2
Pumps (120L/s)	29	23
Vacuum roughing connections	29	23
Fast valves	1	1
Isolation valves	14	13

III. INJECTION INTO THE HER AND LER

In contrast to the single PEP ring, for which the injection lines come down vertically into the plane of the ring and are tangent to the inside, the HER and LER injection lines will be brought down on the outside of the two rings - into the plane of the HER at IR-10 and into the plane of the LER at IR-8. The proposed method of injection is very similar to the one used in PEP. It assumes $\beta_x = 80$ m and $\beta_y = 20$ m in 40-m-long injection regions. Horizontal injection occurs as shown in Fig. 3. The closed orbit of the stored beam is temporarily distorted by means of four DC bump magnets and three kickers. Details of the horizontal phase space (x,x') for the stored and injected beam are shown at three sequential points in time following the turn-on of the DC bump magnets: (i) stored beam is moved by 0.5 cm to DC bumped position, $10\sigma_x$ away from the inner edge of the 3-mm septum; (ii) stored beam is within 6 σ_x of the septum inner edge; incoming beam from the linac is tangent to the stored-beam orbit and within 2 σ_i of the outer septum edge; (iii) approximately four turns later, the stored beam is back to its DC bumped orbit: the incoming beam is inside the ring within $2\sigma_x$ of the inner septum edge, ready to damp and merge with the stored beam. It is assumed that the injected beam has a β_x of 30 m.

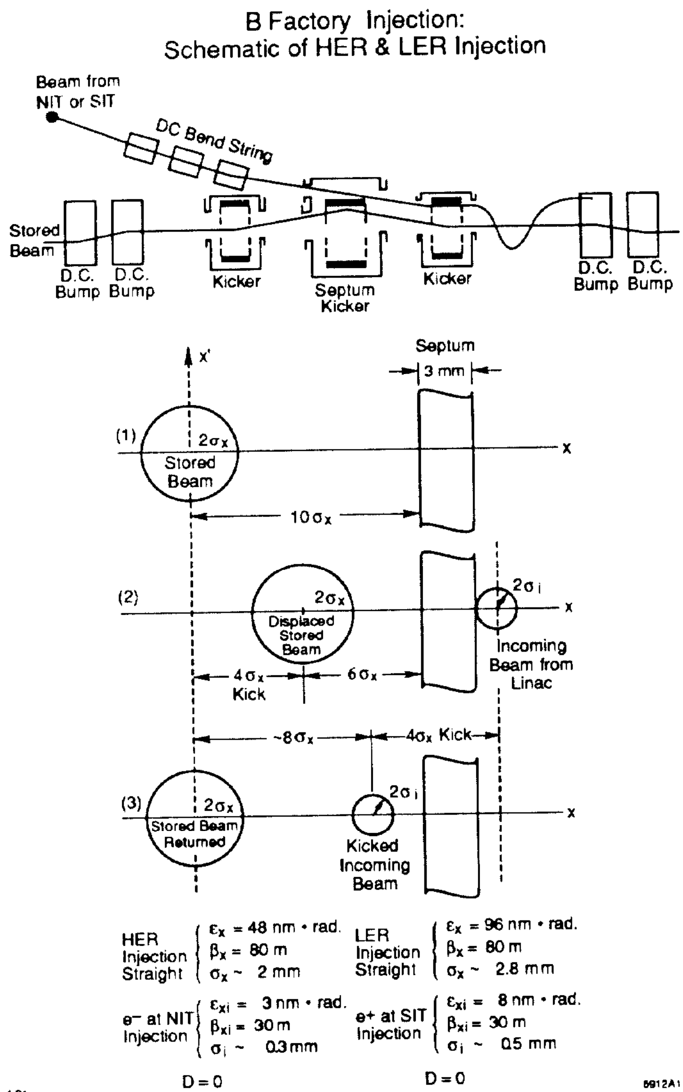

Fig. 3 Schematic of Injection Kicker System, and horizontal transverse phase space (x,x') of stored and incoming beams during three successive steps of the injection process (HER and LER). The diameters of the stored and incoming beams are not drawn to scale.

For injection purposes, each ring is divided into nine rotating "zones" of equal length as shown in Fig. 4. A zone has a length of about 244 m (or 815 ns) and contains 194 bunches. One of these zones in each ring will remain about half empty to leave a gap for ion control. We describe here the process for filling the LER at a 60Hz rate; the HER is filled in a similar way. The transverse damping time for the HER is 38 ms and for the LER 36 ms. If the damping contribution of the wigglers in the LER is ignored, a worst-case situation in terms of injection, then the LER has a damping time of 150 ms. The beginning of each zone is determined by the time onset of the kicker current pulses. All three kicker pulsers are identical, consisting of critically damped RLC circuits that rise and fall to practically zero within less than 1500 ns. The first bucket to be filled in zone n is located roughly 200 ns after the beginning of the kicker pulse so as to ride on the flat top where sensitivity to time jitter is minimized. Since the rise time of the pulse is much shorter than the fall time, bunches recently stored in zone n - 1 are unaffected. Bunches in zone n + 1 (at least 815 ns later) are kicked slightly, but since they have been in the ring for the longest time, their orbits are almost fully damped, and, to the extent that the kickers are matched, these bumps are closed. Thus, single buckets in zones 1 through 9 are filled in succession, after which, 9 times 1/60th of a second, or 150 ms later (that is, one damping time in the LER in the absence of wigglers), the next adjacent buckets (4.2 ns later) in each zone are filled, and so on. With this method, damping in the LER, even without wigglers, is adequate. The entire filling sequence will be computer controlled and automated for both rings.

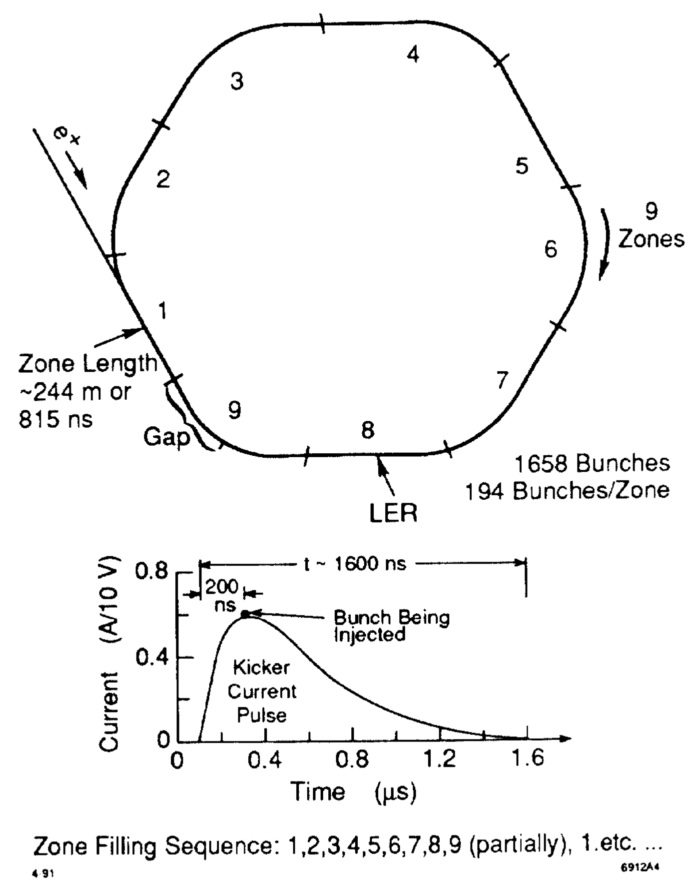

Fig. 4 Azimuthal zone filling sequence for the LER, showing nine zones. The kicker pulse shown (equal for all kickers) was computed by assuming charged, critically damped RLC circuits [$R = 2\,(L/C)^{1/2}$] in which the current reaches its maximum at $t = 2\,L/R$ after a thyratron is fired and allows the circuit to be discharged.