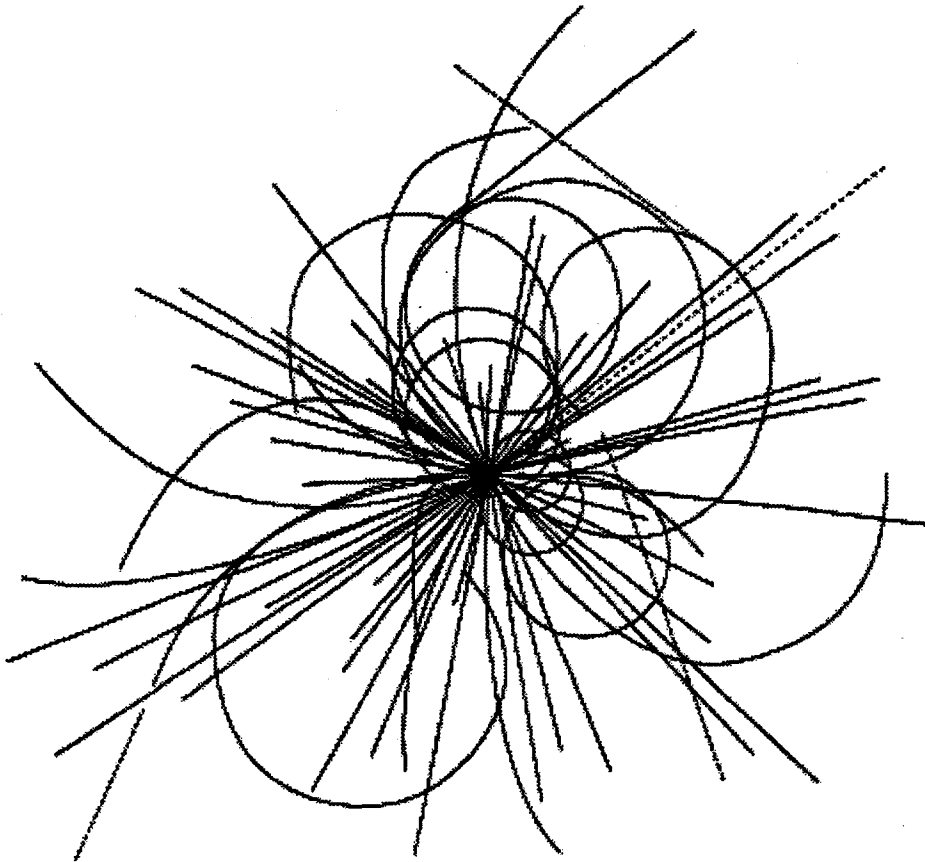


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Injection System of the SSC Medium Energy Booster



**Superconducting Super Collider
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Injection System of the SSC Medium Energy Booster

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Injection System of the SSC Medium Energy Booster

N. Mao, R. Gerig, J. McGill, and K. Brown

Abstract

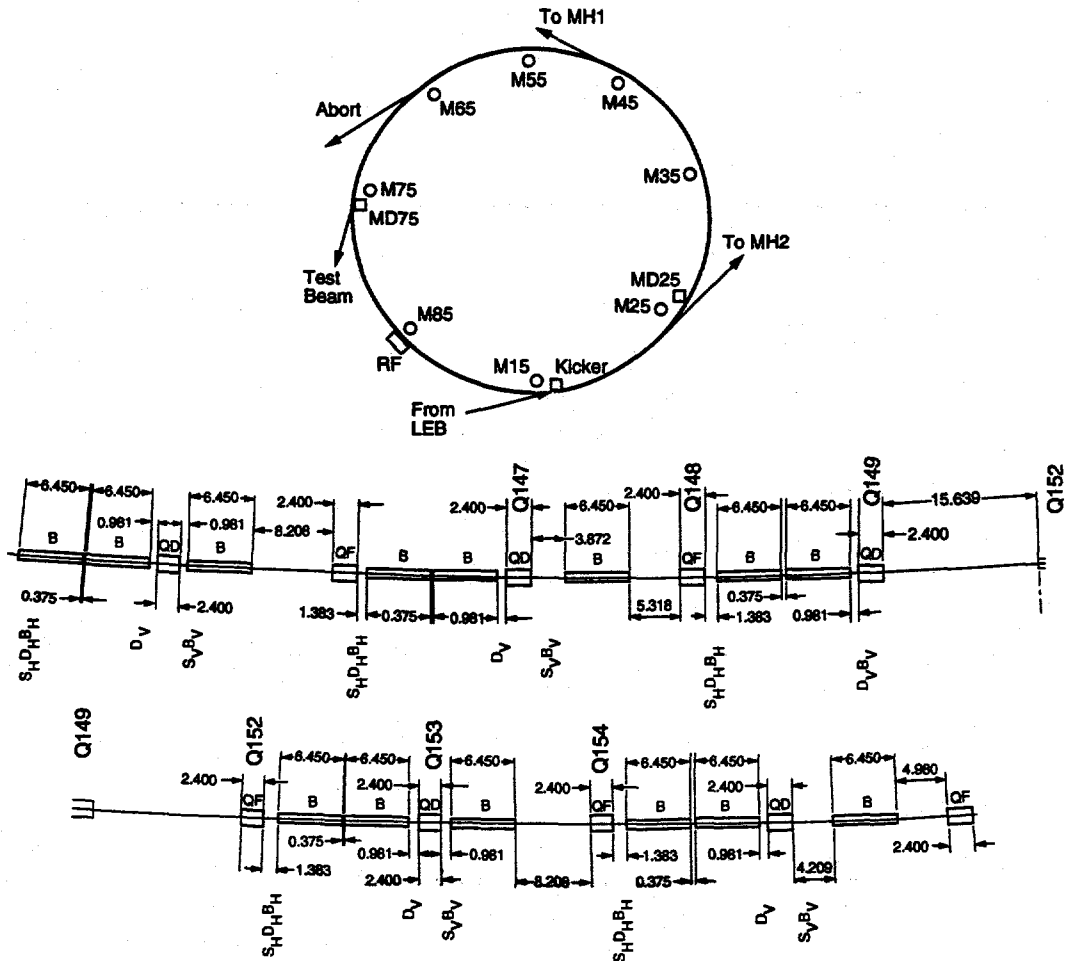
The Medium Energy Booster (MEB) is the third of the SSCL accelerators and the largest of the resistive magnet synchrotrons. It accelerates protons from an injection momentum of 12 GeV/c to a top momentum of 200 GeV/c. A beam injection system has been designed to inject the beam transferred from the Low Energy Booster (LEB) onto the MEB closed orbit in the MEB injection insertion region. The beam is injected via a vertical bending Lambertson septum magnet and a horizontal kicker with appropriate matching and very little beam loss and emittance dilution.

The beam optics of the injection system is described in this paper. The required parameters of the Lambertson septum magnet and the injection kicker are given.

1.0 INTRODUCTION

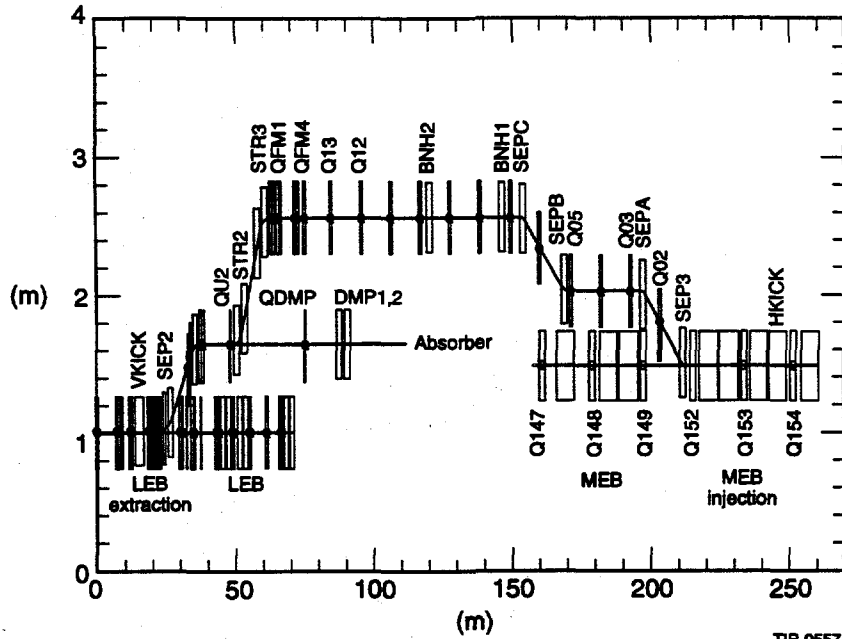
The MEB ring layout and the detail of the MEB injection insertion are shown in Figure 1.¹ The injection insertion adopts the standard FODO quadrupole spacing and uses missing dipoles to provide spaces for the beam transfer line,² septum magnet and kicker. The injection philosophy is as follows. The septum magnet (SEP3, Figures 2 and 3), located right upstream of the focusing quadrupole Q152, bends the beam up by 2.173° onto the MEB closed orbit plane. The horizontal kicker (HKICK), located right upstream of the focusing quadrupole Q154, completes the injection process, placing the beam onto the proper MEB horizontal closed orbit. This scheme takes advantage of the defocusing quadrupole Q153 present between the septum magnet and the horizontal kicker. The defocusing quadrupole bends the injection beam outward in the horizontal plane, thereby lessening the necessary strength of the injection kicker.

The lattice functions of the injection insertion are shown in Figure 4.¹ The functions at the exits of the septum magnet and the injection kicker are also listed in Table 1, lines 38 and 52, respectively. The injection system has been designed to inject the beam in both the collider fill mode and the test beam mode with the normalized transverse emittances (rms) of $0.6 \pi \cdot \text{mm} \cdot \text{mrad}$ and $4.0 \pi \cdot \text{mm} \cdot \text{mrad}$, respectively.



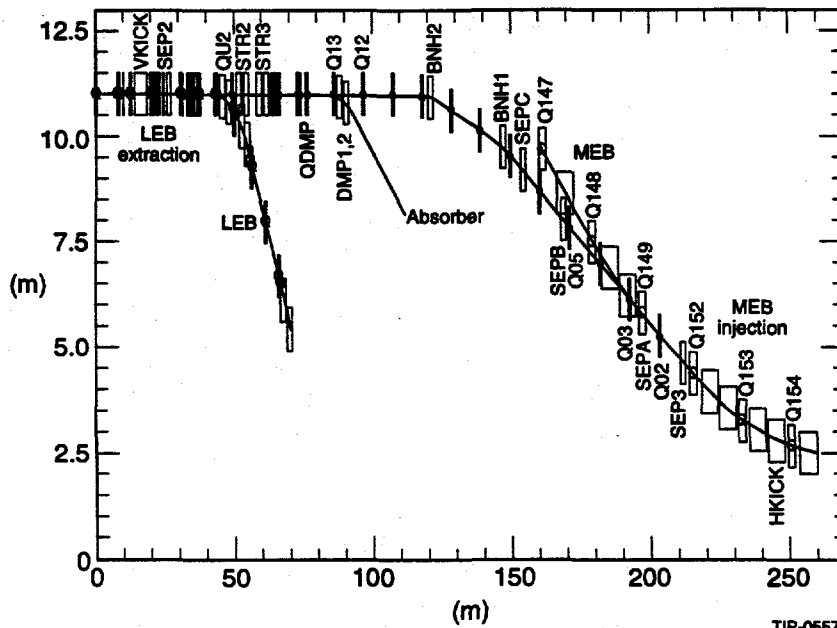
TIP-05570

Figure 1. MEB Ring Layout and Injection Insertion.



TIP-05571

Figure 2. LEB-MEB Transfer Line and Absorber Line (Elevation View, LEB630 and LEB917).



TIP-05572

Figure 3. LEB-MEB Transfer Line and Absorber Line (Plan View, LEB630 and LEB917).

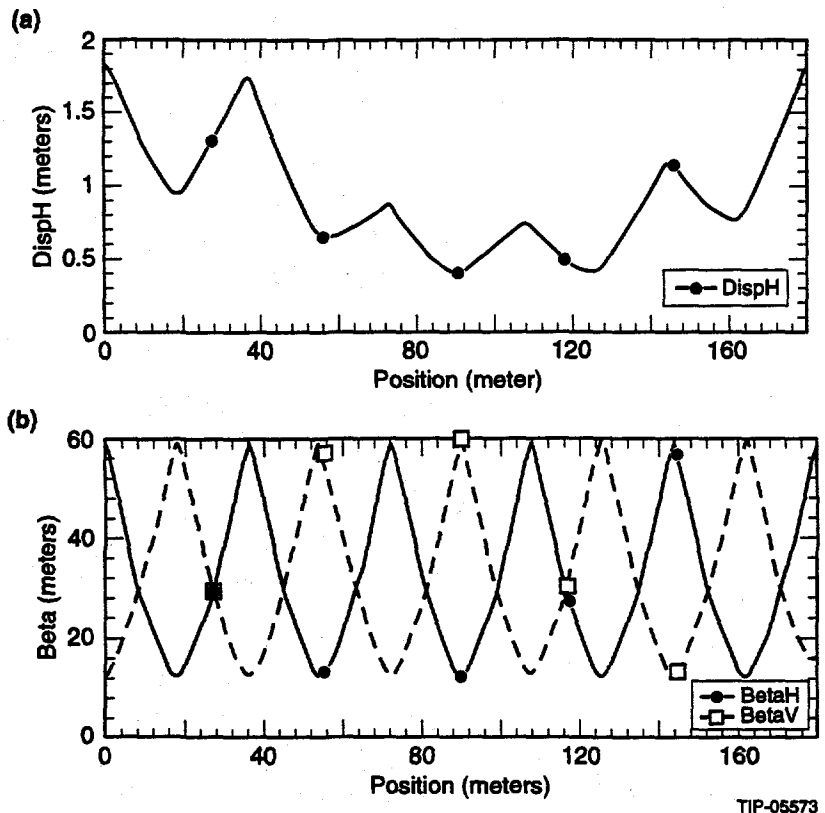


Figure 4. Lattice and Orbit Functions for Injection Insertion.

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Table 1. Lattice Functions for the MEB Injection Insertion.

SYNCH RUN MEB
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90 deg MEB lattices

SYNCH VERSION VAX.8905

***	TRKB		//	INJI CELL								
POS	S	QX		BX	AX	X	DX	QY	BY	AY	Y	DY
0	0.0000	0.000000		59.8268	0.000000	1.846800	0.000000	0.000000	11.9111	0.000000	0.000000	0.000000
5 B	15.8580	0.089819		14.0485	0.694846	0.986929	-0.036702	0.112219	52.5069	-2.137776	0.000000	0.000000
10 B	26.6708	0.197473		27.4022	-1.375607	1.279710	0.054087	0.150734	29.3312	1.454812	0.000000	0.000000
15 QF	37.2788	0.237227		57.0951	2.242003	1.690605	-0.081201	0.252372	12.6105	-0.584100	0.000000	0.000000
20 OOD	52.9183	0.335468		12.7860	0.591278	0.685626	-0.046431	0.351626	56.8462	-2.242883	0.000000	0.000000
25 DXD	70.9577	0.464730		57.0935	-2.241911	0.856447	0.021973	0.457415	12.6084	0.583586	0.000000	0.000000
30 O	81.5657	0.504483		27.4020	1.375603	0.523524	-0.027412	0.559048	29.3349	-1.454346	0.000000	0.000000
35 OOD	92.3785	0.612137		14.0484	-0.694847	0.426085	0.020797	0.597564	52.4969	2.137999	0.000000	0.000000
36 SB	98.8285	0.665449		27.4031	-1.375647	0.560228	0.020797	0.623844	29.3316	1.453517	0.000000	0.000000
37 O	99.2035	0.667586		28.4497	-1.415229	0.568027	0.020797	0.625917	28.2564	1.413721	0.000000	0.000000
38 SB	105.6535	0.694641		51.0973	-2.096029	0.702171	0.020797	0.677654	14.4343	0.729238	0.000000	0.000000
39 OOF	107.0365	0.698716		57.0968	-2.242005	0.730933	0.020797	0.693991	12.6202	0.582472	0.000000	0.000000
40 QF	108.2365	0.701959		59.8299	0.000041	0.738657	-0.007975	0.709701	11.9334	-0.001248	0.000000	0.000000
41 QF	109.4365	0.705201		57.0966	2.242080	0.711942	-0.036376	0.725407	12.6264	-0.585206	0.000000	0.000000
42 OOF	110.8195	0.709277		51.0969	2.096095	0.661635	-0.036376	0.741732	14.4484	-0.732250	0.000000	0.000000
43 B	117.2695	0.736330		28.4496	1.415289	0.483088	-0.018991	0.793390	28.3119	-1.416805	0.000000	0.000000
44 O	117.6445	0.738467		27.4030	1.375705	0.475967	-0.018991	0.795459	29.3895	-1.456638	0.000000	0.000000
45 B	124.0945	0.791776		14.0482	0.694899	0.409548	-0.001605	0.821690	52.5875	-2.139406	0.000000	0.000000
46 OOD	125.0760	0.803441		12.7859	0.591304	0.407972	-0.001605	0.824546	56.8889	-2.243489	0.000000	0.000000
47 QD	126.2760	0.818949		12.0872	0.000055	0.415664	0.014475	0.827800	59.6220	0.001762	0.000000	0.000000
48 QD	127.4760	0.834458		12.7857	-0.591183	0.442985	0.031239	0.831054	56.8807	2.246686	0.000000	0.000000
49 OOD	128.4574	0.846123		14.0477	-0.694769	0.473644	0.031239	0.833910	52.5732	2.142341	0.000000	0.000000
50 B	134.9074	0.899435		27.4004	-1.375517	0.731189	0.048624	0.860163	29.3485	1.457844	0.000000	0.000000
51 O	135.2824	0.901573		28.4469	-1.415098	0.749423	0.048624	0.862235	28.2701	1.417911	0.000000	0.000000
52 SB	141.7324	0.928630		51.0927	-2.095880	1.063048	0.048624	0.914005	14.4093	0.731054	0.000000	0.000000
53 OOF	143.1154	0.932706		57.0918	-2.241853	1.130295	0.048624	0.930376	12.5909	0.583779	0.000000	0.000000
54 QF	144.3154	0.935949		59.8248	-0.000006	1.161841	0.003747	0.946126	11.9000	0.000906	0.000000	0.000000
55 QF	145.5154	0.939191		57.0918	2.241842	1.139219	-0.041304	0.961879	12.5864	-0.581794	0.000000	0.000000
60 OOD	161.1548	1.037435		12.7862	0.591220	0.758176	-0.006534	1.061342	56.7476	-2.240424	0.000000	0.000000
65 DXB	179.1942	1.166690		57.0972	-2.242040	1.804189	0.071550	1.167175	12.6214	0.582155	0.000000	0.000000
66 QF	180.3942	1.169933		59.8304	0.000024	1.847322	0.000059	1.182882	11.9354	-0.001596	0.000000	0.000000

2.0 BEAM OPTICS OF INJECTION SYSTEM

The layout of the injection system is shown in Figure 5. The injection kicker (HKICK) is one cell downstream of the septum magnet (SEP3). The central trajectory separation between the injection beam and the circulating beam at the exit of the septum magnet in the horizontal plane is given by

$$\Delta x = K \sqrt{\beta_1 \beta_2} \sin(\phi_2 - \phi_1) \quad (1)$$

where K is the kicker strength, β_1 and β_2 are the β functions and ϕ_2 and ϕ_1 are the betatron phases at septum magnet exit and the kicker, respectively. Here the kicker is assumed to be a thin one. If the kicker has a length of L , the separation Δx is given by

$$\Delta x = \frac{K}{L} \sqrt{\beta_1} \int_0^L \sqrt{\beta_2(l)} \sin(\phi_2(l) - \phi_1) dl \quad (2)$$

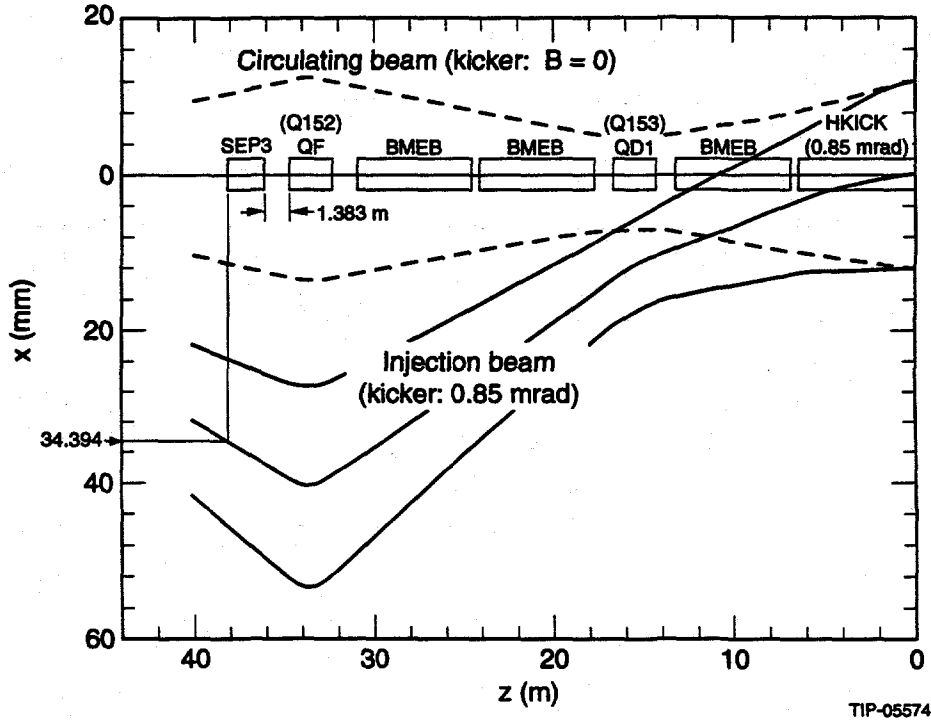


Figure 5. Layout of MEB Injection System.

The requirement for the separation between the two beam centroids at the septum magnet is related to the sizes of two beams, the beam centroid displacements caused by the magnet errors, and the thickness of the septum magnet. The parameters used in the injection system design are as follows:

The normalized beam transverse emittance (3σ test beam) = $9 \cdot 4 \pi \cdot \text{mm} \cdot \text{mrad}$.

The β and η functions at the exit of the kicker,

β_x	=	51.0927 m
β_y	=	14.4093 m
α_x	=	-2.09588
α_y	=	0.731054
η_x	=	-1.063048 m
η_y	=	0 m
η'_x	=	-0.048624
η'_y	=	0.

The beam centroid displacement caused by the magnet errors = 3 mm.

The thickness of the septum = 2 mm.

Using these parameters, both analytical and numerical calculations show that a kicker strength of 0.85 mrad is adequate. It corresponds to a separation of 34.394 mm between the two beam centroids at the entrance of the septum magnet. This amount of separation is large enough to provide a 2.0 mm space for the septum. The numerical calculation is carried out with code TRANSPORT.³ The layout of the injection system is shown in Figure 5; the beam parameters are shown in Figure 6 and explained as follows.

- (1) Beam sizes (3σ , $4\pi \cdot \text{mm} \cdot \text{mrad}$ test beam, $\delta p/p = 0.1\%$)
 - Circulating beam (Run LEB018A):
 - 11.039 mm*7.074 mm, half size, at the entrance of the septum magnet,
 - 12.013 mm*6.374 mm, half size, at the exit.
 - Injection beam (Run LEB018C and LEB630E):
 - 11.028 mm*7.074 mm, half size, at the entrance of the septum magnet,
 - 12.011 mm*6.374 mm, half size, at the exit.
- (2) Separations between the two centroids of circulating beam and injection beam (Run LEB018C and LEB630E)
 - Horizontal separations:
 - 34.394 mm, at the entrance of the septum magnet,
 - 37.219 mm, at the exit.
 - Vertical separations:
 - 37.928 mm, at the entrance of the septum magnet,
 - 0.000 mm, at the exit.

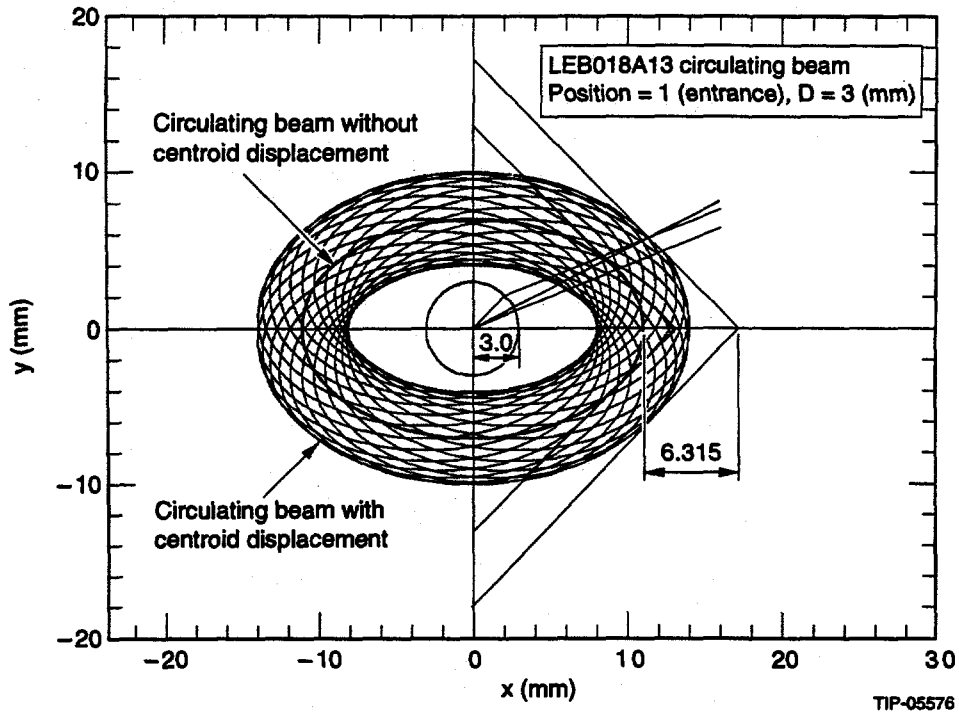


Figure 7. Circulating Beam with or without Centroid Displacement Caused by Magnet Errors.

3.0 PARAMETERS OF SEPTUM MAGNET AND INJECTION KICKER

Based on the beam optics design of the MEB injection system, the main parameters of the injection Lambertson septum magnet are determined as follows:⁴

Number	1
Field aperture (w*h)	>60 mm * ± 15 mm
Field-free aperture (w*h)	50.8 mm * 70 mm
Leakage field in field-free region (max, at the center of circulating beam)	<0.0008 T <0.02 T/m <0.2 T/m ²
Magnet length	2.0 m
Good field region (w*h)	60 mm * ± 15 mm
Field (max)	0.78 T
Field quality ($\Delta BL/BL$)	$1 \cdot 10^{-4}$
TOD of power supply	$1 \cdot 10^{-4}$

Here, w and h are with respect to the magnet gap, h is measured in the gap height direction. The conceptual design of the Lambertson septum magnet is shown in Figure 8.⁵

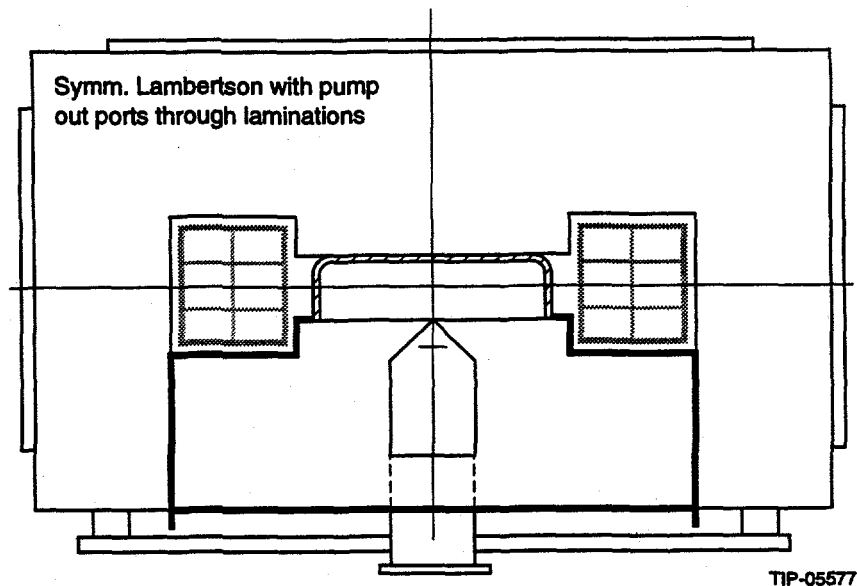


Figure 8. Conceptual Design of the Lambertson Septum Magnet.

The requirements for the injection kickers are as follows:

Number of magnets	≥ 4
Slot length	6.45 m
Aperture (H*V)	100 mm*50 mm
Strength (bending angle)	0.90 mrad
BL	0.036 T*m
TOD of power supply	$1*10^{-2}$

A twelve magnets kicker system design has been reported,⁶ where each magnet consists of ten cells.

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