MUON KICKER MAGNETS

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7.2.6 Pulsed Magnets

G.H. Schröder, CERN

$$Z = \sqrt{L'/C'} \qquad (2)$$

With a magnet inductance L_m the filling time of the magnet is

$$t_m = L_m/Z \qquad (4)$$

<u>Basic design equations</u> For an *ideal* system with negligible pulse generator risetime and negligible losses, the following equations hold. The kick strength required to produce an angle θ [rad] for momentum p [GeV/c] is

$$K[\mathrm{T-m}] = \theta p/0.3 \qquad (7)$$

With a magnetic aperture width w and height h, the magnetic length l_m can approximately be determined from the magnet inductance,

$$L_m = \mu_0\,(w/h)\,l_m \qquad (8)$$

and the magnet filling time t_m [Eq.(4)],

$$l_m = ht_mZ/\mu_0 w \qquad (9)$$

Furthermore, with a magnetic flux density of

$$B = \mu_0 U/2hZ \qquad (10)$$

and a kick strength of

$$K = N_{th} B l_m \qquad (11)$$

the theoretical required number of magnets becomes

$$N_{th} = 2KhZ/\mu_0 l_m U \qquad (12)$$

$(9) \rightarrow N = \frac{2Kw}{tU}$ 80 KV Max

KICKER for the SLC ELECTRON DAMPING RING

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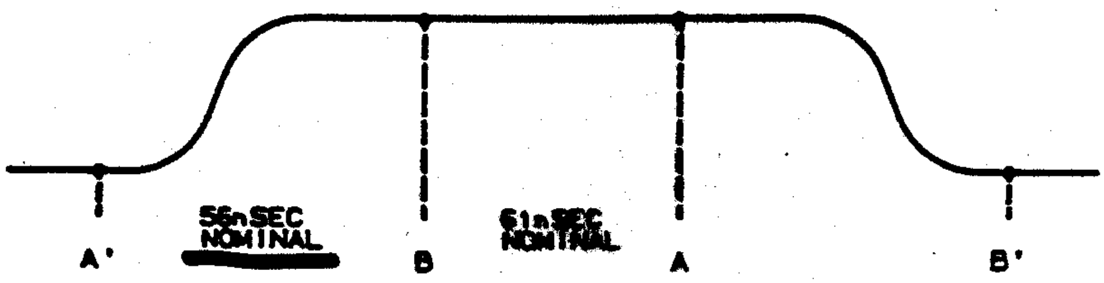
The SLC electron damping ring requires two kickers each providing a 5 mr kick at 1.2 GEV to pairs of electron bunches spaced 61.63 nsec apart. The exact shape of the kick is unimportant, but the specification of Figure 1 applies to the field the bunches see.



	INJECTION KICKER			EXTRACTION KICKER		
	B	A	B'	A'	B	A
RELATIVE AMPLITUDE	1	.999 1.001	.001	5×10^{-4}	1	.001 1.001
AMPLITUDE JITTER	$<10^{-3}$	$<10^{-3}$			10^{-4}	5×10^{-4}

Figure 1

To meet this specification, a coaxial magnet with a characteristic impedance of 12.5 ohms was designed to produce a 203 gauss-meter kick. The energy to generate and maintain this field is stored in a pair of 50 ohm coaxial cables each 145 ft. long. These cables are pulse charged to 60 - 65Kv, then switched across the magnet with a pair of thyratrons, illustrated in Figure 2. The installation is shown in Figure 3.

The magnet is a travelling-wave kicker in which the E-field is electrostatically shielded from the beam pipe which sees only the B-field. It generates a 900G field in a 2.35 x 2.35cm aperture at 2600 amps.

Stackpole 2285 ferrite was selected

PLAIN KICKER, NO STACKING

CERN $\bar{p}$ Cooler

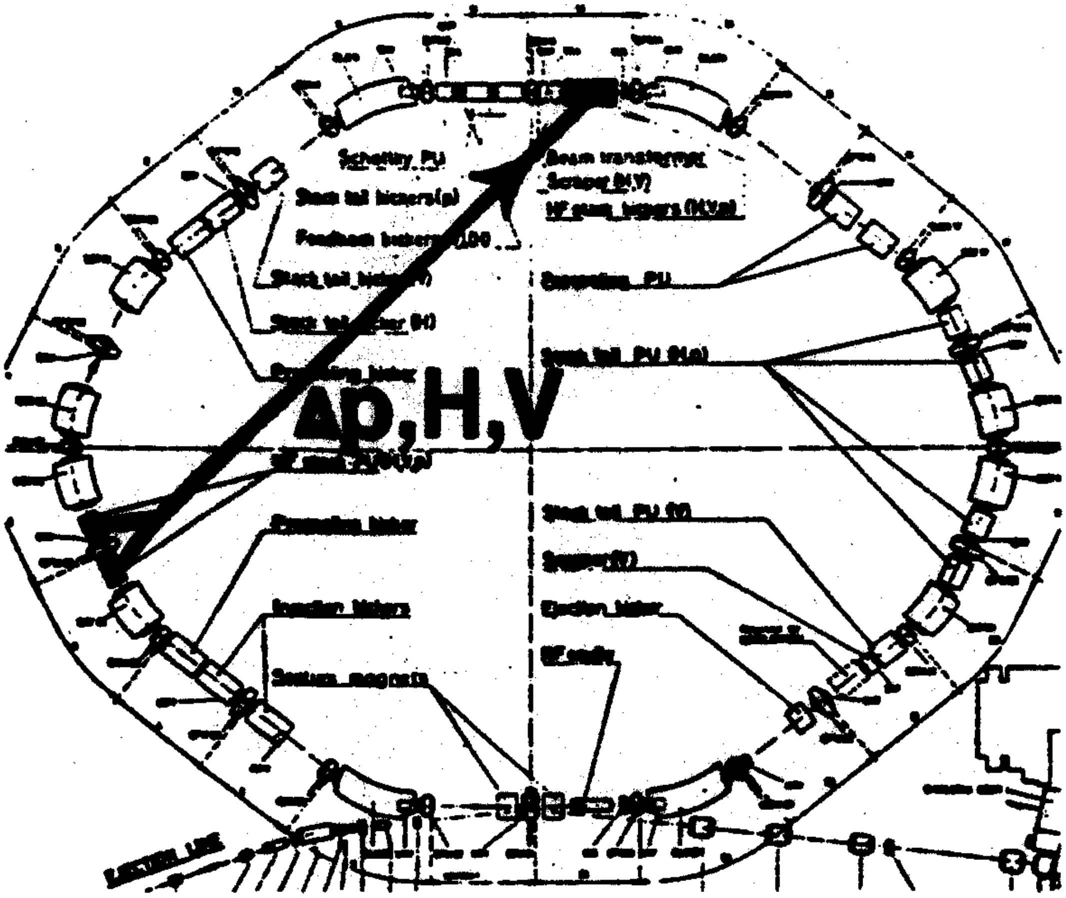


Fig. 1 - Cooling systems. From top to bottom: precooling (150-500 MHz), stack tail cooling (250-500 MHz) and stack core cooling (1-2 GHz). Δp cooling is decoupled from H cooling by placing the kickers where the dispersion is zero or (for precooling) using two sets of kickers at a spacing of half a betatron wavelength.

One Kicker for injection and extraction

CERN $\bar{p}$ Kicker
10 MODULES

The very large emittance of the injected $\bar{p}$ beam demands an unusually large kicker aperture height, varying according to the local β_V, and similarly large useful field region width varying with β_H. The separation between the injected beam trajectory and the injection orbit at the septum determines the nominal deflection angle and hence kick strength (Table 1). The 105 ns bunch interval of the incident target beam is maintained between produced $\bar{p}$ bunches, requiring a short fall-time of the kicker field. The total magnetic length needed is determined by the kick strength, vertical magnet aperture and available pulse current; Fig. 1 shows that the length has to be split between two locations, upstream and downstream of a lattice focussing quadrupole.

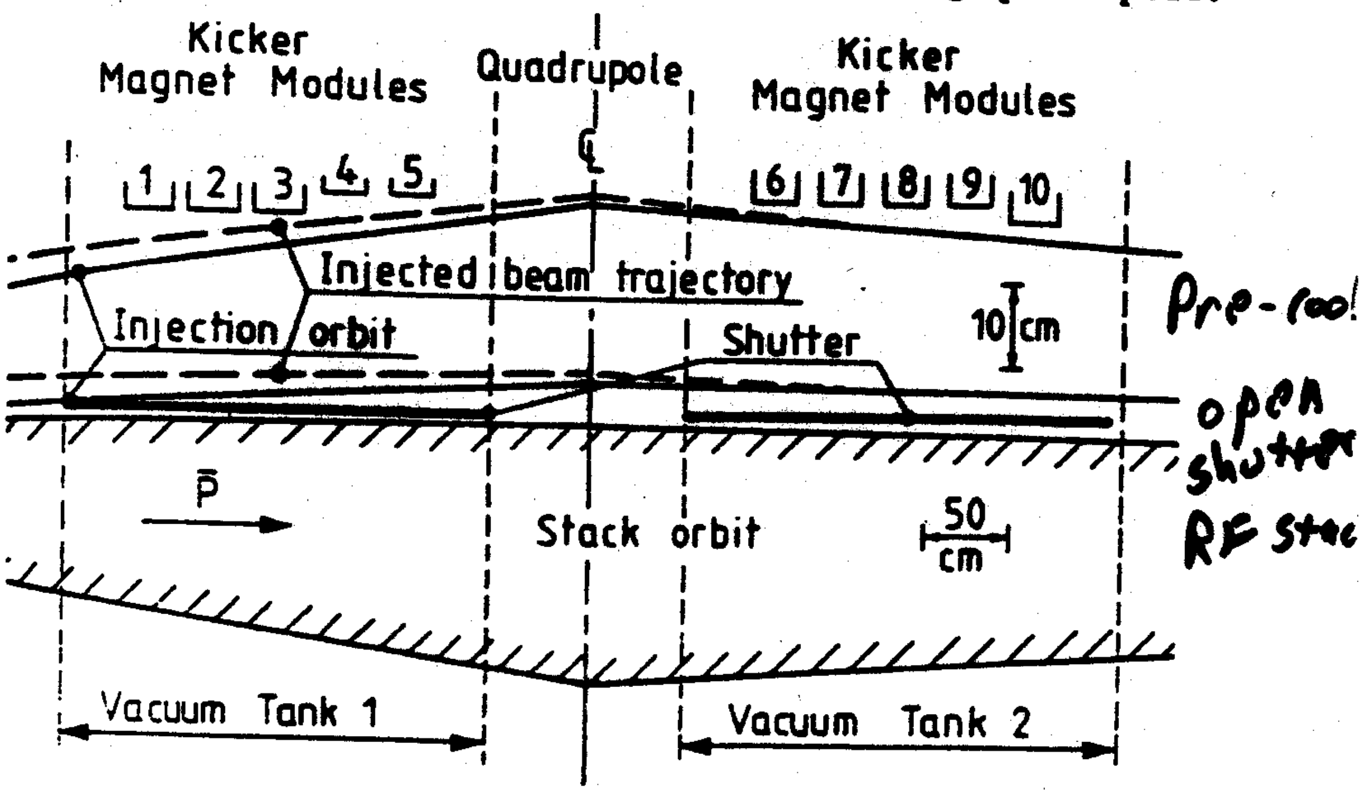


Fig. 1. Beam trajectories in injection kicker region.

3.5 GeV/c
7mr kick

250x100mm aperature
880 gauss-meters
90 ns

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KICKERS AND POWER SUPPLIES FOR THE FERMILAB TEVATRON I ANTIPROTON SOURCE

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Abstract

The Fermilab Antiproton Source Accumulator and Debuncher rings require 5 kickers in total. These range in design from conventional ferrite delay line type magnets, with ceramic beam tubes to mechanically complex shuttered kickers situated entirely in the Accumulator Ring's 10^{-10} torr vacuum. Power supplies are thyratron switched pulse forming networks that produce microsecond width pulses of several kiloamps with less than 30 nanoseconds rise and fall times. Kicker and power supply design requirements for field strength, vacuum, rise and fall time, timing and magnetic shielding of the stacked beam in the accumulator by the eddy current shutter will be discussed.

FNAL $\bar{p}$ ACCUMULATOR
4mr kick of 8 GeV/c $\bar{p}$
-65 MeV RF → RF Stacks

	Core	Stacking orbit	Injection orbit
Distance	-63.3 mm	+14.7 mm	+80.3 mm
Momentum	-0.69 %	+0.17 %	+0.93 %
Energy	-60.5 MeV	+14.5 MeV	+81.5 MeV

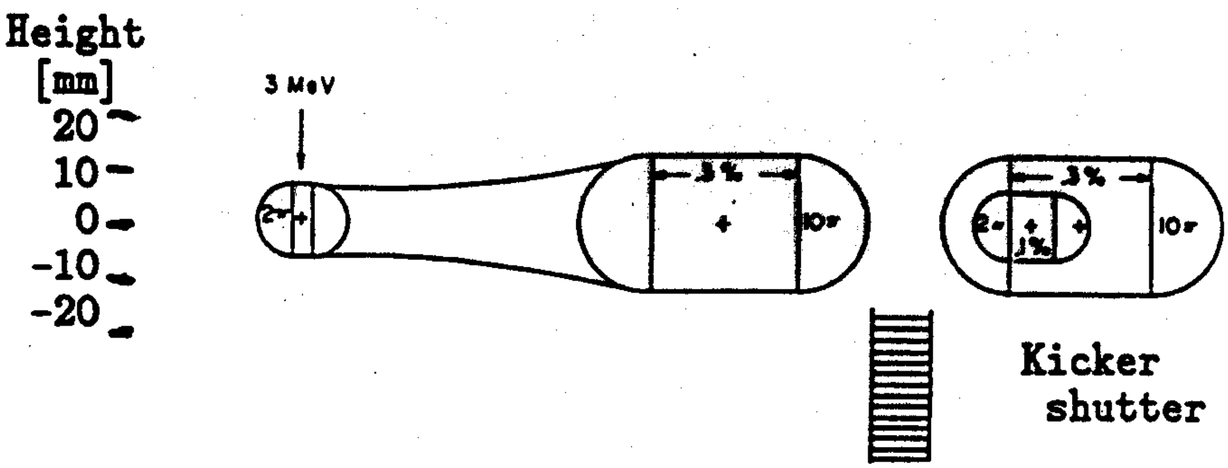
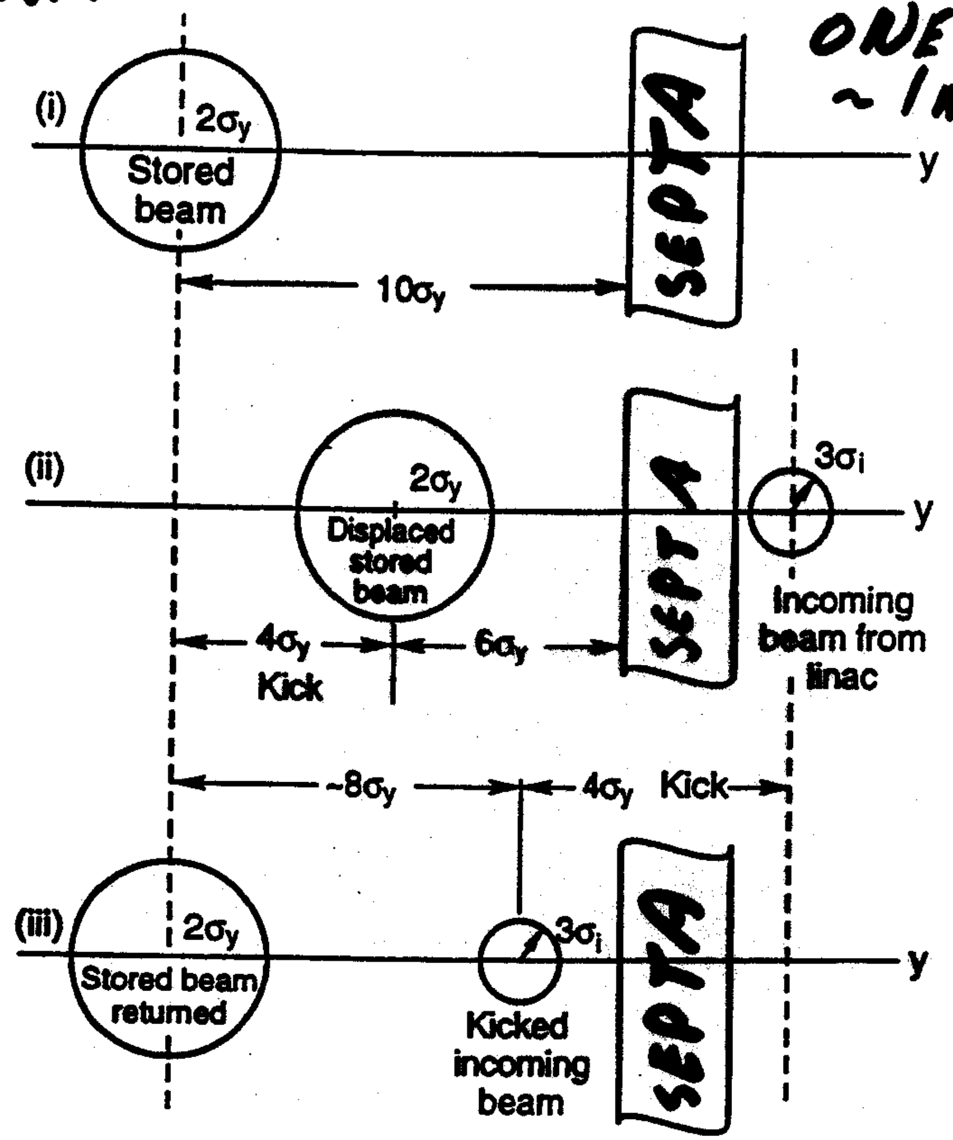


Figure 3. Accumulator beam profile in a high
spersion straight section

PEP-II Stacker
Distant Kickers ONE BEFORE
ONE AFTER
~1mr Kick



HER injection straight: ε_y = 25 nm·rad, β_y = 215 m, $\sigma_y \approx$ 2.3 mm

LER injection straight: ε_y = 33 nm·rad, β_y = 170 m, $\sigma_y \approx$ 2.4 mm

e^- at NIT injection: ε_{yi} = 0.55 nm·rad, β_{yi} = 40 m, $\sigma_{yi} \approx$ 0.15 mm

e^+ at SIT injection: ε_{yi} = 2.5 nm·rad, β_{yi} = 40 m, $\sigma_{yi} \approx$ 0.32 mm

$D_y = 0$ $D_y = 0$

Fig. 6-27. Phase-space diagram of the vertical injection process.

25µ stainless steel vacuum barrier!

TRICKS TO ALLOW A TINY 7mr KICK

CURRENT SHEET SEPTA, UNSHIELDED

CURRENT SHEET SEPTA, IRON SHIELD

INJECT THROUGH THE SIDE OF A QUAD

RF STACKING (~65 MeV FINAL $\bar{p}$)

DISTANT PEP-II KICKER PAIR (LEVER ARM)

MAKE THE BEAM SMALL IN X, Y TO FIT THE KICKER

ROTATE THE PHASE ELLIPSE TO MIMIZE THE KICK

MUON TRICKS

SF_6 IN MAGNET TO EXCEED 80 KV, BUT BETTER SWITCH IS STILL NEEDED

FIXED Beryllium Foil Eddy Current Shield

$\Omega = 4\mu\Omega$-cm

30ns x 4 = 120ns cycle → 8MHz

SKIN DEPTH

$= 5 \times 10^7 \sqrt{\frac{\Omega}{f}}$ microns

$= 35$ microns

4 skin depths

140 microns

<u>Thin</u>

MUON COOLER RING