Preliminary Note on a Separated Function Booster.

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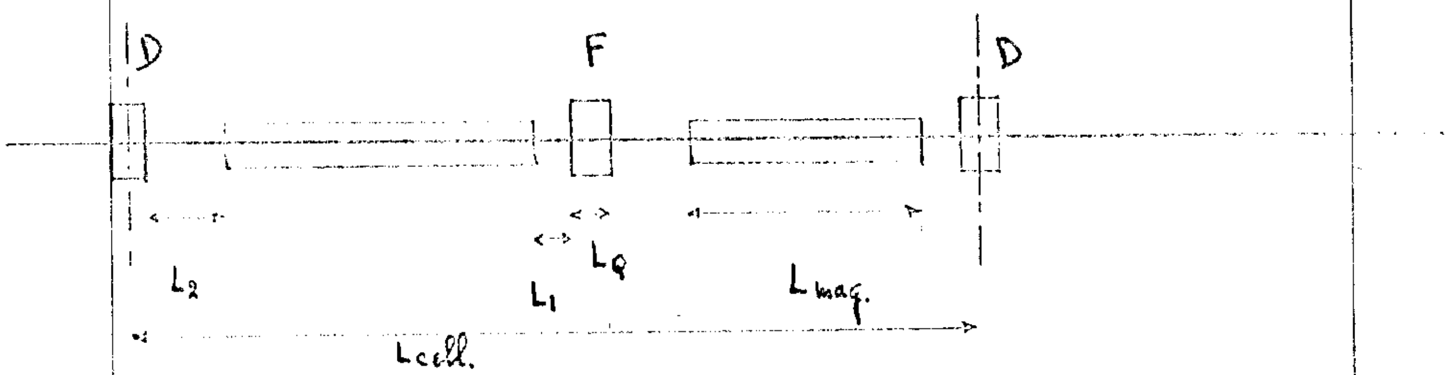
Several separated function lattices have been examined for the Booster injector with the object of reducing cost; radius, total rf requirements and the synchro-betatron coupling problem. (reduction of ν_s, the phase oscillation frequency).

The basic cells, as used here, is indicated below:



Single quads. rather than triplets are used here (EDC Note. July 26, '67)
Long straights are obtained by eliminating a bending magnet in the basic cell.

The following combinations have been examined related to availability of minimum straight sections requirement, rf requirements and general practicability related to injection, ejection and beam manipulation:

R = 100 m, T = 10 Bev. N_{cell} = 32, ν = 6.4 etc.

32	6.4
48	9.6
64	12.8

R = 50 m, T = 5 Bev N_{cell} = 24, ν = 4.8 etc.

24	4.8
32	= 6.4
48	= 9.6

As a result of this exercise it seemed possible to obtain 10 Bev protons with a R = 50 m. radius booster.

An additional requirement for the booster should be that it has a superperiodicity which does not allow for first, second or third order resonances either within or on the (integral) boundaries of the "necktie" diagram and no fourth order resonances within the boundary. (A. Maschke). These requirements are satisfied by a superperiodicity of 7, 11, ≧ 13 (K. Symon).

This led to a set of parameters for a (minimum) booster as follows:

R = 50 m.
T = 10 Bev.
N_c = 22
L_c = 14.28 m
$L_Q B_Q'$ = 63.6 Kg
L_Q = 0.4 m

B_Q' = 159 Kg/m.
μ_c = 69.578°
ν = 4¾
β_{max} = 24.1 m.
β_{min} = 5.55 m.

N_{st} = 11
L_{st} = 6.74 m.
N_{mag} = 33
B_f = 13.1 Kg
ρ = 27.6 m.
$L_{mag.}$ = 5.24

reprate 20 Hz.
L_1 = 0.5 m
L_2 = 1.0 m
$\hat{V}_{rf}$ = 0.83 MV/turn

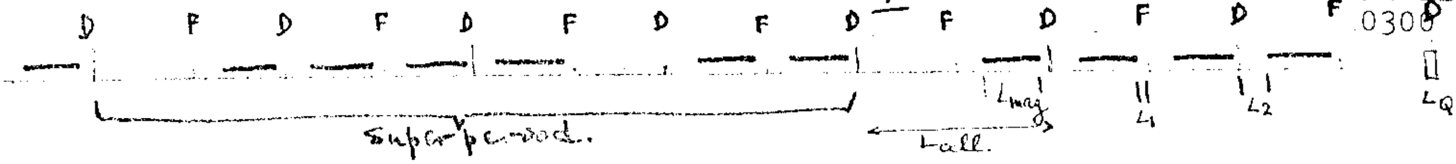
Further details on this R = 50 m, T = 10 Bev. booster will be provided in a later report. Examination of all the required straight section length resulted in a most efficient occupation of the circumference. Only 3 (!). short straight sections of 0.5 m. were left unoccupied.
Also a minor compromise had to be made on the choice of straight section for ejection. This Booster might be considered the lower boundary of what is feasible with R = 50, T = 10 Bev, etc.

To accommodate more more suitably injection (D→F straight and ejection (D→F straight for horizontal ejection, F→D straight for vertical ejection) and also provide somewhat more straight section space for future requirements a R = 62.5 m radius booster has been studied with a 14 superperiodicity (actually 7 + 7). This leaves a clear "window" for a ν value between 5 and 6. Keeping the space charge ν value depression in mind a ν = 5¾ was chosen.

A complete list of parameters follows below, details of calculations will be presented in a later report.

Notwithstanding the larger kick required for the ejection the latter horizontal ejection is preferred to in order to built in the option of two turn turn extraction, which potentially will reduce the main ring filling time by a factor of 2, without a deleterious increase of the booster ν_s value.

This booster will be studied in more detail and orbit parameters will now be obtained by means of the "Sync" Computor program.



Separated function Booster Parameter. R = 62.5 m, T = 10 BeV.

R (m)	62.5
T (BeV)	10.0
p (BeV/c)	10.898
N_c	28
L_c (m)	14.0
L_Q (m)	0.4
B_Q' (Kg/m)	156
μ_c	74°
ν	$5\frac{3}{4}$
$\langle\beta\rangle$ (m)	10.84
$\beta_{max.}$ (m)	23.6
$\beta_{min.}$ (m)	5.8
N_{st}	7+7
L_{st} (m)	6.6
N_{mag}	42
B_f (Kg)	12.0
B_i (Kg)	0.71
ρ (m)	30.2
L_{mag} (m)	4.52
L_1 (m)	0.58
L_2 (m)	1.50
f_{∞} (MHz)	50
γ_{tr}	$\cong 5\frac{3}{4}$
E_{tr} (BeV)	5.4
T_{tr} (BeV)	4.5
$\hat{x}R$ (m)	1.9

per Superperiod:

N_c	4
N_{st}	2
N_Q	8
N_{mag}	6

rep. rate 20 Hz

$\frac{R_{main\ ring}}{R_{booster}} = 16$ $T_f = 0.8$ sec.

$\nu_s = 0.09$

$\hat{V}_{rf} = 1.05$ MV/turn.

$(\hat{V}_{rf})_{ejection, (<1 msec)} = 1.13$ MV/turn.

$V_{2g} = 64$ KV/cavity (2 gaps), cav. length = 3 m.

number of cavities 18.

straights 9 rf, 1 rf spare, 2 eject., 1 inject., 1 beam man[illegible]

rep. rate 30 Hz $T_f = 0.54$ sec.

$\nu_s = 0.11$

$\hat{V}_{rf} = 1.50$ MV/turn.

$(\hat{V}_{rf})_{eject.} = 1.68$ MV/turn.

number of cavities ~~24~~ 22

straights 11 rf, 2 eject., 1 inje[illegible] beam manipulation, shorts.

rep. rate 10 Hz $T_f = 0.4$ sec. 2 turn ejection.

$\nu_s = 0.06$

Beam parameters, Stacked number of protons, Space charge limit, etc.

$\varepsilon_{2,\text{Linac}} = 0.5\ 10^{-5}$ m-rad (100 ma).

Consequently take $A_{\text{emitt. Linac}} = \pi\ 10^{-5}$ m rad, 50 ma.

4 turn injection, factor of 2 dilution.

After debunching in Booster: $A_H = 8\pi\ 10^{-5}$ m-rad   200 MeV.

$A_V = \pi\ 10^{-5}$ m-rad.

at 80 Bev. $A_H = 0.5\ \pi\ 10^{-5}$ m-rad.

$A_V = 0.06\ \pi\ 10^{-5}$ m-rad.

at 10 Bev, 2 turn ejection, 1.5 stacking (main ring) dilution.

$A_H = 0.75\ \pi\ 10^{-5}$ m-rad

$A_V = 0.06\ \pi\ 10^{-5}$ m-rad.

Main Ring Acceptance (betatron only) $A_H = \pi\ 10^{-5}$ m-rad

$A_V = 0.1\ 10^{-5}$ m-rad.

Beam size at injection, booster.

$$a_H = \sqrt{\beta_m}\sqrt{\frac{A_{H\text{ in booster}}}{\pi}} + (\Delta\alpha)_H\,\beta_{m,H}\sqrt{\frac{\beta_{i,H}}{\beta_{m,H}}} + (\hat{\alpha} R)\frac{\Delta p}{p} \longrightarrow a_H = 5.4 \text{ cm.}$$

with dilution only related to multiturn inject. — injection steering effects. — momentum spread effects

$$b_V = \sqrt{\beta_{m,V}}\sqrt{\frac{A_{V,\text{in booster}}}{\pi}} + (\Delta\alpha)_V\,\beta_{m,V}\sqrt{\frac{\beta_{iV}}{\beta_{mV}}} \longrightarrow b_V = 1.7 \text{ cm}$$

Closed orbit allowance, blue book values (scaled (approx.) for higher injection field) scaled for β_{max} difference.

$a_{CO} = 1.2$ cm

$b_{CO} = 0.85$ cm

This results in:

$a_{H,inj}$	= 5.40 cm		b_{inj}	= 1.76 cm
a_{CO}	= 1.20 –		b_{CO}	= 0.85 –
Ins.	= 1.08 –	(20% of $a_{H,inj}$)	Ins	= 0.35 –
	7.68 cm.			2.96 cm.

Vacuum Chamber Aperture ≅ 15.0 cm — 6.0 cm

Chamber wall thickness. — 0.4 –

Magnet aperture and useful field

$\underline{\underline{w = 15 \text{ cm} = 6''}}$ $\qquad$ $\underline{\underline{g = 6.4 \text{ cm} = 2.5''}}$

<u>Stacking capability.</u> $N_S = I_L \left(\frac{2R_0}{ec}\right) \sigma_{st} \frac{\pi}{\beta} (n_{inj})$

$\longrightarrow N_S =$ ~~8 10^{12}~~ 5.4 10^{12} protons/pulse.

σ_{st} = stacking efficiency.
dilution & loss = 0.6.
$n_{inj} = 4$.
$I_L = 50$ ma.

$N_{sp.charge} = 5.6 \; 10^{12}$ protons/pulse

$\bar{B} = 0.1$
other parameters as given above.

2 turn ejection, 8 "shots" into main ring

Capability: $N_{stacked,\,main\,ring} = 4 \; 10^{13}$ pr/pulse

1 turn ejection, 16 "shots" into Main Ring

$N_{stacked,\,main\,ring} = 8 \; 10^{12}$ pr/pulse, i.e. exceeding main ring space charge limit.