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Booster Lower Energy Injection (200 MeV → 150 MeV)

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Assumption N_{st} (Booster) unchanged i.e. $3.85\ 10^{12}$ p/p.

Summary

1. 10 GeV ejected beam sizes are 10.7% larger.

2. Booster aperture sizes are 12% to 14% larger.

3. Booster ν_s maximum increases from 0.10 to 0.12.

4. Number of rf cavities (booster) increases from 18 to 21. This must consequently involve a reexamination of the booster lattice since with 18 rf cavities, nominally 23 out of 24 long straights are occupied.

   [The reexamination of the lattice is separately stated in the following and may be translated into costs by assuming tentatively a 27 cell structure with identical circumference factor. As a consequence B would increase by 24%. This would certainly not be an optimum cost structure and would probably lead to a larger radius booster structure.]

5. Δ Cost, no lattice change, $\hat{B}$ same.

Magnets	199 KB
Power Supply, Components	798 KB
RF System	1200 KB
Total	2197 KB

   (This does not include EDIA).

   [Increasing $\hat{B}$ from 8.32 kg to 10.32 kg would add an additional 1882 KB.]

6. Conclusion:

   A cost increase of minimal 2.2 MB is involved, by changing the Booster injection energy from 200 MeV to 150 MeV. Either our philosophy on rf spare cavities and beam scrapers would have to be reconsidered involving a higher B value or a larger radius structure would be required.

KB = Thousands of Dollars
MB = Millions of Dollars

Booster Lower Energy Injection	200 MeV	150 MeV	
β	0.5661	0.5066	
γ	1.2131	1.1559	(r=1.049)
$\beta\gamma$	0.687	0.587	(r=1.17)
$\beta^2\gamma^3$	0.572	0.400	(r=1.43)
$\beta\gamma^2$	0.833	0.677	
Linac A_2 cm-mr	π	1.17π	
Intensity, ma.	75	54	
Injected Turns	4	5	
Booster $A_{2,H}$ Injection	5π	7.15π	r=1.43
$\left(N_{st} = \eta_{st} n_{inj.} I_L \frac{2\pi R}{\beta ce}\right)$ $A_{2,V}$ Injection	2π	2.86π	$\sqrt{r}$=1.195
Horiz. Dilution	1.25	1.22	
Vert. Dilution	2	2.4	
N_{st}	$3.85\ 10^{12}$	$3.85\ 10^{12}$	
$\left(\text{Ratio } \beta^{-1}(\beta\gamma)^{-1/4}\right)$ $\frac{\Delta p}{p}$ from Linac	$\pm 1.1\ 10^{-3}$	$\pm 1.28\ 10^{-3}$	(r=1.162)
$\frac{\Delta p}{p}$ in booster	$\pm 2.5\ 10^{-3}$	$\pm 2.9\ 10^{-3}$	
$n_{inj.}\ I_{Linac}$ ma. Turns	300	268.5	
$(p_f)/(p_{inj})$	16.92	19.796	
$\sqrt{(p_f)/(p_{inj})}$	4.113	4.449	
γ_s (max.)	0.097	0.119	[1 $\beta^{-3/4}\gamma^{-5/4}$]

Booster Lower Energy Injection		200 MeV	150 MeV	
Injection A_2's		5π	7.15π	
		2π	2.86π	
Betatron Amplitudes	$2a_{D,H}$	5.58	6.67	
	$2a_{F,H}$	7.84	9.37	
	$2b_{D,V}$	4.24	5.07	
	$2b_{F,V}$	3.00	3.58	
	$2b_{D,V}$, eject.	1.03	1.14	
	$2b_{F,V}$, eject.	0.73	0.80^{5}	
Booster ejected beam size, both dimensions			±10.7%	
D magnet, vertical				
	inj. Betatron	4.24	5.07	
	±8% beam ∅	0.68	0.81	
	ejection	1.43	1.54	
	chamber	1.27	1.27	
		7.62	8.69	
		=3.0"	=3.4"	(r=1.13)
F magnet, vertical				
	inj. Betatron	3.00	3.58	
	±5% beam ∅	0.29	0.36	
	ejection	1.15	1.21	
	chamber	1.27	1.27	
		5.71	6.42	
		=2.25"	=2.5"	(r=1.11)
D magnet, horizontal				
	inj. Betatron	5.58	6.67	
	synchrotron	1.06	1.27	
	sagitta	0.86	0.86	
	±12.5% beam ∅	1.40	1.67	
	chamber +1.27 cm	2.54	2.54	
		11.44 =45"	13.01=5.1"	(r=1.14)
F magnet, horizontal				
	inj. Betatron	7.84	9.37	
	synchrotron	1.44	1.73	
	sagitta	1.47	1.47	
	±12.5% beam ∅	1.96	2.34	
	chamber + 1.27 cm	2.54	2.54	
		15.25cm	17.45 cm	
		=6.0"	=6.9"	(r=1.15)

Booster Lower Energy Injection		200 MeV	150 MeV	Factor
Magnets				
F magnet	good field	5.5" x 2.25"	6.4" x 2.5"	
NI	At	37.8 10^3	42.0 10^3	
Size	$Inch^2$	24 x 17	27 x 19	
Iron (48)	Lbs.	460 10^3	584 10^3	
Cu (48)	Lbs.	42 10^3	475 10^3	
U_{st} (48)	y	612 10^3	774.5 10^3	
Power Losses	kw	639	690	
D magnet	good field	4.0" x 3.0"	4.6" x 3.4"	
NI	At	50.4 10^3	57.1 10^3	
Size	$Inch^2$	26 x 18	29 x 20	
Iron (48)	Lbs.	492 10^3	620 10^3	
Cu (48)	Lbs.	57 10^3	64.8 10^3	
U_{st} (48)	y	835 10^3	1078 10^3	
Power Losses	kw	851	956	
Magnets, Total				
Iron (96)	Lbs.	952 10^3	1204 10^3	1.26^5
Cu (96)	Lbs.	99 10^3	112 10^3	1.13
U_{st} (96)	y	1447 10^3	1852.5	1.28
Power losses (magnet)	kw	1490	1646	1.10
				ΔCost
Core Cost		550 KB	695 KB	145 KB
Coil Cost		340 KB	384 KB	44 KB
Cooling Cost 2 losses/ 35K/MW		101.5 KB	111.5 KB	10KB
Power Supply, i.e. chokes, capacitors, AC supply DC supply		2704 KB	3502 KB	798 KB
Increased cost of magnet P.S.				997 KB

Booster Lower Energy Injection	200 MeV	150 MeV	
<u>RF Components</u>			
Basic Assumptions:			
(a) Drive power final stage, same power level per tube is assumed, since no other is available for the range of parameters under consideration.			
(b) Same ferrite flux level is assumed.			
Number of cavities	18	21.4	
Assume		21	
Cost per cavity KB	242	264	
Cost of cavity increases re:			
(a) driver bandwidth, larger $\frac{\Delta f^*}{f}$	1.76	1.97	
(b) more ferrite			
(c) more power			
(d) ferrite μ value **	6.6	8.2	
Cost (18 + 1) 242 + 200 = 4800 KB	4.8 MB		
(21 + 1) 264 + 200 = 6000 KB		6.0 MB	
<u>RF cost increase</u>**			1.2 MB

*Problem might exist related to, second harmonic of injection frequency is now within frequency total swing.

**This does not include the consideration that a different ferrite <u>might</u> have to be used, related to its μ value, which would decrease Q values.