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LONGITUDINAL PARAMETERS AT INJECTION OF BFI

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In order to check that the bunches delivered by the injectors fit into the BFI longitudinal acceptance, we calculate this acceptance and compare it with the long-parameters of the injected beam. The beam intensities are given in a companion paper[1].

1. BFI LONGITUDINAL ACCEPTANCE

Table 1 gives the BFI RF parameters relevant for trapping for 0.35 and 0.50 GHz for the asymmetric and the symmetric machine. The RF parameters[2] for the asymmetric $L = 10^{33}$ $cm^{-2}s^{-1}$ machine are for $\alpha = 0{,}0086$[2][3] and for $\alpha = 0.01$ in all other cases[4]. The larger α means a 5% smaller bucket height. The wigglers in the 3.5 GeV ring are always "OFF". If they are "ON", the voltage is higher and, concomitantly, the RF acceptance is larger. However, then also the energy spread of the stored beam is larger and it is not clear whether wiggler "ON" or "OFF" is better for injection. Hence, it is preferred to claim that injection should also work with wigglers "OFF" remaining aware that there is an important voltage margin when the wigglers are "OFF". Further, we assume that the RF parameters used for trapping in the 8 GeV ring at $L = 10^{34}$ $cm^{-2}s^{-1}$ are identical to the parameters at $L = 10^{33}$ $cm^{-2}s^{-1}$. If a higher harmonic system were used, it would probably be switched "ON" after trapping to compress the bunch. All parameters are for a bending radius of 65 m in BFI.

Table 1. BFI RF PARAMETERS

E(GeV)	3,5	3,5	3,5	5,3	8	8
L ($cm^{-2}s^{-1}$)	10^{33}	10^{33}	10^{34}	4×10^{33}	10^{33}	10^{33}
f (MHz)	348,5	499,7	348,5	348,5	348,5	499,7
V (MV)	1,47	1,10	25,5	87,62	18,1	13,8
φ_s (deg.)	166,2°	160,6	176,5°	178,2°	161,7°	155,6°
f_s (kHz)	7,8	7,9	35,5	53,5	17,9	18,3
$\frac{\Delta E}{E}$ bucket (%)	$\pm$0,43	$\pm$0,28	$\pm$1,94	$\pm$2,99	$\pm$0,91	$\pm$0,59
$\Delta\varphi_{bucket}^{total}$ (deg.)	251°	230°	305°	321°	234°	211
Δt_{bucket} (ns)	$\pm$1,00	$\pm$0,64	$\pm$1,21	$\pm$1,28	$\pm$0.93	$\pm$0,59

2. PARAMETERS OF THE INJECTED BEAM

Table 2 gives the parameters of the beam coming from the PS[5] and SPS[6] to BFI. In the PS, two voltages were considered at 3.5 GeV : the voltage provided by two 114 MHz cavities, as already available, which would produce 1 MV; further 1.5 MV, which would require the addition of one more 114 MHz cavity. This addition is unavoidable for 5.3 GeV operation but it seems not to be required at 3.5 GeV; at least, one could first try to start up without it as it can be added later. These voltages provide a quantum lifetime of about 2s, which is sufficient as known from LEP operation. The number of particles per bunch does not depend strongly on the longitudinal bunch parameters. Longer bunches are possible if required.

In the SPS, the bunch intensity is proportional to σ_s following about the rule

$$N_b = 0.1 \times 10^{10} . \sigma_s \text{ (cm)}$$

due a longitudinal instability[6]. In table 2, the value of σ_s = 8 cm is given pertaining to the nominal value $N_b = 0.8 \times 10^{10}$[1].

The calculated beam emittances $\varepsilon/\pi = \sigma^2/\beta$ are also given in table 2 for completeness. The transfer lines and the BFI injection system are designed to cope with ε_{xo} = 0,4 π µrad.m and ε_y = 0.3 π µrad.m. All σ values are r.m.s values.

Table 2. Parameters of beam injected into BFI

	PS	PS	PS	SPS
E(GeV)	3.5	3.5	5.3	8
V_{rf} in PS (MV)	1.0	1.5	1.5	-
σ_t (ns)	0.31	0.25	0.37	0.27
$\sigma_e/E.10^3$	0.59	0.61	0.61	1.0
ε_x/π (µrad.m)	0.11	0.11	0.40	0.05
ε_y/π (µrad.m)	0.08	0.07	0.23	0.03

3. DISCUSSION

In order to judge how well the bunch fits into the BFI collecting bucket, we form the ratios $\Delta t_b/\sigma_t$ and $\Delta E_b/\sigma_e$. Although we do not examine the detailed trajectories in the bucket despite of the fact that these ratios are not much larger than 1, these ratios give at least an idea of the match, which by the way does not need to be perfect as in proton machines. Table 3 gives these ratios. Its columns correspond to table 1 but include a subdivision for two different PS voltages.

Table 3. Comparison of BFI bucket size and injector bunch sizes

E(GeV)	3.5		3.5		3.5		5.3	8	
$L/10^{33}$ $(cm^{-2}s^{-1})$	1		1		10		4	1	
f(GHz)	0.35		0.50		0.35		0.35	0.35	0.50
V_{PS}(MV)	1.0	1.5	1.0	1.5	1.0	1.5	1.5	-	-
$\Delta t_b/\sigma_t$	3.2	4.0	2.1	2.6	3.9	4.8	3.5	3.4	2.2
$\Delta E_b/\sigma_e$	7.3	7.1	4.8	4.6	33	32	49	91	59

It can be seen that the bunches fit into the BFI buckets in all cases. At 3.5 GeV, the 0.50 GHz BFI bucket is just long enough to trap the bunch coming from the PS operating with 1 MV (column 3) but, as explained previously, there is a considerable voltage margin with the wigglers "OFF" which can be exploited to make longer buckets. If this turned out to be inconvenient, a third PS cavity could be installed increasing the voltage to 1.5 MV. We recommend to start with no additional cavity.

Examination of the 8 GeV cases shows the possibility to work with longer SPS bunch in the case of 0.35 GHz in BFI, which would increase the tolerable bunch charge in the SPS by about 1.5. This margin does not exist with 0.50 GHz.

Rotation of a long bunch in a fairly high bucket can create problems with the dynamic aperture as shown in Fig. 1. Scrutinizing all cases in table 3 indicates that the rotating bunch will hardly exceed an rms energy spread of 0.5%, which is tolerable as the machines will be certainly designed for a dynamic aperture of $\pm$ 1%.

4. CONCLUSIONS

Examination of bucket and bunch dimensions indicates that the bunches fit into the BFI buckets. The PS can provide an adequate beam at 3.5 GeV with two 114 MHz cavities providing in total 1 MV. If after the start-up phase an increased margin were desired, a third cavity could then be installed; this third cavity is imperative for acceleration to 5.3 GeV in the PS. As far as injection is concerned, one would prefer an 0.35 MHz RF system in BFI because it provides somewhat more longitudinal acceptance at 8 GeV for the SPS beam.

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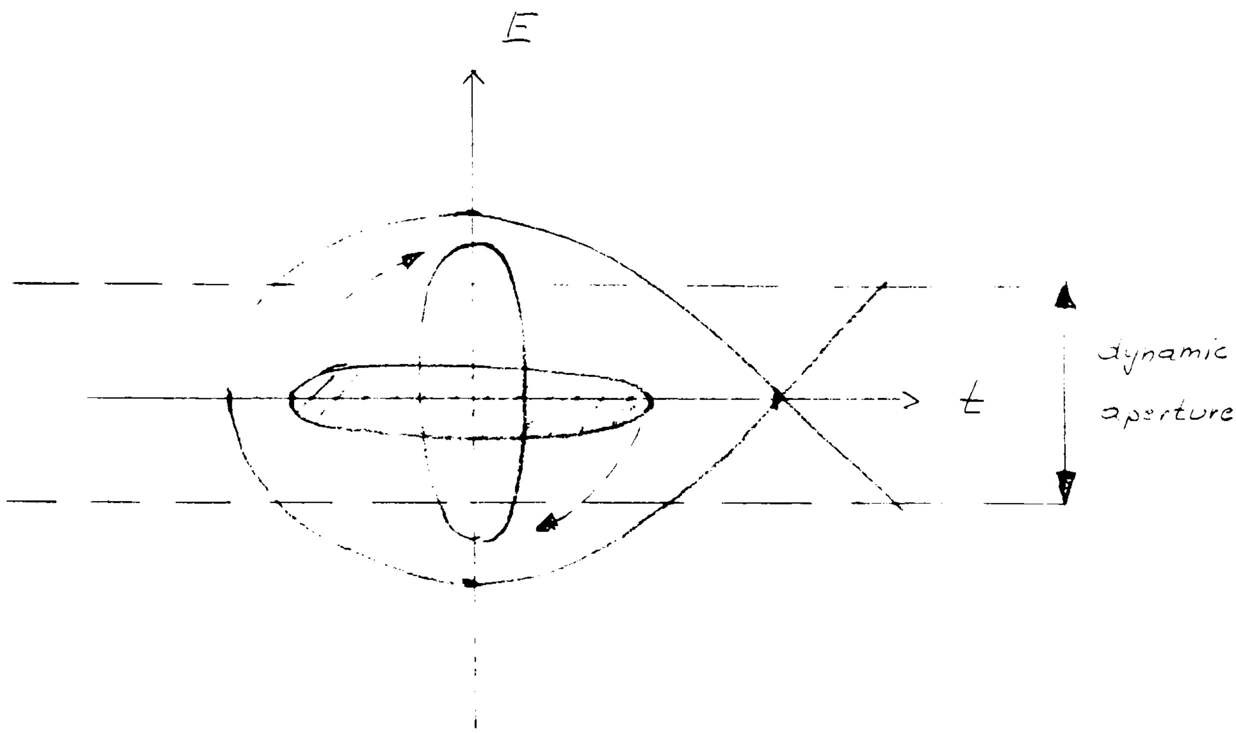

Fig. 1 Injected bunch in
BFI bucket