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MAXIMUM BEAM APERTURE IN STRAIGHT SECTIONS

The maximum semi-aperture of the machine is limited to $\hat{x}_{QF} = 76$ mm in the horizontal plane by the vacuum chamber of the F-quadrupole and to $\hat{z}_{B2} = 24.5$ mm in the vertical plane by the vacuum chamber of a B2 magnet. The latter corresponds to a maximum semi-aperture of $\hat{z}_{QD} = 25.2$ mm in the D-quadrupole.

The maximum beam envelope around the ring is given by

$$\begin{aligned} \hat{x}(s) &= COF_H \sqrt{\beta_H(s)} + \sqrt{\varepsilon_H \beta_H(s)} + \alpha_p(s) \frac{\Delta p}{p} \\ \hat{z}(s) &= COF_V \sqrt{\beta_V(s)} + \sqrt{\varepsilon_V \beta_V(s)} \end{aligned} \tag{1}$$

where ε_H and ε_V are the horizontal and vertical emittance respectively and COF is the "R.M.S. Closed Orbit Factor", i.e. COF . $\beta^{\frac{1}{2}}$ = closed orbit deviation.

The full-aperture beam, a beam that completely fills the available aperture will be defined by a choice of ε_H, ε_V, COF_H, COF_V and $\Delta p/p$ in eqn. (1) at the position where the aperture has its maximum ($\beta = \hat{\beta}$, $\alpha_p = \hat{\alpha}_p$) to give $\hat{x}_{QF} = 76$ mm and $\hat{z}_{QD} = 25.2$ mm. This choice of course can in principle be done in many different ways.

The maximum horizontal beam aperture in the long straights, where α_p is very small, however, strongly depends on the momentum spread assumed for the full-aperture beam. The higher the momentum spread chosen the smaller is the space filled by the beam in the long straights. The gain is of the order of 2 × 4 mm per 1.10^{-3} in $\Delta p/p$ half spread. Therefore, in order to make a safe estimate of the space that should be kept free for the beam in the long straights, the momentum spread of the full aperture beam at injection should be chosen relatively low, say $\pm$ 2.10^{-3}. The vertical envelope of course is independent of the relative choice of the adjusting parameters.

$\pm 0{,}75 \cdot 10^{-3}$

Taking this assumption for the momentum spread, two different schemes of adjusting the full aperture beam have been tried. The first is considered to be the more realistic one. In addition, for comparison purposes also a full aperture beam with a rather large momentum spread of $\pm$ 4.10^{-3} at injection has been considered.

BEAM 1

The residual closed orbit amplitude of x_{COD} = 10 mm and z_{COD} = 5 mm expected after closed orbit correction and the injection emittances of $\varepsilon_H^o = 7\ \pi$ and $\varepsilon_V^o = 3.4\ \pi$ have been equally scaled up at injection

$$\gamma_H \left[10 + (7.0\ \hat{\beta}_H)^{\frac{1}{2}}\right] + 2\ 10^{-3}\ \hat{\alpha}_p = 76 \text{ mm}$$

$$\gamma_V \left[5 + (3.4\ \hat{\beta}_V)^{\frac{1}{2}}\right] = 25.2 \text{ mm}$$

This results in scaling factors of γ_H = 1.79 and γ_V = 1.04 and in injection emittances of the full aperture beam of $\varepsilon_H = 22.54\ \pi$ and $\varepsilon_V = 3.66\ \pi$. At transition there is just enough space left to handle the expected momentum spread of

$$\left(\frac{\Delta p}{p}\right)_{tr} = \frac{6.6\ 10^{-3}}{\sqrt{2.4\ 10^{-3}}} \left(\frac{\Delta p}{p}\right)_{inj}^{\frac{1}{2}} = \pm\ 6.0\ 10^{-3}\ .$$

BEAM 2

It has been assumed that the closed orbit of the full aperture beam still can be corrected down to x_{COD} = 10 mm and z_{COD} = 5 mm. Only the emittances at injection will be adjusted.

$$(\varepsilon_H \hat{\beta}_H)^{\frac{1}{2}} + 10 + 2\ 10^{-3}\ \hat{\alpha}_p = 76 \text{ mm}$$

$$(\varepsilon_V \hat{\beta}_V)^{\frac{1}{2}} + 5 = 25.2 \text{ mm.}$$

The resulting emittances of this beam are $\varepsilon_H = 30.34\ \pi$ and $\varepsilon_V = 3.73\ \pi$. There is space for $(\Delta p/p)_{tr} = \pm\ 6.5\ 10^{-3}$ at transition.

As both the closed orbit deviation and the betatron amplitude are proportional to $\beta^{\frac{1}{2}}(s)$ the envelopes are the same for BEAM 1 and 2. The only difference is the available space for momentum spread at transition.

BEAM 3

For a comparison a beam with a rather large momentum spread of $(\Delta p/p)_{inj} = \pm\ 4\ 10^{-3}$ at injection has been taken, and has been adjusted like BEAM 1. The resulting momentum spread at transition becomes

$$\left(\frac{\Delta p}{p}\right)_{tr} = 0.135\ \left(\frac{\Delta p}{p}\right)^{\frac{1}{2}}_{inj} = \pm\ 8.5\ 10^{-3}\ .$$

With this large momentum spread the horizontal beam aperture is now limited at transition, in contrast to BEAM 1 and 2.

$$\gamma_{H,tr} \left[10 + \left(7.0\ \frac{\beta\gamma_{inj}}{\beta\gamma_{tr}}\ \hat{\beta}_H\right)^{\frac{1}{2}} \right] + 8.5\ 10^{-3}\ \hat{\alpha}_p = 76 \text{ mm}$$

The adjusting parameters are: $\gamma_{H,tr} = 1.40$ and $\varepsilon_{H,inj} = 13.76\ \pi$. In the vertical plane the same parameters apply as for BEAM 1 ($\gamma_V = 1.04$, $\varepsilon_V = 3.66\ \pi$ both at injection).

In Fig. 1 and 2 the maximum semi-apertures in the straight sections are drawn for BEAM 1 and BEAM 3 (Q = 27.75, Stage C). Figure 1 gives the horizontal and vertical semi-aperture in the short straight sections at the entrance of the following quadrupole. At any other point in the straight this may be calculated by inserting the full aperture beam characteristics into formula (1). As expected, the aperture difference between BEAM 1 and BEAM 3 is biggest where α_p is small, i.e. in periods 4, 5, 14, 15 and in the insertion.

Figure 2 shows the maximum semi-aperture of BEAM 1 and BEAM 3 along the long straight section. Also indicated is the semi-aperture corresponding to the good field region ($\hat{x}_{QF}$ = 62.5 mm, $\hat{z}_{QD}$ = 24.3 mm). In order not to cut into the horizontal available machine aperture the inner diameter of the drift tube of the 20 m long RF cavities for example have to be not smaller than ϕ = 130 mm.

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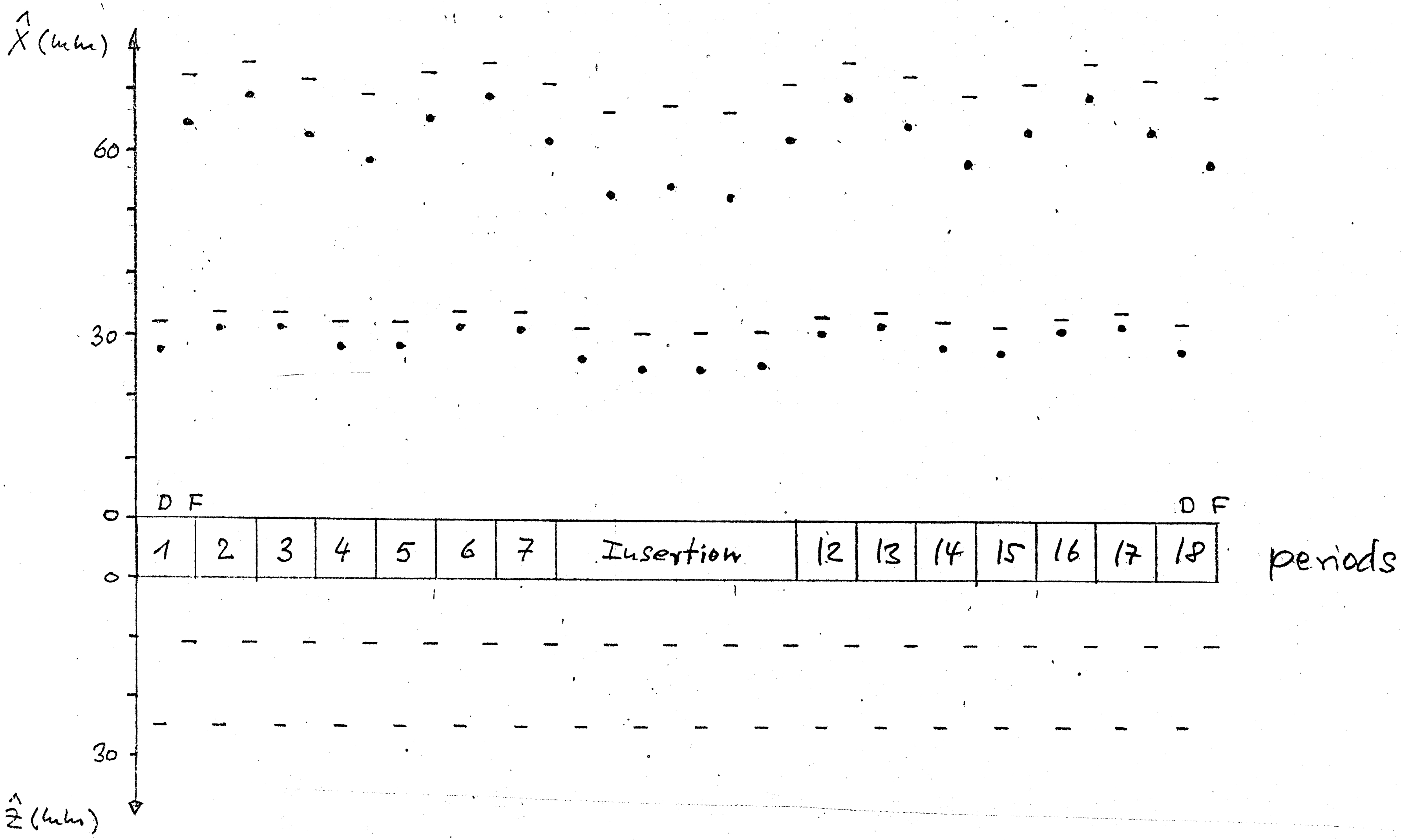

Fig. 1 Maximum Semi-Aperture in the Short Straights

– BEAM 1, • BEAM 3

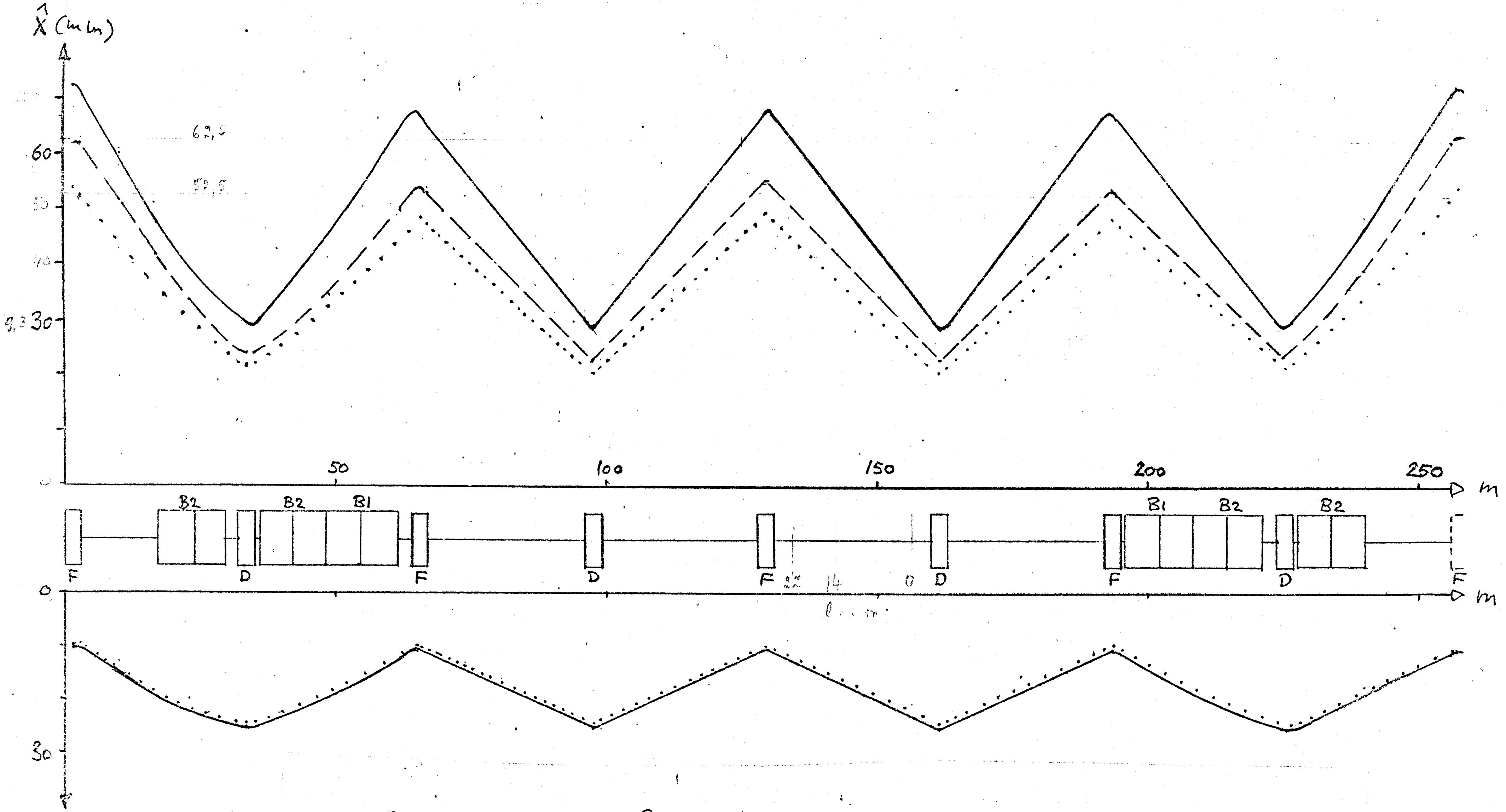

Fig. 2 Maximum Semi-Aperture in the Long Straight.

— BEAM1, -- BEAM3, ··· Good Field Region.