PS/ACOL/Note 28 29 May 1985
MM/afm

ACOL INJECTED AND EJECTED BEAM SIZES DEDUCED FROM A PERTURBATION METHOD BASED ON "ORBIT" DATA

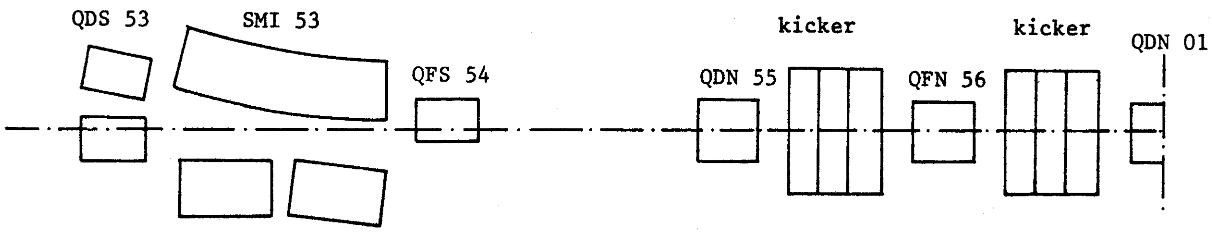
M. Martini

1. INTRODUCTION

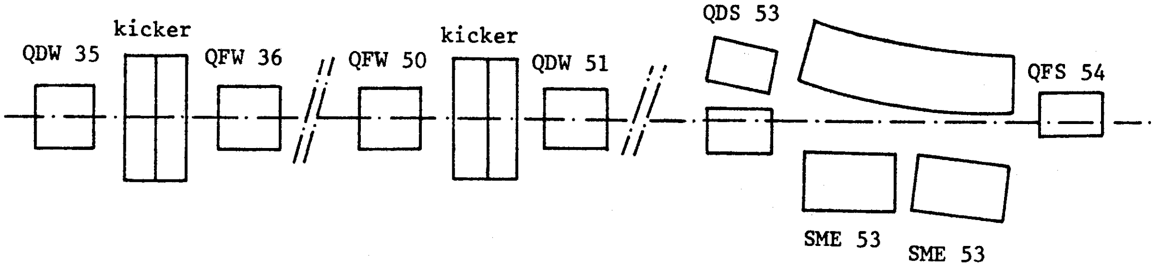
The definition of ACOL apertures requires the calculation of the size of the injected and ejected beams in addition to the circulating beam[1]. The present method uses a technique of trajectory perturbation in a transfer channel[2]. The parameters of injection and ejection have been provided by S. Maury and R. Sherwood[3]. The calculation of the beam size is limited to that part of the beam which is inside the ACOL ring.

2. INJECTION AND EJECTION LAYOUT

The layout of antiproton injection into and ejection from ACOL ring is shown in the following figures. Both injection and ejection septa are located in section 53. The two injection kickers, each made of three magnet modules, are in sections 55 and 56, whilst the two ejection kickers, each made of two magnet modules, are in sections 35 and 50.



Injection layout



Ejection layout

Using the kicker module characteristics shown in Table 1[3], the injected and ejected beam dimensions have been calculated and drawn, along with the circulating beam after injection.

Table 1

Kicker	Module	Azimuthal Location (m)	Magnetic Length (m)	Kick (mrad)
	1 ON	176.7378	0.677	3.0845
Inj. kicker 1	2 ON	177.4398	0.509	2.6803
	3 ON	177.9738	0.509	3.0515
	4 ON	179.7828	0.509	3.0515
Inj. kicker 2	5 ON	180.3168	0.509	2.6803
	6 ON	180.8515	0.677	3.0845
Ej. kicker 1	1 ON	111.8941	0.625	2.467
	2 ON	112.5191	0.625	2.467
Ej. kicker 2	3 ON	160.5051	0.625	-2.467
	4 ON	161.1301	0.625	-2.467

The azimuthal locations give the entrance kicker module locations along the central orbit, starting in the middle of QDN 01.

The computations and plots have been performed with a FORTRAN 77 program running on CYBER computer 875 and using the VERSATEC plotter.

The program input data is:

a) <u>for both injected and ejected beams</u>:

i) AC lattice characteristic functions given by optics program ORBIT[4],

ii) circulating beam horizontal emittance and relative momentum spread (ϵ = 240π mm. mrad at injection and $\Delta p/p = \pm 0.03$).

b) <u>for the injected beam</u>:

i) injected beam horizontal emittance and relative momentum spread,

ii) the number of injection kicker modules ON,

iii) the module locations along the central orbit, the module (magnetic) length and the kicks,

iv) the exit injection septum location on the longitudinal axis (~171.98 m).

c) <u>for the ejected beam</u>:

i) ejected beam horizontal emittance and relative momentum spread after debunching, betatron and momentum cooling (ϵ = 25π mm.mrad and $\delta p/p = \pm 0.0025$),

ii) the number of ejection kicker modules ON,

iii) the module locations, the module lengths and the kicks,

iv) the entrance ejection septa location on the longitudinal axis (~170.23 m).

v) the particle momentum of the ejected beam.

3. BEAM TRAGECTORY CALCULATIONS

a) Ejected beam

Let us describe first the ejection process, given n kicker modules, each being able to give a kick $\Delta\varphi$. The entrance kicker modules are at locations s_i along the longitudinal axis. The beam horizontal displacement $\Delta x(s)$ from the central (or an off-momentum) orbit due to the kicks is[2] :

$$\Delta x(s) = \left(1 + \frac{\delta p}{p}\right)\sqrt{\beta(s)} \sum_{i=1}^{n} \left[\sqrt{\beta(s_i)}\ \sin\Delta\mu(s) - \frac{\ell(s_i)}{2\sqrt{\beta(s_i)}} \left(\cos\Delta\mu(s) + \alpha(s_i)\ \sin\Delta\mu(s)\right)\right]\Delta\varphi(s_i) \tag{1}$$

where

$$\Delta\mu(s) = \mu(s) - \mu(s_i)$$

and

$\beta(s)$, $\mu(s)$ are the horizontal beta function and the phase advance at the longitudinal location s for the given ejected antiproton momentum.

$\beta(s_i)$, $\alpha(s_i)$, $\mu(s_i)$ are the horizontal beta function, its derivative ($\beta'=-2\alpha$) and the phase advance at the entrance of kicker module i.

$\delta p/p$ is the relative momentum spread of the ejected beam ($\delta p/p \approx \pm 0.0025$).

ℓ_i, $\Delta\varphi_i$ are the length and the deflection angle of kicker module i.

$$\ell(s_i) = \begin{cases} \ell_i & \text{if } s > s_i + \ell \\ (s - s_i)/\ell & \text{if } s_i < s < s_i + \ell_i \\ 0 & \text{if } s < s_i \end{cases} \qquad \Delta\varphi(s_i) = \begin{cases} \Delta\varphi_i & \text{if } s > s_i + \ell_i \\ \Delta\varphi_i(s - s_i)/\ell_i & \text{if } s_i < s < s_i + \ell_i \\ 0 & \text{if } s < s_i \end{cases} \tag{2}$$

Hence the ejected horizontal beam width a_x^+ and a_x^- are:

$$a_x^{\pm}(s) = x^*(s) + \Delta x(s) \pm \left(D_x(s)\ \delta p/p + \sqrt{\beta(s)\varepsilon}\right) \tag{3}$$

where

$x^*(s)$ is the radial orbit of the beam to be ejected, whose particle momentum may be equal to p, p-Δp or p+Δp (with $\Delta p/p = 0.03$),

$\beta(s)$ is the horizontal beta function for the given ejected particle momentum,

ε is the ejected beam emittance ($\varepsilon = 25\pi$ mm.mrad),

$D_x(s)$ is the dispersion for the given ejected particle momentum.

Remark

The ejection area is partially located in non-zero dispersion regions. It follows that due to the presence of sextupolar corrections inside the wide quadrupole profiles located in these regions, extra deflection angles have to be considered when computing the ejected beam trajectory. These angles are:

$$\delta\varphi_i = \frac{1}{2}\,(1 + \Delta p/p)^{-1}\,K_i'd_i\,\Delta x^2 \tag{4}$$

where Δx is the effective beam displacement at the entrance of quadrupole i, d_i and K_i' being respectively its length and the focusing strength derivative.

Hence, the sextupole effects give rise to a supplementary beam displacement δx, computed using the relationships (1) and (2), in which $\Delta\varphi_i$ is replaced by $\delta\varphi_i$ and ℓ_i by d_i. Thus, the effective ejected beam trajectory, measured from the central (or an off-momentum) orbit is then:

$$\Delta x(s) = \Delta x(s)_{kicker} + \delta x(s)_{sext.} \tag{5}$$

b) Injected beam

For the injection process, the same relationships (1) to (3) hold but the way the computations are performed is reversed.

The injection septum and kickers, along with the narrow quadrupoles being located in quasi-zero dispersion regions, there is no sextupolar correction inside the quadrupole profiles. Thus the above remark does not apply for the injected beam trajectory.

However, due to the large relative momentum spread, the formula (3) becomes, for the injected horizontal beam widths:

$$a_x^{\pm}(s) = x(s) + \Delta x(s) + \left(x^{\pm}(s) \pm \sqrt{\beta^{\pm}(s)\varepsilon}\right) \tag{5}$$

where:

x, x^+, x^- are the horizontal orbits of the injected beam for the particle momenta p, p + Δp and p - Δp ($\Delta p/p = 0.03$)

β^+, β^- are the horizontal beta functions for the particle momenta p + Δp and p - Δp.

ε is the horizontal injected beam emittance ($\varepsilon = 240\pi$ mm.mrad).

4. PLOT DISCRIPTION

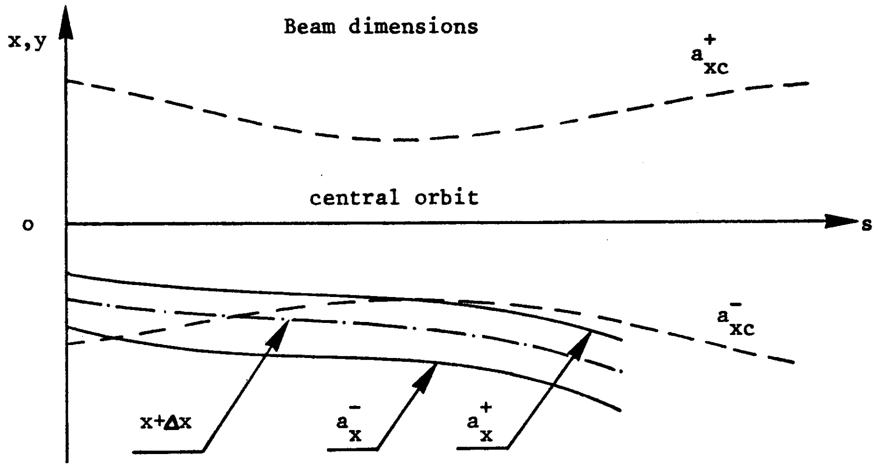
For all plots, the horizontal axes, scaled in meters, represent the distance along the circulating beam central orbit, from an arbitrary origin chosen by the user. The vertical axes, scaled in millimeters, represent the horizontal injected/ejected beam widths a_x^+, a_x^- (continuous curves), the horizontal position of the injected/ejected beam orbit x + Δx (dashed/dotted curve) and the horizontal circulating beam widths before debunching and cooling a_{xc}^+, a_{xc}^- (dashed curves). Vertical injected/ejected beam sizes are not shown, being always included in the vertical envelope of the circulating beam.

Figure 1 is a plot of quadrants III and IV (from middle of QDN 29 to middle of QDN 01 clockwise). The ejected beam is shown between the entrance of the first kicker module (after QDW 35) and the entrance of the ejection septa (after QDS 53). It corresponds to a particle momentum of p = 3.5752 GeV/c (central orbit).

Figures 2 to 5 are blow-ups of critical regions.

Fig. 6 is a plot of quadrant IV (from middle of QDN 43 to middle of QDN 01 clockwise). The injected beam is shown between the exit of the injection septum (before QFS 54) and the exit of the last kicker module (before QDN 01). The momentum of the injected antiprotons is p = 3.5752 GeV/c.

Fig. 7 is a blow-up of the injection region.



REFERENCES

1. M. Martini, ACOL Beam Apertures, PS/AA/ACOL/Note 84-7.
2. B. Autin, Introduction to Beam Optics, CERN/PS/84-18.
3. S. Maury, S. Sherwood, Private communication, 1985.
4. B. Autin, M. Bell, Private communication, 1985.

Fig. 1

Horizontal ejected beam dimension at p = 3.5752 GeV/c
(third and fourth quadrants)

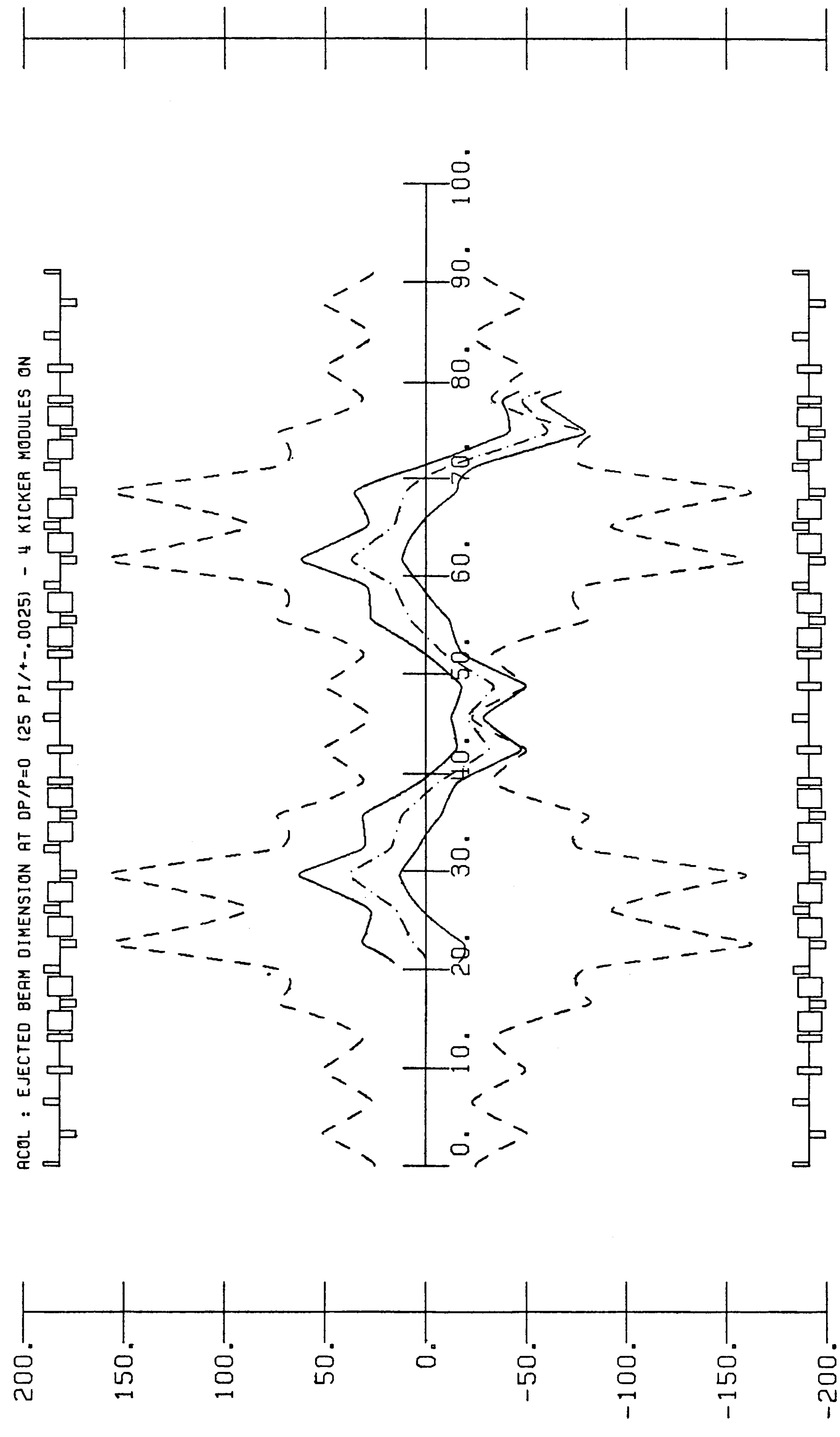


Fig. 2

Horizontal ejected beam dimension at p = 3.5752 GeV/c
in section 35

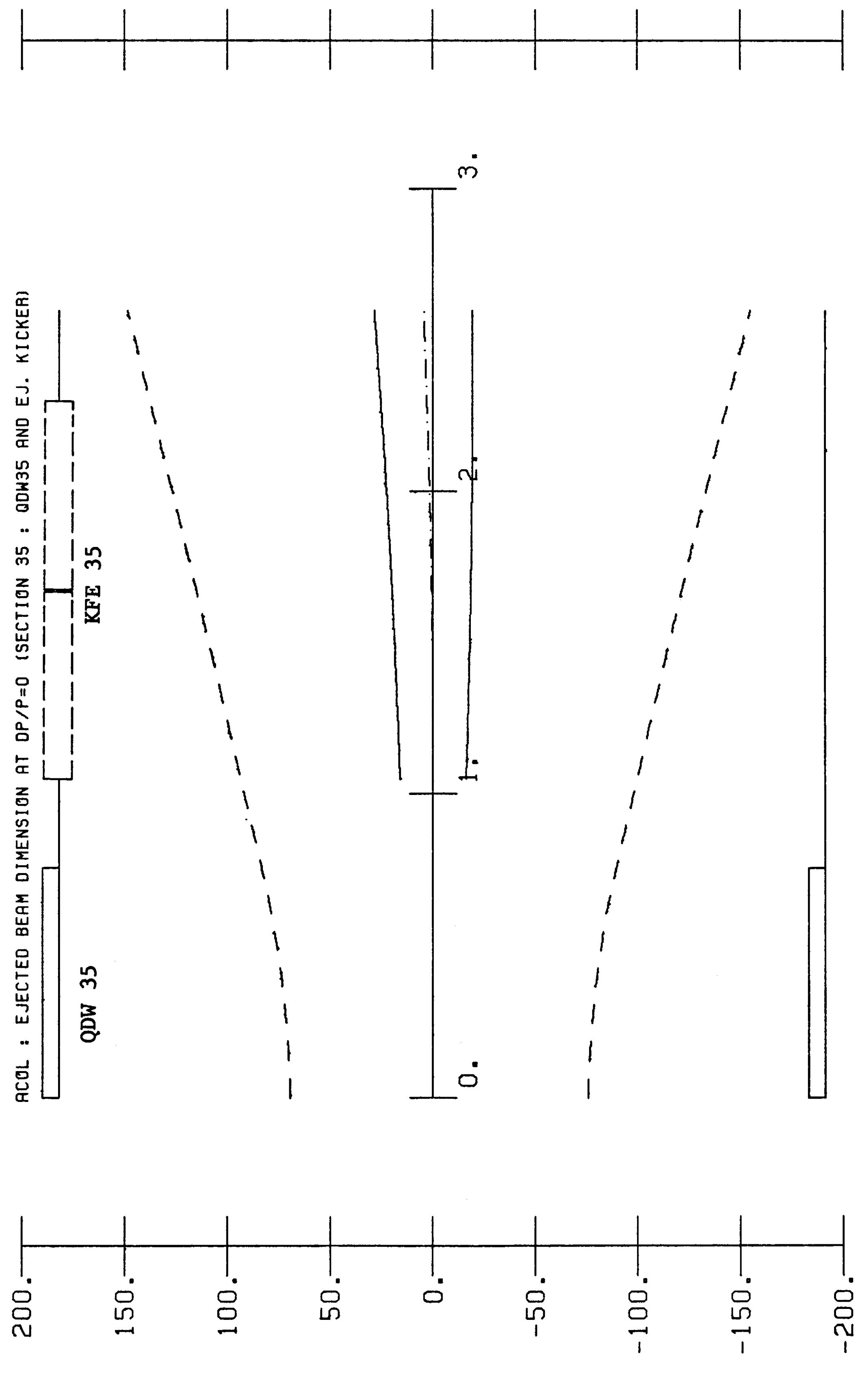


Fig. 3

Horizontal ejected beam dimension at p = 3.5752 GeV/c
in sections 42 to 44

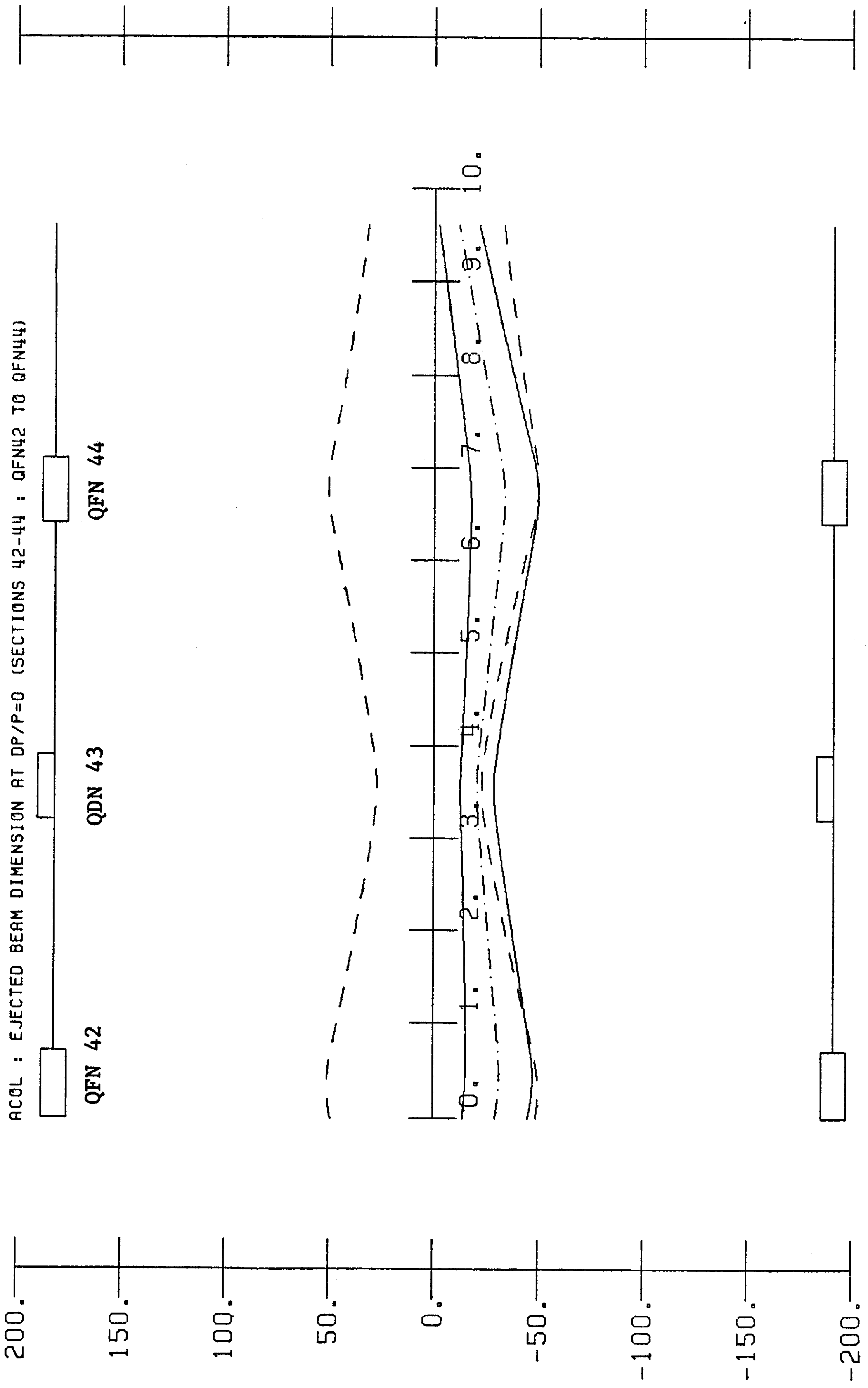


Fig. 4

Horizontal ejected beam dimension at p = 3.5752 GeV/c
in section 50

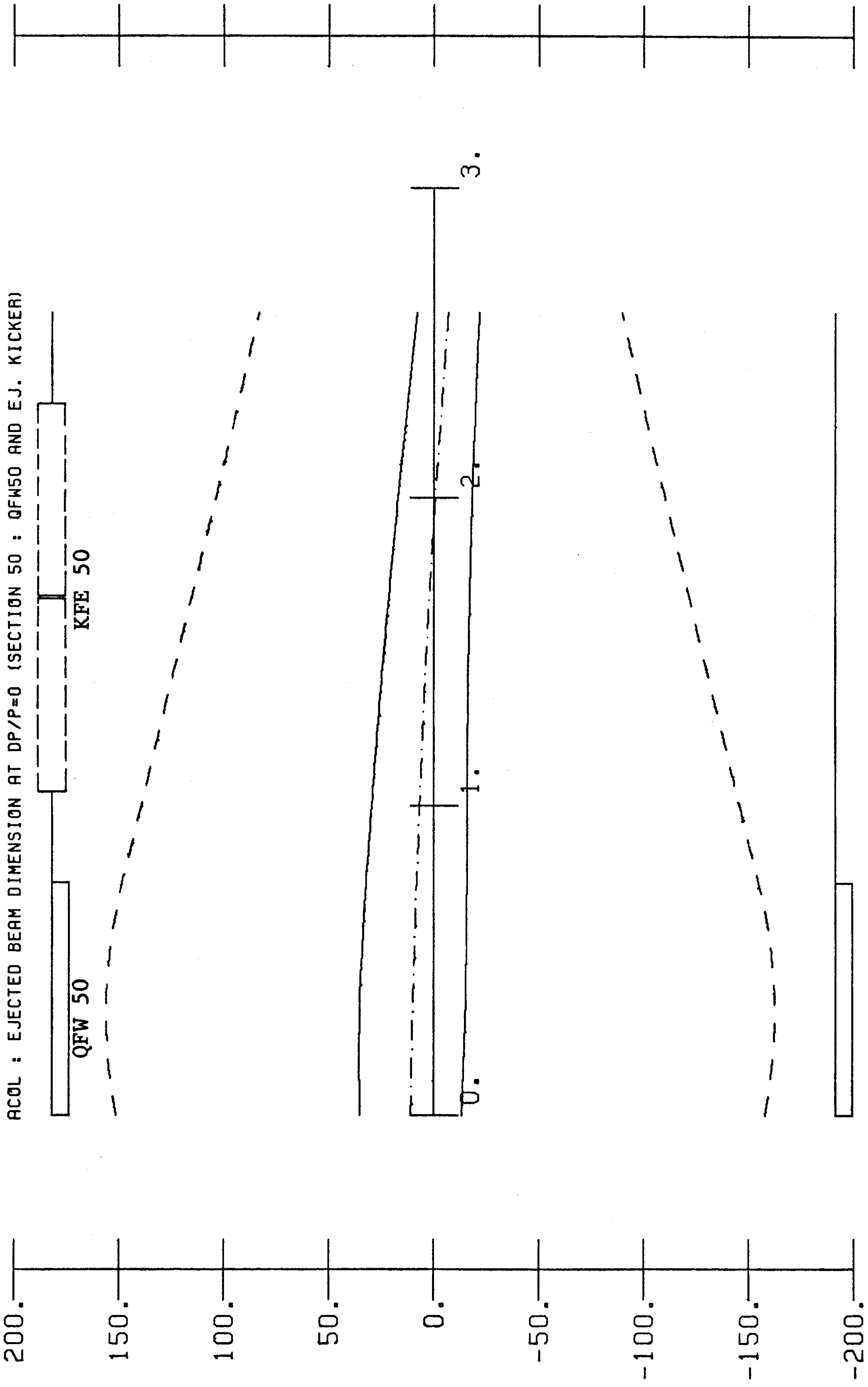


Fig. 5

Horizontal ejected beam dimension at p = 3.5752 GeV/c
in sections 51 to 53

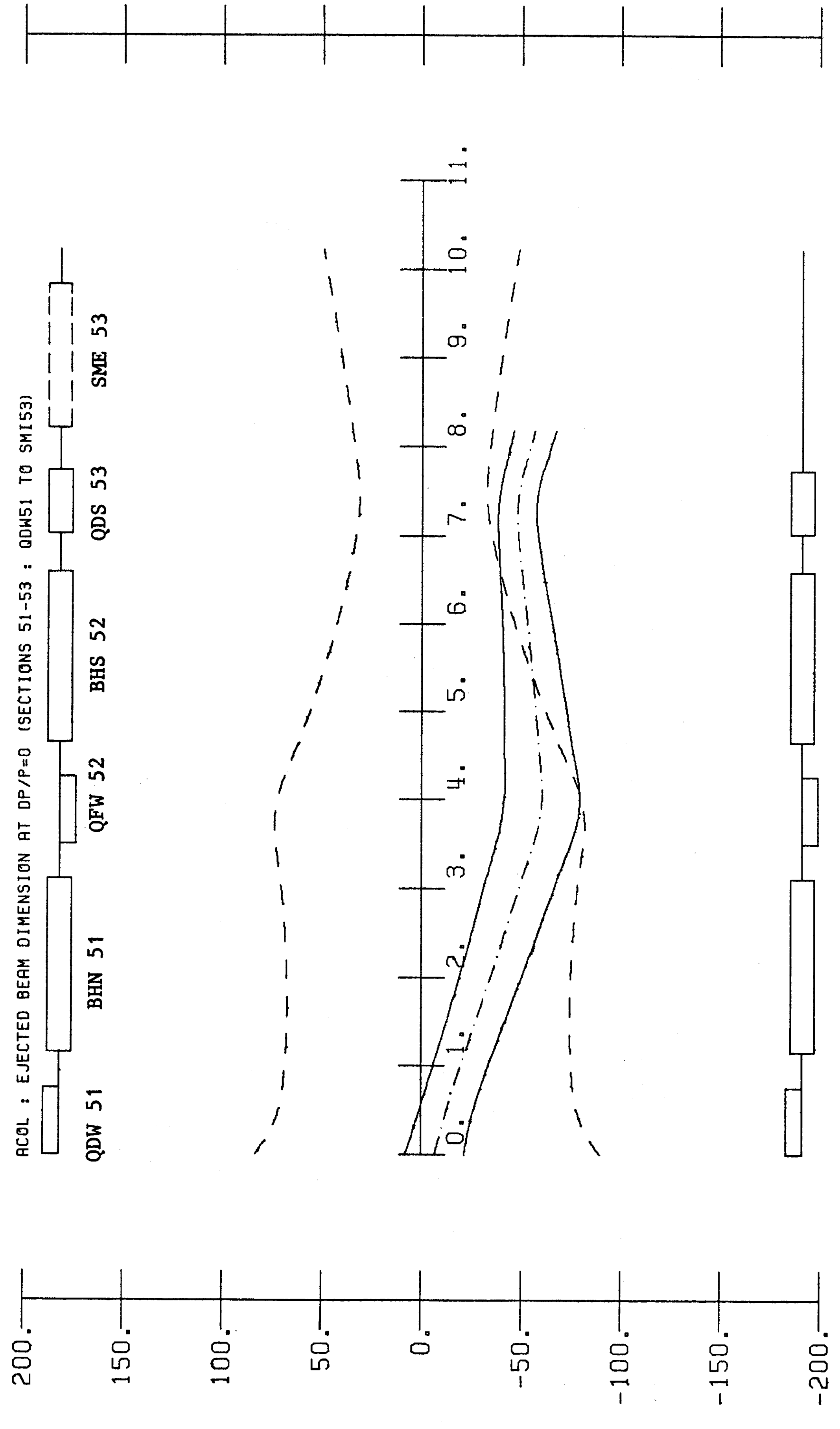


Fig. 6

Horizontal injected beam dimension at p = 3.5752 GeV/c
(fourth quadrant)

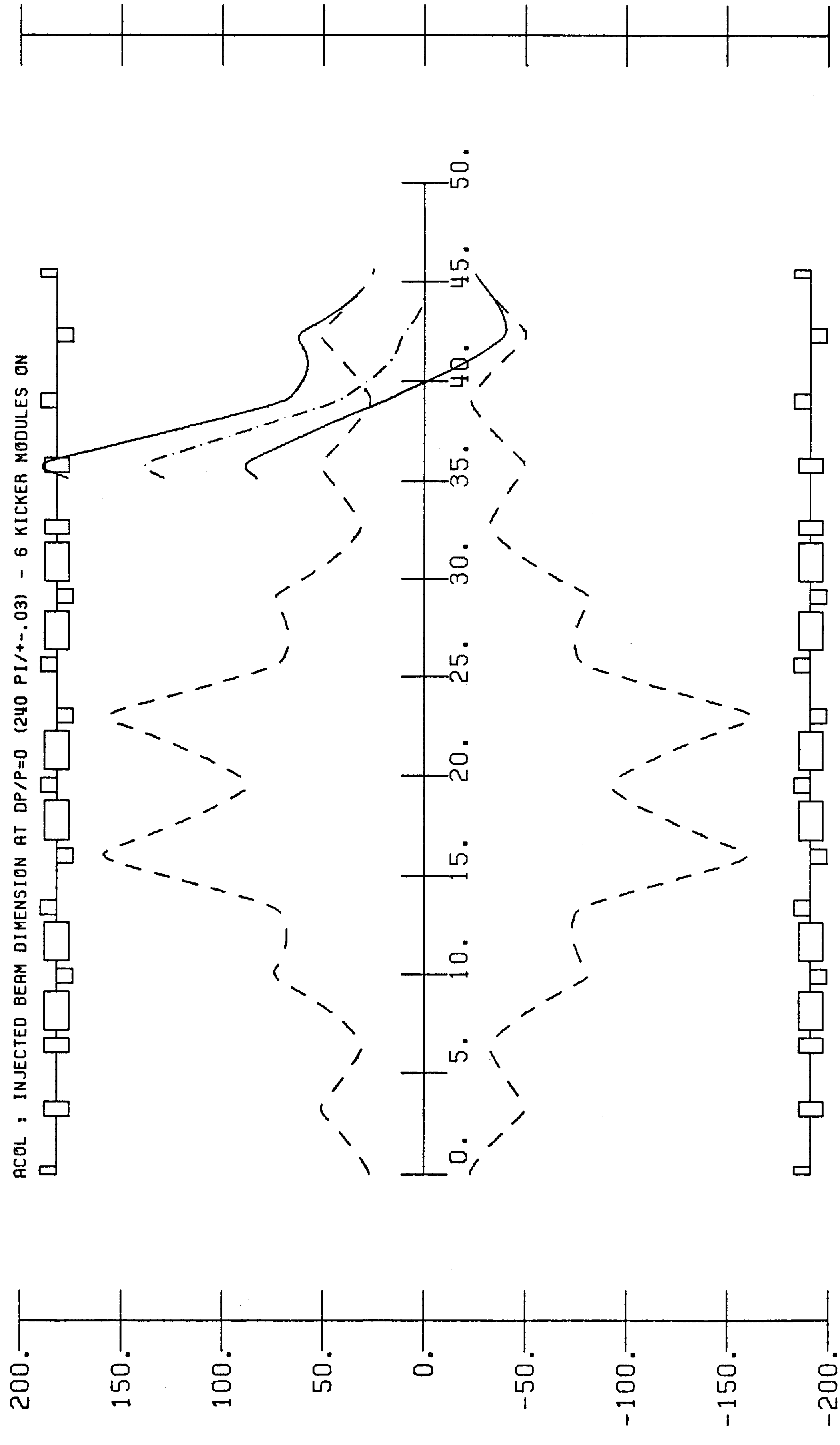


Fig. 7

Horizontal injected beam dimension at p = 3.5752 GeV/c
in sections 53 to 56