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INJECTION SCHEME FOR THE DAΦNE MAIN RING

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The lattice of the Frascati Φ-factory main rings is described in [1] and the proposed injection system from a positron/electron accumulator in [2]. In this framework a first proposal for horizontal injection scheme into the main rings can be made, based on the "classical" arrangement of a pulsed (or d.c.) inflector at the end of the transport channel from the accumulator and a system of fast kickers providing a closed orbit deformation confined to the region in the vicinity of the inflector. With four kickers, two before the septum and two after it, any desired displacement and angle at the septum position can in principle be realized, following also possible changes in the quadrupole gradients for fine tuning of the betatron wavenumbers [1].

It can be seen from the analysis of the lattice presented in [1] that the only region with vanishing dispersion, with the necessary phase advance for the closed orbit bump and with sufficient space in the free straight sections to accommodate the fast kickers and the inflector is the drift at $\pi/2$ from the low-β insertions in the "long" arc. Fig.1 shows the schematic rectified diagram of the lattice in this region, including the two last bending magnets of the dispersive regions. The lattice is symmetric with respect to its center and the phase advance between the two bends is ≈2.8 rad(almost the desired value of π), there are two free 2.5 m drift spaces to accommodate the inflector septum and plenty of smaller straights where 80 cm kickers can be installed. It is therefore worth trying to optimize the kicker positions, in order to find a good compromise between the required kicker strengths and the length of the closed orbit perturbation.

The dynamic aperture for particles on energy in the main ring is ±10 σ's [1] in the horizontal plane. I have assumed this value as the minimum septum distance from the closed orbit, even if the requirements of injection could be fulfilled with a smaller one, thus reducing drastically the required kicker strengths. Assuming the beam travelling from the left to the right in Fig. 1, the second 2.5 m drift is the best one for the septum, since the derivative of the betatron function vanishes near its end, and this is the best point for the minimization of the required main ring acceptance for injection.

The emittance of the beam in the main ring, the value of the horizontal betatron function and the horizontal beam size at this point are:

$$\varepsilon = 10^{-6} \text{ m.rad} \qquad \beta = 7.12 \text{ m} \qquad \sigma = 2.67 \text{ mm} \tag{1}$$

The beam coming from the accumulator has an emittance of $\varepsilon_i = 2.7\times10^{-7}$ m.rad and a relative energy spread $\sigma_p = 4.2\times10^{-4}$ [2]. Assuming a $\pm\,3\sigma$ acceptance for the injected beam, the optimum value for the horizontal betatron function β_i at the end of the transport line is the solution of the following equation [3]:

$$y^4 + \frac{a}{2\sqrt{9\varepsilon_i}}\, y^3 = \frac{\beta^2}{2} \qquad y = \sqrt{\beta_i} \tag{2}$$

where a is the distance between the septum and the closed orbit bump increased by the septum thickness. Assuming a 4σ separation between the already stored beam and the inflector, and 2 mm for the septum thickness, I find:

$$a = 12.7 \text{ mm} \qquad y = 1.64 \text{ m}^{1/2} \qquad \beta_i = 2.69 \text{ m} \tag{3}$$

so that the "worst" particle will pass at 17.8 mm from the central orbit and 9.2 mm from the septum after one turn in the ring. The required betatron acceptance in the ring is:

$$A = \frac{\left[a + 2\sqrt{9\varepsilon_i\beta_i}\ \right]^2}{\beta} = 4.4\text{x}10^{-5} \text{ m.rad} \tag{4}$$

corresponding to ± 6.7 σ's of the stored beam, well within the calculated dynamic aperture. With the septum position at 27 mm from the central orbit, the required fast orbit displacement x_d at the septum comes out to be 16.3 mm. However, it is reasonable to ask for a convenient safety margin on this value, both to compensate closed orbit errors and to bring the stored beam more towards the septum, should it prove useful to increase injection efficiency.

Fig. 1 shows the schematic layout of the long straight section. The structure is symmetric with respect to its center, and the beam is supposed to travel from the left to the right. As explained before, the optimum septum position is in the second 2.5 m drift space, so that more phase advance is available before the septum than after it. As a consequence, the two kickers after the septum are expected to be stronger than the first ones, if the the stored beam trajectory at the septum is parallel to the central orbit.

The strengths of the two kickers after the septum do not depend on the strength of those before it, because they are determined only by the desired displacement and angle of the trajectory at the septum. In Fig. 1 the possible positions for the kickers are indicated with the capital letter K followed by a progressive number. Also the extreme positions K1 and K8 have been taken into account, although they coincide with sextupoles SD12 and SD19, because their phase advances are favourable for the minimization of the required kicker strength: if necessary, it may be worth trying to find a different sextupole layout for chromaticity correction.

The required integrated fields in the kickers are given in **Table I** for any possible combination of the kicker positions for vanishing orbit angle at the septum, and neglecting the effect of sextupoles. For one of these combinations (K2+K5+K6+K7) the angular deflections provided by the kickers have been calculated for different angles of the trajectory at the septum, in order to minimize the maximum kicker strength. In a single case (K3+K5+K6+K7) the nonlinear equations of the trajectory with the effect of the sextupoles have been solved, showing that the maximum required field in the kickers does not change more than 10%.

Fig. 1 shows the closed orbit deformation induced by the kickers in K2 and K5 and the 3 combinations of kicker positions after the septum corresponding to the integrated fields given in Table I.

In Fig. 2 the positions after the septum are chosen as K6 and K7 and all the combinations starting at K1 are taken into account. The same happens for Fig. 3 (combinations starting at K2) and Fig. 4 (starting point at K3). Fig. 5 gives the trajectories given by K2+K5+K6+K7 when the closed orbit angle at the septum is changed with the kicker strengths of Table I. Fig. 6 finally shows the change in the trajectory created by K3+K5+K6+K7 when the sextupole contribution is taken into account: the variation of the closed orbit and of the kicker fields is small, so that, to a first approximation, the contribution of the sextupoles can be neglected in the optimization of the injection layout. It will be however necessary to perform a careful tracking for the particles coming from the injector to precisely determine the requirements on the machine aperture and to estimate the injection efficiency with the complete distribution of sextupoles in the ring.

From the analysis of Table I it is clear that the maximum kicker strength can only be reduced by choosing K8 for the fourth kicker position. This choice reduces the maximum required kicker amplitude by 25%, but sextupole SD19 must be transferred elsewhere. Similarly, on the other side of the septum, the best combination is K1+K3. However, if one is mainly concerned about the maximum field in the kickers, the choice of the kicker positions before the septum is not crucial. The optimization of the trajectory angle at the septum reduces the maximum field by only 13%, at the expense of a rather large displacement in the quadrupoles and sextupoles before the septum (see Fig. 5).

The maximum integrated field required from the extraction kickers in the accumulator is anyway 110.3 Gm [2], only 6% less than the value of K7, so that changing the position of the sextupoles will not reduce substantially the overall effort required for the project of the pulsed elements.

From the above considerations, it seems reasonable to choose K2, K6 and K7 as the positions of the first, third and fourth kicker, leaving the choice of the second one depend on other factors, such as the best position of monitors and correctors. Placing the first kicker in K3 can also be considered, if there will be any reason to minimize the width of the closed orbit deformation.

REFERENCES

[1] M. Bassetti, M.E. Biagini, C. Biscari, S. Guiducci, M.R. Masullo, and G. Vignola: "High emittance lattice for DAΦNE", DAΦNE Technical Note L-1 (30/10/90).

[2] M. Preger: "A positron and electron accumulator for DAΦNE", DAΦNE Technical Note I-1 (9/11/90).

[3] S. Tazzari: "Apertura per l'iniezione (ALA)", Adone Internal Memo EI-4 (18/1/78).

TABLE I - Integrated field in the kickers (Gm) for x_d = 20 mm

Kickers	Sextupoles	Orbit angle (mrad)	First Kicker	Second Kicker	Third Kicker	Fourth Kicker
K1+K2+K6+K7	OFF	0	-19.7	84.1	-66.8	117.0
K1+K3+K6+K7	OFF	0	42.5	41.1	-66.8	117.0
K1+K4+K6+K7	OFF	0	54.8	31.6	-66.8	117.0
K1+K5+K6+K7	OFF	0	66.1	30.5	-66.8	117.0
K2+K3+K6+K7	OFF	0	57.5	13.0	-66.8	117.0
K2+K4+K6+K7	OFF	0	61.9	8.3	-66.8	117.0
K2+K5+K6+K7	OFF	0	64.8	7.0	-66.8	117.0
K3+K4+K6+K7	OFF	0	182.8	-108.8	-66.8	117.0
K3+K5+K6+K7	OFF	0	115.0	-54.8	-66.8	117.0
K2+K5+K6+K7	OFF	0	64.8	7.0	-66.8	117.0
K2+K5+K6+K8	OFF	0	64.8	7.0	-10.6	87.2
K2+K5+K7+K8	OFF	0	64.8	7.0	-22.1	103.7
K2+K5+K6+K7	OFF	0	64.8	7.0	-66.8	117.0
K2+K5+K6+K7	OFF	1.00	47.1	25.9	-92.1	124.5
K2+K5+K6+K7	OFF	-1.00	82.6	-12.0	-41.5	109.5
K2+K5+K6+K7	OFF	-2.07	101.5	-32.2	-14.5	101.5
K3+K5+K6+K7	OFF	0	115.0	-54.8	-66.8	117.0
K3+K5+K6+K7	ON	0	124.3	-74.8	-69.0	-116.3

Deflection angle (mrad) = Integrated field (Gm)/17

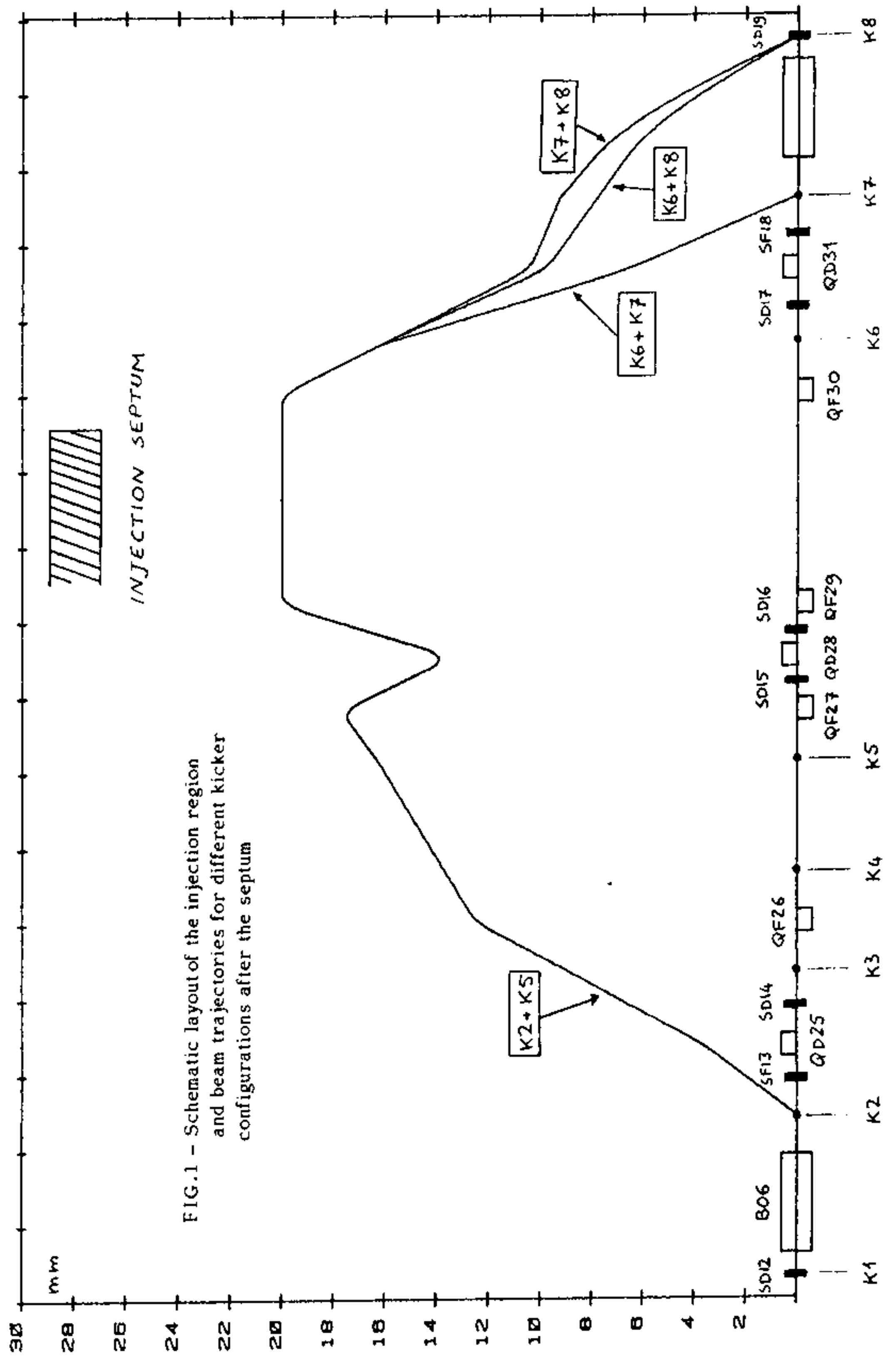

FIG.1 – Schematic layout of the injection region and beam trajectories for different kicker configurations after the septum

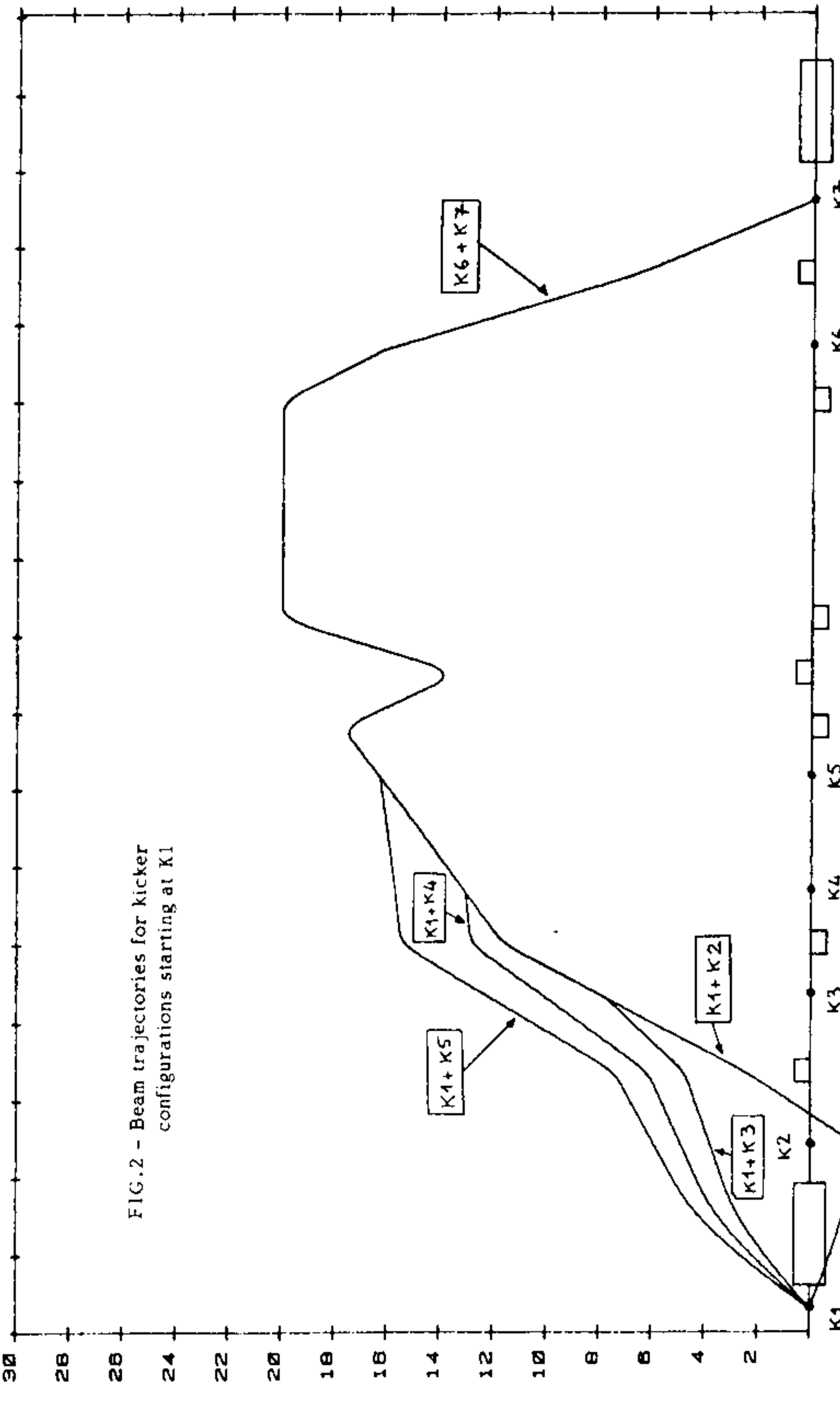

FIG.2 - Beam trajectories for kicker configurations starting at K1

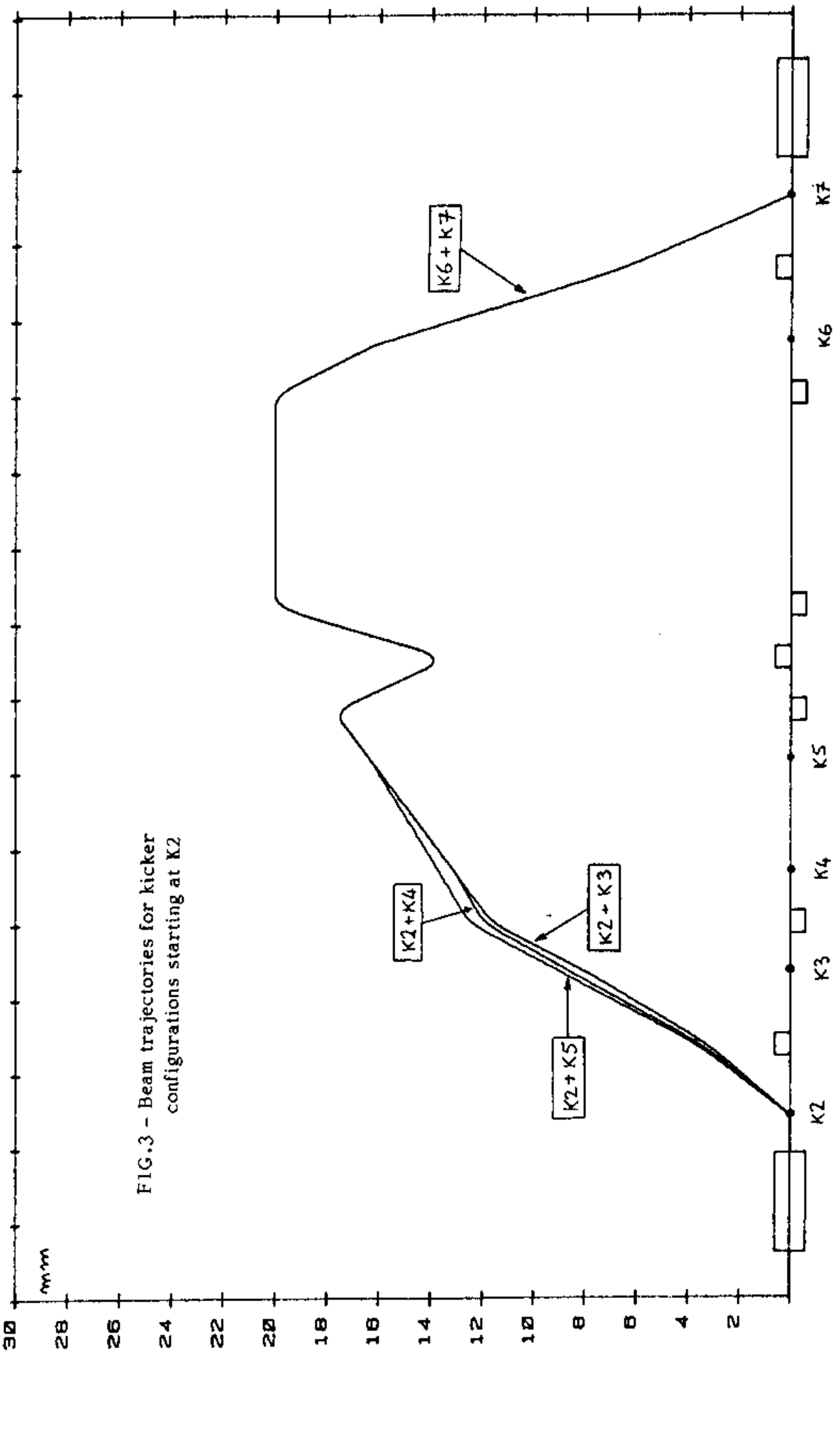

FIG.3 - Beam trajectories for kicker configurations starting at K2

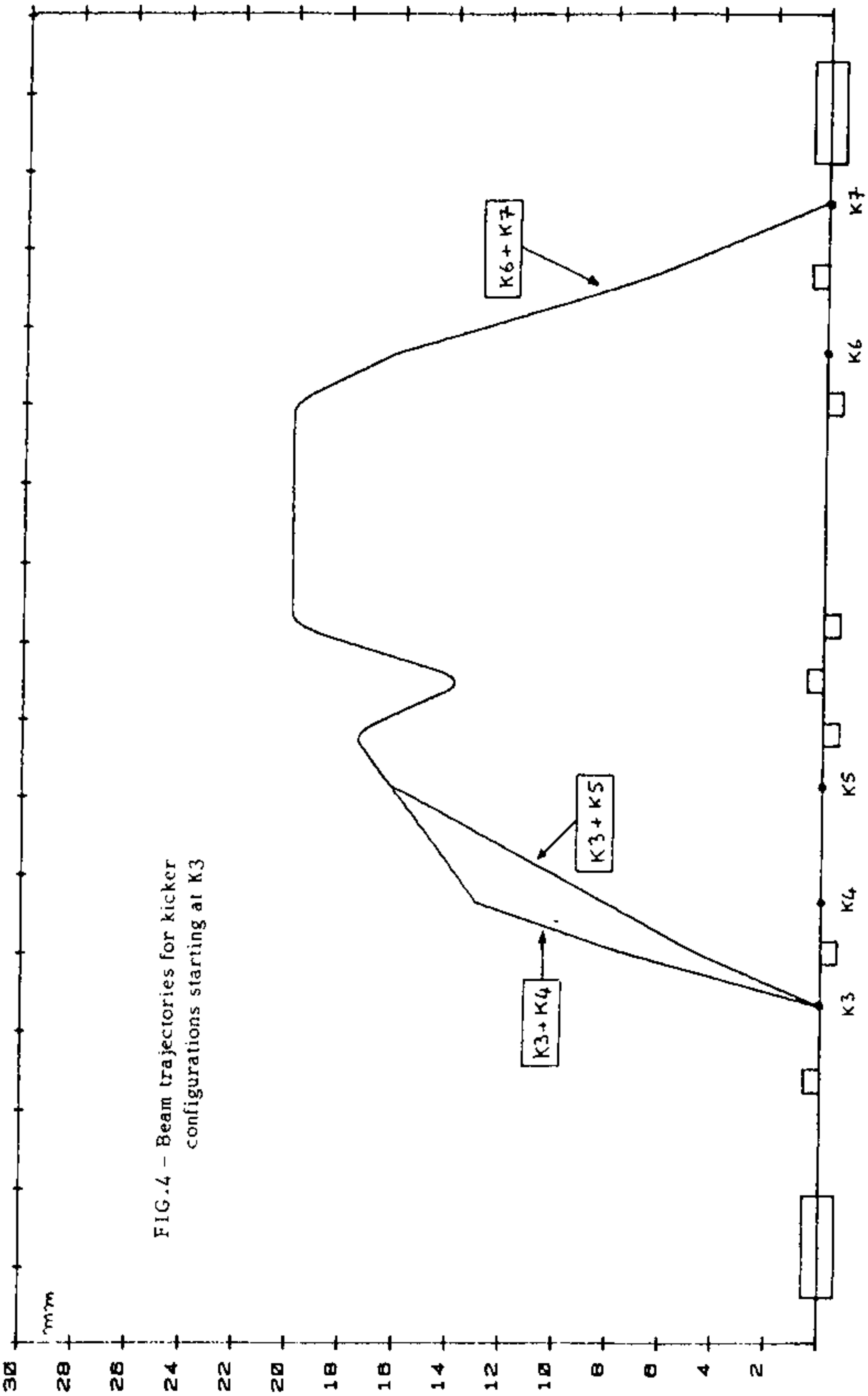

FIG.4 – Beam trajectories for kicker configurations starting at K3

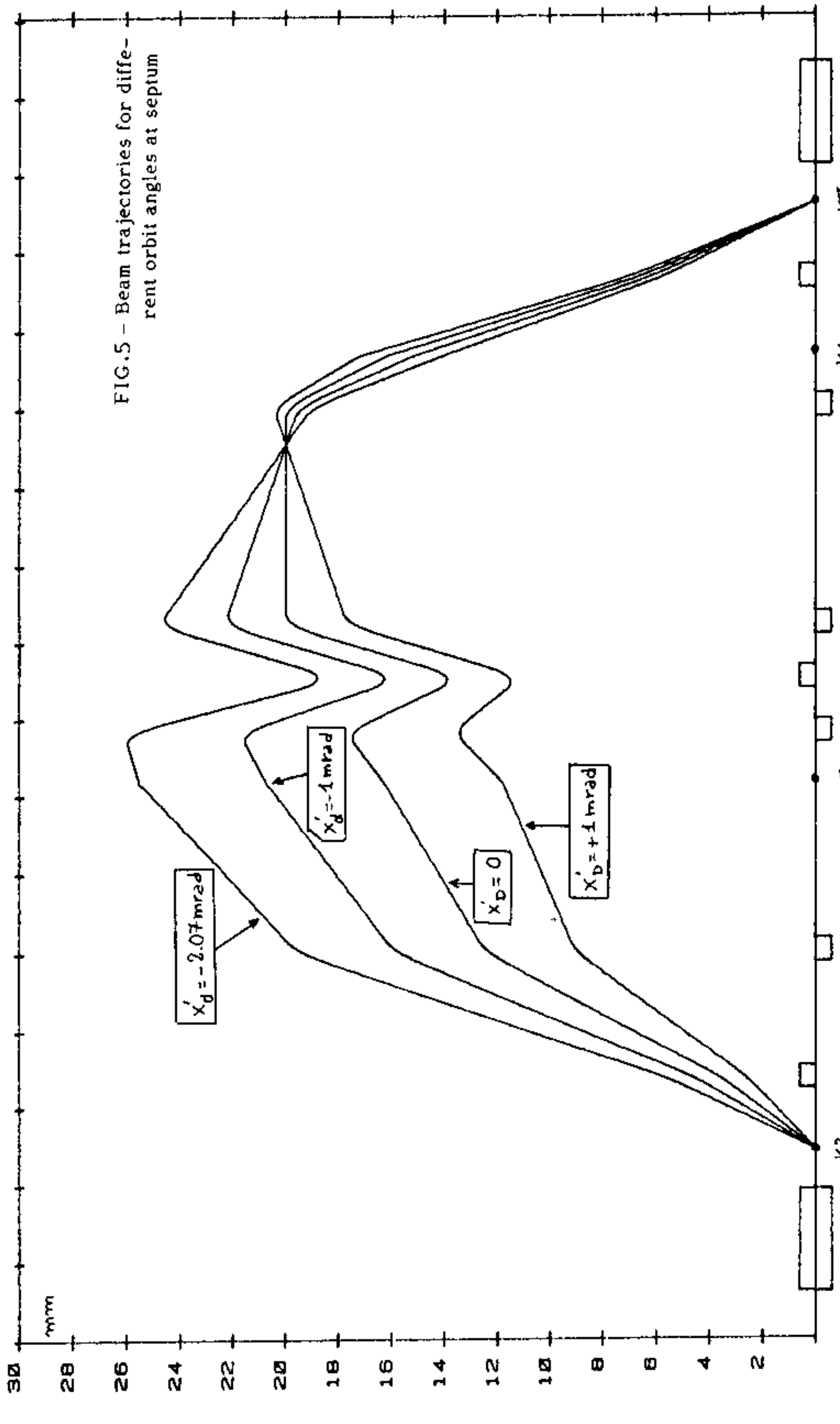

FIG.5 – Beam trajectories for different orbit angles at septum

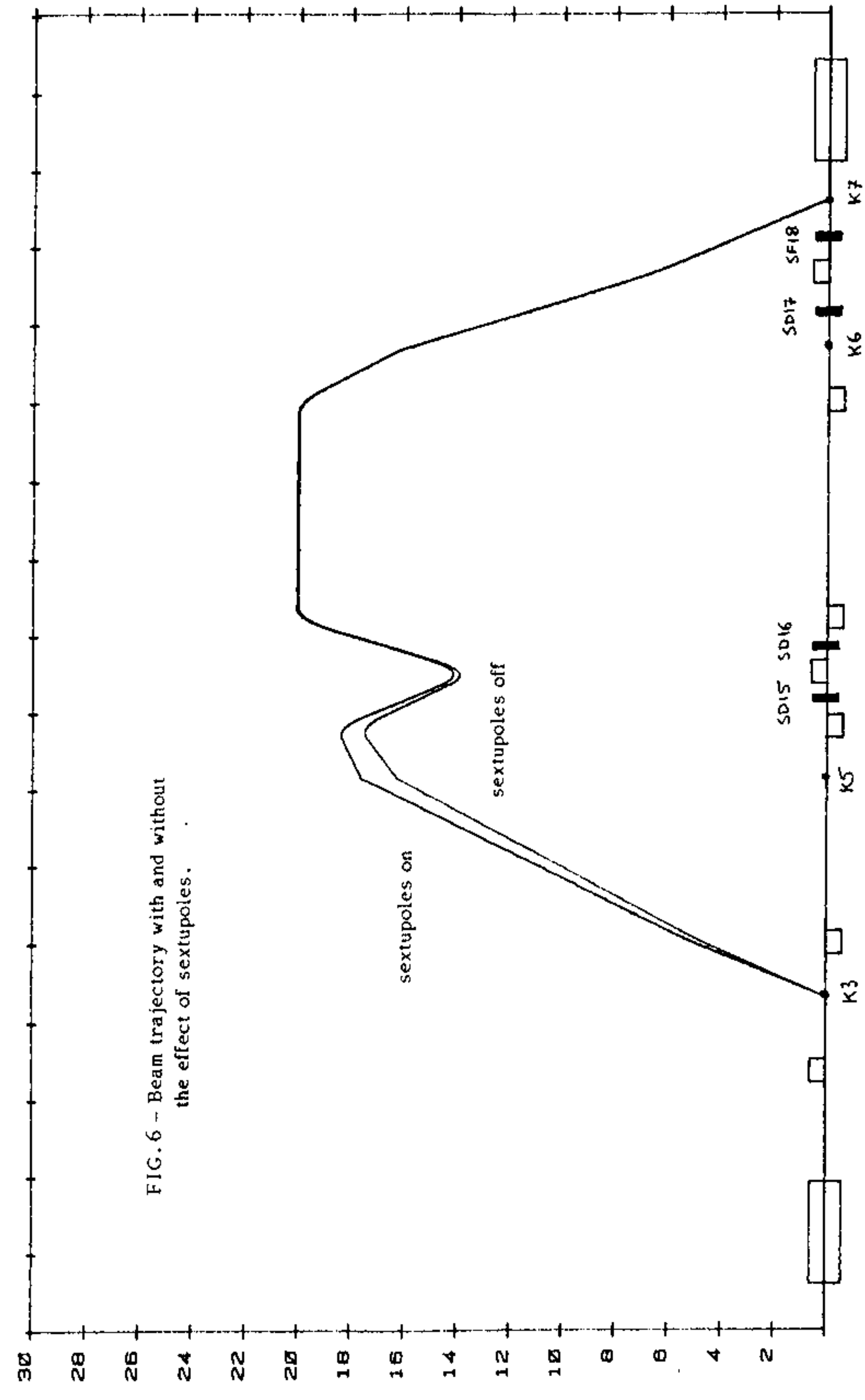

FIG. 6 – Beam trajectory with and without the effect of sextupoles.