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PARTICLE DISTRIBUTION PROCESS ON THE ELECTRON SYNCHROTRON INTERNAL TARGETS

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YEREVAN PHYSICS INSTITUTE

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In the work [1] we have shown that if an accelerated beam is drawn simultaneously onto two (or more) internal targets located in the nearest straight sections between two focusing magnets of a FOFDOD structure, then there exists a mechanism of "mutual influence" (or "shielding") of the targets on each other. Moreover, the strength of this influence depends on the value of Q_z , the number of the betatron oscillations per turn.

In this report the "mutual influence" of two targets on each other is investigated for the case of simultaneous drawing of the accelerated beam onto them in order to make clear the possibilities of the use of the value of Q_z as a redistribution parameter of the beam between the two targets.

In FOFDOD structure the targets are located in the centres of the straight sections between F-magnets. Let $S_1 = 0$ be the azimuth coordinate of the first target. Then the corresponding coordinate of the second target will be $S_2 = p\ell$ where $p = 1.2.3,\ldots,M-1$, ℓ and M are respectively the length and the number of the periods of the gradient of the synchrotron magnet structure. Therefore, the radial deflections of the accelerated particles on the „K" -th revolution after the moment when the perturbation is switched on from the non-perturbated equilibrium orbit (coordinate curve), in the planes $S_1 = 0$ and $S_2 = P\ell$ are given by the expressions [1]

$$\tau(S_1,K) = \tau_{closed}(S_1,K) + A\cos[2\pi\Delta Q(K-1)+\alpha], \qquad (1)$$

$$\tau(S_2,K) = \tau_{closed}(S_2,K) + A\cos[2\pi\Delta Q(K-1)+P\mu+\alpha].$$

Here we have used the designations of the work [1]: A and α are the initial ($K = 1$) amplitude and phase of the particles radial betatron oscillations; $\Delta Q = |Q_\tau - m|$, m is the integer number nearest to Q_τ ; $\mu = 2\pi Q_\tau / M$. The function $\tau_{closed}(S_i, K)$ describes the radial drawing of the beam onto the i -th target.

Assuming that each particle passing through the target is lost from further acceleration due to γ -production for our analysis, we shall use the "rotating circle" method developed in the work [1]. Let us remind the essence of this method.

In the cross section $S_1 = 0$ the initial "circle" which is the beam emmitance in the plane ($\tau, \beta_{max} \cdot \tau'$) is turned by an angle $P\mu$ (in the clockwise direction) when passing the cross section $S_2 = P\ell$ and after a beam revolution it appears to be turned by an angle $\varphi = 2\pi\Delta Q$ as compared with the initial position.

However such rotation does not mean that the target drawn to the beam "works" like a carver on a lathe. The target move

ment into the beam is equivalent to the "cutting" of the "circle", and such a cutting occurs once per turn. At each following turn the cutting occurs on different place of the "circle" shifted by an angle $\varphi = 2\pi\Delta Q$ relative to the previous one. When the two targets "work" simultaneously, the places of the simultaneous "cutting" (at the given turn) are determined by the mutual azimuth locations of the targets. Fig.1 illustrates the case.

Hence, if the condition $\varphi = \mu$, for instance, takes place, the first target "cuts" the circle at each (k +1) turn only in the places where the second target has already made such "cutting" at k-th turn.

The physical meaning of the condition $\varphi = \mu$ consists in the fact that for the same drawing law of the accelerated beam onto the targets located at equal distances from the coordinate curve the particle will hit the first target only in the case when the shifting of the beam to the target (targetting step) takes place during each turn. If the beam shifting to the target takes place after each two or more turns, then starting from (k_0+1) turn the particles will not hit the first target due to the total dynamic overlapping or "shielding" of the first target by the second one [1]. (K_0 is the number of the turn when the first cutting of the circle takes place). To keep the targetting step constant during 3 ÷ 5 turns depending upon Q_τ , it is necessary to provide uniform extraction of γ -beams. As is seen for fig.1a, during these turns the "circle cutting" always occurs in different places sufficiently remoted from each other.

The following targetting step must always occur only at the moment when the "circle" turns to the targets by the side where the "cutting" has already occurred at previous turns. Let us denote the places of the circle cutting by α_1 and α_2 for the first and second targets, respectively. Then the first cutting of the circle will occur at the places

$$\alpha_1 (K_0) = n_1 \cdot 2\pi - 2\pi \Delta Q (K_0 - 1) \tag{2}$$

$$\alpha_2 (K_0) = (2n_2 + \xi) \pi - 2\pi \Delta Q (K_0 - 1) - p\mu \tag{3}$$

Here n_1, n_2 are positive integers, their values being chosen so that they should satisfy the following condition

$$0 \leq \alpha \leq 2\pi \tag{4}$$

and if targets are located on the same side (one-sided targets), with respect to the coordinate curve, then in the expression (3) $\xi = 0$, and in the contrary case (many-sided targets) $\xi = 1$.

One may determine the overlapping places of one target by the other one from the equation

$$\alpha_1 (K_1) = \alpha_2 (K_2) \tag{5}$$

Whence it is possible to define the betatron oscillation frequency critical values.

$$(\Delta Q)_{cr} = \frac{M[(n_2 - n_1) + 0{,}5\xi] - pm}{M(K_2 - K_1) \pm p} \tag{6}$$

It should be noted that if $K_2 - K_1 > 0$ then the first target overlaps the second one, i.e. the second target will cut the "circle" after every $|K_2 - K_1|$ turn always at the places where the first target has already made such cuttings at previous turns.

Similarly, under condition $K_2 - K_1 < 0$ the second target overlaps the first one. It should be noted that full overlapping will occur only at the moment when the targetting step remains unchanged during each $|K_2 - K_1| + 1$ turn.

Another interesting case is the "self-overlapping" when each of the targets, starting with a certain turn, always "cuts" the "circle" in the places where it itself has already "cut" at previous turns. Evidently, in this case the intensity ratio about 1:1 will be provided.

The $(\Delta Q)_{cr}$ values at which the "self-overlapping" occurs are obtained from (6) by substituting $\xi = p = 0$.

Examining the expression (6) for Yerevan synchrotron ($m = 5$, $M = 24$, $p = 1$, $\xi = 0$), one may obtain the dependence of the intensity ratio N_1/N_2 or N_2/N_1 on ΔQ within the interval $0 < \Delta Q < 0{,}5$ in case r_{closed} =const during 1÷8 turns of the accelerated beam and for two one-sided targets (fig.1b). In this case, if the overlapping takes place at $|K_2 - K_1| = 1$, then the value of N_1/N_2 (or N_2/N_1) is accepted equal to 10 (where N_1 and N_2 are the number of particles passing through the first and second targets respectively and $N_0 = N_1 + N_2$ is the number of the particles in the accelerated from 1:0 up to 0:1 is $0.22 < \Delta Q < 0.260$ and $0.239 < \Delta Q < 0.25$… for one-sided and many-sided targets, respectively.

beam). If $|K_2 - K_1| > 1$, the intensity ratio values are graphically displayed after corresponding proportional decreasing.

With the purpose of quantitative evaluation of the targetting step influence on the intensity ratio calculations by computer БЭСМ-6М has been carried out. It was assumed that the distribution of the particles in the "rotating circle" with $A = 1$ is uniform by azimuth and there are equal numbers of particles in rings with equal thickness ΔA .

The number of the particles hitting the target at the given cutting of the circle was calculated by finding out the area of the cut part of the circle by means of special algorithm. As a result we obtained the values of the N_1/N_2 (or N_2/N_1) for two one-sided targets in dependence on the values of ΔQ_r and targetting step. The results of calculations given in fig.2 correspond to the case when the drawing of the particles onto the targets is carried out with a constant step $\Delta \tau$ =const per each turn of the accelerated beam (i.e. the requirements of the extraction uniformity are not taken into account) for spill times corresponding to the variation of the number of turns within the interval K_{max} = 100 - 3500 with ΔQ =0.01.

From figs. 2 and 3 it is seen that in both cases the critical values of ΔQ coincide with each other and that the targetting step value influences noticeably the value of the ratio (N_1/N_2). From the figures one can also see that for the Yerevan synchrotron the suitable interval of varying ΔQ providing intensity distribution between the two targets with ratio

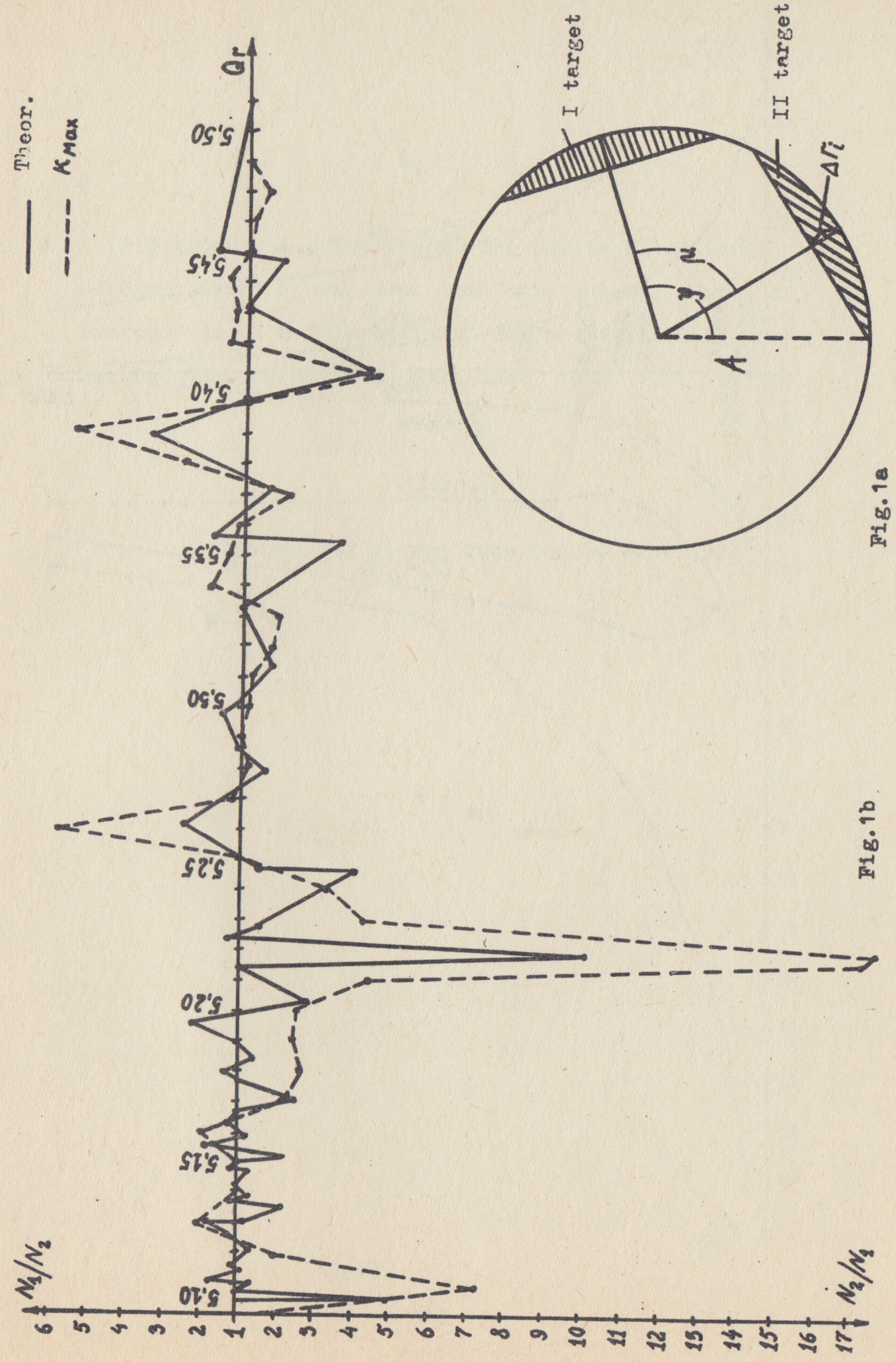

Fig.1a

Fig.1b

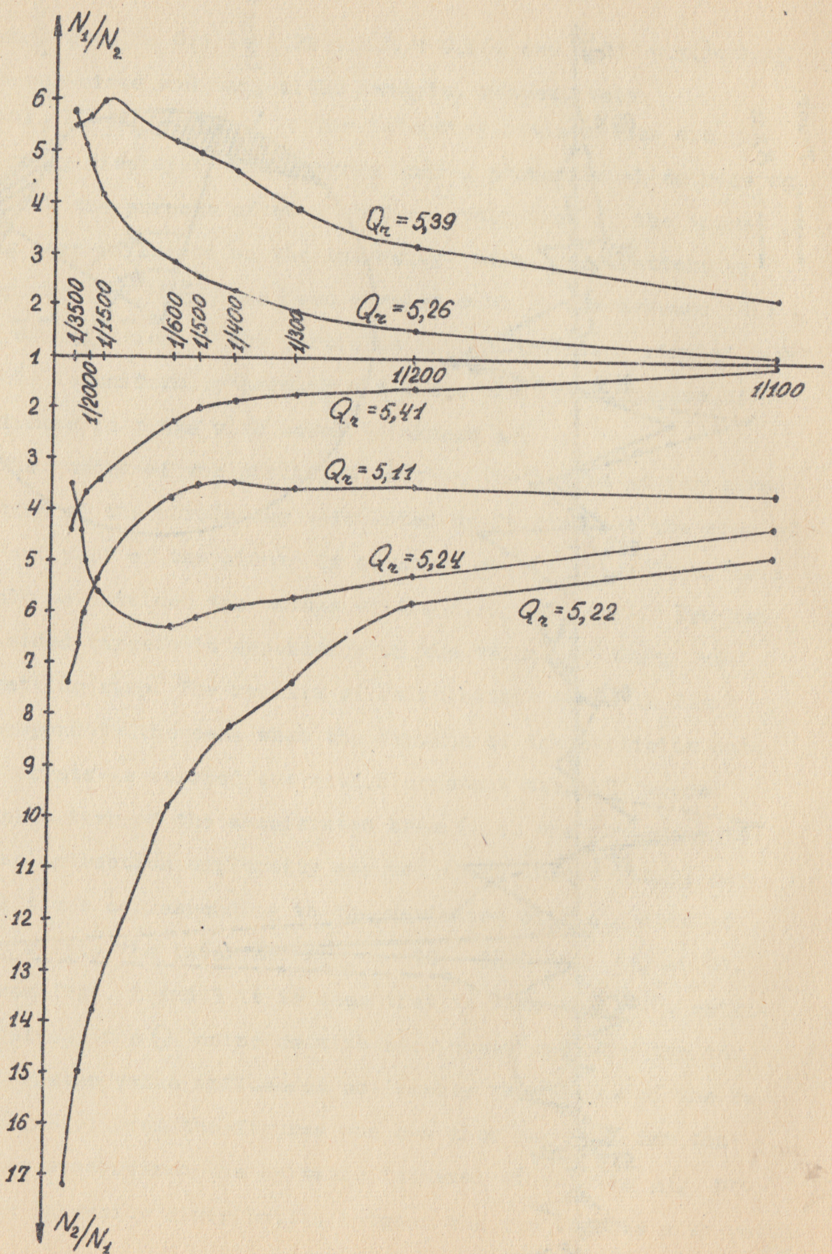

Fig.2

R E F E R E N C E S

1 Kh.A.Simonyan, A.R.Tumanyan, The Double-Plane Deflection of High Energy Synchrotron Beam onto Internal Targets; Proceedings of X International Conference on High Energy Accelerators, Protvino - Serpukhov, 1977, V.2, 170-178.

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Х.А.СИМОНЯН, А.Р.ТУМАНЯН

МЕХАНИЗМ РАСПРЕДЕЛЕНИЯ ЧАСТИЦ ПО ВНУТРЕННИМ МИШЕНЯМ ЭЛЕКТРОННОГО СИНХРОТРОНА

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