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POSSIBLE USE OF A BETATRON CORE ON THE COSMOTRON

MASTER

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A number of authors⁽¹⁾ have discussed the transition from betatron to radio-frequency acceleration in a synchrotron; indeed most existing electron synchrotrons use betatron start. In an electron synchrotron the betatron field accelerates the electrons up to velocities $\beta \approx 1$ so that the radio-frequency remains sensibly constant during the following synchrotron acceleration. It is easy to show that for a nearly monokinetic beam adiabatic radio-frequency turn on captures essentially all of the circulating beam into stable radio-frequency bucket(s). Near adiabaticity obtains for electron synchrotrons because of the high angular frequency of the circulating electrons.

In order to investigate the effect of radio-frequency turn-on rate and initial energy spread we have numerically integrated the equations of synchrotron oscillation for a limited number of cases. The calculations were performed on the N.Y.U. 7090 digital computer. The assumptions made were that the radio-frequency voltage and the sine of the stable phase angle, $(\sin \phi_s)$ increased linearly for a time τ and remained constant thereafter. This corresponds to a rate of change of betatron flux during this period which is proportional to $1-(t/\tau)^2$ which very roughly approximates a saturating B-H curve. The final value of $\sin \phi_s$ was taken to be 0.50.

The differential equation solved is

$$\ddot{\phi} = t/\tau (\sin \phi - t/\tau \Gamma)$$

where dots denote differentiation with respect to t , Γ equals the final value of $\sin \phi_s$, and we measure t , τ , and ϕ in units of Ω where $\Omega = \Omega_0/(1-\Gamma^2)$ and Ω_0 is the small amplitude angular frequency of synchrotron oscillations.

- (1) D. Bohm and L. Foldy, Phys. Rev. 70, 249 (1946)
N. H. Frank, Phys. Rev. 70, 179 (1946)
T. R. Kaiser, Proc. Phys. Soc. (London) 63A, 52 (1950)

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Figure 1 shows the azimuthal extent of monokinetic beam which is captured in a stable bucket as a function of τ . The increase in amount captured goes up quite rapidly for small values of τ and by $\tau = 50$ is well past the knee of the curve. $\tau = 50$ corresponds, for the Cosmotron, to about 2.7 milliseconds. We cannot, of course, achieve an increase in the amount of phase space enclosed by the final stable bucket. For $\tau = 50$ we have calculated the area in phase space at $t = 0$ which transforms into a stable bucket at $t \gg \tau$. Figure 2 shows this area and also the area of the stable bucket. In the units used in Fig. 2 the walls of the vacuum chamber of the Cosmotron correspond to approximately ± 2 . Assuming a maximum betatron flux density of 15 kgauss, the core area required is about 1.5 square meters. Back biasing would, of course, reduce this by a factor of two.

One possible beneficial effect of using a betatron core would be to reduce the aperture required for synchrotron oscillations in the first millisecond or so. A betatron core would probably be more useful for beam "gymnastics" such as aiding capture of several initial high harmonic buckets into a single first harmonic bucket, or to aid in inflector missing if higher energy injection is used.

It may be noted that this type of calculation applies also to the injection scheme proposed at various times by Blachman, Snyder and Teng, wherein capture (or bunching) is started with $\sin \phi_s = 0$ by tracking the radio-frequency, not to the $R = \text{constant}$ proton but to the spiraling-in proton.

I am indebted to L. Leipuner for assistance in programming the 7090.

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FIG. 1

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FIG. 2

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