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DEBUNCHERS FOR SEMI-RELATIVISTIC LINACS*

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Various solutions have been proposed to obviate the long flight path of debuncher systems for proton linacs above 200 MeV. These usually involve the design of magnet systems which cause particles of different momenta to traverse different path lengths in passing through the system. The purpose of this paper is to point out that a simple magnet system will suffice for this application.

The parameter of most interest to the system in question is the ratio of the time difference t to the momentum deviation p. The time difference is due, then, to the difference in the path length and the difference in the velocity. We can write

$$\frac{\Delta t}{t} = \frac{\Delta C}{C} - \frac{\Delta V}{V} .$$

Expressing these quantities in terms of the momentum deviation

$$\frac{\Delta t}{t} = \left[\alpha - \frac{1}{\gamma^2}\right] \frac{\Delta P}{P}$$

* This material has since appeared as MURA Technical Note TN 452, (12/26/63) (Ed.).

Here $\alpha = \frac{\Delta C/C}{\Delta P/P}$ is the usual momentum compaction coefficient, in the case of a circular accelerator. This leads us to ask what type of circular accelerator structure would be useful. It is clear that we would like α to be large to satisfy the debunching requirements. This leads us toward the weak focussing type of accelerator structure. In this case $\alpha = \frac{1}{k+1}$, where $k = \frac{R}{B} \frac{dB}{dR}$.

We would like to put several requirements on the system.

I. The emerging beam should be achromatic with respect to angle and position about the central orbit, at least to first order.

II. The emerging beam should be isochronous with respect to angle and position about the central orbit, at least to first order.

III. Some degree of focussing should be provided for both radial and vertical motion.

It is easy to show, on general grounds, that requirements I and II are the same. Then requirement I is satisfied by causing the beam to undergo an integral number of radial betatron oscillations. Since $\nu_x = (1 + k)^{1/2}$ then if φ is the angle traversed in the ring, we require $\varphi(1+k)^{1/2} = 2\pi m$, where m is an integer. In order to have vertical focussing, we need $k > -1$. A large value of α implies a small value of ν_x, so we need to make φ large. To be certain that the beam does not strike the injection structure, it is preferable, but by no means essential, to choose m = 1. We can allow the beam to coast at least 3 or 4 revolutions in the ring. The value of dt/dp, or the more useful dt/dE is then

$$\frac{dt}{dE} = \frac{R\varphi}{c\beta^3 E}\left[\frac{1}{1 + k} - \frac{1}{\gamma^2}\right]$$

Let us insert some numbers for a 1 GeV linac. The energy spread, as calculated by adiabatic damping from 50 MeV is about ± 1 MeV. Let us assume that changes in gradient, mismatching tank phase errors, etc., raise this to ± 2 MeV. We would like to have this spread over $\pm \frac{\pi}{4}$ of a 200 Mc/sec. wave or $\frac{dt}{dE} = \frac{5}{16} \frac{\text{nsec}}{\text{MeV}}$.

We chose the field in the ring to be 15 kG, so that R = 4m. We now specify the beam to go 1.75 revolutions around the ring. Then $\nu_x = 1/1.75$ and k = -0.7. All parameters are specified, and we calculate the value of $dt/dE = 0.319 \frac{\text{nsec}}{\text{MeV}}$. The required radial aperture due to energy spread is only 2 cm. One would want more to handle the beam properly. A one mrad spread in the ring gives rise to only a 0.6 cm vertical oscillation amplitude. To obtain proper performance, one would insure zero edge angle entrance to the ring by magnetic shielding or shaping of the entrance region. We notice that the phase of the debuncher cavity is shifted 180° from the usual situation and that the beam direction is changed by 90°. This angle can in fact be a design parameter if one chooses different field strengths and radii for the ring.

Discussion (Not reported, Ed.)