BASIC DESIGN CONSIDERATIONS ON AN ELECTRON BEAM STRETCHER

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This paper gives a brief description of some less conventional schemes for injection, extraction and spill out control to be used with an electron beam pulse stretcher ring.

In designing an electron beam stretcher for the 300 MeV Electron Linac of Mainz University the main effort was made to get low transversal beam emittance of the extracted beam and to provide some means for flattening the beam intensity. To be compatible with later recycling of the linac the stretcher should be able to operate up to 600 MeV. The magnet ring will mainly consist of two 180° bending systems connected by two long straight sections. In this paper, however, only some as we think rather unconventional details will be discussed.

Since the emittance of the extracted beam is in part determined by the emittance of the circulating beam we consider it to be of advantage to use a longitudinal stacking in order to keep the emittance as small as possible. The stacking procedure is as follows: The beam is swept between two deflecting cavities of mutual distance L through the aperture of a focussing lens, the focal length of which is L/4. By correct phasing of the RF the beam will not move downstream the device (Fig. 1). The linac beam is fed in obliquely through the first deflector and bent to a regular orbit by

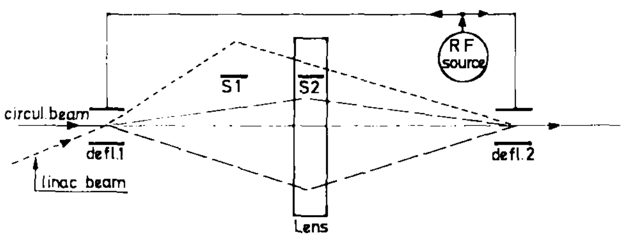

FIG. 1--Longitudinal stacking scheme.

means of two septa. In this manner it is achieved that injection is not affected by the performance of the RF, provided only that the beam passes behind the septa at inflection and in front of it at the successive turns. This scheme should work with reasonable margins for bunch lengths of less than 10^o over 6 turns of injection. To preserve the bunch structure sufficiently during injection the momentum compaction factor should be less than 10^{-3} if an energy range of 2.5% is to be captured. After about 100 turns after injection the original bunch structure may be considered to be totally lost. It is reckoned with a maximum injected linac beam of 170 mA, leading to a maximum circulating beam of about 1 A.

For extraction at some location of the ring dispersion will be provided and it shall have there a large horizontal but small vertical β-function. This gives a flat beam, the position of which is dependent of energy (Fig. 2). At the low

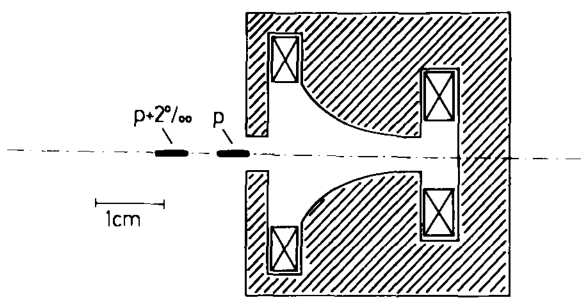

FIG. 2--Semiquadrupol used for extraction. Beam dimension and dispersion in correct scale.

energy side a small semiquadrupole is situated inside the vacuum (gap width about 5 mm). If the energy of the beam is lowered slowly it drifts into the gap of the semiquadrupole and is bent out subsequently. Final extraction is done by a magnetic septum a few meters downstream. The semiquadrupole is acting at a small fraction of the beam at a time only, causing a large Q-shift there of about 0.15 over a few mm. It is believed that this extraction scheme is scarcely affected by field errors in the ring.

The extraction has been computed by tracing many particles by a computer program, taking into account a field distribution in the semiquadrupole as measured at a conductive paper model. Figure 3 gives an example for such a computation. The extracted phase space shown had been obtained

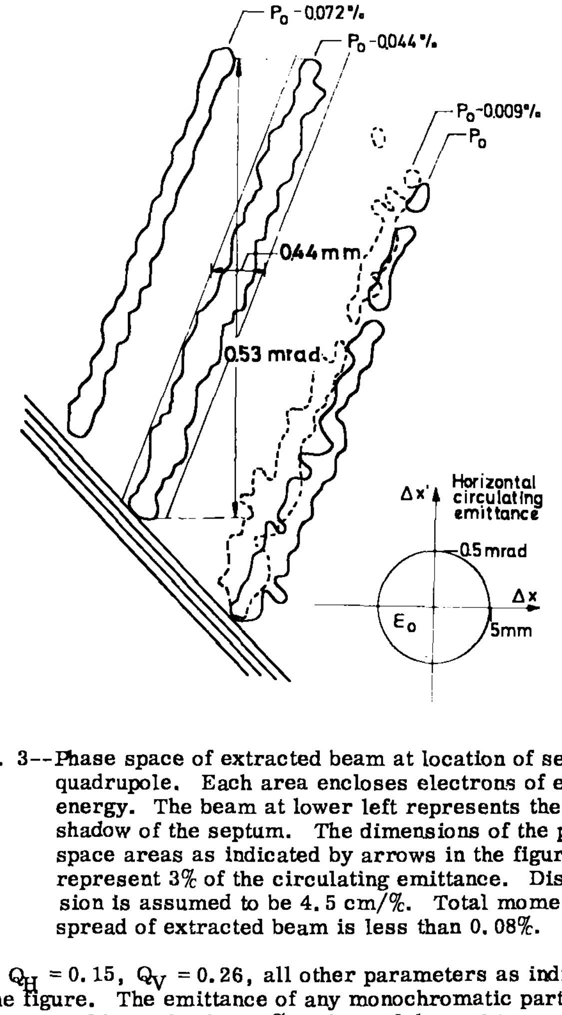

FIG. 3--Phase space of extracted beam at location of semiquadrupole. Each area encloses electrons of equal energy. The beam at lower left represents the shadow of the septum. The dimensions of the phase space areas as indicated by arrows in the figure represent 3% of the circulating emittance. Dispersion is assumed to be 4.5 cm/%. Total momentum spread of extracted beam is less than 0.08%.

with $Q_H = 0.15$, $Q_V = 0.26$, all other parameters as indicated in the figure. The emittance of any monochromatic part of the extracted beam is about 3% or less of the emittance of the circulating beam in horizontal direction, while vertically the emittance is enlarged by a factor of about 1.3. Extraction efficiency is about 90%. Since all monochromatic parts can be arranged to be of equal length and parallel in phase space as shown in Fig. 3 they can easily be brought to complete coincidence by a chromatic deflection system. So the overall emittance is substantially less than the emittance of the injected linac beam.

The slow energy shift necessary for extraction may be done by synchrotron radiation loss at an energy range of about 250 to 330 MeV.[1] Below 250 MeV the electrons lose their energy too slowly. This may be cured by inserting a small accelerator cavity in the ring which will periodically accelerate and decelerate the electrons. Those particles that have suffered enough deceleration will be extracted, the others will remain in the ring until, by a small phase slip per turn, these will meet a decelerating field, too. The process is controlled by proper variation of both amplitude and phase of the RF, thus providing flattening of the extracted beam intensity. At energies higher than 330 MeV, the following scheme may be used to compensate for too quick energy loss by synchrotron radiation: In a RF separator structure there are always transversal and axial forces related by

$$F_{tr} \sim j \cdot \text{grad } F_{ax} ,$$

j indicating a 90^0 phase shift in time.[2] Thus, the inflecting device shown in Fig. 1 may be converted into an accelerating mechanism by inserting a third cavity between the two others. This cavity should be phased in such a way that particles which have suffered maximum deflection in the first cavity meet the accelerating field off axis in the middle one at its maximum value. In this case, any closed orbit particle being deflected at all will be accelerated. By providing a certain RF phase slip between turns a very smooth acceleration of all closed orbit particles may be achieved and it is easily estimated that even for particles undergoing betatron oscillations the energy gain comes to an average rather quickly. Thus, the device described may be used to accelerate an unbunched beam. Though the achievable acceleration is very modest, it is sufficient in our case to compensate the radiation loss which amounts to about 6 keV per turn for electrons at 600 MeV with 2 m bending radius. The RF power requirement of the deflector cavities is in our case mainly determined by the necessity to avoid transverse beam instabilities and amounts to several tens of kilowatts each. Moreover, the interaction of the beam with the two outer deflectors tends to disturb the proper distribution of RF power in these cavities. It is desirable, therefore, to find a similar mechanism using less cavities. At the moment, schemes are investigated in which the setup of a small betatron oscillation by the transverse field of the RF separator mode is used subsequently for acceleration by the axial field of the same mode in a second cavity.

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