INJECTION IN A RING WITH NON LINEAR ELEMENTS AND ENERGY SELECTIVE RESONANT EXTRACTION FROM A RING

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1. Summary

The paper presents the main ideas involved in the injection and extraction procedures for the electron pulse stretcher (E.P.S.) designed for the linear accelerator of the University of Saskatchewan. The E.P.S. is described in another paper presented at the conference (D-5). The interested reader can find more detailed information on injection and extraction in our internal reports.[1]

2. Injection

Previous works[2] showed that complete resonant extraction of a beam requires the injection of a phase space hollow beam. A detailed study of such an injection is described in three internal reports of the ALIS project.[3] The injection is a coupled injection (the beam enters the machine off the closed orbit, both vertically and horizontally) and the analysis is based on the independence of both movements (vertical and horizontal). This last condition imposes a septum whose edge is parallel to the horizontal axis. In the E.P.S. the beam to be injected has a diameter of approximately 4 mm, so the width of the electrostatic septum must be approximately 18 mm. Hence the multiturn injection of a horizontal hollow beam leads to areas (in the horizontal phase plane) of at least 300 x 10^{-6} m.rad (see Fig. 1). This was the set up adopted for ALIS. With that size of beam, the movements are not independent when the extraction sextupoles are 'on'. So these sextupoles have to be pulsed and are expensive because of their great aperture. To reduce the size of the injected beam we use a tilted septum as indicated on Fig. 1. The analysis of the shadow of such a septum is intricate. One can represent this shadow by a family of curves in each phase plane. The parameter of the family in one plane is a function of the position of a given particle in the other plane! We adopted an approximate method by replacing the real septum by a fictitious one as represented by the dotted lines in Fig. 1. The small size of the expected injected beam allows us to keep the sextupoles 'on' during the injection.

In Figs. 2 and 3 we show one example of injection analysis. In the horizontal plane the trajectories have a triangular shape because of the sextupoles and the proximity of the 1/3 resonance. The vertical phase plane is normalized. In Fig. 3 are also shown the position of the closed orbits after the successive turns (p_0 to p_6). The injected beam has a vertical emittance of 25 x 10^{-6} m.rad and the horizontal shape of the beam is best represented by the hatched zone on Figs. 4 and 5 where its inner and outer areas are plotted as a function of energy. The predictions obtained by the graphical analysis just outlined were then checked and confirmed by using the second order transport program OSECO.[4]

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3. Extraction

Resonant extraction for a pulse stretcher is described in reports of the ALIS project.[2] Because of the small size of the injected beam two modes of extraction are possible for the E.P.S.: a chromatic extraction and an achromatic extraction. When the correction sextupoles are 'off' the phase space area of stability is highly dependent on energy. This is shown by the family of stability curves plotted on Fig. 4, where the parameter Q_{px} (strength of the pulsed quadrupoles) is directly linked with the horizontal tuning. As the tuning approaches resonance (during the extraction process) the stability curve moves to the right. The chromatic correction sextupoles change the shape of the stability curves to that shown on Fig. 5. As the tuning approaches resonance the stability curve moves downward.

a. Chromatic extraction

On Fig. 4 the outer area of stable movement for particles of the injected beam varies from the curve marked -0.158 to the curve marked 0.180. So at a given time, particles of the beam within a very narrow energy band are caught by the instability zone and are extracted. Fig. 6 gives a plot of the energy of extracted particles versus time. A detailed analysis with the OSECO program leads to the determination of the emittance of the extracted beam.

b. Achromatic extraction

A similar analysis on Fig. 5 shows that, in this case, practically all energies are extracted simultaneously as shown in Fig. 7. The above results are valid in the absence of radiation loss. At 300 MeV the 1% loss modifies slightly the graphical analysis since the last particles to be extracted have lost 3 MeV.

4. Conclusion

In all cases of extraction the duty cycle is greater than 0.80.

Because of the injection of a very small beam, we are able to use permanent sextupoles and two modes of extraction are possible. The characteristics of the beam as it leaves the E.P.S. are given below.

Chromatic extraction	
Energy spectrum:	0.08%
Energy scan:	2% at 100 MeV
	1% at 300 MeV
Vertical emittance:	30 x 10^{-6} m.rad
Horizontal emittance:	50 x 10^{-6} m.rad at 100 MeV
	25 x 10^{-6} m.rad at 300 MeV
Achromatic extraction	
Energy spectrum:	2% at 100 MeV
	2.5% at 300 MeV
Vertical emittance:	25 x 10^{-6} m.rad
Horizontal emittance:	14 x 10^{-6} m.rad at 100 MeV
	15 x 10^{-6} m.rad at 300 MeV

5. References

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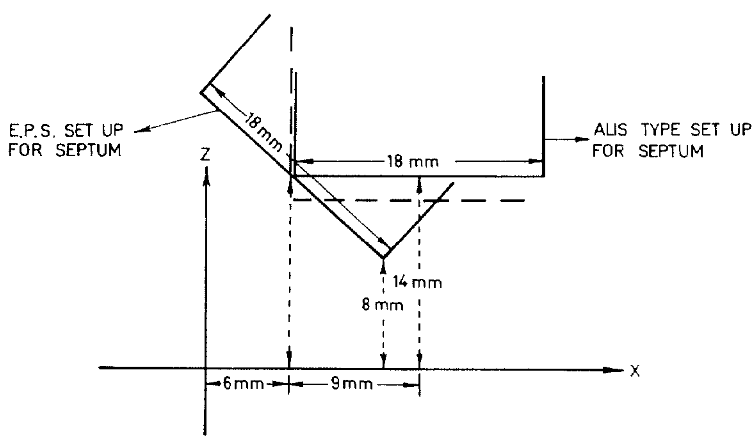

Fig. 1. Injection Septum.

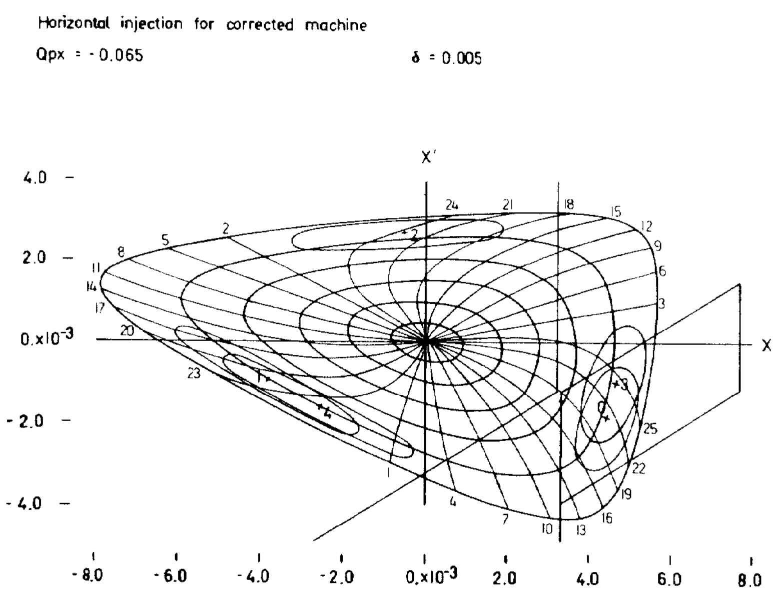

Fig. 2. Injection: Horizontal Analysis.

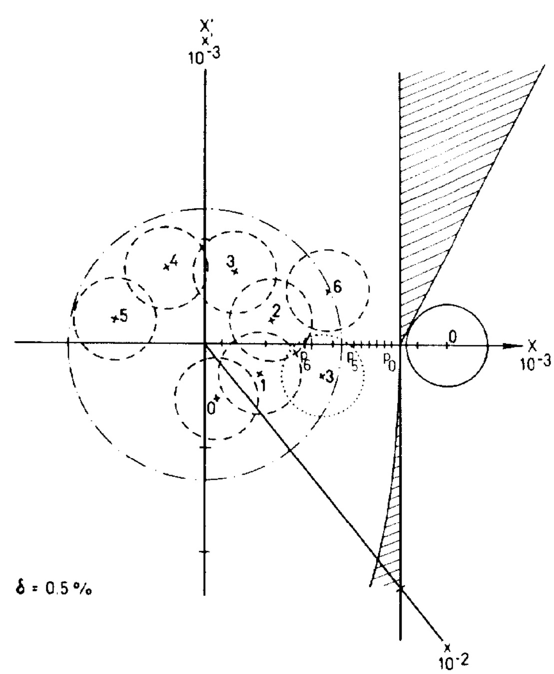

Fig. 3. Injection: Vertical Analysis.

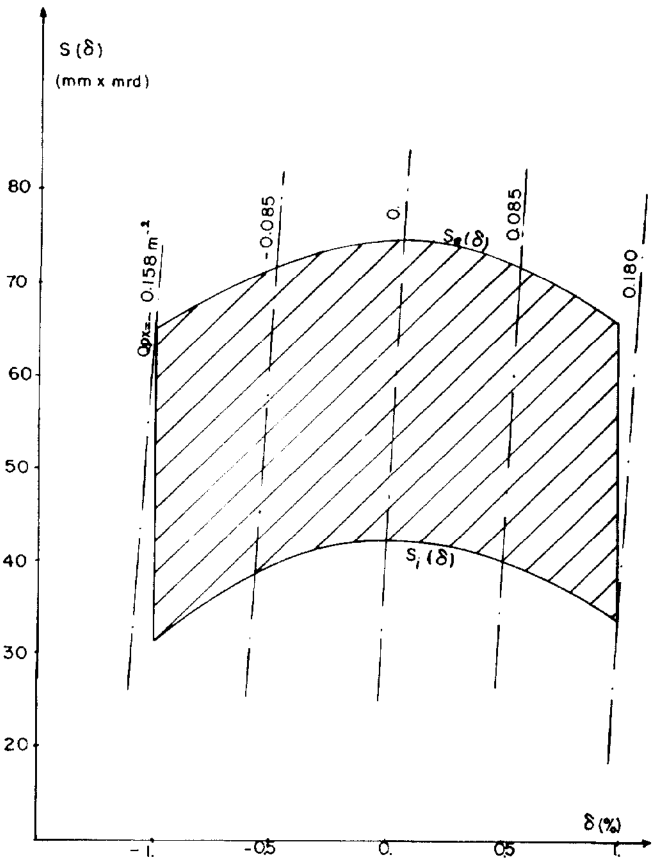

Fig. 4. Stability Curves and Beam (natural machine)

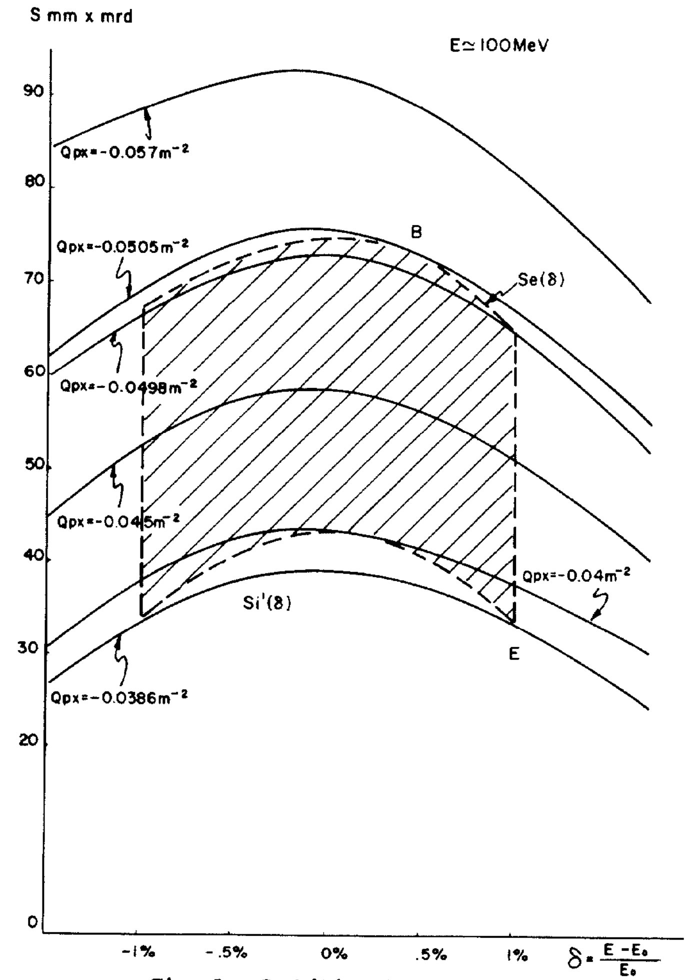

Fig. 5. Stability Curves and Beam (corrected machine)

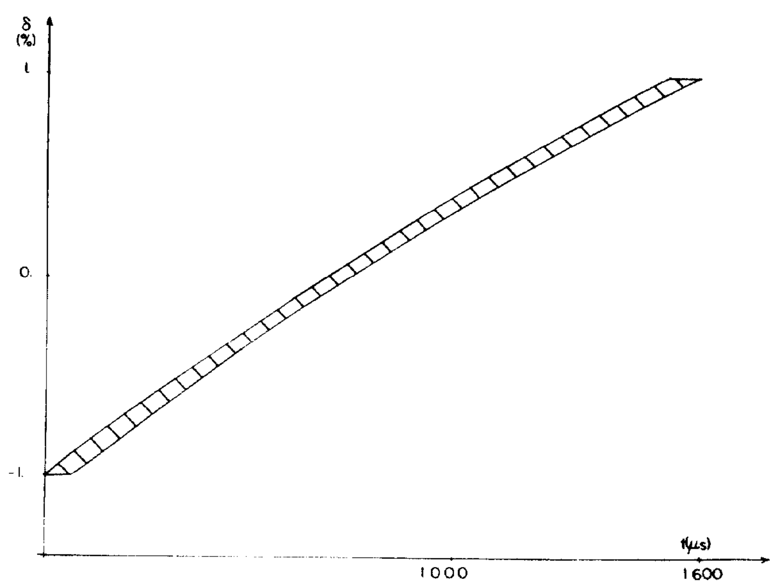

Fig. 6. Energy Spectrum Versus Time (chromatic extraction)

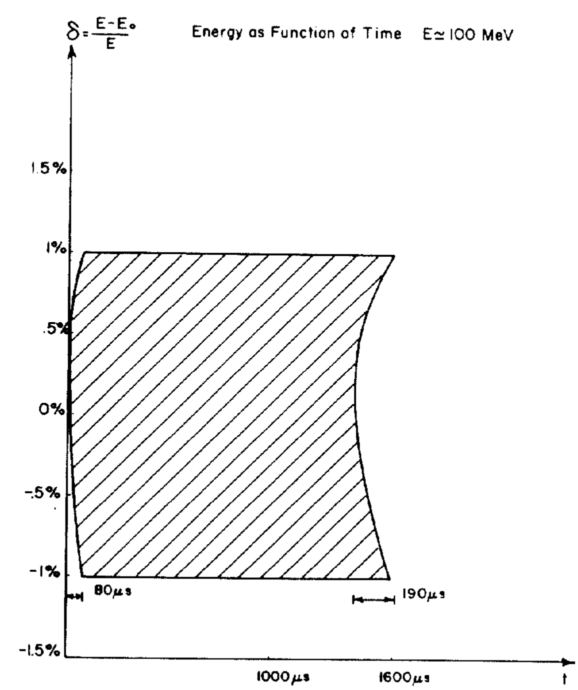

Fig. 7. Energy Spectrum Versus Time. (achromatic extraction)