THE ELETTRA LINAC TO STORAGE RING TRANSFER LINE

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ABSTRACT

The injection system for the ELETTRA storage ring is a full energy linac. It will be located underground outside the storage ring so as not to interfere with the experimental area. It will be constructed and operated in two stages: 1.5 GeV (for initial user operation) and 2 GeV (for final operation) with the option of conversion for positrons in a later stage. To obtain a small beam size as well as to implement many of identical elements, the transfer line exist of 4 achromatic arcs, three in the horizontal and one in the vertical direction. The matching between the achromatic arcs is performed with triplet- and FODO-systems. The longest transfer line (1.5 GeV) with a length of 103m needs 30 quadrupoles, 7 bending magnets and 34 steerer magnets. The largest beam size obtained throughout the transfer line is +/- 12 mm for electrons and +/- 17 mm for positrons. To get 95% of particles (2 GeV-positrons) through the transfer line and considering misalignment errors, the aperture of the magnetic elements has to be +/- 25 mm.

I. INTRODUCTION

The injection systems commonly used for second and third generation synchrotron light sources consist of a preaccelerator and a booster synchrotron. At Sincrotrone Trieste, a full energy linac (2 GeV) is now adapted, instead of the previous linac-booster injection system [1], in order to use the linac not only for injection but also for other purposes [1]. The first design of the transfer line [2],[3] was accomplished without any knowledge about the magnets steerers and monitors. Now all these parts are designed and the final structure of the whole transfer line is fixed.

The emittance for the electron beam from the linac is e (1.5 GeV, 80%) = 0.136 pi*mm*mrad and the energy spread is dp/p (1.5 GeV,68%) = 0.735% [4]. This means that the cross section of the beam in the transfer line is mainly given by the energy spread, hence, the deflection of the beam at the different points of the transfer line has to be performed with achromatic arcs. This has to be underlined if a conversation to positrons takes place, because the emittance and the energy spread increase to e (1.5 GeV, 80%) = 2.6 pi*mm*mrad and dp/p (1.5 GeV, 95%) = 1.95 % [5].

According to the design requirements [2],[3], the structure of the transfer line (see figure 1) consists of 4 parts:

1) the linac section between the end of the linac and the point A, where a horizontal deflection of 2p has to be taken to bend the beam to the inner side of the storage ring from which the injection takes place.

2) the horizontal section between the points A and B, with a horizontal deflection angle p at point B to deflect the beam to the storage ring direction.

3) the vertical section between the points B and C where the vertical deflection at the points V and W with a deflection angle p and -p is performed in order to translate the beam to the level and the neighbourhood of the storage ring.

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4) the injection section between point C and injection point I with a deflection angle p at point C.

II. MAGNETIC STRUCTURE OF TRANSFER LINE

The magnetic structures at points A and B are given by the requirement of an achromatic arc, which consists of two bending magnets (angle p) with a quadrupole in between. For the matching of the beta-functions, 4 quadrupoles are needed between the achromatic arc at point A and the 2 GeV-linac . In order to get small physical dimensions of the magnets, it was choosen to have a high magnetic induction (1.5 T) within the bending magnet and a maximum gradient of 22 T/m within the quadrupole.

The distance between the points A and B in the horizontal section is roughly 40 m. With the conditions at the end and the beginning of the arcs, one has to perform between both points a 1:1 image because in the vertical and horizontal direction the same beta functions exist. The matching can be done with a triplet-, doublet- or FODO-structure [2]. The FODO-structure has the advantage of having the smallest number of quadrupoles, the lowest gradients and the fact that both quadrupoles are identical. The matching to the adjacent achromatic arcs at points A and B can be done with two quadrupoles of opposite sign but with the same excitation. Consequently, for powering the quadrupoles between the points A and B, only two power supplies are needed. To get a higher degree of flexibility three have been taken.
To bridge the space of roughly 33 meters between the 1.5 GeV linac and the achromatic arc at point A in the linac-section, the same FODO-structure is used as in the horizontal one. Hence, identical cells can be used at each side of point A. This means that most of the quadrupoles will have the same excitation and only two power supplies are necessary to power them. This should be very helpful during commissioning.

The vertical section has the task to translate the beam height to the storage ring level. An achromatic arc for this purpose is built up of two magnets, with a deflection angle p each, one to bring the beam up, the other to bend the beam to the storage ring level. In such a structure, one needs at least two quadrupoles between the bending magnets to obtain an achromatic arc [4]. For matching reasons and in order to get a good flexibility, a quadrupole in the middle of the arc has to be added. This quadrupole affects only the beta functions but not the dispersion function.

To decrease the contribution of the energy spread to the beam size, the dispersion function has to be as small as possible. On the other hand, for matching reasons, the beta functions in the vertical and horizontal plane should not exceed 25 m/rad at the ends of the arcs and the difference between both should be as large as possible. These requirements can only be met by using five quadrupoles within the vertical section. These 5 quadrupoles are powered by three power supplies because of the symmetry about the midplane.

To make a dispersion free injection, an achromatic arc between the last bending magnet (point C) and the injection point I has to be build up, too. For the long distance between the bending

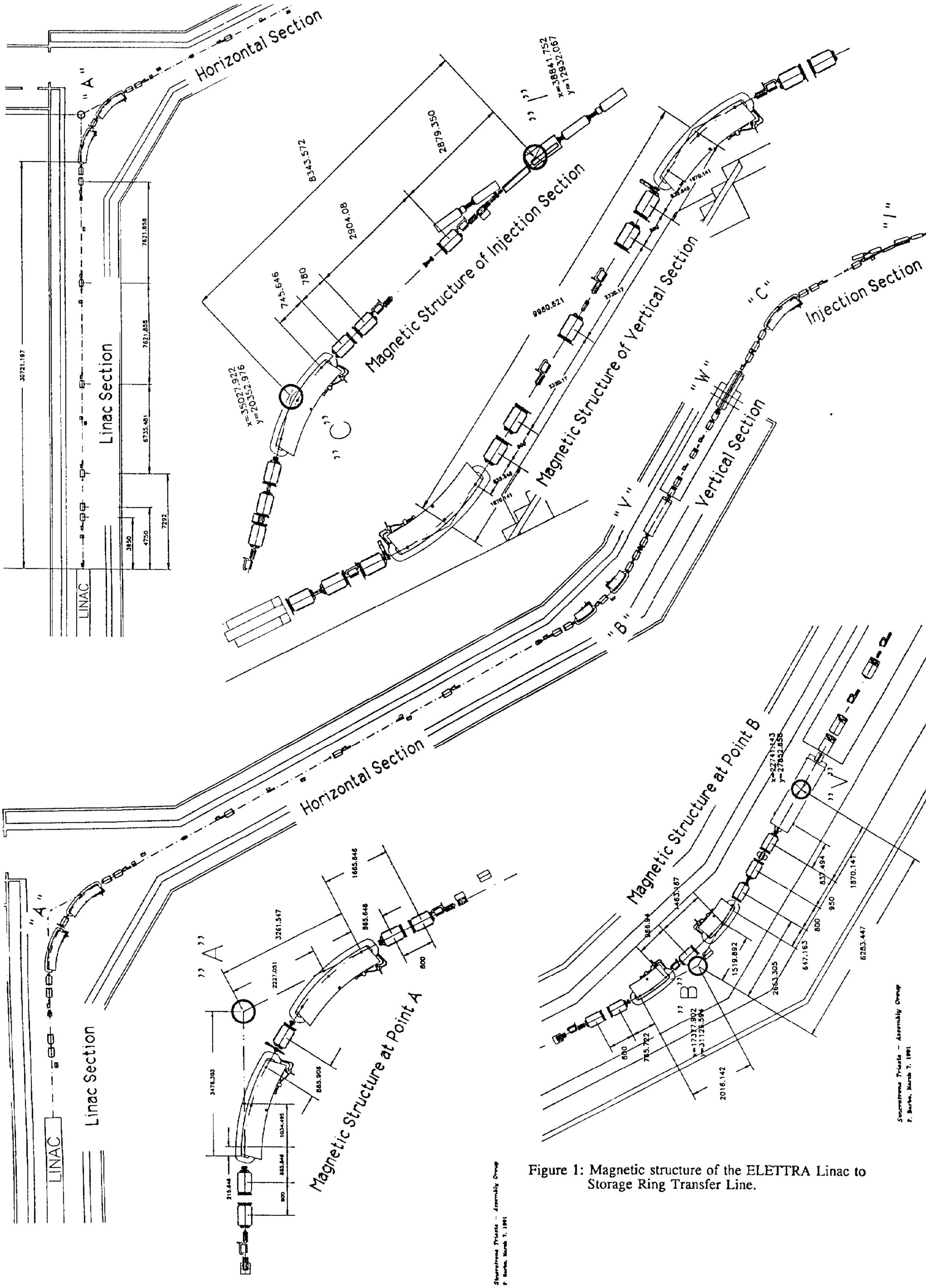


Figure 1: Magnetic structure of the ELETTRA Linac to Storage Ring Transfer Line.

magnet at point C and the injection septum, three quadrupoles are needed. At the end of the transfer line, a matching of the beta functions has to be performed to the values of the storage ring at the injection point. In order to get a smaller bump of the kickers, it might be worthwhile making a matching to bx = 4 m [1]. Furthermore, the injection efficiency is also a function of the injected beam size and, therefore, the injection section of the transfer line must have a high degree of flexibility. Thus, it should be possible to match the phase space of the injected beam in the x- and y-direction to beta values between 2 m/rad and 10 m/rad. To get this high flexibility, one needs at least three quads between the vertical section and the bending magnet at point C and three more quadrupoles between C and injection point I.

The structure of the transfer line is given in figure 1. Considering together all the bending magnets, a total deflection of 180 degree could be performed and with 30 quadrupoles the transfer line has twice as many quadrupoles as in the designed booster synchrotron [1].

III. LATTICE FUNCTIONS AND BEAM SIZES

The lattice functions of the whole "ELETTRA Linac to Storage Ring Transfer Line" are given in figure 2. The beam sizes for a 1.5 GeV electron and positron beam (95 % of particles) are given in figure 3 and 4. The largest beta functions in the transfer line are 35 to 45 m/rad; these are relatively small values for a transfer line and, therefore, gradient errors in the quads don't affect the beam sizes very much. The dispersion functions rise in the arc at points A and C as well as in the vertical section to values of 0.8 m.

These large values, in combination with the energy spread, lead to the prominent peaks of the beam envelopes in the transfer line: in the middle of the achromatic arc at point A, in the vertical section at the positions of the quadrupoles and in the injection section at the position of the quadrupole again. According to the particles, there exist beam sizes of 13 to 19 mm at these points. In the other parts of the transfer line, the beam sizes are roughly 2 mm (electrons) and 7-10 mm (positrons). In accordance with these values, an elliptical aperture (20mm * 30mm) at the dispersion region was chosen and a round aperture of 20 mm in the dispersion free regions. With these apertures, and taking into account misalignement errors, it should be possible to get an overall efficiency of 95% within the transfer line.

[1] ELETTRA Conceptional Design Report, April 1989

[2] D.Einfeld, 'The Transfer Line from 1.5 GeV Linac to Storage Ring', Sincrotrone Trieste Report: ST/M-90/1

[3] D.Einfeld and F.Iazzourene, 'The ELETTRA Linac to Storage Ring Transfer Line', EPAC 90, Proceedings of the 2nd EUROPEAN PARTICLE ACCELERATOR CONFERENCE, Nice, France, June 1990, pp 1294-1297

[4] G.D.Aurio and A.Massarotti, Private Communication

[5] ESRF Foundation Phase Report, Grenoble, France, 1987

[6] D.Tronc, Private Communication

Figure 1: Magnetic structure of the ELETTRA Linac to Storage Ring Transfer Line.

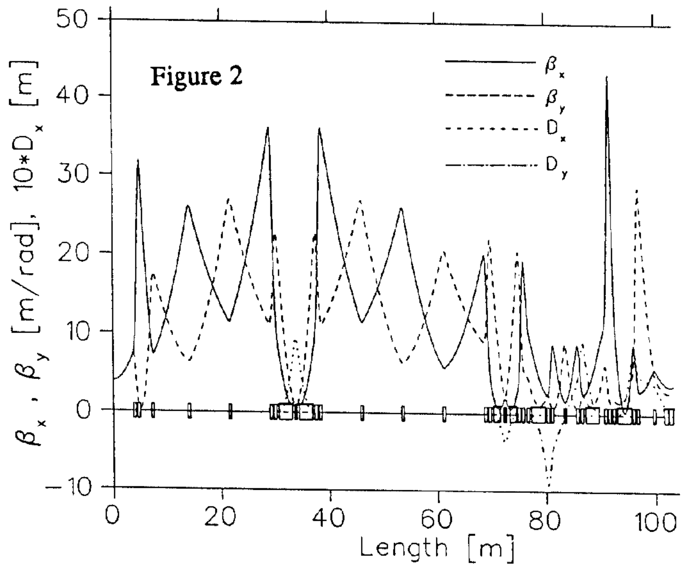
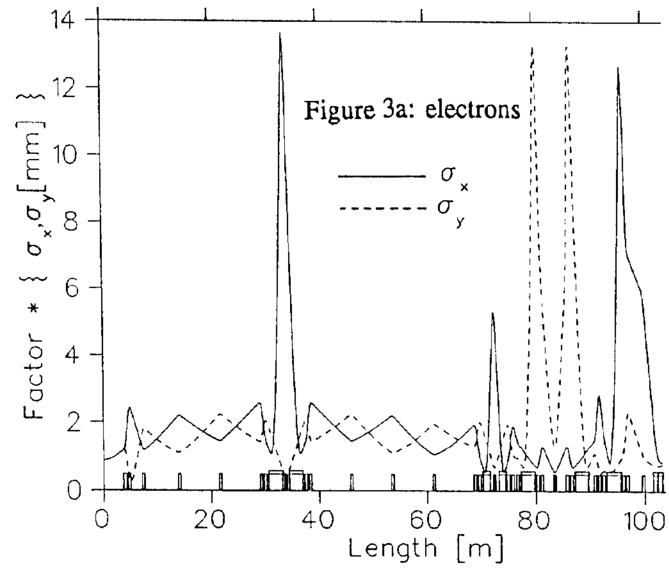


Figure 2: Lattice functions within the ELETTRA Linac to Storage Ring Transfer Line.



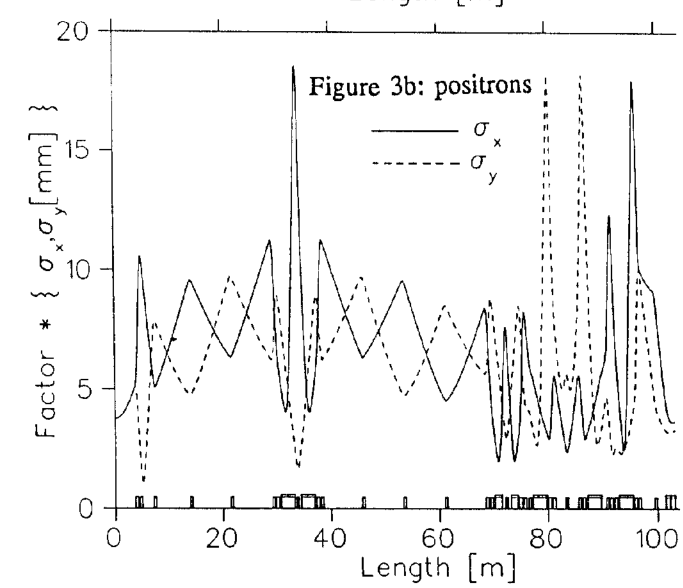


Figure 3: Beam sizes within the ELETTRA Linac to Storage Ring Transfer Line for a 1.5 GeV beam and including 95% of particles (3a: electrons, 3b: positrons).