Vertical Separation for TCF

M. Donald and A.Garren

Introduction

We studied an insertion for electrostatic separation of the electron and positron beams with the aims of:

- increasing luminosity by decreasing the minimum bunch spacing,
- matching the vertical dispersion function (not done in the Jowett[3] lattice)

We looked at three possibilities for the start of the insertion:

- a quadrupole doublet followed by the electrostatic separator (Jowett),
- a quadrupole doublet with the electrostatic separator between the two quadrupoles (Kamada[1]),
- a separator followed by a quadrupole doublet.

The third possibility was immediatly discarded. Although possible for a B-factory with magnetic separation it is impractical for use with electrostatic separation because of the length and cross section of separator required.

The Kamada scheme looked promising for getting very short inter-bunch spacing, but suffered from the disadvantage of requiring a very large ratio of beta functions at the Interaction Point (IP) ($\beta_x^*/\beta_y^* = 100$). (We would rather have a β^* ratio closer to 20 to 1).

We decided to persue the doublet scheme to see whether it could match the performance of Kamada's insertion. We assumed superconducting magnets could be used for the insertion quadrupoles, and we used as strong an electrostatic field for the separator as Kamada.

	Kamada		TCF	
full gap	0.08	m	0.05	m
length	1.35	m	2.00	m
deflection angle	1.91	mr	2.83	mr
bending radius	707	m	707	m
electric field	3.54	Mv/m	3.54	Mv/m
Voltage	283	Kv	177	Kv
$\beta_y(max)$	72.39	m	11.72	m
$\sigma_y(max)$	3.19	mm	1.28	mm
$gap/2\sigma_y$	12.54		19.53	

Table 1: Parameters at the separator plates

Interaction region optics

The layout and lattice functions of the three insertions (Jowett, Kamada and TCF) are shown in figures 1 through 3.

To compare lattices we take a ring 377 m in circumference, having a natural emittance of $281 \times 10^{-9} \times \pi$ meter radian. The Jowett ring has 24 bunches with a bunch spacing of 15.708 m, Kamada' s ring has 64 bunches with a spacing of 5.956 m.

If we wish our ring to have a bunch spacing equivalent to Kamada's, we must examine the vertical separation between electron and positron bunches at 5.956 m from the interaction point, but first we examine the values of separator voltages and electrostatic fields and show the results in table 1. Due to the much lower vertical beta function our design has a much larger clearance between the plates and the beam than does Kamada's, allowing a smaller interplate gap.

We now calculate the bunch separation at the required distance of 5.956 m from the IP and tabulate in table 2.

	Kamada		TCF	
δ_y	11.61	mm	9.22	mm
β_x	58.24	m	10.16	m
β_y	6.60	m	10.73	m
σ_x	4.045	mm	1.690	mm
σ_y	0.963	mm	1.228	mm
$\Delta y/\sigma_y$	5.740		10.905	

Table 2: Bunch separation (total) at 5.956 m from the IP

Strength of superconducting insertion quadrupoles

Using the natural emittance of the rings, and the maximum beta values in the region of the insertion quads, we find the aperture required for the insertion quadrupoles. Allowing 12σ beam-stay-clear + 1 mm for misalignment and 1 mm for the beam pipe thickness, we find the minimum inner radius for the superconducting winding. With this radius and the focussing strength of the quadrupoles we find the pole tip field of the quadrupoles.

$\epsilon = 281 \times 10^{-9} \times \pi$ meter radian

$\beta_x(\mathrm{max}) = 25$ m

$\beta_y(\mathrm{max}) = 36$ m

$\sigma_x = 2.65$ mm

$\sigma_y = 2.25$ mm

$12\sigma(max) + 2$ mm $= 33.8$ mm

K(QD1) = -9.45 m^{-1}

K(QF2) = 5.40 m^{-1}

E = 2.5 Gev

B(QD1) = 2.66 T

B(QF2) = 1.52 T

	Kamada		TCF	
δ_y	18.45	mm	14.72	mm
β_y	3.06	m	11.41	m
σ_y	0.656	mm	1.266	mm
δ_y/σ_y	28.13		11.62	

Table 3: Beam separation (half) at the entrance of the first septum magnet BV1

Vertical septum magnets

We follow Kamada in using two vertically deflecting septum magnets to complete the beam separation that was started with the electrostatic separator. Once again we examine the separation of the beams, this time at the entrance of the first septum magnet BV1 (table 3).

In this case we find that our separation is inadequate, and we will have to make a change in the design (the easiest change is to increase the length of the separator).

Matching the vertical dispersion

To match the vertical dispersion we require about 2π of phase shift in the vertical plane between the septum magnets and the vertical bend BV3. The horizontally defocussing quadrupoles QD4 and QD6 provide this phase shift, the horizontally focussing quadrupole QF5 has minimal effect on the vertical dispersion, and is set so that the maximum horizontal beta function in that region is close to the maximum vertical beta function. The optics of the vertical dispersion suppressor are shown in figure 4.

Matching of the IP to the vertical dispersion suppressor

With greatly reduced values of the beta functions at the insertion quadrupoles, it is not possible to match into the vertical dispersion suppressor without additional focussing. This additional focussing has been provided by adding gradients to the septum magnets BV1 and BV2. (The feasability of these combined function septum magnets has to be determined)

We have not yet investigated the range of beta functions at the IP that can be accomodated (with a reasonable match to the dispersion suppressor) without adjusting the gradients in BV1 and BV2.

Matching to the regular cells

We match the vertical dispersion suppressor into the regular cells (cells of 60 degrees phase shift, identical to those of Jowett) using a missing magnet cell to match the horizontal dispersion function, and we match the beta functions using quadrupoles QD7, QD8 and QF9. The optics from the IP to the normal cells are shown in figure 5.

We really need another quadrupole here and should add QD10 to match into the regular cells, which should then start with a QD rather than a QF.

Chromaticity

The tunes and chromaticities of the Jowett and TCF insertions are shown in table 4. The chromaticities were found by taking the insertion region as far as the first normal cell and reflecting it so as to close the ring. The chromaticities found this way are then the values for the full insertion. It is seen that the chromaticities have been reduced compared to the Jowett ring (particularly in the horizontal plane), even though the vertical dispersion suppressor has been added.

	Jowett	TCF
ν_x	3.806	2.201
ν_y	3.058	3.556
ξ_x	-14.202	-6.542
ξ_y	-23.326	-15.151

Table 4: Tunes and chromaticities of the insertions

Discussion

Our design has inadaquate separation at the first of the vertically deflecting septum magnets. We could either:

- move BV1 and BV2 further from the IP (adding quadrupoles in the place where they were),
- increase the length of the electrostastic separator.

The first solution is probably the better, but it involves both beams going off axis through the quadrupoles. We should also do a few more things.

- We should add another quadrupole to give a more flexible match between the vertical dispersion suppressor and the normal cells.
- We should look closely at the synchrotron radiation from the septum magnets and determine whether it is possible to mask it. Alternativly, a similar separation scheme could be accomplished using crossed electric and magnetic fields as described by Kroll[2].
- We might also wish to add a small tune changing section between the vertical dispersion suppressor and the normal cells to aid in correction of the chromaticity.

Conclusions

We have made a first shot at a vertical separation scheme using electrostatic fields. More work needs to be done to complete the insertion and finish the design of the ring, but we have shown that there are advantages to be gained by moving the insertion quadrupoles as close to the IP as possible.

References

[1] S. Kamada (KEK). *"KEK Tau-Charm Facility Design", this workshop.*

[2] Norman M. Kroll (SLAC/UCSD). *"Cross Electric Magnetic Field Beam Separator for Application to τ-Charm Factory Storage Rings", this workshop.*

[3] John Jowett (CERN). *"The τ-charm Factory Storage Ring", this workshop.*

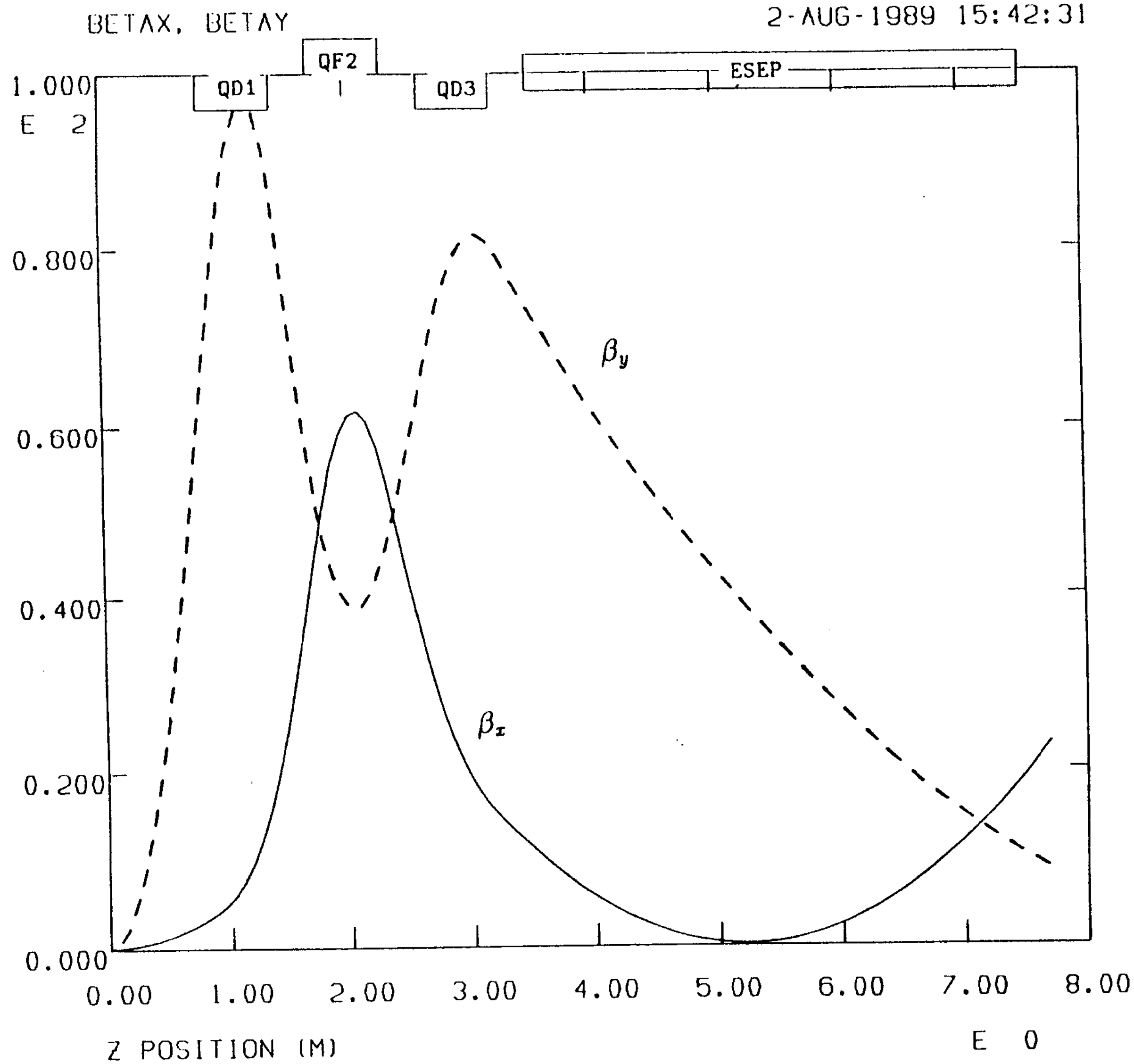

Figure 1: Optics close to the IP - Jowett lattice

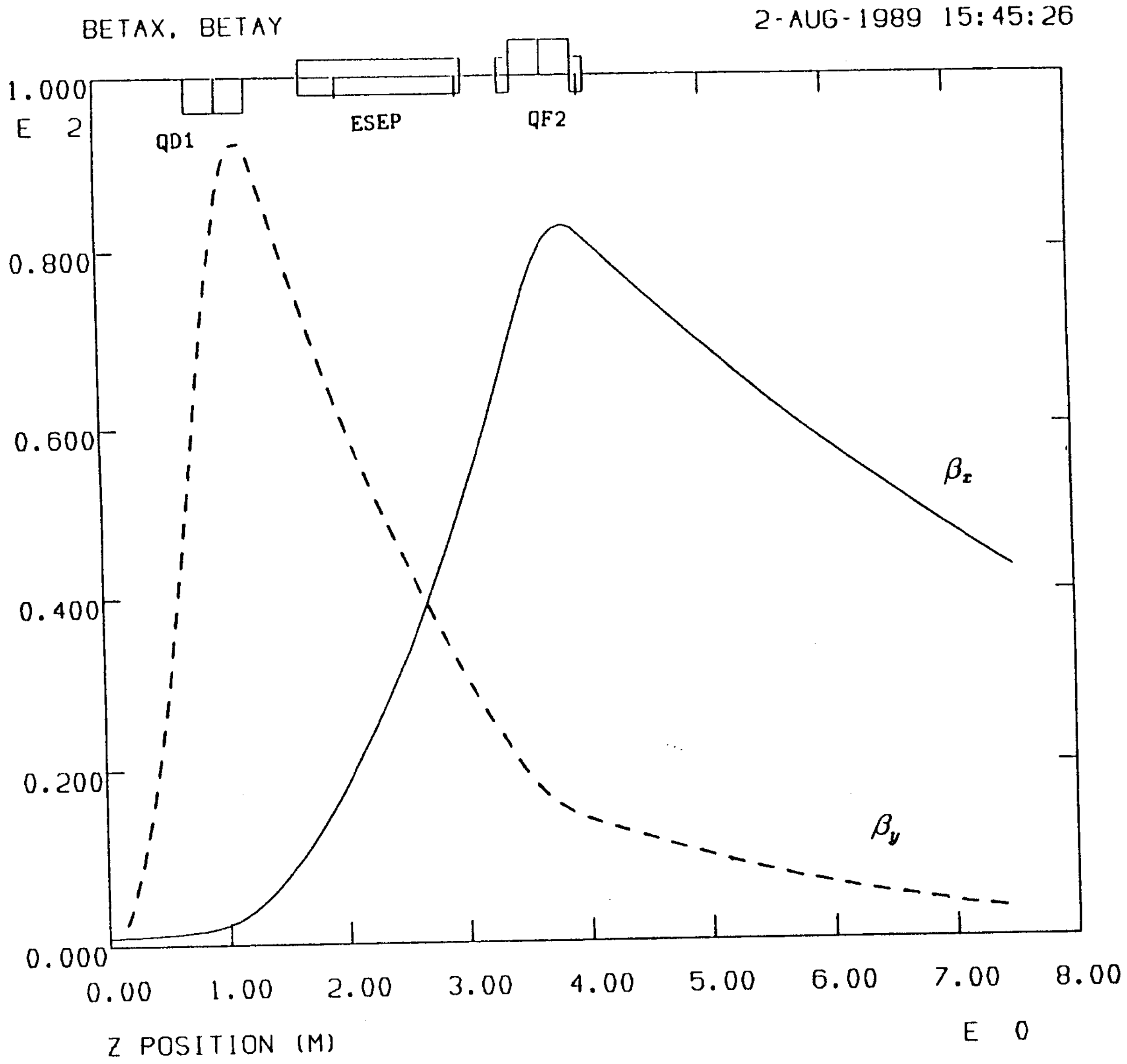

Figure 2: Optics close to the IP - Kamada lattice

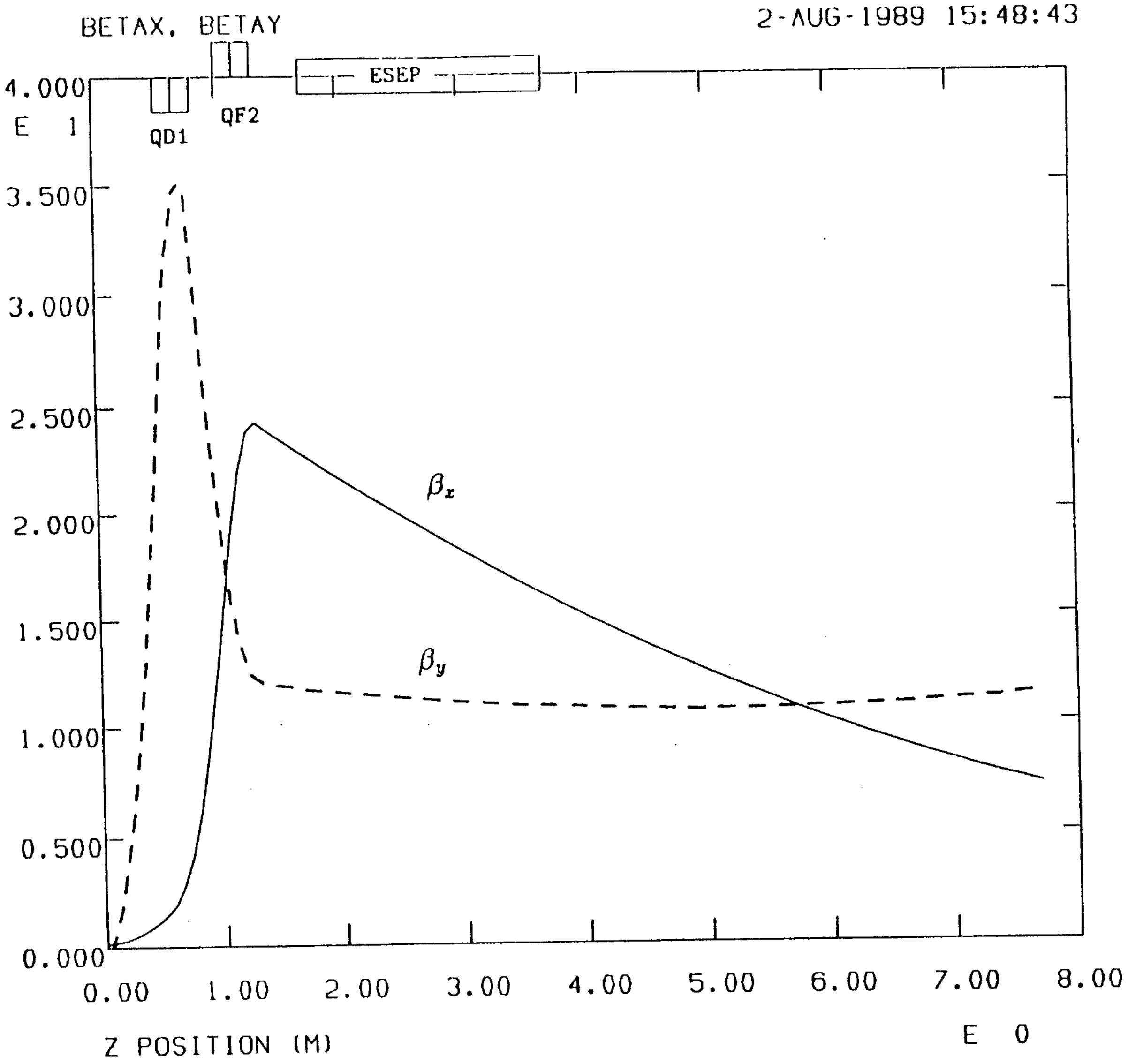

Figure 3: Optics close to the IP - TCF lattice

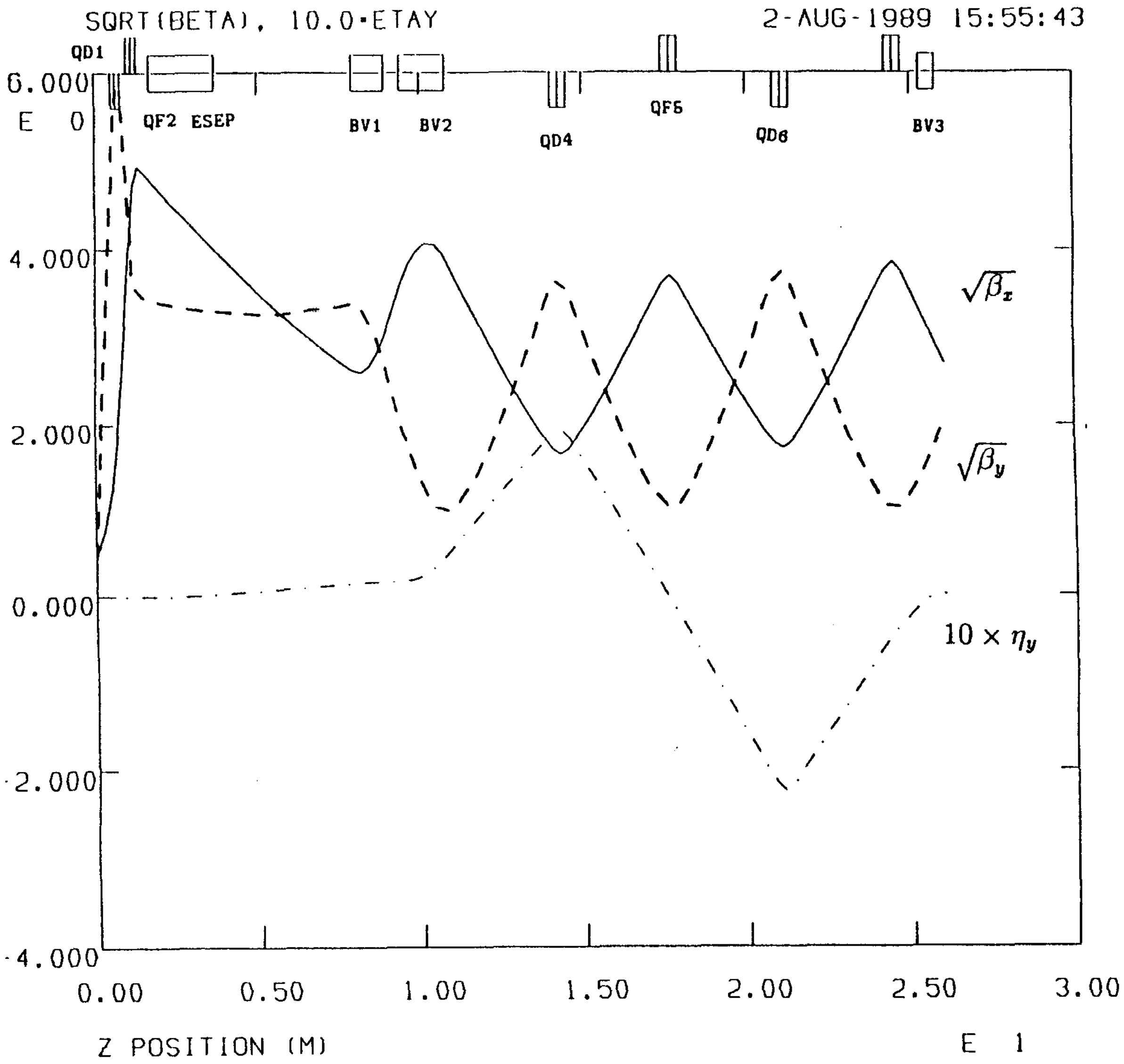

Figure 4: Optics of the vertical dispersion suppressor

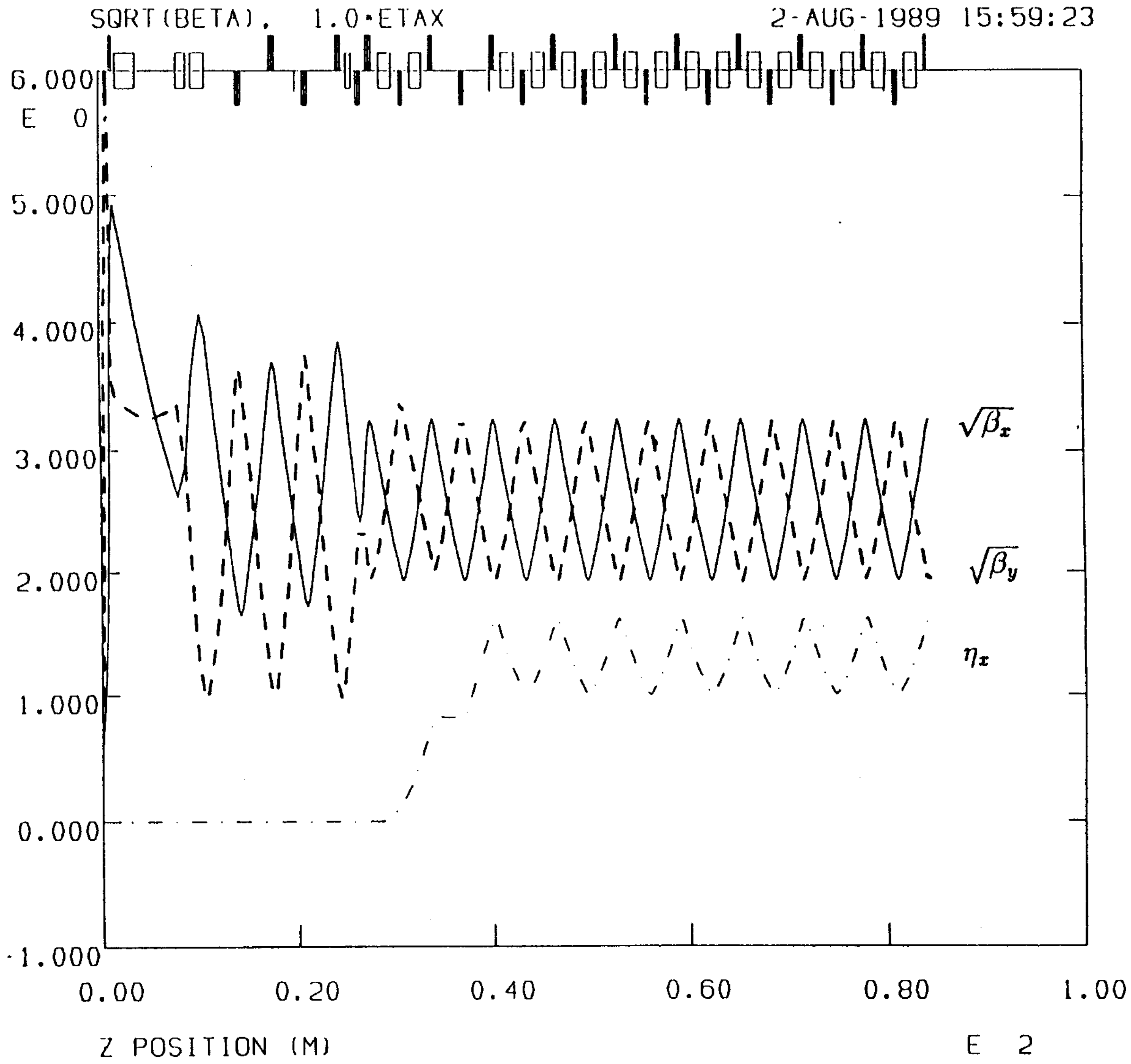

Figure 5: Optics to the normal cells - TCF lattice