DAΦNE TECHNICAL NOTE

INFN - LNF, Accelerator Division

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Note: **I-3**

ELECTRON/POSITRON TRANSPORT-LINES FROM AND TO THE ACCUMULATOR RING FOR DAΦNE

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This note is to describe a preliminary design of a section of the transport lines for the DAΦNE which are utilized to transport electron/positron-beams from the LINAC to the accumulator ring, and from the accumulator ring to the main ring.

One of the difficulties in the design lies in the section which is shared by different beams in different directions. Since the focusing force is both charge and direction-dependent, a polarity of a magnet could change in different cases. There are four different types: an electron beam from the LINAC to the accumulator and from the accumulator to the LINAC, and positron beams also in both directions. The most demanding of all is the positron beam from the LINAC which has the highest emittance (or acceptance) ($\sim 10^{-5}$ m. rad.) and the largest momentum spread ($\sim 10^{-2}$) among those types. Therefore the configurations shown in the following has been optimized for this case and with different types of beams only the strengths of quadrupoles are changed.

Another point which should be reminded is that because of damping in the ring the beams from the accumulator have Gaussian distribution with tails unlike those from the LINAC. Therefore one must at least take $\pm$ 3 σ (~99.5%) to be a stay-clear aperture.

The latest design of the transport lines for the DAΦNE (Fig. 1) eliminates rotated and tilted dipole-magnets in the original design which would inevitably induce a coupling of emittances [1]. A computer-code LEDA [2] was used to calculate the optical functions and to determine the configuration of the focusing magnets. The parameters of the magnetic elements are given in Table I. The path lengths at each element from the injection point to the accumulator are given in Table II.

The half-width of beam envelope is calculated by the following formula.

$$\Sigma_i = C\sqrt{\varepsilon_i\,\beta_i + \left\{\eta_i\left(\frac{\Delta p}{p}\right)\right\}^2} \qquad (1)$$

where i = x or z. ε_i is the emittance for a Gaussian beam or the equivalent acceptance for a square beam. β_i is the betatron function and η_i is the dispersion function. $\Delta p/p$ represents the momentum spread of the beam, and C is multiplication factor (1.1 for the incoming beam and 3.0 for the outgoing beam).

Fig. 2-a shows the optical functions for the incoming beam to the accumulator ring, and the half-widths of the beam-envelopes are shown in Fig. 2-b where the vertical width is shown with a reversed sign. The probable value of the emittance and the momentum spread of the positron beam from LINAC have been chosen to be 1.0×10^{-5} m. rad. and 1.0×10^{-2}, respectively. Fig. 3-a shows the optical functions for the out-going beam from the accumulator, and Fig. 3-b also show the half-widths of the beam envelope. The emittance of the beam from the accumulator is to be around 3.0×10^{-7} m. rad. and the momentum spread are taken to be 1.0×10^{-3}.

For the outgoing beam the horizontal dispersion doesn't have to be zero at the end of the last bending magnet (right most), since it can be compensated in the later section of the transport line towards the main ring. However, when the strengths of magnets between the vertical bending-magnets are changed, the vertical dispersions at the both ends of the vertical bending magnets must disappear in any case.

REFERENCES

[1] See, for example, S. G. Peggs: "Coupling and Decoupling in Storage Ring", CERN SPS/83-12.

[2] G. Vignola and J. Murphy (unpublished).

TABLE 1 - Magnetic Elements

* The number in the parentheses indicates that of elements. Σ's are the maximum values within the element.

SEPTA

Designation	Length (m)	θ (˚)	Dipole field (T)	Σ_x * (mm)	Σ_z * (mm)
SEP1 (2)*	0.4987	2.0	0.119	5.89 (in) 3.36 (out)	8.47 (in) 4.10 (out)
SEP2 (2)	1.2331	34.0	0.824	6.16 (in) 5.03 (out)	8.26 (in) 4.62 (out)

DIPOLES

Designation	Length (m)	θ (˚)	Dipole field (T)	Σ_x (mm)	Σ_z (mm)
VB1 (2)	0.3633	6.542	0.535	20.47 (in) 9.13 (out)	5.80 (in) 3.64 (out)
VB2 (2)	Same as above			12.26 (in) 9.94 (out)	5.38 (in) 3.81 (out)
TR1	1.0	36.0	1.069	11.71 (in) 10.93 (out)	10.55 (in) 8.74 (out)
HB1	1.113	45.0	1.201	11.96 (in) 17.13 (out)	9.05 (in) 8.51 (out)
HB2	Same as above			19.38 (in) 16.74 (out)	8.97 (in) 9.00 (out)

QUADRUPOLES

(INCOMING POSITRONS)

Designation	Length (m)	Gradient (T/m)	Σ_x (mm)	Σ_z (mm)
QA1	0.2	8.51	11.23	8.38
QA2	0.2	1.53	8.51	7.93
QB1	0.4	6.16	26.62	3.58
QB2	0.4	9.02	14.40	8.68
QB3	0.4	4.17	15.96	3.55
QB4	0.4	7.85	7.88	5.60
QB5	0.4	2.55	12.53	3.24
QB6	0.4	1.83	15.41	16.41
QB7	0.4	2.38	22.00	27.87
QB8	0.4	2.01	44.24	19.47
QB9	0.4	1.94	36.63	24.85
QB10	0.4	2.04	56.18	10.52
QB11	0.4	0.97	28.23	3.44

(OUTGOING ELECTRONS/POSITRONS)

Designation	Length (m)	Gradient (T/m)	Σ_x (mm)	Σ_z (mm)
QA1	0.2	7.23	5.97	4.81
QA2	0.2	1.53	11.96	1.51
QB1	0.4	5.78	11.16	1.38
QB2	0.4	8.95	5.81	2.23
QB3	0.4	3.57	5.98	1.68
QB4	0.4	7.83	4.49	3.29
QB5	0.4	2.38	9.41	1.38
QB6	0.4	1.83	6.80	12.17
QB7	0.4	2.38	8.43	9.09
QB8	0.4	2.01	5.84	12.43
QB9	0.4	1.94	12.02	5.64
QB10	0.4	2.04	9.58	3.58
QB11	0.4	0.97	16.13	2.81

TABLE 2 - The Path Length at Each Element

In this table a drift space is designated as O. Defocusing magnet is D and focusing magnet is F in polarity.

Designation	Length (m)	Polarity (in)*	Polarity (out)*	
SEP1	0.4987	+	+	
O	0.5			
SEP2	1.23311	+	+	
O	0.47444			
QA1	0.2	D	D	
O	0.2			
VB1	0.36332	+	+	
O	0.3			
QB1	0.4	F	F	
O	0.4123			
QB2	0.4	D	D	
O	0.5473			
QB3	0.4	F	F	
O	0.72611			
QB4	0.4	D	D	
O	0.621193			
QB5	0.4	F	F	
O	0.3			
VB2	0.36332	-	-	
O	0.60081			
TR1	1.0001	-	-	
O	1.2			
QB6	0.4	D	F	
O	1.1			
QB7	0.4	F	D	
O	1.27416			
QB8	0.4	D	F	
O	1.87419			
QB9	0.4	F	D	
O	1.5708			
QB10	0.4	D	F	
O	1.75			
QB11	0.4	F	D	
O	1.75			
HB1	1.11291	+	-	(must be changed)
O	4.45			
QA2	0.2	F	D	
O	4.34			
HB2	1.11291	off	+	

* For the dipole + means the same polarity as the booster.

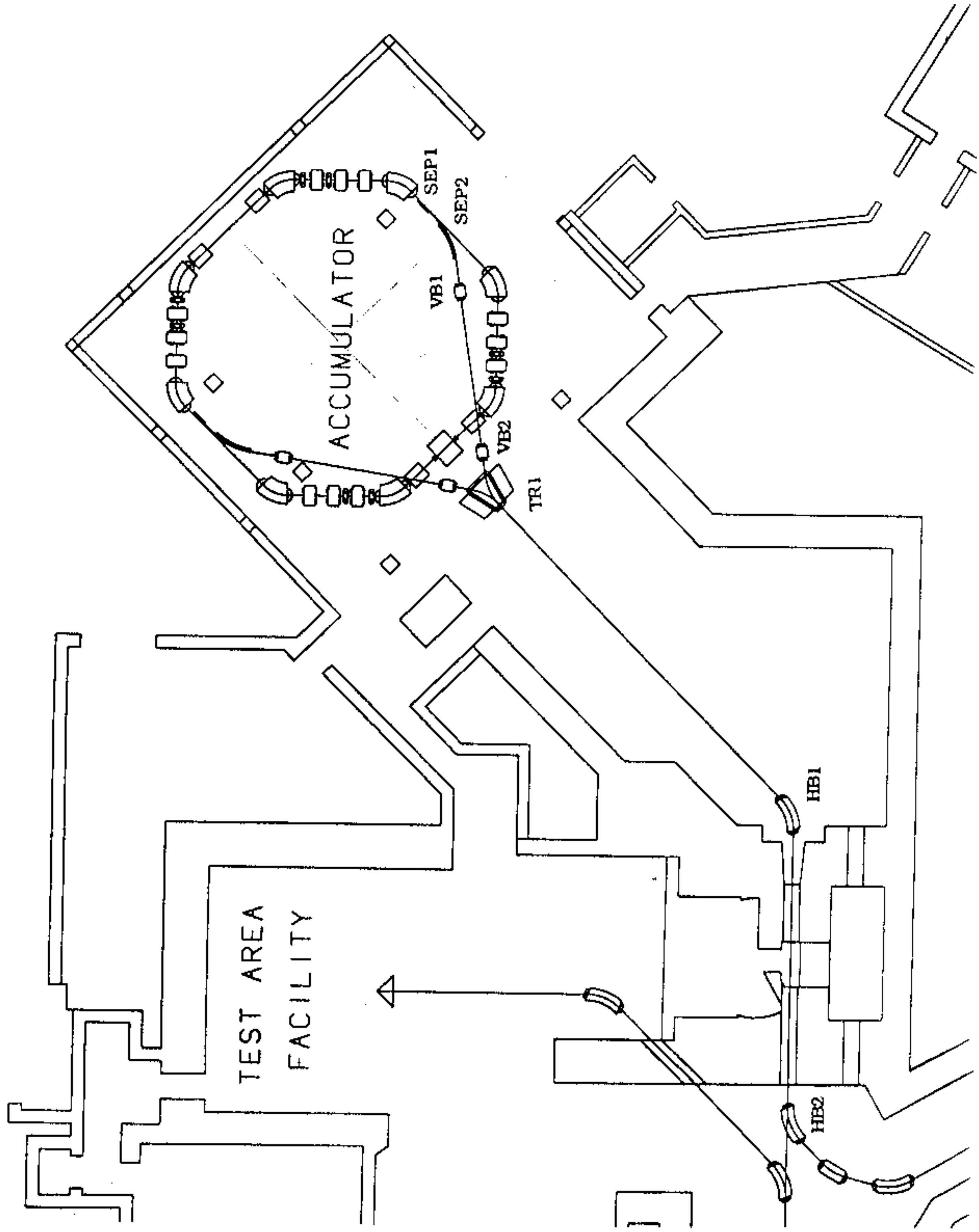

Fig. 1 - The lay-out of the section of transport lines.

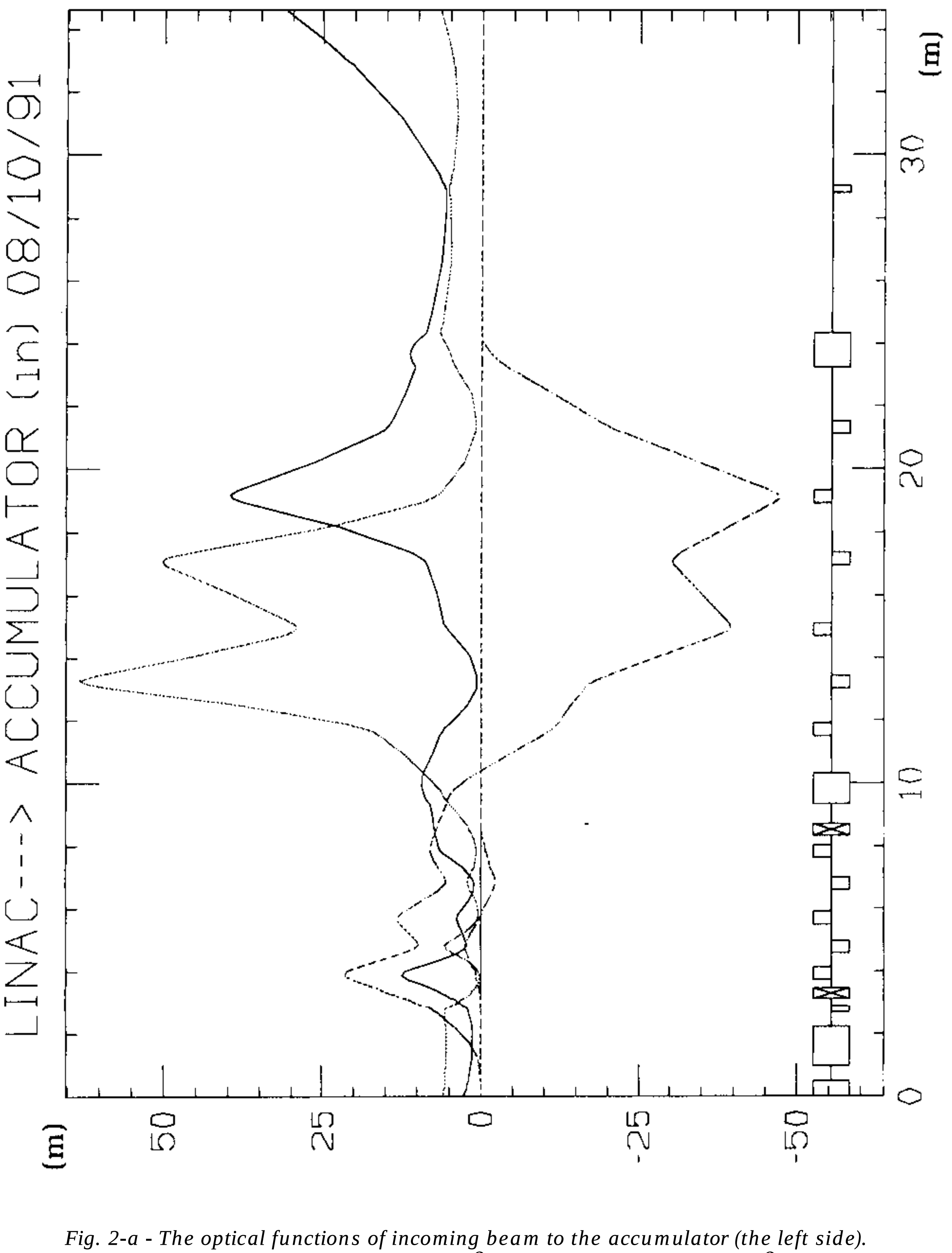

Fig. 2-a - The optical functions of incoming beam to the accumulator (the left side). The solid line corresponds to β_x and the dashed line to β_z. The dot line represents ten times horizontal dispersion (10 η_x) and dot-dashed line is ten times vertical dispersion (10 η_z).

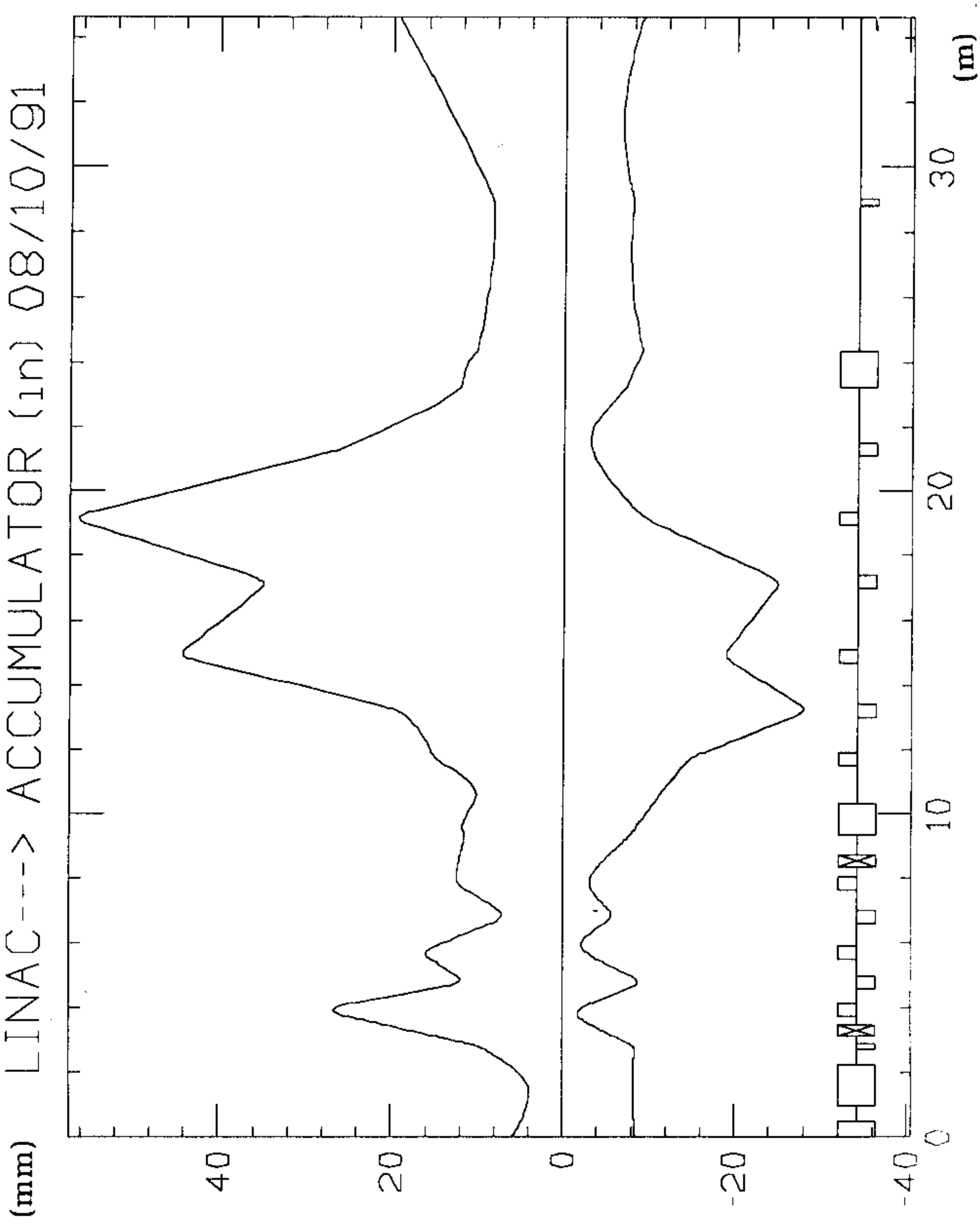

Fig. 2-b -The horizontal and vertical beam-envelope as a function of distance for the incoming beam. The beam-emittance for each plane is 1.0 $\times 10^{-5}$ m.rad. The line in the upper half corresponds to Σ_x and that in the lower half to Σ_z, both with $\left(\frac{\Delta p}{p}\right) = 1.0 \times 10^{-2}$.

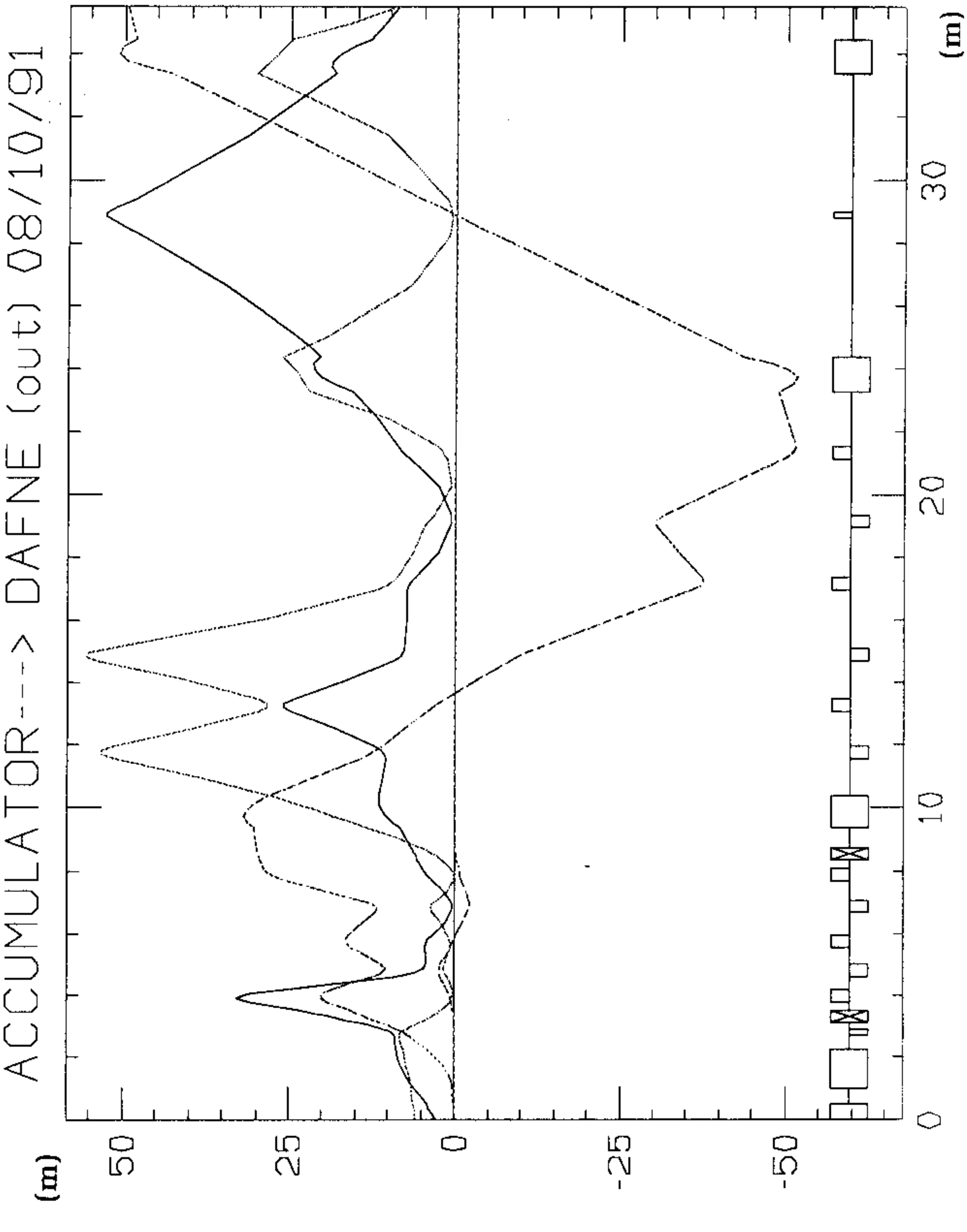

Fig. 3-a - The optical functions of outgoing beam from the accumulator (the left side).
The solid line corresponds to β_x and the dashed line to β_z.
The dot line represents ten times horizontal dispersion (10 η_x)
and dot-dashed line is ten times vertical dispersion (10 η_z).

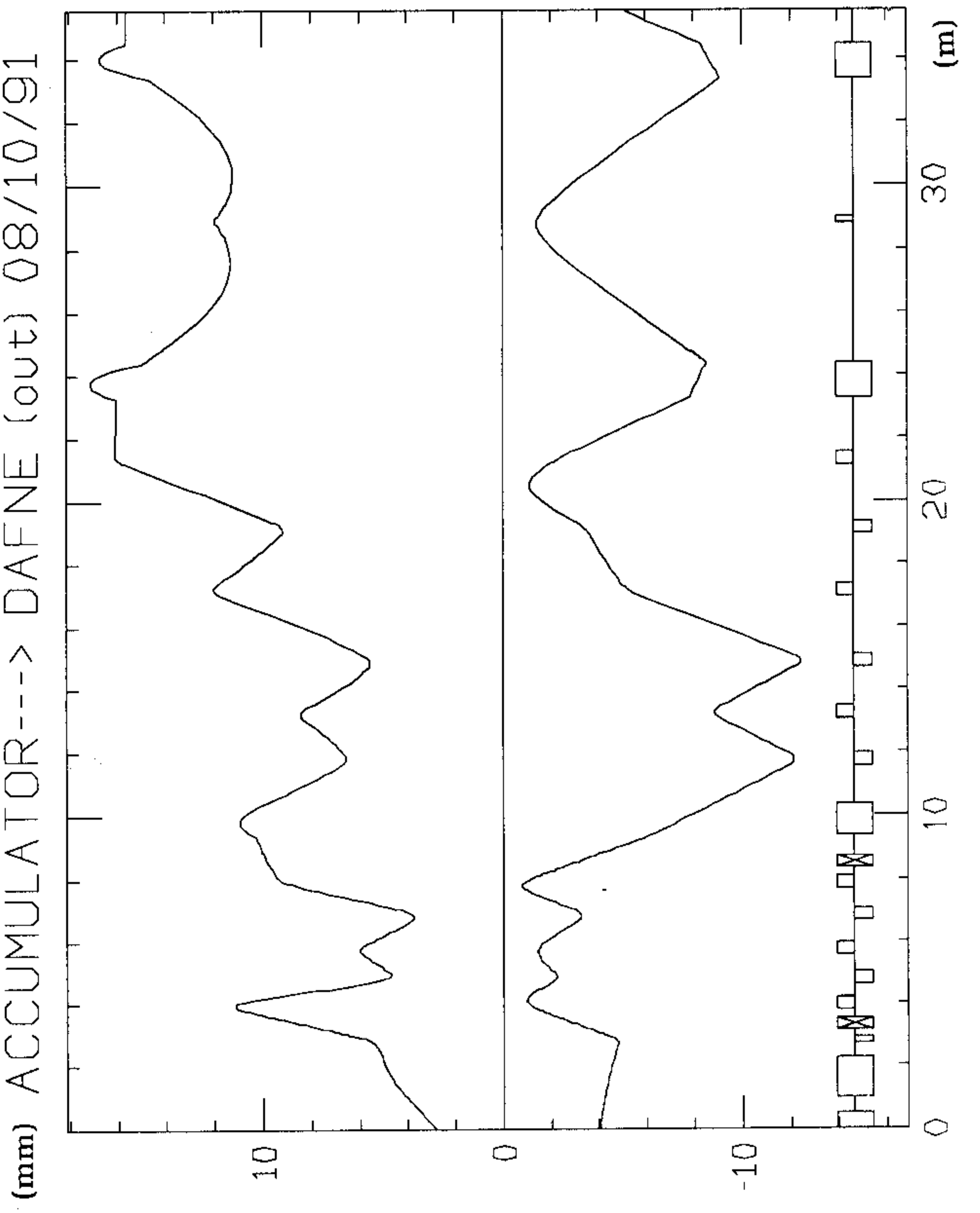

Fig. 3-b - The horizontal and vertical beam-envelope as a function of distance for the outgoing beam. The beam-emittance for each plane is 3.0×10^{-7} m.rad.. The line in the upper half corresponds to Σ_x and that in the lower half to Σ_z, both with $\left(\frac{\Delta p}{p}\right) = 1.0 \times 10^{-3}$.