COMBINER RING AND DELAY LOOP

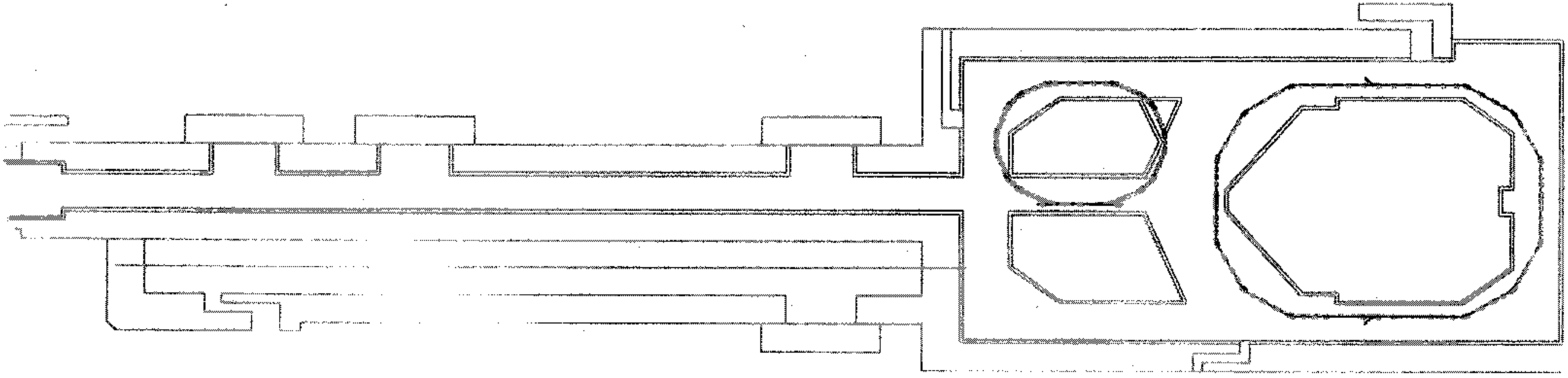
DESIGN STATUS

F. Sannibale

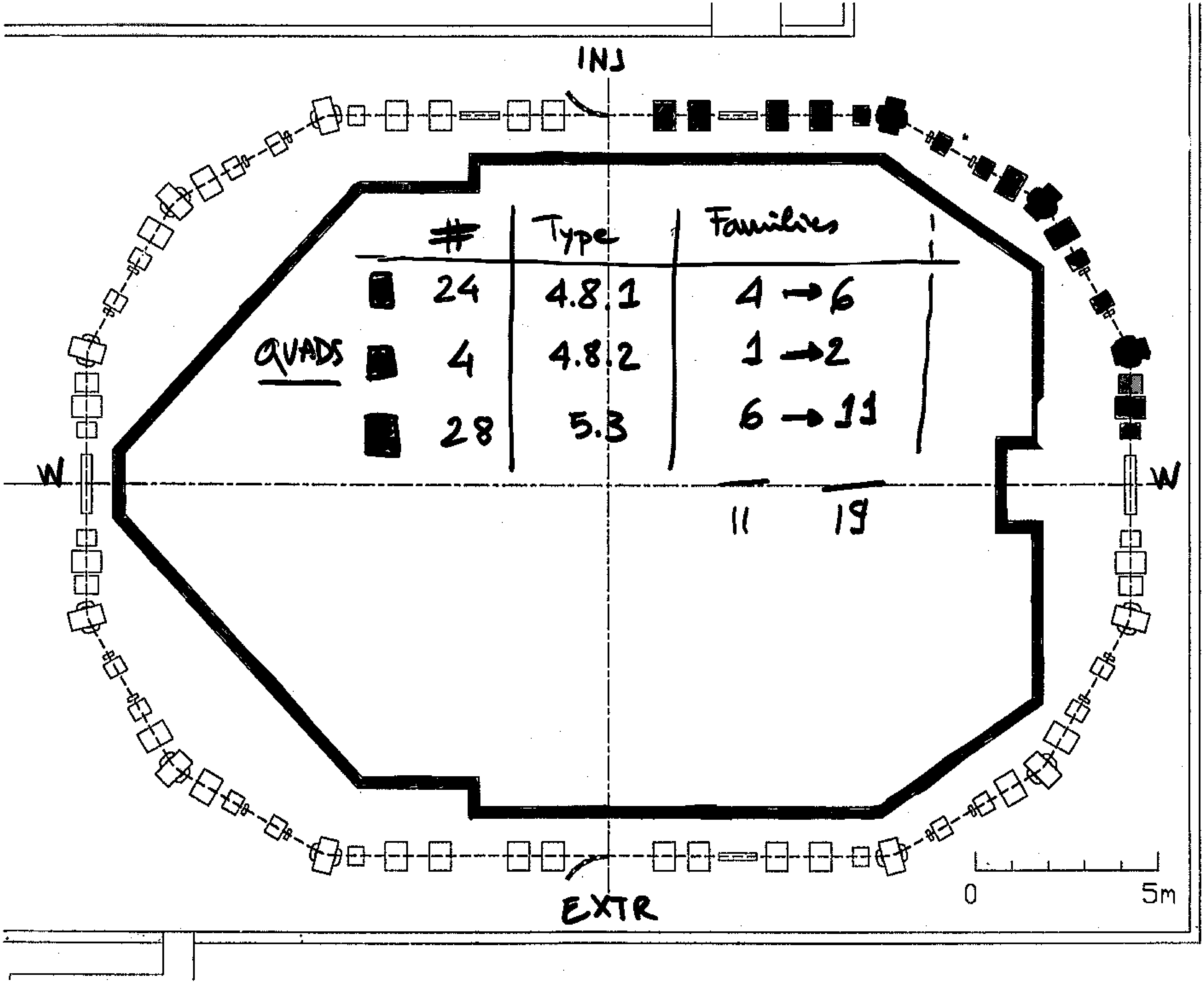
CTF3 COMBINER RING

by C. Biscari

CTF3 Collaboration Meeting

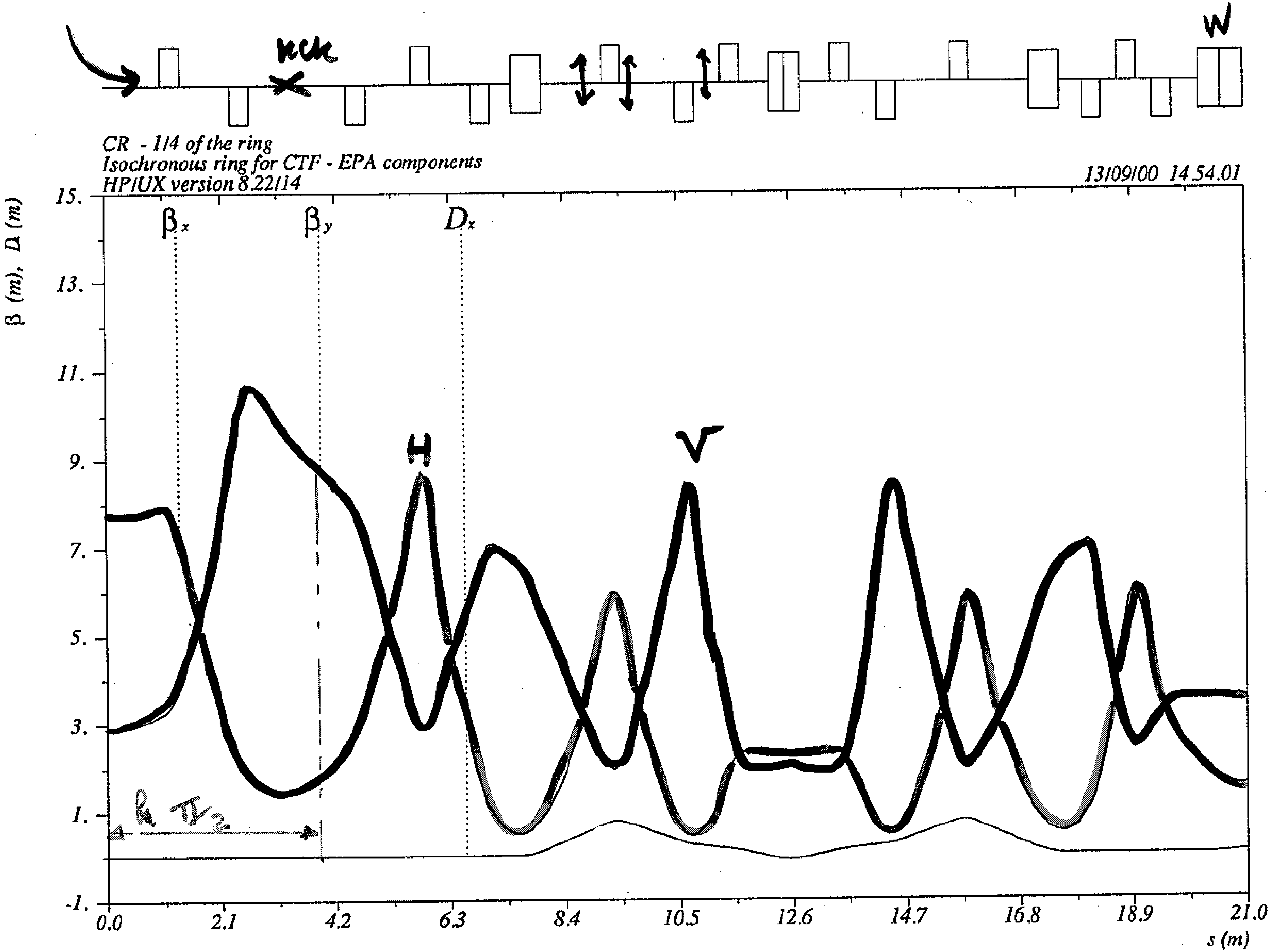


CTF3 BUILDING


INJ
EXTR
W
W
QUADS
#
Type
Families
24
4.8.1
4 → 6
4
4.8.2
1 → 2
28
5.3
6 → 11
11
19
0
5m

COMBINER RING PARAMETERS

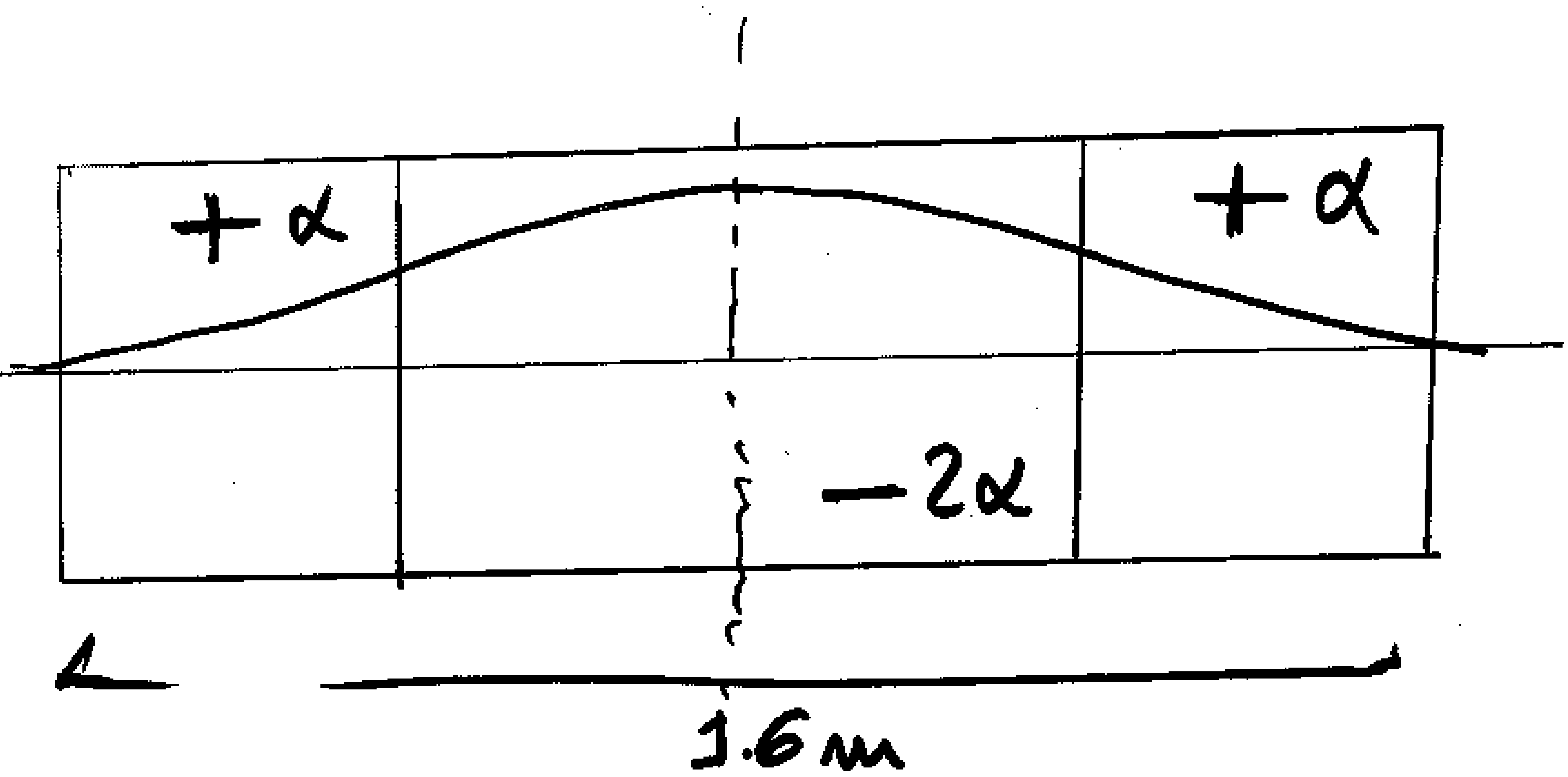
Energy (MeV)	E	180/350
Circumference (m)	C	84
Bending Radius (m)	ρ	1.075
No. Cells	N_C	4
Cell Length (m)	L_C	11.0
No. Dipoles	N_B	12
Dipole Length (m)	L_B	0.56
Dipole Field (T)	B	0.5/1.6
No. Quadrupoles	N_Q	52
Quadrupole Length (m)	L_Q	.35
Max. Gradient (T/m)	G_Q	2.5/7.0
No. Sextupoles	N_S	24
Sextupole Length (m)	L_S	.1
Max. Sext. Gradient (T/m^2)	G_S	50/170
Max. Twiss β-function (m)	β_x, β_y	8.2/10.7
Max. Dispersion (m)	D	.73
Horizontal Tune	Q_x	8.23
Vertical Tune	Q_y	3.52
Horizontal Chromatism	Q_x'	-11
Vertical Chromatism	Q_y'	-9



$\delta E/p_0c$ = 0.

Table name = OPTICS

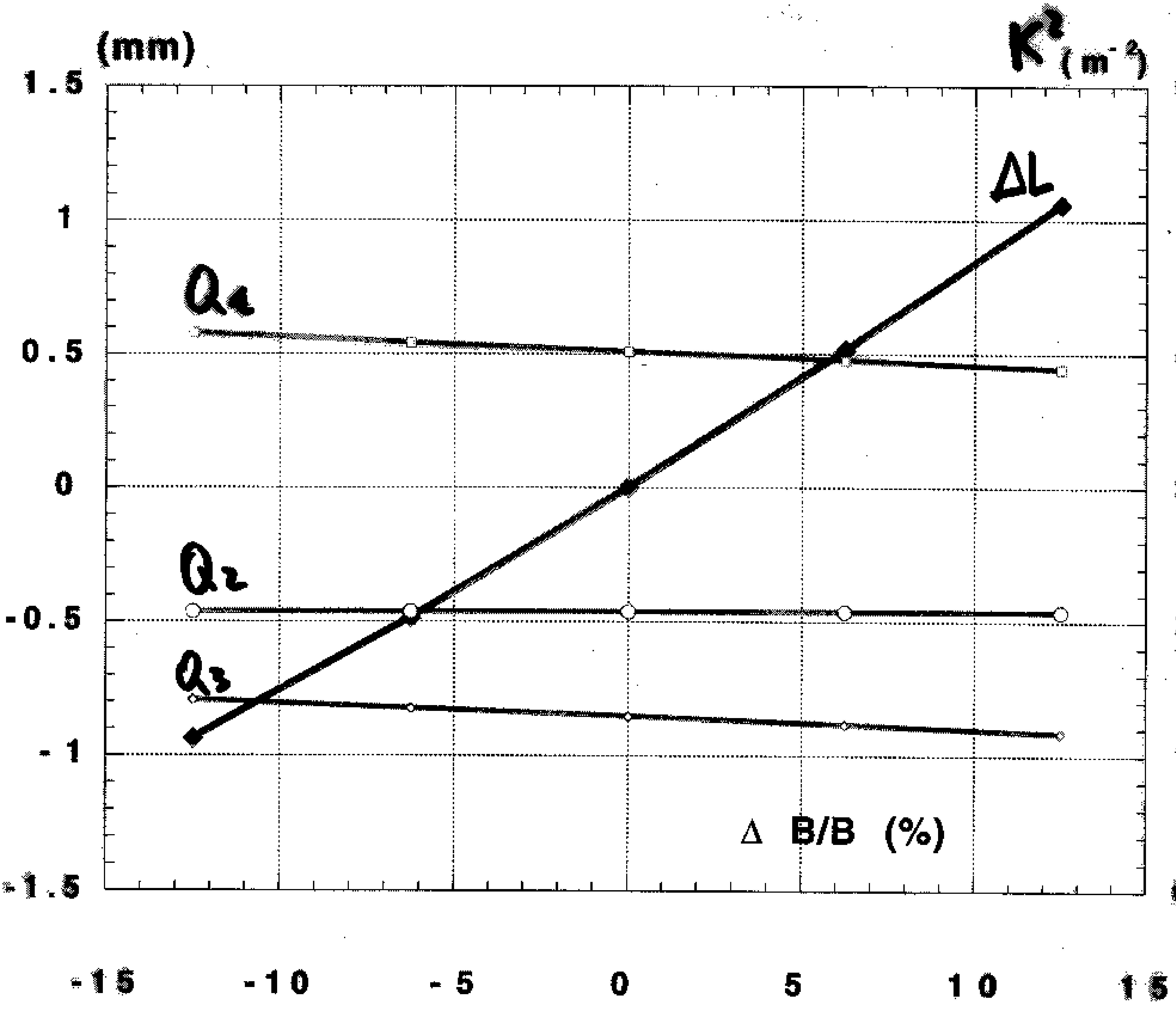
→ WIGGLER – ONE PERIOD



- TRAJECTORY ON AXIS.
- AUTO MATCHED DISPERSION
- R_{56} < CHICANE
- COMPACT DEVICE

$\alpha_0 = 7°$ < 7.8 / 6.2   ΔL < +1 mm / −1 mm

PATH LENGTH MATCHING



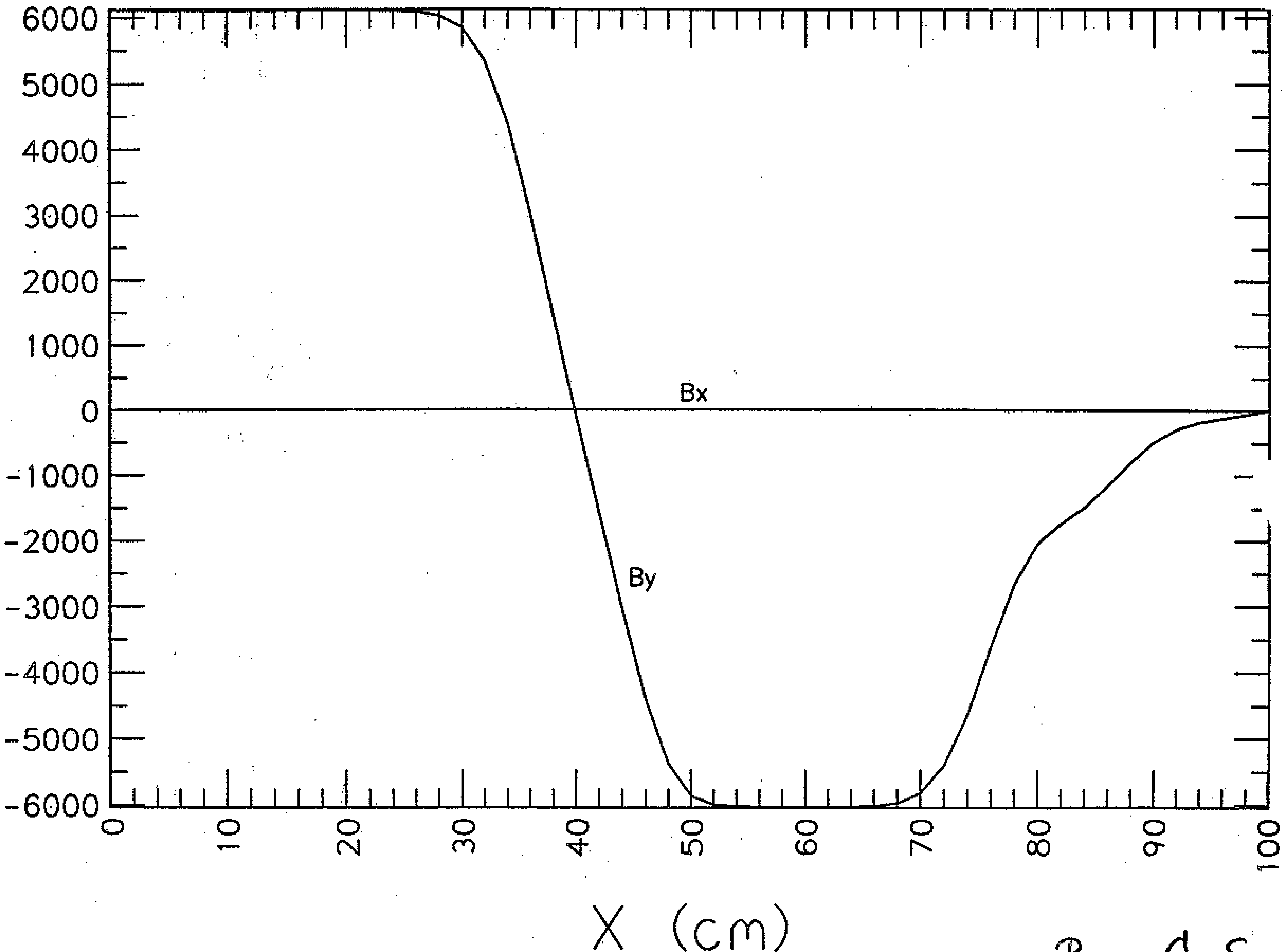
WIGGLER PARAMETER LIST
(3D calculations)

Nom. Magnetic Field	T	0.6
Nom. Magnet Gap	mm	40
Wiggler Period Length	m	1.6
Number of Periods		1
Number of Full Poles		1
Number of Half Poles		2
Wiggler Length	m	1.638
Ampere-turns per pole (full)	A	12330
Ampere-turns per pole (half)	A	9420
Turns per pole		40
Nom. Excitation Current (full pole)	A	308.25
Current Density (full pole)	A/mm^2	4.36
Nom. Excitation Current (half pole)	A	235.5
Current Density (half pole)	A/mm^2	3.33
Nom. Total Power Consumption	W	6410
Water Flow per magnet	l/min	9.3
Water Temperature Rise	°C	10
Iron weight	kg	1925
Copper conductor weight	kg	242

By C. Sanelli

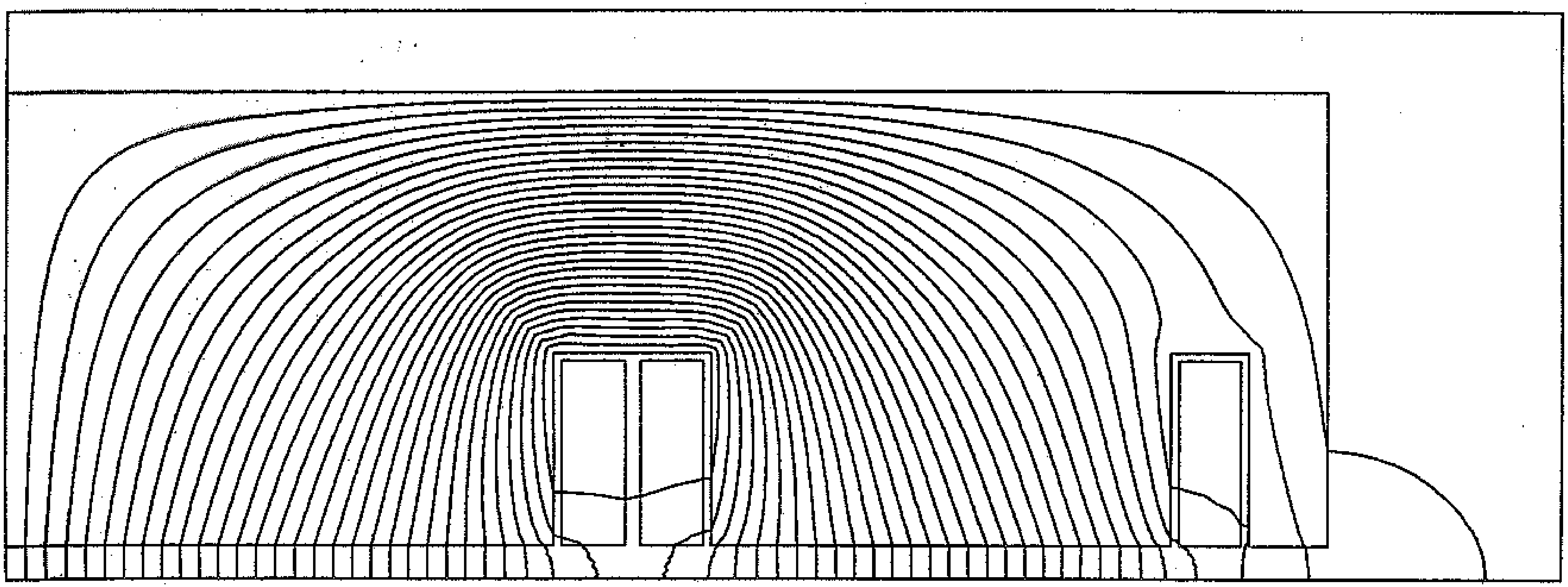
Magnetic field data from the following problem name:
Wiggler CLIC 1/2 of period February 29, 2000

02/29/00 14:14:13

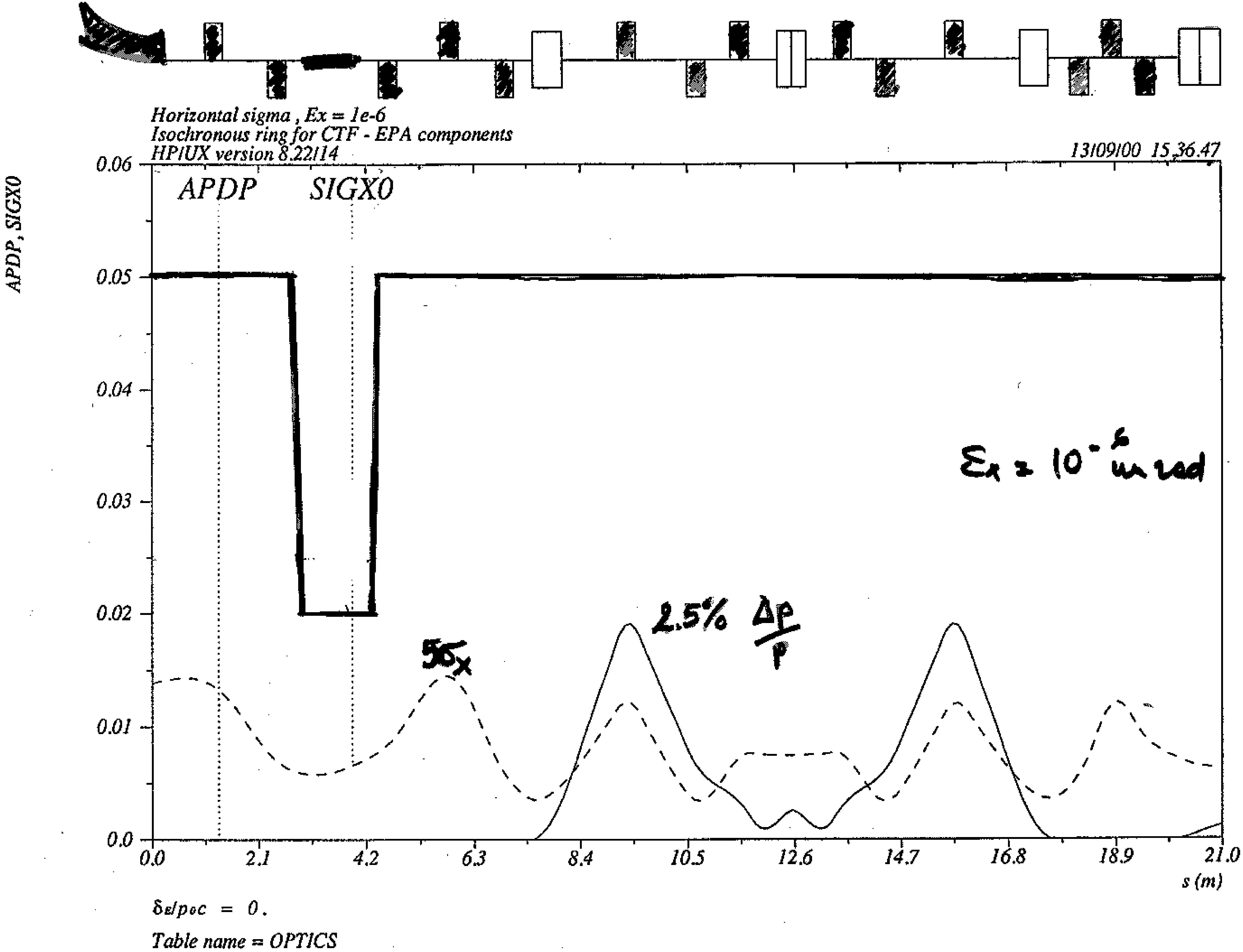


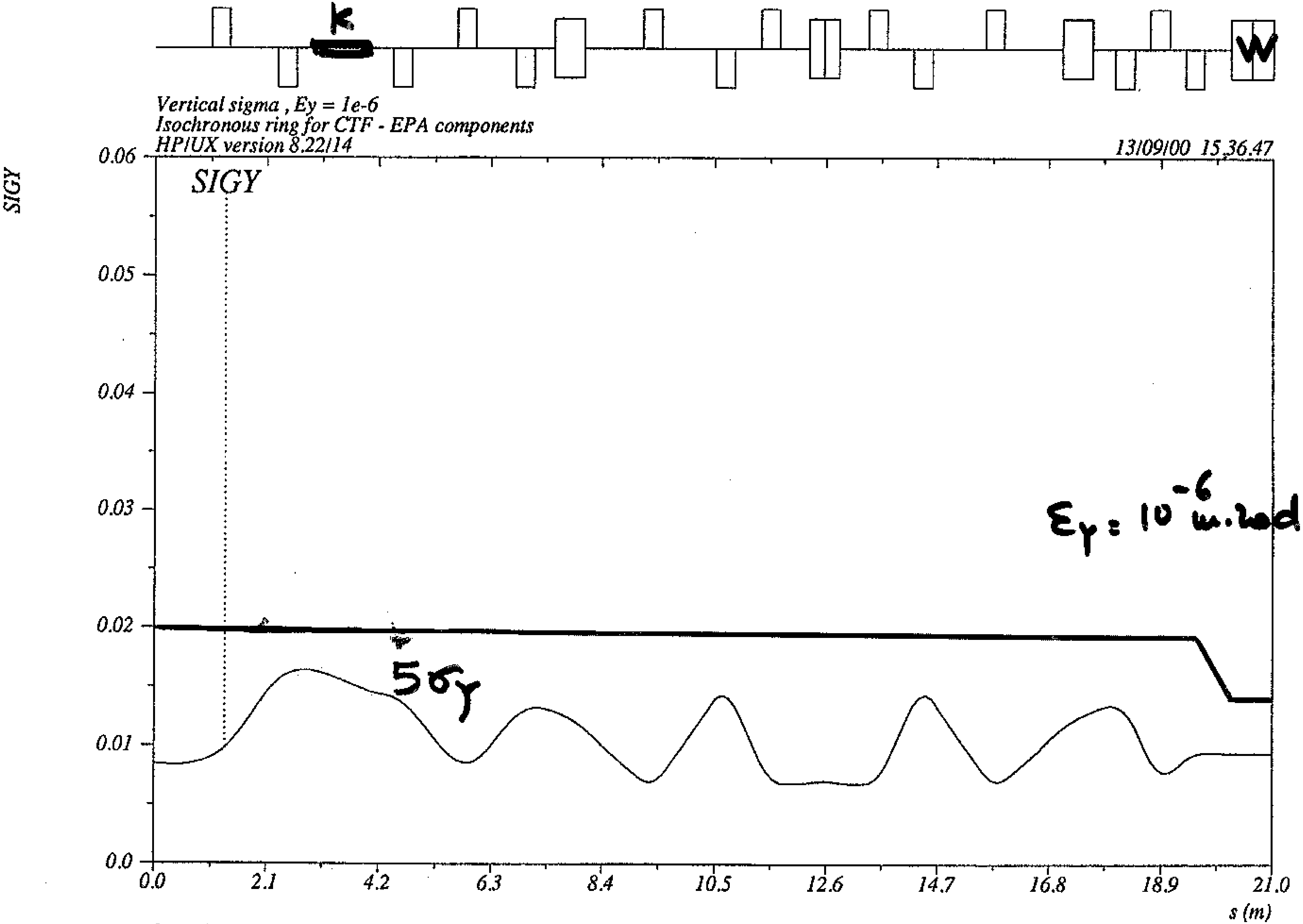
By C. Sanelli

Wiggler CLIC 1/2 of period February 29, 2000 Cycle = 2910



By C. Sanelli

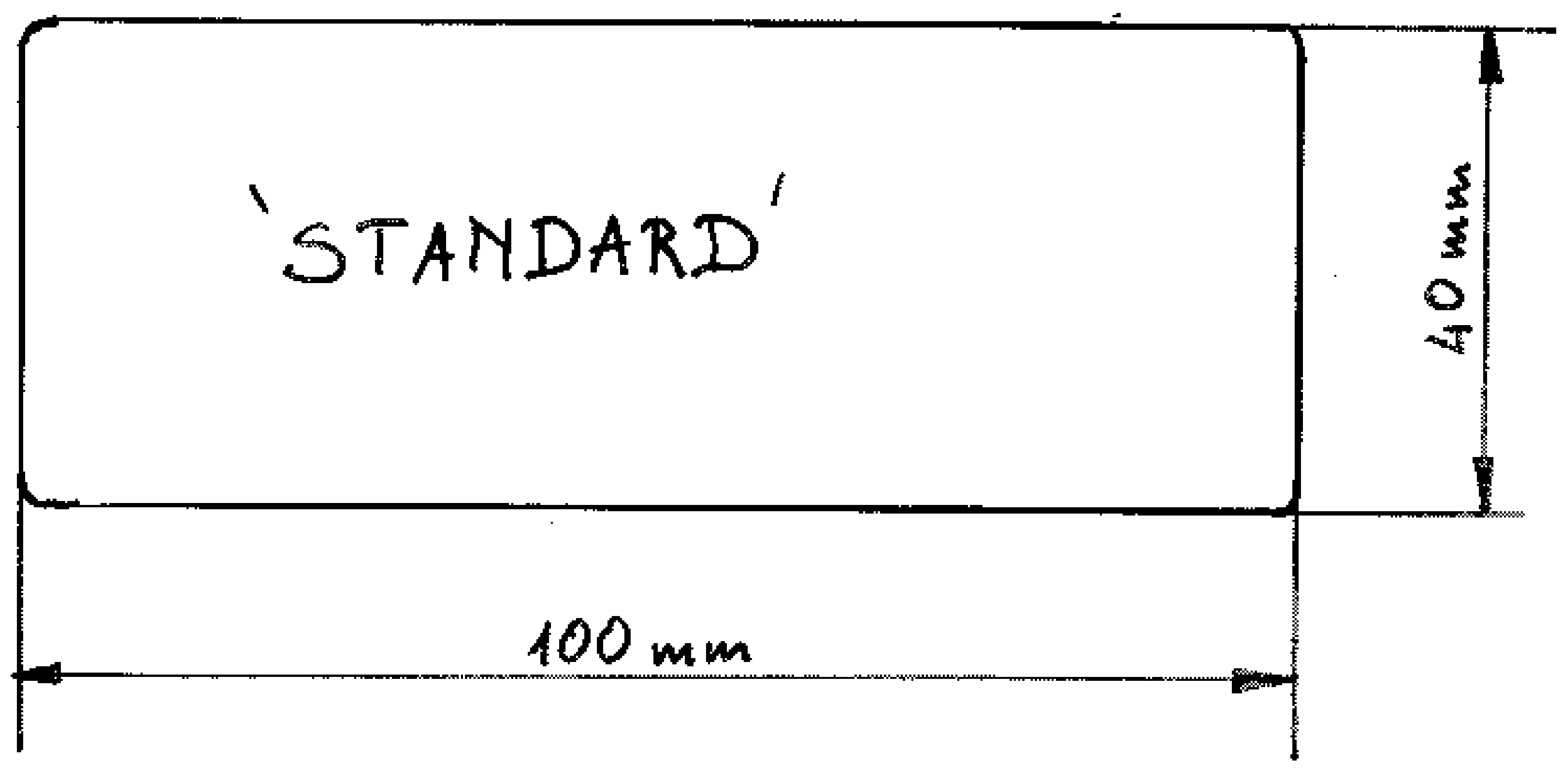

Horizontal sigma , Ex = 1e-6
Isochronous ring for CTF - EPA components
HP/UX version 8.22/14
13/09/00 15.36.47
APDP, SIGX0
APDP
SIGX0
0.06
0.05
0.04
0.03
0.02
0.01
0.0
0.0
2.1
4.2
6.3
8.4
10.5
12.6
14.7
16.8
18.9
21.0
s (m)
$\varepsilon_x = 10^{-6}$ m rad
2.5% $\Delta p / p$
$5\sigma_x$
δε/p₀c = 0.
Table name = OPTICS

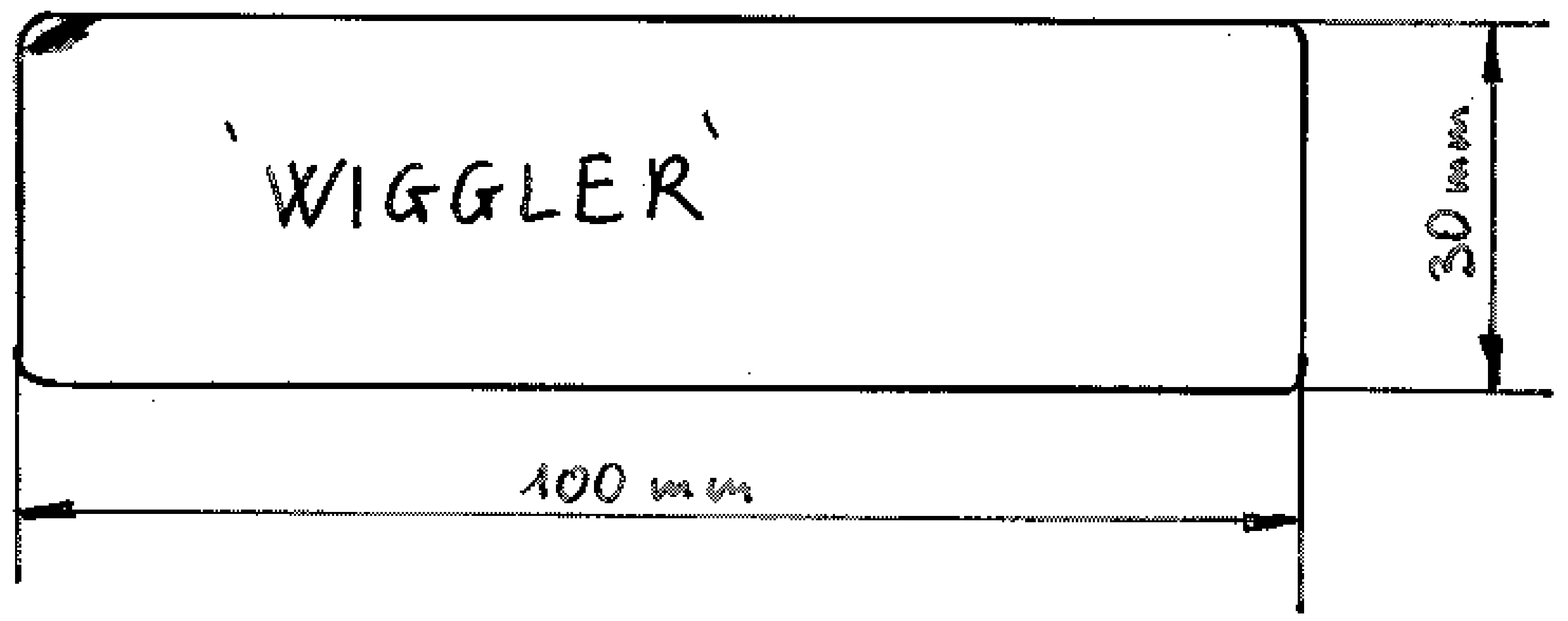


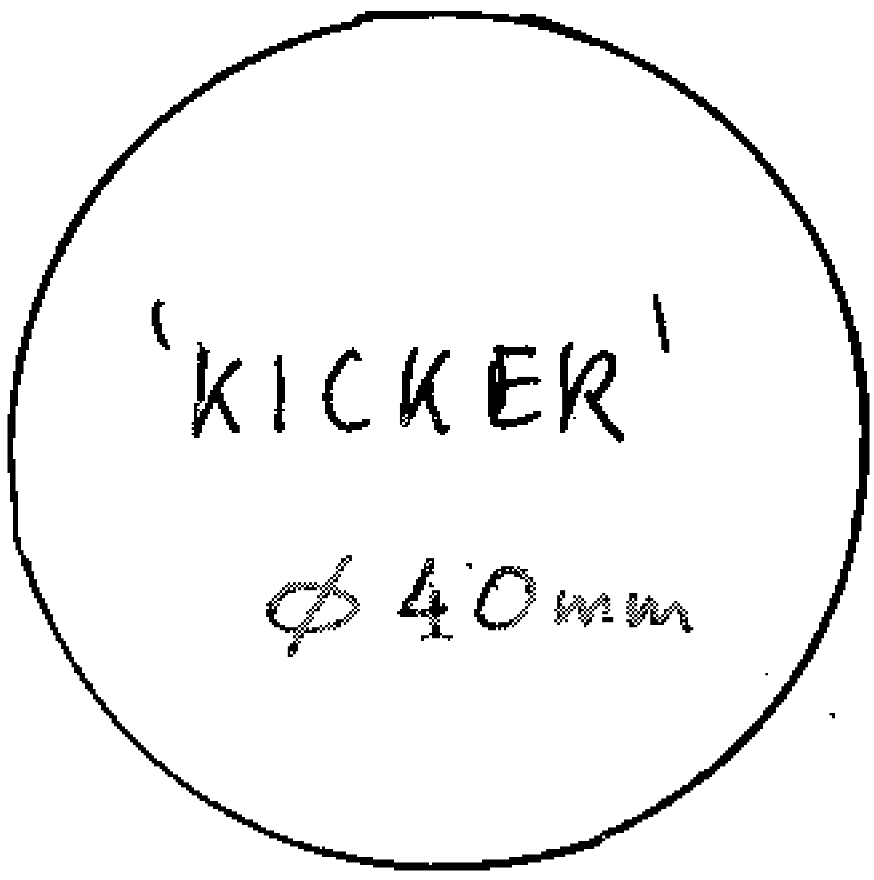
δε/poc = 0.

Table name = OPTICS

Combiner Ring Vacuum Chamber Profile







2nd order isochronism almost corrected - Wx = Wy = 0.
Isochronous ring for CTF - EPA components
HPIUX version 8.22/14

08/07/00 18.08.38

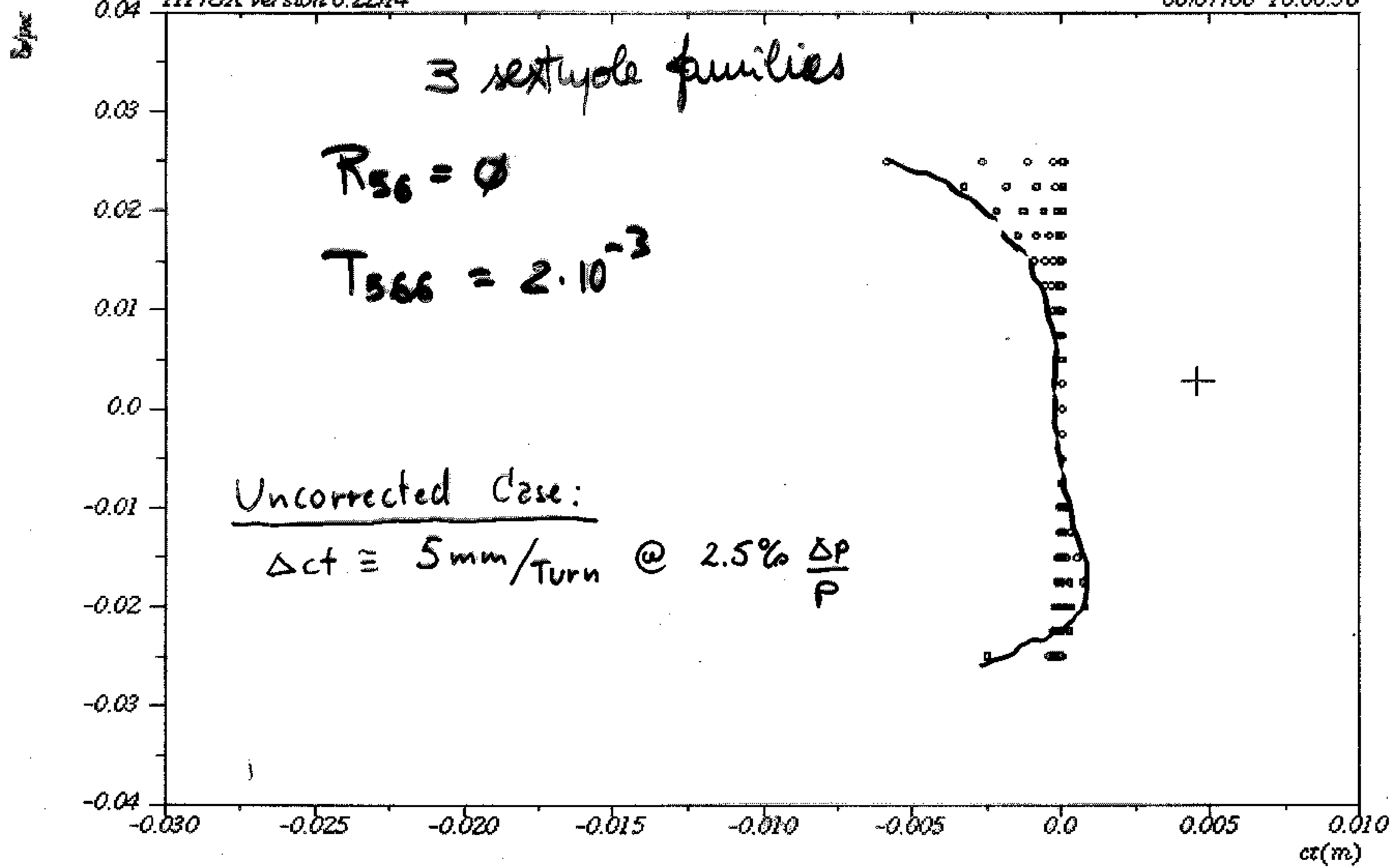
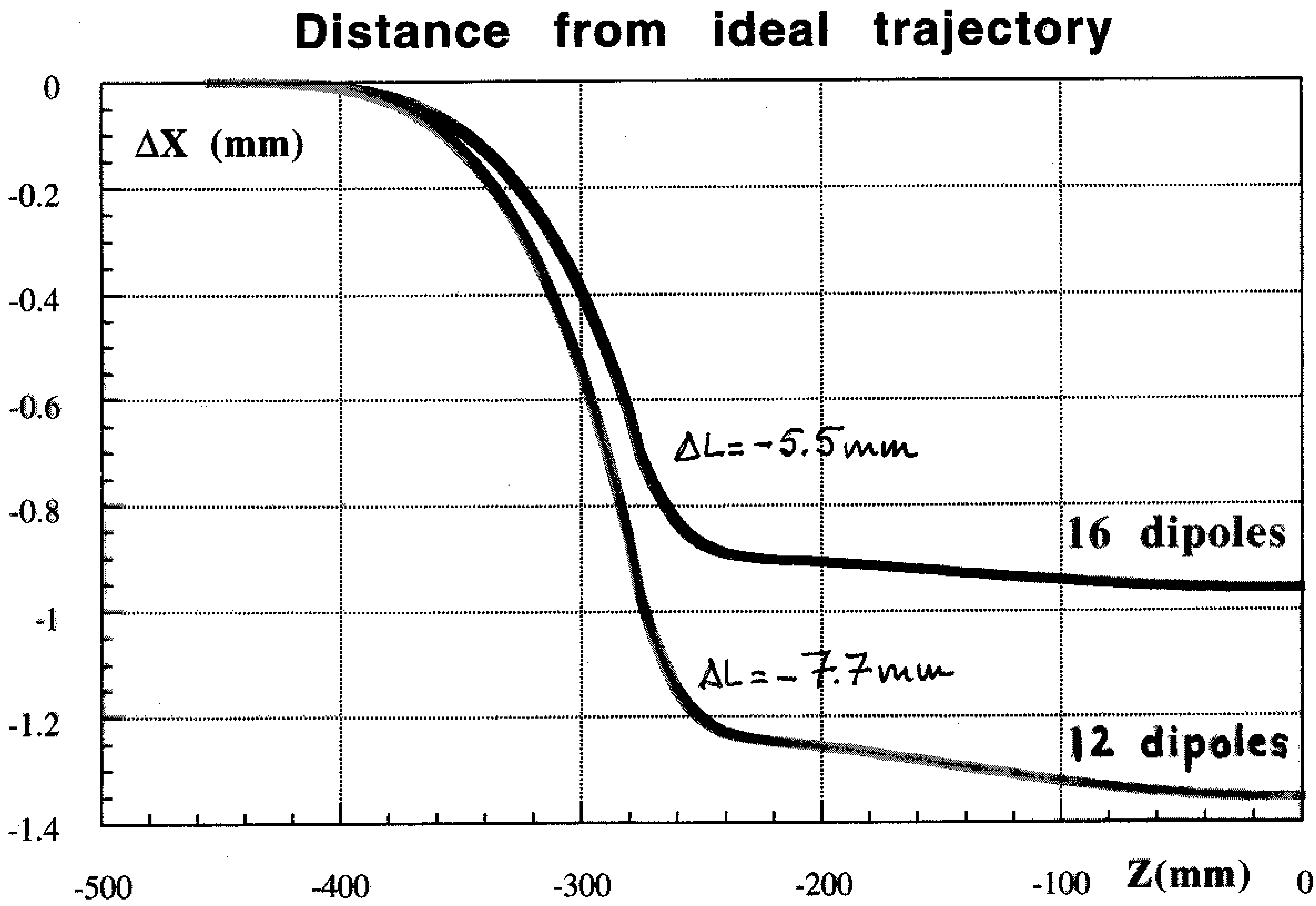


Table name = TRACKING2


Distance from ideal trajectory
ΔX (mm)
0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
-1.4
ΔL = -5.5 mm
16 dipoles
ΔL = -7.7 mm
12 dipoles
-500
-400
-300
-200
-100
Z(mm)
0

CTF3: DESIGN OF DRIVING BEAM COMBINER RING

C. Biscari, A. Ghigo, F. Marcellini, C. Sanelli, F. Sannibale, M. Serio, F. Sgamma, G. Vignola, M. Zobov, LNF-INFN, Frascati, Italy;
R. Corsini, T.E. D'Amico, L. Groening, G. Guignard, CERN, Geneva, Switzerland

Abstract

In CTF3 the beam compression of the driving beam structure between the main linac and the decelerating section is obtained with a delay loop and a combiner ring which increase the pulse current by a factor 10. The design of the combiner ring is presented. Tunable isochronicity condition, corrected up to second order, should assure preservation of the correlation in the longitudinal phase space during the compression. Path-length tuning devices are included in the combiner ring layout to compensate for orbit variations.

1 INTRODUCTION

The first two CLIC Test Facilities, CTF1 and CTF2 have demonstrated the basic principles of rf power production by decelerating a high current electron beam. CTF3 is foreseen to check the feasibility of pulse compression in the driving beam structure [1].

The facility will be installed at CERN, in the existing LIL and EPA buildings, which will be available after LEP shutdown. It will use the existing 3 GHz klystrons and modulators for the production of the beam. The macropulse from the linac is 1.4 μs long and is composed by 140 ns long sequences of *odd* and *even* buckets. Inside each sequence the bunch separation is twice the rf wavelength, 20 cm, with maximum bunch charge of 2.3 nC.

The first compression is done in the delay loop, where each sequence of odd buckets is recombined with the near sequence of even ones. In the resulting beam structure the 140ns bunch trains, in which the bunch separation has become 10 cm, are followed by 140ns long voids.

The second compression phase is done in the combiner ring (CR), 84 m long (twice the delay loop). Each group of successive 5 bunch trains does *n-1/2* turns inside the ring, with *n* from 1 to 4. When they are extracted the bunch separation is reduced down to 2 cm, and the distance between successive bunch trains is four times 140ns.

Preservation of beam emittance and longitudinal correlation during the compression imposes tight requirements on the ring design. The design of the combiner ring is the subject of this paper. A preliminary design, in which the general characteristics were already discussed, is described in [1]. The availability of magnets (dipoles and quadrupoles) of EPA and related transfer lines has suggested the possibility of reuse for the CR project. The following design is based on the use of these magnets.

2 COMBINER RING LATTICE

The ring consists of four isochronous arcs, two short sections housing the path length tuning device and two symmetric opposite long sections for injection and extraction. Quadrupole triplets around the arcs are used for matching. The layout of the ring is shown in Fig. 1 and the main parameters are listed in table I.

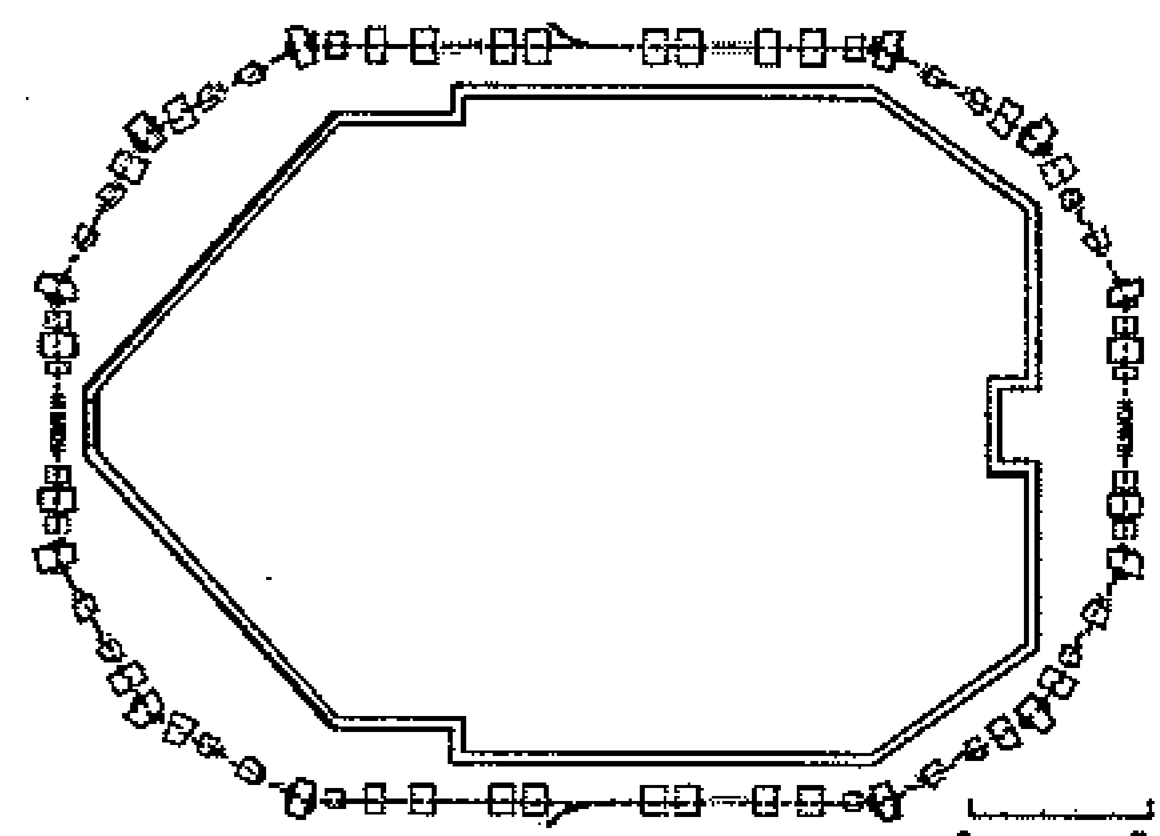


Figure 1: Combiner ring layout.

Table I – CR main parameters

Energy (MeV)	160/350
Circumference (m)	84
Bending Radius (m)	1.075
No. Cells	4
No. Dipoles	12
Dipole Field (T)	0.5/1.1
No. Quadrupoles	52
Max.Int.Gradient (T)	0.9/1.8
No. Sextupoles	24
Max.Int.Gradient (T/m)	6/13
Max. beta (m) (H/V)	11/11
Max. Dispersion (m)	.73
Betatron Tune (H/V)	8.10/3.63
Chromaticity (H/V)	-11/.9

2.1 Isochronous Arc

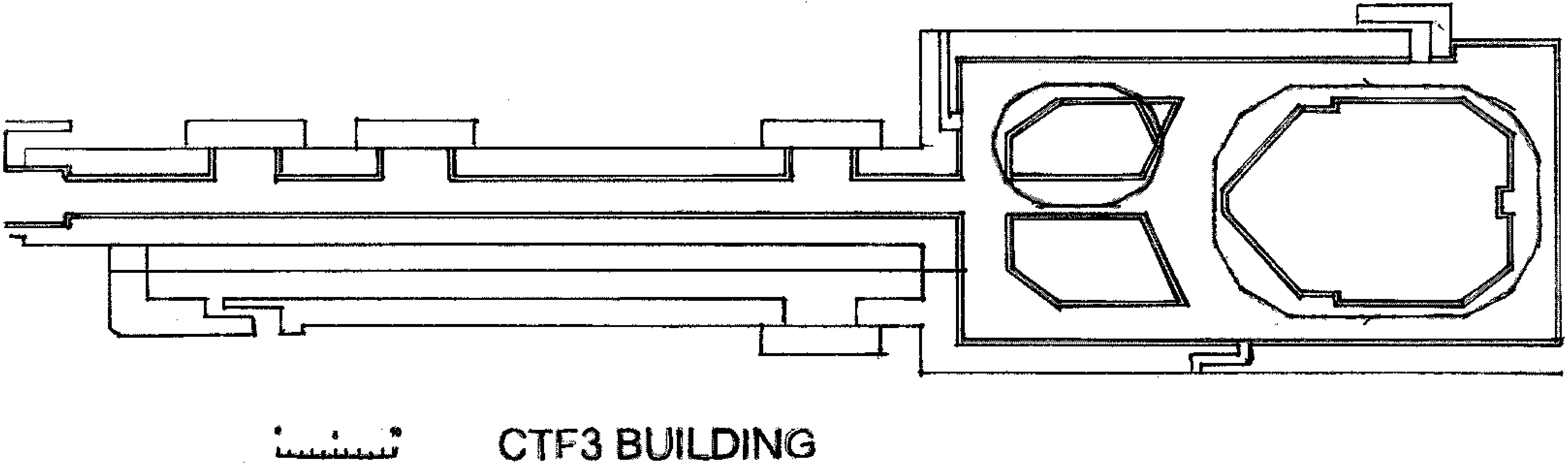
The arcs are triple bend achromats, with negative dispersion in the central dipole, which makes vanish the term of the first order transport matrix relating path length with energy:

$$R_{56} = \int \frac{D_x}{\rho} ds = 0$$

(D_x is the dispersion and ρ the bending radius).

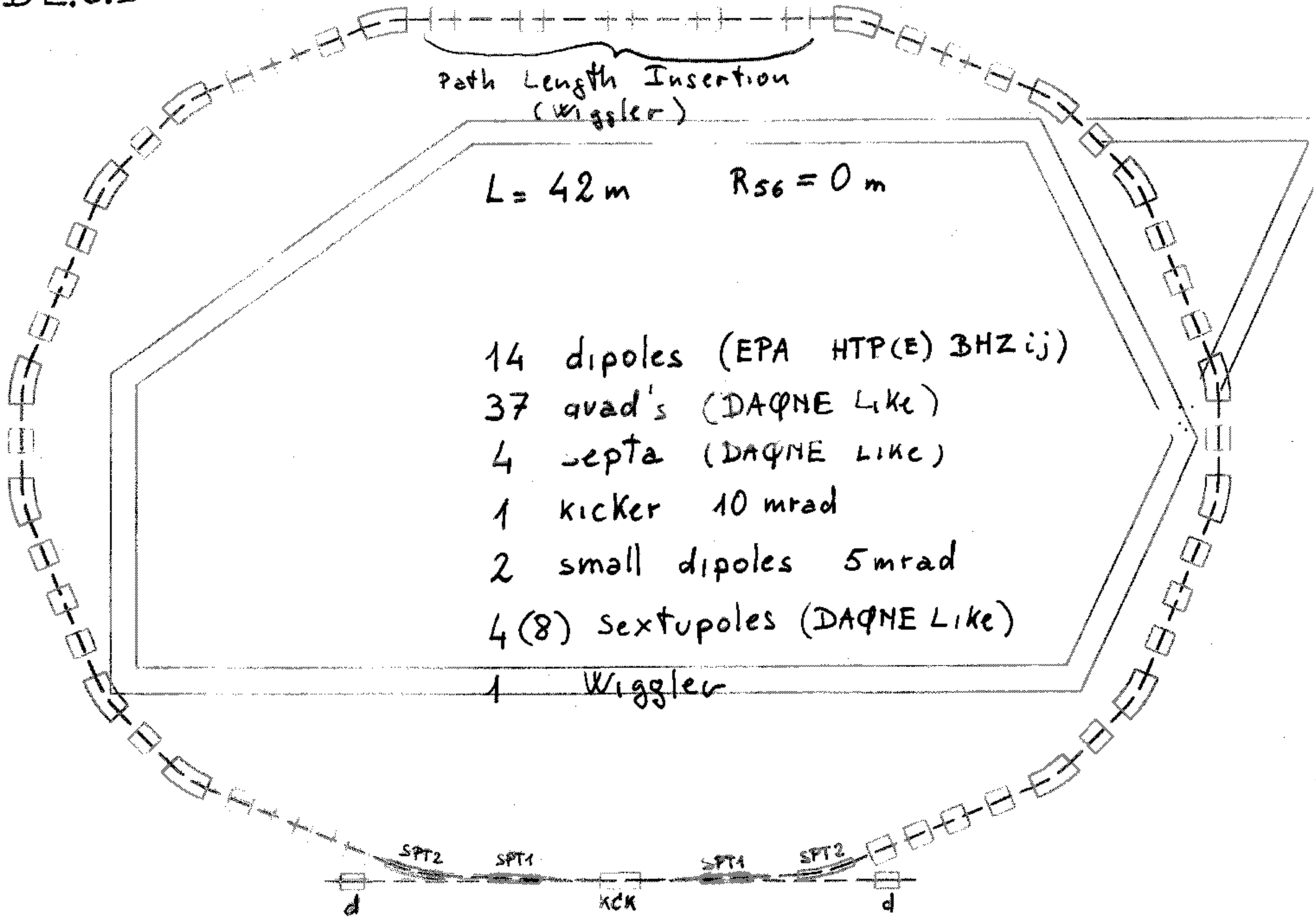
CTF3 DELAY LOOP

F. Sannibale



CTF3 BUILDING

DL.3.1


Path Length Insertion
(Wiggler)
L = 42 m
R_{56} = 0 m
14 dipoles (EPA HTP(E) BHZij)
37 quad's (DAΦNE Like)
4 septa (DAΦNE Like)
1 kicker 10 mrad
2 small dipoles 5 mrad
4 (8) sextupoles (DAΦNE Like)
1 Wiggler
SPT2
SPT1
SPT1
SPT2
d
KCK
d

FROM PS/LPI Note 88-02 March 1988 (rev.)

LEP Preinjector Parameter List EPA part)

.5.2 Scintillation Screens

Utility	trajectors obsrvation	
Names	HIP(E)MTVij	--
Number	6	--
Type	AA	--
Drawing number	?	--

5.5.3 Secondary Emission Monitors

Utility	momentum spread meas.	
Names	HIP(E)MSH20	--
Number	2	--
Type	Linac	--
Drawing number	?	--
Aperture definition range (min./max.)	?/?	%
Momentum definition range (min./max.)	?/?	%

6. Transfer Lines from EPA to PS (HTP.HTE)

==

Vacuum Pumping			
Vacuum valves (number/diameter)	2 of ?	mm	*
Turbomolecular pumps (number/speed)	? of ?	l/sec	*
Ions pumps (number/speed)	? of ?	l/sec	*
Vacuum chamber inner dimensions			
in the general straight sections (diameter)	?	mm	*
in the bending magnets (hor./ver)	?	mm	*

5.2 Bending Magnets and Power Supplies (2 families)

Names	HTP(E)BHZij	--	
Number (total/in series)	8/1,2	--	
Type	straight, pure dipole		
Drawing number	8400.0	PSR	
Bending angle	< 392.70 22.5°	mrad	2
Nominal field at magnet center:			
induction By	< 1.400	T	*
quadrupole field dBy/dx	0.0	T/m	*
sextupole field d2By/dx2	0.0	T/m**2	*
Nominal strength along magnet axis:			
induction strength	< 0.78461	T/m	*
quadrupole strength	0.0	T	
sextupole strength	0.0	T/m	
Nominal current (600 MeV operation)	< 550	A	
Maximum current (650 MeV operation)	< 620	A	
Pole width	230	mm	
Magnetic length	561	mm	
Steel length	510	mm	
Overall length	870	mm	
Available aperture (hor./vert.)	120/45	mm/mm	*
Good field region (" ")	95/35	mm/mm	*
Overall section (" ")	915/570	mm/mm	*
Overall weight	1800	kg	*
Number of winding turns	96	--	*
El. resistance (one magnet/tot. circuit)	35/40.2,75.2	mOhms	*
El. inductance (one magnet)	30	mH	*
Max. current admissible in the magnet	680?	A	*
Max. power dissipation in the magnet	12	kW	*
cooling by	water	--	
differential pressure	6	bar	
water flow rate	7	l/min	

Power supplies

Names	HTP(E).BHZij	--

DAΦNE TECHNICAL NOTE

INFN - LNF, Accelerator Division

Frascati, December 2, 1994

Note: **MM-4**

MEASUREMENTS ON TESLA QUADRUPOLE PROTOTYPE FOR THE DAΦNE ACCUMULATOR AND MAIN RINGS

B. Bolli, F. Iungo, M. Modena, M. Preger, C. Sanelli, F. Sgamma, M. Troiani, S. Vescovi

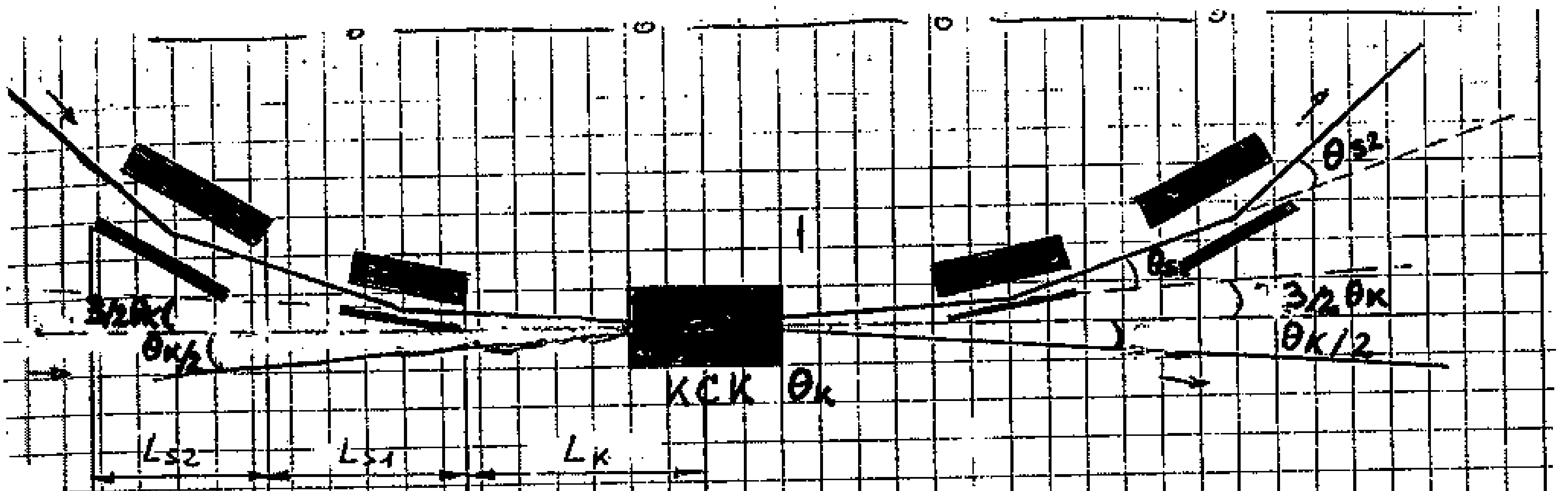
1. INTRODUCTION

The first prototype of the Accumulator quadrupole, built by TESLA Engineering, Water Lane, Storrington (U.K.) has been delivered to LNF on June 21, 1994. It was immediately realized that the mechanical reference holes had been wrongly placed on the magnet joke. We decided to proceed anyway to measure magnetic, electric and thermal properties of the magnet, leaving the check on alignment tolerance on a corrected version of the prototype. We recall in Table 1 the main parameters of the quadrupole magnet.

Table 1 - Prototype quadrupole parameters

Nominal Gradient (Tesla/m)	8.06
Maximum Gradient (Tesla/m)	12.07 ←
Magnet Bore Diameter (mm)	100 ←
Pole shape	Hyperbolic + Straight line
Good field region (mm)	30 ←
Field quality (ΔB/B)	$\leq 5 \times 10^{-4}$
Magnetic length (mm)	300 ←
Turns per pole	32
Conductor Size (mm^2)	8x8
Coolant hole diameter (mm)	5
Current density (A/mm^2)	5.9
Nominal current (A)	261.1
Maximum current density (A/mm^2)	10.73
Maximum current (A)	473
Magnet Resistance (@20°C, mΩ)	43
Magnet Inductance (mH)	10.8
Nominal Voltage (V)	11.2
Maximum Voltage (V)	20.4
Nominal Power (kW)	2.9
Maximum Power (kW)	9.65

Iniezione per DL-S-0 8/6/2000



Ipotesi

$\theta_K = 10$ mrad

$\theta_{S1} = 2° = 34.91$ mrad

$\theta_{S2} = 19.64° = 342.79$ mrad

$L_K = 1.0$ m

$L_{S1} = 1.2207$ m (setto 2° Accumulatore)

$L_{S2} = 0.698$ m (setto 34° Accum. ridotto a 19.64°)

(4)

$L_T = 2(L_K + L_{S1} + L_{S2}) = 2 \cdot 2.759$ m $= 5.517$ m

S_1: $\theta = 2° = 34.91$ mrad
$\rho = 17.751756$ m
$l = 0.6197$ m

S_2: $\theta = 19.64° = 342.79$ mrad
$\rho = 2.077814$ m
$l = 0.7123$ m

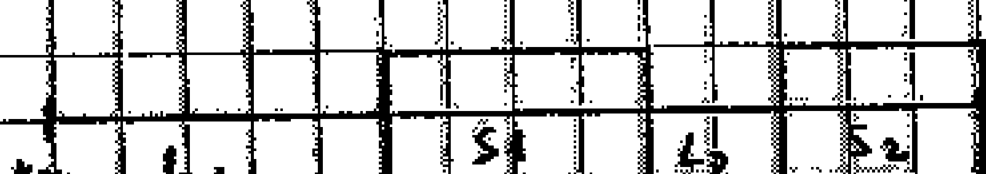
(5)

$\theta_T = \theta_K + \theta_{S1} + \theta_{S2} = 387.7$ mrad $= 22.2°$

(6)

Poiché $\theta_K, \theta_{S1} \ll 1$

si assume
$\theta_K = 10$ mrad
$\theta_{S1} = 2°$
$\theta_{S2} = 19.64°$



(7)

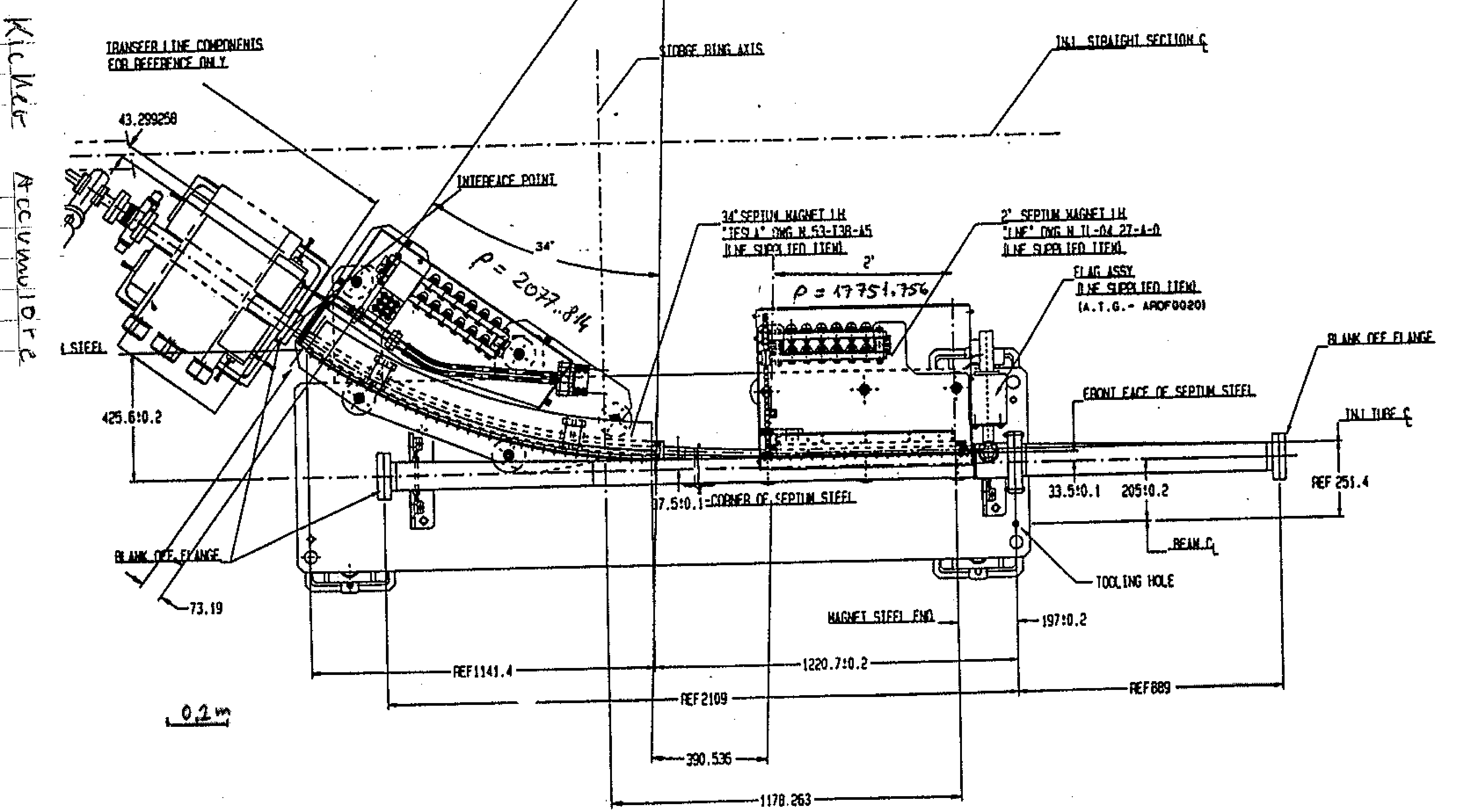
$L_1 = L_K = 1.0$ m

$l_{S1} = \theta_{S1}\rho_{S1} = 0.6197$ m

$L_2 = L_{S1} - l_{S1} = 0.601$ m

$l_{S2} = \theta_{S2}\rho_{S2} = 0.7123$ m

$L_T = 2.933$ m



DAΦNE ACCUMULATOR SEPTA

4.3 Sextupoles

There are two families of chromaticity correcting sextupoles, each powered by a single power supply. All magnets have been measured at LNF and results collected into the DAΦNE Technical Note MM-6. For the place of the magnets into the ring, the same criterion as for the quads has been adopted. We have therefore different calibrations for the two families. The initial set values are those which set both chromaticities to zero, taking into account the sextupole contribution of the dipoles to the overall ring chromaticity (see the DAΦNE Technical Note MM-9). The magnets are linear over the operating range.

SXPA1001, SXPA2002, SXPA3001, SXPA4002

This is a family of horizontally focusing sextupoles.

(a) $L_{nom} = 0.100$
(b) $L_{mag} = 0.105$
(c) $I_{max} = 336$
(d) $S = 0.6772*I$
(e) $\int Sdy = 6.772e\text{-}2*I$
(f) $K = 2.0302e\text{-}2*I/E$
(g) $I = 49.256*K*E$
(h) $K_{set} = 7.29$
(i) $I_{set} = 183.13$

$K_{2\,max}$ @ 180 MeV = 378 m^{-3}

$K_{2\,max}$ @ 350 MeV = 195 m^{-3}

$$K_2 = \frac{1}{(B\rho)} \frac{\partial^2 B}{\partial x^2}$$

SXPA1002, SXPA2001, SXPA3002, SXPA4001

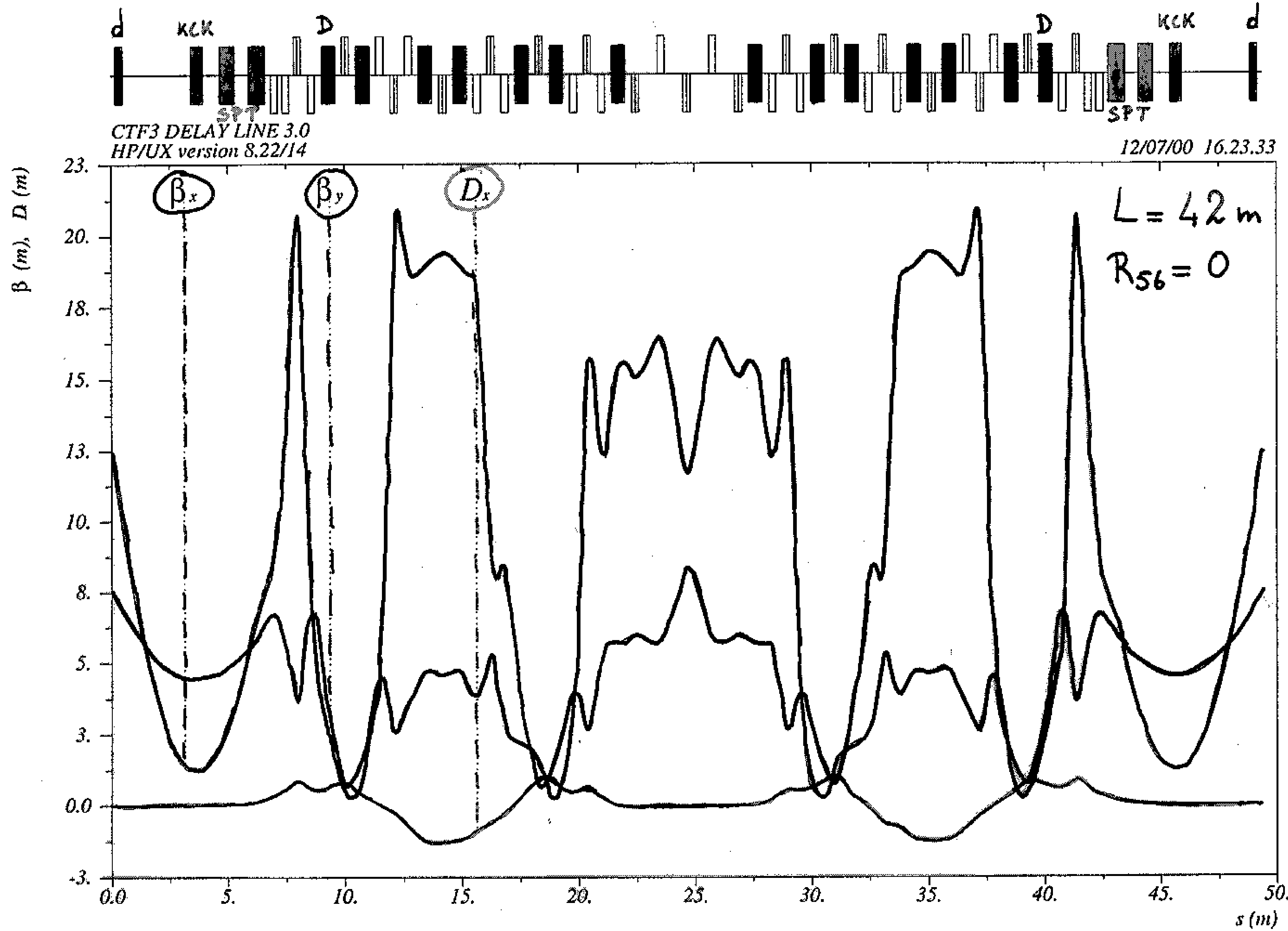
This is a family of horizontally defocusing sextupoles.

(a) $L_{nom} = 0.100$
(b) $L_{mag} = 0.105$
(c) $I_{max} = 336$
(d) $S = 0.6772*I$
(e) $\int Gdy = 6.735e\text{-}2*I$
(f) $K = 2.0191e\text{-}2*I/E$
(g) $I = 49.527*K*E$
(h) $K_{set} = -5.87$
(i) $I_{set} = 148.27$

APERTURE = 100mm ⌀

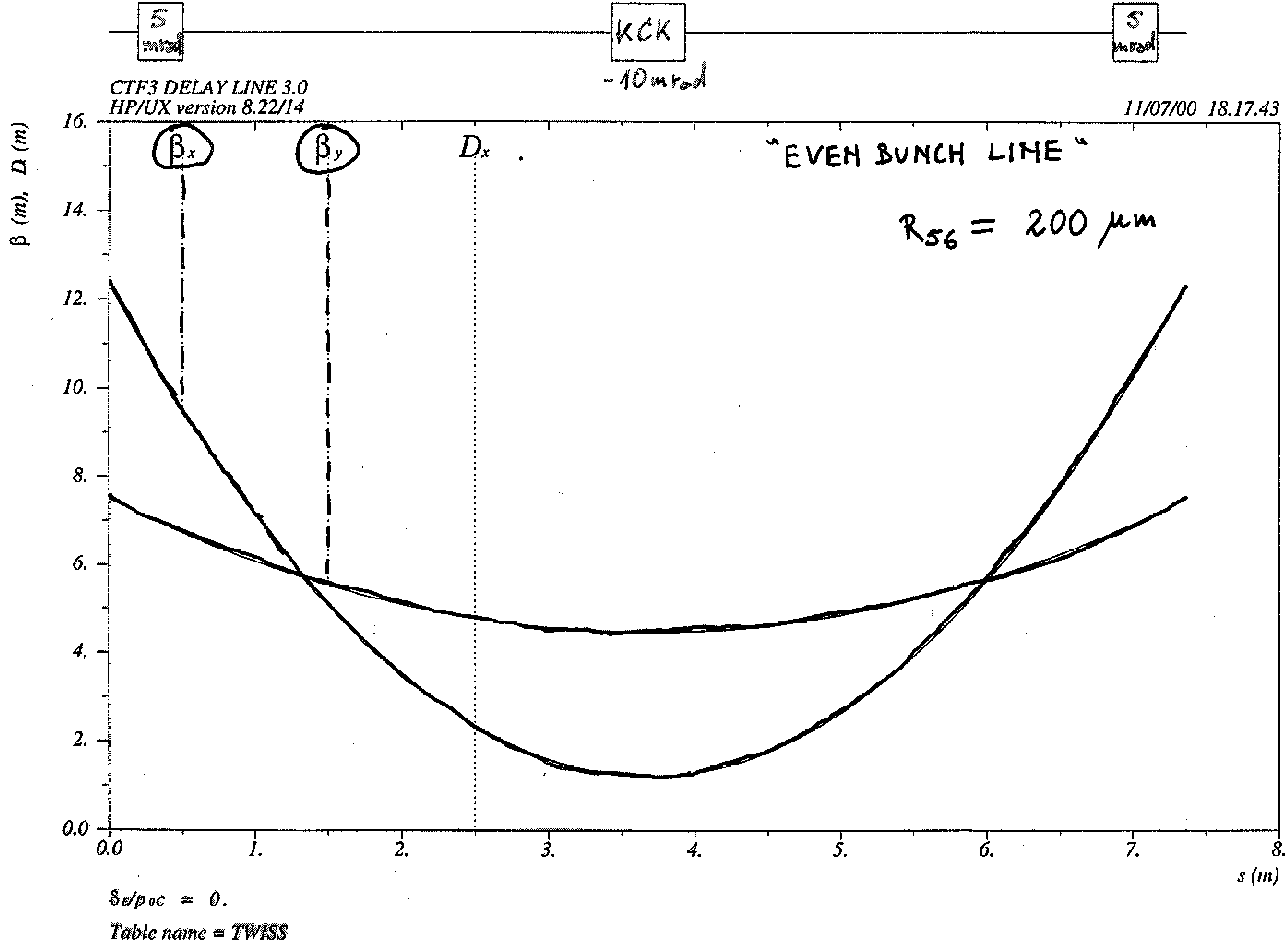
4.4 Correctors

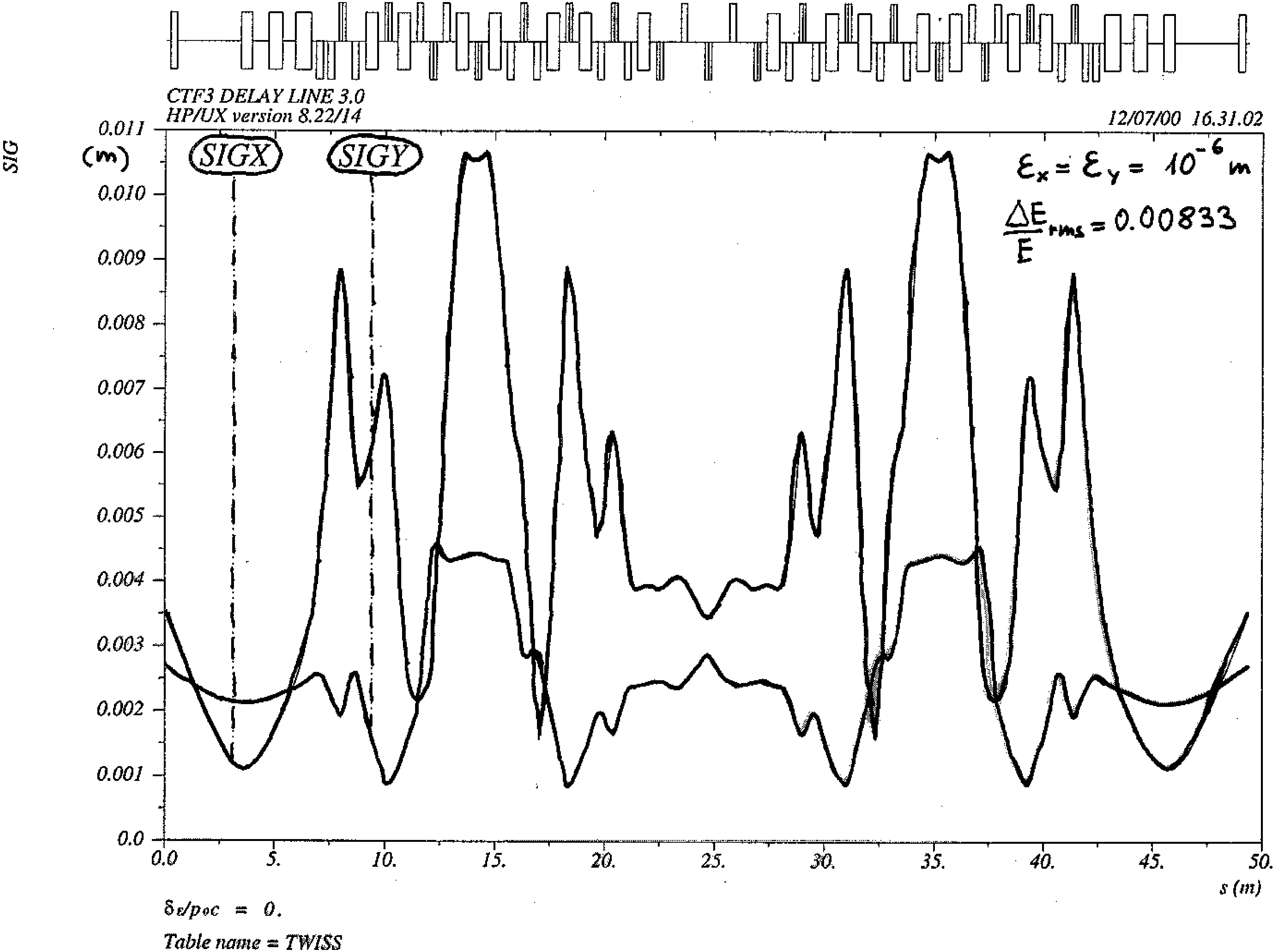
There are two kinds of orbit correctors in the Accumulator, both measured at LNF. Both have a square shape with two independent coils for correction in the horizontal and vertical planes. Six of them, referred to as "Type A" correctors have a 150x150 mm^2 gap. The other two are placed in the kicker and RF sections, and are larger, in order to cope with the larger size of the vacuum chamber; they are "Type B" correctors and the gap is 260x260 mm2. The measurements, available from the Magnetic Measurements Group (C. Sanelli, M. Preger), have been performed separately on the two coils, and the mutual interference has not been checked.



δ_E/p_0c = 0.

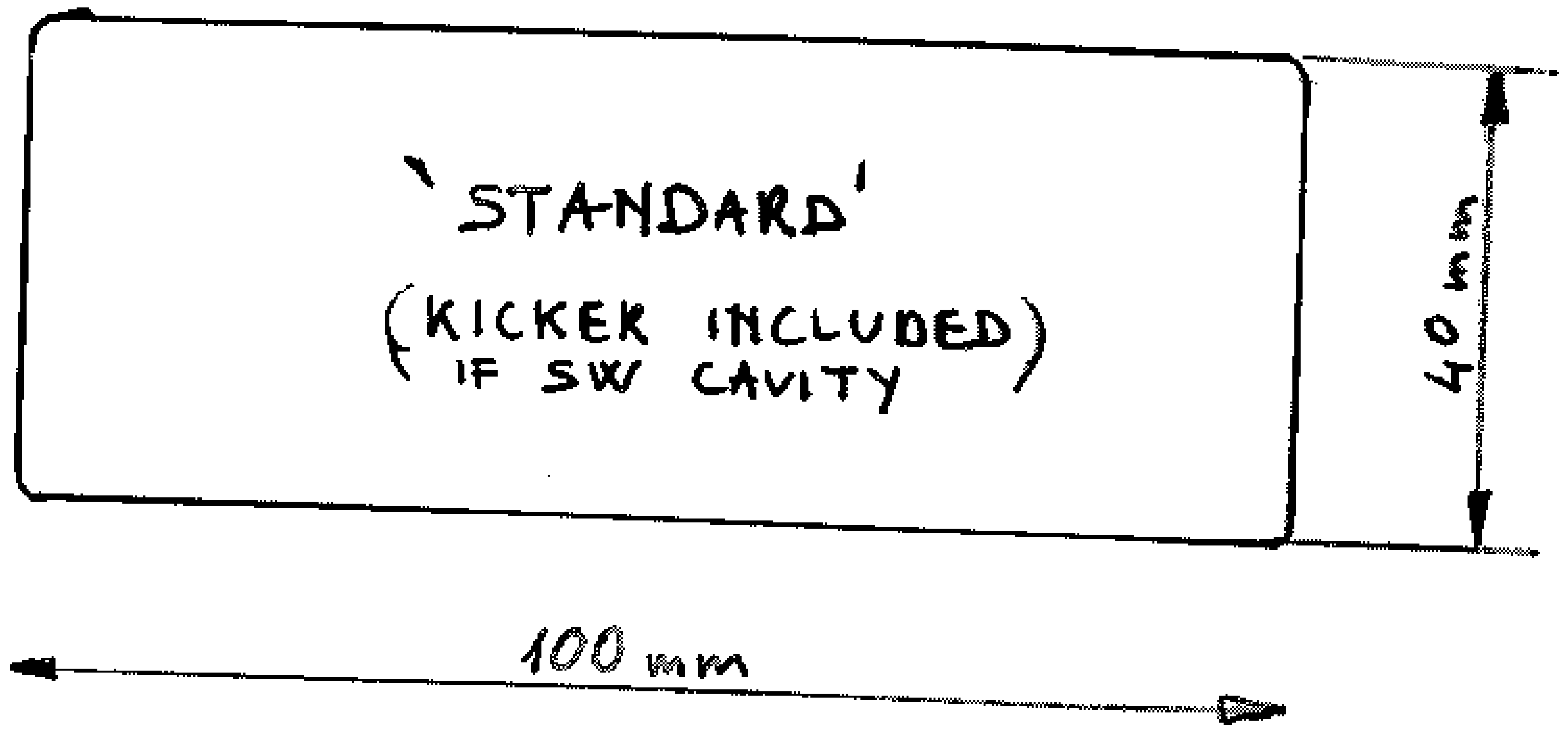
Table name = TWISS

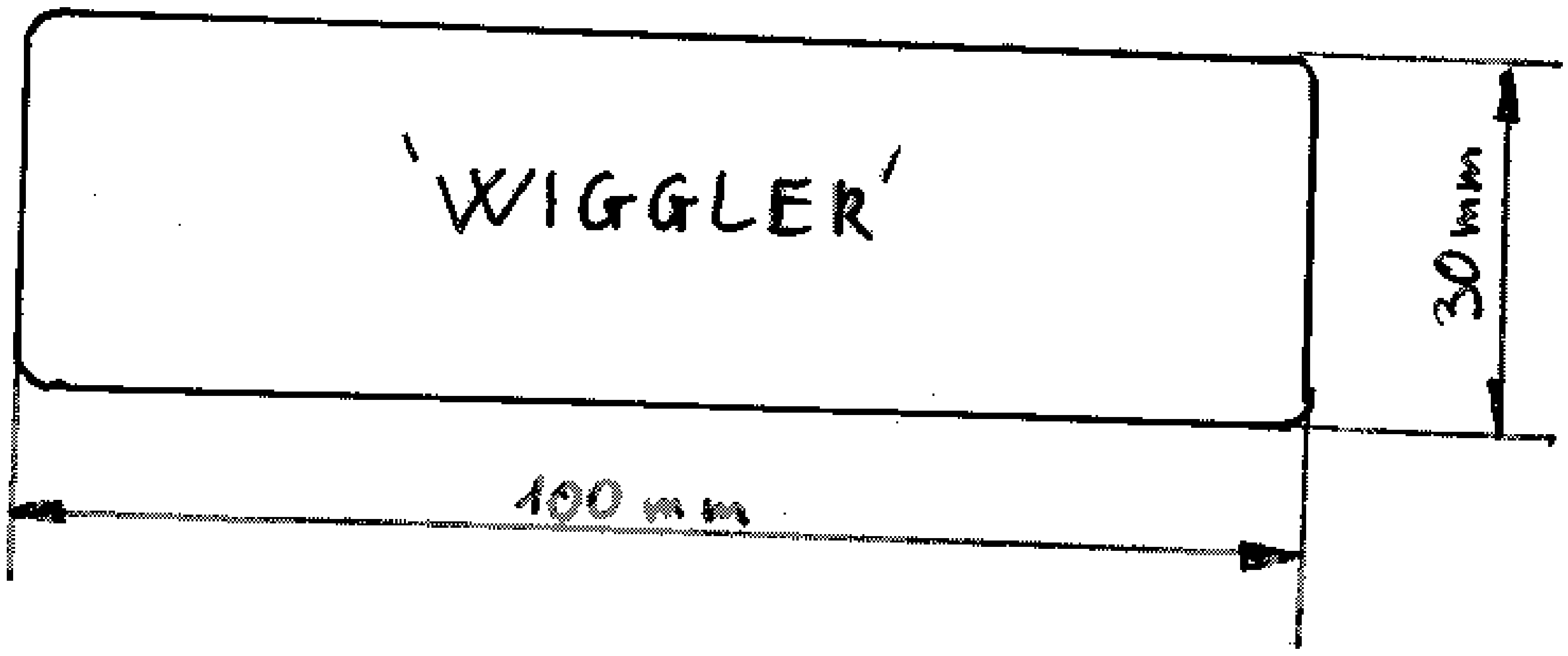

5 mrad
KCK
-10 mrad
5 mrad
CTF3 DELAY LINE 3.0
HP/UX version 8.22/14
11/07/00 18.17.43
β (m), D (m)
βx
βy
Dx
"EVEN BUNCH LINE"
R56 = 200 μm
16.
14.
12.
10.
8.
6.
4.
2.
0.0
0.0
1.
2.
3.
4.
5.
6.
7.
8.
s (m)
δE/p0c = 0.
Table name = TWISS



CTF3 DELAY LINE 3.0
HP/UX version 8.22/14
12/07/00 16.31.02
SIG
(m)
SIGX
SIGY
$\varepsilon_x = \varepsilon_y = 10^{-6}$ m
$\frac{\Delta E}{E}_{rms} = 0.00833$
s (m)
δε/p₀c = 0.
Table name = TWISS

Delay Loop Vacuum Chamber Profile





R56 Tuning in DL 3.0

19/7/2000

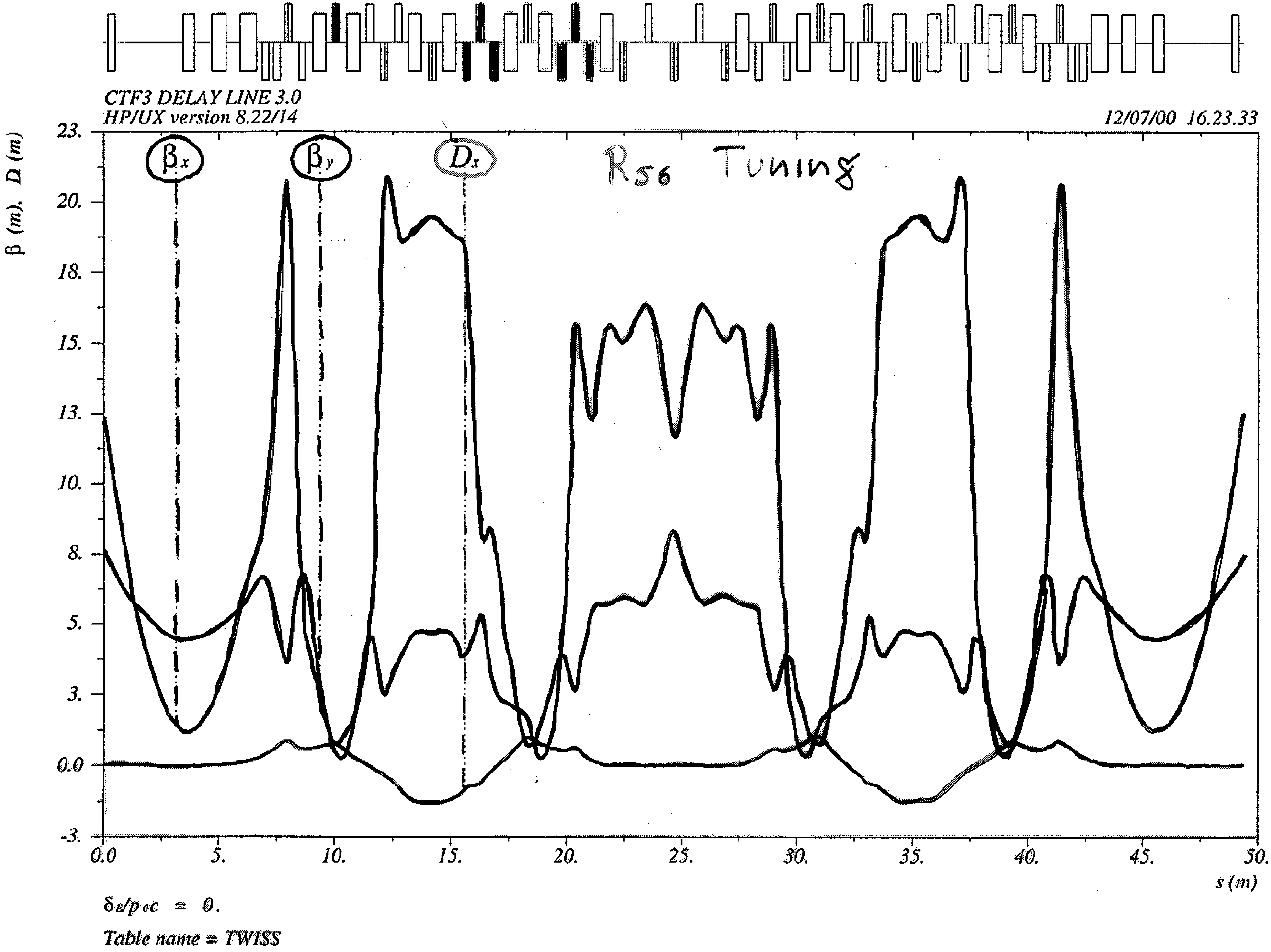
	Quad	R56=0	R56=0.05	Variation	DR56 1m
0	kq11	4.932318	4.930698	-0.001620293	-0.03240585
1	kq12	-4.077414	-4.076292	0.001121998	0.02243996
2	kq13	4.200405	4.421372	0.2209668	4.419336
3	kq14	4.835271	4.839886	0.004615307	0.09230614
4	kq15	-3.751654	-3.754474	-0.002820015	-0.05640030
5	kq16	0.4984184	0.4967303	-0.001688093	-0.03376186
6	kq17	-0.1598367	-0.1633225	-0.003485799	-0.06971598
7	kq21	-2.007960	-2.001396	0.006564140	0.1312828
8	kq22	3.281486	3.122465	-0.1590211	-3.180423
9	kq23	-2.251303	-2.011676	0.2396269	4.792538
10	kq24	4.867753	4.844680	-0.02307320	-0.4614639
11	kq25	-3.609426	-3.610912	-0.001486063	-0.02972126
12	kq26	4.521360	4.519098	-0.002262115	-0.04524231
13	kq27	-2.057421	-2.038672	0.01874900	0.3749800
14	kq28	-0.3294740	-0.3459208	-0.01644680	-0.3289360
15	k1spt	-0.9993581	-0.9998607	-0.0005025864	-0.01005173
16	k2spt	-1.069090	-1.067771	0.001319051	0.02638102

by most of quads

	Quad	R56=0	R56=0.05	Variation	DR56 1m
0					
1	kq13	4.200405	4.300808	0.1004028	2.008057
2					
3	kq21	-2.007960	-1.890111	0.1178491	2.356982
4	kq22	3.281486	2.948038	-0.3334479	-6.668959
5	kq23	-2.251303	-2.064649	0.1866539	3.733077
6					
7	kq25	-3.609426	-3.421805	0.1876211	3.752422
8	kq26	4.521360	4.524221	0.002861023	0.05722046
9	kq27	-2.057421	-2.085593	-0.02817202	-0.5634403

by a reduced set of quads

	Quad	R56=0	R56=2 cm	Variation	DR56 1m
0					
1	kq13	4.200405	4.239865	0.03945971	1.972985
2					
3	kq21	-2.007960	-1.959895	0.04806507	2.403253
4	kq22	3.281486	3.153265	-0.1282210	-6.411052
5	kq23	-2.251303	-2.199620	0.05168295	2.584147
6					
7	kq25	-3.609426	-3.537150	0.07227612	3.613806
8	kq26	4.521360	4.523112	0.001751900	0.08759499
9	kq27	-2.057421	-2.065783	-0.008362055	-0.4181027


CTF3 DELAY LINE 3.0
HP/UX version 8.22/14
12/07/00 16.23.33
R56 Tuning
βx
βy
Dx
β (m), D (m)
s (m)
δε/p0c = 0.
Table name = TWISS

2° Order Effects Correction

$$ct = ct_0 + R_{56}\frac{\Delta p}{p} + T_{516}\,x_0\frac{\Delta p}{p} + T_{526}\,x_0'\frac{\Delta p}{p} + T_{536}\,y_0\frac{\Delta p}{p} + T_{546}\,y_0'\frac{\Delta p}{p} + T_{556}\,ct_0\frac{\Delta p}{p} + T_{566}\left(\frac{\Delta p}{p}\right)^2$$

2° Order Correction ⇒ $T_{5i6} = 0$, $i = 1, 2, \ldots, 6$

* In the CTF3 Delay Loop DL_3_1 after 1° order correction:

$R_{56} = 0$ and $T_{536} = T_{546} = T_{556} = 0$

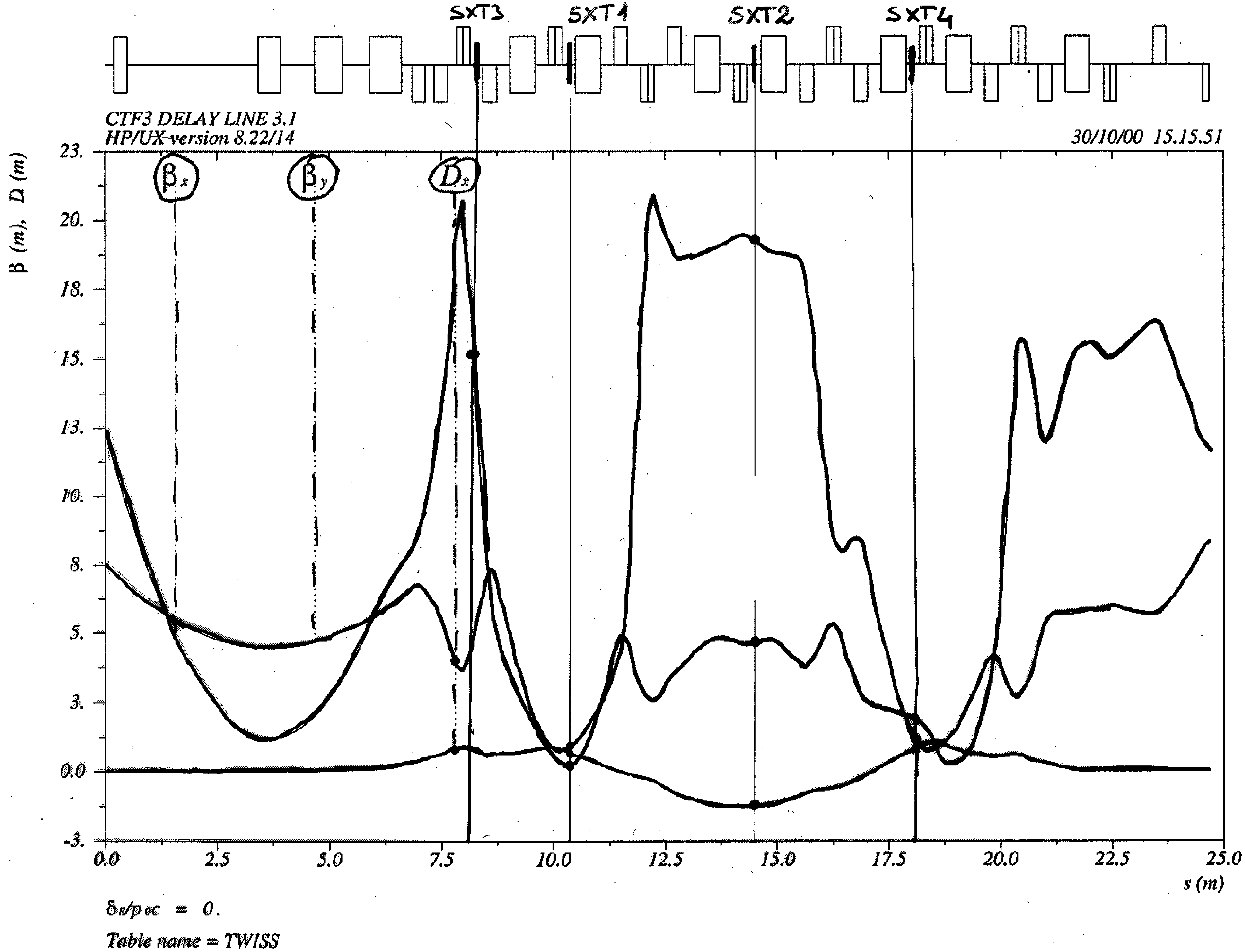
But

$T_{516} \neq 0$

$T_{526} \neq 0$

$T_{566} \neq 0$

⇒ Correction by sextupoles needed!


SXT3
SXT1
SXT2
SXT4
CTF3 DELAY LINE 3.1
HP/UX-version 8.22/14
30/10/00 15.15.51
β_x
β_y
D_x
β (m), D (m)
s (m)
δ_E/p_0c = 0.
Table name = TWISS

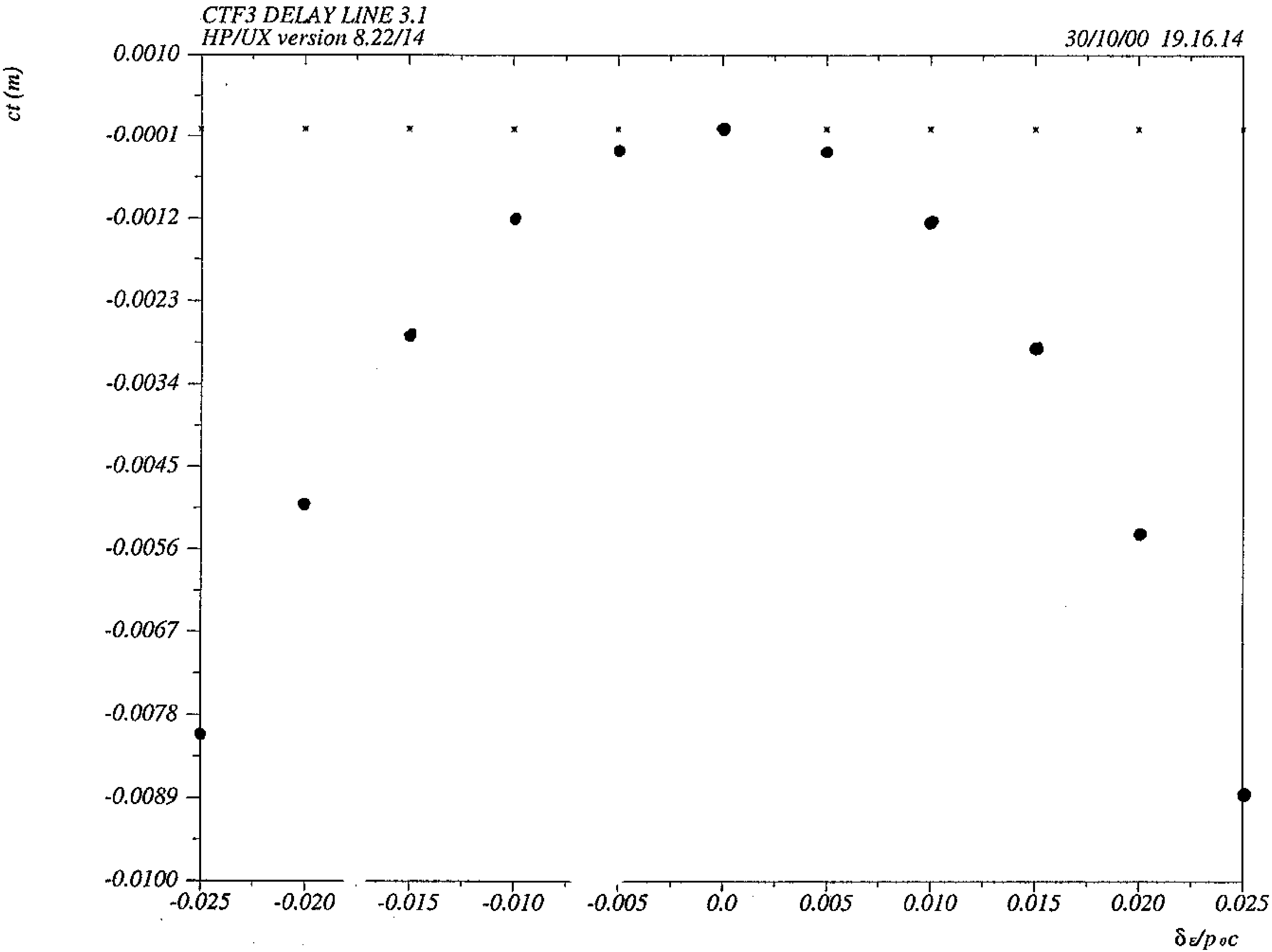
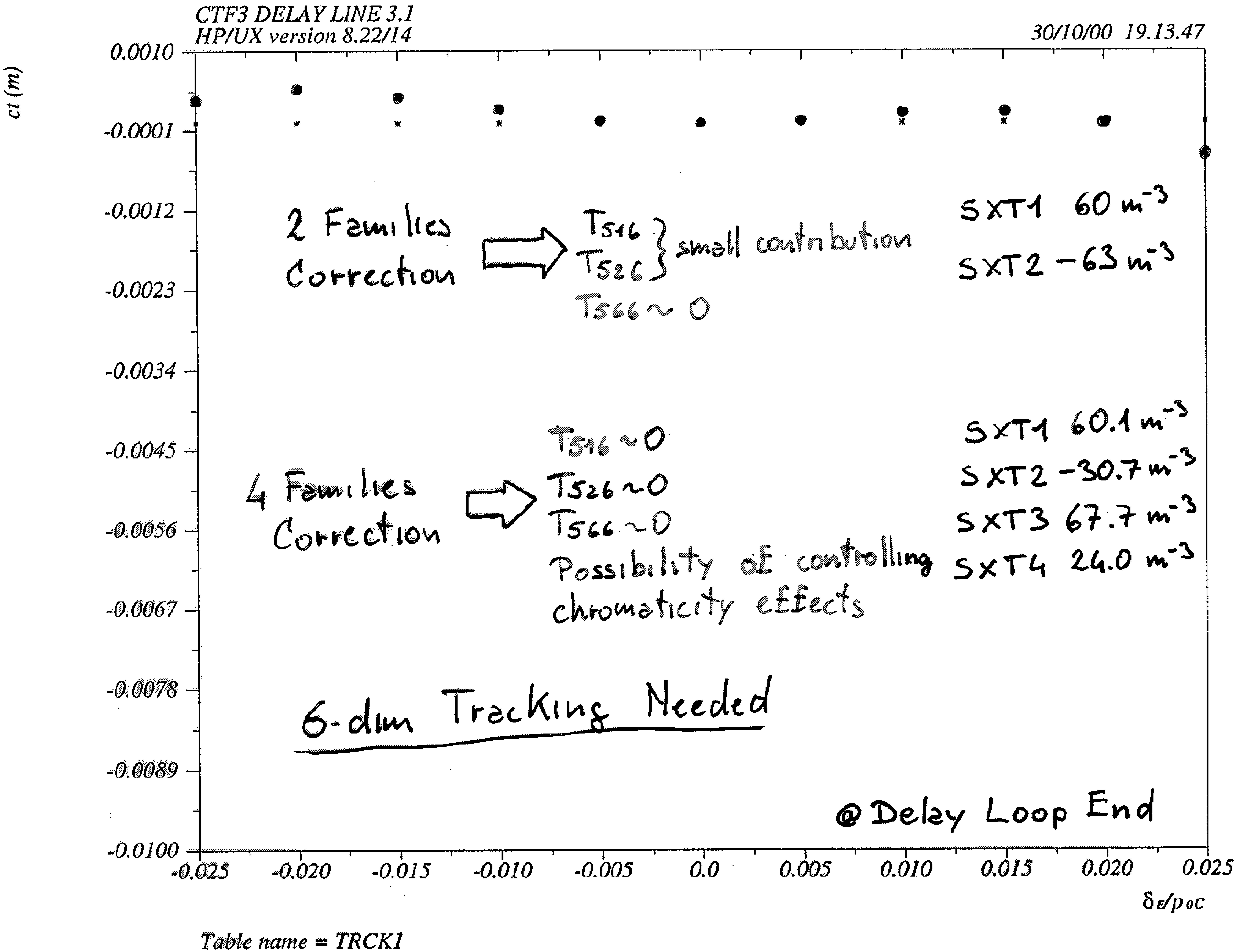


Table name = TRCK1


CTF3 DELAY LINE 3.1
HP/UX version 8.22/14
30/10/00 19.13.47
ct (m)
0.0010
-0.0001
-0.0012
-0.0023
-0.0034
-0.0045
-0.0056
-0.0067
-0.0078
-0.0089
-0.0100
-0.025
-0.020
-0.015
-0.010
-0.005
0.0
0.005
0.010
0.015
0.020
0.025
δε/p₀c
2 Families Correction
T516 } small contribution
T526
T566 ~ 0
SXT1 60 m-3
SXT2 -63 m-3
4 Families Correction
T516 ~ 0
T526 ~ 0
T566 ~ 0
Possibility of controlling chromaticity effects
SXT1 60.1 m-3
SXT2 -30.7 m-3
SXT3 67.7 m-3
SXT4 24.0 m-3
6-dim Tracking Needed
@ Delay Loop End
Table name = TRCK1