DAΦNE TECHNICAL NOTE

INFN - LNF, Accelerator Division

Frascati, March 1, 2001

Note: **L-32**

DETUNED LATTICE FOR DAFNE MAIN RINGS

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Introduction

The two Interaction Regions (IRs) of DAFNE are in the usual configuration two low vertical beta sections. The beams collide in one Interaction Point and are vertically separated in the opposite one.

The KLOE beta value is about 30% higher than the nominal one, while in the second IP it is higher by a factor two. The idea of detuning this second IP [1], changing completely the phase advance in the IR, has been proposed in order to separate more easily the beams, thus decreasing the possible horizontal beam-beam effect, which probably can be troublesome.

Among the correctors used for moving the position of the beams at the IP there are the so-called ‘C’ correctors [2]. It has been pointed out [3] that the sextupole term present in all of them is not negligible, if compared with the usual sextupoles used for chromaticity correction. Tune measurements done as a function of the vertical and horizontal separation at the IPs [4] confirm this fact and the coupling dependence on the vertical position at both IRs measured several times is well explained by this sextupole term.

In this context it is still more interesting to use a detuned lattice for the second IR when colliding in KLOE, so that the separation can be done without using the ‘C’ correctors, or using them at reduced currents.

I describe in this note a lattice structure which fulfils these characteristics. I have computed it assuming the last positron ring linear model, which fits several configurations [5]: usual working point, wigglers-off lattices, half-integer lattice.

Once this lattice is implemented on the ring, the coupling must be corrected tuning the KLOE and compensator solenoids, since they now compensate for the coupling introduced by the ‘C’ correctors. The optics must then be matched with the new values of the solenoids and used for collisions only in KLOE. A beneficial use of the ‘C’ correctors can anyway be done by using properly their sextupole term to increase the dynamic aperture.

The lattice should fit well the positron ring. The same lattice applied to the electron ring will probably have lower tunes (the horizontal tune lower by ~ 0.05 and the vertical one by ~ 0.02), which will lead the e^- ring close to the present colliding tunes.

IRs Description

In IR2 the low beta triplet is usually FDF. This configuration fits the requirement of low vertical beta at the IP, contained horizontal beta along the IR, important for aperture requirements, and the necessary separation at the splitter entrance [6].

I have detuned the insertion by switching off the inner quadrupole, and lowering the defocusing one. The two defocusing quadrupoles (QUAI2002 and QUAI2006) will work in linear regime while now they are in saturation [7]. At the IP the vertical betatron function is high (15 m). The horizontal one (2m) is lower by a factor two than the usual one; therefore the necessary beam vertical separation at the IP to make beams transparent, in the horizontal plane, to each other is decreased by sqrt (2), since it is proportional to the horizontal beam size. The horizontal beam size inside the splitter is also decreased by the same factor. In the vertical plane the separation must be increased by the relative increase of the vertical beam size, which is about a factor 10. A vertical bump at the IP passes through zero inside the splitters and can be as large as the IR stay-clear allows. In the Appendix the example with ±4 mm @ IP is shown.

The beam position at the splitter centre corresponds to a crossing angle larger than the nominal one. The 'C' correctors are usually used, together with the splitter field, to adjust the horizontal crossing angle. The currents in the splitters and in the 'C' as a function of the crossing angle are plotted in Fig. 1, with the assumption that a positive value of 'C' corresponds to a bend with the same sign of the corresponding splitter angle. Let's consider that in the ring a positive current in the correctors gives a kick outward and that the splitters facing the long arcs bend outwards, while those facing the short arcs bend inward. It means that a positive value of the current in the 'C' as shown in Fig. 1 corresponds to a positive value in the 'C' on the long arc and negative in the 'C' in the short arc. The angle corresponding to zero current in the 'C' is 19.2 mrad, with the splitters at 439 A. Considering that the beams will not collide at the IP the larger angle is only an advantage.

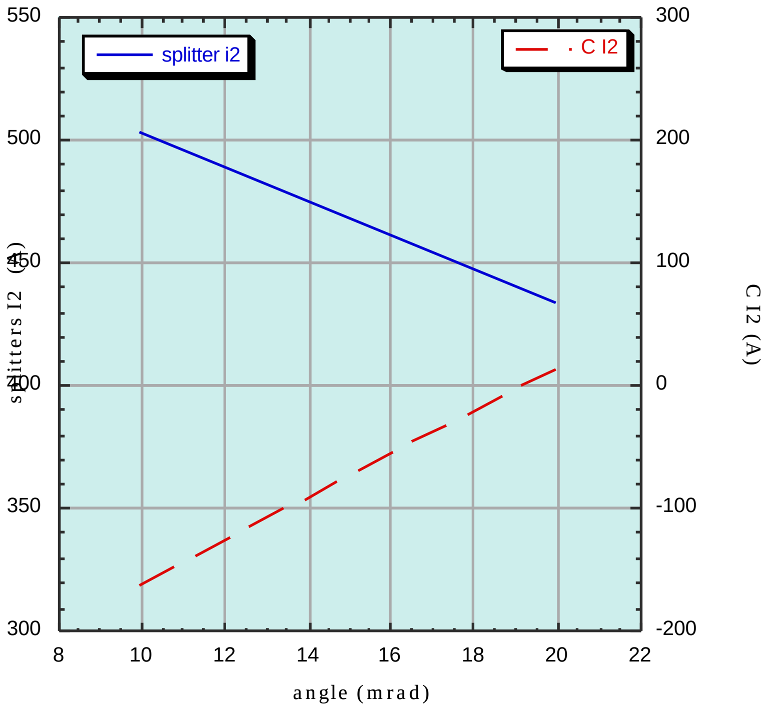


Figure 1 – Splitter and C currents in IR2.

The IR1 optics is strictly defined by the field values of the permanent magnet quadrupoles and of the solenoid field. The lattice has been designed using the nominal values of the betatron functions at the IP (β_x = 4.5 m, β_y = 4.5 cm). In this case the angle corresponding to zero current in the 'C' is 11.8 mrad, with 430 A on the splitters.

Figure 2 shows the values of the splitter and of the corrector as a function of the crossing angle, with the same sign conventions as before.

The figures in the Appendix show the betatron functions, the horizontal separation, the vertical orbit and the beam sizes for the KLOE IR, the usual lattice used in IR2, and the detuned configuration.

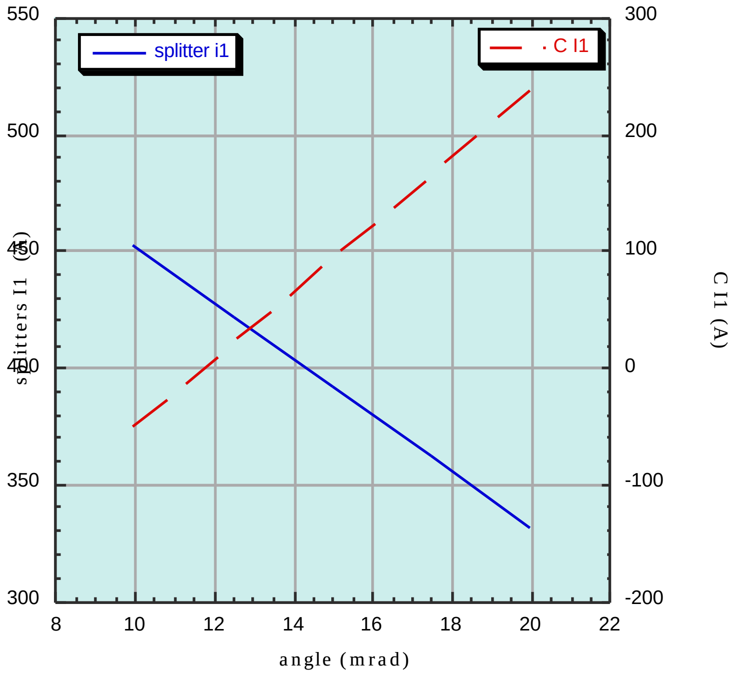


Figure 2 – Splitter and C in IR1

Lattice Description

The usual constraints in the lattice have been maintained: π horizontal phase advance between injection kickers, zero dispersion in the short straight section, low vertical beta in the wigglers. The horizontal betatron functions in the wigglers have been lowered in order to decrease the effect of the wiggler decapole nonlinearity. Tunes are the usual ones (5.15, 5.21). The general parameters are listed in Table I, which is the output of the code MAD. In Table II the set of currents in all quadrupoles are listed. The tune change can be done as usual with the seven quadrupoles of the short section. Figures 3 and 4 show the betatron functions and the dispersion for the whole ring.

Table I

```
Global parameters for POSITRONS, radiate = T:

1 positrons - detuned lattice                    "MAD" Version: 8.22/14   Run: 02/03/01  09.25.55
 Coupled lattice functions.      TWISS          line: WHOLEK                range: #S/#E
 Delta(p)/p:    0.000000        symm: F         super:   1                               page    1
 -----------------------------------------------------------------------------------------------------------------------------
  ELEMENT SEQUENCE            I          M O D E S         I   C O U P L I N G   I  O R B I T        I D I S P E R S I O N
            pos.  element occ.     dist I  beta1      alfa1     mu1      I    R(1,1)      R(1,2)     I    x(co)  px(co)  I    Dx        Dpx
             no.   name    no.      [m]       [m]         [1]       [2pi]    I      [1]           [m]       I   [mm]  [.001]  I    [m]        [1]
                                                   beta2      alfa2      mu2      I   R(2,1)       R(2,2)     I   y(co)  py(co)  I   Dy        Dpy
                                              I   [m]         [1]       [2pi]     I    [1/m]          [1]        I   [mm]  [.001]   I   [m]        [1]
 -----------------------------------------------------------------------------------------------------------------------------
 begin WHOLEK     1     0.000          3.247    -0.020    0.000          0.012    -0.014          0.000    0.000          -1.273    -0.002
                                                  7.100    -0.001    0.000         -0.003    -0.004          0.000    0.000           0.000    0.000
 end   WHOLEK    1    97.690          3.248    -0.020    5.153          0.012    -0.014          0.000    0.000          -1.273    -0.002
                                                  7.100    -0.001    5.208         -0.003    -0.004          0.000    0.000           0.000    0.000
 -----------------------------------------------------------------------------------------------------------------------------
 total length   =         97.689800          Q1           =           5.152779          Q2           =          5.207868
 delta(s)        =         -8.140818 mm
 alfa              =          0.292896E-01    betax(max)   =         9.745746          betay(max)   =         29.920127
 gamma(tr)      =          5.843103            Dx(max)      =         2.675715          Dy(max)       =          0.003325
                                                     Dx(r.m.s.)   =         0.843293          Dy(r.m.s.)   =         0.001423
                                                    xco(max)       =         0.000000          yco(max)      =          0.000000
                                                     xco(r.m.s.)   =         0.000000          yco(r.m.s.)  =         0.000000
 -----------------------------------------------------------------------------------------------------------------------------
     C              97.689800 m            f0              3.068819 MHz             T0            0.325858 microseconds
   alfa             0.293090E-01          eta             0.293080E-01            gamma(tr)       5.841162
    E               0.510000 GeV           gamma          998.044889                beta            0.999999
    U0              0.009289 [MeV/turn]

                                                              M o d e   1         M o d e   2         M o d e   3
 Fractional tunes        undamped              0.15281767          0.20784828          0.01146025
                                      damped              0.15281770          0.20784825          0.01146025

beta* [m]                        x                 0.32485418E+01      0.51646494E-03      0.49978572E+00
                                     y                 0.12901880E-03      0.70979671E+01      0.10858280E-03
                                     t                 0.40843260E-01      0.64845379E-09      0.39735547E+02

 gamma* [1/m]              px               0.30800086E+00      0.26079447E-04      0.71814260E-10
                                     py               0.66672645E-04      0.14090853E+00      0.68473851E-14
                                     pt               0.79163218E-07      0.31499558E-11      0.25166296E-01

 beta(max) [m]               x                 0.97417434E+01      0.52440540E+00      0.41149892E+01
                                     y                 0.87436919E+00      0.29610522E+02      0.70241765E-03
                                     t                 0.17998726E+00      0.19021167E-06      0.39799719E+02

 gamma(max) [1/m]         px               0.36377088E+01      0.24298701E+00      0.71814260E-10
                                       py               0.98542218E+00      0.44335015E+02      0.68473851E-14
                                       pt               0.68051507E-01      0.79711748E-07      0.25166296E-01

 Damping partition numbers              0.87348479               1.00001074               2.12650680
 Damping constants [1/s]                 0.24412861E+02      0.27949111E+02      0.59433336E+02
 Damping times [s]                         0.40962016E-01      0.35779313E-01      0.16825574E-01
 Emittances [pi micro m]                 0.79767411E+00      0.64326986E-04      0.58871608E+01

Delta(p)/p:     0.00000000                M o d e   1                M o d e   2
 Fractional tunes:                 Q1      =      0.15270101     Q2      =      0.20790226

 sextupoles off
 First order chromaticity:         Q1'     -5.48632203     Q2'     -14.91840140
 Second order chromaticity:    Q1"      8.76138693     Q2"    -29.14239402

 sextupoles on
 First order chromaticity:          Q1'     =     -0.56392000     Q2'     =     -0.50753154
 Second order chromaticity:     Q1"     =     51.53203794     Q2"    =   -140.81855687
                                       Beta_1  =  0.32473072E+01 m   Beta_2  =  0.71043515E+01 m
                                     Alpha_1 = -0.20055070E-01 m   Alpha_2 = -0.12804316E-02 m
                                    Gamma_1 =  0.30812165E+00 m   Gamma_2 =  0.14078204E+00 m
 Horizontal extent:                     0.16158078E-02 m             0.10248938E-04 m
 Horizontal divergence:                0.49772463E-03 rad            0.72926333E-05 rad
 Vertical extent:                          0.14406109E-04 m             0.16857463E-02 m
 Vertical divergence:                    0.32150013E-05 rad            0.23730321E-03 rad
 Normalized anharmonicities:    dQ1/dE1 = -0.74510973E+02
                                                     dQ1/dE2 = -0.14297162E+03     dQ2/dE2 =  0.73594783E+02
```

Table II

QUAI2001	213.6
QUAI2002	-185.4
QUAI2003	0
QUAI2005	0
QUAI2006	-185.4
QUAI2007	213.6
QUAPL101	166.689
QUAPL102	-164.918
QUAPL103	173.815
QUAPL104	-62.582
QUAPL105	65.337
QUAPL106	90.729
QUAPL107	84.380
QUAPL108	4.555
QUAPL109	-119.376
QUAPL110	95.226
QUAPS101	55.621
QUAPS102	-80.593
QUAPS103	36.322
QUAPS104	-87.276
QUAPS105	95.824
QUAPS106	52.933
QUAPS107	-133.794
QUAPS108	160.520
QUAPS109	-121.199
QUAPS110	279.235
QUAPS201	-121.199
QUAPS202	160.520
QUAPS203	-133.794
QUAPS204	61.611
QUAPS205	85.307
QUAPS206	-49.408
QUAPS207	-105.081
QUAPS208	78.660
QUAPS209	0.000
QUAPL201	0.000
QUAPL202	86.667
QUAPL203	-110.134
QUAPL204	-49.277
QUAPL205	79.095
QUAPL206	67.045
QUAPL207	-62.582
QUAPL208	173.815
QUAPL209	-164.918
QUAPL210	166.689

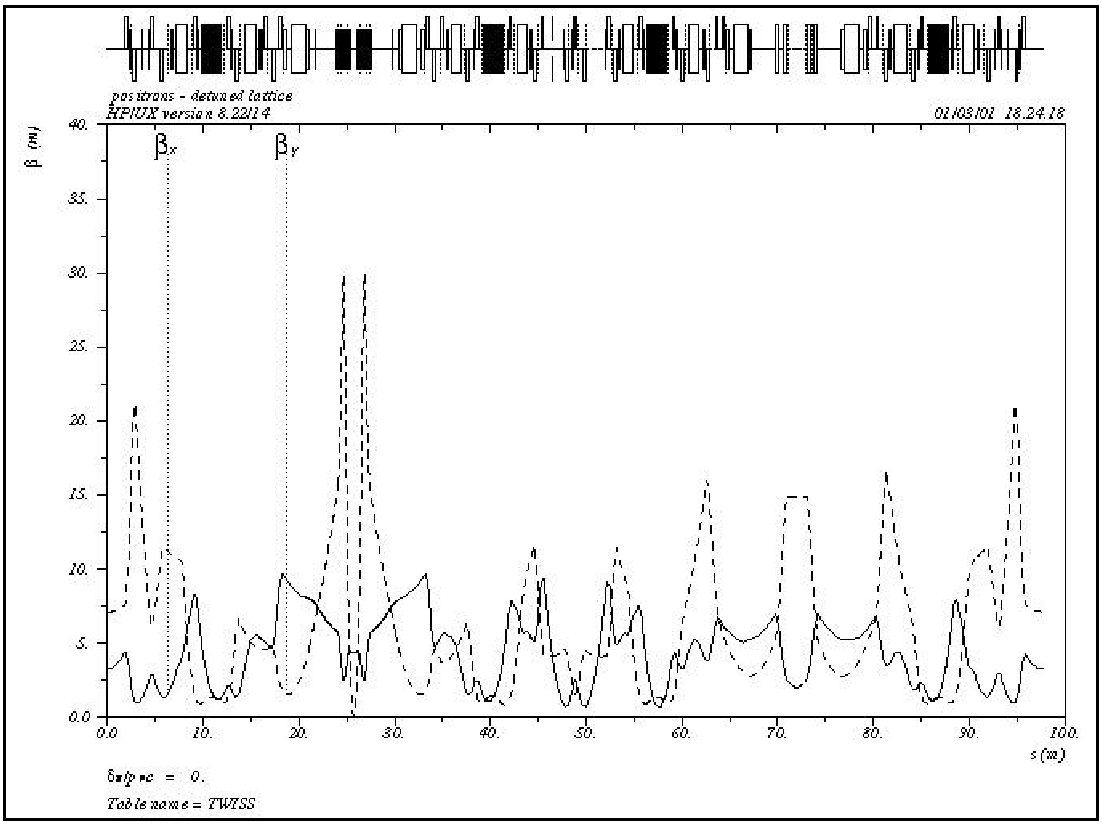


Figure 3 – Optical functions in the ring

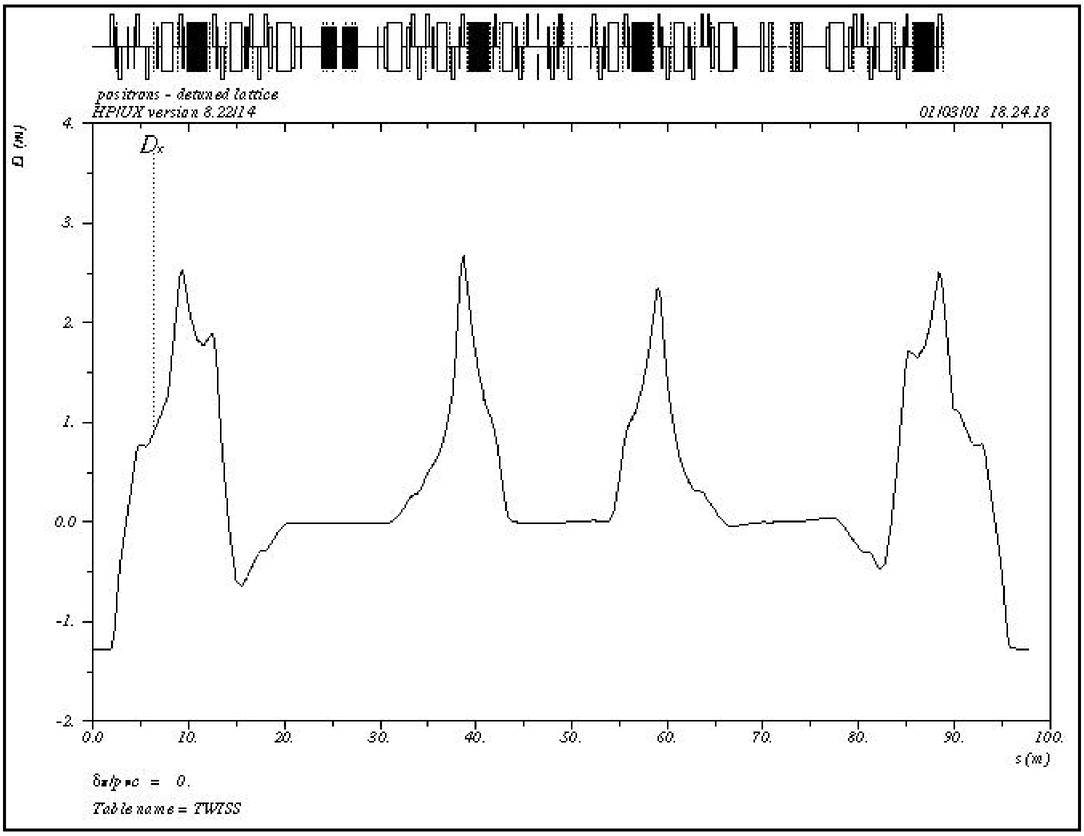


Figure 4 – Horizontal dispersion in the ring

Dynamic Aperture

I have performed a first dynamic aperture evaluation. The lowering of the horizontal betatron functions in the wiggler has the advantage of decreasing the unwanted effect of the wigglers non-linearities, but it has the disadvantage of coupling more the betatron functions at the sextupole positions. So, even if the chromaticity is lower than in the usual structure, the sextupole strengths are not decreased by the same percentage. The dynamic aperture computed without non-linearities in the wigglers exceeds the physical aperture in both planes. Including the multipole term in the wigglers it is decreased by few sigmas. The contribution of the wiggler non-linearity on the second order chromaticity is decreased with respect to the present optics of about a factor 2 on the horizontal plane, while it is increased by 80% on the vertical one. Since our dynamic aperture seems more critical in the horizontal plane, the total change is beneficial.

Figure 5 shows the dynamic aperture simulations, as computed with MAD, tracking particle for 500 turns with the 'LIE3' method. The value of the corresponding sextupole currents are listed in Table III. A further optimisation of the sextupole configuration, taking into account the wiggler non-linearity is still to be done.

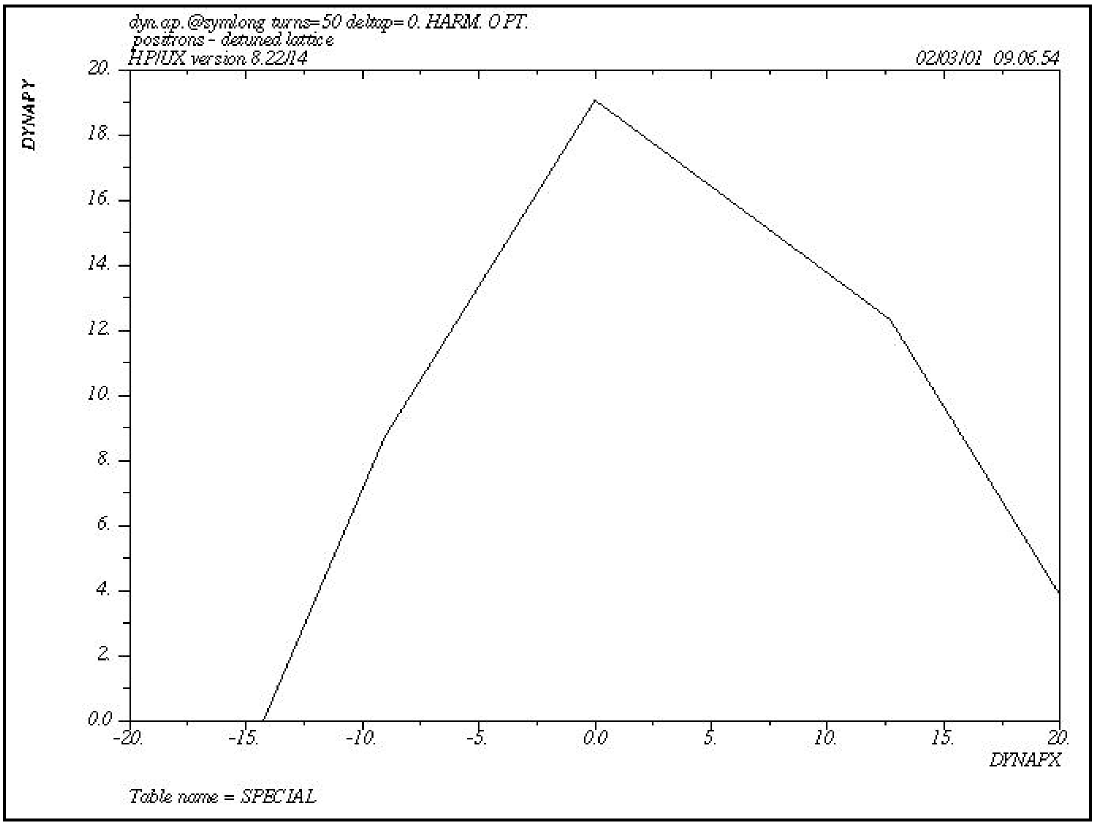


Figure 5 – Dynamic aperture on energy without wiggler non linearity

Table III

SXPPL101	-40
SXPPL102	50
SXPPL103	-115
SXPPL104	0.
SXPPS101	0.
SXPPS102	-85
SXPPS103	30
SXPPS104	0
SXPPS201	0.
SXPPS202	30
SXPPS203	-55
SXPPS204	0
SXPPL201	0
SXPPL202	-55
SXPPL203	50
SXPPL204	-40

References

[1] M. Preger, M. Serio: private communication.

[2] B.Bolli et al.: ‘Measurements on TESLA ‘C’ Correctors Prototype for the DAFNE Main Rings’ – DAFNE Technical Note MM-17 (1996).

[3] G. Benedetti: ‘Sextupole in the "C" Corrector Magnet’ - DAFNE Technical Note BM-5 (2001)

[4] DAFNE logbook (24 – 26 february 2001).

[5] C. Biscari: ‘Linear Optics Model for the DAFNE Main Rings’ - DAFNE Technical Note, in preparation.

[6] M. Bassetti, M.E. Biagini, C. Biscari, S. Guiducci, M.R. Masullo, G. Vignola: ‘High Emittance Lattice for DAFNE’ –DAFNE Technical Note L-1 (1990).

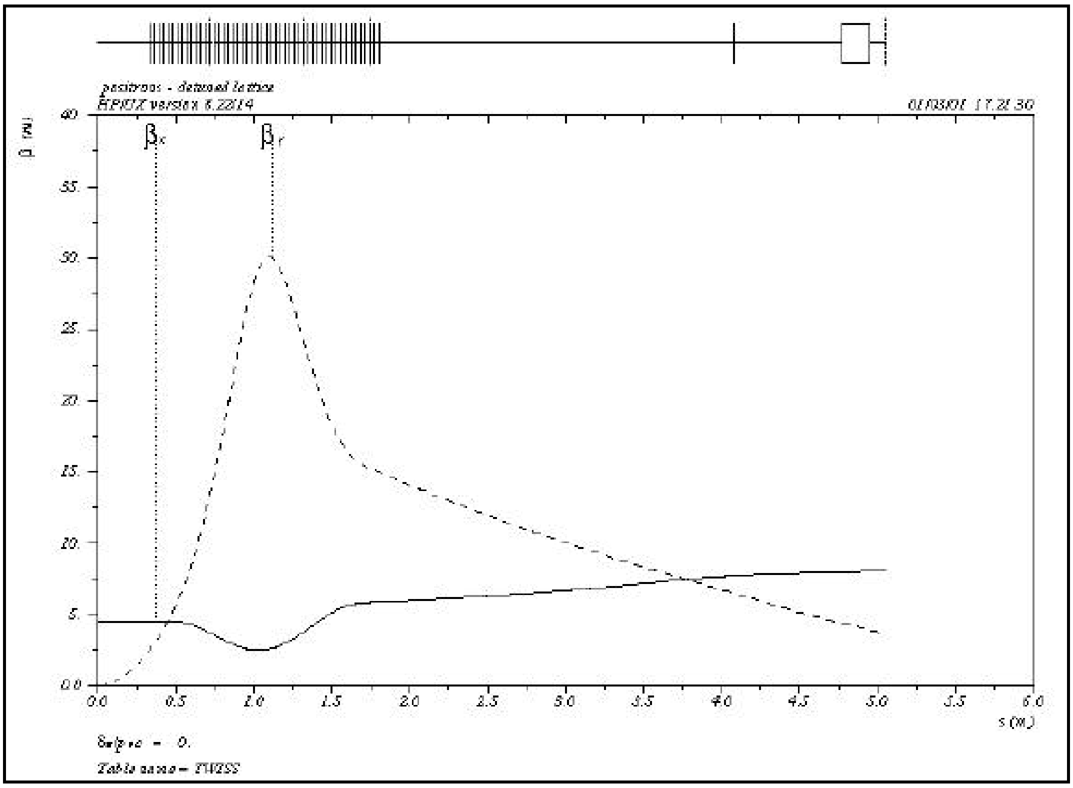
[7] S. Guiducci, M. Preger: ‘Calibration Constants and Nominal Set Points for the Day-One Lattice of the DAFNE Main Rings’ - DAFNE Technical Note C-18 (1997).

APPENDIX

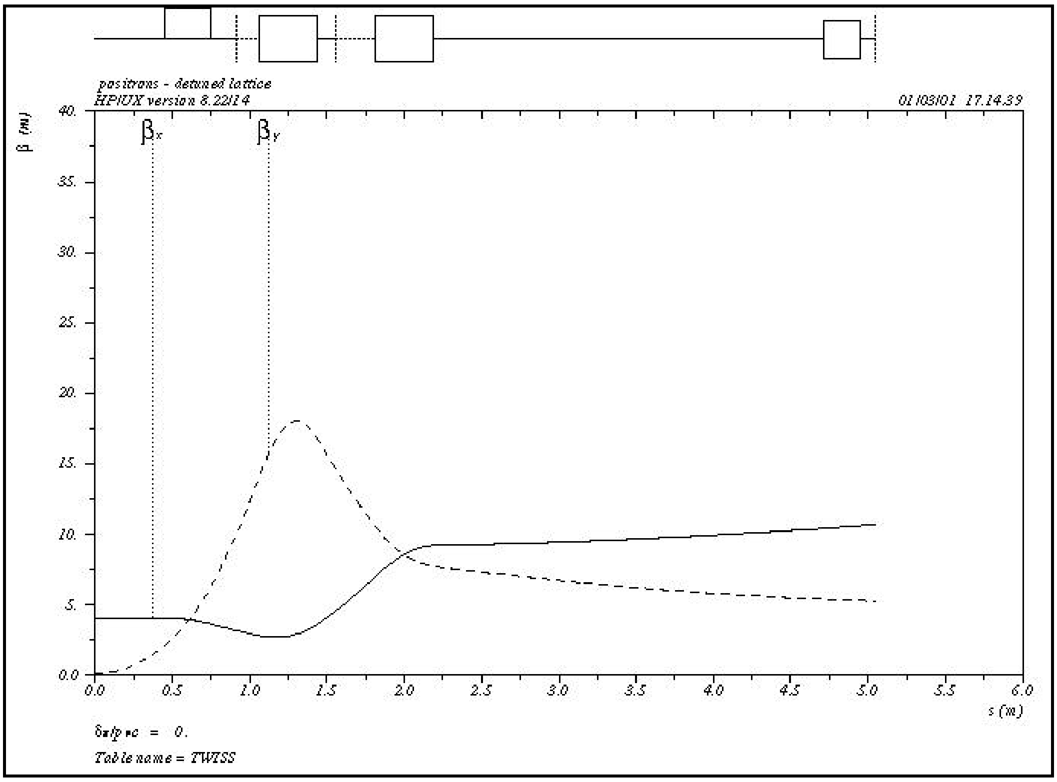
Optical Functions

The values of the optical functions in the three IR lattices at the IP are listed in the following table. Their behaviours along the IRs are shown in the following three figures.

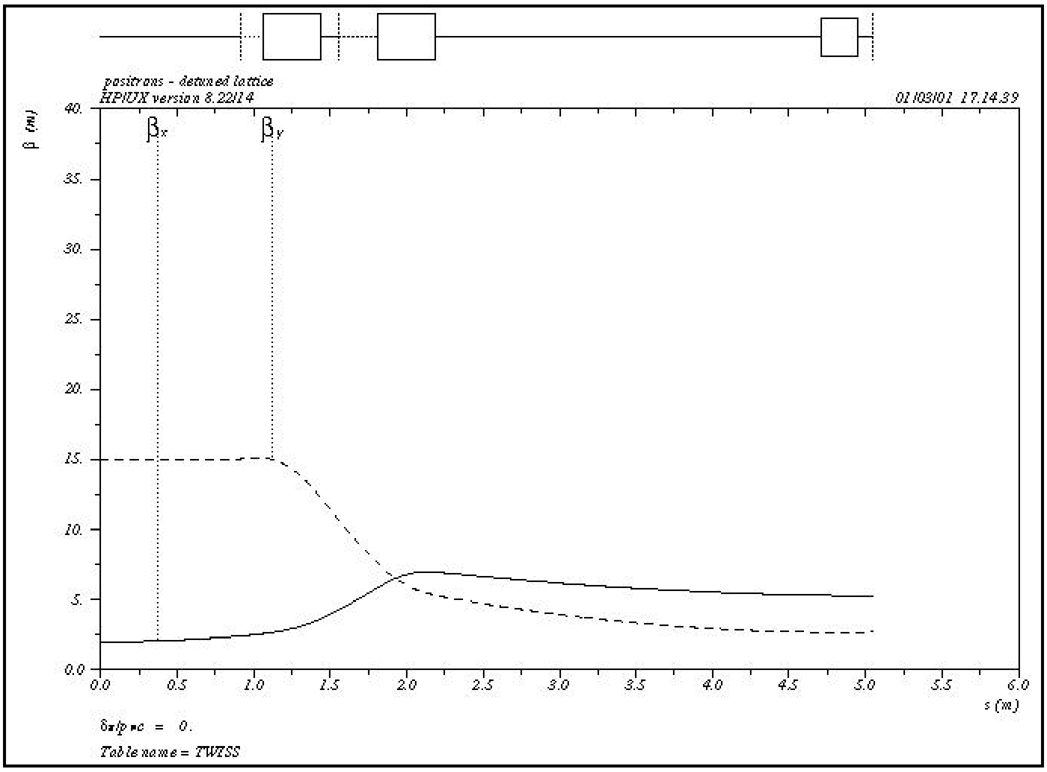
	KLOE	Usual IR2	Detuned IR2
$\beta_x^*(m)$	4.5	4.0	2.0
$\beta_y^*(m)$	0.045	0.10	15.0
$D\,(m)$	0	0	0
$D'(rad)$	0	0.1	0



KLOE IR



IR2 – usual configuration

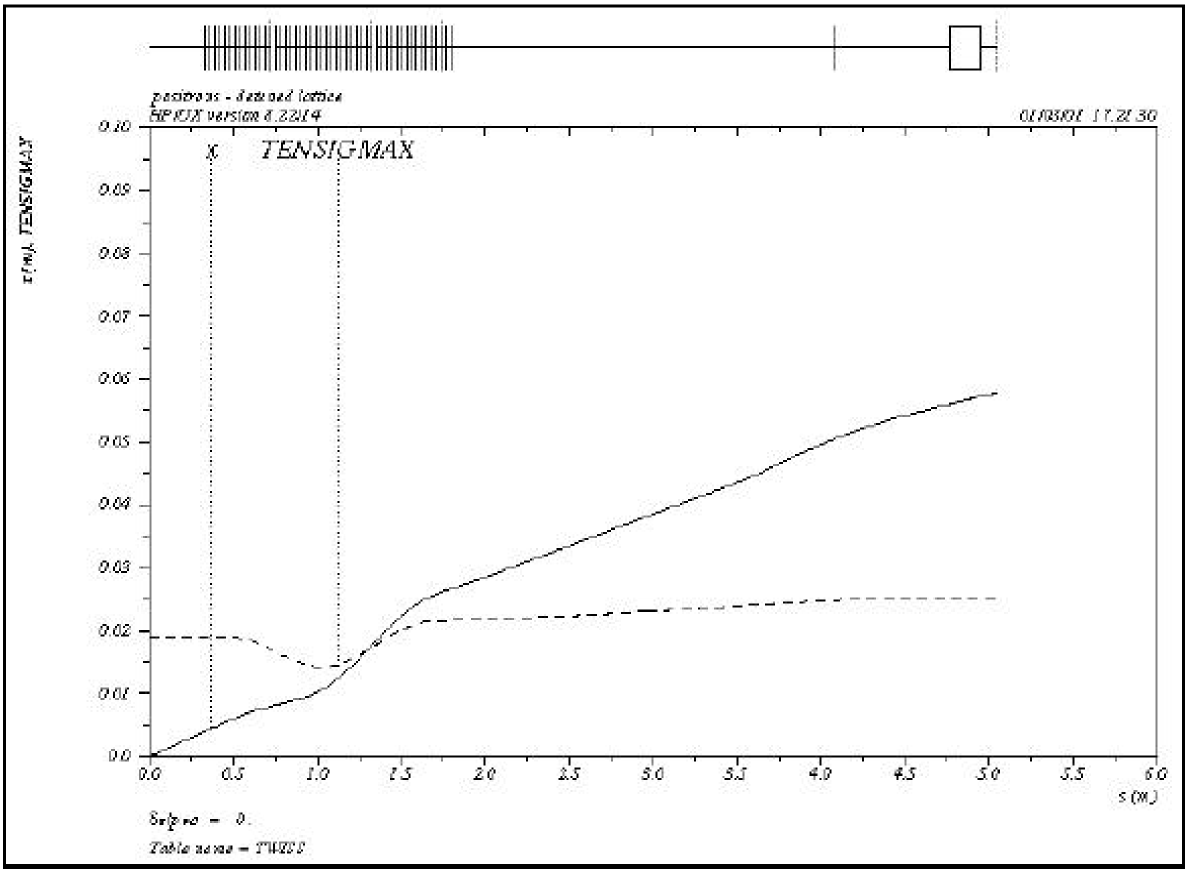


IR2 – detuned lattice

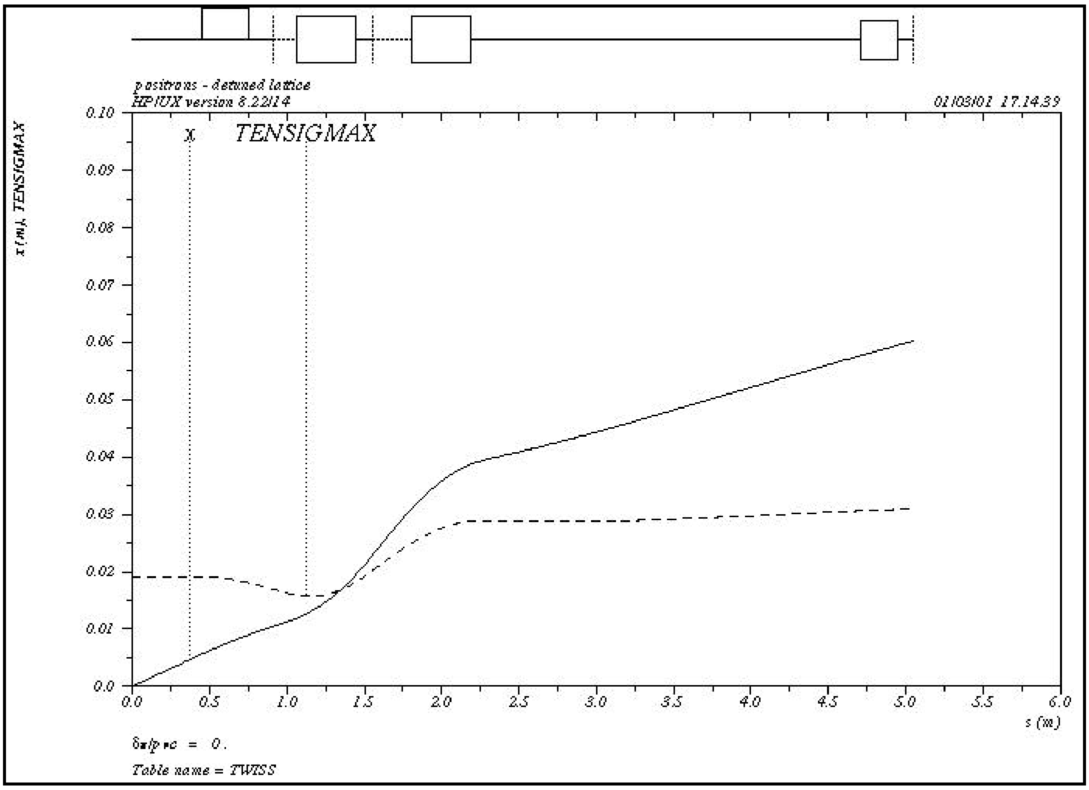
Horizontal Apertures

The horizontal beam separation along the IRs (solid line) and 10 σ_x (dashed line) are shown in following figures.

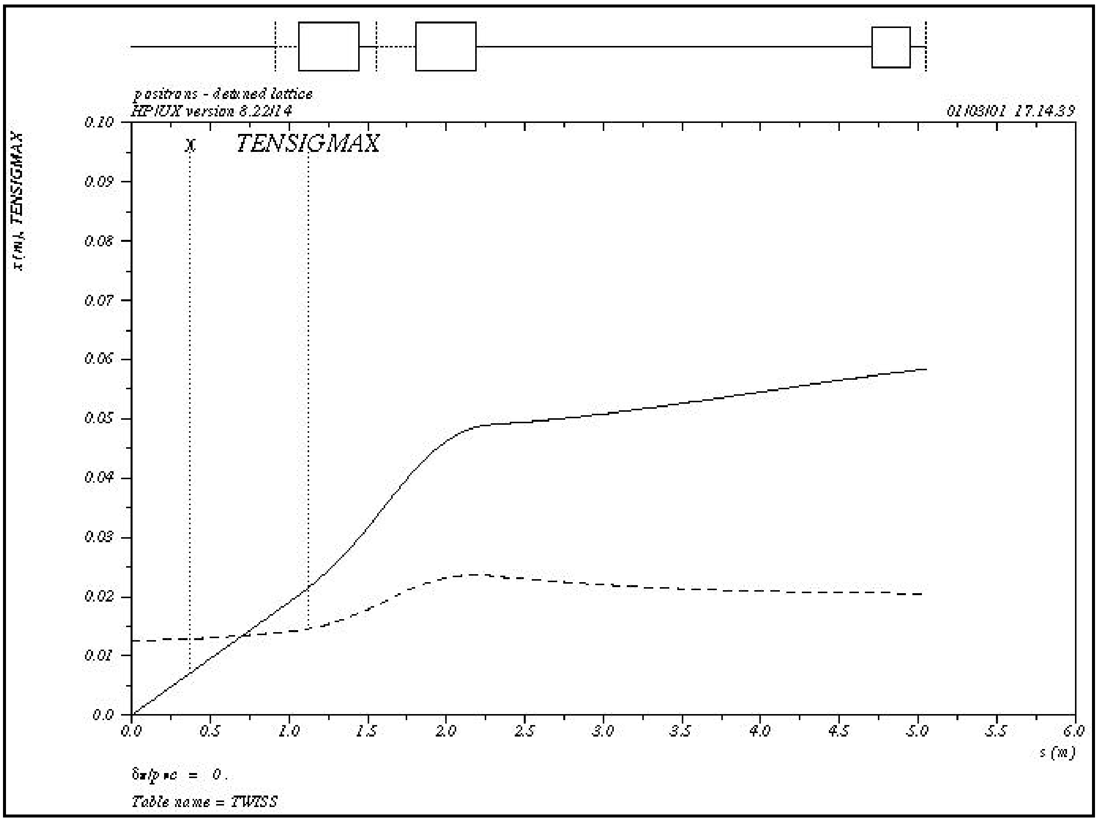
The crossing angle used in simulation is written in the figure caption.



KLOE IR θ = 12.5 mrad



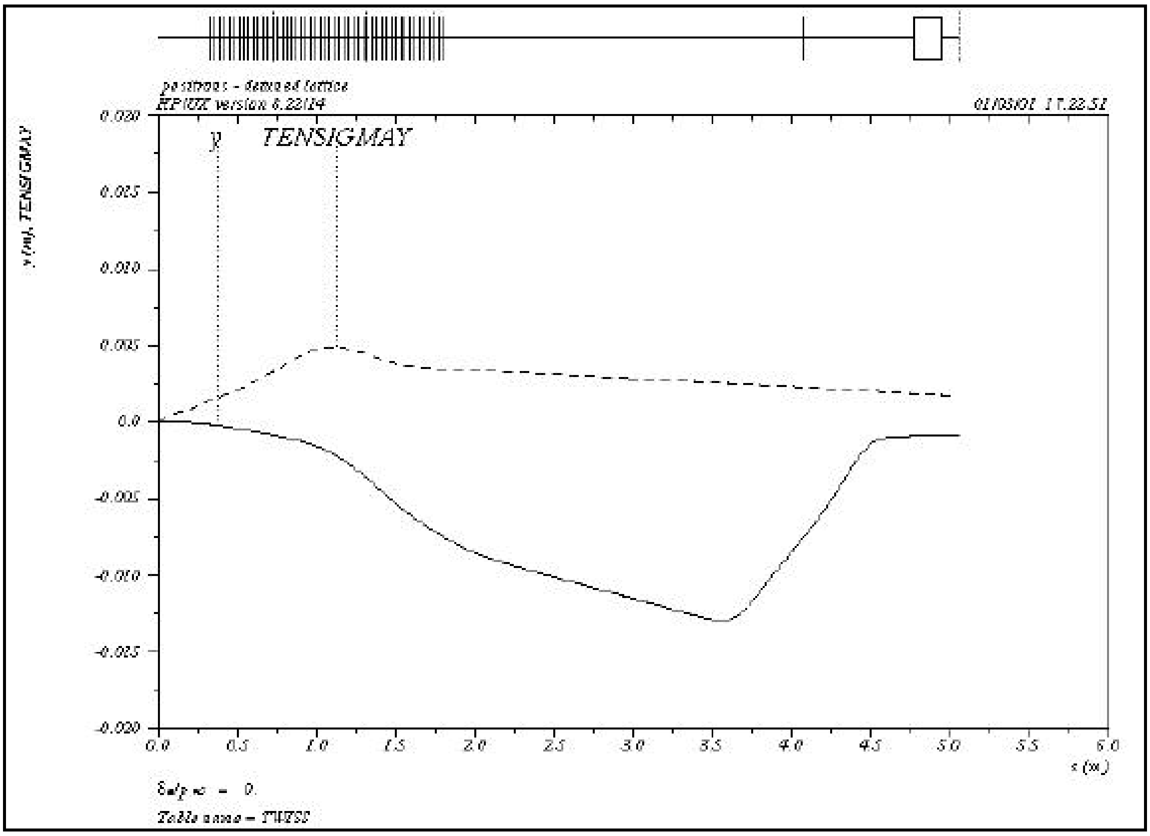
IR2 – low beta θ = 12.5 mrad



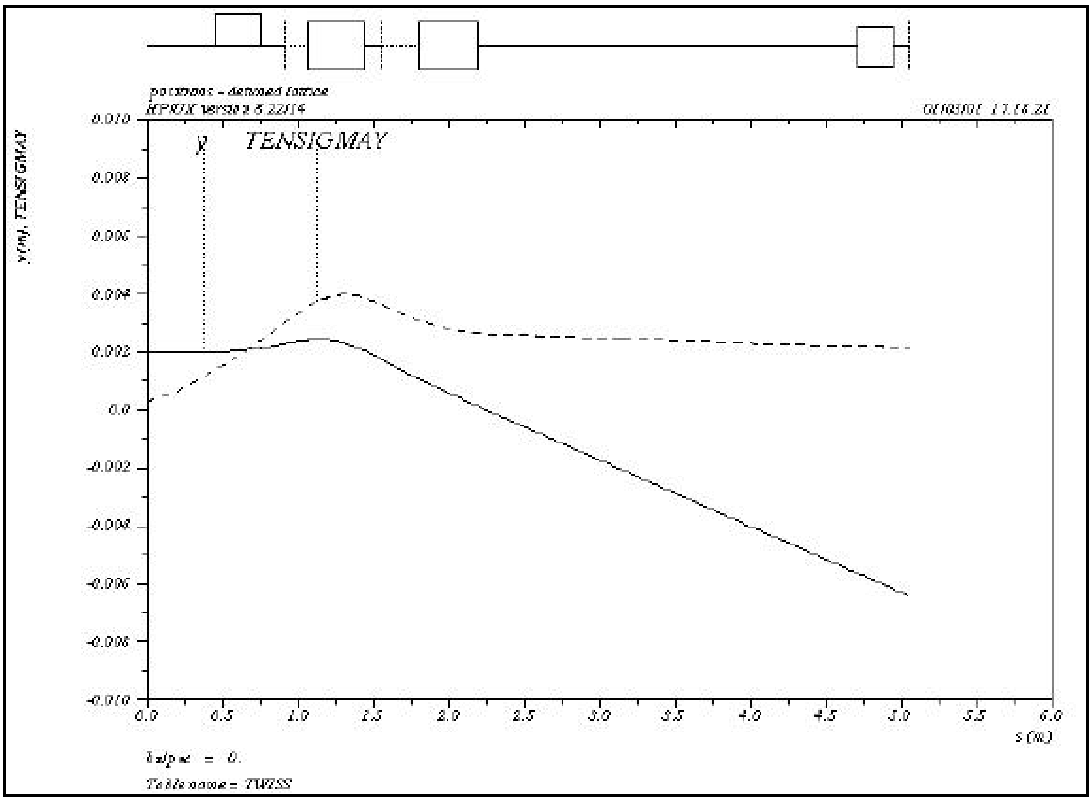
IR2 – detuned θ = 19 mrad

Vertical Apertures

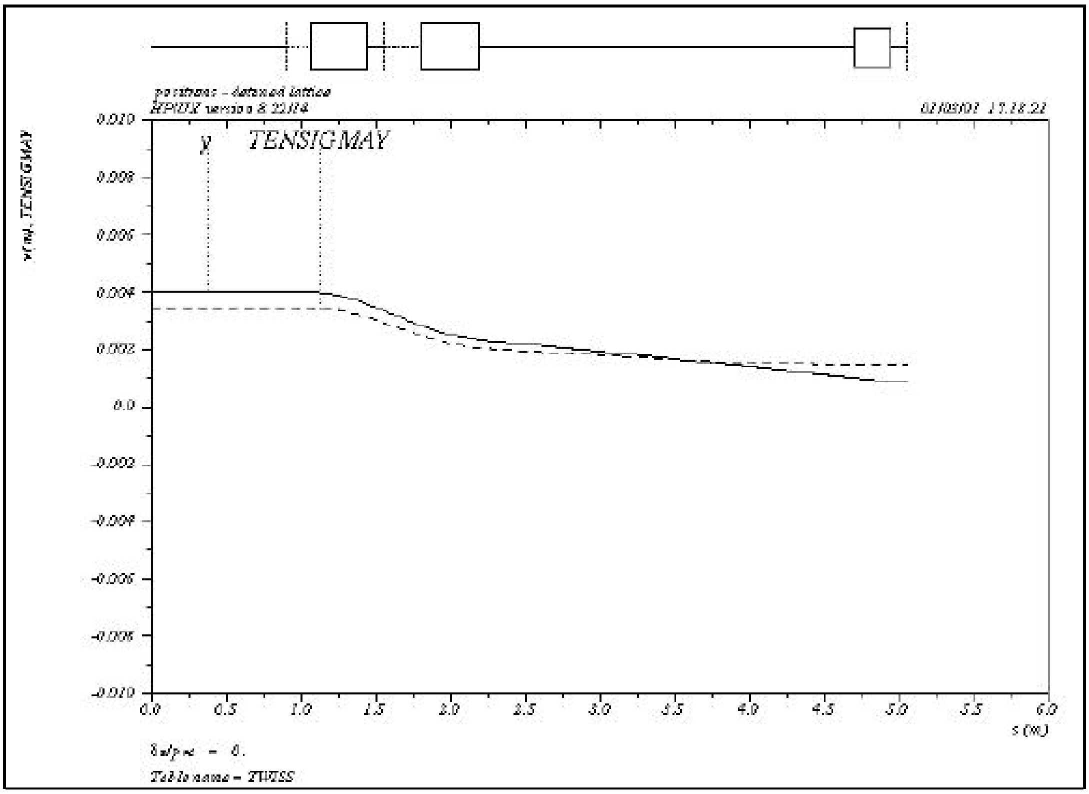
The vertical beam size (10 σ_Y at 1% coupling) are shown (dashed line) together with the vertical orbit in the KLOE-collision configuration (solid line).



KLOE IR - y $_{IP}$ = 0



IR2 – usual configuration y $_{IP}$ = 2mm



IR2 – detuned lattice - y $_{IP}$ = 4mm