CCDTL design update for Linac4

M. Pasini[1]

1) CERN, Geneva, Switzerland

Abstract

The CCDTL section for the future H^- injector Linac4 at CERN was revised after the change of final LINAC energy. A new optimized geometry of the single tank has been obtained and based on this new geometry five possible layout have been calculated. A new generation routine has been implemented: it takes into account a more realistic field calibration and it includes the calculation of the phase slippage. A calculation of the parameters for the magnetic quadrupoles is given. A comparison of the 5 layouts based on cost consideration is also given, together with a first order misalignment study.

Introduction

A design review on the CCDTL section for the SPL [1-4] project is ongoing. The review was requested because of the change of the energy range of the CCDTL section from 40-120 MeV down to 40-90 MeV. While in the previous design at high beta the tanks consisted in 4 gap and 3 drift tubes, all the tanks will consist now only of 3 gaps and 2 drift tubes. This modification has some relevance in the choice of the optimum diameter as a free parameter for "tuning" the geometry in order to gain in shunt impedance along the new energy range.
This note presents also the "history" of the design process of the CCDTL section from October 2004 up to February 2005.

CCDTL Geometry

The solution of the Maxwell equation is done by the code Superfish [6], and the schematic geometry that has been used as for CCDTL tuning program is given in Fig. 1 and 2. In fact all the accelerating tanks comprise of 2 drift tubes, so the figures below are only a reference figures for the determination of the geometrical parameters.

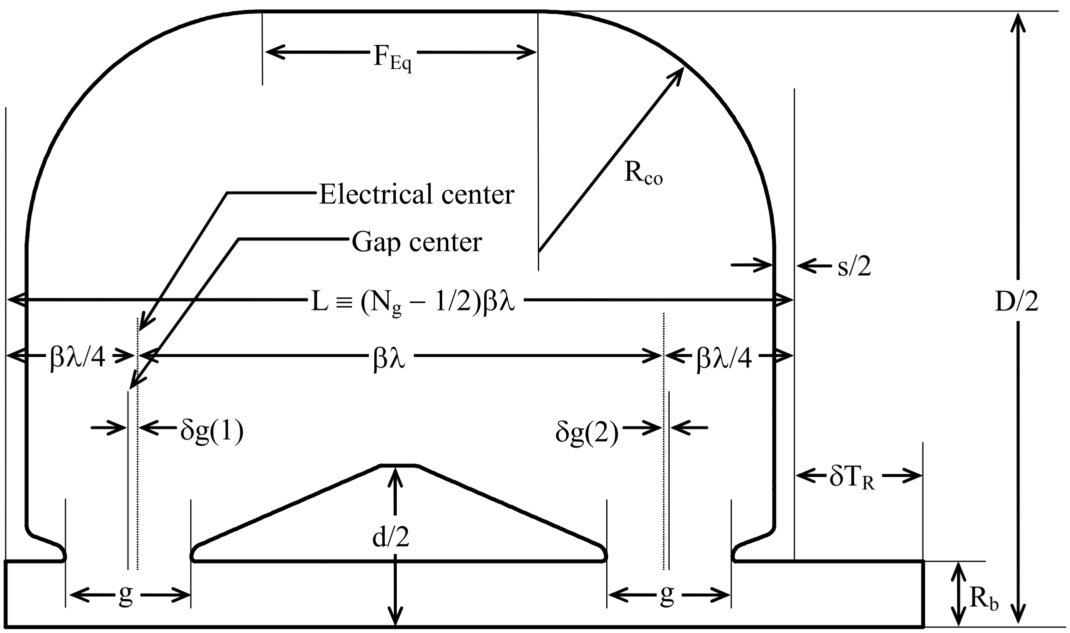

Figure 1. Parametric geometry for the CCDTL tuning program.

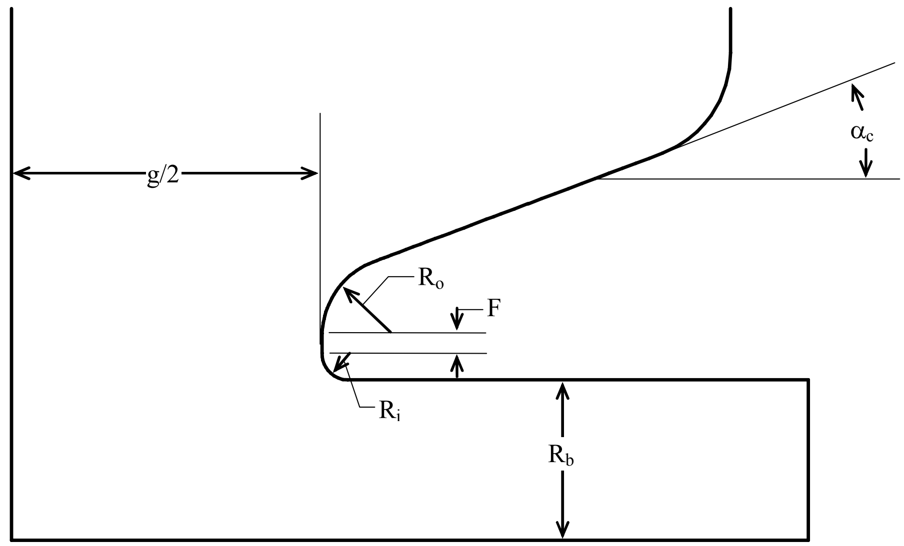

Figure 2. Detail near the nose in a CCDTL cell.

The geometry was already optimized for the previous layout [4]. The present study verified that the diameter which was chosen before is still the optimum for the new energy range.

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Ac TITLE
2-drift-tube CCDTL cavity
352.2-MHz half cell with 2-cm-long bore tube
Tuned by adjusting cavity diameter
Equal face angles on drift tubes
ENDTITLE

PLOTTING OFF
PARTICLE          H-
TEMPerature       25

HALF_cavity
FILEname_prefix     ccdtl_01
SEQuence_number     1
FREQuency           352.2
BETA                0.287
DIAMeter            52.0
!G_OVER_Beta_lambda    0.30
GAP_Length                        6.0
E0_normalization     3.0
!E0T_Normalization    2
NUMBER_of_gaps       3
EQUATOR_flat         53.01
INNER_CORNer_radius   1.5
OUTER_NOSE_radius     0.70
INNER_NOSE_radius     0.3
FLAT_length          0.5
CONE_angle           30
SEPTUM_thickness     0.0
BORE_radius          1.4
LEFT_BEAM_tube       1.
RIGHT_BEAM_tube      1.
DT_DIAMeter          8.5
DT_CORNer_radius     0.25
DT_OUTER_NOSE_radius  1.2
DT_INNER_NOSE_radius  0.3
DT_FLAT_length       0.4
DT_STEM_Diameter     2.4
DT_STEM_Count        2
DT_OUTER_FACE_angle   80
DT_INNER_FACE_angle   80
DELTA_frequency      0.05
MESH_size            0.05
INCrement            2
START                5

; Start codes for CDTFISH:
; 1 No tuning
; 2 Adjust diameter and move gaps for S = 0
; 3 Adjust gap(s) and move gaps for S = 0
; 4 Adjust diameter, gap centers fixed
; 5 Adjust gap(s), gap centers fixed
;  (When S = 0, geometric and electrical centers coincide.)

ENDFILE
```

Figure 3. Example input file for the 1st cavity of the SPL CCDTL section.

An example file for simulating the cavity is shown in Figure 3 and the study was to check the effective shunt impedance which is calculated directly from Superfish for different energies and for different diameter.

Simulation with SUPERFISH

The simulations where performed in the following way: for a given geometry and for a given geometric beta (i.e. the $\beta * \lambda$ that separate the centers of two adjacent gaps) one varies the gap size and let as a free parameter the diameter of the cavity in order to match the correct resonant frequency. The CDTfish program calculates the proper diameter and hence calculates the R.F properties of the cavity. If one does so for different geometric betas, one can have a picture of the parameters environment and then identify the optimum "working point". In Appendix 0, we report the tables with the data calculated from SUPERFISH. The simulations have an error of convergence in the resonance frequency of ±0.1%.

In Figure 4 it is shown the calculated Shunt Impedance as a function of the $g/\beta\lambda$ ratio. The effective shunt impedance decreases rapidly with the particle velocity. This is the reason why around 90 MeV the structure is changed, from the 0-mode CCDTL to a π-mode structure like the SCL.

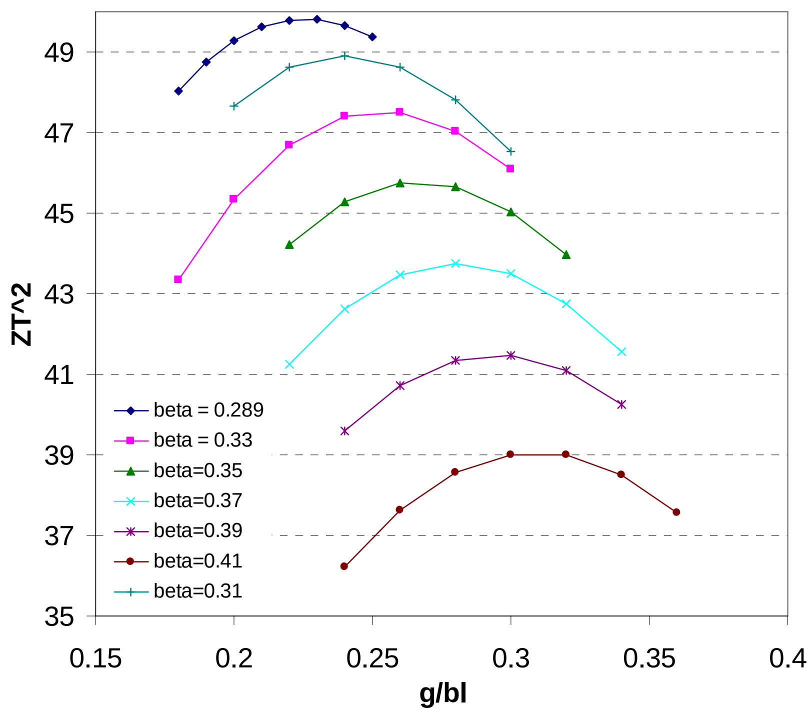

Figure 4 Plot of the Effective Shunt Impedance as a function of the gap over βλ ratio. The figure shows that the shunt impedance goes from a maximum of nearly 50 MΩ/m down to 39 MΩ/m.

In Figure 5 is shown the Effective Shunt Impedance as a function of the diameter of the tank for different particle velocity. The plot shows that the ZT2 factor is maximum at different tank diameters, depending on the particle velocity. In practice, in order to allow constant coupling between tanks and for simplifying the mechanical design, we choose to keep only one diameter for the whole CCDTL section. This choice does not compromise the efficiency of the design because we can choose a diameter which is still in the optimum range for all the particle velocities. In Figure 5 the red line shows an optimum diameter at about 51.5 cm. This value was chosen also considering the mechanical constraints. Installation of the quadrupole will be easier for bigger diameter. All these simulations have been performed keeping the same curvature radius (R_{co}) parameter constant (see **Figure 1**) and the septum distance (s parameter in Fig. 1) equal to zero. The result of this part of simulation is that a tank diameter increase from 495 mm up to 515 mm brings an increment of the shunt impedance of about 2% at low beta and a decrease of 0.5% at high beta.

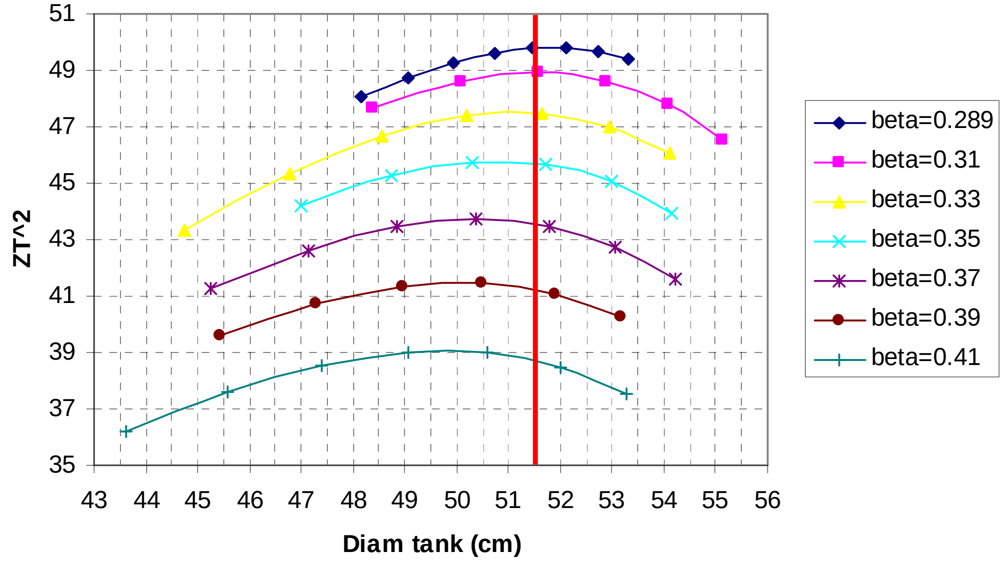

Figure 5. In the figure is plotted the Effective Shunt Impedance as a function of the diameter calculated for matching the resonant frequency. The figure shows that as the energy increases the optimum diameter will be a smaller one. The red line shows that a possible optimum diameter for the proposed energy range is 51.5 cm.

Layout generation

Working principle of CCDTL

The idea behind the CCDTL structure is to use small DTL cavities coupled via a side cavity. Such system operates in a π/2 mode which is intrinsically stable. For the π/2 mode the first-order perturbation theory shows that the accelerating fields are affected by frequency errors only as a second order effect [7].

An important equation that rules out the behavior of the coupled resonating cavities in a π/2 mode is the following:

$$k^2 U = const. \quad (1)$$

where k is the coupling factor and U is the stored energy in the accelerating cavity.
The coupling coefficient can be calculated with an analytic formula if the coupling iris has an elliptical geometry [8]:

$$k = \frac{\pi}{3}\mu_0 e_0^2 L^3 \frac{H_{ac} H_{cc}}{K(e_0) - E(e_0)} \frac{1}{\sqrt{U_{ac} U_{cc}}} e^{-\alpha_H t} \quad (2)$$

where μ is the permeability of the free space, $e_0 = \sqrt{1 - w^2/L^2}$, w is the coupling slot half-width, L is the slot half-length, H_{ac} e H_{cc} are the magnetic fields at the slot position in the accelerating and coupling cavities, $K(e_0)$ and $E(e_0)$ are the complete elliptic integrals of the first and second kind, U_{ac} e U_{cc} are the stored energy in the accelerating and coupling cavities, α_H is the TM cutoff waveguide decay factor of the slot, t is the thickness of the slot. In our

case the results are not precise because the coupling iris is not really elliptical, but the dependence of the parameters is correct.
In this note we have assumed that all the coupled cavities have the same peak accelerating field, or in other words if a bead-pull measurement is performed all the accelerating fields are at the same level. This assumption is found to be correct only within a 5% error. This error cannot be considered a small one but it does not compromise the validity of a layout. The aim of this note is to present several possible CCDTL layouts where all the klystrons have an even power load distribution.

CCDTL layouts

For the first CCDTL layout a series of Superfish run was performed with the aim of having a complete set of field distributions in each accelerating tank. After reviewing the mechanical constraints for the insertion of the quadrupole it has been decided to use a slightly larger diameter that the one that was suggested in the previous section, so all the simulation have been performed for tank diameter of 52 cm.
All the other parameters have been calculated via an Excel file (Figure 6, Figure 7 Figure 8)
The input energy has been assumed as 40.44 MeV (to easy the design [5]). The starting energy of the CCDTL section will be adjusted once the DTL design will be frozen. The structure of the datasheet is done by very simple building blocks and it is based on very few free parameters. Practically, one chooses the accelerating gradient, which is given by a normalization whose calculation is based on the voltage of the first cavity, and the so-called geometric βg that has to be taken in order to maximize the transit time factor.

Eini	40.4	**MeV**
mass	939.294	**MeV**
frequency	352.2	**MHz**
c	3E+08	**m/s**
λ	0.851199	**M**
βini	0.28434	**#**
βλ	0.24203	**M**
current	30.0	**mA**

1	2	3	4	5	6	7	8	9
N. Cav #	**E0 [MV/m]**	**βg #**	**V1 [MV]**	**TTFg1 [#]**	**ϕgap1 [deg]**	**ΔW1 [MeV]**	**E1 [MeV]**	**β end g1 #**
1	**3**	**0.287**	**0.549269**	**0.874251**	**-26.572**	0.429477	40.9	0.285753
2	**3**	**0.2908**	**0.554693**	**0.873912**	**-25.426**	0.4378	42.3	0.290456
3	**3**	**0.2955**	**0.593918**	**0.864886**	**-25.326**	0.464301	43.8	0.295233
4	**3**	**0.301**	**0.587302**	**0.864273**	**-26.22**	0.45536	45.4	0.29999
5	**3**	**0.305**	**0.639823**	**0.85915**	**-25.2**	0.497387	46.9	0.304824

Figure 6. Excel datasheet for the calculation of CCDTL parameters

V2 [MV]	**TTFg2 [#]**	**ϕgap2 [deg]**	**ΔW2 [MeV]**	**E2 [MeV]**	**β end g2 #**	**V3 [MV]**	**TTFg3 [#]**	**ϕgap3 [deg]**
0.731382	**0.871507**	-25.0006	0.577682	41.4	0.287639	0.549269	**0.877833**	-25.8001
0.767232	**0.871058**	-25.0001	0.605689	42.9	0.292393	0.554693	**0.875792**	-26.9617
0.782674	**0.865508**	-25.0001	0.613942	44.4	0.297156	0.593918	**0.867718**	-27.0058
0.806209	**0.863921**	-25.0083	0.631202	46.0	0.301927	0.587302	**0.866535**	-26.1133
0.83538	**0.860178**	-24.9925	0.65129	47.6	0.306781	0.639823	**0.859278**	-27.0827

Figure 7. Excel datasheet for the calculation of CCDTL parameters

ΔW3 [MeV]	E3 [MeV]	β end g3 #	power [kw]	s [cm]	Beam load [kw]	Tot power/cav [kw]	tot power [kw]
0.434103	41.9	0.289046	**83.7044**	**0**	43.23786	145.357228	145.357228
0.432994	43.4	0.293768	**88.98619**	-0.7292683	44.29449058	152.8576481	298.214876
0.459159	44.9	0.298583	**88.98619**	1.02009771	46.1220622	154.6852197	452.900096
0.45697	46.4	0.303319	**93.76561**	-0.05001282	46.30595264	160.6999979	613.600094
0.489502	48.1	0.308241	**99.94362**	1.84508369	49.14535697	171.0765725	784.676666

Figure 8. Excel datasheet for the calculation of CCDTL parameters

The cavity is modeled as three thin lenses (see Figure 9). The synchronous particle dynamic is derived by the drift-kick-drift method. When the synchronous particle arrives at the centre of the first gap, phase is calculated in order to match the design synchronous phase at the centre of the cavity. The particle will then experience a energy gain that is equal to $V1 \cdot TTF1 \cdot \cos(\phi_s)$ which has been calculated from the integration of the field given by Superfish. The same procedure applies to the other 2 gaps and then the synchronous particle dynamics can be determined.

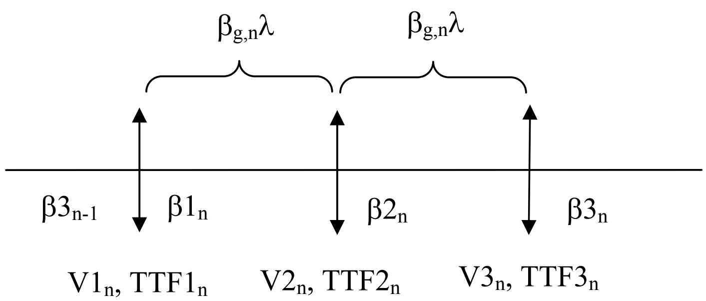

Figure 9. Three lenses CCDTL model

Since the phase of the first gap is always controlled in order to have the proper phase at the center of the cavity, the distance between two adjacent accelerating cavities is not simply equal to $\beta 3_n \lambda/2$ (see Figure 9), which is equivalent to 450 degree of revolution time, but is slightly different due to the phase slip effect. This effect occurs when for practical reason the distance between the gaps is kept constant, even when the particle has a different velocity. This effect is important because it allows the correct calculation of the septum parameter which is the one that make possible to maintain a constant geometry of the coupling cavity.

As one can see, a very important parameter is the geometric reduced velocity, β_g, which has to be chosen in order to maximize the transit time factor. The rule followed was choosing a value that creates a small phase difference between the first and the second gap, so that in case of a perfect synchronicity, the error due to the wrong velocity can be estimated simply by the ratio between the phase difference and the complete period. We know in fact that:

$$\frac{\Delta\phi}{360} = \frac{\beta_g}{\beta_p} \tag{3}$$

where β_p is the velocity of the synchronous particle. If we want an error below 1% is then necessary that $\Delta\phi$ is less then 3 degrees. This rule was also confirmed by modeling the transit time factor of the cavity with a square field distribution: one find the TTF is maximized when

$$\frac{4\cos^2\left(\pi\frac{\beta_g}{\beta_p}\right)-1}{3}-1=0 \tag{4}$$

In all the layouts the chosen geometric reduced velocity shows a maximum variation of the TTF below 10^{-4}.

In Appendix at page 30 we report the full detailed calculation for a case of all cavities at the same field level in the central gap.

We want to stress the point that having the fields at the same level is not really a completely correct assumption. If we look at the accelerating field on the axis, we will find that they differ quite a lot as the design geometric beta β_g increases. In Figure 11 and Figure 10 we show a plot of the E_z field on the axis of a cavity with a designed β_g equal to 0.2955 and 0.399 respectively. As one can see is not very easy to define a level for such different distribution. For practical reason we are picking the peak field on axis as a natural observable with bead pull measurements.

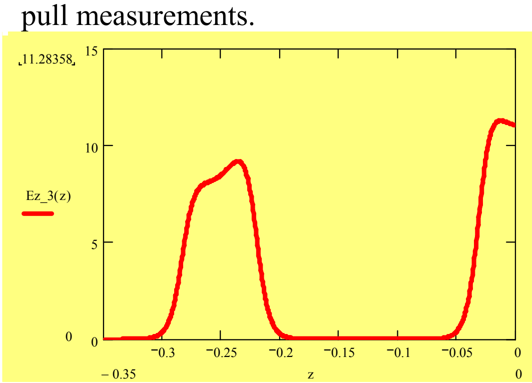

Figure 10. E_z field for a cavity of $\beta_g = 0.2955$

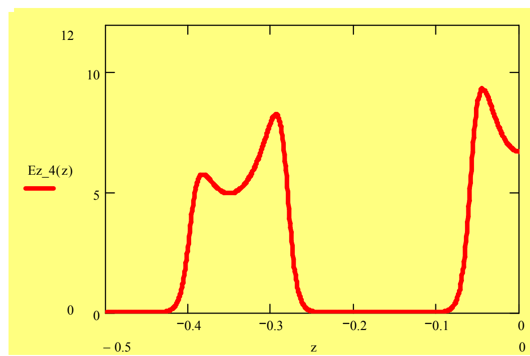

Figure 11. E_z field for a cavoty of $\beta_g = 0.399$

CCDTL parameterization

In this chapter we report all the parameterizations calculated from the table reported in the Appendix at page 30.

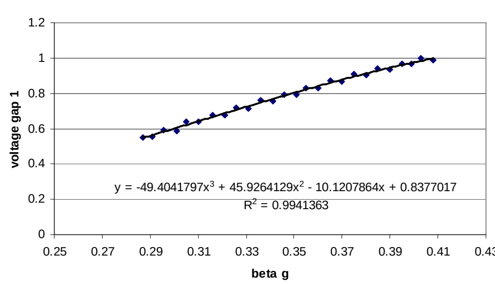

Figure 12. Voltage of gap 1 as a function of β_g for a normalized accelerating gradient of 3MV/m.

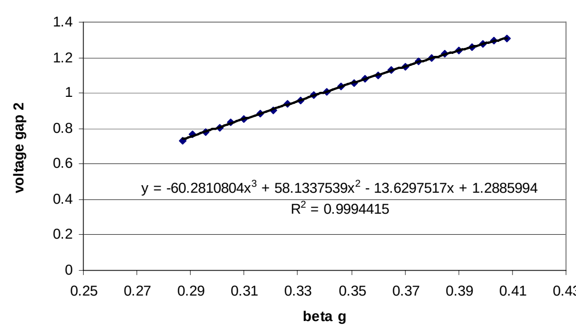

Figure 13. Voltage of gap 2 as a function of β_g for a normalized accelerating gradient of 3MV/m.

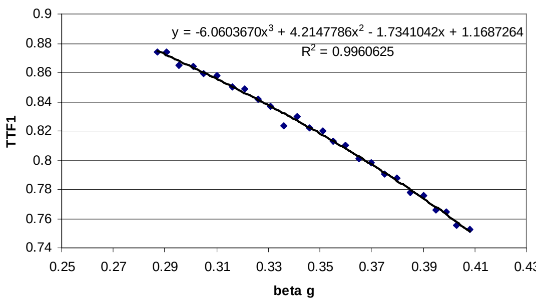

Figure 14. TTF of gap 1 as a function of the β_g.

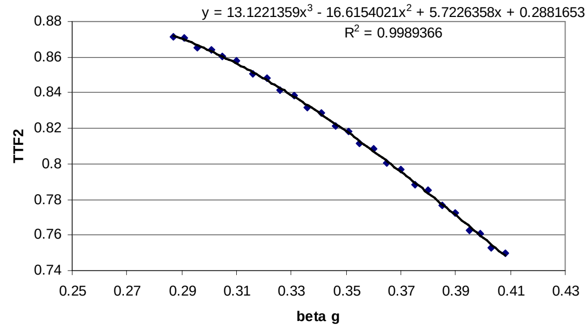

Figure 15. TTF of gap 2 as a function of the β_g.

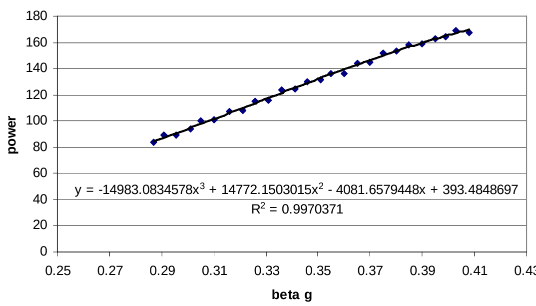

Figure 16. Power losses as a function of the β_g.

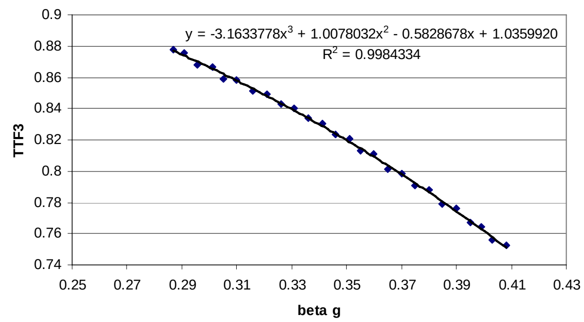

Figure 17. TTF of gap 3 as a function of the β_g.

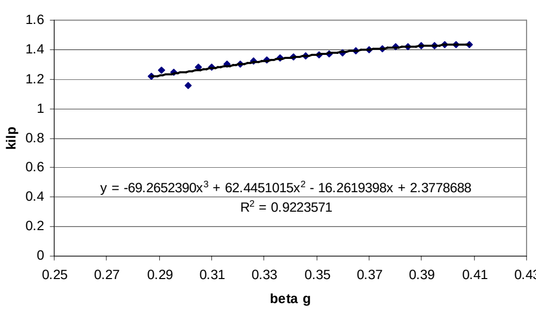

Figure 18. Kilpatrick factor as a function of the β_g.

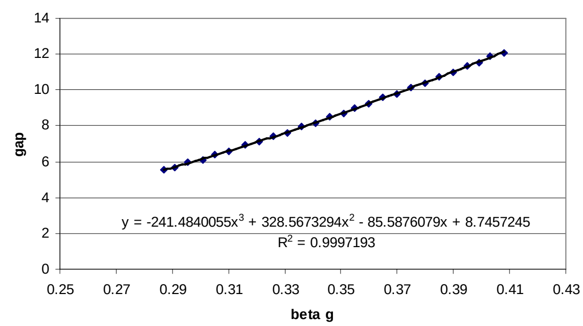

Figure 19. gap length as a function of the β_g.

Using the above parameterizations we have calculated four layouts, where we have satisfied the condition of having a power load per klystron of 750 kW. This power is comprehensive of the power losses calculated by Superfish, of a contingency margin of 20% and of the beam loading for 30 mA current.
In Table 1 we report the initial beam parameters for the evaluation of the layouts.

Particle	H^-	
Initial Energy	40.4	MeV
Mass	939.294	MeV
Frequency	352.2	MHz
β_i	0.28434	
Current	30	mA

Table 1 Initial beam parameter

Layout 1

The data-sheet of the layout is reported in the appendix at page 31. Here we present the summary table and the plot of the main parameters.

Klystron [#]	Cavity/Kly. [#]	Gradient [MV/m]	Power/Kly. [kW]	Energy [MeV]	Max Kilpatrik [#]
1	3	3.95	750	46.4	1.65
1	3	3.67	749	52.5	1.58
1	3	3.45	750	58.8	1.53
1	3	3.26	750	65.1	1.49
1	3	3.13	750	71.5	1.46
1	3	3.02	750	77.9	1.42
1	3	2.93	750	84.3	1.39
1	3	2.87	750	90.6	1.37
Tot. Klystron [#]	Tot. cavity [#]	Average Grad. [MV/m]	Tot. Power [MW]		Tot. length [m]
8	24	3.28	6		25.2

Table 2. Summary table for Layout 1

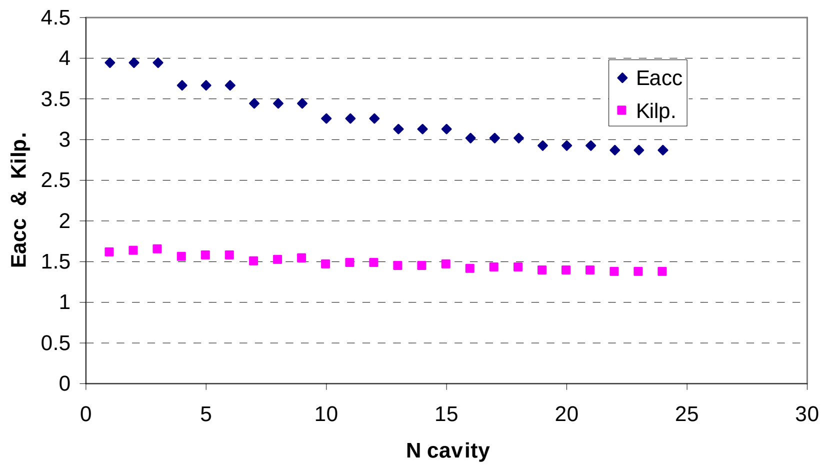

Figure 20. Accelerating field and Kilpatrick factor as a function of the cavity number

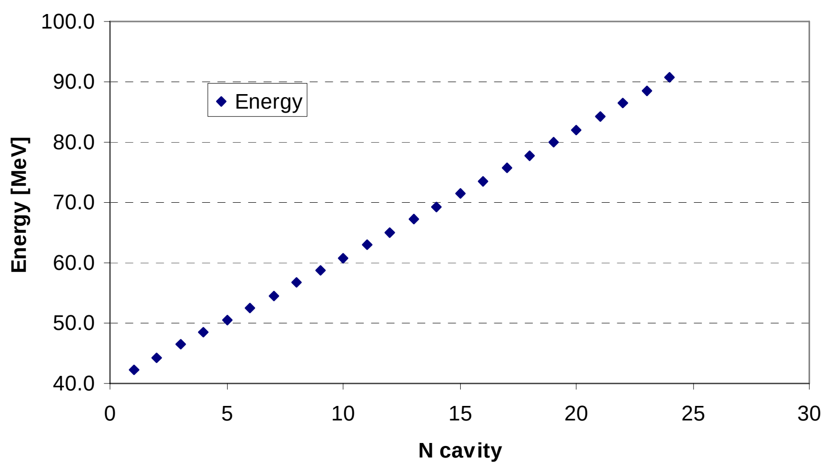

Figure 21. Beam Energy as a function of the cavity number

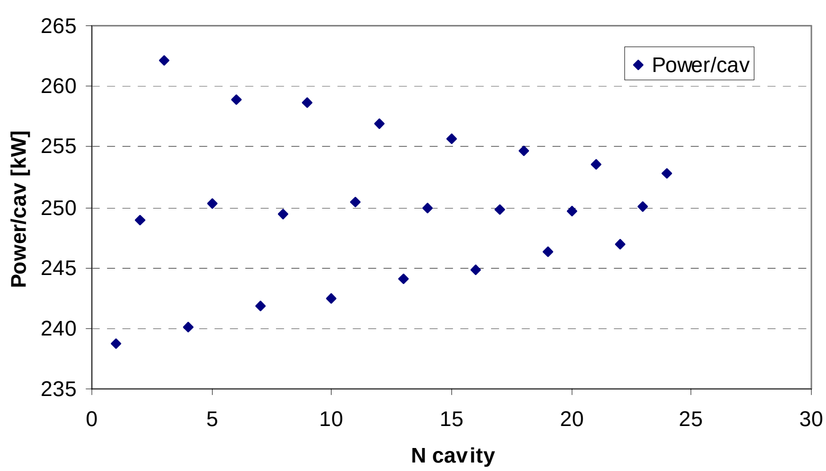

Figure 22. Power consumption in each cavity

Layout 2

The data-sheet of the layout is reported in the appendix at page 32. Here we present the summary table and the plot of the main parameters.

Klystron [#]	Cavity/Kly. [#]	Gradient [MV/m]	Power/Kly. [kW]	Energy [MeV]	Max Kilpatrik [#]
1	4	3.34	750	47.2	1.40
1	4	3.07	750	54.2	1.34
1	4	2.87	750	61.2	1.29
1	4	2.71	750	68.4	1.25
1	4	2.59	750	75.6	1.22
1	4	2.5	750	82.9	1.19
1	4	2.43	750	90.1	1.16
Tot. Klystron [#]	Tot. cavity [#]	Average Grad. [MV/m]	Tot. Power [MW]		Tot. Length. [m]
7	28	2.79	5.25		29.3

Table 3. Summary table for Layout 2

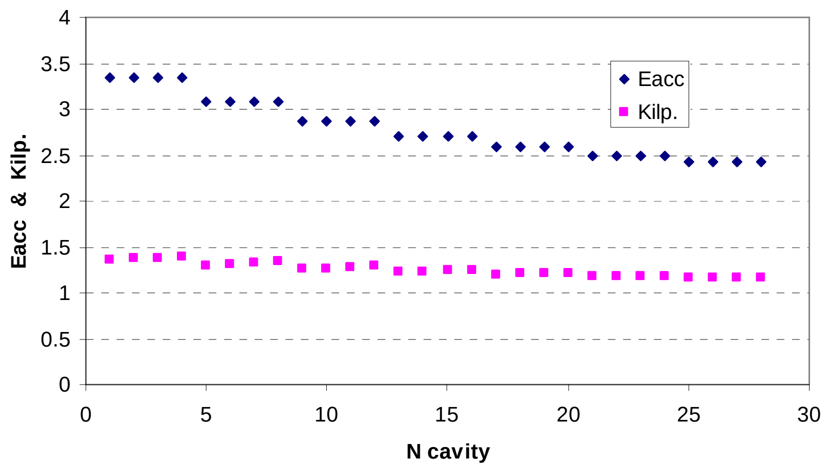

Figure 23. Accelerating field and Kilpatrick factor as a function of the cavity number

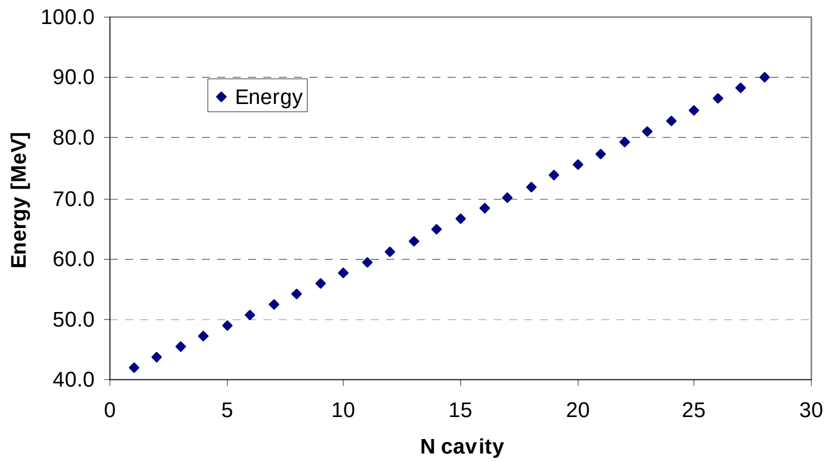

Figure 24. Beam Energy as a function of the cavity number

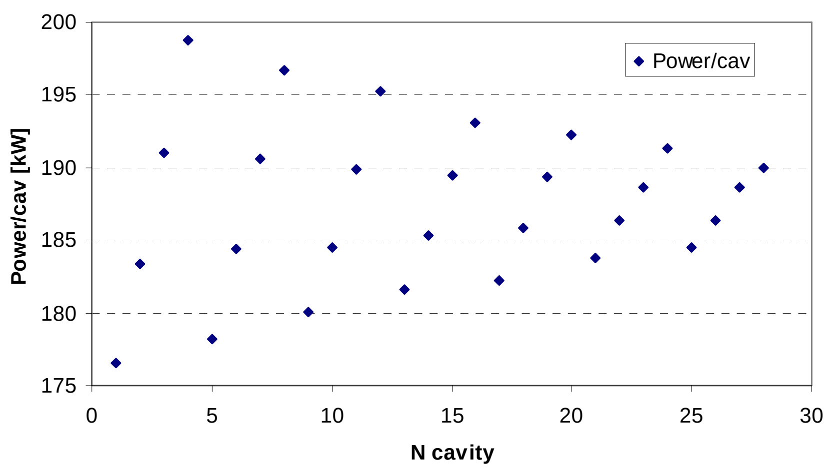

Figure 25. Power consumption in each cavity

Layout 3

The data-sheet of the layout is reported in the appendix at page 33. Here we present the summary table and the plot of the main parameters.

Klystron [#]	Cavity/Kly. [#]	Gradient [MV/m]	Power/Kly. [kW]	Energy [MeV]	Max Kilpatrik [#]
1	4	3.34	750	47.2	1.40
1	4	3.07	750	54.2	1.34
1	3	3.4	750	60.4	1.52
1	3	3.23	750	66.8	1.48
1	3	3.09	750	73.1	1.44
1	3	2.99	750	79.5	1.42
1	3	2.91	750	85.9	1.39
1	3	2.85	750	92.3	1.36
Tot. Klystron [#]	Tot. cavity [#]	Average Grad. [MV/m]	Tot. Power [MW]		Tot. Length. [m]
8	26	3.12	6		27.2

Table 4. Summary table for Layout 3

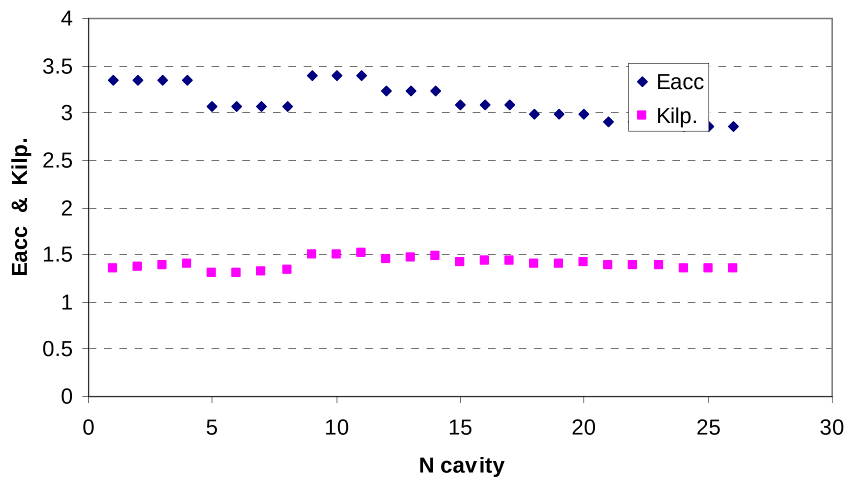

Figure 26. Accelerating field and Kilpatrick factor as a function of the cavity number

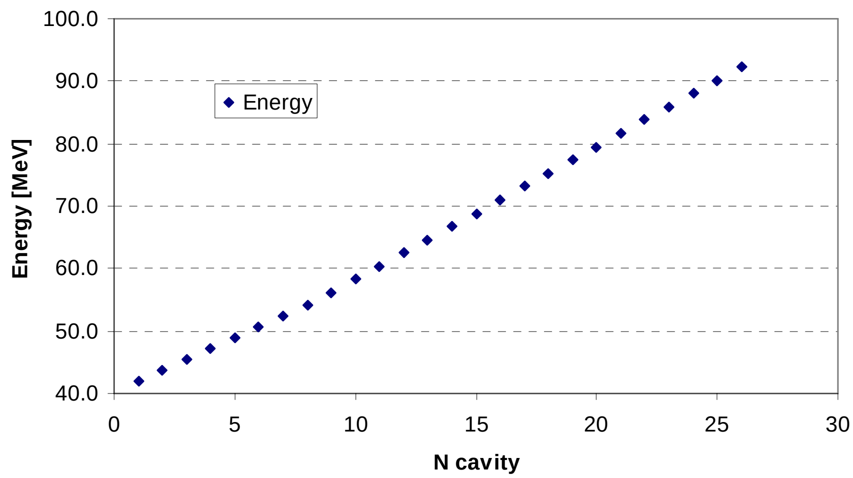

Figure 27. Beam Energy as a function of the cavity number

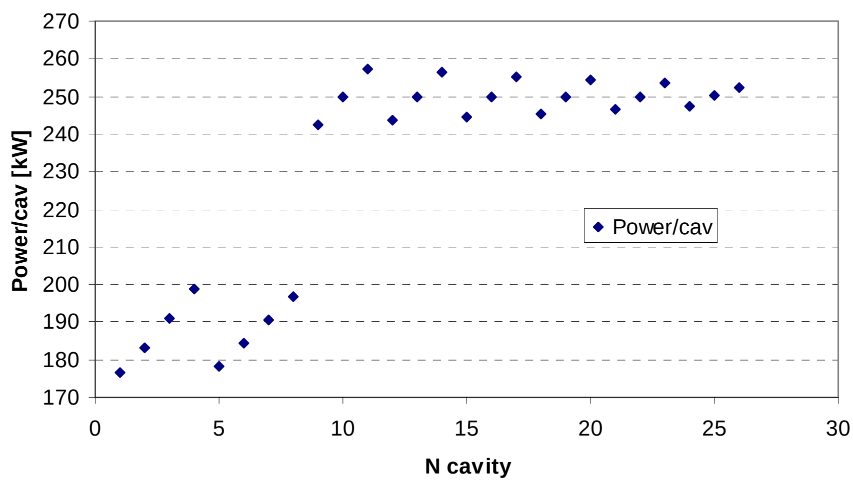

Figure 28. Power consumption in each cavity

Layout 4

The data-sheet of the layout is reported in the appendix at page 34. Here we present the summary table and the plot of the main parameters. The important difference between this layout and the others is that the synchronous phase is been changed to -20 deg instead of -25. This is according to the latest DTL design [8].

Klystron [#]	Cavity/Kly. [#]	Gradient [MV/m]	Power/Kly. [kW]	Energy [MeV]	Max Kilpatrik [#]
1	3	3.92	750	46.6	1.64
1	3	3.645	750	52.9	1.58
1	3	3.4	750	59.4	1.52
1	3	3.224	750	65.9	1.48
1	3	3.084	750	72.5	1.44
1	3	2.975	750	79.1	1.41
1	3	2.893	750	85.7	1.38
1	2	2.833	497	90.1	1.35
Tot. Klystron [#]	Tot. cavity [#]	Average Grad. [MV/m]	Tot. Power [MW]		Tot. Length. [m]
8	23	3.264	5.75		24.1

Table 5. Summary table for Layout 4

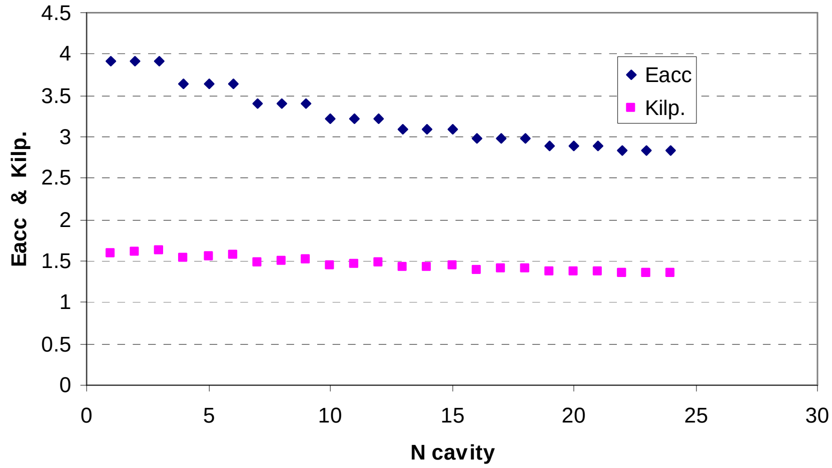

Figure 29. Accelerating field and Kilpatrick factor as a function of the cavity number

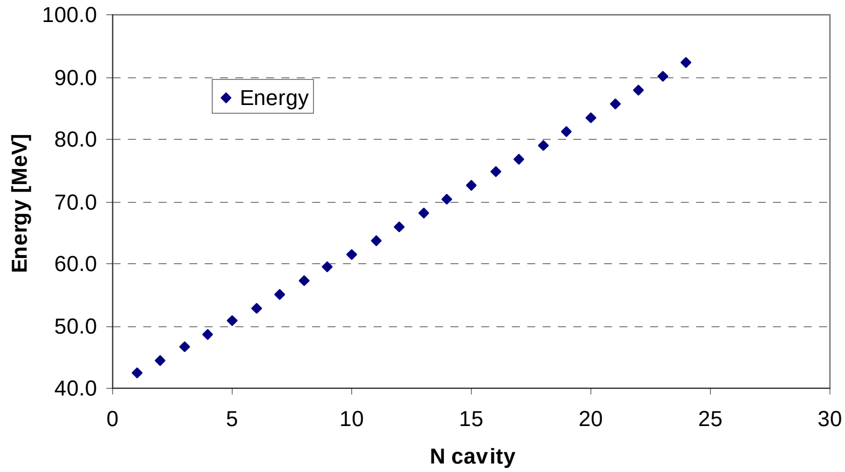

Figure 30. Beam Energy as a function of the cavity number

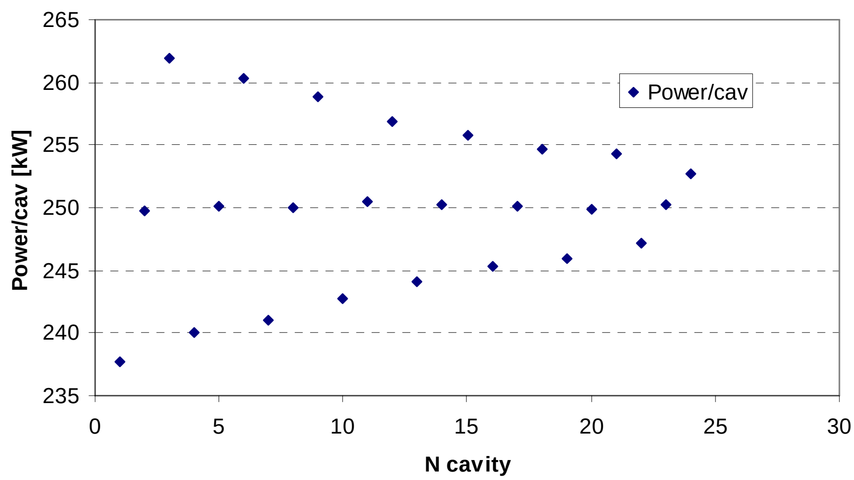

Figure 31. Power consumption in each cavity

Layout 5

The data-sheet of the layout is reported in the appendix at page 36. Here we present the summary table and the plot of the main parameters. This latest layout was calculated to uniform the power distribution to the one that is set for the Alvarez structure in March 2005. This power distribution is set to use 800 kW per klystron with a beam load of 40mA. The synchronous phase is -20 deg. This is according to the very latest DTL design [9].

Klystron [#]	Cavity/Kly. [#]	Gradient [MV/m]	Power/Kly. [kW]	Energy [MeV]	Max Kilpatrik [#]
1	3	3.89	800	46.4	1.62
1	3	3.608	800	52.8	1.56
1	3	3.37	800	59.2	1.50
1	3	3.19	800	65.7	1.46
1	3	3.053	800	72.2	1.42
1	3	2.945	800	78.7	1.39
1	3	2.866	800	85.2	1.36
1	3	2.805	800	91.7	1.34
Tot. Klystron [#]	Tot. cavity [#]	Average Grad. [MV/m]	Tot. Power [MW]		Tot. Length. [m]
8	24	3.264	6.4		25.2

Table 6. Summary table for Layout 5

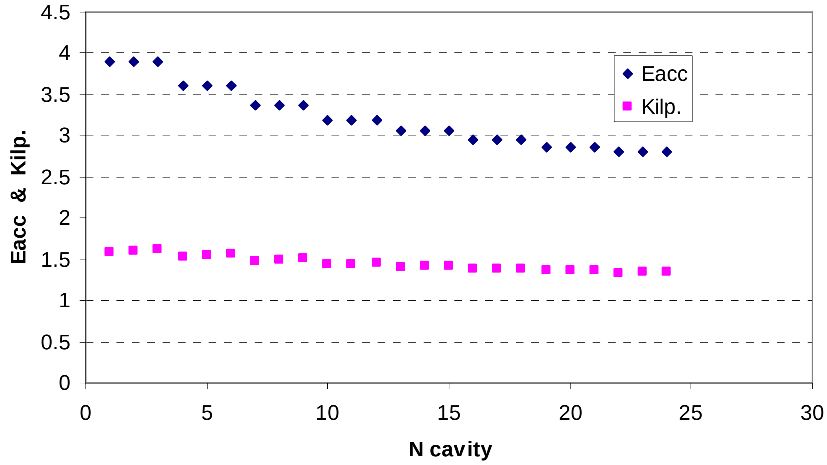

Figure 32. Accelerating field and Kilpatrick factor as a function of the cavity number

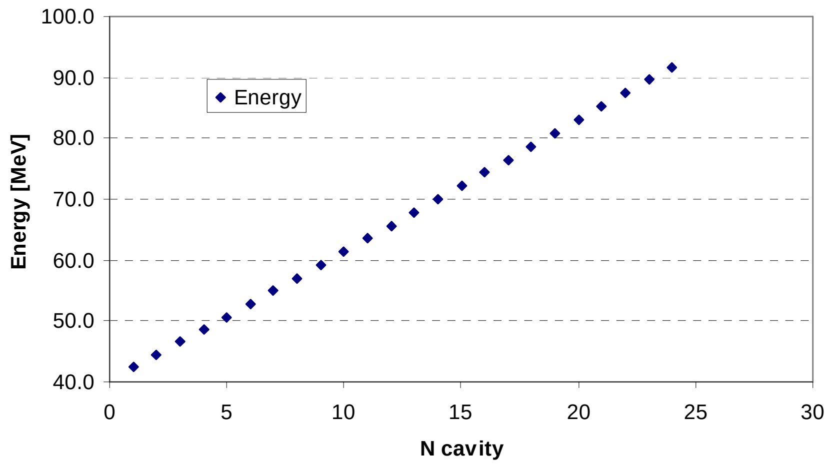

Figure 33. Beam Energy as a function of the cavity number

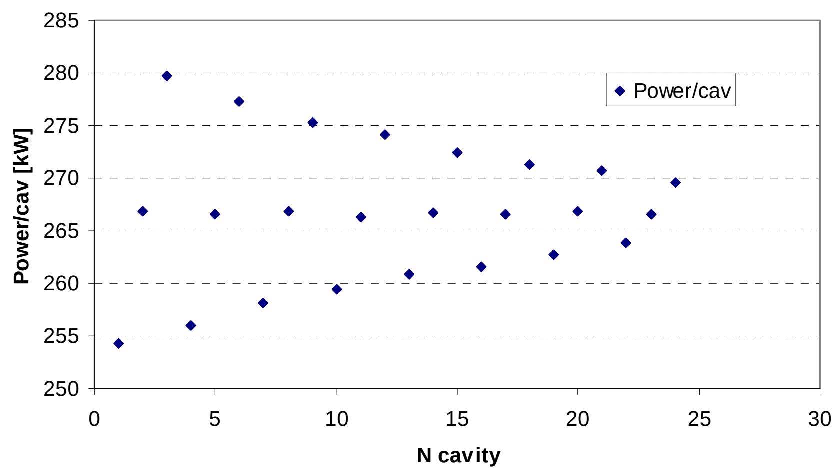

Figure 34. Power consumption in each cavity

Cost comparison

For the CCDTL the following cost figure has been assumed based on some preliminary estimation. The aim is not to give an actual price tag to the accelerator, but to compare different layouts:

Fixed Costs		
Engineering	250	kCHF
Costs per tank		
Structure	90	kCHF/tank
Support/stand	5	kCHF/tank
Vacuum	10	kCHF/tank
Joints	5	kCHF/tank
Quadrupoles	7	kCHF/tank
Power Supply	3	kCHF/tank
Total	**120**	kCHF/tank
RF Costs per unit		
Coupler	20	kCHF/u
Window	50	kCHF/u
Wave guides	20	kCHF/u
Low level controls + interlocks	50	kCHF/u
Installation	50	kCHF/u
Power supply 2 Hz 15 Hz	 200 400	kCHF/u
Average total	**500**	kCHF/u

For the above four layouts we can now calculate the indicative cost:

Layout 1				
N. tank	Tot. Cost tank (kCHF)	N. klystron	Tot. Cost Klystron (kCHF)	Grand Total[1] (MCHF)
24	2880	8	4000	**7.13**
Layout 2				
N. tank	Tot. Cost tank (kCHF)	N. klystron	Tot. Cost Klystron (kCHF)	Grand Total (MCHF)
28	3360	7	3500	**7.11**
Layout 3				
N. tank	Tot. Cost tank (kCHF)	N. klystron	Tot. Cost Klystron (kCHF)	Grand Total (MCHF)
26	3120	8	4000	**7.37**
Layout 4				
N. tank	Tot. Cost tank (kCHF)	N. klystron	Tot. Cost Klystron (kCHF)	Grand Total (MCHF)
23	2760	8	4000	**7.01**
Layout 5				
N. tank	Tot. Cost tank	N. klystron	Tot. Cost Klystron	Grand Total

[1] It includes the 250kCHF of fixed costs of engineering

	(kCHF)		(kCHF)	(MCHF)
24	2880	8	4000	**7.13**

First order error study

A preliminary error study has been performed in order to verify the alignment tolerances of the drift tubes and of the quadrupole lenses. The technique used is based on the matrix formalism and via simple transformation is possible to reproduce the effect of a misaligned element just by applying a linear transformation to the particle coordinates. The result is the tracking of a single particle (in our case the beam centre) when we apply a Gaussian distribution of errors for both drift tubes and quadrupoles. From the envelope of the beam centre displacements we can have an estimation of the increase of the nominal emittance. In fact, if we suppose that the effect of these random "kicks" is a linear effect, then the maximum emittance can be reproduced by drawing the nominal ellipse centred in each point. Comparing this effect to the acceptance of the channel we can decide upon the misalignment error tolerances. Also as a quicker way to look at the problem we can get a superimposition of the physical space from the r.m.s. beam centre. In the figures here below we report the result of the simulations for several cases. The focusing channel is a F0D0 one. In the code a steering card is also inserted at the end of each module. The effect of this card is to set to zero the particle divergence leaving the particle

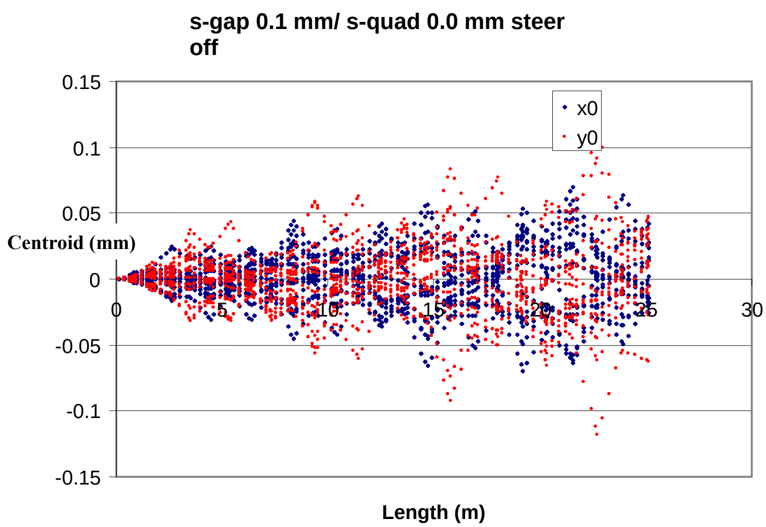

Figure 35. The figure shows the result of 50 runs of the tracking of the beam centre with a Gaussian distribution error of 2σ = ±0.1 mm in the drift tubes and 2σ = 0 mm for the quadrupoles. This is equivalent to a 95% of probability that the misalignment error is within ±0.1 mm. The code allows also a steering correction which is set to zero for this case.

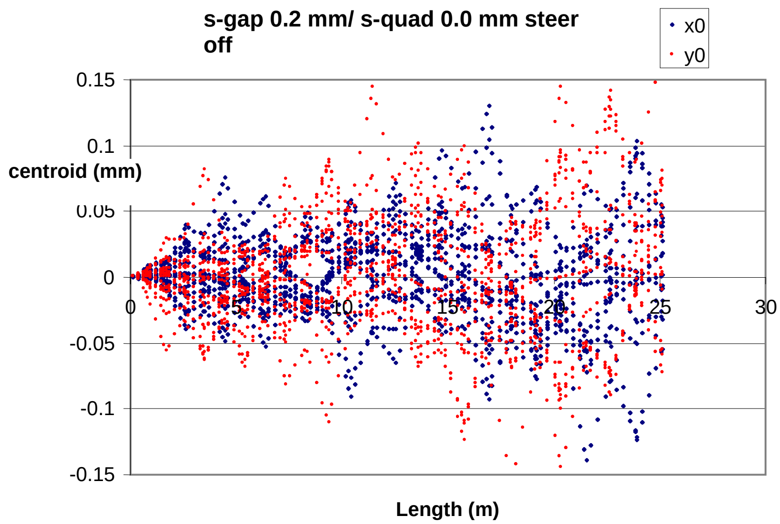

Figure 36. The figure shows the result of 50 runs of the tracking of the beam centre with a Gaussian distribution error of 2σ = ±0.2 mm in the drift tubes and 2σ = 0 mm for the quadrupoles. We can see that in presence of no quadrupole error the shift of the beam centre scales linearly with the error.

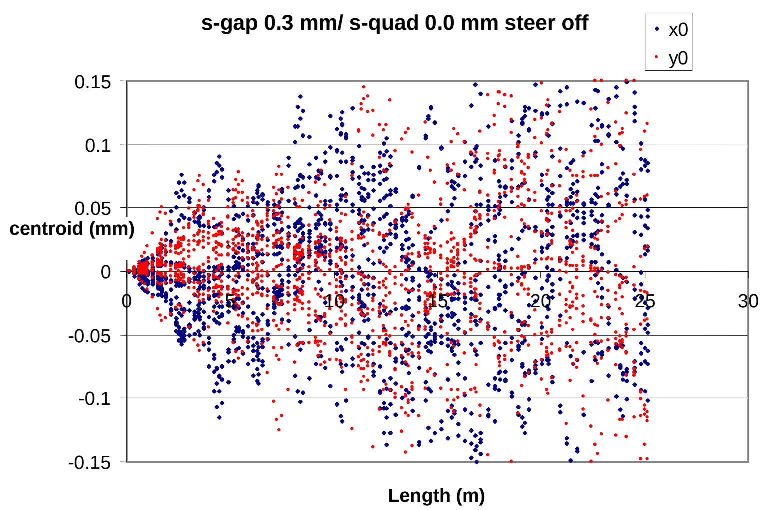

Figure 37. The figure shows the result of 50 runs of the tracking of the beam centre with a Gaussian distribution error of 2σ = ±0.3 mm in the drift tubes and 2σ = 0 mm for the quadrupoles.

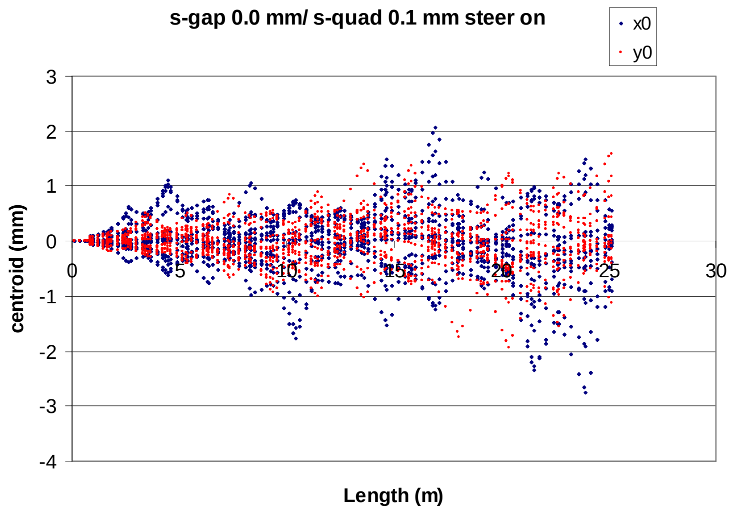

Figure 38. The figure shows the result of 50 runs of the tracking of the beam centre with a Gaussian distribution error of 2σ = 0 mm in the drift tubes and 2σ = ±0.1 mm for the quadrupoles. As one can see respect to
Figure 35 **the effect of the quadrupoles error is one order of magnitude bigger than the error of the drift tubes.**

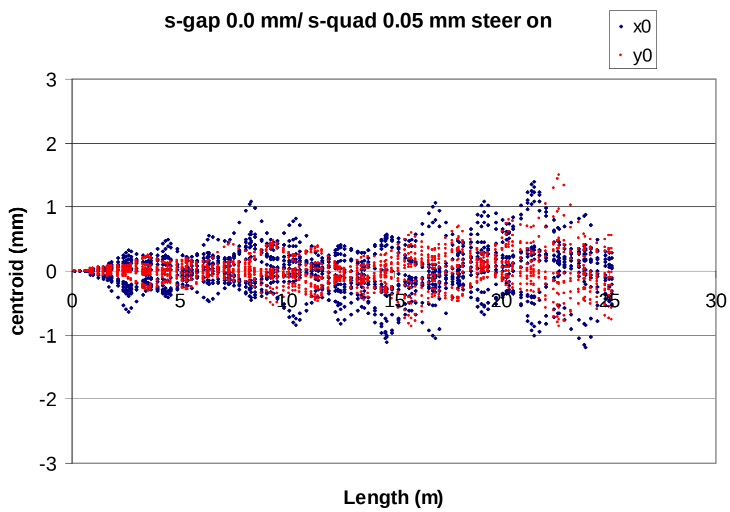

Figure 39. The figure shows the result of 50 runs of the tracking of the beam centre with a Gaussian distribution error of 2σ = 0 mm in the drift tubes and 2σ = ±0.05 mm for the quadrupoles.

The analysis of the single errors leads to the conclusion that the higher tolerances have to be considered only for the quadrupole lenses. This simulation does not take into account any kind of roll and pitch angle that are also very important because they are responsible for mixing the vertical with the horizontal plane. In the following figure we show the effect of the combined errors, both on the drift tubes and quadrupoles.

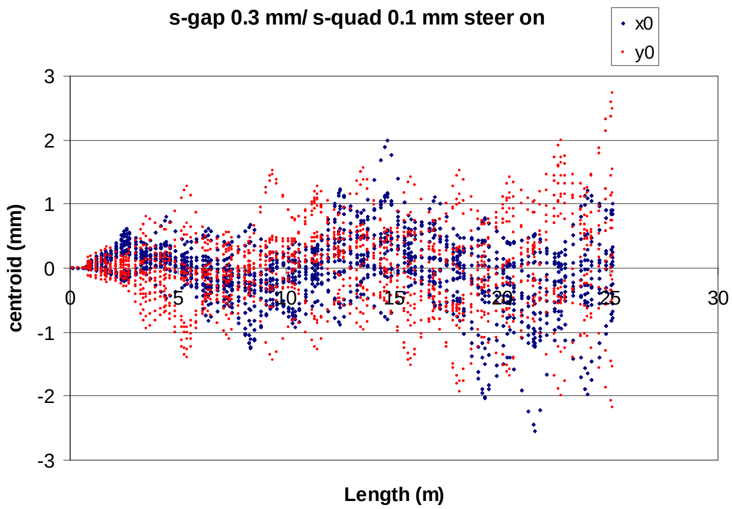

Figure 40. The figure shows the result of 50 runs of the tracking of the beam centre with a Gaussian distribution error of 2σ = ±0.3 mm in the drift tubes and 2σ = ±0.1 mm for the quadrupoles.

The runs have been calculated with a macro program interfaced with an Excel file. The Visual Basic Code is reported in the Appendix at page 36.

Quadrupole magnets specifications.

The quadrupole design should meet the specifications for LINAC4 and also for SPL. The main difference is that the working conditions are changing from a repetition rate of 2 Hz up to 50 Hz. In this latter operation, the power deposition is higher and probably requires water cooling. The cost of a fine laminated quadrupole for 50 Hz is also estimated to be as costly as the coils, so the present choice is to have a lens that will operate in c.w. mode when the LINAC will be pulsed at 50 Hz. This means that from the first installation, the magnet should be equipped with hollow coils that will be used only for the high duty cycle operation.
Because of the limited space between accelerating tanks the magnetic and mechanical design of the quadrupole has to be done carefully. From a preliminary design based on electro-magnetic quadrupoles for DTL structures [10] we have extracted some basics specifications for the quadrupole [11], reported in the table below.

Radial Aperture	18	Mm
Maximum Gradient	20	T/m
N*I	2578	Ampere turn
Proposed N	10	#
I max	~260	A
Resistant load[2]	7	mΩ
Inductance Load[3]	80	μH
Peak power in DC mode	460	W

Table 7. Summary table of the preliminary specifications for CCDTL and SCL electromagnetic quadrupoles.

[2] This value is calculated considering a hollow coil whose section is 7 by 7 mm and the hole diameter is 4 mm. The estimated total length is 360 mm.
[3] This value is calculated from the total magnetic energy of the quadrupole which is assumed to concentrated in the aperture area.

Acknowledgements

We acknowledge the support of the European Community-Research Infrastructure Activity under the FP6 "Structuring the European Research Area" programme (CARE, contract number RII3-CT-2003-506395). In particular the author wants to thank M. Vretenar for the continuous help and for the very fruitful discussions.

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APPENDIX

Data Tables of SUPERFISH for diameter optimization.

Table 1 Values for a β geometric βg = 0.289

g/βλ	Diam (cm)	ZT^2
0.18	48.154	48.044
0.19	49.074	48.755
0.2	49.936	49.278
0.21	50.719	49.619
0.22	51.444	49.796
0.23	52.111	49.809
0.24	52.728	49.67
0.25	53.3	49.396

Table 2 Values for a β geometric βg = 0.31

g/βλ	Diam (cm)	ZT^2
0.2	48.387	47.648
0.22	50.072	48.612
0.24	51.552	48.914
0.26	52.888	48.629
0.28	54.067	47.806
0.3	55.12	46.52

Table 3 Values for a β geometric βg = 0.33

g/βλ	Diam (cm)	ZT^2
0.18	44.728	43.344
0.2	46.763	45.347
0.22	48.564	46.686
0.24	50.193	47.394
0.26	51.635	47.49
0.28	52.938	47.028
0.3	54.102	46.086

Table 4 Values for a β geometric βg = 0.35

g/βλ	Diam (cm)	ZT^2
0.22	46.98	44.204
0.24	48.721	45.269
0.26	50.294	45.749
0.28	51.713	45.658
0.3	52.994	45.044
0.32	54.15	43.954

Table 5 Values for a β geometric βg = 0.37

g/βλ	Diam (cm)	ZT^2
0.22	45.266	41.24
0.24	47.14	42.63
0.26	48.84	43.463
0.28	50.387	43.746
0.3	51.792	43.499
0.32	53.066	42.756
0.34	54.221	41.568

Table 6 Values for a β geometric βg = 0.39

g/βλ	Diam (cm)	ZT^2
0.24	45.449	39.585
0.26	47.273	40.723
0.28	48.95	41.352
0.3	50.4844	41.467
0.32	51.885	41.086
0.34	53.159	40.239

Table 7 Values for a β geometric βg = 0.41

g/βλ	Diam (cm)	ZT^2

0.24	43.6177	36.219
0.26	45.588	37.631
0.28	47.394	38.559
0.3	49.063	39.013
0.32	50.597	38.987
0.34	52.001	38.493
0.36	53.281	37.565

Data for CCDTL parametrization

N. Cav #	E0 [MV/m]	βg #	V1 [MV]	TTFg1 [#]	φgap1 [deg]	ΔW1 [MeV]	E1 [MeV]	β end g1 #	V2 [MV]	TTFg2 [#]	φgap2 [deg]	ΔW2 [MeV]	E2 [MeV]	β end g2 #	V3 [MV]	TTFg3 [#]	φgap3 [deg]
1	3	0.287	0.549269	0.874251	-26.572	0.429477	40.9	0.285753	0.731382	0.871507	-25.00056	0.577682	41.4	0.287639	0.549269	0.877833	-25.80015
2	3	0.2908	0.554693	0.873912	-25.426	0.4378	42.3	0.290456	0.767232	0.871058	-25.00006	0.605689	42.9	0.292393	0.554693	0.875792	-26.96167
3	3	0.2955	0.593918	0.864886	-25.326	0.464301	43.8	0.295233	0.782674	0.865508	-25.00014	0.613942	44.4	0.297156	0.593918	0.867718	-27.00584
4	3	0.301	0.587302	0.864273	-26.22	0.45536	45.4	0.29999	0.806209	0.863921	-25.00832	0.631202	46.0	0.301927	0.587302	0.866535	-26.11333
5	3	0.305	0.639823	0.85915	-25.2	0.497387	46.9	0.304824	0.83538	0.860178	-24.99249	0.65129	47.6	0.306781	0.639823	0.859278	-27.0827
6	3	0.31	0.637592	0.858092	-25.35	0.494431	48.6	0.309707	0.852449	0.857947	-25.00932	0.662784	49.2	0.311657	0.637592	0.857914	-26.92372
7	3	0.316	0.676545	0.8504	-26.64	0.514257	50.2	0.314576	0.886668	0.850447	-25.00991	0.683359	50.9	0.316545	0.676545	0.851638	-25.63022
8	3	0.321	0.67507	0.848497	-26.7	0.511719	52.0	0.319487	0.90441	0.847931	-24.99555	0.695052	52.6	0.32145	0.67507	0.849481	-25.49949
9	3	0.326	0.717505	0.841422	-26.86	0.53859	53.7	0.324402	0.938543	0.841212	-25.08644	0.715038	54.4	0.32638	0.717505	0.842805	-25.50533
10	3	0.331	0.71626	0.836502	-26.8	0.534795	55.5	0.329338	0.955351	0.83867	-24.98366	0.726252	56.2	0.331307	0.71626	0.840415	-25.31682
11	3	0.336	0.758868	0.8235	-26.9	0.557309	57.3	0.334261	0.991493	0.831674	-25.02761	0.747173	58.1	0.336246	0.758868	0.83372	-25.29059
12	3	0.341	0.758406	0.829503	-26.9	0.56103	59.2	0.339224	1.009496	0.828638	-25.01524	0.758038	60.0	0.341196	0.758406	0.830676	-25.22255
13	3	0.346	0.795477	0.822174	-26.9	0.583254	61.1	0.344167	1.038047	0.82118	-24.98263	0.772667	61.9	0.346137	0.795477	0.823301	-25.12545
14	3	0.351	0.794046	0.819778	-27	0.579993	63.1	0.349099	1.056402	0.818184	-25.03919	0.7831	63.8	0.351056	0.794046	0.820516	-25.09658
15	3	0.355	0.831714	0.812844	-26.08	0.607219	65.0	0.354019	1.078437	0.811734	-25.0823	0.792853	65.8	0.355962	0.831714	0.813191	-26.05488
16	3	0.36	0.83001	0.810026	-26.1	0.603771	67.0	0.358901	1.097704	0.808693	-24.99758	0.80455	67.9	0.360834	0.83001	0.810683	-25.82971
17	3	0.365	0.869846	0.801102	-26.3	0.624704	69.1	0.363762	1.127519	0.800329	-25.07436	0.817344	69.9	0.365688	0.869846	0.801497	-25.75118
18	3	0.37	0.868541	0.798548	-26.4	0.62124	71.1	0.368603	1.146136	0.797025	-25.03529	0.827674	72.0	0.370516	0.868541	0.798652	-25.53631
19	3	0.375	0.907423	0.790178	-26.5	0.641691	73.2	0.373417	1.178279	0.788418	-24.97428	0.842115	74.1	0.375327	0.907423	0.79066	-25.28774
20	3	0.38	0.905382	0.787603	-26.7	0.637047	75.4	0.378214	1.198043	0.785009	-25.00044	0.852357	76.2	0.380111	0.905382	0.787664	-25.10523
21	3	0.385	0.939262	0.778053	-26.9	0.651722	77.5	0.38297	1.220657	0.776778	-24.99178	0.8594	78.4	0.384846	0.939262	0.778735	-24.848
22	3	0.39	0.935368	0.77552	-27.2	0.645179	79.7	0.387677	1.24071	0.772646	-25.04327	0.868507	80.6	0.389539	0.935368	0.77597	-24.61697
23	3	0.395	0.965871	0.766023	-27.5	0.656281	81.9	0.392333	1.259573	0.762894	-25.05324	0.870512	82.7	0.394165	0.965871	0.766937	-24.29081
24	3	0.399	0.965974	0.764306	-26.9	0.658414	84.1	0.396946	1.278527	0.761016	-25.03719	0.881552	85.0	0.398768	0.965974	0.764373	-24.82742
25	3	0.403	0.999617	0.755618	-26.3	0.677142	86.3	0.401527	1.293348	0.752597	-24.97906	0.882323	87.2	0.403318	0.999617	0.755817	-25.26246
26	3	0.408	0.988799	0.752538	-26.7	0.664765	88.5	0.40603	1.305805	0.749676	-24.95289	0.887552	89.4	0.407799	0.988799	0.752318	-24.77587

ΔW3 [MeV]	E3 [MeV]	β end g3 #	power [kw]	gap [cm]	s [cm]	Grad Quad [T/m]	Beam load [kw]	Tot power/cav [kw]	tot power [kw]	equator fla [cm]	length/cav [m]	tot length [m]	scale fact [#]	kilp [#]	kilp scaled [#]	d [m]	Δβ [%]	E center [MeV]	β center []	Δ TTF/tank []
0.434103	41.9	0.289046	83.7044	5.53874	0	15	43.23786	145.357228	145.357228	53.07356	0.860735629	0.860736	1	1.2181	1.2181	0.363045	-0.105431	41.15832	0.286698	-1.46E-05
0.432994	43.4	0.293768	88.98619	5.6781	-0.7292683	-15	44.29449058	152.8576481	298.214876	53.15293	0.861529341	1.722265	1.011	1.24504	1.25873544	0.369054	0.215095	42.62191	0.291427	-6.09E-05
0.459159	44.9	0.298583	88.98619	5.958131	1.02009771	15	46.1220622	154.6852197	452.900096	55.90246	0.889024595	2.61129	1.043	1.19629	1.24773047	0.375083	0.235039	44.12902	0.296196	-7.27E-05
0.45697	46.4	0.303319	93.76561	6.124505	-0.05001282	-15	46.30595264	160.6999979	613.600094	56.00275	0.890027483	3.501317	1.0313	1.1228	1.15794364	0.381231	-0.013108	45.66611	0.300961	-2.26E-07
0.489502	48.1	0.308241	99.94362	6.389903	1.84508369	15	49.14535697	171.0765725	784.676666	58.74904	0.917490443	4.418807	1.0857	1.17864	1.27964945	0.387277	0.263176	47.26171	0.305805	-9.11E-05
0.48771	49.7	0.313082	101.0966	6.577753	0.9455469	-15	49.34773519	172.6856084	957.362275	58.91351	0.919135069	5.337943	1.075	1.19227	1.28169025	0.393562	0.220205	48.90268	0.310684	-6.38E-05
0.519479	51.4	0.318032	107.014	6.916037	2.40256521	15	51.51285201	182.0699875	1139.43226	61.64732	0.946473244	6.284416	1.11	1.1706	1.299366	0.399743	-0.138622	50.57772	0.315563	-2.53E-05
0.517598	53.2	0.322901	108.2679	7.112085	1.53845074	-15	51.73105841	183.8178915	1323.25015	61.84721	0.948472093	7.232888	1.1	1.18581	1.304391	0.406063	-0.165167	52.29812	0.320471	-3.59E-05
0.545784	55.0	0.327879	114.9605	7.423561	3.17347939	15	53.98236308	194.2342178	1517.48437	64.54624	0.975462373	8.20835	1.14	1.15933	1.3216362	0.41228	-0.186596	54.05935	0.325393	-4.58E-05
0.544142	56.8	0.332771	116.1256	7.624978	2.39091946	-15	54.15566332	195.8289288	1713.3133	64.82768	0.978276767	9.186627	1.13	1.17444	1.3271172	0.418635	-0.2045	55.86058	0.330324	-5.50E-05
0.572042	58.6	0.337754	123.4334	7.945502	3.94876444	15	56.29571349	206.8845093	1920.19781	67.44952	1.00449521	10.19112	1.17	1.15105	1.3467285	0.424882	-0.222046	57.69874	0.335256	-6.49E-05
0.569926	60.5	0.342669	124.5156	8.157841	3.2298486	-15	56.66981389	208.5788877	2128.7767	67.7946	1.007946045	11.19907	1.16	1.16512	1.3515392	0.431244	-0.23155	59.58442	0.340212	-7.06E-05
0.592949	62.5	0.347639	130.1385	8.491778	4.76354492	15	58.46608703	217.2350047	2346.0117	70.3923	1.033923002	12.23299	1.19	1.143	1.36017	0.43752	-0.245075	61.50295	0.345154	-7.90E-05
0.590019	64.4	0.352521	131.2936	8.702281	4.03696377	-15	58.59336192	218.7715212	2564.78322	70.72972	1.037297184	13.27029	1.18	1.15825	1.366735	0.443865	-0.263024	63.45378	0.350079	-9.10E-05
0.607608	66.4	0.35744	136.479	9.008345	5.77135576	15	60.23039926	226.7347911	2791.51801	73.31531	1.063153099	14.33344	1.21	1.13299	1.3709179	0.450098	-0.002204	65.43899	0.354992	-6.39E-09
0.60565	68.5	0.362279	136.4256	9.222856	5.06653926	-15	60.41911891	226.8583509	3018.37637	73.67449	1.066744928	15.40019	1.2	1.149	1.3788	0.45638	-0.036296	67.44907	0.359869	-1.73E-06
0.627942	70.5	0.367157	144.0574	9.577687	6.50853112	15	62.09967526	237.8497402	3256.22611	76.18048	1.09180484	16.49199	1.23	1.12927	1.3890021	0.462558	-0.075018	69.49037	0.364726	-7.41E-06
0.6259	72.6	0.371953	145.1366	9.797241	5.85443271	-15	62.24441714	239.3110241	3495.53713	76.59038	1.095903849	17.5879	1.22	1.14434	1.3960948	0.468786	-0.118792	71.56206	0.369561	-1.86E-05
0.648711	74.7	0.376788	152.0625	10.15451	7.25065305	15	63.97548458	249.4917346	3745.02886	79.0506	1.120506046	18.7084	1.25	1.12685	1.4085625	0.474909	-0.167233	73.66455	0.374374	-3.68E-05
0.645767	76.9	0.381538	153.2277	10.37675	6.58142304	-15	64.05511551	250.9928886	3996.02175	79.44537	1.124453739	19.83285	1.24	1.1427	1.416948	0.481082	-0.220398	75.79754	0.379164	-6.39E-05
0.663724	79.0	0.386286	157.9554	10.74829	7.96581458	15	65.24535945	257.9509527	4253.97271	81.89376	1.148937648	20.98179	1.26	1.12553	1.4181678	0.487147	-0.283947	77.95091	0.38391	-1.06E-04
0.65985	81.2	0.390944	159.1738	10.97532	7.26246898	-15	65.20608549	259.3980605	4513.37077	82.25442	1.152544186	22.13434	1.25	1.14205	1.4275625	0.49321	-0.357738	80.12376	0.38861	-1.68E-04
0.675182	83.4	0.395577	162.9269	11.3456	8.62628944	15	66.05923882	264.830067	4778.20083	84.68224	1.176822384	23.31116	1.265	1.12622	1.4246683	0.499157	-0.444754	82.3094	0.393251	-2.60E-04
0.670122	85.6	0.400144	164.6208	11.53119	8.10746207	-15	66.30263961	267.1399963	5045.34083	85.01461	1.180146105	24.49131	1.26	1.13925	1.435455	0.505072	-0.286921	84.51903	0.397858	-1.08E-04
0.683271	87.9	0.404696	168.9895	11.86943	9.66142989	15	67.28207106	273.4492503	5318.79008	87.41978	1.204197778	25.6955	1.28	1.11927	1.4326656	0.510903	-0.143215	86.74823	0.402424	-2.70E-05
0.675419	90.1	0.409138	167.7071	12.09318	8.89035941	-15	66.8320992	271.434735	5590.22481	87.71271	1.207127067	26.90263	1.26	1.13815	1.434069	0.516715	-0.266388	88.98121	0.406916	-9.34E-05

Data sheet Layout 1

N. Cav	E0	βg	V1	TTFg1	φgap1	ΔW1	E1	β end g1	V2	TTFg2	φgap2	ΔW2	E2	β end g2	V3	TTFg3	φgap3	ΔW3
#	[MV/m]	#	[MV]	[#]	[deg]	[MeV]	[MeV]	#	[MV]	[#]	[deg]	[MeV]	[MeV]	#	[MV]	[#]	[deg]	[MeV]
1	**3.95**	**0.2885**	0.729559	0.873718	**-27.9**	0.563338	41.0	0.286191	0.984234	0.871304	-24.99568	0.777247	41.8	0.28872	0.729559	0.875756	-25.27054	0.577773
2	**3.95**	**0.294**	0.75895	0.869201	**-26.9**	0.588301	42.9	0.292463	1.019663	0.867913	-25.00804	0.802011	43.7	0.295002	0.75895	0.871351	-26.23067	0.593211
3	**3.95**	**0.301**	0.796619	0.863352	**-27.7**	0.608941	45.0	0.298756	1.065316	0.863159	-24.99559	0.833414	45.8	0.301323	0.796619	0.865589	-25.3811	0.622988
4	**3.666**	**0.307**	0.76944	0.858242	**-27.3**	0.586812	47.0	0.304999	1.025398	0.858711	-24.93833	0.798423	47.8	0.307394	0.76944	0.860505	-25.39987	0.598106
5	**3.666**	**0.313**	0.799574	0.853032	**-27.3**	0.606093	49.0	0.310961	1.062304	0.853937	-24.9389	0.822557	49.8	0.313366	0.799574	0.855285	-25.35931	0.617966
6	**3.666**	**0.318**	0.824658	0.848611	**-26.1**	0.628452	51.1	0.316965	1.093166	0.849722	-24.92431	0.842375	51.9	0.319367	0.824658	0.850827	-26.46476	0.628115
7	**3.45**	**0.324**	0.804301	0.843201	**-26.3**	0.607985	53.1	0.322848	1.063652	0.844394	-25.015	0.813893	54.0	0.325112	0.804301	0.845344	-26.24666	0.609811
8	**3.45**	**0.329**	0.827698	0.8386	**-25.6**	0.625969	55.2	0.328511	1.092707	0.839741	-25.06366	0.831188	56.0	0.33077	0.827698	0.840662	-26.98964	0.620032
9	**3.45**	**0.335**	0.855555	0.832963	**-25.9**	0.641066	57.3	0.334157	1.127464	0.833916	-24.99206	0.852175	58.1	0.33642	0.855555	0.834904	-26.51147	0.639193
10	**3.26**	**0.341**	0.83447	0.827191	**-26.3**	0.618814	59.4	0.339722	1.098023	0.827845	-24.94585	0.82419	60.2	0.341862	0.83447	0.828989	-25.85318	0.62253
11	**3.26**	**0.347**	0.860141	0.821276	**-27**	0.629418	61.5	0.345076	1.130398	0.821544	-24.99296	0.84171	62.3	0.347214	0.860141	0.822913	-25.21478	0.640378
12	**3.26**	**0.352**	0.881207	0.816231	**-26.6**	0.643138	63.6	0.350438	1.157104	0.81613	-24.99587	0.855898	64.5	0.352566	0.881207	0.817725	-25.57334	0.649992
13	**3.13**	**0.356**	0.862016	0.812118	**-25.3**	0.63291	65.7	0.35572	1.13127	0.811699	-25.01654	0.832106	66.6	0.357745	0.862016	0.813491	-26.77216	0.626072
14	**3.13**	**0.361**	0.881628	0.806874	**-25.2**	0.64366	67.8	0.360803	1.156359	0.806043	-25.00316	0.844726	68.7	0.362817	0.881628	0.808091	-26.80566	0.635878
15	**3.13**	**0.366**	0.900845	0.801512	**-25.1**	0.653855	70.0	0.36586	1.181075	0.800268	-24.96261	0.856881	70.8	0.367862	0.900845	0.80257	-26.78513	0.645416
16	**3.016**	**0.371**	0.886133	0.796028	**-25.2**	0.638253	72.1	0.370832	1.161469	0.794382	-25.03665	0.835956	72.9	0.372747	0.886133	0.796926	-26.72367	0.630752
17	**3.016**	**0.376**	0.903777	0.790418	**-25.3**	0.645842	74.2	0.375643	1.18443	0.788396	-24.95816	0.846597	75.1	0.377546	0.903777	0.791156	-26.43231	0.64028
18	**3.016**	**0.381**	0.920927	0.784677	**-25.6**	0.651692	76.4	0.380422	1.206894	0.782318	-25.05322	0.855343	77.2	0.382309	0.920927	0.785258	-26.28537	0.64839
19	**2.929**	**0.386**	0.910503	0.778801	**-25.8**	0.638417	78.5	0.38512	1.193371	0.776161	-24.97744	0.83962	79.3	0.386938	0.910503	0.77923	-25.84998	0.638499
20	**2.929**	**0.39**	0.923022	0.773999	**-25.3**	0.645892	80.6	0.389694	1.209996	0.771183	-25.01688	0.845585	81.5	0.391492	0.923022	0.774312	-26.38844	0.640235
21	**2.929**	**0.395**	0.938145	0.767866	**-25.8**	0.648563	82.8	0.394208	1.23023	0.764904	-25.07645	0.852311	83.6	0.395988	0.938145	0.768043	-25.97478	0.647752
22	**2.865**	**0.399**	0.929049	0.762854	**-25.3**	0.640749	84.9	0.398656	1.218727	0.759842	-24.98962	0.839348	85.7	0.400379	0.929049	0.762929	-26.22993	0.635812
23	**2.865**	**0.4035**	0.941393	0.757099	**-25.4**	0.643832	87.0	0.402984	1.235514	0.754113	-24.93926	0.84484	87.9	0.404689	0.941393	0.75707	-25.9974	0.640585
24	**2.865**	**0.408**	0.953201	0.751217	**-25.7**	0.645226	89.2	0.407263	1.251727	0.748355	-25.04864	0.848634	90.0	0.408948	0.953201	0.751097	-25.88283	0.644129

E3	β end g3	power	gap	s	Grad Quad	Beam load	ot power/ca	tot power	equator fla	length/cav	tot length	scale fact	kilp	kilp scaled	d	Δβ	E center	β center	Δ TTF/tank
[MeV]	#	[kw]	[cm]	[cm]	[T/m]	[kw]	[kw]	[kw]	[cm]	[m]	[m]	[#]	[#]	[#]	[m]	[%]	[MeV]	[]	[]
42.4	0.290583	148.5089	#	**0**	**15**	57.55072	238.7316	238.7316	53.39276	0.863928	0.863928	1	1.2181	1.60701	0.363045	-0.362026	41.39196	0.287459	-1.72E-04
44.3	0.296862	155.2798	#	-0.811991	**-15**	59.50571	248.9471	487.6787	53.75117	0.867512	1.731439	1.011	1.24504	1.625007	0.371016	-0.089894	43.34766	0.293736	-1.06E-05
46.4	0.303223	164.13	#	1.089139	**15**	61.96028	262.1989	749.8776	57.1419	0.901419	2.632858	1.043	1.19629	1.648056	0.379033	-0.319044	45.36753	0.300043	-1.34E-04
48.4	0.309172	148.0578	#	0.190256	**-15**	59.50021	240.1307	240.1307	57.51982	0.905198	3.538057	1.0313	1.1228	1.547896	0.387155	-0.261368	47.39325	0.3062	-8.99E-05
50.4	0.315157	154.8431	#	2.094935	**15**	61.39848	250.3071	490.4378	60.70129	0.937013	4.475069	1.0313	1.1228	1.566111	0.394751	-0.267066	49.40794	0.312166	-9.39E-05
52.5	0.321142	160.5565	#	1.417802	**-15**	62.96827	258.8472	749.285	61.08816	0.940882	5.415951	1.0313	1.1228	1.58112	0.402392	0.053037	51.48682	0.318169	-3.70E-06
54.6	0.326795	148.3064	#	3.29043	**15**	60.9507	241.8845	241.8845	64.23759	0.972376	6.388327	1.0313	1.1228	1.504629	0.410034	-0.005361	53.55105	0.323983	-3.78E-08
56.6	0.332441	153.4164	#	2.468218	**-15**	62.31568	249.4836	491.3682	64.47938	0.974794	7.363121	1.0313	1.1228	1.518215	0.417252	0.194978	55.60938	0.329643	-5.00E-05
58.8	0.338103	159.5456	#	4.335363	**15**	63.97305	258.6187	749.9868	67.62332	1.006233	8.369354	1.0313	1.1228	1.534063	0.424461	0.086849	57.71216	0.335291	-9.93E-06
60.8	0.343465	147.9048	#	3.265924	**-15**	61.96603	242.4098	242.4098	67.83068	1.008307	9.377661	1.0313	1.1228	1.463994	0.43169	-0.060385	59.80835	0.340794	-4.80E-06
63.0	0.348828	153.3059	#	4.973797	**15**	63.34521	250.3784	492.7883	70.81535	1.038154	10.41581	1.0313	1.1228	1.477751	0.438536	-0.246318	61.89324	0.346147	-7.98E-05
65.1	0.354169	157.7543	#	4.124948	**-15**	64.47083	256.9311	749.7193	71.0305	1.040305	11.45612	1.0313	1.1228	1.488642	0.445383	-0.141023	64.02556	0.351504	-2.62E-05
67.2	0.359257	148.6635	#	6.228845	**15**	62.73263	244.1021	244.1021	73.9856	1.069856	12.52598	1.0313	1.1228	1.437245	0.452202	0.205848	66.15247	0.356734	-5.58E-05
69.3	0.364322	152.6525	#	5.262605	**-15**	63.7279	249.9639	494.066	74.08336	1.070834	13.59681	1.0313	1.1228	1.446658	0.458699	0.224342	68.26062	0.361812	-6.62E-05
71.5	0.36936	156.5623	#	7.123337	**15**	64.68457	255.6905	749.7565	77.00809	1.100081	14.69689	1.0313	1.1228	1.455415	0.465166	0.235333	70.40115	0.366863	-7.29E-05
73.6	0.374182	148.9108	#	6.106468	**-15**	63.14883	244.8199	244.8199	77.05522	1.100552	15.79744	1.0313	1.1228	1.41016	0.471598	0.212773	72.53124	0.371791	-5.96E-05
75.7	0.378975	152.3599	#	7.904223	**15**	63.98158	249.8606	494.6806	79.91697	1.12917	16.92661	1.0313	1.1228	1.417178	0.477755	0.158378	74.64911	0.376596	-3.30E-05
77.9	0.383729	155.7014	#	6.80216	**-15**	64.66275	254.6185	749.299	79.87891	1.128789	18.0554	1.0313	1.1228	1.423408	0.483876	0.096263	76.79205	0.381367	-1.22E-05
80.0	0.388311	149.8876	#	8.631415	**15**	63.49605	246.3589	246.3589	82.77216	1.157722	19.21312	1.0313	1.1228	1.387581	0.489945	0.007918	78.92634	0.386031	-8.25E-08
82.1	0.392844	152.2311	#	7.602199	**-15**	63.95137	249.6733	496.0322	82.59415	1.155941	20.36906	1.0313	1.1228	1.391146	0.495796	0.152108	81.05333	0.390594	-3.04E-05
84.3	0.397333	155.0415	#	9.414241	**15**	64.45879	253.6095	749.6416	85.47019	1.184702	21.55377	1.0313	1.1228	1.394782	0.501584	0.025178	83.19108	0.395099	-8.34E-07
86.4	0.401677	150.3939	#	8.382811	**-15**	63.47728	246.9578	246.9578	85.28996	1.1829	22.73667	1.0313	1.1228	1.366478	0.507314	0.129987	85.32541	0.399519	-2.22E-05
88.5	0.405975	152.5937	#	10.19263	**15**	63.87771	250.0421	496.9998	88.05738	1.210574	23.94724	1.0313	1.1228	1.368173	0.512861	0.083771	87.44715	0.403838	-9.23E-06
90.6	0.410219	154.6693	#	8.996735	**-15**	64.13967	252.8362	749.8361	87.81908	1.208191	25.15543	1.0313	1.1228	1.369041	0.518348	0.026159	89.5797	0.408107	-9.00E-07

Data sheet Layout 2

N. Cav	E0	βg	V1	TTFg1	ϕgap1	ΔW1	E1	β end g1	V2	TTFg2	ϕgap2	ΔW2	E2	β end g2	V3	TTFg3	ϕgap3	ΔW3	E3
#	[MV/m]	#	[MV]	[#]	[deg]	[MeV]	[MeV]	#	[MV]	[#]	[deg]	[MeV]	[MeV]	#	[MV]	[#]	[deg]	[MeV]	[MeV]
1	**3.343**	**0.287**	0.610698	0.874939	**-26.4**	0.4786	40.9	0.285914	0.824875	0.872174	-25.03217	0.651858	41.6	0.288039	0.610698	0.876939	-26.33128	0.479979	42.1
2	**3.343**	**0.292**	0.633255	0.870851	**-26**	0.495659	42.5	0.291184	0.852025	0.869182	-24.99151	0.671226	43.2	0.293323	0.633255	0.872965	-26.6152	0.494231	43.7
3	**3.343**	**0.2975**	0.658237	0.866291	**-26.2**	0.511639	44.2	0.296491	0.88223	0.865596	-24.97478	0.692249	44.9	0.298646	0.658237	0.868492	-26.35629	0.512248	45.4
4	**3.343**	**0.303**	0.683342	0.861659	**-26.4**	0.527402	46.0	0.301845	0.912728	0.861714	-25.02298	0.712687	46.7	0.304013	0.683342	0.863909	-26.22299	0.529588	47.2
5	**3.074**	**0.308**	0.649399	0.85738	**-26**	0.500432	47.7	0.307111	0.864959	0.857938	-24.95841	0.672781	48.4	0.309113	0.649399	0.859645	-26.25471	0.500661	48.9
6	**3.074**	**0.313**	0.670456	0.853032	**-26**	0.514039	49.4	0.3121	0.890759	0.853937	-24.96193	0.689598	50.1	0.314109	0.670456	0.855285	-26.23253	0.514372	50.6
7	**3.074**	**0.318**	0.691489	0.848611	**-26**	0.527417	51.1	0.317111	0.916637	0.849722	-24.99082	0.705964	51.8	0.319124	0.691489	0.850827	-26.25908	0.527622	52.4
8	**3.074**	**0.323**	0.71246	0.84411	**-26**	0.54053	52.9	0.322138	0.942548	0.845302	-25.03706	0.721871	53.6	0.324154	0.71246	0.846268	-26.31864	0.540434	54.2
9	**2.868**	**0.328**	0.684189	0.839527	**-26.1**	0.515823	54.7	0.327073	0.903545	0.840686	-25.07978	0.687982	55.4	0.328956	0.684189	0.841607	-26.12552	0.516987	55.9
10	**2.868**	**0.332**	0.699676	0.835798	**-25.2**	0.529132	56.4	0.33179	0.922835	0.836861	-24.97225	0.700085	57.1	0.333669	0.699676	0.837802	-26.77259	0.523351	57.6
11	**2.868**	**0.337**	0.718892	0.831054	**-25.6**	0.53879	58.2	0.336491	0.946863	0.831919	-25.05568	0.713587	58.9	0.338369	0.718892	0.83295	-26.51253	0.535829	59.4
12	**2.868**	**0.342**	0.737916	0.826215	**-25.9**	0.54844	60.0	0.341196	0.970757	0.82681	-25.05126	0.727128	60.7	0.343073	0.737916	0.827987	-26.17698	0.54832	61.2
13	**2.707**	**0.347**	0.714234	0.821276	**-26.2**	0.526316	61.8	0.345821	0.938646	0.821544	-24.97275	0.699044	62.5	0.347592	0.714234	0.822913	-25.58637	0.530115	63.0
14	**2.707**	**0.351**	0.728249	0.817249	**-25.8**	0.535835	63.5	0.350269	0.956406	0.817224	-25.04899	0.708086	64.2	0.352032	0.728249	0.818772	-26.10386	0.535449	64.8
15	**2.707**	**0.3555**	0.743806	0.812636	**-25.8**	0.544192	65.3	0.354694	0.9762	0.812257	-24.98245	0.718737	66.0	0.356452	0.743806	0.814024	-25.94346	0.54446	66.6
16	**2.707**	**0.3595**	0.757427	0.808459	**-25.4**	0.553156	67.1	0.359111	0.993607	0.807753	-25.01007	0.727333	67.9	0.360858	0.757427	0.809723	-26.36465	0.549514	68.4
17	**2.586**	**0.364**	0.737967	0.803671	**-25.5**	0.535307	68.9	0.363441	0.967673	0.802592	-24.94585	0.704191	69.7	0.365103	0.737967	0.804793	-26.03334	0.533651	70.2
18	**2.586**	**0.3685**	0.752082	0.798786	**-25.8**	0.540869	70.7	0.367618	0.985884	0.797338	-24.93661	0.7128	71.4	0.369273	0.752082	0.799763	-25.69036	0.542031	72.0
19	**2.586**	**0.373**	0.765894	0.7938	**-26.1**	0.545971	72.5	0.371778	1.003798	0.791999	-24.91686	0.721008	73.2	0.373425	0.765894	0.794633	-25.32611	0.550111	73.8
20	**2.586**	**0.377**	0.777898	0.789281	**-26**	0.551842	74.3	0.37592	1.01945	0.787187	-24.96581	0.727512	75.1	0.377554	0.777898	0.789987	-25.49423	0.554692	75.6
21	**2.497**	**0.381**	0.762452	0.784677	**-26**	0.537729	76.2	0.379988	0.999209	0.782318	-25.04144	0.708222	76.9	0.381554	0.762452	0.785258	-25.56392	0.54011	77.4
22	**2.497**	**0.385**	0.773497	0.779987	**-26.1**	0.541796	78.0	0.383927	1.013768	0.777398	-25.09363	0.713717	78.7	0.38548	0.773497	0.780446	-25.54195	0.544676	79.2
23	**2.497**	**0.3885**	0.782919	0.77581	**-25.6**	0.54777	79.8	0.387839	1.026256	0.773054	-24.98674	0.719098	80.5	0.38938	0.782919	0.776166	-25.80068	0.547098	81.0
24	**2.497**	**0.393**	0.794682	0.770337	**-26.2**	0.549277	81.6	0.391712	1.041947	0.767422	-25.01634	0.724599	82.3	0.393241	0.794682	0.770567	-25.23737	0.553906	82.9
25	**2.432**	**0.396**	0.78141	0.766622	**-25.4**	0.541139	83.4	0.395535	1.024778	0.763641	-24.97707	0.709375	84.1	0.39701	0.78141	0.766773	-25.89321	0.539013	84.6
26	**2.432**	**0.3995**	0.789824	0.762221	**-25.3**	0.544276	85.2	0.399246	1.036142	0.759207	-25.07138	0.712529	85.9	0.400707	0.789824	0.762284	-26.15541	0.540419	86.4
27	**2.432**	**0.404**	0.800253	0.756451	**-26**	0.544087	87.0	0.402913	1.050339	0.753475	-25.02886	0.717087	87.7	0.404362	0.800253	0.756412	-25.35081	0.547031	88.3
28	**2.432**	**0.407**	0.806953	0.752535	**-25.4**	0.548559	88.8	0.406559	1.059533	0.749636	-25.00946	0.719793	89.5	0.407992	0.806953	0.752434	-25.88508	0.546261	90.1

β end g3	power	s	Grad Quad	Beam load	ot power/ca	tot power	equator fla	length/cav	tot length	scale fact	kilp	kilp scaled	d	Δβ	E center	β center	Δ TTF/tank
#	[kw]	[cm]	[T/m]	[kw]	[kw]	[kw]	[cm]	[m]	[m]	[#]	[#]	[#]	[m]	[%]	[MeV]	[]	[]
0.289592	105.073	**0**	**15**	48.3131	176.5022	176.5022	53.07356	0.860736	0.860736	1	1.2181	1.355931	0.363045	-0.007302	41.24453	0.286979	-7.02E-08
0.294885	109.4447	-0.646682	**-15**	49.83348	183.356	359.8581	53.49088	0.864909	1.725644	1.011	1.24504	1.369737	0.369751	0.087638	42.88171	0.292256	-1.01E-05
0.300228	114.371	0.917264	**15**	51.48409	191.0167	550.8749	56.22523	0.892252	2.617897	1.043	1.19629	1.385036	0.376509	0.023865	44.56932	0.297571	-7.49E-07
0.305611	119.4025	0.18543	**-15**	53.09032	198.7614	749.6363	56.66379	0.896638	3.514535	1.0313	1.1228	1.400377	0.383331	-0.02247	46.31143	0.302932	-6.64E-07
0.310592	104.8914	1.88353	**15**	50.21623	178.1837	178.1837	59.42589	0.924259	4.438793	1.0313	1.1228	1.300491	0.390204	0.037125	48.03419	0.308114	-1.81E-06
0.315596	108.8716	1.036761	**-15**	51.54026	184.3636	362.5473	59.64312	0.926431	5.365225	1.0313	1.1228	1.313209	0.396563	0.034006	49.73008	0.313106	-1.52E-06
0.320618	112.8888	2.733092	**15**	52.83009	190.5544	553.1017	62.40345	0.954035	6.319259	1.0313	1.1228	1.325794	0.402952	0.037654	51.46965	0.31812	-1.87E-06
0.325652	116.931	1.898169	**-15**	54.08506	196.7409	749.8427	62.63253	0.956325	7.275584	1.0313	1.1228	1.338193	0.409365	0.045885	53.25172	0.323148	-2.77E-06
0.330361	105.3144	3.587396	**15**	51.62376	180.1074	180.1074	65.38575	0.983858	8.259442	1.0313	1.1228	1.259861	0.415792	0.004928	55.0129	0.328016	-3.20E-08
0.335064	108.1401	2.828422	**-15**	52.57706	184.5079	364.6153	65.47798	0.98478	9.244222	1.0313	1.1228	1.268742	0.421804	0.219756	56.75305	0.332731	-6.35E-05
0.33977	111.6653	4.446519	**15**	53.64618	189.8778	554.4931	68.16008	1.011601	10.25582	1.0313	1.1228	1.27956	0.427809	0.12805	58.52203	0.337432	-2.16E-05
0.344479	115.1733	3.517316	**-15**	54.71664	195.2281	749.7212	68.29487	1.012949	11.26877	1.0313	1.1228	1.290015	0.433818	0.039748	60.32666	0.342136	-2.08E-06
0.348927	105.7062	5.121197	**15**	52.66425	181.6258	181.6258	70.96275	1.039628	12.3084	1.0313	1.1228	1.227077	0.43983	-0.084112	62.11438	0.346708	-9.31E-06
0.353356	108.163	4.238721	**-15**	53.38109	185.34	366.9657	70.93148	1.039315	13.34771	1.0313	1.1228	1.234349	0.44551	0.043279	63.8839	0.351152	-2.46E-06
0.357774	110.8955	5.976315	**15**	54.22166	189.5142	556.4799	73.62667	1.066267	14.41398	1.0313	1.1228	1.242167	0.451164	0.020973	65.67695	0.355575	-5.79E-07
0.362169	113.2911	5.046444	**-15**	54.9001	193.1153	749.5952	73.548	1.06548	15.47946	1.0313	1.1228	1.248766	0.456806	0.134992	67.4976	0.359986	-2.40E-05
0.366355	105.8094	6.79303	**15**	53.1945	182.282	182.282	76.25218	1.092522	16.57198	1.0313	1.1228	1.199635	0.462418	0.074975	69.29818	0.364273	-7.40E-06
0.370524	108.1815	5.624656	**-15**	53.871	185.8524	368.1343	76.04141	1.090414	17.6624	1.0313	1.1228	1.205861	0.467762	-0.014353	71.0812	0.368447	-2.71E-07
0.374673	110.4996	7.36236	**15**	54.51269	189.3222	557.4566	78.73671	1.117367	18.77976	1.0313	1.1228	1.211595	0.473085	-0.106634	72.8861	0.372603	-1.50E-05
0.378793	112.51	6.274808	**-15**	55.02138	192.2836	749.7402	78.50036	1.115004	19.89477	1.0313	1.1228	1.216251	0.478383	-0.069423	74.71232	0.376738	-6.34E-06
0.382741	106.7252	8.102666	**15**	53.58182	183.7866	183.7866	81.17942	1.141794	21.03656	1.0313	1.1228	1.178465	0.483643	-0.059825	76.52261	0.380772	-4.71E-06
0.386659	108.4992	6.936095	**-15**	54.00566	186.3747	370.1613	80.86405	1.13864	22.1752	1.0313	1.1228	1.182092	0.488684	-0.076788	78.31548	0.384705	-7.76E-06
0.390547	110.0056	8.870357	**15**	54.41898	188.6258	558.7871	83.54311	1.165431	23.34063	1.0313	1.1228	1.184882	0.493686	0.028567	80.12433	0.388611	-1.07E-06
0.394404	111.8748	7.525192	**-15**	54.83346	191.3208	750.1078	83.15554	1.161555	24.50219	1.0313	1.1228	1.187921	0.49865	-0.133025	81.94256	0.392478	-2.33E-05
0.398125	107.2659	9.579686	**15**	53.68584	184.5502	184.5502	85.84843	1.188484	25.69067	1.0313	1.1228	1.158622	0.503575	0.069118	83.75459	0.396274	-6.29E-06
0.401809	108.5501	8.340783	**-15**	53.91672	186.3479	370.898	85.35433	1.183543	26.87422	1.0313	1.1228	1.16015	0.508326	0.119401	85.54883	0.399978	-1.88E-05
0.405461	110.1256	10.09757	**15**	54.24614	188.5994	559.4974	88.06871	1.210687	28.0849	1.0313	1.1228	1.161512	0.513029	-0.089588	87.34814	0.403638	-1.06E-05
0.409075	111.1262	8.915352	**-15**	54.43841	190.0123	749.5097	87.5249	1.205249	29.29015	1.0313	1.1228	1.16203	0.517692	0.067929	89.16217	0.407277	-6.07E-06

Data Sheet Layout 3

N. Cav	E0	βg	V1	TTFg1	ϕgap1	ΔW1	E1	β end g1	V2	TTFg2	ϕgap2	ΔW2	E2	β end g2	V3	TTFg3	ϕgap3	ΔW3
#	[MV/m]	#	[MV]	[#]	[deg]	[MeV]	[MeV]	#	[MV]	[#]	[deg]	[MeV]	[MeV]	#	[MV]	[#]	[deg]	[MeV]
1	**3.343**	**0.287**	0.610698	0.874939	**-26.4**	0.4786	40.9	0.285914	0.824875	0.872174	-25.03217	0.651858	41.6	0.288039	0.610698	0.876939	-26.33128	0.479979
2	**3.343**	**0.292**	0.633255	0.870851	**-26**	0.495659	42.5	0.291184	0.852025	0.869182	-24.99151	0.671226	43.2	0.293323	0.633255	0.872965	-26.6152	0.494231
3	**3.343**	**0.2975**	0.658237	0.866291	**-26.2**	0.511639	44.2	0.296491	0.88223	0.865596	-24.97478	0.692249	44.9	0.298646	0.658237	0.868492	-26.35629	0.512248
4	**3.343**	**0.303**	0.683342	0.861659	**-26.4**	0.527402	46.0	0.301845	0.912728	0.861714	-25.02298	0.712687	46.7	0.304013	0.683342	0.863909	-26.22299	0.529588
5	**3.074**	**0.308**	0.649399	0.85738	**-26**	0.500432	47.7	0.307111	0.864959	0.857938	-24.95841	0.672781	48.4	0.309113	0.649399	0.859645	-26.25471	0.500661
6	**3.074**	**0.313**	0.670456	0.853032	**-26**	0.514039	49.4	0.3121	0.890759	0.853937	-24.96193	0.689598	50.1	0.314109	0.670456	0.855285	-26.23253	0.514372
7	**3.074**	**0.318**	0.691489	0.848611	**-26**	0.527417	51.1	0.317111	0.916637	0.849722	-24.99082	0.705964	51.8	0.319124	0.691489	0.850827	-26.25908	0.527622
8	**3.074**	**0.323**	0.71246	0.84411	**-26**	0.54053	52.9	0.322138	0.942548	0.845302	-25.03706	0.721871	53.6	0.324154	0.71246	0.846268	-26.31864	0.540434
9	**3.395**	**0.329**	0.814503	0.8386	**-26.9**	0.609135	54.8	0.327329	1.075287	0.839741	-25.06253	0.817945	55.6	0.329563	0.814503	0.840662	-25.67789	0.617101
10	**3.395**	**0.334**	0.837366	0.833912	**-26.2**	0.626546	56.8	0.332921	1.103801	0.834905	-25.03323	0.834999	57.7	0.33515	0.837366	0.835874	-26.268	0.627653
11	**3.395**	**0.339**	0.860028	0.82913	**-25.5**	0.643611	58.9	0.338504	1.132186	0.829895	-24.97213	0.851756	59.8	0.340725	0.860028	0.830978	-26.79512	0.637926
12	**3.228**	**0.345**	0.843269	0.823264	**-26.1**	0.62344	61.0	0.343979	1.108652	0.823669	-25.03135	0.827394	61.9	0.34609	0.843269	0.824957	-26.16501	0.624374
13	**3.228**	**0.35**	0.864252	0.818262	**-25.8**	0.636691	63.1	0.349273	1.135201	0.818313	-25.05041	0.841569	64.0	0.351374	0.864252	0.819814	-26.45835	0.634314
14	**3.228**	**0.355**	0.884915	0.813153	**-25.5**	0.649474	65.3	0.354546	1.161473	0.812815	-25.03889	0.85534	66.1	0.356637	0.884915	0.814556	-26.69104	0.644004
15	**3.09**	**0.361**	0.870361	0.806874	**-26.3**	0.629577	67.4	0.359718	1.141581	0.806043	-25.01664	0.833839	68.2	0.361714	0.870361	0.808091	-25.72757	0.633608
16	**3.09**	**0.366**	0.889332	0.801512	**-26.2**	0.639575	69.5	0.364732	1.165982	0.800268	-24.94894	0.846025	70.3	0.366718	0.889332	0.80257	-25.65385	0.643394
17	**3.09**	**0.371**	0.907875	0.796028	**-26.3**	0.647886	71.6	0.369719	1.189967	0.794382	-25.05226	0.856357	72.5	0.371689	0.907875	0.796926	-25.71944	0.651831
18	**2.99**	**0.375**	0.892525	0.791551	**-25.3**	0.638715	73.8	0.374629	1.169705	0.7896	-24.94363	0.837449	74.6	0.376519	0.892525	0.79232	-26.39591	0.633439
19	**2.99**	**0.38**	0.909629	0.785836	**-25.6**	0.644647	75.9	0.379376	1.192077	0.783541	-25.00782	0.846475	76.7	0.38125	0.909629	0.786448	-26.1886	0.64194
20	**2.99**	**0.385**	0.926214	0.779987	**-25.8**	0.650422	78.0	0.384086	1.213923	0.777398	-24.9432	0.855679	78.9	0.385946	0.926214	0.780446	-25.82547	0.650665
21	**2.91**	**0.3895**	0.915499	0.774604	**-25.8**	0.63846	80.2	0.388722	1.200103	0.771807	-25.07991	0.838919	81.0	0.390513	0.915499	0.774931	-26.0139	0.637573
22	**2.91**	**0.394**	0.929102	0.769104	**-25.7**	0.643889	82.3	0.393224	1.218279	0.766164	-24.98986	0.846019	83.1	0.394998	0.929102	0.769308	-25.89988	0.642974
23	**2.91**	**0.3985**	0.942216	0.763486	**-25.8**	0.647661	84.4	0.397681	1.23594	0.760477	-25.05897	0.851433	85.3	0.399436	0.942216	0.763574	-25.90252	0.647174
24	**2.851**	**0.4025**	0.934109	0.758388	**-25.4**	0.639938	86.6	0.402066	1.225812	0.755389	-25.01102	0.839134	87.4	0.403765	0.934109	0.758382	-26.13929	0.635959
25	**2.851**	**0.407**	0.945979	0.752535	**-25.6**	0.641999	88.7	0.406333	1.242076	0.749636	-25.00876	0.843808	89.5	0.408014	0.945979	0.752434	-25.90317	0.640277
26	**2.851**	**0.411**	0.956067	0.747224	**-25.4**	0.645339	90.8	0.410554	1.256034	0.744503	-25.00873	0.847447	91.7	0.412214	0.956067	0.74705	-26.06935	0.641566

E3	β end g3	power	s	Grad Quad	Beam load	t power/c	tot power	equator fla	length/cav	tot length	scale fact	kilp	kilp scaled	d	Δβ	E center	β center	Δ TTF/tank
[MeV]	#	[kw]	[cm]	[T/m]	[kw]	[kw]	[kw]	[cm]	[m]	[m]	[#]	[#]	[#]	[m]	[%]	[MeV]	[]	[]
42.1	0.289592	105.073	**0**	**15**	48.3131	176.5022	176.5022	53.07356	0.860736	0.860736	1	1.2181	1.355931	0.363045	-0.007302	41.24453	0.286979	-7.02E-08
43.7	0.294885	109.4447	-0.646682	**-15**	49.83348	183.356	359.8581	53.49088	0.864909	1.725644	1.011	1.24504	1.369737	0.369751	0.087638	42.88171	0.292256	-1.01E-05
45.4	0.300228	114.371	0.917264	**15**	51.48409	191.0167	550.8749	56.22523	0.892252	2.617897	1.043	1.19629	1.385036	0.376509	0.023865	44.56932	0.297571	-7.49E-07
47.2	0.305611	119.4025	0.18543	**-15**	53.09032	198.7614	749.6363	56.66379	0.896638	3.514535	1.0313	1.1228	1.400377	0.383331	-0.02247	46.31143	0.302932	-6.64E-07
48.9	0.310592	104.8914	1.88353	**15**	50.21623	178.1837	178.1837	59.42589	0.924259	4.438793	1.0313	1.1228	1.300491	0.390204	0.037125	48.03419	0.308114	-1.81E-06
50.6	0.315596	108.8716	1.036761	**-15**	51.54026	184.3636	362.5473	59.64312	0.926431	5.365225	1.0313	1.1228	1.313209	0.396563	0.034006	49.73008	0.313106	-1.52E-06
52.4	0.320618	112.8888	2.733092	**15**	52.83009	190.5544	553.1017	62.40345	0.954035	6.319259	1.0313	1.1228	1.325794	0.402952	0.037654	51.46965	0.31812	-1.87E-06
54.2	0.325652	116.931	1.898169	**-15**	54.08506	196.7409	749.8427	62.63253	0.956325	7.275584	1.0313	1.1228	1.338193	0.409365	0.045885	53.25172	0.323148	-2.77E-06
56.2	0.331235	148.5638	3.421639	**15**	61.32545	242.5733	242.5733	65.4328	0.984328	8.259912	1.0313	1.1228	1.494011	0.415792	-0.167789	55.1712	0.328449	-3.70E-05
58.3	0.336811	153.5111	2.863498	**-15**	62.67595	249.9595	492.5328	65.93865	0.989387	9.249299	1.0313	1.1228	1.507046	0.422921	0.011323	57.24132	0.334038	-1.69E-07
60.4	0.342376	158.443	4.624047	**15**	63.99882	257.2992	749.832	68.7632	1.017632	10.26693	1.0313	1.1228	1.519687	0.43004	0.181689	59.35596	0.339617	-4.34E-05
62.5	0.347671	148.5523	3.806617	**-15**	62.25626	243.4901	243.4901	69.22257	1.022226	11.28916	1.0313	1.1228	1.458783	0.437146	0.010622	61.4569	0.345037	-1.48E-07
64.6	0.352946	152.9344	5.455399	**15**	63.37721	249.9572	493.4473	71.93535	1.049354	12.33851	1.0313	1.1228	1.469782	0.443906	0.092975	63.55245	0.350326	-1.14E-05
66.8	0.358199	157.261	4.82811	**-15**	64.46455	256.323	749.7703	72.37206	1.053721	13.39223	1.0313	1.1228	1.480227	0.450642	0.166903	65.68469	0.355593	-3.67E-05
68.9	0.363221	148.7757	6.23493	**15**	62.91072	244.4171	244.4171	75.05568	1.080557	14.47279	1.0313	1.1228	1.42817	0.457349	-0.078182	67.80286	0.360718	-8.04E-06
71.0	0.368218	152.5862	5.494854	**-15**	63.86982	250.025	494.4421	75.37961	1.083796	15.55658	1.0313	1.1228	1.436815	0.46376	-0.074577	69.91597	0.365727	-7.32E-06
73.1	0.373178	156.3077	7.053923	**15**	64.68222	255.3776	749.8197	78.00268	1.110027	16.66661	1.0313	1.1228	1.44476	0.47014	-0.079404	72.05844	0.370706	-8.30E-06
75.2	0.377939	149.0744	6.565092	**-15**	63.28809	245.1589	245.1589	78.36504	1.11365	17.78026	1.0313	1.1228	1.403631	0.476474	0.153313	74.19589	0.375576	-3.09E-05
77.4	0.382663	152.3806	7.954807	**15**	63.99185	249.8962	495.0551	80.81876	1.138188	18.91845	1.0313	1.1228	1.409967	0.482552	0.082815	76.31594	0.380315	-9.03E-06
79.5	0.387351	155.5722	7.273861	**-15**	64.70296	254.501	749.5561	81.20181	1.142018	20.06047	1.0313	1.1228	1.41548	0.488584	0.004565	78.45938	0.385018	-2.74E-08
81.7	0.391866	149.9778	8.682023	**15**	63.44857	246.4214	246.4214	83.56757	1.165676	21.22614	1.0313	1.1228	1.38171	0.49457	0.030642	80.5958	0.389619	-1.24E-06
83.8	0.396339	152.4927	8.097166	**-15**	63.98645	250.0275	496.449	83.94032	1.169403	22.39555	1.0313	1.1228	1.385086	0.500334	0.02866	82.71974	0.394113	-1.08E-06
85.9	0.400762	154.8956	9.401741	**15**	64.38801	253.3607	749.8096	86.20249	1.192025	23.58757	1.0313	1.1228	1.387699	0.506045	0.015103	84.8591	0.39856	-3.00E-07
88.0	0.405046	150.6323	8.941363	**-15**	63.45094	247.2224	247.2224	86.59331	1.195933	24.7835	1.0313	1.1228	1.361183	0.511692	0.103476	86.99149	0.402917	-1.41E-05
90.2	0.409282	152.7157	10.14218	**15**	63.7825	250.0956	497.318	88.75172	1.217517	26.00102	1.0313	1.1228	1.362232	0.517163	0.042873	89.11092	0.407175	-2.42E-06
92.3	0.413465	154.4596	9.655316	**-15**	64.03056	252.4713	749.7893	89.11606	1.221161	27.22218	1.0313	1.1228	1.362451	0.522571	0.0937	91.24216	0.411385	-1.16E-05

Data Sheets Layout 4

N. Cav	E0	βg	V1	TTFg1	ϕgap1	ΔW1	E1	β end g1	V2	TTFg2	ϕgap2	ΔW2	E2	β end g2	V3	TTFg3	ϕgap3	ΔW3	E3
#	[MV/m]	#	[MV]	[#]	[deg]	[MeV]	[MeV]	#	[MV]	[#]	[deg]	[MeV]	[MeV]	#	[MV]	[#]	[deg]	[MeV]	[MeV]
1	**3.92**	**0.2885**	0.724018	0.873718	**-22.8**	0.583159	41.0	0.286256	0.976759	0.871304	-19.9779	0.799841	41.8	0.288858	0.724018	0.875756	-20.42365	0.594205	42.4
2	**3.92**	**0.295**	0.758511	0.868373	**-22.8**	0.607204	43.0	0.29271	1.018356	0.867264	-19.98399	0.830005	43.9	0.295335	0.758511	0.870539	-20.39178	0.618933	44.5
3	**3.92**	**0.3015**	0.793247	0.86293	**-22.8**	0.631031	45.1	0.299231	1.060482	0.862801	-20.06994	0.859422	46.0	0.301872	0.793247	0.86517	-20.51362	0.642775	46.6
4	**3.645**	**0.307**	0.765032	0.858242	**-21.5**	0.610896	47.2	0.305672	1.019524	0.858711	-19.93578	0.823014	48.0	0.308133	0.765032	0.860505	-21.25963	0.613514	48.7
5	**3.645**	**0.313**	0.794994	0.853032	**-21.4**	0.631401	49.3	0.311808	1.056219	0.853937	-20.02343	0.847424	50.1	0.314277	0.794994	0.855285	-21.4858	0.632696	50.8
6	**3.645**	**0.319**	0.824914	0.847717	**-21.2**	0.651968	51.4	0.317971	1.093048	0.848854	-20.03498	0.871688	52.3	0.320445	0.824914	0.849923	-21.65883	0.651614	52.9
7	**3.4**	**0.326**	0.801884	0.841371	**-22.2**	0.624668	53.6	0.324023	1.059696	0.842555	-20.00316	0.83899	54.4	0.326346	0.801884	0.843484	-20.38434	0.63402	55.0
8	**3.4**	**0.332**	0.829463	0.835798	**-22.3**	0.641414	55.7	0.329834	1.094017	0.836861	-19.93621	0.860674	56.5	0.33216	0.829463	0.837802	-20.10998	0.652559	57.2
9	**3.4**	**0.338**	0.856774	0.830094	**-22.5**	0.657066	57.9	0.335657	1.128181	0.830911	-19.98751	0.880954	58.7	0.337982	0.856774	0.831966	-19.96812	0.669955	59.4
10	**3.224**	**0.343**	0.83376	0.825235	**-21.7**	0.639288	60.0	0.341396	1.096604	0.825769	-20.00838	0.850886	60.9	0.343589	0.83376	0.826982	-20.62581	0.645308	61.5
11	**3.224**	**0.349**	0.859014	0.819271	**-22.2**	0.651595	62.2	0.346895	1.128512	0.819396	-20.01577	0.868845	63.1	0.349085	0.859014	0.820852	-20.10392	0.66216	63.7
12	**3.224**	**0.354**	0.879718	0.814183	**-21.7**	0.665493	64.4	0.352395	1.154811	0.813925	-20.06048	0.882905	65.3	0.354572	0.879718	0.815617	-20.64101	0.671454	65.9
13	**3.083**	**0.3595**	0.862633	0.808459	**-21.7**	0.64798	66.6	0.357789	1.131618	0.807753	-19.97884	0.859058	67.4	0.359862	0.862633	0.809723	-20.34113	0.654936	68.1
14	**3.083**	**0.365**	0.883565	0.802594	**-22**	0.657507	68.8	0.362996	1.158503	0.801432	-20.01241	0.8724	69.6	0.365057	0.883565	0.803684	-20.06893	0.66699	70.3
15	**3.083**	**0.37**	0.902154	0.797135	**-21.8**	0.66771	71.0	0.368179	1.18252	0.795568	-20.01908	0.883932	71.8	0.370225	0.902154	0.798065	-20.23742	0.675531	72.5
16	**2.975**	**0.375**	0.888047	0.791551	**-21.7**	0.65312	73.2	0.373269	1.163836	0.7896	-20.03028	0.863379	74.0	0.375227	0.888047	0.79232	-20.24838	0.660135	74.7
17	**2.975**	**0.38**	0.905065	0.785836	**-21.7**	0.66083	75.4	0.378195	1.186097	0.783541	-19.98158	0.873411	76.2	0.380138	0.905065	0.786448	-20.11202	0.668384	76.9
18	**2.975**	**0.385**	0.921567	0.779987	**-21.8**	0.667406	77.6	0.383081	1.207833	0.777398	-19.99636	0.882361	78.5	0.385006	0.921567	0.780446	-20.00204	0.67585	79.1
19	**2.893**	**0.389**	0.908619	0.775208	**-21.1**	0.657143	79.8	0.387887	1.191054	0.772431	-20.06725	0.864154	80.7	0.389738	0.908619	0.77555	-20.74865	0.658976	81.3
20	**2.893**	**0.394**	0.923675	0.769104	**-21.3**	0.661876	82.0	0.39254	1.211162	0.766164	-19.96125	0.872201	82.8	0.394374	0.923675	0.769308	-20.30267	0.666443	83.5
21	**2.893**	**0.4**	0.940944	0.761586	**-22.6**	0.661581	84.2	0.397141	1.234453	0.758572	-20.00838	0.879901	85.1	0.398958	0.940944	0.761637	-19.06799	0.677336	85.7
22	**2.833**	**0.403**	0.929548	0.757744	**-21.2**	0.656691	86.4	0.401688	1.219897	0.754751	-20.02407	0.86506	87.3	0.403443	0.929548	0.757727	-20.4191	0.660087	87.9
23	**2.833**	**0.4078**	0.942047	0.751481	**-21.5**	0.658671	88.6	0.406095	1.237046	0.748611	-19.98835	0.870282	89.4	0.40783	0.942047	0.751365	-20.01484	0.665071	90.1
24	**2.833**	**0.412**	0.952467	0.74588	**-21.3**	0.661897	90.8	0.410453	1.251495	0.743217	-19.94339	0.874352	91.6	0.412167	0.952467	0.74569	-20.08937	0.667032	92.3

β end g3	power	gap	s	Grad Quad	Beam load	t power/c	tot power	quator fla	length/cav	tot length	scale fact	kilp	kilp scaled	d	Δβ	E center	β center	Δ TTF/tank
#	[kw]	[cm]	[cm]	[T/m]	[kw]	[kw]	[kw]	[cm]	[m]	[m]	[#]	[#]	[#]	[m]	[%]	[MeV]	[]	[]
0.290771	146.2617	5.602462	**0**	**15**	59.31615	237.7554	237.7554	53.39276	0.863928	0.863928	1	1.2181	1.594805	0.363045	-0.326692	41.42308	0.287561	-1.40E-04
0.297272	154.1605	5.891484	-0.909183	**-15**	61.68425	249.7601	487.5155	53.86678	0.868668	1.732595	1.011	1.24504	1.615927	0.371257	-0.331194	43.43941	0.294026	-1.44E-04
0.303828	162.2776	6.190211	1.094964	**15**	63.99685	261.9755	749.491	57.25413	0.902541	2.635137	1.043	1.19629	1.637175	0.379557	-0.314359	45.53409	0.300555	-1.30E-04
0.309951	146.3664	6.450266	0.451042	**-15**	61.42273	239.9897	239.9897	57.7806	0.907806	3.542943	1.0313	1.1228	1.539029	0.387927	-0.030721	47.62898	0.306906	-1.24E-06
0.316103	153.0742	6.741279	2.290289	**15**	63.34562	250.0962	490.0859	60.89665	0.938966	4.481909	1.0313	1.1228	1.557139	0.395745	0.014502	49.70911	0.313045	-2.77E-07
0.322279	159.8568	7.039622	1.574617	**-15**	65.25812	260.2834	750.3692	61.45778	0.944578	5.426487	1.0313	1.1228	1.575023	0.4036	0.066234	51.85333	0.319211	-5.77E-06
0.328086	146.0232	7.396537	3.188716	**15**	62.93035	241.0786	241.0786	64.56147	0.975615	6.402102	1.0313	1.1228	1.488215	0.411485	-0.250031	53.98495	0.325187	-8.23E-05
0.333909	151.9799	7.709689	2.289628	**-15**	64.6394	250.0549	491.1335	64.93918	0.979392	7.381494	1.0313	1.1228	1.504088	0.4189	-0.302084	56.11022	0.331	-1.20E-04
0.339735	157.9227	8.029182	4.084789	**15**	66.23924	258.9049	750.0384	68.01115	1.010111	8.391605	1.0313	1.1228	1.519427	0.426335	-0.349629	58.29066	0.336822	-1.61E-04
0.34524	146.4233	8.300042	3.408241	**-15**	64.06448	242.7009	242.7009	68.3986	1.013986	9.405591	1.0313	1.1228	1.452439	0.433773	-0.147447	60.46582	0.342495	-2.86E-05
0.350742	151.6854	8.630344	5.043646	**15**	65.478	250.5342	493.2351	71.3108	1.043108	10.4487	1.0313	1.1228	1.465806	0.440802	-0.289427	62.62259	0.347993	-1.10E-04
0.356214	156.0134	8.909774	4.337307	**-15**	66.59556	256.9319	750.167	71.66846	1.046685	11.49538	1.0313	1.1228	1.476353	0.447827	-0.145455	64.82612	0.353486	-2.78E-05
0.361431	146.9489	9.221305	6.080627	**15**	64.85924	244.1369	244.1369	74.58218	1.075822	12.57121	1.0313	1.1228	1.422219	0.454814	-0.187293	67.01653	0.358828	-4.62E-05
0.366622	151.1438	9.536957	5.096074	**-15**	65.90687	250.3023	494.4392	74.76803	1.07768	13.64889	1.0313	1.1228	1.43189	0.461475	-0.266813	69.19471	0.364029	-9.37E-05
0.371777	154.867	9.827288	6.942763	**15**	66.81521	255.753	750.1922	77.67872	1.106787	14.75567	1.0313	1.1228	1.43996	0.468103	-0.215689	71.40757	0.369204	-6.12E-05
0.376715	147.5824	10.12064	6.02982	**-15**	65.29901	245.3496	245.3496	77.82977	1.108298	15.86397	1.0313	1.1228	1.396589	0.474684	-0.200418	73.60988	0.37425	-5.29E-05
0.381615	150.8556	10.41685	7.776587	**15**	66.07872	250.1225	495.4721	80.64054	1.136405	17.00038	1.0313	1.1228	1.402894	0.480989	-0.2194	75.79924	0.379168	-6.33E-05
0.386471	154.0152	10.71571	6.809461	**-15**	66.76849	254.667	750.1391	80.73741	1.137374	18.13775	1.0313	1.1228	1.408379	0.487245	-0.248608	78.01291	0.384045	-8.13E-05
0.39114	147.9479	10.9566	8.737629	**15**	65.4082	245.9046	245.9046	83.51678	1.165168	19.30292	1.0313	1.1228	1.37322	0.493446	-0.047797	80.21916	0.388814	-3.01E-06
0.395766	150.7162	11.2598	7.717319	**-15**	66.0156	249.8893	495.794	83.56047	1.165605	20.46852	1.0313	1.1228	1.376995	0.499407	-0.137553	82.40819	0.393459	-2.49E-05
0.400348	153.8569	11.62648	9.122941	**15**	66.56457	254.27	750.0639	86.24289	1.192429	21.66095	1.0313	1.1228	1.380283	0.505314	-0.489623	84.61227	0.398051	-3.15E-04
0.404774	148.9709	11.81088	8.530485	**-15**	65.45515	247.1997	247.1997	86.28883	1.192888	22.85384	1.0313	1.1228	1.352745	0.511164	-0.107608	86.81878	0.402567	-1.52E-05
0.409148	151.146	12.10728	10.11792	**15**	65.82073	250.2189	497.4185	88.89771	1.218977	24.07282	1.0313	1.1228	1.353729	0.516815	-0.205453	89.00521	0.406964	-5.55E-05
0.413467	152.9296	12.36789	9.222766	**-15**	66.09845	252.6725	750.0911	88.89631	1.218963	25.29178	1.0313	1.1228	1.353796	0.5224	-0.167358	91.20449	0.411312	-3.69E-05

Data Sheets Layout 5

N. Cav	E0	βg	V1	TTFg1	φgap1	ΔW1	E1	β end g1	V2	TTFg2	φgap2	ΔW2	E2	β end g2	V3	TTFg3	φgap3	ΔW3	E3
#	[MV/m]	#	[MV]	[#]	[deg]	[MeV]	[MeV]	#	[MV]	[#]	[deg]	[MeV]	[MeV]	#	[MV]	[#]	[deg]	[MeV]	[MeV]
1	**3.89**	**0.2885**	0.718477	0.873718	**-22.8**	0.578696	41.0	0.286241	0.969284	0.871304	-19.95939	0.793813	41.8	0.288824	0.718477	0.875756	-20.3629	0.58989	42.4
2	**3.89**	**0.295**	0.752706	0.868373	**-22.9**	0.602114	43.0	0.292647	1.010562	0.867264	-20.00554	0.82354	43.8	0.295252	0.752706	0.870539	-20.31239	0.614512	44.4
3	**3.89**	**0.3015**	0.787177	0.86293	**-22.8**	0.626202	45.1	0.299121	1.052366	0.862801	-19.93644	0.853568	45.9	0.301745	0.787177	0.86517	-20.22909	0.639033	46.6
4	**3.608**	**0.307**	0.757267	0.858242	**-21.8**	0.603439	47.2	0.305513	1.009175	0.858711	-20.04835	0.814078	48.0	0.30795	0.757267	0.860505	-21.15868	0.607702	48.6
5	**3.608**	**0.313**	0.786924	0.853032	**-21.6**	0.624133	49.2	0.311589	1.045497	0.853937	-19.96964	0.839109	50.0	0.314036	0.786924	0.855285	-21.15724	0.627677	50.7
6	**3.608**	**0.319**	0.816541	0.847717	**-21.4**	0.644473	51.3	0.317698	1.081952	0.848854	-19.92498	0.863442	52.2	0.320152	0.816541	0.849923	-21.22064	0.64694	52.8
7	**3.37**	**0.326**	0.794809	0.841371	**-22.6**	0.617377	53.4	0.323701	1.050346	0.842555	-20.04269	0.831379	54.3	0.326005	0.794809	0.843484	-20.04875	0.629783	54.9
8	**3.37**	**0.3315**	0.819875	0.836267	**-22.2**	0.634809	55.5	0.32947	1.081533	0.837345	-19.98149	0.851101	56.4	0.331773	0.819875	0.838282	-20.27814	0.644689	57.0
9	**3.37**	**0.337**	0.844724	0.831054	**-21.9**	0.651352	57.7	0.33524	1.112597	0.831919	-20.00994	0.869716	58.6	0.337539	0.844724	0.83295	-20.58452	0.65869	59.2
10	**3.19**	**0.343**	0.824968	0.825235	**-22.3**	0.629876	59.9	0.340905	1.08504	0.825769	-20.08792	0.841486	60.7	0.343079	0.824968	0.826982	-20.17077	0.640391	61.3
11	**3.19**	**0.348**	0.845819	0.820275	**-21.7**	0.644636	62.0	0.346362	1.111373	0.820473	-19.99713	0.856876	62.8	0.348526	0.845819	0.821885	-20.54093	0.650969	63.5
12	**3.19**	**0.354**	0.870441	0.814183	**-22.3**	0.655695	64.1	0.351791	1.142632	0.813925	-20.03993	0.873708	65.0	0.353951	0.870441	0.815617	-19.98988	0.667174	65.7
13	**3.053**	**0.359**	0.852331	0.808985	**-21.9**	0.639765	66.3	0.357146	1.118164	0.808321	-20.03127	0.849158	67.2	0.3592	0.852331	0.810265	-20.23204	0.648003	67.8
14	**3.053**	**0.364**	0.871234	0.803671	**-21.7**	0.650565	68.5	0.362309	1.142423	0.802592	-20.0201	0.861494	69.3	0.364351	0.871234	0.804793	-20.36661	0.65733	70.0
15	**3.053**	**0.369**	0.889729	0.798237	**-21.5**	0.660796	70.6	0.367442	1.166291	0.796749	-19.97369	0.873347	71.5	0.36947	0.889729	0.799198	-20.43125	0.666338	72.2
16	**2.945**	**0.374**	0.875665	0.792678	**-21.5**	0.645822	72.8	0.372485	1.147635	0.790802	-20.03601	0.852624	73.7	0.374426	0.875665	0.793479	-20.44514	0.651053	74.3
17	**2.945**	**0.379**	0.892609	0.78699	**-21.5**	0.653594	75.0	0.377366	1.169769	0.78476	-19.94099	0.862949	75.9	0.379292	0.892609	0.787633	-20.21806	0.659729	76.5
18	**2.945**	**0.384**	0.90905	0.781168	**-21.7**	0.659796	77.2	0.382209	1.191394	0.778633	-20.01304	0.871641	78.0	0.384118	0.90905	0.781657	-20.12324	0.667189	78.7
19	**2.866**	**0.388**	0.897088	0.776411	**-21**	0.650247	79.4	0.386975	1.175883	0.773677	-20.0467	0.854635	80.2	0.388812	0.897088	0.776782	-20.7985	0.651432	80.9
20	**2.866**	**0.393**	0.912118	0.770337	**-21.3**	0.654641	81.5	0.391593	1.195923	0.767422	-20.00689	0.862392	82.4	0.393413	0.912118	0.770567	-20.38518	0.65883	83.0
21	**2.866**	**0.398**	0.926559	0.764116	**-21.7**	0.657824	83.7	0.396167	1.215346	0.761111	-20.03447	0.869037	84.6	0.397969	0.926559	0.764216	-20.00598	0.665363	85.2
22	**2.805**	**0.402**	0.917707	0.759031	**-21.2**	0.649427	85.9	0.40067	1.204222	0.756026	-20.00483	0.855492	86.7	0.402412	0.917707	0.759036	-20.37358	0.652997	87.4
23	**2.805**	**0.406**	0.928167	0.753847	**-20.8**	0.654094	88.0	0.405052	1.218529	0.750917	-19.95704	0.860067	88.9	0.406773	0.928167	0.753766	-20.64156	0.654708	89.6
24	**2.805**	**0.411**	0.940641	0.747224	**-21.4**	0.654411	90.2	0.409372	1.235768	0.744503	-19.9686	0.86472	91.1	0.411075	0.940641	0.74705	-20.03385	0.660186	91.7

β end g3	power	gap	s	Grad Quad	Beam load	t power/ca	tot power	equator fla	length/cav	tot length	scale fact	kilp	kilp scaled	d	Δβ	E center	β center	Δ TTF/tank
#	[kw]	[cm]	[cm]	[T/m]	[kw]	[kw]	[kw]	[cm]	[m]	[m]	[#]	[#]	[#]	[m]	[%]	[MeV]	[]	[]
0.290724	144.0315	5.602462	**0**	**15**	78.49595	254.2144	254.2144	53.39276	0.863928	0.863928	1	1.2181	1.5826	0.363045	-0.335178	41.4156	0.287536	-1.48E-04
0.297176	151.81	5.891484	-0.943356	**-15**	81.60664	266.8148	521.0292	53.83261	0.868326	1.732254	1.011	1.24504	1.60356	0.371196	-0.356156	43.41628	0.293953	-1.67E-04
0.303691	159.8032	6.190211	1.093581	**15**	84.75214	279.7121	800.7413	57.25274	0.902527	2.634781	1.043	1.19629	1.624646	0.379434	-0.353914	45.49555	0.300437	-1.65E-04
0.309752	143.41	6.450266	0.333552	**-15**	81.00876	255.9689	255.9689	57.66311	0.906631	3.541412	1.0313	1.1228	1.523407	0.387752	-0.086459	47.57185	0.306735	-9.84E-06
0.31585	149.9823	6.741279	2.312872	**15**	83.63672	266.6151	522.584	60.91923	0.939192	4.480605	1.0313	1.1228	1.541333	0.395491	-0.058949	49.63027	0.312816	-4.57E-06
0.321974	156.6279	7.039622	1.40838	**-15**	86.19419	277.2802	799.8642	61.29154	0.942915	5.42352	1.0313	1.1228	1.559035	0.403277	-0.022439	51.7537	0.318928	-6.63E-07
0.327737	143.4577	7.396537	3.149766	**15**	83.14153	258.1599	258.1599	64.52252	0.975225	6.398745	1.0313	1.1228	1.475083	0.411097	-0.352223	53.86543	0.324856	-1.63E-04
0.333504	148.8223	7.683347	2.224488	**-15**	85.22398	266.7871	524.947	64.76765	0.977676	7.376422	1.0313	1.1228	1.489524	0.418454	-0.264876	55.97126	0.330624	-9.23E-05
0.339265	154.177	7.975506	4.231901	**15**	87.19029	275.2863	800.2333	67.94546	1.009455	8.385876	1.0313	1.1228	1.503528	0.425818	-0.180727	58.12771	0.336392	-4.30E-05
0.34472	143.3512	8.300042	3.186864	**-15**	84.47014	259.3586	259.3586	68.17722	1.011772	9.397648	1.0313	1.1228	1.437122	0.433174	-0.294006	60.27187	0.341995	-1.14E-04
0.350158	147.6489	8.574907	5.182646	**15**	86.09922	266.2309	525.5896	71.237	1.04237	10.44002	1.0313	1.1228	1.448194	0.440139	-0.159324	62.40608	0.347446	-3.34E-05
0.355587	152.7401	8.909774	4.065385	**-15**	87.86308	274.206	799.7956	71.39654	1.043965	11.48398	1.0313	1.1228	1.460784	0.447082	-0.319241	64.57804	0.352873	-1.34E-04
0.360757	143.7245	9.19281	6.070824	**15**	85.47707	260.8209	260.8209	74.46598	1.07466	12.55864	1.0313	1.1228	1.40747	0.454013	-0.230242	66.74641	0.358175	-6.98E-05
0.365897	147.4758	9.47927	5.030637	**-15**	86.77557	266.6961	527.517	74.48979	1.074898	13.63354	1.0313	1.1228	1.416274	0.460614	-0.183827	68.90031	0.363332	-4.45E-05
0.371006	151.1448	9.768974	7.012227	**15**	88.01923	272.4159	799.9329	77.53538	1.105354	14.7389	1.0313	1.1228	1.424407	0.467177	-0.147121	71.08585	0.368458	-2.85E-05
0.375897	143.9671	10.06174	5.918119	**-15**	85.97996	261.6198	261.6198	77.50527	1.105053	15.84395	1.0313	1.1228	1.381165	0.4737	-0.14533	73.261	0.373457	-2.78E-05
0.380755	147.1955	10.35739	7.835735	**15**	87.05091	266.6294	528.2492	80.48689	1.134869	16.97882	1.0313	1.1228	1.387562	0.479945	-0.176911	75.42343	0.378331	-4.12E-05
0.385569	150.3148	10.65573	6.653606	**-15**	87.94503	271.3291	799.5784	80.36876	1.133688	18.1125	1.0313	1.1228	1.393158	0.486147	-0.217902	77.61025	0.383165	-6.25E-05
0.390203	144.6407	10.89623	8.78903	**15**	86.25254	262.7141	262.7141	83.35538	1.163554	19.27606	1.0313	1.1228	1.359549	0.492294	-0.026996	79.79082	0.387895	-9.59E-07
0.394795	147.3831	11.19898	7.521292	**-15**	87.03451	266.8419	529.556	83.15164	1.161516	20.43757	1.0313	1.1228	1.363468	0.498211	-0.126104	81.95541	0.392505	-2.09E-05
0.399339	149.9935	11.50393	9.383103	**15**	87.68895	270.681	800.2371	86.07745	1.190775	21.62835	1.0313	1.1228	1.366469	0.504074	-0.234362	84.13778	0.397069	-7.23E-05
0.403734	145.5793	11.74934	8.318609	**-15**	86.31661	263.9233	263.9233	85.86416	1.188642	22.81699	1.0313	1.1228	1.339055	0.509876	-0.113938	86.31483	0.401542	-1.71E-05
0.408076	147.3898	11.99595	10.30902	**15**	86.75474	266.5703	530.4936	88.70576	1.217058	24.03405	1.0313	1.1228	1.340095	0.515487	-0.021198	88.4797	0.405914	-5.91E-07
0.412367	149.5155	12.30574	8.97947	**-15**	87.17266	269.5816	800.0752	88.44022	1.214402	25.24845	1.0313	1.1228	1.340468	0.521032	-0.188965	90.65121	0.410225	-4.70E-05

Macro Code for Misalignment studies.

```
Sub real_misalignment_with_steering()
'Macro written by Matteo Pasini
'for study of misalignment on CCDTL
'January, 19 2005

'read parameters
A = Worksheets("param").Cells(1, 2)
q = Worksheets("param").Cells(2, 2)
clight = Worksheets("param").Cells(3, 2)
freq = Worksheets("param").Cells(4, 2)
lambda = clight / freq
nelements = Worksheets("listelem").Cells(1, 2)
direc = Worksheets("param").Cells(31, 8)
filenm = Worksheets("param").Cells(32, 8)
E0 = Worksheets("param").Cells(6, 2)

alfx = Worksheets("param").Cells(1, 9)
betx = Worksheets("param").Cells(2, 9)
gamx = (1 + alfx ^ 2) / betx
emitx = Worksheets("param").Cells(4, 9) / 1000000#
alfy = Worksheets("param").Cells(5, 9)
bety = Worksheets("param").Cells(6, 9)
gamy = (1 + alfy ^ 2) / bety
emity = Worksheets("param").Cells(8, 9) / 1000000#
jmax = Worksheets("param").Cells(5, 13)
sigma = Worksheets("param").Cells(12, 13) / 2000
sigmasol = Worksheets("param").Cells(33, 13) / 2000
sigmacav = Worksheets("param").Cells(29, 13) / 2000
ChDir direc
'Logic card for calculation of envelopes
env = Worksheets("param").Cells(2, 13)
steerswt = Worksheets("param").Cells(10, 2)
If env = "Yes" Then
Open "env.dat" For Output As #2
Print #2, "length"; Tab; "xmax"; Tab; "ymax"
Print #2, "m"; Tab; "mm"; Tab; "mm"
End If
'file for steering calculation
Open "steer.dat" For Output As #3
Print #3, "steerX"; Tab; "steerY"; Tab; "BL X"; Tab; "BL Y"
Print #3, "mrad"; Tab; "mrad"; Tab; "G*cm"; Tab; "G*cm"
'other parameters
raw = 1
Pi = 3.1415926536

'initialize output file
Open filenm For Output As #1
Print #1, "length"; Tab; "x0"; Tab; "xp0"; Tab; "y0"; Tab; "yp0"; Tab; "dxbef"; Tab; "dxaft";
Tab; "dxp"; Tab; "dybef"; Tab; "dyaft"; Tab; "dyp"; Tab; "Energy"
Print #1, "m"; Tab; "mm"; Tab; "mrad"; Tab; "mm"; Tab; "mrad"; Tab; "mm"; Tab; "mm"; Tab;
"mrad"; Tab; "mm"; Tab; "mm"; Tab; "mrad"; Tab; "MeV/u"
'realistic field option
'
'
'
'realistic filed option

j = 0
'big loop for multiple run
  Do Until j = jmax
  j = j + 1
  'starts loop read the elements and apply the transport matrix to the initail particle
  i = 0
  Eini = Worksheets("param").Cells(7, 2)
  lgt = 0
  x0 = Worksheets("param").Cells(1, 6)
  xp0 = Worksheets("param").Cells(2, 6)
  y0 = Worksheets("param").Cells(3, 6)
  yp0 = Worksheets("param").Cells(4, 6)
  'Print #1, Format(lgt, "#0.00"); Tab; Format(x0 * 1000, "0.000"); Tab; Format(xp0 * 1000,
"0.000"); Tab; Format(y0 * 1000, "0.000"); Tab; Format(yp0 * 1000, "0.000"); Tab; Format(dxbef
* 1000, "0.000"); Tab; Format(dxaft * 1000, "0.000"); Tab; Format(dxp * 1000, "0.000"); Tab;
Format(dybef * 1000, "0.000"); Tab; Format(dyaft * 1000, "0.000"); Tab; Format(dyp * 1000,
"0.000"); Tab; Format(Eini / 1000000#, "#0.000")
    If env = "Yes" Then
```

```
    Print #2, lgt; Tab; Format(1000 * Sqr(betx * emitx), "#0.0"); Tab; Format(-1000 * Sqr(bety
* emity), "#0.0")
    End If

    ' initialization of the M-matrix that is used to calculate the steering mode 2
'     m11 = 1
'     m12 = 0
'     m13 = 0
'     m14 = 0
'     m21 = 0
'     m22 = 1
'     m23 = 0
'     m24 = 0
'     m31 = 0
'     m32 = 0
'     m33 = 1
'     m34 = 0
'     m41 = 0
'     m42 = 0
'     m43 = 0
'     m44 = 1

      Do Until i = nelements
      i = i + 1
      'A matrix is used as the first term (the one on the right) that moltiplicates the
coordinate
'       a11 = m11
'       a12 = m12
'       a13 = m13
'       a14 = m14
'       a21 = m21
'       a22 = m22
'       a23 = m23
'       a24 = m24
'       a31 = m31
'       a32 = m32
'       a33 = m33
'       a34 = m34
'       a41 = m41
'       a42 = m42
'       a43 = m43
'       a44 = m44

      'initialization of the misalignment parameters
      dxbef = 0
      dxaft = 0
      dybef = 0
      dyaft = 0
      dxp = 0
      dyp = 0

'relativistic parameters
beta = Sqr(1 - 1 / (Eini / E0 + 1) ^ 2)
gamma = (1 - beta ^ 2) ^ -0.5

'read the element in the list
elem = Worksheets("listelem").Cells(raw + i, 1)

'define parameter for drift
If elem = "drift" Then
lg = Worksheets("listelem").Cells(raw + i, 2) / 1000
'this part is not really usefull for the matrix, but I use it for steering calculation
dxbef = 0
dxaft = 0
dybef = 0
dyaft = 0
dxp = 0
dyp = 0
'here I specify the matrix element of a drift
t11 = 1
t12 = lg
t13 = 0
t14 = 0
t21 = 0
t22 = 1
t23 = 0
t24 = 0
```

```
t31 = 0
t32 = 0
t33 = 1
t34 = lg
t41 = 0
t42 = 0
t43 = 0
t44 = 1

'calculate the matrix
x = t11 * x0 + t12 * xp0 + t13 * y0 + t14 * yp0
xp = t21 * x0 + t22 * xp0 + t23 * y0 + t24 * yp0
y = t31 * x0 + t32 * xp0 + t33 * y0 + t34 * yp0
yp = t41 * x0 + t42 * xp0 + t43 * y0 + t44 * yp0
 If env = "Yes" Then
 'sigmamatrix
 s11 = betx * emitx
 s12 = -alfx * emitx
 s13 = 0
 s14 = 0
 s21 = -alfx * emitx
 s22 = gamx * emitx
 s23 = 0
 s24 = 0
 s31 = 0
 s32 = 0
 s33 = bety * emity
 s34 = -alfy * emity
 s41 = 0
 s42 = 0
 s43 = -alfy * emity
 s44 = gamy * emity

 'multiplication of the matrix sigma*R(traspose)
 st11 = s11 * t11 + s12 * t12 + s13 * t13 + s14 * t14
 st12 = s11 * t21 + s12 * t22 + s13 * t23 + s14 * t24
 st13 = s11 * t31 + s12 * t32 + s13 * t33 + s14 * t34
 st14 = s11 * t41 + s12 * t42 + s13 * t43 + s14 * t44
 st21 = s21 * t11 + s22 * t12 + s23 * t13 + s24 * t14
 st22 = s21 * t21 + s22 * t22 + s23 * t23 + s24 * t24
 st23 = s21 * t31 + s22 * t32 + s23 * t33 + s24 * t34
 st24 = s21 * t41 + s22 * t42 + s23 * t43 + s24 * t44
 st31 = s31 * t11 + s32 * t12 + s33 * t13 + s34 * t14
 st32 = s31 * t21 + s32 * t22 + s33 * t23 + s34 * t24
 st33 = s31 * t31 + s32 * t32 + s33 * t33 + s34 * t34
 st34 = s31 * t41 + s32 * t42 + s33 * t43 + s34 * t44
 st41 = s41 * t11 + s42 * t12 + s43 * t13 + s44 * t14
 st42 = s41 * t21 + s42 * t22 + s43 * t23 + s44 * t24
 st43 = s41 * t31 + s42 * t32 + s43 * t33 + s44 * t34
 st44 = s41 * t41 + s42 * t42 + s43 * t43 + s44 * t44

 'multiplication of the matrix above times R
 sn11 = t11 * st11 + t12 * st21 + t13 * st31 + t14 * st41
 sn12 = t11 * st12 + t12 * st22 + t13 * st32 + t14 * st42
 sn13 = t11 * st13 + t12 * st23 + t13 * st33 + t14 * st43
 sn14 = t11 * st14 + t12 * st24 + t13 * st34 + t14 * st44
 sn21 = t21 * st11 + t22 * st21 + t23 * st31 + t24 * st41
 sn22 = t21 * st12 + t22 * st22 + t23 * st32 + t24 * st42
 sn23 = t21 * st13 + t22 * st23 + t23 * st33 + t24 * st43
 sn24 = t21 * st14 + t22 * st24 + t23 * st34 + t24 * st44
 sn31 = t31 * st11 + t32 * st21 + t33 * st31 + t34 * st41
 sn32 = t31 * st12 + t32 * st22 + t33 * st32 + t34 * st42
 sn33 = t31 * st13 + t32 * st23 + t33 * st33 + t34 * st43
 sn34 = t31 * st14 + t32 * st24 + t33 * st34 + t34 * st44
 sn41 = t41 * st11 + t42 * st21 + t43 * st31 + t44 * st41
 sn42 = t41 * st12 + t42 * st22 + t43 * st32 + t44 * st42
 sn43 = t41 * st13 + t42 * st23 + t43 * st33 + t44 * st43
 sn44 = t41 * st14 + t42 * st24 + t43 * st34 + t44 * st44
 'calculate new Twiss parameters
 alfnx = -sn12 / emitx
 betnx = sn11 / emitx
 gamnx = (1 + alfnx ^ 2) / betnx
 alfny = -sn34 / emity
 betny = sn33 / emity
 gamny = (1 + alfny ^ 2) / betny
 End If
End If
```

```
'define parameter for cavity
If elem = "gap" Then
lg = 0
lgap = Worksheets("listelem").Cells(raw + i, 4) / 1000
ETL = Worksheets("listelem").Cells(raw + i, 2)
phi = Worksheets("listelem").Cells(raw + i, 3) * Pi / 180
DW = ETL * q * Cos(phi) / A
betai = Sqr(1 - 1 / (Eini / E0 + 1) ^ 2)
gammai = (1 - betai ^ 2) ^ -0.5
E = Eini + DW
Eave = Eini + DW / 2
betaf = Sqr(1 - 1 / (E / E0 + 1) ^ 2)
gammaf = (1 - betaf ^ 2) ^ -0.5
betaave = Sqr(1 - 1 / (Eave / E0 + 1) ^ 2)
gammaave = (1 - betaave ^ 2) ^ -0.5
'here I set the misalignment on the cavity
dxbef = sigmacav * Sqr(-2 * Log(Rnd) / Log(2.718282)) * Cos(2 * 3.1415926 * Rnd)
dybef = sigmacav * Sqr(-2 * Log(Rnd) / Log(2.718282)) * Cos(2 * 3.1415926 * Rnd)
dxaft = sigmacav * Sqr(-2 * Log(Rnd) / Log(2.718282)) * Cos(2 * 3.1415926 * Rnd)
dyaft = sigmacav * Sqr(-2 * Log(Rnd) / Log(2.718282)) * Cos(2 * 3.1415926 * Rnd)
dxp = (dxaft - dxbef) / lgap
dyp = (dyaft - dybef) / lgap
x0 = x0 + dxbef
y0 = y0 + dybef
xp0 = xp0 + dxp
yp0 = yp0 + dyp
'here I specify the matrix element of a cavity
'here I specify the matrix element of a cavity
t11 = 1
t12 = 0
t13 = 0
t14 = 0
t21 = -(Pi * q * ETL * Sin(phi)) / (A * E0 * betaave ^ 2 * gammaave ^ 2 * betaf * gammaf *
lambda)
t22 = 1
t23 = 0
t24 = 0
t31 = 0
t32 = 0
t33 = 1
t34 = 0
t41 = 0
t42 = 0
t43 = -(Pi * q * ETL * Sin(phi)) / (A * E0 * betaave ^ 2 * gammaave ^ 2 * betaf * gammaf *
lambda)
t44 = 1
t55 = 1
t56 = 0
t65 = 2 * Pi * q * ETL * Sin(phi) / (A * E0 * betaave ^ 2 * betaf * gammaf * lambda)
t66 = beta * gamma / betaf * gammaf

 'calculate the matrix
x = t11 * x0 + t12 * xp0 + t13 * y0 + t14 * yp0
xp = t21 * x0 + t22 * xp0 + t23 * y0 + t24 * yp0
y = t31 * x0 + t32 * xp0 + t33 * y0 + t34 * yp0
yp = t41 * x0 + t42 * xp0 + t43 * y0 + t44 * yp0
'here I reset the correct coordinates for the cavities
x = x - dxbef
y = y - dybef
xp = xp - dxp
yp = yp - dyp
'
Eini = E
 If env = "Yes" Then
 'sigmamatrix
 s11 = betx * emitx
 s12 = -alfx * emitx
 s13 = 0
 s14 = 0
 s21 = -alfx * emitx
 s22 = gamx * emitx
 s23 = 0
 s24 = 0
 s31 = 0
 s32 = 0
 s33 = bety * emity
```

```
 s34 = -alfy * emity
 s41 = 0
 s42 = 0
 s43 = -alfy * emity
 s44 = gamy * emity

 'multiplication of the matrix sigma*R(traspost)
 st11 = s11 * t11 + s12 * t12 + s13 * t13 + s14 * t14
 st12 = s11 * t21 + s12 * t22 + s13 * t23 + s14 * t24
 st13 = s11 * t31 + s12 * t32 + s13 * t33 + s14 * t34
 st14 = s11 * t41 + s12 * t42 + s13 * t43 + s14 * t44
 st21 = s21 * t11 + s22 * t12 + s23 * t13 + s24 * t14
 st22 = s21 * t21 + s22 * t22 + s23 * t23 + s24 * t24
 st23 = s21 * t31 + s22 * t32 + s23 * t33 + s24 * t34
 st24 = s21 * t41 + s22 * t42 + s23 * t43 + s24 * t44
 st31 = s31 * t11 + s32 * t12 + s33 * t13 + s34 * t14
 st32 = s31 * t21 + s32 * t22 + s33 * t23 + s34 * t24
 st33 = s31 * t31 + s32 * t32 + s33 * t33 + s34 * t34
 st34 = s31 * t41 + s32 * t42 + s33 * t43 + s34 * t44
 st41 = s41 * t11 + s42 * t12 + s43 * t13 + s44 * t14
 st42 = s41 * t21 + s42 * t22 + s43 * t23 + s44 * t24
 st43 = s41 * t31 + s42 * t32 + s43 * t33 + s44 * t34
 st44 = s41 * t41 + s42 * t42 + s43 * t43 + s44 * t44

 'multiplication of the matrix above times R
 sn11 = t11 * st11 + t12 * st21 + t13 * st31 + t14 * st41
 sn12 = t11 * st12 + t12 * st22 + t13 * st32 + t14 * st42
 sn13 = t11 * st13 + t12 * st23 + t13 * st33 + t14 * st43
 sn14 = t11 * st14 + t12 * st24 + t13 * st34 + t14 * st44
 sn21 = t21 * st11 + t22 * st21 + t23 * st31 + t24 * st41
 sn22 = t21 * st12 + t22 * st22 + t23 * st32 + t24 * st42
 sn23 = t21 * st13 + t22 * st23 + t23 * st33 + t24 * st43
 sn24 = t21 * st14 + t22 * st24 + t23 * st34 + t24 * st44
 sn31 = t31 * st11 + t32 * st21 + t33 * st31 + t34 * st41
 sn32 = t31 * st12 + t32 * st22 + t33 * st32 + t34 * st42
 sn33 = t31 * st13 + t32 * st23 + t33 * st33 + t34 * st43
 sn34 = t31 * st14 + t32 * st24 + t33 * st34 + t34 * st44
 sn41 = t41 * st11 + t42 * st21 + t43 * st31 + t44 * st41
 sn42 = t41 * st12 + t42 * st22 + t43 * st32 + t44 * st42
 sn43 = t41 * st13 + t42 * st23 + t43 * st33 + t44 * st43
 sn44 = t41 * st14 + t42 * st24 + t43 * st34 + t44 * st44
 'calculate new Twiss parameters
 alfnx = -sn12 / emitx
 betnx = sn11 / emitx
 gamnx = (1 + alfnx ^ 2) / betnx
 alfny = -sn34 / emity
 betny = sn33 / emity
 gamny = (1 + alfny ^ 2) / betny
 End If

End If

'define parameter for quadrupole
If elem = "quad" Then
lg = Worksheets("listelem").Cells(raw + i, 2) / 1000
G = Worksheets("listelem").Cells(raw + i, 3)
'here I set the misalignment on the cavity
dxbef = sigmasol * Sqr(-2 * Log(Rnd) / Log(2.718282)) * Cos(2 * 3.1415926 * Rnd)
dybef = sigmasol * Sqr(-2 * Log(Rnd) / Log(2.718282)) * Cos(2 * 3.1415926 * Rnd)
dxaft = sigmasol * Sqr(-2 * Log(Rnd) / Log(2.718282)) * Cos(2 * 3.1415926 * Rnd)
dyaft = sigmasol * Sqr(-2 * Log(Rnd) / Log(2.718282)) * Cos(2 * 3.1415926 * Rnd)
dxp = (dxaft - dxbef) / lgap
dyp = (dyaft - dybef) / lgap
x0 = x0 + dxbef
y0 = y0 + dybef
xp0 = xp0 + dxp
yp0 = yp0 + dyp
'here I specify the matrix element of a solenoid
Br = A * E0 * beta * gamma / (q * clight)
k = (Abs(G / Br)) ^ 0.5
Ch = (Exp(k * lg) + Exp(-k * lg)) / 2
C = Cos(k * lg / 1000)
sh = (Exp(k * lg) - Exp(-k * lg)) / 2
s = Sin(k * lg)
If G > 0 Then
t11 = C
t12 = s / k
```

```
t13 = 0
t14 = 0
t21 = -k * s
t22 = C
t23 = 0
t24 = 0
t31 = 0
t32 = 0
t33 = Ch
t34 = sh / k
t41 = 0
t42 = 0
t43 = k * sh
t44 = Ch
t55 = 1
t56 = lg / gamma ^ 2
t66 = 1
End If
If G < 0 Then
t11 = Ch
t12 = sh / k
t13 = 0
t14 = 0
t21 = k * sh
t22 = Ch
t23 = 0
t24 = 0
t31 = 0
t32 = 0
t33 = C
t34 = s / k
t41 = 0
t42 = 0
t43 = -k * s
t44 = C
t55 = 1
t56 = lg / gamma ^ 2
t66 = 1
End If
'calculate the matrix
x = t11 * x0 + t12 * xp0 + t13 * y0 + t14 * yp0
xp = t21 * x0 + t22 * xp0 + t23 * y0 + t24 * yp0
y = t31 * x0 + t32 * xp0 + t33 * y0 + t34 * yp0
yp = t41 * x0 + t42 * xp0 + t43 * y0 + t44 * yp0
'here I reset the correct coordinates for the quadrupoles
x = x - dxaft
y = y - dyaft
xp = xp - dxp
yp = yp - dyp
'
 If env = "Yes" Then
 'sigmamatrix
 s11 = betx * emitx
 s12 = -alfx * emitx
 s13 = 0
 s14 = 0
 s21 = -alfx * emitx
 s22 = gamx * emitx
 s23 = 0
 s24 = 0
 s31 = 0
 s32 = 0
 s33 = bety * emity
 s34 = -alfy * emity
 s41 = 0
 s42 = 0
 s43 = -alfy * emity
 s44 = gamy * emity

 'multiplication of the matrix sigma*R(traspost)
 st11 = s11 * t11 + s12 * t12 + s13 * t13 + s14 * t14
 st12 = s11 * t21 + s12 * t22 + s13 * t23 + s14 * t24
 st13 = s11 * t31 + s12 * t32 + s13 * t33 + s14 * t34
 st14 = s11 * t41 + s12 * t42 + s13 * t43 + s14 * t44
 st21 = s21 * t11 + s22 * t12 + s23 * t13 + s24 * t14
 st22 = s21 * t21 + s22 * t22 + s23 * t23 + s24 * t24
 st23 = s21 * t31 + s22 * t32 + s23 * t33 + s24 * t34
```

```
 st24 = s21 * t41 + s22 * t42 + s23 * t43 + s24 * t44
 st31 = s31 * t11 + s32 * t12 + s33 * t13 + s34 * t14
 st32 = s31 * t21 + s32 * t22 + s33 * t23 + s34 * t24
 st33 = s31 * t31 + s32 * t32 + s33 * t33 + s34 * t34
 st34 = s31 * t41 + s32 * t42 + s33 * t43 + s34 * t44
 st41 = s41 * t11 + s42 * t12 + s43 * t13 + s44 * t14
 st42 = s41 * t21 + s42 * t22 + s43 * t23 + s44 * t24
 st43 = s41 * t31 + s42 * t32 + s43 * t33 + s44 * t34
 st44 = s41 * t41 + s42 * t42 + s43 * t43 + s44 * t44

 'multiplication of the matrix above times R
 sn11 = t11 * st11 + t12 * st21 + t13 * st31 + t14 * st41
 sn12 = t11 * st12 + t12 * st22 + t13 * st32 + t14 * st42
 sn13 = t11 * st13 + t12 * st23 + t13 * st33 + t14 * st43
 sn14 = t11 * st14 + t12 * st24 + t13 * st34 + t14 * st44
 sn21 = t21 * st11 + t22 * st21 + t23 * st31 + t24 * st41
 sn22 = t21 * st12 + t22 * st22 + t23 * st32 + t24 * st42
 sn23 = t21 * st13 + t22 * st23 + t23 * st33 + t24 * st43
 sn24 = t21 * st14 + t22 * st24 + t23 * st34 + t24 * st44
 sn31 = t31 * st11 + t32 * st21 + t33 * st31 + t34 * st41
 sn32 = t31 * st12 + t32 * st22 + t33 * st32 + t34 * st42
 sn33 = t31 * st13 + t32 * st23 + t33 * st33 + t34 * st43
 sn34 = t31 * st14 + t32 * st24 + t33 * st34 + t34 * st44
 sn41 = t41 * st11 + t42 * st21 + t43 * st31 + t44 * st41
 sn42 = t41 * st12 + t42 * st22 + t43 * st32 + t44 * st42
 sn43 = t41 * st13 + t42 * st23 + t43 * st33 + t44 * st43
 sn44 = t41 * st14 + t42 * st24 + t43 * st34 + t44 * st44
 'calculate new Twiss parameters
 alfnx = -sn12 / emitx
 betnx = sn11 / emitx
 gamnx = (1 + alfnx ^ 2) / betnx
 alfny = -sn34 / emity
 betny = sn33 / emity
 gamny = (1 + alfny ^ 2) / betny
 End If

End If

'define parameter for steering
If elem = "steer" And steerswt = 1 Then
lg = 0
xp = 0
yp = 0
End If
If elem = "steer" And steerswt = 0 Then
lg = 0
End If
If elem = "steer" And steerswt = 2 And i > 1 Then
steerx = (-a31 * x0 + (a32 * a13 * y0) / a12 + (a32 * a11 * x0) / a12 - a33 * y0) / (a34 -
(a32 * a14) / a12) - yp0
steery = (-a14 * (yp0 + dyp) - a13 * y0 - a11 * x0) / a12 - xp0
steerfieldx = steerx * 1000 * A * 940 * beta / (q * 0.3)
steerfieldy = steery * 1000 * A * 940 * beta / (q * 0.3)
lg = 0
Print #3, Format(steerx * 1000, "#0.000"); Tab; Format(steery * 1000, "#0.000"); Tab;
Format(steerfieldx, "#0.000"); Tab; Format(steerfieldy, "#0.000")
' restart the matrix calculation
t11 = 1
t12 = 0
t13 = 0
t14 = 0
t21 = 0
t22 = 1
t23 = 0
t24 = 0
t31 = 0
t32 = 0
t33 = 1
t34 = 0
t41 = 0
t42 = 0
t43 = 0
t44 = 1

a11 = 1
a12 = 0
a13 = 0
```

```
a14 = 0
a21 = 0
a22 = 1
a23 = 0
a24 = 0
a31 = 0
a32 = 0
a33 = 1
a34 = 0
a41 = 0
a42 = 0
a43 = 0
a44 = 1

dxbef = 0
dxaft = 0
dxp = 0
dybef = 0
dyaft = 0
dyp = 0
End If
'M-matrix for a cavity
'm11 = t11 * (1 + dxbef) + t12 * dxp + t13 * dybef + t14 * dyp - dxaft
'm12 = t11 * dxbef + t12 * (1 + dxp) + t13 * dybef + t14 * dyp - dxaft
'm13 = t11 * dxbef + t12 * dxp + t13 * (1 + dybef) + t14 * dyp - dxaft
'm14 = t11 * dxbef + t12 * dxp + t13 * dybef + t14 * (1 + dyp) - dxaft
'm21 = t21 * (1 + dxbef) + t22 * dxp + t23 * dybef + t24 * dyp - dxp
'm22 = t21 * dxbef + t22 * (1 + dxp) + t23 * dybef + t24 * dyp - dxp
'm23 = t21 * dxbef + t22 * dxp + t23 * (1 + dybef) + t24 * dyp - dxp
'm24 = t21 * dxbef + t22 * dxp + t23 * dybef + t24 * (1 + dyp) - dxp
'm31 = t31 * (1 + dxbef) + t32 * dxp + t33 * dybef + t34 * dyp - dyaft
'm32 = t31 * dxbef + t32 * (1 + dxp) + t33 * dybef + t34 * dyp - dyaft
'm33 = t31 * dxbef + t32 * dxp + t33 * (1 + dybef) + t34 * dyp - dyaft
'm34 = t31 * dxbef + t32 * dxp + t33 * dybef + t34 * (1 + dyp) - dyaft
'm41 = t41 * (1 + dxbef) + t42 * dxp + t43 * dybef + t44 * dyp - dyp
'm42 = t41 * dxbef + t42 * (1 + dxp) + t43 * dybef + t44 * dyp - dyp
'm43 = t41 * dxbef + t42 * dxp + t43 * (1 + dybef) + t44 * dyp - dyp
'm44 = t41 * dxbef + t42 * dxp + t43 * dybef + t44 * (1 + dyp) - dyp
'
'a11 = m11 * a11 + m12 * a21 + m13 * a31 + m14 * a41
'a12 = m11 * a12 + m12 * a22 + m13 * a32 + m14 * a42
'a13 = m11 * a13 + m12 * a23 + m13 * a33 + m14 * a43
'a14 = m11 * a14 + m12 * a24 + m13 * a34 + m14 * a44
'a21 = m21 * a11 + m22 * a21 + m23 * a31 + m24 * a41
'a22 = m21 * a12 + m22 * a22 + m23 * a32 + m24 * a42
'a23 = m21 * a13 + m22 * a23 + m23 * a33 + m24 * a43
'a24 = m21 * a14 + m22 * a24 + m23 * a34 + m24 * a44
'a31 = m31 * a11 + m32 * a21 + m33 * a31 + m34 * a41
'a32 = m31 * a12 + m32 * a22 + m33 * a32 + m34 * a42
'a33 = m31 * a13 + m32 * a23 + m33 * a33 + m34 * a43
'a34 = m31 * a14 + m32 * a24 + m33 * a34 + m34 * a44
'a41 = m41 * a11 + m42 * a21 + m43 * a31 + m44 * a41
'a42 = m41 * a12 + m42 * a22 + m43 * a32 + m44 * a42
'a43 = m41 * a13 + m42 * a23 + m43 * a33 + m44 * a43
'a44 = m41 * a14 + m42 * a24 + m43 * a34 + m44 * a44

'calculate the length of the machine
lgt = lg + lgt

'reinitialize the variable
x0 = x
xp0 = xp
y0 = y
yp0 = yp

 'resetting Twiss parameters
 alfx = alfnx
 betx = betnx
 gamx = gamnx
 alfy = alfny
 bety = betny
 gamy = gamny

 'print the output file
 Print #1, Format(lgt, "#0.00"); Tab; Format(x0 * 1000, "0.000"); Tab; Format(xp0 * 1000,
"0.000"); Tab; Format(y0 * 1000, "0.000"); Tab; Format(yp0 * 1000, "0.000"); Tab; Format(dxbef
* 1000, "0.000"); Tab; Format(dxaft * 1000, "0.000"); Tab; Format(dxp * 1000, "0.000"); Tab;
```

```
Format(dybef * 1000, "0.000"); Tab; Format(dyaft * 1000, "0.000"); Tab; Format(dyp * 1000,
"0.000"); Tab; Format(Eini / 1000000#, "#0.000"); Tab; elem
 If env = "Yes" Then
 Print #2, lgt; Tab; Format(1000 * Sqr(betx * emitx), "#0.0"); Tab; Format(-1000 * Sqr(bety *
emity), "#0.0")
 End If
 Loop
Loop

Close
End Sub
```