DAΦNE TECHNICAL NOTE
INFN - LNF, Accelerator Division

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Note: **L-40**

LOW EMITTANCE LATTICE FOR DAΦNE GAMMA FACTORY

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1. Introduction

An experiment of gamma rays production using Compton collisions between the DAΦNE electron beam and a high average power laser, amplified in a Fabry-Pérot optical resonator, has been proposed and is described in [1]. The proposed gamma beam source has extremely interesting properties in terms of spectral density, energy spread and gamma flux comparable, and even better, with the latest generation gamma sources.

An accelerator layout and a set of DAΦNE parameters dedicated to the gamma beam experiments were presented in [1]. The present DAΦNE horizontal emittance is $\varepsilon_x = 0.28$ mm mrad, a lower emittance would enhance the gamma beam brillance. The conclusion of the previous study was that the beam parameters presented in [1] can be better achieved with an emittance between 0.1 and 0.2 mm-mrad.

A lattice designed to satisfy the parameters listed in Table 1 of [1], with a natural horizontal emittance $\varepsilon_x = 0.163$ mm-mrad and with a layout of the straight section optimized for the installation of the Fabry Perot cavity, is presented in this report.

2. DAΦNE Low Emittance Lattice

The DAΦNE layout has been modified to insert a dogleg needed for the extraction of the gamma beamline. The easiest way to achieve this is to install two splitter magnets in the interaction region straight (present IR2) with an angle of 5 degrees and modify the bending angle of the nearest dipoles. This layout allows to easily extract the gamma beam line from the ring vacuum chamber. These splitter magnets are already available, since they were part of the original DAΦNE layout before 2007.

It is possible to use as Gamma Interaction Region (GIR) for the gamma factory either the center of the straight section (between the dogleg dipoles) or the 2.5 m long straight section adjacent to the "Short" arc. For the lattice presented here the GIR has been located adjacent to the "Short" arc, as shown in Fig. 1.

The optical functions in half of the ring are shown in Fig. 2, the other half ring being symmetric. The lattice parameters are given in the first column of Table 1. The reduction of the emittance is obtained by lowering the dispersion function in the wiggler magnets. As a result the dispersion in the GIR is increased.

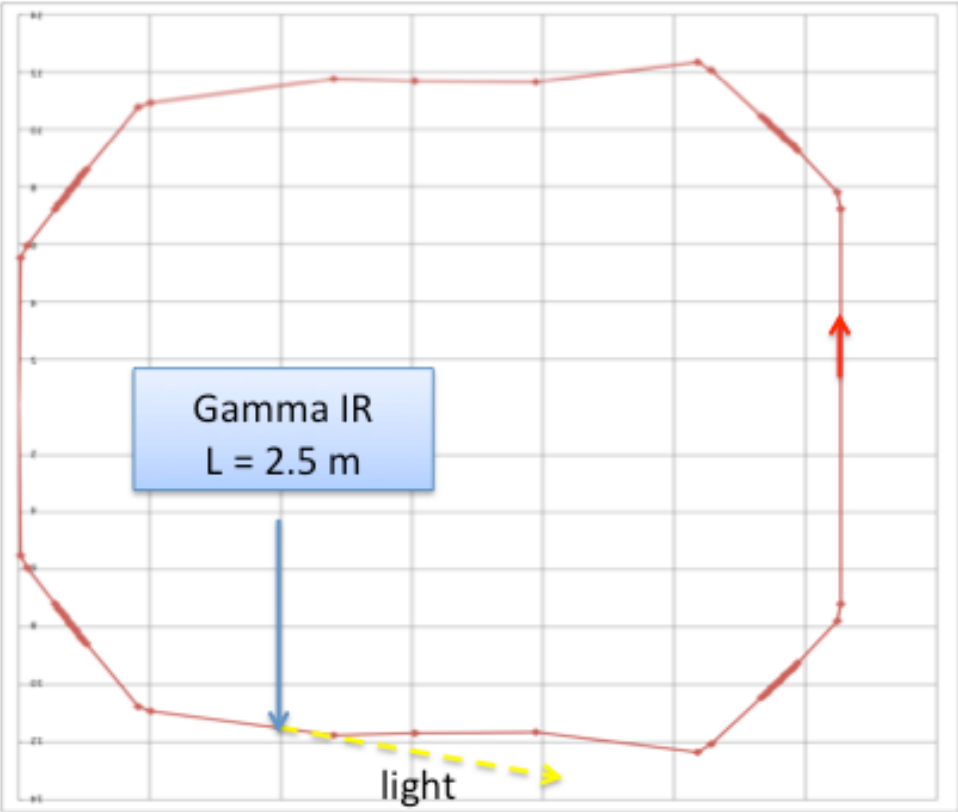

Figure 1: Gamma Factory ring layout.

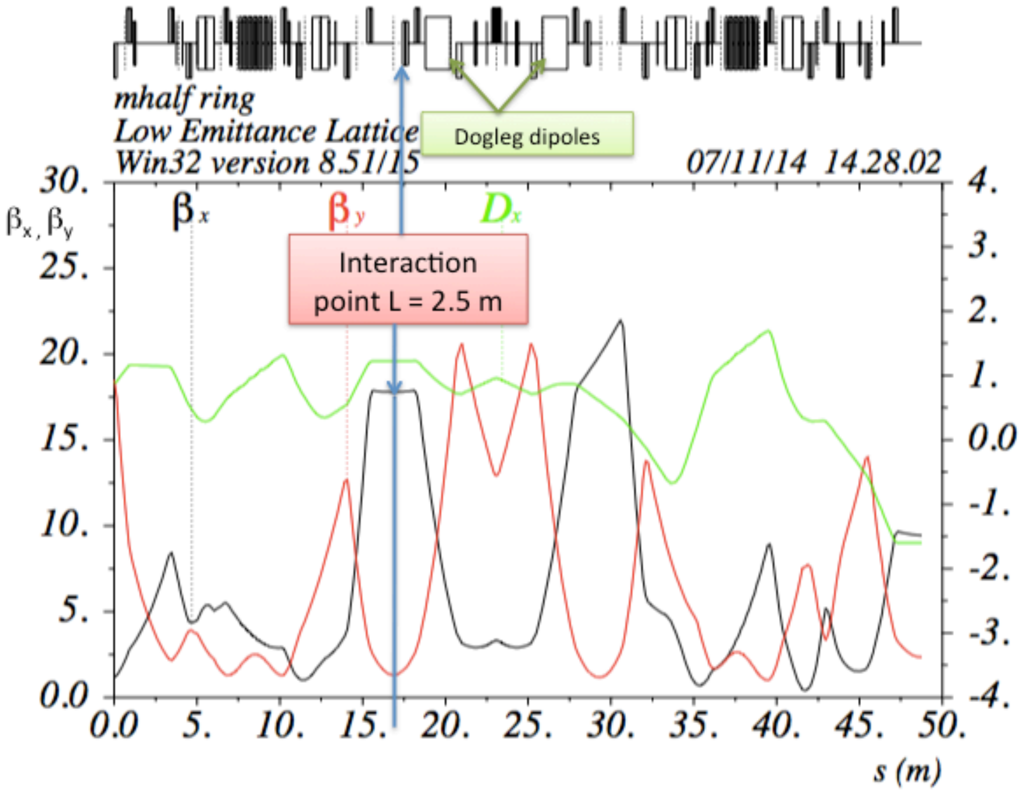

Figure 2: Low emittance lattice optical functions for half ring starting from the RF (Short) straight section. The IR2 straight section is in the middle, the other half ring is mirror symmetric.

The IBS emittance growth is calculated using a model based on the K. Bane's high energy approximation [2, 3]. The average growth rates are found from the growth rates at each point in the lattice, by integrating over the circumference. The lattice natural emittances are assumed as equilibrium values at low bunch current and the equilibrium emittances at high current, in the presence of radiation and IBS, are found by iteration. The results for the nominal bunch charge of 8.15 nC are listed in Table 1, second column.

The IBS is calculated taking into account that at the nominal bunch charge the bunch length and the energy spread are in the lengthening regime. The DAΦNE bunch length as a function of current has been measured for the Siddharta configuration [4]. The electron ring measurements are well fitted by using the bunch lengthening formula given in [5] with an impedance value Z/n equal to 0.45 Ohm. For the present DAΦNE configuration, dedicated to the KLOE2 experiment, the impedance has been further reduced by various vacuum chamber modifications and a value of 0.3 Ohm has been reached [6]. For the parameters listed in Table 1 a bunch lengthening of a factor ~2.0 is estimated with a corresponding reduction of the bunch density. As a consequence, the transverse emittance growth due to IBS is reduced. A drawback is the associated increase of the energy spread that, in the presence of a non zero dispersion at the Gamma Interaction Point (GIP), gives an increase of the transverse beam size. Bunch lengthening simulations performed for the original DAΦNE vacuum chamber [7] have shown that the energy spread increase is smaller than the bunch lengthening. At the same time, the possibility to have a non-zero dispersion in the IP allows envisaging a fine tuning of the energy of the gamma beam by only moving the electron beam in the interaction point, with correctors. These simulations can be repeated taking into account the wake potential of the present vacuum chamber in order to get a more precise estimate of the expected energy spread. In the following we assume an energy spread increase of a factor 1.5. For these parameters the effect of the IBS is below a few percent. In Table 1 is also reported the Touschek beam lifetime evaluated by using the energy acceptance of the DAΦNE RF cavity.

3. Table 1: Low emittance lattice parameters.

	No IBS	With IBS and bunch lenghtening
Beam Energy (GeV)	0.51	
Circumference (m)	97.53	
N/bunch		5.10E+10
alfac	0.011	
Qx	4.809	
Qy	4.630	
Chromaticity x	-7.18	
Chromaticity y	-9.34	
Emittance x (m rad)	1.63E-07	1.65E-07
Emittance y (m rad)	4.08E-09	4.12E-09
Coupling k (%)	2.50	2.50
E loss/turn (MeV)	0.0090	
Transverse damping time (ms)	37	
Relative energy spread rms	4.00E-04	6.01E-04
RF Voltage (KV)	180	
Energy RF acceptance (%)	1.28	
Bunch length (mm)	7.77	15.5
Touscheck beam lifetime (min)	30	70
Horizontal beta function @ IP (m)	17.8	17.8
Horizontal dispersion @ IP (m)	1.22	1.22
Vertical beta function @ IP (m)	1.3	1.3
Horizontal beam size @ IP (μm)	1772	1862
Horizontal beam angle @ IP (μrad)	96	96
Vertical beam size @ IP (μm)	73	73
Vertical beam angle @ IP (μm)	56	56

For completeness, the beam sizes at the GIP have been evaluated by varying one parameter for each case (**b**, **c** and **d**) listed in Table 2, where, for comparison, the parameters listed in the second column of Table 1 are repeated in column **a**. For case **b** the beam parameters are evaluated in the pessimistic hypothesis that the energy spread increase is equal to the bunch lengthening (i.e. a factor 2) at the nominal bunch charge. The corresponding increase of the horizontal beam size at the GIP is only 6%. In case **c** the beam sizes at the GIP are evaluated reducing the coupling factor down to κ = 1%. The beam size increase due to the IBS is still negligible and therefore the vertical beam size and angle are reduced with the square root of the coupling factor. The Touschek beam lifetime is reduced by the same factor but it is still long enough. In column **d** the lattice has been recalculated for a value of the wiggler field reduced by 20% in order to reduce the power consumption of the wiggler magnets. The beam parameters remain the same within a few percent.

Table 2: Variation of beam parameters.

	a	b	c	d
N/bunch	5.10E+10			
B wiggler (T)	1.6			1.3
alfac	0.011			0.010
Emittance x (m rad)	1.65E-07	1.64E-07	1.66E-07	1.49E-07
Emittance y (m rad)	4.12E-09	4.11E-09	1.66E-09	3.73E-09
Coupling k (%)	2.50	2.50	1.00	2.50
Transverse damping time (ms)	37			45
Relative energy spread rms	6.01E-04	8.01E-04	6.03E-04	6.02E-04
RF Voltage (KV)	180			
Bunch length (mm)	15.5	15.5	15.6	15.5
Touscheck beam lifetime (min)	70	82	44	63
Horizontal beam size @ IP (μm)	1862	1969	1869	1801
Horizontal beam angle @ IP (μrad)	96	96	97	91
Vertical beam size @ IP (μm)	73	73	46	70
Vertical beam angle @ IP (μm)	56	56	36	54

3. Conclusions

A preliminary lattice for the DAΦNE gamma factory has been calculated. The DAΦNE lattice has enough flexibility to vary the emittance in the range between 0.28 mm-mrad and 0.045 mm-mrad. The layout of the accelerator straight section includes a chicane to easily extract the light from the GIR. The optical functions at the GIP have been tuned near to the nominal values given in Table 1 of [1]. The vertical beam sizes at the GIP (case **c**) are close to the nominal values in [1] and can be further reduced by reducing the coupling factor, the horizontal beam sizes at the GIP are larger than the nominal values in [1] by less than 20%. To evaluate the corresponding loss in photon flux the code CAIN [8] can be run again with these parameters.

4. References

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