# EFFECTS OF NON LINEAR ELEMENTS ON BACKGROUNDS AT DAΦNE

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*Abstract*

DAΦNE is a high luminosity double ring electron-positron collider working at the energy of the Φ resonance (1.02 GeV c.m.) [1]. The two experiments KLOE and DEAR are strongly affected by beam induced background, mainly due to Touschek scattering.

Touschek background simulation results based on a tracking procedure are presented here. The dependence of the expected background rates on the optical model is studied for the DAΦNE collider; in particular the measured non linearities have been taken into account in the simulation code and their effect on Touschek background is discussed.

## 1 INTRODUCTION

The beam lifetime in DAΦNE and the machine induced background at the experiments are dominated by Touschek scattering: off-momentum particles can exceed the momentum acceptance of the RF bucket or may hit the aperture limit when displaced by dispersion. In addition, a betatron oscillation is excited if the momentum change takes place in a dispersive region.

Reduction of beam induced background is a challenging task in a short machine like DAΦNE. Studies have been carried out to provide a predictive and reliable code that could reproduce the observed backgrounds. In this frame, the home developed tracking code 'STAR' [2] (Simulation of Touschek bAckgRound) has been upgraded.

STAR is used to predict the locations where the off-energy particles hit the vacuum chamber of the rings. The simulation code is used to study the present collimators performance [3] and to find possible positions where additional scrapers could intercept the off-energy particles.

In the following, the modelling of Touschek induced background particles in DAΦNE is discussed. Many features have been added, like tracking of Touschek scattered particles over many turns. All magnetic elements have been considered, including sextupoles and octupolar components in the wigglers. The study of the effects of non linear terms on DAΦNE background is presented.

## 2 SIMULATION

Touschek lifetime is determined by momentum acceptance and bunch density integrated over the lattice structure [4]. In the DAΦNE rings we distinguish two regions: straight sections with vanishing dispersion and arcs with large dispersion. Particles scattered in the straight sections with vanishing dispersion undergo a momentum deviation, but gain no additional betatron oscillation, and will therefore not contribute to the background in the interaction regions (IR), where the dispersion vanishes. However, particles scattered in the arcs gain additional horizontal betatron oscillation amplitude and can therefore get lost on the vacuum chamber inside the IR's, hence producing background at the experiments.

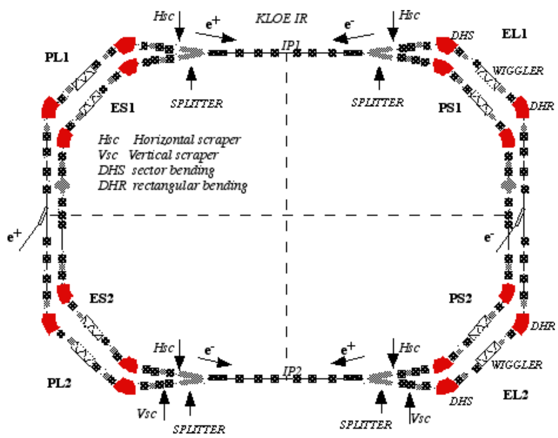


Figure 1: Layout of DAΦNE main rings.

In the simulation Touschek scattered particles are generated separately in the four arcs PL1, PL2, PS2, PS1 shown in fig. 1 for the positron beam (and similarly for the electron one). In this way the different contributions from each arc to the losses in the KLOE IR as well as to the total beam losses can be studied separately.

The particles that get lost are counted as background in KLOE if they hit the aperture between the two splitter magnets.

The main beam parameters used for the simulations presented here are summarised in Table 1. Only Touschek particles with a relative energy deviation between 0.003 and 0.02 have been included, since particles with higher energy deviation get lost locally and do not contribute to the experimental background. On the other hand, particles with lower energy deviation never reach the physical aperture and do not contribute to the beam losses.

Ten thousand particles have been tracked and rates have been scaled to one bunch with 10 mA current. The optical model used for these tracking simulations is the so called “detuned” optics adopted during the KLOE runs in June 2001 [5]. Simulations have been performed with scrapers out.

Table 1: Relevant beam parameters.

| | |
|---|---|
| Particles/bunch | $2\cdot10^{10}$ |
| Hor. Emittance[m rad] | $10^{-6}$ |
| Coupling factor | 0.01 |
| Bunch length [cm] | 1.9 |
| Relative energy spread | $4\cdot10^{-4}$ |
| RF Voltage [KV] | 100 |

## 3 NON LINEAR MODEL

Table 2. Expected losses (KHz) at KLOE IR (central column) and total losses (last column) of particles coming from the four arcs.

| **PL1** | **KLOE BKG (KHz)** | **total losses (KHz)** |
|---|---|---|
| Linear | 30.6 | 198.4 |
| Sextup. Only | 44.6 | 246.6 |
| Octup. Only | 50.0 | 334.7 |
| Sextup.+octup. | 144.4 | 371.9 |
| **PL2** | | |
| Linear | 0.0 | 251.8 |
| Sextup. Only | 0.0 | 884.4 |
| Octup. Only | 0.0 | 884.4 |
| Sextup.+octup. | 0.2 | 884.4 |
| **PS2** | | |
| Linear | 0.0 | 254.3 |
| Sextup. Only | 0.0 | 232.6 |
| Octup. Only | 2.5 | 292.2 |
| Sextup.+octup. | 4.9 | 311.0 |
| **PS1** | | |
| Linear | 0.0 | 271.0 |
| Sextup. Only | 1.3 | 310.2 |
| Octup. Only | 2.5 | 277.6 |
| Sextup.+octup. | 68.6 | 341.4 |

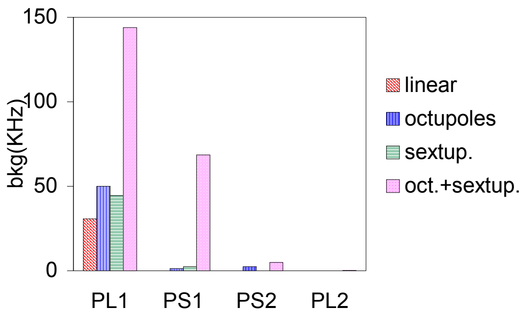


Figure 2: Expected beam losses at the KLOE IR for one bunch of 10 mA: significant contributions are expected from the two arcs PL1 and PS1.

Non linearities have been included in the simulation code in order to investigate their effects on Touschek background and a large increase of beam losses in the KLOE IR has been found. Table 2 describes in detail the results of these simulations: the contributions to the beam losses in the KLOE IR and the total beam losses are shown for the four arcs. The contributions of the different non linear terms are also reported for each arc. These results have been summarized in fig. 2 and fig. 4.

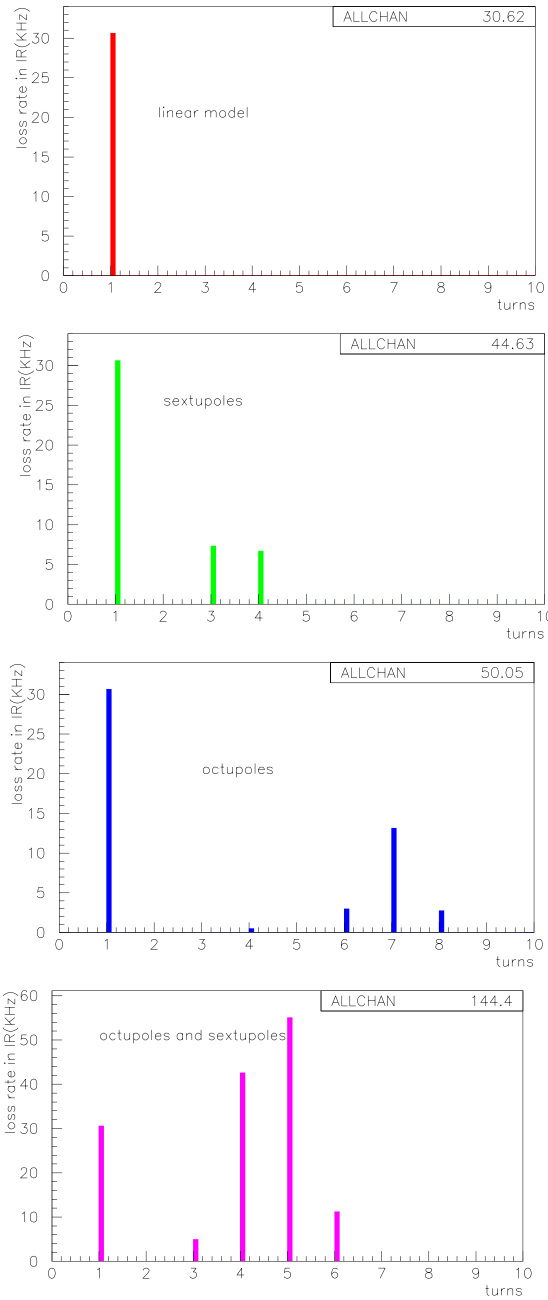


Figure 3: Distribution of lost particles at the KLOE IR versus number of turns in the machine before hitting the vacuum chamber, starting from PL1. Comparison between linear (upper plot) and non linear model (lower plots): only sextupoles included (second plot), only octupolar term in wigglers (third plot) and with machine sextupoles and octupolar terms included (last plot).

In particular it comes out that only two out of four arcs produce most of the Touschek particles which are eventually lost in KLOE IR, the closest to and the farthest from KLOE (PL1 and PS1 respectively, see fig. 1). This is roughly explained by the important role played by the horizontal betatron phase advance of the particle from the position of the Touschek scattering to the IR's.

Fig. 2 shows in more detail the contributions of the different non linear terms to the beam losses at the KLOE IR, for the two arcs PL1 and PS1. In the linear case only particles starting in PL1 get lost in KLOE, in the non linear one also particles generated in PS1 reach IR1. Non linear terms in the model change the expected background significantly, and contributions of sextupoles and octupoles do not sum up linearly.

The KLOE background rate as function of the number of turns is shown in fig. 3, where a comparison between the different non linearities taken into account is presented. In the linear case only particles generated in the arc upstream IR1 (PL1) get lost in KLOE, with a rate of about 30 KHz for one bunch of 10 mA. They all get lost at the first turn.

With sextupoles on there are losses at the third and fourth turn. When octupolar terms in wigglers are included there are losses at the sixth, seventh and eighth turn. When both are taken into account the expected losses strongly increase, and most particles are expected to get lost at the fourth and fifth turn. In any case, losses appear only over the first eight turns.

Figure 4 summarizes the contributions of the four arcs to Touschek total beam losses (in KHz) around the ring. They are nearly the same for the linear optics, but when the non linear terms are taken into account arc PL2 contributes more significantly.

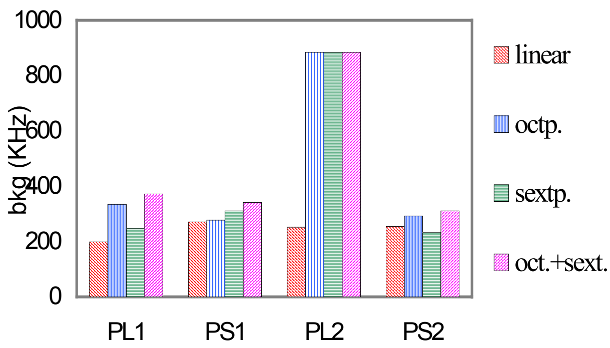


Figure 4: Contributions of the four arcs to beam losses along the ring from one bunch (10 mA) and different non linear configurations.

## 4 SEXTUPOLES OPTIMIZATION

It has been found that losses at KLOE IR are very sensitive to sextupoles settings. Simulations have been performed with two lattices, the "detuned" (called here optics 1) and the "detuned" with lower-$\beta$ at the KLOE IP (optics 2) [1]. Figure 5 shows the results for different sextupoles strengths, whose initial and final values are reported in table 3. The analysis has been performed for the two lattices, varying four sextupoles currents to higher and lower values with respect to their optimal value for chromaticity correction. The most effective sextupole among the investigated ones is found to be SXPPL102. A 37% reduction of background is foreseen at the KLOE IR, as shown in fig. 5 where the decrease of losses has been obtained by changing its strength from 24 A (last plot in fig. 3) to 12 A (fig. 6). The losses at IP1 decrease from 144.4 KHz to 90.9 KHz and the distribution versus turns in the ring is different.

Table 3: Variations induced on sextupoles.

| Sextupole | Initial value (A) | Final value (A) |
|---|---|---|
| SXPPL101 | 30 | 18 |
| SXPPL102 | 24 | 12 |
| SXPPL103 | 80 | 104 |
| SXPPS102 | 80 | 68 |

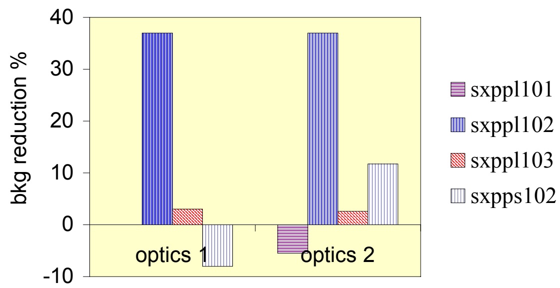


Figure 5: Expected background reduction at KLOE IR for different sextupoles settings. Negative values indicate an increase of loss rates.

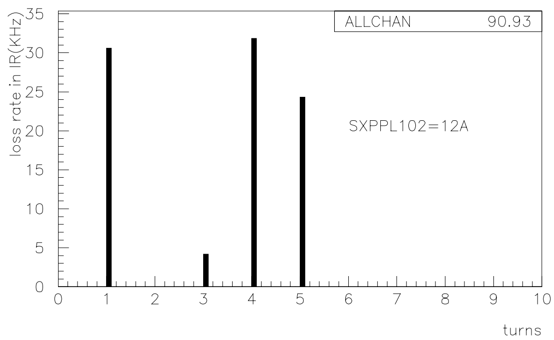


Figure 6: Distribution of lost particles at the KLOE IR along the machine turn number with sextupoles and octupoles included, SXPPL102 set at 12 A.

At DAΦNE each sextupole is powered independently, so that a careful tuning of sextupoles can be performed. The same variations reported in table 3 have been done on the sextupoles of the machine and a reduction of KLOE backgrounds has been obtained. These measurements are not shown here as background reduction has been obtained adiabatically on September 2001, during the KLOE runs with colliding beams. An experimental adjustment of sextupoles settings led to a reduction by a

A comparison between the expected background reduction and the measured one has been performed on the optics 2 by varying four sextupoles close to their setting values (last column of table 3). The comparison has been performed on the hot rates of the KLOE calorimeter, where its efficiency has been evaluated [6] and included in the code. An example of this study for the two sextupoles SXPPL102 and SXPPS102 is reported in upper plot of fig.7 (SXPPL202 and SXPPL203 in lower plot) showing that the experimental behaviour is reproduced by the code.

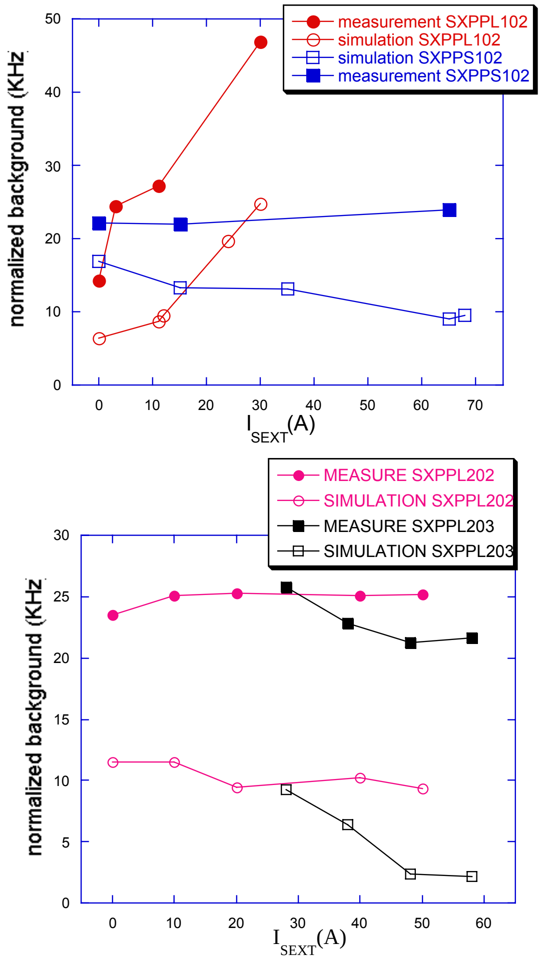


Figure 7: Comparison between expected (open symbols) and observed (full symbols) normalized background versus strength of two sextupoles.

## 4 CONCLUSIONS

Significant progress has been obtained in understanding the machine induced background to the KLOE and DEAR experiments in the DAΦNE collider.

Touschek background modelling has been improved and studied in more detail. Beam losses at the experiments have been found to be very sensitive to machine non linearities.

Careful tuning of sextupoles reduces the background rates at the experiments, in agreement with simulations.

In order to compensate the third order term at the center of the wiggler poles the installation of tunable octupoles is foreseen in January 2002.

## ACKNOWLEDGMENTS


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## 5 REFERENCES


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