EXPERIENCE WITH BEAM INDUCED BACKGROUNDS IN THE DAΦNE DETECTORS

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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]. Two experiments, KLOE [2] and DEAR [3] are presently taking data at DAΦNE. At the beginning of data taking, both experiments suffered from large beam induced background, mainly due to Touschek scattering. Measurements of the background rates in different configurations as well as simulations and tracking studies have been performed in order to find the proper actions that allow reducing these rates. In particular measurements and simulations on the collimation efficiency of the scraper system and the consequent modifications adopted to improve the system are presented.

1 INTRODUCTION

Reduction of beam induced background is a particularly difficult task in a short machine like DAΦNE. In a low energy machine background arises mainly from the Touschek effect. Off-momentum particles can exceed the momentum acceptance given by the RF bucket, or may hit the aperture when displaced by dispersion. In addition, a betatron oscillation is excited if the momentum change happens in a dispersive region.

Machine induced background at the two experiments KLOE and DEAR has been reduced by adjusting several optical parameters like the orbits at the interaction points (IP), the strength of sextupoles or the β_x value upstream the IR's [4].

In the following efforts to reduce the remaining particle backgrounds by adjusting scraper positions are described, as well as simulations of Touschek particles through collimators, that led to the choice of more efficient scraper surfaces. Furthermore the modelling of Touschek induced background particles in DAΦNE is discussed.

2 SCRAPERS

To protect the detectors of the experiments from off-momentum particles remote controlled scrapers have been installed for the incoming beams on either side of each experiment. They are placed before the splitter magnets, about 7.0 m from the interaction point (IP), as shown in Fig.1. Two horizontal jaws per scraper, external and internal, are used to intercept the two off-energy particle families. Until December 2000 the scrapers consisted of rectangular tungsten blocks of 35 mm thickness, which corresponds to 10 r.l. They were shielded by 150 µm of copper to minimize the discontinuity in the vacuum chamber.

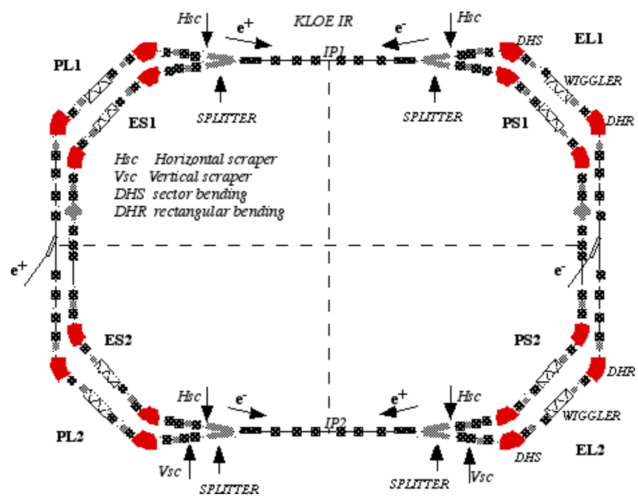

Figure 1: Layout of the DAΦNE main rings.

2.1 Scraper scans

Scraper scans have been performed both with colliding beams during physics data taking and with single beams [5]. Rates of the two forward calorimeters in KLOE have been taken as a function of the opening of the horizontal scrapers upstream IR1. The two rates from the calorimeters ECM2 and ECM4 integrate the signals over the four innermost sectors of the west and east forward calorimeters each. In order to compare measurements with different beam parameters, the calorimeter rates are given per 1 mA bunch and are scaled for a roundness of 0.1, as the beam lifetime (dominated by the Touschek effect) in DAΦNE is proportional to σ_y. The roundness parameter is the ratio of the vertical to horizontal beam size measured at the location of the synchrotron light monitor.

The background rate measured by KLOE for an electron beam versus the KLOE scraper setting is shown in Fig. 2 (dashed blue line) and can be taken as a typical behaviour. It appears that the external jaw reduces the background by about a factor 2.3 at a distance of ≈25 mm from the beam axis, while the closed orbit was measured at -2.7 mm from the center of the chamber. However, a steep increase of the background rate is observed when the scrapers are closed to less than about 23 mm ($9\sigma_x$) from the closed orbit position. Apparently, from this moment on, the scrapers are producing more background particles than they are stopping.

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In an effort to understand the unveiled inefficiency of the used scrapers, simulation of Touschek particles in the accelerator, as well as tracking 510 MeV electrons through the scraper blocks have been performed.

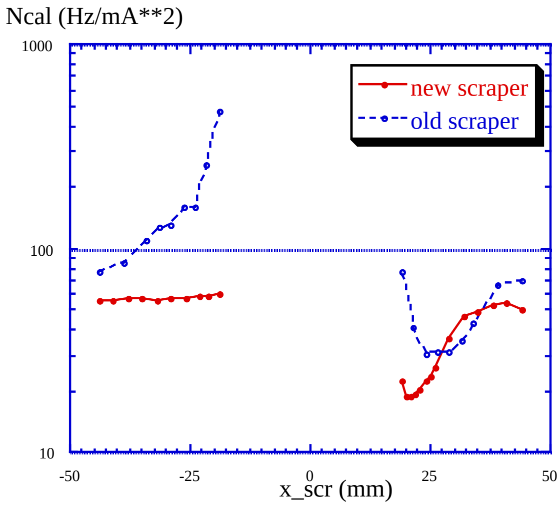

Figure 2: Scan of the normalized background rate versus the position of the inner scraper edge. The scraper openings are measured from the central beam axis.

3 SIMULATIONS

The home-developed tracking code STAR (Simulation of Touschek pARticles) [7] has been upgraded and was run with the present optics conditions; it is used to understand the source of the machine induced background and the locations where most of the off-energy particles get lost.. The main beam parameters used for these simulations are summarized in Table 1.

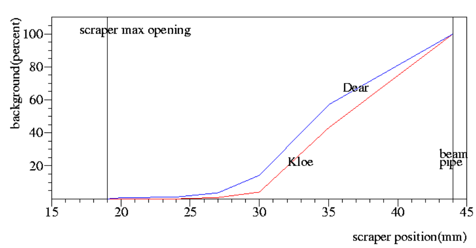

Figure 3: Simulated scraper efficiency for KLOE and DEAR scrapers, assuming completely absorbing scrapers.

Simulations of edge effects of the scrapers have been performed with STAR and GEANT3 [8]. It has been found that with the rectangular shape most of the particles are scattered by the thin copper layer above the tungsten, instead of being absorbed, thereby producing additional background to the experiments.

These calculations resulted in the proposal of new modified scrapers, which were constructed and installed in the DAΦNE rings during January 2001. The inner surface of the new scraper block has been divided into two flat parts. A first 10 mm long section has a slope of 100 mrad towards the beam, in order to increase the impinging angle into the block for most particles. This is followed by a second section of 45 mm length which slopes by 10 mrad in the opposite direction to avoid foreward scattering of electrons back into the beam pipe. A vertical slit has been introduced into the copper shield to ensure that all incident particles only see the tungsten absorber. The total scraper thickness of now 55 mm (about 16 r.l.) is reducing the punch-through probability of 500 MeV electrons to below 10^{-6}.

Table 1: Relevant beam parameters used for Touschek simulations.

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

The behaviour of the new scraper is shown in Fig. 2 (full red line). The external jaw reduces the background by a factor 2.9 at a distance of ≈20 mm from the chamber axis. No background reduction is found when moving in the internal jaw (full line), however, the previously observed strong increase is no longer present (dashed line), indicating an improved stopping efficiency of the scraper blocks.

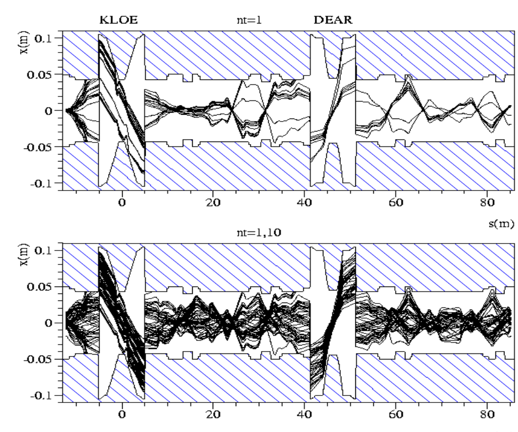

Figure 4: Touschek scattered particles generated in arc PL1 are tracked along the DAΦNE ring with sextupoles included. The upper plot shows the trajectories in the first turn, the lower plot over ten consecutive turns.

The simulated scraper efficiency, for an ideal scraper, which completely absorbs all intercepted particles, is shown in Fig. 3. As was measured, the KLOE scrapers appear to be more effective than the ones around DEAR. In the simulations only Touschek particles produced along the first arc upstream the experiment are included and counted as background when being lost inside the IRs. Touschek lifetime is determined by the momentum acceptance and bunch volume integrated over the lattice structure [6]. In the DAΦNE rings we distinguish two regions: straight sections with vanishing dispersion and arcs with high dispersion. Particles scattered in the straight sections undergo a momentum deviation, but gain no additional betatron oscillation, and will therefore not add to the background. However, particles scattered in the arcs suffer additional horizontal betatron oscillations and can therefore get lost on the vacuum chamber inside the interaction regions, hence producing background at the experiments.

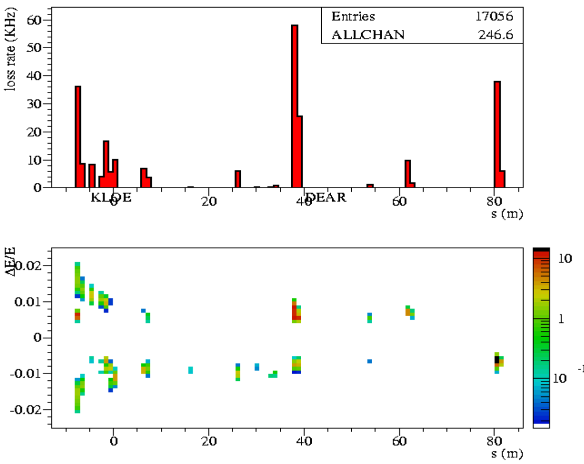

Figure 5: Upper plot: distribution of lost particles at the vacuum chamber along the ring, starting from arc PL1. Lower plot: corresponding energy distribution of lost particles.

In a second phase tracking has been extended to include the whole ring and to track over many turns. Touschek scattered particles are generated separately in the four arcs as shown in Fig. 1: PL1, PL2, PS2 and PS1 for the positron beam (and similarly EL1, EL2, ES2, ES1 for the electron beam). This way the different contributions from each arc to the two experiments as well as to the total beam loss can be separated. Simulations have been performed, both with and without sextupoles. When sextupoles are included a lifetime reduction of 40% is found. Preliminary results are presented below.

An example of the horizontal trajectories of Touschek scattered particles along the ring is shown in Fig. 4. The presently adopted optics for KLOE data taking for the positron beam was used. The discontinuity at the ends of the IRs is due to the change of the reference system in the splitter magnets, as the trajectory of the reference particle passes off-axis in the IR quadrupoles due to the horizontal crossing angle. Only Touschek particles with a relative energy deviation between 0.003 and 0.02 have been included, as particles with higher energy deviation get lost locally and do not contribute to the experimental background. The simulations clearly show the evident role played by the betatron phase and how this is changed when sextupoles are included. In fact, without sextupoles only off-energy particles generated in the arc upstream of IR1 get lost in KLOE and only in their first turn. With sextupoles included also particles generated in the arc PS1 reach IR1 and are lost at the second and third turn. The distribution of loss points around the ring and the corresponding energy of lost particles is shown in Fig. 5. The total loss rate as well as the KLOE background rate as function of the number of turns show that losses appear only over the first few turns.

Table 2 summarises the contributions of the four arcs to Touschek losses around the ring and to the background rates in the two experiments. 10^4 particles have been tracked over ten machine turns. with sextupoles excited or not (in parenthesis).

Table 2: Expected losses with and without sextupoles

BKG(KHz)	All ring	KLOE	DEAR
PL1	246.6 (198.4)	44.6 (30.6)	0.0 (0.0)
PL2	884.4 (251.8)	0.0 (0.0)	0.0 (0.0)
PS2	232.6 (254.3)	0.0 (0.0)	19.2 (19.2)
PS1	310.2 (271.0)	2.5 (0.0)	0.0 (0.0)
Total BKG	1673.8 (975.5)	47.1 (30.6)	19.2 (19.2)

Although these results do not yet allow to fully explain the observed amount and behaviour of the background rates in KLOE and DEAR, good progress has been made in this direction. Further systematic measurements and detailed simulations will be needed to reach the required level of understanding that will allow for further reduction of the background rates.

4 CONCLUSIONS

Important progress has been made in understanding the machine induced background. New, more efficient scraper blocks have been introduced. Progress in the modelling of the origin of background will further help actions to reduce background, which might be at the end the limiting factor for luminosity improvements.

5 REFERENCES

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