SIMULATIONS AND MEASUREMENTS OF THE TOUSCHEK BACKGROUND AT DAΦNE

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Abstract

DAΦNE [1] background is dominated by Touschek scattering. Many efforts have been put in its reduction, by adjusting optical parameters, and by the insertion of additional collimators. Background rate at the experiments KLOE [2] and DEAR [3] has been reduced. Effectiveness of the new collimators installed in the two rings is presented and compared with simulation showing a qualitative agreement.

Studies on the distribution and trajectories of the Touschek particles at KLOE and DEAR interaction regions (IRs) are 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. The reduction of this background is a challenging task in a short machine like DAΦNE.

At the beginning of data taking both experiments KLOE and DEAR suffered from large induced background. Many efforts have been put in its reduction, by adjusting optical parameters, like sextupoles strengths, orbits, β_x at the IRs, by the insertion of additional collimators in the two rings and by properly shielding the DEAR detector. The results of these optimizations show an overall background reduction at the two experiments.

During the last DEAR run (March-April 2002) the background has been reduced by a factor greater than 10.

The KLOE run has started in May 2002 and a background reduction by about a factor 3 has been obtained up to now, with respect to the last 2001 run. For example, we compare two typical days of data taking (6/12/01 and 15/05/02). The average calorimeter rates in the forward regions (endcaps), west for positrons and east for electrons, decrease from values ~130 KHz (~90 KHz) to ~40 KHz (~50 KHz) for the positron (electron) beam. The average luminosity is about the same, ranging from 3.5 to 3.2 $cm^{-2}s^{-1}$, and now the currents are ~10% lower than December.

2 SIMULATION

The home developed tracking code 'STAR' is used to predict the locations where the off-energy particles hit the vacuum chamber of the ring, with particular care at the position of the losses at the two interaction regions.

All magnetic elements are taken into account, including sextupoles and the octupolar components in the wigglers [4]. Touschek scattered particles are generated separately in the four arcs PL1, PS1, PS2 and PL2 for the positron beam (see Fig. 1). Only particles with a relative energy deviation between 0.003 and 0.02 have been considered, since particles with higher energy deviation get lost locally and do not contribute to the experimental background rate. On the other hand, particles with lower energy deviation never reach the physical aperture and do not contribute to the beam losses. The particles are tracked over many turns and those lost at the KLOE IR have been fully simulated in the detector allowing the evaluation of the background counting rates and detailed studies of background properties, namely spatial distribution and energy spectra. Several comparisons have been performed between simulations and KLOE data showing a good qualitative agreement [5] [6].

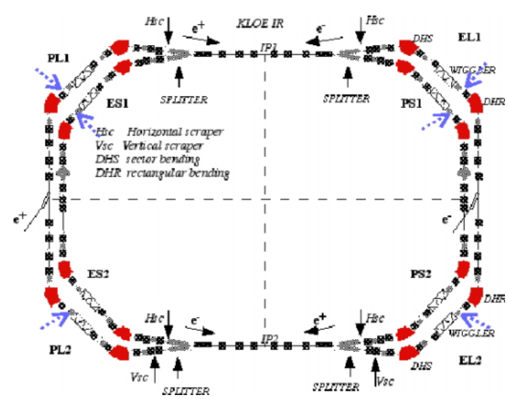

Figure 1: DAΦNE layout with old scrapers (black arrows before splitter magnets) and additional new scrapers (big blue arrows) installed in non-zero dispersion regions.

3 NEW COLLIMATORS EFFECTIVENESS

A set of movable collimators (scrapers) is used at DAΦNE to reduce the background in the detectors. These collimators are placed upstream each IR in the two rings [7]. To obtain a further background reduction three new scrapers have been installed in the arcs of each ring in January 2002 on the basis of the simulation studies [8]. The position of the new scrapers is shown in Fig. 1.

During last DEAR runs, the total background reduction at the CCDs due to the insertion of the scrapers and shielding (see Section 4.1) has been about a factor 3. The measured KLOE calorimeter rates and the positron beam lifetime are shown in Fig. 2 versus position of the inner scraper edge measured in single beam (e+) operation. The scraper opening is measured from the beam pipe edge. About 60% of background reduction is obtained.

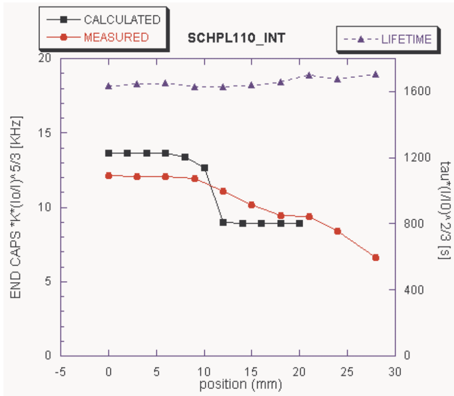

Figure 2: Scan of the background rate in the KLOE forward calorimeter versus position of the internal jaw of the scraper SCHPL110: measured (calculated) normalized rate in red dots (black squares) and normalized lifetime in blue triangles.

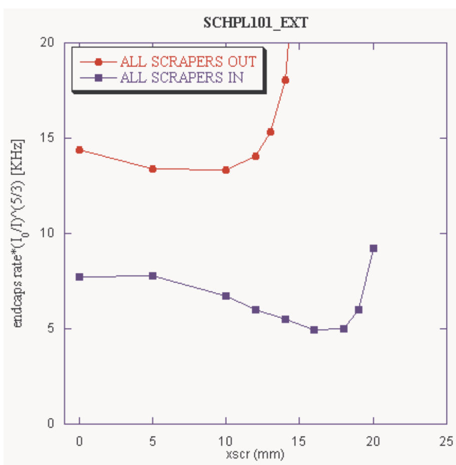

Figure 3: Scan of the normalized background rate in the KLOE forward calorimeter versus position of the external jaw of the positron beam KLOE scraper, with all other collimators out (red dots) and in (blue squares).

The normalizations of the background rate and lifetime are in accordance with the lifetime scaling law: $\tau \propto \sigma_l\, \sigma_x \sigma_y / I$ where σ_l is the current dependent bunch length $\sigma_l \propto I^{1/3}$ [9] and the horizontal and vertical rms beam sizes σ_x and σ_y are related by the roundness $R = \sigma_y / \sigma_x$. Therefore for a constant σ_x we have $\tau \propto R/I^{2/3}$ and the background rate $dN/dt \propto I/\tau \propto I^{5/3}/R$. Fig. 2 shows also the corresponding calculated rate, evaluated by tracking Touschek scattered particles from their origin in the arcs into the KLOE detector. The endcap acceptance has been taken into account by means of full detector simulation including the geometrical details of the IR. There is a qualitative agreement between measurement and simulation.

In addition to a direct background reduction the new collimators help in making the scrapers upstream the experiments more effective. In fact, as they are very close to the detectors, their insertion can increase background. Fig. 3 shows the efficiency of the scraper upstream KLOE with and without the other collimators inserted. A factor 1.6 is gained due to the fact that the scraper can be inserted closer to the center of the pipe. The new scrapers stop particles that would be just deviated by the IR scraper and eventually lost at the experiment. In the present KLOE running configuration the overall effectiveness of the scrapers is a factor ≈ 3 for the positron beam and ≈ 7 for the electron one. However, with the scrapers inserted, the contributions of the two beams to the endcap rates are about the same.

4 BACKGROUND AT IRS

The trajectories of the Touschek particles and their hit position along the beam pipe have been studied in the two IRs with the simulation. The background can be reduced both by properly shielding the detectors and by reducing the beam envelope where the particles are expected to be lost, i.e. by reducing the β_x-function.

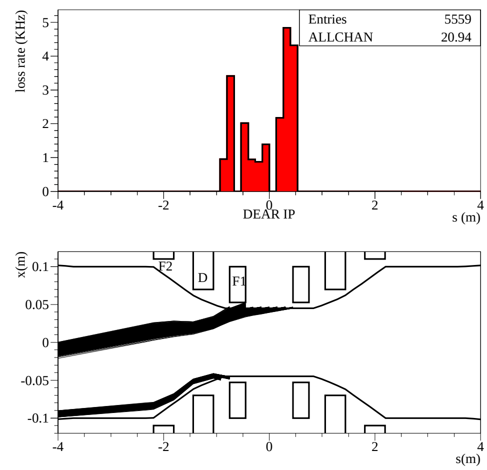

Figure 4: Distribution and trajectories of Touschek particles lost at DEAR IR, β_x (IP2) is 4 m.

4.1 DEAR Experience

The calculated trajectories and distribution of the particles hitting the pipe at the IR are shown in Fig. 4 for the optics used during the first period of data taking. Most particles are lost very close to the DEAR interaction point (IP2), and a reduction of background rate has been achieved by shielding the detector taking into account the simulation. In this particular case the shielding could be easily carried out, as DEAR consists of a small detector placed at ~15cm above the beam line. Touschek particles get lost radially but induce background vertically by scattering and shower with the beam pipe material.

The value of β_x at IP2 was reduced both to improve luminosity performance [10] and to reduce the background. In the following the effect on the background is described. It is shown in Fig. 5 the reduction of β_x at IP2 from $\approx$4.5m to $\approx$1.6m and consequently at the focusing quadrupole (QF1) close to the IP2 With this change the particles get lost at QF2 farther from IP2, as indicated in Fig. 6. These particles have been easily shielded. This optics change brought a background reduction to the experiment of about a factor 3.3.

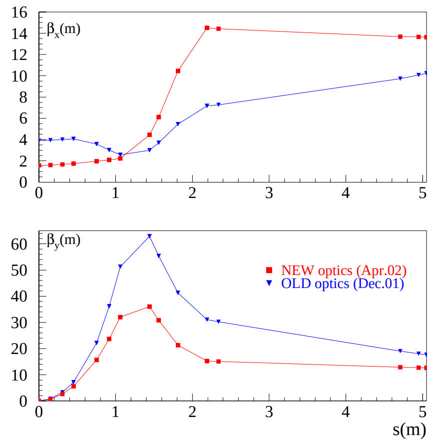

Figure 5: βx (upper) and βy (lower) function in IR2 from IP2 to splitter magnet.

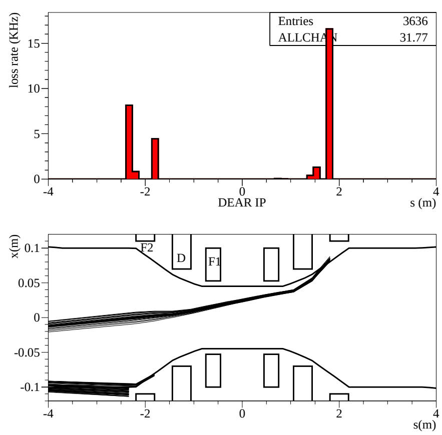

Figure 6: Distribution and trajectories of Touschek particles lost at DEAR IR, β_x (IP2) is 1.5m.

4.2 KLOE Experience

Calculated trajectories and distributions are shown in Fig. 7. Due to the different layout most of the particles are lost at the focusing quad far from IP1 (QF2) and only a small fraction at the first one close to IP1 (QF1). The distribution of this latter background component has been measured with the KLOE detector showing a good agreement with the simulation [7] [8]. Simulations indicate that the background component coming from QF2 could be reduced by a mask insertion just below the quadrupole. The mask cannot be inserted because the IR is inside the detector, therefore it will be mounted in the new IR that will be installed at the end of this year.

In fact, the installation of a new IR has been designed. As in the DEAR case the β_x will be reduced at IP1 in order to decrease the background component coming from QF1. Simulations are under way to optimize the quadrupoles and masks position for the new IR.

5 CONCLUSIONS

Measurements have been performed to investigate the new collimators performance, showing an overall decrease of the induced background rates. A qualitative agreement has been found with simulation.

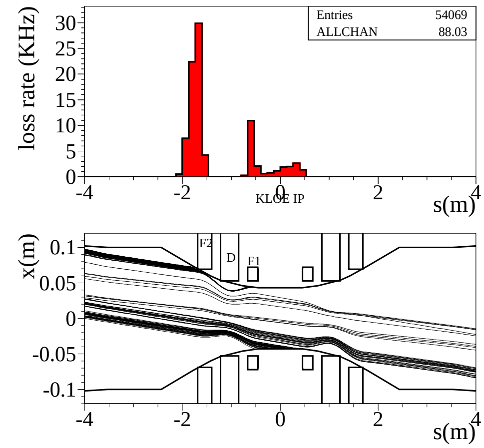

Figure 7: Distribution and trajectories of Touschek particles lost at KLOE IR with the present optics.

The new scrapers also increase the efficiency of the scraper upstream the experiments. In fact, the new collimators stop particles that would be just deviated by the IR scraper and eventually lost at the experiment.

A detailed study of the distribution of the particles hitting the pipe at the two IRs has been very useful to find the proper tools to control the background rates. In particular, the DEAR background has been reduced by a factor greater than 10 by shielding the experiment at the calculated position, by scrapers and by reducing the β_x-function at the focusing quadrupole closest to IP2. The experience gained with DEAR has been useful for the design of a new interaction region for KLOE, to be installed on DAΦNE at the end of the year, which will provide a lower β_x at the focusing quadrupole close to IP1 and shielding behind the other quadrupole farther from IP1.

6 REFERENCES

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