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A STUDY ON DAΦNE SCRAPERS EFFICIENCY

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Abstract

A set of movable collimators (scrapers) is used at DAΦNE to reduce the background in the detectors. These collimators are placed upstream each Interaction Region (IR) in the two rings. To obtain a further background reduction three new scrapers have now been installed in the arcs of each ring in January 2002. Simulation studies have been performed to evaluate the new scrapers efficiency.

Measured collimators efficiencies have been compared to calculated scraper scans. The MonteCarlo reproduces the actual behaviour of the existing collimators; the disagreements are mainly due to a strong edge effect not yet included in the simulation.

1 INTRODUCTION

Background rates are mainly due to Touschek scattered particles. To protect the detectors of the experiments from these off-energy particles tungsten scrapers (IR scrapers), placed for the incoming beams on either side of each experiment, are used. They are placed just upstream of the splitter magnets (see black arrows in Fig. 1). Two horizontal jaws per scraper, external and internal, are required to intercept the two off-energy particle families, those who gained and those who lost energy in the scattering process. The tungsten block can be moved towards the beam and is remotely controlled. In January 2001 the inner surface of the scraper block has been properly shaped and the thickness increased to 55 mm (about 16 r.l.) to reduce the punch through probability of 500 MeV electrons to below 10^{-6} [1].

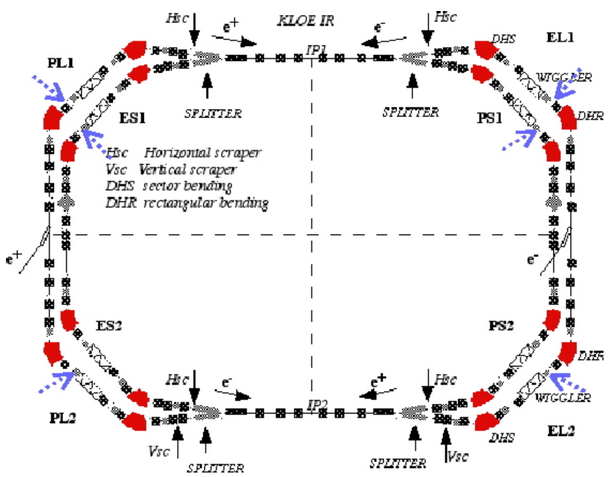

Figure 1: DAΦNE layout with old scrapers (black arrows before splitter magnets) and additional new scrapers (big blue arrows) installed in non-zero dispersion regions.

The efficiency of the scrapers has been simulated by tracking Touschek scattered particles from their origin in the arcs into the KLOE IR and it has been compared to measurements. A brief description of the tracking procedure is presented in section 2. The calorimeter "hot rates" counter has been evaluated by using the KLOE detector simulation program GEANFI [2]. A parametrization of this acceptance as a function of the relevant particle informations (s, x and x') has been included in STAR. In this way a comparison between the measured and the calculated calorimeter hot rates can be performed as a function of the scraper openings. Figure 2 shows an example of a positron hitting the pipe at the low-β quads region tracked into the detector and hitting the calorimeter hot rates ECM4. The particle's initial conditions are taken from the STAR output.

A comparison between calculated and measured IR scrapers scans is presented in section 3. When the IR scrapers are inserted too close to the beam center an increase of the background rates due to an edge effect is clearly observed. On the other hand collimators for this analysis have been assumed perfectly absorbing and infinitely thick. A work is in progress to include this effect in the simulation.

New scrapers (arc scrapers) have been installed in dispersive regions, close to wigglers. Their position is shown by the dotted blue arrows in Fig. 1: two are in the long while one is in the short arc. Their efficiencies have been calculated and are discussed in detail in section 4.
Impedance changes in the rings due to the insertion of new scrapers have not been taken into account in this context.

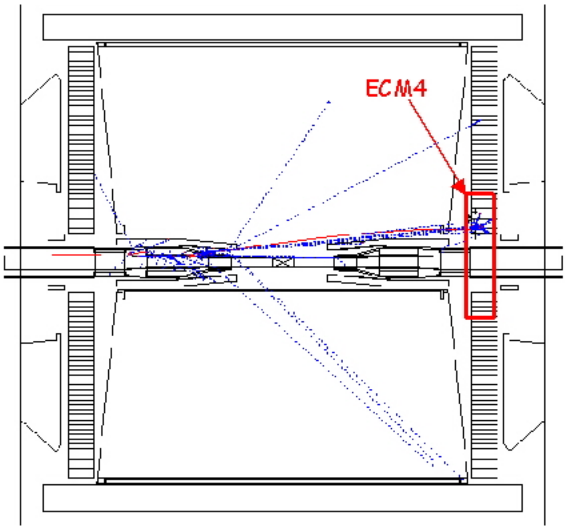

Figure 2: Example of a particle hitting the beam pipe at the low-β region and hitting the calorimeter end caps [2].

2 SIMULATIONS

The home-developed code STAR is used to study the collimators performance [3]. All magnetic elements are considered in the MonteCarlo, including sextupoles and octupolar components in the wigglers [4]. The optical model used for these tracking simulations is the so called "detuned" optics [5] adopted during the KLOE runs in June 2001; scraper scans have been performed with the same dataset.

In the simulation Touschek scattered particles are generated separately in the four arcs PL1, PL2, PS2, PS1 (see Fig. 1) for the positron beam. The main beam parameters used for the following simulations are summarized in Table 1.

Table 1: Relevant beam parameters used for Touschek simulations.

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

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 rate. On the other hand, particles with lower energy deviation never reach the physical aperture and do not contribute to the beam losses.

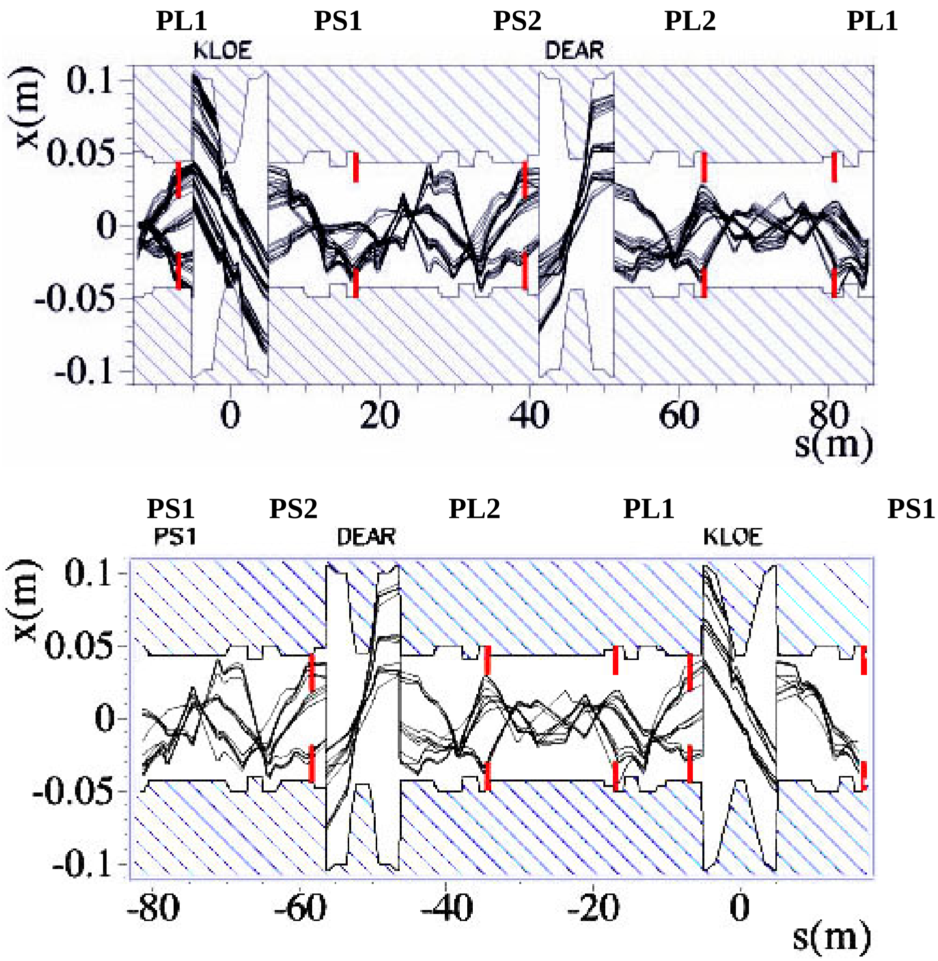

Figure 2: : Touschek scattered particles starting from arc PL1 (*upper plot*) and from PS1 (*lower plot*) tracked along the ring, with no scrapers inserted. The red collimators before the experiments are the old ones (IR scrapers), the other three are the new ones.

Ten thousand particles have been tracked with a bunch current of 5 mA in 20 bunches, corresponding to the measurement. Both measured data and simulations are referred to a roundness of R=0.1, where the roundness parameter R is the ratio of the vertical to horizontal beam size measured at the synchrotron light monitor.

Several comparisons have been already performed between the simulations and the KLOE data showing a good qualitative agreement [6].

Trajectories of Touschek scattered particles which eventually get lost at the KLOE interaction region (IR) starting from arcs PL1 and PS1 are reported in Fig. 2 in the upper and lower plots, respectively. Examples refer to simulations with no scrapers inserted, old and new collimators are drawn in red at the maximum jaw insertion, giving an intuitive indication of their efficiency.

3 COMPARISON BETWEEN MEASUREMENTS AND SIMULATIONS

3.1 KLOE scraper scan

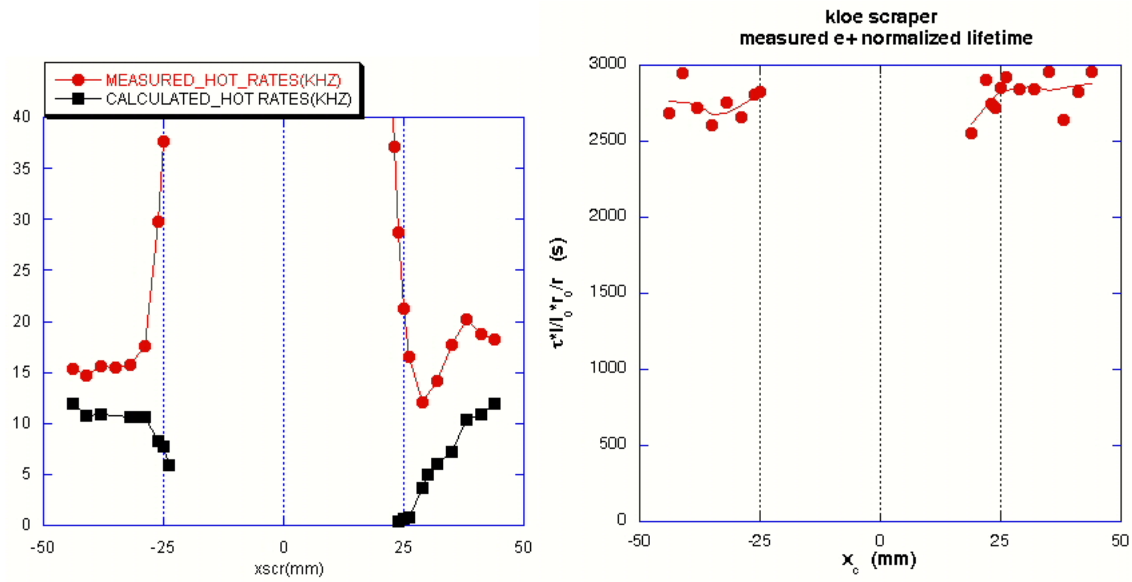

Figure 4 *Left plot*: Scan of the background rate in the KLOE forward calorimeter ECM4 as a function of the opening of the external and internal jaws of the positron beam KLOE scraper (SCHPL101) in single beam operation. Calculated rate is in full black squares and measured rate in red dots. *Right plot:* measured normalized lifetime versus opening of the external and internal jaws.

Figure 4 (left) shows measured and calculated background rate in the KLOE forward calorimeter ECM4 as a function of the opening of the external and internal jaws of the positron beam KLOE scraper (SCHPL101), in single beam condition. The simulated efficiency of the scraper is shown by the black squares; observed data are the red dots. In the plot the center of the beam pipe is at x=0 mm and the beam pipe is at ±44 mm.

External jaw reduces loss rates by about a factor 2, while no reduction of the background rate in the KLOE calorimeters was observed while closing the internal scraper's jaw. It appears that the actual behaviour is reproduced by the MonteCarlo.

A strong increase of the background rate is observed when the jaws are moved closer than 26 mm from the center of the beam pipe. This distance corresponds to 9 standard deviations of a gaussian beam (at the KLOE scraper is: σ_x=2.9 mm, ε_x = 0.87 mm mrad, β_x=9.75 m, D_x=0.04 m). The maximum jaw position (all in) corresponds to 6.5 σ_x. We explain this background increase produced by the jaw insertion as an 'edge effect'. Our MonteCarlo does not yet include this effect, as collimators have been assumed perfectly absorbing and infinitely thick. The right plot of Fig. 4 shows the measured normalized lifetime versus opening of the external and internal jaws. An almost constant lifetime during the scan is evident, so the high increase of loss rate while inserting the scraper is not due to a bunch core cut.

3.2 DEAR scraper scan

Left Fig. 5 shows the measured (red dots) and the calculated (black squares) background rates in the KLOE forward calorimeter ECM4 as function of the position of the external and internal jaws of the DEAR scraper (SCHPS201) in the positron ring. Right Fig. 5 shows the corresponding measured positron beam lifetime.

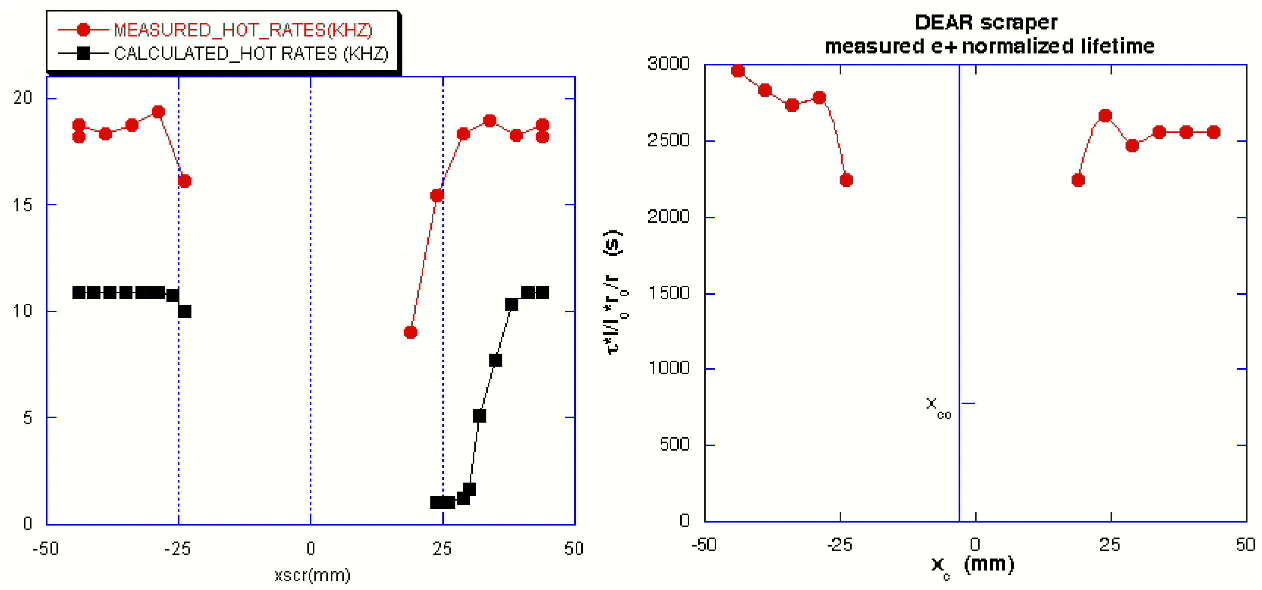

Figure 5 *Left plot*: Scan of the background rate in the KLOE forward calorimeter ECM4 as a function of the opening of the external and internal jaws of the DEAR scraper (SCHPS201) in the positron ring. Calculated rate is in full black squares and measured rates in red dots.
Right plot: measured normalized lifetime versus opening of the external and internal jaws.

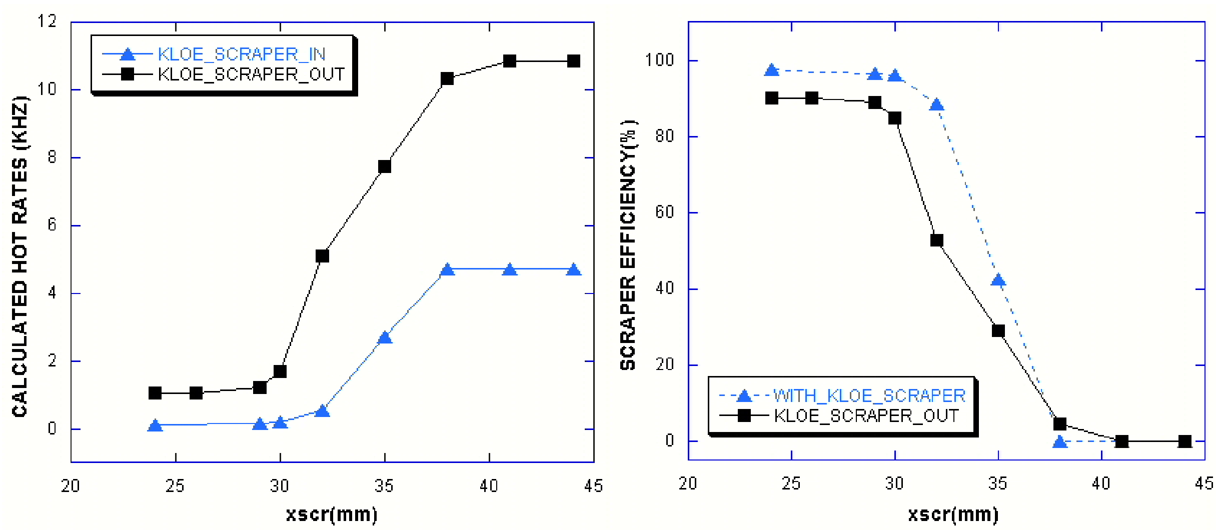

Figure 6: *Left plot:* Internal and external DEAR scraper jaws inserted at the same time with the KLOE scraper inserted at 30 mm (blue triangles) and without the KLOE scraper in (black squares). *Right plot:* DEAR scraper efficiency with (blue triangles) and without (black squares) the KLOE scraper jaws.

The external DEAR scraper is effective in reducing the background in KLOE as expected for simulations. In this case we do not observe a background increase when inserting the jaw too close to the beam. The limit to the scrapers insertion comes from beam lifetime reduction.

The lifetime drops at a jaw's position of 25 mm corresponding to ~7.4 σ_x (at the DEAR scraper is: σ_x=3.4 mm, β_x=13.24 m, D_x=0.33 m). However, the external jaw is expected to be more effective than how it is observed. A disagreement of about a factor 2 between the calculated and observed data is found overall, as in the KLOE scraper scan.

With the KLOE scrapers in at 30 mm the DEAR scrapers are still effective in reducing the background rates, as experimentally observed. Left plot of Fig. 6 shows the calculated hot rates for the DEAR scraper scan with and without the KLOE scraper at 30 mm. It has also been investigated if the DEAR scraper's efficiency changes when the KLOE scraper is inserted (right plot of Fig. 6). Table 2 summarizes the comparison between calculated and measured IR scrapers efficiencies.

Table 2: Summary of scrapers efficiencies at KLOE.
Total beam current of 100 mA and 20 bunches.

	calculated KLOE hot rates (KHz)	Calculated scrapers efficiency	Measured scrapers efficiency
no scrapers	10.85		
KLOE scraper in	4.72	56.5%	
KLOE+DEAR scrapers in	1.1	90 %	75%

4 NEW SCRAPERS EFFICIENCY FOR KLOE

New scrapers have been recently installed in the two rings, their position is shown by the blue arrows in Fig. 1. We have called them SCNPL1, SCNPS1 and SCNPL2. They are placed, respectively, in the arcs PL1, PS1 and PL2. Their longitudinal positions, starting from the symmetry point at the center of the long arc, are: s(SCNPL1)=8.71 m, s(SCNPS1)=42.51 m and s(SCNPL2)=88.98 m. At these positions the horizontal width of the beam pipe is 50 mm.

Simulations have been performed counting the KLOE hot rates, for almost 1 A total beam current and with the beam parameters as for the usual KLOE runs. Table 3 reports the simulation results for the three new scrapers: the first row shows the calculated hot rates, while the last row shows the collimators efficiency. The three scrapers do not cut the same particles, in fact, when they are inserted all together and without the two IR collimators, the efficiency is very high: 76% and 100% for the contributions of the two arcs PL1 and PS1, respectively.

Table 3: Calculated hot rates for particles starting from arc PL1 (and PS1) (I=0.94A, 47 bunches, I_{bunch}=20 mA, σ_z=2.4 cm, κ= 0.01).
Correspondent efficiency of scrapers is reported in last column.

Particles from **PL1 (PS1)**	Calculated hot rates (KHz)	Calc. Scrapers efficiency(%)
No scrapers	203.8 (4.3)	-
SCNPL1 at 30mm	118.9 (3.3)	42 (39)
SCNPS1 at 30mm	102.1 (0.6)	50 (67)
SCNPL2 at 30mm	146.2 (3.1)	28 (9)
all 3 new scrap. at 30 mm	49.5 (0.0)	76 (100)

Looking at the trajectories plotted in Fig. 2 it appears that at the SCNPL2 position the horizontal displacements of the Touschek particles are not very large, so it can be envisaged that this collimator should not be so efficient. After these considerations more detailed simulations have been done on the other two collimators SCNPS1 and SCNPL1.

From Fig. 2 it can be noticed that both trajectories of the particles coming from PL1 and from PS1 do not reach the external jaws of the two scrapers SCNPS1 and SCNPL1. Therefore only their internal jaws are expected to be effective.

A study to check if the two scrapers at arcs PL1 and PS1 are efficient also when the IR scrapers are inserted is presented in the following.

4.1 Scraper SCNPS1

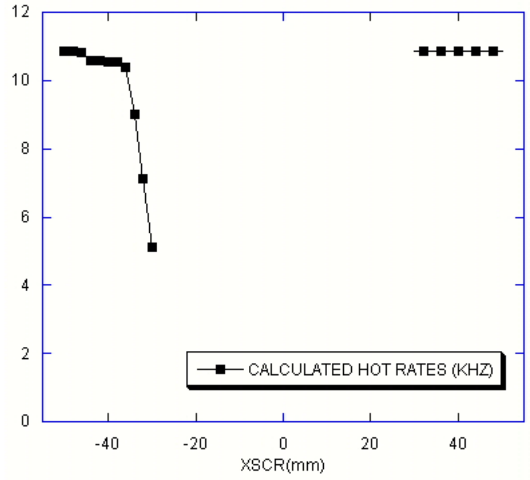

Figure 7: SCNPS1 scraper scan from simulation: KLOE hot rates have been normalized to a total current of 100 mA and 20 bunches. Only the internal jaw reduces KLOE loss rate by 50%.

Figure 7 shows a calculated scan, where the KLOE hot rates are plotted and no other scrapers are inserted along the ring. The internal jaw reduces losses by ~50%, the external jaw does not stop any particles, as expected (Fig. 2). At this position of the ring σ_x is 2.9 mm (β_x = 9.7 m, D_x = 0.35 m), so that the maximum jaw's position at 20 mm from the center of the beam pipe corresponds to ~6.9 σ_x.

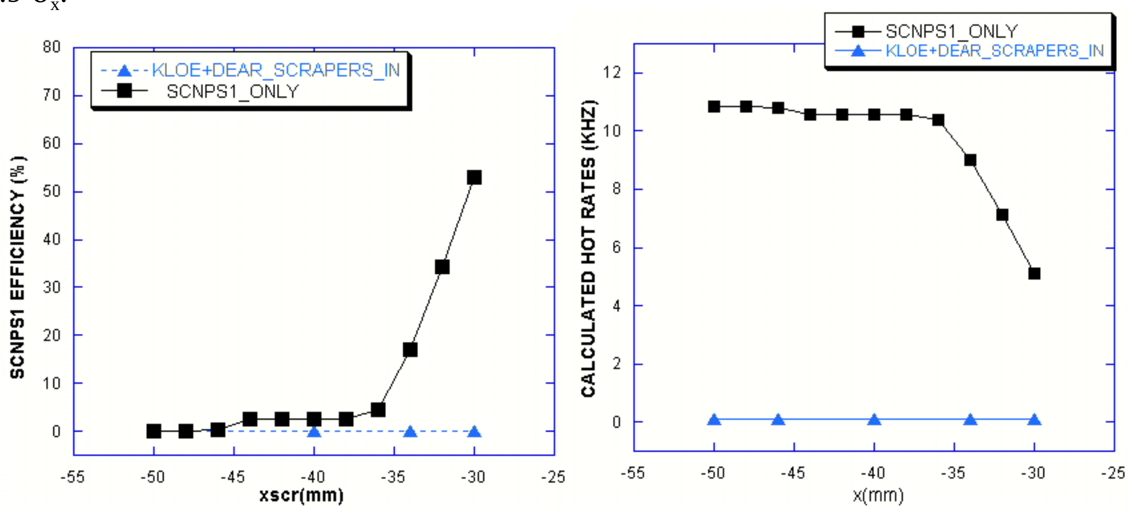

Figure 8: *Left plot:* SCNPS1 simulated efficiency, with (blue triangles) and without (black squares) the IR scrapers inserted. In both cases SCNPS1 stops half of the particles which get lost at KLOE IR. *Right plot:* Calculated rates (KHz) with (blue triangles) and without (black squares) the IR scrapers inserted.

Left plot of Fig. 8 shows a comparison between collimator's SCNPS1 efficiency with (blue triangles) and without (black squares) the insertion of the two scrapers upstream the experiments.

The KLOE scraper jaws have been inserted at ±30 mm and the DEAR scraper jaws at ±26 mm, which are values below the edge effect "threshold" (see Figs. 5 and 6).

4.2 Scraper SCNPL1

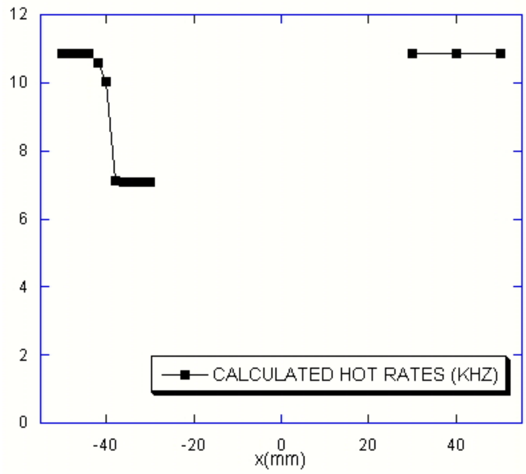

Figure 9: Simulated scraper (SCNPL1) scan. Calculated KLOE hot rates have been normalized to a total current of 100 mA and 20 bunches. Only the internal jaw reduces KLOE loss rate by ~35%.

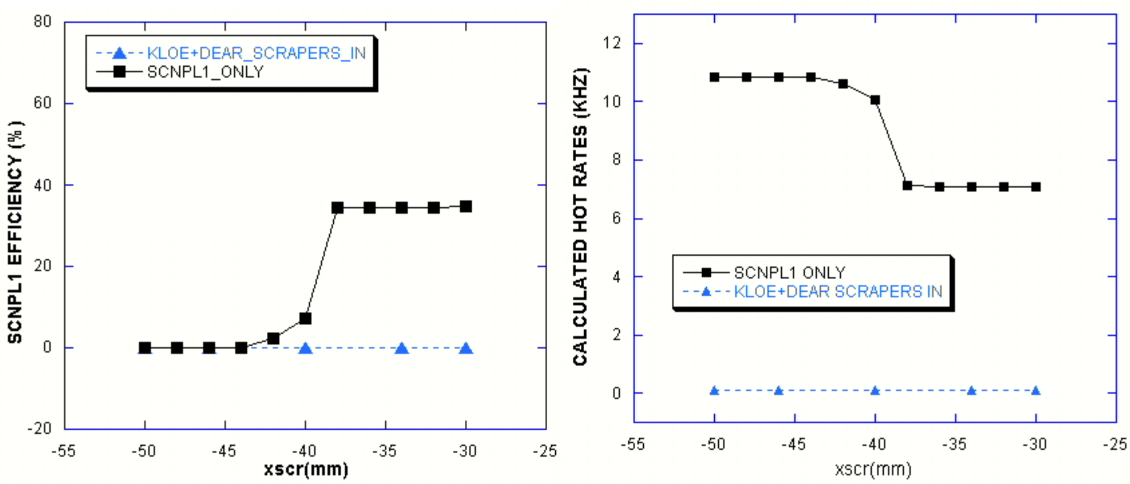

Figure 10: : *Left plot:* SCNPL1 calculated efficiency, with (blue triangles) and without (black squares) the IR scrapers inserted. When no other scraper is inserted only 40% of scattered particles are left; when IR scrapers are in, no further reduction is foreseen at KLOE IR. *Right plot:* Hot rates from simualtions with (blue triangles) and without (black squares) the IR scrapers inserted.

Similarly to SCNPS1 only the internal jaw is expected to be effective. At this position of the ring σ_x is 2.95 mm (β_x = 9.17 m , D_x = 2.18 m) and the maximum jaw position at 20 mm from the center of the beam pipe corresponds to ~6.8 σ_x.

Left plot in Fig. 10 (black sqaures) shows that when no other scrapers are inserted along the ring the background rates at KLOE IR are reduced by ~60%. On the other hand, when the KLOE and DEAR scrapers are inserted at ±30 mm and ±26 mm respectively, SCNPL1 does not give any further background reduction at the KLOE IR. In conclusion, scraper SCNPL1 cuts only particles that are already intercepted by the IR collimators. On the other hand, we expect that cutting particles with the arc scrapers, rather than with the KLOE scraper, will help reducing the losses due to the edge effect.

5 NEW SCRAPERS EFFICIENCY FOR DEAR

The efficiency of the new scrapers for DEAR has been investigated with the optics used for the December 2001 DEAR runs [7]. Results of simulations with the non linear model (sextupoles and octupolar components in wigglers included) are presented in Table 4. In these simulations the DEAR background rates have been calculated by counting the losses in the whole IR, as no background estimators have been yet included in the simulation.
The two arcs which contribute mostly to the production of Touschek particles which eventually get lost at DEAR are PS2 and PL1. However, the particles produced at PS2 get lost immediately at the first turn, so they can be stopped only by the scraper upstream the experiment. The particles produced at PL1 in principle can be stopped by collimators along the ring.

Table 4: Calculated losses at DEAR IR (central column) indicating also the machine turn at which they get lost; total losses (last column) of particles coming from the four arcs, with Dec.'01 DEAR optics and sextupoles and octupolar components in wigglers included.
(I=0.94A, 47 bunches, I_{bunch}=20 mA, σ_z=2.4 cm, κ= 0.01)

Background rates (MHz)	DEAR IR	Total losses
PS2	2.0 (1^{st} turn)	51.90
PS1	0.06 (1^{st} turn)	50.20
PL1	1.1 (1^{st} turn)	76.93
PL2	0.0	82.64

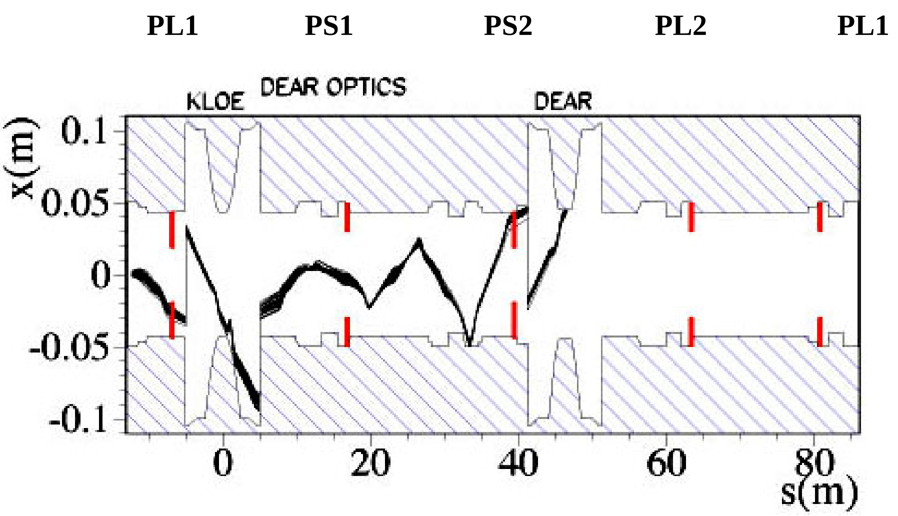

Figure 11: Horizontal trajectories of Touschek scattered particles starting from arc PL1, tracked along the ring with no scrapers inserted. The red collimators before the experiments are the 'old' ones, the other three are the 'new' ones.

Horizontal trajectories of Touschek scattered particles starting from arc PL1 are plotted in Fig. 11. Trajectories are large at the KLOE and DEAR scrapers only. This result is confirmed by experimental observations, where the KLOE scraper is routinely used to reduce the DEAR background.

Simulation results on the scrapers efficiencies are shown in Table 5. It appears that the new collimators are not expected to be efficient in this case.

Table 5: Calculated background rate in whole the DEAR IR with a total beam current of I=0.94A, 47 bunches, I_{bunch}=20 mA, σ_z=2.4 cm, κ= 0.01, for particles starting from arc PL1 (and PS1). Corresponding efficiency of scrapers is reported in last column.

	Calculated losses at DEAR IR (MHz) from **PS2 (PL1)**	Scrapers efficiency(%) from **PS2 (PL1)**
No scrapers	2.0 (1.1)	-
all 3 new scrap. at 30 mm	2.0 (1.1)	0 (0)

6 CONCLUSIONS

Detailed studies have been performed to investigate the present collimators performance comparing them to expectations. A satisfactory qualitative agreement has been found except for the strong edge effect observed and not yet included in the simulations.

Studies for additional scrapers have been performed with the KLOE and the DEAR optics to find the calculated efficiencies for the reduction of the background at the two experiments.

Regarding the KLOE background rates, the new scrapers should stop particles that are already intercepted by the present IR collimators allowing a rejection of such a background far from the IR, with the advantage of reducing the edge effect losses.

Regarding the DEAR background rates, the new scrapers are foreseen to be less efficient than for KLOE.

7 REFERENCES

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