DAΦNE TECHNICAL NOTE

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IR-12

COLLISIONS AT FINUDA: SOME BACKGROUND EVALUATIONS

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Abstract

Calculations of Touschek backgrounds have been done for the machine set for FINUDA data taking.Touschek scattered particles have been tracked along DAΦNE and the rate of particles lost at the FINUDA interaction region has been evaluated together with the total losses around the rings. Results seem encouraging, as calculated loss rates at IR2 are not large and particles get lost quite far from the interaction point. Rates and distributions are discussed in details and compared to calculated losses for the KLOE and the DEAR cases.

1 Introduction

Background rates are mainly due to Touschek scattered particles. The home-developed code STAR is used to study Touschek background.

After the calculations made during the design and project of DAFNE [1] new background simulations are necessary to update the expected losses at FINUDA.

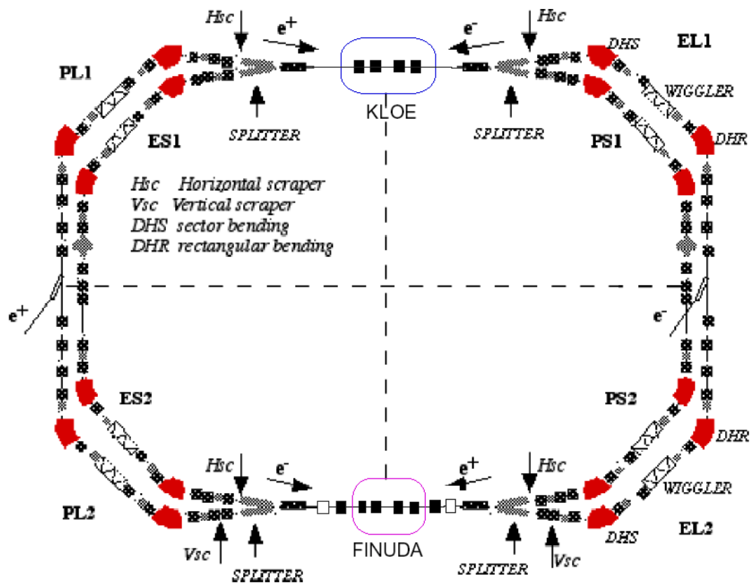

Figure 1: DAΦNE layout.

For the present simulations only the linear model has been used. We have found in the previous background studies [2] for KLOE and DEAR that nonlinear elements contribute significantly to beam losses, so we can take the following rates as lower values. In fact, with nonlinearities the higher machine turns play a role (in any case within 10 turns) and instead in the linear model Touschek particles get lost essentially at the first turn.

The optical model used for these tracking simulations is the FINUDA optics [3] (let's call it *finuda0* optics). It has the main characteristic of being detuned at KLOE: the KLOE detector is down and consequently the solenoid compensators too, together with the KLOE permanent low-β quadrupoles rotated to a 0° angle. The emittance is ε_x=0.75·10^{-6} m·rad and β_x(IP2)=1.5m β_y(IP2)=0.035m. The FINUDA solenoidal field is B=1T.

The horizontal crossing angle at IP2 has been taken θ_x=16 mrad, while at IP1 is θ_x=14 mrad. A short discussion on the optimization of this parameter is done in section 7.

In Figure 2 the β-functions along the machine together with the horizontal dispersion and H-invariant are reported for completeness.

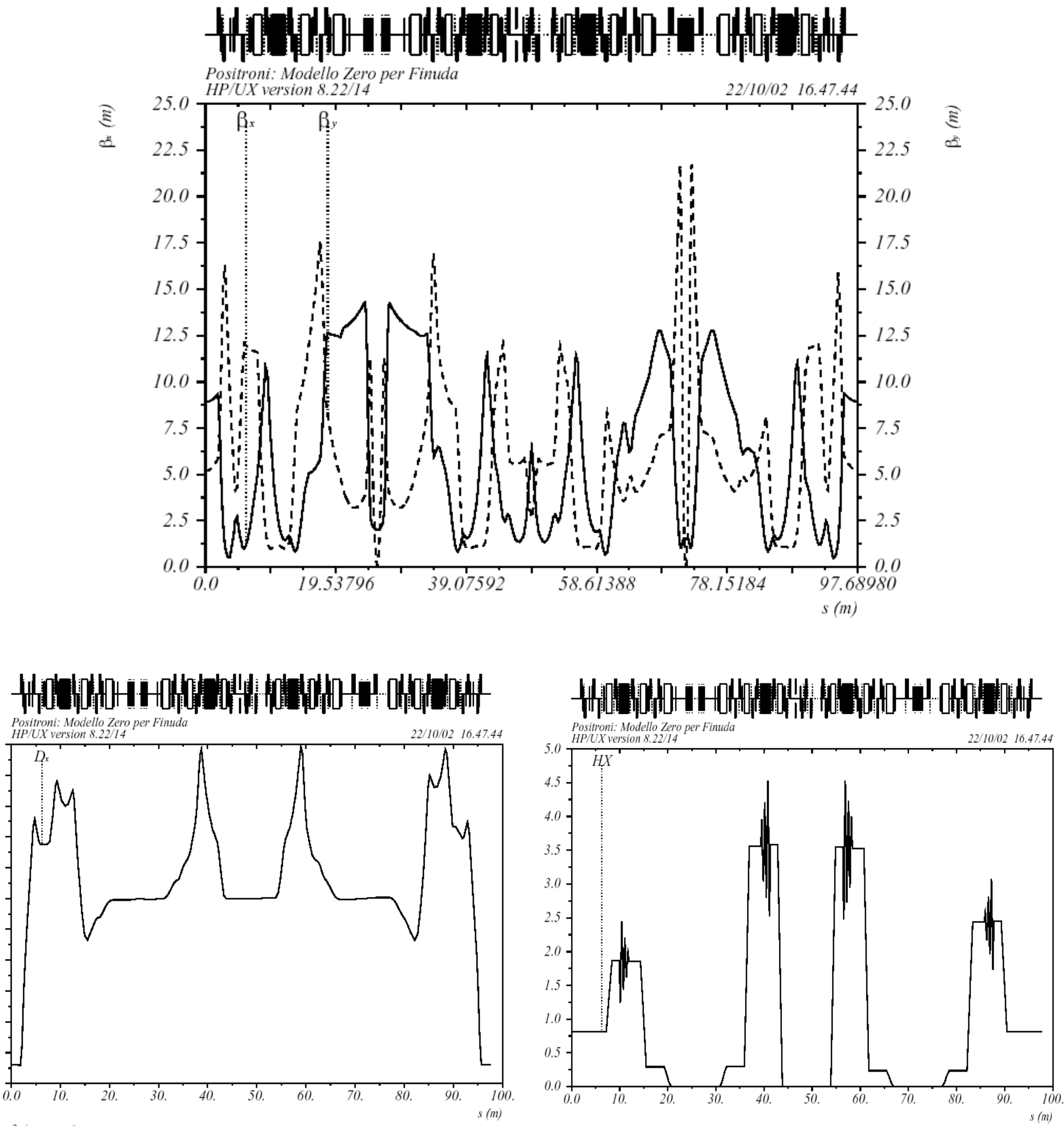

Figure 2: Upper plot: beta functions; lower left: horizontal dispersion;
lower right: H-invariant in the four DAFNE arcs.

2 Simulations

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]	$0.8{\cdot}10^{-6}$
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 rates. On the other hand, particles with lower energy deviation never reach the physical aperture and do not contribute to the beam losses.

Twenty thousand particles have been tracked and table 2 summarizes loss rates normalized to 100 bunches and total current of 1A.

No scrapers have been inserted for the present simulations, so all the rates are referred to a machine configuration without scrapers. Trajectories are plotted overlapping the scrapers jaws, to give an idea of their potential effectiveness with this machine configuration.

The loss rates are referred to the number of particles hitting the pipe. The evaluation of the FINUDA background counting rate can be done by tracking these particles in the detector. This work in under way [4]. This has been done for the KLOE IR where the full simulation in the detector allowed 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 agreement [5] [6].

Table 2: Calculated particle losses at FINUDA IR indicating also the machine turn at which they get lost; loss rates at KLOE IR and total losses (last column) with no scrapers inserted and for a single beam.

(I_{TOT}=1A, 100 bunches)

ARC	**FINUDA IR** Loss rates [MHz]	**KLOE IR** Loss rates [MHz]	**Total losses** Loss rates [MHz]
PS2	**2.8 (1st turn)**	**5.0**	**34.7**
PL2	**0.1 (2nd turn)**	**3.2**	**26.8**
PL1	**5.1 (1st turn)**	**14.7**	**30.4**
PS1	**7.2 (1st turn)**	**14.5**	**42.0**
TOTAL	**15.2**	**37.4**	**133.9**

There are 3 arcs which contribute to FINUDA background: PS2, PL1 and PS1 (second column in table 2). The relative distributions and trajectories of Touschek scattered particles which eventually get lost at the FINUDA interaction region (IR2) are reported in the following sections.

Most of the total losses (last column in table 2) are concentrated at the two positions where the physical aperture is smaller with respect to the beam envelope size. These positions are: the KLOE focusing low-b quadrupoles and the injection septum. Depending on the arc where the Touschek particles are generated (that is: depending on the betatron phase between Touschek particles and the aperture limits) losses are concentrated on one of these two critical positions.

In the configuration used for FINUDA the phases of the Touschek particles coming from the two arcs PL1 and PS1 are such that half of the total losses are at KLOE IR (see upper Fig. 9 and Fig. 12). In the machine configuration used for KLOE data taking, the same arcs contribute mostly to the KLOE background [7].

For the other two arcs PS2 and PL2 most of the total losses are concentrated at the injection septum, which is the first limit in the aperture that these particles encounter (see upper Fig. 3 and Fig. 6).

Lastly, I would like to make a brief comment on the total loss rates. They result ~2MHz for a single beam of 10mA. If we use the well-known relation $1/\tau=(dN/dt)/N$ to make a rough estimate of the Touschek lifetime one would get: $\tau\approx$ 4 hrs and we know this is higher than what experimentally observed. This simply means that for a good lifetime evaluation a dedicated simulation is needed. In any case, interesting informations can be obtained just looking at the losses distributions.

3 Losses from Touschek Particles Generated at Arc PS2

Horizontal trajectories of Touschek scattered particles starting from arc PS2 are plotted in Fig. 3 together with the distribution of particle losses along the machine. Losses at the KLOE focusing low-β quadrupole are found, but most of the beam losses (~20MHz out of 35MHz) are concentrated at the injection septum.

Distributions and trajectories of particles lost at the FINUDA IR are shown in Fig. 4. As shown in the picture, particles are lost far from the IP, at about –4m before the IP, in principle not resulting dangerous for the experiment. They get lost due to the focusing effect of the solenoidal field. As reported in table 2 they are about 2.8 MHz between –4 and 4m, for 1A of total beam current and 100 of bunches. All of these particles get lost at the first turn (see Fig. 5), as expected for a linear model. When nonlinear terms will be included, we expect that successive machine turns will play a role, increasing the loss rates.

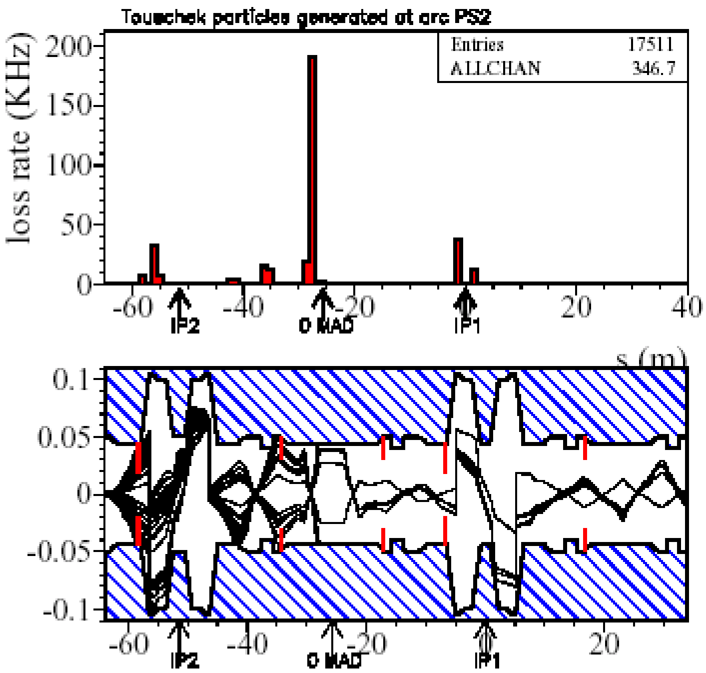

Figure 3: Distributions and trajectories of Touschek scattered particles starting from arc PS2, tracked along the ring. Rates in the plot (as for the similar following plots) refer to 1 bunch of 10mA current. IP1 is KLOE, IP2 is FINUDA and 0MAD is the symmetry point in the middle of the long arc and is very close to the injection septum.

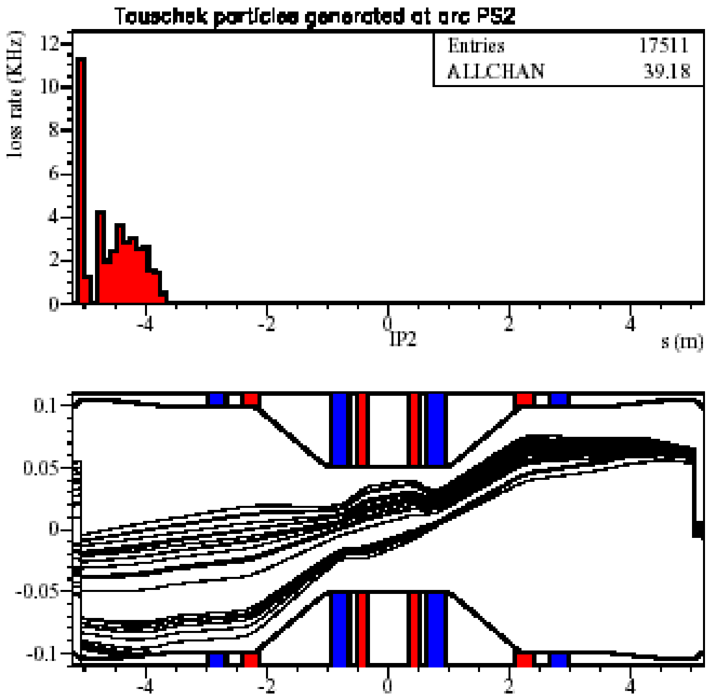

Figure 4: Distribution (upper) and trajectories of Touschek scattered particles at IR2 (lower).

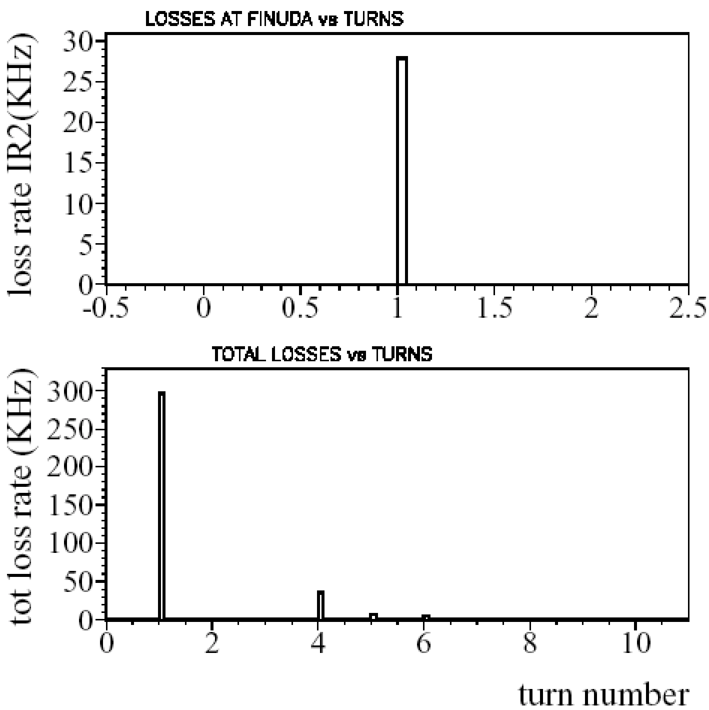

Figure 5: Beam losses as a function of the number of turns: Upper plot: losses at IR2,
Lower plot: total losses.

4 Losses from Touschek Particles Generated at Arc PL2

Touschek particles generated in this arc do not contribute significantly to FINUDA backgrounds (see Fig. 7 and Fig. 8). Most of beam losses are found close to the injection septum; distributions and trajectories are shown in Fig. 6.

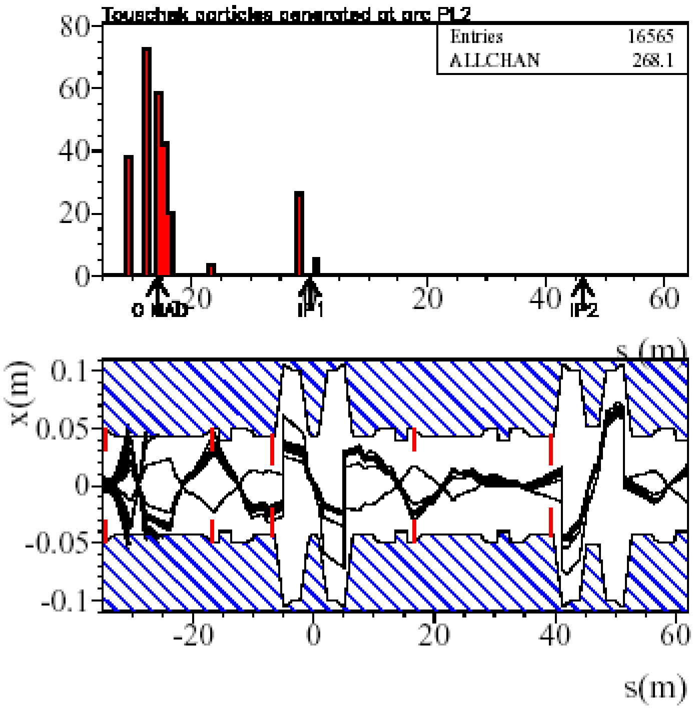

Figure 6: Losses distribution of particles starting from arc PL2, tracked along the ring.

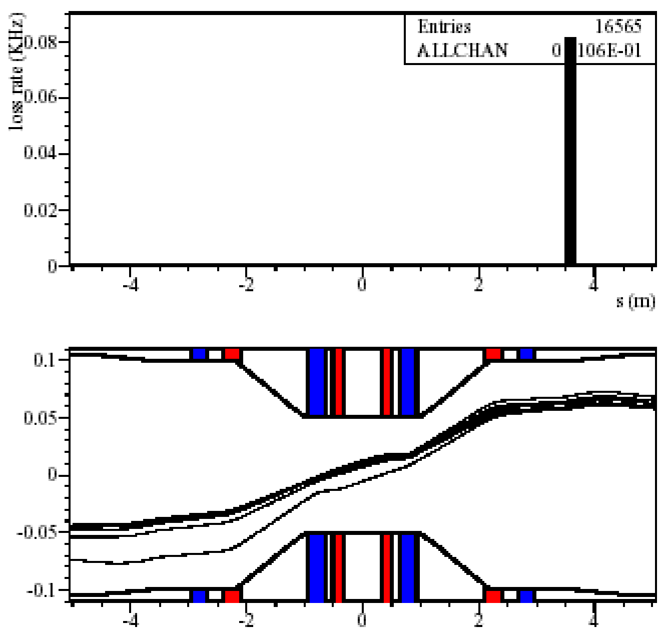

Figure 7: Distribution (upper) and trajectories of Touschek scattered particles at IR2 (lower).

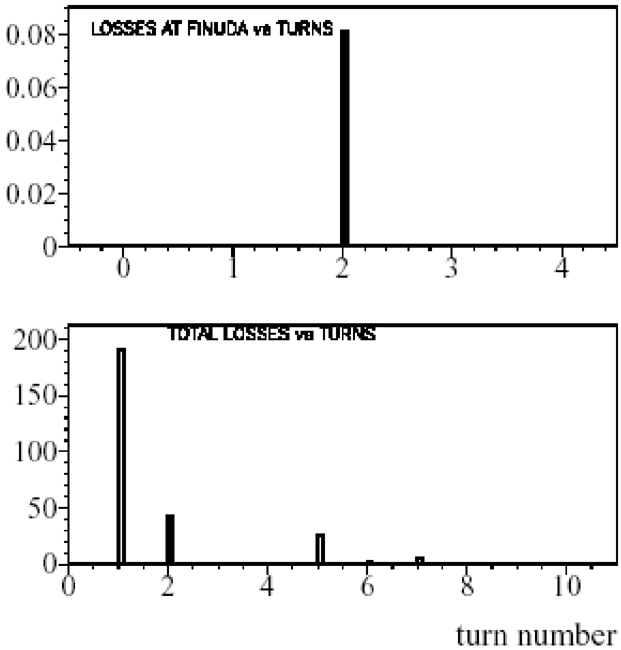

Figure 8: Beam losses as a function of the number of turns: Upper plot: losses at IR2, Lower plot: total losses.

5 Losses from Touschek Particles Generated at Arc PL1

Particles generated at PL1 get lost especially at the KLOE low-β focusing quadrupole (see Fig. 9). In fact, this position produces about half of the total losses in the machine.

In this case the particles which get lost at FINUDA are about twice the ones coming from arc PS2, but they get lost between 2m and 4m after the IP2, starting at the last focusing quadrupole QUAI2002 (Fig. 10). So, in principle, they should not be dangerous. Further investigation with a GEANT simulation for background evaluation in the FINUDA detector is nevertheless recommendable. As expected, losses are concentrated at the first turn (see Fig. 11).

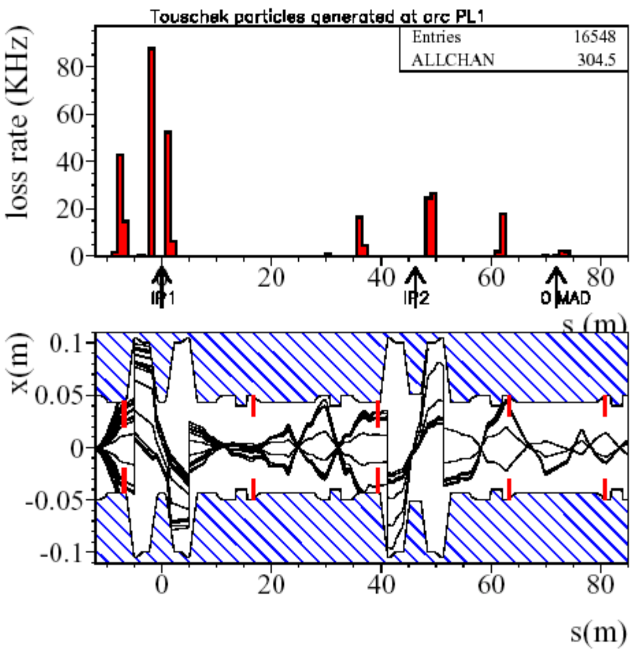

Figure 9: Distributions and trajectories of Touschek scattered particles starting from arc PL1, tracked along the ring.

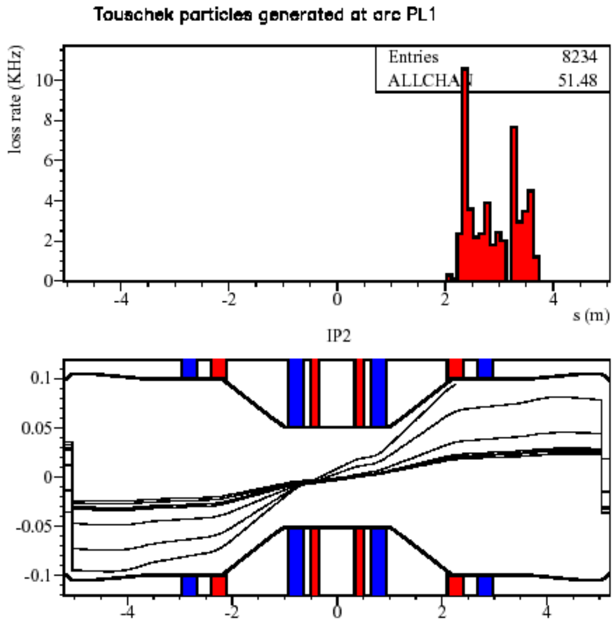

Figure 10: Distribution (upper) and trajectories of Touschek scattered particles starting from arc PL1 plotted at IR2 (lower).

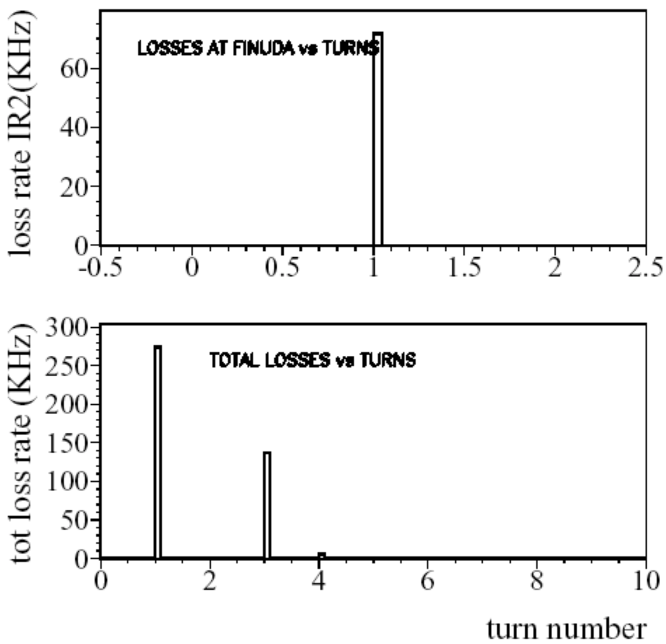

Figure 11: Beam losses as a function of the number of turns: Upper plot: losses at IR2, Lower plot: total losses.

6 Losses From Touschek Particles Generated at Arc PS1

Touschek particles generated at arc PS1 produce about half of the total background in FINUDA IR. As for the PL1 case, most of these particles get lost between 2m and 4 m after the IP2 (see Fig. 13).

Regarding the total losses it appears from fig.12 that losses are high especially at the KLOE IR.

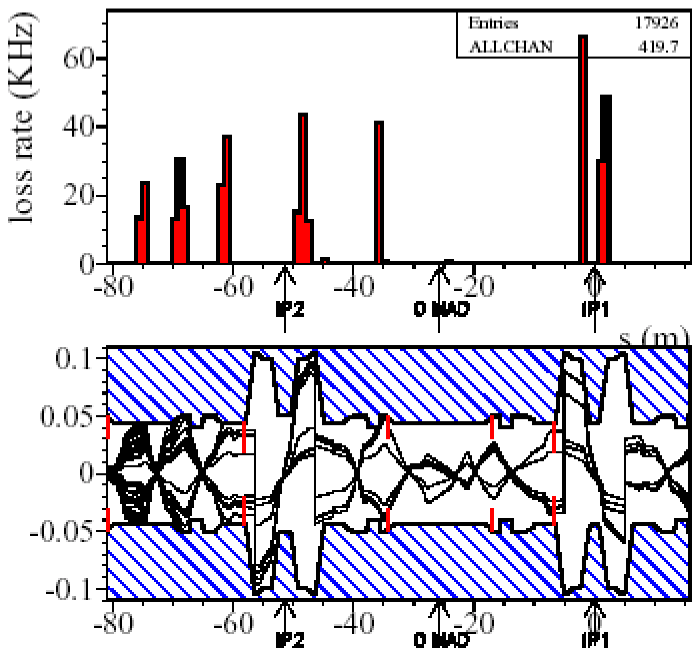

Figure 12: Distributions and trajectories of Touschek scattered particles starting from arc PS1, tracked along the ring.

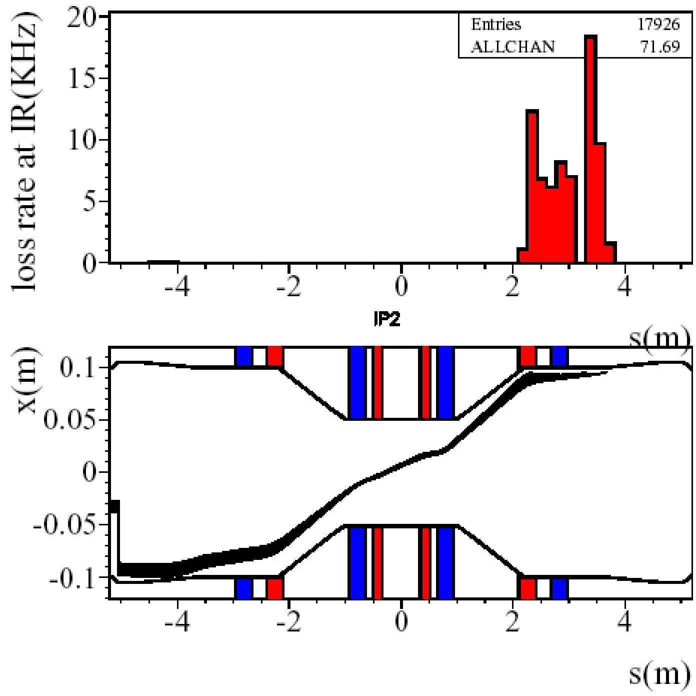

Figure 13: Distributions and trajectories of Touschek scattered particles starting from arc PS1 and lost at the FINUDA IR.

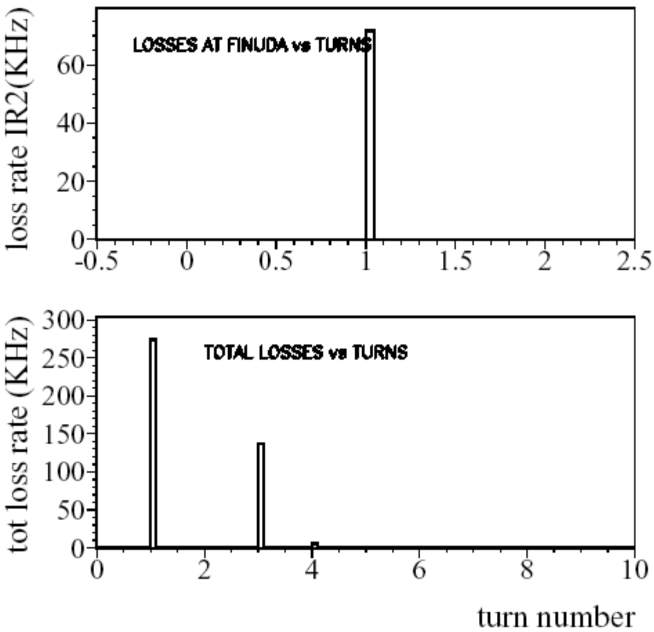

Figure 14: Beam losses as a function of the number of turns: Upper plot: losses at IR2, Lower plot: total losses.

7 KLOE Loss Rates vs Horizontal Crossing Angle at IP1

The losses at the KLOE focusing quadrupole are strongly correlated with the horizontal crossing angle at IP1. In fact, as reported in table 3, going from 14.0 to 15.5 mrad the KLOE losses increase by more than a factor 3 for particles generated at arc PS2 and by about a factor 2 for those coming upstream KLOE.

This comparison suggests to keep this parameter under control in order to get a reasonable lifetime.

Table 3: Loss rates for Touschek particles generated at arc PS2(upper) and PL1(lower). (I=1A, 100 bunches)

ARC	**θx(IP1)** [mrad]	FINUDA IR Loss rates [MHz]	KLOE IR Loss rates [MHz]	Total losses Loss rates [MHz]
PS2	**14.0**	2.8 (1st turn)	**5.0**	34.7
	15.5	2.8 (1st turn)	**16.8**	46.4
PL1	**14.0**	5.1 (1st turn)	**14.7**	30.4
	15.5	5.3 (1st turn)	**26.5**	39.7

8 Comparison with the KLOE and the DEAR cases

We have reported in the following tables the beam losses calculations for the KLOE detuned optics (table 4), and for the DEAR case. Table 5 shows the losses for the December 2001 optics while table 6 refers to the April 2002 optics. To compare rates to the ones for FINUDA (table 2), the same normalization to a total current of 1A and 100 bunches has been made.

Looking at table 4 we see that losses at KLOE are a factor 0.6 of what calculated for FINUDA. Regarding the total losses they are somewhat larger.

Regarding the DEAR case we must comment the higher rates at IR2 found for the present optics (table 6) with respect to the ones of table 5. The point is that as while in December 2001 losses where concentrated at the IP2, in April 2002 the lowering of the βx at IP2 shifted these losses at the farthest focusing low-β quadrupole, allowing the shielding of this background source. In December 2001 βx at IP2 was 3.9m while in April it was decreased to 1.5m. So, the final result was a decrease of the background at the DEAR detector. In any case, the loss rates at IR2 are smaller than the cases of FINUDA and KLOE.

Table 4: Calculated particle losses at KLOE IR with the **detuned optics including nonlinearites**; loss rates at KLOE IR and total losses (last column) with no scrapers inserted and for a single beam. (I_{TOT}=1A, 100 bunches)

ARC	**DEAR IR** Loss rates [MHz]	**KLOE IR** Loss rates [MHz]	**Total losses** Loss rates [MHz]
PS2	1.8	**0.1**	**31.1**
PL2	<< 0.1	<< **0.1**	**88.1**
PL1	<< 0.1	**5.1**	**24.9**
PS1	<< 0.1	**3.7**	**34.1**
TOTAL	1.8	**8.9**	**178.2**

Table 5: Calculated particle losses at DEAR IR with the **DEAR Decemeber 2001optics** and nonlinearities included; loss rates at KLOE IR and total losses (last column) with no scrapers inserted and for a single beam.
(I_{TOT}=1A, 100 bunches)

ARC	**DEAR IR** Loss rates [MHz]	**KLOE IR** Loss rates [MHz]	**Total losses** Loss rates [MHz]
PS2	**1.3**	<< 0.1	**34.9**
PL2	<< **0.1**	<< 0.1	**55.5**
PL1	**0.7**	2.6	**51.7**
PS1	<< **0.1**	<< 0.1	**33.7**
TOTAL	**2.0**	2.6	**175.8**

Table 6: Calculated particle losses at DEAR IR with the **DEAR low-β optics** (April 2002) and nonlinearities included; loss rates at KLOE IR and total losses (last column) with no scrapers inserted and for a single beam.
(I_{TOT}=1A, 100 bunches)

ARC	**DEAR IR** Loss rates [MHz]	**KLOE IR** Loss rates [MHz]	**Total losses** Loss rates [MHz]
PS2	**2.0**	<< 0.1	31.2
PL1	**1.2**	3.0	41.7
TOTAL	**3.2**	3.0	72.9 (just 2 arcs!)

9 Conclusions

Background studies with the machine optimized for FINUDA runs have been carried out. Results show that the pipe at IR2 is large enough to control losses just close to the IP2.

The Touschek particles lost at IR2 will be tracked into the FINUDA detector to check their effect. Simulation studies are under way.

Most of the total losses are concentrated at the two positions where the physical aperture is smaller with respect to the beam envelope size. These positions are: the KLOE focusing low-β quadrupoles and the injection septum. A smaller emittance and a smaller βx value at the KLOE focusing quadrupole and at the injection septum are suggested. On the other hand, we have shown that the horizontal crossing angle at IP1 must be carefully chosen to minimize these losses.

The present calculations are referred to the FINUDA solenoidal field of B=1T and the optics with the nominal field of 1.1T is expected to increase slightly the loss rates, as most of them are just due to its focusing effect.

New calculations with machine nonlinearities and the study of scrapers effectiveness will be the following steps.

References

[1] S. Guiducci, "*Background Evaluation in DAFNE*", DAFNE Tech.Note IR-6, April. 1995.

[2] M. Boscolo, "*Effects of non linear elements on backgrounds at DAΦNE*", given at 23rd Advanced ICFA Beam Dynamics Workshop on High Luminosity e^+e^- Colliders, Cornell Univ. Ithaca, NY (USA), 15-19 October 2001.

[3] S.Guiducci, G.Benedetti, *private communications*.

[4] A. Felicello, *private communications*.

[5] M. Boscolo S. Guiducci, "*A comparison between data and simulations of the DAFNE beam induced background in KLOE*", DAFNE Tech.Note IR-10, Nov. 2001.

[6] M. Antonelli, L. Passalacqua, B. Sciascia, "*Investigation into the physics of DAFNE background*", KLOE Memo 260, 2001.

[7] M. Boscolo, M. Antonelli and S. Guiducci, "*Simulations and Measurements of the Touschek Background at DAFNE*", Proc. Of EPAC2002 Paris, France (2002).