TOUSCHEK BACKGROUND AND BEAM LIFETIME STUDIES FOR THE DAFNE UPGRADE

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Abstract

For the low energy collider DAΦNE the machine induced backgrounds into the experiments as well as the beam lifetime are dominated by the Touschek effect. Many efforts have been put in its reduction: by adjusting optical parameters, by inserting additional collimators, as well as by simulating and tracking scattered particles in order to find the proper actions that allow reducing particle losses especially at the interaction region.

Studies on the distribution and trajectories of the Touschek particles along the ring are discussed here for the Siddharta run configuration with the crabbed waist scheme, together with an evaluation of the corresponding beam lifetime. Efficiency of the collimators has been investigated with the new machine configuration and new optimized positions along the ring have been found.

INTRODUCTION

An upgrade of DAΦNE exploiting the crabbed waist idea will shortly be tested [1,2]. A luminosity increase up to values of the order of 10^{33} cm^{-2} s^{-1} is expected to be given by a combination of large crossing angle, very small transverse beam sizes at the interaction point (IP) and the 'crabbed vertical waist'. Relatively small modifications of the machine are required for this scheme, to be realized between summer and fall 2007. Machine backgrounds and lifetime will be dominated by the single Touschek scattering [3], as it is for the DAΦNE present configuration. Simulations of the Touschek effect with the crabbed waist optics have been performed using an upgraded version of the simulation code used for the lattice of the KLOE [4,5] runs.

TOUSCHEK EFFECT AT DAϕNE

Touschek effect is a source of background due to the off-energy particles arising from the elastic scattering of particles within a bunch. Touschek scattered particles have a betatron oscillation given by

$$x = \frac{\Delta p}{p}\left(|D| + \sqrt{H\beta}\right),$$

proportional to the dispersion D, to the momentum spread $\Delta p/p$ and to the invariant H defined by [6]: $H = \gamma_x D_x^2 + 2\alpha_x D_x D_x' + \beta_x D_x'^2$ (upper plot of Fig. 1). Essentially all losses arise from the Touschek scattered particles in dispersive regions (see Fig.1). The generation of the scattering events in the simulation code is done continuously all over the ring, averaging the Touschek probability density function on every three machine elements. The lower plot in Fig. 1 shows how total particle losses (white histogram) come from the highly dispersive regions; the indicated rates are expressed in KHz and they are referred to a 13 mA bunch. Losses only at the interaction region (IR) are reported in the superimposed yellow histogram; the comparison indicates that most of the particles are lost at the IR.

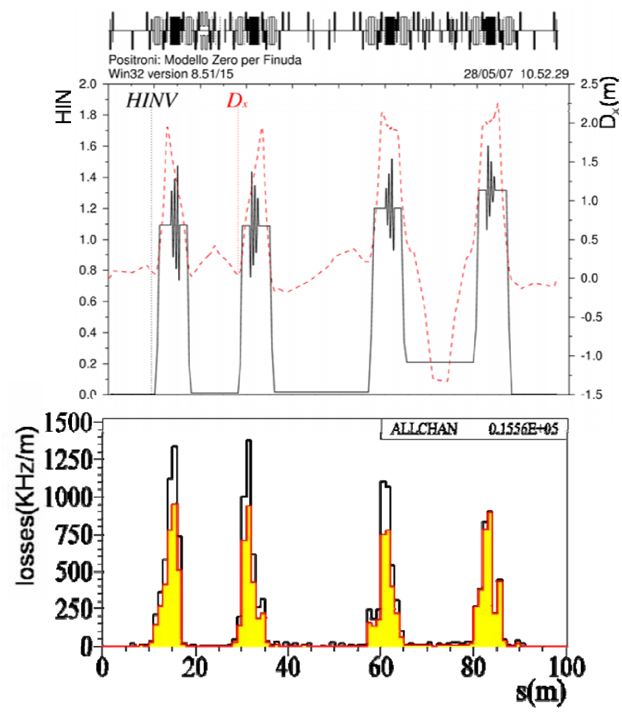

Fig. 1: Upper plot: H and dispersion functions for the DAΦNE upgrade optics. Lower plot: Distribution of Touschek scattering position for losses all over the ring or only at the IR, white and yellow histogram, respectively. The IP is at s=0.

In the simulation Touschek particles are taken within one transversely Gaussian bunch with the proper energy spectra. Particles are tracked over many turns or until they are lost. In this way an estimate of the Touschek losses along the whole ring and at the IR is performed.

Table 1: Relevant beam parameters used for Touschek background simulations.

N_{part}/bunch	$2.6\cdot10^{10}$
I_{bunch} (mA)	13
ε_x (μm)	0.2
Coupling (%)	0. 5
σ_z (mm)	20

Sextupoles are included in the tracking. Recently, the simulation code has been upgraded in order to estimate also the Touschek lifetime τ_{TOU}. This estimate is obtained from the the relation $\tau_{TOU} \cong N/\dot{N}$, where the total

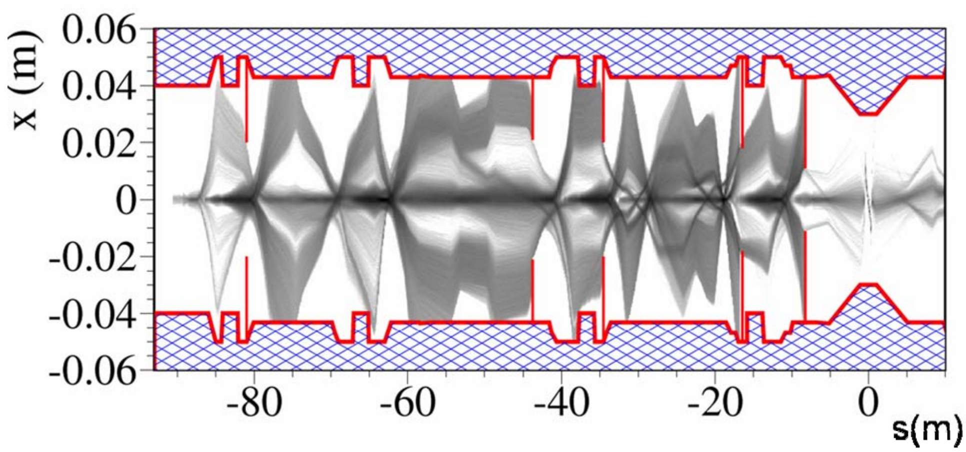

Fig. 2: Touschek particles trajectories plotted with all machine collimators inserted. The IP is at s=0.

particle losses along the ring $\dot{N}$ is given by the tracking simulation and N is the number of particles per bunch (see table 1). Particles within an energy deviation of 0.1% and 4% are tracked for a sufficient number of machine turns, checking at every turn whether they exceed rf or physical acceptance. Results are in agreement with the simulation code used up to now for DAΦNE [7] within ~15%.

SIMULATIONS

Touschek background with this new machine lattice is expected to be high with respect to the rates we have had with the old one. In fact, the strong IR quadrupole doublet requires a small physical aperture. So, the squeezing the beam at the IP that enhances luminosity induces also many particle losses at the focusing low-β quadrupole. For this reason a masking system between the pipe and the low-β quadrupoles will be incorporated to shield the detector from beam-generated background.

The beam parameters used for these simulations are reported in Table 1. Full tracking has been performed for one machine turn, and only particles with a relative energy deviation between 0.003 and 0.02 have been simulated, as particles with higher energy deviations get lost locally and do not contribute to backgrounds in the experiment, and particles with relative energy deviation <0.003 are practically always kept inside the beam pipe.

Table 2: Lost particles per bunch per beam with a beam current of 13mA.

Total losses without collimators (KHz)	$15.5 \cdot 10^3$
IR losses without collimators (KHz)	$11.3 \cdot 10^3$
IR losses with collimators (KHz)	94.2

Careful studies have been performed to estimate efficiency of the five available horizontal collimators. Each one has an external and an internal jaw that can be separately inserted in the vacuum pipe. Tracking studies have indicated for the new optics a better longitudinal position for three of them, and they will be moved accordingly. Fig. 2 shows the trajectories of Touschek particles lost along the ring with the optimized opening of the jaws. It appears that three of them are very efficient; they are, starting from the IP: at s = -8.2 m (SCHPL101), at -16.7 m (SCHPL110) and at -43.7 m (SCHPS201). We remark that these are just the three collimators which have been moved to improve their efficiency for the new optics. Fig. 3 shows the losses over the ring, after the insertion of collimators, indicating also their efficiency in stopping particles. Table 2 reports the calculated rates, from which not only the great efficiency of collimators can be noticed, but also that most of the particle losses are concentrated at the IR.

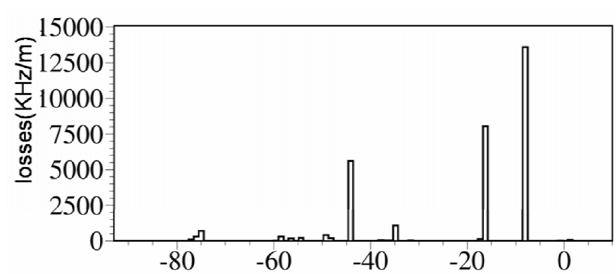

Fig. 3: Distribution of total losses plotted with all machine collimators inserted. The IP is at s=0.

The calculated opening of the IR collimator jaws (SCHPL101) is up to 11 mm from the center of the beam pipe, corresponding to 8.5 σ_x, while for SCHPL110 it is at 18 σ_x and for SCHPS201 at 21 σ_x. Similarly to the KLOE and FINUDA runs, the largest reduction of IR losses associated with Touschek scattering is achieved by the collimator closest to the IR: its optimized longitudinal position is found to be just after a horizontally focusing quadrupole, corresponding to a maximum of β_x.

A scan of the IR losses versus openings of the IR collimator is reported in Fig. 4 (upper plot) together with the corresponding lifetime (lower plot). The collimator openings are measured from the center of the beam axis and expressed in number of σ_x. Black markers are for the particles lost upstream the IP, red dots for the downstream ones. In this simulation all other collimators are inserted.

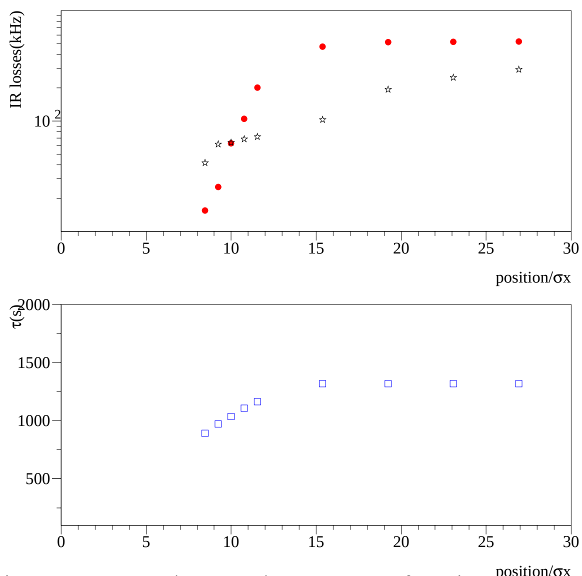

Fig. 4: Upper plot: IR losses as a function of the IR collimators openings measured in number of σ_x from the center of the beam axis. Black dots are losses downstream the IP, red dots are the upstream ones. Lower plot: corresponding Touschek lifetime.

Beam lifetime without collimators is estimated to be about 35 minutes; when all but IR collimators are inserted it drops to 28 minutes. When also IR collimator is at its optimized position, the lifetime is further reduced by about a factor 1/3, down to 19 minutes. So, as expected, studies have shown that there is a trade off between beam lifetime and minimization of background by the collimators and this is true in particular with the insertion of the IR one.

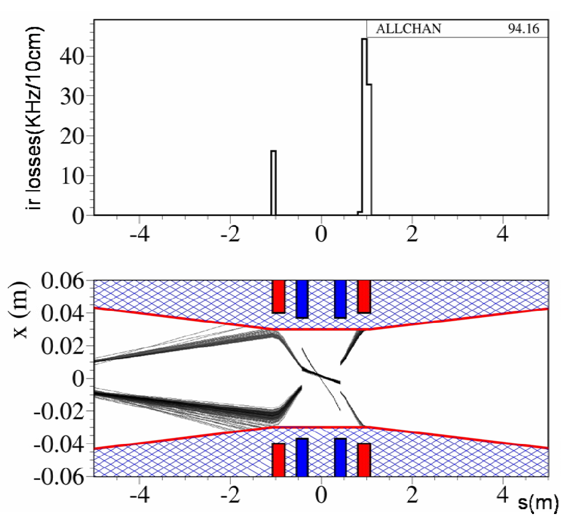

Fig. 5: Distribution (upper) and trajectories (lower) of particle losses at the IR with all machine collimators inserted. Rates are given for a 13mA bunch. The IP is at s=0.

Fig. 5 shows the calculated distribution and trajectories of IR losses with collimators inserted. Most of Touschek particles are lost at the focusing quadrupole of the IR doublet, as expected. Luckily, most of the particles are lost downstream the IP. When collimators are inserted the particle losses at the IR come from the closest arc to the IR, as shown in Fig. 6. These Touschek particles can only be stopped by the IR collimator, thus resulting the most dangerous source of background for the experiments. This background will be reduced with a proper shielding of the detector, as it has been done fruitfully for KLOE and DEAR.

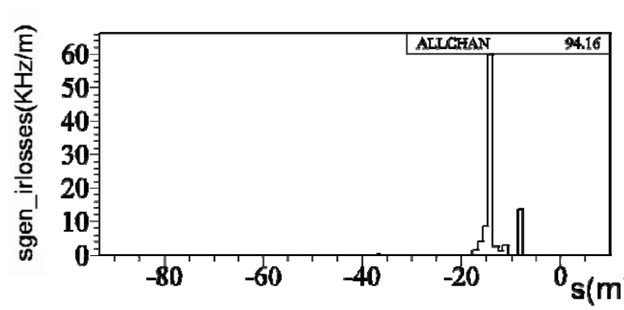

Fig. 6. Location source of Touschek particles getting lost at the IR, with insertion of collimators. Only particles generated in the last arc before the IR are still dangerous for the detector.

CONCLUSIONS

The simulation code for tracking of Touschek particles is now more accurate, as it calculates particle losses all over the ring together with Touschek lifetime. Particle losses due to Touschek effect are expected to be quite high with the Siddharta optics. However, the longitudinal position of collimators has been optimized for the new optics and they are expected to be very efficient, even if a good compromise between losses and lifetime has necessarily to be found experimentally. In addition, careful shielding of the detector is underway.

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