TOUSCHEK EFFECT AT DAΦNE FOR THE NEW KLOE RUN IN THE CRAB-WAIST SCHEME

M. Boscolo, P. Raimondi, INFN-LNF, Frascati, Italy, E. Paoloni, A. Perez, INFN-Pisa, Italy

Abstract

The innovative crab-waist collision scheme [1] has been implemented at DAΦNE with a new KLOE run [2]. Due to the small transverse beam sizes especially at the interaction region (IR) it requires special attention to the Touschek effect, both for the lifetime and the machine induced backgrounds into the detector. These two aspects have been handled by the same Monte Carlo (MC) simulation.

In this paper we report the work done up to now concerning the Touschek effect, for the KLOE-2 run. IR particle losses and lifetime have been optimized numerically by means of a trade-off between critical parameters. Dedicated measurements have been performed to validate these studies, which are still in progress due to a linac gun fault that forced a pause in the run since last May. Operations are foreseen to restart in September. However, first comparisons are promising, as discussed in this paper.

IR distributions of the Touschek particle losses are tracked from the beam pipe into the KLOE calorimeter for direct comparison of measured and expected background rates. In addition, these studies are carried out with the same software tools used for the SuperB design [3], allowing a direct validation test of this approach.

INTRODUCTION

The DAΦNE machine induced backgrounds into the experiments as well as the beam lifetime are dominated by the Touschek effect [4], due to the dense beams at relatively low energy. A dedicated simulation for the Touschek scattering has been developed for handling both the lifetime and the backgrounds since the first experiments data taking [5].

The features of the new CW scheme that affect the Touschek scattering effect are the smaller emittance and the smaller transverse beam sizes, especially at the IP. So, Touschek lifetime results short and particle losses inducing backgrounds into the experiments result high, as we verified during the CW scheme test with the SIDDHARTA run [6]. However, remedies to counteract this effect can be undertaken and at the same time take profit of luminosity enhancement as, for example, implementing proper shielding to decrease the impact of backgrounds on the detector performance.

Dedicated studies for data and numerical simulation comparisons are carried out for the new KLOE-2 run, as done for the previous experiments [7]. The DAΦNE optical model has been tuned to keep the effects of Touschek scattering under control with a trade-off between critical parameters, following the indications given by simulations. However, the run was suspended on May 27th due to the impossibility of injecting beams due to a linac gun fault, in particular, the original cathode was exhausted and a spare one lasted one week. Full comparisons and dedicated runs for lifetime and backgrounds studies are planned as soon as the run will be resumed in September, when new cathodes will arrive.

TOUSCHEK LIFETIME AND LOSSES

New simulation studies have been performed with the actual beam parameters (listed in table 1) and the present lattice for the new KLOE-2 run.

Table 1: Relevant Beam Parameters

N_{part}/bunch	$2{\cdot}10^{10}$
I_{bunch} (mA)	10
ε_x (μm)	0.26
Coupling (%)	0.1- 0. 4
σ_z (cm)	1.4
β_x*(m)	0.25
β_y*(mm)	9

Comparisons between measured and calculated Touschek lifetime have been performed for the electron beam, with and without scrapers, as shown in Fig. 1. The same experimental set of scrapers has been used for simulations. Bunch length has been varied in the simulations accordingly to bunch current, taking into account also the slight difference resulting from the measurements, with or without insertion of scrapers [8].

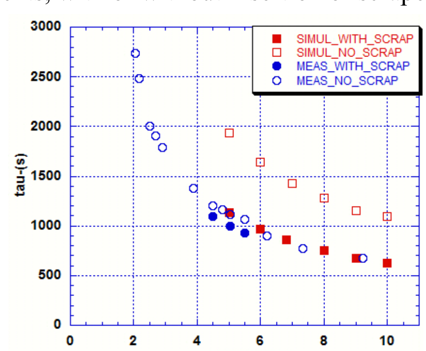

Figure 1: Measured (blue dots) and predicted (red squares) electron beam lifetime vs bunch current, with K=0.4%.

As appears from Fig. 1, there is a good agreement between measured and calculated lifetime with scrapers inserted (blue full dots and red full squares, respectively). On the contrary, the comparison without scrapers (blue empty dots and red empty squares, respectively) shows a disagreement of about a factor 1.9, which might be explained by a misalignment of the on-energy beam orbit that induced beam scraping in the IP2 section, as found after these measurements. We remark that in the simulation the beam is assumed perfectly aligned and centered along the beam vacuum pipe. In addition, dynamic aperture was not optimized in the machine as well as in the MAD lattice used for calculation. To confirm these explanations we will repeat the measurements when operations will be resumed and after optics and coupling re-adjustments. Summarizing, numerical simulations indicate a Touschek lifetime of $\tau = 620$ s for a 10 mA bunch, 0.4% beam coupling, with a calculated set of sextupoles that optimizes dynamic aperture and with the same experimental set of scrapers. This set is: IR1 scraper at -14/+11 σ_x, IR2 scraper at $\pm 9\ \sigma_x$, SCHEL110 at +36 σ_x and SCHES101 at 21 σ_x.

For the KLOE-2 run only the two IR scrapers have been moved, according to the new lattice. IR1 has been placed at about 8 m upstream the IP while the so-called IR2 scraper at a position with high β_x, downstream the old IP2. In addition, the beam stay clear at these two scrapers has been reduced to intercept Touschek scattered particles that would be lost at the IR: the IR1 scraper is at 18 σ_x from the center of the vacuum center already with no jaws inserted, the IR2 is at 14 σ_x.

Fig. 2 shows the comparison of the electromagnetic calorimeter rates in the electron forward region (ECM2) and the calculated IR losses within 4 m from IP. The two quantities are in different units, since the left y-axis stands for the experimental count rate ECM2 and right one for simulated particle loss rate, and they cannot be compared directly. However, Fig. 2 tells us that they scale equally with current, even if the effectiveness of scrapers is somewhat different: experimentally ECM2 rates (blue empty and full dots) are reduced by a factor 9.5, while IR losses, for the same scrapers set, only by a factor 5.4 (red empty and full squares). A direct comparison of calorimeter rates and IR particle losses is possible only after a full simulation of showers into the calorimeter, as discussed in the following section.

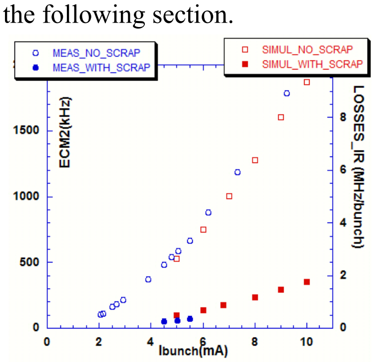

Figure 2: Measured (blue dots, left y-scale) calorimeter rates and predicted (red squares, right y-scale) IR losses (within 4 m from IP) versus bunch current, with K=0.4%.

Adiabatic adjustments of the optical parameters, sextupoles tuning and orbit optimization, especially at the IR, are important knobs that improve backgrounds during data taking.

Fig. 3 shows the corresponding IR particle losses, which are about 1.8 MHz/bunch; upper plot shows the distribution of IR losses and lower plot the corresponding trajectories.

In parallel, a design of the shielding around the IR pipe has been performed to prevent background contamination in the physics events without reducing the detector acceptance; some lead shielding is being implemented between the IP and the first low-β quadrupole QD0.

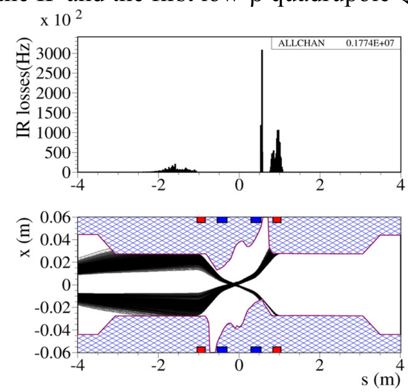

Figure 3: Distribution (upper) and trajectories (below) of Touschek particles lost at IR and used as primaries for further tracking into the calorimeter.

TOUSCHEK BACKGROUNDS

Simulation Tool

A full MC simulation that allows a direct comparison between the expected and the measured background rates at the KLOE electromagnetic calorimeter (EmC) has been developed in the new KLOE-2 configuration. Touschek scattering is the dominant effect for IR particle losses at DAΦNE, so EmC rates can be calculated by tracking particles hitting the IR vacuum chamber due to this process. Consequently, the IR particle losses resulting from the dedicated Touschek scattering code (shown in Fig. 3) have been used as primaries and tracked from their loss point at the vacuum chamber into the different regions of the EmC, composed of a barrel and two endcaps. This MC simulation is done in different steps. As a first step the SuperB factory home developed Geant4 full simulation code Bruno is used to track the Touschek primaries inside the KLOE IR that would impinge the KLOE detector. For this purpose a very detailed description of the KLOE IR has been implemented within the range of 2.5 m, including vacuum chambers, magnetic elements including KLOE solenoidal field and shieldings. As a second step the secondaries produced by the Geant4 simulation are propagated into the KLOE detector by means of the Geant3-based KLOE Monte Carlo and reconstruction code [9]. This final step allows the estimate of the clustering rates on the EmC.

Comparison with Experimental Data

A dedicated run for comparison of the measured and calculated calorimeter rates was performed together with the lifetime and scrapers on/off measurements discussed in the previous section. For this run we injected 60 bunches of electrons, at an initial bunch current of about

13 mA. Only the fraction of the run between two consecutive injections has been analysed in order to ensure stable machine conditions; data have been properly scaled for comparison with MC.

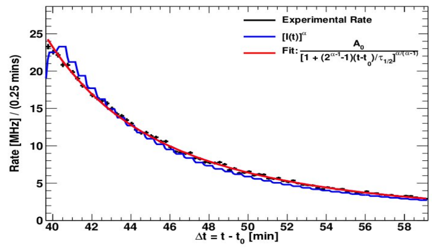

Figure 4: Measured background rates on the EmC barrel during the run (black dots); blue histogram: expected decay of background rates; red curve: fit from data to determine the beam lifetime.

The measured clustering rates on the EmC barrel (black dots) due to machine backgrounds are shown in Fig. 4 as a function of time. The blue histogram is obtained assuming that background rates scale with current as $I_{bunch}^{5/3}$, as expected when taking into account the bunch lengthening effect. The red curve in Fig. 4 is the result of a fit with the expected expression for the rate, $dN/dt = A_0 \big/ [1+(2^{2/3}-1)(t-t_0)/\tau_{1/2}]$, where A_0 is the rate at $t=t_0$, and $\tau_{1/2}$ is the beam half-lifetime. From this expression the extracted half-lifetime is $\tau_{1/2}$=(512±3) s, while the beam half-lifetime extracted from the current decay (443±1) s. The difference may be due to the fact that measured background rates in the EmC are not the primary particle losses, but rather showers deriving from them. So, some processes may not scale as expected for beam particle losses, for example due to a slight orbit displacement.

Table 2: Comparison Between Data and MC for Different Regions of the EmC (Background Rates are in MHz)

EmC Region	Data rates	MC rates	Data/MC
Barrel	24.7	33.3	0.74
Forward	3.0	1.6	1.87
Backward	37.4	78.0	0.48

More significant is the quantitative comparison of the total rates for the different EmC regions of the total rates which are in agreement with calculations that is within a factor 2, as summarized in Table 2.

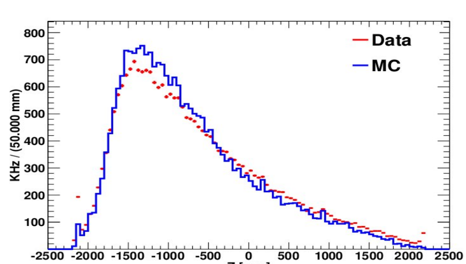

Figure 5: Distribution along the z coordinate of the ECM rates on the barrel, red dots are data, blue histogram MC, after a renormalization of the total rate to measured one.

Fig. 5 shows the spatial distribution along the z coordinate for the EmC barrel clustering rates, where red dots are measured data while the blue histogram is the prediction, after renormalization of the total rate.

A similar analysis for the transverse profile of the backward EmC rates, i.e. for Z<0, shows a good qualitative agreement as well (see Fig. 6).

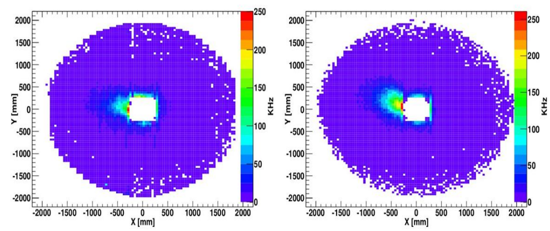

Figure 6: Transverse profile of the backward EmC rates. Left and right plots are data and MC, respectively.

CONCLUSIONS

Touschek studies for the new KLOE-2 configuration are under way. Dedicated simulations and measurements have been compared both for lifetime and background rates, showing promising results. A good agreement for the Touschek lifetime is found with scrapers at the experimental set, while a somewhat larger lifetime is expected from simulations with respect to observations without scrapers. This allows us to expect some margins of optimization, especially by correcting orbit and dynamic aperture. The data/MC background rates are in agreement within a factor of two in the different regions of the KLOE EmC and the main features of the shapes are well reproduced. Additional lattice changes for further improvements will be tested experimentally as DAΦNE operation will be resumed starting from September and further improvements are expected with more dedicated runs and MC tool tests.

ACKNOWLEDGMENTS

The authors thank the KLOE-2 collaboration for providing data and support and G. Sensolini for providing mechanical drawings for the IR description.

REFERENCES

[1] M. Zobov *et al.*, Phys.Rev.Lett. **104** 174801 (2010).
[2] C. Milardi *et al.*, these Proceedings.
[3] M.E. Biagini *et al.*, "SuperB CDR2", (2010) arXiv: 1009.6178v3.
[4] C. Bernardini *et al.*, Phys. Rev. Lett., **10** 407 (1963).
[5] M. Boscolo, S. Bertolucci, C. Petrascu, S. Guiducci, G. von Holtey, PAC01 (2001) p. 2032.
[6] M. Boscolo *et al.*, Nucl. Instr. Meth. A **621** (2010) 121-129.
[7] M. Boscolo, ICFA Beam Dyn. Newslett. 48 p. 59 (2009) and ref. therein.
[8] DAΦNE logbook, 24/1/2011.
[9] F. Ambrosino *et al.*, "Data handling, reconstruction, and simulation for the KLOE experiment," Nucl. Instr. Meth. A **534**, 403 (2004).