DEAR Technical Note IR-13

Preliminary results for DEAR Monte Carlo versus experimental data in background measurements with the NTP setup

C. Petrascu

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1 Introduction

The DEAR NTP setup, with 4 CCDs, was installed on DAΦNE and is taking background data, with beams delivered by DAΦNE, since February 1999. To be mentioned is that no interactions between electrons and positrons have been achieved in the DEAR Interaction Point, and this is the reason for which only background information can be processed and analyzed.

For a description on the NTP setup see Reference [1]. The NTP setup was shielded with lead, in the following way:

- a layer of lead, 2 cm thick, covered by a layer of copper, 1 cm thick, was placed under the target (having an aperture corresponding to the entrance window in the target);
- a layer of lead, 5 cm thick, was placed on the DEAR platform, all around the target;
- small bags filled with spheres and powder of lead were placed in all free spaces around the NTP setup.

The shielding factor using this setup is about 4 (verified by Monte Carlo as well as experimental results, see H. Zmeskal, Report to the International Scientific Committe of LNF).

The goal of this work is to compare experimental results, in terms of hits/(1/2CCD)/min, with Monte Carlo results, taking into account the main effects due to which particles are lost from circulating beams: Touschek effect [2] and beam-gas interaction [3].

For what concerns X rays, statistics was too poor in order to be able to perform any sensible comparison between experimental information and Monte Carlo results.

In what follows we shall proceed by presenting experimental and Monte Carlo results, for 3 different runs (beams) and, finally, we shall draw the conclusions.

2 Experimental results

The criteria used in selecting experimental data to be compared with Monte Carlo ones are the following:

- we selected periods of circulating beams with only one-beam, in order to have a "clean" data set with effects coming only from particle losses;
- we selected data files with CCD occupancy lower than 5%.

Applying these criteria we chose to analyze the following data sets - each one corresponding to 10 minutes acquisition time:

1) **File A0006847** corresponding to a data acquisition on 9 June at 1.51 a.m., and for which the beam intensity (mean values for the 10 minutes data taking interval) was:

   $I_e^- = 60$ mA

   Beam lifetime was about 162 minutes.

   The mean value for the dynamical vacuum in the electron ring during this period was:

   $P_e^- = 3 \cdot 10^{-9}$ mbar

   The number of clusters registered by the 8 half-CCDs were:

CCD	1	2	3	4	5	6	7	8
Nr. Clust.	622	727	414	629	260	288	267	231

   If we normalize to 1 minute and we make a mean over the 8 half-CCDs, we get:

43 ± 2 hits/(1/2CCD)/min

which represents the experimental result for this data set.

2) **File A0006851** corresponding to a data acquisition on 9 June at 2.31 a.m., and for which the beam intensity (mean values for the 10 minutes data taking interval) was:

   $I_e^- = 47$ mA

   Beam lifetime was about 162 minutes.

   The mean value for the dynamical vacuum in the electron ring during this period was:

   $P_e^- = 3 \cdot 10^{-9}$ mbar

   The number of clusters registered by the 8 half-CCDs were:

CCD	1	2	3	4	5	6	7	8
Nr. Clust.	576	543	295	418	215	193	189	188

   If we normalize to 1 minute and we make a mean over the 8 half-CCDs, we get:

   33 ± 2 hits/(1/2CCD)/min

   which represents the experimental result for this data set.

3) **File A0006858** corresponding to a data acquisition on 9 June at 3.41 a.m., and for which the beam intensity (mean values for the 10 minutes data taking interval) was:

   $I_e^- = 46$ mA

   Beam lifetime was about 177 minutes.

   The mean value for the dynamical vacuum in the electron ring during this period was:

   $P_e^- = 3 \cdot 10^{-9}$ mbar

   The number of clusters registered by the 8 half-CCDs were:

CCD	1	2	3	4	5	6	7	8
Nr. Clust.	412	544	299	409	215	232	193	200

If we normalize to 1 minute and we make a mean over the 8 half-CCDs, we get:

31 ± 2 hits/(1/2CCD)/min

which represents the experimental result for this data set.

3 Monte Carlo results

For what concerns Monte Carlo results, we took into accounts Touschek effect and beam-gas interaction, as main sources of particle losses from primary beams.

For the two above mentioned effects we proceeded in the following manner:

Touschek effect simulation

At the beam intensities recorded in the considered data taking, Touschek scattering is expected to be the **main effect** due to which particles are lost from primary beams. As we shall see at the end, it counts for about 80% of the background.

We performed a complete simulation of the NTP setup without shielding in the DEAR Monte Carlo framework.

After having done this, we generated 300.000 lost particles by Touschek effect, namely with the corresponding kinematics and origin as given in ref. [4].

The results of this generation were:

- 80 charged particles (electrons and positrons) registered by the 4 CCDs;
- no X ray below 10 keV was registered.

In order to get the number of hits for (1/2 CCD) per minute corresponding to each one of the 3 experimental sets of data, we normalized the input data with:

- beam lifetime
- intensity of the current

having as starting point the data in ref. [2] corresponding to the DEAR interaction region, **without scrapers**, namely the rate of particles lost before the IP (corresponding to a beam lifetime of about 100 minutes) which amounts to $8.77 \cdot 10^4$/s/bunch/beam.

The formula we applied to calculate the rate of loss particles per secondis:

$$Rate\ of\ loss\ part. = 8.77 \cdot 10^4 \cdot \frac{I_{beam}}{N_B} \cdot \frac{1}{44} \cdot N_B \cdot \frac{100}{\tau} \tag{1}$$

where I_{beam} represents the beam intensity; N_B the number of bunches; 44 mA is the single bunch intensity project value; 100 minutes is the beam lifetime taken as input value in ref. [2], while τ represents the beam lifetime in the present experimental conditions.

Having this rate, we could normalize the result got from the simulation of 300.000 lost particles and calculate, finally, the number of particles registered by CCDs for conditions corresponding to the experimental ones.

$$Time = \frac{300000}{Rate\ of\ loss\ part.} \tag{2}$$

$$Hits/(1/2CCD)/min(no\ shield.)(Toush) = 80 \cdot \frac{60}{Time} \tag{3}$$

Finally, in order to have a number which is directly comparable with the experimental one, we have to take into account the shielding factor namely to divide the number we previously got by 4:

$$Hits/(1/2CCD)/min(Toush) = \frac{Hits/(1/2CCD)/min(no\ shield.)(Toush)}{4} \tag{4}$$

Beam-gas interaction

Background produced by particles lost due to beam-gas interaction, in this NTP configuration, is only a small fraction of the overall background.

In order to get numerical results for this effect, we took as input the data corresponding the the final setup (cryogenic target) without shielding and *extrapolate them to the present experimental conditions of beam intensity and vacuum pressure.*

Normalizing with the pressure along the ring (mean value) and with the current, the formula we applied is:

$$Hits/(1/2CCD)/min(no\ shield)(bg) = \frac{P_{actual}}{P_{project}} \cdot \frac{I_{beam}}{30 \times 44} \cdot \frac{475}{2} \tag{5}$$

where P_{actual} represents the mean value of the pressure along ring for the period when data were collected, $P_{project}$ the project value of the pressure (mean value = 10^{-9}); I_{beam} is the beam intensity; 30×44 is the project beam intensity for 30 bunches; 475/2 is the value obtained with the Monte Carlo simulation for the final (cryogenic) target, without shielding, corresponding to beam-gas interaction for a single beam [5].

Then one has to take into consideration the shielding factor of 4:

$$Hits/(1/2CCD)/min(bg) = \frac{Hits/(1/2CCD)/min(no\ shield.)(bg)}{4} \quad (6)$$

In what follows we shall present the numerical results we obtained applying the procedure previously described.

1) **Simulation corresponding to the data set A0006847**

Background corresponding to Touschek effect:

$$Hits/(1/2CCD)/min(Toush) = 38\ Hits/(1/2CCD)/min \quad (7)$$

while the background corresponding to beam-gas interaction is:

$$Hits/(1/2CCD)/min(bg) = 8\ Hits/(1/2CCD)/min \quad (8)$$

Total background, the sum of the previous two numbers, is:

$$\boxed{Hits/(1/2CCD)/min(total) = 46 \pm 5\ Hits/(1/2CCD)/min}$$

2) **Simulation corresponding to the data set A0006851**

Background corresponding to Touschek effect:

$$Hits/(1/2CCD)/min(Toush) = 29\ Hits/(1/2CCD)/min \quad (9)$$

while the background corresponding to beam-gas interaction is:

$$Hits/(1/2CCD)/min(bg) = 6\ Hits/(1/2CCD)/min \quad (10)$$

Total background, the sum of the previous two numbers, is:

$$\boxed{Hits/(1/2CCD)/min(total) = 35 \pm 4\ Hits/(1/2CCD)/min}$$

3) **Simulation corresponding to the data set A0006858**

Background corresponding to Touschek effect:

$$Hits/(1/2CCD)/min(Toush) = 26\ Hits/(1/2CCD)/min \tag{11}$$

while the background corresponding to beam-gas interaction is:

$$Hits/(1/2CCD)/min(bg) = 6\ Hits/(1/2CCD)/min \tag{12}$$

Total background, the sum of the previous two numbers, is:

$$\boxed{Hits/(1/2CCD)/min(total) = 32 \pm 3\ Hits/(1/2CCD)/min}$$

4 Summary of the results and conclusions

The comparison between the experimental data on background measurements and Monte Carlo calculations is shown in Table 1.

As we can see from Table 1, in these preliminary results which concern only an electron circulating beam, the agreement is fairly good and promising along the way of checking our routines which describe the experimental setup.

No comparison could be done concerning X rays, since statistics (Monte Carlo as well as experimental one) was far too poor.

Table 1: Summary of the results: comparison of experimental data and Monte Carlo calculations.

File	Experimental result Hits/(1/2CCD)/min	Monte Carlo result Hits/(1/2CCD)/min
A0006847	43 ± 2	46 ± 5
A0006851	33 ± 2	35 ± 4
A0006858	31 ± 2	32 ± 3

References

[1] C. Petrascu, "Monte Carlo calculation for the new NTP DEAR setup", DEAR Technical Note, IR-12, 3 February 1999.

[2] S. Guiducci, *Background calculation for the DAΦNE experiments*, Proceedings of the *5th European Particle Accelerator Conference (EPAC'96),* Sitges (Barcelona), Eds. S. Myres *et al.*, Institute of Physics Publishing, Bristol and Philadelphia, 1996, pag. 1365.

[3] S. Guiducci and M.A. Iliescu, *Beam-gas background calculation for DEAR*, Frascati Report LNF-97/002 (IR) (1997).

[4] S. Guiducci, private communication.

[5] DEAR Collaboration, "The DEAR case", LNF-98/039(P), 17 Nov. 1998.