DEAR Technical Note IR-34

"En attendant Godot": background reduction obtained in the NTP setup in the period 16 October - 5 December 2000

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1 Introduction

After the first real determination of the “expected signal”/“measured background” ratio in the second period of DEAR runs - August-September 2000 - it was clear that in order to see any kaonic x-ray line a **substantial reduction** of the background had to be achieved.

“En attendant Godot” - in this case, a mythical, sudden improvement of the machine performance - we, pragmatically, decided to help ourselves: by making the greatest possible effort to reduce the background in the NTP setup by applying new ideas in the technique of shielding.

A variety of different configurations were therefore examined, studied by simulations, applied on the setup and finally systematically organized. All the work was done in between the end of the DEAR runs of September and the planned runs of December, i.e. in the period 16 October - 5 December. The measurements, consequently, were performed with beams colliding in KLOE and split in the DEAR interaction region.

Taking into consideration the not many and not easy possibilities offered by the present NTP setup to be adequately shielded, from a practical point of view (due to the presence on the setup platform around the target of a series of devices as the CCD vacuum chambers, the pumping system, the compressor for cryogenics, etc), the result we obtained is very positive. In fact, a reduction of the background hitting the CCDs of about **one order of magnitude** could be finally obtained.

The present Note describes the ways by which we achieved this good performance.

2 The “basic NTP-setup”

We shall refer to as “basic NTP-setup” the DEAR setup described in Ref. [1], which was shielded, at the beginning of the measurements on DAΦNE, as described in Ref. [2]. The “basic” shielding was:

- a layer of lead, 2 cm thik, covered by a layer of copper, 1 cm thick, under the target, having an aperture of 16 cm diameter in correspondence of the entrance window of the target, which has 15 cm diameter;

- a layer of lead, 5 cm thick, on the DEAR platform, all around the target;
- bags filled with small spheres of lead placed in any free space of the NTP setup.

This shielding gave a shielding factor of about 4, with respect to the "bare" setup, in agreement with the DEAR Monte Carlo simulations. Lead walls at the two sides of the interaction region - in between the last quadrupoles of the two triplets - constitute an additional protection, which turned out efficient at the level of a 2.4 factor, again in agreement with the simulations.

The "basic NTP setup" was used since the installation on DAΦNE until October 2000. It was, therefore, the starting point for the shielding strategies.

3 Background values in the "basic NTP setup": the reference

3.1 Looking for a machine reference configuration

As recalled above, we measured the background on CCDs (clusters and X rays) in a machine configuration in which beams were colliding in KLOE and were split in DEAR. This kind of measurements represents the bulk of the background measurements performed with the NTP setup and described in Refs. [2-9], the exception being represented by the few hours of collisions in DEAR in December 99 (see Ref. [10]), and by the DEAR beam period of September 2000 (see Ref. [11]). During this about one and a half year, KLOE worked always **without** use of scrapers.

The more recent values of the background in DEAR in these conditions was given in Ref. [7]. It is recalled below:

$$\#Clusters = (543 \pm 40)\ D.u., \tag{1}$$

in July 2000. D.u. stands for "DEAR units" = Clusters/CCD/beam loss (mA).

This value was obtained **just before** the DEAR runs of August-September. Therefore, the first check we performed **just after** the DEAR period was the eventual confirmation of it, to test the stability of the machine.

Table 1: The scrapers configuration in the two interaction regionr (IR) when collisions occurred in KLOE

IR	Beam	Scraper	Value
KLOE	e^-	Horizontal Internal	0-3 mm
KLOE	e^-	Horizontal External	10-12 mm
KLOE	e^+	Horizontal Internal	7.5-9 mm
KLOE	e^+	Horizontal External	21 mm
DEAR	e^-	Horizontal Internal	16-18 mm
DEAR	e^+	Horizontal Internal	10 mm

Surprisingly, as, apparently, a consequence of a new optics adopted for KLOE, since middle September, we found:

$$\#Clusters = (760 \pm 50)\ D.u., \tag{2}$$

i.e. about 40% higher than the value measured two months before. This configuration - **no scrapers** - had, in the meantime, become **obsolete** for KLOE, since it did not give sufficient background suppression.

Therefore, we could not use it as "machine reference configuration".

3.2 The starting point: the background value with the "basic NTP setup" in the "machine reference configuration"

Indeed, the new optics adopted for KLOE gave a better performance when scrapers were used as, by the way, occurred in case of collisions in DEAR.

The **"machine reference configuration"** from which we started our efforts to reduce background in the "basic NTP setup" was so characterized by the **scrapers configuration reported in Table 1** (collisions in KLOE):

It can be noticed that the reduction of the background implies to close also the DEAR scrapers, analogously to the situation of collisions in DEAR, when a background reduction in DEAR was obtained by closing (essentially) the KLOE scrapers. Which indicates the poor reliability of the present scrapers of DAΦNE due, probably, to a series of reasons: actual optics and, consequently, questionable position of the scrapers along the machine, shape of the scrapers profile, thickness, etc.

In the "reference machine configuration" we measured, in the "basic NTP setup", the following background:

$$\#Clusters = (950 \pm 50)\ D.u. \tag{3}$$

$$X_{ROI}/Clusters = (8 \pm 1) \cdot 10^{-4}, \tag{4}$$

from which:

$$\#X_{ROI} = (0.76 \pm 0.10)\ D.u. \tag{5}$$

X_{ROI} stands for: X rays in the region of interest of the DEAR programme (6.15 ± 0.6)KeV. The above values represent the **reference values** to which refer any result obtained in the different shielding configurations.

4 The techniques of shielding

The series of efforts done in order to shield the "basic NTP setup" is reported below. Most of the changes were previously simulated with the DEAR Monte Carlo.

1. Two lead bricks (5 cm thick), covered by a layer of copper, 1 cm thick, were put closing completely the target entrance window (as in the measurement performed on 5 August 2000 to look for the background sources, Ref. [9]). In addition, now all the bottom of the target, around the bricks, and for the same height, was covered with bags filled with small lead balls. This was a further check of the Monte Carlo results ([1]), according to which the main part of background enters into the target **through the entrance window**.

2. Two layers of polyethylene, 1 cm thick each, were put on the bottom of the target, covering it completely, and consequently also the entrance window. The aim was to check, and reduce, the low-energy component of the background entering through the entrance window.

3. The target was completely filled by lead - 15 cm along the entrance direction - to check the eventual background from **outside, through the lateral walls**.

4. **Two disk-shaped lead layers** - 2 cm thick each, global thickness 4 cm, hole diameters 16 and 17 cm, respectively - **were put inside the target**: a complementary test to that described in 1), to see which effective reduction could be obtained by putting shielding also inside the target.

5. The zirconium foil, located at the entrance window, to give the energy scale calibration through the electronic x-ray excitation, was removed in order to see if this foil is a source of Bremsstrahlung low-energy X rays.

6. The **lead shielding below the target was increased**, from 2 cm of the "basic NTP setup" up to 4 cm. The 1 cm copper layer was removed in order not to further reduce the solid angle. The central hole, corresponding to the target entrance window (15 cm diameter), was decreased from 16 cm diameter down to 15 cm diameter.

7. **All the cylindrical path through the holes in the lead layers** below and inside the target, **as well as in the aluminium platform**, from the beam pipe to the CCDs windows, **was shielded by polyethylene cylinders**. Low-energy X rays can be produced inside the "tube" formed by the holes in the lead layers below and inside the target and in the aluminium platform hole by large angle Bremsstrahlung of electrons (positrons) coming from the beam pipe. This dangerous background can be absorbed by cylinders of polyethylene inserted in all the apertures.

8. **The cylindrical apertures of the vacuum chambers of the CCDs were shielded by polyethylene cylinders.** It was in fact checked with a specific measurement, reported in ref. [9], that the aluminium electronic peak at 1.4 KeV, seen in the x-ray energy spectrum, comes predominantly from the excitation of the aluminium part of the setup which is close to the CCDs, constituting their frame, at the entrance of the vacuum chambers. This frame can be as well a source of soft

Bremsstrahlung X rays, able to reach directly the nearby chips. One can absorb these low-energy X rays by inserting small cylinders of polyethylene at the entrance of the vacuum chambers.

9. Two different setups of small permanent magnets were put at the corners of the target cell, having the magnetic field (some hundred gauss) oriented so to deviate eventual few KeV electrons. The aim was to eliminate low energy electrons giving **single pixel events**, exactly as low-energy X rays.

10. The target was pressurized up to 2.5 bar of nitrogen. The aim was to check an eventual absorption, due to a higher density, of low energy X-rays.

11. Finally, by taking advantage of what we learned by all the tests, a full shielding of the setup was performed.

    In the Sections which follow, the results of the tests are presented in quantitative terms, together with the final performance obtained in background reduction.

5 Experimental results

5.1 Bottom of the target covered by 5 cm of lead *(n.1 in the list of tests)*

The entrance window was closed by two lead bricks covered by 1 cm thick copper layer. Around the bricks, the bottom of the target was filled by bags containing spheres of lead.

Results:

$$\#Clusters = (120 \pm 30)\ D.u. \tag{6}$$

With respect to the reference value reported in Section 3.2, this means a clusters background reduction of about 87%.

Moreover, we obtained:

$$X_{ROI}/Clusters = (15 \pm 2) \cdot 10^{-4}, \tag{7}$$

which corresponds to:

$$\#X_{ROI} = (0.18 \pm 0.05)\ D.u. \tag{8}$$

Note: the number of clusters is **the same**, within the errors, obtained in August, reported in ref. [9], **despite** two important differences:

I) in August, the background "reference value" for the "basic NTP setup", reported in Section 3.1, was: $\#Clusters = (543 \pm 40)\ D.u.$ Now, the "reference value" is: $\#Clusters = (950 \pm 50)\ D.u.$, as reported in Sect. 3.2.

II) Now, differently than in August measurements, the bottom of the target was fully covered by lead.

5.2 Bottom of the target covered by 2 cm of polyethylene *(n. 2 in the list of tests)*

Inside the target, the bottom was covered completely by two polyethylene layers 1 cm thick, covering also the entrance window.

Result:

$$\#Clusters = (135 \pm 30)\ D.u. \tag{9}$$

Moreover, one obtained:

$$X_{ROI}/Clusters = (16 \pm 2) \cdot 10^{-4}, \tag{10}$$

which corresponds to:

$$\#X_{ROI} = (0.21 \pm 0.05)\ D.u. \tag{11}$$

These results - when compared to the values reported in the paragraph 5.1 - means that one gets the same background reduction, within the errors - both in terms of clusters and in terms of X rays - either by putting inside the target 5 cm of lead covering the bottom, including the entrance window, or by covering completely the target bottom by 2 cm of polyethylene.

In the last case, the low-energy component of the spectrum of the incoming particles from the beam pipe through the entrance window, as well as the low-energy products of the e.m. cascade generated by the electrons and positrons in the materials below the target (aluminium, copper, lead), is cut. In the first case, by putting lead one suppresses high energy particles, leaving, however, the low-energy products of the e.m. cascade through all the materials, below and inside the target, to reach the CCDs.

5.3 Full filling of the target by 15 cm lead *(n. 3 in the list of tests)*

Ten lead bricks, for an overall thickness of 15 cm above the target bottom, were put inside the target. After having checked that about 90% of background on the CCDs comes from **below** the target, directly from the beam pipe, we made this "extreme" test to measure the fraction of background coming from **outside** the target, i.e. present in the environment of the machine.

Results:

$$\#Clusters = (40 \pm 5)\ D.u., \tag{12}$$

which means a reduction of about 96% for clusters, or, in other terms, that about 96% of background which gives clusters on the CCDs comes from the bottom side of the target, while the remaining 4% might reach the CCDs through the lateral sides.

We obtained also:

$$X_{ROI}/Clusters = (14 \pm 2) \cdot 10^{-4}, \tag{13}$$

which corresponds to:

$$\#X_{ROI} = (0.05 \pm 0.01)\ D.u. \tag{14}$$

5.4 Bottom of the target covered by 4 cm of lead, with a hole for the entrance window *(n. 4 in the list of tests)*

In order to realize this test, which had the goal of evaluating the effective reduction obtainable with a lead shielding inside the target - a test exactly complementary to that reported in paragraph 5.1 -, we placed 4 cm of lead on the bottom of the target: 2 lead layers, 2 cm thick, 16 cm and 17 cm diameter, respectively. (The thickness adopted in the complementary test - 5 cm - could not be reached, due to the presence of the CCD windows).

Results:

$$\#Clusters = (350 \pm 40)\ D.u., \tag{15}$$

which means a 63% reduction.

Moreover, we obtained:

$$X_{ROI}/Clusters = (7 \pm 2) \cdot 10^{-4}, \tag{16}$$

which corresponds to:

$$\#X_{ROI} = (0.24 \pm 0.07)\ D.u. \tag{17}$$

5.5 Final shielding

The following tests did **not** give significant background reduction, within the statistical uncertainty:

a) removal of the zirconium foil, as possible source of soft X rays;

b) pressurization of the target up to 2.5 bar, to eventually absorb low-energy X rays;

c) installation of small permanent magnets inside the target, to eliminate few KeV electrons.

By comparing and organizing the whole set of results, we made a final shielding shown in Fig. 1, and reported below:

1) **Below the target:**

   a) reinforcement of the lead shielding from the 2 cm of the "basic NTP setup" to 4 cm (without the copper layer);

   b) reduction of the hole diameter from 16 to 15 cm;

2) **Inside the target:**

   two layers, 2 cm thick each, with increasing diameters from the bottom, 16 cm and 17 cm, respectively.

3) **Inside the cylindrical apertures of the CCDs vacuum chambers:**

   two polyethylene cylinders for each of the two CCDs chambers, 2 mm thick, 67 mm inner diameter, put at the two sides of the kapton window which separates the target cell from the CCDs: high, respectively, 15 mm on the CCD side and 9 mm on the target side.

4) **Inside the holes in the different material layers:**

   a) 10 mm thick, 8 cm high, 13 cm inner diameter cylinder of polyethylene, put inside the holes of the lead layers below the target and in the hole of the aluminium platform;

   b) two polyethylene cylinders 6 mm thick, 2 cm high, 14.8 cm and 15.8 cm inner diameters, respectively, put inside the holes of the lead layers within the target.

The results obtained with the final shielding of the NTP setup were:

$$\#Clusters = (90 \pm 13)\ D.u. \tag{18}$$

Moreover, we obtained:

$$X_{ROI}/Clusters = (10 \pm 2) \cdot 10^{-4}, \tag{19}$$

which corresponds to:

$$\#X_{ROI} = (0.09 \pm 0.01)\ D.u. \tag{20}$$

6 Conclusions

The results of the efforts performed on the NTP setup in order to reduce the machine background, in the period 16 October - 5 December, before the last runs with beams colliding in the DEAR interaction region, are summarized in Table 2.

With respect to the starting configuration reported in Section 3.2 we obtained the following background reduction:

Reduction factor in number of clusters:

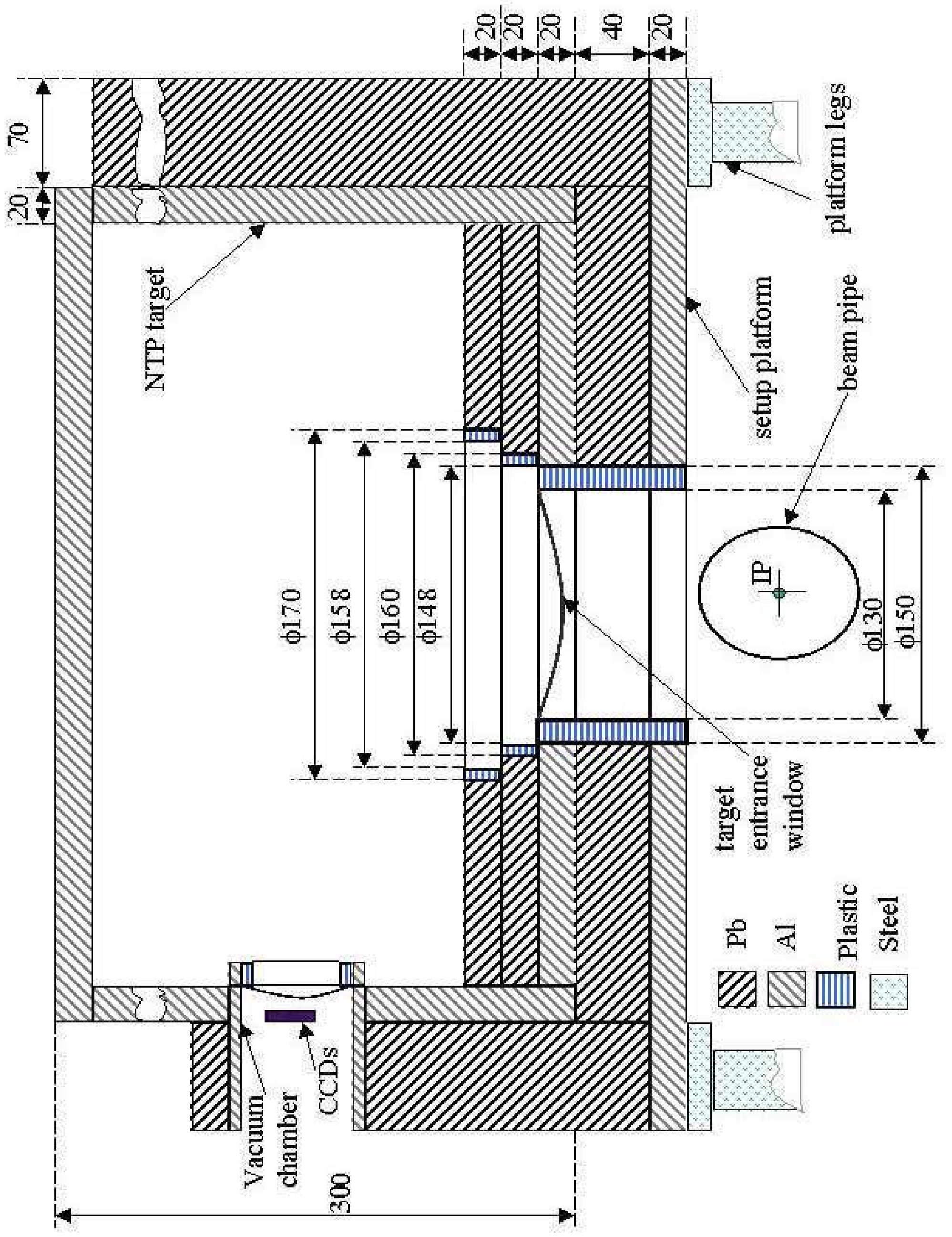

Figure 1: The final shielding of the NTP setup

Table 2: Experimental results obtained with the NTP setup with different shielding configurations in the period 16 October - 5 December 2000, with collisions in the KLOE IR.

Configuration	Background (D.u.)	$X_{ROI}/Clusters$
"Basic"	950 ± 100	$(8 \pm 1) \times 10^{-4}$
Bottom of the target covered by 5 cm of lead	120 ± 30	$(15 \pm 2) \times 10^{-4}$
Bottom of the target covered by 2 cm of polyethylene	135 ± 30	$(16 \pm 2) \times 10^{-4}$
Full filling of the target with 15 cm of lead	40 ± 5	$(14 \pm 2) \times 10^{-4}$
Bottom of the target covered by 4 cm of lead with hole for the entrance window	350 ± 40	$(7 \pm 2) \times 10^{-4}$
Final shielding: see text	90 ± 13	$(10 \pm 2) \times 10^{-4}$

$$\mathbf{10.5 \pm 1.6}$$

Reduction factor in the number of X_{ROI}:

$$\mathbf{8.4 \pm 1.6}$$

References

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