DEAR Technical Note IR-17

The background measurements with the NTP setup in the first period of collisions in the DEAR interaction region

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1) Introduction

The first step of the DEAR scientific program is performed with the DEAR NTP target (Normal Temperature and Pressure) filled with nitrogen. The NTP setup was installed in the DAΦNE hall in February 1999. The goals of these measurements are manyfold:

1. to perform background measurements in different conditions and compare the results with Monte Carlo simulations;
2. to obtain a kaonic nitrogen x-ray spectrum, what will represent the first observation of kaonic nitrogen atoms;
3. to tune the degrader to optimize the yields of the x-ray lines.

Until December 1999 no e^+e^- collisions have been achieved in the DEAR interaction point (I.P.). However, accurate background measurements have been performed with the NTP setup with circulating electrons, positrons and both beams present but separated in vertical in the DEAR interaction region (I.R.). The results of these measurements in terms of CCD blindness and x-ray background are presented in [1].

In December 1999 the first measurements with electron-positron collisions in the DEAR interaction region, ϕ-meson production and subsequent kaons entering the NTP target chamber were done. The results of these measurements are reported in the

present note. The second section is presenting, briefly, the NTP setup. The third section is dedicated to the presentation of the measurements performed (strategy and periods), while the fourth section contains the experimental results for each of the beam periods reported. The last section is summarizing the obtained results.

2) The DEAR NTP-setup

The NTP target used for the present measurements consists of a pure nitrogen volume, at room temperature and atmospheric pressure, filling a cubic box made of pure aluminum (30 x 30 x 35 cm^3) with 1.5 cm thick walls. This box is placed on a thick aluminum platform above the specially designed DEAR beam pipe in the DEAR interaction region. The chamber walls are at 45 degrees with respect to the beam axis. Two CCD detectors with box-shaped housings made of aluminum, each one containing 2 CCD chips (CCD-05) are plugged into two circular openings of the two chamber walls which are on the inner side of the DAΦNE main rings. The active areas of the detectors were located at ~ 142 mm above the DEAR beam pipe and at ~ 187 mm vertical distance from the interaction point. The NTP setup is presented in figure 1, where the setup elements are indicated.

The target chamber and the CCD detectors were shielded during the measurements with lead and copper. In the second part of the measurements additional shielding of two lead walls at the beginning and at the end of the DEAR interaction region (about 1 m away from the interaction point) was used.

To provide an online energy calibration, a pure zirconium foil with a thickness of 15 microns and a total surface of ~ 225 cm^2 was placed inside the NTP target directly above the kaon entrance window.

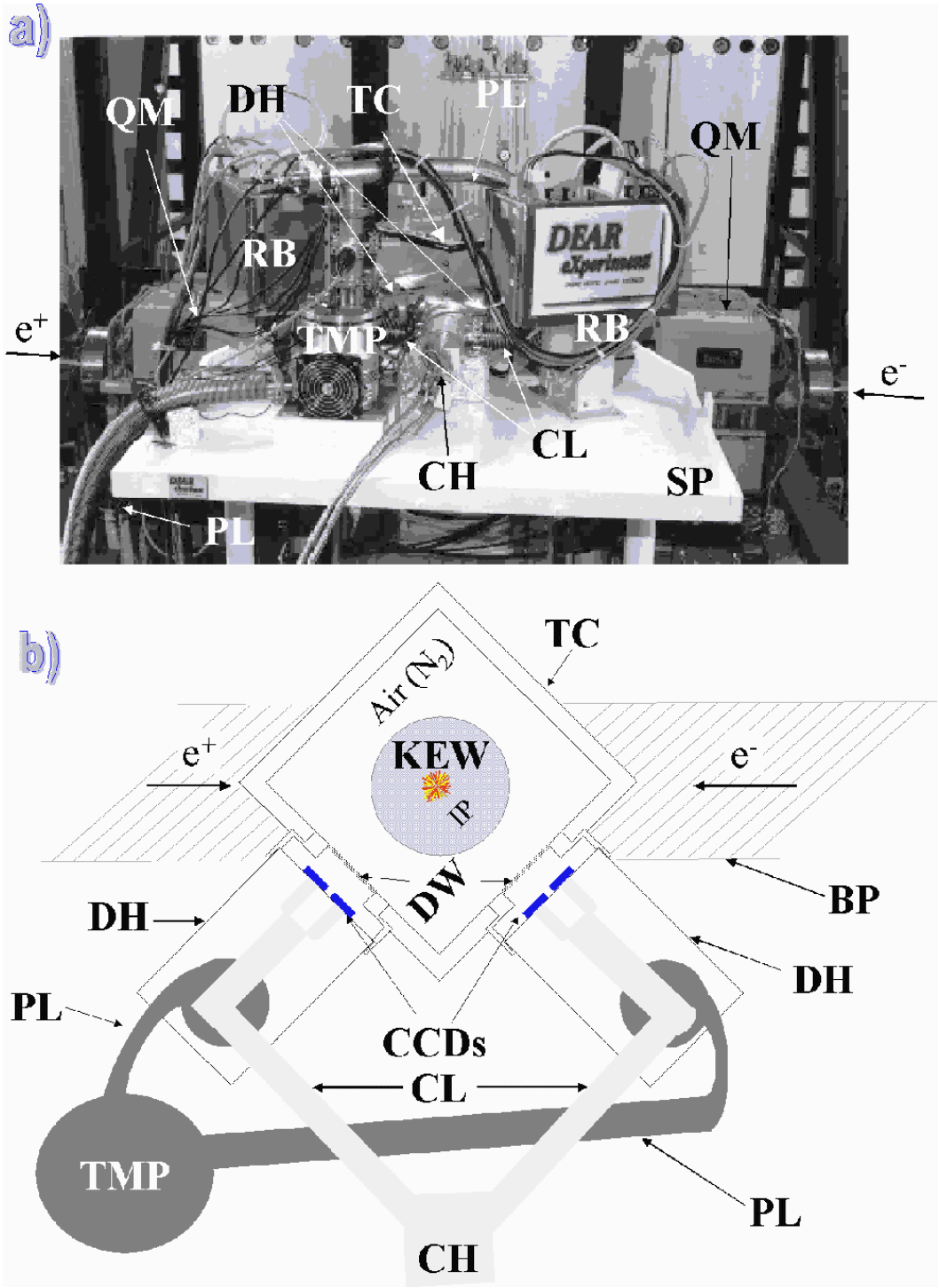

Fig.1: a) The installed NTP setup in the DAΦNE hall as seen from inside the rings.
b) Schematic drawing (view from above) of the NTP setup located in the DEAR interaction region above the interaction point. The setup platform and the magnets of the accelerator are omitted in the drawing for clarity. The displayed components of the experiment are:
RB...readout box (CCD electronics), TMP...turbomolecular pump, CH...cooling head, CL...cooling line, PL...pumping line, TC...target chamber, DH...detector housing, QM...quadrupole magnet, BP...beam pipe, KEW...kaon entrance window, DW...detector window, IP...interaction point, SP...setup platform.

3) The measurements

The period with collisions in which DEAR took data with the NTP setup is ranging from December 18 to 22. The results in the present note refer to this period.

The strategy followed during this short time period was concentrated on performing background measurements and comparisons for the following conditions:

- collisions with respect to no collisions, in order to put in evidence eventual dynamical beam-beam effects on the background. "No collisions" significates electron and positron beams simultaneously circulating in the DAΦNE main rings but with bunches shifted in time and therefore not able to collide;
- effect of additional shielding consisting of two lead walls - 20 cm thick, 100 cm high - placed in between the two quadrupole doublets at the two sides of the DEAR beam pipe.

The strategy of the DAΦNE team concerning the accelerator performance in this period was only to increase luminosity as much as possible. No machine tuning to reduce the background in the DEAR interaction region could be performed. December 18 and 19 were used for the first tuning of the DEAR interaction point. From December 19 until the end of the run period beam conditions remained untouched.

The considered data taking periods according to these beam conditions are reported in table 1. The readout time of the CCDs was selected to be 2 minutes during the whole data taking period. This was short enough to prevent the CCDs from being overexposed. The average occupancy of the CCDs was less than 10 %.

In total, DAΦNE delivered an integrated luminosity of about 60 nb^{-1} in the observed time period.

Data taking periods				
Beam period	Lead walls in I.R.	number of bunches per beam	number of collision periods	total measurement time
A	no	25	49	9 hours
B	no	20	2	50 min
C	no	40	6	2.5 hours
D	yes	23	5	2 hours
E	yes	23 *no collisions*	1	52 min
F	yes	40	2	70 min

Tab.1: Summary of data taking periods with stable beam conditions in the period December 19 - 22, 1999.

4) Measurements with the CCD-detectors

a) Cluster analysis

A CCD detector provides two different quantities to measure: Clusters and X rays. A definition of CCD clusters (multi-pixel hits) and X rays (single-pixel hits) can be found in [1]. The beam current for each measurement was given by the DAΦNE beam monitor.

To determine and compare the observed background levels we have used the quantity "Clusters/CCD / ABCD (mA)", that is the number of Clusters per CCD divided by the added (total) beam current difference "ABCD", defined as:

$$\text{ABCD (mA)} = \Sigma\, I(t_o) - I(t_o+t_m)$$

with Σ sums over electron and positron beams, I is the total circulating current, t_o is the start time of the measurement, t_m is the readout time.

The quantity Clusters/CCD/ABCD is normalized to the beam losses, which are reflected by the clusters recorded by the CCD detectors. Therefore it does not depend on the initial beam currents and beam lifetimes and therefore it makes a comparison between different beam periods possible. Consequently our analysis concentrates on the comparison of the number of Clusters/CCD divided by ABCD, as was already done for the measurements reported in Ref. [1]. The measured values for the given beam conditions are compared in table 2.

Beam period	Meanvalue of Clusters/CCD / ABCD (mA)
without lead walls	
A	358 ± 15
B	373 ± 25
C	368 ± 20
Mean value without walls	366 ± 15
with lead walls	
D	141 ± 10
E (no collisions)	167 ± 10
F	158 ± 10
Mean value with walls	155 ± 8

Tab.2: Results of the cluster analysis.

From table 2 two main results can be derived:

I) There is only a small difference in background levels between beams colliding and beams not-colliding in the DEAR interaction point.

Indeed, by comparing the measurements with collisions and without collisions, a small increase in background was seen for the non-colliding period. This is apparent in figure 2, where several data points, each referring to a 2 minute CCD exposure, are plotted for both beam modes.

II) There is a clearly visible effect due to the insertion of the two lead walls. Experimentally, a shielding factor of 2.4 ± 0.3 was determined from the quantity Clusters/CCD/ABCD in table 2. This is in agreement with the expectation from the Monte Carlo simulation, which results in a shielding factor of about 2. Figure 3 shows this shielding effect for two collision periods; one before and the other after the installation of the two lead walls.

No significant difference was observed for runs with a different number of bunches per beam.

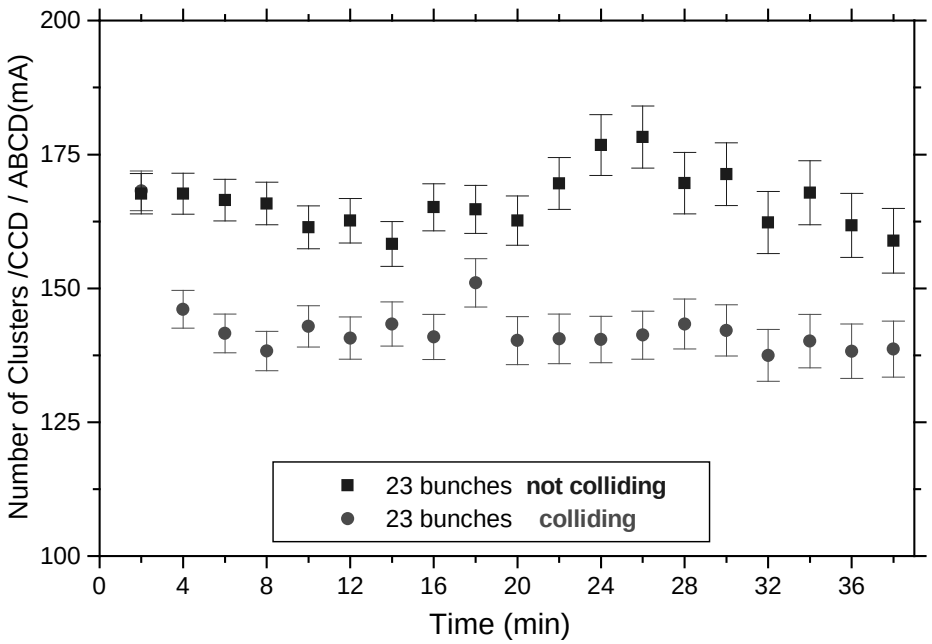

Fig.2: Comparison of beam induced background for colliding and not-colliding beams for subsequent 2 minutes CCD exposures. A difference for the two beam modes is visible.

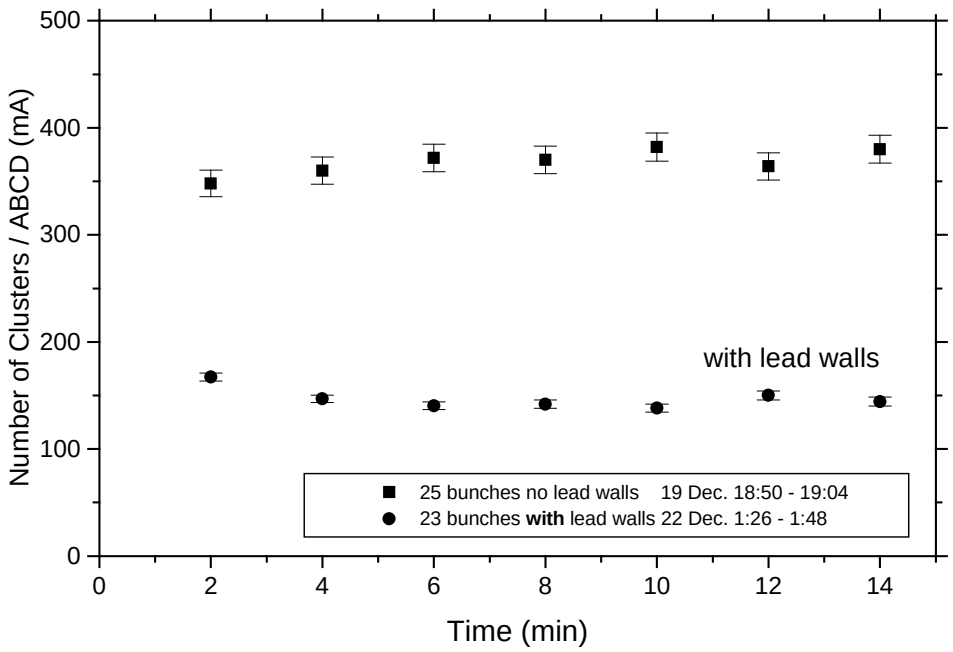

Fig.3: Clusters/CCD/ABCD for two different beam periods with colliding beams for subsequent 2 minutes CCD exposures. The shielding effect of the inserted lead walls is clearly visible.

b) X-ray analysis

Figure 4 shows the x-ray energy spectrum obtained in the period of collisions corresponding to an integrated luminosity of about 60 nb^{-1}. For this integrated luminosity approximately 4 to 6 X rays from kaonic nitrogen 7-6 and 6-5 transitions are expected from Monte Carlo simulations. These are not distinguishable from the present level of background. Electronic aluminum, silicon and zirconium transitions are visible, originating in target, detector and chip materials and in inserted calibration foils.

For the understanding and evaluation of the background it is also important to compare the ratio X rays per keV in the region of interest ($BGX_{\text{Region of Interest}}$), with the region of interest equal to 6.15 ± 0.6 keV, divided by the number of clusters (Clusters). This ratio was found [1] to have the constant value of 7.5 ± 0.5 ($\times 10^{-4}$) for various observed

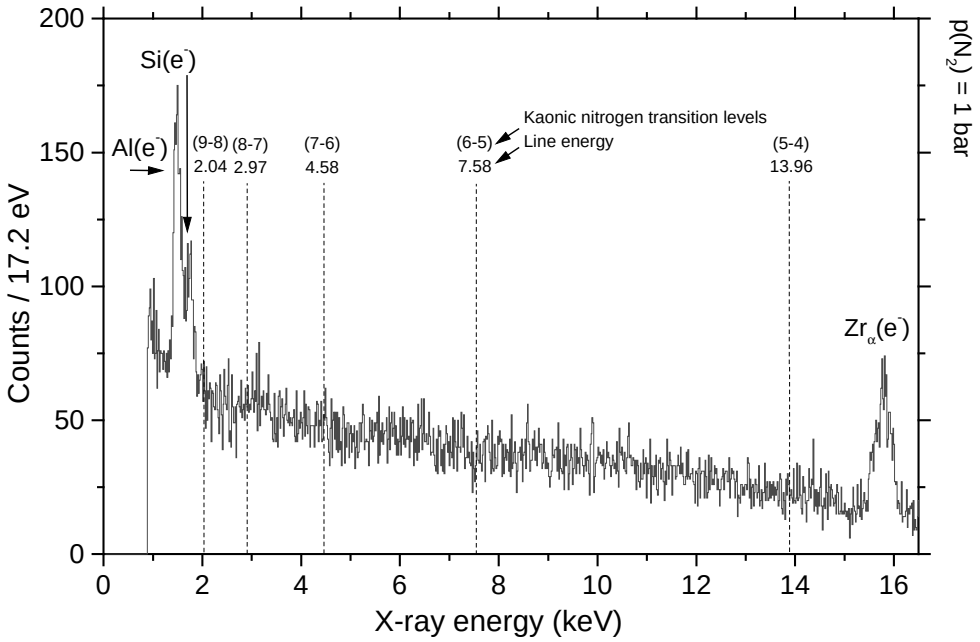

Fig.4: Energy spectrum of X rays observed in the period of beams colliding in the DEAR interaction region (corresponding to about 60 nb^{-1}). The calculated positions of several kaonic nitrogen transitions are indicated. Electronic x-ray lines from aluminum, silicon and zirconium are clearly visible.

beams circulating without collisions and splitted with respect to the beam axis in the DEAR interaction region. The values observed for the present measurements are reported in table 3. The mean value with colliding beams was found to be 8.5 ± 0.7 ($\times 10^{-4}$). The value was constant over an entire collision period and not significantly different from the value found without collisions [1].

The relevant X ray background rate, the rate of X rays in the region of interest per keV per CCD per hour averaged over a fully observed collision period with the beam currents decreasing in 22 minutes from 183 to 123 mA for the electrons and 170 to 78 mA for the positrons and inserted lead walls, was measured to be 31 ± 7.

Beam period	$BGX_{Region\ of\ Interest}$ / Clusters $\times 10^{-4}$
Collisions in DEAR I.P.	
A	7.5 ± 1.2
B	9.6 ± 1.2
C	7.8 ± 0.9
D	9.7 ± 1.7
F	8.0 ± 1.3
Mean value	8.5 ± 0.7
No collisions in DEAR I.P.	
Mean value [1]	7.5 ± 0.5

Tab.3: Observed values for the ratio $BGX_{Region\ of\ Interest}$ / Clusters.

To provide an online energy calibration using electronic fluorescence peaks during the x-ray measurements, a Zr foil was inserted in the target cell. The fluorescence peak of the foil and also of the target cell material (Al) is excited by particles passing through. The efficiency of fluorescence excitation in different foil locations was investigated. The energy spectrum of figure 4 was analysed regarding the x-ray peak-to-background ratio. Size and location of the zirconium foils were changed in comparison to the measurements reported in [1]. The present location of the Zr foil is just above the kaon entrance window. Its total size is 225 cm^2, which compares to a total of 900 cm^2 attached to the target cell walls for the previous analysis. The present configuration had already been adopted in the period immediately preceeding the DEAR measurements with collisions, when electron and positron beams were colliding in the KLOE interaction point and, as always, were splitted in the DEAR region. The corresponding fluorescence peaks can therefore be directly compared with the present measurements with collisions in the DEAR region.

The number of X rays for the observed aluminum and zirconium peaks per cm^2 of surface (X_i^{Peak}, i = Al, Zr) divided by the respective backgrounds under the peaks (BG_i) are reported in table 4 for the different configurations.

Peak	$X_i^{Peak} / BG_i \times 10^{-6}$
collisions in DEAR I.P. *(Zr foil above the kaon entrance window)*	
Al	176 ± 10
Zr	7500 ± 400
collisions in KLOE I.P. *(Zr foil above the kaon entrance window)*	
Al	74 ± 7
Zr	8100 ± 700
circulating not colliding beams (Zr foil on the target walls) [1]	
Al	117 ± 5
Zr	969 ± 55

Tab.4: The peak-to-background ratios per cm^2 of material surface for the aluminum and zirconium peaks for different measurements.

For the Zr peak a strinking increase for the peak-to-background ratio is observed in comparison with the values reported in Ref. [1], which can be attributed to the new location of the foil above the kaon entrance window and not on the walls of the target cell. Comparing the identical foil setup, but beams colliding either only in the KLOE I.P. or only in the DEAR I.P., no difference can be observed. When beams collide in the DEAR region a large peak-to-background ratio was observed. It follows that positioning the foil inside the kaon entrance window provides a more efficient x-ray excitation.

5) Summary

For the first time collisions were achieved in the DEAR interaction point of the DAΦNE collider. The NTP-setup could be successfully operated in this period. Data taking periods of 2 minutes each guaranteed that the active areas of the CCD chips were not overexposed, although the background level was still far above the value

expected for the measurement of kaonic nitrogen. No large difference in background rates between beams colliding and beams not-colliding in the DEAR interaction point could be observed. The shielding effect due to the insertion of lead walls on both sides of the DEAR beam pipe was measured to be 2.4 ± 0.3.

References:

[1] M. Augsburger et al., LNF-99/32(P) (1999), Submitted to Nuclear Instruments and Methods in Physics Research A.