DEAR Technical Note IR-35

Report on the runs period December 2000 with collisions in DEAR IP

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Content

1. Introduction

The results obtained in the third DEAR runs period (11 ÷ 17 December 2000) are reported. The goals of the runs were straightforward: optimization of the collisions in IP2 in terms of background reduction and increase of the luminosity, fixing in the meanwhile a stable set of machine parameters.

The main attention - due to the characteristics of the experiment - was focused on background reduction. A relevant work in this direction had been done during the weeks preceding the DEAR runs, when collisions occurred in KLOE. A sophisticated shielding of the NTP setup had been performed by the DEAR group, being convinced that the drastic necessary improvement of the background condition could hardly come in a near future from the machine side.

This effort turned out in a successful result, documented in Ref. [1]: one order of magnitude in the reduction of the background level could in fact be achieved. The confirmation of this performance for collisions in DEAR was the prioritary objective of the runs.

Only a partial confirmation of this record could, however, be obtained when collisions occurred in IP2, for reasons which can be ascribed only to a poorly optimized optics for DEAR. As far as luminosity is concerned, the peak luminosity turned out, on average, about twice the value of the previous runs. Regarding the overall collected integrated luminosity, due to a series of failures of the machine, of which the most relevant was a quenching of the KLOE solenoid, element of the lattice, the runs were stopped five days in advance with respect to the scheduled period (11 ÷ 12 December 2000). Therefore, in stable machine conditions we could collect only about 60 nb^{-1} in the last night. This corresponds to a rate/hour about 60 % better than that in September runs.

2. Status of art of the experiment at the end of the previous DEAR runs (September 2000)

We recall here how the experiment was left at the end of the September runs [2]. Which - of course - does not absolutely mean, given the actual variety of machine configurations, that, restarting, we should have been there where we were!

2.1 Background reference values

Table 1: DEAR status at the end of the previous DEAR runs (September 2000)

Configuration	# Clusters (D. u.)	X rays / nb^{-1} in 180 eV (FWHM) @ 7.6 keV
“Basic” NTP setup (*) without scrapers	1340 $\pm$ 100	
“Basic” NTP setup with scrapers	**400 $\pm$ 40**	**10 $\pm$ 1**
	reference values	

(*) for the definition see [1]

D. u. stands for “DEAR units” = clusters / CCD / beam loss (mA)

2.2 Luminosity reference values

integrated luminosity: $< \mathcal{L}^{int}_{h} > \cong 3\ nb^{-1} / h$

peak luminosity: $< \mathcal{L} > = 2.5 \times 10^{30}\ cm^{-2}\ s^{-1}$

3. The final shielding of the NTP setup

The results of the efforts performed to shield the setup turned out in the following final configuration [1]:

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 mm 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 aluminum 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 final shielding of the NTP setup is shown in Fig. 1.

4. Experimental results on background reduction

After the results obtained when beams collided in KLOE [1], we were naïvely thinking that the same background reduction - about one order of magnitude - could be achieved - *a fortiori* - when the beams were not split but collided in DEAR.

This expectation turned out to be substantially wrong, since we could cut background only by a factor four. No reasonable explanation was given by the machine in order to explain this result, apart the tautologic argument that the two configurations were different. In practice, taking KLOE as reference, in some way we measured how far is the machine setting in IP2 with respect to that in IP1.

In the subsections which follow, how much the measurements diverged from the expectations, is described.

4.1 Measurements of clusters

We were waiting to measure a number of clusters ten times smaller [1] than that registered in September [2]. What we indeed measured in the initial “no scrapers” configuration is reported below (Tab. 2).

Table 2: # clusters without use of scrapers (collisions in DEAR)

Period	**# Clusters (D. u.)**
September 2000	1340 $\pm$ 100
December 2000: expected value	≈ 130
December 2000: measured value	250 $\pm$ 30

The subsequent phase consisted in tuning the machine, making also use of the scrapers. **Only the KLOE scrapers turned out to be effective.** The DEAR scrapers did not give any improvement. The positions of the KLOE scrapers are reported in Table 3. The final number of clusters is reported in Table 4, together with the value obtained without scrapers, for comparison.

Table 3: Scrapers configuration (collisions in DEAR)

Interaction region	**Beam**	**Type of scraper**	**Position inside machine**
KLOE	e^-	Horizontal internal	20 mm
KLOE	e^-	Horizontal external	24 mm
KLOE	e^+	Horizontal internal	25 mm
KLOE	e^+	Horizontal external	18 mm

no DEAR scrapers.

Table 4: # Clusters (collisions in DEAR)

Collision period	# Clusters (D. u.)
December 2000 without scrapers	250 ± 30
December 2000 with scrapers	100 ± 10

4.2 Measurements of X rays

4.2.1 Ratio X rays / Clusters

The ratio X rays / Clusters is specific of a given setup. It has to be constant during the measurements performed with that setup. It turned out, in fact, that the ratio between the X rays counted within the "region of interest" (ROI) of the DEAR scientific program (6.15 ± 0.6 keV, position of the K_α line of kaonic hydrogen) and the number of clusters was constant for all the measurements and equal to:

$$X_{ROI} \text{ / Clusters} = (8.6 \pm 1.5)\ 10^{-4}.$$

4.2.2 X-ray energy spectrum

A stable working condition to be used for a period of data taking could be achieved only on December 16. Unfortunately, a series of machine problems occurred starting from the next day: in practice, DEAR runs finished at 20:30 of December 17. An x-ray energy spectrum could nevertheless be obtained with about 60 nb^{-1} of integrated luminosity (negative record for DEAR runs). The spectrum is shown in Fig. 2.

Many considerations can be drawn, when comparing this spectrum with that obtained in the previous period of runs, shown in Fig. 6 of Ref. [2]. The spectrum suffers for poor statistics, however, it is rich of well identified electronic excitations. The more striking feature is the almost complete disappearance of the Al peak at about 1.4 keV, the dominant peak in all the energy spectra obtained so far. The cut of the aluminum peak is the unambiguous check of the correct hypothesis that we formulated in the shielding campaign of this fall, which lead to the actual final shielding configuration. It was in fact measured - and reported in ref. [3] - that shielding by polyethylene the aluminum target walls did **neither** change the number of clusters **nor** the ratio X rays / Clusters. This was interpreted as a consequence of the fact that the low-energy X rays generated by Bremsstrahlung of electrons (positrons) in the target walls are absorbed by the gas target (nitrogen, air) and cannot reach the CCDs. Therefore, an additional shielding on the walls is simply ineffective. However, the Al electronic peak is always present in any spectrum, without and with polyethylene on the walls. The only possible explanation is that this peak is due to excitation of the atoms of the aluminum part of the setup which is near to the CCDs, precisely the cylindrical aperture of the CCD vacuum chamber. This aperture can not only generate X rays "useful" for calibration, as the Al peak, it can be also source of low-energy Bremsstrahlung X rays, able to reach directly the nearby CCDs. Therefore, we decided to shield the apertures of the CCDs vacuum chambers by cylinders of polyethylene. The idea turned out fine, as the energy spectrum shows: in fact the Al peak is strongly suppressed, together with its soft x-ray tail.

As a consequence of the suppression of the Al peak, the Si peak coming from the electronic excitation of the silicon atoms of the CCD chips, becomes more apparent - and therefore can eventually be used for calibration - with respect to the small shoulder of the Al peak, as it appeared in all previous spectra.

The second new feature of the spectrum is the appearance of lines corresponding to transitions of excited atoms of lead put inside the target. These X rays can reach the CCDs having energies above 10 keV, but, in principle, could be easily absorbed, as we could check in some tests, by wrapping the lead disks in the target with few hundred microns of aluminum foils. However, these Pb peaks fall in an energy region missing of scientific relevance, therefore their eventual absorption was not taken into consideration.

The more significant information which can be drawn from the spectrum is, obviously, the evaluation of the background at the position - indicated - of the most easily observable kaonic nitrogen transitions. In the interval ($7.20 \div 8.28$) keV around the 7.6 keV line, corresponding to the $6 \rightarrow 5$ transition of kaonic nitrogen, 921 X rays can be counted. This number corresponds to 153 background events within the 180 eV (FWHM, resolution of the setup) width of the line. Needless to stress that the collected integrated luminosity, 60 nb^{-1}, is by far too low to allow to see any signal. The expected counting rate for the 7.6 keV transition, with the present setup, is 0.05 events per nb^{-1}, which corresponds in this case to 3 good events.

5. Present state of the background in DEAR (December 2000)

Table 5: Results in background reduction

<table>
<tr><th>DEAR runs</th><th>Configuration</th><th># Clusters
(D. u.)</th><th># X rays / nb^{-1}
(7.6 keV line)</th></tr>
<tr><td>(1÷11) September 2000</td><td>Basic NTP setup (*)</td><td>400 ± 40</td><td>(10 ± 1)</td></tr>
<tr><td rowspan="2">(11÷17) December 2000</td><td rowspan="2">Final shielded NTP setup (o)</td><td>100 ± 10</td><td>(2.6 ± 0.3)</td></tr>
<tr><td colspan="2">new reference values since December 2000</td></tr>
</table>

(*) see [1]
(o) see text

6. Luminosity in IP2

The DEAR Kaon monitor can be used as luminosity monitor [4]:

$\mathcal{L}$ ($cm^{-2}s^{-1}$) = C_{KM} R

where

$C_{KM} = 7.15 \cdot 10^{30}$ (cm^{-2}) constant of the monitor

R = measured kaons rate (s^{-1})

All the luminosity values given below were obtained in such a way.

6.1 Peak luminosity

We define "peak luminosity" as the average value in the first 2 minutes of each measurement. The average peak luminosity delivered during the stable runs period was:

$< \mathcal{L}_{peak} > = (4.6 \pm 0.55)\ 10^{30}\ cm^{-2}\ s^{-1}$

6.2 Integrated luminosity

We refer only to the short period of data taking in stable machine conditions. Then:

- collected integrated luminosity ≅ 60 nb^{-1} in about 12 hours, which corresponds to an average integrated luminosity per hour:

$< \mathscr{L}^{int}_{h} > \cong 5\ nb^{-1} / h$.

7. Conclusions

The results obtained in the runs period of December 2000 can be summarized as follows.

With respect of the status of art of the experiment, as well as of the machine in IP2, at the end of the previous runs in September, recalled in Section 2, we have:

I) background reduction by a factor:

4.0 ± 0.6	**in terms of clusters**
3.8 ± 0.6	**in terms of X rays** under the 7.6 keV line of the kaonic nitrogen spectrum

We consider **positive** this result - although about 2.5 times poorer than that obtained when beams collided in KLOE - for different reasons. One reason, which concerns the machine and was stressed before, is that this partial result simply reflects the primitive level of optimization of the machine in IP2. Since no conceptual reasons, according to which the DEAR region should be 2.5 times dirtier than the KLOE one, can be reasonably believed, we simply ask to the machine to dedicate more time to optimize IP2 and we are sure that the performance **we obtained** in the KLOE configuration can be repeated in the DEAR configuration. Another reason of satisfaction is that the technique of shielding soft X rays in the specific environment of DAΦNE, learned and applied to a setup - the NTP one - which has a too complicated structure to be fully shielded, can be transferred and applied to the cryogenic setup, which is much more easy to be handled from the shielding point of view. Therefore, we consider possible a further reduction of background in the final setup. Last but not least, we will use the cryogenic setup to measure kaonic nitrogen, installing it during the January 2001 shutdown of DAΦNE.

The cryogenic setup operating with nitrogen at the pressure equivalent to 5 bar at room temperature, equipped with 12 CCD-22 and 4 CCD-05, will be able to increase the signal by a factor more than 20 [5]. This feature alone - for the present measured background in collisions in DEAR - i. e. without any further reduction from the machine side (new scrapers will indeed be installed) - should be sufficient for getting the signal / background ratio in a range where the experiment is able to “enter in business”, measuring the first exotic spectrum from DAΦNE with few pb^{-1} of integrated luminosity [6].

II) increase in luminosity by a factor:

about 2 in peak luminosity

about 60 % in integrated luminosity / hour

It must be noticed, however, that the peak luminosity achieved in IP2 is only about 27 % of the best performance in IP1, whilst the integrated luminosity extrapolated to the 24 hours is seven times less than the KLOE record (obtained with the essential help of the “topping up” technique). Which is another way to say that **much work has to be done in IP2, following also the suggestion of the Scientific Committee.**

References:

[1] M. Bragadireanu et al., “En attendant Godot”: background reduction obtained in the NTP setup in the period 16 October - 5 December 2000, DEAR Technical Note-IR-34, January 9, 2000.

[2] G. Beer et al., Report on the run period August-September 2000: NTP setup with CCD detectors, DEAR Technical Note-IR-29, September 25, 2000.

[3] M. Iliescu, B. Lauss, C. Petrascu, T. Ponta, Check of the background sources with the NTP setup, DEAR Technical Note-IR-25, August 18, 2000.

[4] G. Beer at al., Report on the run period August-September 2000: Kaon Monitor, DEAR Technical Note-IR-30, October 3, 2000.

[5] C. Petrascu, DEAR Monte Carlo results for the cryogenic target setup filled with nitrogen, DEAR Technical Note-IR-32, November 6, 2000.

[6] C. Petrascu, Kaonic nitrogen X-rays detection by background subtraction., DEAR Technical Note-IR-33, November 7, 2000.

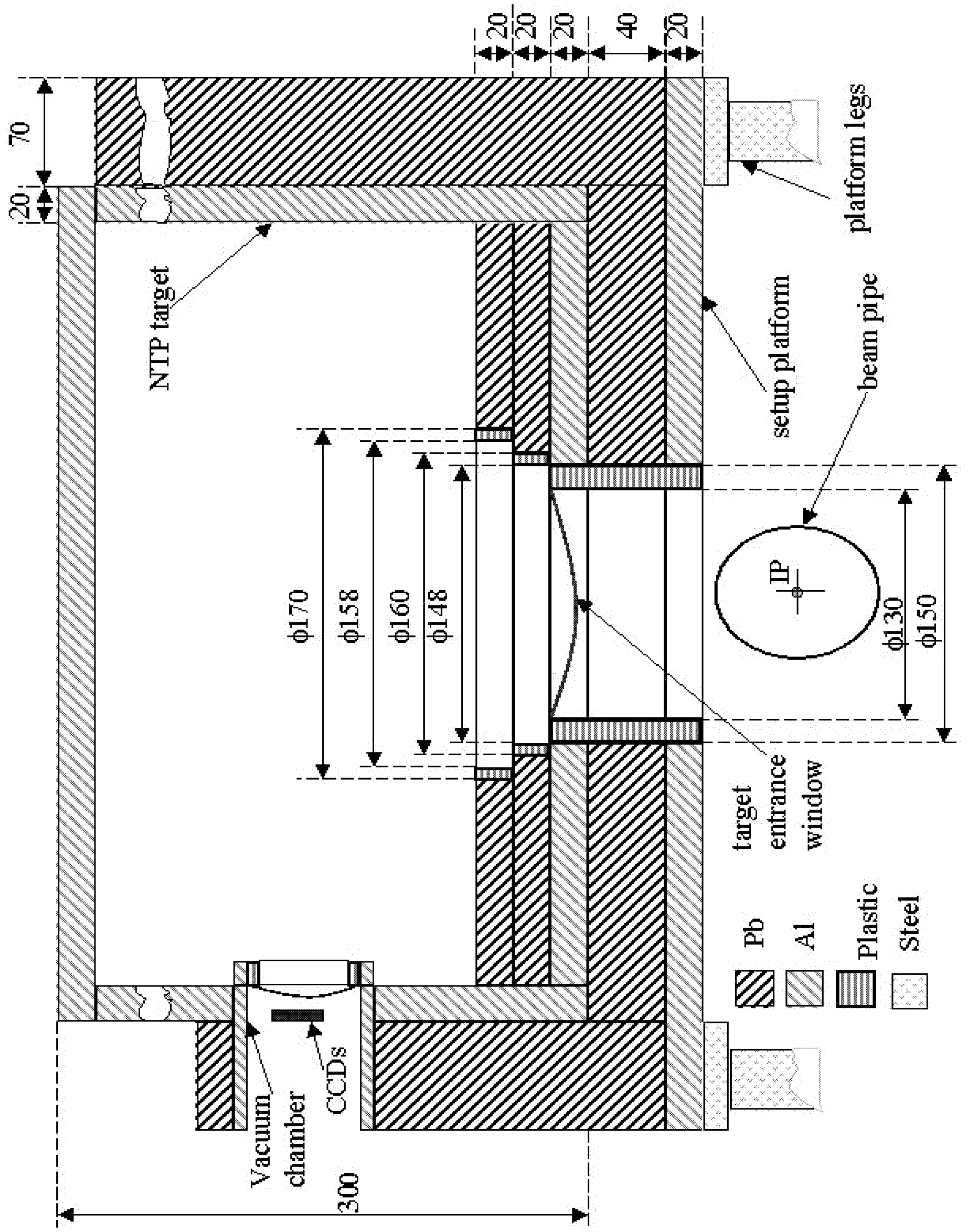

Figure 1: The final shielding of the NTP setup.

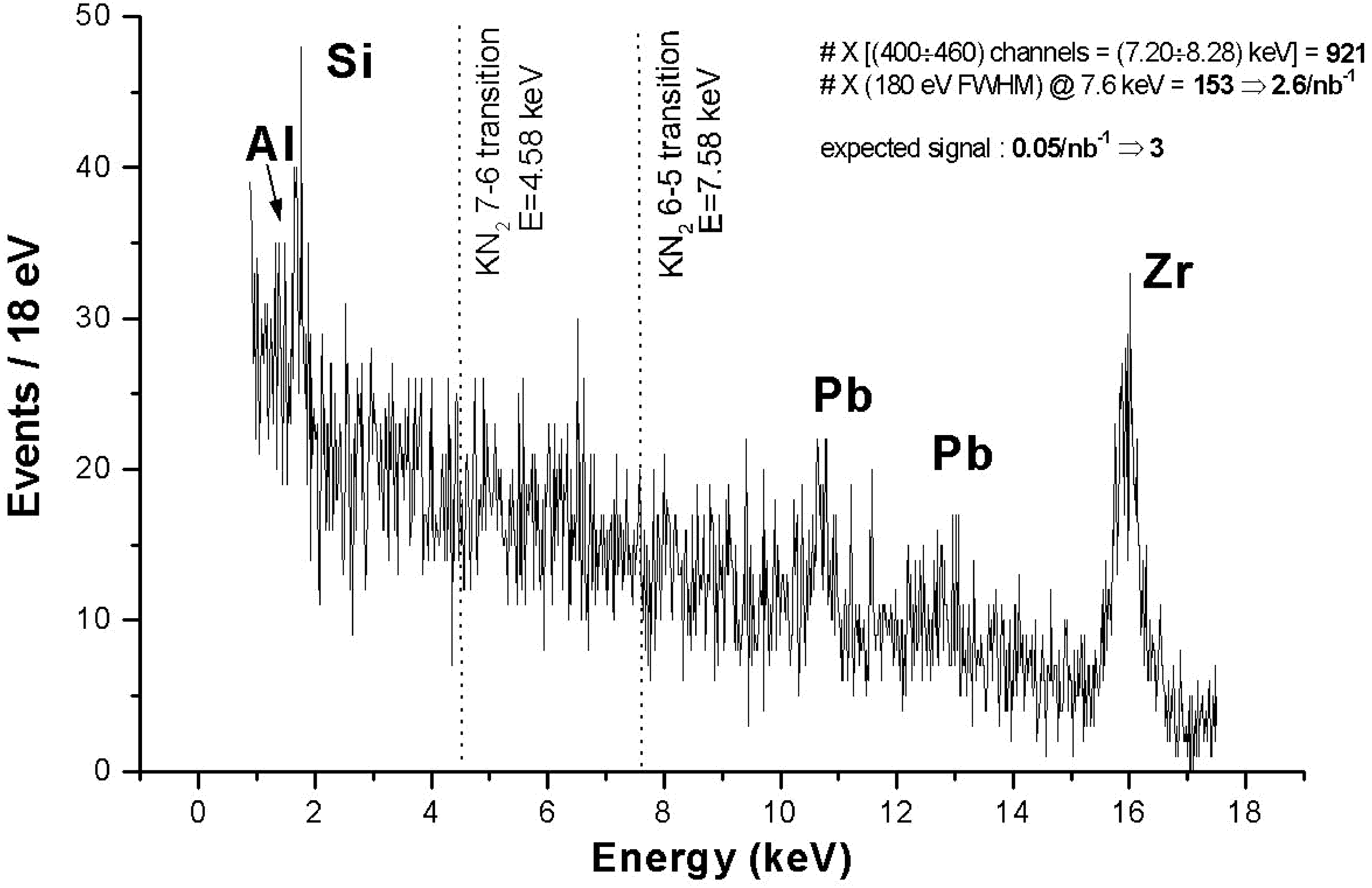

Figure 2: CCD spectrum from December 2000 runs for 60 nb^{-1} integrated luminosity. Electronic x-ray lines from atomic excitation of the materials of the setup are visible. The positions of the two more easily observable kaonic nitrogen lines are indicated.